PHENIX Results on J/Ψ production in Au+Au and Cu+Cu collisions at $\sqrt{s}$ = 200 GeV

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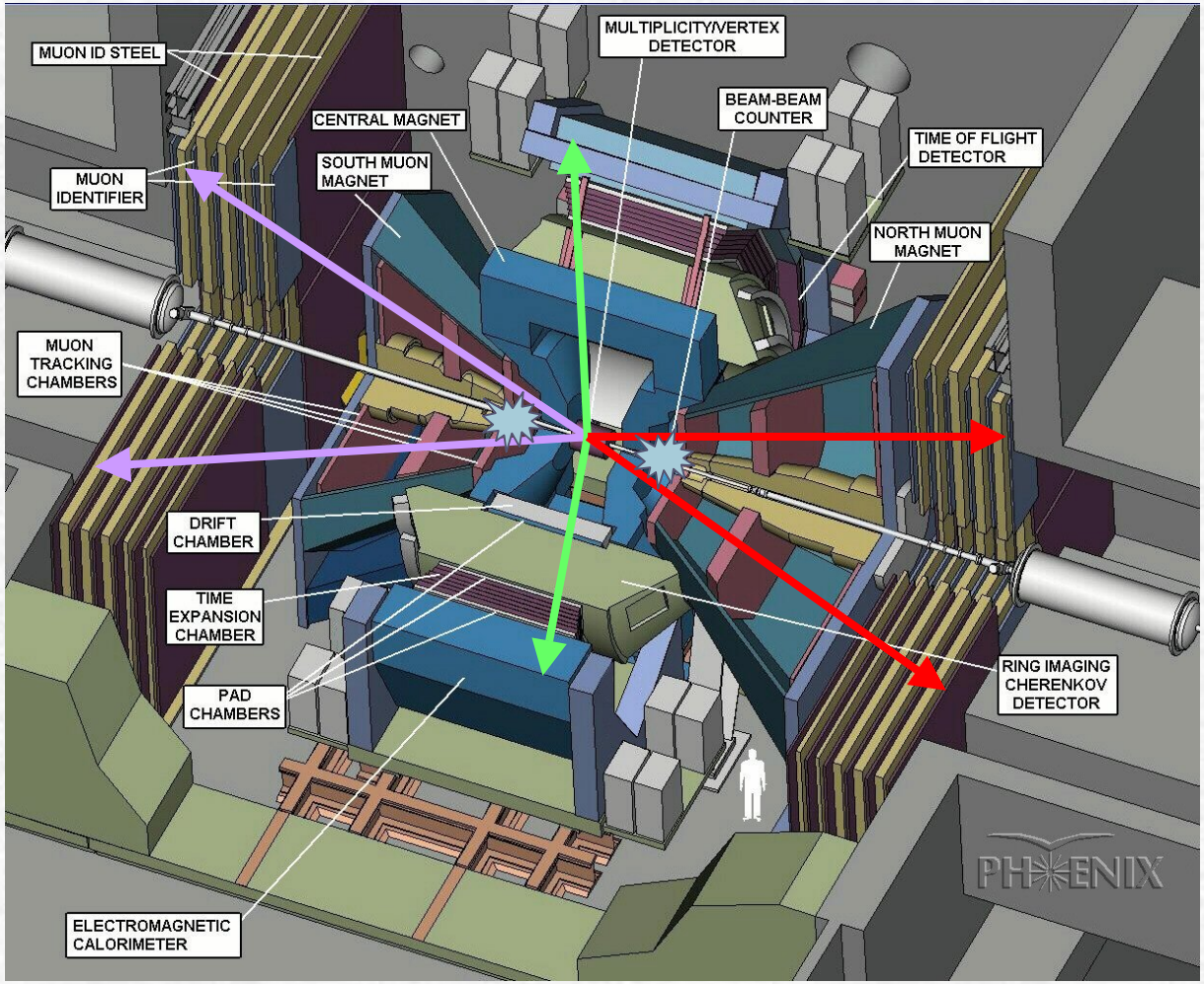
Outline

- PHENIX detectors, data sets
- Raw Results
- Comparison with models

J/Ψ in PHENIX



$J/\Psi \rightarrow e^+e^-$

identified in RICH and EMCal

- $|y| < 0.35$
- $P_e > 0.2$ GeV/c
- $\Delta\Phi = \pi$

$J/\Psi \rightarrow \mu^+\mu^-$

identified in 2 fwd spectrometers

South :

- $-2.2 < y < -1.2$

North :

- $1.2 < y < 2.4$

- $P_\mu > 2$ GeV/c
- $\Delta\Phi = 2\pi$

Event centrality and vertex given by BBC in $3<|\eta|<3.9$ (+ZDC)

Centrality is mapped to Npart (Ncoll) using Glauber model

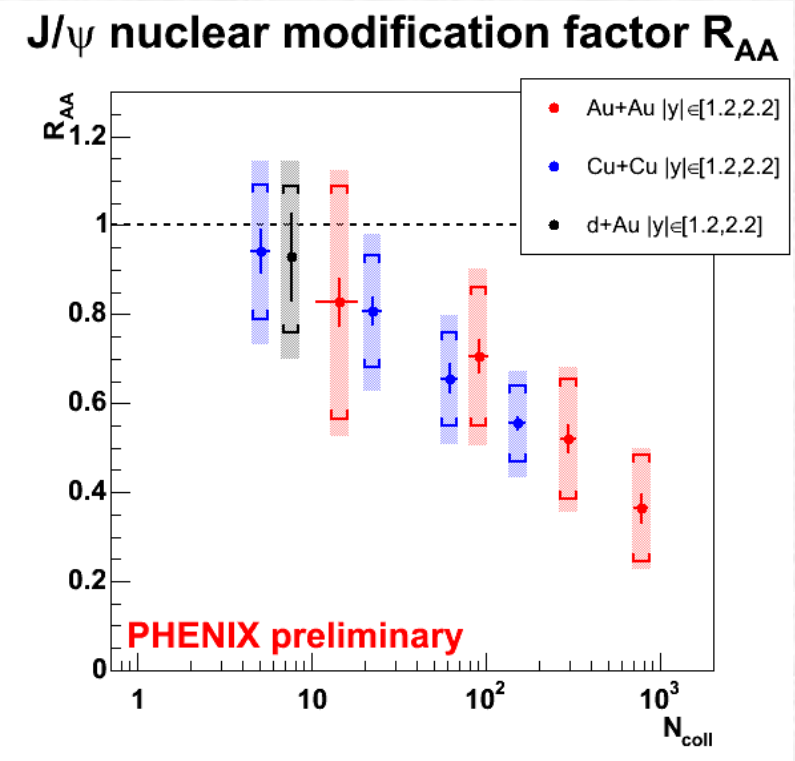
Data sets

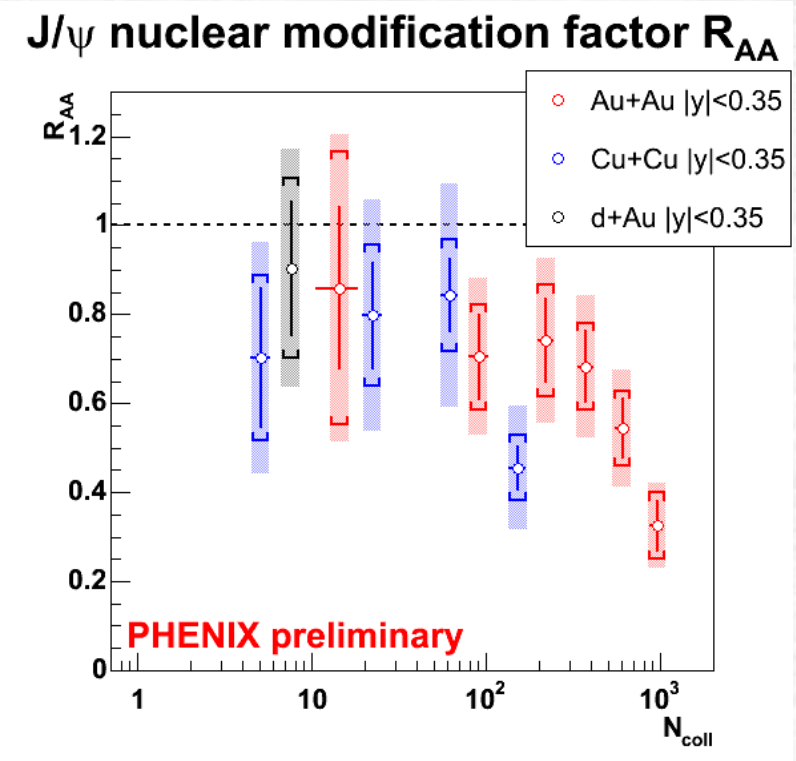
Year	Ions	Luminosity	#Events	J/Ψ
2003	p+p @200GeV d+Au @200GeV	350 nb^{-1} 2.74 nb^{-1}		100 + 420 300 + 1400
2004	Au+Au @200GeV	240 μb^{-1}	1.5×10^9	~800 + ~5000
2005	Cu+Cu @200GeV Cu+Cu @62GeV	3.06 nb^{-1} 190 mb^{-1}	1.08×10^9 425×10^6	~10 000

Results

R_{AA} vs N_{coll} Au+Au and Cu+Cu

$$R_{AA} = \frac{dN^{AA}/dy}{dN^{PP}/dy \times \langle N_{coll} \rangle}$$

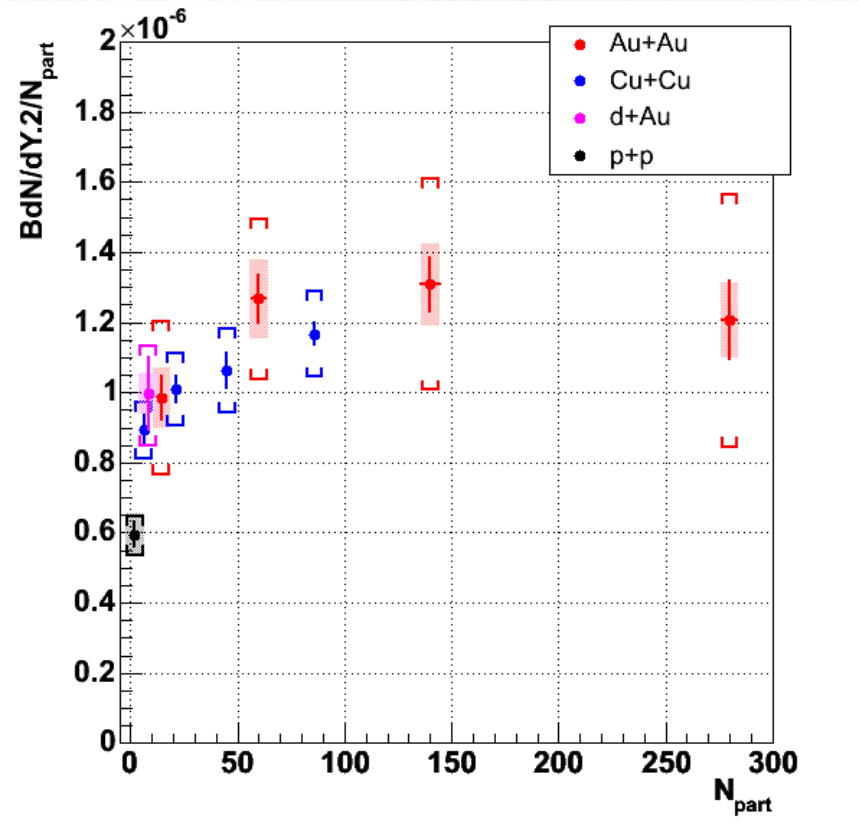


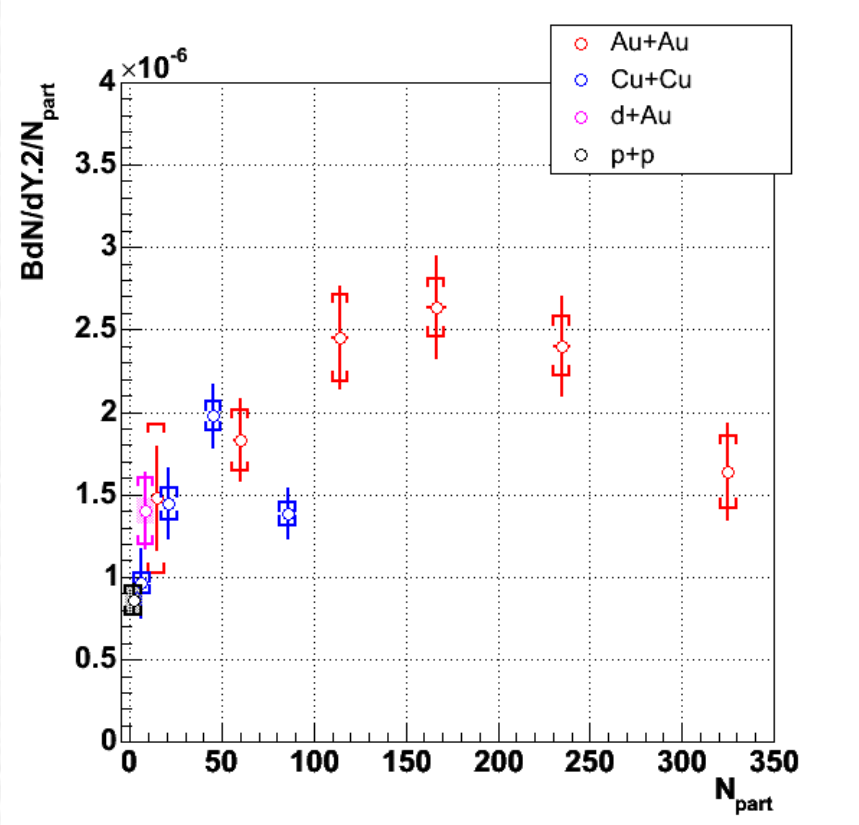


About a factor 3 suppression for most central Au+Au points

N_{part} scaling ?

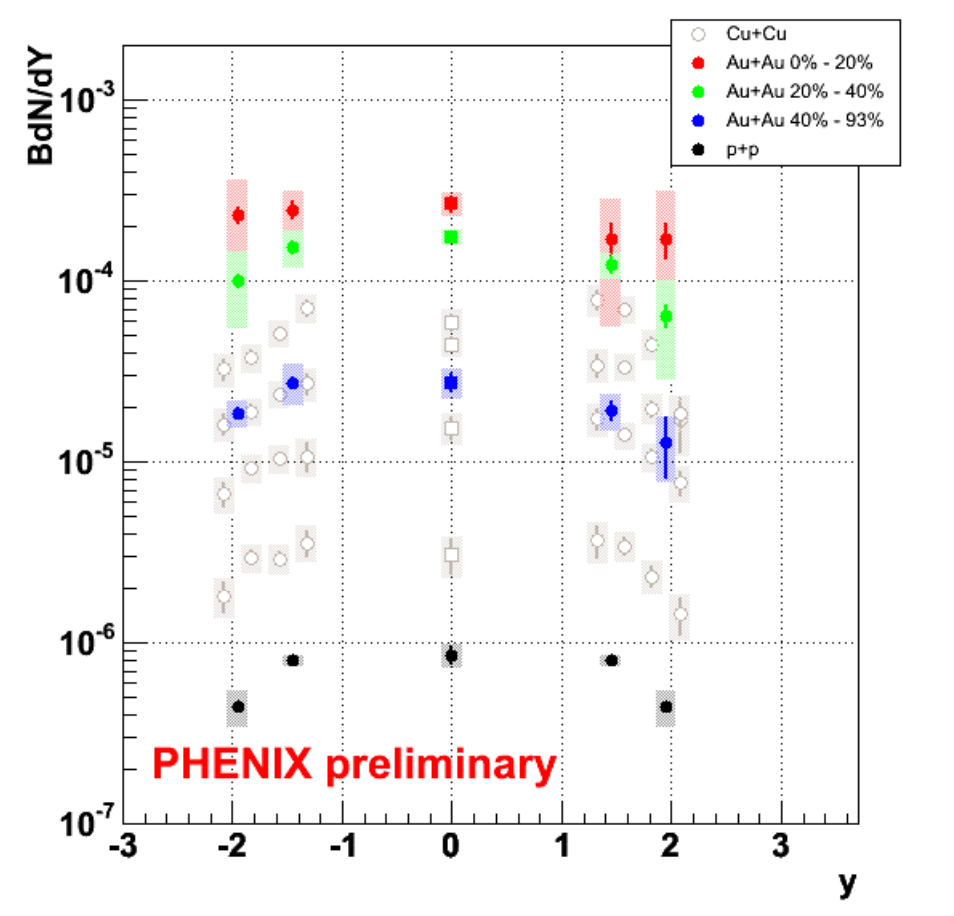
$$\frac{dN^{AA}/dy}{0.5 \times \langle N_{part} \rangle}$$





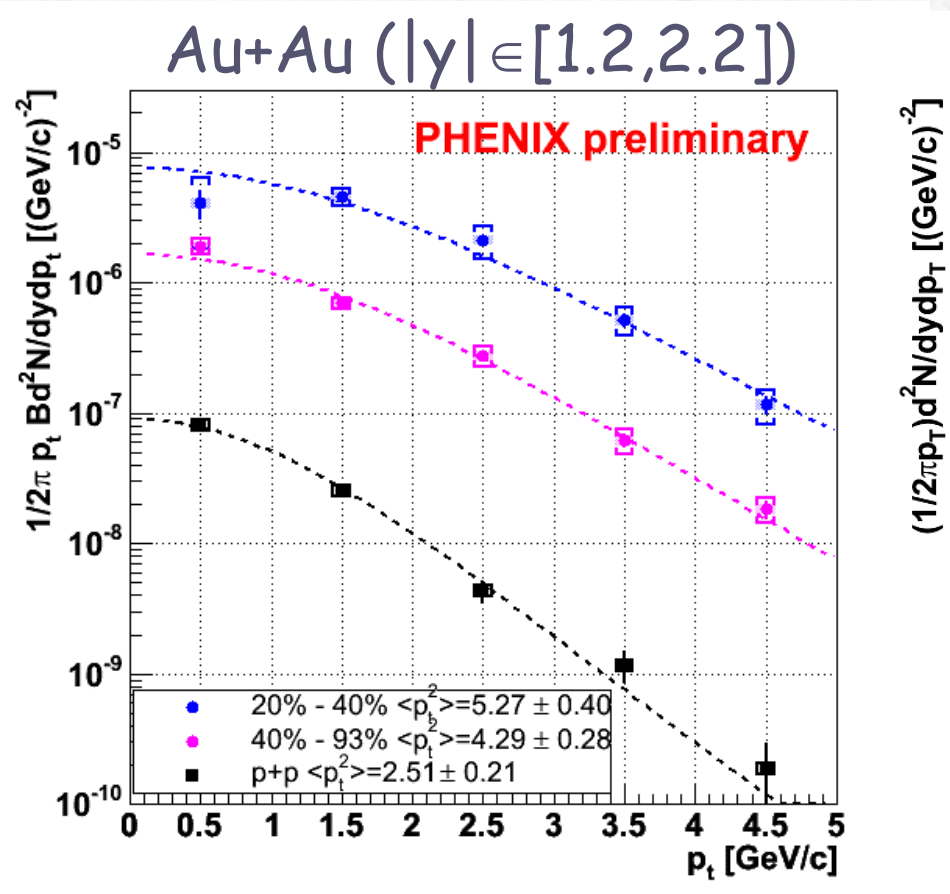
Could be flat in the forward region, but not in the central region

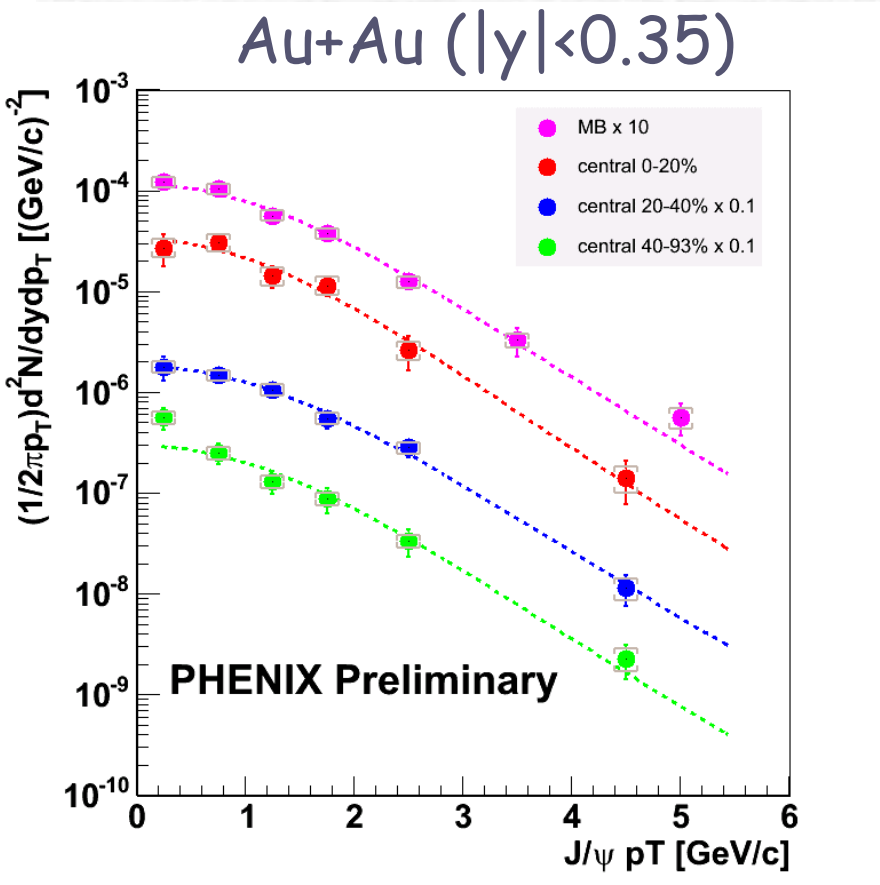
Rapidity distribution



- Cu+Cu yield vs y
- Au+Au yield vs y

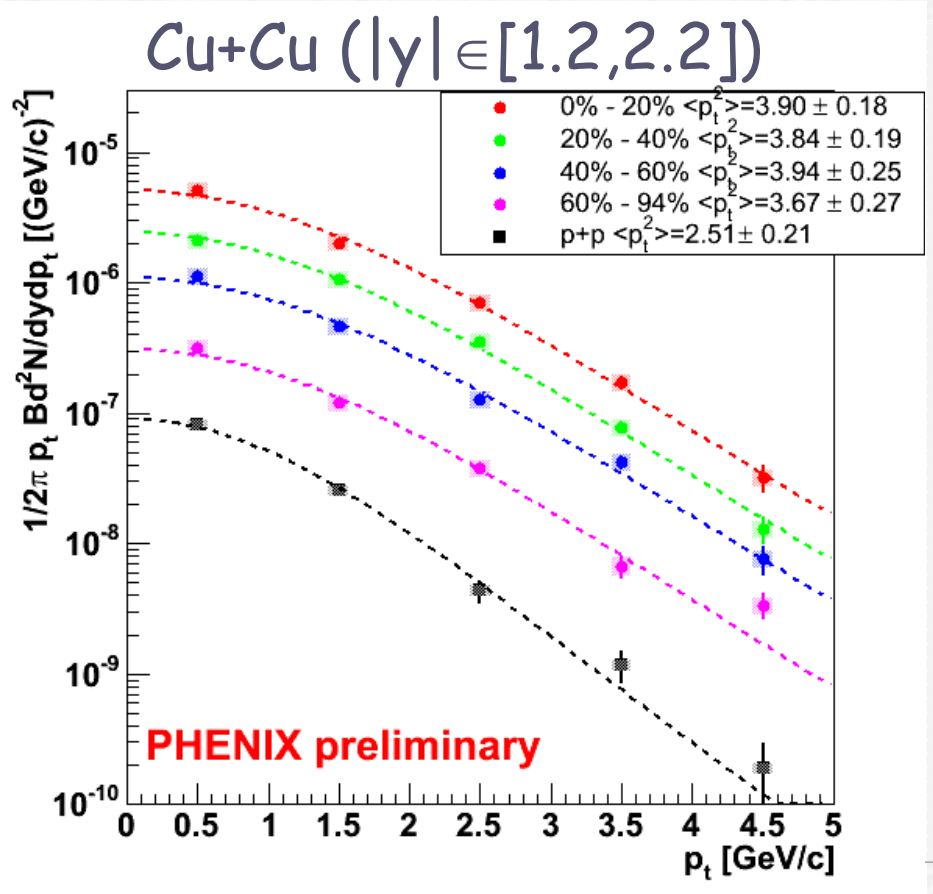
Invariant yield vs P_t Au+Au

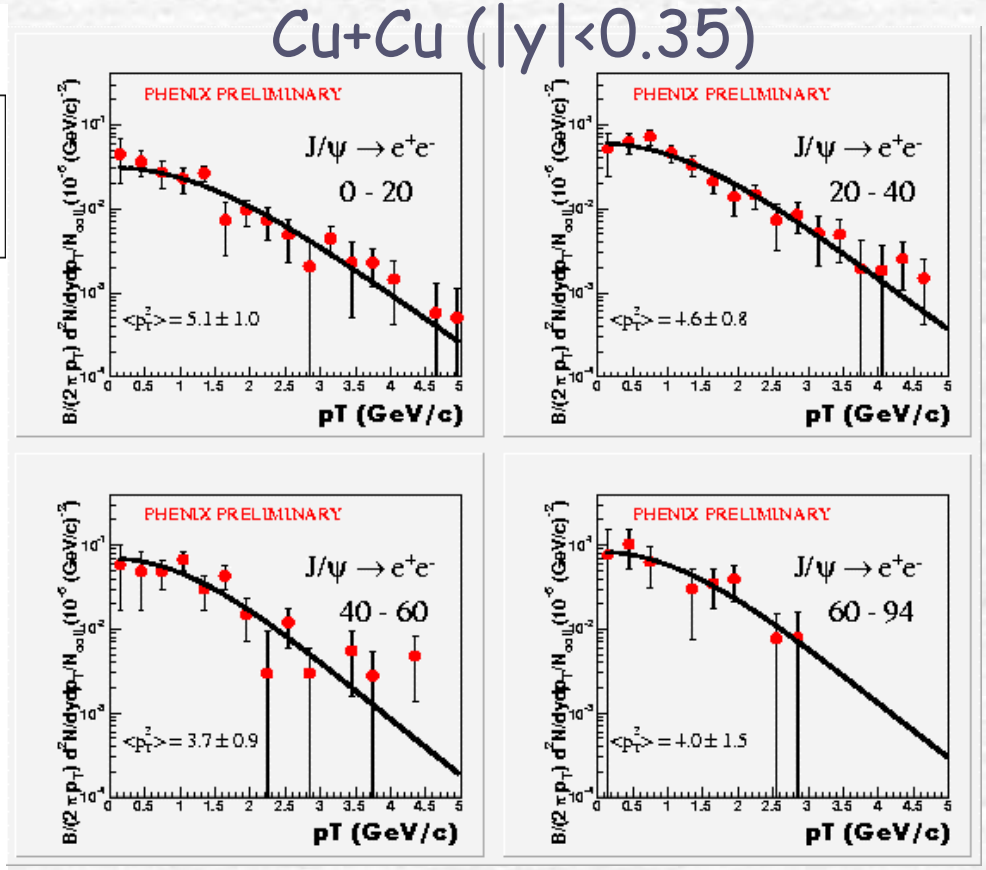




we fit the p_t spectrum using $A[1+(p_t/B)^2]^{-6}$ to extract $<p_t^2>$

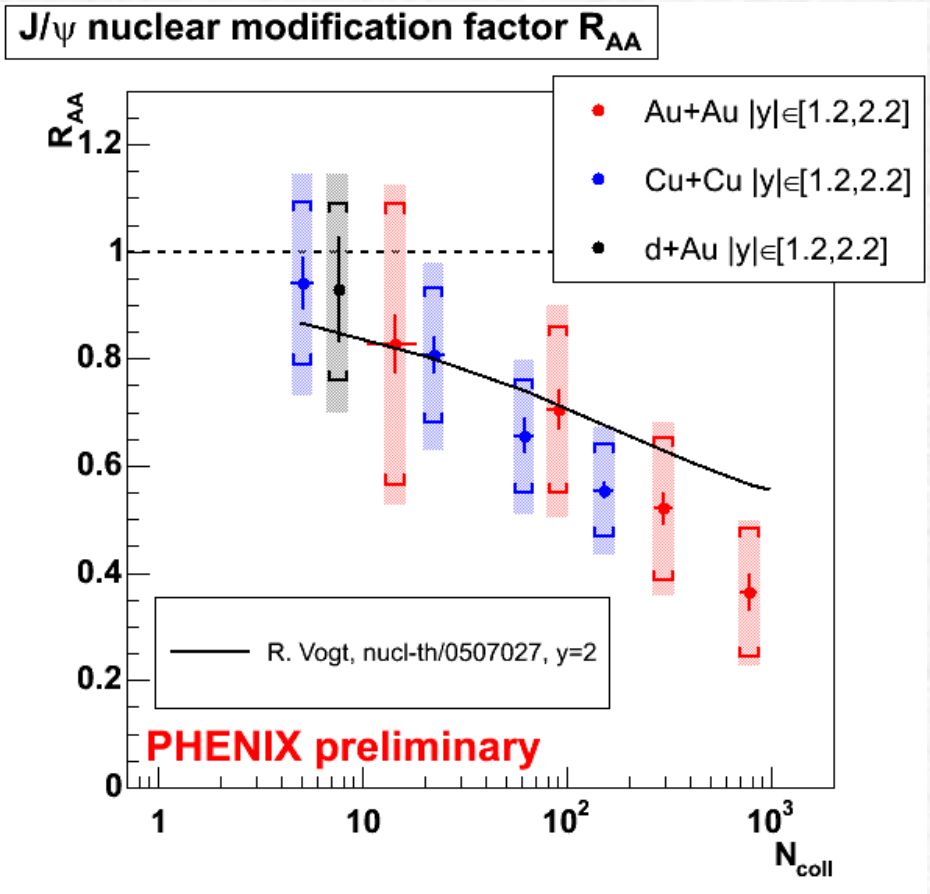
Invariant yield vs P_t Cu+Cu

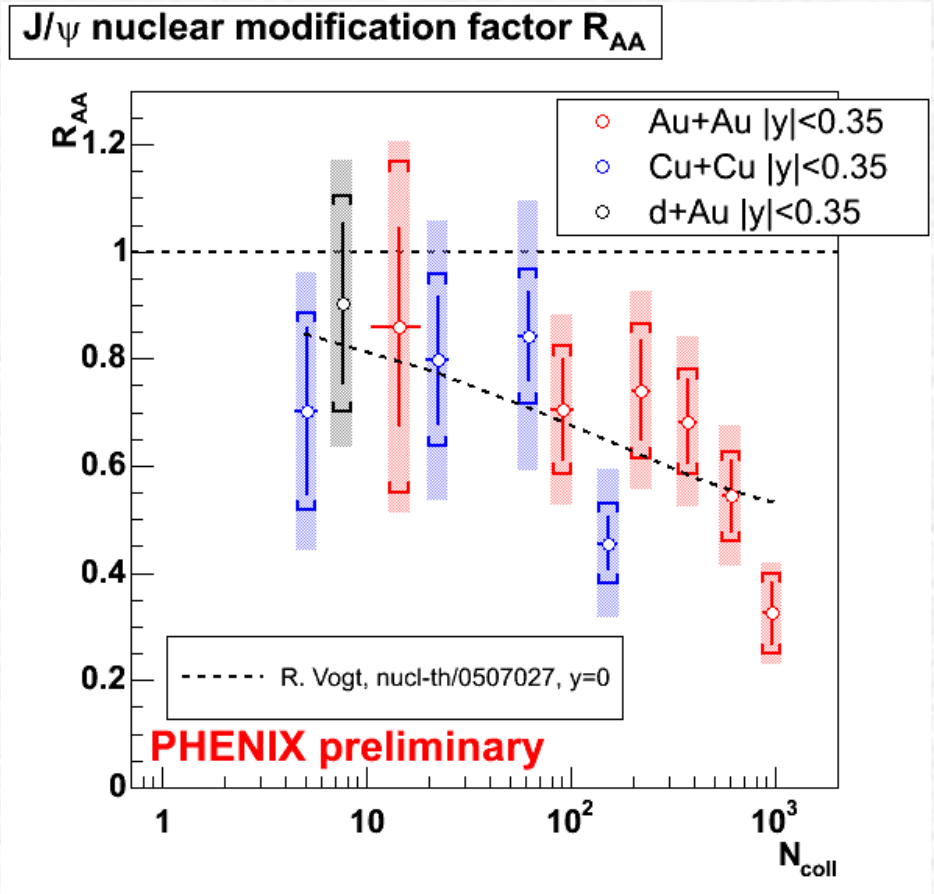




Comparison with models

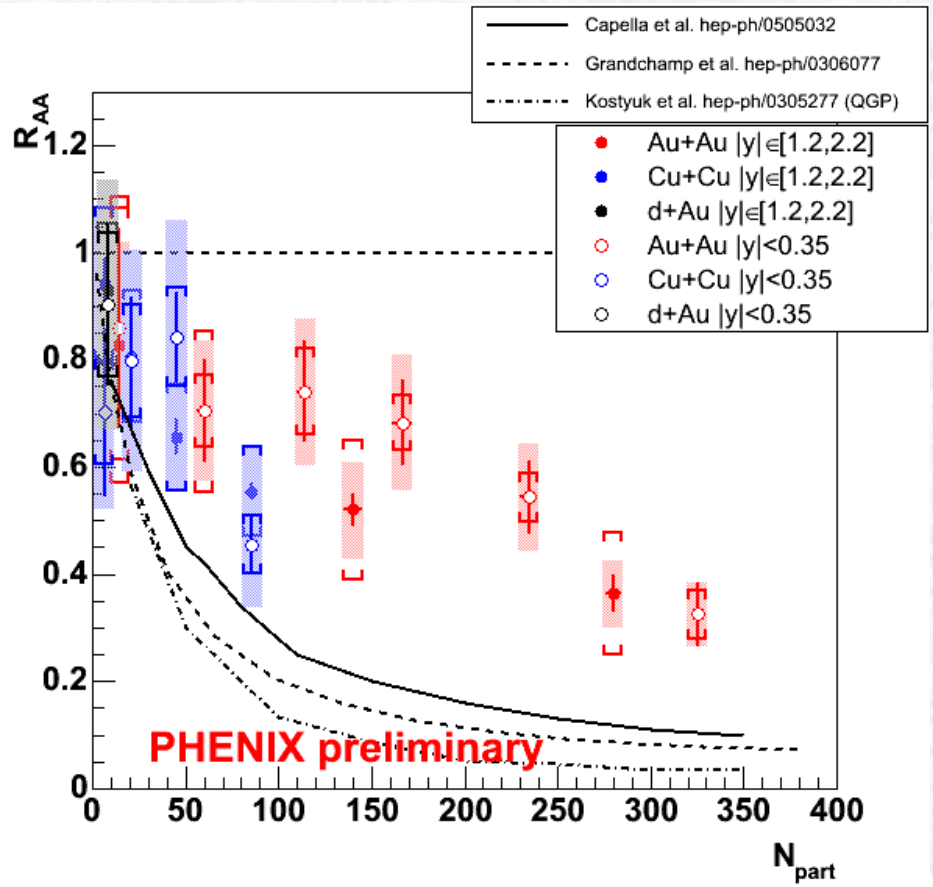
Cold nuclear effects

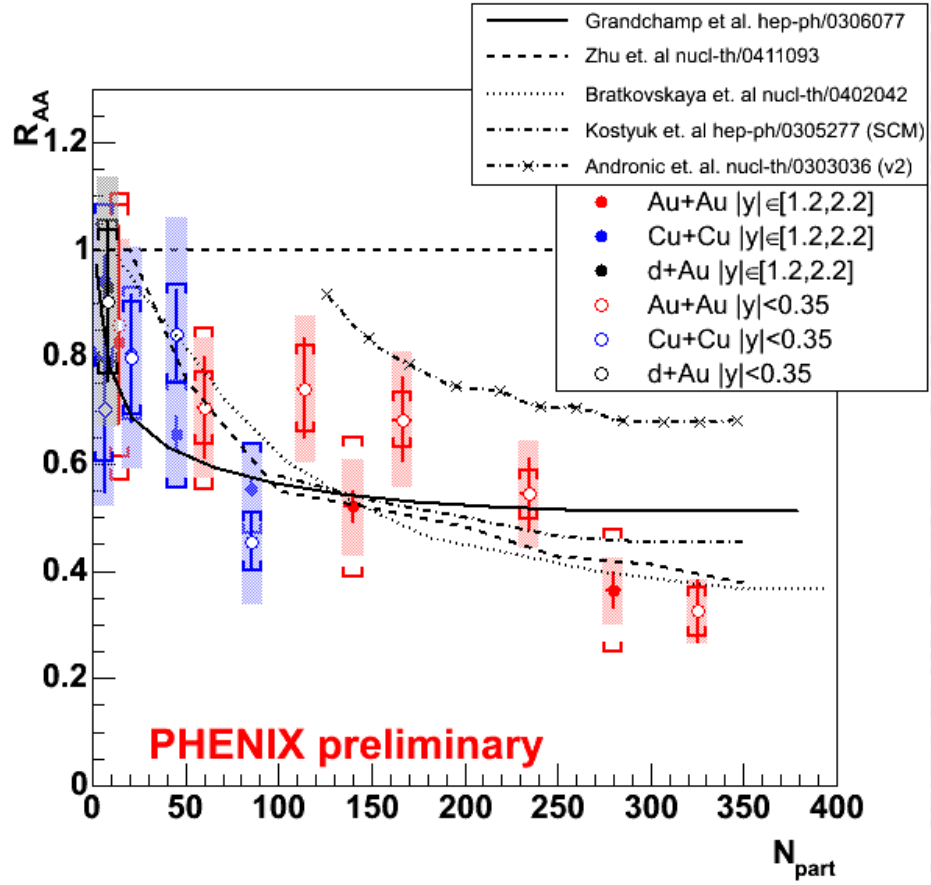




shadowing and σ_{abs} = 3 mb (probably an upper bound)

Suppression models



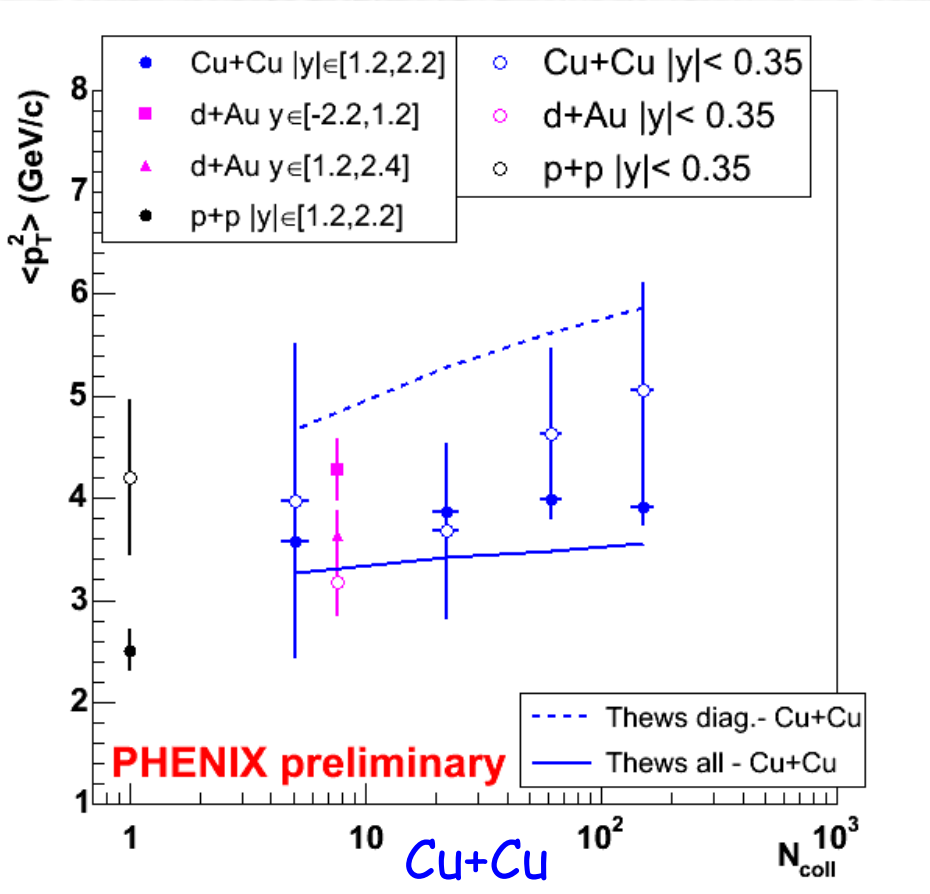


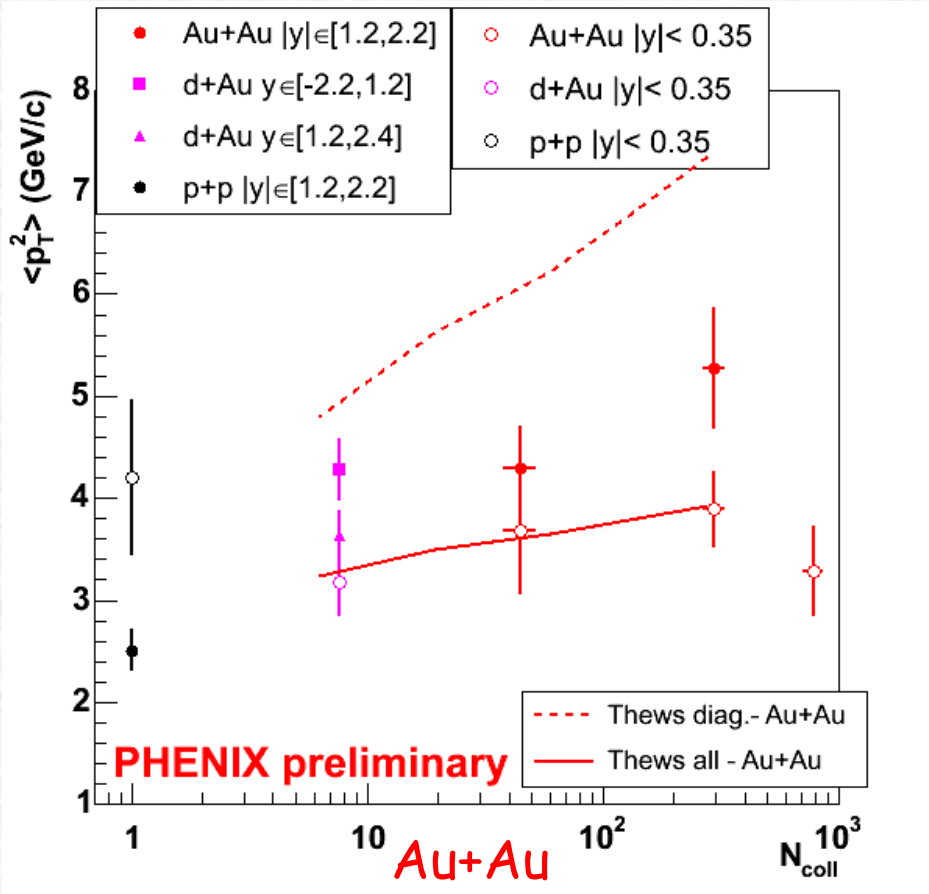
Over estimation of J/ψ suppression (comovers, suppression without regeneration…)

Models that include regeneration or detailed J/ψ transport agree better

$\langle pt^2 \rangle$ vs N_{coll}

Lines are a prediction with/without recombination*

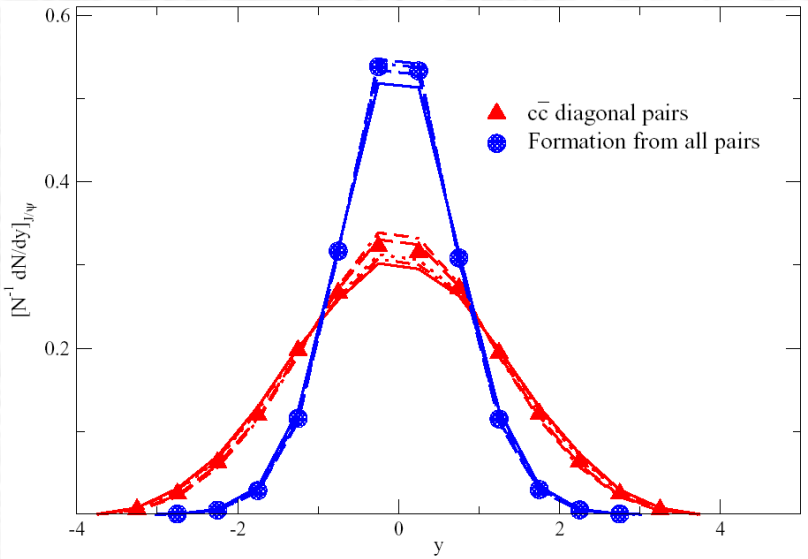




Is $\langle pt^2 \rangle$ compatible with recombination ?

*R.L. Thews et. al. nucl-th/0505055

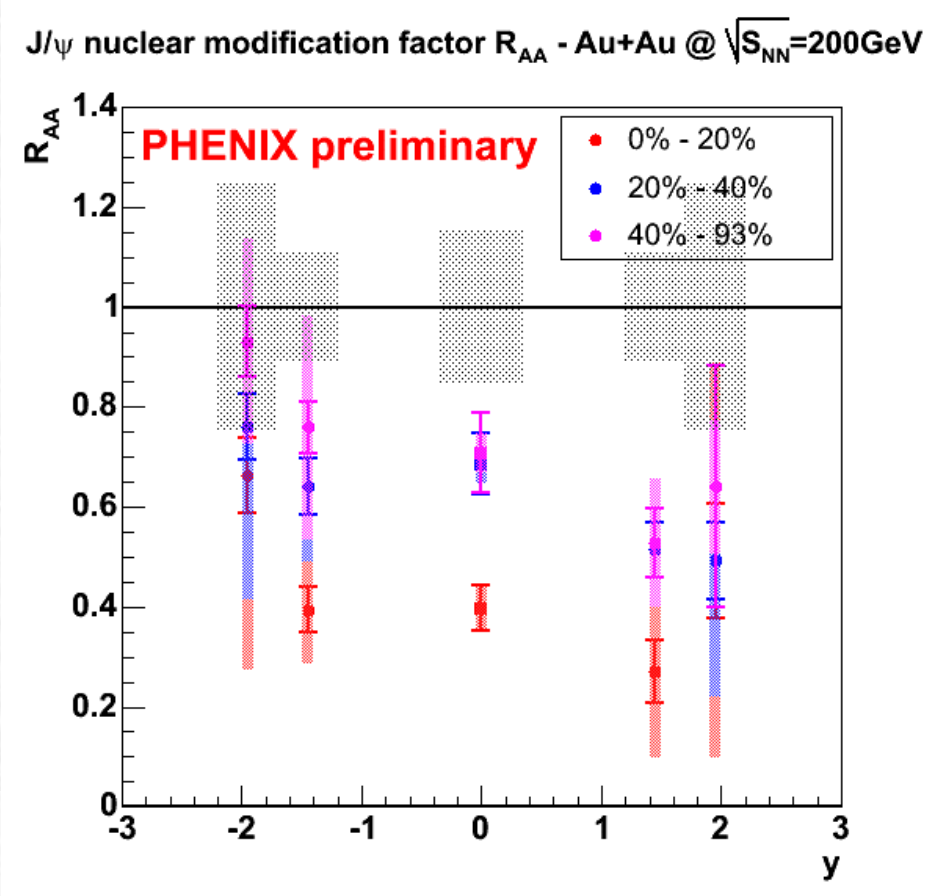
Rapidity



Rapidity distribution of recombined J/ψ is supposed to be peaked at y=0*

R.L. Thews et. al. nucl-th/0505055

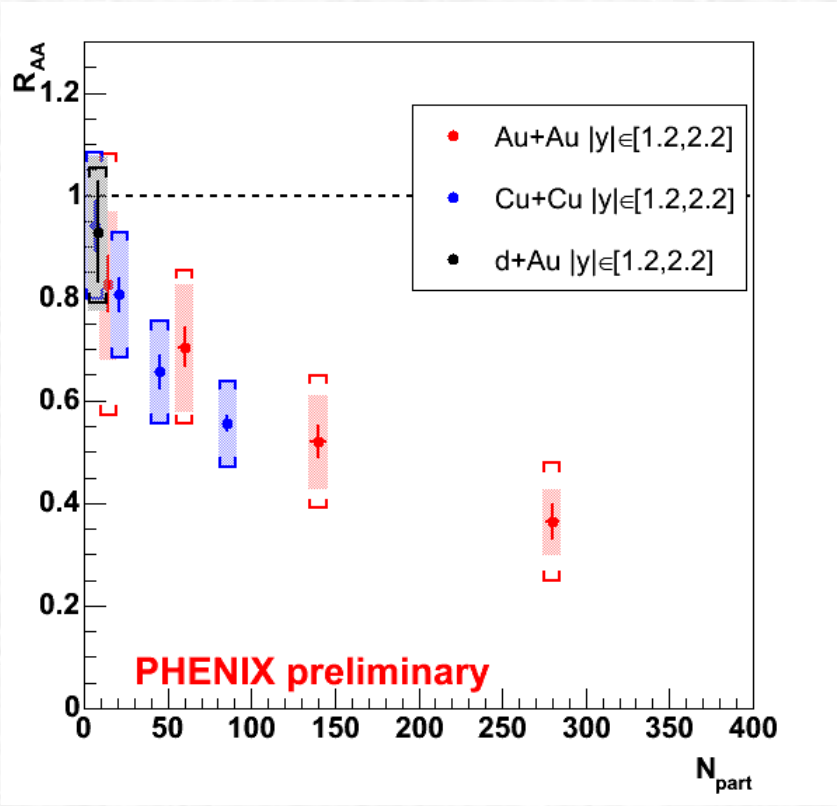
*True if charm distribution ~ J/ ψ in p+p !

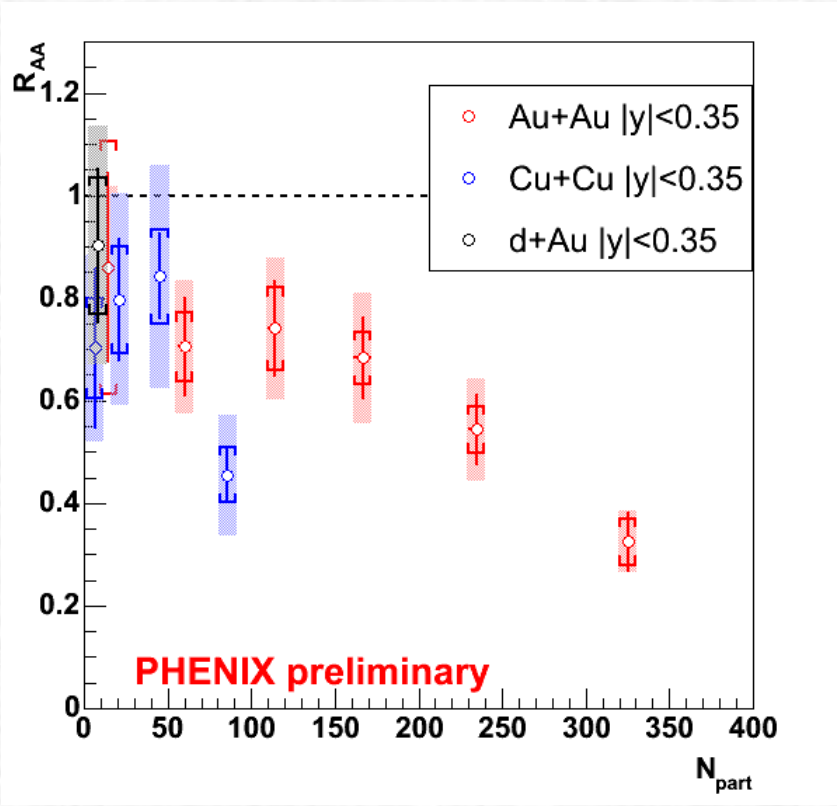


Are rapidity distributions compatible with recombination ?

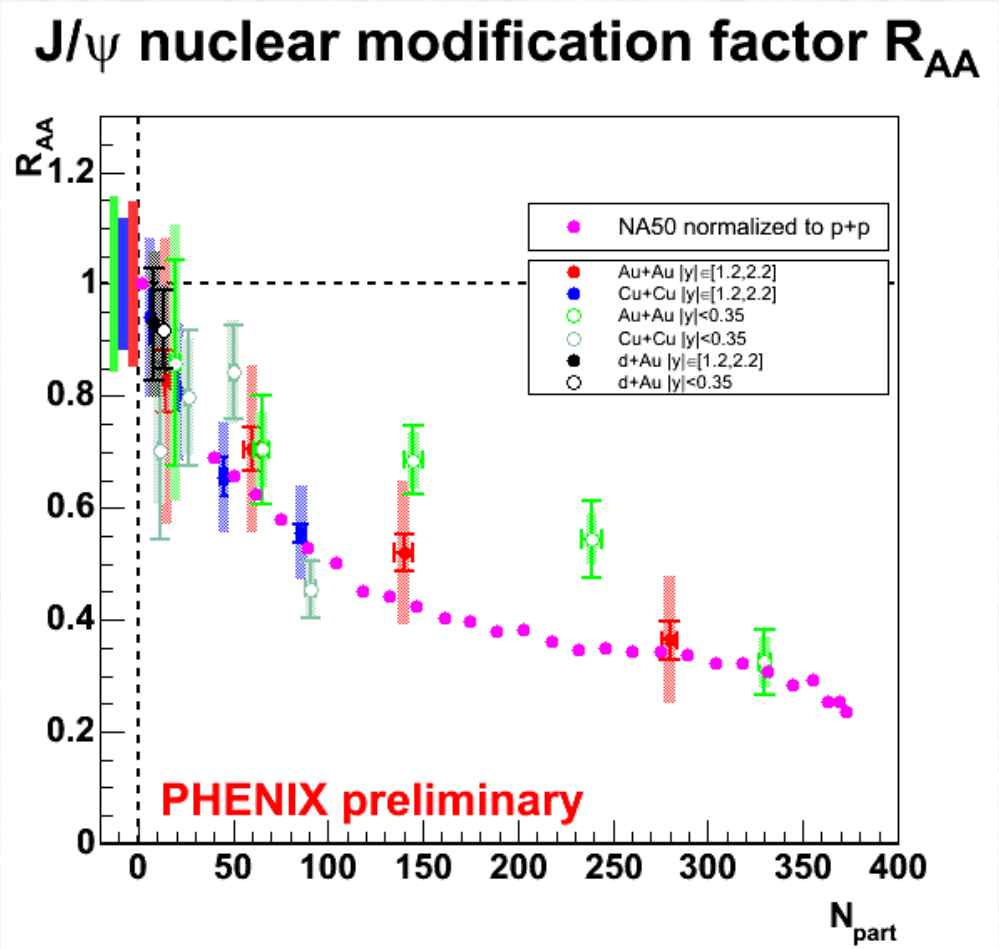
Backup slides

R_{AA} vs N_{part} Au+Au and Cu+Cu





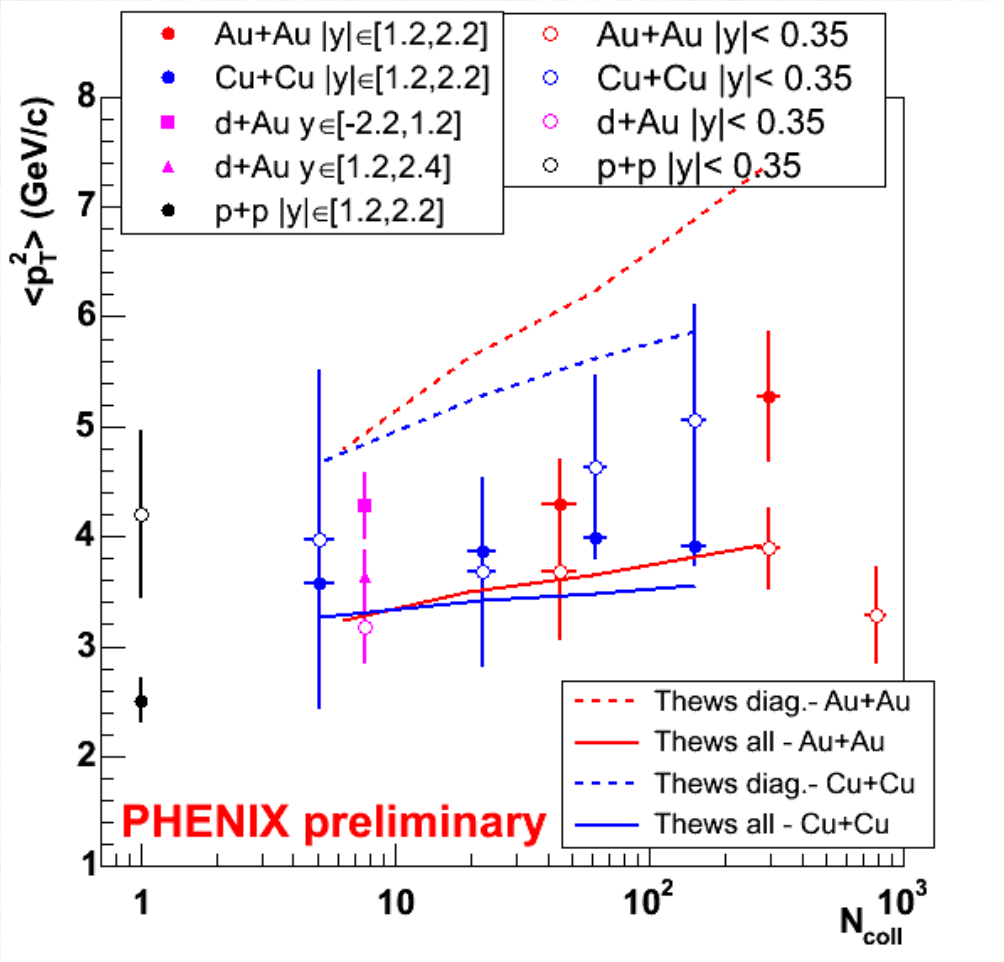
R_{AA} vs N_{part} comparison to NA50 data



- Comparison with NA50 data presented wrt N_{part} and normalized to NA50 p+p point.
- Suppression level is similar between the two experiments, **but**
  1. the collision energy is 10 times higher (200GeV wrt 17GeV)
  2. the rapidity window for NA50 is $|y| \in [0,1]$

Needs more detailed comparison to cope with energy difference

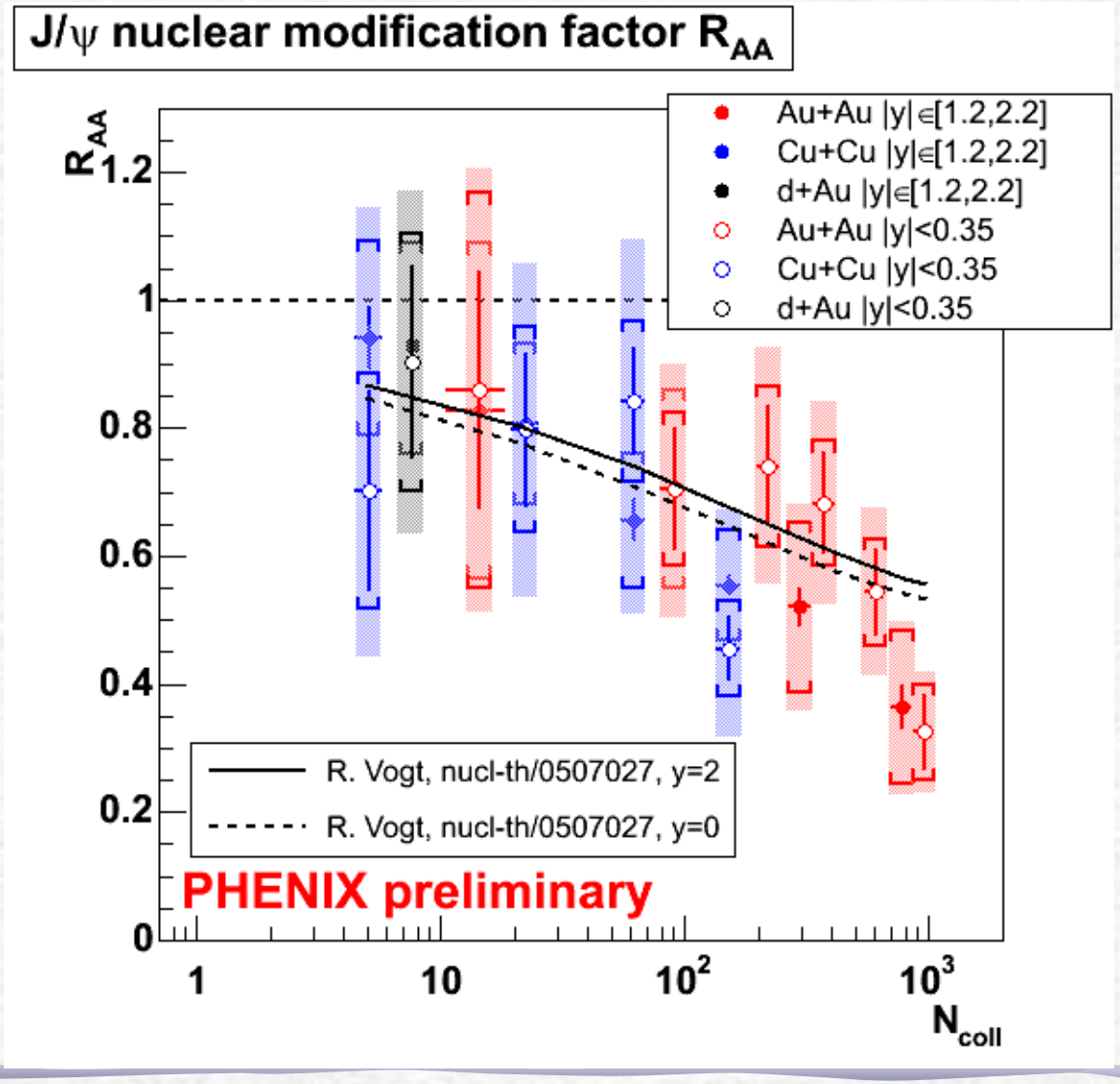
$\langle p_T^2 \rangle$ vs N_{coll}



Au+Au and Cu+Cu

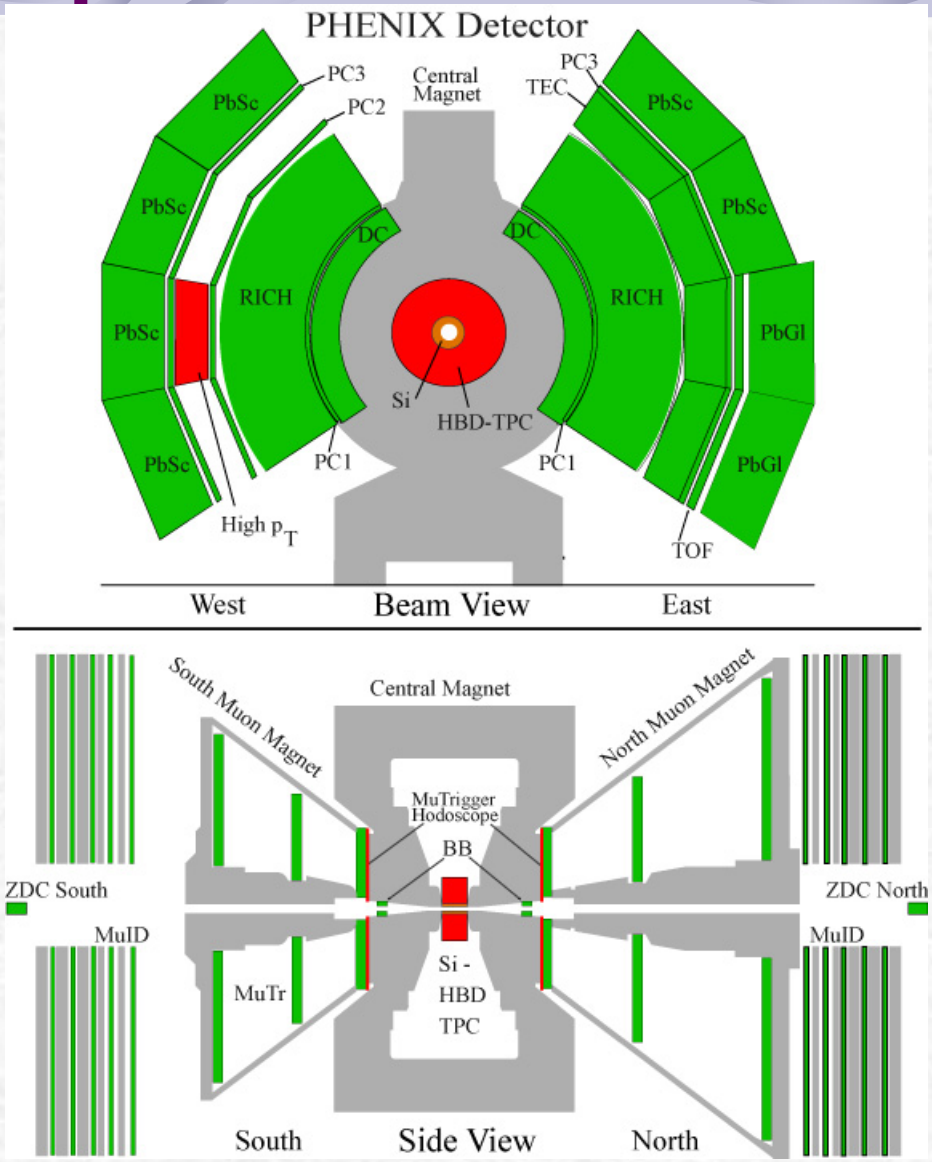
R.L. Thews et. al. nucl-th/0505055

Cold nuclear effect



PHENIX Experiment

- BBC, ZDC
  - centrality
  - z-vertex
- DC, PC1
  - momentum
- RICH
  - Electron ID
- EMCal (PbGl, PbSc)
  - Energy
  - Track Matching



Data analysis in e^+e^-

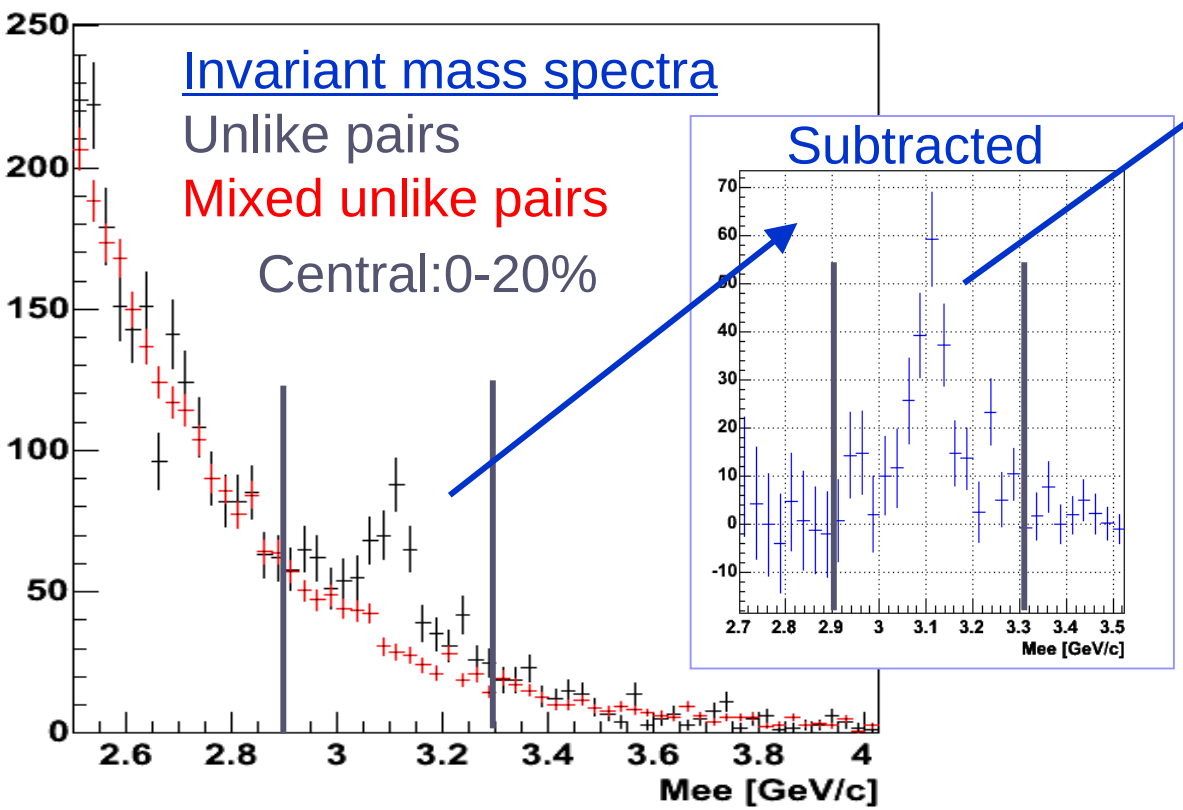
- Invariant Yield

$$B\frac{dN}{dy} = \frac{N_{J/\psi}}{N_{evt}} \times \frac{1}{\Delta y} \times \frac{1}{\epsilon_{acc} \times \epsilon_{eff} \times \epsilon_{run-by-run} \times \epsilon_{embed}}$$

- Centrality selection → N_{evt}
- Signal Counting of J/ψ → $N_{J/\psi}$
  - $e^+ e^-$ Invariant mass
  - subtract combinatorial background
- Correction factors
  - single J/ψ detection efficiency → $\varepsilon_{acc} \times \varepsilon_{eff}$
  - centrality dependence → ε_{embed}
  - Run-by-Run fluctuation of detector acceptance → $\varepsilon_{run\text{-}by\text{-}run}$

Signal counting of J/ψ

- Analyzed 760 M Minimum Bias Data
- $N_{J/\psi} = N_{ee} - N_{mixed\_ee}$ (2.9 <Mee<3.3 GeV)
  - Event mixing method was used.



$N_{J/\psi}$ is counted in this mass range.

Centrality vs. $N_{J/\psi}$

Centrality	$N_{J/\psi}$
0-10%	145.4 +- 25.3
10-20%	155.1 +- 19.2
20-30%	124.2 +- 14.7
30-40%	87.9 +- 11.1
40-60%	70.1 +- 9.6
60-92%	26.7 +- 5.4

How do we get J/Ψ yield in $\mu^+\mu^-$?

Invariant yield :

$$B_{\mu\mu}\frac{dN}{dy}(AA \to J/\psi \to \mu^+\mu^-) = \frac{N_{J/\psi}}{\Delta y\ A\varepsilon_{J/\psi}\varepsilon_{BBC}^{J/\psi}} / \frac{N_{MB}}{\varepsilon_{BBC}^{MB}}$$

$N_{J/\psi}$: number of J/ψ 's reconstructed

$A\varepsilon^{J/\psi}$: probability for a J/ψ thrown and embeded into real data to be found (considering reconstruction and trigger efficiency)

N_{MB} : total number of events

$\varepsilon_{BBC}^{J/\psi}$: BBC trigger efficiency for events with a J/ψ

ε_{BBC}^{MB} : BBC trigger efficiency for minimum bias events

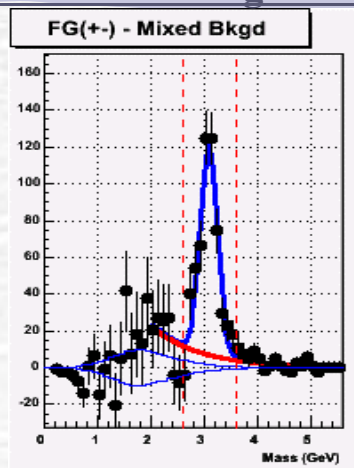
For Au+Au collision : $\varepsilon_{BBC}^{MB} \sim \varepsilon_{BBC}^{J/\psi}$

Analysis procedure

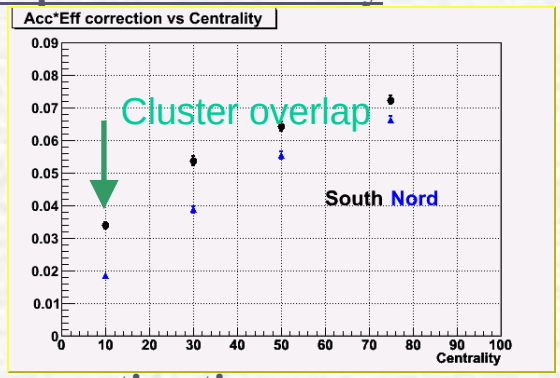
1. **Get momentum of tracks**
   - Muon tracker
2. **Identify muons**
   - Depth in Muon Identifier (MUID)
3. **Get di-muon invariant mass spectra**
4. **Extract J/ψ signal**
   - Event mixing technique
5. **Correct for acceptance and efficiencies**
   - Realistic detector simulation
6. **Calculate corresponding luminosity**
   - run4AuAu Level-2 filtered at *CCF* (70%) - 170 mb^{-1}
7. **Estimate systematic errors**

→ Cross section

Extract signal with event mixing method



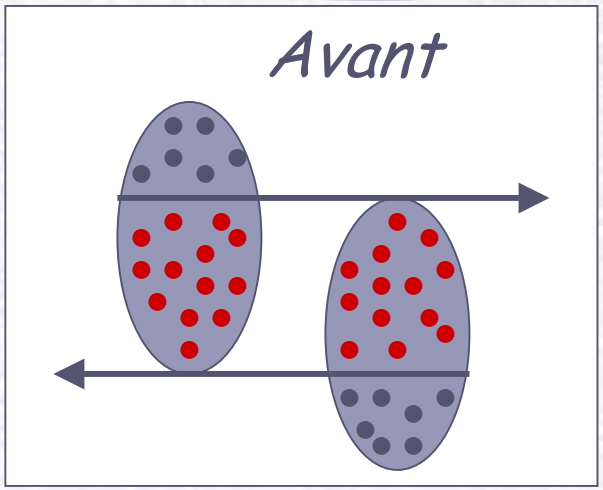
Calculate Acceptance x Efficiency

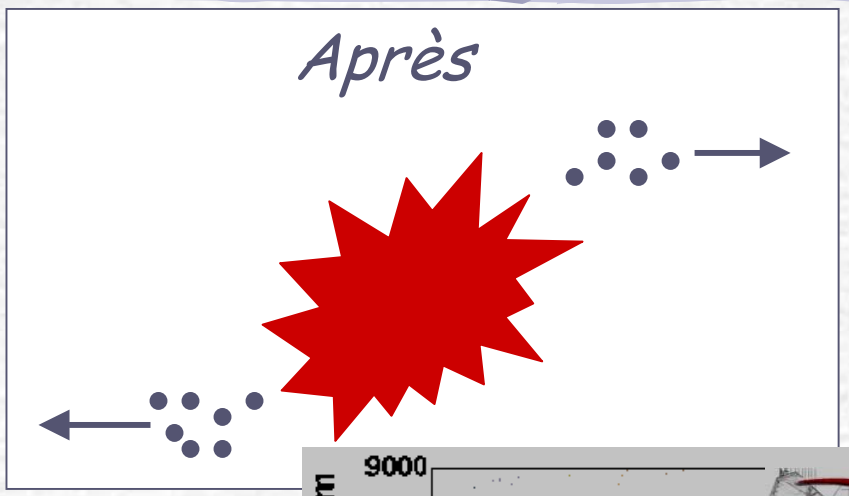


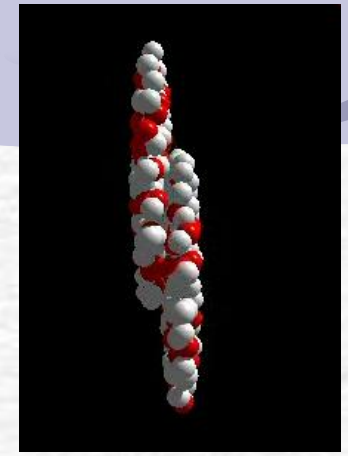
Systematic error estimation

Acceptance efficiency	12 %
Luminosity	2 %
Signal extraction	Different (bin by bin)

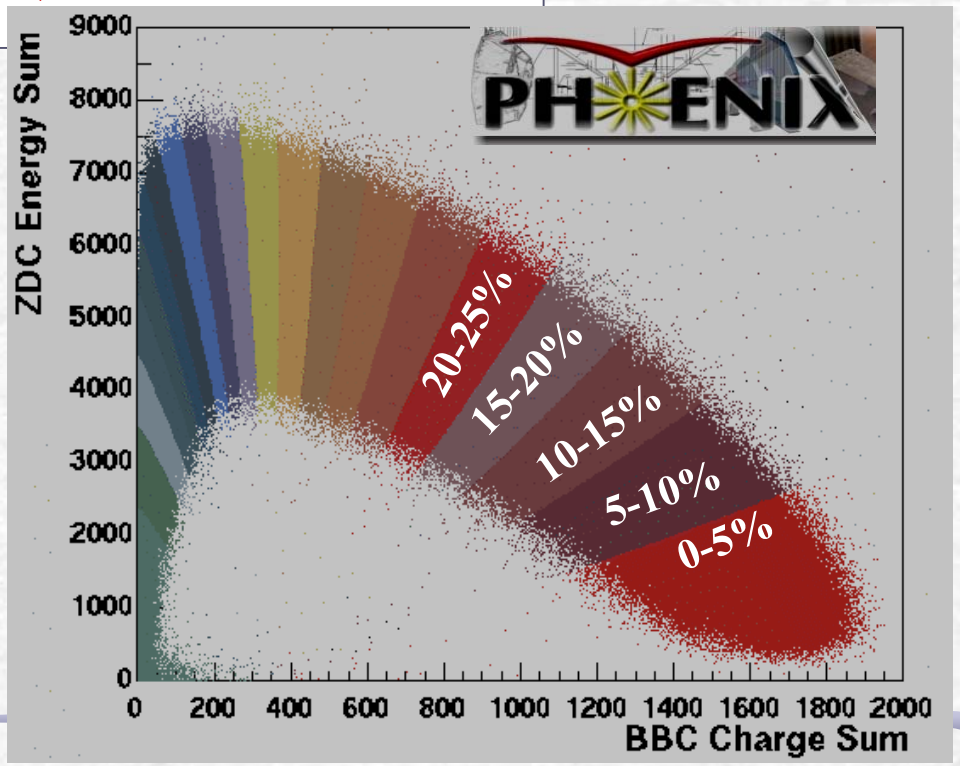
Centralité en or+or





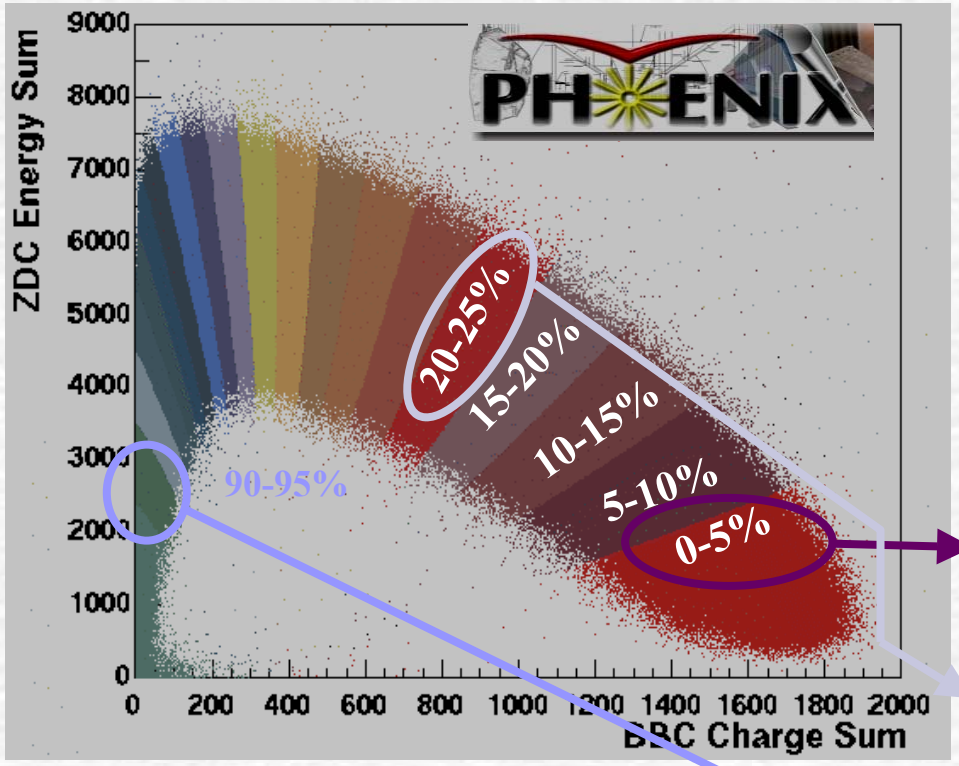


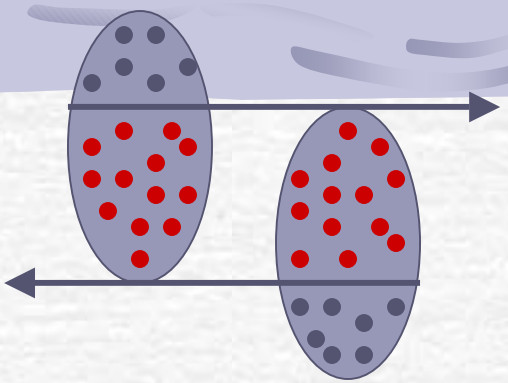
- Les spectateurs (neutres) sont mesurés par 2 calorimètres à zéro degré
- Les participants redistribuent leur énergie dans tous les autres détecteurs, par exemple les Beam-Beam Counters (PHENIX)



➢ Classes de centralités

Déterminer N_{coll}





B (fm)	N_{part}	N_{coll}
2,3 ± 0,9	353 ± 19	1091 ± 102
7,1 ± 0,5	181 ± 16	422 ± 65
14,5 ± 0,3	4,1 ± 2,5	2,8 ± 2,2

+ Modèle de Glauber (géométrie, densité nucléaire, σ_{NN} …)

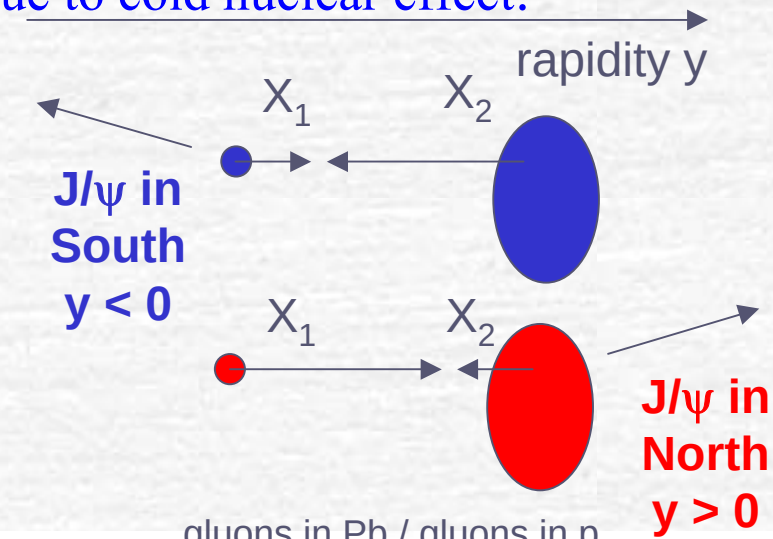
- Paramètre d'impact
- Nombre de participants
- Nombre de collisions…

Physics Motivation: Disentangle Cold Nuclear Effects

J/ψ is expected to be either suppressed or enhanced in QGP.

There's also suppression or enhancement due to cold nuclear effect:

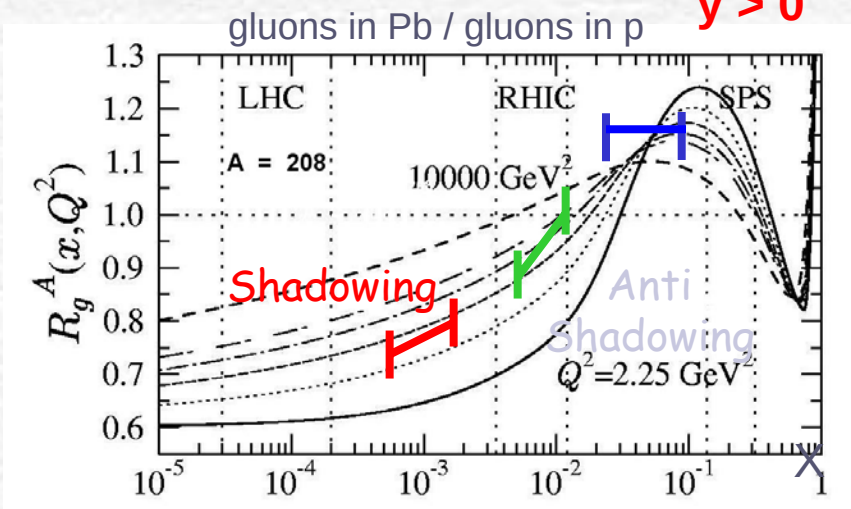
- Gluon (anti-)shadowing
- Nuclear absorption.
- Initial state energy loss.
- Cronin effect



South (y < -1.2) :
- large X_2 (in gold) ~ 0.090

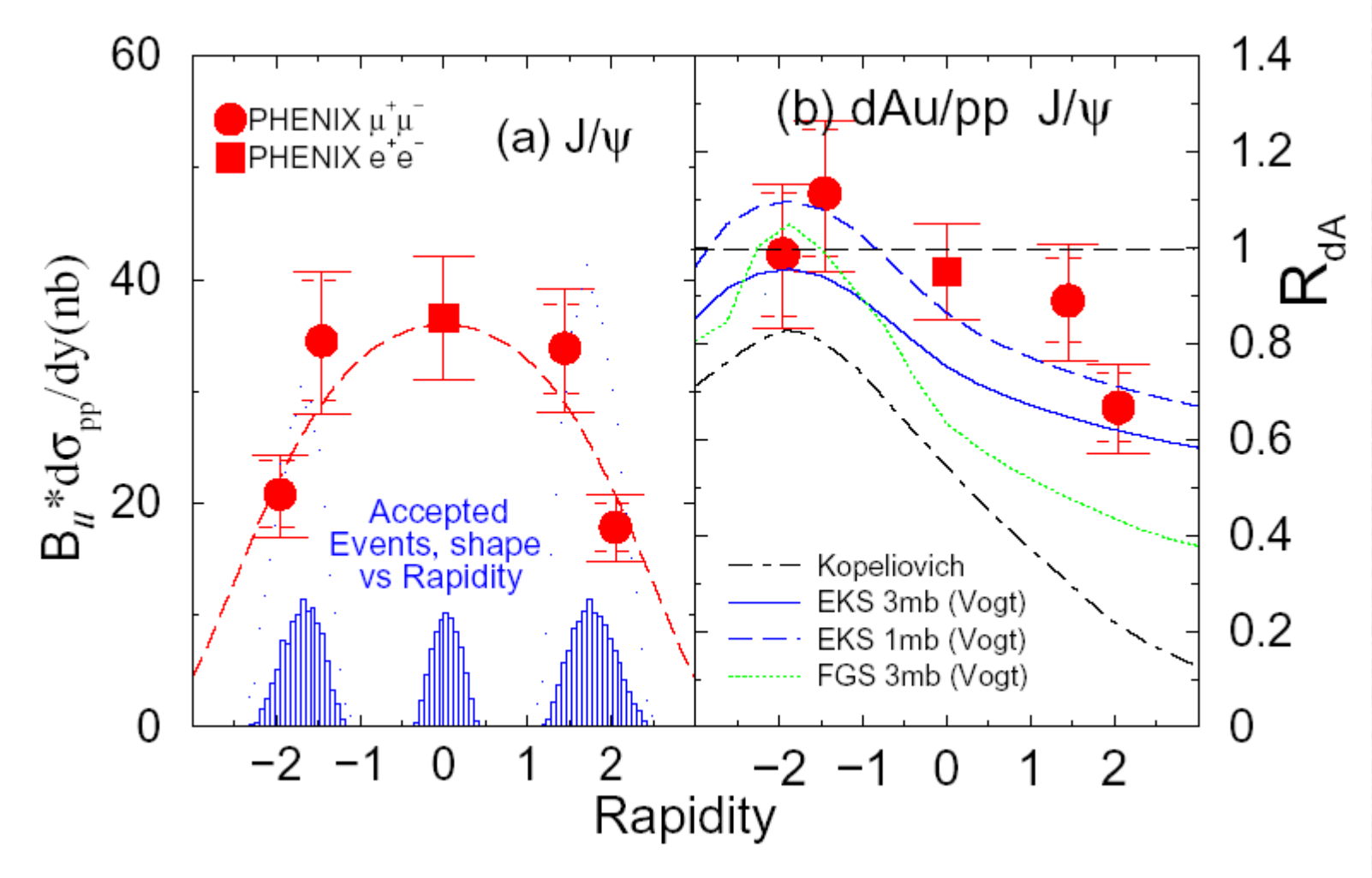
Central (y ~ 0) :
- intermediate X_2 ~ 0.020

North (y > 1.2) :
- small X_2 (in gold) ~ 0.003



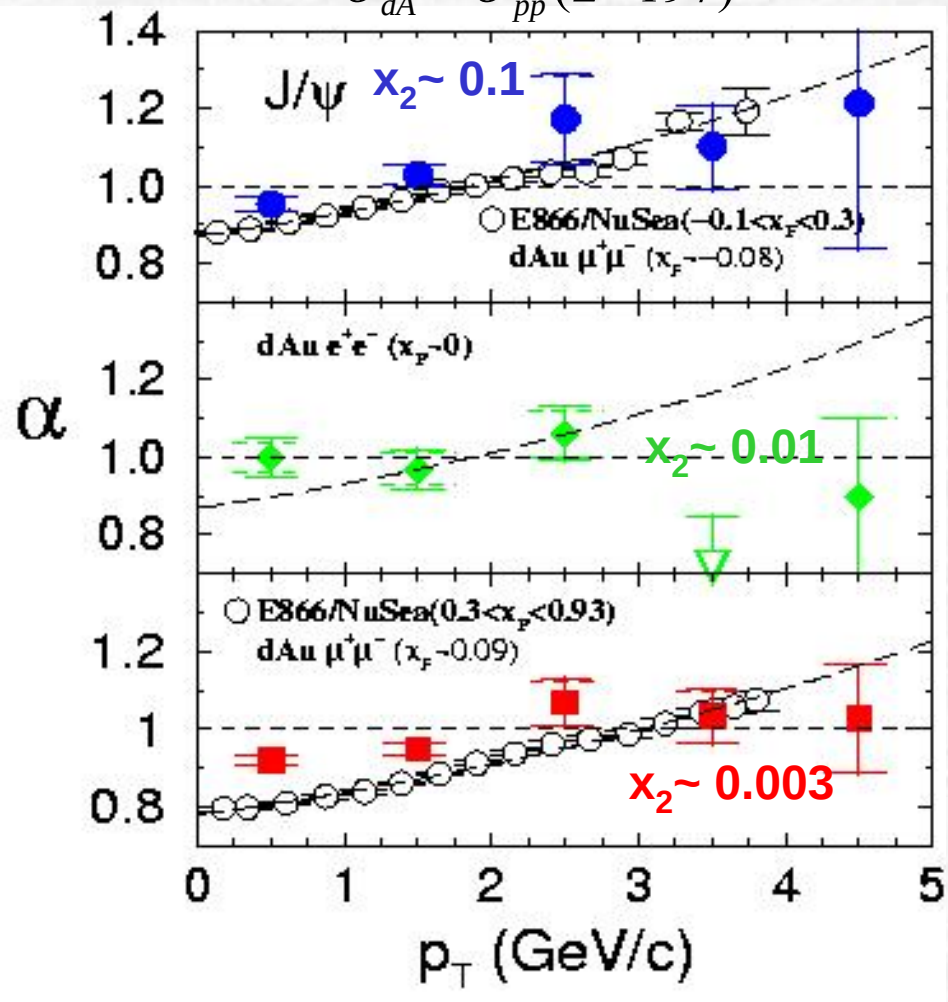
Eskola, et al., Nucl. Phys. A696 (2001) 729-746.

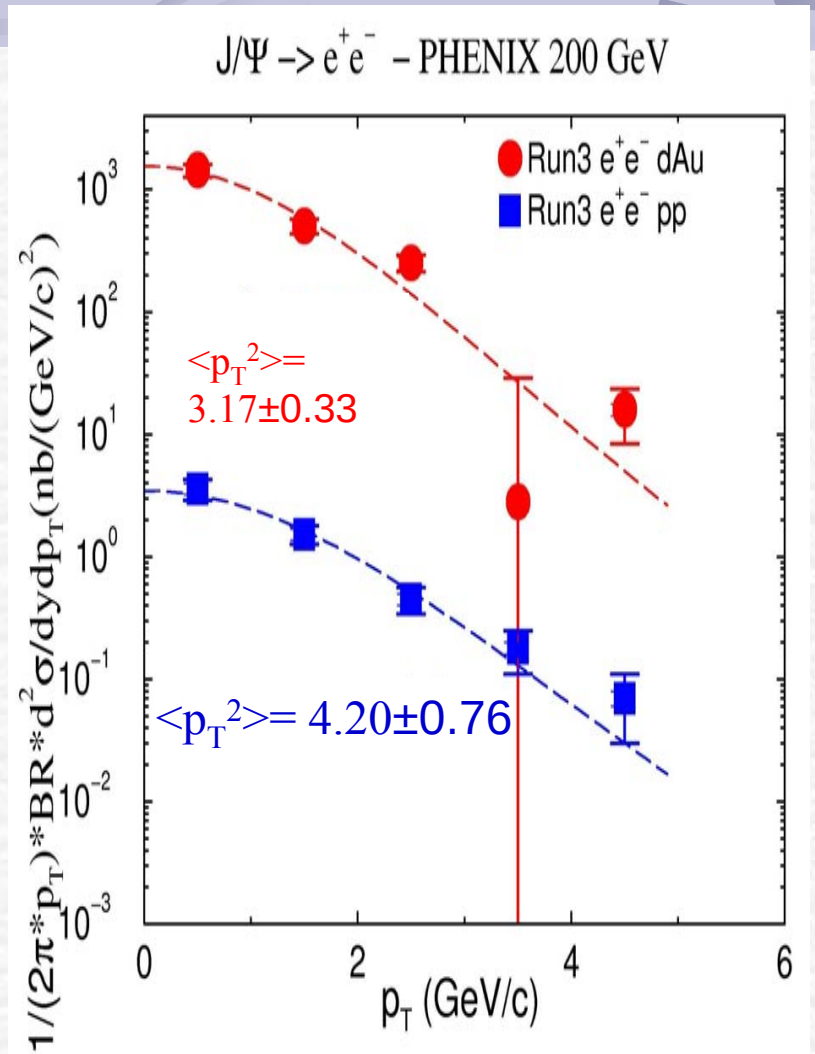
J/ψ d+Au results



p_T broadening: Cronin Effect

$$\sigma_{dA} = \sigma_{pp}(2\times197)^{\alpha}$$



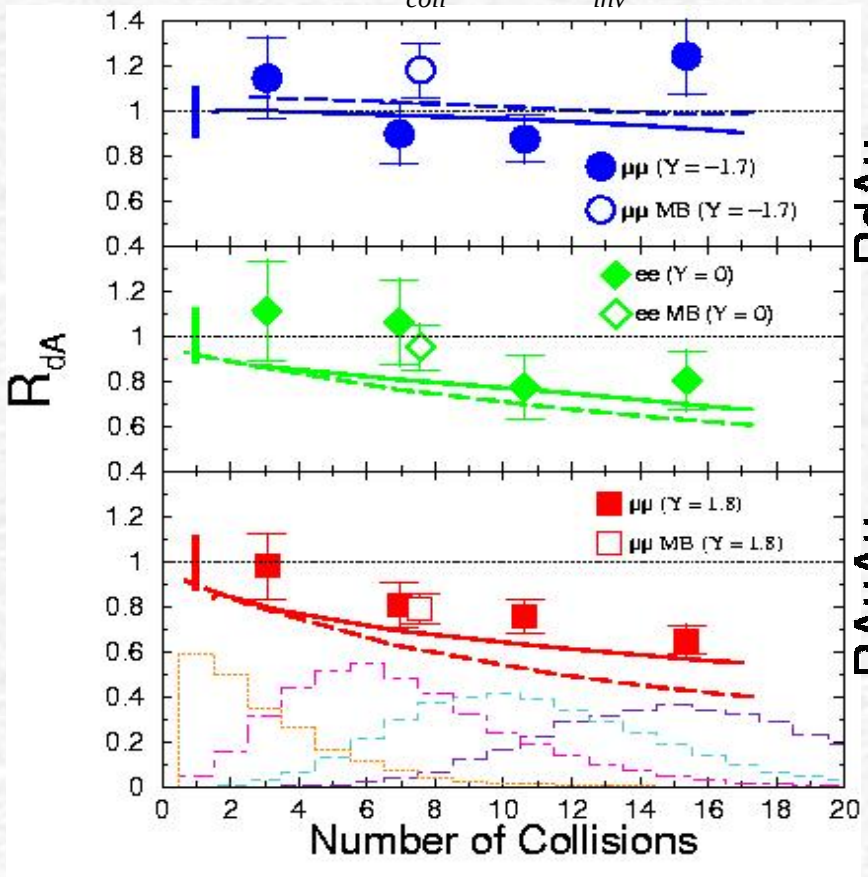


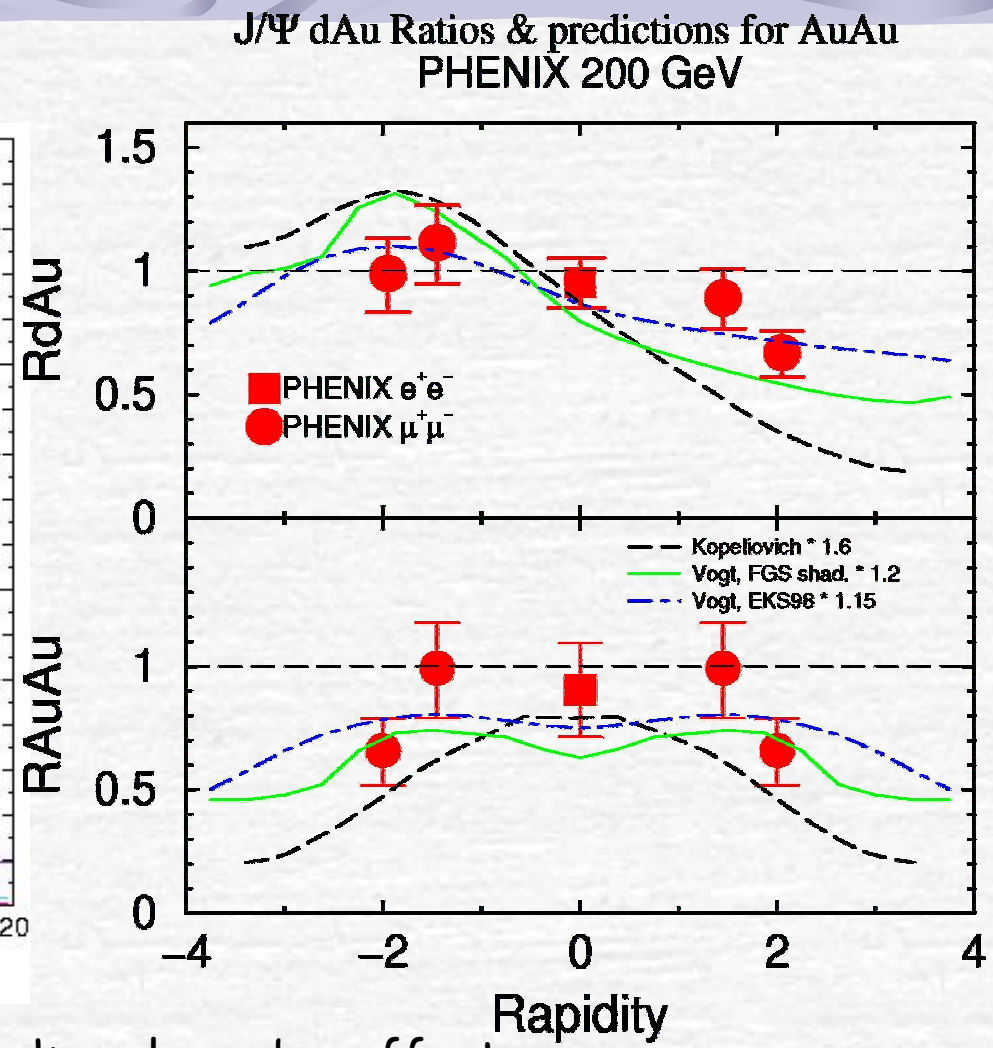
Broadening in forward J/ψ production comparable to lower energy ($\sqrt{s}$ = 39 GeV in E866)

d-Au Central arm result is flat. $\langle p_T^2 \rangle$ in p-p is much higher (4.20±0.76 GeV^2) than muon arm (2.51±0.21 GeV^2). Indicate anything new ?

Rapidity and N_{coll} Dependence of R_{dAu}: Gluon Shadowing and Nuclear Absorption

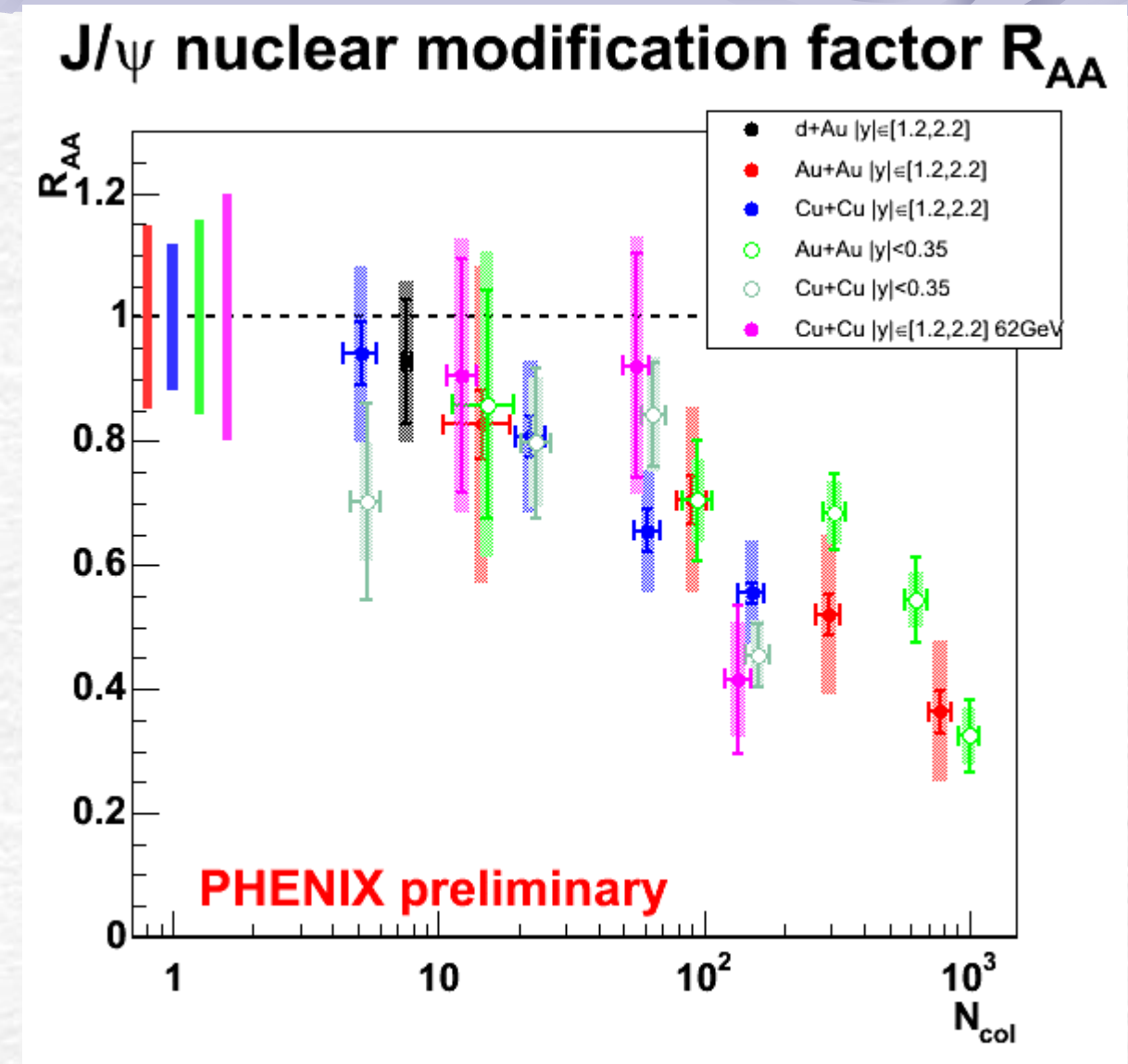
$$R_{dA} = \frac{Yield_{inv}^{dA}}{< N_{coll} > Yield_{inv}^{pp}}$$

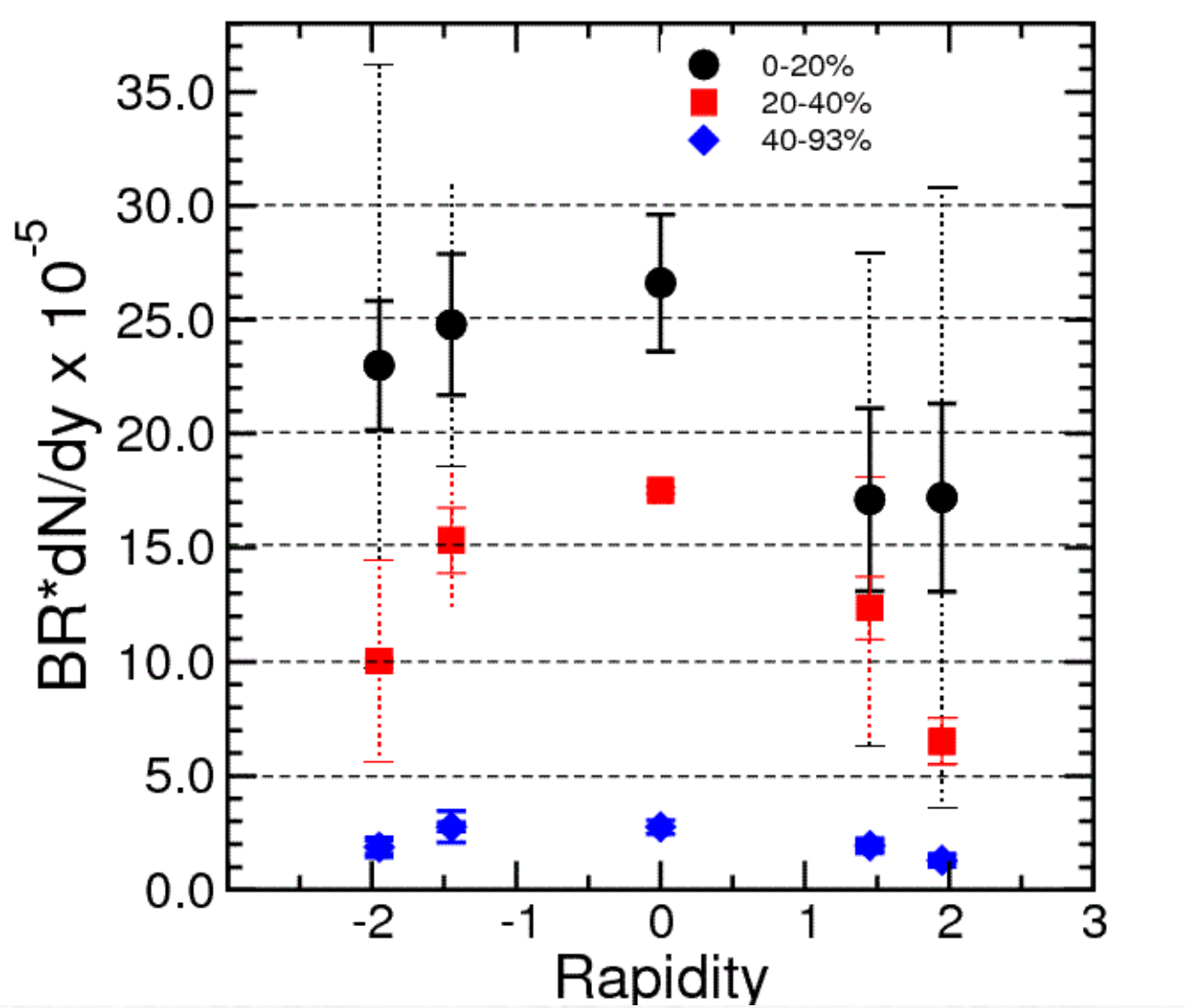




- Data favor weak shadowing and weak nuclear abs. effect.
- More suppression for more central events.
- Nuclear suppression can be obtained directly from d-Au collisions.

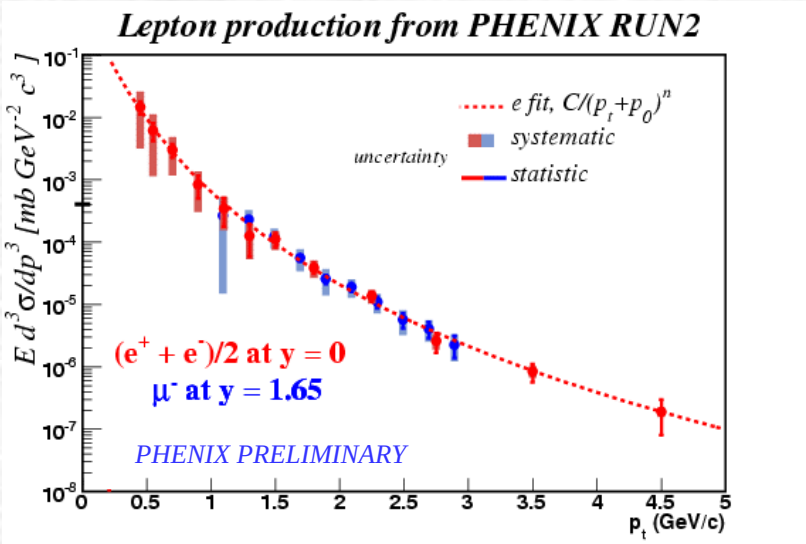
Adding Cu+Cu at 62.4 GeV




0-20%
20-40%
40-93%
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
BR*dN/dy x 10^-5
-2
-1
0
1
2
3
Rapidity

Rapidity distributions

- Comparing charm cross-sections in PHENIX central and muons arms:
  - Au+Au charm rapidity distributions might be very flat in Au+Au !
    - Just an indication, because of the limited P_T domain



- If flat distribution of charm production :
  - Lowers charm density -> less regeneration
  - Rapidity distribution of regenerated less peaked at 0