HADRON2023

Monday, 5 June 2023 - Friday, 9 June 2023

Genova, Italy

Book of Abstracts

Contents

QCD and hadron structure / 4

Gravitational form factors of the delta resonance in chiral EFT

Author: Herzallah H.H. Alharazin[None]

Corresponding Author: herz.alharazin@outlook.de

Effective chiral Lagrangian of deltas, nucleons and pions in external gravitational field and the corresponding energy-momentum tensor will be considered. The gravitational form factors together with the spatial local density distributions of the deltas will be discussed.

QCD and hadron structure / 5

The gluon distribution functions and angular momentum in the proton

Author: Chentao Tan[None]

Corresponding Author: tanchentao@qq.com

We study the leading twist gluon generalized parton distributions (GPDs) and the Wigner distributions of the gluons in the proton within a light-cone spectator model. The model provides an approach to generate the gluon degree of freedom from the proton target, in which the proton is regarded as a two-particle composite system composed of an active gluon (g) and a spectator particle (uud). We present the numerical results of H^g, E^g, $\tilde{H}^g$, H_T^g and E_T^g as functions of x at different $\Delta_\perp$. The Wigner distributions W_{UU}, W_{LU}, W_{UL} and W_{LL} are also provided. Using the above results, we further investigate the total angular momentum, the orbit angular momentum and the spin-orbit correlations of gluons.

QCD and hadron structure / 6

Sivers function of sea quarks in the light-cone model

Author: Xiaoyan Luan[1]

[1] *Southeast University*

Corresponding Author: 230229369@seu.edu.cn

We calculate the Sivers function of $\bar{u}$ and $\bar{d}$ quarks using the overlap representation within the light cone formalism. The light-cone wave functions of the proton are obtained in terms of the $|q\bar{q}B\rangle$ Fock states motivated by the meson-baryon fluctuation model. We consider the final-state interaction at the level of one gluon exchange. In a simplified scenario, the Sivers function of $\bar{u}$ and $\bar{d}$ can be expressed as the convolution of the Sivers function of the pion inside the proton and the unpolarized distribution of $\bar{q}$ inside the pion. The model parameters are fixed by fitting the unpolarized sea quark distributions to the known parameterizations. We present the numerical results for $f_{1T}^{\bar{u}/P}(x,$ $boldsymbolk_T^2)$ and $f_{1T}^{\bar{d}/P}(x,$ $boldsymbolk_T^2)$. The first transverse moment of the sea quark Sivers functions in our model are find to be negative and the magnitude is about 0.004 at most.

Heavy baryon spectroscopy / 8

Perspective studies of charmonium, exotics and baryons with charm and strangeness

Authors: Mikhail Barabanov[1]; Stephen Olsen[2]

[1] *IUPAP*

[2] *UCAS*

Corresponding Author: bara_2009@mail.ru

The spectroscopy of charmonium-like states together with the spectroscopy of charmed and strange baryons is discussed. It is a good testing tool for the theories of strong interactions, including: QCD in both the perturbative and non-perturbative regimes, LQCD, potential models and phenomenological models [1, 2, 3]. An understanding of the baryon spectrum is one of the primary goals of non-perturbative QCD. In the nucleon sector, where most of the experimental information is available, the agreement with quark model predictions is astonishingly small, and the situation is even worse in the strange and charmed baryon sector. The experiments with antiproton-proton annihilation and proton-proton (proton-nuclei) collisions are well suited for a comprehensive spectroscopy program, in particular, the spectroscopy of charmonuim-like states and flavour baryons. Charmed and strange baryons can be produced abundantly in both processes, and their properties can be studied in detail [1, 2, 3].
For this purpose an elaborated analysis of charmonium and exotics spectrum together with spectrum of charmed and strange baryons is given. The recent experimental data from different collaborations (BaBar, Belle, BES, LHCb,$\cdots$) are analyzed. A special attention was given to the recently discovered XYZ-particles. The attempts of their possible interpretation are considered [4 - 7]. The results of physics simulation are obtained. Some of these states can be interpreted as higher lying charmonium and tetraquarks with a hidden charm [5, 6, 7] and strangeness [8, 9]. It has been shown that charge/neutral tetraquarks must have their neutral/charged partners with mass values which differ by few MeV. This hypothesis coincides with that proposed by Maiani and Polosa [10] and need confirmation nowdays. Many heavy baryons with charm and strangeness are expected to exist. But much more data on different decay modes are needed before firmer conclusions can be made. These data can be derived directly from the experiments using a high quality antiproton beam with √Spp\bar up to 5.5 GeV planned at FAIR and proton-proton (proton-nuclei) collisions with √SpN up to 26 GeV planned at NICA.
References
[1] W. Erni et al., arXiv:0903.3905v1 [hep-ex] (2009) 63.
[2] N. Brambilla et al., European Physical Journal C 71:1534, (2011) 1.
[3] J. Beringer et al., Review of Particle Physic, Physical. Review, D 86, (2012).
[4] M.Yu. Barabanov, A.S. Vodopyanov, Physics of Particles and Nuclei Letters, V.8, N.10, (2011) 1069.
[5] M.Yu. Barabanov, A.S. Vodopyanov, S.L. Olsen, Physics of Atomic Nuclei, V.77, N.1, (2014) 126.
[6] M.Yu. Barabanov, A.S. Vodopyanov, S.L. Olsen , Physica Scripta, T 166 (2015) 014019.
[7] M.Yu. Barabanov, A.S. Vodopyanov, S.L. Olsen, A.I. Zinchenko, Physics of Atomic Nuclei, V.79, N 1 (2016) 126.
[8] R. Aaij et al., Phys. Rev. 95, (2017) 012002
[9] R. Aaij et al., Phys. Rev 118 (2017) 022003
[10] L. Maiani, F. Piccinini, A.D. Polosa, V. Riquer, Phys. Rev. Lett. 99 (2007) 182003

Hadron decays, production and interaction / 10

Decays of the fully open flavor state $T^0_{c\bar{s}0}$ in a D^*K^* molecule scenario

Authors: chengjian xiao[1]; dianyong chen[2]; zili yue[2]

[1] *Institute of Applied Physics and Computational Mathematics*

[2] *Southeast University*

Corresponding Author: yuezili@seu.edu.cn

Inspired by the recent observations of $T_{c\bar{s}0}^{0/++}$ in the the processes $B^0 \to \bar{D}^0 D_s^+ \pi^-$ and $B^+ \to D^- D_s^+ \pi^+$ by LHCb Collaboration, we investigate the decay properties of the $T_{c\bar{s}0}^0$ in a $D^* K^*$ molecule scenario, and the widths of $T_{c\bar{s}0}^0 \to D^0 K^0$, $D_s^+ \pi^-$, $D_s^{*+} \rho^-$, $D_{s1}^{(\prime)+} \pi^-$, and $D^{*0}(D\pi)^0$ are estimated. Our estimations indicate that the width of $T_{c\bar{s}0}^0 \to D_s^+ \pi^-$ is sizable to be observed and the dominant decay mode of $T_{c\bar{s}0}^0$ is $D^0 K^0$. Considering the isospin symmetry, we proposed to search $T_{c\bar{s}0}(2900)^{++}$ in the $D^+ K^+$ invariant mass distributions of the process $B^+ \to D^+ D^- K^+$, where some preliminary experimental hints have been observed by LHCb Collaboration.

Hadrons in hot and nuclear environment / 11

Properties of the Tcc(3875) and its heavy-quark spin partner in nuclear matter

Authors: Víctor Montesinos Llácer[1]; Miguel Albaladejo[2]; Juan Nieves[3]; Laura Tolos[4]

[1] *IFIC (UV-CSIC)*

[2] *IFIC*

[3] *IFIC (CSIC-UV)*

[4] *FIAS. University of Frankfurt*

Corresponding Author: victor1montesinos@gmail.com

We discuss the modification of the properties of the tetraquark-like $T_{cc}^+(3875)$ in dense nuclear matter. We consider the T_{cc}^+ in vacuum as a purely molecular isoscalar ($D^0 D^{*+}/D^+ D^{*0}$) bound state in $S-$wave, generated from a heavy-quark symmetry leading-order interaction between the charmed mesons. We compute the D and D^* spectral functions embeded in a nuclear medium and use them to determine the corresponding T_{cc}^+ self energy and spectral function. We find important modifications of the DD^* scattering amplitude and of the pole position of the T_{cc}^+ exotic state already for $\rho_0/2$, with ρ_0 the normal nuclear density. We also discuss the dependence of these results on the DD^* molecular component in the T_{cc}^+ wave-function. Finally, we perform a similar analysis for the isoscalar $J^P = 1^+$ heavy-quark spin symmetry partner of the T_{cc}^+ (T_{cc}^{*+}) by considering the $D^{*0} D^{*+}$ scattering $T-$matrix.

Analysis tools / 13

Can the two-pole structure of the $D_0^*(2300)$ be understood from recent lattice data?

Author: Anuvind Asokan[1]

Co-authors: Meng-Na Tang [2]; Feng-Kun Guo [2]; Christoph Hanhart [3]; Yuki Kamiya [4]; Ulf-G. Meißner [5]

[1] *Institute for Advanced Simulation - 4, Forschungszentrum Jülich*

[2] *Institute of Theoretical Physics, Chinese Academy of Sciences*

[3] *IKP-TH, Forschungszentrum Juelich*

[4] *Helmholtz-Institut für Strahlen- und Kernphysik and Bethe Center for Theoretical Physics, Universität Bonn*

[5] *Univ. Bonn and FZ Jülich*

Corresponding Author: a.asokan@fz-juelich.de

From unitarized chiral perturbation theory analyses, the structure of $D_0^*(2300)$ and $D_1(2430)$ can be understood as the interplay of two poles, corresponding to two scalar/axial-vector isospin doublet states with different SU(3) flavor content. These states emerge from non-perturbative dynamics of D mesons scattering off the Goldstone boson octet. This two pole picture solves various problems

that the experimental observation posed. However, in the recent lattice studies of $D\pi$ scattering at higher pion masses, only one pole was reported in the D_0^* channel, while it was not possible to extract reliable parameters of a second pole from the lattice data. We provide an explanation for this contradiction and further show that the second pole can be extracted from the lattice data by imposing SU(3) constraints on the fitting amplitudes. This approximate symmetry constrain on the K-matrix formalism also reduces the number of fitting parameters.

Hadrons and physics beyond the standard model / 14

Investigating the dark sector with the PADME experiment

Author: Paola Gianotti[1]

[1] *LNF*

Corresponding Author: paola.gianotti@lnf.infn.it

The anomaly observed in the opening angle and invariant mass distributions of e^+e^- pairs produced in the decays of excited ^{8}Be, ^{4}He and ^{12}C nuclei [1-3] can be interpreted with the creation and subsequent decay of a particle of mass approximately 17 MeV which has been named X17.

Along the years, several light particles have been postulated by theoretical extensions of the Standard Model with a wide range of properties, in the attempt of justifying some unexplained phenomena like the (g-2)μ anomaly or the nature of the dark matter. Up to now, none of these new feebly interacting particles has ever been observed. The existence of the X17, if confirmed, will then represent a real breakthrough in the search of physics phenomena beyond the Standard Model.

The Positron Annihilation into Dark Matter Experiment (PADME) is a fixed-target experiment, at the Laboratori Nazionali di Frascati of INFN, searching for a dark photon and other dark sector candidates among the annihilations of a beam of positrons, with energy <500 MeV, on the electrons of the target [4]. PAMDE has already collected a first set of physics-grade data over the last few years that allowed to measure the total cross-section of electron-positron annihilation into photons below 1 GeV.
In 2022 PADME collected a new data set, centered at $\sqrt{s}$ ~17 MeV, to produce on-shell the X17 [5]. These data are under analysis to provide a confirmation of the particle nature of the excesses observed in the spectroscopic measurements of Beryllium, Helium and Carbon.
An overview of the PADME results and of the future scientific program will be given.

References
[1] A.J. Krasznahorkay et al., Phys. Rev. Lett. 116 (2016), 042501.
[2] A.J. Krasznahorkay et al., Phys. Rev. C 104 (2021) 4, 044003.
[3] A.J. Krasznahorkay et al., Phys. Rev. C 106 (2022) L061601.
[4] P. Albicocco et al., JINST 17 (2022) 08, P08032.
[5] L. Darmé et al., Phys. Rev. D 106 (2022) 11, 115036.

Hadrons and physics beyond the standard model / 15

Hadronic structure in BSM searches with CKM unitarity

Author: Mikhail Gorshteyn[1]

[1] *Mainz University*

Corresponding Author: gorshtey@uni-mainz.de

Precision tests of the Standard Model with beta decays and unitarity of the Cabibbo-Kobayashi-Maskawa quark mixing matrix offer a way to search for BSM signals, which is competitive and

complementary to the collider searches. Currently, the CKM top-row unitarity constraint shows a deficit $\Delta_u = |V_{ud}|^2 + |V_{us}|^2 + |V_{ub}|^2 - 1 = -0.0015(7)$ which may point to possible New Physics contributions. To arrive to the impressive 10^{-4} precision, hadronic structure-dependent radiative corrections have to be under control. I review the current status of these SM corrections, and discuss the impact of future developments in theory and experiment.

Hadron decays, production and interaction / **16**

Measurement of the e+e− ⟶ BsX cross section in the energy range from 10.63 to 11.02 GeV

Author: Valentina Zhukova[1]

[1] *Jožef Stefan Institute, Ljubljana*

Corresponding Author: zhukova.valentina07@gmail.com

Studies of the e+e- annihilation into open-bottom final states are very important for understanding of the properties and nature of the bottomonium and bottomonium-like states. We report the first measurement of the inclusive σ(e+e− ⟶ bb̄ ⟶ DsX) and σ(e+ e− ⟶ bb̄ ⟶ D0X) cross sections in the energy range from 10.63 to 11.02 GeV. Based on these results, we determine σ(e+ e− ⟶ Bs X) in the same energy range. The achieved accuracy in σ(e+ e− ⟶ Bs X) is much higher than in the method with a full reconstruction of one Bs meson. The results are obtained using the data collected with the Belle detector at the KEKB asymmetric-energy e+ e− collider.

Light meson spectroscopy / **17**

The $a_1(1260)$ meson from lattice QCD and phenomenology

Author: Michael Doering[1]

[1] *The George Washington University*

Corresponding Author: doring@gwu.edu

The $a_1(1260)$ is cleanly observed in τ decays and can therefore serve as a testbed for resonant three-body physics. The first calculation of a three-body resonance from lattice QCD and its mapping to the infinite volume is presented. In addition, the resulting three-body unitary amplitude is continued to complex energies allowing for the extraction of the a_1 pole and its branching ratios in $(\pi\rho)_S$ and $(\pi\rho)_D$ coupled channels. The very same amplitude can be used to fit experiment in the form of line shape data, paving the way for the consistent understanding of three-body resonance physics from first principles and phenomenology.

Hadron decays, production and interaction / **18**

Hyperon electromagnetic form factors

Author: Ju-Jun Xie[1]

[1] *Insittute of Modern Physics, Chinese Academy of Sciences*

Corresponding Author: xiejujun@impcas.ac.cn

We propose a phenomenological extended vector meson dominance model for the baryon electromagnetic structure, and it is found that the current experimental data on the Lambda, Sigma, and Xi electromagnetic form factors in the time-like region can be well described.

Heavy meson spectroscopy / **19**

Isoscalar axial-vector bottom-charm tetraquarks from QCD

Authors: Archana Radhakrishnan[1]; Nilmani Mathur[2]; Padmanath Madanagopalan[3]

[1] *Tata Institute of Fundamental Research, Mumbai*

[2] *TIFR*

[3] *Helmholtz Institut Mainz*

Corresponding Author: arcradhakrishnan07@gmail.com

The increasing number of discovered heavy quark exotic hadrons call for immediate theoretical investigations based on first principles. Our study focuses on tetra-quark states made up of a bottom and charm quark in the axial-vector (1^+) channel with isospin I=0, using Lattice Quantum Chromodynamics.

These computations were conducted on the state-of-the-art MILC ensembles using dynamical up/down, strange, and charm quark fields implemented with a highly improved staggered quark action. The valence quarks were implemented using an overlap action, with quark masses ranging from light to the charm sector, while the evolution of the bottom quark was studied within a non-relativistic QCD framework. We observe strong evidence of an energy level beneath the elastic threshold, which imply an attractive interaction between the bottom and charm mesons, indicating the possible existance of bound charmed-bottomed tetra-quarks.

Exotic hadrons and candidates / **21**

Exotic states of fully heavy hadrons

Author: Alexey Nefediev[1]

[1] *Institute Josef Stefan*

Corresponding Author: alexey.nefediev@ijs.si

QCD supports the existence of hadrons with a structure richer than quark-antiquark mesons and three-quark baryons that are conventionally referred to as exotic. Many candidates for such states have been discovered experimentally in the spectrum of heavy quarks, with their minimal quark content being four-quark: two heavy plus two light quarks. In addition, recent results of the LHCb Collaboration on the double-J/psi production near the threshold hint at the existence of fully-charmed tetraquark states. In my talk, I will discuss a coupled-channel analysis of the LHCb data and a possible theoretical interpretation of the near-threshold exotic state predicted by this analysis. In the hadronic molecule interpretation, the strength of the interaction in the double-J/psi system mediated by soft-gluon exchanges is proportional to the chromopolarisability of the J/psi. The same low-energy parameter evaluated for a fully-heavy baryon appears several times larger than that for the heavy quarkonium composed of the heavy quarks of the same flavour. Thus the LHCb result may signal a possible existence of di-baryon molecules formed by fully heavy baryons.

The talk is based on:
Phys.Rev.Lett. 126 (2021) 13, 132001

Sci.Bull. 66 (2021) 24, 2462-2470
Eur.Phys.J.C 81 (2021) 8, 692
Phys.Rev.D 107 (2023) 3, 03402

Hadrons and physics beyond the standard model / **23**

The Primakoff Experimental Program at Jefferson Lab

Author: Liping Gan[1]

[1] *University of North Carolina Wilmiongton*

Corresponding Author: ganl@uncw.edu

The system of light pseudoscalar mesons π0, η and η′ provide a unique laboratory to probe fundamental QCD symmetries at the confinement scale. While π0 and η are Goldstone bosons due to spontaneous chiral symmetry breaking, η′ is not due to an axial U(1) anomaly coupling to the gluon field. The chiral anomaly coupling to the electromagnetic field drives the two-photon decays of these mesons. This system harbors information about the effects of SU(3) symmetry and the mixing phenomena of the mesons due to isospin symmetry breaking. A study of this system will have important impact on the low-energy QCD: testing the chiral anomaly and probing the origin and dynamics of chiral symmetry breaking; offering a clean path for model independent determinations of the light quark-mass ratio and the η-η′ mixing angle; and providing inputs to calculate the hadronic light-by-light corrections to the anomalous magnetic moment of the muon. A comprehensive Primakoff experimental program has been developed at Jefferson Laboratory (JLab) to perform high precision measurements of the two-photon decay widths and the transition form factors of π0, η and η′ via the Primakoff effect. A measurement of the π0 radiative decay width was carried out at JLab 6 GeV and the published result achieved a precision of 1.5%. The data collection on the η radiative decay width measurement at JLab 12 GeV was recently completed. The future JLab 22 GeV upgrade will improve the precisions with experimental sensitivities not previously achievable. The status of this program and its physics impact will be discussed.

Hadrons in hot and nuclear environment / **24**

Constraining the formation mechanisms of light (anti)nuclei at the LHC and applications for cosmic ray physics

Author: Giovanni Malfattore[1]

[1] *University of Bologna & INFN Bologna (Italy)*

Corresponding Author: giovanni.malfattore@cern.ch

The formation mechanism of light (anti)nuclei produced in high-energy hadronic collisions is an open question that is being addressed both theoretically and experimentally. Moreover, the study of (anti)nuclei production at particle accelerators is relevant to model the flux of antinuclei produced in cosmic ray interactions, which represents the dominant background for dark matter searches. In fact, according to the most accredited theoretical models, dark matter particles present in the galactic halo could annihilate and produce ordinary matter-antimatter pairs.

At LHC energies, the same amount of matter and antimatter are produced, which makes this facility suited for detailed studies of (anti)nuclei production. ALICE, thanks to its excellent particle identification capabilities, measured (anti)nuclei in all the collision systems and energies provided by the LHC. Measurements of transverse momentum distributions, ratios of integrated yields, and coalescence probabilities are discussed in comparison with two phenomenological models used to describe the production of nuclei.

During the LHC long shutdown 2, the ALICE apparatus underwent a series of major upgrades to take advantage of the luminosity increase of the LHC Run 3. These upgrades will allow the collection of an unprecedented amount of data, opening new paths to probe the formation mechanisms of nuclei with A = 3 and A = 4 with unprecedented precision.
The performance of the upgraded ALICE detector during the Run 3 pp data taking will be discussed together with perspectives for new measurements with applications to searches for antinuclei in cosmic rays for indirect dark matter searches by the AMS and GAPS experiments.

Exotic hadrons and candidates / **26**

A new measurement of $X(3872) \to D^0\bar{D}^{*0}$ at Belle

Author: Kiyoshi Tanida[1]

[1] *Japan Atomic Energy Agency*

Corresponding Author: tanida@post.j-parc.jp

The famous exotic hadron $X(3872)$ (a.k.a. $\chi_{c1}(3872)$) is observed not only in $J/\psi\pi\pi$ but also in $D^0\bar{D}^{*0}$, and the observed mass and width are larger in the latter decay mode with sizable uncertainties. In this presentation, we report a new measurement on
$X(3872) \to D^0\bar{D}^{*0}$ decay using the full data of the Belle experiment and show the result of an analysis on the obtained spectrum shape with the Flatte-like model used in the $X(3872) \to J/\psi\pi^+\pi^-$ by LHCb [PRD102(2020)092005].

Heavy meson spectroscopy / **27**

Structure of heavy mesons in the light-front quark model

Author: Ahmad Jafar Arifi[1]

Co-authors: Ho-moeyng Choi [2]; Chueng-Ryong Ji [3]

[1] *RIKEN*

[2] *KNU*

[3] *NCSU*

Corresponding Author: aj.arifi.ui@gmail.com

In this talk, I will discuss our efforts to explain the mass gaps and decay constants of the ground state and radially excited state heavy mesons in the light-front quark model. We highlight the importance of mixing 1S and 2S harmonic oscillator basis as the trial wave function in the variational analysis. A small mixture is needed to explain available experimental and lattice data. The obtained light-front wave function is then used to investigate the structure of heavy mesons further.

Light baryon spectroscopy / **29**

Mass Spectra of Ξ and Ω Baryons using hypercentral Constituent Quark Model

Author: Chandni Menapara[1]

Co-author: Ajay Kumar Rai [1]

[1] *Sardar Vallabhbhai National Institute of Technology Surat, Gujarat, India*

Corresponding Author: chandni.menapara@gmail.com

Hadron mass spectra have been a topic of investigation since long so as to explore the unknown degrees of freedom of quarks inside a composite system. The non-relativistic approach backed by constituent quark model alongwith hypercentral potential term has been used to obtain a number of excited resonance masses for light, strange baryons. The Ξ and Ω baryons are known with very little information with Particle Data Group. The hypercentral Constituent Quark Model with corrections of order $\frac{1}{m^2}$ to the spin-dependent term incorporated with linear confining term has been used to obtain mass spectra. The results are plotted to observe the linear curve of Regge Trajectories as well. The study is aimed at upcoming experiments particularly PANDA and others namely BESIII that shall look for strange resonances.

Heavy meson spectroscopy / **30**

Quark mass dependence on D_{s0}^* resonance

Authors: Fernando Gil[1]; Raquel Molina Peralta[2]

[1] *IFIC*

[2] *UV-IFIC*

Corresponding Author: fernando.gil@ific.uv.es

We study the light and heavy quark mass dependence of the low-lying charmed mesons in the framework of one-loop HHχPT. The low energy constants are determined by analyzing the available lattice data from different LQCD simulations. Model selection tools are implemented to determine the relevant parameters as required by data with a higher precision. Discretization and other effects due to the charm quark mass setting are discussed.
By fitting energy levels we extract results for the D_{s0}^* quark mass dependence

Hypernuclei and kaonic atoms / **31**

Ξ-hypernuclei spectroscopy with the S-2S spectrometer

Author: Tomofumi Nagae[1]

[1] *Kyoto University*

Corresponding Author: nagae@scphys.kyoto-u.ac.jp

We are going to complete the construction of the S-2S spectrometer at the K1.8 beam line in J-PARC hadron hall, in May, 2023. The S-2S spectrometer is composed of "QQD" magnets to measure the missing-mass spectrum of ${}^{12}\mathrm{C}(K^-, K^+)^{12}_{\Xi}\mathrm{Be}$ reaction with a good energy resolution of 2 MeV(FWHM), which is so far the best energy resolution applied for the reaction. The existence of Ξ-hypernuclei is recently confirmed in several emulsion events, and attraction between Ξ^- and p is demonstrated in LHC-ALICE femtoscopy studies. However, better resolution and statistics data on the Ξ-hypernuclei are needed to pin down both real and imaginary parts of the ΞN potentials. In this talk, perspectives of the S-2S experimental programs will be also discussed.

Hadron decays, production and interaction / **32**

Amplitude analyses of $D_s^+ \to \pi^+\pi^-\pi^+$

Author: Keri Vos[1]

[1] *Siegen University*

Corresponding Author: keri.vos@uni-siegen.de

The study of a heavy meson decaying to three lighter mesons can be described, in general, as quasi-two-body processes through the production of resonance intermediate states. To understand the dynamics of these processes, a full amplitude analysis of the corresponding Dalitz Plot is necessary. The most traditional way to describe it is to use the so-called Isobar Model where the total amplitude is written as a coherent sum of the individual resonance amplitudes, typically described as a product of the resonance propagator, angular functions, and form factors. However, the Isobar Model turns out to be inadequate when dealing with broad scalar states and another approach such as the quasi-model-independent partial wave analysis (QMI) is an interesting alternative. In this talk, we show recent LHCb results of $D_s^+ \to \pi^+\pi^-\pi^+$ and $D^+ \to \pi^+\pi^-\pi^+$ amplitude analyses.

New facilities / **33**

Particle Identification with the ePIC detector at the EIC

Author: Roberto Preghenella[1]

[1] *Istituto Nazionale di Fisica Nucleare*

Corresponding Authors: chandradoy.chatterjee@ts.infn.it, roberto.preghenella@bo.infn.it

The ePIC detector is being designed as a general-purpose detector for the Electron-Ion Collider (EIC) to deliver the full physics program. One of the key challenges at the EIC is particle identification (PID), which requires excellent separation of pions, kaons, and protons over a wide phase space with significant pion/electron suppression. To address this challenge, ePIC utilises multiple advanced particle identification technologies.

The talk will cover the PID subsystems of the ePIC detector, with a specific emphasis on high-momentum particle-identification systems that use DIRC and RICH techniques to exploit Cherenkov light emission from charged particles. R&D activities are under way to evaluate the use of SiPMs as photosensors for RICH detectors, explore the capabilities of novel LAPPD detectors and assess the compatibility of commercial MCP-PMT with the experiment's magnetic field conditions. The presentation will also include a discussion of the projected performance of the PID detector system, which has been studied in detail using Geant4 simulations, as well as potential future upgrades.

Heavy meson spectroscopy / **35**

Ds0*(2317) and Ds1(2460) as hadronic molecules from the perspective of their productions

Author: Li-Sheng Geng[1]

[1] *Beihang University*

Corresponding Author: lisheng.geng@icloud.com

Ds0*(2317) and Ds1(2460) have long been conjectured to be DK and D*K bound states. In this talk, we show that their productions in B decays can be well explained with the triangle mechanism in the molecular picture. Furthermore, we show for the first time that their prompt production yields in

electron-positron collisions can be explained in the coalescence model. The comparison with the statistical model support strongly their nature being hadronic molecules instead of conventional csbar states. The talk is based on the following publications: 2209.01103, 2211.01846.

Hadrons in hot and nuclear environment / **36**

Pion-nucleon ¥$sigma$ term by the pion deep bound states

Authors: Natsumi Ikeno[None]; Satoru Hirenzaki[1]

[1] *Nara Women's University*

Corresponding Author: zaki@cc.nara-wu.ac.jp

We investigate the possibility to determine the value of the pion–nucleon sigma term precisely by the experimental observables of the deeply bound pionic atoms. We discuss the sensitivity of the observables of the deeply bound pionic atoms to the value of the sigma term. We find that the gap of the binding energies and the width of the deeply bound pionic states are good quantities for the sigma term determination by the experimental data. We also discuss the expected difficulties for the accurate determination of the value of the sigma term due to the correlation between the sigma term and the potential parameter in the pion–nucleus optical potential. This abstarct is based on Ref. [1].

[1] Natsumi Ikeno et al., arXiv:2204.09211v2 [nucl-th]

Hypernuclei and kaonic atoms / **37**

Kaonic atom optical potential by the high precision data of Kaonic He atoms

Authors: Junko Yamagata-Sekihara[1]; Satoru Hirenzaki[2]

[1] *Kyoto Sangyo University*

[2] *Nara Women's University*

Corresponding Author: zaki@cc.nara-wu.ac.jp

We investigate the constraints on the kaonic atom optical potential deduced from the latest extremely high precision data of the 2p states of the kaonic ^{3}He and ^{4}He atoms [1].

In our analyses, we consider the phenomenological optical potentials proportional to the nuclear density distributions, and the potentials inspired by the theoretical studies of the chiral unitary model and the $\chi 2$ fitting to the previous data. We find that the data in Ref. [1] together with the previous data of heavier kaonic atoms could provide the relevant constraints to the kaonic atom optical potential [2].

[1] T. Hashimoto et al. [J-PARC E62], Phys. Rev. Lett. 128, no.11, 112503 (2022).
[2] J. Yamagata-Sekihara et al., in preparation.

Light meson spectroscopy / **38**

Search for light Exotics in Coupled Channel Partial Waves Analyses Using PAWIAN

Author: Meike Küßner[1]

Co-authors: Bertram Kopf [1]; Fritz-Herbert Heinsius [2]; Ulrich Wiedner [3]

[1] *Ruhr-Universität Bochum*

[2] *Ruhr-Universitaet Bochum*

[3] *Ruhr-University Bochum*

Corresponding Author: mkuessner@ep1.rub.de

The light meson regime still is not too well understood and holds many open questions that can only be answered using sophisticated analysis strategies to describe the data.
In particular, searching and investigating exotic states e.g. glueballs, hybrids and tetraquarks is a real challenge among the many broad and overlapping resonances, but represent a key point towards a better understanding of QCD. Here, coupled channel partial wave analyses offer promising opportunities to disentangle the different states in the highly populated spectrum of light mesons. Combining data of different production mechanisms, as e.g. gluon-poor two-photon fusion events and gluon-rich reactions, makes the analyses and the achieved results much more reliable and better constrained.
To do so, challenges as interfering and overlapping resonances that decay into multiple channels and occur close to kinematical thresholds have to be dealt with in a proper way and sophisticated dynamical models - as e.g. K-matrix - need to be applied by properly taking fundamental constraints as unitarity and analyticity into account. Such models are, among others, implemented in the here used partial wave analysis package PAWIAN.
In the talk the methods applied together with new results of coupled channel analyses of different production mechanisms, as two-photon fusion, $\bar{p}p$ annihilation, and different scattering data samples, will be covered.

Hadrons and physics beyond the standard model / 39

Study of new physics effects in $\bar{B}_s \to D_s^{(*)}\tau^-\bar{\nu}_\tau$ semileptonic decays using Standard Model lattice QCD form factors and heavy quark effective theory

Author: Neus Penalva[1]

Co-authors: Eliecer Hernández [2]; Jonathan Flynn [3]; Juan Nieves [1]

[1] *IFIC (CSIC-UV)*

[2] *Universidad de Salamanca*

[3] *University of Southampton*

Corresponding Author: neuspe@ific.uv.es

We benefit from the lattice QCD determination of the Standard Model (SM) form factors for the $\bar{B}_s \to D_s^*$ and $\bar{B}_s \to D_s$ semileptonic decays carried out by the HPQCD collaboration in Refs. Phys. Rev. D 105, 094506 (2022) and Phys. Rev. D 101, 074513 (2020), and the heavy quark effective theory (HQET) relations for the analogous $B \to D^{(*)}$ decays obtained by F.U. Bernlochner et al. in Phys. Rev. D 95, 115008 (2017), to extract the leading and sub-leading Isgur-Wise functions for the $\bar{B}_s \to D_s^{(*)}$ decays. Further use of the HQET relations allows us to evaluate the corresponding form factors needed for a phenomenological study of new physics (NP) effects on the $\bar{B}_s \to D_s^{(*)}$ semileptonic decay. In this work, we conduct a study of NP effects on the $\bar{B}_s \to D_s^{(*)}\tau^-\bar{\nu}_\tau$ semileptonic decays by comparing tau spin, angular and spin-angular asymmetry distributions obtained within the SM and three different NP scenarios.

Hadron decays, production and interaction / 41

Measurements of charmonium decays from BESIII

Authors: Beijiang Liu[1]; Giulio Mezzadri[2]

[1] *Institute of High Energy Physics*

[2] *Istituto Nazionale di Fisica Nucleare*

Corresponding Authors: gmezzadr@fe.infn.it, liubj@ihep.ac.cn

This presentation will cover the branching fraction measurements of chi_cJ -> phi phi (J=0,1,2), eta_c(2S) -> pi+ pi- eta, chi_cJ -> Omega+ antiOmega- (J=0,1,2), and psi(3770) -> eta J/psi. The first three measurements are benefitted from the huge psi(2S) samples collected at BESIII and the transitions from psi(2S) to chi_cJ or eta_c(2S). The last one is based on e+ e- annihilation data sample collected at c.m.s 3.773 GeV. The branching fractions of the decays chi_cJ -> phi phi (J=0,1,2) have been measured most precisely, and the polarization parameters of chi_cJ -> phi phi have been determined for the first time via a helicity amplitude analysis. The evidence of eta_c(2S) -> pi+ pi- eta has been found in the decay sequence psi(3686) -> gamma eta_c(2S), eta_c(2S) -> pi+ pi- eta for the first time.The decays chi_cJ -> Omega+ anti-Omega- (J=0,1,2) have been observed for the first time with high significance, respectively, and the relevant branching fractions have been provided.The process e+ e- -> eta J/psi at a center-of-mass energy 3.773 GeV is observed for the first time, its Born cross-section is measured, and the branching fraction of psi(3770) -> eta J/psi is determined by a combined fit with the cross-sections at other energy points, after considering the interference effect for the first time.

Exotic hadrons and candidates / **42**

Search for hexaquark or di-baryon state at BESIII

Author: Beijiang Liu[1]

[1] *Institute of High Energy Physics*

Corresponding Authors: zhengb@usc.edu.cn, liubj@ihep.ac.cn

Using the data sets above 4.0 GeV collected by the BESIII detector on the Beijing Positron Electron Collider, which corresponds a total integrated luminosity greater than 1.5fb-1, the hexaquark or di-baryon state is searched through e+ e- -> 2(p pbar)and e+ e- -> p p pbar nbar pi- + c.c.. We observed these two final states for the first time, and the Born cross sections ofe+ e- -> 2(p pbar)have been measuredin 23center-of-mass energies ranges between 4.009 and 4.6 GeV. The average Born cross sections of the e+ e- -> p p pbar nbar pi- + c.c.within the energy range of (4.160, 4.380) GeV, (4.400, 4.600) GeV and (4.610, 4.700) GeV are measured. By fitting the invariant mass spectra of pn,pppiand pp, we found that their lineshape areconsistent with the phase space distribution, no significant resonance structures were found.

Hadrons and physics beyond the standard model / **43**

Hyperon physics at BESIII

Author: Beijiang Liu[1]

[1] *Institute of High Energy Physics*

Corresponding Authors: varvara.batozskaya@ncbj.gov.pl, liubj@ihep.ac.cn

With the large datasets on ⍰+⍰−-annihilation at the ⍰/⍰ and ⍰(3686) resonances collected at the BESIII experiment, multi-dimensional analyses making use of polarization and entanglement can shed new light on the production and decay properties hyperon-antihyperon pairs. In a series of

recent studies performed at BESIII, significant transverse polarization of the (anti)hyperons has been observed in □/□ or □(3686) to ΛΛ¯ , ΣΣ¯ , ΞΞ¯, and Ω−Ω¯+ and the spin of Ω− has been determined model independently for the first time. The decay parameters for the most common hadronic weak decay modes were measured, and due to the non-zero polarization, the parameters of hyperon and antihyperon decays could be determined independently of each other for the first time. Comparing the hyperon and antihyperon decay parameters yields precise tests of direct, Δ□ = 1 CP-violation that complement studies performed in the kaon sector.

Hadron decays, production and interaction / **44**

Light Meson decays at BESIII

Author: Beijiang Liu[1]

Co-author: Ilaria Balossino [2]

[1] *Institute of High Energy Physics*

[2] *Istituto Nazionale di Fisica Nucleare*

Corresponding Authors: balossino@fe.infn.it, liubj@ihep.ac.cn

The world's largest sample of J/ψ events accumulated at the BESIII detector offers a unique opportunity to investigate η and η′ physics via two body J/ψ radiative or hadronic decays. In recent years the BESIII experiment has made significant progresses in η/η′ decays. A selection of recent highlights in light meson spectroscopy at BESIII are reviewed in this report, including the observation of η′ → π+π−μ+μ−, observation of the cusp effect in η′ →π0π0η, search for CP-violation in η′ → π+π−e+e−, as well as the precision measurement of the branching fraction of η decays.

Exotic hadrons and candidates / **46**

Observation of isoscalar 1^(-+) spin-exotic state, η_1 (1855)

Authors: Beijiang Liu[1]; runqiu ma[2]

[1] *Institute of High Energy Physics*

[2] *Insititute of High Energy Physics, CAS*

Corresponding Authors: marq@ihep.ac.cn, liubj@ihep.ac.cn

Based on a sample of 10 billion Jψ events collected with the BESIII detector, a partial wave analysis of the decay Jψ □(→) γηη' is performed. An isoscalar state with exotic J^PC=1^(-+) quantum numbers, denoted as η_1 (1855), has been observed for the first time with statistical significance larger than 19σ. Its mass is consistent with the predicted mass of 1^(-+) hybrid from Lattice QCD. This is an observation of a new category of hadronic matter, which opens a new direction to complete the picture of spin-exotics.

Hadrons and physics beyond the standard model / **47**

R value measurements at BESIII

Author: Beijiang Liu[1]

[1] *Institute of High Energy Physics*

Corresponding Authors: francesca.demori@to.infn.it, liubj@ihep.ac.cn

The R value, defined as the ratio of inclusive hadronic cross section over dimu cross-section from electron-positron annihilation, is an important quantity that contributes to the SM prediction of the muon anomalous magnetic moment, and in the determination of the QED running coupling constant evaluated at the Z pole. At BESIII, the R value is measured with a total of 14 data points with the corresponding c.m. energy going from 2.2324 to 3.6710 GeV. The statistical uncertainty of the measured R is less than 0.6%. Two different simulation models, the LUARLW and a new Hybrid generated, are used and give consistent detection and initial-state radiation corrections.
An accuracy of better than 2.6% below 3.1 GeV and 3.0% above is achieved in the R values. The precise measurement will be used to calculate the muon anomalous magnetic moment and QED running coupling.

QCD and hadron structure / 48

Recent results of Baryon electromagnetic form factors at BESIII

Author: Beijiang Liu[1]

Co-author: Weiping Wang [2]

[1] *Institute of High Energy Physics*

[2] *USTC*

Corresponding Authors: weipingwang@ustc.edu.cn, liubj@ihep.ac.cn

The electromagnetic form factors (EMFFs) and the pair production cross sections of various baryons have been studied at BESIII, including the nucleon EMFFs and the hyperons. Anomalous enhancement behavior on the Lambda and Lambdac pair are observed. Besides, measurements on the SU(3) decuplet baryon have been
performed, such as Omega and Delta, and will be presented.

Light meson spectroscopy / 49

Light flavor vector mesons between 2 and 3 GeV at BESIII

Authors: Beijiang Liu[1]; Dong Liu[2]

[1] *Institute of High Energy Physics*

[2] *Helmholtz Institute Mainz*

Corresponding Authors: dliu13@mail.ustc.edu.cn, liubj@ihep.ac.cn

At BESIII, the lineshapes of e+e- ->phi eta', phi eta, KK, omega pi0, eta pipi, omega pipi are measured from 2.0 to 3.08 GeV, where resonant structures are observed in these processes. Multiple lineshapes of
intermediate state are obtained by a partial wave analysis of e+e- ->K+ K- pi0 pi0, K+K- pi0 and the structures observed provide essential input to understand the nature of phi2170. These results provide
important information for light flavor vector mesons i.e. excited rho, omega and phi, for energy regions above 2 GeV.

Hadrons and physics beyond the standard model / 50

Search for rare decays at BESIII

Authors: Beijiang Liu[1]; Bo Zheng[2]; Bo Zheng[2]; Jingshu Li[None]

[1] *Institute of High Energy Physics*

[2] *University of South China*

Corresponding Authors: zhengb@usc.edu.cn, zhengbo_usc@163.com, lijsh53@mail2.sysu.edu.cn, liubj@ihep.ac.cn

The BESIII experiment has collected 2.6B psi(2S) events and 10B J/psi events. The huge data sample provide an excellent chance to search for rare processes in charmonium decays. In this talk, we report the recent search for J/psi->D^-e+nu_e, psi(2S)->Lambda_c anti-Sigma^-. The big charmonium sample also produce millions of hyperons, which is used to study the weak decay of \Sigma^- ->pe-e-/Sigma^+X, \Xi^- ->\Xi^0e-nu_e, \Xi^0 ->Sigma e \nu. In addition, LFV process J/psi->e tau/e mu & BNV/LNV process D^0->p e/n e, and the FCNC process D^0 -> pi^0 nu \bar{nu} is also searched at BESIII.

Hadron decays, production and interaction / 51

Charmed meson decays at BESIII

Author: Beijiang Liu[1]

Co-author: Yunxuan Song [2]

[1] *Institute of High Energy Physics*

[2] *EPFL - Ecole Polytechnique Federale Lausanne (CH)*

Corresponding Authors: yunxuan.song@cern.ch, liubj@ihep.ac.cn

BESIII has collected 2.93 and 7.33 fb^-1 of e+e- collision data samples at 3.773 and 4.128-4.226 GeV, which provide the largest dataset of DDbar and DsDs pairs in the world, respectively.

In this talk, we will report the updated measurements of |Vcs| in Ds+->tau+ nu and the form factor studies in Ds+->K+K- e+ nu and pi+pi- e+ nu. In addition, we will report the most updated amplitude analyses of Cabibbo-favored and -suppressed Ds decays at BESIII, including the observation of a new a0-like state at 1.817 GeV, the branching fraction measurements of D mesons decay involving KL0 and multiple kaons/pions, and the doubly Cabibbo-suppressed decay D0 →K+pi-pi0. We will also report the improved measurement of the strong-phase difference in quantum-correlated DD decays. Finally, we will introduce prospect on measurements of charmed meson hadronic decays with the coming 20 fb-1 at 3.773 GeV data collected by BESIII.

Heavy baryon spectroscopy / 53

Recent charmed baryon results from BESIII

Author: Jiaxiu Teng[1]

[1] *USTC*

Corresponding Author: tengjx@mail.ustc.edu.cn

BESIII has collected 4.5 fb^-1 of e+e- collision data between 4.6 and 4.7 GeV. This unique data offers ideal opportunities to study Lambda_c+ decays. We will report the partial wave analysis of Lambda_c+ -> Lambda pi+ pi0 and the observations of Cabibbo-suppressed Decays Lambda_c+ decays, including Λ+c → nπ+ etc. In addition, we will report the form factor measurement in

Lambda_c+ -> Lambda e+ nu, the observation of Lambda_c+->p K-e+nu, and improved measurement of Lambda_c+->Xe+nu.

Plenary / **54**

Spectroscopy of hadrons with heavy quarks from lattice QCD

Author: Sasa Prelovsek[1]

[1] *University of Ljubljana*

Corresponding Author: sasa.prelovsek@ijs.si

I will review lattice QCD results on spectroscopy of conventional and exotic hadrons that contain heavy quarks. These theoretical studies are particularly motivated by the experimental discoveries of exotic hadrons, most of which contain heavy quarks.

New facilities / **55**

The LHCspin project: a polarized target experiment at LHC

Authors: Erhard Steffens[1]; Giuseppe Ciullo[2]; Luciano Libero Pappalardo[3]; Marco Santimaria[3]; Paolo Lenisa[3]; Pasquale Di Nezza[3]; Vittore Carassiti[2]

[1] *Univ. Erlangen*

[2] *FE*

[3] *Istituto Nazionale di Fisica Nucleare*

Corresponding Author: pappalardo@fe.infn.it

A polarized gaseous target, operated in combination with the high-energy, high-intensity LHC beams and a highly performing LHC particle detector, has the potential to open new physics frontiers and to deepen our understanding of the intricacies of the strong interaction in the non-perturbative regime of QCD. Specifically, the LHCspin project aims to perform spin physics studies in high-energy polarized fixed-target collisions using the LHCb detector. Given its forward geometry (2<□<5), the LHCb spectrometer is, in fact, perfectly suitable to cover the forward kinematics of these collisions. Furthermore, being designed and optimized for the detection of heavy hadrons, it will allow to probe the nucleon's structure through, e.g., the inclusive production of c- an b-hadrons, and ideal tool to access the essentially unexplored spin-dependent gluon TMDs. This configuration, with center-of-mass energies ranging from 115 GeV in pp interactions to 72 GeV per nucleon in collisions with ion beams, will allow to explore the nucleon's internal dynamics at unique kinematic conditions by covering a wide backward rapidity region, including the poorly explored high x-Bjorken and high x-Feynman regimes. This ambitious task poses its basis on the recent installation and commissioning of SMOG2, a storage-cell based unpolarized gas target in front of the LHCb spectrometer. With the installation of the proposed polarized target system, LHCb will become the first experiment delivering simultaneously unpolarized beam-beam collisions at 14 TeV and both polarized and unpolarized beam-target collisions at center-of-mass energies of the order of 100 GeV. The status of the LHCspin project is presented along with a selection of physics opportunities.

New facilities / **56**

The Project of Electron-Ion Collider in China

Author: Dexu Lin[1]

[1] *Institute of Modern Physics, China*

Corresponding Author: dxlin@impcas.ac.cn

The Electron-Ion Collider in China (EicC) will be constructed based on the upgrade of the High Intensity Heavy-ion Accelerator Facility (HIAF), which is now under construction in Huizhou of Guangdong. The Collider will provide a large integrated experimental platform for research on nuclear and particle physics and related scientific fields. Electron-nucleon scattering is an ideal tool to explore the internal structure of nucleon (nuclei) and its internal dynamical mechanisms. The electron-ion collision experiment with a high precision can measure the 3D structure function of nucleon, and thus reveal the dynamics of its internal strong interactions. The EicC, with center-of-mass energy ranged between 15 and 20 GeV, will focus on the research of the parton distributions of sea quarks in nucleon, the structures and properties of nuclear matter, and exotic hadrons, and so on. The energy region is close to the production threshold of heavy flavor quarks and has unique advantage in studying the heavy-flavor hadron spectrum with low background, which is possible to discover new exotic hadron states. This talk will report the prospects of the research on nucleon structure and hadron physics on EicC, and the progress of the research and development of its detectors.

New facilities / **57**

The progress of Super Tau Charm Facility in China

Authors: Zhujun Fang[1]; Xiaorong Zhou[2]

[1] *USTC*

[2] *University of Science and Technology of China*

Corresponding Author: fzj19@ustc.edu.cn

The proposed STCF is a symmetric electron-positron beam collider designed to provide e+e− interactions at a center-of-mass energy from 2.0 to 7.0 GeV. The peaking luminosity is expected to be 0.5×10³⁵ cm^{−2}s^{−1}. STCF is expected to deliver more than 1 ab^{−1} of integrated luminosity per year. The huge samples could be used to make precision measurements of the properties of XYZ particles; search for new sources of CP violation in the strange-hyperon and tau−lepton sectors; make precise independent measurements of the Cabibbo angle to test the unitarity of the CKM matrix; search for anomalous decays with sensitivities extending down to the level of SM-model expectations and so on. In this talk, the physics interests and the recent progress on the STCF project R&D will be introduced.

QCD and hadron structure / **58**

Electroweak structure of the nucleon

Authors: Fernando Alvarado[1]; Luis Alvarez-Ruso[None]

[1] *IFIC*

Corresponding Author: falvar@ific.uv.es

Nucleon electroweak form factors contain relevant details about hadronic structure and strong interactions in the nonperturbative regime. This information is encoded in their dependence on the momentum transferred to the nucleon by external probes but also in their quark-mass dependence, which is accessible by Lattice QCD (LQCD) simulations.

In our study we rely on relativistic chiral perturbation theory (ChPT) in two flavors with explicit Delta(1232) degrees of freedom. For the electromagnetic isovector form factors we also employ dispersion theory to account for rho-dominated isovector pion-pion interaction and its quark-mass dependence in the t-channel nonperturbatively and beyond NLO in ChPT. With this framework we explore how LQCD data are described in both the Q2 and mpi dimensions simultaneously. Furthermore, we have performed an NNLO calculation of the nucleon axial form factor, extracting relevant low-energy constants from a combined set of recent LQCD results from different collaborations.

Analysis tools / **60**

Computing polarimeter vector fields with symbolic amplitude models

Author: Remco de Boer[1]

Co-authors: Miriam Fritsch [1]; Stefan Pflüger [1]; Wolfgang Gradl [2]

[1] *Ruhr University Bochum*

[2] *Johannes Gutenberg Universitat Mainz*

Corresponding Author: remco.deboer@rub.de

Recently, the LHCb collaboration has computed the *aligned polarimeter vector field* for the dominant hadronic decay mode of the Λ_c baryon (arXiv:2301.07010). The polarimeter vector field is a model-independent representation of the decay rate for polarized decays that can be used to measure polarisation and to improve the sensitivity of amplitude models.

The computations were performed with a new approach using methods from the ComPWA project. Amplitude models are implemented symbolically with a Computer Algebra System, so that the mathematics can be easily inspected. The symbolic model then serves as a template for fast, numerical back-ends like JAX and TensorFlow. This *symbolic approach* makes it easy to formulate and fit amplitude models in a self-documenting workflow with high performance on large, multidimensional data samples. In addition, the approach proved flexible enough to compute these more complicated polarimeter vector fields.

Heavy baryon spectroscopy / **61**

Pentaquark picture for singly heavy baryons based on a chiral model

Author: Daiki Suenaga[1]

[1] *RIKEN Nishina Center*

Corresponding Author: daiki.suenaga@riken.jp

Recently, a novel pentaquark picture ($Qqq\bar{q}q$) in addition to the conventional three-quark one (Qqq) for describing the Roper-like singly heavy baryons such as $\Lambda_c(2765)$ and $\Xi_c(2970)$ has been invented, based on a chiral model. In this talk, I review roles of chiral symmetry and the $U(1)_A$ axial anomaly for those two states, and present our prediction of the existence of a negative-parity and 5-quark dominant Λ_c baryon.

Hadrons in hot and nuclear environment / **62**

Equation of State for Neutron Stars, Supernovae and Neutron Star Mergers

Author: Adriana Raduta[1]

[1] *IFIN-HH*

Corresponding Author: araduta@nipne.ro

Neutron stars and explosive astrophysical systems - such as supernovae or compact star binary mergers - represent natural laboratories where extreme states of baryonic matter are populated. Modeling such environments assumes, among others, good understanding of zero and finite temperature equations of state (EoS). In this talk I shall first discuss the relation between nuclear matter EoS and neutron star properties. Then I shall review thermal properties of a number of general purpose EoS. Properties of purely nucleonic EoS will be confronted with properties of EoS which account for hyperons, meson condensates, Deltaresonances and quarks. Correlations with parameters of nuclear matter will be discussed along with the dependence on the theoretical framework.

Hadron decays, production and interaction / 63

Phenomenology of hyperon non-leptonic decays

Author: Nora Salone[1]

[1] *National Centre for Nuclear Research - NCBJ*

Corresponding Author: nora.salone@ncbj.gov.pl

Recent results published in Nature Physics (2019) by the BESIII collaboration revealed a substantial discrepancy of the Lambda baryon decay parameter with respect to the world average at the time. We took this development as the starting point for a feasibility study of CP violation tests in strange baryon decays at next generation J/ψ factories. The proposed formalism allows for a direct comparison of particle and antiparticle properties, analyzing the weight of spin-correlation and polarization terms on such tests.
The same weak non-leptonic decays can be studied using chiral perturbation theory (χPT), where S- and P-wave amplitudes are computed up to one-loop corrections. We investigate the behavior of such spherical waves in the light of the recent experimental updates and in a fully relativistic framework.

Hadron decays, production and interaction / 64

Production of D-wave states of bc quarkonium at the LHC

Author: Ilia Belov[1]

[1] *Istituto Nazionale di Fisica Nucleare*

Corresponding Author: ilia.belov@ge.infn.it

We study the hadronic production of D-wave states of $\bar{b}c$ quarkonium. The relative yield of such states is estimated for kinematic conditions of LHC experiments. The direct $B_c(D)$ production is complemented by NRQCD contributions being the same order $O(v^4)$. The NRQCD matrix elements are estimated within naive velocity scaling rule.

Exotic hadrons and candidates / **65**

Can Constituent Gluons Describe Hybrids and Glueballs?

Author: Eric Swanson[1]

[1] *University of Pittsburgh*

Corresponding Author: swansone@pitt.edu

A simple constituent model of gluodynamics that is motivated by lattice field theory and the QCD Hamiltonian in Coulomb gauge is applied to descriptions of hybrid meson flavor mixing and vector hybrid configuration mixing. Good agreement with lattice gauge computations is obtained for flavor multiplet masses, while mixing angles are in approximate agreement, given large errors. The configuration mixing results are also in rough agreement with lattice NRQCD calculations.

Heavy meson spectroscopy / **66**

K-matrix Analysis of e+e– Annihilation in the Bottomonium Region

Author: Eric Swanson[1]

[1] *University of Pittsburgh*

Corresponding Author: swansone@pitt.edu

We perform the first global and unitary analysis of e+e– ⟶ b¯b cross sections. We analyze exclusive cross sections in the BB¯, B∗B¯(+c.c.), B∗B¯∗, Bs∗B¯s∗, Υ(nS)π+π– and hb(nP)π+π– channels as well as the total inclusive cross section for b¯b production. Pole positions and residues are determined for four vector states, which we associate with the Υ(4S), Υ(10750), Υ(5S) (or Υ(10860)), and Υ(6S) (or Υ(11020)). We find strong evidence for the new Υ(10750) recently claimed by Belle.

Hadron decays, production and interaction / **67**

The LHCb state PΛ_{psi s} (4338) as a triangle singularity

Author: Eric Swanson[1]

[1] *University of Pittsburgh*

Corresponding Author: swansone@pitt.edu

We present a model for the J/ψ Λ spectrum in B– ⟶ J/ψ Λ p¯ decays, including the PΛ_{psi s} (4338) baryon recently observed by the LHCb collaboration. We assume production via triangle diagrams which couple to the final state via non-perturbative interactions which are constrained by heavy-quark and SU3-flavor symmetry. The bulk of the distribution is described by a triangle diagram with a color-favored electroweak vertex, while the sharp PΛ (4338) enhancement is due to the ψs triangle singularity in another diagram featuring a 1/2– baryon consistent with Σc(2800).

Exotic hadrons and candidates / **68**

Light QCD exotics at BESIII

Author: Isabella Garzia[None]

Corresponding Author: garzia@fe.infn.it

Using the world's largest samples of J/psi and psi(3686) events produced in e+e- annihilation, BESIII is uniquely positioned to study light hadrons in radiative and hadronic charmonium decays. In particular, exotic hadron candidates including multiquark states, hybrid mesons and glueballs can be studied in high detail. Recent highlights on the light exotics searches, including the observation of an iso-scalar spin-exotic 1-+ state η1(1855) in J/ψ→γηη′, the observation of X(2600) in J/ψ→γπ+π-η′ and a PWA of Jpsi gamma KsKspi0, will be presented.

New facilities / **69**

Status and Prospects of the LEPS2 Solenoid Spectrometer

Author: Masayuki Niiyama[1]

[1] *Kyoto Sangyo University*

Corresponding Author: niiyama@cc.kyoto-su.ac.jp

A high-intensity GeV gamma beam line, LEPS2, was constructed at SPring-8 in Japan in 2013. A large acceptance solenoidal spectrometer has been constructed to detect charged particles, neutrons, and photons. Since 2021, physics data has been collected in order to study kaonic nuclei, and exotic hadrons. Photoproduction of hyperon resonances and mesons has been successfully observed. In this presentation, we will discuss the physics motivations and present preliminary results from our first beam.

Exotic hadrons and candidates / **70**

A comparison between the P_c and P_{cs} systems

Author: Kan Chen[1]

Co-authors: Shi-Lin Zhu [2]; Zi-Yang Lin [2]

[1] 西北大学

[2] 北京大学

Corresponding Author: 20220130@nwu.edu.cn

We construct the effective potentials of the P_c and P_{cs} states based on the SU(3)$_f$ symmetry and heavy quark symmetry. Then we perform the coupled-channel analysis of the lowest isospin P_c and P_{cs} systems. The coupled-channel effects play different roles in the P_c and P_{cs} systems. In the P_c systems, this effect gives minor corrections to the masses of the P_c states. In the P_{cs} system, the $\Lambda_c\bar{D}_s - \Xi_c\bar{D}$ coupling will shift the mass of the $P_{cs}(4338)$ close to the $\Xi_c\bar{D}$ threshold. The $\Lambda_c\bar{D}_s^{(*)} - \Xi_c\bar{D}^{(*)}$ coupling will also produce extra P_{cs} states. We discuss the correspondence between the P_c and P_{cs} states. Our results prefer that the SU(3) partners of the observed $P_c(4312)$, $P_c(4440)$, and $P_c(4457)$ in the P_{cs} system have not been found yet.

New facilities / **71**

The J-PARC Hadron Experimental Facility Extension Project

Author: Fuminori Sakuma[None]

Corresponding Author: sakuma@ribf.riken.jp

The J-PARC Hadron Experimental Facility was constructed with an aim to explore the origin and evolution of matter in the universe through the experiments with intense particle beams. In the past decade, many results on particle and nuclear physics have been obtained at the present facility. To expand the physics programs to unexplored regions never achieved, the extension project of the Hadron Experimental Facility has been extensively discussed. We will discuss the physics of the extension of the Hadron Experimental Facility for resolving the issues in the fields of the strangeness nuclear physics, hadron physics, and flavor physics.

Hadrons in hot and nuclear environment / **72**

Light-flavour hadron production with ALICE at LHC

Author: Alberto Calivà[1]

[1] *University of Salerno*

Corresponding Author: alberto.caliva@cern.ch

Light-flavour hadrons constitute the bulk of particle production in high-energy hadronic collisions at LHC. Measurements of their transverse-momentum spectra, integrated yields, and relative abundances as a function of multiplicity provide crucial information on the hadronization process and on the properties of the system created in different collision systems. These multi-differential measurements in the strangeness sector offer an additional opportunity to investigate the origin of the strangeness enhancement phenomenon in small collision systems.

In this talk, a comprehensive overview of recent ALICE measurements of pion, kaon, proton, and strange hadron production in pp, pA, and AA collisions will be presented. These results will be discussed in the context of state-of-the-art phenomenological models.

Exotic hadrons and candidates / **73**

On the molecular $\eta_1(1855)$ and its SU(3) partners

Authors: Mao-Jun Yan[1]; Adolfo Guevara[1]; Jorgivan Dias[1]; Feng-Kun Guo[1]; Bing-song Zou[2]

[1] *Institute of Theoretical Physics, Chinese Academy of Sciences*

[2] *Institute of Theoretical Physics, Beijing*

Corresponding Author: yanmaojun@itp.ac.cn

In this work, we interpret the newly observed $\eta_1(1855)$ resonance with exotic $J^{PC} = 1^{-+}$ quantum numbers in the $I = 0$ sector, reported by the BESIII Collaboration, as a dynamically generated state from the interaction between the lightest pseudoscalar mesons and axial-vector mesons. The interaction is derived from the lowest order chiral Lagrangian from which the Weinberg-Tomozawa term is obtained, describing the transition amplitudes among the relevant channels, which are then unitarized using the Bethe-Salpeter equation, according to the chiral unitary approach. We evaluate the $\eta_1(1855)$ decays into the $\eta\eta'$ and $K\bar{K}^*\pi$ channels and find that the latter has a larger branching fraction. We also investigate its SU(3) partners, and according to our findings, the $\pi_1(1400)$ and $\pi_1(1600)$ structures may correspond to dynamically generated states, with the former one coupled mostly to the $b_1\pi$ component and the latter one coupled to the $K_1(1270)\bar{K}$ channel. In particular, our result for the ratio $\Gamma(\pi_1(1600) \to f_1(1285)\pi)/\Gamma(\pi_1(1600) \to \eta'\pi)$ is consistent with the measured value, which supports our interpretation for the higher π_1 state. We also report two poles with a mass about 1.7~GeV in the $I = 1/2$ sector, which may be responsible for the $K^*(1680)$.

We suggest searching for two additional η_1 exotic mesons with masses around 1.4 and 1.7~GeV. In particular, the predicted $\eta_1(1700)$ is expected to have a width around 0.1~GeV and can decay easily into $K\bar{K}\pi\pi$.

Hypernuclei and kaonic atoms / **74**

Double-Λ and Ξ hypernuclei : Findings and Prospects

Author: Kazuma Nakazawa[1]

[1] *High Energy Nuclear Physics Lab./ Faculty of education, Gifu Univ.*

Corresponding Author: kazuma.nakazawa@a.riken.jp

Double-Lambda; and Xi; hypernuclei : Findings and Prospects

Kazuma Nakazawa ^{1, 2}

¹ High Energy Nuclear Physics Laboratory, RIKEN
² Faculty of education, Gifu University, Japan

Since the discovery of the doubly-strange hypernucleus in 1963, many efforts have been made but no new discoveries have been made. In the 1980s, we introduced the Emulsion-Counter "Hybrid-method" combining real-time detectors and nuclear emulsion, which led to the discovery of the charn and beauty particles, to our experiment to search for doubly-strange hypernucleus. As a result, we confirmed the existence of double-Lambda; hypernucleus, which decayed sequentially, at an absorption point of a Xi;⁻ particle in the KEK-E176 experiment. With developed hybrid method, the E373 (KEK) experiment succeeded in the unique identification of ⁶<sub>Lambda;Lambda;</su where the interaction between Lambda; and Lambda; particles was understood to be weakly attractive. In the further improved E07 (J-PARC) experiment, we succeeded in detecting 33 cases of doubly-strange hypernuclei and the ground state of Xi; hypernuclei. From the 47 cases we have detected so far and one case in 1963, we found that the interaction between two Lambda; particles is a weak attraction and that the energy at which two Lambda; particles bind to a nucleus seems to depend linearly on the nuclear mass number. Additionally, the existence of the Xi; hypernucleus was confirmed, then the interaction between the Xi; and nucleon works attractively. Regarding the ¹⁵_{Xi;}C hypernuclei, the level stracture can be seen. We are currently developing an efficient detection method for the production and decay of doubly-strange hypernuclei by probing the entire volume of the emulsion and applying a machine learning model, without relying on information from real-time detectors. This development is expected to detect a large number of double-Lambda; hypernuclei emitted from the K⁻ reaction point as well as the Xi;⁻ absorption, which shall conduce to very important and more reliable information for understanding baryons in a unified manner under SU(3)_{f} symmetry.

Hadrons in hot and nuclear environment / **75**

A laboratory for QCD: how to employ LHC to study hadron-hadron interactions

Author: Valentina Mantovani Sarti[1]

[1] *TUM*

Corresponding Author: valentina.mantovani-sarti@tum.de

Improving the knowledge on how the strong interaction acts among hadrons is one of the frontiers in nuclear physics. A large amount of interactions among stable or unstable hadrons have not been

measured yet and theoretical calculations with effective lagrangians and/or starting from first principles, with quarks and gluons as degrees of freedom, are still under development and in need of experimental data.
For nucleons, scattering experiments and measurements of nuclei binding energies have been successfully employed in the past to constrain two- and three-body interactions but when hadrons containing at least one strange or charm quark are involved, the experimental access becomes extremely challenging. The strong interaction involving strange and charm hadrons is relevant in many aspects such as the existence of exotic states and resonances whose nature is still not understood.
In this talk we show how we are able to constrain the hadronic interactions in the baryon and meson sector with strangeness and charm by means of correlations measured in different colliding systems at LHC. This experimental technique, known as femtoscopy, represents a perfect tool to access experimentally the strong interaction with an unprecedented precision in a large variety of hadronic systems.

Hadron decays, production and interaction / **76**

Inclusive production of J/ψ, ψ(2S), and Υ states in pNRQCD

Author: Antonio Vairo[None]

Co-authors: Hee Sok Chung [1]; Nora Brambilla [2]; Xiangpeng Wang [2]

[1] *Technical University of Munich*

[2] *TUM*

Corresponding Author: xiangpeng.wang@tum.de

Under some assumptions on the hierarchy of relevant energy scales, we compute the nonrelativistic QCD (NRQCD) long-distance matrix elements (LDMEs) for inclu- sive production of J/ψ, ψ(2S), and Υ states based on the potential NRQCD (pNRQCD) effective field theory. Based on the pNRQCD formalism, we obtain expressions for the LDMEs in terms of the quarkonium wavefunctions at the origin and universal gluonic cor- relators, which do not depend on the heavy quark flavor or the radial excitation. This greatly reduces the number of nonperturbative unknowns and substantially enhances the predictive power of the nonrelativistic effective field theory formalism. We obtain improved determinations of the LDMEs for J/ψ, ψ(2S), and Υ states thanks to the universality of the gluonic correlators, and obtain phenomenological results for cross sections and polarizations at large transverse momentum that agree well with measurements at the LHC.

Hypernuclei and kaonic atoms / **77**

Systematic measurements of the differential cross sections of Sigma-proton scatterings at J-PARC

Author: Koji Miwa[1]

[1] *Tohoku University*

Corresponding Author: koji.miwa.c4@tohoku.ac.jp

Study of the hyperon-nucleon (YN) interactions is vital to expand our knowledge on the nucleon-nucleon (NN) interaction to the generalized baryon-baryon (BB) interactions within the SU(3) flavor symmetry. It leads to an essential understanding of the baryon-baryon interactions as the interactions between quark clusters. Such inter-quark interactions should play an essential role in generating the repulsive core in the NN interactions. Furthermore, the YN interactions are also a foundation to describe the nuclear system with hyperons such as hypernuclei and neutron stars. Scattering observables between a hyperon and a nucleon are essential inputs to test and improve YN interaction theories. Until now, the hyperon-nucleon scattering experiments have been experimentally difficult

due to the short lifetime of the hyperons. Recently, the J-PARC E40 collaboration has succeeded in providing the differential cross sections of the Σ^+p, Σ^-p and $\Sigma^-p \to \Lambda n$ channels systematically. A 10% level accuracy of the differential cross section has been realized for a narrow angular step of $d\cos\theta$ = 0.1. The differential cross sections of the Σ^-p elastic and $\Sigma^-p \to \Lambda n$ inelastic scatterings are reproduced by theoretical models rather well because these interactions are mainly due to multiplet forces of 27-plet and 10*-plet that can be predicted based on the NN interaction under the SU(3) flavor symmetry. On the other hand, the measured differential cross sections of the Σ^+p channel were very different from any theoretical models. This is because the main contribution comes from a completely unknown multiplet force of 10-plet which includes a repulsive force due to the Pauli-forbidden state in the quark level. By combining all the experimental information, we expect so-called "realistic"hyperon-nucleon interactions will be established in the near future.
We also plan a new Λp scattering experiment, J-PARC E86, as a future project. We also would like to introduce the future project.

QCD and hadron structure / **78**

Mapping Neutrino-Nuclei Interactions Using Electrons

Author: Rhidian Williams[1]

[1] *University of York*

Corresponding Author: rhidian.williams@york.ac.uk

Next generation neutrino facilities, such as DUNE, rely on precise modelling of neutrino induced hadron knockout processes from nuclei in the detector medium (e.g Argon) to determine the initial (untagged) neutrino beam energy and determine the neutrino flux. However, uncertainty in the modelling of these nuclear interactions is currently the largest systematic uncertainty in extracting the key physics, including the neutrino oscillation parameters.

Within the e4nu collaboration at the Thomas Jefferson National Laboratory (JLab) we address this by studying the same knockout reactions exploited at neutrino facilities, but using incident electron beams of precisely determined energy (Up to 12 GeV). A range of hadron knockout reactions from light to heavy nuclesr targets are determined with nearly complete acceptance by the CLAS12 spectrometer. This expansive data set will be used to benchmark nuclear calculations (GiBUU and GENIE) in the poorly constrained kinematic regime of DUNE and will directly affect the achievable accuracy for the key physics outputs of DUNE. Our current results, the first from e4nu at CLAS12, will be presented and implications for neutrino facilities discussed.

QCD and hadron structure / **79**

Insight into Strong QCD and the Emergence of Mass from N* Experiments

Author: Victor Mokeev[1]

[1] *Jefferson Lab*

Corresponding Author: mokeev@jlab.org

Studies of nucleon resonance (N*) electroexcitation amplitudes (gvpN* electrocouplings) within a broad range of virtual photon four-momentum squared Q2 offer unique information on many facets of the strong interaction in the regime of large QCD running coupling (sQCD regime) seen in the generation of different resonances. The results on the gvpN*electrocouplings from exclusive meson electroproduction data measured with the CLAS detector at JLab and their impact on understanding of sQCD dynamics will be presented in this talk. These CLAS data have provided the first and only available results on the evolution of the gvpN* electrocouplings with Q2 to 5 GeV2 for most N*states in the mass range

up to 1.8 GeV. A successful description of the CLAS results on the Q2-evolution of the Delta(1232)3/2+, N(1440)1/2+, and Delta(1600)3/2+ electrocouplings has been achieved within the continuum Schwinger method (CSM) by employing the same momentum dependence of the dressed quark mass inferred from the QCD Lagrangian, which also reproduces the experimental results on the pion elastic electromagnetic form factor and parton distribution functions, and the nucleon elastic form factors. This success has conclusively demonstrated the capability for gaining insight into the emergence of hadron mass (EHM) from the exploration of the Q2-evolution of the gvpN electrocouplings. These studies also allow us to establish either universality or environmental sensitivity of the dressed quark mass function and to explore qq-correlation amplitudes of different spin-parities and the mixing between configurations of different orbital angular momentum. Exploration of the resonance electroexcitation with the CLAS12 detector and in the future with a possible 22 GeV machine at JLab offer the only foreseen opportunity to extend information on the gvpN*electrocouplings for Q2 from 5-30 GeV2. Analyses of these results will cover the full range of distances where the dominant part of hadron mass and N* structure emerge from QCD.

Hadrons and physics beyond the standard model / 80

The CUORE and CUPID double beta decay experiments

Author: The CUORE and CUPID Collaborations[None]

Corresponding Author: stefano.delloro@gssi.infn.it

The Cryogenic Underground Observatory for Rare Events (CUORE) is the first bolometric experiment searching for neutrinoless double-beta ($0\nu\beta\beta$) decay that has been able to reach the one-tonne mass scale. The detector, located at the LNGS in Italy, consists of an array of 988 TeO_2 crystals arranged in a compact cylindrical structure of 19 towers. CUORE began its first physics data run in 2017 at a base temperature of about 10 mK and in April 2021 released its third result of the search for $0\nu\beta\beta$, corresponding to a tonne-year of TeO_2 exposure. This is the most sensitive measurement of $0\nu\beta\beta$ decay in ^{130}Te ever conducted, with a median exclusion sensitivity of 2.8×10^{25} yr. We find no evidence of $0\nu\beta\beta$ decay and set a lower bound of 2.2×10^{25} yr at a 90% credibility interval on the ^{130}Te half-life for this process. The next-generation of experiments aims at covering the Inverted-Ordering region of the neutrino mass spectrum, with sensitivities on the half-lives greater than 10^{27} years. CUPID (CUORE Upgrade with Particle IDentification) will search for the $0\nu\beta\beta$ decay of ^{100}Mo and will exploit the existing cryogenic infrastructure of CUORE. Thanks to about 1600 scintillating Li_2MoO_4 crystals, enriched in ^{100}Mo, coupled to $\sim$1700 light detectors CUPID will have a simultaneous readout of heat and light that will allow for particle identification, and thus a powerful alpha background rejection. Numerous studies and R&D projects are currently ongoing in a coordinated effort aimed at finalizing the design of the CUPID detector and at assessing its performance and physics reach.
In this talk, we present the current status of CUORE search for $0\nu\beta\beta$ and outline the forthcoming steps towards the construction of the CUPID experiment.

Exotic hadrons and candidates / 81

Dynamics of J/psi photoproduction near threshold

Author: Daniel Winney[1]

[1] *South China Normal University*

Corresponding Author: daniel.winney@gmail.com

The near threshold region of heavy quarkonium has received a lot of attention with possible applications to a wide breadth of physics. I will discuss the recent JPAC analysis of new Jefferson Lab data from the GlueX and Jpsi-007 experiments. I will discuss the still wide array of physics scenarios that may underpin the near threshold data including strong coupled channel effects to open charm states and the existence of hidden charm pentaquarks. I highlight the need to disentangle the competing

dynamical processes especially as it relates to extracting meaningful quantities related to nucleon structure and or exotic hadrons.

QCD and hadron structure / **82**

A novel approach for determining spatial moments of the proton charge density

Author: Mariam Atoui[None]

Corresponding Author: atoui@ijclab.in2p3.fr

The internal structure of the nucleon is a field of intensive study. This structure can be experimentally probed through electron elastic scattering off a proton target. This allows the extraction of the proton electric and the magnetic form factors which characterize the charge and the magnetization densities. The spatial moments of the proton charge density are extracted using the electric form factor (EFF) data. Up to now, methods rely on the evaluation of the EFF derivative in the limit of zero four-momentum transfer Q2 enabling access only to positive even orders of spatial moments. A novel approach 1 based on integral forms of the Fourier transform of the density function allows the determination of spatial moments of densities to any real-valued order. Within this approach, we compute spatial moments of different orders from a reanalysis of EFF data obtained with Rosenbluth separation and from low Q2 experiments covering a range of Q2 from 2×10^(-4) up to 8.8 GeV2. We pay specific attention to the evaluation of systematic uncertainties. In this context, the evaluation of the proton charge radius corresponding to the second-order moment of the proton charge density will be discussed.

New facilities / **83**

Intial physics performance and status of the MPD at NICA

Authors: Alejandro Ayala[1]; Ivonne Maldonado[None]

[1] *Instituto de Ciencias Nucleares, UNAM*

Corresponding Authors: ivonne.alicia.maldonado@gmail.com, ayala@nucleares.unam.mx

The Multi-Purpose Detector (MPD) is the flagship experiment in the Nuclotron-based Ion Collider fAcility (NICA) currently under construction at the Joint Institute for Nuclear Research (JINR) in Dubna, Russia. The experiment is designed to run in the collider mode. The MPD will study heavy-ion collisions in the energy range √sNN = 4-11 GeV, starting with Bi+Bi collisions at √sNN = 9.2 GeV. Its initial stage of operation is planned to start at the beginning of 2024. The MPD is an international collaboration consisting of 34 institutions from 10 countries with more than 450 participants. The MPD focuses on the study of the high net-baryon density region of the QCD phase diagram, to search for the conjectured critical end point, the onset and nature of the deconfinement phase transition and the onset of chiral symmetry restoration. In this presentation, we will review the current status of the MPD and its physics program. Also, the feasible physics measurements along with the expected performance of the detector subsystems will be presented.

Exotic hadrons and candidates / **84**

The Sill distribution and its application to exotic hadrons

Author: Francesco Giacosa[1]

Co-author: Vanamali Shastry [2]

[1] *Institut für Theoretische Physik, Johann Wolfgang Goethe-Universität, Frankfurt*

[2] *Jan Kochanowski University*

Corresponding Author: giacosa@th.physik.uni-frankfurt.de

We present a simple alternative to the relativistic Breit–Wigner distribution that (i) contains left-threshold effects, (ii) is properly normalized for any decay width, (iii) can be obtained as an appropriate limit in which the decay width is a constant, (iv) is easily generalized to the multi-channel case (v) as well as to a convoluted form in case of a decay chain and (vi) is simple to deal with. We first apply this distribution to well-known and conventional hadrons and then extend it to the study of exotic hybrid mesons (such as $\eta_1(1855)$ and $\pi_1(1600)$ as well as to some unsettled baryonic resonances.

Hadrons and physics beyond the standard model / 85

Probing low-energy QCD and BSM physics with light meson decays

Author: Sergi Gonzalez-Solis[1]

[1] *Los Alamos National Lab*

Corresponding Author: sergig@lanl.gov

Hadronic and radiative decays of light mesons decays offer a privileged environment to test QCD and search for physics beyond the Standard Model.
A new generation of precision experiments in hadron physics will soon offer new data that will have an impact on determinations of fundamental QCD parameters, such as the ratio of light quark masses or the η-η' mixing parameters, and provide important test of chiral symmetry breaking in QCD.
This new data will also provide sensitive probes to test potential new physics including searches for dark photons, light scalars and axion-like particles that will complement worldwide efforts to detect new light particles in the MeV-GeV mass range.
In this talk, I will give an update on the theoretical developments and discuss the experimental opportunities in this field, paying particular attention to the sensitivity of the η and η' mesons to leptophobic vector bosons and ALPs.

Light meson spectroscopy / 86

Studying the production mechanisms of light meson resonances in two-pion photoproduction: A Regge Approach

Authors: Łukasz Bibrzycki[1]; Nadine Hammoud[2]; Vincent Mathieu[None]; Robert Perry[3]; Adam Szczepaniak[4]

[1] *AGH University of Science and Technology*

[2] *Institute of Nuclear Physics PAS*

[3] *Univerisity of Barcelona*

[4] *Indiana University*

Corresponding Author: perryrobertjames@ub.edu

Hadron photoproduction is an essential experimental tool that gives important information on the spectroscopic and structural nature of hadrons. At large photon energies and low invariant mass of

the $\pi\pi$ subsystem, the differential cross section is dominated by the prominent $\rho(770)$ resonance. At forward angles, the production of the ρ is mostly diffractive, and exhibits a hierachy of partial waves which may be interpreted as the result of approximate s-channel helicity conservation (SCHC). Regge formalism captures these reaction properties in terms of the Pomeron exchange. In this talk, we present a theoretical model of two-pion photoproduction which encodes the prominent ρ resonance and the expected leading background contribution coming from the so-called "Deck" or "Drell-Soding" mechanism. After fitting this model to a subset of moments, we compare our predictions for the angular moments with the CLAS data. We observe the apparent breakdown of SCHC at larger four momentum transfers, and extract the t- dependence of the Regge amplitude residue function for subdominant exchanges.

QCD and hadron structure / **87**

Light cone parton distributions from lattice quantum chromodynamics

Author: Savvas Zafeiropoulos[1]

Co-authors: Anatoly Radyushkin ; Christopher Monahan ; Colin Egerer ; David Richards ; Eloy Romero ; Joseph Karpie ; Kostas Orginos [2]; Raza Sufian ; Robert Edwards

[1] *CNRS and Aix Marseille University*

[2] *College of William and Mary / JLab*

Corresponding Author: savvaslz@gmail.com

The light-cone definition of Parton Distribution Functions (PDFs) does not allow for a direct ab initio determination employing methods of Lattice QCD simulations that naturally take place in Euclidean spacetime. In this presentation we focus on pseudo-PDFs where the starting point is the equal time hadronic matrix element with the quark and anti-quark fields separated by a finite distance. We focus on Ioffe-time distributions, which are functions of the Ioffe-time ν, and can be understood as the Fourier transforms of parton distribution functions with respect to the momentum fraction variable ☒. We present lattice results for the case of the nucleon and the pion addressing among others the physical point and continuum extrapolations. We also incorporate our lattice data in the NNPDF framework treating them on the same footing as experimental data and discuss in detail the different sources of systematics in the determination of the non-singlet PDFs.
Finally, we will present the latest results of the HadStruc collaboration on the gluon, helicity and transversity PDF of the nucleon.

Hadrons in hot and nuclear environment / **88**

Thermal hadron resonances and Ward Identities: results for the QCD phase diagram

Author: Ángel Gómez Nicola[1]

Co-authors: Andrea Vioque-Rodríguez [1]; Jacobo Ruiz de Elvira [1]

[1] *Universidad Complutense Madrid*

Corresponding Author: gomez@ucm.es

I will present relevant results for the QCD phase diagram, within a combined framework of Ward Identities (WI) and Unitarized Effective Theories. On the one hand, WI provide model-independent results for susceptibilities with direct consequences on the relation between chiral and $U(1)_A$ restoration, key to understand the nature of the transition. Those WI also allow to derive scaling laws around T_c which can be checked with lattice screening masses. On the other hand, thermal resonances $f_0(500)$ and $K_0^*(700)$, generated within Unitarized Chiral Perturbation Theory $\pi\pi$ and $K\pi$

scattering at finite temperature,
play a key role regarding chiral and $U(1)_A$ restoration, through saturated scalar susceptibilities in those channels. Novel results for effective theories at nonzero isospin density and nonzero chiral imbalance would also be discussed.

Hadrons in hot and nuclear environment / 89

Quarkonium spectral functions in a bulk-viscous quark gluon plasma

Author: Lata Thakur[1]

Co-author: Yuji Hirono [2]

[1] *Asia Pacific Center for Theoretical Physics (APCTP), Pohang, South Korea*

[2] *Asia Pacific Center for Theoretical Physics (APCTP), South Korea*

Corresponding Author: thakurphyom@gmail.com

In recent years, the bulk viscosity of a quark gluon plasma is gaining
increasing attention concerning the beam energy scan program, since the bulk viscous effect is expected to be enhanced near a critical point. Here we address the question of whether heavy quarkonia, which are produced at the early stage of the heavy ion collisions, are sensitive
to the bulk viscous nature of the quark gluon plasma. If this is the case, we might be able to use heavy quarkonia as a probe of the non-equilibrium properties of the plasma. We incorporate the bulk-viscous
nature of the medium by deforming the distribution functions of thermal quarks and gluons, with which the dielectric permittivity is computed within the hard thermal loop approximation. The modified dielectric permittivity is used to calculate the in-medium heavy quark complex potential, which includes both perturbative Coulombic as well as non-perturbative string-like terms. Based on the modified heavy quark complex potential, we compute the quarkonium spectral function, with which the physical properties such as binding energies and decay widths are computed. We estimate experimental observables such as the ψ' to J/ψ ratio and the nuclear modification factor R_{AA} and discuss the implication of bulk viscous effect on them.

Hadrons and physics beyond the standard model / 90

Rare B decays in the LHC era

Author: Javier Virto[1]

[1] *U. Barcelona, ICCUB*

Corresponding Author: jvirto@ub.edu

I will tell the story (or part of it) of rare B decays of the last ~10 years.

Hadron decays, production and interaction / 91

Extracting the hadron-hadron interaction from the Nambu-Bethe-Salpeter wave functions: separable representation

Author: Lu Meng[1]

Co-authors: Evgeny Epelbaum [1]; Jambul Gegelia [1]

[1] *Ruhr University of Bochum*

Corresponding Author: lu.meng@rub.de

In this talk, I will introduce an alternative method of derivative expansion to extract the hadron-hadron potential from Nambu-Bethe-Salpeter (NBS) wave functions that is more efficient in handling large nonlocality. While the HALQCD method has become popular for obtaining hadron interactions from lattice QCD simulations, its derivative expansion has been criticized for its unclear systemic uncertainties. In this talk, I will use an example to demonstrate that general potentials cannot be accurately fixed by a small number of NBS wave functions. Additionally, we propose using the Ernst-Shakin-Thaler (EST) method to extract the hadron-hadron interaction from NBS wave functions. I will showcase its effectiveness using a realistic nucleon force, which is more efficient than the derivative expansion in handling very nonlocal interactions and also provides a way to estimate the systemic uncertainties of the derivative expansion.

Exotic hadrons and candidates / **92**

Clustering behavior of the tetraquark states

Authors: Lu Meng[1]; Shi-Lin Zhu[2]; Yan-Ke Chen[2]; Yao Ma[2]

[1] *Ruhr University of Bochum*

[2] *Peking University*

Corresponding Author: lu.meng@rub.de

In this presentation, we will discuss our benchmark test calculations of tetraquark states using several different few-body methods. These include the diffusion Monte Carlo (DMC), Gaussian expansion method (GEM), and resonant group method (RGM), within various nonrelativistic quark models such as Silvestre-Brac-Semay models and Salamanca chiral quark models. To investigate resonance states above the two-meson thresholds, we employ the complex scaling method with GEM and RGM. We consider the recently discovered Tcc state as the isospin singlet $cc\bar{q}\bar{q}$ system and use it as a criterion. Our results indicate that the chiral quark models overestimate the coupling between di-meson channels and diquark-antidiquark channels, which allows for a very deep Tcc bound state when complete configurations are included in DMC and GEM. To systematically investigate the doubly heavy tetraquark systems as both bound states and resonances, we only consider the di-meson channels. Our results show that the DMC method can accurately provide the real ground state (two-meson thresholds) of fully tetraquark systems if complete or proper channels are considered.

Hadron decays, production and interaction / **93**

Hadronisation of heavy quarks in small systems with ALICE at the LHC

Author: Tiantian Cheng[1]

[1] *GSI && CCNU*

Corresponding Author: tiantian.cheng@cern.ch

The production cross section of charm hadrons in hadronic collisions can be calculated using the factorisation approach as a convolution of three factors: the parton distribution functions (PDFs), the hard-scattering cross section at the partonic level, and the fragmentation functions of the produced heavy quarks into given species of heavy-flavour hadrons, which is assumed to be universal for

different collision systems. However, recent observations of enhanced baryon-to-meson production yield ratios in hadronic collisions, with respect to the same measurements performed in $\mathrm{e^+e^-}$ or $\mathrm{e^-p}$ collisions, suggest that the charm fragmentation fractions are not universal and depend on the collision system.

In this contribution, we present the measurements of $\mathrm{D^0}$, $\mathrm{D^+}$ and $\mathrm{D_s^+}$ meson production, together with those of Λ_c^+, $\Sigma_\mathrm{c}^{0,++}$, $\Xi_\mathrm{c}^{0,+}$ baryons, as well as the first result for Ω_c^0-baryon production at midrapidity in pp collisions at $\sqrt{s}$ = 13 TeV with ALICE. These measurements confirm that the baryon-to-meson yield ratios in hadronic collisions are significantly larger than those measured in $\mathrm{e^+e^-}$ collisions, and are compared with different predictions assuming either in-vacuum fragmentation or modified hadronisation mechanisms for hadronic collisions.

Furthermore, the first measurement of the nuclear modification factor R_pPb for prompt Ξ_c^0 baryons and non-prompt $\mathrm{D^0}$ mesons at $\sqrt{s_\mathrm{NN}}$ = 5.02 TeV will be shown. In p–Pb collisions, they provide important information about the cold nuclear matter (CNM) effects and help us understand how the possible presence of collectivity could influence the production of heavy-flavour hadrons. Finally, the measured charm fragmentation fractions and $c\overline{c}$ production cross section at midrapidity in pp collisions at $\sqrt{s_\mathrm{NN}}$ = 5.02 TeV will be reported.

Light baryon spectroscopy / **94**

Low-lying baryon resonances from lattice QCD

Author: Colin Morningstar[1]

Co-authors: Amy Nicholson [2]; Andre Walker-Loud [3]; Andrew Hanlon ; Barbara Mora ; Ben Hoerz ; Daniel Mohler [4]; Fernando Romero-Lopez ; John Bulava [5]; Joseph Moscoso ; Pavlos Vranas ; Sarah Skinner

[1] *Carnegie Mellon University*

[2] *Institute for Nuclear Theory*

[3] *College of William and Mary*

[4] *Helmholtz-Institut Mainz*

[5] *University of Southern Denmark, CP3-Origins Institute*

Corresponding Author: cmorning@andrew.cmu.edu

Recent results studying the masses and widths of low-lying baryon resonances in lattice QCD are presented. The s-wave scattering lengths with both total isospins $I = 1/2$ and $I = 3/2$ are inferred from the finite-volume spectrum below the inelastic threshold together with the $I = 3/2$ p-wave containing the $\Delta(1232)$ resonance. A lattice QCD computation employing a combined basis of three-quark and meson-baryon interpolating operators with definite momentum to determine the coupled channel $\Sigma\pi - N\overline{K}$ scattering amplitude in the $\Lambda(1405)$ region is also presented. Our results support the picture of a two-pole structure suggested by theoretical approaches based on $SU(3)$ chiral symmetry and unitarity.

QCD and hadron structure / **95**

Spin-1 quarkonia in a rotating frame and their spin contents

Author: Hyungjoo Kim[1]

Co-authors: Su Houng Lee [1]; Sungtae Cho [2]

[1] *Yonsei University*

[2] *Kangwon University*

Corresponding Author: hugokm0322@gmail.com

We propose a new way of studying the spin content of a hadron by looking at its response in a rotating frame. By collecting all responses of quarks and gluons in a rotating frame, we describe the spin-rotation coupling of spin-1 quarkonia and thereby reveal their spin contents in a fully relativistic way. We demonstrate that both the perturbative and non-perturbative contributions in the operator product expansion follow a universal formula that identifies the spin-rotation coupling with unit strength. This allows us to recognize the total spin-1 of the vector and axialvector quarkonia in terms of the total angular momentum of quarks and gluons. Specifically, we find the spin contents of J/ψ, χ_{c1}, $\Upsilon(1S)$, and χ_{b1} are slightly different from the naive quark model picture. For example, the J/ψ is traditionally considered as an S-wave particle, but we find quarks do not carry all of the total spin.

Hadrons in hot and nuclear environment / **96**

Overview and new directions about light (anti)nuclei measurements with ALICE

Author: Marika Rasà[1]

[1] *Istituto Nazionale di Fisica Nucleare*

Corresponding Author: marika.rasa@ct.infn.it

The production of light (anti)nuclei has been measured over the last decades in many facilities ranging from low collision energies at the AGS and GSI to high energies at RHIC and the LHC. Despite the plethora of experimental results, the production mechanism of light (anti)nuclei is still mysterious and under intense debate in the scientific community. The experimental data are typically described using two different phenomenological models: the statistical hadronization model and baryon coalescence. The measurements of light (anti)nuclei production have also important implications for astrophysics in indirect dark matter searches.

In this talk, a comprehensive overview of recent ALICE results on light (anti)nuclei production measurements will be presented. The global picture emerging from these measurements will be discussed in the context of the available phenomenological models. Recently, ALICE has performed pioneering measurements of the (anti)deuteron coalescence parameter in and out of jets in small collision systems where unexpected and intriguing results were obtained. These will be presented along with perspectives for further developments of this research line in the LHC Run 3.

Hypernuclei and kaonic atoms / **98**

High precision kaonic atoms X-ray spectroscopy with the SIDDHARTA-2 experiment at the DAFNE collider

Author: Francesco Sgaramella[1]

[1] *INFN-LNF*

Corresponding Author: francesco.sgaramella@lnf.infn.it

Kaonic atoms represent a unique laboratory for the study of the antikaon-nucleus interaction at threshold and investigate the low-energy quantum chromodynamics (QCD) in the strangeness sector. State-of-the-art X-ray detectors and modern experimental techniques allow to perform high-precision X-ray kaonic atoms spectroscopy, leading to fundamental input for nuclear, particle, and astrophysics research.
The SIDDHARTA-2 experiment at the INFN-LNF DAΦNE collider is currently performing a data

taking campaign to carry out high-precision X-ray spectroscopy of various kaonic atoms, with a particular focus on the first measurement ever of the kaonic deuterium X-ray transitions to the fundamental level. This measurement aims to allow to determine the isospin-dependent antikaon-nucleon scattering length and contribute to our understanding of the strong interaction in the strangeness sector.
In this talk, I will present the SIDDHARTA-2 experiment, the recent results obtained during the first phase of the experiment, in particular the most precise measurement of kaonic helium X-ray Lα transition in gas and the first measurement ever of the M-type transition, as well as the first measurement of several high-n transitions in other kaonic atoms.
Finally, I will outline the prospects for the ongoing kaonic deuterium measurement and our future plans.

Exotic hadrons and candidates / **99**

Heavy Hybrid Decays to Quarkonia

Authors: Abhishek Mohapatra[1]; Antonio Vairo[None]; Nora Brambilla[2]; Wai-Kin Lai[None]

[1] *Technical University Munich*

[2] *TUM*

Corresponding Author: abhishek.mohapatra@tum.de

The decay rates of the X Y Z exotics discovered in the heavy quarkonium sector are crucial observables for identifying the nature of these states. Based on the framework of nonrelativistic effective field theory, we calculate the rates of semi-inclusive decays of heavy quarkonium hybrids into standard heavy quarkonia. We compute the contributions to the decay rates at leading and subleading power in $1/m_Q$, where m_Q is the heavy quark mass. In particular, we compute for the first time spin-flipping decays and explore heavy quark symmetry breaking in exotic decays. We compare our predictions with experimental data of inclusive decay rates for candidates of heavy hybrids.

Hadrons and physics beyond the standard model / **100**

Radiative corrections in semileptonic tau decays

Authors: Jesús Alejandro Miranda Hernández[1]; Pablo Roig[2]; Rafel Escribano[3]

[1] *IFAE*

[2] *Cinvestav, Mexico City, Mexico*

[3] *Universitat Autònoma de Barcelona*

Corresponding Author: jmiranda@ifae.es

Radiative corrections to one-meson tau decays have become relevant to test CKM unitarity, lepton universality, and non-standard interactions. In this work, we compute the radiative corrections to the $\tau^- \to (P_1, P_2)^- \nu_\tau$ ($P_{1,2} = \pi, K$) decays for the first time using Resonance Chiral Theory (RχT).

Exotic hadrons and candidates / **101**

The Z_{cs} states based on the molecular picture

Author: Natsumi Ikeno[None]

Co-authors: Raquel Molina Peralta [1]; Eulogio Oset [2]

[1] *UV-IFIC*

[2] *IFIC, CSIC University of valencia*

Corresponding Author: ikeno@tottori-u.ac.jp

The Z_{cs}(3985) state was reported as a new exotic state by BESIII collaboration. After its discovery, the Z_{cs}(4000) and Z_{cs}(4220) states were observed at LHCb. We study the Z_{cs}(3985) state based on the $\bar{D}_s D^*$ with the coupled channels of the vector-pseudoscalar mesons 1. We find that we can explain this state by the threshold effect from the coupled-channel interaction and our calculation is in fair agreement with the BESIII data. We also study the Z_{cs} state based on $D_s^* \bar{D}^*$ with the coupled channels of the vector-vector mesons 2. The $D_s^* \bar{D}^*$ system does not develop a bound state, however, the $J^P = 2^+$ channel has enough attraction to create a strong cusp structure that shows up in the $J/\psi K^+$ invariant mass distribution in the $B^+ \to J/\psi\phi K^+$ decay at the $D_s^* \bar{D}^*$ threshold. I will give a presentation based on Refs. 1-2.

1 N. Ikeno, R. Molina and E. Oset, Phys. Lett. B 814, 136120 (2021).
2 N. Ikeno, R. Molina and E. Oset, Phys. Rev. D 105, 014012 (2022).

Heavy meson spectroscopy / **102**

Molecular states of $D^*D^*\bar{K}^*$ and $B^*B^*K^*$ natures

Author: Natsumi Ikeno[None]

Co-authors: Melahat Bayar [1]; Luis Roca ; Eulogio Oset [2]

[1] *Kocaeli University*

[2] *IFIC, CSIC University of valencia*

Corresponding Author: ikeno@tottori-u.ac.jp

We study the interaction of two D^* and a $\bar{K}^*$ by using the Fixed Center Approximation to the Faddeev equations to search for bound states of the three body system. Since the D^*D^* interaction is attractive and gives a bound state, and so is the case of the $D^*\bar{K}^*$ interaction, where the $J^P = 0^+$ bound state is identified with the $X_0(2900)$, the $D^*D^*\bar{K}^*$ system leads to manifestly exotic bound states with ccs open quarks. We obtain bound states of isospin $I = 1/2$, negative parity and total spin $J = 0, 1, 2$. For $J = 0$ we obtain one state, and for $J = 1, 2$ we obtain two states in each case. The binding energies range from 56 MeV to 151 MeV and the widths from 80 MeV to 100 MeV. Using the analogy of $D^*D^*\bar{K}^*$ system, we also study the three-body system $B^*B^*K^*$ containing the bbc open quarks. We obtain bound states for all the channels considered $J = 0$, 1 and 2, all of them with $I = 1/2$ and negative parity. I will give a presentation based on Refs. 1-2.

1 N. Ikeno, M. Bayar and E.Oset, Phys. Rev. D 107, 034006 (2023).
2 M. Bayar, N. Ikeno and L. Roca, Phys. Rev. D 107, 054042 (2023).

Heavy baryon spectroscopy / **103**

Interpretation of the Ω_c decay into $\pi^+\bar{K}\Xi$ from the $\Omega(2012)$ molecular perspective

Authors: Natsumi Ikeno[None]; GENARO TOLEDO[1]; Wei-Hong Liang[None]; Eulogio Oset[2]

[1] *UNIVERSIDAD NACIONAL AUTONOMA DE MEXICO*

[2] *IFIC, CSIC University of valencia*

Corresponding Author: ikeno@tottori-u.ac.jp

We study a mechanism for $\Omega_c \to \pi^+\Omega(2012)$ production through an external emission Cabibbo favored weak decay mode, where the $\Omega(2012)$ is dynamically generated from the interaction of $\bar{K}\Xi^*(1530)$, $\eta\Omega$, with $\bar{K}\Xi$ as the main decay channel. The $\Omega(2012)$ decays latter to $\bar{K}\Xi$ in this picture, with results compatible with Belle data. The picture has as a consequence that one can evaluate the direct decay $\Omega_c^0 \to \pi^+K^-\Xi^0$ and the decay $\Omega_c^0 \to \pi^+\bar{K}\Xi^*$, $\pi^+\eta\Omega$ with direct coupling of $\bar{K}\Xi^*$ and $\eta\Omega$ to $K^-\Xi^0$. We show that, within uncertainties and using data from a recent Belle measurement, all these three channels account for about (12-20)\% of the total $\Omega_c \to \pi^+K^-\Xi^0$ decay rate. The consistency of the molecular picture with all the data is established by showing that $\Omega_c \to \Xi^0\bar{K}^{*0} \to \Xi^0K^-\pi^+$ together with $\Omega_c \to \pi^+\Omega^* \to \pi^+K^-\Xi^0$ account for about 85\% of the total $\Omega_c \to \pi^+K^-\Xi^0$. I will give a presentation based on Refs. 1-[3].

1 N. Ikeno, W. H. Liang, G. Toledo, and E. Oset, Phys. Rev. D 106, 034022 (2022).
2 R. Pavao and E. Oset, Eur. Phys. J. C 78, 857 (2018).
[3] N. Ikeno, G. Toledo, and E. Oset, Phys. Rev. D 101, 094016 (2020).

New facilities / **104**

Introduction on the upgrade project of BEPCII

Author: Huiping Geng[1]

[1] *Institute of High Energy Physics , CAS*

Corresponding Author: genghp@ihep.ac.cn

The Beijing Electron Positron Collider II (BEPCII) has achieved a series of achievements in high energy physics study. Along with the deepening of the research, more important physcis is expected in higher energy region (>2.1GeV). As the upper limit of BEPCII design energy is 2.1 GeV, an urgent upgrade is required. In this paper, the upgrade project of BEPCII (BEPCII-U) will be introduced.

Hadrons in hot and nuclear environment / **105**

News from strong interaction program of NA61/SHINE experiment at CERN SPS.

Author: Szymon Pulawski[1]

[1] *University of Silesia*

Corresponding Author: szymon.pulawski@us.edu.pl

NA61/SHINE is, at the moment, the only multipurpose fixed-target facility studying particle production properties at p+p and A+A at the CERN Super Proton Synchrotron. The main goals of the NA61/SHINE strong-interactions program are to discover the critical point of strongly interacting matter as well as to study the properties of produced particles relevant for the study of the onset of deconfinement - the transition between the state of hadronic matter and the quark-gluon plasma., An analysis of hadron production properties is performed in nucleus-nucleus, proton-proton, and proton-nucleus interactions as a function of collision energy and size of the colliding nuclei to achieve these goals.
The NA61/SHINE results from a strong interaction measurement program will be presented. In particular, the latest results from different reactions p+p, Be+Be, Ar+Sc, and Pb+Pb on hadron spectra and fluctuations will be discussed. The NA61/SHINE results will be compared with worldwide experiments and predictions of various theoretical models, like EPOS, PHSD, UrQMD, and others.

Light meson spectroscopy / **106**

Meson spectroscopy with CLAS12

Author: Derek Glazier[1]

[1] *University of Glasgow*

Corresponding Author: derek.glazier@glasgow.ac.uk

The MesonEx experiment seeks to take advantage ofthe high luminosity electron scattering reactions and large acceptance CLAS12 detector in Hall B of Jefferson Lab. Inclusion of the small angle electron detector allows the tagging of low Q^2 quasi-real meson photoproduction. The high resolution detector systems allow reconstruction of events with missing particles, allowing reactions with recoiling neutrons to be analysed. The energy range accessible with the 11 GeV electron beam allows the study of mesonic states with masses from around 1.3 to 2.5 GeV, where there are many states of interest in the light quark sector. Here we review the methodology and tools and present some preliminary results to a subset of the dataset.

Exotic hadrons and candidates / **107**

Understanding the Tcc(3875) exotic state

Author: Eulogio Oset[1]

Co-authors: Albert Feijoo [2]; Isaac Vidana Haro [3]; Juan Nieves [2]; Lian Rong Dai ; Luciano Abreu ; Miguel Albaladejo [4]; Wei-Hong Liang

[1] *IFIC, CSIC University of valencia*

[2] *IFIC (CSIC-UV)*

[3] *Istituto Nazionale di Fisica Nucleare*

[4] *IFIC*

Corresponding Author: oset@ific.uv.es

I would present results based on the papers: PRD 104, 114015, Arxiv 2304.01870,Arxiv 2303.06078, shared with the collaborators: A. Feijoo, W.H. Liang, I. Vidana, L.R. Dai, L. Abreu, M. Albaladejo and J. Nieves.
I would show how the Tcc appears naturally within an extension of the local Hidden gauge approach, with the correct mass and width and isospin I=0 nature. Then expose a general approach to determine the compositeness of the Tcc as a molecular structure from the D0 D+ *and D+ D*0 channels, or otherwise, using the data of the D0 D0 pi+ mass distribution. Then report on the correlation function of the D0 D+ *and D+ D*0 channels, and the inverse problem on how one can determine the properties of the Tcc from the measurement of the D0 D+ *and D+ D*0 correlation functions.

Hadrons in hot and nuclear environment / **108**

Probing hadron formation at the LHC through the study of strange particles in different collision systems and energies with ALICE at the LHC

Author: Maria Barlou[1]

[1] *National and Kapodistrian University of Athens*

Corresponding Author: m.barlou@cern.ch

Strange hadrons constitute a unique tool for studying hadronization. While their production yield was first proposed as a clean signature of quark–qluon plasma formation in heavy-ion collisions, today the role of strangeness production in large and small collision systems is pivotal in understanding how a colored system streams into the observed gas of mesons and baryons. This started when the ALICE Collaboration made the groundbreaking observation that strange hadron yields increase with charged-particle multiplicity density, regardless of the collision system or the center-of-mass energy, and that transverse momentum spectra in elementary interactions are affected by partonic collectivity even when only few particles are produced at midrapidity.
In this contribution, a complete overview of the latest findings in the study of strange hadron production at the LHC will be presented, with special attention on discussing present and future perspectives of this field in view of the LHC Run 3 data taking campaign.

Hadron decays, production and interaction / 109

Meson interaction and resonance formation in the reaction Ds -> pi+ pi+ pi- eta

Author: Eulogio Oset[1]

Co-authors: Albert Feijoo [2]; Jing Song

[1] *IFIC, CSIC University of valencia*

[2] *IFIC (CSIC-UV)*

Corresponding Author: oset@ific.uv.es

We perform a theoretical study of the D+s $\longrightarrow \pi+\pi+\pi-\eta$ decay. We look first at the basic D+s decay at the quark level from external and internal emission. Then hadronize a pair or two pairs of qq^- states to have mesons at the end. Posteriorly the pairs of mesons are allowed to undergo final state interaction, by means of which the
a0(980), f0(980), a1(1260), and b1(1235) resonances are dynamically generated. The G-parity is used as a filter of the possible channels, and from those with negative G-parity only the ones that can lead to $\pi+\pi+\pi-\eta$ at the final state are kept. Using transition amplitudes from the chiral unitary approach that generates these
resonances, and a few free parameters, we obtain a fair reproduction of the six mass distributions reported in a BESIII experiment.

Hypernuclei and kaonic atoms / 111

Constraining coupled channels dynamics using femtoscopic correlations with ALICE at LHC

Author: Ramona Lea[1]

[1] *Universita' di Brescia and INFN-Pavia*

Corresponding Author: ramona.lea@ts.infn.it

Systems like $\overline{\mathrm{K}}\mathrm{N}$ and baryon–antibaryon ($\mathrm{B}\overline{\mathrm{B}}$) are both characterized by the presence of strong inelastic channels at the production threshold, which can affect the properties and the formation of bound states and resonances. The $\mathrm{K}^-\mathrm{p}$ interaction is characterized by the presence of several coupled channels, systems with a similar mass and the same quantum numbers as the $\mathrm{K}^-\mathrm{p}$ state, like $\overline{\mathrm{K}}^0\mathrm{n}$ and π . The strengths of these couplings to the $\mathrm{K}^-\mathrm{p}$ are crucial for the understanding of the nature of the $\Lambda(1405)$ and the attractive $\mathrm{K}^-\mathrm{p}$ strong interaction. Similarly, $\mathrm{B}\overline{\mathrm{B}}$ systems are

characterized by the dominant contribution of several mesonic channels related to the presence of annihilation processes acting below 1~fm. The possible existence of $B\overline{B}$ bound states is still under debate because of the limited amount of data available for the p–p system, and either scarce or no experimental data is available for $B\overline{B}$ systems containing strangeness.

In this talk, femtoscopic correlations measured by ALICE in pp, p–Pb and Pb–Pb collisions are presented. In particular, results on the $\overline{K}N$ correlation function are shown, providing for the first time experimental constraints of $\overline{K}^0$n and the $\pi\Sigma$ channels to the measured $\overline{K}N$ interaction. Finally, the results from $B\overline{B}$ pairs ($p\overline{p}$, $p\overline{\Lambda}$ and $\Lambda\overline{\Lambda}$) are presented. The effect of annihilation channels on the correlation function and a quantitative determination of the inelastic contributions in the three different pairs are also discussed.

QCD and hadron structure / **112**

Spatial densities, form factors and internal properties of Hadrons

Author: Julia Panteleeva[1]

[1] *Ruhr-University Bochum*

Corresponding Author: panteleevajuly@gmail.com

What can we learn about the internal structure of hadrons from the matrix elements of the electromagnetic current and the energy-momentum tensor?
To give an answer we parametrize these matrix elements in terms of form factors and briefly discuss how the form factors are connected with experimentally measurable quantities, in particular the gravitational form factors with the generalized parton distributions. In the second part of the talk, we will connect the form factors of hadrons with spatial densities possessing access to the internal electromagnetic and gravitational structure of hadrons and their fundamental properties.

Light meson spectroscopy / **113**

The D_s^+ decay into $\pi^+ K_S^0 K_S^0$ reaction and the I=1 partner of the $f_0(1710)$ state

Authors: Lianrong DAI[None]; Eulogio Oset[None]; Lisheng Geng[None]

Corresponding Author: dailianrong@protonmail.com

We have identified the decay modes of the $D_s^+ \to \pi^+ K^{*+} K^{*-}, \pi^+ K^{*0} \bar{K}^{*0}$ reactions producing a pion and two vector mesons. The posterior vector-vector interaction generates two resonances that we associate to the $f_0(1710)$ and the $a_0(1710)$ recently claimed, and they decay to the observed K^+K^- or $K_S^0 K_S^0$ pair, leading to the reactions $D_s^+ \to \pi^+ K^+ K^-, \pi^+ K_S^0 K_S^0$. The results depend on two parameters related to external and internal emission. We determine a narrow region of the parameters consistent with the large N_c limit within uncertainties which gives rise to decay widths in agreement with experiment. With this scenario we make predictions for the branching ratio of the $a_0(1710)$ contribution to the $D_s^+ \to \pi^0 K^+ K_S^0$ reaction, finding values within the range of $(1.3 \pm 0.4) \times 10^{-3}$. Comparison of these predictions with coming experimental results on that latter reaction will be most useful to deepen our understanding on the nature of these two resonances.

Plenary / **114**

Survey of hadronic molecules

Author: Feng-Kun Guo[1]

[1] *Institute of Theoretical Physics, Chinese Academy of Sciences*

Corresponding Author: fkguo@itp.ac.cn

Many of the observed hadronic resonances qualify as candidate hadronic molecules. In this talk, I will discuss the features of hadronic molecules, and a survey of hadronic molecules made of a pair of heavy hadrons will be presented.

Exotic hadrons and candidates / **115**

Reaction of T_{cc} states of D^*D^* and $D_s^*D^*$ molecular nature

Authors: Lianrong DAI[None]; Raquel Molina[None]; Eulogio Oset[None]

Corresponding Author: dailianrong@protonmail.com

We extend the theoretical framework used of describe the T_{cc} state as a molecular state of D^*D and make predictions for the D^*D^* and $D_s^*D^*$ systems, finding that they lead to bound states only in the $J^P = 1^+$ channel. Using input needed to describe the T_{cc} state, basically one parameter to regularize the loops of the Bethe-Salpeter equation, we find bound states with bindings of the order of the MeV and similar widths for D^*D^* system, while the $D_s^*D^*$ system develops a strong cusp around threshold.

Analysis tools / **116**

The compositeness of a bound state constrained by a and r_0 and the role of the interaction range

Authors: Lianrong DAI[None]; Jing Song[None]; Eulogio Oset[None]

Corresponding Author: dailianrong@protonmail.com

We present an approach that allows one to obtain information on the compositeness of molecular states from combined information of the scattering length of the hadronic components, the effective range, and the binding energy. We consider explicitly the range of the interaction in the formalism and show it to be extremely important to improve on the formula of Weinberg obtained in the limit of very small binding and zero range interaction. The method allows obtaining good information also in cases where the binding is not small. We explicitly apply it to the case of the deuteron and the $D_{s0}^*(2317)$ and $D_{s1}^*(2460)$ states and determine simultaneously the value of the compositeness within a certain range,as well as get qualitative information on the range of the interaction.

QCD and hadron structure / **117**

Deeply Virtual Compton Scattering off proton and neutron from deuterium with CLAS12 at Jefferson Lab

Author: Adam Hobart[1]

Co-author: Silvia Niccolai [1]

[1] *IJCLab CNRS-IN2P3*

Corresponding Author: ajhobart@jlab.org

A key step toward a better understanding of the nucleon structure is the study of Generalized Parton Distributions (GPDs). The particularity of GPDs is that they convey an image of the nucleon structure where the longitudinal momentum and the transverse spatial position of the partons inside the nucleon are correlated. Moreover, GPDs allow the quantification, via Ji's sum rule, of the contribution of the orbital angular momentum of the quarks to the nucleon spin, important to the understanding of the origins of the nucleon spin. Deeply Virtual Compton scattering (DVCS), the electroproduction of a real photon off the nucleon at the quark level, is the golden process directly interpretable in terms of GPDs of the nucleon. The GPDs are accessed in DVCS mainly through the measurements of single- or double- spin asymmetries. Combining measurements of asymmetries from DVCS experiments on both the neutron and the proton will allow performing the flavor separation of relevant quark GPDs via linear combinations of proton and neutron GPDs. This talk will mainly focus on recent DVCS off the neutron from deuterium measurement from the CLAS12 experiment at Jefferson Lab with the upgraded ~11 GeV CEBAF polarized electron beam. This process emphasizes mainly, in the kinematic range covered at Jefferson Lab, the access to the GPD E of the neutron which is the least constraind GPD up till now. Details on the data analysis along with results on Beam Spin Asymmetries will be presented.

Exotic hadrons and candidates / **118**

Prospects for exotic mesons at the EIC

Author: Derek Glazier[1]

[1] *University of Glasgow*

Corresponding Author: derek.glazier@glasgow.ac.uk

The identification of exotic states in the charmed quark sector has generated great interest in the hadron physics community. Despite some very clear signals, many questions now arise, particularly with regard to the exact nature of as well as the existence of specific states. A hindrance to this is the fact that almost all of the states are only seen in single production mechanisms, limiting the available information. With the proposed high luminosity Electron Ion Collider, EIC, as well as a possible energy upgrade at Jlab, a new mechanism to study these states will become available, meson photoproduction. For the EIC high photon fluxes are achievable at low Q2, providing significant production of meson in the charm and even bottom sectors. Validation of states in photoproduction would provide clear evidence of their genuine existence, while photo and helicity couplings may provide another window into the nature of the states.
We will demonstrate the feasibility of such measurements with the proposed ePIC detector system at the EIC.

Heavy baryon spectroscopy / **119**

Spectroscopy of heavy baryons

Author: Roelof Bijker[1]

Co-author: Emmanuel Ortiz-Pacheco [2]

[1] *ICN-UNAM*

[2] *Ljubljana*

Corresponding Author: bijker@nucleares.unam.mx

We present a quark model analysis of S- and P-wave baryon states with one, two and three heavy quarks ($Q = c, b$) in the framework of the harmonic oscillator quark model. The study of heavy baryons is based on masses, electromagnetic and strong couplings. The results are found to be in good agreement with the available experimental data.

Analysis tools / **120**

Amplitude Analysis Tools at BESIII

Author: Yi Jiang[1]

[1] *University of Chinese Academy of Sciences (UCAS)*

Corresponding Author: jiangyi15@mails.ucas.ac.cn

Amplitude analysis is a powerful method for studying the intermediate processes of particle decays. However, considering the full kinematics, it can be a complex task that requires a deep understanding of particle physics. With the high statistics data provided by BESIII, analyzing this data simply and efficiently is a significant challenge. In this talk, we will provide a review of the recently developed amplitude analysis tools used in BESIII and introduce our solution to the general amplitude analysis framework, TF-PWA. This presentation aims to simplify the analysis process and improve the efficiency of amplitude analysis using BESIII data.

Heavy baryon spectroscopy / **121**

The $\Xi(1620)$ and $\Xi(1690)$ molecular states from meson-baryon interaction up to next-to-leading order

Authors: Albert Feijoo[1]; Victoria Valcarce Cadenas[2]; Volodymyr Magas[2]

[1] *IFIC (CSIC-UV)*

[2] *University of Barcelona, Spain*

Corresponding Author: vladimir@fqa.ub.edu

We have studied the meson-baryon interaction in the neutral $S = -2$ sector using an extended Unitarized Chiral Perturbation Theory, which takes into account not only the leading Weinberg-Tomozawa term (as all the previous studies in $S = -2$ sector), but also the Born terms and next-to-leading order contribution. Based on the SU(3) symmetry of the chiral Lagrangian we took most of the model parameters from the BCN model 1, where these were fitted to a large amount of experimental data in the neutral $S = -1$ sector.

We have shown that our approach is able to generate dynamically both $\Xi(1620)$ and $\Xi(1690)$ states in very reasonable agreement with the data, and can naturally explain the puzzle with the decay branching ratios of $\Xi(1690)$. Our results clearly illustrate the reliability of chiral models implementing unitarization in coupled channels and the importance of considering Born and NLO contributions for precise calculations.

1 A. Feijoo, V. Magas and A. Ramos, Phys. Rev. C
99 (2019) no.3, 035211.

QCD and hadron structure / **122**

Exploring the gravitational structure of the proton with the dilepton final state using the CLAS12 detector at Jefferson Lab: from Timelike Compton Scattering to near-threshold J/Psi photoproduction

Author: Pierre Chatagnon[None]

Corresponding Author: pierrec@jlab.org

The Gravitational Form Factors (GFFs) give access to the internal distributions of mass, pressure and shear force inside the proton. They were considered experimentally unmeasurable for decades due to the very weak gravitational interaction 1. However, the Generalized Parton Distributions (GPDs), which describe the correlations between the longitudinal momentum and the transverse position of the partons inside the nucleon, have lately been related to the GFFs. For the first time, this relation gives the opportunity to extract GFFs experimentally. In this talk, I will present two ways to access GFFs using data taken in 2018 by the CLAS12 detector with a 10.6 GeV electron beam impinging on a liquid-hydrogen target. First, I will present the first measurement of the Timelike Compton Scattering reaction (the hard photoproduction of a lepton pair), that gives access to the quark GFFs via the angular asymmetry of the electron/positron pair 2. I will then present the current effort to extract the near-threshold J/ψ photoproduction cross section using the same dataset. This later measurement is expected to provide direct insight on the gluons GFFs of the proton.

1 H. PAGELS. Energy-Momentum Structure Form Factors of Particles. Phys.Rev. 144 (1966) 1250-1260
2 P. Chatagnon. First Measurement of Timelike Compton Scattering. Phys.Rev.Lett. 127 (2021) 26, 262501

Analysis tools / **124**

Programmatic access to PDG data

Author: Juerg Beringer[1]

[1] *Lawrence Berkeley National Laboratory*

Corresponding Author: jberinger@lbl.gov

The data published by the Particle Data Group (PDG) in the Review of Particle Physics has traditionally been made available to the HEP community and beyond as a biennial publication in a scientific journal, in print as the PDG Book and the Particle Physics Booklet, and more recently primarily via the PDG website and the interactive pdgLive web application. Except for a number of data files downloadable from the PDG website, these formats are aimed at human reading and do not support programmatic access. In order to make all PDG data easily accessible in machine-readable format for different use cases, PDG is developing a set of new tools, namely a REST API, a downloadable database file containing the PDG data, and an associated Python package. I will present these new tools, discuss the status of their implementation, and give examples of their usage.

Heavy meson spectroscopy / **126**

Bc results from ATLAS and CMS

Author: Vincenzo Mastrapasqua[1]

[1] *Istituto Nazionale di Fisica Nucleare*

Corresponding Author: vincenzo.mastrapasqua@ba.infn.it

Recent results on B_c production and decays from the proton-proton collision data taken by the ATLAS and CMS experiments will be presented.

Exotic hadrons and candidates / **127**

Di-charmonium studies in ATLAS

Author: ATLAS Speaker[None]

A search for potential tetraquarks decaying into a pair of charmonium states will be presented. Two different decay channels, J/psi + J/psi −> 4mu and J/psi + psi(2S) −> 4mu, are studied. Backgrounds are estimated with a hybrid data-driven and MC-based approach. The statistical significance of possible excesses in the di-J/psi and J/psi+psi(2S) channels will be discussed in detail.

QCD and hadron structure / **128**

B-jet fragmentation measurements using ATLAS detector

Corresponding Author: carlo.schiavi@ge.infn.it

Accurate modelling of the b-jet fragmentation is important for measurements at the LHC where b-jets identification is required to isolate signal or reject backgrounds. In this talk, we present the measurement of b-quark fragmentation properties into jets using the decay of B hadrons to J/Psi and Kaon in pp collisions at the centre-of-mass energy of 13 TeV. In addition, charged-particle fragmentation observables are measured in b-jets produced in events with top quark pairs using data collected at the centre-of-mass energy of 13 TeV. The data are corrected for detector effects and compared to the predictions of state-of-the-art Monte Carlo event generators that include various parton shower and hadronisation approaches.

Exotic hadrons and candidates / **129**

Glueballs from DSEs and BSEs

Author: Markus Huber[1]

Co-authors: Hèlios Sanchis-Alepuz [2]; Christian Fischer [3]

[1] *Giessen University*

[2] *Silicon Austria Labs*

[3] *JLU Giessen*

Corresponding Author: markus.huber@theo.physik.uni-giessen.de

The spectrum of QCD is expected to contain, besides bound states of quarks, also bound states of gluons. These glueballs can mix with other states that have the same quantum number. For pure Yang-Mills theory, on the other hand, glueballs are the only physical degrees of freedom which makes the picture much clearer. Using state-of-the-art, parameter-free solutions for the propagators and vertices from Dyson-Schwinger equations (DSEs) as input, I present part of the glueball spectrum as calculated from bound state equations (BSEs). The good agreement of the results with lattice results paves the way for studying the mixing with conventional mesons in the future.

New facilities / 130

Hadron PID in the EIC ePIC detector backward endcap

Author: Alexander Kiselev[1]

[1] *Brookhaven National Laboratory*

Corresponding Author: ayk@bnl.gov

The ePIC general purpose detector for the Electron-Ion Collider (EIC) will be constructed at the Brookhaven National Laboratory in the US by 2030. It will provide an almost hermetic coverage in tracking, electromagnetic and hadronic calorimetry, as well as particle identification (PID) in the pseudorapidity range between -3.5 and +3.5. In particular, the ePIC backward endcap will be equipped with a Ring Imaging CHerenkov (RICH) detector, covering angular acceptance -3.5 < eta < -1.5 and providing pion/kaon/proton PID with a positive kaon identification on a 3 sigma level up to ~7 GeV/c.

By using fast Large Area Picosecond Photodetectors (LAPPDs) as a photosensor, ePIC backward RICH will also provide a high resolution timing reference measurement to the barrel and forward endcap Time of Flight PID subsystems.

Modeling results, including ring imaging and high resolution timing performance evaluation, as well as a selected set of physics simulations, including expected kaon sample purity estimates for semi-inclusive deep inelastic scattering (SIDIS) physics measurements, will be presented.

Hadron decays, production and interaction / 131

Novel technique to access the three-body interactions with ALICE at the LHC

Author: Laura Serksnyte[1]

[1] *TUM (Technical University of Munich)*

Corresponding Author: laura.serksnyte@tum.de

The femtoscopic technique provided insights into the previously experimentally inaccessible strong interaction between hadron pairs, including strangeness or charm. The ALICE Collaboration has, for the first time, extended such measurements to three-hadron and hadron-nucleus systems. Such studies provide a pivotal input to a better understanding of exotic nuclei and three-body dynamics, including genuine three-body interactions. The latter, especially those containing hyperons, constitute an essential ingredient in the calculations of the equation of state of neutron stars.

The measurements of three-hadron correlation functions, including p-p-p, p-p-Λ, p-p-K^+ and p-p-K^- triplets, will be presented in this talk. All results were obtained by analysing high-multiplicity pp collisions at $\sqrt{s}$ = 13 TeV measured by ALICE at the LHC. The three-body effects in these systems were extracted using Kubo's cumulant method by subtracting pair-wise interactions. In the three-baryon case, a non-zero cumulant was observed, providing a hint of the existence of three-body effects. In contrast, such effects were not observed in p-p-K^+ and p-p-K^- systems. Hadron-nucleus correlations, such as p-d and K^+-d systems, also provide access to the three-body dynamics. While effective two-body calculations describe well the experimental K^+-d correlation function, they fail for the p-d system, which can be modelled satisfactorily only if theoretical calculations account for the underlying three-nucleon dynamics.

Hadron decays, production and interaction / 132

Constraining the equation of state of neutron stars with femtoscopy measurements by ALICE

Author: Marcel Lesch[1]

[1] *Technical University of Munich*

Corresponding Author: marcel.lesch@tum.de

In the quest of understanding the nature of neutron stars, the study of the nuclear equation of state (EoS) plays a pivotal role. For constraining the latter, a comprehensive knowledge of the strong interaction among hadrons is crucial. However, probing these interactions in scattering experiments is challenging for strange baryons due to the unstable nature of hyperon beams and thus the available experimental data is scarce. Indeed, due to their possible presence in neutron stars, hyperons can impact the EoS and therefore it is required to understand how they interact with other hadrons. In recent years, the study of interactions between hadrons has been greatly extended with ALICE at the LHC by utilizing the femtoscopy technique. With this, it became feasible to probe the interactions of unstable hadrons in vacuum at short distances (of a few femtometers) and down to zero relative momenta. In this talk, recent results from the ALICE Collaboration for two-body interactions between hadrons involving strangeness in pp collisions at $\sqrt{s} = 13$ TeV are presented. A plethora of results relevant for the study of neutron stars and their EoS are shown, including pΛ and pΞ interactions.

Heavy meson spectroscopy / **133**

Mechanisms of production of exotic $X(3872)$ in proton-proton and e^+e^- collisions and its structure.

Author: Antoni Szczurek[None]

Corresponding Author: antoni.szczurek@ifj.edu.pl

We calculate the total cross section and transverse momentum distributions for the production of the enigmatic $\chi_{c1}(3872)$ (or X(3872)) (see 1) assuming different scenarios:
$c\bar{c}$ state and $D^{0*}\bar{D}^0 + D^0\bar{D}^{0*}$ molecule.
The derivative of the $c\bar{c}$ wave function needed in the first
scenario is taken from a potential $c\bar{c}$ model calculations.
Compared to earlier calculations of molecular state we include not only
single parton scattering (SPS) but also double parton scattering (DPS)
contributions.
The latter one seems to give smaller contribution than the SPS one.
The upper limit for the DPS production of
$\chi_{c1}(3872)$ is much below the CMS data.
We compare results of our calculations with existing experimental data
of CMS, ATLAS and LHCb collaborations.
Reasonable cross sections can be obtained in either $c\bar{c}$
or molecular $D\bar{D}^*$ scenarios for $X(3872)$, provided one takes
into account both directly produced D^0, $\bar{D}^0$, as well as
D^0, $\bar{D}^0$ from the decay of D^*. However, arguments related to
the lifetime of D^* suggest that the latter component is not active.
With these reservations, also a hybrid scenario is not excluded.

We propose to study the structure of the enigmatic $\chi_{c1}(3872)$
axial vector meson through its $\gamma^*\gamma\chi_{c1}(3872)$
transition form factor (see 2). We derive a light-front wave function
representation of the form factor for the lowest $c\bar{c}$ Fock-state.
We found that the reduced width of the state is well within the current
experimental bound recently published by the Belle collaboration.
This strongly suggests a crucial role of the $c\bar{c}$ Fock-state in

the photon-induced production. Our results for the Q^2 dependence can be tested by future single tagged e^+e^- experiments, giving further insights into the short-distance structure of this meson.

1 A. Cisek, W. Sch\"afer and A. Szczurek,
"Structure and production mechanism of the enigmatic $X(3872)$ in high-energy hadronic reactions",
Eur. Phys. Jour. {\bf C882}, (2022) 1062.

2 I. Babiarz, R. Pasechnik, W. Sch\"afer and A. Szczurek,
"Probing the structure of $\chi_{c1}(3872)$ with photon transition form factors",
arXiv:2303.09175, accepted in Phys. Rev. D.

Hypernuclei and kaonic atoms / 134

High-resolution hypernuclear decay pion spectroscopy at MAMI and future

Author: Sho Nagao[1]

Co-authors: Anselm Esser [2]; Björn Sören Schlimme [2]; Christian Helmel [2]; Concettina Sfienti [2]; Harald Merkel [2]; Jan Bernauer [3]; Josef Pochodzalla [2]; Julian Geratz [2]; Kazuki Okuyama [4]; Ken Nishida [1]; Koga Tachibana [4]; Kotaro Nishi [1]; Liguang Tang [5]; Luca Doria [2]; Marcell Steinen [2]; Masashi Kaneta [4]; Masaya Mizuno [4]; Michael Hoek [2]; Michael O. Distler [2]; Michaela Thiel [2]; Pascal Klag [2]; Patrick Achenbach [6]; Philipp Eckert [2]; Ralph Böhm [7]; Ryoko Kino [4]; Satoshi N. Nakamura [8]; Takeru Akiyama [4]; Tatsuhiro Ishige [4]; Tianhao Shao [2]; Ulrich Müller [2]; Werner Lauth [2]; Yuichi Toyama [9]

[1] *The University of Tokyo*

[2] *Johannes Gutenberg University Mainz*

[3] *Stony Brook University*

[4] *Tohoku University*

[5] *Hampton University/Jefferson Lab*

[6] *Jefferson Lab*

[7] *FAIR*

[8] *the University of Tokyo*

[9] *Chubu Univeristy*

Corresponding Author: sho.nagao@nex.phys.s.u-tokyo.ac.jp

Precise measurements of Λ hypernuclear binding energies are essential in understanding the interaction between Λ and nucleons. Thanks to the recent progress of accurate theoretical calculations and cutting-edge experiments for Λ hypernuclei around the light mass regions, the studies of the interaction of the hypernuclear medium have progressed well; for example, the effect of Λ-Σ coupling and the Λ-N Charge Symmetry Breaking. Though recent ${}^{3}_{\Lambda}$H mass and lifetime results from the heavy-ion collision experiments have significantly impacted reconsidering the hypernuclear picture, more accurate measurements are necessary to discuss further.
We have developed a new technique "decay pion spectroscopy" to measure the Λ binding energies of the hypernuclear ground states with an accuracy of better than 100 keV/c^2. In 2015, we successfully measured the Λ binding energy of ${}^{4}_{\Lambda}$H by measuring the momentum of two-body decay pion from ${}^{4}_{\Lambda}$H with a resolution of $<$100 keV/c in FWHM.
We applied the same spectroscopic technique to ${}^{3}_{\Lambda}$H by updating the target system and the energy calibration method. The physics data taking was already done in 2022, and the analysis is ongoing. I will present the updated experiment and the latest analysis status. I will also introduce a plan for high-resolution spectroscopy of Λ hypernuclei.

Analysis tools / 135

Two-particle angular correlations of identified particles in pp collisions at √s = 13 TeV with ALICE

Author: Daniela Ruggiano[1]

[1] *Warsaw University of Technology*

Corresponding Author: daniela.ruggiano@cern.ch

Two-particle angular correlation is one of the most powerful tools to study the mechanism of particle production in pp collision systems by relating the difference between the azimuthal angle ($\Delta\varphi$) and the rapidity (Δy) of a pair of particles. Hadronization processes are influenced by various physical phenomena, such as resonance decays, Coulomb interactions, laws of conservation of energy and momentum, and others, because of the quark content of the particles involved. Therefore, each correlation function is unique and shows a different dependence on p_{T} and/or multiplicity. The angular correlation functions reported by the ALICE collaboration in pp collisions showed for baryon pairs an anti-correlation in short intervals of (Δy$\Delta\varphi$), which is not predicted by any theoretical model.

In this contribution, we investigate this behavior by studying combinations of identified charged particles (i.e., $\pi^{\pm}$, $\mathrm{K}^{\pm}$ and p($\bar{\mathrm{p}}$)) in the Δy$\Delta\varphi$ space in pp collisions at $\sqrt{s}$ = 13 TeV by ALICE. In addition, to distinguish the various physical contributions, collisions with different multiplicities are analyzed separately and diverse normalization methods are applied.

Heavy baryon spectroscopy / 136

Molecular Ω_{cc} , Ω_{bb} and Ω_{bc} states.

Authors: Albert Feijoo[1]; Eulogio Oset[2]; Jing Song[None]; Wen-Fei Wang[1]

[1] *IFIC (CSIC-UV)*

[2] *IFIC, CSIC University of valencia*

Corresponding Author: edfeijoo@ific.uv.es

We study the interaction of meson-baryon coupled channels carrying quantum numbers of Ω_{cc} , Ω_{bb} and Ω_{bc} presently under investigation by the LHCb collaboration. The interaction is obtained from an extension of the local hidden gauge approach to the heavy quark sector that has proved to provide accurate results compared to experiment in the case of Ω_c , Ξ_c states and pentaquarks, P_c and P_{cs}. We obtain many bound states, with small decay widths within the space of the chosen coupled channels. The spin-parity of the states are $J^P = \frac{1}{2}^-$ for coupled channels of pseudoscalar-baryon ($\frac{1}{2}^+$), $J^P = \frac{3}{2}^-$ for the case of pseudoscalar-baryon ($\frac{3}{2}^+$), $J^P = \frac{1}{2}^-, \frac{3}{2}^-$ for the case of vector-baryon ($\frac{1}{2}^+$) and $J^P = \frac{1}{2}^-, \frac{3}{2}^-, \frac{5}{2}^-$ for the vector-baryon ($\frac{3}{2}^+$) channels. We look for poles of the states and evaluate the couplings to the different channels. The couplings obtained for the open channels can serve as a guide to see in which reaction the obtained states are more likely to be observed.

Light meson spectroscopy / 137

Partial-wave analysis of $\tau^- \to \pi^-\pi^-\pi^+\nu_\tau$ at Belle

Author: Andrei Rabusov[1]

[1] *Technical University of Munich*

Corresponding Author: a.rabusov@tum.de

I present preliminary results of a partial-wave analysis of $\tau^- \to \pi^-\pi^-\pi^+\nu_\tau$ in data from the Belle experiment at the KEK $\mathrm{e^+e^-}$ collider. I demonstrate the presence of the $\mathrm{a_1}(1420)$ and $\mathrm{a_1}(1640)$ resonances in τ decay and measure their parameters. I also present validation of our findings using a model-independent approach. These results can improve modeling in simulation studies necessary for measuring the τ electric and magnetic dipole moments and Michel parameters.

Heavy meson spectroscopy / **138**

Shedding light on the $X(3930)$ and $X(3960)$ states with the $B^- \to K^- J/\psi\omega$ reaction

Authors: Albert Feijoo[1]; Eulogio Oset[2]; Juan Nieves[1]; Luciano Abreu[None]; Melahat Bayar[3]; Miguel Albaladejo[4]

[1] *IFIC (CSIC-UV)*

[2] *IFIC, CSIC University of valencia*

[3] *Kocaeli University*

[4] *IFIC*

Corresponding Author: edfeijoo@ific.uv.es

We have studied the contribution of the state $X(3930)$, coming from the interaction of the $D\overline{D}$ and $D_s^+D_s^-$ channels, to the $B^- \to K^- J/\psi\omega$ decay. The purpose of this work is to offer a complementary tool to see if the $X(3930)$ state observed in the D^+D^- channel is the same or not as the $X(3960)$ resonance claimed by the LHCb collaboration from a peak in the $D_s^+D_s^-$ mass distribution around threshold. We present results for what we expect in the $J/\psi\omega$ mass distribution in the $B^- \to K^- J/\psi\omega$ decay and conclude that a clear signal should be seen around $3930\,MeV$. At the same time, finding no extra resonance signal at $3960\,MeV$ would be a clear indication that there is not a new state at $3960\,MeV$, supporting the hypothesis that
the near-threshold peaking structure peak in the $D_s^+D_s^-$ mass distribution is only a manifestation of a resonance below threshold.

Light meson spectroscopy / **139**

The description of meson and glueball spectra within the graviton soft-wall model

Author: Matteo Rinaldi[1]

Co-author: Vicente Vento [2]

[1] *Istituto Nazionale di Fisica Nucleare*

[2] *Departamento de F´ısica Te´orica-IFIC, Universidad de Valencia- CSIC, 46100 Burjassot (Valencia), Spain.*

Corresponding Author: matteo.rinaldi@pg.infn.it

In this contribution we discuss and present the holographic graviton soft-wall model (GSW) description of the meson and glueball spectra. This model relies on a semi-classic approximation of non perturbative QCD. We summarize the main results of Ref. 1 where the scalar and tensor components of the glueball spectrum have been calculated. In particular, we proposed to consider a graviton, propagating in a speific curved space, as the dual

field corresponding to the glueball operator in QCD.
The main outcome of our analysis is that the spectra are described by linear trajectories has expected from lattice QCD. Our prediction for the ground state mass is comparable with that addressed same years later in Ref. 2. Moreover, this model is capable to reproduce quite well the spectra of scalar mesons, the ρ and a1 vectors [3, 4]. Moreover, in Ref. [6] we propose a modification of the approach to properly describe the chiral symmetry breaking mechanism, beyond the inner structure of the pion. In conclusion, a good description of several observables is remarkably provided with only few not flexible parameters.

References

1 M. Rinaldi and V. Vento, Eur. Phys. J. A 54, 151 (2018)
2 E. Klempt, K. V. Nikonov, A. V. Sarantsev and I. Denisenko, Phys. Lett. B 830, 137171 (2022)
[3] M. Rinaldi and V. Vento, J. Phys. G 47, no.5, 055104 (2020)
[4] M. Rinaldi and V. Vento, J. Phys. G 47, no.12, 125003 (2020)
[5] M. Rinaldi and V. Vento, Phys. Rev. D 104, no.3, 034016 (2021)
[6] M. Rinaldi, F. A. Ceccopieri and V. Vento, Eur. Phys. J. C 82, no.7, 626 (2022)
1

Exotic hadrons and candidates / **140**

Exotic spectroscopy in a diquark model with a little help from AdS/QCD

Author: Floriana Giannuzzi[1]

[1] *Istituto Nazionale di Fisica Nucleare*

Corresponding Author: floriana.giannuzzi@ba.infn.it

The AdS/QCD correspondence allows to compute the quark-antiquark potential. We use this result, the Salpeter equation and a hyperfine splitting potential to determine masses of tetraquarks and pentaquarks containing at least two heavy quarks, based on the hypothesis of a diquark-antidiquark and antiquark-diquark-diquark structure.

Light meson spectroscopy / **141**

Scattering of J=0,2 glueballs and their thermodynamic properties

Author: Enrico Trotti[1]

Co-authors: Francesco Giacosa [2]; Alessandro Pilloni [3]; Shahriyar Jafarzade

[1] *UJK, Kielce*

[2] *Institut für Theoretische Physik, Johann Wolfgang Goethe-Universität, Frankfurt*

[3] *UniME & CT*

Corresponding Author: trottienrico@gmail.com

According to lattice QCD results, the two lightest glueballs are the scalar ($J^{PC} = 0^{++}$) and the tensor ($J^{PC} = 2^{++}$). From the well known dilaton potential that depends on a single dimentionful parameter, Λ_G, we study the scattering of two scalar and two tensor glueballs. From the scattering of two scalar glueballs we find that, using a proper unitarization scheme, a bound state, called glueballonium, can form if Λ_G is small enough. The value of the phase shift obtained from this analysis can than be used in a Glueball Resonance Gas model, that describes the YM thermodynamics in the confined phase, to estimate the correction of the interactions to the pressure.

Hadron decays, production and interaction / 142

Measurement of Λ_c^+ production in pp, p–Pb, and Pb–Pb collisions with the ALICE experiment at the LHC

Author: Clara Bartels[None]

Corresponding Author: clara.bartels@cern.ch

Charm quarks, which are created at the beginning of heavy-ion collisions and interact with the produced quark-gloun plasma (QGPP) medium during all the stages of the system evolution, are useful probes of the partonic in-medium energy loss and the quark hadronisation. In particular, the measurement of charmed baryon-to-meson ratio Λ_c^+/D^0 is sensitive to the different hadronisation mechanisms and could provide further insights into the possible modification of the hadronisation in heavy-ion collisions, with respect to smaller collision systems.

In this contribution, recent ALICE measurements of the production of Λ_c^+ baryons are presented in pp, p–Pb and Pb–Pb collisions. The Λ_c^+ production cross section, Λ_c^+/D^0 production yield ratio, and the nuclear modification factor R_{AA} were measured in Pb–Pb collisions at $\sqrt{s_{\mathrm{NN}}} = 5.02$TeV. Measurements were also performed in pp collisions down to $p_{\mathrm{T}} = 0$, as well as in p–Pb collisions, to investigate the impact of cold nuclear matter effects on the charm production and hadronisation. Comparisons to the model calculations will be presented and the interpretation of these measurements will be discussed.

Hadrons in hot and nuclear environment / 143

Light flavour resonance production with the ALICE at the LHC

Author: Neelima Agrawal[1]

[1] *Istituto Nazionale di Fisica Nucleare*

Corresponding Author: agrawal@bo.infn.it

Hadronic resonances produced in high-energy collisions at the LHC are powerful tools to investigate our understanding of QCD as the field theory responsible for hadron formation and, at the same time, describe the state of strongly interacting matter formed in heavy-ion collisions. The $\mathrm{f}_0(980)$ resonance was observed several years ago in $\pi\pi$ scattering experiments. Despite a long history of experimental and theoretical studies, the nature of this short-lived resonance is far from being understood, and there is no agreement about its quark content. According to different models, it has been associated with a meson, considered as a tetraquark or as a KK molecule. Additionally, the measurement of hadronic resonance production in heavy-ion collisions at the LHC has led to the observation of a prolonged hadronic phase after hadronization. Due to their short lifetimes, resonances experience the competing effects of regeneration and rescattering of their decay products in the hadronic medium. The study of how the experimentally measured yields are affected by these processes can extend the current understanding of the properties of the hadronic phase and the mechanisms that determine the shape of particle transverse momentum spectra.

The ALICE experiment's excellent tracking and particle identification are exploited to measure the differential spectra and integrated yield of the $\mathrm{f}_0(980)$ meson produced in pp collisions at the energy of $\sqrt{s}$ = 5 TeV. The results are discussed in comparison with models and the properties of other hadrons. The new preliminary results on the production of the $\Lambda(1520)$ resonance measured in Pb-Pb collisions at $\sqrt{s_{\mathrm{NN}}}$ = 5.02 TeV are also presented. The shape of particle transverse momentum (p_{T}), mean p_{T} and particle ratios are compared with those from the Blast-Wave, MUSIC with a SMASH afterburner and statistical hadronisation model predictions. Moreover, new preliminary results of low-mass vector meson production (ρ, ω, ϕ) decaying in the lepton pair channel, higher mass resonances $\Sigma(1385)$ and $\Xi(1820)$ in pp collisions at the energy of $\sqrt{s}$ = 13 TeV and the overall status of light-flavour resonance production in ALICE will be shown.

Exotic hadrons and candidates / **144**

Search for Exotic Hadrons in η(′)π at GlueX

Author: Malte Albrecht[1]

[1] *Jefferson Lab*

Corresponding Author: malte@jlab.org

The theoretical description of the strong interaction between quarks and gluons that form hadrons is provided by Quantum Chromodynamics. However, the impact of gluonic excitations on the characteristics of hadrons and their role in hadronic structure is yet to be determined.
Recent discoveries of several possibly exotic hadrons highlight the significance of precise spectroscopic measurements in comprehending the nature of the strong interaction. This presentation focuses on the status of the hunt for exotic contributions in photoproduction data obtained with the GlueX experiment at Jefferson Lab in η(′)π systems.

Specifically, I will discuss the investigation of the a2(1320) meson production in these key channels, which is an initial step towards identifying exotic quantum-number hybrid mesons. Furthermore, the discussion will cover the application of an amplitude analysis that exploits the polarization of the photon beam available to the GlueX experiment and its implications for identifying the lightest hybrid meson.

Light meson spectroscopy / **145**

Pole extraction and nature of the f0(980)

Author: Cesar Fernandez-Ramirez[1]

[1] *UNED/ICN-UNAM*

Corresponding Author: cefera@ccia.uned.es

We present a novel extraction of the pole position of the f0(980) from the available dispersive analyses of the $\pi\pi \to \pi\pi, \bar{K}K$ channels using an effective range expansion. Afterwards, we use a neural network as a classifier to investigate the possible nature of the state, finding that a molecular interpretation is the most likely.

Hadron decays, production and interaction / **146**

J/psi photoproduction close to threshold at GlueX

Author: Eugene Chudakov[1]

[1] *Jefferson Lab*

Corresponding Author: gen@jlab.org

Close-to-threshold photoproduction $\gamma p \to J/\psi p$ probes small-size gluon configurations in the proton. Under certain assumptions it allows us to study the proton properties, as gluonic GPDs, anomalous contribution to the mass of the proton, gravitational form factors, and the mass radius of the proton. A careful comparison of the experimental data with the theoretical predictions would help us to verify the validity of those assumptions. The first cross-section measurements of near-threshold reaction $\gamma p \to J/\psi p$ by the GlueX Collaboration (*Phys. Rev. Lett. 123, 072001 (2019)*) has attracted a considerable theoretical interest. Along with the relation to the gluonic properties of the proton,

the measurement exploited a possibility of the LHCb Pentaquark production in the s-channel of the observed reaction, placing a limit of the decay probability $P \to J/\psi p$. Here we present new GlueX results based on a four-times larger data set. The higher statistics along with the full acceptance of the GlueX spectrometer allow us to measure the differential cross section in several energy ranges and compare the results with several theoretical calculations.

Analysis tools / 147

Mathematical ambiguities in eta-pi photoproduction

Author: Wyatt Smith[1]

[1] *Indiana University*

Corresponding Author: smithwya@iu.edu

Mathematical ambiguities in partial wave analyses cause unavoidable problems in interpreting data from scattering experiments. These ambiguities appear as distinct sets of partial waves which can describe the same experimental data. In principle, these ambiguities may be resolved by leveraging knowledge about the physics of the process of interest, or by enforcing additional constraints. We will describe the resolution of mathematical ambiguities in the analysis of the photoproduction of spinless meson resonances, such as in ηπ photoproduction at GlueX. We will present some simulations and fits to toy data and discuss apparent ambiguities which might appear in fits to real data.

Hadrons and physics beyond the standard model / 148

Neutrinoless Double-Beta Decay from Lattice QCD

Authors: Anthony Grebe[1]; David Murphy[2]; Patrick Oare[2]; Phiala Shanahan[2]; William Detmold[2]; William Jay[2]; Zhenghao Fu[2]

[1] *Fermi National Accelerator Laboratory*

[2] *MIT*

Corresponding Author: agrebe@fnal.gov

Neutrinoless double-beta decay ($0\nu\beta\beta$) is a hypothetical nuclear decay that is only possible if the neutrino is a Majorana fermion. This decay can be mediated either by a light Majorana neutrino propagating between two electroweak current insertions or by higher-dimension short-distance operators that appear in some beyond the Standard Model theories. Experimental searches for this process with ever-increasing sensitivity have placed strong constraints on the $0\nu\beta\beta$ half-lives of relevant isotopes. Relating these experimental half-lives to the underlying particle physics – the effective Majorana mass of the neutrino or coefficients of short-distance operators – requires understanding of the nuclear matrix elements for the transition. These matrix elements can be computed within an nuclear effective field theory framework, but input from lattice QCD is necessary to constrain low-energy constants relevant for the decay. This talk will discuss several double-beta decay calculations performed in lattice QCD and their implications for determination of nuclear EFT parameters.

Hadrons in hot and nuclear environment / 149

Chiral symmetry restoration in nuclear medium observed in pionic atoms

Author: Kenta Itahashi[1]

[1] *RIKEN*

Corresponding Author: itahashi@riken.jp

We report the recent results of spectroscopy of deeply bound pionic atoms. After elaborate analyses, we deduced the chiral condensate at the nuclear saturation density to be reduced by a factor of 60+-3% (T. Nishi, K. Itahashi et al., Nat. Phys. (2023) doi:10.1038/s41567-023-02001-x). We also discuss our future plans to make the spectroscopy in the inverse kinematics.

Analysis tools / **150**

Machine learning techniques applied to study light hypernuclei

Author: Takehiko Saito[1]

[1] *High Energy Nuclear Physics Laboratory, RIKEN and GSI*

Corresponding Author: takehiko.saito@riken.jp

Machine learning techniques have become very powerful and practical tools not only in our daily life but also in scientific research. We have performed several developments of machine learning models to study light hypernuclei, especially hypertriton, ${}^{4}_{\Lambda}\mathrm{H}$ and an nnΛ state. We have developed a complex of analysis methods for analyzing the J-PARC E07 nuclear emulsion data to determine precisely the binding energy of hypertriton and ${}^{4}_{\Lambda}\mathrm{H}$ by employing Mask-R CNN and the Generative Adversarial Network (GAN) together with Monte Carlo simulations. Determination of their binding energies are currently in progress. The developed models are being applied and improved for searching double-strangeness hypernuclear events as well as single-strangeness hypernuclear events with multi-body decay modes. We have also developed a new track finding model with the Graph Neural Network (GNN) for the WASA-FRS experiment to study the lifetime of hypertriton and ${}^{4}_{\Lambda}\mathrm{H}$ and whether or not an nnΛ bound state can exist. It has demonstrated that the efficiency and purity in track finding have been significantly improved. In the presentation, details of machine learning developments for the nuclear emulsion data will be discussed, and the development with the GNN will also be briefly discussed.

Hadron decays, production and interaction / **152**

Quarkonium states in strong magnetic fields

Author: Andrew Koshelkin[None]

Corresponding Author: and.kosh59@gmail.com

Based on the constraint formalism for the Dirac equation1 the quarkonium states in a strong uniform magnetic field are studied. The relativistic equations governing the masses of the quarkonium consisting of various flavors in the singlet states are derived in the explicit form. The obtained spectrum is studied in detail. The derived spectrum is found to be in strong dependence on the magnetic field and on the confinement parameters. Relation of the derived quarkonium mass to the experimental results2, as well as a decay and the quarkonium collapse in extreme large magnetic fields, are discussed.

1.H.W.Crater, P. van Alstine, Phys. Rev. D, v.36, 3007 (1987).

2.T.Yoshida, K. Suzuki, Phys. Rev. D, v.94, 074043 (2016).

QCD and hadron structure / 153

Exploring resonance structure with transition GPDs with CLAS12 at JLAB

Author: Stefan Diehl[1]

[1] *2nd Physics Institute JLU Giessen*

Corresponding Author: stefan.diehl@exp2.physik.uni-giessen.de

Generalized Parton distributions (GPDs) correlate the transverse position and the longitudinal momentum fraction of the partons in the nucleon. Over the last two and a half decades, there have been extensive studies of these distributions functions based on different exclusive lepton scattering reactions. The most established reactions are deeply virtual Compton scattering (DVCS), where a real photon is produced, and deeply virtual meson production (DVMP). While these studies have already provided a significant insight into the 3D structure of the ground state nucleon, little is known about the 3D structure of resonances so far. Such information is encoded in so called transition GPDs, which can be accessed for example in DVCS and DVMP reactions with a N⟶N*transition. Because the factorisation of this process amplitude requires constraints on the Mandelstam variable t and the photon virtuality Q2 (-t/Q² « 1) and several final state particles have to be detected for a clean identification, CLAS12 in combination with the upgraded CEBAF accelerator at JLAB provides an excellent opportunity to study such processes. The talk will present first beam spin asymmetry measurements for the hard exclusive π-Δ++ production and compare them to results from the hard exclusive π+ and π0 production 1. In addition, an outlook on upcoming studies of the N⟶N* DVCS process and further N⟶N* DVMP observables will be provided.

1 S. Diehl et al. (CLAS Collaboration), submitted to Phys. Rev. Lett. (2023) https://doi.org/10.48550/arXiv.2303.11762

Hypernuclei and kaonic atoms / 154

The WASA-FRS hypernuclear experiment and developments of machine learning analyses with graph neural network

Author: Hiroyuki Ekawa[1]

[1] *High Energy Nuclear Physics Laboratory, RIKEN*

Corresponding Author: hiroyuki.ekawa@riken.jp

The WASA-FRS hypernuclear experiment has been performed at GSI in 2022 for measuring the lifetimes of hypertriton and ${}^{4}_{\Lambda}\mathrm{H}$ and for confirming whether or not a neutral charged bound state of a Λ hyperon and two neutrons, $nn\Lambda$, can exist. Hypernuclei of interest were produced by the induced reaction with ${}^{6}\mathrm{Li}$ and ${}^{12}\mathrm{C}$ projectiles at $1.96\,A\,\mathrm{GeV}$ on a fixed diamond target with a thickness of $9.87\,\mathrm{g/cm^2}$. Produced hypernuclei are identified by reconstructing invariant mass with detection of π^- by the WASA detector and of residual nuclei by the FRS. Their lifetimes are measured from their decay lengths and kinematics.

Since induced reactions of heavy-ion beams produce a large number of particles in the forward direction, which induce large combinatorial background, track finding in the WASA detector is one of key issues in this experiment. To overcome this difficulty, we have developed a track finding algorithm with machine learning techniques employing the graph neural network (GNN) by using data with Monte Carlo simulations. It is a powerful neural network model for deducing the connection between data nodes. Additionally, analyses with the GNN demonstrate an ability to estimate the momentum and charge of particles from the given track associations.

The current status of the analysis of the WASA-FRS hypernuclear experiment and the developments of the GNN analyses will be discussed.

Hadrons and physics beyond the standard model / 155

Latest results and precision measurements from the NA62 experiment

Authors: Angela Romano[1]; Jacopo Pinzino[2]

[1] *University of Birmingham*

[2] *Istituto Nazionale di Fisica Nucleare*

Corresponding Author: jacopo.pinzino@pi.infn.it

The NA62 experiment at CERN collected the world's largest dataset of charged kaon decays in 2016-2018, leading to the first measurement of the branching ratio of the ultra-rare $K+ \to \pi+\nu\bar{\nu}$ decay, based on 20 candidates, and presented in 2021. In this talk the NA62 experiment reports new results from analyses of $K+ \to \pi+\mu+\mu-$ and $K+ \to \pi+\gamma\gamma$ decays, using a data sample recorded in 2017–2018. The $K+ \to \pi+\mu+\mu-$ sample comprises about 27k signal events with negligible background contamination, and the presented analysis results include the most precise determination of the branching ratio and the form factor. The $K+ \to \pi+\gamma\gamma$ sample contains about 4k signal events with 10% background contamination, and the analysis improves the precision of the branching ratio measurement by a factor of 3 with respect to the previous measurements.
The NA62 experiment can also be run as a "beam-dump experiment"by removing the Kaon production target and moving the upstream collimators into a "closed"position. More than 1017 protons on target have been collected in this way during a week-long data-taking campaign by the NA62 experiment. We report on new results from analysis of this data, with a particular emphasis on Dark Photon and Axion-like particle Models.

Light baryon spectroscopy / 156

Multi-meson photoproduction off the proton - recent results from the CBELSA/TAPS experiment

Author: Tobias Seifen[1]

[1] *HISKP, Uni Bonn*

Corresponding Author: seifen@hiskp.uni-bonn.de

One important step in understanding the baryon spectrum is a precise knowledge of the excited states and their decays. In order to extract the contributing resonances from experimental data a partial wave analysis needs to be performed. To resolve ambiguities, the measurement of polarization observables is indispensable. In the regime of high mass baryon resonances multi-meson final states are of particular importance. Here sequential decays of resonances are observed.
The Crystal Barrel/TAPS experiment is ideally suited to measure the photoproduction of neutral mesons decaying into photons due to its good energy resolution, high detection efficiency for photons, and the nearly complete solid angle coverage. In combination with a longitudinally or transversely polarized target and an energy tagged, linearly or circularly polarized photon beam the experiment allows the measurement of a large set of polarization observables.
This talk will focus on results on $\pi^0\pi^0$ and $\pi^0\eta$ photoproduction. Recent results of the Bonn-Gatchina partial wave analysis which include part of the presented data, revealed systematic differences in the branching ratios for decays of N^* and Δ^* resonances. These are attributed to the internal structure of these excited nucleon states.

Hadrons and physics beyond the standard model / 157

Physics Beyond the Standard Model with NA62

Authors: Angela Romano[1]; OTHER SPEAKER[None]

[1] *University of Birmingham*

The NA62 experiment at CERN took data in 2016–2018 with the main goal of measuring the $K^+ \to \pi^+\nu\bar{\nu}$ decay. The NA62 dataset is also exploited to search for light feebly interacting particles produced in kaon decays. Searches for $K^+ \to e^+N$, $K^+ \to \mu^+N$ and $K^+ \to \mu^+\nu X$ decays, where N and X are massive invisible particles, are performed by NA62. The N particle is assumed to be a heavy neutral lepton, and the results are expressed as upper limits of $O(10^{-8})$ of the neutrino mixing parameter $|U_{\mu 4}|^2$. The X particle is considered a scalar or vector hidden sector mediator decaying to an invisible final state. Upper limits of the decay branching fraction for X masses in the range 10–370 MeV/c^2 are reported. An improved upper limit of 1.0×10^{-6} is established at 90% CL on the $K^+ \to \mu^+\nu\nu\nu$ branching fraction.
Dedicated trigger lines were employed to collect di-lepton final states, which allowed establishing stringent upper limits on the rates of lepton flavor and lepton number violating kaon decays. Upper limits on the rates of several K^+ decays violating lepton flavour and number conservation, obtained by analysing this dataset, are presented.
The NA62 experiment can be run as a "beam-dump experiment" by removing the Kaon production target and moving the upstream collimators into a "closed" position. More than 10^{17} protons on target have been collected in this way during a week-long data-taking campaign by the NA62 experiment. We report on recent results from the search for visible decays of exotic mediators from data taken in "beam-dump" mode, with a particular emphasis on Dark Photon and Axion-like particle Models.

QCD and hadron structure / 158

Testing Predictions of the Chiral Anomaly in Primakoff Reactions at COMPASS

Author: Dominik Ecker[1]

[1] *Technical University Munich*

Corresponding Author: dominik.ecker@tum.de

The chiral anomaly is a fundamental property of quantum chromodynamics (QCD). It governs e.g. the decay of the neutral pion $\pi^0 \to \gamma\gamma$. In general, it relates the coupling of an odd number of Goldstone bosons to vector bosons. In case of three pions, the magnitude of the resulting coupling is $F_{3\pi}$ and the value is precisely predicted by chiral perturbation theory. It can experimentally be measured in $\pi^-\gamma \to \pi^-\pi^0$ scattering.

Here, we report on a precision experiment on $F_{3\pi}$ using the COMPASS experiment at CERN where pion-photon scattering is mediated via the Primakoff effect using heavy nuclei as target. We exploit the interference of the production of the $\pi^-\pi^0$ final state via the chiral anomaly with the photoproduction of the $\rho(770)$ resonance over a wide mass range ($M_{\pi^-\pi^0} < 1\text{GeV}/c^2$). This is in contrast to previous measurements restricting themselves to the threshold region only. Our analysis allows to simultaneously extract the radiative width of the $\rho(770)$ resonance and gives a stronger handle on $F_{3\pi}$ in a unified approach thereby minimizing systematic effects rarely addressed previously.

Light baryon spectroscopy / 159

Evidence of a dibaryon spectrum in coherent $\pi^0\pi^0 d$ photoproduction at forward deuteron angles

Author: Thomas Jude[1]

Co-author: Hartmut Schmieden

[1] *Bonn University*

Corresponding Authors: schmieden@physik.uni-bonn.de, jude@physik.uni-bonn.de

The BGOOD photoproduction experiment at the ELSA facility is uniquely designed to explore kinematics where a charged particle is identified in a forward spectrometer and a recoiling hadronic system is reconstructed in the central calorimeter at low momentum transfer. Typically used to study strangeness photoproduction at low t, the setup also enables studies of coherent reactions off the deuteron where the deuteron takes the majority of the beam momentum.

The reaction, $\gamma d \to \pi^0\pi^0 d$ was studied from threshold to a centre-of-mass energy of 2850 MeV. A full kinematic reconstruction was made, with final state deuterons identified in the forward spectrometer and π^0 decays in the central BGO Rugby Ball. The strength of the differential cross section exceeds what can be described by models of coherent photoproduction and instead supports the three isoscalar dibaryon candidates reported by the ELPH collaboration at 2.38, 2.47 and 2.63 GeV/c^2. A low mass enhancement in the $\pi^0\pi^0$ invariant mass is also observed at the $d^*(2380)$ centre-of-mass energy which is consistent with the ABC effect. At higher centre-of-mass energies, a narrow peak in the $\pi^0 d$ invariant mass at 2114\,MeV/c^2 with a width of 20\,MeV/c^2 supports a sequential two-dibaryon decay mechanism.

Preliminary results for the $\pi^0\eta d$ and $3\pi^0 d$ coherent reaction channels will also be presented.

Supported by DFG projects 388979758/405882627 and the European Union's Horizon 2020 programme, grant 824093.

Analysis tools / 160

Machine Learning exotic hadrons

Authors: A J Rasmusson[None]; Adam Szczepaniak[1]; Alessandro Pilloni[2]; Cesar Fernandez-Ramirez[3]; Jannes Nys[4]; Lawrence Ng[5]; Vincent Mathieu[None]; Łukasz Bibrzycki[6]

[1] *Indiana University*

[2] *UniME & CT*

[3] *UNED/ICN-UNAM*

[4] *Ghent University*

[5] *Florida State University*

[6] *Pedagogical University of Krakow*

Corresponding Author: lukasz.bibrzycki@up.krakow.pl

A densely connected feed-forward neural network is capable to classify poles of scattering matrix if fed with experimentally measured values of energy-dependent production intensity. As shown in 1, such a neural network trained with synthetic differential intensities calculated with scattering length approximated amplitudes classifies the $P_c(4312)$ signal as a virtual state located at the 4th Riemann sheet with very high certainty. This is in line with the results of other analyses but surpasses them by providing the simultaneous evaluation of probabilities of competing scenarios, like eg. the interpretation in terms of the bound state. Studying the dimensionally reduced training and inference data obtained with the Principal Component Analysis gives us a certainty that our physical interpretation is robust. Moreover, using the Shapley Additive Explanations we can identify the energy bins which are key for the physical interpretation.

Bibliography
1. Deep Learning Exotic Hadrons, JPAC Collaboration • L. Ng, Ł. Bibrzycki, J. Nys, C. Fernandez-Ramirez, A. Pilloni, V. Mathieu, A.J. Rasmusson, A.P. Szczepaniak, Phys.Rev.D 105 (2022) 9, L091501

Light meson spectroscopy / **161**

Vector-Pseudoscalar Partial Wave Analysis at GlueX

Author: Amy Schertz[1]

[1] *Indiana University*

Corresponding Author: aschertz@jlab.org

Analysis of vector and axial vector meson systems will give insight into the light quark meson spectrum. Vector-pseudoscalar final states provide access to a rich set of intermediate states, including those mentioned above, but their analysis is complicated by the non-zero spin of the vector meson. A resonance amplitude model in the reflectivity basis is used to perform a partial wave analysis of several vector-pseudoscalar final states photoproduced at the GlueX experiment located at Jefferson Lab in Newport News, VA, USA. This talk will discuss the challenges of performing a partial wave analysis on a vector-pseudoscalar final state, with emphasis on the $\omega\pi$ channel. We will discuss the ongoing search for excited vector states in this and other vector-pseudoscalar channels, some of which are predicted to include gluonic excitation in their wavefunctions.

Light meson spectroscopy / **162**

Cross section measurement for pion pair production in e+e- annihilations with CMD-3 detector

Author: Ivan Logashenko[None]

Corresponding Author: i.b.logashenko@inp.nsk.su

We present the new measurement of the cross section of $e^+e^- \to \pi^+\pi^-$ process in the center of mass energy range from 0.32 to 1.2 GeV. The measurement is based on analysis of more than 30 million pion pairs collected by CMD-3 detector at VEPP-2000 collider (Novosibirsk). We discuss the design of experiment, the key elements of data analysis, the comparison of our result with existing measurements and its impact on the Standard Model evaluation of muon (g-2).

Heavy meson spectroscopy / **163**

Charm meson and charm-meson molecule in an expanding hadron gas

Authors: Eric Braaten[1]; Roberto Bruschini[1]; Liping He[2]; Kevin Ingles[1]; Jun Jiang[3]

[1] *Ohio State University*

[2] *Universität Bonn*

[3] *Shandong University*

Corresponding Author: he.1011@buckeyemail.osu.edu

We study the time evolution of the number of charm mesons after the kinetic freeze-out of the hadron gas produced by a central heavy-ion collision. The $\pi D^* \to \pi D^*$ reaction rates have t-channel singularities that give contributions inversely proportional to the thermal width of the D. The ratio of the D^0 and D^+ production rate can differ significantly from those predicted using the measured D^* branching fractions.
We then study the thermal correction to the propagator of a loosely bound charm-meson molecule in a pion gas to next-to-leading order in the heavy-meson expansion. The correction comes primarily from the complex thermal energy shift of the charm-meson constituents. The remaining correction gives a tiny decrease in the binding energy of the molecule and a tiny change in its thermal width. These results are encouraging for the prospects of observing $X(3872)$ and $T_{cc}^+(3875)$ in the expanding hadron gas produced by heavy-ion collisions.

Plenary / **164**

Heavy hadron spectroscopy: exotic hadrons as molecular states near thresholds

Author: Yasuhiro Yamaguchi[1]

[1] *Nagoya University*

Corresponding Author: yamaguti@rcnp.osaka-u.ac.jp

Hadrons have been understood as a quark-gluon composite state bound by the strong interactions, which is one of the interesting phenomena in the low-energy QCD. In the ordinary hadron picture, baryons and mesons are explained as a three-quark state and quark-antiquark state, respectively. In fact, nucleons (protons and neutrons) can be understood as uud and udd baryons. However, accelerator experiments have reported unexpected states called exotic hadrons. Especially, heavy exotic state, such as XYZ, T_{cc} and P_c, being hidden or double charmed states, have attracted a lot of interest in recent years. There have been many discussion about these states as compact multiquarks, hadronic molecules, triangle singularity, etc, while their natures have not been understood yet.

Near the thresholds, the formation of hadronic molecules is expected, where hadron interactions should have an important role to produce an attraction. The pion exchange potential is a key ingredient of hadron interactions, which has a tensor term producing a strong attraction. In this talk, we study some hadronic molecules such as P_c and T_{cc}, and also discuss the role of the interactions to form the exotic states.

Light baryon spectroscopy / **165**

Exclusive π+π- photoproduction with polarized target and beam at CLAS

Author: Alessandra Filippi[1]

[1] *Istituto Nazionale di Fisica Nucleare*

Corresponding Author: alessandra.filippi@to.infn.it

The exclusive double pion electromagnetic production is an important tool for the study of N*and* excitations and for the search of missing baryonic resonances. In fact, in photoproduction reactions the two pion channel represents the dominant contribution to the total cross section, therefore favoring, especially in the second resonant region, the observation of intermediate states whose decay

leads to an exclusive final state with two pions and a nucleon.
Several measurements of unpolarized p cross sections have been performed so far; however, the integrated information they carry is difficult to be fully exploited for spectroscopic purposes, as several wide resonant states are expected to overlap in the same region of the mass spectrum.
A different approach for their investigation is to resort to the study of polarization variables, which are theoretically related to partial wave amplitudes and for this reason can provide additional information on the amplitude interference. These studies can be pursued exploiting data featuring both a polarized beam and a polarized target. The polarization variables, in fact, are experimentally related to asymmetries in the cross sections, measured in different combinations of beam helicity and target polarization.
Such experimental conditions could be met in the g14 experiment, run at CLAS (Jefferson Lab, USA) in the years 2011-2012: a circularly polarized photon beam, with momentum in the 0.6-2.3 GeV/c range, interacted on a HD longitudinally polarized target. In this talk, results on beam-helicity and target-spin asymmetries in the photoproduction of π+π- pairs with these data will be presented and compared with earlier results by CLAS and other experiments, to disclose the potentialities of this analysis approach.

QCD and hadron structure / **166**

Modeling spin effects in electron-positron annihilation to hadrons

Author: Albi Kerbizi[1]

[1] *Trieste University and INFN*

Corresponding Author: albi.kerbizi@ts.infn.it

We present a recursive quantum mechanical model for the polarized fragmentation process of a string stretched between a quark and an antiquark with entangled spin states. The quarks are assumed to be produced in the e^+e^- annihilation process and are described by a joint spin density matrix that implements the correlations between their spin states. The string fragmentation process is formulated at the amplitude level by using the splitting matrices of the recent string+$^3P_0$ model of polarized quark fragmentation, and accounts for the systematic propagation of the spin correlations in the fragmentation chain. The model is written as a recursive recipe suitable for a Monte Carlo implementation and it is applied to the production of two back-to-back hadrons in e^+e^- annihilation, showing analytically that it reproduces the expected azimuthal distribution of the hadrons. To obtain more quantitative predictions, the model is implemented in the Pythia 8 Monte Carlo event generator allowing for the first time to simulate the e^+e^- annihilation process to hadrons with quark spin effects and to study important observables such as the Collins asymmetries and the Artru-Collins asymmetries. The main simulation results as well as the comparison with the available e^+e^- data on the Collins asymmetries are presented.

Light meson spectroscopy / **167**

f0(1370) Controversy from Dispersive Meson-Meson Scattering Data Analyses

Author: Jose Pelaez[1]

Co-authors: Arkaitz Rodas [2]; Jacobo Ruiz de Elvira [1]

[1] *Universidad Complutense de Madrid*

[2] *Jefferson Lab*

Corresponding Author: jrpelaez@fis.ucm.es

We establish the existence of the long-debated f0(1370) resonance in the dispersive analyses of meson-meson scattering data. For this, we present a novel approach using forward dispersion relations, valid for generic inelastic resonances. We find its pole at (1245±40)-i(300-70+30) MeV in ππ scattering. We also provide the couplings as well as further checks extrapolating partial-wave dispersion relations or with other continuation methods. A pole at (1380-60+70)-i(220-70+80) MeV also appears in the ππ→KK⁻ data analysis with partial-wave dispersion relations. Despite settling its existence, our model-independent dispersive and analytic methods still show a lingering tension between pole parameters from the ππ and KK⁻ channels that should be attributed to data. Reference: Phys.Rev.Lett. 130 (2023) 5, 051902

Hadron decays, production and interaction / 168

Dispersive meson-meson scattering amplitudes for final state interactions and giant CP violation in B to three light-meson decays at LHCb

Author: Jose Pelaez[1]

Co-author: Patricia Camargo Magalhaes [1]

[1] *Universidad Complutense de Madrid*

Corresponding Author: jrpelaez@fis.ucm.es

The LHCb collaboration has recently reported the largest CP violation effect from a single amplitude, as well as other giant CP asymmetries in several BB-meson decays into three charmless light mesons. It is also claimed that this is predominantly due to ππ→KK⁻ππ→KK⁻ rescattering in the final state, particularly in the 1 to 1.5 GeV region. In these analyses the ππ→KK⁻ππ→KK⁻ amplitude is by default estimated from the ππππ elastic scattering amplitude and does not describe the existing ππ→KK⁻ππ→KK⁻ scattering data. Here we show how the recent model-independent dispersive analysis of ππ→KK⁻ππ→KK⁻ data can be easily implemented in the LHCb formalism. This leads to a more accurate description of the asymmetry, while being consistent with the measured scattering amplitude and confirming the prominent role of hadronic final state interactions, paving the way for more elaborated analyses.

Hadrons and physics beyond the standard model / 169

Sensitivity of the η(′) → π0γγ and η′ → ηγγ decays to a sub-GeV leptophobic U(1)B boson

Author: Rafel Escribano[1]

Co-authors: Emilio Royo [1]; Sergi Gonzalez-Solis [2]

[1] *Universitat Autònoma de Barcelona*

[2] *Los Alamos National Lab*

Corresponding Author: sergig@lanl.gov

The sensitivity of the rare decays $\eta^{(\prime)} \to \pi^0\gamma\gamma$ and $\eta' \to \eta\gamma\gamma$ to signatures of a leptophobic B boson in the MeV-GeV mass range is analyzed in this work.
By adding an explicit B-boson resonance exchange, $\eta \to B\gamma \to \pi^0\gamma\gamma$, to the Standard Model contributions from vector and scalar meson exchanges,and employing experimental data for the associated branching ratios,it allows us to improve the current constraints on the B-boson mass m_B and coupling to Standard Model particles α_B.
From these constraints and the analysis of the available experimental $\gamma\gamma$ invariant mass distribution, we show that a B-boson signature in the resonant mass range $m_{\pi^0} \leq m_B \leq m_\eta$ is strongly

suppressed and would be very difficult to experimentally identify, assuming that the leptophobic B boson only decays to Standard Model particles.
In contrast, the limits outside this mass window are less stringent and the corresponding t- and u-channel signatures may still be observable in the data, as it occurs with the nonresonant Standard Model ρ, ω and ϕ meson exchanges.
In addition, we make use of experimental data from the $\eta' \to \pi^0\gamma\gamma$ and $\eta' \to \eta\gamma\gamma$ decays to explore larger B-boson masses.
Our results are relevant for the B-boson search programs at existing and forthcoming light-meson facilities, such as KLOE(-II) and Jefferson Lab Eta Factory experiments.

Hypernuclei and kaonic atoms / **170**

p- and sd-shell Λ-hypernuclei with shell model approach

Author: Atsushi Umeya[1]

[1] *Nippon Institute of Technology*

Corresponding Author: aumeya@nit.ac.jp

Hypernuclear structure studies have been progressing steadily through the K- and π-induced production reaction experiments, especially by the recent γ-ray coincidence measurements with the large volume Ge detector. Moreover a series of recent $(e, e'K^+)$ reaction experiments from the Jefferson Laboratory provide high-resolution data of the low-lying energy levels for p-shell hypernuclei. These data are quite helpful in better understanding of hyperon-nucleon interactions, though the data are still limited to about ten hypernuclear species.

As the next stage of hypernuclear studies, new projects of high-intensity and high-resolution $(K^-, \pi^-\gamma)$ and $(\pi^+, K^+\gamma)$ reaction experiments are being scheduled at the J-PARC facility. New experiments are also planned at the Jefferson Laboratory.

In order to meet these experimental projects, updated theoretical studies are needed for prediction and/or comparison with the coming quality data. So far we have made detailed theoretical analyses of hypernuclear level stuctures, γ-transition rates, and the production cross sections by employing the extended shell models for ${}^{9,10,11}_{\Lambda}$Be, ${}^{11,12}_{\Lambda}$B, ${}^{19}_{\Lambda}$F, etc.

In this talk we focus our attention on the interplay between the hyperon motion and the nuclear core states. First, we discuss that the extended shell-model calculation is successful in explaining the new peak observed in the ^{10}B $(e, e'K^+)$ ${}^{10}_{\Lambda}$Be experiment. It is attributed to the lowering of p_Λ (perpendicular) state due to the strong coupling with α-α like nuclear core deformation as already known in the case of ${}^{9}_{\Lambda}$Be. Second, we will show the results of new calculations for an sd-shell hypernuclear structure of ${}^{27}_{\Lambda}$Mg, in which the even-even core nucleus ^{26}Mg is shown to have rotational bands. Thus we see coupling of the p_Λ orbital and the core deformation. For the ^{27}Al (γ, K^+) ${}^{27}_{\Lambda}$Mg reaction, we also discuss the DWIA cross-section spectra that are calculated with the microscopic shell-model wave functions.

Plenary / **171**

Recent results on time-like baryon electromagnetic form factors

Author: Xiaorong Zhou[1]

[1] *University of Science and Technology of China*

Corresponding Author: zxrong@ustc.edu.cn

Experimental results on the electromagnetic form factors are very useful to constrain the QCD-based theoretical models. The electron-positron collider experiments are powerful tools to study the EMFFs of various baryons in time-like via energy scan or ISR-return methods.In this talk, we will report recent progress of baryon EMFFs in time-like from various experiments, BESIII, Belle, SND and CMD. Prospect from future experiments will also be discussed.

Exotic hadrons and candidates / **172**

A new look at the P_{cs} states from a molecular perspective.

Authors: Albert Feijoo[1]; Bing-song Zou[2]; Chu Wen Xiao[3]; Eulogio Oset[4]; Juan Nieves[1]; Wen-Fei Wang[5]

[1] *IFIC (CSIC-UV)*

[2] *Institute of High Energy Physics, Beijing*

[3] *School of Physics and Electronics, Central South University*

[4] *IFIC, CSIC University of valencia*

[5] *IFIC*

Corresponding Author: edfeijoo@ific.uv.es

We have a look at the P_{cs} states generated from the interaction of $\bar{D}^{(*)}\Xi_c^{(\prime *)}$ coupled channels. We consider the blocks of pseudoscalar-baryon ($\frac{1}{2}^+$, $\frac{3}{2}^+$) and vector-baryon ($\frac{1}{2}^+$, $\frac{3}{2}^+$), and find 10 resonant states coupling mostly to $\bar{D}\Xi_c$, $\bar{D}^*\Xi_c$, $\bar{D}\Xi_c'$, $\bar{D}^*\Xi_c'$, $\bar{D}\Xi_c^*$ and $\bar{D}^*\Xi_c^*$. A novel aspect of the work is the realization that the $\bar{D}\Xi_c$, $\bar{D}_s\Lambda_c$ or $\bar{D}^*\Xi_c$, $\bar{D}_s^*\Lambda_c$ channels, with a strong transition potential, collaborate to produce a larger attraction than the corresponding states $\bar{D}\Sigma_c$, $\bar{D}\Lambda_c$ or $\bar{D}^*\Sigma_c$, $\bar{D}^*\Lambda_c$ appearing in the generation of the strangenessless P_c states, since in the latter case the transition potential between those channels is zero. The extra attraction obtained in the $\bar{D}\Xi_c$, $\bar{D}^*\Xi_c$ pairs preclude the association of these channels to the $P_{cs}(4338)$ and $P_{cs}(4459)$ states respectively. Then we find a natural association of the $P_{cs}(4338)$ state coupling mostly to $\bar{D}^*\Xi_c$ while the $P_{cs}(4459)$ is associated to the state found that couples mostly to $\bar{D}\Xi_c'$. Four more states appear, like in other molecular pictures, and some of the states are degenerate in spin. Counting different spin states we find 10 states, which we hope can be observed in the near future.

Hadron decays, production and interaction / **173**

On the prediction of spectral densities from Lattice QCD: numerical aspects

Authors: Matteo Saccardi[1]; Mattia Bruno[2]

[1] *Istituto Nazionale di Fisica Nucleare*

[2] *Universita' di Milano-Bicocca*

Corresponding Author: m.saccardi@campus.unimib.it

Hadronic spectral densities play a pivotal role in particle physics, a primer example being the R-ratio defined from electron-positron scattering into hadrons. To predict them from first principles using Lattice QCD, we face a numerically ill-posed inverse problem, due to the Euclidean signature adopted in practical simulations. Here we present a recent numerical analysis of the vector isovector spectral density extracted using the multi-level algorithm (recently extended also to the case of dynamical fermions) and discuss its implications.

Hadron decays, production and interaction / 174

On the prediction of spectral densities from Lattice QCD: theoretical aspects

Authors: Matteo Saccardi[1]; Mattia Bruno[2]

[1] *Istituto Nazionale di Fisica Nucleare*

[2] *Universita' di Milano-Bicocca*

Corresponding Author: mattia.bruno@mib.infn.it

Hadronic spectral densities play a pivotal role in particle physics, a primer example being the R-ratio defined from electron-positron scattering into hadrons. To predict them from first principles using Lattice QCD, we face a numerically ill-posed inverse problem, due to the Euclidean signature adopted in practical simulations. Here we review the status of recent numerical approaches to the inverse Laplace transform and present a new analysis of the typical systematic errors associated to a Lattice prediction (e.g. finite-volume effects).

Hadrons and physics beyond the standard model / 175

Lepton Flavour Universality tests using semileptonic b-hadron decays

Authors: Gaya Benane[None]; Keri Vos[1]

[1] *Siegen University*

Corresponding Authors: gaya.benane@cern.ch, keri.vos@uni-siegen.de

In the SM, the electroweak bosons couple to the three lepton families with the same strength, the only difference in their behaviour being due to the difference in mass. In recent years, some deviations have been found in measurements of the ratios of branching fractions for b-hadrons decaying into final states with different lepton flavours. This talk presents recent results of lepton flavour universality tests in $b \to c\ell\nu$ decays, using hadronic or muonic τ decays, performed at LHCb.

Exotic hadrons and candidates / 176

Studies of open-double-charm exotic states at LHCb

Authors: Keri Vos[1]; Mindaugas Sarpis[None]

[1] *Siegen University*

Corresponding Author: mindaugas.sarpis@cern.ch

With LHC Run2 data becoming available, a plethora of new states was discovered at LHCb. Among those, are the open
charm exotic states, namely, tetraquarks with quark content of ($c\bar{c}qq$) and pentaquarks with quark content ($c\bar{c}qqq$). More recently, in 2021 an open-double-charm tetraquark state, named, ${T_{cc}}^{+}$ was discovered,
with a quark content of ($c\bar{u}c\bar{d}$). This is the longest-lived exotic matter particle ever discovered.
Since the nature of tetraquarks states is not fully understood, observation and discovery of new hadrons serve

as an excellent probe into the production mechanism and interaction properties of resonances decaying via the
strong interaction. A tetraquark state having two heavy quarks as a constituent is even more exotic. Such discovery
paves the way to studying a new family of tetraquarks whereby existing theoretical models could be put to the test
or previously unreachable effects could be observed.

Hadrons in hot and nuclear environment / **177**

In-medium properties of light mesons in magnetized matter - effects of (inverse) magnetic catalysis

Authors: Pallabi Parui[1]; Amruta Mishra[1]

[1] *Indian Institute of Technology Delhi*

Corresponding Author: pallabiparui123@gmail.com

In-medium mass of the light vector mesons ρ, ω with $J^{PC} = 1^{--}$, and the parity partner of ρ, the axial-vector A_1 meson with $J^{PC} = 1^{++}$, are studied in the nuclear matter in presence of an external magnetic field, accounting for the effects of (inverse) magnetic catalysis. The in-medium partial decay widths of the possible $A_1 \to \rho\pi$ decay modes are studied from the in-medium masses of the initial and the final state particles, by applying a phenomenological Lagrangian to account for the $A_1\rho\pi$ interaction vertices. The masses are calculated within the QCD sum rule framework by taking the contributions up to dimension-six operators in the operator product expansion. The medium effects of density, magnetic fields etc. are incorporated through the light quark ($\sim \langle\bar{q}q\rangle$; $q = u, d$) and the scalar gluon condensates ($\sim \langle G^a_{\mu\nu} G^{a\mu\nu}\rangle$), as well as the light four-quark condensate ($\sim \langle\bar{q}q\rangle^2$). The condensates are calculated within the effective chiral $SU(3)$ model in terms of the medium modified scalar fields. The scalar isoscalar fields $\sigma \sim (\langle\bar{u}u\rangle + \langle\bar{d}d\rangle)$, $\zeta \sim \langle\bar{s}s\rangle$, scalar isovector $\delta \sim (\langle\bar{u}u\rangle - \langle\bar{d}d\rangle)$, and the scalar dilaton field χ simulates the scalar gluon condensate within the model. The effects of magnetic fields are taken into account due to the magnetized Dirac sea contribution along with the Landau energy levels of protons and anomalous magnetic moments (AMMs) of the nucleons in the magnetized nuclear matter within the chiral effective model framework. The effects of magnetized vacuum lead to an enhancement (reduction) of the light quark condensates with the magnetic field at the nuclear matter saturation density ρ_0 for zero (finite) AMMs of the nucleons, which gives rise to the phenomenon of magnetic (inverse) catalysis. Thus, the effects of (inverse) magnetic catalysis on the in-medium spectral properties of masses and decay widths of ρ, ω, and A_1 mesons lead to the modified spectral functions as well as their production cross-sections in the magnetized nuclear matter. This should have experimental observable consequences in the non-central, heavy-ion collision experiments, where a huge magnetic field can be generated during the early stages of the collisions accompanied by a low density medium. Hence, the magnetic field effect is studied till nuclear matter saturation density. The modifications in the light vector mesons can be measured through their direct electromagnetic decay into dileptons, where the dileptons do not suffer from strong interaction in the produced medium.

Reference:

"In-medium properties of light vector and axial-vector mesons - effects of Dirac sea", Pallabi Parui and Amruta Mishra, arXiv: 2209.02455 [hep-ph].

Exotic hadrons and candidates / **178**

Studies of pentaquark states with strangeness at LHCb

Authors: Bo Fang[None]; Keri Vos[1]

[1] *Siegen University*

Corresponding Author: bo.fang@cern.ch

Study of exotic hadrons provides an important perspective on the nature of QCD. Using the pp interaction dataset collected during the Run1 and Run2 data-taking periods, corresponding to an integrated luminosity of 9 fb^{-1}, LHCb established the first evidence of pentaquark with strangeness, $P^{\Lambda}_{\psi s}(4459)^0$, in $\Xi_b^- \to J/\psi\Lambda K^-$ decays, and further made the first observation of pentaquark with strangeness, $P^{\Lambda}_{\psi s}(4338)^0$, in $B^0 \to J/\psi\Lambda\bar{p}$ decays. This talk will focus on the experimental approach of extracting these pentaquark-candidate signals using LHCb data, and discuss about the potential interpretations about the nature of these exotic states.

Exotic hadrons and candidates / **179**

Studies of four-charm-quark tetraquark states at LHCb

Authors: Keri Vos[1]; Yanxi zhang[2]

[1] *Siegen University*

[2] *Peking University*

Corresponding Author: yanxi.zhang@pku.edu.cn

LHCb results on four-charm quark tetraquarks - abstract to be determined

Hadrons and physics beyond the standard model / **181**

New physics in semi-leptonic tau decays

Author: David Díaz Calderón[1]

[1] *IFIC (UV-CSIC)*

Corresponding Author: david.diaz@ific.uv.es

This talk is based on the main results of the published article *JHEP* **04** (2022) 152. Model independent bounds on new physics are obtained using semi-leptonic tau decays as observables. To do this, We determine the dependence of several inclusive and exclusive τ observables on the Wilson coefficients of the low-energy effective theory describing charged-current interactions between light quarks and leptons. These results are then combined with inputs from other low-energy precision observables. In particular, with nuclear beta, baryon, pion, and kaon decay data.

Plenary / **182**

Exotic states in heavy quark systems

Authors: Elisabetta Spadaro Norella[1]; Keri Vos[2]

[1] *INFN - Milano*

[2] *Siegen University*

Corresponding Author: elisabetta.spadaro@mi.infn.it

The discovery of hadronic states with a manifestly exotic nature, □□, □□□, □□, □□□, and □□□, has given the field of spectroscopy a great boost in recent years. LHCb has been one of the major player in this field observing more than 15 exotic hadrons, thanks to its excellent detector performance which is optimized for the study of beauty and charm particles. In this talk, we will review several benchmark analyses of tetraquark and pentaquark candidates from the LHCb experiment, such as the doubly charmed tetraquark □□□(3875)+, the first tetraquark doublet, □□□(2900)0/++, and the first pentaquark with strangeness, □□□(4338).

Light meson spectroscopy / **183**

Strange-Meson Spectroscopy with COMPASS

Author: Stefan Wallner[1]

[1] *Max Planck Institute for Physics*

Corresponding Author: swallner@mpp.mpg.de

The excitation spectrum of light mesons which are composed of up, down, and strange quarks, allows us to study QCD at low energies and is an important input to other analyses such as searches for CP violation in hadronic B-meson decays. While the non-strange light-meson spectrum is already mapped out rather well, many predicted strange mesons have not yet been observed experimentally and many potentially observed states still need further confirmation and their parameters are poorly determined. Hence, the strange-meson spectrum may hold many surprises.
The $190\,\mathrm{GeV}/c$ hadron beam at CERN's M2 beam line contains a K^- component, which allows us to study the spectrum of strange mesons with the COMPASS experiment, a two-stage magnetic spectrometer. The flagship channel is the $K^-\pi^-\pi^+$ final state, for which COMPASS has acquired the so-far world's largest data set. We performed a partial-wave analysis in order to disentangle the produced mesons by their spin-parity quantum numbers. In this talk, we will focus on recent results from this analysis studying properties of excited strange mesons with various spin-parity quantum numbers in a wide mass range.

Light meson spectroscopy / **184**

Latest hadron Physics results at KLOE-2

Author: Giuseppe Mandaglio[1]

[1] *Department of Physics - University of Messina and INFN Sezione di Catania*

Corresponding Author: gmandaglio@unime.it

KLOE and KLOE-2 collected the largest dataset at an electron-positron collider operating at the ϕ resonance peak ($\sim$ 8 fb^{-1}),
corresponding to the production of about 24 billion of ϕ mesons, namely 8 billion pairs of neutral K mesons and 300 million η mesons.
A wide hadron physics program, investigating rare meson decays, $\gamma\gamma$ interaction, and dark forces, is under investigation by the KLOE-2 Collaboration.

The η decay into $\pi^0\gamma\gamma$ is a test bench for various models and effective theories, like VMD (Vector Meson Dominance) or ChPT (Chiral Perturbation Theory, which predict branching ratio (BR) far from the experimental value. KLOE-2 performed a new precise measurement of this BR, by using its highly pure η sample produced
in $\phi \to \eta\gamma$ process, .

KLOE-2 is currently probing a complementary model to the U boson or "dark photon", where the dark force mediator is a hypothetical leptophobic B boson that could show up in the $\phi \to \eta B \to \eta\pi^0\gamma\,, \eta \to \gamma\gamma$ channel. The preliminary upper limit on the dark $\alpha_{\rm B}$ coupling constant will be shown.

Moreover, results on the Initial State Radiation ω cross-section measurement in the $e^+e^- \to \pi^+\pi^-\pi^0\gamma_{\rm ISR}$ dhannel will be also presented.

The KLOE-2 High Energy Tagger detectors allow the possibility to investigate π^0 production from $\gamma\gamma$ scattering by
tagging final-state leptons from $e^+e^- \to \gamma^*\gamma^*e^+e^- \to \pi^0e^+e^-$ in coincidence with the π^0 in the barrel calorimeter. A preliminary measurement of the $\gamma^*\gamma^* \to \pi^0$ counting obtained by using single tagged events will be reported.

Finally, the search for the double suppressed $\phi \to \eta\,\pi^+\pi^-$ and the conversion $\phi \to \eta\,\mu^+\mu^-$ decays are being performed at KLOE-2 with both $\eta \to \gamma\gamma$ and $\eta \to 3\pi^0$. Clear signals are seen for the first time.

Hadrons and physics beyond the standard model / 185

The CEvNS experiment at Jefferson Lab

Author: Stefano Grazzi[1]

[1] *Universita' di Messina and INFN*

Corresponding Author: stefano.grazzi@ge.infn.it

Coherent elastic neutrino-nucleus scattering (CEνNS) is a process in which MeV energy scale neutrinos scatter on a nucleus, which behaves as a single particle. Within the Standard Model (SM), CEνNS is described by the neutral current interaction of neutrinos and quarks, and, due to the nature of couplings, its cross-section is proportional to the neutron number squared. In 2017, the COHERENT collaboration announced the detection of CEνNS for the first time using a CsI(Na) scintillating crystal detector. The detection of CEνNS has motivated an increasing number of research activities in high-energy physics and in beyond the Standard Model (BSM) physics. It has also motivated the development of larger-scale detectors and technology to extend detectors'sensitivity into lower energy regimes. In addition to providing a new channel for the detection of neutrinos, there are many interesting physics applications of CEνNS-based experiments and, in particular, a new way to extract information on the weak mixing angle that is of great interest to Jefferson Lab (JLab) research activity. In this contribution, I will report on the studies to perform a CEνNS experiment at JLab. Surveying the neutrino production and fluxes at different positions around the experimental Hall A Beam Dump, we found a Decay-At-Rest (DAR) neutrino flux competitive with other facilities planning CEνNS experiments.

Hadrons and physics beyond the standard model / 186

Discovering Neutrinoless Double-Beta Decay in Ge-76 with the LEGEND Experiment

Author: Natalia Di Marco[1]

[1] *Istituto Nazionale di Fisica Nucleare*

Corresponding Author: natalia.dimarco@lngs.infn.it

The search for neutrinoless double beta ($0\nu\beta\beta$) decay is considered as the most promising way to prove the Majorana nature of neutrinos as well as to give an indication on the mass hierarchy and

on the absolute mass scale. The discovery of $0\nu\beta\beta$ decay would moreover open the way for theories predicting the observed matter anti-matter asymmetry of the Universe being a consequence of lepton number violation through leptogenesis.
Building upon the success of GERDA and MAJORANA experiments, the LEGEND (Large Enriched Germanium Detector for Neutrinoless $\beta\beta$ Decay) Collaboration aims at building a ^{76}Ge-based $0\nu\beta\beta$ experiment with a sensitivity on the half-life beyond 10^{28} years, to fully span the inverted neutrino mass ordering region. The LEGEND project will proceed in two steps: in the first phase, 200 kg of enriched germanium detectors are being deployed in the existing GERDA facility at LNGS. With an exposure of 1 t·yr and a BI of 0.5 cts/(FWHM·t·yr), LEGEND-200 will be able to reach a sensitivity of about 10^{27} yr at 90% C.L. In the second phase, the enriched germanium mass will be increased up to 1000 kg. With a background index of 0.025 cts/(FWHM·t·yr) and with an exposure of 10 t·yr, LEGEND-1000 will be able to reach a 3σ half-life discovery sensitivity of 1.3×10^{28} yr.

In this talk an overview of the LEGEND project will be presented together with the status of LEGEND-200, currently taking data at LNGS.

Exotic hadrons and candidates / 187

X and Z_{cs} in $B^+ \to J/\psi\phi K^+$ as s-wave threshold cusps and alternative spin-parity assignments to $X(4274)$ and $X(4500)$

Author: Satoshi Nakamura[1]

[1] *Shandong University*

Corresponding Author: sxnakamura@gmail.com

Recent LHCb's amplitude analysis on $B^+ \to J/\psi\phi K^+$ suggests the existence of exotic X and Z_{cs} hadrons, based on an assumption that Breit-Wigner resonances describe all the peak structures. However, all the peaks and also dips in the spectra are located at relevant meson-meson thresholds where threshold kinematical cusps might cause such structures. This points to the importance of an independent amplitude analysis with due consideration of the kinematical effects, and this is what we do in this work. Our model fits well $J/\psi\phi$, $J/\psi K^+$, and $K^+\phi$ invariant mass distributions simultaneously, demonstrating that all the X, Z_{cs}, and dip structures can be well described with the ordinary s-wave threshold cusps. Spin-parity of the $X(4274)$ and $X(4500)$ structures are respectively 0^- and 1^- from our model, as opposed to 1^+ and 0^+ from the LHCb's. With all relevant threshold cusps considered, the number of fitting parameters seems to be significantly reduced. The LHCb data requires $D_s^{(*)}\bar{D}^*$ scattering lengths in our model to be consistent with zero, disfavoring $D_s^{(*)}\bar{D}^*$ molecule interpretations of $Z_{cs}(4000)$ and $Z_{cs}(4220)$ and, via the SU(3) relation, being consistent with previous lattice QCD results. This contribution is based on Phys.Rev.D 107 (2023) L011504.

Hadrons in hot and nuclear environment / 188

Charm mesons in magnetized nuclear matter – effects of (inverse) magnetic catalysis

Authors: Amruta Mishra[1]; Sourodeep De[1]

[1] *Indian Institute of Technology Delhi*

Corresponding Author: sourodeepde2015@gmail.com

The in-medium masses of the pseudoscalar $(D, \bar{D}, D_s^{\pm})$, and vector $(D^*, \bar{D}^*, D_s^{*\pm})$, open charm mesons are studied in isospin asymmetric magnetized nuclear matter, accounting for the effects

of the magnetized Dirac sea. The in-medium masses of the open charm mesons are calculated from their interactions with the nucleons and scalar mesons within the generalized chiral effective model, in terms of the scalar ($\rho^s_{p,n}$) and number ($\rho_{p,n}$) densities of nucleons and the scalar field fluctuations of $\sigma' \sim (\sigma - \sigma_0)$, $\delta' \sim (\delta - \delta_0)$ in the chiral effective model. For the strange charm mesons D_s, it depends on the fluctuations of the strange quark condensates $\zeta' \sim (\zeta - \zeta_0)$. The free energy of the magnetized vacuum with Landau energy levels and anomalous magnetic moments (AMM) of the charged fermions in the single fermion energies are taken into account in the Dirac sea contribution. The effects of Landau energy levels of protons and AMM of the nucleons are also considered in the magnetized nuclear matter. The light quark condensates are modified considerably with magnetic field, leading to (inverse) magnetic catalysis due to the magnetized Dirac sea effects. The magnetic field causes modifications to occur due to the mixing of the pseudoscalar and the longitudinal component of the vector mesons, along with the lowest Landau level contribution to the ground state energy of the charged mesons as point particle correction. The in-medium partial decay widths of the charmonium states $\Psi(3770) \to D\bar{D}$, and $\Psi(4040) \to D_s^+ D_s^-$ are studied where the effects of the magnetized Dirac sea are incorporated to the mass modifications of the charmonium states through the medium modified scalar dilaton field χ within the chiral model. The in-medium masses and decay widths of the open charm and charmonium mesons thus obtained should have considerable observable consequences in the production of the open charm mesons and charmonia in non-central ultra-relativistic heavy ion collision experiments, where huge magnetic fields are expected to be created in the early time of collisions. The heavy flavor mesons are also created during early stages of the collisions, hence study of the effects of magnetic field on heavy flavor mesons properties are important in this context.

References:

(1) “Open charm mesons in magnetized nuclear matter – effects of (inverse) magnetic catalysis”, Sourodeep De and Amruta Mishra, arXiv: 2208.09820 [hep-ph].

(2) “In-medium decay widths of charm mesons in magnetized nuclear matter – effects of (inverse) magnetic catalysis”, Sourodeep De, Pallabi Parui and Amruta Mishra, arXiv: 2208.14953 [hep-ph].

Analysis tools / **189**

Complete experiments, truncated partial-wave analyses and Bayesian inference

Author: Yannick Wunderlich[None]

Corresponding Author: wunderlich@hiskp.uni-bonn.de

The talk will summarize and relate different ideas from the field of complete-experiment analyses, both for full spin-amplitudes and for partial waves, for the illustrative example of single pseudoscalar-meson photoproduction. Then, the notion of a complete experiment as a minimal set of measurements sufficient to predict all other possible experiments will be reinterpreted using modern methods from Bayesian inference. It will be argued that many of the facts found are generic for all 2 -> 2 reactions among particles with spin.

Hypernuclei and kaonic atoms / **190**

The hypernuclear physics program at Jefferson Lab

Author: Patrick Achenbach[1]

Co-authors: Franco Garibaldi [2]; Guido Maria Urciuoli [2]; Joerg Reinhold [3]; Liguang Tang [4]; Pete Markowitz [3]; Satoshi N. Nakamura [5]; Sho Nagao [6]; Toshiyuki Gogami [7]

[1] *Jefferson Lab*

[2] *Istituto Nazionale di Fisica Nucleare*

[3] *Florida International University*

[4] *Hampton University/Jefferson Lab*

[5] *the University of Tokyo*

[6] *University of Tokyo*

[7] *Kyoto University*

Corresponding Author: patricka@jlab.org

Missing mass spectroscopy of Λ hypernuclei using the (e,e′K+) reaction has been performed at the Thomas Jefferson National Accelerator Facility (JLab) with several experiments in the past in Hall A and Hall C.
One experiment, expected to run in 2026 in Hall C, will provide the first study of the isospin dependence in medium-mass hyperisotopes by populating Λ-K-40 and Λ-K-48 using an isotopically enriched calcium target [JLab E12-15-008]. In the same campaign, it will be possible to study Λ interactions in nuclear matter using a lead target [JLab E12-20-013]. Further solid-state targets such as aluminum are also considered for this campaign.
The high-resolution spectrometers together with thin target foils and high beam currents guarantee an energy resolution on the sub-MeV level, much better than in hadron beam experiments.
The measurement of precise and accurate energy spectra of different hyperisotopes probes the Λ-N interaction in nuclei including the Λ-N-N three-body force. The latter is assumed to play a key role for the stiffness of the nuclear equation-of-state relevant for the stability of neutron stars.

(On behalf of JLab Hypernuclear Collaboration)

Light meson spectroscopy / **191**

Timelike pion form factor from lattice QCD

Author: Felipe Ortega Gama[1]

Co-author: Jozef Dudek [2]

[1] *William & Mary*

[2] *JLab*

Corresponding Author: felipeortegagama@gmail.com

We present a lattice QCD calculation of the electromagnetic form factor of the pion in the timelike region.
This calculation was performed on a lattice with N=2+1 dynamical quark flavors, with a heavier than physical pion mass of 284 MeV.
At this pion mass, the rho meson main contribution to pion-pion scattering and the timelike form factor appears in the elastic energy region.
The scattering phase-shift was also extracted in the inelastic region containing isovector kaon-kaon interactions, allowing future work to study the form factor in the coupled channel energy region from lattice QCD.

Light baryon spectroscopy / **192**

Baryon spectroscopy results from BESIII

Author: Shi Wang[1]

[1] *Lanzhou University*

Corresponding Author: wangshi@ihep.ac.cn

The world's largest samples of J/ψ and $\psi(3686)$ events produced in e^+e^- annihilation provide a clean source of baryon excitations, allowing for a rich baryon spectroscopy programme at BESIII. Based on the large data samples collected by BESIII experiment, the baryon spectroscopy has been studied through decays J/psi -> omega p anti-p, psi(3686) -> Lambda anti-Lambda eta, psi(3686) -> Lambda anti-Lambda omega, e+e- -> Lambda anti-Lambda eta from 3.5106 to 4.6988 GeV and e+e- -> p K- anti-Lambda + c.c. at 4.178 GeV. The recent results for the baryon excited states and threshold enhancement of baryon pairs will be reported in this talk.

Heavy baryon spectroscopy / **193**

Anti-D meson and nucleon interaction: from exotic hadrons to charm nuclei

Author: Shigehiro Yasui[1]

Co-authors: Yasuhiro Yamaguchi ; Atsushi Hosaka [2]

[1] *Hiroshima University*

[2] *RCNP, Osaka University*

Corresponding Author: yasuis@keio.jp

We discuss the interaction between an anti-D meson and a nucleon, which has recently been studied in LHCb experiments, by considering the meson-exchange potential model. Applying the framework of the heavy-hadron effective theory respecting both chiral symmetry and heavy-quark spin symmetry, we build the potential model by the light-meson exchanging between an anti-D meson and a nucleon. In addition to the pion, rho and omega mesons considered in our past works, we newly include the sigma mesons as a middle-distance force for more quantitative study. The model parameters are chosen with a reference to the phenomenological nucleon-nucleon potential, i.e. the Bonn potential. Solving the Schrodinger equation, we find that there can be bound and resonant states. We also discuss the bottom version, B-meson and nucleon systems. Those systems include five quarks at least, and they should be helpful to understanding the structure of exotic hadrons. We furthermore discuss the possible link to the charm or bottom nuclei, where an anti-D or a B meson can be stably bound in atomic nuclei, and present some perspectives for future studies.

Analysis tools / **194**

Progress in the Partial-Wave Analysis Methods at COMPASS

Authors: Florian Kaspar[1]; Julien Beckers[1]

[1] *Technical University of Munich*

Corresponding Author: julien.beckers@tum.de

COMPASS aims at extracting the excitation spectrum of light and strange mesons in diffractive scattering. Resonances are identified through partial wave analysis, which inherently relies on analysis models. Besides statistical uncertainties, systematic effects connected to the analysis methods are a key challenge. We will discuss some sources of systematics connected to $\pi^-\pi^-\pi^+$ and $K^0_sK^-$ final states and present methods of their remedies. We have developed a new approach using a-priori knowledge of signal continuity over adjacent final-state-mass bins to stably fit a large pool of partial-waves to our data, allowing a clean identification of very small signals in our large data sets.

For two-body final states such as $K_s^0 K^-$, mathematical ambiguities in the partial-wave decomposition result in different combinations of amplitude values to describe the same intensity distribution. We will discuss these ambiguities and present solutions to resolve or at least reduce the number of solutions. Resolving these issues will allow complementary analyses of the a_J-like resonance sector in these two final states.

Funded by the DFG under Germany's Excellence Strategy - EXC2094 - 390783311 and BMBF Verbundforschung 05P21WOCC1 COMPASS
Part of the work in collaboration with J. Knollmüller

Light meson spectroscopy / **195**

CMS results on the eta meson decay to 4 muons

Authors: Alessandra Fanfani[1]; CMS Collaboration[None]

[1] *Istituto Nazionale di Fisica Nucleare*

Corresponding Author: alessandra.fanfani@bo.infn.it

The talk will report on the observation of the decay of the eta meson to four muons

Hadron decays, production and interaction / **197**

CMS results on the fs/fu ratio

Author: Alexis Pompili[1]

[1] *Istituto Nazionale di Fisica Nucleare*

Corresponding Author: alexis.pompili@ba.infn.it

The talk will report on the most recent results by the CMS collaboration on the ration between the B_s^0 and B^+ production ratio f_s/f_u.

Heavy baryon spectroscopy / **198**

New results on conventional heavy baryons from CMS

Author: CMS Collaboration[None]

Corresponding Author: adriano.diflorio@ba.infn.it

The talk will report the most recent results by CMS on conventional heavy baryons

Exotic hadrons and candidates / **199**

Results on four-charm-quark states by ATLAS and CMS

Authors: CMS Collaboration[None]; Zhen Hu[1]

[1] *Tsinghua University*

Corresponding Author: zhen.hu@cern.ch

The talk will report on the new results on fully-charmed exotic states in $J/\psi J/\psi$ final state by ATLAS and CMS

QCD and hadron structure / 201

Timelike Compton Scattering on a polarised target with CLAS12 at Jefferson Lab

Author: Kayleigh Gates[1]

Co-authors: Daria Sokhan [2]; Rachel Montgomery [1]

[1] *University of Glasgow, United Kingdom*

[2] *University of Glasgow, United Kingdom. IRFU, CEA Université Paris-Saclay, 91191 Gif-sur-Yvette, France*

Corresponding Author: k.gates.1@research.gla.ac.uk

Time-Like Compton Scattering (TCS) is a hard, exclusive scattering process, in which a real photon scatters from a target nucleon, producing a virtual
(timelike) photon, which couples to a lepton pair in the final state 1.
TCS, via cross section and asymmetry observables, gives access to Generalised Parton Distributions (GPDs), through which we can develop a tomographic mapping of nucleon structure, and access information pertaining to the mechanical properties of hadrons, such as shear forces and pressure distributions. The first published result of TCS in 2021 2 was measured on an unpolarised hydrogen target. This work seeks to present another first measurement by performing the analysis on a longitudinally polarised target, from which Target Spin Asymmetries (TSA) and Double Spin Asymmetries (DSA) can be measured, allowing access to the GPDs H and $\tilde{H}$.
To this end, I present a preliminary extraction of a TCS signal from recent data taking at Jefferson Lab during Run Group C, using quasi-real photons from the 10.6 GeV electron beam and the CLAS12 detector.

References

1 E.R. Berger, M. Diehl, and B. Pire. Timelike compton scattering: exclusive photoproduction of lepton pairs. *The European Physical Journal C*, 23(4):675–689, apr 2002.
2 P. Chatagnon et al. First measurement of timelike compton scattering. *Phys. Rev. Lett.*, 127:262501, Dec 2021.

Hadron decays, production and interaction / 202

A study of K^-d and K^+d interactions via femtoscopy technique

Author: Wioleta Rzęsa[1]

[1] *Warsaw University of Technology*

Corresponding Author: wioleta.rzesa.dokt@pw.edu.pl

Scattering cross section measurements have been used to study the strong interaction between charged kaons and deuterons. However, these studies have not been successful in determining the scattering lengths of the strong interaction between $\mathrm{K}^{+}\mathrm{d}$ and $\mathrm{K}^{-}\mathrm{d}$. Moreover, the currently available theoretical predictions for this $\mathrm{K}^{-}\mathrm{d}$ scattering parameter are largely based on input from kaonic hydrogen measurements, while no theoretical predictions have yet been published for $\mathrm{K}^{+}\mathrm{d}$.

In this talk, the first measurements of the scattering lengths of $\mathrm{K}^{+}\mathrm{d}$ and $\mathrm{K}^{-}\mathrm{d}$ particle pairs are presented. The results were obtained using the femtoscopy, which is a very accurate technique for studying interactions between two particles with low relative momenta.

Light meson spectroscopy / **203**

Further evidence for the lower-lying vector meson $\rho(1250)$ in the $e^+e^- \to \omega\pi^0$ process

Author: Toshihiko Komada[1]

Co-authors: Tomohito Maeda ; Tsuneaki Tsuru [1]; Kenji Yamada [1]

[1] *Nihon University*

Corresponding Author: komada.toshihiko@nihon-u.ac.jp

We examine whether an isovector vector meson with a mass around 1.26 GeV or $\rho(1250)$ is seen in the $e^+e^- \to \omega\pi^0$ process, whose existence was recently reinforced with a multichannel and fully unitary S-matrix analysis of elastic $\pi\pi$ scattering data with crossing-symmetry constraints by Hammound *et al.* 1. The combined cross section data of that process measured by SND 2, CMD-2 [3], and *BABAR* [4] are analyzed in the energy region from threshold to 2 GeV by using the vector meson dominance model. It is found with the method of least squares that the cross section line shape is described well by the coherent sum of five resonant amplitudes of the $\rho(770)$ and four higher-mass ρ-like vector mesons, $\rho^{(1)}$, $\rho^{(2)}$, $\rho^{(3)}$, and $\rho^{(4)}$, around 1.3 GeV, 1.5 GeV, 1.6 GeV, and 1.8 GeV, respectively, together with a nonresonant amplitude for the direct production process. These four resonances correspond to those which were found between 1 and 2 GeV by Hammound *et al.* 1. Then, since the fitted mass and width of the $\rho^{(1)}$ resonance are similar to their obtained values, it would be associated with the $\rho(1250)$, which seems to offer further evidence that it really exists.

References

1 N. Hammoud *et al.*, Phys. Rev. **D102**, 054029 (2020).
2 SND Collaboration, Phys. Rev. **D94**, 112001 (2016); Phys. Lett. **B486**, 29 (2000).
[3] CMD-2 Collaboration, Phys. Lett. **B562**, 173 (2003).
[4] *BABAR* Collaboration, Phys. Rev. **D96**, 092009 (2017).

Light meson spectroscopy / **204**

Understanding the nature of the controversial $\rho(1250)$ meson through the covariant representation of hadrons

Author: Tomohito Maeda[None]

Co-authors: Toshihiko Komada [1]; Masuho Oda [1]; Kenji Yamada [1]

[1] *Nihon University*

Corresponding Author: maeda.tomohito@nihon-u.ac.jp

Recently, performing a reanalysis of elastic P-wave $\pi\pi$ phase shifts and inelasticities 1, it is argued strongly that there existed an isovector vector meson with a mass around 1.26 GeV, that is $\rho(1250)$. Its existence has a long history and is still in a long-standing controversy both experimentally and

theoretically, so that its entry to the PDG listings has not yet been accepted and the relevant observations are listed under the $\rho(1450)2$. In the conventional constituent quark potential models, it is difficult to make the predicted mass of the 2^3S_1 state smaller than that of the Godfrey and Isgur model [3], and therefore the nature of the $\rho(1250)$ state and its properties have not been clarified yet.
In this work we study strong decays with one pion emission of the excited ρ meson states in a framework of the covariant representation scheme for hadrons. In this scheme negative energy components of constituent quarks can be incorporated into the covariant spin wave functions of $q\bar{q}$ states. We discuss a possibility of understanding the properties of the excited ρ mesons, including the controversial $\rho(1250)$, by considering a mixing with states containing negative energy components.
References
1 N. Hammoud, R. Kaminski, V. Nazari, and G. Rupp, Phys. Rev. D102, 054029 (2020).
2 R.L. Workman et al. (Particle Data Group), Prog. Theor. Exp. Phys. 2022, 083C01 (2022).
[3] S. Godfrey and N. Isgur, Phys. Rev. D32, 189 (1985).

Hypernuclei and kaonic atoms / **205**

Reaction spectroscopy of Lambda hypernuclei at JLab and J-PARC

Author: Satoshi N. Nakamura[1]

[1] *the University of Tokyo*

Corresponding Author: nue@nex.phys.s.u-tokyo.ac.jp

Preparation works are now in progress for next-generation Lambda hypernuclear spectroscopy using the (e,e'K^+) reaction at Jefferson Laboratory (JLab) and the (π^+,K^+) reaction at J-PARC. The experiments at JLab aim to clarify the isospin dependence of Lambda hypernuclei using Ca40,48 targets and the mass number dependence from light to heavy hypernuclei such as $^{208}_{\Lambda}$Tl with existing HKS, HES spectrometers and newly constructed PCS magnets. The (π^+,K^+) reaction spectroscopy of Lambda hypernuclei with the new S-2S spectrometer, which was constructed for the Ξ hypernuclear spectroscopy at J-PARC, is also planned.
Based on the results of these experiments, drastic progresses in understanding baryon interactions and solving the hyperon puzzle (why neutron stars with twice Solar mass do not collapse) will be realized by carpet bombing research of hypernuclei at the "Hypernuclear Factory"to be realized in the J-PARC Hadron Experimental Hall Extension Project. The current status and future prospects of the Lambda hypernuclear study at JLab and J-PARC will be discussed. (On behalf of JLab Hypernuclear Collaboration, J-PARC E94 and SπK Collaborations)

Hadron decays, production and interaction / **206**

N(1520) electromagnetic transition form factors

Author: Di An[None]

Co-author: Stefan Leupold [1]

[1] *Uppsala University*

Corresponding Author: di.an@physics.uu.se

The electromagnetic transition form factors of the nucleon provide important information on the internal structure of hadrons. A model-independent dispersive calculation of the Electromagnetic form factors N*(1520)⟶N at low energies will be presented. Taking pion rescattering into consideration, we derived dispersive relations for the N*(1520)⟶N TFFs that relate space-like and time-like regions

from the first principles. Based on the space-like data from JLab, we make predictions for TFFs in the time-like region and our predictions can be tested in future experiments (e.g.HADES).

Exotic hadrons and candidates / 207

Is $f_2(1950)$ the tensor glueball?

Authors: Arthur Vereijken[1]; Francesco Giacosa[2]; Milena Piotrowska[3]; Shahriyar Jafarzade[None]

[1] *UJK kielce*

[2] *Institut für Theoretische Physik, Johann Wolfgang Goethe-Universität, Frankfurt*

[3] *Jan Kochanowski University*

Corresponding Author: arthur.vereijken@gmail.com

Glueballs are still an experimentally undiscovered expectation of QCD. Various theoretical approaches (most famously Lattice QCD) predict a spectrum of glueballs. The tensor ($J^{PC} = 2^{++}$) glueball is the second lightest, behind the scalar glueball.
Here, using a chiral hadronic model, we compute decay ratios of the tensor glueball into various meson decay channels. We find the tensor glueball to primarily decay into two vector mesons, mainly $\rho\rho$ and K^*K^* channels. We compare these results to experimental data of decay rates of isoscalar tensor mesons. We make statements on the eligibility of these mesons as potential tensor glueball candidates: the resonance $f_2(1950)$ turns out to be, at present, the best match as being predominantly a tensor glueball.

Light meson spectroscopy / 208

Meson Spectroscopy with GlueX

Author: Alexander Austregesilo[1]

[1] *Jefferson Lab*

Corresponding Author: aaustreg@jlab.org

The GlueX experiment at Jefferson Lab was specifically designed for precision studies of the light-meson spectrum. For this purpose, a photon beam with energies up to 12 GeV is directed onto a liquid hydrogen target contained within a hermetic detector with near-complete neutral and charged particle coverage. Linear polarization of the photon beam with a maximum around 9 GeV provides additional information about the production process. In 2018, the experiment completed its first phase, recording data with a total integrated luminosity above 400 pb^{-1}. We will highlight a selection of results from this world-leading data set with emphasis on the search for light hybrid mesons. In the mean time, the detector underwent significant upgrades and is currently recording data with an even higher luminosity. The future plans of the GlueX experiment to explore the meson spectrum with unprecedented precision will be summarized.

Light meson spectroscopy / 209

Dispersive determination of the σ resonance from lattice QCD

Author: Arkaitz Rodas Bilbao[1]

Co-authors: Jozef Dudek [2]; Robert Edwards [1]

[1] *Jefferson Lab*

[2] *JLab*

Corresponding Author: arodas@jlab.org

We determine, from Lattice QCD, the elastic $\pi\pi$ scattering amplitude in the three possible isospin channels for various quark masses. We observe that the extraction of the σ pole position is very challenging when the state becomes unstable. By performing a full dispersive analysis, we eliminate the systematic uncertainties associated with model extractions, constrain the low energy scattering region, and determine the σ pole position with accuracy.

Plenary / **210**

Recent highlights from Belle II

Authors: Mario Merola[1]; Sven Vahsen[None]

[1] *Istituto Nazionale di Fisica Nucleare*

Corresponding Authors: mario.merola@na.infn.it, sevahsen@hawaii.edu

The Belle II experiment at the SuperKEKB collider has been collecting asymmetric-energy electron-positron collisions at the $\Upsilon(4S)$ at the world's highest intensities since 2018. A data sample comparable in size to that of predecessor experiments, collected with a novel detector and analyzed with advanced analysis techniques, provides unique or world leading results in indirect searches for non-standard-model physics based on the weak interactions of quarks, determination of fundamental standard-model parameters, and direct searches for low-mass dark matter particles. This talk will present a selection of recent results.

Heavy meson spectroscopy / **211**

Recent quarkonium results from Belle and Belle II

Authors: Sven Vahsen[None]; Valentina Zhukova[1]

[1] *Jožef Stefan Institute, Ljubljana*

Corresponding Authors: zhukova.valentina07@gmail.com, sevahsen@hawaii.edu

Belle II offers unique possibilities for discovering and interpreting exotic multiquark bound states to probe the fundamentals of QCD. This talk presents recent results on a unique data set collected at energies above the $\Upsilon(4S)$, including searches for the hidden bottom transition between Y(10750) and χ_{bJ} and measurements of the energy dependence of the $e^+e^- \to B^{(*)}\bar{B}^{(*)}$ cross section. Recent Belle results on quarkonium will also be shown.

Analysis tools / **212**

Advanced analysis techniques used at Belle II

Corresponding Author: markus.roehrken@cern.ch

Analysis techniques based on statistical learning algorithms such as artificial neural networks or decision trees are known to offer significant improvements in the analysis of large samples of data. Belle II developed and implements a variety of such algorithms in several aspects of physics analysis including online event selection, beam-background prediction, identification of collisions that produce bottom-mesons, inference of bottom-meson flavor, and others. This talk presents an overview of the methods used and of the performance achieved.

QCD and hadron structure / **213**

Pion, Rho and Kaon masses for large N_c and N_f

Author: Dr. Aftab Ahmad[1]

[1] *Institute of Physics,Gomal University*

Corresponding Author: aftab.gu@gmail.com

In this talk, we present the numerical solution of the Schwinger-Dyson equation (SDE) for dynamical quark masses and the homogeneous Bethe-Salpeter equation
for ground-state meson masses. Based on this analysis, we computed
the masses of light hadrons (pion, rho, and kaon) for a higher number of light quark flavors N_f and for a higher number of colors N_c. A symmetry-preserving
Schwinger-Dyson equation (SDE) treatment of the vector-vector CI
model is the basic ingredients of this analysis.

Hadron decays, production and interaction / **214**

Long-range part of the heavy meson-meson static potential

Author: Muhammad Naeem Anwar[1]

[1] *Swansea University*

Corresponding Author: m.n.anwar@swansea.ac.uk

At the large distances compared to the chiral symmetry breaking scale, a four quark state $\bar{Q}\bar{Q}qq$, where Q (q) is the heavy (light) quark, can be approximated by two asymptotic $\bar{Q}q$ mesons and one can analyze the meson-meson potentials to explore the long-range strong force in such systems. To this end, we study the potential between two bottom mesons in the heavy quark limit (HQL) using the chiral effective field theory and dispersion theory 1. In this contribution, methods to deal with the two-pion-exchange interaction between two heavy mesons in the HQL and with non-physical pion mass will be discussed. A possible solution, where we use Khuri-Treiman formalism to properly include the left- and right-hand cuts, will be presented. Finally, a comparison of our results with the corresponding lattice QCD potentials 2 obtained using the Born-Oppenheimer approximation will be made.

1 Muhammad Naeem Anwar, Christoph Hanhart, Feng-Kun Guo, Deciphering Chiral Physics in Lattice Born-Oppenheimer $\bar{b}\bar{b}qq$ Potentials, in preparation.

2 P. Bicudo, M. Cardoso, A. Peters, M. Pflaumer and M. Wagner, $ud\bar{b}\bar{b}$ tetraquark resonances with lattice QCD potentials and the Born-Oppenheimer approximation, Phys. Rev. D 96, 054510 (2017).

Hadrons in hot and nuclear environment / 216

Search for η'-mesic nuclei in $^{12}\mathrm{C}(p, dp)$ reaction with the WASA detector at GSI-FRS

Author: Ryohei Sekiya[1]

[1] *Kyoto University, RIKEN*

Corresponding Author: ryohei.sekiya@riken.jp

η'(958) meson has an exceptionally large mass among pseudoscalar mesons.
The origin of the large mass is considered to be a result of the chiral symmetry breaking and $\mathrm{U}_A(1)$ anomaly.
Many theoretical studies predict the mass reduction of the η' meson ranging in 37 MeV/c^2-150 MeV/c^2 in a nuclear matter where the chiral symmetry is partially restored.
Such a large mass reduction in the nuclear matter is described as an attractive interaction with the nucleus.
The formation of the bound state of η' meson with a nucleus (η'-mesic nuclei) is discussed.

We performed missing-mass spectroscopy in $^{12}\mathrm{C}(p, dp)$ reaction with simultaneous measurement of protons from the decay of η'-mesic nuclei at the fragment separator (FRS) in GSI in 2022 February.
We employed a proton beam with an energy of 2.5 GeV and ^{12}C target with a thickness of 4 g/cm^2.
The missing-mass spectrum was obtained by measuring the forward deuterons momenta with the FRS.
The protons from the decay of the η'-mesic nuclei were identified at the same time by using the WASA detector placed at the F2 focal plane of the FRS.

We report the overview of the experiment and the current status of the analysis.

New facilities / 217

Proof-of-principle test for a charm baryon dipole moment experiment at the LHC

Author: Sara Cesare[1]

[1] *Istituto Nazionale di Fisica Nucleare*

Corresponding Author: sara.cesare@mi.infn.it

Magnetic and electric dipole moments of fundamental particles provide powerful probes for physics within and beyond the Standard Model. For the case of charm baryons these have not been experimentally accessible to date due to the difficulties imposed by their short lifetimes. An experimental test at the insertion region 3 of LHC is foreseen during Run3 to demonstrate the feasibility of a fixed-target experiment with bent crystals. The goal of the proof-of-principle test and the perspective for a future experiment will be presented along with projected sensitivities for different luminosity scenarios.

Light meson spectroscopy / 218

Recent measurements of e+e– annihilation into hadrons at low energies with the $BABAR$ detector

Authors: Dexu Lin[1]; Fabio Anulli[2]

[1] *Institute of Modern Physics, China*

[2] *Istituto Nazionale di Fisica Nucleare*

Corresponding Authors: dxlin@impcas.ac.cn, fabio.anulli@roma1.infn.it

The measurement of exclusivee^+e^- to hadrons processes is a significant part of the physics program of $BABAR$ experiment, aimed to improve the calculation of the hadronic contribution to the muon g–2 and to study the intermediate dynamics of the processes. We present the most recent studies performed on the full data set of about 470 fb^{-1} collected at the PEP-II e^+e^- collider at a center-of-mass energy of about 10.6 GeV.
In particular, we report the results on $e^+e^- \to \pi^+\pi^-\pi^0$. From the fit to the measured 3π mass spectrum we determine the products $\Gamma(V \to e^+e^-)$
$calB(V \to 3\pi)$ for the ω and ϕ resonances and for
$calB(\rho \to 3\pi)$. The latter isospin-breaking decay is observed with 6σ significance. The measured $e^+e^- \to \pi^+\pi^-\pi^0$ cross section is used to calculate the leading-order hadronic contribution to the muon magnetic anomaly from this exclusive final state with improved accuracy.
We show also new results on the study of $e^+e^- \to 2K3\pi$ processes, in an energy range from production threshold up to about 4 GeV. For each process, the cross section is measured as a function of the invariant mass of the hadronic final state. The production of several intermediate final states is also measured, allowing for the search for new decay modes of recently discovered resonances.

Hadrons and physics beyond the standard model / 219

The Heavy Photon Search experiment at Jefferson Lab

Corresponding Author: andrea.celentano@ge.infn.it

Evidence for electroweak-scale Dark Matter (DM) particles arising from direct searches has proven to be extremely elusive so far. However, the existence of light (sub-GeV) particles could also be investigated searching for rare events at accelerators. A simple possibility for light DM is that its constituents belong to some Hidden Sector, uncharged under the Standard Model (SM) forces and coupled to SM through the interaction with the ordinary particles of a new force carrier, in a kinetic equilibrium condition. To this respect, theoretically well-motivated models have proposed the existence of a new U(1) light gauge boson, the heavy (or dark) photon A'. In some versions of these models DM particles can self-interact strongly, providing a viable explanation to the observed DM abundance –these are generally identified as Strongly Interacting Massive Particles (SIMPs). SIMPs are expected to feature a QCD-like pattern, with light dark pions and excited states like dark vector mesons, that are coupling and/or mixing to heavy photons.
The Heavy Photon Search Experiment (HPS) at the Thomas Jefferson National Accelerator Facility (JLab, USA) has been primarily designed to search for heavy photons by exploiting their kinetic mixing with the Standard Model photons. Recent studies disclosed also its potentialities for the investigation of SIMPs through their coupling to the heavy photons and following decays.
Heavy photons could be created in HPS via the interaction of an electron beam on a tungsten target, and could be detected through their subsequent decays to charged lepton (namely, e+e-) pairs. Experimental signatures for detection in HPS are either a resonance peak in the electron-positron invariant mass distribution or the detection of displaced decay vertices; their occurrence would depend on the heavy photon mass and the strength of its coupling.
In this presentation, the design and performance of the HPS detector will be described, together with the results of the analysis of data collected in the first 2016 engineering run and recently submitted for publication. Moreover, the status of and prospects for the ongoing analysis of two larger datasets collected in 2019 and 2021 will be shown, with reference on the expected reach for possible SIMPs observation.

Hadron decays, production and interaction / 220

Renormalization in various schemes of nucleon-nucleon chiral EFT.

Author: Ashot Gasparyan[1]

Co-author: Evgeny Epelbaum [1]

[1] *Ruhr University of Bochum*

Corresponding Author: ashot.gasparyan@rub.de

Renormalizability of an effective field theory allows one
to perform a systematic expansion of the calculated observable
quantities in terms of some small parameter in accordance with
a certain power counting.
We consider chiral effective field theory in application to the
nucleon-nucleon interaction
at next-to-leading order in the chiral expansion.
The analysis of the renormalizability of this theory is complicated
by the nonperturbative nature of the leading order interaction.
The requirement of the renormalizability imposes nontrivial constraints
on a choice of such interaction.
Two different approaches are studied: the finite- and the infinite-cutoff schemes.
The consequences for the realistic nucleon-nucleon interaction are discussed.

New facilities / **221**

Recent measurements and prospects from analysis of fixed-target collisions at LHCb

Author: Luciano Libero Pappalardo[1]

[1] *Istituto Nazionale di Fisica Nucleare*

Corresponding Author: pappalardo@fe.infn.it

The LHCb spectrometer has the unique capability to function as a fixed-target experiment by injecting gas into the LHC beampipe while proton or ion beams are circulating. The resulting beam-gas collisions cover an unexplored energy range that is above previous fixed-target experiments, but below the RHIC or LHC collider energies. Here we present recent results on open charm, J/ψ, and $\psi(2S)$ production from pNe and PbNe fixed-target collisions at LHCb. Also, the status of the commissioning and the prospects for measurements of hadron spectroscopy and hadron structure for the upgraded fixed-target system, SMOG2, will be presented.

Exotic hadrons and candidates / **222**

Towards nature of the Tcc(3875)+ state

Author: Vadim Baru[1]

Co-authors: Menglin Du [2]; Arseniy Filin [3]; Xiang-Kun Dong ; Evgeny Epelbaum Epelbaum [4]; Feng-Kun Guo [5]; Christoph Hanhart [6]; Alexey Nefediev [7]; Juan Nieves [8]; Qian Wang

[1] *Bochum University*

[2] *School of Physics, University of Electronic Science and Technology of China*

[3] *Institut für Theoretische Physik II, Ruhr-Universität Bochum, D-44780 Bochum, Germany*

[4] *Ruhr-Universitaet Bochum*

[5] *Institute of Theoretical Physics, Chinese Academy of Sciences*

[6] *IKP-TH, Forschungszentrum Juelich*

[7] *Institute Josef Stefan*

[8] *IFIC (CSIC-UV)*

Corresponding Author: vbaruru@gmail.com

The recent experimental observation of the first doubly charm exotic state Tcc(3875)+ by the LHCb collaboration has triggered the enormous interest in the community. Indeed, this state has very peculiar properties, since it is located just a few hundreds keV below the D^0D^{*+} threshold and its width stems almost entirely from the only available strong decay channel $DD\pi$, as a consequence of the finite D^* life time. This state has also been recently studied on lattice.

In this talk, we discuss our recent results for the Tcc from the EFT-based analysis of the experimental line shapes. Also, we argue that the left-hand-cut branch point generated by the one-pion exchange for the larger than physical pion masses sets an upper bound on the validity of the effective-range expansion, that has been used so far for extracting pertinent information on the Tcc from lattice. We therefore conclude that for an accurate extraction of the Tcc pole from lattice, the inclusion of the one-pion exchange is necessary.

Exotic hadrons and candidates / **223**

Exotic mesons from COMPASS

Author: Bernhard Ketzer[1]

[1] *University of Bonn*

Corresponding Author: bernhard.ketzer@uni-bonn.de

The COMPASS experiment at CERN's Super Proton Synchrotron has been a key player in the quest for understanding the spectrum of light mesons. Using a high-energy pion beam, an unprecedented data set on diffractively produced isovector mesons was recorded. In addition to extending our knowledge on ordinary mesons, the data also allow us to search for exotic states not fitting the ordinary quark model. The $\pi_1(1600)$ with spin-exotic quantum numbers $J^{PC} = 1^{-+}$ is clearly observed in the $\rho\pi$, $\eta\pi$ and $\eta'\pi$ decay channels. Based on these data, the pole position of the $\pi_1(1600)$ was extracted for the first time, confirming its resonant nature. Corresponding signals are also observed in other decay channels, e.g. $b_1\pi$, consistent with theory expectations for a hybrid meson with gluonic degrees of freedom.

Theory predicts the existence of full multiplets of hybrid states, including ones with strangeness. Their identification, however, is more difficult since there are no spin-exotic quantum numbers for strange mesons. Taking advantage of the admixture of kaons to the hadron beam, COMPASS also studies the spectrum of strange mesons. In the $K\pi\pi$ final state, a total of 11 meson states could be measured, including a pseudoscalar supernumerous state with respect to quark models. One of the goals of the AMBER experiment, a new QCD facility at CERN, is to increase the data set on strange mesons by a factor of 20 with respect to COMPASS.

The talk will give an overview of the results on exotic mesons in COMPASS and provide an outlook towards the plans for strange meson spectroscopy with AMBER.

Light meson spectroscopy / **224**

Non-Strange Light-Meson Spectroscopy at COMPASS

Author: Philipp Haas[1]

[1] *Technical University of Munich*

Corresponding Author: philipp.haas@tum.de

The COMPASS experiment is a multi-purpose fixed-target experiment at the CERN SPS. Part of its physics program is the study of non-strange light mesons produced via diffractive scattering of $190\,\mathrm{GeV}/c$ π^- off a liquid-hydrogen target. This gives access to the excitation spectrum of all isovector mesons a_J and π_J in multiple final states. The spin-exotic meson $\pi_1(1600)$ is of particular interest.
COMPASS observed the $\pi_1(1600)$ in the $\pi^-\pi^-\pi^+$, $\eta\pi^-$, and $\eta'\pi^-$ final states. However, based on lattice QCD predictions the $\pi_1(1600)$ is expected to dominantly decay to $b_1(1235)\pi$. This decay mode is studied in the $\omega(782)\pi^-\pi^0$ final state, for which COMPASS acquired the largest dataset. We disentangle contributing meson resonances in a partial-wave analysis and find clear indications for a resonance-like signal in this final state consistent with the $\pi_1(1600)$. In this talk, we will discuss recent results of non-strange light-meson spectroscopy at COMPASS with focus on the $\omega(782)\pi^-\pi^0$ final state.

Exotic hadrons and candidates / **225**

Revisiting Exotic Decays with XEFT

Author: Lin Dai[1]

Co-authors: Feng-Kun Guo ; Thomas Mehen ; Reed Hodges ; Sean Fleming

[1] *TU Munich*

Corresponding Author: lin.dai@pitt.edu

In this talk, I will report our recent applications of XEFT to the study of decays of exotic hadrons near threshold: including the decay of \chi_{c1}(3872) and the strong decay of Tcc^+ and the consistency of their hadronic molecular description.

Hypernuclei and kaonic atoms / **226**

The present and the future of hypernuclei at the LHC

Author: Maximiliano Puccio[1]

[1] *CERN*

Corresponding Author: maximiliano.puccio@cern.ch

Over the past decade, significant progress has been made in understanding (anti)(hyper)nucleosynthesis at hadronic colliders, such as the Large Hadron Collider (LHC). Research on the production of antinuclei and hypernuclei has broadened our understanding of the field, with the ALICE experiment playing a pivotal role.
As we look towards the future, new experiments and detector technologies at the LHC promise to further advance the study of (anti)(hyper)nuclei.
This presentation will discuss the emerging opportunities for hypernuclei measurements at hadronic colliders, focusing on the LHC. We will explore the prospects of current and future experiments, highlighting their potential for expanding our knowledge of (anti)(hyper)nuclei production mechanisms, interaction cross-sections, and nuclear structure.

Hadron decays, production and interaction / 227

Recent developments in angular correlations of identified particles (experiment & theory)

Author: Lukasz Graczykowski[1]

[1] *Warsaw University of Technology*

Corresponding Author: lgraczyk@cern.ch

Angular ($\Delta\eta\Delta\varphi$) correlations of identified particles measured in ultrarelativistic proton-proton and heavy-ion collisions exhibit a number of features which depend on the collision system and particle type under consideration. Those features are produced by various mechanisms, such as (mini)jets, elliptic flow, resonance decays, and conservation laws. In addition, of particular importance are those related to the quantum statistics (QS) and final-state interactions (FSIs).

Latest measurements of $\Delta\eta\Delta\varphi$ correlations of identified particles from ALICE 1 and STAR 2 show differences in particle production between baryons and mesons. While the correlation functions for mesons exhibit the expected near-side ($(\Delta\eta,\Delta\varphi)\approx(0,0)$) peak dominated by effects of mini-jet fragmentation and are well reproduced by general-purpose Monte Carlo (MC) generators, the story is different for baryons. For pairs of particles of the same baryon number a surprising near-side anti-correlation structure is observed instead of a peak, implying that two such particles are rarely produced with similar momentum. Until recently, this effect has not been reproduced by any of the MC models, however, several developments on the theory side have been made since the publication of experimental results (i.e. [3,4]). The discrepancy poses fundamental questions on the production mechanism of baryons.

Moreover, in our recent work [5] we show how to unfold the QS and FSI contributions in angular correlation functions using momentum correlations (femtoscopy). In particular, we show how those effects modify the shape of the angular correlation function with emphasis on proton-proton pairs. Most importantly, specific structures in the near-side region of the two-baryon angular correlation function, namely a small enhancement in the middle of a depletion for proton-proton pairs is reproduced with the proposed unfolding procedure. However, the unfolding of the FSI and QS effects is not able to explain the wide anticorrelation effect at near-side observed by ALICE and STAR.

1 J. Adam et al. (ALICE Collaboration), Eur. Phys. J. C77 (2017) 56, https://arxiv.org/abs/1612.08975
2 J. Adam et al. (STAR Collaboration), Phys. Rev. C 101, 014916 (2020), https://arxiv.org/abs/1906.09204
[3] L.Y. Zhang et al., Phys. Rev. C 98 (2018) 3, 034912, L.Y. Zhang et al., Phys. Lett. B 829 (2022) 137063
[4] N. Demazure, V. Gonzalez, F. Llanes-Estrada, https://arxiv.org/abs/2210.02358
[5] Ł. Graczykowski, M. Janik, Phys. Rev. C 104, 054909 (2021)

Hadron decays, production and interaction / 229

Spectral reconstruction in lattice QCD for inclusive rates and exclusive scattering amplitudes

Author: John Bulava[1]

[1] *University of Southern Denmark, CP3-Origins Institute*

Corresponding Author: bulava@cp3.sdu.dk

The spectral reconstruction of Euclidean correlation functions is an alternative to standard lattice QCD analyses. Using this approach, inclusive hadronic decays are determined directly from first principles, including the R-ratio and hadronic decays of the tau-lepton. The computed decay rates are smeared with a known kernel, the achievable resolution of which is related to the spatial volume of the simulations. In this regard, the novel 'masterfield' simulation paradigm enables larger volumes

and correspondingly increased resolution. Finally, a novel variant of the spectral reconstruction approach is presented which improves upon traditional lattice QCD spectroscopy. This is exemplified by the finite-volume energies of two nucleons used to infer exclusive scattering amplitudes.

Hadrons in hot and nuclear environment / 230

Thermal masses of D mesons and hidden-charm exotics

Author: Juan Torres-Rincon[1]

[1] *Universitat de Barcelona*

Corresponding Author: torres@fqa.ub.edu

I will explain how we applied thermal effective hadron theories to extract the spectral functions of D and D^* mesons at finite temperature. Then, by modeling the exotic $X(3872)$ / $X(4014)$ as dynamically-generated states out of the D - $\bar{D}^*$ / D^* - $\bar{D}^*$ meson rescattering, I will address the thermal dependence of their masses and decay widths. When these states propagate at finite temperature their properties are severely modified by the presence of the thermal bath, loosing their bound-state character for moderate temperatures. Our results are shown in this publication.

Analysis tools / 231

Model selection in kaon photoproduction

Author: Dalibor Skoupil[1]

[1] *Nuclear Physics Institute, Rez, Czech Republic*

Corresponding Author: skoupil@ujf.cas.cz

New models for photoproduction of kaons on the proton were constructed 1 utilizing new experimental data from LEPS, GRAAL, and particularly CLAS collaborations. The higher spin nucleon (spin-3/2 and spin-5/2) and hyperon (spin-3/2) resonances were included using a consistent formalism and they were found to play an important role in the data description. In order to account for the unitarity corrections at the tree level, we introduced energy-dependent widths of nucleon resonances, which affect the choice of hadron form factors and the values of their cutoff parameters extracted in the fitting procedure.

Once all the ingredients of the model were well prepared, we faced the problem of selecting the appropriate set of resonances. Since a plain χ^2 minimization, which we used in our previous study 1, could not prevent us from overfitting the data, i.e. introducing more parameters (and thus resonances) than were needed for data description, we opted for a regularization method, the least absolute shrinkage selection operator, and information criteria for avoiding this issue and choosing the best fit. In the analysis of new CLAS $K^+\Sigma^-$ data 2, we were then able to arrive at a very economical model including only the most needed resonances [3]. Similarly, in our very recent study of the role of hyperon resonances in the $K^+\Lambda$ channel, we made use of ridge regression to reduce some of the couplings and arrived at a much more robust model [4].

1 D. Skoupil, P. Bydžovský, Phys. Rev. C 93, 025204 (2016).

2 N. Zachariou et al., Phys. Lett. B 827, 136985 (2022).

[3] P. Bydžovský, A. Cieplý, D. Petrellis, D. Skoupil, and N. Zachariou, Phys. Rev. C 104, 065202 (2021).

[4] D. Petrellis, D. Skoupil, arXiv:2212.14305 [nucl-th].

Exotic hadrons and candidates / 232

PANDA perspectives in exotics

Author: Frank Nerling[1]

[1] *Gu Frankfurt & GSI Darmstadt*

Corresponding Author: f.nerling@gsi.de

The new Facility for Antiproton and Ion Research (FAIR) is under construction at GSI in Darmstadt (Germany). Antiprotons are planned to be provided by the High Energy Storage Ring, at which the PANDA experiment will directy be located. It represents the central part of the hadron physics programme. The field of hadron spectroscopy has gained new momentum by the discovery of the so-called charmonium-like and bottominium-like exotic states over the past two decades. The nature of many of the so-called exotic XYZ states in the charmonium region are, however, not yet understood. Precise measurements of hadron masses and widths are mandatory to sort out different theoretical models and clarify the nature of these unxepected states. One example is the $\chi_{c1}(3872)$, formerly known as $X(3872)$ – although being the first of the new charmonium-like states discovered since 2003, the nature of this state is still not clarififed. In $p\bar{p}$ annihilation, such XYZ states can be produced in direct formation, allowing for a precise resonance energy scan. Using the example of the $X(3872)$, we quantified the expected sensitivity of energy scans of narrow resonances and how well we can distinguish between models that turn out to be indistinguishable from the LHCb data.

Exotic hadrons and candidates / 233

Measurement of the photoproduction cross section for $\gamma p \to \phi\pi^+\pi^- p$ and search for the $Y(2175)$ at GlueX

Authors: Frank Nerling[1]; Klaus Goetzen[None]

[1] *Gu Frankfurt & GSI Darmstadt*

Corresponding Author: f.nerling@gsi.de

The $Y(2175)$, recently renamed to $\phi(2170)$, is one of the rare exotic candidates connected to strangeonium instead of the heavier charmonium-like and bottomonium-like exotic states. Originally observed in initial-state radiation by the BaBar experiment in 2006, it is could be a strange partner of the famous charmonium-like exotic vector state $Y(4260)$. Various interpretations exist in the literature, such as conventional strangeonium, tetraquark or hybrid state. Meanwhile, it has been seen in different experiments and decay channels. The available experimental information obtained only from e^+e^- collider experiments is,
however, not sufficient to confirm or disprove any of the proposed interpretations. Information about the production of this state in other processes is required. Using intense photon beams is especially well suited to study strangeonium-like states because of the strong coupling of the photon to $s\bar{s}$. In this talk, we report on our measurement of the production cross section of the reaction $\gamma + p \to \phi\pi^+\pi^- + p$ and the search performed for $Y(2175) \to \phi\pi^+\pi^-$ with the GlueX experiment.

Exotic hadrons and candidates / 234

Molecular pentaquarks from the effective field theory and phenomenological perspectives

Author: Manuel Pavon Valderrama[1]

[1] *Beihang University*

Corresponding Author: mpavon@buaa.edu.cn

The last few years have seen the observation of a series of hidden-charm pentaquarks by the LHCb collaboration. The most recent one is the $P^{\Lambda}_{\psi s}(4338)$, which has the quantum numbers of a Λ baryon. Most of these pentaquarks are close to a meson-baryon threshold and have been readily interpreted as bound (or molecular) states. Here we explore what are the consequences of the molecular hypothesis, particularly when constrained by heavy-quark spin symmetry. From effective field theory arguments we argue that, if the $P^{\Lambda}_{\psi s}(4338)$ is to be interpreted as a $\bar{D}\Xi_c$ bound state, this implies the existence of a $\bar{D}_s\Lambda_c$ partner state with a mass close to 4250 MeV 1 (and possibly other partners as well). Besides, we confront the previous predictions with a phenomenological model 2 (based on the saturation of the pentaquark potential by light-meson exchanges) to find what the converging points between these two approaches are.

1 Mao-Jun Yan, Fang-Zheng Peng, Mario Sánchez Sánchez, Manuel Pavon Valderrama, arxiv:2207.11144
2 Zi-Ying Yang, Fang-Zheng Peng, Mao-Jun Yan, Mario Sánchez Sánchez, Manuel Pavon Valderrama, arxiv: 2211.08211

Light baryon spectroscopy / **235**

Measuring neutron polarisation in pn production using CLAS

Author: William Booth[None]

Corresponding Author: wab510@york.ac.uk

The existence of hexaquark states has far-reaching consequences, such as our understanding of quark structure, and the mechanisms involved inside neutron stars1. Predicted in 19642, and recently discovered, the simplest non-trivial hexaquark, is the d*(2380), an "excited deuteron" state. The deuteron, comprised of a proton and neutron, can be excited to this state during deuteron photo-disintigration reactions with high photon energies (Eγ ~500-600 MeV). Several other bound/quasibound N-N* dibaryonic states can also be studied in this reaction. Unfortunately, the world dataset of deuteron photodisintegration has significant gaps in terms of photon energy and angular coverage, particularly in measurements of polarisation observables. To address this problem, we have utilised experimental data from the CEBAF large acceptance spectrometer (CLAS) in a unique way.
CLAS was a many-component detector housed in Hall B of Jefferson Lab, a world leading international facility. One such component, the start counter, consisting of a set of thin plastic scintillators surrounding the beamline, was used to determine the start time of an event originating in the target via photo-induced reactions. A novel approach that exploits the start counter as a nucleon polarimeter is implemented by this project. We will show analysis that has led to measurements of neutron induced polarisation by circularly polarised photons in deuteron photodisintegration for beam energies of 0.6 to 2.2 GeV, making use of CLAS's wide angular range, covering N-N* reaction dynamics in second and third resonance regions, and providing exciting new insights into hexaquark studies.

1 I. Vidana, M. Bashkanov, D. P. Watts, and A. Pastore, Phys. Lett. B 781, 112 (2018).
2 F. J. Dyson and N.-H. Xuong, Phys. Rev. Lett. 13, 815 (1964).

Hadron decays, production and interaction / **236**

Quarkonium production in small collision systems in ALICE

Author: Michele Pennisi[1]

[1] *INFN UniTO*

Corresponding Author: michele.pennisi@cern.ch

Quarkonium measurements in proton-proton (pp) collisions represent a fundamental tool for studying quantum chromodynamics (QCD), due to the involvement of both perturbative and non-perturbative regimes and their interplay in the resonance formation process. In p–Pb collisions, quarkonium production is sensitive to the nuclear modifications on parton distribution functions and potentially to final-state effects, that can either be related to cold nuclear matter or to the potential formation of a strongly interacting system at high collision energy and particle multiplicity.

The ALICE experiment has measured quarkonia in various collision systems at the LHC, through their dilepton decays.
Quarkonia can be reconstructed in the e^+e^- decay mode at midrapidity ($|y|$<0.9) in the central barrel, and at forward rapidity (2.5<y<4.0) in the muon spectrometer, through their $\mu^+\mu^-$ decay.

In this contribution, a summary of the recent ALICE measurements of quarkonium-related observables in pp and p–Pb collisions will be presented. In pp collisions at $\sqrt{s} = 13$ TeV, preliminary results on Υ(nS) cross section measurements and prompt and not-prompt J/Ψ-tagged jets, as well as final results on double J/Ψ production, will be shown. A preliminary measurement of charm and beauty cross sections at forward rapidity, which can serve as a reference for open heavy flavour and quarkonium measurements in nuclear collisions, will be presented.
Results on J/Ψ elliptic flow v_2 in pp collisions will also be discussed and compared with the corresponding ones in p–Pb. Finally, recently published prompt and non-prompt J/Ψ cross sections and nuclear modification factors in p-Pb collisions at $\sqrt{s_{NN}}$ = 8.16 TeV will be shown. Results will be compared to available theoretical models.

Hadrons and physics beyond the standard model / **237**

The role of convergence methods as fitting functions in the context of the MuonE experiment

Author: Pere Masjuan[1]

Co-authors: Camilo Rojas [1]; Cristiane London [2]; Diogo Boito [3]

[1] *IFAE/UAB*

[2] *IFAE*

[3] *IFSC Sau Paulo*

Corresponding Authors: crojas@ifae.es, masjuan@ifae.es

In the context of the anomalous magnetic moment of the muon, the hadronic contribution plays a crucial role, especially concerning the error budget estimation. Currently, lattice QCD simulations confront the dispersive calculations based on e+e- hadronic cross sections. The new MUonE experimental proposal pretends to shed light on that situation. Still, a powerful method to extract the desired hadronic contribution from such a new experiment should be devised. In this talk, we will show how acceleration-of-convergence methods profiting from the analyticity of the correlator driving the hadronic contribution are key to reaching the required precision.

Plenary / **238**

Effective Field Theories for hadron spectroscopy

Author: Raquel Molina Peralta[1]

[1] *UV-IFIC*

Corresponding Author: raquel.molina@ific.uv.es

In this talk I will review some of the recent advances that Effective Field Theories had done in hadron spectroscopy regarding exotic states. The hidden gauge formalism has been able to predict several exotic states, like the pentaquarks, and flavour exotic states, as doubly charmed states and the recently observed $T_{cs}(2900)$. Some of these states are been also searched for in latticeQCD. There are also predictions of exotic candidates in the bottom sector. The number of exotic hadrons is growing rapidly in the recent years. However, there is not yet consensus whether the recently observed states are molecular or compact states, and there is a lack of a general framework. The investigation of the decay modes and the determination of the scattering parameters are essential tools. I will review some of the tools developed recently to get further insight in the hadron structure of exotic hadrons.

QCD and hadron structure / **239**

Studying Gluon GPDs at the Electron Ion Collider via Deeply Virtual Meson Production

Author: Stuart Fegan[1]

[1] *University of York*

Corresponding Author: stuart.fegan@york.ac.uk

The Electron Ion Collider (EIC) is a next-generation hadron physics facility, planned to be built in the coming decade at Brookhaven National Laboratory (BNL), with the intention of further exploring the quark and gluon substructure of hadrons and nuclei. The EIC will address fundamental questions in QCD, probing the interplay of quarks and gluons to learn how they contribute to overall nucleon properties, and how they are affected by the nuclear environment. With heavy ion beams to enable in-depth studies of nuclear matter, alongside the precision of the electromagnetic interaction and the determinative properties of polarised nucleon beams, the EIC is expected to provide scientific opportunities for decades to come.

Hard exclusive meson electroproduction processes, also known as deeply virtual meson production (DVMP), are complimentary to the deeply virtual compton scattering (DVCS) reaction. In DVMP, the scattering reaction produces a meson instead of a photon, and through the study of heavy vector meson reactions, such as J/ψ, it is possible to probe gluon GPDs and ultimately provide information about saturation when studying the evolution of gluon spatial distribution.

The work presented will focus on studies of J/$\psi \rightarrow e^+e^-$ events from ep collisions, and the evaluation of projected detector performance for DVMP measurements in an EIC detector concept. Prospects for extending these studies to other vector meson channels, from ϕ to Υ, will also be discussed.

Heavy meson spectroscopy / **240**

Femtoscopy for D*0(2300) and D*s0(2317) states

Author: Miguel Albaladejo[1]

Co-authors: Enrique Ruiz Arriola [2]; Juan Nieves [3]

[1] *IFIC*

[2] *Universidad de Granada*

[3] *IFIC (CSIC-UV)*

Corresponding Author: miguelalbaladejo@gmail.com

We predict the correlation functions relevant in femtoscopy studies for S-wave $D_{(s)}\phi$ pairs, with $D_{(s)}$ a pseudoscalar open charm meson and ϕ a Goldstone boson, describing their interactions with next-to-leading order unitarized heavy-meson chiral perturbation theory amplitudes.

In the $(S, I) = (0, 1/2)$ sector, the effect of the two-state structure around 2300 MeV can be clearly seen in the correlation functions of the $D\pi$, $D\eta$, $D_s\overline{K}$ channels. In the $(1, 0)$ sector, a depletion of the correlation function near the DK threshold can be seen, produced by the $D_{s0}^*(2317)^{\pm}$ state lying below the DK threshold.

These correlation functions could be experimentally measured, and will shed light into the hadron spectrum and, in particular, into the nature of these states.

Hadron decays, production and interaction / 241

The three-particle K-matrix at NLO in ChPT

Author: Tomáš Husek[1]

Co-authors: Fernando Romero-López [2]; Johan Bijnens [3]; Jorge Baeza-Ballesteros [4]; Mattias Sjö [3]; Stephen R. Sharpe [5]

[1] *Charles University*

[2] *MIT*

[3] *Lund University*

[4] *IFIC, Valencia*

[5] *Washington University*

Corresponding Author: thusek@cern.ch

The three-particle K-matrix, $\mathcal{K}_{\mathrm{df},3}$, is a scheme-dependent quantity that parametrizes short-range three-particle interactions in the relativistic-field-theory three-particle finite-volume formalism. In this talk, I briefly present our earlier calculation of the six-pion amplitude at next-to-leading order (NLO) in Chiral Perturbation Theory (ChPT) and our recent findings about how it relates to the K-matrix for systems of three pions at maximal isospin. The resulting values are then compared to existing lattice QCD results. The agreement between lattice QCD data and ChPT in the first two coefficients of the threshold expansion of $\mathcal{K}_{\mathrm{df},3}$ is significantly improved once NLO effects are incorporated.

Hypernuclei and kaonic atoms / 242

Measurements of Cross Sections and Polarizations of Lambda-Nucleon and Lambda-Deuteron Elastic Scattering with the CLAS Detector

Author: Yordanka Ilieva[1]

Co-author: Nicholas Zachariou [2]

[1] *University of South Carolina*

[2] *University of York*

Corresponding Author: ilieva@sc.edu

The elementary YN interaction remains of significant and continuing interest in nuclear physics. On the one hand, it is important to understand hadron dynamics in which the strange quark is involved and to construct a comprehensive picture of the baryon-baryon interaction. On the other hand, reliable YN potentials are needed for in-medium calculations, such as of hypernuclear structure and the equation of state of neutron stars. Decades of theoretical and experimental studies of the NN interaction have led to the development of established and tested theoretical frameworks for constructing reliable baryon-baryon potentials, both from phenomenological analyses and chiral effective field theory. These techniques have successfully been extended to the strangeness sector. Yet, the very poor database of YN scattering cross-sections does not allow to determine uniquely the YN phase shifts and all low-energy parameters of the YN potentials. Thus, a comprehensive understanding of the YN interaction is still lacking, and the topic continues to be a fascinating problem in strong physics. While hypernuclear spectroscopy provides valuable information, the extraction of the elementary YN interaction from analysis of hypernuclear binding energies is sensitive to uncertainties related to medium modifications and many-body effects. Parameters, such as scattering lengths, are poorly constrained. In this talk, we will present an experimental program aiming to provide a large set of experimental observables of elastic scattering of lambda off the nucleon and deuteron using high-statistics, high-polarization photoproduction data taken with the CEBAF Large Acceptance Spectrometer (CLAS) at Jefferson Lab. The program utilizes secondary scattering within the same target cell and final-state interactions to access the reactions of interest. We will discuss recent Lambda-proton total elastic scattering cross sections, which have demonstrated the feasibility of the secondary scattering technique and have added new higher-precision data points to the world database. We will also showcase several ongoing studies of LambdaN and LambdaNN measurements and discuss the physics opportunities they present.

Exotic hadrons and candidates / **243**

Overview of XYZ Physics at BESIII

Author: Ryan Mitchell[1]

[1] *Indiana University*

Corresponding Author: remitche@indiana.edu

I will review studies of exotic meson states in the charmonium region (the XYZ states) performed by the BESIII experiment. Recent results include new decay modes of the X(3872), new e+e- cross sections in the region of the Y(4230), and updates on studies of the isospin-one Zc and isospin-half Zcs states. I'll also preview ongoing and future efforts, which will be much enhanced by an upcoming upgrade of the BEPCII accelerator.

Hypernuclei and kaonic atoms / **244**

K- nunleon/nuclei interactions studies by AMADEUS at DAFNE

Author: Kristian Piscicchia[1]

[1] *Istituto Nazionale di Fisica Nucleare*

Corresponding Author: kristian.piscicchia@lnf.infn.it

Experimental investigation of the strong interaction in the low-energy regime is mandatory to constrain models of the low-energy meson-baryon interaction, with implications in several fields, ranging from the search for exotic mesic nuclear bound states, to the structure of compact astrophysical objects like the neutron stars.
In this talk we will review the studies performed by the AMADEUS experiment, at the DAFNE collider of LNF-INFN, of the low-energy kaon-nucleon/nuclei interaction processes. More in detail we

will report on the measurement of the non-resonant hyperon pion formation amplitude below the K-N threshold, of the branching ratios and of the low-energy cross sections of the K- multi-nucleon absorptions on various light nuclear targets and of the recent precise determination of the $K^- p \to (\Sigma^0/\Lambda)\,\pi^0$ cross sections close to threshold.

Light baryon spectroscopy / **245**

Recent results from LEPS2/BGOegg on light-quark baryon spectroscopy

Author: Norihito Muramatsu[1]

[1] *Tohoku University*

Corresponding Author: mura@lns.tohoku.ac.jp

At SPring-8 LEPS2 beamline, a linearly polarized photon beam is available in the tagged energy range of 1.3–2.4 GeV. In this facility, the BGOegg experiment has been carried out using a detector setup with a large-acceptance electromagnetic calorimeter, which has the world's best resolution in the energy range around 1 GeV. A main physics subject in this experiment is the spectroscopy of light-quark baryon resonances, which are excited from a target proton in the photoproduction of a neutral meson decaying into multiple gammas. Differential cross sections and polarization observables for such reactions have been measured as the basic data that should be input into partial wave analyses. Particularly, high linear polarization of the photon beam is unique in the energy region around 2 GeV and useful to obtain photon beam asymmetries Σ for the decomposition of overlapping resonances. In this talk, I will discuss our recent results on π^0, η, and ω photoproduction, an on-going analysis about η' photoproduction, and future prospects in the upgraded BGOegg experiment that is being conducted with nearly full coverage of solid angles by electromagnetic calorimeters.

Hypernuclei and kaonic atoms / **246**

Recent Hypernuclei Measurements from the STAR Experiment

Authors: Iouri Vassiliev[None]; Sevil Salur[1]

[1] *for the STAR Collaboration*

Corresponding Authors: i.vassiliev@gsi.de, salur@physics.rutgers.edu

Hypernuclei, bound 1 states of hyperons and nucleons, have been suggested to be sensitive probes to the medium properties of the nuclear matter created in heavy-ion collisions. Measurements on the intrinsic properties of hypernuclei, such as their lifetimes and binding energies, can also give constraints to the hyperon-nucleon interaction, which is an essential ingredient in the equation-of-state of high baryon density matter.

In this presentation, recent results on the intrinsic properties of light hypernuclei (${}^{3}_{\Lambda}\mathrm{H}$, ${}^{4}_{\Lambda}\mathrm{H}$, and ${}^{4}_{\Lambda}\mathrm{He}$), as well as their production yields in heavy-ion collisions will be discussed. These results are compared with model calculations, and the physics implications will be discussed.

Heavy meson spectroscopy / **247**

Diabatic Representation for Heavy Mesons

Author: Roberto Bruschini[1]

[1] *The Ohio State University*

Corresponding Author: bruschini.1@osu.edu

The Born-Oppenheimer approximation for QCD provides an intuitive yet rigorous framework for the study of mesons containing two heavy quarks. The energy levels of QCD with two static color sources, numerically accessible on the lattice, are translated into potentials for the nonrelativistic motion of the heavy quarks. The mass spectrum is then determined simply by integrating a multichannel Schrödinger equation. In this talk, I discuss the diabatic representation of the Born-Oppenheimer approximation for QCD, where the coupled equations for the heavy-quark motion take a particularly simple form. I show that the diabatic representation provides the most effective Born-Oppenheimer framework in which to study the effects of string breaking and heavy-quark spin symmetry breaking, which are essential ingredients for accurate calculations of exotic heavy mesons.

New facilities / **248**

The Status of SoLID Project at Jefferson Lab

Corresponding Author: yez@tsinghua.edu.cn

The Solenoidal Large Intensity Device (SoLID) is a forward-scattering spectrometer located in Hall-A at Jefferson Lab. With its large acceptance and full azimuthal angular coverage, SoLID is capable of handling high luminosities ranging from 1037 to 1039 /cm2/s, using both polarized and unpolarized targets. The detector makes use of the full potential of the JLab 12 GeV upgrade and is designed to support various programs, including 3D imaging of the nucleon, beyond standard-model searches, and exploration of gluonic forces. Several new experiments have been approved or are currently in active development to further expand these physics programs, requiring the high-intensity and wide acceptance that SoLID uniquely provides. In this presentation, we will introduce the physics topics that SoLID will explore, update the overall status of the program, and report on the current detector research and development activities.

QCD and hadron structure / **249**

J/ψ Near-Threshold Photoproduction off the Proton and Neutron with CLAS12

Author: Richard Tyson[1]

[1] *University of Glasgow*

Corresponding Author: r.tyson.1@research.gla.ac.uk

J/ψ near threshold photoproduction plays a key role in the physics program at the Thomas Jefferson National Accelerator Facility (JLab) 12 GeV upgrade due to the wealth of information it has to offer. J/ψ photoproduction proceeds through the exchange of gluons in the t-channel and is expected to provide unique insight about the nucleon gluonic form factors and the nucleon mass radius.
The JLab based CLAS Collaboration, which uses the CEBAF Large Acceptance Spectrometer (CLAS12), aims to measure the J/ψ near threshold photoproduction cross section using both a proton and a deuteron target. The latter further offers the possibility of comparing the proton and neutron gluonic form factors and mass radii in a first measurement of the cross sections off a proton or neutron within the deuteron target. The analysis towards these measurements is ongoing and well advanced, with machine learning based techniques for particle identification already designed and tested on CLAS12 data taken towards these measurements.
This talk will describe the aims and experimental design for the measurement of J/ψ near threshold

photoproduction off the proton and neutron with the CLAS12 detector along with the current stage of the data analysis.

Hypernuclei and kaonic atoms / 250

Measurements of the hypertriton production and properties with ALICE

Author: Stefania Bufalino[1]

[1] *Istituto Nazionale di Fisica Nucleare*

Corresponding Author: stefania.bufalino@to.infn.it

The hypertriton is the lightest known hypernucleus composed of a proton, a neutron, and a Λ hyperon. This extremely loosely bound system has a radial extension of its wave function of about 10 fm. Measurements of its lifetime and binding energy provide information on the hadronic interaction between hyperons and nucleons which is complementary to that obtained from correlation measurements. Precise modeling of this interaction is a fundamental input for the calculation of the equation of state of high-density nuclear matter inside neutron stars. Moreover, given its large wave function, measurements of its production rate in small collision systems are useful to constrain nucleosynthesis models, such as the statistical hadronization model and baryon coalescence.
In this talk, the most precise measurements of the hypertriton lifetime and lambda separation energy performed by the ALICE Collaboration will be presented. These results will be discussed in the context of state-of-the-art calculations which describe the hypertriton internal structure.
Furthermore, recent results on hypertriton production in pp and p-Pb collisions will be presented and their implications for the available phenomenological models will be extensively discussed.

Heavy baryon spectroscopy / 251

Heavy Baryons and Heavy Quark Symmetry

Author: Juan Nieves[1]

[1] *IFIC (CSIC-UV)*

Corresponding Author: jmnieves@ific.uv.es

In this work, we study the charm and bottom lowest-lying $\frac{1}{2}^-$ and $\frac{3}{2}^-$ Λ_Q resonances using a model which considers the interplay between the nearest baryon-meson and bare constituent quark model (CQM) degrees of freedom. For the former ones, we only consider the scattering of pions off $\Sigma_Q^{(*)}$ baryons. In addition, we constrain the couplings between CQM and meson-baryon states using HQSS.

We show that the $\Lambda(1405)$ chiral two-pole pattern does not have analog in the $\frac{1}{2}^-$ charmed and bottom sectors, because i) the $ND^{(*)}$ and $N\bar{B}^{(*)}$ channels do not play for heavy quarks the decisive role that the $N\bar{K}$ does in the strange sector, and ii) because the notable influence of the bare CQM states for the charm and bottom resonances. Moreover, we will also discuss the great importance of taking into account the chiral $\pi\Sigma_{c,b}^{(*)}$ channels and their interplay with the CQM degrees of freedom.

Heavy meson spectroscopy / **252**

Exotic hadrons with heavy quarks in EFT approach

Author: Alexey Nefediev[1]

[1] *Institute Josef Stefan*

Corresponding Author: alexey.nefediev@ijs.si

The approach to exotic hadrons with heavy quarks based on the Effective Field Theory is overviewed and its application to particular near-threshold exotic states in the spectrum of charmonium and bottomonium is discussed.

Light meson spectroscopy / **253**

Transverse-momentum dependent distribution functions for a pion with Minkowskian dynamics

Authors: Emanuel Ydrefors[1]; Giovanni Salme'[2]; Tobias Frederico[1]; Wayne de Paula[3]

[1] *Instituto Tecnologico de Aeronautica*

[2] *Istituto Nazionale di Fisica Nucleare - Roma*

[3] *Instituto Tecnológico de Aeronáutica*

Corresponding Author: giovanni.salme@roma1.infn.it

The unpolarized twist-2 (leading) and twist-3 (subleading), T-even, transverse-momentum dependent quark distributions in the pion are evaluated for the first time by using the actual solution of a dynamical equation in Minkowski space. The adopted theoretical framework is based on the homogeneous Bethe-Salpeter integral equation with an interaction kernel given by a ladder gluon exchange, featuring an extended quark-gluon vertex. The masses of quark and gluon as well as the interaction-vertex scale have been chosen in a range suggested by lattice-QCD calculations, and calibrated to reproduce both pion mass and decay constant.

The joint use of the Fock expansion of the pion state facilitates a more in-depth analysis of the content of the pion Bethe-Salpeter amplitude, allowing for the first time to determine the gluon contribution to the quark average longitudinal fraction, that results to be $\sim 6\%$.
The current analysis highlights the role of the gluon exchanges through quantitative analysis of collinear and transverse-momentum distributions, showing, e.g. for both leading and subleading-twists, an early departure from the widely adopted exponential fall-off, for $|\mathbf{k}_\perp|^2 > m^2$, with the quark mass $\sim \Lambda_{QCD}$.

QCD and hadron structure / **254**

Looking for strong parity violation in the proton structure

Corresponding Author: matteo.cerutti@pv.infn.it

We present a study of strong parity-violating contributions that can be included in inclusive Deep Inelastic Scattering (DIS) off an unpolarized proton target. We show that a non vanishing parity-violating structure function arise even in the case of pure photon exchange, in contrast with standard results.
The size of the additional strong parity-violating term is estimated by fitting available experimental data on electron and positron beam-spin asymmetries.

QCD and hadron structure / 255

Recent progress in hadron structure from Lattice QCD

Author: Constantia Alexandrou[1]

[1] *University of Cyprus & Cyprus Institute*

Corresponding Author: alexand@ucy.ac.cy

Lattice QCD has made tremendous progress both in the simulation of gauge ensembles as well as in the analysis of more challenging quantities that probe the 3D structure of hadrons like the generalised parton distributions (GPDs) but also in calculating quantities that potentially can reveal new physics, like the muon anomalous magnetic moment reaching a precision that matches the experimental result. In this talk, I will provide an overview of recent progress progress in hadron structure and specifically describe recent results towards the determination of the nucleon GPDs.

New facilities / 256

The NA60+ experiment at the CERN SPS: status and prospects

Author: Enrico Scomparin[1]

[1] *Istituto Nazionale di Fisica Nucleare*

Corresponding Author: enrico.scomparin@to.infn.it

The high-intensity beams provided by the CERN SPS in a wide energy interval offer a unique opportunity to investigate the region of the QCD phase diagram at high baryochemical potential. The fixed-target NA60+ experiment, proposed for taking data with Pb-Pb and p-A collisions at the SPS from 2029, aims at measurements of rare probes of the Quark-Gluon Plasma (QGP) in a beam-energy scan, in the interval sqrt(s_NN)= 6 - 17 GeV.
The experiment will include a MAPS-based vertex spectrometer, immersed in a dipole field, followed by a muon spectrometer with tracking detectors and a toroidal magnet. A rich physics program is foreseen. Electromagnetic observables will be studied, with the measurement of thermal dimuons and the investigation of signals of chiral symmetry restoration. Open/hidden charm and strange hadron production will also be accessible, with the possibility of measuring various hypernuclear states.
In the talk, the status of the project will be discussed, showing recent progress in the R&D phase and the main results on physics performance studies. The competitiveness and complementarity of NA60+ in the landscape of the experiments foreseen at other facilities will also be discussed.

Hadrons and physics beyond the standard model / 257

Assessing the spectral shape of forbidden beta decays

Author: Lorenzo Pagnanini[1]

[1] *Gran Sasso Science Institute & INFN - LNGS*

Corresponding Author: lorenzo.pagnanini@lngs.infn.it

Precision measurements of forbidden β-decays are a crucial benchmark for Nuclear Physics calculations, which in turn play a pivotal role in Astroparticle Physics. In particular, these processes could clarify the long-standing issue of the axial coupling constant (gA) quenching in nuclear medium, which enters the theory when the hadronic current is renormalized at the nucleon level and approximate many-body calculations are performed.**Such strongly suppressed processes are also a common uncertainty source in Dark Matter and Neutrinoless Double Beta Decay experiments, which demand for detailed knowledge of the background shape. For this reasons, a renewed experimental effort is currently underway in the scientific community to address forbidden β-decays measurements in a systematic way. Several detection techniques have been adapted to this physics case, and by exploiting the specific features of the different detectors it is possible to obtain complementary measurements of excellent quality. In this contribution the motivations behind this experimental effort and the most recent measures will be discussed.

Plenary / **259**

Understanding the nature of baryon resonances

Author: Derek Leinweber[1]

[1] *CSSM, University of Adelaide*

Corresponding Author: derek.leinweber@adelaide.edu.au

This presentation will open with a brief review of lattice QCD calculations showing the 2s radial excitation of the nucleon sits at ~1.9 GeV, well above the Roper resonance position. We'll then proceed to reconcile this observation with experimental scattering data, gaining insight into the interplay between quark-model states, meson-baryon interactions and the nature of baryon resonances.

While the idea of dressing quark-model states in a coupled-channel analysis to describe scattering data has been around for decades, it's now possible to bring these descriptions to the finite-volume of lattice QCD for confrontation with lattice-QCD calculations. This combination of lattice QCD and experiment demands that we reconsider our preconceived notions about the quark-model and its excitation spectrum.

Herein, the infinite volume world of experiment and the finite-volume world of lattice-QCD are bridged by Hamiltonian effective field theory (HEFT), a nonperturbative extension of effective field theory incorporating the Luscher formalism. After presenting the formalism in the context of the Delta resonance, we'll explore the low-lying odd-parity nucleon resonances where two nearby quark-model like states introduce new challenges. The results lead to a consideration of the even-parity Roper resonance and its isospin-3/2 Delta-resonance partner.

The presentation will close with the results of a new calculation hinting the 2s radial excitation of the nucleon is associated with the N1/2+(1880) resonance observed in photoproduction. The impact of this on the missing baryon resonances problem will be discussed.

New facilities / **260**

Precision tests of fundamental physics with light meson decays

Author: Susan Schadmand[1]

[1] *GSI Darmstadt*

Corresponding Author: s.schadmand@gmail.com

Decays of the neutral and long-lived η and η′ mesons provide a unique, flavor-conserving laboratory to test low-energy Quantum Chromodynamics and search for new physics beyond the Standard Model. The program will be realized with the Jefferson Lab Eta Factory (JEF), scheduled to run in 2024 in Hall D at Jefferson Lab. The experiment will use the GlueX apparatus with an upgraded Forward Calorimeter (FCAL-II) to study the decays of η and η', emphasizing on rare decay modes. The determination of electromagnetic transition form factors of light mesons contributes to the interpretation of the measurement of the anomalous magnetic moment of the muon. Here, an analysis of data from CLAS experiments in Hall B at Jefferson Lab is beginning and will provide information on time-like transition form factors for η, ω, and η' mesons. In addition, an approved proposal for Hall B aims to determine the space-like transition form factor for the neutral pion.

Light baryon spectroscopy / 261

Search for hybrid baryons with CLAS12 and KY electroproduction

Author: Lucilla Lanza[1]

[1] *Istituto Nazionale di Fisica Nucleare*

Corresponding Author: lucilla.lanza@roma2.infn.it

An experimental program has been approved at the Thomas Jefferson National Accelerator Facility to measure the (ep,e'K+)Y reactions using the CLAS12 setup in Hall B.
Data have been obtained using electron beams with energies of 6.5, 7.5, and 10.2 GeV, impinging upon a liquid hydrogen target in the CLAS12 center. Scattered electrons have been detected in a polar angle range of 2.5° to 4.5° by the Forward Tagger (FT) and at angles greater than 6° in the CLAS12 Forward Detector, allowing to measure the KY electro-production differential cross section and to probe the Q2 evolution of the nucleon resonances electro-couplings in the Q2 range from 0.05 GeV2 to 3 GeV2. The study of the Q2 dependence of the electro-couplings will provide a crucial tool to investigate the possible hybrid nature of the nucleon resonances in the mass range of 2.0 GeV < W < 2.5 GeV where the lightest hybrid baryons are expected to be located based on LQCD studies of the N* spectrum. Experimental results for KY electroproduction will be reported and prospects for future studies will be discussed.

Light baryon spectroscopy / 262

The Delta resonance at different physical parameters

Author: Ferenc Pittler[1]

[1] *Cyprus Institute*

Corresponding Author: f.pittler@cyi.ac.cy

In this presentation we would like to determine the properties of the lightest resonance in the baryonic sector of QCD: the Delta(1232) resonance. We determine the finite volume energy spectrum of $\pi - N$ system. Using Luescher formalism we can predict the mass and the width of the delta resonance. In our analysis we include ensembles with the same pion mass at different spatial volume ($L = 2.7\, and\, 3.7\mathrm{fm}$ and with the same spatial volume at different pion masses ($M_\pi = 200, 250\mathrm{Mev}$). In addition we show our first results at the physical pion mass.Having results from so many different parameters we are in a position to perform controlled chiral extrapolation of the delta resonance parameters.

Hadrons in hot and nuclear environment / 263

Heavy flavour hadronization in ultra-relativistic heavy ion collisions: from AA to pp

Authors: Salvatore Plumari[1]; Vincenzo Greco[1]; Vincenzo Minissale[1]

[1] *Istituto Nazionale di Fisica Nucleare*

Corresponding Author: salvatore.plumari@dfa.unict.it

One of the present challenges for the theoretical understanding of heavy-quark hadronization is represented by the description of the measurements of heavy baryon production in pp, pA and AA collisions. The Λ_c/D^0 ratio observed in AA collisions has a value of the order of the unity, and experimental measurements in pp collisions at both $\sqrt{s} = 5.02\,\mathrm{TeV}$ and $\sqrt{s} = 13\,\mathrm{TeV}$ have shown ratios for charm baryons Λ_c, Ξ_c^0 and Ω_c^0 respect to D^0 meson larger than that measured and expected in e^+e^-, ep collisions.
Using the relativistic Boltzmann transport approach coupled to an hadronization mechanism based on the coalescence and fragmentation processes we show the results obtained in AA collisions for D^0, D_s, Λ_c spectra and the related baryon to meson ratios at RHIC and LHC. where we have found a large Λ_c production resulting in a baryon over meson ratio of order O(1).
Extending this approach to study the production of hadrons containing multiple charm quark, i.e. Ξ_{cc}, Ω_{cc} and Ω_{ccc} and we present here new predictions of these productions in different collision systems (PbPb, KrKr, ArAr).
Furthermore, we present results obtained in pp collisions at top LHC energies assuming the formation of an hot QCD matter at finite temperature for these systems and we show the results for the heavy baryon/meson ratio and the p_T spectra of charmed hadrons with and without strangeness content: D^0, D_s, Λ_c^+, Σ_c and the recently measured Ξ_c baryon, finding an enhancement in comparison with the ratio observed for e^+e^-, ep collisions; with this approach we also predict a significant production of Ω_c respect to D^0 such that $\Omega_c/D^0 \sim 0.15$.

1 V. Minissale, S. Plumari and V. Greco, Physics Letters B 821 (2021) 136622.
2 S. Plumari, V. Minissale, S.K. Das, G. Coci and V. Greco, Eur.Phys.J. C 78 (2018) no.4, 348

Hadrons in hot and nuclear environment / 264

Heavy flavour hadronization from small to large collision

Author: Stefano Trogolo[1]

[1] *TO*

Corresponding Authors: stefano.trogolo@pd.infn.it, stefano.trogolo@to.infn.it

Heavy quarks, namely charm and beauty, are very suitable probes of the colour-deconfined state of the hadronic matter called quark-gluon plasma (QGP) created in heavy-ion collisions. Since they are mainly produced in hard-scattering processes and hence in shorter timescales compared to the lifetime of the QGP, they experience the whole evolution of the system. Measurements of heavy-flavour hadron production in heavy-ion collisions give insight into the mechanisms of heavy-quark interaction with the medium constituents and allow the investigation of the heavy-quark hadronisation processes.
Measurements of the production of heavy-flavour hadrons in proton-proton and protonnucleus collisions provide the baseline for observations of hot-medium effects in heavyion collisions, as well as tests of perturbative QCD calculations. In the last years, they gained additional interest due to the observation of unexpected features typical of the heavy-ion phenomenology. Recent measurements of heavy-flavour baryon production in small systems show a significant deviation from results in e+e− collisions, challenging the assumption of universality of fragmentation functions across colliding systems. These results suggest that the presence of surrounding colour charges may influence the charm quark hadronization. In particular, heavy quarks can hadronize by combining with lighter

quarks in the nearby (i.e. recombination), similarly to what expected in the QGP. Other models, explain the enhanced production of baryons in hadronic collisions, introducing additional topologies for the baryon formation from the colour reconnection mechanisms, within the string fragmentation theory. Additional models describe the observations in the context of the statistical hadronization, including augmented set of baryons.
In this contribution, the most recent results on heavy-flavour-hadron production will be presented, focusing on the baryon and meson measurements in the charm and beauty sector, and discussing their modification from e+e− to pp and Pb-Pb, in comparison with different theoretical models.

Hadron decays, production and interaction / **265**

Nucleon resonance structure from the studies of space- and time-like electroexcitation amplitudes

Author: Philip Cole[None]

Corresponding Author: pcole@lamar.edu

The structure of nucleon resonances (N*), as revealed via N* electroexcitation amplitudes, provide unique information on the many facets of the strongly coupled QCD (sQCD) regime. These amplitudes give insight into sQCD dynamics underlying the generation of a variety of nucleon resonances having different structural features. Exploration of excited nucleon structure in the spacelike region (Q2>0) through exclusive meson electroproduction at CLAS at JLab advances our knowledge of the N*electroexcitation amplitudes. Analyses of these quantities within continuum Schwinger methods shed light on the emergence of hadron mass and N** structure from the QCD Lagrangian. Although the transition amplitudes from CLAS will be the focus of this talk, we shall also touch upon the complementary timelike region (Q2<0), such as HADES at GSI. Spanning across the spacelike (CLAS) and timelike (HADES) in Q2 will further extend insight into the structure of the excited states of the nucleon in the range of distances where the transition from the interplay between meson-baryon and quark degrees freedom to the dominance of three-quark contributions is expected. Progress towards extracting resonance excitation amplitudes by means of virtual photons in both the space- and timelike regions requires a robust multi-channel analysis. The same nucleon resonance must be found in different reaction channels with the same electroexcitation amplitudes and Q2-independent hadronic decay widths. Many nucleon resonances have recently been established in the analyses of the CLAS KY photoproduction data as well as in photo- and electroproduction □□□□p data. For a global multi-channel analyses of the CLAS and CLAS12 data in the N*region –and especially for invariant masses of excited baryons with W>1.6 GeV –precise information on □N → □□N and □N → KY reactions are needed to account for final-state interactions. The data from the upcoming E45 experiment at J-PARC (130x the world's data for the πN → ππN reaction), moreover, will advance our knowledge on amplitudes for N*s that decay through the two-pion mode.

Hadrons and physics beyond the standard model / **266**

Data-driven approximations to the Hadronic Light-by-Light scattering contribution to the muon (g-2)

Author: Pere Masjuan[1]

[1] *IFAE/UAB*

Corresponding Authors: paroig@gmail.com, masjuan@ifae.es

In this talk, we review the recent progress on the numerical determination of the Hadronic Light-by-Light contribution to the anomalous magnetic moment of the muon discussing the role of experimental data on the accuracy of its determination.

Hadrons in hot and nuclear environment / **267**

Heavy-flavor production from pp to nucleus-nucleus collisions

Author: Jing Wang[1]

[1] *CERN*

Corresponding Author: jing.wang@cern.ch

Quantum Chromodynamics (QCD) predicts a deconfined state of quarks and gluons: Quark Gluon Plasma (QGP). Studying the transport and medium properties of QGP will greatly deepen our understanding of the strong interaction. Heavy quarks created in the collisions are golden probes of the medium and provide unique insights into in-medium energy loss, diffusion coefficient, hadronization mechanism and the temperature of QGP. In this talk, I will discuss the fruitful experimental studies of production of open heavy flavor hadrons and heavy quarkonia in heavy-ion collisions and the perspectives for the future experiments.

Analysis tools / **268**

Analysis techniques to study low-energy scattering with correlation techniques in small collision systems at LHC energies

Author: Dimitar Mihaylov[None]

Corresponding Author: dimitar.lubomirov.mihaylov@cern.ch

Femtoscopy is a powerful technique to relate correlations between particles with low relative momentum to the emission source and the final state interaction (FSI). Recent research by the ALICE collaboration has demonstrated the realization of a common baryon-baryon emission source in pp collisions, opening up new avenues for studying the properties of the FSI. The well-constrained source function allowed to test lattice calculations in the multi-strangeness sector by means of p$\Xi-$ and p$\Omega-$ correlations. Further, the pΛ system has been measured with unprecedented precision, and the ongoing Run 3 of the LHC will deliver a similar level of statistical significance in the entire strangeness sector, and possibly in some of the three-body systems, such as ppp and ppΛ. Systematic uncertainties will dominate the interpretation of these data unless the underlying processes are well described. The present contribution will discuss the main analysis techniques used in femtoscopy, the main sources of systematic uncertainties and the ongoing activities to reduce them. A particular focus will be set on the emission source function and a newly developed Monte-Carlo model (CECA), that can be used to study and constrain the properties of hadron emission. Further, the most effective ways of using femtoscopic data to constrain theoretical models will be discussed.

Light baryon spectroscopy / **269**

Coupled-channels meson electroproduction

Author: Michael Doering[1]

[1] *The George Washington University*

Corresponding Author: doring@gwu.edu

Data on the photo- and electroproduction of different hadrons provide access to the spectrum of excited baryons. The amplitudes and resonance properties obtained through this phenomenological

analysis can serve as a point of comparison for theories and models of excited baryons and their dynamics. Recent results from the Julich-Bonn-Washington model will be presented, including extensions to the electroproduction of pions and eta mesons.

Hadrons in hot and nuclear environment / **270**

Open Strange Mesons in (magnetized) nuclear matter

Authors: Amruta Mishra[1]; Ankit Kumar[2]

[1] *Department of Physics, IIT Delhi*

[2] *Indian Institute of Technology Delhi*

Corresponding Author: ankitchahal17795@gmail.com

We investigate the mass modifications of open strange mesons (vector K^* and axial vector K_1) in (magnetized) isospin asymmetric nuclear matter using Quantum Chromodynamics sum rule (QCDSR) approach. The in-medium decay widths of $K^* \to K\pi$ and $K_1 \to K^*\pi$ are studied from the mass modifications of K_1, K^* and K mesons, using a light quark-antiquark pair creation model, namely the $^3P_0$ model. The in-medium decay width for $K_1 \to K^*\pi$ is compared with the decay widths calculated using a phenomenological Lagrangian, derived from a chiral SU(3) model. The effects of magnetic fields are also studied on the mass and the partial decay width of the vector K^* meson decaying to $K\pi$. Within the QCD sum rule approach, the medium effects on the masses of the open strange mesons are calculated through the light quark condensates and the gluon condensates in the hadronic medium. The quark condensates are calculated from the medium modifications of the scalar fields (σ, ζ, and δ) in the mean field approximation within a chiral SU(3) model, while the scalar gluon condensate is obtained from the medium modification of a scalar dilaton field (χ), which is introduced within the model to imitate the scale invariance breaking of QCD.

Hadrons and physics beyond the standard model / **271**

Neutron electric dipole moments in lattice QCD with background field method

Author: Sergey Syritsyn[1]

[1] *Jefferson Lab*

Corresponding Author: syritsyn@alum.mit.edu

Neutron EDM (nEDM) is one of the most promising ways to probe CP-violating quark and gluon interactions and constrain potential extensions of the Standard Model. While nucleon models and low-energy theories provide some ballpark estimates for the nEDM sensitivity to these interactions, they may vary by an order of magnitude or more. Such theoretic uncertainties can only be eliminated by ab initio nonperturbative calculations in lattice QCD.
One of the most elusive sources of nEDM is the QCD theta-term, because its contribution is proportional to the lightest-quark mass. I will present our preliminary results for nEDM induced by theta-QCD calculated using background electric field method. At the moment, we obtain nEDM by chiral extrapolation from calculations with pion masses as light as 330 MeV. Combined with techniques based on low modes of the Dirac equation, it should be possible to perform our calculations directly at the physical point in the next few years. In addition, we plan to extend our work to other CP-violating interactions such as 4-quark operators, which are substantially simplified when using the background field method.

Hadrons and physics beyond the standard model / **272**

Hadronic contributions to the muon g-2 from lattice QCD

Authors: Christoph Lehner[1]; Mattia Bruno[2]

[1] *Regensburg*

[2] *Universita' di Milano-Bicocca*

Corresponding Authors: mattia.bruno@mib.infn.it, christoph.lehner@ur.de

Abstract: Over the last decade lattice QCD methodology has matured significantly and precise first-principles calculations of the hadronic contributions to the muon g-2 are now possible. I will summarize the status of the hadronic light-by-light and the hadronic vacuum polarization contributions and I will give an outlook on expected future progress.

Hadrons and physics beyond the standard model / **273**

Heavy-ion double charge exchange reactions as a tool for double beta decay nuclear matrix elements

Author: Manuela Cavallaro[1]

[1] *INFN -LNS*

Corresponding Author: manuela.cavallaro@lns.infn.it

The presentation aims at describing an overview of the activities related with the NUMEN project at INFN –LNS. NUMEN is an international collaboration which proposes an innovative technique to give information on the nuclear matrix elements entering the expression of the decay rate of double beta decay by cross section measurements of heavy-ion induced Double Charge Exchange (HI-DCE) reactions. The exploration of HI-DCE reactions is of interest not only for double beta-decay investigations, but also for studies of nuclear reaction and nuclear structure. From the experimental side, the characteristically tiny cross sections for HI-DCE processes and the high background generated by other more probable competing reactions is the main challenge, which has hindered HI-DCE spectroscopy until recent years. Modern magnetic spectrometers, such as the MAGNEX spectrometer, have proven to have the requisites to overcome past limitations. From the theory side, the description of the measured HI-DCE cross sections poses manifold challenges. Dealing with processes involving composite nuclei, HI-DCE reactions can, in principle, proceed through several alternative paths. These, in turn, correspond to different reaction mechanisms probing competing aspects of nuclear structure, from mean field to various classes of nucleon-nucleon interactions and correlations. A powerful way to scrutinize the nuclear response to HI-DCE is to consistently link it to the information extracted from the competing quasi-elastic reactions. Indeed, these complementary studies are mandatory in order to minimize the systematic errors in the data analyses and build a many-facets and parameter-free representation of the systems under study.

Exotic hadrons and candidates / **274**

Photocouplings of hidden-charm pentaquarks

Author: Emmanuel Ortiz-Pacheco[1]

[1] *Ljubljana*

Corresponding Author: emmanuel.ortiz@ijs.si

Photocouplings of pentaquarks are crucial ingredients for photoproduction experiments at JLab which aim to confirm the existence of the hidden-charm pentaquarks reported by the LHCb Collaboration using electromagnetic probes. Photocouplings of ground- and excited-state hidden-charm pentaquarks are analyzed in a quark model approach in which we distinguish between light (u, d and s) and heavy (c) quarks. Out of a large amount of possible pentaquark states only very few have nonvanishing photocouplings. Moreover, due to the large momentum of the photon these couplings are largely suppressed. We provide their decay widths as a function of their yet unobserved charge radius.

Hadrons and physics beyond the standard model / **275**

Thermal QCD axion production from the early universe

Author: Alessio Notari[1]

[1] *Universitat de Barcelona*

Corresponding Authors: notari@fqa.ub.edu, notarialessio@gmail.com

The axion is a hypothetical new particle that could explain the absence of CP violation in QCD and has a very rich cosmological phenomenology. In particular a population of thermally produced axions is expected to exist, in addition to a cold dark matter population. I discuss a new conservative bound on the axion mass, from production in the early universe through scattering with pions below the QCD phase transition. In addition I will show that to further improve the bound and exploit the reach of upcoming cosmological surveys, reliable non-perturbative calculations above the QCD crossover are needed.

Light baryon spectroscopy / **276**

Recent results from the A2 collaboration at MAMI

Author: Edoardo Mornacchi[1]

[1] *University of Mainz*

Corresponding Author: emornacc@uni-mainz.de

The study of the excited states of the nucleon is a powerful tool for the understanding of its structure in the non-perturbative regime of QCD, which is one of the major challenges of modern physics.
Meson photoproduction, as well as other photon-induced reactions, allow to study the excitation spectra of the nucleons and, in combination with the use of a polarized beam and/or target, allow to determine the properties of the nucleon resonances by accessing many different polarization observables with high precision.
The A2@MAMI Collaboration has undertaken a broad experimental program for a systematic measurement of these observables, using a linearly and/or circularly polarized photons on longitudinally polarized proton and deuteron targets, for energies up to 1.6~GeV.
An overview of the ongoing studies as well as recent results from the A2 Collaboration on a wide range of different observables will be given, together with an outlook on current and future measurements.

Hypernuclei and kaonic atoms / **277**

Light Λ-hypernuclei and CSB interaction

Author: Martin Schäfer[None]

Corresponding Author: m.schafer@ujf.cas.cz

Charge symmetry breaking (CSB) in the mirror ${}^{4}_{\Lambda}\mathrm{H} - {}^{4}_{\Lambda}\mathrm{He}$ hypernuclei has been known for decades. Recent experimental measurements [1,2] confirmed the large CSB splitting in the corresponding 0^+ states $\Delta B(0^+) = 233 \pm 92$~keV while the experimental value for the 1^+ excited states $\Delta B(1^+) = -83 \pm 94$~keV allows a change of sign, being compatible with zero. Theoretically, it was suggested by Dalitz and von Hippel (DvH) that large hypernuclear CSB might be generated through OPE contribution by allowing $\Lambda - \Sigma^0$ mixing in $SU(3)_f$ flavor octet [3]. This mechanism was later generalized by Gal [4] and used in a study of the 4-body hypernuclear CSB using χEFT(LO) ΛN interaction [5,6]. A rather different approach was adopted in Refs. [7,8] where hypernuclear CSB was introduced through a contact interaction fitted to the experimental $\Delta B(0^+)$ and $\Delta B(1^+)$ splittings. Interestingly, within the LO pionless effective field theory it was found that the CSB interaction fitted to these
energies might be linked through partially conserved baryon-baryon $SU(3)_f$ symmetry back to the DvH mechanism [9]. In my talk, I will review these works in order to give a general overview of the current status.
1 T. O. Yamamoto et al. (J-PARC E13 Collaboration), Phys. Rev. Lett., 115, 222501 (2015).
2 A. Esser et al. (MAMI A1 Collaboration), Phys. Rev. Lett. 114, 232501 (2015); F. Schulz et al. (MAMI A1 Collaboration), Nucl. Phys. A 954, 149 (2016).
[3] R. H. Dalitz and F. von Hippel, Phys. Lett 10, 153 (1964).
[4] A. Gal, Phys. Lett. B 744, 352 (2015).
[5] D. Gazda and A. Gal, Phys. Rev. Lett. 116, 122501 (2016).
[6] D. Gazda and A. Gal, Nucl. Phys. A 954 161 (2016).
[7] J. Haidenbauer, U.-G. Meissner, and A. Nogga, Few-Body Syst. 62, 105 (2021).
[8] H. Le, J. Haidenbauer, U.-G. Meissner, and A. Nogga, Phys. Rev. C 107, 024002 (2023).
[9] M. Sch\"{a}fer, N. Barnea, and A. Gal, Phys. Rev. C 106, L031001 (2022).

Hadrons and physics beyond the standard model / 278

Dark Matter search with the BDX-MINI experiment

Author: Marco Spreafico[1]

[1] *Istituto Nazionale di Fisica Nucleare*

Corresponding Author: marco.spreafico@ge.infn.it

BDX-MINI is a beam dump experiment performed at Jefferson Lab, aimed at searching for Light Dark Matter in the MeV-GeV mass range. Dark Matter is expected to be produced by the interaction of CEBAF high-intensity 2.176 GeV beam with the Hall A beam dump at Jefferson Lab.
The detector, installed in a well located 22 m downstream of the Hall-A beam dump, consists of a PbWO4 electromagnetic calorimeter surrounded by a hermetic veto system for background rejection. LDM detection is performed by measuring the energy released in the detector from electrons scattered by the impinging LDM particles. Despite the small interaction volume, the large accumulated charge of 2.56x10^21 EOT allowed for the BDX-mini measurement to set competitive exclusion limits on the LDM parameters space, comparable to those reported by larger-scale efforts.
In this talk, after a brief introduction to the LDM physics case, I will show the results obtained from the BDX-mini experiment, focusing on few key aspects of the associated experimental campaign and data analysis effort.

Hadron decays, production and interaction / 279

Multiple Parton Scattering from both theoretical and experimental point of views

Author: Hua-Sheng SHAO[1]

[1] *LPTHE Paris*

Corresponding Author: huasheng.shao@lpthe.jussieu.fr

I will first review the recent theoretical and phenomenological progress of studying multiple parton scattering at the LHC in both pp and heavy-ion collisions. I will then breifly summarise the existing experimental measurements. Finally, I will try to highlight the first triple parton scattering study by observing the triple J/psi production process with the CMS detector, and the first double parton scattering measurement of J/psi+open charm and two open charm production in proton-lead collisions by the LHCb collaboration.

Light baryon spectroscopy / 280

Threshold KY photoproduction at the BGOOD experiment: Do we see multi-quark structures in the uds-sector?

Author: Hartmut Schmieden[None]

Corresponding Author: schmieden@physik.uni-bonn.de

The discovery of the X, Y, Z states in the (hidden) charm meson sector first by Belle, and the PC baryon states by LHCb revealed the existence of multi-quark objects beyond the simple quarkantiquark or 3-quark valence configurations. If the emergence of such multi-quark structures was a general feature of QCD, then related structures should appear in the uds-sector as well. The BGOOD experiment at the ELSA electron accelerator of Bonn University is exactly devoted to investigate such possible baryonic structures in meson photoproduction. Particular attention is paid to threshold effects in associated KY photoproduction. I will discuss recent results which include the archetypal meson-baryon 5-quark hyperon Λ(1405), the hypothesised N*(2030/2080) as the strange-sector partners of the charm-sector PC*(4380/4450) pentaquarks, and an intriguing cusp effect at the K Σ(1385) threshold.

This project received funding from the DFG (Project no 50165297 and 405882627), from the European Union's Horizon 2020 research and innovation programme under grant agreement No 824093, and from the Land NRW.

Plenary / 281

Resonant hadron systems from EFT, LQCD and Phenomenology

Author: Maxim Mai[None]

Corresponding Author: mai@hiskp.uni-bonn.de

Reaction independent, universal parameters of resonances are encoded in the analytic structure of transition amplitudes. Symmetries can reduce the family of such amplitudes through the general S-matrix constraints or by using Effective Field Theories, e.g CHPT when dealing with strongly interacting systems. Physical information through experiment or results of numerical calculations of Lattice QCD provide additional valuable constraints at real energies.

In my talk, I will provide an overview of the current frontier and the challenges associated with this workflow, and highlight the recent progress that has been made in overcoming them. I will showcase several examples, including data-driven phenomenological tools and purely theoretical investigations based on Lattice QCD. Finally, synergetic effects between different pathways will be discussed.

Hadrons and physics beyond the standard model / **282**

The search for neutrinoless double beta decay

Author: Claudia Tomei[1]

[1] *Istituto Nazionale di Fisica Nucleare*

Corresponding Author: claudia.tomei@roma1.infn.it

Since the discovery of neutrino oscillations, the search for neutrinoless double beta decay stands among the highest priorities for understanding the nature of neutrinos and the origin of their mass. The experimental observation of this lepton-number-violating process, only hypothesised so far, would demonstrate that neutrinos are Majorana fermions, equal to their own antiparticles. This in turn would represent a manifest signature of physics beyond the Standard Model. The experimental strategy adopted for the search of the elusive neutrinoless double beta decay has seen a significant evolution over the past 30 years. In this talk, I will discuss the main aspects of the double beta decay process and give an overview of the experimental techniques that are exploited to search for this rare decay. I will review the status and prospects of the new generation of experiments being promoted by experimental groups around the world.

Analysis tools / **284**

Techniques for hadron physics analysis at LHCb

Author: mengzhen wang[1]

[1] *INFN milano*

Corresponding Author: mengzhen.wang@cern.ch

The large heavy-flavor dataset collected by the LHCb experiment offers a good opportunity to investigate the inner structure of hadrons and help improve the knowledge of strong interactions. With the ever larger data samples collected by LHCb, constant improvements of analysis methods are in demand, including for example computing techniques and phenomenological tools to handle the huge data sample and to match the improved statistical precision of the analyses. Several selected developments in the past few years will be presented in this talk

New facilities / **285**

Search for Electric Dipole Moments and Axions/ALPS of Charged Particles using Storage Rings.

Author: Paolo Lenisa[1]

[1] *Istituto Nazionale di Fisica Nucleare*

Corresponding Author: lenisa@fe.infn.it

An electric dipole aligned along the spin axis of a fundamental particle, nucleus, or atomic system violates both parity conservation and time reversal invariance. The observation of such a phenomenon would, at present or proposed levels of experimental sensitivity, signal new physics beyond the Standard Model.

The usual method for identifying an electric dipole moment (EDM) in such searches is to observe the rotation of the spin axis or polarization under the influence of a strong electric field. The use of a

storage ring opens the search to charged, polarized particles that would otherwise not be manageable in such a field. The best procedure begins with the alignment of the beam polarization along the velocity of the beam followed by the observation of any slow rotation of that polarization into the vertical direction perpendicular to the ring. Electric ring fields of the right strength or the correct combination of electric and magnetic ring fields are needed to ensure that the polarization does not rotate relative to the velocity ("frozen"spin).

Dedicated studies performed in the past decade at the COSY Storage Ring at FZ-Juelich culminated with a first upper limit for the static and the oscillating EDM of the deuteron. The oscillating EDM can indeed be accessed by exploiting the same methodology of the static one and it is of interest as it might be coupled to the possible axion field in the galaxy.

This presentation is meant to provide a general introduction to the EDM search by means of polarized beams in storage rings, to highlight the developments at the COSY ring and to address the next steps of the research.

Hadrons and physics beyond the standard model / **287**

Non-standard Mechanisms of Double Beta Decay

Author: Frank Deppisch[None]

Corresponding Author: f.deppisch@ucl.ac.uk

Neutrinoless double beta decay is a crucial probe for physics beyond the Standard Model. While it is usually interpreted as being mediated by the exchange of light Majorana neutrinos, non-standard contributions to neutrinoless double beta decay arise in many well-motivated scenarios of New Physics that aim to explain the lightness of neutrinos, such as sterile neutrinos, Left-Right Symmetry and R-parity Violating Supersymmetry. I will highlight such scenarios, the relevant formalism to calculate the decay rate of neutrinoless double beta decay in such a context and results on the constraints on New Physics from existing as well as expected sensitivities from future experimental efforts. While the neutrinoless mode is of main interest, I will also discuss non-standard mechanisms for the Standard Model allowed two-neutrino double beta decay mode and I illustrate how it can provide complementary information on neutrinos and physics beyond the Standard Model.

Plenary / **288**

Multiquark hadrons

Author: Antonio Davide Polosa[1]

[1] *Istituto Nazionale di Fisica Nucleare*

Corresponding Author: antonio.polosa@roma1.infn.it

I will report on recent theoretical studies and ongoing work on the interpretation of exotic mesons and pentaquarks in terms of quark states or hadron molecules.

Hadrons and physics beyond the standard model / **289**

Search for Light Dark Matter with POKER

Author: Luca Marsicano[1]

[1] *Istituto Nazionale di Fisica Nucleare*

Corresponding Author: luca.marsicano@ge.infn.it

Dark Matter (DM) is one of the biggest unanswered questions in modern physics. Despite the astrophysical and cosmological observations suggesting its existence, to date no particle physics experiment detected an unequivocal DM signal, shedding light on its fundamental properties. Among the different hypothetical DM models, vector-mediated Light Dark Matter (LDM) is a compelling paradigm, being theoretically well motivated and largely unexplored. In this scenario, DM is identified with new sub-GeV "Hidden Sector"states, neutral under known interactions and interfacing with the Standard Model via a new force, mediated by the Dark Photon (Heavy Photon, A'), a new massive vector boson. Accelerator-based searches at the intensity frontier are uniquely suited to explore this model; the "missing energy" technique, in particular, has proven especially efficient, as demonstrated by the results of NA64-e at CERN. NA64-e exploits an electron beam impinging on a thick active target (electromagnetic calorimeter) to produce LDM particles via A'-mediated radiative processes; the so produced LDM particles escape the detector carrying away a significant fraction of the primary particle energy. The experimental signal signature is a significant "missing energy", defined as the difference between the energy of the beam and the energy deposited in the active target. The goal of POKER (POsitron resonant annihilation into darK mattER) is to perform a missing energy measurement with a positron beam, using a high resolution active target (lead tungstate calorimeter). A positron beam allows to fully exploit the unique features of the positron resonant annihilation into hidden sector states (e+e- -> A' -> XX), resulting in an outstanding LDM discovery potential. In this talk, after a brief introduction on the LDM scenario, I will thoroughly describe the POKER project, reporting on its current status and future prospects.

Light meson spectroscopy / **290**

Khuri-Treiman analysis of the J/ψ→π+π−π0 reaction

Author: Miguel Albaladejo[1]

[1] *IFIC*

Corresponding Author: miguelalbaladejo@gmail.com

In this talk, recent results from the Joint Physics Analysis Center (JPAC) collaboration will be discussed, mainly based on 2006.01058 and 2304.09736. We will address the decays V to 3pi, with V either the omega or the J/psi meson, in the context of Khuri-Treiman equations. These allow a representation of a three-body decay amplitude that takes into account unitarity (final state interactions) of the three two-body subsystems. In particular, for the decays J/psi and omega to 3pi, elastic di-pion unitarity will be incorporated.

Hadrons and physics beyond the standard model / **291**

The MOLLER Experiment: An Ultra-Precise Measurement of the Weak Mixing Angle using Møller Scattering

Author: Donald Jones[1]

[1] *Jefferson lab*

Corresponding Author: jonesdc@jlab.org

The future MOLLER experiment will measure the parity-violating asymmetry forMøller scattering improving on the previous measurement E158 at SLAC by a factor of five. This measurement will yield the most precise measurement of the weak mixing angle at energies well below the scale of

electroweak symmetry breaking. This new result would be sensitive to the interference of the electromagnetic amplitude with new neutral current amplitudes as weak as $\sim 10^{-3}$·G_{F} from as yet undiscovered dynamics beyond the Standard Model. The resulting discovery reach is unmatched by any proposed experiment measuring a flavor- and CP-conserving process over the next decade, and yields a unique window to new physics at MeV and multi-TeV scales, complementary to direct searches at high energy colliders such as the Large Hadron Collider (LHC). The experiment takes advantage of the unique opportunity provided by the upgraded electron beam energy, luminosity, and stability at Jefferson Laboratory and the extensive experience accumulated in the community after a round of recent successfully completed parity-violating electron scattering experiments.

Light meson spectroscopy / **292**

Pion and kaon structure at the Electron-Ion Collider

Corresponding Author: hornt@cua.edu

New facilities / **293**

Opportunities with positron beams at Jefferson Lab

Author: Eric Voutier[1]

[1] *IN2P3*

Corresponding Author: voutier@ijclab.in2p3.fr

The exploration of the full physics potential of the CEBAF 12 GeV would uniquely benefit from polarized and unpolarized positron beams with quality and modes of operation similar to those of the polarized electron beam. The Jefferson Lab (JLab) Positron Working Group, formed in 2018 and now with over 250 members from 75 institutions, continues to build out a case to support this cause, and has explored an experimental program with high duty-cycle positron beams [Acc21]. Concurrently, the Ce^{+}BAF Working Group has developed the concept of a new positron injector [Hab22, Gra23] to support this physics program. This presentation will discuss the impact of positron beams on the hadronic physics program of JLab and will review the current status of the related accelerator R\&D.

[Acc21] (Jefferson Lab Positron Working Group) A. Accardi et al. Eur. Phys. J. A 57 (2021) 8.
[Hab22] S. Habet et al. JACoW IPAC2022 (2022) 457.
[Gra23] (Ce^{+}BAF Working Group) J. Grames et al. JACoW IPAC2023 (2023) MOPL152.

QCD and hadron structure / **294**

Present knowledge of TMDs

Author: Alessandro Bacchetta[1]

[1] *Istituto Nazionale di Fisica Nucleare*

Corresponding Author: alessandro.bacchetta@pv.infn.it

to be added

Heavy baryon spectroscopy / **296**

Baryons (hadrons) with heavy quarks

Author: Shigehiro Yasui[1]

[1] *Hiroshima University*

Corresponding Author: yasuis@keio.jp

to be added

Heavy baryon spectroscopy / **297**

New results on conventional charmed baryon spectroscopy from LHCb

Author: Zhihao Xu[1]

[1] *University of Chinese Academy of Science*

Corresponding Author: zhihao.xu@cern.ch

Heavy baryon spectroscopy is essential for us to understand the strong interaction and the inner structure of hadrons. With the increasing luminosity and the development of the techniques, more and more results on heavy baryons are reported by LHCb. In this talk, the speaker will introduce some very recent results on the conventional charm baryons from LHCb

Heavy baryon spectroscopy / **298**

Peak-like structures observed in Λ_c decays at Belle

Author: Kiyoshi Tanida[1]

[1] *Japan Atomic Energy Agency*

Corresponding Author: tanida@post.j-parc.jp

In this presentation, we report on two recent results on peak-like structures observed in Λ_c decays at Belle.
One is from $\Lambda_c \to pK^-\pi+$ decay where a peak near the $\Lambda\eta$ threshold is observed in the pK^- mass spectrum. We studied the peak shape using a standard Breit-Wigner and Flatte distributions, and found the latter represents the shape by more than 7σ. This result indicates that the observed peak is actually a threshold cusp.
In the second part, we report on the peak-like structure in $\Lambda\pi^\pm$ mass spectrum near the $\bar{K}N$ threshold in $\Lambda_c \to \Lambda\pi^+\pi^+\pi^-$ decay. We will show results of fits to Breit-Wigner distribution and an effective-range expansion model by Dalitz and Deloff [R. H. Dalitz and A. Deloff, Czech. J. Phys. B 32, 250 (1982)].

Plenary / **300**

From COMPASS to AMBER: from the proton spin crisis to the hadron mass puzzle

Author: Oleg Denisov[1]

[1] *Istituto Nazionale di Fisica Nucleare*

Corresponding Author: oleg.denisov@to.infn.it

Proton spin crisis was initiated by the EMC (CERN, SPS) collaboration measurement in late 80's which says proton spin carried by quarks far smaller than 100%. Where is the rest coming from? Yes, from gluon contribution and orbital momenta, but details still to be understood. Today, the next biggest science question is: why proton is so heavy and pion is so light? The origin of hadron masses is deeply connected to the parton dynamics just like the spin contributions. We are in a very beginning of the journey to find an answer to this question.

AMBER is a newly approved fixed-target facility in the EHN2 experimental hall of the SPS at CERN, devoted to various fundamental QCD measurements. A determination of the valence-quark PDF of the pion, through Drell-Yan and J/Psi di-muon production, Direct Photon production and high precision Hadron Spectroscopy measurement would provide the needed sensitivity to the mechanism(s) responsible for the emergence of mass in QCD. At the initial phase (Phase-1) of the experiment unique measurements of the proton-charge radius and antiproton production cross-section in proton-He4 collisions will as well take place.

Plenary / **301**

Results on quark gluon plasma by ATLAS and CMS

Author: Georgios Krintiras[None]

Corresponding Author: gkrintir@cern.ch

to be added

Plenary / **302**

Welcome

Corresponding Author: devita@jlab.org

Plenary / **304**

Highlights from RHIC

Author: Haiyan Gao[1]

[1] *Brookhaven National Laboratory*

Corresponding Author: hgao@bnl.gov

Plenary / **306**

Light baryon spectroscopy

Corresponding Author: beck@hiskp.uni-bonn.de

Plenary / **308**

Extrinsic and intrinsic sea partons in a nucleon

Corresponding Author: nadolsky@smu.edu

Plenary / **309**

Experimental studies of Generalized Parton Distributions

Corresponding Author: maxime.defurne@cea.fr

Plenary / **310**

New opportunities with Jefferson Lab at 22 GeV

Corresponding Author: rossi@jlab.org

Plenary / **311**

Overview of J-Parc physics

Author: Hiroyuki Noumi[1]

[1] *Research Center for Nuclear Physics, Osaka University*

Corresponding Author: noumi@rcnp.osaka-u.ac.jp

Plenary / **313**

Simon Eidelman Prize: introduction

Corresponding Author: t.j.gershon@warwick.ac.uk

Plenary / **314**

Recent results from BESIII

Corresponding Author: marc@ep1.rub.de

Plenary / **315**

Overview of anomalies in meson decays and of their theoretical interpretations

Corresponding Author: pietro.colangelo@ba.infn.it

Plenary / **317**

Closeout

Plenary / **320**

Results on decays and CP violation from LHCb

Authors: Ao Xu[1]; The LHCb Collaboration[None]

[1] *INFN - Pisa*

Corresponding Author: ao.xu@cern.ch

LHCb has collected the world's largest sample of heavy flavour hadrons. This sample is used to search for and measure the CP violation in heavy flavour decays. The latest LHCb results of CP violation in charm and beauty decays are presented, as well as prospects for future sensitivities.

New facilities / **321**

The Muon Collider: a challenge for the future

Author: Cristina Riccardi[1]

[1] *Istituto Nazionale di Fisica Nucleare*

Corresponding Author: cristina.riccardi@pv.infn.it

The future of high energy physics relies on the capability of exploring a broader energy range than current accelerators, with higher statistics. A muon collider combines the great precision of electron-positron machines, with a low level of beamstrahlung and synchrotron radiation, and the high center-of-mass energy and luminosity of hadron colliders.
For these reasons, studies aimed at designing a muon collider able to reach 10+ TeV center-of-mass energies with luminosity higher than 10^{34} $\mathrm{cm}^{-2}\mathrm{s}^{-1}$ are currently ongoing. These operational conditions open an unprecedented physics program, which ranges from precision studies of the Higgs boson to Beyond Standard Model (BSM) searches.
Among the technological challenges, the ability to produce collimated beams of unstable particles, the muons, for a period long enough to allow high luminosity collisions, together with the treatment of the Beam-Induced Background (BIB) are the most critical issues for the detector design.
This contribution will present the status of the detector design and will discuss the expected reach of the most representative physics processes.

Plenary / **322**

JPAC's role in Hadron Spectroscopy Analysis

Author: Adam Szczepaniak[1]

[1] *Indiana University and JLab*

Corresponding Author: aszczepa@iu.edu

I will summarize 10 years of JPAC operations, and discuss its philosophy and future.

New facilities / **323**

DDVCS measurement with the CLAS12 high-luminosity upgrade

Corresponding Author: baltzell@jlab.org

Hadrons and physics beyond the standard model / **324**

Experimental input to the hadronic corrections of the muon g-2

Author: Christoph Florian Redmer[1]

[1] *Institute for Nuclear Physics, Johannes Gutenberg - University Mainz*

Corresponding Author: redmer@uni-mainz.de

The hadronic contributions to the Standard Model prediction of the muon g-2 have been determined using data-driven approaches. This talk will give an overview of the hadronic cross section measurements relevant for the hadronic vacuum polarization contribution and the transition form factor measurements relevant for the hadronic light-by-light contribution.

Heavy baryon spectroscopy / **325**

Spectroscopy of Heavy Baryons and Roles of Diquarks

Author: Makoto Oka[None]

Corresponding Author: makoto.oka@riken.jp

Symmetry structures of the heavy baryon spectrum are discussed in this talk. Two important symmetries are heavy-quark spin symmetry and chiral symmetry. Due to the heavy-quark spin symmetry, the heavy hadron spectra show spin-doubling structures, while chiral symmetry may cause parity doubling structures. I will show recent studies based on chiral effective theory of diquarks and its consequences on the single-heavy baryon spectrum. We have also found that the axial U(1) anomaly plays important roles in the diquark sector, such that it induces inverse hierarchy of the diquark masses. Properties of diquarks at finite temperature/density are also discussed.

Plenary / **326**

Hadron spectroscopy and decays at ATLAS and CMS

Corresponding Author: semen.turchikhin@cern.ch

Plenary / **327**

The Electron-Ion Collider and the ePIC experiment

Corresponding Author: silvia.dallatorre@ts.infn.it

Analysis tools / **328**

Flavor tagging techniques at ATLAS and CMS

Corresponding Author: alexander.froch@cern.ch

Analysis tools / **329**

Advanced tools for physics analysis in ALICE

Author: Tuba Gündem[None]

Co-author: The ALICE Collaboration

Corresponding Author: tuba.gundem@cern.ch

with a focus on Machine Learning (ML) based optimizations of the TPC dE/dx response

New facilities / **330**

BSM perspective on a Future Muon Collider

Author: Riccardo Torre[1]

[1] *Istituto Nazionale di Fisica Nucleare*

Corresponding Author: riccardo.torre@ge.infn.it

I will discuss the physics cases and opportunities of a future high energy Muon Collider from a Beyond the Standard Model (BSM) perspective.
I will do so by clarifying the role of precision measuements in the search for BSM physics and the role of the BSM parametrization in precision measurements, and reviewing recent studies of the performance of a high energy Muon Collider for precision measurements and BSM searches, also in comparison with other future collider options.

Hadrons and physics beyond the standard model / 331

Effective field theories for neutrinoless double-beta decay

Author: Javier Menendez[1]

[1] *University of Barcelona*

Corresponding Author: menendez@fqa.ub.edu

Neutrinoless double-beta decay (0nbb) is a beyond standard model atomic decay which involves atomic, nuclear and particle physics. Since these different fronts naturally involve separated energy scales, effective field theory (EFT) provides a natural framework to study this process.
In this talk I will present some EFT ideas to study 0nbb. In particular, I will focus on EFTs for the calculation of the nuclear matrix elements that govern 0nbb decay, which include chiral EFT (as EFT of QCD at nuclear energies) and EFTs for the structure of heavy nuclei and for their short-range nuclear correlations.

Heavy meson spectroscopy / 332

Heavy meson spectroscopy results at BESIII

Author: Marco Scodeggio[1]

[1] *Istituto Nazionale di Fisica Nucleare*

Corresponding Author: marco.scodeggio@fe.infn.it

Although the charmonium spectrum seems well investigated, charmonia can still be used as benchmarks to test our QCD predictions, as these states lay in the transition region between perturbative and non-perturbative QCD. Despite the need for experimental confirmations, setbacks arise from limited statistics due to the production of non-vector states. Some charmonium states' properties and decay channels are still far from being well-known. Since 2009, BESIII has been scanning and investigating the energy range between 2.0 and 4.9 GeV. Thanks to its largest data sets of charmonium resonances (J/ψ, $\psi(2S)$, and $\psi(3770)$) in the world as well as other data sets at the centre-of-mass energies above 3.8 GeV, BESIII can overcome statistical limitations to shed light on open questions.

Plenary / 333

Simon Eidelman Prize: presentation by the winner

Plenary / 334

Hadrons in heavy-ion collision at ALICE

Author: Malgorzata Janik[1]

[1] *Warsaw University of Technology*

Corresponding Author: majanik@cern.ch

ALICE (A Large Ion Collider Experiment), one of the CERN Large Hadron Collider experiments, was originally designed to study the properties of the quark–gluon plasma (QGP), a deconfined state of quarks and gluons produced in heavy-ion collisions. The ALICE physics programme has been extended to cover a broader scope of observables related to Quantum Chromodynamics. In this overview, a selection of latest findings and results obtained by the ALICE collaboration will be presented and discussed together with prospects for future measurements in the context of its planned upgrades.

Hadrons and physics beyond the standard model / **335**

Low-Energy Experiments for the determination of the Electroweak Mixing Angle and the P2 experiment

Author: Frank Maas[1]

[1] *Helmholtz-Institut Mainz*

Corresponding Author: maas@uni-mainz.de

Indirect searches for new physics beyond the standard model employ precision measurements of low energy observables like for example the weak mixing angle expressed as $\sin^2\theta_W$. There are several possibilities to measure this quantity, one is the measurement of a parity-violating asymmetry in elastic electron-proton scattering.
The P2 experiment at the upcoming Mainz energy recovering electron accelerator MESA aims for a 2% measurement of such an asymmetry at very low four-momentum transfer of q^2= 0.005 (GeV/c)^2. This measurement allows the extraction of a precise determination of the weak mixing angle with an accuracy of 0.15%.
In combination with the high energy physics measurement of $\sin^2\theta_W$ at the Z-pole it comprises a test of the Standard Model. Any significant deviation is a sign for new physics beyond the Standard Model with a sensitivity to a mass scale up to about 50 TeV. Further measurements employing a Carbon target will increase this reach.

Exotic hadrons and candidates / **336**

Double-Strangeness Molecular-Type Pentaquarks from Coupled-Channel Dynamics

Authors: Angels Ramos[1]; J.A. Marsé-Valera[None]; Volodymyr Magas[2]

[1] *University of Barcelona*

[2] *University of Barcelona, Spain*

Corresponding Author: ramos@ecm.ub.es

The existence of pentaquarks with strangeness content zero and one are major discoveries of the latest years in hadron physics. Most of these states can be understood as hadronic molecules and were predicted prior to their discovery within a model based on unitarized meson-baryon amplitudes obtained from vector meson exchange interactions. Contrary to earlier statements, we show this model to also predict the existence of pentaquarks with double strangeness, at about 4500 MeV and 4600 MeV, which are generated in a very specific and unique mechanism, via an attraction induced by a strong coupling between the two heaviest meson-baryon states.

Plenary / **337**

Recent experimental achievements and perspectives on strangeness nuclear physics

Author: Hirokazu Tamura[None]

Corresponding Author: tamura@lambda.phys.tohoku.ac.jp

Recent achievements and perspectives on strangeness nuclear physics are presented, based mainly on experimental highlights at J-PARC. Their connection to high-density matter in neutrons stars is also discussed.
A high-quality Σ-proton scattering experiment (J-PARC E40) successfully measured differential cross sections of Σ±p elastic and inelastic scattering [1,2]. They provide invaluable information to develop baryon-baryon interaction models, which are necessary to construct a realistic Equation of State for high-density matter in neutron stars. The phase-shift result of the ΣΣp scattering helps us understand the origin of the repulsive core of nuclear force 2. A high-quality Σp scattering experiment is also planned at J-PARC.
Through recent data from heavy ion collisions, it is recognized that the lifetime and the binding energy of the lightest Λ hypernuclei, hypertriton (3ΛH), should be measured reliably and precisely. Updated results have been reported from ALICE and STAR, and new measurements are on-going at J-PARC. In addition, the nnΛ state, suggested to be bound in a GSI experiment, was searched for at JLab [3]. Those data will play essential roles to understand behavior of a Λ hyperon in neutron stars.
Doubly strange hypernuclei were also studied at J-PARC (E07) with a hybrid emulsion technique. Among clearly-observed Ξ hypernuclear events [3,4], two of them have surprisingly large binding energies and naively interpreted as a state with a Ξ in the nuclear 0s orbit [5]. But this interpretation leads to extremely weak ΞN→ΛΛinteraction inconsistent with theoretical predictions. A missing mass spectroscopy experiment of the (K⁻, K⁺) reaction for Ξ hypernuclei (E70), together with a Ξ-atomic X-ray measurement (E96), will soon clarify the situation.
In the future, further investigation of the ΞNN three-body force is necessary to solve the "hyperon puzzle"in neutron stars, through high-resolution Λ hypernuclear spectroscopy at JLab, and then at the extended Hadron Facility at J-PARC [6].

1 K. Miwa et al., Phys. Rev. C 104 (2021) 045204; Phys. Rev. Lett. 128 (2022) 072501.
2 T. Nanamura et al., Prog. Theor. Exp. Phys. 2022 (2022) 093D01,
[3] K.N. Suzuki et al., Prog. Theor. Exp. Phys. 2022 (2022) 013D01; B. Pandey et al., Phys. Rev. C 105 (2022) L051001.
[4] S. H. Hayakawa et al., Phys. Rev. Lett. 126 (2021) 062501.
[5] M. Yoshimoto et al., Prog. Theor. Exp. Phys. 2021 (2021) 7.
[6] K. Aoki et al., arXiv: 2110.04462 [nucl-ex] (2021).

Heavy meson spectroscopy / **338**

Heavy meson spectroscopy results at LHCb

Authors: The LHCb Collaboration[None]; Tim Gershon[1]

[1] *University of Warwick*

Corresponding Author: t.j.gershon@warwick.ac.uk

The LHCb experiment has collected a unique sample of data from high-energy proton proton collisions, that enables a range of studies of heavy meson spectroscopy. As well as high-profile results on exotic states, many of which are covered in other talks, these studies also provide crucial information about conventional mesons. Latest results on charmonia, charm, and beauty mesons are summarised, and prospects for future studies described.

QCD and hadron structure / 339

test

Corresponding Author: raffaella.devita@ge.infn.it