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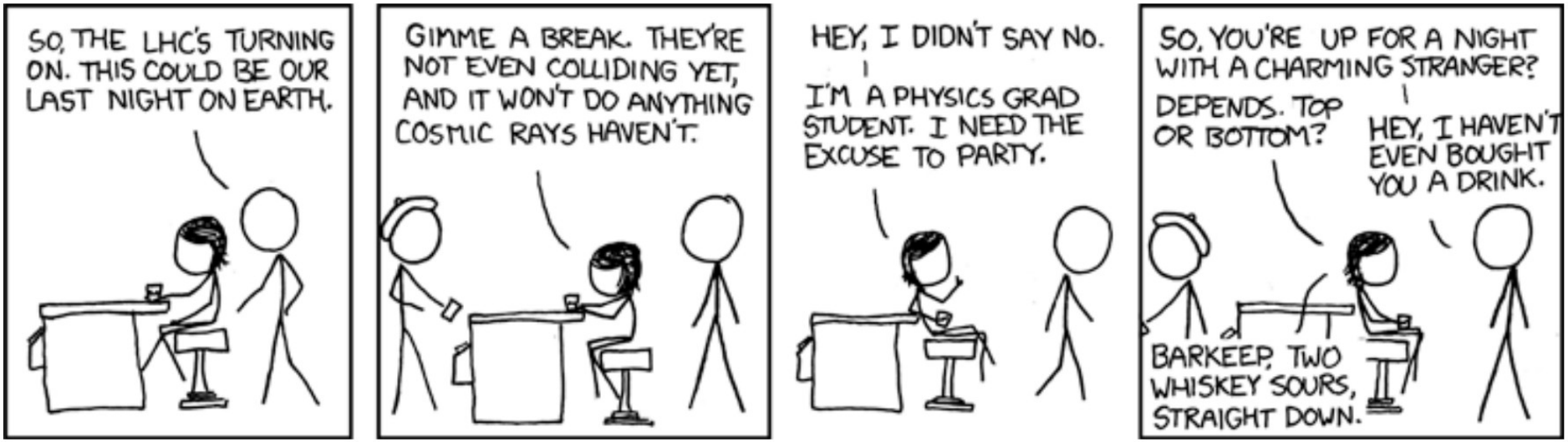
THIS WEEK: IS THERE ENOUGH ENERGY TO MOVE ALL OF HUMANITY OFF-PLANET?

TURN-ON

|< < PREV RANDOM NEXT > >|



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Alan Dion Stony Brook University

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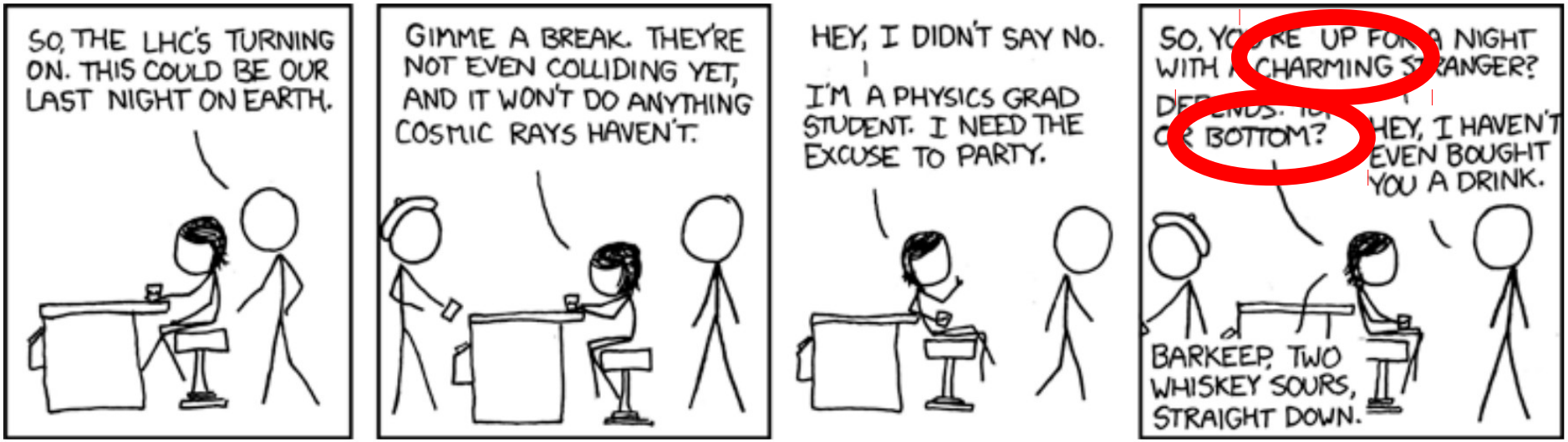

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Surprising Results from the PHENIX experiment

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Surprising Results from the PHENIX experiment

With a focus on quarkonia

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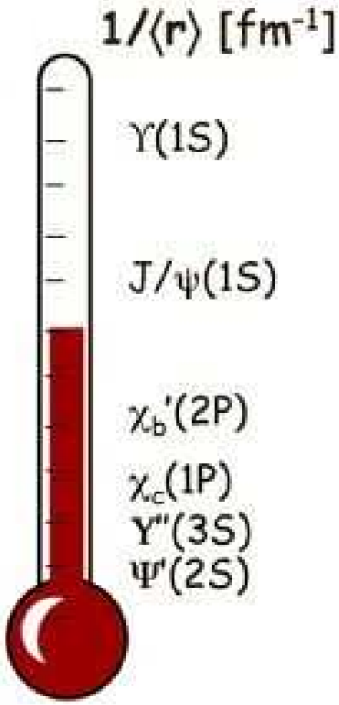
Heavy Quarkonia

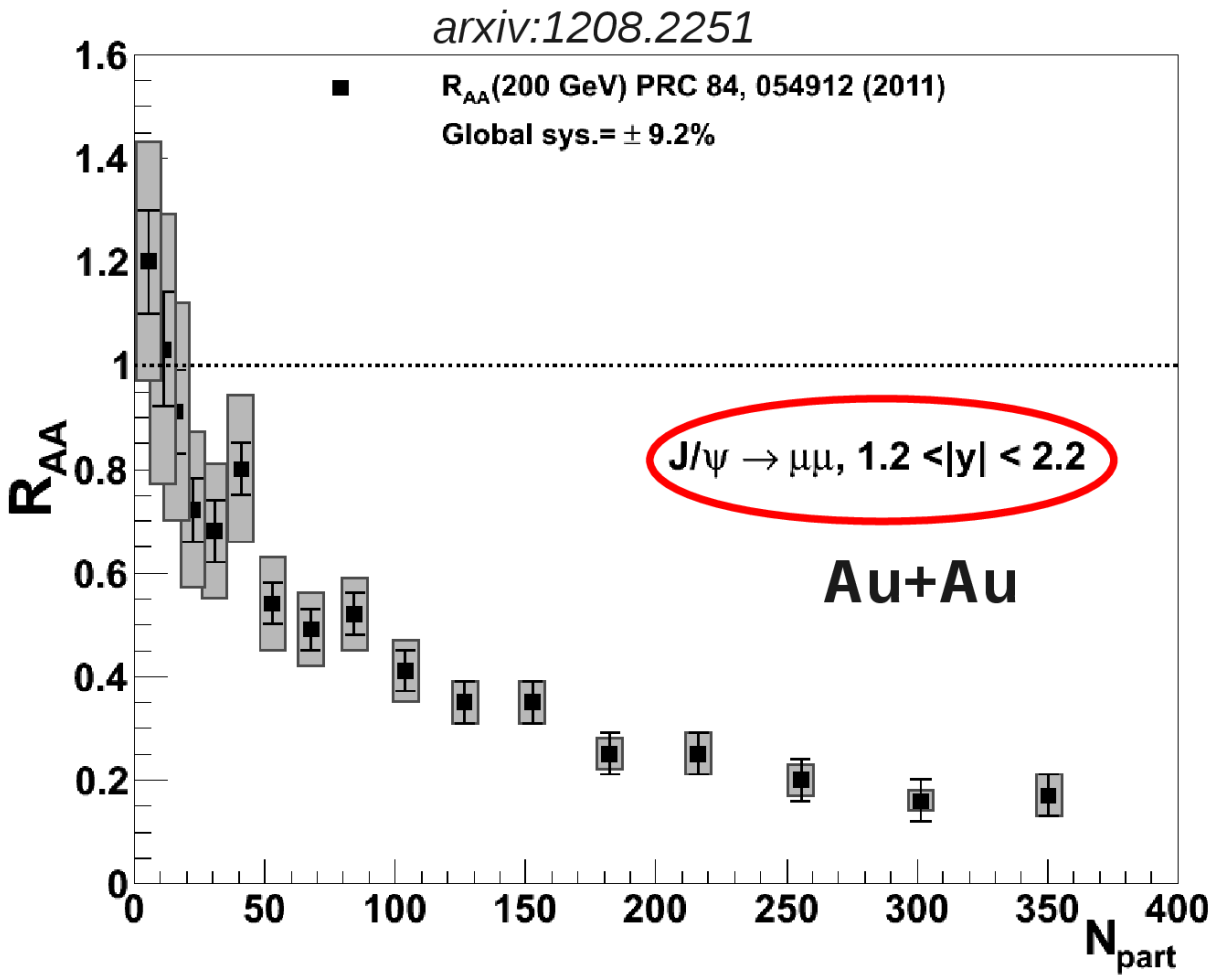
Heavy quarkonia is an ideal tool to measure the screening length in the QGP.

Only works if we know **all** our references!
(Need p+p & p+A)



- Recent results from PHENIX:
  - J/ψ R_{AA} at 39 & 62 GeV
  - J/ψ R_{dAu} vs p_T
  - ψ' R_{dAu} at $|y|<0.35$
  - χ_c at $|y|<0.35$

J/ψ R_{AA} at Low Energy



Previously published results on J/ψ R_{AA} at 200 GeV

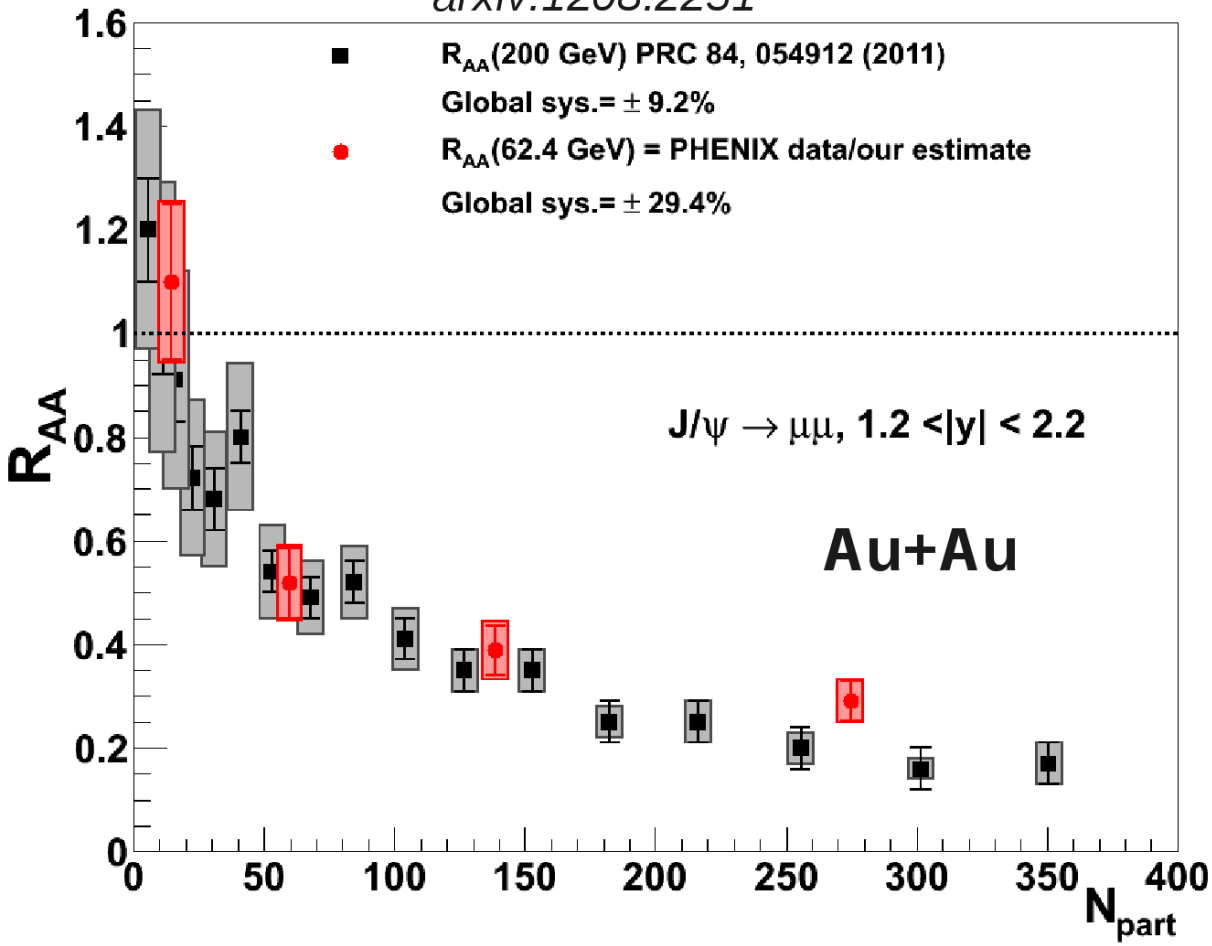
J/ψ R_{AA} at Low Energy

New paper on J/ψ R_{AA} at 39 & 62 GeV at **forward rapidity**

Observe similar suppression at 200 & 62 GeV.

No PHENIX p+p baseline at 62.4 GeV. Use extrapolation from measurements at the ISR.

arxiv:1208.2251



New results on J/ψ R_{AA} at 62.4 GeV

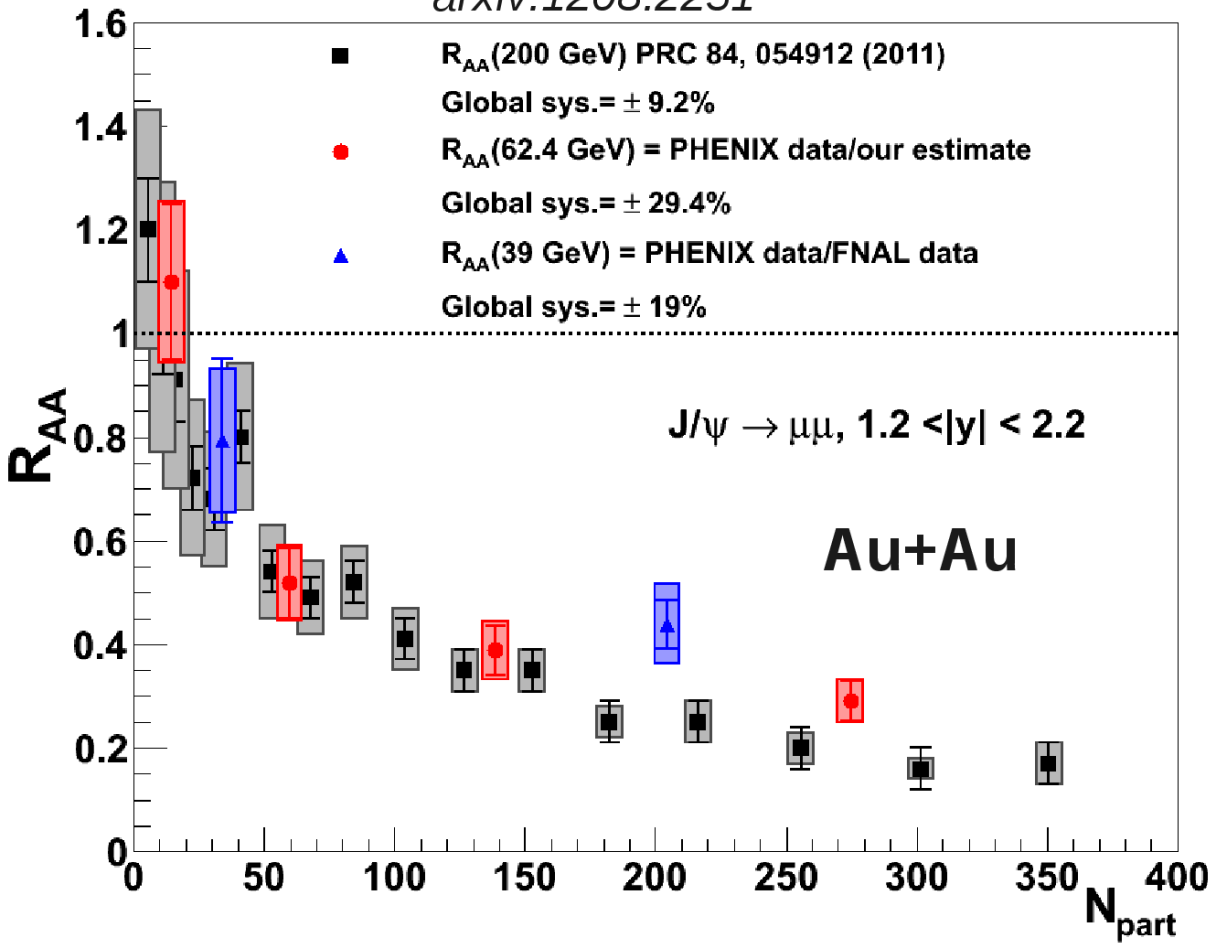
J/ψ R_{AA} at Low Energy

New paper on J/ψ R_{AA} at 39 & 62 GeV at **forward rapidity**

Observe similar suppression at 200 & 62 & 39 GeV.

No PHENIX p+p baseline at 39 GeV. Use extrapolation of results from Fermilab E789 and E866/NuSea.

arxiv:1208.2251



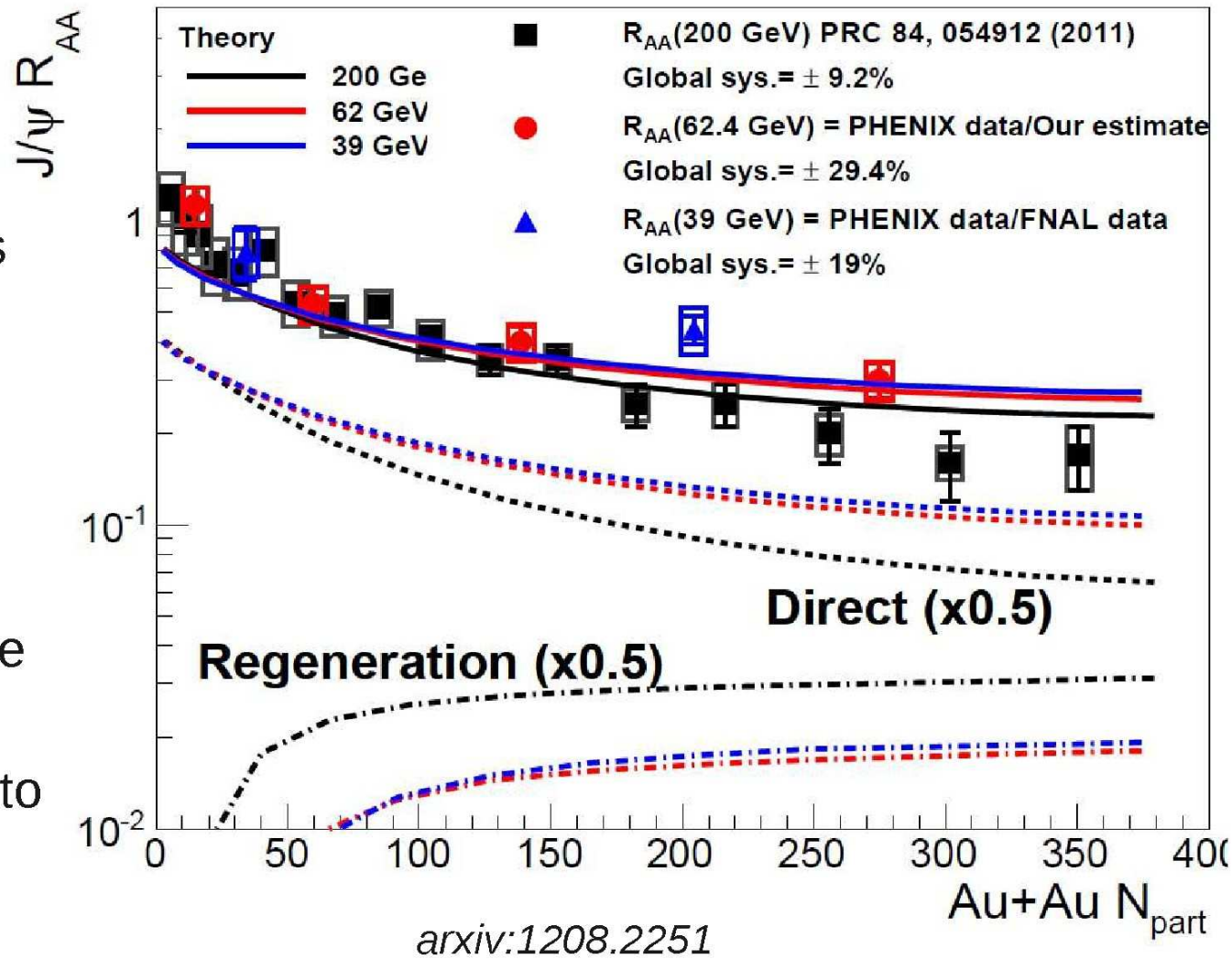
New results on J/ψ R_{AA} at 39 GeV

J/ψ R_{AA} at Low Energy

New paper on J/ψ R_{AA} at 39 & 62 GeV at **forward rapidity**

Calculations by Zhao and Rapp. Include some CNM effects.

- Combined QGP effects are similar at each energy.
  - Direct suppression changes by ~50%
  - Regeneration compensates for the change.
- CNM effects expected to be different at the different energies.



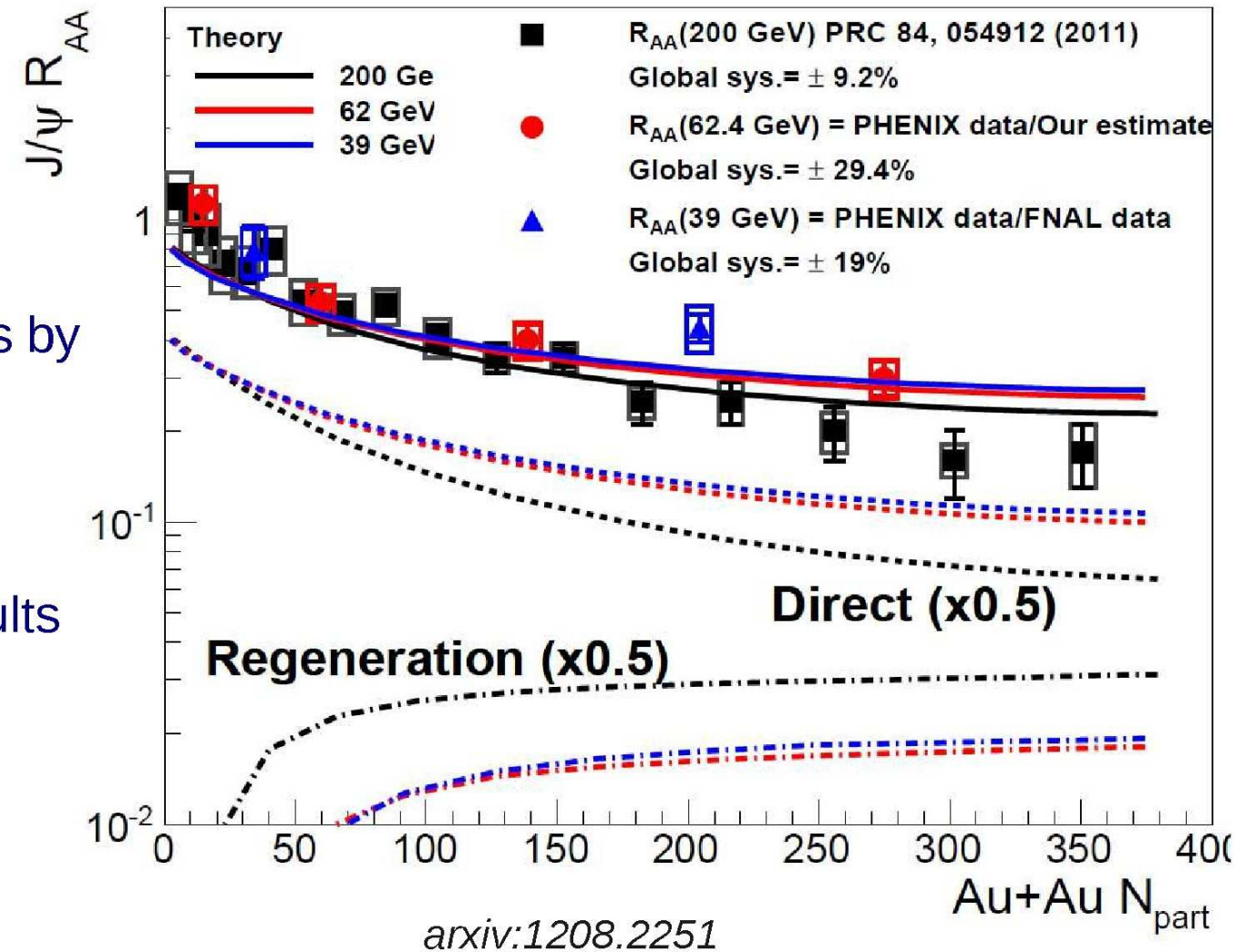
arxiv:1208.2251

J/ψ R_{AA} at Low Energy

New paper on J/ψ R_{AA} at 39 & 62 GeV at **forward rapidity**

Calculations by Zhao and Rapp. Include some CNM effects.

- Available p+A data:
  - p+A measurements by E866/NuSea & 39 GeV.
  - No p+A at 62 GeV
  - d+Au PHENIX results at 200 GeV



arxiv:1208.2251

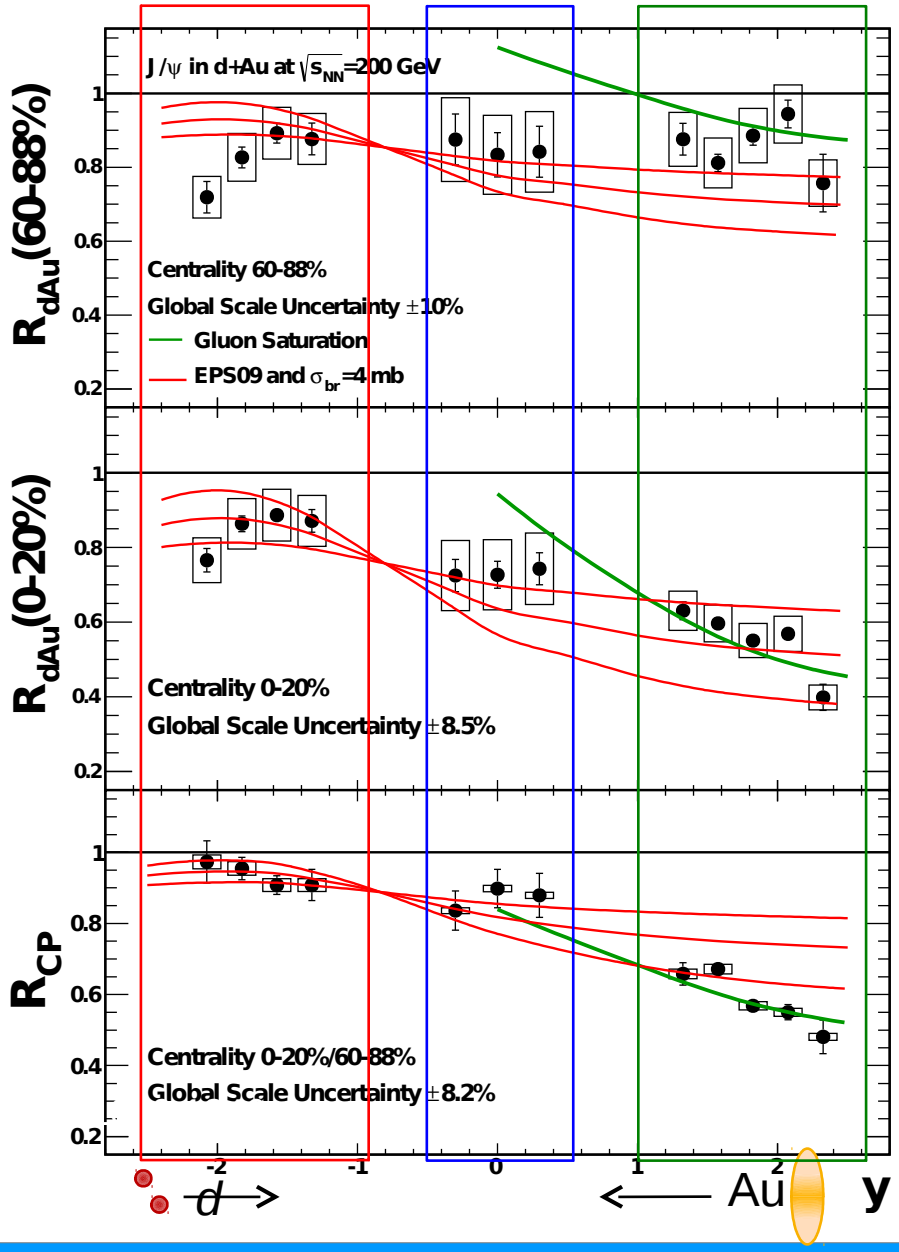
J/ψ in Cold Nuclear Matter

Phys. Rev. Lett. 107 (2011) 142301

J/ψ are suppressed at all rapidities, in all centralities.

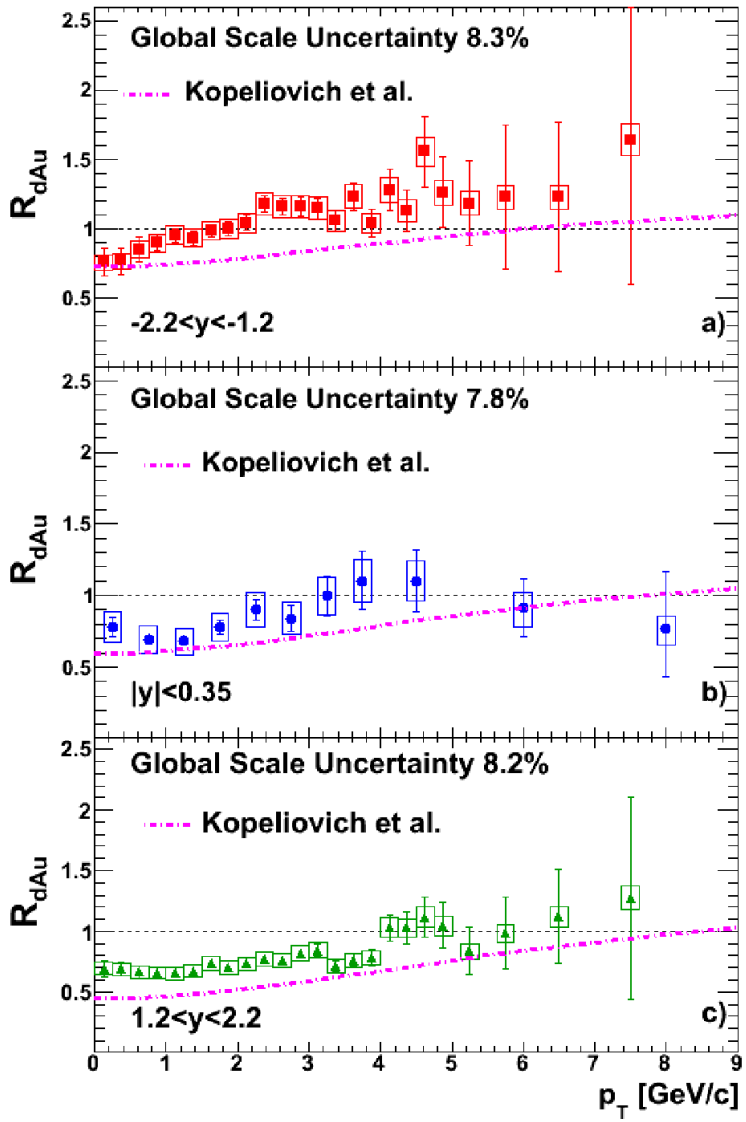
Model using shadowing (EPS09) + σ_{br}

Qualitatively matches what we see, but cannot simultaneously capture the rapidity and centrality dependence.



J/ψ vs. pT

arXiv:1204.0777



*R*dAu rises out to *p*T~5 GeV/*c* at all rapidities.

Largest disagreement with models is at <u>backward rapidity</u>.

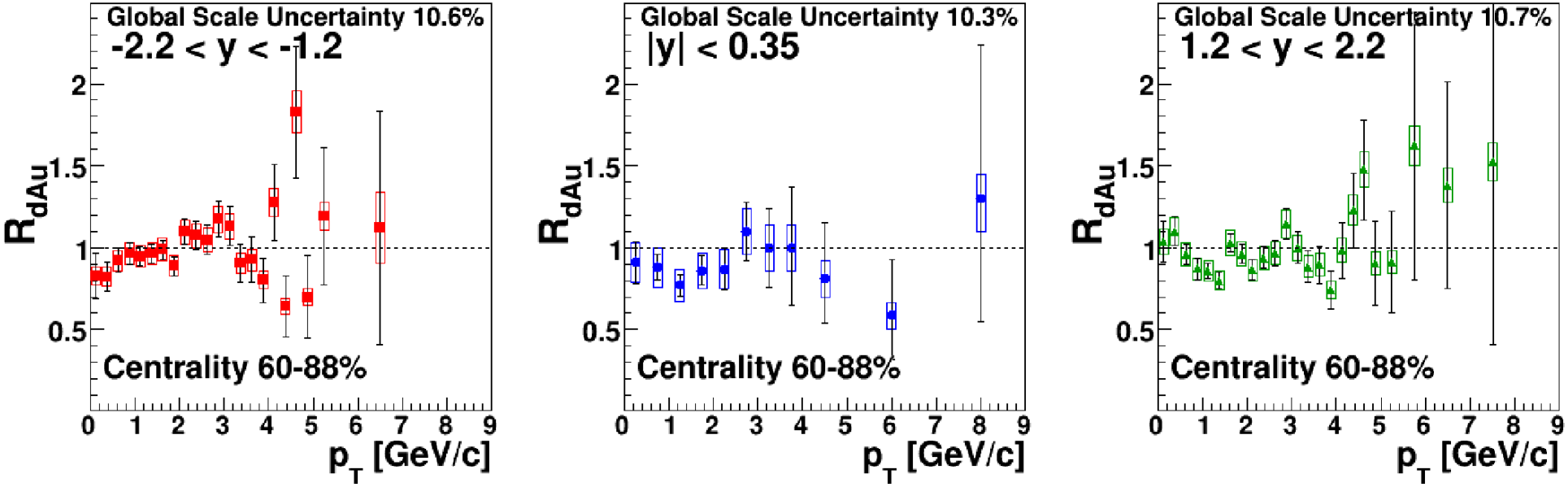
Shadowing + σbr model (no Cronin) does not match the qualitative trend.

Model by Kopeliovich et al. includes Cronin and σbr prediction, qualitatively matches the *p*T shape.

Centrality Dependence

60-88%

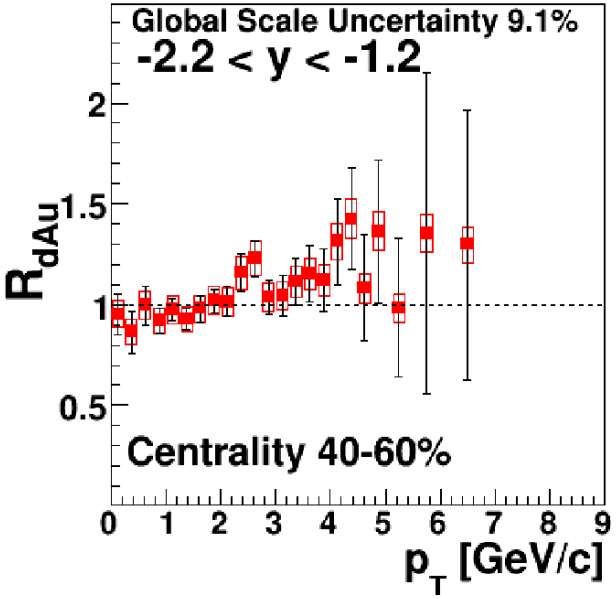
R_{dAu} consistent with 1 at all p_T for peripheral collisions

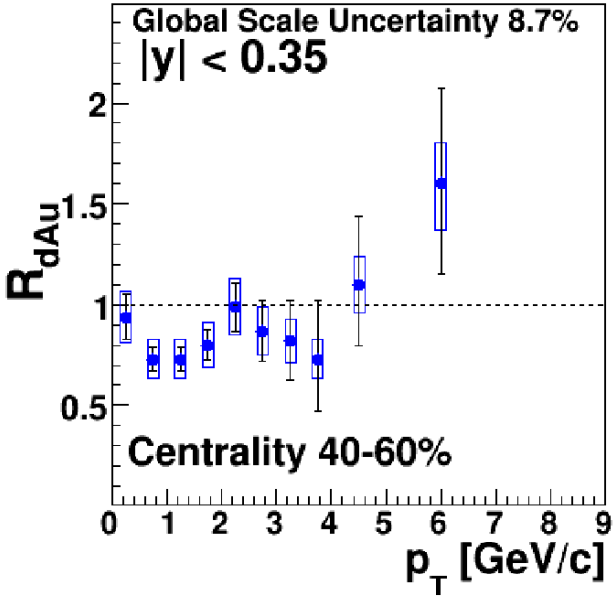


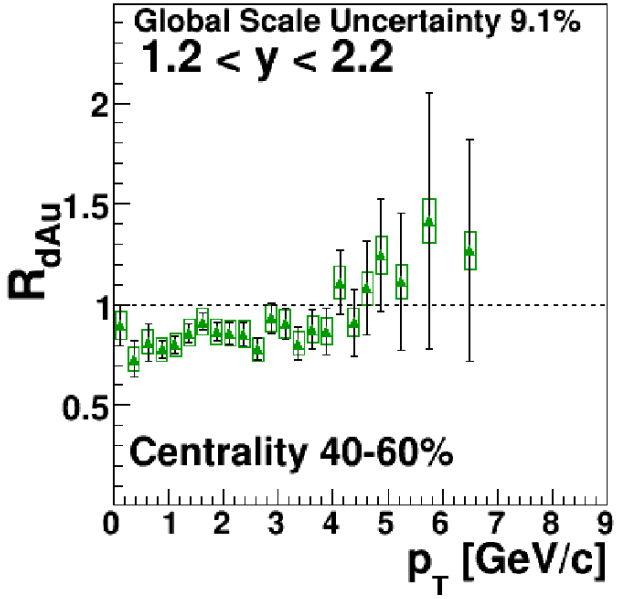
Centrality Dependence

40-60%

Increasing suppression at low-p_T when moving to central events



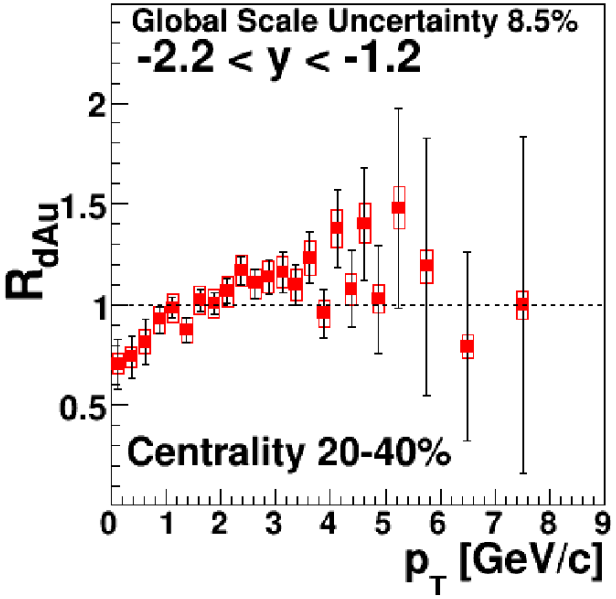


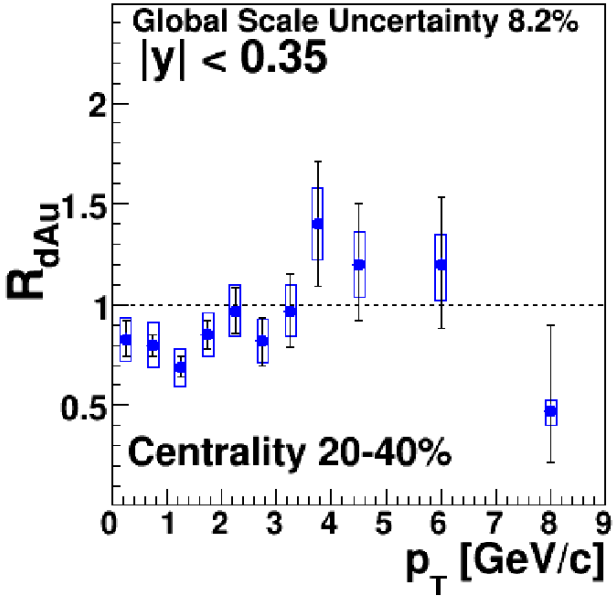


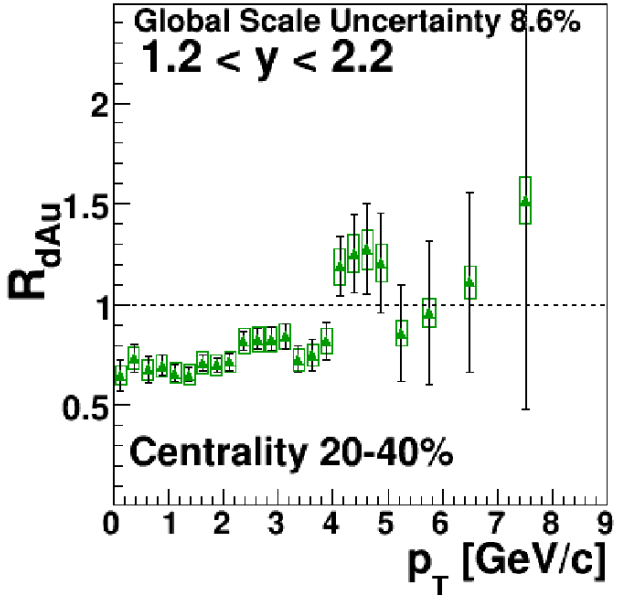
Centrality Dependence

20-40%

Increasing suppression at low-p_T when moving to central events



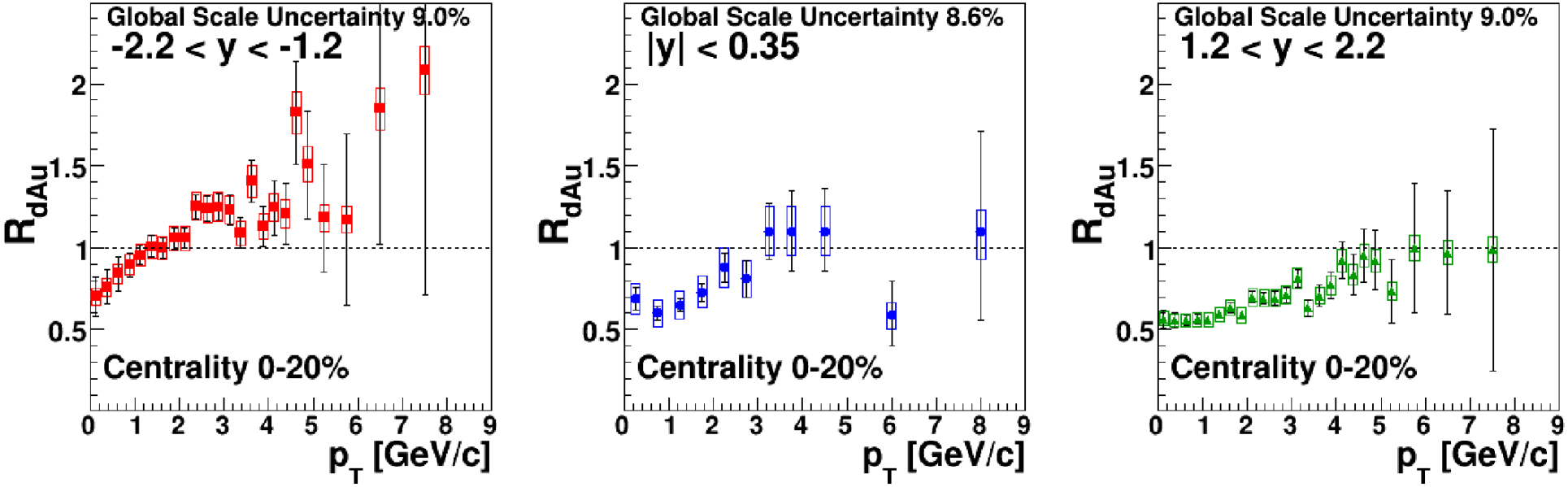




Centrality Dependence

0-20%

Increasing suppression at low-p_T when moving to central events

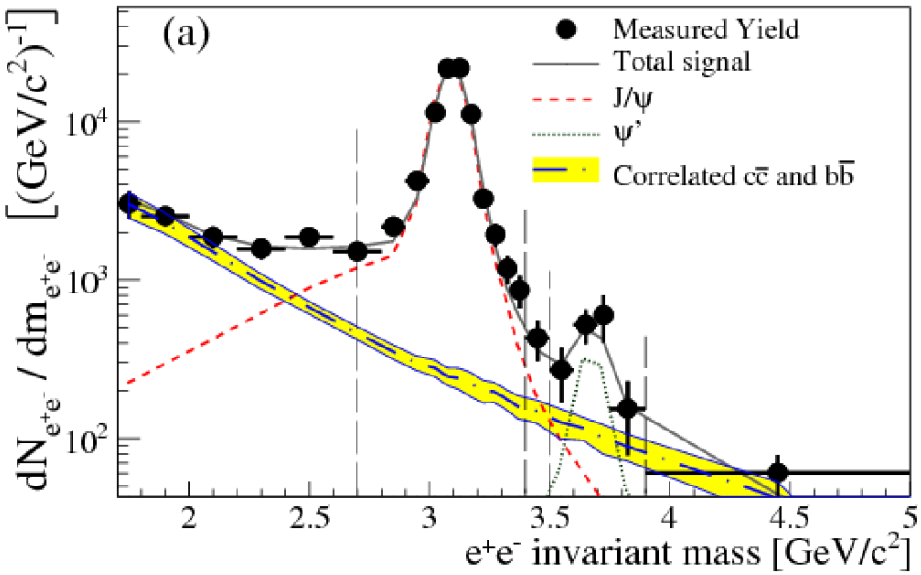


Enhancement at high-p_T at backward rapidity

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

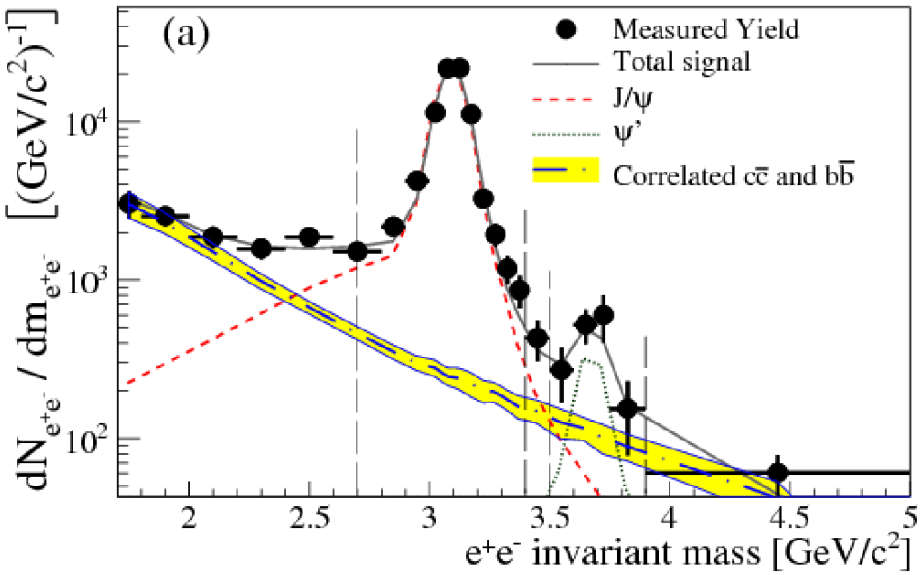
ψ' in d+Au

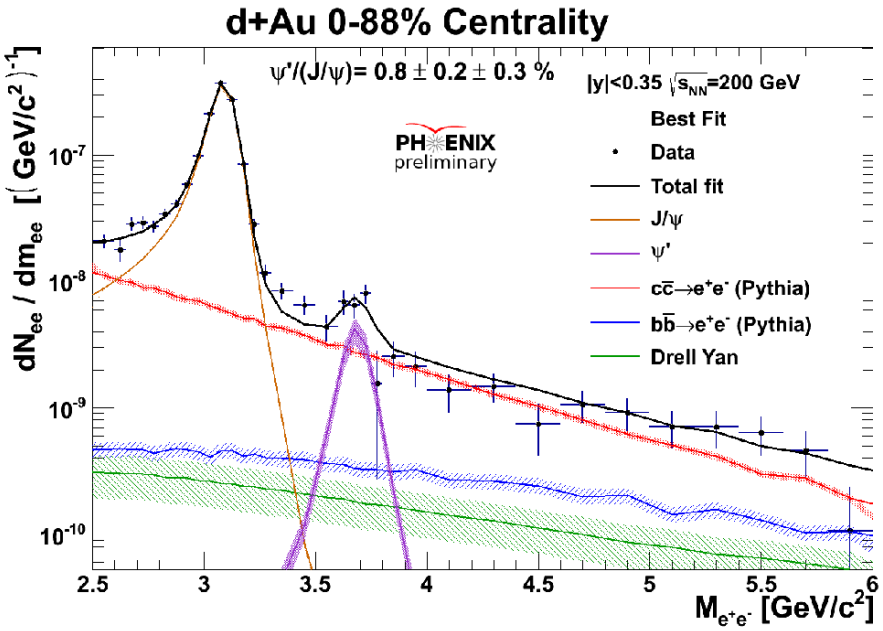
- In p+p PHENIX found a ψ'/(J/ψ) ratio of 2.1±0.5% (*Phys.Rev. D85 (2012) 092004*).



ψ' in d+Au

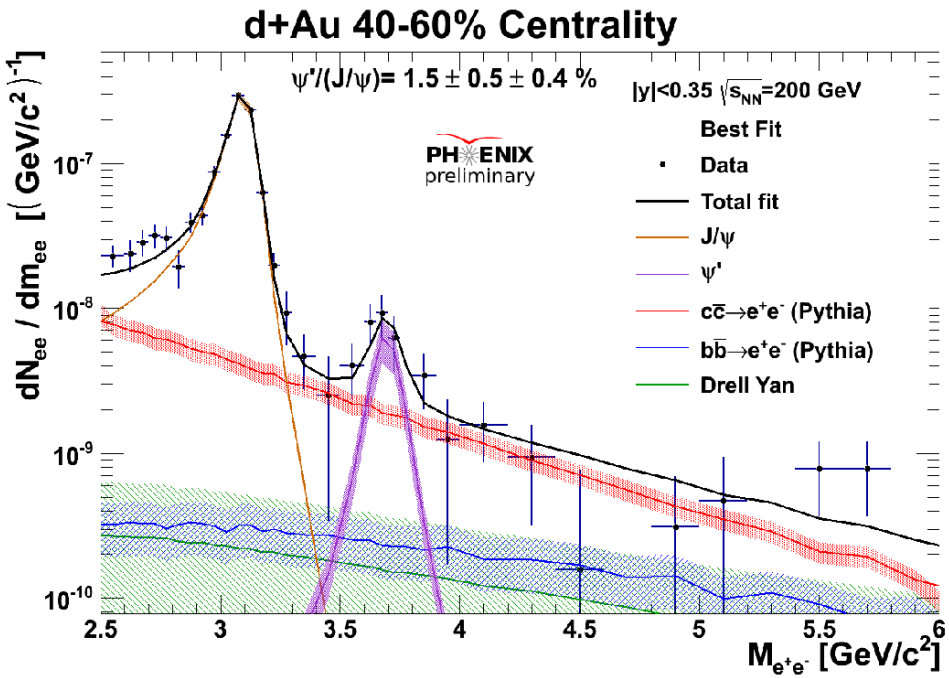
- In p+p PHENIX found a ψ'/(J/ψ) ratio of 2.1±0.5% (*Phys.Rev. D85 (2012) 092004*).
- Extract the ψ'/(J/ψ) ratio in d+Au.
- Fit the mass distribution's in d+Au to extract ψ'/(J/ψ) ratio.
  - Include dielectrons from DY, open charm & open bottom as well as J/ψ and ψ' decays.
- Variations in the ratio due to the fit assumptions are included in the systematic uncertainty.





ψ' in d+Au

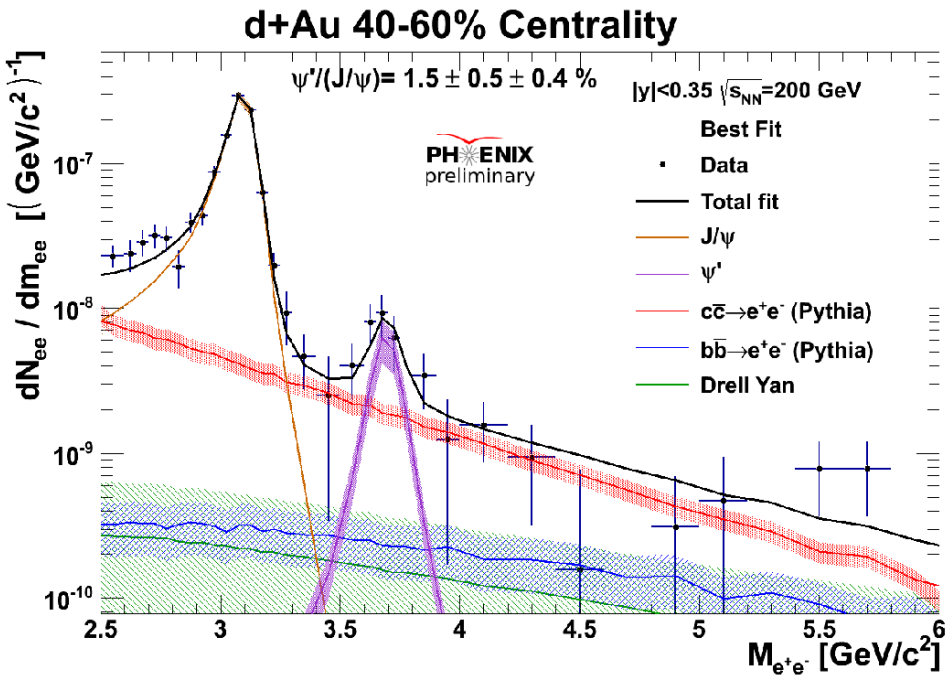
Investigate the centrality dependence

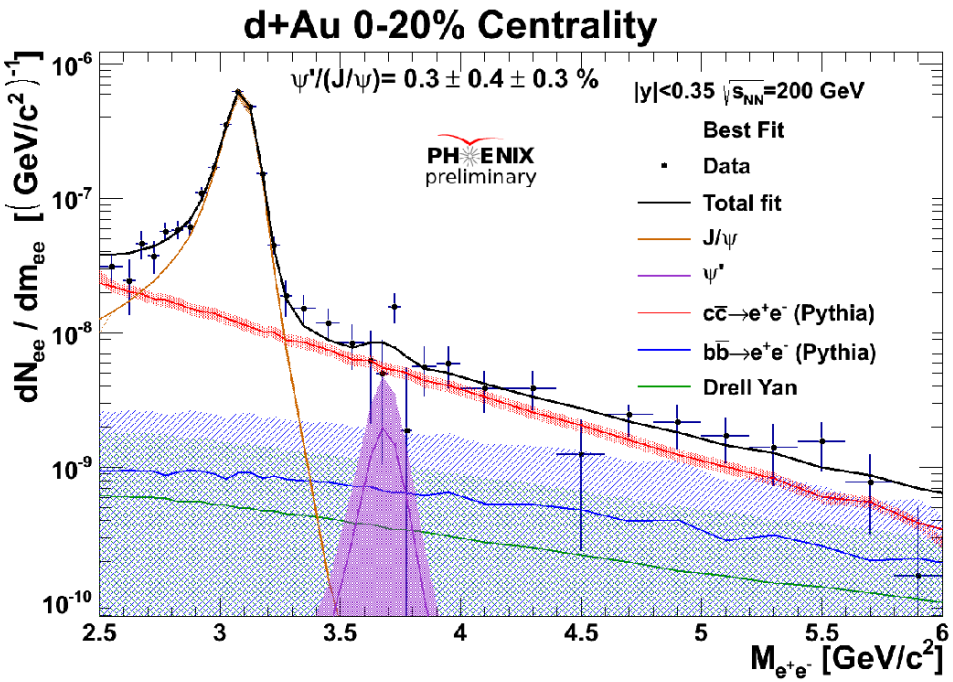


Little suppression in mid-peripheral events.

ψ' in d+Au

Investigate the centrality dependence

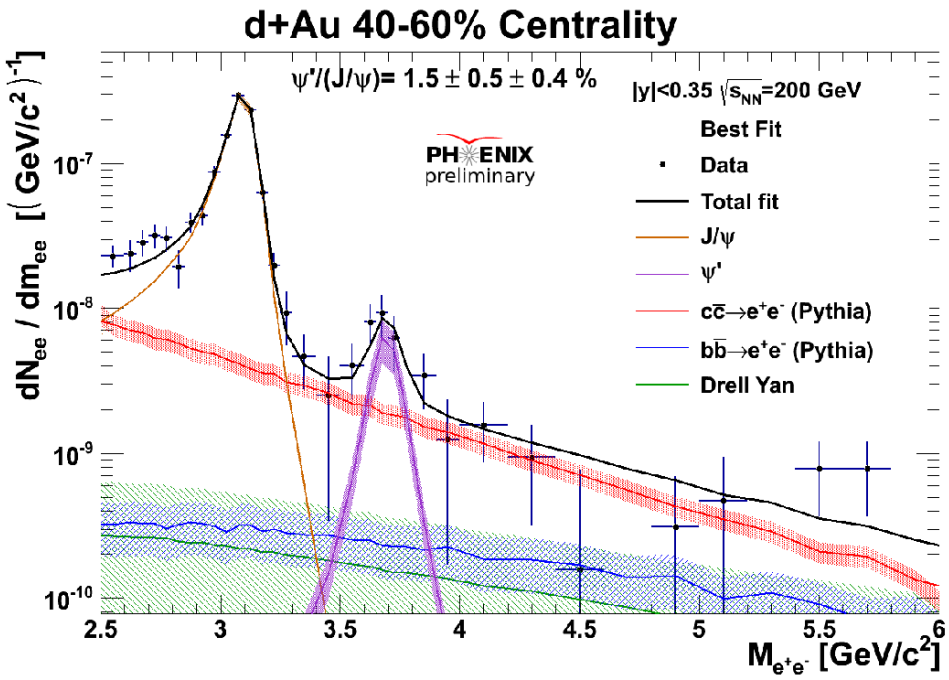


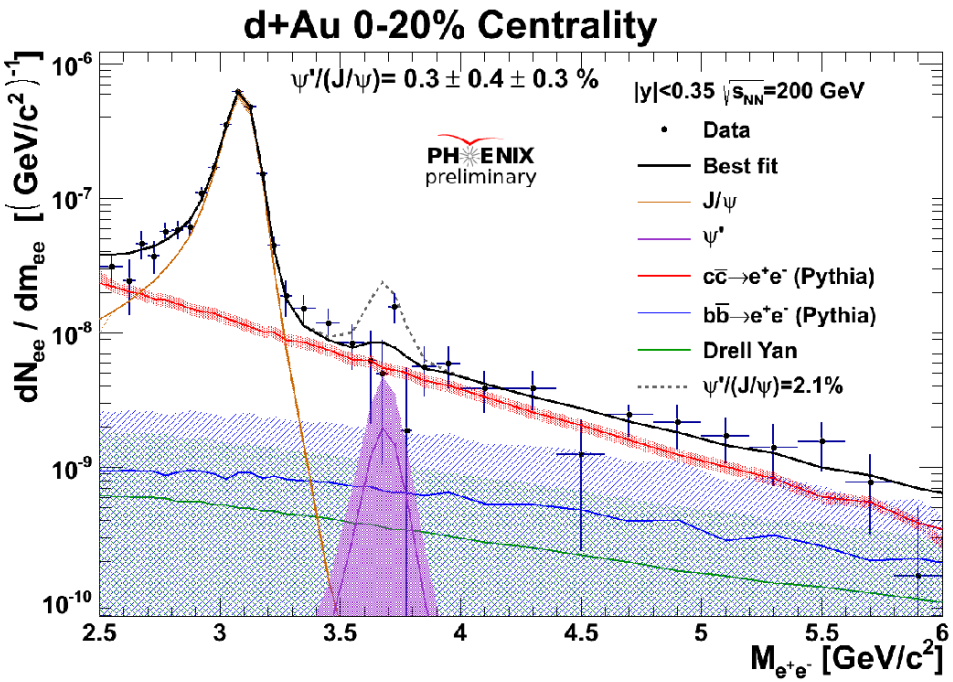


Strong suppression in central events!

ψ' in d+Au

Investigate the centrality dependence





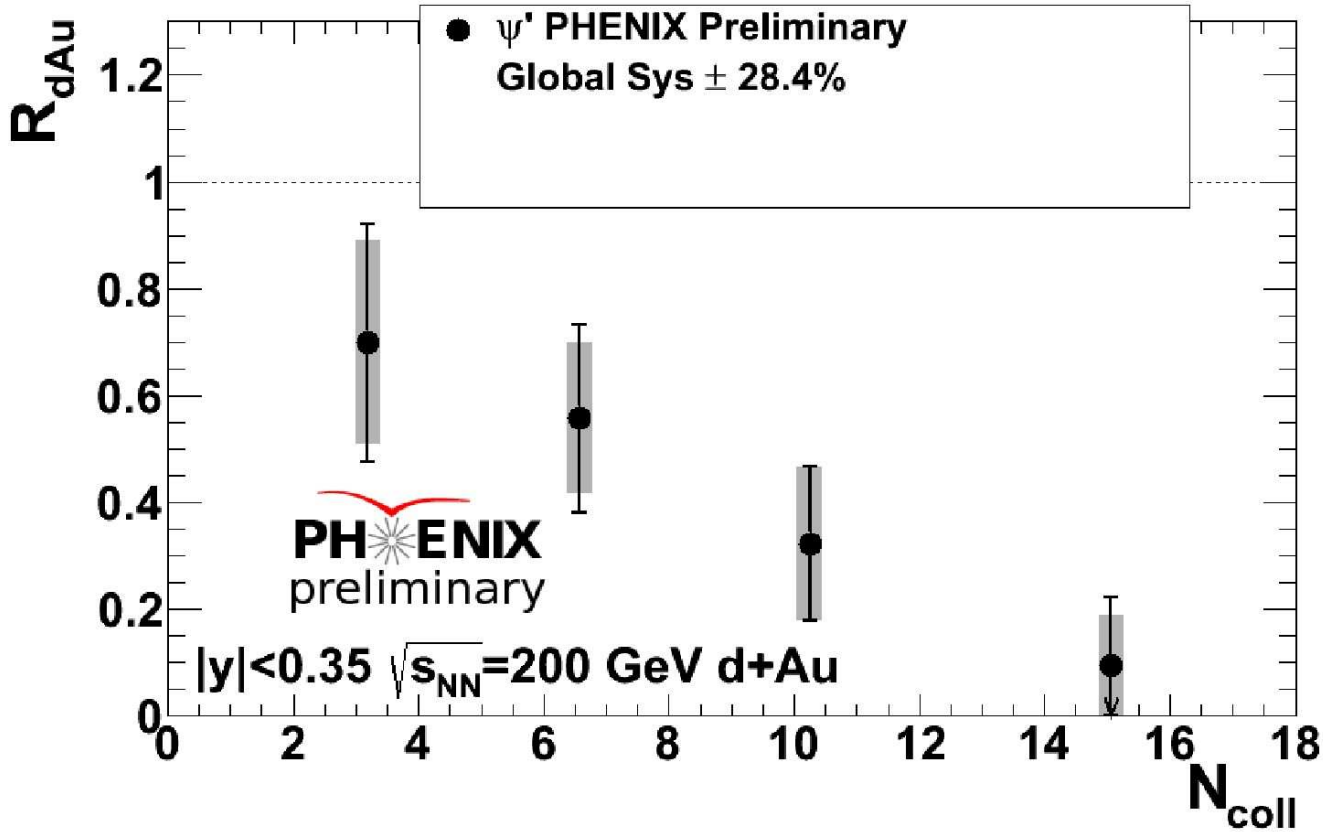
Dashed line – ψ' / (J/ψ) ratio fixed to p+p value (2.1%)

Likelihood ratio test gives probability for p+p ratio of < 10^{-6}

ψ' R_{dAu}

Strong suppression with increasing N_{coll}!

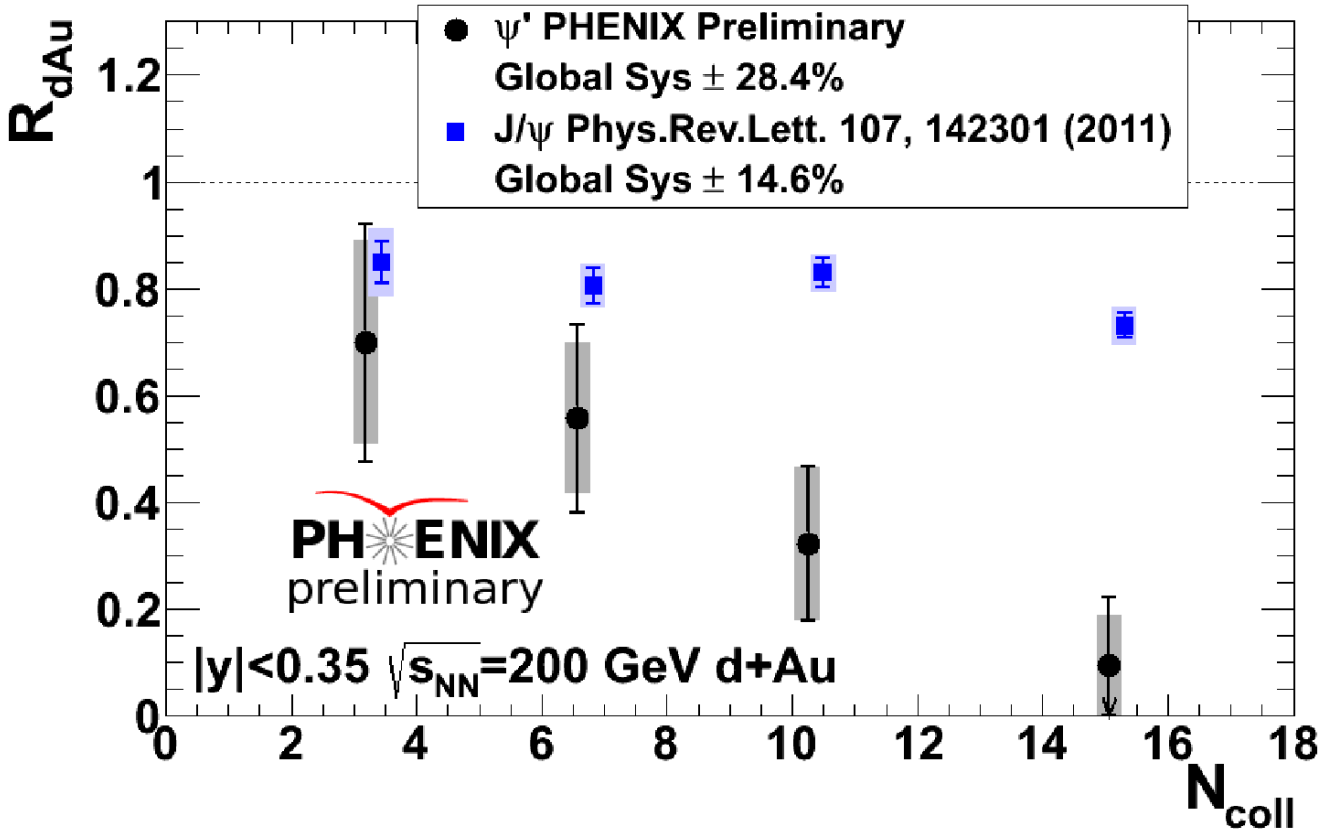
$$R_{dAu}{}^{\psi'} = \frac{[\psi'/(J/\psi)]^{dAu}}{[\psi'/(J/\psi)]^{pp}} R_{dAu}{}^{J/\psi},$$



ψ' R_{dAu}

Centrality dependence of suppression much stronger than J/ψ result at midrapidity.

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

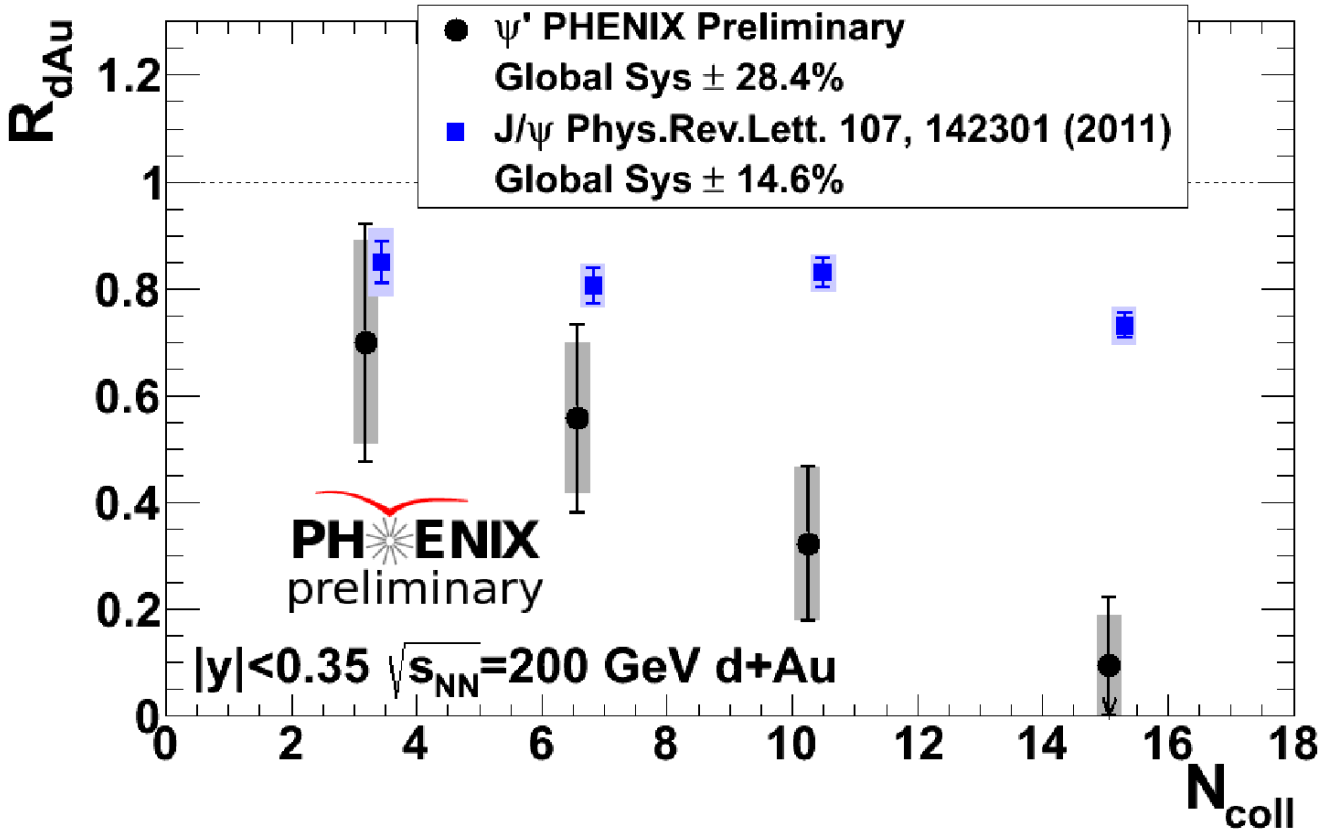


ψ' R_{dAu}

Centrality dependence of suppression much stronger than J/ψ result at midrapidity.

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

How does this result fit with the picture drawn from data at lower energy?

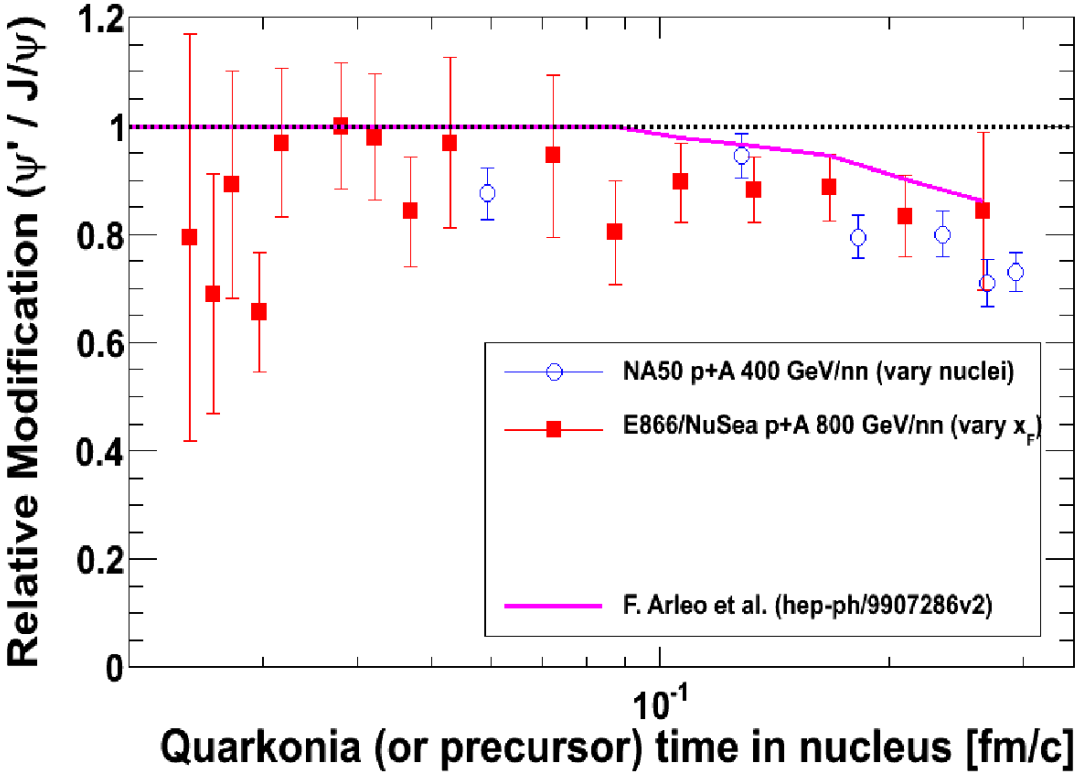


Relative Modification

- Physics idea based on low energy results:
  - If the formation time of the J/ψ(ψ') is shorter than the time spent traversing the nucleus, a larger suppression of the ψ' will be seen due to a larger nuclear breakup effect.
- Calculation based on this idea (pink line) in agreement with NA50 & E866 data

Plot the ψ'/(J/ψ) relative modification vs the proper time spent in the nucleus

Using $y(x_F)$, √s, and <L>, calculate the time spent traversing the target nucleus.



Relative Modification

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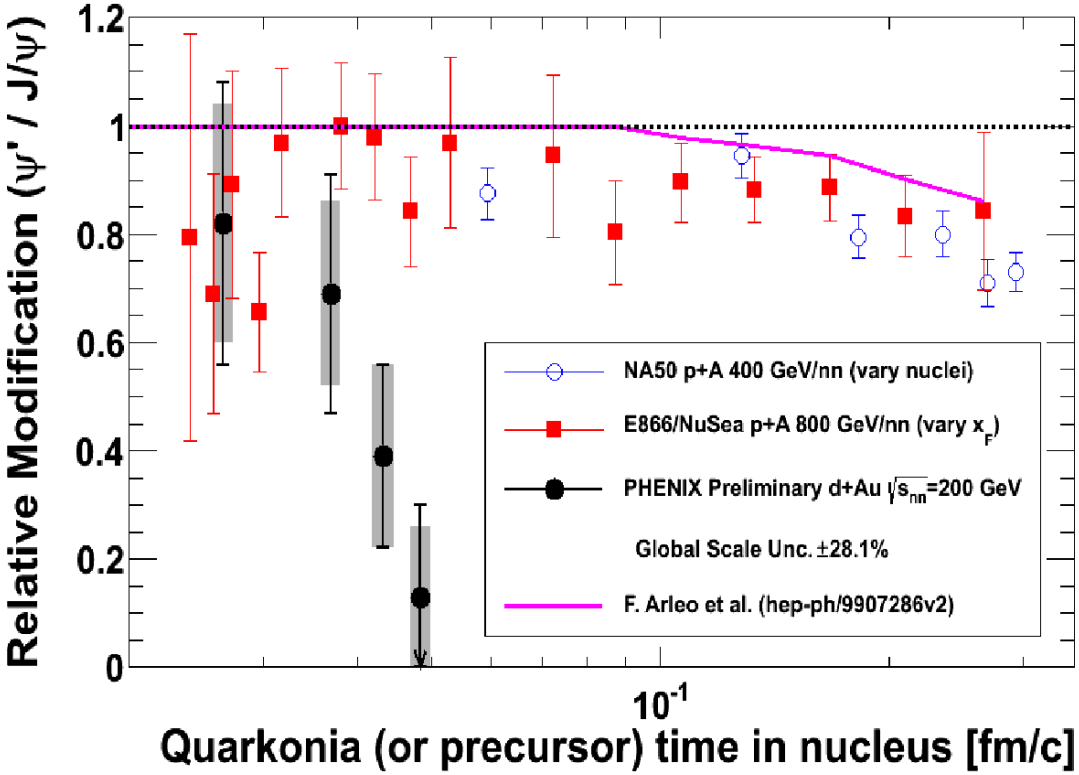
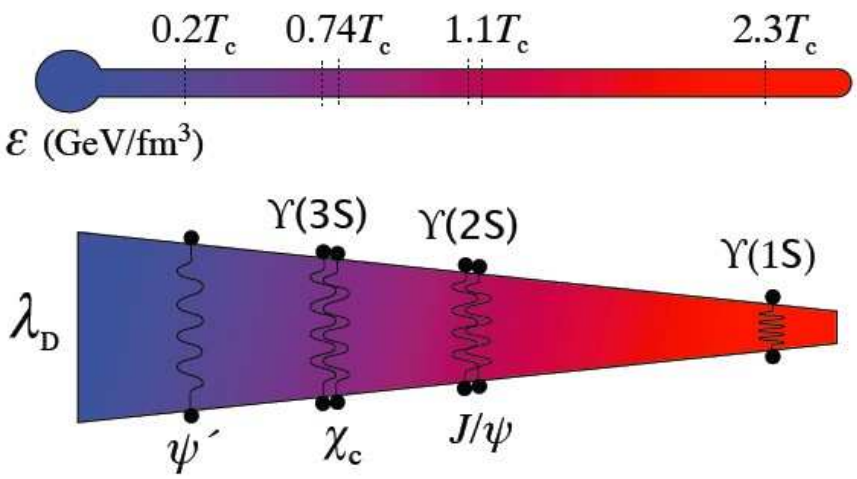
- Calculation based on this idea (pink line) in agreement with NA50 & E866 data

This explanation does not seem to hold at RHIC energies!

Using $y(x_F)$, √s, and <L>, calculate the time spent traversing the target nucleus.

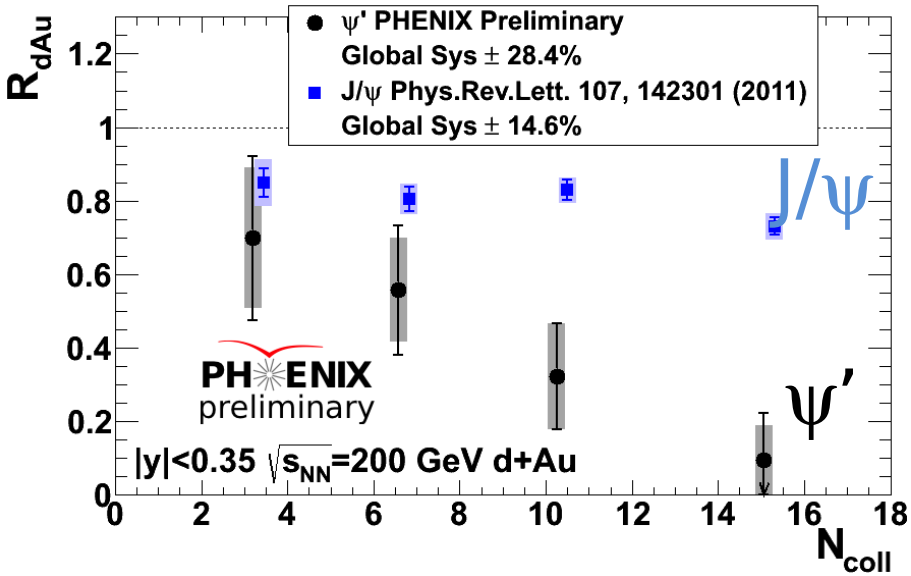


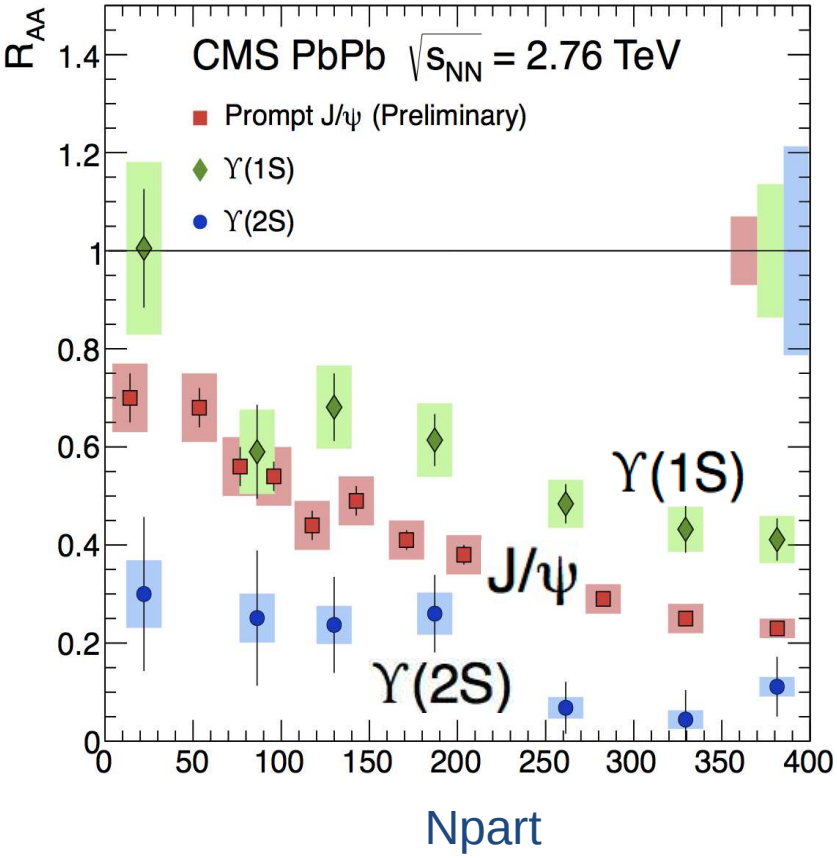
Know Your Baseline



STAR and CMS data consistent with *melting* of Υ(2s,3s)

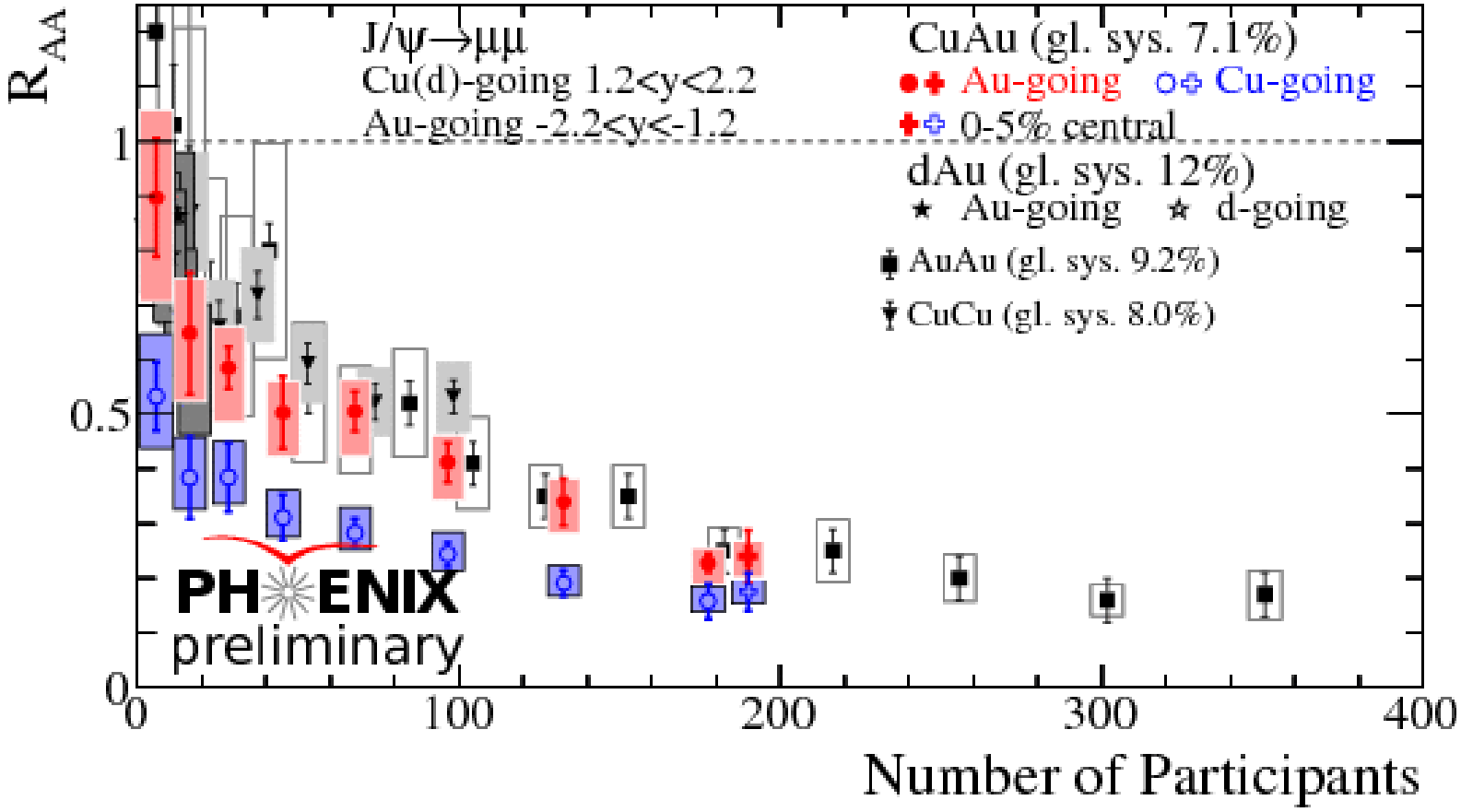
PHENIX d+Au



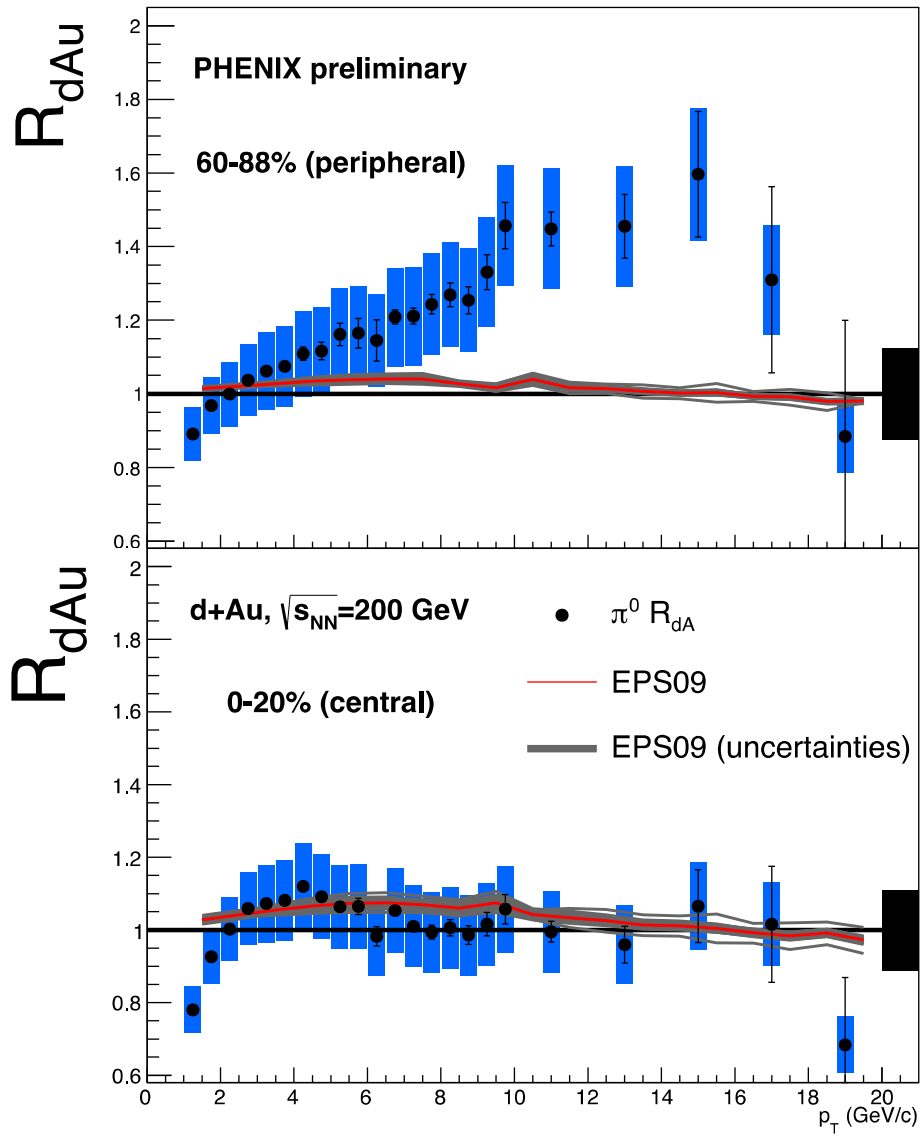


Cu+Au

- J/ψ suppression in Au-going direction is same as Au+Au
- Cu-going direction stronger suppression than in Au+Au



π^0 R_{dAu}



(Very basic) shadowing calculation uses EPS09 PDF modification* + Glauber MC + PYTHIA (*x*,*Q*2) sampling for π0.

Shadowing effects match reasonably well within the global scale uncertainties in central events (where modification is weak), but is not compatible with the *p*T shape in peripheral.

*nPDF modification assumed to scale linearly with longitudinal nuclear thickness.

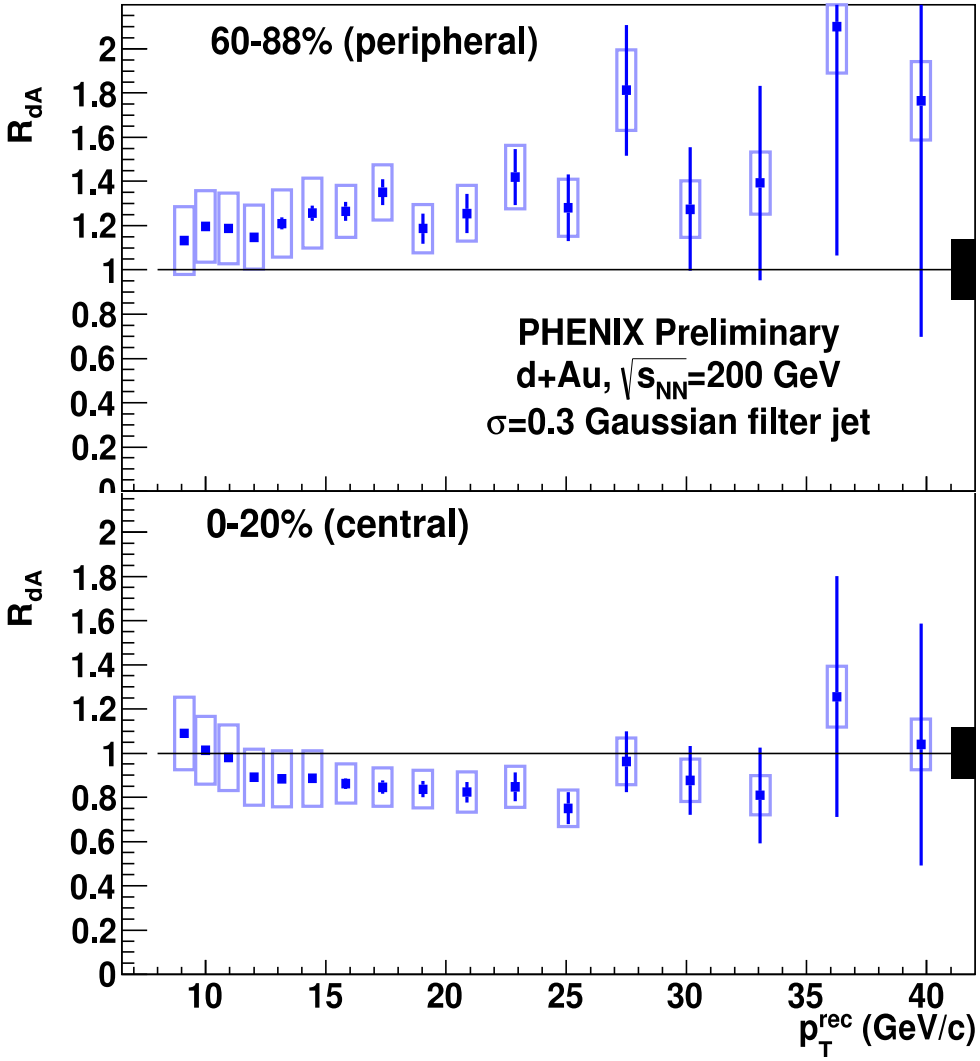
Reconstructed Jets

Jets reconstructed using Gaussian filter algorithm.

- Same algorithm used in Run 5 Cu+Cu and p+p analyses

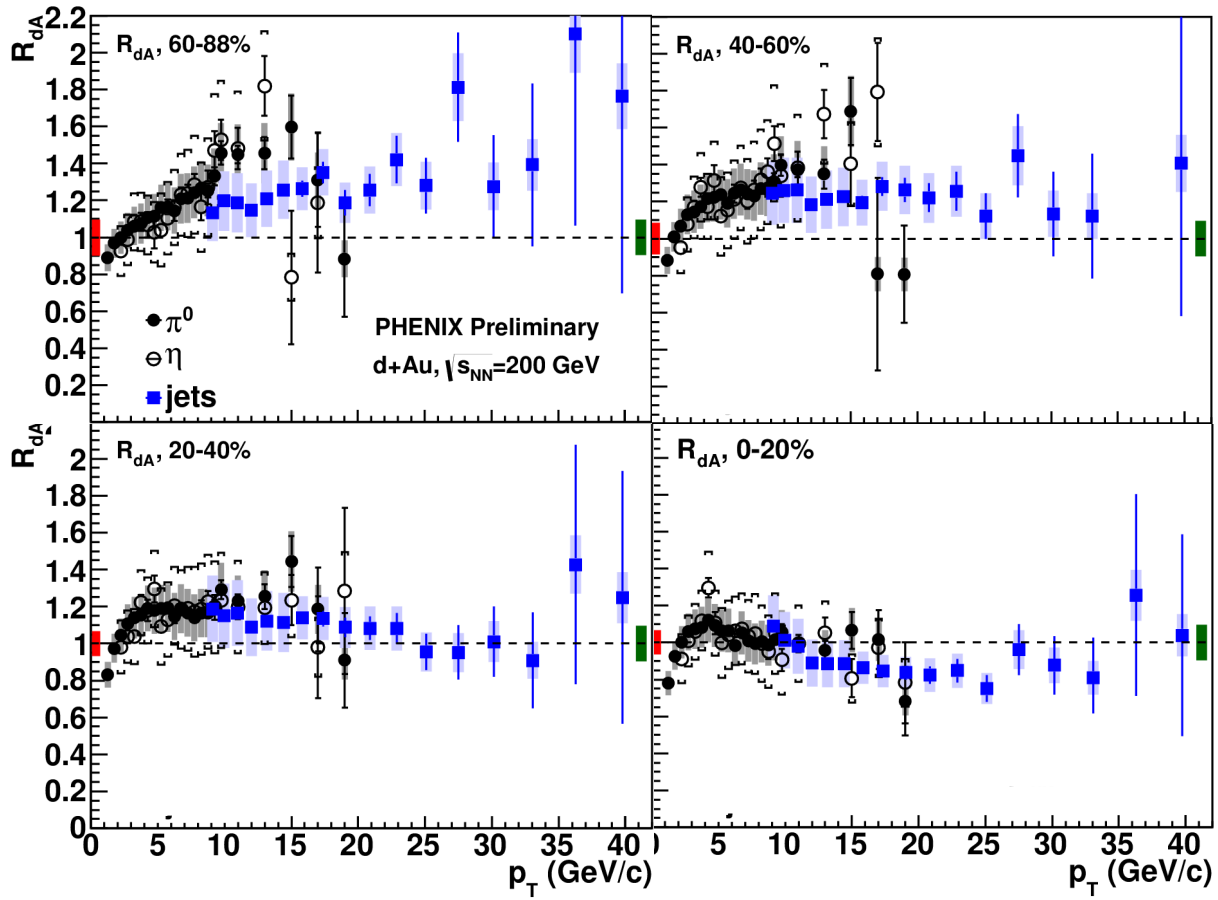
Higher *p*T reach than π0s

Enhancement in peripheral, suppression in central, sound familiar?



Reconstructed Jets

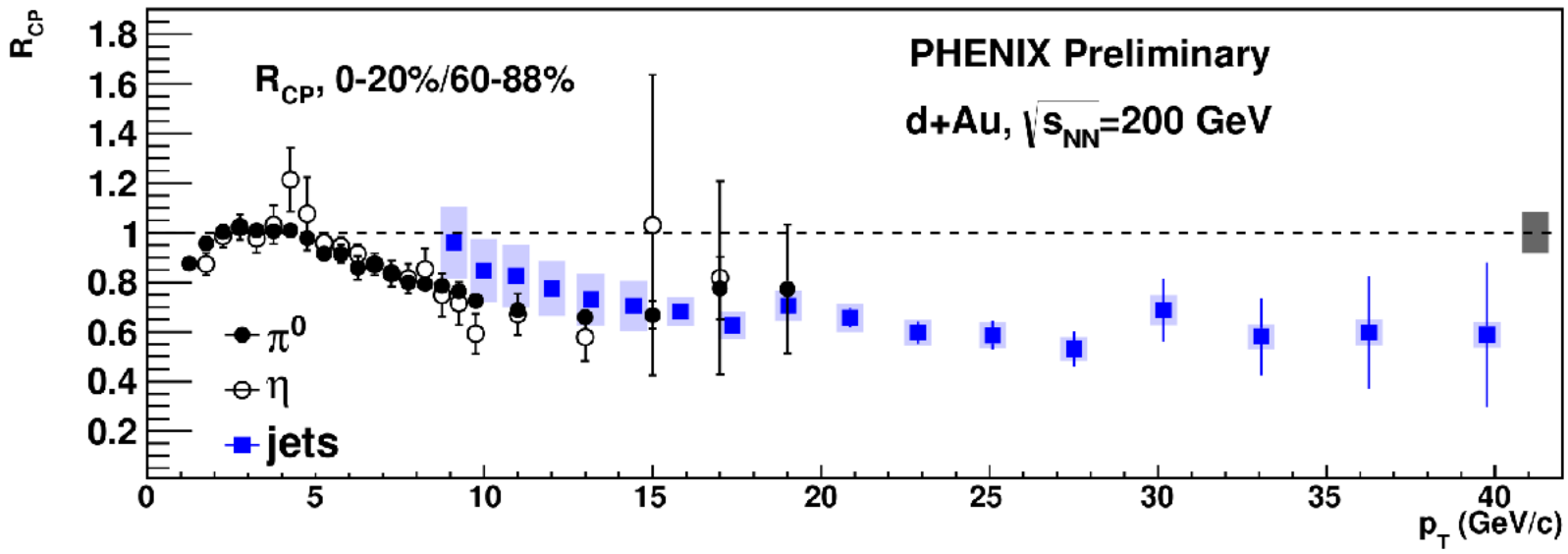
π0 and jets of same *p*T sample slightly different parton scales, but let's overlay them anyways…



Good agreement within uncertainties, and given the difference in observables.

Reconstructed Jets

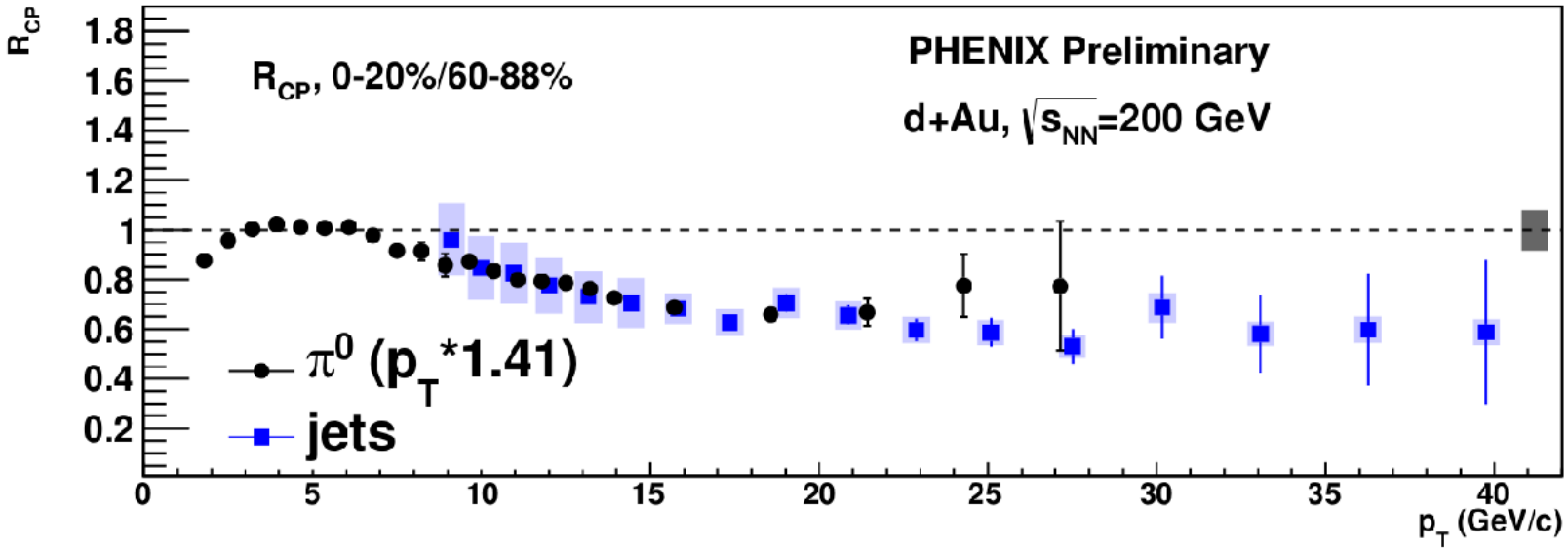
- Preliminary π^0/η measurement with 2008 data



- . . . but **hadrons** & **reconstructed jets** have different p_{T}-scale. . .

Reconstructed Jets

- Scale single hadron p_{T} by $1/\langle z \rangle$ using empirical $\langle z \rangle = 0.7$:

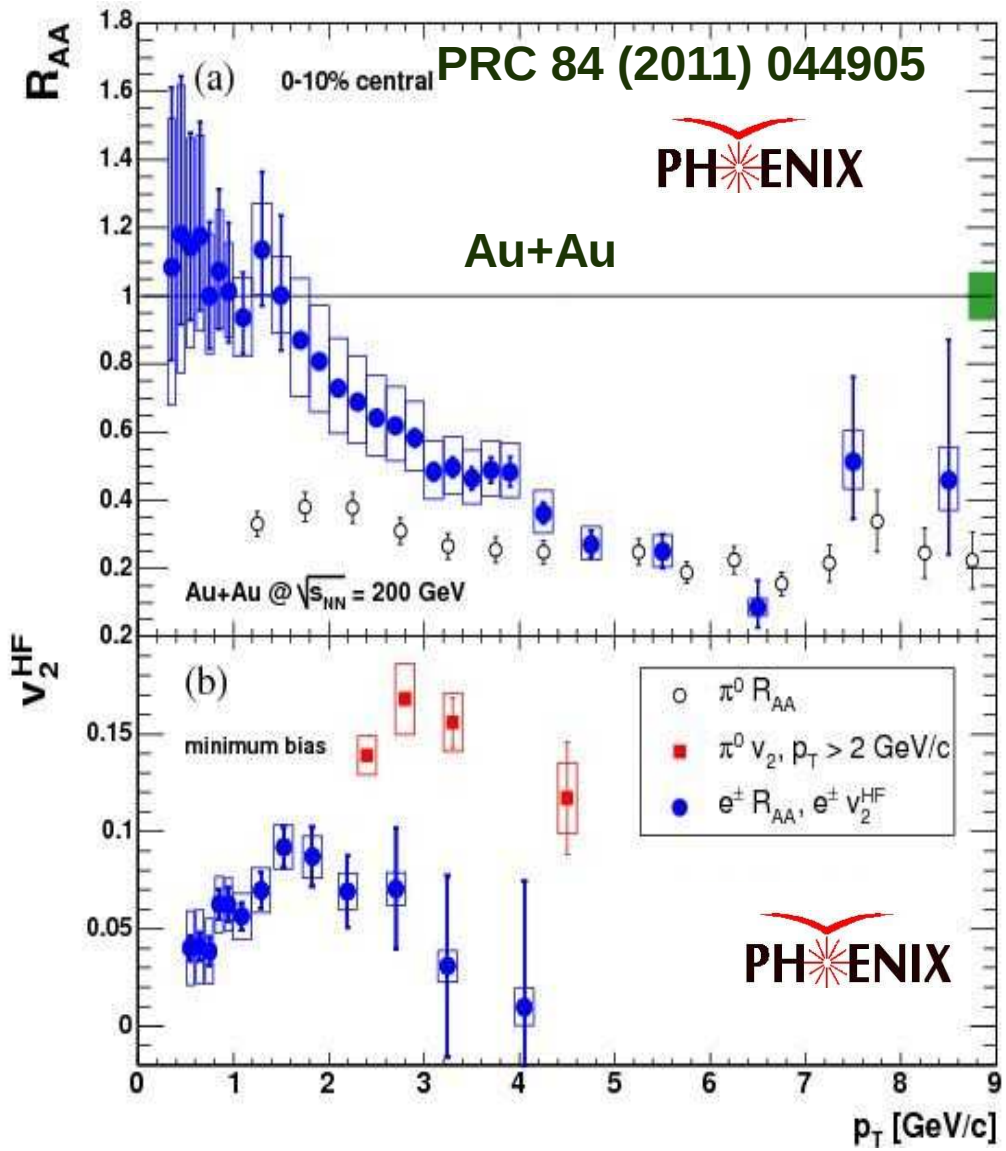


- Excellent agreement in shape between **jets** and **hadrons**
  - ⇒ very different systematics
  - ⇒ large difference in behavior between central vs. peripheral collisions **not** an artifact of jet reconstruction

Open Heavy Flavor

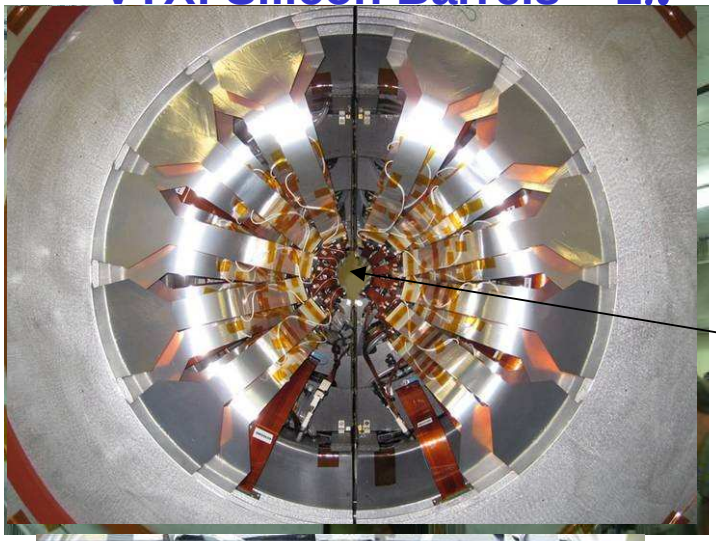
- **Electrons from Heavy quarks are suppressed, and they flow.**

- **Collective behavior is apparent in e^{HF}; but HF v_2 is lower than v_2 of π^0 for $p_T > 2$ GeV/c.**

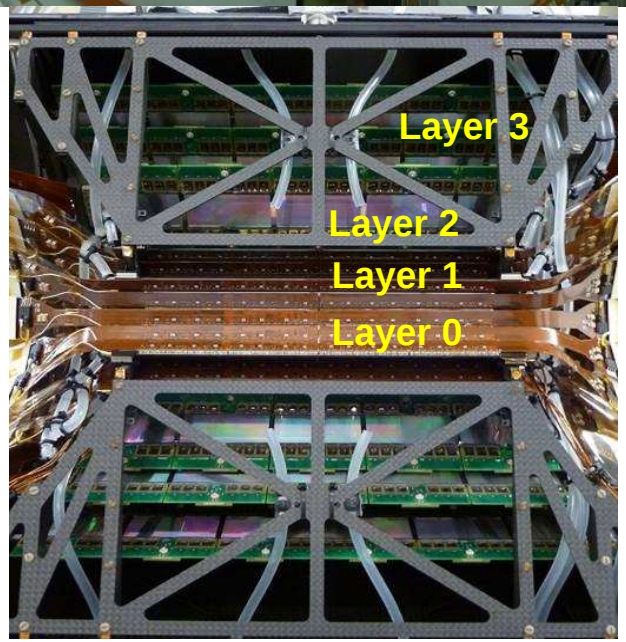


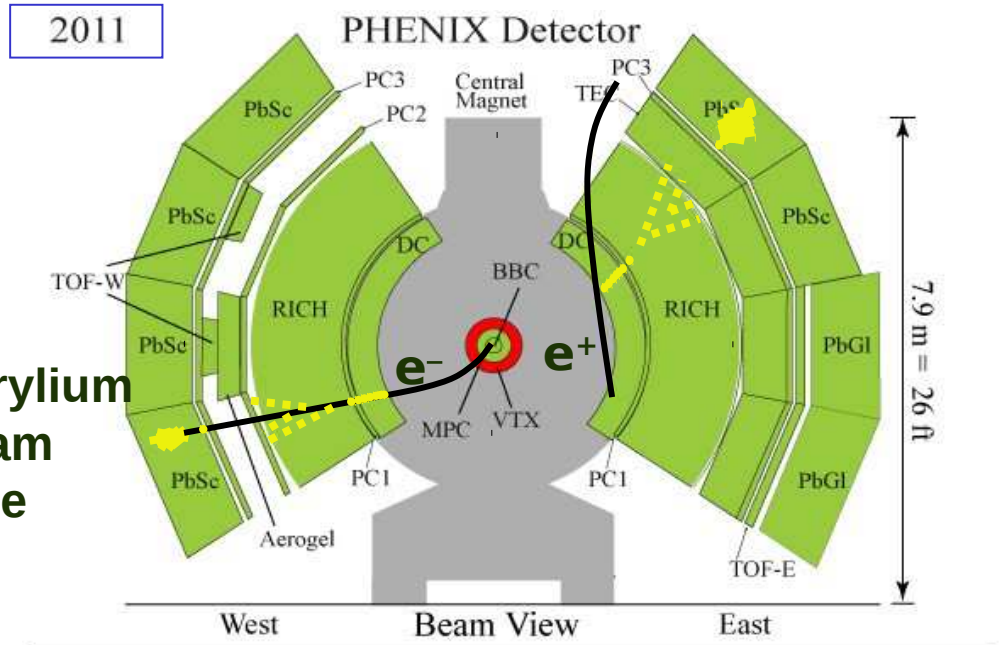
VTX Detector

VTX: Silicon Barrels ~ 2π

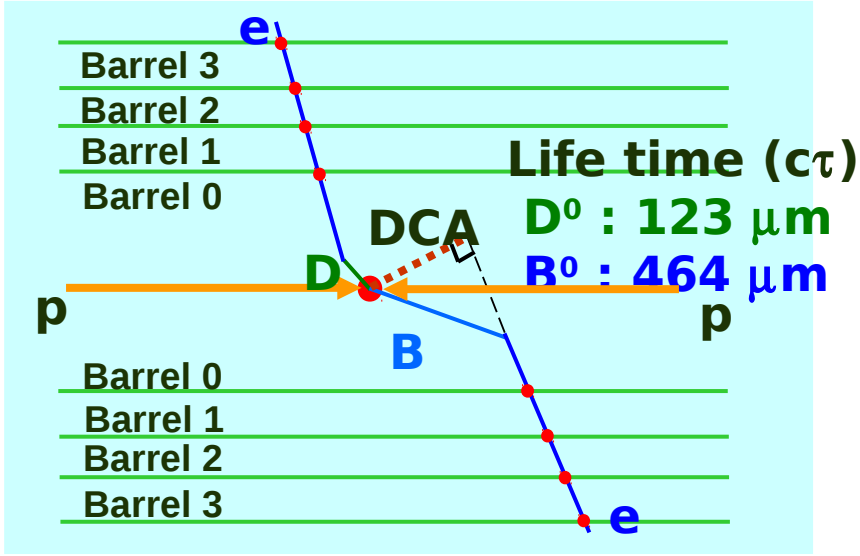


Berylium beam pipe





Main Goal

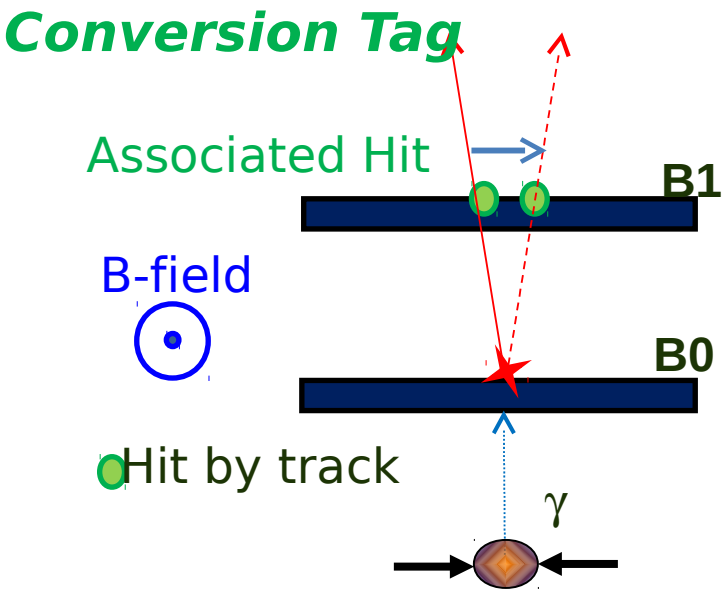


Conversion Rejection

- Challenge in the DCA measurement of single electrons is the Conversion Electron Background (CEB).

- Most conversions happen in the outer layers (total radiation length = 12 % (B0: 1.3%, B1: 1.3%, B2:4.7% and B3: 4.7%). They are suppressed by requiring a hit in inner silicon layer B0.

- Conversions in the beam pipe and B0, and Dalitz are suppressed by rejecting electron tracks with a nearby hit : Conversion Tag and Veto.



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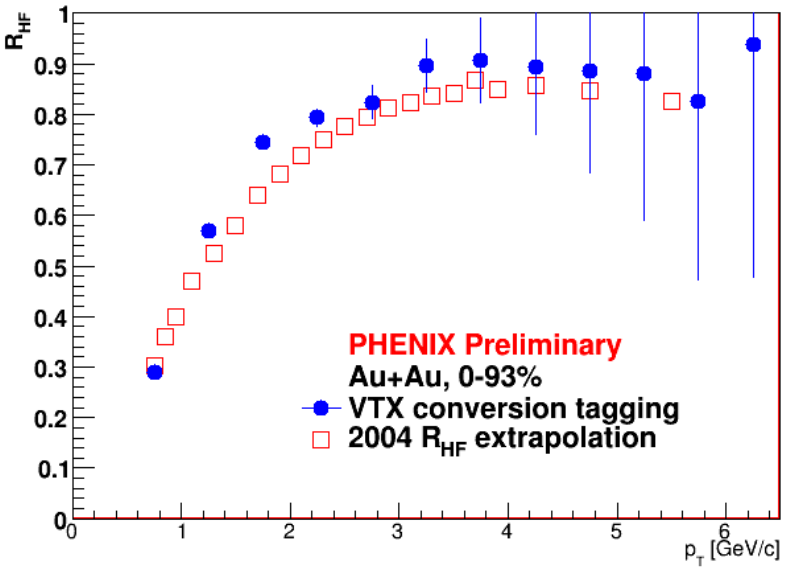
- Conversions in the beam pipe and B0, and Dalitz are suppressed by rejecting electron tracks with a nearby hit : Conversion Tag and Veto.

- Yield of the remaining conversions and Dalitz are estimated using the veto efficiency.

Fraction of HF electron after conversion Veto

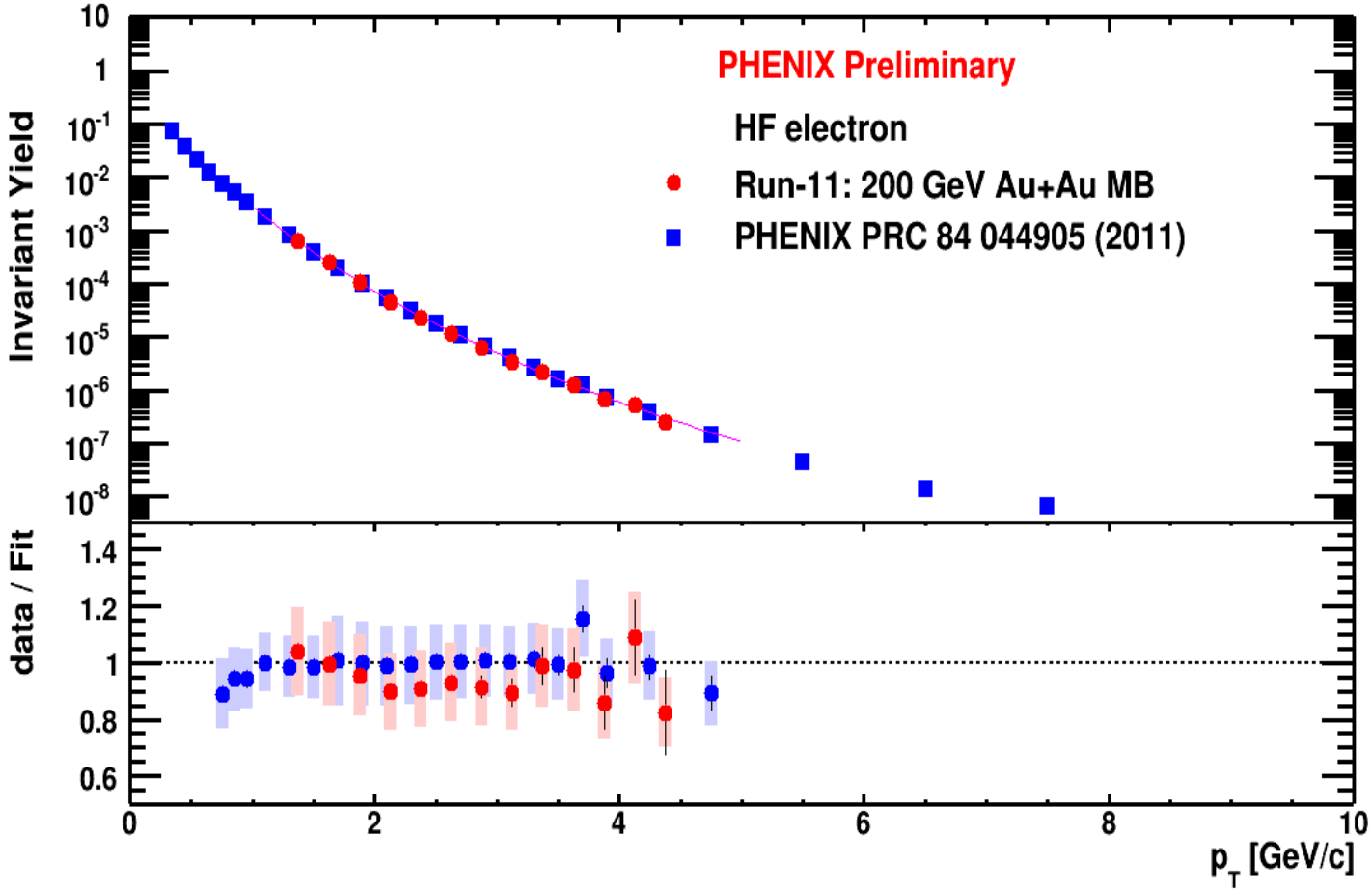
$R_{HF} = e^{HF}/e^{inc} = e^{HF}/(e^{HF} + e^{PH})$



Invariant Yield

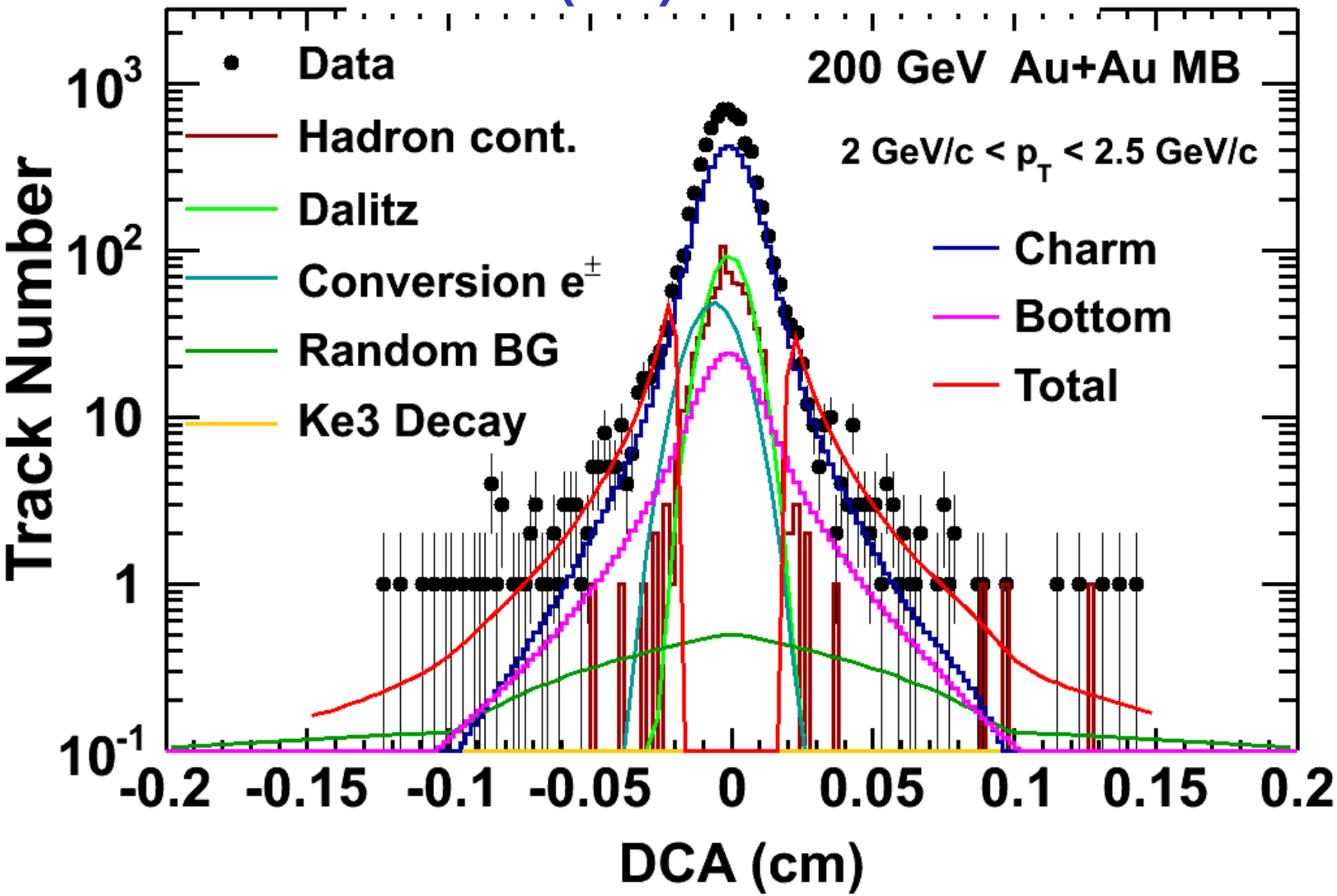
- **Using VTX to tag Dalitz and conversion electrons, we measure the heavy flavor (HF) electron spectra**

Run 2011 HF spectrum consistent with **previously published HF** by PHENIX



DCA Distribution

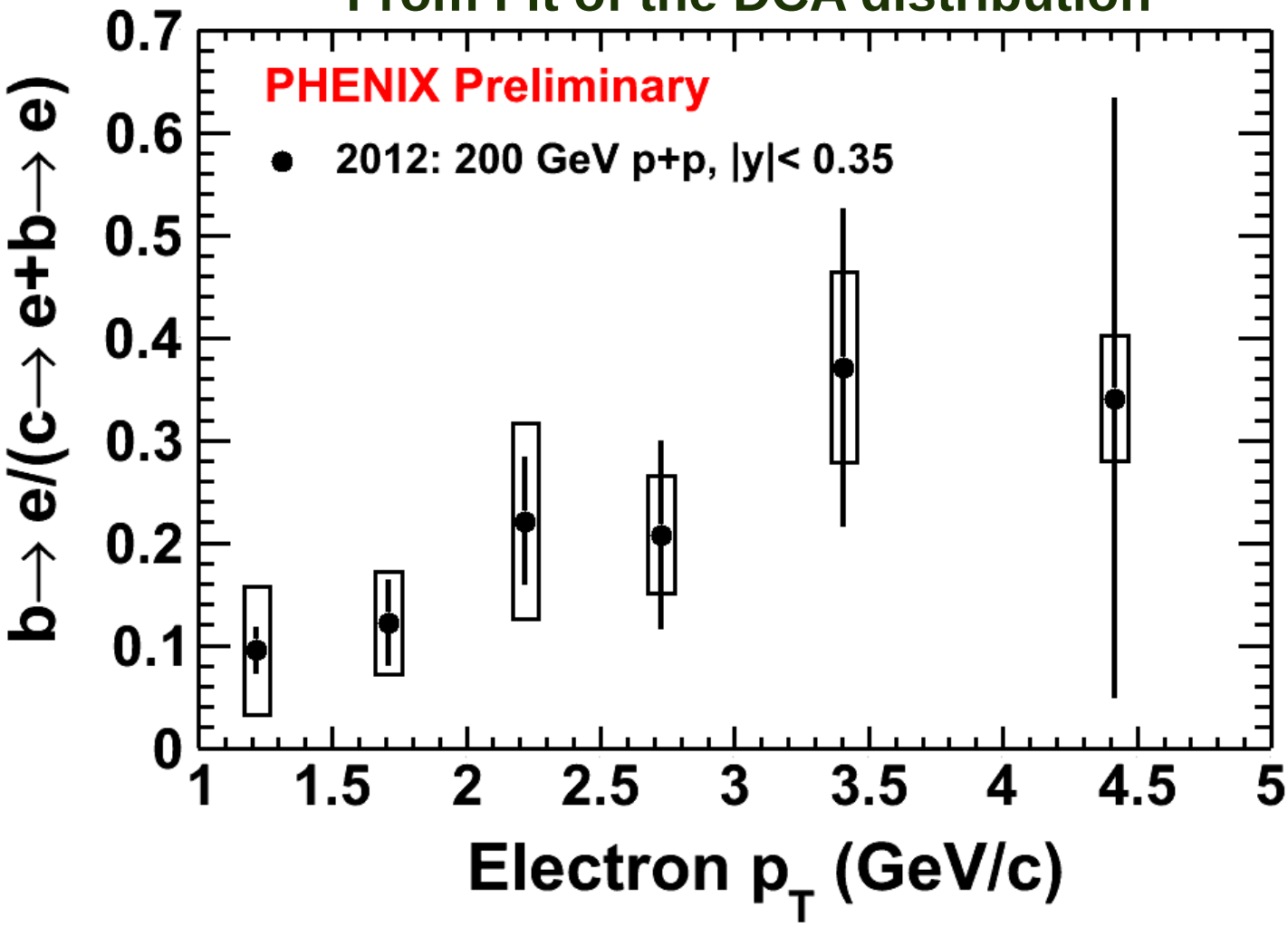
c/(b+c) = 0.92 ± 0.02



Bottom in p+p

First direct measurements of bottom production in p+p at RHIC

From Fit of the DCA distribution



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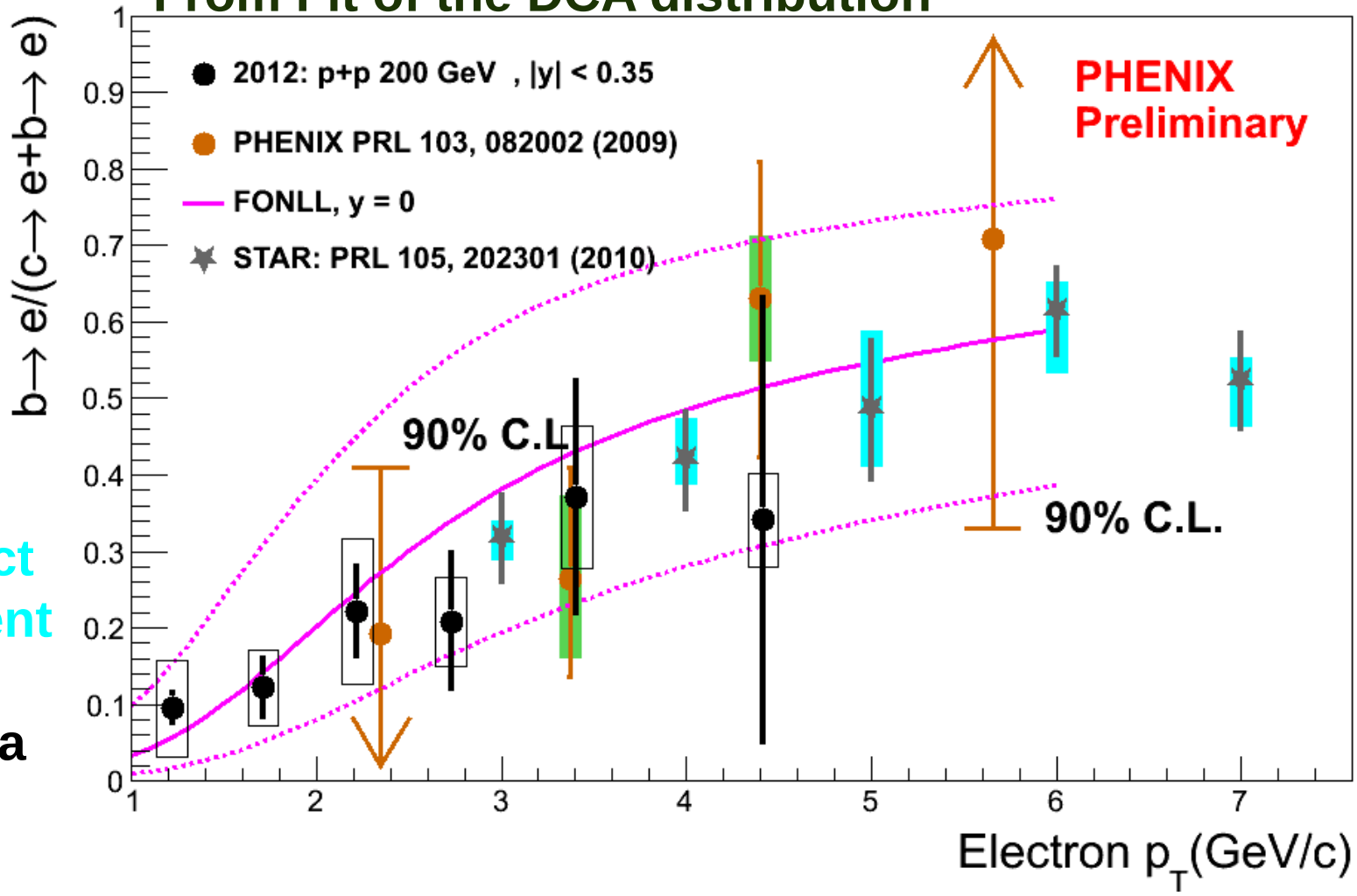
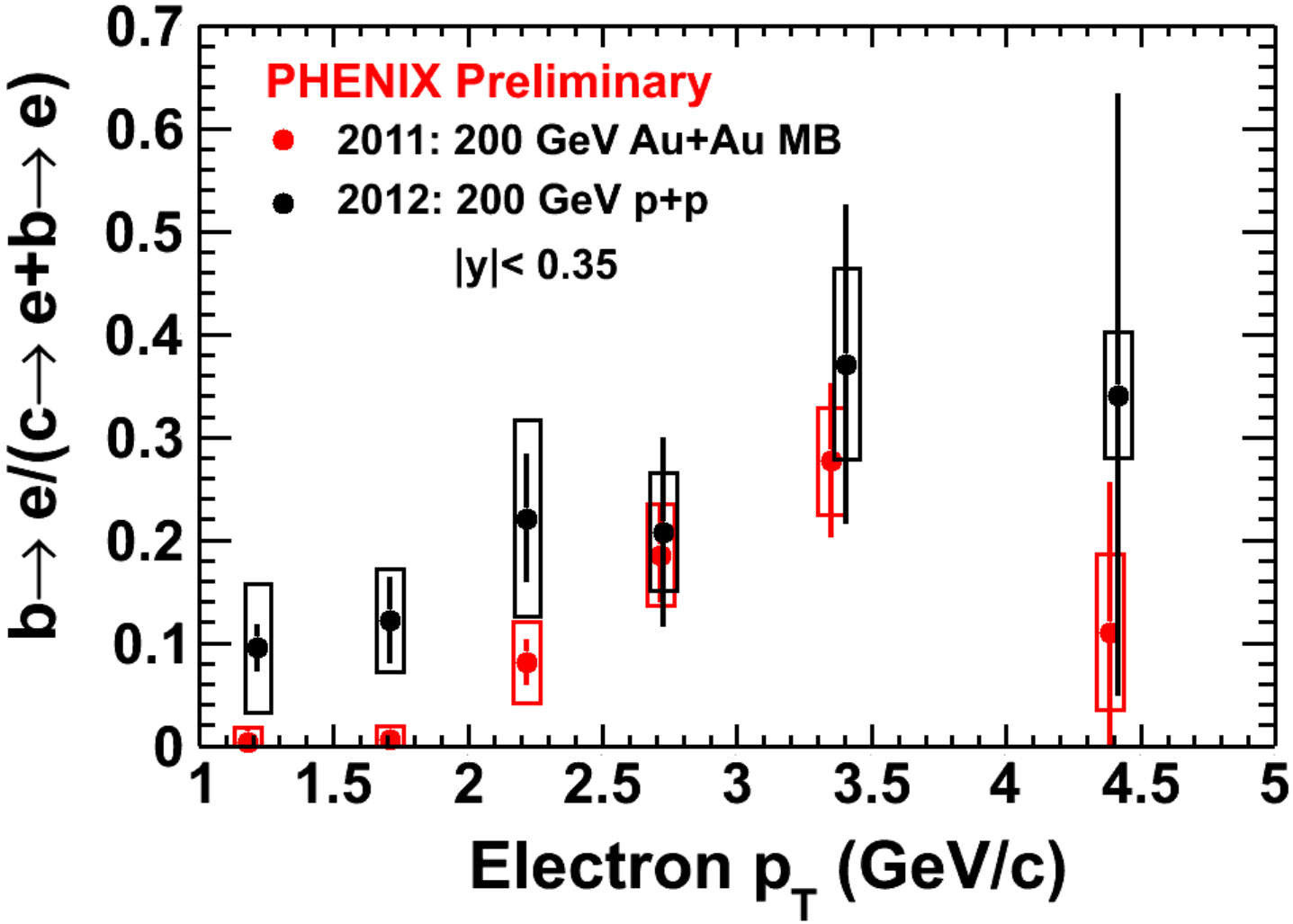


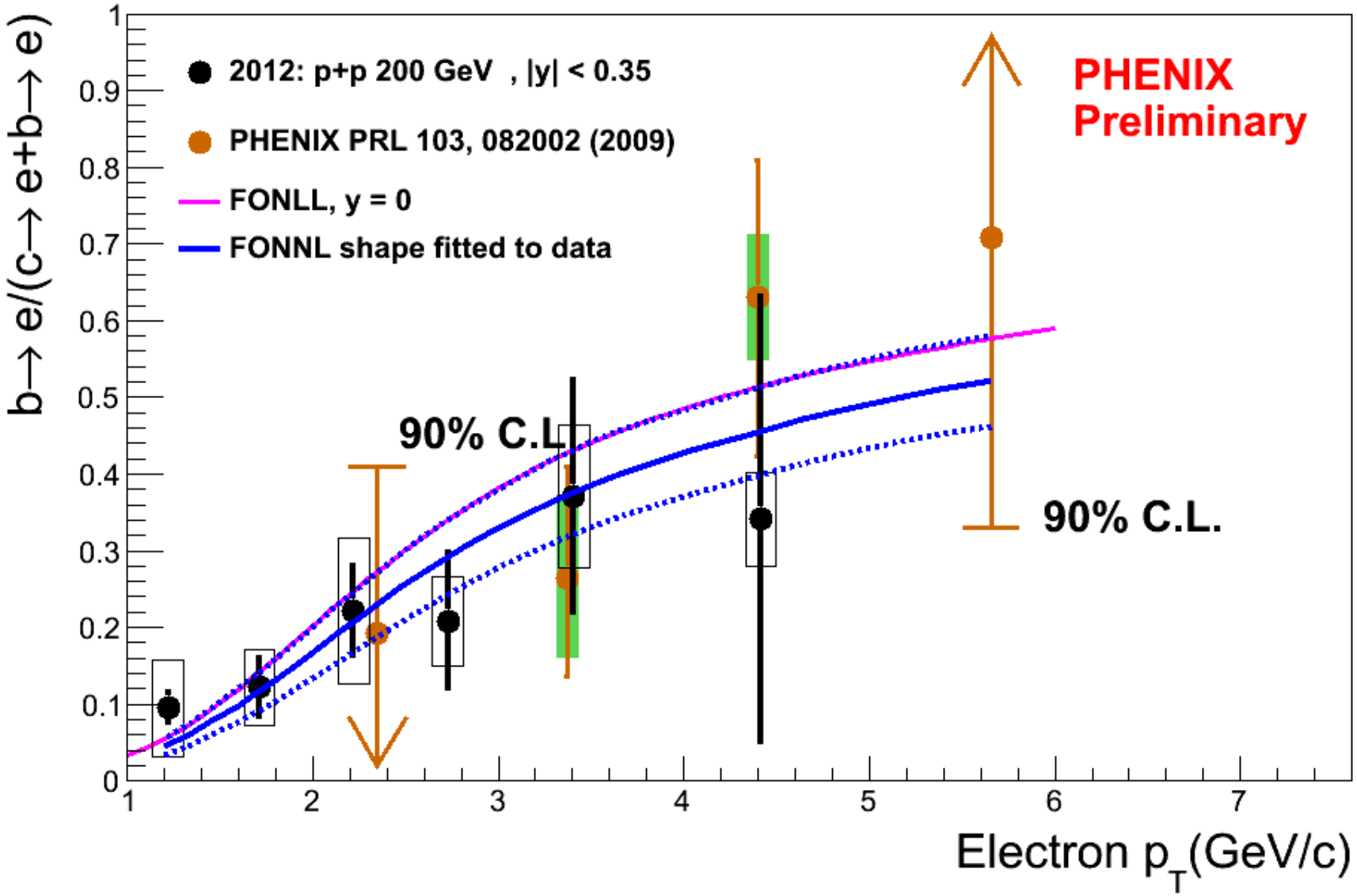
STAR indirect measurement consistent with our data

Bottom in p+p and Au+Au

b→e /(b→e+ c→e) in 200 GeV Au+Au vs p+p
From Fit of the DCA distribution



FONLL Fit to p+p

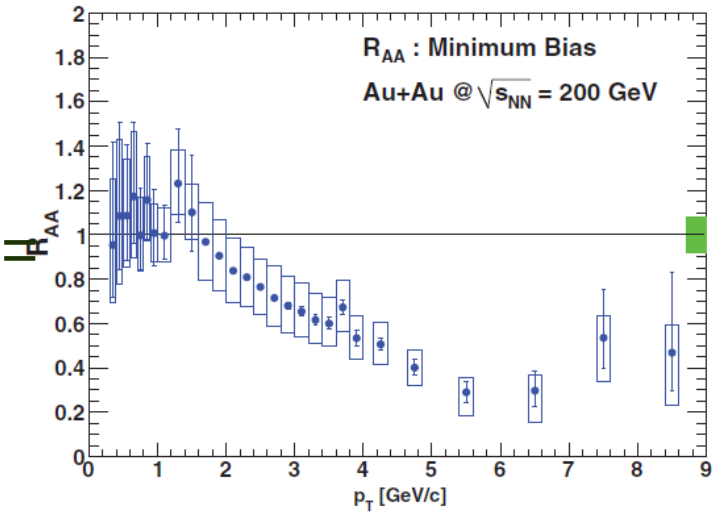


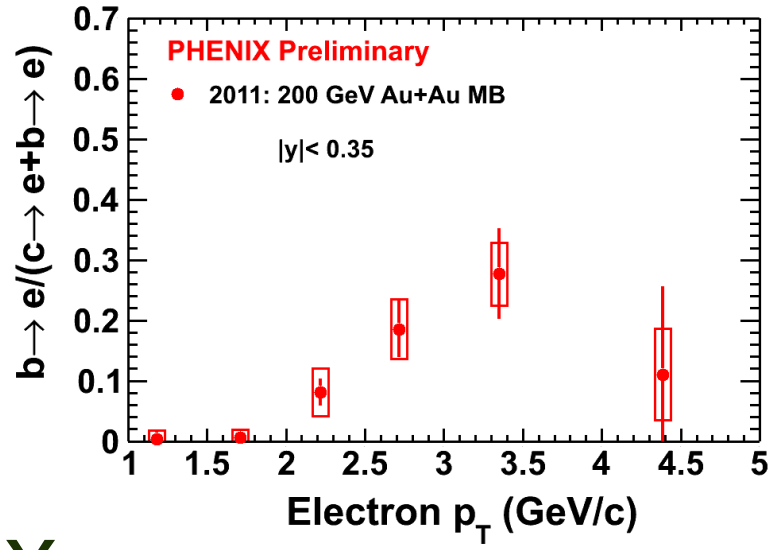
This is a strong assumption that goes into the R_AA

R_{AA} of Bottom Extraction

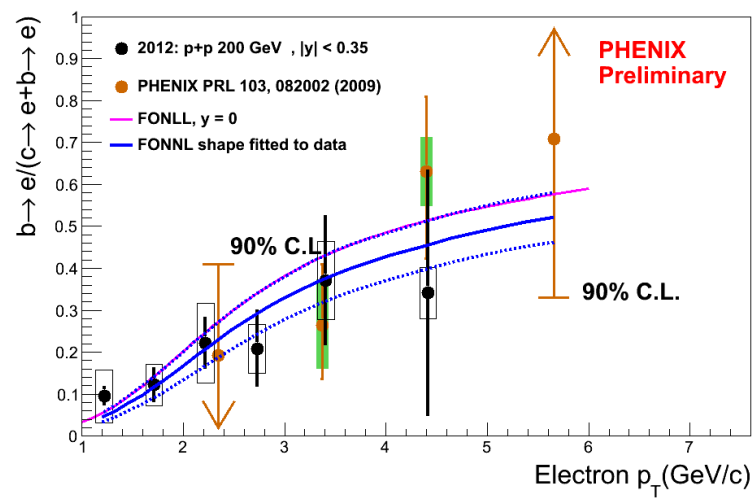
$$R_{AA}^{b\to e} = R_{AA}^{b+c\to e}\frac{\left(\frac{b\to e}{b+c\to e}\right)^{AA}}{\left(\frac{b\to e}{b+c\to e}\right)^{pp}}$$

R_{AA} (b→e) =



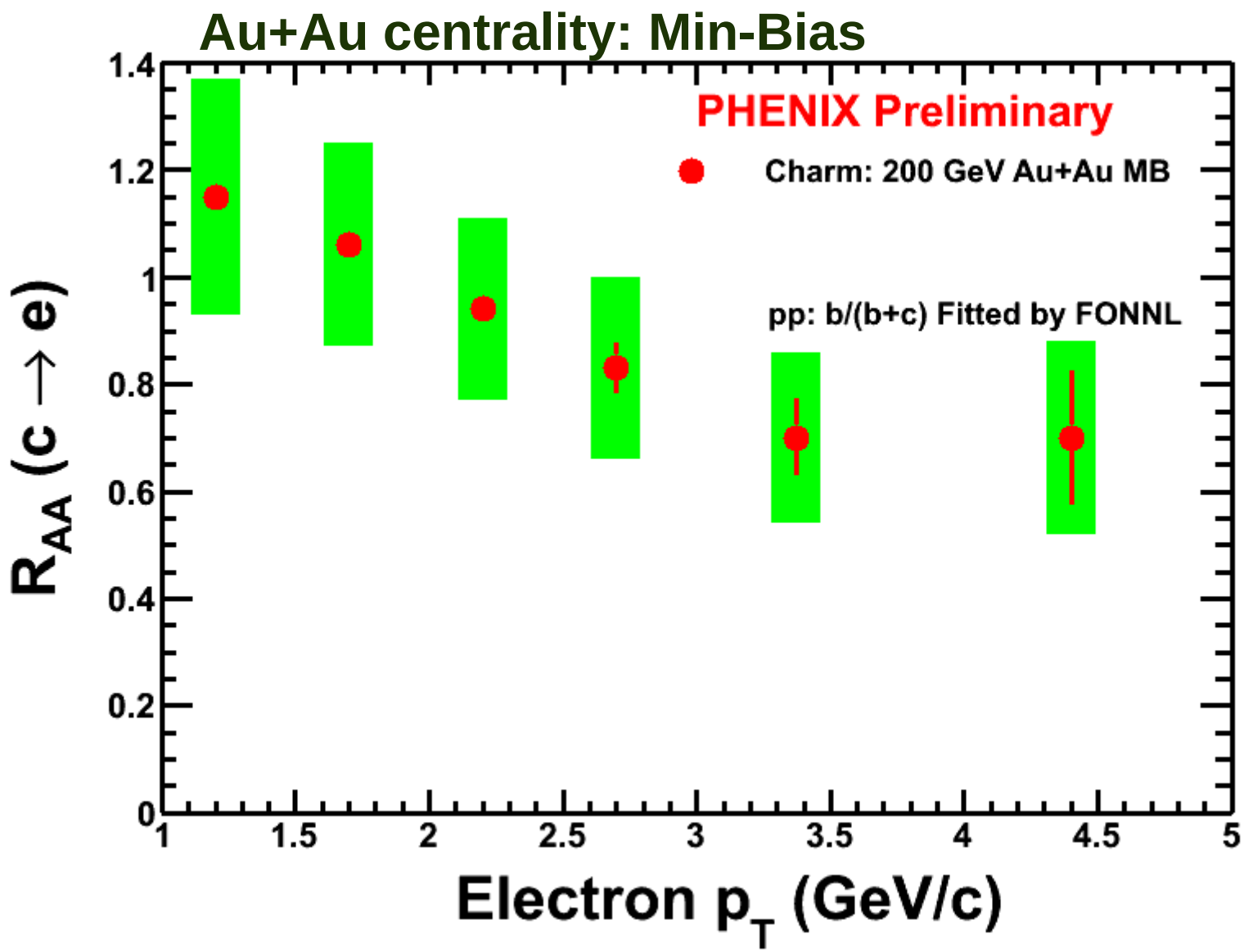


X



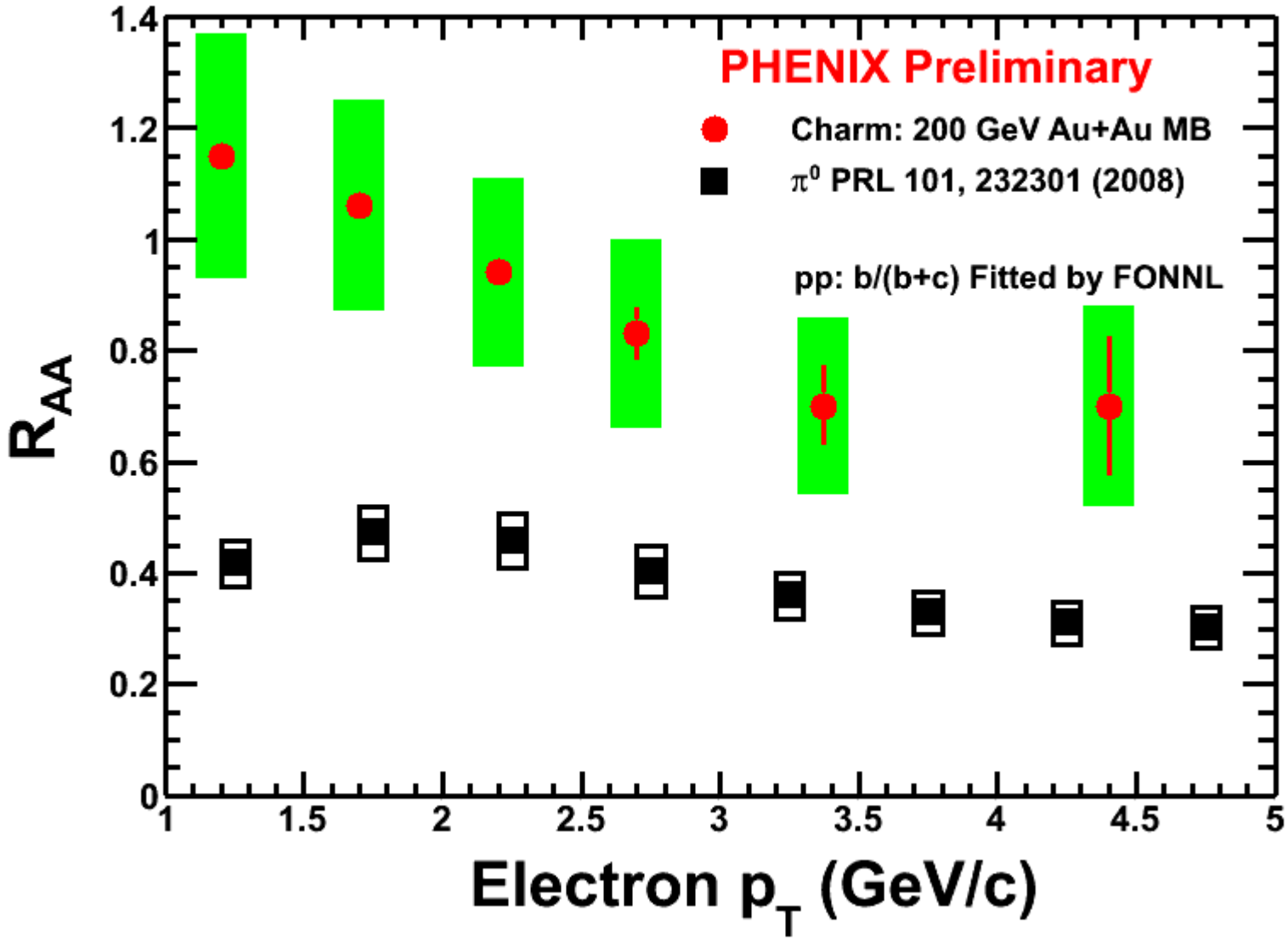
$$R_{AA}^{c\to e} = R_{AA}^{b+c\to e}\frac{1-\left(\frac{b\to e}{b+c\to e}\right)^{AA}}{1-\left(\frac{b\to e}{b+c\to e}\right)^{pp}}$$

Nuclear Modification of Charm

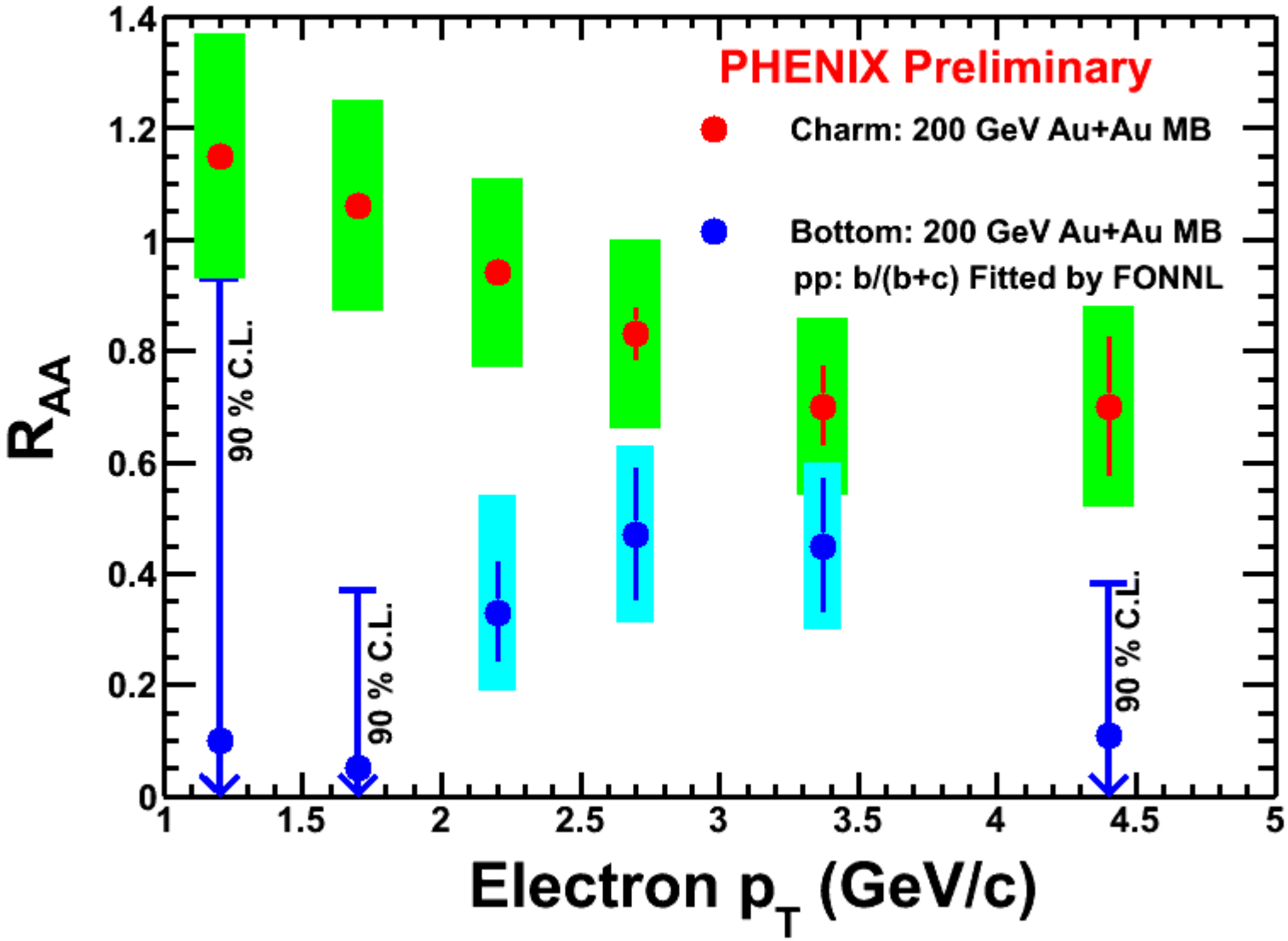


Nuclear Modification of Charm

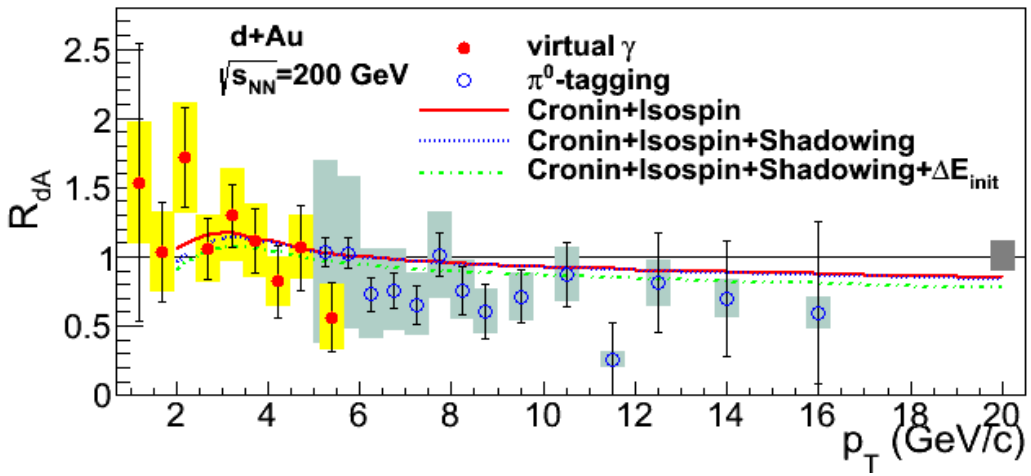
Charm (c→e) is less suppressed than π^0



Nuclear Modification of Bottom

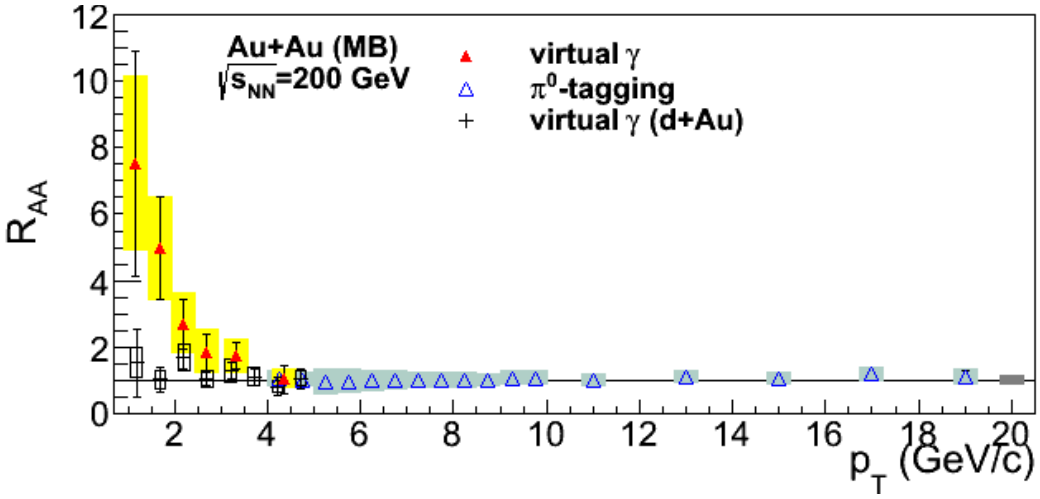


Direct Photons in d+Au and Au+Au



arXiv:1208.1234

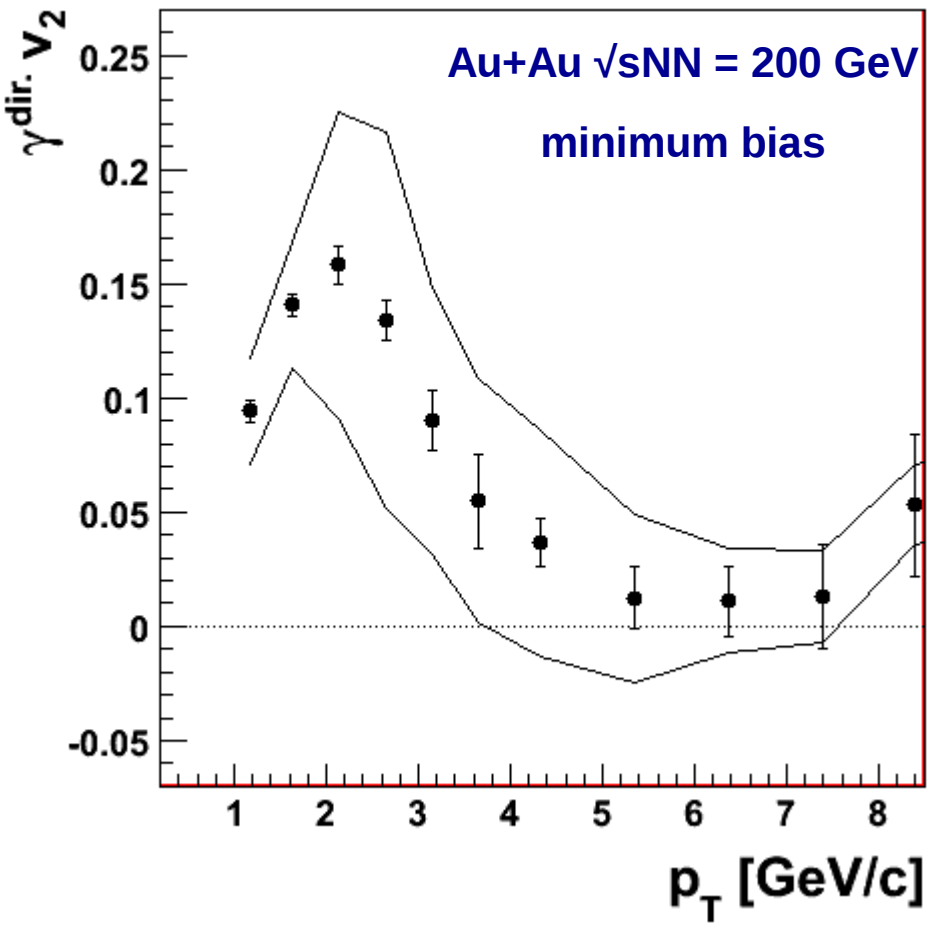
RdA is consistent with unity



- **Large excess of γ observed in Au+Au is not due to initial state effects**
- **Reinforce interpretation of the Au+Au excess as thermal radiation from the QGP**

Direct Photon v2

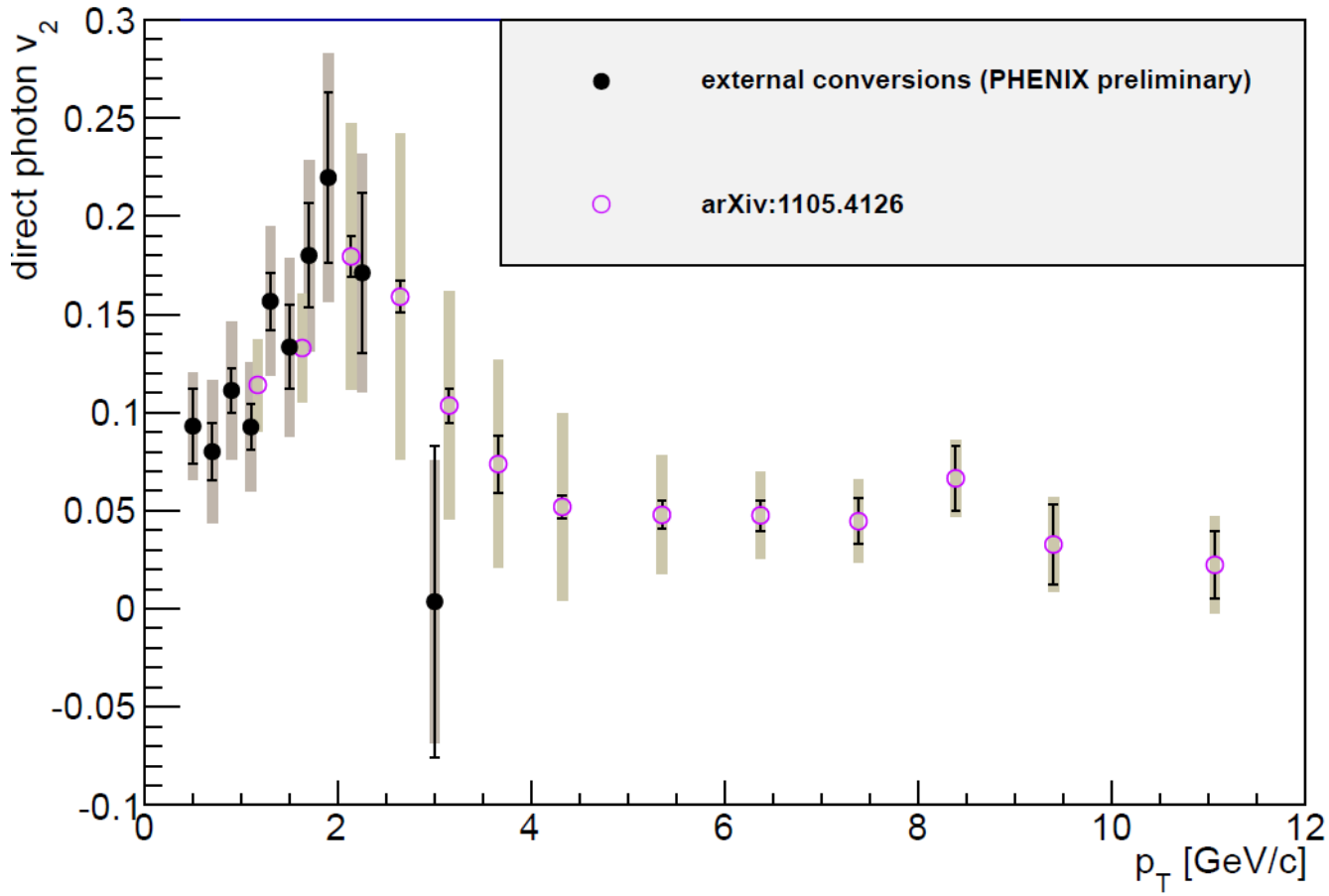
arXiv:1105.4126



- Large v2 at pT < 4 GeV/c where thermal photons dominate
- v2 consistent with 0 at high pT where prompt photons domininate

- **Very surprising result: large v2 implies late emission whereas thermal radiation implies early emission**
- **Models have difficulties in reproducing simultaneously yield and v2 of photons**

External Conversion



- Independent analysis
- Different systematics
- pT range extended down to 0.5 GeV/c

- **Two independent and consistent results**
- **Important confirmation of previous v2 results**

Summary

- Cold nuclear matter effects are large : know your baseline!
- Hints that bottom is suppressed more than charm
- Is direct photon v2 consistent with thermal emission?