A Review of Recent A+A Quarkonia Results from PHENIX

RHIC/AGS User's Meeting

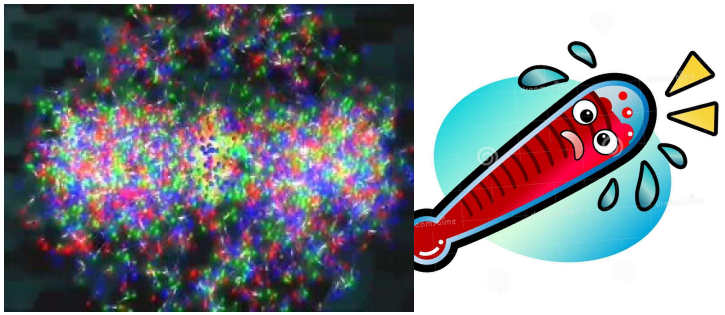
Jeff Klatsky, for the PHENIX Collaboration

June 17th, 2014

Why are we interested in studying quarkonia?

Quarkonia

→ QGP *thermometer*

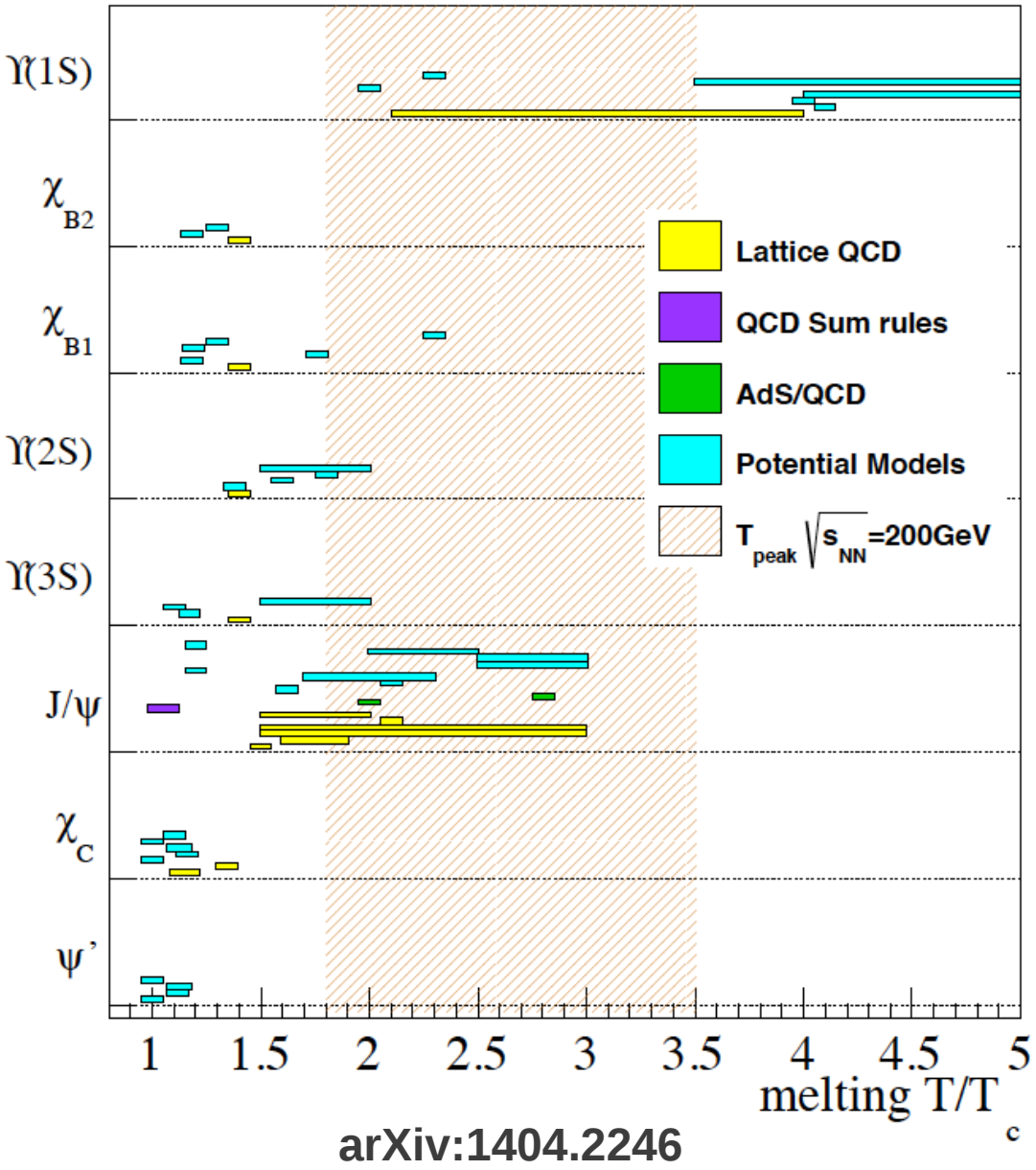


Quarkonia production

→ Many entangled effects!

Solution?

→ Isolate them in different scenarios.



arXiv:1404.2246

What quarkonia measurements have PHENIX made so far?

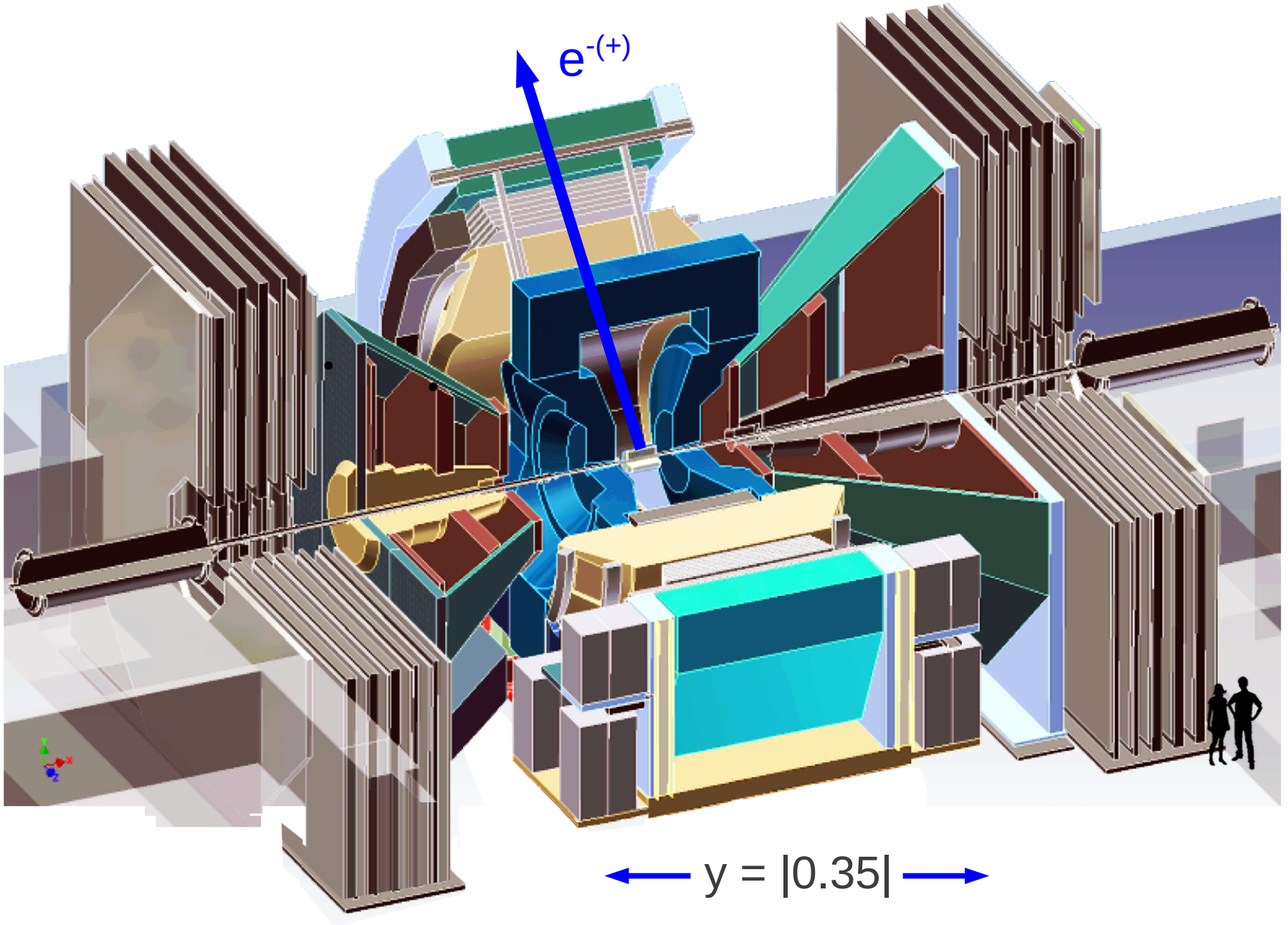
Sqrt(s_{NN})	Collision Species	J/ψ	ψ'	Upsilon
200 GeV	Au+Au	Yes		Yes
	Cu+Au	Yes		
	Cu+Cu	Yes		
	d+Au	Yes	Yes	Yes
193 GeV	U+U	Yes		
62 GeV	Au+Au	Yes		
39 GeV	Au+Au	Yes		

Au+Au beam energy scan, asymmetric Cu+Au, d+Au CNM study, U+U and Cu+Cu vary collision system size.

=> Plenty of variations = interesting physics!

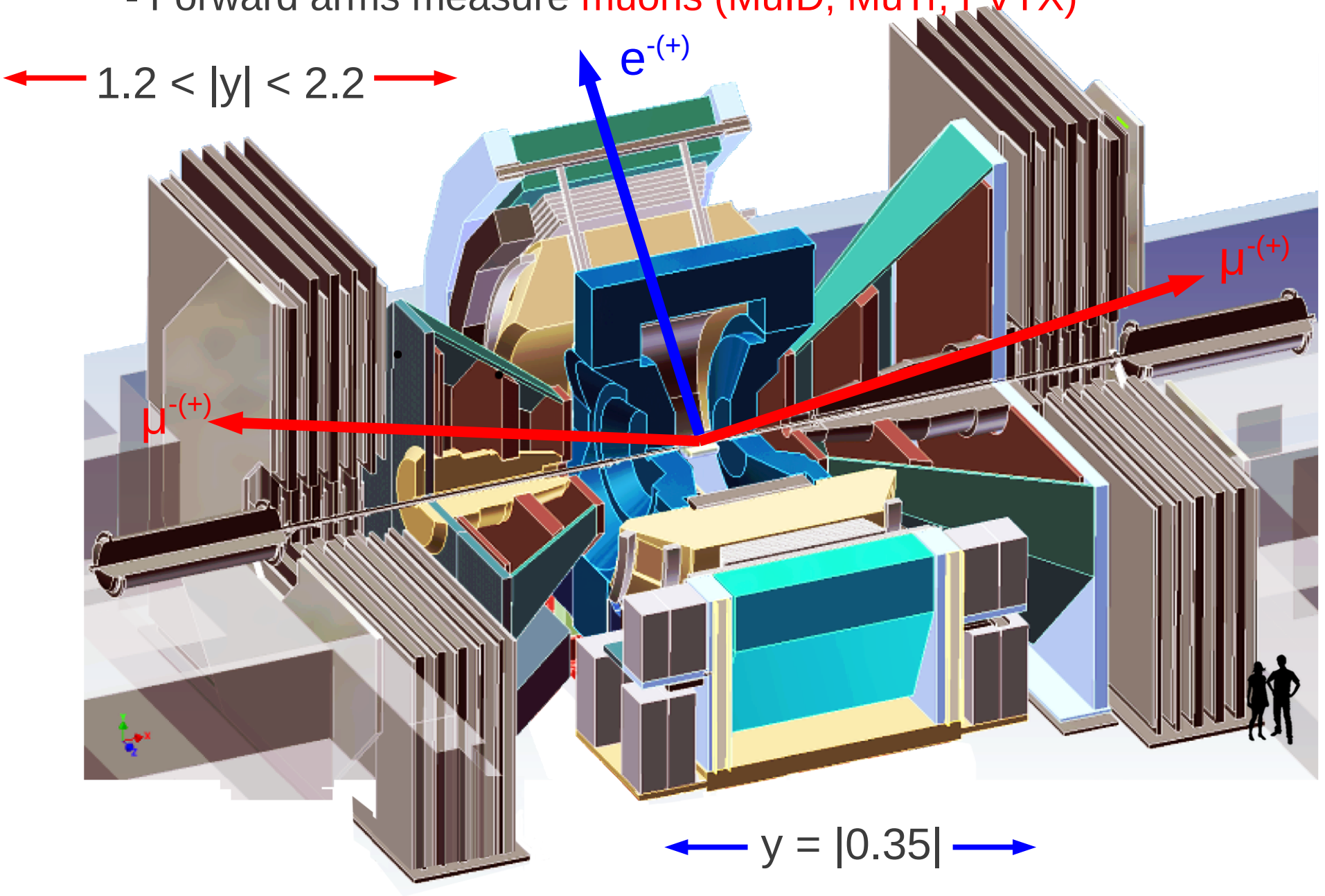
PHENIX

- Central Arms measure electrons (RICH, EMCal, PC, DC, VTX)



PHENIX

- Central Arms measure electrons (RICH, EMCal, PC, DC, VTX)
- Forward arms measure muons (MuID, MuTr, FVTX)



PHENIX 200 GeV Au+Au J/ψ Result

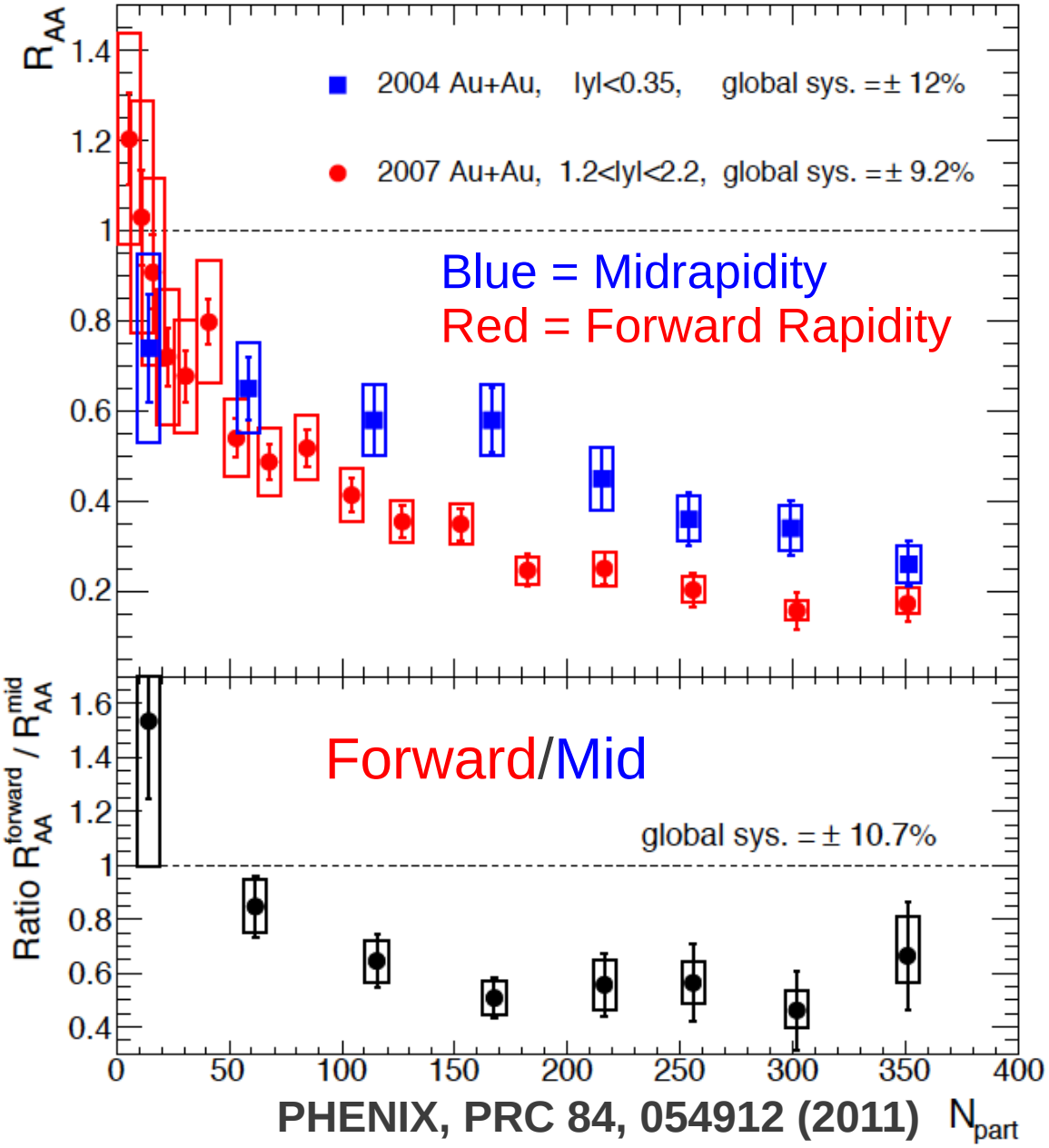
J/ψ R_{AA} vs N_{part}

Expectation from color screening:

$R_{AA}(mid) < R_{AA}(forward)$.

→ Clearly not the case!

CNM effects?



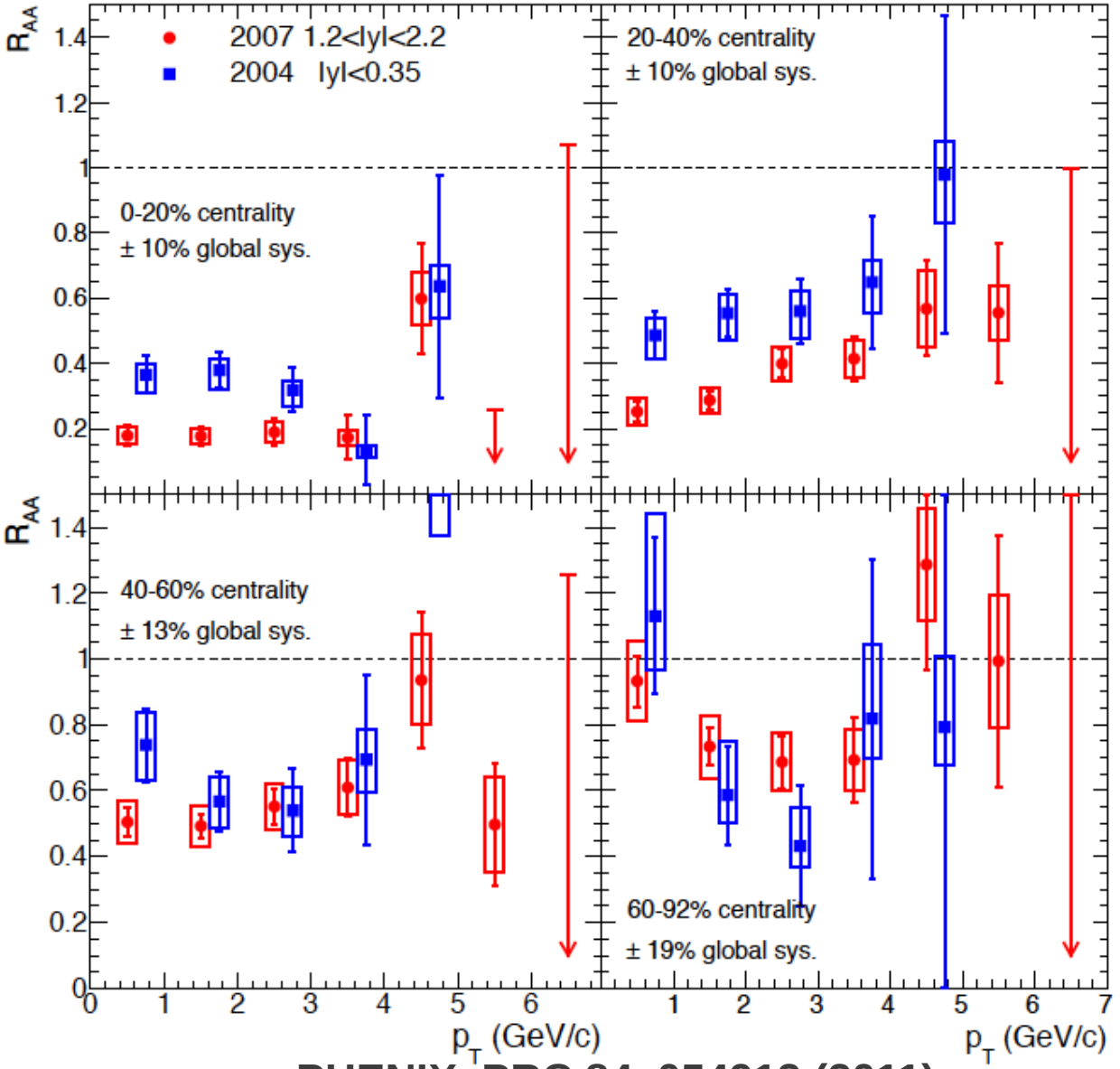
PHENIX 200 GeV Au+Au J/ψ Result

Blue = Midrapidity
Red = Forward Rapidity

J/ψ R_{AA} vs p_T ,four centrality bins.

R_{AA}(forward) < R_{AA}(mid)

R_{AA}(low p_T) < R_{AA}(high p_T)



PHENIX, PRC 84, 054912 (2011)

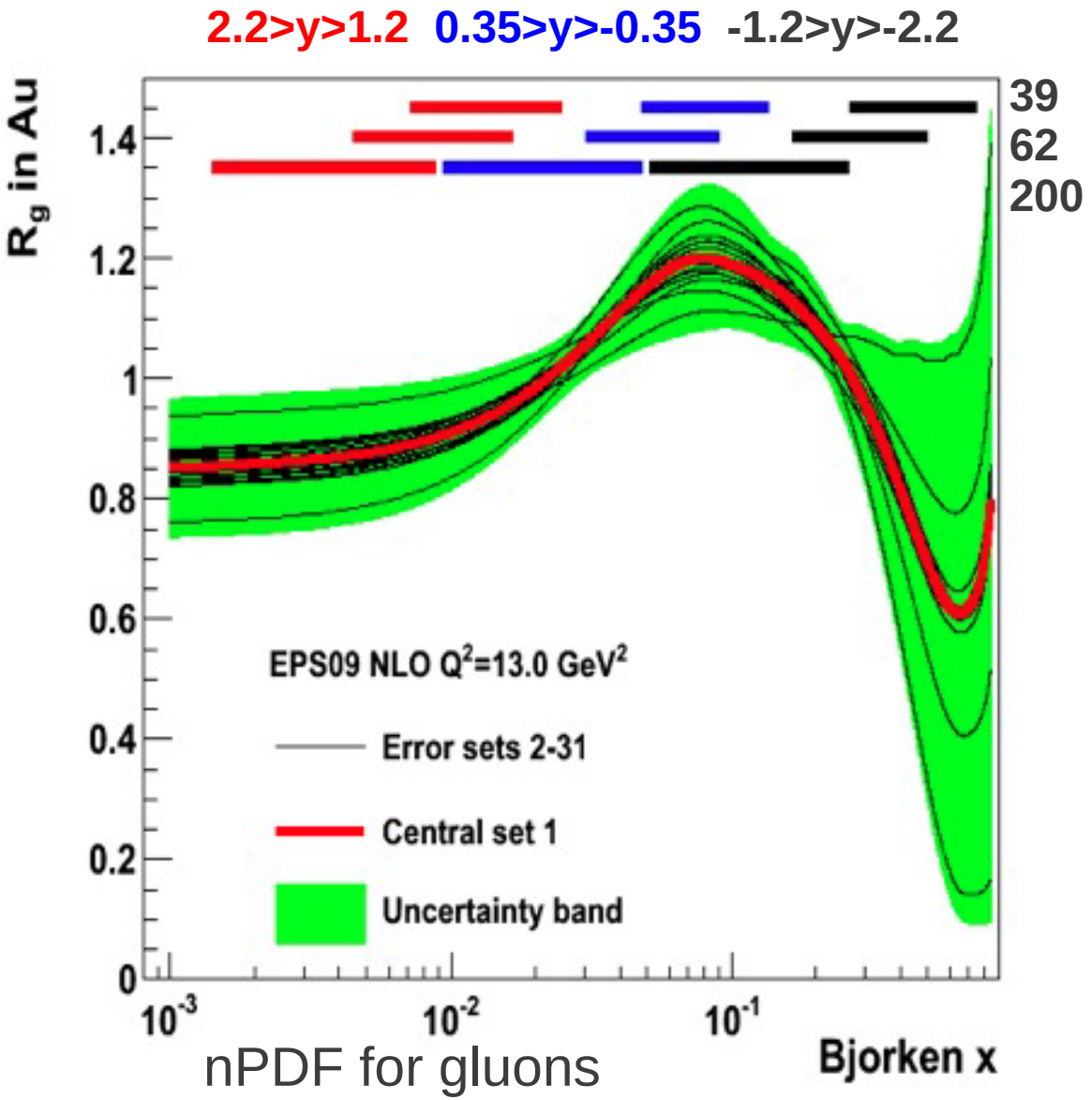
Cold Nuclear Matter Effects

CNM effects : effects on heavy quark production not arising from the presence of the hot, dense medium.

Some of these are:

- **Shadowing** : modified gluon densities in the nucleus, parametrized by nuclear parton distribution functions, such as EKS98 or EPS09. (More on this next slide)
- Parton **energy loss**
- **Gluon saturation** (color glass condensate)
- For c-cbar pairs, **breakup** from collisions with oncoming nucleons (more on this next slide).

Shadowing



nPDF for gluons

Shadowing (reduction in Rg) at forward rapidity, anti-shadowing (enhancement) at backward rapidity.

Smallest effect is at midrapidity.

Strongly dependent on energy and rapidity.

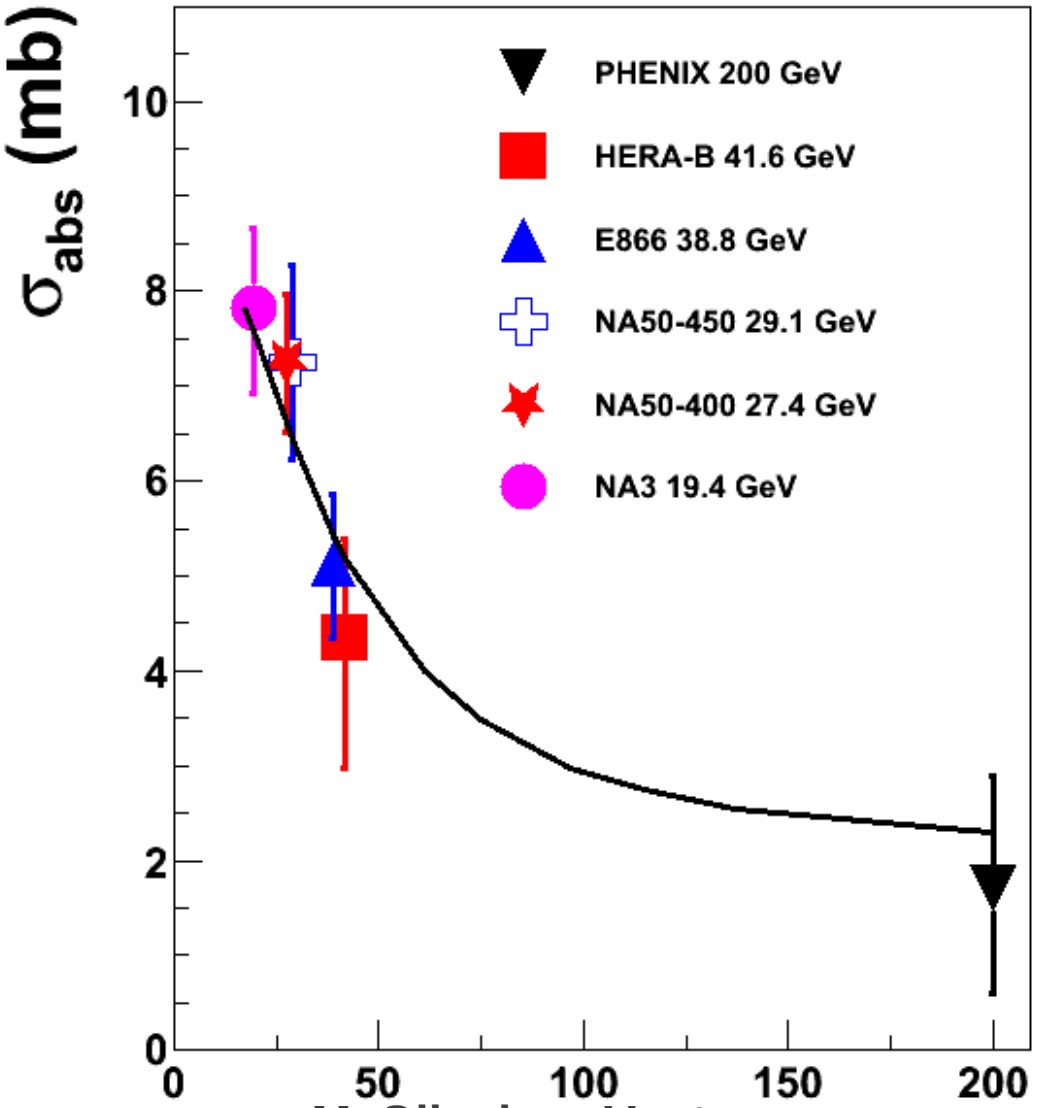
Not very well constrained!

Effective Breakup Cross Section

Parametrize all non-shadowing CNM effects into an “effective” breakup cross section.

Strongly dependent on rapidity and energy.

→ Cannot directly compare R_{AA} between experiments which vary these factors.



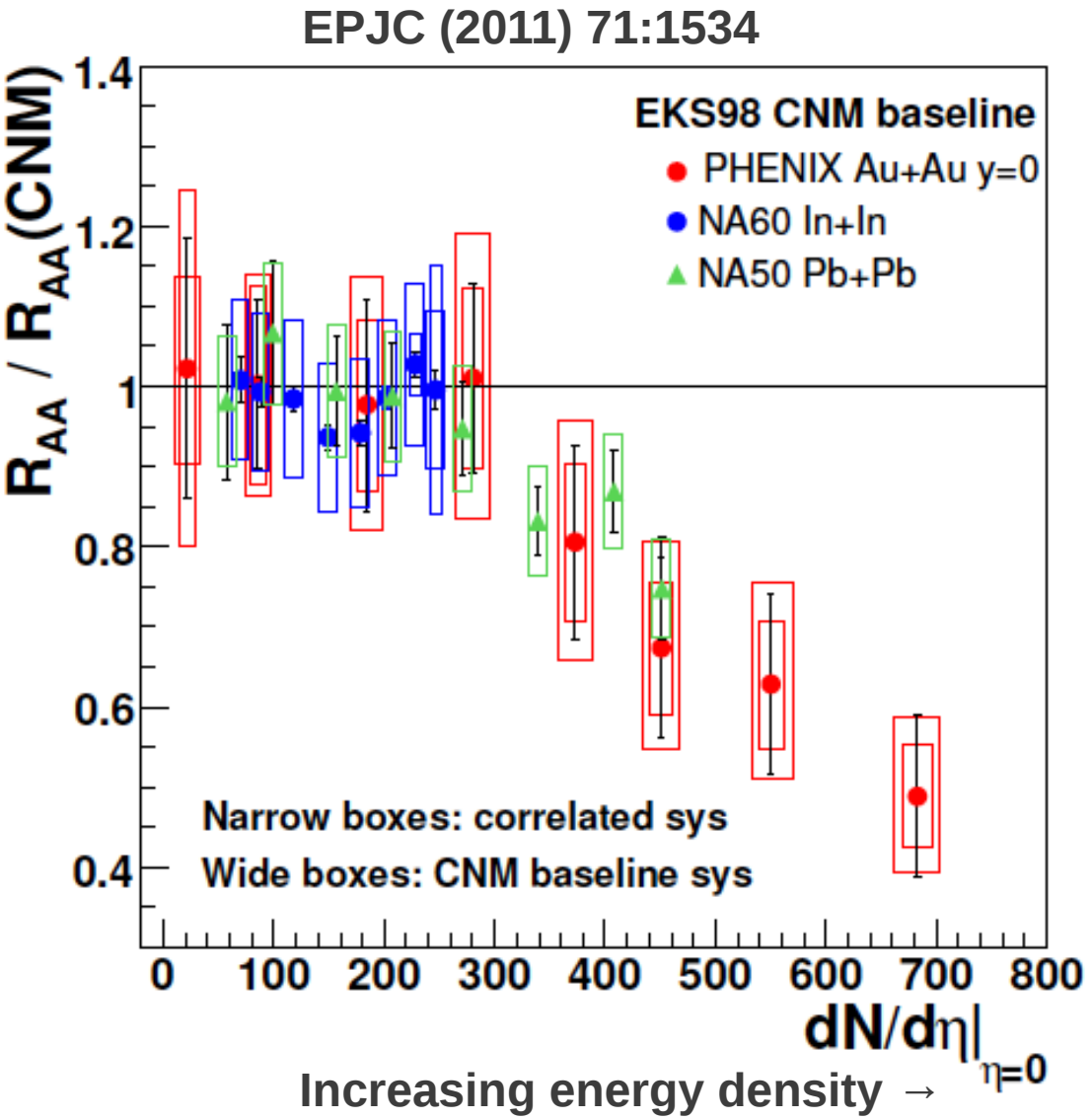
McGlinchey, Vogt, Frawley. PRC 87, 054910 (2013)

Dividing Out CNM Effects

CNM effects parameterized by shadowing + effective absorption cross section.

→ Assumes complete factorization of cold and hot matter effects.

HNM effects similar between NA50, NA60 and PHENIX.



=> Color screening suppression increases with dN/dη

→ only above dN/dη = 300.

HNM effects: Destruction vs Regeneration

Destruction : Color screening dissociates heavy quark pairs.

Regeneration : (Un)correlated charm quarks that are close to being bound can result in charmonia formation at hadronization.

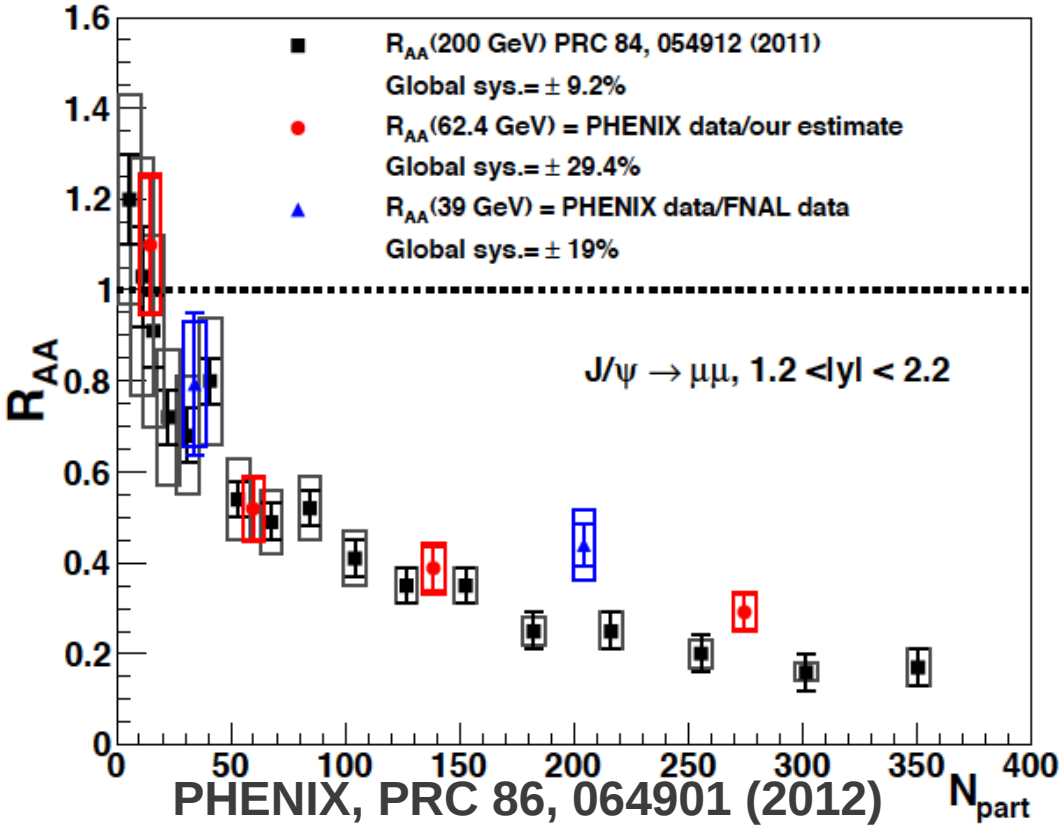
→ Increased probability at higher energies.

Two competing effects!

PHENIX J/ψ R_{AA} for Different Energies

~Similar suppression!

→ Regeneration vs destruction



PHENIX J/ψ R_{AA} for Different Energies

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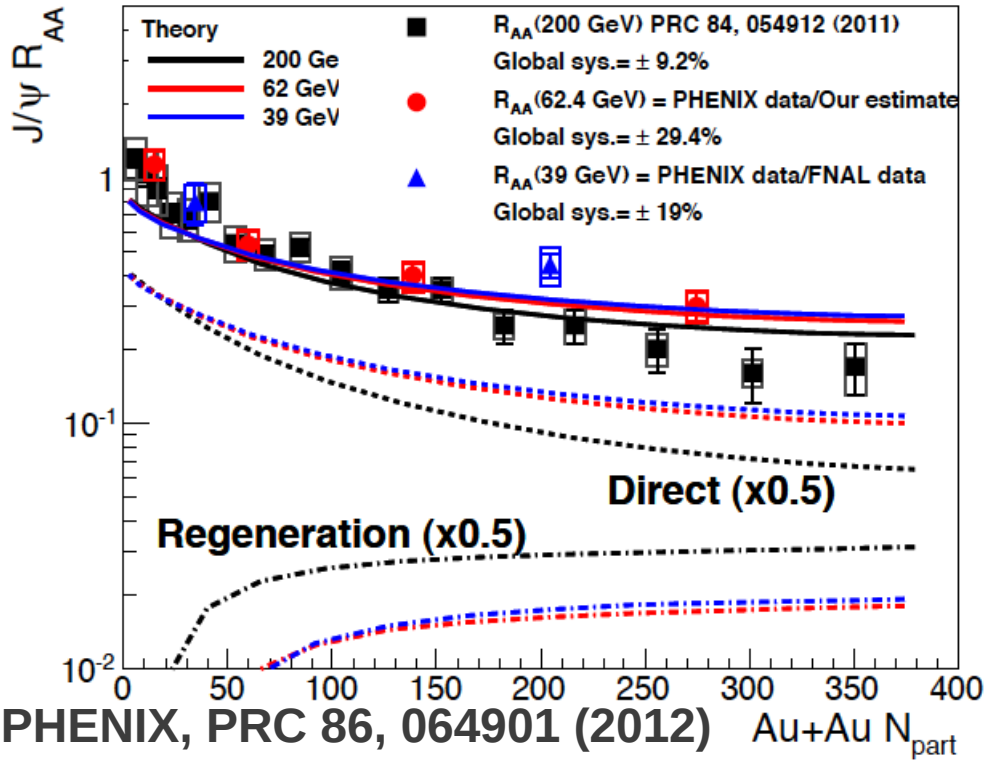
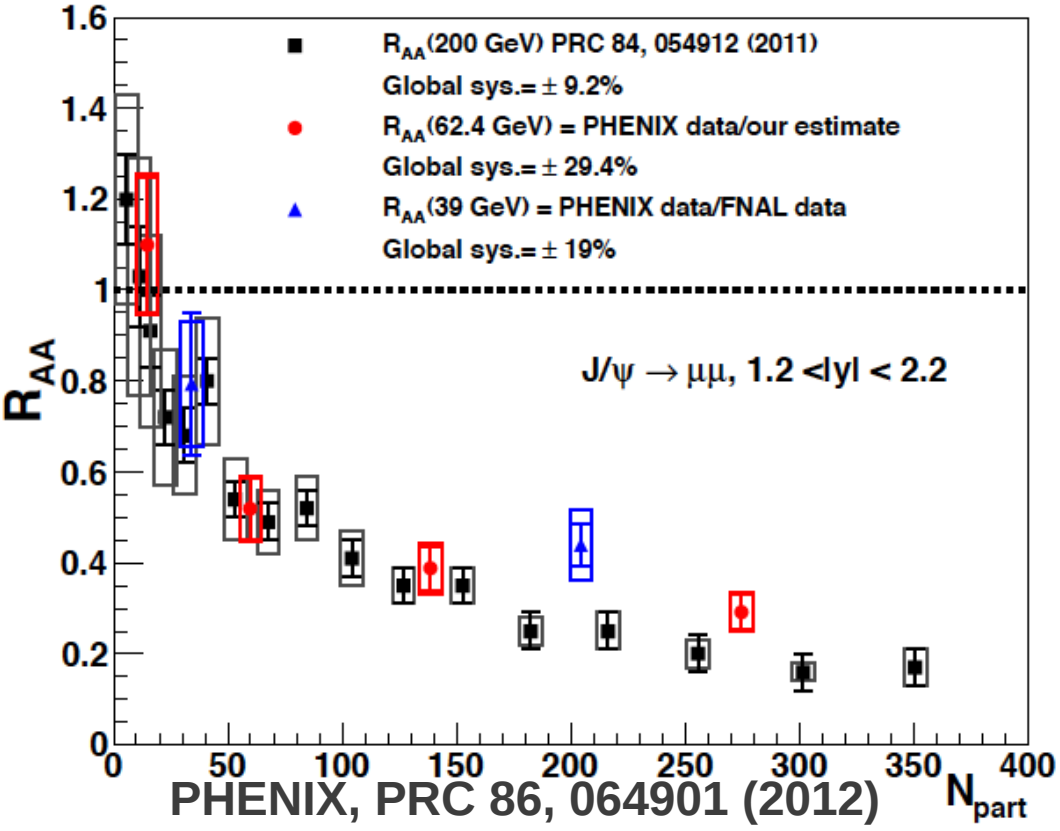


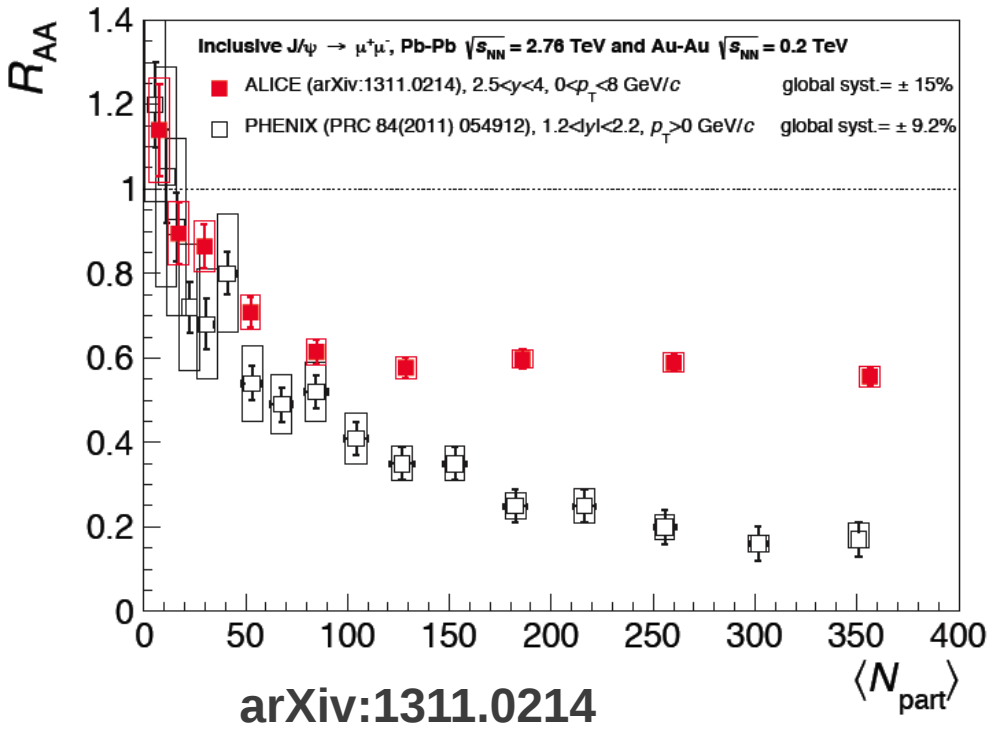


Good agreement with models.

→ **Not** only CNM effects and destruction depend on collision energy!

PHENIX and ALICE : A Comparison vs Centrality

forward rapidity 2.5<y<4

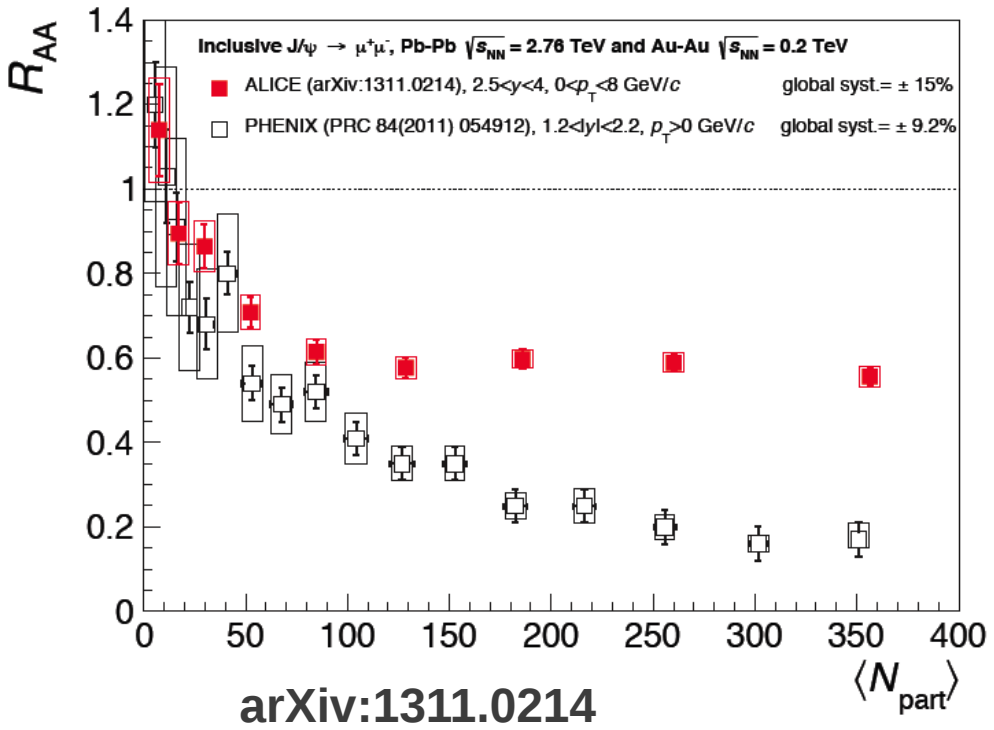


arXiv:1311.0214

ALICE forward : flat for N_{part} >= 70

PHENIX and ALICE : A Comparison vs Centrality

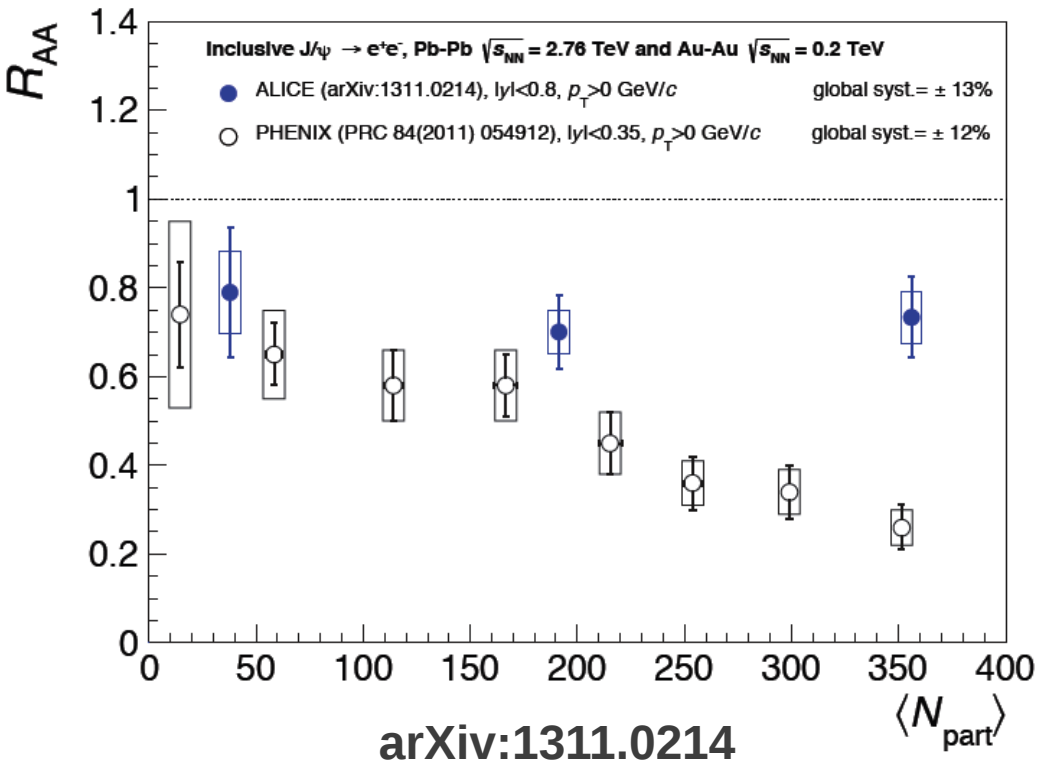
forward rapidity 2.5<y<4



arXiv:1311.0214

ALICE forward : flat for N_{part} >= 70

mid-rapidity |y|<0.8



arXiv:1311.0214

ALICE mid : Trend consistent with forward rapidity.

→ R_{AA}(mid) > R_{AA}(forward)

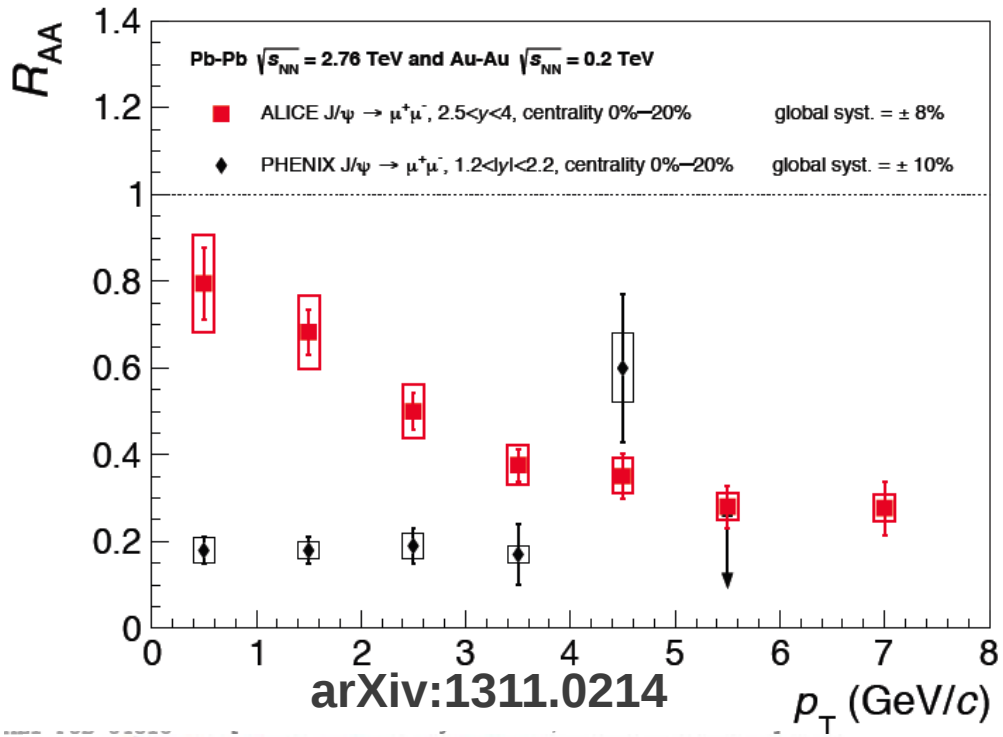
→ Regeneration likely at higher energy!

PHENIX and ALICE : A Comparison vs p_T

ALICE(low p_T) > PHENIX(low p_T)

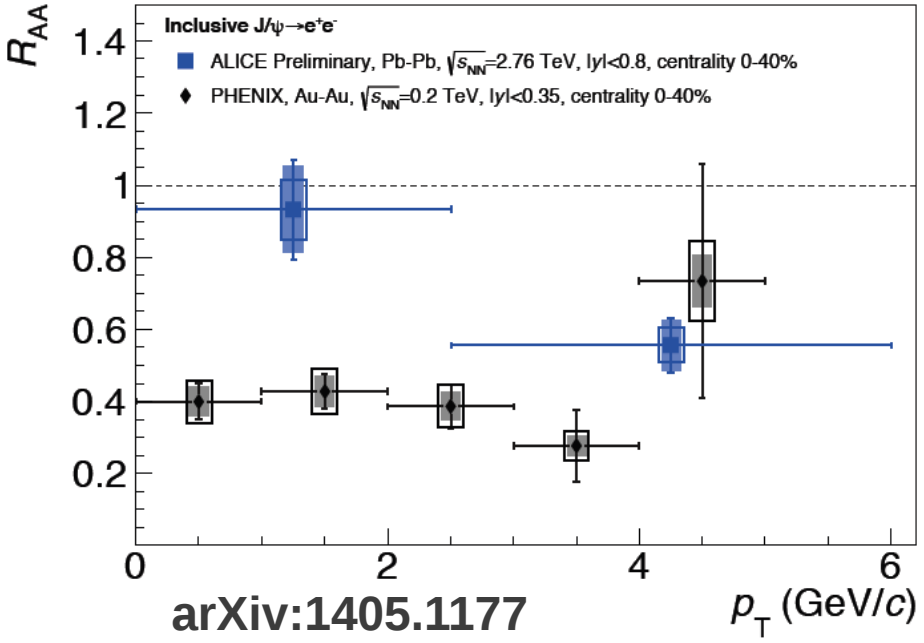
Theory : regeneration is responsible for MOST of the J/ψ's seen at ALICE.

forward rapidity

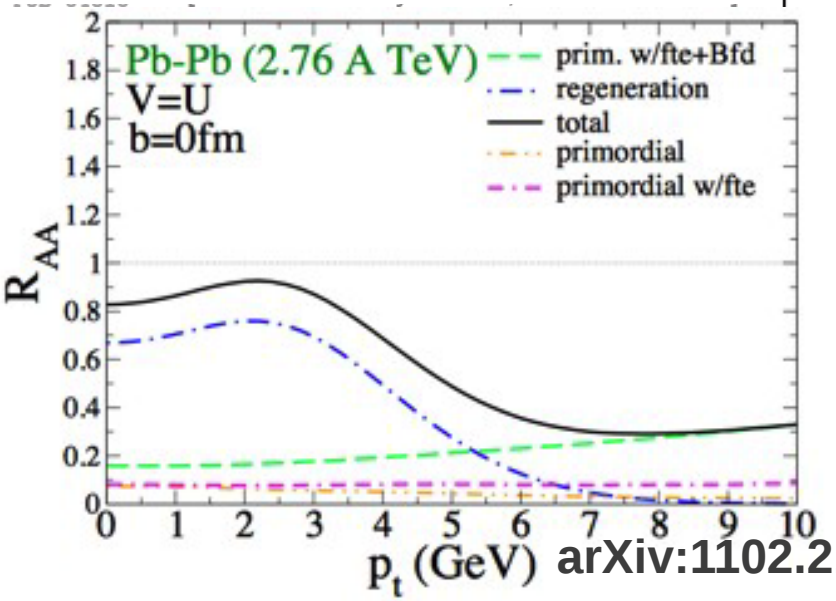


arXiv:1311.0214

mid-rapidity



arXiv:1405.1177



arXiv:1102.2194

A System Size Study at PHENIX

$\varepsilon_B^{UU} > \varepsilon_B^{AuAu}$ (~15%)

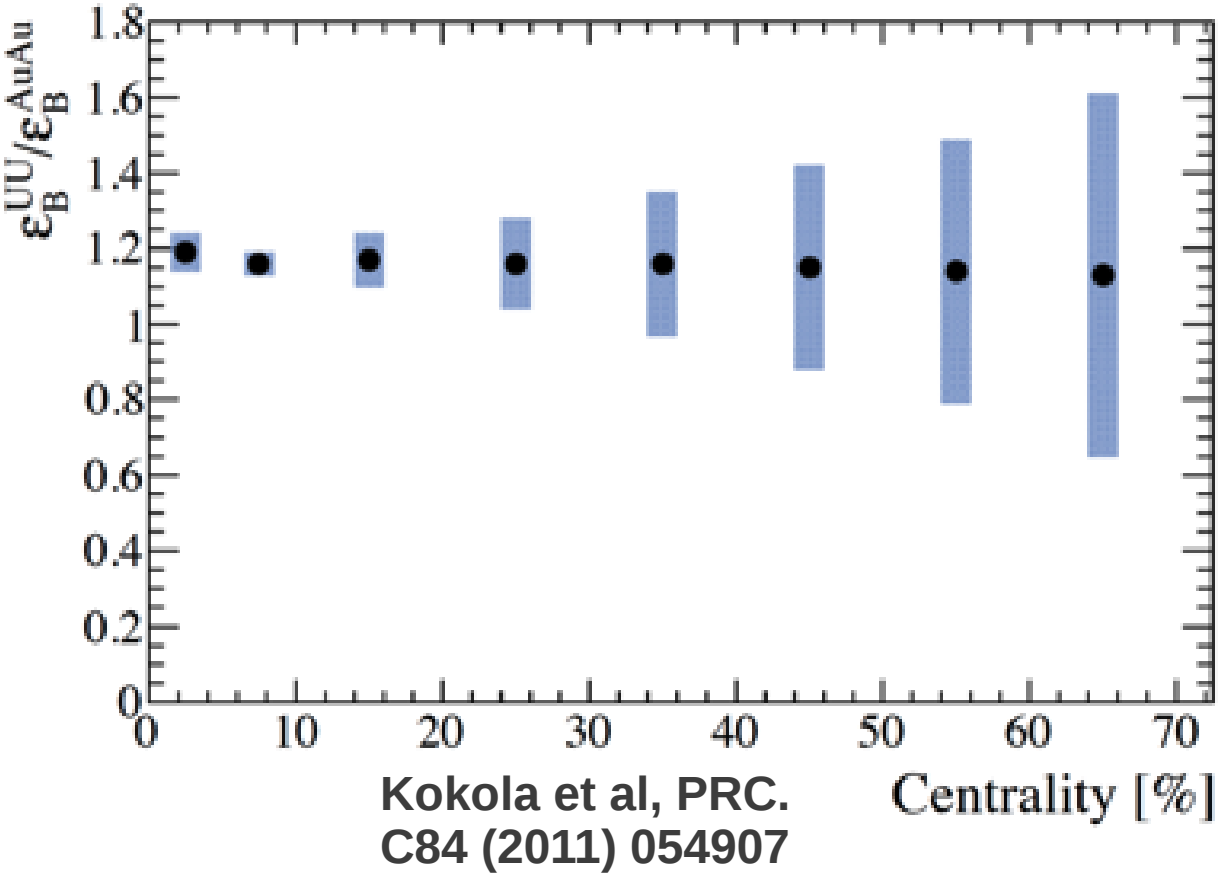
→ Greater suppression due to color screening.

N_{coll} increases

=> N_{charm} increases

→ Greater probability for regeneration.

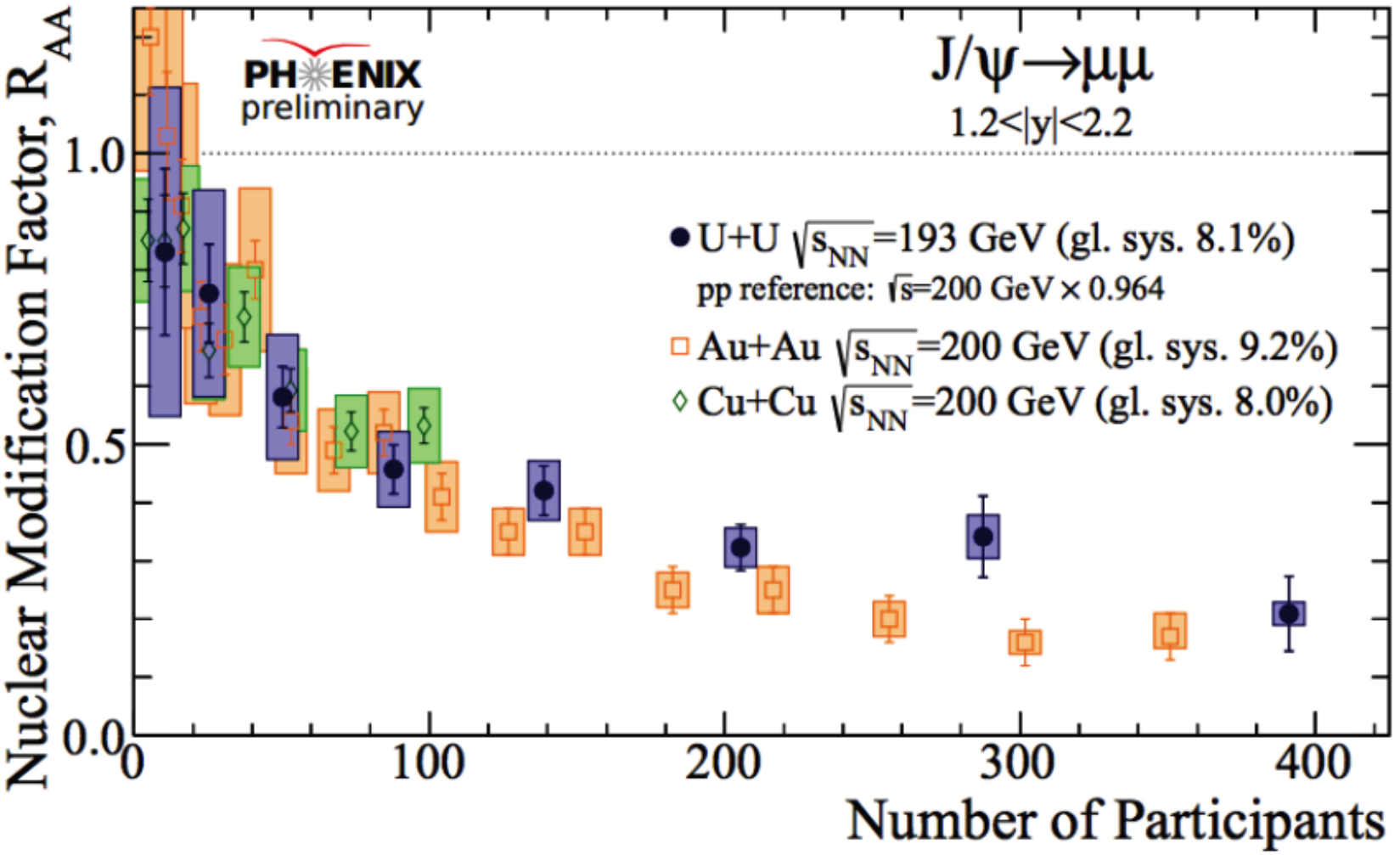
Energy density in Au+Au/energy density in U+U



Kokola et al, PRC. C84 (2011) 054907

Result: Two competing effects!

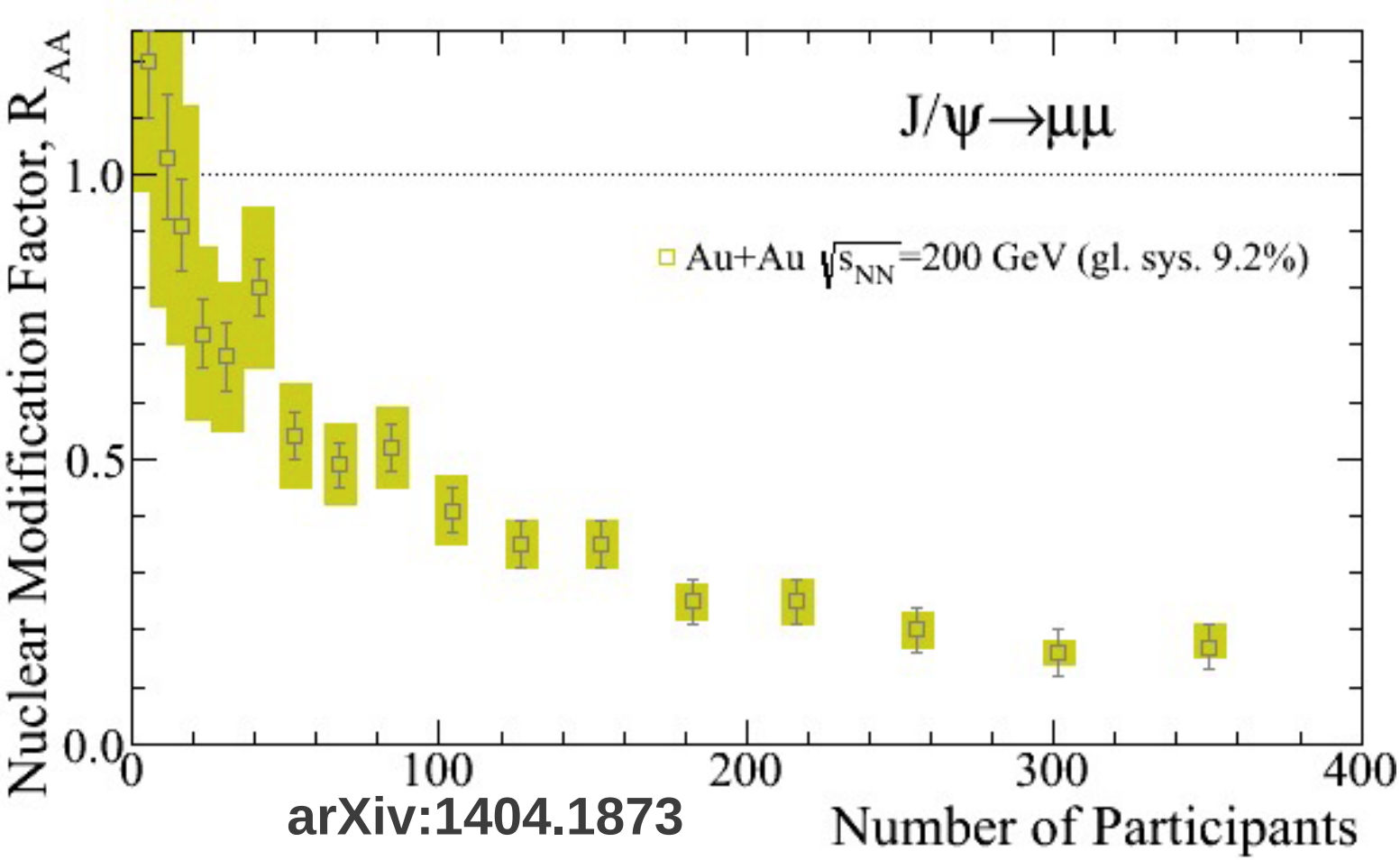
A System Size Study at PHENIX



=> Not much net effect from system size increase.

PHENIX 200 GeV Cu+Au J/ψ Result

2007 Au+Au J/ψ R_{AA}.



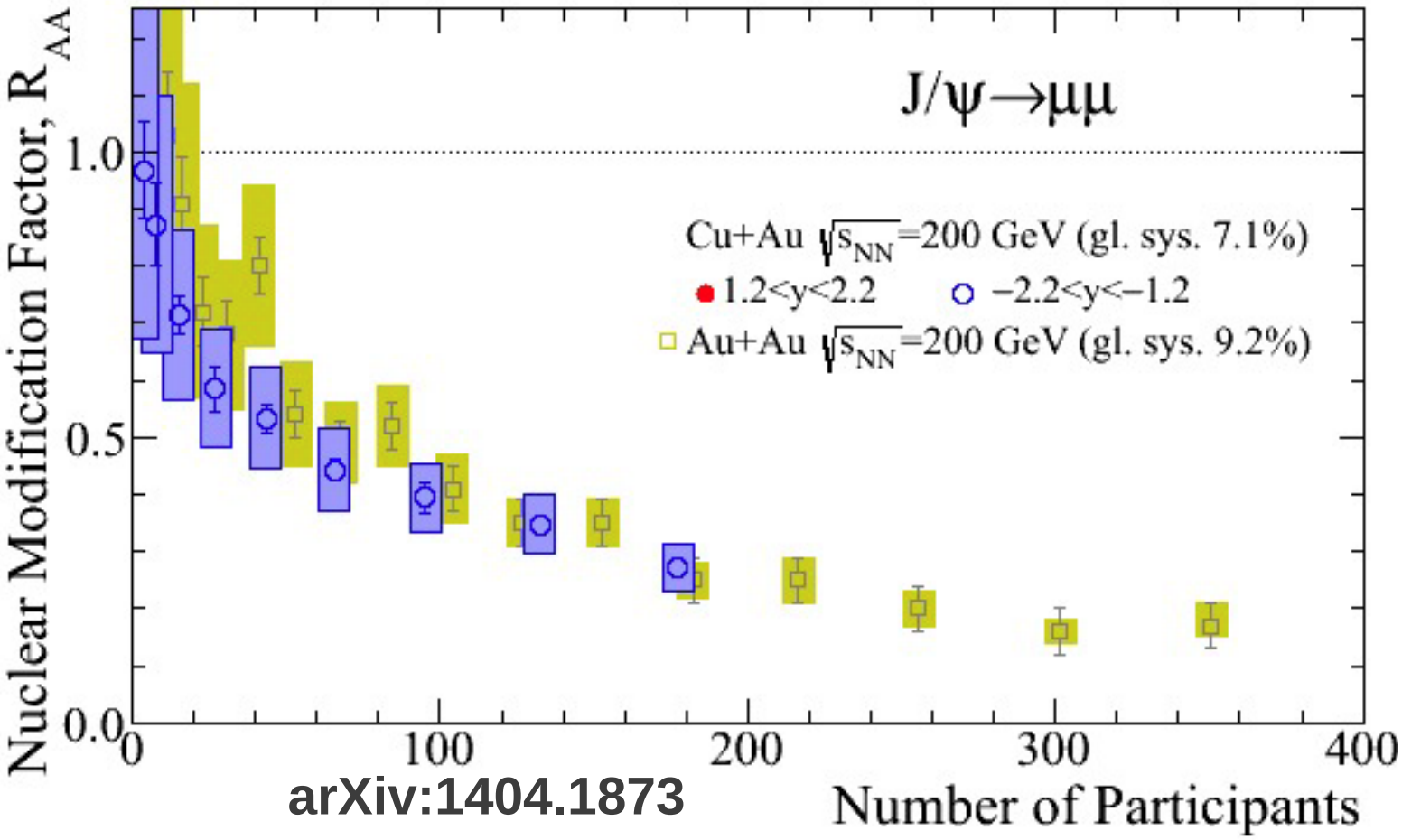
arXiv:1404.1873

Au+Au Run 7 Forward rapidity.

PHENIX 200 GeV Cu+Au J/ψ Result

2007 Au+Au J/ψ R_{AA}.

Add the backward rapidity (Au-going direction)



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Au+Au Run 7 Forward rapidity.

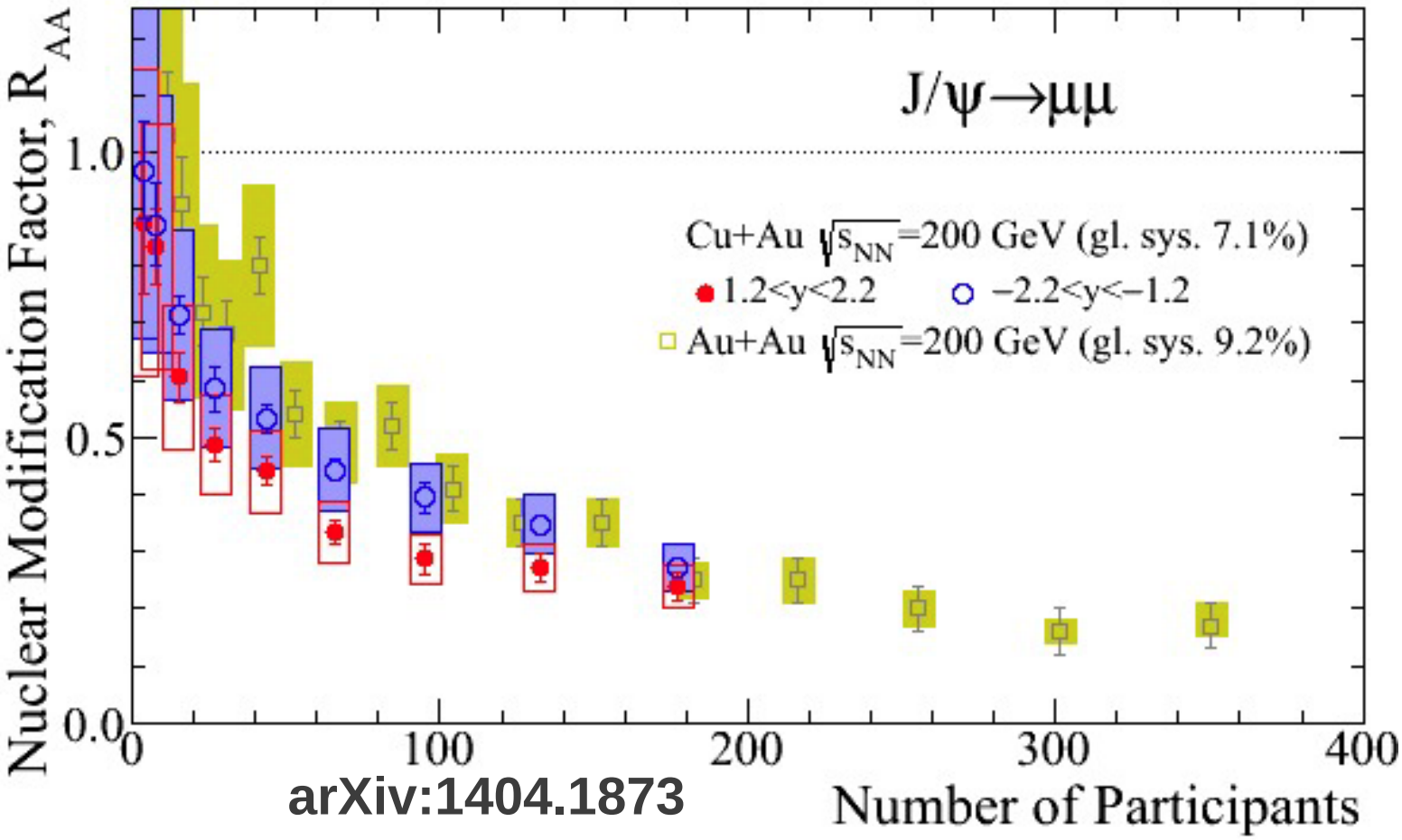
Cu+Au, Au-going direction

PHENIX 200 GeV Cu+Au J/ψ Result

2007 Au+Au J/ψ R_{AA}.

Add the backward rapidity (Au-going direction)

Add the forward rapidity (Cu-going direction)



arXiv:1404.1873

Au+Au Run 7 Forward rapidity.

Cu+Au, Au-going direction

Cu+Au, Cu-going direction

Is this what we expected?

PHENIX 200 GeV Cu+Au J/ψ Result

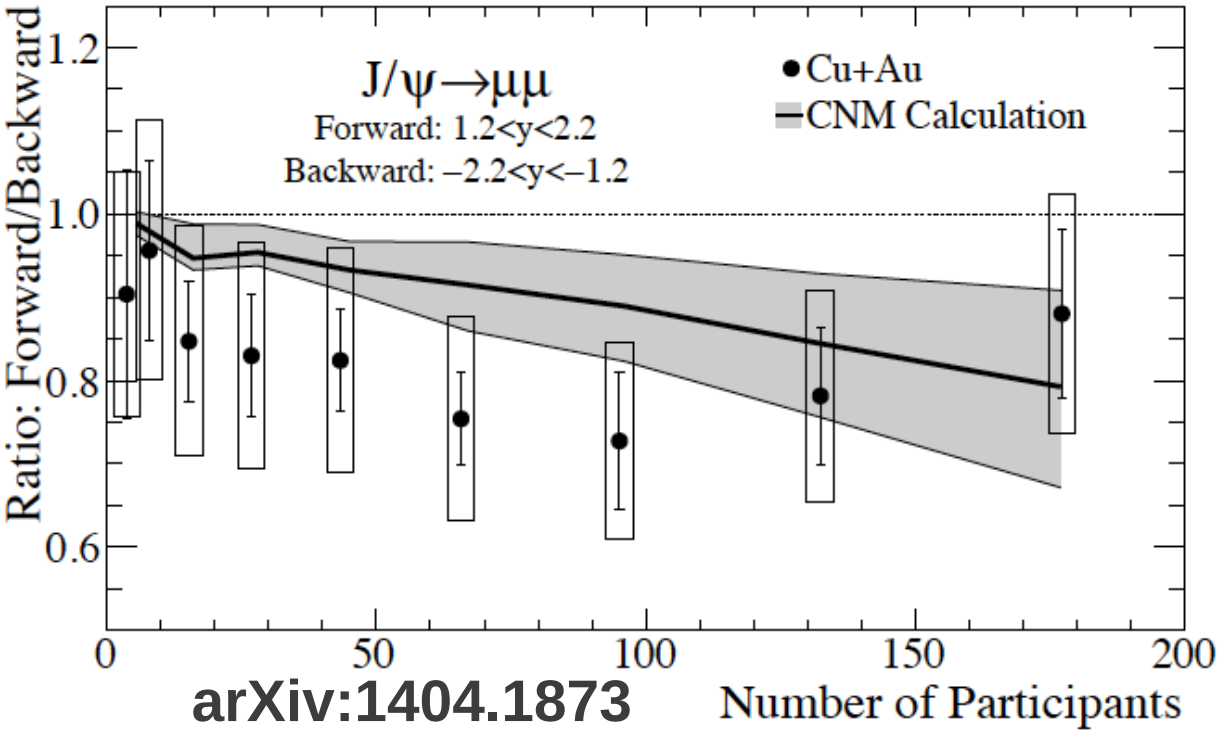
$dN_{ch}/d\eta(Cu) < dN_{ch}/d\eta(Au)$

=> energy density effects should be **smaller** in Cu-going direction

Shadowing(Au) > Shadowing(Cu)

=> Shadowing effects should be **greater** in Cu-goin direction

→ Two competing effects.



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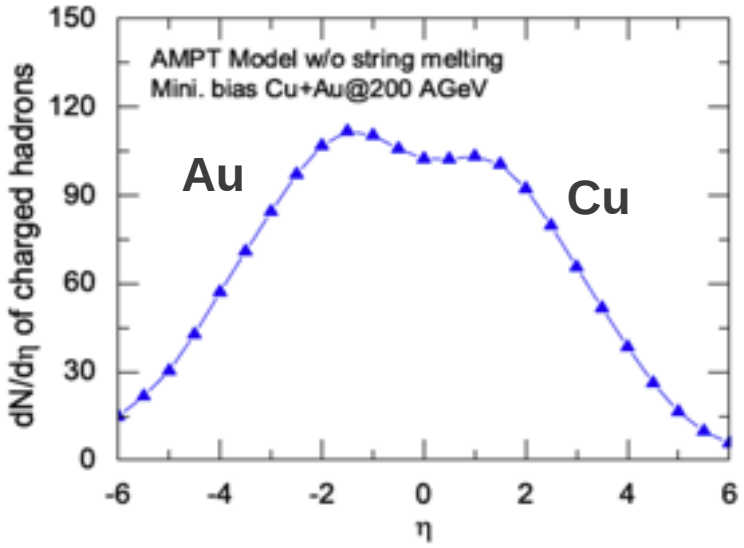


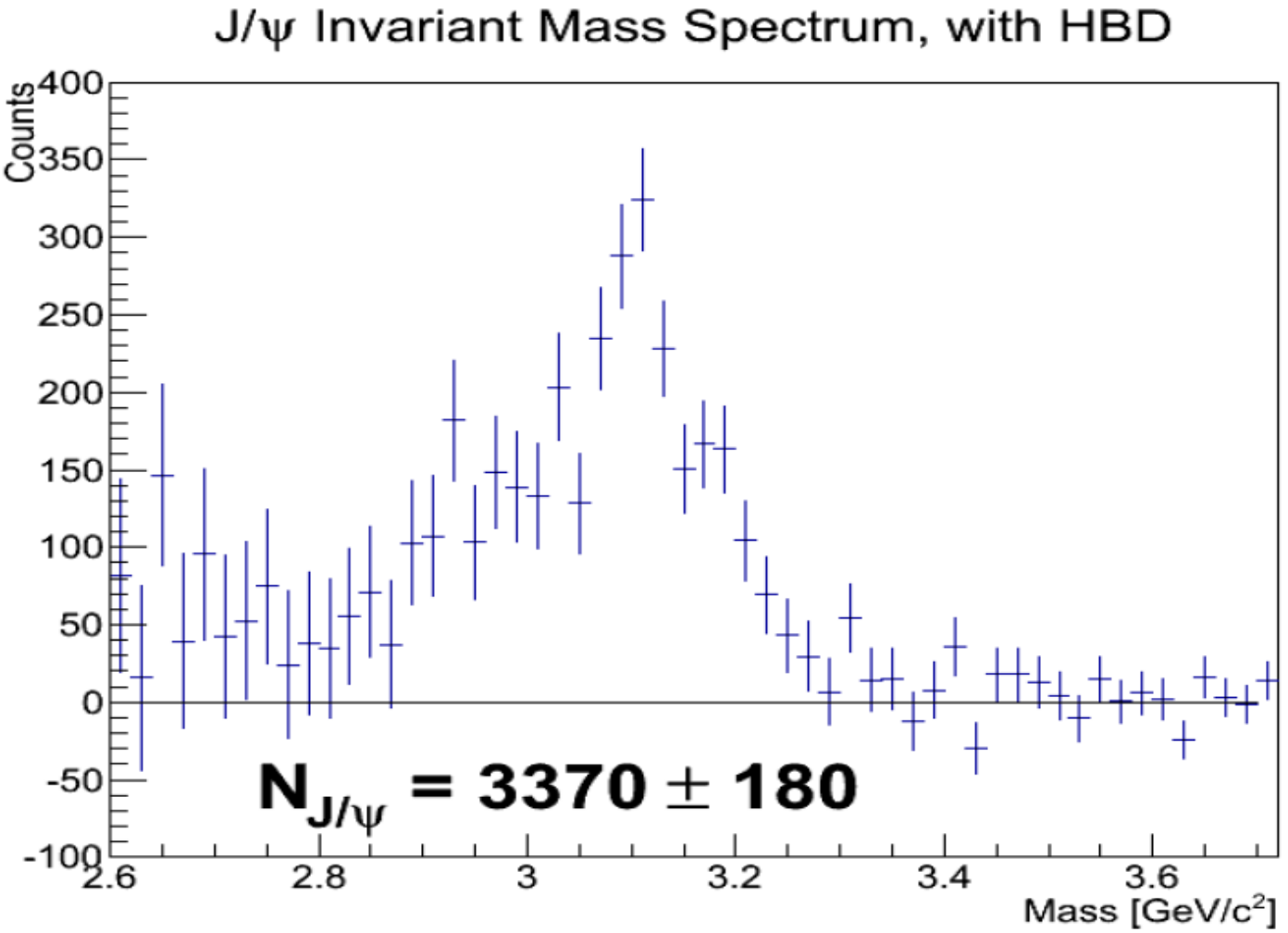
→ Shadowing effects are stronger than suppression effects.

Future J/ψ Analyses

Run 10 Au+Au 200 GeV J/ψ at midrapidity.

→ Increasing statistical precision

→ Using HBD

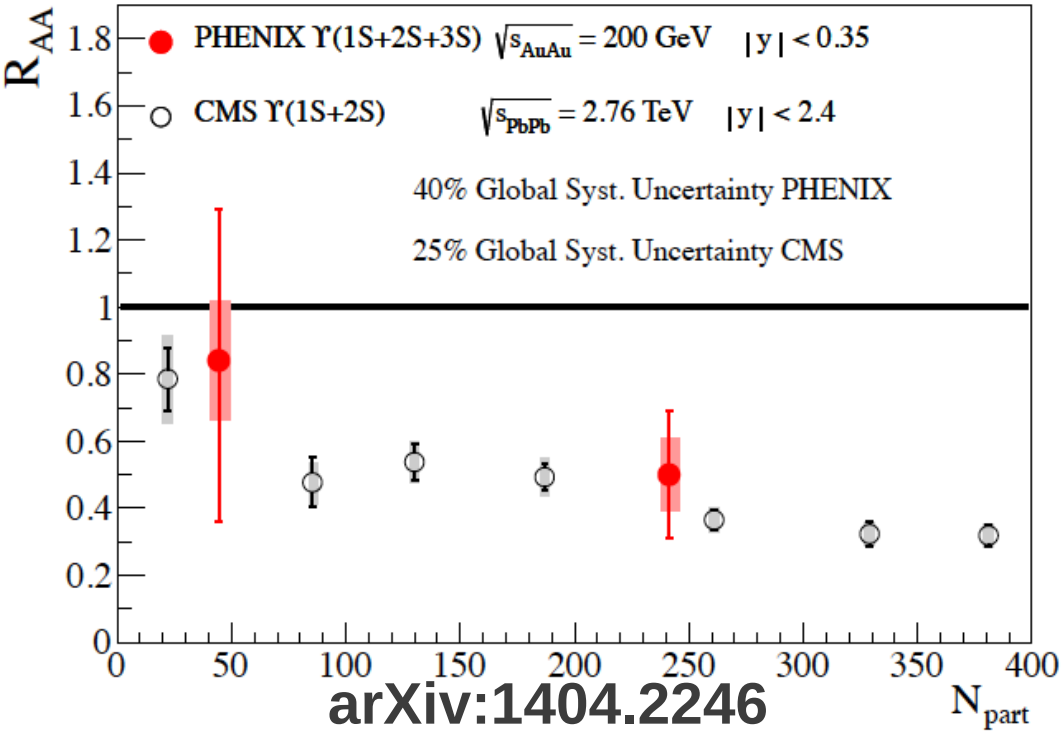


Run 14 : Highest statistics Au+Au run in PHENIX history. (15+B events!)

→ Silicon vertex detectors performing well!

PHENIX 200 GeV Au+Au Υ Result

PHENIX, CMS measure similar R_{AA} for Υ at midrapidity.



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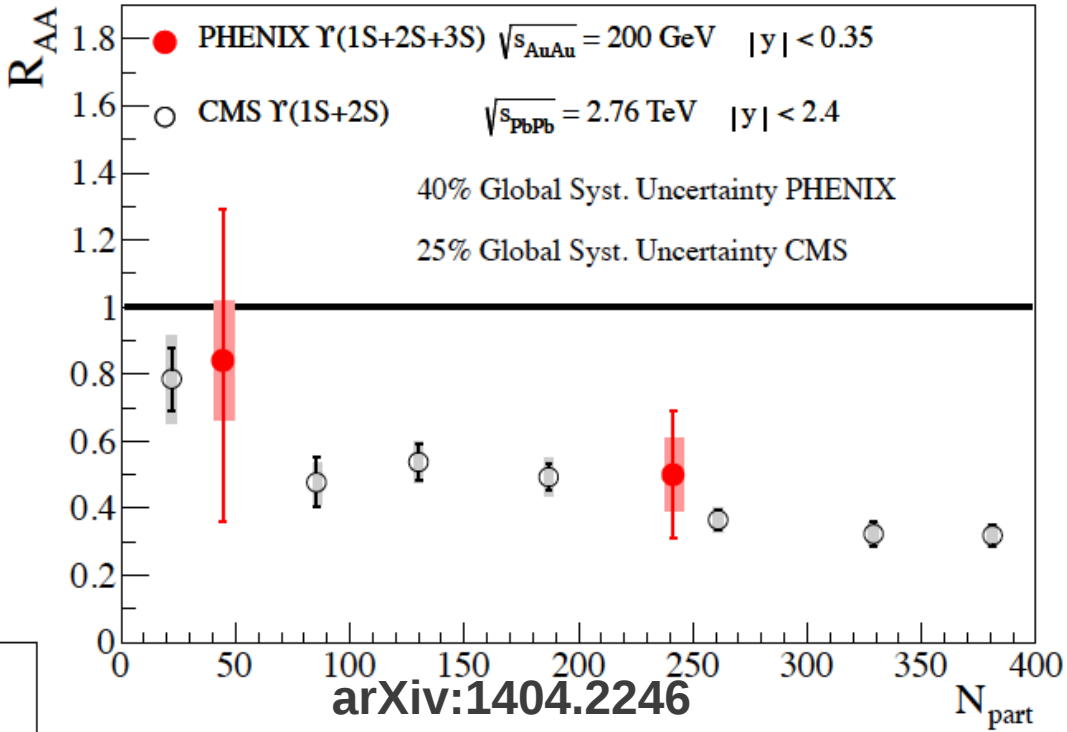
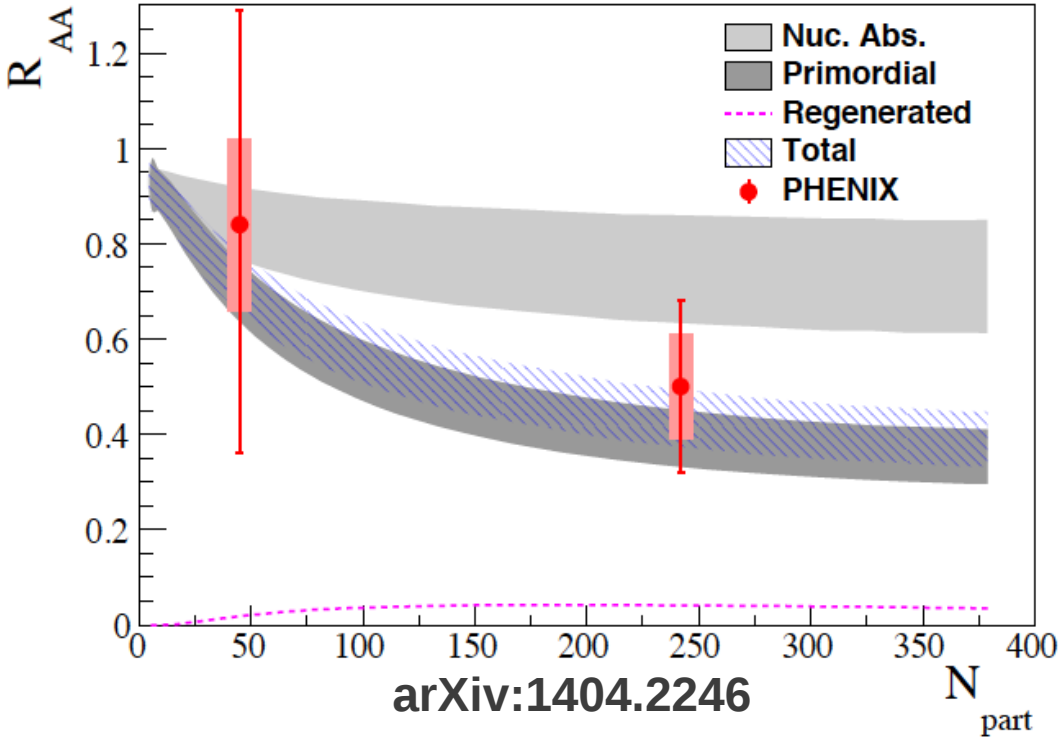




Model from Rapp et al shows good agreement.

→ Minimal regeneration contribution.

→ Dissociation by color screening dominates.

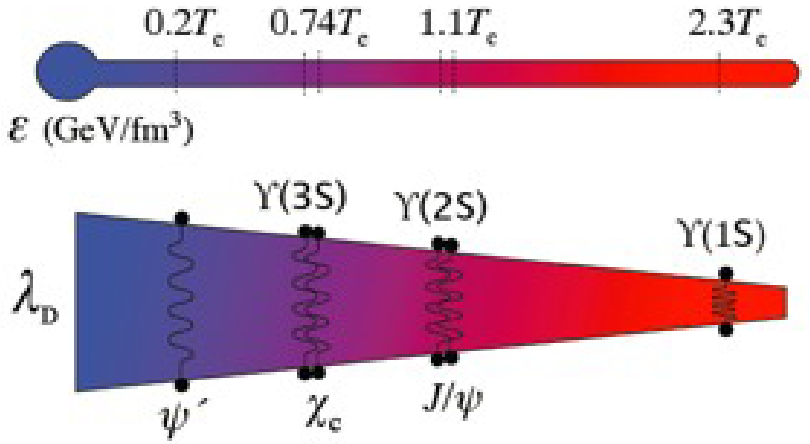
Y in sPHENIX

Regeneration of Y : low probability (even at LHC!)

→ Main effect on Y yields : destruction

=> Ideal for comparing Y R_{AA} between PHENIX and CMS.

R(1S) < R(2S) < R(3S) → Effects on states of different sizes!



Y in sPHENIX

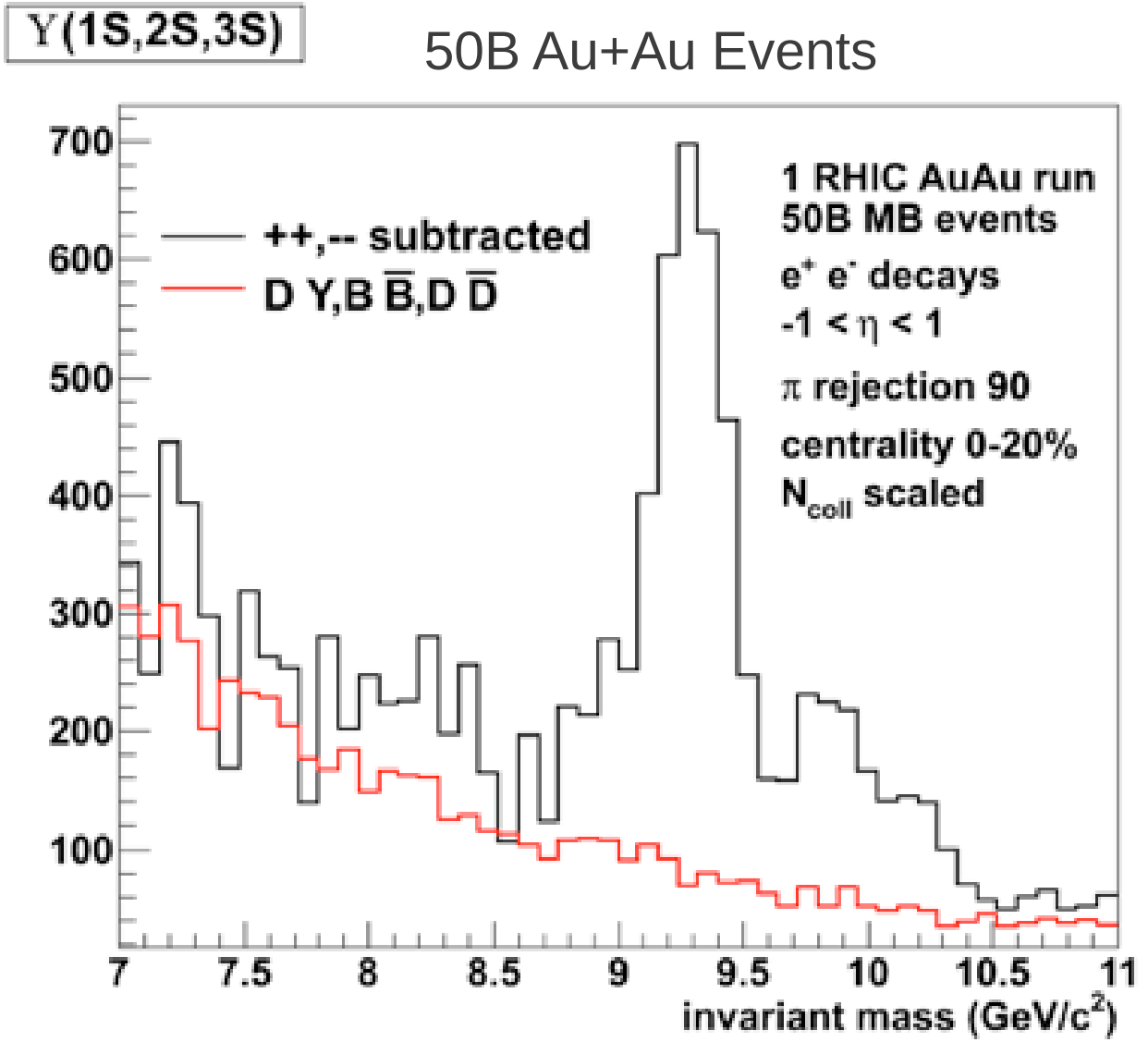
GEANT simulation using preliminary sPHENIX design.

Dark line : Like-sign subtracted signal.

Red line : Estimate of correlated background.

Still room for improvement in:

- Electron ID
- Tracking
- Radiative tail rejection



Conclusions

- Regeneration of quarkonia plays a small role at RHIC energies, larger role at LHC energies.

- Varying system size does not appear to have much effect on J/ψ R_{AA}.

- Shadowing effects for an asymmetric collision system are greater than energy density effects.

- Midrapidity Y results at PHENIX in good agreement with models and CMS data.

- Future results for both J/ψ and Y are promising.

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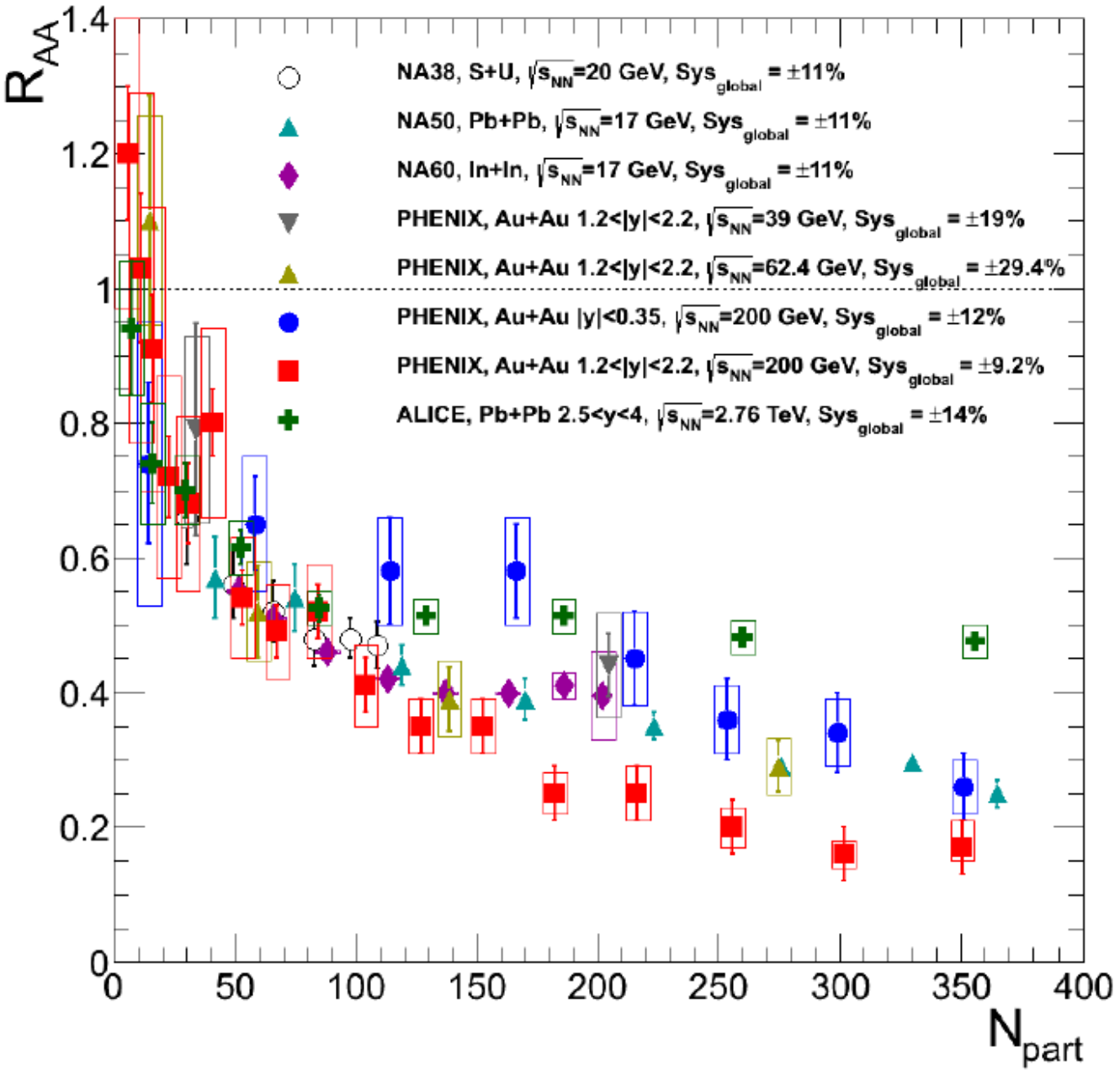
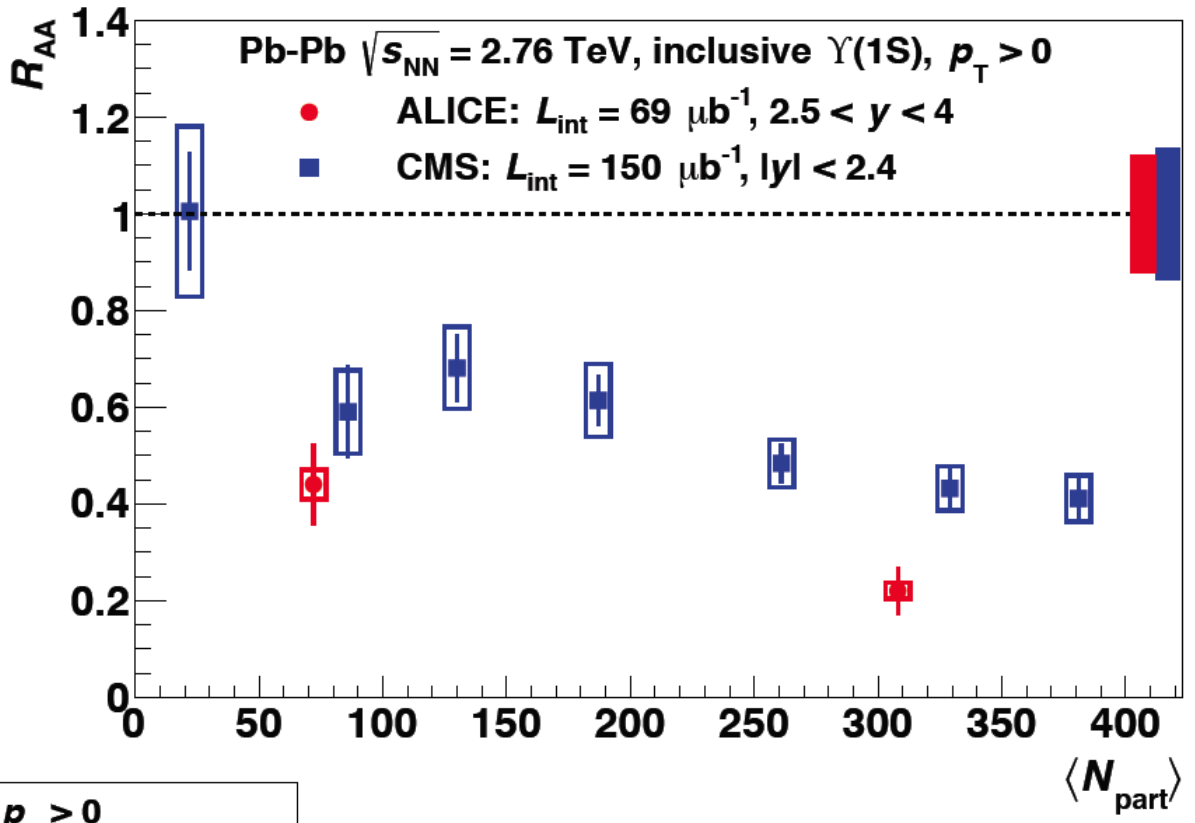
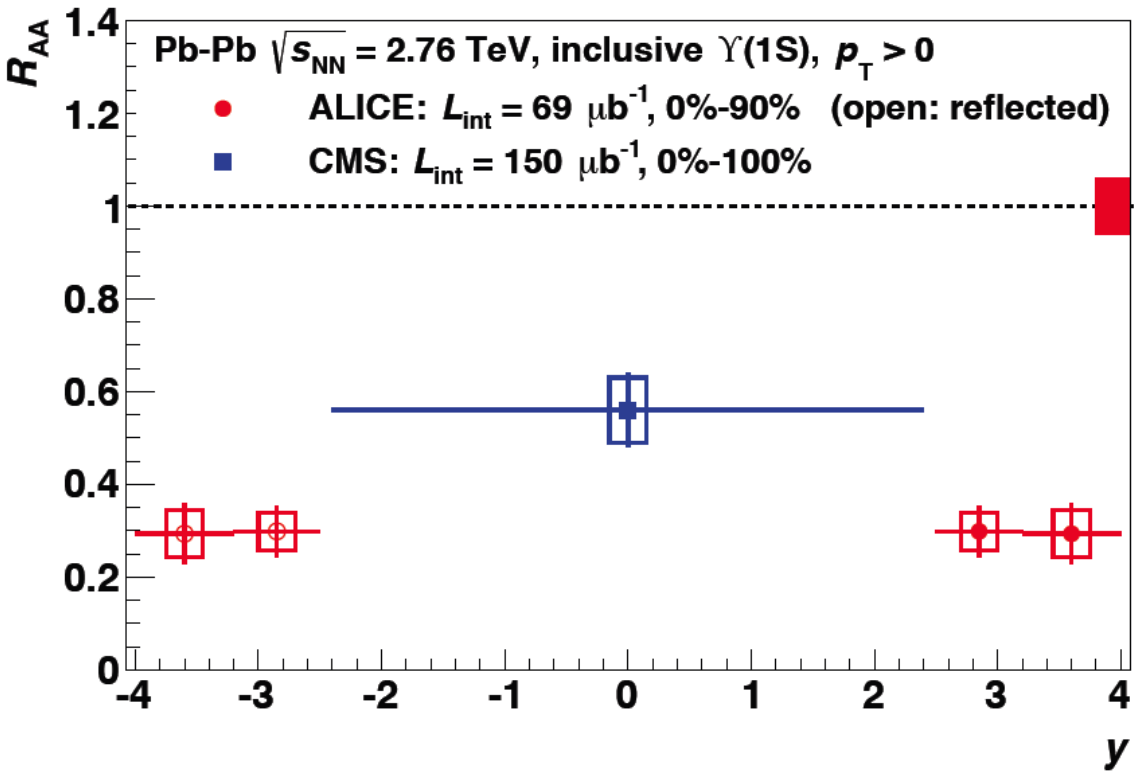
Thanks for your attention!

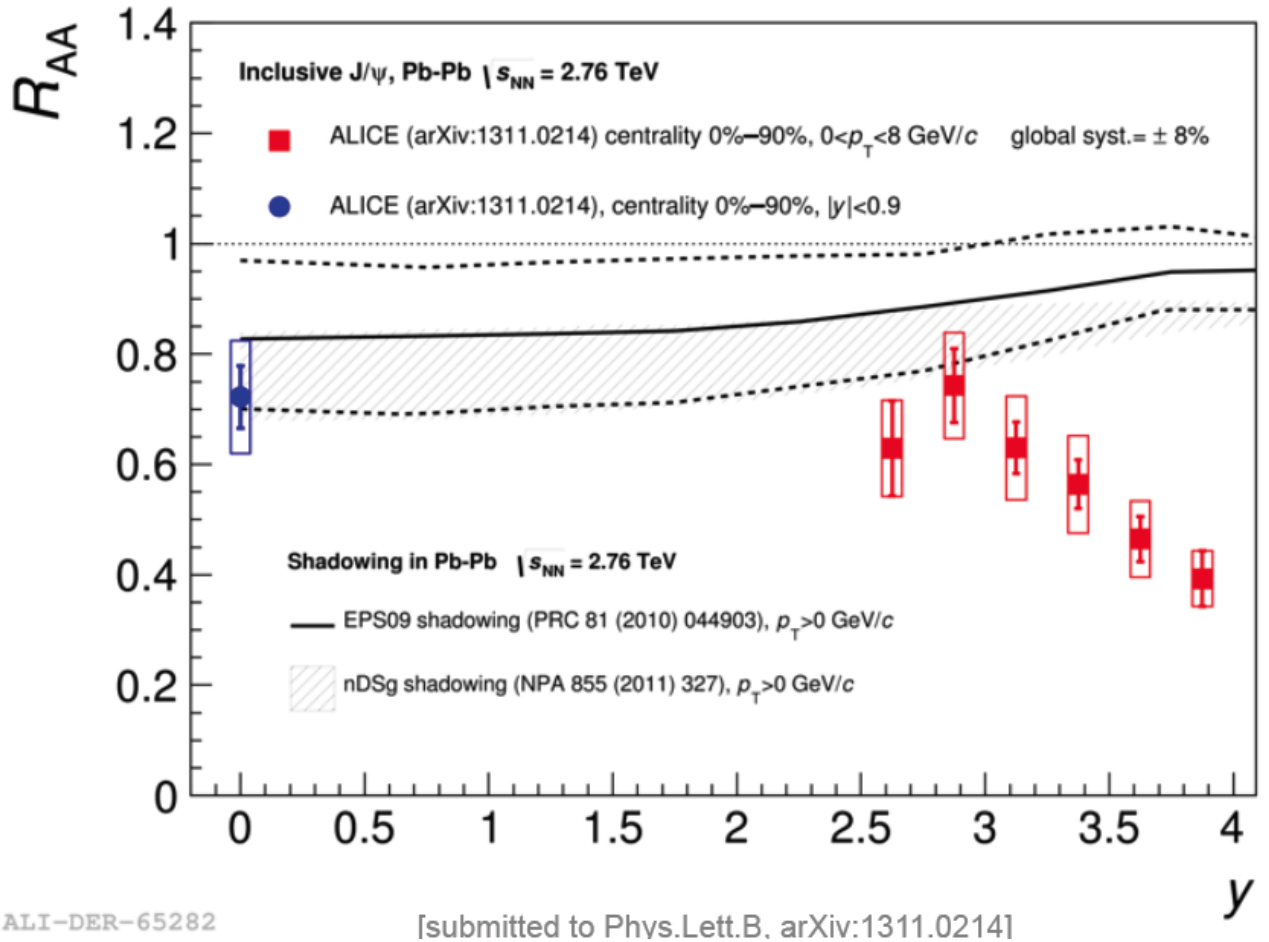
Backup


R_{AA}
N_{part}
NA38, S+U, $\sqrt{s_{NN}}$=20 GeV, Sys$_{global}$ = ±11%
NA50, Pb+Pb, $\sqrt{s_{NN}}$=17 GeV, Sys$_{global}$ = ±11%
NA60, In+In, $\sqrt{s_{NN}}$=17 GeV, Sys$_{global}$ = ±11%
PHENIX, Au+Au 1.2<|y|<2.2, $\sqrt{s_{NN}}$=39 GeV, Sys$_{global}$ = ±19%
PHENIX, Au+Au 1.2<|y|<2.2, $\sqrt{s_{NN}}$=62.4 GeV, Sys$_{global}$ = ±29.4%
PHENIX, Au+Au |y|<0.35, $\sqrt{s_{NN}}$=200 GeV, Sys$_{global}$ = ±12%
PHENIX, Au+Au 1.2<|y|<2.2, $\sqrt{s_{NN}}$=200 GeV, Sys$_{global}$ = ±9.2%
ALICE, Pb+Pb 2.5<y<4, $\sqrt{s_{NN}}$=2.76 TeV, Sys$_{global}$ = ±14%
0
0.2
0.4
0.6
0.8
1
1.2
1.4
0
50
100
150
200
250
300
350
400

ALICE and CMS Upsilons(1S), forward and midrapidity, vs Npart and rapidity.







ALI-DER-65282

[submitted to Phys.Lett.B, arXiv:1311.0214]

CMS and STAR Upsilon (1S, 2S)
comparison, midrapidity, vs centrality.