10th International Conference on Hard and Electromagnetic Probes of High-Energy Nuclear Collisions

Sunday, 31 May 2020 - Friday, 5 June 2020

Online

Book of Abstracts

Contents

3

Searching for Novel Jet Substructure Modifications Using Collinear Drop

Author: Yang-Ting Chien[1]

[1] *Stony Brook University*

I will present a new class of jet substructure observable called collinear drop and its use in the search for novel signatures of jet modifications and medium responses. I will demonstrate using Monte Carlo simulations generated with Jewel how underlying jet-medium interactions can be systematically examined using collinear-drop observables. I will also give analytic insights on the modifications of such observables using soft-collinear effective theory with Glauber gluon interactions.

Collaboration (if applicable):

Track:

Jets and High Momentum Hadrons

Contribution type:

Contributed Talk

Poster session / 4

Probing the partonic degree of freedom in high multiplicity p-Pb at $\sqrt{s_{NN}}$ = 5.02 TeV collisions

Authors: Wenbin Zhao[1]; Huichao Song[None]; Che-Ming Ko[None]; Guang-You Qin[2]; Yu-Xin Liu[3]

[1] *Peking University*

[2] *Central China Normal University*

[3] *Peking Univerisity*

The collective flow and the possible formation of the Quark-Gluon Plasma (QGP) in the small colliding systems are hot research topics in the heavy-ion community. Recently, ALICE, ATLAS and CMS collaborations have measured the elliptic flow and the related number of constituent quark (NCQ) scaling of identified hadrons in p+Pb collisions at $\sqrt{s_{NN}}$ = 5.02 TeV, which are important observables to probe the partonic degree of freedom in the created small system.

In this talk, we focus on the coalescence model calculations for the NCQ scaling of at intermediate p_T for the high multiplicity p+Pb collisions, which includes thermal-thermal, thermal-jet and jet-jet partons recombinations, using the thermal partons from hydrodynamics and jet partons after the energy loss of the Linear Boltzmann Transport (LBT) model. Such coalescence model calculations have also been smoothly connected with the low hydrodynamic calculation and with high jet fragmentation. Within such combined framework, we present a nice description of the spectra and elliptic flow over the p_T range from 0 to 6 GeV, and obtain the approximately NCQ scaling at intermediate p_T as measured in experiment. We also switch off the coalescence process of partons and find that without such coalescence, one can not describe the differential elliptic flow and related NCQ scaling at intermediate p_T. Such comparison calculations also demonstrate the importance of the partonic degree of freedom and indicate the possible formation of QGP in the high multiplicity p+Pb collisions.

Collaboration (if applicable):

Track:

New Theoretical Developments

Contribution type:

Contributed Talk

Parallel / 5

Heavy Flavor Kinematic Correlations in Cold Nuclear Matter

Author: Ramona Vogt[1]

[1] *LLNL*

It has been proposed that the azimuthal distributions of heavy flavor quark-antiquark pairs may be modified in the medium of a heavy-ion collision. This assumption was tested through next-to-leading order (NLO) calculations of the azimuthal distribution, $d\sigma/d\phi$, including transverse momentum broadening, employing $\langle k_T^2 \rangle$ and fragmentation in exclusive $Q\overline{Q}$ pair production [1].

The results have been compared to $p+p$ and $p+\overline{p}$ data on $Q\overline{Q}$ azimuthal correlations [1] as well as $b\bar{b}$ mass, pair p_T, rapidity, rapidity gap, p_T asymmetry and azimuthal difference correlations in $p+p$ collisions through their decays to $J/\psi J/\psi$, as measured by LHCb [2]. Agreement with the data was found to be excellent.

Possible cold and hot matter effects on these correlations are investigated through the effects of nuclear modifications of the parton densities, enhanced k_T broadening and energy loss.

[1] R. Vogt, Phys. Rev. C {\bf 98} (2018) 034907.

[2] R. Vogt, arXiv:1908.05320 [hep-ph], submitted to Phys. Rev. C.

This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344 and supported by the U.S. Department of Energy, Office of Science, Office of Nuclear Physics (Nuclear Theory) under contract number DE-SC-0004014.

Collaboration (if applicable):

Track:

Heavy Flavor and Quarkonia

Contribution type:

Contributed Talk

Parallel / 6

Photon-jet angular correlations in high energy proton-nucleus collisions: from low to high transverse momenta

Author: Jamal Jalilian-Marian[1]

[1] *Baruch College, CUNY*

We calculate the double differential cross section for production of a quark parton and a photon in proton-nucleus collisions using a newly proposed formalism which generalizes the Color Glass Condensate approach by including large x gluons of the target. We investigate transverse momentum, rapidity and A dependence of azimuthal angular correlations between the produced parton and the photon in different collision kinematics.

Collaboration (if applicable):

Track:

New Theoretical Developments

Contribution type:

Contributed Talk

Parallel / 8

Heavy flavor and jet studies for the future Electron Ion Collider

Author: Xuan Li[1]

[1] *Los Alamos National Laboratory*

The proposed high luminosity high energy Electron Ion Collider (EIC) will explore the proton/nuclear structure, search for gluon saturation and precisely determine the nuclear parton distribution functions (nPDFs) in a wide x-Q^2 phase space. Heavy flavor and jet measurements at the future EIC will allow us to better constrain the nPDFs within the poorly constrained high Bjorken-x region, precisely determine the quark/gluon fragmentation processes and directly study the quark/gluon energy loss within the nuclear medium. We propose to develop a new physics program to study the flavor tagged hadrons/jets, heavy flavor hadron-jet correlations and flavor dependent jet fragmentation processes in the nucleon/nucleus going direction (forward region) at the EIC. These proposed measurements will provide a unique path to explore the flavor dependent fragmentation functions and energy loss in heavy nuclei, which can constrain the initial state effects for previous and ongoing heavy ion measurements at the Relativistic Heavy Ion Collider (RHIC) and the Large Hadron Collider (LHC). A forward (proton/nuclei going direction) silicon tracking detector is essential to carry out these measurements at the EIC. In addition to the EIC heavy flavor and jet physics developments, the forward silicon tracking detector R&D and detector design are ongoing with the Los Alamos National Laboratory Lab Directed Research and Developments (LDRD) supports. Details of the proposed new physics program, progresses of the detector and physics simulation studies and the status of the detector R&D will be discussed in this presentation.

Collaboration (if applicable):

Track:

New Experimental Developments

Contribution type:

Contributed Talk

Parallel / 13

Effects of in-medium k_T broadening on di-jet observables

Authors: Martin Rohrmoser[1]; Krzysztof Kutak[2]; Andreas van Hameren[3]; Wiesiek Placzek[4]; Konrad Tywoniuk[5]

[1] *IFJ-PAN Krakow*

[2] *Instytut Fizyki Jadrowej Polskiej Akademii Nauk*

[3] *IFJ PAN*

[4] *Jagiellonian University*

[5] *University of Bergen (NO)*

Heavy ion collisions at high energies can be used as an interesting way to recreate and study the medium of the quark-gluon plasma (QGP). We particularly investigate the jets produced in hard binary collisions and their interactions with a tentative medium. These jets were obtained numerically from the Monte-Carlo simulations of hard collisions using the KATIE-framework [1], where parton momenta within the colliding nucleons were describe by means of transverse momentum distributions (TMD). We evolved these jets within a medium that contains both, transverse kicks (yielding a broadening in momentum transvers to the jet-axis) as well as medium induced radiation within the MINCAS-framework [2] following the works of [3,4]. After favorable comparison of our results with experimental LHC-data on jet-quenching we make predictions for the decorrelation of dijets. In particular, we study deviations from a transverse momentum broadening that follows a Gaussian distribution. References: [1] A. van Hameren, Comput.Phys.Commun. 224 (2018) 371-380 [2] K. Kutak, W. Płaczek, R. Straka, Eur.Phys.J. C79 (2019) no.4, 317 [3] J.-P. Blaizot, F. Dominguez, E. Iancu, Y. Mehtar-Tani, JHEP 1301 (2013) 143 [4] J.-P. Blaizot, F. Dominguez, E. Iancu, Y. Mehtar-Tani, JHEP 1406 (2014) 075

Collaboration (if applicable):

Track:

Jets and High Momentum Hadrons

Contribution type:

Contributed Talk

Parallel / 14

Nuclear modification of jet shape for inclusive jets and γ-jets at the LHC energies

Authors: Ning-Bo Chang[1]; Guang-You Qin[2]; Yasuki Tachibana[3]

[1] *Xinyang Normal University*

[2] *Central China Normal University*

[3] *Wayne State University*

With our coupled jet-fluid model [1, 2, 3], we study the nuclear modifications of full jets and jet structures for single inclusive jets and γ-jets in Pb+Pb collisions at 5.02 ATeV and 2.76 ATeV. The in-medium evolution of full jet shower is described by a set of coupled transport equations including the effects of collisional energy loss, transverse momentum broadening and medium-induced splitting process. The dynamical evolution of bulk medium is simulated by solving relativistic hydrodynamic equation with source term which accounts for the energy and momentum deposited by hard jet shower to soft medium. Our study demonstrates that the hydrodynamic medium response to jet propagation significantly enhances the broadening of jet shape at large angles and is essential for the cone-size dependence of jet energy loss and nuclear modification factor of inclusive jet production.

It is also found that the nuclear modification pattern of jet shape is sensitive to jet energy but has weak dependence on the flavor of the parton that initiates the jet. Our result can naturally explain the different nuclear modification patterns of jet shape functions for single inclusive jet and γ-jet events as observed by the CMS Collaboration, and can be tested in the future by measuring the jet shape function over a wider range of jet energies in heavy-ion collisions.

Reference:
[1] Ning-Bo Chang, Guang-You Qin, Phys.Rev,C94,024902 (2016)
[2] Yasuki Tachibana, Ning-Bo Chang and Guang-You Qin, Phys.Rev,C95,044909 (2017)
[3] Ning-Bo Chang, Yasuki Tachibana and Guang-You Qin, Phys.Lett,B801,135181 (2020)

Collaboration (if applicable):

Track:

Jets and High Momentum Hadrons

Contribution type:

Contributed Talk

Parallel / 15

Nuclear Modification of Dijet at EIC

Authors: Yuanyuan Zhang[1]; Xin-Nian Wang[2]

[1] *Central China Normal University*

[2] *Central China Normal University (China)) / Lawrence Berkeley Na*

We study the nuclear modification for the dijet cross section in eA deeply inelastic scattering (DIS) process. This nuclear modification comes from multiple scattering of final state parton in a large nucleus, including medium induced radiation. This extra modification to dijet cross section depends on transverse momentum dependent (TMD) quark-gluon correlation function, which can be approximately factorized as large-x TMD quark distribution function and small-x TMD gluon distribution function. The small-x TMD gluon distribution is also related to TMD jet transport coefficient in cold nuclei. With input of the large-x TMD quark distribution, the nuclear modified dijet cross section can be used to probe the small-x TMD gluon distribution/ TMD jet transport coefficient inside the nuclei. The quantitative determination of transport coefficient in cold nuclei will shed light on tranport coefficient of hot and dense quark gluon plasma (QGP). Predictions for dijet cross section at large-x region for EIC collider kinematics are given in this study.

Collaboration (if applicable):

OTHER (Please specify in comments field)

Track:

Jets and High Momentum Hadrons

Contribution type:

Contributed Talk

Parallel / 16

Flavor hierarchy of jet quenching in relativistic heavy-ion collisions

Authors: Wen-Jing Xing[1]; Shanshan Cao[2]; Guang-You Qin[1]; Hongxi Xing[3]

[1] *Central China Normal University*

[2] *Wayne State University*

[3] *South China Normal University*

Relativistic heavy-ion experiments have observed similar quenching effects for (prompt) D mesons compared to charged hadrons for transverse momenta larger than 6-8 GeV, which remains a mystery since heavy quarks typically lose less energies in quark-gluon plasma than light quarks and gluons. Recent measurements of the nuclear modification factors of B mesons and B-decayed D mesons by the CMS Collaboration provide a unique opportunity to study the flavor hierarchy of jet quenching. Using a linear Boltzmann transport model combined with hydrodynamics simulation, we study the energy loss and nuclear modification for heavy and light flavor jets in high-energy nuclear collisions. By consistently taking into account both quark and gluon contributions to light and heavy flavor hadron productions within a next-to-leading order perturbative QCD framework, we obtain, for the first time, a satisfactory description of the experimental data on the nuclear modification factors for charged hadrons, D mesons, B mesons and B-decayed D mesons simultaneously over a wide range of transverse momenta (8-300 GeV). This presents a solid solution to the flavor puzzle of jet quenching and constitutes a significant step towards the precision study of jet-medium interaction. Our study predicts that at transverse momenta larger than 30-40 GeV, B mesons also exhibit similar suppression effects to charged hadrons and D mesons, which may be tested by future measurements.

Reference:

[1] Wen-Jing Xing, Shanshan Cao, Guang-You Qin, and Hongxi Xing, arXiv:1906.00413

Collaboration (if applicable):

Track:

Heavy Flavor and Quarkonia

Contribution type:

Contributed Talk

Poster session / 18

Heavy quarkonium suppression beyond the adiabatic limit

Author: Ajaharul Islam[1]

Co-authors: Michael Strickland [1]; Jacob Boyd [1]; Thomas Cook [1]

[1] *Kent State University*

Many prior studies of in-medium quarkonium suppression have implicitly made use of an adiabatic approximation in which it was assumed that the heavy quark potential is a slowly varying function of time. In the adiabatic limit, one can separately determine the in-medium breakup rate and the medium time evolution, folding these together only at the end of the calculation. In this paper, we relax this assumption by solving the 3d Schrodinger equation in real-time in order to compute quarkonium suppression dynamically. We compare results obtained using the adiabatic approximation with real-time calculations for both harmonic oscillator and realistic complex heavy quark potentials. Using the latter, we find that, for the $\Upsilon(1s)$, the difference between the adiabatic approximation and full real-time evolution is at the few percent level, however, for the $\Upsilon(2s)$, we find that

the correction can be as large as 18% in low temperature regions. For the J/Ψ, we find a larger difference between the dynamical evolution and the adiabatic approximation, with the error reaching approximately 36%.

Collaboration (if applicable):

Track:

Heavy Flavor and Quarkonia

Contribution type:

Contributed Talk

Poster session / 19

QLBT: The Linear Boltzmann Transport model for heavy quarks with a medium of quasi-particles

Authors: Feng-lei Liu[1]; Shanshan Cao[2]; Guang-You Qin[3]; Xin-Nian Wang[4]

[1] *CCNU*

[2] *Wayne State University*

[3] *Central China Normal University*

[4] *Central China Normal University (China)) / Lawrence Berkeley Na*

Heavy quarks are ideal probes of the QGP matter. To consistently describe the medium evolution and heavy-quark-medium interaction, we improve the linear Boltzmann Transport (LBT) model [Phys. Lett. B777 (2018) 255-259] by modeling QGP as a collection of quasi-particles with equation of state (EOS) fitted to the lattice QCD data. We call this QLBT model, in which the in-medium scatterings of heavy quarks are described using the linear Boltzmann transport that includes both elastic and inelastic energy loss of heavy quarks within the perturbative QCD framework. The temperature dependences of the quasi-particle masses, as well as the strong coupling parameter among them, are systematically extracted from two different sets of lattice EOS (Hot QCD and Wuppertal-Budapest) with a Bayesian statistical analysis method. With all model parameters fixed by the lattice QCD calculations, QLBT naturally provides a good description of the nuclear modification factors and elliptic flow coefficients of heavy mesons at high transverse momenta. Systematical uncertainties arising from applying two different lattice equations of states are evaluated and turn out to be small for heavy flavor observables.

Collaboration (if applicable):

Track:

Heavy Flavor and Quarkonia

Contribution type:

Contributed Talk

Parallel / 21

Jet quenching in the hadron gas: an exploratory study

Author: Hannah Elfner[None]

Co-authors: Daniel Pablos [1]; Jean-Bernard Rose

[1] *University of Bergen*

The suppression of high momentum particles in heavy-ion collisions in comparison to elementary reactions is one of the main indications for the formation of a quark-gluon plasma. In recent studies, full jets are being reconstructed and substructure observables are gaining importance in assessing the medium modifications of hard probes. In this work, the effect of the late stage hadronic interactions are explored within the hadronic transport approach SMASH (Simulating Many Accelerated Strongly-interacting Hadrons)[1]. High momentum particles are incorporated in a radially expanding hadron gas to analyse the corresponding angular distributions, also referred to as 'jet shape'observables. We find that the full hadron gas can be approximated with a pion gas with constant elastic cross-sections of 100 mb. In addition, the temperature and probe energy dependence of diffusion coefficients $\tilde{q}$ and $\tilde{e}$ quantifying the transverse and parallel momentum transfers are extracted. The species dependence and the importance of different interaction types are investigated. Parametrizations are presented that can be employed in future jet quenching calculations to include the effect of the hadronic phase.

[1] P. Dorau, J.-B. Rose, D. Pablos and H. Elfner, arxiv:1910.07027

Collaboration (if applicable):

Track:

Jets and High Momentum Hadrons

Contribution type:

Contributed Talk

Parallel / 23

Gamma-hadron spectra in p + Pb collisions at $\sqrt{s_{\rm NN}} = 5.02$ TeV

Authors: Man Xie[1]; Xin-Nian Wang[2]; Hanzhong Zhang[3]

[1] *Central China Normal University*

[2] *Central China Normal University (China)) / Lawrence Berkeley Na*

[3] *IOPP, CCNU*

Under the assumption that a quark-gluon plasma droplet is produced in p + A collisions, γ-triggered hadron spectra [1,2] are studied within a next-to-leading-order perturbative QCD parton model with the medium-modified parton fragmentation functions in p + Pb collisions at $\sqrt{s_{\rm NN}} = 5.02$ TeV. The initial conditions and space-time evolution of the small system of hot and dense medium is simulated by superSONIC hydrodynamic model [3] and parton energy loss in such a medium is described by the high-twist (HT) approach [4]. The scaled jet transport coefficient $\hat{q}/T^3$ in this HT approach is extracted from single hadron in central A + A collisions because its values from single and dihadron suppressions are similar [5]. Numerical results show that γ-hadron spectra for $p_T^\gamma = 12 - 40$ GeV/c in this scenario are suppressed by 10% $\sim$ 20% in the most central 0 - 10% p + Pb collisions at $\sqrt{s_{\rm NN}} = 5.02$ TeV. The suppression becomes weaker with higher transverse momentum of the triggered-γ. As a comparison, γ-hadron suppression in Pb + Pb collisions at $\sqrt{s_{\rm NN}} = 2.76$ and 5.02 TeV is also predicted.

References

[1] X. N. Wang, Z. Huang and I. Sarcevic, Phys. Rev. Lett. 77, 231 (1996)

[2] H. Zhang, J. F. Owens, E. Wang and X. N. Wang, Phys. Rev. Lett. 103, 032302 (2009)
[3] R. D. Weller and P. Romatschke, Phys. Lett. B 774, 351 (2017)
[4] W. t. Deng and X. N. Wang, Phys. Rev. C 81, 024902 (2010)
[5] M. Xie, S. Y. Wei, G. Y. Qin and H. Z. Zhang, Eur. Phys. J. C 79, no. 7, 589 (2019)

Collaboration (if applicable):

Track:

Jets and High Momentum Hadrons

Contribution type:

Contributed Talk

Parallel / 25

Transport coefficients from in medium quarkonium dynamics

Author: Miguel Ángel Escobedo Espinosa[1]

[1] *Instituto Galego de Física de Altas Enerxías*

Three are the mechanisms that influence quarkonium suppression in a medium: screening, thermal decay, and recombination. In recent years, a framework that can treat them consistently at the same time has been put forward, the open quantum system approach. In this talk, we will discuss how the combination of open quantum system and Effective Field Theory techniques are useful to understand quarkonium evolution in a medium in the regime in which the temperature is smaller than the inverse of the typical radius. In this case, the interaction parameter depends only on two transport coefficients κ and γ, where κ is the heavy quark diffusion coefficient. Combining these results with recent lattice QCD evaluations of the mass shift and thermal decay width of quarkonium we are able to obtain a non-perturbative determination of κ compatible with state-of-the-art results. This talk is based on the recent paper Phys.Rev. D100 (2019) no.5, 054025.

Collaboration (if applicable):

Track:

Heavy Flavor and Quarkonia

Contribution type:

Contributed Talk

26

Exploration of the properties of the medium produced in large and small collision-systems with azimuthal anisotropy scaling functions

Author: Roy Lacey[1]

[1] *Stony Brook University*

Azimuthal anisotropy scaling functions can provide crucial constraints for the properties of the medium produced in ion-ion collisions, because they leverage the characteristic scaling patterns for viscous-flow and jet quenching, to simultaneously delineate the respective role of initial-state eccentricity ε_n, dimensionless size $RT \propto \langle N_{\rm chg} \rangle^{1/3}$, the viscous correction to the thermal distribution function δ_f, the specific shear $\eta/s(T, \mu_B)$, and bulk $\zeta/s(T, \mu_B)$ viscosities, stopping power of the medium $\hat{q}((T, \mu_B))$ ... The anisotropy scaling functions indicate data collapse on to a single curve for fully constrained scaling coefficients, which in turn, provide constraints for the transport coefficients and the eccentricity spectrum. I will present and discuss anisotropy scaling functions for charged hadrons and identified particle species, obtained from a broad array of collision-system sizes, shapes, and asymmetries for $\sqrt{s_{NN}}$ values spanning RHIC and LHC energies. The scaling coefficients, which provide new and compelling constraints for the transport coefficients will be presented and discussed.

Collaboration (if applicable):

Track:

Jets and High Momentum Hadrons

Contribution type:

Contributed Talk

Parallel / **27**

Jet charge modification in dense QCD matter

Authors: Ivan Vitev[None]; Haitao Li[1]

[1] *Los Alamos National Laboratory*

Jet production and jet substructure modification in heavy-ion collisions have played an essential role in revealing the in-medium evolution of parton showers and the determination of the properties of strongly-interacting matter under extreme conditions. It is imperative to extend these studies to include flavor tagging and to devise observables that are sensitive to the partonic origin of jets. The average jet charge, defined as the momentum-weighted sum of the electric charges of particles inside the jet, is a proxy of the electric charge of the quark or gluon that initiates the jet. We demonstrate how the factorization framework of soft-collinear effective theory can be generalized to evaluate the jet charge in a dense strongly-interacting matter environment, such as the one produced in nuclear reactions at collider energies. Observables that can separate the contribution of in-medium branching from the trivial isospin effects are identified and their connection to established jet quenching effects is elucidated. We present predictions for the transverse momentum dependence of the jet charge distribution in nucleus-nucleus collisions and its modification relative to the proton case.

Collaboration (if applicable):

Track:

Jets and High Momentum Hadrons

Contribution type:

Contributed Talk

Reconstruction of Bottom Jets in Proton-Proton Collisions at $\sqrt{s} = 13$ TeV with ALICE

Author: Katharina Garner[1]

[1] *Westfaelische Wilhelms-Universitaet Muenster (DE)*

When partons traverse the Quark-Gluon Plasma (QGP), they lose energy via collisional and radiative processes. This manifests in a suppression of the measured jet yield and a modification of the jet fragmentation pattern in heavy-ion collisions relative to minimum-bias proton-proton collisions, for which no QGP is expected to form. The amount of energy that is lost is expected to depend on the respective parton flavour and mass. Thus, a detailed understanding not only of the gluon and light-flavour but also of the charm and bottom-jet production is needed for the characterisation of the QGP via parton energy loss.
The long lifetime of B hadrons ($c\tau \sim 500\,\mu$m) manifests in a comparably large separation of their decay products from the primary vertex. If a jet has been initiated by a bottom quark, then constituents originating from the corresponding B hadron decay exhibit the same behaviour which can be utilised for the identification of bottom jets. In this contribution, first results for a bottom jet spectrum in proton-proton collisions at $\sqrt{s} = 13$ TeV obtained via a selection based on track transverse impact parameter distributions will be discussed.

Collaboration (if applicable):

ALICE

Track:

Heavy Flavor and Quarkonia

Contribution type:

Poster

Parallel / 31

Jet quenching and scaling properties of medium-evolved gluon cascade in expanding media

Authors: Souvik Priyam Adhya[1]; Carlos Albert Salgado Lopez[2]; Martin Spousta[3]; Konrad Tywoniuk[4]

[1] *Institute of Particle and Nuclear Physics Faculty of Mathematics and Physics, Charles University*

[2] *Universidade de Santiago de Compostela (ES)*

[3] *Charles University*

[4] *University of Bergen (NO)*

We present a study of the impact of the expansion of deconfined medium on single-gluon emission spectra and the jet suppression factor (Q_{AA}) within the BDMPS-Z formalism. These quantities are calculated for three types of media (static medium, exponentially decaying medium and Bjorken expanding medium). The distribution of medium-induced gluons and the jet Q_{AA} are calculated using the evaluation of in-medium evolution with splitting kernels derived from the gluon emission spectra. A universal behavior of splitting kernels is derived for low-x and high-x regimes in the asymptote of large times and its impact on the resulting jet Q_{AA} is discussed. For the full phase-space of the radiation, the scaling of jet Q_{AA} with an effective quenching parameter is derived. The importance of the medium expansion for precise modeling of jet quenching phenomena as well as steps towards generalizing the results to other jet quenching observables are discussed.

Collaboration (if applicable):

Track:

Jets and High Momentum Hadrons

Contribution type:

Contributed Talk

Poster session / 32

The dipole picture and the non-relativistic expansion

Author: Miguel Ángel Escobedo Espinosa[1]

Co-author: Tuomas Lappi [2]

[1] *Instituto Galego de Física de Altas Enerxías*

[2] *University of Jyväskylä*

We study exclusive quarkonium production in the dipole picture at next-to-leading order (NLO) accuracy, using the non-relativistic expansion for the quarkonium wavefunction. This process offers one of the best ways to obtain information about gluon distributions at small x, in ultraperipheral heavy ion collisions and in deep inelastic scattering. The quarkonium light cone wave functions needed in the dipole picture have typically been available only at tree level, either in phenomenological models or in the nonrelativistic limit. In this paper, we discuss the compatibility of the dipole approach and the non-relativistic expansion and compute NLO relativistic corrections to the quarkonium light-cone wave function in light-cone gauge. Using these corrections we recover results for the NLO decay width of quarkonium to e^+e^- and we check that the non-relativistic expansion is consistent with ERBL evolution and with B-JIMWLK evolution of the target. The results presented here will allow computing the exclusive quarkonium production rate at NLO once the one loop photon wave function with massive quarks, currently under investigation, is known. This talk is based on ArXiv:1911.01136

Collaboration (if applicable):

Track:

Initial State

Contribution type:

Contributed Talk

Parallel / 33

The wake of jets from linearized hydrodynamics

Authors: Jorge Casalderrey Solana[1]; Guilherme Milhano[2]; Daniel Pablos[3]; Krishna Rajagopal[4]; Xiaojun Yao[5]

[1] *University of Barcelona*

[2] *LIP-Lisbon & CERN TH*

[3] *University of Bergen*

[4] *Massachusetts Inst. of Technology (US)*

[5] *Massachusetts Institute of Technology*

Recently, jet substructure observables have been widely used in the study of jets. Some observables are sensitive to the wide angle soft particles within the jet, for example, the Lund plane distribution with different jet radii and soft drop parameters. As the jet loses energy and momentum during its evolution inside the quark-gluon plasma (QGP), the "lost" energy and momentum is deposited in the medium and evolves therein —the wake of the jet. This wake ultimately hadronizes into particles whose net momentum must be correlated with the jet direction, since it corresponds to the momentum lost by the jet. This means that when a jet reconstruction algorithm is then used to find the jet, some of the particles originating from the wake must end up being counted as a part of the jet. Since these particles are generally soft, and are spread over a wide angle with respect to the jet axis, they can significantly modify those jet substructure observables that are sensitive to the soft physics and/or to physics at wide angles. To understand the predictions of any model of jet quenching for such observables, it is mandatory to quantify the dynamics of the back-reaction of the medium to the jet, namely the wake of the jet.

In this talk, we will report progress toward addressing this question by treating the energy and momentum loss as a perturbation on the background of a Bjorken flow. By working to linear order in the perturbation and solving the resulting evolution equations numerically in momentum space, we study how the wake evolves within the hydrodynamically evolving droplet of QGP and explore the dependence of the dynamics of the wake on the viscosity of the QGP and model uncertainties. Via this study, we upgrade the previous numerical implementation of the jet wake in the hybrid model, in particular for the component of the wake that yields particles with transverse momenta of a few GeV after hadronization. Further we will assess the phenomenological impact of the improved wake treatment on a range of jet observables.

Collaboration (if applicable):

Track:

Jets and High Momentum Hadrons

Contribution type:

Contributed Talk

Parallel / 34

Medium modification of jet substructure for inclusive, photon-tagged and heavy flavor jets in heavy-ion collisions

Authors: Tan Luo[1]; Shanshan Cao[2]; Yayun He[3]; Guang-You Qin[3]; Xin-Nian Wang[4]

[1] *IGFAE*

[2] *Wayne State University*

[3] *Central China Normal University*

[4] *Central China Normal University (China)) / Lawrence Berkeley Na*

Recent measurements of jet substructure provide insights into how the hard and soft parts of the jets are modified by jet-medium interaction. One can also learn the flavor dependence of jet quenching via comparisons between boson tagged jet, inclusive jet and heavy flavor jet. In this study, with the Linear Boltzmann Transport (LBT) model, we investigate the jet shape, jet splitting function, and groomed jet mass in single jet, photon-jet and heavy flavor jet events. In order to identify the effect of jet induced medium response on jet substructure, we first fit the jet modification factor both with and without the medium response for a precise study.

Our study on jet shape function shows that the medium modifications for the core of quark jets and gluon jets are quite different and the broadening of jet profile at the edge of the jet cone is mainly carried by soft particles from medium recoil. We also find that the distributions of radiated gluon and recoiled parton are modified strongly by their rescatterings in the medium. The groomed jet study

shows that jet induced medium response is responsible for the enhancement of large groomed mass tail while the jet-medium interaction generally leads to a smaller groomed mass of jets in heavy ion collisions. With different grooming setting, we explore the medium modification of different phase space to distinguish the contributions from medium induced radiation and medium recoil in gluon jet, quark jet and heavy flavor jet events. We further implement different scenarios of coherent and incoherent energy losses in LBT simulation and find that they have a significant impact on the pT dependence of the nuclear modification of jet splitting function.

Collaboration (if applicable):

Track:

Jets and High Momentum Hadrons

Contribution type:

Contributed Talk

Parallel / 35

Bottomonia in QGP from lattice QCD: Beyond the ground states

Author: Rasmus Larsen[1]

Co-authors: Stefan Meinel [2]; Swagato Mukherjee [3]; Peter Petreczky [4]

[1] *Brookhaven Nationanl Laboratory*

[2] *University of Arizona / RIKEN BNL Research Center*

[3] *Brookhaven National Laboratory*

[4] *BNL*

Using novel lattice (non-relativistic) QCD techniques, we will present results pertaining to the fate of Y(1S), Y(2S) and Y(3S) in QGP. We will present results on how the masses of these states change with temperature, as well as how their spatial sizes change. Finally, we will also show new lattice QCD results on the heavy quark potential from Wilson lines.

Collaboration (if applicable):

Track:

Heavy Flavor and Quarkonia

Contribution type:

Contributed Talk

Parallel / 36

A study of open-heavy-flavor, heavy-jet, and correlations using the LIDO transport model

Authors: Weiyao Ke[1]; Wenkai Fan[2]; Steffen A. Bass[2]; Xin-Nian Wang[3]

[1] *University of California, Berkeley*

[2] *Duke University*

[3] *Central China Normal University (China)) / Lawrence Berkeley Na*

Understanding heavy-flavor transport properties and energy loss inside a quark-gluon plasma (QGP) is a major interest of the heavy-ion phenomenology. In this work, we combine both open-heavy and heavy-flavor jet observables to study the average heavy quark energy loss as well as its fluctuations. Low-momentum heavy quark interacts with QGP mainly through elastic collisions; for high-momentum heavy quark, elastic collisions also induce radiative energy loss. Both energy loss mechanisms can be related to the heavy-quark momentum diffusion coefficient ($\hat{q}$). Recently, we have extracted a temperature and momentum-dependent $\hat{q}$ by comparing to open-heavy-flavor observables (R_{AA} and v_2) using the LIDO transport model [1,2]. We find that even after the parameter calibration, the model still has a large degree of freedom to switch between a Boltzmann equation with large-angle perturbative scattering and a diffusion equation with effective transport coefficients. The reason is that inclusive open-heavy flavor observables are more sensitive to the average energy loss, but they are less efficient in discriminating models with different energy-loss fluctuations (e.g. large-angle scattering and diffusion). We argue that the fluctuation information can be studied using the heavy-flavor jet. First, we use the calibrated model to predict the charmed- and bottom-jet nuclear modification factor. Then, we study traces of the heavy-quark energy-loss fluctuations encoded in the angular and transverse momentum correlations between heavy flavor particles and jets. These observables help to understand heavy-quark-medium interaction in greater detail.

[1] W. Ke, Y. Xu, and S. A. Bass, Phys. Rev. C 98, 064901 (2018).
[2] W. Ke, Y. Xu, and S. A. Bass, Phys. Rev. C 100, 064911 (2019).

Collaboration (if applicable):

Track:

Heavy Flavor and Quarkonia

Contribution type:

Contributed Talk

Parallel / 37

Electroweak probes in heavy-ion collisions with ATLAS

Authors: ATLAS Collaboration[None]; Lidija Zivkovic[1]

[1] *Institute of physics Belgrade (RS)*

Electroweak bosons produced in lead-lead (Pb+Pb) collisions are an excellent tool to constrain initial-state effects which affect the rates of hard-scattering processes in nucleus-nucleus interactions. The production yields of massive electroweak bosons, observed via their leptonic decay channels, offer a high-precision test of the binary collision scaling expected in Pb+Pb and a way to quantify nuclear modifications of the parton distribution functions (PDFs).
The large samples of Pb+Pb data at $\sqrt{s_{\mathrm{NN}}}$ = 5.02 TeV collected by the ATLAS experiment in 2015, and the corresponding high-statistics pp data at the same collision energy used as a baseline, allow for a detailed experimental study of these phenomena and comparisons to predictions from a variety of theoretical calculations. This talk presents the latest ATLAS results on electroweak boson production, including updated results on Z production and high-precision W boson results in Pb+Pb collisions. Inclusive production of prompt photons in proton-lead˜(p+Pb) collisions at $\sqrt{s_{\mathrm{NN}}}$ = 8.16 TeV is also covered.
Various predictions of nuclear modifications to PDFs are discussed.

Collaboration (if applicable):

ATLAS

Track:

Electroweak Probes

Contribution type:

Contributed Talk

Parallel / 38

Non-UPC production of dimuons from two-photon scattering in Pb+Pb collisions with the ATLAS detector

Authors: ATLAS Collaboration[None]; Lidija Zivkovic[1]

[1] *Institute of physics Belgrade (RS)*

Muon pairs produced via two-photon scattering processes in hadronic Pb+Pb collisions provide a potentially sensitive electromagnetic probe of the quark gluon plasma.
First measurements by ATLAS and STAR of dileptons produced via two-photon scattering in non-ultra-peripheral (non-UPC) nucleus-nucleus collisions showed an unexpected centrality-dependent broadening of the angular correlation between the two leptons and/or of the two-lepton p_T distribution. ATLAS has recently measured dimuons produced via two-photon scattering in non-UPC Pb+Pb collisions at $\sqrt{s_{\mathrm{NN}}} = 5.02$ TeV using an integrated luminosity of $1.9\ \mathrm{nb}^{-1}$. This data set represents a factor of ~ 4 increase in statistics over the 2015 data set used for the first ATLAS measurement. The increased statistics allow new features to be observed in the data, as well as differential studies of the dependence of the pair-distribution on the transverse-momentum and pseudorapidity of the two muons. The results of the new measurement and the possible physics implications will be discussed.

Collaboration (if applicable):

ATLAS

Track:

Electroweak Probes

Contribution type:

Contributed Talk

Parallel / 39

Production and azimuthal anisotropy of muons from heavy flavor decays in small and large systems with ATLAS

Authors: ATLAS Collaboration[None]; Lidija Zivkovic[1]

[1] *Institute of physics Belgrade (RS)*

Heavy flavor production and collectivity in A+A collisions provide insight into the energy loss mechanism and transport properties of heavy quarks in the QGP medium. In this talk, ATLAS measurements on nuclear modification factor and v_2 and v_3 flow coefficients of muons from heavy flavor decays in Pb+Pb collisions are presented as a function of muon p_T and centralities. Muons with charm and bottom origins are separated based on the transverse impact parameter with respect to the primary collision vertex. To better understand the origin of collectivity in small systems, azimuthal anisotropy of muons from heavy flavor decays is also measured in p+Pb and pp collisions. A template fit method is used in small system to subtract non-flow contributions using simultaneous fit to low and high charged-particle multiplicity samples. The extracted v_2 coefficients are presented as a function of muon p_T and event charged-particle multiplicity.

Collaboration (if applicable):

ATLAS

Track:

Heavy Flavor and Quarkonia

Contribution type:

Contributed Talk

Parallel / 40

Quarkonium production in Pb+Pb collisions with ATLAS

Authors: ATLAS Collaboration[None]; Lidija Zivkovic[1]

[1] *Institute of physics Belgrade (RS)*

The yields of bound quarkonium states in heavy-ion collisions provide a powerful tool to probe the dynamics of the hot, dense plasma. These measurements are sensitive to the effects of color screening, color recombination, and possibly to other, new phenomena affecting dynamics of heavy quarks in the QCD medium. In this talk, the ATLAS results on bottomonium nuclear modification factor and excited-to-ground state ratio using 2018 Pb+Pb data and 2017 pp data both at 5.02 TeV will be presented as a function of transverse momentum and event centrality.

Collaboration (if applicable):

ATLAS

Track:

Heavy Flavor and Quarkonia

Contribution type:

Contributed Talk

41

b-jet quenching in Pb+Pb collisions measured by the ATLAS detector

Authors: ATLAS Collaboration[None]; Lidija Zivkovic[1]

[1] *Institute of physics Belgrade (RS)*

The measurement of modification of jet yields in heavy-ion collisions provides a powerful method to probe the dynamics of the hot, dense medium formed in these collisions at the LHC. Jet quenching in heavy-ion collisions is expected
to depend on the flavor of the fragmenting parton. For light partons, energy loss via gluon bremsstrahlung is expected to dominate, while in the case of heavy-quark-initiated-jets, collisional energy loss may play a more important role. This poster reports the new measurement of b-tagged jets production in pp and Pb+Pb at $\sqrt{s_{\mathrm{NN}}}$ = 5.02 TeV collision energy using the large statistics Pb+Pb data sample collected with ATLAS in 2018 where the tagging utilizes muon-to-jet association.

Collaboration (if applicable):

ATLAS

Track:

Heavy Flavor and Quarkonia

Contribution type:

Poster

Parallel / 42

Measurements of v_n at high-p_{T} and correlation between v_n and mean-p_{T} in p+Pb collisions with the ATLAS detector

Authors: ATLAS Collaboration[None]; Lidija Zivkovic[1]

[1] *Institute of physics Belgrade (RS)*

This talk presents ATLAS measurements of the azimuthal anisotropy for charged particles in 8.16 TeV p+Pb collisions up to a p_T of 50 GeV. The measurements are performed via the two-particle correlation method and the statistics are enhanced at high-p_T by selecting events triggered by a high-p_T jet. Restrictions on other particles are imposed to suppress the contribution from jets. Measurements of the resulting second- and third-order flow coefficients are presented in intervals of p+Pb event activity classes. The results from jet-triggered events are compared to those from minimum-bias p+Pb events, and the differences between the two event samples are analyzed in terms of the different origin of particles in these events, such as the different fraction of particles that arise from the jet fragmentation process.
In A+A collisions non-zero flow coefficients at high-p_T are understood to arise from the path-length dependent energy loss of jets. Thus, these measurements in p+Pb collisions, can provide information on the origin of these collective phenomena.
To further assess properties of the azimuthal anisotropy in p+Pb collisions, the correlation between the mean transverse momentum and the magnitudes of the flow harmonics is also measured. The measurements are performed in 5.02 TeV p+Pb collisions for several intervals of the charge particle transverse momentum and as a function of the event-multiplicity. The measured correlations are compared to similar measurements in Pb+Pb collisions.

Collaboration (if applicable):

ATLAS

Track:

Initial State

Contribution type:

Contributed Talk

Parallel / 43

ATLAS measurements of transverse and longitudinal flow decorrelations in Xe+Xe, Pb+Pb, and p+Pb collisions

Authors: ATLAS Collaboration[None]; Lidija Zivkovic[1]

[1] *Institute of physics Belgrade (RS)*

ATLAS measurements of flow harmonics (v_n) and their fluctuations in Pb+Pb and Xe+Xe collisions covering a wide range of transverse momenta, pseudorapidity and collision centrality are presented. The measurements are performed using data from Xe+Xe collisions at 5.44 TeV, Pb+Pb collisions at 5.02 TeV, and p+Pb collisions at 5.02 and 8.16 TeV. The v_n are measured up to $n = 6$ using the two-particle correlations, multi-particle cumulants, and scalar product methods. The v_n values are also performed using a non-flow subtraction technique that was developed for flow measurements in pp and p+Pb collisions. This non-flow subtraction is found to have a significant effect on the measured v_n at high-p_T and in peripheral collisions. A universal scaling in the p_T dependence of the v_n is observed for both systems.
Measurements of correlations between the v_n for different order n, studied with three- and four-particle mixed-harmonic cumulants, are also presented, and contributions to these correlations from "centrality fluctuations" are also discussed. Measurements of longitudinal flow decorrelations involving two- and four-particle correlations for v_2 and v_3 in Xe+Xe and p+Pb collisions are also presented and compared with the corresponding measurements in Pb+Pb collisions. The four-particle decorrelation is found to not factorize as a product of two-particle decorrelations. The ability of such measurements to distinguish between different models of initial geometry and to reduce the uncertainty in determining the effective shear-viscosity to entropy-density ratio of the QGP is demonstrated.

Collaboration (if applicable):

ATLAS

Track:

Initial State

Contribution type:

Contributed Talk

Parallel / 44

ATLAS measurement of azimuthal anisotropies in Z-boson tagged pp collisions at 8 and 13 TeV and in ultra-peripheral Pb+Pb collisions at 5.02 TeV

Authors: ATLAS Collaboration[None]; Lidija Zivkovic[1]

[1] *Institute of physics Belgrade (RS)*

Measurements of two-particle correlations in pp collisions have demonstrated long-range azimuthal correlations between charged particle pairs, commonly interpreted as arising from a single particle azimuthal anisotropy. To better understand the origin and nature of these collective signatures, ATLAS presents studies in pp collisions with a novel handle on the event geometry, and in photonuclear collisions.

In pp collisions, the impact-parameter dependence of these correlations are studied by selecting events containing a Z-boson, which acts as an independent handle on the impact parameter.
This talk presents measurements of the azimuthal anisotropy in such Z-tagged pp collisions at 8 and 13 TeV. The measurements include studies of the p_T, event-multiplicity, and collision energy dependence of the anisotropy as well as the comparison to the inclusive pp collisions.
In addition, two-particle correlations measured in ultra-peripheral Pb+Pb collisions at 5.02 TeV are also presented. In such ultra-peripheral collisions, the nuclei do not interact hadronically. However, a quasi-real photon from the EM field of one nucleus can interact with the other nucleus. These photons may reach energies up to 80 GeV and readily fluctuate into vector meson configurations. Thus these photo-nuclear collisions may proceed as rho-nucleus collisions albeit at a significantly lower collision energy than the equivalent nucleon-nucleon energy.
This talk presents measurements of two-particle correlations and characterizes the azimuthal distribution of particle production in photo-nuclear collisions as a function of the event multiplicity.

Collaboration (if applicable):

ATLAS

Track:

Initial State

Contribution type:

Contributed Talk

Parallel / **45**

Measurement of jet structure and substructure in heavy ion collisions with ATLAS

Authors: ATLAS Collaboration[None]; Lidija Zivkovic[1]

[1] *Institute of physics Belgrade (RS)*

Measurement of jet structure in heavy-ion collisions allows studying properties of the hot and dense QCD medium created in these collisions and the mechanism of the jet quenching. This talk presents the latest ATLAS measurements of the internal structure of jets to better constrain the modifications of the parton showering process. A new measurement of how the suppression of large-radius jets depends on the internal jet structure characterized by the transverse momentum scale for the hardest splitting will be presented. This measurement brings new information about the evolution of the parton shower in the medium and tests the sensitivity of the jet quenching to color coherence effects. Furthermore, a measurement of the angular distribution of charged particles around the jet axis in Pb+Pb and pp collisions at $\sqrt{s_{NN}} = 5.02$˜TeV will be presented. This measurement is performed for jets with radius parameter $R = 0.4$ but is extended for particles outside the jet cone to a radial distance of 0.8.

Collaboration (if applicable):

ATLAS

Track:

Jets and High Momentum Hadrons

Contribution type:

Contributed Talk

Parallel / 46

Single jet and dijet measurements of jet quenching with the ATLAS detector

Authors: ATLAS Collaboration[None]; Lidija Zivkovic[1]

[1] *Institute of physics Belgrade (RS)*

High energy partons are known to lose energy when passing through the hot and dense medium produced in heavy-ion collision. This results in a modification to the transverse momentum distributions of both charged hadrons and jets. It has been previously shown in Pb+Pb collisions at $\sqrt{s_{NN}} = 2.76$˜TeV that parton energy loss within the Quark Gluon Plasma results in significant modifications to the transverse momentum balance of dijet pairs. More differential measurements are needed to better understand the path length dependence, the role of fluctuations in the energy loss, and the energy redistribution. This talk presents the latest results on the fully unfolded dijet momentum balance in Pb+Pb and pp collisions at $\sqrt{s_{NN}} = 5.02$˜TeV, as well as measurements in Xe+Xe collisions at $\sqrt{s_{NN}} = 5.44$˜TeV with the ATLAS detector at LHC. The dijet momentum balance is measured as a function of the azimuthal angle with respect to the event plane. This talk will present also a measurement of the single jet yields as a function of the azimuthal angle with respect to the event plane in Pb+Pb collisions at $\sqrt{s_{NN}} = 5.02$˜TeV. In addition, charged-hadron nuclear modification function will be presented in Pb+Pb and Xe+Xe systems with detailed comparisons between the two collision systems. These measurements provide new information about the path-length and system-size dependence of jet energy loss within the medium.

Collaboration (if applicable):

ATLAS

Track:

Jets and High Momentum Hadrons

Contribution type:

Contributed Talk

Parallel / 47

Measurements of photon- and Z-tagged jet quenching by ATLAS

Authors: ATLAS Collaboration[None]; Lidija Zivkovic[1]

[1] *Institute of physics Belgrade (RS)*

Measurements of hard-scattered partons produced in conjunction with a high-pT photon or Z boson offer a discerning way to study the quark gluon plasma (QGP) created in ultrarelativistic nucleus-nucleus collisions. The high-pT boson tags the initial energy, direction, and flavor of the opposing parton or partons before they begin to shower and propagate through the QGP, offering a valuable handle for understanding the mechanism of parton energy loss.
ATLAS has performed detailed measurements of the photon-jet transverse momentum balance and the jet fragmentation function in 2015 Pb+Pb data. The significantly larger luminosity of 2018 Pb+Pb data delivered by the LHC, in addition to improvements to the electron reconstruction in heavy ion events, have enabled qualitatively new measurements in these channels with the ATLAS detector, including the first Z-tagged measurements of partonic energy loss and modification.
In this talk we will present the newest measurements of the energy loss of partons created in coincidence with a high-pT Z boson in Pb+Pb collisions without any formal requirement on a reconstructed

jet, comparing the results to predictions provided by multiple models. Prospects for further measurements requiring a reconstructed jet opposite an electroweak boson in the full Run 2 dataset will be discussed, as well as possible future observables in Run 3.

Collaboration (if applicable):

ATLAS

Track:

Jets and High Momentum Hadrons

Contribution type:

Contributed Talk

48

New results on mass and flavor dependence of jet quenching with ATLAS

Authors: ATLAS Collaboration[None]; Lidija Zivkovic[1]

[1] *Institute of physics Belgrade (RS)*

The suppression and enhancement of jets in heavy-ion collisions provides a powerful method to probe the dynamics of the hot, dense plasma formed in these collisions at the LHC. Jet quenching in heavy-ion collisions is expected to depend on the flavor of the fragmenting parton. For light partons, energy loss via gluon bremsstrahlung is expected to dominate, while in the case of heavy-quark-initiated-jets, collisional energy loss may play a more important role.
This energy loss mechanism can be studied by measuring differences in the production of b-tagged jets in pp and Pb+Pb collisions. Further understanding can be gained through a measurement of the modification to the jet mass distribution, which provides sensitivity to the color coherence of the jet object.
In this talk, we report new measurements of jet production as a function of the jet mass as well as b-tagged jets reconstructed from a jet-associated muon in pp and Pb+Pb at $\sqrt{s_{NN}} = 5.02$˜TeV collision energy using the large statistics Pb+Pb data sample collected with ATLAS in 2018.

Collaboration (if applicable):

ATLAS

Track:

Jets and High Momentum Hadrons

Contribution type:

Contributed Talk

Poster session / 49

Exploring jet quenching through the measurement of dijet momentum balance with ATLAS

Authors: ATLAS Collaboration[None]; Lidija Zivkovic[1]

[1] *Institute of physics Belgrade (RS)*

High energy partons are known to lose energy when passing through the hot and dense medium produced in heavy-ion collisions. This results in a modification to the transverse momentum distributions of jets. It has been previously shown in Pb+Pb collisions at $\sqrt{s_{NN}} = 2.76$˜TeV that parton energy loss within the Quark Gluon Plasma results in significant modifications to the transverse momentum balance of dijet pairs. However, additional differential measurements are needed to better understand the path-length dependence as well as the role of medium fluctuations to the energy loss. This poster presents the latest measurements of fully unfolded dijet momentum balance in Pb+Pb and pp collisions at $\sqrt{s_{NN}} = 5.02$˜TeV. Additionally, the dijet momentum balance in Pb+Pb collisions is measured with respect to the second order azimuthal event plane angle, providing further insight on the path-length dependence to energy loss.

Collaboration (if applicable):

ATLAS

Track:

Jets and High Momentum Hadrons

Contribution type:

Poster

50

Measurement of the azimuthal angle dependence of jet yields in Pb+Pb collisions at $\sqrt{s_{NN}} = 5.02$˜TeV with the ATLAS detector

Authors: ATLAS Collaboration[None]; Lidija Zivkovic[1]

[1] *Institute of physics Belgrade (RS)*

It has been shown that high energy partons lose energy when traversing the hot, dense medium produced in heavy-ion collisions. However, the mechanism of the energy loss, including its dependence on the path-length of the shower in the medium, is not fully understood. This poster presents a measurement of single jet yields as a function of the azimuthal angle with respect to the event plane in Pb+Pb collisions at $\sqrt{s_{NN}} = 5.02$˜TeV. Because jets at different angles with respect to the event plane traverse, on average, different path lengths of the medium, this measurement gives insight into the path-length dependence of parton energy loss. The azimuthal angle dependence of the yields is characterized by the parameter v_n^{jet}, which quantifies the magnitude of the modulation of the azimuthal angle distribution with respect to the nth order event plane. While ATLAS has previously reported the v_2^{jet} in Pb+Pb at $\sqrt{s_{NN}} = 2.76$˜TeV, this is the first ATLAS measurement of higher order v_n^{jet}.

Collaboration (if applicable):

ATLAS

Track:

Jets and High Momentum Hadrons

Contribution type:

Poster

Poster session / 51

Measurement of suppression of large-radius jets and its dependence on substructure in Pb+Pb with ATLAS

Authors: ATLAS Collaboration[None]; Lidija Zivkovic[1]

[1] *Institute of physics Belgrade (RS)*

Measurements of the jet substructure in Pb+Pb collisions provide information about the mechanism of jet quenching in the hot and dense QCD medium created in these collisions, over a wide range of energy scales. This poster presents the ATLAS measurement of the suppression of yields of large-radius jets and its dependence on the jet substructure, characterized by the presence of sub-jets and their angular correlations. This measurement is performed using the large Pb+Pb data sample at the center-of-mass energy of 5.02 TeV recorded in 2018 and compared to the result from 2017 pp collisions at the same collision energy. This study of the suppression of inclusive yields of large-R jets brings new information about the evolution of the parton shower in the medium and tests the sensitivity of the jet quenching to the color coherence effects.

Collaboration (if applicable):

ATLAS

Track:

Jets and High Momentum Hadrons

Contribution type:

Poster

Poster session / 52

Measurement of $\gamma\gamma \to \mu^+\mu^-$ pairs in non-ultra peripheral Pb+Pb collisions with the ATLAS detector

Authors: ATLAS Collaboration[None]; Lidija Zivkovic[1]

[1] *Institute of physics Belgrade (RS)*

ATLAS measurements of dimuons produced via $\gamma\gamma$ scattering processes in inelastic, non-ultra-peripheral Pb+Pb collisions at 5.02 TeV are presented using an integrated luminosity of 1.9 nb^{-1}. The $\gamma\gamma \to \mu^+\mu^-$ pairs are identified via selections on pair momentum asymmetry and acoplanarity, and the contribution from the heavy flavor decay background is estimated using a template fit method. The pair yields are measured differentially as functions of the centrality, average transverse-momentum (p_T) and rapidity of the pair. The measurement shows a depletion in the number of muon pairs near zero acoplanarity in central events, resulting in the distributions peaking at non-zero values of acoplanarity. Fits to the perpendicular transverse momentum ($k_\perp$) distributions are used to estimate the centrality dependence of this peak position. The most probable is shown to increase from the most peripheral to the most central collisions, reaching a value of $k_\perp = 36 \pm 1$ MeV in the 0-5\% most-central collisions. The ability of these measurements to qualitatively differentiate between different physical origins of the observed centrality and p_T dependence are discussed.

Collaboration (if applicable):

ATLAS

Track:

Electroweak Probes

Contribution type:

Poster

Poster session / 53

Suppression of charmonia states in Pb+Pb collisions at 5.02 TeV with the ATLAS detector.

Authors: ATLAS Collaboration[None]; Lidija Zivkovic[1]

[1] *Institute of physics Belgrade (RS)*

The suppression of heavy quarkonia states in heavy-ion collisions is a phenomenon understood as a consequence of QGP formation in the hot, dense system produced in high
energy heavy ion collisions. A full assessment of the physics scenario requires a detailed study of effects present in Pb+Pb, in comparison to pp collisions. In this poster, we present the results from the studies of prompt and non-prompt J/ψ and $\psi(2S)$ productions via their di-muon decay channel in 5.02 TeV Pb+Pb collisions collected by the ATLAS experiment at the LHC. We also present in detail how the separation of prompt and non-prompt signal is performed, as well as the description of the systematic uncertainties and technical details of the yield and suppression measurements.

Collaboration (if applicable):

ATLAS

Track:

Electroweak Probes

Contribution type:

Poster

Parallel / 54

Jet substructure via dynamical grooming

Author: Alba Soto Ontoso[1]

Co-authors: Yacine Mehtar-Tani [2]; Konrad Tywoniuk [3]

[1] *Brookhaven National Lab*

[2] *Brookhaven National Laboratory*

[3] *University of Bergen (NO)*

Jet substructure represents a cornerstone in the on-going endeavor to pinpoint the effect of a hot, thermal medium, namely the QGP, on QCD dynamics. In this talk, based on [1], I will present a new set of jet substructure observables and an associated grooming technique, dubbed "dynamical grooming". This procedure is rooted on identifying the hardest splitting in an angular ordered shower and discarding prior splittings that occur at larger angles. First, I will use p+p collisions to benchmark the method with pQCD calculations through the computation of the Sudakov form factor at modified leading-log accuracy in the context of vetoed showers. I will compare the analytic properties of the dynamically tagged splitting such as its momentum sharing fraction with Monte-Carlo simulations. In addition, the resilience of the method to non-perturbative effects together with its performance

on quark/gluon discrimination and boosted W/t/H tagging will be assessed. Finally, predictions for the dynamically groomed z_g in heavy-ion collisions at LHC energies will be presented within a probabilistic picture of energy loss.

[1] arXiv:1911.00375

Collaboration (if applicable):

Track:

Jets and High Momentum Hadrons

Contribution type:

Contributed Talk

Poster session / 56

Local Thermalization of Gluons in a Nonlinear Model

Author: Georg Wolschin[1]

[1] *Heidelberg University*

Analytic solutions of a nonlinear boson diffusion equation (NBDE) with schematic initial conditions account for the fast local equilibration of gluons in relativistic heavy-ion collisions. The exact solutions are achieved through a nonlinear transformation that was proposed in Ref. [1], but in addition, include the singularity at $\epsilon = \mu < 0$, and boundary conditions at the singularity. As a consequence, the analytic time-dependent solutions asymptotically approach the Bose-Einstein distribution not only in the UV, but also in the IR. Calculations are performed with a local equilibration time of $\tau_{\rm eq} \simeq 0.1$ fm/c and a local temperature of the order of 600 MeV in the initial stages of Pb-Pb collisions at energies reached at the Large Hadron Collider (LHC). The nonlinear NBDA solutions are suited to replace the conventional linear relaxation-time approximation that enforces equilibration from the initial nonequilibrium to the thermal distribution.

[1] G. Wolschin, Physica A 499, 1 (2018), and preprint (2020).

Collaboration (if applicable):

Track:

Initial State

Contribution type:

Contributed Talk

Parallel / 57

Simple implementation of color coherence for the resumation of soft BDMPS-Z gluons

Authors: João Barata[1]; Fabio Dominguez[2]; Víctor Vila[2]; Carlos Albert Salgado Lopez[3]

[1] *BNL and University of Santiago de Compostela/IGFAE*

[2] *Universidade de Santiago de Compostela*

[3] *Universidade de Santiago de Compostela (ES)*

The evolution of QCD jets under the influence of a dense colored medium leads to the non trivial modification of the emission spectrum. In the multiple soft scattering regime, for sufficiently large mediums, soft and wide angle emissions can be resummed, at large number of colors, since the emissions become independent up to τ_{br}/L corrections. Similarly to DGLAP evolution, such cascades correspond to pure Markovian processes and therefore interferences between partons are neglected. This constraint means that color coherence effects are absent. In the vacuum this coherence effect is critical to guarantee that the shower is angular ordered.
In this talk, we present a simple procedure to implement into the rate equations corrections coming from the color (de)coherence of the medium cascade. The final equation we obtain is remarkably simple and open to direct physical interpretation.

Collaboration (if applicable):

Track:

Jets and High Momentum Hadrons

Contribution type:

Contributed Talk

58

Measurement of $\mathrm{D_s}$-meson production in pp and Pb-Pb collisions with ALICE at the LHC

Author: Fabio Catalano[1]

[1] *Politecnico e INFN Torino (IT)*

Heavy quarks, charm and beauty, due to their large masses, are produced in hard partonic scattering processes in the initial stages of the collision. In pp collisions, cross section measurements of open-charmed mesons are an essential test for the predictions of models based on perturbative QCD calculations. In Pb-Pb collisions open-charmed mesons allow us to study the properties of the Quark-Gluon Plasma (QGP), since heavy quarks experience all the phases of the QGP evolution propagating through the medium and losing energy interacting with the QGP constituents.

Measurements of open-charmed meson production in presence of the QGP and their comparison with results obtained in pp collisions give important insights into this deconfined matter state. In particular, the measurement of the nuclear modification factor R_{AA} of $\mathrm{D_s}$ mesons compared with that of non-strange D mesons can provide information about the charm-quark hadronization mechanism. Furthermore, the study of the $\mathrm{D_s}$-meson elliptic flow v_2 in semi-central collisions, together with that of non-strange D mesons, allows us to assess the participation of charm quarks in the collective expansion of the system and the transport properties of the charm quark in the deconfined medium.

In this poster the most recent results on production of $\mathrm{D_s}$ mesons measured at mid-rapidity in pp and Pb-Pb collisions obtained by the ALICE Collaboration, exploiting also analysis techniques based on machine learning, will be presented. In particular, the p_{T}-differential R_{AA} and v_2 of $\mathrm{D_s}$ mesons measured for different centrality classes will be shown together with the production cross section of prompt and non-prompt $\mathrm{D_s}$ mesons in pp collisions.

Collaboration (if applicable):

ALICE

Track:

Heavy Flavor and Quarkonia

Contribution type:

Poster

Parallel / 61

Pursuing event activity dependence of Heavy flavor and Quarkonium production in small collision systems

Authors: Kazuhiro Watanabe[1]; Raju Venugopalan[2]; Tomasz Stebel[3]; Yan-Qing Ma[None]

[1] *Jefferson Lab*

[2] *Brookhaven National Laboratory*

[3] *Institute of Nuclear Physics PAN*

Open heavy flavor and quarkonium are valuable probes to identify the underlying QCD dynamics behind high multiplicity events at RHIC and LHC. In previous studies [1,2], we explored D-meson and J/ψ production vs. charged hadron multiplicity in $p+p$ and $p+A$ collisions in the CGC framework; we modeled an initial state effect in terms of the fluctuation of gluon saturation scale, Q_s. In this presentation, we will pursue further this initial state fluctuation effect at different impact parameters in small collision systems in the impact parameter dependent saturation model. We discuss a systematic analysis of the high multiplicity $p+p$ collisions and centrality biased $p+A$ collisions [3]. We will then discuss how those events could clarify the production mechanism of $J/\psi's$ in high multiplicity events. In particular, we will explore whether the initial state fluctuation effect is capable of changing relative contributions of different intermediate states of heavy quark pairs produced at short distance.

[1] Y. Q. Ma, P. Tribedy, R. Venugopalan, and K. Watanabe, Phys.Rev.D98, 074025 (2018).
[2] Y. Q. Ma, P. Tribedy, R. Venugopalan, and K. Watanabe, Nucl.Phys.A982, 747 (2019)
[3] Y. Q. Ma, T. Stebel, R. Venugopalan, and K. Watanabe, in preparation.

Collaboration (if applicable):

Track:

Heavy Flavor and Quarkonia

Contribution type:

Contributed Talk

Parallel / 62

Jet substructure measurements in Pb-Pb collisions at 5.02 TeV with ALICE

Author: ALICE CC chairs[None]

We report new jet substructure measurements in Pb-Pb and pp collisions at $\sqrt{s_{\mathrm{NN}}} = 5.02$ TeV with the ALICE detector. For the first time, fully corrected measurements of the groomed jet momentum

fraction, z_g, the groomed jet radius, $\theta_g \equiv R_g/R$, and the number of Soft Drop splittings, n_{SD}, will be shown in Pb-Pb collisions, along with their ratio to those in pp collisions. We present results with the Soft Drop grooming method for multiple grooming settings, as well as with the Dynamical grooming method. By using stronger grooming conditions and improved background subtraction techniques, these results are fully corrected and can be directly compared to theoretical models of jet quenching - avoiding the large background contamination present in previously reported observables. Additional jet substructure measurements will be shown and compared to recent theoretical predictions, featuring the Lund plane map of radiation phase space and its projections onto distributions of the splitting scale k_T, and the angular distribution between the groomed and ungroomed jet axis.

Collaboration (if applicable):

ALICE

Track:

Jets and High Momentum Hadrons

Contribution type:

Contributed Talk

Poster session / 63

R_{AA} of electrons from open beauty-hadron decays in Pb-Pb collisions at $\sqrt{s_{\mathrm{NN}}}$ = 5.02 TeV with ALICE

Author: Jonghan Park[1]

[1] *Inha University (KR)*

The LHC heavy-ion physics program aims at investigating the properties of strongly-interacting matter in extreme conditions of temperature and energy density, where the formation of the Quark-Gluon Plasma (QGP) is expected. Heavy quarks (charm and beauty) are regarded as unique probes of the properties of the QGP as they are created on a very short time scale in initial hard scattering processes, therefore, they witness the full evolution of the system. In particular, beauty quarks, being four times heavier than charm quarks, can be used to study the in-medium mass dependent energy loss.

Beauty production can be studied via semi-electronic decays of beauty hadrons. The yield of electrons coming from open beauty-hadron decays is obtained by fitting the impact parameter distribution with templates of different electron sources.

In this contribution, the measurements of electrons from beauty-hadron decays in Pb-Pb collisions at $\sqrt{s_{\mathrm{NN}}}$ = 5.02 TeV with the ALICE detector will be presented. For different centrality classes, the R_{AA} of beauty-hadron decay electrons is compared to that of electrons coming from charm and beauty hadron decays and with model calculations.

Collaboration (if applicable):

Track:

Heavy Flavor and Quarkonia

Contribution type:

Poster

Parallel / 64

Search for jet quenching effects in high-multiplicity proton-proton collisions at 13 TeV with ALICE

Author: ALICE CC chairs[None]

Jet quenching is a possible consequence of the formation of a quark-gluon plasma (QGP) in collision systems, but to date no significant jet quenching has been observed in small systems. In this talk, the ALICE Collaboration reports results of a novel approach to jet-quenching measurements in high-multiplicity pp collisions at √⊠=13 TeV, searching for the broadening of the acoplanarity distribution measured by the semi-inclusive distribution of jets recoiling from a high-pT hadron. Charged-jet reconstruction is carried out using the anti-kT algorithm with R=0.4 and a data-driven statistical method is used to correct the measured jet yield for uncorrelated background, which includes multi-partonic interactions. High-multiplicity (HM) pp events are selected based on charged-particle multiplicity registered in forward scintillator detectors and their acoplanarity distributions are compared to that for Minimum Bias (MB) events. Significant broadening is observed in the acoplanarity distribution of HM events, consistent with jet quenching. However, qualitatively similar features are also seen in pp collisions generated by the PYTHIA which does not include the simulation of jet quenching or any other QGP effects. We will discuss the current status of this analysis, and prospects to understand the origin of this striking phenomenon.

Collaboration (if applicable):

ALICE

Track:

Jets and High Momentum Hadrons

Contribution type:

Contributed Talk

Parallel / 65

Jet quenching and acoplanarity via hadron+jet measurements in pp and Pb-Pb collisions at 5.02 TeV with ALICE

Author: ALICE CC chairs[None]

We present the semi-inclusive distribution of charged jets recoiling from a trigger hadron in pp and Pb-Pb collisions at $\sqrt{s_{\mathrm{NN}}}$ = 5.02 TeV. This technique provides a precise data-driven subtraction of the large uncorrelated background contaminating the measurement. It uniquely enables the exploration of medium-induced modification of jet production and acoplanarity over a wide phase space, including the low jet p_{T} region for large jet resolution parameter R. Medium-induced jet deflection may occur via multiple soft scatterings resulting in a broadening of the overall azimuthal correlation between the trigger hadron and the recoiling jet. In addition, the tail of this azimuthal correlation is sensitive to Molière scatterings off quasi-particles in the medium. A search for these phenemona in Run 1 data using hadron-jet acoplanarity showed no evidence of large-angle jet broadening with respect to the vacuum expectation within experimental uncertainties. However, recent theoretical work has highlighted that low hadron trigger p_{T} and low recoiling jet p_{T} configurations show more sensitivity to in-medium modifications to the acoplanarity.

This talk will report measurements of medium-induced jet energy redistribution through the comparison of trigger-normalized recoil jet yields in different centrality intervals for Pb-Pb collisions and in minimum-bias pp collisions, and of jets with different R. We also present a new measurement of hadron-jet acoplanarity in pp and Pb-Pb collisions using high-statistics Run 2 data, with emphasis on the region of low recoil jet p_{T}.

Collaboration (if applicable):

ALICE

Track:

Jets and High Momentum Hadrons

Contribution type:

Contributed Talk

Parallel / 66

Exploring large-R jets and substructure in Pb-Pb collisions at 5.02 TeV with ALICE

Author: ALICE CC chairs[None]

Due to recent advances in jet finding techniques and larger data samples, measurements of inclusive or recoil jets with large resolution parameters are now experimentally accessible via semi-inclusive hadron-jet or machine learning techniques, the latter of which enables the measurement of charged jet spectra down to low jet transverse momentum for jet resolution parameters up to $R = 0.6$. By encompassing additional jet and medium response phase space, jet substructure measurements in these large R jets can provide further constraints on jet and medium properties. Of particular interest is the search for large transverse momentum kicks which may indicate the presence of point-like scatters within the QGP. We explore the jet substructure of inclusive and recoil jets in Pb-Pb collisions at $\sqrt{s_{\mathrm{NN}}} = 5.02$ TeV, utilizing Soft Drop and other grooming methods, as well as the Lund Plane, in order to access the hardest k_{T} splitting.

Collaboration (if applicable):

ALICE

Track:

Jets and High Momentum Hadrons

Contribution type:

Contributed Talk

Parallel / 69

Fragmentation and equilibration of jets in a QCD plasma.

Authors: Ismail Soudi[1]; Soeren Schlichting[1]

[1] *Universität Bielefeld*

We investigate the medium induced fragmentation of jets in a high-temperature QCD plasma. Based on an effective kinetic theory of QCD, we study the non-equilibrium evolution of the jet shower and the chemical equilibration of jet fragments in the medium. By including radiative emissions as well as the elastic interactions evolution, our approach extends all the way from the jet energy scale to the temperature of the medium and includes important effects such as the recoil of the medium. We present results for the in-medium fragmentation, including chemical and kinetic equilibration of the soft fragments and discuss implications of our result to jet quenching physics and the problem of thermalization of the quark-gluon plasma in heavy ion collisions.

Collaboration (if applicable):

Track:

Jets and High Momentum Hadrons

Contribution type:

Contributed Talk

Parallel / 70

Inclusive Jet Measurements in Pb-Pb Collisions at 5.02 TeV with ALICE using Machine Learning Techniques

Author: ALICE CC chairs[None]

Measurements of the jet spectra and nuclear modification factors for inclusive charged jets and inclusive full jets (containing both charged and neutral constituents) in Pb-Pb and pp collisions at $\sqrt{s_{NN}} = 5.02$ TeV recorded with the ALICE detector will be shown. These measurements use a novel machine learning based background correction [1] which reduces residual fluctuations. The improved resolution gives opportunity for measurements to lower transverse momenta and larger jet radii (R) than before. In this method, machine learning techniques are used to correct the jet transverse momentum on a jet-by-jet basis using jet parameters such as information about the constituents of the jet. Studies that investigate and estimate the fragmentation bias of this machine learning approach will also be presented. The R-dependence of the nuclear modification factor will be shown, which can provide insight as to how jets are modified by the medium and the medium response. Model comparisons will be shown where possible.

[1] R. Haake, C. Loizides, Machine learning based jet momentum reconstruction in heavy-ion collisions, arXiv:1810.06324 [nucl-ex] (2018).

Collaboration (if applicable):

ALICE

Track:

Jets and High Momentum Hadrons

Contribution type:

Contributed Talk

Poster session / 71

Measurement of Ξ_c^0 baryon in pp collisions with ALICE at the LHC\

Author: Jin Joo Seo[1]

[1] *Inha University (KR)*

The ALICE detector at the Large Hadron Collider (LHC) has been optimized for studying the strongly-interacting matter - the Quark-Gluon Plasma (QGP) at extremely high densities created in heavy-

ion collisions. Charm quarks are produced in initial hard scattering processes, transport through the whole evolution of the system, and interact with the QGP constituents. Therefore, they are powerful probes of the properties of the QGP. The measurement of charmed baryon production in proton-proton collisions provides an important opportunity to test perturbative quantum chromodynamics (pQCD) and to provide insights into the hadronization processes due to the large mass of the charm quark. In addition, the measurement of charmed baryon production is an interesting reference for heavy-ion collisions where the baryon-to-meson ratio can be modified if charm quarks are hadronized by recombination with light quarks in the deconfined medium. The measurement of Ξ_c^0 also provides additional information on the hadronization mechanism of strange quarks in proton-proton collisions.

In this poster, production of Ξ_c^0 is studied in the semi-leptonic decay channel ($\Xi_c^0 \to e\Xi\nu$) with the ALICE detector using LHC-Run2 data. The p_{T}-differential cross section times branching ratio of Ξ_c^0 in proton-proton collisions at $\sqrt{s}$=13 TeV will be shown.

Collaboration (if applicable):

ALICE

Track:

Heavy Flavor and Quarkonia

Contribution type:

Poster

Parallel / 72

Heavy Quark Radiative Energy Loss in a Non-perturbative Approach

Authors: Shuai Liu[1]; Ralf Rapp[2]

[1] *Institute of Modern Physics*

[2] *Texas A&M University*

The energy loss of heavy quarks propagating through the quark-gluon plasma (QGP) is expected to transit from an elastic regime at low and intermediate momenta to a radiative regime at high momenta. For the latter, a significant amount of energy dissipates by radiating rather soft gluons that can strongly interact with the surrounding medium through non-perturbative many-body effects. In order to investigate these effects, we extend a T-matrix approach [1-3], which describes the equation of state of QGP and yields a small shear viscosity and heavy-quark diffusion coefficient, to include the radiative energy loss of heavy quarks. We analyze several different cases by turning on/off specific non-perturbative many-body effects, to illustrate how the underlying partonic spectral functions and drag coefficients affect the radiation properties, such as the emitted power spectra and the pertinent transport coefficient, qhat. In addition, by scrutinizing the power spectrum, we can test the accuracy of the commonly employed soft and collinear approximations for the kinematics of the radiated gluons. Furthermore, we implement the transport coefficients including both the elastic and radiative contributions into a realistic transport simulations. The comparison of the results to other approaches and experiments will be discussed.

[1] S. Y. F. Liu and R. Rapp, (2016), arXiv:1612.09138 [nucl-th].
[2] S. Y. F. Liu and R. Rapp, Phys. Rev. C 97, 034918 (2018).
[3] S. Y. F. Liu, M. He, and R. Rapp, (2018), Phys.Rev. C99, 055201 (2019).
[4] S. Y. F. Liu, and R. Rapp, (2020), in preparation.

Collaboration (if applicable):

Track:

Heavy Flavor and Quarkonia

Contribution type:

Contributed Talk

Parallel / 74

Measurements of groomed heavy-flavour jet substructure with ALICE

Author: ALICE CC chairs[None]

Recently, a variety of jet shape and substructure measurements in pp and Pb-Pb collisions have provided new insights into the processes of jet fragmentation and the mechanisms of jet interaction with the quark-gluon plasma. Grooming techniques, such as Soft Drop, allow us to access the hard splittings inside a jet by removing soft radiation emitted at large angles. These techniques provide a cleaner handle with which to explore the mechanisms of parton fragmentation both in the vacuum and in the presence of a hot QCD medium.

Thanks to the excellent tracking and particle identification of its detector, the ALICE collaboration is now capable of extending the study of jet substructure to the heavy-flavour sector by studying charm-tagged jets. Such measurements allow for the exploration of the mechanisms of parton fragmentation using a quark-enriched jet sample down to very low jet momenta and can therefore be used to identify differences between quark and gluon fragmentation as well as provide a reference for studying the flavour dependence of quark energy loss in Pb-Pb collisions.

In this talk, we show the first measurements of the groomed jet substructure variables, z_g and R_g, using the Soft Drop algorithm for charged jets tagged by fully reconstructed D^0 mesons. Having access to the jet splittings involving fully reconstructed D^0 mesons also allows for the first direct measurement of the dead cone effect at colliders, by comparing the Lund plane of charm-tagged jets to that of inclusive jets. These results will be presented for pp collisions at $\sqrt{s}$ = 13 TeV and the prospects for similar measurements in Pb-Pb collisions will also be discussed.

Collaboration (if applicable):

ALICE

Track:

Jets and High Momentum Hadrons

Contribution type:

Contributed Talk

75

Measurement of electrons from beauty hadron decays in pp collisions from $\sqrt{s}$ = 2.76 TeV to 13 TeV with ALICE

Author: Vivek Kumar Singh[1]

[1] *Department of Atomic Energy (IN)*

Beauty quarks, due to their large masses are produced in the initial hard scattering processes of hadronic collisions. They witness the whole evolution of the produced medium and serve as an excellent probes for the QGP. In proton–proton collisions, the measurement of beauty-hadron production cross sections are very important to test the perturbative QCD (pQCD) calculations. In addition, it provides the required reference for Pb–Pb collisions to study the mass dependent energy loss in the medium.

In this contribution the production of electrons from beauty-hadron decays in pp collisions at mid rapidity with ALICE will be presented. The Time Projection Chamber (TPC), Time Of Flight (TOF) and ElectroMagnetic Calorimeter (EMCal) are used for particle identification. The presence of EMCal along with the TPC is exploited to measure the beauty decay electron cross section extending in the high transverse momentum region. The pT-differential production cross section of beauty decay electrons in pp collisions at different centre of mass energy($\sqrt{s}$) ranging from 2.76 TeV to 13 TeV measured with ALICE will be presented. In addition, the comparison of these measurements with different models will be shown.

Collaboration (if applicable):

ALICE

Track:

Heavy Flavor and Quarkonia

Contribution type:

Poster

Parallel / **77**

Chemical equilibration of QGP in hadronic collisions

Authors: Aleksas Mazeliauskas[1]; Eero Aleksi Kurkela[1]

[1] *CERN*

We study chemical equilibration in out-of-equilibrium Quark-Gluon Plasma using the QCD effective kinetic theory in longitudinally expanding systems. We find that chemical equilibration takes place after hydrodynamization, but well before local thermalization. By relating the transport properties of QGP and the system size we estimate that hadronic collisions with final state multiplicities $dN_{ch}/d\ 10^2$ live long enough to reach approximate chemical equilibrium for all collision systems. Therefore we expect the saturation of strangeness enhancement to occur at the same multiplicity in proton-proton, proton-nucleus and nucleus-nucleus collisions.

References:
1. Aleksi Kurkela and Aleksas Mazeliauskas, Phys. Rev. Lett. 122, (2019) [arXiv:1811.03040],
2. Aleksi Kurkela and Aleksas Mazeliauskas, Phys. Rev. D99, (2019), [arXiv:1811.03068]

Collaboration (if applicable):

Track:

Initial State

Contribution type:

Contributed Talk

Poster session / 78

Untangling the evolution of heavy ion collisions using direct photon interferometry

Authors: Oscar Garcia-Montero[1]; Nicole Alice Martin[2]; Aleksas Mazeliauskas[3]; Klaus Johannes Reygers[4]; Jürgen Berges[5]

[1] *Goethe Universität Frankfurt*

[2] *GSI - Helmholtzzentrum fur Schwerionenforschung GmbH (DE)*

[3] *CERN*

[4] *Ruprecht Karls Universitaet Heidelberg (DE)*

[5] *Heidelberg University*

Recently, two scenarios have been proposed to resolve the discrepancy between photon yield and the flow coefficients measured in nuclear collisions at RHIC and the LHC. In the first, additional photons are produced from the early pre-equilibrium stage computed from the "bottom-up" thermalization scenario [1-3]. In the second, the thermal rates are enhanced close to the pseudo-critical temperature $T_c \sim 155\,\mathrm{MeV}$ using a phenomenological ansatz [4]. We investigate the measurement of Hanbury Brown-Twiss (HBT) photon correlations [5] as an experimental tool to discriminate between such scenarios. By enhancing standard hydrodynamical simulations with these scenarios, we compute the correlators in terms of the relative momenta of the pair for different values of its transverse momenta, $K_\perp$. We find that the longitudinal correlation is the most sensitive to different photon sources. We compliment this theoretical exploration with a study of the feasibility of measuring a direct photon HBT signal in the upcoming high-luminosity LHC runs. Considering only statistical uncertainties, we find that with the projected $\sim 10^{10}$ heavy ion events a measurement of the HBT correlations for $K_\perp < 1\mathrm{GeV}$ is statistically significant.

[1] J. Berges, K. Reygers, N. Tanji, and R. Venugopalan, Phys. Rev. C95, 054904 (2017), arXiv:1701.05064 [nucl- th]
[2] R. Baier, A. H. Mueller, D. Schiff, and D. T. Son, Phys. Lett. B502, 51 (2001), arXiv:hep-ph/0009237 [hep-ph]
[3] O. Garcia-Montero, (2019), arXiv:1909.12294 [hep-ph]
[4] H. van Hees, M. He, and R. Rapp, Nucl. Phys. A933, 256 (2015), arXiv:1404.2846 [nucl-th]
[5] E. Frodermann and U. Heinz, Phys. Rev. C80, 044903 (2009), arXiv:0907.1292 [nucl-th]

Collaboration (if applicable):

Track:

Electroweak Probes

Contribution type:

Contributed Talk

Parallel / 80

Recent ALICE results on photon-induced J/psi production

Author: ALICE CC chairs[None]

The strong electromagnetic fields generated by ultra-relativistic heavy ions provide the possibility to study photon-induced processes at the LHC in new kinematic regions. ALICE has measured the exclusive and the coherent production of J/ψ in p-Pb and Pb-Pb collisions at a center-of-mass energy of 5.02 TeV. These collisions correspond to photon-proton and photon-Pb interactions, respectively.

In these cases, the mass of the charm quark allows for perturbative QCD computations addressing the phenomena of saturation and nuclear shadowing.

An overview of recent ALICE results will be presented. The p-Pb data allow us to study the evolution of the cross section for exclusive production over three orders of magnitude in Bjorken-x. Regarding the Pb-Pb data, there are two types of measurements: in ultra-peripheral and in peripheral collisions. The new data from LHC Run 2 allow us to cover a larger kinematic range with smaller experimental uncertainties than in the past. The measurements are compared with the predictions of available models to discuss the implications of the new data for our understanding of QCD in these regimes. A brief summary of ALICE plans in this field for LHC Run 3 and 4 will also be presented.

Collaboration (if applicable):

ALICE

Track:

Initial State

Contribution type:

Contributed Talk

Poster session / 81

Validation and improvement of the ZPC parton cascade inside a box

Author: Xinli Zhao[1]

Co-authors: Guoliang Ma [2]; Yugang Ma [2]; Ziwei Lin [3]

[1] *Shanghai Institute of Applied Physics,Chinese Academy of Sciences*

[2] *Fudan University*

[3] *East Carolina University*

The quark-gluon plasma is formed in high energy heavy ion collisions such as those at RHIC and LHC, where parton interactions greatly affect many final state observables. Both elastic and inelastic parton cascade models have been constructed, such as ZPC, MPC and BAMPS. Recent studies from a multi-phase transport (AMPT) model, which includes the ZPC elastic parton cascade, have shown that even a few parton scatterings in a small system is enough to generate significant momentum anisotropies. It is therefore important to ensure that the parton cascade solution is accurate.

In this work [1], we evaluate and then improve the accuracy of the ZPC parton cascade for elastic scatterings inside a box. It is well known that cascade solutions of the Boltzmann equation such as ZPC suffer from the causality violation at high densities and/or parton scattering cross sections (i.e., large opacities), and that the parton subdivision technique can be used to solve this problem. However, parton subdivision alters the event-by-event correlations and fluctuations and is also much more computationally expensive. Therefore our goal is to find an algorithm that is accurate enough without parton subdivision. We first test a dozen different collision schemes for the collision times and ordering time of ZPC and find that the default collision scheme does not accurately describe the equilibrium momentum distribution at large opacities. We then find a particular collision scheme that can describe very accurately the equilibrium momentum distribution as well as the time evolution towards equilibrium even at high opacities. In addition, we use a novel parton subdivision method to obtain the "exact"time evolution of the moment distribution towards equilibrium. This subdivision method is valid for such box tests and is much more efficient than the traditional subdivision method; e.g. we typically use a subdivision factor of 10^6 in this study. This work is the first step towards the validation and improvement of the ZPC parton cascade for scatterings in 3-dimensional expansion cases.

[1] X.L. Zhao, G.L. Ma, Y.G. Ma, Z.W. Lin, arXiv:2001.10140.

Collaboration (if applicable):

Track:

New Theoretical Developments

Contribution type:

Contributed Talk

Parallel / 82

Kinetic and Chemical Equilibration of Quark-Gluon Plasma

Authors: Xiaojian Du[1]; Soeren Schlichting[1]

[1] *Universität Bielefeld*

We establish a non-equilibrium QCD evolution model with light quark and gluon degrees of freedom. By including both elastic and inelastic scattering for quarks and gluon, the model is proficient to describe kinetic and chemical equilibration of quark-gluon plasma, and thus connect the initial (semi-) hard production of partons at early times with the hydrodynamic description of a near-thermalized quark-gluon plasma after the first fm/c of collision. Within this approach, we investigate the time scales and mechanisms for kinetic and chemical equilibration of the quark-gluon plasma at zero and non-zero net-baryon density, and elaborate on the connections to jet quenching physics.

Collaboration (if applicable):

Track:

Initial State

Contribution type:

Contributed Talk

Poster session / 83

Microscopic Charmonium Production from a Boltzmann+Langevin Approach

Authors: Xiaojian Du[1]; Ralf Rapp[2]

[1] *Universität Bielefeld, Texas A&M University*

[2] *Texas A&M University*

We calculate charmonium production in Ultrarelativistic Heavy-Ion Collisions (URHICs) within a semiclassical Boltzmann transport approach for the dissociation and regeneration of charmonium where open charm diffusion is explicitly accounted for. The diffusion of charm quarks is simulated using Langevin dynamics yielding time-dependent quark spectra which serve as input into the regeneration processes of charmonia. The dissociation/regeneration rates for charmonia and relaxation

rate for charm quarks are calculated from the same charm-medium interaction. Relative to perturbative rates, a large K-factor (representing nonperturbative interaction strength) is required to account for the phenomenology of open charm observables, which we implement for both the heavy-quark relaxation rate in the Langevin simulation and for the charmonium reaction rates in Boltzmann simulation. Our approach thus establishes a consistent transport framework for the simultaneous evolution of open and hidden heavy flavor with microscopically calculated transport coefficients in both sectors. The first results of phenomenological applications are presented.

Collaboration (if applicable):

Track:

Heavy Flavor and Quarkonia

Contribution type:

Contributed Talk

Poster session / 84

Novel Methods for Measuring the Fragmentation Function of Jets in Heavy Ion Collisions Using Jet-Hadron Correlations

Authors: Charles Hughes[1]; Christine Nattrass[1]; William Edward Witt[1]; James Neuhaus[1]; Adam Matyja[2]; Soren Sorensen[1]; Alexander Aukerman[1]; Redmer Alexander Bertens[None]

[1] *University of Tennessee (US)*

[2] *Polish Academy of Sciences (PL)*

In high energy nucleus-nucleus collisions a novel state of nuclear matter, the Quark Gluon Plasma (QGP) is created. Hard partonic scatterings which happen inside the bulk of this nuclear matter serve as an important probe of QGP properties through their energy loss. An important observable for studying the extent of this partonic energy loss is the jet fragmentation function. Previous studies have shown modification of the fragmentation function of jets in Pb-Pb collisions at the LHC for $\sqrt{(s)}$ = 2.76 TeV relative to p-p collisions of similar energy. These studies focus on jets with transverse momentum > 85 GeV/c. Detailed investigation of lower momentum jet fragmentation functions may complement these studies by providing more information on energy loss (and thereby more carefully constrain QGP properties). The main difficulty in studying low momentum jets in heavy ion collisions is the presence of a significant uncorrelated background of low momentum hadrons from soft processes which get grouped together with particles from the hard scattering. One way to deal with this background from soft processes is to use the jet-hadron azimuthal correlation to fit and subtract the soft, flow correlated background information from the jet (on the average). This technique allows one to measure the near side yield in the correlation function after background subtraction for a large number of events binned in jet transverse momentum (p_T) and hadron transverse momentum. From these yields binned in p_T, one can then construct an uncorrected fragmentation function. We discuss the specifics of this proposed method of measuring the fragmentation function including corrections for detector effects. We present the results of a Monte Carlo study using Pythia and a custom made Heavy Ion Background Generator (along with mocked up detector effects) that demonstrate the feasibility of this method.

Collaboration (if applicable):

Track:

Jets and High Momentum Hadrons

Contribution type:

Poster

Parallel / 87

Jet fragmentation in a dense medium from perturbative QCD

Authors: Alfred Mueller[1]; Edmond Iancu[2]; Gregory Soyez[3]; Paul Caucal[4]

[1] *Columbia University*

[2] *Université Paris-Saclay (FR)*

[3] *IPhT, CEA Saclay*

[4] *IPhT*

We study the fragmentation of an energetic jet propagating through a
dense quark-gluon plasma within perturbative QCD. We use a recently developed factorisation scheme (and the associated Monte-Carlo generator), in which the standard vacuum-like parton branchings are factorised in time from the medium-induced emissions triggered by multiple soft scattering in the medium. Besides the Monte-Carlo results, we present analytic calculations based on piecewise approximations which render the physical interpretation transparent. Our results for the nuclear modification factor for the jet fragmentation function are in qualitative agreement with the experimental data in Pb+Pb collisions at the LHC. In particular, we reproduce the enhancements seen in the data at both relatively soft and relatively large transverse momenta, with clear physical interpretations. The perturbative predictions however are quite sensitive to the value of the infrared cutoff (the confinement scale), due to the fact that the fragmentation function is not an infrared safe quantity. To remedy this, we propose a new observable — the (primary) subjet fragmentation function — which is infrared safe and has features similar to the fragmentation function. We provide predictions for this observable that could be tested against the experimental data.

Collaboration (if applicable):

Track:

Jets and High Momentum Hadrons

Contribution type:

Contributed Talk

Parallel / 88

Open heavy-flavour production from small to large collision systems with ALICE at the LHC

Author: ALICE CC Chairs[None]

Heavy flavours are effective probes of the hot and dense matter, the Quark-Gluon plasma (QGP), produced in ultra-relativistic heavy-ion collisions. Due to the very short time scale characterising their production, they experience the whole evolution of the system. In particular, measurements of heavy-flavour production in Pb-Pb collisions at the LHC energies, including nuclear modification factors, give insight on the mechanisms of heavy-quark transport and energy loss in the hot and dense QCD matter.

In small hadronic systems like pp and p-Pb, heavy-flavour production provides the baseline for observations of hot-medium effects in heavy-ion collisions, as well as tests of perturbative QCD and measurements of cold-matter effects in the nuclear medium. On top of that, heavy-flavour measurements in small systems recently gained additional interest due to the possibility of observing

specific initial- and final-state effects affecting the production mechanisms, driven by the particle multiplicity acting as an effective scaling parameter.

In this contribution, ALICE results on open heavy-flavour production in pp, p-Pb and Pb-Pb collisions at various energies will be discussed. New measurements will be presented both for fully-reconstructed charmed mesons and for single electrons and single muons from heavy-flavour hadron decays.

Collaboration (if applicable):

ALICE

Track:

Heavy Flavor and Quarkonia

Contribution type:

Contributed Talk

Parallel / 89

Directed, elliptic and triangular flow of D mesons in ALICE

Author: ALICE CC Chairs[None]

Heavy quarks (charm and beauty) are produced in abundance during the early stage of ultra-relativistic heavy-ion collisions. They therefore experience the full evolution of the Quark-Gluon Plasma (QGP). This makes them unique probes of the collective behaviour of particles in the medium as it expands and cools. The anisotropy of the overlap region between the two colliding nuclei in the initial state is translated into a momentum anisotropy of the produced particles in the final state.

The v_2, or elliptic flow, is an observable that reflects the degree of collectivity in this expanding system. At low momenta it provides information on the collective motion of particles and the degree of thermalisation within the system, while at higher momenta it serves to constrain the path-length dependence of the energy loss of heavy quarks in the medium. The effect of quark recombination can be studied by comparing the measured v_2 of non-strange D mesons (D^0, D^+, D^{*+}) with measurements of strange D mesons (D_s^+).

In addition to the elliptic flow, other flow harmonics provide information about the properties of the QGP. The directed flow (v_1) of heavy-flavour particles is sensitive to the unprecedentedly strong magnetic fields present in the early stages of the collision, and so measurements of its charge dependence are key to constraining the electrical conductivity of the QGP. Finally, the triangular flow (v_3) is driven by fluctuations in the initial state of the system, and is sensitive to the ratio of the shear viscosity to the entropy density, η/s. The v_3 measurement therefore serves as an important constraint on hydrodynamic models of QGP formation, which predict a low η/s at RHIC and the LHC.

This talk will present the latest measurements by the ALICE Collaboration on the directed, elliptic and triangular flow of charmed hadrons in Pb-Pb collisions at $\sqrt{s_{\mathrm{NN}}} = 5.02$ TeV. The charge-dependent v_1 of D^0 mesons will be shown, as well as the average D-meson v_2 measured by standard and Event-Shape Engineering (ESE) techniques, and the non-strange D-meson v_3. The non-strange D-meson v_2 results will also be compared with those of strange D mesons. Comparisons with predictions from theoretical models will be discussed.

Collaboration (if applicable):

ALICE

Track:

Heavy Flavor and Quarkonia

Contribution type:

Contributed Talk

Parallel / 90

Open charm and dileptons from relativistic heavy-ion collisions

Authors: Elena Bratkovskaya[1]; Taesoo Song[2]; Pierre Moreau[3]; Wolfgang Cassing[4]

[1] *GSI, Darmstadt*

[2] *GSI, Darmsradt*

[3] *Duke University*

[4] *University of Giessen*

Dileptons are considered as one of the cleanest signals of the quark-gluon plasma (QGP),however, the QGP radiation is masked by many 'background' sources from either hadronic decays or semileptonic decays from correlated charm pairs. In this study we investigate the relative contribution of these channels in heavy-ion collisions from $\sqrt{s_{\rm NN}} = 8$ GeV to 5 TeV with a focus on the competition between the thermal QGP radiation and the semileptonic decays from correlated $D-$meson pairs. As a 'tool' we employ the parton-hadron-string dynamics (PHSD) transport approach to study dilepton spectra in Pb+Pb (Au+Au) collisions in a wide energy range incorporating for the first time a fully microscopic treatment of the charm dynamics and their semileptonic decays. We find that the dileptons from correlated $D-$meson decays dominate the 'thermal' radiation from the QGP in central Pb+Pb collisions at the intermediate masses (1.2 GeV $< M <$ 3 GeV) for $\sqrt{s_{NN}} >$ 40 GeV, while for $\sqrt{s_{\rm NN}} =$ 8 to 20 GeV the contribution from $D, \bar{D}$ decays to the intermediate mass dilepton spectra is subleading such that one should observe a rather clear signal from the QGP radiation. We, furthermore, study the p_T-spectra and the $R_{AA}(p_T)$ of single electrons at different energies as well as the excitation function of the inverse slope of the m_T- spectra for intermediate-mass dileptons from the QGP and from charm decays. We find moderate but characteristic changes in the inverse slope parameter for $\sqrt{s_{NN}} >$ 20 GeV which can be observed experimentally in high statistics data. Additionally, we provide detailed predictions for dilepton spectra from Pb+Pb collisions at $\sqrt{s_{NN}} =$ 5.02 TeV.

Collaboration (if applicable):

Track:

Heavy Flavor and Quarkonia

Contribution type:

Contributed Talk

91

Investigate the electromagnetic field characteristics in AMPT model

Author: Xinli Zhao[1]

Co-authors: Guoliang Ma [2]; Yugang Ma [2]

[1] *Shanghai Institute of Applied Physics, Chinese Academy of Scien*

[2] *Fudan University*

In non-central heavy-ion collisions, the fast-moving charged ions can produce a strong magnetic field with the magnitude about $eB\ m^2\ 10^{18}$ to 10^{19} Gauss from the energy available at the BNL Relativistic Heavy Ion Collider (RHIC) to the energy available at the CERN Large Hadron Collider (LHC). Meanwhile, it is believed that relativistic heavy-ion collisions at RHIC and LHC produce a quark-gluon plasma (QGP), in which some chiral anomalous transport effects could happen, such as the Chiral Magnetic Effect (CME) and Chiral Magnetic Wave (CMW). With the help of a multi-phase transport (AMPT) model, we study the electromagnetic field characteristics in isobar program and Au+Au collisions at the RHIC energy.

However, the current main difficulty of measuring the CME signal is some backgrounds which we do not understand clearly. To isolate the influence of those backgrounds, the isobar program at RHIC has been proposed and it collides $^{96}_{44}$Ru $+^{96}_{44}$ Ru and $^{96}_{40}$Zr $+^{96}_{40}$ Zr elements, since they have a same nucleon number but the 10% difference of proton number. The CME signal is expected to be different between the two isobaric collisions. By investigating the the properties of electromagnetic fields in two isobaric collisions with special emphasis on the correlation between magnetic field direction and participant plane angle Ψ_2 (or spectator plane angle Ψ_2^{SP}), i.e. $\langle \cos2(\Psi_B - \Psi_2)\rangle$ [or $\langle \cos2(\Psi_B - \Psi_2^{SP})\rangle$], we confirm that the magnetic fields of $^{96}_{44}$Ru$+^{96}_{44}$Ru collisions are stronger than those of $^{96}_{40}$Zr$+^{96}_{40}$Zr collisions. Moreover, we find that the deformation of nuclei has a non-negligible effect on $\langle \cos2(\Psi_B - \Psi_2)\rangle$, especially in peripheral events. Because the magnetic field direction is more strongly correlated with Ψ_2^{SP} than with Ψ_2, the relative difference of the chiral magnetic effect observable with respect to Ψ_2^{SP} is expected to be able to reflect much cleaner information about the CME with less influences of deformation [1].

What is more, with the presence of magnetic field, the coupling of the vector and axial currents induced by the chiral anomaly can motivate a collective gapless excitation in QGP, i.e. CMW. The CMW can lead to an electric quadrupole moment in relativistic heavy-ion collision, which explains the observed charge-dependent elliptic flow of pions. In our study, a dipolar distribution of $\mathbf{E}\cdot\mathbf{B}$ is observed at the non-central collisions in Au+Au collisions at the RHIC energy $\sqrt{s}$=200 GeV. More importantly, we find that the coupling of the dipole QED anomaly and magnetic field $\mathbf{B}$ can also induce an electric quadrupole moment which can further lead to the difference in elliptic flows between positive charged particles and negative charged particles through final interactions. The centrality dependence of the density of $\mathbf{E}\cdot\mathbf{B}$ is similar to the trend of the slope parameter γ measured from the difference in elliptic flows between positive pions and negative pions by the STAR collaboration. Therefore, the novel mechanism for electric quadrupole moment generation can offer a new interpretation of the observed charge-dependent elliptic flow of pions, but without the formation of CMW[2].

[1] X. L. Zhao, G. L. Ma and Y. G. Ma, Phys. Rev. C **99**, 034903 (2019).
[2] X. L. Zhao, G. L. Ma and Y. G. Ma, Phys. Lett. B **792**, 413 (2019).

Collaboration (if applicable):

Track:

Initial State

Contribution type:

Poster

Parallel / 92

Photon radiation in hot nuclear matter by means of chiral anomalies

Author: Kirill Tuchin[1]

[1] *Iowa State University*

A new mechanism of photon emission in the quark-gluon plasma is proposed. Photon dispersion relation in the presence of the CP-odd topological regions generated by the chiral anomaly acquires an imaginary mass. It allows photon radiation through the decay $q \to q\gamma$ and annihilation $q\bar{q} \to \gamma$ processes closely related to the chiral Cherenkov radiation. Unlike previous proposals this mechanism does not require an external magnetic field. The differential photon emission rate per unit volume is computed and shown to be comparable to the rate of photon emission in conventional processes. The presentation is based on Phys.Rev. C99 (2019) no.6, 064907, Phys.Rev.Lett. 121 (2018) no.18, 182301.

Collaboration (if applicable):

Track:

New Theoretical Developments

Contribution type:

Contributed Talk

Poster session / 94

Measurement of the ω Meson in pp Collisions at the LHC with ALICE

Author: Jens Robert Luhder[1]

[1] *Westfaelische Wilhelms-Universitaet Muenster (DE)*

ALICE is a dedicated heavy-ion experiment and focusses on the properties of the Quark-Gluon Plasma (QGP), a state of strongly interacting matter expected to be formed in heavy-ion collisions. When performing proton-proton collisions, the energy densities reached are in principle not sufficient to form this medium and hence measurements in this system serve as a baseline to understand the influences of the QGP on the particle production.
Furthermore, cross sections of neutral mesons are needed to test QCD-based theory predictions and to constrain Fragmentation Functions as well as Parton Distribution Functions at high momentum.

This poster will cover the measurement of the invariant cross sections of the ω-meson at mid-rapidity in pp collisions with a center of mass energy of $\sqrt{s} = 13\,\text{TeV}$ produced at the LHC Run2 and measured by ALICE.
The ω is reconstructed via $\omega \to \pi^+\pi^-\pi^0$, where the π^0 decays further in two photons.
In ALICE, the measurement of photons is performed in two different ways:
The first method measures photons via their energy deposits in electromagnetic calorimeters.
The second method is called PCM (Photon Conversion Method) as photons may convert to e^+-e^- pairs when interacting with the detector material. While the e^+-e^- pairs from conversions are identified and measured with help of the Time Projection Chamber (TPC), the charged pions are measured using information of the Inner Tracking System (ITS) in addition.

Collaboration (if applicable):

ALICE

Track:

Jets and High Momentum Hadrons

Contribution type:

Poster

Parallel / 97

Charmed-baryon production and hadronization studies with ALICE

Author: ALICE CC Chairs[None]

The measurements of the charmed baryons are fundamental to investigate charm-quark production and hadronization mechanisms in different collision systems.
Recent measurements of charm-baryon production in small systems at LHC energies show a baryon-over-meson ratio significantly higher than that in e^+e^- and $e^\pm p$ collisions, and higher than expectations from Monte Carlo generators, tuned to reproduce these measurements, suggesting a violation of the universality of the fragmentation of charm in different collision systems.
Various mechanisms are recently being considered in the theory community to describe the measurements, such as multi-parton interactions, colour reconnection, ropes, or statistical hadronization approaches.
In nucleus-nucleus collisions, where a hot and dense Quark-Gluon Plasma (QGP) forms and collectively expands, the enhancement of baryon-to-meson ratios is predicted by theoretical models in which heavy quarks hadronize by coalescence with light quarks from the plasma. Measurements of Λ_c production in nucleus-nucleus collisions hint to a larger ratio to D mesons, with respect to the case of pp collisions.
Furthermore, the measurement of open heavy flavours as a function of multiplicity in pp and p-Pb collisions provides important information to understand how the possible presence of collective effects could modify the production of heavy-flavour hadrons.
The analysis of different charm baryon species, such as Σ_c and Ξ_c, give further insight into the study of the charm hadrons production in all systems.

In this talk, we present measurements of Λ_c, Ξ_c and Σ_c baryons performed with the ALICE detector at mid-rapidity in pp collisions at various collision energies.
The Λ_c/D^0 ratio measured in different collision systems and its multiplicity dependency from pp to p-Pb and Pb-Pb collisions will be shown. The R_{pPb} and the R_{AA} of the Λ_c will be discussed as well.
The results will be compared with predictions from Monte Carlo event generators in the pp system, and with models including CNM effects or the formation of a QGP in larger systems.

Collaboration (if applicable):

ALICE

Track:

Heavy Flavor and Quarkonia

Contribution type:

Contributed Talk

Parallel / 99

Beauty production with ALICE at the LHC

Author: ALICE CC Chairs[None]

In hadronic collisions, beauty quarks are produced in hard scattering processes with large momentum transfer. Their production provides a very important test of perturbative QCD calculations in pp collisions.
In heavy-ion collisions, the measurement of beauty hadron production is a unique tool to investigate the properties of the Quark-Gluon Plasma. In particular, beauty quarks, being four times heavier than charm quarks, can be utilized to study the in-medium mass dependent energy loss. In addition, measurements in p-Pb collisions are crucial to investigate the effects of cold nuclear matter on their production.

With the ALICE detector, beauty quarks are studied by measuring electrons and non-prompt D mesons coming from beauty hadron decays at mid-rapidity. Finally, a more direct access to the initial parton kinematics is obtained by measuring beauty-tagged jets. They can provide further constraints for energy loss models adding information on how the radiated energy is dissipated.

In this contribution, the latest measurements of beauty production using beauty-decay electrons, non-prompt D-mesons and beauty-tagged jets in pp collisions at $\sqrt{s}$ = 5.02 TeV, and their comparison to pQCD calculations will be presented. New measurements of beauty-tagged jet production down to low p_{T} in p-Pb collisions at $\sqrt{s_{\mathrm{NN}}}$ = 5.02 TeV will be discussed. The latest results on the centrality dependence of R_{AA} of beauty-decay electrons and non-prompt D mesons in Pb-Pb collisions at $\sqrt{s_{\mathrm{NN}}}$ = 5.02 TeV compared to different theoretical models will be presented.

Collaboration (if applicable):

ALICE

Track:

Heavy Flavor and Quarkonia

Contribution type:

Contributed Talk

Parallel / 100

Quarkonia production in pPb collisions

Authors: Stefania Ricciardi[1]; Collaboration LHCb[None]

[1] *Science and Technology Facilities Council STFC (GB)*

We present LHCb results on quarkonia production in proton-lead collisions, using the data collected in 2016 at sqrt(s_NN) = 8.16 TeV. Measurements are performed in the forward rapidity region (pseudorapidity between 2 and 5), covering both forward (pPb configuration) and backward (Pbp configuration) rapidities. Measurements for charmonium states include prompt and from-b-decay components which are disentangled. The large increase of the data sample, with respect to the 5 TeV sample collected in 2013, allows a remarkable improvement in the accuracy of the studies of nuclear matter effects.

Collaboration (if applicable):

LHCb

Track:

Heavy Flavor and Quarkonia

Contribution type:

Contributed Talk

Parallel / 101

Entanglement, partial set of measurements, and diagonality of the density matrix in the parton model

Authors: Vladimir Skokov[1]; Alexander Kovner[2]

[1] *North Carolina State University*

[2] *University of Connecticut*

We consider the following conundrum: On one hand the proton as a quantum object is in a pure state and is described by a completely coherent wave function with zero entropy. On the other hand in high energy experiments (DIS) when probed by a small external probe, it behaves like an incoherent ensemble of (quasi-free)
partons.

In this talk, we define the "entropy of ignorance" which quantifies the entropy associated with ability to perform only a partial set of measurement on a quantum system. For a parton model the entropy of ignorance is equal to a Boltzmann entropy of a classical system of partons. We analyze a calculable model used for describing low x gluons in Color Glass Condensate approach, which has similarities with the parton model of QCD. In this model we calculate the entropy of ignorance in the particle number basis as well as the entanglement entropy of the observable degrees of freedom. We find that the two are similar at high momenta, but differ by a factor of order unity at low momenta. This holds for the Renyi as well as von Neumann entropies. We conclude that the entanglement does not seem to play an important role in the context of the parton model.

Collaboration (if applicable):

Track:

New Theoretical Developments

Contribution type:

Contributed Talk

Parallel / 102

X(3872) production in pp with particle multiplicity

Authors: Stefania Ricciardi[1]; LHCb Collaboration[None]

[1] *Science and Technology Facilities Council STFC (GB)*

The last decade of hadron spectroscopy has unveiled a wealth of states that do not have the properties expected of particles composed of 2 or 3 valence quarks. Among the most intriguing of these exotics is the X(3872), which various models attempt to describe as a hadronic molecule, a compact tetraquark, an unexpected charmonium state, or their mixtures. Heavy ion collisions, as well as high multiplicity pp collisions, offer a new window on the properties of this poorly understood hadron. In these systems, promptly produced X(3872) hadrons can interact with other particles in the nucleus and/or those produced in the collision. The influence of these interactions on the observed X(3872) yields provides information that can help discriminate between the various models of its structure, as well as give insight into the dynamics of the bulk particles produced in these collisions. With a full range of precision vertexing, tracking, and particle ID capabilities covering 2 to 5 in units of rapidity, the LHCb experiment is especially well suited to measurements of both prompt and non-prompt exotic hadrons.
This talk will present new LHCb measurements X(3872) production in high multiplicity pp collisions through the decay to $J/\psi\pi^+\pi^-$.

Collaboration (if applicable):

LHCb

Track:

Heavy Flavor and Quarkonia

Contribution type:

Contributed Talk

Parallel / 103

Open heavy flavor production in pA collisions

Authors: Stefania Ricciardi[1]; LHCb Collaboration[None]

[1] *Science and Technology Facilities Council STFC (GB)*

Within the two p-Pb data samples collected by the LHCb detector at sqrt(s_NN) = 5 and 8.16 TeV, a rich set of open charm hadrons is observed with abundant statistics. Thanks to the LHCb forward acceptance that is complementary to general purpose detectors, with excellent performances in particle reconstruction and identification, these charm states are studied down to zero pT with overwhelming precision. In this talk, we present measurements of charm mesons and baryons productions, reconstructed in exclusive hadronic final states. Beauty hadrons, with signal counts up to a few thousands in the fully reconstructed decays in the pPb data samples, are also shown. Comparisons between theory predictions and data regarding the nuclear modification factors, forward-to-backward production ratios and baryon-to-meson ratios are made. The impact of the results, in particular on the improvement of nuclear PDF and parton saturation, are discussed. The open charm production in fixed-target collisions of LHCb is also presented, which provides crucial constraints on intrinsic charm and nuclear parton distribution functions at moderate and large Bjorken x.

Collaboration (if applicable):

LHCb

Track:

Heavy Flavor and Quarkonia

Contribution type:

Contributed Talk

Poster session / 104

Heavy flavor production in PbPb collisions : results and prospects

Authors: Stefania Ricciardi[1]; LHCb Collaboration[None]; Alexandre Belin[2]; Samuel Belin[3]

[1] *Science and Technology Facilities Council STFC (GB)*

[2] *CERN*

[3] *Universita e INFN, Cagliari (IT)*

In 2018, LHCb recorded ˜210 microbarnˆ{-1} integrated luminosity of PbPb collisions at sqrt(s_NN) = 5.02 TeV.
Although limited to peripheral hadronic collisions, this new dataset offers unique opportunities to study simultaneously open and close heavy flavor production, at forward rapidity down to zero pT, at the LHC.
Moreover, with an increase of the luminosity by a factor 20 compared to the previous 2015 PbPb dataset, precise measurements on photo-produced charmonia in ultra-peripheral collisions are foreseen.
All these measurements are sensitive to and would help to constrain the small-x parton distribution functions (nPDFs) in the target nucleus.
Finally, the great momentum resolution of the detector allows to study photo-produced J/psi in collisions with a nuclear overlap.
This new type of prob is sensitive to the geometry of the collisions but also to the electromagnetic field of the Pb nuclei.
In this talk, we present the latest results on heavy flavor productions obtained by LHCb measurements in peripheral and ultra-peripheral PbPb collisions.
Prospectives on this first results are also discussed.

Collaboration (if applicable):

LHCb

Track:

Heavy Flavor and Quarkonia

Contribution type:

Contributed Talk

Parallel / 105

Z production in pPb collisions at LHCb

Authors: Stefania Ricciardi[1]; LHCb Collaboration[None]

[1] *Science and Technology Facilities Council STFC (GB)*

LHCb measurements of the electroweak boson production in forward and backward configuration of proton-lead collisions are sensitive to the nPDFs in a unique kinematic domain, allowing to study in a complementary fashion the structure of the nucleus.
In this talk, we present the latest results obtained on the Z production in pPb and Pbp collisions by LHCb, being the most precise measurements in the rapidity coverage

Collaboration (if applicable):

LHCb

Track:

Heavy Flavor and Quarkonia

Contribution type:

Contributed Talk

Parallel / 106

LHC Run 3 and Run 4 prospects for heavy-ion physics with LHCb

Authors: Stefania Ricciardi[1]; LHCb Collaboration[None]

[1] *Science and Technology Facilities Council STFC (GB)*

The largely unknown parton distribution functions of nuclei and the similarities observed between high-multiplicity pp and pPb events compared to PbPb, often described by means of hydrodynamics, are the main motivations for an extended pPb data taking program during LHC Run 3 and Run 4.
The future increase in luminosity combined with the LHCb unique and improved detector capabilities in the upgrade will allow to perform new and precise measurements.
Moreover, an upgraded internal gas target is going to be installed for the LHCb run 3 fixed target program, allowing a wider choice of target gas species and an increase of the gas density by up to two order of magnitude.
Prospects will be presented on both the LHCb collider and fixed target programs.

Collaboration (if applicable):

LHCb

Track:

New Experimental Developments

Contribution type:

Contributed Talk

Poster session / 107

Longitudinal flow decorrelation in Xe+Xe and p+Pb collisions with the ATLAS detector

Authors: ATLAS Collaboration[None]; Lidija Zivkovic[1]

[1] *Institute of physics Belgrade (RS)*

ATLAS measurements of longitudinal flow decorrelation using two- and four-particle correlations for harmonics n=2 and 3 in Xe+Xe and p+Pb collisions covering a wide range of transverse momenta and collision centrality are presented and compared with Pb+Pb collisions. The measurements are performed using data from Xe+Xe collisions at 5.44 TeV, Pb+Pb collisions at 5.02 TeV, and p+Pb collisions at 5.02 and 8.16 TeV. The energy dependence in p+Pb collisions and the system-size dependence of decorrelation are studied. The measurements provide better understanding of the initial state of heavy-ion collisions and will help in developing full three-dimensional initial-state models.

Collaboration (if applicable):

ATLAS

Track:

Initial State

Contribution type:

Poster

108

Direct photon measurements in p-Pb collisions at #sqrt{s_{NN}} = 5.02 TeV via the photon conversion technique with ALICE

Author: Hikari Murakami[1]

[1] *University of Tokyo (JP)*

Direct photons are a unique probe to investigate properties of a thermalized matter created in relativistic heavy-ion collisions, the quark-gluon plasma (QGP). In particular, direct photons at low transverse momentum are very important since thermal photons are supposed to contribute. In recent years, collective behavior has been observed in high particle multiplicity pp and p-Pb collisions at the LHC. These observations could hint to the formation of thermalized partonic systems such as QGP, even in small colliding systems. Measurements of direct photons in p-Pb collisions are crucial to have a better understanding of the matter created in small colliding systems. In ALICE, direct photons are measured via calorimeters or photon conversions technique. The latter allows us to measure #pi^{0}, #eta mesons, and direct photons down to #it{p}_{T} = 0.4 (GeV/#it{c}). In this poster, current status of direct photon measurements will be presented.

Collaboration (if applicable):

ALICE

Track:

Electroweak Probes

Contribution type:

Poster

Poster session / 110

Heavy Quarkonia in a Magnetic Field

Authors: Binoy Krishna Patra[1]; Mujeeb Hasan[1]

[1] *Indian Institute of Technology Roorkee*

It is predicted that for the noncentral events in
ultrarelativistic heavy-ion collisions (URHICs),
a strong magnetic field is generated at the very early
stages of the collisions. However, as we know
the quarkonia, the physical resonances of $Q\bar{Q}$
states, are formed in the plasma frame at a time,
t_F (=$\gamma\tau_F$), which is order of 1-2 fm,
depending on the resonances and their momenta.
By the time elapsed, the magnetic field may become
weak. This motivates us to explore the effects of
both the weak and strong magnetic fields on the
properties of heavy quarkonia immersed in a thermal medium of
quarks and gluons and then studied how the magnetic field affects the
quasi-free dissociation in the aforesaid medium.
For that purpose, we have revisited the structure of
gluon self-energy tensor in the presence of both weak and strong
magnetic fields in thermal QCD and obtained the relevant form factors,
that in turn computes the real and imaginary parts of the
resummed gluon propagator. Then the linear response theory yields
the real and imaginary parts of the dielectric permittivity from

the respective resummed propagators. Finally, the inverseFourier transform of the permittivities of the above propagators
in the static limit obtains the complex heavy quark potential.
This is the first study to compute the heavy quark potential
perturbatively in the weak magnetic field as compared to earlier
known study of the strong magnetic field. We have observed
that the real-part gets screened more in the presence of weak
magnetic field, whereas it becomes less screened in the strong
magnetic field compared to their counterparts in the
absence of magnetic field. On the other hand, the magnitude of
the imaginary-part becomes larger both in weak and strong
magnetic field as compared to that in the absence of magnetic
field. Further, the real-part of the
potential is used in the Schr\"{o}dinger
equation to obtain the binding energy, whereas the
imaginary part is used to calculate the
thermal width of heavy quarkonia. With the weak and
strong magnetic field both the observed screening in
the real-part of the potential can be attributedin terms of the decrease in the binding energy, whereas the increase in the magnitude of the imaginary-part of the
potential will leads to the enhancement of decay
width of quarkonia. Finally we have studied the
quasi free dissociation of quarkonia and found that
the dissociation temperature in the presence of
weak magnetic field becomes slightly lower, whereas
in the presence of strong magnetic field it becomes
higher compared to the one in absence of magnetic
field.

Collaboration (if applicable):

Track:

Heavy Flavor and Quarkonia

Contribution type:

Contributed Talk

Poster session / 112

Effect of strong magnetic field on the interplay of momentum, heat and charge transports in a hot QCD matter

Authors: Binoy Krishna Patra[1]; Shubhalaxmi Rath[1]

[1] *Indian Institute of Technology Roorkee*

We have studied the effect of strong magnetic field on the interplay
of coefficients related to the transports of momentum, heat and
charge of a hot QCD matter by shear (η) and bulk (ζ)
viscosities, thermal (κ) and electrical ($\sigma_{\rm el}$)
conductivities, and some derived coefficients,
{\em viz.} $\frac{\eta}{s}$, $\frac{\zeta}{s}$, Lorenz (L), Knudsen
(Ω), Prandtl (Pl), Reynolds (Rl) numbers and ratio of momentum
diffusion to charge diffusion. We have also computed the
abovementioned coefficients in the absence (isotropic) and presence
of momentum anisotropy caused by the asymptotic expansion at the early stages
of ultrarelativistic heavy-ion collisions, which facilitates us to
compare the effects of anisotropies with respect to the isotropic

medium. We have first calculated the
viscosities, conductivities and entropy density (s) in the relaxation time approximation of kinetic theory within the quasiparticle model.
Compared to the isotropic medium, both η and ζ get enhanced
in the presence of strong magnetic field, contrary to their
reduction in expansion-driven anisotropy. η increases with temperature
faster in the former case than in the latter case, whereas ζ in the former case decreases with temperature and in the latter case, it is
meagre and vanishes at a specific temperature. We have also observed that
both κ and $\sigma_{\rm el}$ get increased in a strong magnetic field,
but κ increases slowly with the temperature,
contrary to its rapid increase in expansion-driven anisotropy,
whereas $\sigma_{\rm el}$ monotonically decreases with the temperature,
opposite to the increase in expansion-driven anisotropy. Thus, the
viscosities and conductivities could distinguish the effects of strong
magnetic field and expansion-driven anisotropy. In the presence of
momentum anisotropies, the entropy density gets decreased, especially it
is lowest in the B-driven anisotropy due to reduction of
phase-space. Thus, η/s gets enhanced in the B-driven anisotropy
and in the expansion-driven anisotropy, it becomes
smaller than the isotropic one. Similarly ζ/s gets amplified but
decreases faster with the temperature in a strong magnetic field. The
value of the Lorenz number, {\em i.e.}, the ratio,
$\kappa/(\sigma_{\rm el}T)$ in B-driven anisotropy is larger than in
isotropic medium, but smaller than in expansion-driven
anisotropy. The Knudsen number gets reduced in expansion-driven anisotropy,
whereas the strong magnetic field raises its value but to less than one, thus the system stays in local equilibrium. The Prandtl number
gets increased in B-induced anisotropy, whereas it gets decreased in
expansion-induced anisotropy, compared to isotropic one. Since, Pl is
found larger than 1, the sound attenuation is governed by the
momentum diffusion. The strong magnetic field makes the Reynolds number
smaller than one, whereas the expansion-driven anisotropy makes it
larger. Finally the ratio $(\eta/s)/(\sigma_{\rm el}/T)$ is amplified
much in strong magnetic field, whereas the amplification is less
pronounced in the absence of magnetic field. Since, the ratio is found more than one,
so the momentum diffusion prevails over the charge diffusion.

Collaboration (if applicable):

Track:

Electroweak Probes

Contribution type:

Contributed Talk

Poster session / 114

Probing jet medium interactions via $Z(H)$+jet momentum imbalances

Authors: Lin Chen[1]; Shu-yi Wei[2]; Hanzhong Zhang[3]

[1] *Central China Normal University*

[2] *CPHT, Ecole Polytechnique*

[3] *IOPP, CCNU*

Different types of high energy hard probes are used to extract the jet transport properties of the Quark-Gluon Plasma created in heavy-ion collisions, of which the heavy boson tagged jets are undoubtedly the most sophisticated due to its clean decay signature and production mechanism. In this study, we used the resummation improved pQCD approach with high order correction in the hard factor to calculate the momentum ratio x_J distributions of Z and Higgs(H) tagged jets. We found that the formalism can provide a good description of the 5.02 TeV pp data. Using the BDMPS energy loss formalism, along with the OSU 2+1D hydro to simulate the effect of the medium, we extracted the value of the jet transport coefficient to be around $\hat{q}_0 = 4 \sim 8\, GeV^2/fm$ by comparing with the Z+jet $PbPb$ experimental data. The H+jet x_J distribution were calculated in a similar manner in contrast and found to have a stronger Sudakov effect as compared with the Z+jet distribution. This study uses a clean color-neutral boson as trigger to study the jet quenching effect and serves as a complimentary method in the extraction of the QGP's transport coefficient in high energy nuclear collisions.

arXiv:2001.07606

Collaboration (if applicable):

Track:

Jets and High Momentum Hadrons

Contribution type:

Contributed Talk

Parallel / 115

Identification of Quenched Jets with Machine Learning

Authors: Marta Verweij[1]; Lihan Liu[2]

[1] *Nikhef National institute for subatomic physics (NL)*

[2] *Vanderbilt University (US)*

It is believed that the properties of quark-gluon plasma (QGP) can be studied through measurements of the jet quenching phenomenon. More specifically, detailed studies of the jet substructure may reveal the microscopic properties of the QGP.

Recently the modification of groomed jet observables was studied in heavy-ion collisions 1[2]. In addition, the Lund radiation plane was introduced to investigate parton shower modifications in the QGP [3].

In this talk, I am going to show how machine learning techniques can help evaluate how quenched a jet is on a jet-by-jet basis. A classifier based on the long short-term memory (LSTM) model is trained. The LSTM model is an artificial recursive neural network (RNN) and is capable of processing sequential data. This design makes it well-suited for making predictions on jets by taking advantage of the binary structure of parton branchings that form a jet.

Simulations are made with Monte-Carlo event generators including PYTHIA8, JEWEL and the hybrid strong/weak coupling model, the last two of which take the medium response into consideration.

Reference:
1 Measurement of the splitting function in pp and PbPb collisions at √sNN =5.02TeV. arXiv:1708.09429.
[2] Exploration of jet substructure using iterative declustering in pp and Pb-Pb collisions at LHC energies. arXiv:1905.02512v1.
[3] Novel tools and observables for jet physics in heavy-ion collisions. arXiv: 1808.03689.

Collaboration (if applicable):

Track:

Jets and High Momentum Hadrons

Contribution type:

Contributed Talk

Parallel / 116

Isolated photon production and correlations in pp and p-Pb collisions at LHC with ALICE

Author: ALICE CC chairs[None]

Isolated photon production in pp collisions is one of the most clear tests of hard QCD processes and proton structure functions. Their measurement in pA collisions provides the possiblity to check initial geometrical scaling and possible modifications of the nucleon structure function in nuclei. Furthermore, the isolated photons constrain the kinematics of scattered partons and therefore, the measurement of isolated photon-hadron correlations has some advantages in the extraction of parton fragmentation function in pp and pA collisions.
ALICE collected data on pp and p-Pb collisions at several colliding energies. Thanks to the low material budget, ALICE is able to measure isolated photons down to relatively small $p_{\mathrm{T}} \sim 10$ GeV/c, thus probing structure functions down to small x. In this talk, the isolated photon spectra measured in pp collisions at $\sqrt{s}$ = 5.02 and 7 TeV will be presented and compared to those in p-Pb collisions at $\sqrt{s_{\mathrm{NN}}}$ = 5.02 TeV. By constructing the nuclear modification factor even stronger constraints on the geometrical model and the amount of modification of nucleon structure functions in nuclei can be provided due to partial error cancelation. Additionally, the isolated photon-hadron correlations in pp and p-Pb collisions will be presented and contrasted with the corresponding fragmentation functions and jet-hadron correlations at the LHC.

Collaboration (if applicable):

ALICE

Track:

Electroweak Probes

Contribution type:

Contributed Talk

Poster session / 117

f_0(980) resonance production in small collision systems with ALICE

Author: Junlee Kim[1]

[1] *Jeonbuk National University (KR)*

Short-lived resonances are powerful probes to understand the hadronic phase in ultra-relativistic heavy-ion collisions, due to their lifetimes of ∼10 fm/c, comparable to the time span between chemical and kinetic freeze-out. The measurements of short-lived resonances in small collision systems

provide the baseline for heavy-ion collision measurements as well as exploration of cold nuclear matter effects, which can be achieved by comparison between measurements in pp and p-Pb collisions. We present the multiplicity dependence of the production of $f_0(980)$ at mid-rapidity ($|y| < 0.5$) in pp collisions at $\sqrt{s} = 13$ TeV and p-Pb collisions at $\sqrt{s_{\mathrm{NN}}} = 5.02$ TeV. The measurement has been performed with ALICE at the LHC and the particles have been reconstructed in the $f_0(980) \to \pi^+\pi^-$ decay channel. The poster will include details on the signal extraction, transverse momentum spectra, particle yield and mean transverse momenta of $f_0(980)$. In addition, the particle yield ratios and nuclear modification factor, R_{pPb} will be presented to explore the internal structure of $f_0(980)$.

Collaboration (if applicable):

ALICE

Track:

Initial State

Contribution type:

Poster

Parallel / 118

Light meson nuclear modification factor in p-Pb collisions over an unprecedented transverse momentum range with ALICE

Author: ALICE CC chairs[None]

Light meson measurements in high-energy proton-nucleus collisions provide a probe to study the physics of strongly interacting matter and the quark-gluon plasma (QGP). In particular, measuring the nuclear modification factor R_{pA}, where the particle production in pA is compared to a baseline proton-proton reference which is scaled to account for nuclear geometry, provides important insights to the modfication of nucleon structure functions in nuclei and a baseline for the observed strong suppression of hadron yields at high p_{T} in heavy-ion collisions.

In this talk, neutral pion and η meson invariant differential yields and nuclear modification factors at midrapidity are presented with a p_{T} reach beyond 100 GeV/c and up to 40 GeV/c, respectively, and compared to theoretical model calculations. Both neutral mesons are measured via their diphoton decay channel in pp and p-Pb collisions at $\sqrt{s_{\mathrm{NN}}}$ = 5.02 and 8.16 TeV with the ALICE experiment at the CERN LHC. The analysis combines results from several partially independent reconstruction techniques where the decay photons were detected with the electromagnetic calorimeter, EMCal, the photon spectrometer, PHOS, or via reconstruction of e^+e^- pairs from conversions in the ALICE detector material using the central tracking system.

Collaboration (if applicable):

ALICE

Track:

Jets and High Momentum Hadrons

Contribution type:

Contributed Talk

Poster session / 120

Charged-particle production as function of event multiplicity in ALICE

Author: Patrick Huhn[1]

[1] *Johann-Wolfgang-Goethe Univ. (DE)*

The ALICE experiment at the LHC is designed to investigate the properties of the Quark-Gluon Plasma by studying high-energy A–A collisions. Medium effects like parton energy loss can be examined by measuring the production of charged particles at high transverse momentum (p_{T}). In particular, the correlation between p_{T} spectra and event multiplicity of charged particles can give a handle on the different production mechanisms of charged particles.
In this poster, we report on charged-particle p_{T} spectra as a function of the event multiplicity in pp collisions at $\sqrt{s}$ = 2.76, 5.02, 7 and 13 TeV as well as in p-Pb and Pb–Pb collisions at $\sqrt{s_{\mathrm{NN}}}$ = 5.02 TeV to study the energy and system size dependence. By comparing to QCD-inspired models, this measurement can help in understanding the event multiplicity dependence of charged-particle production mechanism.

Collaboration (if applicable):

ALICE

Track:

Jets and High Momentum Hadrons

Contribution type:

Poster

Parallel / 122

Measurement of quarkonium polarization in Pb-Pb collisions at the LHC with ALICE

Author: ALICE CC Chairs[None]

Polarization measurements represent an important tool for understanding the particle production mechanisms occurring in proton–proton collisions. In particular, for quarkonium states, the very small polarization measured at the LHC represents a serious and a long-lasting challenge for theoretical models. When considering heavy-ion collisions, particle polarization could also be used to investigate the characteristics of the hot and dense medium (Quark-Gluon Plasma) created at LHC energies. Recently, it has been hypothesized that quarkonium states could be polarized by the strong magnetic field generated in the early phase of the evolution of the system.
In ALICE, the quarkonium polarization is extracted by measuring the anisotropies in the angular distribution of the muons coming from the quarkonium state decay. In this contribution, final results on the J/ψ and new results on the $\Upsilon(1S)$ polarization in Pb-Pb collisions at a center of mass energy per nucleon pair of $\sqrt{s_{\mathrm{NN}}} = 5.02$ TeV will be presented. The p_{T}-differential measurement was done at forward rapidity (2.5 < y < 4) and the results will be shown in two different reference planes. The results will be also compared with previous measurements from pp collisions. Finally, the status of the analysis dedicated to measure the J/ψ polarization as a function of the collision centrality as well as relative to the event plane will be discussed.

Collaboration (if applicable):

ALICE

Track:

Heavy Flavor and Quarkonia

Contribution type:

Contributed Talk

Poster session / 123

D^{*+} production in pp collisions at $\sqrt{s} = 13$ TeV with ALICE at the LHC

Author: Marco Giacalone[1]

[1] *Universita e INFN, Bologna (IT)*

The ALICE experiment is devoted to study the Quark Gluon Plasma (QGP), which is the high-density state of matter, obtained in high-energy heavy-ion collisions, where quarks and gluons are deconfined. Since heavy quarks (charm, beauty) are created mostly with hard scatterings during the first stages of the collisions and their abundances remain constant while the system evolves, they can be used as effective and calibrated QGP probes.

Production of heavy quarks in pp collisions provides a stringent test to pQCD calculations and allows us to study multi-parton interactions by analyzing their production as a function of charged-particle multiplicity. In this poster, D^{*+} ($c\bar{d}$) production as a function of multiplicity in pp collisions at $\sqrt{s} =$ 13 TeV using data recorded during 2016, 2017 and 2018 running periods will be presented.

Collaboration (if applicable):

ALICE

Track:

Heavy Flavor and Quarkonia

Contribution type:

Poster

Poster session / 124

Investigating collective flow patterns and the influence of electromagnetic fields in relativistic proton-nucleus collisions

Author: Lucia Oliva[1]

Co-authors: Elena Bratkovskaya [2]; Pierre Moreau [3]; Vadim Voronyuk [4]

[1] *Institute for Theoretical Physics (ITP), Frankfurt am Main*

[2] *GSI, Darmstadt*

[3] *Duke University, Durham*

[4] *JINR, Dubna*

The recent experimental observations of azimuthally anisotropic flow in small systems at RHIC and LHC energies has stimulated a big interest in these collisions, traditionally regarded only as control measurements for heavy-ion collisions and now becoming a new study area for the formation and evolution of the quark-gluon plasma. In the early stage of proton-nucleus collisions extremely

intense electromagnetic fields are produced with a magnitude of few m_π^2; unlike symmetric heavy-ion collisions, in these small asymmetric systems the electric field along the impact parameter axis is comparable to the magnetic field perpendicular to the reaction plane. By means of microscopic simulations within the Parton-Hadron-String Dynamics (PHSD) approach we investigate the emergence of collectivity and the influence of electromagnetic fields on final hadronic observables in proton-nucleus collisions at relativistic energy. One of the main effects of the combined asymmetry of electromagnetic fields and particle distributions is a splitting in the rapidity dependence of the directed flow of positively and negatively charged mesons 1.

1 L. Oliva, P. Moreau, V. Voronyuk and E. Bratkovskaya, arXiv:1909.06770.

Collaboration (if applicable):

Track:

Initial State

Contribution type:

Contributed Talk

Poster session / 125

DCA studies for separating prompt and non-prompt dielectrons in p–Pb collisions at $\sqrt{s_{\rm NN}} = 5.02$ TeV with ALICE

Author: Horst Sebastian Scheid[1]

[1] *Johann-Wolfgang-Goethe Univ. (DE)*

Dileptons are a prime probe of the deconfined state of strongly interacting matter, the Quark–Gluon Plasma (QGP), produced in high energy heavy ion collisions, as they are not affected by secondary strong interactions. A measurement of the thermal radiation from the QGP in the dielectron intermediate mass region allows to estimate the medium temperature. In this region the main component of the dielectron continuum is due to correlated semileptonic decays of B and D mesons. The proper decay length for B-mesons is $c\tau \approx 500$ μm and for D mesons it is 100-300 μm, hence the reconstructed decay electrons do not point to the primary vertex of the collision.
Combining the measured distance of closest approach (DCA) of each single electron into a pair variable $\mathrm{DCA_{ee}}$ gives the possibility to separate prompt from non-prompt dielectron pairs or the charm and beauty contributions from each other. In small collisions systems this approach can be used to measure a possible modification of the heavy-flavour sources by cold nuclear matter effects, or to identify thermal radiation on top of the heavy-flavour contributions and with this serve as a reference for measurements in Pb–Pb collisions.
We will present most recent studies in p–Pb collisions at $\sqrt{s_{\rm NN}} = 5.02$ TeV.

Collaboration (if applicable):

ALICE

Track:

Electroweak Probes

Contribution type:

Poster

Parallel / 126

The problem of overlapping formation times: A complete result for QCD

Authors: Peter Arnold[1]; Tyler Gorda[1]; Shahin Iqbal[2]

[1] *University of Virginia*

[2] *Institute of Particle Physics, Central China Normal University*

The splitting processes of bremsstrahlung and pair-production in a medium are coherent over large distances in the high energy limit leading to a suppression known as the Landau-Pomeranchuk-Migdal (LPM) effect. Avoiding soft-emission approximations and working in the large-Nc limit, we consider corrections to the LPM effect from cases where the coherence lengths of two consecutive splittings overlap. In this work, we present (i) complete results for the case of two overlapping gluon splittings (e.g. $g \to gg \to ggg$ and virtual corrections to single splitting $g \to gg^* \to ggg^* \to gg$) and (ii) confirm that earlier leading-log results for these effects are reproduced by our more-complete results in the appropriate soft limit. We also discuss how to combine the effects of overlapping real double splitting with the corresponding virtual corrections to single splitting in order to calculate IR-safe quantities such as in-medium energy loss.

Collaboration (if applicable):

Track:

New Theoretical Developments

Contribution type:

Contributed Talk

Parallel / 128

Evidence of shadowing in inelastic nucleon-nucleon cross section

Authors: Mikko Kuha[1]; Kari J. Eskola[2]; Ilkka Helenius[1]; Hannu Paukkunen[1]

[1] *University of Jyväskylä*

[2] *University of Jyvaskyla*

The Glauber modeling plays a key role in centrality-dependent measurements of heavy-ion collisions.
A central input parameter in Glauber models is the inelastic nucleon-nucleon cross section $\sigma_{\rm nn}^{\rm inel}$ which is nearly always taken from proton-proton measurements. At the LHC energies $\sigma_{\rm nn}^{\rm inel}$ depends on the QCD dynamics at small x and low interaction scales where the shadowing/saturation phenomena are expected to become relatively more important for larger nuclei than proton. Thus, $\sigma_{\rm nn}^{\rm inel}$ e.g. in Pb+Pb collisions may well be lower than what is seen in proton-proton collisions.

In this talk we demonstrate how to use the recent $W^{\pm}$ and Z measurements as a "standard candle" to extract $\sigma_{\rm nn}^{\rm inel}$ in Pb+Pb collisions. Our analysis – built on the ATLAS data, state-of-the-art NNLO QCD calculations and nuclear PDFs – indicate that at the LHC energies $\sigma_{\rm nn}^{\rm inel}$ in Pb+Pb collisions is suppressed relative to the proton-proton measurements by tens of percents. We demonstrate that this is in line with expectations from nuclear PDFs.

Collaboration (if applicable):

Track:

Electroweak Probes

Contribution type:

Contributed Talk

Parallel / 129

Angular de-correlation of forward di-hadrons: on the optimal p_t range to probe gluon saturation

Author: Giuliano Giacalone[1]

Co-authors: Cyrille Marquet [2]; Marek Matas [3]; Shu-yi Wei [4]

[1] *Université Paris-Saclay*

[2] *CPHT - Ecole Polytechnique*

[3] *Czech Technical University*

[4] *ECT**

An important phenomenological consequence of the phenomenon of gluon saturation is the suppression of back-to-back hadron and jet pairs produced in the forward region of pA collisions. We present a new calculation of this process within the dilute-dense formalism of the color glass condensate (CGC) effective theory. Following Ref. 1, we collide a large-x, dilute probe, described in terms of parton distribution functions, off a dense target, described in terms of transverse momentum dependent (TMD) gluon distributions, whose small-x evolution we calculate using rcBK evolution. We then couple this cross section with the formalism introduced in Ref. [2] to implement in an analytically-controlled way the radiation of soft gluons (Sudakov resummation) from the initial and the final state.

We first apply this CGC+Sudakov framework to the production of forward di-jets at high-p_t in pp and pA collisions. We use the same kinematic cuts and collision energy as in a recent analysis by the ATLAS collaboration [3]. We find that the suppression of the di-jet yield at $\Delta\phi = \pi$, predicted by gluon saturation, is essentially washed out by a strong effect of broadening induced by the radiation of soft gluons. Compatibly with ATLAS data, we find that the nuclear modification factor for forward high-p_t dijets is at best of order $R_{pA} \approx 0.9$.

Motivated by this result, we propose to study the production of forward dihadrons (pions) at lower, though moderate, p_t ($\approx$ 10 GeV). We find that, in this case, the suppression of back-to-back pairs genuinely predicted by gluon saturation survives the broadening due to the Sudakov resummation. We indeed obtain $R_{pA} \approx 0.75$ at $\Delta\phi = \pi$ using kinematic cuts compatible with the proposed FoCal upgrade of the ALICE detector. We conclude that forward dihadrons at high p_t provide a sensitive probe of gluon saturation at LHC.

1 J. L. Albacete, G. Giacalone, C. Marquet and M. Matas, https://arxiv.org/abs/1805.05711
[2] A. Stasto, S-Y. Wei, B-W. Xiao, and F. Yuan https://arxiv.org/abs/1805.05712
[3] ATLAS Collaboration https://arxiv.org/abs/1901.10440

Collaboration (if applicable):

Track:

Initial State

Contribution type:

Contributed Talk

Poster session / 130

Measurement of Neutral Mesons in pp Collisions at $\sqrt{s} = 13$ TeV with ALICE

Author: Joshua Leon Konig[1]

[1] *Johann-Wolfgang-Goethe Univ. (DE)*

The precise measurement of the neutral meson production in pp collisions can be used as a constrain for fragmentation functions and parton density functions needed by pQCD calculations. Additionally, those measurements can be used as an input for direct photon analyses. Moreover, the dependence of the neutral meson cross section on the event particle multiplicity and on the event sphericity provides a baseline to study the presence of effects that could be interpreted as the creation of the quark-gluon plasma in the collision, as other measurements might indicate.
The reconstruction of neutral mesons via their two photon-decay channel can be realized in the ALICE experiment with several complementary methods, including the calorimeters and the TPC. The combination of these methods allows for a large p_{T} coverage as well as small statistical and systematic uncertainties.
In this poster, the invariant cross sections as well as the multiplicity and sphericity dependencies of the π^0 and η p_{T} spectra in pp collisions at $\sqrt{s} = 13$ TeV with ALICE will be presented.

Collaboration (if applicable):

ALICE

Track:

Jets and High Momentum Hadrons

Contribution type:

Poster

Parallel / 131

Jets and medium evolution in Pb-Pb collisions at the LHC energies from the EPOS initial state

Authors: Iurii Karpenko[1]; Joerg Aichelin[2]; Pol Gossiaux[3]; Klaus WERNER[4]; Martin Rohrmoser[5]

[1] *FNSPE CTU Prague*

[2] *Subatech/CNRS*

[3] *EMN Nantes*

[4] *University of Nantes*

[5] *IFJ-PAN Krakow*

We present the results for PbPb collisions at 2.76 TeV LHC energy from a parton shower integrated with a hydrodynamic evolution. The initial hard (jet) partons are produced along with soft partons in the initial state EPOS approach (EPOS3 model). The EPOS3 initial state typically contains multiple hard scatterings in each event. The soft partons, represented by strings, melt into a thermalized medium which is described with a 3 dimensional event-by-event viscous hydrodynamic approach. The jet partons then propagate in the hydrodynamically expanding medium. The total jet energy

gets progressively "degraded"according to a state-of-the-art microscopic radiative energy loss Monte Carlo for the low-virtuality jet partons. Also, partons reaching a certain lower cut off are "melted" into the hydrodynamic medium via the source terms. The full evolution proceeds in a concurrent mode, without separating hydrodynamic and jet parts. We discuss two features of PbPb collision:
- a jet overlap effect 1 which emerges due to multiple hard parton production in each heavy-ion collision event,
- jet energy loss in the medium and its modification due to the LPM effect.

1 Iurii Karpenko, Joerg Aichelin, Pol Gossiaux, Martin Rohrmoser, and Klaus Werner, Phys. Rev. C 101, 014905 (arXiv:1908.00836)

Collaboration (if applicable):

Track:

Jets and High Momentum Hadrons

Contribution type:

Contributed Talk

Parallel / 132

Illuminating the early stages of relativistic heavy-ion collisions: the pre-hydro phase as seen through photons and hadrons

Authors: Jean-Francois Paquet[1]; Chun Shen[2]; Bjoern Schenke[3]; Charles Gale[4]

[1] *Duke University*

[2] *Wayne State University*

[3] *Brookhaven National Lab*

[4] *McGill University*

We model relativistic heavy-ion collisions with a hydrid dynamical approach which consists of an IP-Glasma initial state followed by a phase modeled by an effective QCD kinetic theory 1. This then leads into viscous hydrodynamics and finally transport theory (MUSIC + UrQMD) [2]. The system's complete energy-momentum tensor – including the shear and bulk viscous components – is followed through these different stages. The effect of the pre-hydro phase on the spectra and flow coefficients of photons and hadrons is highlighted. We study how that non-equilibrium phase influences the hadron and photon flow coefficients in Pb+Pb, Xe+Xe, and O+O collisions at 5 TeV. Because the space-time volume scales differently from the number of binary collisions from O+O to Xe+Xe and Pb+Pb collisions, a systematic system size comparison of photon production can further shed light on the relative contributions from thermal and prompt sources and provide further insight into early time QGP dynamics. We also explore the effect of early chemical equilibrium on the photon observables.

1 A. Kurkela, A. Mazeliauskas, J.F. Paquet, S. Schlichting, and D. Teaney, "Matching the Nonequilibrium Initial Stage of Heavy Ion Collisions to Hydrodynamics with QCD Kinetic Theory," Phys. Rev. Lett. 122, no. 12, 122302 (2019); "Effective kinetic description of event-by-event pre-equilibrium dynamics in high-energy heavy-ion collisions," Phys. Rev. C 99, no. 3, 034910 (2019)

[2] S. McDonald, C. Shen, F. Fillion-Gourdeau, S. Jeon and C. Gale, "Hydrodynamic predictions for Pb+Pb collisions at 5.02 TeV", Phys. Rev. C 95, no. 6, 064913 (2017)

Collaboration (if applicable):

JETSCAPE

Track:

Electroweak Probes

Contribution type:

Contributed Talk

Parallel / 133

Forward quark jet-nucleus scattering in a light-front Hamiltonian approach

Author: Meijian Li[1]

Co-authors: Guangyao Chen [2]; James Vary [2]; Kirill Tuchin [2]; Pieter Maris [2]; Tuomas Lappi [1]; Xingbo Zhao [3]; Yang Li [2]

[1] *University of Jyväskylä*

[2] *Iowa State University*

[3] *Institute of Modern Physics, Chinese Academy of Sciences*

We investigate the scattering of a quark jet on a high-energy heavy nucleus using the time-dependent light-front Hamiltonian approach. We present the real-time evolution of the quark-jet in a strong classical color field of the incoming nucleus described by the Color Glass Condensate effective theory. We calculate the cross section, the differential cross section, and the quark jet distribution function in coordinate space as well as in color space. We study the sub-eikonal effect by letting the quark jet carry realistic finite longitudinal momenta, and we find sizeable changes on the transverse coordinate distribution of the quark. We then extend our investigation by including dynamical gluons and study jet quenching with gluon emissions.

Collaboration (if applicable):

Track:

Initial State

Contribution type:

Contributed Talk

Parallel / 135

The NA60+ experiment at the CERN SPS: physics goals and prospects

Author: Enrico Scomparin[1]

[1] *Universita e INFN Torino (IT)*

The region of the QCD phase diagram at high μ_{B} can be accessed by fixed-target experiments working at future or existing facilities providing nuclear beams in the multi-GeV energy range. In particular, the CERN SPS is able to provide high-intensity beams over a wide energy interval ($\sqrt{s_{\mathrm{NN}}}$ = 5-17 GeV) that are ideal for the study of rare signals. Recently, an expression of interest has been

presented for a new experiment at the CERN SPS, NA60+, aimed at measuring hard and electromagnetic probes in nuclear collisions with unprecedented precision with an energy scan.
The physics goals of such an experiment are very broad and ambitious. On one hand, NA60+ proposes the investigation of the order of the phase transition to the QGP in the region $\mu_{\mathrm{B}} \sim$ 200-400 MeV with the first measurement of a caloric curve, and the first direct measurement of $\rho - a_1$ chiral mixing by a precision measurement of the dimuon yield in the a_1 mass region. These physics topics can be addressed via the study of the thermal dimuon continuum from threshold up to 3 GeV. On the other hand, the study of the transport properties of the QGP close to the threshold energy for the occurrence of deconfinement can be accessed for the first time by a simultaneous precision study of hidden and open charm. The measurements of charmonium and open charm states are performed through dimuon and hadronic decays, respectively. In this talk, the physics case of the experiment will be reviewed with a detailed discussion of the results of the physics performance studies. The talk will stress the competitiveness and complementarity of the NA60+ program in the landscape of the proposals foreseen at other facilities in this decade.

Collaboration (if applicable):

OTHER (Please specify in comments field)

Track:

Electroweak Probes

Contribution type:

Contributed Talk

Parallel / 137

Lattice QCD calculation of $\hat{q}$ with dynamical fermions

Authors: Amit Kumar[1]; Abhijit Majumder[2]

[1] *Wayne State University*

[2] *Wayne state university*

The jet transport coefficient $\hat{q}$ is the leading property of a strongly interacting medium that effects jet propagation. It introduces momentum transverse to a jet parton's direction, changing its virtuality and thus controls the modification of hard jets in a dense extended medium. In this talk, we present the first unquenched lattice QCD calculation of $\hat{q}$. The calculation is carried out using (2+1)-flavors of quarks, using the highly improved staggered quark action (HISQ) and tree-level Symanzik improved gauge action. The calculation is performed in a wide range of temperatures, ranging from 200 MeV T 800 MeV using the MILC code package.

Following earlier work in quenched SU(2) and SU(3) [1,2], we considered a single hard parton scattering off the glue field of a thermal QCD medium by exchanging a Glauber gluon (whose transverse momentum is larger than its longitudinal components). The hard scale associated with the jet parton allows the coupling of the gluon to that parton to be treated in perturbation theory. The coupling of the gluon to the medium is treated non-perturbatively. This non-perturbative part is expressed in terms of a non-local (two-point) Field-Strength-Field-Strength operator product which can be Taylor expanded after analytic continuation to the deep-Euclidean region. Such an expansion allows us to write $\hat{q}$ in terms of the expectation of a diminishing series of local operators, which are suppressed by factors of the hard parton energy. We also discuss the connection between our formalism and a method outlined in Ref. [3] that allows one to extract light-cone correlations using the matrix elements of frame-dependent, equal-time correlators in the large momentum limit. The calculated $\hat{q}$ and its temperature dependence demonstrates considerable agreement with the phenomenological extractions carried out by the JET collaboration.

1 A. Kumar, A. Majumder, C. Nonaka, PoS LATTICE2018 169 (2018),
arXiv: 1811.01329 [nucl-th].
[2] A. Majumder, Phys. Rev. C87 034905 (2013).
[3] X. Ji, Phys. Rev. Lett. 110, 262002 (2013).

Collaboration (if applicable):

Track:

New Theoretical Developments

Contribution type:

Contributed Talk

Parallel / 138

Nuclear modification factor and flow measurements of quarkonia in p-Pb and Pb-Pb collisions with ALICE at LHC

Author: ALICE CC Chairs[None]

Heavy quarks are produced in the earliest stages of a nucleus-nucleus collision and therefore are an important tool to study the subsequent high energy-density medium formed in relativistic heavy-ion collisions. Over the last few decades major efforts have been undertaken in order to understand the properties of the quark-gluon plasma (QGP) using quarkonia. The extent of medium modification for heavy-quark production in heavy-ion collisions is measured in terms of the nuclear modification factor R_{AA}. However, modifications of quarkonium production may also occur due to cold nuclear matter (CNM) effects such as shadowing of nuclear parton distribution function, gluon saturation and others. In recent data, strong suppression patterns have been seen in Υ R_{AA} whereas a recombination of individual charm quarks as dominant production mechanism for charmonium states, in particular J/ψ for low transverse momentum and most central collisions. These individual charm quarks are expected to be (at least partially) equilibrated and together with initial anisotropies from the collision geometry result in a positive J/psi elliptic flow. At higher transverse momentum, the J/ψ elliptic flow in high-multiplicity p-Pb collisions shows values similar to those from Pb-Pb collisions, suggesting a common production mechanism in this kinematic region.

ALICE J/ψ and Υ R_{AA} results for Pb-Pb collisions at $\sqrt{s_{\mathrm{NN}}}$ = 5.02 TeV will be presented as a function of centrality, p_{T} and rapidity. The inclusive as well as prompt and non-prompt J/ψ production will be discussed for the R_{AA} measurement at mid-rapidity for p-Pb collisions at $\sqrt{s_{\mathrm{NN}}}$ = 5.02 TeV. The CNM effects will be also explored for the Υ and ψ(2S) in p-Pb collisions at $\sqrt{s_{\mathrm{NN}}}$ = 8.16 TeV. The p_{T}-differential inclusive J/ψ elliptic flow at mid-rapidity ($|y| < 0.9$) will be shown together with the J/ψ elliptic and triangular flow at forward rapidity ($2.5 < y < 4$) in Pb-Pb collisions. These results will be compared to $\Upsilon(1S)$ elliptic flow in Pb-Pb collisions. In addition, measurements of J/ψ elliptic flow in p-Pb collisions at $\sqrt{s_{\mathrm{NN}}} = 5.02$ TeV and 8.16 TeV will be presented at forward ($2.03 < y < 3.53$) and backward ($-4.46 < y < -2.96$) rapidity.
Finally, the ALICE results will be compared with those obtained by other LHC experiments and the current theoretical interpretation of the results will be also discussed.

Collaboration (if applicable):

ALICE

Track:

Heavy Flavor and Quarkonia

Contribution type:

Contributed Talk

Parallel / 139

Recent quarkonium measurements in small systems with the ALICE detector at the LHC

Author: ALICE CC Chairs[None]

At the LHC energies Multiple Parton Interactions (MPI) are expected to affect not only processes involving soft particle production, but also the hard momentum scales relevant for the production of heavy quarks, such as charm and beauty. Quarkonium measurements in high-multiplicity proton-proton (pp) collisions can shed light on the role of MPI at such hard momentum scales, as well as on the interplay between hard and soft particle production mechanisms. In addition, quarkonium production measurements in minimum bias pp collisions, besides serving as a reference for heavy-ion collisions collected at the same center-of-mass energy, represent a benchmark test of QCD based models in both perturbative and non-perturbative regimes.
The ALICE detector has unique capabilities at the LHC for measuring quarkonia down to zero transverse momentum. Measurements are carried out at both central and forward rapidity, in the dielectron and dimuon decay channel, respectively.
In this contribution, the latest quarkonium measurements performed by the ALICE collaboration in pp collisions at several center-of-mass energies will be presented. Recent Υ(1S), Υ(2S) and Υ(3S) cross section measurements performed at $\sqrt{s}$ = 5 TeV, down to zero transverse momentum and at forward rapidity, will be shown. A comprehensive study of the multiplicity dependence of the quarkonium production at $\sqrt{s}$ = 13 TeV, based on minimum bias and high-multiplicity triggered events, will be also presented. Such measurements include ψ(2S) production at forward rapidity as a function of the charged particle multiplicity density, as well as the latest multiplicity dependent inclusive J/ψ production measurements at mid-rapidity, based on multiplicity estimators covering different pseudorapidity regions. Similar multiplicity dependent measurements in p-Pb collisions at center-of-mass energies of $\sqrt{s_{\rm NN}} = 5.02$ and 8.16 TeV will also be shown. Results will be compared with available theoretical model calculations.

Collaboration (if applicable):

ALICE

Track:

Initial State

Contribution type:

Contributed Talk

Parallel / 140

Measurement of electroweak-boson production in p-Pb and Pb-Pb collisions at the LHC with ALICE

Author: ALICE CC Chairs[None]

W and Z bosons are created in the hard scattering processes occurring in the initial stage of heavy-ion collisions and they are insensitive to the presence of a strongly-interacting medium. This makes them clean probes of the initial-state effects of the collision, such as the nuclear modification of the parton distribution functions (nPDFs). The measurement of the electroweak-boson production in p-Pb and Pb-Pb collisions at the LHC provides constraints on the nPDFs of the (anti-)quarks in a phase-space region that is poorly constrained by previous experiments.
ALICE measures the electroweak-boson production in the muonic decay channel at forward rapidities ($2.5 < y_{\rm lab} < 4$). In this contribution, recent results on the Z-boson production in Pb-Pb collisions at a center-of-mass energy per nucleon pair of $\sqrt{s_{\rm NN}} = 5.02$ TeV, exploiting the combined 2015 and 2018 data sets, will be presented. The invariant production yield as well as the nuclear modification factor ($R_{\rm AA}$) will be shown as a function of rapidity and collision centrality. Similarly, results on the rapidity dependence of the Z-boson production cross section in p-Pb collisions at $\sqrt{s_{\rm NN}} = 8.16$ TeV will be discussed. The latter will be complemented by new results on the W-boson production cross-section in the same collision system. The different results will be compared

to calculations obtained with or without including nuclear modifications of the PDFs, as well as to results obtained by other LHC experiments.

Collaboration (if applicable):

ALICE

Track:

Initial State

Contribution type:

Contributed Talk

Parallel / 141

Low-mass dielectron measurements in Pb-Pb collisions with ALICE at the LHC

Author: ALICE CC Chairs[None]

The production of low-mass dielectrons is one of the most promising tools for the understanding of chiral symmetry restoration and the thermodynamical properties of the Quark-Gluon plasma (QGP) created in ultra-relativistic heavy-ion collisions. For low invariant masses ($m_{\mathrm{ee}} < 1.1$ GeV/c^2), the dielectron invariant-mass spectrum is sensitive to the properties of short-lived vector mesons in the medium and modifications related to chiral symmetry restoration. Thermal radiation emitted by the system, both during the partonic and hadronic phase, contributes to the dielectron yield over a broad mass range and gives insight into the thermodynamic properties of the medium. In the intermediate-mass region ($1.1 < m_{\mathrm{ee}} < 2.8$ GeV/c^2), the measurement of thermal dielectrons from the QGP is very challenging at the LHC due to the dominant contribution of correlated e^+e^- pairs from semileptonic decays of charm and beauty hadrons. Finally, at very low pair transverse momenta initial photon annihilation and photonuclear processes, triggered by the coherent electromagnetic fields of the incoming nuclei, are expected to play a role in more peripheral collisions.
In this talk, we will present dielectron measurements with ALICE in Pb-Pb collisions at $\sqrt{s_{\mathrm{NN}}}$ = 5.02 TeV for different centralities. In particular, the new results obtained analysing 2018 Pb-Pb data, which provide higher statistical precision compared to previous measurements, will be shown. The results will be compared to the expected dielectron yield from known hadronic sources as well as several predictions for the thermal radiation from the hadronic gas and QGP phases.

Collaboration (if applicable):

ALICE

Track:

Electroweak Probes

Contribution type:

Contributed Talk

Parallel / 147

On gauge invariance of transverse momentum dependent distributions at small x

Authors: Yacine Mehtar-Tani[1]; Renaud Boussarie[2]

[1] *Brookhaven National Laboratory*

[2] *Brookhaven National Lab*

The interplay between the small x limit of QCD amplitudes and QCD factorization at moderate x has been studied extensively in recent years. It was finally shown that semiclassical formulations of small x physics can have the form of an infinite twist framework involving Transverse Momentum Dependent (TMD) distributions in the eikonal limit. In this work, we demonstrate that small x distributions can be formulated in terms of transverse gauge links. This allows in particular for direct and efficient decompositions of observables into subamplitudes involving gauge invariant suboperators which span parton distributions. The application to Dijet production in eA collisions will be discussed beyond the correlation limit as well as a strategy to compute finite energy corrections.

Collaboration (if applicable):

Track:

New Theoretical Developments

Contribution type:

Contributed Talk

Poster session / 149

Measurements of generalized jet angularities in pp collisions at $\sqrt{s} = 5.02$ TeV with ALICE

Author: Ezra Lesser[1]

[1] *University of California Berkeley (US)*

In recent years jet substructure observables have been used at the LHC as instruments to search for new physics as well as to test perturbative and probe non-perturbative processes in QCD. One such observable, the generalized jet angularity, is of particular interest due its infrared and collinear (IRC) safety and thus calculability from first principles. Its general form has two continuous parameters β and κ, which weight the relative jet constituent angle and p_T, respectively. These can be varied along with the jet radius R to recast the observable while maintaining IRC safety, therefore providing various configurations to systematically constrain theoretical calculations. The high-precision capability of the ALICE tracking system allows a unique opportunity at LHC energies to measure tracks with low p_T, permitting both accessibility to the softer components inside jets as well as measurement of jets with altogether lower p_T. We report the generalized jet angularities in ALICE using pp collisions at $\sqrt{s}$ = 5.02 TeV with charged particle tracks. The parameters κ = 1 and β = 1, 1.5, 2 are investigated at both large and small values of R. Results are presented and compared to theoretical models. These measurements will provide a baseline for comparison to Pb-Pb collisions, where jets are modified due to the QCD medium.

Collaboration (if applicable):

ALICE

Track:

Jets and High Momentum Hadrons

Contribution type:

Poster

Parallel / 151

Gradient Tomography of Jet Quenching in Heavy-ion Collisions

Author: Xin-Nian Wang[1]

[1] *CCNU/LBNL*

Transverse momentum broadening and energy loss of a propagating parton are dictated by the space-time profile of the jet transport coefficient $\hat{q}$ in dense QCD medium. Spatial gradient of $\hat{q}$ perpendicular to the propagation direction can lead to a drift and asymmetry in parton transverse momentum distribution. Such an asymmetry depends on both the spatial position along the transverse gradient and path length of a propagating parton as shown by numerical solutions of the Boltzmann transport in the simplified form of a drift-diffusion equation. In high-energy heavy-ion collisions, this asymmetry with respect to a plane defined by the beam and trigger particle (photon, hadron or jet) with a given orientation relative to the event plane is shown to be closely related to the transverse position of the initial jet production in full event-by-event simulations within the linear Boltzmann transport model. Such a gradient tomography can be used to localize the initial jet production position for more detailed study of jet quenching and properties of the quark-gluon plasma along a given propagation path in heavy-ion collisions.

Collaboration (if applicable):

Track:

Jets and High Momentum Hadrons

Contribution type:

Contributed Talk

Poster session / 154

Cold QCD with sPHENIX

Author: Marzia Rosati[1]

[1] *Iowa State University*

The sPHENIX detector at BNL's Relativistic Heavy Ion Collider (RHIC) will enable a spectrum of new or improved cold QCD measurements, enhancing our understanding of the initial state for nuclear collisions. sPHENIX measurements in proton-proton and proton-nucleus collisions will reveal more about how partons behave in a nuclear environment, inform our understanding of the initial state in heavy-ion collisions, and provide comparative data to investigate modification of fragmentation functions. Measurements will also take advantage of RHIC's unique capability to collide polarized protons on nuclei, which provides novel opportunities to study nuclear effects with spin observables. A potential upgrade to sPHENIX with forward instrumentation could significantly enhance these physics capabilities. The cold QCD nuclear physics program for the proposed sPHENIX midrapidity detector as well as the enhanced program enabled with forward upgrades will be presented.

Collaboration (if applicable):

sPHENIX

Track:

New Experimental Developments

Contribution type:

Contributed Talk

Parallel / 155

Heavy flavor physics with the sPHENIX MAPS vertex tracker upgrade

Author: Marzia Rosati[1]

[1] *Iowa State University*

The sPHENIX detector at BNL's Relativistic Heavy Ion Collider (RHIC) will measure a suite of unique jet and Upsilon observables with unprecedented statistics and kinematic reach at RHIC energies. A MAPS-based vertex detector upgrade to sPHENIX, the MVTX, will provide a precise determination of the impact parameter of tracks relative to the primary vertex in high multiplicity heavy ion collisions. The MVTX utilizes the latest generation of MAPS technology to provide precision tracking with high tracking efficiency over a broad momentum range in the high luminosity RHIC environment. These new capabilities will enable precision measurements of open heavy flavor observables, covering an unexplored kinematic regime at RHIC. The physics program, its potential impact, and recent detector development of the MVTX will be discussed in this talk.

Collaboration (if applicable):

sPHENIX

Track:

Heavy Flavor and Quarkonia

Contribution type:

Contributed Talk

Poster session / 156

sPHENIX capabilities for jet-based observables

Author: Marzia Rosati[1]

[1] *Iowa State University*

The sPHENIX detector at BNL's Relativistic Heavy Ion Collider (RHIC) benefits from the extensive detector advances driven by LHC and Electron-Ion Collider (EIC) detector R&D. The combination of electromagnetic calorimetry, hadronic calorimetry, precision tracking, and the ability to record data at a very high rates enables measurements of jets, jet substructure, and jet correlations at RHIC with a kinematic reach that will overlap with similar measurements at the LHC. Jet observables are a particularly useful probe of the Quark Gluon Plasma (QGP) formed in heavy-ion collisions since the hard scatted partons that fragment into final state jets are strongly "quenched", losing energy to the medium as they traverse it. To answer fundamental questions about the physics of this process, we need to characterize the medium induced modification of the jet fragmentation pattern and the correlation of the lost energy with the jet axis. The measurements require removal of the soft, underlying event (UE), and we will show the performance of different UE subtraction techniques for calorimetric jets in sPHENIX. The performance of the detector for photon-jet and jet fragmentation observables will also be shown.

Collaboration (if applicable):

sPHENIX

Track:

Jets and High Momentum Hadrons

Contribution type:

Contributed Talk

Poster session / 157

D0-tagged jets in heavy-ion collisions with ALICE at the LHC

Author: Antonio Carlos Oliveira Da Silva[1]

[1] *University of Tennessee - Knoxville*

Charm quarks are ideal probes of the Quark-Gluon Plasma (QGP). Due to their large mass they are produced in the early stages of ultra-relativistic heavy-ion collisions in hard-scattering processes.

D^0-tagged jets are valuable tools to investigate the charm interaction with the QGP. Furthermore, charmed jets can provide information to study the mass-dependent energy loss by analysing the modification of their yield in Pb−Pb collisions with respect to pp collisions as a function of the jet transverse momentum.

D^0 mesons are reconstructed through their hadronic decay channels $D^0 \rightarrow K\pi$. The large combinatorial background is rejected by applying topological selections exploiting the relatively large lifetime of D^0 mesons and the excellent particle-identification capabilities of the ALICE detector. The signal is extracted using an invariant mass analysis. Charged-track jets are reconstructed with anti-k_{T} algorithm. The ALICE detectors allow us to measure D^0-tagged jets down to low p_{T}, where the probes are more sensitive to the effects of the hot medium. In this contribution, ALICE measurements of the production and fragmentation of D^0-tagged charged jets in Pb−Pb collisions at $\sqrt{s_{\mathrm{NN}}}$ = 5.02 TeV will be presented.

Collaboration (if applicable):

ALICE

Track:

Heavy Flavor and Quarkonia

Contribution type:

Poster

Poster session / 158

Background fluctuations in jet studies in heavy ion collisions

Authors: Christine Nattrass[1]; Antonio Carlos Oliveira Da Silva[2]; Charles Hughes[1]

[1] *University of Tennessee (US)*

[2] *University of Tennessee - Knoxville*

Jets produced in high energy heavy ion collisions are quenched by the production of the quark gluon plasma. Measurements of these jets are influenced by the methods used to suppress and subtract the large, fluctuating background and the assumptions inherent in these methods. We compare measurements of the background by the ALICE collaboration 1 to PYTHIA Angantyr simulations of Pb-Pb collisions and to a data-driven random background generator. Angantyr over-estimates the predictions for the standard deviations of the energy in random cones at an approximate level of 15%, indicating that fluctuations due to mini-jets and resonances are not negligible in Angantyr. We are able to describe the standard deviation of the energy in random cones in the background generator as a convolution of number and momentum fluctuations in agreement with the form predicted in the ALICE paper. The description works well for an azimuthally isotropic background but slightly underestimates the width of the correlations for a flow-modulated background. We derive the expected impact of flow on the background and compare to the data-driven background generator.

1 The ALICE Collaboration, JHEP 2012(3):53, March 2012.

Collaboration (if applicable):

Track:

Jets and High Momentum Hadrons

Contribution type:

Contributed Talk

Poster session / 159

Implementation of jet and jet-hadron analyses in heavy-ion collisions in Rivet

Authors: Antonio Carlos Oliveira Da Silva[1]; Christine Nattrass[2]

[1] *University of Tennessee - Knoxville*

[2] *University of Tennessee (US)*

Rivet (Robust Independent Validation of Experiment and Theory) is a valuable framework for the comparison of data and simulations. Since features required for heavy ion analyses were only recently available, there is a backlog of analyses which need to be implemented. We discuss implementation of heavy ion analyses in Rivet by undergraduates in a Course-Based Undergraduate Research Experience (CURE) in order to address this backlog. Currently, jet analyses in Rivet are restricted to simpler collision systems such as pp or electron-positron.

Complementary tools are currently being developed in order to allow Rivet to analyze jets in heavy-ion collisions. Specifically, the comparison of jet measurements made at the LHC and RHIC to energy loss and flow models is important to understanding of the Quark-Gluon Plasma (QGP). The azimuthal correlations between identified jets and associated particles (jet-hadron correlation) is one observable that can characterize the effects of energy loss of partons in the QGP through their fragmentation.

This contribution presents new Rivet tools for the jet and jet-hadron correlation analyses in heavy-ion collisions. These tools allow analyses to perform jet background subtraction and can take into account v_n contributions.

Collaboration (if applicable):

Track:

Jets and High Momentum Hadrons

Contribution type:

Contributed Talk

Parallel / 160

Probing the multi-scale dynamical interaction between heavy quarks and the QGP using JETSCAPE

Author: Gojko Vujanovic[1]

[1] *Wayne State University*

The dynamics of shower development for a jet traveling through the QGP involves a variety of scales, one of them being the mass for heavy flavors residing inside jets. Though the mass of the heavy quarks plays a subdominant role during the high virtuality portion of the jet, it does affect longitudinal drag and diffusion, stimulating additional radiation from heavy quarks 1. These emissions partially compensate the reduction in radiation from the dead cone effect. In the lower virtuality part of the shower, when the mass is comparable to the transverse momenta of the parton, scattering and radiation processes off heavy quarks are different than off light quarks. All these factors result in a different nuclear modification factor for heavy versus light flavors and thus for heavy-flavor tagged jets.

The heavy quark shower development and the fluid dynamical medium are modeled on an event by event basis using the JETSCAPE Framework [2]. We present a multi-stage calculation that explores the importance of differences between various heavy quark energy-loss mechanisms within a realistically expanding quark-gluon plasma (QGP). Inside the QGP, the highly virtual and very energetic portion of the shower is modeled using the MATTER generator, while the LBT generator models the energetic and close-to-on-shell heavy quarks'showering. Energy-momentum exchange with the medium, essential for the study of jet modification, proceeds using a weak coupling recoil approach. The JETSCAPE framework admits transitions, on the level of individual partons, from one energy-loss prescription to the other depending on the parton's energy and virtuality and the local density. This allows us to explore the effect and interplay between the different regimes of energy loss on the propagation and radiation from hard heavy quarks in a dense medium. The boundary between these stages can be extracted from a comparison with data. We will explore this boundary, via comparisons to experiment, for both charm and bottom quarks.

1 R. Abir, M. Majumder, Phys. Rev. C 94, 054902 (2016)
[2] J.H. Putschke et al., arXiv:1903.07706

Collaboration (if applicable):

JETSCAPE

Track:

Heavy Flavor and Quarkonia

Contribution type:

Contributed Talk

Parallel / 161

First Results from Hybrid Hadronization in Small and Large Systems

Author: Michael Kordell[1]

[1] *Wayne State University*

"Hybrid Hadronization"is a new Monte Carlo package to hadronize systems of partons. It smoothly combines quark recombination applicable when distances between partons in phase space are small, and string fragmentation appropriate for dilute parton systems, following the picture outlined by Han et al. [PRC 93, 045207 (2016)]. Hybrid Hadronization integrates with PYTHIA 8 and can be applied to a variety of systems from $e^+ + e^-$ to A+A collisions. It takes systems of partons and their color flow information, for example from a Monte Carlo parton shower generator, as input. In addition, if for A+A collisions a thermal background medium is provided, the package allows to sample thermal partons that contribute to hadronization. Hybrid Hadronization is available for use as a standalone code and is also part of the JETSCAPE 2.0 release.
In this presentation we review the physics concepts underlying Hybrid Hadronization and demonstrate how users can use the code with various parton shower Monte Carlos. We present calculations of multiplicities, hadron chemistry, fragmentation functions and jet shapes in $e^+ + e^-$, $p + p$ and A+A collisions when Hybrid Hadronization is combined with different parton shower Monte Carlos (PYTHIA 6, PYTHIA 8 and JETSCAPE/MATTER). We compare to calculations using pure Lund string fragmentation as well as to data from LEP, RHIC and LHC. In particular, we discuss observable effects of the recombination of shower partons with thermal partons.

Collaboration (if applicable):

JETSCAPE

Track:

Jets and High Momentum Hadrons

Contribution type:

Contributed Talk

Parallel / 162

Photon-Jet correlations in p-p and A-A collisions using the JETSCAPE framework

Author: Chathuranga Sirimanna[1]

[1] *Wayne State University*

It is now well established that jet modification is a multistage effect; hence a single model alone cannot describe all facets of jet modification. The JETSCAPE framework is a multistage framework that uses several modules to simulate different stages of jet propagation through the QGP medium. These simulations require a set of parameters to ensure a smooth transition between stages. We fine tune these parameters to successfully describe a variety of observables, such as the nuclear modification factors of leading hadrons and jets, jet shape, and jet fragmentation function.

Photons can be produced in the hard scattering or as radiation from quarks inside jets. In this work, we study photon-jet transverse momentum imbalance and azimuthal correlation for both p-p and A-A collision systems. All the photons produced in each event, including the photons from hard scattering, radiation from the parton shower, and radiation from hadronization are considered with an isolation cut to directly compare with experimental data. The simulations are conducted using the same set of tuned parameters as used for the jet analysis. No new parameters are introduced or tuned. We demonstrate a significantly improved agreement with photons from A-A collisions

compared to prior efforts. This work provides an independent, parameter free verification of the multistage evolution framework.

Collaboration (if applicable):

JETSCAPE

Track:

Electroweak Probes

Contribution type:

Contributed Talk

Parallel / 163

Constraints on jet quenching from a multi-stage energy-loss approach

Author: Amit Kumar[1]

[1] *Wayne State University*

A unified description of jet evolution through deconfined QCD matter remains one of the challenging problems in the area of heavy-ion physics. To gain a comprehensive understanding of the properties of the QGP, we need an energy-loss model that effectively captures the physics of multi-scale jet quenching and provides a simultaneous description of a wide variety of integrated and differential jet observables. In this talk, we present such a comprehensive study by performing a model-to-data comparison for leading hadrons, inclusive jets, and jet substructure observables. Within the JETSCAPE framework [1,2], an effective parton evolution is proposed which includes a high-virtuality, radiation dominated region followed by a low-virtuality, scattering dominated phase. Measurements of inclusive jet and single hadron R_{AA} set strong constraints on the phase-space available for each stage of the energy-loss. The jet-medium response is incorporated through a weakly-coupled transport description with recoil particles excited from the QCD medium. This illustrates the central role played by recoil in the description of both integrated jet observables as well as the sub-structure of the jet. We also study cone size dependence of the nuclear modification factor for jets. This serves as an excellent probe to study the detailed mechanism of the lost jet energy inside the plasma.

1 JETSCAPE Collaboration (J. H. Putschke (Wayne State U.) et al.), The JETSCAPE framework, arXiv:1903.07706 [nucl-th] (2019).
[2] JETSCAPE Collaboration (S. Cao (Wayne State U.) et al.), Multistage Monte-Carlo simulation of jet modification in a static medium, Phys. Rev. C96 (2017) no.2, 024909.

Collaboration (if applicable):

JETSCAPE

Track:

Jets and High Momentum Hadrons

Contribution type:

Contributed Talk

Poster session / 164

Improved opacity expansion for in-medium branching: transverse momentum dependent distribution

Authors: Konrad Tywoniuk[1]; Yacine Mehtar-Tani[2]; João Barata[3]

[1] *University of Bergen (NO)*

[2] *Brookhaven National Laboratory*

[3] *BNL and University of Santiago de Compostela/IGFAE*

When an energetic parton propagates in a hot QCD medium it loses energy by emitting radiation induced by the parton scattering in the medium. The emission spectrum for such processes is typically split into either a regime dominated by a single hard scattering (GLV) or by a regime dominated by multiple low momentum transfers (BDMPS-Z). Both these regimes admit a close analytic treatment. Only recently, a complete analytic (and systematic) formula was provided which allows to interpolate between these two regimes by expanding around the multiple soft scattering solution. In this talk, we present new results for the k_t differential spectrum. We show that despite the increase in complexity, the formulas are analytically tractable. We compare our approach to the plain opacity expansion and analyse in particular the convergence of the improved opacity expansion by computing the NNLO. Finally, we comment on Monte Carlo implementations for future applications to jet quenching phenomenology.

Collaboration (if applicable):

Track:

Jets and High Momentum Hadrons

Contribution type:

Contributed Talk

Parallel / 165

How many observables are necessary to constrain light parton transport properties?

Authors: Tianyu Dai[1]; Steffen A. Bass[1]; Jean-Francois Paquet[1]; Derek Teaney[2]

[1] *Duke University*

[2] *Stony Brook University*

Interactions between hard partons and the quark-gluon plasma range from frequent soft interactions to rare hard interactions. While it is reasonable that hard interactions can be described perturbatively, soft interactions likely suffer from significant non-perturbative effects. Since the effect of the soft interactions can be encoded into parton transport coefficients, these non-perturbative effects can in principle be quantified by extracting the drag and diffusion of light partons from heavy ion measurements.

In this work, we perform a proof of principle calculation to determine to what extent the drag and diffusion of light partons can be constrained from jet measurements. We implement this study in the JETSCAPE framework 1 using a hard-soft factorized parton energy loss model derived in the weakly-coupled limit [2]. We first calculate a set of jet observables using known drag and diffusion coefficients. By then applying a Bayesian analysis on these observables, we determine which observables can best constrain the light parton transport coefficients. We use this closures test to understand how adding observables, or reducing uncertainties on specific observables, can improve constraints on the parton's transport coefficients.

1 Putschke, J. H., Kauder, K., Khalaj, E., Angerami, A., Bass, S. A., Cao, S., … & Elfner, H. (2019). The JETSCAPE framework. arXiv preprint arXiv:1903.07706.
[2] Ghiglieri, J., Moore, G. D., & Teaney, D. (2016). Jet-medium interactions at NLO in a weakly-coupled quark-gluon plasma. Journal of High Energy Physics, 2016(3), 95.

Collaboration (if applicable):

Track:

Jets and High Momentum Hadrons

Contribution type:

Contributed Talk

Parallel / 167

Open heavy flavour production in heavy ion collisions

Authors: Elena Bratkovskaya[1]; Pol Gossiaux[2]; Shanshan Cao[3]; Steffen A. Bass[4]; Taesoo Song[5]; Vincenzo Greco[6]; Xin-Nian Wang[7]; Yingru Xu[4]; joerg aichelin[8]

[1] *GSI, Darmstadt*

[2] *Subatech*

[3] *Wayne State University*

[4] *Duke University*

[5] *GSI*

[6] *University of Catania*

[7] *Central China Normal University (China)) / Lawrence Berkeley Na*

[8] *Subatech/CNRS*

Heavy flavor observables provide valuable information on the properties of the hot and dense quark gluon plasma (QGP) created in ultrarelativistic nucleus-nucleus collisions. Various microscopic models have successfully described many of the observables associated with its formation. Their transport coefficients differ, however, due to different assumptions about the underlying interaction of the heavy quarks with the plasma constituents, different initial geometries and formation times, different hadronization processes, and a different time evolution of the QGP as well as by different transport equations for the heavy quarks. Recently the different groups joined efforts to investigate systematically how these assumptions influence the heavy quark properties at the end of the QGP expansion. For this purpose the same initial condition and the same model for the QGP expansion has been imposed on these models and the influence on RAA and v2 as well as the difference in box calculations has been studied. We report about these results and identify what steps are necessary to reduce the present ambiguities.

Y. Xu et al. Phys.Rev. C99 (2019) 014902
S.Cao et al. Phys.Rev. C99 (2019) 054907
T. Song et al. arXiv:2001.07951

Collaboration (if applicable):

Track:

Heavy Flavor and Quarkonia

Contribution type:

Contributed Talk

Parallel / 168

Coupled Transport Equations for Quarkonium Production in Heavy Ion Collisions

Author: Xiaojun Yao[1]

Co-authors: Steffen A. Bass [2]; Weiyao Ke [2]; Berndt Mueller [3]; Yingru Xu [2]

[1] *Massachusetts Institute of Technology*

[2] *Duke University*

[3] *Brookhaven National Laboratory*

The production of heavy quarkonium in heavy ion collisions has been used as an important probe of the quark-gluon plasma. To describe the in-medium evolution of quarkonium, one has to take into account plasma screening effects and recombination in a consistent way. Many previous studies calculate dissociation rates from QCD but use recombination models that are based on detailed balance or coalescence. Thus the implementations of dissociation and recombination are not in the same theoretical framework.

Motivated by the recent developments in applying open quantum system to study quarkonium in-medium dynamics, we construct a set of coupled transport equations of open heavy quarks and quarkonia. In our framework, both dissociation and recombination rates are calculated from QCD. The recombination process depends on real-time distributions of open heavy quarks. An important feature of our implementation of recombination is the cross-talk recombination: an excited quarkonium state that dissociates early in the evolution when the plasma is hot may recombine into the ground state shortly after the dissociation and vice versa when the temperature drops. In this talk, we will show new phenomenological results on Upsilon production based on our coupled transport equations approach, with an improved treatment of feed-down contributions in the hadronic stage. We will also discuss the importance of the cross-talk recombination in phenomenology.

Collaboration (if applicable):

Track:

Heavy Flavor and Quarkonia

Contribution type:

Contributed Talk

Poster session / 169

MPI dependence of the near- and away-side pT spectra for 5 TeV pp, p-Pb and Pb-Pb collisions with the ALICE detector at the LHC

Author: ALICE CC chairs[None]

The similarities between pp, p-A and A-A collisions have not been fully understood. One issue when comparing e.g. transverse momentum (p_{T}) distributions for different colliding systems at similar mid-rapidity multiplicity, is that selection biases and autocorrelations may play different

roles. Recently, the use of the correlation between relatively high-p_{T} tracks ($p_{\mathrm{T}}^{\mathrm{leading}} > 5$ GeV/c) and hadrons at lower momenta ($0.5 < p_{\mathrm{T}}^{\mathrm{associated}} < 5$ GeV/c) has been proposed in order to introduce a new multiplicity estimator. Based on distinct regions defined by $\Delta\phi = \phi_{\mathrm{leading}} - \phi_{\mathrm{associated}}$, the so-called transverse region, $\pi/3 < |\Delta\phi| < 2\pi/3$, can be used to build a multiplicity estimator (N_{T}) which by definition does not contain the leading and sub-leading jet peaks. In pp collisions simulated with QCD-inspired event generators like PYTHIA, N_{T} is sensitive to Multiple Partonic Interactions (MPI).

This MPI-motivated analysis has been successfully applied to ALICE $\sqrt{s} = 13$ TeV pp data; we now extend the study to bigger systems like p-Pb and Pb-Pb collisions. In this work, the p_{T} spectra in the near ($|\Delta\phi| < \pi/3$), away ($|\Delta\phi| > 2\pi/3$) and transverse regions will be presented a function of N_{T}. Results include measurements for pp, p-Pb and Pb-Pb collisions at $\sqrt{s_{\mathrm{NN}}} = 5.02$ TeV. Comparisons among the near and away side p_{T} spectra, at the same N_{T} and $\sqrt{s_{\mathrm{NN}}}$, will be shown. The role of auto-correlations and potential effects of MPI in p-Pb and Pb-Pb collisions will be discussed. Comparisons with existing QCD-inspired event generators will be shown.

Collaboration (if applicable):

ALICE

Track:

Jets and High Momentum Hadrons

Contribution type:

Contributed Talk

Parallel / 170

Prospects for new measurements using advanced silicon technologies in ALICE

Author: ALICE CC chairs[None]

A Large Ion Collider Experiment plans intensive use of silicon technologies for extensions of the experiment, beyond the currently ongoing upgrade during the Long Shutdown 2 of the LHC. For Run 4, we will discuss the plans for the installation of three new layers of the Inner Tracking system, based on wafer-sized sensors sufficiently thinned to be rolled to a cylinder. This will lead to an unprecedentedly low material budget, and consequently drastically reduced interaction probabilities and unparalleled vertexing performance. For Run 5 and beyond, we will present ideas for a next-generation heavy-ion experiment fully based on silicon sensors for tracking, time-of-flight and shower measurements. This combines the advantages of extremely low material budget, fast read-out and high resolution.

Collaboration (if applicable):

ALICE

Track:

New Experimental Developments

Contribution type:

Contributed Talk

Parallel / 171

Radial profile of heavy quarks in jets in high-energy heavy-ion collisions

Authors: Sa WANG[1]; Wei Dai[2]; Ben-Wei Zhang[1]; Enke Wang[1]

[1] *Central China Normal University*

[2] *China University of Geosciences*

Heavy flavor physics in high-energy heavy-ion collisions is a promising and active area to study the " jet quenching " effects both at the RHIC and the LHC. The recent reported D^0 meson radial profiles in jets measured by CMS collaboration provide new experimental constraints on the mechanisms of heavy flavor production in proton-proton collisions and give new insights into the in-medium interaction mechanisms of heavy quarks inside the quark-gluon plasma (QGP). In this talk, we present the first theoretical calculations of the charm and bottom radial distributions relative to the jet axis both in p+p and Pb+Pb collisions at $\sqrt{s_{NN}} = 5.02$TeV. In our work, the in-medium parton propagations are described by a Monte Carlo transport model which uses the next-to-leading order (NLO) plus parton shower (PS) event generator SHERPA as input and includes elastic (collisional) and inelastic (radiative) interaction for heavy quarks as well as light partons, the cold nuclear matter(CNM) effects are also taken into accout. Our simulated results show that, at low D^0 p_T, the radial distribution shifts to larger radius indicating a strong diffusion effect of charm quarks due to the in-medium interactions, but no significant modification observed at high D^0 p_T, which are consistent with the experimental data. In the further study, we estimate the net effect on the heavy quark diffusion from collisional and radiative mechanism, and demonstrate the p_T dependence of this diffusion effect. We find that collisional process has significant effects at low p_T, especially dominates at $0 - 5$GeV, and the radiative process has a non-zero effect even at high $p_T \sim 50$GeV. The total diffusion effect decreases with charm p_T which explains the significant modification at low D^0 meson p_T observed in experiment. As for the bottom quarks, no significant modification on their radial profile in jets is observed in A+A collisions. Actually, due to the mass effect, the in-medium diffusion effects of bottom quarks are smaller both in collisional and radiative interaction relative that of charm quarks. Our study suggests more precise measurements on the charm and bottom radial distributions in jets in heavy ion collisions to disentangle the contributions from collisional and radiaive energy loss, especially at $p_T^Q < 20$GeV.

Collaboration (if applicable):

Track:

Heavy Flavor and Quarkonia

Contribution type:

Contributed Talk

Poster session / 172

sPHENIX EMCal design, construction and test beam results

Author: Marzia Rosati[1]

[1] *Iowa State University*

The sPHENIX detector at BNL's Relativistic Heavy Ion Collider (RHIC) is designed to accurately study proton-proton, proton-nucleus, and nucleus-nucleus collision systems. The design of sPHENIX, including full azimuthal calorimeter coverage, will allow it to precisely study properties of the Quark Gluon Plasma through open heavy flavor production, jet modification, and Upsilon measurements. It will also perform a variety of cold QCD studies. Helping to enable the broad measurement capabilities of sPHENIX is the Electromagnetic Calorimeter (EMCal), which is the primary detector for identifying and measuring the energy of photons and electrons. The EMCal is constructed of scintillating fibers embedded in blocks of tungsten powder in an epoxy matrix, with the emitted

light collected with acrylic light guides and read out through Silicon Photomultipliers (SiPMs). This poster will discuss the design and construction of the EMCal as well the results from a 2018 Beam Test.

Collaboration (if applicable):

sPHENIX

Track:

New Experimental Developments

Contribution type:

Poster

Poster session / 173

sPHENIX EMCal module prototyping and production plan in China

Author: Marzia Rosati[1]

[1] *Iowa State University*

The sPHENIX detector at BNL's Relativistic Heavy Ion Collider (RHIC) will probe the strongly interacting Quark-Gluon Plasma (QGP) with jets, heavy flavor tagged jets and Upsilon production. The sPHENIX electromagnetic calorimeter (EMCal) detector is essential for these measurements. The Chinese sPHENIX EMCal Consortium includes groups from Fudan, PKU and CIAE, and the consortium is planning to build sPHENIX EMCal modules covering the pseudorapidity range ±(0.8–1.1), significantly extending the experimental acceptance and greatly enhancing the physics capability for jets and Upsilon measurements. We will show the status of the Chinese prototyping project including investigations on the quality of tungsten powder from Chinese vendors and the quality assurance procedures under development. We will also report on the status of our development of a machine to precisely place scintillating fibers automatically.

Collaboration (if applicable):

Track:

New Experimental Developments

Contribution type:

Poster

Poster session / 176

sPHENIX capabilities for measuring Λc_cc production in Au+Au collisions

Author: Marzia Rosati[1]

[1] *Iowa State University*

A strong enhancement of Λ_c/D⁰ ratio compared to the fragmentation baseline is observed in Au+Au collisions at the top energy of the RHIC. This also suggests that Λ_c may be an important component for the total charm cross section. Precision measurements of charm baryons over a broad momentum range are needed for a detailed understanding of hadronization and parton energy loss mechanisms as well as to characterize QGP transport properties. sPHENIX is a planned next-generation high-rate jet, Upsilon and open heavy-flavor detector at RHIC. A state-of-the-art MAPS-based silicon detector (MVTX) is proposed to enhance heavy flavor detection capabilities greatly. We will present simulation studies of Λ_c baryon measurements in 200 GeV Au+Au collisions utilizing the full sPHENIX tracking capabilities with MVTX. The simulation method for estimating the expected signal and background will be discussed. Statistical projections of the Λ_c/D⁰ ratio will be presented.

Collaboration (if applicable):

sPHENIX

Track:

Heavy Flavor and Quarkonia

Contribution type:

Poster

Poster session / 177

The sPHENIX heavy flavor jet physics physics program

Author: Marzia Rosati[1]

[1] *Iowa State University*

Jets initiated by the fragmentation of heavy flavor quarks (HF-jet) are sensitive to collisional energy loss of the high energy parton when traversing through Quark Gluon Plasma. Using the state-of-the-art jet detector at RHIC, sPHENIX, we will perform the first HF-jet measurement at RHIC, which includes the nuclear modification and flow of b-jets, and the momentum balance in di-b-jet pairs. A variety of b-jet tagging algorithms have been developed, which select a HF-jet sample rich in tracks displaced from the primary collision point as measured by the high precision MAPS vertex tracker for sPHENIX. The detection method, physics projection and possible impacts to the field of heavy ion physics will be presented.

Collaboration (if applicable):

sPHENIX

Track:

Jets and High Momentum Hadrons

Contribution type:

Poster

Poster session / 178

The sPHENIX MAPS-based vertex detector Simulation and Tuning with Test Beam Data

Author: Marzia Rosati[1]

[1] *Iowa State University*

Recent data from RHIC and LHC show that R_{AA} and v₂ of charm hadrons are very similar to that of light and strangeness hadrons. The R_{AA} of bottom decay daughters at low p_T seems to be less suppressed than that of light and charm hadrons, suggesting a mass suppression hierarchy. Precision open bottom measurements over a broad momentum range are needed for a detailed understanding of parton energy loss mechanisms and to characterize the transport properties of the strongly-coupled QGP medium. The sPHENIX detector at BNL's Relativistic Heavy Ion Collider (RHIC) will have extensive capabilities for jet and Upsilon measurements. A fast MAPS-based silicon vertex detector (MVTX) is proposed to greatly enhance the heavy flavor detection capabilities of sPHENIX. We will present physics simulation studies on the open bottom measurements within the full sPHENIX tracking environment including the MVTX detector. Open bottom reconstruction has been explored via the inclusive non-prompt D⁰ daughters and the full exclusive reconstruction of B⁺→D⁰π⁺. Statistical projections on the nuclear modification factor and the elliptic flow measurements will be presented.

Collaboration (if applicable):

sPHENIX

Track:

Heavy Flavor and Quarkonia

Contribution type:

Poster

Poster session / 179

The sPHENIX MAPS-based vertex detector

Author: Marzia Rosati[1]

[1] *Iowa State University*

The sPHENIX detector at BNL's Relativistic Heavy Ion Collider (RHIC) will study QGP properties with heavy bottom quark jets (B-jets) produced in high-energy heavy ion collisions. B-jets are expected to offer a unique set of observables due to the large bottom quark mass, but need to be measured across an unexplored kinematic regime, particularly at low pT where the expected mass-dependence effects are large but the underlying backgrounds are also high. We will use a three-layer Monolithic-Active-Pixel-Sensor (MAPS) based vertex detector, originally developed for the ALICE ITS upgrade, to identify the signal and suppress the background. The MVTX will serve as the innermost tracking system of sPHENIX, covering 2 cm to 4 cm radially and a pseudorapidity range of $|\eta| < 1.1$. The very fine 27 μm x 29 μm pixels allow us to identify B-decay secondary vertices and B-jets in heavy ion collisions with high efficiency and high purity. In this presentation, we show the current status of R&D efforts towards custom readout and mechanical systems to integrate the MVTX detector into the sPHENIX system.

Collaboration (if applicable):

sPHENIX

Track:

New Experimental Developments

Contribution type:

Poster

Poster session / 180

sPHENIX MAPS prototype test beam results

Author: Marzia Rosati[1]

[1] *Iowa State University*

The sPHENIX MVTX detector will be a state-of-the-art monolithic active pixel (MAPS) vertex detector, used by the sPHENIX collaboration, which will allow the study of heavy flavor physics within heavy ion collisions at RHIC. The detector is at an advanced stage of testing with several test beam activities having taken place through 2019. Three test beams have been performed since 2018 to evaluate the physics readiness, the integration of the system with other detectors within sPHENIX (both using four staves, two readout boards and one front end link exchange), and the demonstration of the full readout capability of the minimal detector segment (using eight staves, eight readout boards and one front end link exchange) is expected to be complete by the end the summer of 2019. The results of these tests are being used to drive the collaboration to production-readiness in late 2019 while simultaneously evaluating the track reconstruction software that will be used within the heavy flavor environment experienced by the MVTX.

Collaboration (if applicable):

sPHENIX

Track:

New Experimental Developments

Contribution type:

Poster

Poster session / 181

Beam test results of the sPHENIX HCal prototype and Performance Characterization of Scintillator Tiles

Author: Marzia Rosati[1]

[1] *Iowa State University*

The sPHENIX detector at BNL's Relativistic Heavy Ion Collider (RHIC) will quantify the properties of quark-gluon plasma created in relativistic heavy ions collisions with a focus on the measurements of jets and Upsilon states. A crucial component to the sPHENIX detector design for jet measurements is the hadronic calorimeter (HCal) which is located outside of the solenoid magnet and composed of alternating layers of tapered steel plates and scintillator tiles. sPHENIX has performed four tests of the HCal prototypes at Fermilab since 2015 and pre-production design of the EMCal and HCal in the η~1 configuration was tested at the Fermilab Test Beam Facility as experiment T-1044 in the spring of 2018. We will present the results of 2018 HCal prototype beam test, the results of sPHENIX-like calorimeter system and corresponding GEANT4 simulations. The energy linearity and resolution of pions and electrons will also be presented.

Collaboration (if applicable):

sPHENIX

Track:

New Experimental Developments

Contribution type:

Poster

182

Streaming readout of the sPHENIX detector

Author: Marzia Rosati[1]

[1] *Iowa State University*

The sPHENIX detector at BNL's Relativistic Heavy Ion Collider (RHIC) will enable a comprehensive measurement of jets in relativistic heavy ion collisions. The detector will cover the full azimuth and a pseudorapidity range of $|\eta| < 1.1$. The tracking system will consist of a silicon detector (MVTX) based on MAPS (Monolithic Active Pixel Sensors), followed by an Intermediate Tracker (INTT), and then by a TPC. The calorimetry system consists of an electromagnetic calorimeter, and, for the first time at a RHIC experiment, a mid-rapidity hadronic calorimeter.
The calorimeter signals are sampled with silicon photomultipliers and waveform digitizing electronics. The digitized waveforms are read out with custom PCIe boards in a "classic" event-driven scheme. Conversely, the three tracking detectors are read out in streaming mode, where data are pushed from the front-end and captured continuously. Only streaming data overlapping with RHIC beam crossings that were triggered for the calorimeter readout are permanently stored.
Streaming readout is widely believed to be the readout method best suited for the detectors at a future Electron-Ion Collider. A sPHENIX TPC prototype has successfully been read out with near-final readout electronics at the Fermilab test beam in streaming mode. The analysis of the streaming data is under way. We will give an overview of the streaming readout technology and present the advantages of the technology, and highlight results from the test beam.

Collaboration (if applicable):

sPHENIX

Track:

New Experimental Developments

Contribution type:

Poster

Parallel / 183

Beyond the wake: Hydrodynamic and non-hydrodynamic response of an expanding Quark-gluon plasma to a moving energetic probe

Authors: Yi Yin[1]; Weiyao Ke[2]

[1] *Institutite of Modern Physics (Lanzhou), CAC*

[2] *Duke University/UC Berkeley/LBNL*

We study the response of a Bjorken-expanding quark-gluon plasma (QGP) to the passage of an energetic parton through it. We compute the non-equilibrium stress-energy tensor induced by such moving energetic parton using linearized Boltzmann equation under the relaxation time approximation. At large distances and large Bjorken time, the QGP exhibits hydrodynamic response, meaning the disturbance induced by the energetic parton forms a Mach cone and diffusive wake. However, the transition from hydrodynamic response to non-hydrodynamic response occurs at the intermediate distances and times. We will characterize the features of the non-hydrodynamic response due to the competition among multiple time scales of the problem: the expansion rate of the medium, the equilibration rate of the medium and the rate of energy/momentum loss of the energetic parton. Finally, we will discuss the phenomenological implication of our study.

Collaboration (if applicable):

Track:

New Theoretical Developments

Contribution type:

Contributed Talk

Poster session / 184

Testbeam Results for the sPHENIX TPC Prototype

Author: Marzia Rosati[1]

[1] *Iowa State University*

A Time Projection Chamber (TPC) will be the central tracking detector in the sPHENIX experiment. Its main task is to provide a high tracking efficiency and excellent momentum resolution for precise upsilon spectroscopy and jet measurements. The TPC will cover the full azimuth and a pseudorapidity range of up to $\pm$ 1.1.
A small scale prototype TPC with a radial extension of 40 cm and a similar drift length has been manufactured which can accommodate a full size amplification module as for the sPHENIX TPC.
The prototype has been exposed to a 120 GeV proton beam at the Fermilab Test Beam Facility (FTBF). The results of the test-beam campaigns including SAMPA readout electronics will be presented.

Collaboration (if applicable):

sPHENIX

Track:

New Experimental Developments

Contribution type:

Poster

Parallel / 185

Production of W/H+jets in Relativistic heavy-ion collisions

Authors: Shan-Liang Zhang[1]; Xin-Nian Wang[2]; Ben-Wei Zhang[1]

[1] *Central China Normal University*

[2] *Central China Normal University (China)) / Lawrence Berkeley Na*

Gauge boson associated with jet production is a perfect channel for jet quenching. Z+jet and γ+jet correlations have already been investigated by several theory models and experimental groups in both p+p and Pb-Pb collisions at $\sqrt{s} = 5.02$ TeV. However, W+jets are dominated by quark jet and H+jet are mainly gluon jet, the comparison of W+jet and H+jet would provide complementary information of jet quenching.

In the talk, we report a systematic calculation of W/H+jet production in Pb-Pb collisions at the LHC including jet quenching effects in the QGP. In the model, a nice baseline description of W+jet in p+p is achieved by utilizing Sherpa, a Monte Carlo event generator which combines the NLO with resummation by a matched parton shower (PS), and the parton energy loss in hot/dense QCD medium is simulated by Linear Boltzmann Transport(LBT) model.

We make predictions for the first time for the modifications of W/H+jet events due to jet-medium interactions: the modification of the distributions of events as a function of the vector sum of the lepton and jets $|\vec{p}_T^{Miss}|$, which is enhanced in small $|\vec{p}_T^{Miss}|$ region and suppressed in large $|\vec{p}_T^{Miss}|$ region due to jet energy loss in the opposite direction of the W boson. This observable can be easily observed in experimental and provide new information of jet quenching. While $|\vec{p}_T^{Miss}|$, is significantly broadened in PbPb collisions for H+jet event. Furthermore, we have investigated the shift of W/H+jet p_T imbalance distribution x_{jV}, the suppression of jet yield per W/H trigger R_{jV} and the modification of W/H+jet azimuthal angle correlations $\Delta\phi_{jV}$ as Z+jets, multi-jets have important contributions in small $\Delta\phi_{jV}$ and x_{jV} phase space and the differences between W/H+jet and Z+jet will be discussed. We find that, H have much less jet partners and the tagged jet has smaller energy, but they loss the same fraction of its energy. What's more, we extended the Webber hadronization model to Pb+Pb collisions, with which we can make nice descriptions on the jet profile and jet fragmentation function both in p+p and Pb+Pb collisions.

Collaboration (if applicable):

Track:

Electroweak Probes

Contribution type:

Contributed Talk

Poster session / 186

Monte Carlo Studies of Correlations between Leading Hadrons and Jets

Author: Caitie Beattie[1]

[1] *Yale University*

Renewed interest in the question of QGP formation in small systems (pp, pA) has revived investigations into whether there is jet modification associated with these collision systems. One such modification of interest is broadening of jet acoplanarity, which is attributed to jet broadening in the medium. While this broadening has not been observed in minimum bias events at the LHC, ALICE data for pp collisions at 13 TeV suggests such an effect may be present in high multiplicity pp events. This broadening cannot be considered as evidence of QGP formation, however, until other possible explanations for its observation are dismissed. A possible contributing effect relates to the spatial distribution of trigger hadrons and the extent to which they serve as proxies for their associated jets. For this purpose, and to address other potential contributing factors, studies of correlations between jets and leading hadrons using PYTHIA 8 will be presented.

Collaboration (if applicable):

Track:

Jets and High Momentum Hadrons

Contribution type:

Poster

Parallel / 187

Influence of the Multiplicity Fluctuations Distribution on Initial Conditions

Authors: Patrick Carzon[1]; Jacquelyn Noronha-Hostler[2]; Matthew Sievert[3]

[1] *University of Illinois at Urbana-Champaign*

[2] *Rutgers University*

[3] *Los Alamos National Laboratory*

One of the greatest uncertainties in heavy-ion collisions is the description of the initial state. Different models predict a wide range of initial energy density distributions based on their underlying assumptions. Final flow harmonics are sensitive to these differences in the initial state due to the nearly linear mapping between eccentricities and anisotropic flow harmonics. The Trento code uses a model-agnostic approach by phenomenologically parameterizing the initial state and constraining those parameters from a Bayesian analysis. In this framework, multiplicity fluctuations are determined by a one parameter gamma distribution. While this approach covers a broad class of initial-state models, it is not universal. Notably, initial-state models arising from the Color-Glass Condensate (CGC) framework lead to an initial energy density which is outside the functional form considered in Trento and its later Bayesian analyses. Instead, in the CGC approach the multiplicity fluctuations normally use a log-normal distribution. In this work we compare $T_A T_B$ scaling (CGC-like) to $\sqrt{T_A T_B}$ scaling (preferred from a Trento Bayesian analysis) and determine that the choice in a gamma distribution may inadvertently exclude $T_A T_B$ scaling from a Bayesian analysis.

Collaboration (if applicable):

Track:

Initial State

Contribution type:

Contributed Talk

Parallel / 188

Event-by-event jet anisotropy and hard-soft tomography in heavy-ion collisions

Authors: Xin-Nian Wang[1]; Yayun He[None]; Tan Luo[2]; LongGang Pang[3]; Shanshan Cao[4]; WEI CHEN[5]

[1] *Central China Normal University (China)) / Lawrence Berkeley Na*

[2] *IGFAE*

[3] *Lawrence Berkeley National Laboratory*

[4] *Wayne State University*

[5] *CCNU*

Jet anisotropy can provide insight into the path-length dependence of jet quenching and closely relate to the bulk anisotropy in high energy heavy-ion collisions. We show a weak dependence of colliding energy and jet p_T for inclusive jet anisotropy v_{jet}^2 at different centrality classes within the linear Boltzmann jet transport model coupled with the dynamic evolution of the QGP provided by the 3+1D CLVisc hydrodynamic model with fully fluctuating event-by-event initial conditions. By studying the hard-soft tomography, jet anisotropy follows a similar dependence on the system size as the bulk anisotropy does, and an approximately linear correlation between v_{jet}^2 and bulk v_2 is observed. In the meantime, jet triangle flow coefficient v_{jet}^3 shows a small but not vanishing value due to the initial fluctuation and jet quenching.

Collaboration (if applicable):

Track:

Jets and High Momentum Hadrons

Contribution type:

Contributed Talk

Parallel / 189

The dynamics of leading jets and the jet energy loss

Author: Felix Ringer[1]

[1] *Lawrence Berkeley National Laboratory*

In heavy-ion collisions the Quark Gluon Plasma (QGP) is recreated which is believed to have filled our universe shortly after the Big Bang. The quenching of highly energetic jets which are also produced in these collisions are powerful probes of the QGP. We propose the measurement of leading and subleading jets as a new probe of the underlying dynamics of the QGP. The dynamics of leading jets are significantly more complicated than inclusive jets but allow for a more precise use of jets as probes of the underlying parton dynamics that carry information about the QGP. In particular, leading jets allow for a definition of the so-called jet energy loss at the cross section level. The measurement of subleading jets further allows for a quantitative exploration of how the lost energy is distributed in the final state phase space. We present results for the factorization and evolution of leading and subleading jets both in proton-proton and heavy-ion collisions and outline possible measurements to better illuminate the interaction of the QGP with hard probes.

Collaboration (if applicable):

Track:

Jets and High Momentum Hadrons

Contribution type:

Contributed Talk

Parallel / 192

Probing initial and final state effects with Z bosons in PbPb and Drell-Yan in pPb with the CMS detector

Author: Serguei Petrushanko[1]

[1] *M.V. Lomonosov Moscow State University (RU)*

The differential yields of Z bosons decaying to lepton pairs are measured in PbPb collisions collected in 2018 by the CMS experiment at the LHC. The measurement uses 1.8 nb^{-1} of 5.02~TeV data. The yields in various centrality bins are compared to the HG-PYTHIA model, which indicates that geometric and selection biases could be present for peripheral events. In some cases, the uncertainties of the measurement are smaller than the modeling uncertainties of the Glauber model, showing that Z-counting could be a preferred experimental measure of effective nucleon-nucleon luminosity. Additionally, a high precision measurement of the Z boson azimuthal anisotropy (v_2) is presented. This observable provides a second method to study whether Z bosons reconstructed in the leptonic decay channel experience significant final-state modifications. This is relevant for measurements in which a high-p_T Z boson is used as a tag of a recoiling jet's p_T. The final state modification of these jets is quantified by examining the p_T imbalance of Z boson + jet pairs. A new measurement of the Drell-Yan (DY) process is also presented in pPb collision at the center of mass energy of 8.16 TeV with the CMS detector. The rapidity dependence of this process is particularly sensitive to nPDFs, but further information can be gained by studying the mass dependence of DY production, measured for the first time in pPb collisions at 8.16 TeV, down to 15 GeV. In addition, differential measurements in the dimuon p_{T} or ϕ^* (an angular variable correlated with p_{T} measured for the first time in pPb) provide insights on soft gluon emission at low p_{T}.

Collaboration (if applicable):

CMS

Track:

Electroweak Probes

Contribution type:

Contributed Talk

Parallel / 193

Fragmentation of J/ψ-jets in PbPb collisions with the CMS experiment

Author: Serguei Petrushanko[1]

[1] *M.V. Lomonosov Moscow State University (RU)*

J/ψ mesons have been found to be produced with more jet activity than predicted by models in pp collisions at the LHC. J/ψ production has long been known to be modified in nuclear collisions, via Debye screening, as well as by other effects. Indirect evidence, in particular, the non-vanishing v_2 of J/ψ at large transverse momentum, however, suggests that jet quenching may also play an important role in J/ψ suppression. We present the first measurement of reconstructed J/ψ-jets in heavy-ion collisions. We measure the jet fragmentation function of jets containing a J/ψ meson, to study the dependence of quenching effects on the degree of associated hadro-production inside the jet.

Collaboration (if applicable):

CMS

Track:

Heavy Flavor and Quarkonia

Contribution type:

Contributed Talk

Poster session / 194

Constraining nPDFs with Drell-Yan production in pPb collisions with the CMS experiment

Authors: Serguei Petrushanko[1]; Émilien Chapon[2]

[1] *M.V. Lomonosov Moscow State University (RU)*

[2] *Chinese Academy of Sciences (CN)*

Nuclear parton distribution functions (nPDFs) of quarks and antiquarks affect the production of electroweak bosons in proton-lead (pPb) collisions. In this presentation, a new measurement of the Drell-Yan (DY) process is presented in pPb collision at the center of mass energy of 8.16 TeV with the CMS detector. The rapidity dependence of this process is particularly sensitive to nPDFs, but further information can be gained by studying the mass dependence of DY production, measured for the first time in pPb collisions at 8.16 TeV, down to 15 GeV. In addition, differential measurements in the dimuon p_{T} or ϕ^* (an angular variable correlated with p_{T} measured for the first time in pPb) provide insights on soft gluon emission at low p_{T}. Comparisons to theory calculations show that these data are sensitive to the presence of nuclear modifications to the parton distributions in the lead nucleus, and can help improve and constrain theoretical calculations.

Collaboration (if applicable):

CMS

Track:

Electroweak Probes

Contribution type:

Contributed Talk

Parallel / 195

Probing QCD medium effects in pPb collisions via the multiplicity dependence of J/ψ and ψ(2S) production with the CMS experiment

Author: Serguei Petrushanko[1]

[1] *M.V. Lomonosov Moscow State University (RU)*

Evidence for collectivity and effects beyond nPDF modifications and energy loss in small systems has been observed in recent years. In high-multiplicity pPb events, J/ψ is found to show a surprisingly large long-range elliptic anisotropy signal, comparable to that for light and open-heavy flavor hadrons. In addition, results on prompt J/ψ and $\psi(2S)$ production in pPb data at 5.02 TeV exhibit a different modification of the ground and excited state, especially in the Pb-going direction, hinting to a possible breakup of the weaker bound excited states from interactions with final state particles.

To better understand the production mechanism of charmonia in small systems as well as the importance of final-state effects, the multiplicity dependence of J/ψ and $\psi(2S)$ production yields and forward-backward asymmetries in pPb collisions at 8.16 TeV using full LHC run 2 statistics have been studied, and the results will be presented in this talk.

Collaboration (if applicable):

CMS

Track:

Heavy Flavor and Quarkonia

Contribution type:

Contributed Talk

Parallel / 196

Measurements of nuclear modification factors of B_S^0 and B^+ mesons in PbPb collisions with the CMS experiment

Author: Serguei Petrushanko[1]

[1] *M.V. Lomonosov Moscow State University (RU)*

Beauty quarks are considered as one of the best probes of the strongly interacting medium created in relativistic heavy-ion collisions because they are predominantly produced via initial hard scatterings. Measurements of B meson production provide information about the diffusion of beauty quarks and the flavor dependence of in-medium energy loss. In these studies, clarifying the hadronization mechanism is crucial for understanding the transport properties of beauty quarks. Measurements of B_S^0 production can shed light on the mechanisms of beauty recombination in the medium and provide information about strangeness enhancement in the quark-gluon plasma. In this talk, we will present a new measurement of the ratio of B_S^0 to B^+ mesons in PbPb collisions at 5.02 TeV with the CMS detector, using data recorded in 2018.

Collaboration (if applicable):

CMS

Track:

Heavy Flavor and Quarkonia

Contribution type:

Contributed Talk

Parallel / 197

Evidence of X(3872) production in PbPb collisions with CMS experiment

Author: Serguei Petrushanko[1]

[1] *M.V. Lomonosov Moscow State University (RU)*

The structure of the exotic meson $\chi_{c1}(3872)$, also known as $X(3872)$, is still under debate. The similarity of the $\chi_{c1}(3872)$ mass and the $D - \bar{D}^*$ mass threshold inspired the interpretation that $\chi_{c1}(3872)$ is a $D-\bar{D}^*$ "molecule"with small binding energy. Another explanation is that this meson is a tetra-quark, consisting of a di-quark and di-antiquark. Relativistic heavy-ion collisions produce an extremely hot and strongly interacting medium, which provides a new environment in which to study the nature of multi-quark states. Because of the dramatically different radii of a $D - \bar{D}^*$ "molecule"and a tetra-quark, the interactions of these two proposed states are expected to interact differently with the medium. Therefore, the yield of $\chi_{c1}(3872)$ in heavy-ion collisions can provide insight into its structure. The ratios of production cross-section of fully reconstructed $\chi_{c1}(3872)$ over $\psi(2S)$ in PbPb collisions at a nucleon-nucleon center-of-mass energy of 5.02 TeV with the CMS detector are presented.

Collaboration (if applicable):

CMS

Track:

Heavy Flavor and Quarkonia

Contribution type:

Contributed Talk

Parallel / 198

Evidence for top quark production in nucleus-nucleus collisions with the CMS experiment

Author: Serguei Petrushanko[1]

[1] *M.V. Lomonosov Moscow State University (RU)*

Evidence for the production of top quarks in heavy ion collisions is reported in a data sample of lead-lead collisions recorded in 2018 by the CMS experiment at a nucleon-nucleon center-of-mass energy of $\sqrt{s_{\mathrm{NN}}} = 5.02$ TeV, corresponding to an integrated luminosity of $1.7 \pm 0.1\,\mathrm{nb}^{-1}$. Top quark pair (tt) production is measured in events with two opposite-sign high-p_{T} isolated leptons ($\ell^{\pm}\ell^{\mp} = \mathrm{e}^{+}\mathrm{e}^{-}$, $\mu^{+}\mu^{-}$, and $\mathrm{e}^{\pm}\mu^{\mp}$). We test the sensitivity to the tt signal process by requiring or not the additional presence of b-tagged jets, and hence the feasilibilty to identify top quark decay products irrespective of interacting with the medium (bottom quarks) or not (leptonically decaying W bosons). To that end, the inclusive cross section (σ_{tt}) is derived from likelihood fits to a multivariate discriminator, which includes different leptonic kinematic variables, with and without the b-tagged jet multiplicity information. The observed (expected) significance of the tt signal against the background-only hypothesis is 4.0 (6.0) and 3.8 (4.8) standard deviations, respectively, for the fits with and without the b-jet multiplicity input. After event reconstruction and background subtraction, the extracted cross sections are $\sigma_{\mathrm{tt}} = 2.02 \pm 0.69$ and $2.56 \pm 0.82\,\mu\mathrm{b}$, respectively, which are consistent with each other and lower than, but still compatible with, the expectations from scaled proton-proton data as well as from perturbative quantum chromodynamics predictions. This measurement constitutes the first step towards using the top quark as a novel tool for probing strongly interacting matter.

Collaboration (if applicable):

CMS

Track:

Initial State

Contribution type:

Contributed Talk

Parallel / 199

Study of quenching of b-jets with the CMS experiment

Author: Serguei Petrushanko[1]

[1] *M.V. Lomonosov Moscow State University (RU)*

Jet quenching is used to explore the detailed dynamics of QCD at high densities and temperature. In order to study the parton energy loss dependence on the flavor, we measure the b-jet nuclear modification factor with the latest recorded data-sets of pp and PbPb collisions at 5.02 TeV with CMS detector in 2017 and 2018. The higher center-of-mass energy, compared to the previous study at 2.76 TeV, allows us to access a larger range of b-jet transverse momentum. The use of the latest multi-variate b-tagging algorithms, as well as in-situ method to determine the b-jet efficiency and mistagging rate, dramatically reduce the uncertainties on the measurement. The result is unfolded to the particle level in order to facilitate the comparison to theoretical developments and other experiments. In addition to the nuclear modification to the b-jet spectra, the jet internal structure is studied via the jet shapes. We present the differential jet shape of b jets in pp collisions, as measured by the jet-track correlation method, and compare it to inclusive jet shapes and theoretical predictions.

Collaboration (if applicable):

CMS

Track:

Jets and High Momentum Hadrons

Contribution type:

Contributed Talk

Parallel / 200

Parton modification studies using electroweak-boson-tagged hadrons with pp and PbPb collisions at 5.02 TeV with the CMS experiment

Author: Serguei Petrushanko[1]

[1] *M.V. Lomonosov Moscow State University (RU)*

Electroweak bosons can be used to constrain the kinematics, as well as the flavor, of the recoiling parton, before its interaction with the quark-gluon plasma. While photons are more abundant, they suffer from larger systematic uncertainties, particularly at low transverse momentum (p_{T}), from the background photons from neutral meson decays. Tagging with Z bosons is a complementary way to study modifications of low p_{T} partons as well as the soft particles from the medium response. The talk will present studies of kinematics correlations between electoweak bosons and charged particles in pp and PbPb collisions at $\sqrt{s_{\mathrm{NN}}} = 5.02\,\mathrm{TeV}$ using data collected with the CMS detector.

Collaboration (if applicable):

CMS

Track:

Jets and High Momentum Hadrons

Contribution type:

Contributed Talk

Parallel / 201

Studies of quark-like and gluon-like contributions to jets using jet charge measurements in pp and PbPb collisions with the CMS experiment

Author: Serguei Petrushanko[1]

[1] *M.V. Lomonosov Moscow State University (RU)*

Jets can be used to study in-medium modifications of the parton shower and the energy loss mechanisms in heavy-ion collisions. Several recent works have alluded to a modification in the fractions of quark and gluon jets in QGP due to color-charge dependent quenching. The jet charge is defined as the momentum-weighted sum of charges of particles inside a jet. The sensitivity of jet charge to the electric charge of the initiating parton can be used to discriminate between jets of different origins. In this talk, the unfolded jet charge distributions are presented using data with pp and PbPb collisions at 5.02 TeV collected by the CMS experiment. A template-fitting method is presented to extract the quark-like and gluon-like jet fractions in pp and PbPb collisions using templates from simulations. We also present a jet charge based tagging technique to decompose the inclusive jet shape measurements into the respective quark-like and gluon-like jet shape distributions. These results provide crucial input towards a better understanding of the flavor-dependent medium modifications of the parton shower.

Collaboration (if applicable):

CMS

Track:

Jets and High Momentum Hadrons

Contribution type:

Contributed Talk

Parallel / 202

Measurement of jet nuclear modification factor with large radius in PbPb collisions at 5.02 TeV with the CMS experiment

Author: Serguei Petrushanko[1]

[1] *M.V. Lomonosov Moscow State University (RU)*

Partons are colored probes that interact with the quark-gluon plasma (QGP). By studying jets, the observable final state product of partons, we can improve our understanding of the interaction mechanism between partons and the QGP. Jet nuclear modification factor (RAA) is a simple yet profound observable that measures the amount of suppression with respect to a reference of proton-proton

collisions at the same nucleon-nucleon center-of-mass energy. CMS has measured, for the first time in heavy-ion collisions, the RAA for inclusive jets up to a resolution parameter of 1.0, with PbPb data collected at 5.02 TeV. The result complements well both the traditional jet observables and jet substructure observables.

Collaboration (if applicable):

CMS

Track:

Jets and High Momentum Hadrons

Contribution type:

Contributed Talk

Poster session / 204

Recent measurements of the azimuthal anisotropy of prompt D^0 mesons in PbPb collisions with the CMS detector at the LHC

Author: Serguei Petrushanko[1]

[1] *M.V. Lomonosov Moscow State University (RU)*

In PbPb collisions at the LHC, heavy-flavor (charm and bottom) quarks are predominantly produced at the initial stages of the collision via hard scattering, and they evolve with the whole system. The D^0 mesons provide insights on the heavy-quarks and details about the system at initial stages, for example, the potential effects of strong electromagnetic (EM) fields created by collision participants and spectators. In this talk, measurements of the flow harmonics (v_2 and v_3) of D^0 ($\bar{u}c$) and $\bar{D}^0$ ($u\bar{c}$) mesons are presented as functions of rapidity (y), transverse momentum, and collision centrality for PbPb collisions at 5.02 TeV, using the large data samples collected by the CMS experiment during the LHC Run 2. The wide rapidity coverage ($|y| < 2$) of these new charm mesons measurements allow for a better understanding of the 3-dimensional evolution of the medium formed in heavy-ion collisions. To search for possible effects from strong EM fields created in PbPb collisions, measurements of Δv_2 between D^0 and $\bar{D}^0$ are presented as functions of rapidity. Finally, based on the scalar product method, a four-particle cumulant technique is employed to measure D^0 v_2 for the first time in PbPb collisions. These results strengthen the evidence of collective phenomena in large hadronic collision systems.

Collaboration (if applicable):

CMS

Track:

Heavy Flavor and Quarkonia

Contribution type:

Contributed Talk

Parallel / 205

New opportunities in heavy ion physics at HL-LHC with a MIP Timing Detector at the CMS experiment

Author: Serguei Petrushanko[1]

[1] *M.V. Lomonosov Moscow State University (RU)*

The Compact Muon Solenoid (CMS) detector at the CERN Large Hadron Collider (LHC) is undergoing an extensive Phase II upgrade program to prepare for the challenging conditions of the High-Luminosity LHC (HL-LHC). A new timing layer is designed to measure minimum ionizing particles (MIPs) with a time resolution of ˜30 ps and hermetic coverage up to a pseudo-rapidity of $|\eta|$=3. The precision time information from the MIP timing detector (MTD) will serve as an excellent time-of-flight detector for particle identification in QCD and heavy-ion physics. Together with the wide coverage of tracker and calorimetry, the MTD will enable a broad range of new and unique opportunities in heavy-ion physics at CMS. We present the current status and ongoing R&D of the MTD and performance of extending heavy-ion physics program at CMS with particle identification, focusing on measurements involving hard probes such as heavy flavor hadron reconstruction over wide rapidity down to a very low transverse momentum, correlations of jets and identified hadrons.

Collaboration (if applicable):

CMS

Track:

New Experimental Developments

Contribution type:

Contributed Talk

206

Azimuthal anisotropy of Upsilon states in PbPb collisions with the CMS experiment

Author: Serguei Petrushanko[1]

[1] *M.V. Lomonosov Moscow State University (RU)*

Measurement of the azimuthal anisotropy (v_2) of the hadrons in heavy-ion collisions has provided significant information on the collective behavior of the Quark-Gluon Plasma. In the case of bottomonia states, the contribution from late-stage recombination effects is smaller since the bottom quark is much heavier than the temperature scale of the QGP. In this presentation, we will review the measurement of the second order Fourier coefficient v_2 of the azimuthal flow of $\Upsilon(1S)$ and $\Upsilon(2S)$ meson in PbPb collisions at 5.02 TeV with the CMS detector.

Collaboration (if applicable):

CMS

Track:

Heavy Flavor and Quarkonia

Contribution type:

Poster

Parallel / 207

Open and hidden strangeness production study via high pT di-hadron correlations in pp and p-Pb collisions with ALICE at the LHC

Author: ALICE CC chairs[None]

Complementary to jet reconstruction, two-particle correlations in $\Delta\eta$ and $\Delta\varphi$ are used to study jets, and in particular their particle composition. While in Pb-Pb collisions this is done to characterize the quark-gluon plasma, pp and p-Pb collisions serve as a reference and are of interest on their own for their input into the understanding of particle production mechanisms. Recent ALICE results on the production of strange particles in small systems (pp and p-Pb collisions) reveal the possibility of having similar strange hadron production mechanisms in all collision systems. We study the production mechanism of hidden strangeness (ϕ meson) and open strangeness (K^0_S meson and Λ ($\bar{\Lambda}$) baryon) in jets via two-particle correlations between the strange hadrons and charged primary hadrons in pp collisions at $\sqrt{s} = 13$ TeV and p-Pb at $\sqrt{s_{NN}} = 5.02$ TeV collected with the ALICE experiment at the LHC.

In this talk, the dependence of the per-trigger yields of strange hadrons on the transverse momenta of the trigger and associated particles, as well as on the event multiplicity, will be presented on both the near-side and away-side of the h-V^0 and h-ϕ correlation functions. Moreover, the ratios of these yields to the yields extracted from the h-h correlation function will be shown. The presented results will be compared among the three hadron species. In addition, a comparison to different MC generators will be presented, which will allow us to better understand differences in the production of open strange mesons, baryons and hidden strange resonances.

Collaboration (if applicable):

ALICE

Track:

Jets and High Momentum Hadrons

Contribution type:

Contributed Talk

Poster session / 208

The NA60+ experiment: high precision measurements of hard and electromagnetic processes at CERN-SPS energies

Author: Gianluca Usai[1]

[1] *Universita e INFN, Cagliari (IT)*

The energy range covered by the CERN SPS is unique for the investigation of the region of the QCD phase diagram corresponding to finite μ_B. In this talk we will describe the studies for a new fixed target experiment, NA60+, aimed at a precision study of heavy quark and thermal dimuons in Pb-Pb collisions via an energy scan in the interval of incident beam energy 20-160 GeV/nucleon. High statistics measurements of rare processes require interaction rates of ~ 1 MHz. In addition, a large angular acceptance is required to provide a good coverage around mid-rapidity. The apparatus is designed to reach a mass resolution below 10 MeV in the low mass dimuon region and to collect a statistics ~ 100 times larger than the original NA60 experiment.
These aspects pose challenging requirements to the apparatus, that will be discussed in the talk, highlighting the original solutions and concepts that will be adopted. Muons will be measured by a spectrometer, including a toroidal magnet based on a new light-weight and general-purpose concept. The system of tracking and triggering devices, covering almost 200 m^2, will be based on GEM and RPC detectors, respectively. The system will have to cope a 50-100 kHz dimuon trigger rate, but a triggerless scheme is also under investigation to record all interactions in order to measure

simultaneously dimuons and open charm decays in an unbiased way. A silicon spectrometer placed in front of a hadron absorber provides an accurate measurement of the muon tracks, the primary interaction vertex and the secondary decay vertices. This detector will profit from the tremendous advance of monolithic active pixel sensors occurred in recent years. A new R&D will lead to a sensor suited for the operation in a high rate fixed target experiment with ideal features: spatial resolution at the micron level, data rate capability of $\sim$ 100 MHz/s and radiation tolerance exceeding $\sim 10^{14}$ n_{eq}/cm^2. The stitching technology, available in commercial CMOS imaging processes, will allow the new sensor to reach a wafer-scale area of 15x15 cm^2 or even more. This will lead to the possibility to design a practically massless tracker, with all services and connections to outer world confined to the edges of the silicon planes. The implication of the choice of MAPS will be discussed in relation to physics performance, in particular for what concerns the measurement of open cham at low energies.

Collaboration (if applicable):

OTHER (Please specify in comments field)

Track:

New Experimental Developments

Contribution type:

Contributed Talk

Parallel / 209

Resolving the spacetime structure of jets with medium

Authors: Adam Takacs[1]; Daniel Pablos[1]; Konrad Tywoniuk[2]

[1] *University of Bergen*

[2] *University of Bergen (NO)*

Away from the strictly soft and collinear limit of QCD radiation the choice of evolution scale in a parton shower algorithm is ambiguous and several options have been implemented in existing Monte Carlo event generators for proton-proton collisions 1. However, the resulting space-time evolution could result in subtle differences depending on the particular choice. In this work we quantify measurable consequences of the choice of the evolution variable and show how the implications of such a choice propagates into jet quenching observables. We develop a parton shower algorithm for a general evolution variable, that includes as special cases the virtuality, angle, transverse momentum and formation time. We study the interplay between the shower history for different evolution variables and the phase space affected by parton energy loss. In particular, we implement effects of jet quenching in the dense and dilute medium limits and highlight the role of color coherence effects [2,3]. We compare the results of the different ordering variables to existing Monte Carlo shower implementations on the parton level by analyzing primary and secondary Lund planes. Finally, we study the sensitivity of quenched jets to the choice of evolution variable by confronting our results for certain key observables, such as the inclusive jet spectrum, the (groomed) momentum sharing fraction or the jet mass, against theoretical expectations and experimental data.

References

1 T. Sjostrand, *Status and developments of event generators*,PoS LHCP2016, 007 (2016).
[2] J. Casalderrey-Solana, D. Pablos and K. Tywoniuk, *Two-gluon emission and interference in athin QCD medium: insights into jet formation*, JHEP1611, 174 (2016).
[3] Y. Mehtar-Tani and K. Tywoniuk, *Sudakov suppression of jets in QCD media*, Phys. Rev. D98, no. 5, 051501 (2018).

Collaboration (if applicable):

Track:

Jets and High Momentum Hadrons

Contribution type:

Contributed Talk

Parallel / 210

Impact of the initial glasma and electromagnetic fields on HQs

Author: Yifeng Sun[1]

Co-authors: Vincenzo Greco [2]; Salvatore Plumari [3]; Santosh Kumar Das [4]; Marco Ruggieri ; Gabriele Coci [5]

[1] *INFN-LNS*

[2] *University of Catania*

[3] *University of Catania (Italy)*

[4] *School of Physical Science, Indian Institute of Technology Goa, India*

[5] *GSI - Hemohilzzentrum für Schwerionenforschung GmbH*

Heavy quarks are excellent probes to study the initial stages of heavy ion collisions since they are generated in the early times around 0.1 fm/c together with a thermalization time that is comparable to the lifetime of the QGP phase. In this talk we want to focus on two novel aspects of the HQs dynamics related with the very early stage of their evolution (t< 0.5-1 fm/c). The first is the evolution of HQ distribution in the initial glasma fields w.r.t. the standard HQs interaction with the quark and gluon particles. The second is the impact of the initial strong magnetic field and large vorticity. From the interaction between glasma field and HQs, we find that the field can lead to an initial enhancement of RAA of charm quarks contrary to the pattern of the standard particle interaction; this furthermore leads to a larger elliptic flow v2 after the interaction with the QGP.
In the second part it will be discussed how the strong initial EM field and vorticity can lead to a large directed flow v1 of D0 and anti-D0 and a splitting that depends critically on the time evolution of the magnetic field. In particular, if the large and positive sign of v1 splitting of D mesons measured by Alice Collaboration is due to EM field, then we should expect that the lifetime of EM field at that energy is around 0.4 fm/c. Finally, we propose a study of the effects of EM field on v1 of the leptons from Z0 boson decay and its correlation to the D meson one. We will discuss how this can be exploited to probe if the large directed flow splitting of D meson is truly due to EM field, thus opening a new way to constrain the EM field.
1 Y. Sun, G. Coci, S. K. Das, S. Plumari, M. Ruggieri and V. Greco, Phys. Lett. B 798, 134933 (2019).
[2] M. Ruggieri and S. K. Das, Phys. Rev. D 98, 094024 (2018).
[3] Y. Sun, V. Greco, S. Plumari, in preparation.

Collaboration (if applicable):

Track:

Heavy Flavor and Quarkonia

Contribution type:

Contributed Talk

Poster session / 211

Λ_c production in pp collisions at $\sqrt{s} = 13$ TeV with ALICE at the LHC

Author: Luigi Dello Stritto[1]

[1] *Universita e INFN, Salerno (IT)*

Charm quarks are a powerful probe of the Quark-Gluon Plasma (QGP) formed in high-energy heavy-ion collisions. Produced in hard scattering processes on a timescale shorter than the QGP formation time, they experience the whole evolution of the medium interacting with its constituents. The measurements of charm-hadron production allow testing the mechanisms of in-medium parton energy loss. Moreover, the study of charm-baryon production in heavy-ion collisions and, in particular, the baryon-to-meson ratio, provides unique information on hadronisation mechanisms, constraining the role of coalescence and testing the predicted presence of diquark states in the medium.
Measurements of charm-baryon production in pp and p–Pb collisions are essential to establish a baseline for Pb–Pb collisions. In particular, the Λ_c/D_0 ratio is expected to be enhanced with respect to the proton-proton baseline if charm quarks hadronise via recombination with the surrounding light quarks in the QGP. In this scenario, the presence of diquark bound states in the QGP could further increase the Λ_c production. Thus, charm baryons are ideal tools to investigate unexplored aspects of the QGP. The ALICE detector is well suited to detect charm baryons down to low p_T thanks to the excellent tracking, vertexing and particle identification capabilities.

In this poster, the new ALICE results about the Λ_c in pp collisions at $\sqrt{s} = 13$ TeV will be shown. The measurement of Λ_c production at mid-rapidity ($|y| < 0.5$) as a function of charged-particle multiplicity will be discussed.

Collaboration (if applicable):

ALICE

Track:

Heavy Flavor and Quarkonia

Contribution type:

Poster

Parallel / 213

String shoving effects on jets in pp, pA and AA collisions

Author: Smita Chakraborty[1]

Co-authors: Christian Bierlich [2]; Gosta Gustafson [1]; Leif Lönnblad [2]

[1] *Lund University*

[2] *Lund University (SE)*

The collective effects in high-multiplicity proton-proton, proton-nucleon and nucleon-nucleon collisions have not yet been attributed to a common mechanism. Within the Lund string model of partons, the interaction force between strings (aka. string shoving) could be responsible for such effects. So far, this aspect has only been present for pp in the existing PYTHIA8 framework, but after the Angantyr model (arXiv: 1806.10820) was implemented, it has been possible to include such a machinery also for pA and AA.

In the previous shoving model implementation for pp (arXiv:1612.05132), only strings parallel to the beam axis were considered for calculating the interaction force. This was a special case since most

strings in events with jets do not satisfy this condition and hence, completely dismissed the chance to study possible effects on jets.

Jet observables in dijet events are excellent probes to study collision dynamics in dense systems. Interacting Lund strings will affect jet observables and suggests a new common mechanism responsible for jet modification in pA and AA. In this talk, we present our new implementation of the string shoving mechanism in PYTHIA8 which lets us study the effects on jet observables in pp, pA and AA collisions. We also present preliminary results showing the effects in hadron-jet correlation studies.

Collaboration (if applicable):

Track:

Jets and High Momentum Hadrons

Contribution type:

Contributed Talk

Parallel / 216

Probing X(3872) structure via final state interactions

Authors: Angelo Esposito[1]; Elena G. Ferreiro[2]; Luciano Maiani[3]; Antonio Polosa[4]; Carlos A. Salgado[2]

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

[2] *Universidade de Santiago de Compostela (ES)*

[3] *Sapienza Universita e INFN, Roma I (IT)*

[4] *Universita' La Sapienza, Roma - Italy*

Recently, LHCb collaboration has presented the relative production rates of promptly produced X(3872) over ψ(2S) as a function of particle multiplicity, given by the total number of charged particle tracks reconstructed in the VELO detector for the forward pseudorapidity region, $2 < \eta < 5$. This ratio is found to decrease with increasing multiplicity.

In fact, suppression of weakly-bound quarkonia states has been studied for decades in proton-nucleus collisions. Models incorporating final state effects, such as breakup via interactions with comoving hadrons, are able to describe the relative suppression of excited-over-ground quarkonium states in pA collisions.
In the case of proton-proton collisions, these final state effects can affect the quakonia production for multiplicities higher than the mean value, giving rise to a suppression that evolves with the increase of comoving particles.

We present our results for the ratio of X(3872) over ψ(2S) compared to LHCb data from proton-proton collisions. They are consistent with the interpretation of the X(3872) as being a tetraquark with a size between 1 to 2 fm and a biding energy of the order or smaller than the one of the ψ(2S). They disfavor the interpretation of the X(3872) as weakly bound hadronic molecule of large size.

We extend our study to PbPb collisions by the inclusion of recombination effects and compare our results to the available CMS data.

Collaboration (if applicable):

Track:

Heavy Flavor and Quarkonia

Contribution type:

Contributed Talk

218

Development of Si-W Calorimeter for the ALICE FoCal upgrade

Author: Shunya Chiba[None]

The LHC-ALICE experiment is considering to install a Forward Calorimeter (FoCal) during LS3 in 2025-2026 at the LHC. The FoCal is a sampling calorimeter composed of an electromagnetic calorimeter (FoCal-E) and a hadronic calorimeter (FoCal-H) covering forward pseudo-rapidity of $3.2 \leq \eta \leq 5.8$.
The FoCal-E consists of 20 alternating layers of tungsten absorber plates and two types of silicon layers, which are low granularity readout layers with silicon pad (PAD) for the measurement of photon energy and high granularity readout layers with Monolithic Active Pixel Sensors (PIXEL) to distinguish between direct photons and decay photons.
With the measurement of direct photons at forward pseudo-rapidities, we expect to clarify the gluon saturation effects and the formation of a Color Glass Condensate (CGC) at small-x~$\approx 10^{-5}$, and provide a further key to understand the early thermalization of the Quark Gluon Plasma (QGP).

We have constructed a prototype calorimeter consisting of 20 layers of tungsten and silicon pad sensors. We evaluated the performance of this prototype using positron and hadron beams at CERN PS and SPS in 2018, and compared it with the simulation results. In this poster presentation, we will present those results with the test beam, particularly focusing on the comparison between simulation and data. We will also discuss the future plan of hardware development.

Collaboration (if applicable):

ALICE

Track:

New Experimental Developments

Contribution type:

Poster

Parallel / 219

What attracts to attractors?What attracts to attractors?

Authors: Wilke Van Der Schee[1]; Urs Wiedemann[1]; Eero Aleksi Kurkela[1]; Bin Wu[1]

[1] *CERN*

Whether, how, and to what extent solutions of Bjorken-expanding systems become insensitive to aspects of their initial conditions is of importance for heavy-ion collisions. In this talk I will present attractor solutions in hydrodynamics, kinetic theory and holography, whereby we show that in hydrodynamics and kinetic theory the attractor extends to arbitrarily early times, whereas in holography the attractor solution is reached at the same timescale as the hydrodynamization timescale. Interestingly, in holography this can be intuitively understood by the presence of higher-order correlations, which are related to the initial conditions being present close to the black hole horizon in the dual gravitational theory.

Collaboration (if applicable):

Track:

Initial State

Contribution type:

Contributed Talk

Parallel / **222**

Jet suppression from small to large radius

Author: Daniel Pablos[1]

[1] *University of Bergen*

The angular dependence of jet suppression encodes key information about the process of energy and momentum hydrodynamization, and for this reason can be used to greatly improve our understanding of fundamental aspects of the jet/QGP interaction. In this work we study jet suppression from small to very large radius, for low and very high energy jets at the LHC and RHIC. We use the hybrid strong/weak coupling model for jet quenching that combines perturbative shower evolution with an effective strongly coupled description of the energy and momentum transfer from the jet into the QGP. Because of momentum conservation, the wake created by the jet enhances or depletes the amount of particles generated at the freeze-out hypersurface depending on their orientation with respect to the jet. We find that jet suppression is surprisingly independent of the anti-k_T radius R, first slightly increasing as one increases R, then at larger values of R very slowly decreasing 1. This nearly independence of jet suppression with increasing values of R arises mainly from two competing effects, namely the larger energy loss of the hard jet components, which tends to increase suppression, versus the partial recovery of the lost energy due to medium response, reducing suppression. We also find that the boosted medium from the recoiling jet reduces the amount of plasma in the direction opposite to it in the transverse plane, increasing the amount of jet suppression due to an over-subtraction effect. We show that this characteristic signature of the hydrodynamization of part of the jet energy can be quantified by selecting samples of dijet configurations with different relative pseudorapidities between the leading and the subleading jet.

1 D. Pablos, arXiv:1907.12301 - accepted by PRL

Collaboration (if applicable):

Track:

Jets and High Momentum Hadrons

Contribution type:

Contributed Talk

Parallel / **223**

Elliptic flow of electrons from heavy-flavor decays in 54.4 and 27 GeV Au+Au collisions from the STAR experiment at RHIC

Author: STAR Collaboration[None]

Measurements of heavy-flavor hadron production and elliptic flow (v_2) provide unique and indispensable information for understanding the properties of the quark-gluon plasma. Recent STAR measurements indicate that in Au+Au collisions at $\sqrt{s_{\rm NN}} = 200$ GeV D^0 mesons develop large v_2 similarly as light-favor hadrons, implying that charm quarks interact strongly with the thermalized medium at the top RHIC energy. Interestingly, at lower collision energies the electrons from heavy-flavor decays seem to exhibit much lower v_2, unlike the light-flavor hadrons. However, the precision of the previous results from STAR at $\sqrt{s_{\rm NN}}$ = 62.4 and 39 GeV did not allow for firm conclusions.

Thanks to the large data samples recorded by STAR in 2017 and 2018, we are now able to perform more precise measurements of the v_2 of electrons from heavy-flavor decays in Au+Au collisions at $\sqrt{s_{\rm NN}} = 54.4$ and 27 GeV. The collected data sample at $\sqrt{s_{\rm NN}}$ = 54.4 GeV and 27 GeV are more than 10 times larger than those at $\sqrt{s_{\rm NN}}$ = 62.4 and 39 GeV respectively, used in the previous STAR analysis. In this talk, we will present the new results from the STAR experiment on the v_2 of electrons from heavy-flavor decays, at $\sqrt{s_{\rm NN}}$ = 54.4 and 27 GeV, as a function of electron transverse momentum. We will also discuss physics implications of these results by comparing to theoretical model calculations.

Collaboration (if applicable):

STAR

Track:

Heavy Flavor and Quarkonia

Contribution type:

Contributed Talk

Parallel / 225

Measurements of electron production from heavy flavor decays in p+p and Au+Au collisions at $\sqrt{s_{\rm NN}}$ = 200 GeV with the STAR experiment

Author: STAR Collaboration[None]

Heavy quarks are predominantly produced at the early stages of relativistic heavy-ion collisions before the formation of the quark-gluon plasma (QGP) medium. Heavy quarks subsequently traverse the QGP throughout its whole evolution, and thus are suggested as excellent probes to study the properties of the QGP. Theory predicts heavy quarks lose less energy than light quarks through gluon radiation. Measurements of the production of electrons from open heavy flavor hadron decays (Heavy Flavor decayed Electron, HFE), in p+p and Au+Au collisions and the nuclear modification factor, R_{AA}, of HFE provide valuable tool to understand the interactions of heavy quarks with the QGP medium. Furthermore, measurements of the HFE R_{AA} can be combined with separate measurements of the open bottom decayed electron fraction in HFE to evaluate the R_{AA} of open bottom decayed and open charm decayed electrons and investigate the mass hierarchy of parton energy loss in the QGP.

In this talk, we will present the new results of HFE production in p+p collisions at $\sqrt{s}$ = 200 GeV from the STAR experiment with significantly improved precision compared to the previous measurements. We will also report measurements of the nuclear modification factor, R_{AA}, for HFE production in Au+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV.

Collaboration (if applicable):

STAR

Track:

Heavy Flavor and Quarkonia

Contribution type:

Contributed Talk

Parallel / **227**

Measurement of $D^{\pm}$ meson production in Au+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV with the STAR experiment

Author: STAR Collaboration[None]

Charm quarks are an excellent probe of the quark-gluon plasma created in heavy-ion collisions as they are produced at very early stages of such collisions and subsequently experience the whole evolution of the system. At STAR experiment, charm quark production can be accessed by direct topological reconstruction of open-charm hadrons thanks to an excellent track pointing resolution provided by the Heavy Flavor Tracker.

In this talk, we will present a measurement of $D^{\pm}$ meson production in Au+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV by STAR using data collected in 2014 and 2016. Supervised machine-learning techniques were used to optimize the yield extraction from the three body hadronic decay channel $D^{\pm} \rightarrow K^{\mp}\pi^{\pm}\pi^{\pm}$. The $D^{\pm}$ invariant spectra were then obtained in 0-10\%, 10-40\%, and 40-80\% central Au+Au collisions. The measured nuclear modification factor R_{AA} as a function of transverse momentum (p_T) reveals a significant suppression of high-p_T $D^{\pm}$ mesons in central and mid-central Au+Au collisions with respect to p+p collisions. The $(D^{+}+D^{-})/(D^{0}+\overline{D^{0}})$ yield ratio has also been extracted and compared to that from PYTHIA calculations.

Collaboration (if applicable):

STAR

Track:

Heavy Flavor and Quarkonia

Contribution type:

Contributed Talk

Parallel / **228**

QCD Correlations in Multiple Gluon Bremsstrahlung

Author: William Alexander Horowitz[1]

[1] *University of Cape Town (ZA)*

We compute for the first time the spectrum for emitting 1, 2, and 3 soft and collinear gluons from a hard scattering process in full QCD. This result is important because 1) all current energy loss calculations assume QED-like independent emissions of multiple gluons, which obviously misses all correlations from the non-Abelian nature of QCD, and 2) the average high-p_T parton emits ˜3 gluons as it escapes the medium. QCD correlations are therefore critical for any realistic comparison of theoretical predictions to experimental data on jets and jet substructures in heavy ion collisions.

These calculations additionally provide a benchmark for jet Monte Carlo algorithms. As part of the talk, we will give a brief overview of the spinor helicity formalism, sometimes referred to as a twistor expansion or the use of maximal helicity violating (MHV) techniques, which provide the massive simplifications necessary for performing the novel derivations.

Collaboration (if applicable):

Track:

New Theoretical Developments

Contribution type:

Contributed Talk

Parallel / 229

Production of $D_s^{\pm}$ mesons in Au+Au collisions at $\sqrt{s_{\mathrm{NN}}}$ = 200 GeV by STAR

Author: STAR Collaboration[None]

Charm quarks are excellent probes to study properties of the Quark-Gluon Plasma (QGP) created in ultra-relativistic heavy-ion collisions. In particular, measurements of the $D_s^{\pm}$ meson production can provide valuable information on the strangeness enhancement in the QGP as well as the charm quark hadronization mechanism in heavy-ion collisions. In this talk, we will present results from the STAR experiment on invariant yields of $D_s^{\pm}$ mesons as a function of transverse momentum for different centrality classes of Au+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV. The measurements utilize the data with the Heavy Flavor Tracker detector from 2014 and 2016. The ratio between strange ($D_s^{\pm}$) and non-strange (D^0) open charm mesons will also be shown, and compared to PYTHIA and model calculations. A clear enhancement relative to the PYTHIA calculation is seen in the ratio, while model calculations incorporating strangeness enhancement and charm quark coalescence hadronization can describe the observed enhancement reasonably well. These results suggest that recombination of charm quarks with equilibrated strange quarks in the QGP plays an important role in charm quark hadronization.

Collaboration (if applicable):

STAR

Track:

Heavy Flavor and Quarkonia

Contribution type:

Contributed Talk

Parallel / 230

Getting into the Swing of things in Heavy Ion Collisions

Author: Leif Lönnblad[1]

Co-authors: Christian Bierlich [1]; Smita Chakraborty [2]; Gosta Gustafson [2]

[1] *Lund University (SE)*

[2] *Lund University*

In proton-proton collisions the underlying event is rather well reproduced by general purpose event generators such as Herwig, Pythia and Sherpa. The key to this success has been the modelling of multi-parton interactions (MPI). Since long it has been recognised that the (semi-) soft partonic sub-scatterings in such a scenario cannot be treated completely independent and the concept of "colour reconnections" was introduced, where the hadronising strings in an event may be spanning partons from several different sub scatterings.

The Anganty model for generating fully hadronic exclusive final states in heavy ion collisions in Pythia8 originally did not include any collective effects. Rather it simply stacked a number nucleon-nucleon collisions from Pythia on top of each other, without allowing any crosstalk. Nevertheless Angantyr is able to reproduce fairly well general features of events in pA and AA, such as multiplicity and transverse momentum distributions of charged particles.

In this talk I will present the so-called Swing model for colour reconnectsions, which originally was developed for the Ariadne/DIPSY program. Contrary to the standard reconnection models (eg. the ones implemented for pp in Pythia), the swing is applied already on the perturbative level and will also affect jet evolution. This model is now being implemented in the Pythia8/Angantyr program where it allows for colour reconnections between partons from different nucleon-nucleon sub-collisions in pA and AA. This requires a proper treatment of the space-time structure of heavy ion collisions in general, and in particular of the jet evolution in such events. I will present preliminary preliminary results from this model with emphasis on jet-related observables.

Collaboration (if applicable):

Track:

Jets and High Momentum Hadrons

Contribution type:

Contributed Talk

Parallel / 232

J/ψ production in jets in p+p collisions at $\sqrt{s}$ = 500 GeV by STAR

Author: STAR Collaboration[None]

The suppression of J/ψ production caused by the color-screening effect in heavy-ion collisions is considered as an evidence of the creation of quark-gluon plasma. To interpret the observed suppression in heavy-ion collisions, a good understanding of its production mechanism in p+p collisions is needed. However, the production of J/ψ in hadronic collisions remains not fully understood and requires further studies. Recently, J/ψ production in jets was proposed as a useful observable to help explore the J/ψ production mechanism, and to differentiate various J/ψ production models.

In this talk, we will present the measurement of the fraction of charged jet transverse momentum (p_T) carried by the J/ψ meson, z(J/ψ) $\equiv p_T(J/\psi)/p_T(jet)$, at mid-pseudorapidity ($|\eta| < 1$) with a kinematic cut of $p_T(J/\psi)$ >5 GeV/c in p+p collisions at $\sqrt{s}$ = 500 GeV by the STAR experiment.

The comparison to model calculations and similar measurements carried out at the LHC will be presented, and its physics implications will be discussed.

Collaboration (if applicable):

STAR

Track:

Heavy Flavor and Quarkonia

Contribution type:

Contributed Talk

Parallel / 233

Cold Nuclear Matter Effects on J/ψ and Υ Productions at RHIC with the STAR Experiment

Author: STAR Collaboration[None]

Quarkonia are excellent probes for studying the properties of quark-gluon plasma formed in relativistic heavy-ion collisions at RHIC. In order to fully understand the observed suppression of quarkonium production in Au+Au collisions at $\sqrt{s_{\mathrm{NN}}}$ = 200 GeV, it is essential to understand well the cold nuclear matter (CNM) effects on the quarkonium production. Collisions of p+Au at the same energy can be used to study the CNM effects since these effects are expected to be dominant in such systems.

In this talk, we will present measurements of inclusive J/ψ and Υ cross-sections in p+p collisions and their modification in p+Au collisions (the nuclear modification factor R_{pAu}) at $\sqrt{s_{\mathrm{NN}}}$ = 200 GeV. The results are extracted from data recorded by the STAR experiment in 2015 using the di-electron decay channel of the quarkonia. Comparisons are made to results from other experiments as well as to model calculations and physics implications will also be discussed.

Collaboration (if applicable):

STAR

Track:

Heavy Flavor and Quarkonia

Contribution type:

Contributed Talk

Parallel / 234

Dependence of semi-inclusive jet and high-p_T charged particle production on event activity at high backward-rapidity in $\sqrt{s_{\mathrm{NN}}}$ = 200 GeV p+Au collisions at STAR

Author: STAR Collaboration[None]

Observations of flow-like signals in small-system collisions, pp and p/d+A, have led to a resurgence of interest and measurements, the results of which have perhaps permanently challenged the naive

picture of initial geometry and subsequent early-time dynamics for these systems. In the wake of this renewed interest, jet and high-p_{T} particle measurements in small systems are proving similarly fruitful and challenging. While no clear signal of jet quenching has been observed, inclusive measurements at both LHC and RHIC energies of p/d+A collisions show jet spectra enhancement/suppression at high Bjorken-x when binned by event activity (EA) at high backward-rapidity (the A-going direction). In this talk we present the first semi-inclusive small-system jet spectra measurements at RHIC energies. The results show significant suppression of the jet spectra normalized per trigger in high-EA relative to low-EA collisions. PYTHIA 8 simulations verify that the modification of these spectra is not the result of trivial autocorrelations. Surprisingly, these simulations do show a qualitatively similar modification and studies to understand the cause will be presented. Finally, we present charged particle correlations with EA at high backward-rapidity, which hint at energy conservation or fluctuating proton effects.

Collaboration (if applicable):

STAR

Track:

Initial State

Contribution type:

Contributed Talk

Parallel / 235

Jet substructure in p+p and p+Au collisions at $\sqrt{s_{\mathrm{NN}}}$ = 200 GeV at STAR

Author: STAR Collaboration[None]

In order to attribute the partonic energy loss within jets (jet quenching) observed in A+A collisions to the traversal of partons through the hot QCD medium, it is necessary to examine cold nuclear matter (CNM) effects on the corresponding jets. Such examination has historically been done using p+A collisions. In this talk, we present fully corrected measurements of jet substructure - with a focus on jet mass - in p+A collisions at STAR at $\sqrt{s_{\mathrm{NN}}} = 200$ GeV as a function of the event activity (EA) to increase or decrease the magnitude of CNM effects. EA is determined in backward (Au-going) rapidity ($3.3 < |\eta| < 5.0$) by the STAR Beam-Beam Counter detector to minimize auto-correlation effects of jet measurements at mid-rapidity. By differentiating the measured jets by rapidity, we explore potential Bjorken-x dependence in jets exiting the gold nucleus or proton. Finally, we compare the results in p+A collisions to fully corrected corresponding measurements in p+p collisions and current vacuum and heavy-ion Monte Carlo models to isolate these CNM effects in anticipation of an upcoming jet mass measurement in A+A collisions.

Collaboration (if applicable):

STAR

Track:

Jets and High Momentum Hadrons

Contribution type:

Contributed Talk

Parallel / 236

Evolution of jet shapes and fragmentation functions in Au+Au collisions at $\sqrt{s_{\mathrm{NN}}} = 200$ GeV with the STAR experiment at RHIC

Author: STAR Collaboration[None]

The modification of jet substructure in heavy-ion collisions compared to that in the vacuum reference is one of the main features of jet quenching. Such modification has been observed at LHC kinematics with various observables, such as jet fragmentation and jet shapes. In this talk, we report measurements of the differential jet shape and semi-inclusive jet fragmentation functions in Au+Au collisions at $\sqrt{s_{\mathrm{NN}}} = 200$ GeV with the STAR detector at RHIC.

Based on the semi-inclusive population of jets recoiling from a high-p_T trigger hadron, the fragmentation functions are constructed from the fraction of the transverse momentum of charged particles projected onto the jet axis over that of the jet. The fragmentation functions are corrected for uncorrelated background effects and instrumental effects via the Mixed-Event technique and unfolding, and the results for central and peripheral collisions will be compared. Similarly, the differential jet shape, $\rho(r)$, is defined as the average fraction of the transverse momentum contained inside an annulus with inner radius $r_a = r - \delta/2$ and outer radius $r_b = r + \delta/2$. The differential jet shapes will be measured for full (charged + neutral) jets at low p_T (10-40 GeV/c) using constituent information jet-by-jet. This kinematic range will provide a complementary measurement to the LHC to demonstrate whether there is a modification and a broadening of the jet profile at RHIC energies. The differential jet shapes will explore the dependence of modifications based on jet size (R), centrality, event-plane angle (defined by the beam direction and the vector of the impact parameter), and additionally include a comparison to baseline p+p collisions. Both jet fragmentation function and jet shape results indicate medium-induced modifications in heavy-ion collisions.

Collaboration (if applicable):

STAR

Track:

Jets and High Momentum Hadrons

Contribution type:

Contributed Talk

Parallel / 237

Measurement of fully-reconstructed inclusive jet production in Au+Au collisions at $\sqrt{s_{\mathrm{NN}}}$ = 200 GeV by the STAR experiment

Author: STAR Collaboration[None]

The STAR Collaboration at RHIC reports the measurements of both charged and fully-reconstructed inclusive jet production in central (0-10\%) and peripheral (60-80\%) Au+Au collisions at $\sqrt{s_{\mathrm{NN}}}$ = 200 GeV. The charged jet analysis utilizes a dataset corresponding to 70 $\mu\mathrm{b}^{-1}$ recorded in 2011, while the new fully-reconstructed jet analysis utilizes a dataset corresponding to 184 $\mu\mathrm{b}^{-1}$ recorded in 2014. Both datasets were recorded using a Minimum Bias trigger. Jets are reconstructed using charged-particle tracks in the Time Projection Chamber and neutral energy measured by the Barrel Electromagnetic Calorimeter with $p_{\mathrm{T}}(E_{\mathrm{T}}) > 0.2$ GeV/c (GeV). Jet reconstruction is carried out using the anti-k_{T} algorithm with resolution parameter R = 0.2, 0.3 and 0.4. The large background yield to the jet signal in heavy ion collisions is suppressed by requiring high-p_{T} leading charged or neutral radiation in accepted jet candidates. The bias imposed by this requirement is assessed, and the p_{T}-region in which this bias is negligible is identified. Charged jet and fully-reconstructed jet inclusive distributions are reported in central and peripheral Au+Au collisions for p_{T}^{jet} >10 GeV/c. Yield suppression, corresponding to medium-induced parton energy loss, is observed for central Au+Au collisions relative to both peripheral Au+Au collisions and vacuum reference. Medium-induced jet

broadening is measured using the R-dependence of yields. The results are compared to jet measurements at the LHC and theoretical calculations.

Collaboration (if applicable):

STAR

Track:

Jets and High Momentum Hadrons

Contribution type:

Contributed Talk

Parallel / 238

γ+jet and π^0+jet Measurements in Au+Au Collisions at $\sqrt{s_{\mathrm{NN}}}$ = 200 GeV with the STAR Experiment

Author: STAR Collaboration[None]

Jets recoiling from a direct photon are seen as a relatively clean probe, due to the more tightly constrained initial hard scattering kinematics compared to di-jet measurements. In this talk, we will present semi-inclusive measurements of jets recoiling from direct-photon and π^0 triggers in Au+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV, both their yield and the transverse momentum imbalance ($x_{J\gamma} = p_{T,Jet}/p_{T,\gamma}$). The dataset used has integrated luminosity 13 nb^{-1} recorded by the STAR experiment in 2014, with isolated photon and π^0 triggers with $9 < \mathrm{E}_T^{trig} < 20$ GeV and recoil jets reconstructed with the anti-k$_T$ algorithm. We report fully corrected direct-photon and π^0-triggered charged recoil jet yields for resolution parameter R=0.2 and R=0.5. A Mixed Event technique developed previously by STAR is used to correct the charged recoil jet yield for uncorrelated background, enabling recoil jet measurements over a broad $\mathrm{p}_{T,jet}$ range. The comparison between direct-photon and π^0-triggered recoil jets is of particular interest because of the access to the different underlying physics between the two cases, such as differences in parton flavor, initial parton energy, and the level of surface bias. We also discuss the radial dependence of in-medium parton energy loss at the top RHIC energy. The transverse momentum imbalance ($x_{J\gamma}$) will be presented for uncorrected full and charged jets (with R=0.4) as compared to baseline expectations. An outlook to $x_{J\gamma}$ with different constituent selections will also be shown.

Collaboration (if applicable):

STAR

Track:

Jets and High Momentum Hadrons

Contribution type:

Contributed Talk

Parallel / 240

Measurements of dielectron production in Au+Au collisions at $\sqrt{s_{\mathrm{NN}}}$ = 27 and 54.4 GeV with the STAR experiment

Author: STAR Collaboration[None]

Dielectron production is suggested as an excellent probe of the hot and dense medium created in relativistic heavy-ion collisions due to their minimal interactions with the partonic and hadronic medium. They can carry the information from the initial to the final stage of a collision. The study of the dielectron mass spectrum could help to disentangle various contributions. In the low mass region (LMR, $M_{ee} < M_{\phi}$), the mass spectra of vector mesons are modified due to their interaction with the medium which could provide an access to the chiral symmetry restoration. In the intermediate mass region (IMR, $M_{\phi} < M_{ee} < M_{J/\Psi}$), dielectrons from thermal radiation are predicted as a QGP thermometer, meanwhile the contributions from heavy quark semi-leptonic decays make the extraction of the thermal radiation contribution very challenging.

In this talk, we will present the latest dielectron spectra in Au+Au collisions at $\sqrt{s_{\mathrm{NN}}}$ = 27 and 54.4 GeV with the STAR experiment. The 1.5 B (1.3 B) minimum-bias events of Au+Au collisions at $\sqrt{s_{\mathrm{NN}}}$ = 27 (54.4) GeV taken in 2018 (2017) significantly enhance the precision of the in-medium ρ modification measurement compared to the STAR BES-I results. Lower heavy quark semi-leptonic decay contributions compared to those at top RHIC energies and the large data samples may allow the first extraction of the medium temperature with IMR dielectrons at RHIC. The physics implications of these measurements will be discussed and put into context of previous results.

Collaboration (if applicable):

STAR

Track:

Electroweak Probes

Contribution type:

Contributed Talk

Parallel / 241

Charmonia production with a density operator model

Author: Pol Gossiaux[1]

Co-authors: joerg aichelin [2]; Denys Yen Arrebato Villar [3]

[1] *Subatech*

[2] *Subatech/CNRS*

[3] *IMT Atlatique*

Quarkonia production in AA collisions has been the subject of vivid discussions since it was proposed as a signature of the quark-gluon plasma formed in these collisions. By now, it seems there is little doubt that both mechanisms of dynamical suppression and recombination are necessary in order to understand the most common observables, the nuclear modification factor RAA of J/Psi as well as its elliptic flow v2. On the level of models, there exist only a few which include these mechanisms and are able to address the comparison with experimental data. While some good agreement has been reached for the RAA, the explanation of the v2 remains problematic. Besides, some quantum features are still lacking proper implementation. From the theory side, a step in the direction of dealing with the formation of charmonia out of a large number of c and cbar quarks has been made recently 1 but still at the price of semi-classical approximations. Besides, to our knowledge, the numerical application to realistic AA collisions has not been achieved yet.

In our contribution, we present the application of a density operator model to charmonia production in AA collisions. The idea of the formalism goes back to the work of Remler, Gyulassy and Frankel [2,3] in which a general scheme connecting composite particle cross section with time-dependent density operators was derived from Von Neumann's equation in the context of deuteron production. The formalism is indeed able to deal with the dynamical coalescence of many particles towards

bound states. It inholds a unification of both the suppression and recombination processes, which is aguably an improvement of the existing models. We will present both the fundamental ingredients of the density operator formalism, its concrete implementation in EPOS-HQ and its application to RAA and v2 of J/psi at RHIC and LHC energies.

Bibliography
1. J-P Blaizot and M A Escobedo, JHEP 1806 (2018) 034
2. E.A. Remler, Annals of Physics 136 (1981) 293
3. M. Gyulassy and K. Frankel and E.A. Remler, Nuclear Physics A402 (1983) 596

Collaboration (if applicable):

Track:

Heavy Flavor and Quarkonia

Contribution type:

Contributed Talk

242

Dielectron production in Au+Au collisions at $\sqrt{s_{\mathrm{NN}}} = 54$ GeV at STAR

Author: STAR Collaboration[None]

Dielectrons are excellent probes of the Quark-Gluon Plasma (QGP) created in high-energy heavy-ion collisions. Because they can be produced at all stages of the collision system evolution and do not interact with the medium strongly, dielectrons carry the information from the initial stage to the final stage. In the low mass region (LMR, $\mathrm{M_{ee}} < \mathrm{M}_{\phi}$), the mass spectra of vector mesons will be modified by the hot and dense medium which is related to the chiral symmetry restoration in the medium. In the intermediate mass region (IMR, $\mathrm{M}_{\phi} < \mathrm{M_{ee}} < \mathrm{M}_{\mathrm{J}/\psi}$), QGP thermal radiation can be used as a QGP thermometer. However, it is complicated to measure the QGP thermal radiation because of the heavy flavor semi-leptonic decay contributions.

In this poster, we will present the dielectron production in Au+Au collisions at $\sqrt{s_{\mathrm{NN}}} = 54$ GeV at STAR. With a 10 times larger data sample than that at 62 GeV from the first phase of the STAR Beam Energy Scan (BES-I) program, in-medium ρ modification can be studied with better precision and compared to different theoretical predictions. With lower heavy flavor semi-leptonic decay contributions compared to those at RHIC top energies, QGP thermal radiation in the IMR will be discussed. Furthermore, physics implications of these measurements will be discussed.

Collaboration (if applicable):

STAR

Track:

Electroweak Probes

Contribution type:

Contributed Talk

Parallel / 243

Dipole model at Next-to-Leading Order meets HERA data

Author: Henri Hänninen[1]

Co-authors: Guillaume Beuf ; Tuomas Lappi [1]; Heikki Mäntysaari [1]

[1] *University of Jyväskylä*

Deep inelastic scattering (DIS) total cross section data at small-x as measured by the HERA experiments is well described by Balitsky-Kovchegov (BK) evolution in the leading order dipole picture [1-3]. Recently the full Next-to-Leading Order (NLO) dipole picture total cross sections have become available for DIS [4-6], and a working factorization scheme has been deviced which substracts the soft gluon divergence present at NLO [7].
We report our ongoing work in which we make the first comparisons of the NLO DIS total cross sections to HERA data. The non-perturbative initial condition to BK evolution is fixed by fitting the HERA reduced cross section data. As the NLO results for the DIS total cross section are currently available only in the massless quark limit, we also fit a light quark only cross section constructed with a parametrization of published total and heavy quark data. We find an excellent description of the HERA data. Since the full NLO BK equation is computationally expensive [8], we use a number of beyond LO prescriptions for the evolution that include most important higher order corrections enhanced by large transverse logarithms, including the recent version of the equation formulated in terms of the target rapidity [9].

[1] T. Lappi, H. Mäntysaari, Phys.Rev. D88 (2013) 114020
[2] E. Iancu, J.D. Madrigal, A.H. Mueller, G. Soyez, D.N. Triantafyllopoulos, Phys.Lett. B750 (201
[3] B. Ducloué, E. Iancu, G. Soyez, D.N. Triantafyllopoulos, arXiv:1912.09196 [hep-ph]
[4] G. Beuf, Phys.Rev. D94 (2016) no.5, 054016
[5] G. Beuf, Phys.Rev. D96 (2017) no.7, 074033
[6] H. Hänninen, T. Lappi, R. Paatelainen, arXiv:1711.08207 [hep-ph]
[7] B. Ducloué, H. Hänninen, T. Lappi, Y. Zhu, Phys.Rev. D96 (2017) no.9, 094017
[8] T. Lappi, H. Mäntysaari, Phys.Rev. D91 (2015) no.7, 074016
[9] B. Ducloué, E. Iancu, A.H. Mueller, G. Soyez, D.N. Triantafyllopoulos, JHEP 1904 (2019) 081

Collaboration (if applicable):

Track:

Initial State

Contribution type:

Contributed Talk

Parallel / 245

Low-p_T $\mu^+\mu^-$ pair production in Au+Au collisions at $\sqrt{s_{\mathrm{NN}}}$ = 200 GeV at STAR

Author: STAR Collaboration[None]

In high energy heavy-ion collisions, the strong electromagnetic (EM) fields of the nuclei can produce energetic, high-density photon fluxes, leading to photon-induced interactions. Recently, significant enhancements of e^+e^- pair and J/ψ production at very low transverse momentum (p_T) were observed by the STAR [1, 2] and ALICE [3] collaborations in peripheral hadronic A+A collisions. The excess yields exhibit a much weaker centrality dependence compared to the expectation for hadronic production, and are consistent with coherent photon-photon and photon-nucleus interactions. The measured p_T broadening for e^+e^- pairs may indicate the existence of a strong magnetic field in the

medium. Measurements with $\mu^+\mu^-$ pairs provide a complementary channel to investigate these phenomena.

In 2014 and 2016, the STAR experiment at RHIC recorded large samples of Au+Au collisions at $\sqrt{s_{\rm NN}}$ = 200 GeV with di-muon triggers utilizing the Muon Telescope Detector. In this talk, we will present invariant mass and yield distributions as a function of centrality for inclusive $\mu^+\mu^-$ pair production at \mbox{$p_T < 0.15$ GeV/c} in the mass range between 2.6 and 10 GeV/c^2. The p_T^2 distribution of the excess yields for these very low p_T $\mu^+\mu^-$ pairs will also be shown. Physics implications will be discussed together with model comparisons.

References:
1 J. Adam et al. (STAR Collaboration), Low-p_T e^+e^- Pair Production in Au + Au Collisions at $\sqrt{s_{\rm NN}}$ = 200 GeV and U + U Collisions at $\sqrt{s_{\rm NN}}$ = 193 GeV at STAR, Phys. Rev. Lett. 121, 132301 (2018).
[2] J. Adam et al. (STAR Collaboration), Observation of excess J/ψ yield at very low transverse momenta in Au + Au Collisions at $\sqrt{s_{\rm NN}}$ = 200 GeV and U + U Collisions at $\sqrt{s_{\rm NN}}$ = 193 GeV at STAR, arXiv: 1904.11658.
[3] J. Adam et al. (ALICE Collaboration), Measurement of an Excess in the Yield of J/ψ at Very Low p_T in Pb-Pb Collisions at $\sqrt{s_{\rm NN}}$ = 2.76 TeV, Phys. Rev. Lett. 116, 222301 (2016).

Collaboration (if applicable):

STAR

Track:

Electroweak Probes

Contribution type:

Contributed Talk

246

Inclusive jet measurements in p+Au collisions at $\sqrt{s_{\rm NN}}$ = 200 GeV in STAR

Author: STAR Collaboration[None]

With the observation of flow-like correlations in small system collisions (p+Pb, p+Au and d+Au) at the LHC and RHIC, the existence of quark-gluon plasma (QGP) in small systems, which was initially assumed to be absent, became an open question and has been actively investigated over recent years. High momentum partons produced at early stages of heavy ion collisions generate collimated sprays of hadrons called \textit{jets}. Jets have been well established as a hard probe for the existence and properties of the QGP. These partons lose energy when passing through the medium, forming an effect usually known as "jet quenching". While previous jet-quenching analysis in small systems using minimum bias datasets are consistent with the non-existence of the QGP, various modifications are observed when collisions are categorized based on the event activity (EA).

In this poster, we aim to present investigation on p+Au collisions at $\sqrt{s_{\rm NN}} = 200$ GeV at STAR for possible evidence of jet quenching by studying the binary-scaled inclusive jet yield. Studies involving both full (charged + neutral) and charged jets will be presented. We will also present the EA definition of collision events based on backward (Au-going direction) signals. Relevant simulation procedures will also be discussed, including simulation using the Glauber model and corresponding detector response. Progress towards the resultant nuclear modification factor $R_{\rm pAu}$, after combining with the results from the Glauber model calculation, as well as the comparison between yields in high and low EA bins, will be discussed.

Collaboration (if applicable):

STAR

Track:

Jets and High Momentum Hadrons

Contribution type:

Poster

Poster session / 247

Measuring the groomed shared momentum fraction (z_g) in Au+Au collisions at $\sqrt{s_{\mathrm{NN}}} = 200$ GeV at STAR using a semi-inclusive approach

Author: STAR Collaboration[None]

Jet quenching is one of the main signals used to investigate the properties of a strongly interacting quark-gluon plasma (QGP). Jet quenching can manifest as more than just energy loss, it can also be seen in the modification of jet substructure. This work focuses on measuring the substructure observable z_g, a byproduct of softdrop grooming, which probes the physics of the first hard splitting of a hard-scattered parton. This analysis employs a semi-inclusive approach, selecting candidate jets found within the recoil region of a high transverse momentum trigger particle. Requiring a high transverse momentum trigger object induces a surface bias on the event selection, causing selected candidate jets in the recoil region to be biased towards having a longer path length within the medium. Jets with a longer path length in the medium are expected to be more quenched and thus are good candidates to search for modification of z_g at RHIC energies. Contribution from combinatorial jets due to the large fluctuating background found in central Au+Au events is subtracted from the signal at the ensemble level, using a mixed events technique. This approach to eliminate combinatorial jet contributions differs from a past measurement of z_g at STAR that did not find any modification of z_g, which imposed a hard core requirement for jet candidates, effectively biasing the selection of jets to have a shorter path-length in the QGP medium and reducing the potential signal for modification of z_g. In this poster we will present the techniques used and the current preliminary results from the ongoing analysis at STAR.

Collaboration (if applicable):

STAR

Track:

Jets and High Momentum Hadrons

Contribution type:

Poster

Poster session / 248

Measurement of semi-inclusive jet fragmentation functions in Au+Au collisions at $\sqrt{s_{\mathrm{NN}}}$ =200 GeV in STAR

Author: STAR Collaboration[None]

Jet quenching refers to interaction of the jet shower with the QCD medium (QGP) generated in relativistic heavy ion collisions, which can have multiple phenomenological consequences: jet energy loss; modification of jet substructure; and induced acoplanarity. In this poster we report a measurement of the fragmentation of jets in central and peripheral Au+Au collisions at $\sqrt{s_{\mathrm{NN}}} = 200$ GeV by the STAR experiment at RHIC, using a semi-inclusive population of jets recoiling from a high

transverse momentum trigger hadron. The fragmentation function is constructed from the fraction of the momentum of charged particles projected onto the jet axis over that of the jet. In a previous STAR publication of the semi-inclusive charged-jet spectra, the Mixed-Event technique was used along with the semi-inclusive approach to remove the uncorrelated background contributions 1. Such techniques have proven to be an excellent tool for isolating contributions from hard-scattered partons, and are now further developed for the measurement of jet fragmentation functions. The fragmentation functions are corrected for uncorrelated background effects and instrumental effects via unfolding, and the results for central and peripheral collisions will be compared. The measurements indicate medium-induced modification of jet fragmentation in heavy ion collisions.

References:
1 STAR Collaboration, Phys. Rev. C 96 (2017) 24905.

Collaboration (if applicable):

STAR

Track:

Jets and High Momentum Hadrons

Contribution type:

Poster

Poster session / 249

Jet and Di-jet Underlying Event in p+Au collisions at $\sqrt{s_{\mathrm{NN}}}$ = 200 GeV at STAR

Author: STAR Collaboration[None]

Proton-ion collisions have been included in runs at the LHC and RHIC in addition to proton-proton and heavy ion collisions as a means of studying cold nuclear matter (CNM) effects. These asymmetric systems have yielded some unexpected trends, notably in measurements of nuclear modification factors at different centralities. Detectors at forward/backward rapidity have been used as a proxy for centrality or event activity (EA) in p+Au collisions in order to avoid auto-correlations in mid-rapidity measurements. In this poster, we show correlations of backward-rapidity (Au-going) event activity with mid-rapidity underlying event (UE) in p+Au collisions at $\sqrt{s_{\mathrm{NN}}}$ = 200 GeV measured with the STAR detector. We present UE measurements and show the trends of UE in relation to EA for high-transverse momentum (p_T) jet events vs. di-jet events. Additionally, we will study collision kinematics via observables including jet rapidity (η) and jet p_T as a means of investigating the initial hard scattering of partons in these events.

Collaboration (if applicable):

STAR

Track:

Jets and High Momentum Hadrons

Contribution type:

Poster

Parallel / 250

Revisiting heavy quark radiative energy loss in nuclei with in the high-twist approach

Authors: Xin-Nian Wang[1]; Yilun Du[2]; Yayun He[3]; Hongxi Xing[4]; Hong-shi Zong[5]

[1] *Central China Normal University (China)) / LBNL*

[2] *University of Bergen*

[3] *Central China Normal University*

[4] *South China Normal University*

[5] *Nanjing University*

We revisit the calculation of multiple parton scattering of a heavy quark in nuclei within the framework of recently improved high-twist factorization formalism, in which gauge invariance is ensured by a delicate setup of the initial partons'transverse momenta. We derive a new result for the heavy quark radiative energy loss in deeply inelastic scattering. By taking the massless limit, it is consistent with the previous calculation of light quark energy loss. But in the heavy quark case, it leads to a new correction term, which vanishes in the soft gluon radiation limit. We show numerically the significance of the new correction term in the calculation of heavy quark energy loss as compared to previous studies and with soft gluon radiation approximation.

Collaboration (if applicable):

Track:

New Theoretical Developments

Contribution type:

Contributed Talk

Parallel / 252

An extraction of jet transport coefficient in cold nuclear matter from world data

Authors: Peng Ru[1]; Zhongbo Kang[2]; Enke Wang[1]; Hongxi Xing[1]; Ben-Wei Zhang[3]

[1] *South China Normal University*

[2] *UCLA*

[3] *Central China Normal University*

Quantifying the nuclear modification due to multiple scatterings between jet and nuclear medium can provide a solid baseline for the identification of the medium fundamental property, which can be partly encoded in the nonperturbative jet transport coefficient ($\hat{q}$). In this work, we perform the first global extraction of the $\hat{q}$ for cold nuclear matter within the framework of the higher-twist expansion, which has been shown to be a successful approach to describe the nuclear effects observed in heavy ion collisions. The analysis takes into account the world data on the transverse momentum broadening in semi-inclusive eA deep inelastic scattering and in Drell-Yan dilepton and heavy quarkonium production in pA collisions, as well as the nuclear modification of the structure functions in DIS related to the coherent dynamical shadowing. The results of this work provide a quantitative evidence that the $\hat{q}$ for cold nuclear matter is a probing-scale dependent quantity similar to the standard parton distribution functions of proton, rather than a constant value usually used in heavy-ion study, which is expected to motivate a more precise understanding of the jet transport property of the quark-gluon plasma.

Collaboration (if applicable):

Track:

Jets and High Momentum Hadrons

Contribution type:

Contributed Talk

Poster session / **253**

Direct Photon and π0 Identification in Au+Au Collisions at √sNN= 200 GeV in the STAR Experiment

Author: STAR Collaboration[None]

Jets recoiling from a direct-photon have long been seen as a golden probe of the quark gluon plasma created in relativistic heavy ion collisions, due to the ability to tightly constrain the initial hard scattering kinematics. Until recently, the ability to measure this channel and the ensuing observables at RHIC were largely statistics-limited, owing to the small cross-section of direct photon production compared to, for example, the most abundant di-jet cross-section. In this poster, we will present methods for identifying direct photons and π^0, using the 13 nb^{-1} of $\sqrt{s_{NN}} = 200$ GeV Au+Au data recorded in 2014 by the STAR experiment.

Collaboration (if applicable):

STAR

Track:

Jets and High Momentum Hadrons

Contribution type:

Poster

Parallel / **254**

Microjet spectrum and intra-jet distributions in heavy-ion collisions

Authors: Konrad Tywoniuk[1]; Yacine Mehtar-Tani[2]; Daniel Pablos[3]

[1] *University of Bergen (NO)*

[2] *Brookhaven National Laboratory*

[3] *University of Bergen*

Jets in the vacuum correspond to multi-parton configurations that form predominantly via a branching process sensitive to the soft and collinear divergences of QCD. In heavy-ion collisions, energy loss processes, stimulated via interactions with the medium, affect jet observables in a profound way. On the level of Feynman diagrams this can be traced back to the difference of medium modifications imprinted in resolved and unresolved, including virtual, emissions along the cascade that is taking place inside and outside of the medium. This leads to a novel, non-linear resummation of jet energy loss through the so-called collimator function. In this talk we present new results on the combined effects of small-R resummation and energy loss to compute the R-dependent jet spectrum (called microjet spectrum) in heavy-ion collisions. We extend this analysis to the intra-jet distribution of inclusive hadrons and discuss the non-trivial role of factorization in this context. Finally, we set

up a systematic inclusion of small-angle, medium-induced radiation and discuss its role on these observables.

Collaboration (if applicable):

Track:

Jets and High Momentum Hadrons

Contribution type:

Contributed Talk

Parallel / 259

Full solution of the medium-induced radiation spectrum

Authors: Fabio Dominguez[1]; Carlota Andres[2]; Liliana Apolinario[3]

[1] *Universidade de Santiago de Compostela*

[2] *Jefferson Lab*

[3] *LIP (PT)*

New measurements of jet quenching observables at RHIC and at the LHC, such as jet substructure observables, demand an increased precision in the theory calculations describing medium-induced radiation of gluons. Closed expressions for the gluon spectrum including a full resummation of multiple scatterings have been known for the past 20 years, but have only been evaluated in specific limits either taking a few terms in an opacity expansion or by employing a gaussian approximation for the interaction potential —which misses important physical effects. We present here a new flexible method to compute the full spectrum for a realistic interaction potential, thus allowing us for the first time to properly quantify the effect of the all-order resummation of multiple scatterings. This new approach paves the way for precision phenomenological studies including multiple scattering effects such as coherence phenomena.

Collaboration (if applicable):

Track:

Jets and High Momentum Hadrons

Contribution type:

Contributed Talk

Parallel / 260

Heavy-flavour studies with a high-luminosity fixed-target experiment at the LHC

Author: Barbara Antonina Trzeciak[1]

[1] *Czech Technical University in Prague*

Extraction of the multi-TeV proton and lead LHC beams with a bent crystal or by using an internal gas target allows one to perform the most energetic fixed-target experiment ever. pp, pd and pA collisions at $\sqrt{s_{NN}} = 115$ GeV and Pbp and PbA collisions at $\sqrt{s_{NN}} = 72$ GeV can be studied with high precision and modern detection techniques over a broad rapidity range.
Using the LHCb and ALICE detectors in a fixed-target mode offers unprecedented possibilities to access heavy-flavour production in a new energy domain, half way between the SPS and nominal RHIC energies.

In this talk, we will review projection studies for quarkonium and open charm and beauty production with both detector set-ups used with various nuclear targets and the LHC lead beams.
We will also discuss prospects of novel observations, e.g. χ_C suppression measurements and new quarkonium-correlation studies.

Collaboration (if applicable):

OTHER (Please specify in comments field)

Track:

Heavy Flavor and Quarkonia

Contribution type:

Contributed Talk

Parallel / 261

Medium response from mini-jets and in-medium hadronization in relativistic heavy ion collisions

Author: Sangwook Ryu[1]

Co-authors: Scott McDonald [2]; Chun Shen [1]; Sangyong Jeon [2]; Charles Gale [2]

[1] *Wayne State University*

[2] *McGill University*

In ultra-relativistic heavy-ion collisions, partons with intermediate energy (5-10) GeV excite ripples as they travel through the Quark-Gluon Plasma (QGP).
These ripples' effect on particle production phenomenology is not very well studied.
In this work, we extend our previous work \cite{Ryu:2018ckh} and present study using a state-of-the-art hybrid framework that consists of the IP-Glasma pre-thermalization dynamics, viscous hydrodynamics (MUSIC), jet energy loss (MARTINI), and hadronic re-scatterings (UrQMD). This framework consistently handles both soft and hard physics involved in relativistic heavy ion collisions.
We consider the energy loss of mini-jets, whose energy is between 5 to 10 GeV, and their induced medium excitation.
The energy and momentum lost from the mini-jets are treated as either free-streaming wave-packets or causal diffusive perturbations of the hydrodynamic flow.
They alter the energy-stress tensor evaluated on the particlization hypersurface during the hadronization as jet induced medium response.
In addition, this approach uses a novel in-medium fragmentation where the color neutrality of a string is enforced locally.
We quantify the importance of the medium response from mini-jets propagation and their in-medium hadronization on identified particle p_T-spectra and their flow anisotropic coefficients.

S. Ryu, S. McDonald, C. Shen, S. Jeon and C. Gale,
"Effects of hadronic rescattering in mini-jet production and energy loss at the LHC"
PoS High-pT 2017, 014 (2019).
doi:10.22323/1.320.0014

Collaboration (if applicable):

Track:

Jets and High Momentum Hadrons

Contribution type:

Contributed Talk

Parallel / 264

X(3872) Transport in High-Energy Heavy-Ion Collisions

Authors: Biaogang Wu[None]; Xiaojian Du[1]; Ralf Rapp[2]

[1] *Texas A&M University, Bielefeld University*

[2] *Texas A&M University*

We investigate the in-medium kinetics of the X(3872) particle in ultrarelativistic heavy-ion collisions. Toward this end we employ our well-tested rate equation approach for charmonia to compute the time evolution of the X(3872) distribution with its two pertinent transport parameters, i.e., the equilibrium limit and inelastic reaction rate. The former is entirely determined by the X(3872)'s mass and the previously calculated charm-quark fugacity. The key new parameter is the reaction rate, believed to depend on the structure of the X(3872) particle ("large" for a DD* molecule and "small" for a diquark-antidiquark bound state). We evaluate the sensitivity of the final X(3872) abundance and pT spectra on different scenarios for its width and initial conditions. In particular, within the same transport approach, we obtain results for the X / Psi(2S) ratio as measured in experiment.

Collaboration (if applicable):

Track:

Heavy Flavor and Quarkonia

Contribution type:

Contributed Talk

Parallel / 265

Study of in-medium momentum broadening with photon-jet momentum correlations in PbPb collisions at 5.02 TeV in the CMS experiment

Author: Serguei Petrushanko[1]

[1] *M.V. Lomonosov Moscow State University (RU)*

Studies of jet energy loss and momentum broadening with photon-jet momentum and angular correlations will be presented, with PbPb data at 5.02 TeV collected by the CMS detector. Photon-jet events provide a means of probing in-medium jet energy loss with good constraints on the initial parton kinematics and flavor. Studies of momentum and angular correlations in photon-jet events can enable precision measurements of jet quenching effects, such as energy loss and momentum

broadening, which are important towards a full understanding of the underlying mechanisms of jet quenching.

Collaboration (if applicable):

CMS

Track:

Initial State

Contribution type:

Contributed Talk

Parallel / **266**

Study charm hadronization via Λ_c and D_s production in pp and PbPb collisions with the CMS experiment

Author: Serguei Petrushanko[1]

[1] *M.V. Lomonosov Moscow State University (RU)*

Because of their large mass, the interactions of heavy quarks with the quark-gluon plasma (QGP) may be different from those of light quarks and hence can provide essential inputs in understanding the QGP. With strange quark yields being enhanced in the presence of a QGP, the production of D_s^+ is expected to be enhanced if recombination plays an important role in the hadronization process. Furthermore, studies of the lightest charm baryon, Λ_c^+, can provide further information to charm quark hadronization. Models involving quark coalescence predict a large enhancement of Λ_c^+ production in PbPb collisions compared to pp collisions. The Λ_c^+ and D_s production in both pp and PbPb collisions at a nucleon-nucleon center-of-mass energy of 5.02 TeV have been measured in the CMS experiment. Results of Λ_c^+ and D_s differential cross-sections, and the ratios of these two yields over those for D^0 in pp and PbPb collisions, as well as R_{AA} for D_s and Λ_c^+, are presented.

Collaboration (if applicable):

CMS

Track:

Heavy Flavor and Quarkonia

Contribution type:

Contributed Talk

Parallel / **270**

Probing initial- and final-state effects with $\mu^+\mu^-$ pairs produced from $\gamma\gamma$ scattering in PbPb collisions at $\sqrt{s_{\mathrm{NN}}}$ = 5.02 TeV with the CMS detector

Author: Serguei Petrushanko[1]

[1] *M.V. Lomonosov Moscow State University (RU)*

The CMS Collaboration reports on new differential measurements of $\gamma\gamma \to \mu^+\mu^-$ production in PbPb collisions at $\sqrt{s_{\mathrm{NN}}}$ = 5.02~TeV, using data collected during the 2018 LHC run with an integrated luminosity of 1.6~nb^{-1}. Photon-photon interactions have been observed in hadronic heavy-ion collisions by STAR and ALTAS experiments at very low transverse momentum (p_T) regions and the measured p_T and azimuthal angular correlations of lepton pairs via $\gamma\gamma$ scattering in hadronic events exhibit significant broadening compared to that from vacuum production in ultra-peripheral events. There is still no consensus on the origin of the observed broadening, which is mainly from p_T hardening of initial scattered photons as impact parameter decreases toward central hadronic collisions or final-state electromagnetic modifications of lepton pairs in presence of a QGP medium. In this talk, the azimuthal angular correlations and mass spectra of $\mu^+\mu^-$ pairs via $\gamma\gamma$ scattering will be presented as a function of centrality and rapidity. The centrality dependence of $\gamma\gamma \to \mu^+\mu^-$ production provides key insight to the origin of observed broadening for photon-photon produced lepton pairs in hadronic collisions while rapidity dependence constrains the relative contributions from leading order and high order photon-photon interactions to measured $\mu^+\mu^-$ pairs.

Collaboration (if applicable):

CMS

Track:

Electroweak Probes

Contribution type:

Contributed Talk

Parallel / 271

Nuclear modification and exclusive photoproduction of Upsilon in pPb collisions with the CMS experiment

Author: Serguei Petrushanko[1]

[1] *M.V. Lomonosov Moscow State University (RU)*

Results of nuclear modification of Upsilon production in pPb collisions at 5.02 TeV and exclusive Upsilon photoproduction in Ultraperipheral collisions (UPC) of pPb at 8.16 TeV, are presented. The nuclear modification factors in pPb collisions are measured to quantify nuclear effects in such a small system and sequential suppression is observed among the three states following the ordering of their binding energies. Exclusive photoproduction of Upsilon states in UPC of protons and Pb using data collected by the CMS in 2016 with an integrated luminosity of 178.4 nb^{-1}, is presented. The $\Upsilon(1S)$ photoproduction cross-section is extracted in the region $|y| < 2.2$ as a function of the photon-proton centre-of-mass energies $W_{\gamma p}$, which provides valuable information of the gluon distribution at small values of parton fractional momenta x. The results are compared to other experimental results as well as various theoretical predictions.

Collaboration (if applicable):

CMS

Track:

Heavy Flavor and Quarkonia

Contribution type:

Contributed Talk

272

Light-by-light scattering and search for axion-like particles with the CMS detector

Author: Serguei Petrushanko[1]

[1] *M.V. Lomonosov Moscow State University (RU)*

The very strong electromagnetic fields found in PbPb collisions at the LHC make it effectively a photon-photon collider. Observation of the light-by-light scattering process, $\gamma\gamma \to \gamma\gamma$, in ultraperipheral PbPb collisions at a centre-of-mass energy per nucleon pair of 5.02 TeV recorded in 2018 by the CMS experiment is reported. The exclusive production of dielectrons is used as a process of similar production mechanism and experimental signature to control both the theoretical modeling and the reconstruction of low energy electromagnetic objects in the detector. Differential distributions in diphoton p_T, rapidity, mass, and acoplanarity are reported. The $m_{\gamma\gamma}$ distribution is used to set new exclusion limits on the production of pseudoscalar axion-like particles, via the $\gamma\gamma \to a \to \gamma\gamma$ process, down to 5 GeV.

Collaboration (if applicable):

CMS

Track:

Electroweak Probes

Contribution type:

Contributed Talk

Parallel / 273

Probing the gluonic intial state with inclusive dijets in pPb and exclusive dijets in ultra-peripheral PbPb collision at $\sqrt{s_{\mathrm{NN}}}$ = 5.02 TeV with the CMS experiment

Author: Serguei Petrushanko[1]

[1] *M.V. Lomonosov Moscow State University (RU)*

Dijet processes can be used in several ways to probe the nuclear initial state. Exclusive dijet photoproduction in ultra-peripheral heavy-ion collisions has recently been suggested as a probe of the gluon Wigner distribution. In particular, the angular correlation of exclusive dijets can asses the azimuthal anisotropy of the gluon distribution in the nuclear target. In this talk we present, for the first time, the measurement of the angular correlations of dijets in ultra-peripheral PbPb collisions at $\sqrt{s_{\mathrm{NN}}}$ = 5.02˜TeV with the CMS experiment. The dependence of the second harmonic of the angular distribution as a function of the vectorial sum of the leading and subleading jets will be discussed. In addition, the pseudorapidity of the inclusive dijet system in pPb collisions is a probe of the nuclear parton distribution function (nPDF) of the gluon: the recent CMS result will be presented, and its impact on nPDF models will be discussed.

Collaboration (if applicable):

CMS

Track:

Initial State

Contribution type:

Contributed Talk

Parallel / 275

DREENA framework as a multipurpose tool for QGP tomography

Author: Dusan Zigic[1]

Co-authors: Igor Salom [1]; Jussi Auvinen [1]; Marko Djordjevic [2]; Magdalena Djordjevic [1]

[1] *Institute of Physics Belgrade*

[2] *Faculty of Biology, University of Belgrade*

DREENA framework is based on our dynamical energy loss formalism, which takes into account finite size, finite temperature QCD medium consisting of dynamical (moving) partons. Both radiative and collisional energy losses are calculated under the same theoretical framework in the dynamical energy loss formalism, which is applicable to both light and heavy flavor observables. We generalized the formalism to the case of finite magnetic mass, running coupling,and towards removing widely used soft-gluon approximation. Importantly, DREENA provides a natural framework where temperature profile from any medium evolution can be straightforwardly implemented. We exploit this by implementing different state-of-the-art medium evolutions (both event-by-event hydrodynamics and kinetic transport theory) within DREENA framework.DREENA does not use free parameters, i.e. its only input is the temperature profile that comes directly from various hydrodynamics and kinetic theory models. This opens possibility to use DREENA on both light and heavy flavor to test and differentiate between different available QGP evolution models, including both large and smaller systems, making DREENA a multipurpose QGP tomography tool. Our results on these tests will be presented, which enables us to gain a better understanding of the bulk QGP medium created at RHIC and LHC. As a highlight, contrary to the existing models, which for full hydro evolution models lead to v_2 puzzle, with DREENA we surprisingly obtain a very good joint agreement between R_{AA} and v_2 data.This well known puzzle therefore appears to be a consequence of a simplified energy loss commonly used by other models–once a proper description of parton medium interactions is used, v_2 puzzle is abolished. While a widely accepted paradigm is that proper medium evolution description dominates in explaining high pt data, this result strongly suggests that proper description of parton-medium interactions is much more important.

Collaboration (if applicable):

Track:

Heavy Flavor and Quarkonia

Contribution type:

Contributed Talk

Poster session / 276

PHENIX Results on In-Medium Jet Modification Using π^0 and Direct Photon-Triggered Two-Particle Correlations

Author: Anthony Hodges[1]

[1] *Georgia State University*

nbsp;nbsp;nbsp;nbsp;nbsp;Jets in $A + A$ collisions are modified both in terms of their particle yield and that they appear broader when compared to their counterparts in $p+p$ collisions. This modification stems from the energy loss of hard-scattered partons traversing the Quark Gluon Plasma (QGP) before fragmenting into jets. Examining the jet modification allows us to study how the jet energy energy diffuses as the hard-scattered partons traverse the QGP, as well as the possible modification of the fragmentation function, $D(z)$, due to energy loss. PHENIX has made new measurements using two particle correlations to study jet modification. By spatially correlating all charged hadrons in an event to a high p_T trigger, one can observe modifications to the yield and angular distribution of the away-side jets peaking opposite the trigger particle direction. I_{AA}, the ratio of the away-side integrated yield in $A + A$ to that in $p + p$, is extracted from two-particle correlations. For direct photon triggered two-particle correlations in particular, I_{AA} provides insight into fragmentation function modification as the integrated conditional yields Y_{AA} and Y_{pp} are related to the fragmentation functions, $D_{AA}(z)$ and $D_{pp}(z)$, i.e.: $I_{AA} = \frac{Y_{AA}}{Y_{pp}} \approx \frac{D_{AA}(z)}{D_{pp}(z)}$.
nbsp;nbsp;nbsp;nbsp;nbsp;This poster will show the latest two-particle correlation results by PHENIX in $Au + Au$ collisions at $\sqrt{s_{NN}} = 200$˜GeV collisions, utilizing both the π^0 and the direct photon as the trigger species. To quantify modification of the recoil jets opposite the trigger particle, measurements of the away-side I_{AA} and Gaussian jet width σ will be shown as a function of the associate particle p_T. Additionally, a new PHENIX result, the I_{AA} as a function of the separation angle between the trigger and associate particle, $\Delta\phi$, probes modification to the fragmentation function spatially and in p_T.

Collaboration (if applicable):

PHENIX

Track:

Jets and High Momentum Hadrons

Contribution type:

Poster

Parallel / **277**

Finite Nc corrections in the Balitsky-Kovchegov equation at next-to-leading order

Author: Andrecia Ramnath[1]

Co-authors: Tuomas Lappi [2]; Heikki Mäntysaari [2]

[1] *University of Jyvaskyla*

[2] *University of Jyväskylä*

The Colour Glass Condensate effective field theory is a useful framework for studying heavy ion collisions at ultrarelativistic energies, such as those reached at the Large Hadron Collider at CERN. In this framework, we study the rapidity evolution of Wilson lines that appear explicitly in cross section expressions. The next-to-leading order BK (Balitsky-Kovchegov) equation for the 2-point Wilson line correlator involves 6-point correlators of Wilson lines. These correlators are typically calculated only in the large-Nc limit. I will present a fully analytic calculation of these correlators in the finite Nc case, using the Gaussian Truncation. We use these results to find the relative importance of finite Nc corrections to the next-to-leading order evolution equation. We show numerically that the finite Nc corrections are negligible, as expected.

Collaboration (if applicable):

Track:

Initial State

Contribution type:

Contributed Talk

Parallel / 278

Heavy flavor hadronization and hadron chemistry in heavy-ion collisions

Authors: Shanshan Cao[1]; Kai-Jia Sun[2]; Guang-You Qin[3]; Che-Ming Ko[None]

[1] *Wayne State University*

[2] *Shanghai Jiao Tong University*

[3] *Central China Normal University*

A solid hadronization model is essential for understanding hadronic observables in high-energy nuclear collisions, while still remains a challenge due to its non-perturbative nature. We have developed an advanced hadronization model for heavy quarks 1 and studied their suppression, flow and hadron chemistry in heavy-ion collisions. A complete set of both s and p-wave hadronic states are included, which naturally cover all major heavy flavor hadron states observed in the Particle Data Group, and normalize the coalescence probability of zero momentum heavy quarks with proper hadron sizes. With a strict energy-momentum conservation implemented, the boost invariance of the coalescence probability and the thermal limit of the produced hadron spectrum are guaranteed.

By combining this newly developed hadronization scheme with the state-of-the-art Langevin-hydrodynamics model 2 that incorporates both elastic and inelastic energy loss of heavy quarks inside the realistic QGP medium, we provide a good description of the nuclear modification factor and elliptic flow of D mesons, as well as the corresponding flavor hierarchy between D and B-decayed electrons. A good description of the charmed hadron chemistry – both p_{T}-integrated and differentiated $_c/D^0$ and D_s/D^0 ratios – is also obtained. Our study indicates that the in-medium size of charmed hadrons should be larger than the size in vacuum, which can be tested by hadronic model calculations. It is also found that the inclusion of the p-wave states and the radial flow of the QGP is crucial for understanding the chemical composition of charmed hadrons observed in relativistic heavy-ion collisions.

1 S. Cao, K.-J Sun, S. Liu, W.-J Xing, G.-Y. Qin and C.-M. Ko, arXiv:1911.00456.
2 S. Cao, G.-Y. Qin and S.A. Bass (2015) Phys. Rev. C92 024907 (arXiv:1505.01413)

Collaboration (if applicable):

Track:

Heavy Flavor and Quarkonia

Contribution type:

Contributed Talk

Parallel / 279

A comprehensive description of open-heavy flavour observables in heavy-ion collisions within a transport approach

Authors: Andrea Beraudo[1]; Francesco Prino[2]; Marco Monteno[3]; Marzia Nardi[4]; Arturo De Pace[4]

[1] *INFN, sezione di Torino (IT)*

[2] *Universita e INFN Torino (IT)*

[3] *INFN Torino (IT)*

[4] *INFN*

We present recent developments of the POWLANG transport model for the study of heavy-flavour (HF) production in heavy-ion collisions. In particular we focus on the results of recent/ongoing work concerning:

1. Event-shape engineering studies of D-meson distributions;
2. Full 3+1 transport simulations validated against soft-particle production data. The realistic 3+1 hydrodynamic background allows us to study the HF directed flow v_1 and the HF decay muons at forward rapidity, so far neglected in most theoretical calculations. ;
3. Medium-induced changes in the HF hadronization, accounting for 4-momentum conservation, space-momentum correlations and modification in the HF-hadrochemistry, this motivated by the experimental data on the production of D_s meson and Lambda_c baryons.

Collaboration (if applicable):

Track:

Heavy Flavor and Quarkonia

Contribution type:

Contributed Talk

281

Prediction of jet modification in both large and small systems using the Lido transport model

Authors: Wenkai Fan[1]; Steffen A. Bass[1]; Weiyao Ke[2]

[1] *Duke University*

[2] *University of California, Berkeley*

Jets are excellent probes of the properties of the quark-gluon-plasma. Understanding the evolution of jets inside the hot and dense medium requires a good understanding of the interaction between the medium and the leading parton within the jet. We use a newly developed transport model called LIDO to study this phenomenon. The model includes both large-angle scattering and diffusion processes, as well as improved treatment of parton bremsstrahlung. We conduct a Bayesian analysis of jet parameters in order to determine a high-likelihood range of parameters that is capable of describing various jet observables as well as open heavy flavor observables within a large pT and centrality range in both large and small systems.

Collaboration (if applicable):

Track:

Jets and High Momentum Hadrons

Contribution type:

Poster

282

Heavy quarkonium suppression at LHC in the intermediate temperature regime

Author: Miguel Ángel Escobedo Espinosa[1]

Co-author: Jean-Paul Blaizot

[1] *Instituto Galego de Física de Altas Enerxías*

Heavy quarkonium is one of the probes of the formation of a quark-gluon plasma in heavy-ion collisions. Recently, it has been found that its interaction with the medium can be described, in the intermediate temperature regime, by a rate equation for the singlet to octet transition combined with a Langevin equation for the octet to octet transition. Such a description can be justified from first principles using the open quantum system formalism and it can be shown that it leads to the correct thermalization of the system. In this talk, I will present an application of this model to the prediction of the suppression pattern of Upsilon(1S) at LHC and I will discuss how non-perturbative input from the lattice computation of the real part of the potential can be introduced in the model. The results that are found, using just a simple Bjorken evolution, are in qualitative agreement with experimental observations.

Collaboration (if applicable):

Track:

Heavy Flavor and Quarkonia

Contribution type:

Contributed Talk

Poster session / 283

Light-by-light scattering in ultra-peripheral Pb+Pb collisions in the ATLAS experiment

Authors: ATLAS Collaboration[None]; Lidija Zivkovic[1]

[1] *Institute of physics Belgrade (RS)*

The ultra-peripheral Pb+Pb collisions at $\sqrt{s_{\mathrm{NN}}} = 5.02$ TeV performed at the ATLAS experiment are used to study a rare light-by-light scattering process,
$\gamma\gamma \to \gamma\gamma$, allowed in Quantum Electrodynamics via a loop

diagram. The poster summarises recent light-by-light measurements conducted using a combination of 2015 and 2018 datasets recorded by the ATLAS experiment, corresponding to an integrated luminosity of 2.2 nb^{-1}. The light-by-light event candidates are required to consist of only two photons produced exclusively, each with transverse energy $E_{\mathrm{T}} > 2.5$ GeV, pseudorapidity $|\eta| < 2.4$, diphoton invariant mass $m_{\gamma\gamma} > 5$ GeV, and with diphoton transverse momentum $p_{\mathrm{T}\gamma\gamma} < 1$ GeV and acoplanarity below 0.01. The differential distributions, presented as functions of kinematic and angular variables of the final-state photons, are unfolded for detector effects. The fiducial and differential cross-sections are presented and compared with theoretical predictions. The diphoton invariant mass distribution is
used to set limits on the production of axion-like particles.

Collaboration (if applicable):

ATLAS

Track:

Initial State

Contribution type:

Poster

Poster session / 284

Neutral Pion-Hadron Correlations in Pb-Pb Collisions at $\sqrt{s_{\mathrm{NN}}} = 5.02$ TeV at the LHC with ALICE

Author: Michael Henry Oliver[1]

[1] *Yale University (US)*

A longstanding interest in the heavy-ion physics community has been the measurement of jets associated with high p_{T} photons. At leading order, these photons are produced back-to-back with a jet (usually a quark jet), with balanced transverse momentum, during the early stages of the collision. As photons do not interact strongly with the quark-gluon medium, they do not lose energy and thus hard scattering interactions producing them are not subject to a surface bias effect. As a result of these facts, high p_{T} photons provide an unbiased measurement of the transverse momentum of the recoiling jet.

Neutral pions provide the greatest experimental challenge to these ideal measurements, as their decay photons dominate the background to direct photons, and they become increasingly indistinguishable from single photons when measured at higher momenta due to the decreasing opening angle between the decay photons and the finite angular resolution of calorimeters. One solution to this problem is to take measurements with identified π^0 triggers and subtract them from identical measurements using inclusive electromagnetic trigger, after scaling for the ratio between decay photons and inclusive photons, another important measurement in this area. This analysis provides a foundation for such a project by measuring π^0-hadron correlations with high p_{T} π^0s using the ALICE Electromagnetic Calorimeter (EMCal, which also served as an event trigger) and charged particles measured with the ALICE central barrel trackers. These correlations can be analyzed with varying trigger momenta and event centralities. Additionally, the correlations are measured in separate bins of trigger angle with respect to the event plane, both in order to apply the Reaction Plane Fit method for background subtraction and in order to measure path-length dependent modification of jets.

Collaboration (if applicable):

ALICE

Track:

Jets and High Momentum Hadrons

Contribution type:

Poster

Parallel / 286

Jet quenching tests of the QCD Equation of State

Authors: Xabier Feal[1]; Carlos Albert Salgado Lopez[2]; Ricardo Vazquez[2]

[1] *BNL*

[2] *IGFAE - Universidade de Santiago de Compostela*

Jet quenching has become a fundamental tool to study
the hot QCD matter produced in heavy ion collisions. While
important theoretical and experimental advances have been made in the last two decades, the extraction of the medium properties
and the comparison with finite temperature QCD is still particularly worrisome.
In this work we show that improvements in the calculation of the medium-induced
gluon spectrum are required for a correct extraction of these parameters without temperature issues. In particular, we employ an improved numerical implementation of multiple scatterings that resums all possible terms in the opacity expansion beyond the Gaussian approximation. We find significant differences in the extracted medium parameters when comparing with two of the most used approximations in phenomenological analyses to date, the first order opacity expansion and the Gaussian approximation. We also make a first attempt to compare the extracted medium parameters with lattice results.

Collaboration (if applicable):

Track:

Jets and High Momentum Hadrons

Contribution type:

Contributed Talk

Parallel / 287

System size scan of D meson RAA and vn using PbPb, XeXe, ArAr, and OO collisions

Authors: Jacquelyn Noronha-Hostler[1]; Caio Prado[2]; Roland Katz[3]; Alexandre Alarcon Do Passo Suaide[4]

[1] *University of Illinois Urbana Champaign*

[2] *Central China Normal University (CN)*

[3] *Subatech, Nantes*

[4] *Universidade de Sao Paulo (BR)*

Experimental measurements indicate no suppression (e.g. RpPb ~ 1) but a surprisingly large D meson v2 was measured in pPb collisions. In order to understand these results we use Trento+v-USPhydro+DAB-MOD to make predictions and propose a system size scan at the LHC involving

$^{208}PbPb$, $^{129}XeXe$, $^{40}ArAr$, and ^{16}OO collisions. We find that the nuclear modification factor approaches unity as the system size is decreased, but nonetheless, in the 0–10% most central collisions v2{2} is roughly equivalent regardless of system size. These results arise from a rather non-trivial interplay between the shrinking path length and the enhancement of eccentricities in small systems at high multiplicity. Finally, we also find a surprising sensitivity of D mesons v2{2} in 0–10% at pT = 2–5 GeV to the slight deformation of 129Xe recently found at LHC.

Collaboration (if applicable):

Track:

Heavy Flavor and Quarkonia

Contribution type:

Contributed Talk

Parallel / **288**

The Forward Rapidity Upgrade for the STAR Detector

Author: STAR Collaboration[None]

The STAR Collaboration designs, constructs, and installs a suite of new detectors in the forward rapidity region (2.5<η<4) over the next two years, enabling a program of novel measurements in pp, pA, and AA collisions. This extension of STAR's kinematic reach will allow detailed studies of cold QCD physics at both very high and very low partonic momentum fraction, i.e., when the colliding quarks and gluons carry very large or very small amounts of the nucleon energy. Previous STAR efforts using the Forward Pion Detector (FPD) and Forward Meson Spectrometer (FMS) detectors have demonstrated that there are outstanding QCD physics opportunities in the forward rapidity region. To fully explore these physics opportunities, the forward upgrade 1 has detection capability for neutral pions, hadrons, photons, electrons, and jets, and adds charged-particle tracking, electromagnetic, and hadronic calorimetry to STAR's capabilities at high pseudorapidity. The upgrade will greatly expand the kinematic reach for ongoing measurements of the spin and flavor structure of the nucleon, and will enable studies of the longitudinal structure of the nuclear initial state that leads to breaking of boost invariance in heavy-ion collisions. Transport properties of the hot and dense matter formed in heavy-ion collisions will also become accessible with the new measurement capabilities at forward rapidity. Details on the planed upgrade and the scientific opportunities it will enable will be presented.

Reference:
1 The STAR Forward Calorimeter System and Forward Tracking System, https://drupal.star.bnl.gov/STAR/starnotes/public/sn06

Collaboration (if applicable):

STAR

Track:

New Experimental Developments

Contribution type:

Contributed Talk

Parallel / **289**

New PHENIX Results on Mid-Rapidity Bottom and Charm Production in Au+Au collisions at $\sqrt{s_{NN}}$= 200 GeV

Author: Gabor David[1]

[1] *Brookhaven National Laboratory*

Energy loss of quarks in the hot and dense medium has been studied for decades. Both the experimental and theoretical efforts hinted that the energy loss is quark mass dependent (the yield of heavier quarks will be less suppressed). It was found that the electrons from heavy quarks (charm, and bottom) are less or similarly suppressed compared to that of light hadrons. The mass ordering of the suppression between charm and bottom was not clear by now due to large experimental uncertainties. We have fully exploited the events recorded at PHENIX from Au+Au collisions from RHIC Year-2014 run, and with the new charm and bottom p_T spectra from p+p collisions from Year-2015 run, we can obtain the new R_{AA} for charm and bottom quarks with smaller uncertainties. We will show the latest results on the R_{AA} of electrons and unfolded hadrons from charm and bottom quarks separately, and implications on the understanding of the quark mass dependence of the energy loss.

Collaboration (if applicable):

PHENIX

Track:

Heavy Flavor and Quarkonia

Contribution type:

Contributed Talk

Poster session / 290

Heavy Quark Nuclear Modification at Forward Rapidity in Au+Au collisions at $\sqrt{s_{NN}}$= 200 GeV

Author: Gabor David[1]

[1] *Brookhaven National Laboratory*

Experimental results from RHIC and LHC show an indication of a mass ordering on the quark energy loss when crossing the hot and dense medium formed in A+A collisions. The ordering is more evident at low p_T region, where the quark mass is more relevant for the energy loss mechanisms. However, this final-state quark energy loss competes with other effects such as nuclear shadowing and initial-state energy loss which may also depend on the quark mass. This presentation is going to show the status of the analysis of charm and bottom nuclear modification (R_{AA}) in the rapidity 1.2< $|y|$ <2.2 at $\sqrt{s_{NN}}$=200 GeV. These measurements are performed by the PHENIX forward vertex detectors and muon arms using the $B \to J/\psi + X$ and muon decay channels. This rapidity region allows the exploration of different initial-state effect contributions to the heavy flavor R_{AA}.
Besides, the forward measurements have more access to the low-p_T region because of the additional boost of the non-prompt decay products from heavy flavor hadrons.

Collaboration (if applicable):

PHENIX

Track:

Initial State

Contribution type:

Contributed Talk

Poster session / 291

PHENIX measurement of the high pT direct photon production in p+A collisions and its implication to the initial state of the system

Author: Gabor David[1]

[1] *Brookhaven National Laboratory*

High transverse momentum direct photons are penetrating probes in relativistic heavy ion collisions. Once produced, they leave the collision region virtually unaffected, even if a hot, dense partonic medium was formed. This is also the reason why direct photons are immune to the suppression observed for high pT hadrons and jets in heavy ion collisions, but can probe the initial state effects. The nuclear modification factor of high pT photons has been found consistent with unity in Au+Au collisions. It is of interest whether this applies to not only for p+p and A+A but also for p+A collisions, especially the most central collisions. Comparing the centrality dependence of direct photon and hadron production in p+Au system will provide a test of the applicability of the Glauber model in such systems which has indeed been an interesting question. The talk will present the first measurement of high pT photons in this asymmetric collision system.

Collaboration (if applicable):

PHENIX

Track:

Electroweak Probes

Contribution type:

Contributed Talk

Parallel / 292

PHENIX results on nuclear modification of hadron production in small and large systems

Author: Gabor David[1]

[1] *Brookhaven National Laboratory*

The intermediate pT region is ideal for studying hadronization and the transition from soft to hard physics. Quark mass and flavor are key ingredients in hadronization as well as elucidating the details of energy loss mechanisms in the hard sector. For this reason, it is essential to study a variety of different particle species, and PHENIX is ideally-suited for many resonance decay analyses. In this talk we present spectra and nuclear modification factors of identified particles π^0, ω, K_S, K^*, and ϕ in p+Al, p+Au, d+Au, 3He+Au, Cu+Au, Au+Au, and U+U collisions. Implications for hadronization and energy loss will be discussed.

Collaboration (if applicable):

PHENIX

Track:

Jets and High Momentum Hadrons

Contribution type:

Contributed Talk

Poster session / 293

PHENIX results on quark flavor dependence of flow in Au+Au collisions

Author: Gabor David[1]

[1] *Brookhaven National Laboratory*

An outstanding puzzle in heavy ion physics is the mechanism that generates collective motion of heavy quarks (charm and bottom) in large collision systems. The measured azimuthal anisotropy coefficient v_2 of electrons from heavy quarks closely resemble those of light quarks, despite the several orders of magnitude differences in quark mass. In order to further understand the quark mass dependence of the flow, we have measure v_2 of electrons from charm and bottom quark decays separately. In contrast to the apparent heavy quark flow, attempts to measure the J/ψ, a charmonium state, have so far only yielded results consistent with zero. Consistent understanding of the results will need results with better precision as well as comparisons with models including quark recombination process. We will present v_2 vs p_T of J/ψ and of electrons originating from charm and bottom decays measured at mid-rapidity in Au+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV. Implications for the origins of collective motion of heavy quarks and quarkonia will be discussed.

Collaboration (if applicable):

PHENIX

Track:

Heavy Flavor and Quarkonia

Contribution type:

Contributed Talk

Parallel / 294

PHENIX results on J/psi from small systems

Author: Gabor David[1]

[1] *Brookhaven National Laboratory*

Charmonium is considered a valuable probe to study the medium produced in collisions involving nuclei and/or nucleons. With the recent observations of collective behavior of produced particles in small system collisions, measurements of the modification of charmonium in these systems have become increasingly relevant. In this talk we will present the PHENIX results of J/ measurements at forward and backward rapidities (1.2<|y|<2.2) in p+Al, p+Au and 3He+Au at = 200 GeV beam energy. These data complement previously published d+Au data, and comprise the most extensive study of J/ in small systems including system size, centrality, transverse momentum and rapidity dependencies. The observed modifications of J/ production depends strongly on target size but is very similar for different projectiles. This presentation will show the conclusion of this experimental effort and discuss the implication on the current understanding of charmonia interaction with nuclear media.

Collaboration (if applicable):

Track:

Initial State

Contribution type:

Contributed Talk

Parallel / 295

PHENIX results on direct photon production from Au+Au collisions

Author: Gabor David[1]

[1] *Brookhaven National Laboratory*

PHENIX measurements of low p_T direct photons in Au+Au collisions at 200 GeV show large yields that have simultaneously a large anisotropies with respect to the reaction plane, and that scale with the charged multiplicity to a power of 5/4, independent of transverse momentum and collision centrality. Calculations of thermal photon emission fall short in describing these three features. Furthermore, a recent publication of the STAR collaboration indicates lower direct photon yields in Au+Au collisions than observed by PHENIX. In order to provide new PHENIX has shown first results from Au+Au data taken in 2014. These data have 10 fold statistics compared to published results. In this talk we will show the latest direct photon results from this data set.

Collaboration (if applicable):

PHENIX

Track:

Electroweak Probes

Contribution type:

Contributed Talk

Parallel / 296

Reconstructed Jet Measurements in p+p, p+Au and Cu+Au collision using PHENIX

Author: Gabor David[1]

[1] *Brookhaven National Laboratory*

In addition to the previously reported inclusive jet spectra and nuclear modification factors in d+Au, and Cu+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV at mid-rapidity, measurements of jets in p+A and jet substructure in p+p and Cu+Au have also been performed in PHENIX. Jets are reconstructed from charged particle tracks and electromagnetic calorimeter clusters with the anti-kT algorithm. The measurements are unfolded for detector response. While the nuclear modification factor for centrality integrated data in d+Au collisions is found to be consistent with unity, the centrality-selected modification factor shows substantial deviations from unity. New measurements in p+Au collisions will provide crucial information for understanding the anomalous relationship between hard and soft processes in p/d+A systems. Meanwhile the Cu+Au collision system offers an intermediate testing ground for heavy ion jet reconstruction between small systems and those with the largest heavy ions. The underlying event in Cu+Au events is smaller when compared to that in the largest heavy ion systems, simplifying the extraction of the jet signals, but still achieving the large energy densities needed to drive substantial in-medium energy loss. To further explore the modification of the jets in Cu+Au collisions, jet fragmentation functions and jet grooming studies accessing the jet substructure have been performed. This talk will present the latest results from the reconstruction jet studies in PHENIX and their implications for energy loss in the quark gluon plasma.

Collaboration (if applicable):

PHENIX

Track:

Jets and High Momentum Hadrons

Contribution type:

Contributed Talk

Poster session / 297

Jet modification with two particle correlations in Au+Au collisions at PHENIX

Author: Gabor David[1]

Co-author: Megan Elizabeth Connors

[1] *Brookhaven National Laboratory*

Two particle correlations which use a high momentum trigger particle are a useful probe for exploring energy loss in the quark gluon plasma, particularly in the high multiplicity environment of heavy ion collisions. Previous direct photon-hadron correlation measurements in PHENIX have demonstrated the energy loss observed as the suppression of high momentum particles is redistributed to low momentum particle production at wide angles from the jet. The direct photon gives access to the kinematics from the initial hard scattering, which can be used to directly measure the fragmentation function of the opposing jet. However, it has been observed that the transition from suppression to enhancement appears at a fixed associated particle p_T rather than at a fixed z, the fragmentation function variable. Recent π^0-hadron correlations have explored these modifications more differentially as a function of associate hadron p_T and angular distance, $\Delta\phi$, from the approximated jet axis. This talk will report on the latest two-particle correlation measurements in Au+Au collisions compared to p+p collisions from PHENIX, their relation to fully reconstructed jet measurements and the implications of these measurements on our understanding of jet energy loss in the QGP.

Collaboration (if applicable):

PHENIX

Track:

Jets and High Momentum Hadrons

Contribution type:

Contributed Talk

Parallel / 298

Exploring potential jet modification in small collision systems with two particle correlations at PHENIX

Author: Gabor David[1]

[1] *Brookhaven National Laboratory*

Flow results in small systems at RHIC and the LHC indicate QGP droplets are formed in these collision systems. Measurements of jet R_{pA} on the other hand are consistent with no modification to the jets produced. However, non-zero v_n values for high momentum particles, which in A+A collisions are attributed to path-length dependent energy loss, have been observed in small systems. To further probe possible modification to jet particles, PHENIX measures the relative modification of the near and away-side jet particles in pi0-hadron correlations in 200 GeV d+Au and 3He+Au collisions. Modifications similar to the high p_T suppression and low momentum enhancement of associated particles observed in A+A collisions have been observed in d+Au collisions. These surprising results have now also been seen in 3He+Au data. These PHENIX measurements and possible interpretations of these intriguing results will be presented.

Collaboration (if applicable):

PHENIX

Track:

Initial State

Contribution type:

Contributed Talk

Poster session / 299

Direct photon measurements in pp collisions at sqrt(s)=510 GeV by PHENIX

Author: Gabor David[1]

[1] *Brookhaven National Laboratory*

At RHIC energies high pT direct photons are mainly produced by the quark-gluon Compton scattering process. Being not disturbed by fragmentation processes, they provide access to initial condition of partonic collisions. Direct photon production in pp collisions serves an ideal probe for gluon parton distribution functions (PDF), whereas quark PDFs are well constrained by deeply inelastic lepton-nucleon scattering. Similarly, longitudinally polarized pp collisions provide direct access to gluon helicity distribution within the proton, and therefore contribute to resolving the long standing puzzle of the proton spin decomposition. We will present the status of the direct photon analysis from pp collisions at sqrt(s)=510 GeV by PHENIX for both unpolarized and helicity dependent measurements, and comparison to previous measurements at different sqrt(s) and to NLO pQCD calculations

Collaboration (if applicable):

PHENIX

Track:

Electroweak Probes

Contribution type:

Contributed Talk

Parallel / 300

Jets are modified at both high and low virtuality

Authors: Chathuranga Sirimanna[1]; Shanshan Cao[1]; Abhijit Majumder[2]

[1] *Wayne State University*

[2] *Wayne state university*

Jet modification is a multi-stage (multi-scale) process: an initial high virtuality stage gives way to a lower virtuality transport stage for high energy partons, and a strongly coupled phase for lower energy parts of the shower. The transition from the high virtuality medium-modified DGLAP stage

takes place when the virtuality reaches the medium induced scale $\hat{q}\tau$, where τ is the lifetime of a given parton. A recent outstanding dispute has arisen on the role of energy loss in the high virtuality phase, and its contribution to jet observables [1,2]. In this presentation, we demonstrate that in a realistic dynamically evolving medium, the effect of the higher virtuality stage on leading hadron suppression is comparable or dominant to the lower virtuality stages. This is due to the fact that, for most jets, $\hat{q}$ scales with entropy density, and thus falls faster than the virtuality of the leading partons. As a result, the combined lifetime of partons with virtuality larger than the medium induced scale is sufficiently long that these partons scatter with the plasma multiple times before reaching the medium scale.

To systematically address this, we derive the complete next-to-leading twist single gluon emission contribution. Going beyond previous work, we include higher-twist contributions from both the modulus of the amplitude and the phase in interference terms. We also include all momentum fraction (y) suppressed contributions from quark scattering prior to emission. This calculation allows us to successfully address the issues raised in the work by Aurenche et al. [3,4]. Based on this formalism, a Monte-Carlo framework (MATTER+LBT+hydrodynamics) is further developed for simulating parton showers through the QGP. We demonstrate that while the medium-modified DGLAP process dominates jet observables at high p_T, the subsequent near-on-shell transport process dominates at low p_T. Only by combining these two stages can we naturally obtain a simultaneously good description of the nuclear modification factors of hadrons and jets.

References:
1. Caucal, P., Iancu, E., Mueller, A. H., & Soyez, G. (2018). Vacuumlike jet fragmentation in a dense qcd medium. Physical review letters, 120(23), 232001.
2. Casalderrey-Solana, J., Mehtar-Tani, Y., Salgado, C. A., & Tywoniuk, K. (2013). New picture of jet quenching dictated by color coherence. Physics Letters B, 725(4-5), 357-360.
3. Aurenche, P., Zakharov, B. G., & Zaraket, H. (2008). Failure of the collinear expansion in the calculation of the induced gluon emission. JETP letters, 87(11), 605-610.
4. Aurenche, P., Zakharov, B. G., & Zaraket, H. (2008). Comment on"Success of collinear expansion in the calculation of induced gluon emission". arXiv preprint arXiv:0806.0160.

Collaboration (if applicable):

Track:

Jets and High Momentum Hadrons

Contribution type:

Contributed Talk

Parallel / 301

Photon emission at hadronization from quark-gluon plasma

Authors: Kazunori Itakura[1]; Hirotsugu Fujii[2]; Chiho Nonaka[3]

[1] *KEK*

[2] *University of Tokyo*

[3] *Nagoya University*

We investigate photon emission at the hadronization stage of high-energy heavy-ion collisions. According to coalescence/recombination models for hadronization from a quark-gluon plasma (QGP), quarks and antiquarks closely locating in the phase space are assumed to suddenly form a hadron. Transition from free quark/antiquark states to hadrons (bound states of quarks or antiquarks) is, however, an energy violating process, and should be accompanied by emission of other particles to compensate the energy difference between the initial and final states.We consider the case where the additional particle is a photon, which is an analog of the "radiative recombination,"a well-known process in plasma physics. The radiative recombination, such as $e^- + p^+ \longrightarrow \mathrm{H}^0 + \gamma$, occurs when

an electromagnetic plasma goes back to an atomic gas. When a QGP hadronizes, we expect similar processes, such as $q+\bar{q} \to \pi^0 + \gamma$, to take place. As a simplest and phenomenological realization of the radiative recombination for hadronization, we modify the recombination model so that the energy is conserved by the introduction of photon emission. Our "radiative hadronization"picture which is realized by this simple model has the following properties: (i) it brings about enhancement of the photon yield, (ii) radiated photons flow similarly as hadrons, and (iii) the p_T distribution of emitted photons mimics thermal distribution whose effective temperature is given by blue-shifted quark's temperature. We also present numerical results combined with a hydrodynamic model on the pT spectrum and elliptic flow parameter of the photon at RHIC and LHC energies.

Collaboration (if applicable):

Track:

Electroweak Probes

Contribution type:

Contributed Talk

Parallel / 303

Fully coherent energy loss effects on light and open heavy-flavour hadrons in pA collisions

Author: Francois Arleo[1]

[1] *Laboratoire Leprince-Ringuet*

Fully coherent energy loss (FCEL), predicted from first principle QCD calculations, affects the yields of hadrons in proton-nucleus collisions at all energies. The FCEL effects on quarkonia have been succesfully compared to existing measurements over the last few years. In this talk, our approach is generalized systematically to $2 \to 2$ processes allowing for the first computation of FCEL effects on light ($h^{\pm}$) and open heavy-flavour (D, B) hadron production in pA collisions at the LHC. Results indicate that significant FCEL effects are to be expected, at mid-rapidity and even more so at forward rapidity, and should be taken into account in the standard nPDF global fit analyses. The FCEL baseline calculations are provided and compared to data whenever available.

References:
F. Arleo and S. Peigné, to appear
F. Arleo, F. Cougoulic, S. Peigné, to appear

Collaboration (if applicable):

Track:

Initial State

Contribution type:

Contributed Talk

Parallel / 304

A study of Jet Quenching properties using JEWEL framework coupled with v-USPhydro forhydrodynamic simulation along TRENTo and MC-KLN initial conditions

Authors: Fabio Canedo[1]; Marcelo Gameiro Munhoz[2]; Jacquelyn Noronha-Hostler[3]; Jorge Noronha[4]

[1] *Universidade de São Paulo*

[2] *Universidade de Sao Paulo (BR)*

[3] *Rutgers University*

[4] *University of Illinois at Urbana-Champaign*

High energy partons has been a useful tool to study the hot and dense matter produced in heavy-ion collisions. To this end, it has been shown that is important to incorporate the most realistic description of the Quark Gluon Plasma using relativistic hydrodynamics in order to study many properties at high pT. Therefore, in this work we couple a modified JEWEL code to event-by-event relativistic hydrodynamics (v-USPhydro). Here we compare two different event-by-event initial conditions TRENTO and mckln coupled to a full 2+1 hydrodynamic model to smooth Glauber initial conditions with only a Bjorken longitudinal expansion. The jet v2 and v3, substructure, and shape variables are calculated for LHC PbPb 2.76TeV collisions. We find that vn's have the largest influence from a realistic medium.

Collaboration (if applicable):

Track:

Jets and High Momentum Hadrons

Contribution type:

Contributed Talk

305

Low p_T direct photon in small systems at PHENIX experiment

Author: Veronica Canoa Roman[1]

[1] *Stony Brook University*

PHENIX has observed in A+A collision systems a large yield of low p_T direct photon, as an indication of a hot strongly-coupled system being formed.

In recent years, data from small systems have revealed evidence for collective behavior in small systems. In such a scenario, we expect that the matter formed in small system also radiates thermal photons.

PHENIX is in an ideal position to search for thermal photon in small systems like p+Au, d+Au and He+Au. Recent results from most central p+Au collisions show a hint of excess of thermal photons over the p+p baseline.

In this poster, I will present the status of thermal photon measurements in small systems.

Collaboration (if applicable):

PHENIX

Track:

Electroweak Probes

Contribution type:

Poster

Poster session / 306

Neutral pion v2 at low and high pT in Central dAu collisions measured with PHENIX at the RHIC top energies

Authors: Carlos Eugenio Perez Lara[1]; Carlos Perez Lara[1]

[1] *Stony Brook University*

The observation of multiparticle correlations in heavy ion collisions are usually associated to collective behavior in the formed medium. Recent results at RHIC provide strong arguments for QGP formation in smaller systems.
In this poster, I present the status of the neutral pion second harmonic coefficient v2 as a function of transverse momentum at low and high pT for very central d+Au collisions at 200 GeV. At low pT the v2 is sensitive to the hydrodynamic flow; while at high pT, v2 is sensitive to the in-medium path length dependence thus allowing to constrain qhat.
The data was recorded during the 2016 operational period in PHENIX. The analysis makes use of the central rapidity electromagnetic calorimeter. These results provides strong insight into the dynamics governing the evolution of the fireball at such scales.

Collaboration (if applicable):

PHENIX

Track:

Jets and High Momentum Hadrons

Contribution type:

Poster

Parallel / 309

Probing gluon saturation through precision studies of inclusive dijet and photon+dijet production in e+A DIS at small x

Authors: Kaushik Roy[None]; Raju Venugopalan[1]

[1] *Brookhaven National Laboratory*

We present the first computation of the next-to-leading order (NLO) impact factors for inclusive dijet and photon+dijet production in e+A DIS at small x in the framework of the Color Glass Condensate (CGC) effective field theory. When combined with the recent derivation of JIMWLK small x evolution to next-to-leading logarithm in x accuracy, these results provide us with a prediction of the photon+dijet and dijet cross-sections in e+A DIS to O($\alpha_S^3 \ln(1/x)$) accuracy. The novel momentum space computational techniques developed in our work allow us to extend our work to higher loop orders and we will discuss the progress towards that direction in the context of inclusive dijet production.
This methodology can also be employed in precision computations for p+A collisions and the realization of these precision studies at small x, both for DIS and hadron-hadron (nucleus) collisions, will pave the way towards the quantitative global analyses of data required for a definitive understanding of the systematics of gluon saturation.

Collaboration (if applicable):

Track:

Initial State

Contribution type:

Contributed Talk

Poster session / 311

Multiplicity Fluctuations in Relativistic Heavy Ion Collisions

Author: Mary Cody[1]

Co-authors: George Moschelli [1]; Brendan Koch [1]; Mark Kocherovsky [1]

[1] *Lawrence Technological University*

Fluctuations in the multiplicity of particles produced in relativistic nuclear collisions influence many multi-particle correlation measurements. In each nuclear collision, the number of produced particles fluctuates because the number of particle sources fluctuates and the number of particles emerging from each source also fluctuates. Further, we expect that jet and thermal source models of particle production should produce different fluctuation patterns. We search for a method to categorize collision events by the regions of phase space that provide the largest contribution to multiplicity fluctuations. In particular we seek to develop a method for comparison of different collision systems including proton-proton, proton-nucleus, and nucleus-nucleus collisions.

Collaboration (if applicable):

Track:

Initial State

Contribution type:

Poster

Poster session / 312

Multiplicity-Momentum Correlations in Relativistic Heavy Ion Collisions

Author: Mark Kocherovsky[1]

Co-authors: Mary Cody [1]; Brendan Koch [1]; George Moschelli [1]

[1] *Lawrence Technological University*

The observation of anisotropic collective flow in the small systems produced by proton-proton and proton-nucleus collisions at the Relativistic Heavy-Ion Collider and the Large Hadron Collider has led theorists to the hypothesis that hydrodynamics can occur without thermal equilibration. Viscous hydrodynamic flow has the effect of smoothing out fluctuations in particle momenta, but conversely jets have the effect of simultaneously increasing particle number and transverse momentum while inducing fluctuations. We study a new observable that indicates the covariance of multiplicity and

momentum of particles produced in nuclear collisions to discover if it can distinguish jet verse hydrodynamic dynamics. This observable is also sensitive to the level of equilibration. We use simulated events of proton-proton and nucleus-nucleus collisions to compare the behavior of our observable for collision events with high and low multiplicities.

Collaboration (if applicable):

Track:

Initial State

Contribution type:

Poster

Poster session / 313

Incomplete Thermalization and Two-Particle Correlations

Author: Brendan Koch[1]

Co-authors: Mark Kocherovsky [1]; Mary Cody [1]; George Moschelli [1]

[1] *Lawrence Technological University*

We propose a set of correlation and fluctuation observables that, taken together, could indicate the level of equilibration of the matter produced in relativistic nuclear collisions. Theoretical models of the expansion and cooling of QGP used to estimate properties like viscosity and the shear relaxation time generally assume that the QGP reaches local thermal equilibrium. However, it is not likely that experimental systems fully reach this equilibrated state. As a consequence, experimental estimates of QGP properties that rely on theoretical models might yield inaccurate results. We argue that multiplicity fluctuations, transverse momentum correlations, multiplicity-momentum correlations, and correlations of momentum fluctuations are all influenced differently by various physical mechanisms including particle production, viscous forces, initial state fluctuations, and temperature fluctuations. We use simulated proton-proton and nucleus-nucleus collision events to test the behaviors of these observables with respect to the number of particles created in these collisions and attempt to constrain an estimate of the level of equilibration of the matter created in high energy nuclear collisions.

Collaboration (if applicable):

Track:

Initial State

Contribution type:

Poster

Parallel / 315

Photoproduction of J/ψ-mesons off deuteron in d+Au Ultra-Peripheral Collisions using the STAR detector

Author: STAR Collaboration[None]

Nuclear dynamics at short distances among nucleons is one of the most outstanding phenomena in nuclear physics. Understanding the role of QCD in generating nuclear forces is important for uncovering the underlying physics of Short-Range Correlations (SRCs). In recent years, SRCs have been observed from light to heavy nuclei using fixed target experiments at Jefferson lab via high energy electron-nucleus scattering. It has been recently suggested that the exclusive J/ψ production of electron-deuteron scattering at the Electron-Ion Collider (EIC) would provide new insights into the SRCs, in particular from the aspect of the underlying quark-gluon dynamics. In the absence of electron-nucleus data from an EIC, data from deuteron-gold (d+Au) ultra-peripheral collisions (UPCs) recorded by the STAR detector at the Relativistic Heavy Ion Collider can be used as a proxy to test various techniques and hypotheses. The coherent and incoherent cross sections of J/ψ photoproduction in d+Au UPC events are measured, and the implications of the results will be discussed. The reported results will be a first-time measurement of J/ψ-meson photoproduction off deuteron in high energy collisions.

Collaboration (if applicable):

STAR

Track:

Initial State

Contribution type:

Contributed Talk

Poster session / 319

Disentangling the origins of jet modification using Monte Carlos

Authors: Jasmine Brewer[1]; Quinn Brodsky[1]; Yen-Jie Lee[2]; Andrew Lin[1]; Krishna Rajagopal[2]

[1] *Massachusetts Institute of Technology*

[2] *Massachusetts Inst. of Technology (US)*

Jet modification is an essential probe of the quark-gluon plasma produced in heavy-ion collisions. However, current jet modification measurements compare proton-proton and heavy-ion jets that had different properties when they were produced. Extracting the essential modification of jets by the quark-gluon plasma from these measurements requires an in-depth understanding of how jet observables are modified and to what extent they control energy loss. We present an extensive study of how a suite of groomed and ungroomed jet observables are modified and how they impact jet energy loss in Jewel and the hybrid model. We use information available in these models, but not in data, to identify how a jet's properties after quenching are related to those it had when it was produced. This enables us to focus on those observable features of a heavy-ion jet that provide maximal information about the properties it had before quenching and study the extent to which these conclusions are model-independent. The insights obtained through this model study are a crucial step toward a data-driven analysis of the relation between jet observables and energy loss in experimental data.

Collaboration (if applicable):

Track:

Jets and High Momentum Hadrons

Contribution type:

Poster

Poster session / 320

Multiple parton interaction in jets from forward-backward multiplicity correlations

Authors: Edgar Dominguez Rosas[1]; Eleazar Cuautle Flores[1]

[1] *Universidad Nacional Autonoma (MX)*

Forward-backward multiplicity correlations have been studied in different colliding system, for all them, the difference with experimental results reveals physical phenomenon not well understood. In this work we present a study of forward backward multiplicity correlations on jets produced in proton-proton collisions using the PYTHIA event generator from UA5 to LHC energías. The analysis is done event by event and event classes according to a jet classification.
We show that color reconnection and multiple parton interaction produce effects which will take into account to explain the experimental data. Furthermore, is shown that from measurements of multiplicity correlations is possible to extract the average number of multiple parton interactions in the event producing these correlations, and albeit model depending, to predict the strength of these correlations, not yet measured, for higher energy collisions.

Collaboration (if applicable):

Track:

Jets and High Momentum Hadrons

Contribution type:

Contributed Talk

Plenary / 330

ATLAS Overview: Recent Results and Future Plans

Collaboration (if applicable):

Track:

Contribution type:

Plenary / 331

Electroweak Probes: Experimental Overview

Collaboration (if applicable):

Track:

Contribution type:

Plenary / **332**

Saturation Physics at e-p, e-A and p-A Colliders

Collaboration (if applicable):

Track:

Contribution type:

Plenary / **333**

Early Time Dynamics and Bulk

Collaboration (if applicable):

Track:

Contribution type:

Plenary / **334**

Jet: Overview

Collaboration (if applicable):

Track:

Contribution type:

Plenary / **335**

Jets: Medium Modifications

Collaboration (if applicable):

Track:

Contribution type:

Plenary / **336**

Jets: Substructure

Collaboration (if applicable):

Track:

Contribution type:

Plenary / **337**

Jets: Back Reaction onto the Medium

Collaboration (if applicable):

Track:

Contribution type:

Plenary / **338**

Monte Carlo Modeling

Collaboration (if applicable):

Track:

Contribution type:

Plenary / **339**

Lattice and Effective Field Theories for Hard Probes

Collaboration (if applicable):

Track:

Contribution type:

Plenary / **340**

Open Heavy Flavor: Theory

Collaboration (if applicable):

Track:

Contribution type:

Plenary / 341

Quarkonia: Theory

Collaboration (if applicable):

Track:

Contribution type:

Plenary / 342

Open Heavy Flavor: Experiment

Collaboration (if applicable):

Track:

Contribution type:

Plenary / 343

Quarkonia: Experiment

Collaboration (if applicable):

Track:

Contribution type:

Plenary / 344

Future Facilities: EIC

Collaboration (if applicable):

Track:

Contribution type:

Plenary / **345**

Future Facilities: FCC

Collaboration (if applicable):

Track:

Contribution type:

Plenary / **346**

Summary: Heavy Flavor and Quarkonia

Collaboration (if applicable):

Track:

Contribution type:

Plenary / **347**

Summary: Electroweak Physics

Collaboration (if applicable):

Track:

Contribution type:

Plenary / **348**

Summary: Jets and High-PT

Collaboration (if applicable):

Track:

Contribution type:

Plenary / 349

Summary: Saturation and Initial State

Collaboration (if applicable):

Track:

Contribution type:

Plenary / 350

Multi-Parton Interactions and Underlying Event: A PYTHIA Perspective

Collaboration (if applicable):

Track:

Contribution type:

Plenary / 351

Future Facilities: RHIC Plans

Collaboration (if applicable):

Track:

Contribution type:

Plenary / 352

LHCb: Recent Results and Future Plans

Collaboration (if applicable):

Track:

Contribution type:

Plenary / 353

Welcome

Collaboration (if applicable):

Track:

Contribution type:

Plenary / 354

Electroweak Probes: Theory Overview

Collaboration (if applicable):

Track:

Contribution type:

Plenary / 355

Future Facilities: LHC Plans

Collaboration (if applicable):

Track:

Contribution type:

Plenary / 356

PHENIX Overview

Collaboration (if applicable):

Track:

Contribution type:

Plenary / 357

Introduction of Hard Probes 2022

Plenary / 358

Close and Adjourn

Collaboration (if applicable):

Track:

Contribution type:

Student Lectures / 359

Electroweak Probes

Collaboration (if applicable):

Track:

Contribution type:

Student Lectures / 360

Jets: Theory

Collaboration (if applicable):

Track:

Contribution type:

Student Lectures / 361

Jets: Experiment

Collaboration (if applicable):

Track:

Contribution type:

Student Lectures / 362

Open Heavy Flavor

Collaboration (if applicable):

Track:

Contribution type:

Student Lectures / 363

Quarkonia

Collaboration (if applicable):

Track:

Contribution type:

Student Lectures / 364

EIC Physics Overview

Collaboration (if applicable):

Track:

Contribution type:

Student Lectures / 365

String Theory and QCD

Author: Saso Grozdanov[1]

[1] *MIT*

Collaboration (if applicable):

Track:

Contribution type:

Plenary / 366

CMS: Recent Results and Future Plans

Collaboration (if applicable):

Track:

Contribution type:

Plenary / 367

STAR Overview

Collaboration (if applicable):

Track:

Contribution type:

Plenary / 368

ALICE Overview

Collaboration (if applicable):

Track:

Contribution type:

Student Lectures / 369

Student Day Welcome

Collaboration (if applicable):

Track:

Contribution type:

Student Lectures / 370

Initial State Physics

Collaboration (if applicable):

Track:

Contribution type:

371

IAC Meeting

Collaboration (if applicable):

Track:

Contribution type:

Plenary / 372

Flash Talk 1

Author: Timothy Thomas Rinn[1]

[1] *University Of Illinois (US)*

Collaboration (if applicable):

Track:

Contribution type:

Plenary / 373

Flash Talk 2

Author: Lin Chen[1]

[1] *Central China Normal University*

Collaboration (if applicable):

Track:

Contribution type:

Plenary / **374**

Flash Talk 3

Author: Wenkai Zou[1]

[1] *Columbia University (US)*

Collaboration (if applicable):

Track:

Contribution type:

Plenary / **375**

Flash Talk 4

Author: Oscar Garcia Montero[1]

[1] *Karl-Ruprechts-Universität Heidelberg*

Collaboration (if applicable):

Track:

Contribution type:

Plenary / **376**

Flash Talk 5

Author: Jonghan Park[1]

[1] *Inha University (KR)*

Collaboration (if applicable):

Track:

Contribution type:

Plenary / **377**

Flash Talk 6

Author: Saehanseul Oh[1]

[1] *LBNL*

Collaboration (if applicable):

Track:

Contribution type:

Plenary / 378

Flash Talk 7

Author: Desmond Mzamo Shangase[1]

[1] *University of Michigan (US)*

Collaboration (if applicable):

Track:

Contribution type:

Plenary / 379

Flash Talk 8

Author: Quinn Brodsky[1]

[1] *Massachusetts Institute of Technology*

Collaboration (if applicable):

Track:

Contribution type: