PHENIX Results on J/ψ and ψ' from d+Au Collisions

Xiaochun He, Georgia State University
For
The PHENIX Collaboration

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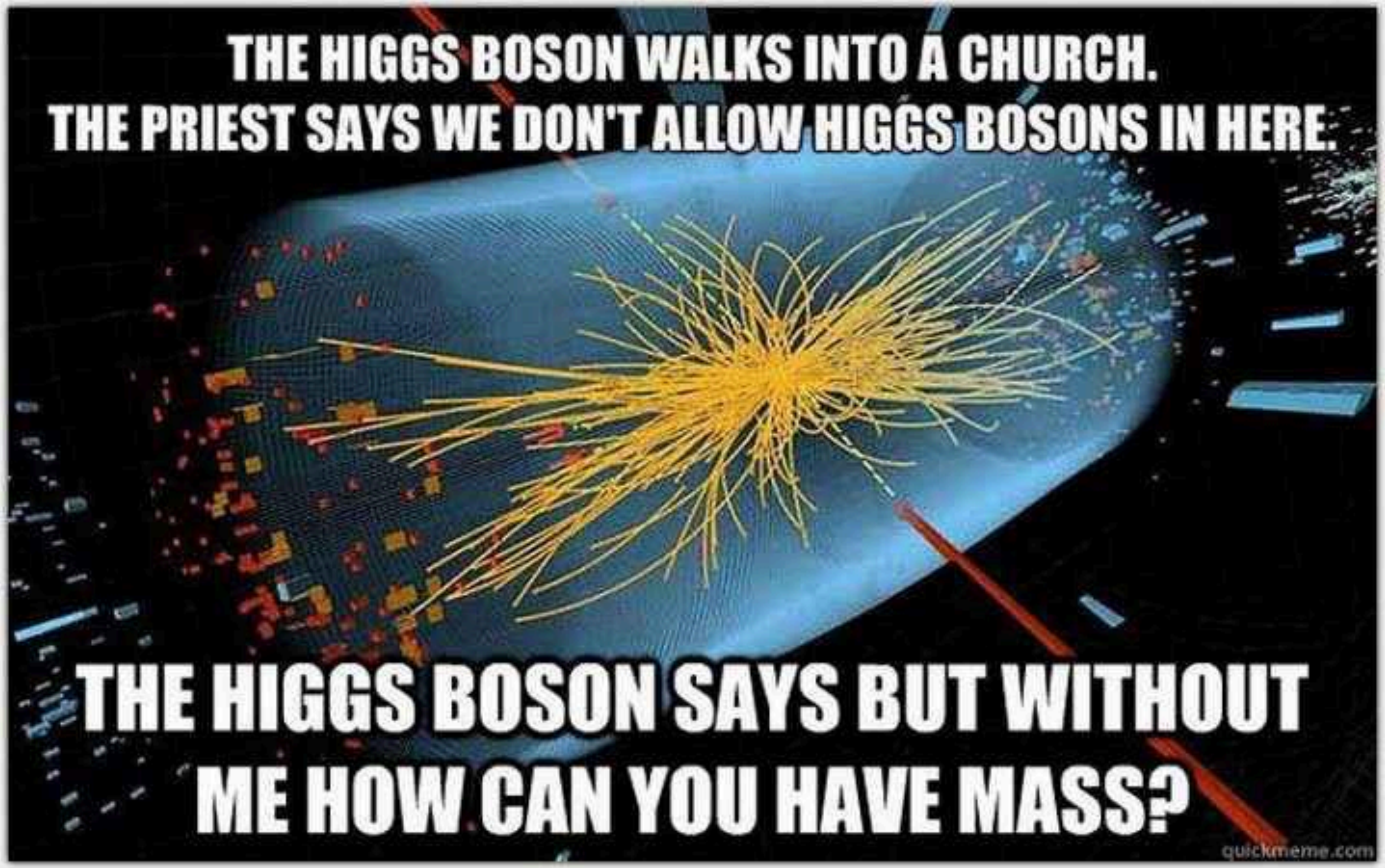
Outline

- Brief Introduction
- PHENIX Results
  - J/ψ and ψ' results from d+Au collisions
  - Implications for cold nuclear matter effects
- Summary and Outlook

It looks like nowadays if one wants to have more audience to listen to a talk, one has to speak about “higgs”

PHENIX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ME HOW CAN YOU HAVE MASS?
quickmeme.com

A 27-year-old Theory Prediction

- Quarkonia melt in QGP - Matsui & Satz 1986.

" ... If high energy heavy ion collisions lead to the formation of a hot quark-gluon plasma, then color screening prevents c-cbar binding in the deconfined interior of the interaction region ... It is concluded that J/Ψ suppression in nuclear collisions should provide an unambiguous signature of quark-gluon plasma formation."

Melting Quarkonia

state	J/ψ	χ_c	Ψ'	Υ_{1S}	Υ_{2S}	Υ_{3S}
mass [GeV]	3.10	3.53	3.68	9.46	10.02	10.36
radius [fm]	0.25	0.36	0.45	0.14	0.28	0.39

hep-ph/0609197v1 H. Satz

- Each quarkonium has different binding radius.

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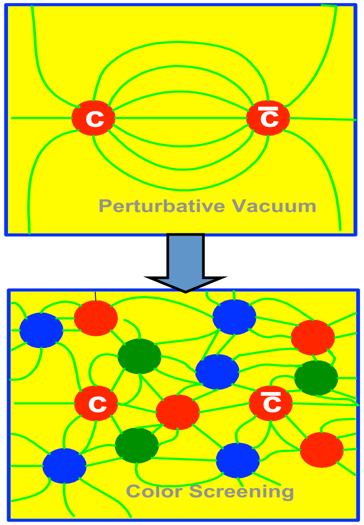
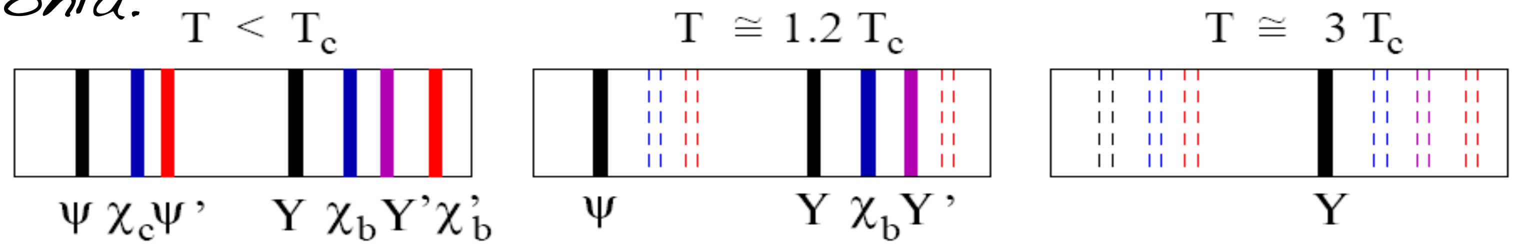
- Temperature of QGP can be probed by measurement heavy quarkonia.





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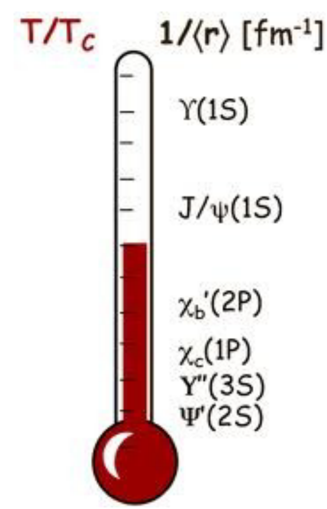
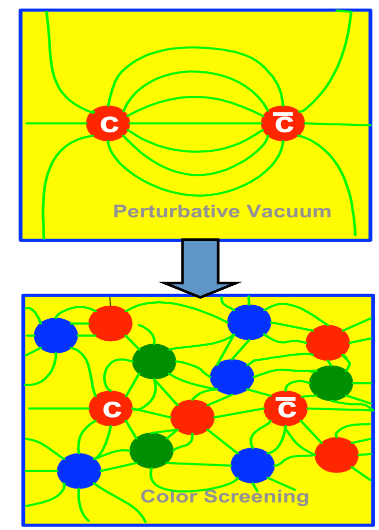
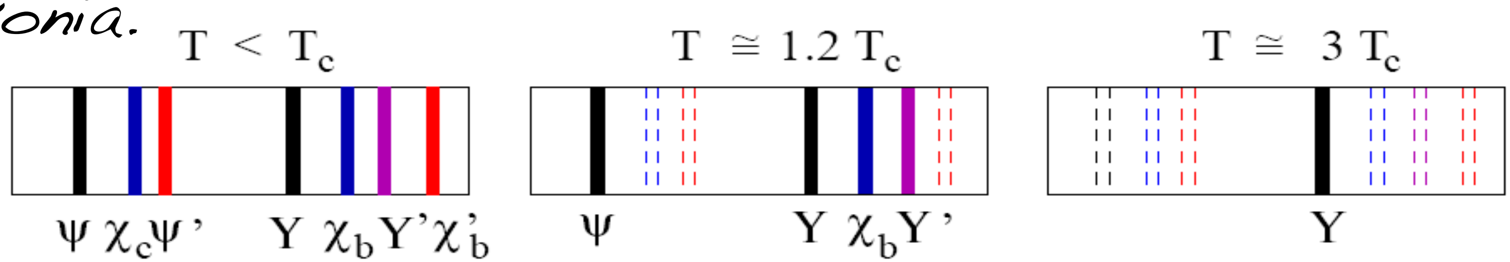
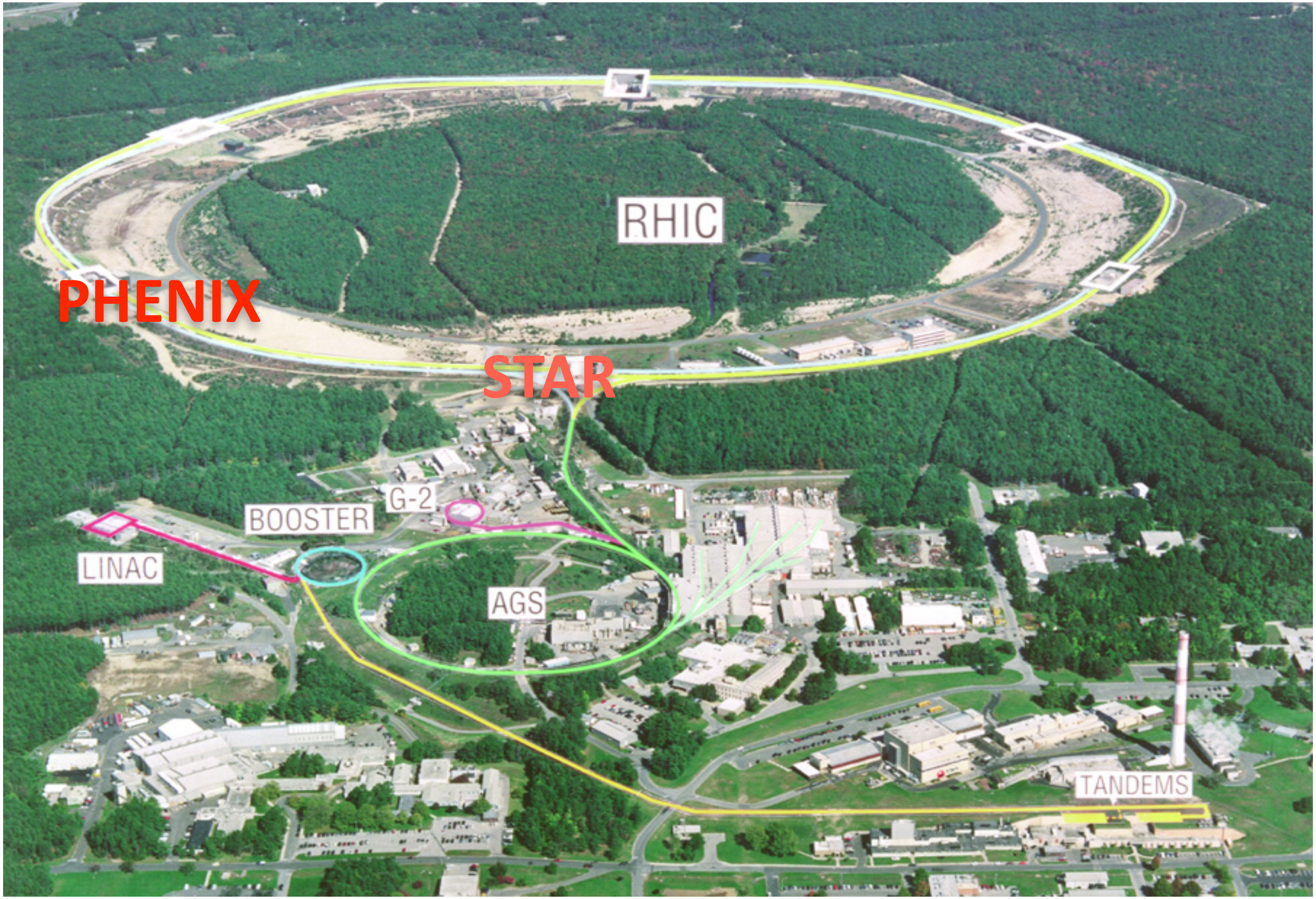






RHIC Birdview



PHENIX/RHIC Run Summary

- RHIC has run with many colliding species which range from p+p, d+Au, Au+Au, Cu+Cu, Cu+Au, U +U.
- RHIC has run at variety center of mass energies.
- RHIC beam scan program has started and will continue for years to come.

RHIC-Run	Year	Species	Energy	Ldt
Run-1	2000	Au+Au	130 GeV	1 μb^{-1}
Run-2	2001/2	Au+Au	200 GeV	24 μb^{-1}
		p+p	200 GeV	150 nb^{-1}
Run-3	2002/3	d+Au	200 GeV	2.74 nb^{-1}
		p+p	200 GeV	0.35 nb^{-1}
Run-4	2003/4	Au+Au	200 GeV	241 μb^{-1}
		Au+Au	62.4 GeV	9 μb^{-1}
Run-5	2005	Cu+Cu	200 GeV	3 nb^{-1}
		Cu+Cu	62.4 GeV	0.19 nb^{-1}
		Cu+Cu	22.4 GeV	2.7 μb^{-1}
Run-6	2006	p+p	200 GeV	10.7 pb^{-1}
		p+p	62.4 GeV	100 nb^{-1}
Run-7	2007	Au+Au	200 GeV	813 μb^{-1}
Run-8	2007/8	d+Au	200 GeV	80 nb^{-1}
		p+p	200 GeV	5.2 pb^{-1}
Run-9	2009	p+p	200 GeV	16 pb^{-1}
		p+p	500 GeV	14 pb^{-1}
Run-10	2010	Au+Au	200 GeV	1.3 nb^{-1}
		Au+Au	62.4 GeV	100 μb^{-1}
		Au+Au	39 GeV	40 μb^{-1}
		Au+Au	7.7 GeV	260 mb^{-1}
Run-11	2011	p+p	500 GeV	27 pb^{-1}
		Au+Au	200 GeV	915 μb^{-1}
		Au+Au	27 GeV	5.2 μb^{-1}
		Au+Au	19.6 GeV	13.7 M
Run-12	2012	p+p	200 GeV	9.2 pb^{-1}
		p+p	510 GeV	30 pb^{-1}
		U+U	193 GeV	171 μb^{-1}
		Cu+Au	200 GeV	4.96 nb^{-1}

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PHENIX/RHIC Run Summary

Discovery and Diagnostic Period

Beam-energy scan continues

New era of heavy flavor physics

Better knowledge on geometry

Medium Characterization Started

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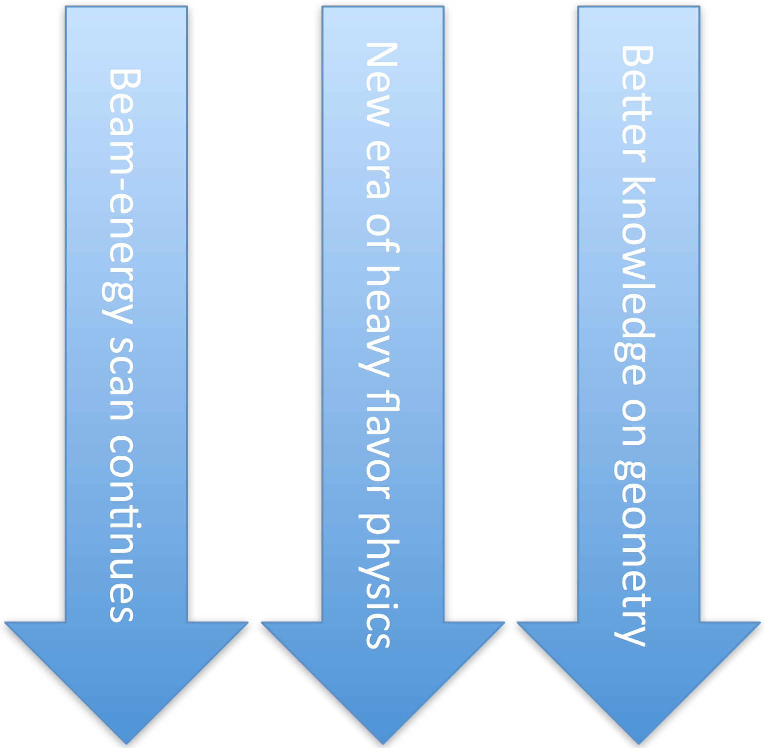

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PHENIX Detectors

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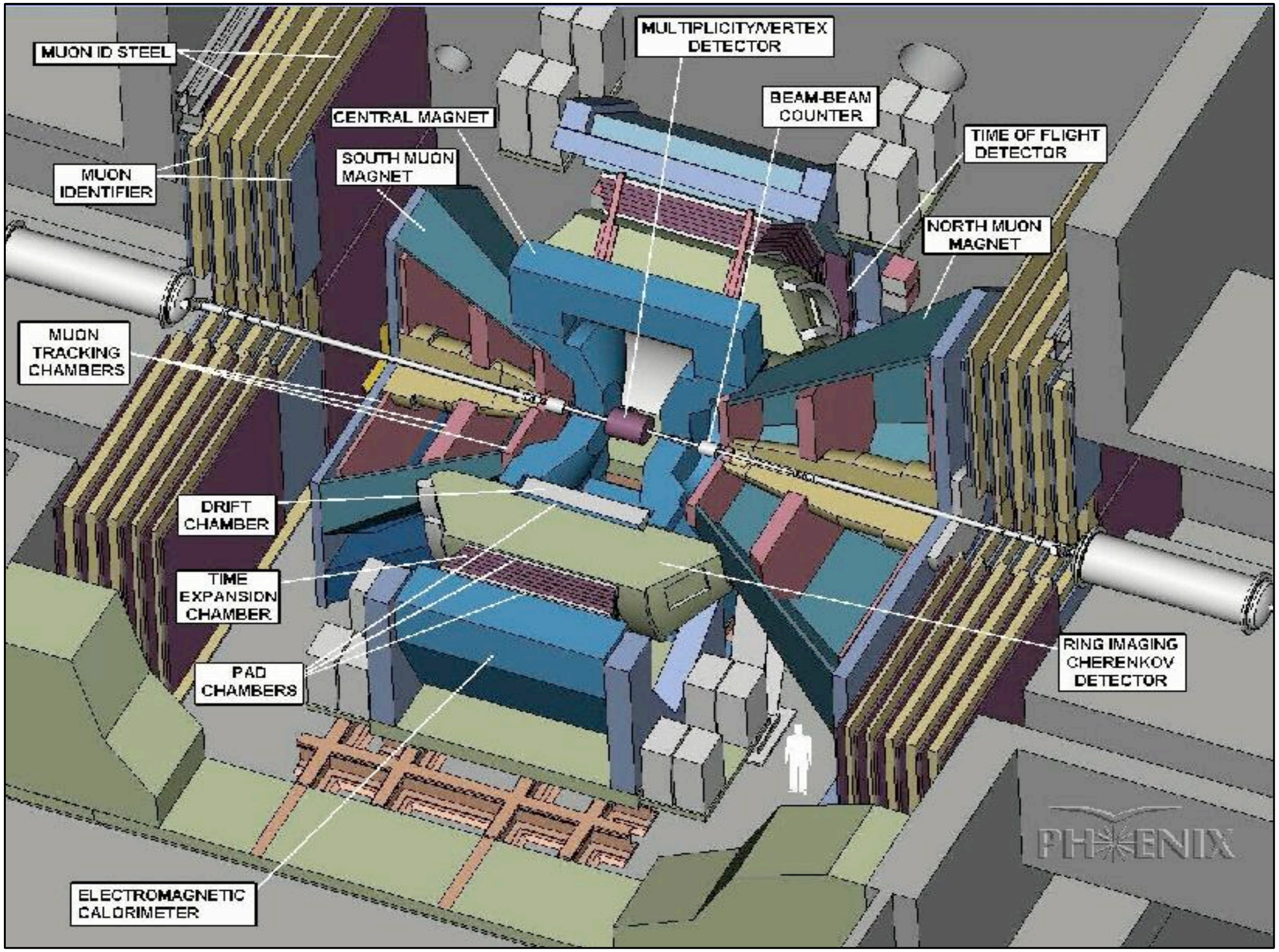
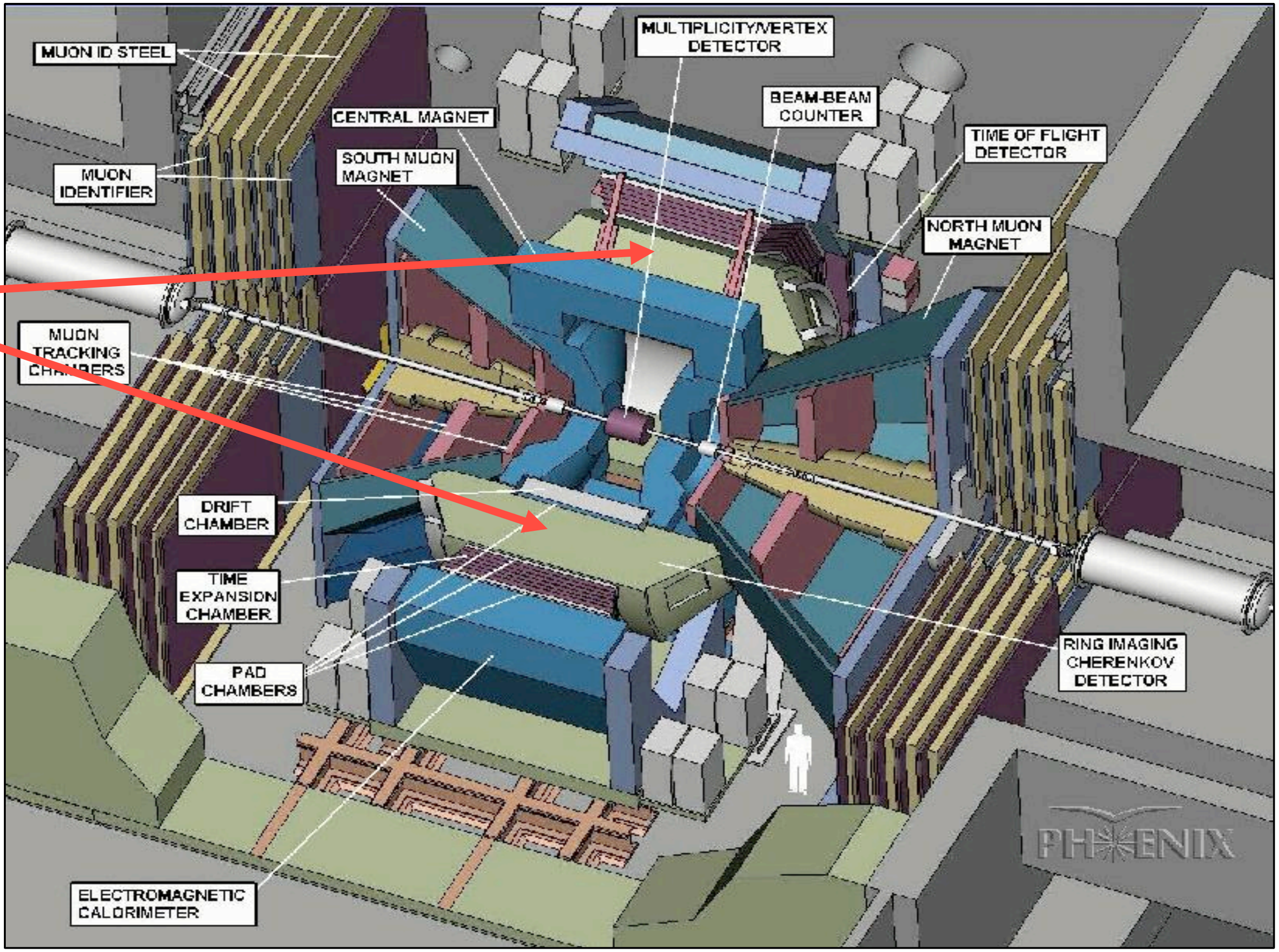


PHENIX Detectors

Central arms:
hadrons, photons,
Electrons:
$p > 0.2$ GeV/c
$|y| < 0.35$
$\Delta\phi = \pi$



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Muon arms:
muons at forward
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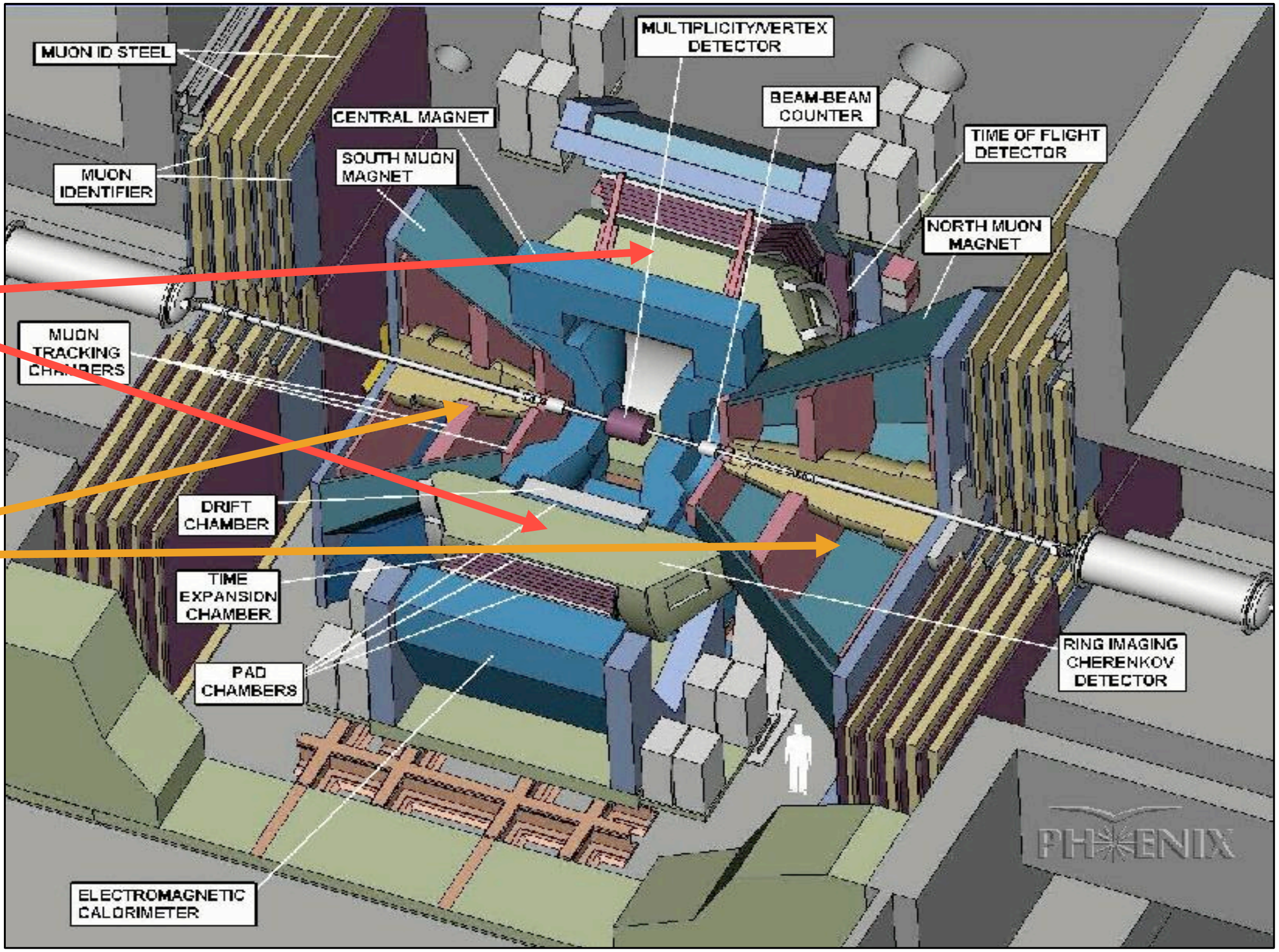

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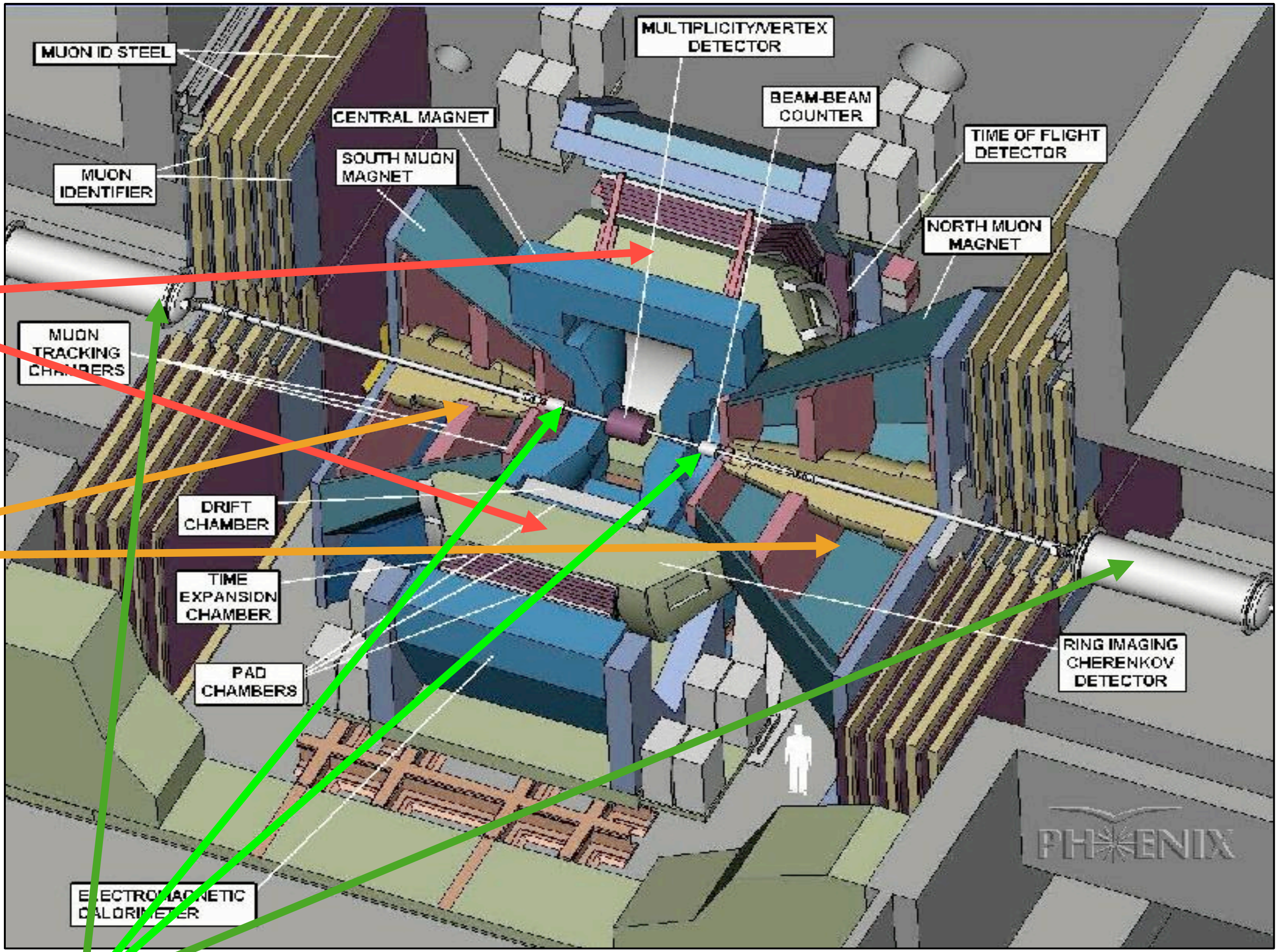

Centrality measurement:
We use beam beam counters together with zero degree calorimeters
Centrality is mapped to N_{part} (N_{col}) using Glauber model

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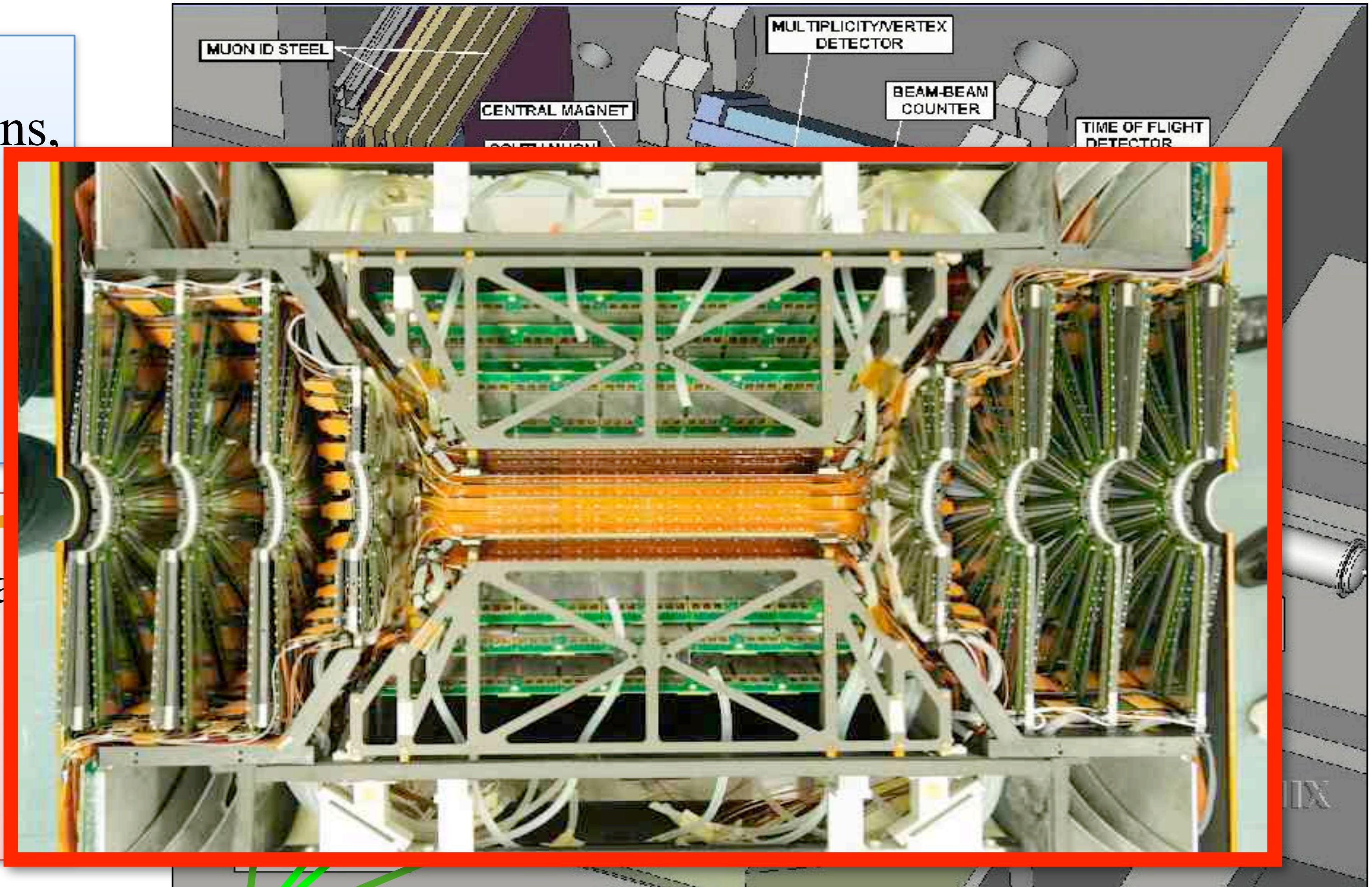

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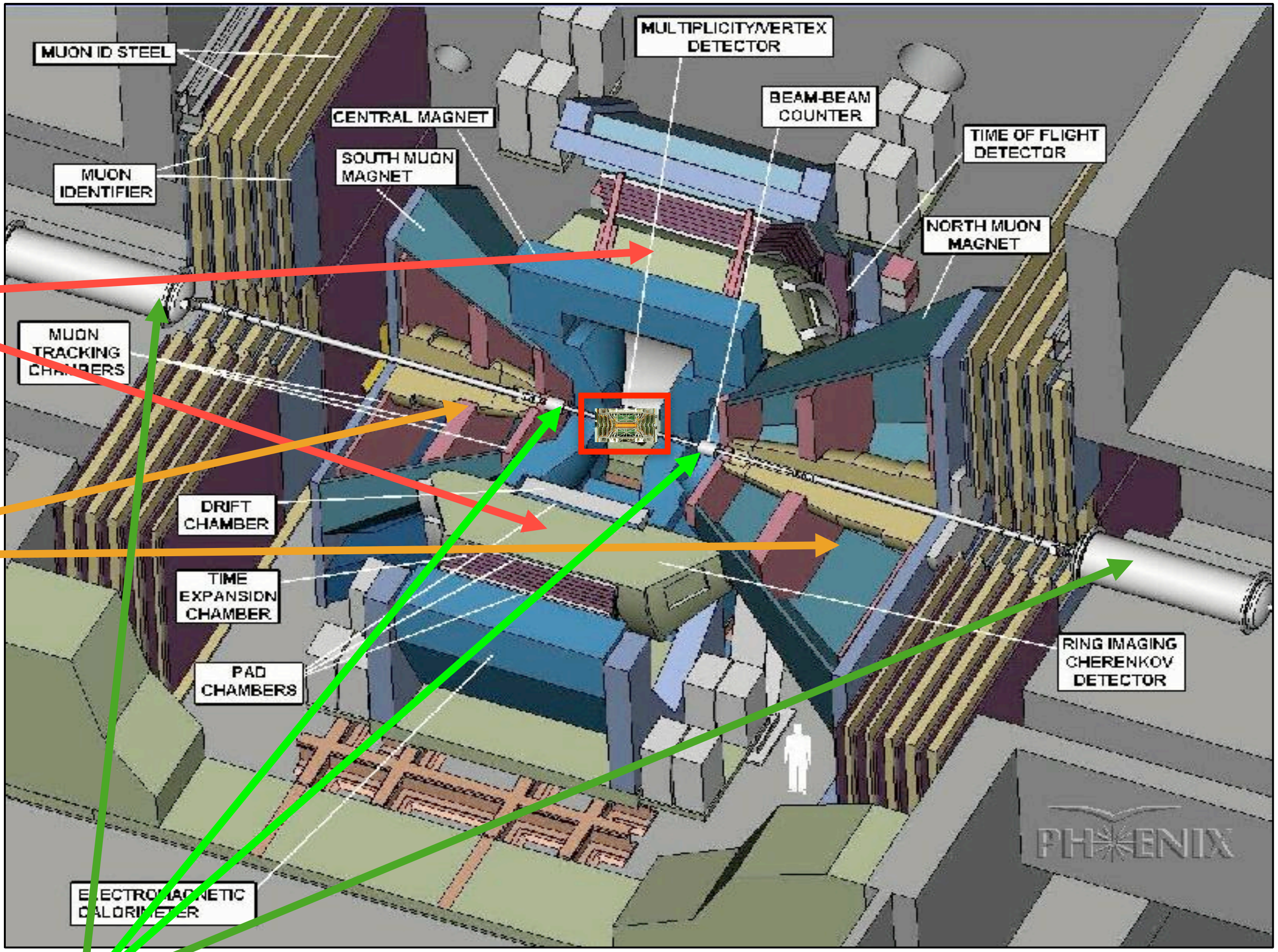

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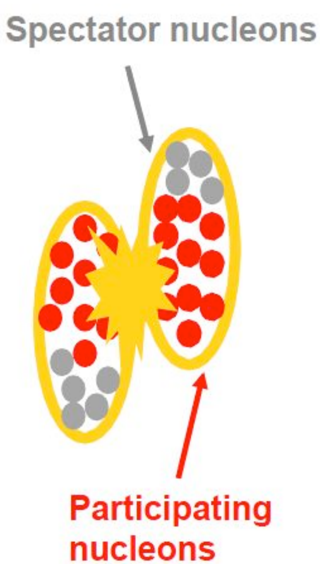
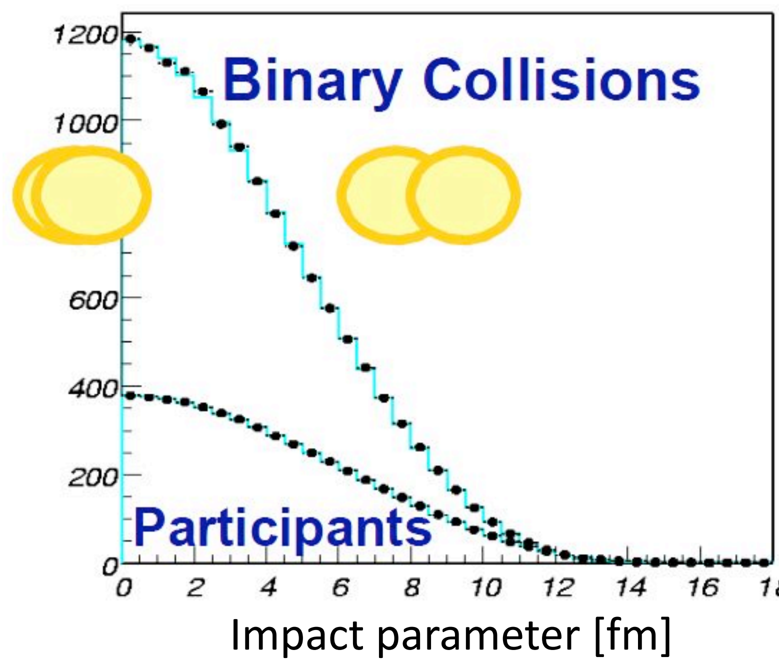
Nuclear Modification Factor R_{AA}

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

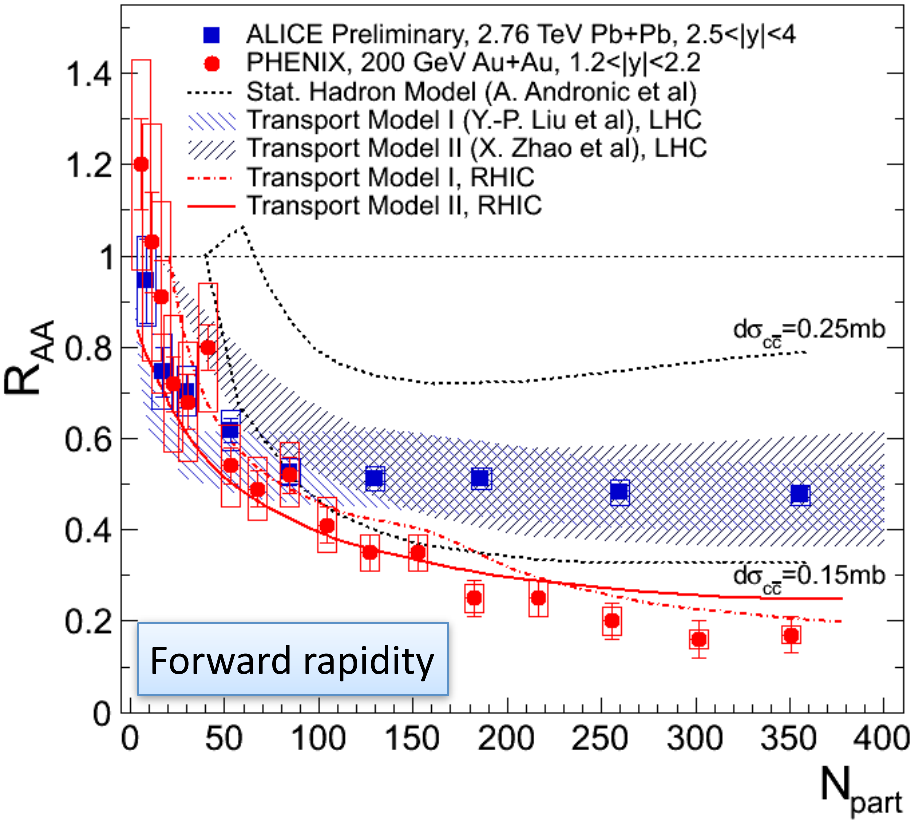
Yield in nucleus-nucleus collisions divided by p+p yields and scaled by the appropriate number of binary collisions N_{COLL}, which is calculated using Glauber model.

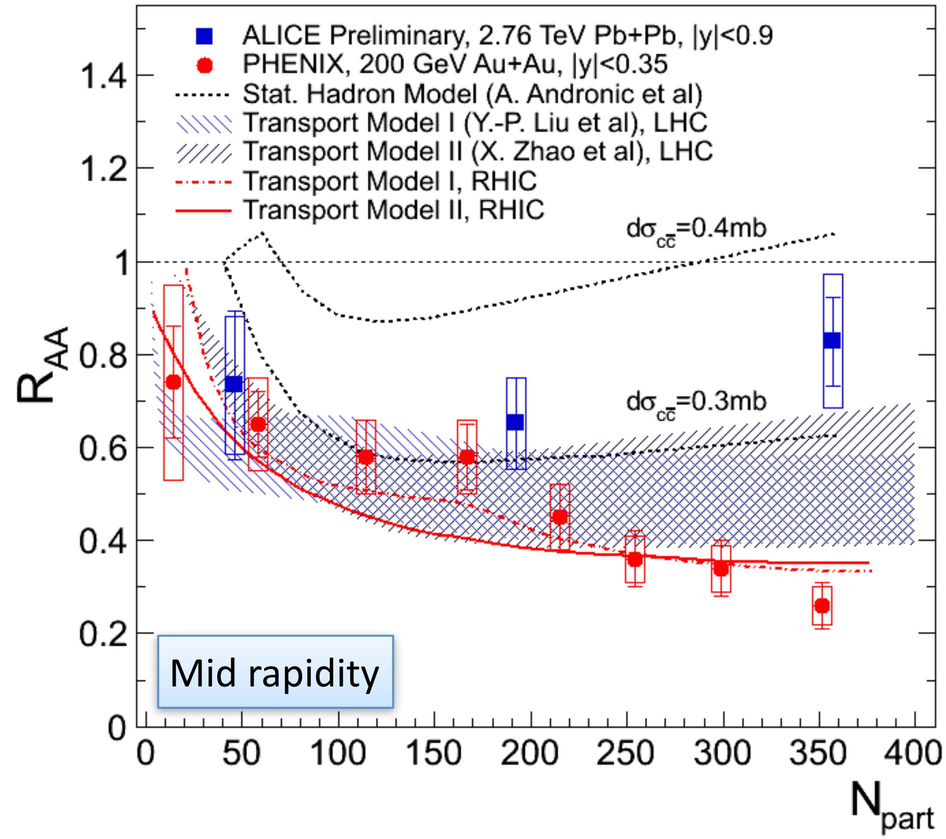


Centrality of collision is described by number of participant nucleons N_{PART}



J/ψ Production vs Centrality





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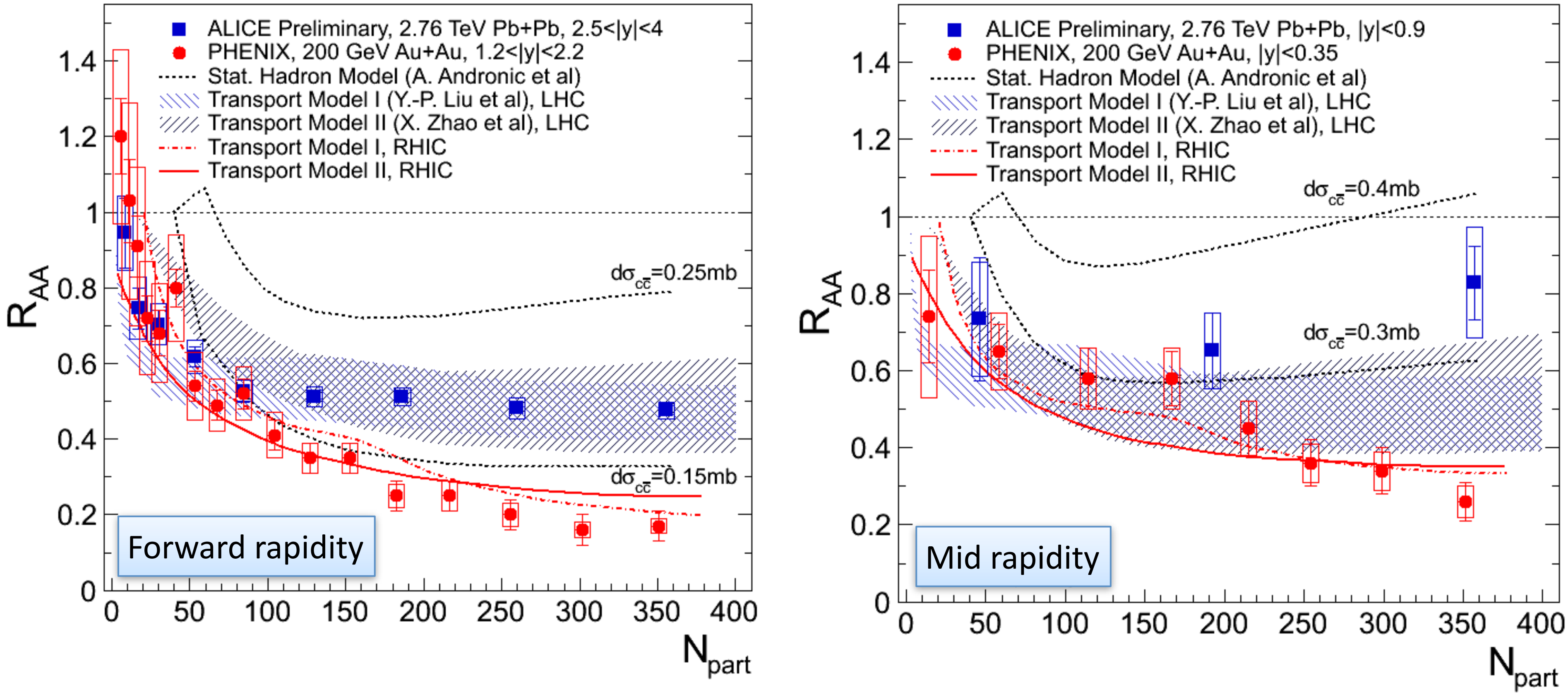
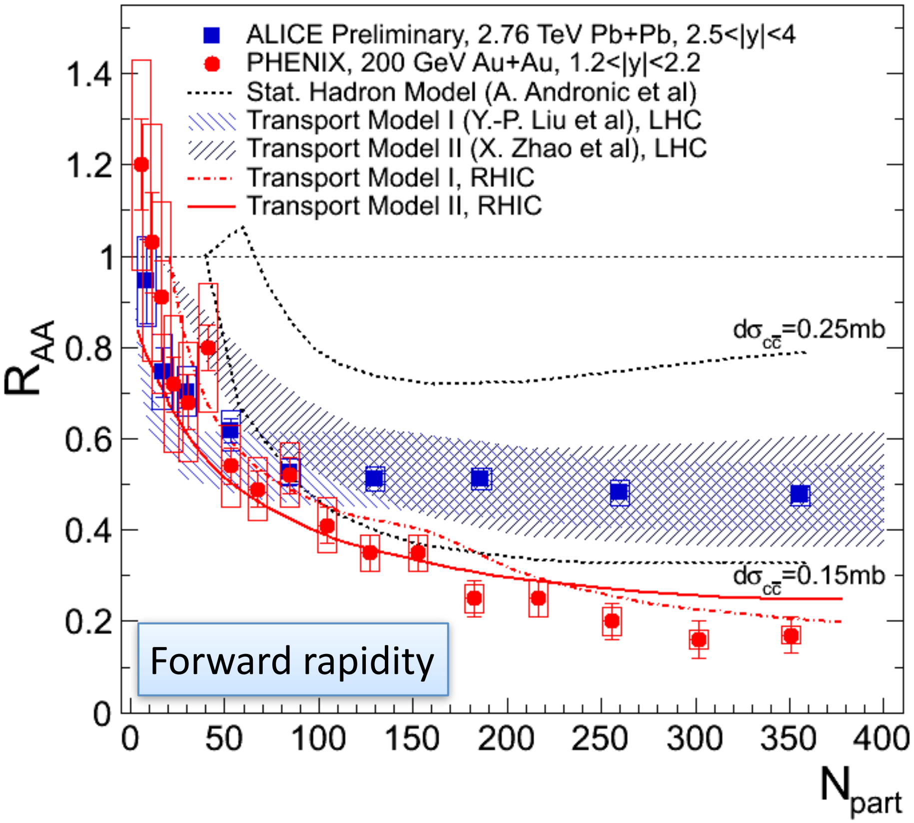
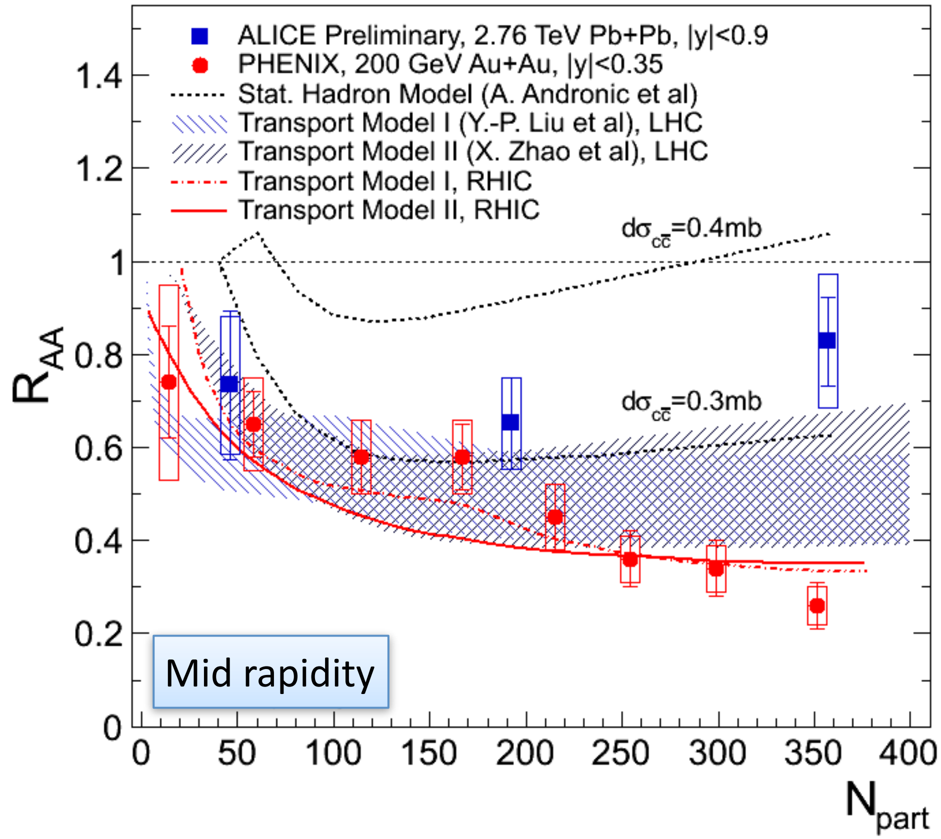


N_{part} dependence of J/ψ R_{AA}: less suppression at LHC compared to at RHIC in central collisions.

Puzzle #1 J/ψ Production vs Centrality





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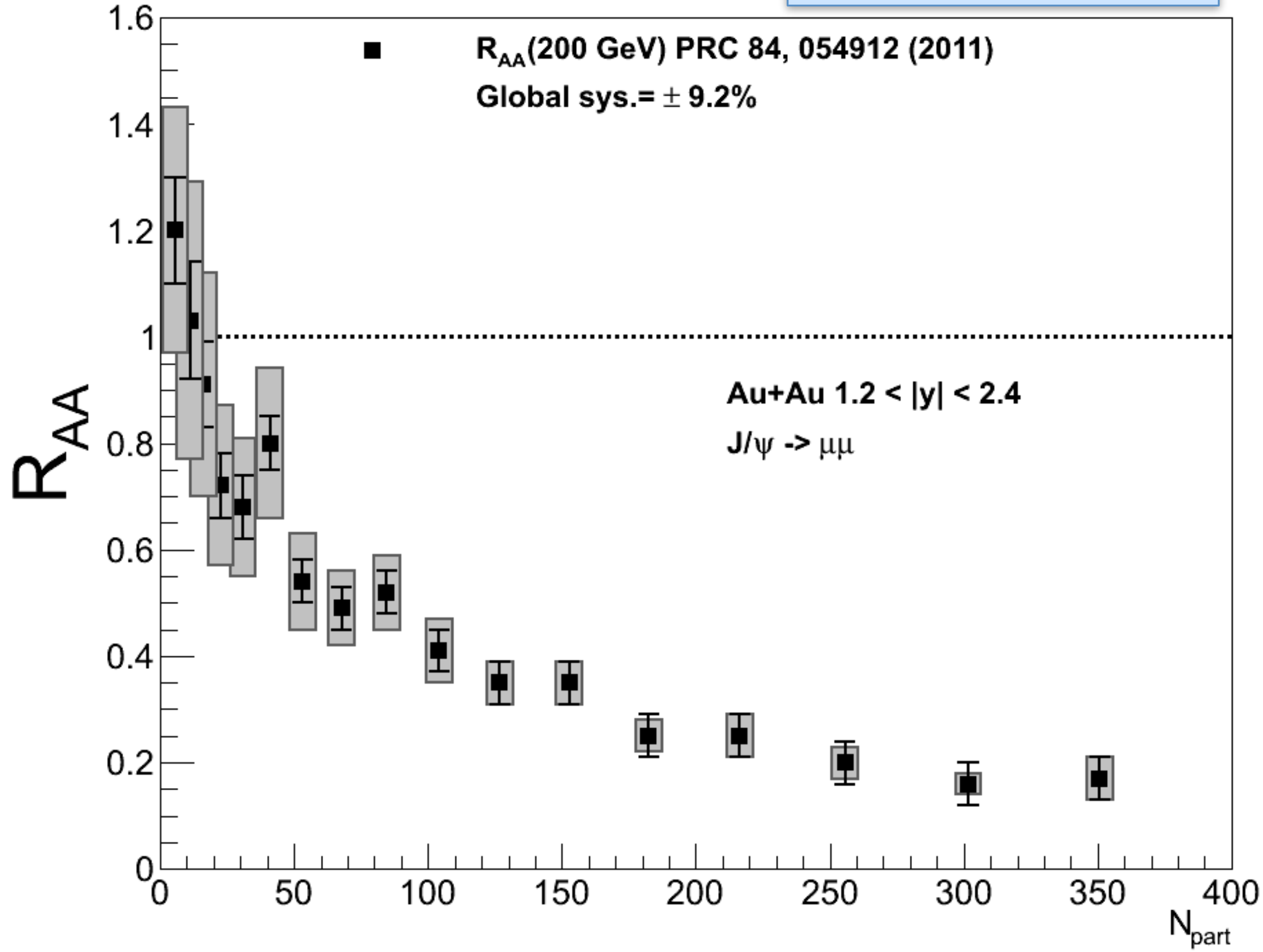
J/ψ Production vs Energy

PRC 86, 064901 (2012)



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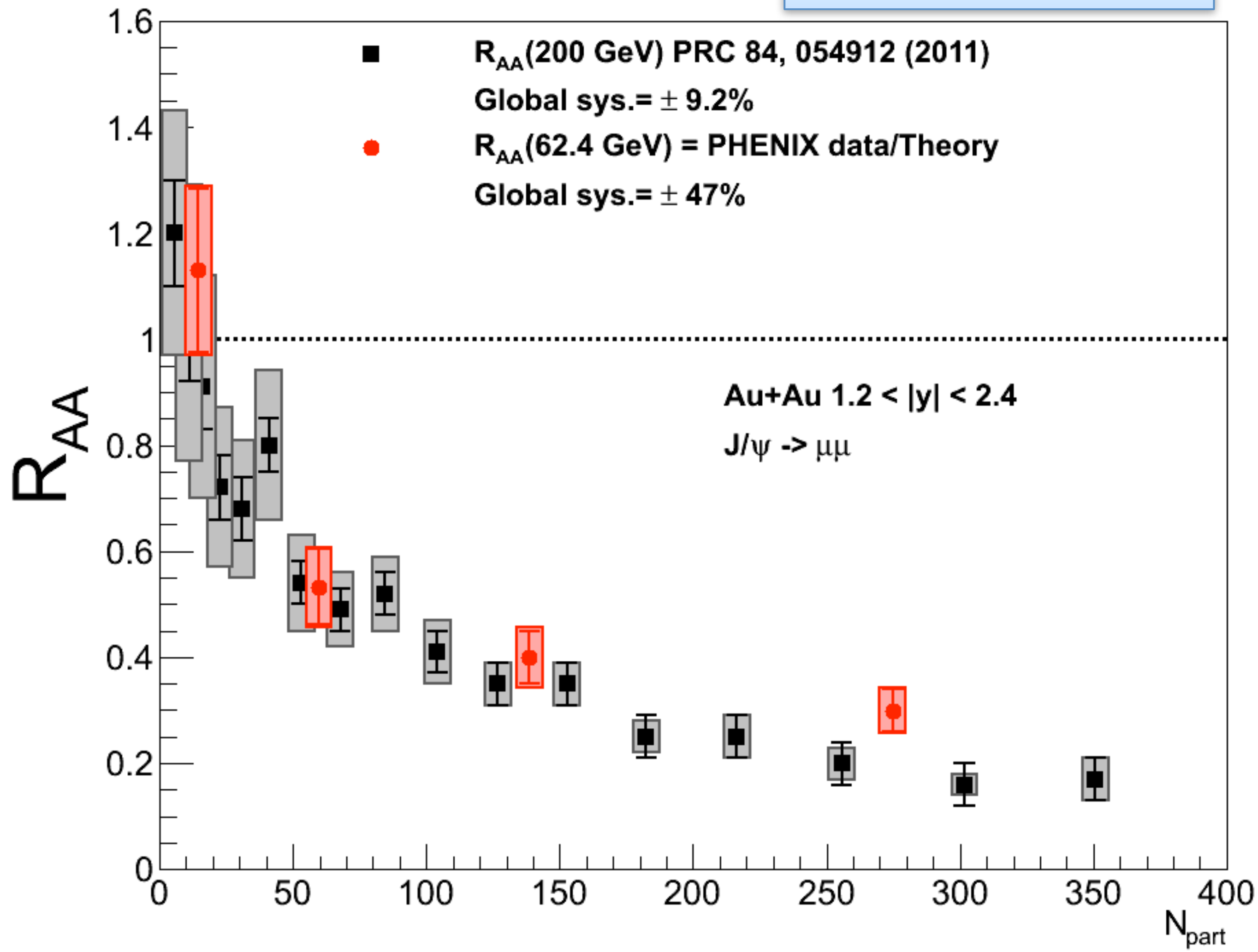

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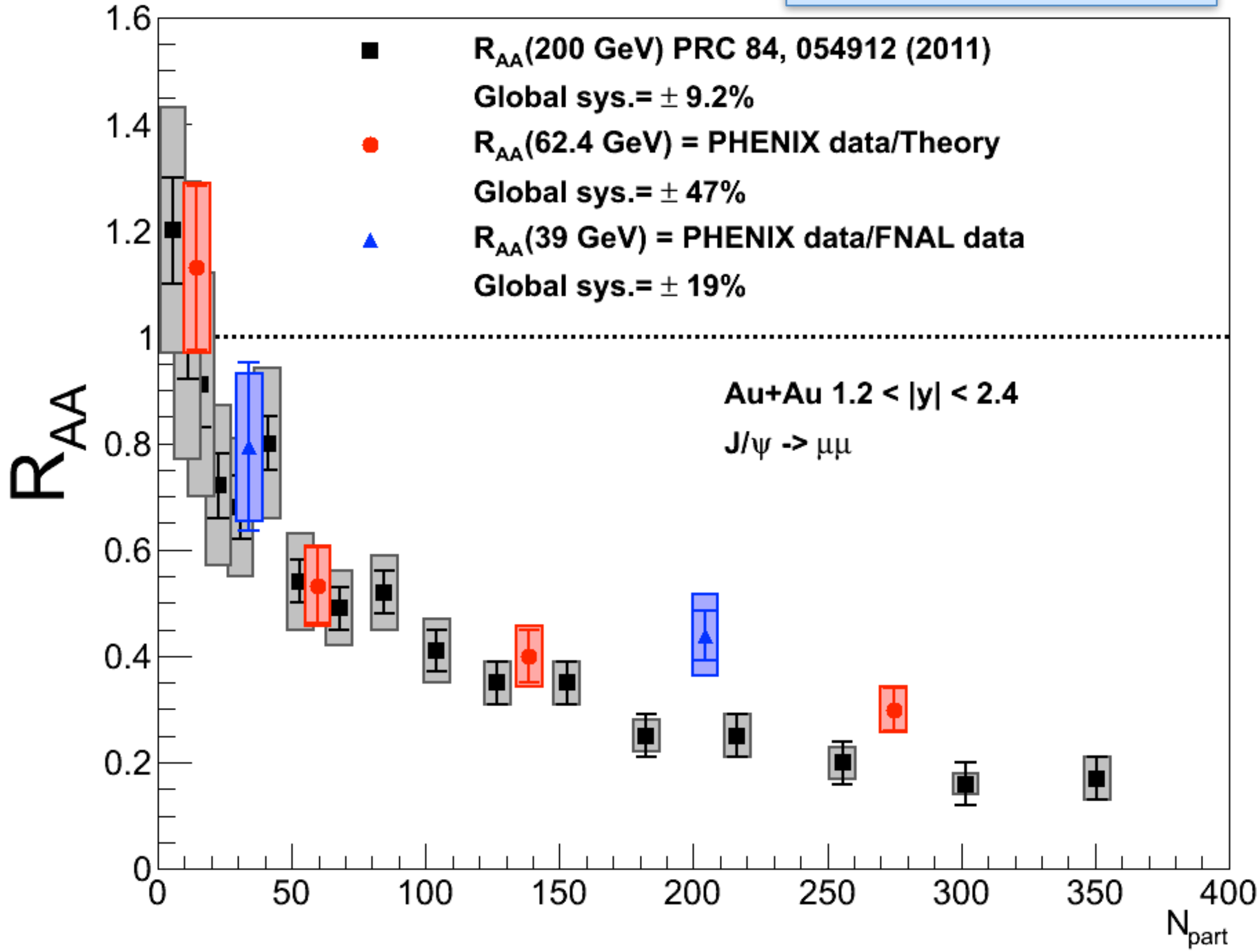

J/ψ Production vs Energy

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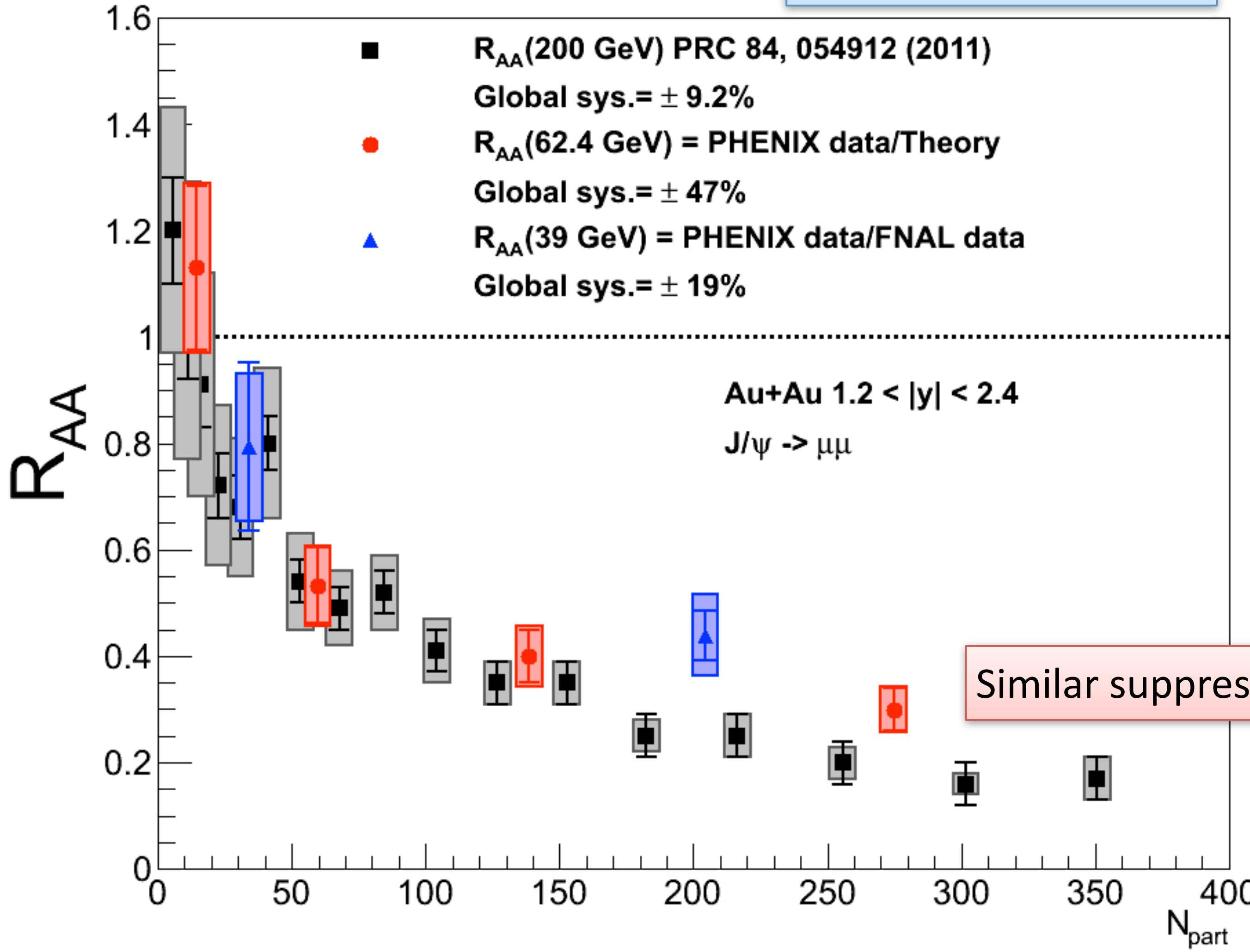
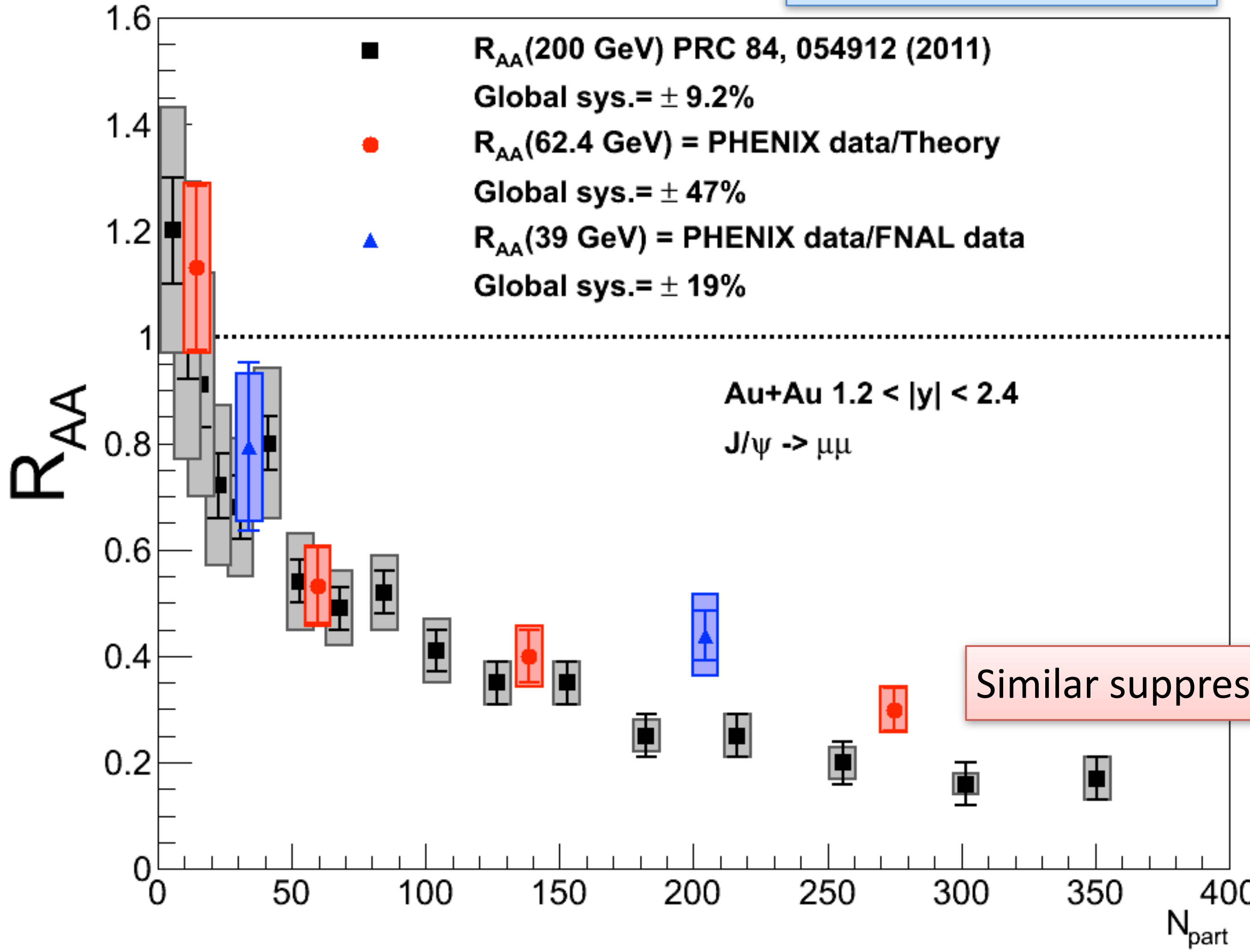


Similar suppression level !!!

J/ψ Production vs Energy

Puzzle #2

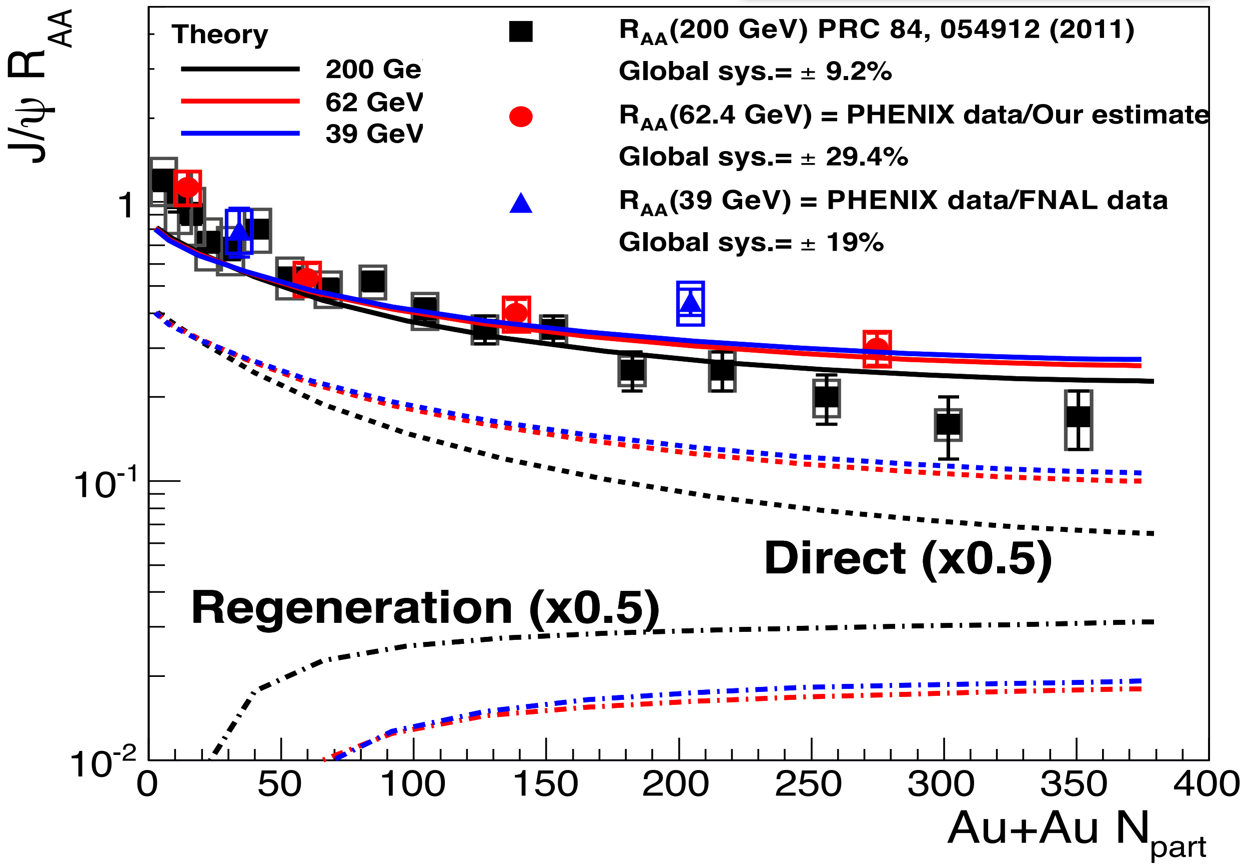
PRC 86, 064901 (2012)



Similar suppression level !!!

Comparison with Theory

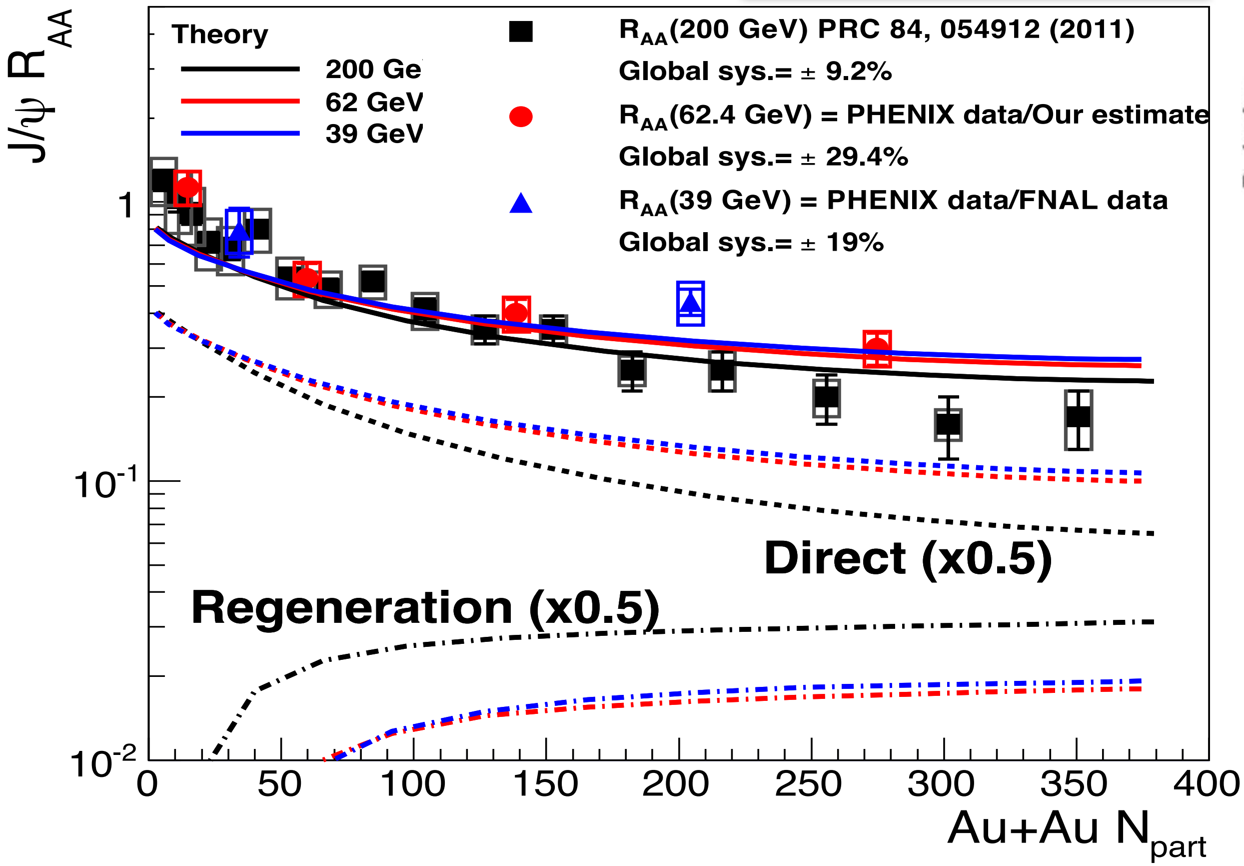
PRC 86, 064901 (2012)

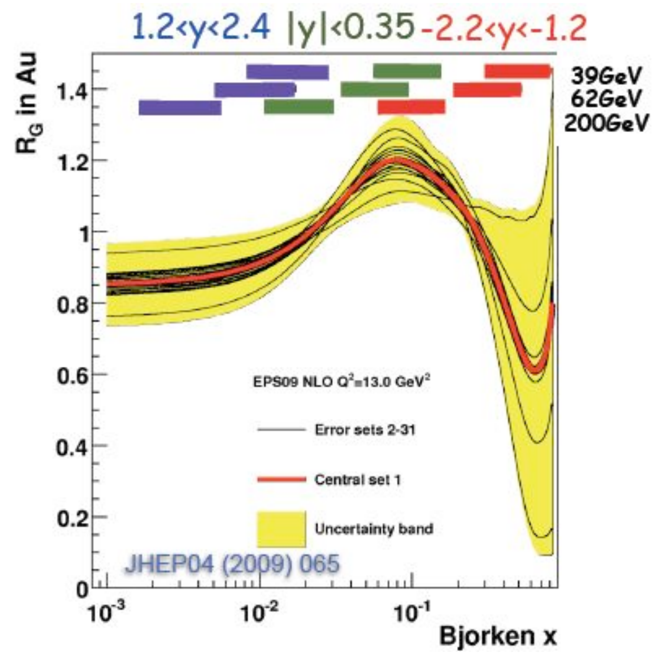


Regeneration compensates for suppression in QGP. Calculations are done by X. Zhao and R. Rapp [Phys. Rev. C 82, 064905 (2010)].

Comparison with Theory

PRC 86, 064901 (2012)





But cold nuclear matter effects should be different!

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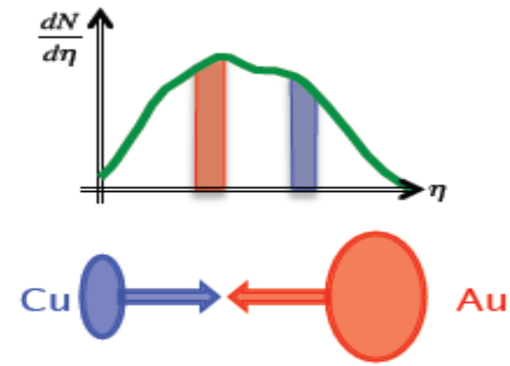
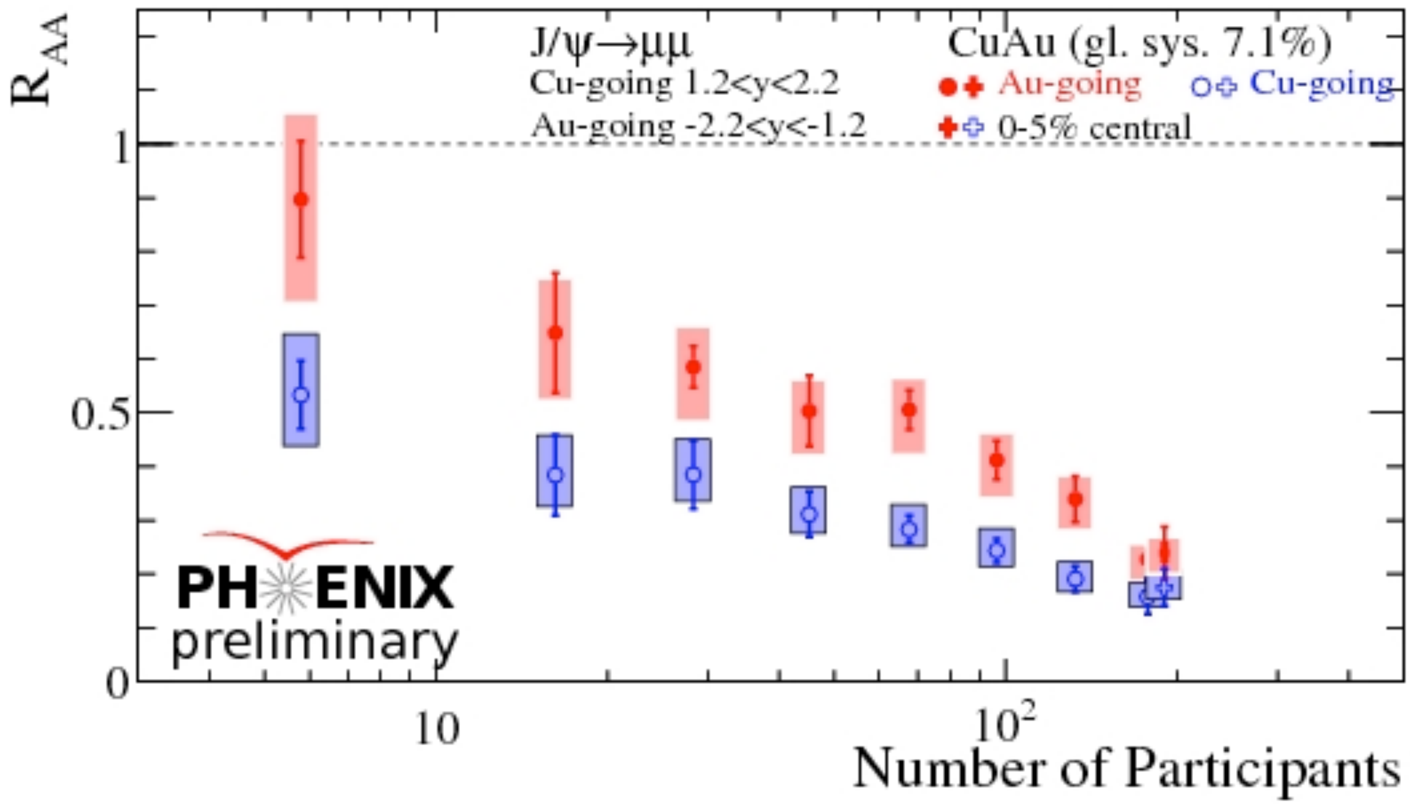
Cu+Au
(Controlled Geometry)





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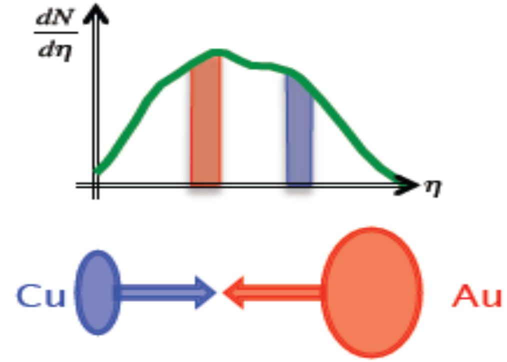

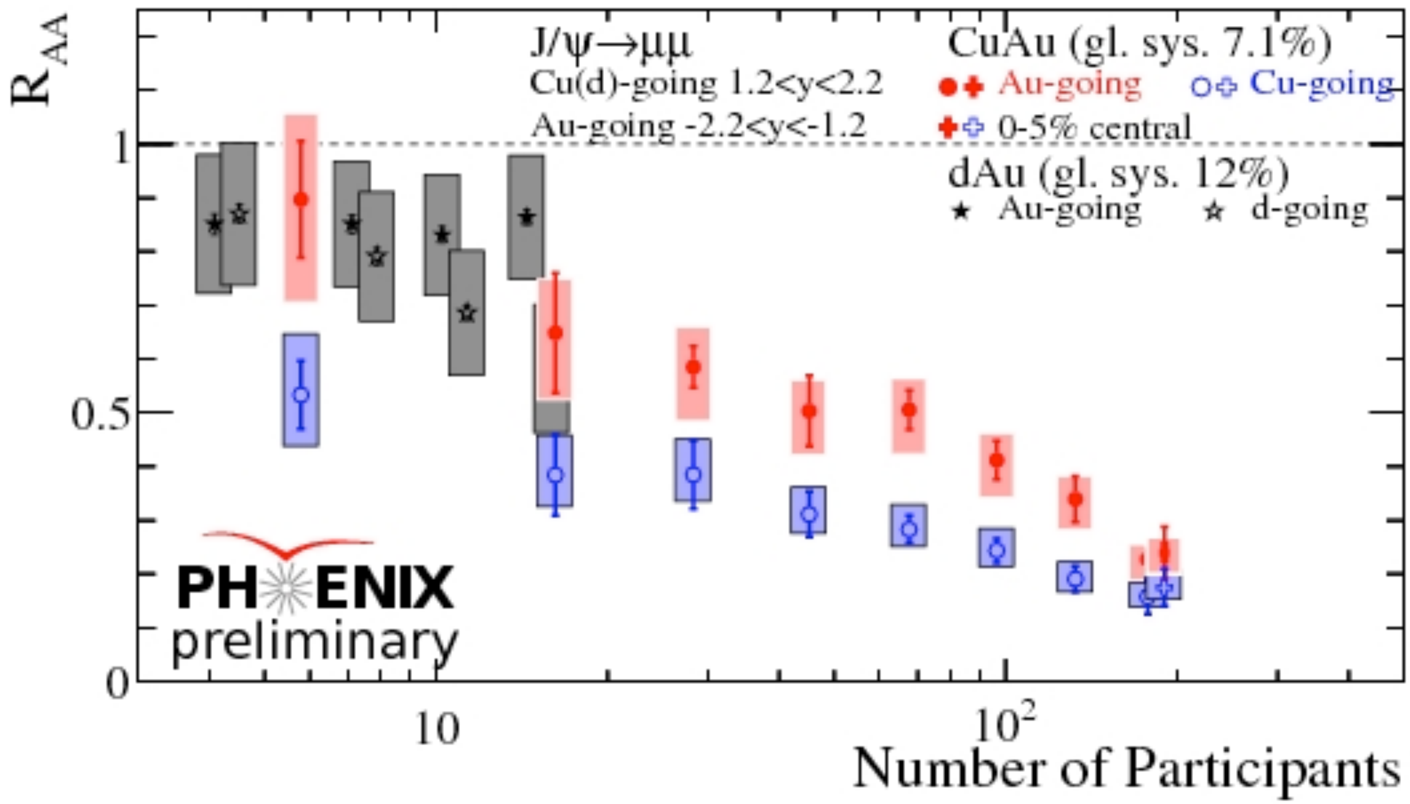

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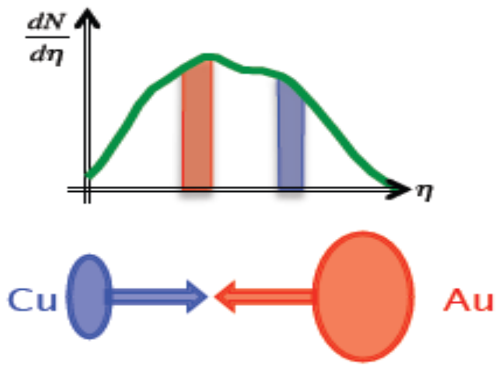
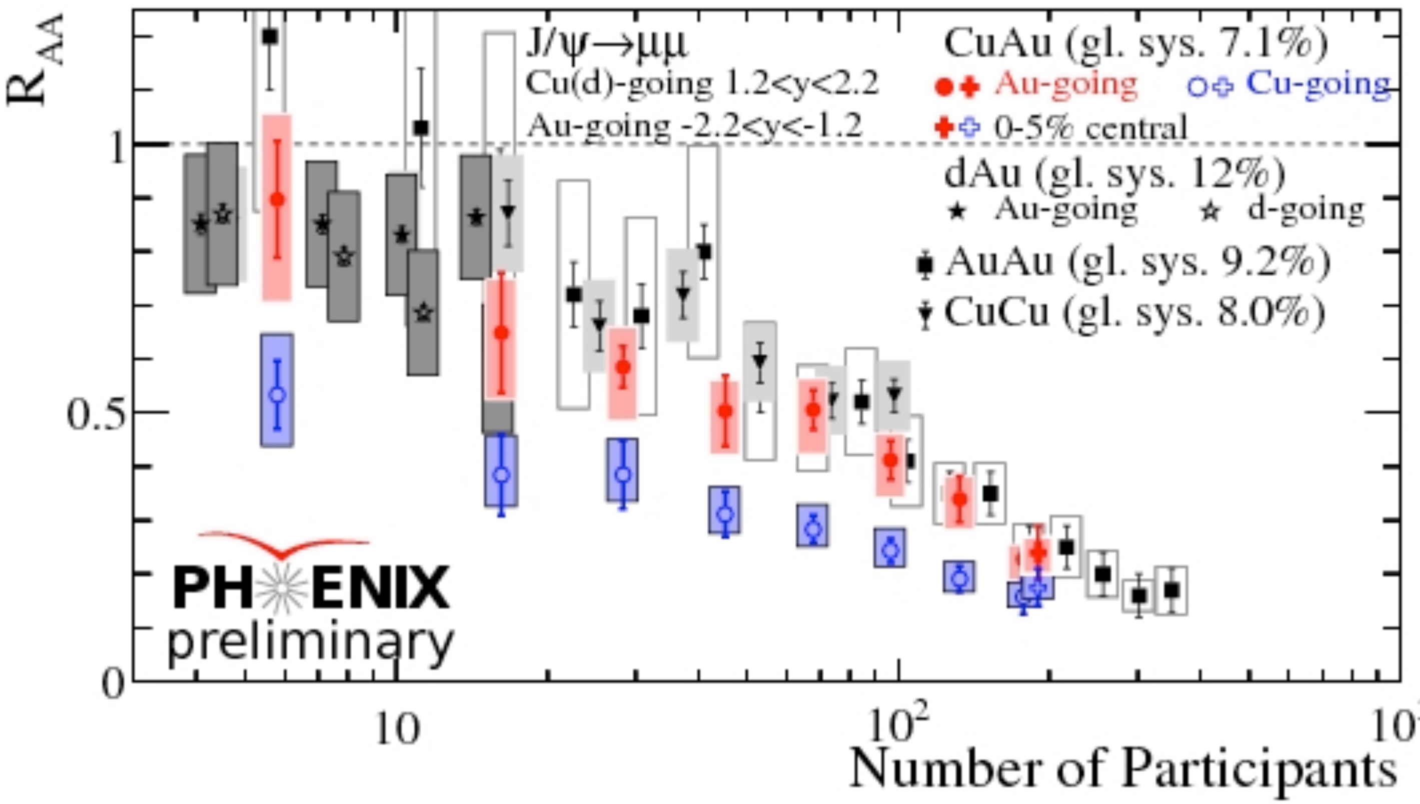
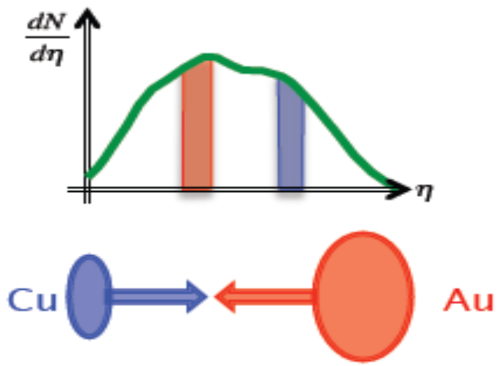
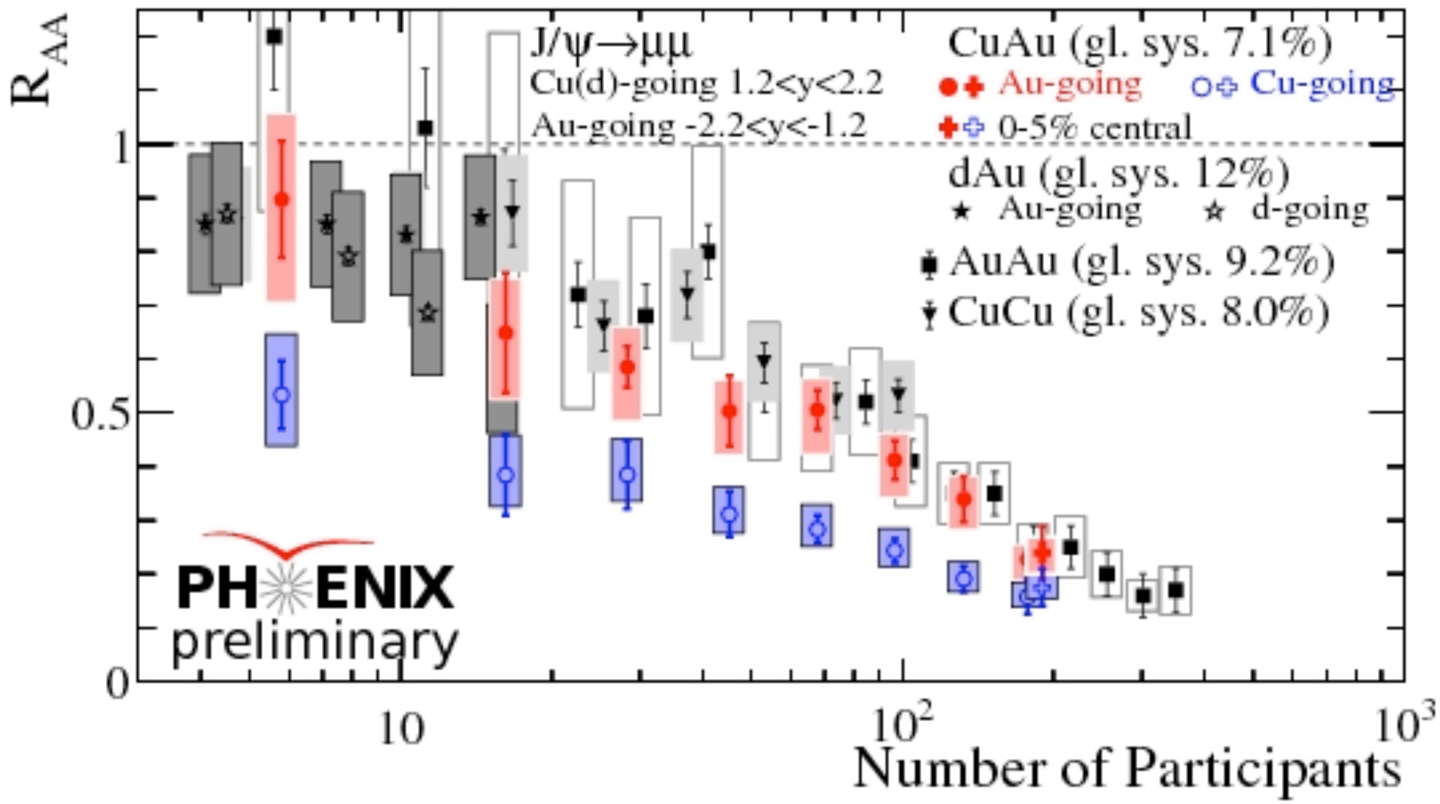




Puzzle #3

Cu+Au (Controlled Geometry)





Quantify Cold Nuclear Matter Effects

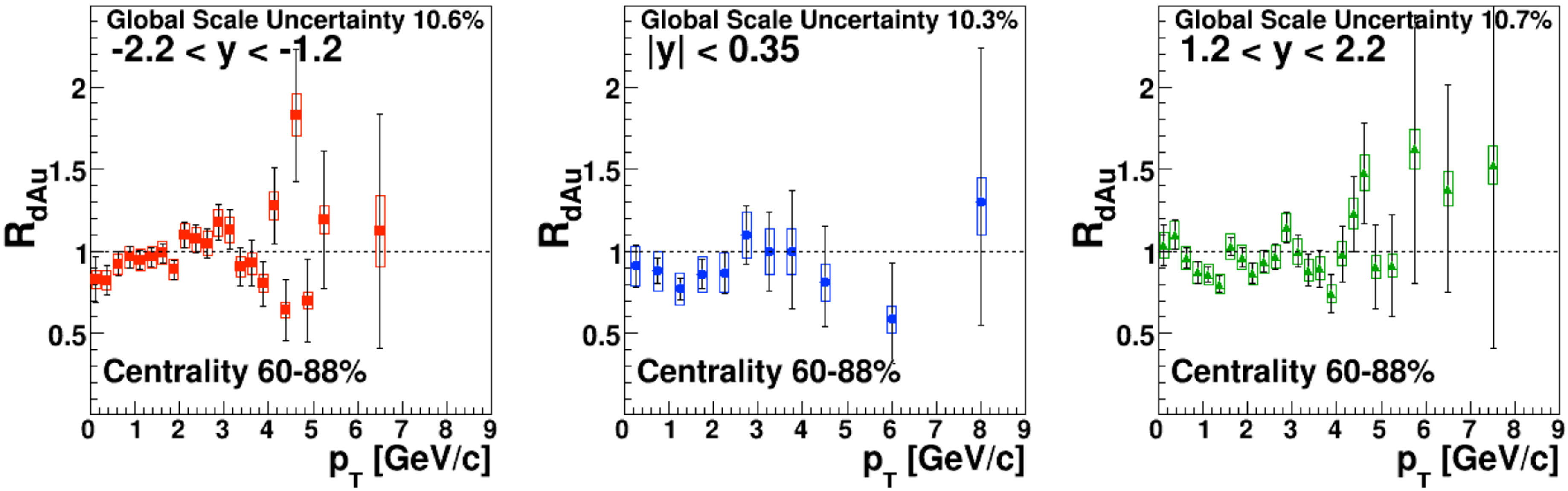
High statistics d+Au data set taken in 2008

- J/ψ production at 200 GeV at backward, mid, and forward rapidities as a function of centrality, y, and (new) p_T.
- (new) ψ' at midrapidity as a function of centrality.
- (new) χ_c at midrapidity

Centrality Dependence

60-88%

R_{dAu} consistent with 1 at all p_T for peripheral collisions



Phys. Rev. D 86, 092006 (2012)

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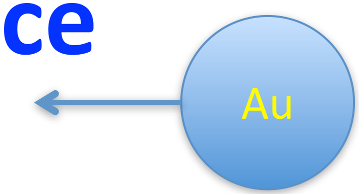

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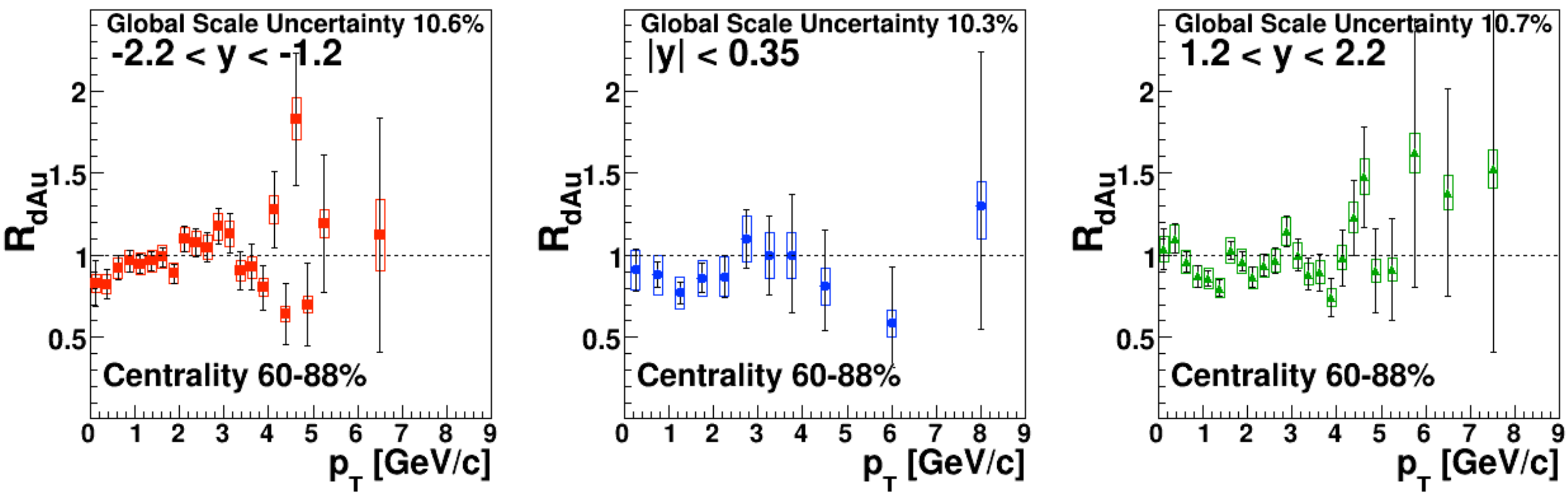
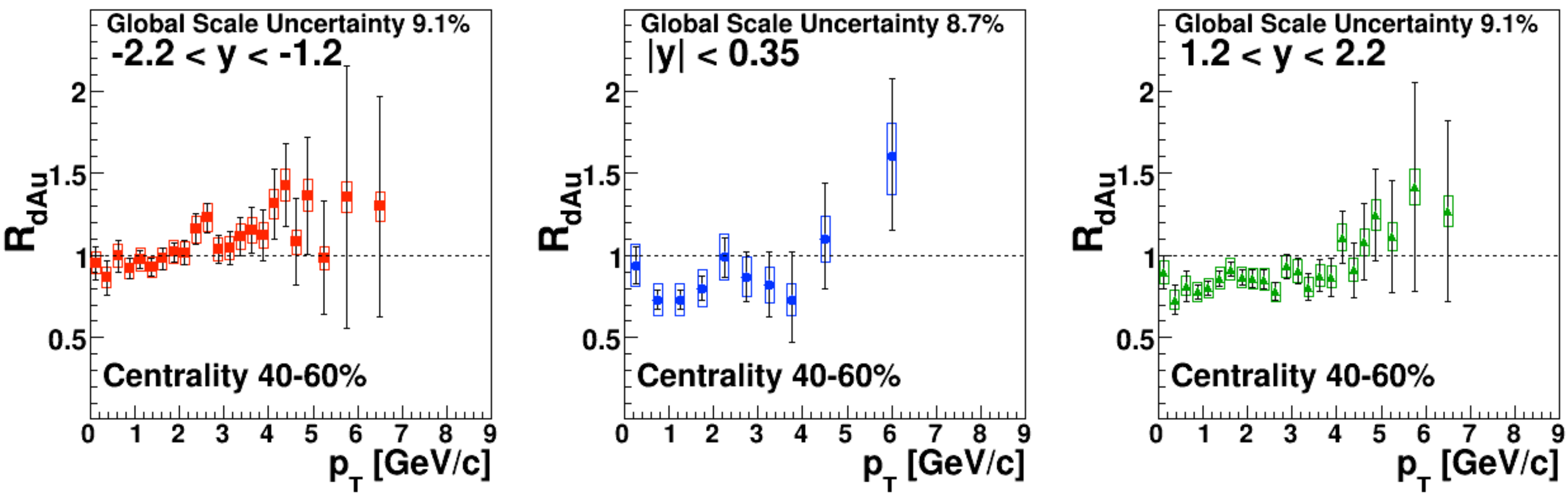


Phys. Rev. D 86, 092006 (2012)

Centrality Dependence

40-60%

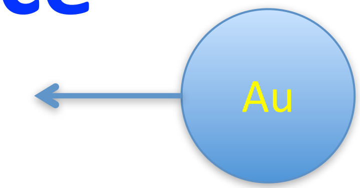
Increasing suppression at low-p_T when moving to central events



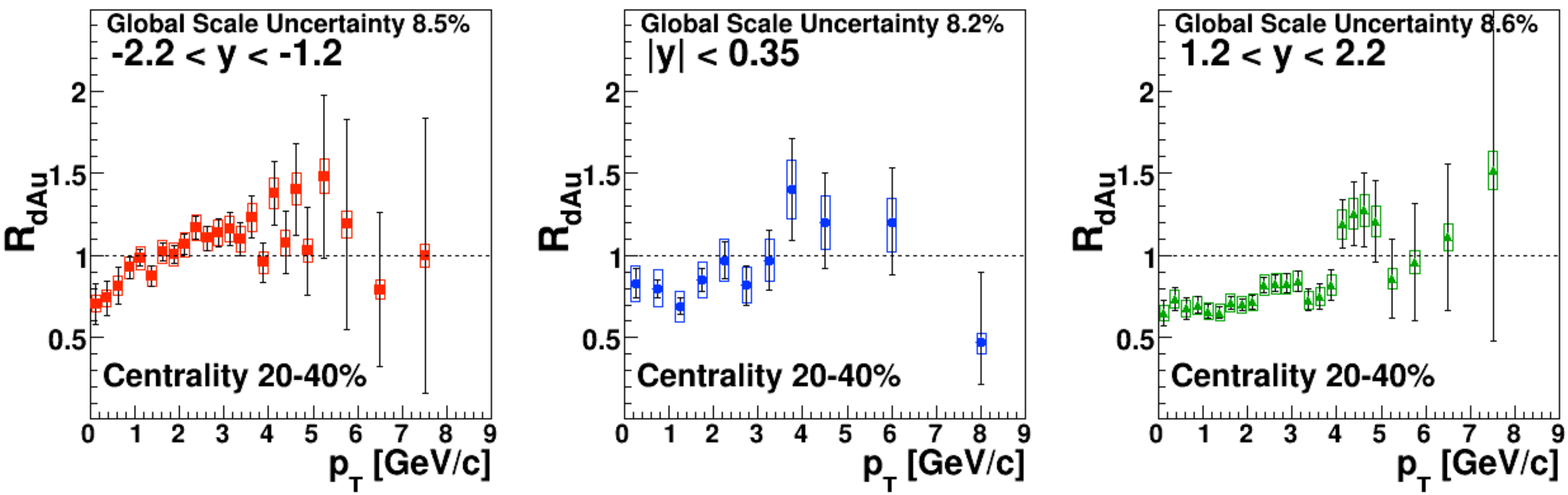
Phys. Rev. D 86, 092006 (2012)

Centrality Dependence

20-40%



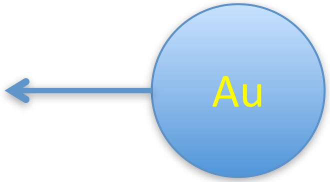
Increasing suppression at low-p_T when moving to central events



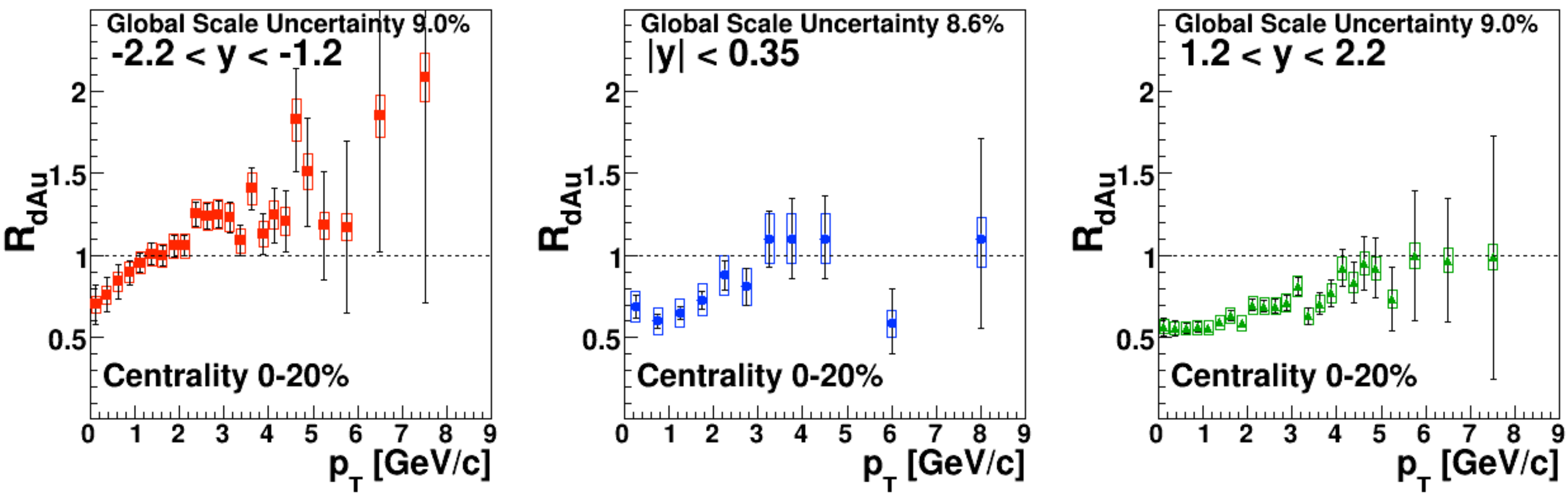
Phys. Rev. D 86, 092006 (2012)

Centrality Dependence

0-20%



Increasing suppression at low-p_T when moving to central events



Enhancement at high-p_T at backward rapidity

Implies R_{AA}(CNM) ≥ 1 at high-p_T in Au+Au

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J/ψ vs. p_T (0-100% centrality)

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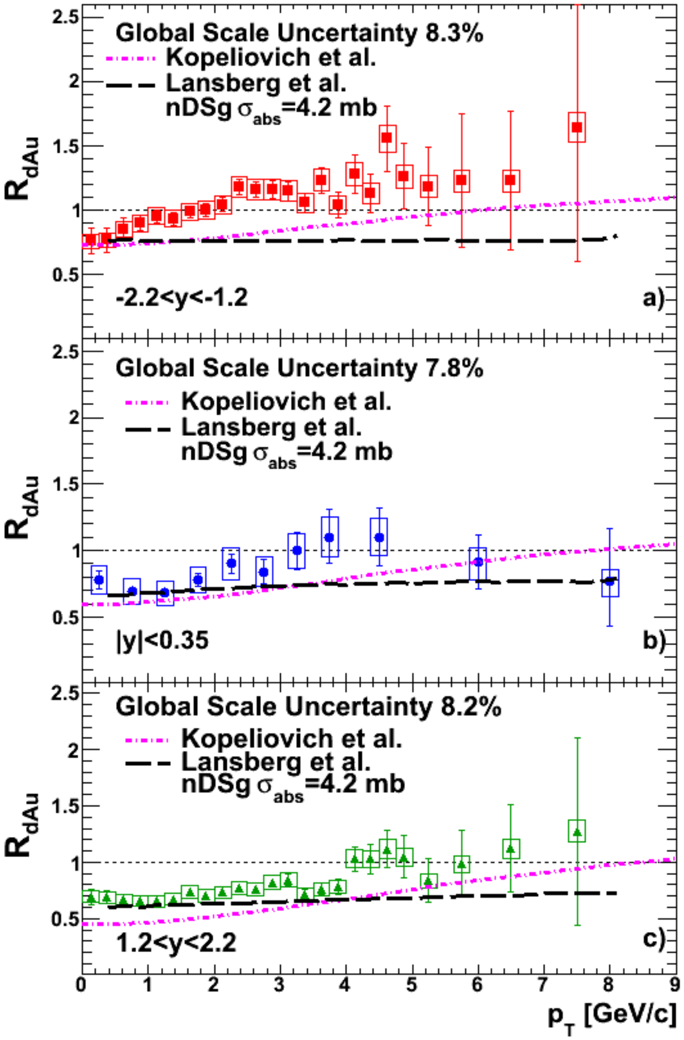


Minimum bias results.

Similar suppression at mid-rapidity and forward (d-going) rapidity.
Suppression below ≈ 4 GeV.
R_{dAu} ≈ 1 above 4 GeV.

Different R_{dAu} p_T dependence at forward (Au-going) rapidity.
Enhancement above ≈ 1 GeV.

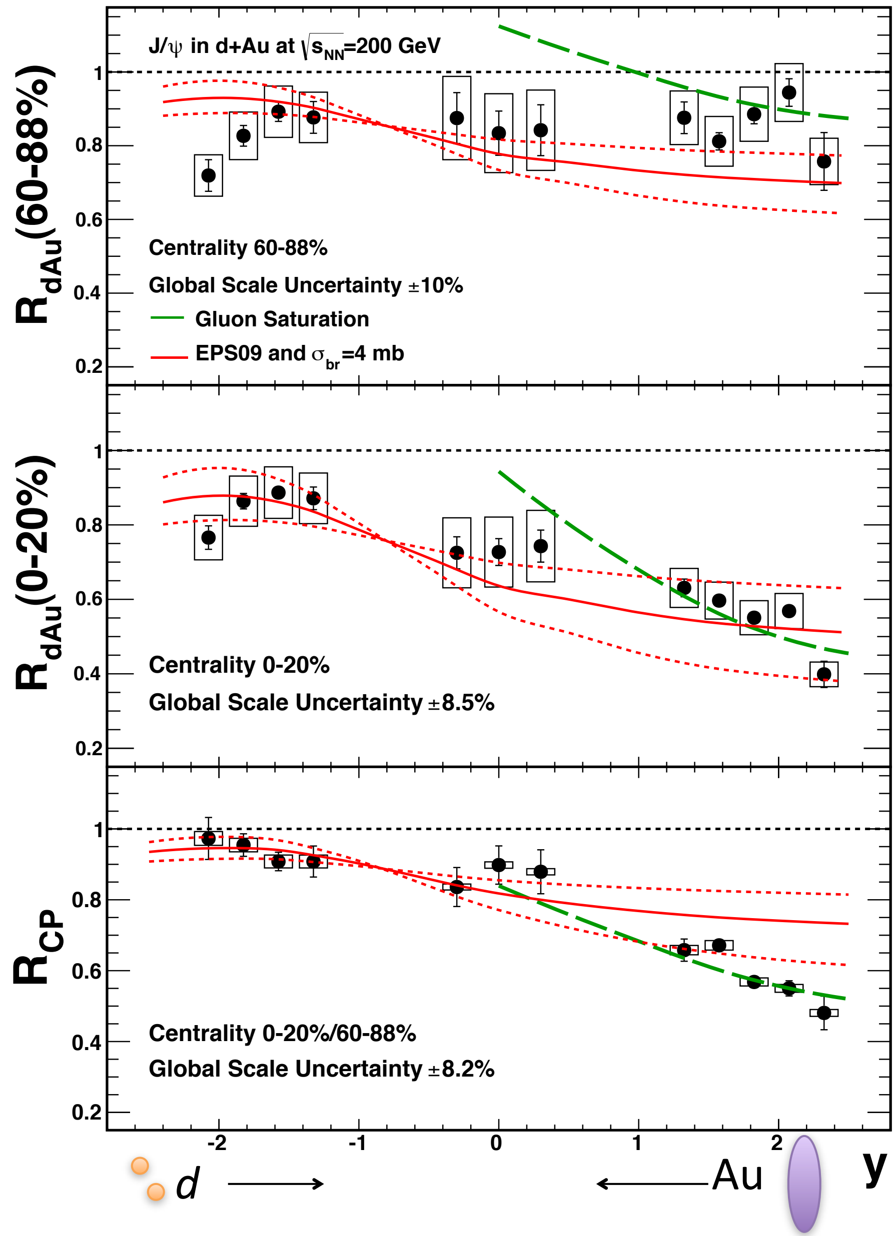
No clear explanation from theory for the forward result.

J/ψ in CNM

Phys. Rev. Lett. 107 (2011) 142301

J/ψ (integrated over pT) are suppressed at all rapidities, in all centralities.

The model, using shadowing (EPS09) + b$\sigma_{r,}$ qualitatively matches what we see, but cannot simultaneously capture the rapidity and centrality dependence.



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J/ψ in CNM

Phys. Rev. Lett. 107 (2011) 142301

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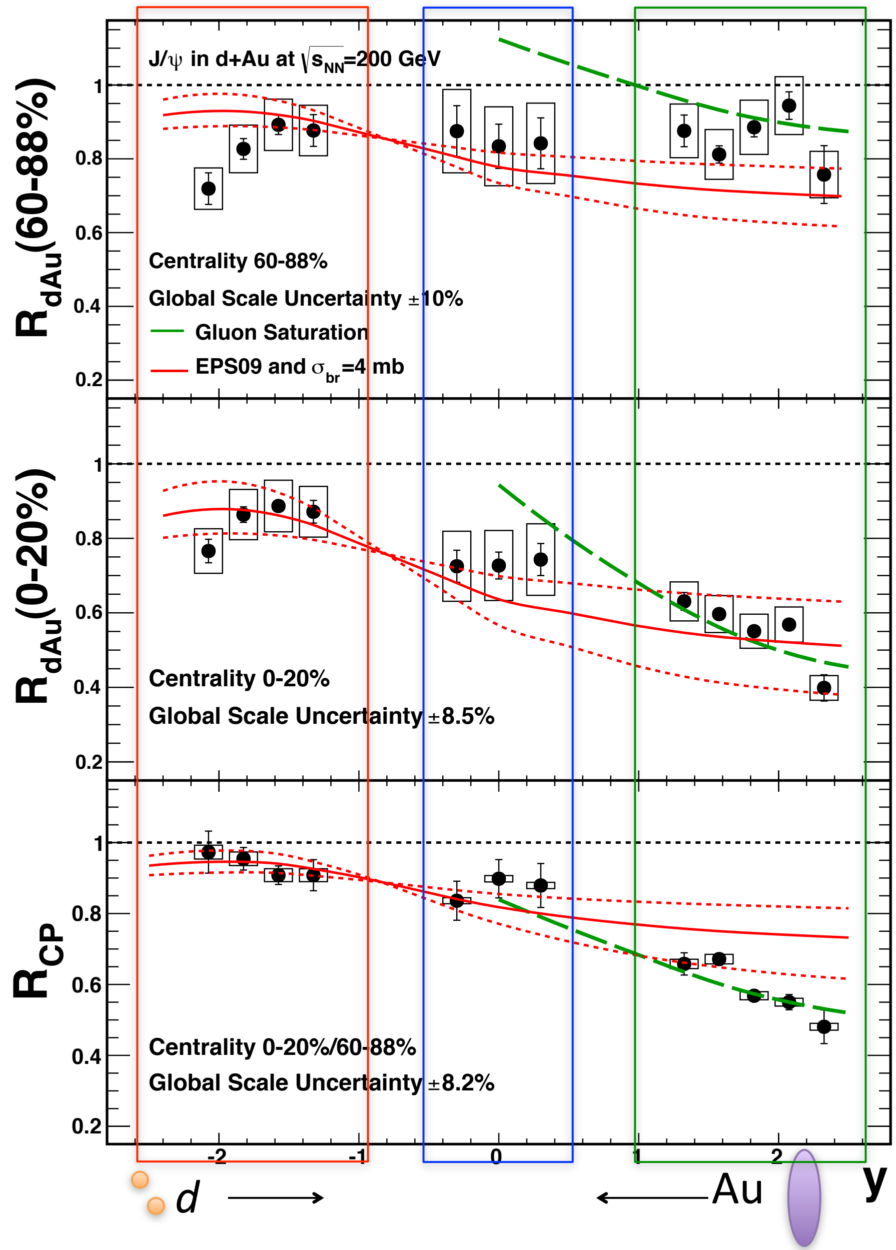
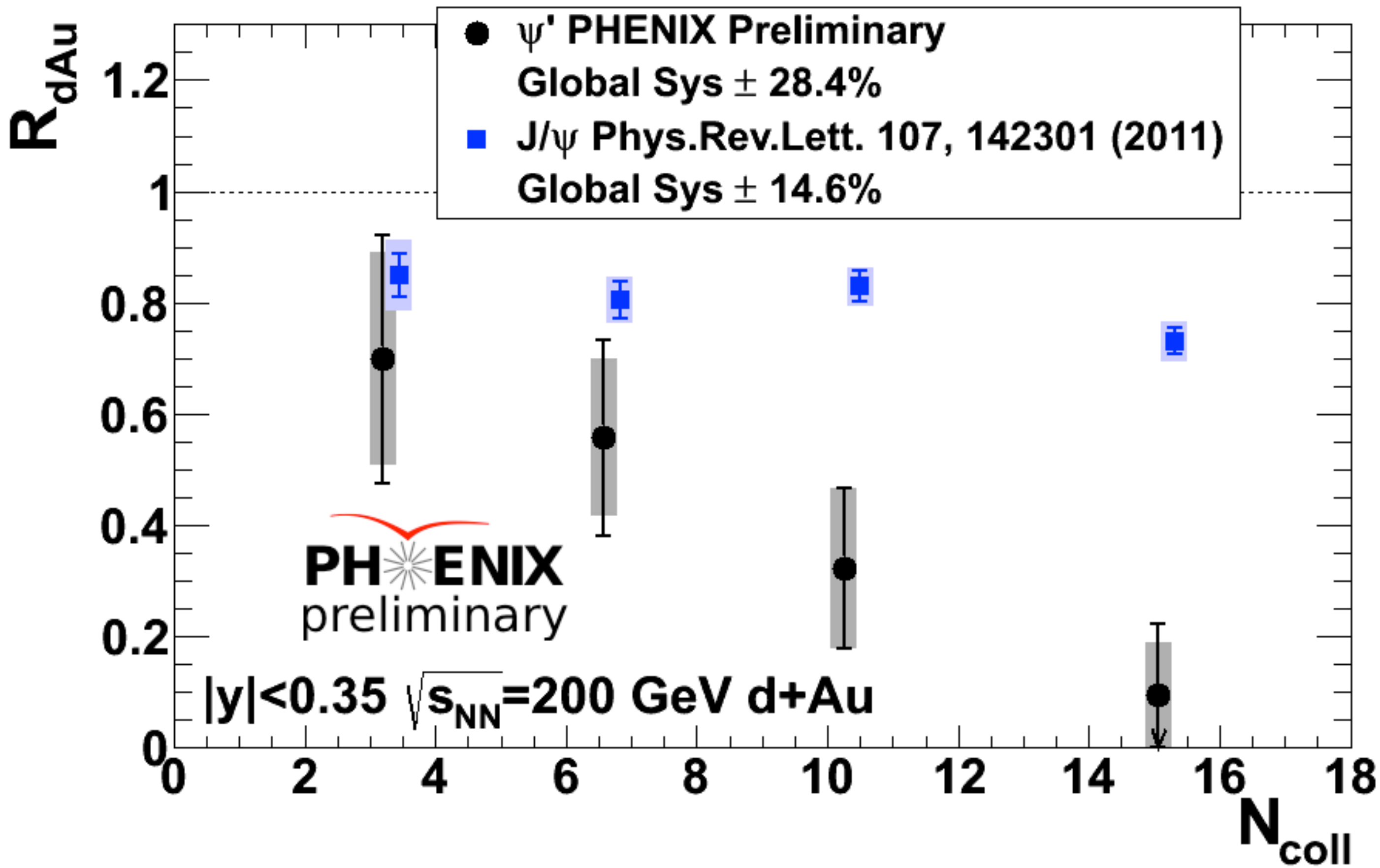


ψ' R_{dAu}

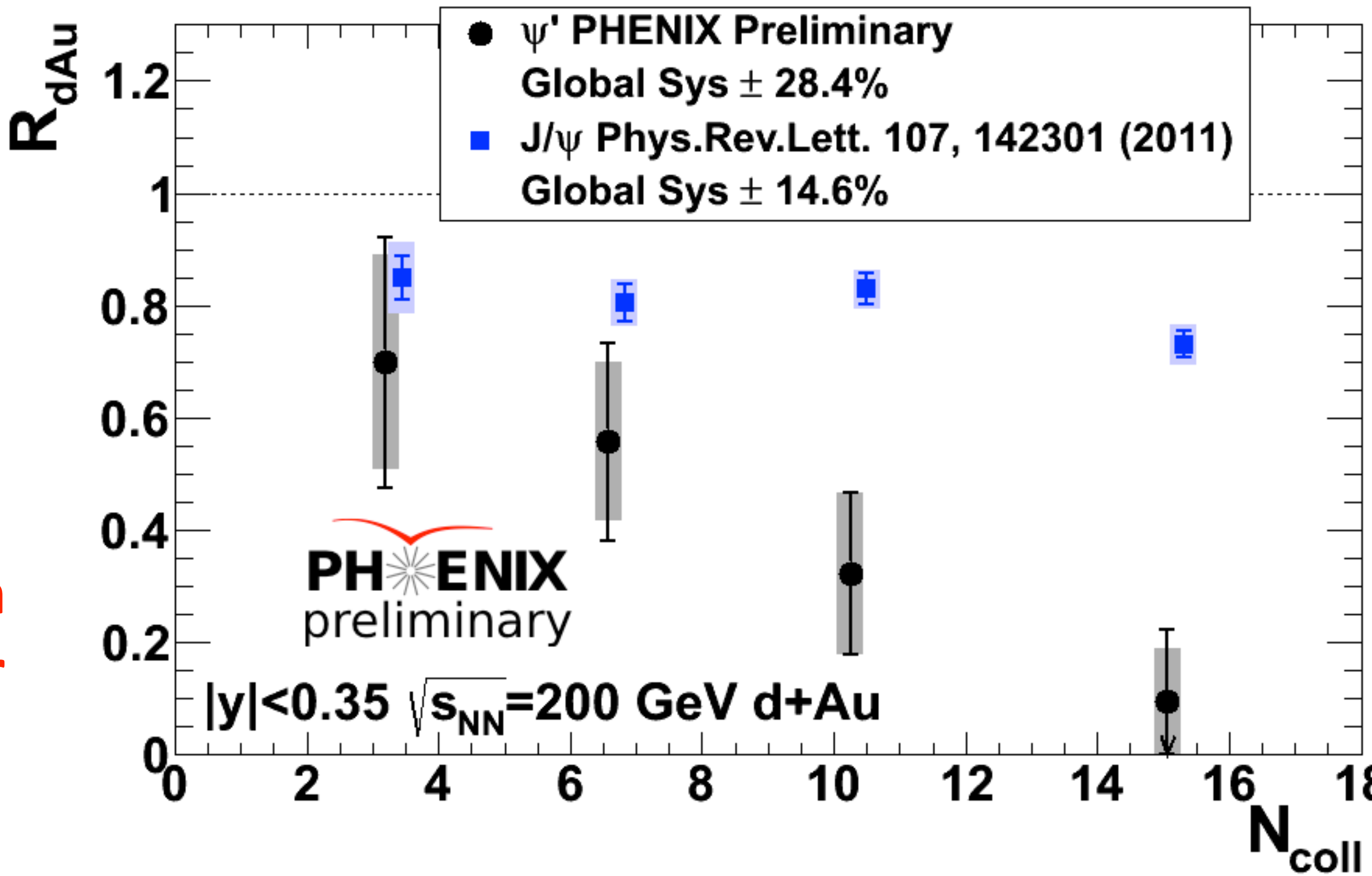
$$R_{dAu}{}^{\psi'} = \frac{[\psi'/(J/\psi)]^{dAu}}{[\psi'/(J/\psi)]^{pp}} R_{dAu}{}^{J/\psi},$$



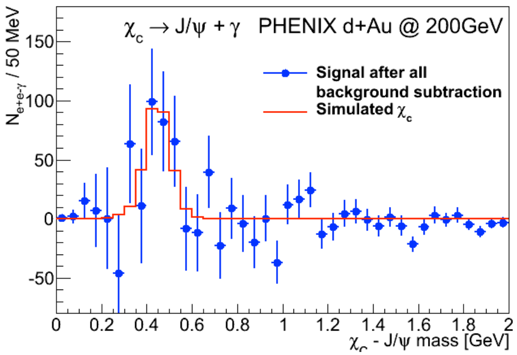
ψ' R_{dAu}

$$R_{dAu}{}^{\psi'} = \frac{[\psi'/(J/\psi)]^{dAu}}{[\psi'/(J/\psi)]^{pp}} R_{dAu}{}^{J/\psi},$$

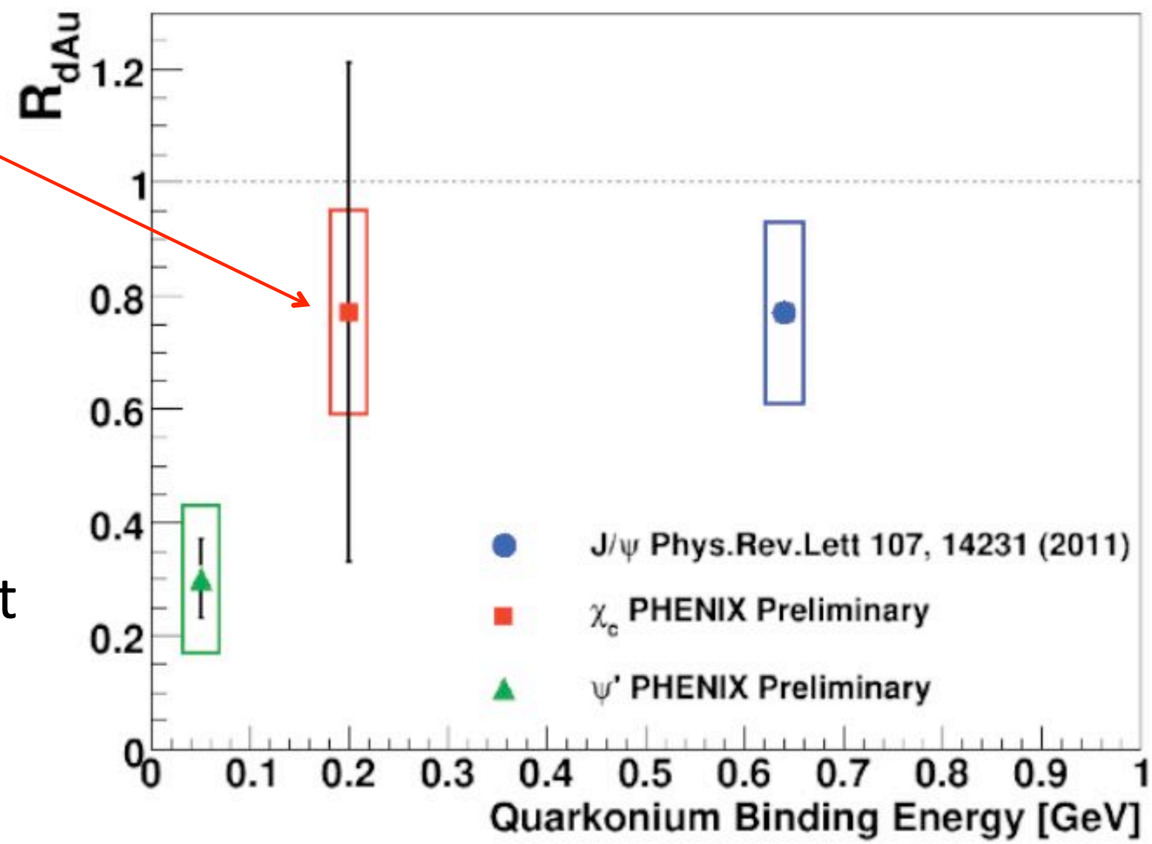
- Strong suppression with increasing Ncoll
- Centrality dependence of the suppression is even stronger at the mid-rapidity.



χ_c in d+Au



Charmonium R_{dAu} seems to depend on binding energy. Better χ_C measurement is needed though.



Summary and Outlook

- Showed three puzzles about J/ψ production at 200 GeV Au+Au collisions in comparison with the results from LHC Alice experiment and at RHIC low energy runs.
- All signs indicate that one has to carefully disentangle the cold nuclear matter effects on J/ψ production in order to exclusively extract color screen effects from a QGP medium.
- PHENIX has made measurement of J/ψ production from d+Au collisions at 200 GeV in 2008. This data set allows us to study the J/ψ production as a function of collision centrality, pT, and rapidity, which provides important constraints on theoretical modeling of cold nuclear effects on quarkonium production.
- This work only presents one part of our systematic studies of QGP properties using heavy flavor probes in heavy ion collisions. Stay tuned!

Thank you

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14 countries, 73 institutions, Jan. 2013

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Direct-γ R_{AA} is near zero