J/ψ production and interaction with the meduim

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Properties and Signatures of sQGP II Workshop

J/ψ in the medium

J/ψ's 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

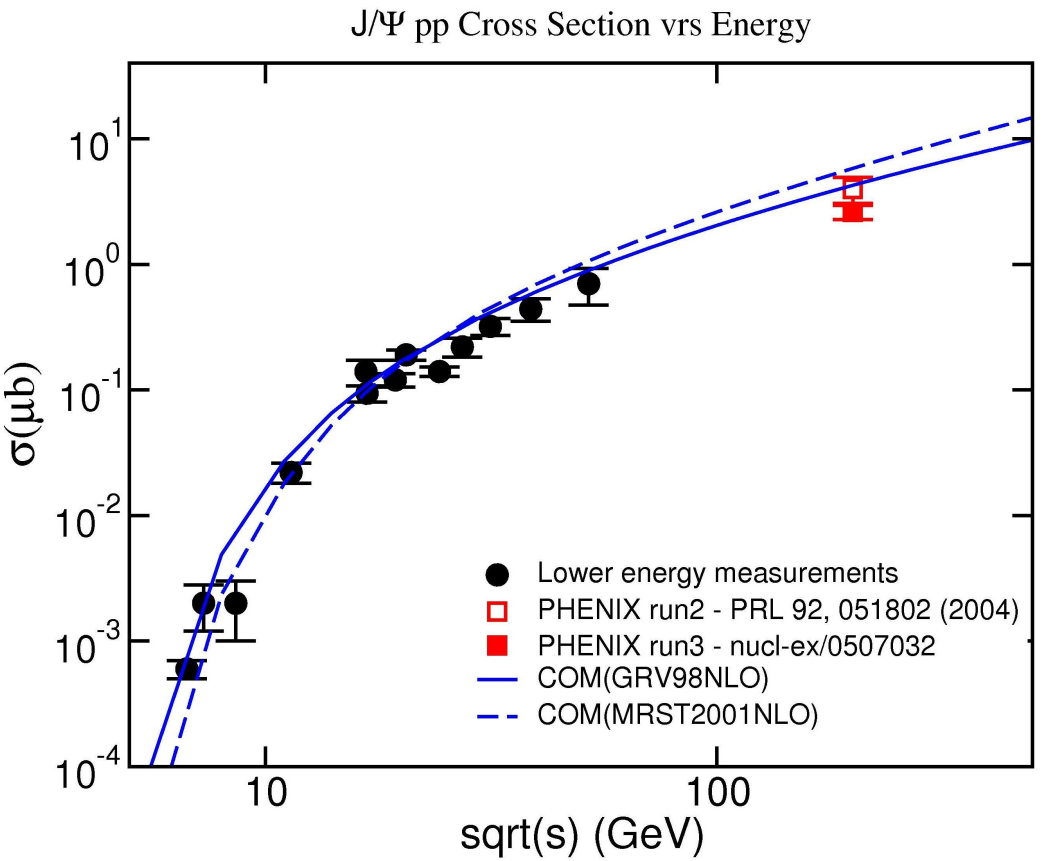
- in nucleus-nucleus collisions:
  - cold nuclear matter effects
    - nuclear absorption, shadowing/anti-shadowing, Cronin effect...
  - suppression due to color screening in QGP?
  - regeneration?

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

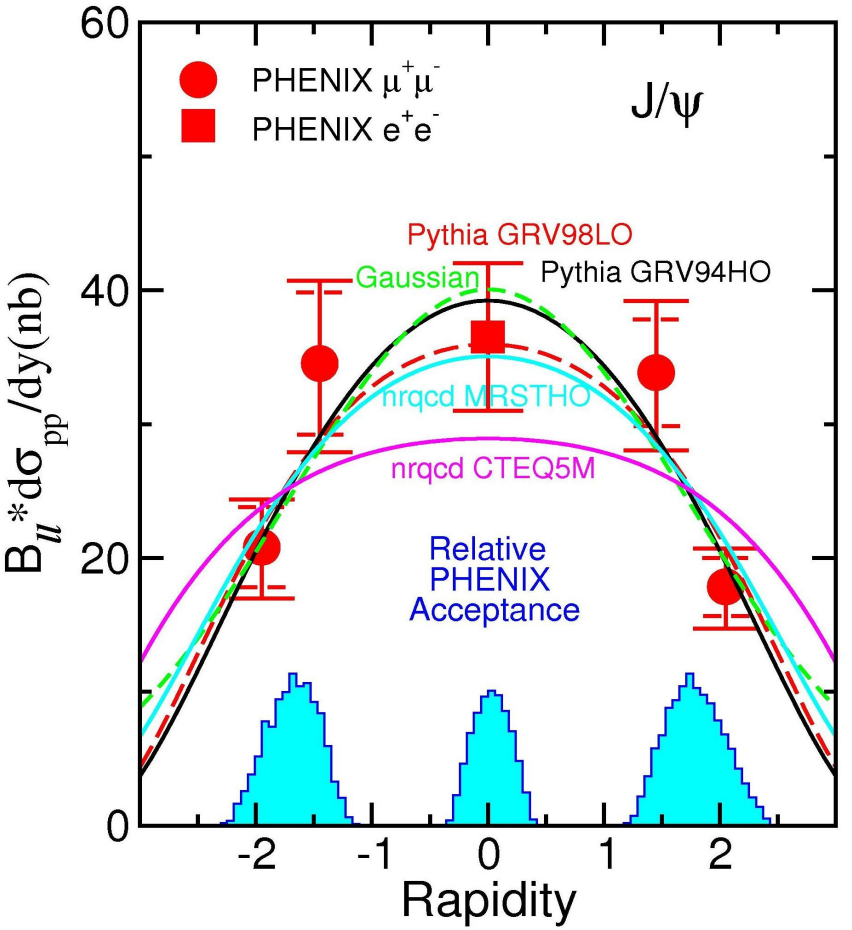
need systematic study: *A, P_T, y, centrality*, $\sqrt{s}$ ...

J/ψ in pp collisions

baseline measurement



Consistent with color octet predictions, statistical errors do not allow to choose between pdfs



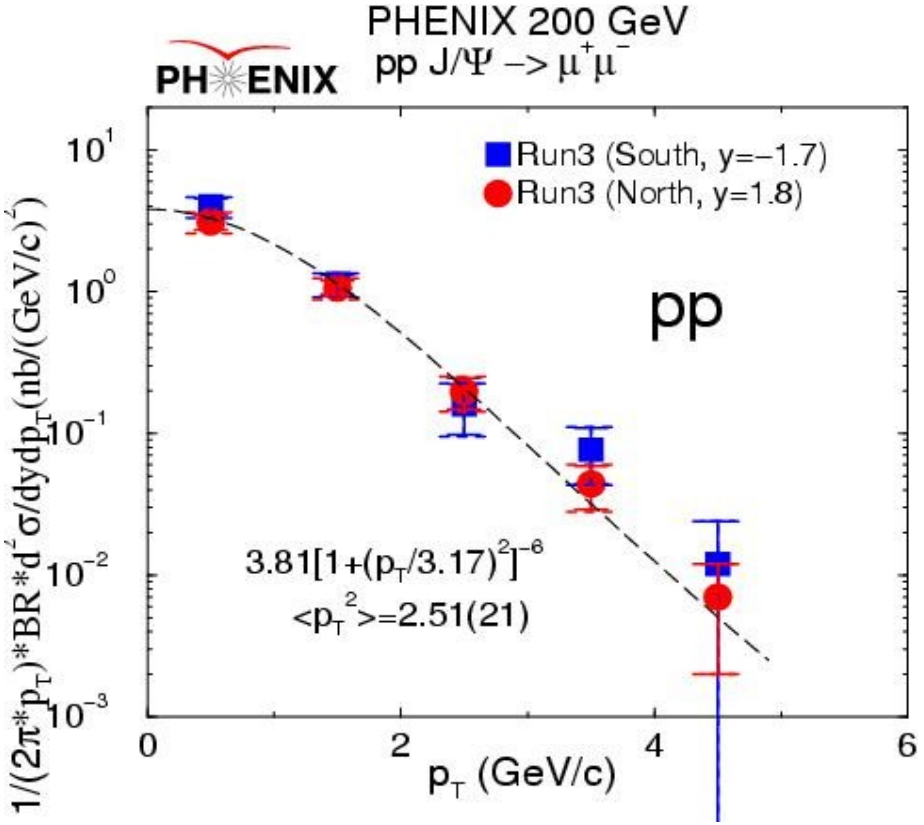
Good agreement with pythia shape, variation in pdf small compared to errors

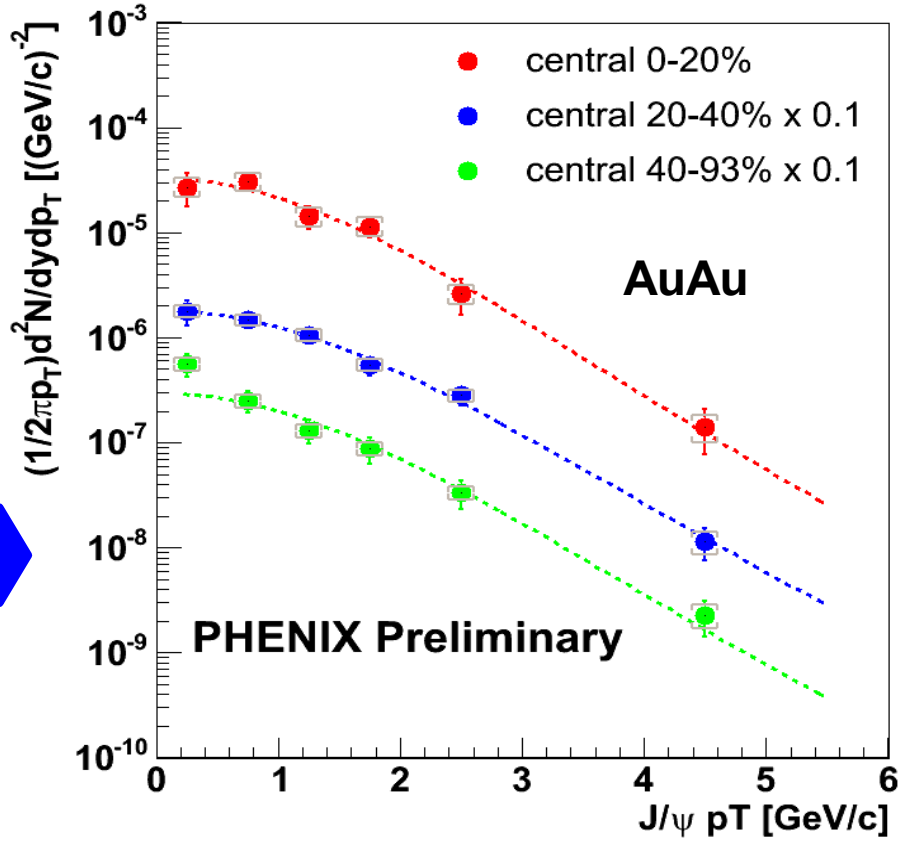
Nuclear modification factor R_{AA}

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

N_{COLL} is calculated by Glauber model

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



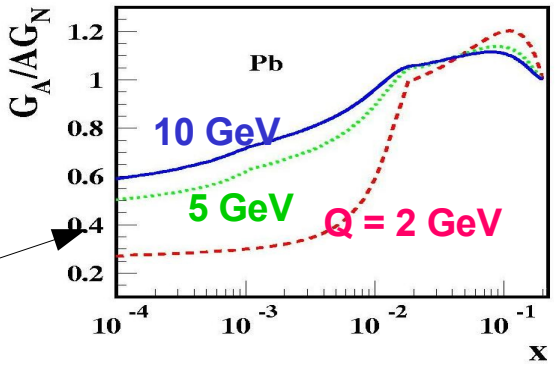


J/ψ in dAu collisions

understanding cold nuclear matter effects

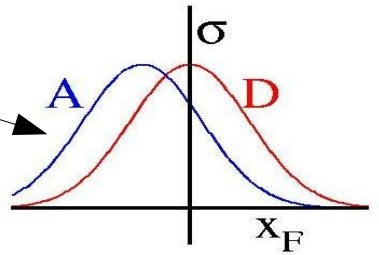
Interaction in medium

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



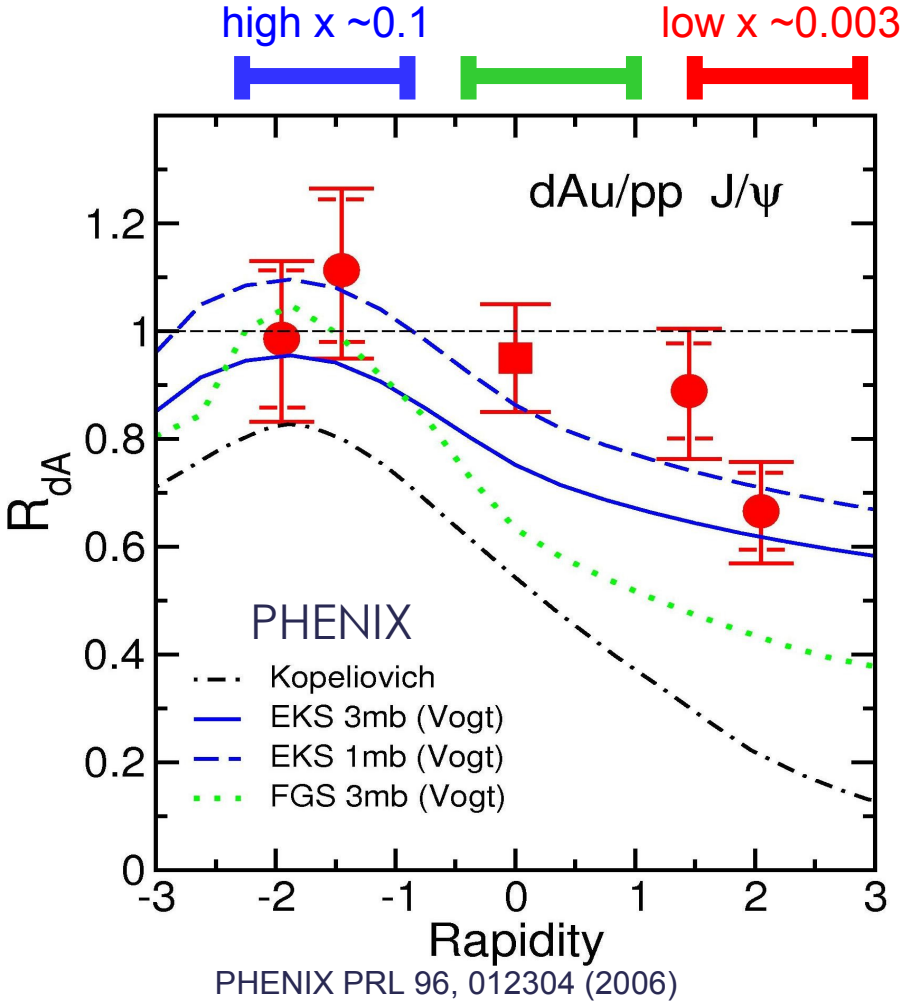
Modification of gluon pdf

- shadowing: depletion of low momentum gluons accompanied by 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

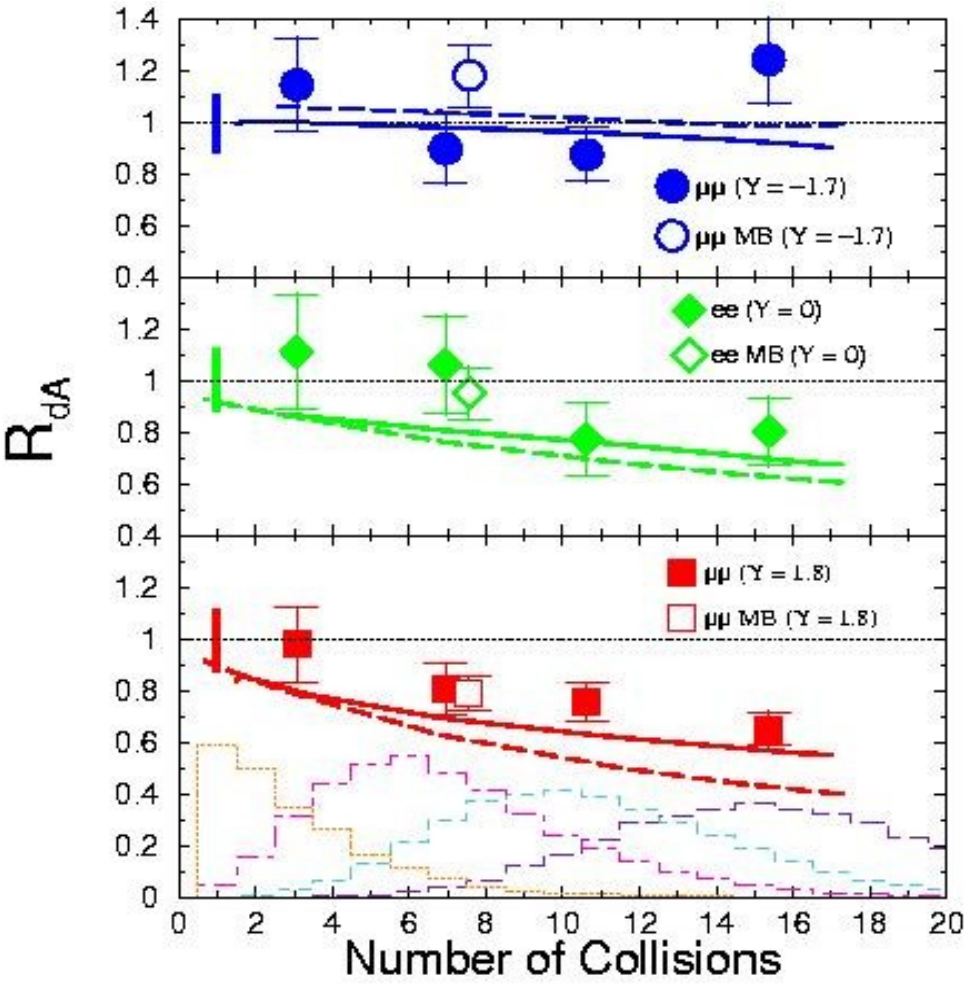


$x_F = 2p_Z/\mathrm{sqrt}(s)$ $x_1 = x_d = 0.5(x_F+\mathrm{sqrt}(x_F^2+4\tau))$ $x_2 = x_{Au} = x_1-x_F$

J/ψ in dAu collisions



PHENIX PRL 96, 012304 (2006)

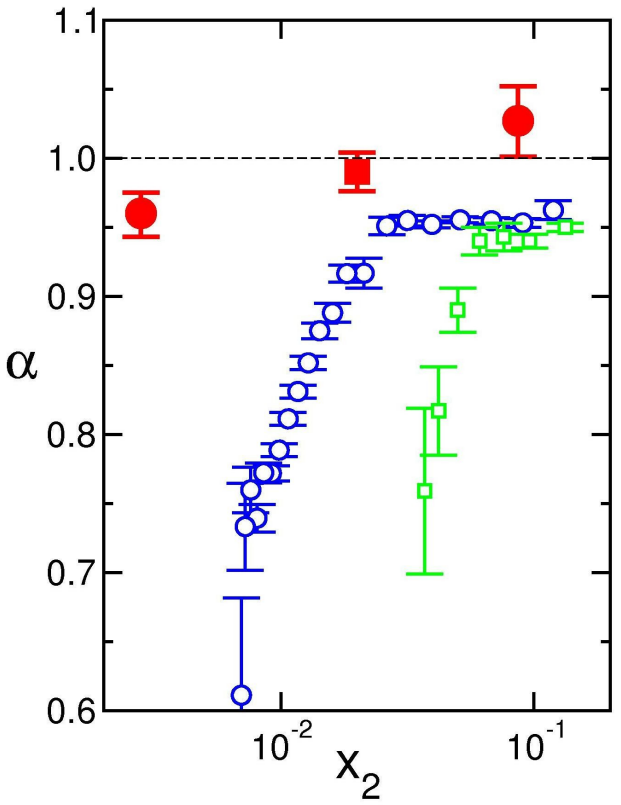


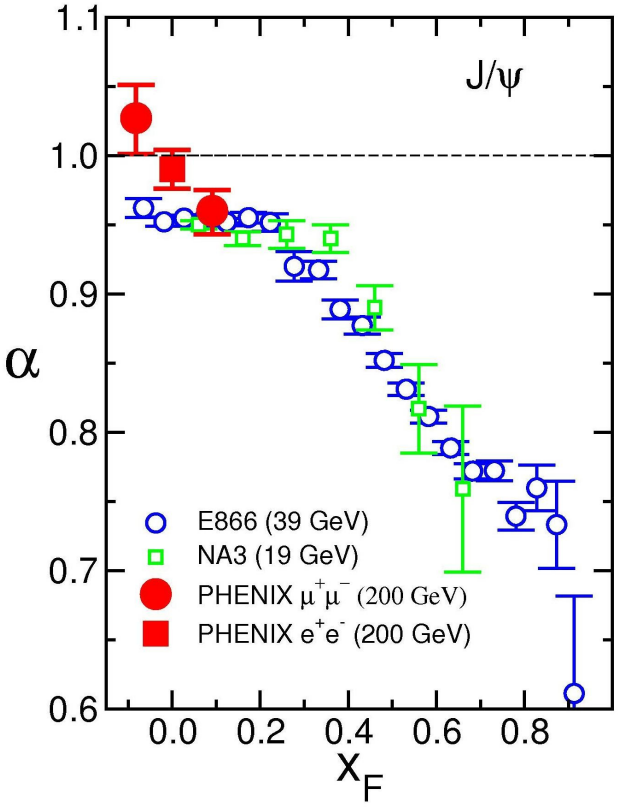
Vogt, PRC71, 054902 (2005), Kopeliovich, NP A696, 669 (2001)

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

J/ψ in dAu collisions

Nuclear dependence at different sqrt(s)





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

Shadowing predicts scaling with x_2

Scaling with x_F instead.

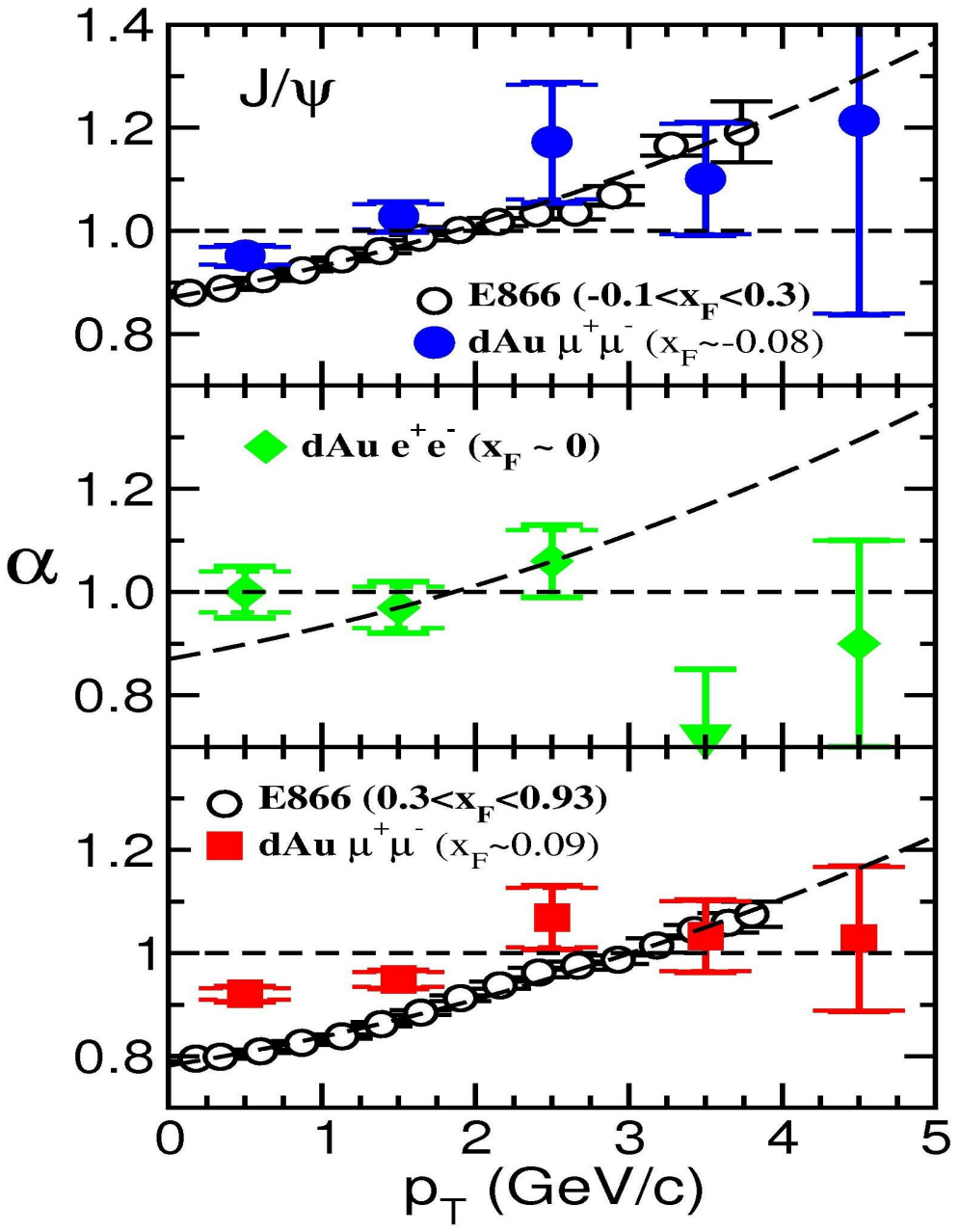
- Initial state gluon energy loss?
- Sudakov form factor? ~$(1-x_F)$

$x_F = 2p_z/\mathrm{sqrt}(s)$

$x_1 = 0.5(x_F+\mathrm{sqrt}(x_F^2+4\tau))$

$x_2 = x_{Au} = x_1 - x_F$

J/ψ in dAu collisions



P_T broadening

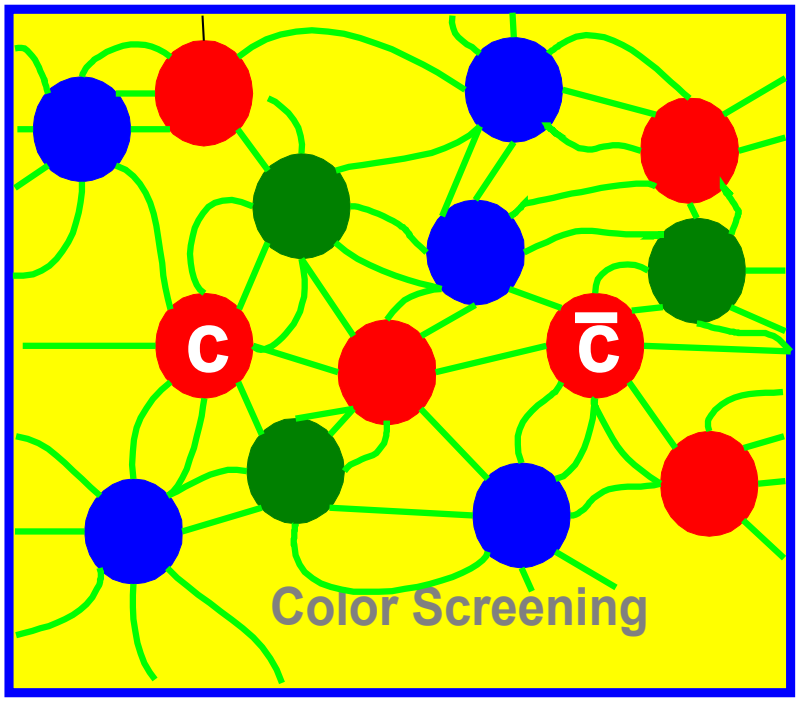
x ~0.1

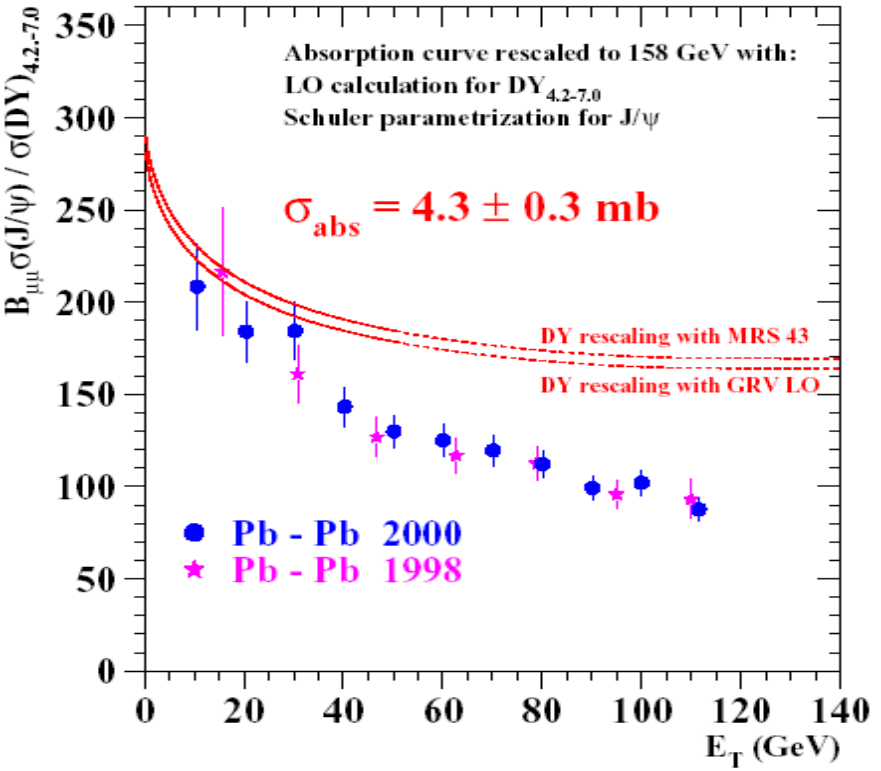
P_T broadening at RHIC comparable to that at lower $\sqrt{s}$ = 39 GeV

x ~0.003

J/ψ in AuAu collisions

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



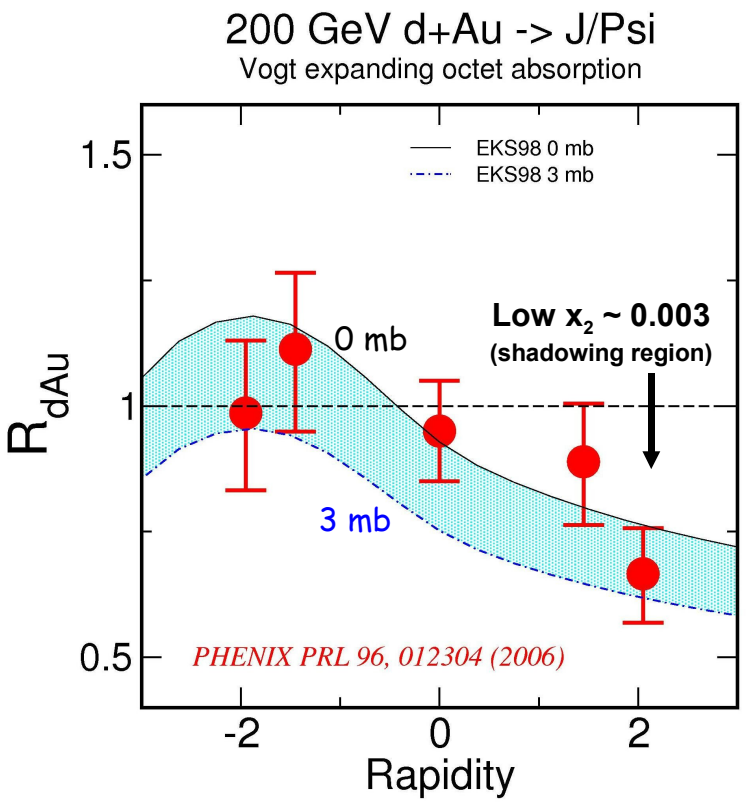


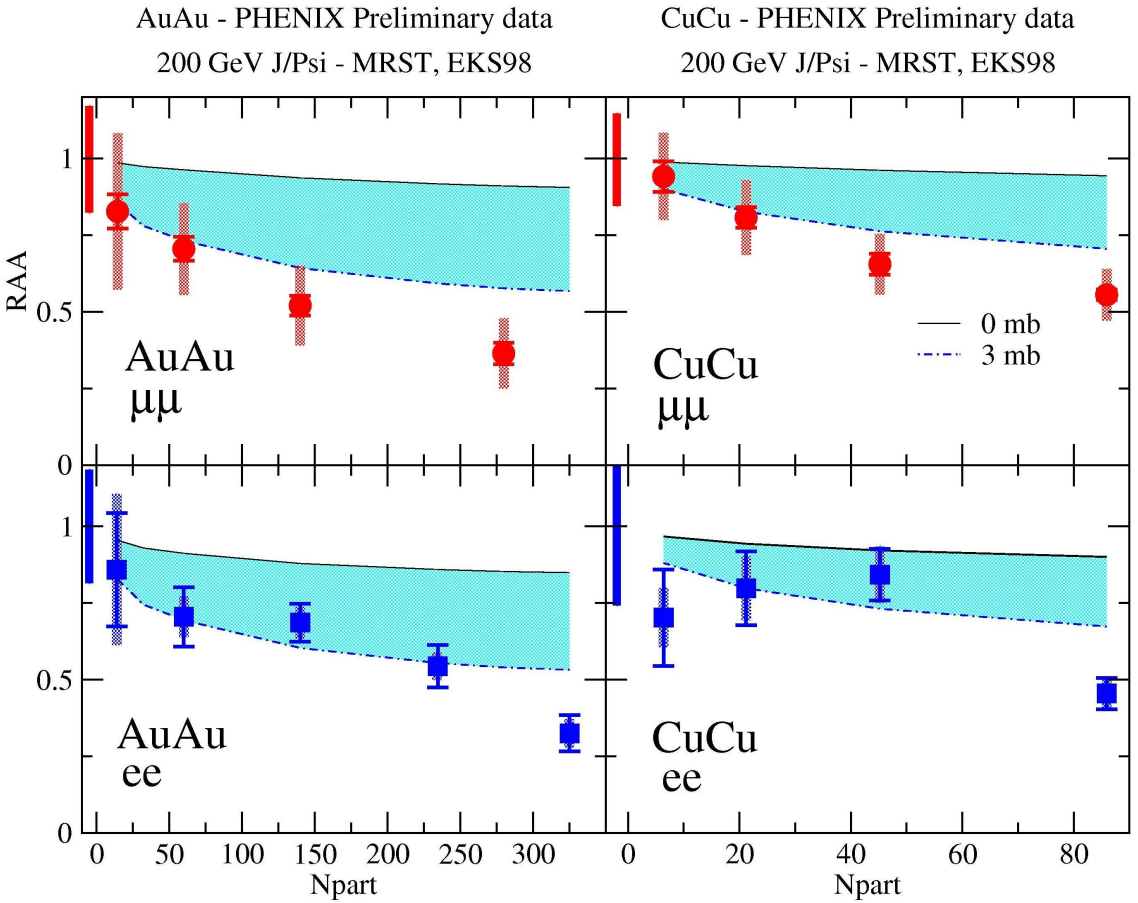
At RHIC energies the situation is more complicated:

- recombination due to high density of charm quarks
- J/ψ not screened at all? (sequential dissociation)

J/ψ in AuAu collisions

Comparison to dAu: cold nuclear matter (cnm) effects



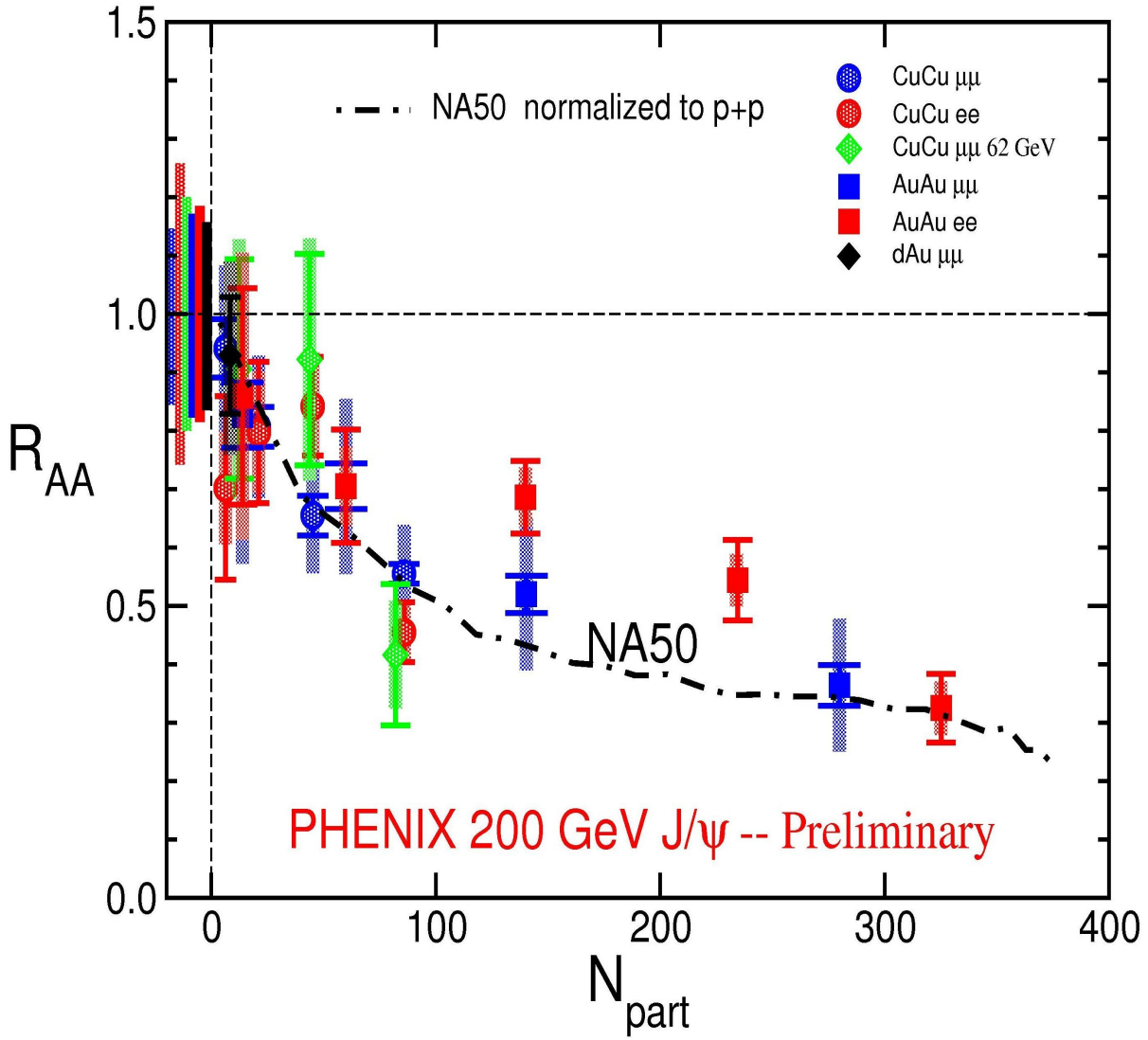


cnm calculation with absorption and shadowing limits $\sigma_{abs} < 3$mb

AuAu suppression is somewhat stronger than cnm effects, but we need better dAu statistics

J/ψ in AuAu collisions

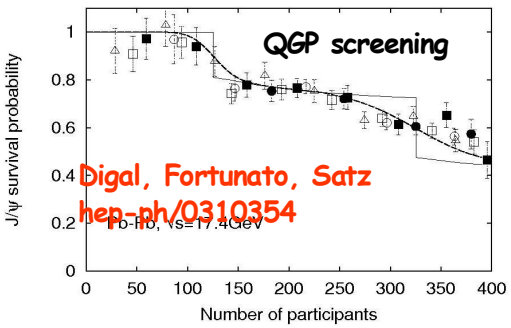
Comparison RHIC to SPS

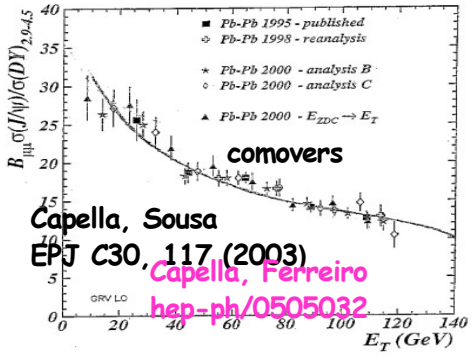


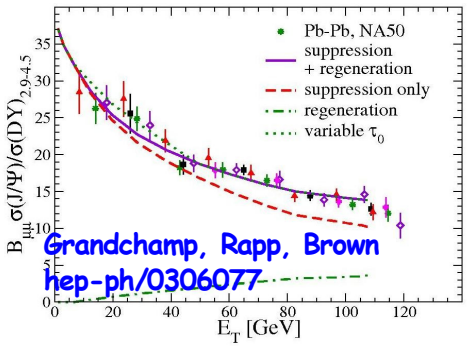
Similar suppression seen at RHIC and SPS, although energy density is higher at RHIC

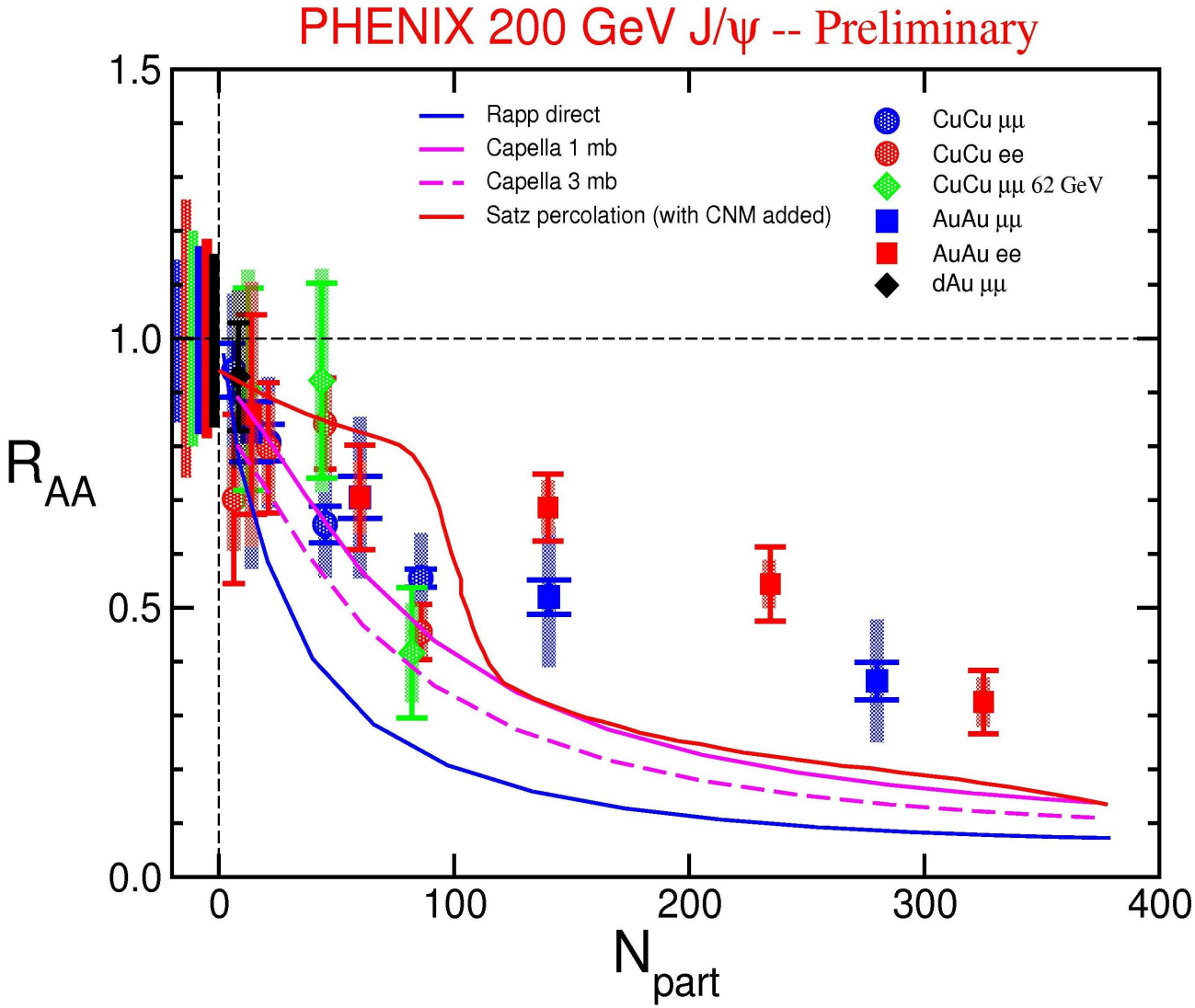
J/ψ in AuAu collisions

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









J/ψ in AuAu collisions

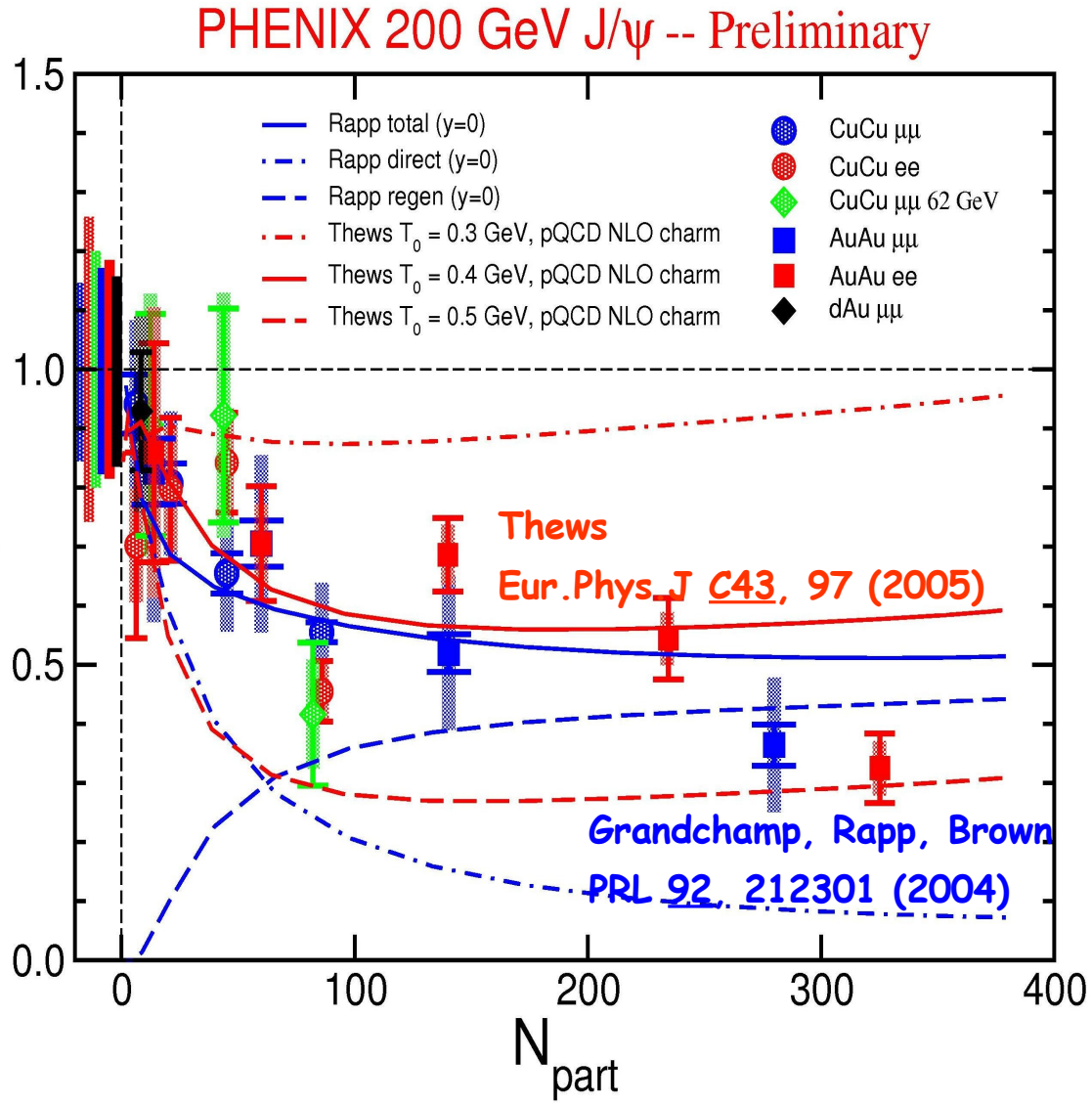
Models with J/ψ regeneration

Models with suppression plus recombination/coalescence work much better!

- Recombination goes with σ_{cc}^2, with is still poorly known at RHIC

- Alternative explanations: Sequential screening of the higher mass resonances down to J/ψ

Must check other observables!

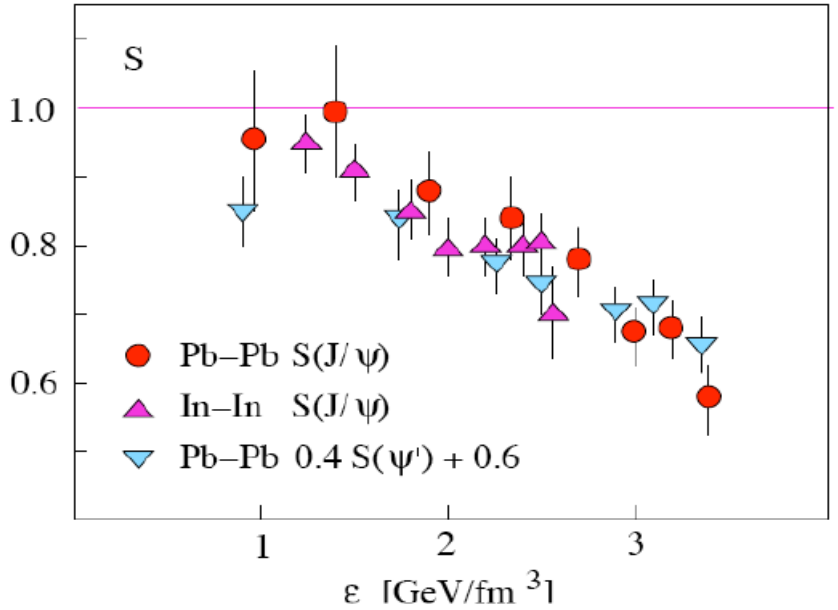


Sequential dissociation

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



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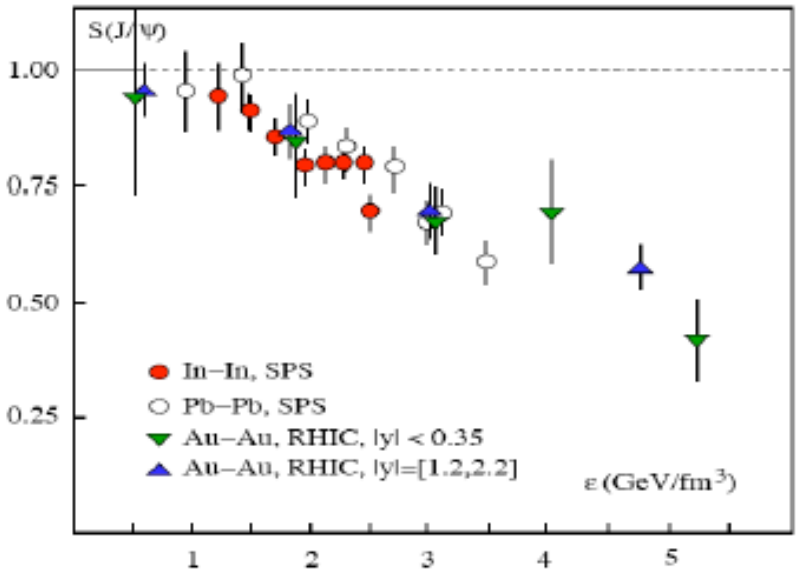
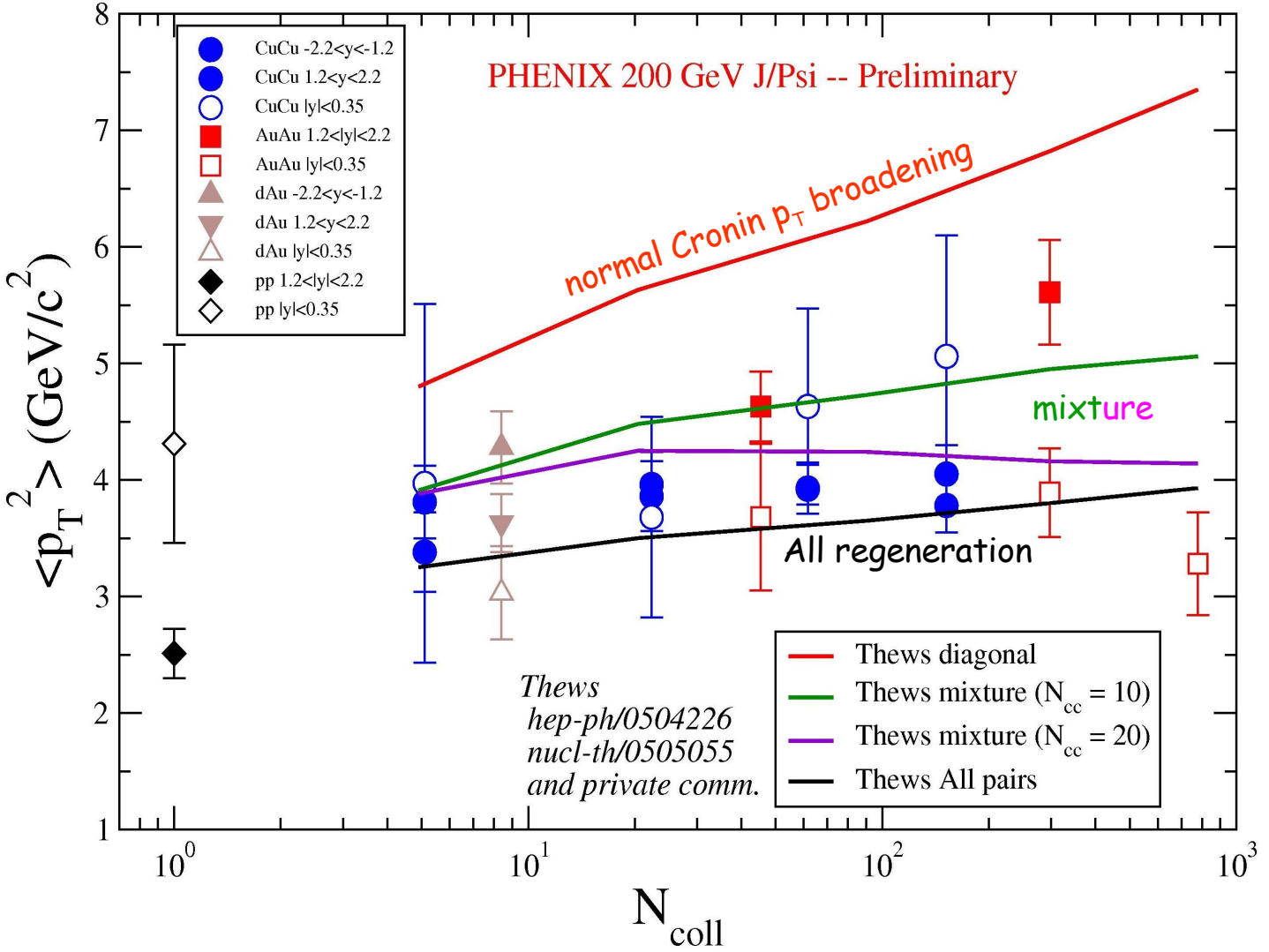


To understand J/ψ suppression at RHIC we need more charmonium measurements: ψ', χ_c, ...

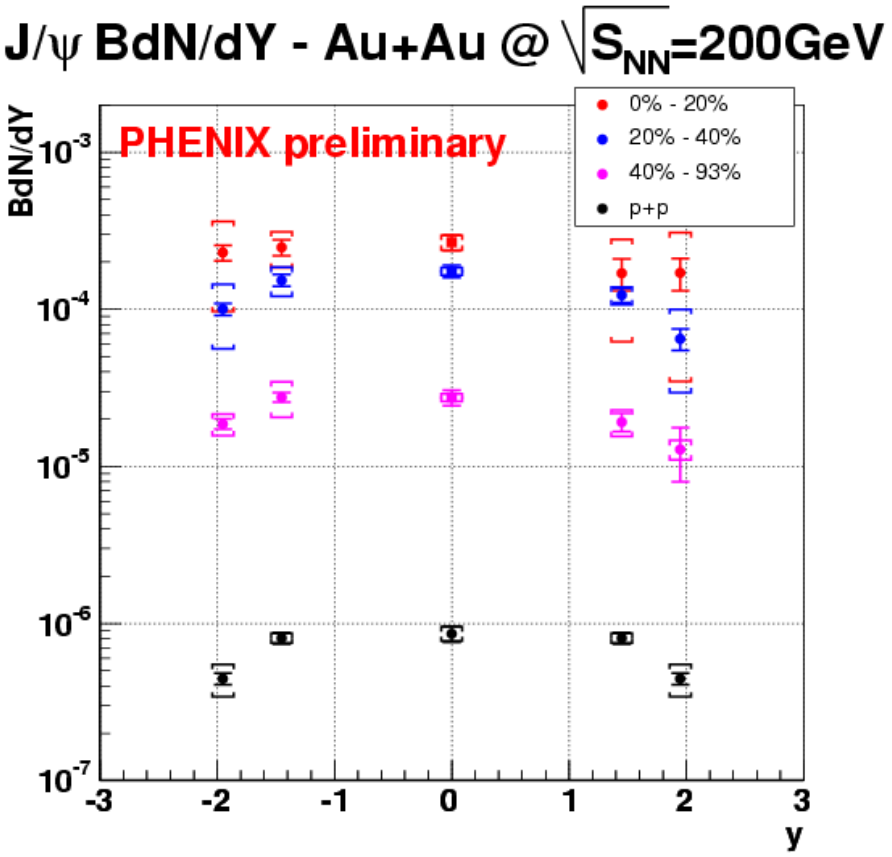
J/ψ in AuAu collisions

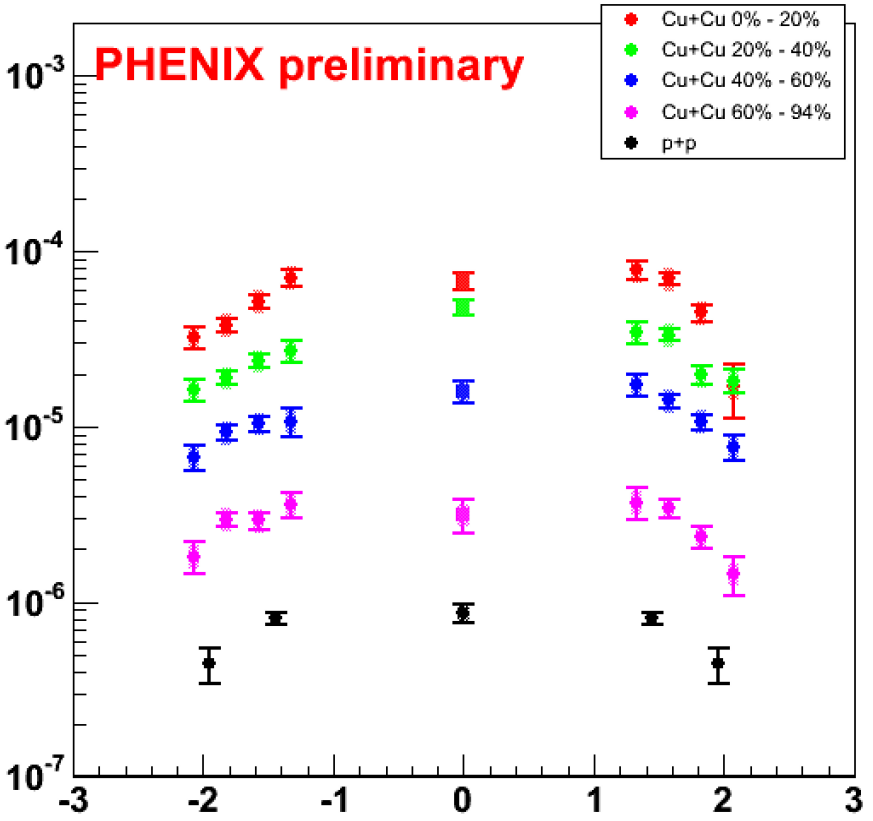
Recombination (e.g. Thews et al., nucl-th/0505055) predicts a narrower p_T and rapidity distributions



J/ψ in AuAu collisions

Rapidity distribution width





Experimentally no significant change from pp to CuCu to AuAu

Is σ_{ccbar} flatter than what we think it is?

Conclusions

- J/ψ cross-section in pp collisions consistent with color octet.

- 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.
  Results suggest significant contribution from regeneration,
  but other explanations possible.

Need more experimental data!

- More dAu statistics to pin down cnm effects.

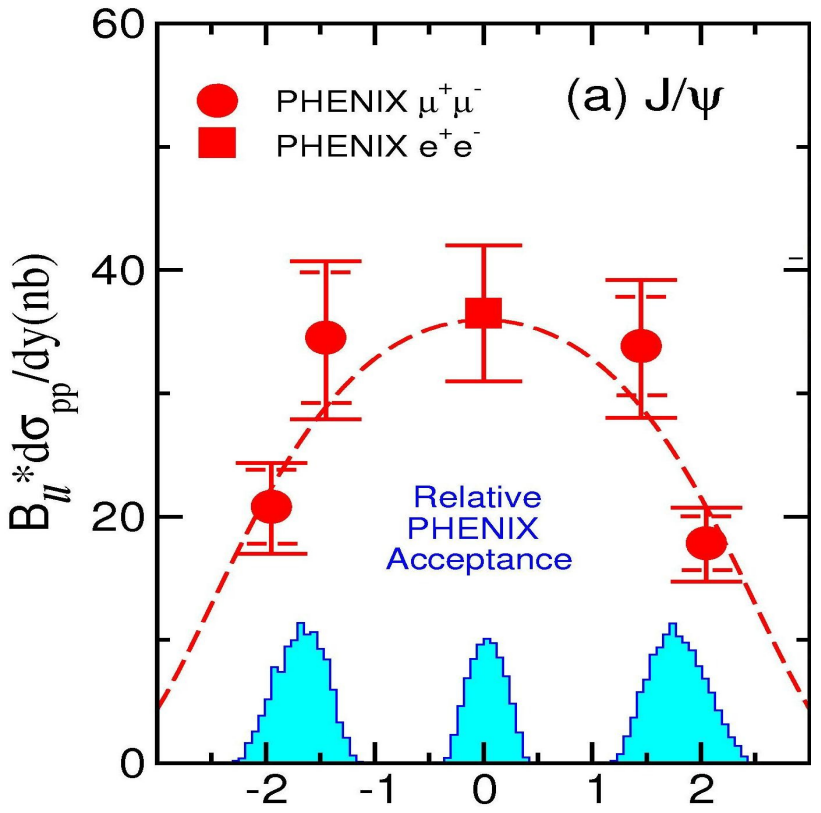
- Measurements of other charmonium/bottonium states.

- Measurements of polarization and flow.

- More accurate open charm crossection...

Backup slides

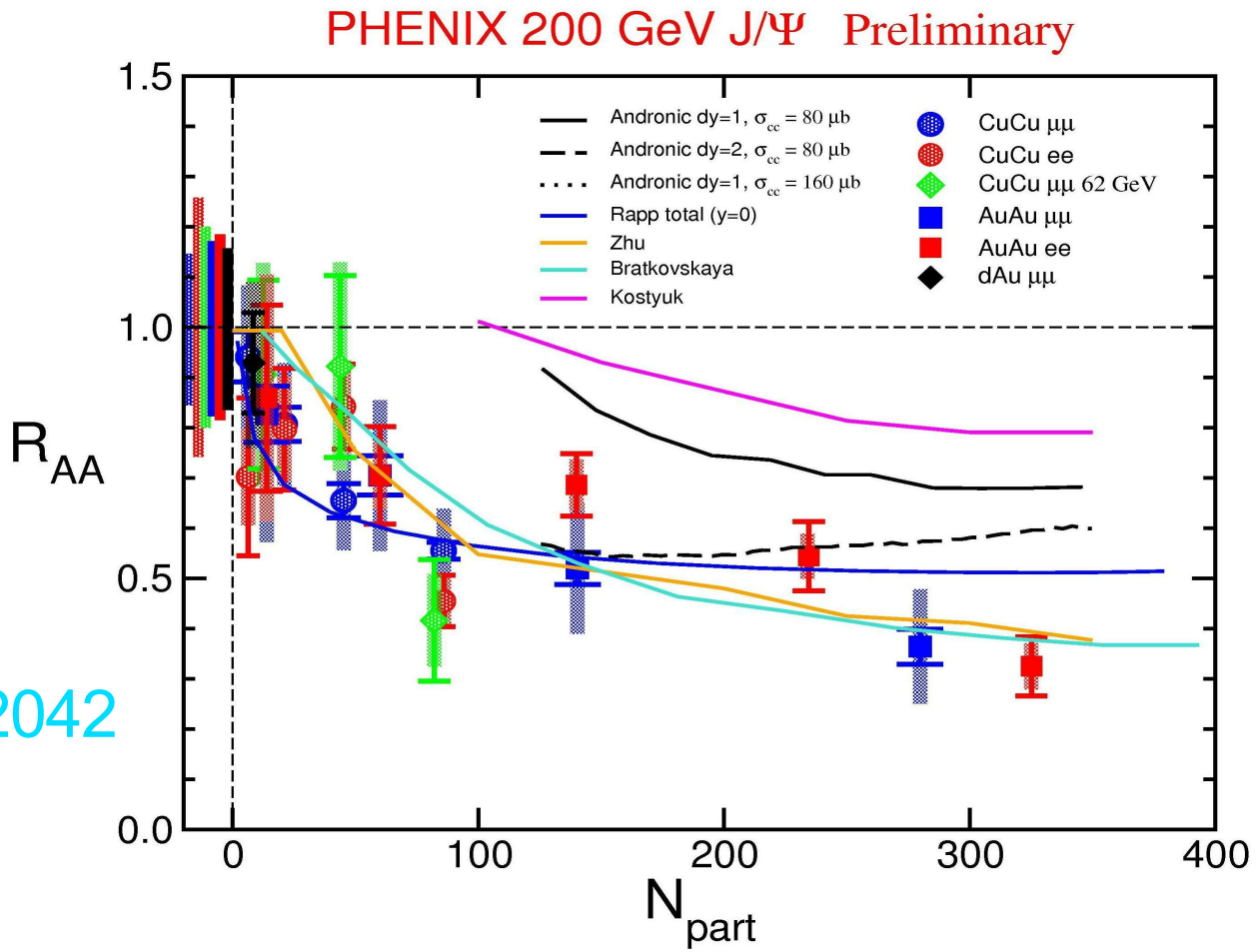
$\sqrt{s}$


PHENIX μ+μ-
PHENIX e+e-
(a) J/ψ
Relative
PHENIX
Acceptance
B_ll*dσ_pp/dy(nb)
60
40
20
0
-2
-1
0
1
2

Transport models

Combine hydro equations for QGP evolution and transport equations for primordially produced J/ψ

Can describe both SPS and RHIC data



Zhu nucl-th/0411093

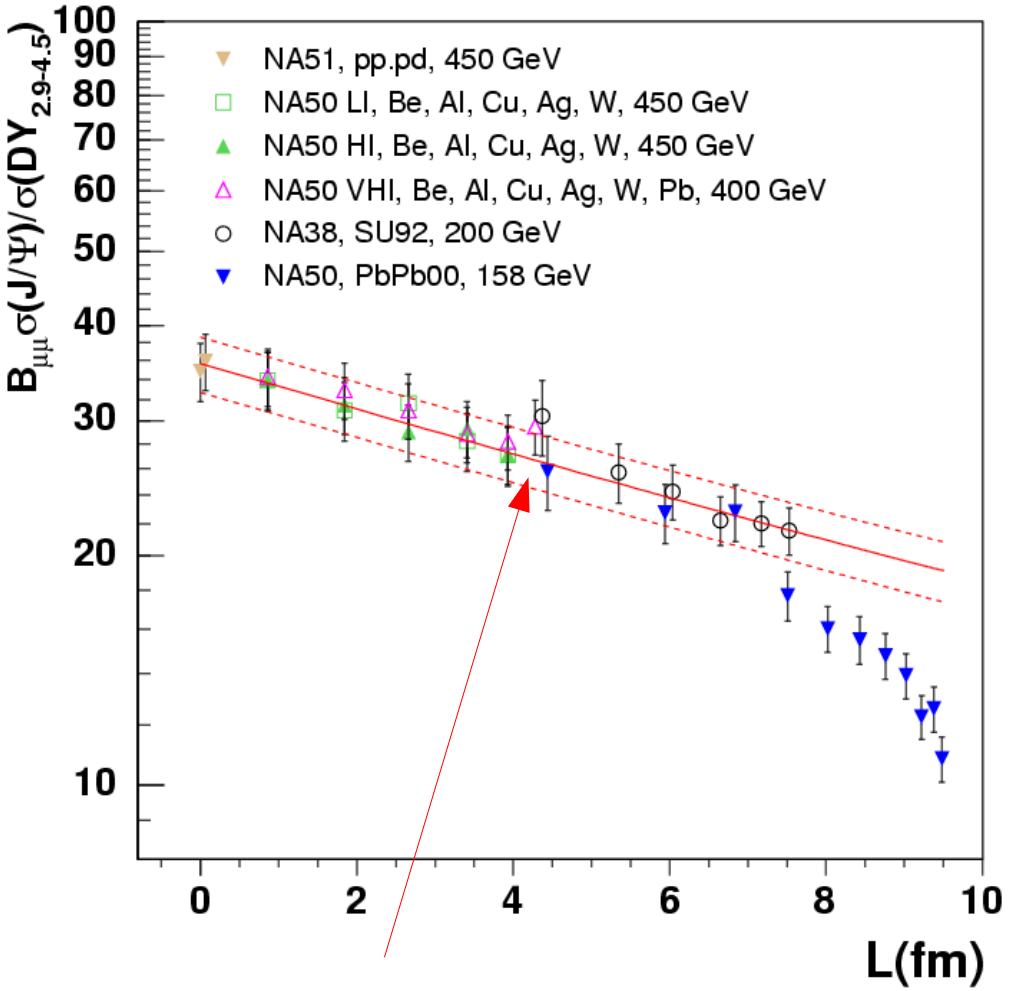
Bratkovskaya nucl-th/0402042

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.



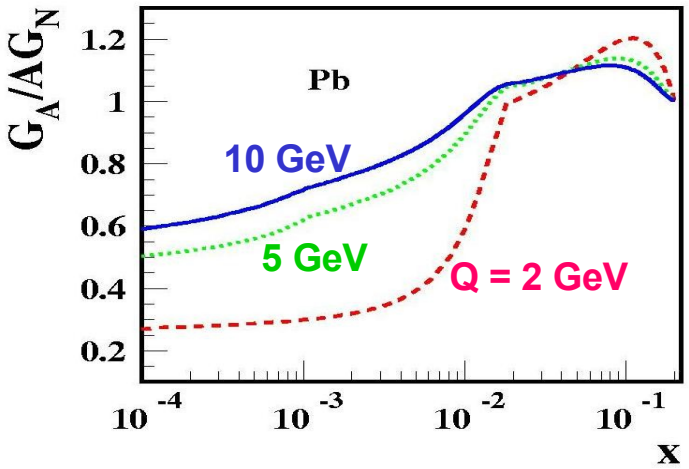
"normal" nuclear absorption

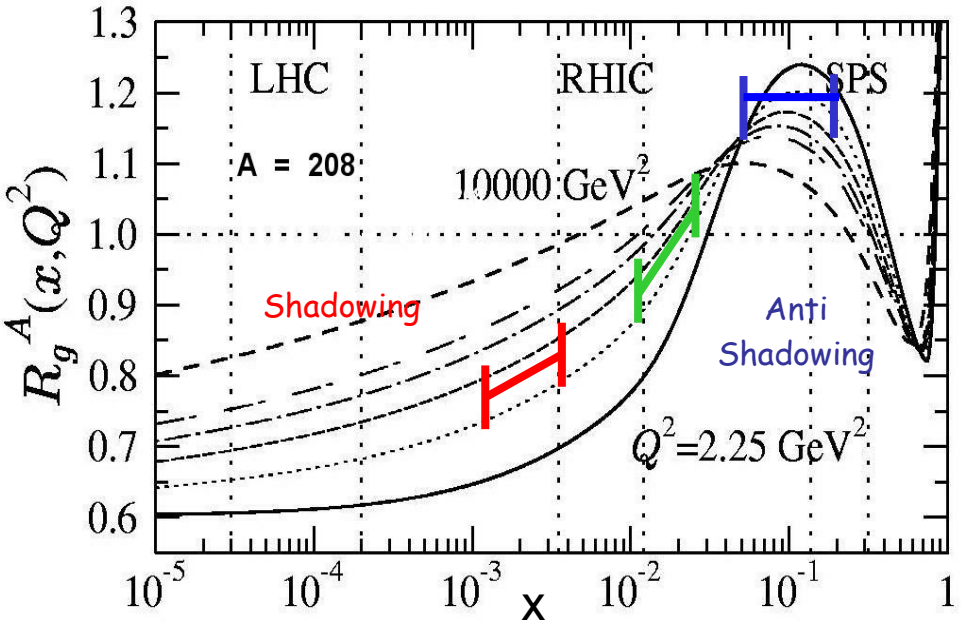
J/y in dAu collisions

gluon shadowing

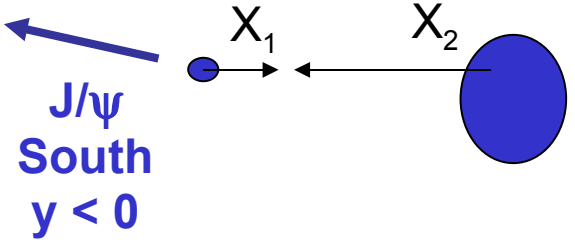
Modification of pdf of gluons

- shadowing: depletion of low momentum gluons in the initial state
- gluon saturation at low x: Color Glass Condensate





Nucl. Phys. A696 (2001) 729-746



J/ψ in AuAu collisions

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