Cold Nuclear Matter Effects on J/ψ Production at High Baryon Densities

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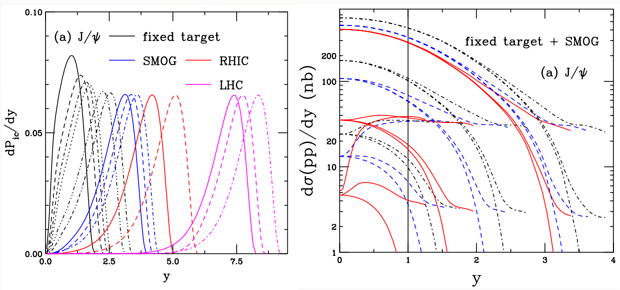
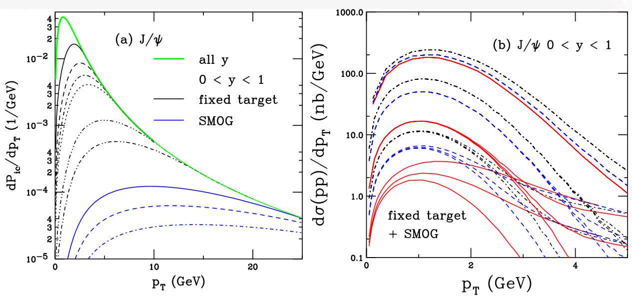
Intrinsic charm x_F distribution is independent of beam energy but the rapidity distribution shifts forward with energy while pQCD production is always peaked at midrapidity

The J/ψ x_F distribution has an average x_F of ~0.53, the average y increases with center of mass energy until it is too forward peaked to be captured in a detector. At low energies with minimal boost, IC can dominate while it may only make a small contribution at large y at the LHC.



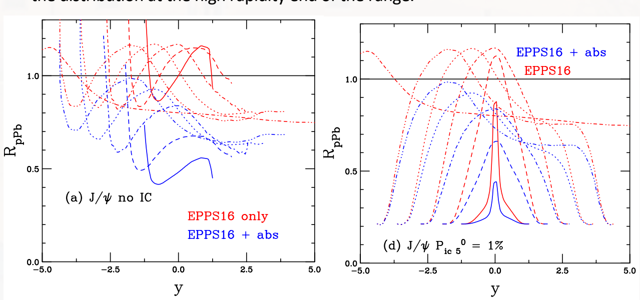
Transverse momentum distribution for intrinsic charm:

The IC p_T distribution is independent of energy with a long tail. However, the rapidity range can reduce the IC contribution at low p_T.



The nuclear modification factor as a function of rapidity:

(Left) No IC, with and without absorption. (Right) With 1% IC. The effect due to IC is strongest at the lowest energy and decreases with energy until it only affects the distribution at the high rapidity end of the range.



Abstract: Open heavy flavors and quarkonium have played important roles in understanding of the QCD matter produced at high temperatures and low baryon densities. However, they could also provide crucial information about QCD at the lowe center of mass energies employed to probe high baryon density matter at existing or planned facilities. For example, a nonperturbative contribution to charm production, intrinsic charm, has long been speculated, with much contradictory empirical evidence. LHCb recently reported evidence for intrinsic charm in Z + jet events at 13 TeV. While J/ψ production by intrinsic charm would normally only manifest itself outside the range of the LHC detectors, even at forward rapidity, the high Q^2 of these events allowed for their detection. On the other hand, at low center of mass energies, J/ψ and production by intrinsic charm could manifest itself at midrapidity, as described for the SeaQuest experiment at Fermilab. This poster explores the rapidity and p_T dependence of an intrinsic charm signature for p_{lab} of 40 GeV and higher, both in p + p and p + A interactions and places the results in context of previous experimental evidence.

Approach:

- J/ψ production is calculated in the color evaporation model. In p + A collisions, the central EPPS16 set is employed, along with k_T broadening in the nucleus, and nucleon absorption. The broadening in p + p collisions is energy dependent, between 0.95 GeV^2 at the lowest energy and 1.5 GeV^2 at the highest LHC energy. The broadening is the nucleus is A dependent but is assumed to not vary with energy in any significant way. The lowest x values reached in the nucleus depends on the energy with shadowing at forward rapidity and generally reaching the antishadowing region at backward rapidity with the location of the antishadowing peak shifting toward negative rapidity with center of mass energy. The absorption cross section is assumed to decrease with energy until it is negligible at the LHC.

$$\sigma_{pA} = \sigma_{\rm CEM}(pA) = S_A^{\rm abs} F_C \sum_{i,j} \int_{4m^2}^{4m_H^2} ds \int dx_1\, dx_2\, F_i^p(x_1,\mu_F^2,k_T)\, F_j^A(x_2,\mu_F^2,k_T)\, \hat\sigma_{ij}(\hat s,\mu_F^2,\mu_R^2)\ ,$$

- A contribution from intrinsic charm (IC) is included assuming the proton is in a 5-particle Fock state configuration |uudcc>. The Jψ is formed from the cham-anticharm pair in the state assuming coalescence, calculated using the appropriate delta functions. IC probabilities of 0.1%, 0.3% and 1% are used in the calculations. The J/ψ cross section from IC is calculated based on these probabilities.

$$dP_{{\rm ic}\,5} = P_{{\rm ic}\,5}^0 N_5 \int dx_1 \cdots dx_5 \int dk_{x\,1} \cdots dk_{x\,5} \int dk_{y\,1} \cdots dk_{y\,5} \frac{\delta(1-\sum_{i=1}^5 x_i)\delta(\sum_{i=1}^5 k_{x\,i})\delta(\sum_{i=1}^5 k_{y\,i})}{(m_p^2 - \sum_{i=1}^5 (\widehat{m}_i^2/x_i))^2}\ ,$$

$$\sigma_{\rm ic}(pp) = P_{{\rm ic}\,5}\sigma_{pN}^{\rm in}\frac{\mu^2}{4\widehat{m}_c^2} \qquad \sigma_{\rm ic}^{J/\psi}(pp) = F_C\sigma_{\rm ic}(pp)\ . \qquad \sigma_{\rm ic}^{J/\psi}(pA) = \sigma_{\rm ic}^{J/\psi}(pp)\, A^\beta$$

- The total J/ψ cross section, including both the CEM and IC, is then calculated in p + A and p + p collisions and R_{pA} is formed

$$\sigma_{pA} = \sigma_{\rm CEM}(pA) + \sigma_{\rm ic}^{J/\psi}(pA)$$

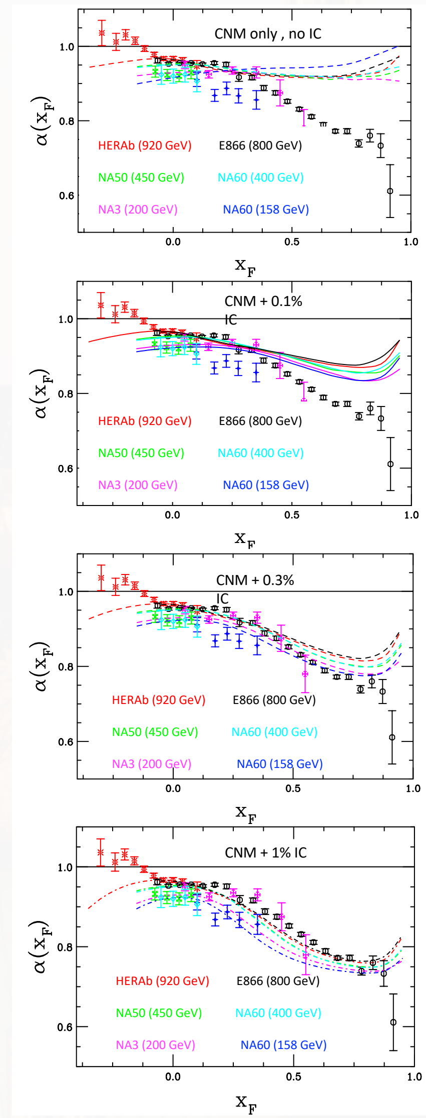
- The results are shown here for p + p collisions on the left-hand side, upper and middle plots while R_{pA} is shown in the bottom plots both without and with a 1% IC contribution. A Pb nuclear target is assumed in all cases. On the right-hand side, the exponent α is given as a function of x_F and compared to earlier fixed-target data both without and with IC for all three probabilities assumed.

- A paper with all the results, including for D meson production, is in preparation and will be submitted soon. Another publication, comparing to SMOG data from LHCb for both J/ψ and D production with the appropriate energies and targets is also in preparation. In that work, the asymmetries in D and D production will also be presented. See the LHCb presentation on their p + Ne results for preliminary calculations. The details of the calculations will be presented in those forthcoming papers.

Comparison to previous fixed-target x_F dependent data:

$\alpha(x_F)$ has been measured by several previous experiments over the energy range p_{lab} = 158 to 920 GeV.

Calculations with and without IC but including other CNM effects (shadowing, k_T broadening, nucleon absorption) are made. At forward x_F, the agreement with data is poor without IC. Calculations are made for each energy and all targets employed at that energy and α is then obtained by averaging the cross section per nucleon over the number of targets.



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