J/ψ production cross-sections in low energy collisions at SPS and FAIR: a data driven approach

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The suppression of the production yield of J/ψ mesons in heavy-ion collisions with respect to proton-proton (p+p) and proton-nucleus (p+A) collisions was proposed as an experimental signature of deconfinement transition and formation of Quark-Gluon Plasma (QGP) [1, 2]. The p+p collisions is usually believed to mimic the QCD vacuum. On the other hand, in p+A reactions, the nascent J/ψ mesons during the pre-resonance or resonance stage of evolution may interact with the nucleons present in the target nucleus, the so-called primary medium, which might lead to their dissociation. Quantification of such Cold Nuclear Matter (CNM) effects were traditionally attempted within the Glauber model framework, by analyzing the target mass dependence of the production cross-section of J/ψ mesons in p+A collisions [3]. An effective "absorption" cross-section $\sigma^{eff}_{J/\psi}$ measures the overall suppression present in the data. Systematic analysis of the data collected in these p+A reactions reveals a significant dependence of the absorption cross-section on collision energy with more dissociations at lower energies, as originally predicted in Ref. [4]. Experimental confirmation of this fact was subsequently obtained by the NA60 Collaboration at SPS [5].

In nuclear collisions, no measurement on J/ψ production below top SPS energy (158 A GeV) has been attempted till date, owing to extremely low charm production cross-sections. J/ψ measurements in low energy collisions demand accelerators with unprecedented beam intensities and detectors with very high rate capabilities. The Compressed Baryonic Matter (CBM) experiment, currently being constructed at the Facility for Anti-proton and Ion Research (FAIR) accelerator complex in Darmstadt, Germany aims at the measurement of J/ψ mesons via their decay into dileptons in proton and ion induced collisions [6]. CBM aims to take data in the centre-of-mass energy range of $\sqrt{s_{NN}} \sim 2.7$ - 5.5 GeV. The foreseen unprecedented beam intensities for both protons and heavy-ions at FAIR would enable the detection of J/ψ mesons in p+A and nucleus-nucleus (A+A) collisions. At FAIR, J/ψ production would occur close to its kinematic production threshold. The physics perspectives of the planned J/ψ measurements [7] include a stringent test of the perturbative QCD (pQCD) based models of charmonia production near threshold, the investigation of charm production and propagation through dense baryonic medium and the possibility of discovering the predicted sub-threshold charm production [8] in ion-ion collisions among the others.

Another complementary experiment to CBM is the NA60+ experiment at CERN-SPS [9]. The NA60+ experiment plans to extend the existing study by making measurements in the beam energy range 40 A to 160 A GeV, corresponding to the center of mass energy range of $\sqrt{s_{NN}} \sim 6$ -17 GeV. Thus with the data from CBM and NA60+, the dynamics of the J/ψ, likely to be produced in the early stages of the collisions, can be probed over a large energy range, in a rather unexplored energy domain. In addition to the unavailability of A+A data, no systematic measurements have been performed so far on J/ψ production below 158 GeV in p+A collisions.

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This certainly calls for phenomenological investigations on J/ψ production at low energies relevant for the upcoming experimental programs.

In the present contribution, we adopt the conventional geometrical Glauber formalism for calculating the cross-section of the J/ψ mesons, produced in the early stages of p+A and A+A collisions at foreseen CBM and NA60+ energies. In literature, J/ψ production in elementary collisions is generally modelled as a two step process: initially compact $c\bar{c}$ pairs produced via hard scattering are treated with perturbative QCD (pQCD), whereas subsequent resonance binding of the pair is non-perturbative in nature and treated phenomenologically. The application of such two component models is based on QCD factorization, which separates the initial $c\bar{c}$ production from the formation of the bound state. However at low collision energies, like those will be available at FAIR or CERN-SPS, the validity of the QCD factorization is questionable. We thus employ here a theory agnostic data driven parametrization to calculate the J/ψ production in elementary $p+p$ collisions. The corresponding production cross-section in $p+A$ and $A+A$ collisions are estimated employing the Glauber framework, where the so called CNM suppression effects are incorporated via an effective absorption cross-section. No additional medium effect is incorporated in our calculations, even for A+A collisions. Our estimations would thus serve as a reference baseline for the upcoming measurements, with respect to which possible genuine secondary medium effects on charmonium production if present, can be isolated.

The data of inclusive J/ψ production cross-sections available from the NA50 and NA60 experiments are used to parameterize the J/ψ absorption cross-section as a function of the center of mass energy and that parametrization is used to estimate the inclusive J/ψ production cross-section at SPS and FAIR energies. The per nucleon J/ψ production cross-section is shown in Fig. 1 for pA and AA systems. For AA collision systems, three different collision systems namely Ni+Ni, Au+Au

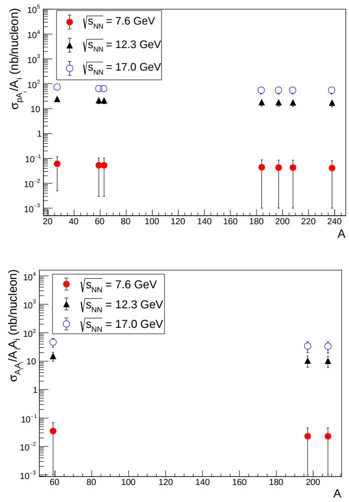

FIG. 1: J/ψ production cross-section per nucleon for pA (top) and AA (bottom) collision systems at center of mass energies relevant for CBM experiment at FAIR and NA60+ experiment at SPS.

and Pb+Pb are used. Seven different collision systems namely p+Al, p+Ni, p+Cu, p+W, p+Au, p+Pb and p+U are used for the pA systems. The details of the used data samples, parameterization techniques and the results will be highlighted in this contribution.

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