WPCF 2023 - XVI Workshop on Particle Correlations and Femtoscopy & IV Resonance Workshop 2023

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Book of Abstracts

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Day 1 - Morning / 98

Welcome Address by S. Romano, Director of the Physics and Astronomy Department, UNiversity f Catania

Corresponding Author: romano@lns.infn.it

Day 1 - Morning / 52

Tre facce della stessa medaglia: Coalescence, Thermal Production and the Koonin Equation

Author: Scott Pratt[1]

[1] *Michigan State*

Corresponding Author: prattsc@msu.edu

Resonance production is often treated either as a thermal process or through coalescence. I will discuss how these treatments are more alike than different, and point out how the formalisms overlap with the way in which we model femtoscopic correlations through the Koonin equation. I will explain when they're the same, when they're different, when one is more justified than another, and finally, when none are justified.

Day 1 - Morning / 38

Femtoscopy in heavy-ion collision experiments at various \mu_B

Author: Hanna Zbroszczyk[1]

[1] *Warsaw University of Technology*

Corresponding Author: hanna.zbroszczyk@pw.edu.pl

Geometry and dynamics of the particle-emitting source in heavy-ion collisions can be inferred via the femtoscopy method. Two-particle correlations at small relative momentum exploit Quantum Statistics (QS) and the Final State Interactions (FSI), which allow one to study the space-time characteristics of the source of the order of 10^{−15} m and 10^{−23} s. Femtoscopic measurements allow one to study FSI, especially the Strong one, which is unknown for many two-particle systems. Various experiments at LHC, RHIC, and SIS-18 facilities cover a significant part of the QCD Phase Diagram using collisions of heavy-ions for several beam energies, in which regions with different \mu_B are studied via femtoscopy. Strange hadron measurements and non-strange ones provide complementary information about source characteristics. This talk will exhibit the femtoscopic measurements of various particle combinations at different collision energies.

Day 1 - Morning / 32

Bose-Einstein correlations at LHCb

Author: Marcin Kucharczyk[1]

[1] *Institute of Nuclear Physics PAN, Krakow, Poland*

Corresponding Author: marcin.kucharczyk@ifj.edu.pl

A study of the Bose-Einstein correlations for same-sign charged pions originating from proton-proton and proton-lead collisions recorded in the LHCb experiment at sqrt(s) = 7 TeV centre-of-mass energy and sqrt(sNN) = 5.02 TeV centre-of-mass energy per nucleon. Both measurements are the first of this type performed in the forward region at LHC energies. The proton-proton (proton-lead) dataset used in the analysis was recorded in 2011 (2013) and corresponds to an integrated luminosity of 1.0 fb-1 (1.6 nb-1). Correlation parameters are determined for different regions of charged-particle multiplicity. It is observed that the correlation radius (the intercept parameter) increases (decreases) with the charged-particle multiplicity, which is consistent with observations from other experiments at the LHC in the central rapidity region. The measured correlation radii scale linearly with the cube root of the charged-particle multiplicity. Such a behaviour is compatible with predictions based on the hydrodynamic models. Moreover, hints for a dependence of the correlation radius on pseudorapidity are observed.

Day 1 - Morning / 40

Proton-proton and proton-cluster femtoscopy at the HADES experiment

Author: Maria Stefaniak[1]

[1] *The Ohio State University*

Corresponding Author: stefaniak.9@osu.edu

The coherent description of nuclear matter properties at high baryon densities is of utmost importance. The limited number of experimental references in the region of the phase diagram corresponding to Neutron Stars (NS) and NS mergers poses major challenges for constructing a universal Equation of State. The matter created in heavy-ion collisions at the HADES experiment can be characterized by similar thermodynamic quantities as NS mergers, thus becoming an essential reference for the studies of these compact stellar objects [1]. Understanding the properties of the newly created matter, such as the strong interaction between hadrons or the presence of bound states, provides substantial insight for such investigation.

One of the methods applied in these studies is femtoscopic correlations (FC). It is a unique tool for the determination of the interactions between hadrons and searching for possible nuclear matter exotic states. Nonetheless, FC is found to be sensitive to variations of EoS, which makes it a valuable reference for its studies.
This talk will present the newest results on the proton-proton and proton-cluster (deuteron, triton, and He-3) FC at the HADES experiment showing the presence of unbound ground state Li-4 and excited states of He-4. The interactions between proton and clusters will be discussed as well. Subsequently, the sensitivity of EoS in the UrQMD model simulations to proton-proton femtoscopy will be shown.

This research brings us closer to understanding the essential properties of nuclear matter at higher baryon densities.

[1] HADES Collaboration: Nature Physics volume 15, pages 1040–1045 (2019)

Day 1 - Morning / 99

Welcome address by the Director of the Laboratori Nazionali del Sud (LNS) of INFN, Santo Gammino

Day 1 - Morning / 30

Coulomb effects on pion spectra and HBT correlations at few GeV/A beam energies

Author: Malgorzata Gumberidze[1]

[1] *GSI Helmholtzzentrum für Schwerionenforschung GmbH(GSI)*

Corresponding Author: m.gumberidze@gsi.de

The fireball produced in a relativistic heavy-ion collision has a net positive electric charge, due to the protons from both the target and the projectile nuclei, that affects the charged particles ejected from the expanding fireball. The effect of these long-range Coulomb interactions on the charged pion momentum distributions, as well as on pion-pion momentum correlations (HBT), has been measured by the HADES collaboration in Au+Au and Ag+Ag collisions at a few-GeV centre-of-mass energies. Indeed, the study of Coulomb effects has the potential to reveal information about the properties of the pion source at freeze-out.

In our contribution, we will present results on the extraction of the Coulomb potential energy, the resulting source radii, and the corresponding freeze-out baryon density.

Day 1 - Morning / 39

A novel method for calculating Bose-Einstein correlation functions with Coulomb final-state interaction

Author: Marton Nagy[1]

[1] *Eötvös University, Budapest*

Corresponding Author: nmarci@elte.hu

The main goal of femtoscopy in heavy-ion physics is to map out the space-time structure of the particle emitting source utilizing Bose-Einstein correlation measurements. Such measurements already have played a crucial role in the discovery and exploration of the Quark-Gluon-Plasma (QGP) created in high-energy heavy-ion collisions. With the accumulation of high statistics, high quality data, it becomes possible to perform more and more precise investigations of Bose-Einstein correlation functions, and it becomes absolutely necessary to have a robust understanding of the phenomenology of such correlations. In this talk a novel method for the calculation of the two-particle correlation functions including Coulomb final-state interaction is presented. It relies on an exact calculation of many of the necessary integrals of the Coulomb wave function, and can be utilized to calculate the correlation function for any source function with an easily accessible Fourier transform. In this way, it is eminently applicable to Levy-stable source functions that have recently been increasingly successfully utilized to precise investigations of correlation functions. The presented new method, besides being mathematically interesting and elegant on its own, allows for a numerically more stable and robust investigation of a wider range of source function parameters than the previously utilized techniques, and can be readily applied to correlation function measurements.

Day 1 - Morning / 15

Studying the low-energy scattering among hadrons using correlation techniques at the LHC

Author: Dimitar Mihaylov[None]

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

Femtoscopy is a technique used to study correlations between particles with low relative momentum, which are related to the emission source and the final state interaction. The ALICE collaboration demonstrated that a common emission source for all baryons exists in small collision systems, and its properties have been constrained. This allowed to perform studies on the low-energy scattering properties between pairs, which were previously difficult or impossible to access experimentally. For example, the recent ALICE precision measurement of the pΛ channel allows to significantly improve the existing experimental constraints on theoretical models, greatly benefiting the construction of a realistic nuclear equation of state, which in turn has consequences on the modeling of neutron stars. This study is complemented by investigating the three-body forces by measurements of the proton-deuteron and ppΛ correlations. Further, measurements of exotic systems, e.g. ΛK^- , provide a gateway toward the physics of coupled channel dynamics and the nature of complex states as the $\Xi(1690)$.

Day 1 - Morning / **49**

Two-particle interferometry with Lévy-stable sources in $\sqrt{s_{NN}}$ = 200 GeV Au+Au collisions at STAR

Author: Daniel Kincses[1]

[1] *Eotvos Lorand University*

Corresponding Author: kincses@ttk.elte.hu

Measurements of femtoscopic correlations in high-energy heavy-ion collisions aim to unravel the space-time structure of the particle-emitting source (the quark-gluon-plasma). Recent results indicate that the pion pair-source exhibits a power-law behavior and can be described well by a Lévy distribution. In this study, Lévy fits were performed to the measured one-dimensional two-pion correlation functions in Au+Au collisions at $\sqrt{s_{NN}}$=200 GeV. The three extracted source parameters are the Lévy scale parameter, R, which relates to the size of the source, the correlation strength parameter, λ, and the Levy exponent, α, which characterizes the power-law tail of the source. In this talk, we report the current status of the analysis of the extracted Lévy source parameters and present their dependence on average transverse mass, m_T, and on centrality.

Day 1 - Afternoon / **43**

Exotic Spectroscopy at LHCb

Author: Tadeusz Lesiak[None]

Corresponding Author: tadeusz.lesiak@ifj.edu.pl

Studies of exotic hadrons comprise a natural and privileged playground for a more thorough elucidation of the nature of quantum chromodynamics. In this contest the LHCb experiment, dedicated to study heavy flavor hadrons produced from pp collision at the LHC, plays a vital role, already providing evidence for several exotic hadrons.

The talk will deliver an overview of the selected, latest LHCb on the subject of exotic hadron spectroscopy. It encompasses, in particular, the observations of pentaquarks, tetraquarks and the status of experimental knowledge about the state χc1(3872).

Day 1 - Afternoon / **66**

Microscopic Model for Quarkonia Production in Heavy-Ion collisions

Author: Joerg Aichelin[1]

[1] *SUBATECH*

Corresponding Author: aichelin@subatech.in2p3.fr

Quarkonia are a very interesting probe for the study of thequark gluon plasma (QGP), created in ultrarelativisitc heavy-ion collisions. They can elucidate several features of the QGP, which are not accessible to other probes. These include the energy loss of color neutral states and open heavy flavour partons in the QGP, the possible recombination of heavy quarks during the expansion of the QGP and the influence of the potential between c(b) and $\bar{c}(\bar{b})$, which is modified in the QGP environment, on the production of quarkonia.

We present the first microscopic approach for the study of quarkonia. It follows the heavy quarks from their initial production to the detection as a part of a quarkonium or as open heavy flavour hadron. After being produced in EPOS4 by (shadowing modified) initial collisions, the heavy quarks interact mutually by a potential, calculated on the lattice. When the temperature of the surrounding QGP environment falls below the dissociation temperature of the quarkonia species, a density matrix, based quantum approach of Remler [1], describes the formation and destruction of quarkonia due to its interaction with the QGP medium while the QGP medium expands.
The expanding QGP is described by the EPOS4 approach, which has shown to reproduce a multitude of experimental observables in the light hadron sector. At freeze out the free heavy quarks combine through hadronization to open heavy flavour partons, which are well reproduced in this approach. We compare the J/ψ as well as the ψ', produced in Remler approach with the available data on transverse momentum spectra, R_{AA} and v_2 and analyse, including feed down corrections, how the above processes influence the production of quarkonia. First results of this approach have been published in [2].

[1] E.A.Remler, Annals Phys. 136, 293, 1981

[2] D. Villar, J. Zhao, J.Aichelin and P. Gossiaux, Pol Bernard, Phys.Rev.C 107 (2023) 5, 054913

Day 1 - Afternoon / 71

Hadronic resonance production with ALICE at LHC

Author: Bong-Hwi Lim[1]

[1] *Istituto Nazionale di Fisica Nucleare*

Corresponding Author: bong.hwi.lim@to.infn.it

Hadronic resonances have been used as a useful tool for studying the hadron gas phase produced in the late stages of high-energy nuclear collisions. The resonance yields are affected by the hadronic interactions happening during the hadron-gas phase, thus measuring resonance production is useful to constrain the hadron-hadron interactions. The ALICE experiment is suitable for measuring hadronic resonances thanks to its excellent tracking and particle identification capabilities over a broad momentum range. In this talk, the most recent results on resonances in pp, p−Pb, Xe−Xe and Pb−Pb collisions at various centre-of-mass energies, highlighting new results on ⊠(770)0, K*(892), Φ(1020), Σ(1385)±, Λ(1520), Ξ(1530)0, and Ξ(1820) are presented. These results are used to interpret the system-size and collision-energy evolution of transverse momentum spectra, yields, average transverse momentum, and yield ratios to longer-lived hadrons with comparison to lower energy measurements from previous experiments and model calculations.

Day 1 - Afternoon / 48

Heavy flavour hadronization from AA to pp collisions

Author: Salvatore Plumari[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 AA, pA and pp collisions.
The coalescence hadronization approaches have predicted an unexpected large Λc/D0 ratio is of O(1) in AA collisions,
that has been first observed at RHIC energies and recently in pp, pA and AA collisions at LHC.
The large ratio observed in small collision systems appears to be a strong violation of the universality of the
fragmentation function seen in elementary collision systems, where the observed Λc/D0 is of O(10−1).
Within a relativistic Boltzmann transport approach coupled to an hadronisation mechanism based on the
coalescence and fragmentation processes we will show the results obtained in AA collisions for D0, Ds, Λc spectra
and the related baryon to meson ratios at RHIC and LHC. Furthermore, we will present results obtained extending
this analysis to smaller systems like in pp collisions at top LHC energies for the heavy baryon/meson ratio and
the pT spectra of charmed hadrons with and without strangeness content: D0, Ds, Λc , Σc and the recently
measured Ξc baryon, finding an enhancement in comparison with the ratio observed for e +e −, ep collisions;
we will show prediction of a significant production of Ωc respect to D0. Finally, we discuss the particle
yields of multi-charmed baryons focusing mainly on the production of Ξcc and Ωccc. We will provide first
predictions for charmed and multi-charmed hadrons in PbPb collision in 0−10% centrality class and then
we explore the system size dependence through KrKr , ArAr and OO collisions, planned within the ALICE3 experiment.

[1]V.Minissale, S.Plumari, Y.Sun and V.Greco, arXiv:2305.03687 [hep-ph].
[2] V. Minissale, S. Plumari and V. Greco, Physics Letters B 821 (2021) 136622.
[3] S. Plumari, V. Minissale, S.K. Das, G. Coci and V. Greco, Eur.Phys.J. C 78 (2018) no.4, 348

Day 1 - Afternoon / 53

Charm and Bottom quarks dynamics in Heavy-Ion Collisions: anisotropic flows v_n and their correlations with Event-Shape Engineering technique.

Authors: Maria Lucia Sambataro[1]; Yifeng Sun[2]; Vincenzo Minissale[3]; Salvatore Plumari[3]; Vincenzo Greco[3]

[1] *Università degli Studi di Catania-INFN(LNS)*

[2] *Shanghai Jiao Tong University*

[3] *Istituto Nazionale di Fisica Nucleare*

Corresponding Author: mlsambataro@gmail.com

We describe the propagation of heavy quarks (HQs), namely charm and bottom, in the quark-gluon plasma by means of a full Boltzmann transport approach including event-by-event initial state fluctuations.
The non-perturbative dynamics of the interaction between plasma particles and HQs have been taken into account through a Quasi-Particle Model(QPM) while the hadronization process is described by hybrid coalescence plus fragmentation approach. We show the D-mesons R_{AA} and v_2 at RHIC and LHC energies. Furthermore, we discuss the extension to high-order anisotropic flows ($v_n(p_T)$) also evaluated within the Event-Shape Engineering technique which consists in selecting events in the same centrality class but characterized by different geometry in the initial state. In this context, we show event-shape selected D-meson spectra and v_n but also predictions for correlations between different D-meson flow harmonics at LHC energies in different range of centrality selections. Within this approach we extract a space-diffusion coefficient D_s for charm quark which is in a agreement with lattice QCD results within the systematic uncertainties. In the same scheme, we extend our approach to study bottom quark dynamics: we find that QPM approach is able to
correctly predict the first available data on R_{AA} and v_2 of single-electron from B decays. We show also predictions for centralities where data for both v_2 and v_3 are not yet available .

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[1] M.L.Sambataro, Y.Sun, V.Minissale, S.Plumari and V.Greco, Eur.Phys.J.C 82 (2022) 9, 833.

[2] M.L.Sambataro, V. Minissale, S.Plumari and V.Greco. Submitted to Phys. Lett. B. e-Print: 2304.02

[3] S.Plumari, G.Coci, V.Minissale, S.K.Das, Y.Sun and V.Greco, Phys. Lett. B 805 (2020), 135460.

[4] M.L.Sambataro, S.Plumari and V.Greco, Eur. Phys. J. C 80, no.12, 1140 (2020).
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Day 1 - Afternoon / 20

Production of resonances in partial chemical equilibrium

Authors: Boris Tomášik[None]; Sándor Lökös[None]

Corresponding Author: boris.tomasik@cern.ch

In high energy collisions, a dense, strongly interacting medium could be created, the quark gluon plasma. In rapid expansion, from the soup of quarks and gluons a gas of resonance and stable particles is formed at the chemical freeze-out and after that, as the system cools down, the ki- netic freeze-out takes place and interaction between particles ceases. By measuring resonance ratios one could get information about the dominant physical processes in the intermediate temperature ranges, i.e. between the chemical and kinetic freeze-out. These quantities are measured at RHIC and LHC energies. In the present analysis we employ the hadron resonance gas model assuming partial chemical equilibrium to characterize these measured data. We calculate the ratios of several resonances to their stable counterpart and compare these model calculations to available experimental data.

Day 1 - Afternoon / 7

Vector resonances as a probe of spin hydrodynamics

Author: Giorgio Torrieri[1]

[1] *State University of Campinas (Unicamp),Brasil*

Corresponding Author: torrieri@unicamp.br

We show that vector and higher spin resonances are a sensitive probe of a fundamental aspect of spin hydrodynamics - the lack of equilibrium between spin and vorticity. This is because the purity structure of the density matrix is measurable via the off-diagonal density matrix elements.
We illustrate this via coalescence models for light mesons and potential models for quarkonium states, and illustrate further directions for both theory and experimental analysis.

Based on
https://arxiv.org/abs/2305.02985
and
https://arxiv.org/abs/2104.12941

Day 1 - Afternoon / 25

Searches for the Chiral Magnetic Effect in Xe–Xe and Pb–Pb collisions with ALICE

Author: Andrea Danu[1]

[1] *Institute of Space Science*

Corresponding Author: andrea.danu@cern.ch

An important characteristic of the strong interaction that can be explored through heavy-ion collisions is the observation of local parity violation. This phenomenon, which manifests as charge separation along the direction of the magnetic field, is called the Chiral Magnetic Effect (CME). We present results on the centrality dependence of the charge-dependent two- and three-particle correlators in Xe-Xe and Pb-Pb collisions selected using the event shape engineering technique at $\sqrt{s_{\mathrm{NN}}} = 5.44$ TeV and 5.02 TeV, respectively. Comparisons with theoretical calculations are used to estimate background effects in the charge dependence of the three-particle correlator, which is often used as evidence for the CME. Furthermore, these measurements, combined with Monte-Carlo Glauber and T$_{\mathrm{R}}$ENTo simulations of the magnetic field, are used to derive an upper limit on the CME contribution.

Day 1 - Afternoon / 61

Flow and hyperon polarization at RHIC BES from multi-fluid dynamics

Author: Iurii Karpenko[1]

[1] *FNSPE CTU in Prague*

Corresponding Author: yu.karpenko@gmail.com

We present a study of flow and hyperon polarization observables at RHIC BES energies in a MUlti Fluid simulation for Fast IoN collisions (MUFFIN) model. MUFFIN is based on a multi-fluid approach to relativistic heavy-ion collisions, and treats the initial stage of heavy-ion reaction as mutual interpenetration of baryon-rich fluids. It is implemented from scratch with the use of a versatile 3+1 dimensional relativistic viscous hydrodynamic code vHLLE. The model is aimed at describing heavy-ion collision dynamics at lower RHIC BES energies, including the fixed-target mode, and energies of the future FAIR facility.
Global angular momentum and directed flow have the same prerequisites, which are baryon stopping and finite impact parameter. Therefore, we study them together. We discuss underlying vorticity development in multi-fluid approach, hyperon - anti-hyperon splitting, and compare our results to the recent data for hyperon polarization. We examine directed flow observable at different collision energies, and show its equation-of-state dependence and the effects of final-state hadronic cascade, in a full-fledged dynamical model.

Day 1 - Afternoon / 12

Two-particle angular correlations of identified particles - recent developments and current status

Author: Lukasz Graczykowski[1]

[1] *Warsaw University of Technology*

Corresponding Author: lgraczyk@cern.ch

Angular (ΔηΔφ) 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 ΔηΔφ 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 ((Δη,Δφ)≈(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.

Until recently, this effect has not been reproduced by any of the MC models, posing fundamental questions on the production mechanism of baryons. However, several developments on the theory side have been made since the publication of experimental results (i.e. [3,4]).

In addition, in our recent work [5] we discuss 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, Few Body Systems 64, 57 (2023)
[5] Ł. Graczykowski, M. Janik, Phys. Rev. C 104, 054909 (2021)

Day 2 - Morning / 97

Introduction to Stella Intensity Interferometry

Author: Michael Lisa[1]

[1] *Ohio State University*

Corresponding Author: lisa.1@osu.edu

Day 2 - Morning / 85

An Angular Diameter Measurement of Merak via Stellar Intensity Interferometry with VERITAS

Author: Michael Lisa[1]

[1] *Ohio State University*

Corresponding Author: lisa.1@osu.edu

The age of the Ursa Major moving group has been assessed from the ages of its members, including nuclear member Merak (β UMa), an A1-type subgiant, by comparing effective temperature and luminosity constraints to model stellar evolution tracks. Previous interferometric limb-darkened angular diameter measurements of β UMa inthe near-infrared (CHARA Array, 1.149 ± 0.014 mas) and mid-infrared (Keck Nuller,1.08 ± 0.07 mas), together with the measured parallax and bolometric flux, have constrained the effective temperature. To obtain the first measured angular diameter at visual wavelengths and to independently constrain the limb-darkened angular diameter, we used the VERITAS imaging air Cherenkov telescope array to perform stellar intensity interferometry (SII) observations of β UMa. We extract squared visibilities from ns-scale time correlations. We fit the resulting squared visibilities to find a limb-darkened angular diameter of 1.07 ± 0.03 (stat) ± 0.05 (sys) mas, using synthetic visibilities from a stellar atmosphere model that provides a good match to the spectrum of β UMa in the optical wave band. The VERITAS-SII limb-darkened angular diameter yields an effective temperature of 9800 ± 200 ± 200 K and, using MESA Isochrones and Stellar Tracks (MIST), an age for β UMa of 390 ± 20 ± 29 Myr.

In addition to the specifics of this measurement, I will discuss the principle and operation of the VERITAS stellar intensity interferometer. Hanbury Brown, whom I met in Catania more than 25 years ago, would have loved to see the field as it is being revived today.

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Stellar Intensity Interferometry at H.E.S.S.

Author: Naomi Vogel[None]

Corresponding Author: naomi.vogel@fau.de

Stellar Intensity Interferometry (SII), originally developed by Hanbury Brown & Twiss in the late 1950s, enables high angular resolution astronomical observations in the optical band. By measuring and correlating the photon streams of at least two telescopes with varying baselines, the technique becomes almost insensitive to atmospheric effects. Since Imaging Atmospheric Cherenkov Telescopes have very large light collecting areas they are the ideal candidates for Intensity Interferometers. Our II setups were designed for the Phase I H.E.S.S. telescopes in Namibia. Two measurement campaigns, in 2022 and 2023, have already taken place in Namibia. In this contribution we give a brief introduction into the method, present our technical setup and the results we have gathered so far.

Day 2 - Morning / 79

Intensity interferometry with optical telescopes: recent progress and future plans

Author: William Guerin[1]

[1] *Université Côte d'Azur*

Corresponding Author: william.guerin@univ-cotedazur.fr

I will present the current status of the work done by our "Intensity Interferometry at Calern" (I2C) consortium in Nice (France) on the revival of intensity interferometry with optical telescopes.

In short, we have demonstrated intensity correlations using stellar light for the first time in the photon-counting regime, using 1m-class telescopes at Calern Observatory. We have then dedicated some effort to demonstrate the simplicity and portability of our instrument by adapting and using it successfully on different telescopes worldwide, including a 1m portable telescope at Calern, the Auxiliary Telescopes at ESO-Paranal Observatory, and the 4m SOAR telescope. Besides these technical demonstrations, we have also performed a few measurements of astrophysical interest, in particular on the Halpha emission line of P Cygni.
In addition, I'll present our short-term plans to improve the sensitivity: using superconducting nanowire single-photon detectors and performing wavelength multiplexing. Finally, I'll discuss some of our long-term dreams, for instance measuring the angular diameter of Sirius B!

Day 2 - Morning / 81

Astronomical HBT interferometry: inside-out femtoscopy?

Author: Prasenjit Saha[1]

[1] *University of Zurich*

Corresponding Author: psaha@physik.uzh.ch

Astronomical HBT interferometry is simultaneously just like femtoscopy and yet as different as can be. Perhaps one can think of astronomical HBT interferometry (or intensity interferometry) as probing (transverse) momentum on scales of nano eV/c by measuring particle correlations on scales of hundreds of metres.

This talk will try to make the connection, present some new results on massive stars, and give a feeling for the exciting developments expected in the coming years.

Day 2 - Morning / 86

Search for collective behavior in very small and in large colliding systems

Author: Sandra Padula[1]

[1] *Sao Paulo State University (UNESP)*

Corresponding Author: sandra.padula@cern.ch

Signs of collectivity were initially seen in AuAu collisions at RHIC through measurements of two-particle long-range correlations in (pseudorapidity) $\Delta\eta$, within small (azimuthal) $\Delta\varphi$ angles. In addition, in 2010 a similar ridge-like behavior was observed in high multiplicity proton-proton (pp) collisions at 7 TeV at the LHC by CMS, extended afterwards also to pPb and PbPb collisions. Several orders of anisotropic flow Fourier harmonics were measured later, showing a collective behavior compatible with hydrodynamic expectations. Signs of possible collectivity were also searched for in e+e- collisions at LEP, with negative results. However, those experiments were limited to lower multiplicity ranges (< 40 particles per event), where collectivity was not expected, posing the question about the system size threshold and conditions for collectivity to arise.
This talk shows recent results from the CMS Collaboration for two extreme sizes of colliding systems. On the lowest side, the results focus on the search for a ridge-like behavior in high multiplicity pp collisions at 13 TeV inside a single jet, originated from a highly energetic parton. On the other extreme, PbPb collisions at sqrt{s_{NN}} = 5.02 TeV are employed to probe deeper into the quark-gluon plasma formed in such collisions, by measuring the speed of sound and the effective temperature in this medium.

Day 2 - Morning / 27

Femtoscopy of p – Λ system obtained in heavy-ion collision in the HADES experiment

Author: Narendra Rathod[1]

[1] *Warsaw University of Technology, Warsaw, Poland*

Corresponding Author: nsrathore.rajput@gmail.com

Over recent decades, substantial attention has been directed toward the characteristics of hyperons in dense matter, particularly in the context of stars. Energetically, hyperons might exist in the inner layers of neutron stars, where the structural arrangement is notably influenced by the equation of state (EOS) describing nuclear matter at densities exceeding saturation. The inclusion of hyperons in the core causes the equation of state (EOS) to soften, resulting in neutron stars having masses lower than twice that of the Sun (2M). This enigmatic contradiction is commonly referred to as the "hyperon puzzle in neutron stars". Femtoscopy is an important technique for experimentally understanding hyperon-nucleon interactions within the two-body system by analyzing two-particle correlations in momentum space. This approach has solidified its reputation as a robust tool in deciphering parameters pertaining to strong interactions and lifetimes within the realm of heavy-ion physics. Femtoscopy provides the means to quantify the space time characteristics of the collision-generated system, despite its fleeting existence on the order of 10 −23 seconds and its confined scale on the femto-meter level (10 −15 meters).

Utilizing the HADES detectors, which form part of the GSI Helmholtz Center for Heavy-Ion Research in Darmstadt, Germany, the analysis focuses on experimental data from Ag-Ag heavy-ion collisions at an energy of 1.58 AGeV. To delve deeper into the realm of strong interactions, particles carrying strange quarks offer an ideal avenue. These include particles such as Λ (Lambda) and K0s (K-short). It's worth noting that particles with strangeness are relatively scarce in heavy-ion collisions at the energy typical of the HADES experiment. To study these particles, Λ's are reconstructed through the decay channel Λ ⟶ π- + p, which has a branching ratio of 64%. The selection of pions and protons relies on their distinct energy loss and time-of-flight characteristics. A significant aspect involves employing the off-vertex-decay technique, to reconstruct the secondary vertex. HADES has achieved a significant milestone by measuring the correlation function of p and Λ in a heavy-ion collision for the first time, accompanied by the disclosure of strong interaction parameters for distinct spin states. It is also found that the strong interaction induces a prominent peak in the correlation function and provides more sensitive source size measurements than pp correlations under some circumstances.

Day 2 - Morning / 47

Forward correlations with the LHCb detector

Author: Samuel Belin[1]

[1] *Universidade de Santiago de Compostela (ES) IGFAE - LHCb*

Corresponding Author: samuel.belin@cern.ch

Particle correlations are a powerful tool to study the properties of the bulk nuclear matter produced in relativistic heavy ion collisions. The momentum correlations between identical particles originating from the same particle-emitting source, referred to as the Bose-Einstein correlations, measure scales that are related to the geometrical size of the source. The two-particle azimuthal angular correlations measure the spatial anisotropy of produced particles, providing information on collective phenomena arising in the dense nuclear medium. This contribution will discuss new LHCb measurements of Bose-Einstein correlations

and, for the first time, the collective flow coefficients in the far forward rapidity region at LHC energy.

Day 2 - Morning / 9

Forward-backward correlations with the Σ quantity in the wounded-constituent framework at energies available at the CERN LHC

Author: Iwona Sputowska[None]

Corresponding Author: iwona.sputowska@cern.ch

Σ is a new correlation measure, quite recently introduced to heavy-ion physics. This measure, defined in the independent source model as a strongly intensive quantity, is expected to be free of the effects of system volume and volume fluctuations. In this talk, the forward-backward (FB) correlation quantified with the Σ observable calculated in the framework of the wounded nucleon model (WNM) and wounded quark model (WQM) will be discussed. Findings show that the wounded-constituent approach outperforms the commonly used heavy-ion Monte Carlo generators, such as HIJING, AMPT, or EPOS, by accurately describing the experimental data on FB correlations with Σ measured by the ALICE Collaboration in Xe-Xe reactions at √sNN = 5.44 TeV and in Pb-Pb collisions at √sNN = 2.76 and 5.02 TeV. This talk demonstrates that Σ can be a unique tool for determining the fragmentation function of a wounded constituent in a symmetric nucleus-nucleus collision. However, it is no longer a strongly intensive quantity in the wounded-constituent framework.

Day 2 - Morning / 5

Probing particle production and transport in small collision systems with ALICE

Author: Lucia Anna Tarasovicova[1]

[1] *PJ Safarik University (SK)*

Corresponding Author: lucia.anna.husova@cern.ch

Many recent measurements in small collision systems such as pp and p–-Pb collisions show signs of collective behavior of produced particles. The two-particle number and transverse momentum (differential) correlators and charged-particle balance function measurements in Pb–Pb collisions provided valuable information about the particle production mechanisms and their time evolution as well as about the transport properties of the created medium, such as the ratio of shear viscosity to entropy density. Thus, these correlation functions have a great potential to help disentangle the particle production mechanisms and the origin of the collective-like behavior in small collision systems.

In this talk, the two-particle correlation function and the charged-particle balance function will be presented in pp and p–Pb collisions at different energies. Their widths will be compared with the widths in Pb–Pb collisions showing the evolution of the correlation functions with the charged-particle multiplicity. The results are compared with different Monte Carlo models, such as PYTHIA, DPMJET and HIJING. Moreover, the first measurement of these correlation functions in pp collisions at 13.6 TeV, collected during Run 3, will be presented, where the large collected data set enables for a significant reduction of statistical uncertainties.

Day 2 - Afternoon / 35

Dineutron correlation in neutron drip-line nuclei

Author: Yuki Kubota[1]

[1] *RIKEN Nishina Center*

Corresponding Author: kubota@ribf.riken.jp

The dineutron is a hypothetical bound state of two neutrons in a nuclear medium and a spatially compact pair, different from the one realized by the BCS mechanism[1].The dineutron correlation is expected to appear in various circumstances, such as the surface of weakly bound neutron-rich systems and the inner crust of neutron stars. It has been studied using various approaches, such as the breakup reactions[2,3]. However, previous measurements were insufficient to discuss the magnitude of the dineutron correlation and its density dependence due to the sensitivity of the probe[4].
In the present study, it is found for the first time that the dineutron in the ^{11}Li nucleus is localized on the surface of the ^{11}Li nucleus. The use of the quasi-free (p, pn) reaction was essential to extract the radial information of the dineutron and to minimize the effect of the final state interactions[5]. The published results [6] and recent updates will be presented.

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Day 2 - Afternoon / 93

On the long-standing quest for the tetra-neutron system: a recent observation of four-neutron correlations and future perspectives

Author: Stefanos Paschalis[1]

[1] *University of York*

Corresponding Author: stefanos.paschalis@york.ac.uk

The search for chargeless nuclei consisting only of neutrons has been a long-lasting challenge in nuclear physics, dating more than six decades back (see Ref. [1] for a recent review). The tetraneutron, in particular, has attracted a lot of experimental and theoretical attention. Most models agree that nuclear forces cannot bind four neutrons together without destroying many of the other successful predictions for light nuclei. The theoretical models, however, struggle to provide reliable and consistent predictions regarding the possibility of four neutrons forming a resonance system. On the other hand, no solid experimental information on possible correlations between four neutrons was available until recently as experiments suffered from low statistics and/or large background. The possibility of the tetraneutron forming a resonance state is still an open and fascinating question, which can now be probed theoretically with state-of-the-art ab-initio calculations and studied experimentally by employing new techniques in the upgraded, high-intensity, radioactive-ion beam facilities. In this talk, I will present a brief overview of this long-standing quest and discuss some recent, high-quality results from a novel experiment that was performed at the SAMURAI setup in RIKEN, Japan. This experiment probes the correlation energy between the four remaining neutrons after the quasi-elastic removal of alpha cluster from 8He projectiles and has provided for the first time a notably clean experimental signature. The results have been recently published in Nature [2]. The quest now continues with renewed interest as theoretical models attempt to reproduce the

experimental result and new experiments aim to confirm and refine the measurement; hence, this talk will conclude with a brief discussion of these new perspectives.

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Day 2 - Afternoon / 63

Perspectives on neutron detection and multi-neutron correlations measurements at FRIB

Author: Aldric Revel[1]

[1] *FRIB/Michigan State University*

Corresponding Author: revel@frib.msu.edu

Pairing interactions play crucial roles in atomic nuclei and quantum many- body physics in general. In finite nuclei, two-neutron and/or two-proton pairing are responsible for the odd-even staggering observed in the binding energy of atomic masses and for the fact that all even nuclei have a J = 0+ ground state. Pairing correlations also imply a smoothing of the level occupancy around the Fermi energy surface, an enhancement of pair transfer probabilities, as well as a superfluid behavior in nuclear rotation and vibration.
Recently, the formation of tetra-neutron resonances, either from an ensem- ble of four interacting neutrons or from the coupling of four neutrons inside atomic nuclei were proposed on the basis of experimental results. If confirmed, tetra-neutron excitations would require a higher range of (four-body) nucleon interactions, with expected important consequences in the description of finite nuclei, of nuclear matter and in the determination of neutron captures in the Big Bang and in neutron-star mergers. Despite of its tremendous importance, the real observation of the decay of paired or tetra nucleons is still lacking or very scarce as difficult to evidence. By generalizing the Ikeda conjecture, initially proposed to account for the presence of α cluster states close to α emis- sion thresholds, such two- or four-nucleon resonances would similarly appear at energies close to the corresponding emission thresholds.
I will present recent results on the study of n-n correlations in light neutron- rich nuclei in order to illustrate the technique used and its challenges. Then I will present perspectives on future plans to conduct such experiments aiming to investigate multi-neutron correlations at FRIB.

Day 2 - Afternoon / 3

NArCoS: a new correlator for neutrons and charged particles with high angular and energy resolution

Author: Emanuele Vincenzo Pagano[1]

Co-authors: Andrea Castoldi [1]; Angelo Pagano [1]; Brunilde Gnoffo [2]; Chiara Guazzoni [1]; Ciro Boiano [1]; Concettina Maiolino [1]; Cristina Zagami [1]; Elena Irene Geraci [1]; Enrico De Filippo [1]; Fabio Risitano [1]; Francesca Rizzo [1]; Francesco Noto [1]; Gaetano Lanzalone [1]; Gianluca Santagati [1]; Giuseppe Cardella [1]; Giuseppe Politi [1]; Marina Trimarchi [2]; Nunzia Simona Martorana [1]; Paolo Russotto [1]; Sara Pirrone [1]

[1] *Istituto Nazionale di Fisica Nucleare*

[2] *CT*

Corresponding Author: epagano@lns.infn.it

The advent of new facilities for radioactive ion beams mainly rich in neutrons, SPES @ LNL, FRAISE @ LNS and FAIR @ GSI only to give some examples, imposes the joint detection and discrimination of neutrons and charged particles in heavy radioactive ion collisions, with high angular and energy resolutions. The construction of novel detection systems suitable for this experimental task is both a scientific and a technological challenge.
The contribution will illustrate the results of recent tests performed on a new plastic scintillator material, the EJ276, both in the "green-shifted" and in the base version, coupled with PMTs and SiPMs. The talk will focused ok the preparatory work (on both the experimental and the simulation side) done in order to tailor the setup for the CROSSTEST experiment scheduled for the end of this year at LNL. This experimental activity pave the way for the construction of a workhorse of a novel detector for neutrons and charged particles featuring high energy and angular resolution, based on a 3D cluster of scintillation units. This project is funded by the Italian Project PRIN ANCHISE (2020H8YFRE)

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Geant4 simulations to study the efficiency and the cross-talk probability in the new neutron correlator NArCoS

Authors: Gianluca Santagati[1]; Emanuele Vincenzo Pagano[2]

Co-authors: Ciro Boiano [3]; Giuseppe Cardella [1]; Andrea Castoldi [4]; Enrico De Filippo [1]; Elena Irene Geraci [5]; Brunilde Gnoffo [6]; Chiara Guazzoni [7]; Gaetano Lanzalone [8]; Concettina Maiolino [2]; Nunzia Simona Martorana [1]; Angelo Pagano [1]; Sara Pirrone [1]; Giuseppe Politi [5]; Fabio Risitano [9]; Francesca Rizzo [10]; Paolo Russotto [2]; Marina Trimarchi [11]; Cristina Zagami [10]

[1] *Istituto Nazionale di Fisica Nucleare CT*

[2] *Istituto Nazionale di Fisica Nucleare LNS*

[3] *Istituto Nazionale di Fisica Nucleare MI*

[4] *Politecnico di Milano, Dipartimento Elettronica, Informazione e Bioingegneria, Istituto Nazionale di Fisica Nucleare MI*

[5] *Istituto Nazionale di Fisica Nucleare CT, Università di Catania, Dipartimento di Fisica e Astronomia*

[6] *Istituo Nazionale di Fisica Nucleare, Università di Catania, Dipartimento di Fisica e Astronomia*

[7] *Politecnico di Milano Dipartimento Elettronica, Informazione e Bioingegneria, Istituto Nazionale di Fisica Nucleare MI*

[8] *Istituto Nazionale di Fisica Nucleare LNS, Università di Enna "Kore"*

[9] *Istituto Nazionale di Fisica Nucleare CT, Università di Catania, Università di Messina, Dipartimento di Scienze MIFT*

[10] *Istituto Nazionale di Fisica Nucleare LNS, Università di Catania, Dipartimento di Fisica e Astronomia, CSFNSM-Centro Siciliano di Fisica Nucleare e Struttura della Materia*

[11] *Istituto Nazionale di Fisica Nucleare CT, Univerità di Messina Dipartimento di Scienze MIFT*

Corresponding Author: gianluca.santagati@ct.infn.it

The detection of neutrons and light-charged particles represents a crucial aspect in the future experiments with radioactive beams, provided by new heavy ion facilities, such as FRAISE at LNS, SPES at LNL, and FAIR at GSI.
The aim of the ANCHISE project is the development of a new detection system able to detect with high angular and energy resolution neutrons and light-charged particles at the same time. The idea is to use the new-generation of plastic scintillators EJ276-G coupled with a SiPM photosensor as the elementary detection cell of a segmented multidetector.
In the present contribution, we simulated two geometrical configurations of the elementary cell with the GEANT4 toolkit, in order to study the detection efficiency and the cross-talk probability as a function of the incident neutron energy and of the detection threshold. The results supports the idea of the construction of NArCos, the novel neutron correlator for application in fundamental nuclear and applied physics.

Day 2 - Afternoon / 56

Matter - antimatter interactions

Author: Malgorzata Janik[1]

[1] *Warsaw University of Technology*

Corresponding Author: majanik@cern.ch

Hadron physics faces several challenges nowadays. On the one hand the field moves towards the search of exotic states beyond the predictions of the quark model, while on the other the detailed knowledge of the effective interaction among hadrons is still an open issue. The nature of the strong interaction between particles is also a fundamental problem in various areas of nuclear physics and astrophysics. Of particular interest is probing the matter-antimatter interaction at low relative momentum, which could determine whether a given baryon pair forms
a bound state (referred to as baryonia).

This talk aims at cross-experimental review of the matter-antimatter interaction measurements, with a focus on the results obtained with correlation techniques.

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Charged kaon and pion femtoscopy in the RHIC Beam Energy Scan at the STAR experimen

Author: Yevheniia Khyzhniak[1]

[1] *Ohio State University*

Corresponding Author: eugenia.sh.el@gmail.com

The RHIC Beam Energy Scan (BES) program aims to study the properties of strongly interacting matter in relativistic heavy-ion collisions at various energy densities and temperatures. Correlation femtoscopy technique is a useful tool to study systems undergoing QCD phase transitions, and can extract valuable information about the size, shape, and lifetime of the particle-emitting source in heavy-ion collisions.

This study presents the first comprehensive femtoscopic analysis of identical kaons and pions produced in Au+Au collisions at $\sqrt{s_{NN}}$ = 14.6 - 200 GeV from the RHIC Beam Energy Scan phases I and II, focusing on charge, transverse momentum, and centrality-dependent properties. The charge-dependent analysis reveals differences at the level of correlation functions for both kaons and pions for the first time at these energies. This observation is consistent with Coulomb field effect due to residual charge after the collision and hadronic final state effects, as implemented in UrQMD. The three-dimensional femtoscopic analysis reveals that the extracted radii, assuming Gaussian distribution for emission source, increase with collision energy, decrease with transverse mass, and are generally larger for kaons compared to pions under the same conditions. The study compares experimental data with UrQMD and discusses the implications of the trend of the extracted size and lifetime of the particle source with the change of collision energy.

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Hidden puzzle of the correlation femtoscopy at the top RHIC and LHC energies and its possible solution

Author: Yuri Sinyukov[None]

Corresponding Author: yu.sinyukov@gmail.com

We considered the two puzzle femtoscopic observations in ultrarelativistic heavy ion collisions. The first one is closeness of the observed maximal emission times of pions at the quite different collision energies: from top RHIC to top LHC energies. Another paradoxical effect is that despite the long enough duration of the post-hydro- dynamic/afterburner cascade stage, the observed times of the maximal emission are close to the particlization times. The detail analysis of the peculiarities of the system hydrodynamic evolutions at different energies of colliding nuclei and structure of the pion and kaon emission function at the afterburner stage shad light on these paradoxid results.

Day 2 - Afternoon / 31

Non-equilibrium effects and spherocity in relativistic proton-nucleus collisions

Authors: Elena Bratkovskaya[1]; Lucia Oliva[2]; Pierre Moreau[3]; Steffen Bass[3]; Wenkai Fan[3]

[1] *GSI, Darmstadt & Frankfurt Uni.*

[2] *Istituto Nazionale di Fisica Nucleare*

[3] *Duke University*

Corresponding Author: lucia.oliva@dfa.unict.it

The experimental observations of quark-gluon plasma signals in proton-proton and proton-nucleus collisions at RHIC and LHC energies has attracted a big interest in these small systems due to the possible formation of short-lived droplets of this deconfined state of strongly interacting matter. We study the effects of nonequilibrium dynamics in relativistic proton-nucleus collisions by comparing a microscopic nonequilibrium transport approach, the Parton-Hadron-String-Dynamics (PHSD), with a macroscopic 2D+1 viscous hydrodynamical model, VISHNew. We analyse the medium evolution and properties through quantities like the energy density and the viscous corrections as well as by applying the event-shape engineering through the transverse spherocity. This observable is capable of classifying different final-state event topologies and may help to investigate particle production as well as collective flows in small systems.

Day 2 - Afternoon / 44

Probing the dynamical evolution of QGP using charge-dependent correlations and fluctuations at CMS

Author: Sayan Chatterjee[1]

[1] *Indian Institute of Technology, Madras*

Corresponding Author: sayan.chatterjee@cern.ch

We present the first studies of net-charge fluctuations and charge-balance functions using the broad rapidity coverage of the CMS experiment. These types of event-by-event fluctuations are a powerful tool to characterize the thermodynamic properties of the quark-gluon plasma (QGP). The net-charge of the system is a conserved quantity, meaning its fluctuations are sensitive to the QGP formation and phase transition. It therefore provides an understanding of strong interactions complementary to that from the charge balance function. Relative to past measurements which probed a limited phase space region, we extract fluctuations up to a pseudorapidity separation of $\Delta\eta$ = 4.8, and as such, significantly improving the sensitivity to test what has been theoretically predicted for the QGP formation. In turn, the width of the balance function, both in relative $|\eta|$ and relative azimuthal angle, is found to decrease with multiplicity for low particle transverse momentum ($p_{\mathrm{T}} < 2$ GeV /c). The effect is observed for both collision systems, and it is consistent with a late hadronization

scenario, where particles are produced at a later stage during the system evolution. The multiplicity dependence is weaker for higher p_{T}, which signifies that the balancing charge partners are strongly correlated compared to the low-p_{T} region. Model comparisons cannot reproduce the multiplicity dependence of the width in $\Delta\eta$. However, a model which incorporates collective effects can reproduce the narrowing of the width.

Day 2 - Afternoon / 17

Flow correlations and flow-transverse momentum correlations at ALICE

Author: Mingrui Zhao[1]

[1] *China Institute of Atomic Energy*

Corresponding Author: mingrui.zhao@cern.ch

In the past years, evidence of anisotropic flow has been observed in small collision systems at the LHC; however, its precise origin remains unknown.
In this talk, we will present the measurements of correlations between different flow harmonics in pp and Pb–Pb collisions.
The measurement of the correlation between the mean transverse momentum and flow coefficients, $\rho(v_n^2, [p_{\mathrm{T}}])$, in pp, p–Pb, and Pb–Pb collisions will also be discussed.
The correlations between different flow harmonics coefficients provide tight constraints on the fluctuating initial geometry and allow us to explore how anisotropic flow develops from the initial geometry through the dynamic evolution in the small collision systems.
The correlations between flow harmonics and transverse momentum provide information on the correlation between the shape and size of the created QCD matter in collisions.

Day 3 - Morning / 75

Investigating clustering in 12C using gamma-beams and a TPC detector

Author: Robin Smith[1]

[1] *Sheffield Hallam University*

Corresponding Author: robin.smith@shu.ac.uk

Alpha particle clustering is thought to be widespread throughout the nuclear chart, and light nuclei provide an ideal testing ground for state-of-the-art theoretical calculations, such as the Algebraic Cluster Model (ACM) [1]. The predicted 2+ rotational excitation of the Hoyle State was first unambiguously measured using gamma beams and an Optical TPC detector [2]. To explore further rotational states built on the Hoyle state in carbon-12, a similar experiment was performed using the HIγS gamma-beam facility at Duke University in 2022. Gamma beams from 8.6 to 13.9 MeV were incident on a CO2 active target contained within a new electronic TPC, built by the university of Warsaw [3]. By examining the photo-dissociation of 12C through an intermediate state in 8Be, 12C(α,γ)8Be, we search for new states predicted by the ACM.
Three-alpha-particle events, corresponding to 12C photodissociation, form a fraction of all measured events. This presents a significant data analysis challenge, since typical experimental signatures, such as total charge deposition and track lengths, strongly overlap with those of competing reaction channels, e.g. 16O(α,γ)12C. This paper discusses the use of convolutional neural networks for event classification –ResNet-18/ResNet-50 [4] and ResNeXt [5] –alongside more traditional data analysis techniques. The performance of these neural networks is discussed and preliminary results such as angular distributions and Dalitz plots are presented.
[1]

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Day 3 - Morning / 26

Proton-proton correlations in ground-state two-proton radioactivity

Author: Chiara Mazzocchi[1]

[1] *University of Warsaw*

Corresponding Author: chiara.mazzocchi@fuw.edu.pl

Away from the beta-stability valley, when nuclei become unbound towards emission of two protons ($2p$), ground-state $2p$ radioactivity becomes possible and is a characterising decay mode for even-Z elements beyond the $2p$ drip-line. It is this a very exotic decay mode, so far observed experimentally only for a handful of cases, for light and medium-mass isotopes with $Z \leq 36$ [1,2]. Simultaneous emission of $2p$ from nuclear ground states is indeed predicted to be observable for every even-Z element with $Z \leq 52$, i.e. up to tellurium isotopes. Beyond tellurium, sequential emission of the $2p$ is expected to dominate the decay of $2p$-unbound nuclei, rather than simultaneous.

In recent years, so-called discovery experiments, which identify new $2p$ emitting isotopes, have been complemented by precision studies to probe nuclear structure from $2p$-decay observables. In particular, momentum correlations between the two protons emitted are expected to bring a deeper insight into the initial wave function composition [1].
Several experimental and theoretical efforts are ongoing to shed light on the $Z = 28$ shell closure by looking at $p - p$ correlations in the three "classical" cases ^{45}Fe, ^{48}Ni, and ^{54}Zn.
In this contribution, an overview will be provided of the current status of this research.

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Day 3 - Morning / 46

Three-body resonances and two-nucleon decays

Author: Jesús Casal[1]

[1] *University of Seville*

Corresponding Author: jcasal@us.es

Nuclei that present a three-body character have attracted particular interest over the past few decades. Of particular relevance is the case of two-neutron halo nuclei, e.g., ^{6}He, ^{11}Li or ^{14}Be, which exhibit exotic features in nuclear collisions. These are Borromean systems, or three-body systems in which all binary subsystems cannot form bound states. The correlations between the valence neutrons, often described in terms of pairing, are known to play a fundamental role in shaping the properties of these systems [2,3]. The evolution of these correlations beyond the driplines gives rise to two-neutron emitters, e.g., ^{13}Li, ^{16}Be or ^{26}O [4]. A similar situation can be found for proton-rich nuclei. For instance, the Borromean ^{17}Ne nucleus has been proposed to exhibit a two-proton halo, while other exotic systems, such as ^{6}Be and ^{11}O, are two-proton emitters [5]. Since they have a marked core+N+N character, three-body models are a natural choice to describe their structure and processes involving them [6]. The description of the continuum in three-body nuclei, however, is not an easy task. In Ref. [7] we proposed a method to characterize few-body resonances by studying the time dependence of the lowest eigenstates of a resonant operator, with the aim of studying the population of resonances of two-nucleon emitters. The method was applied to ^{16}Be, obtaining a remarkable agreement with calculations of the actual three-body continuum [8] for the 0^+ ground-state resonance, and predicting an excited 2^+ resonance. A summary of this work will be presented, and the calculation of the corresponding relative-energy distributions in the decay dynamics will be shown [9]. Results will be compared with recent experimental observations [10], with focus on the initial-state neutron-neutron correlations.

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Day 3 - Morning / **19**

Timing the hadronic rescattering phase with non-identical particle femtoscopy

Author: Adam Kisiel[1]

[1] *Warsaw University of Technology*

Corresponding Author: adam.kisiel@pw.edu.pl

Femtoscopy is traditionally used to determine the size of the particle emitting region in heavy-ion collisions. The non-identical particle femtoscopy is additionally able to measure the difference in average emission points (so-called emission asymmetry) between two types of particles. This asymmetry is sensitive to details of the dynamics of the system created in the collision, and depends on the interplay of collective flow, thermal velocity and details of hadronic resonance production, propagation and decay. The sensitivity of the technique to those phenomena will be presented.

In particular the correlations between charged pions and kaons have been measured recently by ALICE. The emission asymmetry in this case is influenced by the their mutual interaction via the K* resonance, which has a lifetime comparable to the duration of the hadronic rescattering phase. We will show how non-identical femtoscopy for pion-kaon pairs can be used to directly estimate the duration of this phase, in a way that is independent and complementary to other methods of accessing this observable, such as measuring the yields of hadronic resonances. We will discuss the interpretation of the ALICE results via comparison of data to predictions from models with varying approach to modelling the hadronic rescattering phase.

Day 3 - Morning / **22**

First measurement of properties of strong interaction between (anti-)deuterons and charged kaons in Pb–Pb collisions with ALICE

Author: Wioleta Rzęsa[1]

[1] *Warsaw University of Technology*

Corresponding Author: wioleta.rzesa@cern.ch

The interaction between charged kaons and (anti-)deuterons has been a missing piece of information in the field of the low-energy (anti-)kaon-nucleon interactions for more than 40 years. So far, the only experimental studies of the strong interaction have come from scattering experiments that provided the scattering cross sections at intermediate momenta. Specific information on the strong interaction can be accessed also via kaonic deuterium X-ray spectroscopy but such measurements are challenging due to the available detection efficiency. Moreover, the theoretical description of the strong interaction of the system is also not well understood. Therefore, predictions of f_0 value for $\mathrm{K^-d}$ have been made based on an input from kaonic hydrogen measurements, while there are no published predictions for $\mathrm{K^+d}$.

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

Day 3 - Morning / 42

Precise physics of atomic species utilizing antimatter

Author: Tomasz Sowinski[1]

[1] *Institute of Physics, Polish Academy of Sciences*

Corresponding Author: tomsow@ifpan.edu.pl

Several high-precision experiments at the Antiproton Decelerator complex at CERN aim to look for any significant differences between matter and antimatter. One of these experiments is AEgIS, whose primary goal is to test the weak equivalence principle for antimatter by measuring (with atomic accuracy) the free fall of a neutral antihydrogen atom in the Earth's gravitational field. It turns out that the experimental setup and techniques developed at AEgIS, when expanded appropriately, probably can be used to produce on-demand complex bound states of matter and antimatter, and then to study their spectroscopic properties. One such natural direction is the possibility of producing neutral antiprotonic atoms, i.e., atoms in which one of the electrons is substituted by almost 2,000 times heavier antiproton. Taking medium-heavy odd-A antiprotonic atoms as an example, during my talk I will present how this research can contribute to a better understanding of the bound states of matter and antimatter, as well as the internal structure of atomic nuclei, and how it could potentially become yet another opportunity in precise testing of fundamental theories.

Day 3 - Morning / 68

Constraining the light (anti)nuclei production in and out of jets in small systems with ALICE

Author: Marika Rasà[1]

[1] *Istituto Nazionale di Fisica Nucleare*

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

The production mechanism of light (anti)nuclei in hadronic collisions, despite the several experimental results from low collision energies at the AGS and GSI to high energies at RHIC and at the LHC, is still mysterious and under intense debate in the scientific community. The experimental measurements can be described by two competing phenomenological models, the statistical hadronization model and the baryon coalescence. In the latter, the nuclei are formed if, at the kinetic freeze out, the constituent nucleons are close in the phase space and the sum of their spins is compatible with that of the bound system. The advanced implementation of the coalescence model uses the Wigner formalism and femtoscopy measurements to constrain the nucleon emitting source size. A testing ground for the coalescence model is the study of the light (anti)nuclei production in small systems in and out of jets, that are collimated sprays of strongly correlated particles. In fact, due to the close vicinity of nucleons inside the jet cone, the antinuclei formation probability is expected to be enhanced with respect to the production probability in the underlying event.

In this contribution, the results on the coalescence parameter for (anti)deuterons in and out of jets in pp an p-Pb collisions will be presented. These measurements are compared with the available prediction from the coalescence model and a reaction-based production mechanism. In addition, the prospects for light (anti)nuclei measurements in jets and underlying event during the Run 3 will be discussed.

Day 3 - Morning / 34

Correlations between anisotropy flow and mean transverse momentum using subevent cumulants in small systems at CMS

Author: Rohit Kumar Singh[1]

[1] *Indian Institute of Technology Madras*

Corresponding Author: rohit.kumar.singh@cern.ch

Measurements at the LHC have provided evidence for collective behavior in high-multiplicity proton-proton (pp) and proton-lead (pPb) collisions through multiparticle correlation techniques. To investigate detailed properties of this collectivity, a comprehensive study of differential Fourier coefficients (v_n) in particle transverse momentum (p_T) and event multiplicity is presented in proton-lead (pPb) collisions recorded by the CMS experiment at a nucleon-nucleon center-of-mass energy $\sqrt{s_\mathrm{NN}} = 8.16$ TeV. In particular, new measurements of p_T-differential multiparticle cumulants using the subevent cumulant method in distinct subevent regions are presented. Relative to past CMS measurements, the new study probes an extended phase space region up to a high particle p_T, putting the observation of a nonzero high-p_T v_2 in a small-sized medium into stringent tests. In addition, correlations between multiparticle cumulants and the mean transverse momentum ($[p_\mathrm{T}]$) in pp and pPb, and peripheral lead-lead collisions recorded by the CMS experiment at different $\sqrt{s_\mathrm{NN}}$ are presented as a function of charged particle multiplicity. Predictions based on color-glass condensate and hydrodynamic models are compared to the experimental $[p_\mathrm{T}]$ results.

Day 3 - Morning / 92

Evaluation of the thermal photon radiation from a recent solution of relativistic hydrodynamics

Author: Gábor Kasza[1]

[1] *Wigner RCP & MATE KRC*

Corresponding Author: kaszagabor.24@gmail.com

Recently, we have found a new and finite, exact family of solutions of 1+1 dimensional relativistic hydrodynamics with accelerating velocity field. After reviewing some earlier application, I present a new analytic formula derived from the mentioned family of solutions that describes the thermal

photon radiation in high energy heavy ion collisions. I compared this new formula to the most recent nonprompt spectrum of direct photons for Au+Au@200 GeV collisions.

Day 3 - Afternoon / 70

Study of exotic f_0 and f_1 states with ALICE

Author: Francesca Bellini[1]

[1] *Istituto Nazionale di Fisica Nucleare*

Corresponding Author: francesca.bellini@bo.infn.it

Despite most of the known observed hadrons fit into the quark model picture formulated back in the 1960s', there exist several resonances whose properties suggest an exotic structure. In particular, the nature of f_0(980), f_1(1285), and f_0(1710) states is still debated, as these have been proposed as ordinary two-quark states, compact tetraquarks, hadronic molecules, hybrid states or glueballs. Building on observables well known in the heavy-ion physics field, the nuclear modification factors in A−A and p−A collisions relative to pp collisions, as well as the elliptic flow coefficient, have been proposed as tools to investigate their internal structure.
In this contribution, the results on the production of f_0(980) and f_1(1285) states from the ALICE experiment at the LHC will be reviewed. These include the measurement of the production of f_0(980) in pp and p−Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV as well as the first measurement of $f_1(1285)$ production in pp collisions at $\sqrt{s} = 13$ TeV. Results will be presented in comparison to models and in light of their sensitivity to the internal structure of these exotic states. Perspectives for measurements of f_0(1710) will be discussed, motivated by the search for glueball states.

Day 3 - Afternoon / 55

Resonance production in the STAR experiment

Author: Mohammad Nasim[1]

[1] *Indian Institute of Science Education and Research, Berhampur (IISER Berhampur)*

Corresponding Author: nasim@iiserbpr.ac.in

Relativistic heavy ion collisions provide a unique opportunity for investigating nuclear matter's characteristics under extreme conditions of high temperature and density. Resonance particles, such as K∗0 and φ, are considered good tools for probing the medium generated during these collisions. Specifically,K∗0, with a relatively short lifetime of approximately 4 fm/c, undergoes decay within the fireball, allowing its decay products to interact with the surrounding medium. Consequently, the properties of the measured K∗0 can be altered by these in-medium interactions. In contrast, due to its significantly longer lifetime of approximately 42 fm/c, the φ meson primarily decays outside the fireball, allowing its decay daughters only limited time for rescattering in the hadronic phase. Thus, comparing the behavior of K∗0 and φ mesons in this context is of significant interest. Additionally, the φ meson is regarded as a pristine probe of partonic collectivity, given its anticipated minimal hadronic interaction cross-section. In the forthcoming presentation, we will present the invariant yield of K∗0 and φ as a function of beam energy (ranging from √sNN = 7.7 GeV to 200 GeV), as measured by the STAR experiment. We will also depict the ratips of resonance to non-resonance particles (φ/K and K∗0/K) as a function of collision centrality at various beam energies. Furthermore, we will present the anisotropic flow (v1 and v2) of φ mesons, across different beam energies.

Day 3 - Afternoon / 90

In-medium effects in φ meson production in heavy-ion collisions from subthreshold to relativistic energies

Author: Elena Bratkovskaya[1]

[1] *GSI, Darmstadt & Frankfurt Uni.*

Corresponding Author: e.bratkovskaya@gsi.de

We investigate the hidden strange ϕ meson production in heavy-ion collisions from subthreshold ($E_{kin} \sim 1$ A GeV) to relativistic ($E_{kin} \sim 21$ A TeV) energies as well as its coupling to the open strange mesons (kaons, antikaons) and their productions.
Our study is based on the off-shell microscopic Parton-Hadron-String Dynamics (PHSD) transport approach which is applicable for the dynamical description of strongly interacting hadronic and partonic degrees-of-freedom created in heavy-ion collisions.
Implementing novel meson-baryon and meson-hyperon production channels for ϕ mesons, calculated within a T-matrix coupled channel approach based on the extended SU(6) chiral effective Lagrangian model, along with the collisional broadening of the ϕ-meson in-medium spectral function, we find a substantial enhancement of ϕ meson production in heavy-ion collisions, especially at sub- and near-thresholds. This allows to describe the experimentally observed strong enhancement of the ϕ/K^- ratio at low energies without including hypothetical decays of heavy baryonic resonances to ϕ as in alternative approaches. Moreover, we show that in spite of a stronger contribution from enhanced ϕ to K^- production, the majority of the experimental data for different A+A systems at low energies favour the scenario with in-medium modifications of the kaon and antikaon properties in the hot and dense environment. Moreover, we study the influence of the final state interactions of $K, \bar{K}$ mesons on the reconstruction of ϕ's by the by invariant mass method.

Day 3 - Afternoon / 84

LHCb on technical aspects how to search and find resonances, also using AI techniques.

Author: Paolo Gandini[1]

[1] *Istituto Nazionale di Fisica Nucleare*

Corresponding Author: paolo.gandini@mi.infn.it

I will describe how to look for resonances at the LHCb experiment at CERN. Searches usually involve small signal yields, therefore careful and advanced techniques are required to reject the huge background coming from the hadronic collisions.

Day 3 - Afternoon / 45

Measurement of azimuthal anisotropy of the $\mathrm{f}_0(980)$ and D^0 mesons in heavy ion collisions at CMS

Author: Nihar Ranjan Saha[1]

[1] *Indian Institute of Technology, Madras (IN)*

Corresponding Author: nihar.ranjan.saha@cern.ch

We present novel insights into the elusive $\mathrm{f}_0(980)$ hadron's quark composition and the interaction of heavy charm quarks with the quark-gluon plasma (QGP) through the anisotropic flow measurement of D^0 in Heavy-Ion collisions. The $\mathrm{f}_0(980)$, whose precise configuration has remained controversial,

is reconstructed for the first time via its dominant decay channel, $f_0(980) \rightarrow \pi^+\pi^-$, using data from proton-lead collisions at 8.16 TeV, as collected by the CMS experiment. The azimuthal angle anisotropy v_2 of $f_0(980)$ relative to the event plane is also investigated, allowing us to extract the v_2 parameter for the $f_0(980)$ and compare it with other hadrons. In addition, we also investigate how heavy quarks interact with QGP by measuring the coefficients of azimuthal anisotropy (v_n) of D^0 mesons in lead-lead collisions at 5.02 TeV with CMS experiment. The measurements cover a wide range of transverse momentum and thus reveal the flow formation mechanisms of heavy charm quarks, illuminating the diffusion and path-dependent parton energy loss.

Day 4 - Morning / 10

Resonance production with EPOS4 and the role of collectivity in elementary collisions

Author: Klaus Werner[1]

[1] *Subatech*

Corresponding Author: werner@subatech.in2p3.fr

EPOS4 is a (recently released) multipurpose event generator for simulating high energy proton-proton and nucleus-nucleus collisions, which allows to treat within the same formalism very high pt processes and also low-pt phenomena. We will first present the basic ideas, including the question of collectivity in small systems, and then discuss in particular applications concerning resonance production.

Day 4 - Morning / 64

Experimental highlights on collectivity in small collision systems

Author: Alberto Calivà[1]

[1] *University of Salerno*

Corresponding Author: alberto.caliva@cern.ch

Measurements of azimuthal flow and multi-particle correlations in heavy-ion collisions are typically attributed to a collective expansion of the system created in these collisions that is driven by relativistic hydrodynamics. Surprisingly, similar measurements in small collision systems, such as pp and p–Pb collisions, show striking similarities to the corresponding measurements in heavy-ion collisions. However alternative explanations based on initial state dynamics are able to describe many characteristic features of these measurements. In this contribution, a review of recent experimental highlights on collectivity effects observed in small systems will be presented. These results will be discussed in the context of existing phenomenological models.

Day 4 - Morning / 51

Sources of multiparticle correlations –a microscopic perspective

Author: Christian Bierlich[1]

[1] *Lund University*

Corresponding Author: christian.bierlich@hep.lu.se

The emergence of collective phenomena in small systems, proton-proton and proton-ion collisions, have over the past decade been a puzzle with many attempts at a solution. On one hand, it is unclear that a Quark-Gluon Plasma would be able to form in such small volumes, and if it can, it would question a lot of what we know about pp phenomenology. On the other hand, a microscopic description valid in pp, without assuming a QGP, could also be valid in AA, and question the paradigm of QGP formation.

In this talk I will present attempts going the latter route. The PYTHIA models of interacting strings have proven fairly successful to describe collectivity in small systems, and I will discuss ongoing attempts to use the models for large collision systems as well.

Day 4 - Morning / 11

Investigating collective effects in small collision systems using PYTHIA8 and EPOS4 simulations

Author: Alexandru Manea[1]

Co-authors: Alexandru Florin Dobrin [1]; Andrea Danu [1]; Catalina Diana Brandibur [1]

[1] *Institute of Space Science*

Corresponding Author: alexandru.manea@cern.ch

Studies have yielded strong evidence that a deconfined state of quarks and gluons, the quark–gluon plasma, is created in heavy-ion collisions. This hot and dense matter exhibits almost zero friction and a strong collective behaviour. An unexpected collective behaviour has also been observed in small collision systems. In this talk, the origin of collectivity in small collision systems is addressed by confronting PYTHIA8 and EPOS4 models using measurements of azimuthal correlations for inclusive and identified particles. In particular, anisotropic flow coefficients measured using two- and four-particle correlations with various pseudorapidity gaps, per-trigger yields, and balance functions are reported in pp collisions at $\sqrt{s} = 13.6$ TeV and p–Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV. The results are compared with the available experimental data.

Day 4 - Morning / 65

Searching for the X17 with the PADME experiment

Author: Fabio Ferrarotto[1]

[1] *Istituto Nazionale di Fisica Nucleare*

Corresponding Author: fabio.ferrarotto@roma1.infn.it

Certain classes of dark matter theory predict the existence of a new, hidden "Dark Sector"of particles which interact with Standard Model particles only through the exchange of a new, massive mediator particle. This is the scenario that the Positron Annihilation into Dark Matter Experiment (PADME) was originally designed to test, using the positron beam at the Beam Test Facility (BTF) at the INFN Laboratori Nazionali di Frascati (LNF) [1,2].
The 2021 confirmation of the X17 anomaly, observed in internal pair creation nuclear decays at the ATOMKI institute in Debrecen, Hungary, kindled significant interest in this anomaly within the particle physics community [3]. Assuming that the anomaly comes from the decay of a new particle

to an e^+ e^- pair, time-reversal symmetry means that the new particle must be producible in e^+ e^-annihilation. Since the beam used at PADME is the only positron beam in the world with the correct energy to create this new particle on resonance, the PADME collaboration pivoted to study the X17 anomaly in the reaction e^+ e^-⟶X17⟶e^+ e^-, aiming to confirm/disprove the particle hypothesis [4].
In 2022, PADME Run 3 was dedicated specifically to this search. Approximately 1010 positrons on target were collected for each of the 47 beam energy values in the range 262 - 298 MeV.
This talk will give an overview of the scientific program of the experiment and of the data analyses ongoing.

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Day 4 - Morning / 96

Possibilities for phase and source function reconstruction in HBT correlations and in elastic proton-proton scattering

Author: Tamas Csorgo[1]

[1] *Wigner RCP Budapest and MATE IoT KRC, Gyongyos, Hungary*

Corresponding Author: tcsorgo@cern.ch

I will discuss novel possibilities for particle holography, allowing for a phase reconstruction from experimental data in elementary particle and nuclear physics. Two examples will beconsidered, one is elastic proton-proton and proton-nucleus scattering, the other is Bose-Einstein or HBT correlations in high energy heavy ion physics.

Day 4 - Morning / 77

Dielectron measurements with ALICE

Author: Harald Appelshäuser[1]

[1] *University Frankfurt*

Corresponding Author: appels@ikf.uni-frankfurt.de

Dielectrons are unique observables in ultra-relativistic heavy-ion collisions. Thanks to their penetrating nature, they carry information from all stages of the collision and can provide knowledge about pre-equilibirium dynamics, QGP temperature and transport coefficients, and chiral symmetry restauration. On the other hand, experimental challenges are enormous because production cross sections are small and the signal of interest is eclipsed by a huge combinatorial and physics background from light- and heavy-flavour hadron decays. In this talk the status of dielectron measurements with ALICE is shown and the perspectives with the recently installed ALICE detector upgrades are discussed.

Welcome address by the Director of the INFN Sezione di Catania, Prof. a. Tricomi

Day 4 - Afternoon / 23

Two-particle Bose-Einstein correlations and their Lévy parameters in PbPb collisions at 5.02 TeV

Author: Mate Csanad[1]

[1] *Eotvos Lorand University (ELTE)*

Corresponding Author: csanad@elte.hu

Two-particle Bose-Einstein momentum correlation functions are studied for charged-hadron pairs in lead-lead collisions at a center-of-mass energy per nucleon pair of $\sqrt{s_{NN}} = 5.02$ TeV. The data sample, containing 4.27×10^9 minimum bias events corresponding to an integrated luminosity of 0.607 nb^{-1}, was collected by the CMS experiment in 2018. The experimental results are discussed in terms of a Lévy-type source distribution. The parameters of this distribution are extracted as functions of particle pair average transverse mass and collision centrality. These parameters include the Lévy index or shape parameter (α), the Lévy scale parameter (R), and the correlation strength parameter (λ). The source shape, characterized by α, is found to be neither Cauchy nor Gaussian, implying the need for a full Lévy analysis. Similarly to what was previously found for systems characterized by Gaussian source radii, a hydrodynamical scaling is observed for the Lévy R parameter. The λ parameter is studied in terms of the core-halo model.

Day 4 - Afternoon / 62

Femtoscopy with Lévy sources at NA61/SHINE

Author: Barnabas Porfy[1]

[1] *Eotvos University, Wigner RCP*

Corresponding Author: barnabas.porfy@cern.ch

One of the most important goals of NA61/SHINE is to investigate and
understand the phase structures of hadronic matter. The investigation of the phase-diagram can be achieved by varying the beam momentum (13A-150(8)A GeV/c) and by changing the collision system (p+p, p+Pb, Be+Be, Ar+Sc, Xe+La, Pb+Pb). This method enables to perform a two-dimensional scan of the phase diagram of QCD. Investigating femtoscopic correlations are related to the critical exponent η, describing the spatial coordinates. The search in the collisions reveals the properties of sQGP and possible signs of the critical endpoint.
The recent measurements of femtoscopic correlations at NA61/SHINE, using small and intermediate systems, unravel that the shape of the article emitting source is not Gaussian. The analysis of measurements is based on alpha-stable symmetric L\'evy sources, and we discuss the average pair transverse mass dependence of the source parameters. One of the parameters, the L\'evy exponent α, is of particularly importance. It describes the shape of the source, which, in the vicinity of the critical point of the phase diagram, may be related to the critical exponent η. Its measurement hence may contribute to the search for and characterization of the critical endpoint of the phase diagram.

Day 4 - Afternoon / 24

Spheroidal expansion and freeze-out geometry of heavy-ion collisions in the few-GeV energy regime

Author: Jedrzej Kolas[1]

Co-authors: Hanna Zbroszczyk [1]; Joachim Stroth [2]; Małgorzata Gumberidze [3]; Małgorzata Kurach [1]; Piotr Salabura [4]; Radosław Ryblewski [5]; Szymon Harabasz [6]; Tetyana Galatyuk [7]; Wojciech FLORKOWSKI [8]

[1] *Warsaw University of Technology*

[2] *Goethe-Universitat Frankfurt*

[3] *GSI Helmholzzentrum*

[4] *Jagiellonian University*

[5] *IFJ PAN*

[6] *TU Darmstadt*

[7] *TU Darmstadt / GSI*

[8] *UJK Kielce / IFJ PAN Krakow*

Corresponding Author: jedrzej.kolas.dokt@pw.edu.pl

Abstract

The applicability of statistical hadronization-based models to the high baryon density regions of the QCD phase diagram still remains unresolved. In our previous work [1], we have proposed a spherical geometry of the fireball and the corresponding expansion shape into the THERMal heavy IoN generATOR (THERMINATOR) 2 [2], a statistical hadronisation based model implementing a single freeze-out approximation. This approach has yielded a satisfactory reproduction of bulk particle transverse-mass distributions but failed to meet the expectations regarding rapidity distributions. Based on these results, we have proposed a spheroidal symmetry instead, which allowed us to reproduce well the rapidity distributions of the most abundant particles measured by the HADES collaboration in Au+Au 10% central collisions at $\sqrt{s_{NN}} = 2.4$ GeV [3]. We analyse experimentally measured spectra and results from femtoscopic correlation analysis to constrain the parametrisation of the fireball's shape and expansion profile. Moreover, in light of recent publications analysing this topic [4], we extend our study to discuss different formulations of the statistical hadronisation models, aiming to understand better the statistical nature of particle production in heavy-ion collisions. We also pursue implementing a Pok Man Lo distribution [5] for the most common resonances present in few-GeV collisions: Δ^{++} and Δ^0 for THERMINAOTOR 2.

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Day 4 - Afternoon / 94

Entanglement Enabled Spin Interference

Author: Daniel Brandenburg[1]

[1] *Ohio State University*

Corresponding Author: brandenburg.89@osu.edu

In quantum mechanics, interference traditionally occurs only between indistinguishable particles. In stellar intensity interferometry, this means measuring two photons of the same wavelength (color),

and in high energy experiments it means femtoscopic correlation measurements must investigate pairs of identical particles ($\pi^+\pi^+$, $\pi^-\pi^-$ etc.). However, nearly a decade ago Cotler and Wilczek proposed a quantum device which utilizes entanglement to enable optical intensity interferometry between photons of different wavelengths, suggesting that certain forms of entanglement make interference of non-identical quantum particles possible. Recently, a spin interference phenomenon was discovered in ultra-peripheral heavy-ion collisions through photonuclear production of $\rho^0 \to \pi^+\pi^-$ pairs. In this process interference is observed even through the final observation is a $\pi^+\pi^-$ pair - pions of clearly distinguishable charge. Besides its novelty as a general quantum phenomenon, this discovery of entanglement enabled spin interference in the angular distribution of $\rho^0 \to \pi^+\pi^-$ from diffractive photonuclear interactions has opened new avenues for investigating the gluon distributions in heavy nuclei and for studying the structure of heavy nuclei at high energy. In this talk I will review the experimental discovery and goals of the ongoing experimental measurements from various collaborations. Finally, I will discuss the emerging theoretical description of this novel phenomenon and comment on the various theoretical calculations that have appeared recently.

Day 4 - Afternoon / 36

First characterization of Short-Range Correlations in an exotic nucleus at R3B

Author: Andrea Lagni[1]

[1] *CEA Saclay*

Corresponding Author: andrea.lagni@cea.fr

Most of the knowledge we have to date about Short Range Correlations (SRC) in nuclei comes from electron induced quasi-free scattering (QFS) experiments in large momentum transfer kinematics. Experiments performed at Jefferson Lab with a 12C nucleus showed that the high-momentum tail of the nuclear momentum distribution is dominated by SRC and that the neutron/proton pairs are about 20 times more abundant than isospin-like pairs due to the tensor part of the nucleon-nucleon (NN) interaction [1]. Moreover, indications of a possible dependence of the high momentum fraction of protons and neutrons with the N/Z ratio was proposed from measurements on stable nuclei [2].
In this talk, I will present a novel experiment performed at the GSI accelerator facility with the R3B setup [3]. For the first time we made use of a short-lived nucleus scattering off a proton probe in inverse kinematics, allowing a more direct and systematic access to SRC properties as function of the N/Z ratio. The study of 16C will add a new measurement at N/Z = 1.67, above the largest available N/Z (208Pb) and at a much smaller mass, close to the one of the reference system 12C measured in the same experiment. Furthermore, we aim to extract the ratio of np/pp pairs as function of missing momentum and thus gain information about the NN interaction in comparison to different NN interaction theories. The concept of this experiment and some preliminary results will be discussed.

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[2] M. Duer et al. (CLAS Collaboration), Nature, 560:617, 2018.
[3]https://www.gsi.de/work/forschung/nustarenna/nustarenna_divisions/kernreaktionen/activities/r3b.

Day 4 - Afternoon / 60

Correlation Functions and Signatures of Short-Range Correlations in collisions of intermediate energy projectiles

Authors: Kris Hagel[1]; Kris Hagel[None]

[1] *Cyclotron Institute, Texas A & M University*

Corresponding Author: hagel@comp.tamu.edu

Understanding the effects of short-range nucleon-nucleon correlations (SRC), fluctuations when nucleons form pairs with high relative momentum and small center of mass momentum for short periods of time, is an important ingredient in theoretical models to understand the density dependence of symmetry energy at both sub and supra saturation densities. Characteristics and properties of SRCs have historically been investigated at GeV scale energies. Recent theoretical calculations of lower intermediate energy heavy ion collisions have shown that signatures of SRC may be observed. We have analyzed energy spectra of protons at forward angles in intermediate energy heavy ion reactions of various projectile target combinations. We show that this analysis indicates evidence of observation of high momentum tails at these intermediate energies and shows a dependence on projectile energy as well as the mass/charge asymmetry of projectile and target. We also present data from recent experiments using position sensitive silicon detectors showing high resolution correlation measurements.

Day 4 - Afternoon / 21

Photon-photon correlations in Ag+Ag collisions at $\sqrt{s_{NN}} = 2.55$ GeV

Author: Mateusz Grunwald[1]

[1] *Warsaw University of Technology*

Corresponding Author: mateusz.grunwald.dokt@pw.edu.pl

The investigation of femtoscopic correlations between pairs of photons emitted from heavy-ion collisions offers a unique opportunity to investigate the evolving source spacetime characteristics and properties. Unlike commonly studied charged particle correlations, photons are not influenced by strong or electromagnetic interactions, and thus have a longer mean free path. These characteristics indicate that the information they carry remains minimally distorted from their point of origin until detection in experiment. Consequently, it becomes feasible to examine source characteristics not solely based on post thermal freeze-out phases, but also encompass earlier stages of the expansion, without significant distortions caused by neighboring particles.

However, photon detection presents a non-trivial challenge, necessitating eighter a specialized approach of reconstructing photons converted into dilepton pairs, or detectors capable of detecting neutral particles. Additionally, the photon yield is vastly dominated by the decay of π^0 mesons, happening way after thermal freeze-out. Hence femtoscopy is sensitive to the emission sequence of particles, may offer a plausibility of distinguishing between the femtoscopic signal of direct photons and decay photons.

As a constituent of the FAIR/GSI scientific complex, the HADES experiment specializes in detecting light vector mesons through dielectron ($e^{\pm}$) channels generated during high-energy collisions of heavy ions, typically at energies around several (1-2) A GeV. By utilizing various detectors within the spectrometer, a photon sample can been acquired.

The preliminary results from data of Ag+Ag collisions at $\sqrt{s_{NN}} = 2.55$ GeV, as measured by HADES experiment, will be presented.

Day 5 - Morning / 58

Non-identical femtoscopy in Au+Au collisions at √sNN = 3 GeV in STAR

Author: Srikanta Tripathy[1]

[1] *Warsaw Univ. of Technology, Poland*

Corresponding Author: srikanta.tripathy@pw.edu.pl

Femtoscopy studies involving two-particle correlations arising from quantum statistics (Fermi- Dirac or Bose-Einstein) and Final State Interactions (Coulomb, strong) provides understanding of the space-time properties of the matter and final state interactions of particles formed in a relativistic collision. While source function can be used to determine the geometry and dynamic properties, two particle wave function can be used to determine the interactions.
With the recent fixed-target Beam Energy Scan II program, STAR extends the collision energy range to √sNN = 3 GeV towards higher baryon chemical potential regions (μB = 720 MeV). We will present the latest results of kaon-proton femtoscopic measurement in Au+Au collisions at √sNN = 3 GeV from the STAR experiment.

Day 5 - Morning / **29**

Femtoscopic measurements from STAR to CBM

Author: Daniel Wielanek[1]

[1] *Warsaw University of Technology, Faculty of Physics*

Corresponding Author: daniel.wielanek@pw.edu.pl

STAR is an experiment taking data for more than two decades. Recently, this collaboration performed the BES-I, BES-II, and FXT programs that allow extending the range of probing the diagram of strongly nuclear matter. CBM is a future experiment covering the lower range of collision energies measured by STAR.

In my talk, I will briefly discuss the femtoscopic measurements done in STAR experiments in the context of measurements in CBM experiment. I would also discuss the possibility of synergy between both collaborations regarding data analysis, emphasizing software development.

Day 5 - Morning / **14**

Advanced coalescence model based on femtoscopy measurements

Author: Chiara Pinto[1]

[1] *Technische Universitaet Muenchen (DE)*

Corresponding Author: chiara.pinto@cern.ch

The production of deuterons in pp collisions at $\sqrt{s} = 13$ TeV is simulated on an event-by-event basis using a coalescence afterburner based on a state-of-the-art Wigner-function formalism, and EPOS 3 and PYTHIA 8.3 as event generators. The nucleon-emitting source is modelled such to reproduce the $m_{\rm T}$-dependence of the source size measured by ALICE using femtoscopy. For the first time, the results of this model show that using a realistic wavefunction for deuterons, namely Argonne v_{18}, it is possible to reproduce the measured deuteron spectra with no free parameters.

Day 5 - Morning / **41**

Correlation Function constraints on meson-baryon interaction from UChPT in S=-2 sector

Author: Isaac Vidana Haro[1]

[1] *Istituto Nazionale di Fisica Nucleare*

Corresponding Author: isaac.vidana@ct.infn.it

As it is well known, for heavier hadrons, there is no possibility of performing scattering experiments due to technical limitations related to the extremely short life time of these particles. Instead, Lattice QCD (LQCD) simulations have played a key role in understanding the dynamics of heavy sectors, being more precise. A successful reproduction of the lattice data is regarded as a strong evidence that the Effective Field Theory EFT employed to such an end can describe reality in the energy regime considered. This leads one to see LQCD as a benchmark scheme to discriminate among theoretical models developed from EFTs in use. However, due to the lack of experimental data in these sectors, the theoretical models have been limited to describe the current hadron spectroscopy or to predict new states (exotic or not) that can be seen in different decay processes.
In contrast, the promising Femptoscopy Techinique in High-Energy Nuclear Collisions offers a direct connection to experimental observables, from which the corresponding scattering parameters can be extracted. The reason lies in the fact that, in high-energy heavy-ion collisions and high-multiplicity events of pp, pA and AA collisions, the hadron production yields are well described by the statistical models, thereby leaving the correlations between outgoing particles relying upon the final state interactions.

Day 5 - Morning / 83

Investigating strangeness enhancement via in-jet and medium production in p–Pb collisions at $\sqrt{sNN}$ = 5.02 TeV with ALICE

Author: Justin Blair[1]

[1] *University of Texas at Austin*

Corresponding Author: jtblair@utexas.edu

By measuring the angular correlation between a high-momentum trigger hadron (h) acting as a jet-proxy and a produced strange hadron ($\phi(1020)$, Λ), strangeness production in an event can be differentiated between hard production processes (jet-like) or softer processes (underlying event). Measuring these correlations in mid-rapidity p—Pb collisions at $\sqrt{s_{\rm NN}}$ = 5.02 TeV as a function of event multiplicity provides insight into the microscopic origin of strangeness enhancement in small collision systems. With this technique, the jet-like and underlying event strangeness production as a function of multiplicity are compared between a lower and higher momentum region, and the evolution of the per-trigger yields within the near-side (jet) and away-side (medium modified jet) are studied separately. The width of the near and away jet peaks is also studied for the h-Λ correlation as a function of multiplicity and compared to the dihadron distribution. Furthermore, the h-$\phi(1020)$ and h-Λ pairs within the underlying event give access to a production regime that is dominated by soft production processes, which can be compared to the in-jet production directly. Comparisons between strange and dihadron correlations show that the strangeness production is dominated by the underlying event, with the fraction of non-jet, underlying event production growing as a function of multiplicity. Additionally, the strange content in jets is seen to increase slightly with event multiplicity, pointing to a multiplicity-dependent modification of the jet fragmentation. Results are also compared to model predictions (PYTHIA, DPMJET).

Day 5 - Morning / 74

Measurements of pp,p\Lambda,p\Xi^- Correlation Functions at 3GeV Au+Au Collisions at RHIC-STAR

Author: Zhi Qin[1]

Co-author: STAR Collaboration

[1] *Tsinghua University*

Corresponding Author: qinz18@outlook.com

Two particle correlation function in heavy ion collisions mainly depends on the phase space of the emitting source, and the final-state interactions. So it is widely used to investigate the source size after collision, and also provide an effective experimental approach to study the nucleon-nucleon and hyperon-nucleon interactions, which are crucial to understand the inner structure of compact stars.

In this work, we will present the results of baryon correlation functions for the pairs of pp, $p\Lambda$, $p\Xi^-$ in Au+Au collisions at $\sqrt{s_{NN}} = 3$ GeV recorded by the fixed target program at STAR. The correlation functions are obtained after corrections for purity and feed-down effects and considering momentum resolution, track merging and splitting effects. The source size r_G of different pairs for different centrality and strong interaction parameters scattering length f_0 and effective range d_0 of the pairs are extracted. UrQMD and CRAB models are used to calculate the correlation function theoretically to compare with the experimental result.

Day 5 - Morning / 18

Femtoscopic correlations of lightest nuclei

Author: Stanislaw Mrowczynski[1]

[1] *National Centre for Nuclear Research, Warsaw, Poland*

Corresponding Author: stanislaw.mrowczynski@ncbj.gov.pl

Light nuclei are abundantly produced in relativistic heavy-ion collisions. We derive a formula of the femtoscopic correlation function of the lightest nuclei, which include protons, deuterons, tritons, helium 3. As the correlations are generated simultaneously with the bound state formation, the source function of a given light nucleus, which enters the correlation function, non-trivially depends on its mass number. This fact allows one to distinguish various production mechanisms of the nuclei. The correlation functions also carry information on production unstable nuclei like lithium 4.
The talk is based on a series of publications:

S. Bazak and St. Mrówczyński,
Production of 4Li and p-3He correlation function in relativistic heavy-ion collisions, European Physical Journal A 56, 193 (2020)

St. Mrówczyński and P. Słoń,
Hadron-Deuteron Correlations and Production of Light Nuclei in Relativistic Heavy-Ion Collisions, Acta Physica Polonica B 51, 1739 (2020)

St. Mrówczyński and P. Słoń,
Deuteron-Deuteron Correlation Function in Nucleus-Nucleus Collisions, Physical Review C 104, 024909 (2021)

St. Mrówczyński,
Production of light nuclei at colliders - coalescence vs. thermal model, European Physical Journal Special Topics 229, 3559 (2020)

Day 5 - Morning / 88

Study of the three-body dynamics at short range via femtoscopy by ALICE at the LHC

Author: Oton Vazquez Doce[1]

[1] *Istituto Nazionale di Fisica Nucleare*

Corresponding Author: oton.vazquezdoce@lnf.infn.it

Femtoscopy measurements in small systems like pp collisions have been demonstrated to be very sensitive to the effects of the final-state strong interaction. Such studies face now a new challenge with the extension for the first time to three-body systems. The study of three- and many-body dynamics has been a long-standing goal in nuclear physics, particularly for understanding the structure of light nuclei and describing neutron-rich and dense nuclear matter.

We present results obtained using high-multiplicity pp collisions at $\sqrt{s}$ = 13 TeV recorded by ALICE at the LHC. The first measurement of the genuine three-body effects obtained from p–p–p, p–p–Λ, p–p–K^+ and p–p–K^- correlation functions are obtained by utilising the formalism of the three-particle cumulants. Such measurements provide information on the genuine three-particle interaction and constitute important inputs for the calculation of the equation of state of neutron stars and the formation of kaonic nuclei.

We present as well a new experimental method to study three-body nuclear systems by utilizing correlations deuteron-hadron pairs. Measurements of the K^+−d and p−d correlations are compared with effective two-body calculations anchored to results from K^+−d and p−d scattering experiments. An excellent description of the measured K^+−d correlation is achieved, but the calculations fail to describe the p−d system. This discrepancy can only be resolved by performing a full three-body calculation, demonstrating that nucleons are the explicit degrees of freedom and opening the possibility of investigating the effect of genuine many-body nuclear interactions at the LHC in the future, including as well systems with strangeness and charm.

Day 5 - Morning / 80

Femtoscopic correlation studies between D0 mesons and charged hadrons in Au+Au collisions at √sNN = 200 GeV by STAR

Author: Priyanka Roy Chowdhury[1]

[1] *Warsaw University of Technology*

Corresponding Author: priyanka.roy_chowdhury.dokt@pw.edu.pl

Heavy quarks are produced in hard partonic scatterings at the very early stage of heavy-ion collisions and they experience the whole evolution of the Quark-Gluon Plasma medium. Femtoscopic correlations, i.e. two-particle correlations at low relative momentum, are sensitive to the final-state interactions as well as to the extent of the region from which the correlated particles are emitted. A study of such correlations between charmed mesons and identified charged hadrons could shed light on their interactions in the hadronic phase and the interaction of charm quarks with the medium.
In this presentation, we will show the first measurement of femtoscopic correlations between $D^0-hadron$ pairs at mid-rapidity in Au+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV by the STAR experiment. D^0 mesons are reconstructed via the $K^- - \pi^+$ (and its charge conjugate) decay channel using topological criteria enabled by the Heavy Flavor Tracker with excellent track pointing resolution. We will present the femtoscopic correlation function for D^0 transverse momentum above 1 GeV/c in the $0-80\%$ centrality. We will also compare the experimental results with available theoretical models and discuss physical implications.

Day 5 - Afternoon / 72

Event-by-event Hadron Yield Fluctuations in Pb —Pb Collisions at sNN = 2.76 TeV with ALICE

Author: Claude Pruneau[1]

[1] *Wayne State University*

Corresponding Author: aa7526@wayne.edu

We discuss measurements of event-by-event relative hadron yield fluctuations with the νdyn observable in Pb —Pb collisions at sNN = 2.76 TeV. Fluctuation measurements presented include the relative yield of charged hadrons, the relative yield of identified pions (π) vs. kaons (K), π vs. protons (p) , K vs. p, as well as the more recent measurements of fluctuations of K+ vs. K− yields and charged kaons (K±) vs. neutral kaons (K0s) yields. Measured values of νdyn as well as values of νdyn scaled by the produced particle multiplicity are reported as a function of Pb —Pb collision centrality. Measured and scaled data are compared to predictions from various models, including the HIJING and AMPT models. It is found that while most relative yield fluctuations considered exhibit an approximate scaling with inverse multiplicity, which is qualitatively reproduced by HIJING and AMPT, the relative yields of π vs. p and K± vs. K0s fluctuations show strong departure from simple scaling behavior. The former exhibits a change of sign from peripheral to central collisions whereas the latter exhibits strongly enhanced scaled values in central collisions. The K± vs. K0s anomalous behavior is discussed in light of recent theoretical considerations, including the possibility of strange Disoriented Chiral Condensates (DCC) and Disoriented Isospin Condensate (DIC).

Day 5 - Afternoon / 33

Correlation Function studies at intermediate energies at CSHINE

Author: Yijie Wang[1]

Co-author: Zhigang Xiao [1]

[1] *Department of Physics, Tsinghua University*

Corresponding Author: yj-wang15@tsinghua.org.cn

The isospin-dependent equation of state of nuclear matter, i.e. symmetry energy $E_{sym}(\rho)$ plays an important role in the study of nuclear physics and Astrophysics. In terrestrial lab, heavy ion collision provides a unique way to constrain $E_{sym}(\rho)$. So a compact spectrometer for heavy ion experiment （CSHINE） is built and particle correlation functions are measured.
The HBT correlation function method is applied as an chronometer to extract the emission timescale and emission order of hydrogen isotopes from the intermediate velocity source formed in $30MeV/u^{40}Ar+^{197}Au$. The proton emission timescale $\tau_p \approx$ 100 fm/c is extracted by the fit of Koonin-Pratt equation with CRAB code. And the dynamic emission order of τ_p τ_d τ_t is evidenced via the correlation functions of nonidentical particle pairs, indicating that the neutron rich particles are emitted earlier. Meanwhile, transport model simulations demonstrate that the emission order of isospin dependent particles depends sensitively on the stiffness of the nuclear symmetry energy [PLB, 825, 136856 (2022)].

Day 5 - Afternoon / 37

The pixelation technique applied to FARCOS correlator in the CHIFAR experiment

Authors: Cristina Zagami[1]; Emanuele Vincenzo Pagano[1]; Paolo Russotto[1]; Enrico De Filippo[1]

Co-authors: LUIS ARMANDO ACOSTA SANCHEZ ; Tomasz Cap ; Giuseppe Cardella [1]; Filippo Fichera [2]; Elena Irene Geraci [1]; Brunilde Gnoffo [2]; Chiara Guazzoni [1]; Gaetano Lanzalone [1]; Concettina Maiolino [1]; Nunzia Simona Martorana [1]; Tomasz Matulewicz ; Angelo Pagano [1]; Massimo Papa [1]; K. Piasecki ; Sara Pirrone [1]; Massimo Piscopo [1]; Roman Planeta ; Giuseppe Politi [1]; Fabio Risitano [1]; Francesca Rizzo [1]; Gaspare Sacca' [1]; Gianluca Santagati [1]; Krystyna Siwek-Wilczynska ; Izabela Skwira-Chalot ; Marina Trimarchi [2]

[1] *Istituto Nazionale di Fisica Nucleare*

[2] *CT*

Corresponding Author: cristinazagami@alice.it

The CHIFAR experiment was proposed to study the emission probability of Intermediate Mass Fragments (IMFs) in non-central Heavy Ion collisions. This phenomenon is linked to the features of the Equation of State of the nuclear matter, focusing also on the role of the isospin degree of freedom of the colliding nuclei. The CHIMERA collaboration has investigated three nuclear reactions at the incident beam energy of 20A.MeV: ^{124}Sn+^{64}Ni, ^{112}Sn+^{58}Ni and ^{124}Xe+^{64}Zn.
For the first time the experimental setup was equipped with ten telescopes of FARCOS (Femtoscope ARray for COrrelation and Spectroscopy) correlator in its final configuration, coupled with the 4π CHIMERA multi-detector allowing to study correlations among IMFs and light charged particles produced in a nuclear reaction.
Each FARCOS telescope is composed of two stages of Double Sided Silicon Strip Detectors (DSSSD), with 300 μm and 1500 μm of thickness respectively, and 4 CsI(Tl) crystals of 6 cm of thickness. Energy and angular resolution of FARCOS is very good, making it an appropriate tool for intended research.
The contribution will illustrate results of the energy calibration and resolution of the two DSSSDs, and the particles identification using the ΔE-E technique. The analysis also moved in the so called "pixelations"step, i.e. the assignment for each detected particle its pixel, determined from the crossing of a strip of the front side to another of the back side, its angle in the laboratory frame, the polar angle θ and the azimuthal angle ϕ.

Day 5 - Afternoon / 57

A Pixellation method for the FARCOS array

Author: LUIS ARMANDO ACOSTA SANCHEZ[None]

Corresponding Author: giuseppe.cardella@ct.infn.it

A Pixellation method for the FARCOS array
G. Cardella1, L. Acosta7, E. De Filippo1, E. Geraci1,2, B. Gnoffo1,2, C. Guazzoni3,4, C. Maiolino5, N.S. Martorana1, A. Pagano1, E.V. Pagano5, S. Pirrone1, G. Politi1,2, F. Risitano1,6, F. Rizzo1,5, P. Russotto5 , G. Santagati1 , M. Trimarchi1,6 and C. Zagami2,5
1 INFN, Sezione di Catania, Catania, Italy.
2 Dipartimento di Fisica ed Astronomia, Università di Catania, Catania, Italy.
3 INFN, Sezione di Milano, Milano, Italy
4 Politecnico di Milano, Dip. Elettronica, Informazione e Bioingegneria, Milano, Italy.
5 INFN, Laboratori Nazionali del Sud, Catania, Italy
6 Dipartimento di Scienze MIFT, Università di Messina, Messina, Italy
7 Instituto de Fisica, Universidad Nacional Autonoma de Mexico, Mexico City, Mexico.
A new pixellation method for the Double Sided Silicon Strip Detectors (DSSSD) of the FARCOS [1,2] array has been developed and tested with data collected at INFN-LNS laboratory with an alpha particle beam impinging on a 12C target. We concentrated on the reconstruction of two and three alpha particles coincidence events. Respect to other recent works [3,4] we underline the need to use the arrival time of each signal to clean the events from noise and spurious coincidences. The method is able also to clean coincidence data of two neighbouring strips from interstrip events. This allows to reconstruct the kinematical coincidence path of two alpha particles also for neighbouring strips. The method used is also able to clean from the noise generated by events interacting with the detector near the guard ring. This noise affects mostly the data collected in the more external strips of the detector. The analysis performed allows us to evaluate also the efficiency in the reconstruction of interstrip events as a function of the ionization power of detected particles. The energy resolution

of well reconstructed interstrip events was evaluated by looking at two alpha particles coincidences. No difference was observed respect to the good energy resolution measured for single pixel events.

[1] E De Filippo et al epja in preparation
[2] E.V. Pagano, et al., EPJ Web Conf. 117 (2016) 10008
[3] S.Kundu et al NIMA 943(2019)162411.
[4] F.Guan et al NIMA 1029(2022)166461.

Day 5 - Afternoon / 6

Deuteron-Xi correlation function studied with three-body model

Author: Tokuro Fukui[1]

[1] *Faculty of Arts and Science, Kyushu University*

Corresponding Author: tokuro.fukui@artsci.kyushu-u.ac.jp

Nowadays, the three-nucleon force is considered essential within the framework of nuclear forces. Additionally, three-hadron forces are thought to have a notable impact on hadronic systems beyond many-nucleon systems. The correlation function involving the deuteron and hadrons has emerged as a potential tool for exploring the three-hadron force. However, a comprehensive understanding of this deuteron-hadron correlation function is lacking. Particularly, it is necessary to clarify how the weak binding nature of the deuteron affects the correlation function.

To address this, we investigate the channel coupling between bound and continuum states, as well as continuum-continuum states, of the deuteron in scattering processes that are relevant to the d-Ξ^- correlation function. This channel coupling is described using the continuum-discretized coupled channels (CDCC) method. The CDCC method, a fully quantum-mechanical and nonperturbative reaction model, is founded on a three-body description of systems.

Our calculations indicate that the aforementioned channel coupling has a noticeable yet not overwhelmingly significant effect. Consequently, it is reasonable to simulate the deuteron-hadron correlation function without considering the deuteron-continuum states.

Day 5 - Afternoon / 95

Probing Equation of State of Dense Baryonic Matter with Heavy-Ion Collisions and Transport Simulations

Author: Pawel Danielewicz[1]

[1] *Michigan State University*

Corresponding Author: daniel@frib.msu.edu

High compression of nuclear matter occurs in central energetic collisions of heavy nuclei, commonly referred to just as Heavy Ion Collisions (HIC). Inferring the nuclear Equation of State (EoS) requires a careful selection of observables from HIC and comparisons to transport model simulations incorporating different EoS. Current status and plans on both the experimental and theoretical sides will be reviewed, with some emphasis on the symmetry energy. Connection to astrophysical EoS inferences will be discussed, too.

Day 5 - Afternoon / 89

Source function from two-particle correlations via deblurring

Author: Pierre Nzabahimana[None]

Corresponding Author: nzabahim@nscl.msu.edu

In the context of heavy-ion collisions, low relative-velocity two-particle correlations play a pivotal role in understanding the space-time characteristics of particle emission. These characteristics are typically represented by a relative emission source, which is determined through the Koonin-Pratt (KP) convolution formula, utilizing the relative wave-function of the particles. Previous studies have commonly approximated this source with a Gaussian parametrization and fit it to the correlation function, although broader inferences have also been made through fitting methods. Here, we propose the application of the Richardson-Lucy (RL) optical deblurring algorithm to extract the source from a correlation function. The RL algorithm, grounded in probabilistic Bayesian principles, relies on the positive definiteness of intensity distributions for the optical object, its image, and the convolution kernel, which align with the relevant quantities in the KP formula. Additionally, we employ a transport model to analyze two-proton (p-p) correlations in heavy-ion collisions at low incident energies per nucleon (E/A). Specifically, we utilize the Boltzmann-Uehling-Uhlenbeck (BUU) transport model to simulate the p-p source. Subsequently, we integrate this source and the p-p kernel within the KP formula to calculate the correlations. By comparing the correlations obtained from the BUU simulation with those from the RL algorithm, we aim to gain a deeper understanding of the impact of fast and slow emissions on the measured correlations. Drawing insights from this comparison, we correct the BUU source function by incorporating a tail to account for the contribution of secondary decay emissions, which cannot be accurately captured by BUU simulations. To illustrate our approach, we examine p-p correlations measured in Ar + Sc reactions at E/A = 80 MeV, considering both momentum-independent and momentum-dependent nuclear equations of state (EOS).

Day 3 - Morning / 91

Physics and Gender, few open questions

Author: Alessia Bruni[1]

[1] *Istituto Nazionale di Fisica Nucleare*

Corresponding Author: alessia.bruni@bo.infn.it

Why physics, which is considered objective and not affected by who is doing the research, teaching and learning, is so dominated by men?
Why do so many groups of people decide not to come to physics, or to leave this field?
How do we make physics or scientific institutions more welcoming and inclusive for a larger part of the population?