6th International Conference on

Critical Point and Onset of Deconfinement

JINR Dubna, August 23-29, 2010

and

HIC-for-FAIR School and Workshop on

Dense QCD phases in Heavy-Ion Collisions

JINR Dubna, August 21- September 4, 2010

Booklet of Abstracts

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Preface

The International Conference on "Critical Point and Onset of Deconfinement" is the 6th in the series that started 2004 with a workshop at the ECT* in Trento. Subsequent meetings were held at the University of Bergen in 2005 , at the Galileo Galilei Institute in Florence in 2006, at GSI/Darmstadt in 2007 and at BNL Brookhaven in 2009. The purpose of the conference series is to discuss theoretical and experimental progress in studies of the QCD phase diagram and properties of strongly interacting matter at high temperature and density. Particular emphasis is put on the physics at non-zero baryon number density that shall be probed in future low energy experiments at BNL, CERN, GSI and JINR.

The HIC-for-FAIR School "Dense QCD Phases in Heavy-Ion Collisions" embracing this conference will support attendance for young researchers. The School will focus on the problem of the appearance of novel phases of matter where symmetries encoded in the QCD Lagrangian get (partly) restored and/or due to the internal quantum numbers of QCD degrees of freedom (color, flavor and spin) new collective phenomena might occur. As a profound theoretical basis for the description of the equation of state and transport properties of QCD matter and the phase transformation between hadronic and quark degrees of freedom this School will provide series of lectures on nonperturbative quantum field theories and many-body physics of strong interactions applied to this problem. Another part of the lectures will be devoted to the discussion of observable signals for QCD phases in heavy-ion collisions like those planned at FAIR Darmstadt and NICA Dubna. Topics to be covered by the School include:

- Nonequilibrium and Transport Phenomena in Dense Matter
- Equation of State and QCD Phase Transitions
- Hadron Production in Heavy-Ion Collisions
- QCD phases in Compact Stars, Supernovae and Mergers

We wish the CPOD 2010 conference as well as the HIC-for-FAIR School a successful work and hope for sustainable results! Projects for future heavy-ion collision experiments need well trained young researchers with high motivation and excellent new ideas!

Dubna, August 2010 The Local Organisation Committee

Plenary Talks

The core-corona model

J. Aichelin[a]

[a] Subatech, Nantes, France

Personal notes

Strangeness and onset of deconfinement

F. Becattini[a]

[a] INFN, Florence, Italy

In this talk I will review the current status of global strangeness production in relativistic heavy ion collisions and discuss its relevance for the detection of the onset of deconfinement.

Personal notes

First results from the ALICE experiment

I. Belikov[a]

[a] IPHC, Strasbourg, France

We will present the results from the first series of measurements performed by the ALICE detector at CERN LHC. These results include the charged-particle pseudo-rapidity densities, multiplicity distributions and transverse momentum spectra, and other results obtained by analysing the data collected in 2009 and 2010 at three different center-of-mass energies of 0.9, 2.36 and 7 TeV. The results are compared to previous proton-antiproton data and to model predictions.

Personal notes

Perspectives in dynamical models of heavy ion collisions

M. Bleicher[a]

[a] FIAS, Frankfurt, Germany

Personal notes

System Size Dependence of Particle Production at the SPS

C. Blume[a]

[a] Institut fuer Kernphysik, University of Frankfurt, 60438 Frankfurt am Main, Germany

Recent results on the system size dependence of net-baryon and hyperon production as measured at the CERN SPS will be shown. The observed Npart-dependencies of the yields, but also of dynamical properties, such as average transverse momenta, can be described in the context of the core corona approach. The implications of this observations for a search for a critical point in the QCD phase diagram will be discussed. Also, the fluctuations of the relative core to corona source contributions could influence fluctuation observables (multiplicity, K/π). The size of this effect will be investigated.

Personal notes

The CBM experiment - a status report

V. Friese[a]

[a] GSI Darmstadt, Germany

The CBM experiment is being designed to measure nuclear collisions at the upcoming FAIR accelerator facility in Darmstadt. Its physics focuses are the deconfinement phase transition of QCD matter, the QCD critical point, and the properties of hadrons in high net-baryon density matter. We will report on the status of the experiment in terns of physics performance studies and detector developments.

Personal notes

Energy dependence of transverse momentum and multiplicity fluctuations at the CERN SPS

T. Cetner[a] and K. Grebieszkow[a] for the NA61/SHINE Collaboration, (to be presented by M. Gazdzicki[b,c])

[a] Warsaw University of Technology, Warsaw, Poland [b] University of Frankfurt, Frankfurt, Germany [c] Jan Kochanowski University, Kielce, Poland

Theoretical calculations locate the QCD critical end-point at energies accessible at the CERN Super Proton Synchrotron (SPS). Event-by-event transverse momentum and multiplicity fluctuations are considered as one of the most important tools to search for the critical point.
Pilot studies of the energy dependence and the system size dependence of both transverse momentum and multiplicity fluctuations were performed by the NA49 experiment and an intriguing non-monotonic behavior was found for the system size dependence at the top SPS energy.
The NA61/SHINE ion program is a continuation of the NA49 efforts. In particular, NA61 aims to search for the critical point of strongly interacting matter by performing a two-dimensional scan in collision energy (beam momentum 10A-158A GeV/c) and system size (p+p, B+C, Ar+Ca, and Xe+La).
The scan program of NA61/SHINE started in 2009 by recording high-statistics samples of p+p collisions at 20-158 GeV/c beam energies. After briefly reviewing the essential NA49 results on fluctuations we will discuss the technical methods we plan to apply for future transverse momentum and multiplicity fluctuation analyzes.

Personal notes

Confining but chirally symmetric dense and cold matter

L. Glozman[a]

[a] University of Graz, Graz, Austria

Personal notes

Statistical Models of Hadron Production

M. Gorenstein [a]

[a] BITP (NAS), Kiev, Ukraine

Particle number fluctuations and correlations in nucleus-nucleus collisions are studied within statistical approach. An extension of the standard concept of statistical ensembles is suggested. Examples and possible applications are discussed.

Personal notes

Baryon Stopping in Heavy-Ion Collisions at from AGS to SPS energies

Yu. Ivanov[a]

[a] Kurchatov Institute, Moscow, Russia

It is argued that the experimentally observed baryon stopping may indicate (within the present experimental uncertainties) a non-monotonous behaviour as a function of the incident energy of colliding nuclei. This can be quantified by a midrapidity reduced curvature of the net-proton rapidity spectrum. The above non-monotonous behaviour reveals itself as a "zig-zag" irregularity in the excitation function of this curvature. The three-fluid dynamic calculations with a hadronic equation of state (EoS) fail to reproduce this irregularity. At the same time, the same calculations with an EoS involving a first-order phase transition into the quark-gluon phase do reproduce this "zig-zag" behaviour, however only qualitatively.

Personal notes

Scientific Program at NICA - JINR accelerator facility

V. Kekelidze[a]

[a] JINR, Dubna, Moscow region, Russia

The accelerator facility NICA including existing superconducting accelerator Nuclotron-M and future collider NICA are briefly presented. Experiments at the NICA complex are discussed in more details. These experiments are dedicated first of all to study of the phase transition in hot and dense baryonic matter, and to search for mixed phase and the critical endpoint. Possible experiments on the spin-dependent nucleon structure and spin phenomena in few nucleon systems are discussed as well.

Personal notes

Quarkyonic Chiral Spirals

T. Kojo[a]

[a] RIKEN-BNL, Upton, USA

We argue the chiral symmetry breaking/restoration in cold, dense quark matter with confinement.

Personal notes

Status and plans of the NA61/SHINE physics programme

S. Kowalski[a] for the NA61/SHINE Collaboration

[a] Institute of Physics, University of Silesia, Katowice, Poland

The NA61/SHINE expeiment at the SPS facility is a successor of former NA49 experiment. The aim of the new project is to explore the QCD phase diagram within the range of thermodynamical variables (like e.g. temperature and baryon chemical potential). The detector and data acquisition system upgrades will result in an increase of the data rate by an order of magnitude as compared to the standard NA49 data rate. This will allow to perform a 2D scan of the phase diagram by varying energy and size of the colliding nuclear systems.
The main goal of the scan is a search for the critical point and the onset of QGP formation. The increase in the data rate will also give a unique possibility to measure high-pT particle production at SPS energies which provides excellent information about the properties of the created matter. Moreover, the NA61/SHINE physics program provides precision hadro-production measurements which are required to compute the neutrino beam spectrum of the T2K experiment at J-PARC and to analyse cosmic-ray (Pierre Auger Observatory, KASCADE-Grande and KASCADE) experiments.

Personal notes

The HADES-at-FAIR project

K. Lapidus[a,b]

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The HADES experiment (GSI Helmholtzzentrum für Schwerionenforschung, Darmstadt) is currently located at the SIS-18 synchrotron, where it performs measurements of di-electron and hadron production in different collision systems. After completing its experimental program at SIS-18, the HADES detector will be transferred to the SIS-100 synchrotron at the FAIR accelerator complex and will continue investigations at beam energies up to 10 AGeV. The physics motivation for HADES-at-FAIR and the upgrade of the experimental setup, needed to make measurements at higher energies possible, will be discussed.

Personal notes

Evidence for the Onset of Deconfinement and Quest for the Critical Point by NA49 at the CERN SPS

G.L. Melkumov[a] for the NA49 Collaboration

[a] BLTP JINR 141980 Dubna, Russia

Experimental study of predicted features of the phase diagram of strongly interacting matter such as the deconfinement transition and the critical point is the primary goal of a number of contemporary experiments, developing projects and numerous theoretical investigations. The NA49 results on hadron production obtained in Pb+Pb collisions at SPS energies from 20A GeV to 158A GeV will be shown and discussed as evidence for the onset of deconfinement. This interpretation is based on the consistency of the experimental data with the Statistical Model of the Early Stage, which predicts the transition to a system of quasi-free quarks and gluons (QGP) at low SPS energies. The major measures used in the energy scan analysis are the pion yield, the kaon to pion ratio and the slope of transverse mass distributions. In order to characterize the deconfinement transition the NA49 collaboration has analyzed predicted signatures of the critical point. In particular NA49 studied event-by-event mean transverse momentum and particle multiplicity fluctuations as well as particle ratio fluctuations. The anisotropic flow and anti-baryon to baryon ratios were also analyzed to look for the possible sign of the critical point. The energy dependence of these observables was measured in central Pb+Pb collisions in the full SPS energy range while for analysis of the system size dependence data from p+p, C+C, Si+Si and Pb+Pb collisions at the top SPS energy were used. A more comprehensive study in a broad range of the phase diagram will be continued in the successor NA61/SHINE experiment by performing an energy scan (10A-158A GeV) with lighter nuclei, which enables, together with existing Pb+Pb data, to confirm the evidence for the onset of deconfinement at low SPS energies and to search for appearence of the critical point.

Personal notes

Status of NICA project

I. Meshkov[a]

[a] BLTP JINR 141980 Dubna, Russia

The project of Nuclotron-based Ion Collider fAcility (NICA) is under development at JINR. The goal of the project is construction of the ion collider facility that allows to provide heavy ions collisions in the energy range of $\sqrt{s} = 4 - 11$ GeV/u at luminosity of 5E25 - 1E27 standard units. Presently the project has reached the stage of technical design. In the report the modern (modified) scheme of the facility and its parameters are presented. The physics of colliding beams limiting luminosity is discussed as well. The project status and schedule are presented.

Personal notes

Hydrodynamic modeling of deconfinement/chiral phase transitions in and out of equilibrium

I.N. Mishustin[a]

[a] Kurchatov Institute, Moscow, Russia

Observation of deconfinement and chiral phase transitions remains in the focus of present and future experiments with relativistic heavy-ion beams. The main difficulty here is that these phase transitions should occur at intermediate stages of the reaction when the collective expansion of matter is very fast. In this situation nonequilibrium effects are expect to play an important role. In this talk I first summarize predictions of the equilibrium hydrodynamic model and then present several new developments incorporating nonequilibrium effects. The evolution of fluctuations of the order-parameter field are investigated within the linear sigma model with constituent quarks. It is demonstrated that crossover and second-order types of phase transitions in fast dynamical background do not leave any significant signals. However, a strong first-order phase transition leads to significant supercooling and reheating effects.

Personal notes

Beam Energy Scan Program at RHIC - STAR experience

G. Odyniec[a] for the STAR Collaboration

[a] LBNL, Berkeley, USA

One of the most important goals for high-energy nuclear collisions is to understand the phase structure of matter with partonic degrees of freedom. In this talk, a brief overview of the scientific program of the Beam Energy Scan (BES) at RHIC, with emphasis on the search for the QCD Critical Point (CP) in the nuclear phase diagram and on the onset of deconfinement, will be presented. The STAR experiment's first experience with data taking in 2010 at $\sqrt{s_{\rm NN}}$ = 7.7, 11.5 and 39 GeV Au+Au collisions will be discussed.

Personal notes

Prospects for probing the mixed phase at NICA by spinodal separation

J. Randrup[a]

[a] BNL; Berkeley, USA

Personal notes

Multipurpose detector (MPD) to study hot, dense baryonic matter at the NICA collider

O. Rogachevsky[a]

[a] JINR Dubna, 141980 Dubna, Russia

Personal notes

Dilepton and strangeness production probed with HADES

A. Rustamov[a] for the HADES Collaboration

[a] GSI Darmstadt, Germany

With the High Acceptance Di-Electron Spectrometer (HADES) at GSI we have studied dilepton production in the few-GeV energy regime in various collisions systems, from elementary NN, over p+A, up to the medium-heavy Ar+KCl system. We have thus confirmed the puzzling results of the former DLS collaboration at the Bevalac. While we have traced the origin of the excess pair yield in C+C collisions to elementary pp and pn processes, in our Ar+KCl data contribution from the dense phase of the collision has been identified. Properties of such an exotic radiation will be shown and discussed in this presentation. From a comparison of the 3.5 GeV p+p and p+Nb interactions, vector-meson production and, in particular, its medium modifications can be addressed. These results will also be presented. Together with the e^+e^- pairs, we have obtained in the Ar+KCl system at 1.76 AGeV a high-statistics data set on open and hidden strangeness, i.e. $K^{\pm}$, K^0_S, Λ, ϕ, and Ξ^-, allowing for a comprehensive discussion of strangeness production in this system. I will discuss these results as well.

Personal notes

Thermodynamics of dense nuclear matter in a parity doublet model

C. Sasaki[a], and I. Mishustin[a]

[a] Frankfurt Institute for Advanced Studies, D-60438 Frankfurt am Main, Germany

We study thermodynamics of nuclear matter in a two-flavored parity doublet model under the mean field approximation. The model describes a liquid-gas transition of nuclear matter and a chiral crossover or phase transition at higher density. At finite temperature the pion decay constant experiences a reduction at an intermediate chemical potential, which is traced back to the presence of the liquid-gas transition. This induces a "transition" from meson-rich to baryon-rich matter.

Personal notes

Beam Energy Dependence of Azimuthal Anisotropy at RHIC-PHENIX

A. Taranenko[a], for PHENIX Collaboration

[a] Department of chemistry, SUNY Stony Brook, NY, 11794-3400, USA

A central goal of current experiments at the Relativistic Heavy ion Collider (RHIC) is to study the properties of the hot and dense QCD matter produced in energetic heavy ion collisions. Such studies can give insight on the QCD phase diagram, as well as the transport coefficients of the strongly-coupled Quark Gluon Plasma (sQGP). Harmonic Flow measurements play an essential role for such studies. During the 2007-2010 running period, the PHENIX experiment performed a comprehensive set of flow measurements for identified hadrons in Au+Au collisions at $\sqrt{s_{NN}} = 39,\ 62,\ 200$ GeV) with enhanced statistical significance and pT reach. The measurements, performed for particles produced at mid-rapidity ($|eta| < 0.35$) for four separate reaction-plane detectors positioned in the range $1.0 < |eta| < 3.9$, allow precision studies of scaling violations important to the extraction of thermodynamic and transport properties. The influence of fluctuations and a possible $|eta|$-dependent non-flow contribution to the measurements will be discussed as well.

Personal notes

Measuring Dynamical K/π and p/π Fluctuations in Au+Au Collisions from the STAR Experiment

T. Tarnowsky[a], for STAR Collaboration

[a] Michigan State University, East Lansing, USA

Results from new measurements of dynamical K/π and p/π ratio fluctuations are presented. Dynamical fluctuations in global conserved quantities such as baryon number, strangeness, or charge may be observed near a QCD critical point. The STAR experiment has previously acquired data in Au+Au collisions at the energies: $\sqrt{s_{NN}}$ = 200, 130, 62.4, and 19.6 GeV. The commencing of a QCD critical point search at RHIC has extended the reach of possible measurements of dynamical K/π and p/π ratio fluctuations from Au +Au collisions to lower energies. N ew results are compared to previous measurements and to theoretical predictions from the models UrQMD, HSD, and HIJING.

Personal notes

Anomalies and asymmetries in quark-gluon matter

O. Teryaev[a]

[a] BLTP JINR, Dubna, Moscow region, Russia

Various manifestations of axial anomaly in rotating medium are considered. The structures in bilinear current correlators and their relations to dileptons angular distribution are also analyzed.

Personal notes

Energy and system-size dependence of the chiral magnetic effect

V. Toneev[a], E. Bratkovskaya[b] , W. Cassing[c] , D. Kharzeev[d] , V. Konchakovski[c,e] , V. Skokov[f], S. Voloshin [g], and V. Voronyuk[a]

[a] JINR Dubna, Russia; [b] ITP&FIAS, Frankfurt, Germany; [c] University of Gießen, Gießen, Germany; [d] BNL, Upton, USA; [e] Bogolyobov Institute for Theoretical Physics, Kiev, Ukraine; [f] Helmholtzzentrum für Schwerionenforschung (GSI), Darmstadt, Germany; [g] Wayne State University, Detroit, USA

The energy dependence of the local CP-odd violation in Au+Au an Cu+Cu collisions is estimated within a simple phenomenological model. Model predictions are made for the LHC and energies which are planned to be reached at the future SIS300 and NICA accelerators. The evolution of the magnetic field formed in heavy-ion collisions is also discussed.

Personal notes

Chiral magnetic effect and U+U collisions

S. Voloshin[a], E. Bratkovskaya[b], W. Cassing[c], D. Kharzeev[d], V. Toneev[e], and V. Voronyuk[e]

[a] Wayne State University, Detroit, USA; [b] ITP&FIAS, Frankfurt, Germany; [c] University of Gießen, Gießen, Germany; [d] BNL, Upton, USA; [e] JINR Dubna, Russia

Personal notes

Viscosity and thermal conductivity effects in the hydrodynamical description of the first-order phase transitions in HIC

D. Voskresensky[a]

[a] MEPhI, Moscow, Russia

Effects of viscosity and thermal conductivity on the dynamics of first-order phase transitions are studied. The processes of growth and dissolution of seeds of various sizes and shapes in meta-stable phases (like super-cooled vapor and super-heated liquid) are considered, as well as the dynamics of unstable modes in the spinodal region. Important consequences of a difference of the isothermal and adiabatic spinodal regions are discussed. It is shown that in hydrodynamical calculations at non-zero thermal conductivity, onset of the spinodal instability occurs, when the system trajectory crosses the isothermal spinodal line. Applications to the description of the hadron-quark transition in the high energy heavy-ion collisions are discussed.

Personal notes

High-Energy Nuclear Collisions - Explore the QCD Phase Structure

N. Xu[a]

[a] LBNL, Berkeley, USA

Personal notes

Contributed Talks

Resonance structure in the $\gamma\gamma$ invariant mass spectrum in pC, dC and dCu interactions

Kh.U. Abraamyan[a], M.I. Baznat[b], A.V. Friesen[a], K.K. Gudima[b], M.A. Kozhin[a], S.A. Lebedev[c], M.A. Nazarenko[d], S.A. Nikitin[a], G.A. Ososkov[c], S.G. Reznikov[a], A.N. Sissakian[e] , A.S. Sorin[e], and V.D. Toneev[e]

[a] VBLHEP JINR, 141980 Dubna, Russia, [b] Institute of Applied physics, MD-2028 Kishinev, Moldovam [c] LIT JINR, 141980 Dubna, Russia, [d] Institute of Radioengineering, Electronics and Automation, RU-119454 Moscow, Russia, [e] BLTP JINR, 141980 Dubna, Russia

Along with π^0 and η mesons, a resonance structure in the invariant mass spectrum of two photons at $M = 360 \pm 7 \pm 9$ MeV is observed in dC interactions at momentum 2.75 GeV/c per nucleon. Estimates of its width and production cross section are 63.7 ± 17.8 MeV and $98 \pm 24 + 93 - 67\mu$b. The collected statistics amount to 2339 ± 340 events of 1.5×10^6 triggered interactions of a total number about 10^{12} of dC interactions. This resonance structure is not observed in pC collisions at the beam momentum 5.5 GeV/c. The result obtained in the reaction d+C is confirmed by the second experiment carried out on the deuteron beam at momentum 3.83 GeV/c per nucleon with a copper target: $M = 382 \pm 13$ MeV, $\Gamma = 62.0 \pm 37.2$ MeV and $\sigma = 273 \pm 75 + 320 - 96\mu$b.

Personal notes

On the magnetic mass of gluons in Abelian magnetic background field

M. Bordag[a], and V. Skalozub

[a] Leipzig University, Leipzig, Germany

We address the issue of the magnetic mass of gluons in a constant chromo magnetic background field. Such fields are likely to be created spontaneously due to the large magnetic moment the gluons have. The magnetic mass in such fields is of interest, for example, for the excitations of a quark-gluon plasma. An explicate determination is difficult due to the complicated structure of the polarization tensor in the background field at finite temperature. We use the representation developed earlier (Phys. Rev. D 75, 125003 and D 77, 105013) and calculate the magnetic masses of both, neutral and charged, gluons in the limit of high temperature. As expected, there is an imaginary part from the tachyonic modes. For the neutral gluons, the magnetic mass vanishes such that there is no screening. For the charged gluons we find the corresponding shift of the Landau levels and we discuss its effect on a stabilization of the spectrum.

Personal notes

Dynamics of hot and dense nuclear and partonic matter

E. Bratkovskaya[a]

[a] ITP&FIAS, Frankfurt, Germany

The dynamics of hot and dense nuclear matter is discussed from the microscopic transport point of view. The basic concepts of the hadron-string-dynamical transport model (HSD) - derived from Kadanoff-Baym equations in phase phase - are presented as well as 'highlights' of HSD results for different observables in heavy-ion collisions from 100 A MeV (SIS) to 21 A TeV (RHIC) energies. Furthermore, a novel extension of the HSD model for the description of the partonic phase - the Parton-Hadron-String-Dynamics (PHSD) approach - is introduced. PHSD includes a nontrivial partonic equation of state - in line with lattice QCD - as well as covariant transition rates from partonic to hadronic degrees of freedom. The sensitivity of hadronic and electromagnetic observables to the partonic phase is demonstrated for relativistic heavy-ion collisions.

Personal notes

Inhomogeneous chiral symmetry breaking phases

M. Buballa[a], S. Carignano[a], and D. Nickel[b]

[a]Inst. f. Kernphysik, TU Darmstadt, Germany, [b] INT, University of Washington, Seattle, USA

We investigate inhomogeneous chiral symmetry breaking phases in the phase diagram of the two-flavor Nambu-Jona–Lasinio model, concentrating on phases with one- dimensional modulations. It is found that the first-order transition line in the phase diagram of homogeneous phases gets completely covered by an inhomogeneous phase which is bordered by two second-order transition lines. Moreover, the inhomogeneous phase turns out to be remarkably stable when vector interactions are included, in contrast to the critical endpoint in the homogeneous case.

Personal notes

Physical Mechanism of the (Tri)critictal Point Generation

K. Bugaev[a]

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On the basis of several exactly solvable models I discuss the physical mechanism to generate the (tri)critical endpoint of the QCD phase diagram. Such a mechanism is typical for the liquid-gas phase transitions and has nothing to do with the chiral symmetry restoration. Using the results of exactly solvable models, I introduce two order parameters which allow one to unambiguously distinguish all phases and transition lines related to deconfinement. The role of surface tension of large/heavy quark-gluon plasma bags in generating the triple point of the QCD phase diagram is also discussed.

Personal notes

Charm production in p-p collisions at $\sqrt{s} = 7$ TeV with the ALICE detector

D. Caffarri[a] for the ALICE Collaboration

[a] INFN and University Padova, 35131 Padova, Italy

The main goal of the ALICE experiment is the investigation of the properties of strongly-interacting matter in a very high density deconfined state, that should be formed in Pb-Pb collisions. The ALICE experiment has started collecting p-p collisions data at $\sqrt{s} = 0.9$ TeV in November 2009 and at 7 TeV in March 2010. The first run with heavy-ion collisions is expected in November 2010. The measurement of the charm production cross section in p-p collisions at the LHC will allow to test perturbative QCD calculations in a new energy regime. The p-p collisions data are also important as a reference for the study of medium effects in Pb-Pb collisions, where heavy quarks are expected to be sensitive probes for the medium properties, as they are formed at shorter time scale than the medium. We will present the status of the ongoing open charm analyses, considering the D0, D+ and D*+ mesons reconstruction, in the central rapidity region. We will also discuss the prospects for the same measurements in the next heavy- ion run.

Personal notes

How to extract physics from nudyn

P. Christiansen[a], E. Haslum[a], and E. Stenlund[a]

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Fluctuations in high energy physics are of great interest both in understanding collective behavior and in the search for long range correlations indicative of phase transitions.
The variable vudyn has been proposed [1] for studying particle number fluctuations as it has well behaved mathematical properties: statistical fluctuations are automatically subtracted (no need for event mixing) and it is independent of detection efficiency.
In a recent paper [2] we have shown how nudyn can be interpreted in terms of simple physics models, such as pair production.
In this talk I will illustrate our results with new ideas on how to use nudyn for studying observables of interest for collective behavior in pp collisions, e.g., forward-backward correlations. These new nudyn observables might also be of interest in AA collisions.
Finally I would like to show how one can generalize nudyn to continous variables and discuss also the problems with such an anlysis.

References

[1] C. Pruneau, S. Gavin, and S. Voloshin, Phys.Rev.C **66**, 044904 (2002).

[2] P. Christiansen, E. Haslum and E. Stenlund, Phys.Rev.C **80**, 034903 (2009).

Personal notes

Search for the QCD critical point in nuclear collisions at the CERN SPS

N. Davis[a], F. Diakonos[a], and N. Antoniou[a]

[a] University of Athens, Athens, Greece

We present results for an analysis of pion production in nuclear collisions at the SPS with the aim to search, in a restricted domain of the phase diagram, for power-laws in the behaviour of correlations which are compatible with critical QCD. We have analysed interactions of nuclei of different size (p+p, C+C, Si+Si, Pb+Pb) at 158AGeV adopting, as appropriate observables, scaled factorial moments in a search for intermittent fluctuations in transverse dimensions. The analysis is performed for opposite charged dipions with invariant mass very close to the two-pion threshold. Our results indicate the presence of power-law fluctuations in the freeze-out state of the Si+Si system approaching in size the prediction of critical QCD while for the Pb+Pb system the proposed analysis technique cannot be applied without entering the invariant mass region with strong Coulomb correlations. As a result the treatment becomes inconclusive in this case.

Personal notes

Quantum simulations of thermodynamic and kinetic properties of strongly coupled electromagnetic and quark-gluon plasmas

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Determining the properties of strongly coupled hydrogen, electron - hole or quark - gluon plasmas is one of the main challenges of strong-interaction physics, both theoretical and experimental. The main difficulty is that interaction, quantum and statistics effects should have a strong influence on the properties of these systems. Formation of Coulomb bound states, of many-particle clusters, of Coulomb liquids or electron-hole droplets at the Mott density are examples of the large variety of correlation phenomena which have to be taken into account. In electromagnetic plasmas (EMP), reliable simulations have to cover a broad range of masses of the different charged particles or quasi-particles. Similarly, in a many-component quark-gluon plasmas (QGP) a wide range of parameters of color quasi-particles has to be described consistently. Here, we propose a stochastic simulation of thermodynamic and kinetic properties of the strongly correlated Coulomb systems in a wide range of temperature, density and quasi-particle masses [1]. We use the direct quantum path integral Monte Carlo method (PIMC) developed for finite temperature within Feynman formulation of quantum mechanics to do calculations of internal energy, pressure and pair correlation functions. EMP quasi-particles representing electrons and holes as well as QGP quasi- particles representing dressed quarks, antiquarks and gluons interact via an electromagnetic or color quantum Kelbg pseudopotential, respectively. For the QGP quasi-particles we use different approximations for the temperature dependence of density, effective masses and coupling constant. Our calculations for EMP and QGP have shown surprisingly good agreement with the available analytical, numerical and experimental data, which gives us confidence that our approach correctly captures the main properties of the nonideal EMP and QGP. Our calculations include the region of appearance and decay of the bound states, Mott transition from neutral plasma to metallic–like clusters, formation of clusters in the dense liquid-like region as well as the formation of a Wigner- type crystal in case of a plasma with strong mass asymmetry [2]. While PIMC gives first principles thermodynamic results, it is not able to treat dynamical and transport properties of the EMP and QGP. A promising approach to study the dynamical and transport properties of strongly coupled Coulomb systems is based on the Wigner formulation of quantum dynamics. We present a numerical procedure which combines molecular dynamics and Monte Carlo methods for solving the quantum integral Wigner-Liouville equation which was applied to EMP before.

Extending this concept to the QGP this approach, in addition, includes Wongs dynamics of the color variables of the quasi-particles representing dressed quarks, antiquarks and gluons. To study the influence of the Coulomb and color Coulomb interaction on kinetic properties, we simulate the quantum dynamics in a canonical ensemble at finite temperature for both weakly and strongly coupled EMP and QGP. The main calculated quantities based on the Green-Kubo relations are the different temporal correlation functions and their frequency-domain Fourier transforms [3]. We have done calculation of the diffusion coefficients, conductivity, thermo-conductivity and shear viscosity.

References

[1] V. Filinov, M. Bonitz, Y.B. Ivanov, V.V. Skokov, P.R. Levashov, and V.E. Fortov, Contrib. Plasma Phys. **49**, 7-8, 536-543 (2009).

[2] M. Bonitz, V.S. Filinov, V.E. Fortov, P.R. Levashov, and H. Fehske, Phys. Rev. Lett. **95**, 235006 (2005)

[3] V.S. Filinov, M. Bonitz, Y.B. Ivanov, V.V. Skokov, P.R. Levashov, and V.E. Fortov, submitted to Contrib. Plasma Phys. (2010).

Personal notes

Quark matter and meson properties in a nonlocal SU(3) chiral quark model at finite temperature

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We study the finite temperature behavior of light scalar and pseudoscalar meson properties in the context of a three-flavor nonlocal chiral quark model. The model includes mixing with active strangeness degrees of freedom, and takes care of the effect of gauge interactions by coupling the quarks with the Polyakov loop. We analyze the chiral restoration and deconfinement transitions, as well as the temperature dependence of meson masses, mixing angles and decay constants.

Personal notes

The single flavor color Superconductivity in a Magnetic Field

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Personal notes

Determination of the Hot Equation of State of Dense Matter

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The equation of state is calculated for temperatures less than 30 MeV and densities less than four times the saturation density of nuclear matter.

Personal notes

Hypothetical Non-Congruence of QH Phase Transition and Critical Point

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Non-congruence (or incongruernce) is discussed as the most general form of phase transition (PT) in cosmic matter and laboratory. In terrestrial applications non-congruent phase transition (NCPT) means coexistence of phases with different chemical composition. A great number of such PT-s in simple mixtures and chemical compounds are non-congruent. Features of NCPT for thermo- and hydrodynamics are discussed and illustrated on example of non-congruent evaporation in high-T/high-P uranium-oxygen system [1], hypothetical product of severe accident in nuclear reactor [2]. Phase transitions in planets and substellar objects, in white dwarfs and outer layers of neutron stars, are numerous candidates for such type of phase transformations in cosmic applications [3]. Non-congruent scenario for gas-liquid (VdW-like) and quark-hadron (QH) phase transitions in interiors of compact stars and in supernova explosions as well as in products of high-energy ionic collisions, are discussed as the hypothetical exotic examples of NCPT in high energy density matter [4]. Different variants for structure of phase boundary(s) and critical (end) point(s) are discussed depending on different variants of relevant EOS(s) for quark and hadron phases (separate or unique) and their mixture (solution or suspension) as well as for different scenarios of QH phase transformation: coexistence of macroscopic phases or intermediate stage of highly dispersive mixture, simple (mixed phase) or structured (pasta) etc.

References

[1] I. Iosilevskiy, G. Hyland, E. Yakub, C. Ronchi, Trans. Amer. Nucl. Soc. **81**, 122 (1999).

[2] C. Ronchi, I. Iosilevskiy, E. Yakub, *Equation of State of Uranium Dioxide*, Springer, Berlin, (2004).

[3] I. Iosilevskiy, V. Gryaznov, E. Yakub, C. Ronchi, V. Fortov, Contrib. Plasma Phys. **43**, 316 (2003).

[4] I. Iosilevskiy, Acta Physica Polonica B (Suppl.) **3**, 589 (2010).

Personal notes

Critical phenomena in deep inelastic scattering

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Saturation in deep inelasctic scattering (DIS) and deeply virtual Compton scattering (DVCS) is associated with a phase transition between the partonic gas, typical of moderate x and Q^2, and, a partonic fluid (liquid), appearing at increasing Q^2 and decreasing Bjorken x. In the statistical interpretation of DIS, the large-x, $(1-x)^n$ factor in the SF is associated with the ideal statistical (F-B, B-E, or Boltzmann) distribution (perfect gas), while the low$-x$, Regge behaved factor $x^{b(Q^2)}$ introduces deviation from the perfect gas and ultimately leads to a gas-liquid phase transition. The "critical (saturation) point (line)" in the $x-Q^2$ plane of the nucleon structure function $F_2(x,Q^2)$ is associated with a possible phase transition, including a mixed phase, in the partonic system, described e.g. by the Van der Waals equation of state $P(T,V)$.

References

[1] V.G. Boyko, L.L. Jenkovszky, and V.M. Sysoev, Physics of Particles and Atomic Nuclei (PEPAN) **22** (1991) 675.

[2] L.L. Jenkovszky, S.M. Troshin, and N.E. Tyurin *Saturation and Critical Phenomena in DIS*, In the Proc. of the EDS09 ("Blois") Conference, CERN, 2010; arXiv:0910.0796.

Personal notes

Quark correlation function in magnetic field background: square root vs. linear dependence on B

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We show that the quark correlation function in quark matter at non-zero temperature and density in strong magnetic field scales as square root of the magnetic field. The same is true for the thermodynamic potential and transport coefficients. We explain why the previously adopted linear dependence is not correct.

Personal notes

AdS/QCD at finite density and temperature

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Based on recent revelopments in AdS/QCD (or holographic QCD), we attempt to understand QCD phase diagram at finite temperature and density. Results from various studies based on AdS/CFT are going to be summarized. Things to be improved to be more QCD-like are also to be discussed.

Personal notes

The search for collective phenomena in hadron interactions

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New results of the search for collective phenomena have been obtained and analyzed in the presented report. The experimental study is carried out on U-70 accelerator in Protvino. It is suggested that these phenomena can be discovered at the energy range of 50-70 GeV in the extreme multiplicity region since the high density matter can form in this very region. The collective behavior of secondary particles is considered to manifest in the Bose–Einstein condensation of pions, Vavilov–Cherenkov gluon radiation, excess of soft photon yield and other unique phenomena. The perceptible peak in the angular distribution has been revealed recently. It was interpreted as the gluon radiation in parton medium. The search for Bose-Einstein condensation is continuing. The gluon dominance model predictions have shown good agreement with the multiplicity distribution at high multiplicity and confirmed the guark-gluon medium formation under these conditions.

Personal notes

Mechanism of ϕ meson production and change of the effective degrees of freedom in heavy-ion collisions

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Personal notes

Fluctuations and Correlations as a Signal of Deconfinement

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The multiplicity fluctuations in A+A collisions at SPS and RHIC energies have been studied within the HSD transport approach. We find a dominant role of the fluctuations in the nucleon participant number for the final fluctuations. In order to extract physical fluctuations one should decrease the fluctuations in the participants number. This may be fulfilled by considering very central collisions. Futhermore, event-by-event fluctuations of the K/π, K/p and P/π ratio in nucleus-nucleus collisions have been studied for SPS and RHIC energies. We find that the HSD model can qualitatively reproduce the measured excitation function for the K/π ratio fluctuations in central Au+Au (or Pb+Pb) collisions from low SPS up to top RHIC energies. Moreover, substantial differences in the HSD and statistical model results are found for the multiplicity fluctuations and correlations. These predictions impose a challenge for future experiments. The di-jet azimuthal correlations also have been investigated within the HSD transport approach. We found that the suppression of the away-side jet in the hadronic medium is not enough to explain the experimental data from RHIC. The additional suppression should be attributed to a QGP produced at relativistic heavy-ion collisions.

Personal notes

The centrality determination for the NICA/MPD

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The problem of centrality determination for the NICA/MPD [1] is discussed. It was shown from simulation that different event generators predict quite different spectators distributions. As the result of this feature two different scenarios of centrality determination could be proposed. It is shown that for the scenario for events with UrQMD generator [2] the centrality can be determined using Zero Degree Calorimeter (ZDC) only in the limited interval of the impact parameters. The LAQGSM [3] and SHIELD [4] generators predict no monotonic dependence of ZDC signal from impact parameters. The experimental data for spectator dependence from impact parameters [5] are discussed in order to make a choice between these two kinds of models. It is shown that UrQMD [2] generator cannot describe experimental data. From the simulation it was obtained that impact parameter can be determined by using ZDC and TPC information.

References

[1] J. Phys. G: Nucl. Part. Phys. **36** 069808, (2009)

[2] http://urqmd.org/

[3] S.G. Mashnik, K.K. Gudima, I.V. Moskalenko, R.A. Prael and A.I. Sierk, arXiv:nucl-th/0210065v2

[4] http://www.nea.fr/abs/html/iaeal287.html

[5] The NA49 collaboration, Eur. Phys. J. A2, **383** (1998)

Personal notes

Duality of thermal and dynamical descriptions in particle interactions

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We suggest a duality between the statistical and standard (dynamical) distributions of partons in the nucleons. The temperature parameter entering into the statistical form for the quark distributions is estimated. It is found that this effective temperature is practically the same for the dependence on longitudinal and transverse momenta and, in turn, it is close to the freeze-out temperature in high energy heavy-ion collisions.

Personal notes

Identity method: a new tool for the study of chemical fluctuations in particle production reactions

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Event-by-event fluctuations of the chemical composition of the hadronic system produced in nuclear collisions are believed to be sensitive to the properties of strongly interacting matter, in particular to the onset of deconfinement. The NA49 results on the fluctuations of the K/π ratio in central Pb-Pb collisions show a rapid increase at low SPS energies [NA49 collaboration, Phys. Rev. C79, 044910, 2009]. The origin of this behaviour is under intensive discussion. These results, as well as the new NA61 ion program, motivated the development of new techniques to study fluctuations which would be free from the difficulties of the established methods. In this presentation a new technique to study chemical fluctuation, the identity method, is introduced and its properties are discussed. Preliminary results from Pb-Pb collisions registered by the NA49 experiment at the CERN SPS will be shown.

Personal notes

Shear viscosity of the Quark-Gluon Plasma from a virial expansion [1]

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Recent observations at the Relativistic Heavy-Ion Collider (RHIC) indicate that the quark gluon plasma (QGP) created in ultrarelativistic Au + Au collisions is interacting more strongly than hadronic matter. In this context, one of the most intriguing experimental findings is the large elliptic flow v_2 of hadrons at RHIC which is significantly larger than at SPS energies. This result has led to the BNL announcement about the discovery of the nearly perfect fluidity of the strongly-coupled quark-gluon plasma (sQGP) produced at RHIC. Therefore a dynamic calculation of the shear visosity η is desiderable. In the quark-gluon plasma phase we calculate the shear viscosity η within a virial expansion approach with particular interest in the ratio of η to the entropy density s, i.e. η/s. We derive a realistic equation of state using a virial expansion approach which allows us to include the interactions between the partons in the deconfined phase and to evaluate the corrections to a single-particle partition function. In the latter approach we start with an effective interaction with parameters fixed to reproduce thermodynamical quantities of QCD such as energy and/or entropy density. We also directly extract the effective coupling α_{V} for the determination of η. Our numerical results give a ratio $\eta/s = 0.097$ at the critical temperature T_{c}, which is very close to the theoretical bound of $1/(4\pi)$. Furthermore, for temperatures $T \leq 1.8T_{\mathrm{c}}$ the ratio η/s is in the range of the present experimental estimates $0.1 - 0.3$ at RHIC. When combining our results for η/s in the deconfined phase with those from chiral perturbation theory or the resonance gas model in the confined phase we observe a pronounced minimum of η/s close to the critical temperature T_{c}.

Personal notes

[1] This work is supported by etc, etc.

Kinetics of Chiral Phase transition in hot and dense quark matter

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We study the kinetics of chiral transitions in hot and dense quark matter using a microscopic frame work (Nambu–Jona-Lasinio model) and a phenomenological model (Ginzburg-landau free energy). We focus on far from equillibrium coarsening dynamics subsequent to a quench from the massless quark phase to the massive quark phase. The morphology of the ordering system is characterised by the scaling of the order parameter correlation function. The domain growth process obeys Allen-Cahn growth law $L(t) \sim t^1/2$. We also study the growth of bubbles of the stable masisve phase in a background of the meta stable massless phase.

Personal notes

Nonperturbative effects for the Quark Gluon Plasma Equation of State

V. Begun[a], M. Gorenstein[a] and O. Mogilevsky[a]

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Modified versions of the bag model equation of state (EoS) are considered. They are constructed to satisfy the main qualitative features observed for the quark-gluon plasma EoS in lattice QCD calculations. A quantitative comparison with the lattice results in SU(3) gluodynamics is done at temperatures T above the transition temperature T_c. Our analysis advocates a presence of a term linear in temperature which contributes to the pressure function p and does not contribute to the energy density ϵ. This term is found to guarantee both the correct behavior of p/T^4 at high T and its strong drop at $T \cong T_c$. A negative value of the bag constant B brings the behavior of ϵ/T^4 in agreement with the MC lattice results.

Personal notes

On hyperon phase in high energy heavy-ion collisions

G. Musulmanbekov[a]

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A new interpretation of the enhanced yield of hyperons and strange mesons (horn effect) observed in central heavy ion collisions in the experiment NA49 at SPS is given. We argue that the data indicate the transition of the nuclear matter in the overlap region of colliding nuclei to the hyperon phase. The model based on the quark structure of nuclei is proposed to explain the effect.

Personal notes

A novel strong coupling expansion of the QCD Hamiltonian

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A novel strong coupling expansion of the QCD Hamiltonian in the form of an expansion in the number of spatial derivatives is presented. Introducing an infinite spatial lattice with box length a, a systematic expansion of the physical QCD Hamiltonian in $\lambda = g^{-2/3}$ can be obtained, with the free part being the sum of the Hamiltonians of the quantum mechanics of constant fields for each box, and interaction terms proportional to λ^n $(n = 1, 2, 3, \ldots)$ with n spatial derivatives connecting different boxes. The method is illustrated for the case of SU(2)Yang-Mills theory, where the corresponding physical Hamiltonian and its expansion in the number of spatial derivatives, can be obtained explicitly, using the symmetric gauge $\epsilon_{ijk} A_{jk} = 0$. As an example, the energy of the gluon vacuum and the lowest scalar glueball is calculated up to order λ^2.

Personal notes

SU(3)×SU(3) nonlocal quark model and QCD phase transition

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The QCD phase transition is studied in the framework of an SU(3)×SU(3) nonlocal PNJL model. A comparison with lattice QCD results on the behavior of the quark condensate, pressure, energy-density and quark number susceptibilities is performed. Special attention is paid to the role of mesonic fluctuations in the thermodynamics.

Personal notes

Energy dependence of high-moments of net-proton distributions at RHIC

X.F. Luo[a], B. Mohanty[b], H.G. Ritter[a], N. Xu[a]

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RHIC has started a beam energy scan program to explore the QCD phase diagram and to search for the QCD critical point. Critical behavior is expected to be visible in high-order moments of distributions of conserved quantities, like the net-proton distributions. High-order moments can be directly related to the corresponding thermodynamical susceptibilities and have been predicted by Lattice-QCD calculations.
In this talk, after briefly discussing the recently published STAR results, we will analyze the energy dependence of net-charge distributions from transport and thermal models in terms of kurtosis and skewness and will present the model calculations as references for the data from the energy scan program.

Personal notes

The phase structure of the Polyakov-quark-meson model beyond mean field

B.-J. Schaefer[a]

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In this talk the Polyakov-loop-extended quark meson model is invetigated beyond mean-field approximation and its phase structure discussed. Both the quantum fluctuations to the QCD matter sector and the back-reaction of the matter fluctuations to the QCD Yang-Mills sector are included. Results on the chiral and confinement-deconfinement crossover/phase transition lines, the location of a possible critical endpoint and consequences for the quarkyonic phase are presented.

Personal notes

On the need for isospin averaged elementary reference data

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So far charged particle production in p+p reactions has been used as reference when searchung for collective phenomena (matter effects) in nuclear collisions. Although this approach is probably valid at RHIC and LHC energies, it has shortcomings for FAIR, NICA and SPS energies due, for example, to isospin effects. In particular (more) experimental data on charge exchange processes and on the p+n (n+p) reactions are needed. We shall discuss an experimental programme for the measurement of p+p and d+p interactions with neutron and spectator proton detection capabilities.

Personal notes

Energy scan in heavy ion collisions and search for a critical point

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Search for the clear signatures of phase transition of nuclear matter and the location of a possible Critical Point in heavy ion collisions (HIC) is main goal of the Beam Energy Scan programs at SPS and RHIC. Experimental data on inclusive spectra measured in heavy ion collisions at RHIC and SPS over a wide range of the energy $\sqrt{s_{NN}} = 9 - 200$ GeV are analyzed in the framework of z-scaling. Microscopic scenario of constituent interactions in the framework of this approach is discussed. Dependence of the energy loss on the momentum of the produced hadron, energy and centrality of the collision is studied. Self-similarity of the constituent interactions in terms of momentum fractions is used to characterize the nuclear medium by a "specific heat" and the colliding nuclei by fractal dimensions. Preferable kinematical regions for search for signatures of phase transition of nuclear matter produced in HIC are discussed. Discontinuity of a "specific heat" is assumed to be a signature of phase transition and a Critical Point.

Personal notes

The nuclear liquid-gas phase transition at large N_c in the Van der Waals approximation

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We examine the nuclear liquid-gas phase transition at large number of colors (N_c) within the framework of the Van Der Waals (VdW) model. We argue that the VdW equation is appropriate at describing inter-nucleon forces , and discuss how each parameter scales with N_c. We demonstrate that $N_c = 3$ is not large with respect to the other dimensionless scale relevant to baryonic matter, the number of neighbours in a dense system. Consequently, we show that the liquid-gas phase transition looks dramatically different at $N_c \to \infty$ with respect of our world: The critical point temperature becomes of the order of $\Lambda_{\rm QCD}$ rather than below it. The critical point density becomes of the order of the baryonic density, rather than an order of magnitude below it. These are precisely the characteristics usually associated with the "Quarkyonic phase". We therefore argue that at large N_c the nuclear liquid phase coincides with the conjectured quarkyonic phase, although the two are thought to occur at very different scales in our world.

Personal notes

Linear sigma model with vector mesons

G. Wolf[a]

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We built a linear sigma model including vector mesons and baryons. We fitted its parameter to well measured masses, decay constants and scattering lengths. The model will be used to describe chiral symmetry restoration at high temperature and densities.

Personal notes

Poster Talks

Search for multidimensional solitons in $SU(2)$ gauge theory

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The production of Λ hyperons study from primary p+A reactions on the basis of experemental and FRITIOF model fort heir basic kiematical distributions in the laboratory frame. Λ hyperons production study from secondary $K^-C \to \Lambda X$ (and with protons) interactions. Exotic strange baryon states have been observed in the effective mass spectra of: $\Lambda\gamma$, $p\gamma$, Λp, $\Lambda\Lambda$, and $\Lambda\pi^- p$ subsystems. There are enhancement production for all observed hyperons.

Personal notes

Finite formation time of hadrons: the QGP signatures

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Personal notes

The static screening potential from AdS/CFT

L. Hui[a]

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Our recent calculation shows the polarization tensor of R-photon from AdS/CFT is qualitatively different with the one from perturbative theory. It contains an infinite number of poles instead of a branch cut on the imaginary momentum axis. This mathematical discovery may result in a different screening potential between quarks. We studied the static screening potential based on this fact and point out that the potential between strongly-coupled quarks decays more slowly than the traditional Debye screening potential. Relevant physics are also discussed.

Personal notes

Quarkonium dissociation in a PNJL quark plasma

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We investigate the Mott effect for heavy quarkonia due to Debye screening of the heavy quark potential in a plasma of massless quarks and antiquarks [1]. The influence of residual color correlation is investigated by coupling the light quark sector to a temporal gauge field driven by the Polyakov loop potential. This leads to an increase of the Mott dissociation temperatures for quarkonia states which stabilizes in particular the excited states, but has marginal effect on the ground states. The temperature dependence of binding energies suggests that the dissciation of the charmonium (bottomonium) ground state by thermal activation sets in at temperatures of 200 MeV (250 MeV).

References

[1] J. Jankowski, D. Blaschke, H. Grigorian, Acta Phys. Pol. B Proc. Suppl. **3**, 741 (2010).

Personal notes

Phase transition in baryon-dense matter with account of finite size effects

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We consider a model of chiral phase transitions in nuclei, suggested by T.D. Lee et al., and argue that such transitions might be seen in cumulative effect investigations. Finite-range effects arising from the smallness of the system is briefly discussed. Some general proposals for future NICA and CBM experiments are given.

Personal notes

Critical behavior in (2+1)-dimensional QED

A. Kotikov[a]

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QED in 2+1-dimensions is analyzed in the leading and next-to-leading orders of the $1/N$ expansion.

Personal notes

Renormdynamics and scaling functions of the multiparticle production processes

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For Quantum Field theory models, Renormdynamic equations of motion for observable quantities and their solution are given. Universal scaling functions of multiparticle production in High energy physics are considered. Explicit forms of the KNO, and z-Scaling functions are constructed; new equation for NBD distribution invented.

Personal notes

Finite-size scaling as a tool for the search of the critical endpoint of QCD in heavy ion data

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Given the short lifetime and the reduced volume of the quark-gluon plasma formed in high-energy heavy ion collisions, a possible critical endpoint will be blurred in a region and the effects from criticality severely smoothened. Nevertheless, the non-monotonic behavior of correlation functions near criticality for systems of different sizes, given by different centralities in heavy ion collisions, must obey finite-size scaling. We study the applicability of the predicting power of scaling plots in the search for the critical endpoint of QCD in heavy ion collisions. For this purpose, we use data from RHIC and SPS. From a given data set we extrapolate our results to predict the behavior of new data at at lower center-of-mass energy. We exclude some possibilities, discuss the region currently being investigated in the Beam Energy Scan program at RHIC, and present the limitations of the method.

Personal notes

Isolated neutron stars in the Galaxy: from magnetars to antimagnetars

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Using the model with decaying magnetic fields we are able to describe with one smooth (log-gaussian) initial magnetic field distribution three types of isolated neutron stars: radiopulsar, magnetars, and cooling close-by neutron stars. The same model is used to make predictions for old accreting isolated neutron stars. It is shown that using the updated field distribution we predict a significant fraction of isolated neutron stars at the stage of accretion. Results are published in MNRAS, see Refs. [1, 2].

References

[1] S.B. Popov, J.A. Pons, J.A. Miralles, P.A. Boldin, B. Posselt, "Population synthesis studies of isolated neutron stars with magnetic field decay", arXiv:0910.2190 [astro-ph.HE].

[2] P.A. Boldin, S.B. Popov, "Evolution of isolated neutron stars till accretion. The role of initial magnetic field", arXiv:1004.4805 [astro-ph.HE].

Personal notes

Cluster decomposition for dense quark matter

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A cluster expansion technique is applied to quark matter within a confining potential model. The dissociation of nucleonic bound states of quarks is described as a Mott effect due to the Pauli blocking of quark phase space. The critical densities for this transition are obtained and their dependence on the isospin asymmetry is given.

Personal notes

Two Particle correlations in dense quark matter

D. Zablocki[a,b], D. Blaschke[b,c], R. Anglani[d,e], Yu.L. Kalinovsky[f]

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Recent laboratory experiments with ultracold gases of fermionic atoms allow to investigate dense Fermi systems with their coupling strength tunable via Feshbach resonances. Below a critical temperature, bosonic correlations form a condensate and this transition appears as BEC-BCS crossover, which in quark matter is of particular theoretical interest due to the ultrarelativistic regime for massless (Nambu - Goldstone) bosons. A systematic treatment of these effects is possible within the path integral formulation for finite temperature quantum field theories.

Personal notes

Student Contributions

Low density symmetry energy effects in the neutron star crust properties

D. Alvarez[a]

[a] Institute for Nuclear Physics of PAN, Krakow, Poland

The form of the nuclear symmetry energy E_s around the saturation point density leads to a different crust-core transition point in the neutron star and affects the crust properties. We show that the knowledge about E_s close to the saturation point is not sufficient, because the very low density behaviour is relevant. We also claim that crust properties are strongly influenced by the very high density behaviour of E_s , so in order to conclude about the form of the low density part of the symmetry energy one must isolate properly the high density part.

Personal notes

Fluctuations around the Critical Point in the PNJL Model

P. Büscher[a,b]

[a] Institut für Kernphysik, Technische Universität Darmstadt, Darmstadt, Germany

[b] Department of Physics, Kyoto University, Kyoto, Japan

We discuss long wavelength fluctuations up to fourth order in the mean-field approximation of the Polyakov-loop extended Nambu-Jona-Lasinio (PNJL) model and investigate how the vector interaction influences the results.
The behavior of the fluctuations in vicinity of the critical point (CP) is discussed by considering the critical mode leading to the divergence of the susceptibilities and the Ginzburg-Levanyuk criterion which allows to examine the applicability of the employed model. Furthermore, we check whether quadratic fluctuations might "overshadow" quadratic fluctuations in experiments by looking at the ratio of fourth moments over the squared susceptibilities.

Personal notes

R-Mode and Rocket Term in Superfluid Neutron Stars

G. Colucci[a]

[a] INFN and University of Bari, I-70126 Bari, Italy

In this talk we discuss the damping mechanism of r-mode oscillations in a simplified model of standard neutron star due to processes that change the number of protons, neutrons and electrons. These processes comprise beta decays and interactions between the neutron fluid and the crust. We employ a two-fluid description of the system: one fluid consists of all the charged components that are assumed to be locked together by the electromagnetic interaction, the second fluid consists of superfluid neutrons. Deviations from equilibrium between the two number species lead to the appearance of the so-called rocket term in the Euler equations. Such a term affects the dynamical evolution of the r-mode oscillations of a rotating neutron star. The talk is structured as follows. Firstly, we intorduce an identity card of a superfluid neutron star and the value of the parameter used in the numerical calculations. Secondly, we explain the difference between the standard r-modes and the superfluid r-modes, whose presence is due to the two fluid model adopted for the description of the interior of the star. Next, we introduce the rocket term and the related dissipation mechanism. Finally, we show how this dissipation mechanism affects the growing time of the r-modes amplitude due to the emission of gravitational waves for both the standard r-mode and the superfluid one. In particular, in the former case we find that the dissipation mechanism associated with the rocket term is not effective in preventing the growth of r-mode instabilities. In the latter case the rocket term prevents the growth of the r-mode instability for temperatures larger than about 10^9 K.

Personal notes

Phase diagrams and critical end point determination in nonlocal PNJL models with wavefunction renormalization

G.A. Contrera [a]

[a] Physics Department, Tandar, CAC-CNEA, Buenos Aires, Argentina

We study the phase diagram of strongly interacting matter in the framework of a non-local SU(2) chiral quark model which includes wave function renormalization and coupling to the Polyakov loop. Both non-local interactions based on the frequently used exponential form factor, and on fits to the quark mass and renormalization functions obtained in lattice calculations are considered. Special attention is paid to the determination of the critical points, both in the chiral limit and at finite quark mass. In particular, we study the position of the Critical End Point as well as the value of the associated critical exponents for different model parameterizations.

Personal notes

The Quest for Quarkyonic Matter

J. Jankowski[a]

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I present new ideas about the phases of dense and cold nuclear matter based on insights from the large N limit of Quantum Chromodynamics (QCD) [1]. These concern the so-called "quarkyonic phase" of matter [2] which is expected to be confined, approximately chirally symmetric and with large energy density. Its possible experimental implications for particle production in heavy-ion collisions will be presented [3]. The strategy of using Dyson-Schwinger equations [4] to attack this problem will be discussed.

References

[1] E. Witten, "Baryons in 1/N expansion," Nucl. Phys. B 160 (1979) 57.

[2] L. McLerran and R. Pisarski, "Phases of Cold, Dense Quarks at Large Nc," Nucl. Phys. A 796 (2007) 83.

[3] A. Andronic et al., "Hadron Production in Ultra-relativistic Nuclear Collisions: Quarkyonic Matter and a Triple Point in the Phase Diagram of QCD," Nucl. Phys. A 837 (2010) 65.

[4] C.D. Roberts and S.M. Schmidt, "Dyson-Schwinger equations: Density, temperature and continuum strong QCD", Prog. Part. Nucl. Phys. 45 (2000) S1.

Personal notes

Analysis of linear amplification regime and self-excitation of inhomogeneous broadband helix TWT

T.A. Karetnikova[a]

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One of the main tasks on research traveling-wave tube (TWT) operating regimes is the simulation of the parametric code describing operation of helix TWT in a linear regime and a self-excitation. In this report TWT operating in a linear regime with inhomogeneity of slow wave structure of device along interaction region and reflections from inhomogeneities is studied. Using this parametric code we can calculate linear gain and conditions of self-excitation parasitic oscillation in inhomogeneous helix TWT taking into account foregoing features.

Personal notes

The simplest and universal constituents for description of the leptons and hadrons

O. Kosmachev[a]

[a] BLTP JINR 141980 Dubna, Russia

Personal notes

Constraints from compact star phenomenology on the equation of state of cold, dense matter

R. Łastowiecki[a]

[a] IFT, University of Wroclaw, Wroclaw, Poland

We will present constraints on the equation of state of cold, dense matter following from observations of the compact stellar objects, with particular emphasis on mass-radius relations for compact stars. The analysis will be performed within the PNJL framework for quark matter, supplemented with selection of hadronic equations of state.

Personal notes

The dynamic of “dissipative web map”

E.U. Latukhina[a]

[a] Saratov State University, Saratov, Russia

In this report special type of structures named the stochastic web, arises in phase space of degenerate Hamiltonian systems, that dont satisfy the conditions of KAM theorem, is investigate. It was observed by the example of map for nonlinearly driven linear system with weak dissipation. The Zaslavskys map for linear conservative system was formed the basis. The investigation of attractor evolution by changing of driven parameters, conditions of their appearance and disappearance, bifurcation types, possible crisis are aims of this work.

Personal notes

Large N Expansion for Strongly-coupled Boson-Fermion Mixtures

K. Maeda[a]

[a] University of Tokyo, Tokyo, Japan

We study a many-body mixture of an equal number of bosons and two-component fermions with a strong contact interaction. In this system bosons and fermions can be paired into composite fermions, and we construct a large N extension so that these composite fermions become scalar in terms of the $\mathcal{O}(N)$ external group, since due to the central limit theorem the scalar fields have controllable fluctuation suppressed by $1/N$ factors and yield an effective theory with a systematic $1/N$-expansion. We derive an effective action described by composite fermions up to the next leading order term in the large N expansion, and show that there can be the BCS superfluid state of composite fermions at sufficient low temperatures.

Personal notes

Two different approaches to the problem of initial conditions in non-equilibrium statistical physics and application to the Unruh model

S. Mathey[a]

[a] University of Geneva, Geneva, Switzerland

We start by introducing the problem of initial conditions in non-equilibrium statistical physics and give two different ways to tackle it with their drawbacks and advantages. The first is the straightforward approach where we choose an initial, arbitrary, state for the system. The second considers all the times in the past as initial and averages all the corresponding statistical operators. Next, we show the results we have obtained applying both approaches to a simple analytically solvable model of decoherence: the Unruh model.

Personal notes

Droplets in the cold and dense linear sigma model with quarks

L.F. Palhares[a], and E.S. Fraga[a]

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The linear sigma model with quarks at very low temperatures provides an effective description for the thermodynamics of the strong interaction in cold and dense matter, being especially useful at densities found in compact stars and protoneutron star matter. Using the $\overline{\text{MS}}$ one-loop effective potential, we compute quantities that are relevant in the process of nucleation of droplets of quark matter in this scenario. In particular, we show that the model predicts a surface tension of $\Sigma \sim 5$–15 MeV/fm^2, rendering nucleation possible during the early post-bounce stage of core collapse supernovae. Including temperature effects and vacuum logarithmic corrections, we find a clear competition between these features in characterizing the dynamics of the chiral phase conversion, so that if the temperature is low enough the consistent inclusion of vacuum corrections could help preventing the nucleation of quark matter during the collapse process. We also discuss the first interaction corrections that come at two-loop order.

Personal notes

Quantum Harmonic Oscillator Model for J/ψ supression

C. Peña[a]

[a] IFT, University of Wroclaw, Poland

Personal notes

Aspects of the PNJL model at imaginary chemical potential

D. Scheffler[a], and M. Buballa[a]

[a] Institut für Kernphysik, Tehcnische Universität Darmstadt, Darmstadt, Germany

In a Polyakov loop extended NambuJona-Lasinio (PNJL) model, the phase structure in the $\mu^2 - T$-plane is investigated. Due to the sign problem of lattice QCD, simulations on the lattice are not possible at $\mu^2 > 0$. As a workaround an extrapolation from imaginary to real chemical potential can be applied. Since direct calculations are possible in the PNJL model in both regions, we have used the PNJL model to check the reliability of this extrapolation method. We first study the PNJL model at imaginary quark chemical potential and find the Roberge-Weiss (RW) periodicity as well as the RW phase transition. In the imaginary chemical potential region the PNJL model possesses the extended Z_3 symmetry of QCD. Using a PNJL model with two light and one heavier quark flavor we perform extrapolations from imaginary to real chemical potential and compare to direct calculations. In a two-flavor PNJL model we furthermore study the order of the RW phase transition endpoint for different Polyakov loop potentials and analyze its dependence on the relative strength of the potentials.

Personal notes

Equations of motion for a classical colored particle in background non-Abelian bosonic and fermionic fields

A.A. Shishmarev[a], Yu.A. Markov[a] and M.A. Markova[a]

[a] Institute for System Dynamics and Control Theory, Irkutsk, Russia

Based on the most general principles of reality, gauge and reparametrization invariance, a problem of constructing the action describing dynamics of a classical color-charged particle interacting with background non-Abelian gauge and fermion fields, is considered. The cases of the linear and quadratic dependence of a Lagrangian on background Grassmann fermion field, are discussed. It is shown that in both cases in general there exists an infinite number of interaction terms, which should be included in the Lagrangian in question. Employing a simple iteration scheme, examples of the construction of the first few gauge-covariant currents and sources induced by a moving particle with non-Abelian charge, are given. It is found that these quantities by a suitable choice of parameters, exactly reproduce additional currents and sources obtained previously in [1] on the basis of heuristic considerations.

References

[1] Yu.A. Markov, M.A. Markova, Nucl. Phys. A **784**, 443 (2007).

Personal notes

Thermal photons in QGP and non-ideal effects

V. Sreekanth[a]

[a]Physical Research Laboratory, Ahmedabad, India

We investigate the thermal photon production-rates using one dimensional boost-invariant second order relativistic hydrodynamics to find proper time evolution of the energy density and the temperature. The effect of bulk-viscosity and non-ideal equation of state are taken into account in a manner consistent with recent lattice QCD estimates. It is shown that the *non-ideal* gas equation of state, i.e., $\varepsilon - 3\,P \neq 0$ behaviour of the expanding plasma, which is important near the phase-transition point, can significantly slow down the hydrodynamic expansion and thereby increase the photon production-rates. Inclusion of the bulk viscosity may also have similar effect on the hydrodynamic evolution. However the effect of bulk viscosity is shown to be significantly lower than the *non-ideal* gas equation of state. We also analyze the interesting phenomenon of bulk viscosity induced cavitation making the hydrodynamical description invalid. It is shown that ignoring the cavitiation phenomenon can lead to a very significant over estimation of the photon flux.

Personal notes

Two Particle correlations in color superconducting quark matter

D. Zablocki[a,b]

[a] Institut für Kernphysik, Technische Universität Darmstadt, Darmstadt, Germany, [b] Institute for Theoretical Physics, University of Wroclaw, Wroclaw, Germany

We study two flavor quark matter including a color superconducting phase. Pion, sigma and diquark degrees of freedom are investigated in the 2SC phase with inclusion of the sigma-diquark mixing terms. The pion is found to be stable in the whole 2SC, whereas the diquark manifests as Goldstone boson. Another massive and unstable mode is found.

Personal notes

Lectures

Heavy quarks in a hot plasma

J.-P. Blaizot[a]

[a] CEA Saclay, France

Personal notes

Simulations of heavy-ion collisions

M. Bleicher[a]

[a] FIAS, Frankfurt, Germany

Personal notes

Observables of the deconfinement transition

E. Bratkovskaya[a]

[a] ITP&FIAS, Frankfurt, Germany

In this lecture the possibility of the experimental observation of the deconfinement transition from the hadronic to the partonic matter - QGP - will be reviewed in terms of different observables. 'Soft' probes such as dileptons or multi-strangeness enhancement etc. as well as 'hard' probes such as charm particles or jets will be considered. The comparison of observables with theoretical models and uncertainties in the 'subtraction' of physical signals from experimental observables will be discussed.

Personal notes

Color superconducting quark matter

M. Buballa[a]

[a] TU Darmstadt, Darmstadt, Germany

Deconfined quark matter at high density and low temperatures is expected to be a color superconductor, where the quarks, in analogy to the electrons in a conventional superconductor, form Cooper pairs. After introducing the basic concepts (pairing patterns, symmetries, gap equations, ...) I will discuss selected topics, including the effect of neutrality constraints in compact stars, inhomogeneous ('LOFF') phases and the role of the axial anomaly.

Personal notes

Core collapse supernovae in the QCD phase diagram

T. Fischer[a]

[a] GSI, Gesellschaft fuer Schwerionenforschung GmbH, Darmstadt, Germany

Stars more massive than 8 times the mass of the sun produce extended iron cores at the end of stellar evolution, which contract due to the photodisintegration of heavy nuclei as well as due to electron captures. The subsequent collapse increases the central density up to nuclear densities. The repulsive nuclear interaction, which in turn stiffens the equation of state, causes the collapse to halt. It leads to the formation of a protoneutron star at the centre. Protoneutron stars are hot and lepton-rich in which sense they differ from neutron stars. Furthermore, protoneutron stars cannot be considered as static objects. However, the long term post-explosion protoneutron star evolution, i.e. deleptonisation and cooling, turns the protoneutron star slowly into a neutron star. We discuss the evolution of two standard stellar models, i.e. 15 and 40 solar mass progentiors. We illustrate the thermodynamic conditions obtained during the radiation hydrodynamics evolution, which is given by mass accretion and neutrino heating. Our model as based on general relativistic radiation hydrodynamics and three- flavour Boltzman neutrino transport in spherical symmetry. The standard scenario of core collapse supernovae, where the explosion mechanism of massive stars is a hot and active subject of research, assumes hadronic matter. We rise the question about the state of matter at conditions obtained in protoneutron stars, i.e. temperatures of tens of MeV and densities of several times nuclear saturation density and a low proton-to-baryon ratio, where the transition from hadronic matter to quark matter can be considered. We discuss the evolutionary trajectories of matter in core collapse supernovae in the phase diagram and illsutrate the critical conditions necessary in order to obtain the quark hadron phase transition.

Personal notes

Onset of Deconfinement in nucleus-nucleus collisions

M. Gazdzicki[a]

[a] Universität Frankfurt, Frankfurt, Germany

This lecture is part of the "warmup" program for young scientists on the eve of the 6^{th} International Conference on "Critical Point and Onset of Deconfinement - CPOD 2010". It is divided into two parts:

(1) History, present and future of multi-particle production in high energy collisions

First, I will briefly sketch history of experimental and theoretical efforts to understand in multi-particle production in high energy collisions. Next, I will confront the most popular ideas with the recent experimental data. Finally, possible future developments shall be discussed.

(2) Onset of deconfinement in nucleus-nucleus collisions

Evidence for the energy threshold of creating the quark-gluon plasma in nucleus-nucleus collisions, the so-called onset of deconfinement, has been found by the energy scan program of the NA49 experiment at the CERN SPS. In this talk I will review the experimental and theoretical status of this phenomenon. First, the basic, qualitative ideas shall be presented for non-experts. Next, the latest experimental results will be compared to a statistical model within which the onset of deconfinement and its signals had been predicted.

Personal notes

The quarkyonic phase

T. Kojo[a]

[a] Brookhaven National Laboratory, Upton, New York, USA

This lecture is structured as follows:

1. 1/Nc expansion: Quick Review (10min.)
2. Basics of Quarkyonic Matter (15min.)
3. Chiral symmetry in Quarkyonic Matter (10-15min.)
4. Near Nuclear-Quarkyonic boundary: N-N interactions in large Nc (10min.)

Personal notes

Phases of QCD and critical point from the lattice

M.-P. Lombardo[a]

[a] INFN Frascati, Frascati, Italy

We will introduce lattice QCD thermodynamics, highlighting the field theoretical aspects shared with the continuum formulation, the lattice discretization and the main numerical tools. We will discuss basic observables and analysis techniques, making contact with the theory of phase transitions and critical phenomena. The approach will be practical, starting from status-of-the-art results. Specific issues posed by finite baryon density and the sign problem will be addressed as well, including the search of the elusive QCD critical point. The aim is to provide the audience with the tools needed to follow the rapidly evolving literature, and to make a critical assessment of the results. A small set of pedagogical mini-projects will be proposed as well.

Personal notes

Compact star constraints on dense matter

S. Popov[a]

[a] Sternberg Astronomical Institute, Moscow, Russia

In these lectures I describe how astrophysical observations help to understand properties of high density matter. In particular, I describe how masses and radii of neutron stars are derived, and how different observations of cooling compact objects constrain properties of their interiors.
Masses can be determined directly in binary systems. In future there is some hope to detemine neutron star masses with microlensing. Radii can be determined in several ways, sometimes even together with masses. A radius can be estimated for thermally emitting neutron stars from the spectral fit. Joint mass and radius measurement are availiable in some binary systems, for example, in X-ray bursters. At the moment precise radii measurements do not exist. Masses are precisly measured for binary radio pulsars, but then we have no information about radii.
Cooling of compact objects up to roughly few $\times 100000$ years is determined by neutrino emission from interiors. Then, comparing model predictions with observational data one can test a theory of thermal evolution, and so, indirectly, the corresponding model of internal structure of a neutron star. I describe some of such tests.
In addition to this subjects, I give a brief review of some key modern results in neutron star astrophysics, and discuss some other approaches to study interiors of compact objects with astrophysical observations (glitches, nutation, kicks, etc.).
A large set of references on all subjects of discussion is provided. Lectures are available at http://xray.sai.msu.ru/∼polar/html/presentations.html.

Personal notes

Instabilities at the phase transition

J. Randrup[a]

[a] LBNL, Berkeley, USA

Personal notes

Clusters and liquid-gas transition in nuclear matter

G. Röpke[a]

[a] Rostock University, Rostock, Germany

Starting from a Hamiltonian approach to nuclear matter, the quantum statistical derivation of the equation of state is given using the method of thermodynamic Green functions. The single nucleon spectral function is related to the self energy that is treated in cluster expansion. In-medium wave equations for few-particle quasinuclei states are derived. The in-medium corrections for the nuclear statistical equilibrium model are given, and the transition to the relativistic mean field description is shown. The equation of state for warm dense nuclear matter as well as the composition is shown. Further properties such as symmetry energy and formation of quantum condensates are discussed.

Personal notes

QCD phase diagram and functional renormalization group

B.-J. Schaefer[a]

[a] University of Graz, Graz, Austria

In this lecture chiral and deconfinement aspects of strongly-interacting matter under extrem conditions and their phase structure are reviewed. Due to the sign problem at finite chemical potential first-principle Monte Carlo simulations fail to explore the QCD phase diagram at large densities. Effective models which incorporate chiral symmetry breaking and certain aspects of confinement, serve as a useful tool to elucidate the phase structure of QCD. The role of quantum and thermal fluctuations on the phase diagram is addressed by means of the functional renormalization group in the second part of the lecture.

Personal notes

Fluid dynamics, viscosity and the perfect fluid in HIC

G. Torrieri[a]

[a] Uiversität Frankfurt, Frankfurt, Germany

Personal notes

Experiments with ultracold atomic gases

A. Turlapov[a]

[a] Institute of Applied Sciences, Russian Academy of Sciences, Nizhniy Novgorod, Russia

An ultracold gas of neutral fermionic atoms can model other Fermi systems in the nature including nuclear matter and quark gluon plasma. Despite being very dilute, the atomic gas can be made strongly-interacting, with the interaction energy of the order of the Fermi energy.
The phenomena observed in the atomic Fermi gases include

- stability of a strongly-interacting Fermi matter;
- superfluidity in a strongly-coupled regime;
- low-viscosity hydrodynamics in the normal and superfluid phase; and
- crossover from Fermi superfluidity to BoseEinstein condensation of tightly bound pairs of atoms.

Compared to other Fermi systems, the atomic gases provide unique possibilities for experimental observations of some of these phenomena. These observations will be discussed. I will also describe the basic experimental techniques of ultracold atoms.

Personal notes

Collective effects and flow in HIC

S. Voloshin[a]

[a] Wayne State University, Detroit, USA

Analyses of azimuthal anisotropies in particle production become one of the most important source of information about the properties of the system created in high energy nuclear collisions. In this lecture I will present the main results obtained from the analysis of anisotropic flow, as well as introduce to most important techniques used in such an analysis.

Personal notes

Kinetics and hydrodynamics of phase transitions in HIC

D. Voskresensky[a]

[a] Helmholtzzentrum for Heavy-Ion Research (GSI), Darmstadt, Germany

[b] Moscow Engineering Physical Institute, Moscow, Russia

This lecture will cover the following topics:

- Phase transitions in different systems including HIC. A general description.
- Mean field description. Relativistic bosons in external fields. 2^{nd} and 1^{st} order phase transitions. Dynamical description.
- Phenomenological description of 2^{nd} and 1^{st} order phase transitions in non-relativistic systems. Dynamical description.
- Role of fluctuations of the order parameter and of noise. Example of color superconducting transition.
- Manifestation of instabilities in the solution of the quasiparticle kinetic equation (on the example of Bose-Einstein condensation in a pion gas with elastic collisions) and in the solution of the Kadanoff-Baym equation in the case of finite particle mass-width (on the example of pion condensation in nuclear matter).
- Back to the dynamics of the mean field but now for the phase transition to a state with finite momentum.
- Hydrodynamical description of 1^{st} order phase transitions of the liquid-gas type (on example of the hadron-quark 1^{st} order phase transition). Demonstration of the important role of non-zero viscosity and thermal conductivity.

Personal notes