QUARK MATTER

Plenary Session Abstract Book

2009

Knoxville, Tennessee

Monday 30 March 2009

09:00->*10:20* **Plenary 1 – Opening Session**

09:00	Opening Session	Thom Mason (*ORNL*) , Jan Simek (*University of Tennessee*)
09:20	Quark Matter 2009 Pre-Summary: Problems, Progress, and Prospects	William Zajc (*Columbia University*)
09:50	Finite Temperature Lattice QCD: Present Status	Peter Petreczky (*BNL*)

10:50->*12:20* **Plenary 2 - Experiment Reports I**

10:50	Probing the Early Medium in Heavy Ion Collisions	Gang Wang (*UCLA*)
11:20	Highlights from PHENIX I - Initial State and Early Times	Michael Leitch (*LANL*)
11:50	Lessons from PHOBOS	Wit Busza (*MIT*)

14:00->*16:00* **Plenary 3 - Experiment Reports II**

14:00	BRAHMS - Retrospect and Latest Results	Flemming Videbaek (*BNL*)
14:30	The Long Slow Death of the HBT Puzzle	Scott Pratt (*Michigan State University*)
15:00	Probing the Energy Loss Mechanisms	Joern Putschke (*Yale University*)
15:30	Highlights from PHENIX II - Exploring the QCD Medium	Carla Vale (*Brookhaven National Laboratory*)

16:30->*18:10* **Plenary 4 - LHC Prospects**

16:30	Studying Hot and Dense QCD Matter in the LHC Era	Urs Achim Wiedemann (*CERN PH/TH*)
17:00	Commissioning and Prospects for Early Physics in ALICE	Paul Kuijer (*CERN / NIKHEF*)
17:30	Status of ATLAS and Preparation for the Pb-Pb Run	Jiri Dolejsi (*Charles University Prague*)
17:50	Heavy Ion Physics with CMS Detector at LHC	Olga Kodolova (*Institute of Nuclear Physics Moscow State University*)

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Quark Matter 2009 Pre-Summary: Problems, Progress, and Prospects

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In the past decade, extraordinary progress has been made in the understanding of hot and dense nuclear matter. This talk will present a brief, selective, and incomplete view of the current status, emphasizing lessons learned as a guide towards future efforts. Expected progress, both at this meeting and in the near-future, will be presented.

[1] This work is supported by U.S. Department of Energy FG-02-86-ER-40281.

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Finite Temperature Lattice QCD: Present Status

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I will discuss the current status of finite temperature lattice calculations with improved staggered fermions with special emphasis on the properties of matter in the high temperature region. I will show new results on equation of state, fluctuations of conserved charges and spatial correlation functions. I will compare the lattice results with the hadron resonance gas model at low temperatures and weak coupling results at high temperatures. I will also mention problems with lattice calculations in the transition region.

Highlights from STAR I - Probing the Early Medium in Heavy Ion Collisions

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In the high-energy nuclear collisions at RHIC, we have collected clear evidence for the formation of the hot and dense matter with strong collectivity developed at the partonic stage of the collisions [1]. This is an important step toward the understanding of the Equation of State of the medium created in such collisions. With its large acceptance and excellent particle identification, the STAR experiment has been focusing on extracting the EoS parameters. In this talk, I will highlight the most recent progresses.

I wish to emphasize that in order to explore the properties of the QCD phase diagram, we should take advantages of the RHIC Energy Scan program. The recent results from a brief run at $\sqrt{s_{NN}} =$ 9.2 GeV will also be presented in this talk.

References

[1] J. Adams *et al.*, (STAR Collaboration), Nucl. Phys. **A757**, (2005) 102.

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Highlights from PHENIX I - Initial State and Early Times

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We will review the latest physics developments from PHENIX concentrating on cold nuclear matter effects, the initial state for heavy-ion collisions, and probes of the earliest stages of the hot-dense medium created in those collisions. Recent physics results from $p + p$ and d+Au collisions; and from direct photons, quarkonia and low-mass vector mesons in A+A collisions will be highlighted. Insights from these measurements into the characteristics of the initial state and about the earliest times in heavy-ion collisions will be discussed.

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Lessons from PHOBOS

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A discussion is given of the most significant results from PHOBOS, past and present.

BRAHMS - Retrospect and Latest Results

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The BRAHMS experiment was designed to measure and characterize in particular the properties of rapidity dependence of particle production in heavy ion collisions. The data taking is now over, results of several years of analysis have been published and demonstrates several important features of the rapidity dependence, not envisioned from the start of the RHIC program. Particle production in AA exhibits longitudinal scaling in many variables. Also the properties of the system formed at high rapidity resembles that of systems for lower energies at mid-rapidity when viewed via the baryo-chemical potential. New physics essentially is observed at mid-rapidity including demonstration that high-p_T suppression is a final state effect. One notable exception is that of d+A collisions where at RHIC energies very low-x of the nucleus was probed and a strong suppression of pion production was observed, consistent with the picture of gluon saturation.

The latest results examines the centrality and rapidity dependence of nuclear stopping, the particle production of pions, collective expansion vs. rapidity, and the baryon enhancement at intermediate values of p_T.

The Long Slow Death of the HBT Puzzle

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Two particle correlation measurements (also known as HBT measurements) provide detailed femtoscopic insight into the space-time evolution of heavy ion collisions. At the onset of the RHIC era, the field's most sophisticated hybrid hydrodynamic/cascade models failed to provide even a qualitative description of HBT data, and fared much worse than some simple hadronic cascade prescriptions that ignored the phase transition altogether. Furthermore, parametric descriptions of the data (e.g. blast-wave models) suggested that the matter was dissolving much earlier than expected and at much higher densities than should be possible for breakup. These mysteries took on the moniker "HBT Puzzle", and has been the focus of the HBT theory community for the last eight years. Finally, the solution to the puzzles have been clarified as coming from the conspiracy of multiple effects and shortcomings of the models, none of which accounted for more than half the discrepancy. The importance of these effects were analyzed by several theory groups from numerous perspectives, and included viscosity, pre-thermal flow and incorporating a stiffer equation of state. The field is now poised to reach a critical milepost, and satisfactorily reproduce all the soft hadronic observables characterizing the underlying bulk evolution. This progress is crucial if the community is to rigorously extract bulk properties of super-hadronic matter and provide a quantitatively validated picture from which one can base detailed predictions of rare probes and fluctuations.

References

[1] S. Pratt, arXiv.org: nucl-the 0811.3363 (2008).

[1]Supported by U.S. Dept. of Energy Office of Science, grant # DE-FG02-03ER41259

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Highlights from PHENIX II - Exploring the QCD Medium

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Much of the present experimental effort at RHIC is now directed towards understanding the properties of the hot and dense colored medium created in A+A collisions. Recent results from PHENIX on the dynamical evolution of the medium and its response to high momentum probes will be presented, and their impact on our overall understanding of heavy-ion collisions will be discussed.

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Studying Hot and Dense QCD Matter in the LHC Era

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I shall provide arguments for why the unprecedented kinematical reach of heavy ion collisions at the LHC will lead to qualitatively novel insights into the nature of hot and dense QCD matter.

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Commissioning and Prospects for Early Physics in ALICE

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The ALICE detector has been commissioned and is ready for taking data at the Large Hadron Collider. The first proton-proton collisions are expected in 2009. This contribution describes the current status of the detector and its capabilities to contribute to the understanding of both $p + p$ and Pb+Pb collisions.

Status of ATLAS and Preparation for the Pb+Pb Run

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The ATLAS experiment took its first beam data in September 2008 and is actively preparing for the planned start of LHC collision data-taking in September 2009. This preparation includes hardware and software commissioning, as well as calibration and cosmic data analysis. The status and performance of the ATLAS detector will be discussed, with a view towards the Pb+Pb run expected in 2010.

References

[1] The ATLAS Experiment at the CERN Large Hadron Collider, JINST 3:S08003,2008

Heavy Ion Physics with CMS detector at LHC

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We will present the capabilities of the CMS experiment to explore the heavy-ion physics programme offered by the CERN Large Hadron Collider (LHC). Collisions of lead nuclei at energies $\sqrt{s_{NN}} = 5.5$ TeV, will probe quark and gluon matter at unprecedented values of energy density. The prime goal of this research is to study the fundamental theory of the strong interaction (QCD) in extreme conditions of temperature, density and parton momentum fraction. This presentation will give the overview of the potential of the CMS to carry out a full set of representative Pb-Pb measurements both in "soft" and "hard" regimes. Measurements include "bulk" observables – charged hadron multiplicity, low p_{T} inclusive hadron identified spectra and elliptic flow – which provide information on the collective properties of the system; as well as perturbative processes – such as quarkonia, heavy-quarks, jets, γ-jet, and high p_{T} hadrons — which yield "tomographic" information of the hottest and densest phases of the reaction.

[1]The author also gratefully acknowledges support from Russian Foundation for Basic Research (grant No 08-02-91001) and Massachusetts Institute of Technology

Tuesday 31 March 2009

09:00->*10:30* **Plenary 5 - Jet Theory**

09:00	Jet Quenching in the Evolving QCD Medium	Sangyong Jeon (*McGill University*)
09:30	Gauge/Gravity Duality and Jets in Strongly Coupled Plasmas	Paul Chesler (*University of Washington*)
10:00	From R_{AA} via Correlations to Jets - The Long Road to Tomography	Thorsten Renk (*University of Jyväskylä*)

11:00->*12:30* **Plenary 6 - Jet Experiment**

11:00	Jet-Medium Interactions and Hadron Formation: Identified Particles at Intermediate and High p_T	Anne Sickles (*Brookhaven National Lab*)
11:30	Full Jet Reconstruction in Heavy Ion Collisions	Sevil Salur (*LBL*)
12:00	Ridge, Bulk, and Medium Response (How to Kill Models and Learn Something in the Process)	James Nagle (*University of Colorado*)

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Jet Quenching in the Evolving QCD Medium

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Modification of jet properties by QGP is one of the best tools we have to study the properties of the hot and dense deconfined matter. In this talk, I will summarize phenomenological and theoretical advances that occurred within the last decade and what we learned from the experiments and what to expect in new experiments.

Gauge/Gravity Duality and Jets in Strongly Coupled Plasmas

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Quarks moving through a plasma experience a drag force and lose energy to the surrounding medium. The rate of energy loss and the distribution of radiated four momentum are important quantities which are relevant for understanding jets in heavy ion collisions. Gauge/gravity duality provides a controlled setting to study the dynamics of energy loss for quarks moving through certain strongly coupled non-Abelian plasmas. Via gauge/gravity duality, I will discuss the energy loss rate and radiation produced by quarks moving through $\mathcal{N} = 4$ supersymmetric Yang-Mills plasma. I will also discuss the thermalization of both heavy and light quarks.

References

[1] C. P. Herzog, A. Karch, P. Kovtun, C. Kozcaz and L. G. Yaffe, JHEP **0607**, 013 (2006) [arXiv:hep-th/0605158].

[2] S. S. Gubser, Phys. Rev. D **74**, 126005 (2006) [arXiv:hep-th/0605182].

[3] S. S. Gubser, S. S. Pufu, F. D. Rocha and A. Yarom, arXiv:0902.4041 [hep-th].

[4] P. M. Chesler and L. G. Yaffe, Phys. Rev. D **78**, 045013 (2008) [arXiv:0712.0050 [hep-th]].

[5] S. S. Gubser, D. R. Gulotta, S. S. Pufu and F. D. Rocha, JHEP **0810**, 052 (2008) [arXiv:0803.1470 [hep-th]].

[6] P. M. Chesler, K. Jensen, A. Karch and L. G. Yaffe, arXiv:0810.1985 [hep-th].

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From R_{AA} via Correlations to Jets - The Long Road to Tomography

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The main motivation to investigate hard (high p_T) probes in heavy ion collisions has been to do tomography, in other words, to infer something about the medium properties and evolution from the in-medium modification of hard processes. Yet while the suppression of high p_T hadrons has been observed experimentally for some time, solid tomographic information deduced from these measurements was slow to emerge. The reason for this can be traced back to theoretical uncertainties and ambiguities in modelling both medium evolution and parton-medium interaction. Ways to overcome these difficulties are to constrain models better and to focus on more differential measurements. Correlations of high p_T hadrons offer non-trivial information beyond what can be deduced from the single hadron suppression factor R_{AA}. They reflect not only the hard reaction being modified by the medium, but also the back reaction of the medium to the hard probe. In my talk, I review the theoretical progress on understanding correlations at various momentum scales. Models for hard back-to-back correlations are now very well constrained by a wealth of data and allow insights into the nature of the parton-medium interaction as well as first true tomographic results. Models of full in-medium jet evolution are being actively developed, but have yet to make substantial contact with data. Progress is slower in the understanding of low p_T correlations, the ridge and the cone, although finally a qualitative understanding of the nature of the physics behind these correlations starts to emerge.

Jet-Medium Interactions and Hadron Formation:
Identified Particles at Intermediate and High p_T

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Identified particles have long been of great interest at RHIC in large part because of the baryon/meson differences observed at intermediate p_T and the implications for hadronization via quark coalescence. With recent high statistics data identified particles are also now central to understanding the details of the jet-medium interactions and energy loss at intermediate and high p_T. In particular, correlations triggered on direct photons, π^0s or electrons from heavy flavor decay with hadrons can provide information about how medium modifications to jet fragmentation depend on parton type. I will review recent results with identified particles both in heavy ion systems and the reference measurements in $p + p$ collisions.

Full Jet Reconstruction in Heavy Ion Collisions

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Full jet reconstruction has traditionally been thought to be difficult in heavy ion events, due to large multiplicity backgrounds. The search for new physics in high luminosity $p+p$ collisions at the LHC similarly requires the precise measurement of jets over large backgrounds due to pile-up. This has motivated the development a new generation of jet reconstruction algorithms which are also applicable in the heavy ion environment [1]. In this talk, we will review the latest results on jet-medium interactions as seen in A+A collisions at RHIC, focusing on the new techniques for full jet reconstruction. We will assess the implications of these results for the LHC.

References

[1] M. Cacciari, G. P. Salam, G. Soyez, JHEP 0804:005 (2008), hep-ph/0802.1188; and references therein;

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Ridge, Bulk, and Medium Response (How to Kill Models and Learn Something in the Process)

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In this talk, various experimental observations associated with soft and hard trigger particles (sometimes speculated to be from a response of the bulk medium) will be reviewed. There will be a focus on what can be learned from simple existing measurements and more quantitative comparisons with theoretical calculations. We review a subset of theoretical interpretations, and attempt to map out a path forward towards greater understanding of this rich physics.

Wednesday 01 April 2009

09:00->*10:30* **Plenary 7 - J/Ψ and Tagged Energy Loss**

09:00	J/ψ Production in p-A and A-A Collisions at Fixed Target Experiments	Roberta Arnaldi (*INFN - Turin (Italy)*)
09:30	From Production to Suppression, a Critical Review of Charmonium Measurements at RHIC	Loren Linden Levy (*University of Colorado*)
10:00	Experimental Access to Parton Propagation and Hadron Formation in the Space-Time Domain	William K Brooks (*Universidad Técnica Federico Santa María*)

11:00->*12:30* **Plenary 8 - Low Energy Scan / Charge Correlations**

11:00	SPS Low-Energy Scan Results and Physics Prospects at FAIR	Claudia Hoehne (*GSI, Darmstadt, Germany*)
11:30	Experimental Study of the Spontaneous Strong Parity Violation	Sergei Voloshin (*Wayne State University*)
12:00	Quark Matter in Neutron Stars	Mark Alford (*Washington University, St Louis*)

J/ψ Production in p+A and A+A Collisions at Fixed Target Experiments

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A review of J/ψ results obtained in p+A and A+A collisions, in particular from the fixed target program at CERN SPS, will be presented.

In order to understand charmonium suppression, observed in nucleus-nucleus collisions, it's extremely important to study how J/ψ production is affected by cold nuclear matter. These cold matter effects can be evaluated from p+A collisions, which, therefore, represent a fundamental tool to clarify the J/ψ behaviour.

For the first time the NA60 experiment has collected p+A data under the same kinematical conditions as those of In+In (NA60) and Pb+Pb (NA50) collisions, providing a robust reference for the charmonium production study. Final results will be discussed and previous nucleus-nucleus data will also be reviewed taking into account the newly available information.

Finally, new J/ψ polarization results from NA60 p+A and A+A collisions will be discussed, presenting the J/ψ complete decay angular distributions (polar and azimuthal components) in different polarization frames. The comparison between polarization results obtained in several fixed target experiments (E866, HERA-B, NA60...) will be discussed.

From Production to Suppression, a Critical Review of Charmonium Measurements at RHIC

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Charmonium suppression in hot and dense nuclear matter has been argued to be a signature for the production of the quark gluon plasma (QGP). In order to search for this effect in heavy ion collisions one must have a clear understanding of all the factors that can contribute to such a suppression. These may include shadowing of the partons in a nuclear environment, breakup of a correlated $c-\bar{c}$ pair as it traverses the nuclear fragment, suppression of feed-down from higher mass states as well as other initial state interactions. In order to disentangle these effects one must measure charmonium production rates in both proton+proton ($p+p$) and proton+nucleus (p+N) collisions. The $p+p$ collisions serve as a baseline for searching for suppression compared to binary scaling predictions, allow one to quantify the amount of feed-down from higher states as well as serve as a tool to distinguish between different theoretical calculations for charmonium production mechanisms. In order to quantify nuclear effects it is also necessary to study charmonium production in p+N collisions where the temperature and density of the system are low compared to a heavy ion collision. These measurements allow one to determine the influence of nuclear shadowing and breakup in "cold" nuclear matter which can be extrapolated to heavy ion collisions in order to determine the amount anomalous suppression. Of course, extrapolations that rely on a model based technique depend heavily on the assumption of a production mechanism, a fact that reinforces the importance of the $p+p$ measurements. The PHENIX and STAR experiments at Brookhaven National Laboratory have measured charmonium production in $p+p$, d+Au, Au+Au and Cu+Cu collisions at $\sqrt{s_{NN}} = 200$ GeV for both forward and mid rapidities. I will present and review of the latest measurements from both experiments with an emphasis on what we have and can still learned from them about charmonium production and suppression with these experimental apparatuses.

Experimental Access to Parton Propagation and Hadron Formation in the Space-Time Domain

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Over the past decade, new data have become available from HERMES, Jefferson Lab, Fermilab, and RHIC that connect to parton propagation and hadron formation. Semi-inclusive DIS on nuclei, the Drell-Yan reaction, and heavy-ion collisions all bring different kinds of information on parton propagation within a medium, while the most direct information on hadron formation comes from the DIS data. Over the next decade one can hope to begin to understand these data within a unified picture. I will briefly survey the most relevant data and the common elements of the physics picture, then highlight the new Jefferson Lab data, and close with prospects for the future.

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SPS Low-Energy Scan Results and Physics Prospects at FAIR

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In this talk experimental results from the runs at lower SPS energies will be reviewed. Focus will be put on selected topics such as strangeness production, scan of the (T, μ_B) phase plane, fluctuations and correlations trying to find indications for the onset of deconfinement and the existence of the QCD critical point. The experimental results from the lower SPS energies clearly show interesting behavior, however, for a precise understanding of the underlying physics better and more extended data sets are necessary fully exploring also rare probes such as charm and dileptons at these energies. An outlook about prospects and capabilities of upcoming studies in this interesting energy region at RHIC, SPS, and in particular with CBM at FAIR, will be given.

Experimental Study of the Spontaneous Strong Parity Violation in Heavy Ion Collisions at RHIC

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Quantum Chromo Dynamics (QCD) is the theory of strong interactions. At present, perturbative QCD is firmly established and thoroughly tested experimentally. In the non-perturbative sector, QCD links chiral symmetry breaking and the origin of hadron masses to the existence of topologically non-trivial classical solutions describing the transitions between the vacuum states with different Chern-Simons numbers. Quark interactions with topologically non-trivial classical gluonic fields change the quark helicity and are $\mathcal{P}$ and $\mathcal{CP}$ odd. It was suggested in [1] that metastable $\mathcal{P}$ and $\mathcal{CP}$ odd domains, characterized by non-zero topological charge, might be created in ultra-relativistic heavy ion collisions. More recently, it was noticed [2,3] that in non-central collisions such domains can demonstrate themselves via the asymmetry in the emission of charged particle w.r.t. the system's angular momentum. Such charge separation is a consequence of the difference in the number of particles with positive and negative helicities positioned in the strong magnetic field of a non-central nuclear collision [2,4], the so-called *Chiral Magnetic Effect*. Since the direction of the separation may vary event by event in accord with the changing sign of the topological charge of the domain, the observation of the effect is possible only by correlation techniques. Such an observable, $\mathcal{P}$-even, but directly sensitive to the charge separation effect, has been proposed in [5] and is based on 3-particle mixed harmonics azimuthal correlations. In STAR, this method has been applied to data from 200 GeV and 62 GeV Au+Au and Cu+Cu collisions at RHIC. The preliminary results are in rough qualitative agreement with theoretical predictions [2–4].

In this talk I discuss approach, details, and the signal background issues of the experimental analysis, as well as future directions for study of the spontaneous strong parity violation.

References

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Quark Matter in Neutron Stars

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Quark matter at high density and low temperature is expected to be a color superconductor, which is a degenerate Fermi gas of quarks with a condensate of Cooper pairs near the Fermi surface. At the highest densities, where the QCD coupling is weak, rigorous calculations are possible, and the ground state is a particularly symmetric state, the color-flavor locked (CFL) phase. At lower densities the CFL phase suffers from flavor-symmetry-breaking stresses, so alternative phases, some of which break translation and/or rotation invariance, may be favored. I will review the state of our understanding of these phenomena, and discuss the effort to develop signatures of the presence of color superconducting quark matter in neutron stars.

References

[1] M. Alford, K. Rajagopal, T. Schäfer, A. Schmitt, Rev. Mod. Phys. **80**, 1455, 2008; [arXiv:0709.4635].

Thursday 02 April 2009

09:00->*10:30* **Plenary 9 - Early Times/Saturation/ Spectral Functions**

09:00	Early Time Dynamics in Heavy Ion Collisions from CGC and from AdS/CFT	Yuri Kovchegov (*The Ohio State University*)
09:30	Understanding Saturation and AA Collisions with an eA Collider	Tuomas Lappi (*CEA/Saclay*)
10:00	Quarkonium Spectral Functions	Agnes Mocsy (*Pratt Institute*)

11:00->*12:30* **Plenary 10 - Leptons/Photons**

11:00	Open Heavy Flavor in Heavy Ion Collisions	James Dunlop (*Brookhaven National Laboratory*)
11:30	Dileptons and Direct Photons at SPS	Ruben Shahoyan (*CERN, LIP*)
12:00	(Subject) Di-leptons/photons (RHIC)	Axel Drees (*Stony Brook University*)

Early Time Dynamics in Heavy Ion Collisions from CGC and from AdS/CFT

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We will discuss medium production in heavy ion collisions at small gauge coupling (using Color Glass Condensate (CGC) approach) and at large gauge coupling (using anti-de Sitter/ Conformal Field Theory (AdS/CFT) correspondence). We will stress the similarity between the two approaches: they are both based on classical physics. We will then show that classical CGC approach leads to production of a free-streaming medium. In contrast to this behavior, AdS/CFT dynamics is likely to lead to a medium described by ideal hydrodynamics. We will discuss the difficulties of the AdS/CFT approach to heavy ion collisions: we will argue that the large-coupling dynamics from AdS/CFT makes the nuclei stop right after the collision likely resulting in Landau-type hydrodynamics [1,2]. As such behavior appears to be in conflict with RHIC baryon stopping data, we will discuss possible ways around this problem and argue that the medium produced in realistic RHIC collisions is probably weakly-coupled at early times and is described by CGC, while it becomes strongly-coupled at later times and is best described then by AdS/CFT. Hence the full description of heavy ion collisions should include both the physics of CGC and of AdS/CFT.

References

[1] J. L. Albacete, Y. V. Kovchegov and A. Taliotis, JHEP 0807:100, 2008, arXiv:0805.2927 [hep-th].

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Understanding Saturation and A+A Collisions with an e+A Collider

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The initial conditions in high energy nucleus-nucleus collisions are determined by the small momentum fraction part of the nuclear wavefunction. This is the regime of gluon saturation and the most direct way to experimentally study it would be deep inelastic scattering at a high energy electron ion collider (EIC). This talk discusses some of the measurements that could be done with the EIC and their implications for interpreting the physics of nucleus-nucleus collisions.

Quarkonium Spectral Functions

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It has been proposed that the hot and dense medium created in ultrarelativistic nuclear collisions can screen the binding of quarkonium states. Suppression of the states was, therefore, proposed as a signal for QGP formation. Medium effects, however, may not be as simple as originally conceived and other effects can change the spectral function of the heavy quark-antiquark pair. I will discuss our current theoretical understanding of how quarkonium spectral functions are modified in a static thermal medium, highlighting the individual merits and current drawbacks of the three main lines of studies: effective field theories, potential models, and numerical lattice calculations. I will emphasize the picture emerging when considering the consistent results from these approaches and will discuss how modifications to the spectral functions can impact experimental phenomenon.

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Open Heavy Flavor in Heavy Ion Collisions

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The interaction of heavy partons, charm and beauty, with the matter created in heavy ion collisions has been of great interest in recent years. Heavy partons were predicted to interact less strongly with the matter than light partons. In apparent contrast to these predictions, unexpectedly strong suppression of non-photonic electrons from heavy flavor decays has been seen. However, significant experimental uncertainties remain, both in the measurements themselves and in the separation of the contribution from charm and beauty, which have complicated the interpretation of these results. I will review the current experimental situation and discuss prospects for making these measurements more easily interpretable.

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Dileptons and Direct Photons at SPS

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The study of dilepton and direct photon emission was one of the main topics of the experimental program at the SPS devoted to the search of signals for QGP formation. Three generations of experiments, Helios-3, NA38/NA50, CERES and NA60 measured e^+e^- or $\mu^+\mu^-$ production in various colliding systems and at different energies. While lepton pair production in p+A collisions was found to be reasonably well described by the expected sources, all experiments observed an excess of the yield above the extrapolation from p+A. As a result of this joint experimental effort we have currently a large amount of information characterizing this excess: its mass spectrum over the full range from 0.2 GeV/c^2 up to the J/ψ, its transverse momentum spectra including their mass dependence, its angular distributions, its dependence on collision centrality over the complete range etc. Putting together all this information leads to the conclusion that what we observe is the long-sought thermal radiation from the fireball.

I will review the main results of the dilepton measurements at the SPS and also include comparisons with theoretical models. I will conclude with selected prospects for the LHC heavy ion program.

Friday 03 April 2009

09:00->*10:30* **Plenary 11 - Hydrodynamics and Transport**

09:00	Relativistic Viscous Hydrodynamics - Status Update	Paul Romatschke (*INT, University of Washington*)
09:30	Transport Properties of the Quark-Gluon Plasma from Lattice QCD	Harvey Meyer (*Massachusetts Institute of Technology*)
10:00	Probing the QCD Phase Diagram with Chiral Effective Models	Chihiro Sasaki (*Department of Physics, Technische Universitaet Muenchen, Garching, Germany*)

11:00->*12:30* **Plenary 12 - AdS/CFT, Cold Atoms and Flow**

11:00	Using String Theory to Study the Quark-Gluon Plasma: Progress and Perils	Steven Gubser (*Princeton University*)
11:30	Is an Ultra-Cold Strongly Interacting Fermi Gas a Perfect Fluid?	John Thomas (*Duke University*)
12:00	Footprints of the (Nearly) Perfect Liquid - Experimental Review of Anisotropic Flow Results	Aihong Tang (*Brookhaven National Lab*)

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Relativistic Viscous Hydrodynamics – Status Update

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I review the recent progress in the theory of relativistic viscous hydrodynamics as well as applications to the problem of ultrarelativistic nuclear collisions.

Transport Properties of the Quark-Gluon Plasma from Lattice QCD

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I review the progress made in extracting transport properties of the quark-gluon plasma from lattice QCD simulations. The information on shear and bulk viscosity, the "low-energy constants" of hydrodynamics, is contained in the retarded correlators of $T_{\mu\nu}$, the energy-momentum tensor. Euclidean correlators, computable on the lattice, are related to the retarded correlators by an integral transform. The most promising strategy to extract shear and bulk viscosity is to study the shear and sound channels where the hydrodynamic modes dominate the Euclidean correlator [1]. I present preliminary results from a comprehensive study of the purely gluonic plasma between $0.95T_c$ and $3.5T_c$ and finish by estimating the cost of a comparable calculation in full QCD.

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Probing the QCD Phase Diagram with Chiral Effective Models

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Fluctuations of conserved charges have been proposed as probes of the QCD phase transitions [1]. In particular, a non-monotonic behavior of the net baryon and electric charge fluctuations as functions of $\sqrt{s}$ has been considered to be a signature for a critical point (CP) [1]. I will show expected signals of the CP accessible in heavy-ion collisions along with an update on the QCD phase diagram obtained from chiral effective models. I will also discuss a new phase of dense matter, Quarkyonic Phase [2], and present a remnant at real $N_c = 3$ world of the phase structure in large N_c [3]. The transport coefficients around the phase transition will be also illustrated using a chiral model [4].

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Using String Theory to Study the Quark-Gluon Plasma: Progress and Perils

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The gauge-string duality is a powerful tool for studying strongly coupled phenomena in four-dimensional gauge theories starting from supergravity or string theory in five or ten dimensions. Considerable progress has been made in calculating quantities of phenomenological interest, including total entropy, shear and bulk viscosity, thermalization time, and the energy lost by hard probes. Comparing such calculations to properties of the quark-gluon plasma cannot be wholly systematic because of the differences between the string theory constructions and QCD. Nevertheless, successes to date are impressive enough to motivate further effort, both theoretical and experimental.

I will review some aspects of the gauge-string duality which are widely accepted as true. I will present the results of several string theory calculations motivated by heavy-ion phenomenology, including drag force on heavy quarks, high-angle emission from energetic probes, bulk viscosity, and estimates of total multiplicity. And I will argue that a well motivated comparison between super-Yang-Mills theory and QCD yields estimates of some physical observables that are close to the experimentally favored range. I will also point out some concerns about extrapolating the string theory calculations to LHC energies.

Is an Ultra-Cold Strongly Interacting Fermi Gas a Perfect Fluid?

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An optically-trapped mixture of spin $\frac{1}{2}$-up and spin-$\frac{1}{2}$-down ^{6}Li atoms provides a new paradigm for exploring strongly interacting Fermi systems in nature. This ultracold atomic gas offers unprecedented opportunities to test theoretical techniques that cross interdisciplinary boundaries. A bias magnetic field is used to tune the gas near a collisional (Feshbach) resonance, where the s-wave scattering length diverges and the interparticle spacing sets the only length scale. Even though it is dilute, an atomic Fermi gas near a Feshbach resonance is the most strongly interacting non-relativistic system known, enabling tests of recent theories in disciplines from high temperature superconductors to nuclear matter. Strongly interacting Fermi gases also exhibit extremely low viscosity hydrodynamics, of great interest in the quark-gluon plasma and string theory communities, where it has been conjectured that the ratio of the shear viscosity to the entropy density has a universal lower bound, which defines a perfect fluid.

I will describe our all-optical cooling methods and our studies of the thermodynamic and hydrodynamic properties of the ^{6}Li cloud. Our measurements of the entropy[1, 2] reveal a high temperature superfluid transition, which occurs at a large fraction of the Fermi temperature. Our most recent estimates of the shear viscosity are obtained from observations of the hydrodynamic expansion of a rotating cloud[3]. Together, these results suggest that a strongly interacting Fermi gas may be the most perfect quantum fluid ever studied.

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Footprints of the (Nearly) Perfect Liquid
– Experimental Review of Anisotropic Flow Results

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In this talk, experimental progress on the study of anisotropic flow will be reviewed. The role of anisotropic flow in the understanding of the bulk property of the (nearly) perfect liquid will be discussed. The connection to theoretical work will be made, and future perspective will be presented.