A d+Au data-driven prediction of cold nuclear matter (CNM) effects on J/ψ production in Au+Au collisions at RHIC

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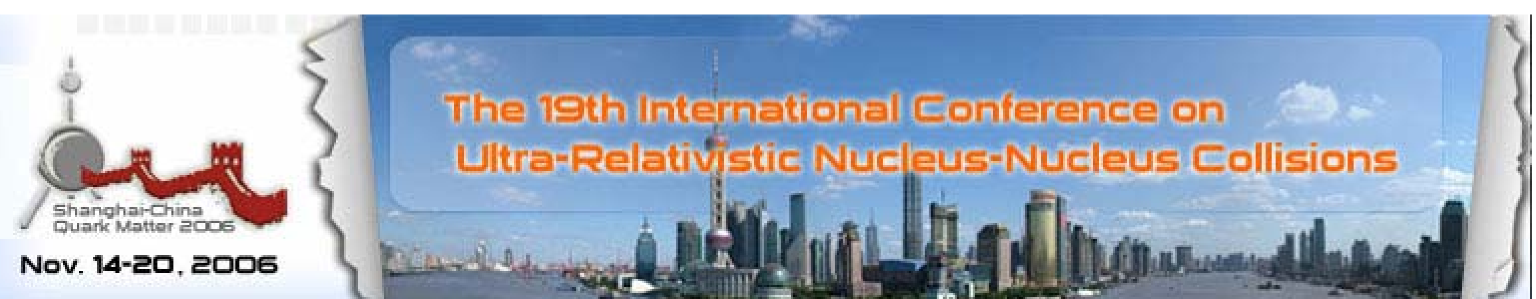
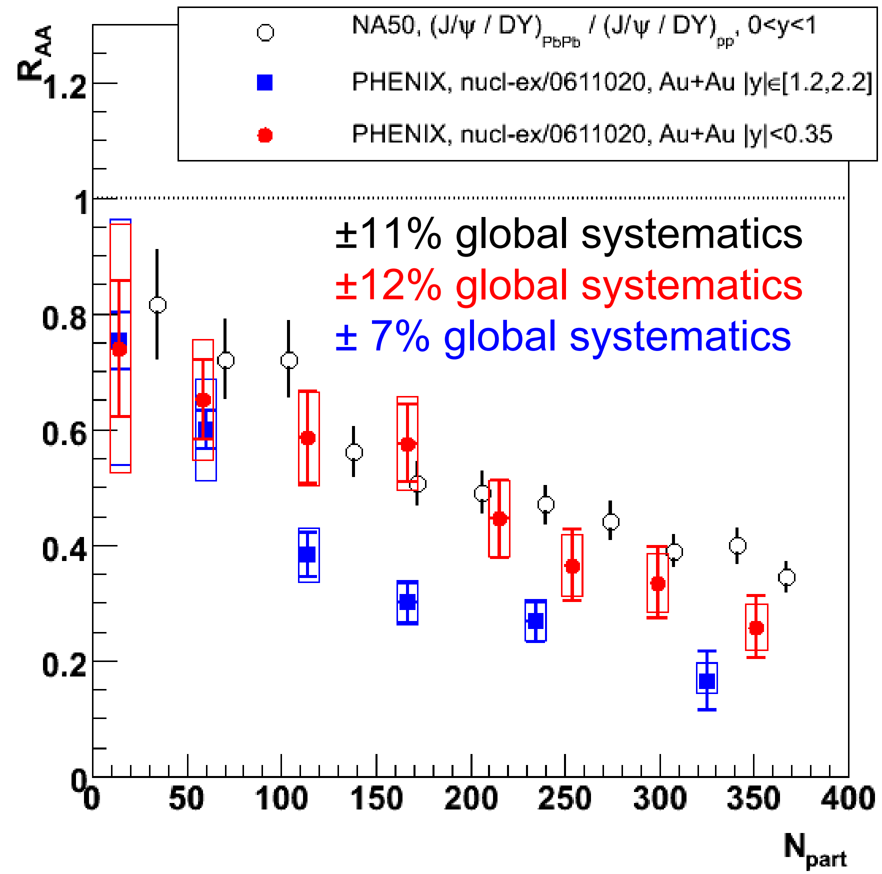
(thanks to Jean Gosset & Klaus Reygers)



Motivation & outline

- Subtracting cold nuclear matter (CNM) effects is crucial to interpret J/ψ suppression
  - How is it done @ SPS ?
  - How is it done @ RHIC ?
  - A new method for RHIC…

J/ψ nuclear modification factor

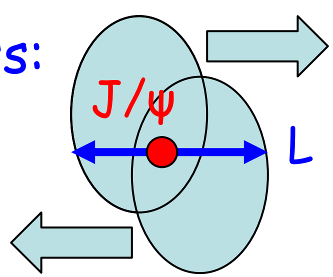


Cold nuclear matter @ SPS

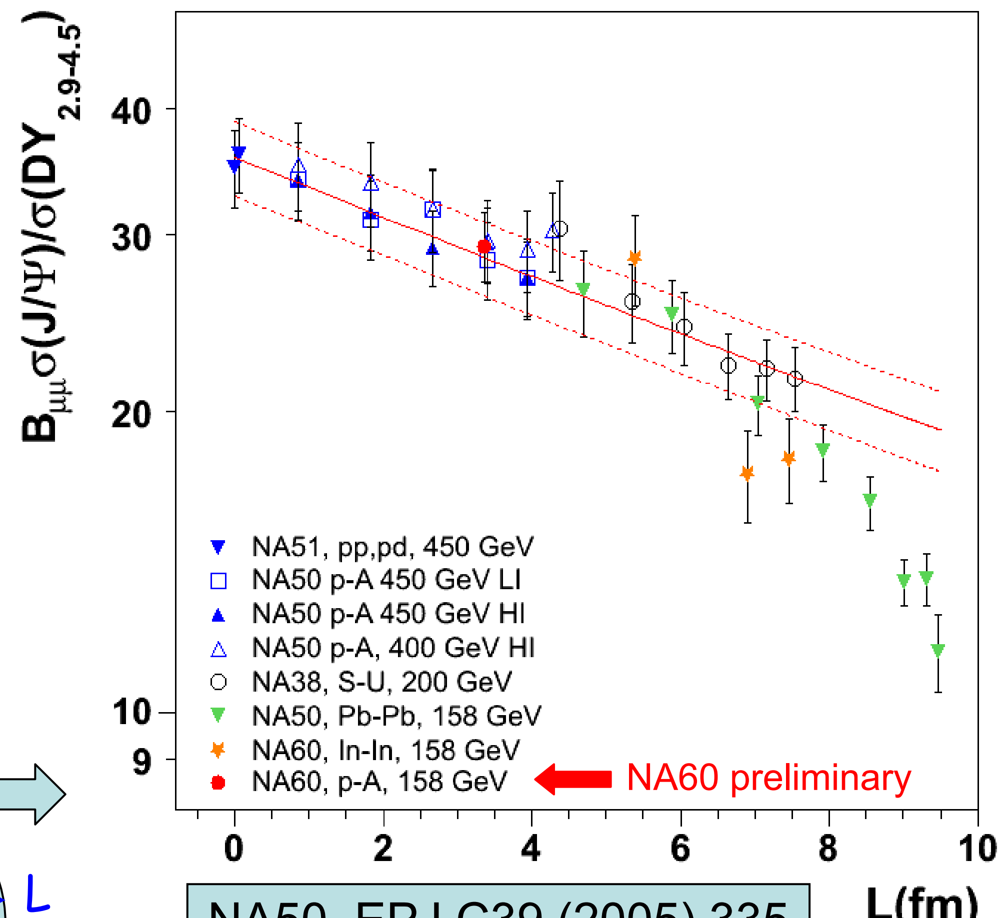
<u>Normal nuclear absorption alone</u> does a splendid job in describing pA, SU, and peripheral PbPb & InIn…

- (including preliminary pA @ 158 GeV from NA60)

- $\exp(-\sigma_{abs}\,\rho_0\,L)$
  - (or in Glauber model)
  - σ_{abs} = 4,18 ± 0,35 mb
  - L nuclear thickness:



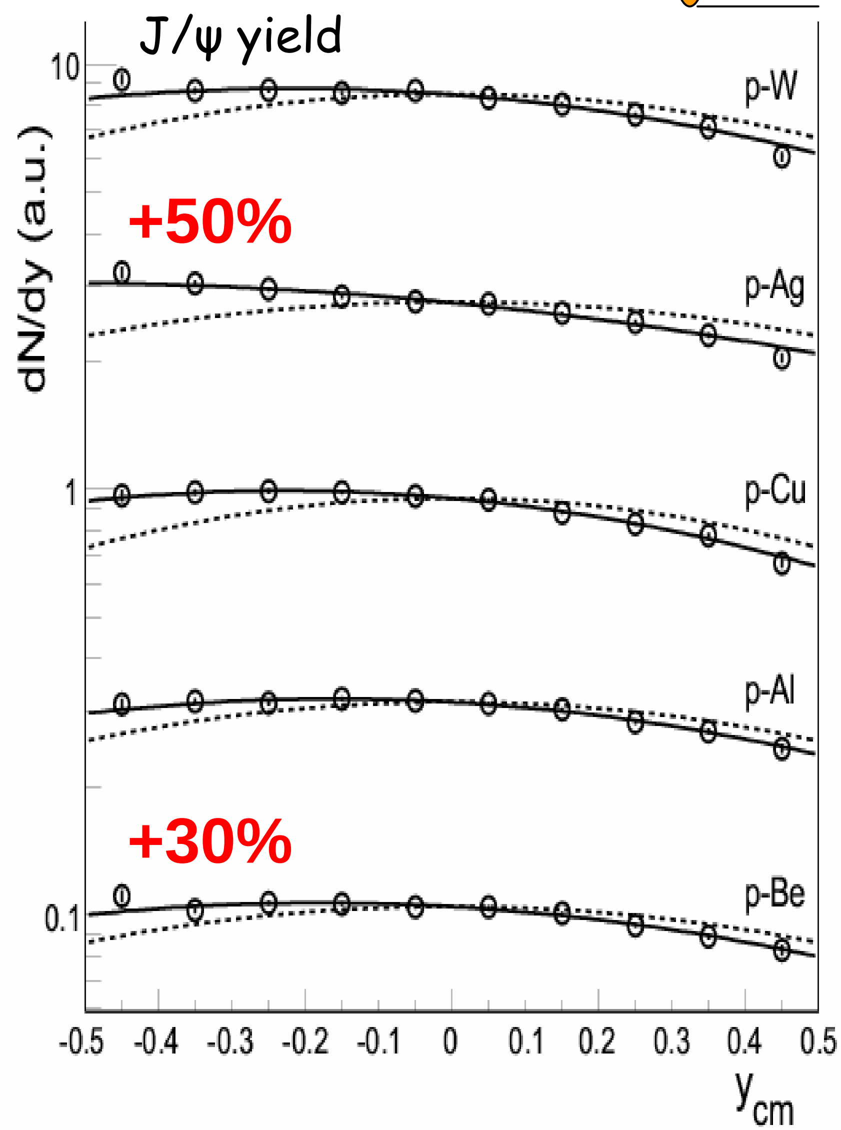
J/ψ / DY rescaled to 158 GeV



NA50, EPJ C39 (2005) 335
& E. Scomparin's talk

(Anti) shadowing @ SPS ?

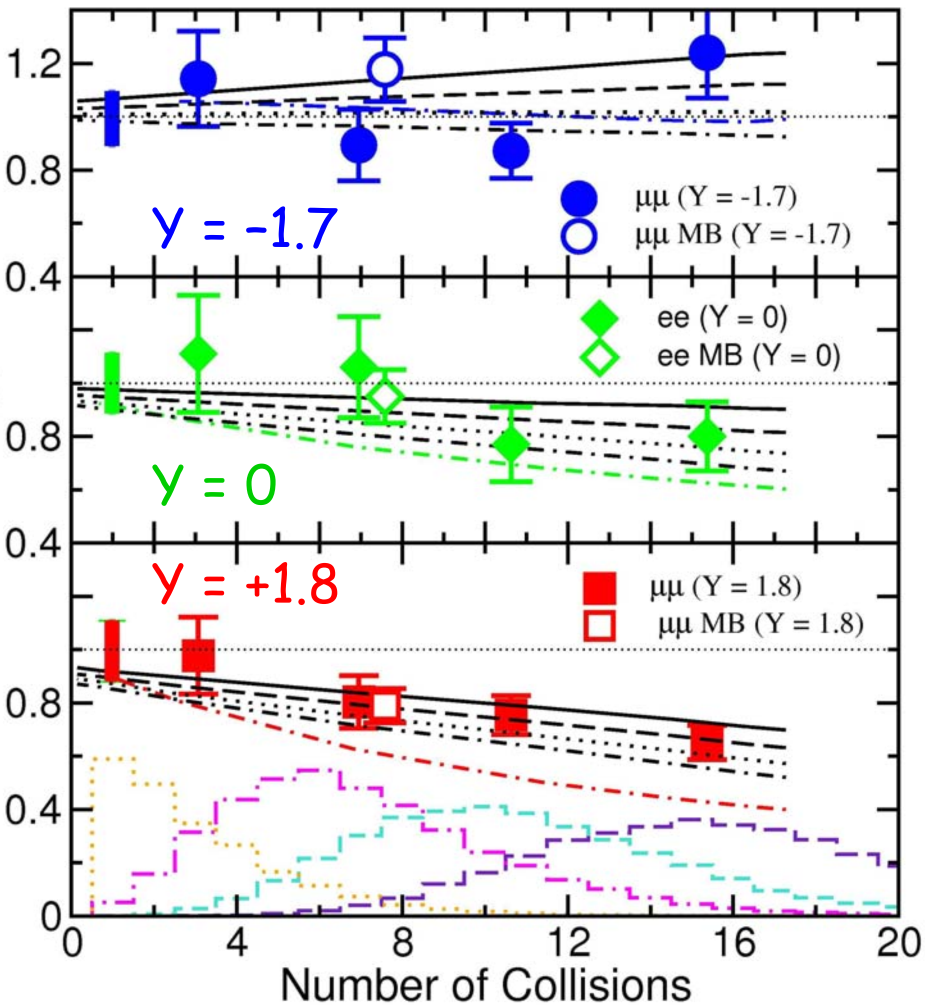
- Do we fully understand CNM @ SPS ?
- Not these surprising rapidity distribution asymmetries →
  - Variation of ~30 to ~50% in one unit of rapidity !
  - Is it (anti)shadowing ?
  - Not taken into account in CNM extrapolation…



NA50, CERN-PH-EP/2006-018, to appear in Eur. Phys. J. C.

Cold nuclear matter @ RHIC

R_{dAu}



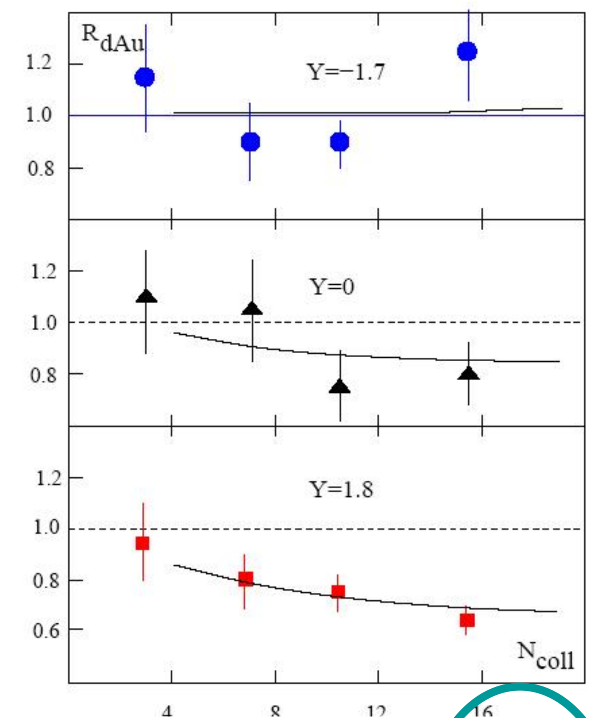
- First centrality dependence in dA (or pA) of J/ψ production !
- Reproduced by Ramona Vogt
  - Black lines: EKS98 shadowing + σ_{abs} = 0 to 3 mb
  - Colored lines: FGS shadowing + σ_{abs} = 3 mb
- Favoring moderate shadowing + moderate absorption…

PHENIX, PRL96 (2006) 012304
Klein,Vogt, PRL91 (2003) 142301

From dA to AA @ RHIC

What is on the market ?

1. Model of nuclear absorption + inhomogeneous (anti)shadowing
   (Ramona Vogt, nucl-th/0507027)
2. $\exp -[(\sigma_{diss}(y)+\sigma_{diss}(-y))\, \rho_0 L]$
   - (Karsch, Kharzeev & Satz PLB637(2006)75)
   - σ_{diss} from fits on dA data →
   - (unrealistic error bars)
   - But shadowing doesn't go like L…

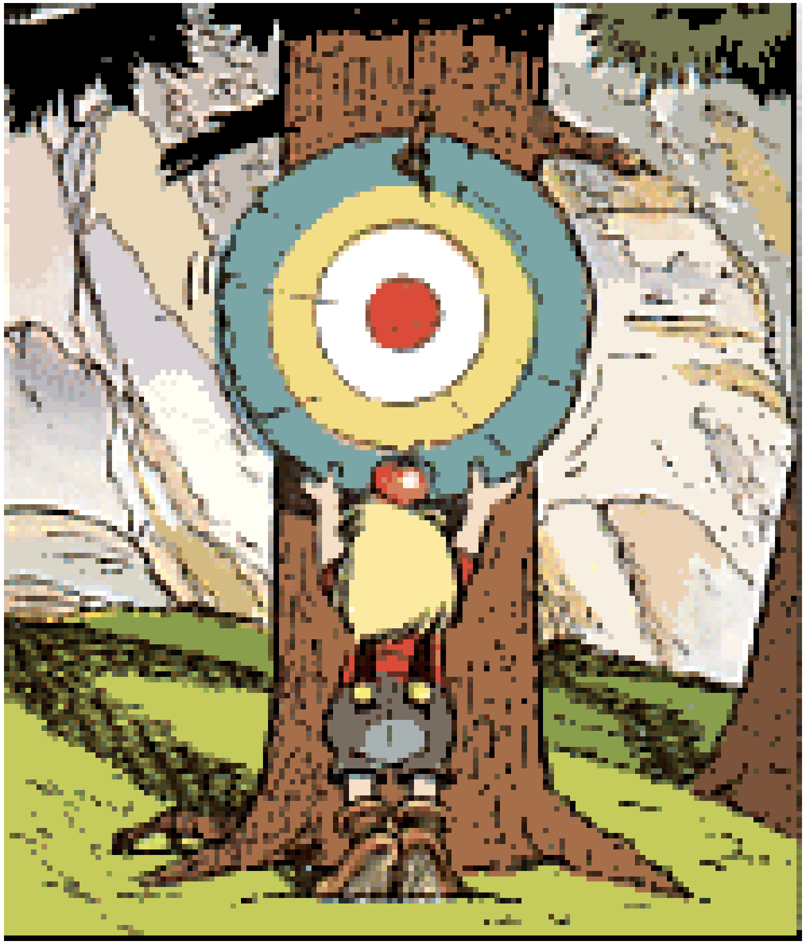


$$\sigma_{\rm diss}(y=1.8) = 3.1 \pm 0.2 \text{ mb}$$
$$\sigma_{\rm diss}(y=0) = 1.2 \pm 0.4 \text{ mb}$$
$$\sigma_{\rm diss}(y=-1.7) = -0.1 \pm 0.2 \text{ mb}$$

KKS, PLB637(2006)75

3. Another approach…

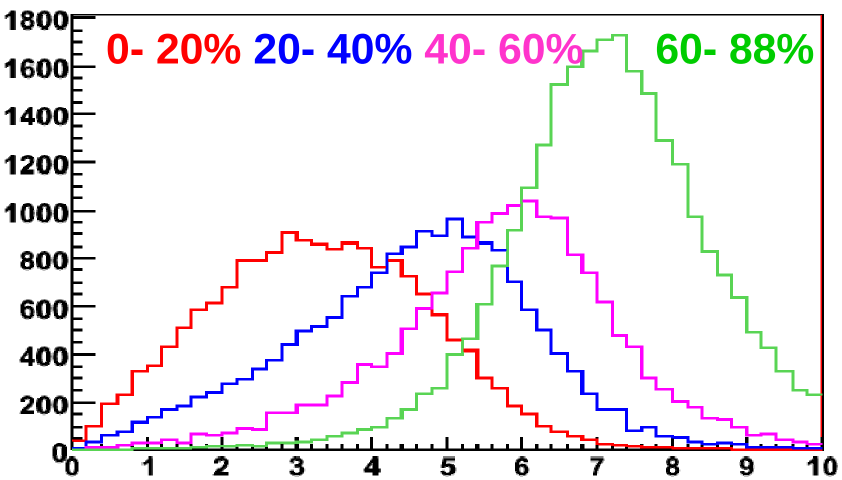
- Goal
  - Predict R_{AA} from R_{dA}
- Concerns
  - Stay as much as possible data-driven
  - Take full advantage of dAu centrality-dependence…

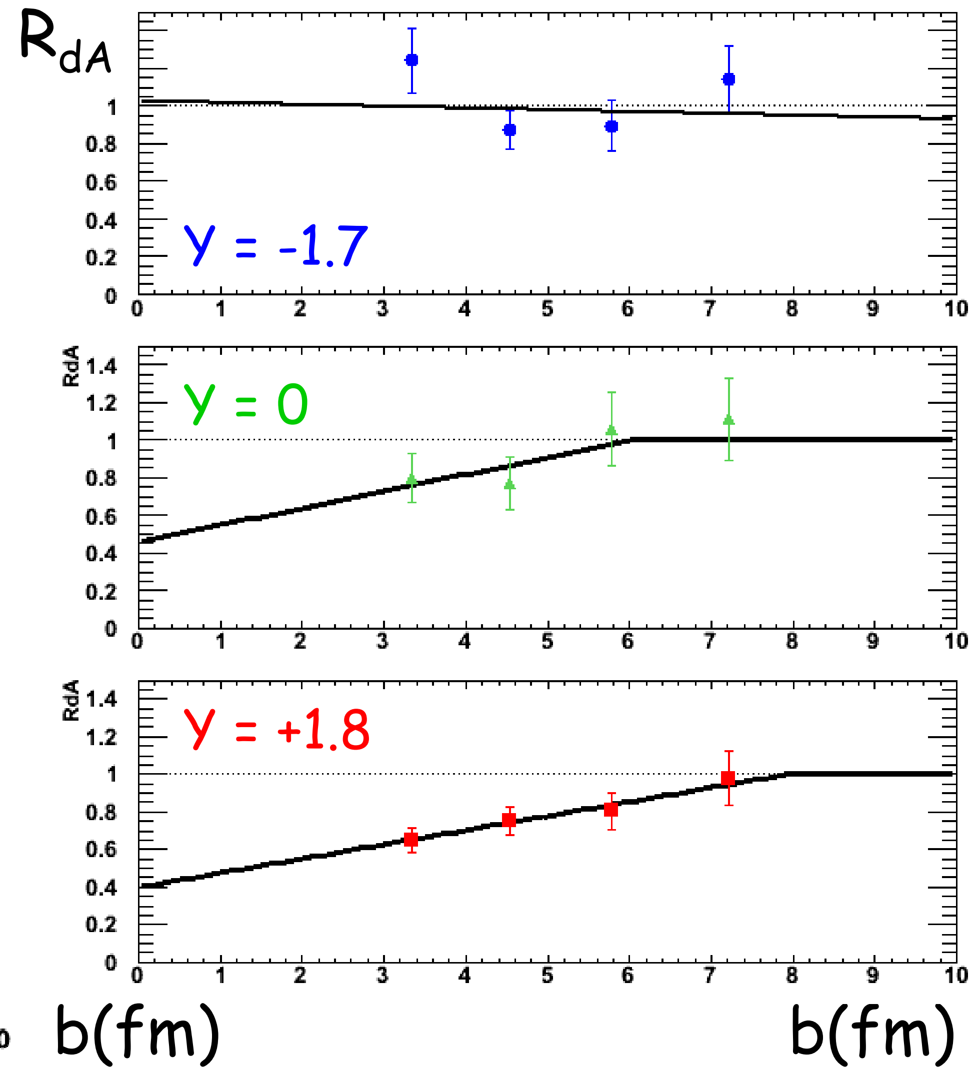


© Uderzo & Goscinny, Asterix chez les helvètes

R_{dA} vs impact parameter b

- Re-plot PHENIX R_{dA} vs impact parameter b from Glauber model
- Phenomenological fit to $R_{dA}(b)$ →
- Cut off RdA=1 at high b
  - Physically expected
  - OK for an upper bound of CNM





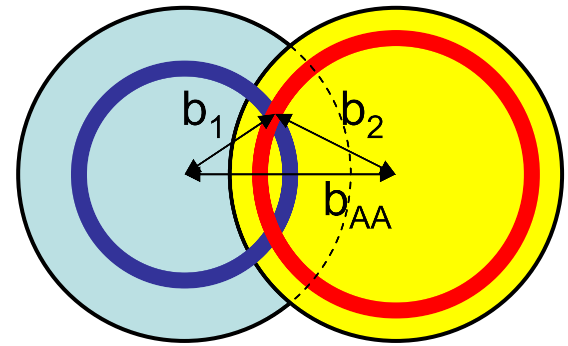
Plugged in Glauber model

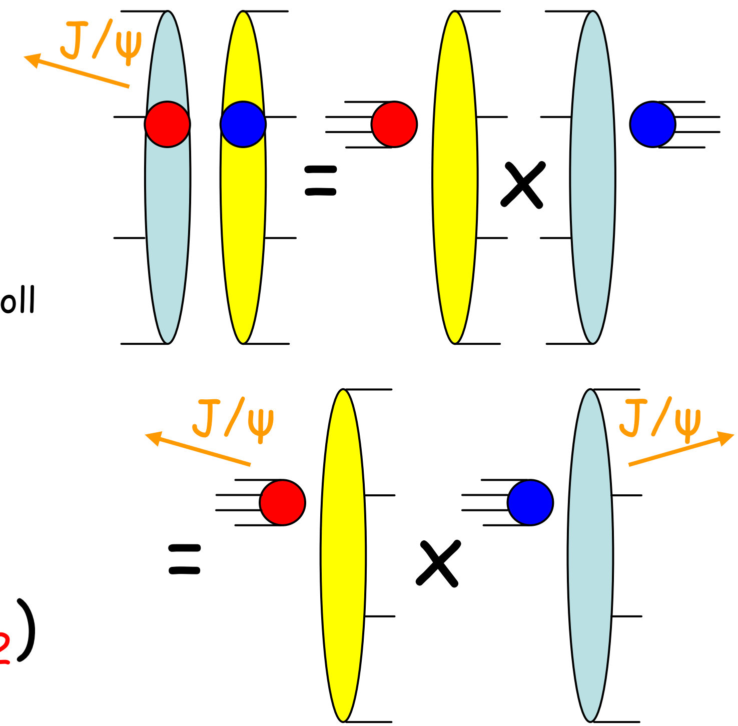
- Glauber provides, for a given A+A collision at b_{AA}, a set of N+N collisions occurring at b^i_1 and b^i_2.
- One minimal assumption is rapidity factorization: $R_{AA}(|y|,b_{AA}) =$

$$\Sigma_{collisions} \left[R_{dA}(-y,b^i_1) \times R_{dA}(+y,b^i_2) \right] / N_{coll}$$

- Works (at least) for absorption & shadowing since production

$$\sim \text{pdf1} \times \text{pdf2} \times \exp -\rho\sigma(L_1+L_2)$$

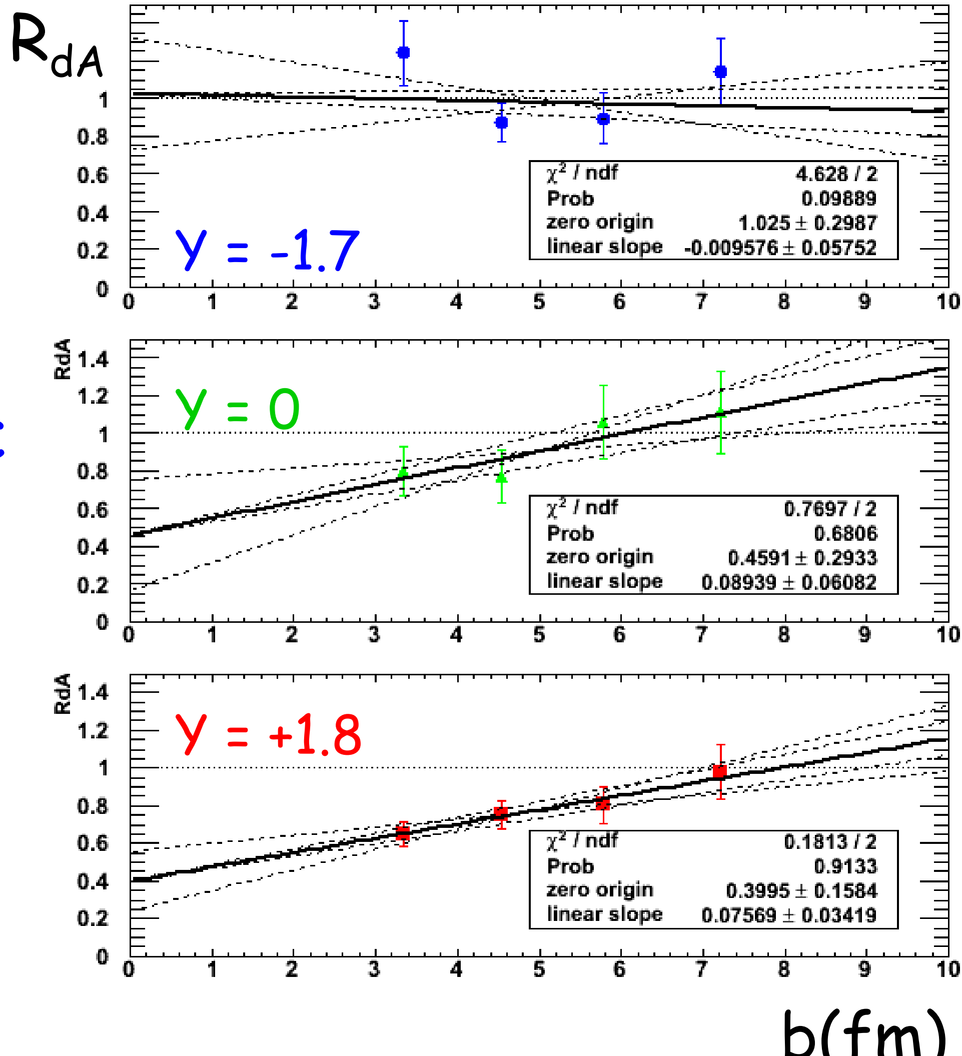




Propagating dA error

1. Varying the fit parameters
   - Uncorrelated
   - Within ±1σ

to propagate the statistic + systematic dAu uncertainties throughout the Glauber computation

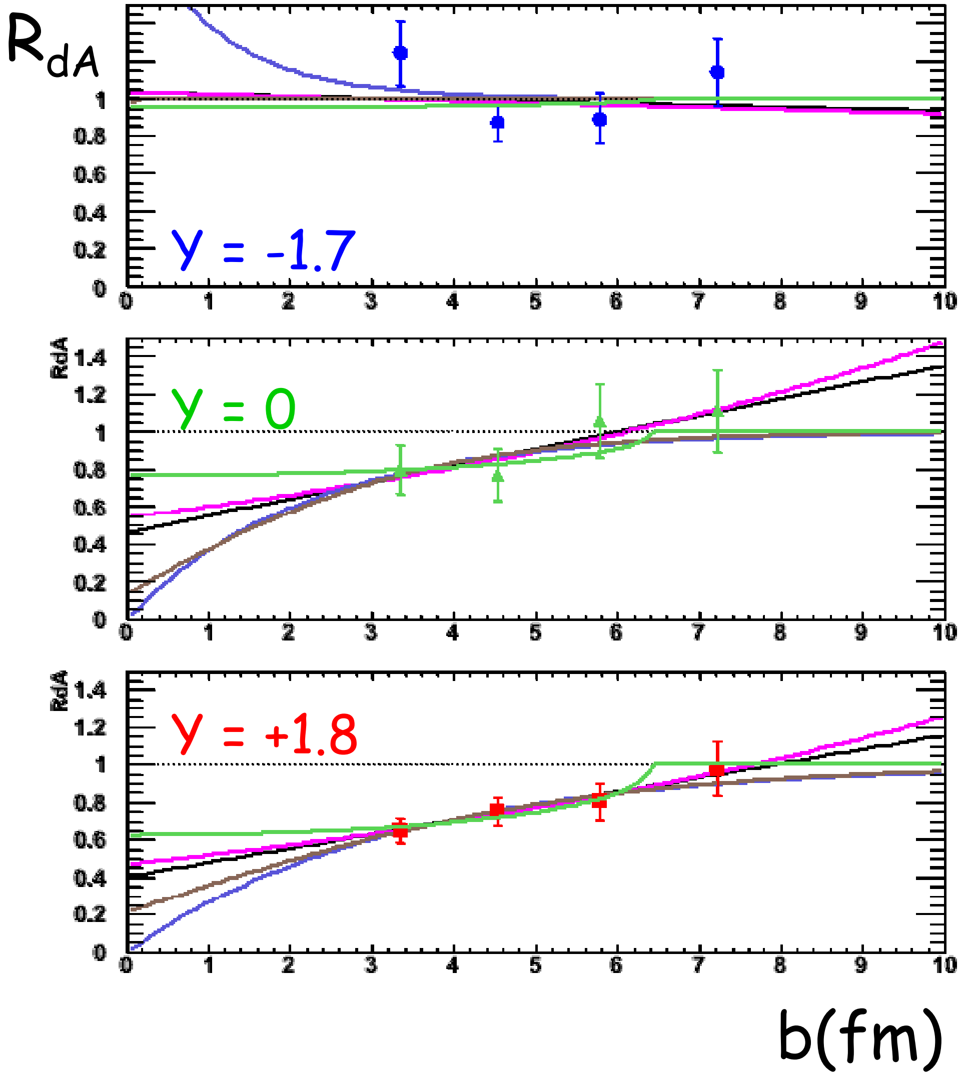


Systematic uncertainties

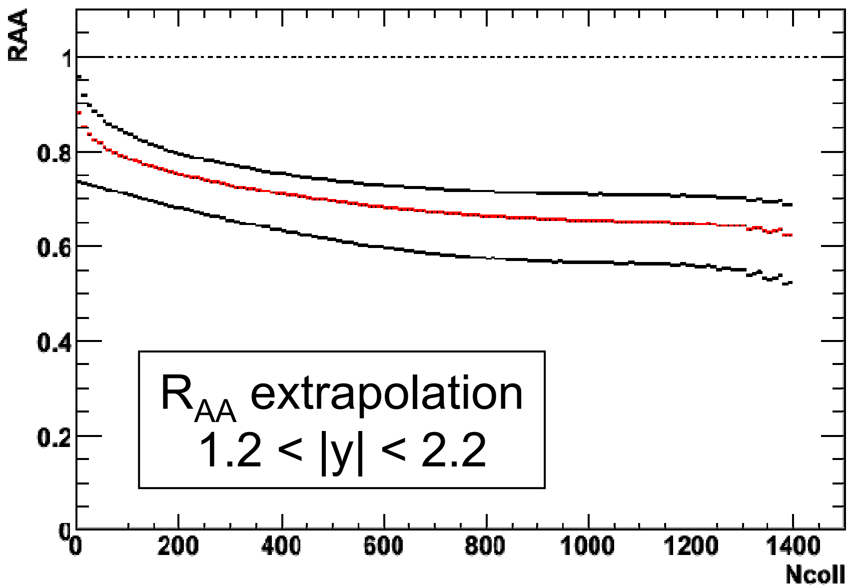
2. Varying line shapes →
   - 3 to 5% @ y ~ 1.7
   - 3 to 12% @ y ~ 0

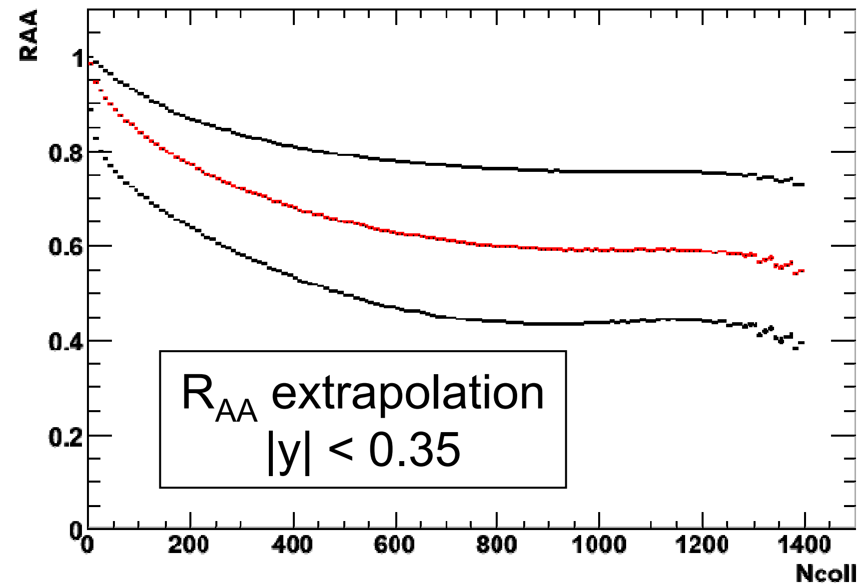
   (asymmetric and depending on centrality)

3. Varying Glauber parameters (pp total cross section, Woods Saxon parameters,...)
   - 2% @ y ~ 1.7
   - 4% @ y ~ 0



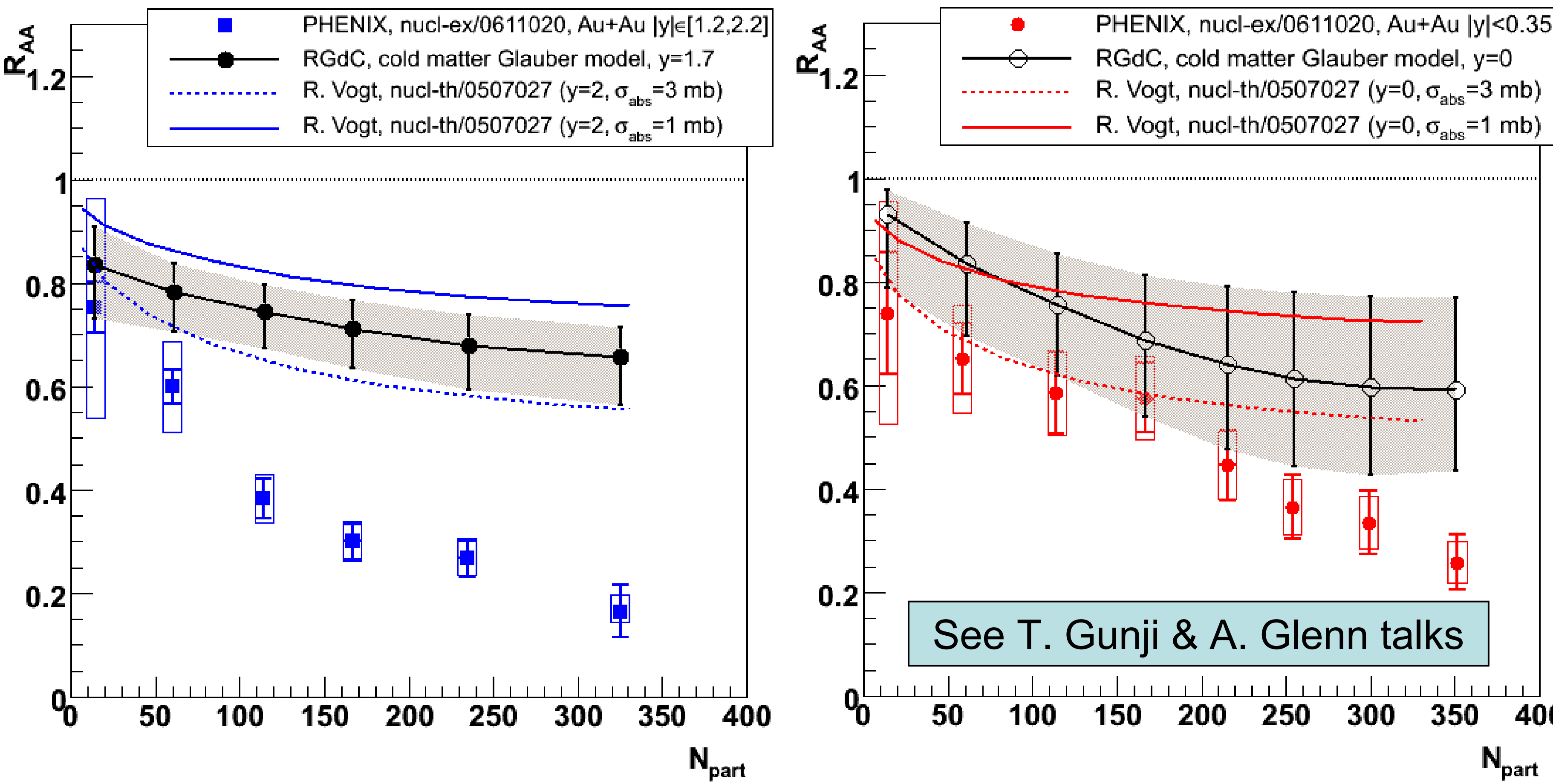
The output: R_{AA} (N_{coll})





- Black curves reflect stat. and syst. errors from dAu
- Much less constrained @ y~0 because:
  - $R_{dA}(0)$ measurements are less precise than $R_{dA}(-1.7)$ and $R_{dA}(+1.7)$
  - and squared while computing RdA(-y) x RdA (+y)
- Then, take the average in experimental centrality classes

Comparison to models & data



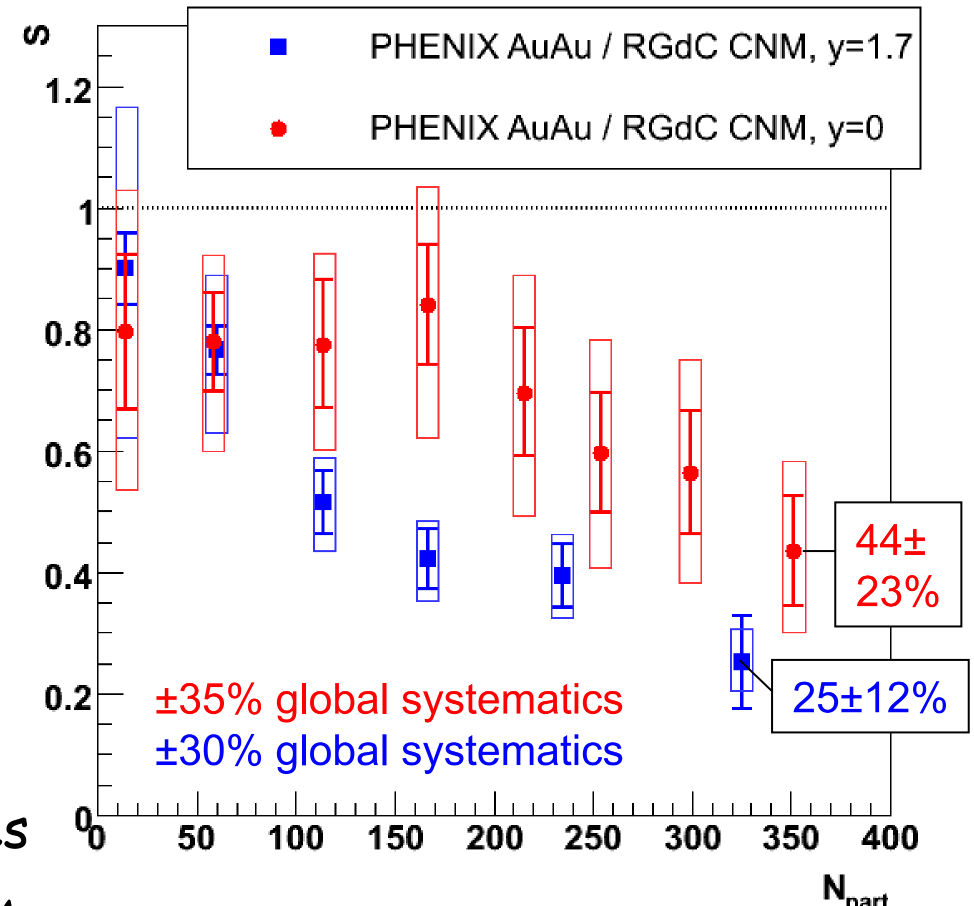
- Consistent with Vogt's prediction (EKS shadowing + 1 or 3 mb σ_{abs})
- Prediction @ y~1.7 is much more powerful than @ y~0

R_{AA} / CNM @ RHIC

- First RAA/CNM extraction including (proper) error propagation
- Boxes are correlated errors from AuAu & dominant CNM
- Important: missing overall global relative uncertainty
  - 30% @ y ~ 1.7 / 35% @ y ~ 0
  - Due to different pp references that don't cancel in R_{dA} and R_{AA}

$$R_{AA}(|y|) / R_{dA}(-y) \times R_{dA}(+y)$$

J/ψ survival beyond CNM

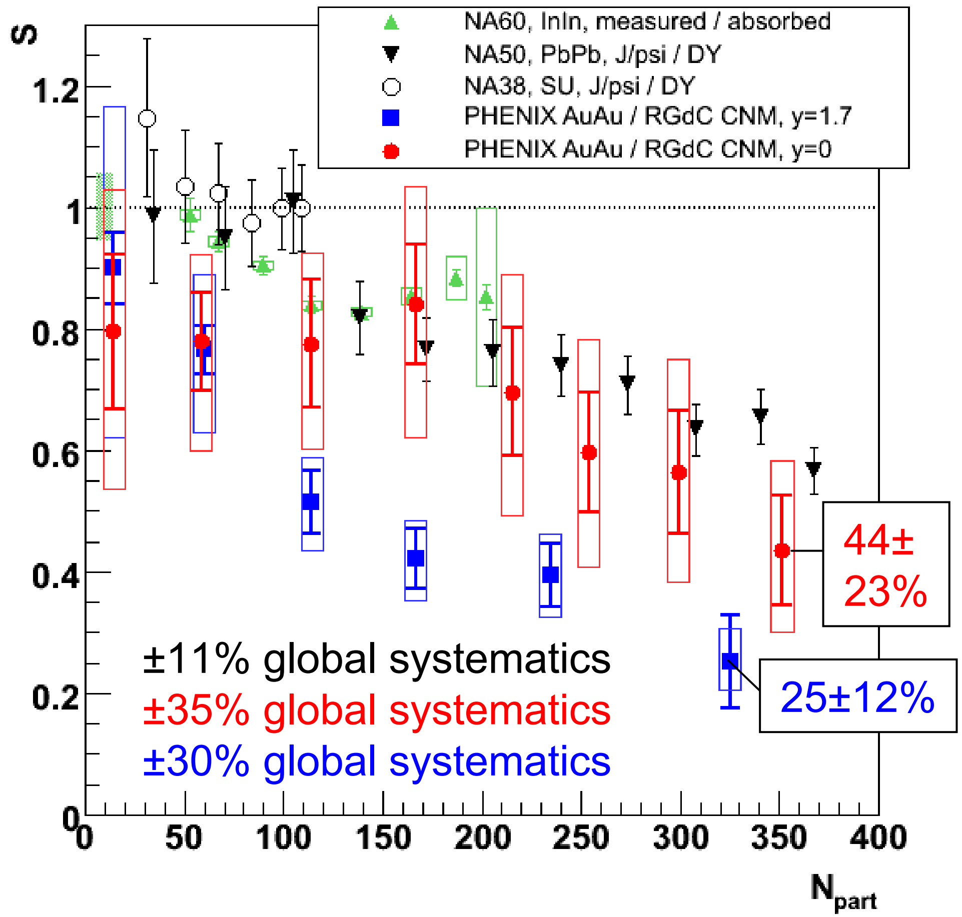


← This will decrease by recomputing RdA with new pp data (A.Bickley's talk)

Quick comparison to SPS

- At mid-rapidity, the amount of surviving J/ψ @ RHIC is compatible with SPS (~60%) but depends a lot on CNM (and pp references)…
- At forward rapidity, RHIC anomalous suppression is much stronger !

J/ψ survival beyond CNM



Conclusions

- Pro's
  - Very little model dependence (apart from Glauber)
    - (no σ_{abs} , no shadowing scheme, y=0 & 1.7 independence,…)
  - Proper error propagation from dAu (and pp)
  - Proper centrality selection (experimental classes)

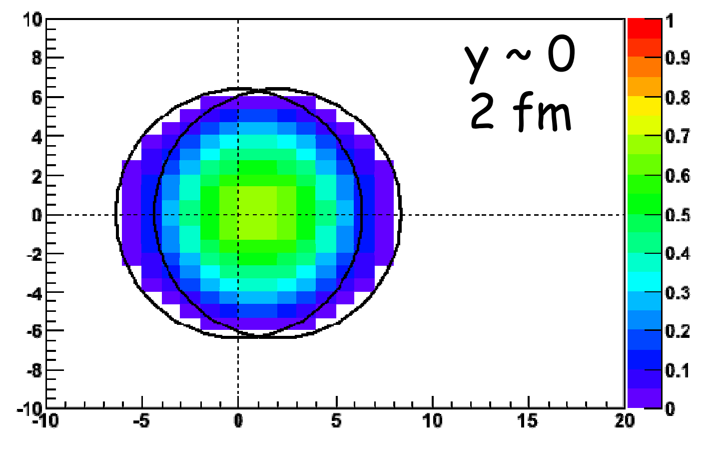
  → J/ψ survival of 25±12% @ y=1.7 & 44±23% @ y=0
- Con's
  - Not applicable without p+*A* (or d+*A*) centrality dependence at <u>same energy</u> and at <u>both</u> +y and -y wrt *A*+*A* collisions (thus not at SPS or LHC)
  - Limited by dAu statistic ! We need more !
    - Especially @ y~0 (and dCu to apply this to CuCu)

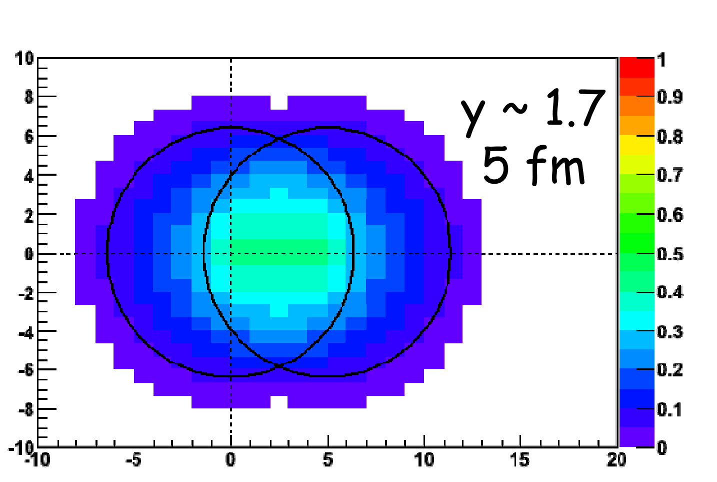
Back-up slides

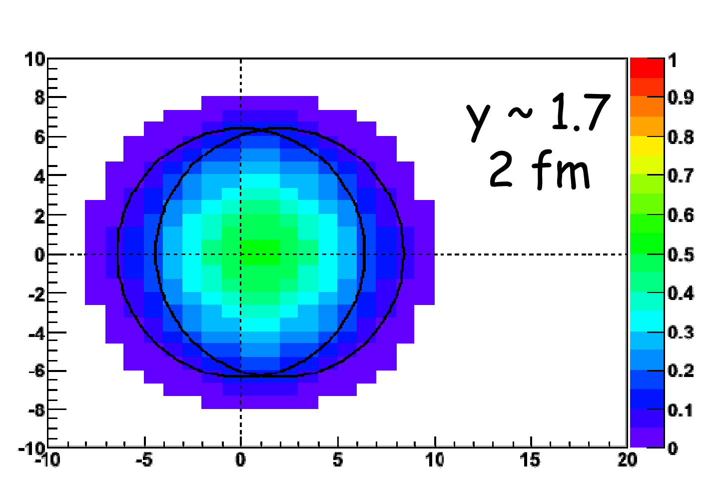
Collision display

- Disappearance probability
  - No assumption on production point
  - Weighted by Woods Saxon

Disappearance probability







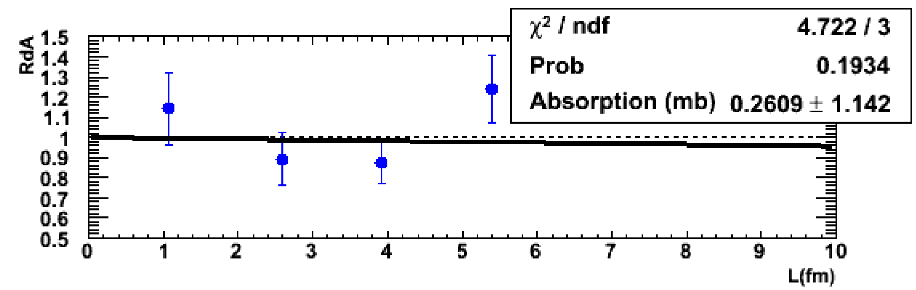
Nuclear absorption only

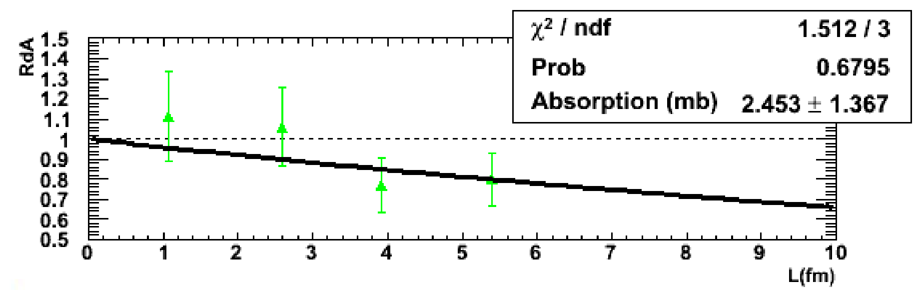
- Compute L with Glauber model
- Fit $\exp(-\sigma_{abs}\,\rho_0\,L)$
- Results are different wrt KKS numbers

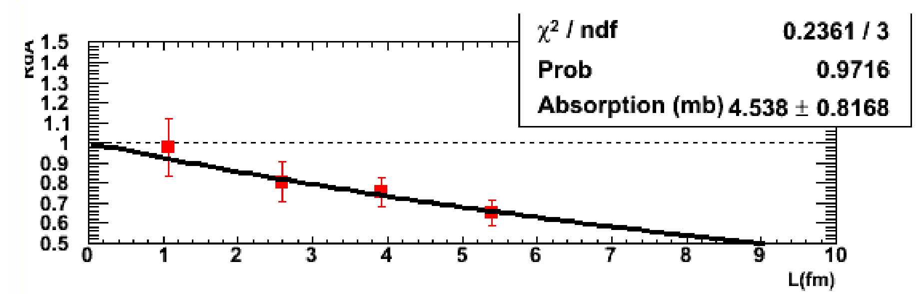
Rapidity	KKS fit [4]	My fit
$y = -1.7$	-0.1 ± 0.2 mb	0.3 ± 1.1 mb
$y = 0$	1.2 ± 0.4 mb	2.4 ± 1.4 mb
$y = 1.8$	3.1 ± 0.2 mb	4.5 ± 0.8 mb

TAB. 1 – σ_{diss} values from KKS and my analysis.

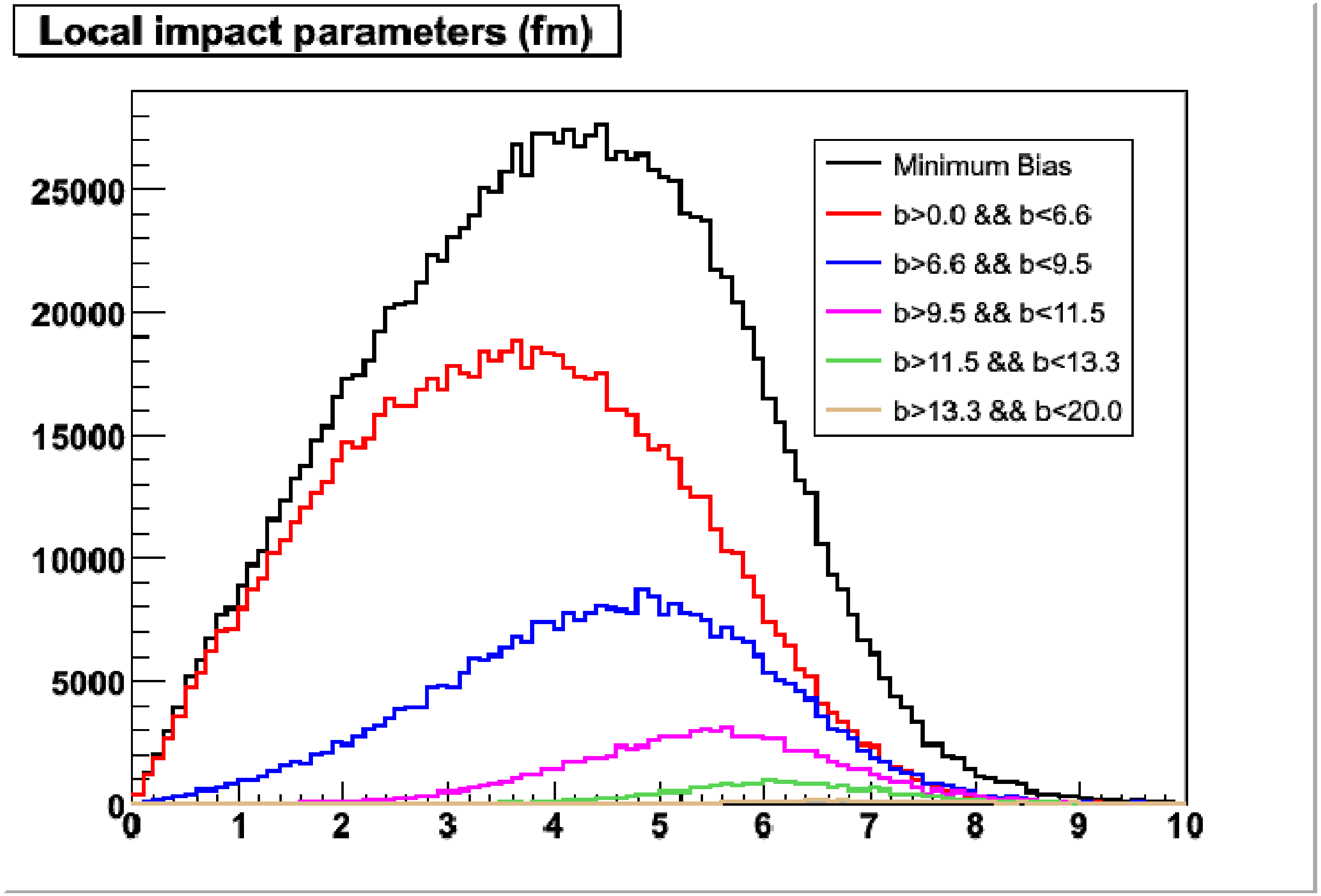
KKS, PLB637(2006)75



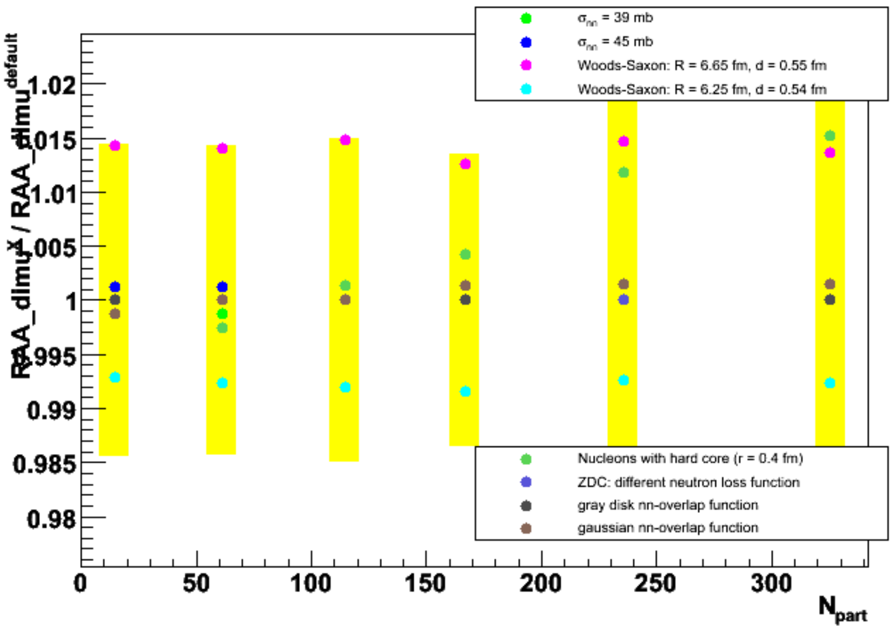


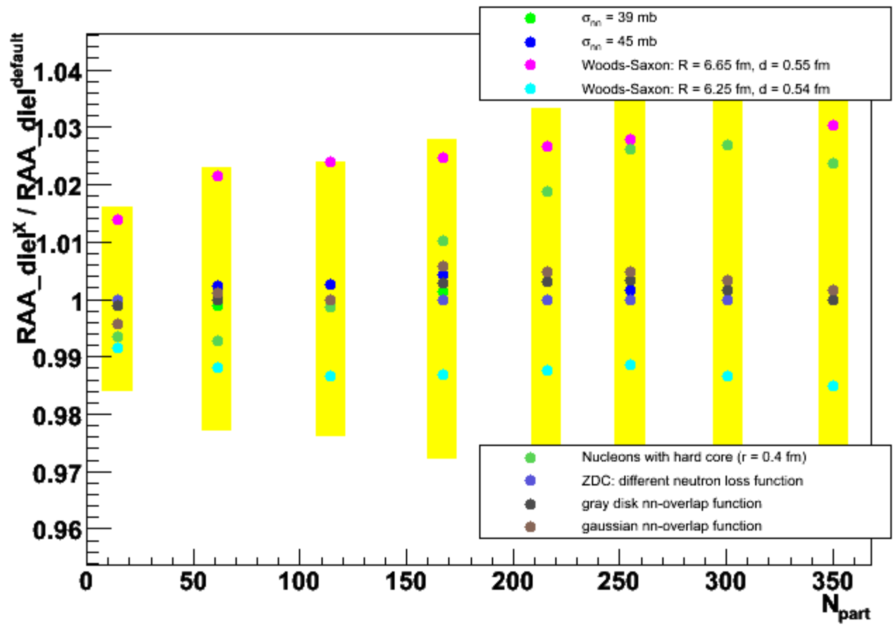


Sampling local impact parameter in AuAu

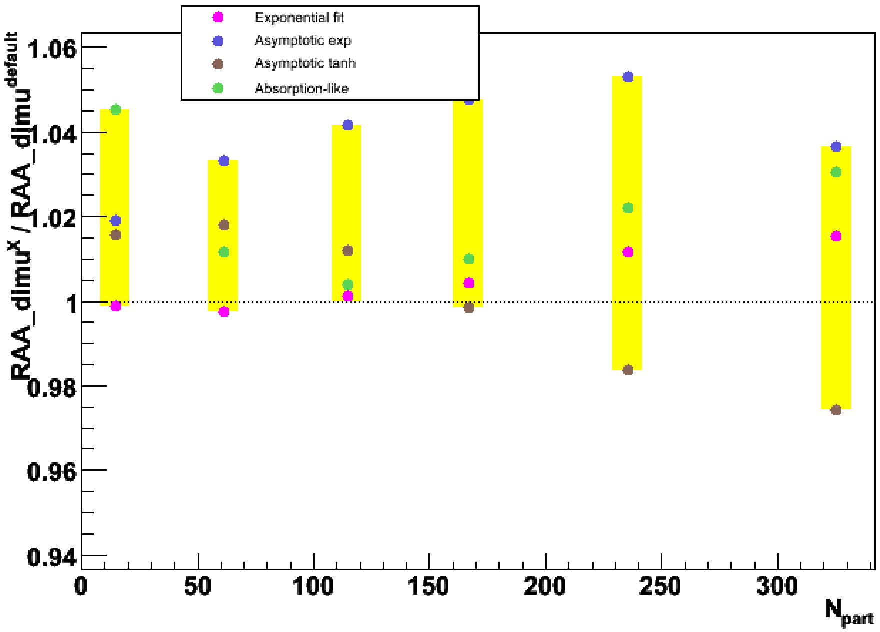


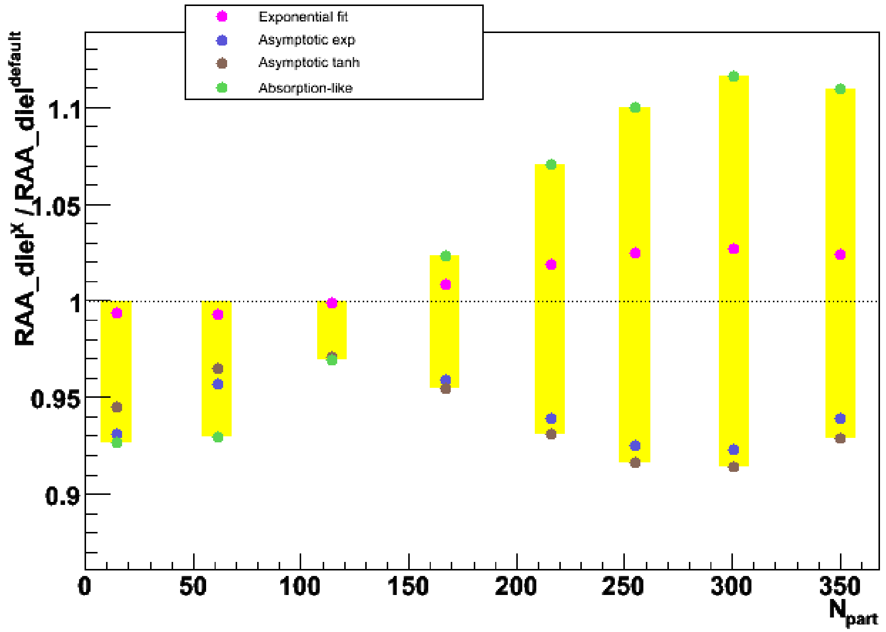
Varying Glauber parameters





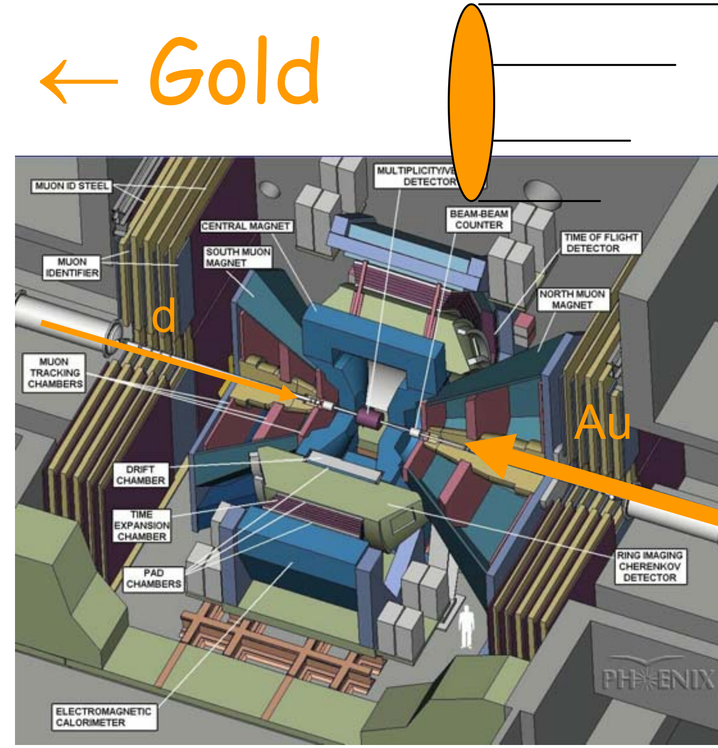
Varying the line shape



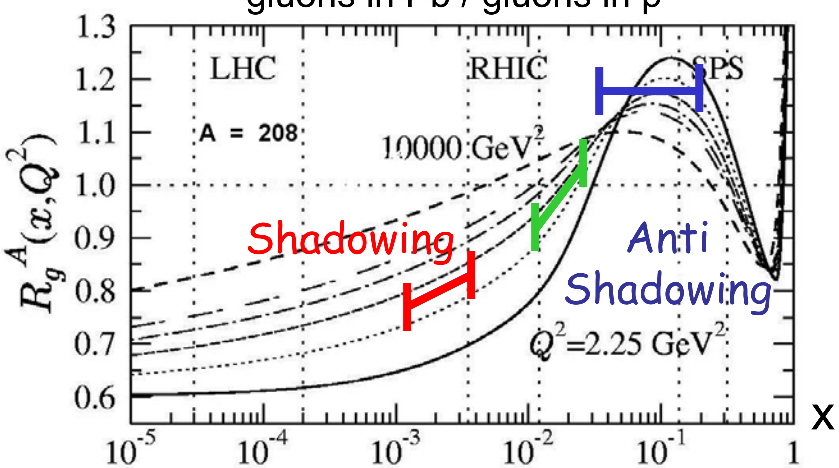


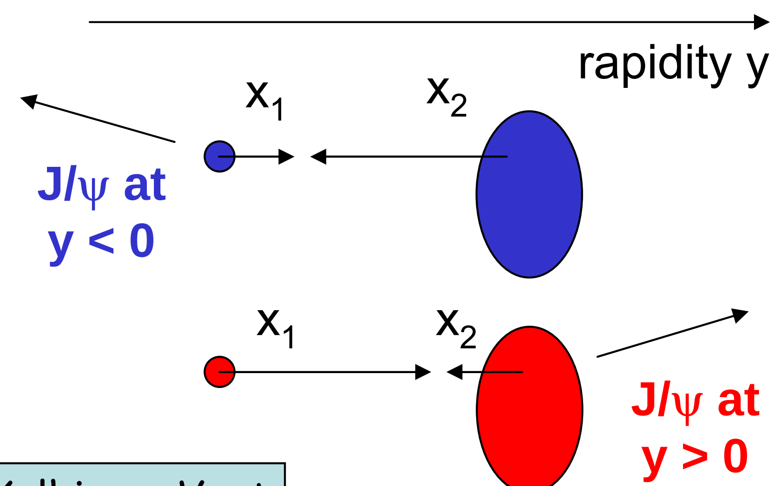
Deuteron → ← Gold

- In PHENIX, J/ψ mostly produced by gluon fusion, and thus sensitive to gluon pdf
- Three rapidity ranges probe different momentum fraction of Au partons
  - South ($y < -1.2$) : large x_2 (in gold) ~ 0.090
  - Central ($y \sim 0$) : intermediate x_2 ~ 0.020
  - North ($y > 1.2$) : small x_2 (in gold) ~ 0.003



An example of gluon shadowing prediction

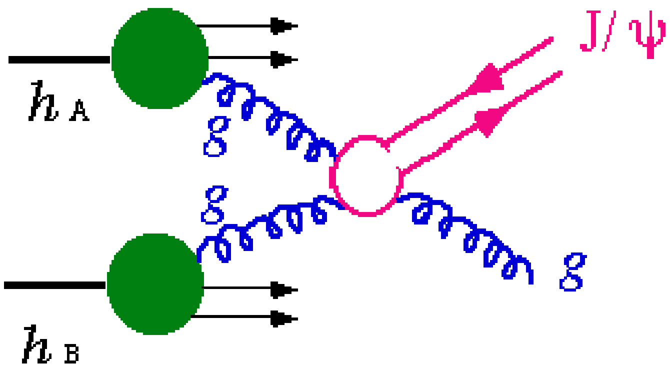




Eskola, Kolhinen, Vogt
NPA696 (2001) 729

Cold nuclear matter effects ?

- J/ψ (or $c\bar{c}$) absorption
- (Anti) shadowing
  (gluon saturation, CGC…)
- Energy loss of initial parton
- p_T broadening (Cronin effect)
- Complications from feeddown ψ' & χ_c ?
- Something else ?



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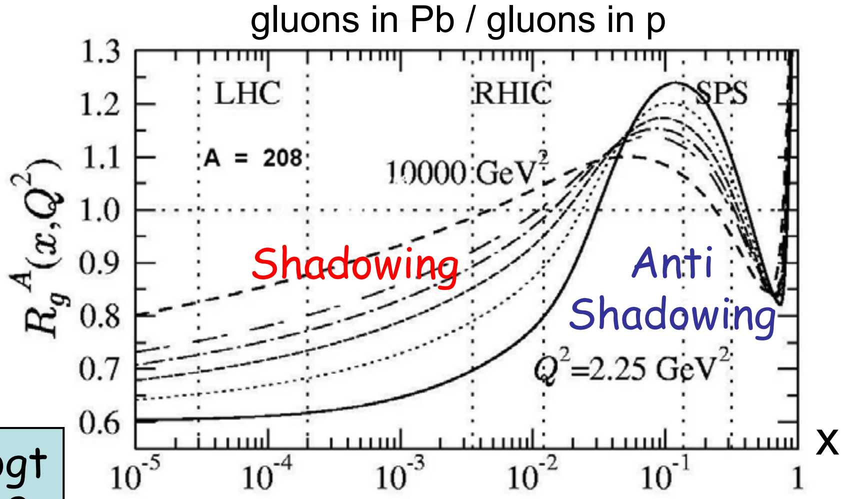

Eskola, Kolhinen, Vogt
NPA696 (2001) 729

Cold nuclear matter effects ?

A real puzzle ! Especially when one goes to low x_2, high x_F...

$\sigma_\psi(pA) = \sigma_\psi(pp) \times A^\alpha$