J/ψ suppression in relativistic heavy-ion collisions

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J/ψ suppression in high energy heavy-ion collisions, has long been predicted to be a prominent signature for the de-confinement transition in nuclear collisions [1]. If QGP is produced in the collision zone, the $c\bar{c}$ binding potential gets shielded by Debye screening of colored partons leading to the reduction in the J/ψ yield. The expected reduction of the J/ψ production in nucleus-nucleus $(A + A)$ collisions was put into evidence in various experiments at CERN SPS. However experimental investigations also revealed a considerable suppression of the charmonium production already present in proton-nucleus $(p+A)$ collisions [2]. This is attributed to the cold nuclear matter (CNM) of target nucleus and conventionally analyzed within Glauber model framework [3] with an effective "absorption" cross-section $\sigma^{eff}_{J/\psi}$ quantifying the suppression. With this approach, NA50 Collaboration at CERN-SPS first observed significant anomalous suppression of J/ψ yield, in $Pb + Pb$ collisions at a beam energy of 158 A GeV ($\sqrt{s_{NN}} = 17.3$ GeV) [4]. However the theoretical origin of the additional suppression is still unsolved and debated, as the data have been found to be explained by a variety of models [5], with or without incorporation of the deconfinement scenario. The J/ψ suppression pattern measured in $\sqrt{s_{NN}} = 200$ GeV $Au + Au$ collisions at RHIC [6], revealed almost the same suppression pattern as of SPS. Such an observation found consistent with the scenario that at higher collision energy the expected larger suppression is compensated by regeneration of J/ψ mesons by recombination of two independently produced charm quarks. A plethora of charmonia results have also now become available in $Pb+Pb$ collisions at $\sqrt{s_{NN}} = 2.76$ TeV, at LHC.

In contrast, charmonium production is much less explored in nuclear collisions at lower energies. Till date no measurement exists on J/ψ production in heavy-ion collisions below the top SPS energy. This is primarily due to extremely low charm production cross sections which in turn demands accelerators with very high beam intensities and detectors enabled with unprecedented high rate capabilities. The Compressed Baryonic Matter (CBM) experiment at Facility for Antiproton and Ion Research (FAIR) [9], in GSI, Germany is planning to perform pioneering measurements on charmonium production in nuclear collisions, in the beam energy range $E_b = 10 - 40$ A GeV. Due to very low charm production cross sections, the regeneration effects are negligibly small at FAIR. There are quite a few theoretical calculations to estimate the charmonium production in the FAIR energy regime. In [10], J/ψ production in proton induced collisions have been estimated at FAIR. The modified version of the two component QVZ [11] model has been employed for this purpose. For $p + A$ collisions the model takes into account both the initial state modification of parton distributions inside the target nuclei and the final state interaction of the produced $c\bar{c}$ pairs with the target nucleons. In contrast to Glauber approach, the final state dissociation is modeled via multiple scattering of the evolving $c\bar{c}$ pair with the nucleons inside the target. Different parameters of the model are tuned by the existing data on J/ψ production in $p + p$ and $p + A$ collisions from different fixed target experiments. The model has then been applied to predict the J/ψ production and suppression expected in $p + A$ collisions at energies relevant to FAIR. The amount of suppression, for different mechanisms of J/ψ hadronization has been found

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to be distinguishably different. These studies have been extended further in [12] to calculate the centrality dependence of J/ψ production in $Au + Au$ collisions at FAIR. Spatial dependence of the shadowing factors are incorporated in the calculations, assuming shadowing is proportional to the local nuclear density. A much larger J/ψ suppression is foreseen from CNM effects alone. The possible anomalous suppression induced by a dense baryonic medium, anticipated at FAIR energies, is also calculated in the literature. Within HSD transport model framework [13], anomalous suppression is simulated in two different scenarios namely 'QGP threshold melting' and 'hadronic co-mover absorption'. Both the scenarios were found to describe the then available SPS data reasonably well. At FAIR, the two scenarios were found to generate distinguishably different amount of suppression, with hadronic scenario giving larger suppressions. A different variant of the QGP threshold melting is studied in [14], to estimate the J/ψ suppression from Debye screening in a hot baryonic plasma. The results predict a much weaker suppression due to Debye screening compared to the CNM suppressions at FAIR energies.

In this talk, a broad overview will be presented on the existing J/ψ measurements from different experiments at SPS, RHIC and LHC. The theoretical predictions on charmonium suppression at FAIR energy domain will be discussed in detail. The simulations on the feasibility of J/ψ detection with CBM experiment will also be highlighted.

References

[1] T. Matsui and H. Satz, Phys. Lett. B**178**, 416 (1986).

[2] L. Kluberg and H. Satz, arXiv:0901.3831 [hep-ph]

[3] R.J. Glauber, Lectures on theoretical Physics (Inter-Science, New York, (1959) Vol. I.

[4] B. Alessandro *et al.* (NA50 Collaboration), Eur. Phys. J. **C39**, 335 (2005).

[5] J. P. Blaizot, P. M. Dinh and J.Y. Ollitrault, Phys. Rev. Lett. **85**, 4012 (2000); A. Capella, E. G. Ferreiro and A. B. Kaidalov, Phys. Rev. Lett. **85**, 2080 (2000); L. Grandchamp, R. Rapp and G. E. Brown, Phys. Rev. Lett. **92**, 212301 (2004).

[6] A. Adare *et al.* (PHENIX Collaboration), Phys. Rev. C **84**, 054912 (2011); Z. Tang (STAR Collaboration), J. Phys. G **38**, 124107 (2011).

[7] A. Andronic, P. Braun-Munzinger, K. Redlich and J. Stachel, Phys. Lett. B **571**, 36 (2003).

[8] B. Muller, J. Schukraft and B. Wyslouch, Ann. Rev. Nucl. Part. Sci. **62**, 361 (2012); P. Shukla (CMS Collaboration), arXiv:1405.3810 [nucl-ex].

[9] P. Senger, Nucl. Phys. A **862-863**, 139 (2011).

[10] P. P. Bhaduri, A.K. Chaudhuri and S. Chattopadhyay, Phys. Rev. C **84**, 054914 (2011).

[11] J. Qui, J.P. Vary and X. Zhang, Nucl. Phys. A698, 571 (2002); Phys. Rev. Lett. **88** 232301 (2002).

[12] P. P. Bhaduri, A. K. Chaudhuri and S. Chattopadhyay, Phys. Rev.C **85**, 064911 (2012).

[13] O. Linnyk, E. L. Bratkovskaya, W. Cassing and H. Stocker, Nucl. Phys. A **786**, 183 (2007).

[14] P. P. Bhaduri and S. Gupta, Phys. Rev.C **88**, 045205 (2013).