FT&CP: Field Theory and Critical Phenomena

M.P. Lombardo

March 18, 2016

Our activities focusses on Quark Gluon Plasma, and strongly coupled gauge theories.

Our knowledge of strongly interacting hot QCD matter has greatly increased thanks to theoretical and experimental efforts. However several outstanding issues remain: which is the nature of the state created after the collision? how is thermalization reached? which is the nature of the plasma state, and the ultimate microscopic origin of its strongly itneracting nature?

Addressing these questions is particularly urgent in view of the ongoing LHC heavy ions runs, and their upcoming analysis. It requires a sinergistic effort theory-experiment in which we are participanting, both within INFN and internationally.

During 2015 we have focussed on three specific lines of research related to the Quark Gluon Plasma:

1) Bottomonium properties and suppression. We know that bottomonium signals are particularly clear at LHC. The huge literature on the subject has established with confidence that bottomonium is sequentially suppressed. However solid quantitative results on the spectral functions are still missing. We are aiming at obtaining such results by a) combining a special lattice formulation (anisotropic lattices), b) usage of NRQCD approach at finite temperature that we have proposed and c) an array of cross checks among different Bayesian methods and direct inversion of the propagators analized in Euclidean time. During 2015 we have for the first time attacked point point c), preliminary results have been presented at conferences and the analysis are still in progress.

2) Properties of the plasma with full quark content. At the temperatures explored by the LHC analytic studies based on hard thermal loops predict that a dynamical charm might well be relevant. It is important then to study the input to hydrodynamics – equation of state, trasport coefficients – on the configurations with correct matter content. During 2015 we have continued and sharpened our study of the Equation of State in the temperature range 150-500 MeV with full dynamical first and second generation of quarks, by use of a fermionic action with good continuum and chiral properties – the twisted mass action. Since the fermionic formulation we are using has not been applied before at finite temperature we have also completed a study of the two flavor theory as a baseline.

3) Physics mechanisms of the strongly interactive quark gluon plasma. We have also began a study of topological observables which will help clarify issues related with the long standing problem of the fate of the $U_a(1)$ symmetry at the transition. This innovative project will systematically compare analysis performed with the new scale setting with Wilson flow with direct calculation of the topological observables with overlap operator

More generally, in our previous work we have noted that the strongly interacting quark gluon plasma is continuously connected with a strongly interacting cold conformal phase. This observation might offer a rationale for the application f AdS/CFT methods to the analysis of the quark gluon plasma, and help understanding why such a strongly interacting medium is amenable to a near-conformal description. We have pioneered these studies by considering some properties of the transition with varying Nf, and after our preliminary results will be finalized we plan to address more systematically the properties of the plasma. Large Nf theories offer an unique laboratory for the understanding of the plasma properties, and these studies are just beginning.

1 List of Conference Talks by LNF Authors in Year 2015

1. Spectral Functions from Anisotropic Lattice QCD, at Quark Matter 2015, Kobe, Japan, parallel talk, October
2. Scale separation, walking dynamics and approach to criticality in QCD with many flavors, invited talk at Gauge Field Topology Workshop, Simons Center, Stonybrook, August
3. Baryons on the lattice, cold and hot dense matter, invited talk at ECT* for Lattice Nuclei, Nuclear Physics and QCD, July
4. Phases of Strong Interactions, lattice results, invited talk at GGI for Holographic Methods for Strongly Coupled Systems, March
5. Adding flavours to strong interactions, invited talk at EdwinFest, Bielefeld, October

2 Publications

1. An advanced course in computational nuclear physics - Bridging the scales from quarks to neutron stars, Springer Lecture Notes in Physics, to appera in 2016, M. Hjorth-Jensen, M.P. Lombardo, U. van Kolck, editors.
2. A. Dainese *et al.*, "INFN What Next: Ultra-relativistic Heavy-Ion Collisions," arXiv:1602.04120 [nucl-ex].(MpL topic convenor)
3. A. Trunin, F. Burger, E. M. Ilgenfritz, M. P. Lombardo and M. Mller-Preussker, J. Phys. Conf. Ser. **668** (2016) 1, 012123

4. F. Burger, E. M. Ilgenfritz, M. P. Lombardo, M. Muller-Preussker and A. Trunin, J. Phys. Conf. Ser. **668** (2016) 1, 012092

5. A. Andronic *et al.*, Eur. Phys. J. C **76** (2016) no.3, 107

6. M. P. Lombardo, K. Miura, T. J. Nunes da Silva and E. Pallante, PoS CPOD **2014** (2015) 059

7. J. I. Skullerud *et al.*, AIP Conf. Proc. **1701** (2016) 060018

8. F. Burger *et al.* [tmfT Collaboration], Phys. Rev. D **91** (2015) 7, 074504