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Book of Abstracts

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Opening

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Experimental Perspectives on Electromagnetic Hadron Physics

Author: Zein-Eddine Meziani[1]

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In this presentation, I will discuss selected highlights in electromagnetic hadron physics since the last edition of EINN held remotely in 2021

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Theory Perspectives on Electromagnetic Hadron Physics

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I give a broad overview of recent theory developments and open questions for a subset of topics discussed at this conference. The focus lies on different ways of 'imaging' the nucleon, from form factors to parton distributions.

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Recent measurement and experimental prospects of the Muon g-2 experiment at Fermilab

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The Muon g−2 experiment at Fermilab aims to measure the anomalous magnetic moment of the muon, $a_\mu = (g-2)/2$, with a final accuracy of 140 parts per billion, representing one of the most precise tests of the Standard Model. The experiment's first result from the 2018 dataset, Run 1, was published in 2021 and confirmed the previous result obtained at Brookhaven National Laboratory with a similar sensitivity. We present here the result based on the 2019 and 2020 datasets, Runs 2 and 3, which contain a factor of four more data than in Run 1, thus entering a new sensitivity regime to g−2.

We discuss the experimental and the analysis improvements with respect to Run 1 result and the experiment's future prospects for the next years.

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Leading hadronic contribution to the muon magnetic moment from lattice QCD

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Over twenty years ago, in an experiment at Brookhaven National Laboratory, physicists detected what seemed to be a discrepancy between measurements of the muon's magnetic moment and theoretical calculations of what that measurement should be, raising the tantalizing possibility of physical particles or forces as yet undiscovered. The Fermilab team has announced 2021 and then in 2023 that their precise measurement supports this possibility. The reported significance for new physics was first 4.2 sigma and according to the latest result it is 5.1 sigma, just slightly above the discovery level of 5 sigma. However, an extensive new calculation of the muon's magnetic moment using lattice QCD by the BMW-collaboration reduces the gap between theory and experimental measurements. The lattice result appeared in Nature on the day of the first Fermilab announcement. In this talk both the theoretical and experimental aspects are summarized with two possible narratives: a) probable discovery or b) Standard Model re-enforced. Some details of the lattice calculation are also shown.

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New measurements of the gluonic gravitational form factors

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Heavy quarkonium production serves as a powerful tool to investigate the gluonic structure of the nucleon. The latest generation of experiments being conducted at Jefferson Lab in the 12 GeV era use near-threshold J/ψ production to explore the mass structure of the nucleon. In this presentation, I will focus on both current and forthcoming experiments aimed at unraveling the proton's gluonic gravitational form factors. I will discuss the new and upcoming results from $J/\ \psi$ -007 in Hall C, GlueX, and CLAS12, with a particular emphasis on the recent experimental determination of the proton's gluonic gravitational form factors and mass radius. Additionally, I will explore future opportunities with the SoLID experiment at Jefferson Lab and with ePIC at the EIC.

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Precision experiments at the MESA accelerator

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The Mainz Energy-Recovery Superconducting Accelerator MESA, currently under construction at the Institute of Nuclear Physics at Mainz, provides the basis for precision experiments in the areas of nuclear, hadron, and particle physics. In this talk, we report on the comprehensive physics program of the three fixed-target experiments prepared for MESA: (i) MAGIX, (ii) P2, and (iii) DarkMESA.
MAGIX will make use of MESA's innovative energy recovery technique, which enables very high beam intensities. The setup is equipped with a gas jet target, surrrounded by two high-resolution magnetic spectrometers. The combination of a high-intensity electron beam with such a windowless gas jet target is innovative and will allow for instance for determinations of the proton radius, searches for dark sector particles, and measurements of reactions of relevance for nuclear astrophysics.
The P2 experiment will be operated in the external beam mode of MESA and will measure the parity-violating spin asymmetry, which in turn yields a measurement of the electroweak mixing angle at low momentum transfer. The comparison of such a measurement with the Standard Model (SM) prediction will allow to test extensions of the SM at scales of up to 50 TeV. Furthermore, the neutron skin of nculei can be extracted.
Finally, the DarkMESA beam dump experiment, located behind the beam dumo of P2, will search for hypothetical light dark matter particles

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Dark matter search via positron's interactions

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Dark matter exploration is become a central or side topic of many experiments at particle accelerators. Even if this approach, up-to-now, has not produced evidences, it helped in setting stringent limits on the characteristics of dark matter.
In this panorama is inserted the Positron Annihilation into Dark Matter Experiment (PADME) ongoing at the Laboratori Nazionali di Frascati of INFN. PADME was conceived to search a Dark Photon signal [2] by studying the missing-mass spectrum of single photon final states resulting from positron annihilations with the electrons of a fixed target. Actually, the PADME approach allows to look for any new particle produced in e^+e^- collisions through a virtual off-shell photon such as long lived Axion-Like-Particles (ALPs), proto-phobic X bosons, Dark Higgs …
After the detector commissioning and the beam-line optimization, the PADME collaboration had different periods of data acquisition and and some results have been already published [3].
In the second half of 2022 a special data taking was conducted with the scope to confirm/disprove the particle nature of the X17 anomaly observed in the ATOMKI nuclear physics experiments studying de-excitation via e^+e^- emission of several light nuclei [4].
About 10^{10} positrons have been stopped on the target for each of the 47 beam energy values in the range 262 - 298 MeV. This precise energy scan was intended to study the reaction $e^+e^- \to X17 \to e^+e^-$.
The talk will give an overview of the scientific program of the experiment and of the data analyses ongoing.

[1] P. Agrawal et al., Eur. Phys. J. C 81 (2021) 11, 1015.
[2] P. Albicocco et al., JINST 17 (2022) 08, P08032.
[3] F. Bossi et al., Phys. Rev. D 107 (2023) 1, 012008.
[4] L. Darmé et al., Phys. Rev. D 106 (2022) 11, 115036.

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Probing nucleon spin structure - Recent advances in spin-physics measurements

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A summary of experimental measurements unveiling spin-dependent nucleon structure prior to the arrival of the Electron-Ion Collider is given. Results from fixed-target experiments at Jefferson Lab, CERN, and DESY and collider experiments from RHIC will be presented. The measurements will be discussed in the context of transverse proton or parton spin and transverse parton momenta (TMDs), and their (spin-orbit) correlations, and generalized parton distributions (GPDs), the latter of which map the proton in transverse position space. The GPDs and TMDs provide complementary pathways to mapping multi-dimensional nucleon structure.

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Nucleon PDFs: precision meets replicability

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In the first part of the talk, I will review the recent progress on nucleon parton distributions in the global QCD analysis. In the second part, I will discuss the important role of epistemic uncertainties on PDFs in the increasingly common situation when other experimental and theoretical uncertainties are small. The AI techniques may complicate, rather than simplify, estimation of such uncertainties. Future comparisons of nucleon and other PDFs against predictions from lattice and nonperturbative QCD must balance between the precision and replicability of results.

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Theoretical interpretation of experimental tests of fundamental symmetries in QCD

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Electroweak structure of light nuclei and its implication for neutrino scattering

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In this talk, I will report on recent progress in Quantum Monte Carlo calculations of electron and neutrino interactions with nuclei in a wide range of energy and momentum transfer and their connections to current experimental efforts in fundamental symmetries and neutrino physics.

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3D Nucleon Structure: GPDs and TMDs

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Over the last decades, tremendous progress has been made in understanding the 3D partonic structure of strongly-interacting systems like the nucleon in terms of generalized parton distributions (GPDs) and transverse-momentum-dependent parton distributions (TMDs). In this presentation, we briefly describe the status of this field and highlight some recent developments.

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Parton fragmentation functions

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Fragmentation functions describe the formation of confined, final state hadrons out of asymptotically-free, high-energetic partons. They therefore help us understand the process of confinement. Additionally, they are also the most important tool to learn about the flavor, spin and transverse momentum of the fragmenting partons and thus access the corresponding parton distribution functions in semi-inclusive DIS or hadronic collisions. In addition to these two processes, fragmentation functions can be probed in electron-positron annihilation, particularly at the B factories, where the absence of hadrons in the initial state provide the cleanest environment to study hadronization.
The latest status of fragmentation function measurements will be reported.

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Lattice QCD calculation of distribution functions

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Many interactions with nuclei can be described in terms of convolutions of universal parton distributions. These parton distributions describe the way quarks and gluons conspire to create the hadrons. Over the past decade these distributions have been inferred from matrix elements calculating with Lattice QCD. These matrix elements are similar convolutions of the parton distribution as cross sections. Even more the Lattice QCD matrix elements can be included as prior information in global analysis of experimental cross sections. The complementary information gives improved results than either could individually.

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The new AMBER experiment at CERN

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AMBER is a new fixed-target experiment at the CERN/SPS for the study of
Hadron Physics, thanks to a versatile beamline capable of providing muon and hadron beams over a wide energy range and a multipurpose modular spectrometer. The emergence of hadron mass phenomenom, central for our undertanding of QCD, can be experimentally addressed from the AMBER measurements of hadron radii, polarizabilities, form factors and distribution functions.

The pion and kaon induced Drell-Yan processes will be measured, providing input for the extraction of these ligh mesons parton distribution functions and studies of their transverse motion dependence. Sea to valence separation is accessed from the use of both beam charges. A measurement of direct photon production in meson-nucleon collisions allows to infer on the gluon contribution. A first-ever measurement of the kaon polarizabilities, accessed from the Primakoff reaction, complements the
characterization of kaons in the low energy regime.

A rich program on hadron spectroscopy in the light and strange meson sector is proposed. Additionally a series of unique hadron charge radii measurements are planned. The already approved high energy muon-proton elastic scattering study will address the long standing issue of the proton charge radius. The pion and kaon charge radii may be accessed from the elastic scattering on the electron cloud of target nuclei in inverse
kinematics.

Finally, AMBER measures the antiproton production cross section in proton on Helium and proton on Hydrogen targets. A beam energy scan in the range 60 to 250 GeV is performed. The precise knowledge of these cross sections is a necessary input for the interpretation of antiproton cosmic fluxes in the context of Dark Matter searches.

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New experimental results on GPDs and perspectives at JLab with a positron beam

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The Generalized Parton Distributions (GPDs) paradigm has profoundly renewed the understanding of the nucleon structure. As describing the correlations between partons, GPDs allow us to access static and dynamical information about the nucleon structure, ultimately learning about the mechanics of Quantum Chromodynamics. This comprises the total angular momentum of the nucleon carried by the quarks, the distribution of forces experienced by partons inside the nucleon or the gravitational form factors of the nucleon. This presentation will focus on the new experimental results about GPDs from the 12 GeV CEBAF (Continuous Electron Beam Accelerator Facility) and the future measurement projects with an emphasis on the possibilities offered by the perspective of positron beams at CEBAF.

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Electromagnetic structure of the Proton from Generalized Polarizabilities

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The polarizabilities of a composite system such as the proton are elementary structure constants. They describe its response to an external electromagnetic (EM) field and quantify the deformation of the charge and magnetization distributions inside the proton caused by the electric or magnetic field, respectively. When studied through the virtual Compton scattering process, the virtuality of the photon gives access to the generalized polarizabilities and allows to map out the resulting deformation of the densities in a proton subject to an EM field. These measurements provide unique access to the underlying system dynamics and are a key for decoding the proton structure in terms of the theory of the strong interaction that binds its elementary quark and gluon constituents together. Of particular interest are puzzling measurements of the proton's electric generalized polarizability, that have challenged the theoretical predictions in recent years. This talk will present an overview on the topic, followed by the discussion of new results and of future prospects.

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Probing nuclear parton density and fluctuation with ultra-peripheral collisions at RHIC

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The STAR experiment at the Relativistic Heavy-Ion Collider has recently released findings regarding exclusive coherent and incoherent photoproduction of J/ψ mesons in Au+Au ultra-peripheral collisions (UPCs). In this talk, I will delve into the preliminary findings and examine how they influence our understanding of nuclear parton density within heavy nuclei and the event-by-event density fluctuation. The data will be rigorously assessed through quantitative comparisons with various models. Furthermore, I will outline prospective avenues for future research opportunities in UPCs.

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Machine learning-based methods in quantum chromodynamics

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Machine learning and AI are rapidly growing areas of research offering various avenues for exploration in high-energy nuclear physics. Novel tools including generative modeling, regression, and classification are poised to have a significant impact on theoretical and experimental research efforts. In this talk, I will review recent progress in the context of hadron structure, spin physics, uncertainty quantification, and simulations of collider experiments.

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QCD phase diagram from lattice simulations

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Different parts of the QCD phase diagram in the plane temperature - baryon density are expected to be relevant for early stages of the Universe, neutron stars, heavy ion collision experiments.
From theoretical point of view a lot of information about the QCD phase diagram and QCD thermodynamics
can be extracted using lattice ab-initio methods. In this talk I present an overview of
the lattice studies of QCD phase diagram, current status of the field and possible future directions.

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Quantum Computing: a future perspective for scientific computing

Author: Karl Jansen[1]

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Quantum computing is rapidly emerging as a new method of scientific computing. It has the potential to solve problems much faster than it is possible with classical computers. Examples are applications in logistics, drug design, medicine finances and many more. In addition, with quantum computers problems can be tackled that are very hard or even impossible to address with classical computers.
After providing an introduction to quantum computing we will discuss why quantum computing can lead to a quantum advantage. We then give several real world examples of applications which can already now be computed on existing quantum computers.

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Baryon spectroscopy: new results and perspectives

Author: Annalisa D'Angelo[1]

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The study of baryonic excited states provides fundamental information on the internal structure of the nucleon and on the degrees of freedom that are relevant for QCD at low energies. N* are composite states and are sensitive to details of the how quarks are confined. Meson photo-and electroproduction reactions have provided complementary information on light quark baryon spectroscopy for several decades, but a crucial step forward has been the advent of large solid angle detectors, together with polarized beam and targets, which gave access to single and double polarization observables. The Q2 dependence of excited baryons electro-couplings has also been measured, gaining insight into the internal structure of baryons.
The CLAS12 energy upgrade opened an "exciting"new era in baryon spectroscopy, including the search for hybrid hadrons, in which gluons appear as constituent components beyond the valence quarks.

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Application of dispersive techniques in the analysis of experimental and lattice spectroscopy data

Author: Oleksandra Deineka[1]

Co-authors: Igor Danilkin [1]; Marc Vanderhaeghen [2]

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We present a data-driven analysis of the S-wave $\pi\pi \to \pi\pi$ and $\pi K \to \pi K$ reactions using the partial-wave dispersion relation. The contributions from the left-hand cuts are accounted for in a model-independent way using the Taylor expansion in a suitably constructed conformal variable. The fits are performed to experimental and lattice data. Our central result is the hadronic Omnes functions, which allows us to find the poles associated with the lightest scalar resonances $\sigma/f_0(500)$ and $\kappa/K_0^*(700)$ for the physical and unphysical pion mass values.
The obtained coupled channel $\{\pi\pi, K\bar{K}\}$ Omnes matrix is used to describe the double-virtual photon-photon scattering to two pions, which is required for the dispersive implementation of the $f_0(980)$ resonance to $(g-2)_\mu$. In addition, we consider the $a_0(980)$ resonance. Since the hadronic data in the $I = 1\{\pi\eta, K\bar{K}\}$ channel is not available, the Omnes function is obtained using the fits to the different sets of experimental data on two-photon fusion processes with $\pi\eta$ and $K\bar{K}$ final states.

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Summary workshop I

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Summary workshop II

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Directions in hadron physics (Theory)

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Directions in Hadron Physics (Experiment)

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The US Nuclear Physics community recently completed its Long Range Plan process. The US Nuclear Science Advisory Committee (NSAC), a federal advisory committee appointed jointly by the US Department of Energy, Office of Science, and Directorate for Mathematical and Physical Sciences, the US National Science Foundation, approved the 2023 Long Range Plan "A New Era of Discovery - 2023 Long Range Plan for Nuclear Science" on October 4, 2023. In this report, several fundamental questions in hadron physics have been identified. In this talk, I will discuss how these questions will be addressed in the coming decade and beyond both at existing facilities, and new facilities under construction including new detector(s) proposed for the existing facilities. Synergies with other subfields of nuclear physics, and physics in general will be touched upon as well.

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Closing

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Exploring Gluon Momentum Fraction in Mesons through Lattice Quantum Chromodynamics Simulations

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Oral presentation of three best posters / 156

X17 discovery potential from γD → e+e-pn with neutron tagging

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Oral presentation of three best posters / 157

Scale separation in exotic atoms

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Electron-Ion Collider Progress and Plans

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An overview of the progress preparing the Electron-Ion Collider (EIC) for construction. The presentation addresses the EIC design requirements, conceptual design, and construction schedule. Current efforts to promote international engagement and collaboration will be described, including opportunities for contributions to the design and construction of the accelerators and collaboration on the experimental program.

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The EIC Accelerator - Design Highlights and Project Status

Author: Christoph Montag[1]

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The design of the electron-ion collider (EIC) at Brookhaven National Laboratory is well underway, aiming at a peak electron-proton luminosity of 10^34 cm^-2 sec^-1. This high luminosity and wide center-of-mass energy range from 29 to 141 GeV (e-p) require innovative solutions to maximize the performance of the machine, which makes the EIC one of the most challenging accelerator projects to date. The complexity of the EIC will be discussed, and the project status and plans will be presented.

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ePIC Detector design philosophy

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Understanding the properties of nuclear matter and its emergence through the underlying partonic structure and dynamics of quarks and gluons requires a new experimental facility in hadronic physics known as the Electron-Ion Collider (EIC).
The EIC will address some of the most profound questions concerning the emergence of nuclear properties by precisely imaging gluons and quarks inside protons
and nuclei, such as the distribution of gluons and quarks in space and momentum, their role in building the nucleon spin and the properties of gluons in nuclei at
high energies.
A new detector collaboration has been formed around one of two possible interaction regions, the ePIC collaboration. This presentation will present the requirements for the ePIC detector, present in detail its design philosophy, and discuss the overall status and plans.

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ePIC Tracking System Overview and Performance

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On behalf of the ePIC Collaboration

The future Electron-Ion Collider (EIC) at Brookhaven National Laboratory will collide polarized electrons with polarized proton/ions. The electron Proton and Ion Collider (ePIC) detector is being designed as the day one EIC detector. The EIC physics program requires precision tracking and particle identification (PID) capabilities that extend over a large kinematic acceptance. To meet these challenges ePIC is being designed as a highly integrated detector. One critical component of the detector is the tracking system, consisting of silicon layers near the interaction region, and then transitioning into large area micropattern gas detectors (MPGDs) further from the integration region. In the current ePIC design, the MPGDs play a critical role in providing fast timing hit points for pattern recognition and signal to background discrimination, which are needed for track reconstruction. Additionally, MPGDs located near PID subsystems could provide a precision space point measurement to better determine the angle that the particle enters the PID subsystem, ultimately leading to better Cherenkov ring reconstruction and PID performance.

An overview of the current ePIC tracking system and its projected performance will be presented.

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Particle Identification with the ePIC detector at the EIC

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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, which comprise a of time-of-flight (TOF) detector for low-momentum PID and several high-momentum particle-identification systems that use DIRC and RICH techniques to exploit Cherenkov light emission from charged particles.

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Calorimetry with the ePIC Project

Author: David Hornidge[1]

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This talk will cover some of the electromagnetic calorimetry plans for the ePIC detector with a concentration on the design of the central barrel calorimeter based on the current GlueX BCAL at JLab.

The requirements (as specified in the ePIC Project) include energy resolution of $10\%/\sqrt{E} \oplus (2-3)\%$ and electron-pion suppression great than 10^3, which will be comfortably met by a novel imaging calorimeter that combines AstroPix silicon sensors for position resolution and lead-scintillating-fiber matrix for energy resolution. Specific Canadian contributions to the EIC effort will also be presented.

Parallel workshop 1 / 98

Experimental measurements of GPDs—From fixed target experiments to the future Collider (EIC).

Author: Silvia Niccolai[1]

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Generalized Parton Distributions (GPDs) are nowadays the object of an intense effort of research, in the perspective of understanding nucleon structure. They describe the correlations between the longitudinal momentum and the transverse spatial position of the partons inside the nucleon and they can give access to the contribution of the orbital momentum of the quarks and gluons to the nucleon spin.
Deeply Virtual Compton scattering (DVCS), the electroproduction on the nucleon, at the partonic level, of a real photon, is the process more directly interpretable in terms of GPDs of the nucleon. Depending on the target nucleon (proton or neutron) and on the DVCS observable extracted (cross sections, target- or beam-spin asymmetries, $\cdots$), different sensitivity to the various GPDs for each quark flavor can be exploited. Gluon GPDs can also be accessed by probing specific kinematic regimes. And, besides DVCS, other exclusive reactions, such as Timelike Compton Scattering, Double DVCS, or the exclusive electroproduction of mesons, can provide information on GPDs.
This talk will provide an overview on recent and new, promising, GPD-related experimental results, mainly obtained at Jefferson Lab on fixed target experiments with a 12-GeV electron beam, for various target types and final states. These data open the way to a "tomographic"representation of the structure of the nucleon, allowing the extraction of transverse space densities of the quarks at fixed longitudinal momentum, as well as providing an insight on the distribution of forces inside the nucleon.
The perspectives for future GPD experiments at the Electron-Ion Collider (EIC) with the ePIC detector will also be outlined: these experiments will pave the way to perform the tomography of the nucleon in terms of its sea-quarks and gluons content.

Parallel workshop 1 / 55

Electron and Hadron Beam Polarimetry at EIC

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Beam polarimetry will play an important role in meeting the goals of the planned EIC physics program. However, the EIC beam properties will make achieving the level of precision required challenging for both electron and hadron beam polarimetry.

In this talk, I will give a brief overview of the techniques used to measure electron and hadron beam polarization at high energies, and discuss the plans for meeting the EIC beam polarimetry requirements.

Parallel workshop 1 / 90

Luminosity measurements at the EIC —guided by experience from HERA

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Precise measurements of the electron-hadron cross sections are the corner stone of scientific program at the future Electron-Ion Collider, hence the high demands towards the EIC luminosity measurements –at least a 1% accuracy is required for the absolute luminosity determination and only a 0.01% uncertainty for the relative, bunch-to-bunch, luminosity measurements. As was demonstrated at HERA –the first electron-hadron collider –the bremsstrahlung process can be successfully used to precisely measure the luminosity of high energy ⊠⊠ collisions. Such a technique can be also used at the EIC, but it poses major challenges, and a wide range of the electron beam energies and a large variety of hadron species, from protons to gold nuclei, will only increase that challenge. I will describe conceptual detector designs and measurement techniques being studied to overcome these huge challenges and to meet the target performance.

Parallel workshop 1 / 123

Status of high momentum-transfer form factor program at JLab and EIC

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The investigation of nucleon elastic electromagnetic form factors (EMFFs) at large momentum transfer has generated a large and increasing amount of experimental and theoretical interest over the last several decades. EMFFs provide precision benchmarks for theoretical modeling of nucleon structure and ab initio predictions in lattice QCD. Additionally, precise knowledge of the form factors at large Q^2 values is required as input to the interpretation of many other experiments in nuclear and hadronic physics, including studies of the Generalized Parton Distributions (GPDs) in Deeply Virtual Compton Scattering (DVCS). The experimental study of nucleon EMFFs at very large Q^2 is presently a unique worldwide capability of the Continuous Electron Beam Accelerator Facility at Jefferson Lab (JLab). The Super BigBite Spectrometer (SBS) Collaboration is presently carrying out a comprehensive program of high-Q^2 measurements of proton and neutron form factors in JLab's Hall A. The program started in October 2021, is approximately 50% complete as of this writing, and will continue to occupy Hall A through early 2025. In terms of luminosity and access to relevant kinematics for the measurement of polarization observables in elastic electron-nucleon scattering, the existing 11 GeV CEBAF and a proposed upgraded CEBAF to 22+ GeV are superior to the planned Electron-Ion Collider (EIC). However, the high center-of-mass energies available at the planned EIC allow for a significantly higher Q^2 reach than will ever conceivably be accessible in fixed-target experiments. Moreover, the detector and luminosity requirements for currently envisioned measurements of DVCS and other hard exclusive processes at the EIC are similar to those required for elastic form factor measurements. As such, the EIC can make a unique contribution to the knowledge of elastic electron-nucleon scattering cross sections at very large Q^2, albeit only for longitudinally polarized virtual photons. In this talk, I will review the current status of the SBS form factor program, including ongoing and planned experiments, the analysis of partially collected data, and the preliminary results of already completed experiments. I will also discuss the challenges involved in such measurements, and the prospects for extending their Q^2 reach beyond the SBS program, at the planned Electron-Ion Collider (EIC) and elsewhere.

Parallel workshop 1 / 106

Measurement of Transverse Spin Dependent $\pi^+\pi^-$ Asymmetry and Unpolarized $\pi^+\pi^-$ Cross Section in polarized pp Collisions at RHIC

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The transversity distribution function of quarks, $h_1^q(x)$, encapsulates the transverse spin structure of the proton at leading twist, where x represents the longitudinal momentum fraction carried by the quark q. Extracting $h_1^q(x)$ poses a formidable challenge due to its chiral-odd nature. Measurements of final-state hadron pairs in transversely polarized proton-proton ($p^{\uparrow}p$) collisions directly probe collinear quark transversity through its coupling with a chiral-odd interference fragmentation function (IFF), $H_1^{sphericalangle,q}$. This coupling leads to an experimentally measurable azimuthal correlation asymmetry, A_{UT}.
To extract $h_1^q(x)$ from A_{UT} asymmetry measurements, precise knowledge of IFF and unpolarized di-hadron fragmentation functions is needed.
The former is provided from e^+e^- experiments, owing to the factorization and universality of the physics mechanism in the collinear framework.
On the other hand, the latter is largely unknown but can be extracted from unpolarized di-hadron cross-section measurements in pp collisions.
In this presentation, we will present preliminary results of A_{UT} using $p^{\uparrow}p$ data collected in 2015 at $\sqrt{s} = 200\,\mathrm{GeV}$ and in 2017 at $\sqrt{s} = 510\,\mathrm{GeV}$, and the unpolarized cross section using pp data collected in 2012 for $\pi^+\pi^-$ pairs at $\sqrt{s} = 200$ GeV by the STAR experiment. The presentation will also discuss prospects for additional data at both $\sqrt{s} = 200\,\mathrm{GeV}$ and $\sqrt{s} = 510\,\mathrm{GeV}$.

Parallel workshop 1 / 54

New Experimental Physics Opportunities with Meson Beams at EIC

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During the past several decades a large quantity of high-quality mesonic photo- and electro-production data have been measured at electromagnetic facilities worldwide. By contrast, meson-beam data for these same final states are mostly outdated, largely of poorer quality, or even non-existent, especially those involving spin asymmetries and polarizations. Thus, existing meson beam results provide inadequate input to interpret, analyze, and exploit the potential of the new electromagnetic data. To achieve full benefit of these high-precision electromagnetic data, new high-statistics data from measurements with meson beams, with good angle and energy coverage for a wide range of reactions, are critically needed to advance our knowledge in baryon and meson spectroscopy and other related areas of hadron physics. To address this situation, new, state-of-the-art meson-beam facilities are needed. This presentation summarizes unresolved issues in hadron physics and outlines the opportunities and advances that are possible with facilities such as the EIC.

Parallel workshop 1 / 84

Case for the second Detector

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Parallel workshop 1 / 145

Designing the second interaction region and detector

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In its report, the DPAP observed that "there is significant support in the community and from the panel for a second general-purpose detector system to be installed in IR8 when resources are available." Such a detector would unlock the full discovery potential of the EIC by providing cross checks of results from ePIC, and reduce the combined systematic uncertainties. And in combination with a novel IR design, it could provide new and unique physics opportunities. In particular, the 2nd focus that has been incorporated into IR8 will greatly enhance far-forward detection, making it possible to detector protons and light nuclei all the way down to $p_T = 0$, and significantly improve the ability to detect nuclear breakup. The latter would enhance the ability to veto breakup in exclusive and diffractive scattering on nuclei, and even make it possible to study the level structure (gamma spectroscopy) of isotopes produced in electron-ion collisions. Improved veto efficiency would make measurements like coherent diffraction on heavy nuclei much less challenging, and open the way for coherent DVCS not only on He, but also heavier nuclei such as ^{12}C, ^{16}O, or even Ca, and in the future maybe polarized ^{7}Li.The combination of excellent low-t acceptance and coverage of the low-Q^2 region in-between photoproduction and 1 GeV^2, could also open up the possibility to study the elusive but important double-DVCS process at lower x, where rates are high. To fully take advantage of these and other new opportunities, the design of the IR and central detector should from the outset be designed to maximize the synergies. For instance, a higher magnetic field and improved tracking resolution would help studies of coherent diffraction, a high-resolution barrel EMcal would be important for DVCS on nuclei, and purpose-built and fully optimized muon detection would be necessary for double-DVCS - but also advantageous for, *e.g.*, charmonium production.

Parallel Workshop 2 / 32

Phenomenology of TMDs

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Parallel Workshop 2 / 103

Progress on the transverse SSA in single-inclusive jet production at an EIC at NLO

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We present a brief report on our ongoing efforts to calculate the transverse single-nucleon spin asymmetry of single-inclusive jet production in lepton-nucleon collisions at NLO accuracy within the collinear twist-3 factorization framework. This observable can very well be measured at a future Electron-Ion Collider (EIC). Such data will give new insight into both the partonic structure of the nucleon as well as the QCD dynamics inside the nucleon.

Parallel Workshop 2 / 131

TMD factorization at next to leading power

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We present our results on transverse momentum dependent factorization and resummation at sub-leading power in Drell-Yan and semi-inclusive deep inelastic scattering. In these processes the sub-leading power contributions to the cross section enter as a kinematic power correction to the leptonic tensor, and the kinematic, intrinsic, and dynamic sub-leading contributions to the hadronic tensor. By consistently treating the power counting of the interactions, we demonstrate renormalization group consistency. We calculate the anomalous dimensions of the kinematic, intrinsic, and dynamical sub-leading correlation functions at one loop and find the evolution equations. Additionally we calculate the hard and soft functions associated with each of these contributions and and compare them to the leading power results. We also calculate the one loop soft function associated with the intrinsic and kinematic sub-leading transverse momentum dependent distributions and compare them to the leading power results. Using this information, we establish the factorization formalism at sub-leading power for these processes at the one-loop level. We also focus on the matching of the large and small transverse momentum contributions in semi-inclusive deep inelastic scattering processes and Drell Yan. We pay special attention to azimuthal modulations of unpolarized cross sections such as the Cahn effect. Finally we present our findings on the QCD equation of motion relations beyond tree level.

Parallel Workshop 2 / 91

Nucleon axial and pseudoscalar form factors from Lattice QCD simulations at the physical point

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We present results for the nucleon axial and pseudoscalar form factors extrapolated at the continuum limit using three $N_f = 2 + 1 + 1$ twisted mass fermion ensembles with all quark masses tuned to their physical values. Convergence to the ground state matrix elements is assessed using multi-state fits. We study the momentum dependence of the three form factors and check the partially conserved axial-vector current (PCAC) hypothesis and the pion pole dominance (PPD). We show that in the continuum limit, the PCAC and PPD relations are satisfied. We also show that the Goldberger-Treimann relation is approximately fulfilled and determine the Goldberger-Treiman discrepancy.

Parallel Workshop 2 / 148

Flavor dependence of TMDs

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In global extractions of Transverse momentum dependent (TMD) distributions, the limit of small transverse distances is constrained using the matching to collinear parton density functions (PDF). Naturally, the TMDPDFs depend on the baseline PDF set used certain features of the former might be due to the latter, rather than genuinely due to TMD behaviour f the partons. To shed light on the issue, we study the influence of the PDF choice on the determination of unpolarized TMDPDFs and the description of TMD Drell-Yan-pair and Z-boson production data. We find that the selection of a PDF essentially biases the extraction of TMDPDFs, impacting the quality and shape of the distributions. This bias is alleviated once the PDF uncertainty is taken into account, making the non-perturbative TMD profile is flavor-dependent. This drives an improvement of the agreement between theory and experiment, substantially increase the uncertainty in extracted TMD distributions, and should be taken into account in future global analyses.

Parallel Workshop 2 / 143

News on polarized PDFs

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We review the current status of the nucleon's helicity PDFs. We describe recent progress on "global" analysis of the distributions, highlighting advances on the theoretical side especially in terms of higher-order perturbative calculations. We discuss the relevance of these advances for the spin program at the future EIC.

Parallel Workshop 2 / 70

Nucleon axial, scalar, and tensor charges from lattice QCD simulations at the physical point

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We present results for the axial, tensor, and scalar charges of the nucleon using lattice QCD simulations of twisted mass fermions with two degenerate light, a strange, and a charm quark, with masses tuned to their physical values (physical point simulations). The axial charge is well known experimentally and therefore provides for an important benchmark of our methodology, while the scalar and tensor charges are less well known and their determination from first principles can provide input for precision measurements probing the existence of novel scalar and tensor interactions.

Our results are obtained at three values of the lattice spacing, allowing for a first extrapolation to the continuum limit directly at the physical point.

Parallel Workshop 2 / 110

The gravitational form factors of the nucleon and the pion from Lattice QCD

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The gravitational form factors (GFFs) of hadrons are related to the matrix elements of the energy-momentum tensor of QCD. In recent years, the proton and pion GFFs have been constrained for the first time from experimental measurements. We compute the quark and gluon GFFs of the pion and the nucleon in the kinematic region $0 < -t < 2$ GeV^2 on a clover improved lattice QCD ensemble with $a = 0.091$ fm and $m_\pi = 170$ MeV, employing non-perturbative renormalization via the RI-MOM scheme. Our results for the pion GFFs agree with chiPT predictions, while from fits to the proton GFFs, we obtain estimates for its total D-term, and for its energy and mechanical distributions.

Parallel Workshop 2 / 53

Evidence for intrinsic charm quarks in the proton

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The theory of the strong force, Quantum Chromodynamics, describes the proton in terms of quarks and gluons. The proton is a bound state of two up and one down quark, but quantum theory predicts that in addition there is an infinite number of quark-antiquark pairs. Both light and heavy quarks, whose mass is respectively smaller or bigger than the proton's, are revealed inside the proton in high-energy collisions. However, it is unclear whether heavy quarks also exist as a part of the static nucleon wave-function: so-called intrinsic heavy quarks. It has been argued for long that the proton could have a sizable intrinsic component of the lightest heavy quark, the charm quark. Innumerable efforts to establish intrinsic charm in the proton have remained inconclusive. We provide first evidence for intrinsic charm by exploiting a high- precision determination of the quark-gluon content of the nucleon based on machine learning and a large experimental dataset. We disentangle the intrinsic charm component from charm-anticharm pairs arising from high-energy radiation. We establish the existence of intrinsic charm at the 3σ level, with a momentum distribution in remarkable agreement with model predictions. We confirm these findings by comparing to very recent data on Z production with charm jets from the LHCb experiment.

Parallel Workshop 2 / 127

Revisiting evolution of GPDs

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In this contribution, I will present a recomputation of the evolution kernels of generalised parton distributions (GPDs) at one-loop accuracy for all of the three possible leading-twist polarisations: unpolarised, longitudinally polarised, and transversely/linearly polarised.

I will discuss the analytic and numerical properties of these kernels presenting a number of numerical results for the evolution of GPDs deriving from the their implementation in a public code.

Parallel Workshop 2 / 44

DVCS at NNLO

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Parallel Workshop 2 / 93

Lattice QCD calculation of pion and kaon distribution amplitudes with domain wall and HISQ fermions at physical pion mass

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We present the first direct lattice QCD calculation of the x-dependent pion distribution amplitudes on domain wall gauge ensembles at physical pion mass. We use the large momentum effective theory to directly calculate the x-dependence of meson DAs with several recently developed self-consistent precision control methods. We perform a leading renormalon resummation to remove linear corrections in $1/P_z$, and resum the renormalization group logarithms to include higher order large log terms at small quark momenta xP_z and anti-quark momenta $(1-x)P_z$. Such techniques guarantee the precision of our calculation in mid-x region. Finally, constraining with short-distance factorization analysis, we are able to model the endpoint regions of DA more reliably in all region. Measurements of both pion and kaon DAs on HISQ ensembles at physical pion mass are also analyzed for comparison, from which we examine the chiral symmetry breaking effect on meson DAs.

Parallel Workshop 2 / 125

Axial and trace anomalies in DVCS

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In this presentation, we delve into the calculation of perturbative corrections for the Deeply Virtual Compton Scattering process within a unique kinematic domain, specifically where $t \gg \Lambda^2_{\mathrm{QCD}}$, with t representing the change in nucleon momentum following scattering. Working within this unconventional domain necessitated a distinctive approach, particularly dealing with non-zero values of t. Our calculation unveiled a previously undisclosed connection between Generalized Parton Distributions (GPD) and the chiral, as well as trace, anomalies of QCD. Of particular interest is the emergence of anomalies as infrared singularities when t approaches zero. Subsequently, we validate factorization up to one-loop order by systematically incorporating these singularity-related anomalies into the GPDs. This development not only expands the horizons of GPD research to encompass quantum anomalies but also opens up novel avenues for exploring their implications in both high-energy exclusive processes and the domain of lattice QCD investigations.

Parallel Workshop 2 / 120

Jet Production in Polarized Deep Inelastic Scattering

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In this talk I present our work on the calculation of exclusive single jet and dijet production cross sections in polarized DIS. The NLO accuracy results are obtained with our extension of the dipole subtraction method to account for initial state polarized processes. In the case of single jet production, we also reach NNLO accuracy by applying the projection-to-Born (P2B) subtraction method. We consider the case of pure photon exchange as well as full neutral-current (NC) and charged-current (CC) processes where the weak boson W± and Z are involved. The calculation is fully implemented in our Monte Carlo code POLDIS, which is used to study the phenomenological implications of the results obtained in the kinematics of the future Electron-Ion Collider (EIC) and how they will impact on our knowledge on the spin decomposition of hadrons.

Parallel Workshop 2 / 108

Nucleon axial-vector form factor, neutrino cross sections, and QED nuclear medium effects

Authors: Clarence Wret[1]; Ivan Vitev[2]; Kevin McFarland[3]; Oleksandr Tomalak[2]; Qing Chen[4]; Rajan Gupta[2]; Richard Hill[5]; Roberto Petti[6]; Tanmoy Bhattacharya[2]

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Charged-current quasielastic neutrino scattering is the signal process in neutrino oscillation experiments and requires precise theoretical prediction for the analysis of modern and future experimental data, starting with the nucleon axial-vector form factor. In this talk, I compare a new MINERvA measurement of this form factor with lattice-QCD calculations and deuterium bubble-chamber data,

provide uncertainty projections for future extractions, and present recent calculations of radiative corrections to charged-current processes. The exchange of photons with nuclear medium modifies (anti)neutrino and electron scattering cross sections. We study the distortion of (anti)neutrino-nucleus and charged lepton-nucleus cross sections and estimate the QED-medium effects on the final-state kinematics and scattering cross sections. We find new permille-to-percent level effects, which were never accounted for in either (anti)neutrino-nucleus or electron-nucleus scattering.

Parallel Workshop 2 / **88**

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

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A deeper understanding of the nucleon structure can be achieved through 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 preliminary results on Beam Spin Asymmetries will be
presented.

Parallel Workshop 2 / **139**

Partonic Structures from Lattice QCD: Life After NLO

Author: Swagato Mukherjee[1]

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I will present some recent lattice QCD results on parton distribution functions, generalized parton distribution functions and distribution amplitudes. I will focus on results obtained using perturbative matching coefficients computed beyond the next-to-leading order in the strong coupling, specifically

using next-to-next-to-leading order matching coefficients as well as incorporating various resummations.

Parallel Workshop 2 / 119

Generalized Parton Distributions from lattice QCD: new developments

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Generalized parton distributions (GPDs) are important quantities that characterize the 3-D structure of hadrons and complement the information extracted from TMDs. They provide information about the partons'momentum distribution and also on their distribution in position space. The non-perturbative part of the cross-section of high-energy processes may be expanded in terms of the process's large energy scale. This gives rise to a tower of distribution functions labeled by their twist (mass dimension minus spin). The leading twist (twist-2) contributions have been at the center of experimental measurements, theoretical investigations, and lattice QCD calculations. It has been recognized that twist-3 contributions to distribution functions can be sizable and should not be neglected. However, it is challenging to disentangle them experimentally from their leading counterparts, posing limitations on the structure of the proton.

Most of the information from lattice QCD is on the Mellin moments of GPDs, namely form factors and their generalizations. Calculating the x-dependence of GPDs from lattice QCD has become feasible in the last few years due to novel approaches. In this work, we employ the approach of quasi-distributions, which relies on matrix elements of fast-moving hadrons coupled to non-local operators. The quasi-distributions are matched to the light-cone distributions using Large Momentum Effective Theory (LaMET). The approach has been extensively used for twist-2 PDFs, and is now extended to twist-2 GPDs. More recently, the feasibility of the approach for twist-3 PDFs and GPDs was discussed. In this talk, we present an overview of selected results on x-dependent GPDs. This demonstrates the potential of lattice QCD calculations to complement other theoretical and experimental efforts toward the 3-D structure of hadrons.

Parallel Workshop 2 / 102

The Delta resonance at different physical parameters

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In this presentation we would like to determine the properties of the lightest resonance in
the baryonic sector of QCD: the Delta(1232) resonance. Using two-hadron operators we calculate the finite volume QCD energy spectrum of $\pi - N$ in the p-wave. Using Luescher formalism we can predict the mass and the width of the delta resonance. In our analysis we probe the Luescher formula by including several volumes and pion masses down to the physical point. Having results from so many different parameters we are in a position to perform controlled chiral extrapolation of the delta resonance parameters.

Parallel Workshop 2 / 92

Investigation of two-particle contributions to nucleon matrix elements

Authors: Constantia Alexandrou[1]; Ferenc Pittler[2]; Giannis Koutsou[2]; Marcus Petschlies[3]; Yan Li[4]

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We investigate contributions of excited states to nucleon matrix elements by studying the two- and three-point functions using nucleon and pion-nucleon interpolating fields. This study is made using twisted mass fermion ensembles with pion masses 346 MeV and 131 MeV. We construct an improved nucleon interpolating field with the generalized eigenvalue problem of two-point functions, and use it to study three-point functions. This method itself is also discussed in more details. We compare results obtained using these two ensembles and show preliminary results for nucleon charges.

Poster session / 96

Second-order pion-nucleus potential for scattering and photo production

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Coherent pion photoproduction on nuclei is an efficient tool for studying nucleon density and determining neutron skin thickness. However, a reliable description of pion scattering and other medium effects is needed for these purposes. We build a universal model describing both pion scattering and photoproduction on spin-zero nuclei within the same framework. We develop second-order momentum space scattering and photoproduction potentials based on the Delta(1232) effective self-energy modification and nucleon two-body correlation functions. The model's parameters are determined by fitting pion-carbon scattering data and are shown to be universal. We demonstrate the importance of the charge and spin exchange corrections for nuclear pion photoproduction.

Poster session / 62

Study of Neutral-Pion Pair Production in Two-Photon Scattering at BESIII

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The anomalous magnetic moment of the muon, $a_\mu = (g-2)_\mu/2$, is one of the most precisely measured observables of the Standard Model. However, its value shows a sizeable discrepancy to the Standard Model prediction. It is still under discussion whether this discrepancy is a hint for New Physics or a proof for the limited understanding of strong interaction at low energies. To get a better understanding of this discrepancy, one needs to reduce the uncertainty of both, the Standard Model prediction and the direct measurement.

Information on the production of pion pairs in two-photon fusion processes plays an important role in the dispersive calculation of the hadronic light-by-light scattering contribution to a_μ, which is one of the two large contributions to the Standard Model predictions uncertainty. The BESIII experiment, located at the institute of high energy physics in Beijing/China, offers a perfect testbed for the investigation of two-photon processes at small momentum transfers. The process $e^+e^- \to e^+e^-\pi^0\pi^0$ is measured at the BESIII experiment at centre-of-mass energies between 3.68 and 4.7 GeV with a total integrated luminosity of more than 20 fb^{-1}, with more data being available in future. This presentation will discuss the current status of the analysis.

Poster session / 63

Search for Light Dark Matter with the DarkMESA Experiment

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The search for Dark Matter is an integral part of New Physics searches, however, Dark Matter has yet to be observed directly. Theoretical models provide a large parameter space for Dark Matter and allow for different properties of the particles. Models incorporating so-called portal interactions, where Dark Matter interacts with Standard Model particles through a mediator particle, are of special interest. Examples for these are Dark Photon and Axion models, which can be studied at low energy accelerator facilities.
The DarkMESA experiment is a beam dump experiment located at the upcoming accelerator MESA at the JGU Mainz. The accelerator provides an electron beam of 155 MeV and 150 μA in extracted beam mode, which, along with the high-power beam dump of the P2 experiment, provides an ideal environment for Light Dark Matter searches.
To accurately predict the expected reach and the impact of the detector design of the DarkMESA experiment on it with respect to different Dark Matter models, most notably Dark Photon and Axion mediated models, a GEANT4 simulation is used. Here, the current status of the simulations is discussed.

Poster session / 64

Small Angle Initial State Radiation Analysis of the Pion Form Factor at BESIII

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The anomalous magnetic moment of the muon $a_\mu = (g_\mu - 2)/2$ is one of the most precisely measured quantities in modern physics. However, there is a sizable discrepancy between the Standard Model (SM) prediction of the Muon $g-2$ Theory Initiative and the experimental average of the latest direct measurements at BNL and FNAL. This discrepancy is known as the Muon $g-2$ puzzle. For the SM prediction the main uncertainty arises from hadronic contributions and can be improved systematically using measurements of hadronic cross sections at e^+e^- colliders. One of the most important processes is $e^+e^- \to \pi^+\pi^-$. Using a data set of $1.9\,\mathrm{fb}^{-1}$ (in the near future $20\,\mathrm{fb}^{-1}$) at a center of mass energy of $3.77\,\mathrm{GeV}$, the $\pi^+\pi^-$ cross section is measured at the BESIII experiment located at the BEPCII collider in Beijing, exploiting the initial state radiation technique at small angles. The analysis aims to determine the pion form factor at masses above $0.8\,\mathrm{GeV}$, which is also interesting for hadron spectroscopy. The poster will discuss the current status of this work.

Poster session / 60

Improved Limits on Lepton-Flavor-Violating Decays of Light Pseudoscalars via Spin-Dependent $\mu \to e$ Conversion in Nuclei

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Lepton-flavor-violating decays of light pseudoscalars, $P = \pi^0, \eta, \eta' \to \mu e$, are stringently suppressed in the Standard Model up to tiny contributions from neutrino oscillations, so that their observation would be a clear indication for physics beyond the Standard Model.
However, in effective field theory such decays proceed via axial-vector, pseudoscalar, or gluonic operators, which are, at the same time, probed in spin-dependent $\mu \to e$ conversion in nuclei.
We derive master formulae that connect both processes in a model-independent way in terms of Wilson coefficients, which in the case of $\mu \to e$ conversion in nuclei requires input for the nuclear matrix elements including the charge density to account for the bound-state physics, and study the implications of current μ ⟶ e limits in titanium for the P ⟶ μe decays. We find that these indirect limits surpass direct ones by many orders of magnitude.

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Poster session / 61

The all-charm tetraquark and its contribution to two photon processes.

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Over the past two decades a plethora of new exotic states containing heavy quarks have been discovered above open heavy-flavor thresholds.
For these states, which cannot be interpreted as quark anti-quark bound states, a number of different explanations have been put forward in terms of tetraquark states based on QCD diquarks, QCD hybrids, hadronic molecules, among others. In the past couple of years, LHCb has reported the first observation of exotic states, in particular the X(6900), comprised of only heavy quarks decaying into $J/\Psi\ J/\Psi$. Very recently, several more states have been reported by the CMS and ATLAS collaborations in the di-J/Ψ and $J/\Psi\ \Psi(2S)$ spectra, which have been interpreted as all-charm tetraquarks.
In this work, we review non-relativistic potential models for the all-charm tetraquark states, as diquark anti-diquark bound states, and explore how well these describe the structures obtained from the various experiments. Within such models, the most plausible explanation for $X(6900)$ is either as a scalar (0^{++}) meson or as a tensor (2^{++}) meson. Subsequently, we calculate the two-photon decay widths of these states within the potential model for both 0^{++} and 2^{++} quantum number assignments. The resulting two-photon decay widths allow to predict the light-by-light scattering cross sections and check if any excess, in comparison to the Standard Model prediction, seen in ongoing ATLAS experiments can be attributed to such exotic states.

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Scale separation in exotic atoms

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Spectroscopy experiments at the precision frontier allow us to study low-energy nuclear structure, test bound-state QED, refine fundamental constants, and potentially find New Physics. As the experimental uncertainties are continuously improved, theory predictions need to follow suit.
The finite-size corrections to the spectra of hydrogen-like atoms are often expanded in terms of the moments of the nuclear charge distribution, e.g. the charge and Friar radii. Contributions to the form factors that involve scales lighter than the inverse Bohr radius of the system can break this expansion.
In this poster, we illustrate the breaking and explain how spectroscopy experiments can probe physics beyond the Standard Model.

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X17 discovery potential from γD → e+e-pn with neutron tagging

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We propose a novel direct search experiment for the hypothetical X17 particle. In recent years researchers from the ATOMKI Collaboration have reported anomalous signals around 17 MeV in excited 8Be, 4He and 12C nuclear decays via internal pair creation. On the theory side this has set off a flurry of research, which found that the anomalies could be explained by a new light (~17 MeV) pseudoscalar, vector or axial-vector boson, dubbed X17. To provide an independent confirmation of

such particle in the production process on a nucleon, the γn ⟶ e+e-n process has been proposed. Experimentally it is possible to study this reaction in quasi-free production on a deuteron, i.e., γD ⟶ e+e-pn, using neutron tagging, where the neutron is bound inside a deuteron.

We calculate the cross section for dilepton photoproduction on a quasi-free nucleon, and optimize the kinematics for the quasi-free neutron region with the upcoming MAGIX@MESA experiment in mind. We show that the X17 signal is clearly visible above the QED background. Moreover, we show that the same measurements can be used to extract the neutron polarizabilities.

Poster session / 69

Studying Short-Range Nuclear Forces short range correlations through ρ0 photoproduction at Jefferson Lab

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Short Range Correlations (SRCs) are a phenomenon found in all nuclei where two nucleons form a strongly interacting, close-proximity pair in the nucleus, leading to a large relative momentum between the nucleons. Electron-scattering experiments, many of them conducted at Jefferson Lab, have determined that the prevalence of SRCs increase with nuclear size, and furthermore that most SRCs form between a neutron and a proton, a property called 'np-dominance.'Since these observations have largely come from the same type of experiment, it is possible that they are biased by reaction-specific effects, for example, final state interactions interactions. To test thisthe validity of previous observations, an experiment was conducted in Hall D in Fall 2021 using a photon beam on deuterium, helium, and carbon targets to probe SRCs through photoproduction reactions , a radically different approachto test the validity of many previous SRC observations. A preliminary look at the data showsThe preliminary results show clear signatures of SRCs, marking the first time that SRCs have been isolated in photoproduction. Using the ρ0 reaction channel, I plan to compare the rate of proton-proton SRC pairs to that of one proton SRC pairs to test for np-dominance. To assess relative abundances of SRC pairs between heavier targets, I will compare the rates of SRC events from ρ0 photoproduction in carbon and helium to deuterium. I will also show how these results compare to Monte Carlo simulations.

Poster session / 94

Simulating Lattice Gauge Theories with Continuous Flows

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A well-known challenge when simulating Lattice Gauge theories (LGT) is so-called critical slowing down, which refers to the exponential increase of the autocorrelation time as the lattice spacing is reduced and approaches the continuum limit. Previously, normalizing flows, combined with Lüscher' s trivializing maps, have been proposed as an alternative approach to Hybrid Monte Carlo (HMC), involving flowing gauge-field configurations, sampled independently from a uniform distribution, to the desired theory. The flow can be modelled by a parametrized function, namely a bijective map with parameters that can be trained using machine learning techniques. The trained model can then be used to generate proposals in a Markov Chain Monte Carlo (MCMC). In this talk, we present an application of this approach to simulate the U(1) gauge theory in two dimensions. We begin with an introduction of the method, details of the approach used, discuss its scalability, and conclude with some preliminary results.

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Lattice Chern-Simons term for (2+1)-dimensional QED

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Chern-Simons gauge theories have a deep and broad impact on a wide range of physics research, ranging from parity anomalies in quantum field theory to the theory of the integer and fractional quantum Hall effects, and the effective field theory description of chiral spin liquids in condensed matter physics. Despite the fact that Chern-Simons theories are well understood as a continuum field theory, there is still limited knowledge on how to find a compact Hamiltonian lattice formulation in 2+1 dimensions. This task turns out to be highly nontrivial, and we take a first step towards a lattice formulation by considering quantum electrodynamics on the lattice in the presence of a Chern-Simons term. We propose a compact lattice formulation for the Chern-Simons term in terms of the usual operators acting on the links, which we benchmark numerically against theoretical predictions. Our formulation is completely general and also suited for other Hamiltonian approaches such as quantum computing.

Poster session / 100

Pion and kaon transverse momentum-dependent parton distribution functions in lattice QCD

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We evaluate the transverse momentum-dependent parton distribution functions for the pion and kaon by computing the quasi-beam functions with asymmetric staple-shaped quark bilinear operators and combine it with the soft function and Collins-Soper kernels. These are computed within lattice QCD using an $\mathcal{N}_f = 2 + 1 + 1$ twisted mass fermion ensemble of lattice size $24^3 \times 48$, lattice spacing $a = 0.093$ fm, pion mass of 350 MeV and kaon mass of 554 MeV. We study the mixing pattern of the extended operators composed of an asymmetric staple-shaped Wilson line through symmetry arguments and implement non-perturbative renormalization within both the RI/MOM scheme and a variant scheme, where the renormalization factors are computed at short distances.

Poster session / 97

Exploring Gluon Momentum Fraction in Mesons through Lattice Quantum Chromodynamics Simulations

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We compute the quark and gluon momentum fraction for the pion and kaon. This is done by employing lattice quantum chromodynamics simulations. We use three gauge ensembles of twisted mass fermions generated by the Extended Twisted Mass Collaboration with two degenerate light quarks and non-degenerate strange and charm quarks. All quark masses are tuned to approximately their physical values. Stout smearing is used on the gluon loops to reduce ultra violet gauge noise. We use these three gauge ensembles with lattice spacings a = 0.08 fm, 0.068 fm and 0.57 fm to take, for the first time, the continuum directly at physical pion mass. Renormalisation factors are computed non-perturbatively within the RI'scheme for the quark and gluon operators. Mixing between the quark and gluon is taken into account perturbatively. We check the momentum sum in the continuum limit.

Poster session / 101

Exploring Phase structure of the Schwinger model on superconducting Quantum Computers

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We explore the phase structure of the lattice Schwinger model in the presence of a toplogical θ-term, a regime in which conventional Monte Carlo simulations suffer from the sign problem, using the variational quantum eigensolver (VQE). Constructing a suitable variational ansatz circuit for the lattice model using symmetry-preserving 2-qubit gates, we perform classical simulations showing that the ansatz is able to capture the relevant physics. In particular, we observe the remnants of the well known first-order phase transition at $\theta = \pi$ occurring in the continuum model for large enough fermion masses. Furthermore, we implement our ansatz on IBM's superconducting quantum hardware. Using state-of-the art noise suppression techniques, namely readout error mitigation, dynamical decoupling, Pauli twirling, and zero-noise extrapolation, we are able to explore the phase structure of the model directly on quantum hardware with up to 12 qubits. We study two regimes on the hardware device, a fermion mass well below the transition point and a fermion mass well above. In both cases, our ansatz performs well and we obtain data, which are in good agreement with exact diagonalization.

Poster session / 150

Improved constraints for axion-like particles from 3-photon events at e^+e^- colliders

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Axions and axion-like particles (ALPs) are one of the most widely discussed extensions of the Standard Model when it comes to the strong CP problem and dark matter candidates. Current experiments are focused on the indirect searches of invisible pseudoscalars in a wide parameter range. In this paper we investigate limits on ALP mass, and its couplings to photons and leptons from 3-photon annihilation at e^+e^- colliders. We provide detailed calculations and apply them to the particular kinematics of the Belle II experiment, covering the ALP mass range from few hundred MeV to around 10 GeV. Our results, which improve upon previous analyses by also including the ALP coupling to electrons, show that such future analyses will allow to significantly extend the ALP search range and impose much more stringent restrictions on their couplings.

Poster session / 135

The Plasma Window as a Vacuum-Atmosphere Interface for Measurements of Stellar Neutron-Induced Reaction Cross Sections

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Neutrons play a dominant role in the stellar nucleosynthesis of heavy elements. We review a scheme for the experimental determinations of neutron-induced reaction cross sections using a high-intensity neutron source based on the 18O(p,n)18F reaction with an 18O-water target at SARAF's upcoming Phase II. The quasi-Maxwellian neutron spectrum with effective thermal energy kT ≈ 5 keV, characteristic of the target (p,n) yield at proton energy Ep ≈ 2.6 MeV close to its neutron threshold, is well suited for laboratory measurements of MACS of neutron-capture reactions, based on activation of targets of astrophysical interest along the s-process path. 18O-water's vapour pressure requires a separation in between the accelerator vacuum and the target chamber. The high-intensity proton beam (in the mA range) of SARAF is incompatible with a solid window in the beam's path. Our suggested solution is the use of a Plasma Window, which is a device that utilizes ionized gas as an interface between vacuum and atmosphere, and is useful for a plethora of applications in science, engineering and medicine. The high power dissipation (few kW) at the target is expected to result in one of the most intense sources of neutrons available at stellar-like energies. Preliminary results concerning proton beam energy loss and heat deposition profiles for target characteristics and design, a new full-scale 3-dimensional computer-aided design model of the Plasma Window (as well as its operation principles) and the planned experimental scheme, will be reviewed.