HLPW08 - March 2008, Belgium

J/ψ shadowing at RHIC : P_T dependence

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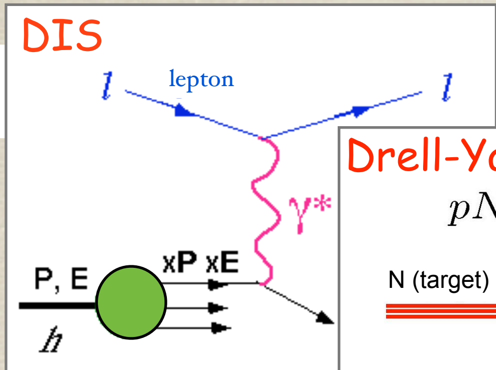
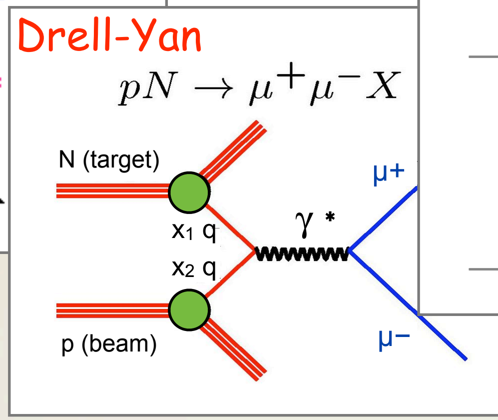
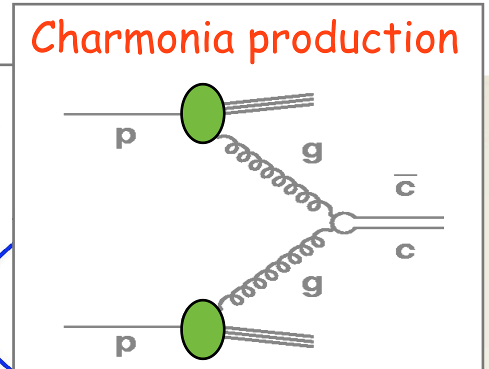
E. G. Ferreiro, F. Fleuret, A. R. arXiv:0801.4949

d+Au @ $\sqrt{s_{NN}}$ = 200 GeV

Shadowing : a cold *nuclear matter* effect







Processes used to probe :

- nucleon struct. f.

$$F_2 = \sum_i e_i^2 \, . \, x f_i(x, Q^2)$$

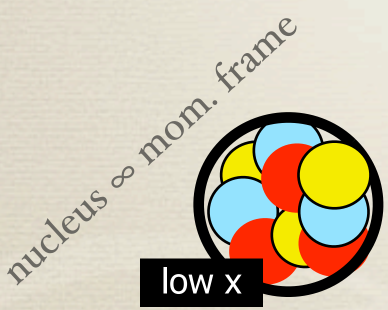
with $f_i(x, Q^2)$ = PDF and $i = q, \bar{q}, g$

- nuclear struct. f. per nucleon

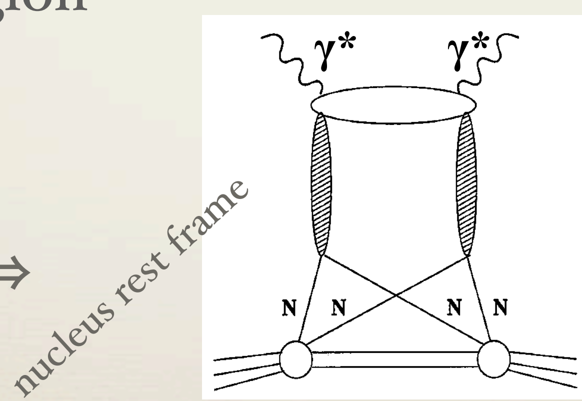
$$R^A_{F_2} = \frac{\text{nuclear}}{\text{nucleon}}$$

(Anti-)shadowing :

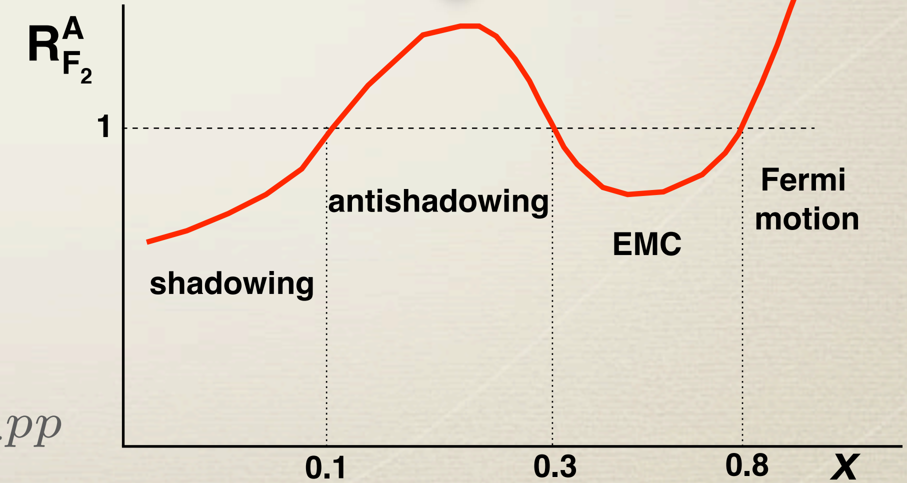
- initial-state effect "calibrated" in d(p)+A
- refers to low-x region
- coherence effect



⇔



at a given Q² :



- (enhances) decreases σ^{pA} wrt $\langle N_{\rm coll}\rangle \, \sigma^{pp}$

Shadowing models / experiment's goal

- When considering shadowing as the *sole* nuclear effect :

correction factor

$$\sigma^{pA} = R^A_{\text{shadow}} \times \langle N_{\text{coll}} \rangle \, \sigma^{pp}$$

CF-like approach [1, 2] EKS-like approach [3]

- Favorite experimental observable = nuclear modif. factor :

$$R_{pA} = \frac{dN^{J/\psi}_{pA}}{\langle N_{\text{coll}} \rangle \, dN^{J/\psi}_{pp}}$$

[1] Capella, Kaidalov & Tran Thanh Van, Heavy Ion Phys. 9, 169 (1999)
[2] Capella & Ferreiro, Eur. Phys. J. C42, 419 (2005)
[3] Eskola, Kolhinen & Salgado, Eur. Phys. J. C9, 61 (1999)

How is the shadowing predicted?

- CF-like approach
  - physical origin described using multiple scattering formalism

$$R^A_{\rm shadow}(b, y, p_T) = \frac{1}{1 + N^A(b).F(y, p_T)}$$

accounts for initial interactions between gluons

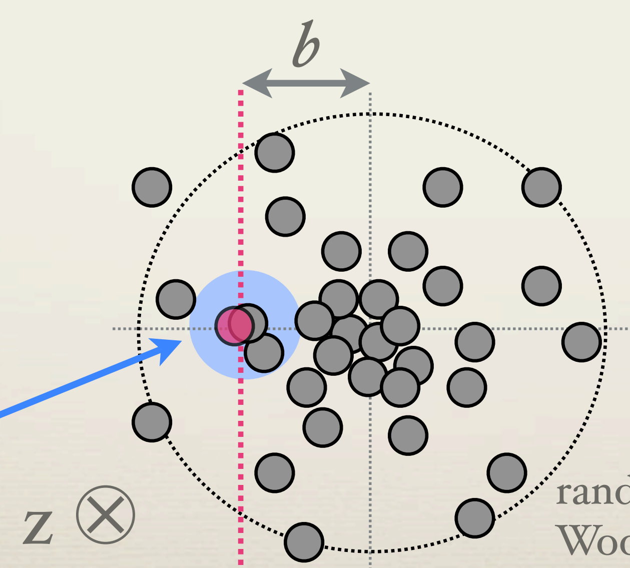
- EKS-like approach
  - use data to parametrize $R_i^A(x, Q_0^2)$ and DGLAP to get it at $Q^2 > Q_0^2$

$$R^A_{\rm shadow}(b, x, Q^2) = 1 + \frac{N^A(b)}{< N^A >} \times [R_g^A(x, Q^2) - 1]$$

accounts for the gluon PDF modification in nucleus

How is the shadowing predicted?

CF-like approach	EKS-like approach
physical origin described using multiple scattering formalism	use data to parametrize and DGLAP to get it at $Q^2 > Q_0^2$
$$R^A_{\text{shadow}}(b, y, p_T) = \frac{1}{1 + N^A(b)\, F(y, p_T)}$$	$$R^A_{\text{shadow}}(b, x, Q^2) = 1 + \frac{N^A(b)}{\langle N^A \rangle} \times \left[R^A_g(x, Q^2) - 1\right]$$
$N^A(b)$: number of nucleons that contributes to shadowing at b	$\langle N^A \rangle$: average value of N^A



nucleon tr. size σ_{tr} = 3.94 fm²

assumption : coherent interaction between parton $i \in$ p and all partons $\in$ A along its path

random spatial position of A nucleons following Wood-Saxon density profile

Where is the p_T dependence ?

- CF-like approach
  - explicit dependence : $F(y, p_T)$

- EKS-like approach
  - for the charmonia production, relate (x_1, x_2) to (y, p_T)
  - our choice : $x_{1,2} = \frac{m_T}{\sqrt{s_{NN}}} e^{\pm y}$

    with $m_T = \sqrt{m^2 + p_T^2}$
    - often used in litterature
    - $g + g \to c\bar{c}$ with non-zero initial gluon p_T
  - scale chosen accordingly :

$$Q^2 = (2m_c)^2 + (p_T)^2$$

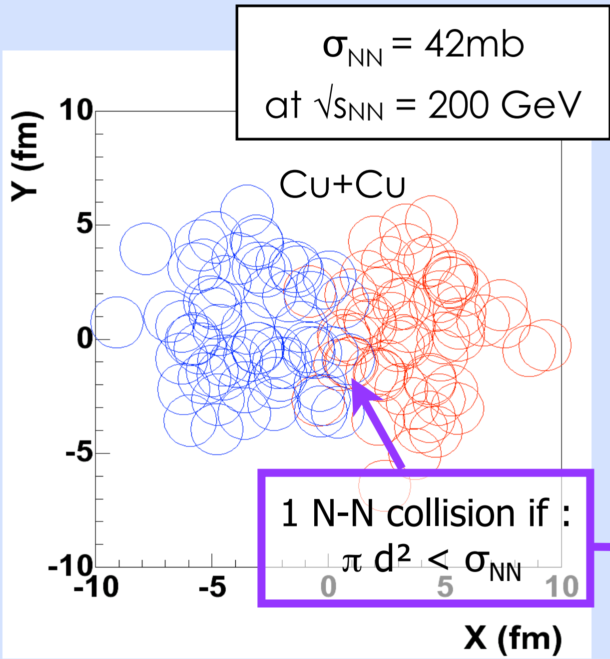
with $m_c = 1.2\,\mathrm{GeV}/c^2$

Our Monte-Carlo approach for J/Ψ production

1 — 2 — 3

1

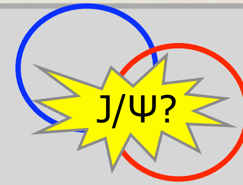
Glauber MC



Random :

- b according to 2π b db
- position of nucleons ∈ A, B according to Woods-Saxon

2



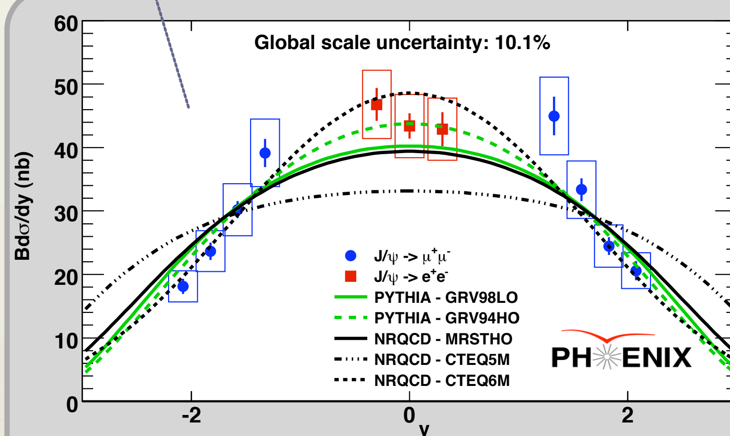
For each N-N collision

J/Ψ candidate produced

- according to $\sigma_{J/\Psi} \leq \sigma_{NN}$

with random :

- **y** and **p_T** according to p+p data
- random p_T orientation **φ** uniformly distributed in [0, 2π]



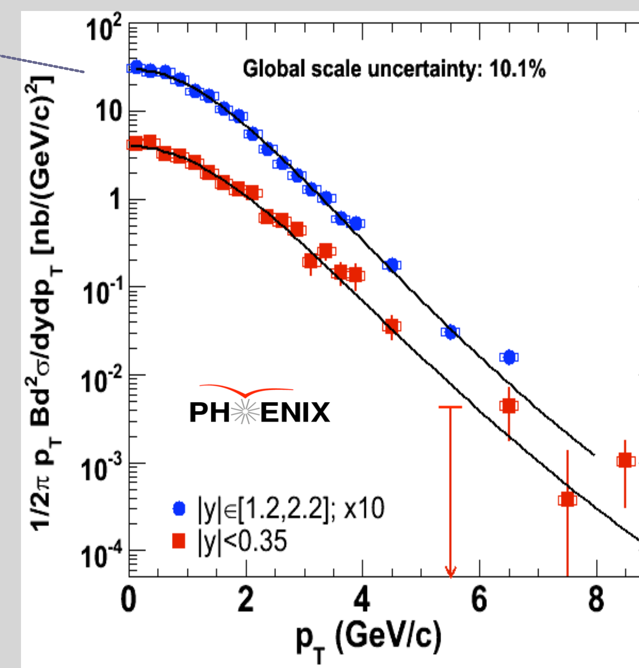
Kinematics for J/Ψ candidate:
y, p_T, φ, M ⇒ p_x , p_y , p_z , E

3

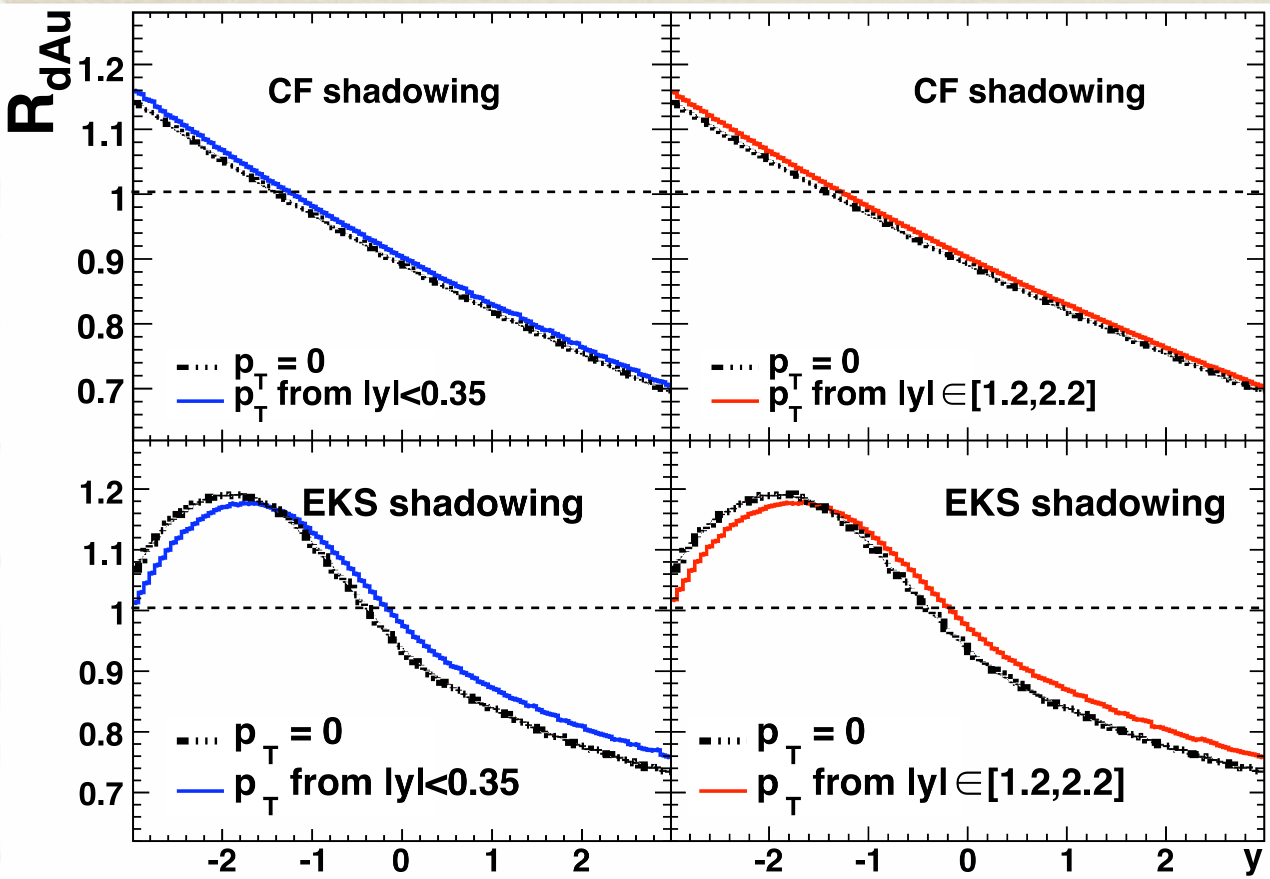
J/Ψ canditate ⇒ real J/Ψ if :
random[0,1] < R_{shadow} × $\sigma_{J/\Psi}$ / σ_{NN}

computed using **CF** or **EKS**

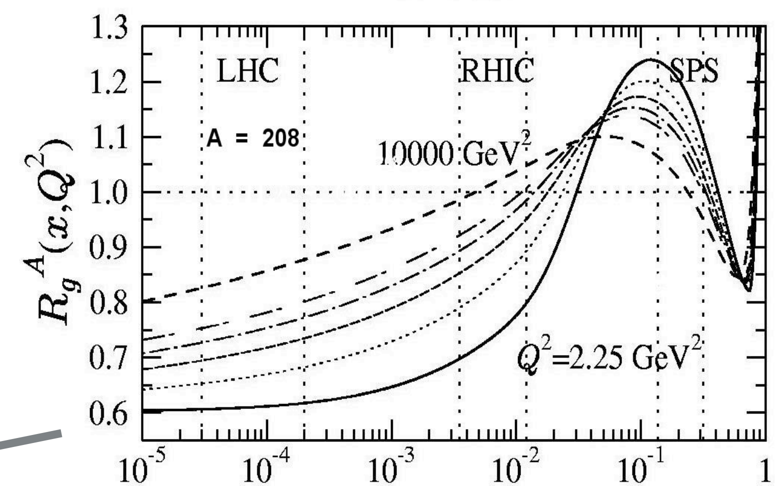
Nuclear modif. factor =
$dN_{real\ J/\Psi}$ / $dN_{J/\Psi\ canditate}$



Results :1) R_{dAu} vs y



- Larger amount of anti-shadowing for EKS
- Adding p_T : small effect because $\langle p_T \rangle < 2\,\mathrm{GeV}/c < m_{J/\psi}$



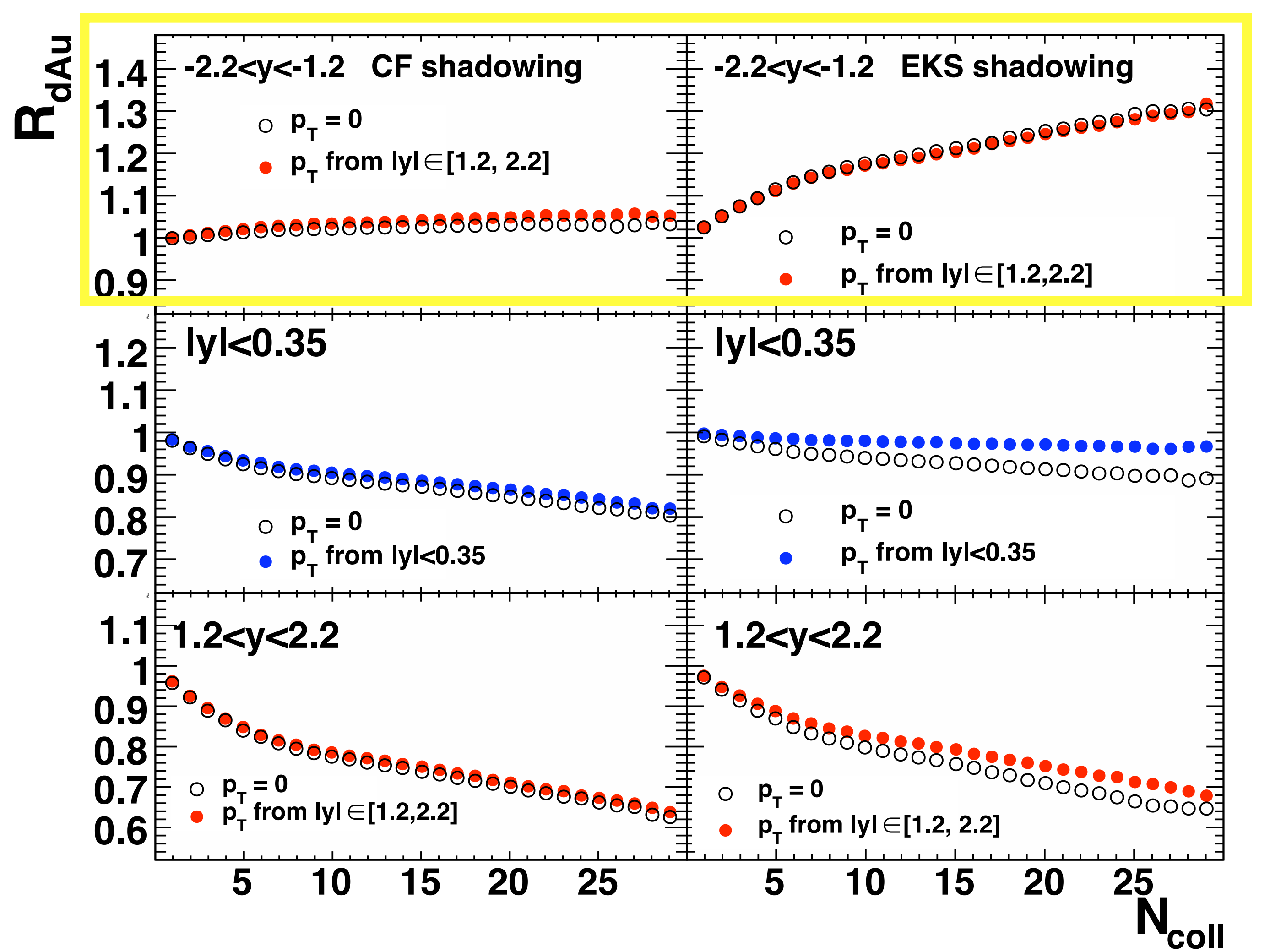
Nucl. Phys. A696 (2001) 729-746

- For EKS : larger $p_T \Rightarrow$ larger Q^2

➡ smaller R_g^A in anti-shadowing region ⇒ smaller R_{dAu} ...

- For CF : $F(y, p_T)$ monotonic function, increasing with y, decreasing with p_T

Results : 2) R_{dAu} vs N_{coll}

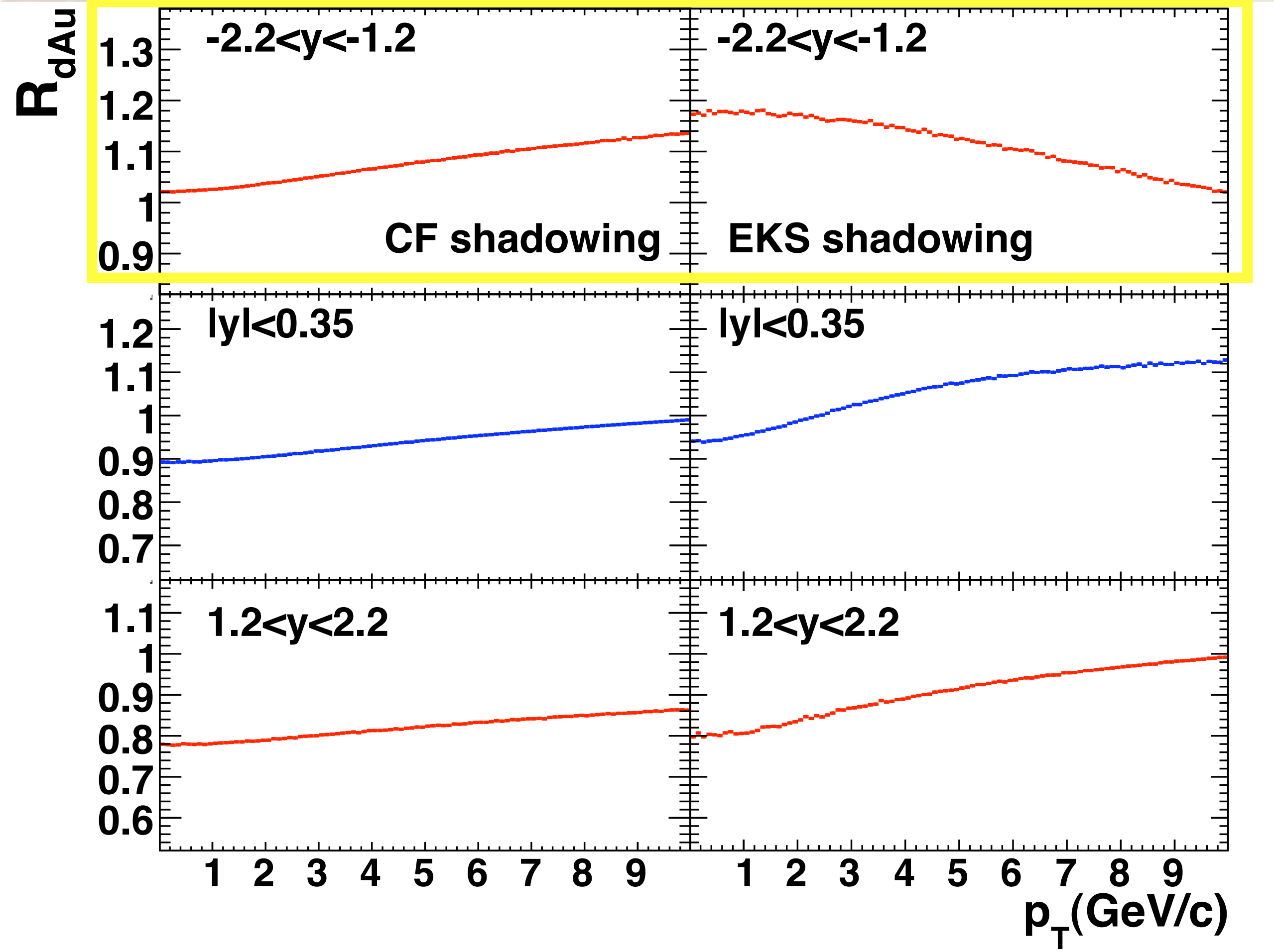


- Adding p_T : small effect
- Remarkable difference between CF and EKS at y<0 :

  diff. amount of anti-shadowing in each model

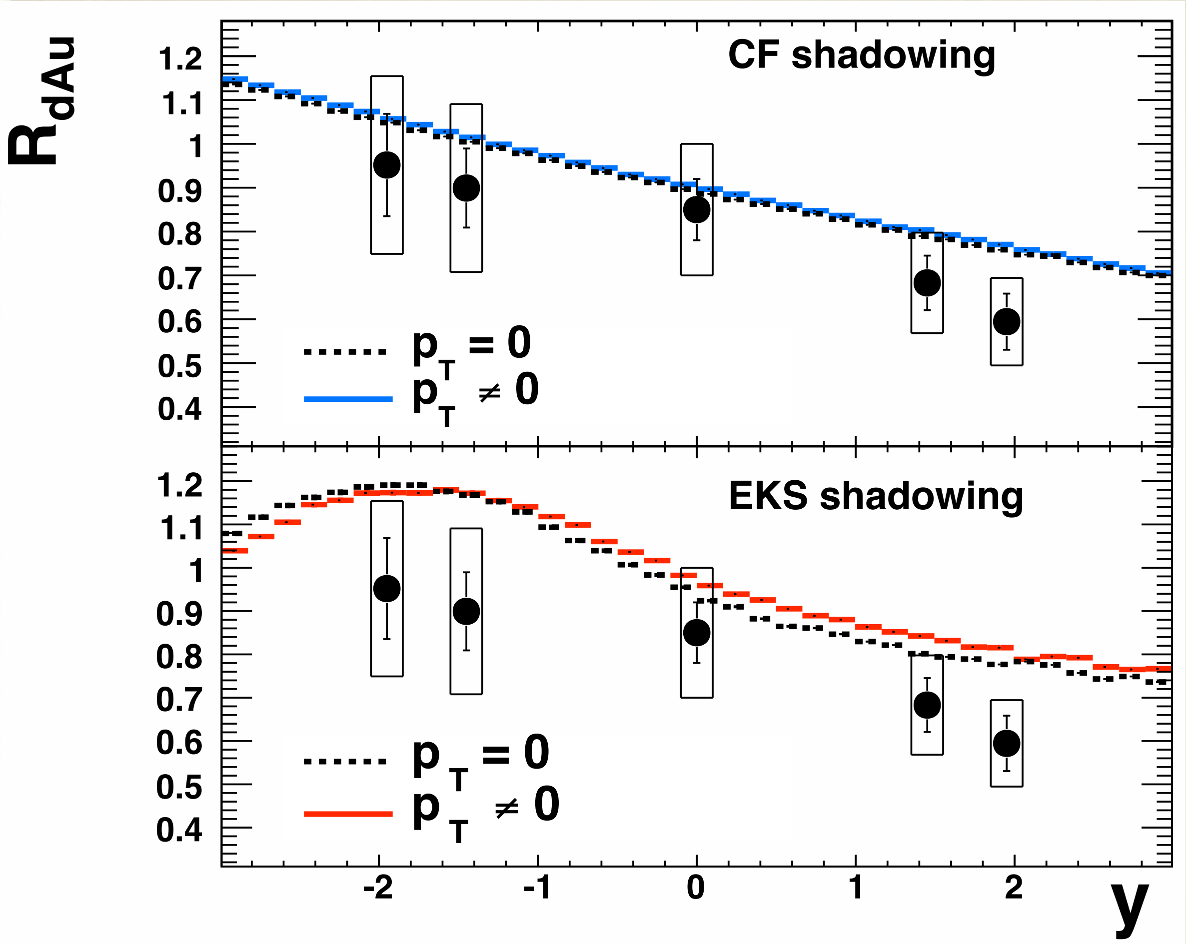
Results : 3) R_{dAu} vs p_T

Main result !



- Up to 20% amplitude variation with p_T
- EKS : stronger p_T dependence
- Striking : opposite behaviour for CF vs EKS at y<0

Comparison to the data [1]



Bar = pt-to-pt uncorrelated err. (stat. + syst.)
Box = pt-to-pt correlated err. (syst.)

- PHENIX data (2003) :

  400 + 1250 J/ψ

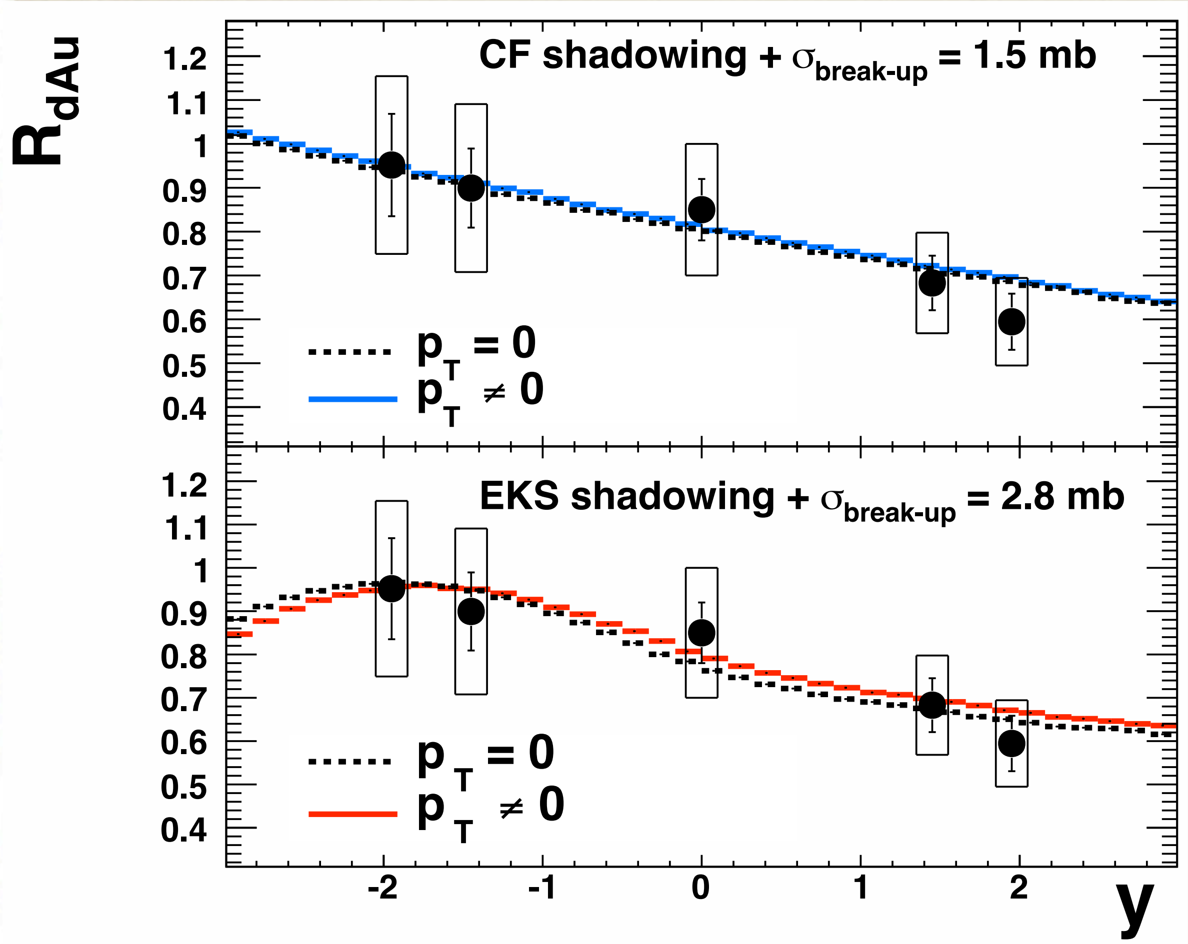
  $|y| < 0.35\ :\ J/\psi \to e^+e^-$

  $1.2 < |y| < 2.2\ :\ J/\psi \to \mu^+\mu^-$

- predicted R_{dAu} overshoot the data
- need a break-up cross-section

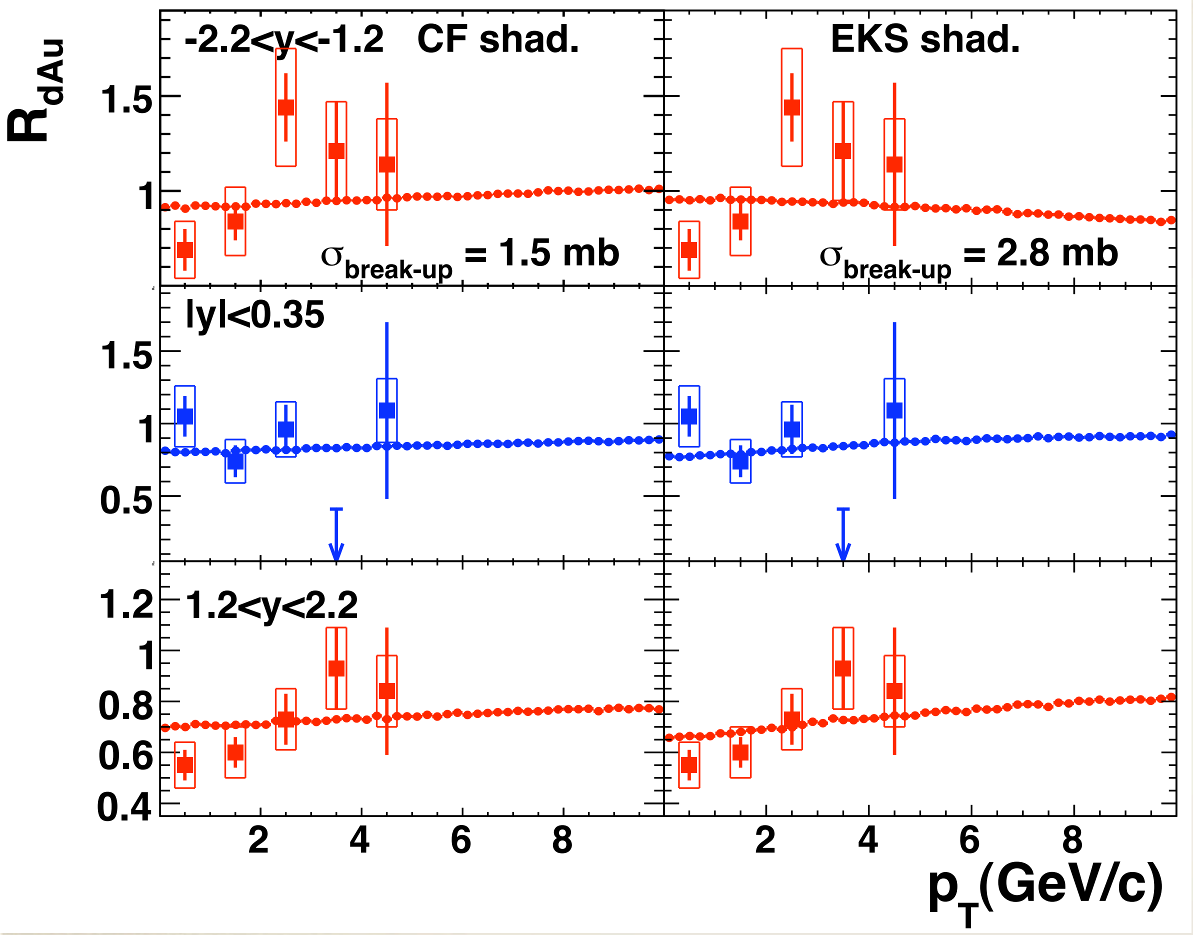
[1] PHENIX, Phys. Rev. C77, 024912 (2008)

Comparison to the data



- Good matching obtained for both models
- But with diff. values of $\sigma_{break\text{-}up}$

Comparison to the data



- data with large uncertainties and limited range in p_T
- at y<0, EKS seems to not match the trend
- crude matching elsewhere
- at y>1.2, both models seem to have a smaller slope than seen in the data

Summary

- Glauber MC (no dynamic)

  + (y, p_T) spectra from input pp data

  + two different shadowing models

- First results for the p_T dependence of the J/ψ shadowing

- In general : more suppression in CF than in EKS shadowing

- But at y≈-1.7 for R_{dAu} vs p_T : increasing for CF, decreasing for EKS shadowing

Open questions

- Vanishing break-up cross-section at high energies ? [A. Capella *et al.*, arXiv:0712.4331]

- ...

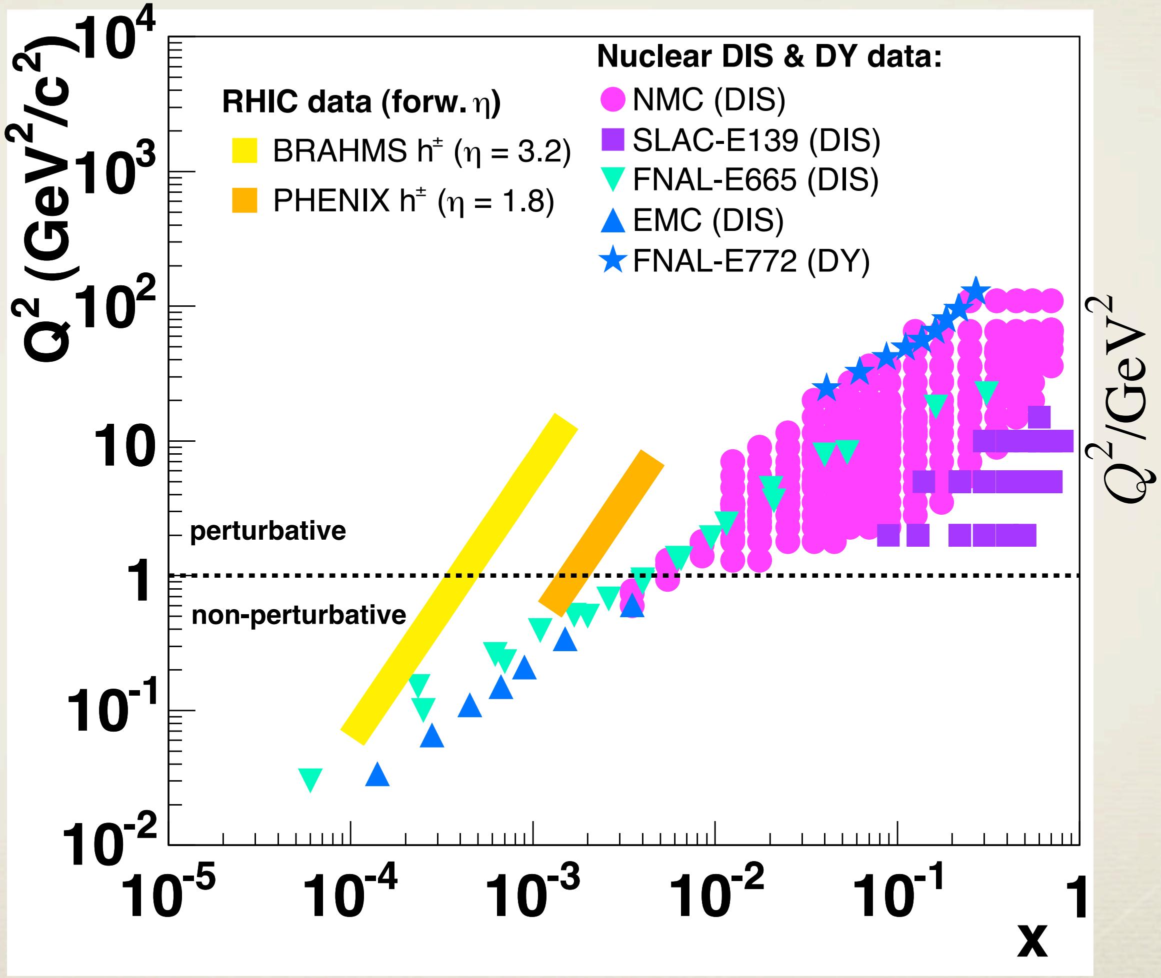
Outlook

- High statistics (> 30×Run3) dAu from RHIC Run8
- Shadowing in AA as predicted by our Monte-Carlo
- Recent (x, Q^2) parametrisations of nPDF/A×PDF
  - NLO [de Florian & Sassot, Phys. Rev. D69:074028]
  - updated constrains on low-x gluon PDF from RHIC data [Eskola, Paukkunen & Salgado, arXiv:0802.0139]
- Use a better way to relate (y, p_T) to (x_1, x_2)
  - from $g + g \rightarrow J/\psi + g$ cross-section computation [Haberzettl & Lansberg, PRL 100, 032006 (2008)]
  - allows to free the MC from any pp data input

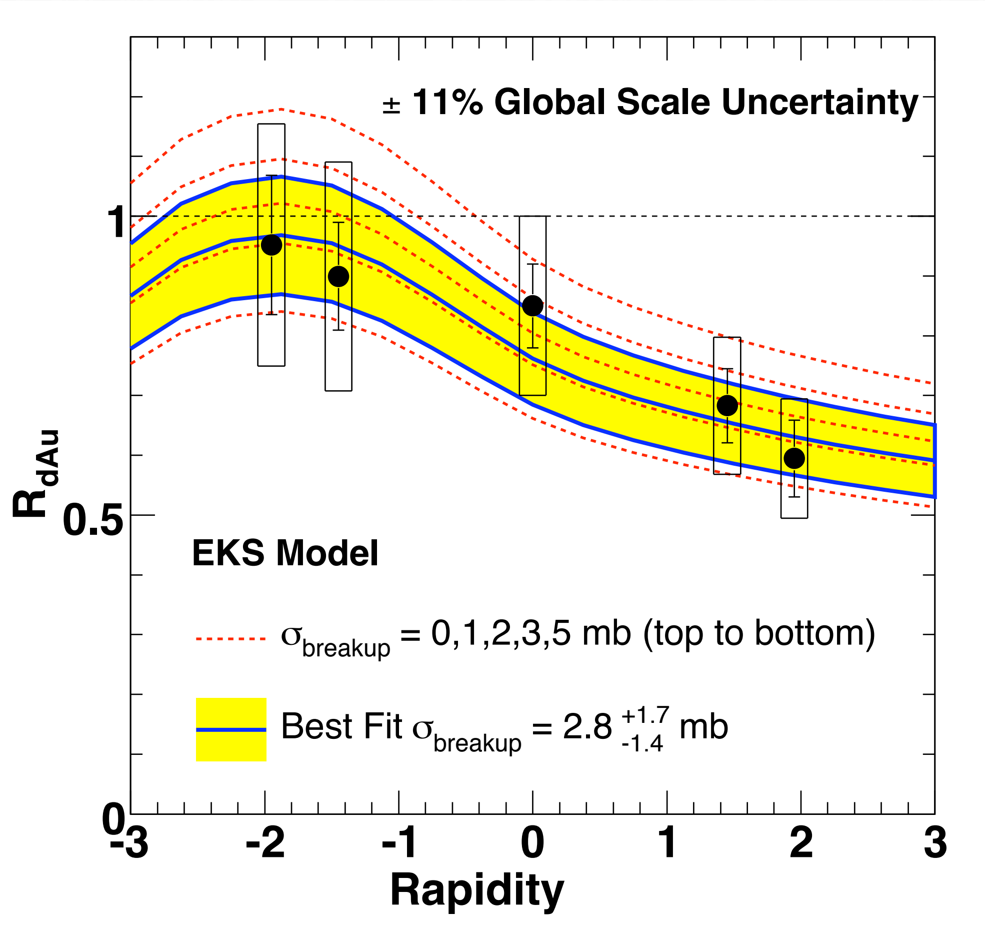
    ➡ predictions at LHC energies

Back-up

Range in x, Q^2 covered by the available data



Constraints on the CNM effects (I)



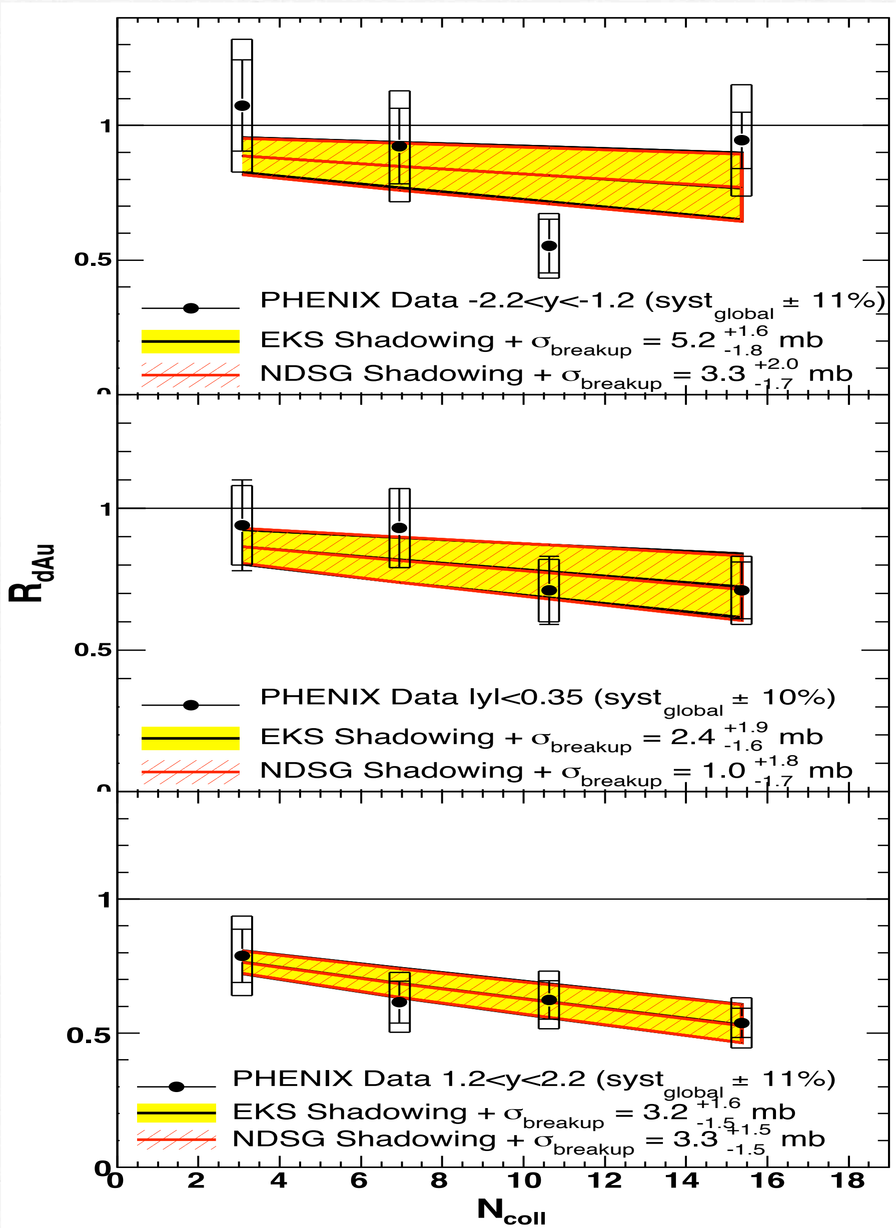
Bar = pt-to-pt uncorrelated err. (stat. + syst.)
Box = pt-to-pt correlated err. (syst.)
Global err. = quoted on the fig.

CNM effects =
shadowing (EKS) + $\boldsymbol{\sigma}_{cc\ \text{break-up}}$

<u>R_{dAu} vs y</u>

- ☐ Best fit : $\sigma_{breakup} = 2.8^{+1.7}_{-1.4}$ mb
- ☑ large uncertainties
- ☑ consistent with lower energy value at CERN-SPS 4.2±0.5 mb

Constraints on the CNM effects (II)



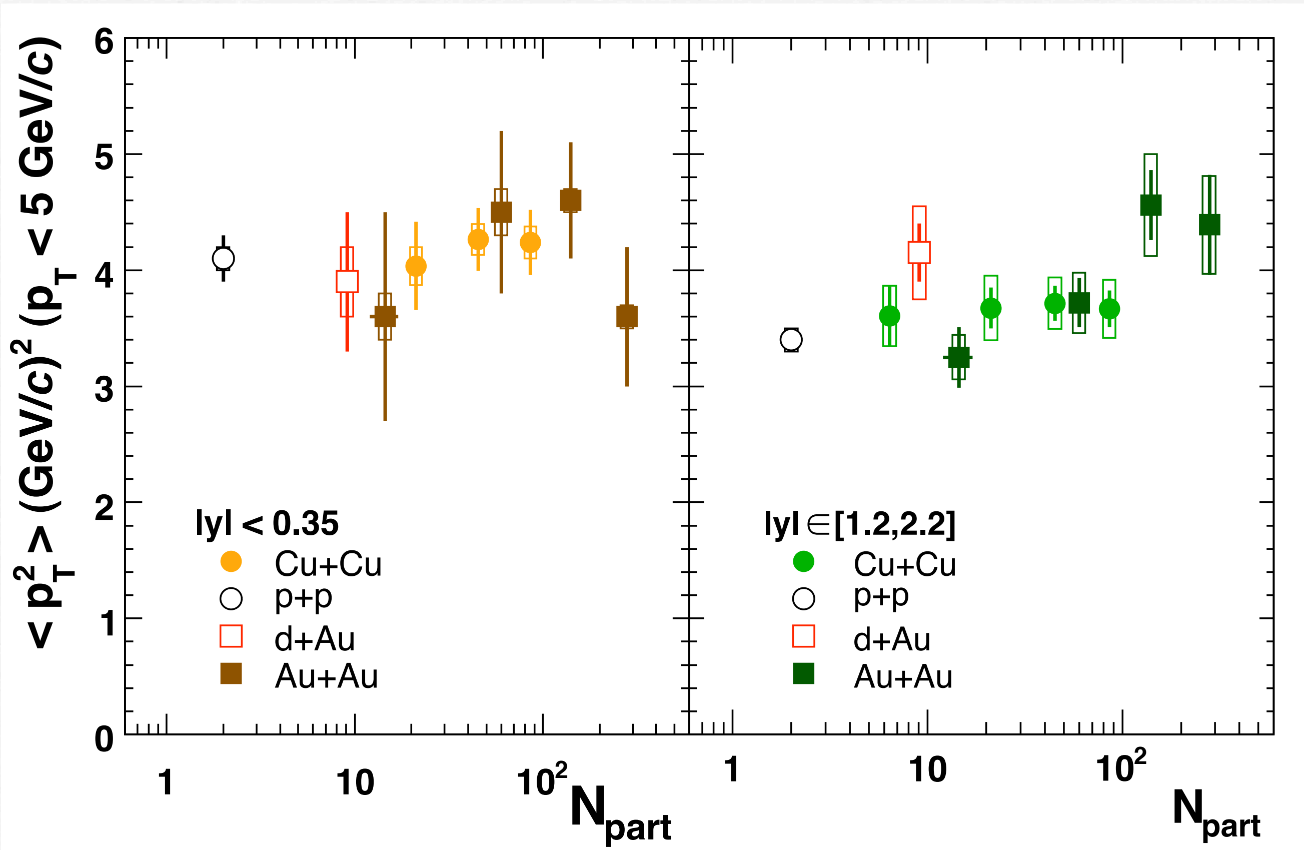
CNM effects =

shadowing (EKS) + $\sigma_{cc\ break\text{-}up}$

R_{dAu} vs N_{coll}

- ☐ constraints the geometric parametrization of the nPDF wrt the location of the parton in the nucleus
- ☐ $\sigma_{cc\ break\text{-}up}$:
  - ☑ large uncertainties
  - ☑ different values obtained
  - ☑ consistent with the value from R_{dAu} vs y

The p_T-broadening picture



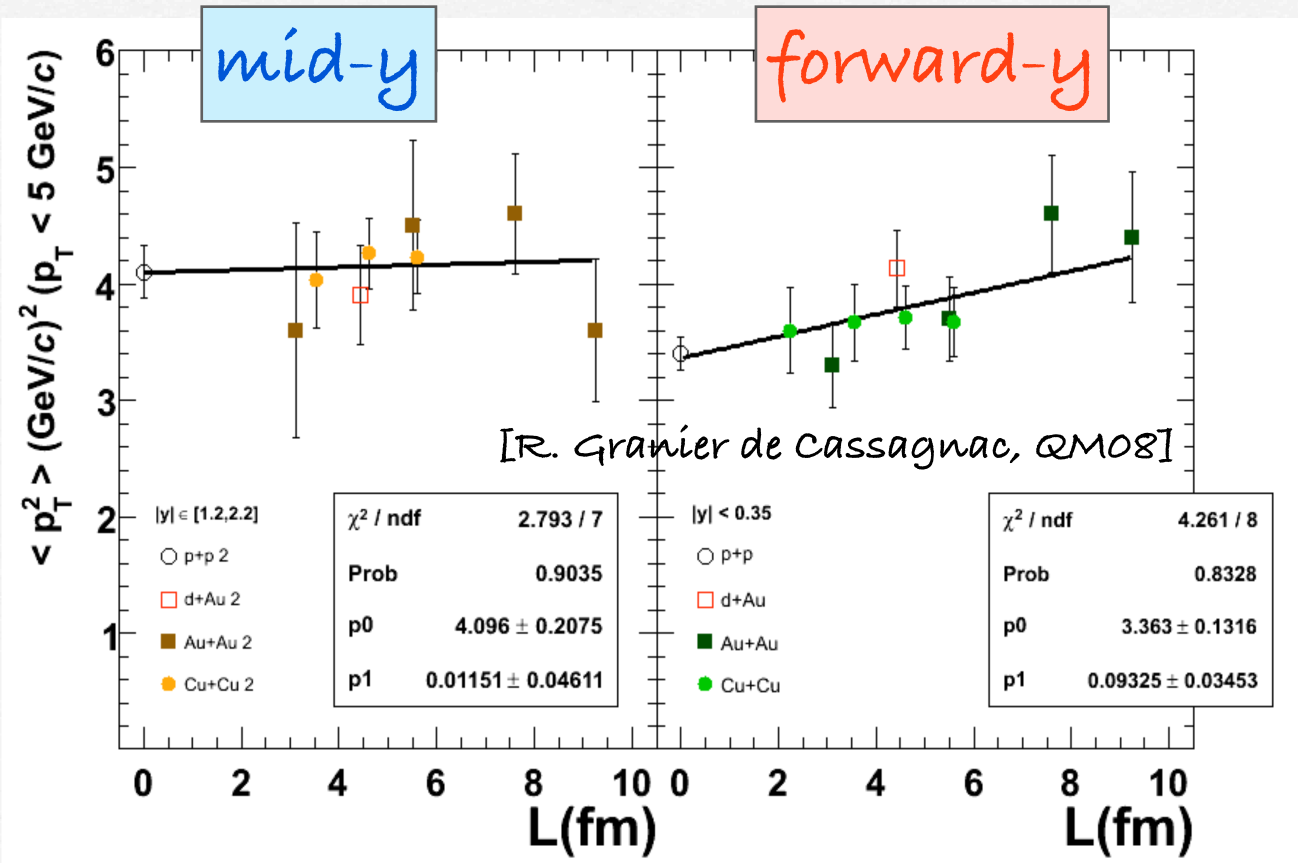
$<p_T^2>$ vs N_{part}

- ☐ flat or moderate broadening
- ☐ if brodened, what origin(s) ?
  - cold effect (shadowing, Cronin)
  - hot effect (recombination)

Bar = pt-to-pt uncorrelated err. (stat. + syst.)

Box = pt-to-pt correlated err. (syst.)

p_T-broadening due to random walk ?



$$\langle p_T^2 \rangle_{AA} = \underbrace{\langle p_T^2 \rangle_{pp}}_{p0} + \underbrace{\rho_0\, \sigma_{g-\mathrm{N}}\, \Delta p_T^2}_{p1} \times \mathrm{L}_{AA}$$

$<p_T^2>$ vs L

- random walk of the initial gluons in the transverse plane
- at mid-y : slope compatible with zero
  $p1 = 0.011 \pm 0.046$
- at forward-y :
  $p1 = 0.093 \pm 0.034$
  compatible with mid-y