Charmonium Production in the PHENIX Experiment at RHIC

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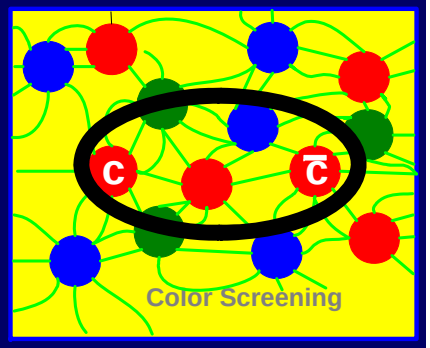
Probing Deconfinement with Charmonium

- *"If high energy heavy ion collisions lead to the formation of a hot quark-gluon plasma, then colour screening prevents* $c\bar{c}$ *binding in the deconfined interior of the interaction region."*

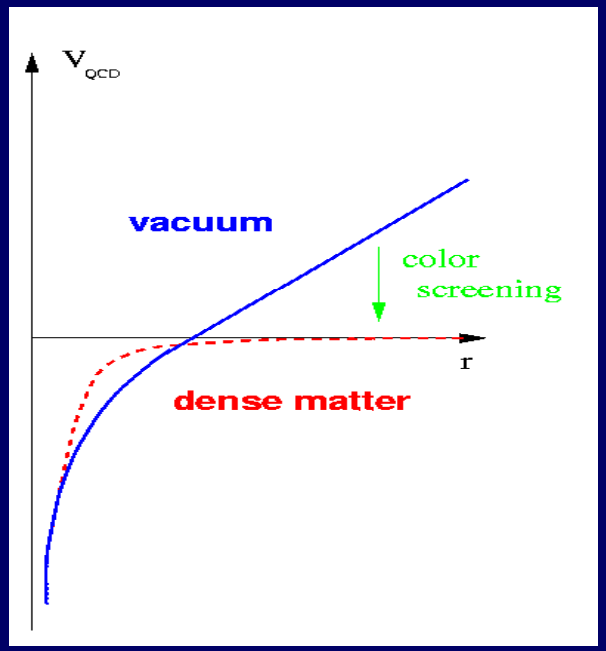
  - Matsui & Satz, 1986

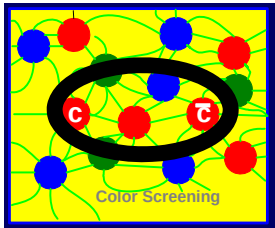


- Debye screening (from EM plasmas) is a modification a particle's potential due to the charge density of the surrounding medium.

- One way to look at it is that the charmonium potential well is modified in the medium to become shallower.

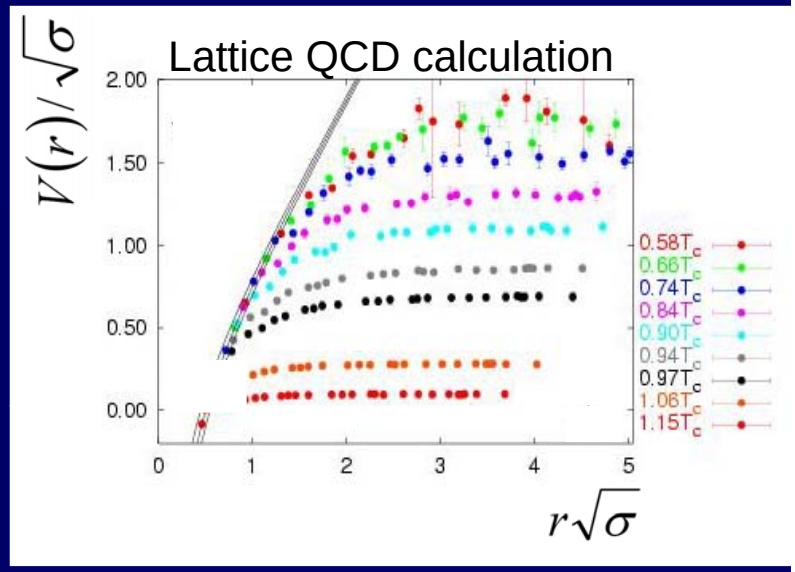
$$V(r) = \kappa\, r - \frac{\alpha}{r} \longrightarrow V(r) = -\frac{\alpha\, e^{-r/\lambda_D}}{r}$$

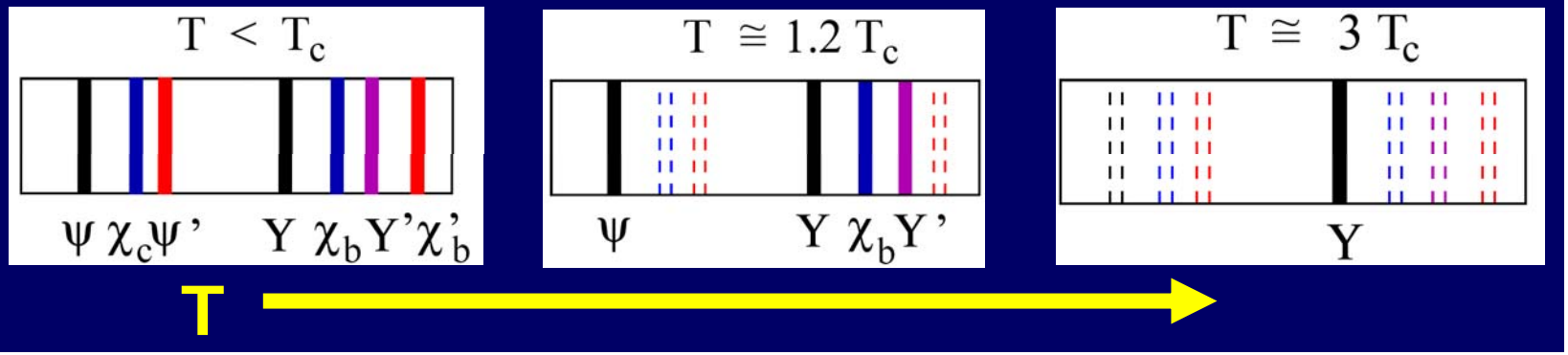




Quarkonium in QCD at Finite T

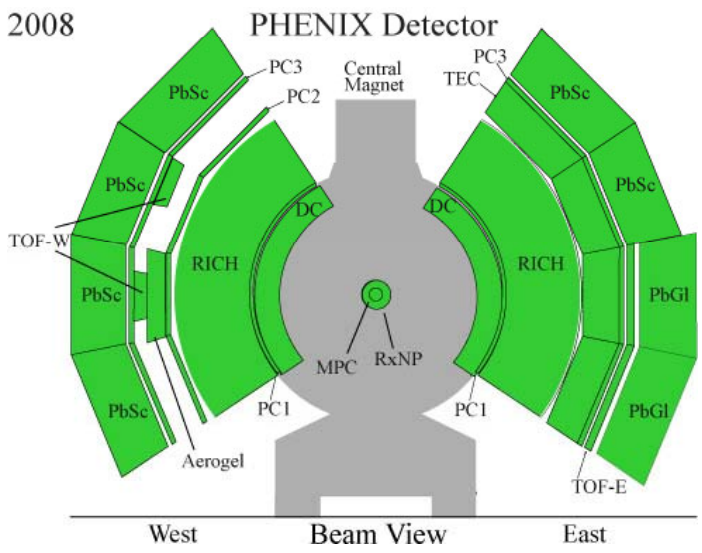
- Lattice QCD makes a clear prediction for the onset of deconfinement, different quarkonia states test the degree of color screening
- PHENIX has good capabilities to measure several $c\bar{c}$ and $b\bar{b}$ states to probe quarkonia deconfinement and other phenomena like dissociation by gluon and regeneration from heavy $q\bar{q}$ pairs



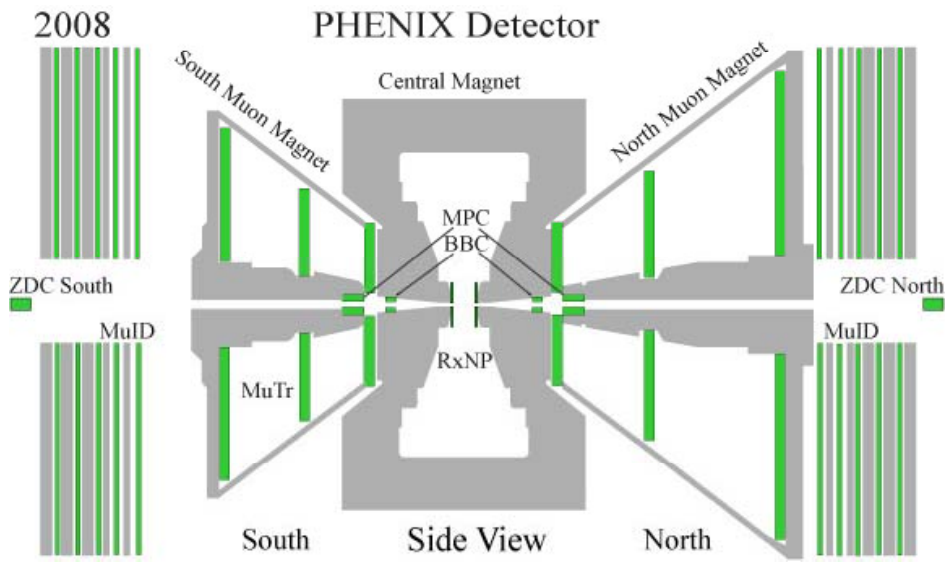


PHENIX Experiment

Central Arms



Forward Arms



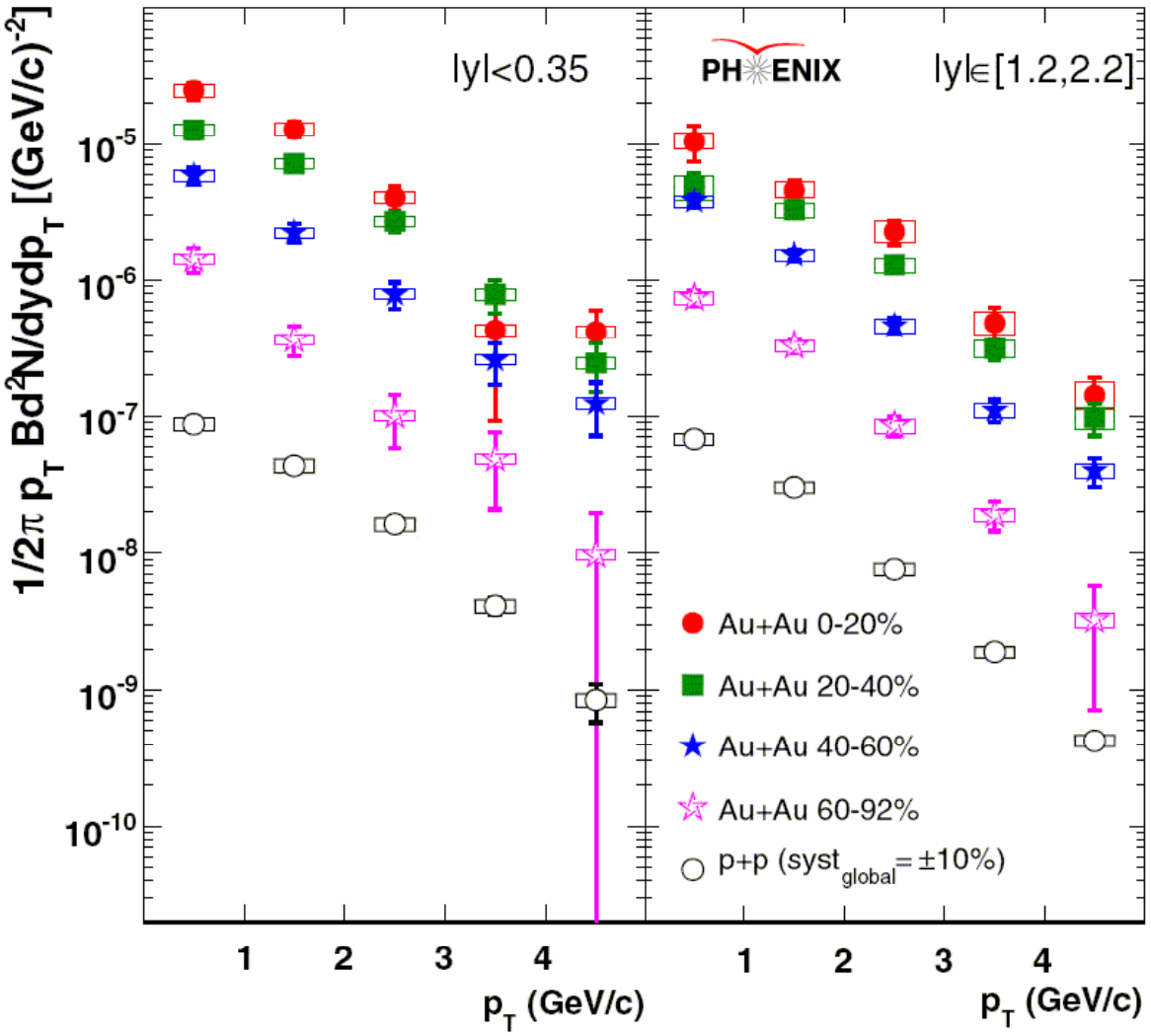
Hadrons, electron, photons

$|\eta|<0.35$ $\Delta\Phi= 2 \times \pi/2$
$p > 0.2$ GeV/c

Muons

$-2.2<\eta<-1.2$ $1.2<\eta<2.2$ $\Delta\Phi=2\pi$
$p>2$ GeV/c

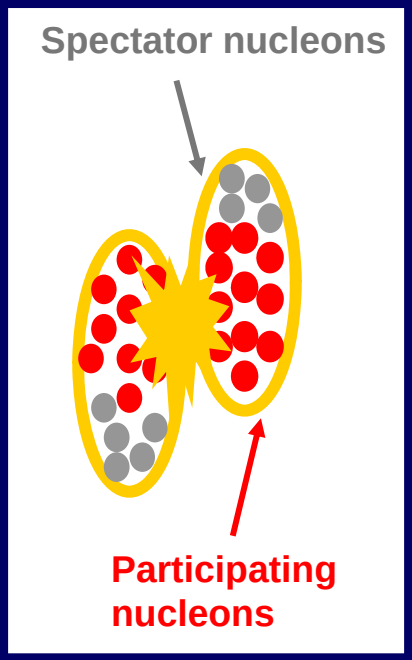
J/ψ Yield vs Transverse Momentum

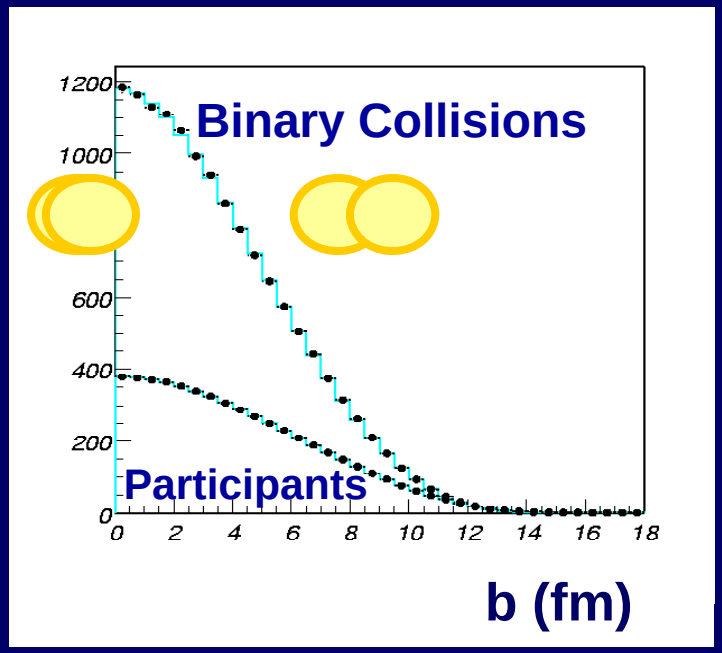


Characterizing Nuclear Collisions: Nuclear Modification Factor

$$R_{AA} = \frac{dN_{AA}^{J/\psi}/dy}{N_{coll} dN_{pp}^{J/\psi}/dy}$$

The yields from nuclear collisions are divided by p+p yields, scaled by the appropriate number of binary collisions

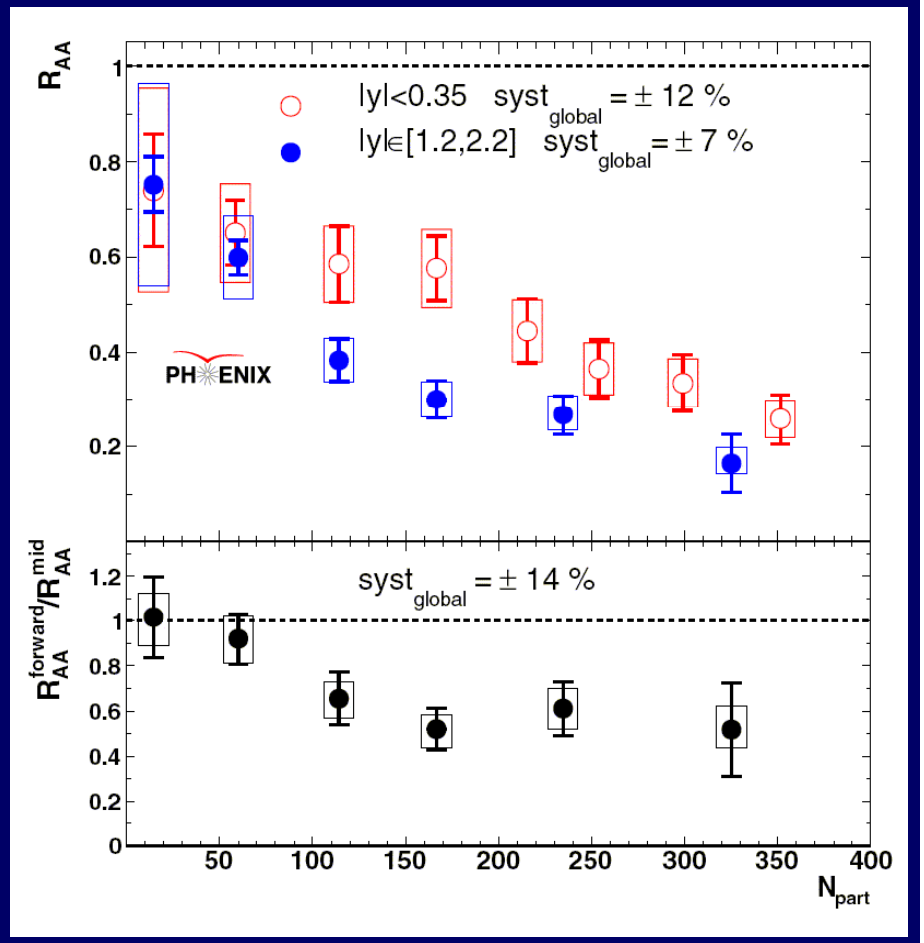




Nuclear Modification Factor

$$R_{AA} = \frac{dN_{AA}^{J/\psi}/dy}{N_{coll} dN_{pp}^{J/\psi}/dy}$$

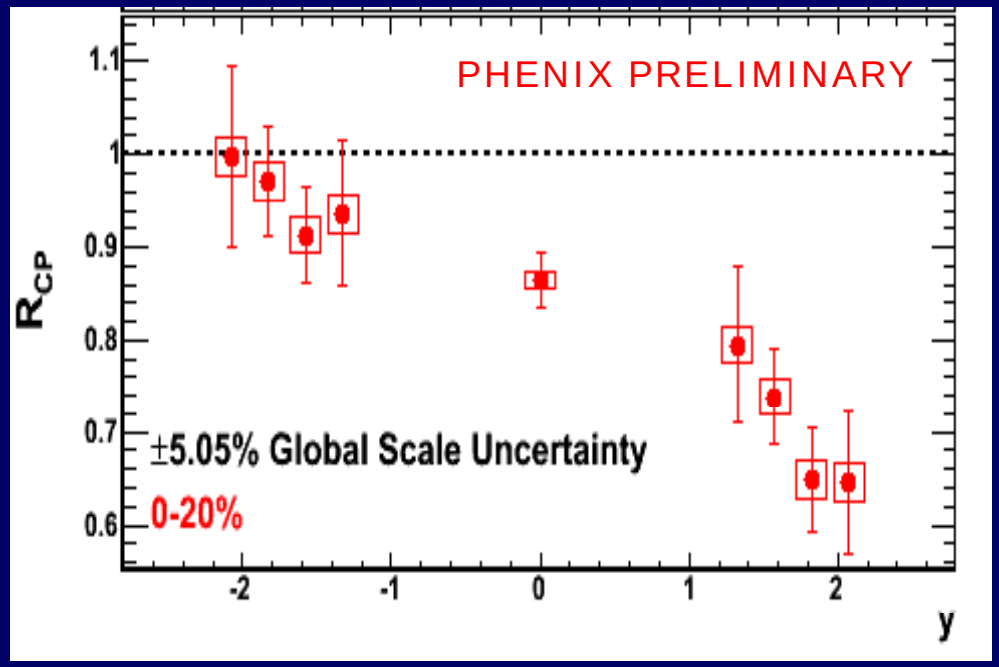
- Strong J/ψ suppression for most central collisions
- Forward rapidity more suppressed than mid-rapidity
- Does the J/ψ show anomalous suppression? Need a measurement of cold nuclear matter effects



Cold nuclear matter effects

- Measure J/ψ production in 200GeV d+Au collisions

$$R_{cp} = \frac{\left(\frac{dN_{J/\psi}}{dy}/N_{coll}\right)}{\left(\frac{dN^{60-80\%}_{J/\psi}}{dy}/N^{60-80\%}_{coll}\right)}$$

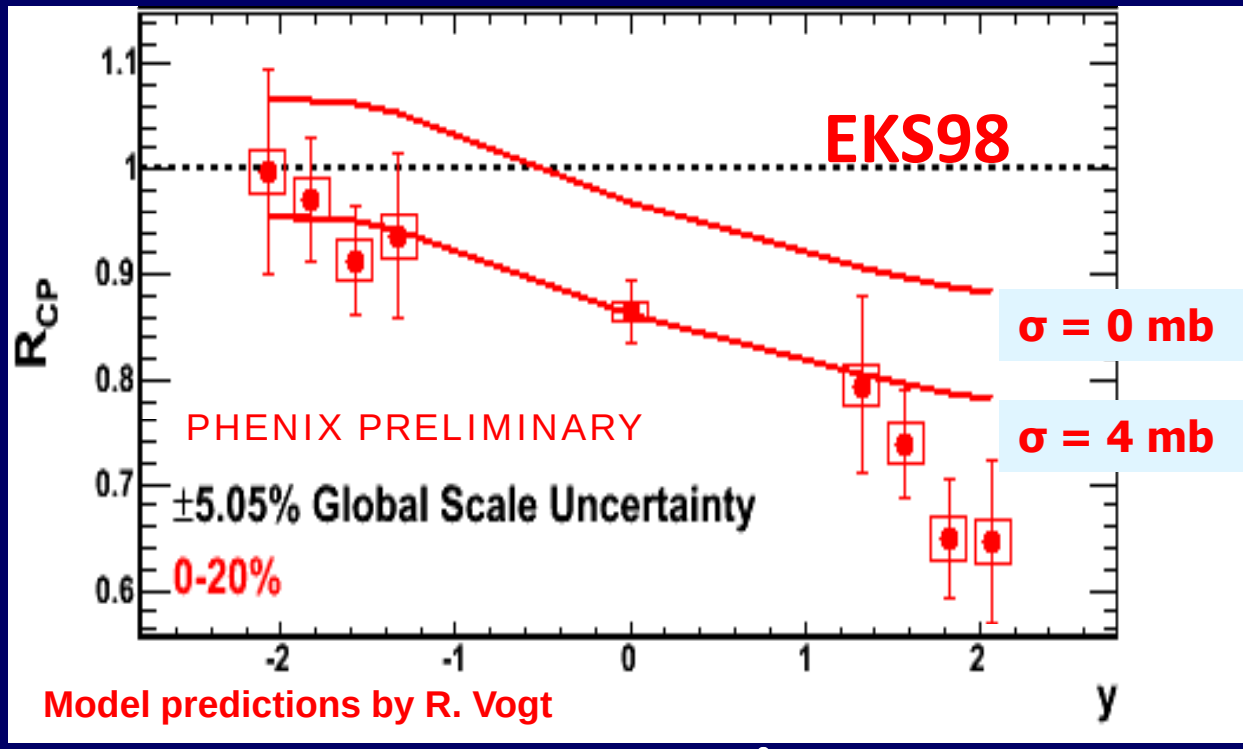


- R_{CP} flat at backward rapidity
- R_{CP} decreases at forward rapidity (small-x)

Cold nuclear matter effects

- In PHENIX, J/ψ mostly produced by gluon fusion, and thus sensitive to shadowing effects in the gluon PDFs
- J/ψ breakup by collisions with projectile nucleons

$$R_{cp} = \frac{\left(\frac{dN_{J/\psi}}{dy}/N_{coll}\right)}{\left(\frac{dN^{60-80\%}_{J/\psi}}{dy}/N^{60-80\%}_{coll}\right)}$$



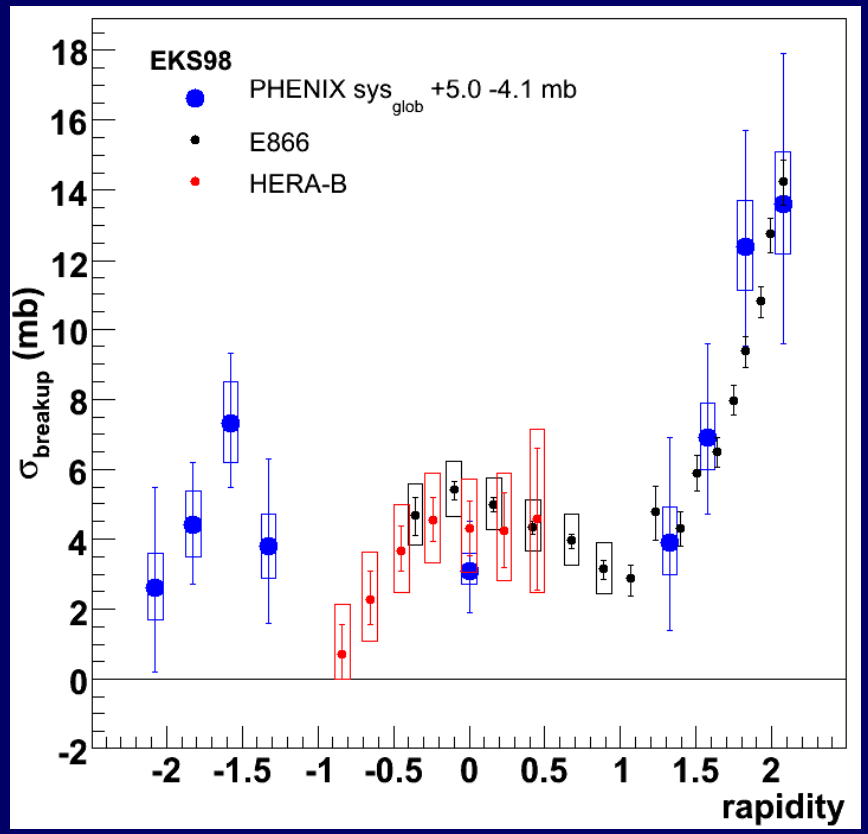
Model predictions by R. Vogt

Effective breakup cross section

- Use d+Au data to extract <u>effective</u> breakup cross section as a function of rapidity to parametrize all the effects that shadowing is missing
  (R. Vogt, T. Frawley)

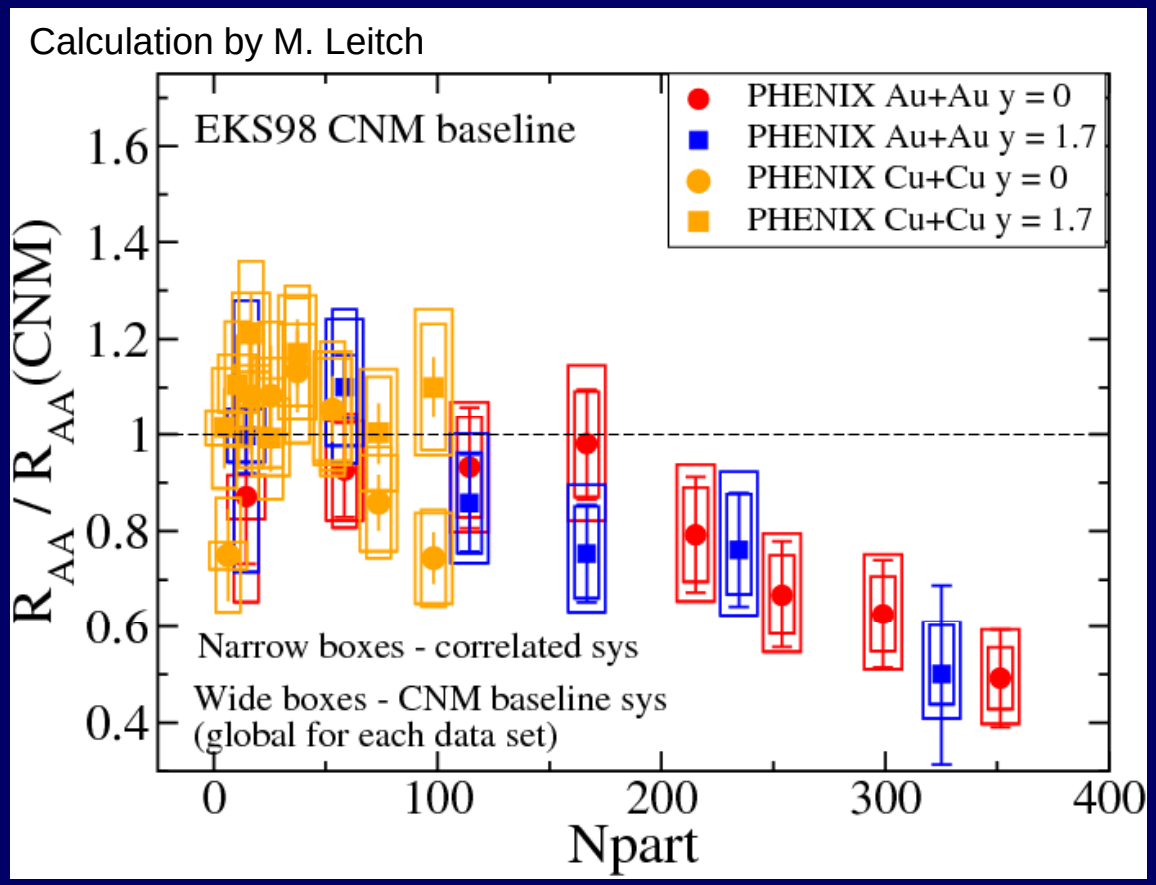
- Same trend observed by E866 & HERA-B

  (Lourenco, Vogt, Woehri arXiv:0901.3054)



Anomalous Suppression

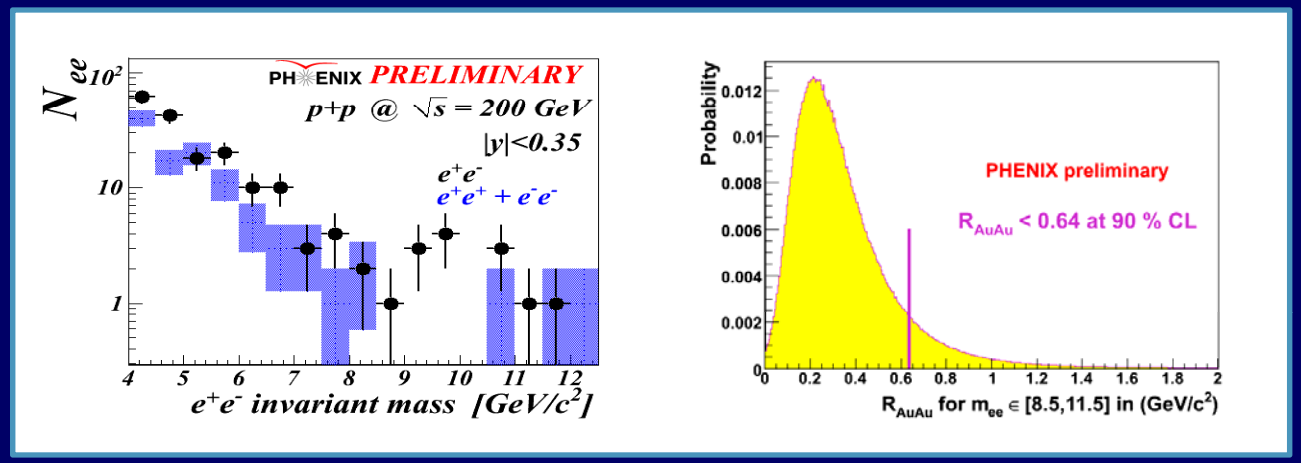
- Using the breakup cross section extracted in d+A collisions we can predict suppression in HI collisions



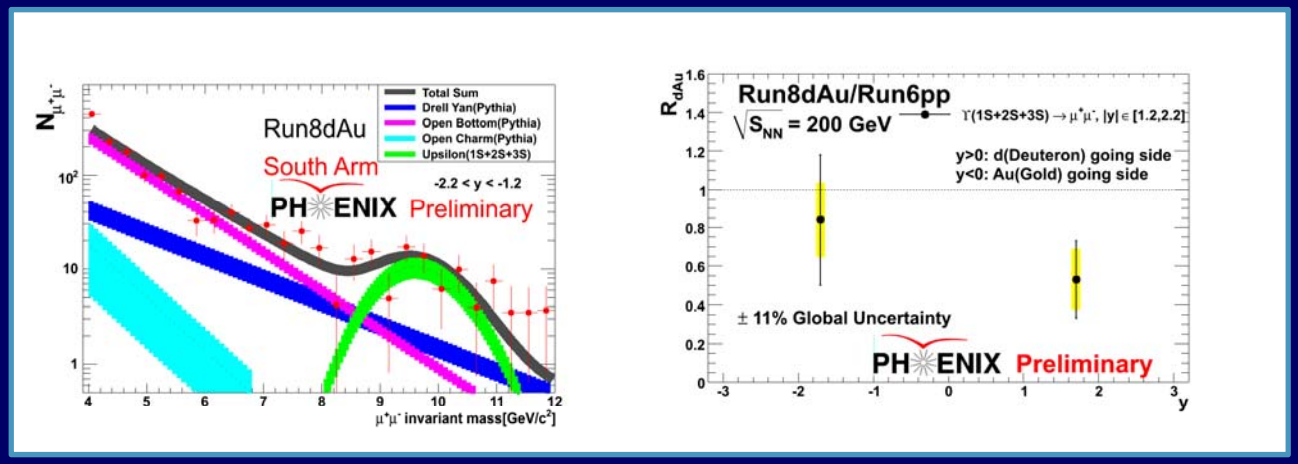
- Evidence of suppression in Au+Au beyond cold nuclear matter effects
- Need higher statistic Au+Au run to measure feed-down contributions

Other Quarkonia States

- First look at Υ nuclear modification factors



- At y=0
  R_{AuAu}<0.64 at 90%CL
  Run 10 expected 4 x Au+Au data



- At forward rapidity
  R_{dAu}=0.53 ±0.20±0.16

Conclusions

- PHENIX has made a set of systematic measurement of J/ψ production in p+p, Au+Au, d+Au
- d+Au data clearly shows that Cold Nuclear Matter effects are not completely understood in terms of shadowing and a breakup cross-section.
- Au+Au data shows anomalous suppression consistent with deconfinement
- Higher statistics Au+Au data set will allow measurements for other quarkonia states such as Υ and ψ'