Latest J/ψ results from PHENIX

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Selected Topics on Heavy Flavor Production in High-Energy Collisions

Outline

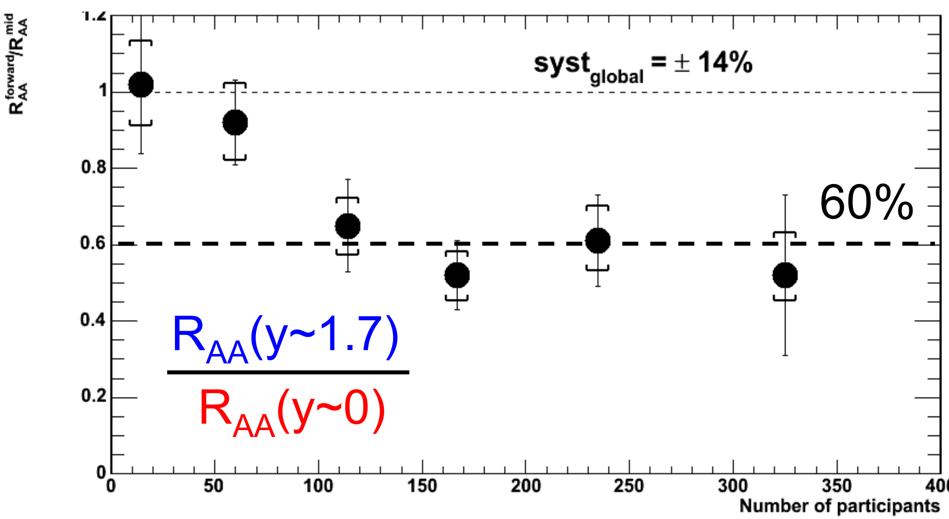
1. The facts, and only the facts
   - (nucl-ex/0611020)
2. A word of caution
   - Cold nuclear matter is not under control
3. Comparison with multiple models...

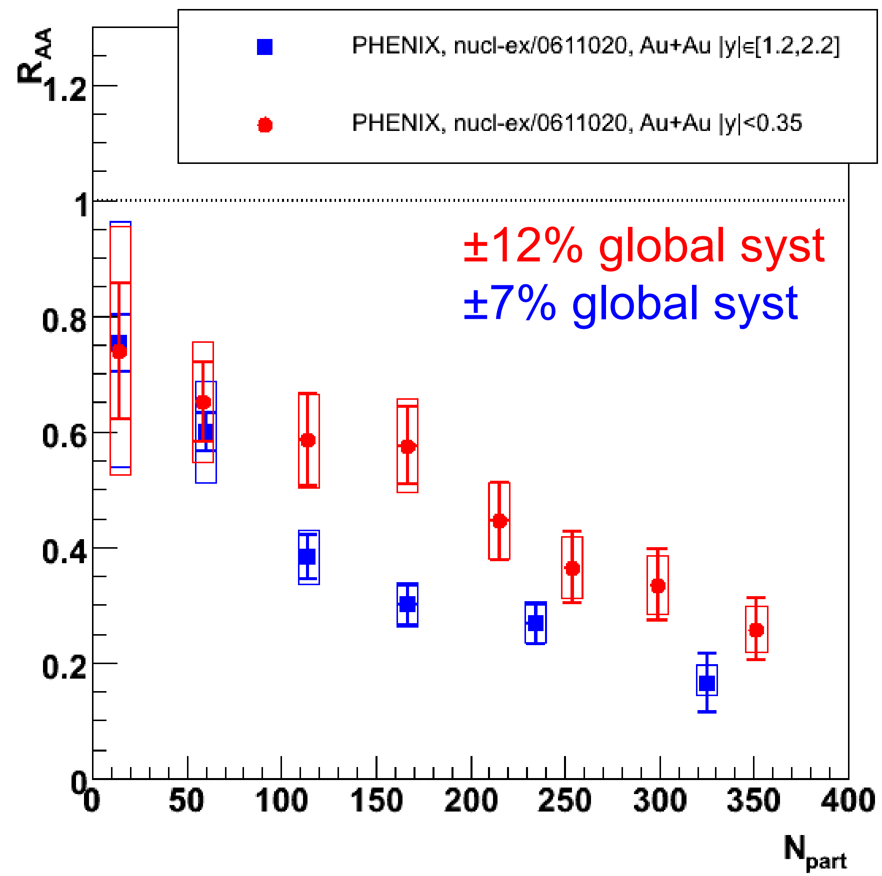
Stolen materials from A.Bickley, P.Braun-Munzinger, A.Glenn, T.Gunji, M.Leitch, E.Scomparin, P.Zhuang, RGdC @ QM06

The facts
(nucl-ex/0611020)

R_{AuAu} (y~0) > R_{AuAu} (y~1.7)

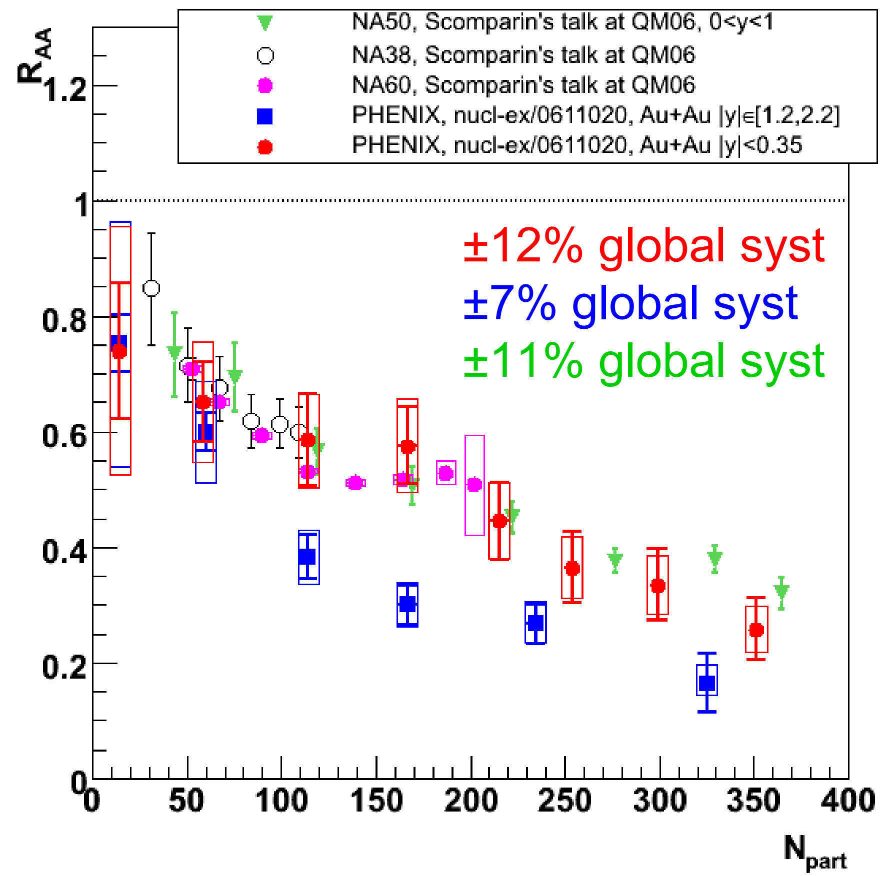
- More suppression at forward rapidity !



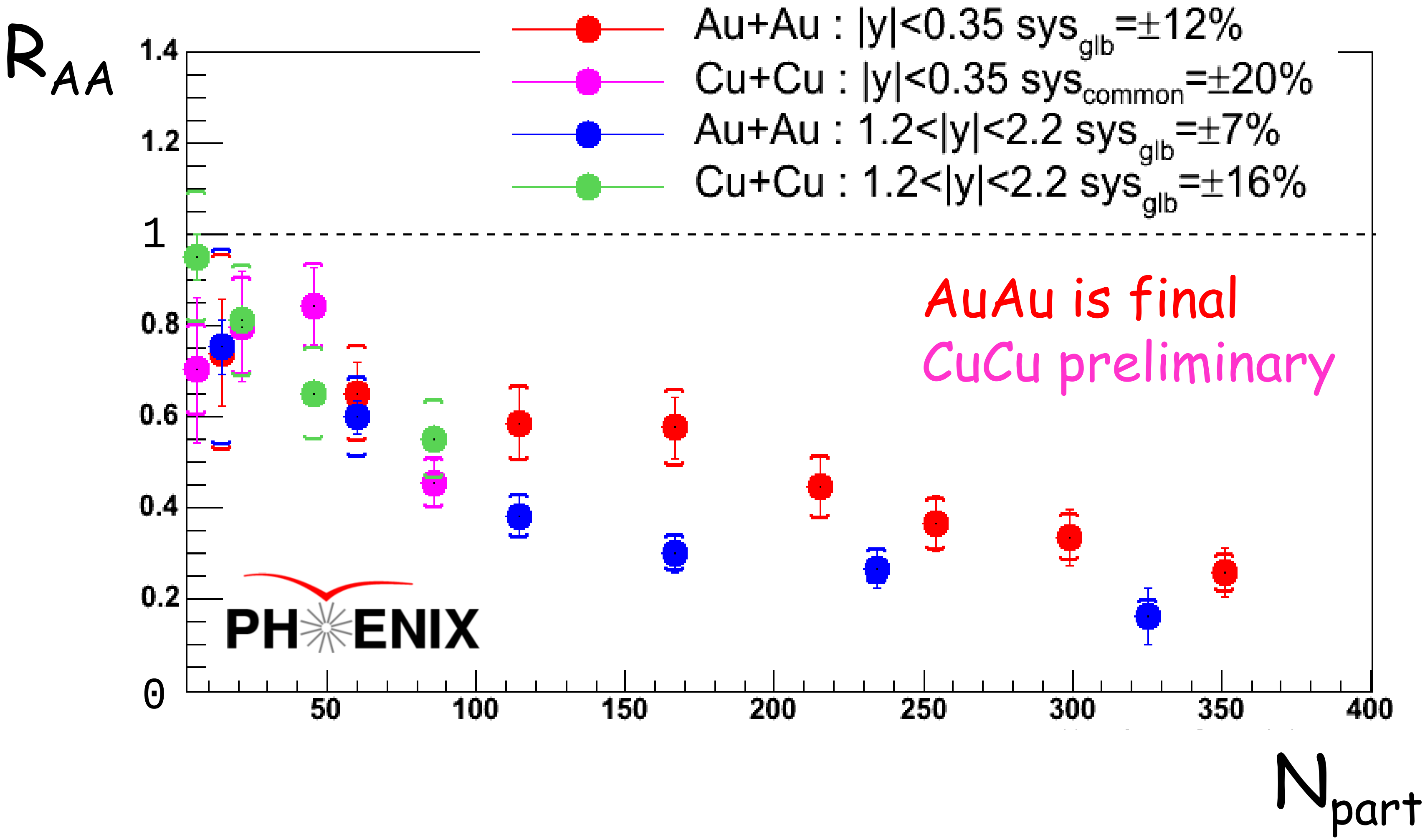


R_{AuAu} (y~0) ~ R_{AuAu} (SPS)

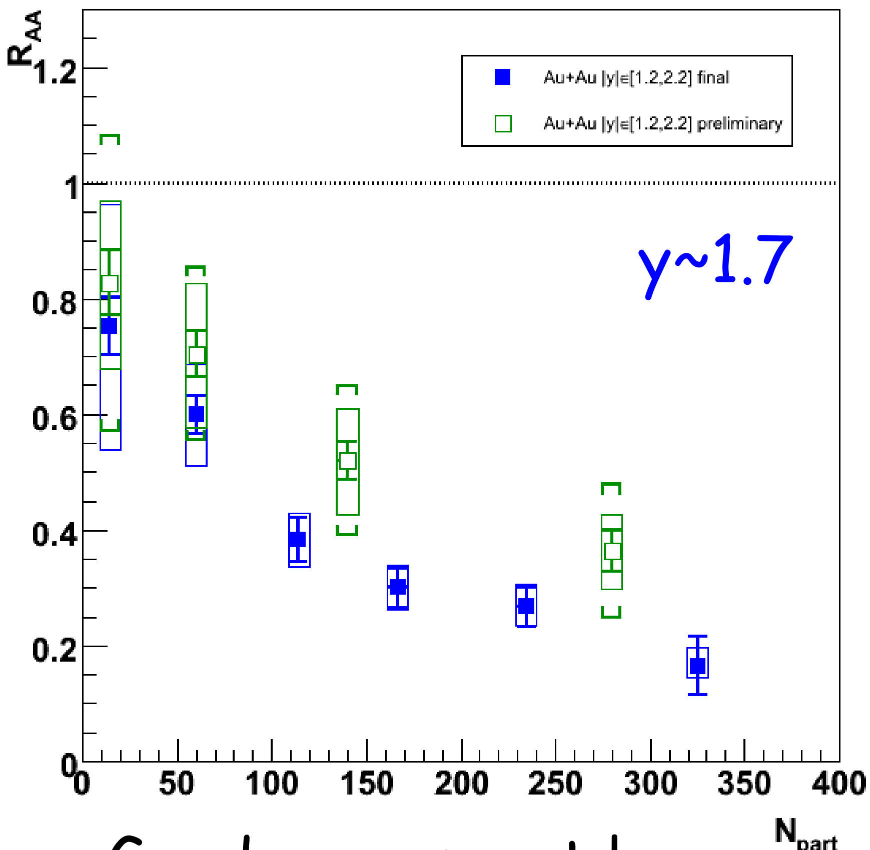
- Lower rapidity R_{AA} look surprisingly similar, while there are obvious differences:
  - Cold nuclear matter effects ($x_{Bjorken}$,…)
  - Energy density
  - …

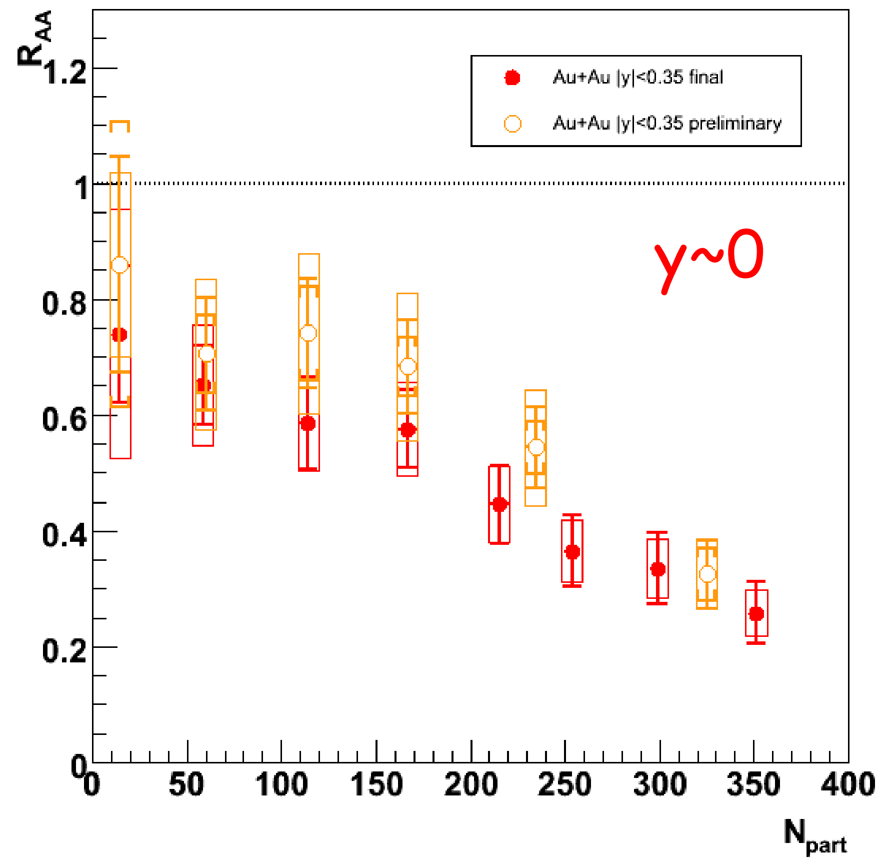


AuAu versus CuCu



QM06 versus QM05



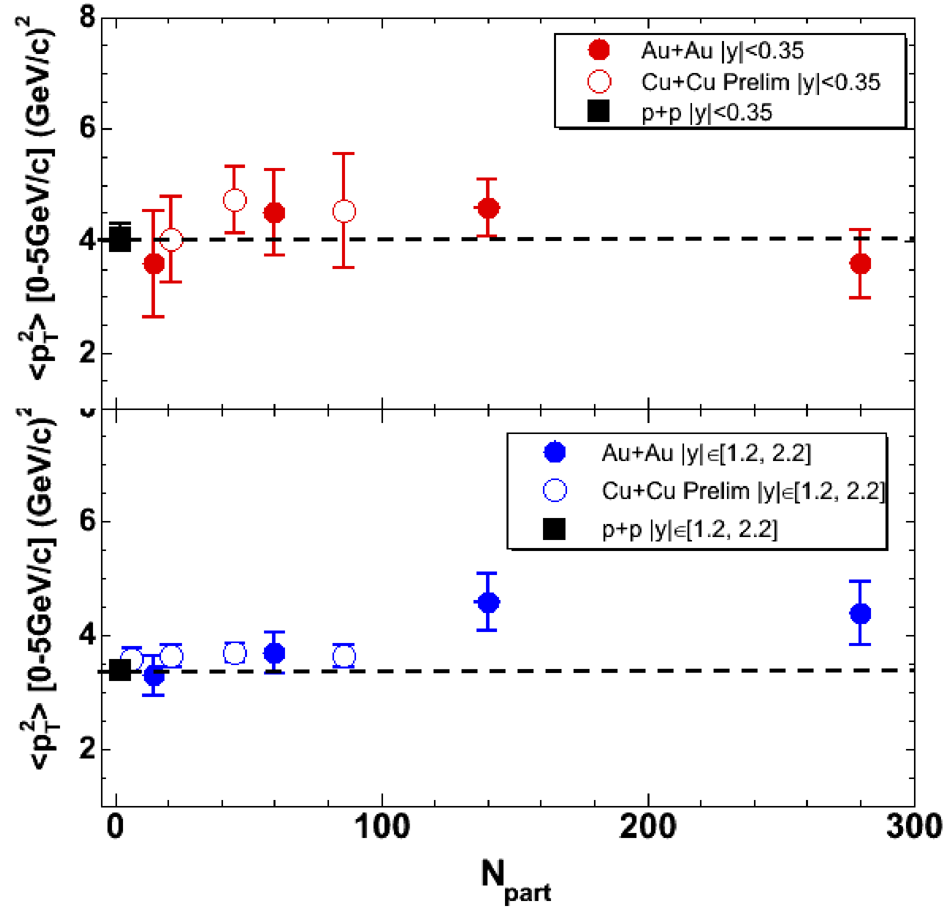


Good agreement !

- At forward rapidity, on the lower edge of systematics
  - (better handling of backgrounds and new pp reference)
- At midrapidity, less <u>subjective</u> “onset” like shape…

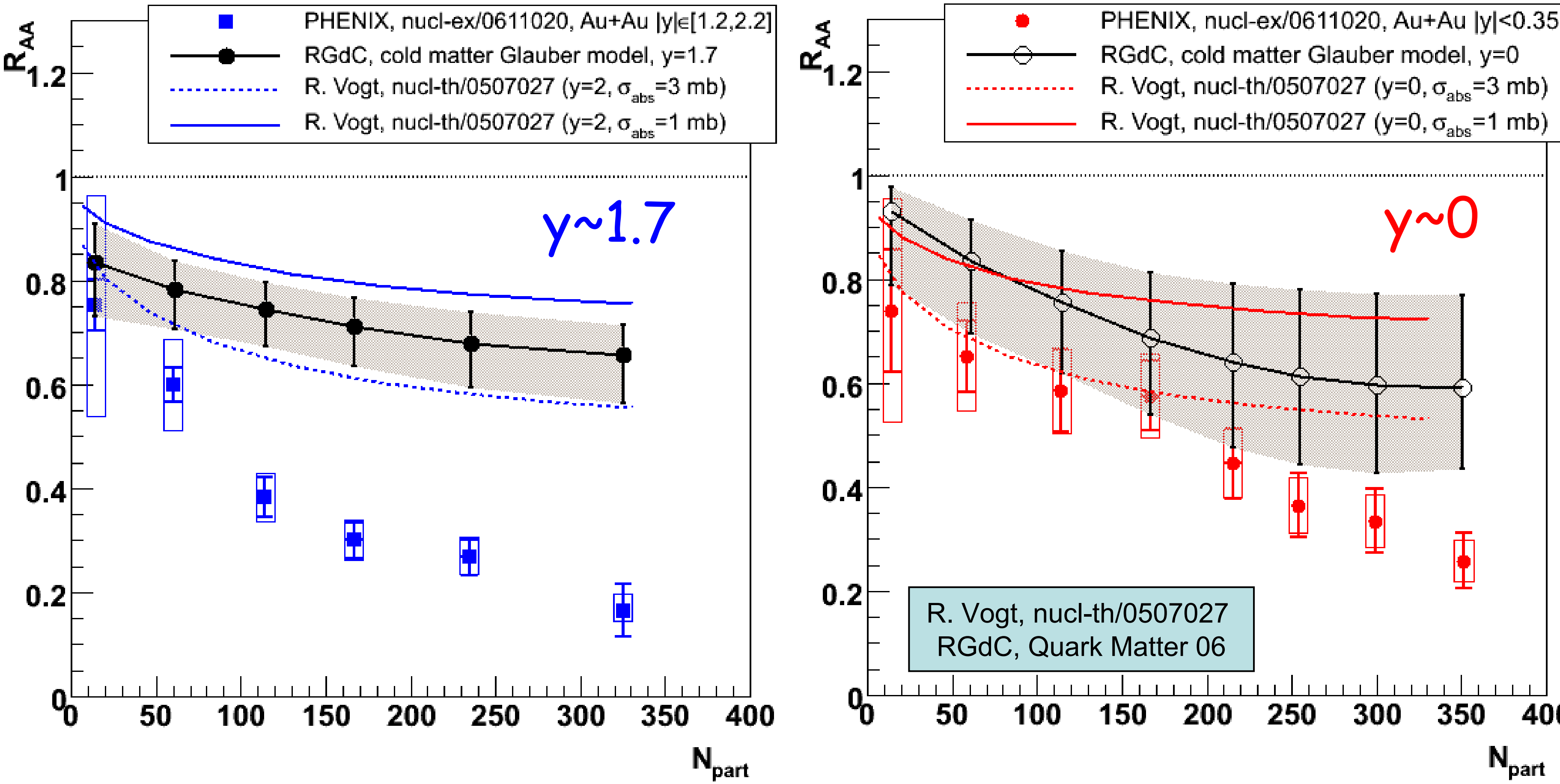
$\langle p_T^2 \rangle$

- No dependence of $\langle p_T^2 \rangle$
  - Maybe a modest rise at forward rapidity.
- Note that PHENIX discard an earlier $\langle p_T^2 \rangle$ at forward rapidity in p+p:
  - 2.51 ± 0.20 $(GeV/c)^2$



First, beware of cold nuclear matter (CNM) effects !

R_{AA} from cold nuclear matter



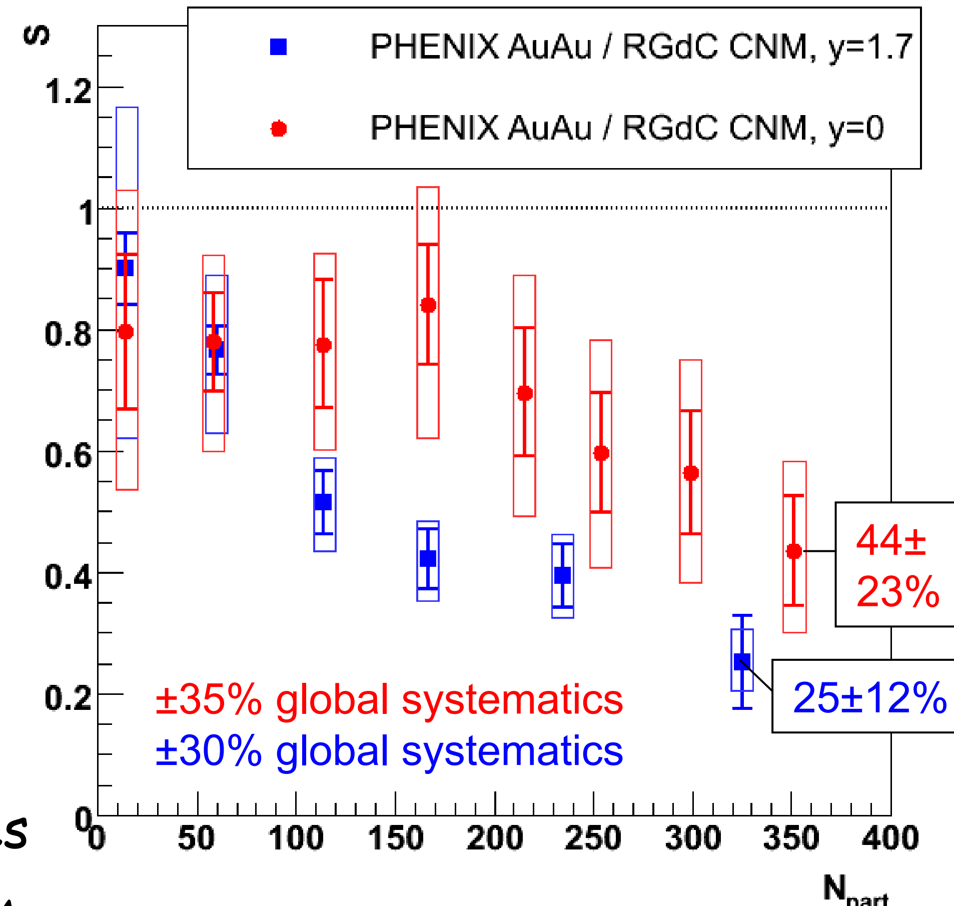
- Two CNM methods agree quite well
  - (shadowing+absorption by Vogt and dA-driven Glauber by RGdC)
- Clear anomalous suppression (stronger @ y~1.7)

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}

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

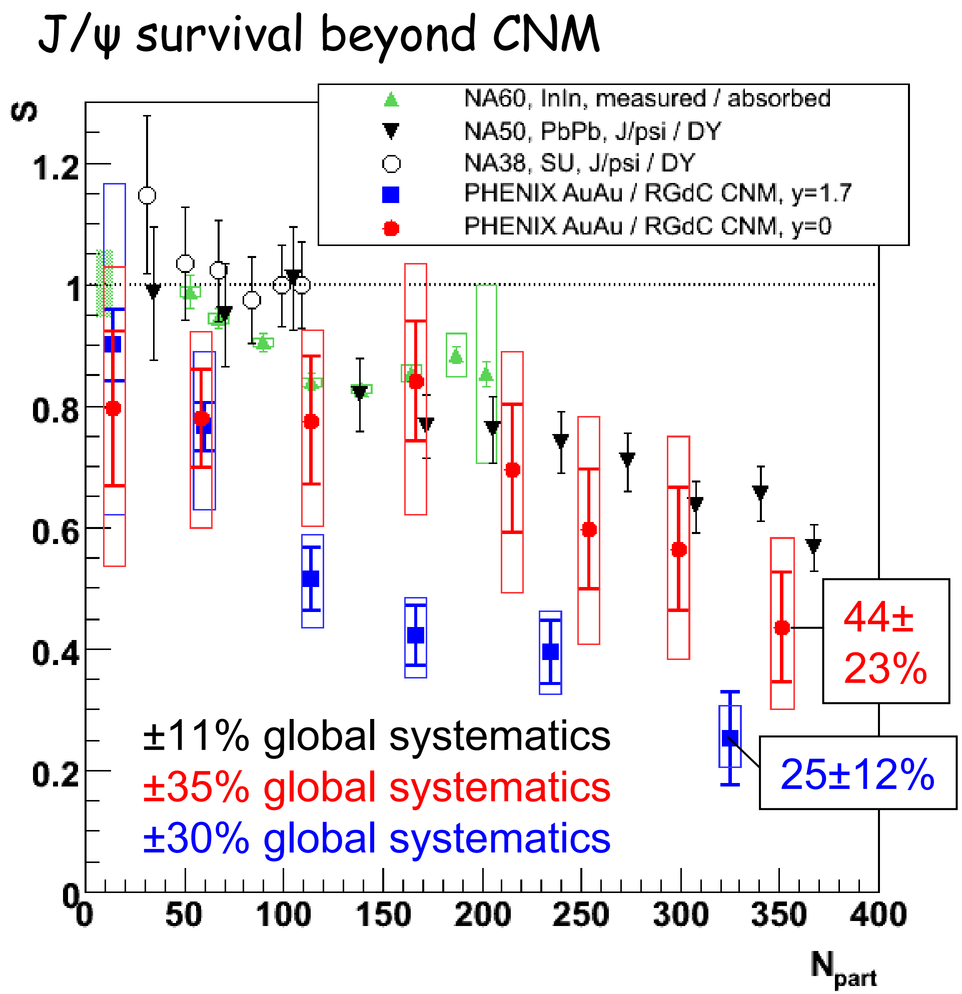
J/ψ survival beyond CNM



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

Quick comparison to SPS

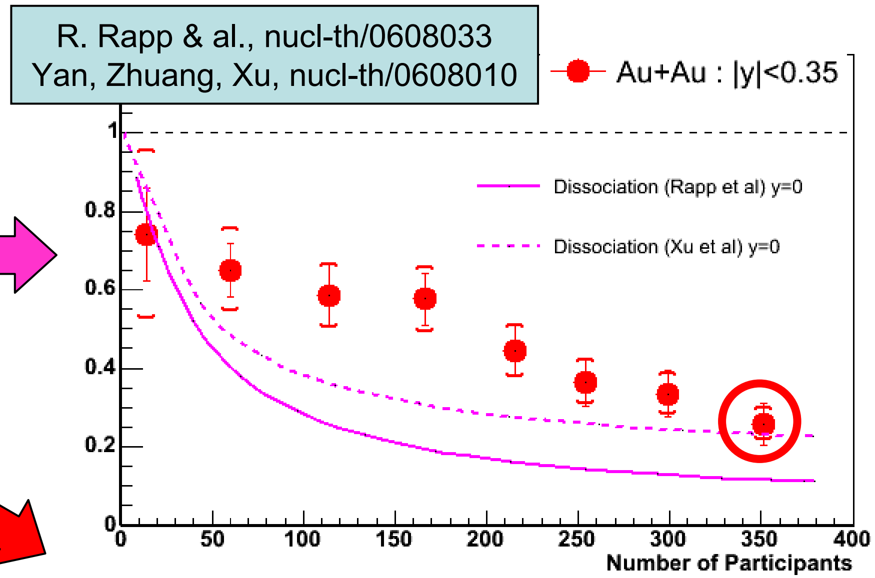
- At mid-rapidity, the amount of surviving J/ψ @ RHIC is compatible with SPS (~60%) but depends a lot on CNM (and pp references)…
- At forward rapidity, RHIC anomalous suppression is much stronger !

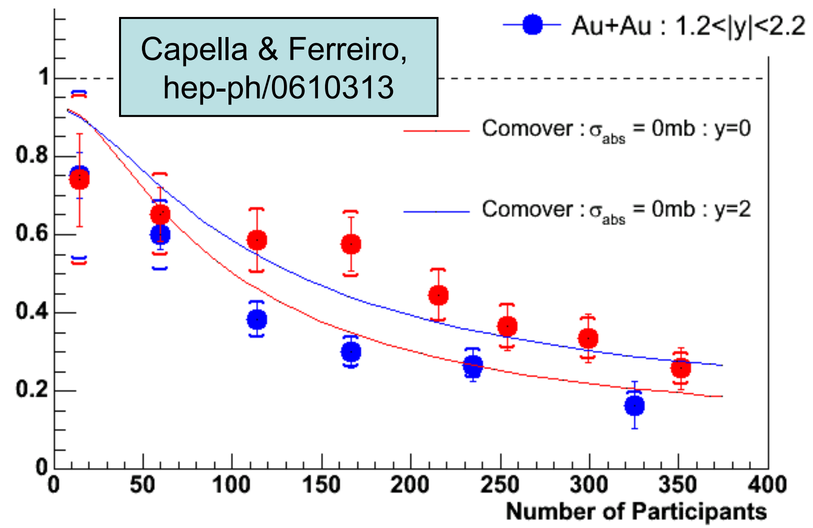


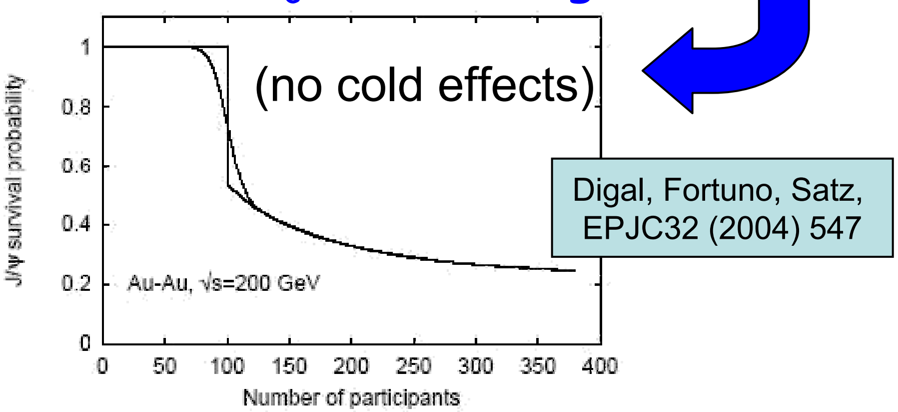
Then… What's going on with the anomalous suppression ?

"NA50 only" effects

- Most of the models that did a good job at SPS fail !
  - Gluon dissociation (y~0) doesn't give the right trend and/or amount of suppression
  - Comovers (of unknown partonic/hadronic nature) give $R_{AA}(y=2) > R_{AA}(y=0)$
  - Parton percolation has an onset at N_{part} ~ 90 and simultaneous $J/\psi + \chi_c + \psi'$ melting

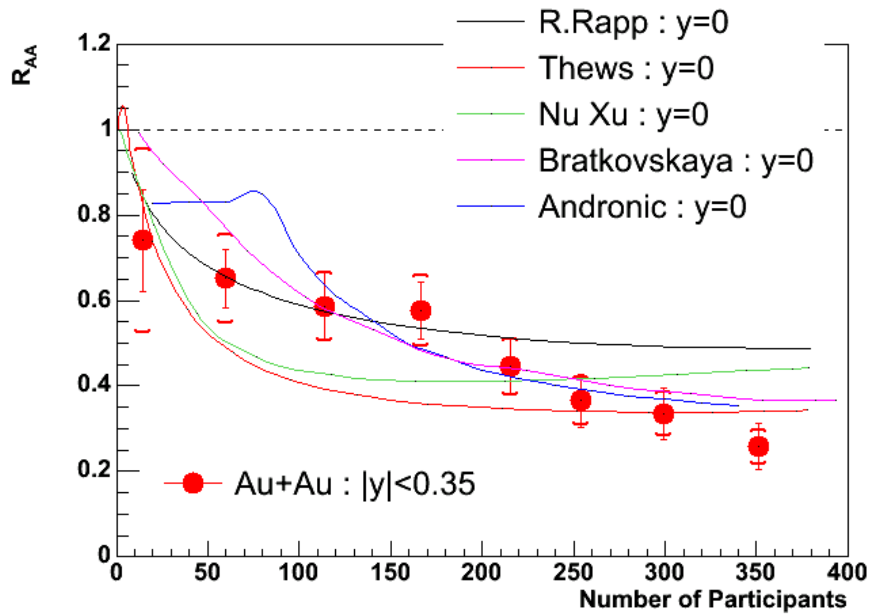






Regeneration ?

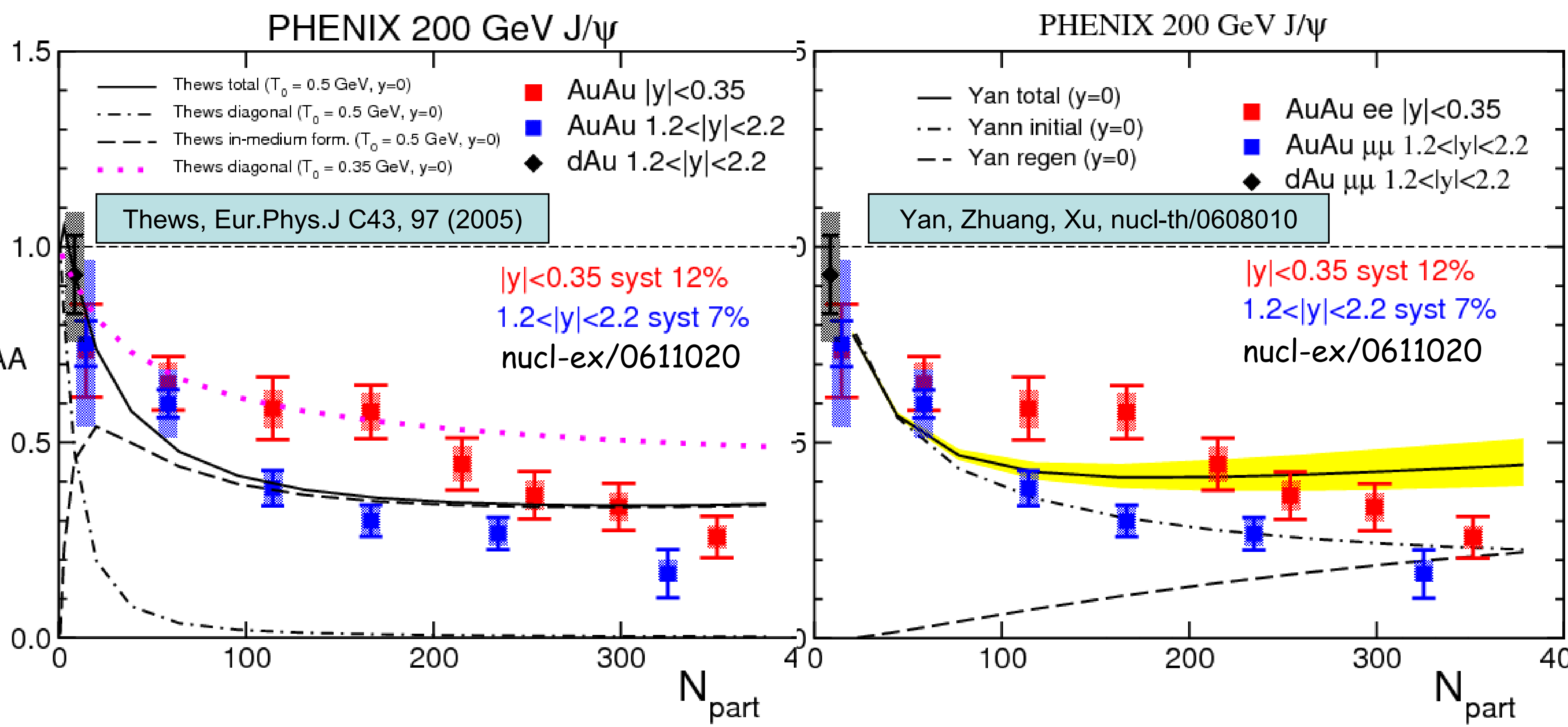
- Various coalescence / recombination approaches…
- Better match
  - (look in particular Bratkovskaya's)
- Depend a lot on poorly known cc reference
- But can accommodate
  - rapidity narrowing
  - $\langle p_T^2 \rangle$ flatness



R. Rapp et al.PRL 92, 212301 (2004)
R. Thews et al, Eur. Phys. J C43, 97 (2005)
Yan, Zhuang, Xu, nucl-th/0608010
Bratkovskaya et al., PRC 69, 054903 (2004)
A. Andronic et al., nucl-th/0611023

Veterans/newbies balance

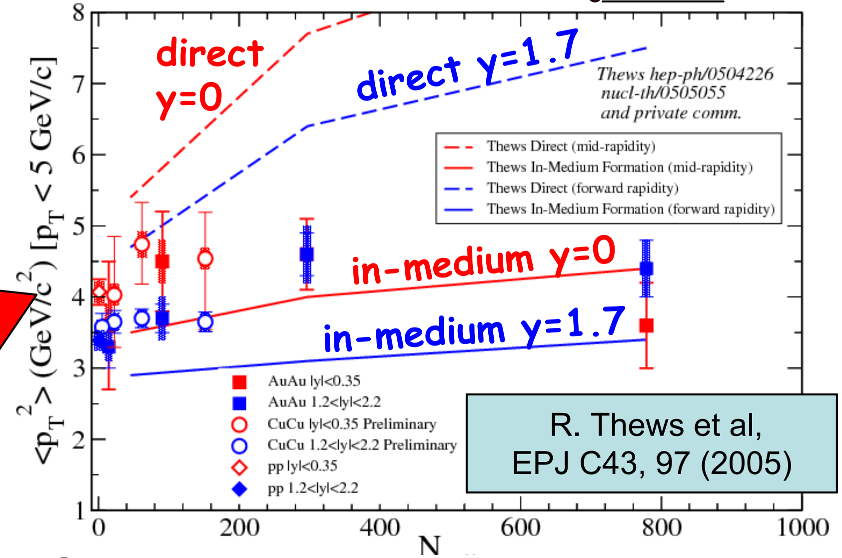
- Detailed shape is not easy to get!
- Experimental J/ψ keep falling down…



$\langle p_T^2 \rangle$ vs recombination ?

- Initial production depends a lot on initial p_T broadening (Cronin effect)
  - Earlier (run3) dAu/pp data showed clear broadening @y~1.7
  - Not clear with new (run5) pp data

used here



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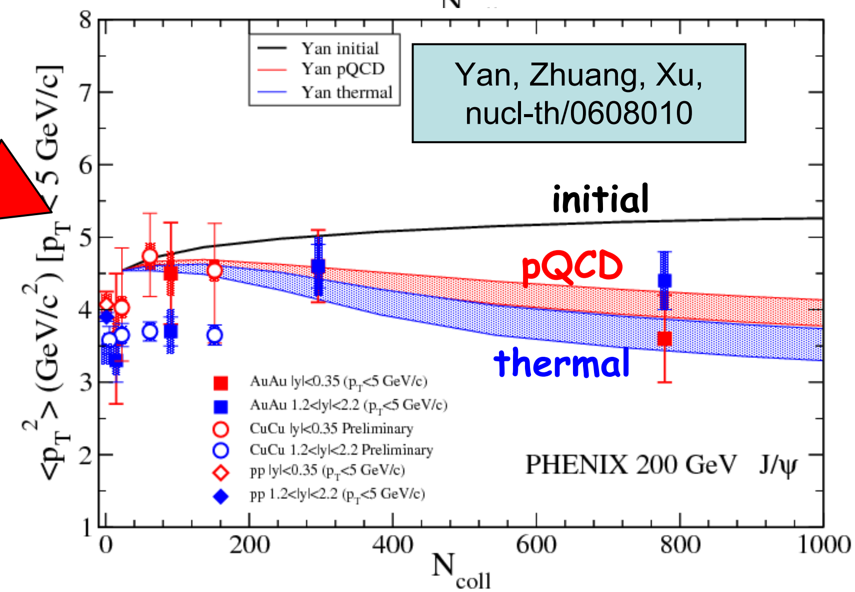


Sequential melting ?

- Before QM06, it was conceivable that only the excited states melt

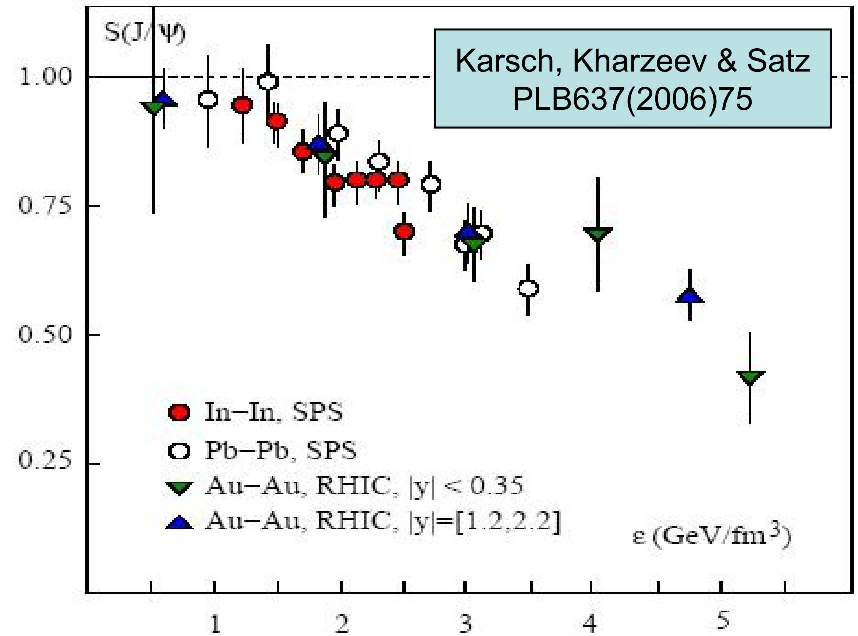
  $J/\psi \sim 0.6 J/\psi + 0.3\chi_c + 0.1\psi'$

  (with ~10% uncertainty)

- Now, survival = (25±12)%

  → direct J/ψ do melt @y~1.7 ?

- Why not/less @y~0 ?
- Isn't $R_{AA}(y\sim0) > R_{AA}(y\sim1.7)$ ruling out all "density" effects ?



Please, be careful with this plot !

- No systematic uncertainties on PHENIX points
- No uncertainties from CNM…
- ε is given by Bjorken formula for τ_0 = 1fm/c but is the formula applicable for SPS crossing time of 1.6 fm/c ?

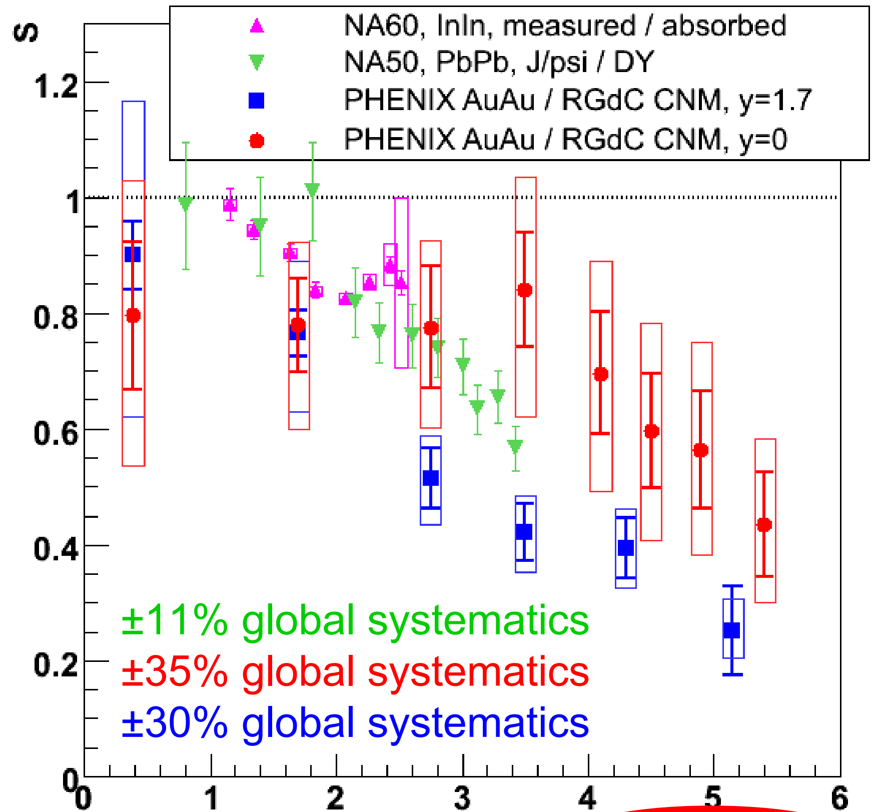
Sequential melting ?

- Before QM06, it was conceivable that only the excited states melt

  $J/\psi \sim 0.6 J/\psi + 0.3\chi_c + 0.1\psi'$

  (with ~10% uncertainty)
- Now, survival = (25±12)%

  → direct J/ψ melt @y=1.7
- Why not/less at y=0 ?
- Isn't $R_{AA}(y\sim0) > R_{AA}(y\sim1.7)$ ruling out all "density" effects ?



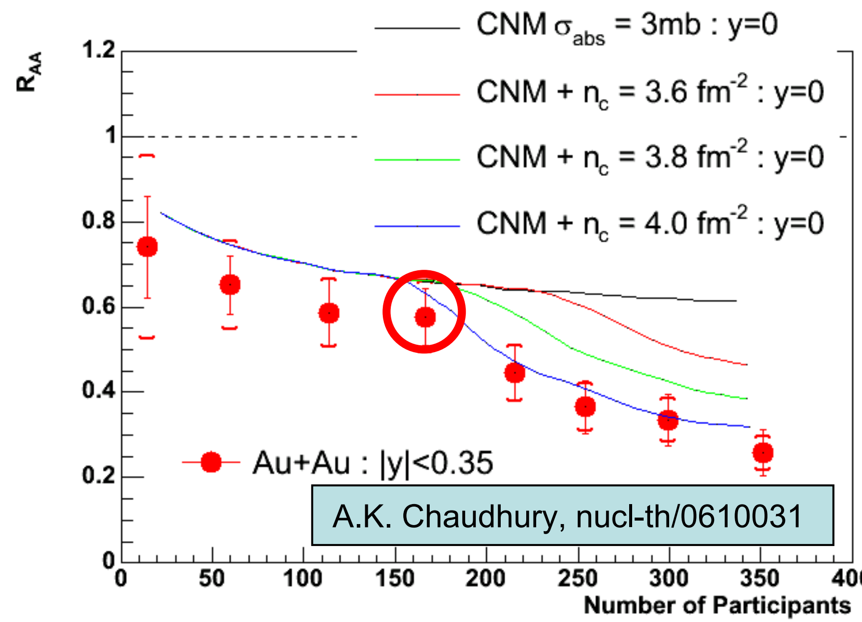
My version of this plot…

- Latest PHENIX results
- CNM from my Glauber model
- $\varepsilon \times \tau_0$ to label x-axis…

The picture is not clear at all !

Density threshold ?

- The shape of the preliminary data probably motivated a threshold approach
  - New data show little threshold (only the 4th point is high)
  - It worked only for AuAu @ y=0 (and not CuCu @ y=0 acc. to author)
  - What about y~1.7 ?

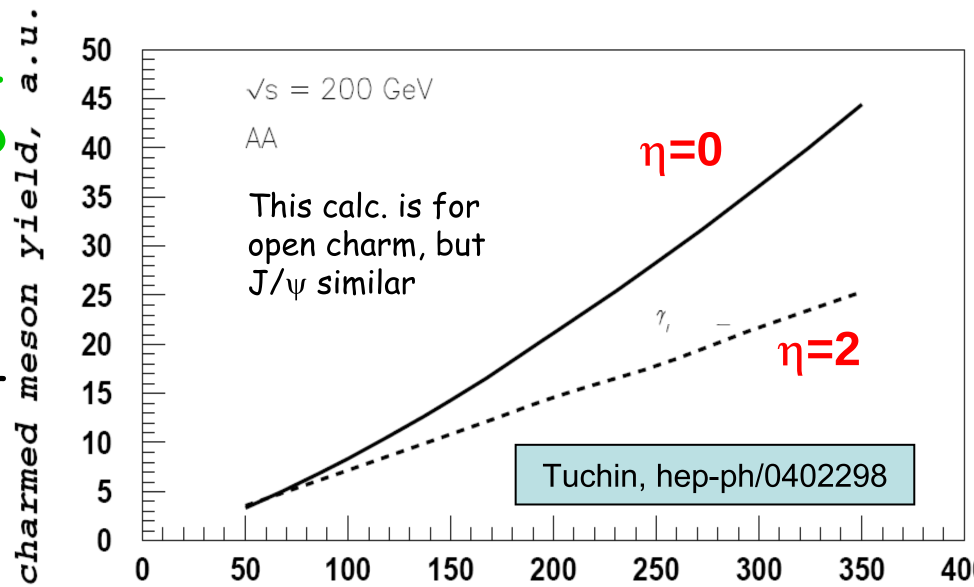


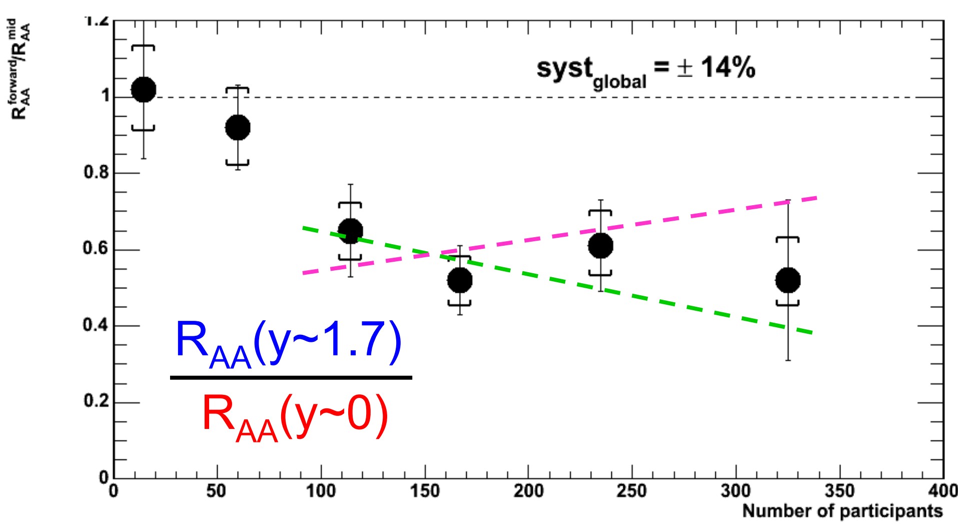
- Again, isn't $R_{AA}(y\sim0)$ > $R_{AA}(y\sim1.7)$ ruling out all "density" effects ?

Something else ?

- Strong initial states effect ala color glass condensate ?
  - But they have to violate rapidity symmetrisation RAA(|y|) = RdA(-y)xRdA(+y)
  - (otherwise taken into account in RGdC CNM)
- Could this + sequential melting produce $R_{AA}(y\sim0)$ and $R_{AA}(y\sim1.7)$?
- Double ratio should drop…

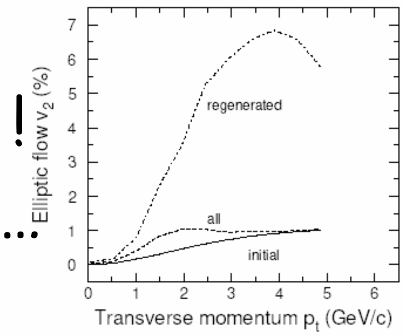
- If regeneration is responsible, shouldn't the double ratio fall too ?
  - (narrowing of rapidity)





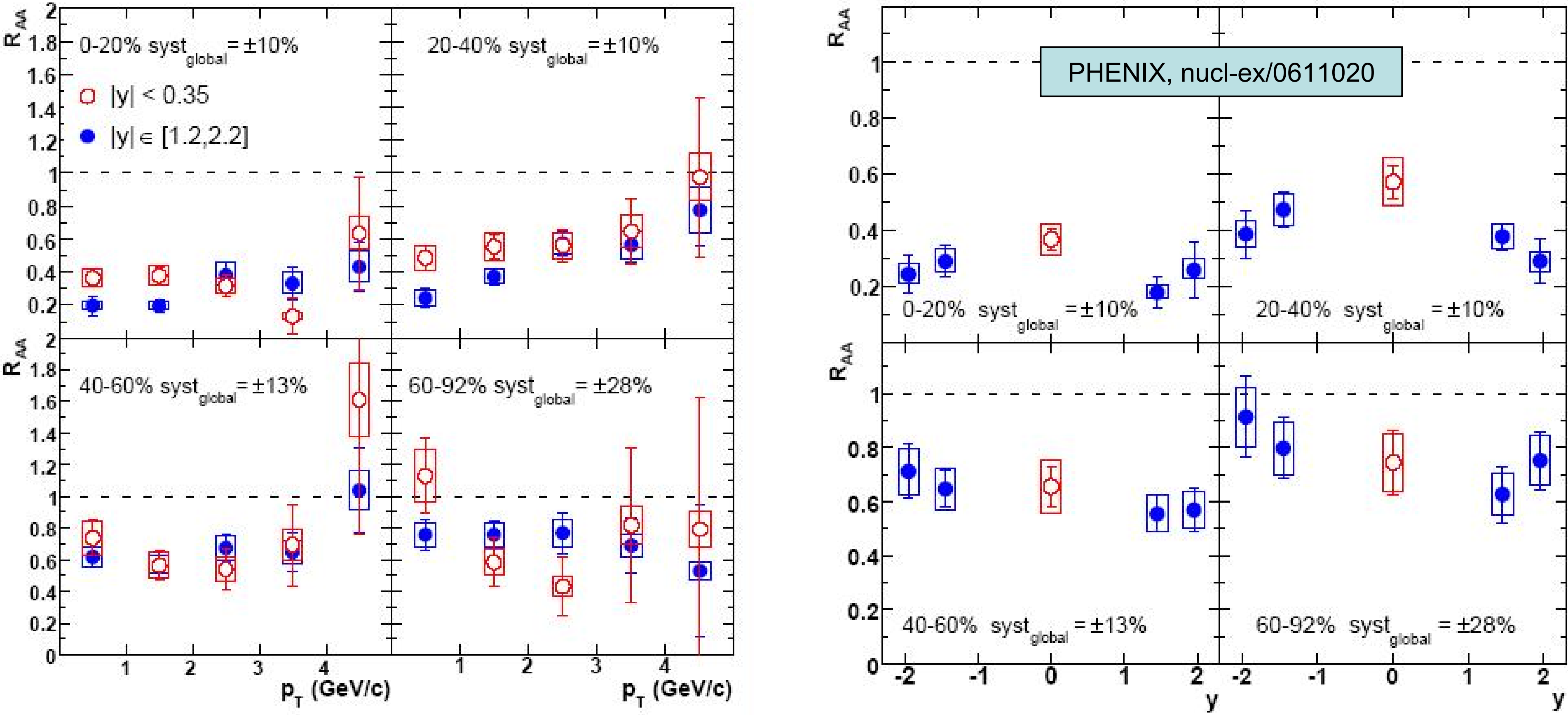
Conclusions

- Two qualitative possible scenarios
  1. Large melting + some regeneration
  2. Initial effects (CGC) + melting (of ψ', χ_c ?)
     - Need better handle of CNM
     - Need better open charm measurements !
     - Smoking gun would have been a J/ψ rise…
     - v_2 could become the smoking gun
       - (maybe run7 with 4 x run4 and reaction plane detector)



- Data is young, new ideas may arise…

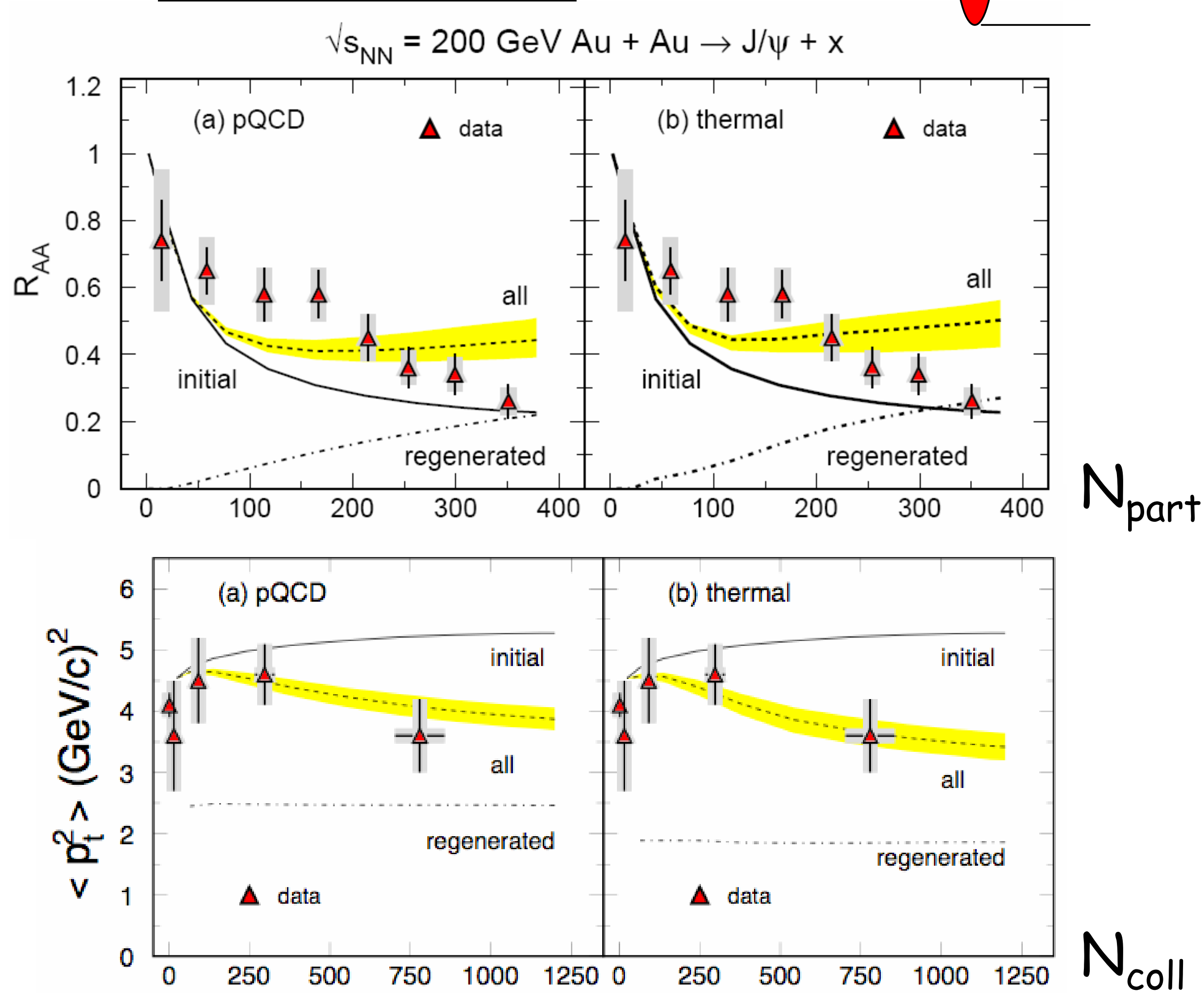
Back to the facts



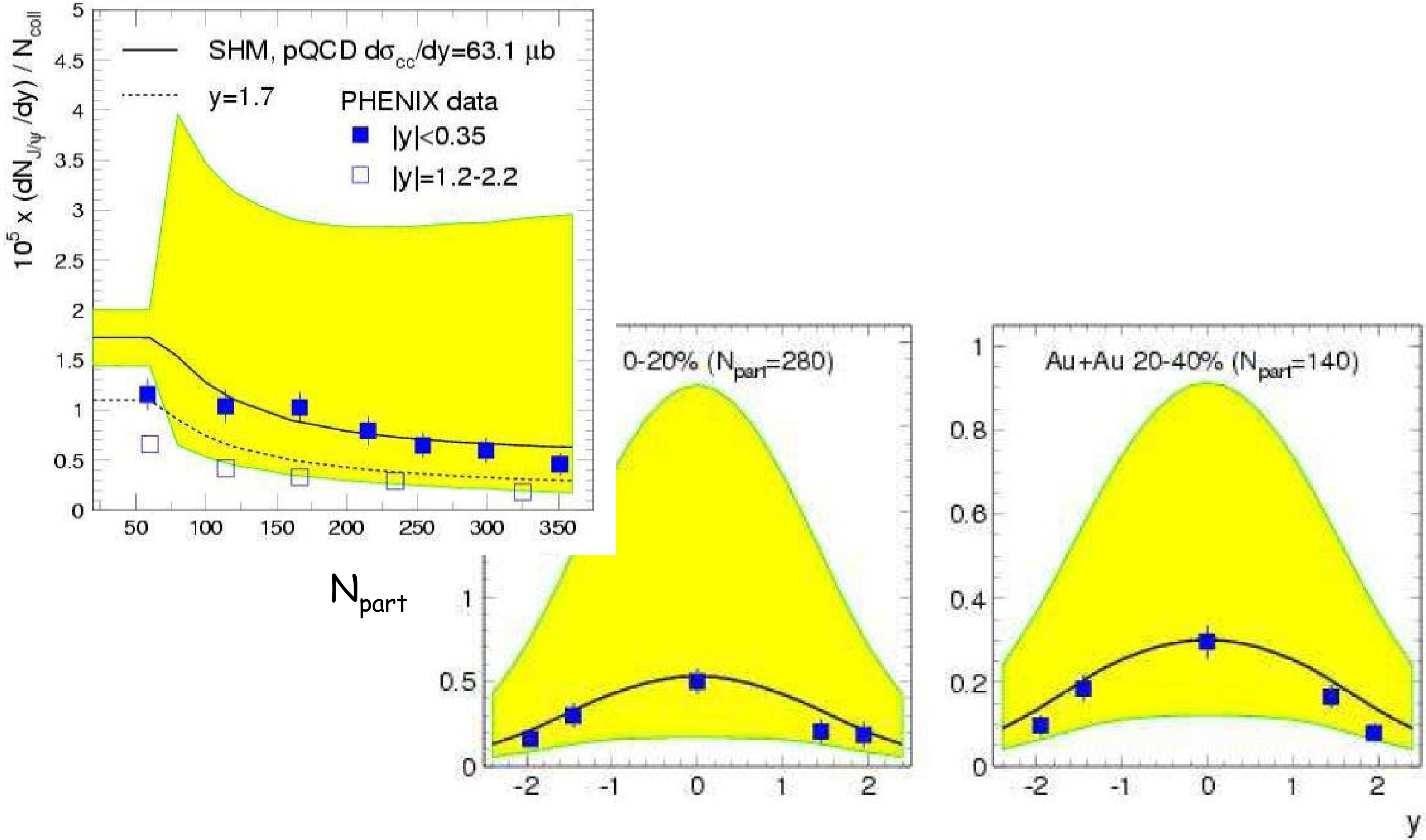
- Should help constraint the models…

Back-up slides

Details from Pengfei's talk

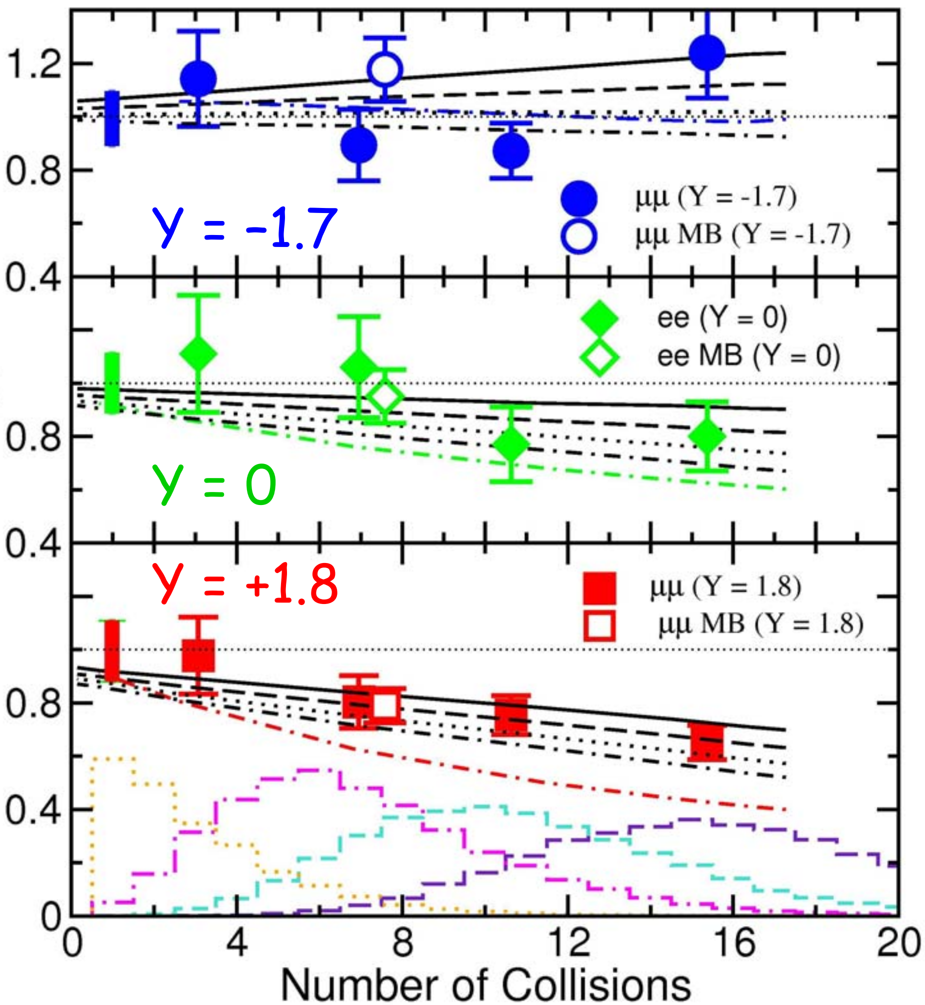


Details from Peter's talk



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

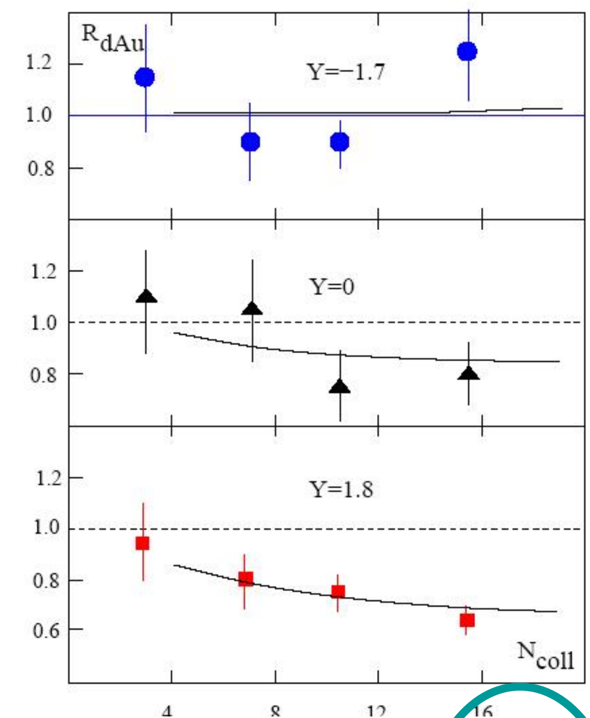
From dA to AA @ RHIC

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…



$$\sigma_{\rm diss}(y=1.8) = 3.1 \pm 0.2 \text{ mb}$$

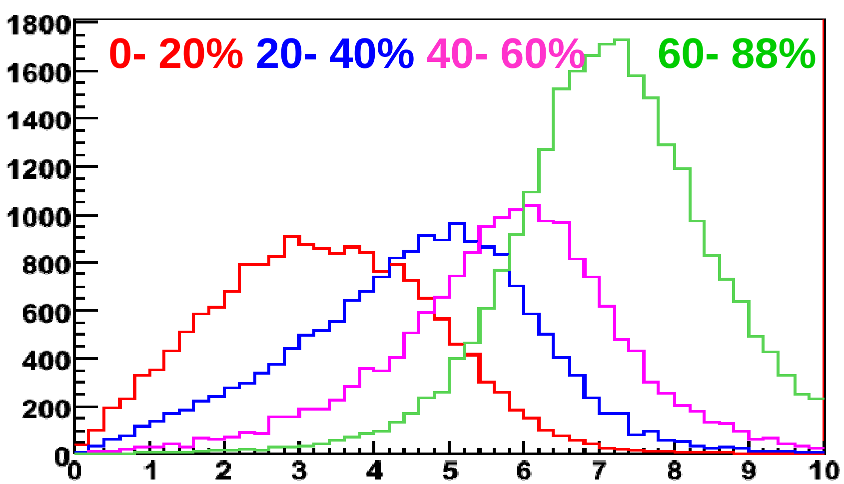
$$\sigma_{\rm diss}(y=0) = 1.2 \pm 0.4 \text{ mb}$$

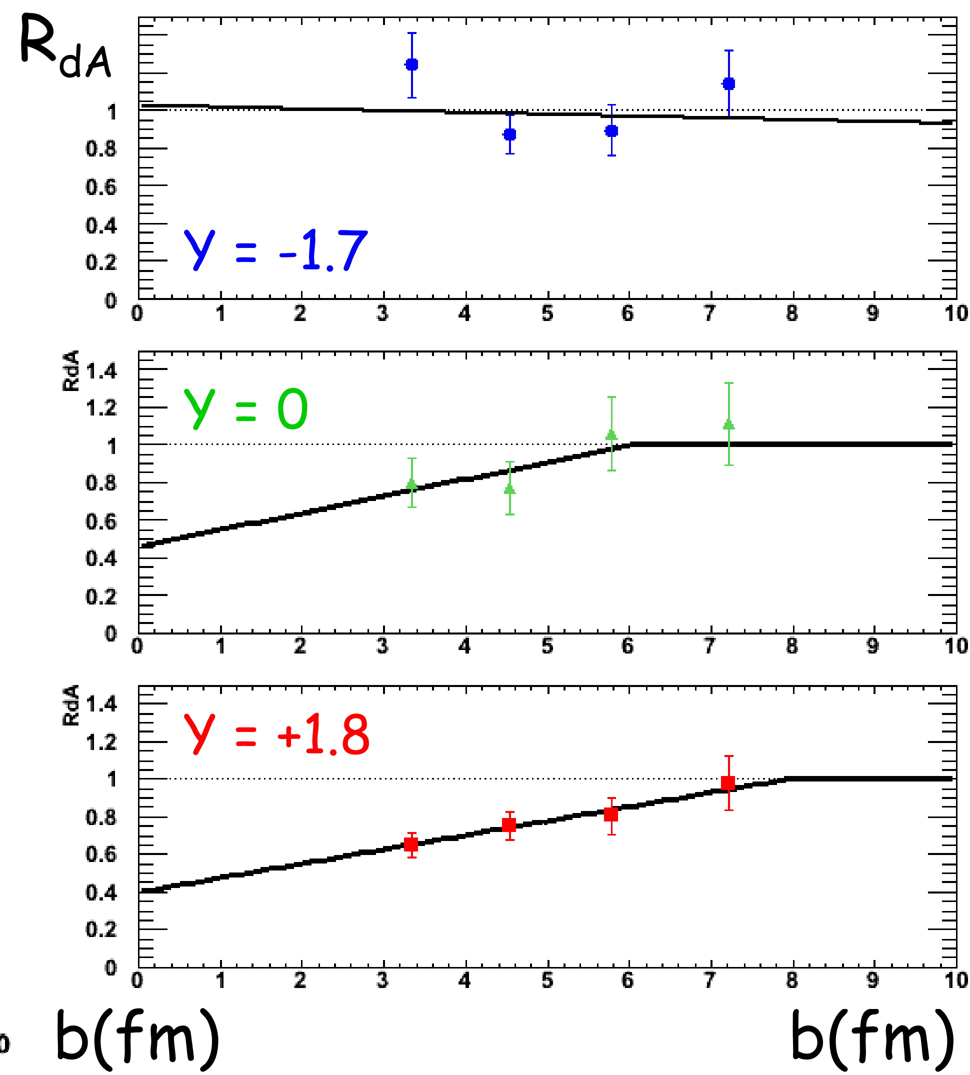
$$\sigma_{\rm diss}(y=-1.7) = -0.1 \pm 0.2 \text{ mb}$$

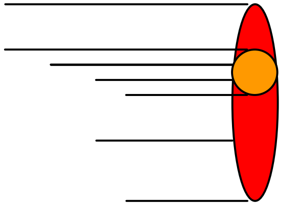
KKS, PLB637(2006)75

R_{dA} vs impact parameter b

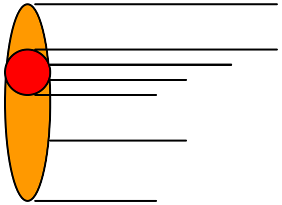
- Re-plot PHENIX R_{dA} vs impact parameter b from Glauber model
- Phenomenological fit to $R_{dA}(b)$ →
- Cut off RdA=1 at high b
  - Physically expected
  - OK for an upper bound of CNM



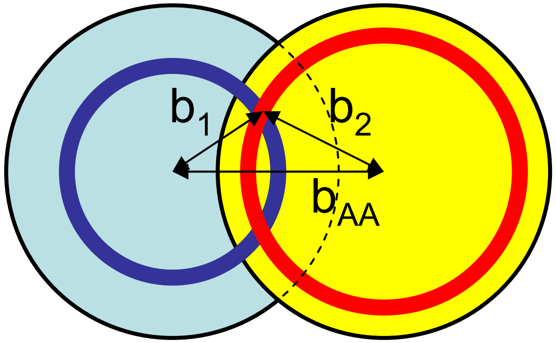




Plugged in Glauber model

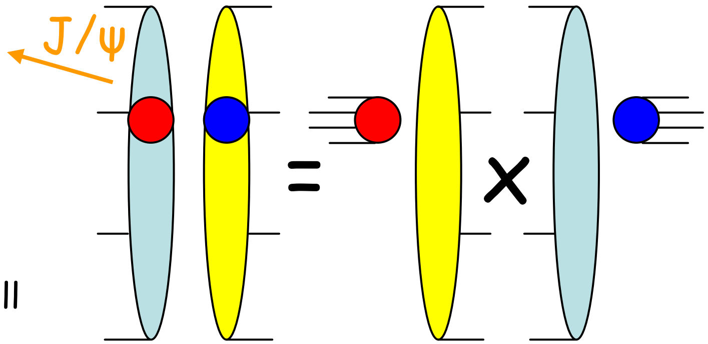


- Glauber provides, for a given A+A collision at b_{AA}, a set of N+N collisions occurring at b^i_1 and b^i_2.



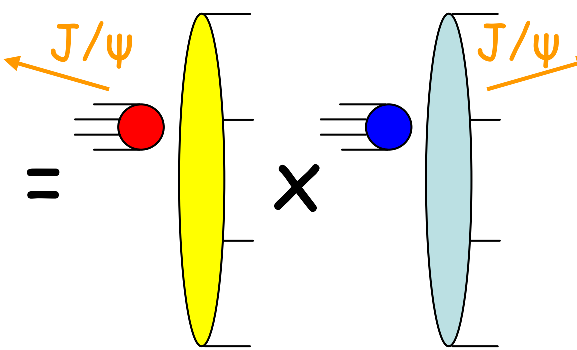
- One minimal assumption is rapidity factorization: $R_{AA}(|y|,b_{AA}) =$

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

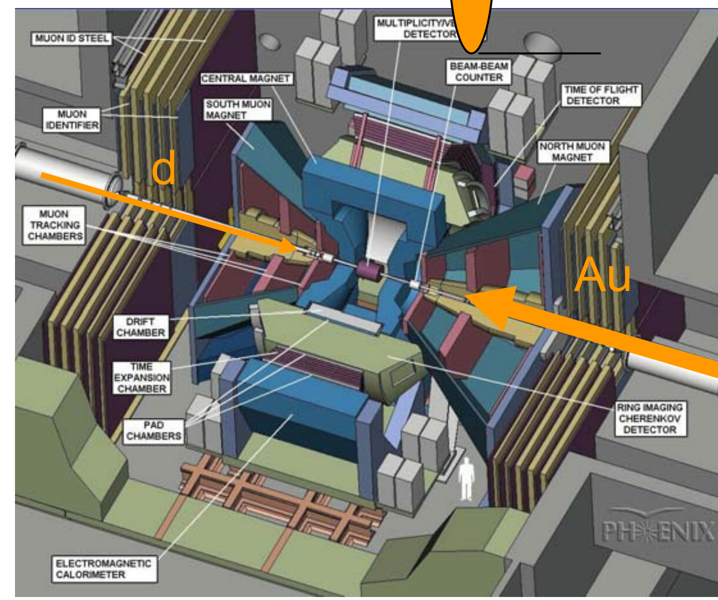


- Works (at least) for absorption & shadowing since production

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

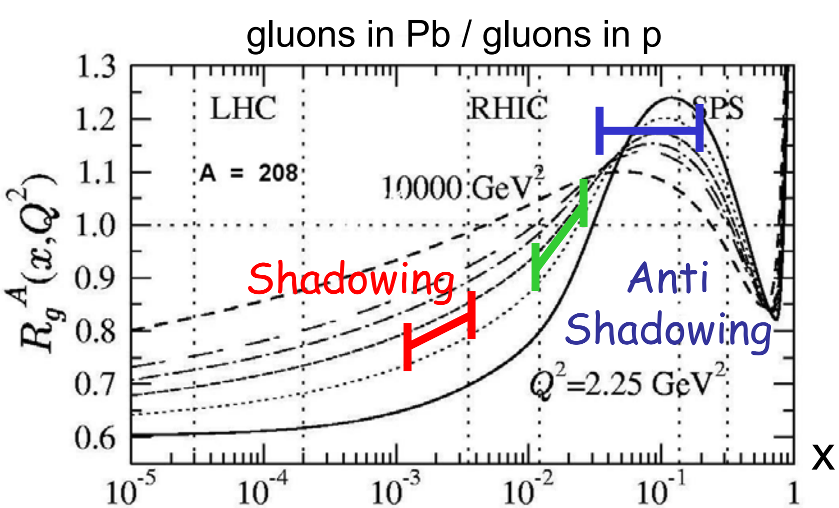


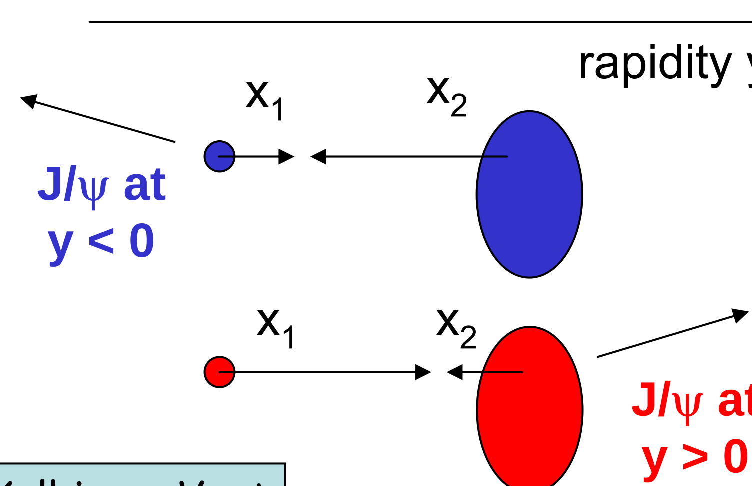
Deuteron → ← Gold



- 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 ~ 0) : intermediate x_2 ~ 0.020
  - North (y > 1.2) : small x_2 (in gold) ~ 0.003

An example of gluon shadowing prediction

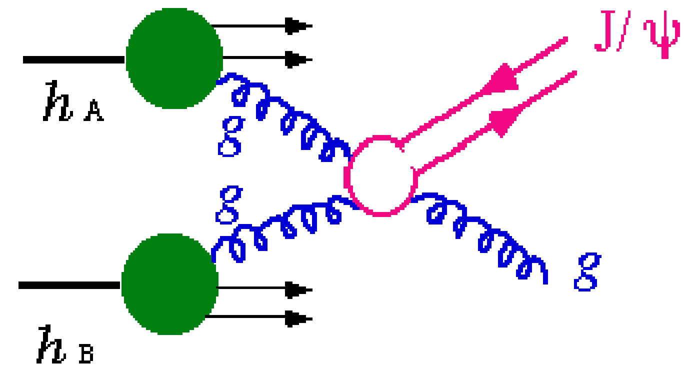




Eskola, Kolhinen, Vogt
NPA696 (2001) 729

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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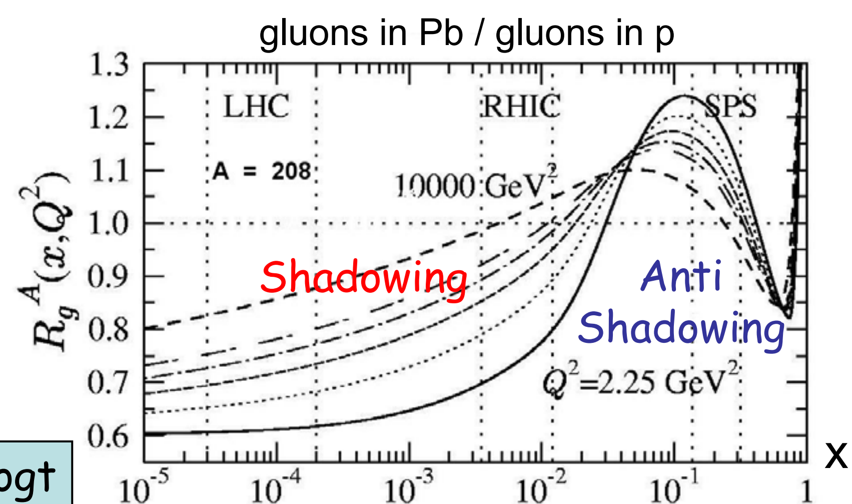

Eskola, Kolhinen, Vogt
NPA696 (2001) 729

Cold nuclear matter effects ?

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

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