PHENIX Quarkonium Results

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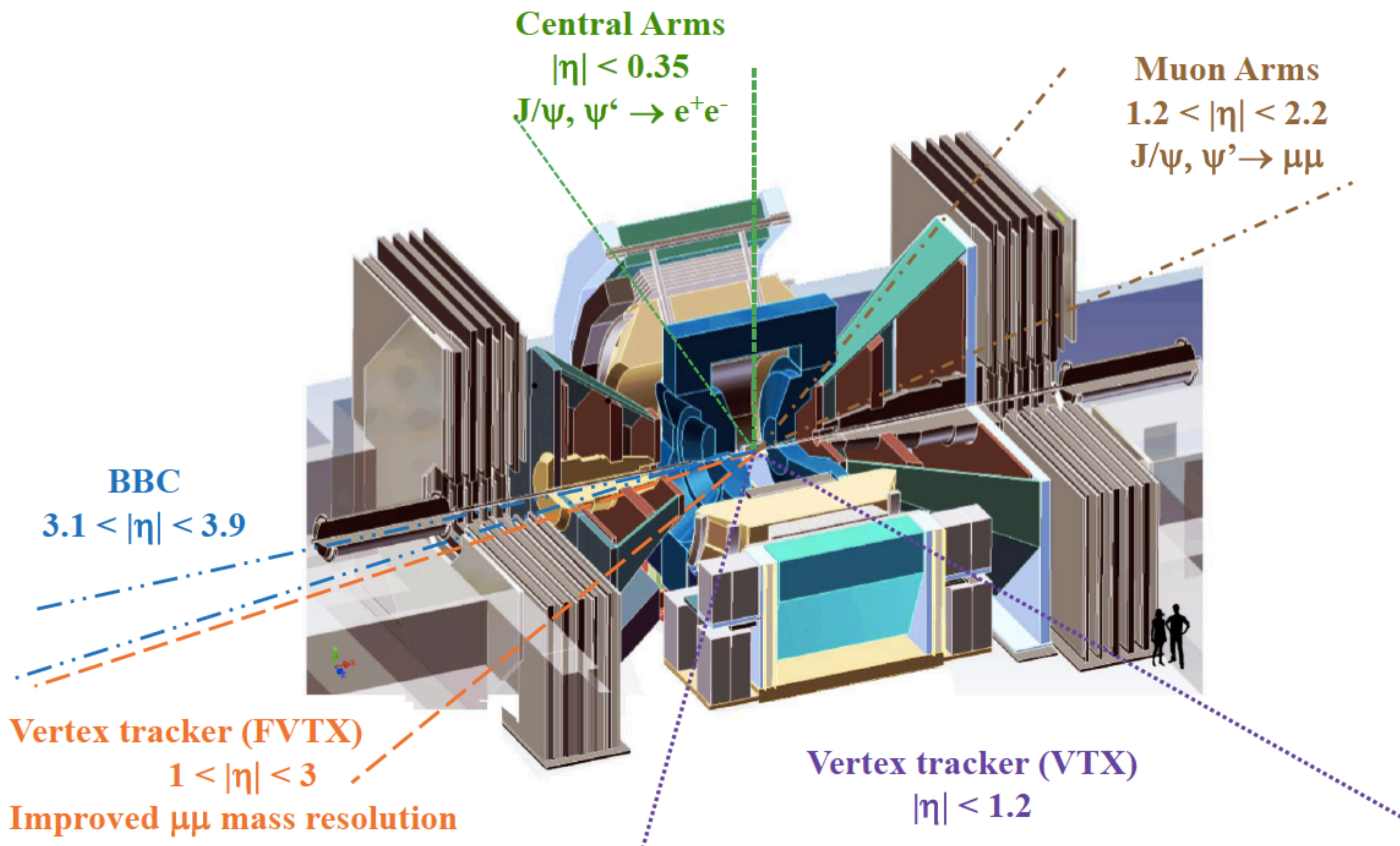
Quarkonia - PHENIX



Di-leptons measured in y = (-2.2, -1.2) (-0.35, 0.35) (1.2, 2.2)

- No triggering required in Au+Au
- Efficient triggers in p+p, (p,d,^{3}He)+A

Introduction

Recent quarkonium analyses in PHENIX have focused on small systems results for J/ψ and ψ(2S).

p+Al, p+Au and ^{3}He+Au data from the 2014 and 2015 RHIC runs have been added to our d+Au data from 2008.

The recent quarkonium data are all at forward and backward rapidity (no new central arm data).

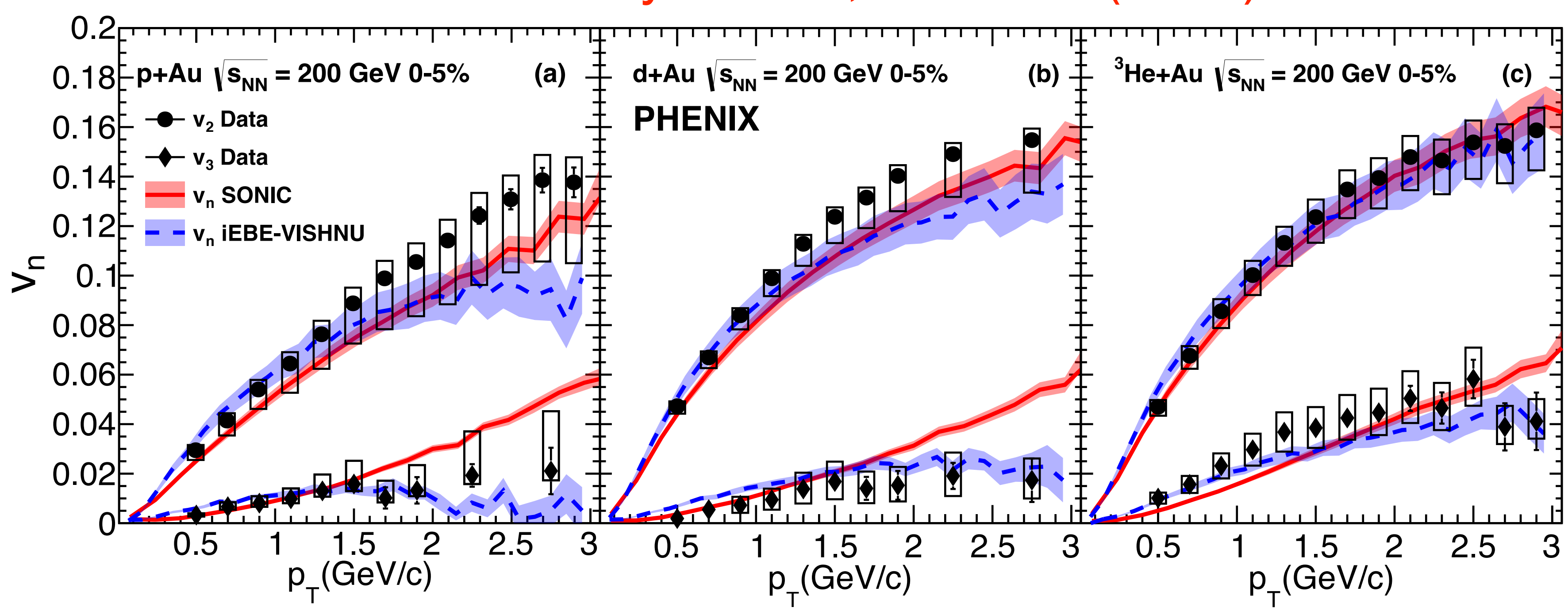
In the in-medium program, we measure modifications of quarkonia production in p+A or A+A collisions **relative to** p+p collisions.

- Interested in low/medium p_T, where modifications are largest.
- Not sensitive to production mechanism.
- Not sensitive to some experimental systematic uncertainties.

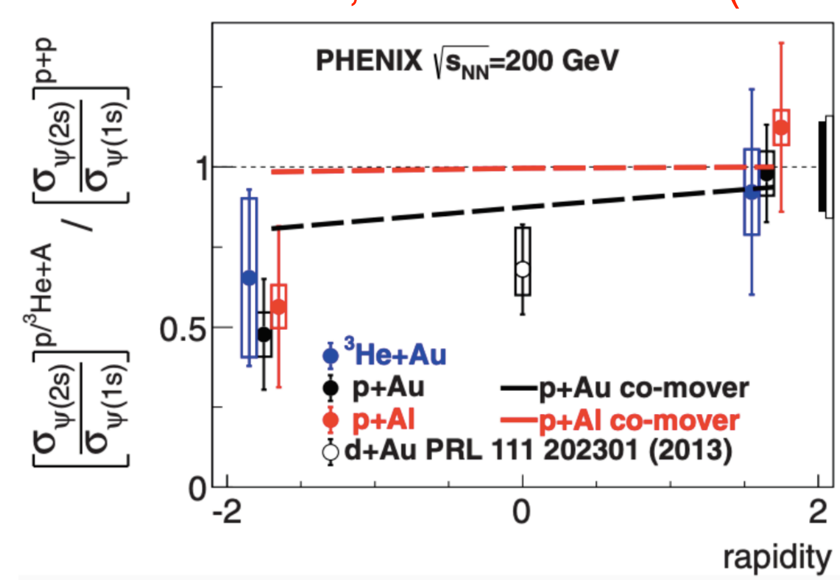
Motivation for studying light systems

- Interest in p+A partly motivated by the A+A program
  - p+A is sensitive to initial state effects that are not theoretically well understood.
  - Assumed for a long time only initial state effects present in p+A.
- **But:**
  - Unexpectedly strong suppression of the ψ(2S) observed in d+Au collisions at RHIC, and then in p+Pb collisions at LHC.
  - The observation of flow in small systems, observed first at LHC and then at RHIC.
  - Final state effects on quarkonia production in p+A?

Nature Physics 15, 214-220 (2019)



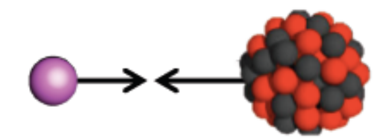
PHENIX, PRC95 034904 (2017)

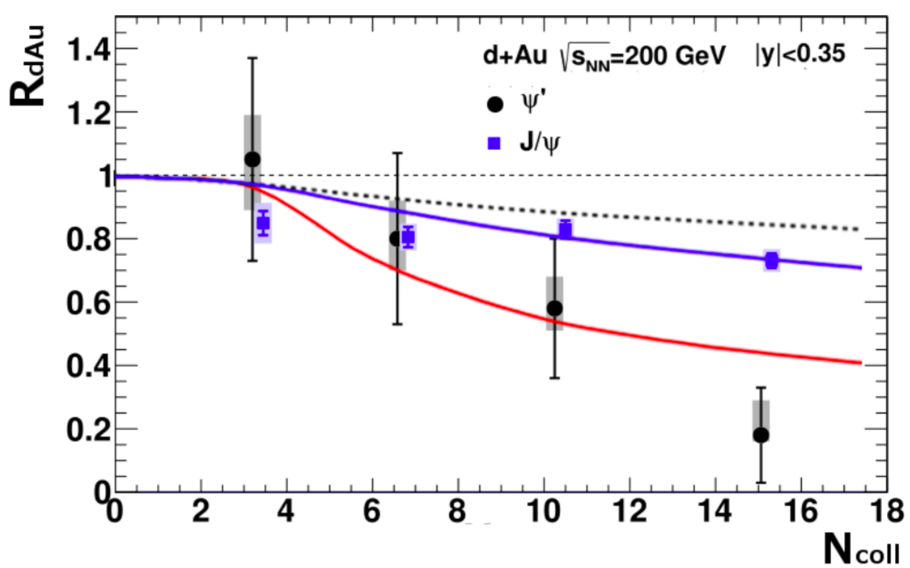


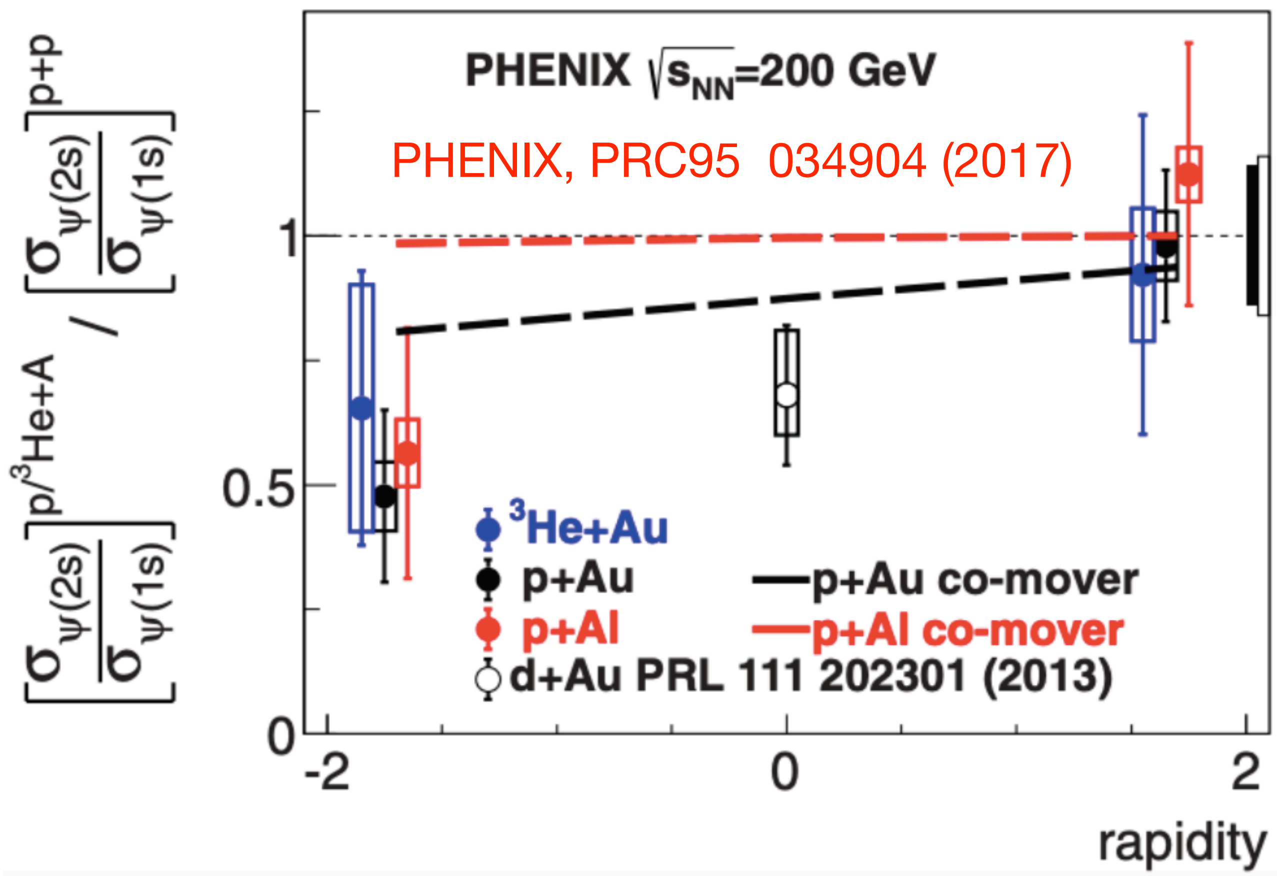
ψ(2S) results

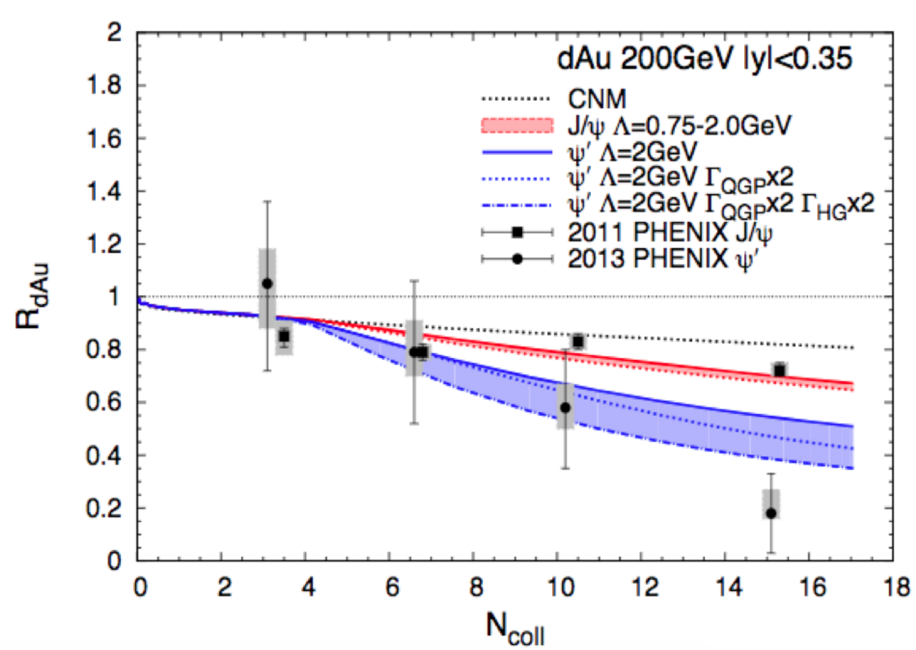
Strong suppression at backward rapidity relative to J/ψ

- Not explained by CNM effects
- Suggestive of a final state effect





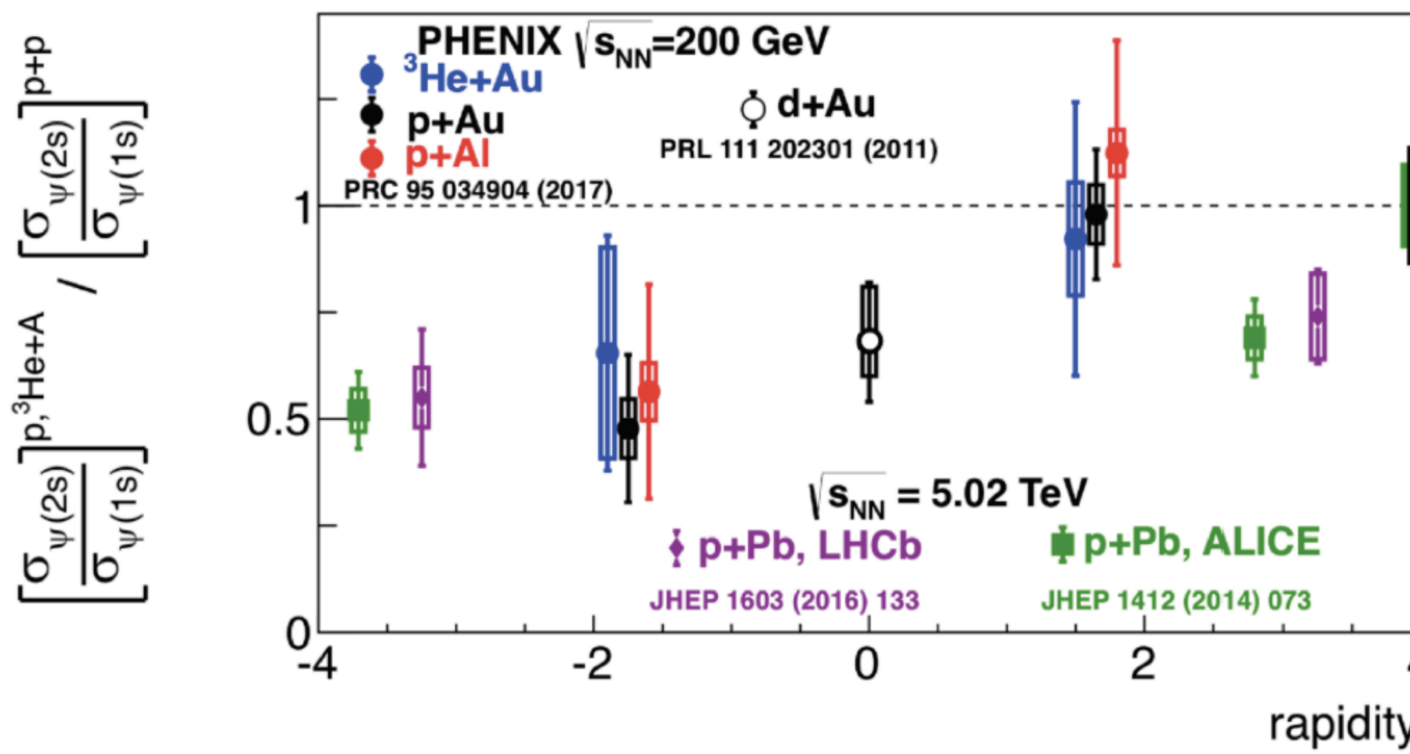


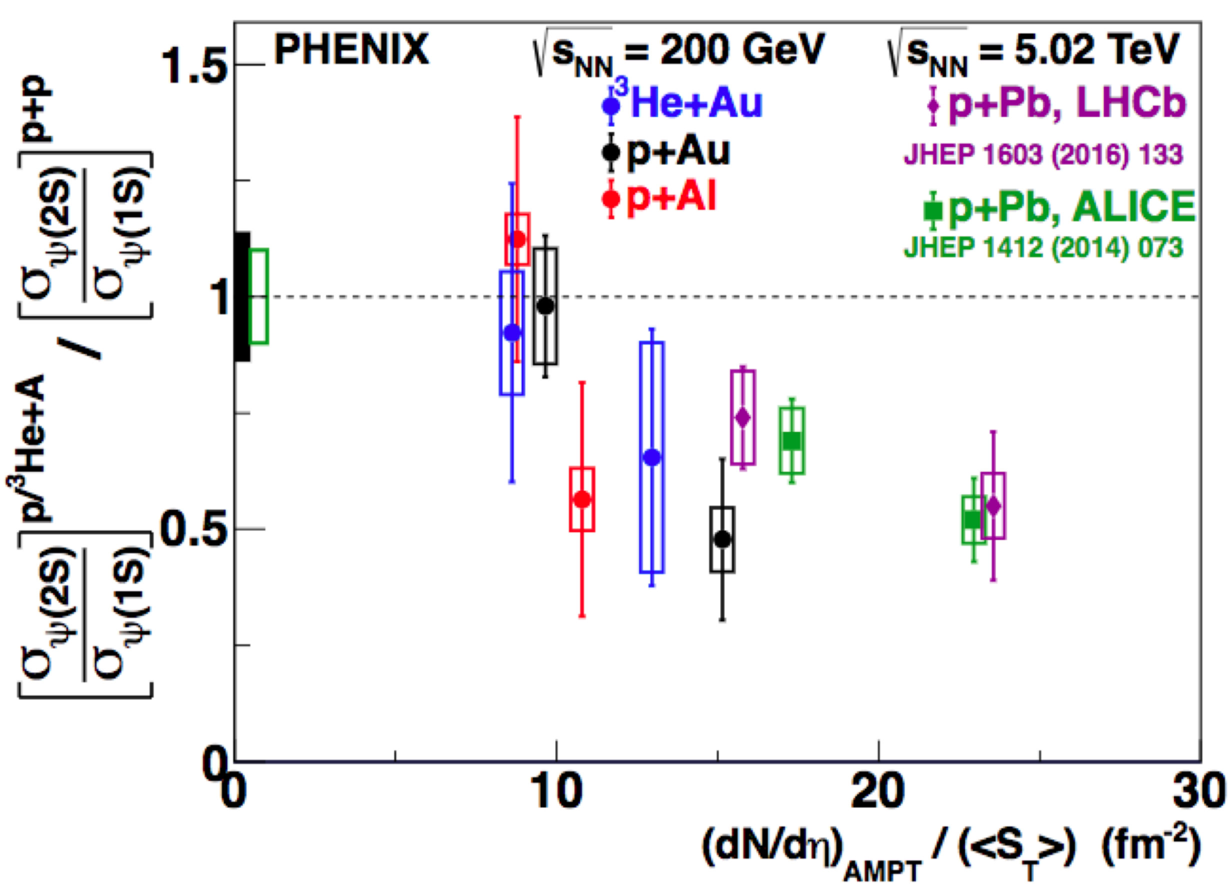


Mid-rapidity data are well described by calculations involving comovers or a short lived plasma phase

RHIC + LHC ψ(2S) data compared

Pattern not so clear when plotted against rapidity





But it makes more sense when plotted vs dN/dη

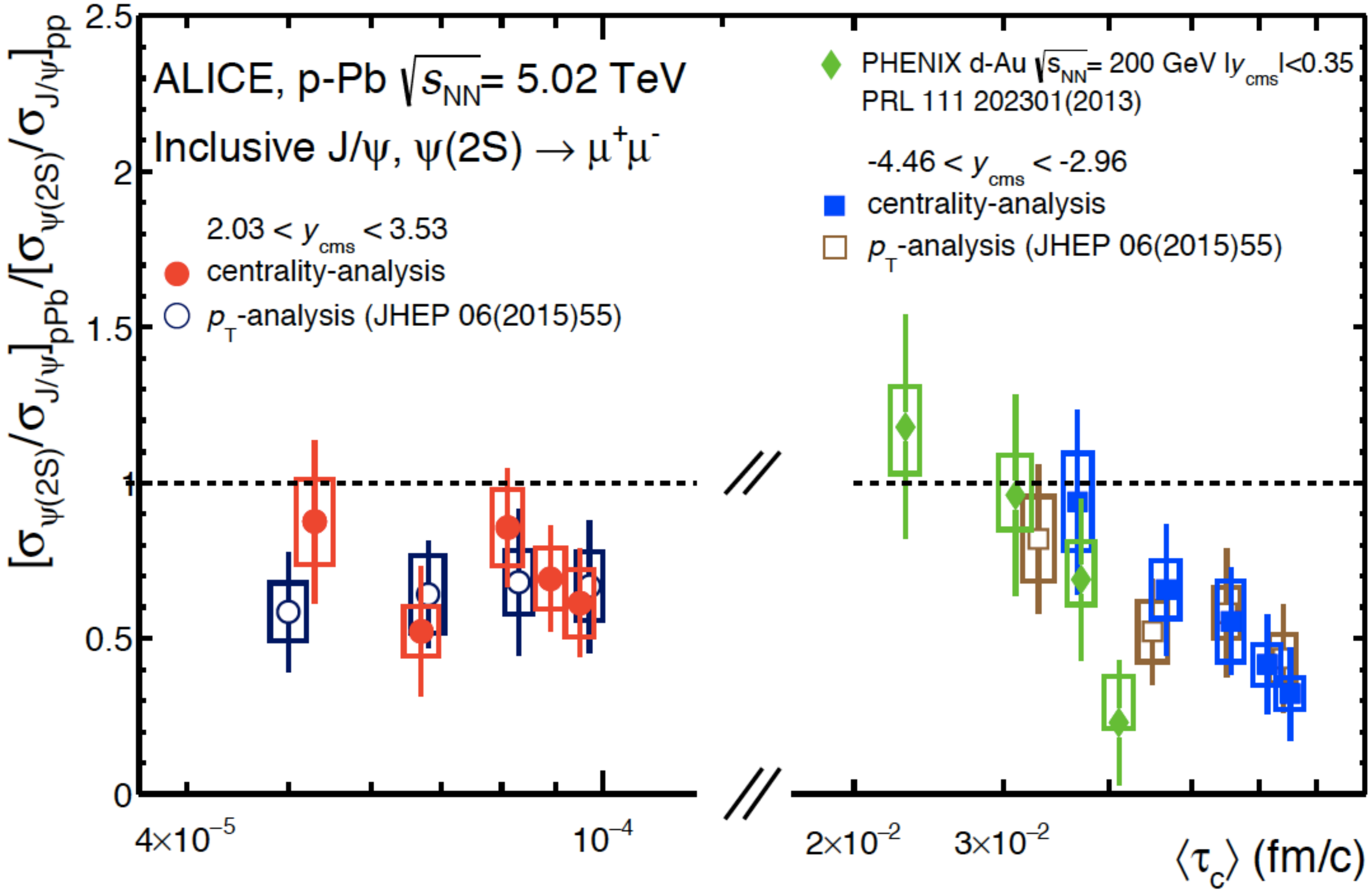
However: ψ(2S) in p+Pb at 5.02 TeV, d+Au at 0.2 TeV - dependence on time in nucleus?

Hmm…

Not clear what mechanism would produce strong differential suppression at ~0.5 - 1 fm/c.

forward/backward rapidity measurements in PHENIX would help a lot to fill this in!

ALICE, JHEP 1606 (2016) 050



An attempt to put p+A charmonium together

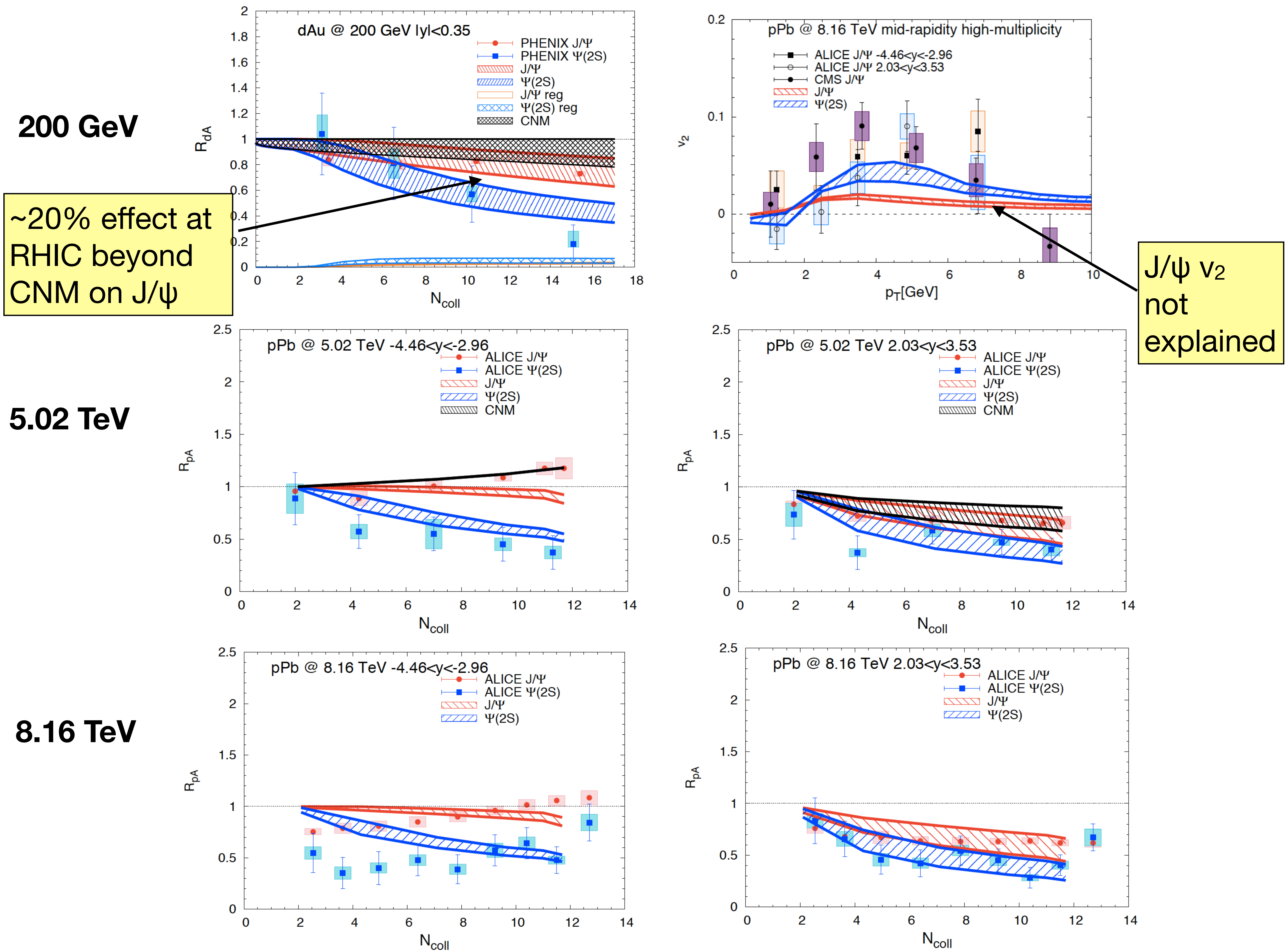
Du and Rapp (JHEP 1903 (2019) 015) have adapted their transport model, used to describe heavy ion collisions, for small systems. They try to describe all available charmonium J/ψ and ψ(2S) data from RHIC and LHC, including the J/ψ v_2.

The transport model uses

- A rate equation approach within a fireball model
- Initial geometry of the fireball from a Monte-Carlo event generator
- Initial anisotropies are caused by fluctuations
- Includes corrections for CNM effects

The results for J/ψ, ψ(2S) centrality dependence and J/ψ v_2 are shown on the next slide.

- The calculations also provide a good description of the p_T dependence — not shown here.


200 GeV
~20% effect at RHIC beyond CNM on J/ψ
dAu @ 200 GeV |y|<0.35
PHENIX J/Ψ
PHENIX Ψ(2S)
J/Ψ
Ψ(2S)
J/Ψ reg
Ψ(2S) reg
CNM
R_dA
N_coll
pPb @ 8.16 TeV mid-rapidity high-multiplicity
ALICE J/Ψ -4.46<y<-2.96
ALICE J/Ψ 2.03<y<3.53
CMS J/Ψ
J/Ψ
Ψ(2S)
v_2
p_T[GeV]
J/ψ v_2 not explained
5.02 TeV
pPb @ 5.02 TeV -4.46<y<-2.96
ALICE J/Ψ
ALICE Ψ(2S)
J/Ψ
Ψ(2S)
CNM
R_pA
N_coll
pPb @ 5.02 TeV 2.03<y<3.53
ALICE J/Ψ
ALICE Ψ(2S)
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ALICE J/Ψ
ALICE Ψ(2S)
J/Ψ
Ψ(2S)
R_pA
N_coll
pPb @ 8.16 TeV 2.03<y<3.53
ALICE J/Ψ
ALICE Ψ(2S)
J/Ψ
Ψ(2S)
R_pA
N_coll

J/ψ results

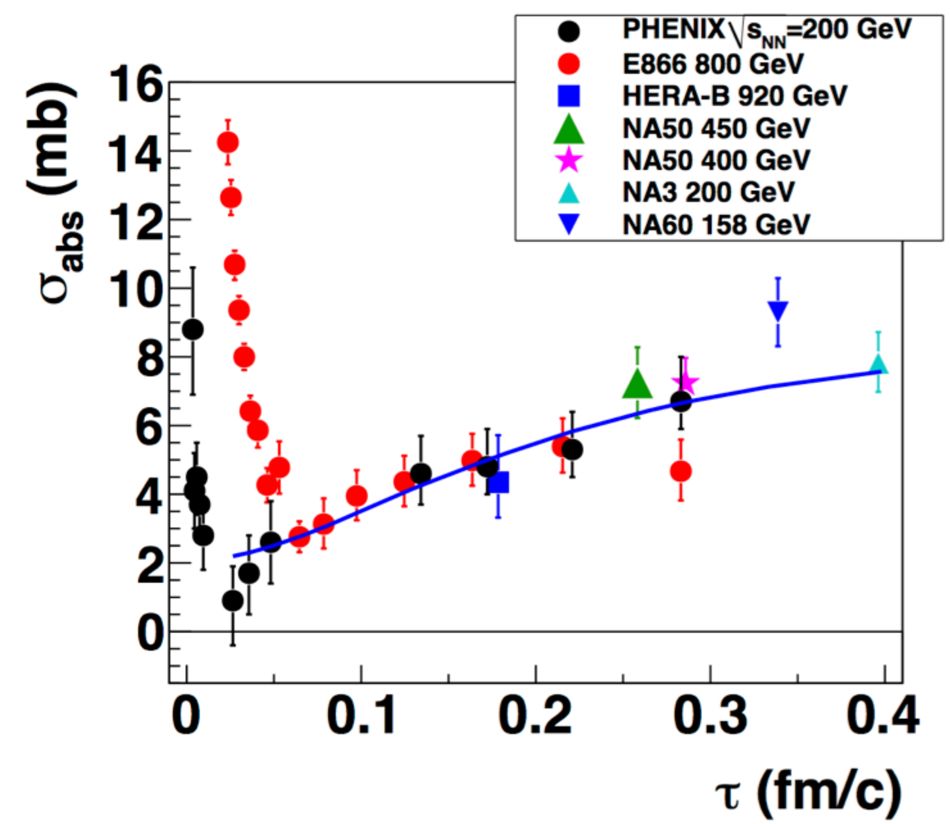
Explore in detail the effect of projectile size on inclusive J/ψ modification in p/d/^{3}He+Au collisions.

Expect any such effects to be largest at backward rapidity.

Note that backward rapidity J/ψ in PHENIX experience a significant breakup cross section from collisions with target nucleons (in addition to substantial anti-shadowing).

- However there is no reason to expect either shadowing or breakup to be different for these three light projectiles.

Phys.Rev. C87 (2013) 5, 054910

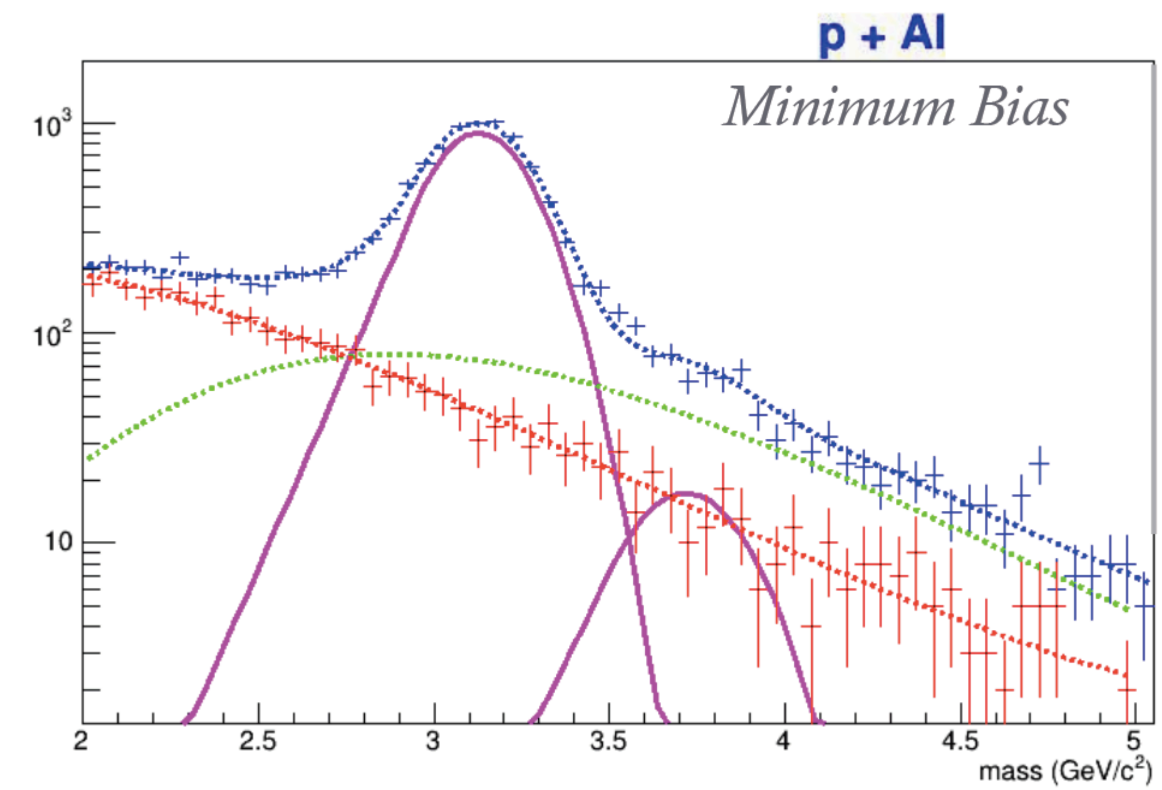


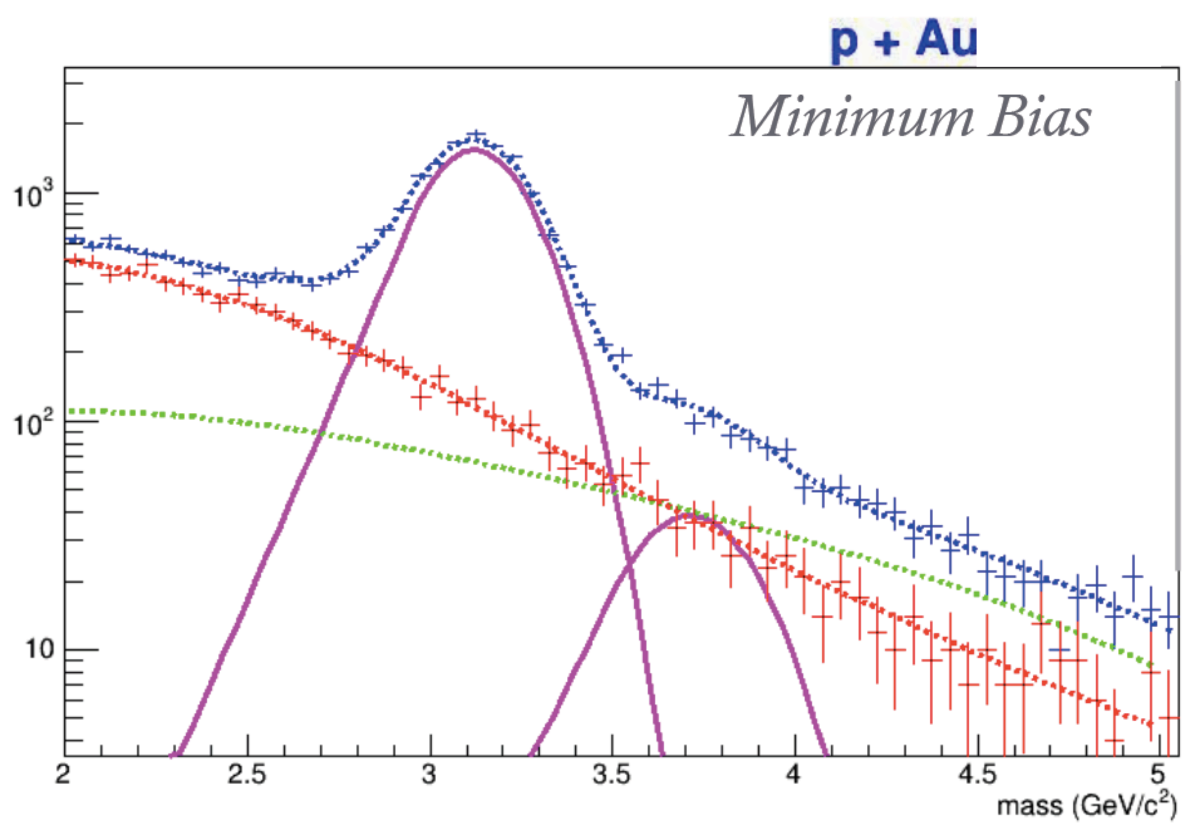
J/ψ Measurement

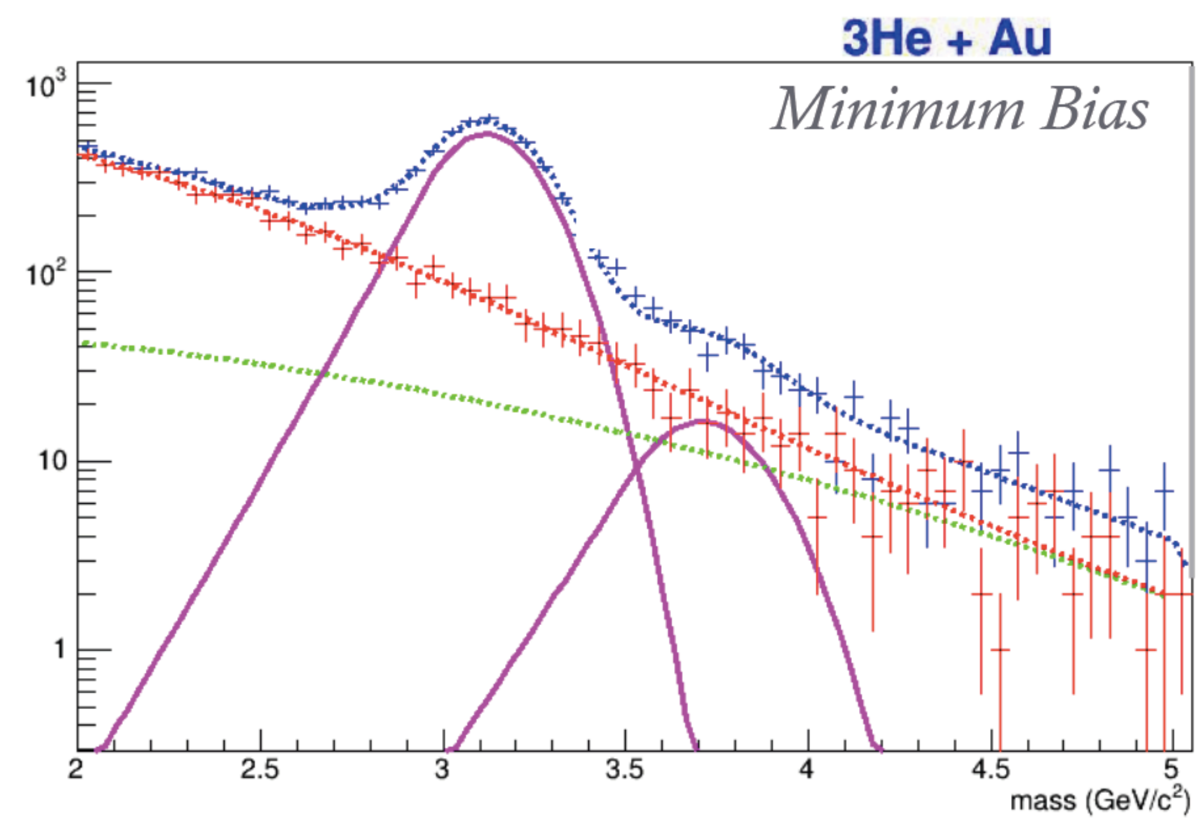
Dimuon invariant mass spectra for p+Al, p+Au and ^{3}He+Au

With fitted J/ψ peak and various background sources shown

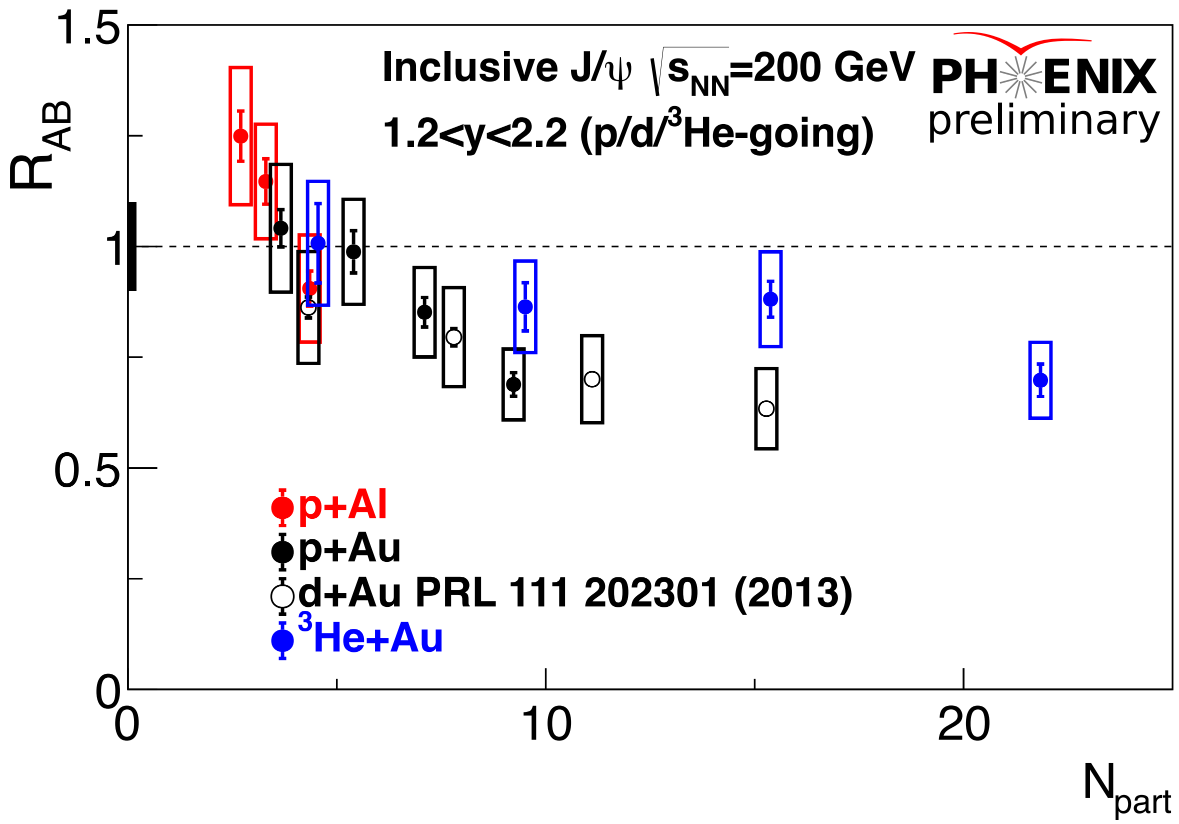
- Red : combinatoric from like-sign.
- Green: non- combinatoric (physics) background estimate.

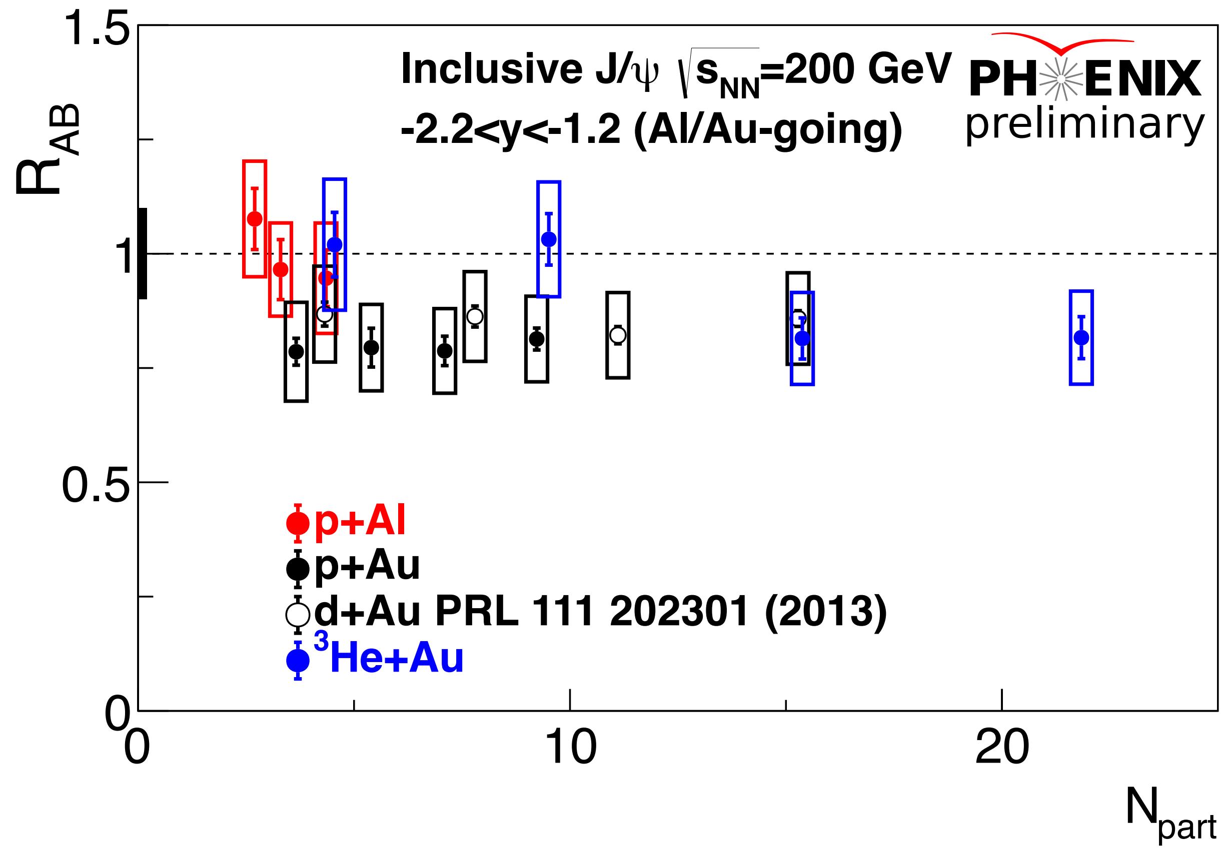






p_T integrated J/ψ vs centrality



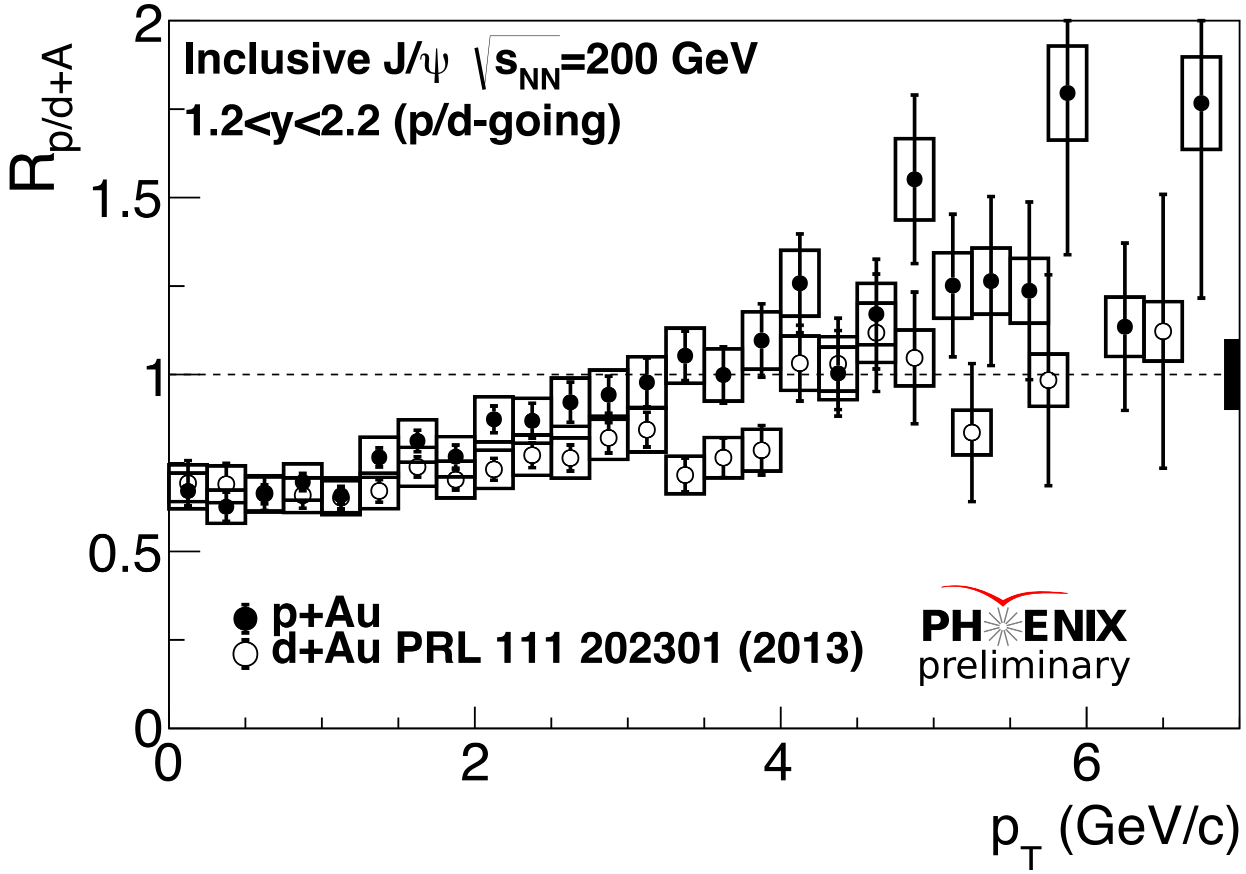


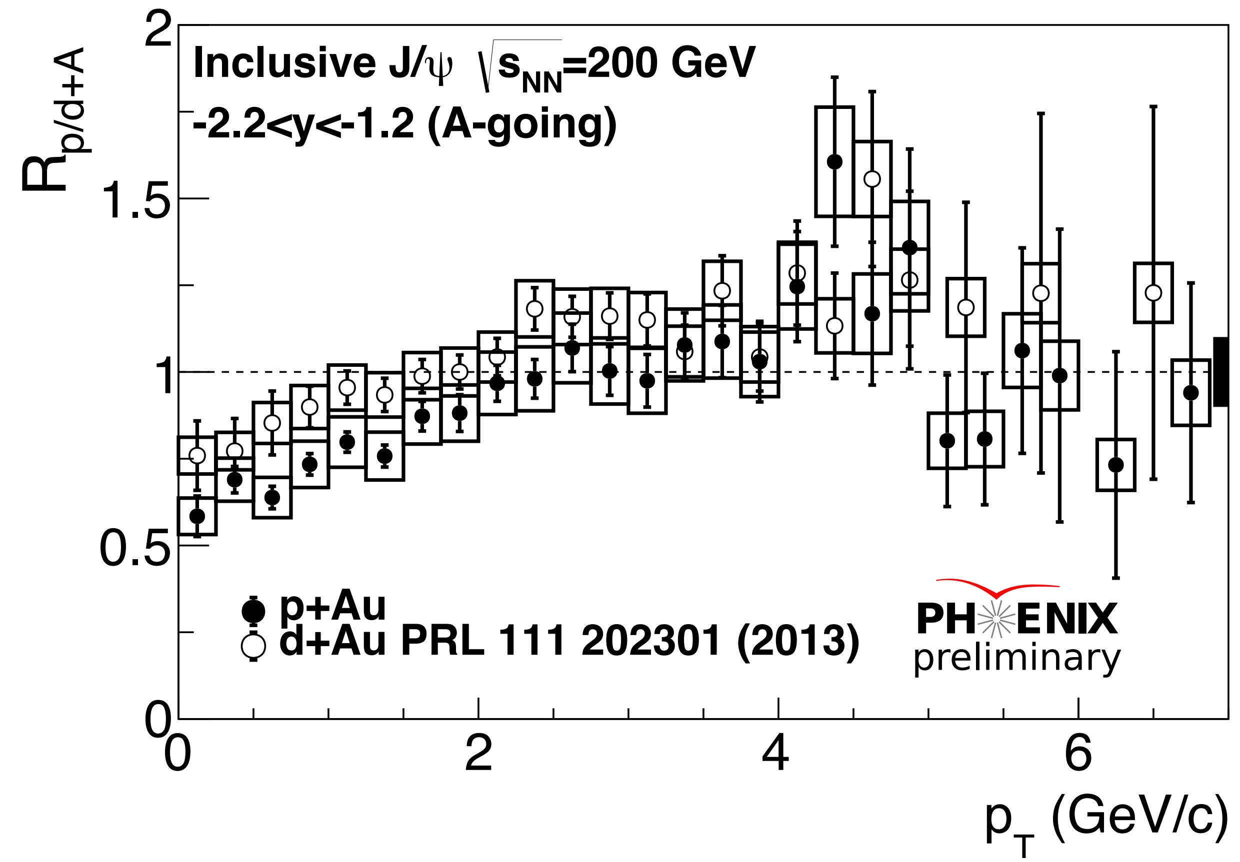
No apparent scaling with N_{part} at forward rapidity.

Hard to tell at backward rapidity, since Ncoll is relatively flat.

J/ψ p+Au (2015) vs d+Au (2008)

0-100% centrality



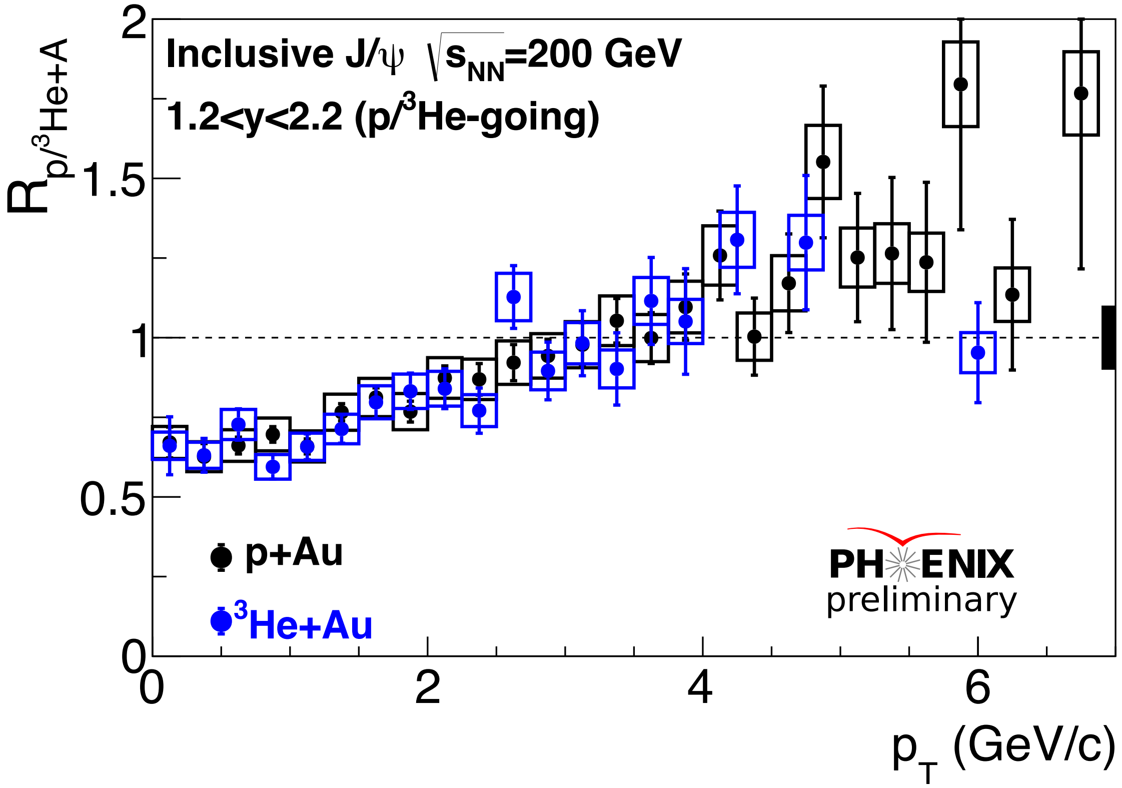


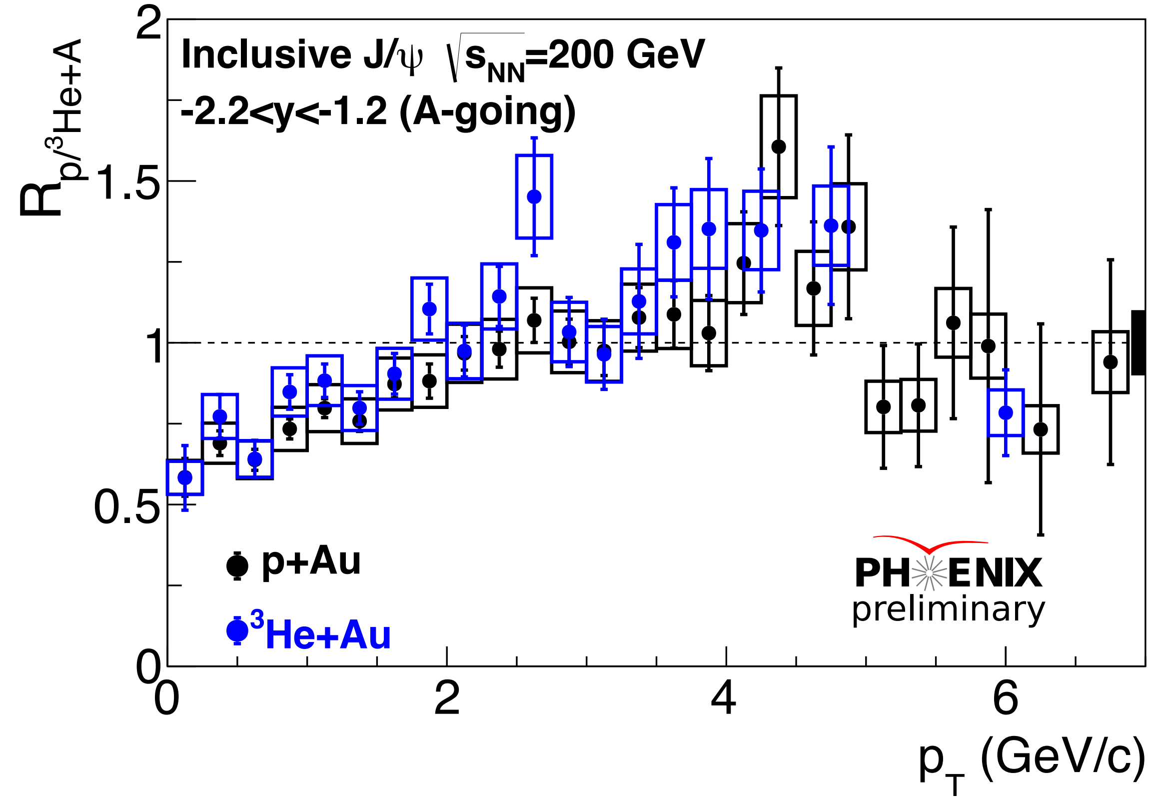
These data were recorded 7 years apart

- Different p+p references.
- Significant changes to the detector between these runs.
- So the systematic errors (boxes) are not strongly correlated between runs.

J/ψ p+Au (2015) vs ^{3}He+Au (2014) J/ψ vs p_T

0-100% centrality



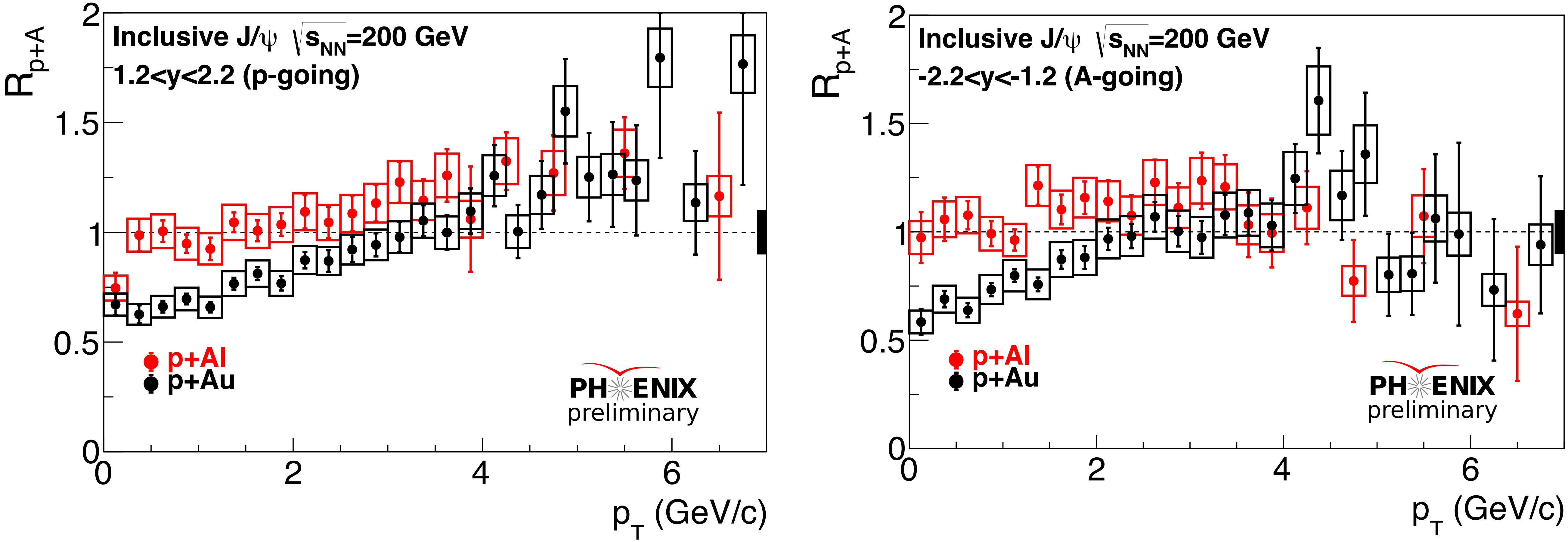


These data were recorded with the same detector 1 year apart

- Same p+p reference
- Same simulations model
- The systematic errors have significant correlations between runs

J/ψ p+Au (2015) vs p+Al (2015) J/ψ vs p_T

0-100% centrality



The p+Al data show little modification in 0-100% centrality data.

New: centrality selected J/ψ results

New preliminary results

- For p+Au and ^{3}He+Au, released only at backward rapidity for now.
- Forward rapidity p+Au and ^{3}He+Au almost done.
- p+Al analysis is still underway.

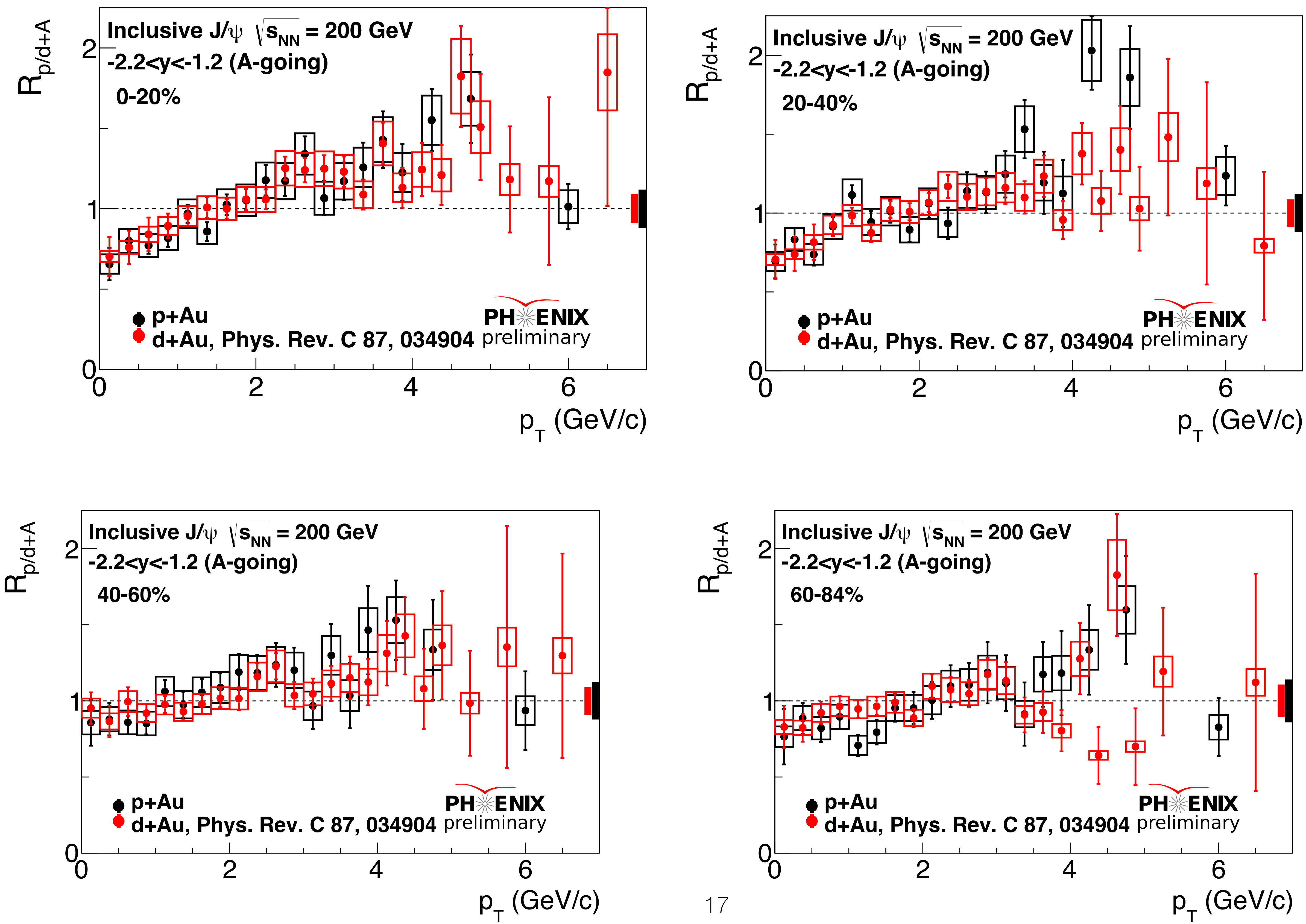
Four centrality bins for p+Au

- 0-20, 20-40, 40-60, 60-84%

Three centrality bins for ^{3}He+Au (statistics limited in peripheral data)

- 0-20, 20-40, 40-84%

p+Au vs d+Au centrality selected

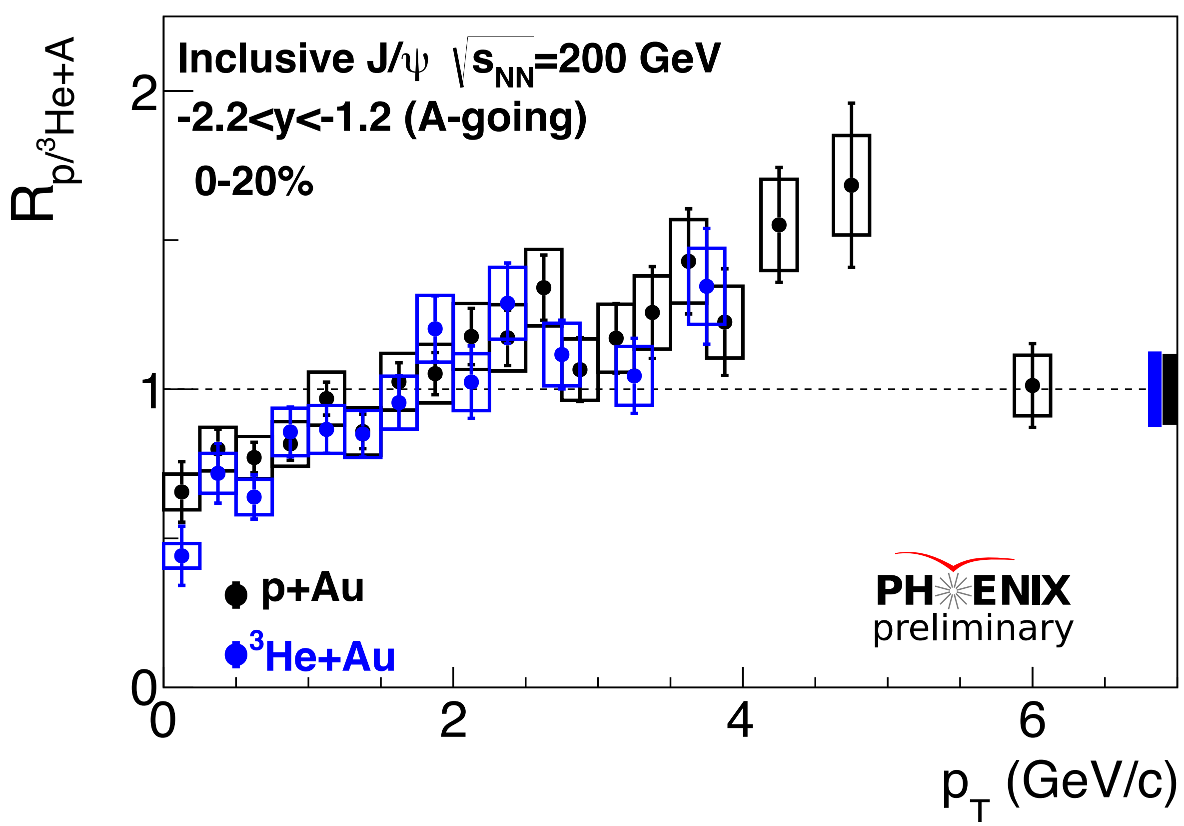


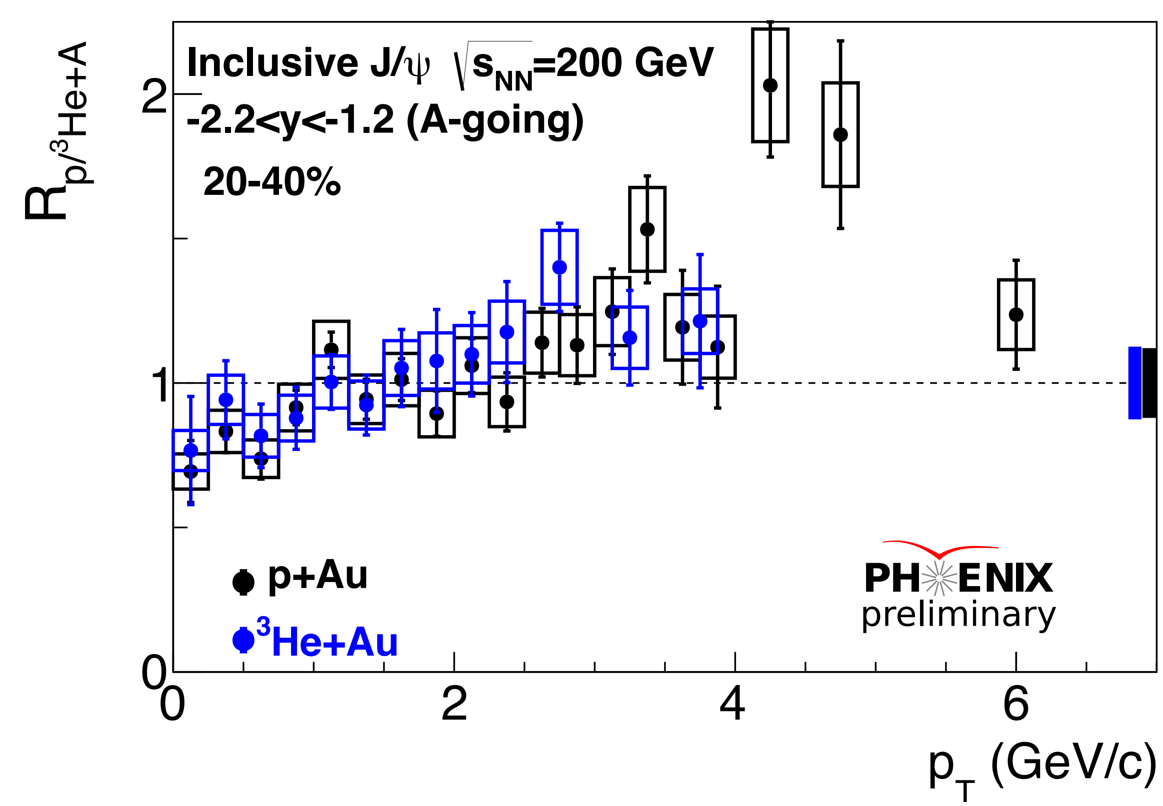
p+Au vs ^{3}He+Au centrality selected

^{3}He+Au produces three times as much energy in the collision.

No significant difference observed in modification between the two projectiles.

- Indicates dominance of CNM effects over those due to energy production in the collision.

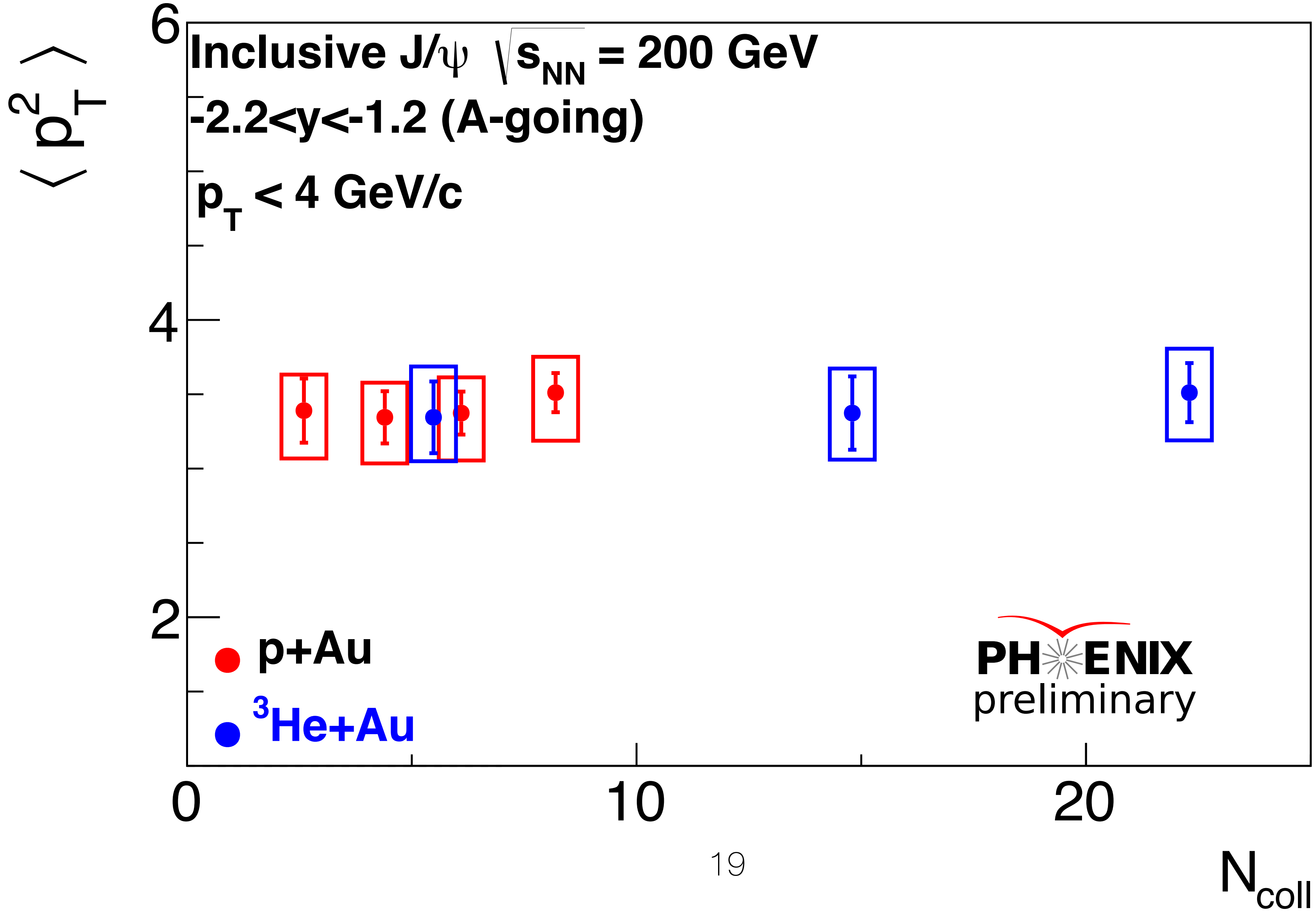




p+Au vs ^{3}He+Au $< p_T^2 >$ vs N_{coll}

Limited to pT < 4 GeV/c because of ^{3}He+Au statistics.

- No evidence of any effects due to projectile size.



Summary

We report preliminary new centrality selected data on inclusive J/ψ modifications studied in two small systems - p/^{3}He+Au.

- Only backward rapidity data are available as yet.

The new centrality selected data are compared with each other, and with existing d+Au data.

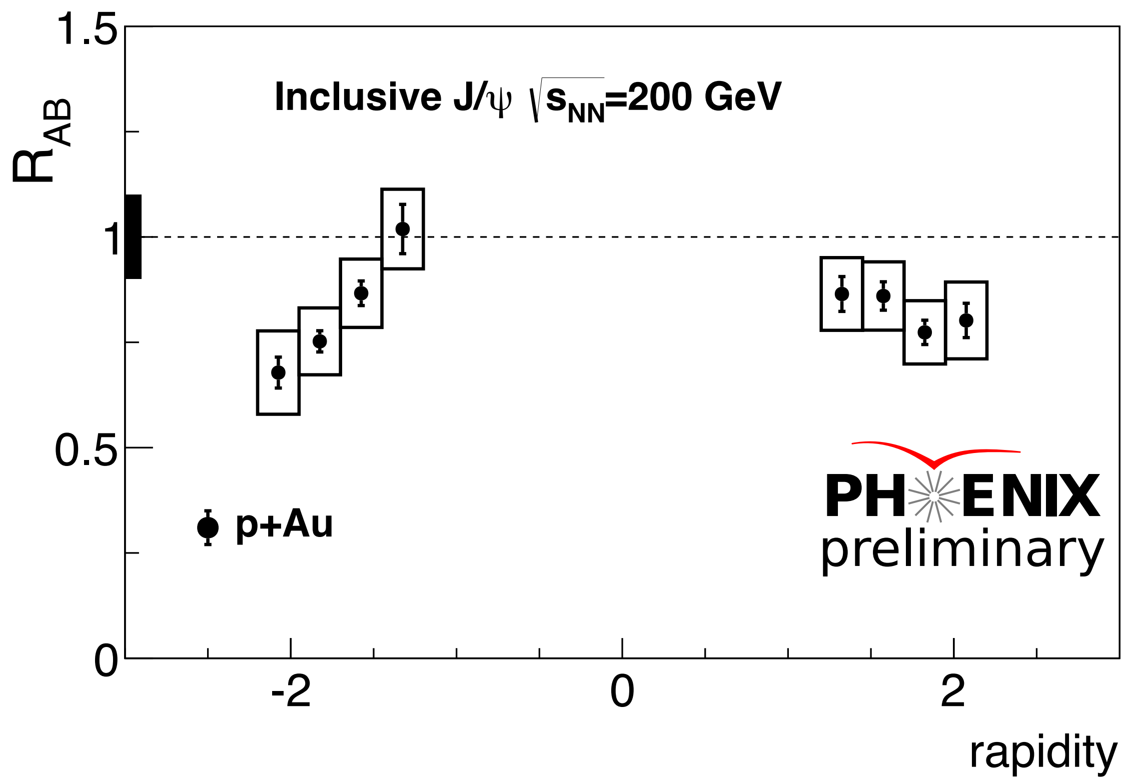
We observe no difference in modification between the p+Au and ^{3}He+Au systems.

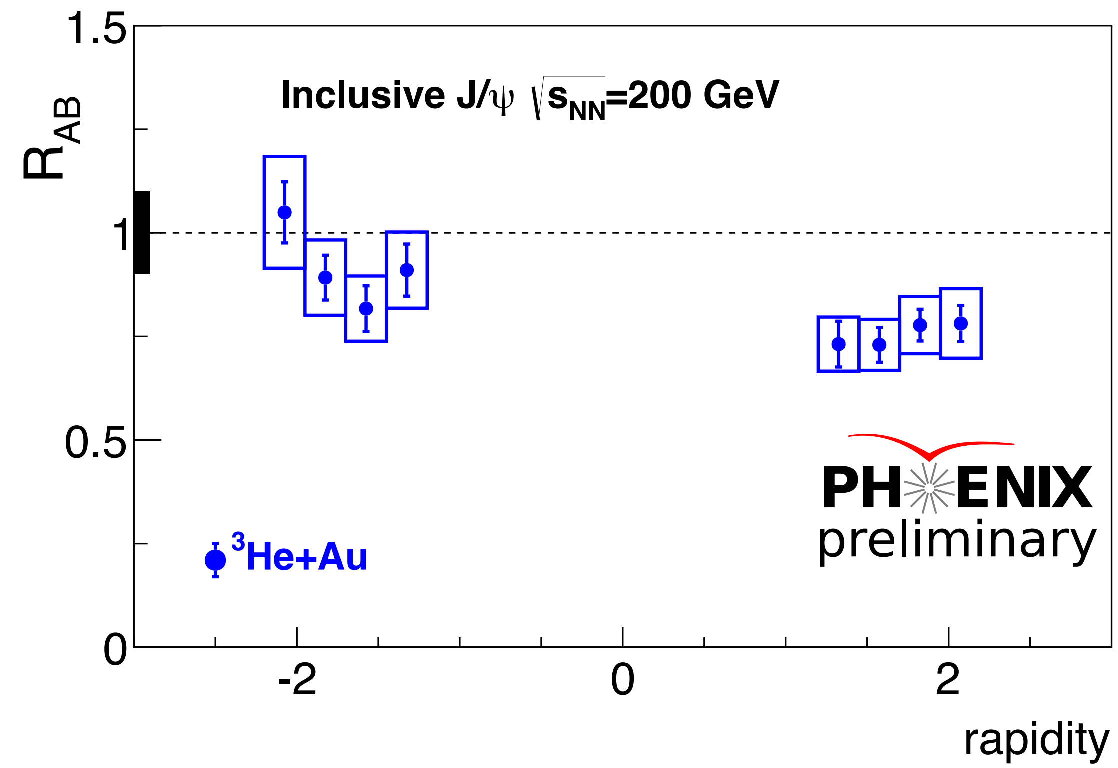
To come:

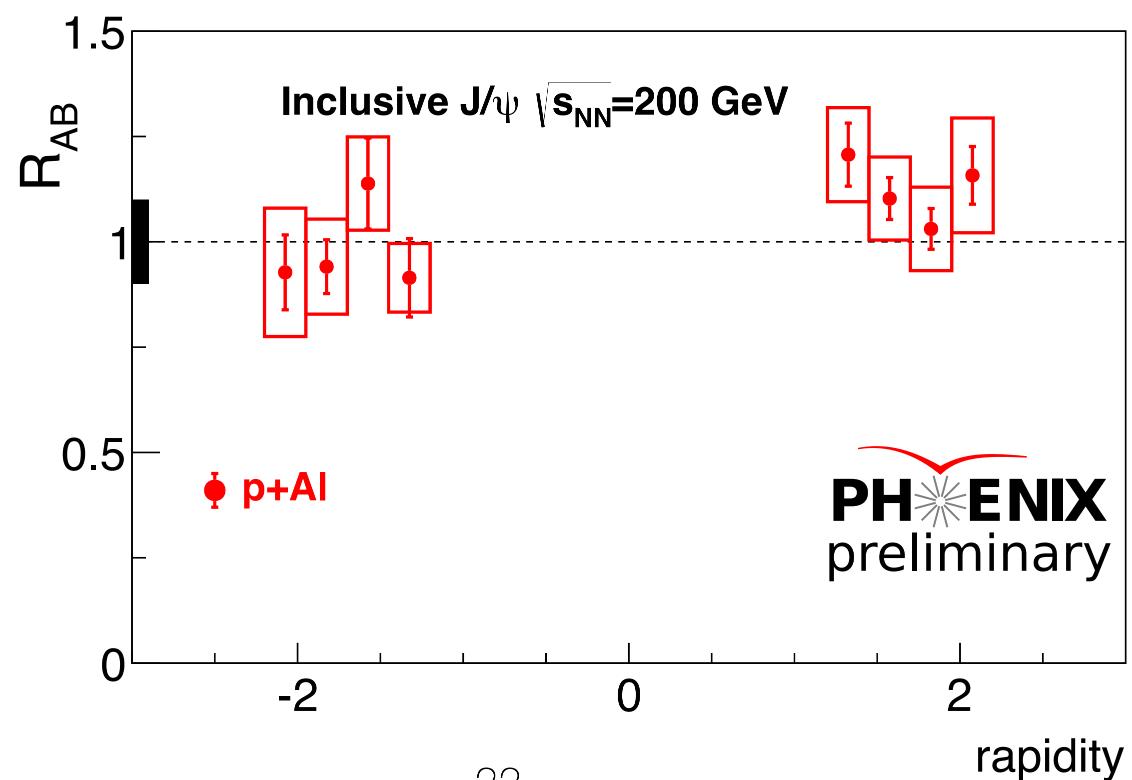
- p+Au and ^{3}He + Au at forward rapidity
- p+Al at forward and backward rapidity
- Possibly J/ψ v_2 in Au+Au (dimuons, 2014 run)
- We are also considering whether we can extract ψ(2S) centrality dependent data at forward/backward rapidity for p+Au.

Backup

J/ψ centrality and p_T integrated *y* dependence







Cold nuclear matter effects from p,d + A

Combine PHENIX d+Au J/ψ data at 12 rapidities, and J/ψ data from 6 fixed target experiments

All cross sections parameterized with EKS98 or EPS09 shadowing plus absorption parameter σ_{abs}

Plot absorption parameter vs nuclear crossing time (τ) for p+A or d+Au at 17.3A - 200A GeV CM collision energy

For Au + Au collisions: fold forward & backward rapidity CNM effects together in1.2 < η< 2.2

- Stronger CNM suppression than at mid rapidity

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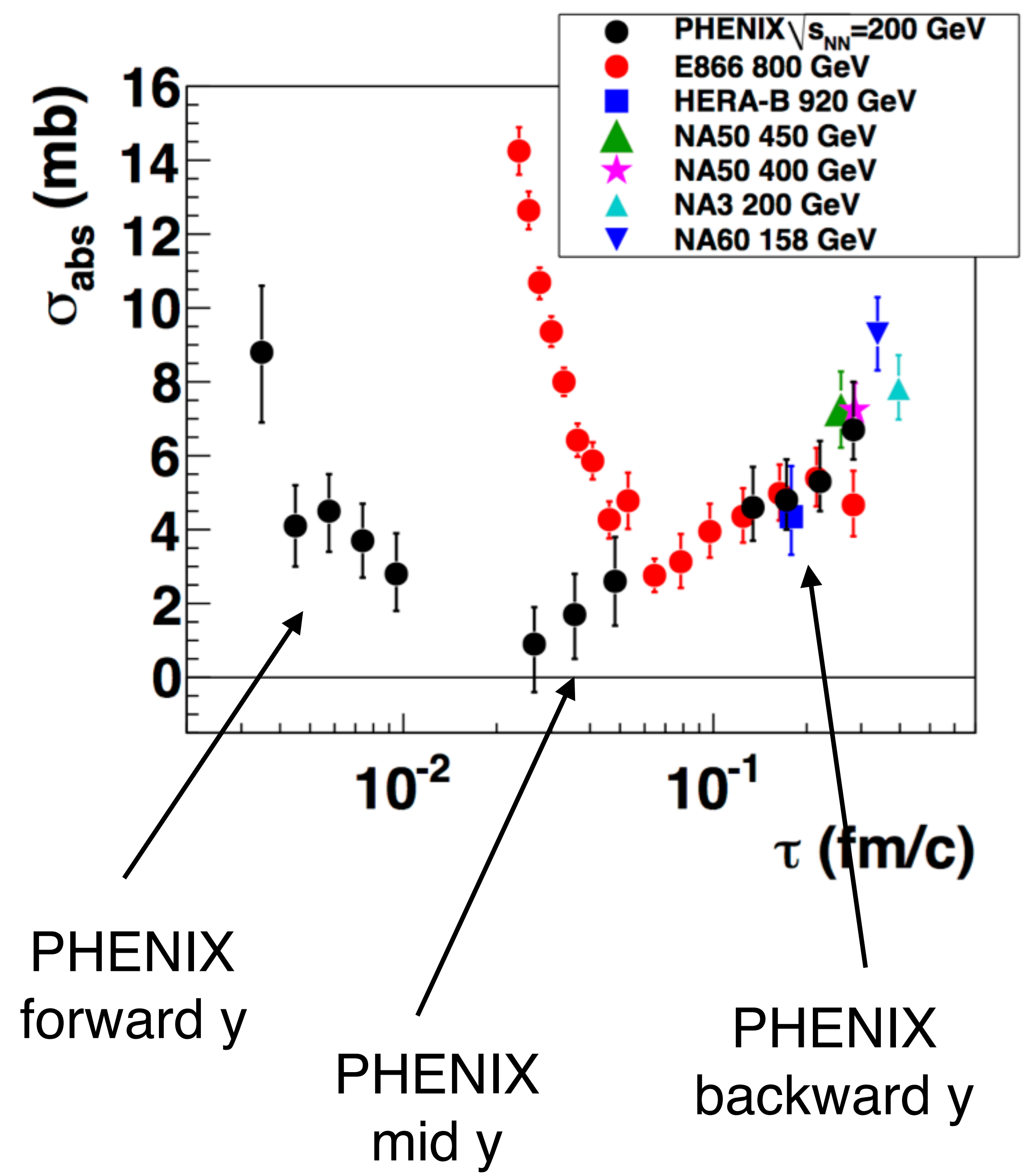
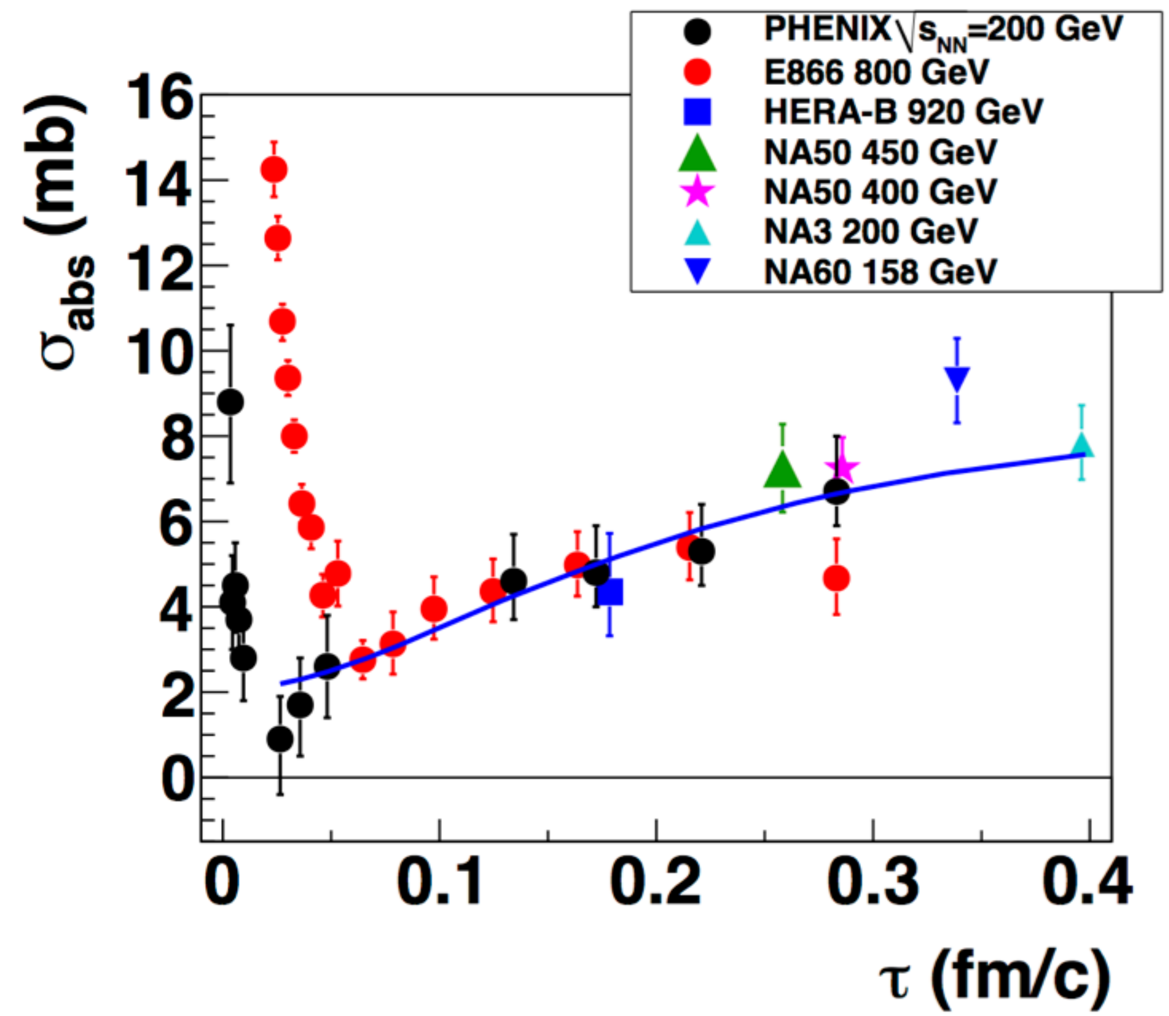


Aside: What is the source of σ_{abs}?

Fit region above τ ~ 0.05 fm/c with model of **expanding color neutral meson**

- Suggests we really have breakup at backward rapidity (large τ), **something else** at forward rapidity (small τ)

The suppression at forward rapidity (small τ) seems to be well explained by energy loss in cold nuclear matter



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