

EMMI/ECT Workshop:
Chiral Symmetry and Confinement
in Cold, Dense Quark Matter
July 19 - 23, 2010

1. *Organizers:*

L. Ya. Glozman
Institute for Theoretical Physics, University of Graz, Universitätsplatz 5,
A-8010, Graz, Austria
leonid.glozman@uni-graz.at
t. +43-316-3805249; f.: +43-316-3809820

K. Fukushima
Yukawa Institute for Theoretical Physics Kyoto University, Oiwake-cho
Kitashirakawa Sakyo-ku, Kyoto 606-8502, Japan
fuku@yukawa.kyoto-u.ac.jp
t. +81-75-753-7027; f. +075-753-7010

L. McLerran
Dept. of Physics, Brookhaven Natl. Lab, Upton, NY 11973
mclerran@bnl.gov
t. +1-631-344-8294; f.+1-631-344-7561

Robert D. Pisarski
Dept. of Physics, Brookhaven Natl. Lab, Upton, NY 11973
pisarski@quark.phy.bnl.gov
t. +1-631-344-5161; f. +1 631 344 5568

2. **Scientific Case**

The purpose of the workshop was to gather about 40 theorists to attack problems related to confinement, chiral symmetry and their interrelations in cold, dense matter in QCD. This included those who work on phenomenology in QCD, those working in numerical simulations on the lattice, string theorists, and experimentalists, Understanding these issues has a direct impact on the proper formulation of planned experimental programs to explore the QCD phase diagram at large baryon density at BNL,

GSI and JINR. It also impacts our understanding of different astrophysical phenomena in neutron stars and the like.

On Monday, there was an introductory talk on Quarkyonic matter by L. McLerran. There were then further talks on Quarkyonic matter by Y. Hidaka, and on the large N_c limit by T. Cohen.

In the afternoon, M. Stephanov talked about signatures of a critical endpoint.

Then there were two people who work on the Schwinger-Dyson approach to QCD, R. Alkofer and J. Papavassiliou, who were specifically invited. Cold, dense quark matter is a real opportunity for this approach. Unfortunately, there still is not agreement on a standard method, which was clear from these two talks: Alkofer used a skeleton expansion, whilst Papavassiliou used the "pinch" technique. The last talk on Monday was by L. Glozman, who discussed parity doubling in the meson and baryon spectra.

On Tuesday, A. Szczepaniak gave a very nice discussion of using Coulomb gauge to compute non-perturbatively, using various ansatzes for the gluon propagator. Then M. Thies gave an excellent talk, summarizing his work on exactly soluble models in 1+1 dimensions. The work is very technical, but his talk was clear, to the point, and very useful. T. Kojo then gave a talk on how Quarkyonic matter forms patches which cover the Fermi surface.

After lunch, J. Skellerud and S. Hands discussed their work on dense quark matter for two colors. They studied this numerically, as it is free of the sign problem. This was fascinating, and will surely serve as a real benchmark for effective models. There were various details, especially a peak in the energy density in the confined (quarkyonic) phase, that were most perplexing and intriguing.

K. Langfeld then gave a nice discussion of how an approximate $Z(3)$ symmetry is present even in theories with dynamical quarks. H. Toki gave a talk on the "FWpPNJL" model (Fukushima-Weise-pisarski-Polyakov-Nambu-Jona-Lasino) model.

On Wednesday, A. Nakamura gave a talk on his recent lattice work, especially of lattice propagators at nonzero temperature. J. Pawłowski discussed the Functional Renormalization Group analysis of the deconfining phase transition. His results, especially on the renormalized Polyakov loop, were very interesting, and do not agree with lattice calculations. They may indicate a finite renormalization not yet accounted for on the lattice.

P. Sorensen gave a nice summary of the low energy run at RHIC. P. Braun-Munzinger and J. Stachel gave extremely interesting discussions of the applicability of statistical models to heavy ion collisions. The former

emphasized that they do not work for $e+e-$, nor pp collisions, while the latter showed how they can explain the "Matterhorn", the peak in the K/π ratio at \sqrt{s} of 10 GeV.

On Wednesday and Thursday, Redlich, Fukushima, Weise, and Schafer talked about dense quark matter in the FWpPNJL model.

Also on Thursday were talks by T. Kunihiro, on how a pseudogap arises in a color superconductor; M. Rho, on dense nuclear matter in the Skyrme model; and I. Zahed, on the same in holographic models.

Lastly, K. Hashimoto gave a masterful summary of results on dense nuclear matter in the Sakai-Sugimoto model. It was most impressive and informative.

Friday ended with talks by P. de Forcrand, on dense quark matter in a strong coupling expansion on the lattice, and D. Blaschke, on the pPNJL model. R. Pisarski gave the summary talk.

4. **Relation to EMMI**

From the above, it is clear that the workshop directly addresses two of the four main research areas of EMMI, namely:

1. Properties of the quark-gluon plasma and the phase structure of strongly interacting matter.

and

2. Structure and dynamics of neutron matter.

4. **Expenditure of funds from EMMI**

We hereby certify that the EMMI funds were used for travel and accommodation of speakers and young participants of the workshop. More than half of the EMMI funds were used for supporting young participants.

References