XII Workshop on Particle Correlations and Femtoscopy

Monday, June 12, 2017 - Friday, June 16, 2017

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Book of Abstracts

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pt-Angular power spectrum in ALICE events

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We study the particles emitted in the fireball following a Relativistic Heavy Ion Collision with the traditional angular analysis employed in cosmology and earth sciences, producing Mollweide plots of the p_t distribution of a few actual, publically released ALICE-collaboration events and calculating their angular power spectrum. With the limited statistics at hand, we do not find evidence for acoustic peaks but a decrease of C_l that is reminiscent of viscous attenuation, but subject to a strong effect from the rapidity acceptance which probably dominates (so we also subtract the m=0 component). As an exercise, we still extract a characteristic Silk damping length (proportional to the square root of the viscosity over entropy density ratio). The absence of acoustic-like peaks is also compatible with a crossover from the QGP to the hadron gas (because a surface tension at domain boundaries would effect a restoring force that could have driven acoustic oscillations). Presently an unexpected depression appears in the l=6 multipole strength, which should be revisited by the ALICE collaboration with full statistics to confirm or discard it.

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Velocity fluctuations of fission fragments

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We propose event by event velocity fluctuations of nuclear fission fragments as an additional interesting observable that gives access to the nuclear temperature in an independent way from spectral measurements and relates the diffusion and friction coefficients for the relative fragment coordinate in Kramers-like models (in which some aspects of fission can be understood as the diffusion of a collective variable through a potential barrier). We point out that neutron emission by the heavy fragments can be treated in effective theory if corrections to the velocity distribution are needed.

Read More: http://www.worldscientific.com/doi/abs/10.1142/S0218301316500099

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Strongly intensive observable for multiplicities in forward and backward windows in string model

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The strongly intensive observable involving multiplicities in two separated rapidity intervals (forward and backward) is analyzed in the model with particle production from the fragmentation of strings. In the case with independent identical strings the model calculation confirms that this observable does not depend on nor the number of string, nor its event-by-event fluctuation. The expression of the observable through the two-particle correlation function of a string, characterizing the strength of the correlation between particles produced from the fragmentation of a same string, is found.

Using this connection and the explicit form of the two-particle correlation function of a string, obtained earlier by the parametrization of the pp ALICE data on correlations between multiplicities in windows separated in azimuth and rapidity, the dependence of the strongly intensive observable on the width of observation windows and the distance between them is calculated.

The influence of the string fusion processes on this observable is discussed.The results of the MC simulation of the variable by means of PYTHIA event generator for a wide scope of psevdo rapidity separation between observation windows are also presented. The work was funded by the grant of the Russian Science Foundation (project 16-12-10176).

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The Critical Point and Particle Correlations under Thermal Stochastic Influence

Author: Gennady Kozlov[None]

The critical phenomena of strongly interacting matter are presented in the dual flux tube model at finite temperature. The phase transitions are considered in systems where the Critical Point (CP) is a distinct singular one existence of which is dictated by the dynamics of conformal symmetry breaking.
The physical approach to the effective CP is predicted through the influence fluctuations of two-particle quantum correlations to which the critical mode couples. The finite size scaling effects are used to extract location of deconfinement phase transition.
We obtain the size of the particle emission source, the transverse momenta of correlated particles affected by the stochastic forces in thermal medium characterized by the Ginzburg-Landau (GL) parameter (for the vacuum criterium) which is defined by the correlation length of characteristic dual gauge field. The size above mentioned is blows up when the temperature approaches the critical value, where GL parameter tends to infinity as correlation length becomes large enough.
The results are the subject to the physical programs at accelerators to seach the hadronic matter produced at extreme conditions.

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Correlations of anisotropic flow in relativistic heavy-ion collisions at the LHC

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Anisotropic flow is one of the key observables used to probe the properties and evolution of the hot and dense matter produced in heavy-ion collisions.
It was recently realized that event-by-event initial geometry fluctuations in heavy-ion collisions lead to a new type of correlation between different order anisotropic flow, which has unique sensitivity to initial conditions and shear viscosity over entropy density ratio η/s.
In this talk, I discuss the correlation strength between various anisotropic flow harmonics, named (normalized-)symmetric cumulants, in both transport and hydrodynamic model calculations. In addition, the correlations between different order flow symmetry plane will be presented. The results can be naturally understood with recent development of non-linear hydrodynamic response of the created hot and dense matter to initial anisotropy coefficients. A detailed comparison of model calculations and recent experimental measurement, is also presented. Last but not least, I will show how to improve the current development of global Bayesian analysis on constraining the initial conditions and the extraction of the properties of the created QGP in relativistic heavy-ion collisions.

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Transverse energy per charged particle at LHC: Is it a signature of non-equilibrium or gluon saturation?

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The pseudorapidity density of transverse energy per charged particle ($\frac{dE_T}{d\eta}/\frac{dN_{ch}}{d\eta} \equiv E_T/N_{ch}$) is an important
observable in high energy heavy-ion collisions, which reveals about the mechanism of particle production and the freeze-out criteria. Its collision energy and centrality dependence is exactly like the chemical freeze-out temperature till top RHIC energy and the LHC measurement at 2.76 TeV brings up a challenge to understand the same from the point of view of gluon saturation or non-equilibrium phenomena being prevalent at high energies. The statistical hadron gas model (SHGM) with a static fireball approximation has been successful in describing both the centrality and energy dependence till top RHIC energies. However, the SHGM predictions for higher energies are highly underestimated by the LHC data. In order to understand this, we have incorporated radial flow effect in an

excluded volume SHGM. The hard-core radius of baryons at lower collision energies plays an important role in the description of a hadronic system. In view of this, in order to make a complete energy dependence study from FAIR to LHC energies, we have considered the excluded volume SHGM. Our studies suggest that the collective flow plays an important role in describing E_T/N_{ch} and it could be one of the possible parameters to explain the jump observed in E_T/N_{ch} from RHIC to LHC energies. We make a comparative study of gluon saturation picture with the finding of the discussed dynamical SHGM at high energies, in order to explain the above behaviour in experimental data. In contrast to the gluon saturation picture, the excluded volume SHGM gives a clear picture over a broad range of energies from few GeV to TeV.

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Is Longitudinal scaling of multiparticle production valid at LHC ?

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Limiting fragmentation (LF) or the longitudinal scaling is a well-studied phenomenon in multiparticle production processes observed at various heavy-ion collision experiments and in different types of colliding systems like- e^+e^-, $pp(\bar{p})$. It is interesting to verify the validity of this phenomenon at LHC energies. We study this phenomenon using the rapidity spectra of pions starting from AGS to LHC energies. The hard-core radius of baryons at lower collision energies plays an important role in the description of a hadronic system. For an energy dependence study of LF hypothesis, we use an excluded volume statistical hadron gas model (SHGM) with the dynamics encoded in the collective flow in longitudinal as well as in the transverse direction. Our analysis points to the validity of limiting fragmentation in the rapidity spectra of pions at energies from AGS to below top RHIC energy, while its violation at top RHIC and LHC energies. This is in accordance with the basic requirement of the LF hypothesis, which requires a constant inelastic interaction cross-section (σ_{inel}) with collision energy and in turn, the recent ATLAS results show a clear energy dependence of σ_{inel}. Hence a violation of LF hypothesis at higher energies is expected. Our findings go inline with the above expectations. We give prediction for the higher LHC energies, where these studies could be tested. In addition, we give a clear micro and macroscopic description of the LF phenomena.

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Transverse Momentum Spectra and Nuclear Modification factor in Pb+Pb collisions at $\sqrt{s_{NN}}$ =2.76 TeV using non-extensive statistics

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Search for Quark-Gluon Plasma (QGP) and characterization of the matter formed at high temperature and energy density are the major goals of studying ultra-relativistic heavy-ion collisions at RHIC and the LHC. The bulk properties of QGP are governed by the light quarks and the heavy quarks are important probes of QGP as they are produced during initial hard scattering and they witness the entire plasma evolution. Due to the parton (quarks and gluons) energy loss in the medium, suppression in particle yields is observed in nucleus-nucleus collisions relative to pp collisions, where the formation of a medium is usually not expected. This medium modification is measured by the nuclear modification factor (RAA). In this contribution, the RAA is derived using the relaxation time approximation of the Boltzmann Transport Equation (BTE). The initial distribution is represented by thermodynamically consistent Tsallis distribution and the final distribution includes both the equilibrium and Tsallis distribution. The equilibrium distribution is represented by Boltzmann-Gibbs (BG) distribution and Boltzmann-Gibbs blastwave (BGBW) distribution separately. The experimental data from LHC are analyzed in this framework. It is shown that, the proposed approach explains the transverse momentum spectra and RAA of light as well as heavy flavored hadrons over wide range of transverse momenta at LHC. In addition, the mass ordering of the radial flow and relaxation time is shown.

In this formalism, we find that the final distribution function describes the transverse momentum spectra and the nuclear modification factor of pions, kaons, protons, K^{*0} and ϕ upto considerably high p_T. The extracted radial flow seems to be mass dependent and favors a hydrodynamic behavior. R_{AA} is found to be independent of the degree of non-extensivity, q_{pp} after $p_T \sim 8$ GeV/c. The flatness in R_{AA}, which is seen in higher-p_T, is observed to shift towards lower-p_T for higher q_{pp}-values. The non-extenisvity parameter, q_{pp} is mass dependent and it decreases for higher mass particles. Higher mass particles have a tendency of fast equilibration. The inclusion of radial flow, β_r in the theory, favours the non-extensivity, as is expected intuitively.

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Multiplicity Dependence of Thermodynamic Parameters for Strange and Multi-Strange Hadrons in Proton-Proton Collisions at $\sqrt{s}$ = 7 TeV at the LHC

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The transverse momentum (p_{T}) spectra in proton-proton collisions at $\sqrt{s}$ = 7 TeV, measured by the ALICE experiment at the LHC are analyzed with a thermodynamically consistent Tsallis distribution. The information about the freeze-out surface in terms of freeze-out volume, temperature and the non-extensivity parameter, q, for K^0_S, $\Lambda + \bar{\Lambda}$, $\Xi^- + \bar{\Xi}^+$ and $\Omega^- + \bar{\Omega}^+$ are extracted by fitting the p_{T} spectra with Tsallis distribution function. The freeze-out parameters of these particles are studied as a function of charged particle multiplicity density ($dN_{ch}/d\eta$). In addition, we also study these parameters

as a function of particle mass to see any possible mass ordering. The strange and multi-strange particles show mass ordering in volume, temperature, non-extensive parameter and also a strong dependence on multiplicity classes.

It has been observed that the Tsallis distribution provides a very good description of the transverse momentum distributions of strange and multi-strange particles produced in $p + p$ collisions at $\sqrt{s}$ = 7 TeV without incorporating the radial flow. The parameters obtained show variations with the multiplicity in the collision. Notably is the variation of the non-extensive parameter, q which decreases towards the value one as the multiplicity increases, except for the K^0_s, which shows no clear dependence. This shows the tendency of the produced system to equilibrate with higher multiplicities. This goes inline with the expected multi-partonic interactions, which increase for higher multiplicities in $p + p$ collisions and is thus responsible for bringing the system towards thermodynamic equilibrium. The variable T shows a systematic increase with multiplicity, the heaviest baryons showing the steepest increase. This is an indication of a mass hierarchy in particle freeze-out. The radius has a tendency to remain constant at high multiplicities. These changes have implications for the kinetic freeze-out conditions where the heavy multi-strange hadrons are seen to have an earlier kinetic freeze-out, meaning they come from a smaller volume at a higher temperature. These results show that the Tsallis distribution is an excellent tool to analyze high-energy $p + p$ collisions.

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Baryon Stopping at RHIC Beam Energy Scan and its Possible Effect on net-protons higher moment analysis

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One of the main motivations of heavy ion collision is to explore the QCD phase diagram of strong interaction. In the QCD phase diagram, at large μ_B the existence of critical point (CP) is expected. It is believed that, the non-monotonic behavior of higher moments of the distribution of conserved numbers with $\sqrt{s_{NN}}$ is a probe of the QCD critical point. The net-proton $\kappa\sigma^2$, measured by STAR experiment [1] hints for the possibility of existence of critical point around $\sqrt{s_{NN}}$ = 19.6 GeV. However, the measured protons by STAR experiment contain the protons from heavy resonance decay, from baryon stopping and from production.

Since there is a significant contribution of stopped protons at RHIC lower energies it will be important to quantify the stopped protons in their acceptance. Also, these stopped protons fluctuate from event-to-event, which can contribute to the net-proton fluctuations significantly. In the present work we formulate a procedure to estimate the stopped protons in the STAR acceptance [2]. Further, we briefly discuses it's implication to the net-proton fluctuation results by STAR experiment.

References:

[1] "Energy Dependence of Moments of Net-proton Multiplicity Distributions at RHIC"
L. Adamczyk et al.[STAR Collaboration], Phys. Rev.Lett.112, 032302 (2014).

[2] "Estimation of Stopped Protons at RHIC BES Energies"
arXiv:1611.05078 (Phys. Rev. C (In Press))

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Femtoscopy and correlation studies in A+A, p+p , p+A and e+-e- collisions at relativistic, intermediate and low energies / 13

HBT in collisions of Au(1.23A GeV)+Au measured with HADES@SIS18

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We present first results on identical pion intensity interferometry (HBT) studied in collisions of Au$(1.23A\mathrm{GeV})$+Au. The data are taken with the HADES spectrometer at SIS18/GSI Darmstadt. We study the dependence of the space-time extent of the pion emitting source on the pair transverse momentum and on the collision centrality. We compare our femtoscopic findings taken at an available energy of $\sqrt{s_{NN}} = 2.4$ GeV to similar results derived at higher collision energies, both with fixed-target and collider experiments. A surprising uniformity of the three-dimensional (Bertsch-Pratt parameterized) source is found, extending now over three orders of magnitude in collisions energy from LHC over RHIC, SPS, and AGS down to the virtually lowest one at SIS18.

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PHENIX results on three particle Bose-Einstein correlations in $\sqrt{s_{\mathrm{NN}}}$ = 200 GeV Au+Au collisions

Authors: Mate Csanad[1]; Tamas Novak[2]

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Bose-Einstein correlations of identical hadrons reveal information about hadron creation from the sQGP formed in ultrarelativistic heavy ion collisions. The measurement of three particle correlations may in particular shed light on hadron creation mechanisms beyond thermal/chaotic emission. In this talk we show the status of PHENIX measurements of three pion correlations as a function of momentum differences within the triplets. We will analyze their shape through the assumption of

Levy sources and a proper treatment of the Coulomb interaction within the triplets. We plan to determine Levy parameters scale (R), shape (α) and three particle correlation strength (λ_3), where the latter, together with two particle correlation strength λ_2, encodes information about hadron creation mechanisms. From a consistent analysis of two- and three-particle correlation strength we may be able to establish an experimental measure of thermalization and coherence in the source.

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Collision energy and centrality dependent HBT Levy analysis in Au+Au collision at RHIC PHENIX experiment

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Investigation of the femtoscopic correlation functions in heavy ion reactions is an important tool to access to the space-time structure of the hadron production of the sQGP. The description of the measured correlation functions is often assumed to be Gaussian, but a detailed analysis reveals that the statistically correct assumption is a generalized Gaussian, the so-called Lévy distribution. One of the resulting source parameters, the Lévy stability parameter alpha, describing the shape of the source, is related to one of the critical exponents (the so-called correlation exponent eta), and thus may shed light on the location of the critical endpoint on the phase diagram. In this talk we present the status of the measurement of two-pion Bose-Einstein correlation functions in Au+Au collisions at PHENIX. We investigate the collision energy, centrality and transverse mass dependence of the Lévy parameters of the correlation functions: the strength or the intercept parameter lambda, the Lévy scale parameter R and the Lévy stability parameter alpha.

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PHENIX results on Bose-Einstein correlation functions using a Levy analysis in Au+Au collisions at RHIC

Authors: Sándor Lökös[None]; Mate Csanad[1]

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The RHIC beam energy scan program allows for the investigation of the phase diagram of QCD matter by varying the beam energy in the region where the change from crossover to first order phase transition is expected to occur. The nature of the quark-hadron transition can be studied through analyzing the space-time structure of the hadron emission source. One of the best tools to gain information about the source is the measurement of Bose-Einstein or HBT correlations of identical bosons. In recent measurements, we utilize Levy-type sources to describe the measured correlation functions. In this presentation we report the detailed measurement of the Levy source parameters as a function of transverse mass in Au+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV. In particular

we discuss the observation of a new scaling parameter, $\hat{R}$, as well as the shape of the correlation strength versus transverse mass ($\lambda(m_T)$) and its relation to the η' mass.

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Effect of a Hubble-expanding random field on the strength of multi-particle quantumstatistical correlation functions

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Quantum statistical correlation measurements represent an important tool to obtain information about the space-time structure of the particle emitting source. There are several final state effects which may modify the measured femtoscopic correlation functions and hence they have to be considered. One of these is the Coulomb-interaction (in case of charged particles), another (in case of protons) is the strong interaction. An other important effect may be the interaction of the investigated particles with the expanding cloud or fireball of the other final state particles. This may cause the trajectory of the particles to be modified. This effect could be interpreted as an Aharonov–Bohm-like effect in the sense the possible paths of pair represent a closed loop with an internally present field. In my talk I present the possible role of this effect in heavy ion experiments with an analytical calculation and a toy model simulation. We investigate the modification of the strength of the Bose–Einstein correlation functions and propose a measurable quantity from the toy model, sensitive to this effect.

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Measurement of the sixth order cumulant of net-proton multiplicity distribution in Au+Au collisions at $\sqrt{s_{NN}}$~=~200~GeV from the STAR experiment

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Cumulants of conserved quantities are the powerful tools to study the QCD phase structure. According to the Lattice Gauge Theory calculation, at small μ_B a "smooth cross-over" for the transition from QGP to hadronic system occurs in heavy-ion collisions [1]. One of the possible ways to test the prediction is to measure the higher order cumulants of net-baryon or net-charge multiplicity distribution [2]. Net-proton multiplicity distributions can be studied as a reasonable proxy for net-baryon distributions [3].

The STAR experiment measured the fourth order cumulant ratio ($\kappa\sigma^2 = C_4/C_2$) of net-proton multiplicity distribution in Au+Au collisions and its value was ~ 0.92 at $\sqrt{s_{NN}}$ =200 GeV, which is consistent with the model prediction of a hadronic gas [4].
Generally the higher order cumulant is measured, the more sensitive it is to the correlation length. Thus one might observe the fluctuations caused by the smooth crossover through the measurements of higher order cumulants. In this talk, we present the centrality, rapidity and transverse momentum dependencies of the sixth order cumulant ratio (C_6/C_2) of net-proton multiplicity distribution in Au+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV.

[1] Y. Aoki, G. Endrodi, Z. Fodor, S. D. Katz and K. K. Szabo, Nature, 443, 675 (2006)

[2] B. Friman, F. Karsch, K. Redlich, V. Skokov, Eur. Phys. J. C 71, 1694 (2011)

[3] M. Kitazawa, M. Asakawa, Phys. Rev. C. 86, 024904 (2012)

[4] Xiaofeng Luo (for the STAR collaboration), Proceedings, 9th International Workshop on Critical Point and Onset of Deconfinement (CPOD 2014), Vol. CPOD2014 (2015)

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Examination of the heavy ion collisions using EPOS model in frame of BES program

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Collisions of heavy-ions are major method used to study properties of matter. Such studies are performed with comparison of experimental data and model simulations.

One of theoretical description is Parton-Based Gribov-Regge theory included in the phenomenological model EPOS. It was originally created to explain the processes at the highest energies obtained with LHC complex. EPOS gives possibility to study different observables what helps to understand better processes present during not only as proton-proton collisions but also as during much more complex reactions with heavy-ions. Various collision energy scans are considered as well.

So far the EPOS model have been used to describe higher collision energies obtained with RHIC complexes and LHC data. However, there is another interesting program currently under investigation at RHIC: Beam Energy Scan (BES), conducted at Brookhaven National Laboratory. Main goals of this project are to examine the Phase Diagram, study the characteristics of the first- order phase transition between Hadron Gas and Quark Gluon Plasma phases of nuclear matter. The search of Critical Point between first-order phase transition and transition of "cross-over" is another absorbing topic. RHIC, one of the biggest accelerators in the world, collides beams of Au nuclei at selected energies as: $\sqrt{s_{NN}} - 7.7, 11.5, 19.6, 27, 39$ and 62.4 GeV. The variety of initial conditions provides covering as widest part of Phase Diagram of nuclear matter as possible.

Simulated with EPOS data will be verified using two-particles femtoscopic correlations, which allow one to measure the size of sources determined by newly created particles. The studies of elliptic flow will be performed as well.

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Global polarization of Lambda hyperons in Au+Au Collisions at RHIC BES

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Non-central heavy-ion collisions have large ($\sim 10^3\hbar$) angular momentum which may be transferred, in part, to the quark-gluon plasma through shear forces that generate a vortical substructure in the hydrodynamic flow field. The vortical nature of the system is expected to polarize emitted hadrons along the direction of system angular momentum. Λ and $\overline{\Lambda}$ hyperons, which reveal their polarization through their decay topology, should be polarized similarly.

These same collisions are also characterized by dynamic magnetic fields with magnitudes as large as 10^{14} Tesla. A splitting between Λ and $\overline{\Lambda}$ polarization may signal a magnetic coupling and provide a quantitative estimate of the field strength at freeze out.

This presentation will cover the first observation of a global hyperon polarization in non-central Au+Au collisions at Beam Energy Scan energies as well as the dependence of this signal on Λ kinematic variables (ϕ, y, and p_T).

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Correlation Analysis Tool using the Schrödinger equation

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Femtoscopy is a method used to investigate particle correlations by using the experimentally accessible two-particle momentum correlation function C_k. This function can be mathematically obtained by integrating the product of the source function and the two-particle wave function. The main goals of femtoscopy are to investigate the properties of the emission source and the interaction potential between particles.

Currently there is a lot of focus on investigating hyperon-nucleon interactions, e.g. by using experimental data collected by ALICE at LHC and by HADES at GSI. In order to interpret the results one should be capable of obtaining the theoretical C_k for a given source and interaction potential. Presently there are tools capable of performing those tasks, however most of them are not tuned to work with very small sources (below 1-1.5 fm) or are not flexible enough to be incorporated without significant modifications into any external analysis framework. This motivated the development of a C++ software tool called "Correlation Analysis Tool using the Schrödinger equation" (CATS) which relies entirely on numerical methods to evaluate the correlation function. The tool is designed to

handle any short-range potential with or without the inclusion of the Coulomb interaction and/or quantum statistics. The wave function is computed by solving the Schrödinger equation fully numerically and thus obtaining an accurate solution for any source size. Furthermore CATS is capable of working with either an analytical or a data-defined source. This allows to extract the emission source from transport models.

The methods used by CATS and the first results obtained using this tool will be presented in this talk. There will be a detailed discussion of those results and how they relate to experimental data and other theoretical calculations of the correlation function, e.g. using the Correlation Afterburner (CRAB) or the Lednický model.

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Study of Lambda polarization at RHIC BES energies and beyond

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In hydrodynamic approach to heavy ion collisions, hadrons with nonzero spin produced out of the fluid can acquire polarization via spin-vorticity thermodynamic coupling mechanism [1]. The hydrodynamical quantity steering the polarization is the thermal vorticity, that is minus the antisymmetric part of the gradient of four-temperature field $\beta^\mu = u^\mu/T$.

Based on this idea, it has been shown in the framework of cascade+viscous hydro model, UrQMD+vHLLE [2] that in Au-Au collisions at RHIC Beam Energy Scan (BES) the mean polarization of Lambda hyperons grows with decreasing collision energy up to 1.5% at sqrt{s}=7.7 GeV RHIC Au-Au collisions. This goes in line with recent measurements of Lambda polarization by STAR experiment [3].

We complement the existing Lambda polarization studies at RHIC BES [1] by exploring:

- polarization splitting between Lambda and anti-Lambda, and related effect of magnetic field at hadronization,
- centrality dependence and connection between angular momentum of the system and polarization of produced Lambda,
- longitudinal component of polarization, which persists at high (full RHIC and LHC) energies.

[1] F. Becattini, V. Chandra, L. Del Zanna, E. Grossi, Ann. Phys. 338 (2013) 32.

[2] I. Karpenko, F. Becattini, Eur. Phys. J. C (2017) 77: 213

[3] STAR collaboration, arXiv:1701.06657

List of tracks:

Chiral magnetic effect and wave, chiral vortical effect

Femtoscopy at RHIC and LHC: links to QGP physics / **23**

K0s-Kch femtoscopy in Pb-Pb collisions at sqrt(sNN) = 2.76 TeV and pp collisions at sqrt(s) = 7 TeV from the LHC ALICE experiment

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Femtoscopic correlations between K^0_S and $K^{\pm}$ are studied for the first time. Unlike the case of identical-kaon pairs which have correlations from quantum statistics and, if charged, the Coulomb interaction, $K^0_S K^{\pm}$ correlations can only take place through a strong final-state interaction. Analyses were performed on data from Pb-Pb collisions at $\sqrt{s_{\rm NN}} = 2.76$ TeV and pp collisions at $\sqrt{s} = 7$ TeV measured by the ALICE experiment. The observed correlations are found to be consistent with final-state interactions proceeding via the $a_0(980)$ resonance. The extracted radius and lambda parameters for $K^0_S K^-$ are found to be equal within the experimental uncertainties to those for $K^0_S K^+$ in each case. Comparing the results of the present study with those from published identical-kaon femtoscopic studies by ALICE, constraints are placed on the $a_0(980)$ mass and coupling parameters. In addition, the results from the present study are used to address the question of the quark composition of the $a_0(980)$ resonance, and suggest that it is a tetraquark state.

List of tracks:

Resonance decays at low, intermediate and at RHIC and LHC

Fluctuation in initial conditions, collective flow and correlations / **24**

Azimuthal Anisotropy of Particles from Asymmetric Systems Measured in PHENIX at the RHIC

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The study of azimuthal anisotropy of particles produced in Heavy Ion collisions provides strong constrains to the evolution of the strongly coupled QCD medium and its event-by-event geometry fluctuations. The strength and predominance of these observables have long been identified as a manifestation of a strong collective behaviour in the formed medium.
However recent measurements of non-zero anisotropy in small systems both at RHIC and LHC have posed new questions: How small can a system be and still present collective effects? Are there other mechanisms different from collectivity that could give rise to such high degree of anisotropy?
Experimentally we can address these questions by a systematic study of azimuthal correlations for different collision systems. These studies are being pursued by the PHENIX experiment profiting from the different beam configurations in the RHIC during the last years. In this talk I will present the latest results from PHENIX on azimuthal anisotropy obtained from a variety of collisional systems and using different techniques.

List of tracks:

Fluctuation in initial conditions, collective flow and correlations

Chiral magnetic effect and wave, chiral vortical effect / 25

The search for magnetic-induced charged currents in Pb-Pb collisions with ALICE

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In non-central heavy-ion collisions unprecedented strong magnetic fields are expected to be produced (O 1018 Gauss), whose interplay with quantum anomalies of the Quark-Gluon Plasma (QGP) has been predicted to lead to a number of interesting phenomena, such as the Chiral Magnetic Effect (CME). While several experimental observations are partially consistent with predictions of a CME signal, it is often hard to distinguish them unambiguously from a combination of more mundane phenomena present in the anisotropic expansion of the QGP. This makes it imperative to establish that the early-time magnetic field has observable consequences on final-state charged particles and to calibrate its strength. We test a recent prediction of a pure electromagnetic effect which may arise in heavy-ion collisions. The varying magnetic field would induce a current within the QGP, which is expected to leave a very peculiar imprint on final-state particles: a contribution to directed flow which is asymmetric both in charge and pseudorapidity. We report the measurement of such an effect for unidentified charged particles in Pb-Pb collisions at √sNN = 5.02 TeV.

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Chiral magnetic effect and wave, chiral vortical effect

Charge fluctuations, correlations and balance functions / 26

Angular correlations of pions, kaons, protons and lambdas in 7 TeV pp collisions with ALICE

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Two-particle angular correlations are a robust tool which allow the explaration of the underlying physics phenomena of particle production in collisions of both protons and heavy ions by studying the distributions of angles in $\Delta\eta\Delta\phi$ space (where $\Delta\eta$ is the pseudorapidity difference and $\Delta\phi$ is the azimuthal angle difference between two particles). These correlations open up the possibility to study a number of mechanisms simultaneously. Many phenomena, including mini-jets, elliptic flow, Bose-Einstein correlations, resonance decays, conservation laws, are sources of these correlations.

In this talk, we report measurements of the correlations of identified particles and their antiparticles (for pions, kaons, protons, and lambdas) at low transverse momenta in pp collisions at sqrt(s) = 7 TeV, recently submitted for publication by the ALICE Collaboration [arXiv:1612.08975]. The analysis of identified particles in pp collisions reveals differences in particle production between baryons and mesons, which reflect the specific conservation laws for these quantum numbers. The correlation functions for mesons exhibit the expected peak dominated by effects of mini-jet fragmentation and are reproduced well by general purpose Monte Carlo generators. For baryon pairs where both particles have the same baryon number, a near-side anti-correlation structure is observed instead of a peak. Such effects have usually been connected to conservation laws in e^+e^- collisions and were thought to be under theoretical control; however, our results present a challenge to the contemporary models (PYTHIA, PHOJET). This surprising effect is further interpreted in the context of baryon production mechanisms in the fragmentation process.

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Fluctuation in initial conditions, collective flow and correlations

Charge fluctuations, correlations and balance functions / **27**

Forward-backward correlations between multiplicities and event-mean transverse momenta in pp and Pb-Pb collisions with ALICE

Author: Igor Altsybeev[1]

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Forward-backward (FB) correlations are usually measured between observables obtained in an event-by-event analysis in two separated pseudorapidity intervals. Such correlations are considered to be a powerful tool for the exploration of the initial conditions of hadronic interactions. The conventional observable for the FB correlations analysis is the charged particle multiplicity. FB correlations between multiplicities were measured by ALICE
in pp collisions at $\sqrt{s} = 0.9$, 2.76 and 7 TeV. For Pb-Pb collisions, besides the multiplicity, we studied FB correlations using an intensive observable, namely the event-averaged transverse momentum of particles measured in each of the two pseudorapidity intervals. The strength of the FB correlations between event-mean transverse momenta is robust against volume fluctuations and thus the centrality determination methods, which provides higher sensitivity of this quantity to the properties of the initial state and evolution of the medium created in AA collisions. The magnitude of the FB correlation strength is obtained at different centralities of the Pb-Pb collisions measured at $\sqrt{s_{\rm NN}} = 2.76$ and 5.02 TeV with the ALICE detector. Results are compared to event generators and to a Monte Carlo model with fusion of quark-gluon strings.

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Fluctuation in initial conditions, collective flow and correlations

Femtoscopy at RHIC and LHC: links to QGP physics / **28**

Kaon femtoscopy in Au+Au collisions at $\sqrt{s_{\rm NN}} = 200$ GeV at the STAR experiment

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In contrast to the traditional femtoscopic analysis of identical pions, measurements with kaons can serve as a cleaner probe as they are less affected by resonance decays. Kaons contain strange quarks and have smaller cross section with hadronic matter than pions, so they may be sensitive to different effects and/or earlier collision stages.

Moreover, non-identical kaon femtoscopy can provide complementary information to the measurements at very low relative momenta. It has been predicted that correlations due to the strong final-state interaction in a system with a narrow resonance will be sensitive to the source size in the

resonance region. The unlike-sign kaon pairs are particularly suitable for such measurements because of the narrow $\phi(1020)$ resonance.

In this talk, I will present the STAR preliminary results on femtoscopic measurement of kaon correlations from the high-statistics dataset of Au+Au collisions at $\sqrt{s_{\rm NN}} = 200$ GeV. The kaon source is measured as a function of the centrality and the transverse pair mass $m_{\rm T}$. The high-statistics measurement enables the extraction of freeze-out parameters using Blast-Wave parameterization.

The sensitivity of the unlike-sign kaon correlation function in the resonance region is systematically studied as a function of the centrality and transverse pair momenta $k_{\rm T}$. Experimental results are compared with Lednický's model including the final-state interaction as well as the resonance within the femtoscopic framework.

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Femtoscopy at RHIC and LHC: links to QGP physics

Fluctuation in initial conditions, collective flow and correlations / 29

Angular correlation measurements in Pb-Pb collisions by ALICE

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Angular correlation measurements are powerful tools to study jets in a transverse momentum ($p_{\rm T}$) regime where jet reconstruction algorithms are difficult to use because of the large fluctuating background. In such measurements, the relative azimuthal angle ($\Delta\varphi$) and relative pseudorapidity ($\Delta\eta$) of particle pairs is measured. Jets manifest themselves as a peak around $(\Delta\varphi, \Delta\eta) = (0, 0)$, and by studying the centrality and momentum dependence of the shape of the peak in heavy-ion collisions, the interaction of the jets with the produced flowing medium can be studied.

In this contribution, results from angular correlation measurements in Pb-Pb collisions from the ALICE experiment will be presented. It will be shown that the near-side peak broadens in central events at low $p_{\rm T}$, and that a novel feature, a depletion around $(\Delta\varphi, \Delta\eta) = (0, 0)$, appears at low $p_{\rm T}$ in the most central events. These results will be compared to results from pp collisions and to Monte Carlo generators to study the effects of the flowing medium in heavy ion collisions.

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Fluctuation in initial conditions, collective flow and correlations

Femtoscopy and correlation studies in A+A, p+p , p+A and e+-e- collisions at relativistic, intermediate and low energies / 30

Identical charged kaon femtoscopic correlations in p-Pb collisions at sqrt(sNN) = 5.02 TeV with Alice at the LHC

Author: Elena Rogochaya[1]

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Particle correlations at small relative momenta due to quantum statistics effects and final-state interactions are used to measure the space-time characteristics of particle production on the femtoscopic (fm=10^{-15} m) level in high-energy collisions. Kaons are a convenient tool to study, in particular, for Bose-Einstein correlations. They are less influenced by resonance decays than pions and therefore more effectively probe directly-produced particles.

In this talk, correlations of two charged identical kaons measured in p-Pb collisions at $\sqrt{s_{\rm NN}}$ = 5.02 TeV by the ALICE experiment at the LHC are presented. The femtoscopic invariant radii and correlation strengths are extracted from the one-dimensional kaon correlation functions and are compared to those obtained in pp at $\sqrt{s}$ = 7 TeV and Pb-Pb at $\sqrt{s_{\rm NN}}$ = 2.76 TeV collisions. Kaon femtoscopy in p-Pb is an important supplement to that in pp and Pb-Pb collisions because it allows one to understand the particle production mechanisms at different multiplicities. It also complements the existing pion correlation results. The obtained radii increase at higher multiplicities and decrease with increasing pair transverse momentum. At comparable multiplicity, the radii measured in p-Pb collisions are comparable to those observed in pp collisions and seem to be below those observed in Pb-Pb collisions.

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Femtoscopy in A+A, p+p , p+A and e+-e- collisions at relativistic, intermediate and low energies

Charge fluctuations, correlations and balance functions / **31**

Jet fragmentation in two particle correlation in Pb-Pb sqrt(sNN)=2.76 TeV

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The modification in jets measured in heavy-ion collisions as compared to jets measured in pp collisions is a rich source of information on the medium properties. The medium-induced modifications are typically seen more clearly at low-$p_{\rm T}$, where full jet reconstruction is difficult due to the very large background in heavy ion collisions. Two-particle correlations provide a way to study jets in the low- and intermediate-$p_{\rm T}$ regime. Jet fragmentation is observed as a peak around $(\Delta\eta, \Delta\phi) = (0, 0)$ in two-particle correlations, where $\Delta\eta$ and $\Delta\phi$ are the differences in pseudorapidity and azimuthal angle, respectively, between a trigger particle and associated particles.

In this talk, we will present ALICE measurements of $I_{\rm AA}$, the jet peak yield in Pb-Pb divided by the yield from pp collisions, at $\sqrt{s_{\rm NN}} = 2.76$ TeV. From $\Delta\eta$-dependent $I_{\rm AA}$, we observe that jets with $6<p_{\rm T,trig.}<8$ GeV/c and $8<p_{\rm T,trig.}<15$ GeV/c show a narrowing in pseudorapidity. This effect is prominent in central collisions and for high trigger momentum while it vanishes in peripheral collisions or for low trigger momentum. From the integrated, $p_{\rm T}$-dependent $I_{\rm AA}$ we see enhancement at low-$p_{\rm T}$ in central collisions. These observations can be used to constrain energy loss models, particularly models that predict broadening of the jet by interactions with the medium.

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Charge fluctuations, correlations and balance functions

Chiral magnetic effect and wave, chiral vortical effect / **32**

Electromagnetic fields in p+Pb collisions

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We study the correlation between the primordial electromagnetic (EM) fields $\vec{E}$ and $\vec{B}$ and the initial matter geometry in p+Pb collisions. The angular correlation between $\vec{B}$ and the second eccentricity harmonic $\vec{\varepsilon}_2$ is substantially diminished in p+Pb compared to heavy ion collisions (HICs), while those between $\vec{E}$ and the first eccentricity harmonic $\vec{\varepsilon}_1$ is of similar magnitude. Unlike in HICs, the EM fields in p+Pb are mainly sourced by the protons in the same nucleus and this results in non-zero angular correlations between the $\vec{E}$ and $\vec{B}$ fields. This gives rise to interesting phenomenological consequences for heavy quark flow and chiral magnetic effects in p+Pb.

List of tracks:

Chiral magnetic effect and wave, chiral vortical effect

Fluctuation in initial conditions, collective flow and correlations / 33

Higher-order anisotropies in the Blast-Wave Model

Author: Jakub Cimerman[1]

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The hot matter excited in ultrarelativistic heavy-ion collisions exhibits a sizeable anisotropy in particle production. We formulate a generalisation of the blast-wave model which is suitable for description of higher order azimuthal anisotropies in hadron production. The model includes anisotropy in density profile as well as an anisotropy in the transverse expansion velocity field. These two kinds of anisotropy influence the single-particle distributions and the correlation radii of two-particle correlation functions. Particularly we focus on the third-order anisotropy and attention is given to the averaging over different orientation of the event plane.

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Fluctuation in initial conditions, collective flow and correlations

Femtoscopy at RHIC and LHC: links to QGP physics / 34

Azimuthally differential pion femtoscopy with respect to second and third order event planes and event shape engineering in Pb-Pb collisions at $\sqrt{s_{NN}}$ = 2.76 TeV

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Azimuthally differential HBT is a powerful tool for investigating the source shape at freeze out.
In heavy ion collisions, the medium expansion through radial and anisotropic flow has been observed.
These hydrodynamic expansions result the deformation of the initial geometry.
Studying the deformation of the source shape by such strong expansion is the key to quantify the dynamics of the system evolution.

The azimuthal anisotropy flow coefficients v_n fluctuate significantly even within a same centrality range due to fluctuations in the participant shape.

Recently, event shape engineering (ESE) has been suggested as a powerful tool to control event-by-event flow fluctuations
by selecting the magnitude of flow vectors q_2 and q_3.
Azimuthally differential HBT with ESE offers the detailed analysis of the relation between anisotropic flow and
the deformation of source shape.

In this talk, we present azimuthally differential pion femtoscopy with respect to second and third order event planes and
the study of how the source eccentricity changes with large q_2 and q_3 cuts.

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Femtoscopy at RHIC and LHC: links to QGP physics

Charge fluctuations, correlations and balance functions / **35**

N-N, PT-N and PT-PT correlations and fluctuations quantified by strongly intensive quantities for nucleus-nucleus collisions measured by the NA61/SHINE experiment at SPS energies

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The NA61/SHINE experiment aims to discover the critical point of strongly interacting matter and study the properties of the onset of deconfinement. For these goals a scan of the two dimensional phase diagram (T-μB) is being performed at the SPS by measurements of hadron production in proton-nucleus and nucleus-nucleus interactions as a function of collision energy and system size.

In this contribution preliminary results on pseudorapidity dependences of transverse momentum and multiplicity fluctuations expressed in terms of strongly intensive quantities from the Be+Be and Ar+Sc energy scan will be presented. It will be shown how non-trivial effects evolve from the poissonian-like fluctuations for small pseudorapidity intervals with expansion of the analyzed acceptance. These fluctuations are expected to be sensitive to the existence of the critical point. The results will be compared to the predictions of the EPOS model.

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Fluctuation in initial conditions, collective flow and correlations

Fluctuation in initial conditions, collective flow and correlations / 36

Anisotropic flow of inclusive and identified particles in Pb–Pb collisions at $\sqrt{s_{\rm NN}} = 5.02$ TeV

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Measurements of azimuthal anisotropic flow provide valuable information on the properties of the matter created in heavy-ion collisions. In this talk we present the elliptic, triangular and quadrangular flow of inclusive and identified charged particles measured in Pb–Pb collisions at $\sqrt{s_{\rm NN}} = 5.02$ TeV recorded by the ALICE detector. The measurements are presented for a wide range of particle transverse momenta within the pseudo-rapidity region $|\eta| < 0.8$. The results are compared to the measurements at lower energy reported by the LHC experiments and also to theoretical predictions.

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Fluctuation in initial conditions, collective flow and correlations

Chiral magnetic effect and wave, chiral vortical effect / 37

Anomalous hydrodynamic modeling of anomalous chiral transport in heavy ion collisions

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Chiral Magnetic Effect (CME) is the macroscopic manifestation of the fundamental chiral anomaly in a many-body system of chiral fermions, and emerges as anomalous transport current in the fluid dynamics framework. Experimental observation of CME is of great interest and has been reported in Dirac and Weyl semimetals. Significant efforts have also been made to search for CME in heavy ion collisions. Encouraging evidence of CME-induced charge separation in those collisions has been reported, albeit with ambiguity due to background contamination. Crucial for addressing such issue, is the need of quantitative predictions for CME signal with sophisticated modelings. In this paper I will introduce a tool developed by us, named the Anomalous Viscous Fluid Dynamics (AVFD) framework, which simulates the evolution of fermion currents in QGP on top of the data-validated VISHNU bulk hydrodynamic flow. With realistic initial conditions and magnetic field lifetime, the AVFD-predicted CME signal could be quantitatively consistent with measured change separation in 200AGeV AuAu collisions.

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Chiral magnetic effect and wave, chiral vortical effect

Fluctuation in initial conditions, collective flow and correlations / **38**

Measurements of two- and multi-particle cumulants in pp, p-Pb and Pb-Pb collisions

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The formation of the QGP in heavy-ion collisions is well established by numerous measurements and their comparison to hydrodynamic models. This matter was not expected to be formed in smaller systems, such as p–Pb or pp collisions. However, in recent years, a growing number of results in small collision systems suggest that this hot and dense medium can be created in high multiplicity p–Pb collisions. Two- and multi-particle cumulants have proven to be an excellent tool to probe the properties of the Quark-Gluon Plasma created in Pb–Pb collisions. Therefore, these measurements play leading role in the investigation of possible signs of collectivity in p–Pb collisions. Recent observations in high multiplicity pp collisions at 13 TeV produced a lot of excitement after the presence of long-range correlations was observed, as well as the negative sign of the measured 4-particle cumulants, which is an indication of collectivity in small systems. However, there are many caveats which must be considered when performing the cumulants measurements in pp collisions. The most important ones are multiplicity fluctuations and non-flow effects, which are able to mimic the signs of collectivity.

In this talk, we will present ALICE measurements of 2- and multi-particle cumulants across different collision systems, with the main focus on small systems. We will discuss latest developements in cumulant measurements that are able to further suppress non-flow effects. Such phenomena are dominant in small systems, therefore this path in the experimental approach is important for the exploration of novel QCD dynamics in small collision systems. These results shed more light into the nature of the created nuclear medium in high energy pp, p–Pb and Pb–Pb collisions.

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Fluctuation in initial conditions, collective flow and correlations

New methods and facilities / **39**

Perspectives of correlation femtoscopy studies at NICA and STAR BES energies.

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The main features of the femtoscopy measurements at top RHIC and LHC energies are considered as a manifestation of strong collective flow and are well interpreted within hydrodynamic models employing equation of
state (EoS) with a crossover type transition between Quark-Gluon Plasma (QGP) and hadron gas phases. The femtoscopy at lower energies was intensively studied at AGS and SPS accelerators and is being studied now in the Beam Energy Scan
program (BES) at the BNL Relativistic Heavy Ion Collider in the context of exploration of the QCD phase diagram. We present femtoscopic observables calculated for Au-Au collisions at $\sqrt{s_{NN}} = 7.7 - 62.4$~GeV in a viscous hydro + cascade model \texttt{vHLLE+UrQMD} and their dependence on the EoS of thermalized matter. We also discuss the perspectives of femtoscopy studies
at NICA energies scale $\sqrt{s_{NN}} = 4 - 11$~GeV.

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New methods and facilities

Femtoscopy at RHIC and LHC: links to QGP physics / **40**

Lambda-Kaon Femtoscopy in Pb-Pb Collisions at 2.76 TeV with ALICE

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Lambda-Kaon Femtoscopy in Pb-Pb Collisions at $\sqrt{s_{NN}}$ = 2.76 TeV with ALICE

We present results from a femtoscopic analysis of Lambda-Kaon correlations in Pb-Pb collisions at $\sqrt{s_{NN}}$ = 2.76 TeV by the ALICE experiment at the LHC. All pair combinations of Λ and $\bar{\Lambda}$ with K^+, K^- and K^0_S are analyzed. The femtoscopic correlations are the result of strong final-state interactions, and are fit with a parametrization based on a model by R. Lednicky and V. L. Lyuboshitz[1]. This allows us to both characterize the emission source and measure the scattering parameters for the particle pairs. We observe a large difference in the Λ-K^+ ($\bar{\Lambda}$-K^-) and Λ-K^- ($\bar{\Lambda}$-K^+) correlations in pairs with low relative momenta (k* $<$ 100 MeV). Additionally, the average of the Λ-K^+ ($\bar{\Lambda}$-K^-) and Λ-K^- ($\bar{\Lambda}$-K^+) correlation functions is consistent with our Λ-K^0_S ($\bar{\Lambda}$-K^0_S) measurement. The results suggest an effect arising from different quark-antiquark interactions in the pairs, i.e. $s\bar{s}$ in Λ-K^+ ($\bar{\Lambda}$-K^-) and $u\bar{u}$ in Λ-K^- ($\bar{\Lambda}$-K^+).

[1] R. Lednicky and V.L. Lyuboshitz, Sov. J. Nucl. Phys. 35, 770 (1982)

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Femtoscopy at RHIC and LHC: links to QGP physics

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Angular correlations of identified particles in the STAR BES data.

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The angular correlation function (CF) refers to the correlation of particles in the relative pseudo-rapidity and relative azimuthal angle. It is used to study strongly interacting matter properties at relativistic energies. Recent results from the ALICE experiment at LHC show unexpected structures of CF in the proton-proton and antiproton-antiproton correlations. Also results from the STAR experiment at RHIC on directed flow (dv_1/dy) for the net-baryons are intriguing. Both observations are suggesting that study of CF of identified particles can provide more detailed insight into nuclear matter properties, in comparison with measurements of unidentified particles.

The STAR capability of identifying particles at mid rapidity, paired with the data from broad energy range of Au+Au collisions in the Beam Energy Scan program, provide unique opportunity to investigate the phase diagram of strongly interacting matter through the CF analysis. In this talk recent STAR experimental results from the Au+Au collisions at $\sqrt{s_{NN}} = (7.7-200)\ GeV$ from the RHIC's Beam Energy Scan will be presented.

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Fluctuation in initial conditions, collective flow and correlations

Femtoscopy at RHIC and LHC: links to QGP physics / **42**

Femtoscopic correlations of pions and kaons measured in the BES program at STAR

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In high-energy heavy-ion collisions, a hot and dense strongly interacting system of deconfined quarks and gluons (sQGP) is created. The Beam Energy Scan program at RHIC was performed to map the QCD phase diagram. Femtoscopy allows one to measure the space-time extent of the particle emitting source created in heavy-ion collisions. In this talk, we present preliminary results of the measurement of like-sign two-pion and two-kaon correlations from the BES program at STAR. Since kaons contain strange quark and have smaller cross-sections, compared to that of pions, with hadronic matter, they may provide additional information about the system evolution. The extracted Bertsch-Pratt radius parameters of kaons are studied as a function of collision centrality and transverse mass (m_T) of the particles and compared to those of pions.

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Femtoscopy at RHIC and LHC: links to QGP physics

Fluctuation in initial conditions, collective flow and correlations / **43**

Transverse momentum fluctuations and correlations

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We study the fluctuations and correlations of the average transverse momentum of particles emitted in heavy-ion collisions. The momentum fluctuations are related to event-by-event fluctuations of the size and entropy of the initial source. Hydrodynamic calculations using a Glauber model with quark degrees of freedom reproduce the data. We study correlation of the average transverse momentum in different rapidity bins. We propose a definition of the observable that can be directly related to correlations of the collective flow variables. The correlation as function of rapidity separation can serve to pin down possible sources of momentum fluctuations in the initial state and the dynamics.

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Fluctuation in initial conditions, collective flow and correlations

Resonance decays at low, intermediate and at RHIC and LHC / 44

Measurement of the production of hadronic resonances in Pb-Pb collisions with ALICE

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The lifetimes of short-lived hadronic resonances are comparable to that of the hadronic phase which is present in the late stages of the evolution of heavy-ion collisions. Thus, these resonances are sensitive to the re-scattering and regeneration processes in the time interval between the chemical and kinetic freeze-out, which might affect the observed resonance yields. Recently, the centrality dependent suppression of several resonances has been observed in Pb-Pb collisions, which possibly indicates the dominance of re-scattering over regeneration processes. In this talk, we present recent results on short-lived hadronic resonances obtained by the ALICE experiment in Pb-Pb collisions at LHC energies for ρ^0, K^{*0}, ϕ, * and *. Results on transverse momentum spectra, yields and their ratios to long-lived particles, and nuclear modification factors will be discussed. The findings will be compared with model predictions and measurements at lower energies.

List of tracks:

Resonance decays at low, intermediate and at RHIC and LHC

Femtoscopy and correlation studies in A+A, p+p , p+A and e+-e- collisions at relativistic, intermediate and low energies / 45

PRODUCTION AND CORRELATIONS OF STRANGE MESONS AND BARYONS AT RHIC AND LHC IN HYDROKINETIC MODEL

Authors: Yuri Sinyukov[1]; Volodymyr Shapoval[1]

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The recent results on the theoretical analysis of particle production and correlation in relativistic heavy-ion collisions at the LHC and RHIC within the hydrokinetic model (HKM) and its extended version — integrated hydrokinetic model (iHKM) are addressed. The study of strange K meson spectrum and femtoscopy scales is discussed along with the pion ones for the case of LHC Pb+Pb collisions at the energy 2.76 TeV per nucleon pair. The m_T-dependence of spectra and longitudinal femtoscopy scales at the LHC, obtained in HKM simulations, is compared with the results given by simple analytical formulas including the effective temperature at the hypersurface of maximal particle emission, emission proper time, and transverse flow intensity. The influence of K*(892) resonance decays and hadron re-scatterings at the afterburner stage of the collision on the interferometry radii is analyzed. The related problem of K*(892) effective identification and reliable yield measurement in view of hadron re-scatterings is also investigated for RHIC and LHC energy cases. The application of the FSI formalism with account for residual correlation effect to modeling of the p-Lambda and p-Cascade correlation functions is also considered.

List of tracks:

Femtoscopy in A+A, p+p , p+A and e+-e- collisions at relativistic, intermediate and low energies

Resonance decays at low, intermediate and at RHIC and LHC / 46

Resonance production in small systems with ALICE

Author: Enrico Fragiacomo[1]

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The production of hadronic resonances such as K*(892)^0, ϕ(1020), Σ(1385)$^{\pm}$, Λ(1520) and $\Xi(1530)^0$ has been measured as a function of multiplicity by the ALICE experiment in pp and p-Pb collisions at various energies at the LHC. These resonances differ by mass and strangeness content and thus can be used to provide insights on the mechanisms driving the recently observed multiplicity-dependent enhancement of strangeness production in small systems. In this talk, we present new measurements of resonance production in pp collisions at $\sqrt{s}$ = 7 and 13 TeV as well as in p-Pb collisions at 5.02 TeV. Results include transverse momentum spectra, average p_{T}, yield ratios to long-lived hadrons in minimum bias collisions and as a function of multiplicity.

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Resonance decays at low, intermediate and at RHIC and LHC

Femtoscopy at RHIC and LHC: links to QGP physics / 47

Proton-Proton, Proton-Antiproton and Antiproton-Antiproton Correlations

Author: Sebastian Siejka[1]

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Through experiments with heavy-ion collisions at high energies we can study the properties of nuclear matter under extreme conditions. The information on the sizes of the particle-emitting sources can be inferred via the method of femtoscopy.

The femtoscopy method uses Quantum Statistics effects and the Final State Interactions to determine the space-time properties of the source. The radii of the sources extracted from two-baryon femtoscopy along with those obtained from two-meson and meson-baryon correlations provide complementary information about the source characteristics.

In this talk, a status report of a STAR analysis of proton and antiproton femtoscopic correlations in Au+Au collisions at $\sqrt{s_{NN}}$ of 39 GeV, 11.5 GeV and 7.7 GeV will be presented.

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Femtoscopy at RHIC and LHC: links to QGP physics

Femtoscopy at RHIC and LHC: links to QGP physics / **48**

Two-particle correlations using THERMINATOR model for BES program.

Authors: Paweł Szymański[1]; Hanna Zbroszczyk[2]

[1] *Warsaw University of Technology*

[2] *Warsaw Univesroty Of Technology*

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THERMINATOR model is dedicated to heavy-ion collisions. Its current description allows one to work with data for the highest collision energies achieved by LHC and RHIC colliders. However it is possible to adapt THERMINATOR model to the lower energy spectrum as is used in Beam Energy Scan (BES) program at RHIC.

Femtoscopy of two particles investigates the properties of matter produced in heavy-ion collisions. It allows one to study the space-time characteristics of the medium.

We present single- and two-particle momentum distributions of particles generated for the energy spectrum for BES program. To verify how model preditions agree with experimental results, we present the correlation functions obtained for identical pions in Au+Au collisions at $\sqrt{s_{NN}} = 7.7 - 39$ GeV.

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Femtoscopy at RHIC and LHC: links to QGP physics

Charge fluctuations, correlations and balance functions / **49**

Multiplicity and forward energy fluctuations in Ar+Sc and Be+Be collisions at the CERN SPS from NA61/SHINE.

Author: Andrey Seryakov[1]

[1] *St Petersburg State University (RU)*

Corresponding Author: andrey.seryakov@cern.ch

Preliminary results for multiplicity and forward energy fluctuations are presented for Be+Be and Ar+Sc collisions at 13A, 19A, 30A, 40A, 75A and 150A GeV/c beam momentum. The data were obtained by the NA61/SHINE detector at the CERN SPS. Centrality selection and forward energy measurement are based on the nucleon spectator energy in the forward hemisphere determined by the Projectile spectator detector. The scaled variance ω of the multiplicity distribution and the strongly intensive measure Ω of multiplicity fluctuations were calculated for all, negatively and positively charged hadrons. The presented Ω quantity shows, in particular, complete elimination of volume fluctuations for the most central Ar+Sc collisions. A comparison with p+p results from NA61/SHINE, Pb+Pb data of NA49 and EPOS 1.99 simulations is shown.

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Charge fluctuations, correlations and balance functions

Fluctuation in initial conditions, collective flow and correlations / 50

Skewness of Event-by-event Elliptic Flow Fluctuations in PbPb collisions at $\sqrt{s_{NN}} = 5.02$~TeV with CMS detector

Author: Elizaveta Nazarova[1]

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

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Event-by-event elliptic flow harmonic distributions $p(v_2)$ are measured in PbPb collisions at $\sqrt{s_{NN}} = 5.02$~TeV using the CMS detector for the integrated p_T range $0.3 < p_T < 3.0$~GeV/c and pseudorapidity range $|eta| < 1.0$. In order to gain insight on the nature of the initial geometry fluctuations, cumulant flow harmonics are calculated from the moments of the v_2 probability distribution $p(v_2)$. A fine-level splitting between the higher-order cumulants is observed. The skewness with respect to the reaction plane is estimated from the cumulants and found to be negative, which suggests a non-Gaussian nature for the initial-state fluctuations, as predicted by hydrodynamic models. These observations suggest a non-Gaussian nature of the initial-state fluctuations. Furthermore, assuming that the flow harmonics are linearly proportional to the initial-state eccentricities, the $p(v_2)$ distributions are fitted using an elliptic power law parameterization to study the initial-state geometry fluctuations.

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Fluctuation in initial conditions, collective flow and correlations

Femtoscopy at RHIC and LHC: links to QGP physics / 51

Azimuthally differential pion femtoscopy collisions relative to the second and third harmonic in Pb-Pb 2.76 TeV collisions from ALICE

Author: Mohammad Ahmad Saleh[1]

[1] *Wayne State University (US)*

Corresponding Author: m.saleh@cern.ch

Azimuthally differential femtoscopic measurements, being sensitive to spatiotemporal characteristics of the source as well as collective velocity fields at freeze-out, provide very important information on the nature and dynamics of
the system evolution. While the radii modulations with respect to the second harmonic event plane reflect mostly the spatial geometry of the source, the third harmonic results are mostly defined by the system dynamics. In this talk, we present the azimuthally differential measurements of the pion source in Pb-Pb collisions relative to the second and the third harmonic event planes as a function of the pion-pair transverse momentum (kT) for different centralities of the collision. The dependence of the side-, out-, and long-radii on the pion-pair emission angle with respect to the second harmonic event plane qualitatively agrees with theoretical calculations, but the details show significant deviations. The final-state source eccentricity, estimated via side radius oscillations, is found to be significantly smaller than the initial-state source eccentricity, but remains positive at all measured kT – an indication of the out-of-plane extended
source even after strong in-plane expansion. The observation of the radii modulations with respect to the third harmonic event plane unambiguously signal a
collective expansion and anisotropy in the flow field. We compare our results to the existing model predictions.

List of tracks:

Femtoscopy at RHIC and LHC: links to QGP physics

New methods and facilities / **52**

The STAR Event Plane Detector - An Upgrade for 2018+

Author: Mike Lisa[1]

[1] *Ohio State University (US)*

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The first phase of the RHIC Beam Energy Scan program (BES-I) has revealed intriguing trends in observables as a function of collision energy in the region $\sqrt{s_{NN}} \sim 7 - 30$ GeV. These include directed flow and global polarization measurements, which require an accurate determination of the first-order event plane. They also include measurement of higher-order moments of the net-proton distribution, which require an accurate determination of the collision centrality in a region well-separated from the zone of interest at midrapidity.

The next phase of the program, BES-II, will explore this region in greater detail, exploring additional collision energies, improving statistics, and implementing detector upgrades. The Event Plane Detector (EPD) is one such upgrade, providing high-segmentation charged-particle measurements at pseudorapidy $2 < |\eta| < 5$. This is expected to roughly double the first-order event plane resolution and provide a separation $\Delta\eta$
$gtrsim1$ between the region used for centrality and that used to calculate the net-baryon moments, greatly reducing uncertainties from hadronic cross-talk.

The detector consists of two wheels, each composed of 372 tiles of scintillator read out by wavelength-shifting fibers optically coupled to silicon photomultipliers (SiPMs). I will discuss the detector design, as well as results from a prototype and a partial install of the full detector in RHIC runs 2016 and 2017, respectively. I will also discuss the production status of the full detector, scheduled for installation at the end of this year.

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New methods and facilities

Resonance decays at low, intermediate and at RHIC and LHC / 53

Non-identical particle correlation analysis in the presence of non-femtoscopic correlations

Author: Adam Kisiel[1]

[1] *Warsaw University of Technology (PL)*

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Femtoscopic correlations of two non-identical particles have a unique feature, differentiating them from "traditional" identical particle correlations, of being sensitive to the difference in average emission position of the two particle types. For pion-kaon pairs the femtoscopic signal arises from Coulomb interaction between particles. Its strength is comparable to the magnitude of effects of non-femtoscopic origin. We identify main sources of these background correlations as real "physics" correlations coming from elliptic flow. We propose a robust method to estimate them and account for their influence in the femtoscopic analysis of experimental data. We validate the proposed correction method on a data sample generated with the THERMINATOR 2 model and provide a recipe for experimentalists.

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Femtoscopy at RHIC and LHC: links to QGP physics

Fluctuation in initial conditions, collective flow and correlations / 54

Kinetic theory equilibration for realistic heavy ion initial conditions

Author: Aleksas Mazeliauskas[None]

Co-authors: Eero Aleksi Kurkela [1]; Jean-Francois Paquet [2]; Soeren Schlichting [3]; Derek Teaney [2]

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We present explicit implementation of effective kinetic theory ("bottom-up") thermalization scenario for the transverse perturbations in a realistic boost invariant initial conditions for heavy ion collisions. Linearized transverse energy and momentum perturbations are propagated by leading order weak coupling kinetic theory response functions to the time when system is described by relativistic hydrodynamics. We demonstrate that the subsequent hydrodynamic evolution is independent of hydro initialization time tau_init in the overlap region and that the kinetic theory pre-equilibrium evolution reproduces the important physics of equilibration and transverse flow dynamics.

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Fluctuation in initial conditions, collective flow and correlations

Resonance decays at low, intermediate and at RHIC and LHC / 55

Measurement of quarkonia production in heavy-ion collisions with the ATLAS detector

Author: Sebastian Tapia Araya[1]

[1] *Federico Santa Maria Technical University (CL)*

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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 interactions of heavy ions at high energy. In addition to hot matter
effects, cold nuclear effects can play an important role in quarkonia production. Therefore, a full assessment of
different physics scenarios requires detailed studies on the effects present in Pb+Pb and p+Pb collisions in
comparison to the pp collisions. Results of the studies based on p+Pb data collected in 2013 and pp and Pb+Pb data
collected in 2015 at the LHC by the ATLAS experiment at the centre of mass energy of 5.02 TeV allowed studying
prompt and non-prompt J/ψ and ψ(2S) productions as well as Y(nS) (n = 1, 2, 3) production via the di-muon decay
final states. The results of the measurements presented as a function rapidity and transverse momentum as well as
the ratios between different species and systems are presented and discussed in the talk.

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Resonance decays at low, intermediate and at RHIC and LHC

Resonance decays at low, intermediate and at RHIC and LHC / 56

Quarkonia in pp, pPb and PbPb collisions with CMS

Author: Emilien Chapon[1]

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Quarkonia are excellent probes of the rich physics at play in heavy ion collisions. They are sensitive to a wide variety of effects, such as sequential melting and regeneration in the QGP and its hydrodynamic evolution, but also shadowing, energy loss and comovers effects. We will review recent results on charmonium (pT > 3 GeV) and bottomonium (pT > 0 GeV) production in pp, pPb and PbPb collisions in CMS: production measurements of J/psi, psi(2S) and upsilon(nS) as a function of transverse momentum, rapidity and centrality (including ratios between different collision systems and states) and the v2 of prompt J/psi.

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Resonance decays at low, intermediate and at RHIC and LHC

New methods and facilities / **57**

Event-by-event fluctuation analyses in view of the ALICE TPC Upgrade

Author: Mesut Arslandok[1]

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By measuring event-by-event fluctuations over an ensemble of events via cumulants or moments of particle multiplicity distributions, one can study the freeze-out conditions in heavy-ion collisions and clarify their relation to the QCD phase transition. Higher order cumulants of fluctuations of conserved quantities like electric charge and baryon number are related to thermodynamic susceptibilities, which can be calculated in the Grand Canonical Ensemble formulation of thermodynamics such as Lattice QCD or statistical models. Cumulants beyond the second order are more sensitive to the underlying physics but require large statistics.

The data collected by ALICE during RUN1 and RUN2 allows for the analysis of the cumulants up to 4th order. In the current detector configuration, the main limitation on the data collection rate is the readout rate of the Time Projection Chamber (TPC), which is the main tracking and PID detector of ALICE. Currently the TPC is equipped with a gating grid that prevents ions from the amplification stage from entering the drift region. This imposes a maximum rate limit of 3.5 kHz. For the upgrade of the TPC the present MWPC-based readout chambers will be replaced by stacks of four Gas Electron Multipliers (GEMs), which allows for continuous read-out and thus an increase by about a factor of 100 in the data collection rate. This will make it possible to extend the measurements of cumulants up to 6th and 8th order, where recent theory calculations predict a rapid change in the net baryon number fluctuations in the crossover region of QCD phase diagram.

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New methods and facilities

Resonance decays at low, intermediate and at RHIC and LHC / **58**

ϕ Meson Measurements at Forward/Backward Rapidity at RHIC with PHENIX Detector

Author: Xiaochun He[1]

[1] *Georgia State University*

Corresponding Author: xhe@gsu.edu

Given the relatively small hadronic interaction cross section, ϕ meson production provides a unique and complimentary method for exploring the hot and dense medium properties created in the relativistic heavy ion collisions. PHENIX measured ϕ production in a wide range of transverse momentum and rapidity in many collision systems. This talk will focus on the ϕ measurements at forward and backward rapidities in p+p, p+Al, p+Au, d+Au, ^{3}He+Au, Cu+Au collisions in the PHENIX experiment at RHIC.

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Resonance decays at low, intermediate and at RHIC and LHC

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Exploring excited States of Nuclei Through Alpha-particle Decay Correlations

Author: Martin Freer[None]

The study of the nature of nuclei above particle decay thresholds is challenging with the more traditional tool of gamma-ray spectroscopy, since the branching ratio for the electromagnetic decay processes is strongly suppressed. However, it is above these thresholds that the structure may also be most rich. As predicted by Ikeda et al, here nuclei can adopt a structure in which the constituent nucleons may condense out into alpha-particles and where the overall nuclear properties may be described in terms of alpha-particle clusters. These clusters may arrange themselves into geometric shapes, or as predicted in recent times, a Bose condensate of alpha-particles. How the experimental decay patterns may be used to reveal the structure of the states in such nuclei is the subject of this talk.

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Resonance decays at low, intermediate and at RHIC and LHC

Chiral magnetic effect and wave, chiral vortical effect / 60

Magnetic field in heavy-ion collisions: case for isobaric collisions

Author: Vladimir Skokov[1]

[1] *Brookhaven national laboratory*

Corresponding Author: v.skokov@gsi.de

In this talk, I will review the current status of theoretical studies of magnetic filed and associated observables in heavy-ion collisions. I will focus on the Chiral Magnetic Effect and discuss new ideas

aiming at its unique identification. Specifically I will present the case for colliding nuclear isobars and report on
theoretical predictions and expectations.

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Chiral magnetic effect and wave, chiral vortical effect

Chiral magnetic effect and wave, chiral vortical effect / 61

Chiral magnetic effect and wave studies with CMS

Author: Sang Eon Park[1]

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Chiral magnetic effect and wave, chiral vortical effect

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Initial states and collectivity in small systems: recent progress and outstanding issues

Author: Wei Li[1]

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Corresponding Author: wei.li@cern.ch

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Fluctuation in initial conditions, collective flow and correlations

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Long-range collectivity in small systems

Author: Jiangyong Jia[1]

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Corresponding Author: jjia@bnl.gov

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Charge fluctuations, correlations and balance functions / 64

Fluctuations and the QCD Critical Point

Author: Misha Stephanov[1]

[1] *UIC*

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I will discuss the physics of fluctuations near the QCD critical point and corresponding experimental signatures.

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Charge fluctuations, correlations and balance functions

Femtoscopy and correlation studies in A+A, p+p , p+A and e+-e- collisions at relativistic, intermediate and low energies / 66

Probing the EoS of asymmetric matter

Author: William Lynch[None]

Corresponding Author: lynch@nscl.msu.edu

The Equation of State (EoS) of Asymmetric matter governs the properties of dense matter within neutron stars and influences the properties of the neutrino-sphere and the proto-neutron star created during a core-collapse supernova. Constraining the EoS via laboratory experiments constitutes one the principal objectives of nuclear science. During this presentation, I will review the status of current constraints and discuss current efforts to improve the constraints both at sub-saturation and supra-saturation densities.

List of tracks:

Femtoscopy in A+A, p+p , p+A and e+-e- collisions at relativistic, intermediate and low energies

Femtoscopy and correlation studies in A+A, p+p , p+A and e+-e- collisions at relativistic, intermediate and low energies / 67

HBT overview

Author: Tamas Csorgo[1]

[1] *Hungarian Academy of Sciences (HU)*

Corresponding Author: tamas.ferenc.csorgo@cern.ch

This talk will address some of the fundamental questions, related to the applications of the Hanbury-Twiss effect in high energy physics: Is the two-particle HBT correlation function unity plus a positive definitene form – or not? Can it be described by two-particle symmetrization effects – or not? Is the shape of the correlation function a Gaussian – or not? The overview also includes some recent results related to the sensitivity of the HBT measurements to UA(1) symmetry restoration as well as to a signal of QCD phase transition in cross-over or second-order phase transitions.

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Femtoscopy in A+A, p+p , p+A and e+-e- collisions at relativistic, intermediate and low energies

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Welcome speech

Corresponding Author: panos.christakoglou@cern.ch

Femtoscopy and correlation studies in A+A, p+p , p+A and e+-e- collisions at relativistic, intermediate and low energies / 69

The tau-model of BEC in e+e- and pp interactions

Author: Wesley Metzger[1]

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

Corresponding Author: wesley.metzger@cern.ch

The dependence of BEC parameters on the jet structure of e+e- events (LEP) is discussed. The parametrization provided by the tau-model is used. This parametrization is also found to work well for pp minimum bias events (LHC). The BEC parameters of e+e- and pp events are compared.

List of tracks:

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Femtoscopy and correlation studies in A+A, p+p , p+A and e+-e- collisions at relativistic, intermediate and low energies / 70

Choice of the reference distribution for the Bose-Einstein correlations studies

Author: Robert Astalos[1]

[1] *Comenius University (SK)*

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The choice of the reference sample is a crucial component of the the Bose-Einstein correlations studies, with a great impact on the results obtained. Four reference samples are discussed. The unlike-sign pairs reference sample is affected by decay products of resonances. The momentum vector rotation of one track of the pair by an angle is found not to sufficiently remove correlations present in the signal sample. Reference sample created by the momentum vector inversion of one track of the pair is found to be compatible with one where two tracks of the pair are taken from different events. Possible limitations of these reference samples at high pair transverse momentum are also studied.

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Femtoscopy in A+A, p+p , p+A and e+-e- collisions at relativistic, intermediate and low energies

Femtoscopy and correlation studies in A+A, p+p , p+A and e+-e- collisions at relativistic, intermediate and low energies / **71**

Effects of rotation in exact non-relativistic multi-component solutions of fireball hydrodynamics

Author: Gábor Kasza[1]

[1] *Eötvös Loránd University*

Corresponding Author: kaszagabor.24@gmail.com

We describe fireballs that rehadronize from a perfectly fluid quark matter to a chemically frozen, multi-component hadron gas. In the hydrodynamics of these fireballs, we utilize the lattice QCD equation of state, however, we also apply non-relativistic kinematics for simplicity and clarity. A realistic, linear mass scaling of the slope parameters of the single particle spectra of various hadronic species is obtained analytically, as well as an also realistic, linear mass scaling of the inverse of the squared HBT radius parameters of the Bose-Einstein correlation functions. Observables are presented that are sensitive to the effects of hadrochemical freeze-out and the differences between cross-over and second order phase transitions.

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Femtoscopy and correlation studies in A+A, p+p , p+A and e+-e- collisions at relativistic, intermediate and low energies / **73**

Femtoscopic Bose-Einstein correlations in pp collisions at 13 TeV: experimental methods

Author: Sandra Padula[1]

[1] *UNESP - Universidade Estadual Paulista (BR)*

Corresponding Author: sandra.padula@cern.ch

Three different experimental techniques used in the measurements of two-particle, quantum-statistical (Bose-Einstein) femtoscopic correlations in proton-proton collisions at 13 TeV are introduced and discussed. Each one of them adopts a different analysis approach, with variable degrees of dependence

on Monte Carlo event generator models. These are employed for estimating and correcting the non-Bose-Einstein contributions (resonances and mini-jets) that contaminate the signal sample. All of them, however, return values for the resulting one-dimensional fit parameters (lengths of homogeneity and correlation intensity) that are consistent within the experimental uncertainties in the analysis. These methods are successfully applied in the investigation of minimum bias, as well as of high multiplicity events.

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Femtoscopy in A+A, p+p , p+A and e+-e- collisions at relativistic, intermediate and low energies

Femtoscopy and correlation studies in A+A, p+p , p+A and e+-e- collisions at relativistic, intermediate and low energies / **74**

Correlation studies with 4π detectors at intermediate energies

Author: Abdou Chbihi[1]

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Corresponding Author: chbihi@ganil.fr

Coming soon...

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Femtoscopy and correlation studies in A+A, p+p , p+A and e+-e- collisions at relativistic, intermediate and low energies / **75**

Multi-alpha correlations in nuclear structure and dynamics

Author: Daniele Dell'Aquila[1]

[1] *University of Naples & INFN-Napoli*

Corresponding Author: dellaquila@na.infn.it

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Femtoscopy in A+A, p+p , p+A and e+-e- collisions at relativistic, intermediate and low energies

Femtoscopy and correlation studies in A+A, p+p , p+A and e+-e- collisions at relativistic, intermediate and low energies / **76**

Symmetry energy and correlations at intermediate energies

Author: Zbigniew Chajecki[1]

[1] *Warsaw University of Technology*

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Femtoscopy in A+A, p+p , p+A and e+-e- collisions at relativistic, intermediate and low energies

Femtoscopy and correlation studies in A+A, p+p , p+A and e+-e- collisions at relativistic, intermediate and low energies / **77**

FAST IN-MEDIUM FRAGMENTATION OF PROJECTILE NUCLEI IN ASYMMETRIC HEAVY ION COLLISIONS

Author: Giuseppe Verde[None]

Corresponding Author: verde@ipno.in2p3.fr

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IAC meeting in N328 (Nikhef building)

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Workshop photo

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Announcment: next edition of WPCF

Corresponding Author: lednicky@fzu.cz

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Closing speech

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