HEAVY FLAVOR AND DILEPTON PRODUCTION IN STAR EXPERIMENT

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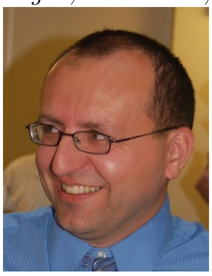

Heavy quarks are produced in early stage of the nucleus-nucleus collision and they are good probes of hot and dense nuclear matter created in such collisions. However, the mechanisms of their interaction with a nuclear medium is not yet well understood. The nuclear modification factor of non-photonic electrons from charm and beauty decays as well as open charm mesons measured in central Au+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV in STAR is comparable to that of light hadrons. The heavy quarkonia production is expected to be sequentially suppressed, due to Debye screening of the quark-antiquark potential, depending on the temperature of the produced nuclear matter. The measurement of Υ meson at RHIC is a clean probe of this effect due to negligible levels of background effect such as contribution from $b\bar{b}$ recombination and non-thermal suppression from co-mover absorption. Dileptons are bulk penetrating probes of all stages of collision dynamics in heavy ion collisions. Their spectra in the low and intermediate mass regions are sensitive to vector meson in-medium modifications and the Quark Gluon Plasma (QGP) thermal radiation. These regions are as well sensitive to charm modification since the dominant physical background in intermediate mass region is from correlated charm pairs. In this paper we discuss the recent STAR results in heavy flavor and dilepton production.

1 Open heavy flavour

The study of heavy quark production in heavy ion collisions is an important probe of the properties of hot and dense nuclear matter that is produced in these collisions. The calculations of the Quantum Chromodynamics on lattice showed that at energy densities of about 1 GeV/fm^3 and at temperature of about 170 MeV, that are exceeded in energetic collisions at Relativistic Heavy Ion Collider in Brookhaven National Laboratory, the phase transition from quark-gluon-confined matter to quark-gluon-deconfined matter, Quark Gluon Plasma should take place[1]. This form of matter has several interesting properties [2]. The production of heavy quarks happens during the initial part of the collision and therefore this is a sensitive probe of properties of QGP. It is however very important to understand the heavy flavor production in elementary reference system such as p+p collisions. The STAR experiment can measure charm production both directly via hadronic decays and also indirectly by non-photonic electrons. The Figure 1(left)

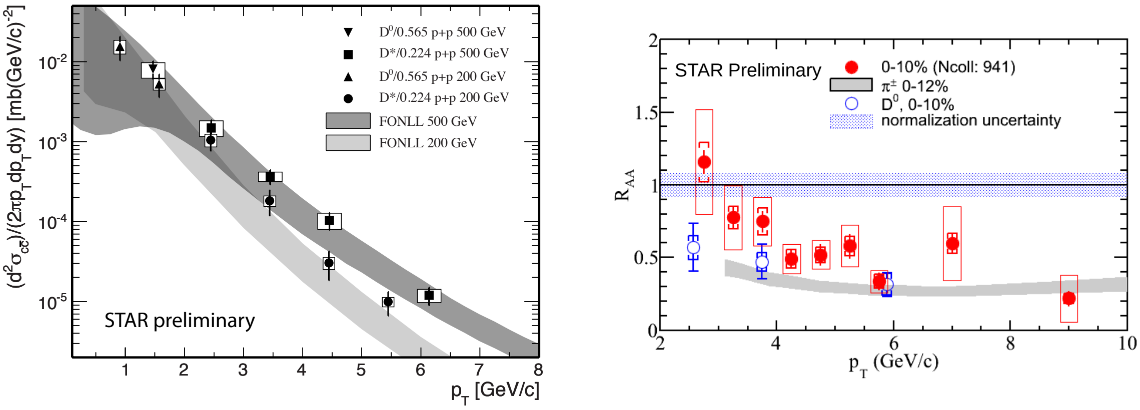

Figure 1: Right: Transverse momentum dependence of $c\bar{c}$ production cross section extracted from D^0 and D^* measurement in p + p collisions at $\sqrt{s} = 200$ GeV and $\sqrt{s} = 500$ GeV is shown. The data are compared to FONLL calculations. Left: Nuclear modification factor as function of transverse momentum of non-photonic electrons (red full circles) and D^0 mesons (blue open circles) for 0-10% most central Au+Au collisions. For reference also the pions for 0-12% centrality are also shown (grey band).

shows the measurement of $c\bar{c}$ production cross section from hadronic decays of D^0 and D^* mesons (using branching fractions) in p+p collisions at 200 GeV [3] and 500 GeV [4]. The measurement is compared to the FONLL calculations [5]. These calculations can describe the charm spectra well within the uncertainty bands of data and calculations.

It is expected that energy loss of heavy quarks could be different as compared to light quarks and gluons.The mechanism of energy loss of heavy quarks in hot and dense medium is not yet fully understood and the discussions about the importance of radiative and collisional energy loss are ongoing. The previous nuclear modification factor (R_{AA}) measurements of non-photonic electrons at RHIC, dominantly originating from c and b decays, showed no significant difference when compared with light hadrons. The new STAR measurement of R_{AA} of non-photonic electrons as well as D^0 meson in 0-10% most central 200 GeV Au+Au collisions are presented in Figure 1(right). There is no significant difference between the suppression of charm mesons and pions. The R_{AA} of non-photonic electrons and charm mesons are also consistent with each other within uncertainties and also when taking into account the momentum smearing due to kinematics of the decays.

2 Quarkonium

The quarkonium suppression is considered to be an excellent probe of color deconfinement in the QGP. This is due to a color Debye screening of di-quark potential in hot and dense nuclear matter that could play important role in production of quarkonium. It is predicted that due to different binding potential of various quarkonium states their production is suppressed above some temperature, that is different for each particular state [6]. However, the effects of color deconfinement have to be disentangled from other competing effects that could influence the quarkonium production. These include cold nuclear matter effects (nuclear interaction break-up, shadowing) and recombination. Previous measurements at RHIC energies showed that the suppression of J/ψ as a function of collision centrality is similar to that observed at the CERN SPS energy. This is puzzling since the temperature and energy density reached in these collisions is significantly lower than at RHIC.

In Figure 2(left) the nuclear modification factor of J/ψ production as a function of number of participating nucleons, measured by STAR experiment, is presented. The suppression of J/ψ production is observed with R_{AA} ~0.4 for most central collisions. No significant dependence on centrality is observed above N_{part} =150. The suppression of J/ψ with large transverse momentum $p_T > 5$ GeV/c is significantly smaller as compared to J/ψ p_T integrated values.

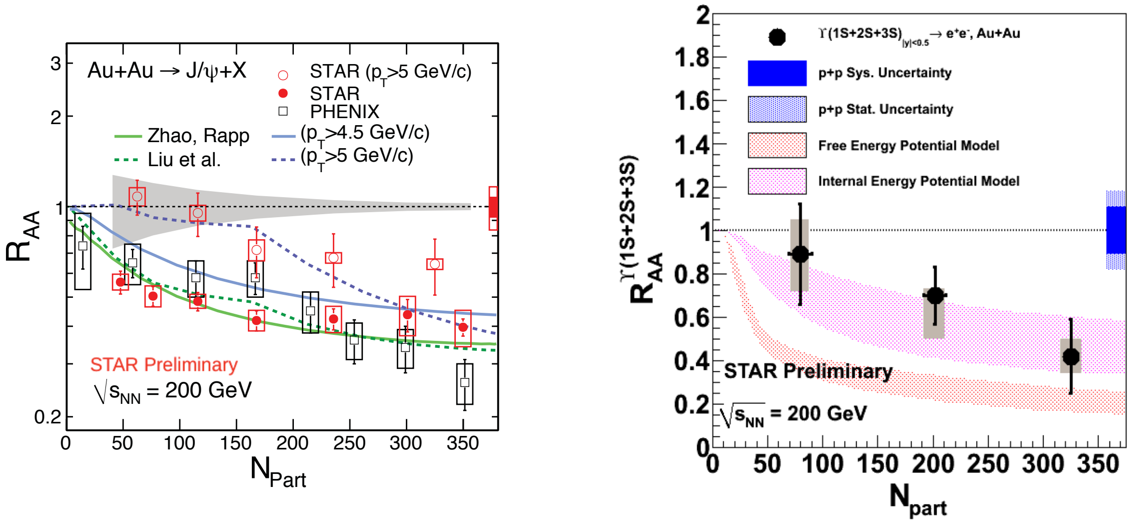

Figure 2: The nuclear modification factors as function of number of participating nucleons in Au+Au collisions with $\sqrt{s_{NN}}$=200GeV measured by STAR experiment. Left: J/ψ (red full circles), J/ψ with p_T >5 GeV/c [7](red open circles), J/ψ measurement by PHENIX (black open rectangles). Theoretical models of Liu[8] and Zhao[10] are also shown. Right: Υ(1S,2S,3S) measurement. Theoretical model of Strickland[9] is also shown

Another quarkonium that is of a great interest is the Υ. It is expected that Υ(1S) state does not dissociate at RHIC energies[6], but Υ(2S) and Υ(3S) do. This could provide the information about the temperature reached in heavy-ion collisions. STAR has reported measurements in p+p [11], d+Au [12] and Au+Au [13] collisions. However, so far it was not possible to address each Υ state separately. Recently STAR reported Υ results from large statistics data sample collected year 2010 for Au+Au 200 GeV collisions [14], see Figure2(right). The increase of suppression as a function of the number of participants was observed. The Υ(1S,2S,3S) suppression is consistent with the scenario that 2S, 3S and excited states completely melt. Future measurements with recently installed Muon Telescope Detector in STAR will make possible to separate Υ states in di-muon channel at midrapidity.

3 Dilepton production

Dileptons are sentitive to various phases of the evolution of nuclear matter in heavy ion collision. They have very low interaction cross section with created QCD matter. Different invariant mass ranges of dilepton spectrum are sensitive to different physics. In the low invariant mass $M_{ll} < 1.1$ GeV/c^2 the in-medium modifications of vector meson properties ρ(770), ω(782) and ϕ(1020) can be studied. The modifications of mass and width of the spectral functions are expected, related to possible chiral symmetry restoration. The intermediate mass range, $1.1 < M_{ll} < 3.0$ GeV/c^2 is sensitive to the thermal radiation of the Quark-Gluon Plasma. The important source of background in this region comes from the semileptonic decays of a correlated pairs of open charm or bottom hadrons. The production of these hadrons can be modified in heavy ion collisions. In the high mass region above 3.0 GeV/c^2 the production of quarkonia and color screening effects, as it was discussed in previous section, plays a role. Additional important source here is Drell-Yan process.

The STAR experiment has measured the dielectron production in p+p collisions at 200 GeV and the spectrum is consistent with the cocktail simulation of individual sources [15]. In Figure 3 the dielectron production is shown, as it was measured at $\sqrt{s_{NN}}$ =19.6, 62.4 and 200 GeV. The enhancement above the expected cocktail of sources is observed in low mass region. This enhancement can be described, for all energies, with a hadronic cocktail of expected sources (without ρ(770)) and in-medium modified ρ(770) spectral function[16].

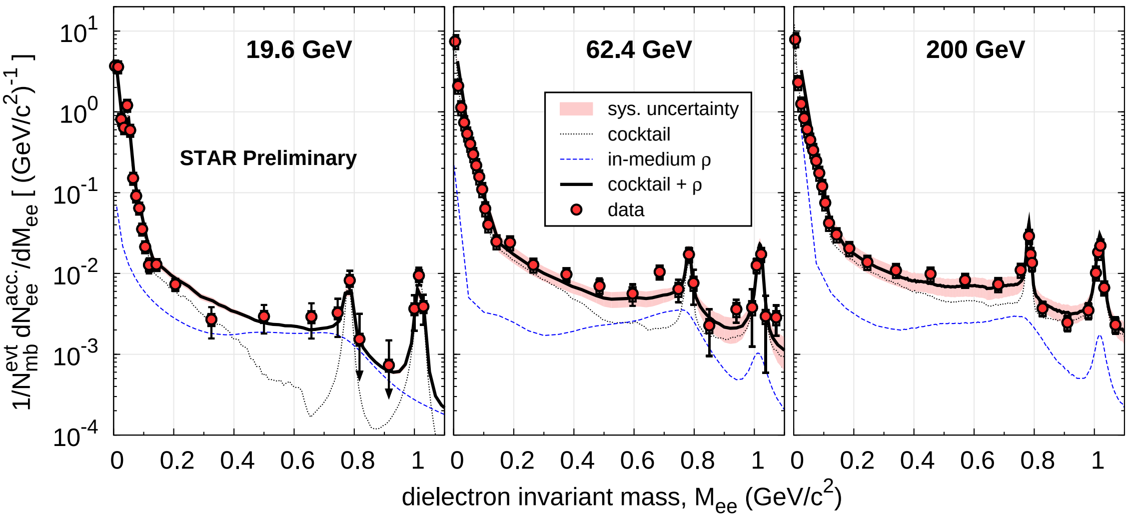

Figure 3: Dielectron invariant mass spectrum measured in Au+Au collisions $\sqrt{s_{NN}}$ =19.6, 62.4 and 200 GeV. The line correspond to the hadronic cocktail (dotted, not including the rho meson), the in-medium calculation of the rho meson[16] (dashed, including QGP contributions), and the sum of the two (solid).

4 Summary

In summary, the measurements of heavy flavor and dilepton production provide important information about the properties of hot and dense nuclear matter. The open heavy flavor production in p+p collisions is well described by FONLL calculations. The strong suppression of open heavy flavor production is observed in central 200 GeV Au+Au collision, similar to light hadrons. The suppression of J/ψ is observed and it is decreasing with larger p_T. The Υ suppression was observed in central Au+Au collisions and it is consistent with only 1S state survival. The enhancement of dielectron production in low mass region is observed in energy range down to SPS energies and it is consistent with in-medium ρ modifications. New upgrades of STAR detectors with Heavy Flavour Tracker and Muon Telescope Detector will allow to perform more precise lepton measurements in near future at RHIC.

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