Inclusive J/ψ production in forward proton-proton and proton-lead collisions at high energy

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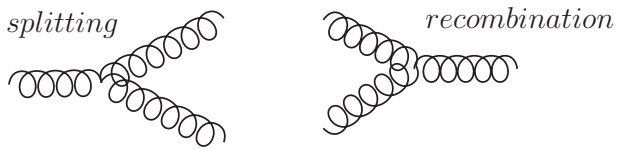
Centre of Excellence in Quark Matter

Gluon saturation

- High-energy (small-x) regime $\rightarrow$ strong increase in gluon density



$$Q_s^2 \sim M_{J/\psi}^2$$

- Forward ($y \gg 1$) rapidity in pA and pp collisions

$$x_p = \frac{\sqrt{M_{J/\psi}^2 + p_\perp^2}}{\sqrt{s}} e^{y} \lesssim 1 \qquad x_A = \frac{\sqrt{M_{J/\psi}^2 + p_\perp^2}}{\sqrt{s}} e^{-y} \ll 1$$

Inclusive J/ψ production

$$d\sigma_{\mathrm{J}/\psi} = \sum_{\kappa} d\hat{\sigma}^{\kappa} \langle \mathcal{O}_{\kappa}^{\mathrm{J}/\psi} \rangle \qquad \kappa = {}^{2S+1}\mathrm{L}_J^{[C]}$$

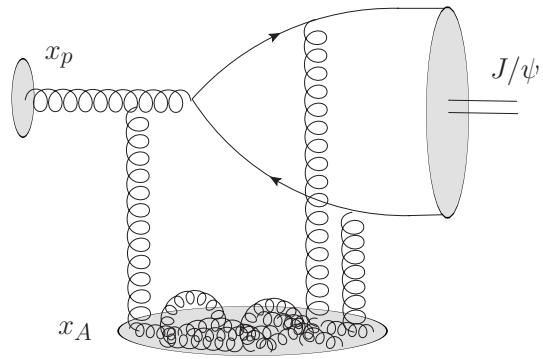
Color Glass Condensate (CGC) + Non-Relativistic QCD (NRQCD)

Kang,Ma,Venugopalan 1309.7337v2

NRQCD factorization formalism

$$d\sigma_{\mathrm{J}/\psi} = \sum_{\kappa} d\hat{\sigma}^{\kappa} \langle \mathcal{O}_{\kappa}^{\mathrm{J}/\psi} \rangle$$

$$\kappa = {}^{2S+1}\mathrm{L}_J^{[C]}$$



Quarkonium production: CGC

- Target described as a classical gluon field A
- Dilute-dense collision
- Proton collinear limit

Hadronization: NRQCD

Non-perturbative Long-Distance Matrix Elements (LDME) from experimental data

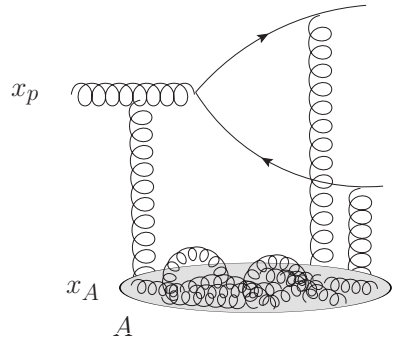
$$\langle \mathcal{O}^{\mathrm{J}/\psi}({}^3\mathrm{S}_1^{[1]}) \rangle \quad \langle \mathcal{O}^{\mathrm{J}/\psi}({}^1\mathrm{S}_0^{[8]}) \rangle \quad \langle \mathcal{O}^{\mathrm{J}/\psi}({}^3\mathrm{S}_1^{[8]}) \rangle \quad \langle \mathcal{O}^{\mathrm{J}/\psi}({}^3\mathrm{P}_J^{[8]}) \rangle$$

Chao et al. 1201.2675v4

Eikonal Interaction

Wilson Line $\rightarrow$ parton-nucleus scattering

$$V(x_\perp) = \mathcal{P} \exp\left(-ig \int^{x^+} dy^+ A^-(x^+, x_\perp)\right)$$



Dipole Amplitude

$$D_{x_\perp - y_\perp} = \frac{1}{N_C} \langle \mathrm{Tr}[V_F(x_\perp) V_F^\dagger(y_\perp)] \rangle$$

- Initial condition (MV model) fit to HERA data + BK rapidity evolution
  Lappi, Mäntysaari 1309.6963

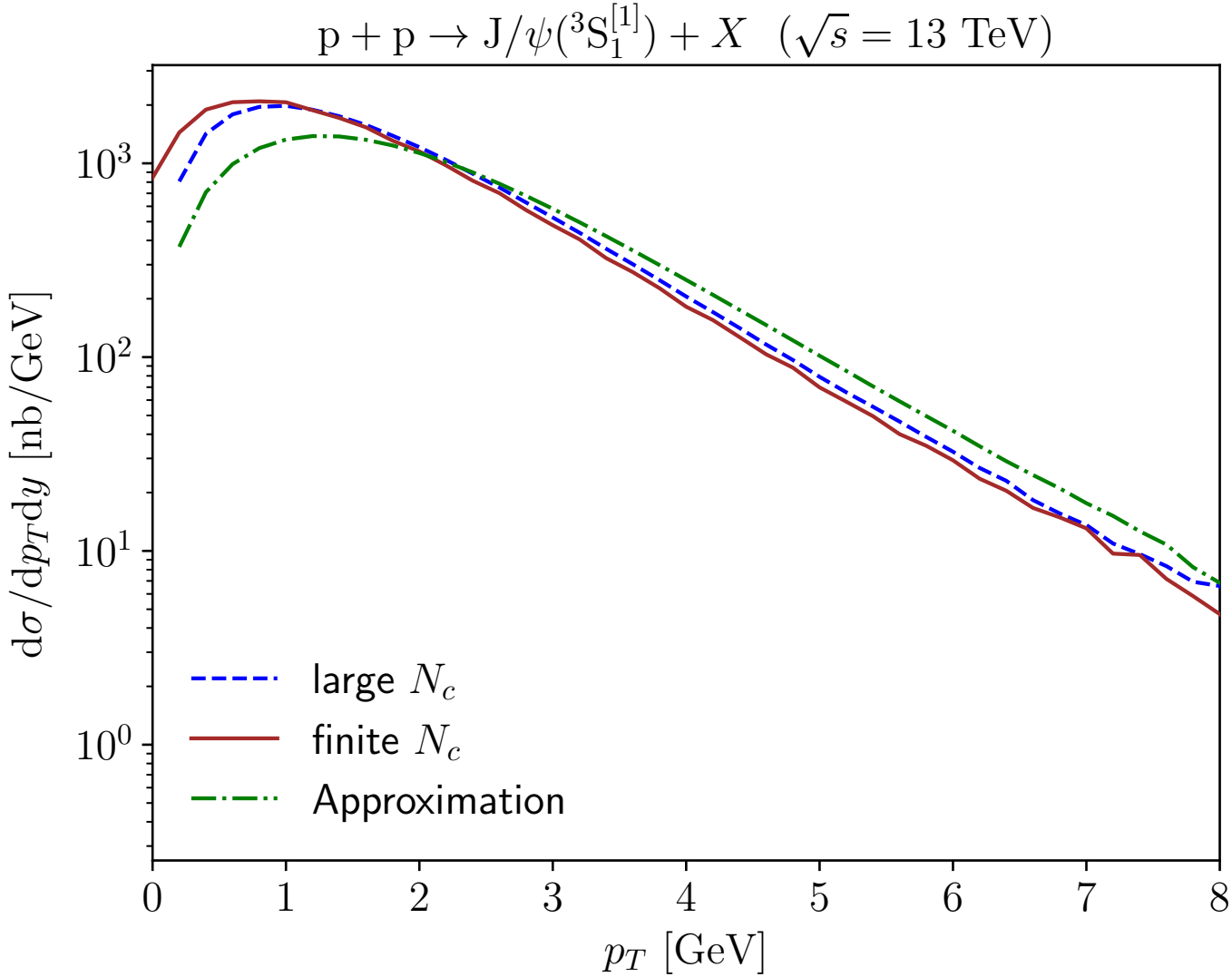
Quadrupole Operator

$$Q_{x_\perp, x'_\perp, y'_\perp, y_\perp} = \frac{1}{N_C} \left\langle \mathrm{Tr}\left[V_F(x_\perp) V_F^\dagger(x'_\perp) V_F(y'_\perp) V_F^\dagger(y_\perp)\right] \right\rangle$$

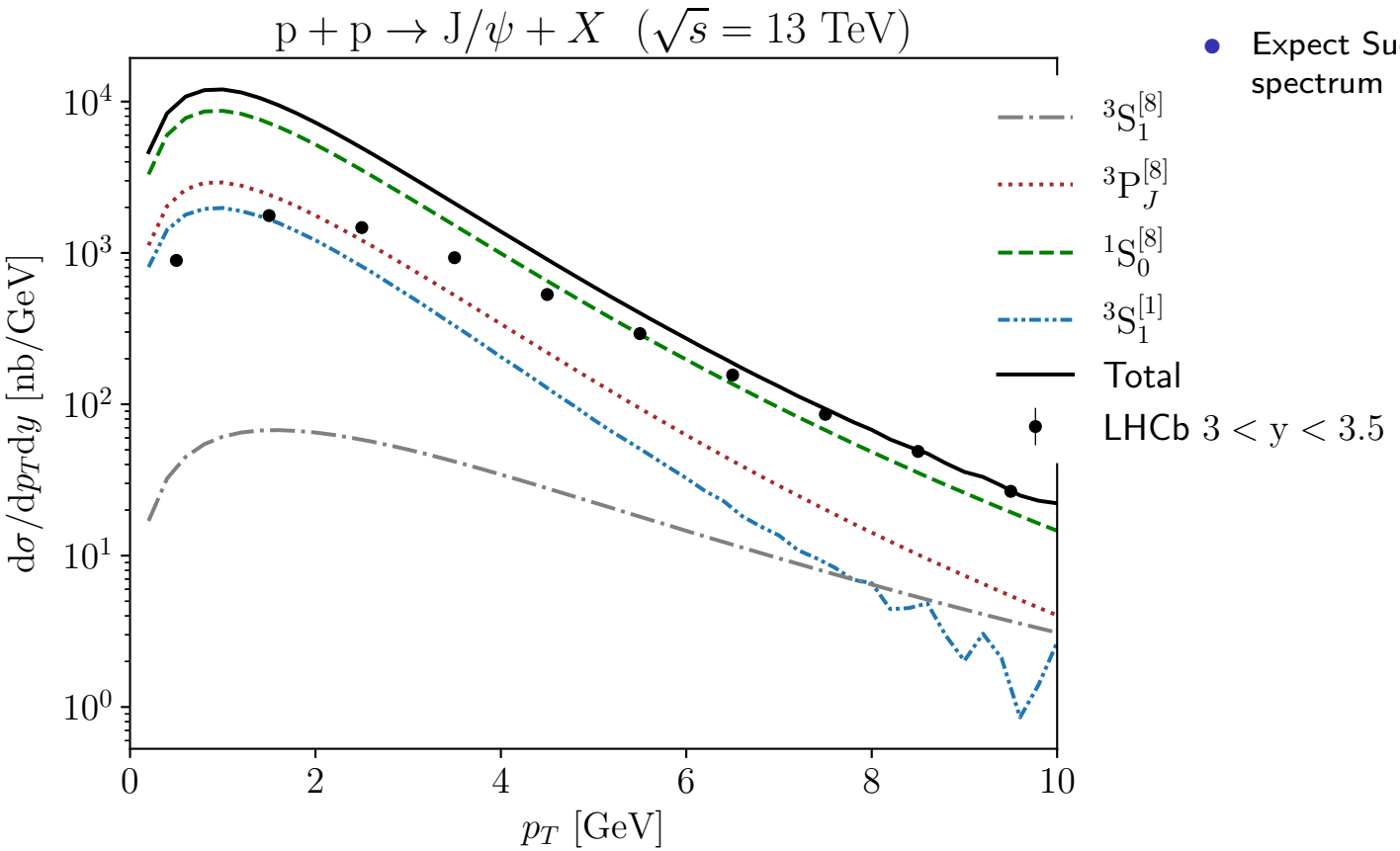
- JIMWLK/BK evolution equation
- Explicit expression in the finite and large-N_c limit
  Dominguez et al. 1101.0715v2

Preliminary results: color singlet channel

Approximated (arXiv:1408.4075v2) vs finite/large-N_c quadrupole



Preliminary results: pp in all channels



- $R_p = 16.36$ mb obtained from MV model fit to DIS data. $Q = M_{J/\psi} = 3$ GeV
- Expect Sudakov factor to change p_t spectrum

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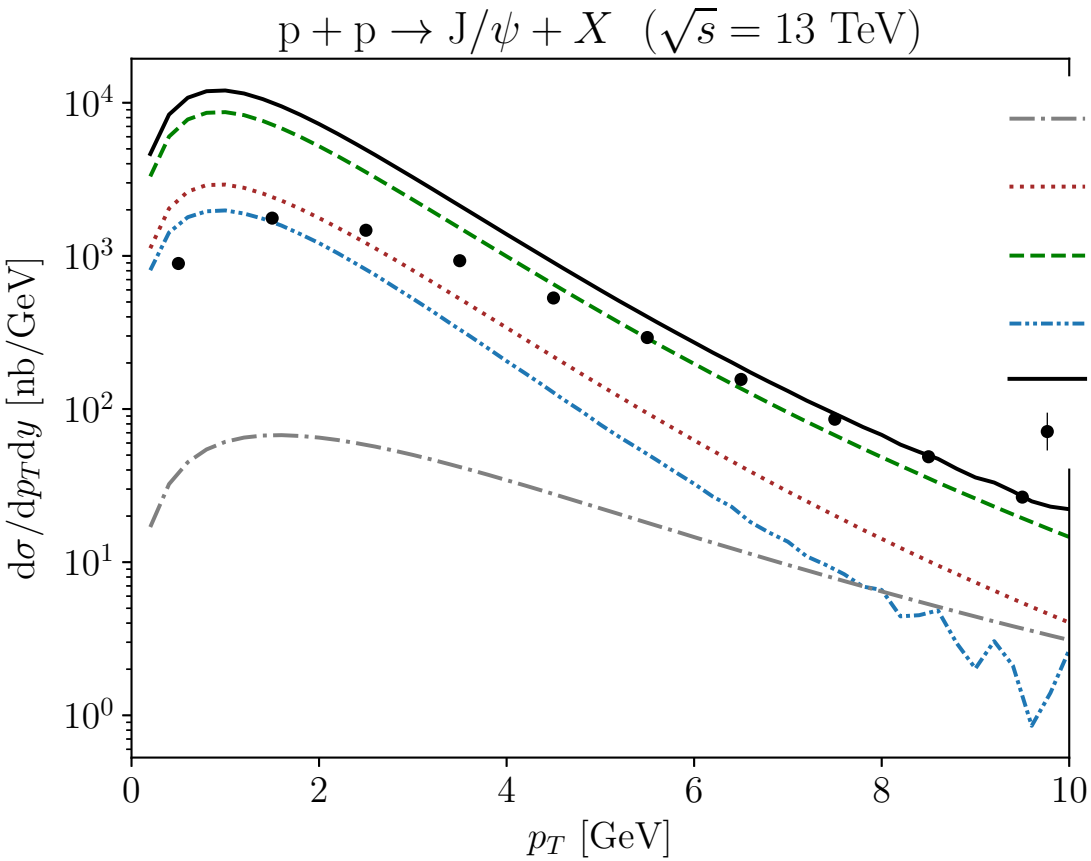

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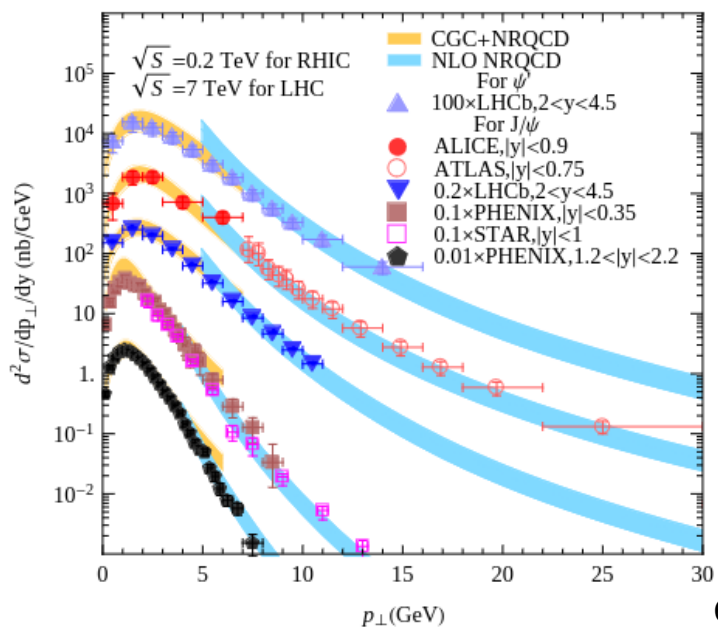
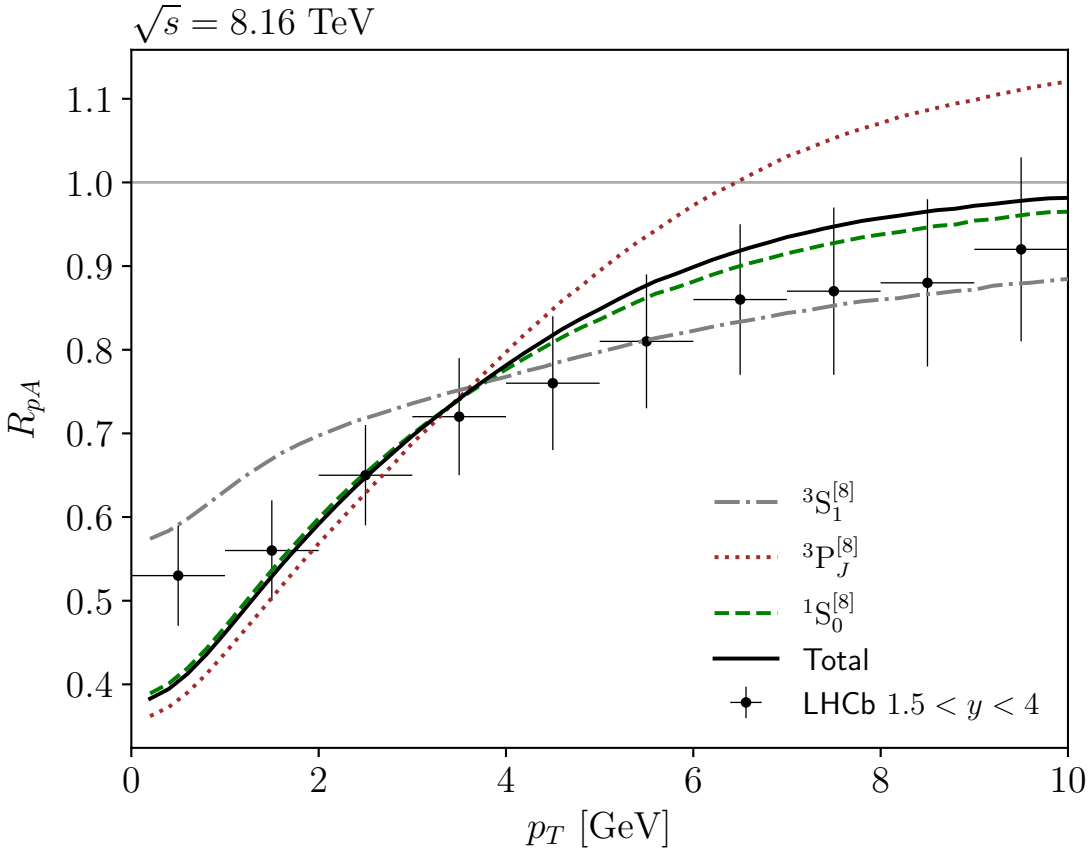


Ma, Venugopalan 1408.4075v2

- $R_p = 0.48$fm and $Q = 5.1$GeV obtained from interpolation between pdfs with unintegrated gluon distribution
- k_T-factorization formalism

Preliminary results: Nuclear modification ratio



$$R_{pA} = \frac{d\sigma_{pA}}{A d\sigma_{pp}}$$

Preliminary results without CS channel (10% contribution) and unintegrated rapidity y=3.25)

- Nuclear supression $\rightarrow$gluon saturation
- Cronin enhancement $^3P_J^{[8]}$ channel

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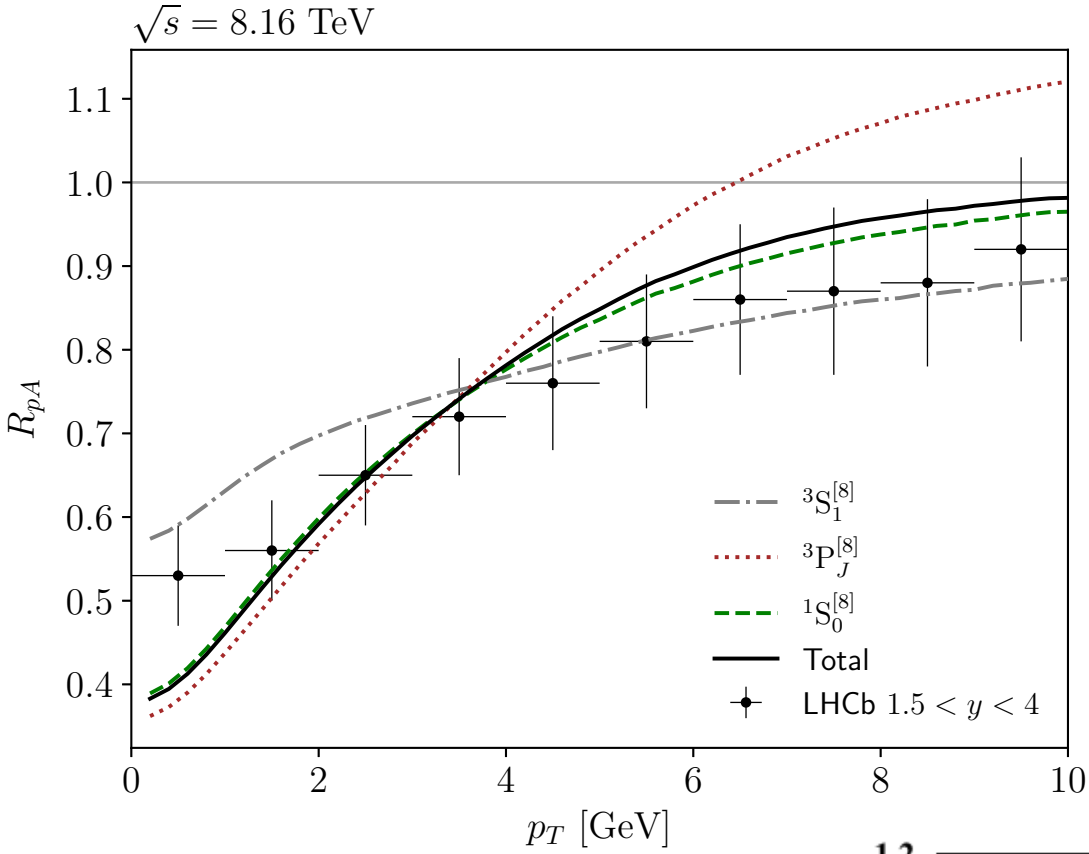

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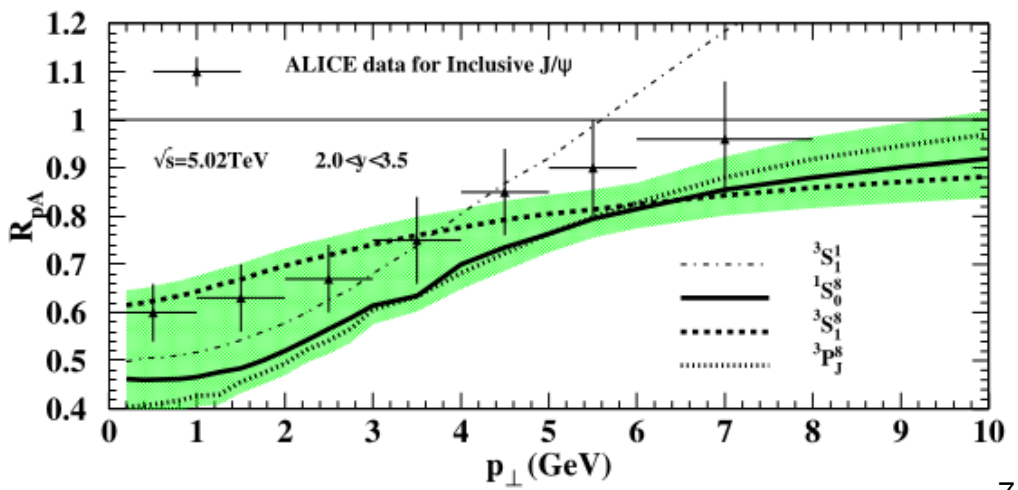

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- Cronin enhancement $^3S_1^{[1]}$ channel

Conclusions

- Calculated J/ψ production in forward pp and pA collisions with CGC+NRQCD.
- Used full quadrupole in the large-N_c limit.
- The nuclear modification ratio exhibits the expected nuclear supression at high-p_t. Results within the experimental error bars, with a similar trend as the R_{pA} calculation in the CGC+CEM model. (Ducloué, Lappi, Mäntysaari 1503.02789v2)
- With the explicit expression for the quadrupole operator used in this work, need of Sudakov correction at NLO + fit initial conditions for BK equation to hadron production for a more precise treatment of inclusive J/ψ production in CGC+NRQCD.