Charmonium production in proton-nucleus collisions at RHIC and the LHC

Xiaojian Du and Ralf Rapp

Large efforts in both experimental and theoretical research have been devoted to study hot and dense QCD matter via ultra-relativistic heavy-ion collisions (URHICs) over several decades. Heavy quarkonia can serve as promising probe of the in-medium heavy quark anti-quark force in these reactions [1]. Proton-nucleus (pA) collisions have become a rather hot topic in recent years, to study whether a quark-gluon plasma (QGP) can also form in rather small systems.

In this work, we investigate J/ψ and ψ(2S) production in pA collisions at LHC energies with an earlier constructed transport approach [2,3]. We have extended the fireball evolution model to account for small system sizes and elliptic expansion geometries appropriate for pA collisions using a Monte-Carlo based event generator based on initial-state fluctuations. Final-state interactions of charmonia are implemented in both QGP and hadronic phases. We calculate the nuclear modification factor (R_{pA}) as a function of both collision centrality (Fig. 1) and transverse momentum (Fig. 2). In the proton-going

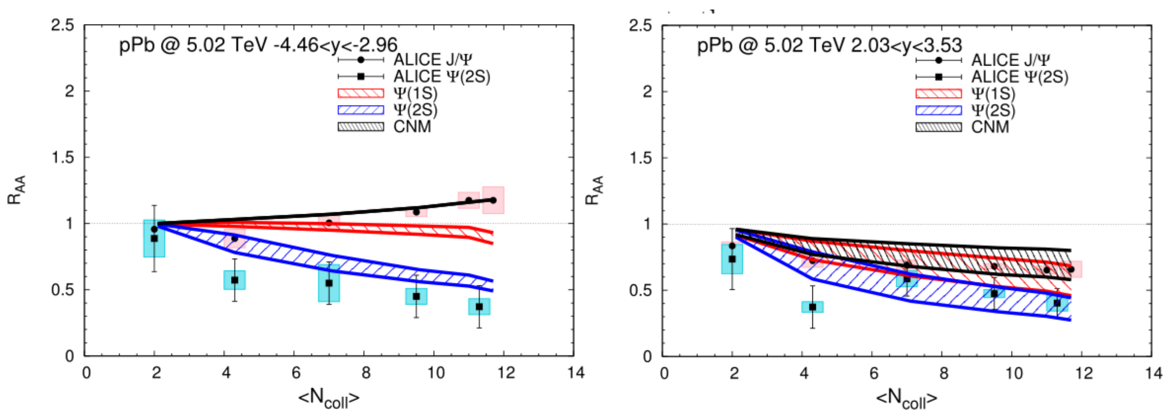

FIG. 1. Centrality dependent R_{pA} calculated for J/ψ (red bands) and ψ(2S) (blue bands) in 5.02 TeV p-Pb collisions at the LHC, compared to ALICE data [5] in the Pb-going direction (left panels) and p-going direction (right panel). Black lines indicate shadowing effects.

direction (positive rapidity), the suppression of J/ψ and ψ(2S) is similar, mostly caused by parton shadowing in the initial incoming nucleus [4]. On the other hand, in the nucleus-going direction (negative rapidity), where the charged-particle multiplicity is much higher, we find significantly stronger suppression for the excited state ψ(2S) than the ground state J/ψ, caused by its smaller binding energy which leads to stronger dissociation due to final-state interactions. The agreement with data [5,6,7] is fair.

We have also studied the elliptic flow (v_2) of the J/ψ due to its transport in the elliptic fireball, characterizing the azimuthal asymmetry in its momentum spectra. In pA collisions, an initial spatial asymmetry is due to fluctuations in the initial nucleon-nucleon collisions. The v_2 of the primordially produced the J/ψ's is mainly due the suppression from different path lengths through the elliptic fireball. The v_2 of J/ψ's regenerated from charm-quark recombination is due to the collective flow picked up from the medium, which is significantly larger. We find that the resulting v_2 of the J/ψ's is rather small since

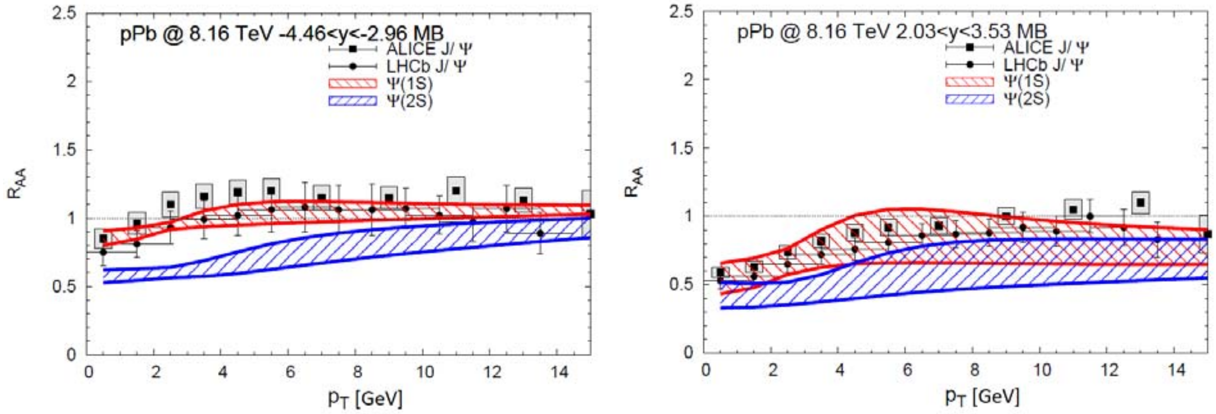

FIG. 2. Transverse-momentum dependent R_{pA} calculated for J/ψ (red bands) and ψ(2S) (blue bands) in 8.16 TeV p-Pb collisions at the LHC, compared to ALICE [6] and LHCb [7] data in the Pb-going direction (right panel) and p-going direction (left panel).

the contribution from primordial production dominates. This is quite different from the experimental data which show appreciable v_2 values, see Fig. 3 [8,9]. Our results therefore imply that the observed large v_2 for J/ψ's in pA collisions is not from final-state interactions, but might rather originate from anisotropies in initial transverse-momentum spectra or cold nuclear matter effects.

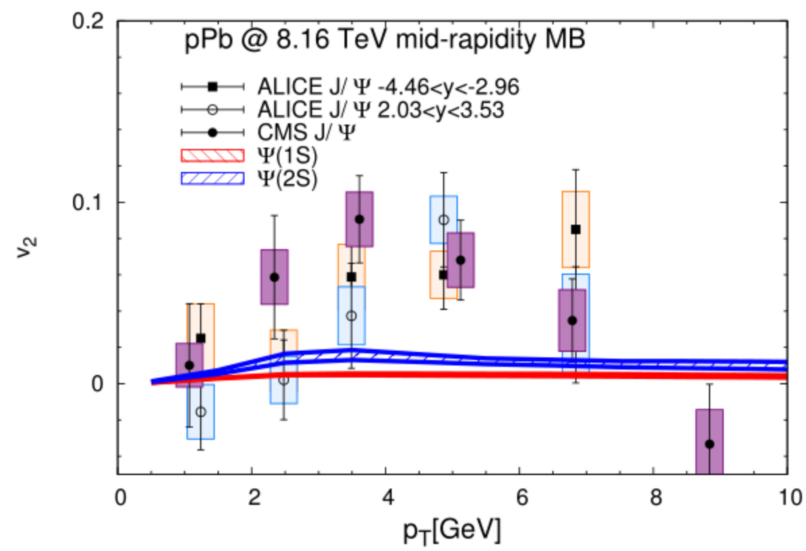

FIG. 3. Transverse-momentum dependent v_2 calculated for J/ψ (blue band) and ψ(2S)(red band) in 8.16 TeV p-Pb collisions at the LHC, compared to ALICE [8] and CMS data [9].

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