Critical Point and Onset of Deconfinement 2016

Monday, 30 May 2016 - Saturday, 4 June 2016

University of Wrocław

Book of Abstracts

Contents

Plenary session / **58**

Status of Lattice QCD Simulations

Author: Frithjof Karsch[1]

[1] *Bielefeld University*

Corresponding Author: karsch@physik.uni-bielefeld.de

Plenary session / **59**

Limits on the experimental search for the CEP

Author: Nu Xu[1]

[1] *LBNL*

Corresponding Author: nxu@lbl.gov

Plenary session / **76**

From Glasma to QCD phase boundary

Author: Larry McLerran[1]

[1] *BNL*

Corresponding Author: mclerran@bnl.gov

Plenary session / **54**

News from strong interactions program of the NA61/SHINE experiment

Author: Katarzyna Grebieszkow[1]

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

Corresponding Author: katarzyna.perl@cern.ch

The results from the analysis of fluctuations and correlations can help to discover the critical point of strongly interacting matter. In the NA61/SHINE experiment the strategy of locating the critical point relies on performing a two dimensional phase diagram (T-mu_B) scan by measurements of fluctuations and correlations in proton-proton, proton-nucleus and nucleus-nucleus interactions as a function of collision energy and system size. Close to the critical point increase of fluctuations is predicted.

In this contribution the latest NA61/SHINE results on fluctuations and correlations from the p+p, Be+Be, and Ar+Sc energy scans will be presented. The NA61 experimental results will be compared with existing NA49 data and with model predictions.

Plenary session / **94**

Future facilities for HIC

Author: Volker Friese[1]

[1] *GSI Darmstadt*

Corresponding Author: v.friese@gsi.de

Plenary session / **109**

Systematic Extraction of QGP Properties

Author: Steffen Bass[1]

[1] *Duke University*

Corresponding Author: bass@phy.duke.edu

One of the motivations for the RHIC beam energy scan program was its capability of providing data for the determination of the temperature- and baryon-density dependence of QGP transport coefficients, such as the specific shear viscosity. This task is complicated by the rich set phenomena that computational models commonly used for the determination of the transport coefficients need to address, ranging from pre-equilibrium evolution to fluctuations around the QCD critical point.

In my talk I will demonstrate an new method for determining the physics parameters that drive the dynamics of computational models, utilizing Bayesian statistics and a multi-parameter model to data comparison. We shall use a state-of-the-art hybrid model for calculating the time-evolution of a heavy-ion collision, including that of the QGP phase and its subsequent decay into the hadronic final state. RHIC-BES data will be utilized to extract first hints for a possible baryo-chemical potential dependence of the QGP specific shear viscosity.

Plenary session / **111**

Fluctuations of charges at the phase boundary

Author: Kenji Morita[1]

[1] *Kyoto University*

Corresponding Author: kmorita@yukawa.kyoto-u.ac.jp

In this talk, I will first summarize the critical behavior of fluctuations of conserved charges expected in the vicinity of the chiral phase boundary. Then, I will show how the finite quark mass or finite volume modifies the divergent cumulants in QCD-like model calculations.Particular emphasis will be put on the importance of the regular contribution to the fluctuations when the singular part contribution is smeared. I will show that the electric charge fluctuations can have non-trivial effects by imposing momentum cuts even in the absence of the criticality.

Parallel session 1 / **1**

Existence of the critical endpoint in the vector meson extended linear sigma model

Author: Gyorgy Wolf[1]

[1] *Wigner FK*

Corresponding Author: wolf.gyorgy@wigner.mta.hu

In the framework of an SU(3) (axial)vector meson extended linear sigma model with additional constituent quarks and Polyakov loops, we investigate the effects of (axial)vector mesons on the chiral phase transition. The parameters of the Lagrangian are set at zero temperature and we use a hybrid approach where in the effective potential the constituent quarks are treated at one-loop level and all the mesons at tree-level. We have four order parameters, two scalar condensates and two Polyakov loop variables and their temperature and baryochemical potential dependence are determined from the corresponding field equations. We investigate the thermodynamics of the system, and at zero temperature we compare our results with lattice calculations. We study, furthermore, the changes of the tree-level scalar meson masses in the hot and dense medium.

Parallel session 2 / 5

Surprises for the chemical freeze-out line from the new data in proton-proton and nucleus-nucleus collisions

Author: Viktor Begun[1]

[1] *Jan Kochanowski University*

Corresponding Author: viktor.begun@gmail.com

New results of the NA61/SHINE and HADES collaborations, as well as the updated data from NA49, and the existing data from other collaborations are analyzed within the transport models and the hadron resonance gas (HRG) statistical model. The chemical freeze-out parameters in $p+p$ interactions and central $A+A$ collisions are found and compared with each other in the $\sqrt{s_{NN}}$ = 3.2–17.3 GeV energy range.

The chemical freeze-out temperatures in $p+p$ interactions are found to be larger than the corresponding temperatures in central $A+A$ collisions. The temperature in $p+p$ slowly grows with energy from 130 to 175 MeV, in contrast to $A+A$ temperature, which increases very fast from zero and saturates at $T_{\rm A+A} \simeq 156$ MeV. This value is lower than predicted by chemical freeze-out line in HRG previously, but is very close to the temperature found in HRG in $A+A$ at the LHC.

The largest difference $T_{\rm p+p} - T_{\rm A+A} \simeq 60$ MeV is at low energies. These temperatures are very close $T_{\rm p+p} \simeq T_{\rm A+A}$ at $\sqrt{s_{NN}} = 6.3 - 7.7$ GeV, and then the difference grows again reaching 20 MeV at the highest SPS energy. The radius $R_{\rm A+A}$ increases with collision energy, while $R_{\rm p+p}$ is approximately constant. More data at low energies are needed. The minimal requirements to the set of measured particles are obtained, see arXiv:1512.08025 for details.

Parallel session 2 / 8

Inverse Magnetic Catalysis in Nambu–Jona-Lasinio Model beyond Mean Field

Author: Shijun Mao[1]

[1] *Xian Jiaotong University*

Corresponding Author: maoshijun@mail.xjtu.edu.cn

We study inverse magnetic catalysis in the Nambu–Jona-Lasinio model beyond mean field approximation. The feed-down from mesons to quarks is embedded in an effective coupling constant at finite temperature and magnetic field. While the magnetic catalysis is still the dominant effect at low temperature, the meson dressed quark mass drops down with increasing magnetic field at high temperature due to the dimension reduction of the Goldstone mode in the Pauli-Villars regularization scheme.

Parallel session 1 / 16

Cumulative production of pions by heavy baryonic resonances in proton-nucleus collisions

Author: Anton Motornenko[1]

[1] *Taras Shevchenko National University of Kyiv*

Corresponding Author: a.motornenko@gmail.com

Pion production in the backward direction in the target rest frame is considered in proton-nucleus (p+A) collisions. Pions outside the kinematical boundary of proton-nucleon (p+N) collisions, the so called cumulative effect, is studied. Basic restrictions on the energy of pions emitted in the backward direction in p+N and p+A reactions are considered. These are restrictions that follow from energy-momentum conservation. It is argued that resonances with very high masses are the only source of the cumulative pions. The resonances are first created in p+N reactions. Due to successive collisions with nuclear nucleons, the masses of these resonances may increase and simultaneously their longitudinal velocities decrease. It is suggested that these two effects give an explanation of the cumulative pion production. The heavy hadron-like systems with very high masses (heavy resonances, Hagedorn fireballs, quark-gluon bags, baryon and meson strings) are of primary importance for properties of strongly interacting matter at high temperatures and/or baryonic density. They may have also decisive influence on the transition between hadron matter and quark-gluon plasma, and define the type of this phase transition and existence of the QCD critical point itself. We also use the Ultra relativistic Quantum Molecular Dynamics model to describe the existing data and analyze some microscopic aspects of cumulative pion production in p+A reactions.

Parallel session 2 / 4

Chiral magnetic effect and chiral kinetic theory

Author: Shi Pu[1]

[1] *USTC, China*

Corresponding Author: shipu@ustc.edu.cn

A power expansion scheme is set up to determine the Wigner function that satisfies the quantum kinetic equation for spin-1/2 charged fermions in a background electromagnetic field. Vector and axial-vector current induced by magnetic field and vorticity are obtained simultaneously from the Wigner function. The chiral magnetic and vortical effect and chiral anomaly are shown as natural consequences of the quantum kinetic equation. The axial-vector current induced by vorticity is argued to lead to a local polarization effect along the vorticity direction in heavy-ion collisions.

Parallel session 1 / **46**

Repulsive interactions and their effects on the thermodynamics

Author: Pok Man Lo[1]

[1] *GSI*

Corresponding Author: pmlo@gsi.de

In this talk we compare two approaches in modeling repulsive interactions among hadrons: the excluded-volume approximation and the S-matrix formalism. The latter provides a consistent treatment of broad resonances based on empirical scattering phase shifts. We shall apply these techniques to study the thermodynamics of the (πNΔ) system, with a particular focus on the fluctuation of Baryon charge in the thermal medium.

Parallel session 1 / **15**

Charm diffusion coefficent from nonzero momentum Euclidean correlator in temporal channel

Author: Atsuro Ikeda[1]

[1] *Osaka University*

Corresponding Author: a-ikeda@kern.phys.sci.osaka-u.ac.jp

We study a charm quark diffusion coefficient with nonzero momentum
correlator on the quenched lattice. Starting from rather general requirements on the spectral function, we derive inequalities to constrain the value of the diffusion coefficient. These inequalities have quantities which can be measured on the lattice
from temporal correlator with nonzero momentum. Using the inequalities and the numerical simulation on the lattice, we constrain the value of the diffusion coefficient
for 1.5<T/T_c<4.5.

Parallel session 2 / **102**

Centrality determination and multiplicity fluctuations in Ar+Sc collisions at CERN SPS from NA61/SHINE

Author: Andrey Seryakov[1]

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

Corresponding Author: andrey.seryakov@cern.ch

The preliminary centrality determination procedure and charge hadron multiplicity fluctuations are investigated in the new Ar+Sc data at 13A, 19A, 30A, 40A, 75A, 150A GeV/c with NA61/SHINE at the SPS. The centrality analysis is based on nucleon-spectator energy in the forward hemisphere from the Projectile spectator detector. The scaled variance for all, negatively and positively charged hadrons is presented for different centrality classes. Results are discussed and compared with p+p and Be+Be NA61/SHINE data and the EPOS 1.99 simulations.

Parallel session 2 / **43**

Transverse momentum and multiplicity fluctuations in Ar+Sc collisions at CERN SPS from NA61/SHINE

Author: Evgeny Andronov[1]

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

Corresponding Author: evgeny.andronov@cern.ch

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-μ_B) 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 transverse momentum and multiplicity fluctuations expressed in terms of strongly intensive quantities from the Ar+Sc energy scan will be presented. These fluctuations are supposed to be sensitive to the critical point existence. The NA61/SHINE results are compared with p+p and Be+Be energy scan as well as NA49 measurements and model predictions.

Parallel session 1 / **31**

Critical fluctuations in models with van der Waals interactions

Author: Volodymyr Vovchenko[None]

Corresponding Author: v.vovchenko@gsi.de

Particle number fluctuations are considered within the full van der Waals (VDW) equation,
which contains both attractive (mean-field) and repulsive (eigenvolume) interactions.
Two steps to extend the VDW equation and make it appropriate for new physical applications are carried out:
(i) the grand canonical ensemble (GCE) formulation which allows to calculate the particle number fluctuations,
and (ii) the inclusion of the quantum statistics which allows to describe the nuclear matter as a system of interacting nucleons.
The VDW equation is used to calculate the scaled variance, skewness, and kurtosis of nucleon number fluctuations
in nuclear matter, and these quantities show singular behavior with rich structures around the critical point.
The strongly intensive measures Delta and Sigma of the particle number and excitation energy fluctuations are also considered,
and, similarly, show singular behavior near the CP. The Delta measure is shown to be more sensitive to the

proximity of the critical point than the Sigma measure. Based on universality argument, similar behavior is expected to occur in the vicinity of the QCD critical point.
Additionally, the role of repulsive (eigenvolume) VDW interactions in the hadron resonance gas model is considered.
It is shown that the extraction of the chemical freeze-out parameters is very sensitive to
the choice of eigenvolumes for different hadrons. Comparison to the lattice QCD is also explored.

Parallel session 1 / **29**

Novel picture of the soft modes at the QCD critical point based on the FRG method

Author: Takeru Yokota[1]

[1] *Kyoto University, Japan*

Corresponding Author: tyokota@ruby.scphys.kyoto-u.ac.jp

One of remarkable features in the expected structure of the QCD phase diagram is the existence of QCD critical point (CP), which is the end point of the phase boundary of the first-order between the hadronic phase and the QGP phase. At the CP, the phase transition becomes second order, and thus there should be gapless and long-life modes called the soft modes, which govern the low-energy dynamics. Thus revealing the precise nature of the soft modes has a decisive importance for understanding the dynamical properties of the system around the CP.
In this talk, we shall report on an intensive investigation [1] of the soft mode at the QCD CP on the basis of the functional renormalization group (FRG) method in the local potential approximation. We calculate the spectral function as a function of the energy and momentum in the scalar and pseudo-scalar channels in the quark-meson model on the basis of the recent development[2]. At finite baryon chemical potential with a finite quark mass, the baryon-number fluctuation is coupled to the scalar channel and the spectral function in the sigma channel has a support not only in the time-like and but also in the space-like regions, which correspond to the mesonic and the particle-hole phonon excitations, respectively. We find that the energy of the peak position of the latter becomes vanishingly small with the height being enhanced as the system approaches the QCD CP, which is a manifestation of the fact that the phonon mode is the soft mode associated with the second-order transition at the CP, as was suggested by some authors[3,4]. We also extract the dispersion curves of the mesonic and the phonon modes, which leads to a novel and striking finding that the dispersion curve of the would-be sigma mesonic mode crosses the light-cone into the space-like region, and then eventually merge into the phonon mode as the system approaches further close to the CP. This suggests that the sigma-mesonic mode also becomes soft at the CP, in contrast to the pionic mode. We also discuss implications of the results on the type of possible inhomogeneous phases at higher densities and experiments, and theoretical elaboration to incorporate higher-derivative effects.

[1] T. Yokota, T. Kunihiro and K. Morita, arXiv:1603.02147.
[2] R. A. Tripolt, L. von Smekal and J. Wambach, Phys. Rev. D 90, no. 7, 074031 (2014).
[3] H. Fujii and M. Ohtani, Phys. Rev. D 70, 014016 (2004).
[4] D. T. Son and M. A. Stephanov, Phys. Rev. D 70, 056001 (2004).

Parallel session 2 / **125**

Pion spectra in Ar+Sc interactions at SPS energies

Author: Maciej Lewicki[1]

[1] *University of Wroclaw*

Corresponding Author: maciej.piotr.lewicki@cern.ch

The aim of the NA61/SHINE ion programme is to explore the QCD phase diagram within the range of thermodynamical variables accessible by the SPS. In addition the experiment provides precision hadron production measurements for description of the neutrino beam of the T2K experiment at J-PARC and for simulation of cosmic-ray showers for the Pierre Auger Observatory and KASCADE experiments. The main physics goals of the NA61/SHINE ion programme are the study of the properties of the onset of deconfinement and the search for signatures of the critical point of strongly interacting matter. These goals are pursued by performing an energy (beam momentum 13A-158A GeV/c) and system size (p+p, p+Pb, Be+Be, Ar+Ca, Xe+La, Pb+Pb) scan. In this talk I will discuss recent analysis results of Ar+Sc interactions at six beam momenta: 13A, 19A, 30A, 40A, 75A, 150A GeV/c. I will present the rapidity and transverse mass spectra of pions obtained with the "h-" analysis method. The newly obtained data will be compared with different collision systems, namely: p+p, Be+Be and Pb+Pb.

Parallel session 1 / 110

Chiral symmetry breaking in continuum QCD

Author: Mario Mitter[1]

[1] *Univ. Heidelberg*

Corresponding Author: mitter@thphys.uni-heidelberg.de

Model parameter free investigations of Yang-Mills theory and quenched QCD in the vacuum are presented as a necessary prerequisitve for corresponding investigations of the QCD phase structure with the functional renormalisation group equation. Preliminary results for Yang-Mills theory at finite temperature are discussed. Finally, a phenomenological application of the vacuum results to the etaprime-meson mass at the chiral crossover is presented.

Parallel session 2 / 115

Mean pion multiplicities in Ar+Sc collisions

Author: Michał Naskręt[1]

[1] *University of Wroclaw (PL)*

Corresponding Author: michal.naskret@cern.ch

The investigation of preliminary results for mean negatively charged pion multiplicities $\langle \pi^- \rangle$ from Ar+Sc collisions is the main topic of the talk.
The data has been taken recently by the NA61/SHINE collaboration for a wide range of momenta - 13, 19, 30, 40, 75 and 150 A GeV/c. Starting with rapidity distibution of differential spectra
$\frac{dn}{dy}$ extrapolated to unmeasured regions, the procedure of obtaining the final multiplicities is presented. The mean number of wounded nucleons
$\langle W \rangle$ extracted from Glissando MC model is used to obtain the $\langle \pi^- \rangle / \langle W \rangle$ ratio. Using data from other experiments,
the comparison of $\langle \pi^- \rangle / \langle W \rangle$ for different collisions and momenta is discussed.

Plenary session / 66

Horizons, causality and information transfer

Author: Helmut Satz[1]

[1] *Univ. Bielefeld*

Corresponding Author: satz@physik.uni-bielefeld.de

Plenary session / **67**

Chiral criticality: confronting models with data

Author: Bengt Friman[1]

[1] *GSI*

Corresponding Author: b.friman@gsi.de

Plenary session / **75**

Fluctuations in a finite volume

Author: Bernd-Jochen Schaefer[None]

Corresponding Author: bernd-jochen.schaefer@theo.physik.uni-giessen.de

Plenary session / **68**

Observation of the Critical Point in the Phase Diagram for Hot and Dense Nuclear Matter

Author: Roy Lacey[1]

[1] *State University of New York (US)*

Corresponding Author: roy.alphanso.lacey@cern.ch

Plenary session / **24**

Anisotropic hydrodynamics

Author: Wojciech Florkowski[1]

[1] *Institute of nuclear Physics, Krakow*

Corresponding Author: wojciech.florkowski@ifj.edu.pl

Recent developments in anisotropic hydrodynamics will be reviewed.

Plenary session / **119**

Directed flow in heavy-ion collisions and softening of equation of state

Author: Akira Ohnishi[1]

[1] *Kyoto University*

Corresponding Author: ohnishi@yukawa.kyoto-u.ac.jp

We analyze the directed flow (v_1) of protons and pions
in high-energy heavy-ion collisions in the incident energy range
from $\sqrt{s_{NN}} = 7.7$ GeV to 27 GeV
within a microscopic transport model [1].
Standard hadronic transport approaches do not explain the collapse of directed flow below
$\sqrt{s_{NN}} \simeq 20$ GeV.
By contrast, when we take acount of a softening of the equation of state
via the attractive orbit scattering [2],
we can well describe the behavior of directed flow data recently obtained by the STAR collaboration [3].
We argue that the observed collapse of directed flow at midrapidity at $9\,\mathrm{GeV} \leq \sqrt{s_{NN}} \leq 20$ GeV
is the evidence for the softening of the QCD equation of state.
We also discuss the possible density region where the softening takes place.

[1] Y. Nara, A. Ohnishi, H. St\"ocker, arXiv:1601.07692 [hep-ph].
[2] H. Sorge, Phys. Rev. Lett. 82 (1999), 2048;
P. Danielewicz and S. Pratt, Phys. Rev. C 53 (1996), 249.
[3] L. Adamczyk et al. [STAR Collaboration], Phys. Rev. Lett. 112 (2014), 162301.

Plenary session / **32**

Vorticity in the QGP liquid and Lambda polarization at the RHIC BES energies

Author: Iurii Karpenko[1]

[1] *INFN Firenze*

Corresponding Author: yu.karpenko@gmail.com

We study the formation of collective flow vorticity in non-central heavy ion collisions at RHIC Beam Energy Scan collision energy range, $\sqrt{s_{\rm NN}} = 7.7 \ldots 200$ GeV with state-of-the-art viscous hydro model, vHLLE+UrQMD. With the model adjusted to approach the experimental data for rapidity, transverse momentum distributions and elliptic flow of produced hadrons, we explore the collision energy and centrality dependence of the thermal vorticity and the resulting polarization of produced Lambda baryons. We show the dependence of polarization on transverse momentum and rapidity.

COST Action MP1304 "NewCompStar" WG2 Meeting / **38**

Recent Results on Equation of States from NewCompStar

Author: Gergely Barnafoldi[1]

[1] *Wigner RCP Hungarian Academy of Sciences*

Corresponding Author: gergely.barnafoldi@cern.ch

A biref summary on the recent result on compact star equation of state will be presented. I summarize the directions and activities of the NewCompStar working group on the physics of the strong interaction in cold dense nuclear and QCD medium exists in compact stars.

COST Action MP1304 "NewCompStar" WG2 Meeting / 108

Quark matter in neutron stars

Author: Gordon Baym[1]

[1] *University of Illinois*

Corresponding Author: gbaym@illinois.edu

This talk will describe the continuing development of a consistent picture of the liquid interiors of neutron stars, driven by three recent advances: observations of heavy neutron stars with masses ~2.0 solar masses; determinations of masses and radii simultaneously for an increasing number of neutron stars; and an emerging understanding in QCD of how nuclear matter can turn into deconfined quark matter in the interior.

COST Action MP1304 "NewCompStar" WG2 Meeting / 118

QCD in stars

Author: Toru Kojo[1]

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

Corresponding Author: kojo.toru@gmail.com

We delineate properties of cold, dense QCD matter through equations of state supposed from observational constraints on neutron stars.

COST Action MP1304 "NewCompStar" WG2 Meeting / 71

Inhomogeneous chiral condensates in the QCD phase diagram

Author: Michael Buballa[1]

[1] *T*

Corresponding Author: michael.buballa@physik.tu-darmstadt.de

COST Action MP1304 "NewCompStar" WG2 Meeting / 72

Consequences of simultaneous chiral symmetry restoration and deconfinement for the QCD phase diagram

Author: Thomas Klaehn[1]

[1] *University of Wroclaw*

Corresponding Author: thomas.klaehn@gmail.com

COST Action MP1304 "NewCompStar" WG2 Meeting / 25

Bayesian analysis of new class of realistic hybrid EoS models based on M-R data

Author: Alexander Ayriyan[1]

[1] *JINR*

Corresponding Author: ayriyan@jinr.ru

We performed a Bayesian analysis of a new class realistic models of two-phase equations of state (EoS) for hybrid stars and demonstrated that the observation of such a pair of high-mass twin stars would have a sufficient discriminating power to favor hybrid EoS with a strong first order phase transition over alternative EoS.
The new class of two-phase EoS is characterized by three main features:
(1) stiffening of the nuclear EoS at supersaturation densities due to quark exchange effects (Pauli blocking) between hadrons, modelled by an excluded volume correction,
(2) stiffening of the quark matter EoS at high densities due to multiquark interactions and
(3) possibility for a strong first order phase transition with an early onset and large density jump.
The third feature results from a Maxwell construction for the possible transition from the nuclear to a quark matter phase and its properties depend on the two parameters used for (1) and (2), respectively. Varying these two parameters one obtains a class of hybrid EoS that yields solutions of the Tolman-Oppenheimer-Volkoff (TOV) equations for sequences of hadronic and hybrid stars in the mass-radius diagram which cover the full range of patterns according to the Alford-Han-Prakash classification following which a hybrid star branch can be either absent, connected or disconnected with the hadronic one. The latter case often includes a tiny connected branch. The disconnected hybrid star branch, also called "third family", corresponds to high-mass twin stars characterized by the same gravitational mass but different radii.

COST Action MP1304 "NewCompStar" WG2 Meeting / 73

Cooling of neutron stars with stiff stellar matter

Author: Hovik Grigorian[1]

[1] *Joint Institute for Nuclear Research*

Corresponding Author: hovik.grigorian@gmail.com

Plenary session / 90

Particle production at QCD phase boundary

Author: Peter Braun-Munzinger[1]

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

Corresponding Author: p.braun-munzinger@gsi.de

Plenary session / **91**

Production of light flavor hadrons in pp, p-Pb and Pb-Pb collisions with ALICE

Author: Helmut Oeschler[1]

[1] *Technische Universitaet Darmstadt (DE)*

Corresponding Author: h.oeschler@gsi.de

Plenary session / **92**

Chiral symmetry restoration versus deconfinement in heavy-ion collisions at high baryon density

Author: Elena Bratkovskaya[1]

[1] *FIAS*

Corresponding Author: elena.bratkovskaya@th.physik.uni-frankfurt.de

Plenary session / **121**

Photon emission in the vicinity of a critical point

Author: Burkhard Kampfer[1]

[1] *HZDR & TU Dresden*

Corresponding Author: kaempfer@hzdr.de

We address holographically (i) an emulation of deconfinement upon temperature increase as sequential or instanteneous melting (disappearence) of normalizable eigenmodes of hadron states with a Regge type spectrum in vacuum, and (ii) the phase diagram within the updated DeWolfe-Gubser-Rosen model. Photon emission rates are calculated and found to map out the pecularities (CEP and first-order phase transition) of the phase diagram emerging from a quark-meson model with linearized fluctuations.

Plenary session / **33**

The Compressed Baryonic Matter (CBM) Experiment at FAIR

Author: Christoph Blume[1]

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

Corresponding Author: christoph.blume@cern.ch

The CBM Experiment is one of the main four scientific pillars of the new Facility for Antiproton and Ion Research (FAIR). Its main objective is the study of the QCD phase diagram in the region of high baryon-densities. With nucleus-nucleus collisions at the SIS100 accelerator at beam energies up to 14 A GeV strongly interacting matter with densities about 10 times as high as normal nuclear matter can be produced. The experimental setup is designed to cope with highest interaction rates (up to 10 MHz), which for the first time will also allow to measure rare probes (open charm, light and heavy vector mesons) in the FAIR energy regime. We will report on the current status of the CBM experiment. Many detector subsystems have already completed their technical design reports, or will finalize them in 2016. The main achievements and challenges of these developments will be discussed. Also, a lot of effort is being spend on evaluating the physics performance of the experiment. An overview on the main results in the context of the CBM physics program will be given.

Plenary session / **107**

STAR BES-I highlights and RHIC BES-II program

Author: Zhangbu Xu[1]

[1] *Brookhaven National Laboratory*

Corresponding Author: xzb@bnl.gov

Plenary session / **101**

Hadron production at SIS energies: an update from HADES

Author: Manuel Lorenz[1]

[1] *University Frankfurt*

Corresponding Author: m.lorenz@gsi.de

Data on particle production in heavy ion collisions in the energy regime of 1-2 A GeV have been collected over almost three decades now. As most of the newly created hadrons are produced below or slightly above their free NN-thresholds, data are usually interpreted with the help of phenomenological models, rather than comparing to elementary reference measurements. Driven by advance in detector technology, more and more rare and penetrating probes have become accessible, and still keep challenging our knowledge about the properties of the created system and its dynamical evolution. In this contribution we give an overview of the recent findings on strangeness production from HADES, with a special emphasis on the data from Au+Au collisions at 1.23 A GeV. We discuss particle yields with respect to several transport and a statistical model fit and put a special emphasis on the rise of the ϕ/K− ratio towards lower energies and its implication for the interpretation of sequential kaon freeze-out.

Plenary session / **96**

Heavy flavor production at the QCD phase boundary

Author: Johanna Stachel[1]

[1] *Ruprecht-Karls-Universitaet Heidelberg (DE)*

Corresponding Author: stachel@physi.uni-heidelberg.de

Plenary session / **97**

Fluctuation observables in heavy ion collisions

Author: Volker Koch[1]

[1] *LBNL*

Corresponding Author: vkoch@lbl.gov

Plenary session / **98**

QCD transition and chemical freezeout in the presence of magnetic field

Author: Kenji Fukushima[1]

[1] *The University of Tokyo*

Corresponding Author: fuku@phys.s.u-tokyo.ac.jp

Plenary session / **99**

Effective dynamical models for fluctuations at the QCD transition

Author: Marlene Nahrgang[None]

Corresponding Author: nahrgang@th.physik.uni-frankfurt.de

Plenary session / **47**

On spectral functions and transport coefficients in QCD

Author: Jan M. Pawlowski[1]

[1] *University of Heidelberg*

Corresponding Author: j.pawlowski@thphys.uni-heidelberg.de

The computation of single particle spectral functions and transport coefficients with functional continuum methods is discussed. Results are presented for quark and meson, and glue ball spectral functions, as well as the temperature-dependent shear viscosity over entropy ratio.

Plenary session / **13**

Understanding experimentally-observed fluctuations

Author: Masakiyo Kitazawa[1]

[1] *Osaka University*

Corresponding Author: kitazawa@phys.sci.osaka-u.ac.jp

Fluctuation observables in relativistic heavy ion collisions measured by event-by-event analysis are important observables for the study of thermodynamics in primordial stage. In this talk, I will discuss some problems which have to be considered seriously when one compares the experimental results on fluctuations with theoretical study. In particular, I will discuss (1)non-equilibrium property of fluctuations, (2)finite-volume effects, and (3)effects of non-perfectf efficiency of detectors on the measurement of fluctuations.
Approaches to resolving these problems will also be discussed.

Plenary session / **100**

From cold Fermi fluids to the hot QGP

Author: Marcus Bluhm[1]

[1] *North Carolina State University*

Corresponding Author: mbluhm@ncsu.edu

Parallel session 1 / **83**

How to use Lattice and Experimental data for QCD Critical Point Search

Author: Atsushi Nakamura[1]

[1] *Hiroshima Univ*

Corresponding Author: nakamura@riise.hiroshima-u.ac.jp

Parallel session 2 / **28**

Thermal Dileptons as Fireball Probes at SIS Energies

Author: Florian Seck[1]

[1] *TU Darmstadt*

Corresponding Author: f.seck@gsi.de

Electromagnetic probes are radiated during the whole time evolution of a heavy-ion collision. They decouple from the collision zone once they are produced and carry valuable information about the properties of matter created inside the hot and dense fireball to the detector.

In particular, the yield of low-mass dileptons was identified to be sensitive to the fireball lifetime, while the slope in the intermediate-mass region of the dilepton invariant-mass spectrum can serve as a thermometer which is unaffected by blue-shift effects caused by the collective expansion of the medium [1].

Realistic thermal dilepton emission rates and an accurate description of the fireball's space-time evolution are needed to properly describe the contribution of in-medium signals to the dilepton invariant-mass spectrum.

Utilizing a coarse-graining method we extract local temperature, baryon and pion densities from hadronic transport simulations of Au+Au collisions at SIS energies. These serve as an input for the calculation of the pertinent radiation of thermal dileptons based on an in-medium ρ spectral function that describes available spectra at ultrarelativistic collision energies.

The obtained yields and slopes of the invariant-mass spectra [2] will be compared to the excitation function of the lifetime and temperatures of the fireball established at higher energies [1]. The results can serve as a baseline for future explorations by the HADES and CBM experiments at FAIR as well as the RHIC beam energy scan phase II.

[1] R. Rapp and H. van Hees, Phys. Lett. B 753 (2016) 586.

[2] T. Galatyuk, P. M. Hohler, R. Rapp, F. Seck and J. Stroth, arXiv:1512.08688 [nucl-th].

Parallel session 1 / **41**

Evaluation of the Motion of confined Particles

Author: David Miller[1]

Co-author: Dirk Rollmann [2]

[1] *Penn State*

[2] *Bielefeld University*

Corresponding Authors: om0@psu.edu, rollmann@physik.uni-bielefeld.de

We carry out numerical evaluations of the motion of classical particles in Minkowski space $calM^4$ which are confined to the inside of a bag. In particular, we analyze the structure of the paths evolving from the breaking of the dilatation symmetry, the conformal symmetry and the combination of both together. The confining forces arise directly from the corresponding nonconserved currents. We demonstrate in our evaluations that these particles under specific initial conditions move toward the interior of the bag.

Parallel session 2 / **112**

Electromagnetic probes from SIS18 to LHC energies in coarse-grained transport simulations

Author: Stephan Endres[1]

[1] *Frankfurt University / Frankfurt Institute for Advanced Studies*

Corresponding Author: endres@th.physik.uni-frankfurt.de

Electromagnetic radiation in heavy-ion collisions at SIS18, FAIR, SPS, RHIC and LHC energies is studied within an approach which uses coarse-grained transport simulations to calculate thermal

dilepton and photon emission applying in-medium spectral functions from hadronic many-body theory and partonic production rates based on lattice calculations. The microscopic output from the Ultra-relativistic Quantum Molecular Dynamics (UrQMD) model is hereby put on a grid of space-time cells which allows to extract the local temperature and chemical potential in each cell via an equation of state. The comparison of data and model outcome shows that the invariant mass and transverse momentum spectra can be described by a cocktail of hadronic decay contributions together with thermal emission from broadened vector-meson spectral functions and (for higher collision energies) from the Quark-Gluon Plasma phase. Besides a comparison to existing experimental data, predictions for LHC energies are presented and it is analysed under which conditions one might observe signals of a phase transition at FAIR energies. We argue that the high luminosities available at the future Facility for Antiproton and Ion Research enable systematic studies of - e.g. - system size, energy and momentum dependence, which would allow for better constraints on existing models and a deeper insight into the structure of the QGP phase diagram.

Parallel session 2 / **12**

Non-perturbative production rate of photons with a lattice quark propagator – effect of vertex correction –

Author: Taekwang Kim[1]

[1] *Osaka University*

Corresponding Author: kim@kern.phys.sci.osaka-u.ac.jp

We analyze the production rate of photons from the deconfined medium with a quark propagator obtained from a lattice QCD numerical simulation. We calculate the production rates non-perturbatively at two temperatures above $T_{\rm c}$. The photon-quark vertex is determined gauge-invariantly so as to satisfy the Ward-Takahashi identity. It is found that the vertex correction modifies spectra quantitatively. The photon production rate shows a peculiar structure reflecting the dispersion relations and kinematics of quasi-particles. We discuss the origin of this structure.

Parallel session 1 / **42**

Particle production in nucleus-nucleus and pion-nucleus collisions at $E_{\rm kin} = 0.8 - 2A$ GeV

Author: Vinzent Steinberg[None]

Corresponding Author: vinzent.steinberg@gmail.com

SMASH is a new hadronic transport model designed to describe the non-equilibrium evolution of heavy-ion collisions. After a brief introduction to the model, it will be shown that SMASH correctly reproduces the cross sections and maintains detailed balance. First comparisons to pion spectra measured by FOPI and HADES will be presented, demonstrating that the energy deposition and transverse expansion are correctly described. Predictions for the particle production in pion-nucleus collisions recently measured by HADES will be given. Understanding the hadronic interactions is the basis for the future exploration of effects of the phase transition.

Colloquium for Marek Gaździcki / **86**

Energy scan programs in HIC

Author: Peter Seyboth[1]

[1] *Jan Kochanowski University (PL)*

Corresponding Author: pxs@mppmu.mpg.de

Colloquium for Marek Gaździcki / 85

Evolution of the QCD phase diagram

Author: Gordon Baym[1]

[1] *University of Illinois*

Corresponding Author: gbaym@illinois.edu

Colloquium for Marek Gaździcki / 87

Critical Point of Nuclear Matter

Author: Mark Gorenstein[1]

[1] *Bogolyubov Institute for Theoretical Physics*

Corresponding Author: goren@bitp.kiev.ua

Colloquium for Marek Gaździcki / 88

Marek & Event-by-Event Fluctuations

Author: Stanisław Mrówczynski[1]

[1] *Jan Kochanowski University*

Corresponding Author: mrow@fuw.edu.pl

Colloquium for Marek Gaździcki / 129

The Mar(e)k of QGP: Strangeness and Entropy

Author: Johann Rafelski[1]

[1] *University of Arizona*

Corresponding Author: johann.rafelski@cern.ch

I look back at the early results of S+S collisions at 200 A GeV and related theoretical data analysis of more than 20 years ago, and compare these results with those we have since obtained in Pb-Pb reactions at SPS and LHC. The key signatures, strangeness and multistrange antibaryons, as well as entropy content of this small system do indicate development of conditions that are today associated with the formation of quark-gluon deconfined phase of matter. The forthcoming experimental effort to characterize the threshold of QGP formation as a function of collisions energy and reaction volume will be placed into strangeness and entropy context.

Plenary session / **60**

Energy scan programs in HIC

Author: Anar Rustamov[1]

[1] *National Nuclear Research Center (AZ)*

Corresponding Author: a.rustamov@cern.ch

Plenary session / **36**

Interplay between deconfinement and chiral properties

Author: Hideo Suganuma[1]

[1] *Kyoto University*

Corresponding Author: suganuma@scphys.kyoto-u.ac.jp

We study the relation between quark confinement and chiral symmetry breaking, and investigate interplay between confinement/deconfinement and chiral properties at finite temperatures. We analytically derive some relations of the Polyakov loop or its fluctuations with Dirac eigenmodes in temporally odd-number lattice QCD [1,2]. For the these quantities related to confinement, the contribution from the low-lying Dirac eigenmodes is found to be negligibly small, while the modes are essential for chiral symmetry breaking. This result indicates that there is no direct, one-to-one correspondence between confinement/deconfinement and chiral symmetry breaking in QCD.

[1] T. M. Doi, K. Redlich, C. Sasaki and H. Suganuma, Phys. Rev. D92, 094004 (2015).

[2] T. M. Doi, H. Suganuma and T. Iritani, Phys. Rev. D90, 094505 (2014); H. Suganuma, T. M. Doi and T. Iritani, Prog. Theor. Exp. Phys. 2016, 013B06 (2016).

Plenary session / **44**

$SU(2N_F)$ symmetry of QCD at high temperature and its implications

Author: Leonid Glozman[None]

Corresponding Author: leonid.glozman@uni-graz.at

Given a gap in the Dirac spectrum at $T > T_c$ we show that the high-temperature QCD has a $SU(2N_F)$ symmetry. This symmetry prohibits the on-shell propagation of quarks and the only possible elementary objects in Minkowski space-time are confined $SU(2N_F)$ symmetric "hadrons". We discuss what should be measured on the lattice in order to clarify a structure of these objects in order to understand what kind of matter we have in QCD at high temperature. An important question is also how we could experimentally distinguish it from the "quark-gluon plasma" picture.

Plenary session / **14**

Thermal Model Description of Collisions of Small Nuclei.

Author: Jean Cleymans[1]

[1] *University of Cape Town*

Corresponding Author: jean.cleymans@gmail.com

The dependence of particle production on the size of the colliding nuclei is analysed in terms of the thermal model using the canonical ensemble.
The concept of strangeness correlation in clusters of sub-volume V_C is used to account for the suppression of strangeness.
A systematic analysis is presented of the predictions of the thermal model for particle production in collisions of small nuclei.
The pattern of the maxima in particle ratios as a function of beam energy is quite special, as they do not occur at the same beam energy.
Also, the Λ/π^+ ratio shows a clear maximum even for the smallest systems while the maximum in the K^+/π^+ ratio disappears in small systems.

Plenary session / **2**

Search for a mixed phase of QCD matter at NICA

Author: Alexander Sorin[1]

[1] *Joint Institute for Nuclear Research, Dubna*

Corresponding Author: alexander.sorin@cern.ch

The Nuclotron-based Ion Collider Facility (NICA) project is now under active realization at the Joint Institute for Nuclear Research (JINR, Dubna). The main goal of the project is an experimental study of hot and dense strongly interacting matter in heavy ion (up to Au) collisions at centre-of-mass energies up to 11 GeV per nucleon. Two modes of the operation are foreseen, collider mode and extracted beams, with the two detectors, MPD and BM@N. In the collider mode the average luminosity is 10E27 cm-2 s-1 for Au(79+). The fixed target experiment BM@N at the JINR superconducting synchrotron Nuclotron is in a preparation stage. Extracted beams of various nucleus species with maximum momenta 13 GeV/c (for protons) will be available. The NICA project also foresees a study of spin physics with the detector SPD with extracted and colliding beams of polarized deuterons and protons at centre-of-mass energies up to 27 GeV (for protons). The proposed program allows to search for possible signs of the phase transitions and critical phenomena as well as to shed light on the problem of nucleon spin structure. General design, construction status and physics program of the NICA complex will be presented.

Plenary session / **120**

Polyakov loop fluctuations in terms of Dirac eigenmodes

Author: Takahiro Doi[1]

[1] *Japan/Kyoto University*

Corresponding Author: doi@ruby.scphys.kyoto-u.ac.jp

We investigate the relation between quark confinement and chiral symmetry breaking in the finite-temperature lattice QCD. First of all, we derive analytical formulae to express the Polyakov loop and its fluctuations in terms of the Dirac eigenmodes[1-3]. Based on the analytical formulae, it is shown that the low-lying Dirac modes have little contribution to the quantities such as the Polyakov loop and its fluctuations while these modes are important for chiral symmetry breaking. In other words,

the result means no direct one-to-one correspondence between confinement and chiral symmetry breaking in QCD. In our talk, we present our results including the numerical results and the recent developments.

[1] T. M. Doi, K. Redlich, C. Sasaki and H. Suganuma, Phys. Rev. D92, 094004 (2015).

[2] T. M. Doi, H. Suganuma and T. Iritani, Phys. Rev. D90, 094505 (2014).

[3] H. Suganuma, T. M. Doi and T. Iritani, Prog. Theor. Exp. Phys. 2016, 013B06 (2016).

Plenary session / **133**

Generalized Beth-Uhlenbeck approach to quark-hadron matter

Author: David Blaschke[1]

[1] *University of Wroclaw*

Corresponding Author: david.blaschke@gmail.com

An effective model for low-energy QCD thermodynamics is presented which provides a microscopic interpretation of the transition from a gas of hadron resonances to the quark-gluon plasma by Mott dissociation of hadrons. The self consistent approximation scheme of the Φ-derivable approach is applied to describe the thermodynamics of the Polyakov loop extended Nambu–Jona-Lasinio (PNJL) model which is shown to take the form of a Generalized Beth-Uhlenbeck (GBU) equation of state. This approach goes beyond the mean-field description of quark matter by taking into account hadronic correlations (bound and scattering states) as well as their backreaction on the quasiparticle properties of the constituents. The approach is straightforwardly extended to include more hadronic degrees of freedom than just the low-lying pseudoscalar mesons. To this end a model for the generic behavior of hadron masses and phase shifts at finite temperature is employed which shares the basic features with the PNJL model for correlations in quark matter. The results compare well with data from lattice QCD simulations [1].

[1] D. Blaschke, A. Dubinin, L. Turko, in preparation (2016)

Parallel session 1 / **48**

Across deconfinement transition

Author: Claudio Bonati[1]

[1] *University of Pisa*

Corresponding Author: claudio.bonati@df.unipi.it

The deconfinement transition at vanishing chemical potential can be reliably studied by lattice simulations and its general features are by now well known. On the contrary, what happens at finite density is still largely unknown and in this talk I will review the results obtained in the last year regarding the dependence, for small density, of the (pseudo)critical temperature on the baryonic chemical potential.

Parallel session 2 / **55**

Higher order moments of net-charge multiplicity distribution in p+p interactions at SPS energies from NA61/SHINE

Author: Maja Katarzyna Maćkowiak-Pawłowska[1]

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

Corresponding Author: maja.m.pawlowska@gmail.com

NA61/SHINE at the CERN SPS is a fixed-target experiment pursuing a rich physics program including measurements for heavy ion, neutrino and cosmic ray physics. The main goal of the ion program is to study the properties of the onset of deconfinement and to search for the signatures of the critical point. Specific property of the critical point – increase in the correlation length – makes fluctuations its basic signal. Recently, special interest is paid towards fluctuations of higher order moments as they are more sensitive to the correlation length than typically studied second order moments.

In this contribution preliminary results on higher order fluctuations of negatively charged hadrons and net-charge distribution in p+p interactions will be shown. The new data will be compared with model predictions.

Parallel session 2 / **18**

Dynamical fluctuations near the QCD critical point and their impact on the net-proton kurtosis

Author: Christoph Herold[1]

[1] *Suranaree University of Technology*

Corresponding Author: herold@g.sut.ac.th

We investigate the kurtosis of the net-proton number and the chiral order parameter within the model of nonequilibrium chiral fluid dynamics for a crossover scenario near the critical point. Our model describes the interplay between a dynamical order parameter and a quark-gluon fluid during the expansion of the hot fireball created in a heavy-ion collision. A subsequent particlization process allows us to study experimental observables via an event-by-event analysis. We aim at understanding the different impact of two distinct sources of fluctuations: First, initial state fluctuations and second, critical fluctuations created at the phase transition. Our results show that only the latter ones help develop a characteristic signal in the net-proton kurtosis around the crossover transition. We demonstrate that a suppression of the kurtosis is related to the equilibrium signal for criticality as seen in the net-baryon number susceptibility. Although effects of finite size and inhomogeneity are present, the signal in the net-proton kurtosis develops clearly.

Parallel session 1 / **80**

Searching for the QCD critical point through power-law fluctuations of the proton density in heavy ion collisions

Author: Nikolaos Davis[1]

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

Corresponding Author: nikolaos.davis@cern.ch

Parallel session 2 / **50**

PHENIX results on collective effects in small systems

Author: Arkadiy Taranenko[1]

[1] *National Research Nuclear University MEPhI (RU)*

Corresponding Author: arkadiy.taranenko@cern.ch

Extensive measurements of azimuthal anisotropy
in heavy-ion collisions, have provided invaluable
insights on the expansion dynamics and the transport properties of the
strongly interacting matter produced in collisions at RHIC and the LHC.
However, recently a number of measurements from high-multiplicity collisions
in small systems at RHIC and LHC, such as p+p, p+A, or d+Au, have found strong
presence of flow-like collective effects.
A crucial open question is whether a fundamental change occurs in the
reaction dynamics and the particle production mechanism, when the
collision system-size is reduced from the values produced in central and
mid-central heavy-ion collisions, to those obtained in small systems.

In recent experiments, the PHENIX Collaboration has made detailed differential
measurements of anisotropic flow coefficients v_n of charged hadrons emerged
from p+Au, d+Au and 3He+Au collisions at 200 GeV.
The results from these measurements will be presented and discussed.
Detailed comparisons to different model predictions and LHC data will be shown
as appropriate.

Parallel session 1 / **122**

Critical Phenomena in the Nonextensive Nambu Jona-Lasinio Model

Author: Jacek Rożynek[1]

[1] *NCBJ Warsaw Poland*

Corresponding Author: rozynek@fuw.edu.pl

We present a thermodynamical analysis of the nonextensive, QCD-based, Nambu - Jona-Lasinio model (NJL) of strongly interacting matter in the critical region. It is based on the nonextensive generalization of the Boltzmann-Gibbs (BG) statistical mechanics, used in the NJL model, to its nonextensive version. This can be introduced in different ways, depending on different possible choices of the form of the corresponding nonextensive entropies, which are all presented and discussed in detail. Unlike previous attempts the present approach fulfils the basic requirements of thermodynamical consistency. Detailed calculations of entropy and specific heat are presented. Phase diagram in the critical region, in the in the (T,μ) plane, is shown for different values of non-extensivity.

Parallel session 2 / **19**

Measurement of virtual photons radiated from Au+Au collisions at beam = 1.23A GeV with HADES

Author: Szymon Harabasz[1]

[1] *TU Darmstadt / Jagiellonian University*

Corresponding Author: s.harabasz@gsi.de

Dileptons are a unique probe to study microscopic properties of nuclear matter under extreme conditions of temperature and density achieved in heavy-ion collisions. The low-mass excess radiation
(above cocktail) observed from SIS to top RHIC energies is well understood theoretically in terms of strict VMD assuming strong broadening of the in-medium rho spectral function. This broadening is linked to the coupling of vector mesons to baryons and anti-baryons and is expected to be maximal in
baryon-rich medium as formed at lowest beam energies.
This is the paramount topic of the experimental program of HADES conducted at SIS18 accelerator in GSI. Strong, non-linear system size dependence of the integrated yield above the NN reference has been extracted from former C+C and Ar+KCl runs [1].
This contribution will present results on virtual photon production from high statistics Au+Au at $_{beam}$ = 1.23A GeV data and confront them with the reference measured by HADES as well as with available model predictions. The integrated excess yield will be put in context of the dilepton excitation function measured in RHIC beam energy scan.

[1] G. Agakishiev et al. [HADES Collaboration], Phys. Rev. C **84** (2011) 014902

This work has been supported by TU Darmstadt: VH-NG-823, Helmholtz Alliance HA216/EMMI and GSI.

Parallel session 1 / **49**

Dynamical gap generation in graphene with frequency dependent renormalization effects

Author: Margaret Carrington[1]

[1] *Brandon University*

Corresponding Author: carrington@brandonu.ca

In recent years there has been much interest in the study of graphene, which is a 2-dimensional crystal of carbon atoms that exhibits many interesting electronic properties and quantum effects. The dynamical generation of a gap would cause the system to undergo a phase transition to an insulating state. From a technological point of view, a finite gap would make graphene more promising as a potential material for producing novel electronic devices. A gap would also be theoretically interesting as a concrete realization of the phenomena of chiral symmetry breaking.

We consider the simplest form, mono-layer suspended graphene at half filling. The low energy dynamics are described by a continuum quantum field theory. The effective coupling is of order c/v_F ~ 300 times the fine structure constant of QED, where v_F is the velocity of a free electron in graphene. The system is strongly coupled and non-perturbative.

We solve a set of coupled Schwinger Dyson equations for frequency dependent fermion dressing functions. We include vertex corrections (using an ansatz which is constructed to preserve gauge invariance). We study frequency dependencies in the renormalization of the fermion Green functions and their influence on dynamical gap generation. The result is a critical coupling of ~3.2. This is slightly larger than the most recent calculations in the literature and predicts (in agreement with experiment) that the insulating state does not form.

Parallel session 1 / **51**

Field-particle dynamics for the kinetics of the chiral phase transition

Author: Hendrik van Hees[1]

[1] *Goethe University Frankfurt*

Corresponding Author: hees@fias.uni-frankfurt.de

We simulate the kinetics of the chiral phase transition in hot and dense strongly interacting matter within a novel kinetic-theory approach. Employing an effective linear σ model for quarks, σ mesons, and pions we treat the quarks within a test-particle ansatz for solving the Boltzmann transport equation and the mesons in terms of classical fields. The decay-recombination processes like $\sigma \leftrightarrow \bar{q} + q$ are treated using a kind of wave-particle dualism using the exact conservation of energy and momentum. After demonstrating the correct thermodynamic limit for particles and fields in a "box calculation" we apply the simulation to the dynamics of an expanding fireball similar to the medium created in ultrarelativistic heavy-ion collisions.

Parallel session 2 / 20

PHENIX Levy analysis of Bose-Einstein correlation functions

Author: Dániel Kincses[1]

[1] *Eötvös Loránd University Budapest*

Corresponding Author: kd94@windowslive.com

The importance of the RHIC beam energy scan program is that comparing results at different energies (varied in the region where the transition from hadronic to quark matter is expected to occur) allows us to investigate the structure of QCD matter, and the quark-hadron transition. One of the best tools to gain information about the (soft) particle-emitting source is the measurement of Bose-Einstein or HBT correlations of identical bosons. Today, high energy physics experiments measure the scale parameter of these correlation functions (often called HBT radii) as a function of particle type, transverse momentum, azimuthal angle, collision energy, collision geometry. In this talk I present results from the RHIC PHENIX experiment, related to Bose-Einstein correlations and the search for the critical point. In our latest measurements, we utilize Levy-type sources, whose index of stability alpha may also yield information on the nature of the quark-hadron phase transition. I will discuss what the beam energy dependence of the pion source tells us about the critical point, then I present the latest status of the analysis of the Levy source parameters as a function of transverse momentum, and explain how the non-Gaussian shape of correlation functions is related to one of the critical exponents.

Parallel session 2 / 30

Event-by-event multiplicity fluctuations in relativistic heavy ion collisions

Author: Haojie Xu[1]

[1] *Peking University*

Corresponding Author: haojiexu@pku.edu.cn

Non-critical thermal fluctuations are important baselines in search of the critical point for the RHIC beam energy scan program. In this talk, we present our investigations on the non-critical baselines of cumulants of (net-conserved) charge distributions in relativistic heavy ion collisions. By deriving a general formula of multiplicity distribution in connect with the method used in experiment, we demonstrate the mismatch between experimental measurements (conditional probability distributions) and previous theoretical calculations (probability distributions in a given thermal system) on multiplicity distributions. From the general formula, we investigate how to obtain the basic statistical expectations of higher order cumulants from experiments with the help of the data of the reference multiplicity distribution and mean value distribution. We find that the improved baseline measure for multiplicity distribution mimics the negative binomial distribution instead of Poisson one, though the Poisson distribution was used as input in a specific statistical ensemble. Recently, we implement this idea to event-by-event hybrid model simulations, and calculate the higher order cumulants of charge (proton) distributions in HIC. Our results reasonably reproduce the data at $\sqrt{s_{NN}} = 200$ GeV but shows deviations at lower collisional energies.

References:

HJX, On the multiplicity distribution in statistical model: (I) negative binomial distribution, arXiv:1602.06378.

Jixin Li, HJX, Huichao Song, Event-by-event multiplicity fluctuations in VISHNU hybrid model, in prepare.

Parallel session 1 / 56

Symmetry breaking effect on the inhomogeneous chiral phase in the external magnetic field

Author: Ryo Yoshiike[1]

[1] *Kyoto university*

Corresponding Author: yoshiike@ruby.scphys.kyoto-u.ac.jp

The existence of the inhomogeneous chiral phase, where the chiral condensate is spatially modulated has been discussed from some effective model analysis.
The phase seems to emerge in compact stars because it appears around the conventional chiral phase transition line in the QCD phase diagram.
Assuming an inhomogeneous configuration called “dual chiral density wave (DCDW)”, where both scalar and pseudoscalar condensates are spatially modulated,
the external magnetic field extends the DCDW phase over the low chemical potential (μ) region except for $\mu = 0$ in the chiral limit [1].
It seems the spread DCDW phase can be explored by the lattice QCD simulation.

Therefore we constitute the thermodynamic potential including the finite current quark mass around the critical point by the generalized Ginzburg-Landau expansion [2] to consider the effect of the explicit chiral symmetry breaking on the inhomogeneous chiral phase transition.
Consequently, we can see that the strong magnetic field extends the DCDW phase over the low μ region even if the current quark mass is finite [3].
The possibility of the exploration by the lattice QCD is phenomenologically discussed based on the result.
Besides, the inverse magnetic catalysis is also argued in the present model.

Reference

[1] T. Tatsumi, K. Nishiyama and S. Karasawa, Phys. Lett. B743, 66 (2015)

[2] D. Nickel, Phys. Rev. Lett. 103, 072301 (2009)

[3] R. Yoshiike and T. Tatsumi, Phys. Rev. D92, 116009 (2015)

Parallel session 1 / **134**

Relaxation rates and phase transitions

Author: Jakub Jankowski[1]

[1] *Jagiellonian University*

Corresponding Author: jakubj@th.if.uj.edu.pl

Using a bottom-up gauge gravity constructions, relaxation rates of strongly coupled field theories are computed. A variety of phase structures are considered, from a crossover up to a first order phase transition. It is established that near the transition the applicability of a hydrodynamic description breaks down at lower momenta than in the conformal case. In the case of the first order phase transition, a spinodal region appears at temperatures for which the speed of sound squared is negative. An estimate of the preferential scale attained by the unstable modes is also given. Additionally we observe a novel diffusive regime for sound modes over a range of wavelengths. Additionally, for a range of wavelengths we observe a novel diffusive regime for sound modes.

Parallel session 2 / **6**

Fluctuations of the freeze-out temperature in Pb-Pb collisions at LHC

Author: Dariusz Prorok[1]

[1] *University of Wroclaw, Poland*

Corresponding Author: dariusz.prorok@ift.uni.wroc.pl

Many data in the High Energy Physics are, in fact, sample means. It is shown that when this exact meaning of the data is taken into account and the most weakly bound states are removed from the hadron resonance gas, the acceptable fit to the whole spectra of pions, kaons and protons measured at midrapidity in central Pb-Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV is obtained. The invariant distributions are predicted with the help of the Single-Freeze-Out Model (SFOM) in the chemical equilibrium framework. The new idea introduced into the SFOM in this work is to randomize one of the parameters of the model. It has turned out that the successful improvement is achieved only when the freeze-out temperature becomes a random variable and nothing is gained with the randomization of geometric parameters of the model. Low p_T pions and protons are reproduced simultaneously as well as p/π ratio. Additionally, correct predictions extend over lower parts of large p_T data. The method is applied to other centrality bins of Pb-Pb collisions and the results are also presented. Some more general, possible implications of this approach are pointed out.

Based on: D.Prorok, "Single Freeze-Out, Statistics and Pion, Kaon and Proton Production in Central Pb-Pb Collisions at $\sqrt{s_{NN}} = 2.76$ TeV", J. Phys. G: Nuclear and Particle Physics **43** (2016) 055101.

Plenary session / **35**

Transport Theory Based on the Nambu—Jona-Lasinio Lagrangian

Author: Joerg Aichelin[1]

[1] *Subatech*

Corresponding Author: aichelin@subatech.in2p3.fr

Starting from the (Polyakov-) Nambu-Jona-Lasinio Lagrangian, (P)NJL, we formulate a transport theory which allows for describing the expansion of a quark-antiquark plasma and the subsequent transition to the hadronic world —without adding
any new parameter to the standard (P)NJL approach, whose parameters are fixed to vacuum physics. This transport theory can be used to describe ultrarelativistic heavy-ion reaction data as well as to study the (first-order) phase
transition during the expansion of the plasma. (P)NJL predicts such a phase transition for finite chemical potentials. In this contribution we give an outline of the necessary steps to obtain such a transport theory and present first results.

Plenary session / **26**

Correlated fluctuations near the QCD critical point

Author: Huichao Song[1]

[1] *Peking Univ.*

Corresponding Author: huichaosong@pku.edu.cn

Recently, the STAR beam energy scan (BES) measured the multiplicity distributions of net protons with the maximum transverse momentum extended from 0.8 GeV to 2 GeV. The related higher cumulants (moments) present large deviations from the poisson baselines, showing the potential of discovery the QCD critical point in experiment.

In this talk, we introduce a freeze-out scheme for the dynamical models near the QCD critical point through coupling the classical particles with the correlated fluctuating sigma field [2]. For an infinite and stationary medium, such freeze-out scheme can reproduce the standard Staphanov formulas [3] for critical fluctuations. Within this framework, we calculate the correlated fluctuations of net protons emitted from the hydrodynamic freeze-out surface at various collision energies. A comparison with recent STAR BES data shows that our model could reproduce kurtosis (and C4) through tuning the related parameters, but always over-predicts the C2 and C3 data with the poisson/binomial baselines due to the positive contributions from the static critical fluctuations [2]. In the later part of this talk, we will briefly discuss the dynamical critical fluctuations, showing that the sign of C3 could be solved by the memory effects after a dynamical evolution [4].

[1] X. Luo PoS CPOD2014, 019 (2014).
[2] Lijia Jiang, Pengfei Li, Huichao Song, arXiv:1502.06164[nucl-th].
[3] M. Stephanov, Phys. Rev. Lett. 102, 032301 (2009).
[4] Lijia Jiang and Huichao Song, in preparation.

Plenary session / **23**

Collective dynamics in smal sysytems

Author: Piotr Bożek[1]

[1] *AGH University of Science and Technology*

Corresponding Author: piotr.bozek@fis.agh.edu.pl

The presence of collective expansion in small collision is discussed.
Approaches based on relativistic hydrodynamics are compared to existing data.
Possibilities to study fluctuations in the interaction region in small collision systems
are described.

Plenary session / **113**

Recent progress in understanding deconfinement and chiral symmetry breaking transitions

Author: Edward Shuryak[1]

[1] *Stony Brook University*

Corresponding Author: edward.shuryak@stonybrook.edu

While the crucial role of gauge topology was recognized from 1970's,
confinement was associated with monopoles and chiral symmetry breaking with instantons.
Recognizing presence of non-zero holonomy, van Baal and others discovered
splitting of the instantons into their constituents — the instanton-dyons.
Several groups now work out properties of their ensembles, which generate
both
the deconfinement and chiral phase transitions in QCD-like theories.
Introducing variable phases for quark periodicity conditions — known as flavor holonomies — one
can switch fermion coupling to different dyons, and thus dramatically
change both the order and temperature of both transitions. First lattice studies of
modified — so called Z_N-symmetric QCD — have also found these effects.

Plenary session / **106**

Off-equilibrium Non-Gaussian Cumulants: criticality, complexity, and universality

Author: Swagato Mukherjee[1]

[1] *Brookhaven National Laboratory*

Corresponding Author: swagato@bnl.gov

Non-equilibrium evolution of cumulants of critical fluctuations for space-time trajectories on the cross-over side of the QCD phase diagram we be discussed in detail. Memory effects are important. Utilizing a simple model of the space-time evolution of a heavy-ion collision, we demonstrate that, depending on the relaxation rate of critical fluctuations, Skewness and Kurtosis can differ significantly in magnitude as well as in sign from equilibrium expectations. Furthermore, we demonstrate that key features of the Kibble-Zurek framework of non-equilibrium phase transitions can be employed to extract the dynamics of critical cumulants for differing protocols–trajectories in the space of parameters in the vicinity of the QCD critical point. For a broad classification of crossover protocols, universal scaling functions are obtained for the cumulants that are insensitive to the parameters governing the protocols. As a consequence of this non-equilibrium universality, a map of the details of critical dynamics in heavy-ion collisions to the relevant Kibble-Zurek parameters is feasible and provides powerful model independent guidance in searches for the QCD critical point.

Plenary session / **45**

Probing the nature of phases across the phase transition at finite isospin chemical potential

Author: Rajiv V Gavai[1]

[1] *Tata Institute, Mumbai, India*

Corresponding Author: gavai@tifr.res.in

We compare the low eigenvalue spectra of the Overlap Dirac
operator on two sets of configurations at $\mu_I/mu_I^c = 0.5$ and 1.5 generated with dynamical staggered fermions at these isospin chemical potential on $24^3 \times 6$ lattices. We find very small changes in the number of zero modes and low lying modes across the transition which is in stark contrast with those across the corresponding finite temperature phases where one sees a drop across the phase transition. Possible consequences
are discussed.

Plenary session / **37**

Wounded quarks at the LHC

Author: Wojciech Broniowski[1]

[1] *IFJ PAN*

Corresponding Author: wojciech.broniowski@ifj.edu.pl

We apply the wounded quark model to particle production and properties of the initial fireball in A+A, p+A, and p+p collisions at the Large Hadron Collider (LHC). We find uniformity of the approach, as similar production of initial entropy per source
is needed to explain particle production in all studied reactions and at all centralities. We also investigate event-by-event initial eccentricities and sizes, finding results as good or better than from the Glauber model with nucleons. In conclusion, the wounded quarks can be used as effective degrees of freedom at the LHC.

Poster session / **117**

Quasi-Particle Quark-Nuclear Hybrid EoS with Excluded Volume Effects

Author: Mark Kaltenborn[1]

[1] *University of Wrocław*

Corresponding Author: markaltenborn@gmail.com

In this poster, we outline a two-phase description of the quark-nuclear matter hybrid equation of state that takes into account effects of phase space occupation (excluded volume) in both, the hadronic and the quark matter phases. For the nuclear matter phase, the reduction of the available volume at increasing density leads to a stiffening, while for the quark matter phase a reduction of the effective string tension in the confining density functional is obtained. The deconfinement phase transition in the resulting hybrid equation of state is sensitive to both excluded volume effects. As an application, we consider matter under compact star constraints of electric neutrality and β-equilibrium. We obtain mass-radius relations for hybrid stars that fulfill the $2M_\odot$ constraint

and exhibit the high-mass twin phenomenon. Both features depend sensitively on the excluded volume.

Poster session / **123**

Phase diagram of the three-flavor PNJL model

Author: Alexandra Friesen[1]

[1] *Joint Institute for Nuclear Research, Dubna*

Corresponding Author: avfriesen@theor.jinr.ru

The QCD phase diagram and transitions between quark and hadron phases are in the focus of recent investigations in both theoretical and experimental fields of heavy energy physics. For a description of matter at high temperature and density effective models of Nambu-Jona-Lasinio-type have proven most useful. On the basis of NJL-type models it is possible to describe the chiral restoration transition and to describe the quark-gluon coupling and confinement transition, when the Polyakov loop is included. The Polyakov loop extended NJL (PNJL) model can reproduce results of lattice QCD at zero and imaginary chemical potential, where LQCD has no sign problem. In this poster contribution we present the dependence of the first-order
phase transition line and its critical endpoint in the PNJL model phase
diagram when the following aspects are taken into
account:

- different parametrizations of the effective potential $U(\Phi, \bar{\Phi}; T)$
- including the coupling of quarks to a repulsive vector mean field,
- modification of the quark interaction by “entanglement” with the Polyakov loop.

Poster session / **114**

Centrality determination in heavy-ion collisions with CBM experiment

Authors: Ilya Selyuzhenkov[1]; Viktor Klochkov[2]

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

[2] *GSI*

Corresponding Authors: ilya.selyuzhenkov@gmail.com, klochkov44@gmail.com

The size and evolution of the medium created in a heavy-ion collision depends on collision geometry. Experimentally collisions are characterized by the measured particles multiplicities around midrapidity or energy measured in the forward rapidity region, which is sensitive to the spectator fragments. In the CBM experiment the multiplicity of produced particles is measured with the silicon tracking system (STS). The projectile spectator detector (PSD) is sensitive to spectator fragments. We present the procedure of collision centrality determination in CBM and its performance using the PSD and the STS information.

Poster session / **103**

Composite particles - effects of substructure

Author: Simon Leibing[1]

Co-author: David Blaschke [2]

[1] *TU Freiberg*

[2] *University of Wroclaw*

Corresponding Author: simon.liebing@physik.tu-freiberg.de

The concept to classify particles as bosons and fermions and to assume certain properties is very successful in physics. One should keep in mind that for composite particles these classification is an approximation. In that case the investigated particles are not primitive particles and truly are composed by several bosons or
fermions.

The authors try to get estimates on the errors made, by the assumption of primitive particle properties. Also we look for effects that could be missed by such a treatment. One easy example is the interaction of deuterons, which is influenced by the properties of the forming protons. This could be extended to baryons and other composite fermions.

Poster session / **135**

vHLLE, a code for hydrodynamic modelling of relativistic heavy ion collisions

Author: Iurii Karpenko[1]

[1] *Frankfurt Institute for Advanced Studies*

Corresponding Author: yu.karpenko@gmail.com

vHLLE solves the equations of relativistic viscous hydrodynamics in 3+1 dimensions using Israel-Stewart framework. In addition to energy and momentum, charge densities are explicitly propagated and included in the equation of state, making the code suitable for simulations of matter expansion with nite baryon density. With the help of ideal-viscous splitting, we keep the ability to solve the equations of ideal hydrodynamics in the limit of zero viscosities using a Godunov-type algorithm. Milne coordinates are used to treat the predominant expansion in longitudinal (beam) direction effectively.

Poster session / **136**

The Physics of core-collapse supernovae - Towards 3–dimensional models

Corresponding Author: tobiswiss@gmail.com

Poster session / **126**

Mott-hadron resonance gas and lattice QCD thermodynamics

Author: Dubinin Aleksandr[1]

[1] *University of Wrocław*

Corresponding Author: aleksandr.dubinin@ift.uni.wroc.pl

We present an effective model for low-energy QCD thermodynamics which provides a microscopic interpretation of the transition from a gas of hadron resonances to the quark-gluon plasma by Mott dissociation of hadrons and compare results with data from lattice QCD simulations. We consider the thermodynamics of the Polyakov-loop extended Nambu–Jona-Lasinio (PNJL) model within the self consistent approximation scheme of the ϕ-derivable approach. This allows us to obtain the Generalized Beth-Uhlenbeck (GBU) equation of state. Our approach goes beyond the mean-field description of quark matter by taking into account hadronic correlations (bound and scattering states) as well as their backreaction on the propagator of constituents. The next step in our work is to include more hadronic degrees of freedom than just the low-lying pseudoscalar mesons. For that purpose we discuss a model for the generic behavior of hadron masses and phase shifts at finite temperature which shares basic features with recent developments within the PNJL model for correlations in quark matter.

Poster session / **127**

CBM performance for anisotropic flow measurements

Author: Vitalii Blinov[1]

[1] *Frankfurt University / GSI*

Corresponding Author: vitalii.blinov@cern.ch

Compressed Baryonic Matter experiment (CBM) at FAIR has a potential of discoveries in the area of QCD phase diagram with high net baryon densities and moderate temperatures. Anisotropic transverse flow is one of the key observables to study the properties of matter created in a heavy-ion collisions.

CBM performance for anisotropic flow measurements is studied with Monte-Carlo simulations of gold ions at SIS-100 energies using heavy-ion event generators. Different combinations of the CBM detector subsystems are used to investigate the possible systematic biases in flow measurement and to study effects of detector azimuthal non-uniformity. Resulting performance of the CBM for flow measurements is demonstrated for directed flow as a function of pseudorapidity and transverse momentum in different centrality classes.

Poster session / **128**

Non-local Quark Model for modelling the composite Higgs particle

Author: Aliaksei Kachanovich[1]

[1] *University of Wrocław*

Corresponding Author: zxz12m@yahoo.com

In this poster, we propose an approach for the Higgs boson as top-quark condensate within non-local Nambu–Jona-Lasinio (NJL) model. The advantage of non-local models over local ones is the spectrum of composed particle masses, which has a lower value than the sum of masses of particles of which it consists. By adjusting two parameters in the non-local NJL, the interaction range and the coupling, we can simultaneously describe the top quark mass and the Higgs boson mass.

Poster session / **130**

Hybrid Equation of State for Heavy-Ion Collisions and Astrophysics

Author: Niels-Uwe Bastian[1]

[1] *University of Wrocław*

Corresponding Author: niels-uwe.bastian@ift.uni.wroc.pl

The aim of our work is to develop a unified equation of state (EoS) for nuclear and quark matter for a wide range in temperature, density and isospin so that it becomes applicable for heavy-ion collisions as well as for the astrophysics of neutron stars, their mergers and supernova explosions. As a first step, we use improved EoS for the hadronic and quark matter phases and join them via Maxwell construction. For this we work with a generalized density functional approach for the self energies in a quasi particle picture, which gives us the possibility to start with a reasonable physical basis and apply improvements to fit constraints from lattice QCD and neutron star measurements.

Poster session / **131**

Dynamical freeze-out in event-by-event hydrodynamics

Author: Pasi Huovinen[1]

[1] *Goethe-Universität*

Corresponding Author: huovinen@th.physik.uni-frankfurt.de

We employ a dynamical freeze-out criterion, which requires the hydrodynamical expansion rate to be equal to the pion scattering rate, in an ideal fluid hydrodynamical calculation of spectra at RHIC (EoS s95p-PCE-v1, $T_{chem} = 150$ MeV). We find that the p_T spectra are very similar to those evaluated using freeze-out in constant temperature, but pion $v_2(p_T)$ is reduced by $\sim 10\%$.

Poster session / **132**

Temperature effects on superfluid phase transition in Bose-Hubbard model with three-body interaction

Author: Michał Szymański[1]

[1] *University of Wrocław*

Corresponding Author: michal.w.szymanski@gmail.com

We study the combined effects of two and three-body local interactions as well as the finite temperature on the phase diagram of simple lattice bosons model. In order to handle system with strong local interactions we use the resolvent expansion technique, based on the contour integral representation of a partition function, and to find the phase diagram we derive Landau-type expansion for free energy in terms of the superfluid order parameter. Since superfluidity is expected to appear in the QCD phase diagram at large density, presented model and computational techniques may be helpful in development of effective models of dense quark matter.

Poster session / 124

Physical properties of Polyakov loop geometrical clusters in SU(2) gluodynamics

Author: Oleksii Ivanytskyi[1]

Co-authors: Dmytro Oliinychenko [2]; Eduard Nikonov [3]; Ernst-Michael Ilgenfritz [4]; Gennady Zinovjev [1]; Igor Mishustin [5]; Kyrill Bugaev [6]; Violetta Sagun

[1] *National Academy of Sciences of Ukraine (UA)*

[2] *CERN*

[3] *Joint Institute for Nuclear Research (JINR)*

[4] *Joint Institute for Nuclear Research Dubna, Russia*

[5] *Goethe University*

[6] *Bogolyubov Institute for Theoretical Physics of NAS of Ukraine*

Corresponding Author: oleksii.ivanytskyi@cern.ch

A novel approach to identify the geometrical (anti)clusters formed by the Polyakov loops of the same sign and to study their properties in the lattice SU(2) gluodynamics is developed. The (anti)cluster size distributions are analyzed for the lattice coupling constant $\{\beta$ =[2.3115; 3]$\}$. $The found distributions are similar to the ones existing in 2-and 3-dimensional Ising systems$ [1]. U 2.52 as a transition between two liquids during which one of the liquid droplets (the largest cluster of a certain Polyakov loop sign) experiences a condensation, while another droplet (the next to the largest cluster of opposite Polyakov loop sign) evaporates. The clusters of smaller sizes form two accompanying gases, which behave oppositely to their liquids. The liquid drop formula is used to analyze the distributions of the gas (anti)clusters and to determine their bulk, surface and topological parts of free energy. Surprisingly, even the monomer multiplicities are reproduced with high quality within such an approach. The behavior of surface tension of gaseous (anti)clusters is studied. It is shown that this quantity can serve as an order parameter of the deconfinement phase transition in SU(2) gluodynamics. Moreover, the critical exponent of surface tension coefficient of gaseous clusters is found in the upper vicinity of critical temperature. Its value coincides with the one found for 3 dimensional Ising model within error bars. The Fisher topological exponent of (anti)clusters is found to have the same value 1.806 ± 0.008, which agrees with an exactly solvable model of the nuclear liquid-gas phase transition [2] and disagrees with the Fisher droplet model [3], which may evidence for the fact that the SU(2) gluodynamics and the model [2] are in the same universality class.

[1] L. Moretto et al., Phys. Rev. Lett. 94, 202701 (2005).

[2] V. Sagun, A. Ivanytskyi, K. Bugaev and I. Mishustin, Nucl. Phys. A 924, 24 (2014).

[3] M. E. Fisher, Physics 3, 255 (1967).

Poster session / 137

In-medium quark mass-gap equation solutions

Corresponding Author: mat.cierniak@gmail.com