Cold Nuclear Matter effects at RHIC

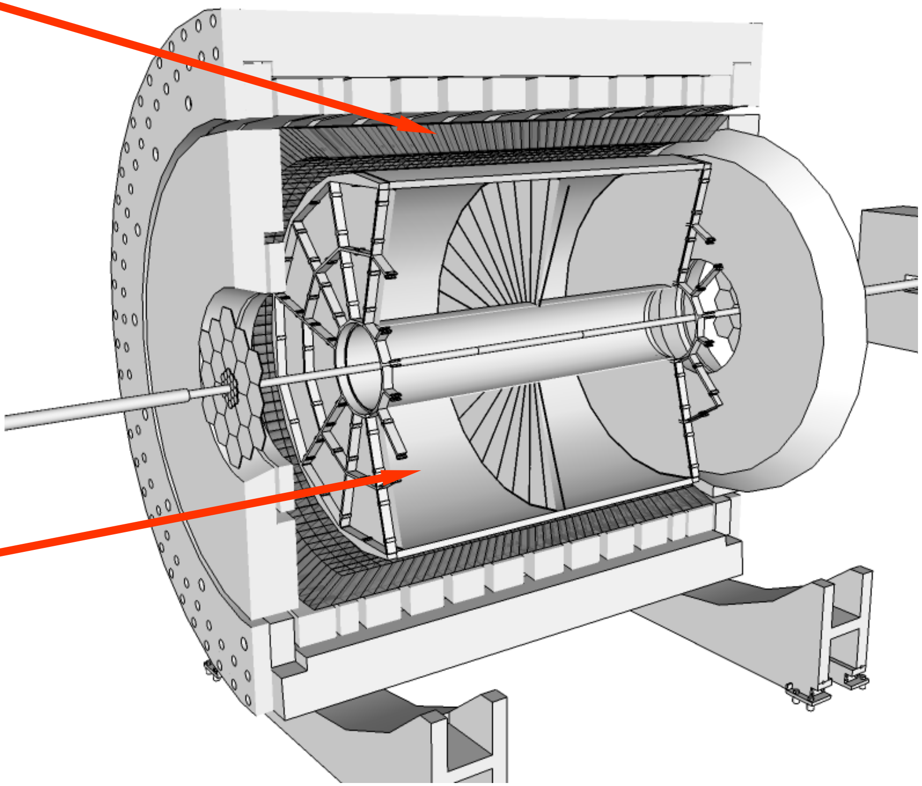
Data samples

$\Upsilon$and J/Ψ results

Results against CNM predictions

Phenix empirical approach

STAR & PHENIX



BEMC

$|\eta| < 1$

$0 < \phi < 2\pi$

E/p → electron ID

High-energy tower trigger (p_T>3GeV)

TPC

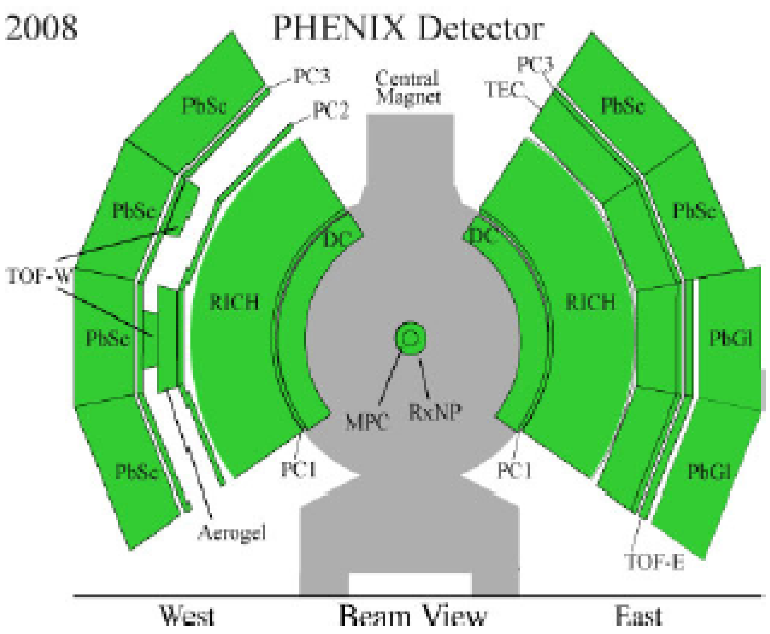
$|\eta| < 1$

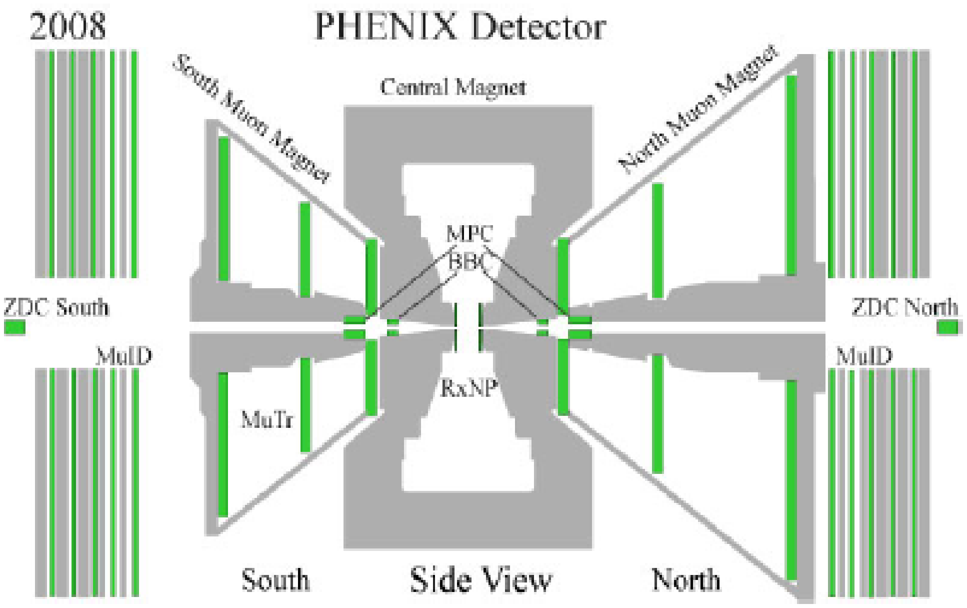
$0 < \phi < 2\pi$

Tracking → momentum

ionization energy loss → electron ID

STAR & PHENIX





$D, B \rightarrow e^{\pm}$

$J/\psi \rightarrow e^+e^-$

$-0.35 < y < 0.35$

$\Delta\Phi = \pi$

$D, B \rightarrow \mu^{\pm}$

$J/\psi \rightarrow \mu+\mu^-$

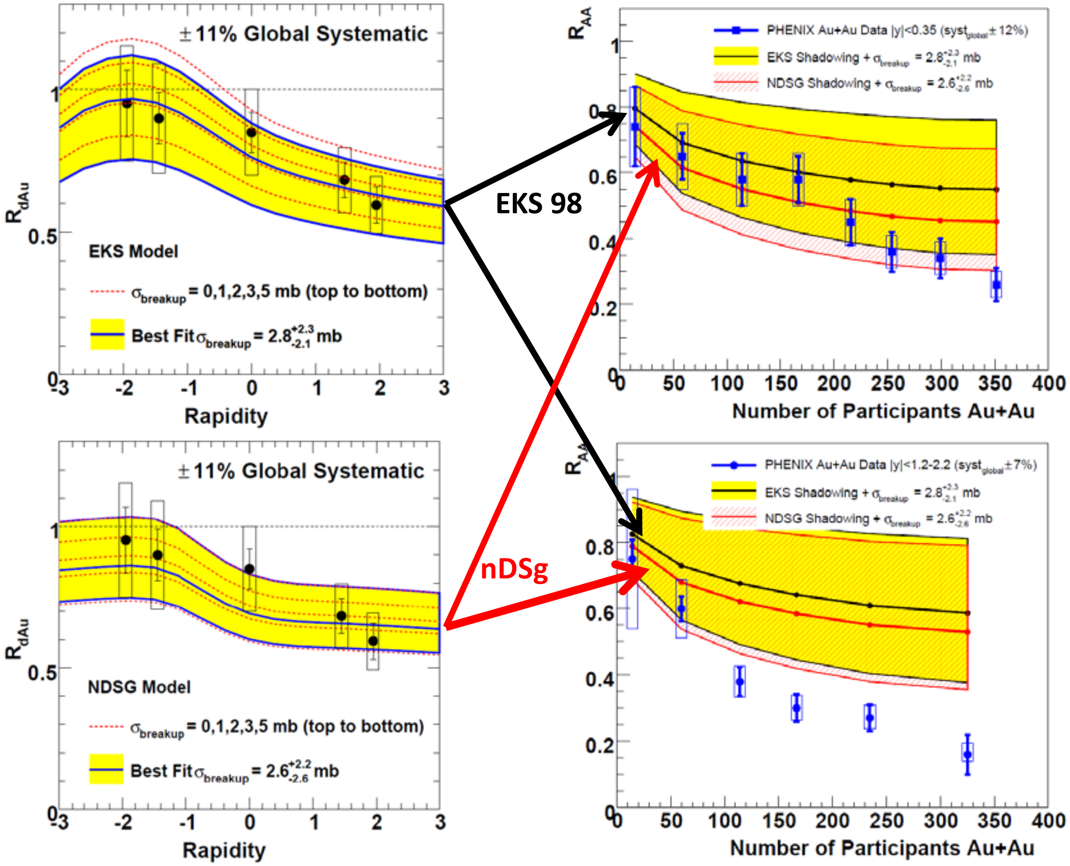
$1.2<|y|<2.2$

$\Delta\Phi = 2\pi$

Data : 1st d+Au run in 2003

Extrapolation from d+Au to Au+Au for J/Ψ
mandatory to measure HDM effects

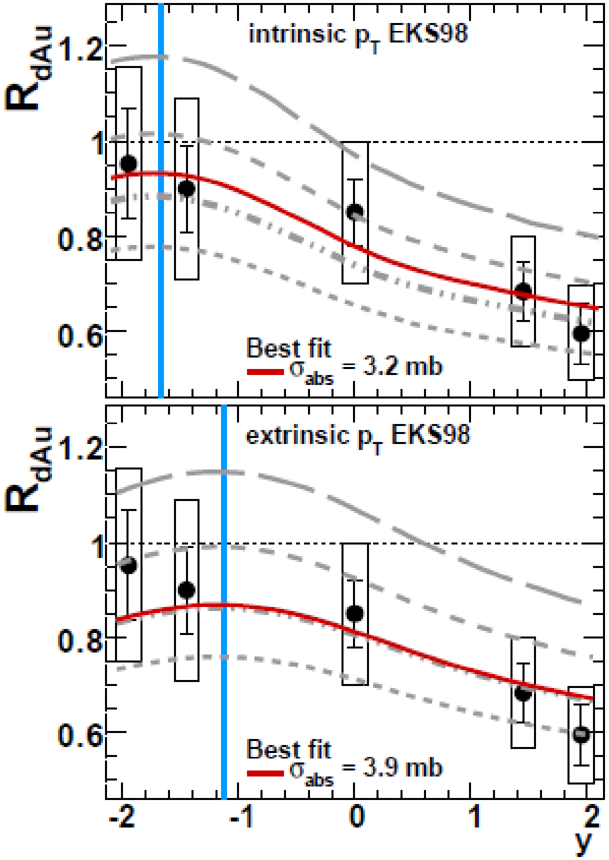
Phys. Rev. C 77, 024912



➔ Need better precision on d+Au

Effect of the J/Ψ production mecanism
Extrinsic pT (2→2) .vs. Intrinsic (2→1)

Phys. Rev. C 81, 064911

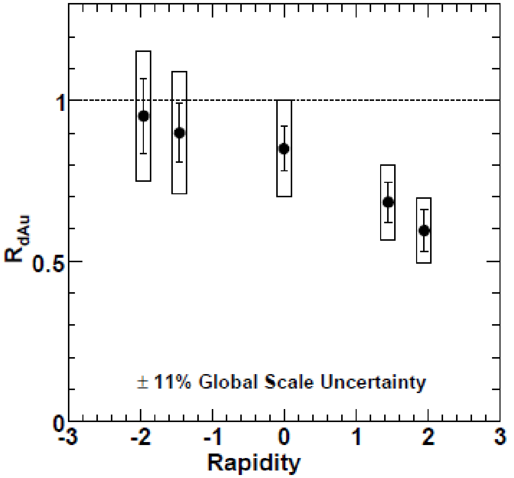


➔ Need better precision on d+Au

Data : New d+Au run in 2008

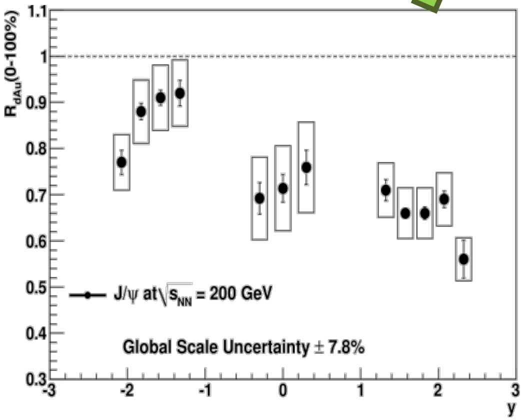
- PHENIX example

~30 times larger statistic in 2008 .vs. 2003



PHENIX run 3

better precision for J/Ψ
first measurement of Υ

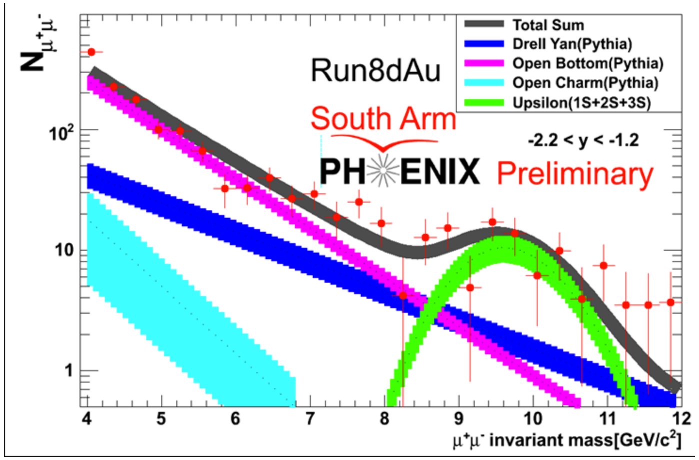


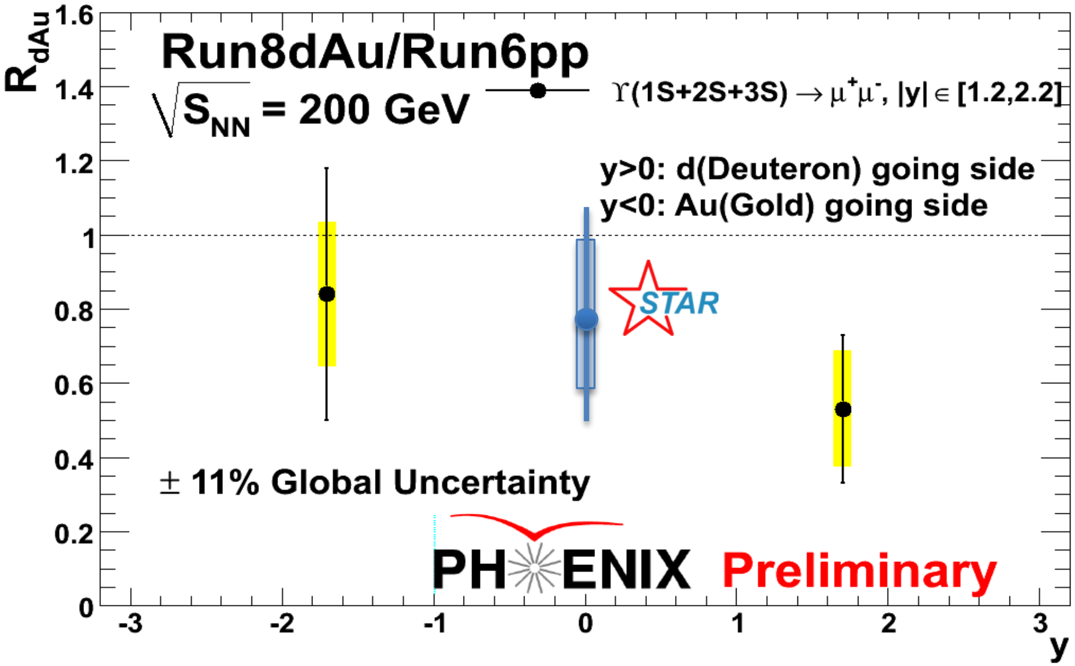
PHENIX run 8

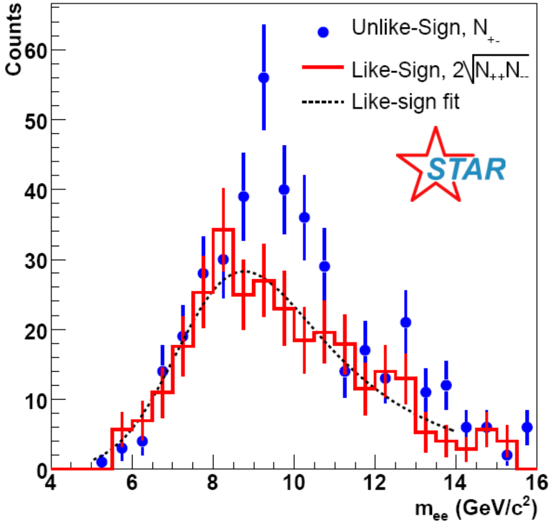
Campagne	Espèces	Énergie (GeV)	Luminosité intégrée (Phenix)
2000/2001	Au+Au	130	1,0 μb^{-1}
2001/2002	Au+Au p+p	200 200	24,0 μb^{-1} 0,15 pb^{-1}
2002/2003	**d+Au** p+p	**200** 200	**2,74 nb^{-1}** 0,35 pb^{-1}
2003/2004	Au+Au Au+Au	200 62	241 μb^{-1} 9 μb^{-1}
2004/2005	Cu+Cu Cu+Cu Cu+Cu p+p	200 62 22.5 200	3 nb^{-1} 0,19 nb^{-1} 2,70 μb^{-1} 3,80 pb^{-1}
2005/2006	p+p p+p	200 62	10,7 pb^{-1} 0,1 pb^{-1}
2006/2007	Au+Au	200	810 μb^{-1}
2007/2008	**d+Au** p+p	**200** 200	**80 nb^{-1}** 5,2 pb^{-1}
2008/2009	p+p p+p	200 500	8,6 pb^{-1} 13 pb^{-1}
2009/2010	Au+Au Au+Au Au+Au Au+Au	200 62 39 7,7	1,3 nb^{-1} 0,11 nb^{-1} 40 μb^{-1} 0,26 μb^{-1}

Υ : first measurement in d+Au

- Made by both STAR and PHENIX (run 2008)



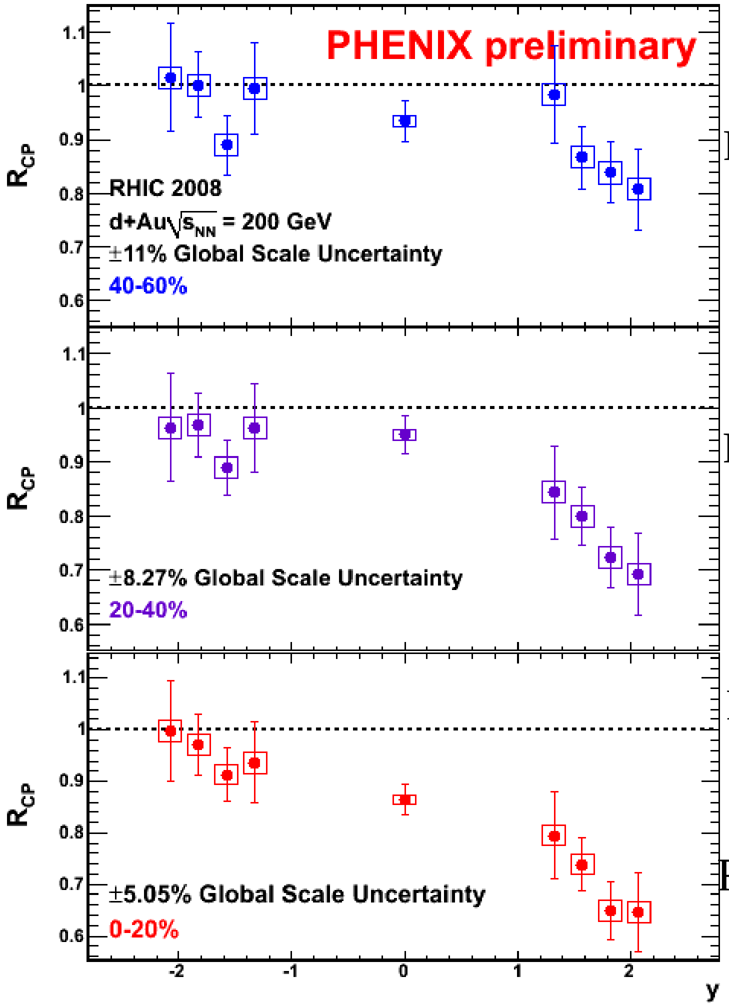




See Nicolas's talk for CNM effect discussion

J/Ψ measurement in dAu 2008

- PHENIX : R_{dAu} and R_{CP}



Most peripheral

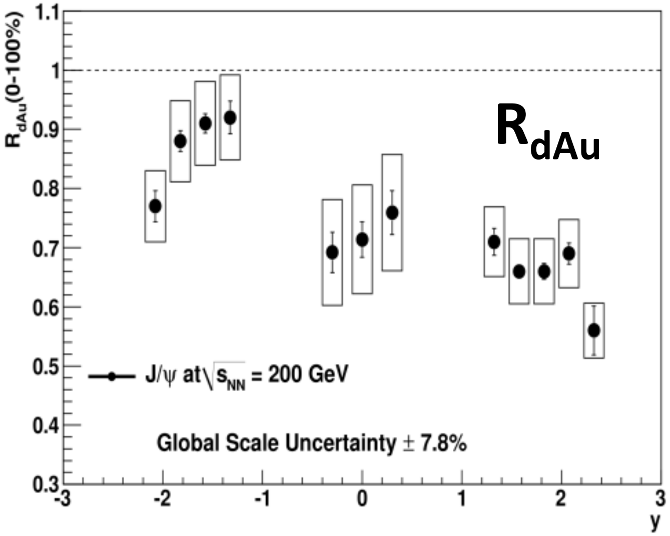
$$R_{CP} = \frac{(40-60)\%}{(60-88)\%}$$

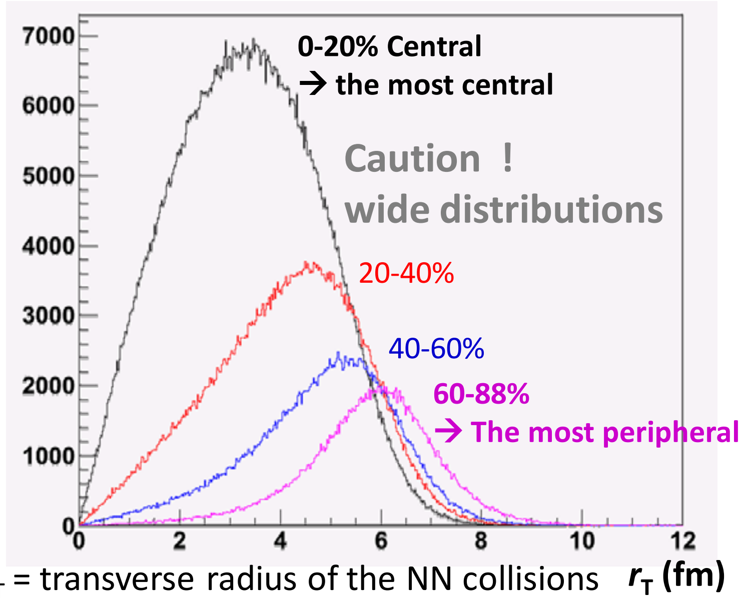
$$R_{CP} = \frac{(20-40)\%}{(60-88)\%}$$

$$R_{CP} = \frac{(0-20)\%}{(60-88)\%}$$

Most central

$$R_{CP} = \frac{\text{central}}{\text{peripheral}}$$



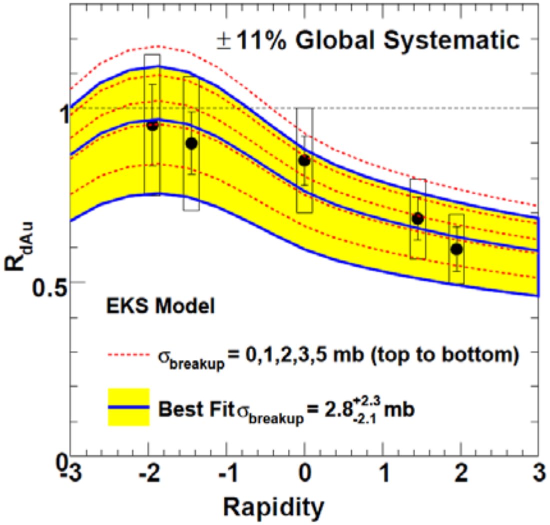


r_T = transverse radius of the NN collisions wrt the center of the Au nucleus

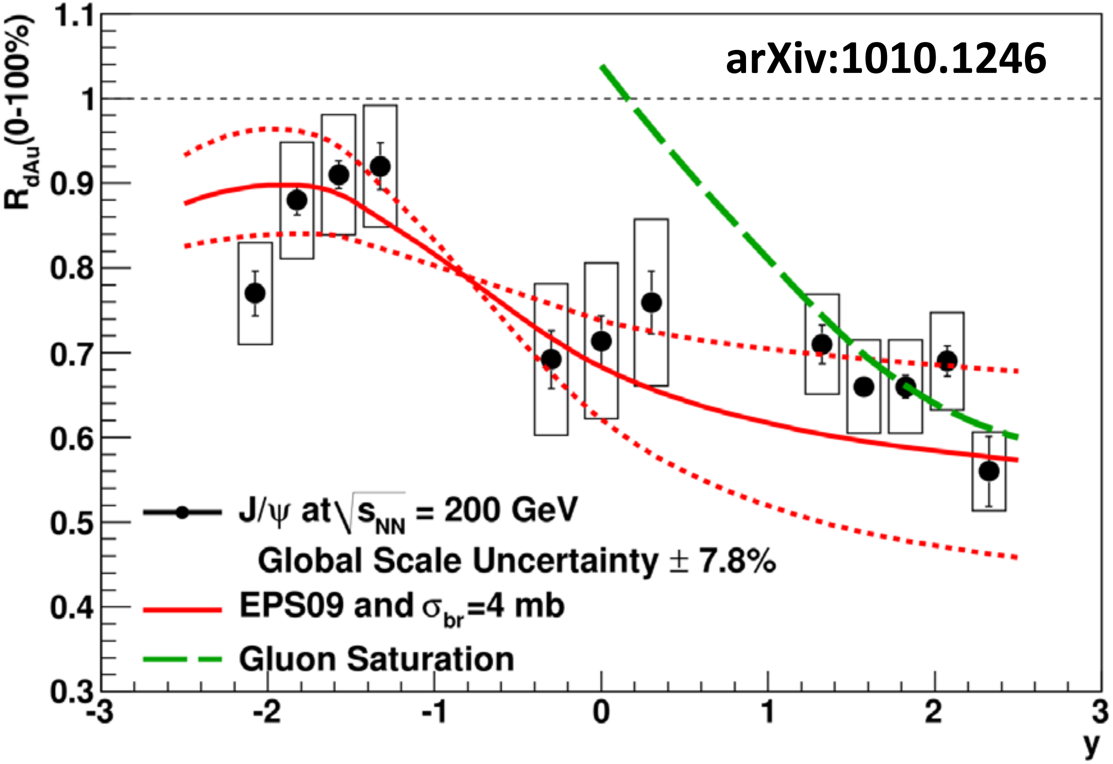
CNM measurement

- PHENIX : R_{dAu}

2003 data



2008 data



Production mecanism = intrinsic p_T : R. Vogt, Phys. Rev. C71, 054902 (2005)

Gluon saturation : D. Kharzeev and K. Tuchin, Nucl. Phys. A735, 248 (2004)

arXiv : 1010.1246

« find a reasonable agreement within uncertainties with the unbiased R_{dAu} data »

Intrinsic p_T → reasonable agreement

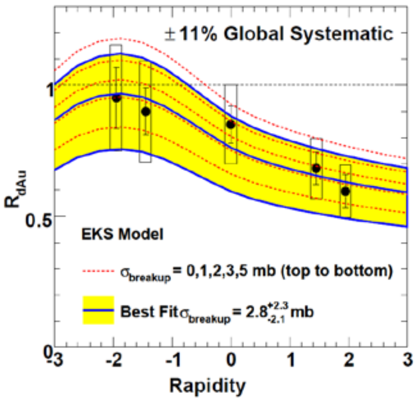
Gluon saturation miss mid y

CNM measurement

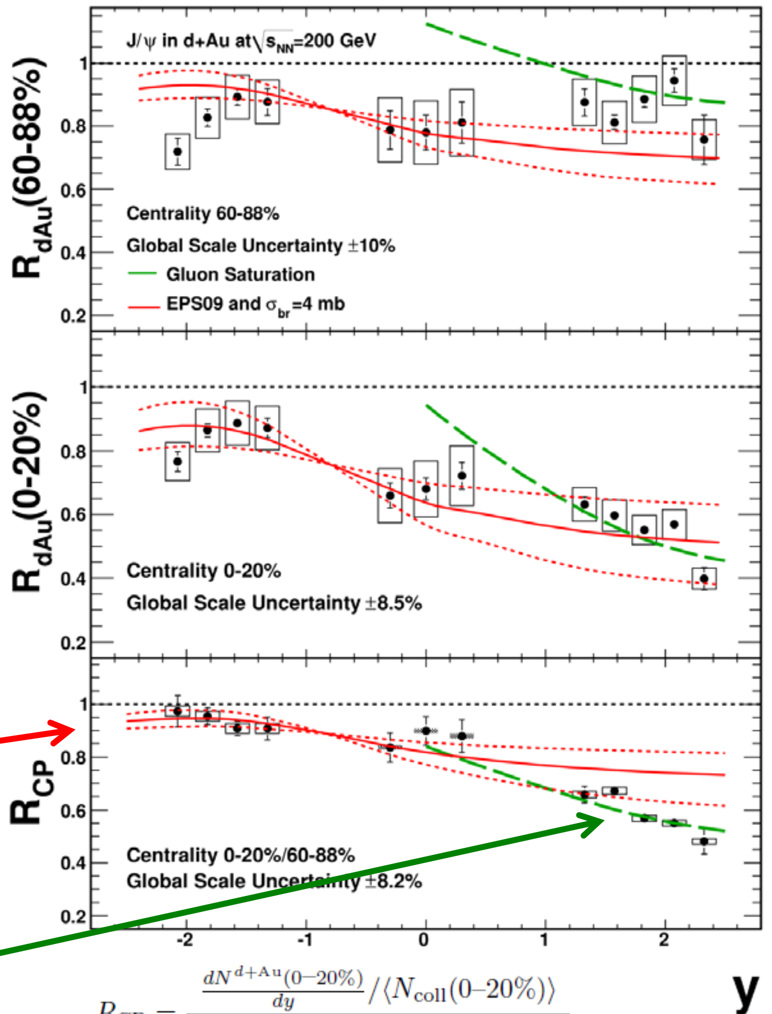
- PHENIX : R_{CP}

$$R_{CP} = \frac{\text{central}}{\text{peripheral}}$$

2003 data



2008 data



$$R_{CP} = \frac{\frac{dN^{d+Au}(0\text{–}20\%)}{dy} / \langle N_{coll}(0\text{–}20\%)\rangle}{\frac{dN^{d+Au}(60\text{–}88\%)}{dy} / \langle N_{coll}(60\text{–}88\%)\rangle}$$

R_{CP} has the advantage of cancelling most of the systematic uncertainties.

Intrinsic p_T + EPS09

- R_{dAu} ➔ « reasonable agreement »
- R_{CP} ➔ miss forward rapidity

Gluon saturation :

- R_{dAu} ➔ miss mid rapidity
- R_{CP} ➔ « reasonable agreement »

CNM measurement

- About Extrinsic p_T ?

(See Nicolas’s talk)

Intrinsic p_T : (2→1) + EPS09

- R_{dAu} → « reasonable agreement »
- R_{CP} → miss forward rapidity

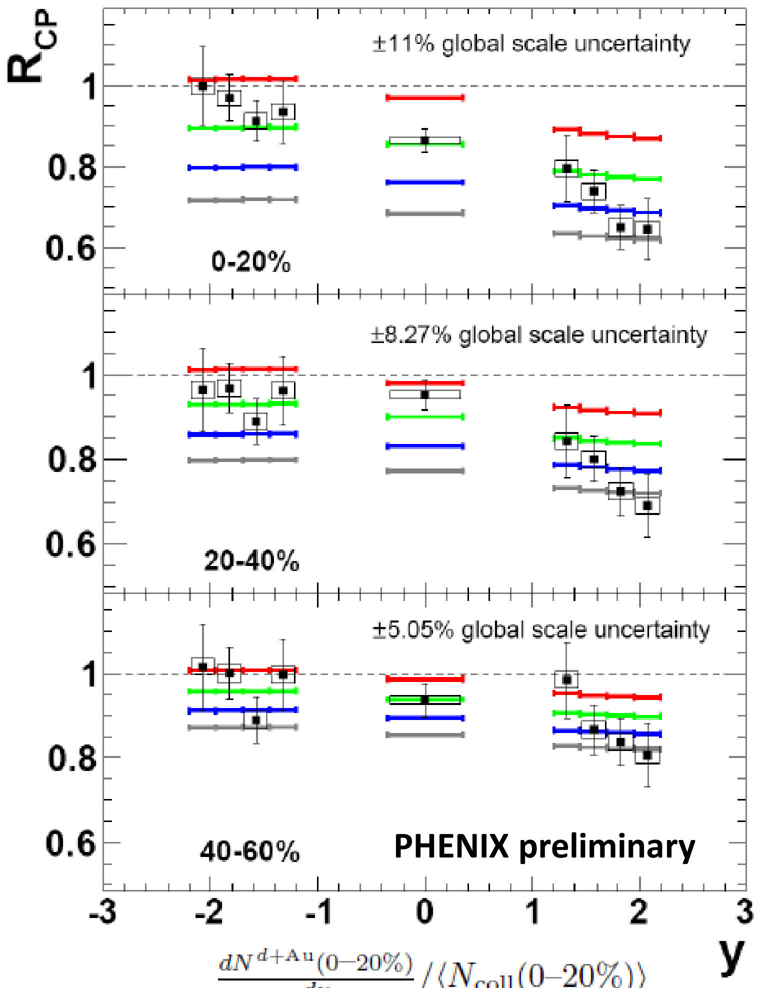
Gluon saturation :

- R_{dAu} → miss mid rapidity
- R_{CP} → « reasonable agreement »

Extrinsic p_T : (2→2) + EKS98

- R_{CP} → better agreement than intrinsic (and saturation)
  → still missing very forward y

σ_{abs} = 0, 2, 4, 6 mb



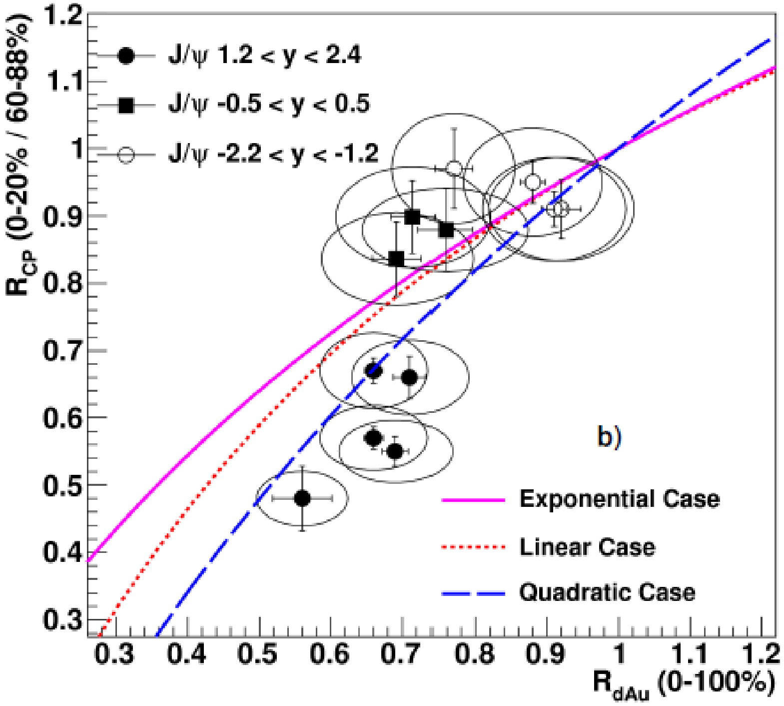
$$R_{CP} = \frac{\frac{dN^{d+Au}(0\text{–}20\%)}{dy} / \langle N_{coll}(0\text{–}20\%)\rangle}{\frac{dN^{d+Au}(60\text{–}88\%)}{dy} / \langle N_{coll}(60\text{–}88\%)\rangle}$$

Phenix Empirical approach

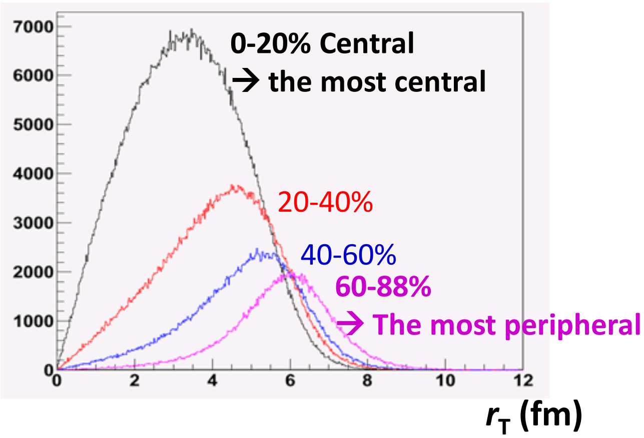
- Phenix ArXiv:1010.1246
- goal : explore the centrality and rapidity dependence of the nuclear effects

$$R_{pA} = \frac{\sigma_{pA}}{\langle N_{coll} \rangle \sigma_{pp}}$$

$$R_{pA} = \frac{\sigma_{\text{p in vacuum} + \text{N in A}}}{\sigma_{\text{p in vacuum} + \text{p in vacuum}}} \equiv \frac{\sigma_{\text{pp in A}}}{\sigma_{\text{pp in vacuum}}}$$



As a function of centrality in d+Au : given r_T = transverse radius of the NN collisions wrt the center of Au nucleus



Empirical parametrization of CNM: $R_{dAu}(r_T) = M(r_T)$

- linear → inhomogenous shadowing
- exponential → absorption
- Quadratic → energy loss

How it works : inhomogenous shadowing →

Shadowing

- Homogenous shadowing

– Starting point

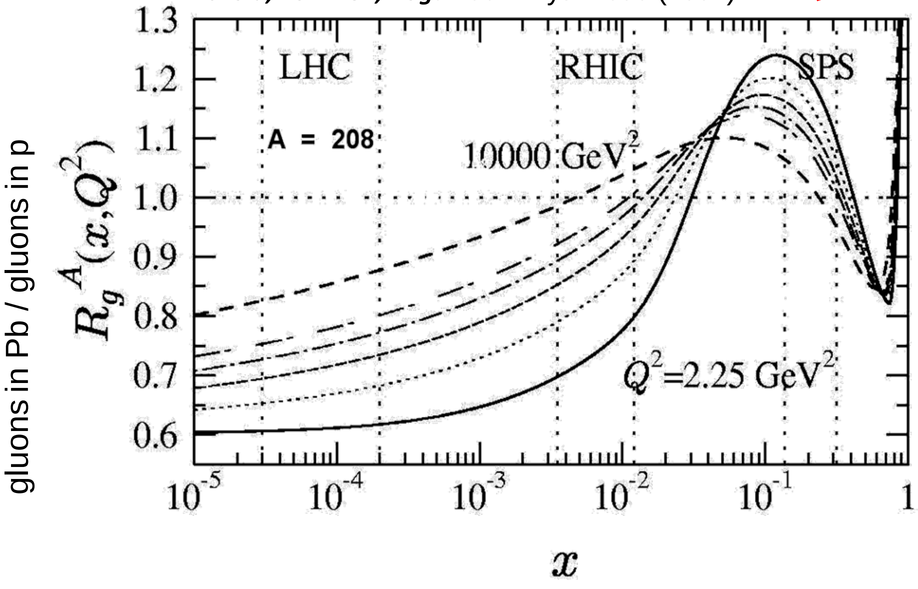
- Shadowing parametrizations are given as a function of x, Q^2 and A
- All integrated in b (impact parameter)
  - no spatial dependence available
  - **not possible to study shadowing as a function of centrality**

– Idea

- Proposed by R. Vogt and S.R. Klein (2003)
- See Phys. Rev. Lett. 91 142301 (2003)
- « we discuss how the shadowing and its spatial dependence may be measured … We find that inhomogenous shadowing has a significant effect on central dA collisions »

$$\sigma_{J/\Psi}^{\text{pp in A}} = \sigma_{J/\Psi}^{\text{pp in vacuum}} \times \overbrace{R_g\left(x, Q^2, A\right)}^{\text{The shadowing part}}$$

Eskola, Kolhinen, Vogt Nucl. Phys. A696 (2001)

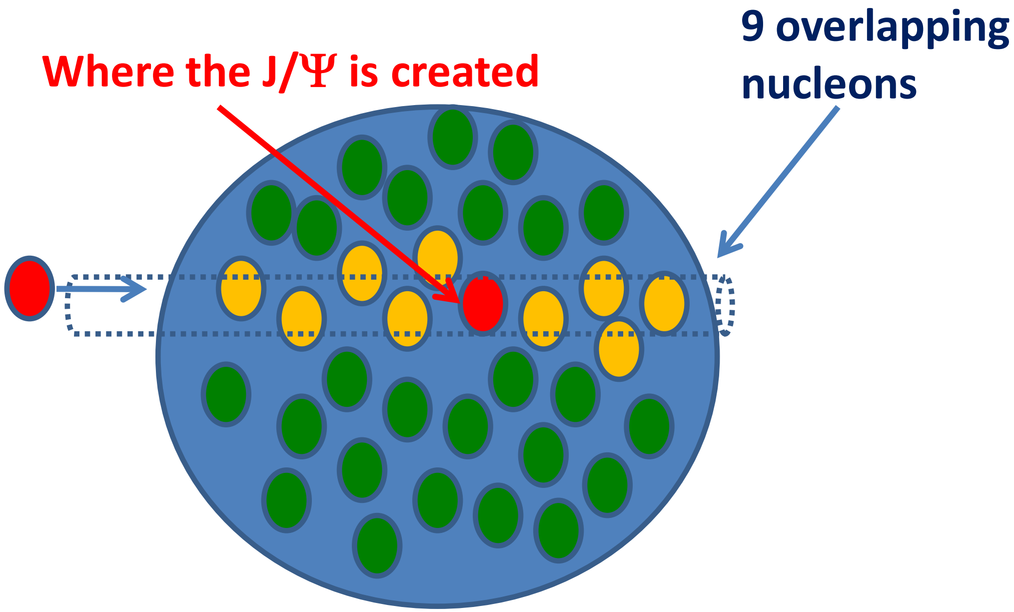


Inhomogenous shadowing

- Inhomogenous shadowing : (on MC basis)

$$\sigma_{J/\Psi}^{\text{pp in A}} = \sigma_{J/\Psi}^{\text{pp in vacuum}} \times \overbrace{\left(1+\left(\left(R_g\left(x,Q^2,A\right)-1\right)\times\frac{\text{number of overlapping nucleons}}{\left\langle\text{number of overlapping nucleons}\right\rangle}\right)\right)}^{\text{The shadowing part}}$$

PRL91:« the incident parton interacts coherently with all the target partons along its path length »



Inhomogenous shadowing

- Back to PHENIX arXiv:1010.1246

$$\sigma_{J/\Psi}^{\text{pp in A}} = \sigma_{J/\Psi}^{\text{pp in vacuum}} \times \left(1 + \left(\left(R_g\left(x, Q^2, A\right) - 1\right) \times \frac{\text{number of overlapping nucleons}}{\left\langle \text{number of overlapping nucleons} \right\rangle}\right)\right)$$

The density weighted longitudinal thickness

$$\Lambda\left(r_T\right) \equiv \frac{1}{\rho_0} \int dz\, \rho\left(z, r_T\right)$$

$$\sigma_{J/\Psi}^{\text{pp in A}} = \sigma_{J/\Psi}^{\text{pp in vacuum}} \times \left(1 + \left(\underbrace{\left(R_g\left(x, Q^2, A\right) - 1\right)}_{-a} \times \Lambda\left(r_T\right)\right)\right) \equiv \sigma_{J/\Psi}^{\text{pp in vacuum}} \times \left(1 - a\Lambda\left(r_T\right)\right)$$

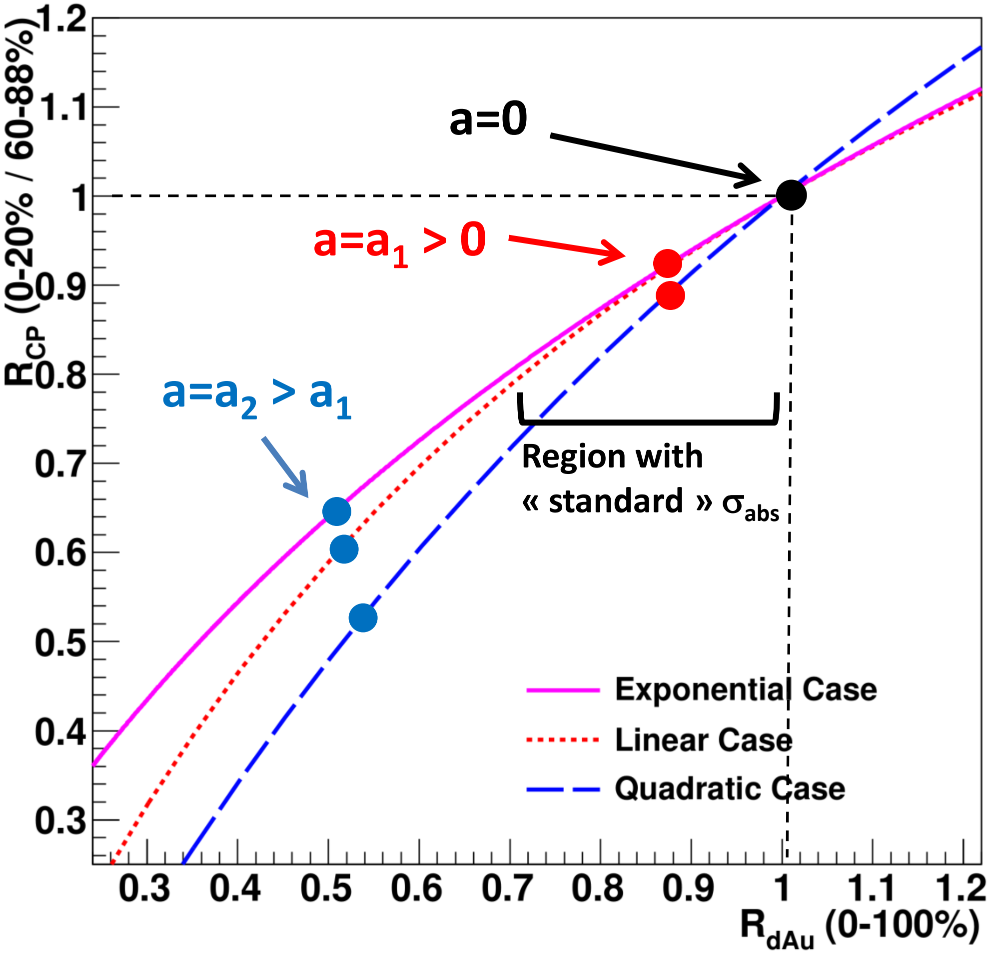
$$M\left(r_T\right) = 1.0 - a\Lambda\left(r_T\right)$$

Shadowing ➔ Linear dependence with longitudinal thickness

Phenix empirical approach

- Parametrizations

$$\sigma_{J/\Psi}^{\text{pp in A}} = \sigma_{J/\Psi}^{\text{pp in vacuum}} \times M(r_T)$$



linear $$\boxed{M(r_T) = 1.0 - a\Lambda(r_T)}$$

exponential $$\boxed{M(r_T) = e^{-a\Lambda(r_T)}}$$

quadratic $$\boxed{M(r_T) = 1.0 - a\Lambda(r_T)^2}$$

Note :

- *nuclear absorption is usually quoted as $e^{-\rho l \sigma}$*
  - *ρ = 0.17 nucleon/fm³*
  - *σ ~ 4 mb = 0.4 fm²*
  - *l = length of nuclear matter ~ few fm*

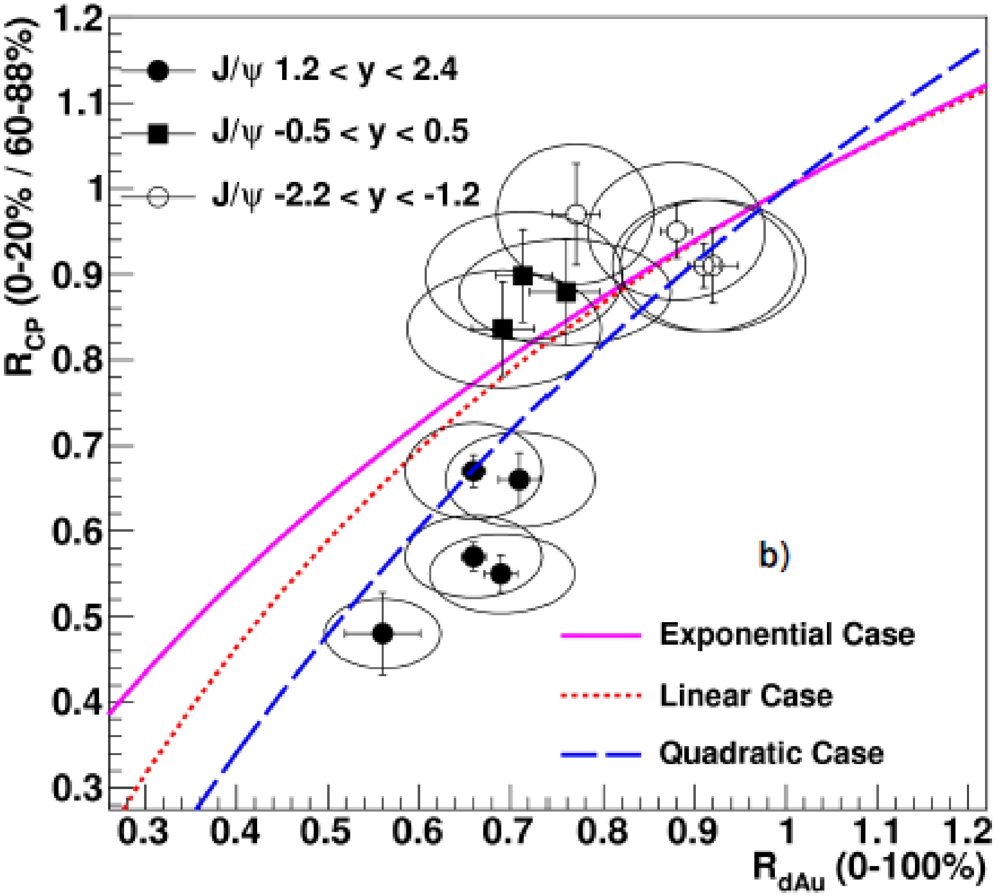
➔ *$\rho l \sigma$ is small*

Phenix empirical approach

- Parametrizations against data

Backward and mid-rapidity points agree within uncertainties for the three cases presented here.

Forward rapidity points require the suppression to be stronger than exponential or linear with the thickness.



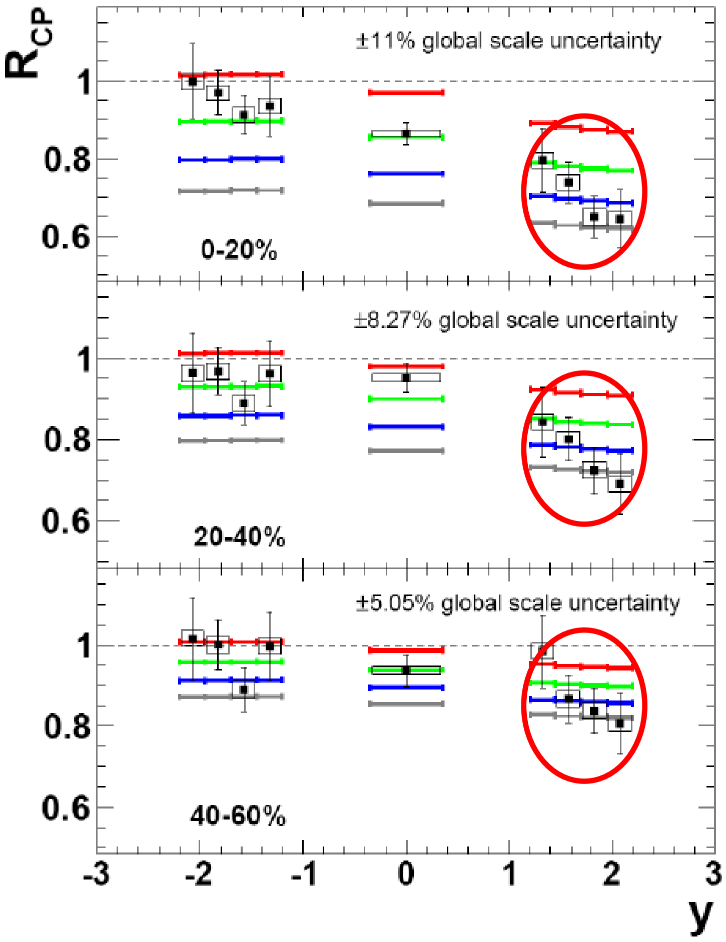
Some quadratic dependence in forward region ➔ energy loss ?

Cautious, this picture can be misleading

- backward rapidity → anti shadowing
  ➔ $a_{shadowing} < 0$
- need nuclear absorption to fit the data
  ➔ $a_{abs} > 0$

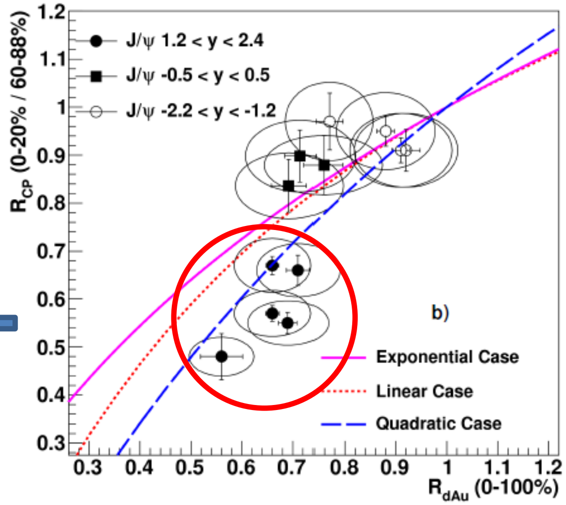
(in real life, effects should be added together)

Summary



Extrinsic p_T

- does fit the data well
- still missing very forward data



J/Ψ R_{CP} .vs. R_{dAu} :

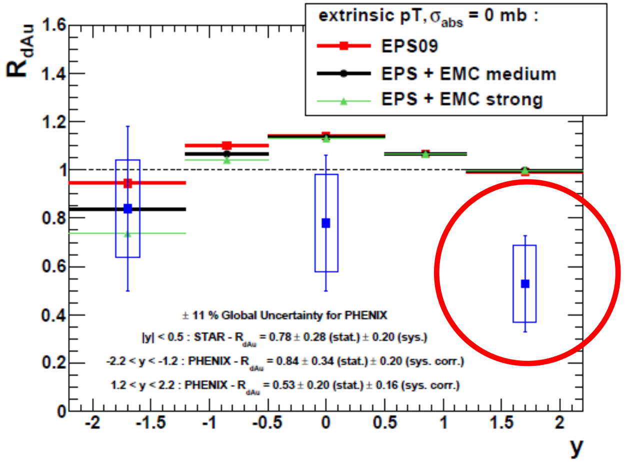
Quadratic dependence

For forward data

May want to add energy loss for both J/Ψ and Υ

Υ R_{dAu} : extrinsic p_T

Missing very forward data



Conclusion

- New data available
  - 30 times more statistic in run 2008 .vs. 2003
  - First R_{dAu} for Υ
  - High statistical sample for J/Ψ
- Results
  - Data may indicate some energy loss in forward rapidity region
  - Should come in the future :
    - J/Ψ R_{dAu}.vs.p_T
    - J/Ψ R_{dAu}.vs.N_{coll}