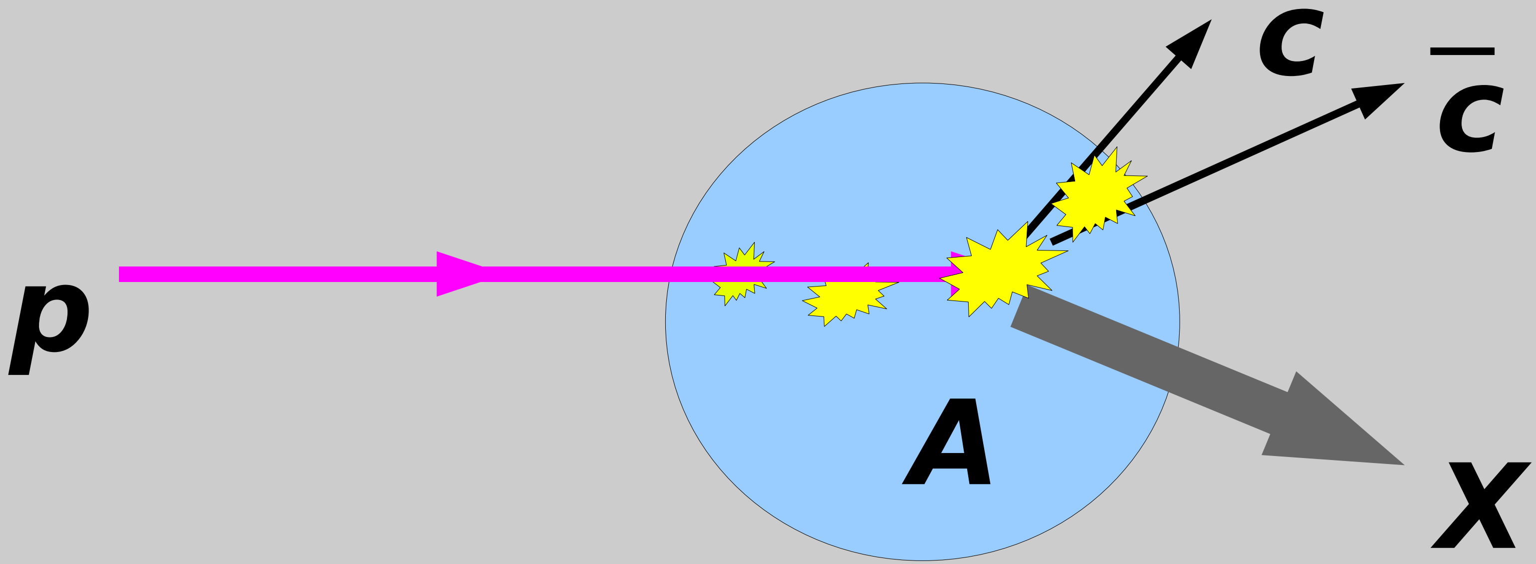
Heavy flavor production in pA collisions within the MV+BK framework

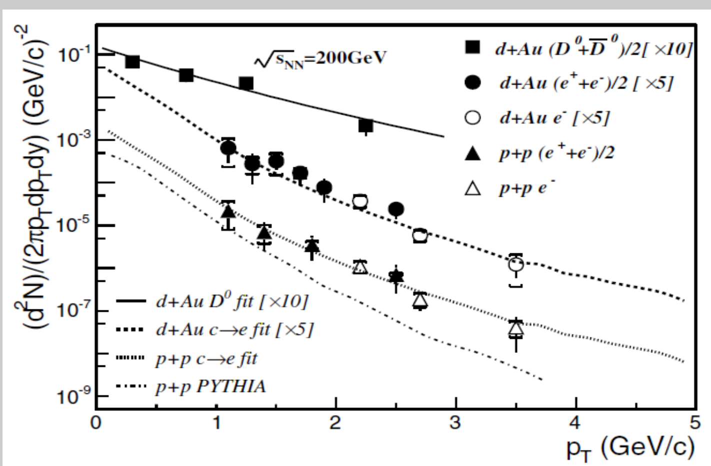


H. Fujii (U. Tokyo, Komaba)
with F. Gelis (Saclay) and R. Venugopalan (BNL)

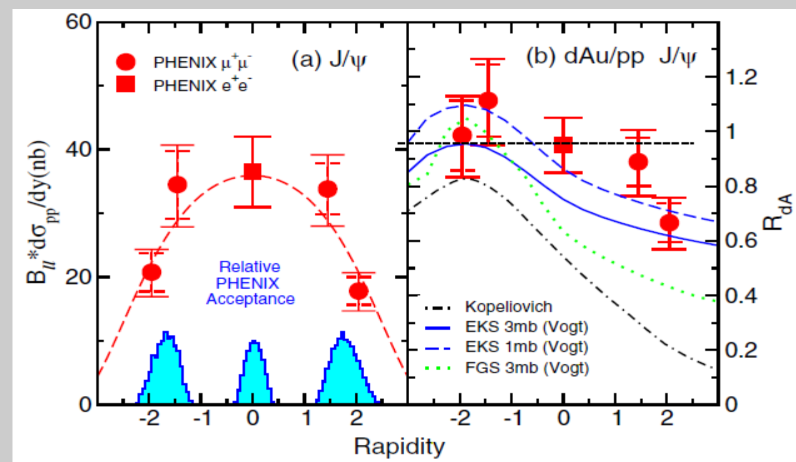
Heavy flavors in pA

- Understanding nuclear effects
  - Interplay : multiple scatterings & saturation
  - Test of saturation picture / CGC
  - Baseline for studying plasma effect

- Charm at RHIC



STAR, PRL94, 062301



PHENIX, PRL96, 012304

- How large the effect at LHC?

Outline

- Introduction
- Formulation : CGC for dilute-dense system
  - Nuclear Effect as
    multiple scatterings & saturation
- Numerical results
  - Open charm and Jpsi in CEM
- Summary and Outlook

$Q\bar{Q}$ from Color Glass Condensate

F.Gelis' talk

- YM eqn with source $\rho_{A,p}$ on light-front

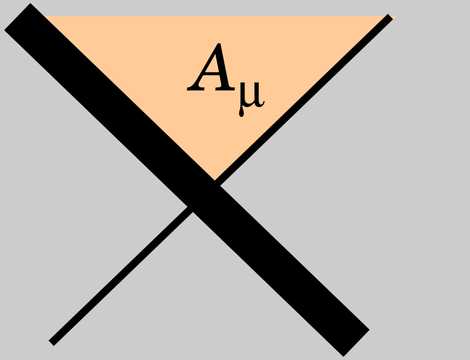
Blaizot-Gelis-Venugopalan, Kovchegov-Muller, Dumitru-McLerran, ...

$$[D_\mu, F^{\mu\nu}] = J^\nu$$

$$J_a^\nu = g\delta^{\nu +}\delta(x^-)\,\rho_{p,a}(\boldsymbol{x}_\perp) + g\delta^{\nu -}\delta(x^+)\rho_{A,a}(\boldsymbol{x}_\perp)$$

Kharzeev-Tuchin, Kovchegov-Tuchin,...
Albacete's talk.

- Analytic solution A_μ known to $O(\rho_p{}^1\,\rho_A{}^{\mathrm{infty}})$



- Quark production on back-ground A_μ (COV)

$$\frac{d\sigma_{q\bar{q}}}{d^2\vec{p}_\perp d^2\vec{q}_\perp dy_p dy_q} = \frac{\alpha_s^2 N}{8\pi^4 d_A}\int_{\vec{k}_{1\perp},\vec{k}_{2\perp}} \frac{\delta(\vec{p}_\perp + \vec{q}_\perp - \vec{k}_{1\perp} - \vec{k}_{2\perp})}{k_{1\perp}^2 k_{2\perp}^2}$$
$$\times\Big\{\int_{\vec{k}_\perp,\vec{k}'_\perp} \mathrm{tr}\Big[(\not{q}+m)T_{q\bar{q}}(\vec{k}_\perp)(\not{p}-m)T^*_{q\bar{q}}(\vec{k}'_\perp)\Big]\,\phi_A^{q\bar{q},q\bar{q}}(\vec{k}_{2\perp}|\vec{k}_\perp,\vec{k}'_\perp)$$
$$+\int_{\vec{k}_\perp} \mathrm{tr}\Big[(\not{q}+m)T_{q\bar{q}}(\vec{k}_\perp)(\not{p}-m)\not{L}^* + \mathrm{h.c.}\Big]\,\phi_A^{q\bar{q},g}(\vec{k}_{2\perp}|\vec{k}_\perp)$$
$$+\mathrm{tr}\Big[(\not{q}+m)\not{L}(\not{p}-m)\not{L}^*\Big]\,\phi_A^{g,g}(\vec{k}_{2\perp})\Big\}\varphi_p(\vec{k}_{1\perp})$$

hard nucleus proton

- 4-, 3-, 2-pt nuclear correlations ϕ's are needed
  - Violation of k_T factorization

Blaizot-Gelis-Venugopalan NPA, HF-Gelis-Venugopalan PRL, ...

- LO calculation in α_s – but **all orders in ρ_A**

Shanghai-China Quark Matter 2006
Nov. 14-20, 2006

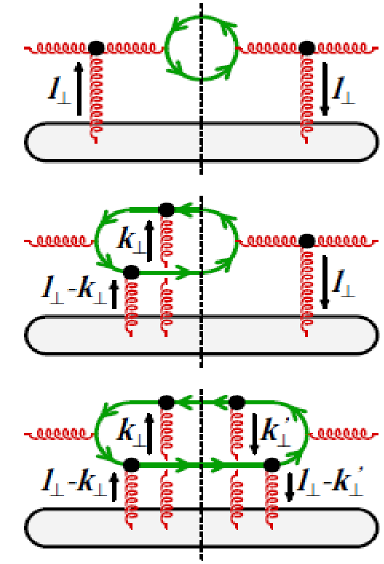
Nuclear correlations ϕ

- Defined as nuclear target average of 2-, 3-, 4-eikonal phases
  - Blobs = multiple scatterings

$$\phi_A^{g,g}(l_\perp) =$$

$$\phi_A^{q\bar{q},g}(l_\perp;k_\perp) =$$

$$\phi_A^{q\bar{q},q\bar{q}}(l_\perp;k_\perp,k'_\perp) =$$



- Satisfy a sum rule

$$\int_{k_\perp,k'_\perp} \phi_A^{q\bar{q},q\bar{q}}(l_\perp;k_\perp,k'_\perp) = \int_{k_\perp} \phi_A^{q\bar{q},g}(l_\perp;k_\perp) = \phi_A^{g,g}(l_\perp)$$

- Related to usual pdf : $xG(x, Q^2)$

$$xG_p(x,Q^2) = \frac{1}{4\pi^3}\int_0^{Q^2} dl_\perp^2\,\varphi_p(l_\perp)$$

- Simplification in the **large-*N* approx** $\phi^{qq,qq} = \phi^{qq} \times \phi^{qq}$

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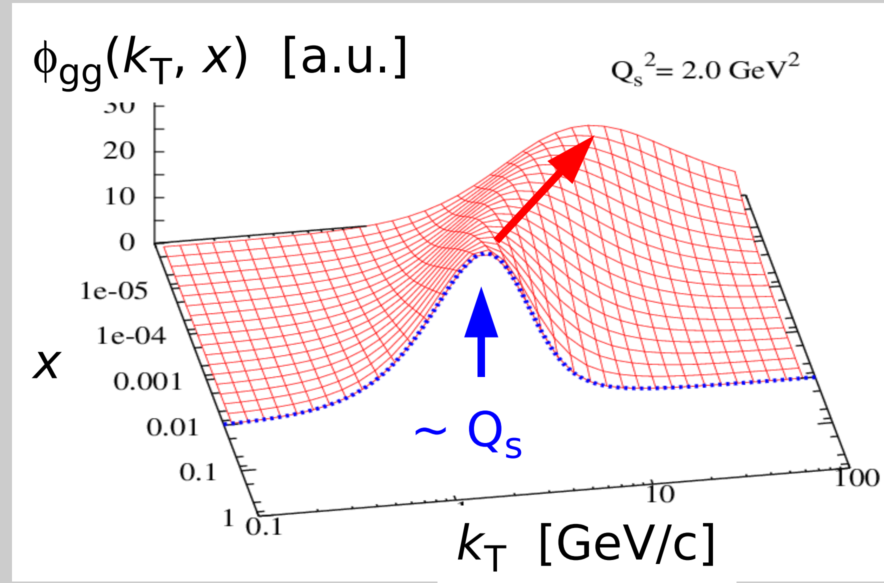
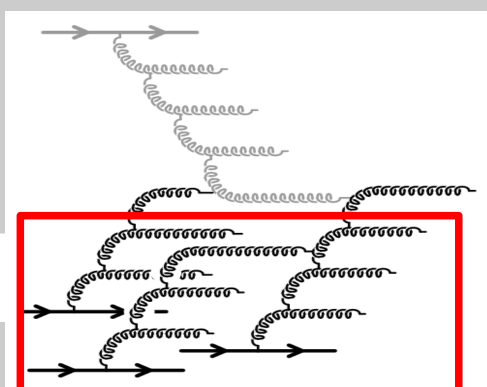
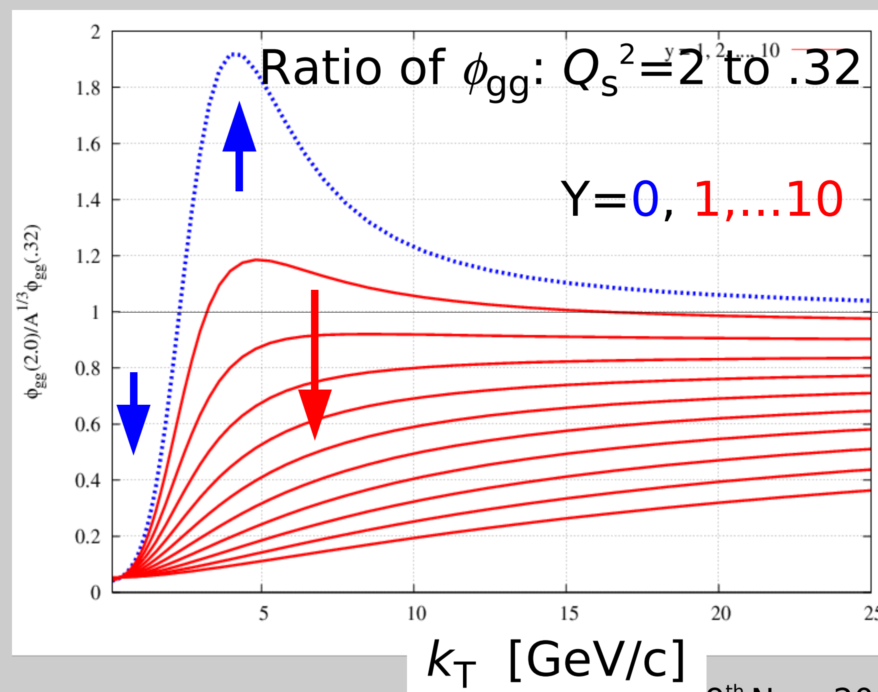
ϕ's from BK evolution with MV init cond

- McLerran-Venugopalan model @ ***x0=0.01***
  - Multiple scatterings of a probe
  - Exch mom ~ ***Qs^2 ~ $A^{1/3}$***
- x- (energy) dependence via Balitsky-Kovchegov evolution
  - BFKL cascade and saturation
  - Qs increases with y=ln(x0/x)
  - No control for x > x0



$\phi_{gg}(k_T, x)$ =





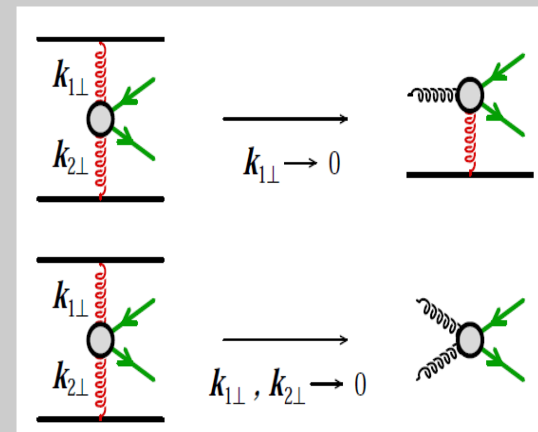
Asymmetric treatment

- Collinear factorization is recovered when $m_T >> k_T \sim Qs$, thanks to the sum rule for ϕ's

Gelis-Venugopalan,
Blaizot-Gelis-Venugopalan

- We use collinear approximation on dilute proton side :

$$xG_p(x, Q^2) = \frac{1}{4\pi^3} \int_0^{Q^2} dl_\perp^2 \varphi_p(l_\perp)$$



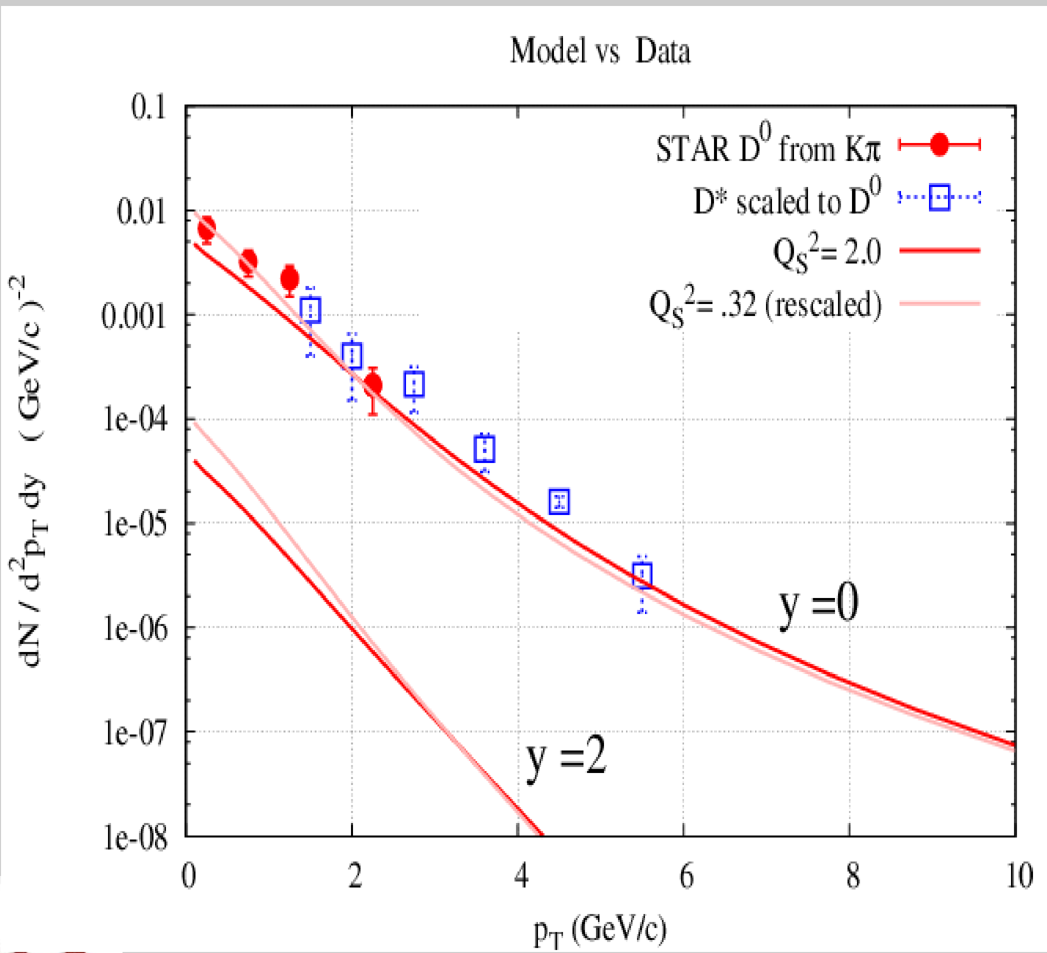
- Cross section for dilute-dense system :

$$dN = \int (hard) \otimes xG(x, Q^2) \otimes \phi^{qq,g}(k_2, k)$$

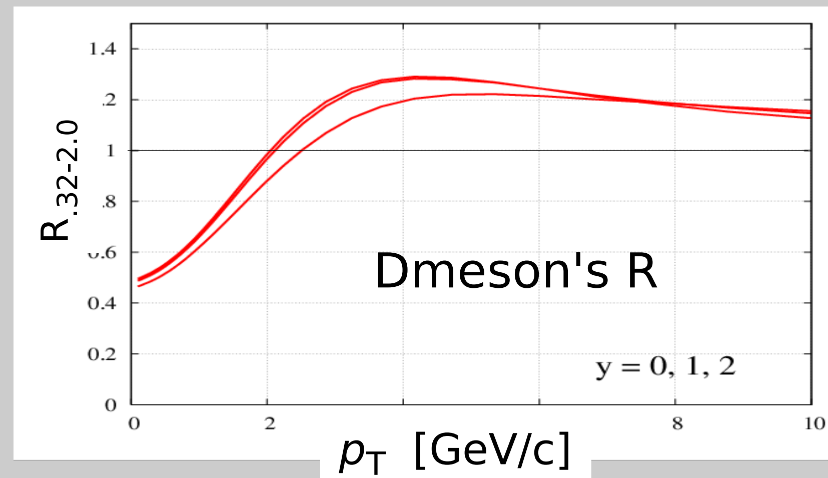
Numerical results

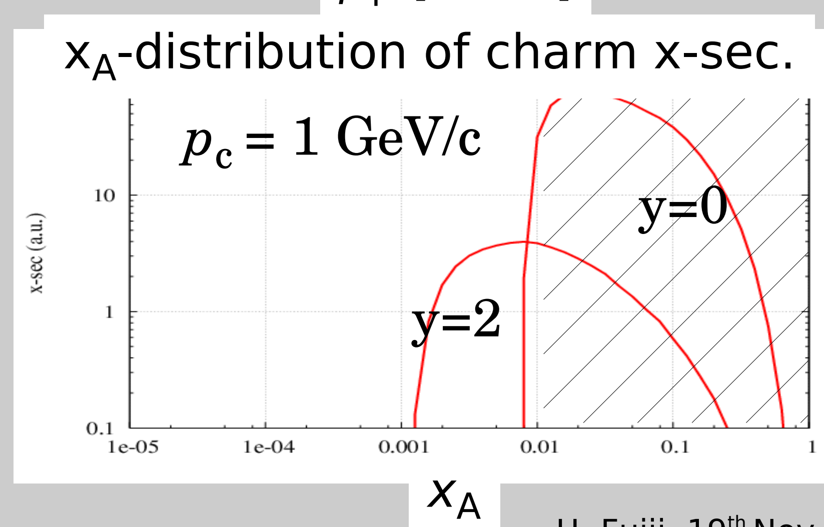
Open charm production

- Asymmtric treatment: proton=xG(x,Q^2), nucleus=CGC(**2.0**)
  - Looks consistent w/ data @y=0
  - For "saturation" effect, compare w/ Q_s^2= 0.32 simulating "pp"



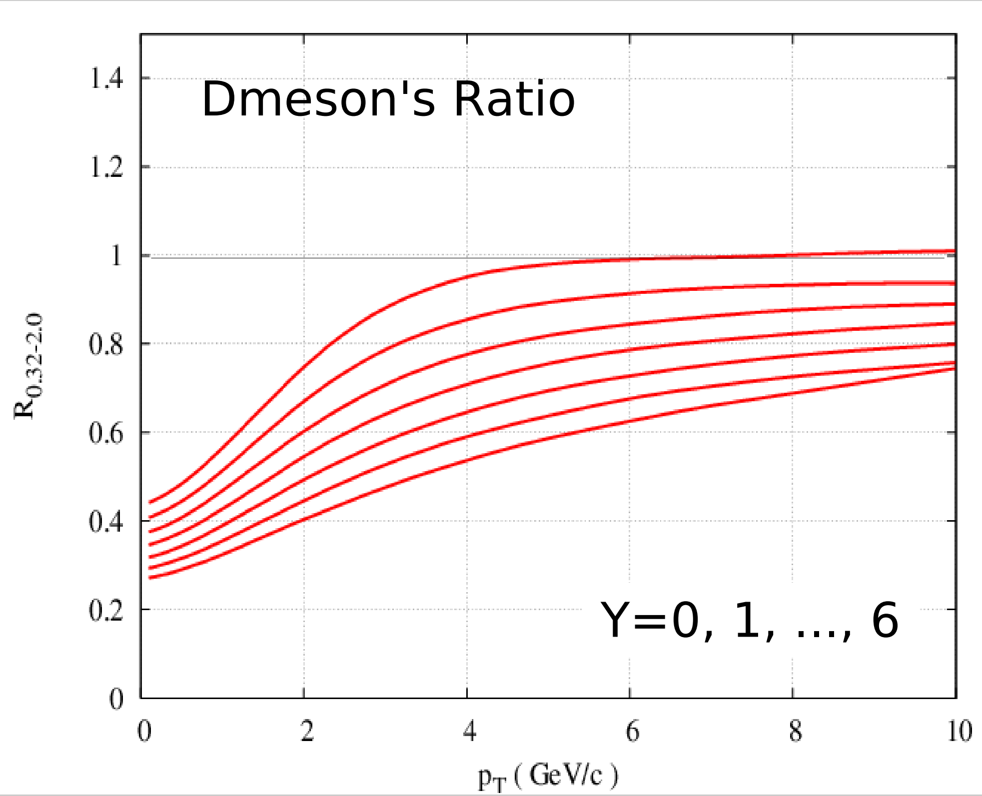
Similar work by Kharzeev-Tuchin

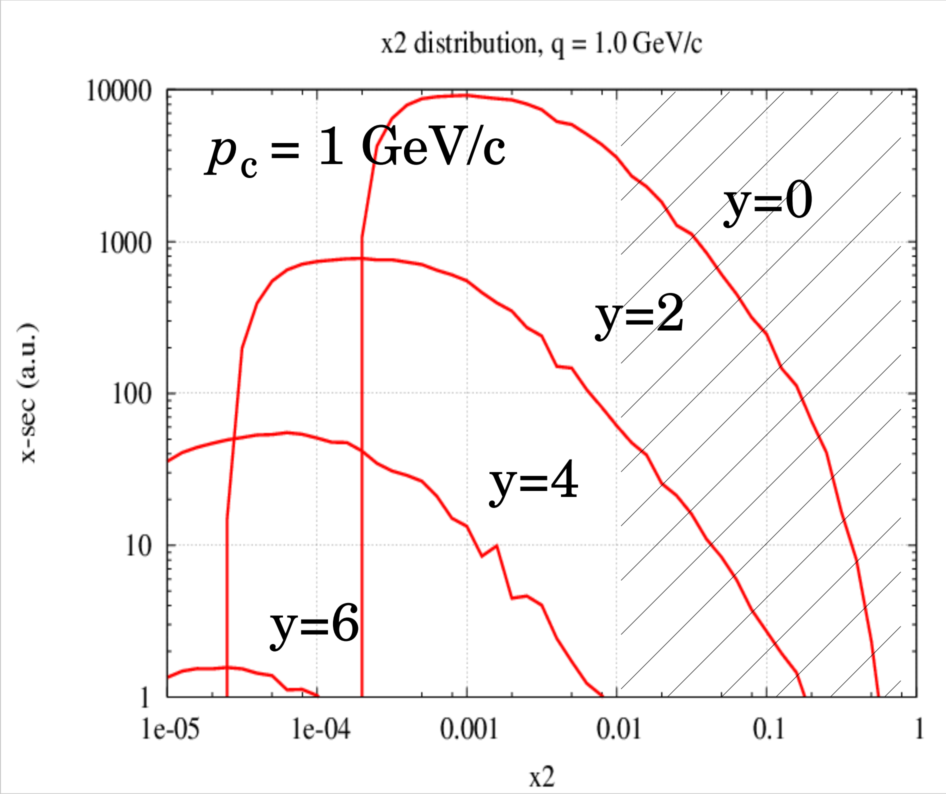




Open charm

- pA @ LHC (8.5 TeV)
  - Large window for testing "small-x" with charm
  - For bottom, x ~ 0.001@y=0

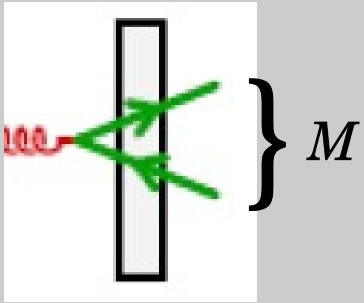




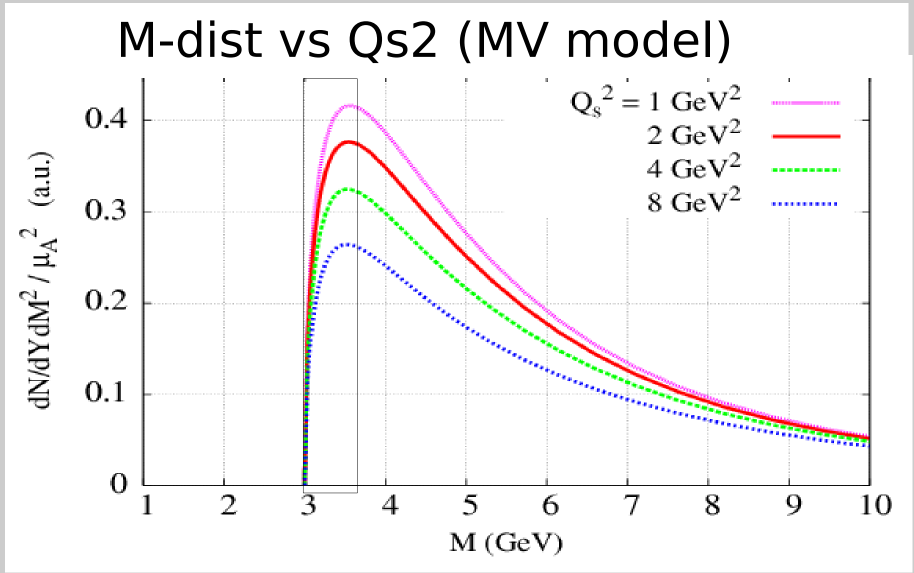
Quarkonium via Color Evaporation

- Assumption: separation of pair production and J/psi formation

$$\frac{dN_{J/\psi}}{dY\,d^2\boldsymbol{P}_\perp} \underset{CEM}{=} F_{J/\psi} \int_{4m^2}^{4m_D^2} dM^2 \, \frac{dN}{dY\,d^2\boldsymbol{P}_\perp dM^2}$$

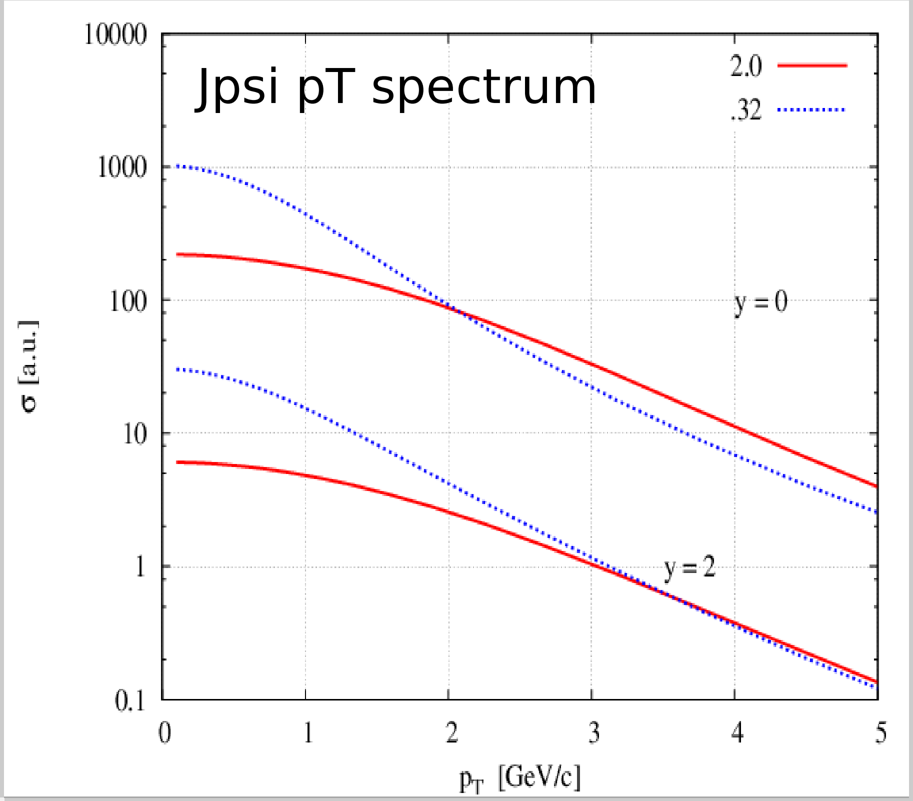


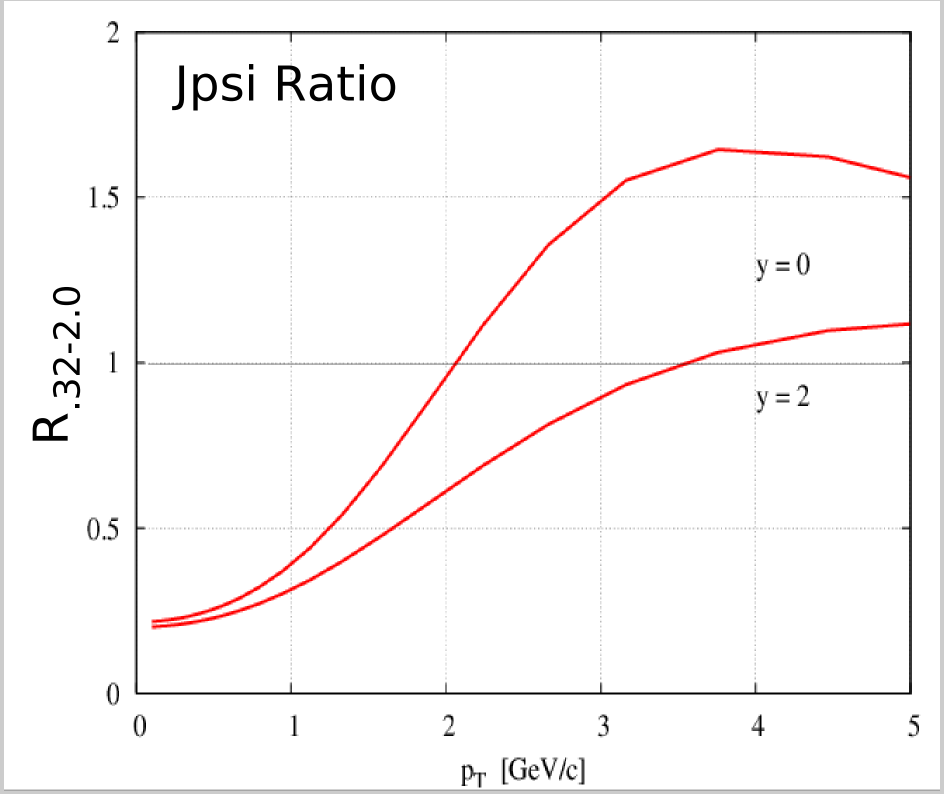
- Two effects of dense gluons on Jpsi:
  1. Depletion of initial gluon number
  2. Suppression of small M^2 pair due to multiple scatterings



Quarkonium via Color Evaporation

- J/pi p_T-spectrum @ RHIC
  - Comparison of "pA" and "pp" : Qs^2=2.0 & .32
  - Suppression at small p_T, enhancement at larger p_T





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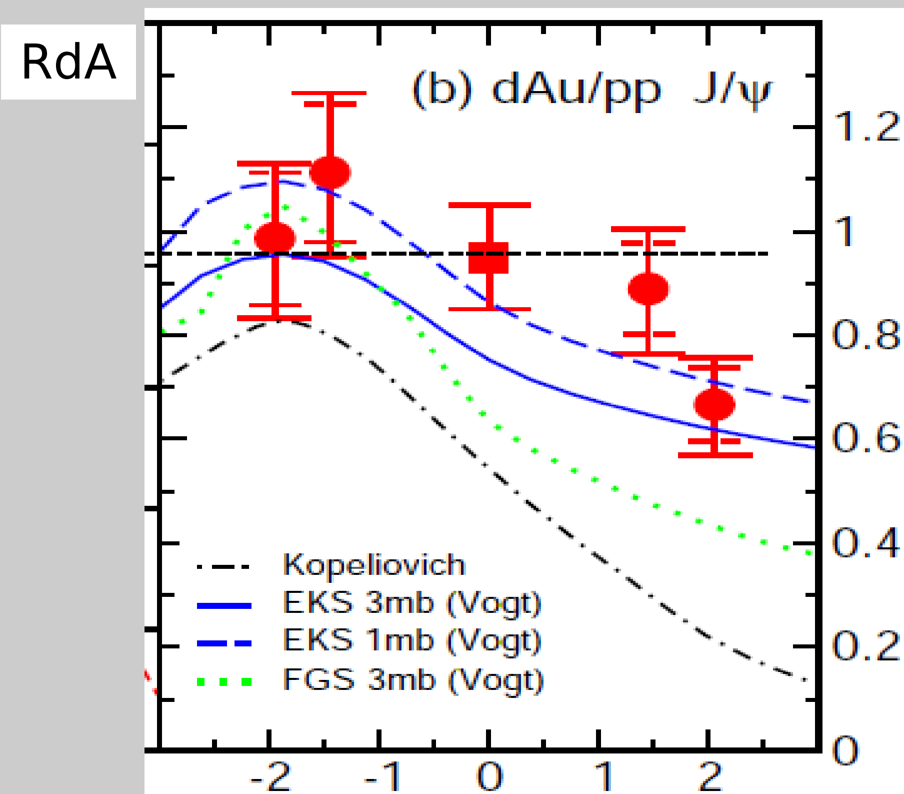
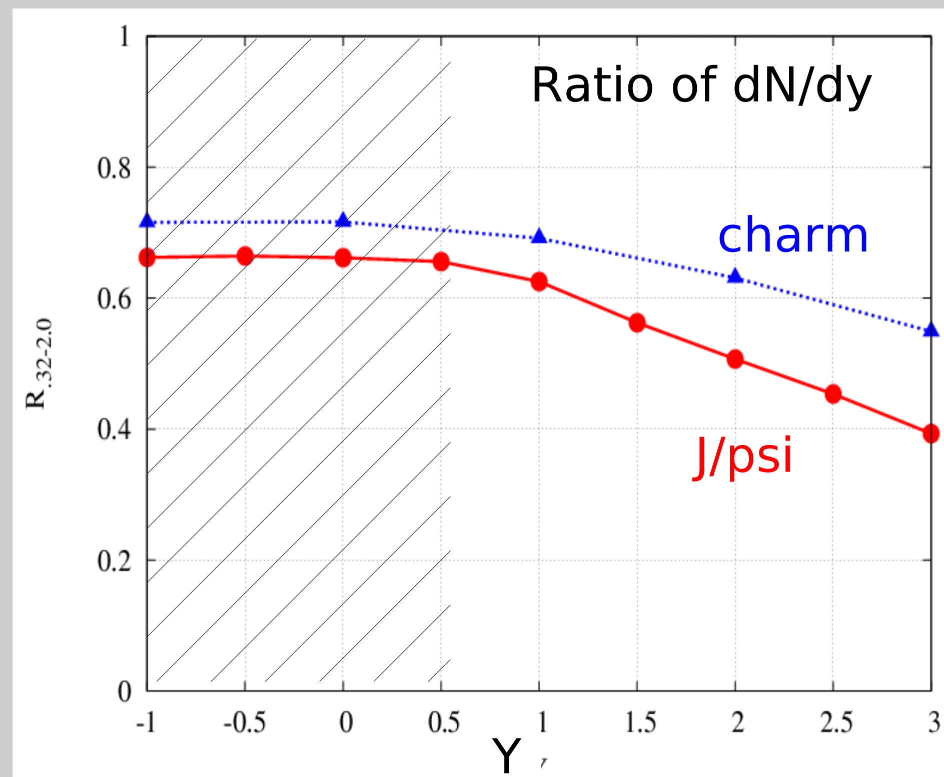
Quarkonium via Color Evaporation

- J/psi, charm suppression at forward Y
  - J/psi more suppressed : more sensitive to multiple scatterins



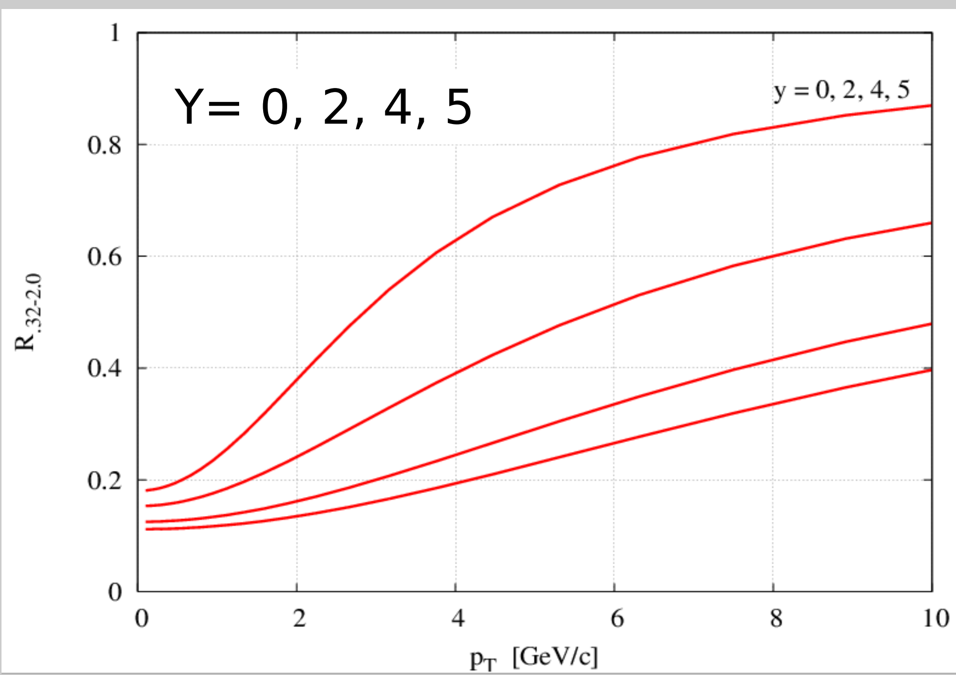


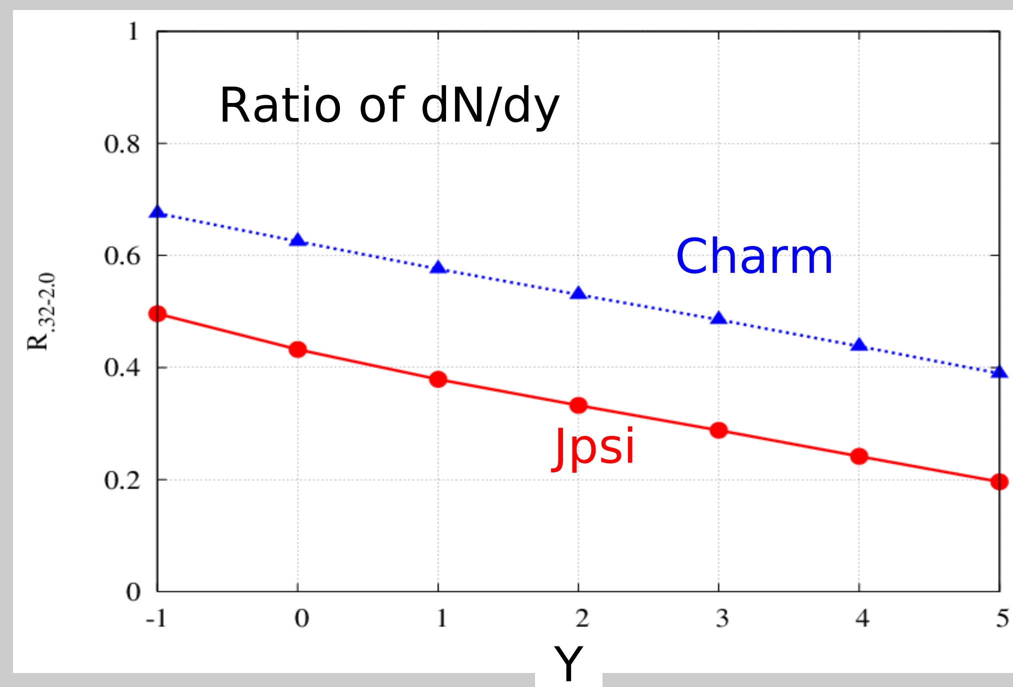
Quarkonium via Color Evaporation

Very preliminary

- J/psi @ LHC (8.5TeV)
  - Suppression for all p and for y >= 0

N.B. Bottom contrib not included





Summary and outlook

- Heavy flavor in pA : cleaner place to test "saturation"
- A controlled CGC approach for dilute-dense system is given
  - Charm data at RHIC is encouraging
  - More info on nuclear WF from p_T- , y-deps of heavy flavors
  - Preliminary results are shown, and systematic detailed study is now underway

- Outlook
  - More post-dictions and predictions for exp't in our framework
  - Improved treatment for onium production mechanism
  - How about AA? ... and more !