10th Asian Triangle Heavy-Ion Conference - ATHIC 2025

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Book of Abstracts

Contents

Astro / 6

Stochastic relativistic advection-diffusion equation and viscous hydrodynamics in density frame

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We study an approach to simulating the stochastic relativistic advection-diffusion equation based on the Metropolis algorithm. We show that the dissipative dynamics of the boosted fluctuating fluid can be simulated by making random transfers of charge between fluid cells, interspersed with ideal hydrodynamic time steps. The random charge transfers are accepted or rejected in a Metropolis step using the entropy as a statistical weight. This procedure reproduces the expected strains of dissipative relativistic hydrodynamics in a specific (and non-covariant) hydrodynamic frame known as the density frame. Numerical results, both with and without noise, are presented and compared to relativistic kinetics and analytical expectations. An all order resummation of the density frame gradient expansion reproduces the covariant dynamics in a specific model. In contrast to all other numerical approaches to relativistic dissipative fluids, the dissipative fluid formalism presented here is strictly first order in gradients and has no non-hydrodynamic modes. The physical naturalness and simplicity of the Metropolis algorithm, together with its convergence properties, make it a promising tool for simulating stochastic relativistic fluids in heavy ion collisions and for critical phenomena in the relativistic domain. In addition, we compare our full density frame viscous hydrodynamics with BDNK and MIS, and found very good agreement in small shear viscosity regime and better in large viscosity regime.

Astro / 7

Electromagnetic field fluctuation and its correlation with the participant plane in Au + Au and isobaric collisions at $\sqrt{s_{NN}} = 200$ GeV

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Intense transient electric (**E**) and magnetic (**B**) fields are produced in the high energy heavy-ion collisions. The electromagnetic fields produced in such high-energy heavy-ion collisions are proposed to give rise to a multitude of exciting phenomenon including the Chiral Magnetic Effect. We use a Monte Carlo (MC) Glauber model to calculate the electric and magnetic fields, more specifically their scalar product $\mathbf{E} \cdot \mathbf{B}$, as a function of space-time on an event-by-event basis for the Au+Au collisions at $\sqrt{s_{NN}} = 200$ GeV for different centrality classes. We also calculate the same for the isobars Ruthenium and Zirconium at $\sqrt{s_{NN}} = 200$ GeV. In the QED sector $\mathbf{E} \cdot \mathbf{B}$ acts as a source of Chiral Separation Effect, Chiral Magnetic Wave, etc., which are associated phenomena to the Chiral Magnetic Effect. We also study the relationships between the
electromagnetic symmetry plane angle defined by $\mathbf{E} \cdot \mathbf{B}$ ($\psi_{E.B}$) and the participant plane angle ψ_P defined from the participating nucleons for the second-fifth order harmonics.

Parallel A / 8

Unveiling Initial State Fluctuations Using $[p_{\mathrm{T}}]$ Cumulants With ATLAS

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The event-by-event variations in the initial conditions and subsequent expansion of the Quark-Gluon Plasma (QGP) directly affects the distribution of the event-averaged transverse momentum ($[p_{\mathrm{T}}]$) of particles. Typically, the contributions to the transverse momentum from radial flow velocity and thermal components are extracted using simultaneous Blast-Wave fits to p_{T} spectra of identified hadrons. However, disentangling these contributions on an event-by-event basis arising from fluctuations in the overlap area ("Geometrical component") from all other sources at fixed geometry ("Intrinsic component") remains a challenge.
In this talk, I will present new, precise ATLAS measurements of $[p_{\mathrm{T}}]$ cumulants up to third order in heavy-ion collisions as a new tool to disentangle Geometric and Intrinsic fluctuations. The observables exhibit distinct behavior, particularly in ultra-central collisions where geometrical variations are suppressed as the overlap area reaches its maximum. These measurements provide the first experimental means to disentangle different sources of fluctuations arising from the initial state and medium evolution, offering new constraints on key properties of the QGP, such as the speed of sound.

Parallel B / 9

Spin alignment of vector mesons in heavy-ion collisions

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The global spin alignment of vector mesons has been observed by the STAR collaboration at the Relativistic Heavy Ion Collider (RHIC) at Brookhaven National Laboratory (BNL). It provides a unique opportunity to probe the correlation between the polarized quark and antiquark in the strongly coupled quark-gluon plasma (sQGP) produced in relativistic heavy ion collisions, opening a new window to explore the properties of sQGP. In this talk, I will present a brief overview on theoretical and experimental advances in the study of vector meson's spin alignments in heavy-ion collisions.

10

Electromagnetic fields in low-energy heavy-ion collisions with baryon stopping

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We investigate the impact of baryon stopping on the temporal evolution of electromagnetic fields in vacuum at low-energy Au+Au collisions with $\sqrt{s_{NN}} =$ 4-20 GeV. Baryon stopping is incorporated into the Monte-Carlo Glauber model by employing a parameterized velocity profile of participant nucleons with non-zero deceleration. The presence of these decelerating participants leads to noticeable changes in the centrality and $\sqrt{s_{NN}}$ dependence of electromagnetic fields compared to scenarios with vanishing deceleration. The influence of baryon stopping differs for electric and magnetic fields, also exhibiting variations across their components. We observe slight alteration in the approximate linear dependency of field strengths with $\sqrt{s_{NN}}$ in the presence of deceleration.

Additionally, the longitudinal component of the electric field at late times becomes significant in the presence of baryon stopping.

Parallel A / 11

Performance study of Gas Electron Multiplier chamber for future heavy ion experiment

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Gas Electron Multiplier (GEM) is a cutting edge Micro Pattern Gaseous detector (MPGD) technology suitable as tracking device in high rate Heavy-Ion (HI) experiments for their high rate handling capability and good spatial resolution. The performance studies including the detector efficiency, gain, energy resolution and also the long-term stability study under high radiation are the most important aspects need to be investigated before using the detector in any experiments. In this work all of the above mentioned aspects are investigated for a single mask triple GEM chamber prototype operated with premixed Ar/CO_2 gas mixtures using a 5.9 keV ^{55}Fe X-ray source. The gain and energy resolution are corrected for the variation of ambient temperature/pressure ratio (T/p). The effect of the variation of bias current on the performance of the detector is also studied. The details of the experimental setup, methodology, and results will be discussed.

Parallel D / 12

Understanding of quarkonia production in forward rapidity region

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Due to the heavy-quark symmetry of Non-Relativistic Quantum Chromodynamics (NRQCD), the cross-section for the production of η_c can be predicted. This NRQCD prediction when confronted with data from the LHCb is seen to fail miserably. However, modified NRQCD provides a neat solution to the LHCb η_c anomaly and provides an understanding of all the features of the η_c data. Furthermore, we compare the recent LHCb data for the integrated cross-section of h_c production at $\sqrt{s}$ = 13 TeV in the kinematic range 5.0 $< p_T <$ 20.0 GeV and 2.0 $< y <$ 4.0 with the theoretical predictions using NRQCD and modified NRQCD. Modified NRQCD gives an agreement with the recent LHCb experimental data.
Motivated by the success of modified NRQCD, we have extended
the work to study charmonia production in the forward rapidity region.

13

Effect of Magnetic Field on Urca Processes in Neutron Star mergers

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Isospin-equilibrating weak processes, called "Urca" processes, are of fundamental importance in astrophysical environments like (proto-)neutron stars, neutron star mergers, and supernovae. In these environments, matter can reach high temperatures of tens of MeVs and be subject to large magnetic fields. We thus investigate Urca rates at different temperatures and field strengths by performing the full temperature and magnetic-field dependent rate integrals for different equations of state. We find that the magnetic fields play an important role at temperatures of a few MeV, especially close to or below the direct Urca threshold, which is softened by the magnetic field. At higher temperatures, the effect of the magnetic fields can be overshadowed by the thermal effects. We observe that the magnetic field more strongly influences the neutron decay rates than the electron capture rates, leading to a shift in chemical equilibrium.

14

Heavy Quark Dynamics in Hot QCD Matter: A Fractional Approach

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The dynamics of heavy quarks (HQs) in a hot QCD medium are revisited with a focus on anomalous diffusion, modelled through the fractional Langevin equation using the Caputo fractional derivative. A numerical method is developed to solve the FLE, demonstrating that the mean square displacement of the HQs deviates from the standard linear time dependence. The study also calculates the mean squared momentum, momentum spread, and the nuclear suppression factor (R_{AA}) for the HQs. The presence of the superdiffusion impacts the R_{AA} significantly.

Parallel C / 15

The role of the pion mass on the QCD phase diagram in the $T - eB$ plane

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We investigate the effect of the pion mass on the quantum chromodynamics (QCD) phase diagram in the presence of an external magnetic field, aiming to understand it, for the first time, using Nambu\textendash Jona-Lasinio like effective models [1]. We compare results from both the local and nonlocal versions, finding that inverse magnetic catalysis (IMC) near the crossover is eliminated with increasing pion mass, while the decreasing trend of the crossover temperature with increasing magnetic field persists for pion mass values up to at least 440 MeV. Thus, the models are capable of capturing qualitatively the results found by lattice QCD (LQCD) for heavy (unphysical) pions. The key feature of these models is incorporating the reduction of the coupling constant with increasing energy. This not only reproduces the IMC effect but also describes the effects of heavier current

quark masses without additional parameters. In the local NJL model, this agreement depends on parameter fitting at the physical point, whereas the nonlocal version naturally exhibits IMC effect around the crossover region, capturing the physics more naturally. We further use the nonlocal framework to determine the pion mass beyond which the IMC effect in the transition region no longer exists.

1. Mahammad Sabir Ali, Chowdhury Aminul Islam and Rishi Sharma arXiv:2407.14449 [hep-ph]

Parallel D / 16

First measurement of high p_{T} azimuthal anisotropy using subevent cumulants in pPb collisions at CMS

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Measurements at the LHC have provided evidence for collective behavior in high-multiplicity proton-lead (pPb) collisions through multiparticle correlation techniques. Yet, no conclusive evidence of jet quenching, indicating the energy loss of high-p_{T} partons as they traverse the medium, has been detected in pPb. This raises the intriguing question: How can a medium described by hydrodynamics, and that significantly modifies the distribution of final-state hadrons, yet has no significant impact on the distribution of high-pT particles? To investigate this, a comprehensive study of differential Fourier coefficients (v_n) in particle transverse momentum (p_{T}) and event multiplicity is presented in 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 method probes an extended phase space region up to a high particle p_{T}. Additionally, we compare the results between pPb and PbPb collisions in the same multiplicity window. This comparison will help assess similarities and differences in the medium's interaction with high-p_{T} particles in these two collision types.

17

Study of Quarkonia Dissociation at finite magnetic field

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The study investigates the behavior of heavy quarkonia in a hot and magnetized quark-gluon plasma. We incorporated the inverse magnetic catalysis (IMC) effect by modifying the Debye mass through magnetic-field-dependent effective masses. Our analysis yields the real and imaginary components of the heavy quark potential within this magnetized environment.

After evaluating the binding energy and decay width, we study the dissociation temperature of heavy quarkonia in the presence of a magnetic field.

Parallel A / 18

Status overview of Korean group activities for MTD Endcap Timing Layer development

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During the High-Luminosity phase of the LHC (HL-LHC), the CMS experiment will be upgraded with a new MIP Timing Detector (MTD), which will provide precise time measurements for charged particles up to a pseudorapidity of |eta| = 3. This precise timing capability will help address the complex pile-up environment anticipated at HL-LHC, thereby extending the experiment's sensitivity to new physics. The forward region of the MTD, known as the Endcap Timing Layer (ETL), will cover a pseudorapidity range of 1.6 < |eta| < 3 and will be equipped with Low-Gain Avalanche Diodes (LGADs) paired with the Endcap Timing Read Out Chip (ETROC). This talk will present an overview of the activity of the Korean MTD group.

Parallel A / 19

Understanding the hadronic phase with resonance studies with ALICE at LHC Energies

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Hadronic resonances, with lifetimes comparable to the duration of the hadronic phase, can be used as effective probes for studying its evolution in heavy-ion collisions. Exploring the dynamics of the hadronic phase reveals the roles of rescattering and regeneration in resonance production. In particular, rescattering reduces the resonance yields and may alter their transverse momentum, while regeneration can lead to their enhancement. By analyzing the ratios of resonance yields to those of long-lived particles across various charged-particle multiplicities, valuable insights into hadronic interactions and system evolution are obtained. Additionally, comparing results from smaller collision systems, such as pp and p−Pb, with larger systems like Xe−Xe and Pb−Pb collisions highlights potential collective phenomena and variations in the lifetime of the hadronic phase.

This contribution presents ALICE results from Run 2 and Run 3 on mesonic and baryonic resonances across various collision systems at LHC energies. Focus on the $\mathrm{K}^{*0}(892)$, $\Lambda(1520)$, $\Sigma^{\pm}(1385)$, $\Xi^{0}(1530)$, and $\phi(1020)$ resonances will be given, in particular on their transverse momentum (p_{T}) distributions, their p_{T}-integrated yields, and the ratios of p_{T}-integrated resonance yields to those of long-lived particles. Furthermore, the experimental results will be compared with theoretical predictions to understand the particle dynamics in the hadronic phase.

Parallel B / 20

Shear evolution in non-resistive magnetohydrodynamics with momentum dependent relaxation time

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Strong magnetic fields are expected to exist in the early stages of heavy ion collisions and there is also an increasing evidence that the energy dependence of the cross-sections can strongly affect the dynamics of a system even at a qualitative level. This led us to the current study where we developed second-order non-resistive relativistic viscous magnetohydrodynamics (MHD) derived from kinetic theory using an extended relaxation time approximation (ERTA), where the relaxation time of the usual relaxation time approximation (RTA) is modified to depend on the momentum of the colliding particles. A Chapman-Enskog-like gradient expansion of the Boltzmann equation is employed for a charge-conserved, conformal system, incorporating a momentum-dependent relaxation time. The resulting evolution equation for the shear stress tensor highlights significant modifications in the coupling with the dissipative charge current and magnetic field. The results were compared with the recently published exact analytical solutions for the scalar theory where the relaxation time is directly proportional to momentum. Our approximated results show a very close agreement with the exact results. This can lead us to transport coefficient calculations for various theories for which exact results are not yet known.

Parallel A / **21**

Multiparticle Cumulants to Constrain the Initial State in Xe-Xe and Pb-Pb Collisions in the CMS Experiment

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Xenon (Xe) nuclei are deformed and have a non-zero quadrupole moment, whereas lead (Pb) nuclei are considered spherical in shape. The study of Xe-Xe collisions at a center-of-mass energy per nucleon pair of $\sqrt{s_{\mathrm{NN}}} = 5.44$ TeV opens up a window to study nuclear deformation at LHC. When compared to Pb-Pb collisions at $\sqrt{s_{\mathrm{NN}}} = 5.36$ TeV, one can explore the dependence of the Fourier flow harmonics (v_n) on the size and initial-state geometry of the colliding systems. For the first time, correlations between higher-order moments ($\langle v_n^k v_m^l \rangle$, where $n, m = 2, 3, 4$ and $k, l = 2, 4, 6$) between two (v_2 and v_3 or v_2 and v_4) or even three flow harmonics (v_2, v_3 and v_4) are measured and compared between Xe-Xe and Pb-Pb collisions as a function of collision centrality. These new measurements have been calculated with multiparticle mixed harmonic cumulants (upto 8th order) using charged particles in the wide pseudorapidity region of the CMS detector ($|\eta| < 2.4$) and in the transverse momentum range of $0.5 < p_{\mathrm{T}} < 3.0$ GeV/c. The results have also been compared to several theoretical model predictions. The observables measured in this analysis have been used to closely probe the non-linearities between v_2, v_3 and v_4 and their corresponding eccentricities ϵ_2, ϵ_3 and ϵ_4. This not only helps us to constrain the deformation parameters of Xe nuclei, but can also significantly constrain initial-state model parameters and give us a better understanding of the evolution of the quark-gluon plasma created in heavy-ion collisions at LHC.

Parallel D / **22**

Diffusion coefficients of D-meson in rotating Hadron gas

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In off-central heavy ion collisions (HIC), the initial orbital angular momentum (OAM) of the colliding heavy nuclei can be transferred to the participants and subsequently to the nuclear medium formed. This finite OAM can lead the system to rotate with some finite angular velocity. The transport properties, like electrical conductivity, viscosities, thermal conductivity, heavy meson diffusion, etc, of the rotating nuclear medium are generally modified with respect to their non-rotating counterparts. The diffusion coefficients of heavy mesons and the corresponding nuclear suppression factor RAA are useful probes to understand the nature of the medium formed in the HIC experiments. In this work, we have determined the anisotropic spatial diffusion coefficients of D-meson diffusing under the background of rotating hadronic gas. To calculate the diffusion coefficients, we have set up a covariant Boltzmann transport equation in the rotating frame using the relaxation time approximation. The background hadron gas has been modeled by the popular hadron resonance gas model (HRG). The relaxation time is determined by assuming a hard-sphere-type scattering model of the D-meson with the HRG. The range for the scattering length "a"of the D-meson-HRG interaction is obtained by varying "a"to cover the results of the existing model calculation of the parallel component of diffusion. After calibrating the scattering length, we obtain the variation of the perpendicular and hall diffusion coefficients both with respect to temperature and angular velocity.

Parallel A / 23

Quantum Hall effect for quarks in chiral effective model

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A net baryon density up to 2-6 times the nuclear saturation density and high magnetic fields are expected in the reaction zone of upcoming CBM/NICA experiments. Such densities are also likely in the core of massive neutron stars, possibly with mixed quark-hadron phases. The chiral effective model, based on the principles of chiral symmetry breaking and broken scale invariance, is employed to incorporate the in-medium effects of constituent quarks within hadrons. The classical and quantized versions of electrical conductivity and resistivity are studied in the relaxation time approximation framework of kinetic theory. Anisotropic electrical conductivity and resistivity tensors are investigated by considering cyclotron motion and Landau quantization. In the presence of strong magnetic fields, the Landau quantization of perpendicular momenta results in quantized anisotropic transport coefficients of the system. Two interesting macroscopic manifestations of Landau quantization are the Shubnikov-de Haas (SdH) oscillations and the Quantum Hall Effect (QHE) [1]. In this work, we explore the possibility of SdH/QHE type oscillations in low temperature and high magnetic field conditions present in the interior of the dense neutron stars, as well as in future facilities of CBM/NICA experiments. Finally, we also present a quantitative estimate of the same in the interior of a neutron star where the magnetic field varies as a function of the baryon density.

References
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Parallel B / 24

Thermal diffusion properties of a rotating QGP medium

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This work involves the study of the effects of rotation on the thermal diffusion properties of the QGP medium. The noncentral heavy ion collisions could possess finite angular momentum with a finite range of angular velocity, so, rotation gets induced in the produced medium. Like other extreme conditions, the rapid rotation can conspicuously alter various properties of the QGP medium including its thermal diffusion properties. The thermal diffusion is associated with the rate of heat transfer in the medium. This is characterized by both the thermal conductivity and the specific heat at constant pressure. In determining the thermal conductivity, we have used the novel relaxation time approximation for the collision integral in the relativistic Boltzmann transport equation within the kinetic theory framework in conjunction with the finite angular velocity. It is observed that the onset of rotation enhances the thermal conductivity of the medium. Additionally, the specific heat at constant pressure gets increased due to the emergence of rotation, leading to larger changes in enthalpy and energy density with temperature as compared to the nonrotating case. However, with increasing angular velocity, the growth in the specific heat at constant pressure surpasses the rise in the thermal conductivity, resulting in a decrease in the thermal diffusion constant at finite angular velocity. Smaller value of the thermal diffusion constant indicates slower heat transfer in a rotating medium as compared to that in a nonrotating medium.

25

Anisotropy effects on heavy quark dynamics in Gribov modified gluon plasma

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During the early stages of relativistic heavy ion collisions, the momentum distribution of the quark-gluon plasma is anisotropic in nature, which leads the system to instability owing to chromomagnetic plasma modes. We considered the anisotropic momentum distribution of the medium constituents, which can be obtained by squeezing or stretching the isotropic momentum distribution in one direction. We have estimated the anisotropy effects on the heavy quark dynamics utilizing the nonperturbative Gribov resummation approach in the ambit of the Fokker-Planck equation. In particular, the impact of the strength of the weak anisotropy on the heavy quark transport coefficient (two drag and four diffusion coefficient) has been studied, along with the angular dependence between the anisotropy vector and the heavy quark motion direction. Furthermore, the obtained drag coefficients have been utilized to estimate the energy loss of heavy quarks, combining both the elastic collisions and inelastic processes. It has been observed that both the momentum anisotropy and the angular dependence play a crucial role in the heavy quark dynamics.

Parallel D / 26

Constrainingts the color-charge effects of energy loss with jet axis-based substructure studies in PbPb collisions at 5.02 TeV

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Jets are well-established tools for studying the properties of the QGP. In this talk, we present a new measurement of jet substructure modification using the observable Δj, which characterizes the distance between two types of jet axes constructed from the same jet constituents. We use E-scheme and WTA axes, which have different sensitivities to soft and semi-hard medium-induced radiation. The reported fully unfolded distributions represent the first CMS measurements of the angular separation between these axes for anti-k_T $R = 0.4$ jets in 5.02 TeV PbPb collisions across several collision centralities and jet p_T intervals. Significant modifications in the Δj distributions are observed in central compared to peripheral collisions across all p_T intervals, suggesting a progressive narrowing of angular correlations, likely due to QGP-induced jet substructure modification. Alternatively, this narrowing could be explained by the predicted color-charge dependence of energy loss, leading to a larger migration of gluon-initiated jets toward lower final-state energies. We compared the data to predictions from several models, including two energy loss models with modified quark/gluon fractions due to in-medium energy loss. We found that differences in quark/gluon energy loss alone cannot fully describe the central data, suggesting the need to account for medium-induced substructure modification. These measurements probe jet substructure in a previously unexplored kinematic domain and provide new constraints on the color-charge dependence of energy loss.

Parallel A / **27**

Anisotropic Electrical Conductivity in Rotating Hadron Gas

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In non-central heavy-ion collisions, substantial orbital angular momentum (OAM) is produced and transferred to the QGP and hadronic matter, leading to effects like spin polarization and the chiral vortical effect. Previous studies have explored the impact of OAM on electrical conductivity under a non-relativistic, globally rotating QGP. In this work, we have developed a relativistic framework, relaxing earlier assumptions, to study the electrical conductivity of rotating hadronic matter. We have used the Boltzmann transport equation, integrating the Coriolis force that arises due to rotation in the hadron resonance gas (HRG) model. We have observed that similar to the Lorentz force, the Coriolis force induces anisotropy in the medium, which can be classified into three components: Hall ($\sigma^{\times}$), perpendicular ($\sigma^{\perp}$), and parallel ($\sigma^{||}$). In a rapidly rotating HRG, the Hall component ($\sigma^{\times}$) becomes dominant up to T ≈ 0.20 GeV, reflecting significant anisotropy in the medium.

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2. Effect of the Coriolis force on the electrical conductivity of quark matter: A nonrelativistic description, Ashutosh Dwibedi, Cho Win Aung, Jayanta Dey, and Sabyasachi Ghosh, Phys. Rev. C 109 (2023), 034914

28

On the local thermodynamic relations in relativistic spin hydrodynamics

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In this talk, I will present our latest research building upon the findings of PLB 850 (2024) 138533, which demonstrated that the entropy current can be derived from first principles using the quantum statistical method, bypassing the need for assumed traditional local thermodynamic forms. Our study uncovers that the local thermodynamic relations, which have been conventionally used as educated guesses in relativistic hydrodynamics with spin based on global thermodynamic equilibrium, are generally inadequate. We will present two specific examples to illustrate this: a system of massless and massive free fermions under rotation and acceleration at global thermodynamic equilibrium. Our findings reveal that the traditional local thermodynamic relations are incomplete when the spin tensor is considered. Notably, we show that the derivative of the pressure function with respect to the spin potential deviates from the spin density, acquiring corrections due to acceleration and rotation. These results suggest that for an accurate derivation of constitutive relations in relativistic spin hydrodynamics, the traditional thermodynamic relations must be extended.

Parallel D / 29

Prompt and non-prompt production of charm hadrons in proton-proton collisions at the Large Hadron Collider using machine learning

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The studies of heavy flavor (charm or bottom) hadrons in relativistic collisions provide an undisputed testing ground for the theory of strong interactions, quantum chromodynamics (QCD). As the majority of the heavy flavor particles are produced in the initial stages of the heavy-ion collisions, they experience the whole QCD medium evolution. The lightest open charm meson, D^0, and hidden charm vector meson, J/ψ, are particularly useful as they are abundantly produced as compared to other open and hidden charm hadrons, respectively. The D^0 and J/ψ mesons that are either directly formed during initial scattering or as the decay products of higher charm stages are referred to as the prompt production, which is essential to probe the QCD medium. On the other hand, the non-prompt D^0 and J/ψ mesons are usually formed as the decay products of beauty hadrons and can provide a key understanding of beauty hadrons.

In this contribution, we use machine learning (ML) models to segregate the prompt and non-prompt productions of D^0 and J/ψ mesons in proton-proton (pp) collisions at $\sqrt{s} = 13$ TeV using the track-level information of the particles like an experimental environment. We have used the PYTHIA8 event generator to simulate the events for the study, which provides a good qualitative description of experimental measurements. We have considered the $D^0 \to \pi^+ K^-$ and J/$\psi \to \mu^+\mu^-$ decay channels for our study. To separate prompt from non-prompt sector of charmonia and open charm mesons, topological production of D^0 and J/ψ are considered. We have used XGBoost, CatBoost, and

Random Forest models for D^0 related studies, whereas for J/ψ, we have used XGBoost and LighGBM models. For D^0, we have used invariant mass ($m_{\pi K}$), pseudoproper time (t_z), pseudoproper decay length (c_τ), and distance of closest approach ($\mathrm{DCA}_{\mathrm{D}_0}$) as the training inputs. For J/ψ meson, the input sample is chosen keeping ALICE Run 3 muon forward tracker upgrade in mind, which includes, invariant mass ($m_{\mu\mu}$), transverse momentum, pseudorapidity, and c_τ. The machine learning models provide up to 99\% accuracy to dissect the prompt and non-prompt production of both D^0 and J/ψ. Transverse momentum, rapidity and multiplicity differential comparisons between the true and predicted values are compared to evaluate the performance of the models. Experimental comparisons are also made wherever applicable. The ML methods used in the present study can replace the traditionally used fitting method with the added advantage of track label identification. The present ML-based identification of prompt and non-prompt charm hadrons can be useful in experiments that require precise measurements.

Parallel D / 30

Possibility of charm diffusion in an interacting hadronic matter

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We estimate the diffusion coefficient matrix for baryon number, strangeness, electric charge, and charm quantum numbers in an interacting hadron gas. For the first time, this study provides insights into the charm current and estimates the diffusion matrix coefficient for charmed states, treating them as part of a quasi-thermalized medium. We analyze the diffusion matrix coefficient as a function of temperature and center-of-mass energy, assuming van der Waals-like interactions among hadrons, which include both attractive and repulsive forces. The diffusion coefficients are determined using the relaxation time approximation to the Boltzmann transport equation, showing good agreement with existing model calculations in the hadronic regime. We observe that at low $\sqrt{s_{NN}}$, hadrons carrying conserved charges such as baryon number (B), electric charge (Q), and strangeness (S) diffuse more rapidly compared to charmed hadrons. As a result, charm fluctuations generated in the early stages of heavy-ion collisions remain significant until freeze-out. In experiments, the net proton number cumulants are typically used as a proxy for net baryon fluctuations. However, the greater diffusion of baryons could lead to a smearing of the critical point signal. Thus, we propose using net charm number fluctuations as a new probe to locate the QCD critical point.

Parallel C / 31

Induced electric field due to thermoelectric effects in an evolving quark-gluon plasma

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We have estimated the induced electric field in quark-gluon plasma (QGP) due to its thermoelectric effects. At present, the relativistic heavy-ion collisions are capable of creating QGP, a locally thermalized medium composed of quarks and gluons.

During the space-time evolution of the QGP medium, interesting thermoelectric phenomena occur due to the presence of electrically charged particles (quarks) in the QGP medium. These phenomena result in the generation of an electromagnetic (EM) field within the medium, even in central heavy-ion collisions. In peripheral collisions, the presence of a spectator current at the early stage generates a transient magnetic field and disrupts the isotropy of the induced electric field. For numerical estimation of the induced electric field, we used a quasiparticle-based model that incorporates the lattice quantum chromodynamics (lQCD) equation of state (EoS) for QGP. The cooling rates used in our calculations are derived from Gubser hydrodynamic flow, while the thermoelectric coefficients —such as Seebeck, magneto-Seebeck, and Nernst coefficients—are crucial for estimating the induced electric field. Furthermore, we explore the effects of an external time-varying magnetic field on the induced electric field and also consider the quantum effects of Landau quantization. Our findings reveal that the space-time profile of the induced electric field is zero at the center and increases away from the center. During the early stages of QGP evolution, the electric field can reach a maximum value of approximately $eE \approx 1\ m_\pi^2$, which gradually weakens over time.

Parallel D / 32

Exploring the effects of α-clustered structure of ^{16}O nuclei in anisotropic flow fluctuations in ^{16}O-^{16}O collisions at the LHC within a CGC+Hydro framework

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Azimuthal anisotropy quantified as anisotropic flow coefficients are important observables that can provide key information about the collectivity of the system formed during heavy-ion collisions. The anisotropic flow coefficients are sensitive to both the geometrical configuration of the collision overlap region and the transport properties of the medium. Recently, hints of collectivity in small collision systems like pp and p-Pb have been reported, which are traditionally used for baseline measurements to study the quark-gluon plasma (QGP) signatures and cold nuclear matter effects in heavy-ion collisions. This makes O-O and p-O collisions interesting, as they bridge the multiplicity gap between pp, p-Pb, and Pb-Pb collisions and can provide pivotal information about the observed QGP signatures in small systems. In addition, ^{16}O is a doubly magic nucleus and possesses α-cluster nuclear configuration, where one can imagine four α-particles arranging themselves at the corners of a randomly rotated regular tetrahedron.

In this contribution, we shall present the effect of the presence of the α-cluster nuclear configuration of ^{16}O on elliptic flow (v_2), triangular flow (v_3) and elliptic flow fluctuations in O-O collisions at $\sqrt{s_{\mathrm{NN}}} = 7$ TeV using a hybrid CGC+hydro model based on IPGlasma+MUSIC+iSS+UrQMD framework. The results of α-cluster nuclear configuration of ^{16}O are also compared with the Woods-Saxon nuclear profile. The results show an enhanced value of v_2 and v_3 in the highest multiplicity regions for the α-cluster case as compared to the Woods-Saxon profile. Further, a strong increase in the value of v_3/v_2 is observed when going from the top 10-20% to the top 0-10% multiplicity class for the case with α-clusters. Additionally, we find that the elliptic flow fluctuations show opposite trends with a decrease in final state multiplicity for α-cluster and Woods-Saxon nuclear density profiles. We conclude that the observables related to fluctuations are more sensitive and suited to study the effects of the α-clustered geometry in O-O collisions.

Parallel A / 33

Shear and bulk viscosity for a pure glue theory using an effective matrix model

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At nonzero temperatures, the deconfining phase transition can be analyzed using an effective matrix model to characterize the change in holonomy. The model includes gluons and two-dimensional ghost fields in the adjoint representation, or "Teens". As ghosts, the teen fields are responsible for the decrease of the pressure as $T \rightarrow T_d$, with T_d the transition temperature for deconfinement. Using the solution of this matrix model for a large number of colors, the parameters of the teen fields are adjusted so that the expectation value of the Polyakov loop is close to the values from the lattice. The shear, η, and bulk, ζ, viscosities are computed in weak coupling but nonzero holonomy. In the pure glue theory, the value of the Polyakov loop is relatively large in the deconfined phase, $\approx 1/2$ at T_d. Consequently, if s the entropy density, while η/s decreases as $T \rightarrow T_d$, it is still well above the conformal bound. In contrast, ζ/s is largest at T_d, comparable to η/s, then falls off rapidly with increasing temperature and is negligible by $\sim 2T_d$.

Parallel C / 34

Implications of Gravitational Waves data on exotic composition of Neutron stars

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A decade of Gravitational Wave observations by LIGO-Virgo collaborations has opened a new window to the Universe peeking into the exotic lives of stellar black holes and compact stars. With the observation of GW170817, the first GW observation from coalescence of binary neutron stars along with the associated multi-wavelength spectral observation such as γ-rays, X-rays, UV, IR and Radio, leading to plethora of information about such systems initiated what is fondly called as the multi-messenger era in Astronomy \& Astrophysics and cosmology. This particular observation provided vital inputs to constrain the theoretical aspects of the underlying equation of state (EoS) and therefore on the global properties of neutron stars as well, be it mass (2.73 - 3.29) $M_\odot$ or inferred radius of the canonical 1.4 $M_\odot$ object which turns out to be $\approx$ 14 km. In the present scenario, many such observations are expected to happen which may sprung surprises in the very domain of observational Astrophysics and therefore to the underlying theories as well.
\par
Theories, being the only way to understand the composition of neutron stars/ pulsars need to compliment the observations of their properties and signatures from various dynamical aspects of these compact systems. Within the mean field framework, we would present some of these results where the neutron star will be composed of various baryonic resonances as well as exotic particles such as dark matter. Finally the results will be tested to the compatibility of the GW data available.

35

Neutron star properteis constrained by the chiral effective field theory and astrophysical observations

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Chiral effective field theory has played a significant role in exploring nuclear structure and the properties of nuclear matter. It has now become foundational in understanding various nuclear phenomena. However, the theory's applicability to the nuclear matter equation of state (EOS) is limited at densities exceeding twice nuclear saturation density due to its inherent cutoff dependence. Observational data from neutron stars, such as tidal deformabilities and constraints on mass and radius,
can help extend these limits. In this presentation, we provide statistical results for neutron star characteristics—such as maximum mass, mass-radius relationship, proton fraction, and speed of sound using a nuclear energy density functional constrained by chiral effective field theory and astrophysical observations. Additionally, we discuss potential improvements to the nuclear EOS for dense nuclear matter.

Parallel C / **36**

Modelling Finite Volume Effects in the QCD Phase Diagram

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We investigate the impact of finite volume effects on the QCD phase diagram, particularly in the context of ultrarelativistic heavy ion collisions. Utilizing the Nambu-Jona-Lasinio (NJL) model, we analyze the chiral transition line in the (T, μB) plane with MIT boundary condition, simulating confinement within a fireball of limited dimensions. Our findings reveal that the transition temperature, number density, and its susceptibilities exhibit significant dependence on system volume. Notably, while the shift in the crossover transition line is modest, the first-order transition region displays pronounced volume sensitivity, particularly affecting the location of the critical point. These results underscore the necessity of accounting for finite size effects when interpreting experimental signatures of the QCD phase diagram, especially in light of ongoing and future low-energy experiments exploring regions of high baryonic density.

Parallel C / **37**

Axion effects on the nonradial oscillations of neutron stars

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We investigate the effects of including strong charge parity violating effects through axion field on the structure and the oscillation modes of the neutron stars with the possibility of a quark matter core. The effects of axions in quark matter is described through a t Hooft determinant interaction in the flavor space within the ambit of a three flavor Nambu–Jona-Lasinio model. The presence of axions seem softens the equation of state with having a larger core of quark matter compared to the case when their absence. This leads an enhancement of the f mode oscillation frequencies in hybrid stars.

38

Light nuclei production in ultra-relativistic heavy-ion collisions at LHC

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Collision of heavy nuclei at ultra-relativistic energies offer a unique opportunity to study the formation dynamics of light nuclei. Being loosely bound systems via residual strong interactions, their existence in the hot and dense medium, is very unlikely and possess interesting questions on their production mechanism in these energetic collisions. In the present contribution we will describe a "thermo-coalescence" model, a hybrid mechanism to describe the light nuclei production at ultra-relativistic energies. In this approach the transverse momentum distribution of protons are first fitted following a hydro-inspired boost-invariant blast-wave model. The extracted parameters are then used to describe the spectra of light nuclei using a coalescence prescription. Analysis of the measured yield and spectra of the deuterons produced in $\sqrt{s_{NN}} = 2.76$ TeV and $\sqrt{s_{NN}} = 5.02$ TeV Pb-Pb collisions at LHC for various centralities will be discussed in detail

Parallel B / 39

Kubo formula for a dissipative spin hydrodynamic framework with spin chemical potential as the leading order term in the hydrodynamic gradient expansion

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We present a first-order dissipative spin hydrodynamic framework, where the spin chemical potential $\omega^{\mu\nu}$ is treated as the leading term in the hydrodynamic gradient expansion, i.e., $\omega^{\mu\nu} \sim \mathcal{O}(1)$. We argue that for the consistency of the theoretical framework, the energy-momentum tensor needs to be symmetric at least up to order $\mathcal{O}(\partial)$. We consider the phenomenological form of the spin tensor, where it is anti-symmetric in the last two indices only. A comprehensive analysis of spin hydrodynamics is conducted using both macroscopic entropy current analysis and microscopic Kubo formalism, establishing consistency between the two approaches. A key finding is the entropy production

resulting from spin-orbit coupling, which alters the traditional equivalence between the Landau and Eckart fluid frames. Additionally, we identify cross-diffusion effects, where vector dissipative currents are influenced by gradients of both spin chemical potential and chemical potential corresponding to the conserved charge through off-diagonal transport coefficients. Two distinct methods for decomposing the spin tensor are proposed, and their equivalence is demonstrated through Kubo relations.

Parallel D / **40**

Understanding medium anisotropy in p–O and p–C collisions at the LHC with exotic α-clustered nuclear density profiles

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One of the major motivations for the planned p–O and O–O collisions at the LHC is to explore the possibilities of small system collectivity. Such transverse collective expansion results in the appearance of long-range azimuthal correlation and is quantified via the coefficients, v_{n}, of Fourier expansion of the azimuthal momentum distribution of the final-state particles. These flow coefficients serve as the medium response to the initial spatial anisotropy and are sensitive to the density profile of the colliding nuclei. Light nuclei such as ^{12}C and ^{16}O are theorized to possess extra stability due to the presence of an α-clustered arrangement of its nucleons. In this context, studies on ultra-relativistic p–A collisions involving ^{12}C or ^{16}O nuclei can serve a dual purpose: exploring small system collectivity along with investigating the effects of a clustered nuclear geometry on the medium anisotropy. With this motivation, for the first time, we study p–O and p–C collisions at $\sqrt{s_{\mathrm{NN}}}$ = 9.9 TeV through a multi phase transport model (AMPT) simulations. We attempt to explore how an initial α-clustered nuclear structure of ^{16}O and ^{12}C influences the production yield, initial eccentricities and flow coefficients in the final state, in comparison to an unclustered density profile, Sum-Of-Gaussians (SOG). The flow coefficients are estimated via a two-particle Q-cumulant method.

The results show that $\langle\epsilon_2\rangle$ varies with centrality in a unique manner for α-clustered p–O and p–C collisions, similar to O–O collisions. However, the centrality dependence of $\langle\epsilon_2\rangle$ and $\langle\epsilon_3\rangle$ is not effectively carried forward to the final state v_2 and v_3, owing to lesser participants. We also see that the dependence of v_2 on centrality is much less in comparison to v_3, which is reflected in the v_3/v_2, $v_2/\langle\epsilon_2\rangle$ and $v_3/\langle\epsilon_3\rangle$ ratios studied in our work. We notice that the α-clustered case shows almost a flatter trend of v_3 with centrality than the corresponding collisions with a SOG profile, possibly indicating the discretized internal structure of an α-clustered nucleus. Thus, by probing the effects of the nuclear structure employing ultra-relativistic collisions, this work serves as a transport-model-based prediction for the upcoming p–O collisions in the LHC Run 3.

Parallel C / **41**

Studying liquid-gas phase transition under the effect of rotaion in a hadron resonance gas

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Understanding the phases of quantum chromodynamics (QCD) matter has become one of the important research areas for both theoretical and experimental high-energy physics community. In the QCD phase diagram, which is characterised by temperature (T) and baryochemical potential (μ_B), a first-order phase transition is expected at high μ_B and low T, which ends at a possible critical point. This is followed by a crossover transition from hadron to quark matter as predicted by lattice QCD calculations. In addition to the magnetic field, a huge amount of vorticity is expected to be produced in a non-central heavy ion collision. This vorticity or rotation (ω) can affect the evolution of the system and, hence, the phase diagram of the QCD matter. In this work, we study the effect of rotation on the phase diagram of hadronic matter. We find that rotation plays a similar role to baryochemical potential on the thermodynamic properties of hadron gas. The rotation adds a new kind of chemical potential called rotational chemical potential. Therefore, the phase transition can occur not only in the $T - \mu_B$ plane but also in the $T - \omega$ plane. We use an interacting hadron resonance gas model with van der Waals kind of attractive and repulsive interaction among the hadrons. We observe a liquid-gas phase transition under the effect of rotation, even at zero baryochemical potential. These results allow us to reinvestigate the QCD matter properties under the effect of rotation and study the phase diagram in the $T - \mu_B - \omega$ plane.

Parallel C / 42

QCD Phase Diagram: QGP and Neutron Star Cores

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The proposed QCD Phase Diagram speculates deconfined Quark Matter at aymptotic high Temperature and Baryonic Densities. The region of QCD phase diagram characterized with low temperature and high baryonic density is been speculated to be found in the cores of neutron stars which are prone to phase transitions. The transition between the chiral and diquark condensate is being studied while reproducing some numerical results. The thermodynamic grand potential of system is minimized with respect to the order parameters m and Δ to get the form of the gap equations. Using Numerical Techniques, we analyse these gap equations to study the strong competition between chiral and diquark condensate in the 2 Flavour Superconducting Phase. The region of QCD phase diagram characterized with high temperature and low baryonic density corresponds to early stage of universe. Quark-Gluon plasma (QGP) under a statistical model is revisited. While revisiting some additional parameters having consider to compute the thermodynamic properties of the QGP. Hence the results after considering new parameters are compared with the earlier results.

Parallel B / 43

Enhancing Bayesian parameter estimation by simultaneously adapting to multiple energy-scales with RHIC and LHC data

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The evolution of the strongly interacting medium formed in heavy-ion collison is modelled with multi-stage models. The models are driven by a large number of parameters that quantify the properties of the medium and the initial stage of the heavy-ion collision. The need to find model parameters which give the best description of the experimental data imposes a multidimensional optimization problem. The Bayesian analysis has shown to be successful in constraining the parameter values, and the combined inclusion of LHC Pb—Pb 5.02 and 2.76 TeV data with additional flow observables has greatly narrowed down the uncertainties [1].

In this talk, we present our latest study in inferring the transport properties of QGP by including the RHIC Au—Au collision data in addition to the LHC data used in the previous studies [1]. Additionally, we now define the centrality separately for all parametrisations instead of using a singular definition for all of them. With the added Au—Au data and exclusive centrality calibration, the data now favour smaller values for nucleon width and minimum distance between nucleons. The model calculations with the *maximum a posteriori* (MAP) parameters give notably better agreement with the data for the anisotropic flow and the identified particle yields than the previous results.

Furthermore, we quantify the sensitivities of newly developed flow observables, Asymmetric Cumulants and Symmetry Plane Correlations, highlighting the importance of measuring independent and sensitive observables. Finally, we explore alternative initial-state models with fewer parameters to improve the estimation and address the current model limitations. This is further studied by comparing the marginal likelihood of the models. These efforts require ongoing advancements in both theoretical frameworks and computational methods.

[1] J.E. Parkkila *et al.*, New constraints for QCD matter from improved Bayesian parameter estimation in heavy-ion collisions at LHC, *Physics Lett. B 835*, 137485

44

Investigation of dynamical fluctuations of pions at different centralities in pp collisions at $\sqrt{s}$ = 5.02 TeV using AMPT model : An in-depth analysis with factorial correlator

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The work represents the bin-bin correlation using factorial correlator in pp interactions at $\sqrt{s}$ = 5.02 TeV taking into account the pseudorapidity dependence and centrality i.e. from most central to mid-central (0-10%, 10-20%, 20-30%, 30-40%, 40-50%) and Minimum bias (MB) events. To generate data sets, the study uses the Monte Carlo-based heavy-ion event generator called A Multi-Phase Transport (AMPT) model in string-melting and default mode. In this study, we have considered the pseudorapidity interval of width twelve (i.e. $\Delta\eta$ =12) around the peak of the η distribution for the generated data samples of pp collisions by the AMPT model at c.m. energy $\sqrt{s}$ = 5.02 TeV for different centrality. To analyze the properties of the factorial correlators at different bin widths, the considered phase space has been subdivided into 40 and 20 bins of widths $\delta\eta$ = 0.3 and 0.6 respectively. The slope values are extracted from the linear fit in the region $0.3 \leq D \leq 3$, and $0.6 \leq D \leq 6$ for bin width $\delta\eta$ = 0.3 and 0.6 respectively for various order of the factorial correlators. The data shows strong correlation with decreasing bin-bin separation D, supporting the validity of log-normal approximation and α model. It also demonstrates the strength of the correlation from most central to mid-central is consistent with log normal approximation. It is interesting to note that with change in $\delta\eta$, no major substantial difference has been observed from most central to mid-central and MB events.

Parallel D / 46

Cold nuclear matter effects on charmonium production in fixed target proton-nucleus collisions

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Charmonia ($c\bar{c}$) states are believed to undergo considerable suppression, if quark-gluon plasma (QGP) is formed relativistic heavy-ion collisions. However a precise identification of the "anomalous" suppression pattern and its interpretation as a signature of color deconfinement, demands a detailed understanding of charmonium production and suppression in proton-nucleus ($p + A$) collisions. In these collisions charmonium production is affected due to the presence of several different effects inside the target nucleus, collectively known as cold nuclear matter (CNM) effects resulting an increase in production cross section less than linearly with the number of target nucleons. In the foreseen contribution we plan to make detailed evaluation of the different CNM effects, namely initial state parton energy loss, nuclear shadowing and final state absorption of the nascent $c\bar{c}$ pairs in their pre-resonance or resonance stage by analyzing the available data on charmonium production in fixed target $p + A$ collision experiments from SPS, Fermilab and HERA-B. Extrapolating the observed pattern we give a prediction of the level of "normal" absorption in the upcoming experiments NA60+ at CERN SPS and CBM at FAIR.

Parallel B / 47

Elucidating QGP at finite baryon density with (3+1)D Bayesian analysis at the RHIC Beam Energy Scan program

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We present a systematic Bayesian analysis of Quark-Gluon Plasma (QGP) properties at finite baryon density using measurements of Au+Au collisions at the RHIC Beam Energy Scan program. The theoretical model simulates event-by-event (3+1)D dynamics of relativistic heavy-ion collisions with the state-of-the-art hybrid hydrodynamics and hadronic transport theory. We analyze the model's 20-dimensional posterior distributions obtained using three Gaussian Process emulators with different accuracy and demonstrate the essential role of training an accurate model emulator in the Bayesian analysis [1]. Our analysis provides robust constraints on the Quark-Gluon Plasma's transport properties and various aspects of (3+1)D relativistic nuclear dynamics using heavy-ion measurements from 7.7 to 200 GeV [2]. By running full model simulations with a few parameter sets sampled from the posterior distribution, we make timely predictions for pT differential observables, anisotropic flow rapidity decorrelation, and flow observables in O+O collisions with systematic theory uncertainties, which can be compared with the upcoming measurements from the STAR Collaboration. Finally, we highlight a detailed experimental design analysis to elucidate how individual experimental observables constrain different model parameters, providing valuable physics insights into the phenomenological model for heavy-ion collisions.
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Parallel A / 48

Chaos and thermalization in SU(2) gauge theory under in- and out-of-equilibrium conditions

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We measure the Lyapunov exponent in SU(2) gauge theory under both in and out-of-thermal equilibrium conditions to understand the chaotic nature of non-Abelian gauge theories and its implications. Very close to the deconfinement temperature T_c, we use the fact that $SU(2)$ gauge theory falls within the same universality class as a Z_2 scalar field theory and calculate the Lyapunov exponent using out-of-time-ordered correlation (OTOC) function constructed out of the scalar fields. On the other hand in a high temperature ($T >> T_c$) thermal plasma, where the hard, electric and magnetic scales are well separated, we measure the Lyapunov exponent within the effective Hamiltonian theory of the soft gauge fields (magnetic modes). For measuring the degree of chaoticity from the Lyaponov exponent we consider a particular out-of-equilibrium state of SU(2) which describes a classical fixed point of the Hamiltonian evolution of the gauge fields and exhibit self-similar scaling. Such a state is obtained through classical evolution of gauge fields whose infrared momentum modes are over-occupied, and shows similar separation of hard and soft scales similar to a thermal plasma. We show that such a state is also chaotic. By calculating the Lyapunov exponent in this non-equilibrium state and comparing with its corresponding values at similar energy density in a thermalized SU(2) plasma we provide an estimate of the equilibration time. Our study can provide some insights about the thermalization time of the non-Abelian plasma formed in the heavy-ion collisions.

Parallel A / 49

Constraint on initial conditions from nonlinear causality

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Relativistic hydrodynamics has played a vital role in understanding the bulk and the transport properties of the deconfined nuclear matter, the quark gluon plasma, created in high-energy nuclear collision. It is often supposed that the local equilibrium is reached rapidly after the collisions and that the created matter starts to behave as a fluid with small viscous effects subsequently. It is, however, not at all trivial from which stage just after the collision the fluid picture can be applied to the system. In this study, we address this issue from a point of view of nonlinear causality.

In a recent study, necessary and sufficient conditions have been obtained for the system to be causal from the analysis of characteristic velocity of nonlinear relativistic dissipative hydrodynamic equations [1]. By analyzing numerical solutions of hydrodynamic equations from these conditions, it turned out that the causality is likely to be violated in the early stage [2]. This strongly suggests that the violation of causality occurs when the system is away from the local equilibrium.

In this study, we employ a one-dimensional expanding system [3], establish a relation between a degree of nonequilibrium and violation of causality and scrutinize whether solutions for given initial conditions obey causality. We find the inverse Reynolds number, which is a measure of nonequilibrium, is highly constrained from nonlinear causality. We also demonstrate how the solution violates

or obeys the causality in a one-dimensional expanding system. We also obtain the minimum initial proper time allowed from the nonlinear causality and the observed transverse energy at RHIC and LHC. This sheds light on understanding the initial stages in high-energy nuclear collisions.

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50

Heavy quark diffusion along temperature and density axes

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We have explored the heavy (charm) quark drag and diffusion coefficient along the two extreme directions - temperature axis at zero baryon chemical potential and baryon density axis at finite temperature. Quark condensate melts down as we go along either temperature axis or density axis. Hence, being proportionally connected with condensate, constituent quark mass also melts down to current quark mass. Using the lattice QCD calculation predicted condensate profile, we have provided the heavy quark drag, diffusion estimation along temperature axis. On the other hand, using chiral model based condensate profile, we have estimated the same along the density axis. In both results, we have shown the non perturbative QCD contribution by using the temperature and density dependent constituent quark mass from LQCD and chiral model respectively and also by comparing with the current quark mass estimation.

Parallel D / 51

Open heavy-flavour hadron decay muon production with ALICE at the LHC

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The measurements of heavy-flavour (charm and beauty) production in proton-proton (pp) collisions at the LHC provide stringent test for perturbative Quantum Chromodynamics (pQCD) calculations. Furthermore, studies in pp collisions serve as a necessary baseline for similar measurements in proton-nucleus (p-A) and nucleus-nucleus (A-A) collisions in order to investigate the influence of cold- and hot-nuclear-matter effects on heavy-flavour production. In ALICE, measurements of open heavy-flavour can be performed at midrapidity and forward rapidity via semi-electronic and semi-muonic decays of heavy-flavour hadrons, respectively. The presence of Muon Forward Tracker in the upgraded ALICE detector for the LHC Run 3 provides vertexing capabilities to the Muon Spectrometer and enables to separate the open charm and beauty components. The impact of the medium formed in heavy-ion collisions on heavy quark production and dynamics can be quantified via the nuclear modification factor (R_{AA}) of muons from heavy-flavour hadron decays. The results in the measurement of R_{AA} point toward a significant heavy-quark energy loss at intermediate p_{T}. In this

contribution, the latest measurements from Run 2 and the status from Run 3 of open heavy-flavour decay muon production at forward rapidity with ALICE will be presented.

Parallel B / 52

Causal third-order viscous hydrodynamics from kinetic theory

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We derive a linearly stable and causal theory of relativistic third-order viscous hydrodynamics from the Boltzmann equation using the relaxation-time approximation. We employ a Chapman-Enskog-like iterative solution to the Boltzmann equation to obtain the viscous correction to the distribution function. Our derivation emphasizes the necessity of incorporating a new dynamical degree of freedom: specifically, an irreducible tensor of rank three. This approach differs from the recent formulation of causal third-order theory derived from the method of moments, which requires two dynamical degrees of freedom: an irreducible third-rank tensor and a fourth-rank tensor. We verify the linear stability and causality of the proposed formulation by examining perturbations around a global equilibrium state.

53

Quarkonium production in pp and Pb-Pb collisions with ALICE at the LHC in Run 3

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Quarkonium is one of the most important tools to study the strongly interacting medium under extreme conditions formed in heavy-ion collisions. Heavy quarks ($\bar{c}c$ and $\bar{b}b$) are produced in the early stages of the collisions and thus experience the whole Quark Gluon Plasma (QGP) evolution. In addition, its significant (re)generation (recombination of uncorrelated charm quark pairs) makes it a unique and interesting candidate for studying the formed QCD medium. The study of quarkonia in high-energy proton-proton (pp) collisions is used as a testing ground for quantum chromodynamics (QCD) to investigate both perturbative and non-perturbative dynamics. The initial stage, governed by hard parton-parton scatterings is described by perturbative QCD, while the later stage involves low momentum scales, and it is intrinsically non-perturbative.

The azimuthal anisotropy measurements in heavy-ion collisions provide insights on the nature of the QGP medium and of its evolution in heavy-ion collisions. The second-order Fourier coefficient (v_2) of J/ψ mesons is an observable sensitive to the degree of thermalization of charm quarks in the medium at low p_{T}, as well as to its path-length dependence on energy loss at high p_{T}. The Pb−Pb data sample collected by the ALICE experiment during LHC Run˜3 is approximately twice that collected in Run 2, representing a unique opportunity to achieve higher precision in statistics-driven measurements. This presentation will discuss the new results of the J/ψ v_2 via the dimuon decay channel using event-plane methods for Run 3 Pb−Pb data at $\sqrt{s_{\mathrm{NN}}}$ = 5.36 TeV at forward rapidity (2.5 $<$ y $<$ 4). The preliminary results on the double ratio of $\psi(2S)$-to-J/ψ as well as inclusive quarkonium yields in pp collisions at $\sqrt{s}$ = 13.6 TeV, measured by the ALICE Collaboration, will be presented and compared with current theoretical model predictions. Additionally, results from ALICE's ongoing measurements of the exotic particle X(3872) in pp collisions at $\sqrt{s}$ = 13.6 TeV will also be discussed.

Parallel C / 54

Fluctuations and correlations of net-conserved quantities at LHC energies with ALICE

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Fluctuations and correlations of net-conserved quantities, including net-baryon, net-charge, and net-strangeness, are pivotal for exploring the QCD phase structure, as they are directly related to thermodynamic susceptibility ratios in lattice QCD (LQCD) calculations. These quantities probe the thermal properties of the medium and shed light on the nature of the strongly interacting matter created in high-energy nuclear collisions

We present results on second-order diagonal and off-diagonal cumulants of net-charge, net-proton, and net-kaon, with the net-proton and net-kaon serving as proxies for the net-baryon and net-strangeness number, respectively. The measurements are performed at mid-rapidity, as a function of centrality in Pb−Pb collisions at $\sqrt{s_{\mathrm{NN}}}$ = 5.02 TeV using data recorded by the ALICE detector. The results are compared with corresponding results at lower collision energies from the STAR experiment at RHIC, and with theoretical predictions from the HIJING, EPOS and Hadron Resonance Gas model (Thermal-FIST).

Recent lattice QCD studies have highlighted the significant impact of magnetic field (eB) on these thermodynamic susceptibility ratios. Interesting experimental results for observables that are claimed to be sensitive to initial magnetic field effects will also be discussed in this presentation.

Parallel D / 55

Quarkonium polarization measurement in hadronic and nuclear collisions at forward rapidity

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Quarkonium production in ultra-relativistic collisions is an essential probe for understanding the deconfined phase of QCD matter. Further, quarkonium suppression in heavy-ion collisions supports the existence of the deconfined, thermalized, and strongly interacting QCD medium known as quark-gluon plasma (QGP). However, phenomena like collective flow, which is assumed to be another crucial feature of QGP, have been recently observed in relativistic pp collisions at the LHC energies. As pp lacks the baseline, the measurement of quarkonium suppression becomes infeasible in the conventional way. However, polarization measurements of quarkonium states may serve as a baseline-independent probe for investigating the QGP medium because it depends on the shape of the angular distribution of dileptons along a quantization axis. Analyzing quarkonium polarization in these collisions constrains the underlying production mechanisms and sheds light on the formation of bound states. Recently, the finite spin alignment of J/ψ in Pb-Pb collisions at $\sqrt{s}_{NN}$ = 5.02 TeV advocates the possible existence of spin-vorticity coupling in thermally rotating media [1]. Although a range of sources could potentially contribute to this phenomenon, it is assumed that the primary contribution arises due to the vorticity field, electromagnetic field and the strong vector meson force field. In this presentation, we summarize the quarkonium polarization measurement obtained so far using the muon spectrometer of ALICE at forward rapidity in Pb-Pb and pp collisions at LHC energies for helicity, Collins-soper and the event plane frames [1-4]. Additionally, the comparison of various theoretical model predictions with respect to experimental observation will be presented. With the help of newly built Muon Forward Tracker the precise measurements of

quarkonia polarization in hadronic and nuclear collisions along with the separation of prompt and non-prompt quarkonium states can be performed using the high statistics Run 3 data.

56

Pion and Kaon internal Structure from Light-front dynamics.

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Upcoming electron-ion collider is one of the important experiment to study the pion and Kaon internal Structure through Sullivan process. In this work, we have studied the pion and Kaon internal structure in the form of quark parton distribution function (PDFs) and form factors (FFs) in light front quark model (LFQM). These quark PDFs have been evolved to high Q^2 to compare with experimental results as well as other model predictions. As we know, there is no experimental data available for Kaon quark PDFs, so we have compared them with lattice predictions. The electromagnetic FFs of both pion and Kaon has also been extracted from generalized parton distribution. These FFs has also been compared with experimental data and lattice simulations along with their radius. We have also tried to find the effect of Baryonic Density on PDFs and FFs of these Mesons using chiral SU (3) quark mean field model.

Parallel D / 57

NON-PERTURBATIVE HEAVY QUARK DIFFUSION IN A WEAKLY MAGNETIZED THERMAL QCD MEDIUM

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Heavy quarks (HQ) are considered to be excellent probes of the hot QCD matter produced in the high-energy heavy-ion collisions. HQ diffusion coefficient is one of the fundamental transport properties of the hot QCD matter. In this work, we have calculated the HQ momentum (κ) as well as spatial (D_s) diffusion coefficients in an ambient background weak magnetic field via evaluating the scattering rate of HQ's with light thermal partons. To that end, we calculate the HQ self-energy in the presence of a weak magnetic field by using the HQ potential as a proxy for the resummed gluon propagator. The information about the magnetic field comes in via the HQ potential, wherein, the light thermal partons are assumed to occupy all Landau levels. In this potential formulation, one can consider a non-perturbative ansatz for the gluon propagator which produces a string-like confining effect in coordinate space, thus allowing for the calculation of non-perturbative contribution to the HQ transport coefficients. We have computed the heavy quark diffusion coefficients at both zero and finite momentum, observing that non-perturbative effects play a dominant role at low momentum and low temperature. Our spatial diffusion coefficient, $2\pi TD_s$, shows good agreement with recent

LQCD results. These findings can be used to calculate the heavy quark directed flow at RHIC and LHC energies.

Parallel B / 58

Viscous effects of a hot QGP medium in time dependent magnetic field and their phenomenological significance

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Momentum transport in a medium is characterized quantitatively by its shear and bulk viscosities. The shear viscous coefficient (η) governs the momentum transport transverse to the hydrodynamic flow while its bulk counterpart (ζ) does the same along the flow. In the context of quark gluon plasma (QGP), both η and ζ are very important transport coefficients, controlling phenomenologically important quantities such as the QGP thermalization time, sound attenuation length, elliptic flow, etc.

It is now well known that large initial magnetic fields (which subsequently decay) are produced in the heavy-ion collisions at RHIC and LHC, which have been shown to influence the evolution of the QGP medium. However, most studies in the literature are made with the assumption of a constant magnetic field.

In this work, we have studied, for the first time, the impact of a realistic picture of a time dependent electric and magnetic field on the shear and bulk viscosities of the medium. Both the electric and magnetic fields are considered to be exponentially decaying with time, and the study is valid in the regime where the magnetic field strength is weak ($eB \ll T^2$). The evaluation has been done in the kinetic theory framework wherein we have solved the relativistic Boltzmann equation within the relaxation time approximation type collision kernel. We have shown that the constant weak field results as well as the $B = 0$ results in the literature can be obtained as special cases of our general results. We have observed that the shear and bulk viscosities increase with time and conversely decrease with the strength of the magnetic field. To connect these observations with the experiment we have obtained the thermalization time, the sound attenuation length and other various phenomenologically significant quantities, using our results of η and ζ.

Parallel B / 59

Rapidity scan with DCCI at LHC energy

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In recent years, analyses using RHIC-BES data have been actively conducted to explore the high baryon number density region in the QCD phase diagram. Meanwhile, even in high-energy collisions, such as RHIC and LHC energies, the presence of high baryon number density matter in the

forward rapidity region has been suggested [1]. This implies that, in addition to the analysis of BES data, a rapidity scan—analyzing data along the collision axis in such high-energy collisions—could serve as complementary ways to explore the high baryon number density region in the phase diagram. However, a model that provides a comprehensive description of the collision, from low p_T to high p_T and from midrapidity to forward rapidity, is essential for precise studies of the rapidity scan. Furthermore, since it is not at all trivial whether the produced matter has reached equilibrium in the forward rapidity region, a model capable of describing the dynamical evolution of both equilibrium and non-equilibrium components is required.

The state-of-the-art dynamical core-corona initialization (DCCI) model [2] is a novel framework that dynamically describes the space-time evolution of both equilibrium and non-equilibrium components including their interactions. Consequently, it has a great success in comprehensively describing experimental data of high-energy collisions from low p_T to high p_T at midrapidity. Thus, the DCCI model would be a strong candidate for rapidity scan studies. In this study, we extended the DCCI model by including baryon number current within the ideal hydrodynamics and modeled the dynamical deposition of baryon number into the fluid, enabling us to describe a gradual thermalization process of baryon number alongside the fluid formation through the dynamical initialization. Using this model, we aimed to clarify the baryon number distribution of each core (equilibrium) and corona (non-equilibrium) component across the entire system at the LHC energy. Specifically, we determined which regions of the QCD phase diagram are accessible with the rapidity scan at the LHC energy and showed which rapidity regions of high-energy collisions are comparable to the baryon number densities achieved in low-energy collisions. This study strongly supports the existence of high baryon number density as equilibrated matter in the forward rapidity region at the LHC energy.

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60

A Bayesian approach to revisit the dense matter equations of state in light of the compact object HESS J1731-347

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The recent observation of the compact object HESS J1731-347, with a mass of 0.77 $^{+0.20}_{-0.17}$ $\mathrm{M}_\odot$ and radius $10.4^{+0.86}_{-0.78}$ km, make it one of the most intriguing objects if it truly is a neutron star. In this paper, we explore the dense matter equation of state (EoS) in the context of this object being a neutron star. We consider three EoS categories—neutron stars, strange stars, and hybrid stars—and apply Bayesian model selection to evaluate them. Our results indicate that for hadronic models, a stiffer EoS at intermediate densities is favored. Consequently, the Brueckner-Hartree-Fock approximation and models using Effective-interactions diverge from recent astrophysical data when HESS J1731-347 is included. For strange stars, EoSs with three-flavor quark matter prefer smaller bag parameters. When examining hybrid EoS models with a first-order phase transition, we find a tendency for early phase transitions. Overall, when comparing preferred EoS across these categories, hybrid EoSs best align with current astrophysical constraints.

Plenary / 61

Observation of the Antimatter Hypernucleus

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Matter-antimatter asymmetry is a research topic of fundamental interest, as it is the basis for the existence of the matter world, which survived annihilation with antimatter in the early Universe. High energy nuclear collisions create conditions similar to the Universe microseconds after the Big Bang, with comparable amounts of matter and antimatter.
Much of the antimatter created escapes the rapidly expanding fireball without annihilation, making such collisions an effective experimental tool to create heavy antimatter nuclear objects and study their properties.

In this presentation, we give a brief review of the history of antimatter hypernuclear research, then we report the first discovery of the heaviest antimatter particle ($^{4}_{\bar{\Lambda}}\overline{\mathrm{H}}$) ever seen on Earth, composed of an anti-Lambda ($\bar{\Lambda}$), an antiproton and two antineutrons.
$^{4}_{\bar{\Lambda}}\overline{\mathrm{H}}$ is reconstructed through its two-body decay in ultrarelativistic heavy ion collisions at the STAR experiment at the Relativistic Heavy Ion Collider.A total of about 6.4 billion U+U, Au+Au, Ru+Ru, and Zr+Zr collision events with center-of-mass energy per colliding nucleon-nucleon pair $\sqrt{s_{NN}}$=193GeV (U+U) or 200GeV (other systems) are used in this analysis.
The measurement of antihypernuclei $^{4}_{\bar{\Lambda}}\overline{\mathrm{H}}$ lifetime is achieved for the first time and compared with lifetime of their corresponding hypernuclei $^{4}_{\Lambda}\mathrm{H}$, which allows for further tests of the CPT symmetry. Production yield ratios among (anti)hypernuclei and (anti)nuclei are also measured and compared with theoretical model predictions, shedding light on their production mechanism.

Parallel A / 62

Study of resonances flow and production in Pb-Pb collisions at $\sqrt{s_{\mathrm{NN}}}$ = 5.36 TeV with ALICE

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Hadronic resonances play an important role in understanding the different phases of the evolution of relativistic heavy-ion collisions. Due to the short lifetime of resonances, their yields may be influenced by interactions in the final stage hadronic phase where rescattering can alter the momentum of the resonance decay products, preventing their reconstruction through invariant-mass analysis, while pseudo-elastic hadron scattering can regenerate them. ALICE measurements have shown evidence of the rescattering effect through the measurements of resonance yields and comparing them with stable hadrons. Another key observable that provides insight into final-state effects is the measurement of elliptic flow (v_2), which results from the system's anisotropic expansion due to the initial spatial asymmetry in the collision geometry. Late-stage hadronic rescattering can alter the momentum distributions of resonances, thereby influencing their elliptic flow. Therefore, measuring the elliptic flow of resonances like K^{*0} and ϕ along with their yields can provide deeper insights into the impact of rescattering effects.

In this contribution, we present the latest ALICE results from Run 3, focusing on the measurement of elliptic flow and the production of K^{*0} and ϕ resonances in Pb-Pb collisions at $\sqrt{s_{\mathrm{NN}}}$ = 5.36 TeV. The measurements will be compared with the ALICE results from Run 2 data.

Parallel B / 63

Global and local spin-polarization of Λ-hyperons in relativistic heavy-ion collisions

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As recently observed by the STAR and ALICE collaborations, the global and local spin polarization of Λ-hyperons provides new insights into spin dynamics in heavy-ion collisions. There are various contributing factors that could be the source of hyperon polarization. However, among them, the vorticity field is widely considered as the primary source of particle polarization in heavy-ion collisions. Recent findings suggest that the transverse component of the vorticity field drives global spin polarization, while the longitudinal component accounts for local polarization. For the first time, within the framework of second-order relativistic viscous hydrodynamics, we incorporate vorticity, viscosity, and magnetic field effects into a unified hydrodynamic model to estimate the global polarization of Λ-hyperons, using vorticity evolution data at the freeze-out hypersurface. Additionally, to further elucidate spin-polarization dynamics, we explore the local polarization of Λ-hyperons due to thermal vorticity and the thermal shear tensor in Au+Au and Pb+Pb collisions at $\sqrt{s_{NN}} = 200$ GeV and 5.02 TeV, respectively, by employing hydrodynamic and transport models. As the coupling between vorticity, viscosity, and magnetic field makes medium evolution highly complex, our findings provide a unique insight into understanding the hyperon polarization in relativistic heavy-ion collisions

64

Chiral and magnetic effects on the heavy quark dynamics in the hot and dense medium

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Relativistic viscous hydrodynamics has been a major breakthrough in describing QGP evolution, and now, data-driven methods are gaining attention as QGP research moves into a high-precision era [1]. Hard probes, on the other hand, like jets and heavy quarks, provide insight into the QGP due to their interaction with its constituent as they travel through it, which is key to understanding the experimental observable jet quenching. Recent interest has also grown around chiral anomalies and parity-violating effects, where interactions between chiral quarks and gluonic fields create an imbalance between left- and right-handed fermions [2]. Additionally, the strong magnetic field present in the early stages of heavy-ion collisions has been shown to induce medium anisotropy [3,4], affecting QCD properties and spurring phenomena like the Chiral Magnetic Effect (CME), which is one of the active areas of ongoing studies in contemporary physics [5]. Both magnetic fields and chiral asymmetry influence parton energy loss and motivate to explore these effects on parton behaviour in the QGP.

We investigate how chiral imbalance, as well as the strength and direction of the magnetic field, influence the soft contribution of parton energy loss. Using a semi-classical framework, we develop a formalism to describe the energy loss of an energetic parton as it interacts with chromodynamic fields in the QCD medium. The parton's motion within the plasma is modelled using Wong's equations, treating it as a classical particle with SU(Nc) color charge. The effect of the parton on the color field configuration is incorporated via the linearized Yang-Mills equations. Our findings indicate that both chiral asymmetry and the magnetic field shape the mechanisms of parton energy loss.

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65

Is charmonia a good probe to investigate on hot QCD matter in ultra-relativistic $p-p$ collisions at the LHC energies?

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Recent observations on the high-multiplicity $p-p$ collisions suggest possible formation of the strongly interacting quark-gluon plasma (QGP), based on the phenomenon similar to those observed in heavy-ion (A—A)collisions. Inspired by these observations, we attempt to investigate the existence of a QGP-like medium in $p-p$ collision. However, unlike A—A collisions, the system size is expected to be much smaller $p-p$ collisions, which implies comparable transverse and longitudinal dimensions, leading to rapid cooling of the medium. Consequently, it changes the dynamics of charmonium states, which is highly unlike the charmonium dynamics in heavy-ion collisions. As medium dynamics affect charmonium yield, we first employ second-order viscous hydrodynamic to obtain the medium evolution and its thermal velocity. As charmonium traverses through the medium, the relative velocity between charmonium and medium induces the relativistic Doppler shift, leading to an effective temperature for charmonium. The implicit temperature of the particle depends on its velocity and medium thermal velocity. In this work, we observed that quarkonia traversing through the medium does not carry the same temperature as a medium due to the relativistic Doppler shift effect. Here we show how particle velocity (v_Q) or transverse momentum (p_T) influences the suppression and regeneration of the charmonium in the medium. The present study incorporates the QGP-induced suppression effects, such as collisional damping, which arises because of the energy loss due to interactions of the charmonium with the medium and gluonic dissociation as the consequence of quarkonium states into a color octet lead interactions with gluons. It also includes the regeneration of charmonium states within the medium due to the transition from the color octet state to the color singlet state. Additionally, we observe that the temperature evolution is fast enough in $p-p$ collision, which induces rapid changes in the Hamiltonian of the system, causing the transition from J/ψ to ψ(2S) state. This transition between charmonium states is obtained by considering the non-adiabatic framework for evolving charmonium states. Through these combined effects, we explore the dependence of charmonium yield on transverse momentum (p_T) and event multiplicity in $p-p$ collisions, providing new insights into the dynamics of strongly interacting matter and serving as a potential probe for the existence of a thermalized QCD medium in small collision systems.

Parallel B / 66

Investigation of the cluster structures in light nuclei through photon flow in O+O collisions at LHC energies

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In relativistic nuclear collisions, spatial anisotropies characterized by initial eccentricity, triangularity, and higher-order eccentricities arise from the geometry of the collision and fluctuations in the initial energy density distribution. These spatial anisotropies subsequently manifest as momentum anisotropies in the final-state particles through the collective expansion of the hot and dense medium produced in such collisions. The presence of cluster structures in light nuclei, such as ^{7}Be, ^{9}Be, ^{12}C, and ^{16}O, induces nuclear deformities, resulting in significant spatial anisotropies in the overlap region when collided at relativistic energies.
A recent proposal for dedicated ^{16}O-^{16}O collision runs at 7 TeV at the LHC has opened up the opportunity for experimental verification of cluster structures at such energies and investigation of α-cluster structures in light nuclei by examining final state observables in relativistic nuclear collisions. Moreover, the system size of ^{16}O-^{16}O collisions is comparable to high-multiplicity proton-proton (pp) and peripheral lead-lead (Pb-Pb) collisions which provides a unique opportunity to investigate the origins of collective behavior in small collision systems.
In this work, we investigate the initial state produced in collisions of α-clustered oxygen nuclei at 7 TeV assuming tetrahedral structures. We use GLISSANDO initial conditions and study the resulting flow observables for photons within the framework of the MUSIC hydrodynamics model and state-of-the-art rate of photon production. Our study compares these results with those from unclustered ^{16}O-^{16}O collisions, revealing significant qualitative and quantitative differences in photon observables between the two cases.
We demonstrate that photon observables in ^{16}O-^{16}O collisions can serve as a valuable probe for investigating the nucleon-level geometry as well as the initial state produced in relativistic nuclear collisions.

Parallel A / 67

Neural network study of the impact of nuclear structures in heavy ion collisions

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Understanding the nuclear structure in heavy-ion collisions is essential, as it critically influences final state observables. However, characterizing the structure of heavy nuclei in high-energy collisions remains challenging. Current simulation methods for modeling final state events based on initial state data are highly reliant on model parameters, requiring extensive tuning and adjustment. To simplify nuclear structure estimation and minimize model parameter dependencies, we propose a novel approach of using a state-of-the-art neural network architecture that maps final state observables directly with initial nuclear structure characteristics. We train this model with $^{238}U +^{238} U$ ($\sqrt{s_{NN}} = 193$ GeV) and $^{129}Xe +^{129} Xe$ ($\sqrt{s_{NN}} = 5.44$ TeV) collision data to ensure model robustness across system sizes and collision energies. This allows us to extract quantitative information on nuclear deformation from event-by-event correlations of final state observables, effectively minimizing parameter influence. Our study leverages various three-particle and four-particle correlations, alongside their combinations, to train the models, analyze error distribution patterns, and identify the most effective observables for accurate and precise nuclear deformation estimation. We found that prediction accuracy strongly depends on the type of nuclear deformation used to train the models, with accuracy ranging from $90\% - 100\%$, depending on the specific deformation parameters. The results also reveal that flow-transverse momentum correlation plays the leading role. The method developed in this study aims to advance our understanding of the initial state in heavy-ion collisions, potentially providing a robust framework for probing nuclear structures with reduced computational constraints.

Parallel B / 68

An investigation of forward-backward correlations in hybrid UrQMD-hydro generated data

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One of the prime objectives of heavy ion collisions (HIC) is to find experimental evidence of the deconfinement phase transition from hadronic matter to quark-gluon plasma (QGP) in the reaction products of heavy ion collisions. Various hadronic models are used to study the investigation of the signature of QGP. One of the most successful models is the hybrid UrQMD-hydro model. It is a micro+macro hybrid approach that incorporates a hydrodynamic phase into the UrQMD hadronic model using Equations of State (EoS's). The evolution of the system is divided into three parts: (i) initialize with particle degrees of freedom; (ii) evolve with hydrodynamics; and (iii) free particle production with the Cooper-Frye approach.\par
Numerous observables are used to study correlations and fluctuations in HIC. One such important observable is forward-backward (F-B) correlations in rapidity or pseudorapidity space. The source of the fluctuations in the final state phases is the initial event-by-event fluctuation in energy density. Many researchers have already studied F-B correlations. A rigorous study on F-B correlations in nucleus-nucleus collisions has been reported by NA22 Collaboration, STAR of RHIC, and ALICE of LHC. The same study will be significant to be carried out at the highest SIS100 energy of FAIR as according to the hydrodynamical calculations the deconfined phase boundary will be accessible around the same energy. In this study, an attempt has been made to investigate the F-B correlation in UrQMD-hydro generated data for 10 AGeV Au+Au collisions.

Parallel C / 70

Investigations of event-by-event fluctuations of mean transverse momentum ($\langle p_{\mathrm{T}} \rangle$) in pp collisions at $\sqrt{s}$= 13 TeV with PYTHIA8 and HERWIG7 models

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The study of event-by-event mean transverse momentum ($\langle p_{\mathrm{T}} \rangle$) fluctuations is reported in terms of the integral two-particle correlator ($\langle \Delta p_{\mathrm{T}} \Delta p_{\mathrm{T}} \rangle$) and skewness of the event-wise $\langle p_{\mathrm{T}} \rangle$ distribution in proton−proton (pp) collisions at $\sqrt{s} = 13$ TeV. The simulations were carried out using the Monte Carlo event generators PYTHIA8 and HERWIG7. Charged particles with transverse momentum (p_{T}) and pseudo-rapidity (η) ranges $0.15 \leq p_{\mathrm{T}} \leq 2.0$ GeV/c and $|\eta| \leq 0.8$ were taken into the consideration. The correlator $\langle \Delta p_{\mathrm{T}} \Delta p_{\mathrm{T}} \rangle$ is observed to follow distinct declining trends with the average charged particle multiplicity ($\langle N_{\mathrm{ch}} \rangle$) for PYTHIA8 and HERWIG7 models. Furthermore, both models yield positive finite skewness in low-multiplicity events. The observables are additionally studied using the transverse spherocity estimator (S_0) to comprehend the relative contributions of hard scattering (jets) and soft multi-partonic interactions (MPI) to the observed fluctuations. The comparative measurements using these models would help in understanding the fluctuation dynamics and constraint the particle productions in such models.

Parallel D / 71

Observation of asymmetric jet shape in a longitudinally boosted flowing medium in PbPb collisions with CMS

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The interactions between jets and the longitudinal-boosted quark-gluon plasma (QGP) lead to softer particles drifting away from the jet core, where high-p_{T} particles remain concentrated, resulting in an intra-jet asymmetry. Investigating this asymmetry, particularly at forward rapidities, offers a novel avenue to probe jet-medium dynamics. Using the PbPb and pp data at $\sqrt{s_{\mathrm{NN}}} = 5.02$ TeV collected by the CMS detector, the near-side jet peak of two-particle correlation functions have been examined to explore jet modifications and novel boost invariance phenomena in forward rapidity. The peak exhibits substantial broadening along the longitudinal ($\Delta\eta$) axis from peripheral to central PbPb collisions, indicating energy loss by the progenitor parton. A significant rapidity-dependent asymmetry in associated particle yields has been observed for the first time, with a pronounced difference between $\Delta\eta > 0$ and $\Delta\eta < 0$ that increases at forward rapidity and in central PbPb collisions. This finding, particularly evident for high-p_{T} particles, points to a potential violation of boost invariance at forward rapidity. Comparisons with different theoretical models will be discussed to understand the influence of jet-medium interactions on jet structure.

Parallel D / **72**

Collective flow measurement of $D_{\mathrm{s}}^{\pm}$ meson in PbPb collision at 5.02 TeV with CMS experiment

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The interaction of heavy quarks with the quark-gluon plasma (QGP) significantly influences their azimuthal distribution and transverse momentum (p_{T}) spectrum, making azimuthal anisotropy coefficients (v_n) and nuclear modification factors (R_{AA}) essential tools for studying QGP properties, as they reveal collective flow and energy loss mechanisms of heavy quarks. In this talk, we present the first measurements of the elliptic (v_2) and triangular (v_3) flow coefficients of $D_s^{\pm}$ mesons in lead-lead (PbPb) collisions at a center-of-mass energy of 5.02 TeV, using the CMS experiment. The measurements, performed as a function of transverse momentum across various centrality classes, set a new standard of precision at this energy, expanding the kinematic range compared to previous studies. The broader kinematic coverage and the first-ever v_3 measurement of $D_s^{\pm}$ mesons provide new insights into charm quark flow generation mechanisms and the impact of hadronization on flow. We compare the flow of $D_s^{\pm}$ mesons with that of D^0 mesons to investigate the potential effect of strange quark hadronization. These results also offer a unique opportunity to explore the influence of initial-state effects on heavy quark dynamics. Additionally, comparison with theoretical models provides critical validation of the underlying physics mechanisms governing these processes.

Parallel B / **73**

Probing the hottest droplet of fluid through correlations and fluctuations of collective observables

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The matter produced in an ultra-relativistic heavy-ion collision, dubbed as the QGP, posses a temperature 10^5 times that of Sun's core and survives for a very short time (10^{-22} s), producing thousands of particles which exhibit collective motion described by some global observables, e.g. charged particle multiplicity(N_{ch}), mean transverse momentum per particle ($[p_T]$), harmonic flow (V_n) etc. Fluctuations and correlations between these observables contain crucial information of the QGP medium as well as of the nuclear properties. We study in hydrodynamic model Pearson correlation coefficient between $[p_T]$ and v_n^2, which serves as an excellent tool to map the correlations present in the initial state. We generalize such correlations to higher order in terms of the normalized symmetric cumulants which put additional useful constraints on the initial state models. To probe p_T-dependent event-by-event fluctuation of V_n, we study factorization breaking coefficient, which shows decorrelation at higher p_T-bins. We study these observables for different centralities and compare our model results with the experimental data. We further our study for the fluctuation of $[p_T]$ in ultra-central Pb+Pb collision and explain the sudden fall in the ATLAS data over a narrow range of multiplicity. We show in our model that this sharp fall is a consequence of the underlying thermalization assumption of the system. We also make further robust predictions for mean, skewness and kurtosis in the ultra-central domain. We also study recently introduced $v_0(p_T)$ which is similar to anisotropic flow in terms of its collective nature and, it correlates the spectra with the event-by-event mean transverse momentum per particle. Furthermore, we study multiplicity in ultra-central p+Pb collision as a function of pseudorapidity, and centrality defined from the energy deposited in a calorimeter, and show that fluctuations of the multiplicity and the centrality estimator are predominantly due to quantum fluctuations, with impact parameter fluctuations playing negligible role. We argue that by repeating the same analysis with a different centrality estimator, direct information can be obtained about the rapidity decorrelation in particle production. Through these above-mentioned studies, we present an overall picture how correlations and fluctuations of the collective observables can be used to study the dynamics and properties of the QGP medium. (arXiv: 2103.15338, 2109.07781, 2303.15323, 2405.14671, 2407.17313)

Parallel A / 74

Development of an ALPIDE telescope and its test results at PF-AR in KEK

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The ALICE collaboration at the LHC is preparing for the Inner Tracking System 3 (ITS3) upgrade during the Long Shutdown 3 period. A chip test setup, namely, a telescope, consisting of 6 ALPIDE chips aligned along the beam path, enables us to reconstruct beam particle tracks and investigate a DUT (Device Under Test) chip placed between the chip layers. The Korean ALICE TeleScope, named KATS, was developed following the CERN version. The Korean ALICE experiment group (KoALICE) successfully conducted a test operation of KATS with a bent ALPIDE as a DUT using an electron beam at PF-AR, KEK. This talk will introduce the KATS and its performance with the test results.

Parallel D / 75

Multiplicity and rapidity dependent study of (multi)-strange hadrons in small collision system using the STAR detector

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Strangeness enhancement has long been considered as a signature of the quark-gluon plasma formation in heavy-ion collisions. Strangeness enhancement has also been observed in small systems at the LHC, but the underlying physics is not yet fully understood. This motivates studies of strange hadron production in small systems at RHIC, where the energy density of the created system is expected to be smaller than that at the LHC and therefore a hot and deconfined medium is less likely to be created. Results on the multiplicity dependence of strange hadron production in small systems can be compared to peripheral heavy-ion collisions, and help to understanding the role of event multiplicity in strange hadron production. Study of rapidity asymmetry ($\mathrm{Y}_{\mathrm{Asym}}$) of the strange hadron production and nuclear modification factors ($\mathrm{R}_{\mathrm{dAu}}$) in d+Au collisions can also give insight on cold nuclear matter effects.

We present measurements of (multi)-strange hadrons (K^0_S, Λ, Ξ and Ω) in d+Au collisions at $\sqrt{\mathrm{s_{NN}}}$ = 200 GeV, collected by STAR in 2016. We investigate the multiplicity dependence of (multi)-strange hadron transverse momentum (p_{T}) spectra, p_{T}-integrated rapidity density distributions (dN/dy), average transverse momentum ($\langle p_{\mathrm{T}} \rangle$), and yield ratios to pions. $\mathrm{R}_{\mathrm{dAu}}$ and $\mathrm{Y}_{\mathrm{Asym}}$ for these particles are presented. The implications of these measurements on the possible formation of a hot and deconfined medium and the origin of strangeness enhancement in small systems are discussed.

Parallel C / **76**

Higher order cumulants of net-particle distributions in pp collisions at $\sqrt{s}$ = 13 TeV using Pythia and Herwig

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Higher order cumulants of the distributions of conserved quantities, like net-charge, net-baryon and net-strangeness in heavy-ion collisions, are regarded as sensitive observables to determine the freeze-out parameters and the nature of phase transitions at the LHC energies. Recently, several experimental results suggest the possible formation of QGP medium in high-multiplicity pp collisions. Therefore, baseline measurements of the higher order cumulants of the net-particle distributions in pp collisions are essential to compare with the experimental results for understanding the dynamics of small systems. In this work, we report the first and a detailed Monte-Carlo study of the measurements of cumulants and their ratios for net-charge, net-hadron, net-kaon, net-baryon, and net-proton distributions in pp collisions at $\sqrt{s}$=13 TeV using pQCD models like Pythia8 and Herwig. We also discuss the effect of different particle production mechanisms, kinematic acceptance, and volume fluctuations on higher-order cumulants. This simulation study will serve as a baseline for the upcoming measurements at the LHC. Additionally, it will shed more light on the measurement of cumulants and the connection between small systems and heavy-ion collisions at the LHC.

Parallel A / **77**

Understanding properties of the Dirac eigenspectrum in QCD and approach to thermalization

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In this work, we study the localization properties of the eigenstates of non-Abelian SU(3) gauge theory both with and without dynamical quark flavors in a gauge invariant manner, using first-principles lattice gauge theory techniques. We use the eigenspectrum of a probe (overlap) Dirac operator to understand the properties of thermal gauge ensembles of 2+1 flavor QCD generated using domain wall fermions as well as pure SU(3) gauge theory. Focusing on the infrared part of eigenspectrum that lie within the non-perturbative magnetic scale, we propose suitable observables that allow us to unambiguously categorize different regions of the eigenspectrum. While most of these so-called magnetic modes are completely delocalized and chaotic, with nearest-neighbor level spacing fluctuations similar to random matrices of a Gaussian unitary ensemble (GUE), few eigenmodes with fractal-like properties start to appear at temperatures just near and above the chiral crossover temperature. We show that their fractal dimensions carry information about the universality class of the chiral transition in QCD.

Having demonstrated that at sufficiently high temperatures, the non-Abelian plasma is gluon dominated with large occupation numbers in the infra-red and exhibits properties similar to a chaotic system, we discuss its consequences for heavy-ion experiments. Starting from a non-equilibrium initial state of SU(3) gluons inspired by the Color
Glass Condensate effective theory, a real-time classical-statistical evolution leads to a self-similar scaling regime where we show that infrared magnetic modes are also over-occupied and chaotic. Thus by matching the evolving magnetic scale in this non-equilibrium scaling regime with that of a typical thermal state of QCD, we estimate a thermalization time of ~ 1.44 fm/c.
Reference: Understanding the approach to thermalization from the eigenspectrum of non-Abelian gauge theories, Harshit Pandey, Ravi Shanker, Sayantan Sharma, arXiv:2407.09253 [hep-lat]

Parallel C / 78

Chiral cross-over in Hadron Resonance Gas model

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We investigate the behavior of the chiral condensate within a Hadron Resonance Gas model, incorporating repulsive mean-field interactions among baryons. By calibrating the strength of these interactions to match the lattice QCD estimations of higher-order baryon charge susceptibilities, we can extend this model to higher baryon densities, where lattice QCD encounters challenges due to the sign problem. Our analysis focuses on estimating the chiral pseudocritical line by studying the temperature dependence of the chiral condensate as a function of μ_B. We describe the crossover line using a parametric form, $T_{pc}(\mu_B)/T_{pc}(0) = 1 - \kappa_2(\mu_B/T_{pc}(0))^2 - \kappa_4(\mu_B/T_{pc}(0))^4$. Our findings yield $\kappa_2 = 0.0150(2)$ and $\kappa_4 = 3.1(6) \cdot 10^{-5}$. The agreement of κ_2 with lattice QCD results is excellent, and our study marks the first identification of a non-negligible κ_4 term within this context. Moreover, the separation between the freeze-out curve and the pseudo-critical line widens at higher densities, suggesting a prolonged hadronic phase at lower collision energies.

Parallel B / 79

Insights into Nuclear Modification Factors in O-O collisions at LHC energies with a transport model

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Extensive research at the Large Hadron Collider (LHC) and the Relativistic Heavy Ion Collider (RHIC) on Pb-Pb and Au-Au collisions have helped us develop and understand the properties of the quark-gluon plasma (QGP) in heavy-ion collisions. Recent investigation suggests that QGP-droplets may occur in small collision systems such as high-multiplicity pp collisions. O-O collisions are anticipated in the upcoming run at the LHC. This will provide an important and timely opportunity to investigate the effects seen in high-multiplicity pp and p-Pb collisions with a system having a similar number of participating nucleons and final-state multiplicity but with a larger geometrical transverse overlap, thereby enhancing jet-quenching effects, which depend on path length. In the current work, we have implemented both Woods-Saxon and an α-cluster tetrahedral structure in the oxygen nucleus using a multi-phase transport (AMPT) model. We report the nuclear modification factor (RAA) for all charged hadrons and identified particles for most central, mid-central, and peripheral collisions in the O-O collisions at $\sqrt{s_{NN}}$ = 7 TeV in the case of both Woods-Saxon and α-clustered density profiles. Additionally, we study the rapidity dependence of RAA for all charged hadrons. We have also observed the behavior of RAA with the same multiplicity environment between O-O and Pb-Pb collisions. A study like this will assist us in understanding the implications of nuclear density profiles and provide a realistic baseline measurement to compare experimental results in the future.

Parallel A / 80

Effects of collision dynamics on pϕ femtoscopy

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Femtoscopy in high-energy nuclear collisions is a novel phenomenological tool to study low-energy hadron interactions, and active studies in the past decade have demonstrated its usefulness [1]. Thus, hadron interaction study via femtoscopy is now advancing to unravel less understood interactions, such as baryon-vector meson interactions. However, since existing studies have assumed simple static Gaussian source functions, the influence of collision dynamics and kinematics has not yet been fully understood.

In this study, we utilized a state-of-the-art dynamical model, DCCI [2], to investigate the influence of collision dynamics and kinematics on the pϕ correlation function in high-multiplicity p+p collisions. Regarding pϕ femtoscopy, a recent study using a Gaussian source [3] indicated the possible existence of a bound state from the ALICE correlation data. We reanalyzed the correlation function using DCCI and found that the collision dynamics, such as collectivity and hadronic rescattering, leads to a non-Gaussian momentum-dependent source [4]. Consequently, the correlation function slightly differs from that obtained using a Gaussian source. This emphasizes the importance of considering collision dynamics and kinematics for future high-precision femtoscopic studies.

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Parallel C / 81

Understanding flavor mixing from the curvature of chiral crossover line

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Using a $(2+1)$-flavor Nambu–Jona-Lasinio (NJL) model, we study the effects of the strangeness chemical potential (μ_S) and vector interactions on the chiral crossover lines, which we then use to examine flavor mixing within this framework. With the curvature coefficients, κ_2's, showing excellent agreement with available lattice QCD (LQCD) findings, we estimate the permissible strength of various types of vector interactions. A key finding is that κ_2^B exhibits a nontrivial decreasing trend with increasing μ_S, eventually becoming negative at sufficiently high μ_S. This behavior strongly depends on flavor mixing due to the $U(1)_A$-breaking 't Hooft interaction and vector interaction. We propose this unique trend as a valuable metric for quantifying flavor mixing in both NJL-like models and QCD, advocating for further exploration of this effect in LQCD.

Parallel D / 82

Study of identified particle production in high multiplicity pp collisions at $\sqrt{s}$ =13 TeV with ALICE at the LHC

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In proton-proton and proton-lead collisions at the LHC, signatures like those observed in lead-lead collisions arise as the multiplicity of charged particles produced in the collision increases. In AA collisions, these features are attributed to the formation of a deconfined state of matter formed by quarks and gluons, known as the Quark–Gluon Plasma (QGP). Most notably, these include a mass-dependent hardening of the transverse momentum distributions (explained as an effect of the radial flow) and an enhancement of strange hadrons (understood as a release from canonical suppression). The origin of these phenomena in small collision systems has yet to be understood, warranting new measurements that bridge the gap between small and large collision systems. This contribution presents the measurements of $\pi^{\pm}$ $K^{\pm}$ and p($\bar{p}$) obtained in high-multiplicity triggered events with the ALICE detector at the LHC.

This new set of results allows us to probe the light-flavour particle-production mechanisms at unprecedented charged-particle multiplicities of about five times the one obtained on average in pp collisions, filling the gap between pp and larger systems. The results are compared as a function of the charged-particle multiplicity to measurements in pp, pA, and AA collisions. The particle-production mechanisms affecting dynamics and hadrochemistry are tested by measuring the average transverse momentum and integrated particle yields. The results are compared to predictions from the state-of-the-art Monte Carlo models such as Pythia and EPOS.

83

Anisotropy in magnetized quark matter

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We study the characteristics of quark matter under the influence of a background magnetic field with anomalous magnetic moment (AMM) of quarks at finite temperature and quark chemical potential in the framework of Polyakov loop extended Nambu Jona-Lasinio (PNJL) model, which is relevant for the physical scenario of non-central relativistic heavy ion collisions (HICs). It is observed that the presence of AMM lowers the transition temperature from the chirally broken phase to the restored phase indicating inverse Magnetic catalysis (IMC). In contrast, without AMM, the transition temperature rises showing Magnetic catalysis (MC). Another important finding is the anisotropy which is created due to the presence
of magnetic field in various thermodynamic quantities such as speed of sound, isothermal compressibility dividing into parallel and perpendicular components with respect to the direction of the background magnetic
field. Though the qualitative nature of parallel and perpendicular components of squared speed of sound appear similar, they differ in magnitude at lower values of temperature. The parallel and perpendicular
components of isothermal compressibility decrease with increasing temperature, indicating a trend towards increased incompressible strongly interacting matter. On inclusion of the AMM of quarks, the perpendicular
component of isothermal compressibility becomes greater than the parallel component. Additionally, we investigate the quark number susceptibility normalized by its value at zero magnetic field, which may indicate
the presence of magnetic fields in the system.

Parallel D / 84

Production of light-flavoured particles in ALICE RUN 3 data for pp collisions

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Multiplicity-dependent yield ratios of light-flavour particles, such as p and strange hadrons relative to π, provide key insights into hadron production mechanisms and strangeness enhancement across collision systems. Observable like (multi-)strange to non-strange ratios show a smooth transition from small to large systems, shedding light on collective behaviour and production dynamics. Leveraging the high-luminosity data from LHC Run 3 and the advanced O^2 (online-offline) framework, the ALICE experiment enables precise measurements of these phenomena in pp collisions at $\sqrt{s} = 13.6$ TeV. This work presents the results on particle yield ratios as functions of charged-particle multiplicity ($\mathrm{d}N_{\mathrm{ch}}/\mathrm{d}\eta$) are compared to state-of-the-art QCD-inspired models to understand further the microscopic origins of observed phenomena such as strangeness enhancement and collective behaviour in hadronic collisions.

Parallel D / 85

Non-perturbative Heavy Quark diffusion in the non-eikonal domain of the gluon bremsstrahlung

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Drag and diffusion coefficients of the Heavy Quarks (HQs), such as charm and bottom, are one of the prime tools for discerning the properties of the deconfined QCD medium created in the heavy ion collisions experiments. The innate non-perturbative nature of the QCD medium renders it imperative to estimate the transport coefficients in that domain. The present work evaluates the drag and diffusion coefficients of the moving HQ interacting with the medium particles via two-body collisional and three-body radiative processes to the first order in opacity by employing Gribov mechanism for the non-perturbative regime. We proffer the latest results of the HQ transport coefficients computed for the non-perturbative and non-eikonal gluon radiation off the HQ. We emphasize particularly on the importance of the non-eikonality in the non-perturbative domain. The calculations show significant increment of the transport coefficients with the increasing non-eikonality by juxtaposing the results with those of the perturbative and eikonal regions. We hope to shed fresh light towards explaining the experimental data on the nuclear modification factor, R_{AA}, the elliptic flow, v_2 of the HQ by advocating the importance of the non-eikonality of the gluon radiation off the HQ.

Parallel D / 86

Thermodynamics of heavy Quarkonia using the SUSYQM method in the presence of baryonic chemical potential

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In this study, we employ medium-modified Cornell (MMC) potential to investigate the thermodynamic properties of ground states of heavy quarkonium systems in N-dimensional space through the Supersymmetric Quantum Mechanics (SUSYQM) approach. To account for the effects of baryonic chemical potential on quarkonia, we incorporate the quasi-particle Debye mass. The Schrödinger equation is solved to obtain the energy eigenvalues of the system. Using the derived partition function, we calculate essential thermodynamic properties such as internal energy, entropy, and free energy, examining their behavior under varying temperature and dimensionality number.

Parallel A / 87

Exploring Hyperon Properties in Dense Baryon Matter and Neutron Stars

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We examine the properties of hyperons (Λ, Σ, Ξ) in dense baryon matter and neutron stars using a modified relativistic Dirac formalism (MRDF). In this approach, the quark meson (σ, ω) couplings are derived self-consistently at the quark level, where quark confinement is modelled through a scalar-vector linear potential, and corrections are incorporated for centre-of-mass motion, one-gluon exchange, and pionic contributions. We start by calculating the masses of baryons in a vacuum and then proceed to evaluate them within a medium. This work examines the properties of baryon matter, "such as the equation of state, compressibility, binding energy, and pressure. In addition, we compute essential parameters, including the baryon charge radius, axial-vector coupling constant, pion coupling constant, baryon sigma term, symmetry energy, density slope (L), and incompressibility (K_0)".

Parallel C / 88

SYMMETRIC AND ASYMMETRIC PROPERTIES OF NEUTRON STAR

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Our approach offers a phenomenological model for investigating nuclear matter by employing the modified relativistic Dirac formalism coupled with the σ–ω and ρ mesons in the quark-meson coupling model. By considering scalar and vector linear potential for quark confinement and accounting with quantum corrections such as the centre-of-mass motion, gluonic, and pionic corrections, we establish a foundation to calculate fundamental properties of nucleons and calculate nucleon mass in a vacuum as well as in medium. Our methodology then allows for a thorough exploration of nuclear matter properties, extending into nuclear EOS, binding energy, symmetry energy, and thermodynamic instability, which are important for understanding nuclear interactions and matter under extreme conditions. The systematic exploration of the correlation between symmetry energy and its density slope provides valuable data that can help refine existing nuclear models and provide a deeper understanding of nuclear matter in beta equilibrium at finite densities. In addition, we examine the mass-radius variations of neutron stars.

Parallel D / 89

Transport model calculations of jet energy loss and jet shape modifications

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We have developed a consistent model that combines parton jet shower production from perturbative QCD and the complicated interactions between the full jet with the medium soft partons in a MultiPhase Transport (AMPT) model. In addition to the elastic binary collisions existing in the model, we have incorporated the crucial energy-momentum modifications of the parton showers via medium-induced multiple gluon radiation in the higher-twist formalism of jet energy loss. Given the remarkable success of AMPT in addressing the anisotropic bulk medium flow, and noting the importance of jet modifications on the space-time dynamics of medium, the unified jet-medium parton transport framework can be used to make realistic predictions of the jet based observables. We

have compared the numerical results of the model with the experimental data in central Pb-Pb collisions at the LHC energy of 5.02 TeV, to ascertain the impact of the medium and in particular the medium-induced radiation effects, on the jet energy loss, dijet asymmetry, and modifications of the full jet shapes.

Parallel C / 90

Studying the onset of Dimensional Reduction in finite temperature QCD and its consequences

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One of the outstanding challenges in the theory of strong interactions described by Quantum Chromodynamics is to understand its non-perturbative properties which can explain many important phenomena e.g., color confinement. In this work we study the non-perturbative sector of magnetic gluons whose momenta are given by $|\vec{p}| \leq g^2T/\pi$
in a finite temperature (T) QCD plasma described by strong coupling strength g, both in presence of 2+1 flavors of dynamical quark flavors and without. By performing lattice computations of the spatial Wilson line correlators for a wide range of temperatures from 160-1000 MeV on different lattice spacings corresponding to $N_\tau = 8, 12, 16$ for pure SU(3) gauge theory and $N_\tau = 8, 10$ for 2+1 flavor QCD we extract the spatial string tension. From the temperature dependence of the spatial string tension we show that QCD can be described by a dimensionally reduced effective theory, EQCD at temperatures beyond 600 MeV. We further extract the pseudo-potential whose long distance part is characterised by the spatial string tension and the short distance perturbative part described within perturbative EQCD. We demonstrate how this potential can explain the deviation of the screening masses of pseudo-scalar and vector meson-like long-distance
excitations of the QCD plasma from the perturbative estimates at high temperatures and provide an explanation for the significant difference between these screening masses that cannot be explained within perturbative QCD.

Parallel D / 91

Quarkonia Spectral Function at Finite Momenta

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Heavy quark-antiquark bound states such as $c\bar{c}$ and $b\bar{b}$, serve as essential tools for probing the properties of quark-gluon plasma (QGP). However, its finite momentum behaviour remains largely unexplored, despite its experimental significance. Here, we present an extension of quarkonia dynamics from zero-momentum to finite-momentum by observing its spectral function. We obtained the spectral function in threshold region by solving the Schrödinger equation with finite-momentum perturbative potential. We will model this spectral function with perturbative vacuum part to describe the lattice correlators at temperatures of 1.20 T_c, 1.40 T_c, and 1.62 T_c in 2+1 flavor QCD.

Parallel D / **92**

Effects of memory on quarkonium evolution in quark gluon plasma

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Heavy-Quarkonia evolution in quark-gluon plasma (QGP) can be studied using the framework of open quantum systems. The density matrix of the quarkonia satisfies a simple Lindblad-type equation if one assumes that the binding energy E_b is much smaller than the medium temperature T. This approximation does not hold for a significant part of the QGP evolution. We study the evolution of quarkonia in the regime when $E_b \sim T$ by solving general master equations for the density matrix, which include the effects of memory. Mainly we calculate suppression of $\Upsilon(1S)$ at CMS and RHIC energies. For the background medium, we use results from a realistic viscous 2+1 hydrodynamic simulation, which gives a good description of the phenomenology of the soft particles.

Parallel C / **93**

Precision measurement of (Net-)proton Number Fluctuations in Au+Au Collisions from BES-II Program at RHIC-STAR

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Higher-order cumulants of (net-)proton multiplicity distributions are sensitive observables for studying the QCD phase structure. At low baryon chemical potential (μ_B), lattice QCD calculations establish the quark-hadron transition to be a crossover, while at large μ_B, QCD-based models predict a first-order phase transition that ends at a critical point.

Here, we focus on the search for the possible existence of the QCD critical point. We report precision measurements of cumulants (C_n) and factorial cumulants (κ_n) of (net-)proton multiplicity distribution upto fourth order in Au+Au collisions with $\sqrt{s_{NN}}$ =7.7 - 27 GeV measured by the STAR experiment from second phase of Beam Energy Scan program (BES-II) at RHIC. Using the high statistics data collected with upgraded detectors, we select protons and antiprotons at mid-rapidity $|y| < 0.5$ within 0.4 $< p_T(GeV/$c$) <$ 2.0. The dependence of measured cumulants and factorial cumulants on the collision energy and centrality will be presented. The measured data will be compared with calculations from lattice QCD, and expectations from various non-critical point models, such as the transport model UrQMD and the thermal model HRG.

Parallel B / **94**

Diffusion coefficient matrix for multiple conserved charges: a Kubo approach

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The strongly interacting matter created in relativistic heavy-ion collisions possesses several conserved quantum numbers, such as baryon number, strangeness, and electric charge. The diffusion process of these charges can be characterized by a diffusion matrix that describes the mutual influence of the diffusion of various charges. We derive the Kubo relations for evaluating diffusion coefficients as elements of a diffusion matrix. We further demonstrate that in the weak coupling limit, the diffusion matrix elements obtained through Kubo relations reduce to those obtained from kinetic theory with an appropriate identification of the relaxation times. We illustrate this evaluation in a toy model of two interacting scalar fields with two conserved charges.

Parallel C / 95

Proton Intermittency analysis in Au + Au Collisions: Exploring Critical Behavior in the FAIR Energy Range

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In this presentation, we extend our previous investigations on intermittency using the Scaled Factorial Moment (SFM) technique in Au + Au collisions within the FAIR energy range of 2–12A GeV. Building on our findings published in Eur.Phys.J.A 59 (2023) 4, 92, we now focus on the fluctuations in the number of protons, motivated by QCD-inspired predictions that suggest critical behavior associated with net baryon density fluctuations. Employing a hybrid version of the Ultra-relativistic Quantum Molecular Dynamics (UrQMD) event generator, we analyze the intermittency across pseudorapidity $\chi(\eta)$ and azimuthal $\chi(\phi)$ spaces. Utilizing three equations of state (EoS)—pure Hadron Gas (HG), Chiral + HG, and Bag Model EoS—we explore the distinct intermittent emission patterns and their dependence on incident beam energy. Our findings reveal distinct intermittent behaviors dependent on the chosen EoS, with the Bag Model EoS exhibiting stronger intermittency compared to Chiral+HG. Furthermore, we observe that the strength of intermittency decreases with increasing beam energy. These results highlight the significance of investigating proton fluctuations as a key approach to understanding the critical dynamics of QCD phase transitions and provide insights into the evolution of matter in high-energy collisions.

Parallel B / 96

Lambda directed flow for validating the Lambda potential from chiral EFT: Bridging heavy-ion collisions, hypernuclei, and neutron stars

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We investigate the validity of the Λ single-particle potential (Λ potential) in dense matter that is based on chiral effective field theory (chiral EFT) that is sufficiently repulsive to solve the hyperon puzzle of neutron stars. We discuss that the model calculations with the Λ potential are consistent with the Λ hypernuclear spectroscopy [1] and the Λ directed flow v_1 [2] in heavy-ion collisions.

A unified approach integrating heavy-ion collisions, other nuclear experiments, and neutron stars with the modern nuclear force from chiral EFT has provided valuable insights into the properties of the equation of state (EOS) of dense matter (e.g. Ref. [3]). This approach contributes to a more comprehensive understanding of both nuclear experiments and astrophysical observations. For a microscopic description of dense matter, such an approach must be performed also for the hyperon sector. A precise understanding of the hyperon potentials in nuclear matter is essential for addressing the long-standing hyperon puzzle of neutron star physics.

In this talk, we consider the Λ directed flow v_1 [2] at RHIC-BES energies to verify the Λ potential based on chiral EFT [4]. This potential is sufficiently repulsive at high densities to solve the hyperon puzzle and has proven by us to be consistent with the Λ hypernuclear spectroscopy [1]. We employ a relativistic quantum molecular dynamics (RQMD) implemented into the Monte-Carlo event generator JAM2. We show that the model with the Λ potential from chiral EFT can reproduce the experimental data [2], while a more attractive Λ potential also reproduces the data. Thus, additional constraints on the Λ potential are demanded.

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Parallel B / 97

Selected results from isobar collisions at RHIC

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Recent experiments involving isobar collisions of $^{96}_{44}$Ru+$^{96}_{44}$Ru and $^{96}_{40}$Zr+$^{96}_{40}$Zr have been carried out at the Relativistic Heavy Ion Collider (RHIC). These studies aim to explore various phenomena, including the initial conditions of the collision process, baryon stopping, the chiral magnetic effect, and collective flow, which are all essential for understanding the dynamics of heavy-ion collisions. Although the two nuclei have the same mass number, understanding the differences between their isobar collisions is valuable for exploring nuclear structure and deformation.

In this talk, we will discuss selected measurements related to particle production, collective flow, and the chiral magnetic effect of charged and identified hadrons at mid-rapidity for Ru+Ru and Zr+Zr collisions at $\sqrt{s_{\mathrm{NN}}}$ = 200 GeV. The dependence of the transverse momentum (p_T) for various centrality intervals will be shown. Additionally, system size dependence will be explored by comparing the results in isobar collisions with those from Cu+Cu, Au+Au, and U+U collisions. Furthermore, experimental results will be compared with transport model calculations to provide insight into the nuclear structure of the isobars.

Parallel A / 98

Study of first-order event plane correlated anisotropic flow in heavy-ion collisions at high baryon density region

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Anisotropic flow parameters (v_n) are important observables as they provide insight into the collective expansion and transport properties of the medium produced in relativistic heavy-ion collisions. Among these parameters, directed flow (v_1) describes the collective sideward motion of produced particles in heavy-ion collisions. It is an important probe to study the in-medium dynamics as it is predicted to be sensitive to the equation of state (EoS) of the produced medium. Minimum in the slope of directed flow (dv_1/dy) as a function of collision energy has been proposed as a signature of the first-order phase transition between hadronic matter and Quark-Gluon Plasma (QGP). Triangular flow (v_3) typically arises from the initial state fluctuations and is expected to be uncorrelated with the reaction plane. However, recent measurements at lower collision energies (higher baryon chemical potential (μ_B)) of $\sqrt{s_{NN}}$ = 2.4 and 3 GeV, show a correlation between v_3 and the first-order event plane angle (Ψ_1).\\
In this presentation, we will report the measurements of $v_1\{\Psi_1\}$ and $v_3\{\Psi_1\}$ for π, K, p, net-kaon, net-proton, d, t, and ^3He in Au+Au collisions at $\sqrt{s_{NN}}$ = 3.2, 3.5, 3.9, and 4.5 GeV taken in fixed-target mode from the second phase of the beam energy scan (BES-II) program at RHIC-STAR. We will show the dependencies of $v_1\{\Psi_1\}$ and $v_3\{\Psi_1\}$ on rapidity, p_T, centrality, and collision energy, and subsequently, discuss their physics implications. The experimental measurements will be compared with the results from the JAM model to understand the the transport properties of the medium at low collision energies.

Parallel C / 99

Production of light nuclei in Au+Au collisions from STAR BES-II

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Light (anti-)nuclei production in heavy-ion collisions can be described by two different mechanisms: the thermal and coalescence models. By analyzing the yields and ratios of the light (anti-)nuclei, we can gain valuable insights into their formation processes and the properties of the system at freeze-out. The enhancement in the compound ratios of light nuclei, such as $N_t N_p / N_d^2$ from the expected coalescence baseline, has been proposed as a tool to probe critical phenomena in the Quantum Chromodynamics phase diagram. In the first phase of the RHIC Beam Energy Scan (BES-I), a notable increase in the compound light nuclei yield ratio $N_t N_p / N_d^2$ was observed in the most central Au+Au collisions at $\sqrt{s_{NN}}$ = 19.6 and 27 GeV, with a combined significance of 4.1σ. The larger datasets ($\sim 10\times$ BES-I) collected by the STAR during the second phase of the BES program (BES-II) and improved detector capabilities are expected to provide more precise measurements.

In this talk, we will explore the centrality and energy dependence of the transverse momentum (p_T) spectra of p, $\bar{p}$, d, $\bar{d}$, and ^3He in Au+Au collisions across BES-II energies $\sqrt{s_{NN}}$ = 7.7 - 27 GeV. Additionally, we will report the centrality and energy dependence of the p_T integrated yields (dN/dy) and the mean p_T ($\langle p_T \rangle$) of light nuclei. Furthermore, we will discuss the centrality and p_T dependence of the coalescence parameters, B_A, with their broader physics implications.

100

Anisotropic Flow of Strange and Multi-Strange Hadrons in O+O Collisions at $\sqrt{s_{\mathrm{NN}}} = 200$ GeV

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Recent measurements on collectivity of charged hadrons in both asymmetric and symmetric small collision systems have far-reaching implications on the origins of final state momentum anisotropy driven by nucleonic as well as sub-nucleonic degrees of freedom present during initial state. During the data taking in 2021, STAR had recorded large statistics of minimum bias and high multiplicity events of O+O collisions at $\sqrt{s_{\mathrm{NN}}} = 200$ GeV. We present the first measurements of anisotropic flow of strange and multi-strange hadrons in O+O collisions. These hadrons are considered as good probes for initial state dynamics given their production at the early stages of medium evolution. In particular, we study the transverse momentum (p_{T}) and centrality dependence of elliptic (v_2) and triangular (v_3) flow of $\mathrm{K}^0_{\mathrm{S}}$, $\Lambda + \overline{\Lambda}$ and ϕ. System size dependence of the same is also shown by comparing with existing measurements of strange hadron collectivity in relatively larger systems (such as Cu+Cu, Au+Au and U+U) at the same collision energy. Formation of Quark-Gluon Plasma (QGP) in small collision systems has long been argued given their extremely short lifetime. In this regard, we test the number-of-constituent-quark (NCQ) scaling hypothesis for strange hadron v_2 and v_3 in central O+O collisions to understand the influence of partonic phase on the origins of collectivity.

Parallel B / 101

Relativistic second-order spin hydrodynamics: A correlation function approach using Zubarev's non-equilibrium statistical operator

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Utilizing Zubarev's nonequilibrium statistical operator, we derive the second-order expression for the dissipative tensors in relativistic spin hydrodynamics, namely the rotational stress tensor ($\tau_{\mu\nu}$), boost heat vector (q_μ), shear stress tensor ($\pi_{\mu\nu}$), and bulk viscous pressure (Π). The emergence of the first two terms, $\tau_{\mu\nu}$ and q_μ, is attributed to the inclusion of the antisymmetric part in the energy-momentum tensor. In this work, we also treat the spin density ($S^{\mu\nu}$) as an independent thermodynamic variable alongside energy density and particle density, leading to an additional transport coefficient characterized by the correlation between $S^{\mu\nu}$ and $\tau_{\mu\nu}$. Finally, we derive the evolution equations for the aforementioned tensors—$\tau_{\mu\nu}$, q_μ, $\pi_{\mu\nu}$, and Π.

Parallel B / 102

Investigating the Chiral Magnetic Wave at RHIC-STAR

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In heavy-ion collisions, the Chiral Magnetic Wave (CMW) is theorized to produce an electric quadrupole moment, leading to differences in elliptic flow between positively and negatively charged particles. This CMW signal can be detected by examining the correlation between charge-dependent elliptic flow and event charge asymmetry. This study focuses on the difference in covariance of elliptic flow (v_2) and charge asymmetry $A_{textupch}$ for positively and negatively charged particles across various collision centralities.

To explore collision system dependence, we will analyze results from Au+Au collisions as well as isobar (Ru+Ru and Zr+Zr) collisions at a center-of-mass energy of $\sqrt{s_{textupNN}}$ = 200 GeV. A comparison between the two isobar systems will be conducted to investigate any potential enhancement of the CMW signal in Ru+Ru collisions, which may be attributed to the stronger magnetic field generated by the additional four protons in Ru. Additionally, we will present correlations between triangular flow (v_3) and $A_{textupch}$ to assess background contributions.

103

Study of pixel clusters produced by an $^{241}\mathrm{Am}$ radioactive source in the ALPIDE pixel chip

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The ALPIDE is a Monolithic Active Pixel Sensor used in the ALICE Inner Tracking System installed during LS2 of the LHC and currently being operated in pp and Pb-Pb collisions. In the ALPIDE, electron-hole pairs are produced by the energy loss caused by incident charged particles, and the electrons are collected by the pixel diodes. The cluster size corresponding to the number of pixels fired by each incident particle indicates how widely the electrons are spread out and how many pixels responded to them over the threshold. Thus, the cluster size distribution provides the information on the incident particle trajectory and energy loss. In this presentation, the cluster size distribution produced from $^{241}\mathrm{Am}$ alpha source will be shown at various collimator sizes and alpha particle energies, and the response of the ALPIDE chip will be discussed.

Parallel B / 104

Production of Light Nuclei in Heavy-Ion Collisions using Hadron Resonance Gas Model

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The study of light nuclei production in relativistic heavy-ion collisions provides valuable insights into the properties of the dense, hot medium produced in these collisions, which is assumed to mimic conditions of the early universe. In this work, we analyze the production of light (anti-)nuclei, such as d, $\bar{d}$, t, and ^{3}He, in the framework of the Hadron Resonance Gas (HRG) model – a theoretical approach that treats the hadronic phase as a gas composed of hadrons and their resonances. Following the approach of applying the nuclear equivalent of the Saha equation, we explore the evolution of light nuclei abundances post-chemical freeze-out, where disintegration and regeneration reactions are assumed to proceed in relative chemical equilibrium within the hadronic phase. Using the HRG model in Partial Chemical Equilibrium (PCE) available in the Thermal-FIST package, we study the

sensitivity of light nuclei yields to temperature at the RHIC energies. The resulting predictions are compared with experimental data from the STAR Collaboration, offering a comprehensive understanding of the thermal properties and reaction kinetics in the expanding fireball.

Parallel B / 105

Global spin polarization of Λ and $\overline{\Lambda}$ hyperons in Au+Au collisions at RHIC-STAR

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In non-central heavy-ion collisions, large angular momentum is generated, leading to significant vorticity and subsequent spin polarization of particles with finite spin. The global polarization of Λ and $\overline{\Lambda}$ hyperons (P_Λ and $P_{\overline{\Lambda}}$), measured along the direction of global angular momentum, serves as an effective probe of both vorticity and spin degrees of freedom. P_Λ has been measured over a wide range of collision energies. The data from Beam Energy Scan II (BES-II) program at RHIC, including the collider and recent Fixed-Target (FXT), have provided a unique opportunity to study spin degrees of freedom in a wide region of baryon density. In this energy range, P_Λ is observed to be sensitive to the equation of state of the nuclear medium.

In this talk, we will present measurements of global Λ polarization in Au+Au collisions at $\sqrt{s_{NN}} = 3.0, 3.2, 3.5, 3.9, 4.5, 5.2,$ and 6.2 GeV, along with global Λ and $\bar{\Lambda}$ polarization and their differences in Au+Au collisions at $\sqrt{s_{NN}} = 7.7, 9.2, 11.5, 14.6, 17.3,$ and 19.6 GeV from BES-II. The dependence of the measured global polarization on collision energy, centrality, rapidity, and transverse momentum will be discussed.

Parallel B / 106

Azimuthal anisotropic flow measurements in Au+Au collisions using RHIC BES-II data

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One of the objectives of the STAR experiment is to study the phase transition from hadronic matter to Quark Gluon Plasma (QGP). This can be investigated by studying the collective flow of various particle types produced in heavy-ion collisions, particularly by testing whether the number of constituent quark (NCQ) scaling holds or breaks across different energies. Specifically, the elliptic (v_2) and triangular (v_3) flow coefficients, which represent second- and third-order azimuthal anisotropies in particle momentum distributions, provide insights into the equation of state and transport properties of the medium, the shear viscosity to entropy density ratio (η/s).

Recently, STAR completed data taking for the Beam Energy Scan phase-II (BES-II) with upgraded detector capabilities and extended rapidity coverage. In this presentation, we will showcase high-precision measurements of v_2 and v_3 for various identified hadrons, including $\pi^+(\pi^-)$, $K^+(K^-)$, $p(\bar{p})$, K^0_S, ϕ, $\Lambda(\bar{\Lambda})$, $\Xi^-(\bar{\Xi}^+)$, and $\Omega^-(\bar{\Omega}^+)$, from Au+Au collisions at $\sqrt{s_{NN}}$= 3.0-19.6 GeV. The results will cover the centrality and transverse momentum dependence as well as the NCQ scaling of v_n. Finally, we will discuss the implications of these measurements in understanding onset of partonic collectivity.

Parallel A / 107

Probing hadronic rescattering via K^{*0} resonance production at RHIC

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Relativistic heavy-ion collisions provide a unique setting to investigate QCD matter under varied temperatures and densities. As the collision energy rises, the baryon chemical potential (μ_B) decreases, resulting in a mid-rapidity region rich in baryons at the lower Beam Energy Scan (BES) program energies and in mesons at top RHIC energies. Short-lived resonances like K^{*0} (lifetime $\sim$ 4.16 fm/c) are effective probes of the hadronic medium. As they primarily decay within the fireball, their decay products undergo in-medium effects like rescattering and regeneration, potentially modifying K^{*0} properties. However, due to change in the chemical composition of the system produced at low and high collision energies, distinct difference in the particle interaction can be expected. The measurement of K^{*0} meson over a broad collision energy range will help shed light on this phenomenon.

In this presentation, we will report precision measurements of K^{*0} mesons in isobar (Zr+Zr and Ru+Ru) collisions at $\sqrt{s_{NN}}$ = 200 GeV and in Au+Au collisions at $\sqrt{s_{NN}}$ =7.7,11.5,14.6,19.6, and 27 GeV, using high-statistics STAR BES-II data. Results will include transverse momentum (p_T) spectra, yields (dN/dy), and mean transverse momentum ($\langle p_T \rangle$). Additionally, the K^{*0}/K ratio as a function of multiplicity across different systems and energies will be discussed, providing insights into the underlying physics of the hadronic medium.

Parallel D / 108

A model study for the understanding of particle production through jet-hadron correlation in pp collisions at 13 TeV

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At large hadron collider energies, a remarkable similarity has been observed in particle production mechanisms between large and small collision systems. In particular, the enhancement in baryon-over-meson ratios at intermediate transverse momentum and/or relative enhancement in production of particles with higher strangeness content at large multiplicities indicates that it may be possible that a partonic medium is also produced in the collisions of small systems. To classify broadly, particles are either produced via some non-perturbative QCD processes that involve quark-hadron duality or from hard QCD processes like jet-fragmentation which are theoretically better constrained. To understand the anomalous particle production in small systems it is important to separate the particles produced in hard processes (jets) from those produced in the soft underlying events. This would provide a better understanding of the similarities and differences in the particles production mechanism from small to large collision systems.
In this work we use jet-hadron correlation technique to separate particles which are produced in association with a hard process or jet from the underlying events in MPI-enabled PYTHIA8. This model has reasonable success in describing some features of the data in small systems which are generally linked with the medium formation. We calculate baryon-over-meson ratios of the particles in jets and in underlying events in minimum bias as well as high multiplicity events to understand whether the enhancement of baryon-over-meson ratios are linked with any modification of jet-fragmentations particularly in high multiplicity events or it comes from underlying events. We also compare our calculations with inclusive results and the available data.

Parallel A / 109

Development of Ultra-Thin LGADs with Enhanced Timing Capabilities and Radiation Hardness for Future Collider Applications

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\documentclass[12pt]{article}
\usepackage{amsmath}
\usepackage[margin=1in]{geometry}

\begin{document}

\title{Development of Ultra-Thin LGADs with Enhanced Timing Capabilities and Radiation Hardness for Future Collider Applications}
\author{Jaideep Kalani[1], Saptarshi Datta[2], Ganesh J. Tambave[2], Prabhakar Palni[1]\\
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\date{}
\maketitle

\begin{abstract}
This study investigates Low Gain Avalanche Detectors (LGADs) for future particle collider experiments, aiming to improve timing resolution ($<$ 20 ps) under very high-radiation environments. Using the WeightField2 simulation program, we optimized an n-in-p type LGAD design, focusing on ultra-thin sensors ($\sim<$ 50 μm) with p-doped Silicon bulk. Our results show that a 20 μm thick sensor achieves optimal performance. \sloppy Simulations were performed under High Luminosity LHC conditions (temperature $\approx -15\,^{\circ}$C, luminosity $\approx 7 \times 10^{34}$ cm^{-2} s^{-1}), taking into account radiation damage, gain quenching, and lattice defects. Further studies were extended to Silicon Carbide (SiC) bulk material due to its superior properties, such as a wide band-gap and high atomic displacement energy, which provide strong resistance to irradiation. Its high electron saturation drift velocity and thermal conductivity make it a fast-responding detector with lower thermal sensitivity. After irradiation, the study investigates fast charge collection, breakdown voltage, leakage current, and radiation tolerance, comparing these with conventional Silicon-based LGADs. For instance, SiC-based LGADs demonstrated lower leakage current and enhanced radiation tolerance. Additionally, simulations were conducted using laser with wavelength falling in near-infrared region, to observe charge collection across the detector strip, identifying the optimal zone for MIP hitting. These findings underline the potential of optimized LGADs in maintaining performance under high radiation regime.

\end{abstract}

\noindent \textbf{Keywords:} LGAD, timing resolution, radiation hardness, ultra-thin sensors, Silicon Carbide, WeightField2 simulation

\end{document}

Parallel D / 110

Understanding biases in experimental multiplicity estimations for pp collisions at the LHC

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Measurements from the LHC and RHIC of proton-proton (pp) and proton-lead (pPb) collisions have revealed that the onset of phenomena normally associated with heavy-ion collisions also appear in smaller collision systems, particularly in collisions that produce large particle densities. However, unlike their larger heavy-ion counterparts, multiplicity production in pp collisions is dominated by large, spatial fluctuations. The origin of these fluctuations is model-dependent, currently understood to be driven by large parton showers or collisions with several multiple-parton interactions.

Consequently, measurements of high multiplicity pp collisions will necessarily be biased toward different phenomenological processes, considering which phase-space the multiplicity estimate is performed.This is particularly the case for experiments at RHIC and the LHC, where various subdetectors have limited azimuthal and pseudorapidity coverage, complicating direct comparisons of multiplicity-differential studies between different experiments.

This contribution examines how the different experiments at RHIC and the LHC measure multiplicity production in pp collisions, and discusses whether it is feasible to directly compare different estimations of "high-multiplicity" events selected with nonidentical phase-space constraints. Model simulations from state-of-the-art Monte Carlo generators are presented to highlight that these effects arise not from detector geometries or inefficiencies, but rather from the phase-space selection itself in relationship to the underlying physics processes. Furthermore, several observables commonly utilized to estimate the size of the underlying event, such as transverse spherocity, transverse charged particle density, and flattenicity will be discussed in this context.

Parallel B / 111

Characterization of flavor dependance of Chiral Magnetic Effect with multiple correlators

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We study the flavor dependance of the Chiral Magnetic Effect (CME) using two of the primary correlators used to characterize the charge separation effect. These are the correlator $\Delta\gamma$ and the correlator R_{ψ_2}. We use the AMPT (A Multiphase Transport Model) model to study the sensitivity of these correlators to two and three flavors of quarks. The AMPT model used has a centrality dependent charge separation introduced in the initial stage. We find that both the correlators indicate a strong flavor dependence in $(30-50)\%$ centrality bins. We then create a classification model with a neural network architecture and train the model using numerous combinations of the final state particle distributions. We evaluate patterns of error distribution and determine which observables are best suited for precise and accurate CME flavor estimation. We additionally implement the model to estimate the R_{ψ_2} correlator from the final state particle distribution and minimize the flow-related background effects. This method represents a novel approach to characterizing the CME flavors while reducing the background effect.

Parallel B / 112

Hadron production at centre of mass energies 62.4, 200 and 2760 GeV , RHIC and LHC energies through recombination model

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We use the Recombination Model to explain the hadron production data at center of mass energies 62.4, 200 and 2760 GeV at LHC and RHIC. The Recombination model considers the effective valence quark energy and momentum without taking the sea quarks and gluons explicitly into account. This model has been quite successful in explaining the larger-than-expected baryon-to-meson ratio and the leading particle effect in heavy ion collision experiments. This model also provides a general framework to describe the whole momentum spectrum of the matter created in such experiments, without any restriction to the high or low transverse momenta regime for p_T<20 GeV/c. In this model, the hadron yield is a convolution of the probability of finding the valence quarks with the specific momenta and the probability of recombination of the quarks to produce the hadron. The sources of the recombining quarks can be classified as either of thermal (having transverse momenta < 3 GeV/c) origin or of shower origin (having transverse momenta > 3 GeV/c). We propose the expressions for the probability of recombination of the quarks into produced hadrons with the help of energy-momentum conservation laws. We consider the effect of the confinement of valence quarks inside the hadrons explicitly. For low transverse momentum, we use a thermal distribution of the recombining quarks, and for high transverse momentum, we take the momentum distribution from the fragmentation functions obtained in previous works. Using this formalism, we were able to explain the meson production at low transverse momentum (p_T < 3 GeV/c) satisfactorily for the first time. We also present an empirical formula for the dependence of the hadron yield on the center of mass energy and the number of participants in the collision. We were also able to reproduce the low and intermediate transverse momentum spectra (0 < p_T < 8 GeV/c) of the hadrons satisfactorily.

Parallel D / 113

Spherocity-Dependent Study of Relative Transverse Multiplicity Activity Event Classifier in the Underlying Event

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This study investigates the intricate relationship between transverse spherocity (S_0) and the relative transverse multiplicity activity event classifier (R_T) in proton-proton collisions at the Large Hadron Collider (LHC) with a center-of-mass energy of 13 TeV. Through a detailed analysis across different spherocity regions, we examine various observables to understand underlying event dynamics in high-energy particle collisions. We have used the PYTHIA 8 Monte-Carlo (MC) with a different implementation of color reconnection and rope hadronization models to demonstrate the proton-proton collision data at $\sqrt{s}$ = 13 TeV. The sensitivity to the multi-partonic interaction is studied using a new differential approach to understand the underlying event and jetty-like domain. Furthermore, the baryon-to-meson production ratio and the average transverse momentum (p_T) are evaluated across R_T for selected spherocity classes, revealing significant dependencies on the event topology. These measurements offer insight into the complex nature of strange particle production and underlying event structure in high-energy collisions, with implications in quantum chromodynamics (QCD) studies. Experimental confirmation of these results is feasible using ALICE Run 3 data which will provide more insight

into the soft physics in the transverse region which is useful to understand the small system dynamics.

Parallel A / 114

Study of exotic resonances in pp collisions with ALICE at LHC

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Quantum Chromodynamics (QCD) is a fundamental theory on which the Standard Model of particle physics is based, describing strong interactions between quarks and gluons. While conventional hadrons are composed of bound states of quark-antiquark ($q\bar{q}$) pairs or three-(anti)quark (qqq or $\bar{q}\bar{q}\bar{q}$) combinations, QCD also predicts exotic hadrons, such as $\mathrm{f}_0(980)$ and $\mathrm{f}_1(1285)$, which could be a tetraquark state or molecular state of mesons. Additionally, QCD predicts the existence of glueballs, which are bound states of gluons whose internal structure remains unknown, offering unique insights into the non-perturbative regime of QCD. The large statistics data collected by the ALICE detector in Run~2 in the pp collisions at $\sqrt{s} = 13$ TeV is used to perform detailed studies of exotic resonances.

This contribution reports on the measurements of production yields, mass spectra, and decay channels of the resonances $\mathrm{f}_0(980)$ and $\mathrm{f}_1(1285)$. Based on the lattice QCD prediction of the lightest scalar glueball candidate in the mass range of 1500 to 1700 MeV/c^2, we will also show the measurements of higher mass resonances at midrapidity in the mass range of 1000–2000 MeV/c^2 through $\mathrm{K^0_S K^0_S}$ and $\mathrm{K^+K^-}$ decay channels, aiming to explore their internal structure, production mechanisms, and alignment with QCD predictions.

Parallel B / 115

Exploring the flow harmonic correlations via multi-particle symmetric and asymmetric cumulants in Au+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV

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We study multi-particle azimuthal correlations in Au+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV. We use initial conditions obtained from a Monte-Carlo Glauber model and evolve them within a viscous relativistic hydrodynamics framework that eventually gives way to a transport model in the late hadronic stage of the evolution. We compute the multi-particle symmetric and asymmetric cumulants and present the results for their sensitivity to the shear and bulk viscosities during the hydrodynamic evolution. We also check their sensitivity to resonance decay and hadronic interactions. We demonstrate that while some of these observables are more sensitive to transport properties than traditional flow observables, others are less sensitive, making them suitable for studying different stages of the evolution.

Parallel B / 116

Phenomenology of baryon stopping and diffusion at RHIC BES

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A baryon-rich medium is created in low-energy heavy-ion collisions. Using a hydrodynamic model that incorporates finite baryon density, we investigate the role of baryon stopping and diffusion in RHIC-BES phenomenology, focusing on the directed flow (v_1) observable. The v_1 splitting between protons and anti-protons has been an elusive observable for a long time, primarily due to improper modeling of initial baryon stopping. We propose an initial baryon deposition model capable of reproducing the v_1 of protons and anti-protons across collision energies $\sqrt{s_{\mathrm{NN}}} = 7.7$–$200$ GeV. Notably, we find that the sign change of proton v_1 at $\sqrt{s_{\mathrm{NN}}} = 7.7$ GeV arises from a combined effect of initial baryon stopping and strong baryon diffusion—previously interpreted as a signature of a first-order phase transition. Using this baryon stopping model, we provide the first estimate of the baryon diffusion coefficient in the baryon-rich QGP medium.
Furthermore, leveraging our phenomenologically successful model, which accurately describes bulk observables at STAR BES energies, we explore the centrality-dependent splitting of the $v_1(y)$ slope, $\Delta(dv_1/dy)$, between positively and negatively charged hadrons. This splitting, recently measured by the STAR collaboration, has been suggested as a potential signature of the electromagnetic field generated during collisions. However, our calculations—accounting solely for baryon diffusion and not electromagnetic field effects—effectively reproduce the centrality trend of the v_1 slope splitting between protons and anti-protons. In this context, I will discuss how initial-stage baryon stopping provides a substantial background to electromagnetic field signals. Additionally, we demonstrate the significance of measuring rapidity-even v_1 splitting between baryons and anti-baryons, shedding light on the baryon junction conjecture, which has garnered considerable interest.

117

Phase diagram of two and three color QCD

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Phase diagram of two color and three color QCD are reviewed. The dualities of QCD phase diagram are discussed in both two and three color cases. It has been shown that the phase diagram of two color QCD is quite helpful and it has a lot of common features with three color one, and predictions recently made in two color QCD was shown to hold qualitatively in real three color QCD. Showing that two color QCD is indeed great lab to study dense quark matter. The dualities has been shown in two color QCD. Duality between chiral symmetry breaking and charged pion condensation phenomena has been demonstrated from first principles in QCD itself. Also there will be discussed color superconductivity phenomenon and the influence of chiral imbalance on its properties.

Despite the fact that the thermodynamic potential in three color case (Nc=3) does not have properties of all three dualities found in the two-color case, it turned out that the phase portrait qualitatively contains these dualities.

Parallel B / 118

Longitudinal spin polarization with dissipative corrections

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In this work, we address the problem of longitudinal spin polarization of Λ hyperons produced in relativistic heavy-ion collisions. We employ a relativistic kinetic theory framework that incorporates spin degrees of freedom treated classically, combined with the freeze-out parametrization used in previous investigations. This approach allows us to include dissipative corrections—stemming from thermal shear and gradients of thermal vorticity—into the Pauli-Lubanski vector, which determines spin polarization and can be directly compared with experimental data. As in similar studies, we find that successfully describing the data requires additional assumptions. In our case, these involve using projected thermal vorticity and suitably adjusting the spin relaxation time (τ_s). From our analysis, we determine that τ_s $\approx$ 5 fm/c, which is comparable to other estimates. We also present our progress on numerical simulations.

Parallel D / **119**

Study of Heavy Quark Momentum Broadening in a Non-Abelian Plasma in- and out-of-equilibrium

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Heavy quarks are formed in the earliest stages of heavy-ion collisions and hence carry comprehensive information about the entire evolution of the initial non-equilibrium glasma phase to a quark-gluon plasma phase, its subsequent hydrodynamic evolution and hadronization at later stages. One of the quantities of interest to model this evolution and to compare with experimental observations is the heavy quark momentum diffusion coefficient κ, which determines how strongly these interact with the medium. We first estimate κ relevant for the pre-thermalization stage in a highly occupied state of SU(2) gauge fields inspired from the color glass condensate (CGC) effective theory. For this we implement for the the first time, relativistic evolution of heavy quarks in the mass range of charm and bottom quarks in a background of over populated SU(2) gauge fields which are evolved using classical-statistical real-time lattice techniques. Based on a novel methodology to extract the momentum broadening for relativistic quarks, in out-of-equilibrium conditions, we find that the momentum distribution of heavy quarks exhibit interesting non-perturbative features at initial times eventually going over to a diffusive regime, where we extract the momentum diffusion coefficient [1]. We find a sizeable discrepancy between the results, calculated earlier in the static limit. We further extend our techniques to estimate κ for heavy quarks in SU(2) gauge theory at high temperatures where its magnetic modes can be described classically within an effective theory [2]. By combining these results we also can provide a comparative study of kinetic equilibration times for charm and bottom quarks relevant for heavy-ion experiments.

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Parallel D / 120

Investigating Radius-Dependent Jet Quenching Dynamics with the JETSCAPE Framework

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In this work, we extend the JETSCAPE framework to investigate the dependence of the jet nuclear modification factor, R_{AA}, on the jet radius parameter (R) for larger jet cones with radii up to $R = 1.0$. The study primarily aims to explore high-p_T inclusive jets, reaching up to 1 TeV, to analyze quenching effects within the quark-gluon plasma created in the most-central (0-10\%) Pb-Pb collisions at $\sqrt{\mathrm{s_{NN}}} = 5.02$ TeV. To achieve this, we couple the MATTER module, which models the high-virtuality stage of parton evolution, with the LBT module for the low-virtuality phase, as well as with the AdS/CFT and MARTINI modules for enhanced precision across different interaction regimes. The MUSIC (2+1)D model is employed to present the hydrodynamic evolution of the quark-gluon plasma in these Pb-Pb collisions. These calculations are then compared to experimental data collected from ATLAS and CMS detectors, with JETSCAPE predictions showing consistency across high-p_T values and large jet radii, within the deviations of 10-25\%. A major aspect of this work is computing the double ratio ($R^{\mathrm{R}}_{\mathrm{AA}}/R^{\mathrm{R=small}}_{\mathrm{AA}}$), which helps to isolate the effect of jet radius on energy retention within the QGP, providing new insights into its dependence on jet-R and jet-p_T and advancing our understanding of jet quenching dynamics in a strongly interacting QCD medium. The observed trends align well with JETSCAPE's multi-stage hydrodynamic model of parton shower evolution.

Parallel D / 121

Exploring flow signals and jet modification in small systems at the LHC

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In ultrarelativistic collisions of nuclear matter, one of the emerging topics is the possible formation of quark-gluon plasma (QGP) droplets in small collision systems. Recent measurements with flow-like behavior imply collectivity in high-multiplicity pp collisions at the LHC. It is also crucial to look for evidence of possible jet-quenching effects in such systems. The results of jet quenching studies in pp collisions at $\sqrt{s} = 13$ TeV will be discussed. The di-hadron correlations are measured for various p_{T}-intervals as a function of charged particle multiplicity. Since small collision systems are biased through non-flow effects such as jets, it is important to develop methods for unbiased flow measurements. The recent progress in non-flow subtraction used to measure flow in small

collision systems will be discussed [1,2]. These studies offer the testing of the limit of multiplicity for flow signals in small systems. This method will also be applied in studying the charm flow and fragmentation in small systems by accounting for the sophisticated background subtraction involved in D^0 meson studies. Furthermore, these results will be compared to various model calculations such as PYTHIA8, PYTHIA String shoving, EPOS, AMPT, and JETSCAPE, wherever possible.

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Parallel B / 122

Bose-Einstein correlations of charged hadrons in RHIC and LHC energies

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In proton-proton collisions at a center-of-mass energy of $\sqrt{s}$ = 13 TeV, gold-gold collisions at energies ranging from $\sqrt{s}$ = 7.7 GeV to 200 GeV, and lead-lead collisions at 2.76 TeV and 5.02 TeV, Bose-Einstein correlations of charged hadrons are examined across the entire multiplicity spectrum of reconstructed charged particles. The CMS data are then compared with results from proton-proton collisions at $\sqrt{s}$ = 13 TeV. Computational data are generated using two theoretical models, AMPT and PYTHIA 8. In the case of PYTHIA 8, data are produced under conditions with and without Bose-Einstein correlations. For AMPT, data are generated under conditions with and without string melting.

Plenary / 123

Non-equilibrium evolution of slow-mode correlation and spectral functions near the QCD critical point

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We investigate the non-equilibrium effects on the structure of the correlation and spectral functions of the slow modes as the collision system evolves through the vicinity of the QCD critical point, within the time-dependent Ginzburg-Landau approximation. We model the time-evolution equation for the slow modes, by allowing the coefficients to be time-dependent. Within this framework, we study a competition between the diverging fluctuation and critical slowing in the critical region.

124

Enhancing Signal Identification in Rare Higgs Boson Decay to Zγ and Complex Decay Processes at LHC Energies

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Higgs Boson is characterized by J$^{\pi}$ = 0^{+} and fundamentally forms the cosmos by interacting with other particles to impart mass in standard model discovered in 2012 at CERN. This study is focused on Zγ channel of Higgs with branching ratio of $\beta(H \to Z\gamma) = (1.57 \pm 0.09) \times 10^{-3}$. Feynman diagram for Z$\gamma$ channel is similar to $\gamma\gamma$ channel and loop diagrams in this process are particularly sensitive to BSM physics. Recent studies have measured $\kappa_{Z\gamma} = 1.65^{+0.34}_{-0.37}$ indicating a uncertainty 40\% . Deviation in standard model prediction $\kappa_{Z\gamma} = 1$ can affect the decay rate $H \to Z\gamma$ and the Higgs production cross-section indicating the need for thorough research into $Z\gamma$. We have used PYTHIA8 Monte Carlo (MC) event generator for the analysis of $H \to Z\gamma \to \mu^{+}\mu^{-}\gamma$ or $e^{+}e^{-}\gamma$ in proton-proton collisions at centre-of-mass energy $\sqrt{s}$ = 13 TeV. This research further explores a novel method to address challenges such as complex background noise and pile-up in dense media, as well as the detection of heavy resonance signals within the domain of heavy-ion physics. By employing an angular correlation technique, the study aims to enhance the Higgs signal-to-background ratio in both heavy-ion and proton-proton experiments. Higgs mass is reconstructed by employing selection criteria focused on certain kinematic variables at various stages and signal-to-background ratio computed. Further analysis involves examining relation between P_Z vs $\theta_{\ell+\ell-}$ and P_H vs $\theta_{Z\gamma}$ - refers to 1^{st} and 2^{nd} angular correlation respectively both were applied up to 1σ, which significantly increased the signal-to-background ratio by several orders of magnitude. Utilizing this approach in conjunction with several kinematic cuts is expected to improve signal detection in complex data sets. Furthermore, this study has also taken into the acceptance and efficiency to incorporate these factors into the cross-section calculation.

Parallel B / **125**

Study of identified particle production as a function of transverse event activity classifier, S_T in p−p collisions

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The underlying events (UE) in proton-proton (p−p) collisions encompass aspects of the interaction not attributed to the primary hard scattering, but arising from accompanying interactions of the rest of the proton.
Traditionally, UE studies involve defining topological regions relative to the leading particle in an event, with the transverse region being especially sensitive to UE activity. Various classifiers have been used to discriminate the extent of UE activity regions.

This contribution introduces a new observable, S_T, defined as the sum of the transverse momentum of charged particles ($\sum_i p_{T_i}$) produced in p−p collisions at LHC energies to probe the underlying events. The production of identified particles like $\pi^{\pm}$, $K^{\pm}$, p , K^0_S, and Λ^0 are studied in different ranges of this transverse activity classifier in p−p collisions at $\sqrt{s} = 13$ TeV using pQCD inspired PYTHIA 8 event generator. A comparative analysis of the identified particle spectra, mean multiplicity and mean transverse momentum has been carried out with respect to S_T and the performance of this new observable is gauged by comparing the results with previously defined R_T observable.

Parallel C / **126**

Pionic and thermodynamic properties of hot QCD with two flavours from an effective field theory approach

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We construct an Euclidean effective field theory (EFT) for thermal Quantum Chromodynamics (QCD) with $N_f = 2$ for physics near crossover temperature using the global symmetries of QCD. A cut-off scale is used along with the $\overline{\text{MS}}$ regularization scheme and all dimension six operators including current-current interactions and a gradient cubed term are utilized. The gradient cubed term contributes to the free energy in the mean field theory (MFT) and modifies the gap equation, as a result of which its coefficient is constrained. Pion fluctuations around the MFT is treated to one-loop in fermions and used to match the theory to lattice computations. Matching the EFT at two temperature allows prediction of the temperature dependence of pion properties and thermodynamic quantities near the cross over.

Parallel A / 128

On Transportation of Baryon Number in pp Collision at √s = 0.9 and 7 TeV

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The estimation of the anti-baryon to baryon ratio is considered to be a useful tool for studying baryon number transport in pp, pA and AA collisions. For this study, the PYTHIA8.3 event generator with various tunes is used to measure the $\bar{\Lambda}/\Lambda$ ratio as a function of rapidity (y), transverse momentum (pT), and multiplicity within both ALICE and LHCb acceptances. The results obtained using various MC data for pp collisions at √s = 0.9 and 7 TeV are compared with the experimentally measured values of ratio of $\bar{\Lambda}/\Lambda$ of ALICE and LHCb experiments. Out of the various studied tunes of PYTHIA 8.3, the String Junction model is found to be the most successful one in describing the experimentally observed results. Evidence of considerable baryon number transportation from the beam fragmentation to the ALICE and LHCb acceptances could be recognized. The widths of the rapidity distribution of produced particles with the studied PYTHIA8.3 Monash and String Junction generated data are found to follow similar separate mass scaling for mesons and baryons as observed in AA collision at SIS, AGS to RHIC and SPS to LHC energies.

Parallel B / 129

Energy and baryon emission surfaces in relativistic heavy ion collisions via HBT Correlations

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The Hanbury Brown-Twiss (HBT) interferometry technique uses the two-particle correlation function to extract the three HBT radii, which measure the spatial and temporal dimensions of the particle emission source at freeze-out in heavy-ion collisions. In this study, we have employed a hybrid model combining hydrodynamic evolution with hadronic transport to simulate the collision dynamics in the presence of QCD conserved charges, most importantly the baryons. We investigate the possibility of accessing the emission sources of energy and baryon via meson-baryon-antibaryon splitting in the HBT radii that offer a unique insight into the freezeout processes and through that into their respective initial conditions.

130

Effects of magnetic field on the evolution of energy density fluctuations

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We study the effects of a static and uniform magnetic field on the evolution of energy density fluctuations present in a medium. By numerically solving the relativistic Boltzmann-Vlasov equation within the relaxation time approximation, we explicitly show that magnetic fields can affect the characteristics of energy density fluctuations at the timescale the system achieves local thermodynamic equilibrium. A detailed momentum mode analysis of fluctuations reveals that a magnetic field increases the damping of mode oscillations, especially for the low momentum modes. This leads to a reduction in the ultraviolet (high momentum) cutoff of fluctuations and also slows down the dissipation of relatively low momentum fluctuation modes. We discuss the phenomenological implications of our study on various sources of fluctuations in relativistic heavy-ion collisions.

131

Rotating strongly interacting matter in a cylindrical geometry

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We discuss the effect of rotation on the confining and chiral properties of QCD using the linear sigma model coupled to the Polyakov loop in an attempt to resolve discrepancies between the first-principle based numerical and model-based analytical results. Working in a homogeneous approximation, we obtain the phase diagram at finite temperature, baryon density, and angular frequency. We demonstrate that in this model, the critical temperatures of both transitions diminish in response to the increasing rotation, being in contradiction with the first-principle lattice results. We enforce the

causality constraint by implementing the spectral boundary conditions and obtain a splitting between the deconfinement and chiral transitions as a boundary effect [1]. We also investigate the Tolman-Ehrenfest law within this consistent framework for the rotating strongly interacting matter in the cylindrical geometry.

[1] "Inhibition of splitting of the chiral and deconfinement transition due to rotation in QCD: the phase diagram of linear sigma model coupled to Polyakov loop". Pracheta Singha, Victor E. Ambrus, Maxim N. Chernodub . e-Print: 2407.07828 [hep-ph] (to be published in Physical Review D).

Parallel C / 132

Hybrid Regression and Explainable AI for Phase Transition Analysis of two flavour Quark Matter

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We investigate a hybrid approach of parametric and nonparametric regression techniques to analyse the phase boundary between the confined and deconfined phases of two-flavour quark matter. Data derived from the Nambu-Jona-Lasinio (NJL) and Polyakov-loop extended NJL (PNJL) models are trained and further used for the prediction of phase transition boundaries with enhanced accuracy. We also observe the classification of the order of phase transition and interpret the model's predictions with extreme gradient boosting and SHapley Additive exPlanations(SHAP) values. Our findings demonstrate that this learning method effectively captures the complex behaviour of quark matter transitions and is also useful to balance interpretability and flexibility.

Parallel C / 133

System size, energy and event shape dependence of the mean transverse momentum fluctuations with ALICE at the LHC

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Measurement of the event-by-event fluctuations of the mean transverse momentum, $\langle p_{\mathrm{T}} \rangle$, help to characterize the properties of the bulk of the system created in ultrarelativistic heavy-ion collisions, called the quark-gluon plasma (QGP). The fluctuations are closely related to the dynamics of the phase transition from the QGP to a hadron gas.

In this presentation, the $\langle p_{\mathrm{T}} \rangle$ fluctuations of charged particles produced in pp, Xe-Xe and Pb-Pb collisions at the LHC will be presented. The fluctuations are measured via the integral correlator, $\langle\langle \Delta p_{\mathrm{T}} \Delta p_{\mathrm{T}} \rangle\rangle$. The strength of the correlator is found to decrease monotonically with increasing charged-particle multiplicity measured at mid-rapidity in all three systems. In Xe-Xe and Pb-Pb collisions, the multiplicity dependence of the correlator is found to deviate significantly from a simple power-law scaling and from the predictions of the HIJING and AMPT models. The observed deviation is expected to arrise from the transverse radial flow in semicentral to central heavy-ion

collisions. The correlation strength is also studied in pp collisions by classifying the events based on their event shape, transverse spherocity. Jetty events feature a larger correlation strength than isotropic events. The strength and multiplicity dependence of jetty and isotropic events are compared with calculations from PYTHIA 8 and EPOS LHC models.

Parallel A / 134

Strange hadrons production in Au+Au collisions at $\sqrt{s_{NN}}$ = 19.6 GeV from STAR

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The main goal of the Beam Energy Scan (BES) program at RHIC is to search for and study key features in the QCD phase diagram such as the conjectured critical point, the expected first order phase transition between hadronic and partonic matter, and the chiral phase transition. Strangeness production is considered a sensitive probe of the early dynamics in the deconfined matter created during heavy-ion collisions. Results from BES phase I (BES-I) have shown indications of increased hadronic interactions and a weakening of the quark-gluon plasma signatures with decreasing collision energies. However, the data from BES-I do not provide the precision needed for conclusive findings. The BES-II program, which provides data samples with enhanced statistics and featured upgrades like the iTPC, enables improved measurements with broader rapidity range from mid-rapidity ($|y| < 0.5$) to a larger rapidity range ($|y| < 1.5$) at $\sqrt{s_{NN}} \leq 19.6$ GeV. In this presentation, we will discuss new STAR measurements of strange hadrons (K_s^0, Λ, $\overline{\Lambda}$, Ξ^-, $\overline{\Xi}^+$, Ω^-, $\overline{\Omega}^+$) production in Au+Au collisions at $\sqrt{s_{NN}}$ = 19.6 GeV from BES-II. We will show transverse momentum and rapidity spectra at extended rapidity, nuclear modification factors, antibaryon-to-baryon ratios, and baryon-to-meson ratios. These measurements offer new insights into the collision dynamics at this energy.

Parallel B / 135

Dependence of directed flow on system size and net conserved charges from quark coalescence in heavy-ion collisions

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The properties of the QGP medium produced in relativistic heavy-ion collisions can be explored using the directed flow (v_1) of the azimuthal angle distribution in momentum space. Hydrodynamic and nuclear transport models indicate that v_1 in the midrapidity region is sensitive to expanding participant matter during the early collision stages. Spectator nucleons influence the directed flow of identified hadrons, especially when the nuclear passage time is not short compared to the medium expansion time, which is also related to the radii of the colliding nuclei. Thus, studying the system size dependence of v_1 can provide insights into the QGP properties. This talk will present rapidity-odd directed flow (v_1) in various collision systems (O+O, Cu+Cu, Ru+Ru, Zr+Zr, Au+Au, U+U) at $\sqrt{s_{NN}} = 200$ GeV using the AMPT model. We will discuss the slope of directed flow (dv_1/dy) across different systems.

A non-zero Δv_1 at non-zero Δq has been proposed as a violation of the coalescence sum rule and attributed to electromagnetic fields, especially if Δv_1increases with Δq. Our recent study suggests a coalescence sum rule for the v_1 difference (Δv_1) among seven hadron species (K^-, $\phi, \overline{p}$, $\overline{\Lambda}$, $\overline{\Xi}^+$, Ω^- and $\overline{\Omega}^+$). We found that Δv_1 depends linearly on both the electric charge difference, Δq and strangeness difference, ΔS. This talk will also discuss the results of the coalescence sum rule in the beam energy range of $\sqrt{s_{NN}}$ = 7.7-200 GeV using the AMPT model.

Parallel C / 137

Gravitational Wave Signatures of Spin-Polarized Dense Matter in Neutron Stars

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The presence of ultra-strong magnetic fields in magnetar induces significant spin polarization of baryons, profoundly affecting the equation of state (EoS) of dense nuclear matter. This study employs the CDM3Y interaction, a G-matrix-based M3Y interaction, within the Hartree-Fock framework to model spin-polarized nuclear matter in the presence of such extreme magnetic fields. By incorporating spin polarization into the EoS, we analyze its impact on the structure and deformability of neutron stars.
The study explores gravitational wave (GW) signals generated by time-varying quadrupole moments and it is proposed that spin polarized EoS, modifying the star's quadrupole moment can affect the amplitude and characteristics of the emitted GWs.
Future GW observations also will be able to offer unique opportunity to constrain the spin polarization of highly magnetized neutron stars, providing valuable insights into the spin-polarized physics of dense matter.

Parallel D / 138

Impact of Initial State and Energy Loss Models on Heavy-Flavor Azimuthal Correlations in Ultra-Relativistic Collisions

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Heavy flavors (charm and beauty) are created via initial hard scatterings in ultra-relativistic heavy-ion collisions. Their early production allows them to experience the entire evolution of the collision. Azimuthal angular correlations of open heavy flavor hadrons with charged particles is an excellent tool to investigate different stages of heavy-ion collisions, as it is sensitive to various stages of the heavy-ion collision.

Heavy quarks propagate through the hot and dense quark-gluon plasma (QGP) medium, losing energy via collisional and radiative processes. Recent studies on initial stages emphasize the importance of a pre-equilibrium glasma phase in understanding heavy flavor dymanics in heavy-ion collision. Although it lasts for less than 1 fm/c, this phase has a significant impact on heavy quark behavior and energy loss before the formation of the quark-gluon plasma (QGP).

This contribution aims to investigate the impact of different initial state and energy loss models on the charm quark via azimuthal angular correlations of D mesons and $^{+}_{\mathrm{c}}$ baryons with charged hadrons in pp, and Pb—Pb collisions at $\sqrt{s_{\mathrm{NN}}}$ = 5.02 TeV using the JETSCAPE event generator. The effects of different initial states and energy loss models are quantified by measuring the yield and width of the near side and away side peaks of the azimuthal angular correlation distribution. This study is crucial for drawing robust conclusions regarding heavy quark thermalization and energy loss in the QGP.

Parallel B / 139

Exploring Event-by-Event p_{T} Fluctuations in pp Collisions at $\sqrt{s} = 13$ TeV: An Insights from ALICE

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Event-by-event fluctuations of the mean transverse momentum (p_{T}) of relativistic charged particles are analyzed using the two-particle correlator, $\sqrt{C_m}/M(p_{\mathrm{T}})_m$ which quantifies the correlations strength in units of the mean p_{T} in proton-proton collision at $\sqrt{s} = 13$ TeV in ALICE both for Minimum Bias and and High-multiplicity triggered events. The non-monotonic variations in p_{T} correlations with changing energy could serve as a signature of QGP formation. A comprehensive investigation across soft, intermediate, and hard p_{T} regions could provide crucial insights into both equilibrium (e.g., thermal radial flow) and non-equilibrium (e.g., jet/minijet) contributions to p_{T} fluctuations. The dependence of the correlator on particle multiplicity for different p_{T} window widths and positions is explored. The correlator values are found to decrease with increasing charged particle density, following a power-law behavior similar to observations in both small and large systems at lower energies. Additionally, the influence of p_{T} range on the power-law coefficient is studied and results are compared with predictions from Monte Carlo models, such as PYTHIA (pQCD string model) and EPOS (core-corona model), to enhance understanding of the underlying mechanisms driving p_{T} fluctuations.

Parallel A / 140

Extracting baryon initial condition and diffusion - a Bayesian approach

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Bayesian analysis is employed to extract significant parameters related to the baryon initial condition and dissipation in the hot and dense strongly interacting matter produced in relativistic heavy ion collisions eventually leading towards significant understanding of the properties of the baryon rich QCD matter.

Parallel C / 141

Photon emission rate from Quark-gluon plasma in the presence of finite baryonic density

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The photon emission from a finite baryonic Quark-Gluon Plasma is analyzed through annihilation and Compton processes using the Boltzmann distribution function. This analysis incorporates a finite baryonic parameter into the quark mass and coupling constant. Accounting for this parameter enhances the photon production rate compared to earlier theoretical predictions based on this distribution function. The observed improvement in the emission rate suggests the formation of Quark-Gluon Plasma in such baryonic matter.

Parallel C / 142

Energy Evolution of QGP under two loop correction at finite chemical potential

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We calculate the energy evolution of quark gluon plasma (QGP) under the two loop correction at finite chemical potential. The calculation shows a good improvement over the energy evolution without chemical potential and the stability formation is also obtained at the size of 1.8 fm. This indicates that QGP droplet can be found with changing the quark and gluon flow parameters. However there is a lot of change in the stability of QGP droplet depending on the parameters contained in the system

Parallel C / 143

The comparative Polyakov loop potential between temperature and chemical potential dependance

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We calculated the comparative Polyakov loop potential with chemical potential with temperature and chemical potential dependance. The result of Polyakov loop in these comparative outputs shows that there will be effect in the calculation of equation of state of Polyakov loop with the chemical potential dependance. There are number of calculations in this equation of state of the Polyakov loop at finite temperature. So we can further calculate equation of state using this chemical potential in the Polyakov loop.

Parallel C / 144

Deciphering accretion-driven starquakes in recycled millisecond pulsars using gravitational waves

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Recycled millisecond pulsars are susceptible to starquakes as they are continuously accreting matter from their binary companion. A starquake happens when the rotational frequency of the star crosses its breaking frequency. In this study, we perform a model analysis of an accreting neutron star suffering a starquake. We analyse two models: a spherical star with accreting mountains and a deformed star with accreting mountains. We find that as the star crosses the breaking frequency and suffers a starquake, there is a sudden change in the continuous gravitational wave signal arriving from it. The amplitude of the gravitational wave signal increases suddenly both for the spherical and deformed star. For the spherical star, the accreting matter entirely dictates the amplitude of the gravitational wave. For the deformed star, both the accreting matter and the deformation from spherical symmetry play a significant role in determining the amplitude of the gravitational wave signal. This sudden change in the continuous gravitational wave signal in recycled millisecond pulsars can be a unique signature for such pulsars undergoing a starquake.

Parallel C / 145

Transport properties of hot hadronic matter in heavy ion collisions.

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We estimate the transport coefficients like shear and bulk viscosities of hot hadronic matter in van der Walls hadron resonance gas (VDW HRG) model in the relaxation time approximation. We also have compared these results with excluded volume hadron resonance (EV HRG) calculations. η/s decreases as the temperature of the hadronic system increases at a fixed baryon chemical potential. η/s in VDW HRG is always less than that of EV HRG case due to the large entropy density in VDW HRG compared to EV HRG case. At a fixed chemical potential, ζ/s in VDW HRG is also less than that of EV HRG case. We also have estimated these transport coefficients along the freezeout curve. There is an increase in chemical freezeout temperature in VDW HRG case determined from the universal condition $E/N=\epsilon/n{\sim}1$ GeV. We also have calculated the variation of attraction parameter along the freezeout curve $E/N=\epsilon/n{\sim}1$ GeV keeping the freezeout parameters same as in ideal HRG and the repulsion parameter fixed. We observe a nontrivial variation of attraction parameter along the freezeout curve where it increases in the meson dominated region and decreases in the baryon dominated region along the chemical freezeout curve. η/s in EV HRG is always large than that VDW HRG along the freezeout curve. This is also true for ζ/s.

146

Dual QCD Formulation at Finite Temperature and Chemical Potential

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In terms of dual gauge potentials, a Dual QCD formulation for the SU(3) colour gauge has been established, which takes into account the dynamics of the colour gauge group's topological and local structure. The dynamical configuration of the resulting dual QCD vacuum and its flux tube

configuration have been studied in order to investigate the nonperturbative properties of QCD. In order to study the kinetics of the quark-hadron phase transition at finite chemical potential, the thermal behaviour of the nonperturbative QCD vacuum has been examined. The dual QCD-based hadronic bag, which ensures the necessary parameters and related critical points for quark-hadron phase transition, has also been used to explore related thermodynamic quantities and the equation of state (EoS) to characterise quark matter. It is anticipated that these thermodynamic values will be crucial in determining the order of quark-hadron phase transitions and will probably be able to forecast the characteristics of a first-order quark-hadron phase transition for limiting chemical Furthermore, by building the free energy change and the corresponding surface tension for the quark-hadron phase transition, we have examined the bulk properties of quark matter. We also compared our results with known lattice QCD results and the most recent three-loop Hard Thermal Loop perturbative results for consistency and compatibility checks, and we found that they were reasonable agreements.

Parallel D / 147

Effect of initial states on the production of heavy flavors using azimuthal angular correlation

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Heavy flavors (charm and beauty) are created via initial hard scatterings in ultra-relativistic heavy-ion collisions. The study of thermalization of heavy flavors in the Quark Gluon Plasma (QGP) is one of the major physics goals of the upcoming heavy-ion experimental programs. Azimuthal angular correlations ($\Delta\varphi$) of open heavy flavour species are expected to be influenced by the thermalization of heavy quarks. Besides thermalization, $\Delta\varphi$ distributions of heavy flavors also serve as an excellent tool to look into heavy flavor production processes. Furthermore, differential studies in $\Delta\varphi$ correlations will give ample information about heavy quark dynamics in the heavy-ion collision at different kinematic ranges.\\

In this contribution, we present a transverse momentum (p_{T}) differential study of the azimuthal angular correlations of $\mathrm{D}^0 - \mathrm{D}^0$ and $\mathrm{B} - \mathrm{B}$ mesons in pp and Pb–Pb collisions at $\sqrt{s_{\mathrm{NN}}}$ = 5.5 TeV using PYTHIA8. We also perform multiplicity differential calculations to examine the effects of the multi-parton interactions (MPIs) on the $\Delta\varphi$ distributions. Our findings suggest that MPI modifies the $\mathrm{D}^0 - \mathrm{D}^0$ correlations significantly, especially at low p_{T}, while a weak multiplicity-dependence is observed for $\mathrm{B} - \mathrm{B}$ correlations. In Pb–Pb collisions, azimuthal angular correlations of $\mathrm{D}^0 - \mathrm{D}^0$ are important from the perspective of charm thermalization while checking for additional initial state effects. We quantify the effect of nuclear parton distribution functions (PDF) on $\mathrm{D}^0 - \mathrm{D}^0$ and $\mathrm{B} - \mathrm{B}$ correlations by measuring the yield and width of the respective $\Delta\phi$ distributions. The correlation distribution also show sensitivity to the parton level processes, gluon splitting show its imprints in the NS peak of correlation distribution in the form of double NS peak at low trigger p_{T} observed for both charm as well as beauty quark. This study is crucial for drawing robust conclusions about the thermalization of heavy quarks in the QGP.

Parallel D / 148

Lattice study of correlators for quarkonium decay

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Quarkonia are among the most studied probe of the quark-gluon plasma created in relativistic heavy ion collisions. But a nonperturbative theoretical formalism for quarkonia in plasma is difficult, and one relies on an effective field theory formalism coupled with lattice studies. If the system size is much less than the inverse temperature, as is expected for bottomonia, the interaction of the system with the medium can be approximated by a color electric field, and the decay of the quarkonia can be studied as a transition to an octet state through the interaction with the medium. In an open quantum system framework, such interactions are encapsulated in transport coefficients.

We will present results of a lattice study of the correlators relevant for this process, at temperatures in the range 1-2 times the deconfinement temperature, for a gluonic plasma. We will also discuss the difference between this transport coefficient and the one used for the diffusion of a heavy quark in the plasma.

Parallel B / 149

Exploring transverse momentum fluctuations via study of $v_0(p_T)$ in the AMPT and PYTHIA model

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Transverse momentum fluctuations serve as a powerful tool for probing the properties and evolution dynamics of the system formed in high energy heavy-ion collisions. Momentum fluctuations are sensitive to the equation of state as well as to the bulk-viscosity of the QCD system. An observable known as $v_0(p_T)$ which quantifies the momentum fluctuations has been suggested to measure in experiments as it is strongly correlated with the fluctuations in the entropy per area, thereby providing a new handle on one of the most important initial state parameters. Hydrodynamic simulations with the hybrid models predict that $v_0(p_T)$ shows a discernible mass hierarchy for pions, kaons, and protons. Recent studies also suggest that measurement of $v_0(p_T)$ could serve as a valuable tool for refining our understanding of the bulk viscosity of the system and the speed of the sound in the medium formed in heavy-ion collisions.

In this work, we study the observable $v_0(p_T)$ in p+p and Au+Au collisions at centre-of-mass energy 200 GeV using the PYTHIA8 and AMPT model, respectively. This study is performed in the kinematic acceptance range of p_T from 0.2 to 5 GeV/c for inclusive charged hadrons and for identified particle species such as pion, kaon, and proton. The observable is calculated in a similar way as the harmonic flow $v_2(p_T)$, using a gap in pseudo-rapidity to reduce non-flow effects. The effect of different hadronisation mechanisms in the models will be investigated. These model results would be useful for the future measurements in heavy-ion collision experiments.

Parallel D / 150

Open Quantum System approaches for quarkonium evolution in the QGP

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This is a mini-review talk.

151

Enhanced ψ' yield and $\psi'/(J/\psi)$ yield ratio, a signature of QGP formation in high multiplicity $p+p$ collisions

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Suppression in the yield of quarkonia (heavy quark-antiquark bound states) has been considered one of the important signatures of the formation of the thermalized deconfined partonic matter, also known as the Quark Gluon Plasma (QGP), in Relativistic Heavy Ion Collision Experiments (RHICE). Traditionally, the in-medium dissociation of quarkonium states has been presented by implicitly assuming an adiabatic approximation, which considers that the heavy quark Hamiltonian changes slowly over time owing to change in the medium. However, in high multiplicity smaller systems, such as in $p+p$ collisions, the early development of transverse flow resulting from the finite transverse size of the locally thermalized medium may cause the quarkonium states to undergo a non-adiabatic evolution. It has been argued that in the presence of such a non-adiabatic evolution, the suppression of heavy quark-antiquark bound state yields may not reliably indicate QGP formation~\cite{Bagchi:2023vfv}. We propose that, rather than
concentrating on the suppression of J/ψ yields, the enhancement in the yield ratio of ψ' to J/ψ (i.e., $\psi'/(J/\psi)$), along with an increase in ψ' yield, should be considered as a probe of QGP formation for small systems. Our findings, based on realistic modeling of the time evolution of small systems, suggest that the yield ratio $\psi'/(J/\psi)$ and the yield of ψ' increase as a function of hydrodynamization temperature incorporating the non-adiabatic transitions in high multiplicity $p+p$ collisions.

Parallel B / 152

Recent results on light nuclei and hypernuclei production at RHIC

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This is a mini-review talk.

Inauguration / Welcome / 153

Welcome address - Director, IISER Berhampur

Inauguration / Welcome / 154

Address by VC, Berhampur University

Inauguration / Welcome / 155

Address by Organiser

156

test

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157

Optimising Gas Electron Multiplier for improved detector performance using ANSYS and Garfield++

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Micro-Pattern Gas Detectors (MPGDs) are a type of gaseous ionization detector that use microelectronics. They are characterized by a very small gap between the anode and cathode electrodes, which are maintained at high voltage and are usually filled with gaseous medium. When a high-energy particle interacts with the gas, it produces ions and electrons that are propelled in opposite directions by the electric field in the detector region. The electrons that are deflected can induce further ionization,resulting in more electron-ion pairs through an avalanche effect. These resulting particles can be detected with high precision at the readout stage.

One specific kind of MPGD is the Gas Electron Multiplier (GEM), which is made from a polyimide film sandwiched between two conductive layers of copper under a high voltage difference. Tiny holes in the foil allow for electron avalanches to occur. However, the current design of the GEM detector, used in various experiments is suboptimal for achieving maximum gain and performance. This study aims to achieve the best possible configuration of GEM foil to get optimal electric field, higher gain and lesser back-flow of ions without compromising the detector's capability. In this research, we have modified the geometry of the GEM detector to improve gain, minimize ion back flow and enhance overall performance. This geometry has been modeled in ANSYS and additional analyses have been conducted using Garfield++.

158

On the convergence of the gradient expansion of the Boltzmann equation

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When two heavy nuclei collide in relativistic heavy ion collisions, the resulting system is initially in a non-equilibrium state. The evolution of the system towards equilibrium can be studied by using the Boltzmann equation. However, approximating the solution to the Boltzmann equation using a gradient expansion leads to a divergent series. Using an integral solution to the Boltzmann equation in relaxation time approximation, we obtain its full gradient expansion which contains exponentially decaying non-hydrodynamic terms. It is shown that this gradient expansion can have a finite radius of convergence. We further argue that, in the relaxation time model, proximity to local thermal equilibrium is not necessary for the system to be described by hydrodynamic equations.

159

Data driven analysis of jet energy loss distribution in relativistic heavy ion collision

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We present a numerical investigation of partonic energy loss in the Quark-Gluon Plasma (QGP) using a data-driven Bayesian inference framework. This study explores the energy, transverse momentum, and angular characteristics of the energy loss distribution associated with medium-induced multiple gluon emissions by hard partons traversing the QGP. The inference process employs the Markov Chain Monte Carlo method, implemented via the Metropolis-Hastings algorithm. Independent radiation mechanisms are modeled under the effects of boost-invariant longitudinal expansion, incorporating gamma and log-normal energy distribution functions to examine transverse momentum broadening and angular profiles of partonic cascades, providing insights into the interplay between medium properties and partonic evolution. Our results demonstrate consistent nuclear modification factor RAA values with the LHC data across both energy distributions.

160

Study of charm fragmentation using charm-hadron angular correlation measurements with ALICE

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In recent years, measurements of charm baryon-to-meson yield ratios highlighted a modification of the hadronization process in proton–proton collisions with respect to e+e− collisions. This invalidated the assumption at the basis of several theoretical calculations based on a factorisation approach that the cross section of charm hadrons can be calculated by parametrising the transition from charm quarks to charm hadrons with fragmentation functions tuned on to e+e− data. Additionally, the measurement of charm-hadron-tagged jets and correlations provides direct insights into initial parton kinematics, fragmentation processes, and hadronization mechanisms, underscoring their significant importance.

In this presentation, we introduce the latest ALICE results on angular correlations between heavy-flavour (HF) hadrons (triggers) with charged particles, and on jets containing HF particles. In particular, we report the results of angular correlations between strange and non-strange D-meson triggers with charged particles in pp collisions, including the first studies performed on Run 3 data. We also show the comparison between angular correlations obtained considering charm mesons and charm baryon (Λ+c) triggers in pp collisions. These measurements will give insights into the differences in the charm fragmentation between
charm baryons and mesons. We also present the final measurement of the longitudinal momentum fraction of jets carried by Λ+c baryons in pp collisions at √s = 13.6 TeV. This observable is particularly valuable as it provides a more direct link to the charm fragmentation functions and imposes more stringent constraints on hadronization mechanisms.

161

Demystifying the effects of QCD radiation, color reconnection, and rope formation mechanism on forward-backward multiplicity correlations in proton-proton collisions at LHC energies

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Forward-backward multiplicity correlation in minimum biased pp collisions has been studied within the PYTHIA8 framework at LHC energies. One of the findings of this study highlights the interplay between SRCs and LRCs in shaping the correlations among produced particles in various azimuth and pseudorapidity. Our study concludes that the azimuthal sectors with φ are predominantly affected by LRCs, whereas are primarily driven by sep > π/4 φsep < π/4 SRCs. Another notable observation is the strong dependence of the Initial State Radiation (ISR) and Final State Radiation (FSR) on the FB multiplicity correlation strength parameter b , with ISR having a more significant effect than FSR. The role of Multi-parton corr (mult.) Interaction (MPI), Color Reconnection (CR), and color rope formation on FB multiplicity correlation is also studied. We find good quantitative agreement with ALICE results [1] for MPI-based CR (CR Range 3.6 and 5.4) and QCD-based CR + Ropes across all the studied energies. On the other hand, the MPI-based CR (CR Range 1.8, default) fails to explain the
experimental data at all energies. This study serves as a baseline for exploring more interesting high-multiplicity (HM) pp collisions, which often exhibit collective behavior.

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162

Resonances production in-and-out of jets in pp collisions at sqrt(s) = 13.6 TeV

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Recent experimental results on two-particle correlations within jets with extremely high multiplicities in pp collisions highlight a strong flow-like correlation among constituents. This has led to the hypothesis that a hot and dense QCD medium may form within these jets, a phenomenon previously thought to occur exclusively in heavy-ion collisions. One notable characteristic of such medium formation is the altered production ratio among different species of particles. We aim to investigate this phenomenon by analyzing the yields of K*and Φ mesons within high-multiplicity jets in pp collisions at $\sqrt{s}$ = 13.6 TeV with LHC Run 3 data obtained with ALICE. The analysis utilizes charged-particle jets and per-jet yields of K* and Φ are investigated in and out of such jets. The focus on these particles is expected to provide valuable insights into the intricate dynamics of QCD medium creation and its influence on particle production patterns.

Plenary / **163**

Search for baryon junction

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Search for baryon junction

Plenary / **164**

Signature of electromagnetic field in heavy-ion collision

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Signature of electromagnetic field in heavy-ion collision

Plenary / **165**

Physics of high baryonic matter

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Physics of high baryonic matter

Plenary / 166

The physics of strong electromagnetic fields in heavy ion collisions

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The physics of strong electromagnetic fields in heavy ion collisions

Plenary / 167

Quarkonium measurements in relativistic heavy ion collisions

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Quarkonium measurements in relativistic heavy ion collisions

Plenary / 168

Spin polarization in heavy ion collisions and relativistic spin hydrodynamics

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Spin polarization in heavy ion collisions and relativistic spin hydrodynamics

Plenary / 169

Quantum kinetic theory and spin polarisation in relativistic heavy ion collisions

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Quantum kinetic theory and spin polarisation in relativistic heavy ion collisions

Plenary / 170

Physics at sPHENIX

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Physics at sPHENIX

Plenary / 171

Imaging nuclei by smashing them: how can shapes be revealed despite violent collisions?

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Imaging nuclei by smashing them: how can shapes be revealed despite violent collisions?

Plenary / 172

Application of machine learning and quantum computation in high energy physics

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Application of machine learning and quantum computation in high energy
physics

Plenary / 173

Chiral instabilities in relativistic heavy ion collisions

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Chiral instabilities in relativistic heavy ion collisions

Plenary / 174

Jet shape measurements in relativistic heavy ion collisions

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Jet shape measurements in relativistic heavy ion collisions

Plenary / 175

Experimental overview on recent measurements of resonances and exotics

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Experimental overview on recent measurements of resonances and exotics

176

Physics opportunities at the EIC

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Physics opportunities at the EIC

Plenary / 177

Experimental overview on the open heavy flavor measurement in relativistic heavy ion collisions

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Experimental overview on the open heavy flavor measurement in relativistic heavy ion collisions

Plenary / 178

Some recent theoretical advances in studying dense QCD phase transition

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Some recent theoretical advances in studying dense QCD phase transition

179

Probing the QCD critical point with electromagnetic probes

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Probing the QCD critical point with electromagnetic probes

Plenary / 180

Jets in relativistic heavy ion collisions: Theory perspective

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Jets in relativistic heavy ion collisions: Theory perspective

Plenary / 181

Drell Yan as a probe of the nucleus

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Drell Yan as a probe of the nucleus

Plenary / 182

Forward Physics at LHC-ALICE

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Forward Physics at LHC-ALICE

Plenary / **183**

Experimental Status of QCD Phase Diagram

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Experimental Status of QCD Phase Diagram

Plenary / **184**

Studying the QCD phase diagram via fluctuations

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Studying the QCD phase diagram via fluctuations

Plenary / **185**

Heavy flavor on lattice

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Heavy flavor on lattice

Plenary / **186**

Indian participation in ePIC at EIC

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Indian participation in ePIC at EIC

Plenary / 187

Recent results from lattice QCD on the phase diagram

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Recent results from lattice QCD on the phase diagram

Plenary / 188

Overview of current status

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Overview of current status

Plenary / 189

Out of equilibrium physics in the vicinity of the QCD critical point and in the initial state

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Out of equilibrium physics in the vicinity of the QCD critical point and in the initial state

Plenary / 190

Indian contribution to build FAIR at GSI

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Indian contribution to build FAIR at GSI

Plenary / 191

Overview of neutron stars and their connection to QCD phase diagram

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Overview of neutron stars and their connection to QCD phase diagram

Plenary / 192

Observational constraints on the properties of the neutron star matter

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Observational constraints on the properties of the neutron star matter

Plenary / 193

Collectivity with system size

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Collectivity with system size

Plenary / 194

Relativistic resistive magnetohydrodynamic framework to study heavy ion collisions

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Relativistic resistive magnetohydrodynamic framework to study heavy ion collisions

Plenary / 195

Results on magnetohydrodynamics simulations with BHAC-QGP

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Results on magnetohydrodynamics simulations with BHAC-QGP

Plenary / 196

Electron Ion Collider (EIC) - Theory perspective : Spin Physics

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Electron Ion Collider (EIC) - Theory perspective : Spin Physics

Plenary / 197

Physics opportunities at the EIC

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Physics opportunities at the EIC

Plenary / 198

EIC physics: Recent theoretical advances from the BLFQ collaboration

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EIC physics: Recent theoretical advances from the BLFQ collaboration

Plenary / 199

Light flavor resonance production in heavy ion collisions

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Light flavor resonance production in heavy ion collisions

Plenary / **200**

Overview of PHENIX results

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Overview of PHENIX results

Plenary / **201**

Recent developments in charm phenomenology

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Recent developments in charm phenomenology

Plenary / **202**

Experimental overview of recent jet measurements in relativistic heavy ion collisions

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Experimental overview of recent jet measurements in relativistic heavy ion collisions

Plenary / **203**

Baryon and strangeness number fluctuation at LHC energies

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Baryon and strangeness number fluctuation at LHC energies

Plenary / 204

Polarization measurement in relativistic heavy ion collisions

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Polarization measurement in relativistic heavy ion collisions

Closing Session / 205

Concluding remarks

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Closing Session / 206

Next ATHIC

Closing Session / 207

Presentation and Vote of thanks

Plenary / 208

Shock wave collisions

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Shock wave collisions

Parallel A / 209

Electromagnetic field fluctuation and its correlation with the participant plane in Au + Au and isobaric collisions at $\sqrt{s_{NN}} = 200$ GeV

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Intense transient electric (**E**) and magnetic (**B**) fields are produced in the high energy heavy-ion collisions. The electromagnetic fields produced in such high-energy heavy-ion collisions are proposed to give rise to a multitude of exciting phenomenon including the Chiral Magnetic Effect. We use a Monte Carlo (MC) Glauber model to calculate the electric and magnetic fields, more specifically their scalar product $\mathbf{E} \cdot \mathbf{B}$, as a function of space-time on an event-by-event basis for the Au+Au collisions at $\sqrt{s_{NN}} = 200$ GeV for different centrality classes. We also calculate the same for the isobars Ruthenium and Zirconium at $\sqrt{s_{NN}} = 200$ GeV. In the QED sector $\mathbf{E} \cdot \mathbf{B}$ acts as a source of Chiral Separation Effect, Chiral Magnetic Wave, etc., which are associated phenomena to the Chiral Magnetic Effect. We also study the relationships between the
electromagnetic symmetry plane angle defined by $\mathbf{E} \cdot \mathbf{B}$ ($\psi_{E.B}$) and the participant plane angle ψ_P defined from the participating nucleons for the second-fifth order harmonics.

Parallel B / 210

Anisotropic Electrical Conductivity in Rotating Hadron Gas

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In non-central heavy-ion collisions, substantial orbital angular momentum (OAM) is produced and transferred to the QGP and hadronic matter, leading to effects like spin polarization and the chiral vortical effect. Previous studies have explored the impact of OAM on electrical conductivity under a non-relativistic, globally rotating QGP. In this work, we have developed a relativistic framework, relaxing earlier assumptions, to study the electrical conductivity of rotating hadronic matter. We have used the Boltzmann transport equation, integrating the Coriolis force that arises due to rotation in the hadron resonance gas (HRG) model. We have observed that similar to the Lorentz force, the Coriolis force induces anisotropy in the medium, which can be classified into three components: Hall ($\sigma^{\times}$), perpendicular ($\sigma^{\perp}$), and parallel ($\sigma^{||}$). In a rapidly rotating HRG, the Hall component (σ×) becomes dominant up to T ≈ 0.20 GeV, reflecting significant anisotropy in the medium.

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2. Effect of the Coriolis force on the electrical conductivity of quark matter: A nonrelativistic description, Ashutosh Dwibedi, Cho Win Aung, Jayanta Dey, and Sabyasachi Ghosh, Phys. Rev. C 109 (2023), 034914

Parallel A / 211

Physics overview of CBM detector at FAIR

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Physics overview of CBM detector at FAIR

Parallel C / 212

Neutron star physics in the multi-messenger era

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Neutron star physics in the multi-messenger era

Parallel C / 213

Impact of Dissipation on the Dynamics of Neutron Star Mergers

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Impact of Dissipation on the Dynamics of Neutron Star Mergers

Parallel A / 214

Relativistic Hydrodynamics - A causality-stability perspective

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Relativistic Hydrodynamics - A causality-stability perspective

Parallel B / 215

Double-slit experiment at the femtometer scale with ALICE

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Double-slit experiment at the femtometer scale with ALICE

Parallel B / 216

Baryon dynamics from recent measurements on directed flow and polarisation

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Baryon dynamics from recent measurements on directed flow and polarisation

Parallel D / 217

QGP tomography

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QGP tomography

Parallel B / 218

Photons as a probe of the strongly interacting matter in heavy ion collisions

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Photons as a probe of the strongly interacting matter in heavy ion collisions

Parallel D / 219

Heavy quarks in glasma

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Heavy quarks in glasma

Parallel A / 220

Jets in expanding medium

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Jets in expanding medium

Parallel D / 221

Recent developments in open heavy-flavour physics: ALICE highlights

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Recent advances in the field of open heavy-flavour physics have provided profound insights into the behavior of heavy quarks (charm and beauty) in extreme conditions of matter created in high-energy heavy-ion collisions. The ALICE experiment at the Large Hadron Collider (LHC) has been at the forefront of these studies, offering precision measurements and groundbreaking results that shed light on the properties of the quark-gluon plasma (QGP).

This mini-review talk will summarize recent ALICE highlights in open heavy-flavour physics, focusing on the production, propagation, and hadronization of heavy quarks in heavy-ion collisions. Key topics include the energy loss of heavy quarks in the QGP, constraints on the transport coefficients of the medium, and the interplay between heavy-flavour hadronization and the surrounding QGP. Results from proton-proton (pp) and proton-lead (p-Pb) collisions will also be discussed.

In addition, the presentation will offer a glimpse into upcoming challenges and opportunities in the field, highlighting planned upgrades to ALICE and prospects for future measurements. With the next phase of experiments on the horizon, the discussion will emphasize how these new findings will shape our understanding of heavy-flavour interactions and the properties of the QGP.

Parallel A / 222

Heavy quark potential in anisotropic medium

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In this work, the real part of the static potential of a heavy quark-antiquark system in an anisotropic plasma medium is studied. The collective dynamics of the plasma constituents is described using hard-loop perturbation theory. The distribution function of the medium is characterized by a general set of anisotropy parameters. We calculated the real part of the heavy quark potential numerically and studied the angular dependence of the distortion of the potential relative to the isotropic one. Our study suggests that plasma anisotropy plays an important role in the dynamics of heavy quarkonium.