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Charmonium production at SPS and FAIR energies

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Quarkonium states, and in particular charmonium, have been recognized as sensitive probes of the properties of hot and dense strongly interacting matter created in relativistic heavy-ion collisions. Since the pioneering work of Matsui and Satz, who proposed that the suppression of the J/ψ meson could signal the onset of quark–gluon plasma (QGP) formation, numerous theoretical and experimental efforts have been devoted to understanding the mechanisms governing charmonium production, dissociation, and regeneration in such environments.

At finite baryon chemical potential (μ_B), lattice QCD predicts a smooth crossover transition between hadronic and partonic matter, whereas at larger μ_B, beyond the conjectured critical end point, the transition possibly becomes first order. Studying charmonium behavior in baryon-rich systems—such as those accessible at SPS and the upcoming GSI/FAIR facilities—therefore provides a unique opportunity to explore the QCD phase diagram in regions of high net baryon density.

In this work, we employ the Parton–Hadron–String Dynamics (PHSD) transport approach to investigate the influence of baryon-rich matter on charmonium production and dissociation. The Remler coalescence formalism is implemented to dynamically model charmonium formation from charm–anticharm pairs. As a validation step, the formalism is first benchmarked against experimental data from elementary p+p collisions and then extended to p+A systems to extract the effective nuclear absorption cross section of charmonium. This extracted cross section is subsequently applied in A+A collisions to quantify medium-induced effects.

Our results demonstrate that the Remler formalism provides a quantitatively consistent description of charmonium production at SPS energies when the charmonium interaction rate in the QGP phase is comparable to that of open-charm pairs. The approach is then extrapolated to GSI/FAIR energies, where predictions for charmonium yields and survival probabilities are presented. These findings highlight the relevance of the Remler formalism as a dynamical framework for studying heavy-quark bound-state formation in strongly interacting baryon-rich matter and offer theoretical guidance for future experimental programs at FAIR and NICA aimed at mapping the QCD phase structure.

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