Quarkonia production at PHENIX

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RHIC-AGS Users Meeting Workshop 6
Heavy Flavor and Quarkonia Production
June 20, 2007

J/ψ in the medium

Charm quarks are produced in hard scatterings at the early stages of collision, and interact with the collision medium, thus providing information about the properties of this medium.

- main production mechanism: gluon fusion
  - sensitive to initial state gluon density

- in nucleus-nucleus collisions:
  - cold nuclear matter effects
    - nuclear absorption, shadowing/anti-shadowing, Cronin effect...
  - suppression due to Debye color screening
  - regeneration at later stages of collision

- feed-down from higher mass resonances (ψ' ~10% and χ_C ~30%)

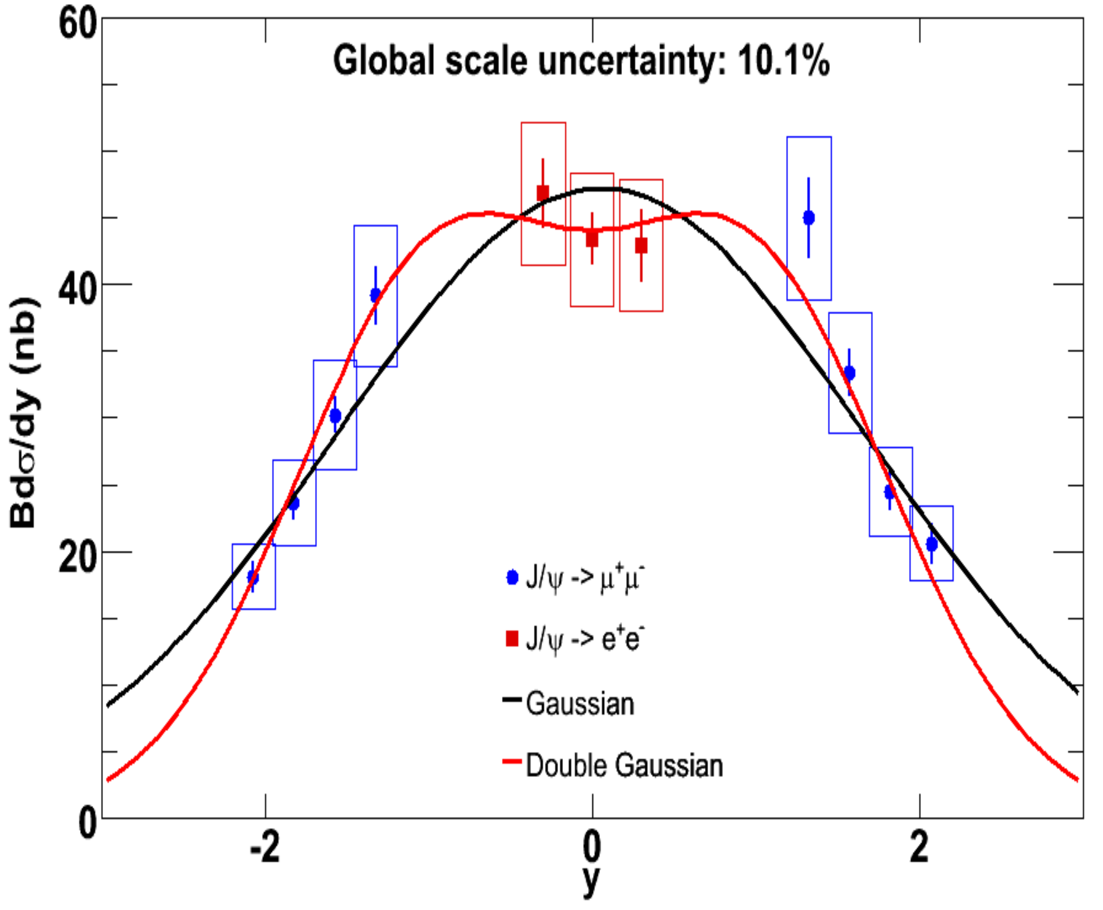
<u>need systematic study: *A*, P_T, *y*, *centrality*, $\sqrt{s}$ ...</u>

J/ψ and PHENIX

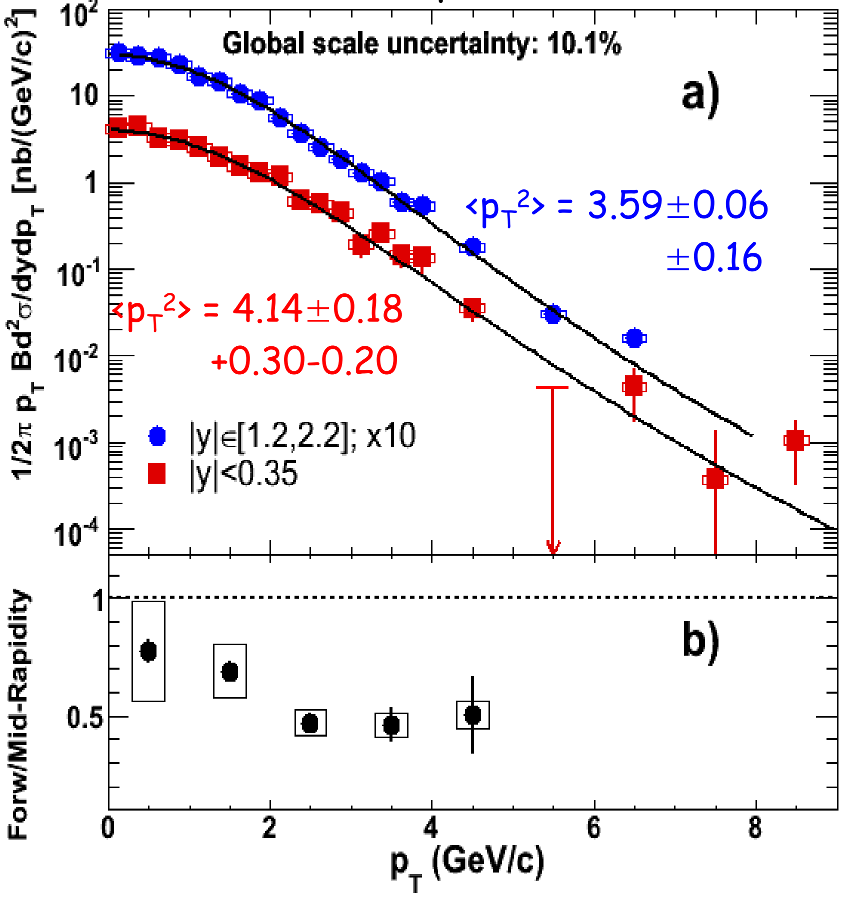
The PHENIX Experiment has excellent ability to measure quarkonia.
In di-electron channel at mid-rapidity $|\eta|<0.35$
In di-muon channel at forward/backward rapidity $1.2<|\eta|<2.2$.

Run	Ions	Luminosity	J/ψ (ee + mm)	Status	
3	dAu @ 200 GeV	2.74 nb-1	360 + 1700	PRL 96, 012304 (2006)	
4	AuAu @200 GeV	241 μb^{-1}	1000 + 4500	PRL 98, 232301 (2007)	NEW!
5	CuCu @200 GeV	4.8 nb-1	2300 + 10000	Preliminary	
5	pp @ 200 GeV	3.8 pb-1	1500 + 8000	PRL 98, 232302 (2007)	NEW!
6	pp @ 200 GeV	10.7 pb-1		Analysis in progress	
7	AuAu 2 200 GeV	~750 μb-1		Data taking	

Baseline measurement



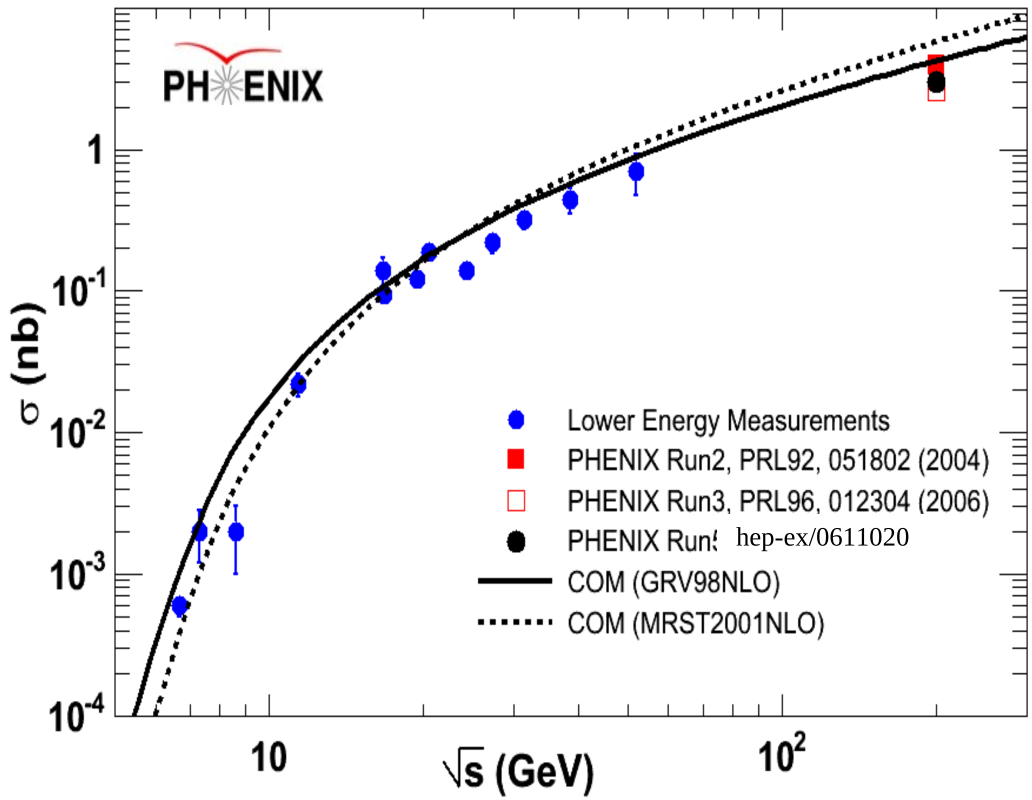
PHENIX - hep-ex/0611020

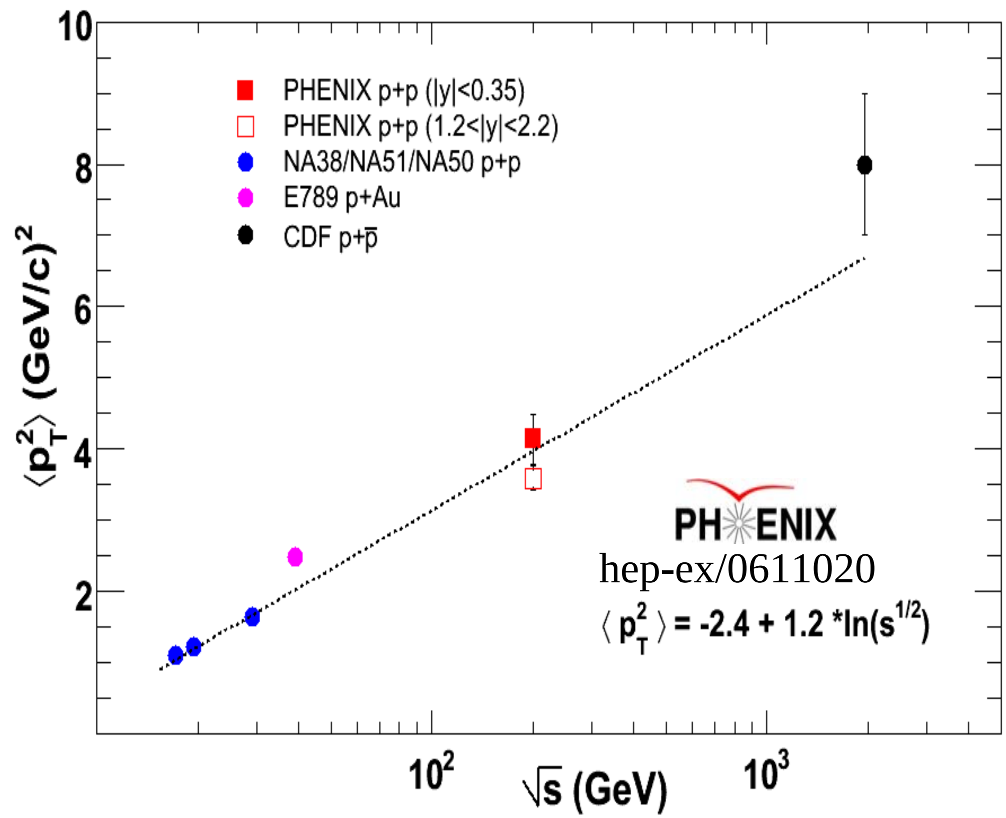


Accuracy is now limited by systematic error.
New run5 data slightly favors flatter shape at mid-rapidity.

Forward rapidity spectra are softer than at mid-rapidity

Comparison to lower energies





Consistent with COM, but unable to differentiate between pdf's

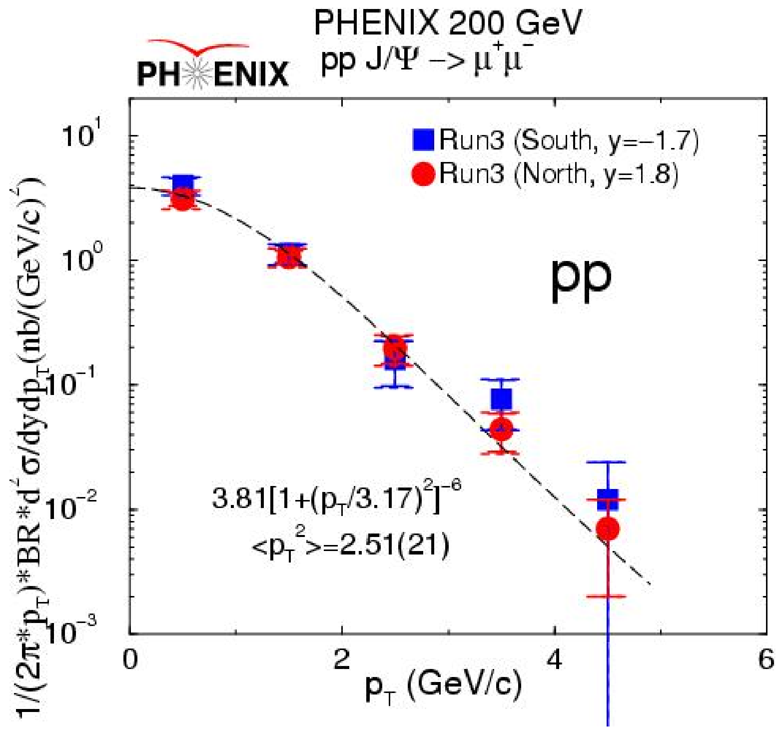
Linear dependence on ln(s)

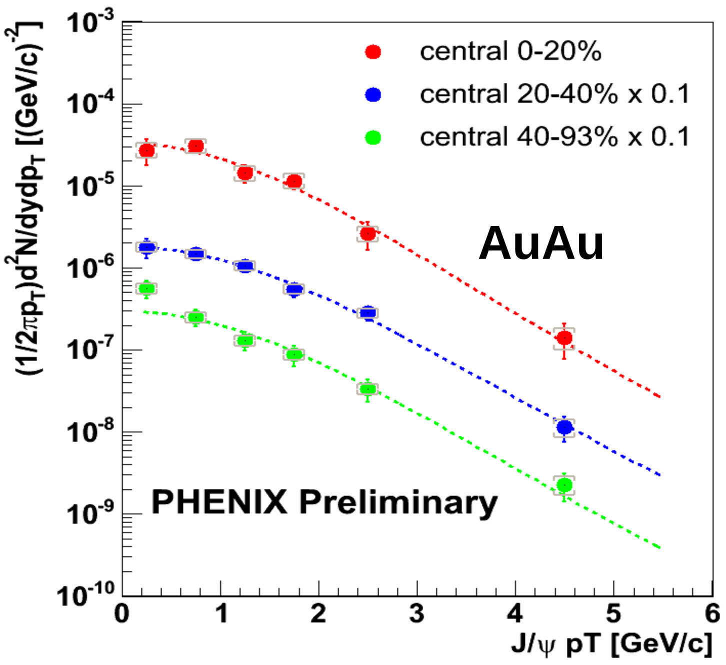
Nuclear modification factor R_{AA}

$$R_{AA} = \frac{d^3N_{J/\psi}^{AuAu}/dp^3}{d^3N_{J/\psi}^{pp}/dp^3 \times \langle N_{coll}\rangle}$$

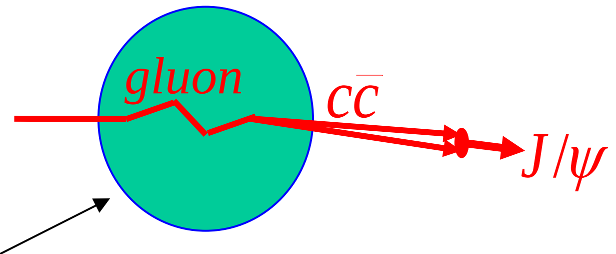
N_{COLL} is calculated by Glauber model

$R_{AA} = 1$ if no nuclear effects



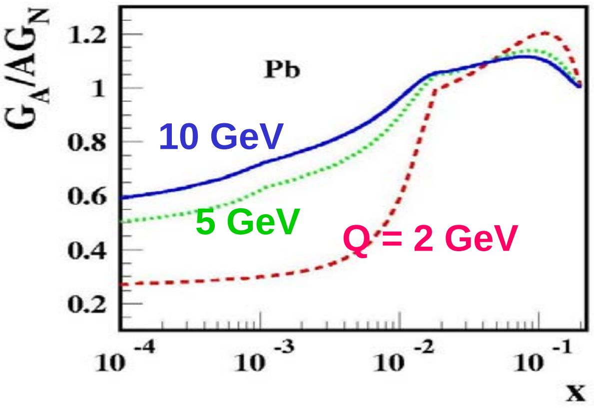


Understanding cold nuclear matter effects



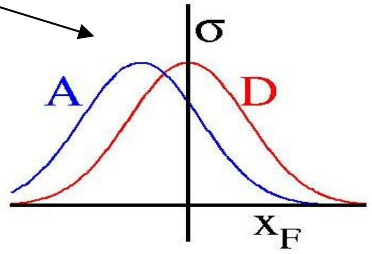
Interaction in medium

- absorption (dissociation) of J/ψ
- gluon multiple scattering in initial state (Cronin effect) resulting in P_T broadening

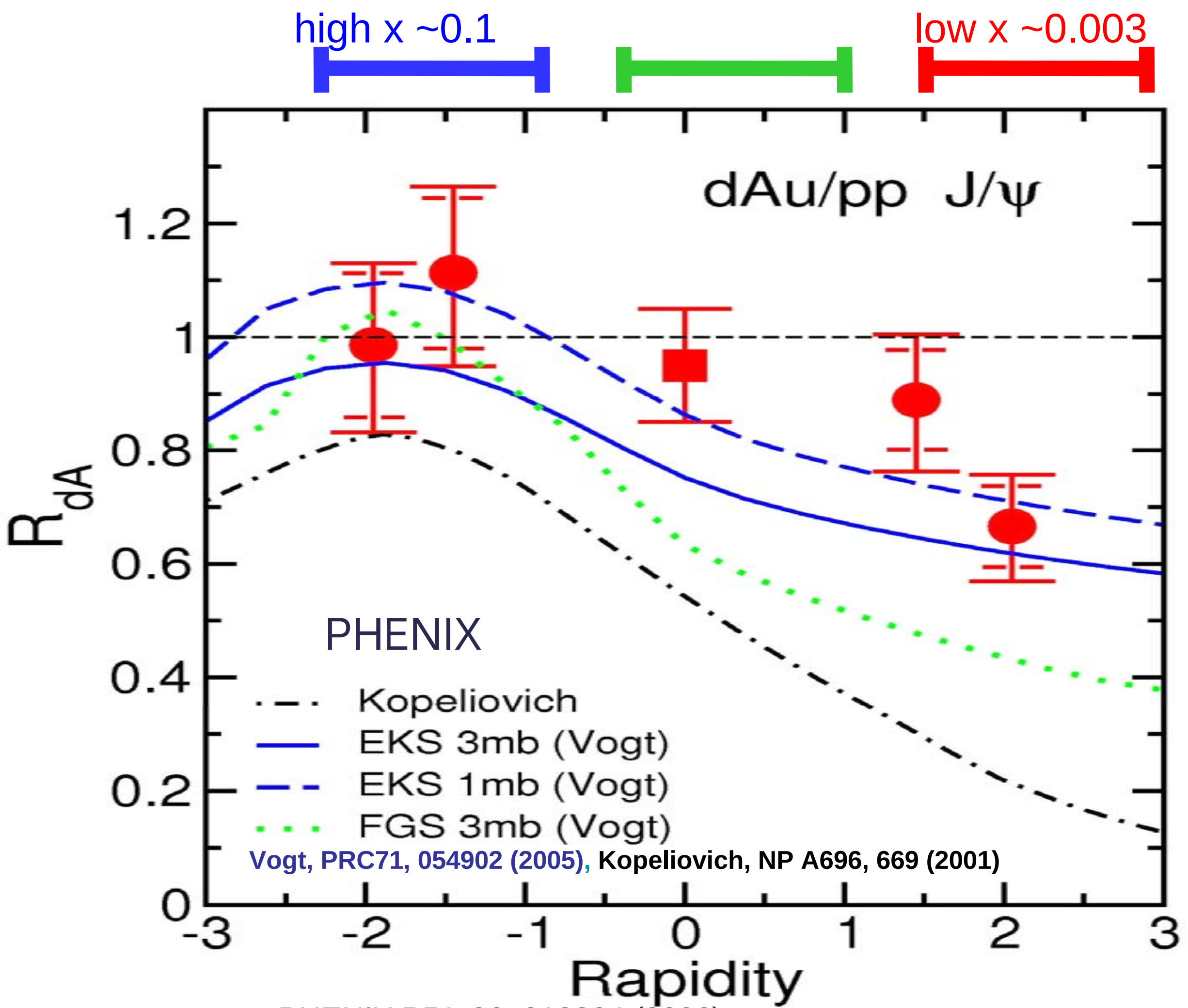


Modification of gluon pdf

- shadowing: depletion of low momentum gluons (and anti-shadowing at high x)
- gluon energy loss in initial state (shift in x_F resulting in suppression)
- gluon saturation at low x: Color Glass Condensate



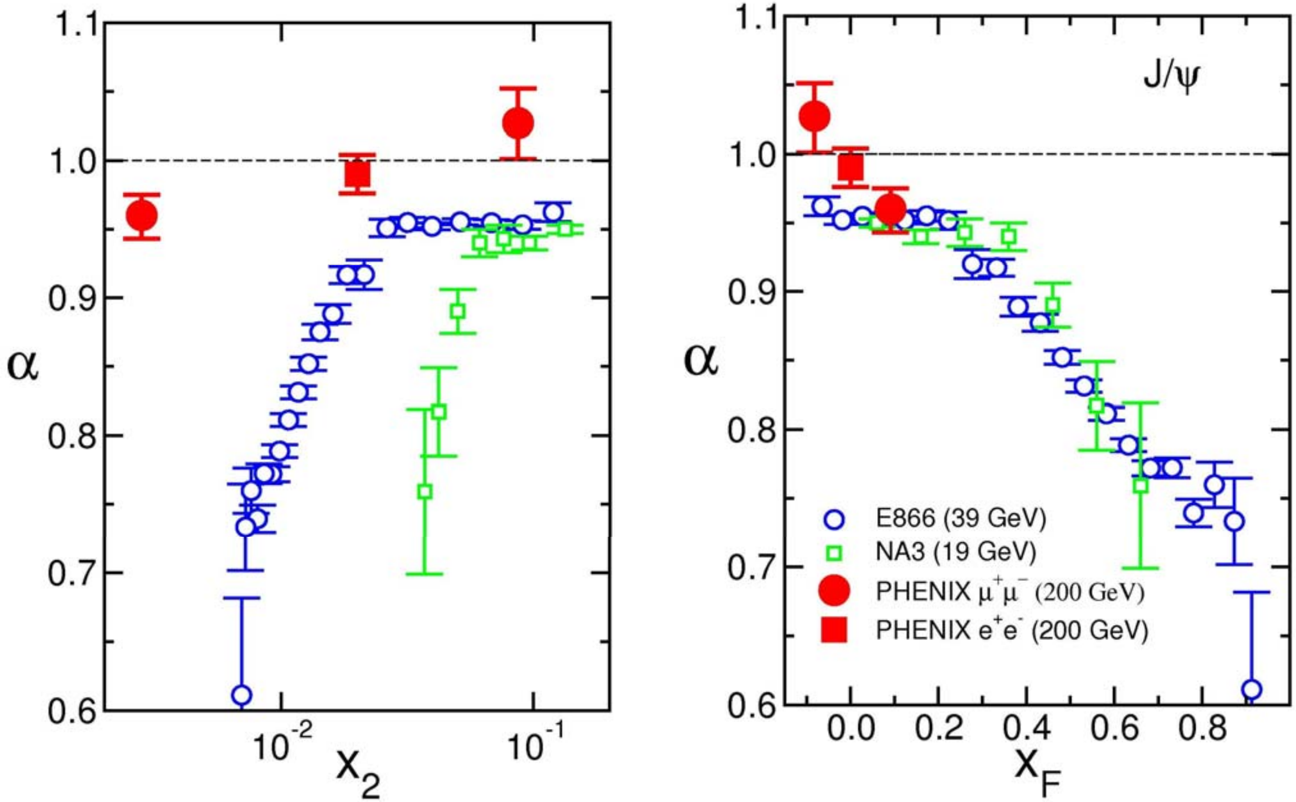
R_{dAu} vs rapidity



PHENIX PRL 96, 012304 (2006)

Shadowing: slope; Absorption: overall scale;
PHENIX data are compatible with weak shadowing and weak absorption
NEED MORE STATISTICS!

Nuclear dependence scaling

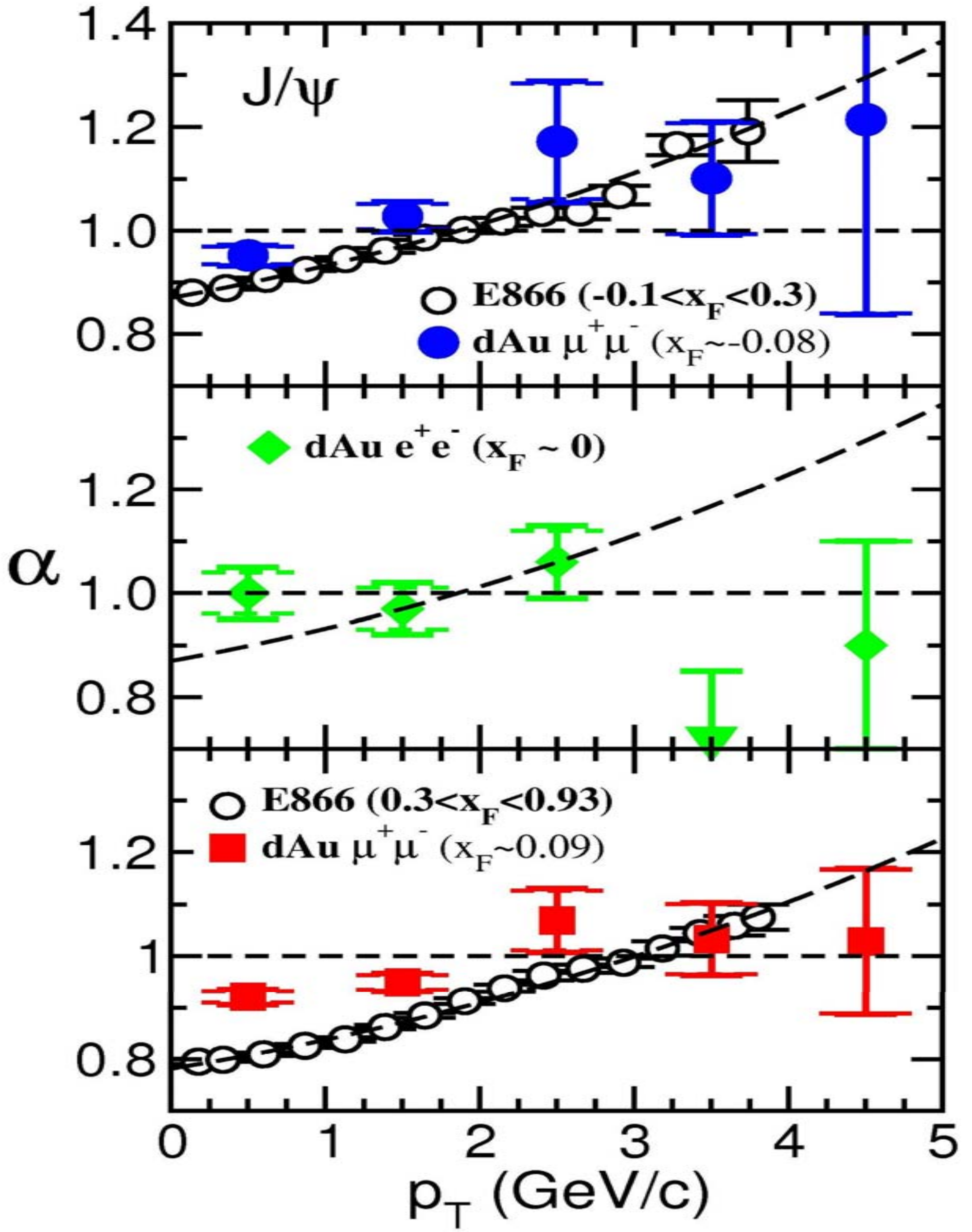


$$\sigma_{dA} = \sigma_{pp}(2x197)^{\alpha}$$

$x_F = 2p_Z/\mathrm{sqrt}(s)$
$x_1 = 0.5(x_F+\mathrm{sqrt}(x_F{}^2+4\tau))$
$x_2 = x_{Au} = x_1 - x_F$

Shadowing predicts scaling with x_2
Scaling with x_F instead.
- Initial state gluon energy loss?
- Sudakov form factor? $\sim(1-x_F)$

P_T broadening



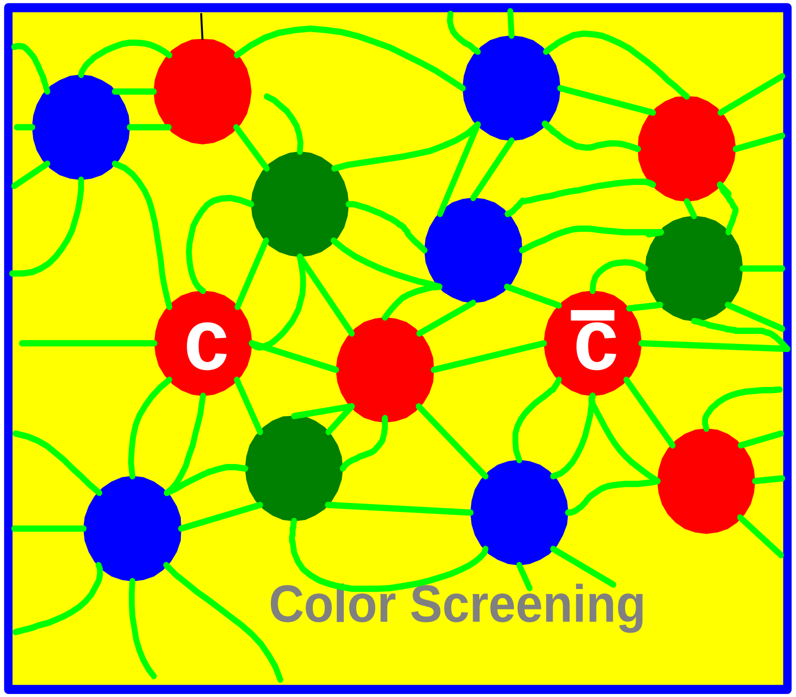
x ~0.1

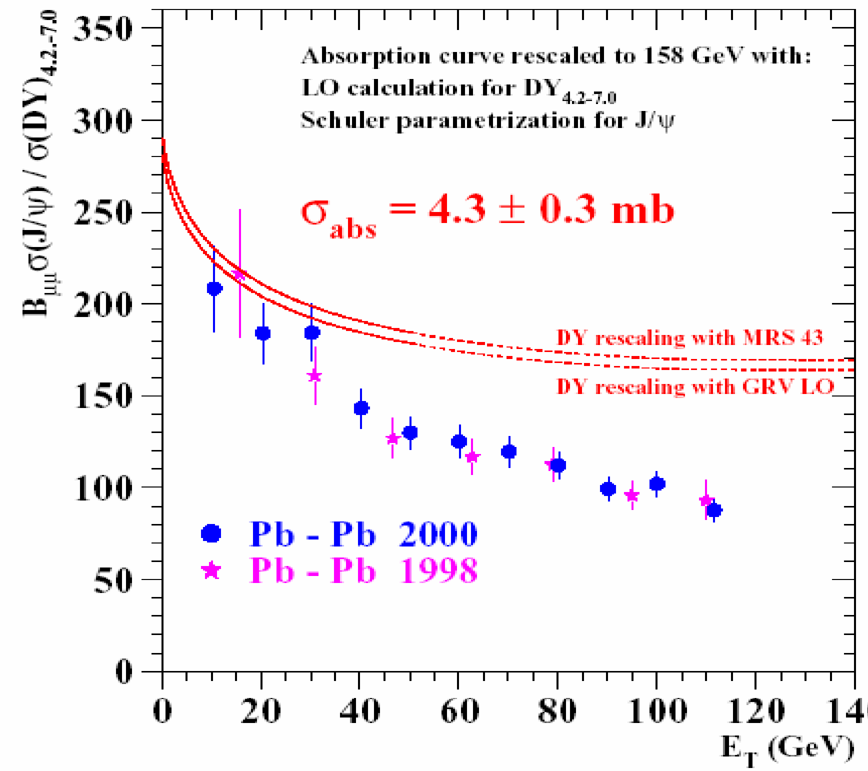
P_T broadening at RHIC comparable to that at lower $\sqrt{s}$ = 39 GeV

x ~0.003

J/ψ in AuAu collisions

Debye color screening predicted to destroy J/ψ's in a QGP



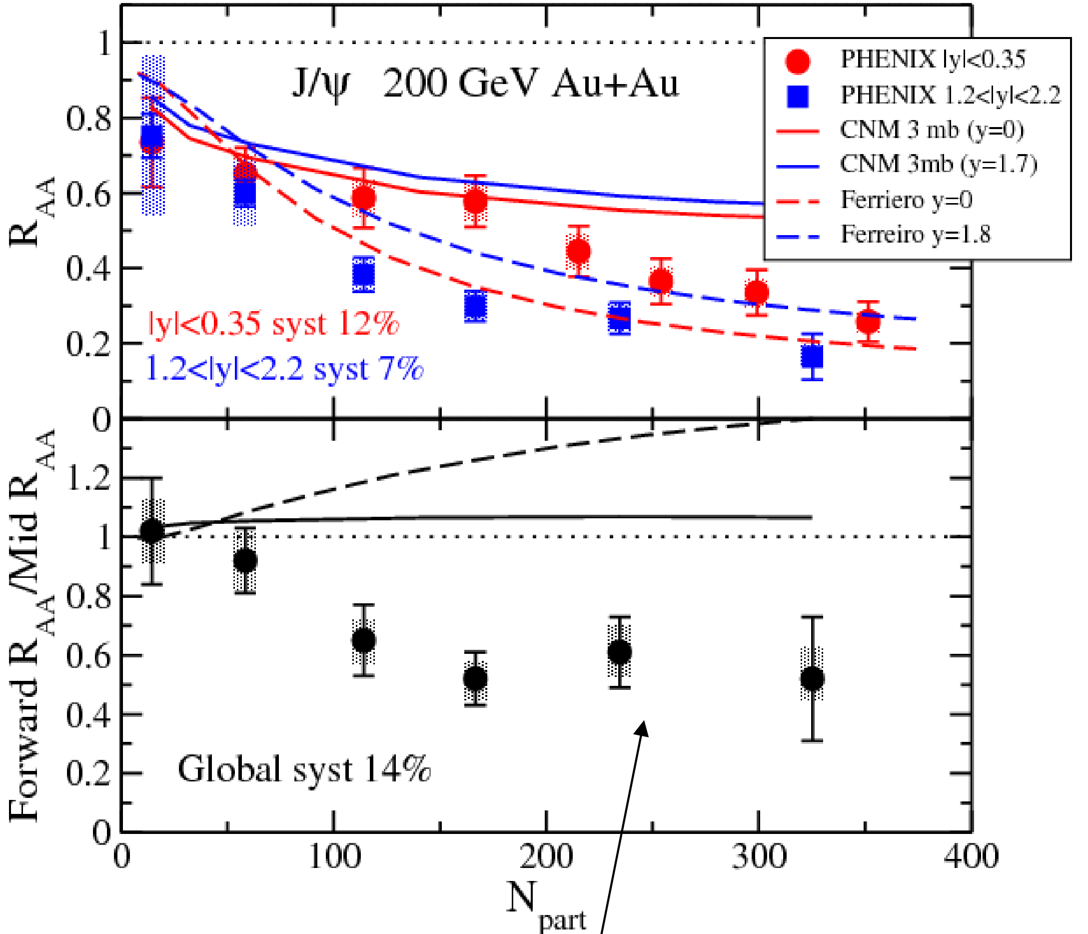


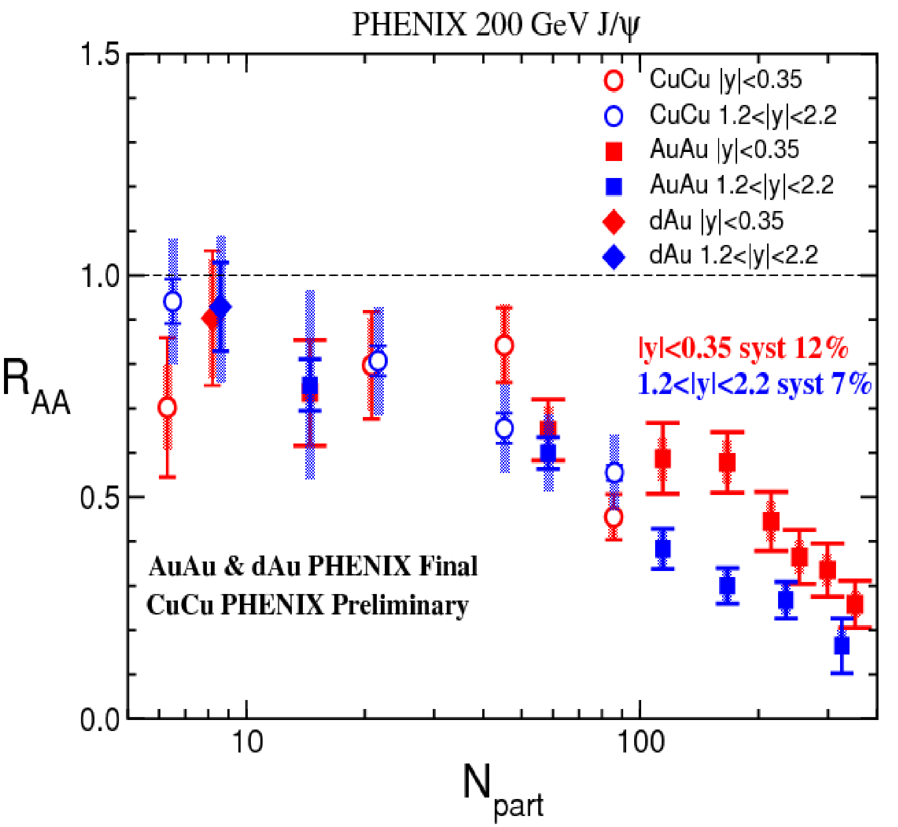
At RHIC energies the situation is more complicated:

- 2-3 times larger gluon density:
  recombination due to high density of charm quarks
- Recent lattice calculations: J/ψ not screened at all?
  suppression due to feed-down from higher mass resonances.

R_{AA} in heavy ion collisions

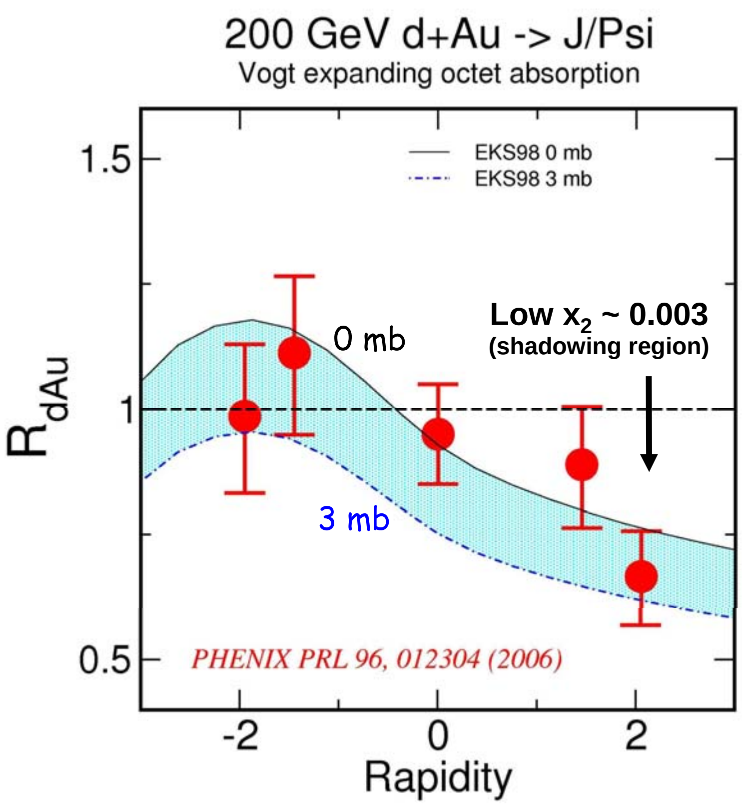
Suppression to ~0.2-0.3 in most central AuAu collisions.
Forward/Backward suppression stronger than at mid-rapidity

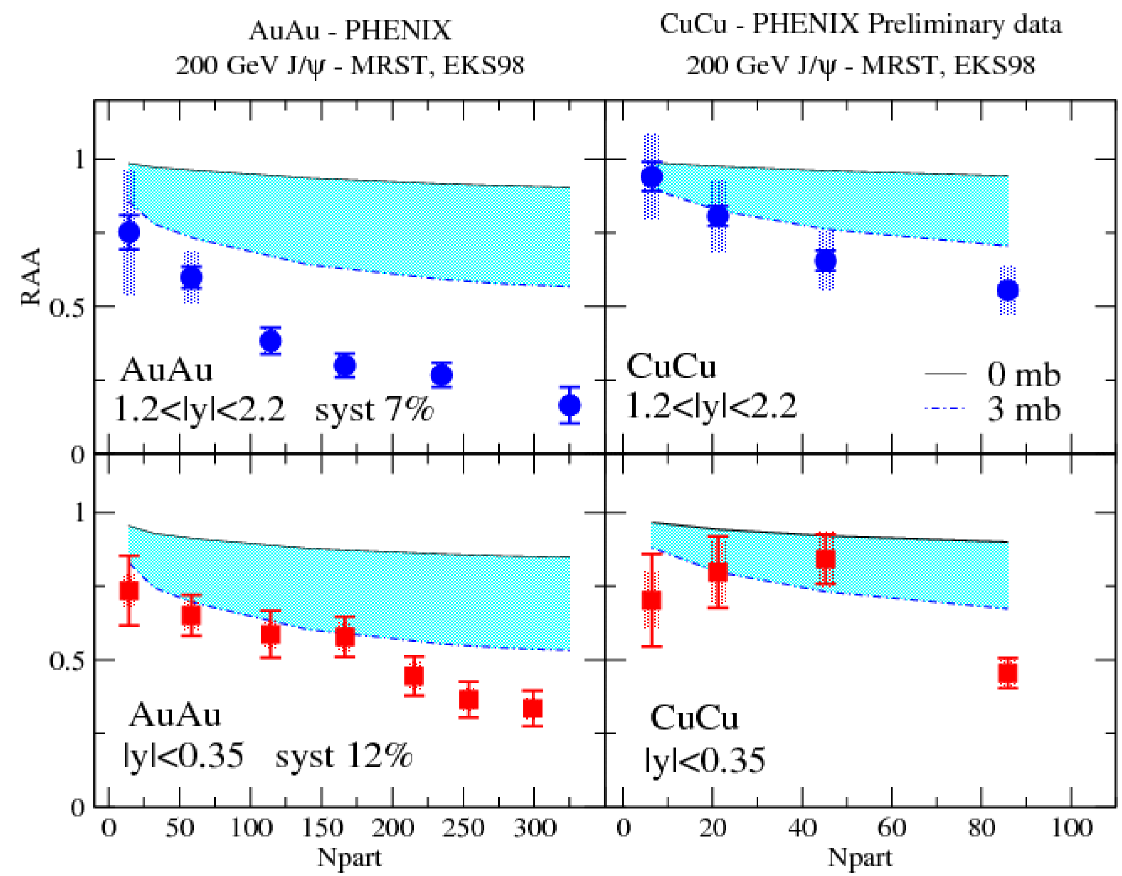




Saturation at N_{PART}>100?

AuAu vs dAu: cnm effects





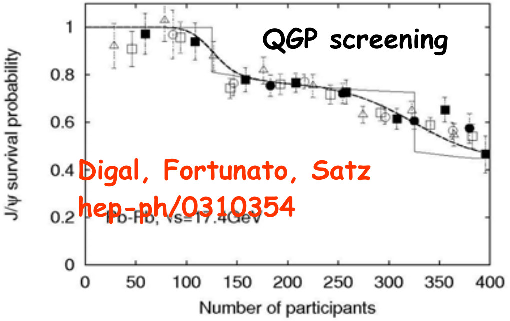
cnm calculation with absorption and shadowing limits σ_{abs}< 3mb

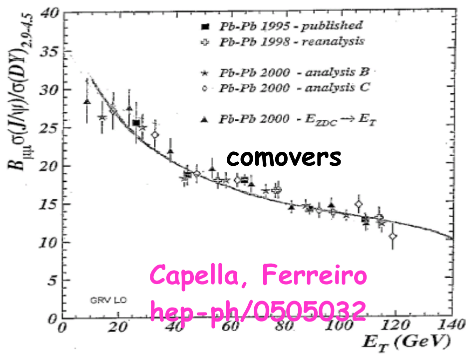
R. Vogt, nucl-th/0507027

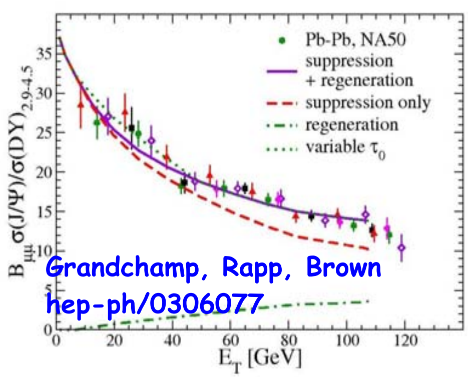
In AuAu suppression is stronger than cnm effects, especially at forward rapidity and most central collisions, but we need better dAu statistics

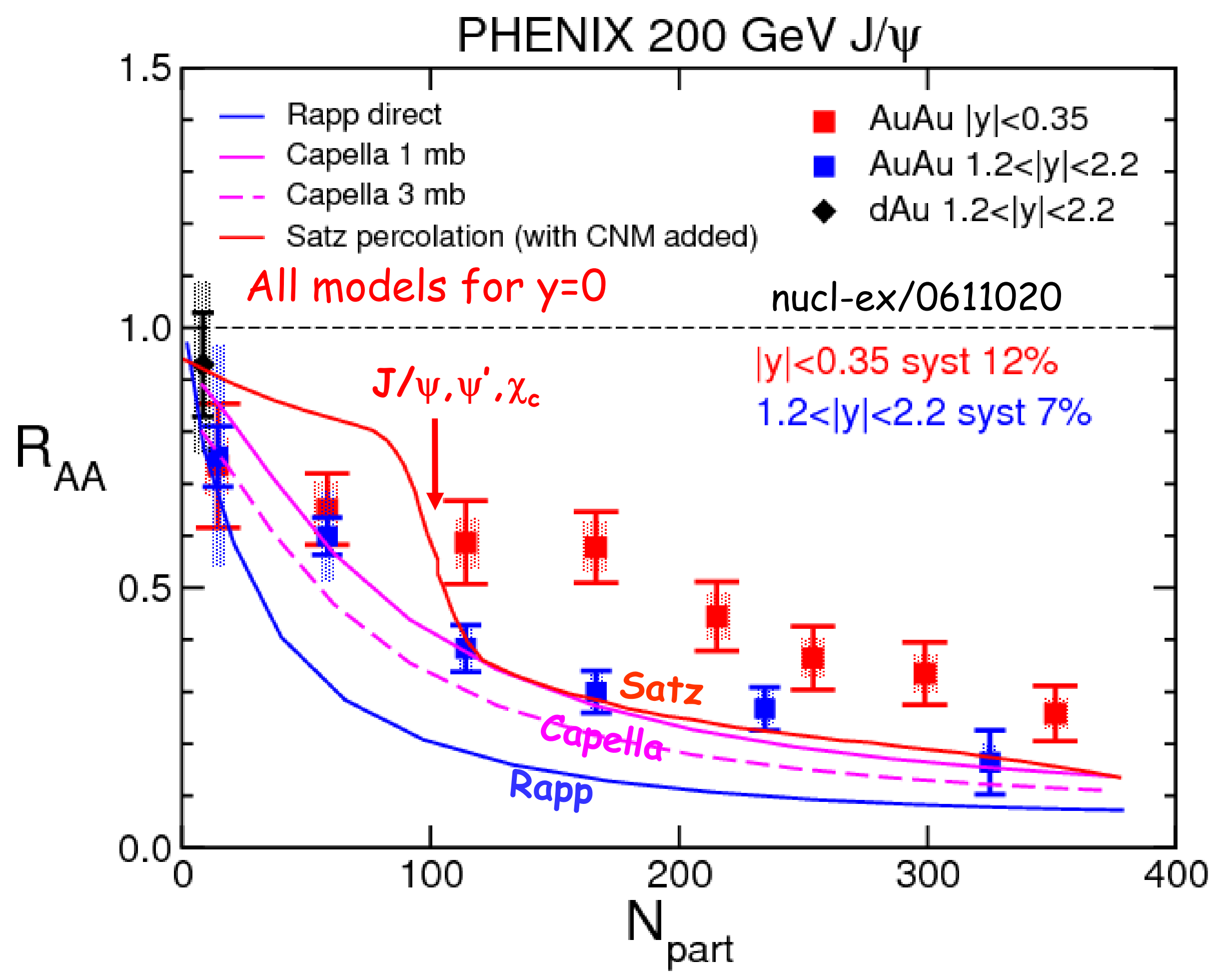
Suppression only models

Suppression only models that reproduce NA50 results, predict too much suppression at RHIC at midrapidity





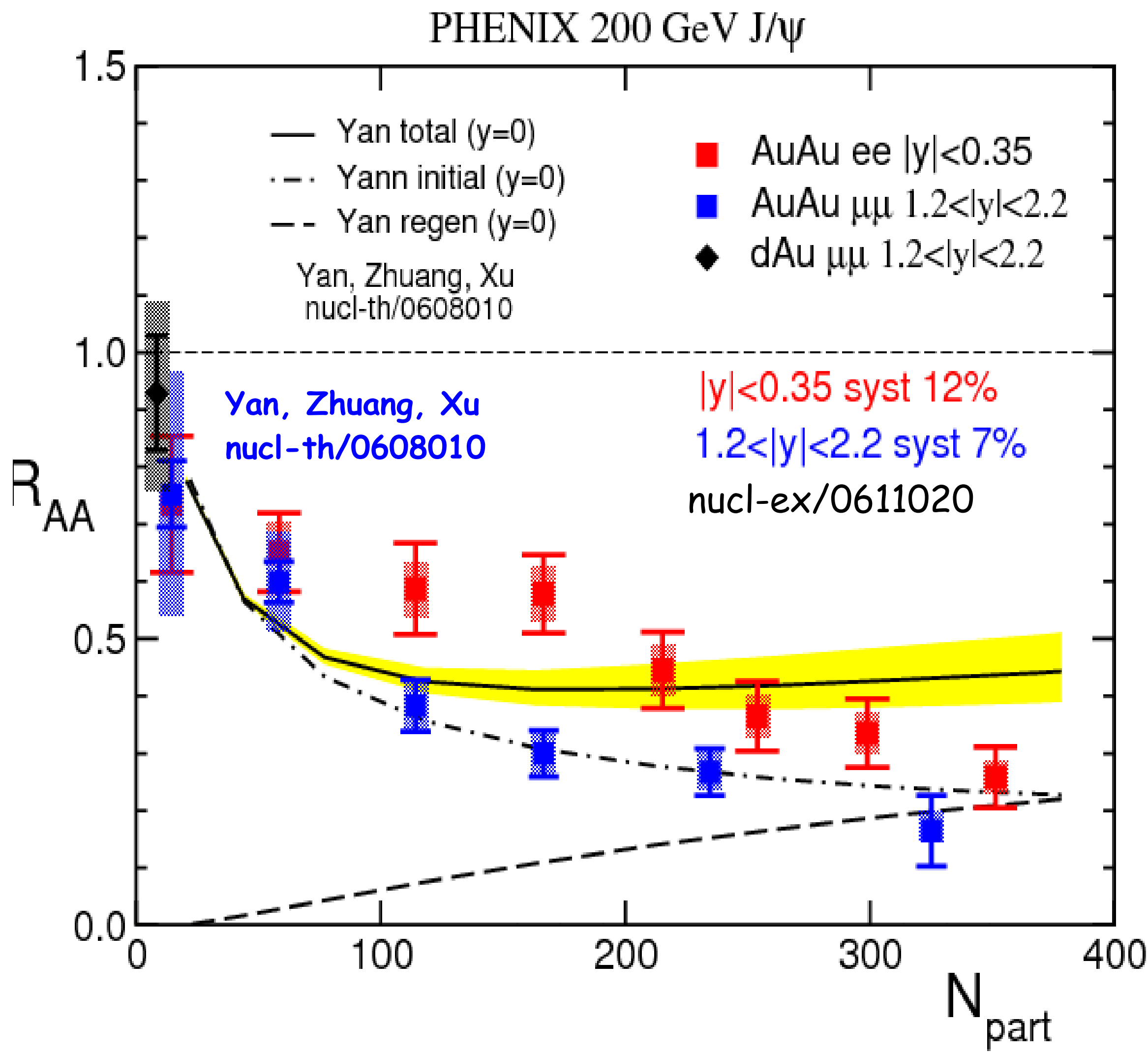


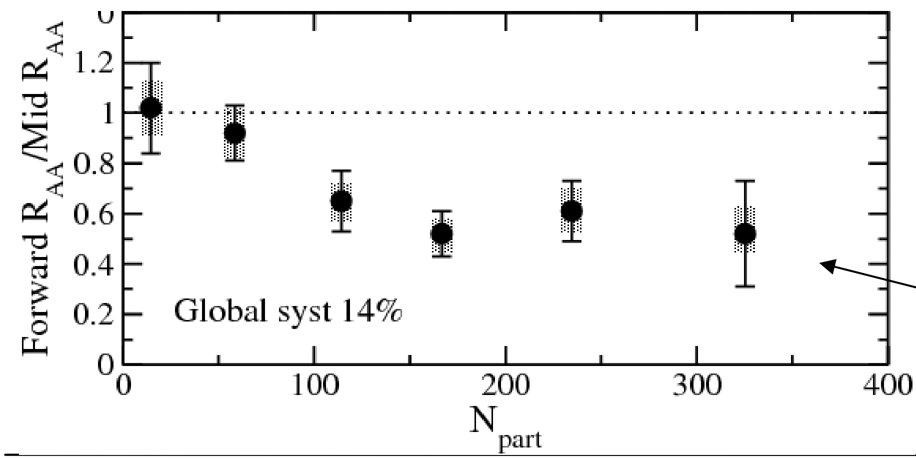


Models with J/ψ regeneration

At RHIC gluon density is 2-3 times larger than at SPS, and recombination of c-cbar at later stages of the collision should be more important.

Recombination should result in narrowing of rapidity and P_T distributions, and J/ψ flow.

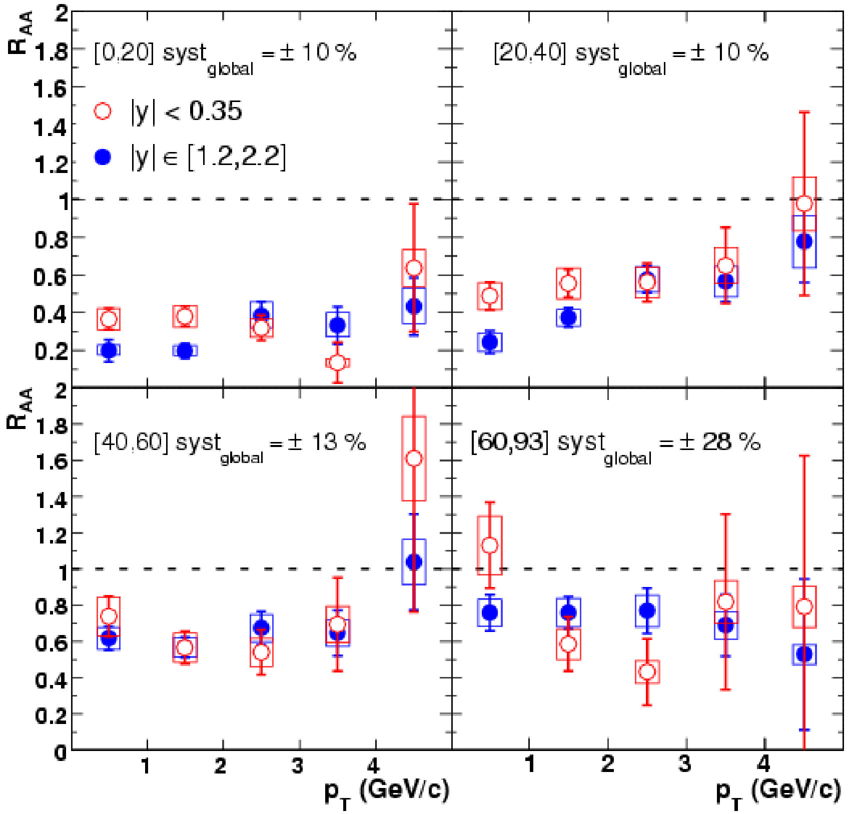


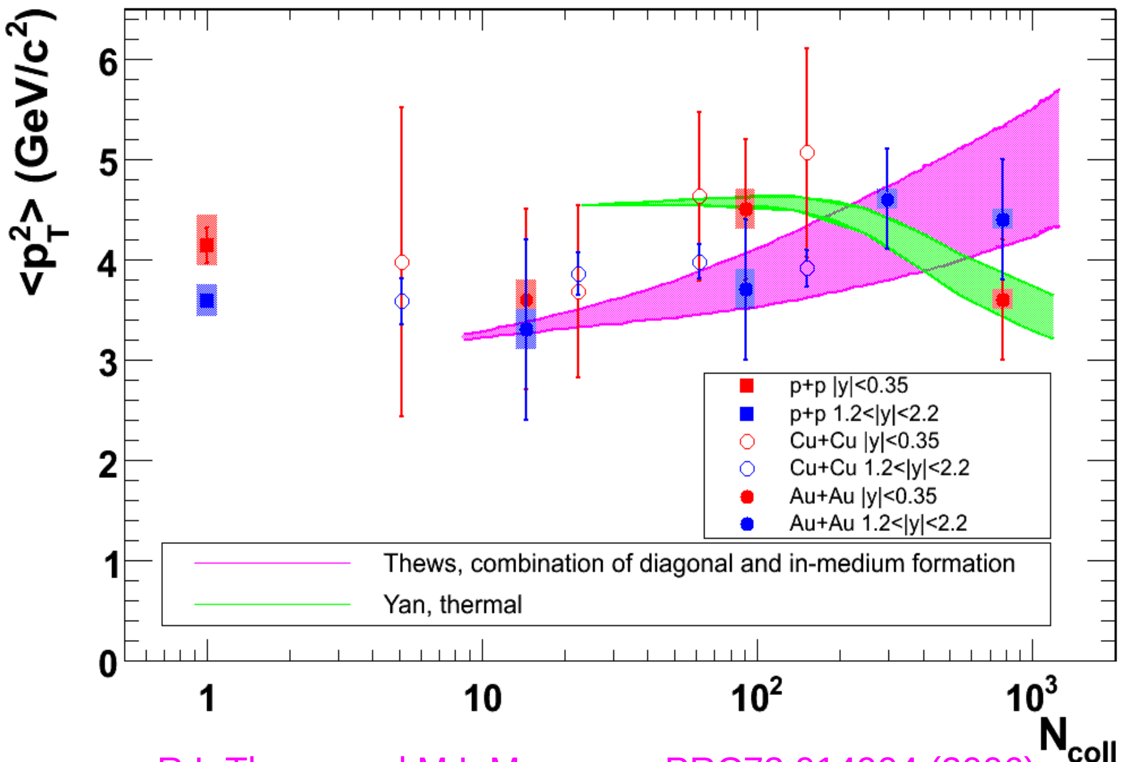


Flattening of forward/central ratio above N_{PART}>100!?

J/ψ in AuAu collisions

Regeneration – narrowing of P_T distribution?





R.L.Thews and M.L.Mangano, PRC73 014904 (2006)
L.Yan, P.Zhuang and N.Xu, PRL97 232301 (2006)

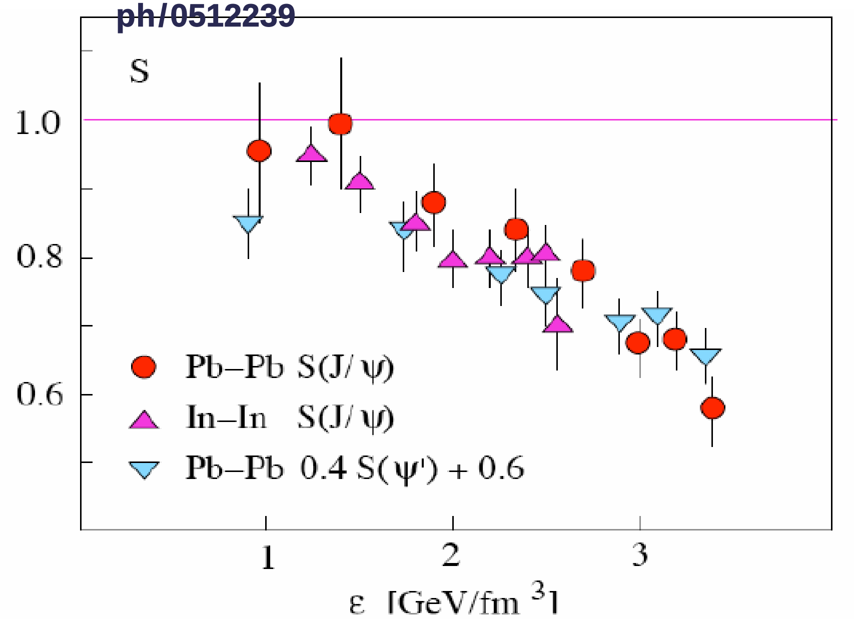
No strong P_T dependence of R_{AA}
No strong centrality dependence of $<p^2_T>$
Flow measurement would be very useful

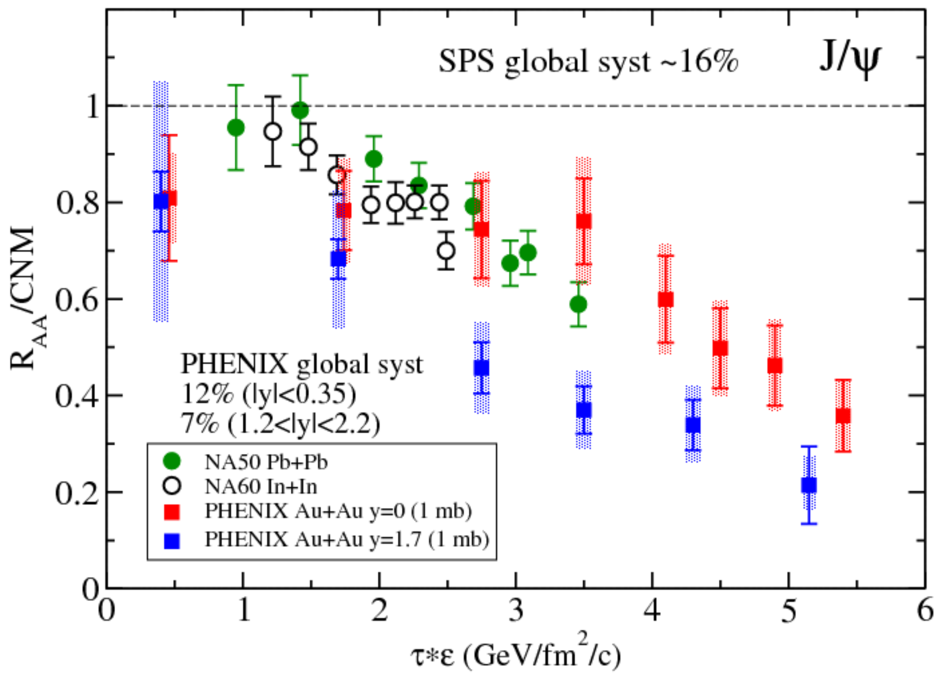
Sequential dissociation

Recent lattice QCD calculations predict high dissociation temperature for J/ψ (~2T_C), but rather low for ψ' and χ_C (~1.1T_C)

Survival probability $S_{J/\psi} = 0.6\ S_{DIRECT} + 0.3\ S\chi_C + 0.1\ S\psi'$

Karsch, Kharzeev and Satz, hep-ph/0512239





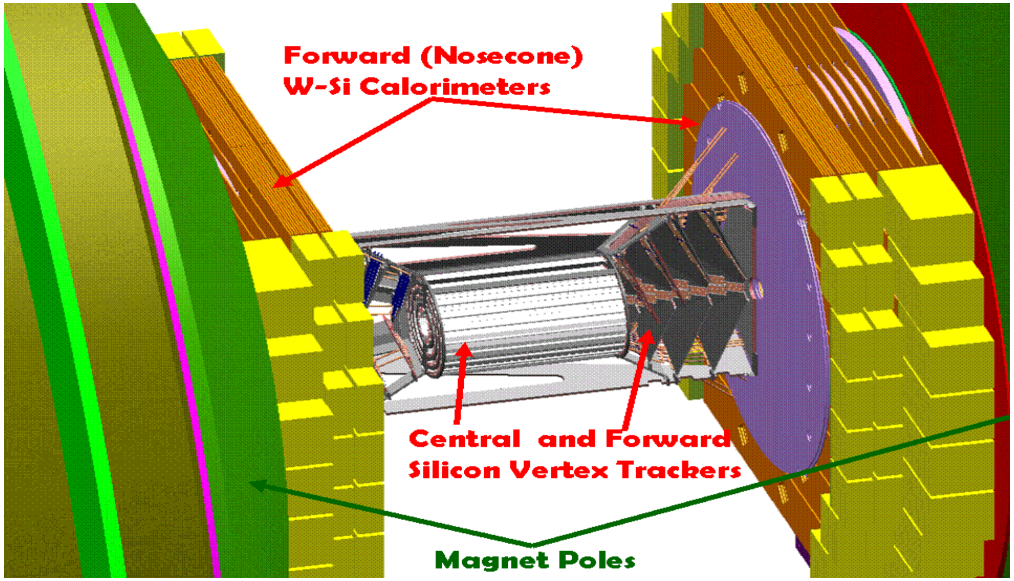
To understand J/ψ suppression at RHIC we need more charmonium measurements: ψ', χ_C, ...

The Future

RHIC-II upgrade: increased luminosity (~10 times for AuAu)
- better statistics, upsilons...

PHENIX upgrade: Silicon Vertex Detector
- improved background & mass resolution for quarkonia
- charm/beauty separation

PHENIX upgrade: Nosecone Calorimeter: χ_C measurement



Conclusions

- J/ψ cross-section in pp collisions consistent with color octet, mean Pt scales as ln(s).

- Weak shadowing and absorption observed in dAu. Nuclear dependence scales with x_F, not x_2.

- Suppression in NN collisions similar at RHIC and SPS.
- Suppression larger at forward rapidity
- Forward/Central ratio seems to flatten out for Npart>100

Need more experimental data!

- More dAu statistics to pin down cnm effects.
- Measurements of other quarkonia (psi', chi_c, upsilon).
- Measurements of polarization and flow.
- More accurate measurement of open charm crossection...

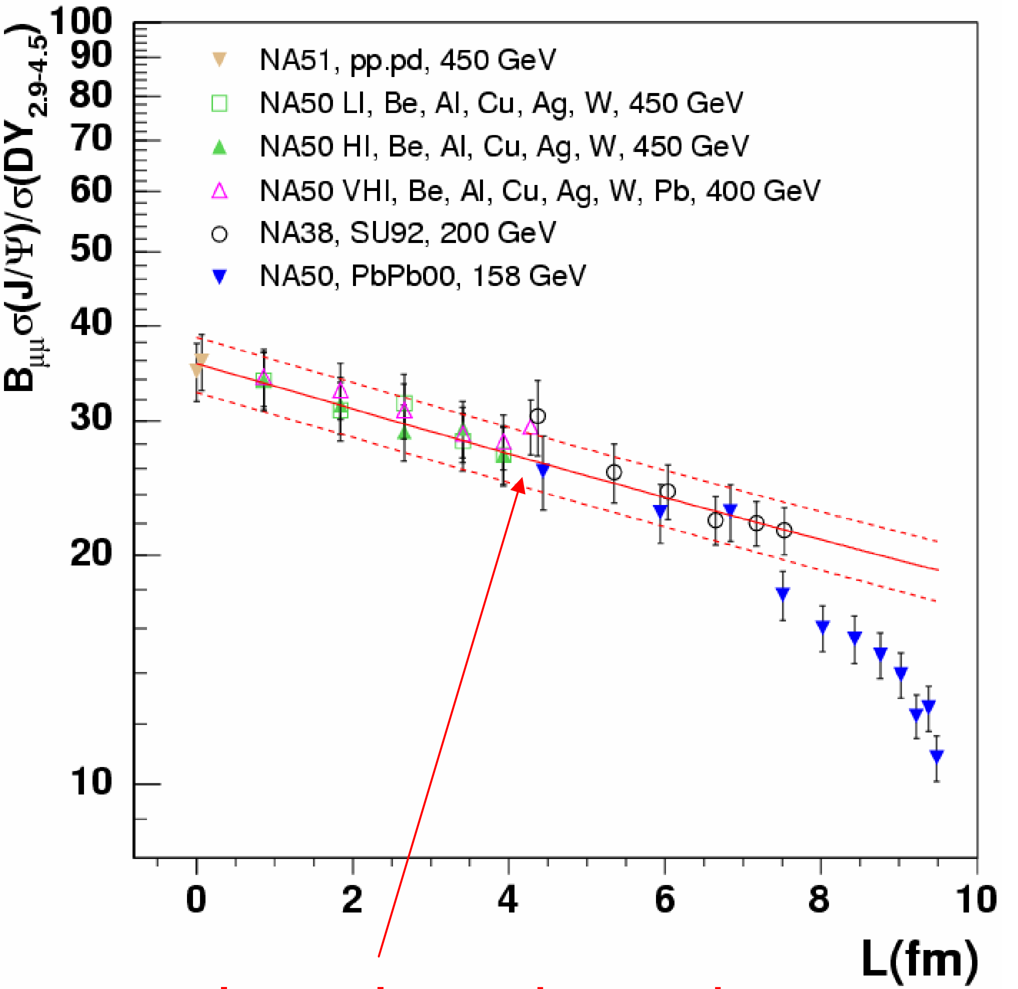
Backup slides

J/y in dAu collisions

nuclear absorption

At SPS: σ = 4.18 +- 0.35 mb

Naively one would expect larger absorption at RHIC, since energy density is higher.



"normal" nuclear absorption

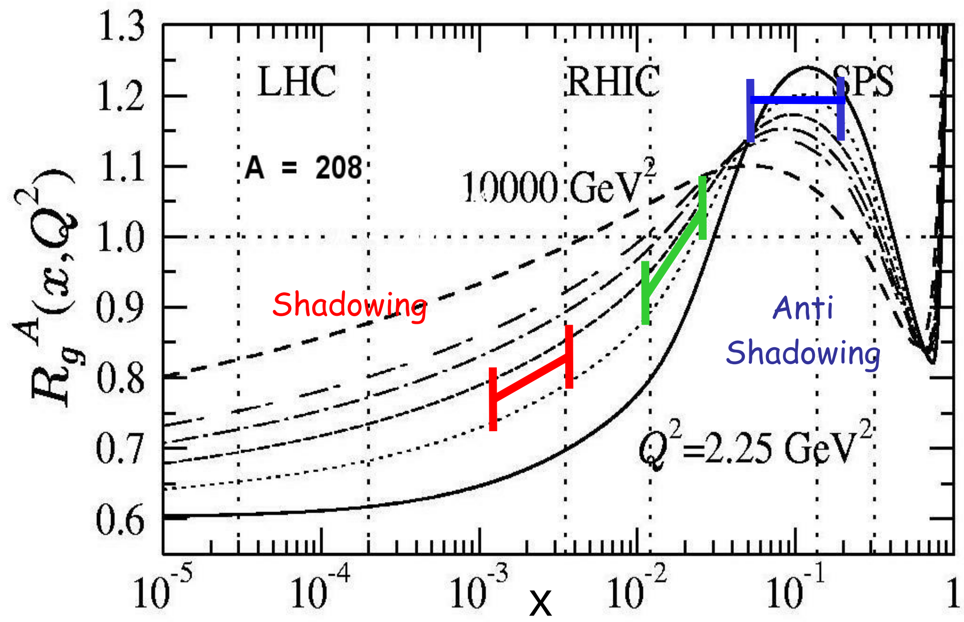
J/y in dAu collisions

gluon shadowing

Modification of pdf of gluons

shadowing: depletion of low momentum gluons in the initial state

gluon saturation at low x: Color Glass Condensate



Nucl. Phys. A696 (2001) 729-746