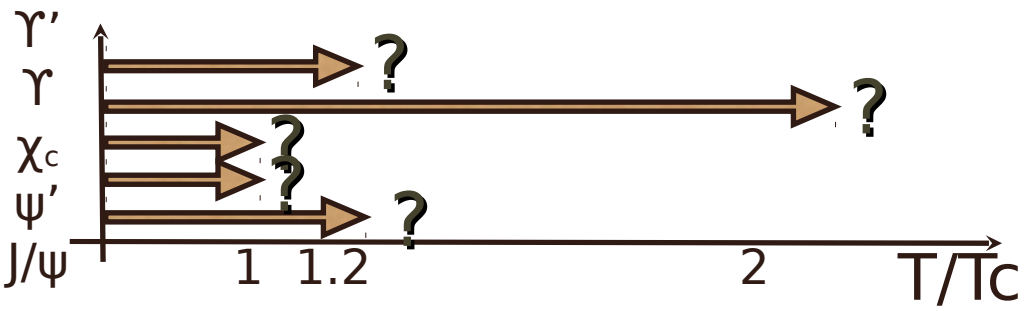
Results from PHENIX

Todd Kempel – Iowa State University

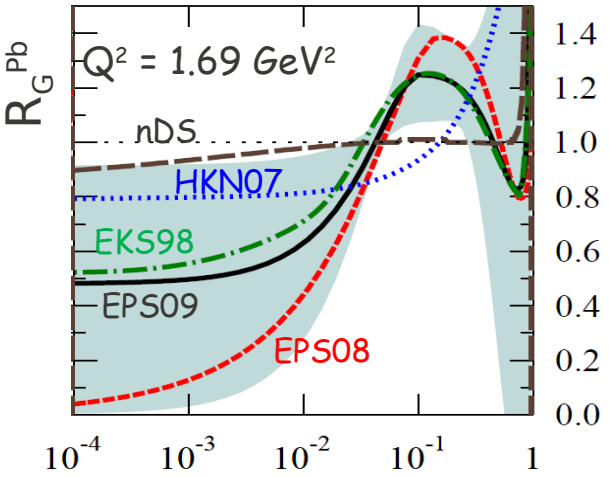
Physics with Quarkonia at RHIC



A+A
- 'Thermometer' for QGP
(but requires knowledge of CNM effects)

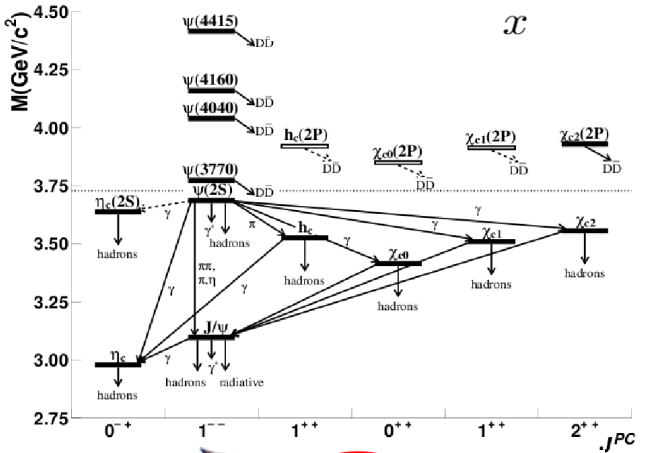
d+Au collisions

- parton distribution modifications
- charmonium breakup in hadronic matter
(but requires knowledge of production mechanism)

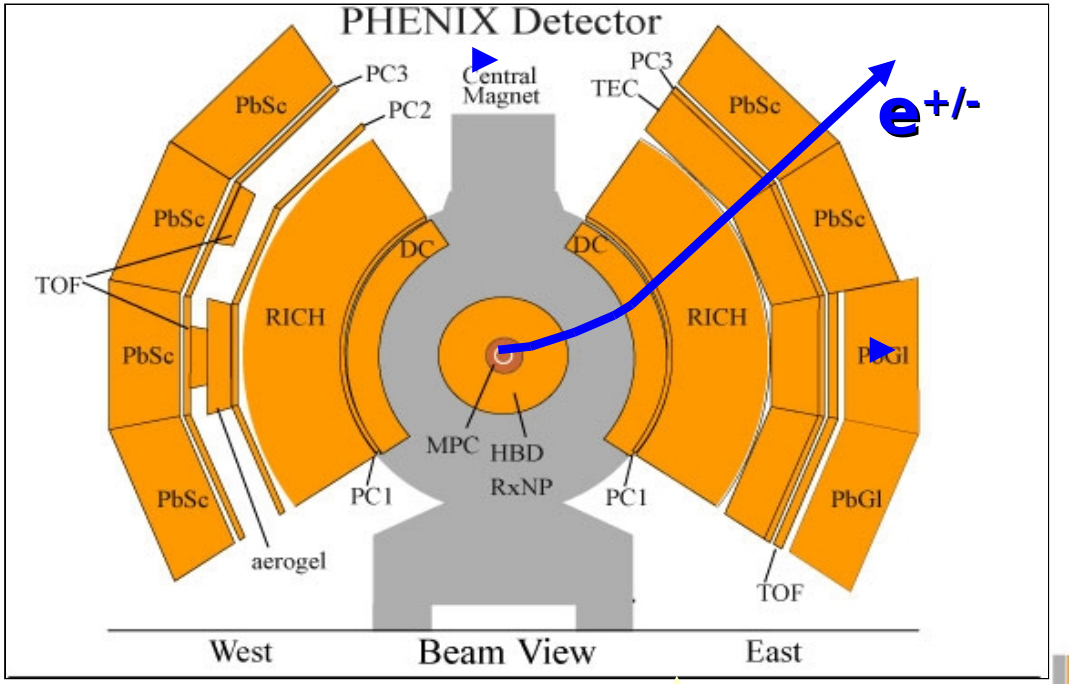


p+p collisions

- access to production mechanism
- feed down contributions to J/ψ



PHENIX was Built to Measure Leptons



$|\eta| < 0.35$

$\Delta\varphi = 2 * (\pi/2)$

$\pi^0/\gamma/\eta$
Electromagnetic Calorimeter

π^+/π^-
Drift Chamber
Ring Imaging Cherenkov Counter

e^+/e^-
HBD

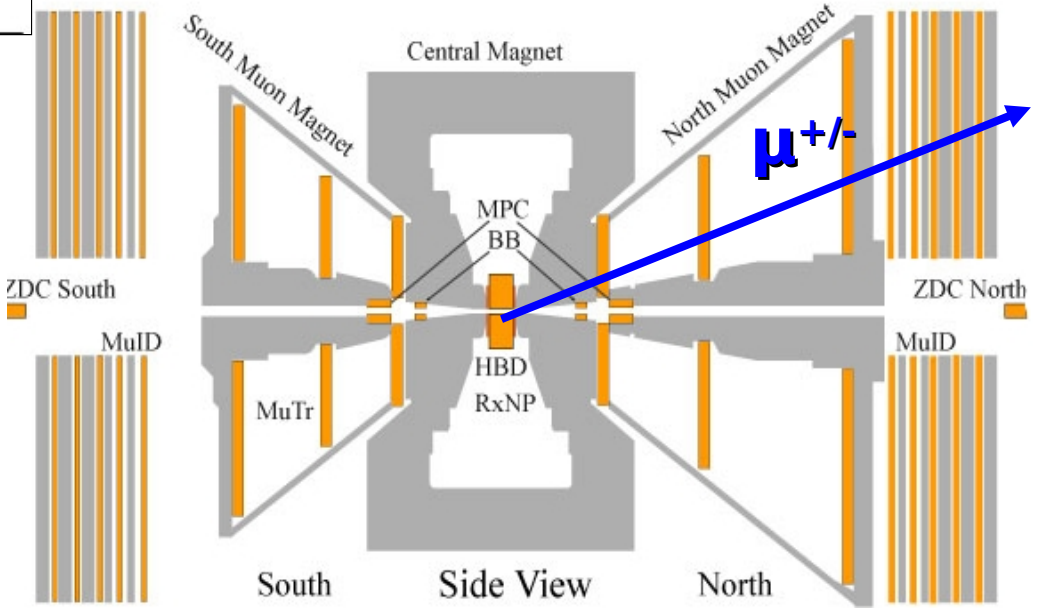
Philosophy (initial design):

High rate capability & granularity
Good mass resolution & particle ID
Sacrifice acceptance

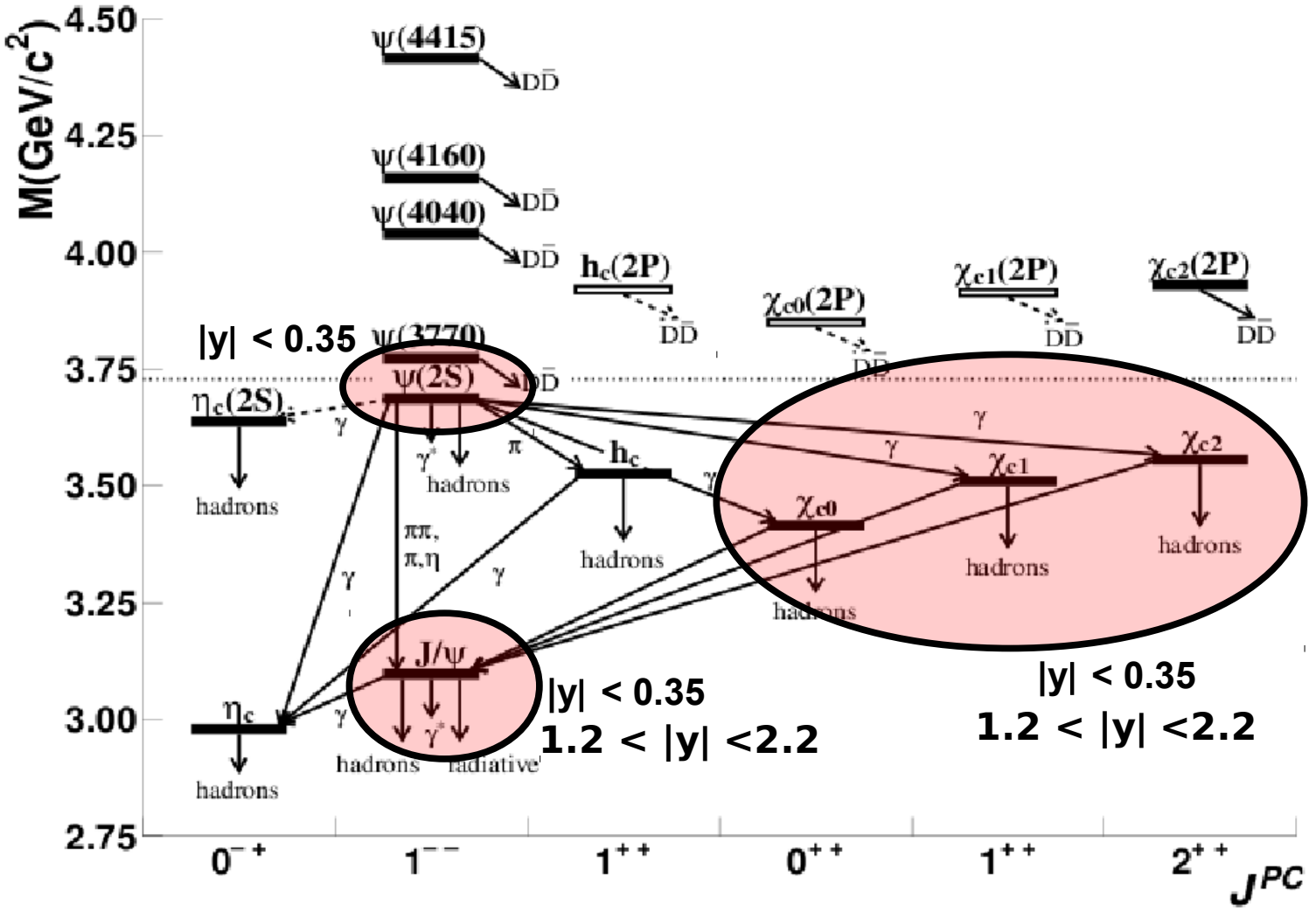
μ^+/μ^-
Muon Tracking Detector
Muon Identifier

$1.2 < |\eta| < 2.2$ (2.4)

$\Delta\varphi = 2\ \pi$



Charmonium States at PHENIX



ϒ states

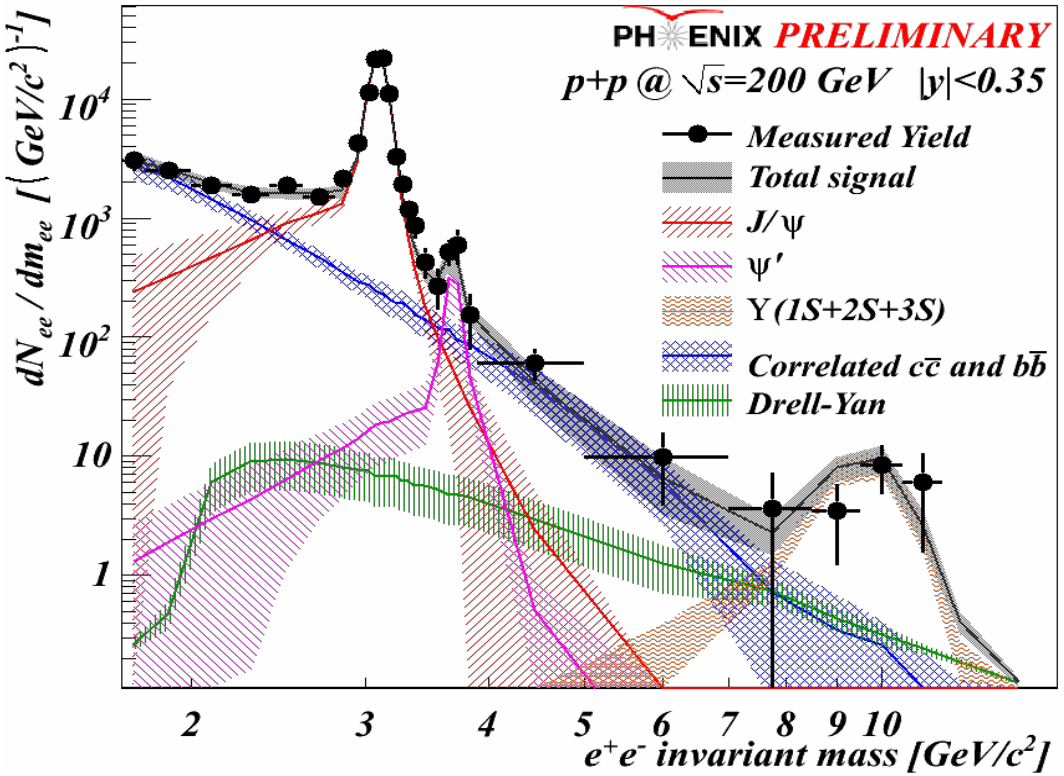
|y| < 0.35

1.2 < |y| <2.2

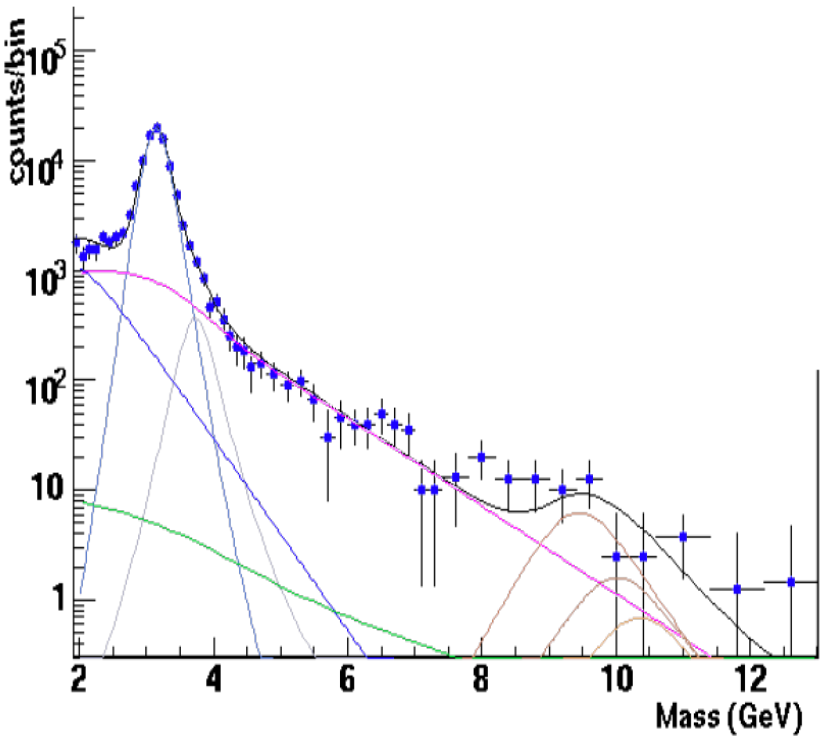
Results from p+p collisions

Dilepton continuum at PHENIX

e^+e^- **|y| < 0.35**

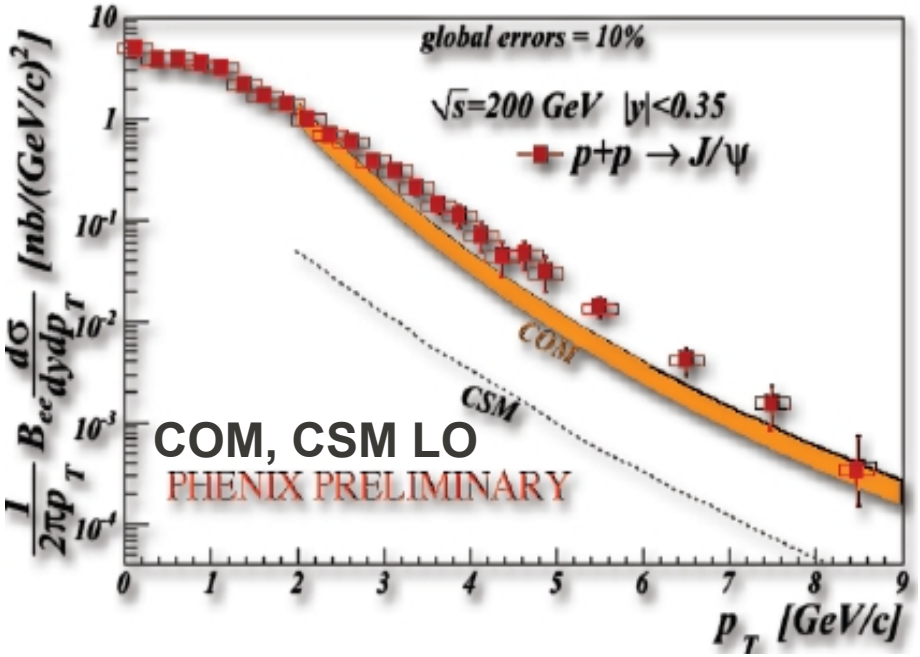


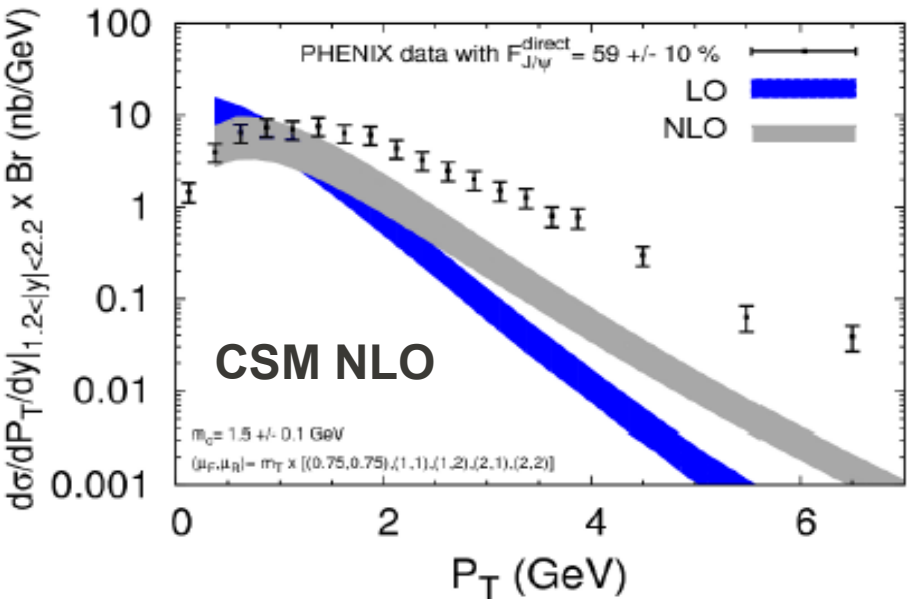
$\mu^+\mu^-$ **1.2 < |y| <2.2**

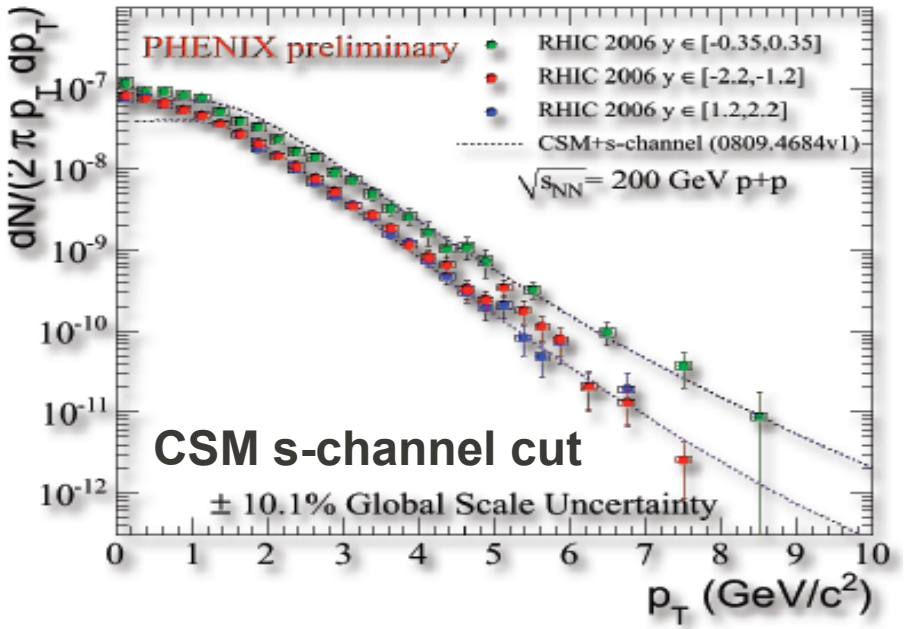


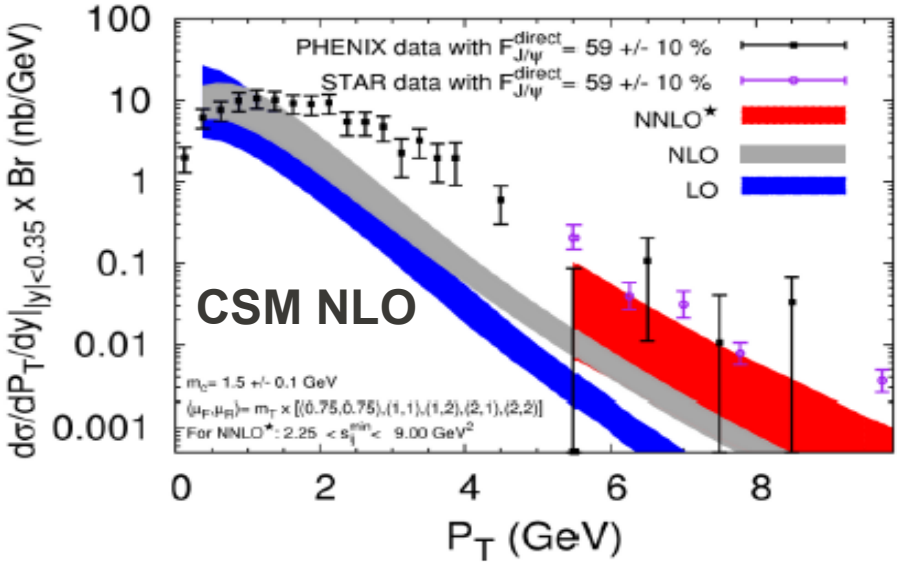
Backgrounds well understood for |y|<0.35
Moderately well understood for 1.2 < |y| < 2.2

J/ψ cross-sections compared to models



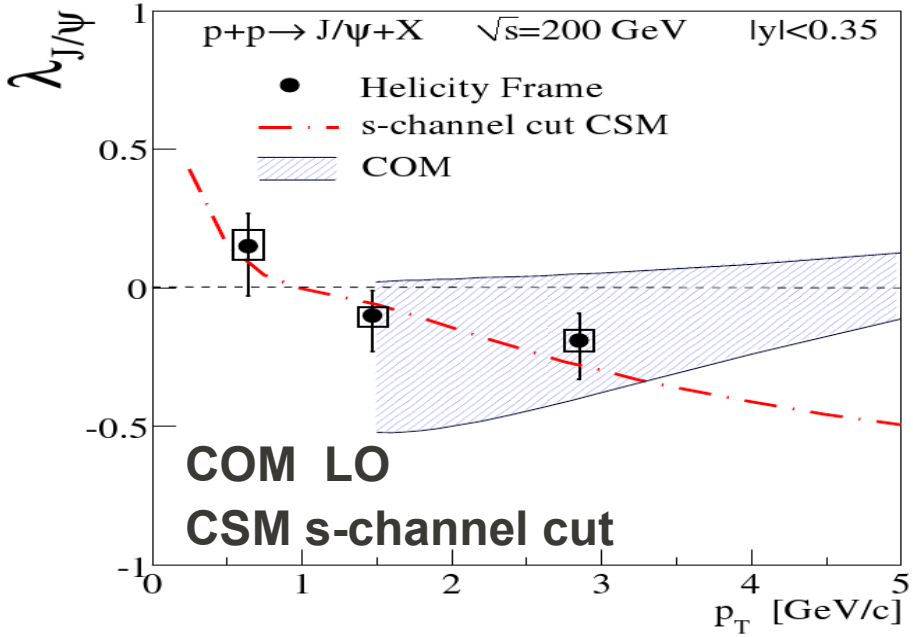


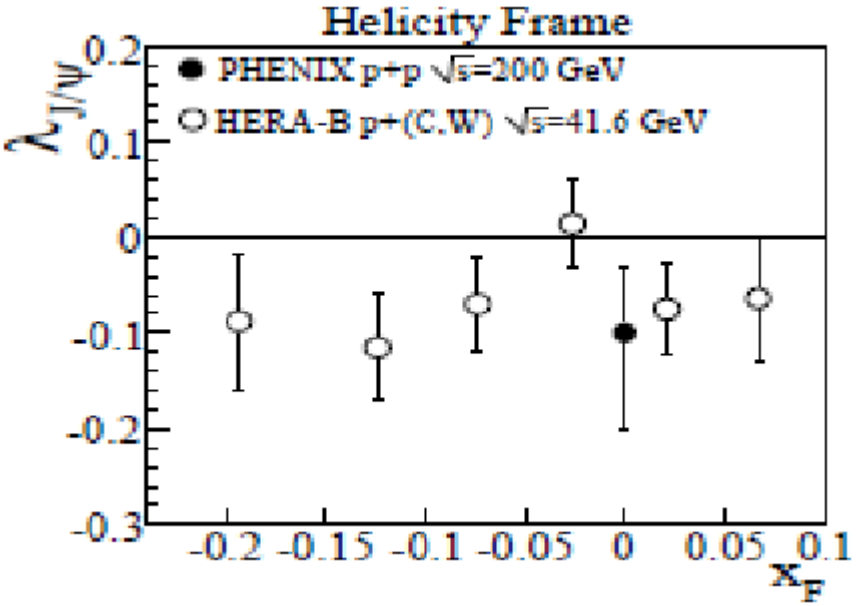


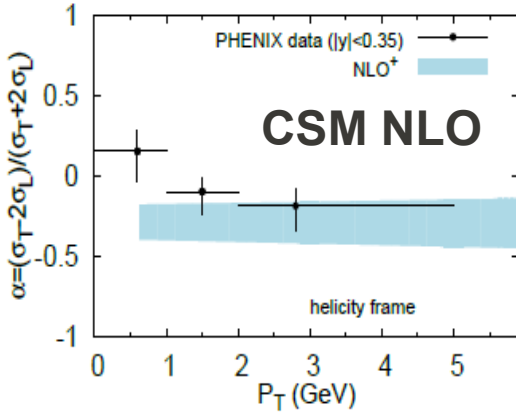


Best agreement is with CSM s-channel cut

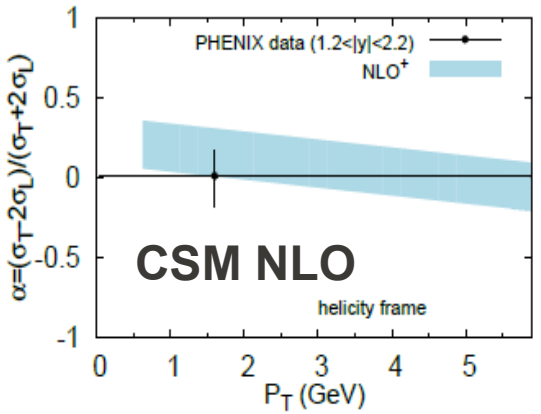
J/ψ spin-alignment compared to models



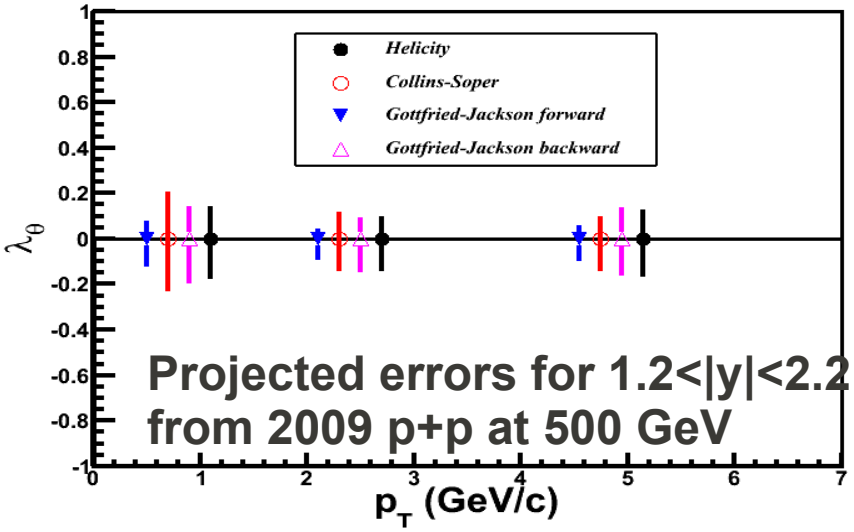




(a) central



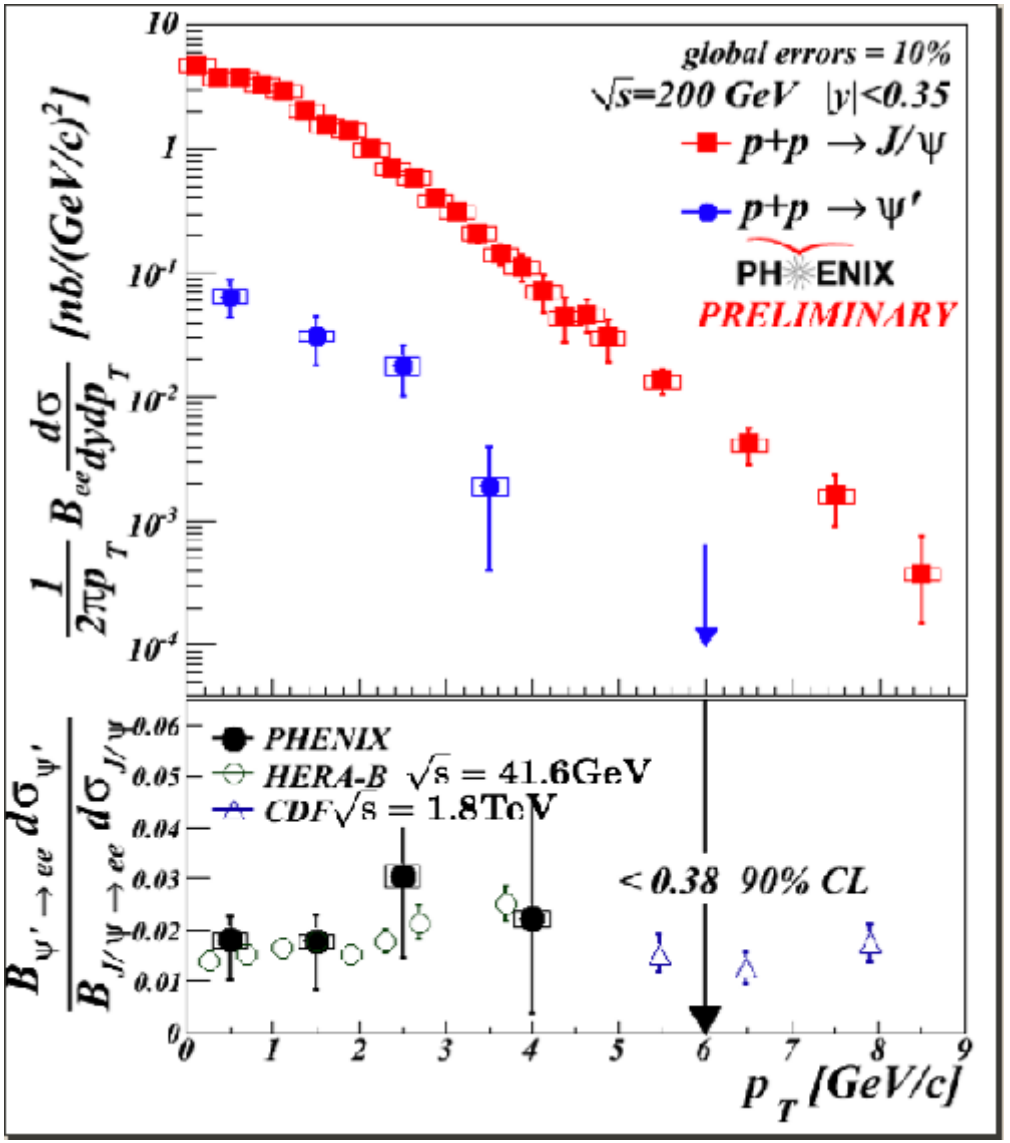
(b) forward



Data isn't very conclusive. 500GeV forward data may provide a better constraint

PHENIX

$\psi' \rightarrow e^+e^-$

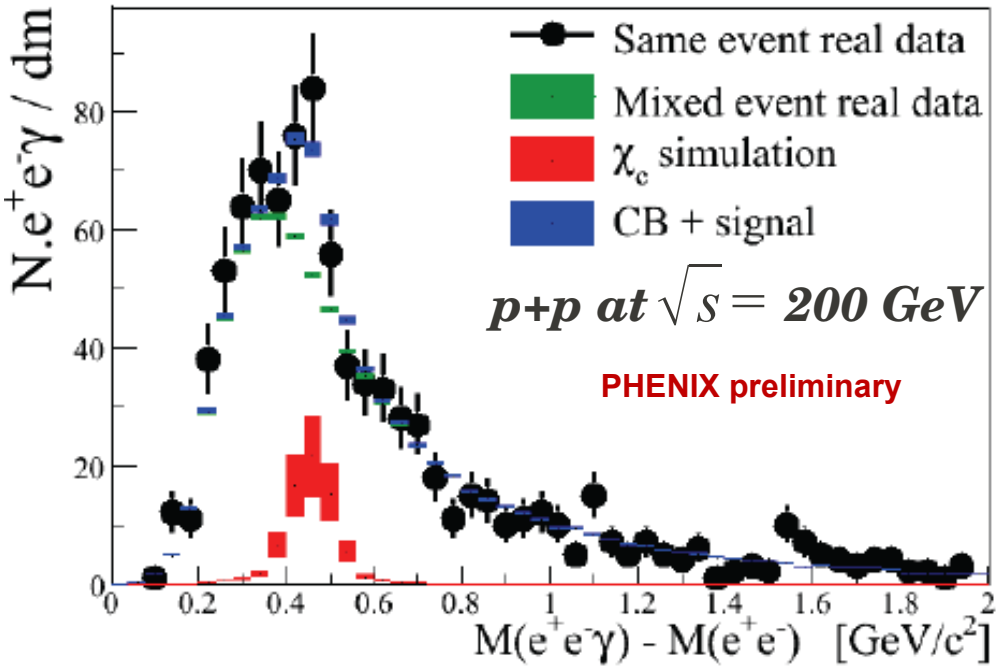


ψ'/ J/ψ ratio in the dielectron channel about 2%
(consistent with HERA-B and CDF)

J/ψ from ψ' = (8.6 ± 2.5)%

world average: (8.1 ± 0.3) %
[Faccioli, JHEP 0810:004,2008]

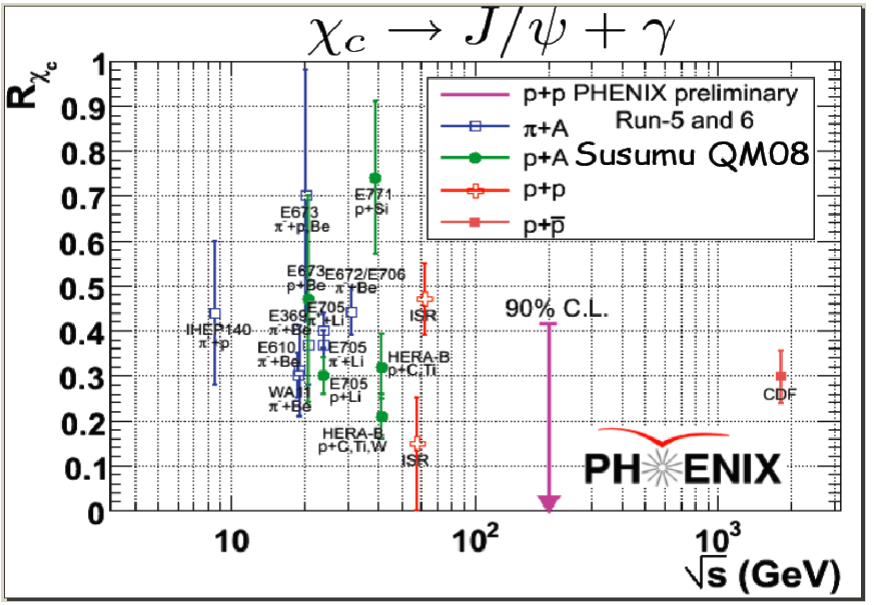
$\chi_c \rightarrow J/\psi + \gamma$

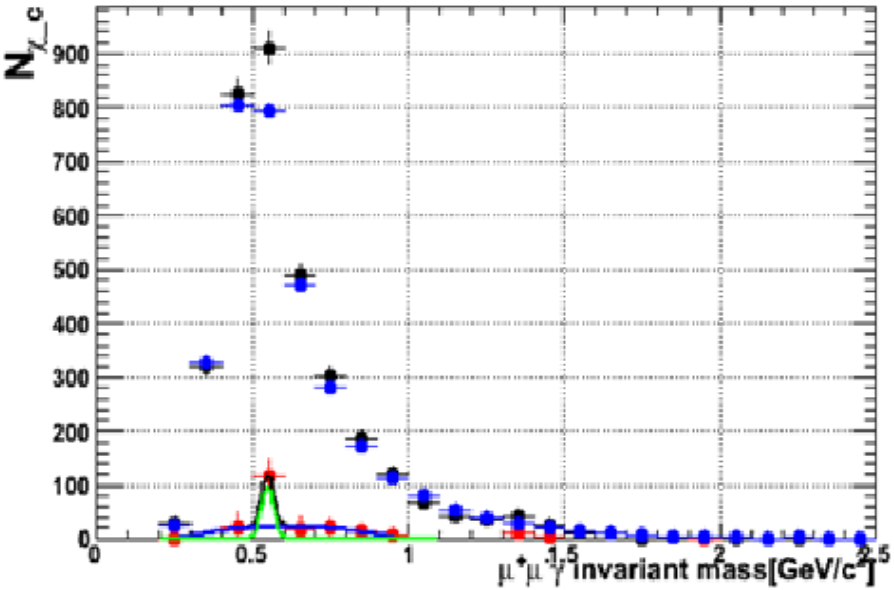


Large Background from π^0
Also contributions from physical sources:
$\psi' \rightarrow J/\psi + \pi^0 \rightarrow e^+e^-\gamma\gamma$

J/ψ from χ_c < 42% (90% CL)

world average (25±5)%
[Faccioli, JHEP 0810:004,2008]



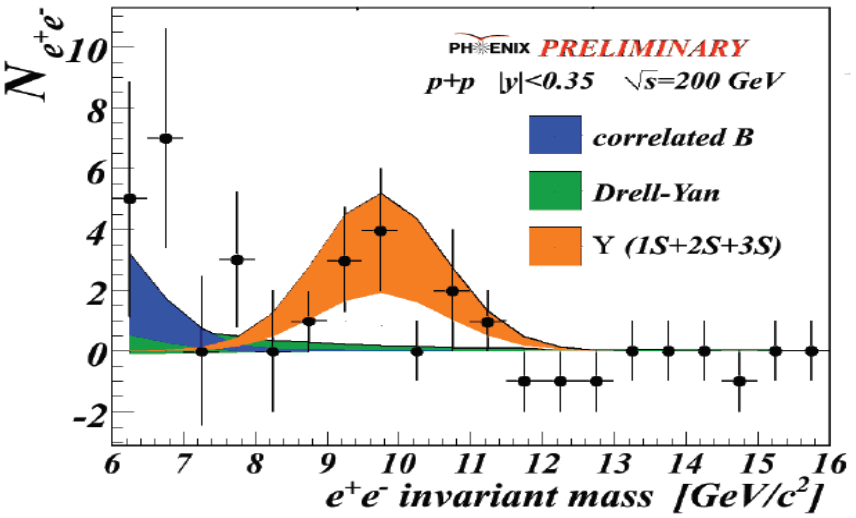


Near **future**: *forward* rapidity χ_c study is under way in d+Au and p+p

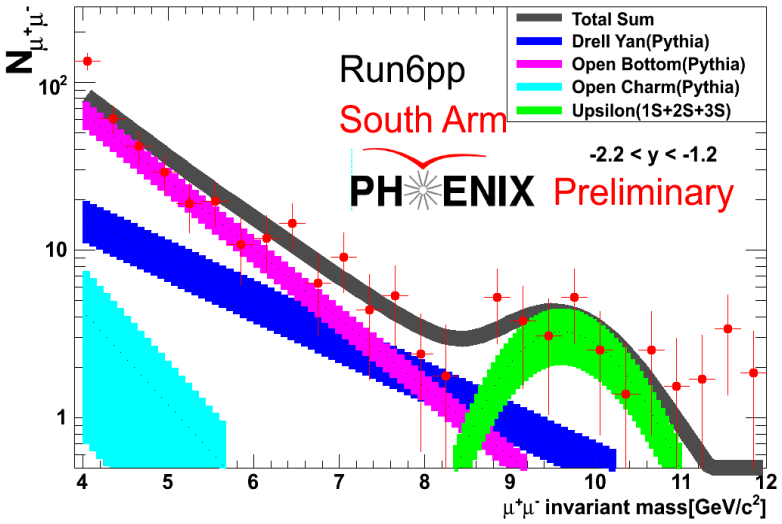
First Observations of Υ from 2006 data

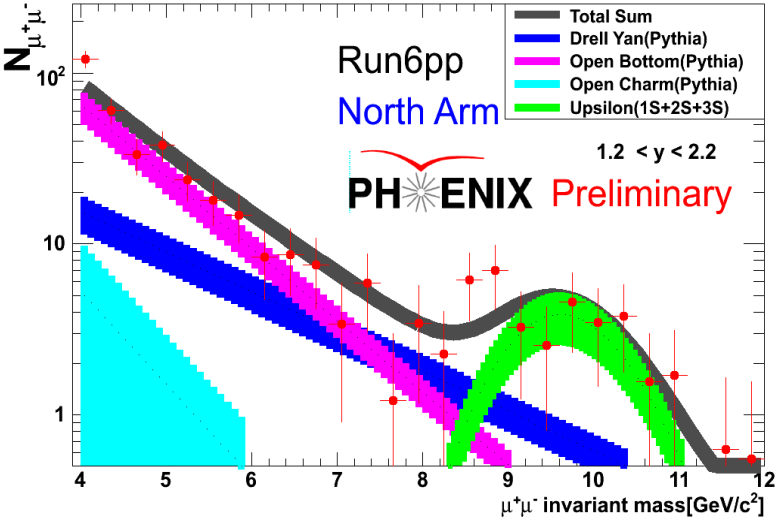
$\Upsilon(1S+2S+3S) \rightarrow e^+e^-$

|y| < 0.35

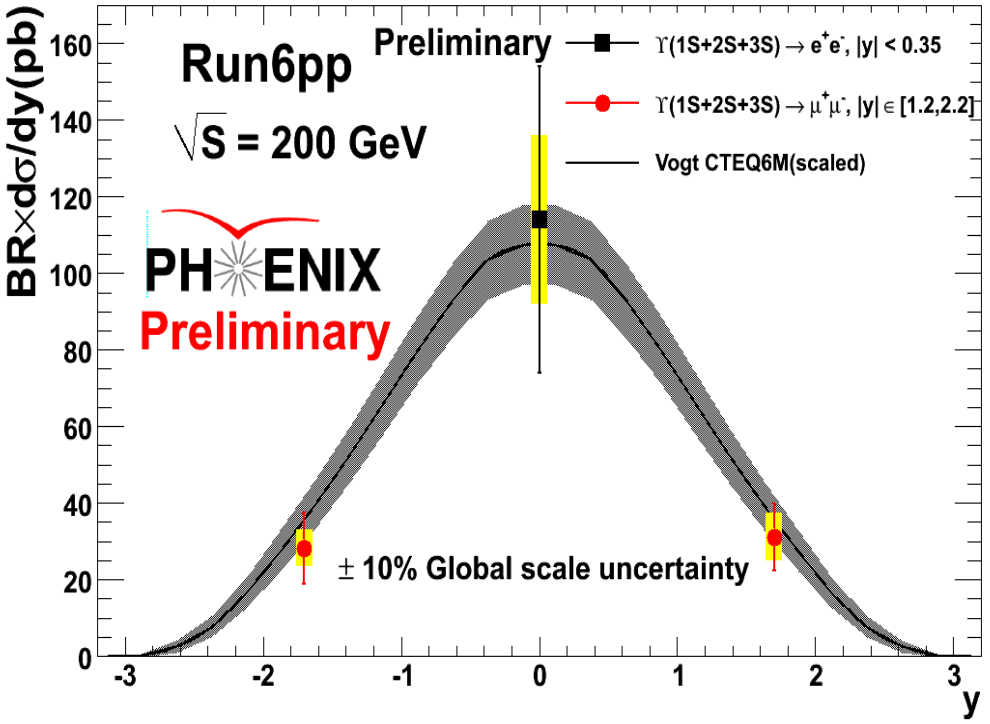


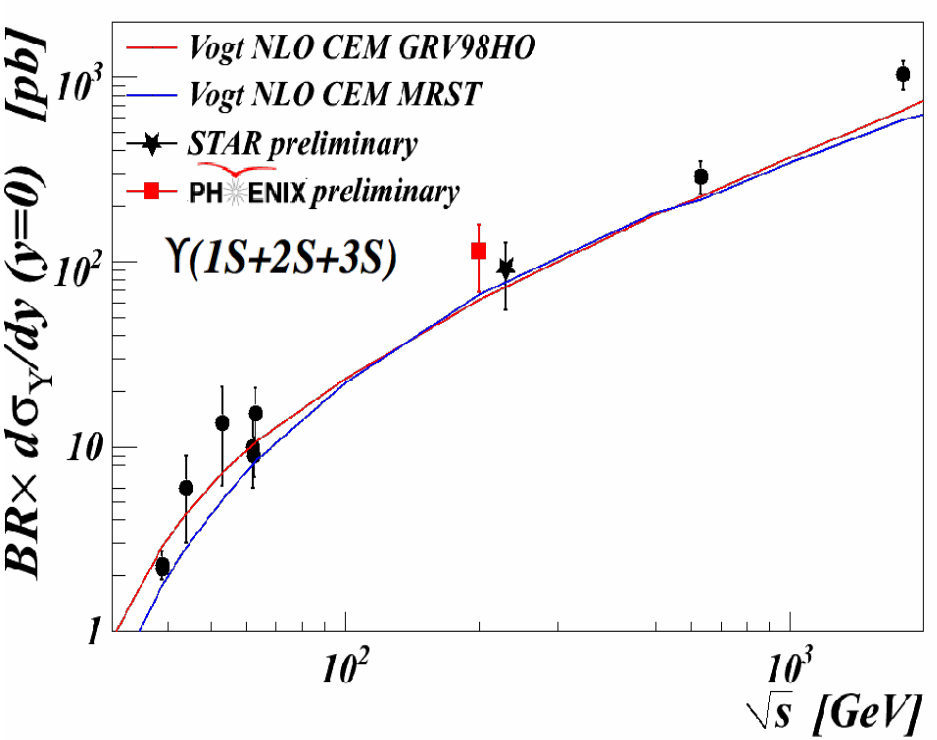
$\Upsilon(1S+2S+3S) \rightarrow \mu^+\mu^-$ **1.2 < |y| <2.2**





Cross section at y~0 follows world trend
Compatible with STAR measurement.





BR*dσ/dy = 28.2±9.4(stat.)±4.8(syst.)pb, y∈[-2.2, -1.2]
BR*dσ/dy = 31.1±8.7(stat.)±6.2(syst.)pb, y∈[1.2, 2.2]

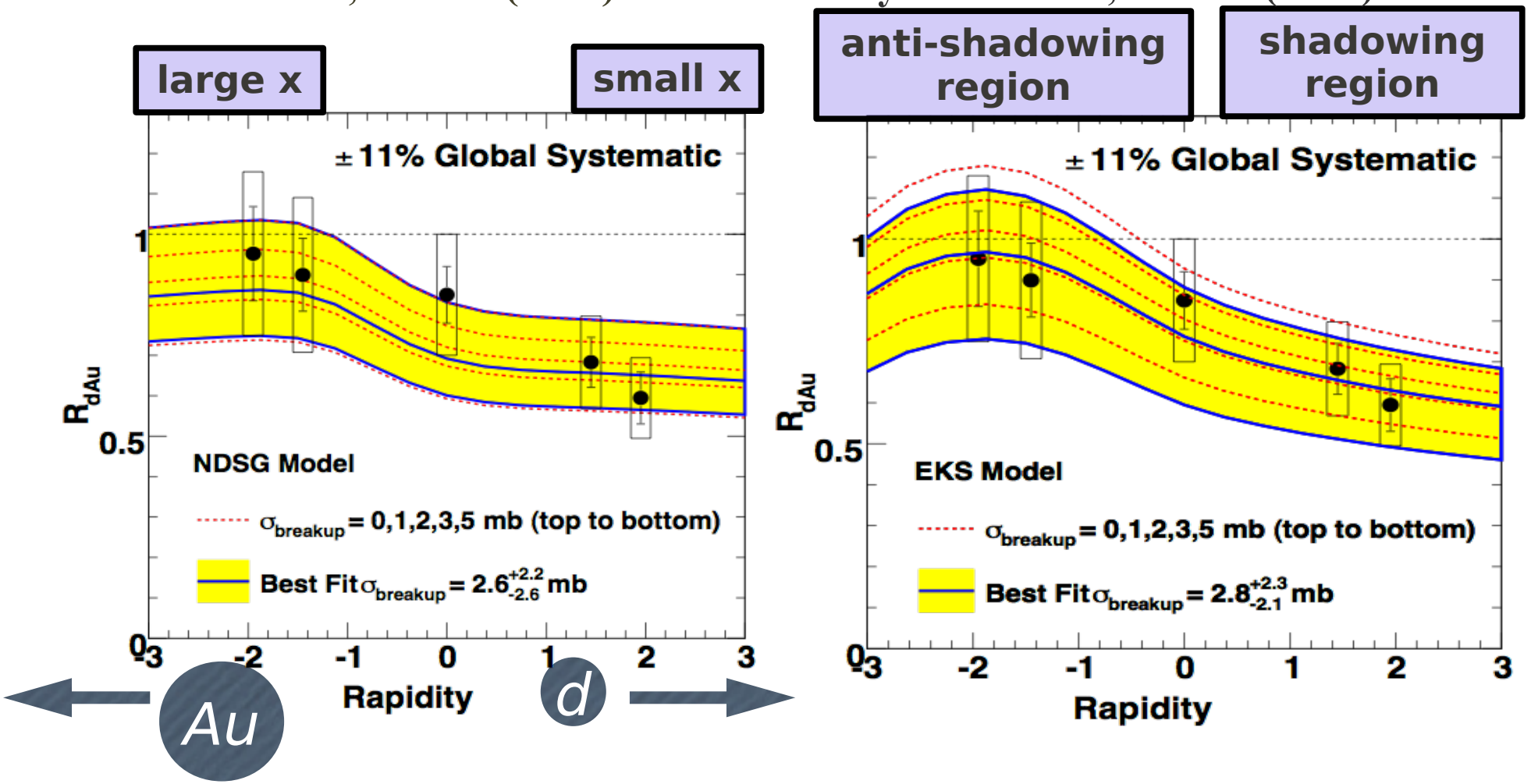
$$B\frac{d\sigma_\Upsilon}{dy}\Big|_{|y|<0.35} = 114^{+46}_{-45} pb$$

Results from d+Au collisions

Revised Fits to 2003 R_{dAu} data

Now account for all systematic errors

PRC 77, 024912 (2008). Erratum: Phys. Rev. C 79, 059901 (2009)



Calculations assume Color Evaporation Model, but different mechanisms correspond to different translation between x and J/ψ p_T and y

2008 Data Provide Better Access

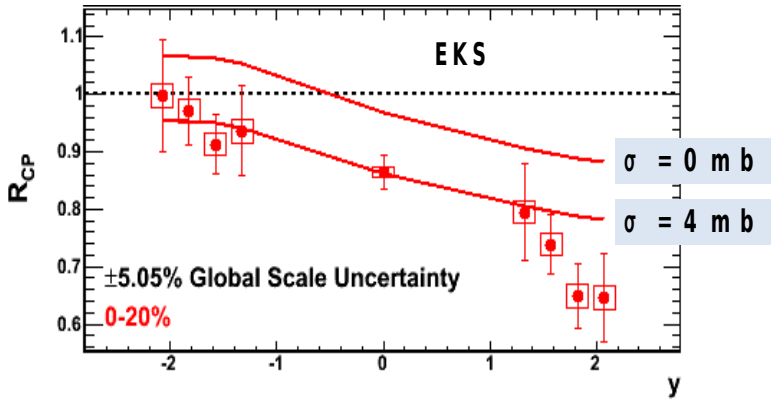
$$R_{cp} = \frac{1}{N_{coll}/N_{coll}^{p}} \frac{dN/dy}{dN/dy^{p}}$$

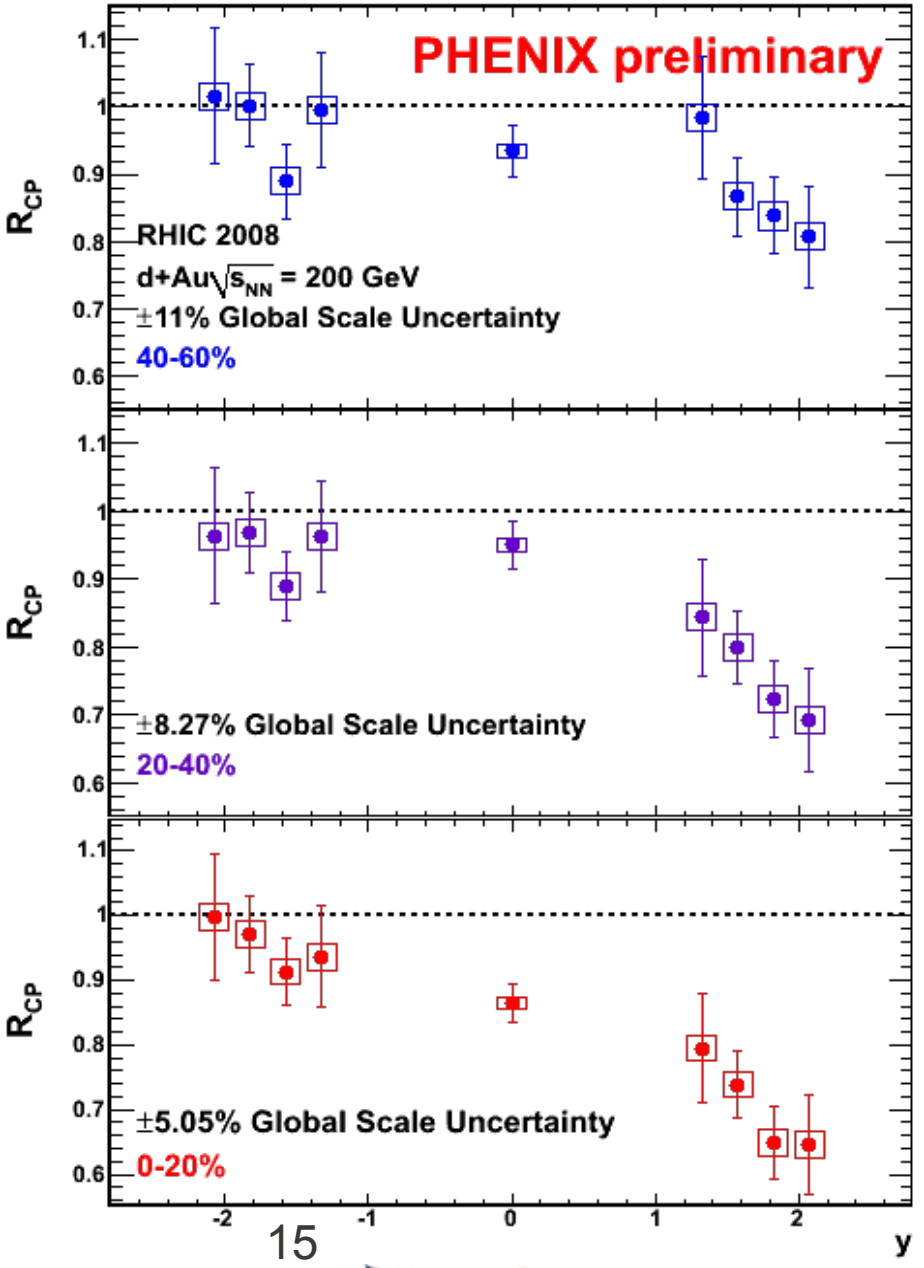
$$p \equiv \text{60-88\% centrality}$$

30x more statistics than 2003 run.

Most of systematic errors cancel out in R_{cp}.

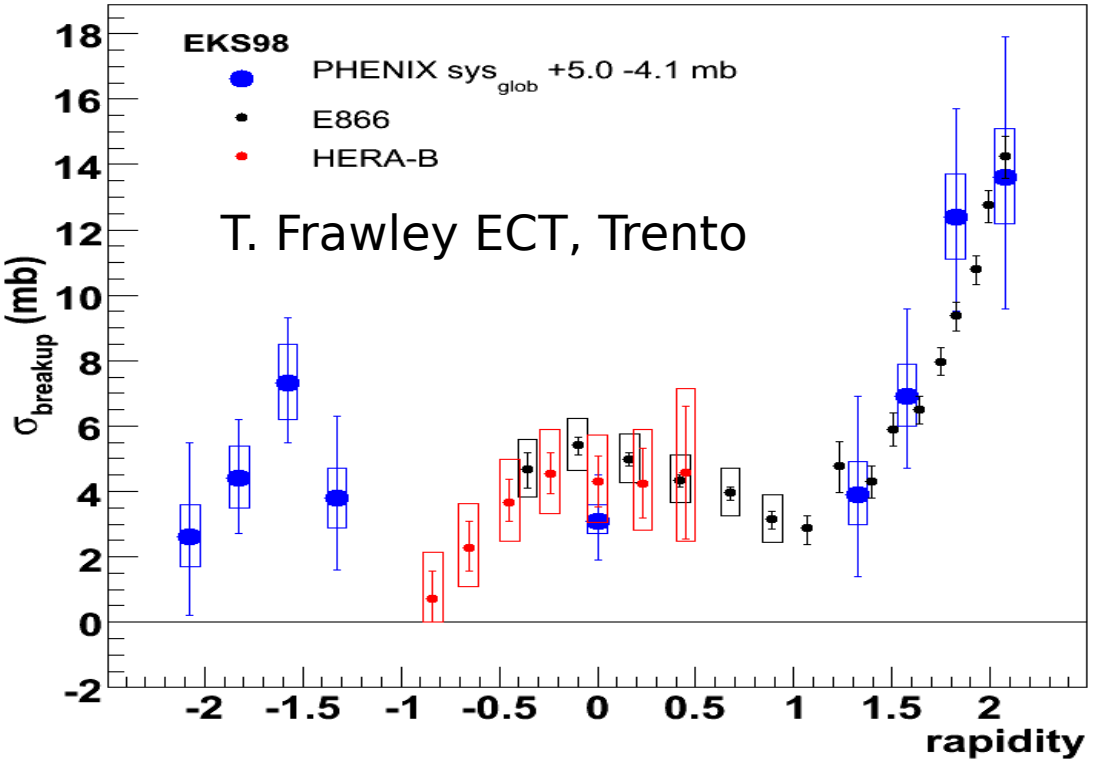
Upcoming fits to R_{dA} can better constrain $\sigma_{breakup}$.





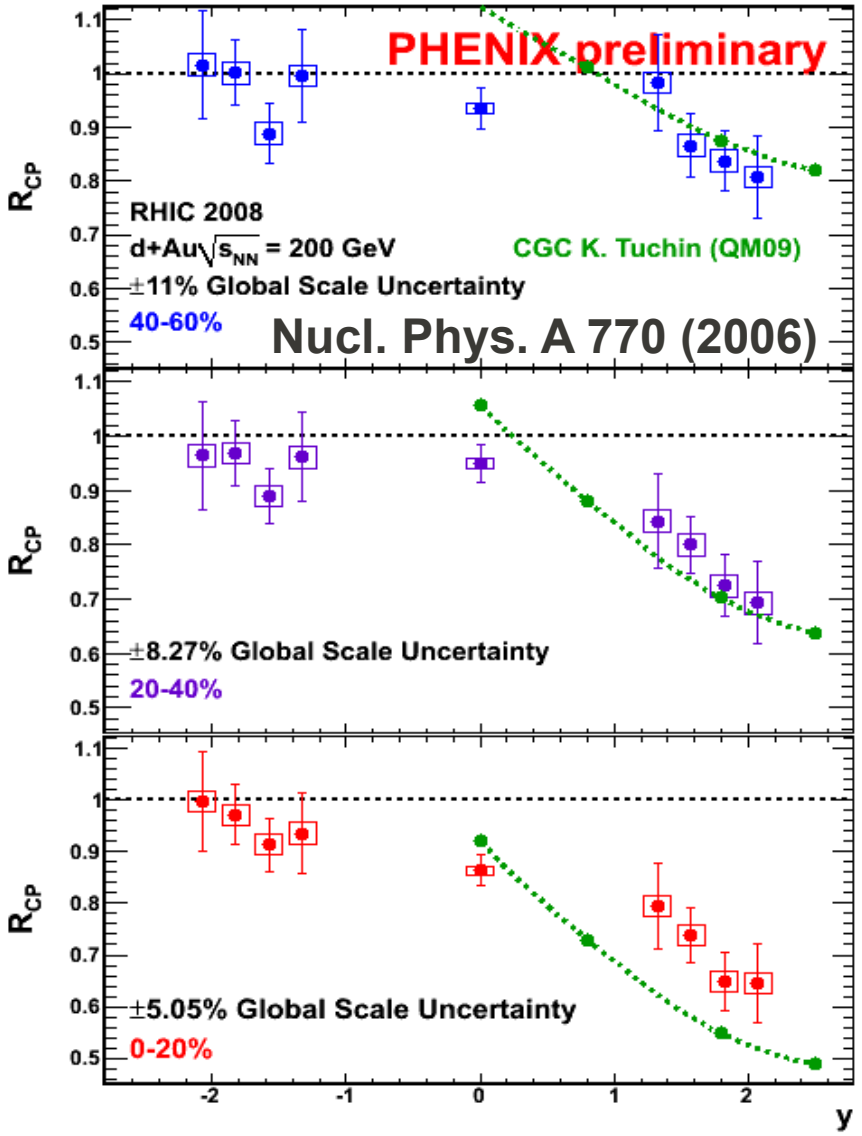
Maybe the models aren't complete.

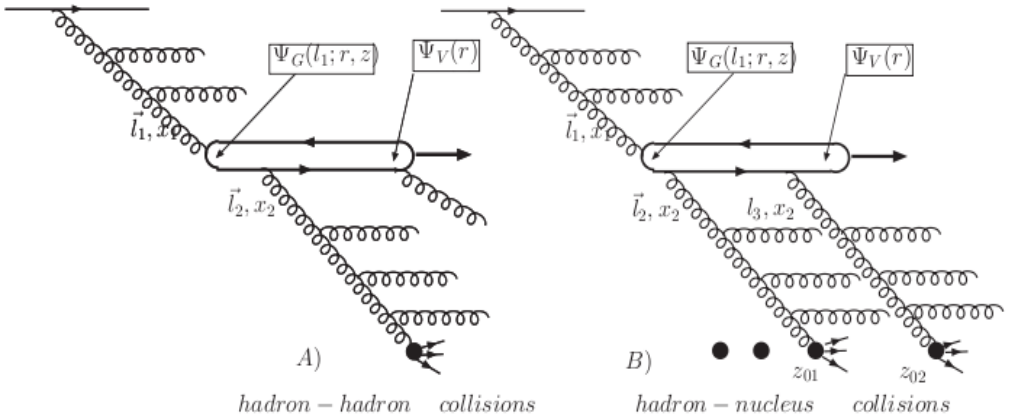
Lourenco, Vogt, Woehri arXiv:0901.3054



- Shadowing + fixed $\sigma_{breakup}$ don't match the observed rapidity dependency
- Use d+Au data to extract effective breakup cross section as a function of rapidity to parametrize all the effects that shadowing is missing
- Same trend observed at mid rapidity in E866 and HERA-B data, and at forward rapidity in E866 and PHENIX data

Or maybe it can all be explained by Coherent Scattering (CGC)...





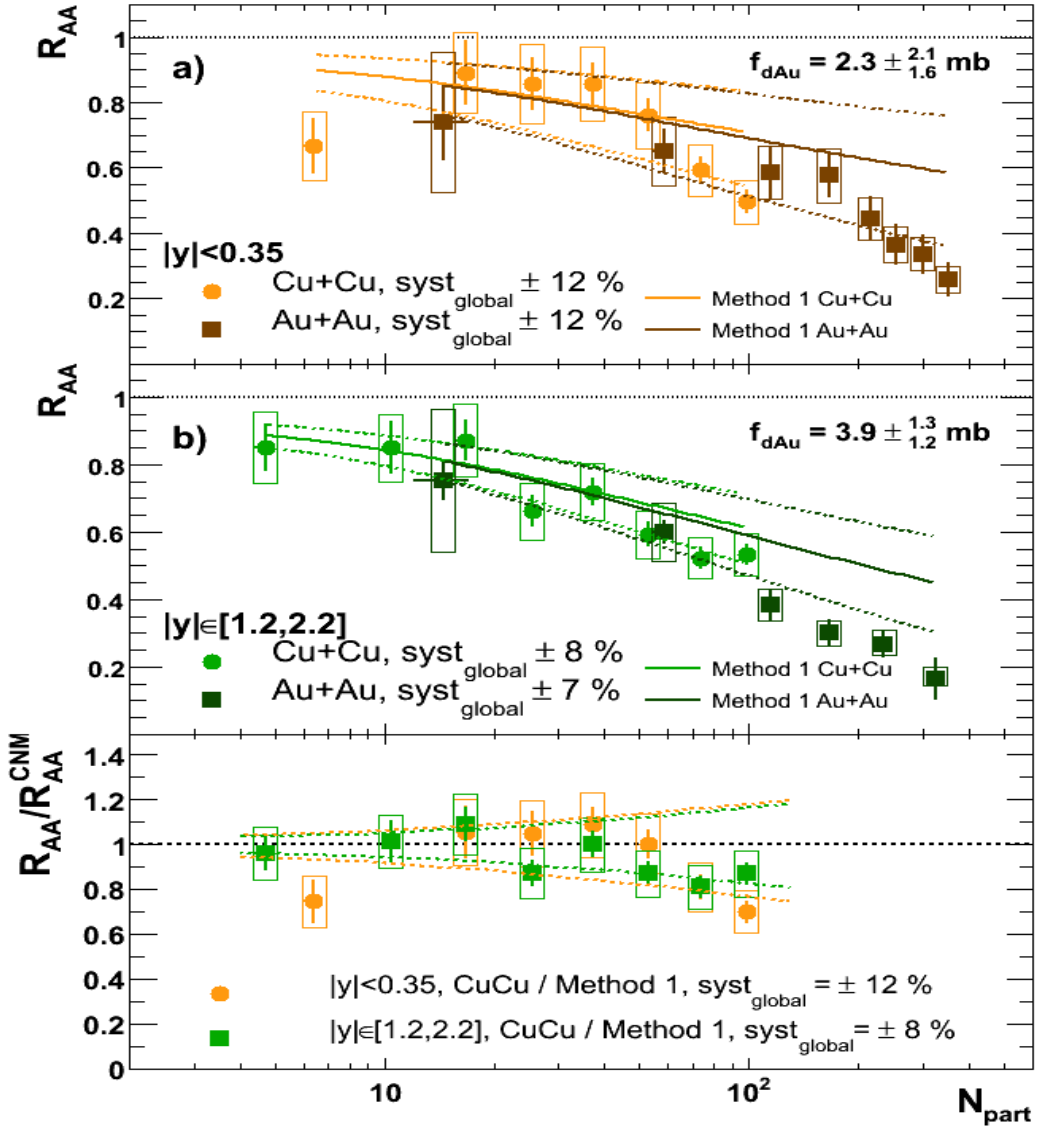
J/ψ production mechanism could be different in hadron-nucleus collisions than in hadron-hadron.

Note: the calculations have since been expanded to have less simplified nuclear geometry and have been applied to R_{AA} as well **Phys.Rev.Lett.102:152301,2009**

Results from A+A collisions

J/ψ R_{AA} vs centrality (N_{part}) in Au+Au and Cu+Cu

Phys. Rev. Lett. 101, 122301 (2008)



peripheral ⟶ central

Data are from 2005 Cu-Cu and 2004 Au-Au. Lines are cold nuclear matter effects extrapolated from 2003 d-Au data

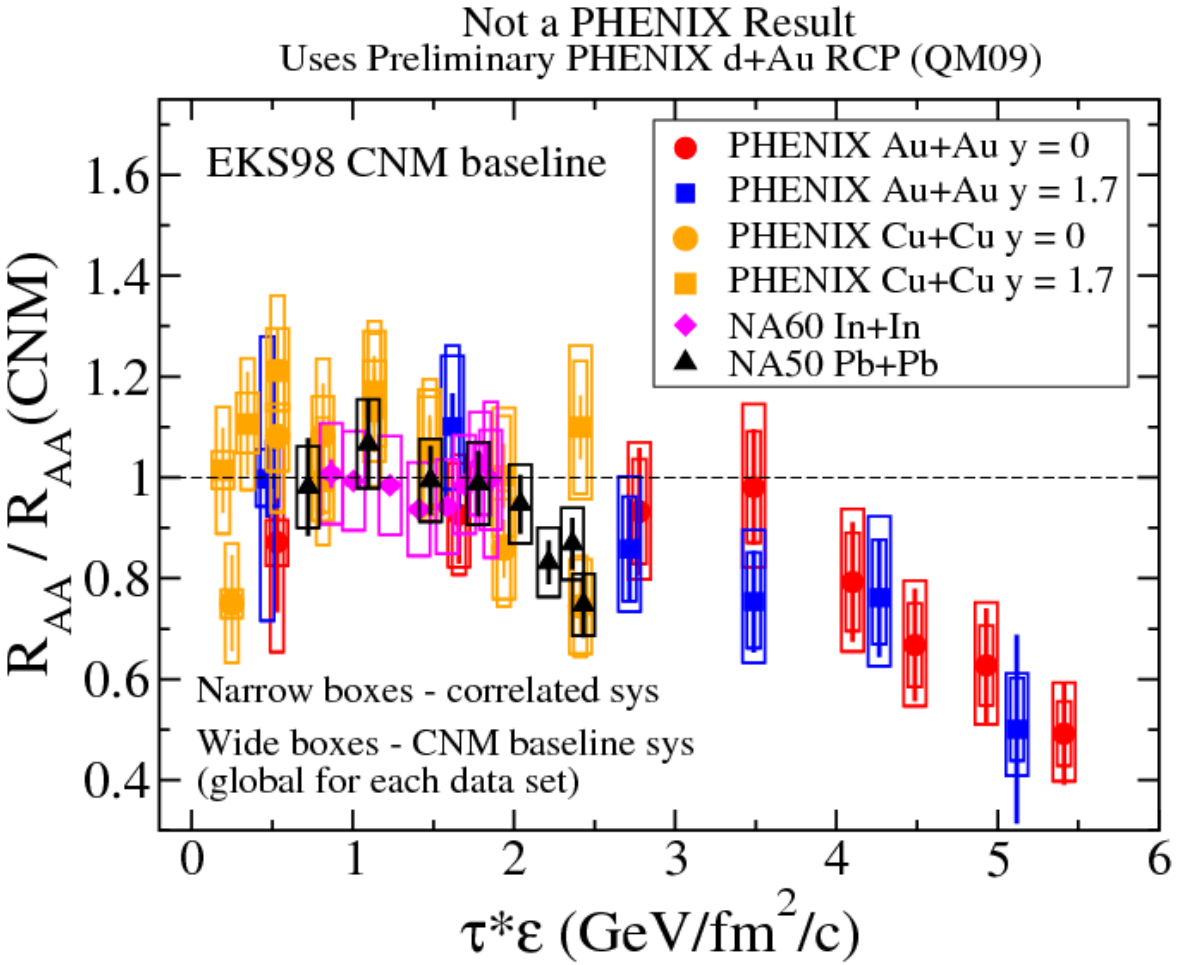
Cu-Cu and Au-Au ratios match well where they overlap.
In Au+Au the suppression is larger than expected from CNM

There is more suppression at forward rapidity than at mid-rapidity, although the difference might be absorbed by CNM

Note: The errors on the CNM error bands on these plots is underestimated (slightly) due to the erratum on slide 14.

J/ψ R_{AA} over CNM in Cu+Cu and Au+Au

Work by Tony Frawley and Mike Leitch using rapidity dependent break-up cross-section and errors estimated from 2008 data



Difference between mid and forward rapidity measurement is washed out.

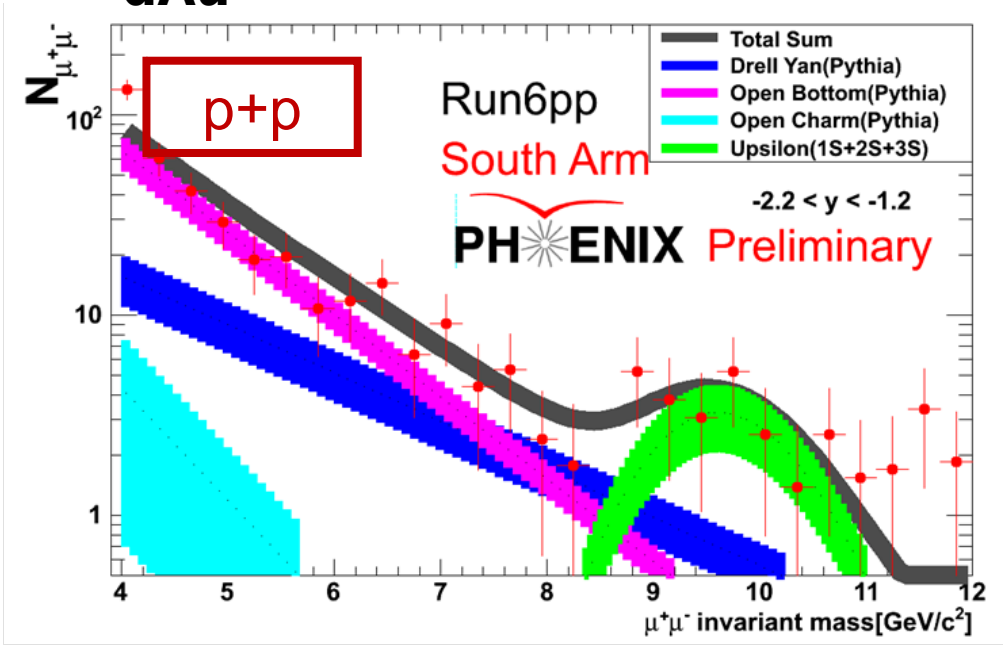
Suppression beyond cold nuclear matter effects is observed

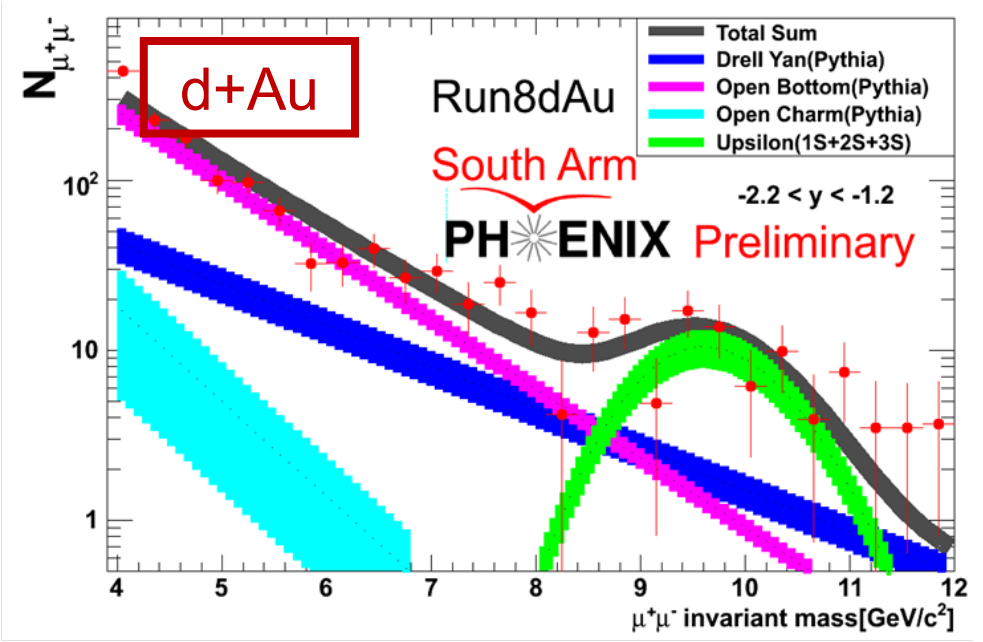
Note: We don't measure R_{dCu} – so the Cu+Cu R_{AA} (CNM) has some model dependence

Future Possibilities:

Υ states from d+Au and A+A collisions

R_{dAu} from Υ(1S+2S+3S)

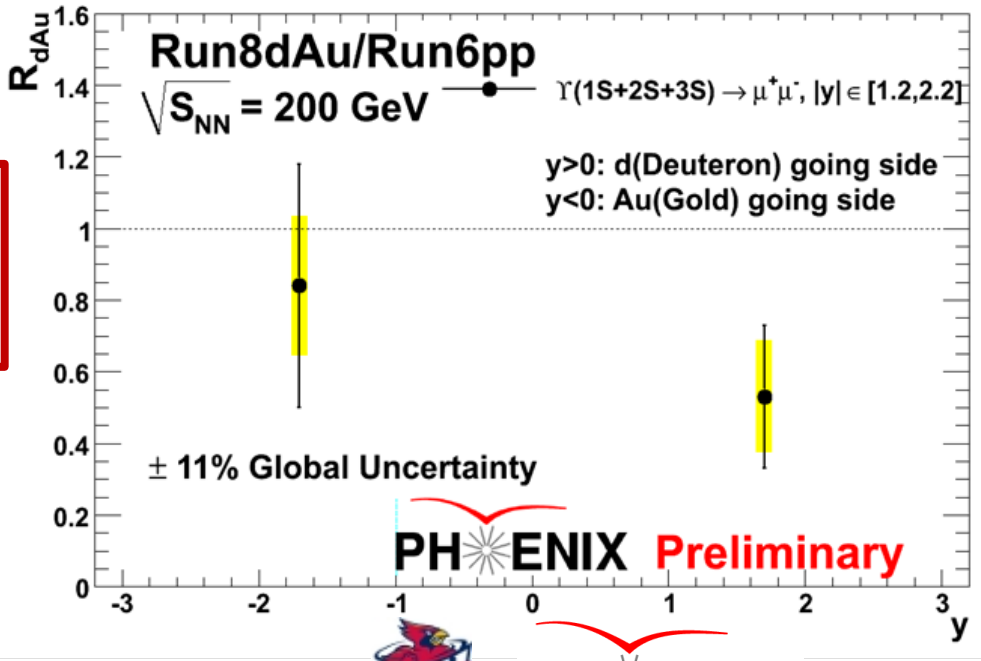




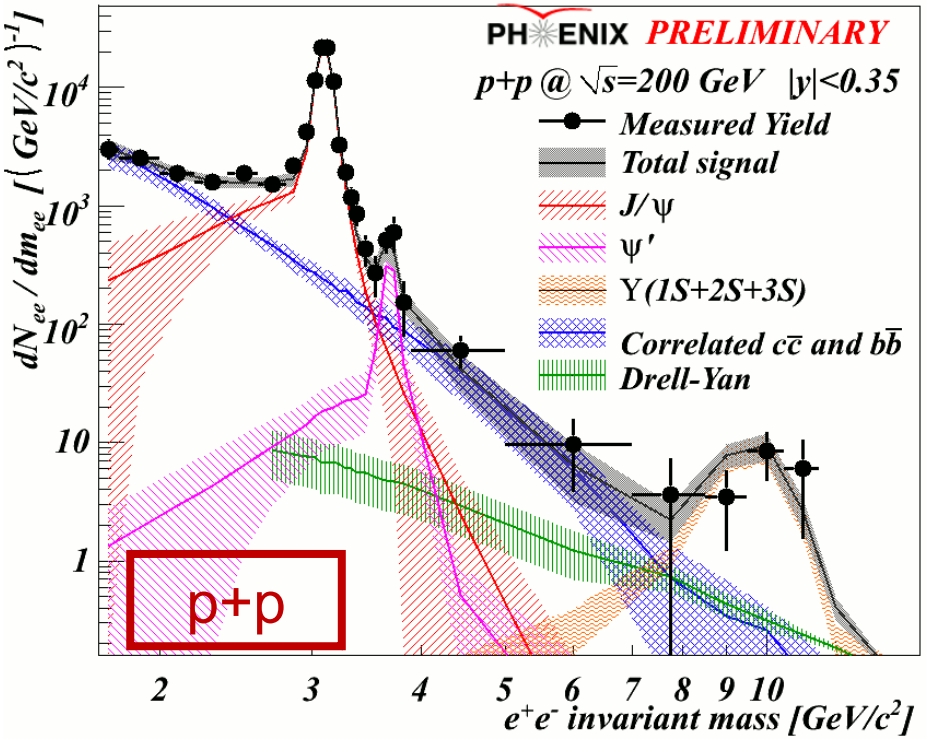
R_{dAu} = 0.84±0.34(stat.)±0.20(sys.), y [-2.2, -1.2]

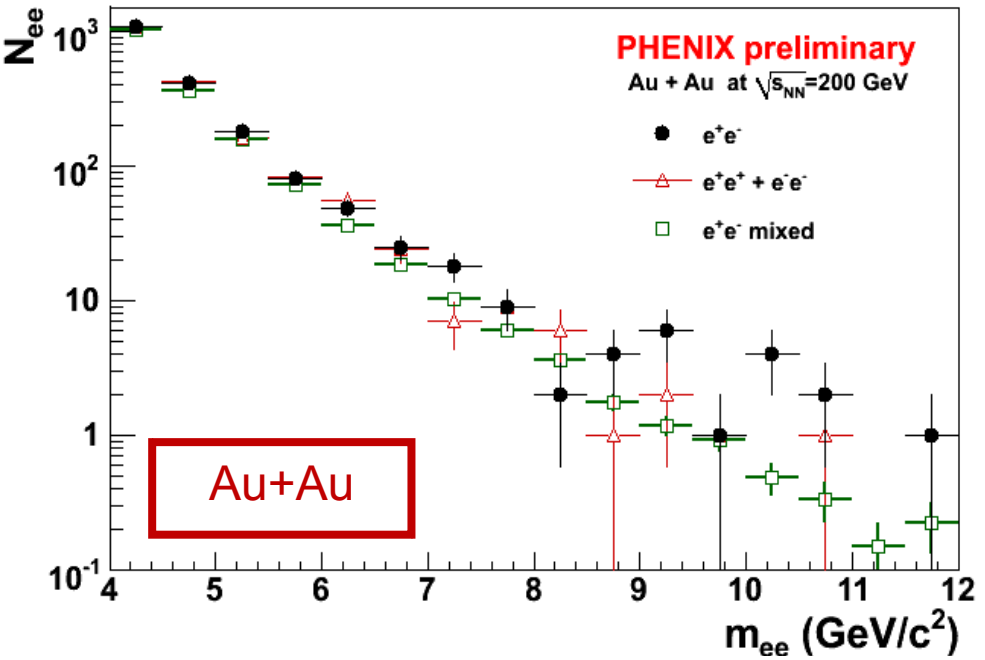
R_{dAu} = 0.53±0.20(stat.)±0.16(sys.), y [1.2, 2.2]

No measurement available (yet) at mid-rapidity



High Mass di-lepton R_{AA}



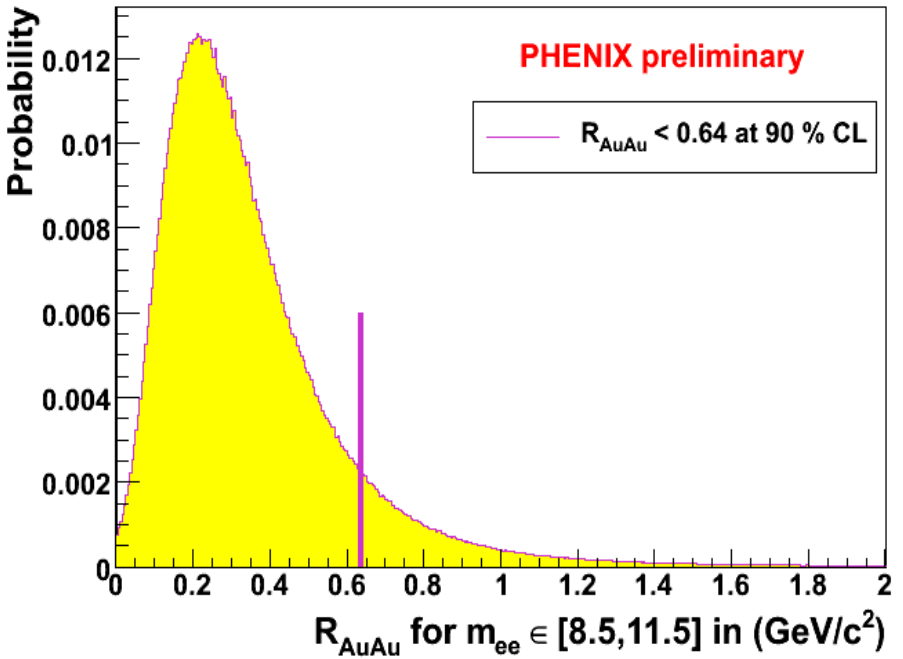


Excess over combinatorial background at high mass (m>8GeV/c^2) attributed to

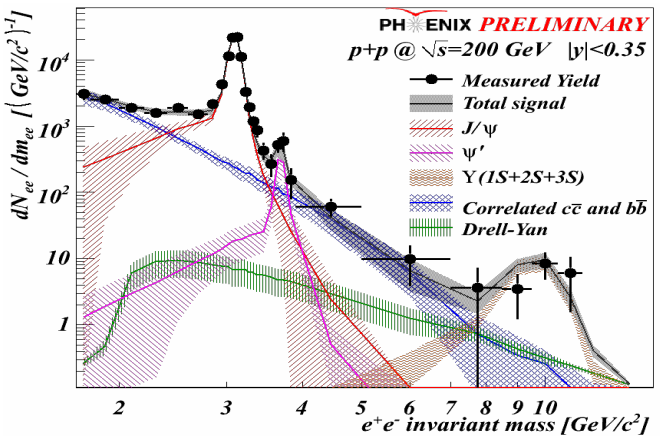
- Upsilons
- Open beauty
- Drell-Yan

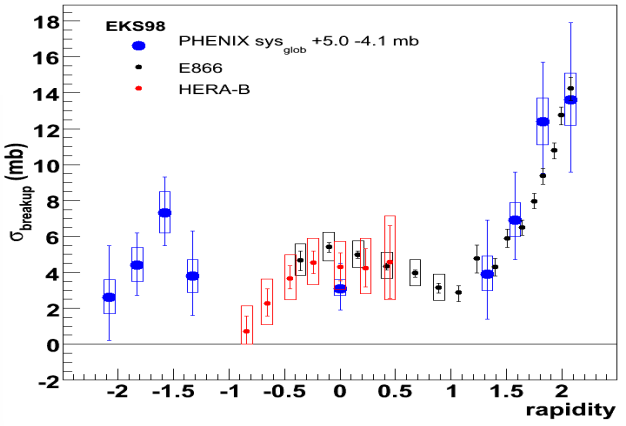
High mass di-lepton R_{AA}:

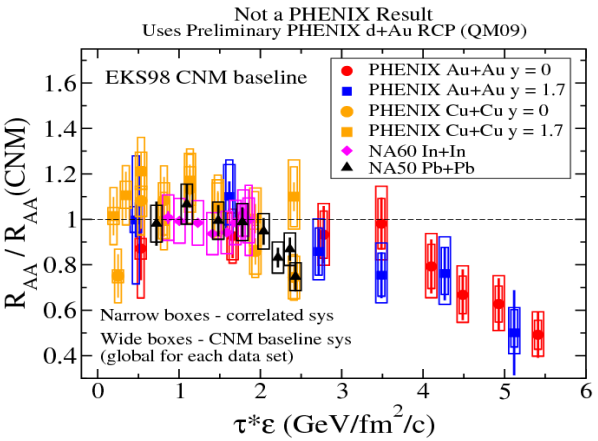
R_{AuAu} [8.5,11.5] < 0.64 at 90% C.L.



No measurement available (yet) at forward rapidity







Summary

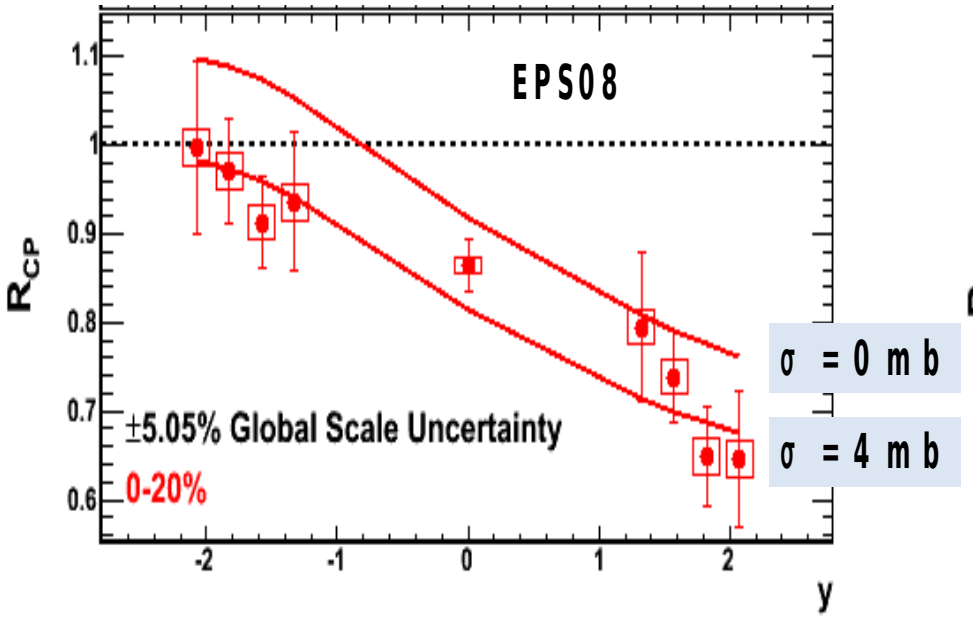
- Quarkonia continues to provide exciting physics in p+p, and it is an important probe in d+Au, and Au+Au.

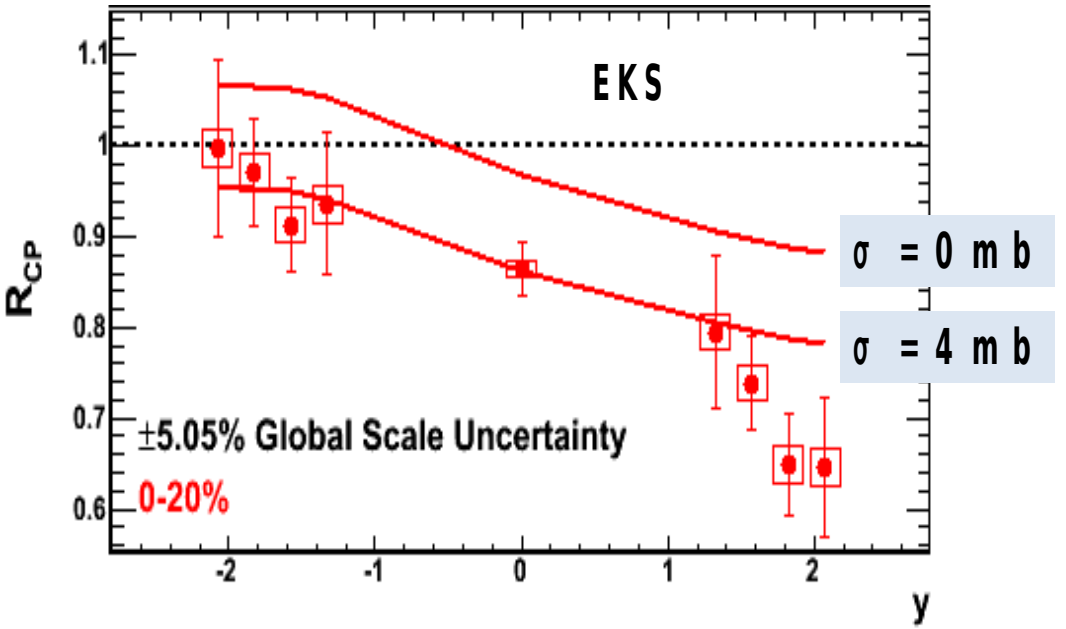
- PHENIX is able to make contributions through a large number of diverse measurements

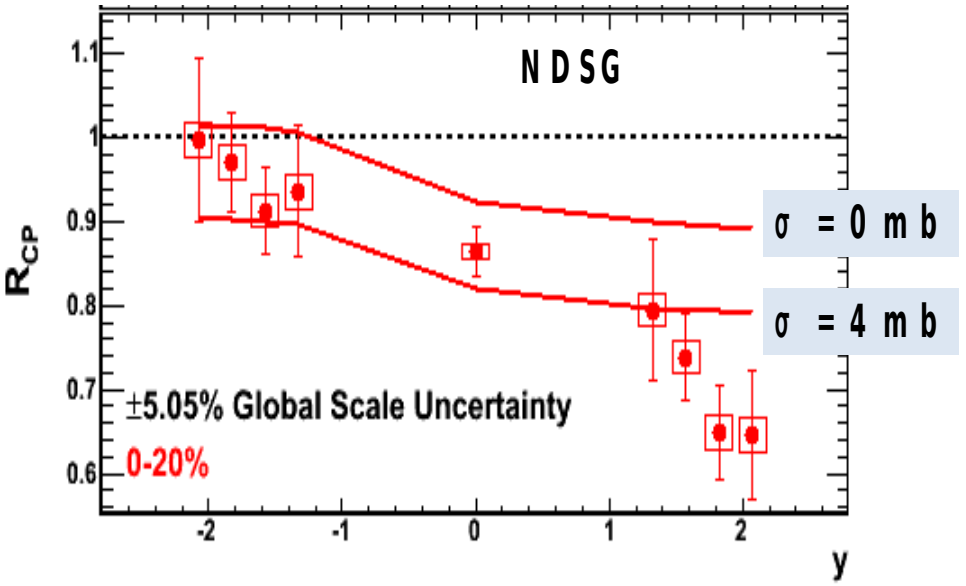
- The future holds great promise for increasing our understanding of the J/ψ and of using χ_c and Υ to enrich our understanding of CNM effects and the QGP.

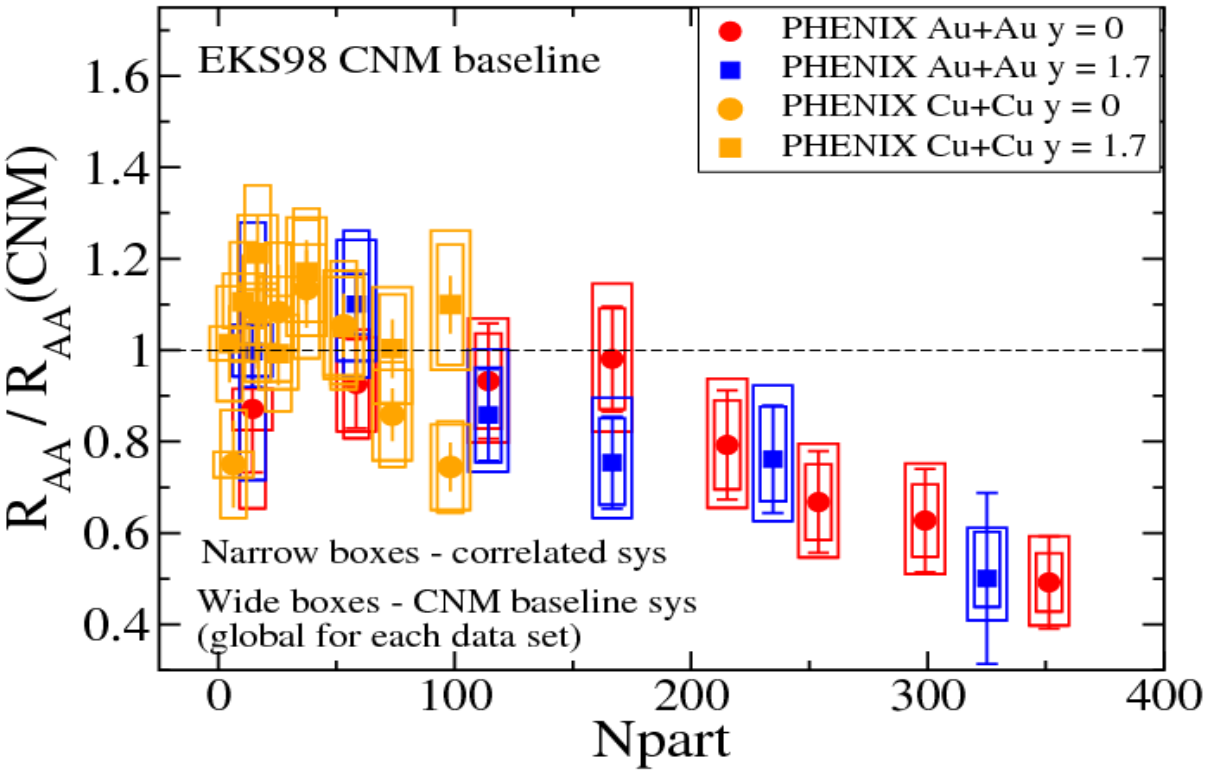
Backup

$\sigma_{breakup}$ Fits to 2008 Data





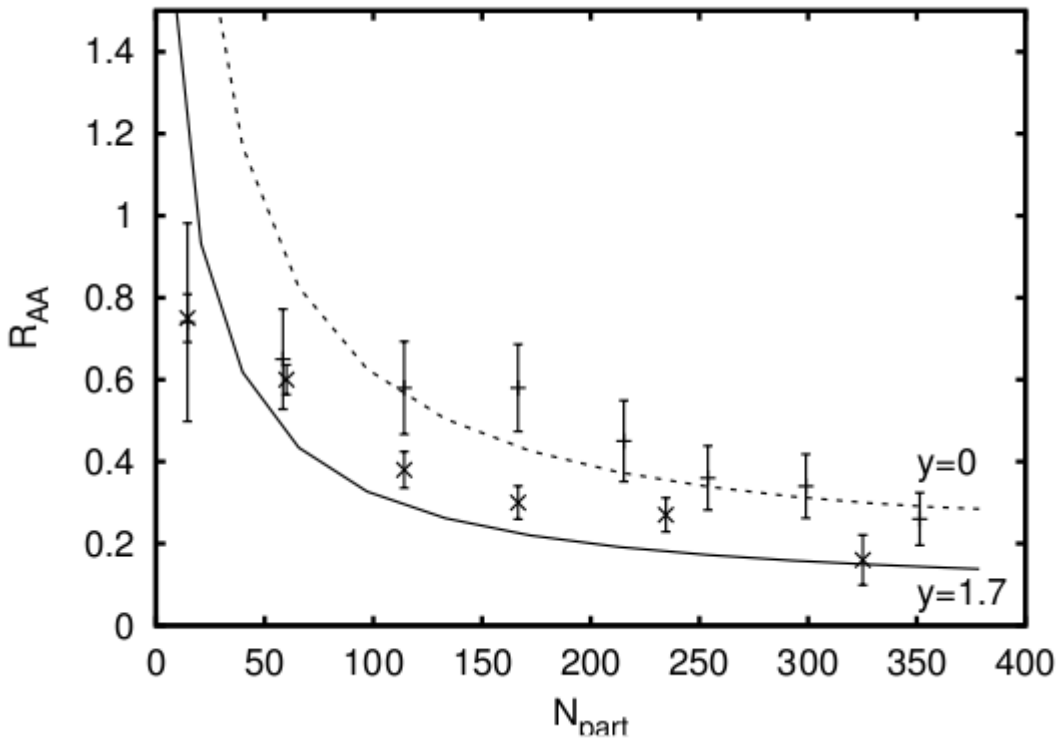




Differences between mid and forward rapidity measurement is washed out.

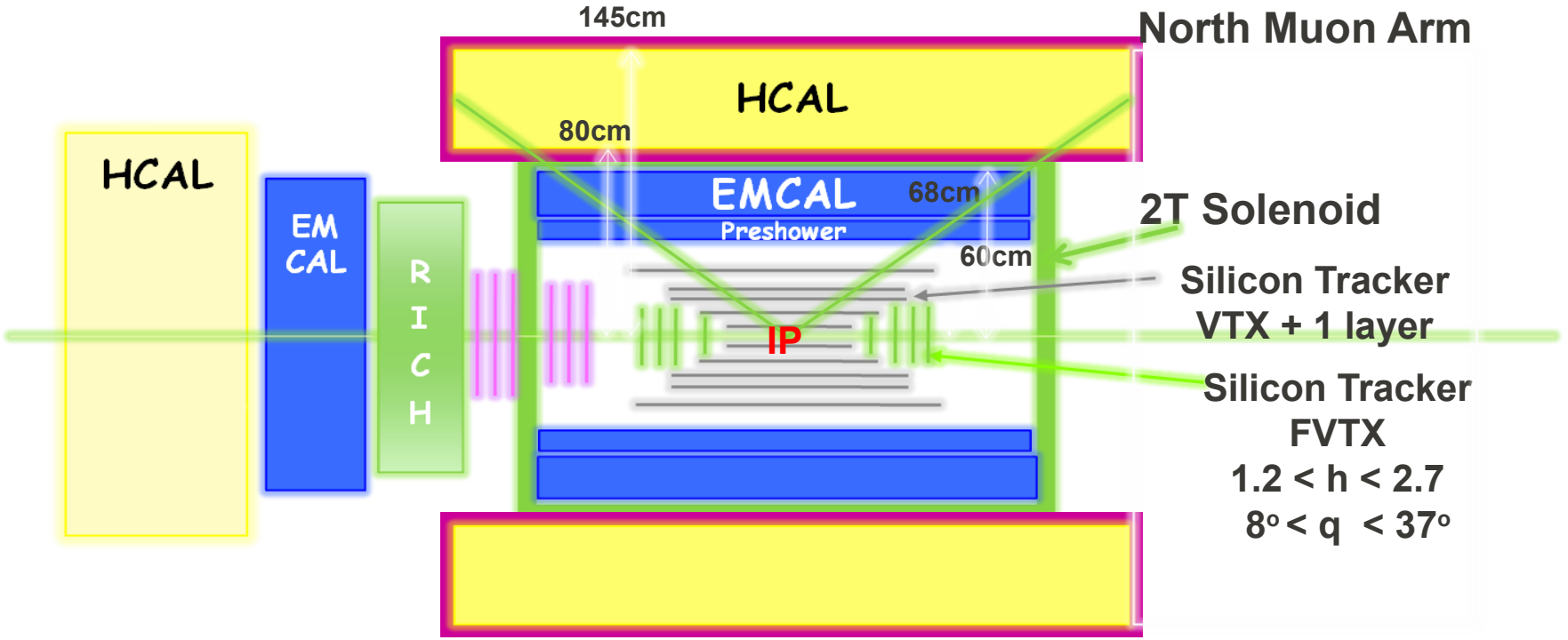
Suppression beyond cold nuclear matter effects is observed

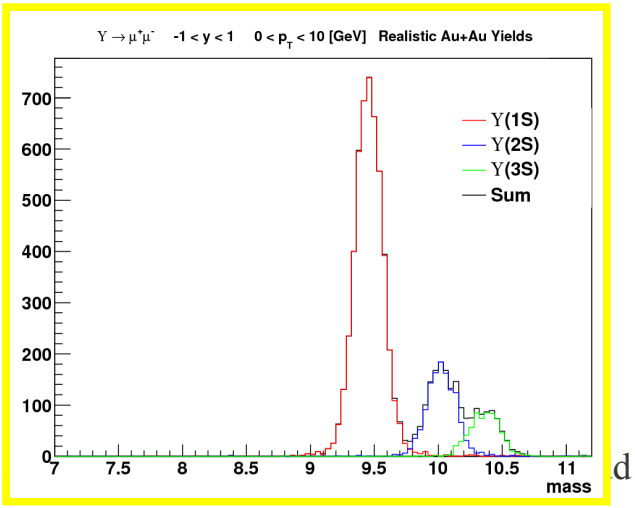
Using Coherent Scattering (CGC) to describe R_{AA}



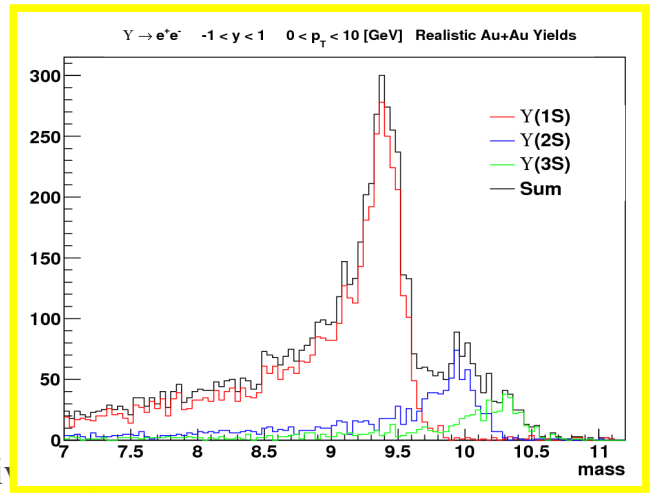
sQGP full characterization needs sPHENIX

superPHENIX

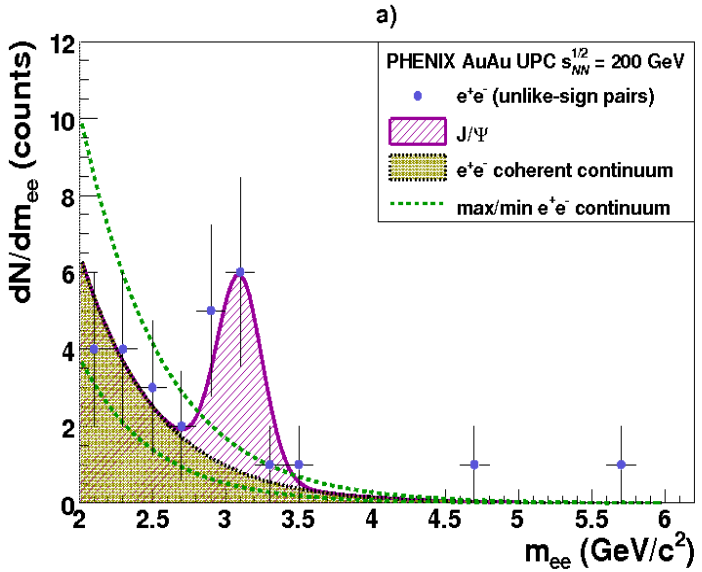


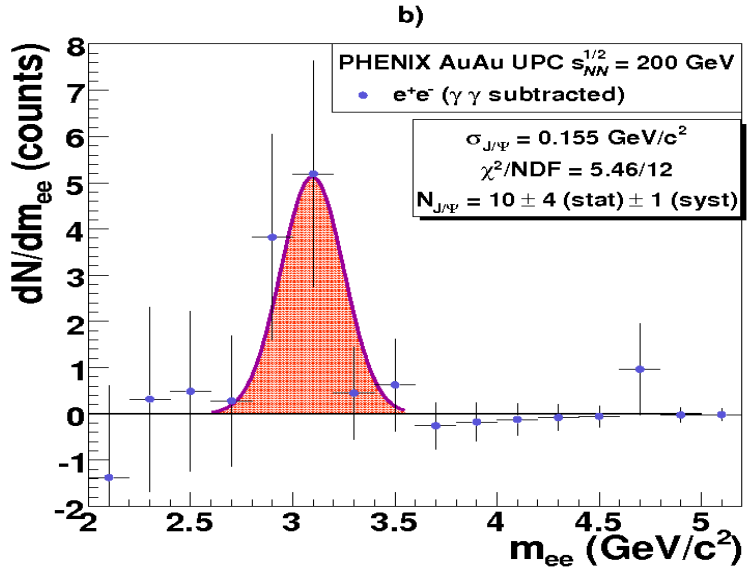


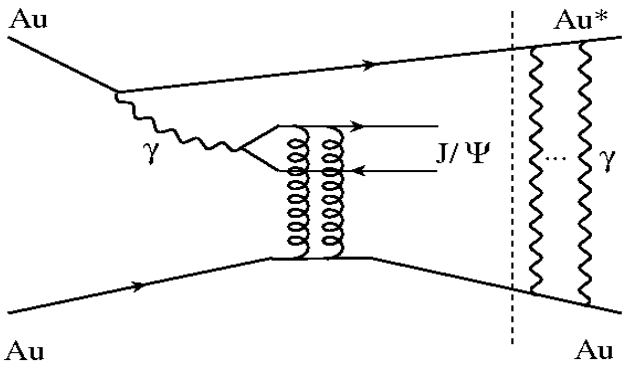
Upsilon
G4
Simulation

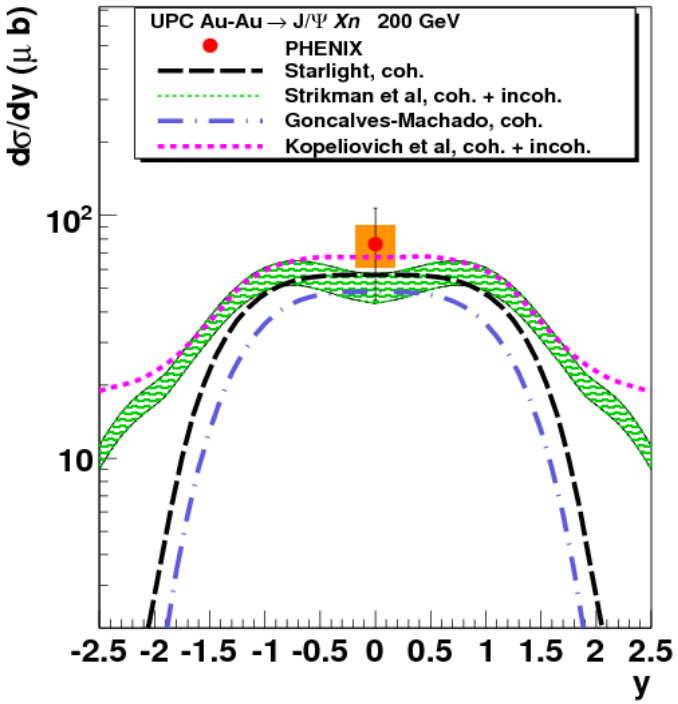


Ultraperipheral J/ψ (photoproduction)









Number of J/ψ: 9.9 ± 4.1 (stat) ± 1.0 (syst).

J/ψ photoproduction cross-section at y~0: 76 ± 31 (stat) ± 15 (syst) μb,