Laboratoire de physique subatomique et des technologies associées
Unité Mixte de Recherche 6457
École des Mines de Nantes - IN2P3/CNRS, Université de Nantes

The theory group of SUBATECH (Nantes, France) has an opening for a 3 year

PhD position on "improved theoretical treatment of quarkonia production in ultrarelativistic heavy ion collisions through dynamical recombination"

The context: The interpretation of the ultrarelativisitc heavy ion collision (URHIC) data collected at the CERN and RHIC Collider is the center of interest of the high energy theory group at Subatech. We have developed in the recent years the event generator EPOS3 to study the soft physics as well as EPOS-HQ to study heavy quarks which traverse the plasma of quark and gluons, formed in these reactions. The goal of this approach is to develop a program which reproduces simultaneously the heavy as well as the light quark physics to reduce the uncertainties inherent in this approaches because the underlying theory of strong interactions, the Quantum-Chromo-Dynamics (QCD) can only solved in special cases.

Among various "hard probes" of particular interest is the so called "quarkonia suppression" suggested by Matsui and Satz. Quarkonia are bound states of heavy quarks, stable in the vacuum which would be dissolved at finite temperature when immerged in a quark gluon plasma due to the QCD equivalent of the Debye screening mechanisms. Due to such phenomenon, quarkonia are often referred to as "QGP thermometer", as various bound states would dissolve at different temperature above the deconfinement temperature T_c. Although this picture is quite appealing, its concrete implementation in numerical models is often performed with pretty crude approximations and assumptions, for instance neglecting finite dynamical time scales inherent to the ultrarelativistic heavy ion collision. In recent years, one has also realized that some quarkonia could be formed at or prior to the transition towards the confined phase by 2 heavy quarks stemming from disconnected origins. This so called "recombination mechanism" is usually modelled assuming quasi-stationary bound states what also constitutes a questionable approximation.

During the last years, we (among some researchers) have started to investigate the feasibility to deal with quarkonia formation in URHIC adopting the viewpoint and concepts of the so-called "open quantum system" (see f.i. ref. [1-3]), which appears to be the correct dynamical framework for such situation. In particular, we were able to treat the somehow simpler case of bottomonia production at the large hadron collider (LHC) where only one beauty-antibeauty pair is considered, with promising perspectives. More recently, we have investigated the question of open-quantum system resorting to Linblad-like equations acting on the operator-density, simplified by resorting to semi-classical approximations [4]. This approach could be quite relevant in order to deal with the production of charmonia in AA collisions, a process which appears to be dominated by the recombination of exogenous pairs happening when the QGP cools down. Oppositely to what is often admitted in the literature, it appears that this recombination process is a rather slow process, requiring energy dissipative exchanges with the heat bath to happen efficiently…

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The thesis project: During the PhD thesis, we plan to pursue the investigation of quarkonia production in URHIC resorting to the concepts and methods of open quantum systems. In particular, we will focus our investigations on the topic of the dynamical Q-Qbar confinement that is restored during the cooling down of the QGP, that will be treated in the open-quantum system approach; possibly, the method will be extended to address the question of the hadronization of heavy quarks into open flavor mesons (and hadrons) in order to aim at a universal description,… Apart from theoretical developments, some part of the PhD is expected to be devoted to phenomenological studies on the URHIC studied experimentally at RHIC and LHC colliders. This could encompass some extension to the proton-nucleus case as well. This project offers the possibility to perform significant progresses in this highly debated topic of probing one of the most intriguing state of matter ever discovered by Mankind. It will help the candidate to develop skills both in the field of theoretical nuclear and particle physics, as well as in statistical physics, while being balanced between theoretical developments and numerical investigations. It can thus be considered as a real springboard for the candidate's future career.

The candidate: We expect from the candidate a solid background in theoretical physics, especially of the different aspects of QCD as well as basic knowledge in numerical physics. Candidates with good knowledge of open quantum systems are encouraged to apply as well, even if they have a less extended background in QCD. In addition to disciplinary knowledge, the expected skills are: hindsight, ability to carry out long and complex tasks by implementing control processes, spirit of initiative, imagination.

The group: The theory group of SUBATECH is composed of 14 permanent senior researchers (among them 9 oriented towards high energy physics), 2 postdocs and 6 PhD students. Further general information can be found on our website http://www-subatech.in2p3.fr.

The position: 3 year PhD CNRS-fellowship with social and health benefits starting from fall 2021.

The process: Candidates should apply on the CNRS link https://bit.ly/3b6ZL0P . Candidates should post there a resume including a transcript of their grades during their master studies, a statement of their research interests and a motivation letter. Candidates for the auditions should be ready to provide two letters of recommendation. The recruitment process will follow HRS4R label as well the the 3M graduate school rules. Further information can be obtained from Prof. P.B. Gossiaux (gossiaux@subatech.in2p3.fr).

References:

1. "The Schrödinger–Langevin equation with and without thermal fluctuations", R. Katz and P.B. Gossiaux; Annals Phys. 368 (2016) 267-295, arXiv:1504.08087
2. "Upsilon suppression in the Schrödinger–Langevin approach", Pol Bernard Gossiaux, Roland Katz; Nucl.Phys. A956 (2016) 737-740
3. "Dynamical bottomonium-suppression in a realistic AA background ", P.B. Gossiaux et R. Katz, Journal of Physics: Conf. Series 779 (2017) 012041
4. «Quarkonium dynamics with a 1D quantum master equation », Stéphane Delorme et al. ,Quarkonia as tools 2020 Ausoin; https://indico.cern.ch/event/853361/contributions/3670302/

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