Recommendations from
WG2 and WG3 meeting in Athens

The first meeting of the WG2 was held—together with the WG3 and the GDRE "Heavy Quark"—was held on September 6-8, 2017 in the Cabo Verde Hotel, 41 Possidinos Ave.,19005 Mati, Attica, Greece.

The main goal of this meeting was to asses the present status of our understanding of the physics which we learn by the observation of heavy mesons in ultrarelativistic heavy ion collisions. Hard probes such as large transverse-momentum (p_T) jets and heavy-flavor (HF) hadrons play an essential role in the study of the properties of the quark-gluon plasma (QGP) created in high-energy heavy-ion collisions. The large energy-momentum scale typically involved with these hard probes is large enough to enable perturbative-QCD (pQCD) calculations of their initial production rate and, at high p_T, of the medium modification of the final spectra and correlations. They can therefore provide important information about the hot QCD medium probed by these particles. Due to their large mass the thermal production of heavy quarks is negligible in the QGP within the range of temperatures that can be reached in heavy-ion collisions at the Relativistic Heavy Collider (RHIC) and the Large Hadron Collider (LHC). Therefore heavy-quark (HQ) physics utilises the modification of their spectra caused by the interactions with the light quarks and gluons during their propagation in a dynamically evolving QCD medium.

At high momentum, the propagation of heavy quarks is similar to that of energetic light quarks and gluons. Their interactions with the medium can be described by scattering with medium partons. Perturbative-QCD calculations [1–7] show that the energy loss experienced by high-energy partons is dominated by induced gluon radiation that leads to a suppression of final hadrons with large p_T, known as jet quenching [8, 9]. The parton energy loss and the suppression factor for final leading high-p_T hadrons is determined by a jet transport coefficient, $\hat{q}(E)$ [2], which is essentially the average transverse momentum broadening squared per unit length of propagation of an energetic parton with an energy E. Such a jet transport coefficient encodes the coupling between the jet parton and the medium, as well as its energy density, at the energy and momentum scale of typical scatterings [10–12]. It is therefore an important property of the QGP medium as probed by propagating energetic partons. In the limit of the jet parton energy approaching that of a thermal parton $E \sim T$, the jet transport coefficient has been related to the shear viscosity [13], $\eta/s \approx 1.25T^3/\hat{q}$, and hence to the bulk properties of the medium characterising the coupling among medium partons.

The large mass of heavy quarks has several implications in this context. It suppresses small-angle gluon radiation leading to smaller radiated energy loss as compared to light quarks and gluons [14–17]. At low momentum, elastic scatterings become dominant. Since thermal pair production and annihilation processes are negligible, HQ propagation through the hot medium can be described as a diffusion process akin to Brownian motion. The large mass also slows down the equilibration rate of heavy quarks in the medium relative to their light counterparts. The non-equilibrated heavy quarks in the final state can therefore provide information on their interaction with medium throughout their propagation in the QGP medium. The spatial diffusion constant, D_s, characterises the low-momentum interaction strength of heavy quarks in the medium, and has also been related to the shear viscosity of the medium, $D_s(2\pi T) \sim \eta/s$[18]. It encodes the p_T broadening of the heavy quark, while the drag coefficient A describes the longitudinal-momentum or energy loss in the diffusion process. In this way HQ transport yields valuable information on the coupling strength and properties of the interaction in the QGP [19–21].

To discuss this issue it seemed to us meaningful to have a common meeting of the WG3 which studies the creation of heavy quarks and their properties in a static QGP and the WG2 which concentrates on the expansion of the QGP and the interaction of heavy quarks with the constituents. In addition to these theoretical working groups those experimentalists have been invited who are involved in the analysis of heavy meson data and who are organised in the GDRE "Heavy quarks". These heavy meson results are so involved that only a continuous discussion between theorists and experimentalists can assure a comprehensive interpretation of the experimental results. Besides of the discussion of the analysis and the theoretical interpretation of the present experimental findings a second objective of the meeting was to start the discussion about what can and should be measured in the heavy on experiments at CERN after the long shut down and the upgrading of many of the detectors.

In the discussion the follwoing recommendtions were made:

(a) The differences between the theoretical approaches should be made transparent

(b) The results of the different theoretical approaches should be compared in a way that the influence of the different ingredients (initial condition, expanding QGP, elementary interaction between heavy quarks and plasma constituents, hadronzation) can be judged. This is a long term project about which there should be a regular reporting.

(c) The next WG meeting of the WG 2 should be together with the WG1 to discuss with the people from the lattice gauge calculation community which input their calculation can provide

(d) The experimentalists should explore to which extend correlation observables can be made available

(e) For the recommendation of the experimental program at LHC after the shut down a separate working group should be installed which collects in a continuous discussion between theory and experiment the different ideas, proposal ad recommendations.

Apart from two experimentalists all participating scientist gave a talk and special emphasis was made, when planning the schedule, to have sufficient time for discussion but it turned out that there was even more need to than foreseen, so part of the long pause after lunch was finally used for further discussions. In these discussion it became evident that the different approaches which have been advanced from the different theory groups should be compared among each other and the different.

It turned out that it was a good choice to accommodate all participants in the same hotel. This allowed for a lot of spontaneous discussions and people got acquainted with each other. Common dinners allowed for establishing a good basis for the future work.

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