Workshop "Exploring Quark-Gluon Plasma through soft and hard probes"

Monday, 29 May 2023 - Wednesday, 31 May 2023

SANU (Serbian Academy of Science and Arts) - Belgrade, Serbia

Programme

Monday 29 May 2023

:: Jets 1 (09:00-10:30)

-Conveners: Elena Bratkovskaya

time	title
09:00	Welcome
09:10	Everything You Always Wanted to Know About Jets*... and More *Presenter: HARRIS, John* The energy loss of fast partons (quarks or gluons) in relativistic heavy-ion collisions can provide information on parton energy-loss mechanisms in a quark-gluon plasma (QGP) and serve to probe its microscopic structure. Understanding the parton energy-loss processes as partons propagate through a QGP requires measurement of large transverse momentum (high-pT) hadrons and jets. Suppression of the yield of high-pT hadrons at RHIC was the first indication of parton energy loss. More recently with the advent of higher collision energies at the LHC, the quenching of jets has been studied extensively in heavy-ion collisions. In this presentation I will provide an overview of high-pT hadron suppression, jet quenching and jet substructure measurements in heavy-ion collisions at RHIC and LHC. * but were afraid to ask!
09:40	What we can learn about the QGP dynamics from jets *Presenter: MEHTAR-TANI, Yacine* QCD jets play a central role in probing QCD at high precision and in new physics searches at colliders. They are also extensively studied in ultra relativistic heavy ion collisions as multi-dimensional probes of the quark gluon plasma (QGP) that is created in the aftermath of the collisions. While the theory for jet evolution in vacuum is well established, in the presence of a hot and dense QCD medium new emergent phenomena take place as a result of jet-medium interactions that have been recently uncovered and are currently being studied. In this talk, I will focus on the emblematic observable of jet quenching that is the nuclear modification factor and show that by exploring its dependence on jet pT, collision centrality and jet cone size we can extract valuable information about the dynamics and mechanisms of jet energy loss. I will in particular present a recent theoretical calculation that accounts for quantum interferences effects on energy loss that parton shower undergo in the QGP. I will also show predictions that were recently compared to ATLAS and ALICE data.
10:05	Determining the onset of color coherence with energy correlators *Presenter: ANDRES, Carlota* We present a new approach to jet substructure in heavy-ion collisions based on the study of correlation functions of energy flow operators (energy correlators). This approach is based on the insight that the dynamics of the QGP is imprinted at specific time scales in the jet, which will be reflected as changes in the shape of the correlator. We analyze the two-point correlator of an in-medium massless quark jet within three jet quenching formalisms: BDMPS-Z with the harmonic oscillator approximation, BDMPS-Z with a Yukawa (Gyulassy-Wang) parton-interaction model, and the first opacity DGLV framework. We show that the spectra of correlation functions is sensitive to color coherence, which allows us to robustly identify the resolution scale of the QGP: the energy scale at which in-medium emissions start to be resolved by the QGP.

:: Coffee break (10:30-11:00)

:: Jets 2 (11:00-12:35)

-Conveners: Shanshan Cao

time	title
11:00	Hard probes from the view point of open quantum systems *Presenter: BLAIZOT, Jean-Paul* Hard probes are produced at early stages of heavy ion collisions and carry with them information about the medium they traverse before being detected. Some of them are elementary, but some, like quarkonia are complex. In this talk I shall argue that it is interesting to consider such complex hard probes from the point of view of open quantum systems. I shall in particular establish interesting connection between the propagation of heavy quarkonia in a quark-gluon plasma and some aspects of jet physics.

11:30	Jet quenching in evolving anisotropic matter *Presenter: SADOFYEV, Andrey* Over the last decades, the theoretical picture of how hadronic jets interact with nuclear matter has been extended to account for the medium's finite longitudinal length and expansion. However, only recently a first-principle approach has been developed that allows to couple the jet evolution to the medium flow and anisotropic structure in the dilute limit. In this talk, I will show how to extend this approach to the dense regime, where the resummation of multiple in-medium scatterings is necessary. Particularly, I will consider the modifications of the single particle momentum broadening distribution and single gluon production rate in evolving matter. The resummation is performed by either computing the opacity series or starting from the all order BDMPS-Z formalism. I will also discuss the (novel) resulting modifications to jets' substructure and the effects of mass in the case of heavy-flavor quarks.
11:50	Effect of higher orders in opacity on high-pT observables *Presenter: ILIC, Bojana* Historically, high-pT radiative energy loss is calculated under the assumptions of the optically thin or optically thick medium within pQCD. These are two limiting (and opposite) approximations, corresponding to a jet experiencing only one or an infinite number of scatterings with medium constituents, respectively. However, in general, QGP created at the RHIC and the LHC is estimated to have 4-5 scattering centers, indicating the inadequacy of such approximations. Theoretical efforts to relax these approximations are still inconclusive, and lack verification against experimental data. To address these issues, we generalize our dynamical energy loss and DGLV formalisms toward finite orders in opacity, providing explicit analytical expressions up to the 4th order. These complex expressions, which are highly oscillatory, are obtained for the first time to our knowledge. Further, we implement them into an adequately generalized DREENA framework to assess the effects of higher orders in opacity on a comprehensive set of high-pT observables. Analytical and numerical results, as well as the interpretation of nonintuitive observations, are provided.
12:10	Low-pt and high-pt probes in the EPOS4 framework *Presenter: WERNER, Klaus* EPOS4 is a (recently released) multipurpose event generator for simulating high energy proton-proton and nucleus-nucleus collisions, which allows to treat within the same formalism very high pt processes and also low-pt phenomena. We will first present the basic ideas, and then discuss applications concerning high-pt particle production as well as collective effects in high-multiplicity pp events, based on light and heavy flavor particles.

:: Lunch break (12:35-14:15)

:: Early times (14:15-15:45)

-Conveners: Jakub Cimerman

time title

14:15	Initialization and fluctuations of QGP fluids in Bjorken expansion *Presenter: TETSUFUMI, Hirano* We discuss two topics in hydrodynamic description of QGP fluids in high-energy nuclear collisions. We first constrain the initial conditions in the Bjorken expansion model by considering causality. When the system is far away from local equilibrium, the relativistic hydrodynamic equations tend to violate the causality. Within the conformal fluids in one-dimensionally expanding system, we find initial conditions are largely constrained due to causality conditions. This sheds a light on importance of core-corona initialization in high-energy nuclear collisions. We next discuss thermal fluctuations during hydrodynamic evolution (a.k.a. hydrodynamic fluctuations) in the Bjorken expansion model. We take account of the second order terms, which are required from causality, in linear perturbation of Bjorken's equations and analyze correlation functions of energy density in the longitudinal direction. We find a typical behavior of correlation functions which reflect transport properties of the QGP. We also argue generalized constitutive equations from a viewpoint of hydrodynamic fluctuations.

14:40	How to explore initial stages and QGP anisotropy by using high-pt data? *Presenter: STOJKU, Stefan* In this talk, we will discuss how high-pt data can be used to constrain tau0, the onset time of energy loss and fluid-dynamical evolution, an important parameter of our description the evolution of QGP created in relativistic heavy-ion collisions. We first consider a scenario without pre-equilibrium evolution, and demonstrate that high-pt data clearly prefers later tau0. Then, we consider several more sophisticated scenarios with pre-equilibrium evolution and show that high-pt RAA and v2 are sensitive to different initializations and early expansion dynamics and that they prefer later onset of energy loss and transverse expansion. Moreover, we consider the spatial anisotropy of the QGP, as it is one of the main properties of this system. We propose a novel method to extract the spatial anisotropy from high pt data. Based on numerical calculations and comparisons with experimental data, we show that a modified ratio of v2 and RAA reaches a well-defined saturation value, which is directly proportional to the time-averaged anisotropy of the evolving QGP. We relate this ratio to a new observable, which we call jet-perceived anisotropy, and we argue that it can provide constraints on bulk-medium simulations.
15:00	System size dependence of pre-equilibrium and applicability of hydrodynamics in HIC *Presenter: WERTHMANN, Clemens* We simulate the space-time dynamics of high-energy collisions based on a microscopic kinetic description in the conformal relaxation time approximation, in order to determine the range of applicability of an effective description in relativistic viscous hydrodynamics [1,2]. We find that hydrodynamics provides a quantitatively accurate description of collective flow when the average inverse Reynolds number Re−1 is sufficiently small and the early pre-equilibrium stage is properly accounted for. We further discuss the implications of our findings for the (in)applicability of hydrodynamics in proton-proton, proton-nucleus and light nucleus collisions. [1] arXiv: 2211.14379 [hep-ph] [2] arXiv: 2211.14356 [hep-ph]
15:20	Interplay between core and corona from small to large colliding systems *Presenter: KANAKUBO, Yuuka* Properties of quark gluon plasma (QGP) have been studied in high-energy nuclear collisions. Since it is difficult to describe the dynamical phenomena by first-principle calculations, an approach via phenomenological models is indispensable to scrutinize the QGP properties through experimental data. We have developed a Monte Carlo event generator based on the hydrodynamic picture of the QGP, Dynamical Core-Corona Initialization framework (DCCI2). In this talk, I emphasize the importance of a phenomenological model that includes both equilibrium (core) and non-equilibrium (corona) components for more precise studies of QGP properties. In particular, I show that the corona component, which has not been considered in heavy-ion collision reactions, plays an important role in the interpretation of experimental data.

:: Coffee break (15:45-16:15)

:: Flow (16:15-17:50)

-Conveners: Jussi Auvinen

time title

16:15	Transverse momentum fluctuations in ultracentral Pb+Pb collisions at the LHC *Presenter: OLLITRAULT, Jean-Yves* The ATLAS collaboration has analyzed event-to-event fluctuations of the transverse momentum per particle as a function of the particle multiplicity. In the most central collisions, the variance of fluctuations decreases steeply. I show that this can be explained simply, provided that one takes into account two combined effects: First, for a fixed collision multiplicity, the impact parameter spans a range of values. Second, still for fixed multiplicity, the momentum per particle increases as a function of impact parameter. Based on this analysis, I derive accurate predictions for the increase of the mean transverse momentum in ultracentral collisions, which is yet unobserved.
16:40	Higher-order moments of the elliptic flow distribution in 5.02 TeV Pb-Pb collisions *Presenter: MILOSEVIC, Jovan* The hydrodynamic flow-like behavior of charged hadrons in high-energy lead-lead collisions is studied through their multiparticle correlations. The elliptic anisotropy harmonic values based on different orders of multiparticle cumulants, v2{2k}, are measured up to the tenth order (k = 5) as functions of the collision centrality at a nucleon-nucleon center-of-mass energy of 5.02 TeV. The data were obtained by the CMS experiment at the LHC with an integrated luminosity of 0.607 nb-1. A fine splitting is observed between the coefficients, with v2{2} > v2{4}□ v2{6} □ v2{8} □ v2{10}. The subtle differences in the higher-order cumulants allow for a precise determination of the underlying hydrodynamics. Based on these results, centrality-dependent moments for the fluctuation-driven event-by-event v2 distribution are determined, including the skewness, the kurtosis and, for the first time, the superskewness. Assuming a hydrodynamic expansion of the produced medium, these moments directly probe the initial-state geometry in high-energy nucleus-nucleus collisions.

17:00	Fluctuations and correlations of the anisotropic flow *Presenter: TOMÁŠIK, Boris* The azimuthal anisotropy of the observed distribution of hadrons results from the anisotropy of the initial conditions. A more detailed picture is in principle provided by correlations of the flow coefficients in various kinematic regions. This includes the decorrelation of flow anisotropy in rapidity, the correlation of the anisotropy with mean pt, or the decorrelation of the anisotropy in different pt bins. We present the results of a hybrid model that employs vHLLE for the deconfined phase and uRQMD or SMASH for the hadronic phase.
17:25	Deep learning predicted elliptic flow of identified particles in HIC at the RHIC and LHC *Presenter: BARNAFÖLDI, Gargely Gabor* Recent developments on a deep learning feed-forward network for estimating elliptic flow (v2) coefficients in heavy-ion collisions have shown us the prediction power of this technique. The success of the model is mainly the estimation of v2 from final state particle kinematic information and learning the centrality and the transverse momentum (pT) dependence of v2. The deep learning model is trained with Pb-Pb collisions at 5.02 TeV minimum bias events simulated with a multiphase transport model (AMPT). We extend this work to estimate v2 for light-flavor identified particles such as π±π±, K±K±, and $p+p^{-}p+p^{-}$ in heavy-ion collisions at RHIC and LHC energies. The number of constituent quark (NCQ) scaling is also shown. The evolution of pT-crossing point of v2(pT), depicting a change in meson- baryon elliptic flow at intermediate-pT, is studied for various collision systems and energies. The model is further evaluated by training it for different pT regions. These results are compared with the available experimental data wherever possible. See: [1] Physical Review D 105, 114022 (2022) [2] https://arxiv.org/abs/2301.10426"

Tuesday 30 May 2023

:: Jets 3 (09:00-10:30)

-Conveners: Carlota Andrés

time	title
09:00	Transport coefficients in the pre-equilibrium stage *Presenter: LAPPI, Tuomas* The initial pre-equilibrium stage of a heavy ion collision can have a significant impact on hard probes of the quark gluon plasma such as jets and heavy quarks. In weak coupling QCD the properties of this pre-equilibrium phase can be understood by effective kinetic theory, which can follow the development of the system from the glasma to hydrodynamics. We compute the jet quenching parameter q̂ and the heavy quark momentum diffusion coefficient using the effective kinetic theory this bottom-up isotropization phase. To a first approximation these coefficients are similar to a thermal system with the same energy density. However, unlike the thermal case these coefficients are also anisotropic. They are also enhanced in the earliest overoccupied phase and suppressed in the later, underoccupied, stage of thermalization. [1] Heavy quark diffusion coefficient in heavy-ion collisions via kinetic theory, K. Boguslavski, A. Kurkela, T. Lappi, F. Lindenbauer, J. Peuron, arXiv:2303.12520 [hep-ph] [2] Jet momentum broadening during initial stages in heavy-ion collisions, K. Boguslavski, A. Kurkela, T. Lappi, F. Lindenbauer, J. Peuron, arXiv:2303.12595 [hep-ph]
09:25	Exploring jet transport coefficients by elastic and radiative scatterings in the sQGP *Presenter: GRISHMANOVSKII, Ilia* We study the interaction of leading jet partons in a strongly interacting quark-gluon plasma (sQGP) medium based on the effective dynamical quasi-particle model (DQPM). The DQPM describes the non-perturbative nature of the sQGP at finite temperature T and baryon chemical potential μB based on a propagator representation of massive off-shell partons (quarks and gluons) whose properties (characterized by spectral functions with T,μB dependent masses and widths) are adjusted to reproduce the lQCD EoS for the QGP in thermodynamic equilibrium. We present the results for the jet transport coefficients, i.e. the transverse momentum transfer squared per unit length q̂ and the energy loss per unit length ΔE=dE/dx in the QGP and investigate their dependence on the temperature T and baryon chemical potential μB as well as on jet properties such as the leading jet parton momentum, mass, flavor, and the choice of the strong coupling constant. In this work both elastic and radiative scattering processes of leading jet parton with the sQGP partons are considered. We compute the cross sections and transport coefficients and compare the contributions from elastic partonic scattering and radiative processes for the emission of massive gluons. We present a comparison of our results for the elastic energy loss in the sQGP medium with pQCD results as well as with lattice QCD and also with estimates for q̂ by the JET and JETSCAPE Collaborations based on a comparison of hydrodynamical calculations with experimental heavy-ion data.
09:45	Constraining η/s through high-pt tomography *Presenter: KARMAKAR, Bithika* Typically, the bulk properties of Quark Gluon Plasma (QGP) are studied using the low-pt data. However, the high-pt probes can also serve as powerful tomography tools, since they are sensitive to global QGP features, such as different temperature profiles or initial conditions. In this study, we try to determine if it is possible to constrain the η/s of the medium formed in the heavy-ion collisions using the high-pt data/theory. We assume three different parametrizations of (η/s)(T) and compute the high-pt RAA and flow coefficients v2, v3, and v4. Our results demonstrate that the high-pt data can not distinguish between different (η/s)(T) assumptions when the evolution is constrained to reproduce the low-pt data. As a second approach, we utilize our dynamical energy loss model to compute the quenching strength (q̂/T^3) and then transform it into the (η/s)(T) of the evolving medium. The temperature dependence of (η/s) computed in this approach agrees surprisingly well with the (η/s)(T) inferred through state-of-the-art Bayesian analysis of the low-pt data.
10:05	A New Model for Jet Energy Loss in Heavy Ion Collisions *Presenter: KARPENKO, Iurii* We present a new model for jet quenching from coherent radiation in a brick medium. The jet energy loss is simulated as a perturbative final-state vacuum parton shower followed by a medium-induced shower originating from elastic and radiative collisions with the medium constituents. Coherency is achieved by starting with trial gluons that acts as field dressing of the initial jet parton. These are formed according to a Gunion-Bertsch seed. The QCD version of the LPM effect is attained by increasing the phase of the trial gluons through elastic scatterings with the medium. Above a phase threshold, the trial gluon will be realised and can produce coherent radiation themselves. The model has been implemented in a Monte Carlo code and has been validated by successfully reproducing the BDMPS-Z prediction for the energy spectrum. The realistic case with minimal assumptions are also produced and shown.

:: Coffee break (10:30-11:00)

:: Jets 4 (11:00-12:30)

-Conveners: Andrey Sadofyev

time	title
11:00	Fully Coherent Energy Loss in pA and AA collisions *Presenter: PEIGNÉ, Stéphane* In high-energy proton-nucleus (pA) collisions, an incoming energetic parton crosses the target nucleus and suffers medium-induced, fully coherent gluon radiation. I will review the theoretical status of this effect, and present the phenomenological consequences of the corresponding fully coherent energy loss (FCEL) on light hadron, heavy meson and quarkonium production in pA collisions. I will briefly recall that the extrapolation of FCEL to AA collisions shows that this « cold nuclear matter effect » should not be neglected compared to the hot, QGP effects.
11:25	ebeDREENA framework as a QGP tomography tool *Presenter: ZIGIC, Dusan* We present a novel framework ebe-DREENA, based on a state-of-the-art dynamical energy loss model, which can include any temperature profile from bulk medium simulations. The framework is fully optimized to exploit different state-of-the-art medium evolutions - both event-by-event hydrodynamics and kinetic transport theory. It does not use fitting parameters within the energy loss model, allowing it to fully exploit differences in temperature profiles, as the only input in the framework. The framework applies to both light and heavy flavor observables, and both large (A+A) and small (e.g. p+A) systems. We calculate high-pt harmonics up to 6th order and exploit how the differences in the temperature profiles affect them, which will be especially useful with the upcoming high-luminosity measurements at RHIC and LHC. These comparisons of predictions and data are done within the same formalism and parameter set. We, therefore, propose ebe-DREENA as a unique tomography tool, which allows systematic and comprehensive mapping of QGP properties.
11:45	Advances in Jet thermalization using QCD kinetic theory *Presenter: GARCIA-MONTERO, Oscar* In this work we use linearized QCD kinetic to study how highly energetic parton -proxy for a jet- interacts with the hot Quark-Gluon Plasma (QGP), We find that the parton loses energy to the medium mainly through a radiative turbulent gluon cascade, down to the temperature, at which dissipation starts taking place. The distribution of energy takes place in two stages, first, a highly collimated collinear energy cascade, which as the redistributed energy arrives to the plasma temperature, triggers an angular cascade. This transports the energy to large angles with respect to the jet axis. Furthermore, we will show the importance of the jet cone size in reducing/enhancing the details of dissipation in jet observables.
12:05	Hadronization in Vacuum and in Medium *Presenter: FRIES, Rainer J* Hybrid Hadronization is based on the idea of describing hadronization at short and long distances by different hadronization models, namely parton recombination, and string fragmentation. The latter dominates in the vacuum at large energies. The former becomes important at lower energies and in the presence of a bath of partons, e.g. for jet showers or heavy quarks in quark gluon plasma. Hybrid Hadronization allows for jet partons to form strings or hadrons that include partons from the thermal bath. In this talk we review some basic concepts of Hybrid Hadronization, and discuss results for various systems from e+e- to AA collisions

:: Lunch break (12:30-14:15)

:: High density (14:15-15:45)

-Conveners: Clemens Werthmann

time	title
14:15	Dileptons at low energies: prospects and challenges *Presenter: TSERRUYA, Itzhak* Results obtained from dilepton measurements over the past 25 years at energies from SPS energies up to RHIC and LHC energies will be reviewed. The motivation for extending these measurements to lower energies will be discussed with emphasis on the onset of the deconfinement phase transition, the onset of chiral symmetry restoration and the search for a first order phase transition. The current status of the NICA facility and the possibility to perform these measurements with the MPD detector will be presented.

14:45	Fluctuations near the liquid-gas and chiral phase transitions in hadronic matter *Presenter: MARCZENKO, Michał* We investigate the fluctuations of the net-baryon number density in dense hadronic matter. Chiral dynamics is modeled via the parity doublet Lagrangian, and the mean-field approximation is employed to account for chiral criticality. We focus on the qualitative properties and systematics of the second-order susceptibility of the net-baryon number density for individual positive- and negative-parity nucleons whose masses become degenerate at the chiral restoration. It is shown that the second-order susceptibility of the positive-parity state can become negative when the chiral symmetry is restored, as a natural consequence of the unique relationship of the mass to the order parameter. Moreover, we find that such negative fluctuations are indicative of approaching the critical point on the chiral phase boundary. Our results may have consequences for the interpretation of the experimental data on net-proton fluctuations in heavy-ion collisions.
15:05	Transport coefficients and comparison of the QGP evolution in transport and hydro approach *Presenter: SOLOVEVA, Olga* We study equilibrium as well as out-of-equilibrium properties of the strongly interacting QGP medium under extreme conditions of high temperature T and high baryon densities or baryon chemical potentials μB within a kinetic approach. We present the thermodynamic and transport properties of the QGP close to equilibrium in the framework of effective models with Nf=3 active quark flavors such as the Polyakov extended Nambu-Jona Lasinio (PNJL) and dynamical quasiparticle model with the CEP (DQPM-CP). Considering the transport coefficients and the EoS of the QGP phase, we compare our results with various results from the literature. Moreover, we find a good agreement between resulting transport coefficients at μB=0 to the predictions from the lattice QCD and estimates from a Bayesian analysis by the JETSCAPE Collaboration. Furthermore, out-of-equilibrium properties of the QGP medium and in particular, the effect of a μB- dependence of thermodynamic and transport properties of the QGP are studied within the Parton-Hadron-String-Dynamics (PHSD) transport approach, which covers the full evolution of the system during HICs. We compare our results with the hybrid approaches taking into account the values of transport coefficients. We find that bulk observables and flow coefficients for strange hadrons as well as for antiprotons are more sensitive to the properties of the QGP, in particular to the μB - dependence of the QGP interactions.
15:25	MUFFIN: Next-generation multi-fluid hydrodynamic model for RHIC BES *Presenter: CIMERMAN, Jakub* The hydrodynamic modelling of heavy-ion collisions at energies from few to tens of GeV per NN pair brings new challenges as compared to simulations at top RHIC or LHC energies. The contraction of the incoming nuclei is much weaker resulting in a long inter-penetration phase and a more complex initial-state geometry. Conventional hydrodynamic models, where the fluid phase starts at a fixed proper time τ0, therefore miss the compression stage of collision and may be therefore less sensitive to the EoS of the medium. Multi-fluid dynamics treats the incoming nuclei as two baryon-rich droplets of cold nuclear fluid creating a third baryon-free fluid from the friction between the two colliding fluids. We present MUFFIN (MUlti Fluid simulation for Fast IoN collisions), a next-generation event-by-event three-fluid dynamic model to simulate heavy-ion collisions at RHIC BES, newly reimplemented with the use of 3+1 dimensional relativistic viscous hydrodynamic code vHLLE. We discuss the challenges in constructing the approach and present benchmark calculations for Au-Au collisions at different RHIC BES energies.

:: Coffee break (15:45-16:15)

:: Spin and CME (16:15-17:50)

-Conveners: Yuuka Kanakubo

time	title
16:15	Exploring the phase diagram with femtoscopy and Lévy sources from SPS to RHIC and LHC *Presenter: CSANAD, Mate* Exploring the space-time extent of particle production is an important goal of heavy-ion physics, and substantial effort has been made in order to understand the underlying physics behind the experimental observations of non-Gaussian behavior, in particular with respect to connections to the phase diagram. In experiments, femtoscopic (momentum) correlations are utilized to gain information about the space-time geometry of the particle emitting source. The correlation functions are characterized by the Lévy exponent alpha and the Lévy scale R, as well as correlation strength lambda. The transverse mass dependence of these parameters was recently explored from SPS through RHIC to LHC. In this talk an overview of these results is presented, with implications on the origins of non-Gaussian behavior, particle production mechanisms, as well as possible searches for the critical point.

16:40	Signatures of Baryonic spin Hall effect in hot and dense QCD matter *Presenter: FU, Baochi* The spin Hall effect (SHE) is a generation of spin polarization for moving spin carriers in materials under an external electric field and has been observed in semiconductors, metals, and insulators at or below room temperature. Recent theoretical analyses show that spin Hall current can be induced by the baryon chemical potential gradient which plays the role of the analogous electric field and which becomes sizable in the fireballs created in heavy-ion collisions at beam energy of O(10) GeV. In this talk, we focus on this important mechanism and predict the signature of the SHE using a (3+1) D viscous hydrodynamic model MUSIC with AMPT initial condition. We propose to use the second Fourier coefficients of the net spin polarization of Lambda hyperon as sensitive probes to search for the SHE. Those SHE observables show a qualitative difference in both the sign and beam energy dependence for the situations with and without the SHE. Future experimental observation of these distinct qualitative features would provide strong evidence for the existence of the SHE in the hot and dense QCD matter at trillions of degrees.
17:00	Relativistic magnetohydrodynamics for spin polarized media *Presenter: RYBLEWSKI, Radoslaw* The kinetic-theory-wise formulation of relativistic dissipative nonresistive magnetohydrodynamics for massive spin-half particles in the presence of a magnetic field is presented. Using a relaxation-time approximation for the collision kernel of the underlying relativistic Boltzmann equation the nonequilibrium corrections to the phase-space distribution function and multiple transport coefficients are calculated. The emergence of the well-known Einstein–de Haas and Barnett effects from the resulting framework is shown. It is demonstrated that the coupling between spin and the magnetic field appears in the first order of the gradient expansion. Reference: Phys. Rev. Lett. 129 (2022) 19, 192301
17:25	Experimental search for the chiral magnetic effect *Presenter: WANG, Fuqiang* Chiral Magnetic Effect (CME) is a phenomenon in which electric charge is separated by a strong magnetic field from local domains of chirality imbalance and parity violation in quantum chromodynamics (QCD). The CME-sensitive, charge-dependent three-point azimuthal correlator Δγ is contaminated by a major physics background proportional to the particle elliptic flow anisotropy v2. To mitigate the background, isobar collisions were conducted and a blind analysis of the isobar data were performed. In this talk, I will review the experimental efforts in searching for the CME before and with the isobar collisions, new insights on nuclear structures from the isobar data, and discuss future perspectives on the CME.

Conference dinner (20:00-22:00)

Wednesday 31 May 2023

:: Experimental advances (09:00-10:40)

-Conveners: Lidija Zivkovic

time	title
09:00	Exploring the sQGP with sPHENIX *Presenter: ZAJC, William A.* The strongly-coupled nature of the quark-gluon plasma was discovered nearly twenty years ago. Since that time, we have learned a great deal about the sQGP and its transport properties, but the question of how quarks and gluons, the microscopic degrees of freedom, produce the near-perfect liquid properties observed in the bulk remains open. The sPHENIX experiment, the first collider detector to be built in the U.S. in over two decades, is designed to investigate the sQGP with jets and heavy flavor probes to reveal these essential aspects of thermal QCD matter. I will present both the intended sPHENIX program, and the experiment's current status, with first beam expected at essentially the time of this workshop.
09:30	ALICE upgrades *Presenter: BRUNO, Giuseppe* The ALICE collaboration pursues several upgrades to further extend the reach of heavy-ion physics at the LHC. For LHC Run 4 (2029-2032), ALICE is pioneering the use of bent, wafer-scale pixel sensors to produce truly cylindrical tracking layers with very low material budget to replace the three innermost layers of the inner tracking system. The resulting improvement in pointing resolution will allow new measurements of heavy-flavour hadrons and dielectrons. In addition, a Forward Calorimeter (FoCal) system combines a high-granularity electromagnetic silicon-tungsten calorimeter with excellent two-shower separation for neutral pion reconstruction with a conventional hadronic calorimeter for photon isolation. Direct photon measurements with FoCal will provide unique constraints on the low-x gluon structure of protons and nuclei via forward measurements of direct photons. Furthermore “ALICE 3” is proposed as the next-generation experiment for LHC Run5 and beyond to address unresolved questions about the quark-gluon plasma by precise measurements of heavy-flavour probes as well as electromagnetic radiation in heavy-ion collisions. In order to achieve the best possible pointing resolution a concept for the installation of a high-resolution vertex tracker in the beampipe is being developed. It is surrounded by a silicon-pixel tracker covering roughly 8 units of pseudorapidity. To achieve the required particle identification performance, a combination of a time-of-flight system and a Ring-Imaging Cherenkov detector is foreseen. Further detectors, such as an electromagnetic calorimeter, a muon identifier, and a dedicated forward detector for ultra-soft photons, are being studied. In this presentation, I will outline the detector concept as guided by the desired physics reach.
09:55	Physics opportunities for nuclear structure studies in high-energy nuclear collisions *Presenter: JIA, Jiangyong* Hydrodynamic simulations of the quark-gluon plasma (QGP) permit us not only to gauge the transport properties of hot QCD matter from data, but also to constrain the conditions that set the stage for the formation of such matter. Recent measurements from RHIC and LHC demonstrate that the QGP initial condition is impacted by the shape and radial structure of the colliding nuclei. Based on a recent community white paper (arXiv:2209.11042), we discuss physics opportunities for nuclear structure and QGP studies offered by high-energy nuclear collisions, with an emphasis on isobar collisions to clean access to the structural properties of the colliding ions. Recent updates from the INT program 23-1a dedicated to this topic will also be covered.
10:20	Measuring open/hidden charm at SPS energy in the NA60+ experiment *Presenter: SCOMPARIN, Enrico* Heavy quark production represents one of the main tools for the QGP characterization, as shown by the vast amount of results obtained in nuclear collisions at collider energies. At fixed-target energies, these measurements become more difficult because of the vanishing production cross sections, and for the moment only charmonium results at top SPS energy (sqrt(s_NN)=17 GeV) are available. A new experiment at the CERN SPS is being proposed, to carry out measurements down to sqrt(s_NN)~6 GeV. In this talk I will review the physics topics that can be addressed in this energy domain and show the results of the corresponding physics performance studies. The status of advance of the experiment preparation will also be briefly described.

:: Coffee break (10:40-11:10)

:: Heavy quarks 1 (11:10-12:25)

-Conveners: Bithika Karmakar

time	title

11:10	Study of the heavy quark hadronisation from small to large systems with ALICE *Presenter: COLAMARIA, Fabio* The production of heavy-flavour hadrons in hadronic collisions can be calculated with a factorisation approach, as a product of parton distribution functions (PDFs), partonic hard- scattering cross section, and parton-to-hadron fragmentation functions, assumed to be universal among di□erent collision systems. Recent measurements of baryon-to-meson production yield ratios at the LHC, observed to be enhanced compared to measurements in e+e– and e+p collisions, challenged this assumption, suggesting a modified hadronization of heavy quarks in hadronic collisions with respect to in-vacuum fragmentation. Additional modifications to the heavy-quark hadronisation process are expected in heavy-ion collisions, where the large density of deconfined quarks may favour the formation of hadrons via the coalescence mechanism, the increased abundance of strange quarks could enhance the production of charm-strange hadrons, and the presence of collective motion of the medium can a□ect the momentum distribution of the produced hadrons. In this presentation, a selection of recent results from the ALICE Collaboration on prompt and non-prompt charm meson and baryon production in pp, p-Pb and Pb-Pb collisions, as well as baryon-to-meson ratios for several charm-baryon species, will be shown. The measurements will be compared to results available from the other LHC Collaborations, as well as to model calculations with di□erent modeling of the heavy-quark hadronisation.
11:35	Heavy flavor measurements in STAR experiment *Presenter: BIELČÍK, Jaroslav* In ultra-relativistic heavy-ion collisions, a dense and hot QCD medium, the Quark-Gluon Plasma (QGP) is created. Heavy quarks (charm and beauty) are produced dominantly in hard partonic scatterings in the early stage of the collisions and experience the whole medium evolution. Measurements of open heavy-flavor hadron production provide information on the transport properties of the QGP, the degree of the heavy quark thermalization, and the hadronization mechanism. The measurements of quarkonium production in heavy-ion collisions give us insight into the color screening mechanism, which causes the quarkonium bound states to dissociate in the QGP, and thermodynamic properties of the QGP. In this talk, we will report recent results on open heavy-flavor and quarkonium production in the STAR experiment at RHIC. Measurements of the J/ψ suppression and elliptic flow in isobar (Ru+Ru and Zr+Zr) collisions at 200 GeV, as well as studies of the system size and energy dependence of the J/ψ suppression will be shown. Production o quarkonia in p+p collisions, including J/ψ production in jets and with jet activity, will also be presented. Moreover, we will show measurements of electrons from open heavy-flavor hadron decays, and D0,D±, Ds and Λc production in Au+Au collisions at 200 GeV. The extracted total charm quark production cross section per nucleon-nucleon collision in Au+Au collisions will be reported. We will also present the measurements of the production yield and radial profile of D0-tagged jets in Au+Au collisions at 200 GeV. Prospects of heavy-flavor measurements in STAR with high luminosity Au+Au RHIC Runs in 2023 and 2025 at 200 GeV will be also discussed.
12:00	Missing beauty of proton-proton interactions *Presenter: MILOV, Alexander* Multiparton interactions in proton-proton collisions have long been a topic of great interest. A new look at them has begun to emerge from work being done to understand the dynamics of ‘small systems’, a topic that is taking center stage in the physics of relativistic heavy-ion interactions. Numerous studies conducted at the LHC and lower energies reveal that proton-proton collisions at high energy form a system in which final state interactions substantially impact experimentally observable quantities in the soft sector. However, until recently, no evidence was shown that final state interactions could also affect observables produced in the hard scattering processes. Studies performed by the LHC experiments and in [PRD 107, 014012] present strong evidence that the final state interactions in proton-proton collisions have a drastic impact on the b-quark bound states production, whose yields may be reduced by more than a factor of two.

:: Lunch break (12:25-14:10)

:: Heavy quarks 2 (14:10-15:45)

-Conveners: Bojana Ilic

time	title
14:10	Recent developments in the theoretical modelling of quarkonia production *Presenter: GOSSIAUX, Pol-Bernard* The global picture of quarkonia production in heavy ions collisions has recently reached some good consensus in the community. However, before turning it into a precision tool to better characterize QGP, some theoretical challenges still need to be met. In this talk, I will review some of the recent progress achieved for the description of quarkonia production, focusing on both fully quantum approaches as well as semi-classical treatments.

14:35	A new microscopic approach to understand the quarkonium production in pp and AA collisions *Presenter: AICHELIN, Joerg* We present the first microscopic model, which allows to describe the formation of charmonia in ultrarelativistic heavy ion collisions. We follow the heavy quarks from their initial production in hard collisions, followed by their passage through the quark gluon plasma where the heavy quarks interact with the plasma constituents and among themselves with a potential obtained by lattice gauge calculations. We apply the density matrix formalism to study how charmonia disintegrate and the heavy quarks form charmonia during the passage through the QGP. We finally compare the results with data.
15:00	Challenges in quarkonium and exotic-state production: from small to large systems *Presenter: G. FERREIRO, Elena* The behavior of quarkonia and open-heavy flavour hadrons in hadronic collisions provide a unique testing ground for understanding quantum chromodynamics (QCD). Although there has been significant progress, our understanding of hadronic collisions has been challenged by the observation of intriguing effects in high-multiplicity proton-proton and proton-Pb collisions, such as the discovery of correlations and the suppression of quarkonium excited states in those systems. Those phenomena show a smooth continuation of heavy-ion features to small systems and lower density, whose origin is still not clear. Two serious contenders remain today as possible explanations, one based on initial-state correlations and another that requires final-state interactions to be at play. In this talk, I will present different results, considering the possibility of final-state interactions for the explanation of quarkonium excited states. Moreover, the structure of exotic resonances that do not trivially fit the usual quark model expectations has been a matter of intense scientific debate during the last two decades. I will show that a possible way of estimating the nature of these states is to study their behavior when immersed in QCD matter.
15:25	Heavy Quark Diffusion coefficient in light of Gribov-Zwanziger action *Presenter: BANDYOPADHYAY, Aritra* The heavy quark momentum diffusion coefficient (□) is one of the most important ingredients for the Langevin description of the heavy quark dynamics. In the temperature regime relevant for the heavy ion collision phenomenology, there exists a substantial difference between the lattice estimations of □ and the corresponding leading order (LO) result from the hard thermal loop (HTL) perturbation theory. Moreover, the indication of poor convergence in the next-to-leading order (NLO) perturbative analysis has motivated the development of several approaches to incorporate the non-perturbative effects in the heavy quark phenomenology. In this work [1], we estimate the heavy quark diffusion coefficient based on the Gribov-Zwanziger prescription. In this framework, the gluon propagator, depends on the temperature dependent Gribov mass parameter which has been obtained self consistently from the one loop gap equation. Incorporating this modified gluon propagator in the leading order analysis, we find a reasonable agreement with the existing lattice estimations of □ within the model uncertainties. [1] Estimation of the diffusion coefficient of heavy quarks in light of Gribov-Zwanziger action ; Sadaf Madni, Arghya Mukherjee, Aritra Bandyopadhyay, Najmul Haque; Published in: Phys.Lett.B 838 (2023) 137714

:: Coffee break- (15:45-16:15)

:: EoS and hadronisation (16:15-17:50)

-Conveners: Olga Soloveva

time title

16:15	Constraining the QGP properties using heavy quarks *Presenter: CAO, Shanshan* Heavy quarks serve as a clean probe of the color-deconfined QGP matter produced in relativistic heavy-ion collisions. We develop a unified perturbative and non-perturbative Boltzmann transport model for studying the elastic and inelastic scatterings of heavy quarks inside the QGP. A generalized Cornell-type potential is implemented, which incorporates both the short-range Yukawa interaction and the long-range color confining interaction. By combining this new approach to a (3+1)-dimensional viscous hydrodynamic model for the QGP evolution and a hybrid fragmentation-coalescence model for heavy quark hadronization, we obtain a satisfactory description of nuclear modification of heavy flavor observables from low to intermediate to high transverse momenta. From the model-to-data comparison, we extract the in-medium heavy quark potential from open heavy flavor observables for the first time, which is shown in agreement with the lattice QCD calculation. And by combining this Boltzmann transport model with a quasi-particle description of the QGP, we perform a first extraction of the Equation of State of the QGP using the open heavy flavor data, which is shown consistent with the lattice QCD result as well.

16:40	The post-mortem QGP analysis: the statistical hadronization model for heavy quarks *Presenter: ANDRONIC, Anton* The statistical hadronization model is very successful in reproducing the experimental data in Pb-Pb collisions, both for light-quark and heavy-quark hadrons. In particular the detailed comparisons for charmonium lead us to infer quasi-complete thermalization of charm quarks in QGP and concurrent hadronization with the lighter quarks. The large yield measured for the Λc baryon at the LHC can only be explained in the model by assuming a large number of missing charm-quark baryon resonances. For the beauty quarks, the model comparison to data suggests incomplete thermalization, not surprisingly, given the significantly-heavier b quark.
17:05	Light Nuclei production in Coalescence Model *Presenter: WU, Shanjin* As a hadronization model in relativistic heavy-ion collisions, coalescence (recombination) model has achieved great success in the description of the production of hadron and light nuclei. This talk focuses on light-nuclei production within the framework of the coalescence model. By employing the characteristic function of the phase space density, we derive the yield of light nuclei in terms of various orders of cumulants for the density distribution function. We found that the leading terms of the phase-space cumulants in the yield nuclei share a similar form and could be canceled out in light-nuclei ratio, whereas the higher order ones (non-Gaussian shaped density profile) remain and play an important role in the interpretation of the behavior of light nuclei yield ratio. In addition, the critical correlation contributed to the higher-order phase-space cumulants will also be discussed.
17:25	Hard thermal loops and soft deconfinement in the EoS for quark-hadron matter *Presenter: BLASCHKE, David* We describe multiquark clusters in quark matter within a Beth-Uhlenbeck approach in a background gluon field that is coupled to the underlying chiral quark dynamics using the Polyakov-gauge and an effective potential for the traced Polyakov-loop. A higher multiquark cluster of size n is described as a binary composite of smaller subclusters n1 and n2 (n1+n2=n) with a bound state and scattering state spectrum. For the corresponding cluster-cluster phase shifts we use two simple ansätze that capture the Mott dissociation of quark clusters as a function of temperature and chemical potential, the soft deconfinement. We compare the simple ""step-up-step-down"" model that ignores continuum correlations with an improved model contains them in a generic form. In order to explain the model, we restrict ourselves here to the cases where 1≤n≤6. A striking result is the suppression of the abundance of colored multiquark clusters at low temperatures by the coupling to the Polyakov loop. This is understood in close analogy to the suppression of quark distributions by the same mechanism and we derive here the corresponding Polyakov-loop generalized distribution functions of n-quark clusters. For a successful comparison with lattice QCD thermodynamics it is important to include perturbative QCD contributions, the hard thermal loops.