Centrality dependence of forward rapidity $J/\psi \rightarrow \mu^+\mu^-$ production in Cu+Cu collisions at $\sqrt{s_{NN}}$ = 200 GeV

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for the PHENIX collaboration

Quark Matter '05

Budapest, August 2005

Outline

- Motivation - why interest in quarkonia
- Dimuon analysis in PHENIX, Cu+Cu collisions
  - Signal extraction, corrections and systematic errors for the 200 GeV run (2005).
  - Centrality dependence results
  - Theory comparisons
- Summary and Outlook

Also see related PHENIX posters on forward rapidity J/ψ production in Cu+Cu collisions by:

A. Rakotozafindrabe, A. Glenn, A. Bickley (#129)

[And Au+Au posters: M. Brooks (#130), M. Kweon (#139), V. Tram(#171).

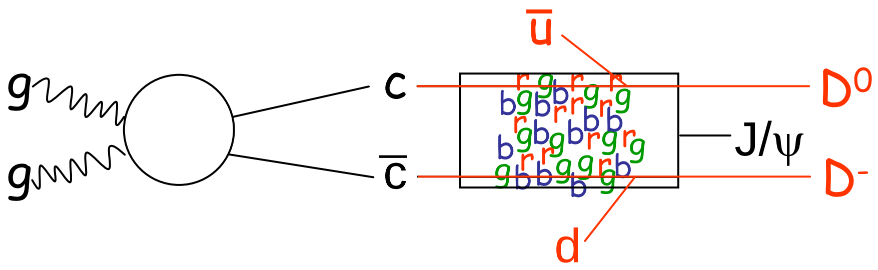
Mid-rapidity posters: A. Lebedev (Au+Au, #148), D. d'Enterria (UPC,#180), K. Das (Cu+Cu, #181), T. Gunji (Au+Au, #187)

Also several posters on J/ψ production for d+Au, and p+p.]

J/Ψ production – Color Screening and the QGP

- Matsui and Satz (Phys. Lett. **B178,** 416.) first articulated the consequences of color screening on quarkonium production. The basic idea is as follows.
- c,c-bar pairs are primarily produced through gluon fusion early in the collision.
- Most often the c and c-bar quarks pair off with a light quark and exit the system as D-mesons.
- Occasionally the c and c-bar pair up with their primordial partner. Due to the attractive strong-force potential they can form bound states like the J/ψ through a non-perturbative process.

- If the bound state is formed in, or passes through, a QGP, the free color charges will screen that potential (in a manner completely analogous to Debye screening in a Coulomb plasma).
- In this case the J/ψ will melt (or never form in the first place) and the c and c-bar quarks will again leave the system as D-mesons, having found a ubiquitous light quark. => relative suppression of J/ψ



Centrality Dependence – Example Theory Predictions

A. Capella: **hep-ph/0505032**

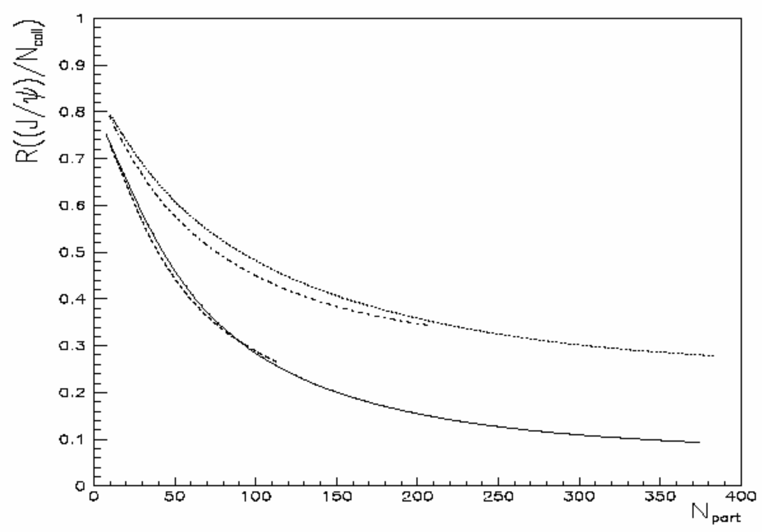
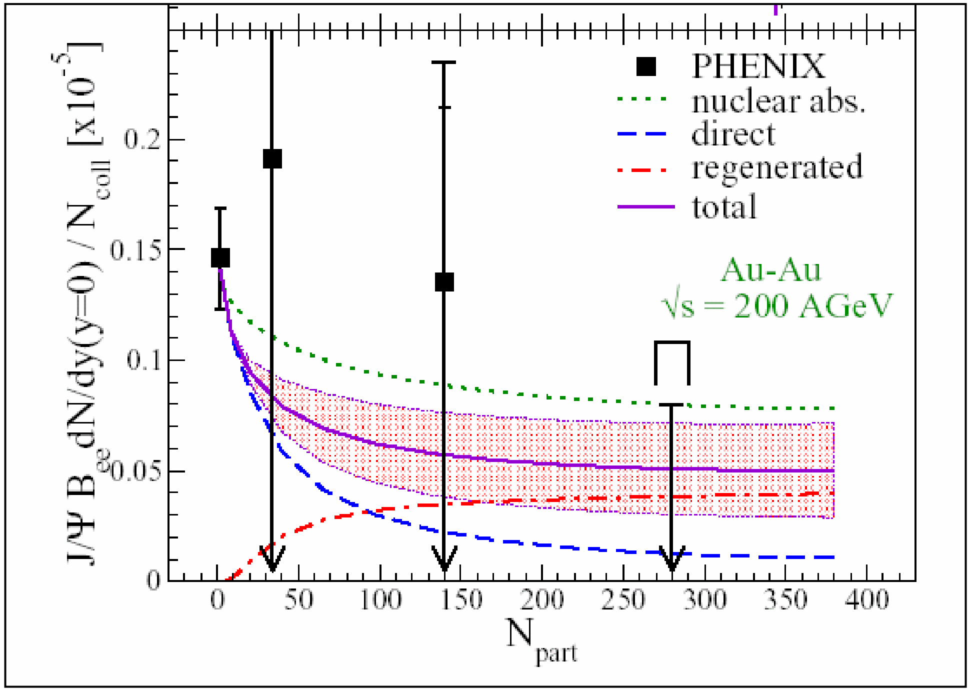


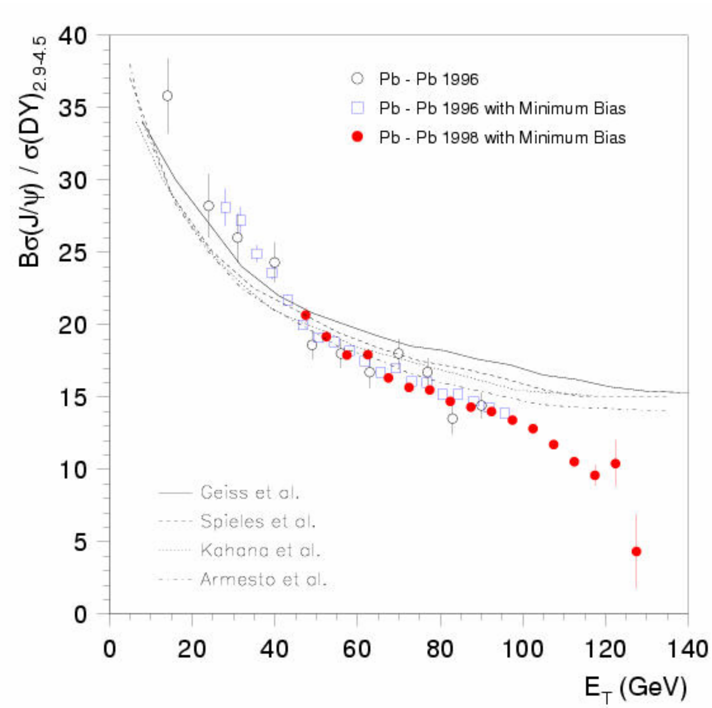
FIG. 2. $R_{AB}^{J/\psi}(b)$ for $AuAu$ collisions at $\sqrt{s} = 200$ GeV (full curve), $CuCu$ collisions at $\sqrt{s} = 200$ GeV (dashed curve), $PbPb$ at $p_{lab} = 158$ GeV/c (dotted curve) and $InIn$ at $p_{lab} = 158$ GeV/c (dashed-dotted curve). All the results have been obtained with $\sigma_{co} = 0.65$ mb and $\sigma_{abs} = 4.5$ mb.

L Grandchamp et al. : **hep-ph/0306077**



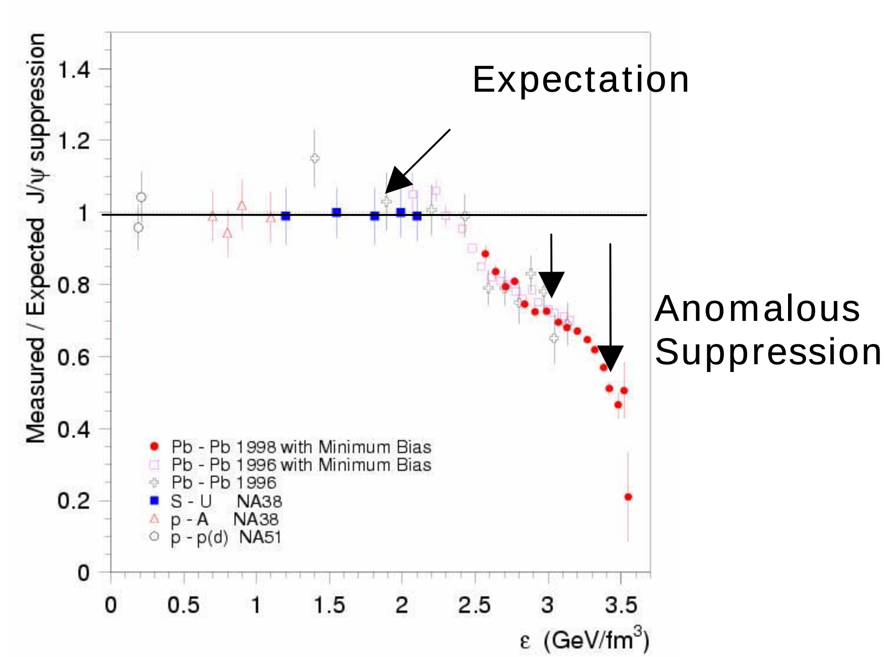
Significant suppression predicted already for Cu+Cu collisions, where we also have well-defined centrality bins in the Npart<100 region, where there are expected drastic changes in the production rates.

Observation at CERN (NA50)



J/ψ normalized to
Drell-Yan vs "Centrality"

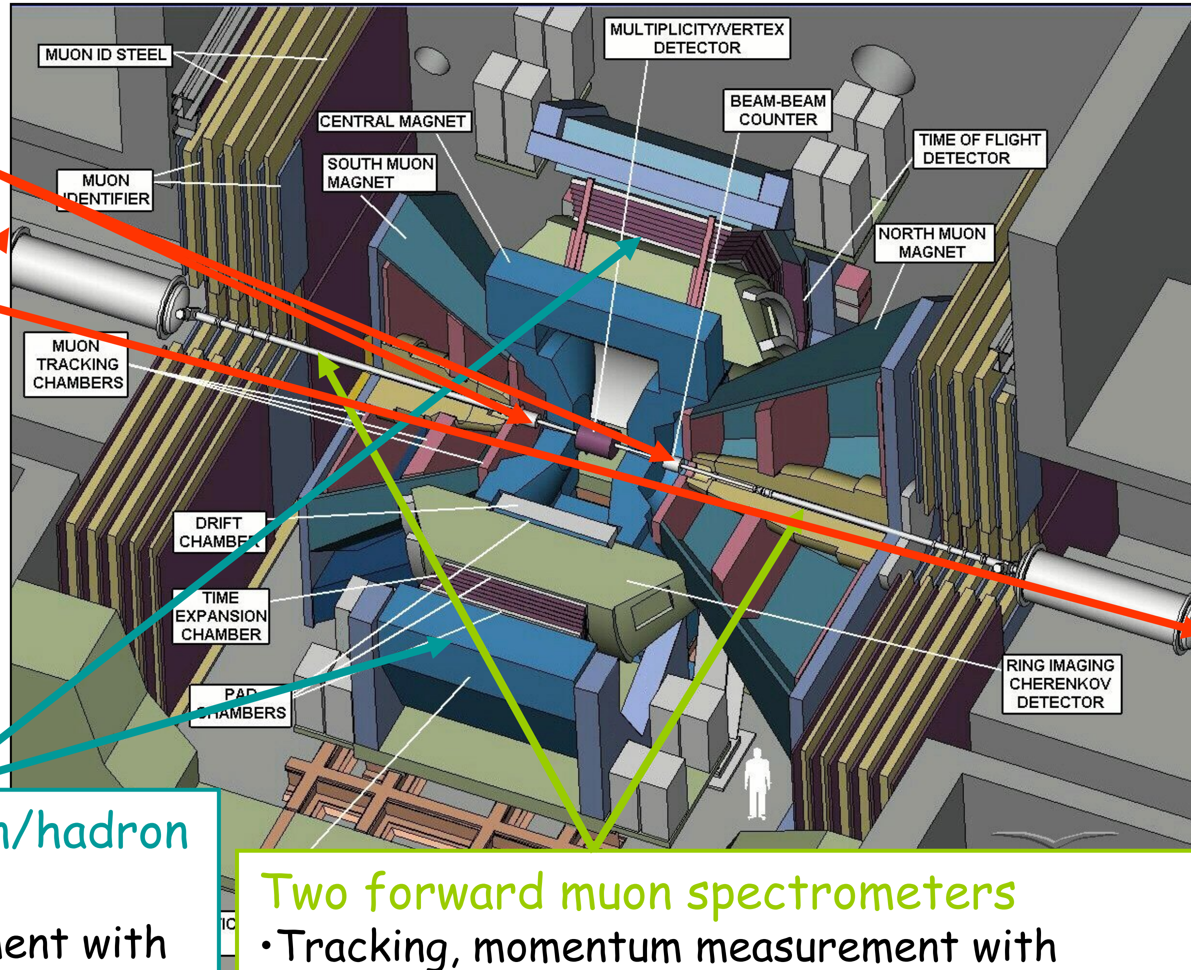
Pb-Pb collisions show suppression in excess of "normal" nuclear suppression



NA50, Phys. Lett. B477 (2000) 28.

PHENIX

Two sets of forward-rapidity detectors for event characterization
- Beam-beam counters measure particle production in $3.0<|\eta|<3.9$. Luminosity monitor + vertex determination.
- Zero-degree calorimeters measure forward-going neutrons.
- Correlation gives centrality

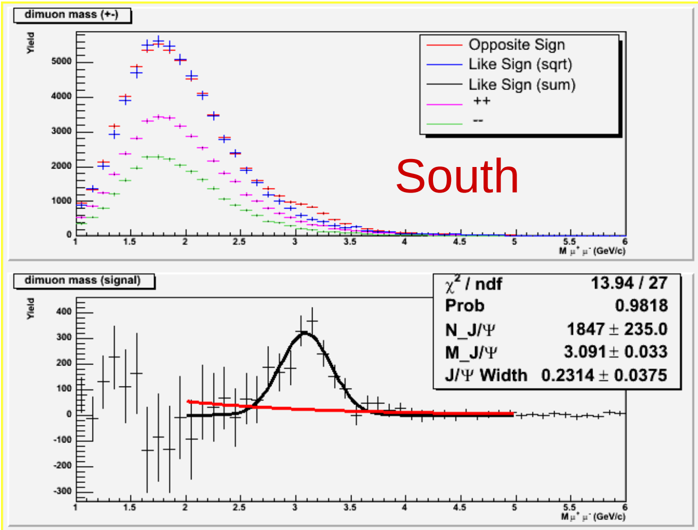


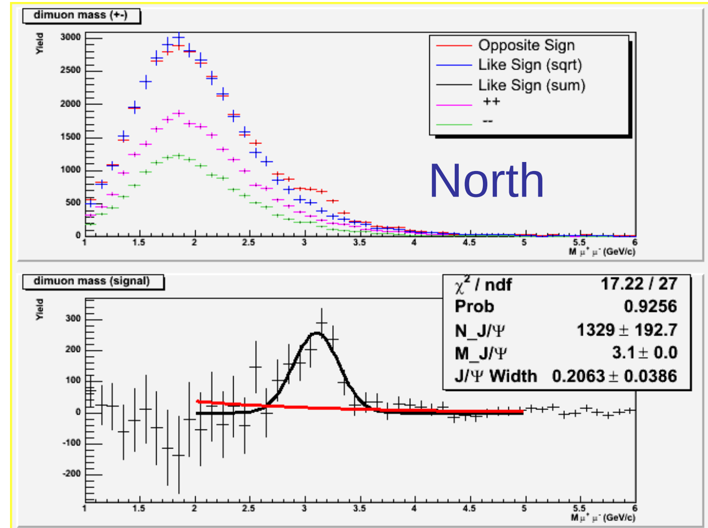
Two central electron/photon/hadron spectrometers:
- Tracking, momentum measurement with drift chamber, pixel pad chambers
- e ID with E/p ratio in EmCAL + good ring in RICH counter.

Two forward muon spectrometers
- Tracking, momentum measurement with cathode strip chambers
- μ ID with penetration depth / momentum match

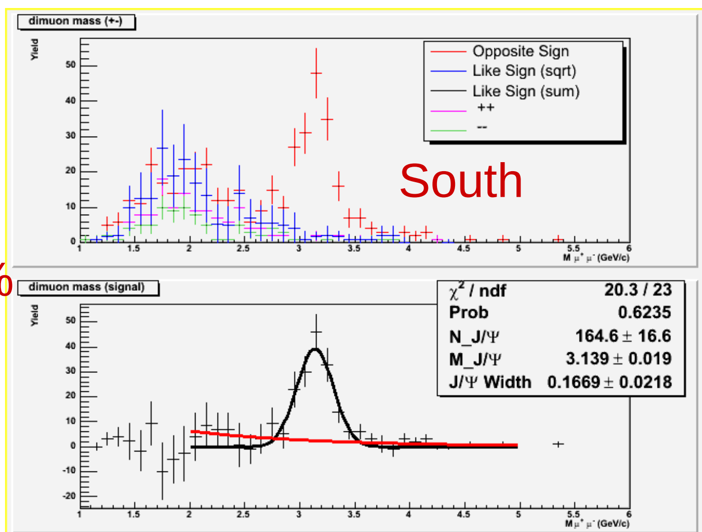
Example Mass Plots : Cu+Cu 200 GeV

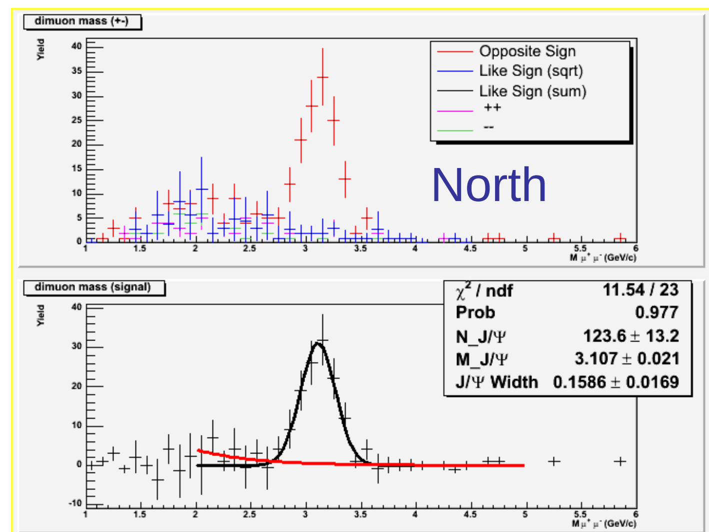
Cent
0 – 10%





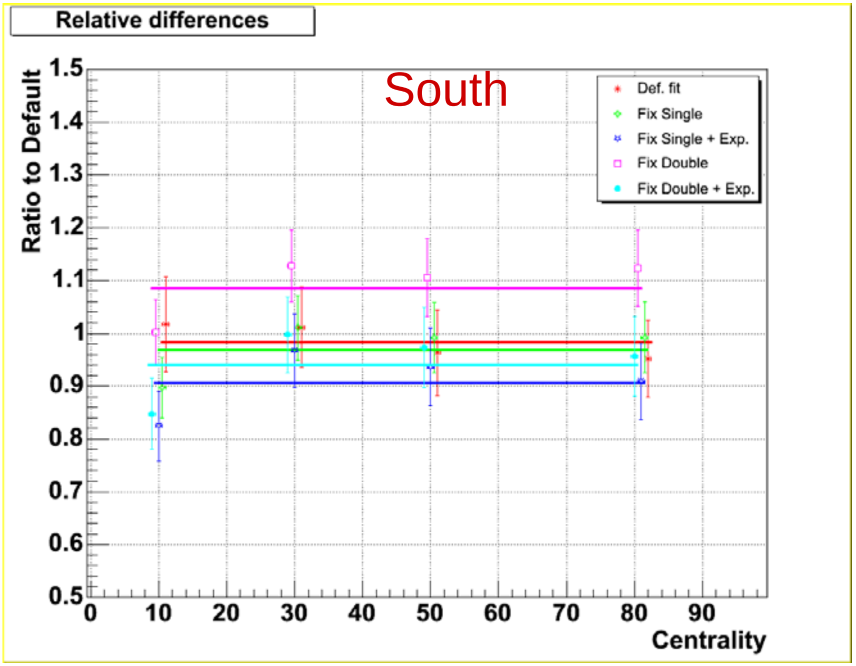
Cent
70 – 94%

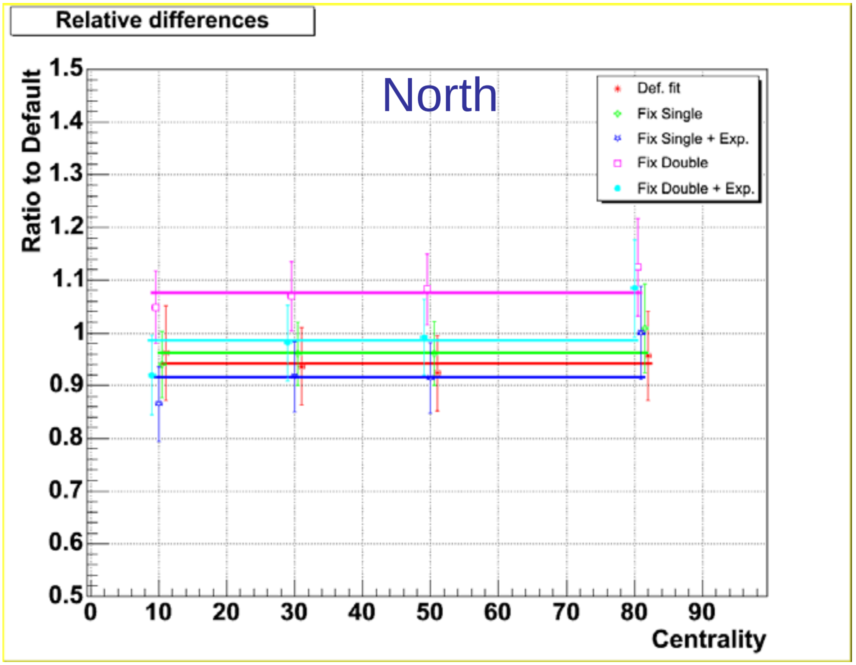




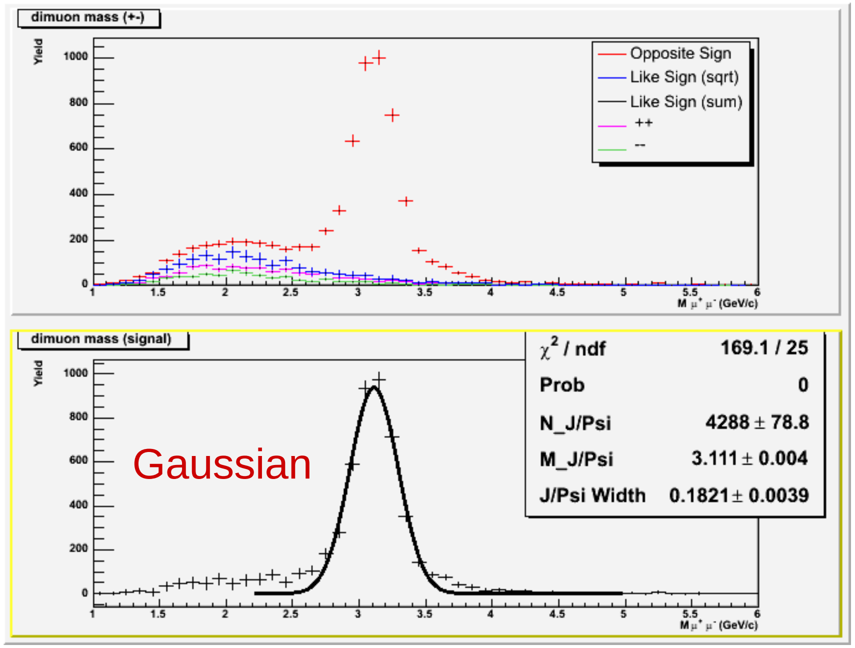
Yield Extraction – Method Comparisons

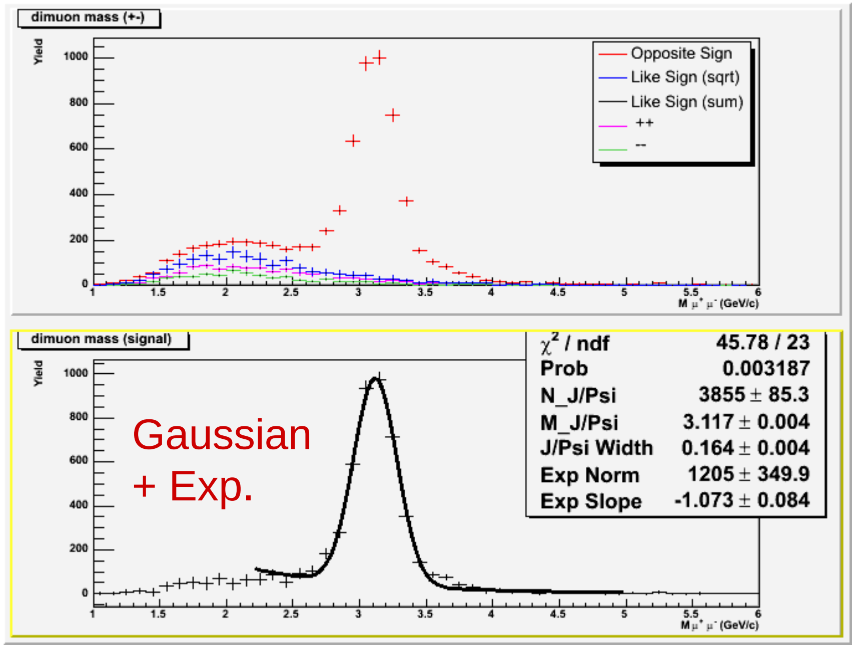
We estimate the J/ψ signal by a bin-counting method which subtracts the like-sign combinatorial background estimate [2*sqrt(N++ * N--)] from the unlike-sign dimuon combinations over the 2.6-3.6 GeV/c^2 mass-window.
This method thus includes the possibility that some physical background from open charm and Drell-Yan is included in the signal counts, and this is accounted for in our one RMS systematic error estimate. Below we compare the results of several applied fits (described on the next slide), relative to the bin-counting results.





Fit Method Comparisons



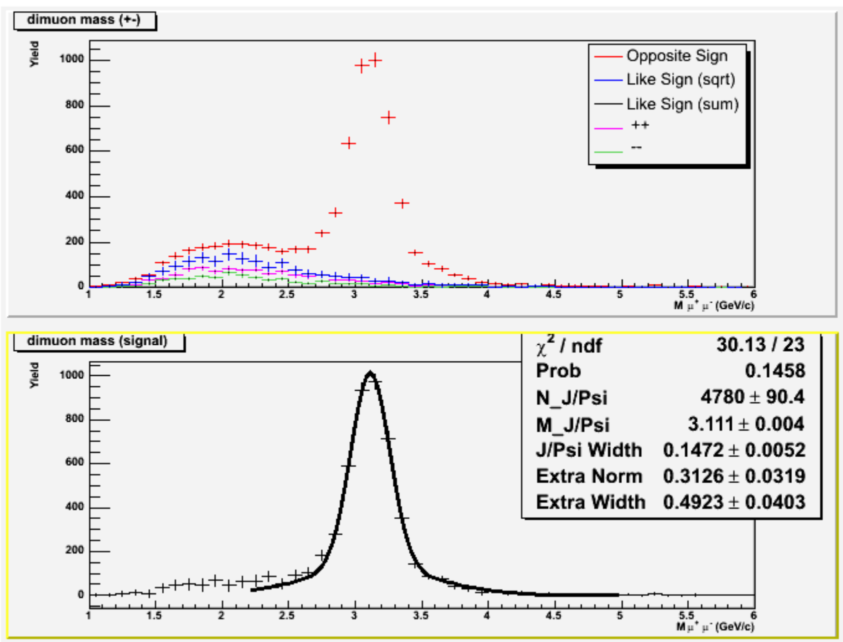


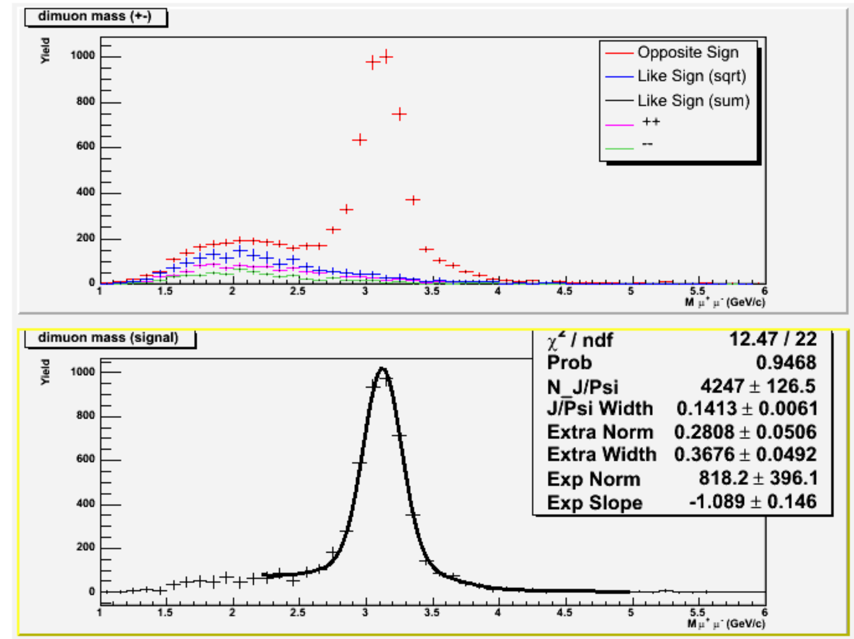
Signal line-shape (also in MC) looks more like a double Gaussian, perhaps due to imperfect alignment. The data here is from run5 p+p collisions; the largest and cleanest J/ψ sample at RHIC to date.

Single Gaussian fits will miss some signal in the tails of the wider second Gaussian component, but they will also include physical background.

Single Gaussian fits w/ exponential background subtraction will pick up the wider Gaussian component in the exponential, and won't include any physical background. So these are likely under-predictions of the real signal.

Fit Method Comparisons II





Double Gaussian fits will pick up physical backgrounds in the wider component and so are likely over-predictions of the real signal.

Double Gaussian fits w/ exponential background subtraction might be expected to be give reasonable results. [Note: This is also the only fit to the data with a high/reasonable probability]

So, with these fits, and the ones on the preceding slide, we think have covered the uncertainties due to physical background in our mass counting window, as well as the possibility of some signal tail falling outside the counting window.

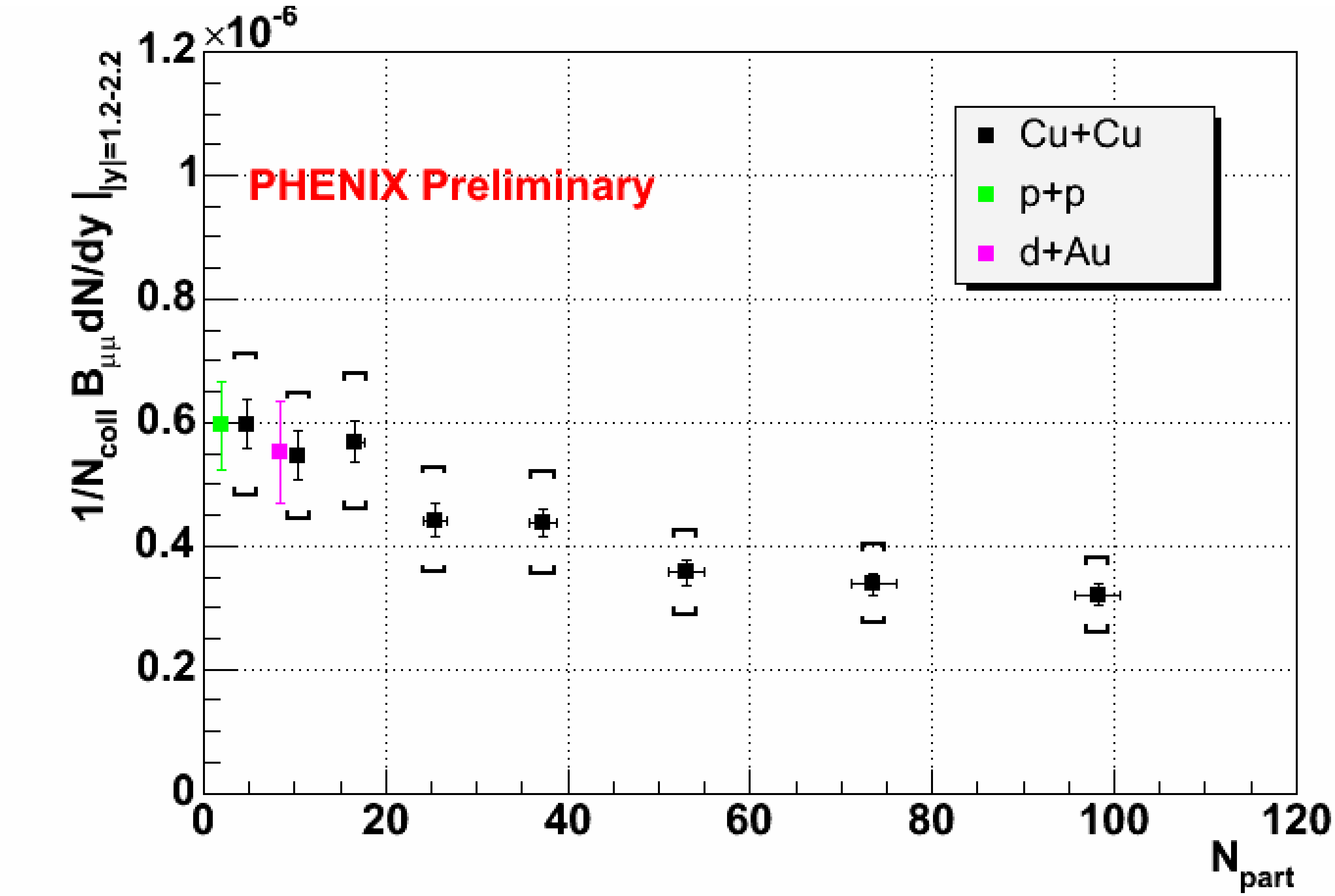
Systematic Errors

See poster by A. Rakotozafindrabe for how we estimate and apply the Acceptance*Efficiency correction factors.
The table below summarizes our estimated main systematic errors for the J/ψ yield measurements.

Error on #MB triggers/events	1%
Vertex, bunch crossing checks	3%
Acc*Eff: MC input distributions (vtx, pt, y), cuts	5%
Mutr bad FEM handling Muid efficiency	2% 5%
Run to Run variations	8%
Syst. on signal extraction	10%

The quadrature sum of these numbers is about 15%.
In addition, there is a Glauber syst on N_{coll} also of about 15%.

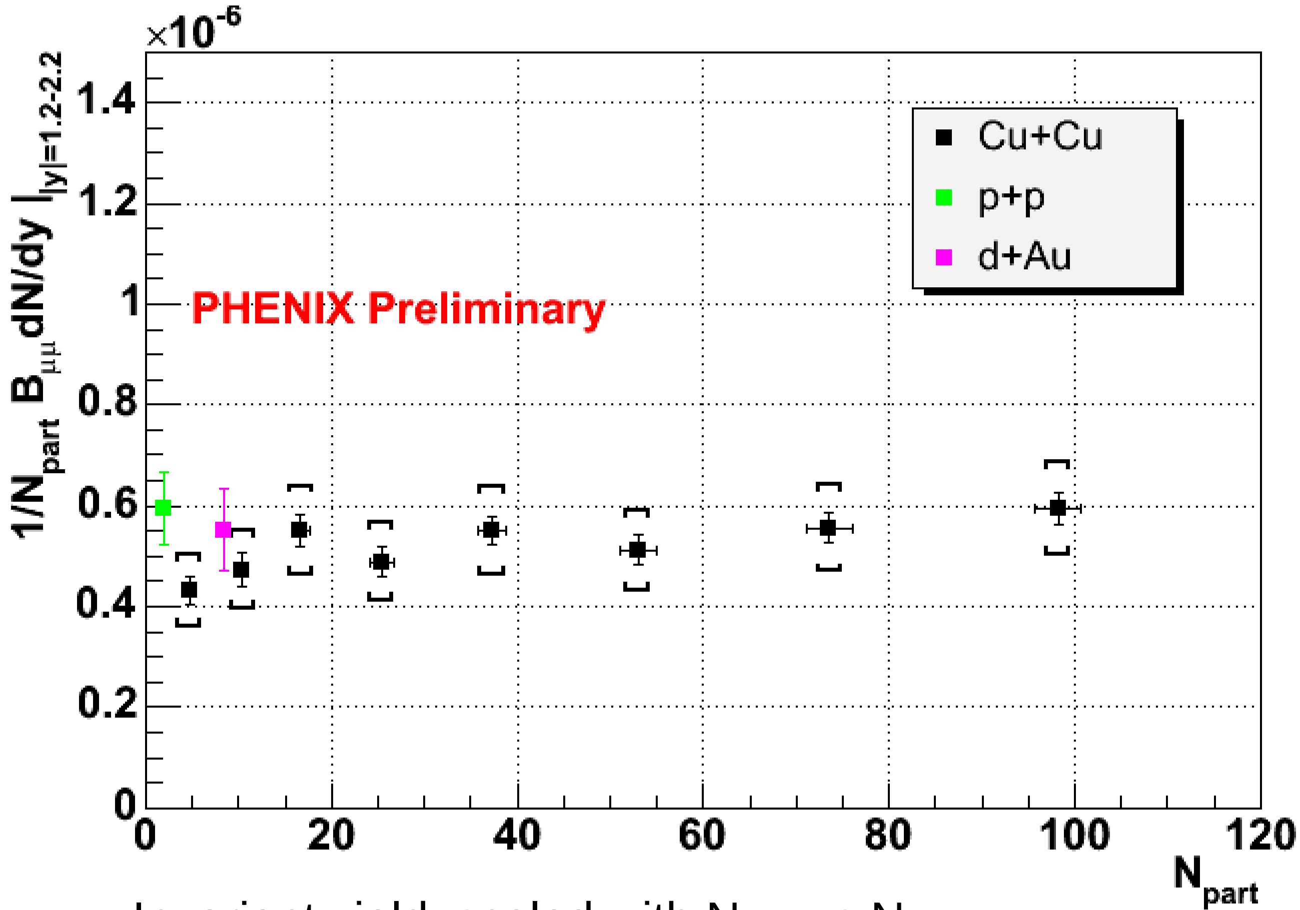
Centrality Dependence: Yield/N_{coll}



Invariant yield, scaled with N_{coll} vs N_{part}.

Factor ~2 suppression from peripheral to central collisions.

Centrality Dependence: Yield/N_{part}

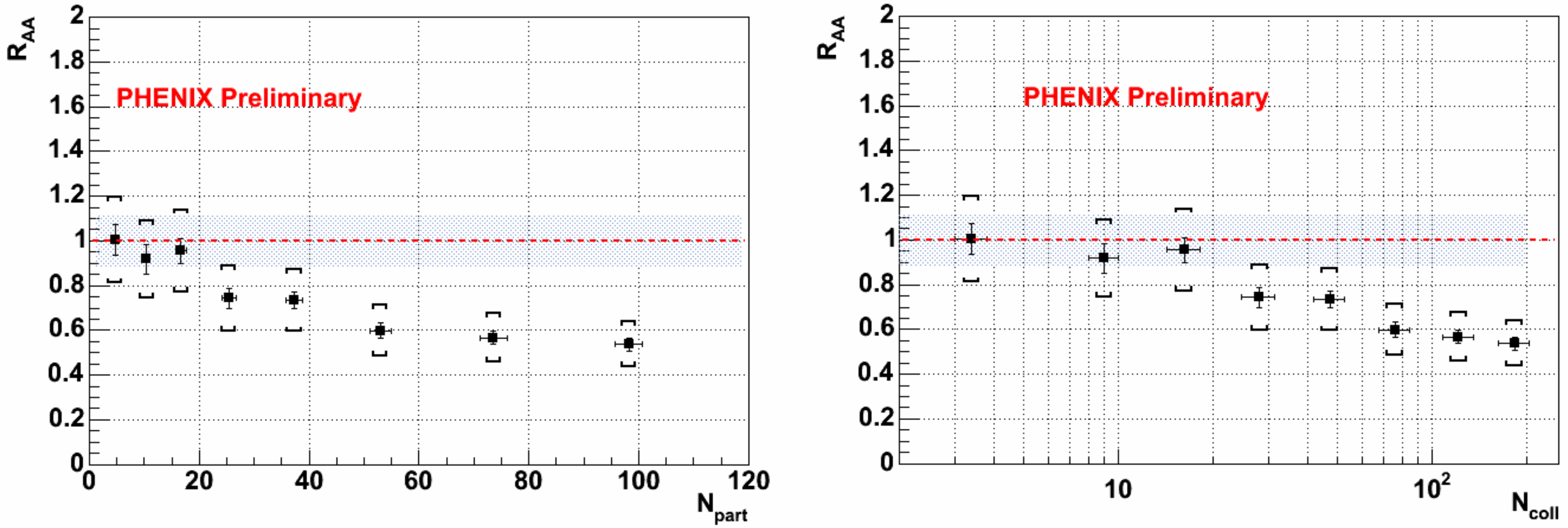


Invariant yield, scaled with N_{part} vs N_{part}.

Not so much change with centrality.

Nuclear Modification Factor

Invariant yield, scaled with N_{coll} and p+p reference.



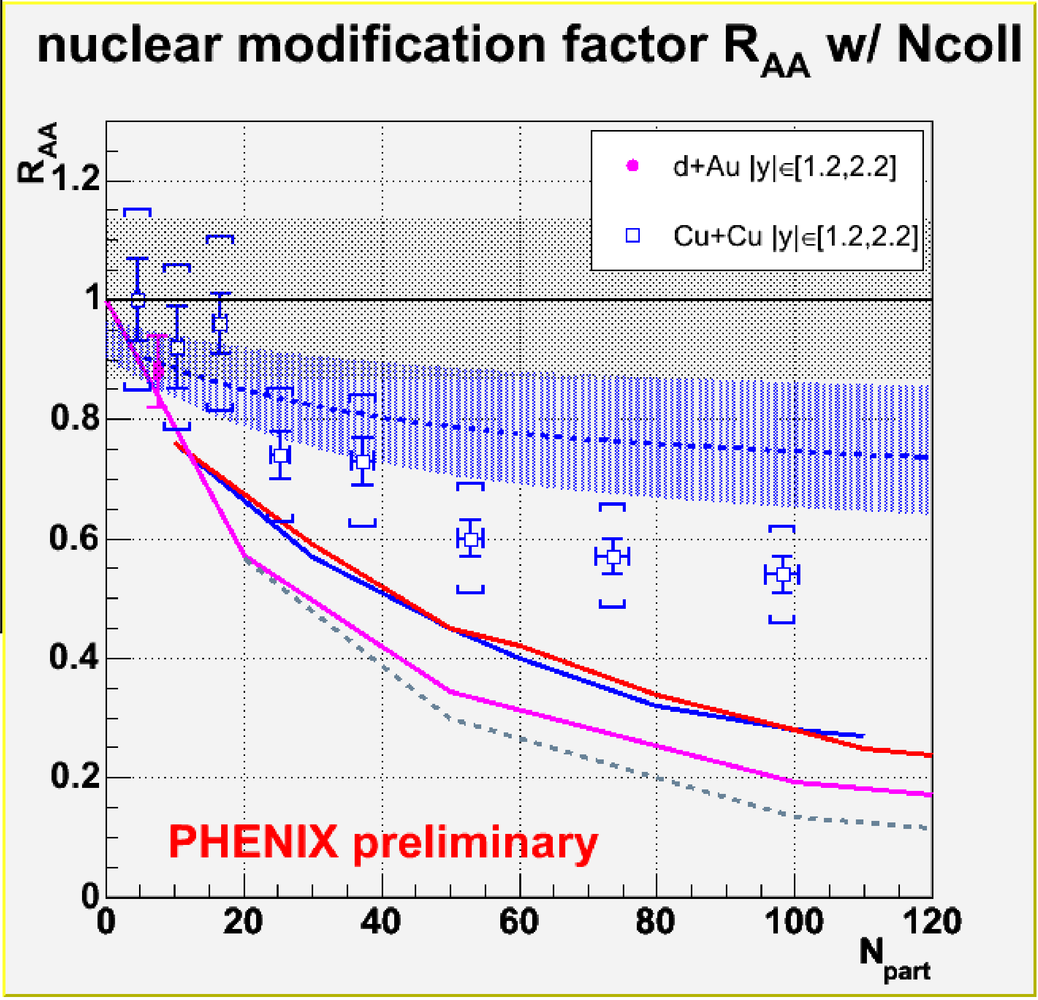
as a function of **participants** and **binary collisions**

Comparisons - Models without Re-generation

Au+Au:
Capella et al. hep-ph/0505032
Suppression from co-mover
Grandchamp et al. hep-ph/0306077
Suppression (not including regeneration)
Kostyuk et al. hep-ph/0305277
Suppression in QGP

Cu+Cu:
Capella: blue (solid) curve

Absorption calc.: blue band around dotted Line – normal absorption from 1.5 to 4.5 mb.



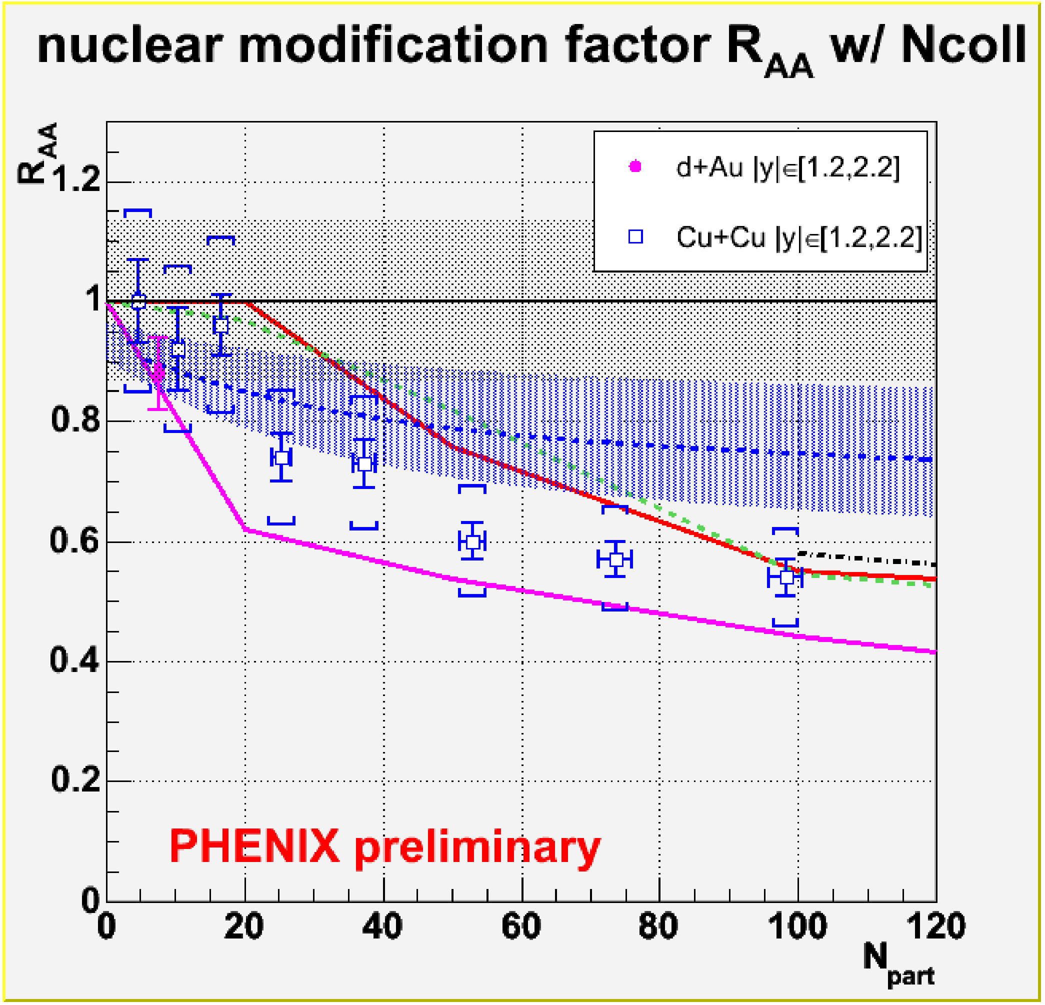
Collection of models that seem to underpredict the trend observed in the data.

Note: model calculations/curves are (mostly) for Au+Au, not Cu+Cu!
[However at least Capella curve, agrees rather well for Cu+Cu and Au+Au]

Comparisons - Models With Regeneration

Au+Au:
Kostyuk et al. hep-ph/0305277
SCM Coalescence
Bratkovskaya et al. nucl-th/0402042
HSD Model
Zhu et al. nucl-th/0411093
Transport in QGP
Grandchamp et al. hep-ph/0306077
Suppression + Regeneration

Cu+Cu:
Blue band - absorption from 1.5 to 4.5 mb.
Dotted line corresponds to 3.0 mb.



These models (several of same authors from previous slide) are in better agreement with the trend observed in the data.

Note: model calculations/curves are for Au+Au, not Cu+Cu!

Summary and Outlook

Early possible conclusions:

1) There is an indication of suppression beyond normal nuclear absorption with a J/ψ-nucleon cross section of 3.0 mb (or more).

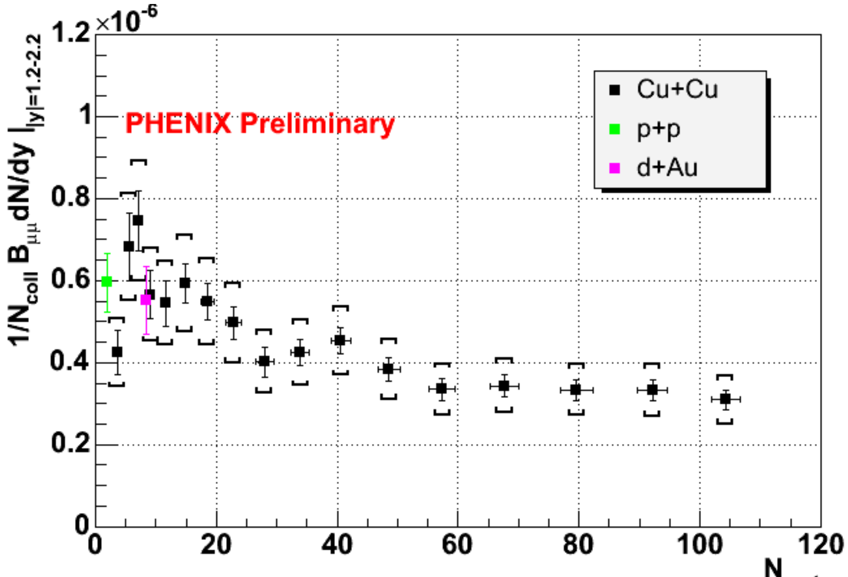
2) Models explaining J/ψ suppression at SPS energies via co-movers or QGP significantly overpredict the suppression at RHIC!

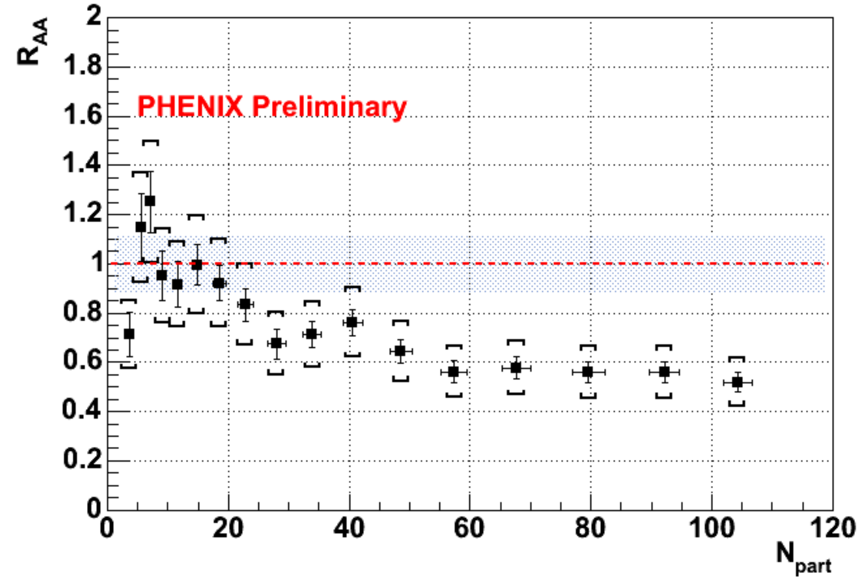
3) There are many models that include regeneration, detailed balance and other effects that are consistent within errors of the data.

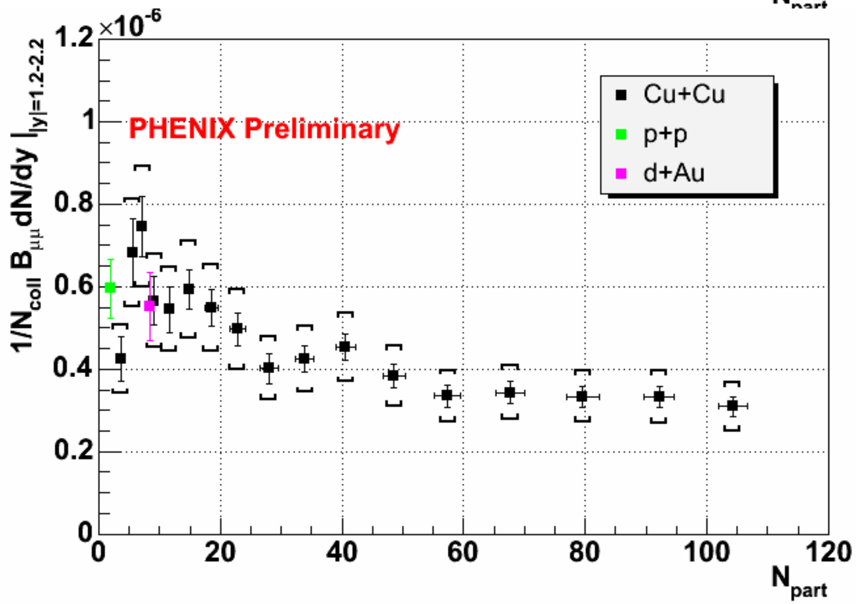
=> Also need to study other variables, such as the p_T, rapidity, and energy dependence (and for different species) to understand J/ψ production at RHIC.

For these other variables, see related posters on forward rapidity J/ψ production in Cu+Cu collisions by: A. Bickley, A. Glenn, A. Rakotozafindrabe.

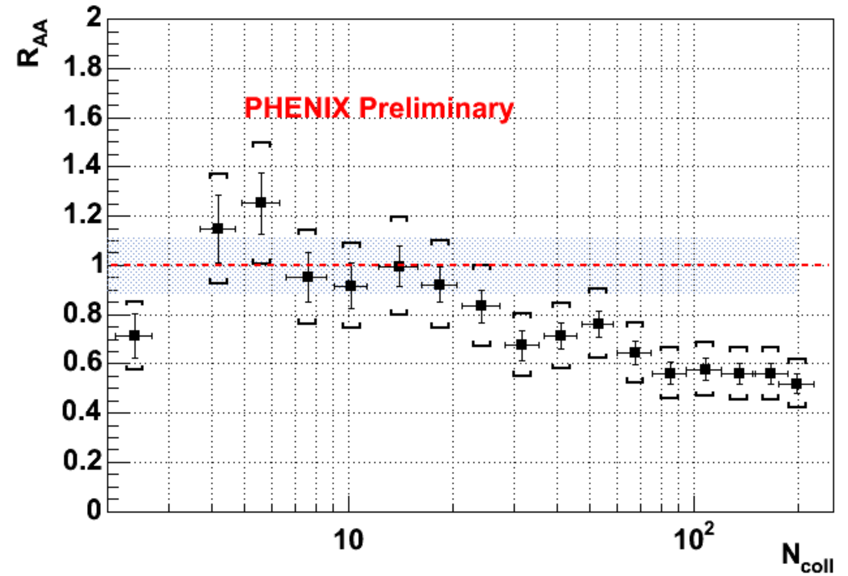
Centrality Dependence (17 bins)



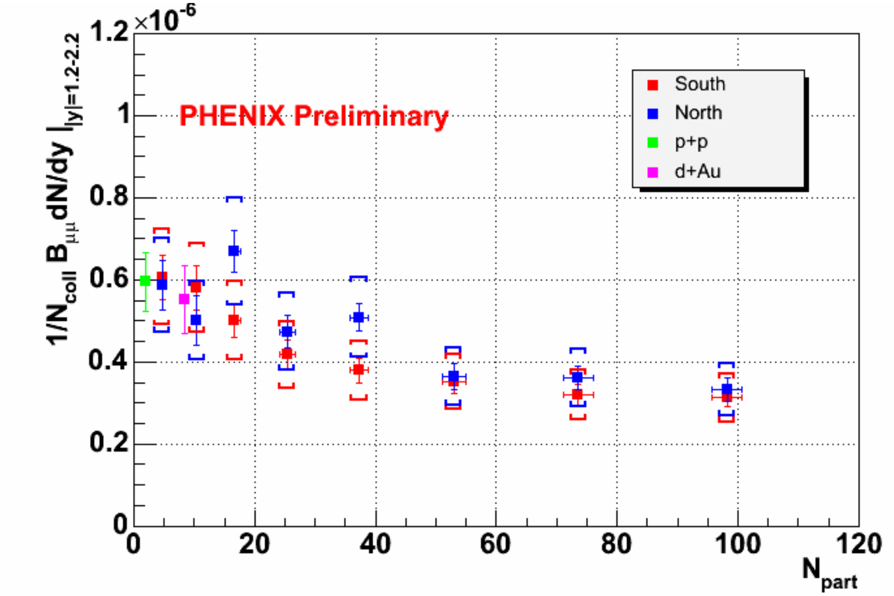




nyr, F



Centrality Dependence



BOTH ARMS