Hidden beauty and charm of relativistic heavy ion collisions

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The goal of the SPS, RHIC, and LHC heavy-ion programs is to validate the existence and study the properties of the quark-gluon plasma (QGP), a phase of strongly-interacting matter at high energy density where quarks and gluons are no longer bound within hadrons. The quarkonia states (J/ψ and Υ) have been among the most popular tools since their suppression was proposed as a signal of QGP formation [1]. This is thought to be a direct effect of deconfinement, when the binding potential between the constituents of a quarkonium state, a heavy quark and its antiquark, is screened by the colour charges of the surrounding light quarks and gluons. This feebly bound quarkonia state then can be broken up by the gluon collisions [2].

The first such measurement was the 'anomalous' J/ψ suppression discovered in PbPb collisions at $\sqrt{s_{NN}}$ = 17.3 GeV at the SPS, which was considered as a hint of QGP formation. The RHIC measurements in AuAu at $\sqrt{s_{NN}}$ = 200 GeV [3, 4] showed almost the same suppression at a much higher energy contrary to the expectation [5]. Such an observation was consistent with the scenario that at higher collision energy the expected greater suppression is compensated by regeneration of J/ψ by recombination of two independently produced charm quarks [6]. Since the LHC first performed Pb+Pb collisions at $\sqrt{s_{NN}}$ = 2.76 TeV, a plethora of quarkonia results have become available [7, 8] which also inspire a great deal of theoretical activities [9, 10].

The CMS experiment carries out J/ψ measurements at high transverse momentum (p_T > 6.5 GeV/c) and in mid the rapidity range $|y| \leq 2.4$ [13, 14] while ALICE J/ψ results cover the low p_T range at forward rapidity $2.5 \leq y \leq 4.0$ [11]. Combining these results with the PHENIX and STAR measurements at RHIC [3, 4] inferred that high p_T J/ψs are more suppressed at LHC but surprisingly suppression is small for low p_T J/ψ. First time at LHC energies, the Υ states are measured with good statistics in heavy ion collisions. The CMS measurements [12, 15] reveal that the higher Υ states, Υ(2S) and Υ(3S), are more suppressed relative to the ground state Υ(1S), a phenomenon known as sequential suppression of quarkonia. The ALICE measurements [16] indicate that suppression is more in forward rapidity indicating the significance of cold nuclear matter effects.

To understand different mechanism of suppression in hot and cold nuclear matter experiments utilizes proton-lead (pPb) collision data provided by LHC in the start of 2013. This data provides an essential reference to understand initial state effects and may also provide insight into cold nuclear effects that may be distinct from the suppression effects observed in PbPb collisions. The measurement by CMS [17] suggest presence of final state effects in pPb and PbPb collisions, which affect more strongly excited states Υ(2S) and Υ(3S) than Υ(1S).

Other than quarkonia, measurement of open heavy flavour (D, B mesons) provides a unique handle on the properties of strongly interacting deconfined medium . Heavy quarks, i.e. charm and beauty, are considered calibrated probes for the Quark Gluon Plasma formed in heavy-ion collisions. Produced in hard scattering processes in the initial stages of the collision, they interact with the medium, lose energy and, depending on the coupling strength to the medium, take part in the collective motion of the QCD mat-

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ter. CMS offers B meson measurements via detecting secondary J/ψ coming from a displaced vertex [13, 14]. Combining CMS B meson results with the ALICE measurements of D-meson [18] containing c-quarks it follows that at low p_T there is mass hierarchy in the amount of suppression such that, $R_{\rm AA}^{\rm light\ hadrons} < R_{AA}^{\rm D\ meson} < R_{AA}^{\rm B\ meson}$. Several theoretical models claims to get similar mass scaling if they include both collisional as well as radiative energy loss [19, 20].

An overview of these measurements will be presented in the talk. How these measurements compare with other experiments at RHIC and LHC and have improved the understanding of heavy ion collisions will be discussed. The results will be compared with the relevant theoretical calculations and new physics insights will be discussed

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