High p_T: Energy Loss Physics at PHENIX

Michael P. McCumber
(University of Colorado)
for the PHENIX Collaboration

Quark Matter 2012
Washington, DC

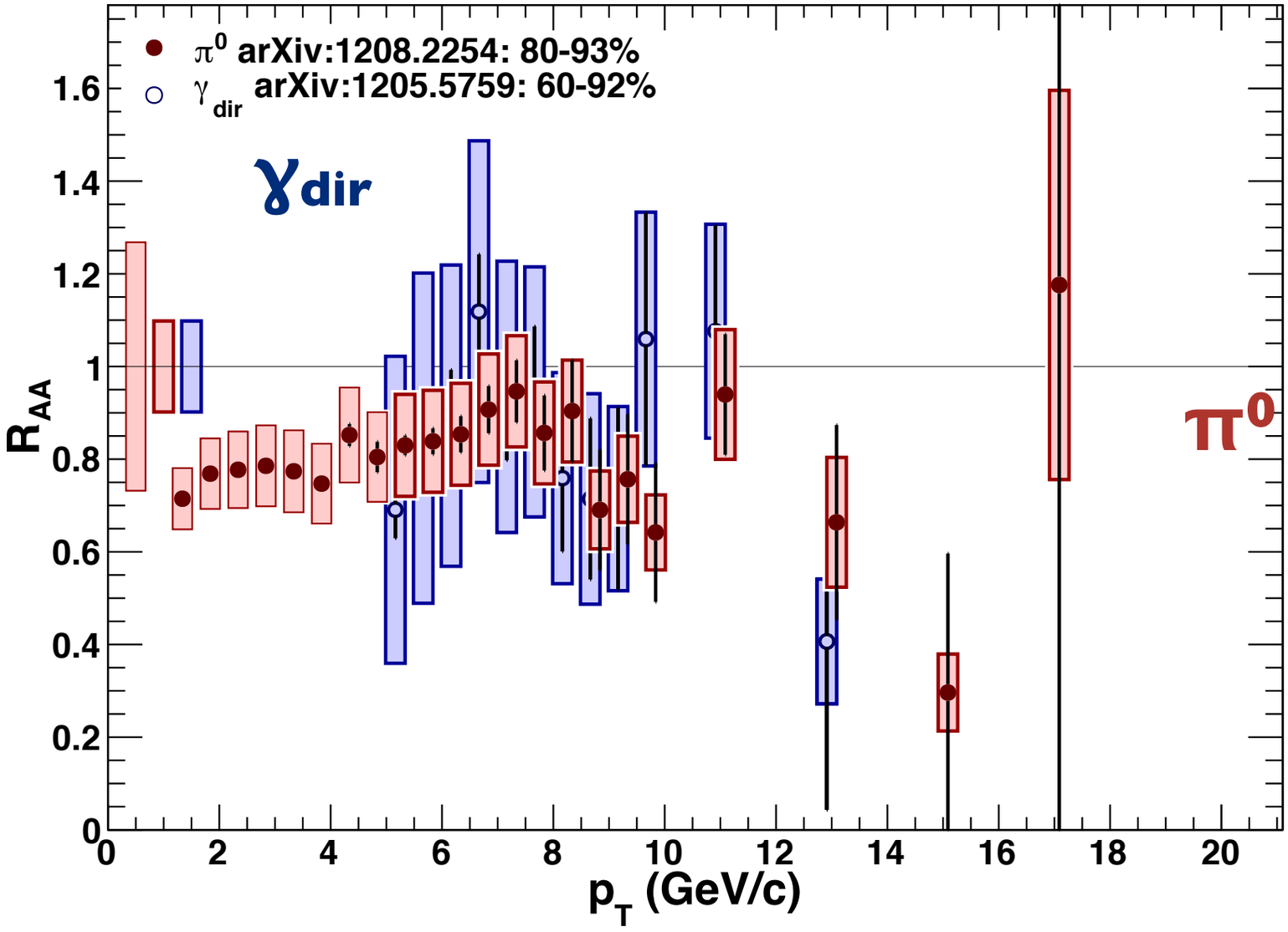
Nuclear Suppression

$$R_{AA}(p_T) = \frac{(1/N^{evt})d^2N_{AA}/dp_T dy}{\langle T_{AB}\rangle \times d^2\sigma_{pp}/dp_T dy}$$

Large π^0 suppression is observed in central Au+Au collisions

Data tables are now available in preprint

Both the centrality and reaction plane dependencies reported



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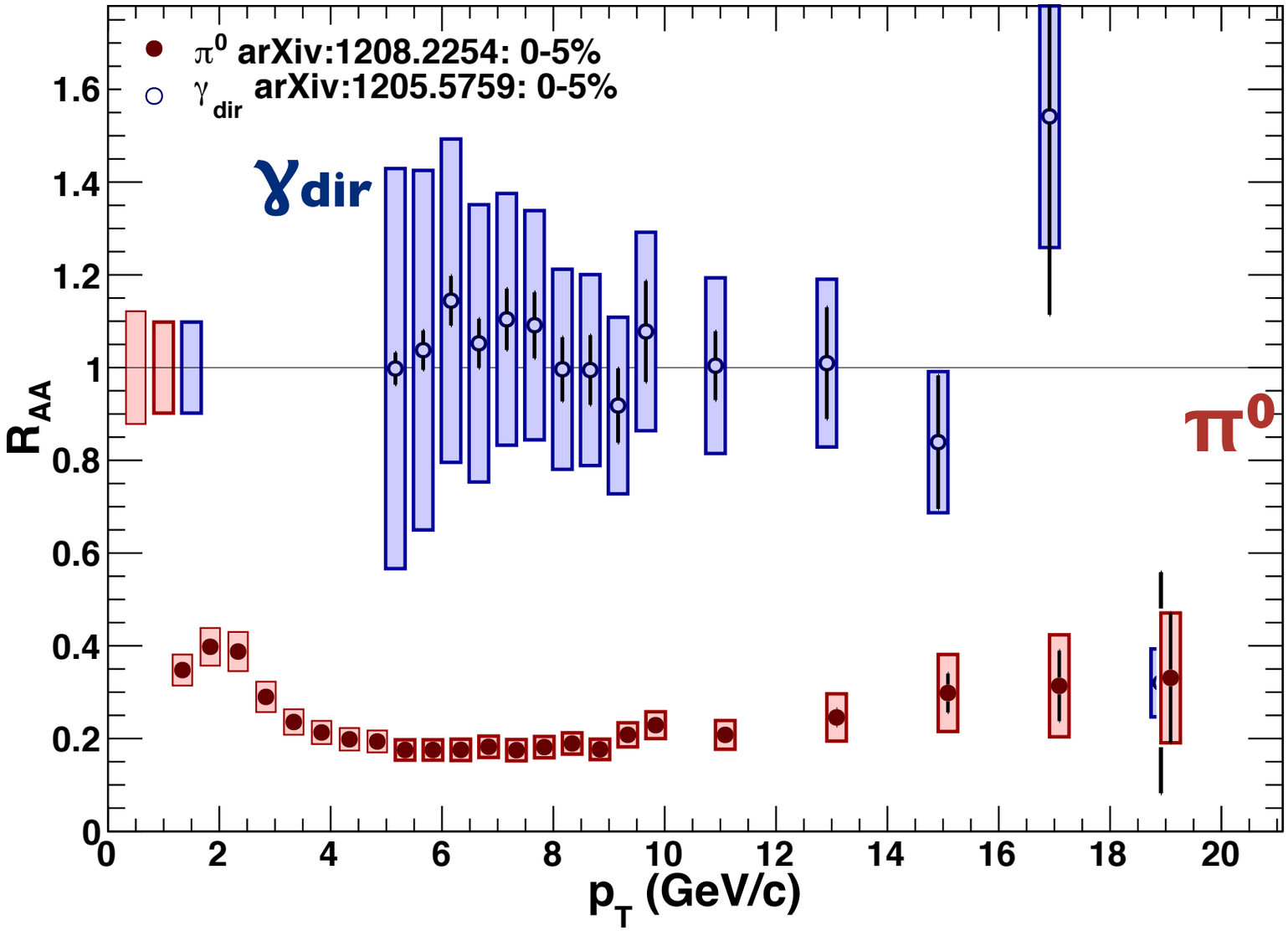
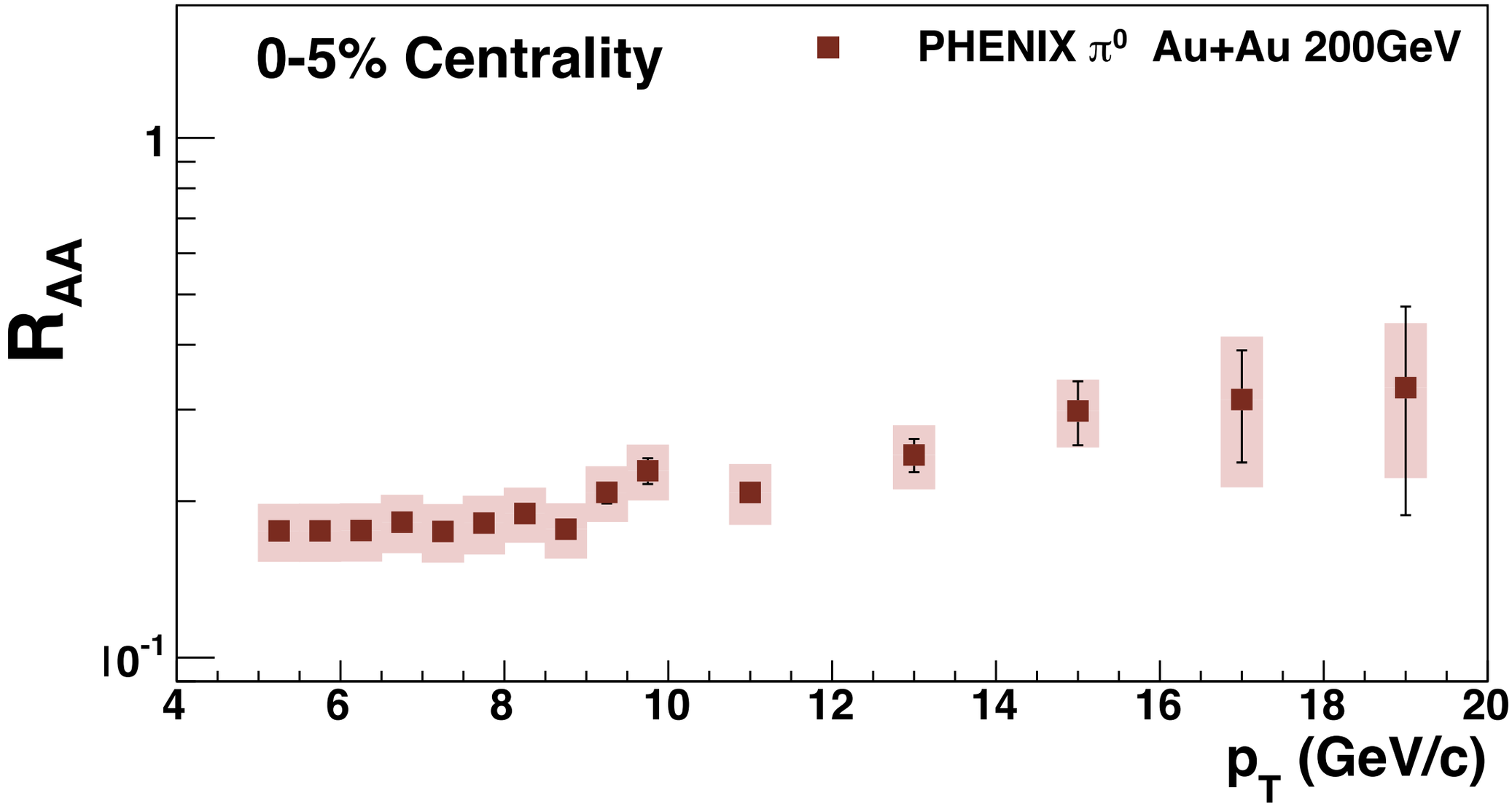


Central Collision R_{AA}



Improved PHENIX data have now quantified the slow rise in p_T.

Slope = $(1.06^{+0.34}_{-0.29}) \times 10\text{-}2$ (GeV/c)-1

Significant above flat, i.e. slope = 0.0

Central collision R_{AA} is very similar between RHIC and LHC

Spectral shapes are not

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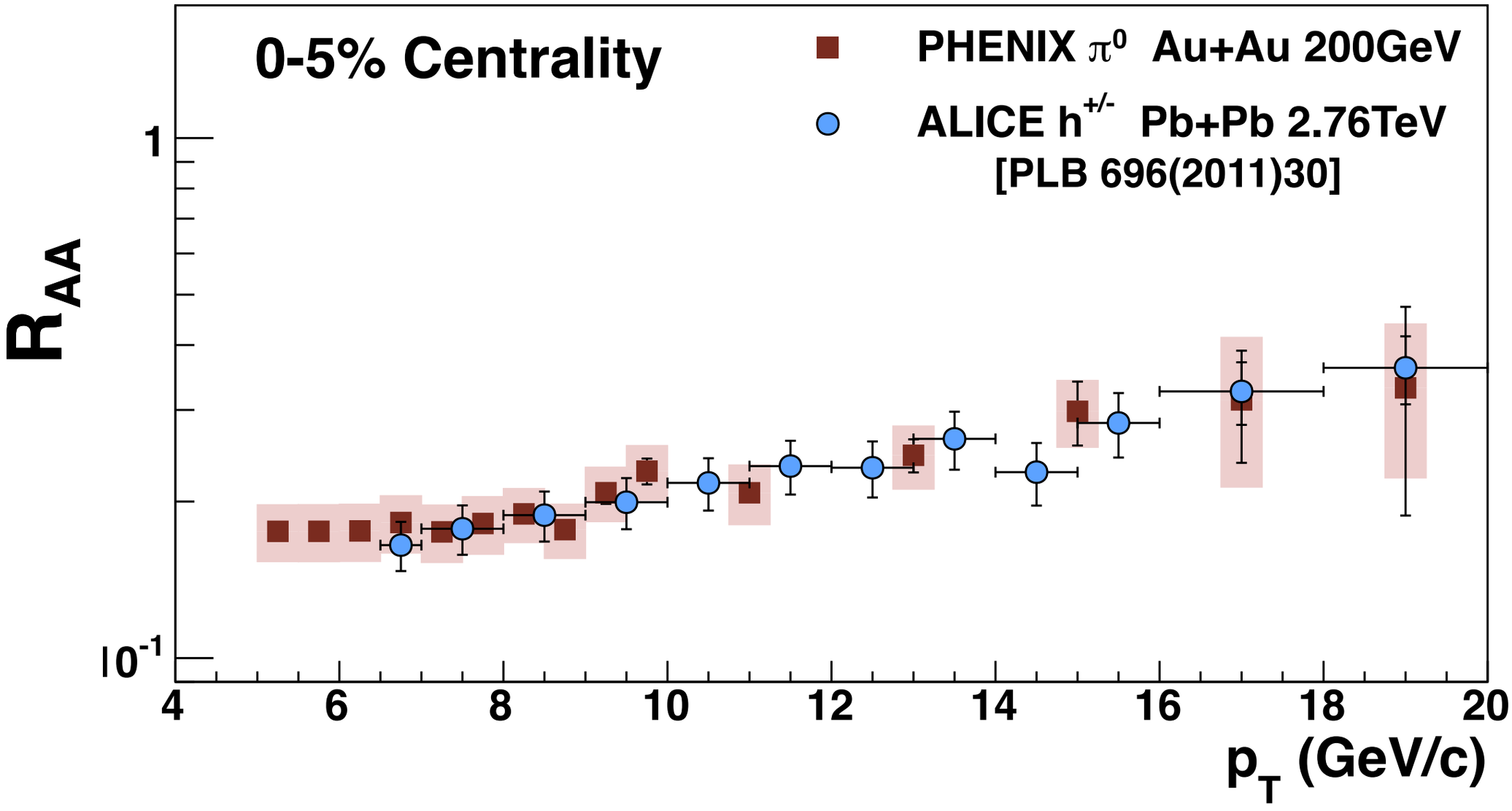

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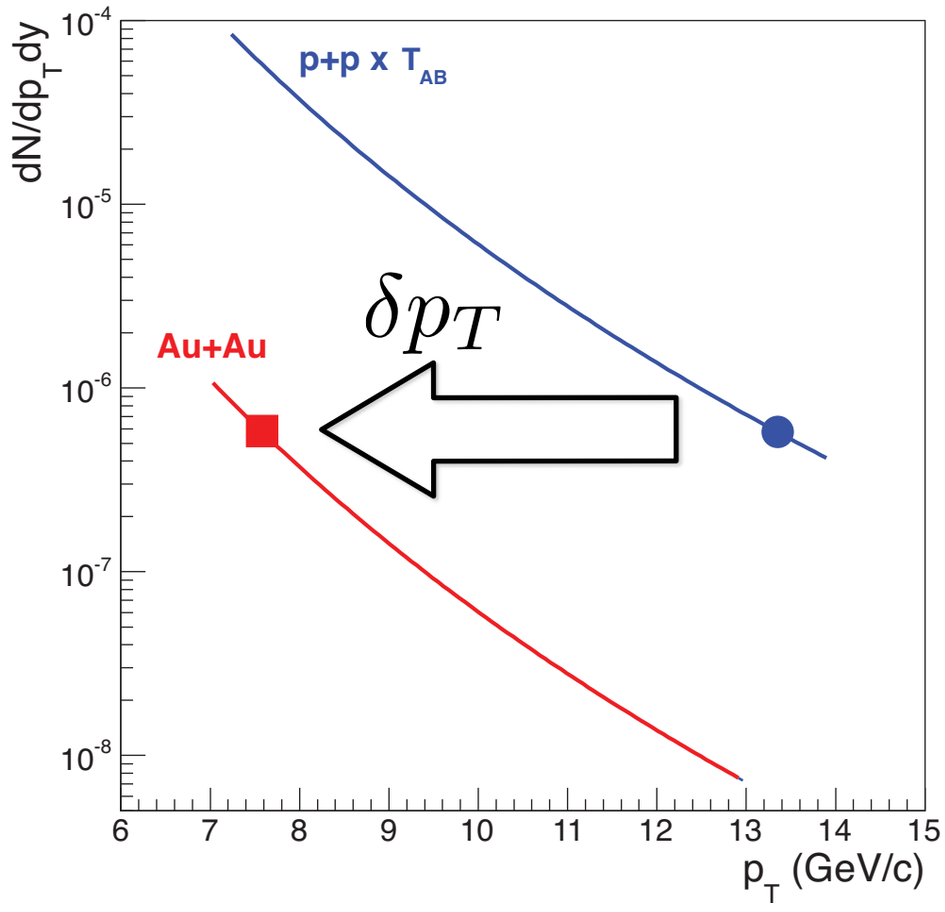
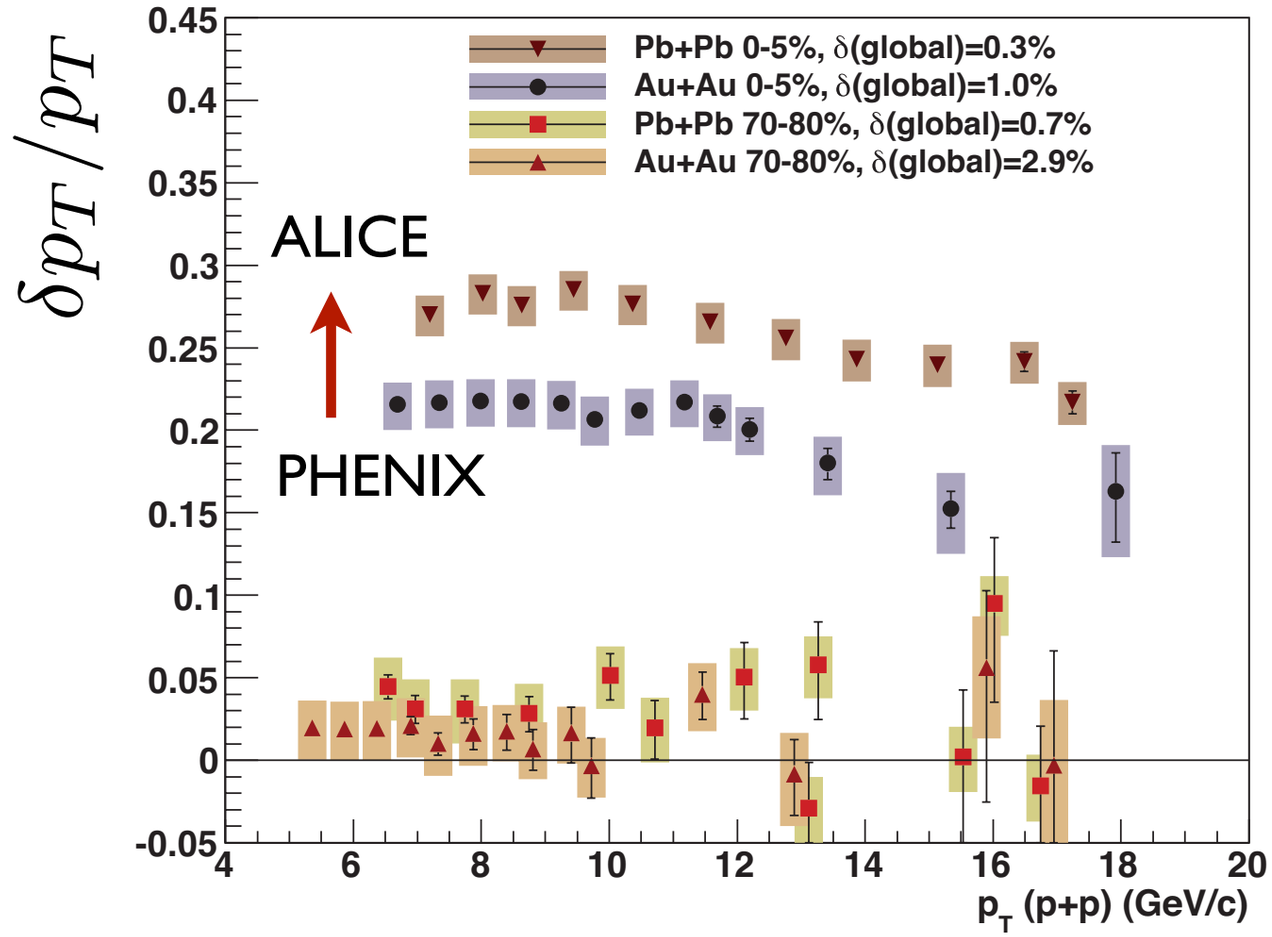
Fractional Energy Loss



Spectral Shift Model

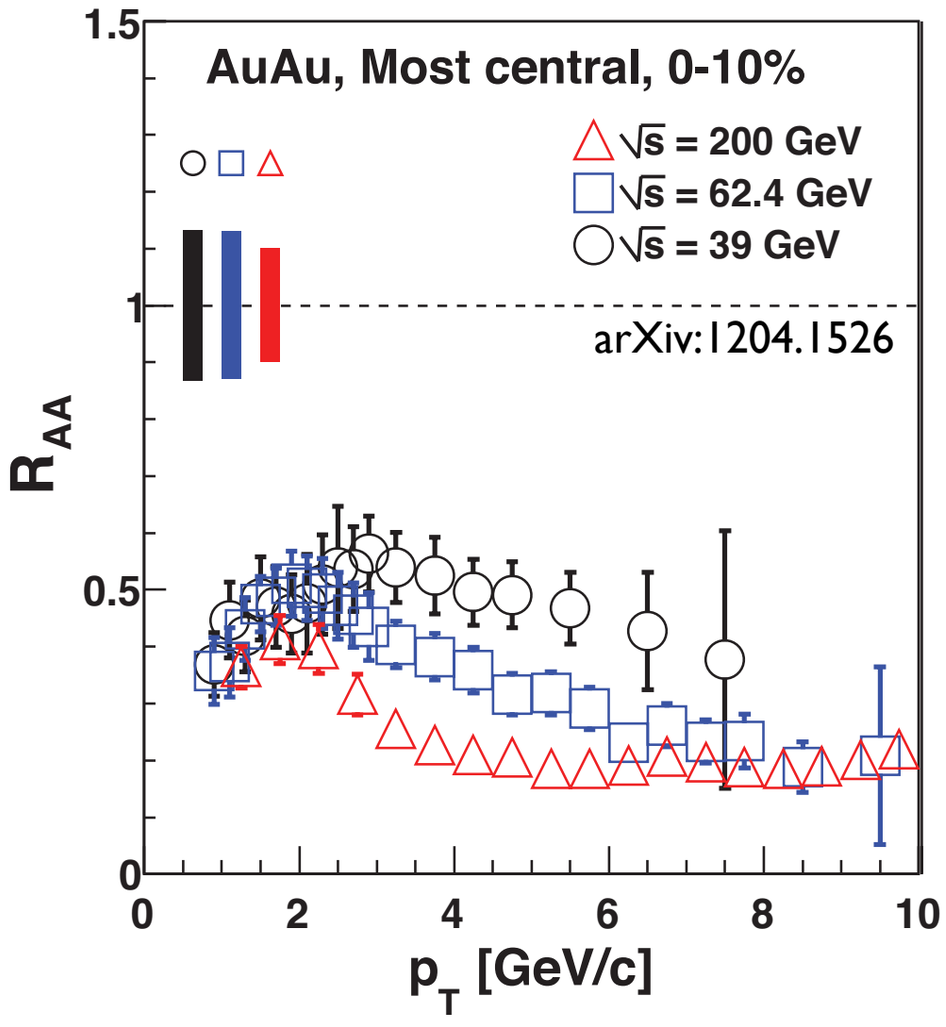
...a simple phenomenological model accounting for the spectral shape

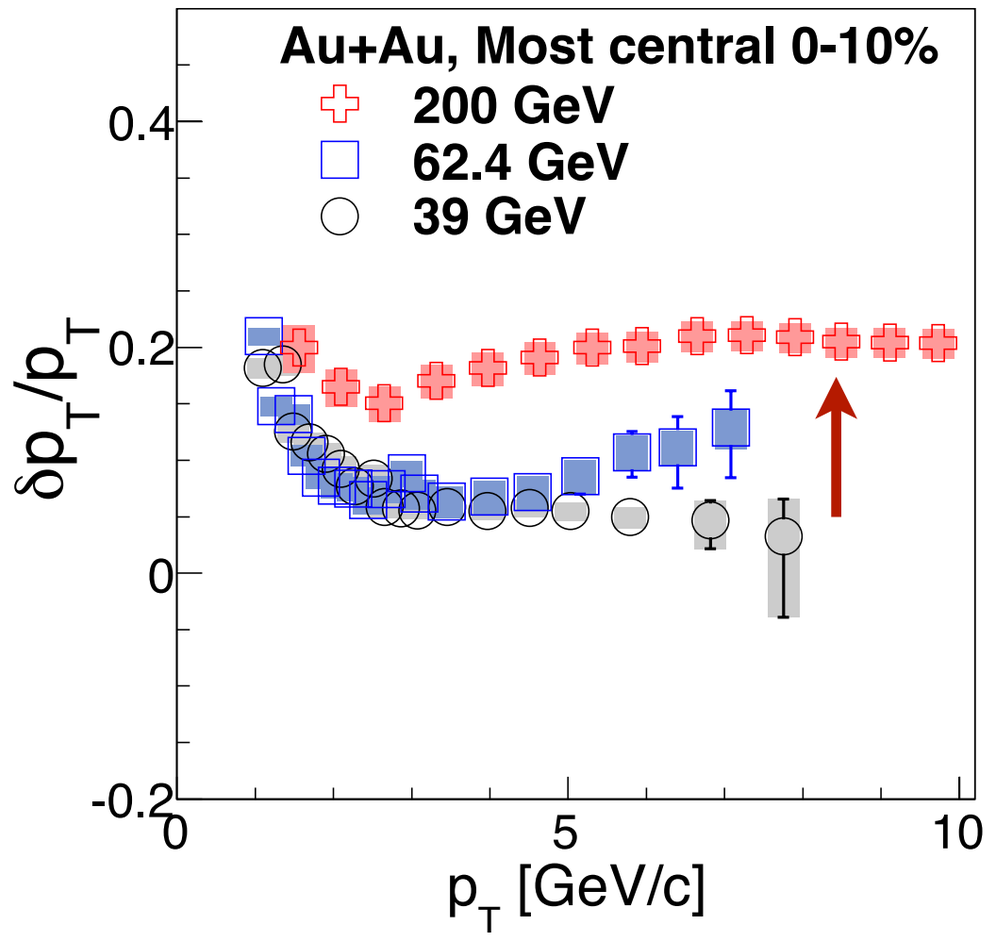


Energy loss parameter increases at the LHC even when R_{AA} is nearly equivalent between the two

$\delta p_T/p_T$ vs Energy

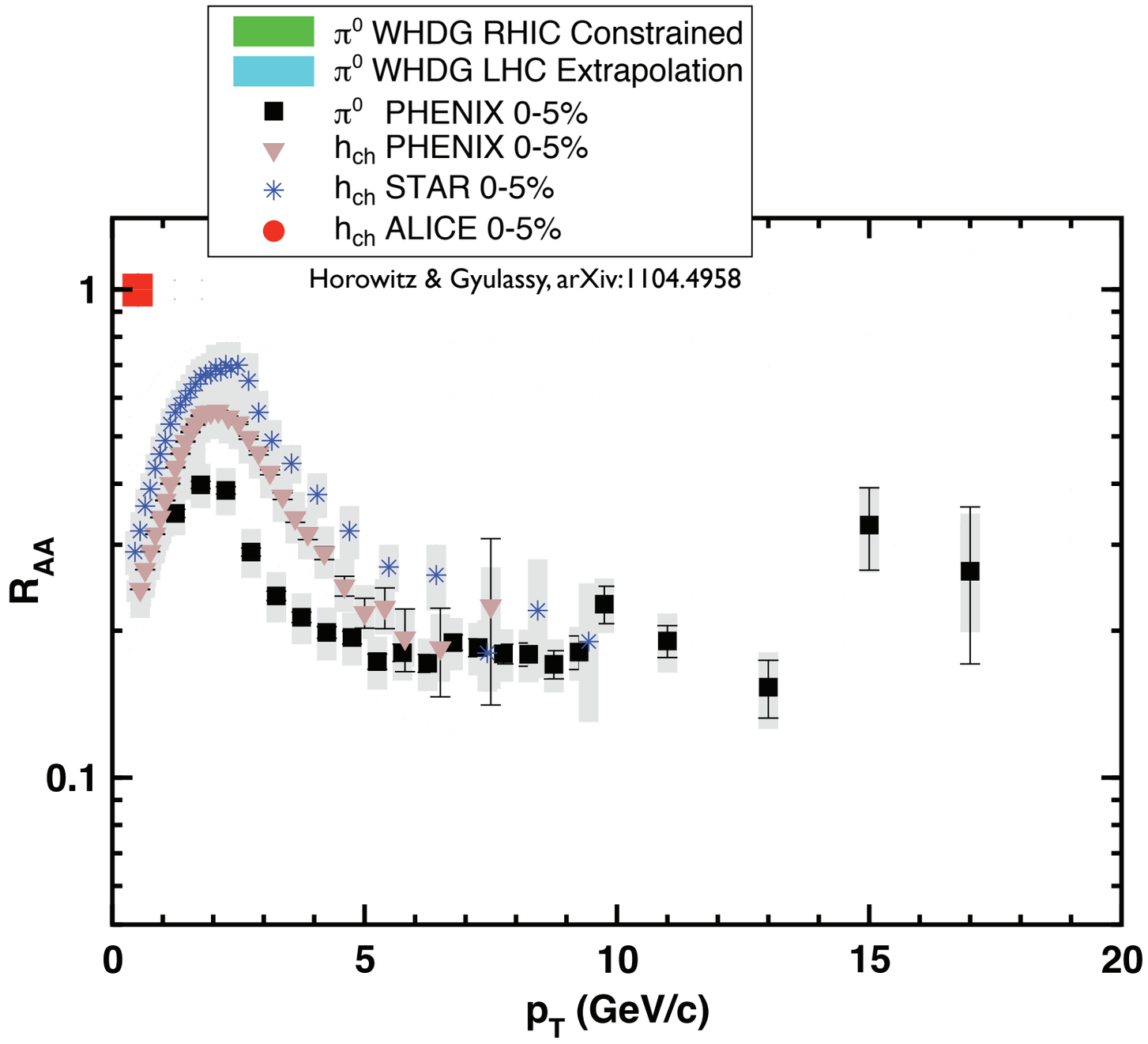
RHIC has run at multiple lower beam energies, and a similar examination gives...





the earlier part of the trend, the energy loss parameter rises from lower RHIC beam energies to higher

Projecting Energy Loss to the LHC



If energy loss calculations calibrate against the RHIC data and follow the expected color charge density dependence...

...then results can over-predict the LHC suppression.

Energy loss is not a simple function of color charge density at fixed coupling.

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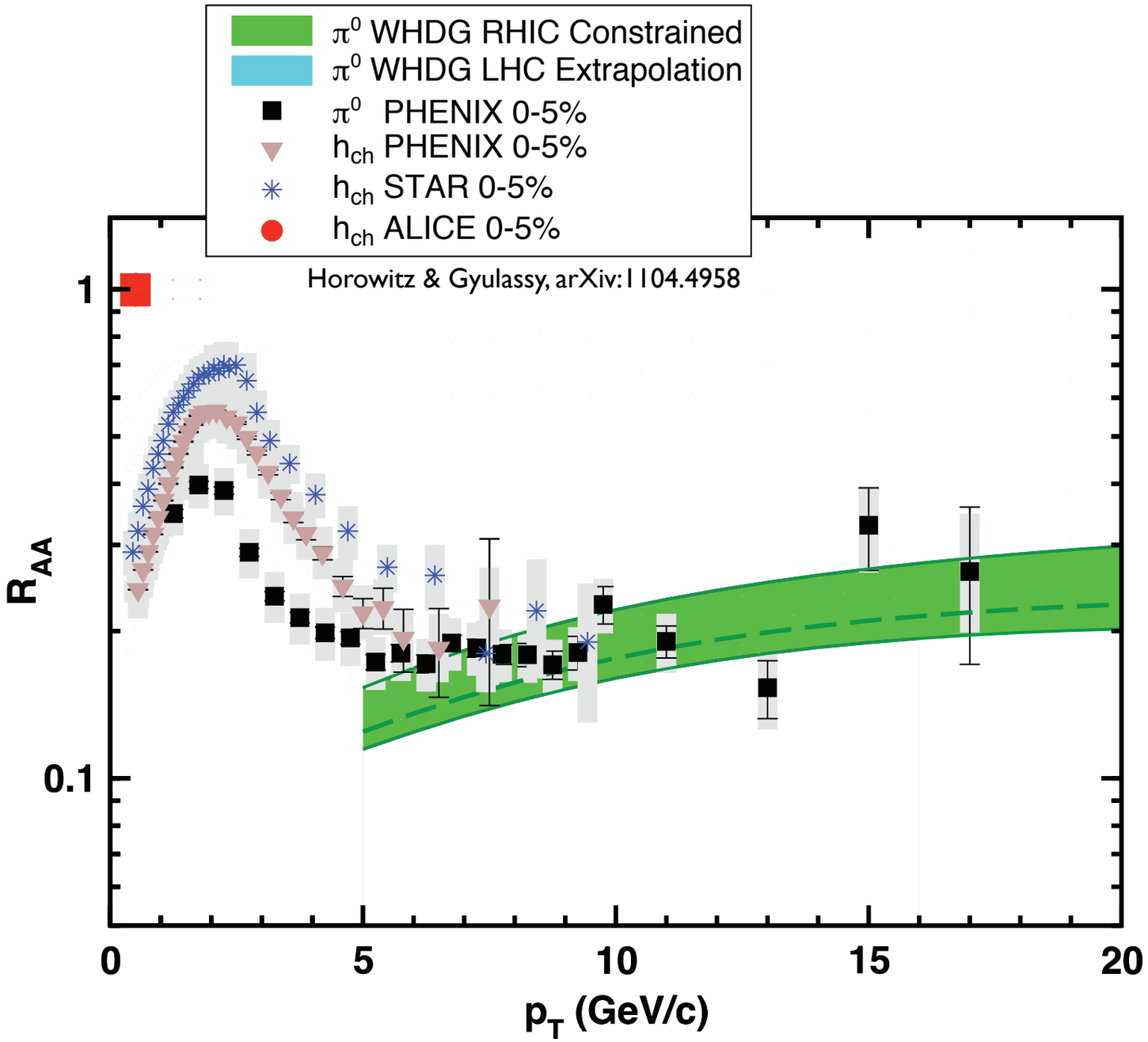

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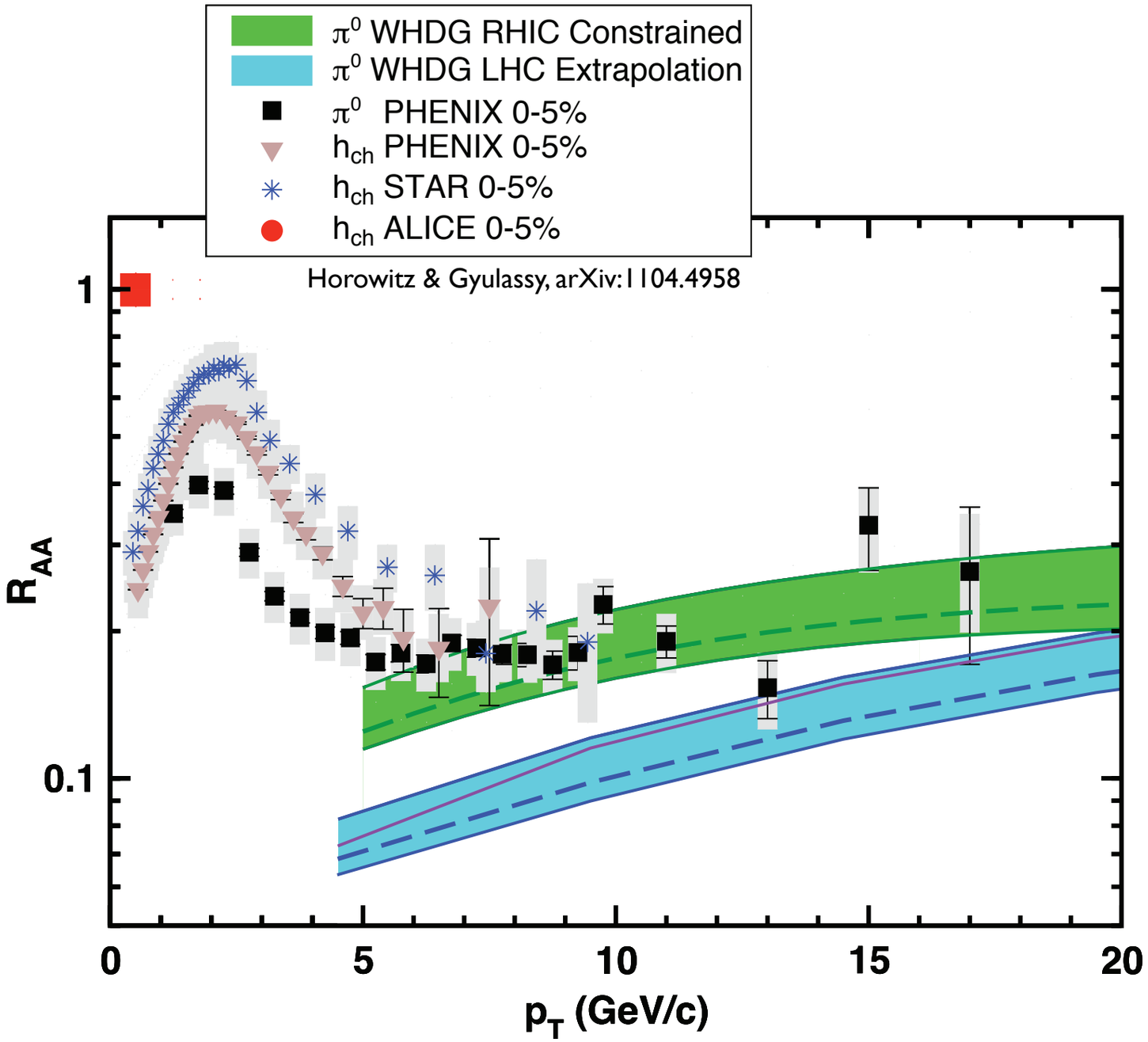

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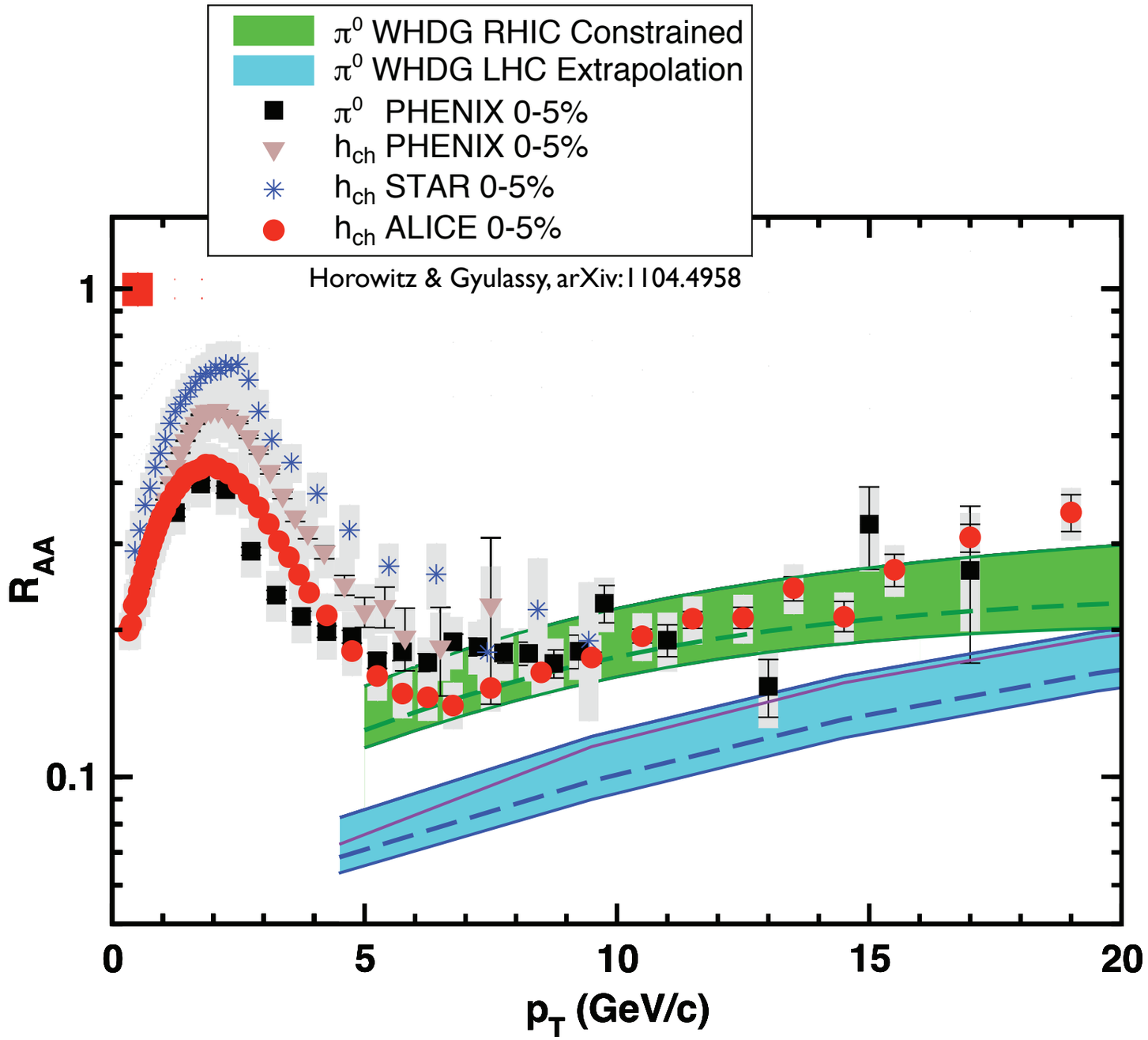

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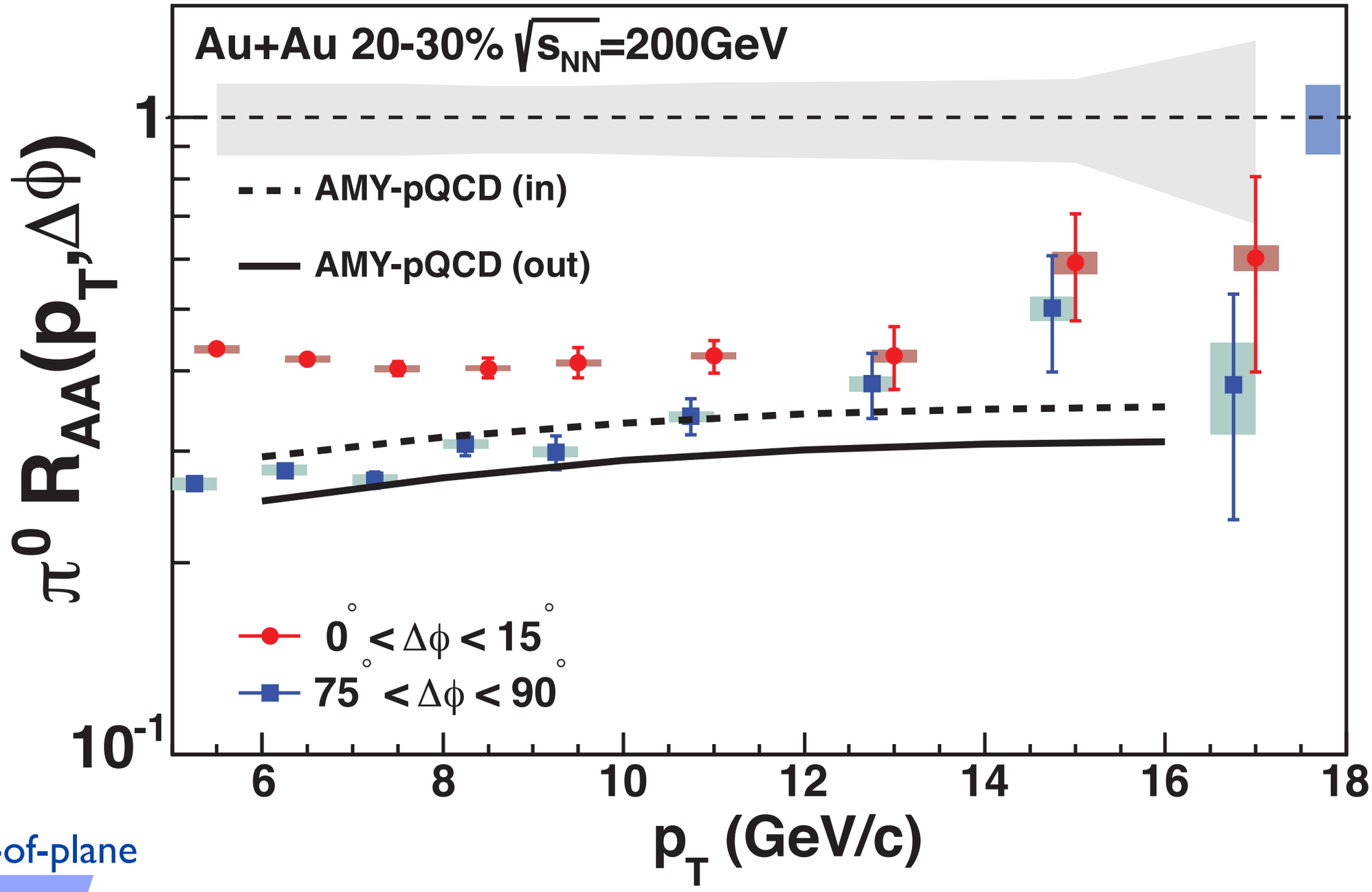
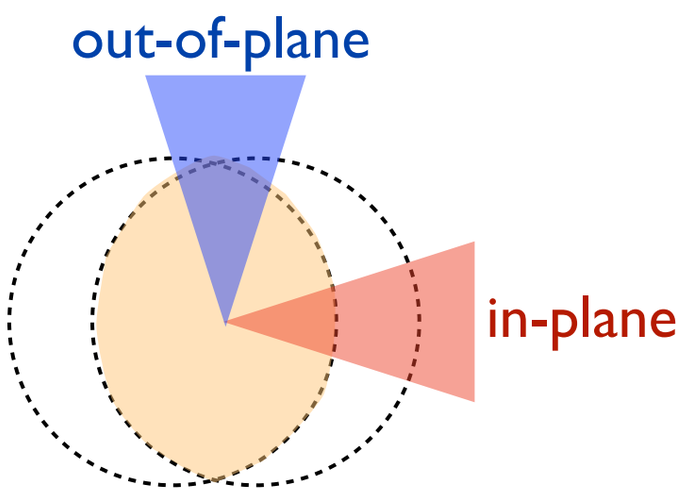
Path-length Dependence of R_{AA}





Models with a perturbative framework have difficulty reproducing the reaction plane dependence

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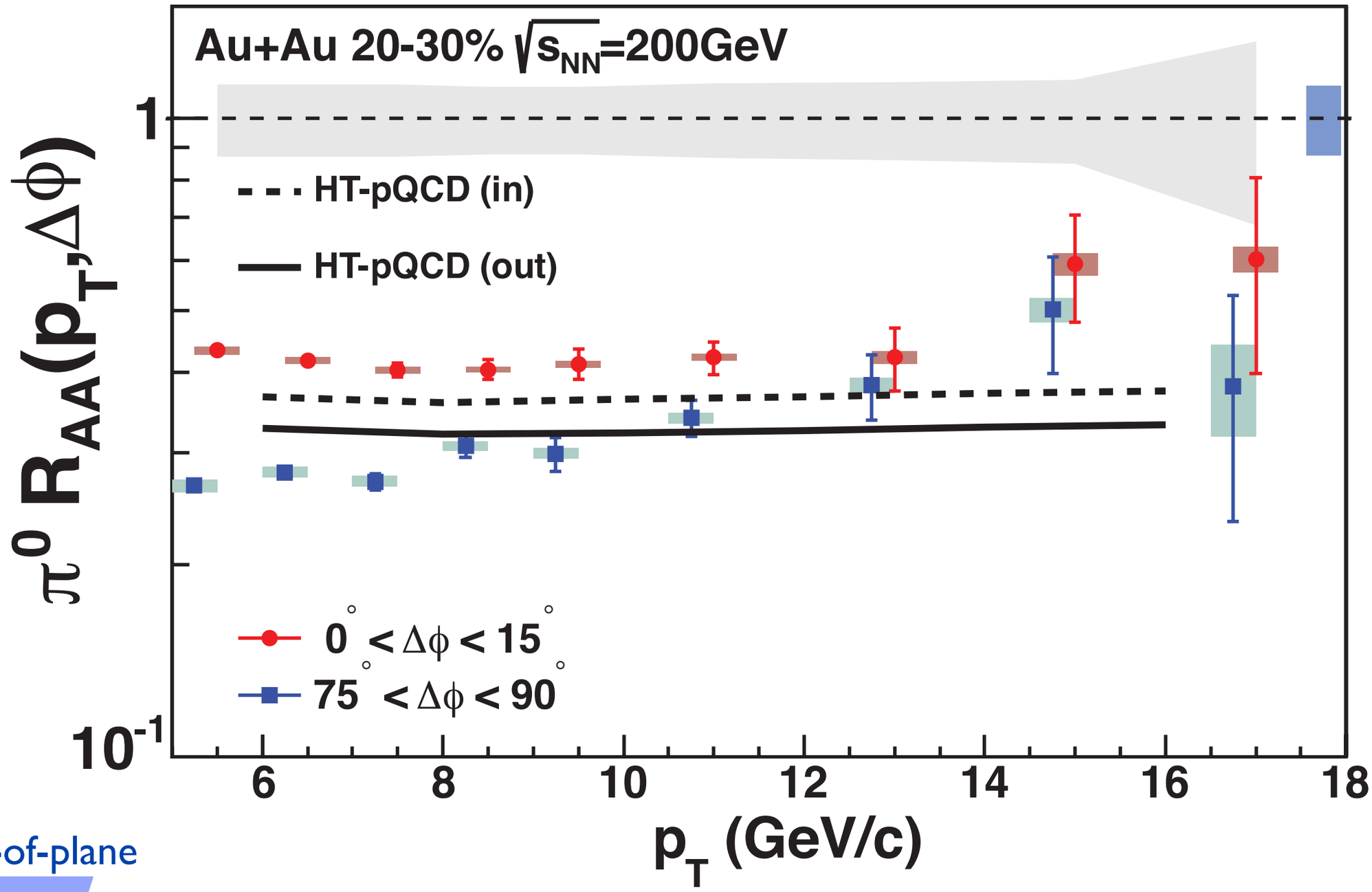

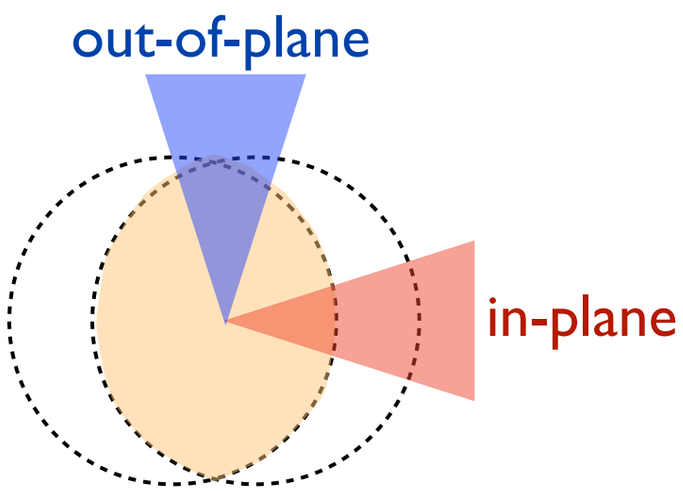

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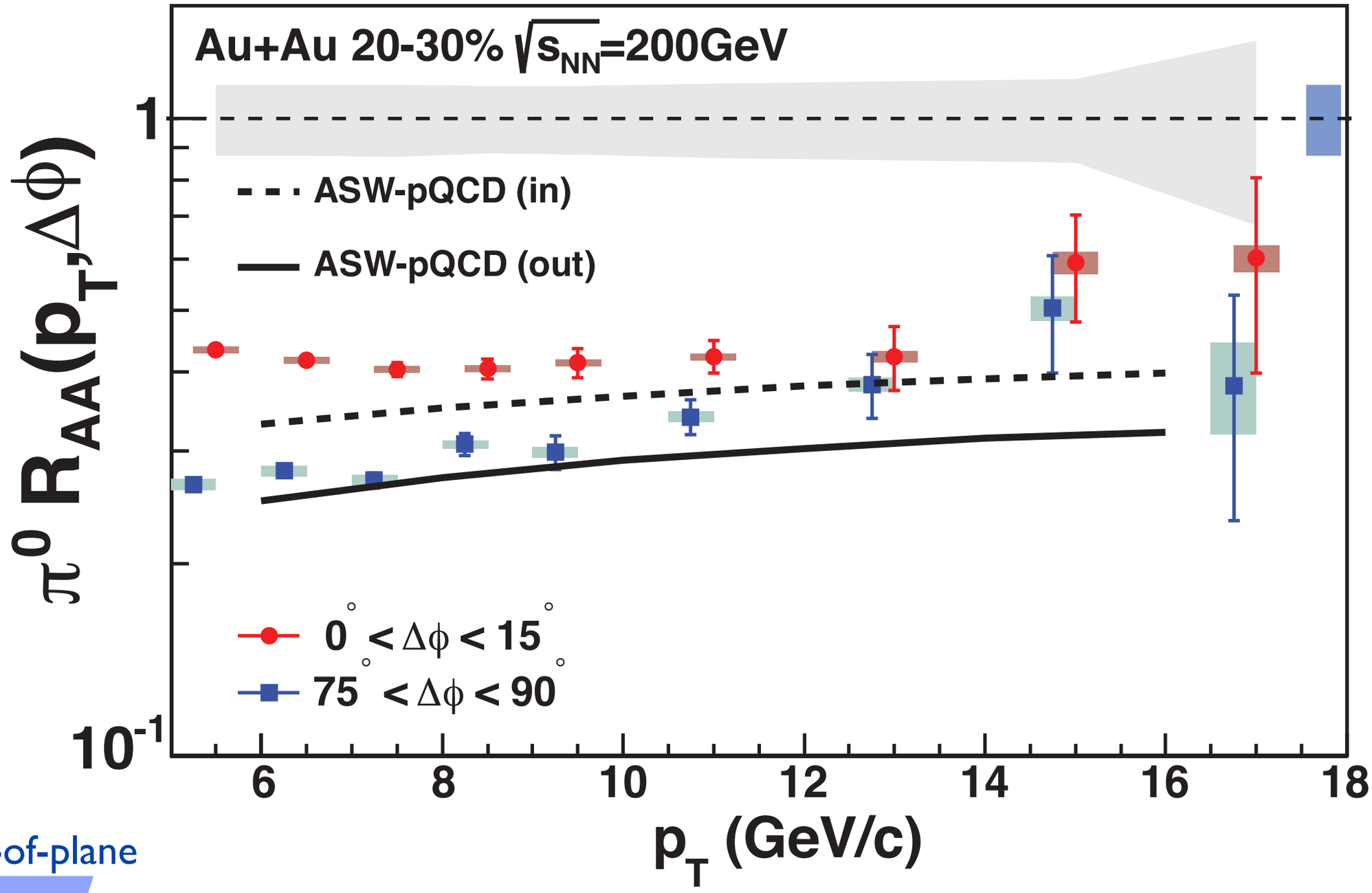

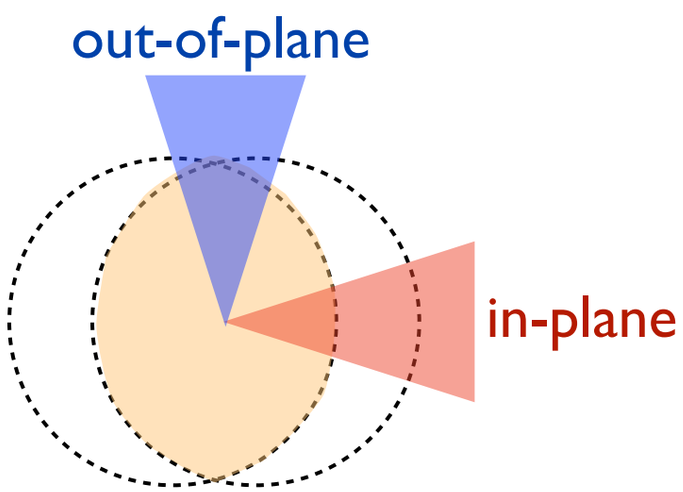

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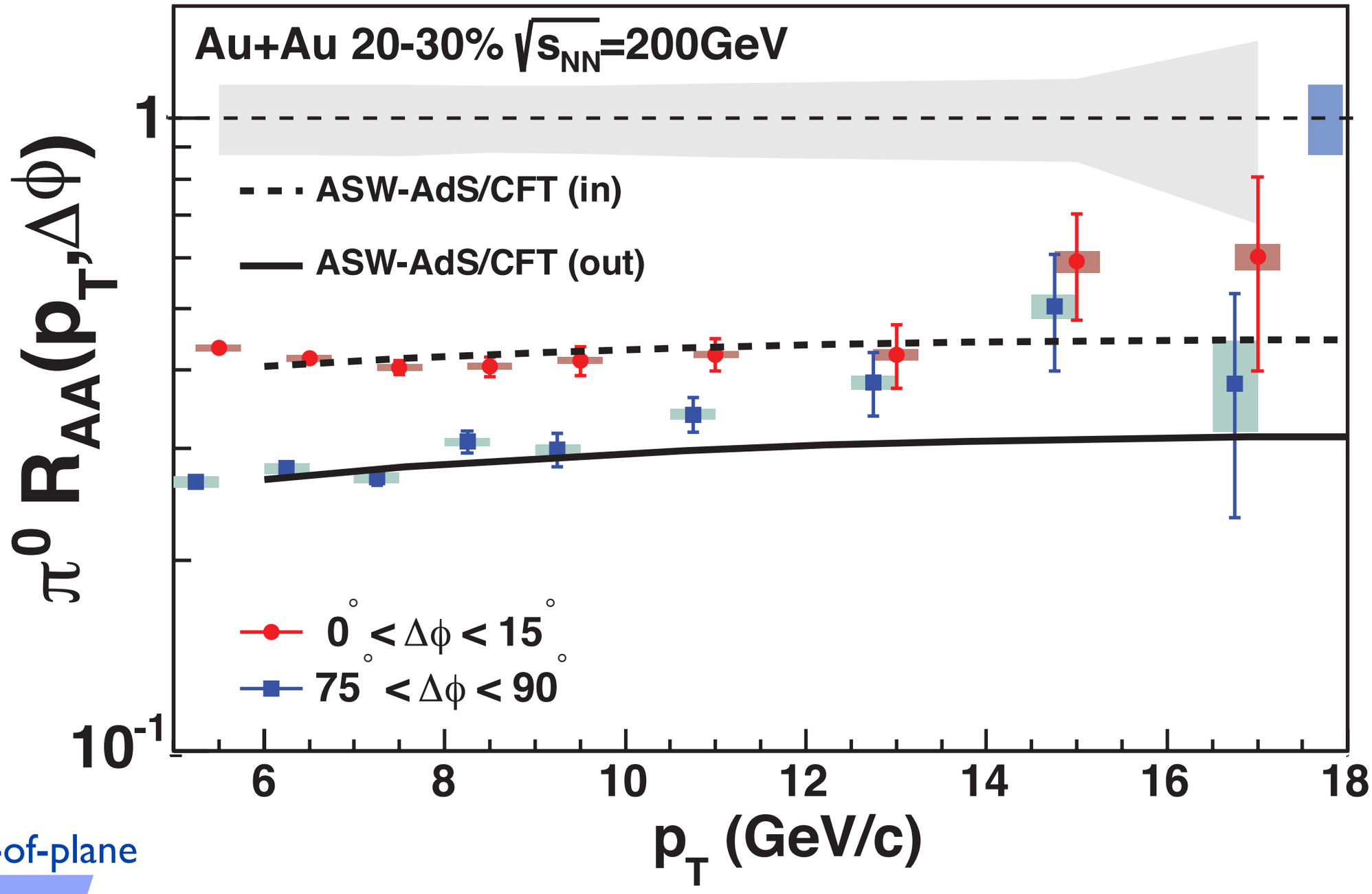

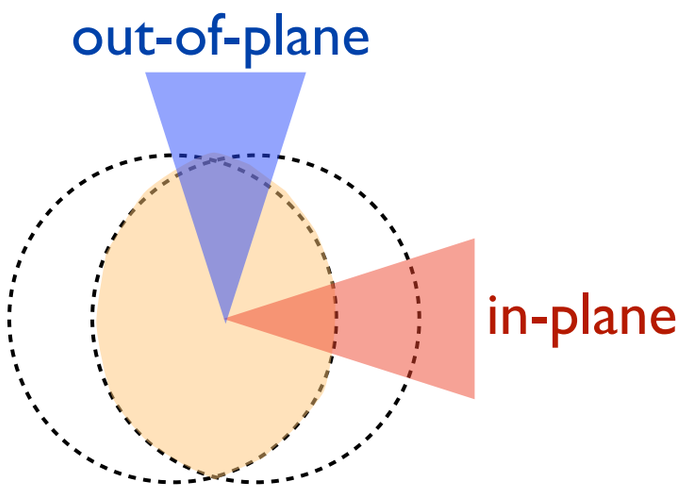

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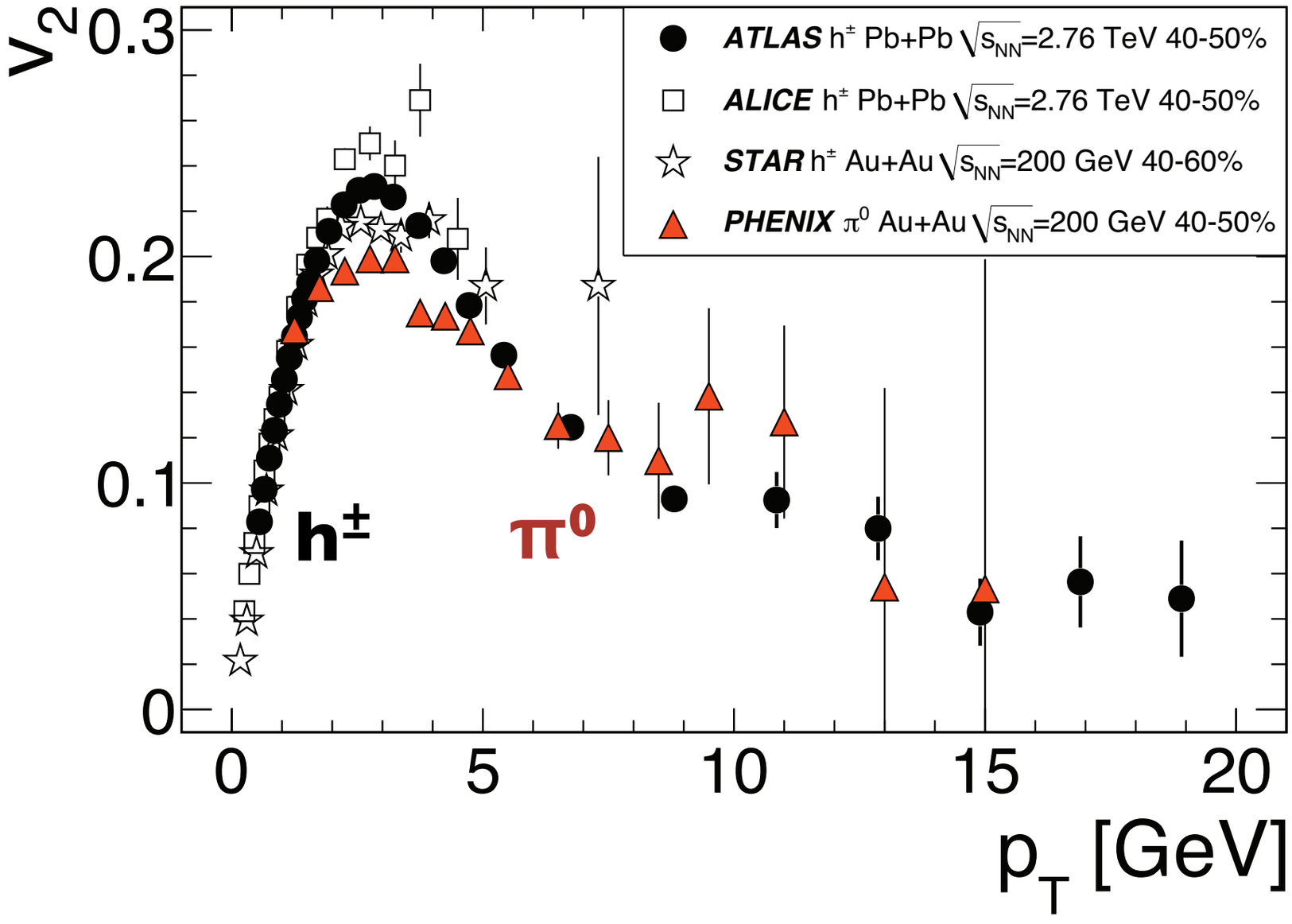
v_2 Comparisons



ATLAS, PLB 707 (2012) 303

ALICE, PRL 105 (2010) 252302

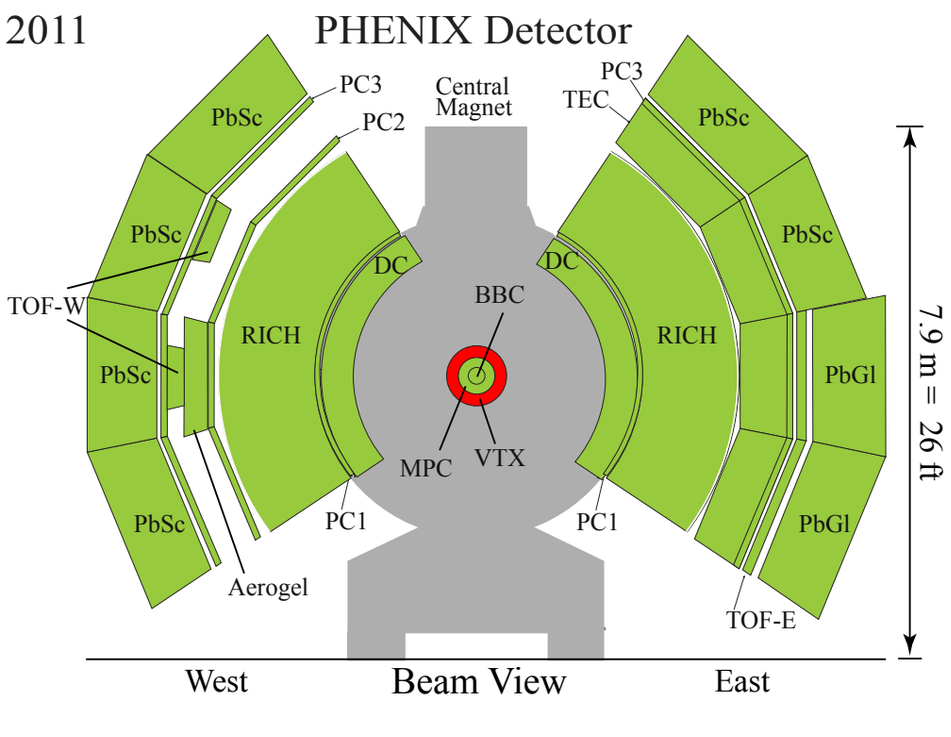
STAR, PRC 72 (2005) 014904

PHENIX, PRL 105 (2010) 142301

Low p_T comparison influenced by baryon-meson admixture

v_2 at large momentum is also very similar despite the change in beam energy

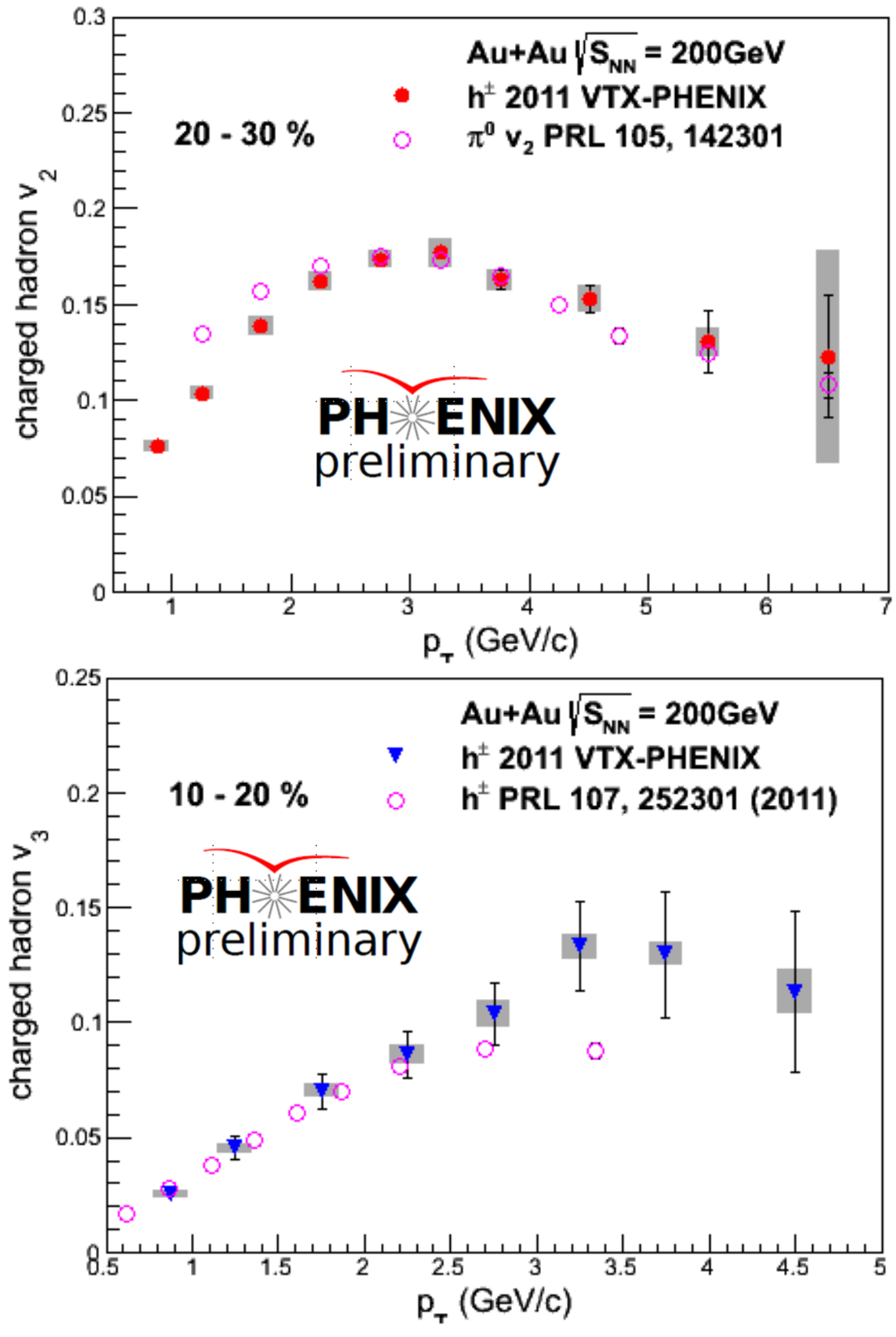
New Capabilities



Additional inner tracking layers remove off-vertex decay backgrounds

Gives a new ability to track out to large momenta

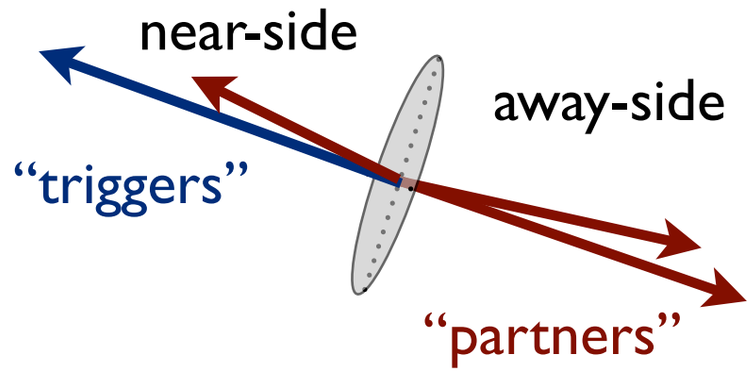
See more: M. Kurosawa (Parallel 3A)



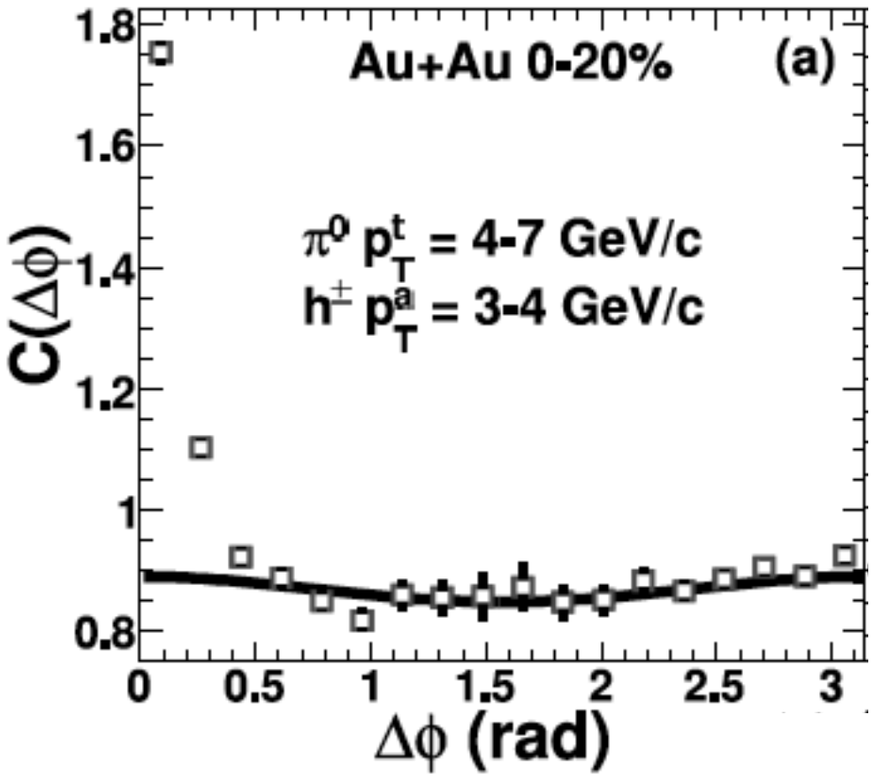
Two Particle Correlations

Angular correlations between two final state particles contain at least two sources: jet fragments and flow

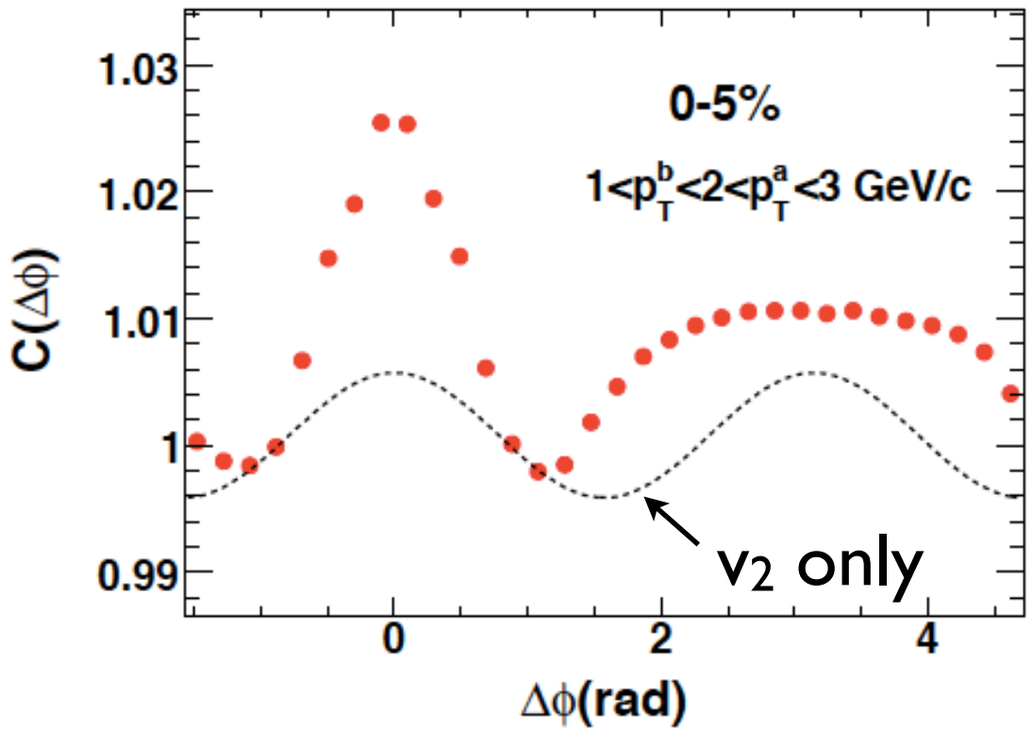
Intermediate p_T jet fragments have poor S/B because of contributions from flow



Larger p_T



Smaller p_T



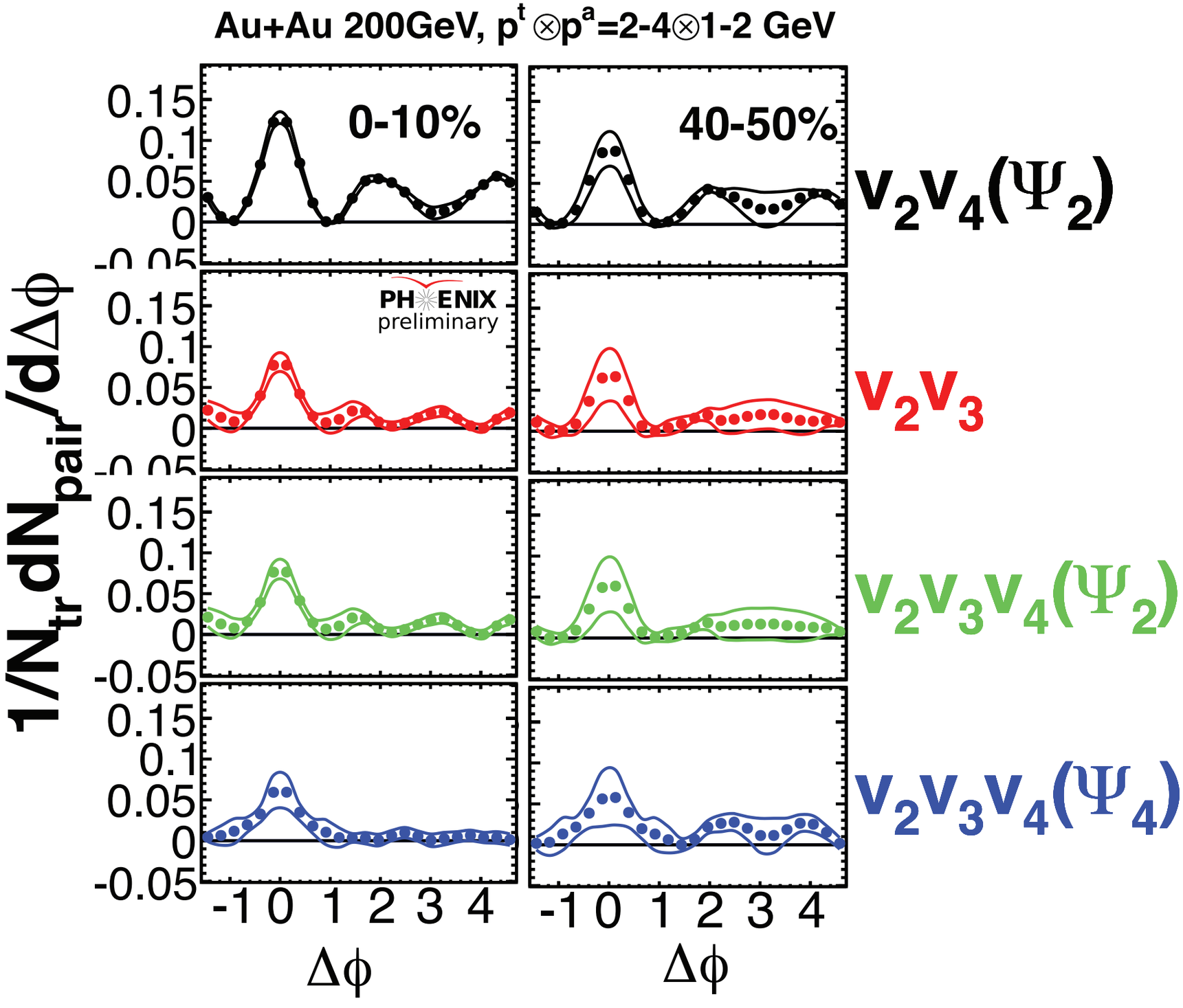
Jet-Induced Correlations

Extensive study of flow subtraction moments at intermediate p_T

v_3 subtraction largely removes away-side structure

Away-side residual depends strongly on v_4 treatment

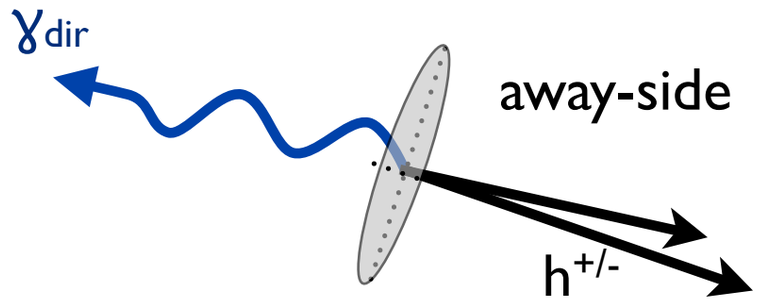
v_1 impact very small



See more: T. Todoroki (Parallel 6D)

γ_{dir}-$h^{+/-}$ Correlations

Photons escape medium without energy loss & at LO tags the initial energy of the away-side parton



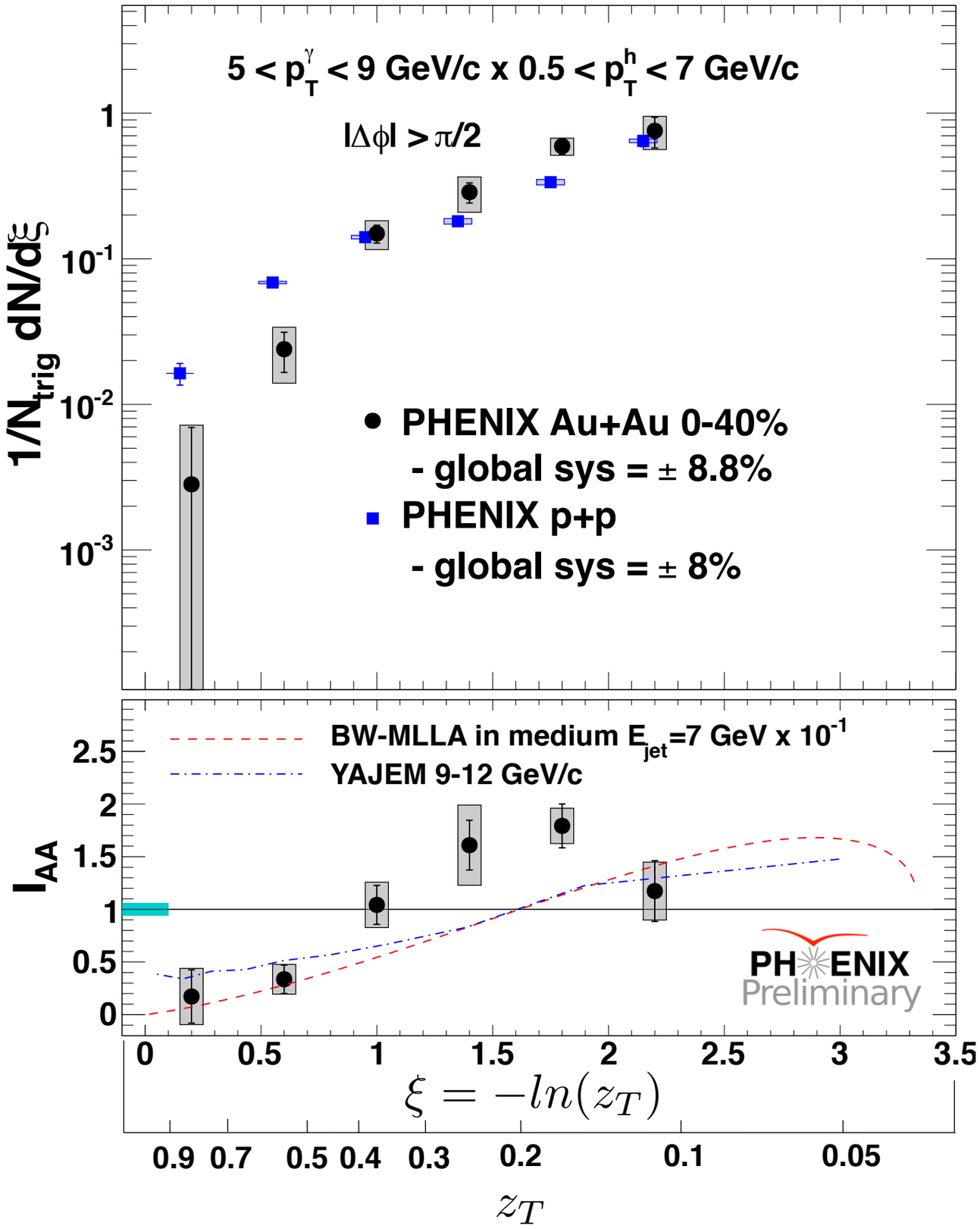
Fragmentation function variables:

$$\xi \equiv -ln(z_T) \equiv -ln(p_T^{h^\pm}/p_T^{\gamma_{dir}})$$

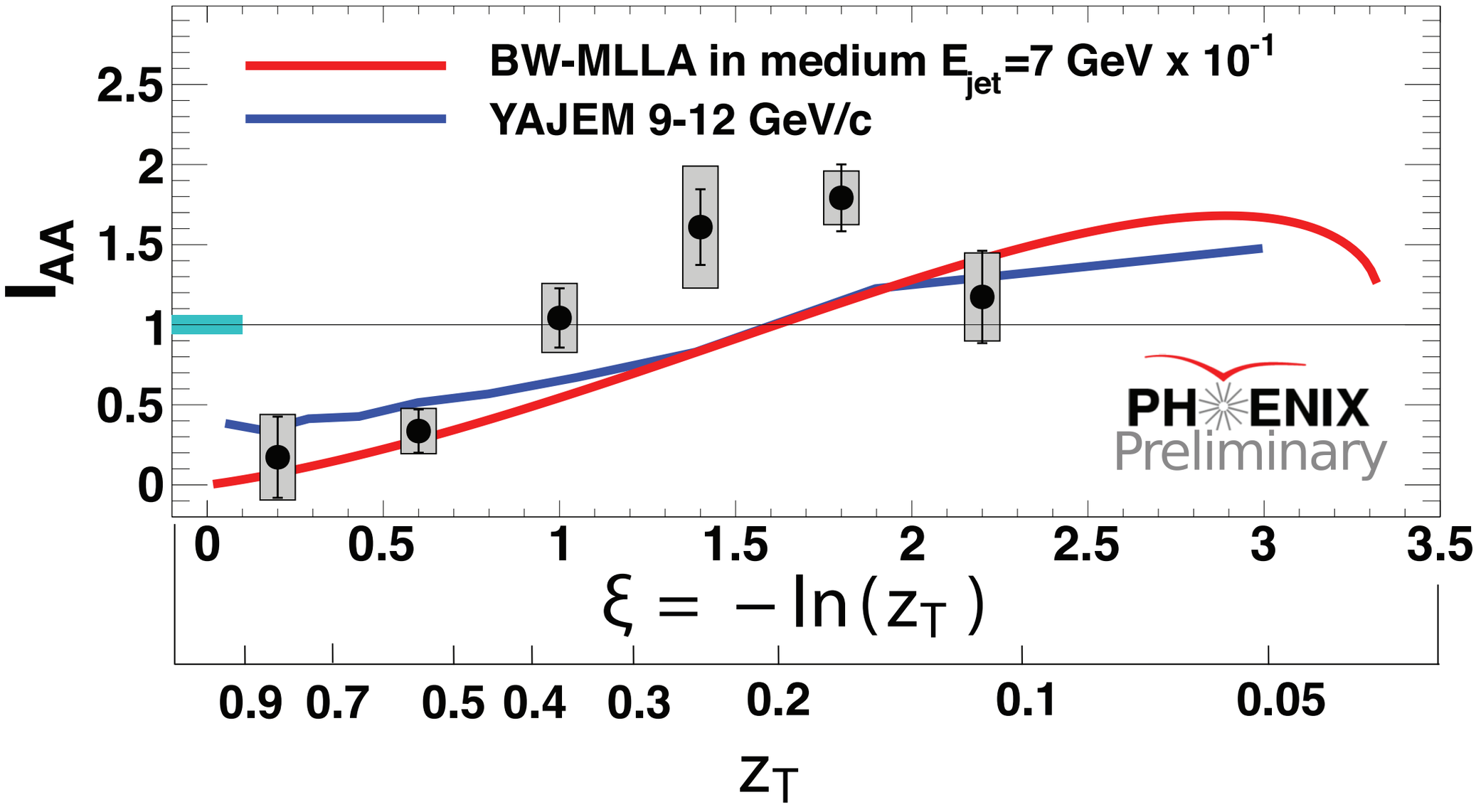
Nuclear modification:

$$I_{AA} \equiv \frac{(1/N_{trig}dN/d\xi)_{AA}}{(1/N_{trig}dN/d\xi)_{pp}}$$

Combined statistics from 2007 + 2010



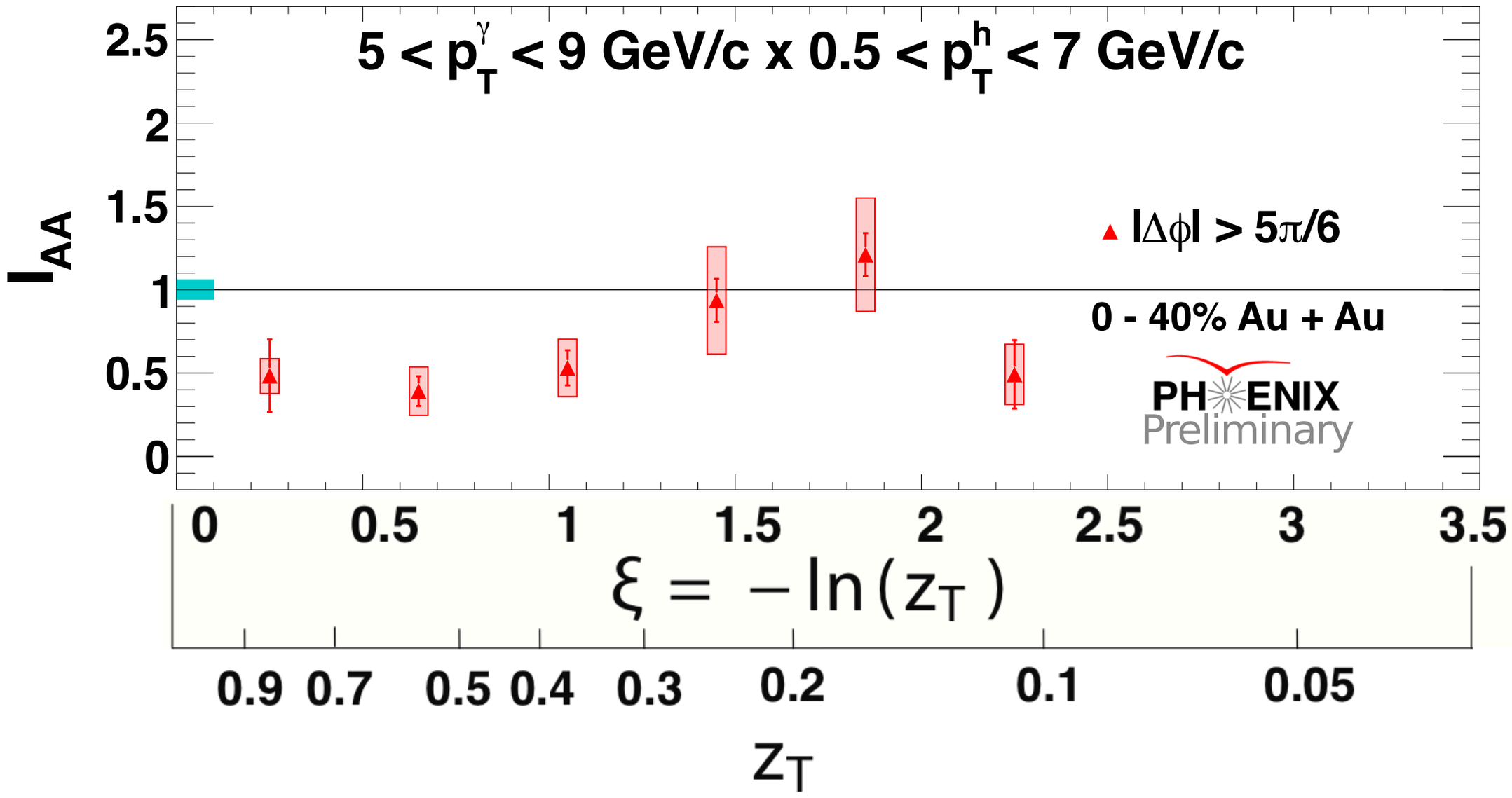
Away-side Modification



Significant large suppression at small ξ
Sizable enhancement at large ξ

Energy loss depletion + wide angle recovery
These features present in theory calculations

Away-side Angular Shape



No angular dependence at small ξ

Evidence of broadening found at large ξ

Is this low p_T recovery of lost energy?

Not higher harmonics, robust against inclusion of v_N

See more: J. Frantz (Parallel 1B)

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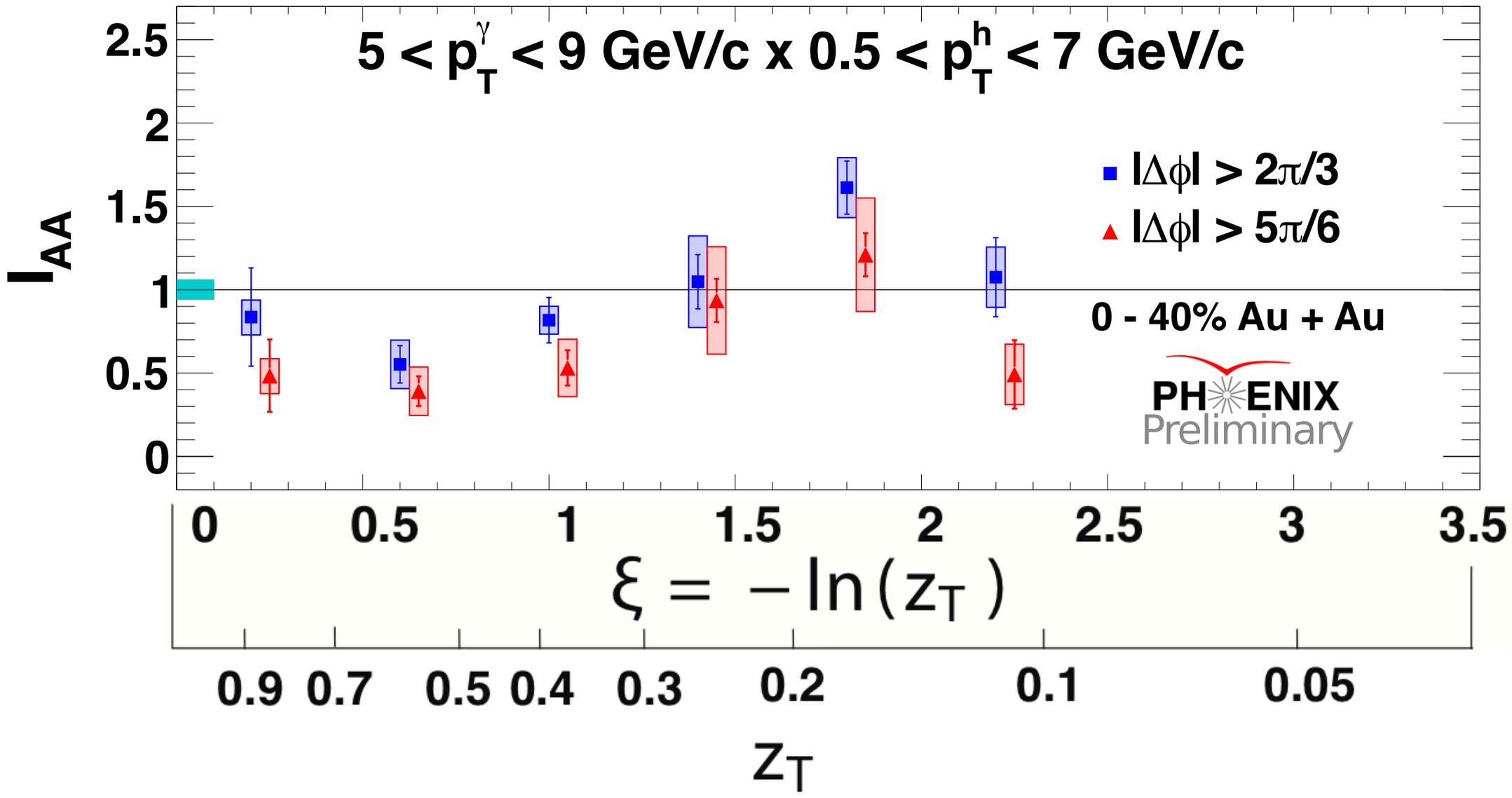

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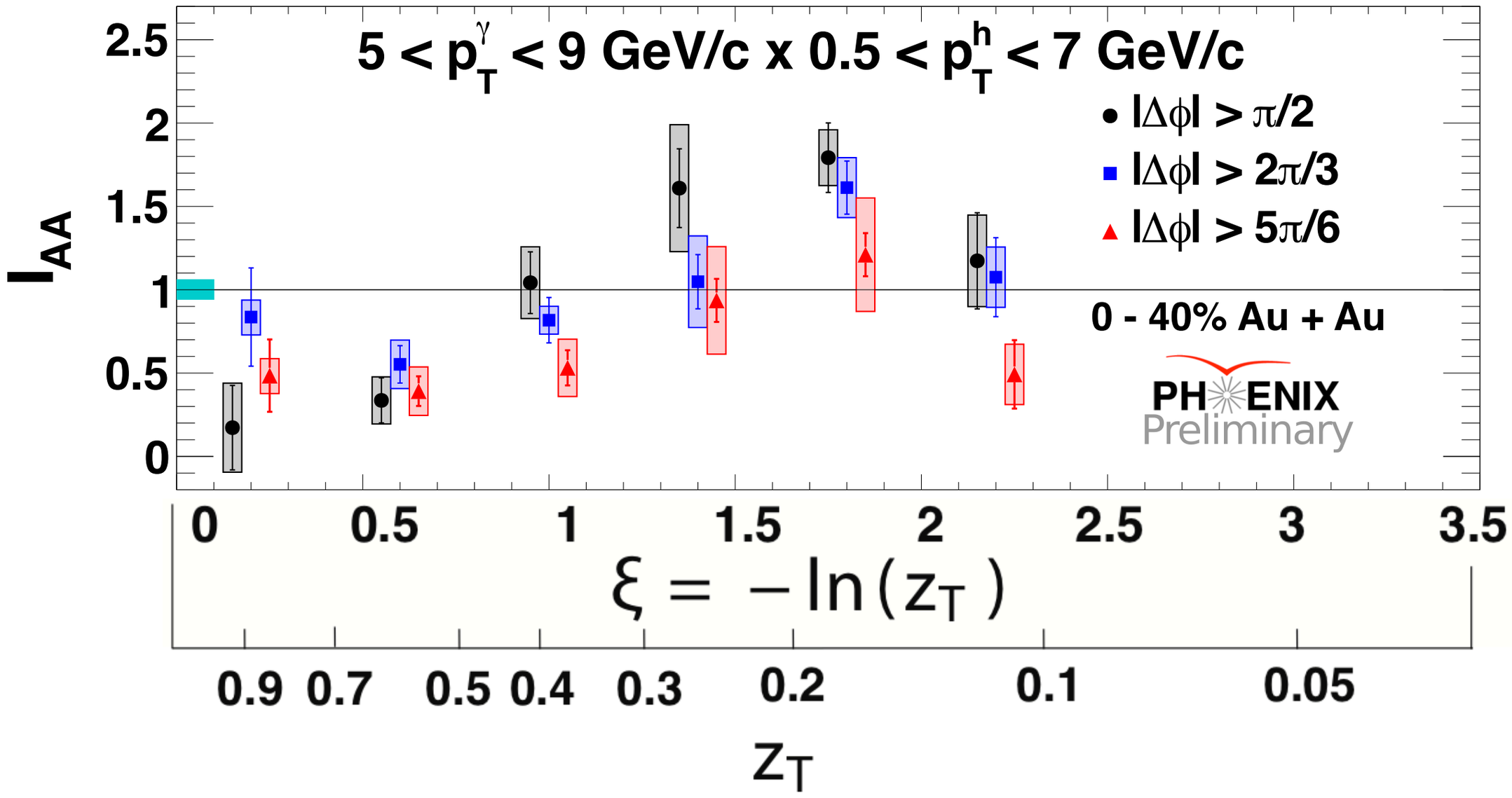

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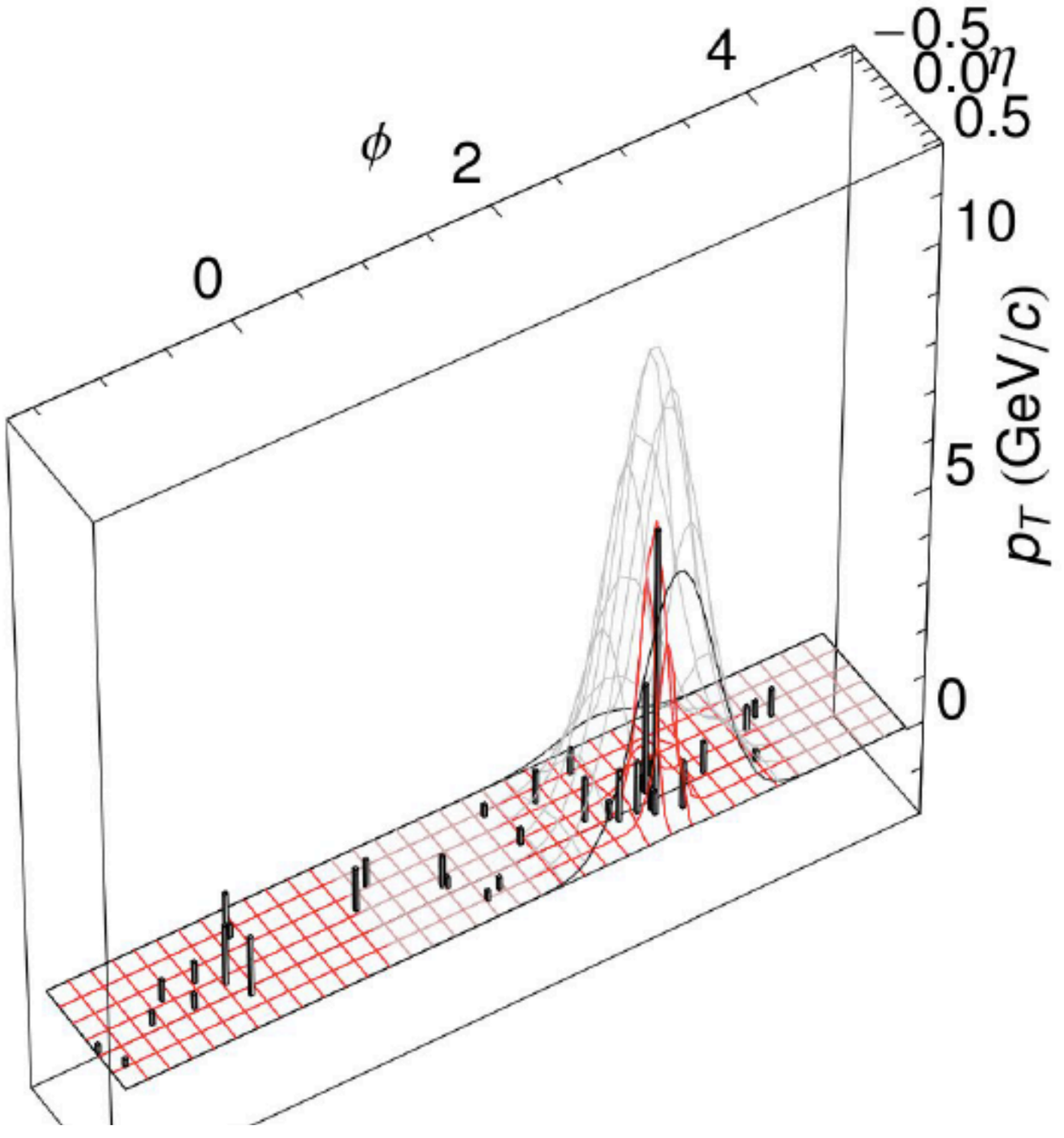
Reconstructed Jets in PHENIX

Gaussian Filter:
a seedless, cone-like algorithm

Developed for heavy ion collision backgrounds at RHIC

Optimized to find the energetic core of jets

Stabilizes jet axis against background particles



$$p_{\mathrm{T}}^{\mathrm{jet}} \equiv \max\left\{ \int\int d\eta' d\phi' p_{\mathrm{T}}\left(\eta', \phi'\right) e^{-(\Delta\eta^2+\Delta\phi^2)/2\sigma^2} \right\}$$

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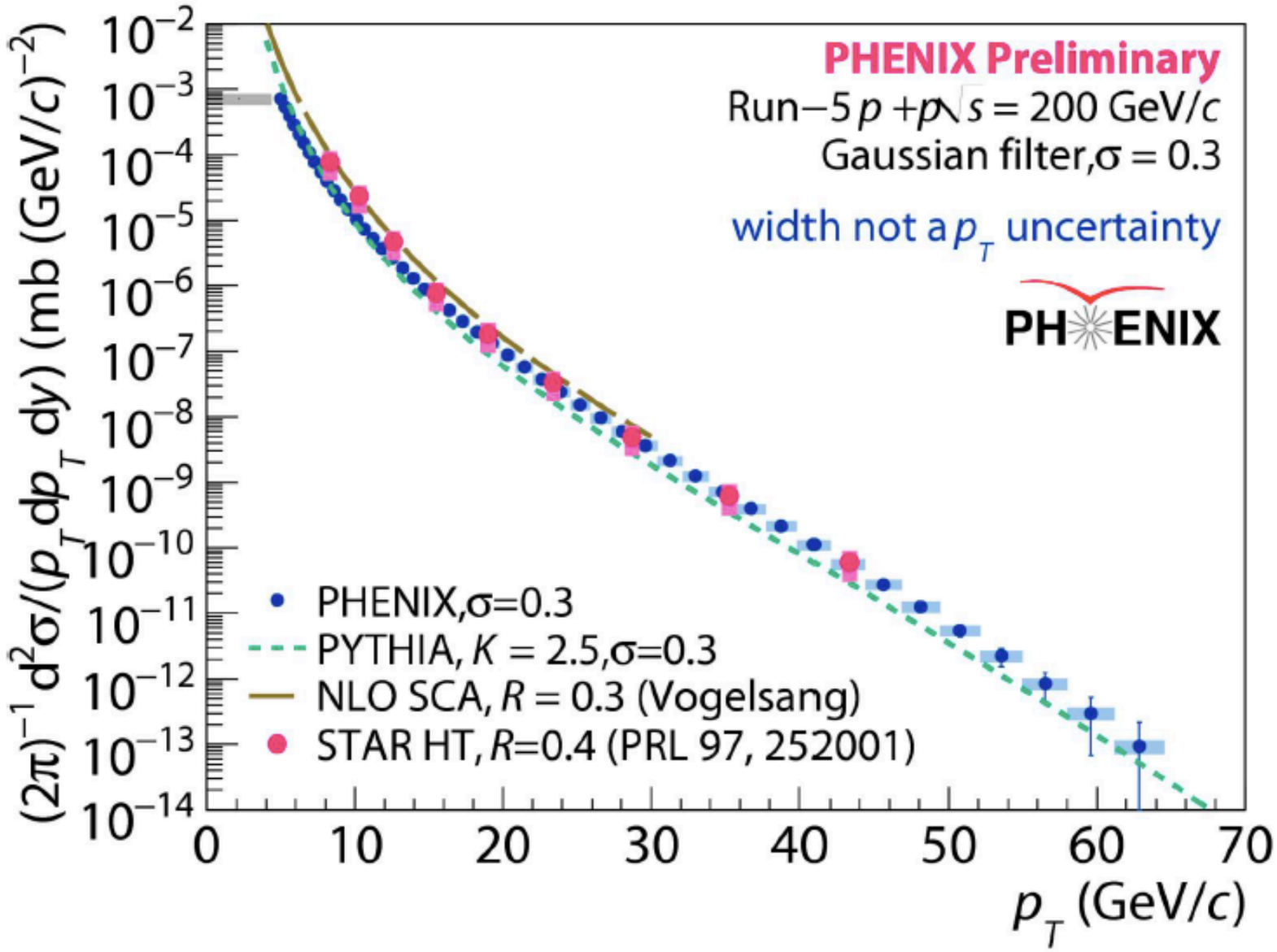
p+p measurements benchmark well with NLO



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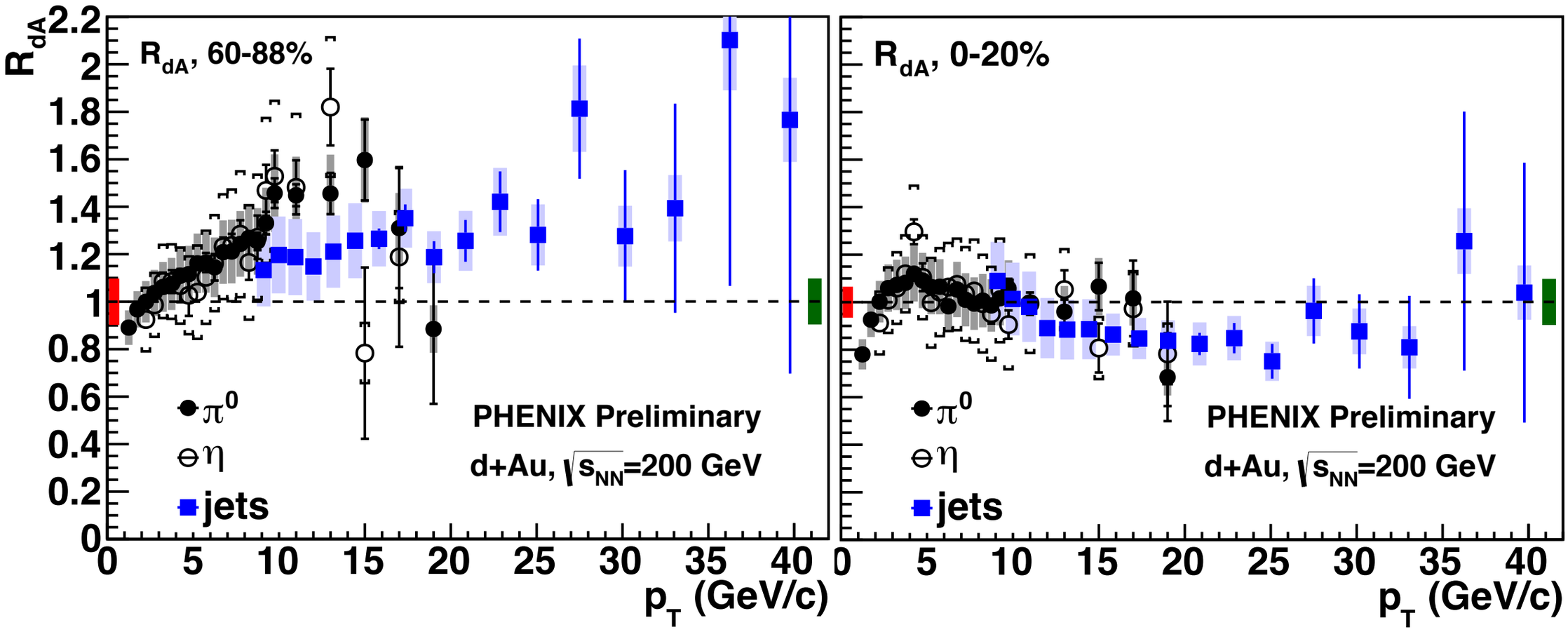
CNM Jet Baseline



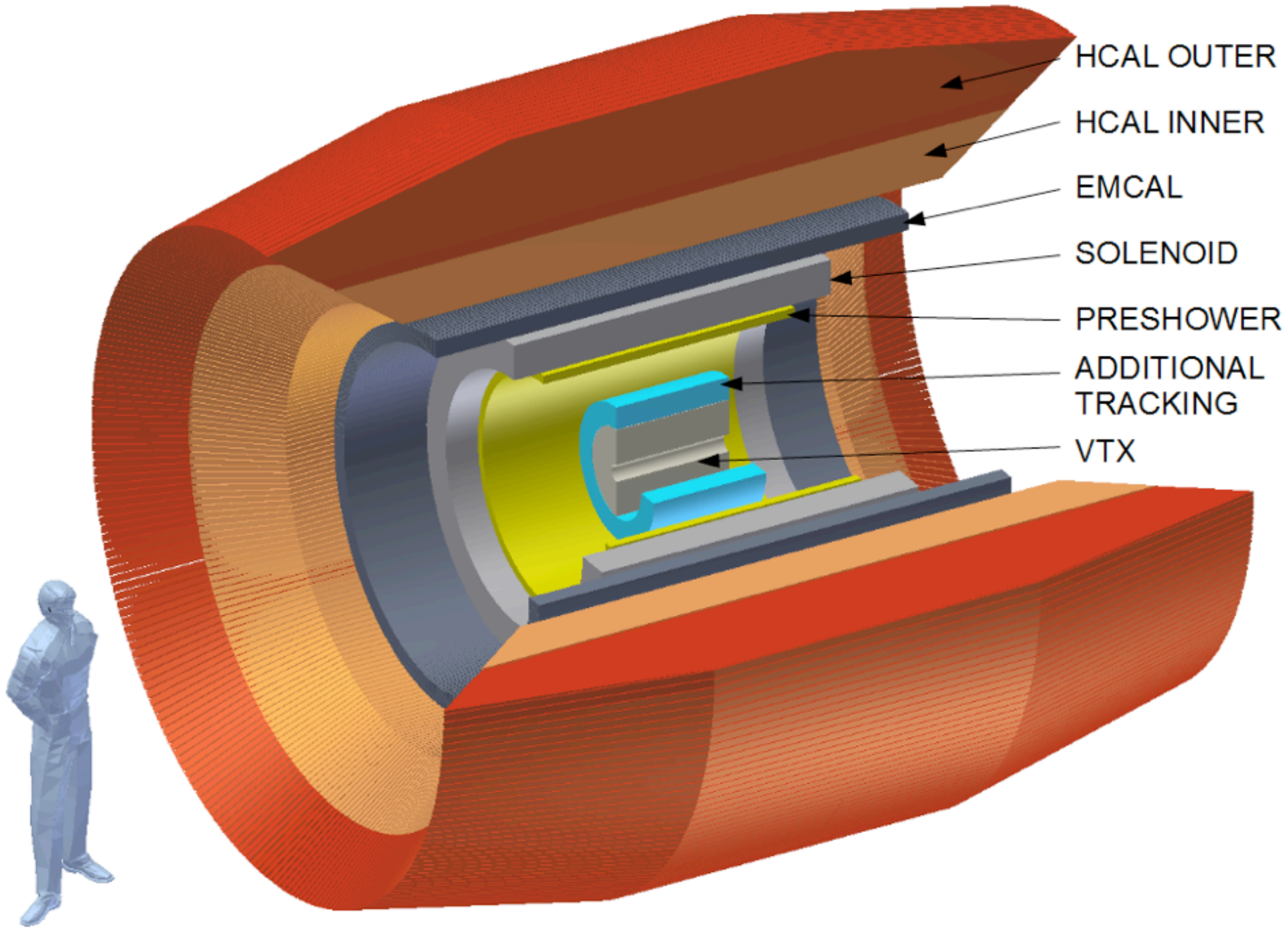
The extended kinematic reach of reconstructed jets measures CNM effects out to much higher momenta.

Different sources of uncertainty between jets and π^0.

We expect: the Cronin and EMC effects
Surprised by: large and rapid centrality dependence.

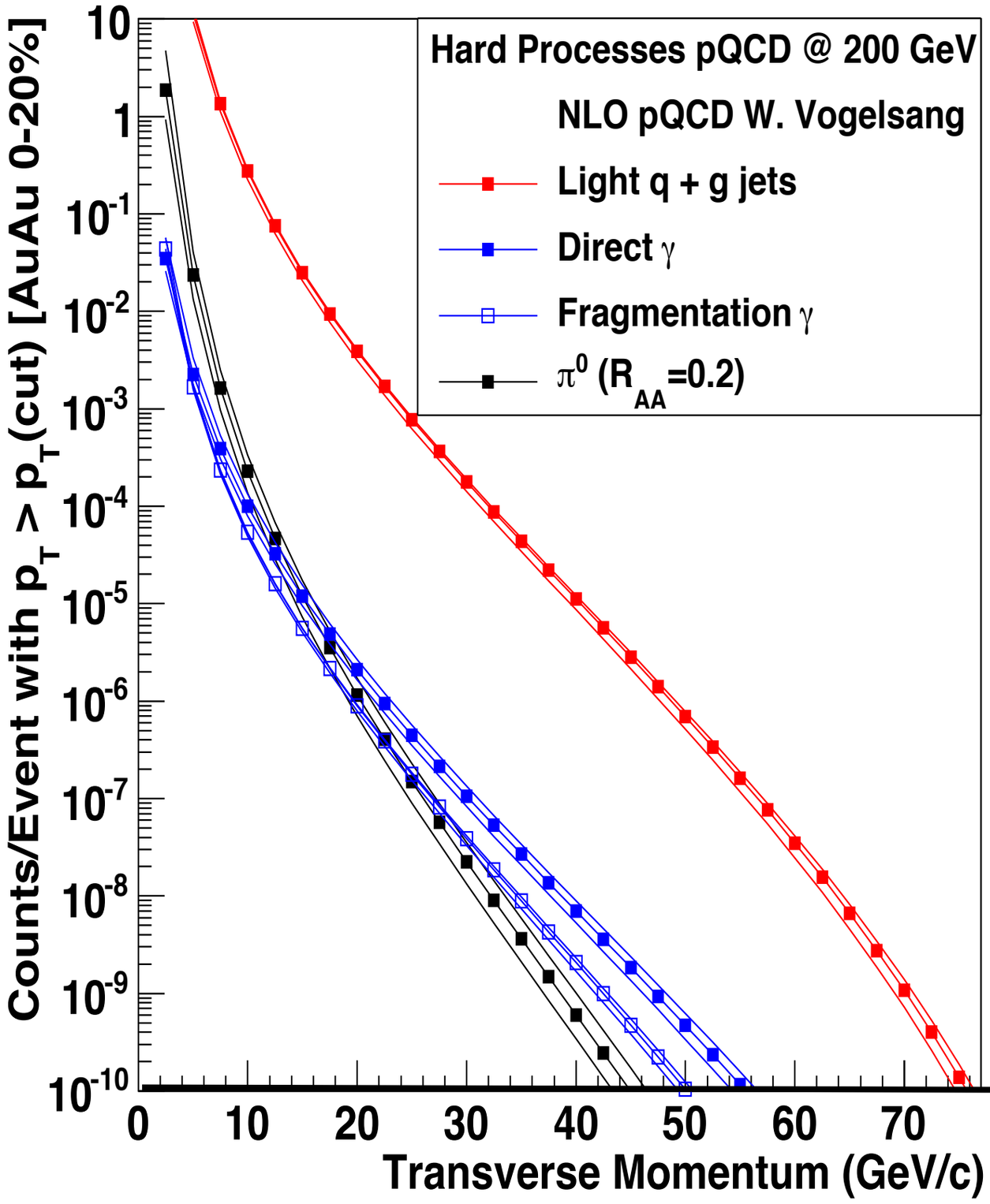
See more: M. Wysocki (Plenary IC), B. Sahlmueller (Parallel 3D), D. Perepelitsa (Poster)

Got sPHENIX?



sPHENIX Proposal: arXiv:1207.6378

sPHENIX Data Rates



Annual statistical reach

>30 GeV/c: 10^6 Jets

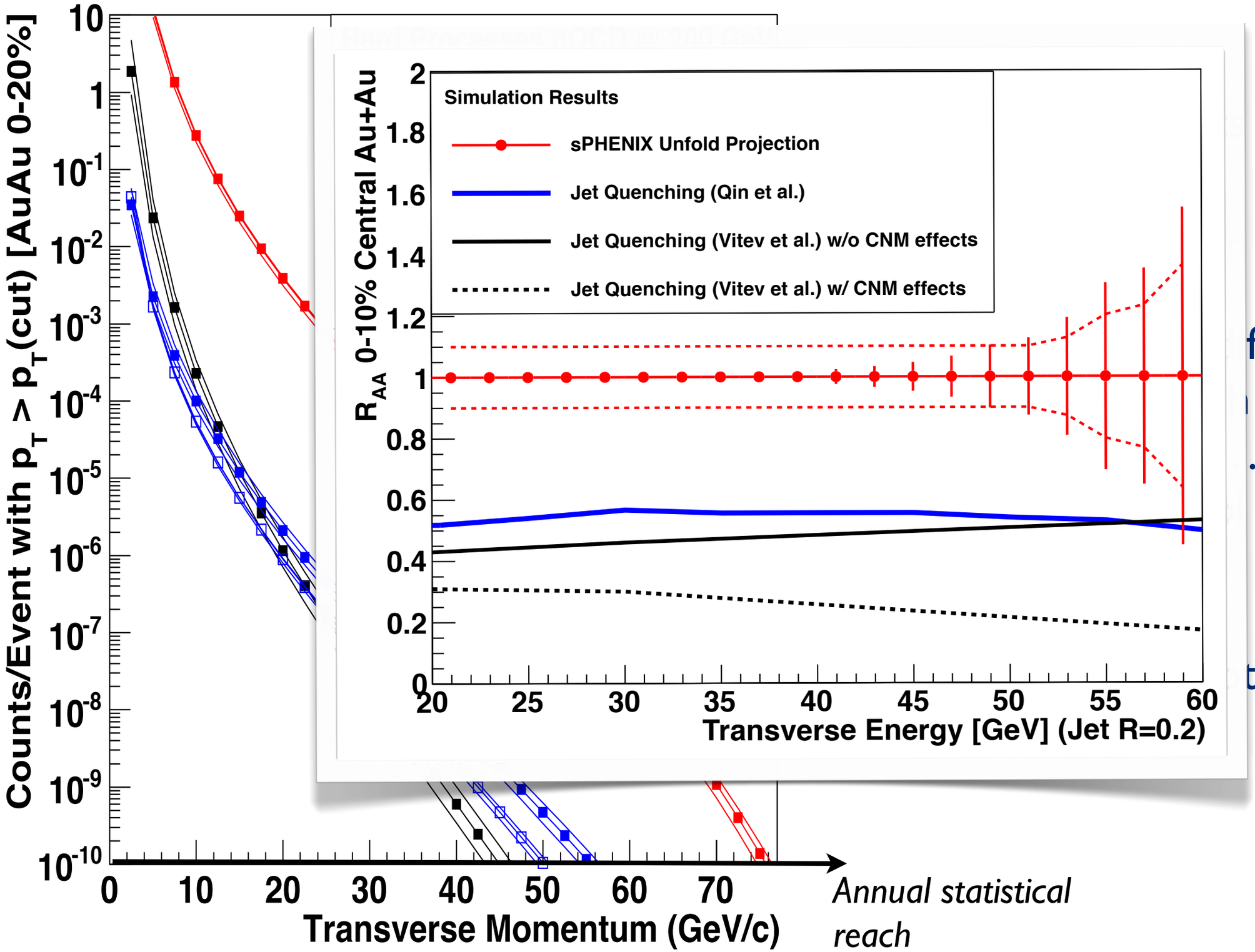
>20 GeV/c: 10^4 γ_{dir}

Huge rates allow differential measurements with geometry (v_2, v_3, A+B, U+U, …) and precise control measurements (d+Au & p+p).

Large coverage captures 80% of di-jets!

See more: J. Haggerty (Parallel 6C)

sPHENIX Data Rates



Annual statistical reach

fferential

geometry

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measurements

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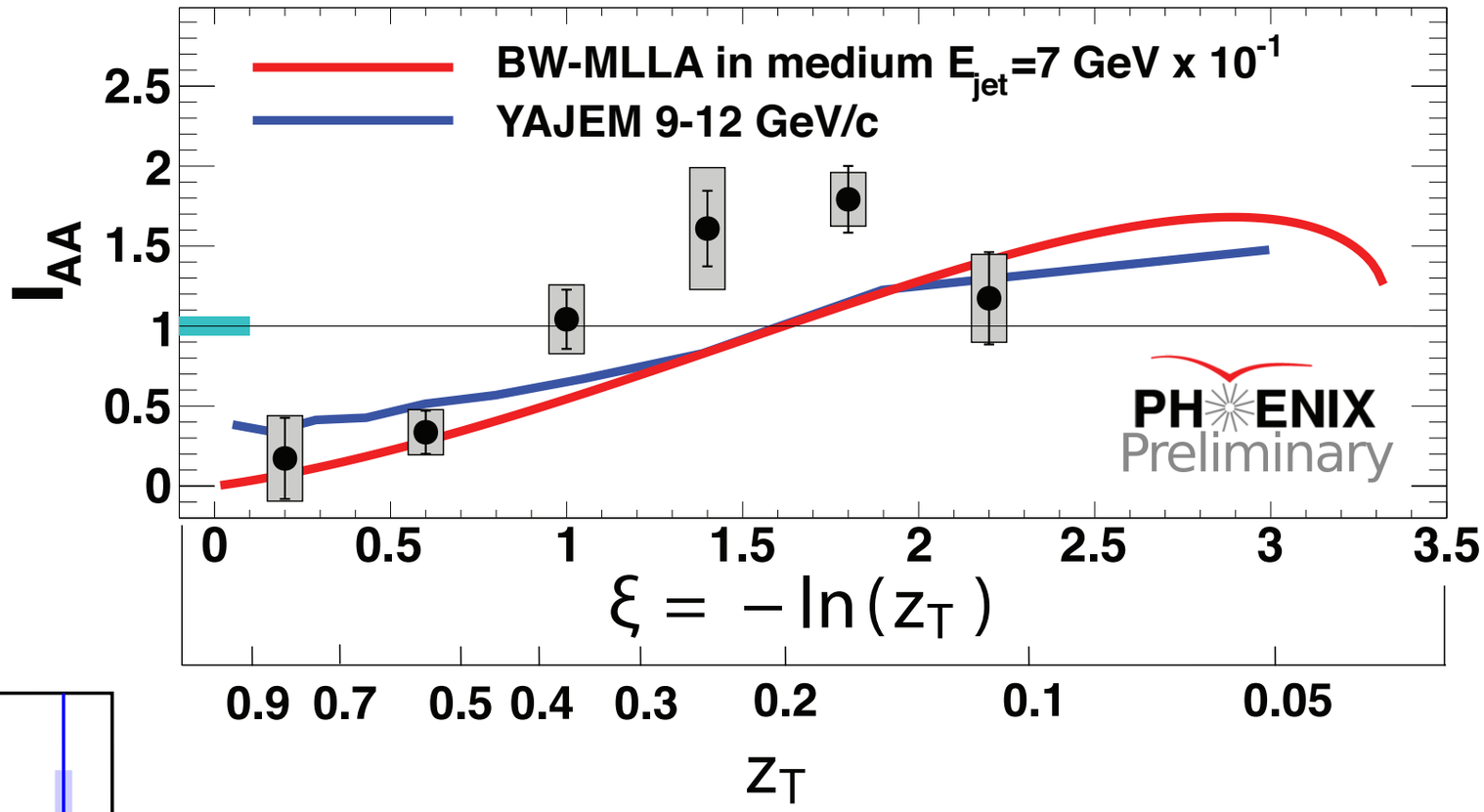
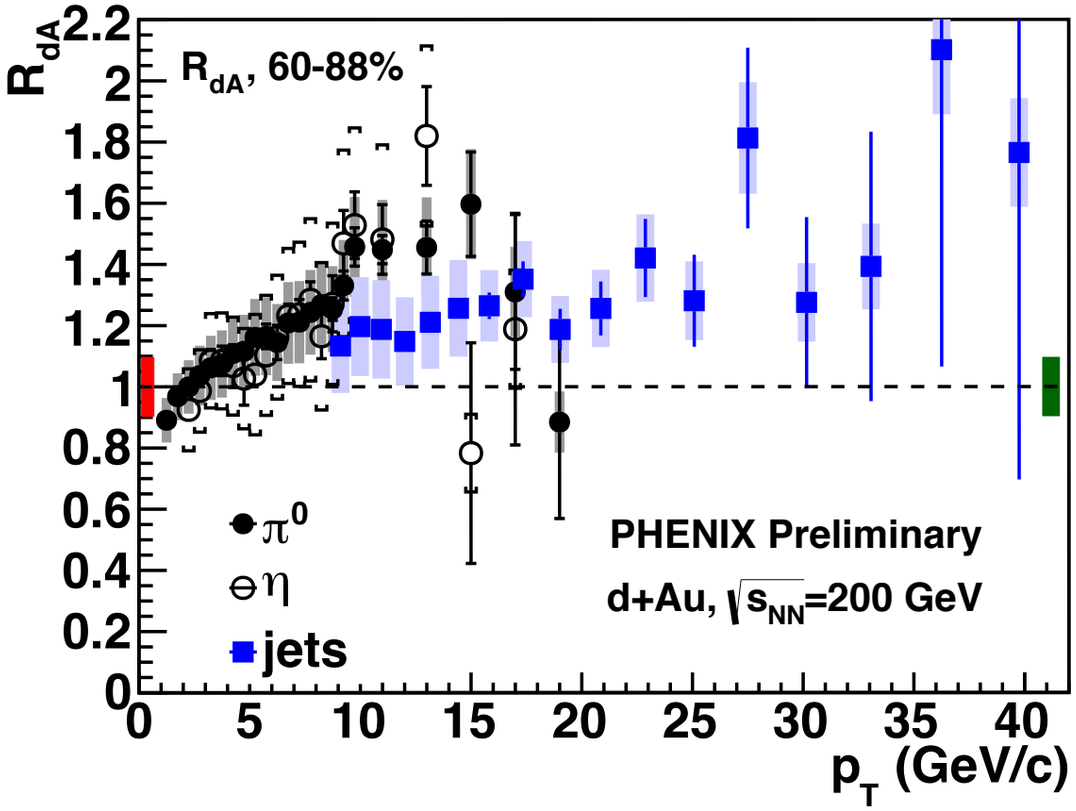
See more: J. Haggerty (Parallel 6C)

New Physics to Remember

- Large suppression and recovery of energy loss in γ_{dir} correlations





- Rapid large centrality dependence in CNM baseline will require treatment for energy loss calculations

More Information

Additional Talks:

- John Haggerty on sPHENIX
- Justin Frantz on γ_{dir}-h correlations
- Maki Kurosawa on V_N measurements
- Takahito Todoroki on Two-particle correlations

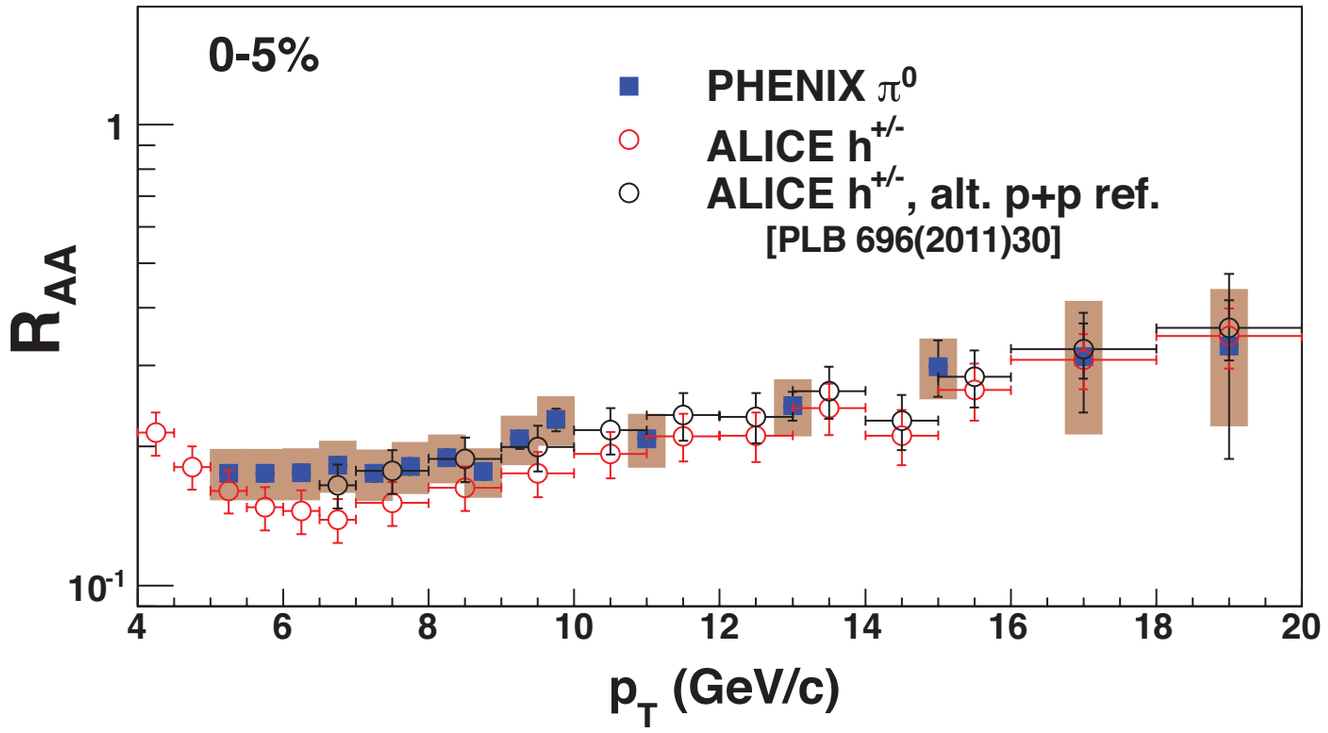
Posters:

- Dennis Perepelitsa on Jets in CNM
- Bing Xia on on γ_{dir}-h in d+Au
- Theo Koblesky on Correlations and Tracking in the VTX

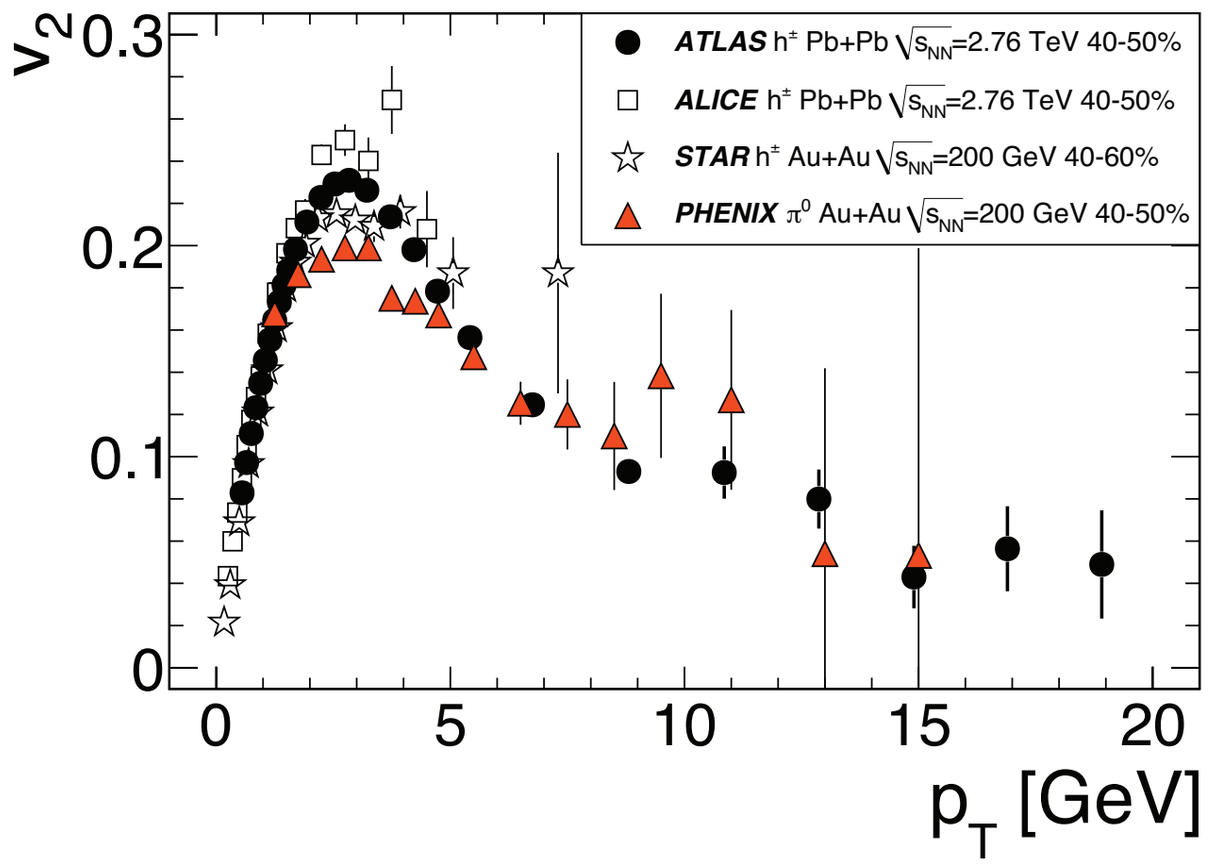
Backups

Comparison Backup

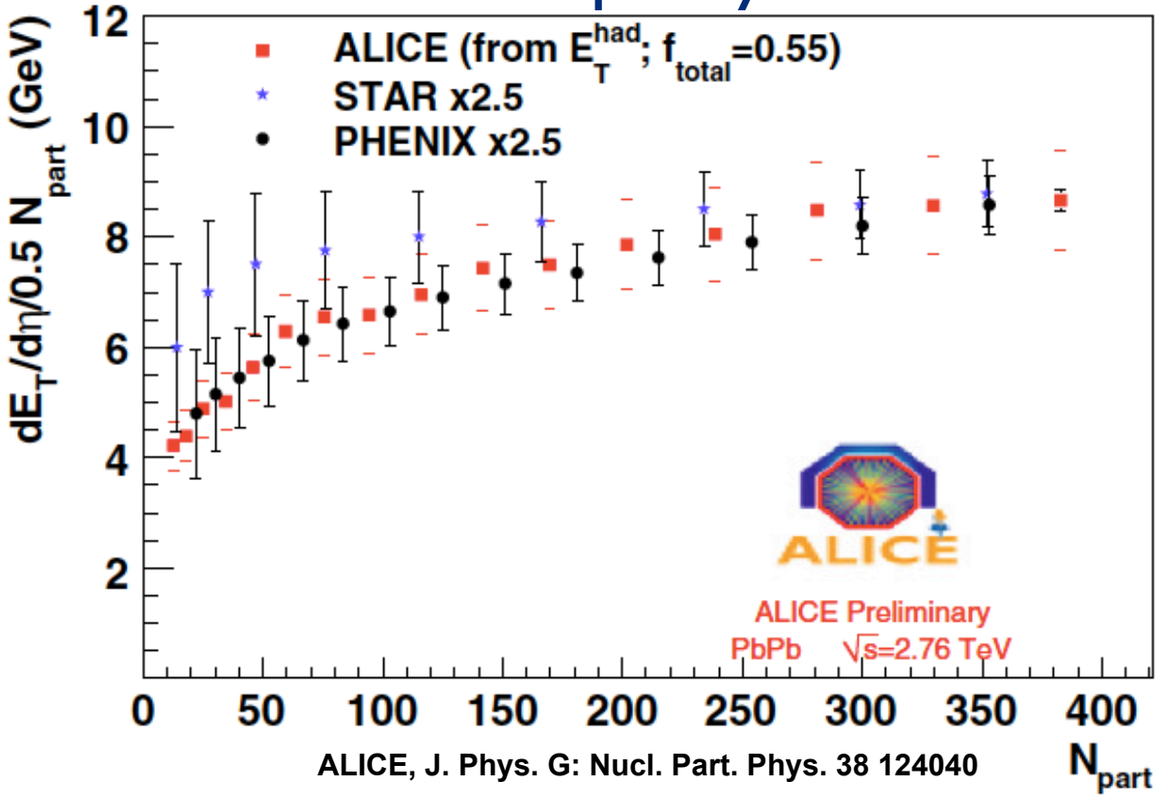
Nuclear Modification



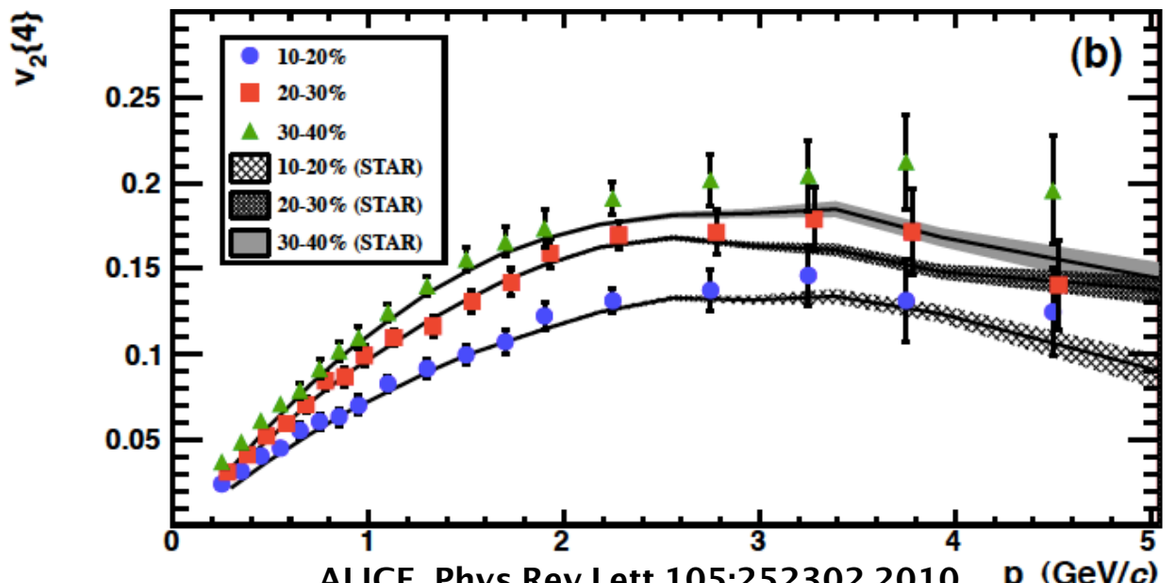
Path-length dependence



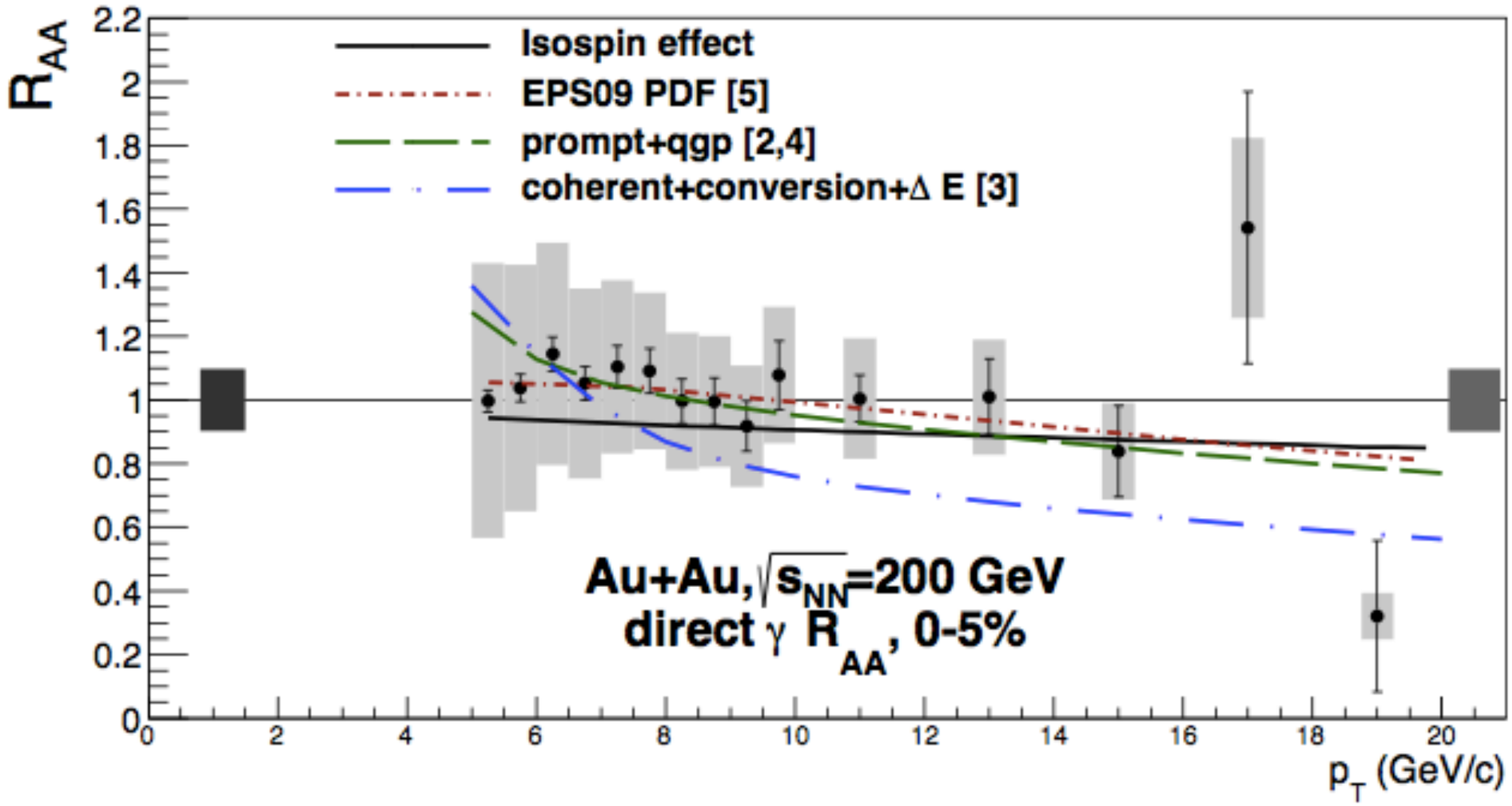
Multiplicity



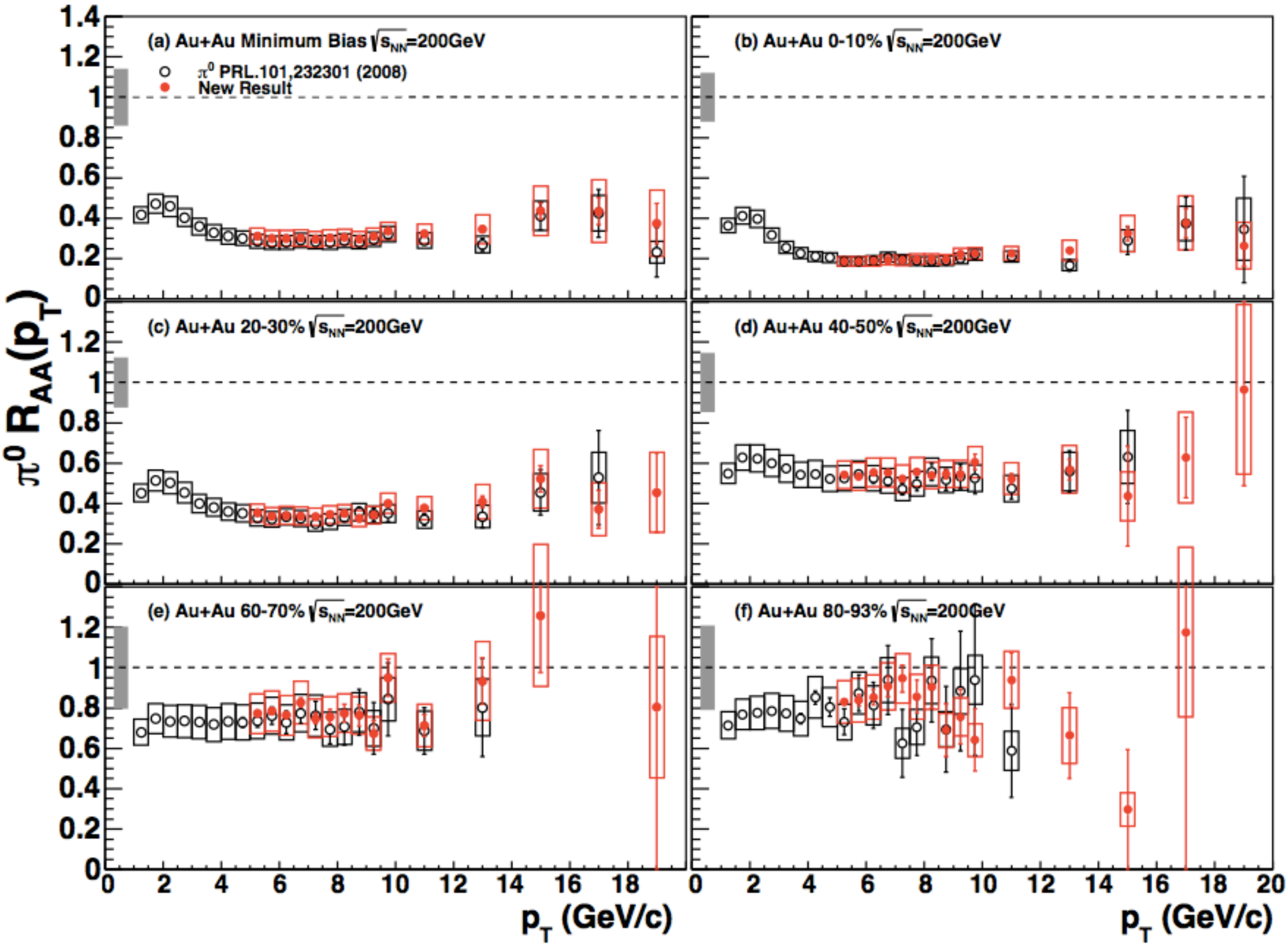
Flow



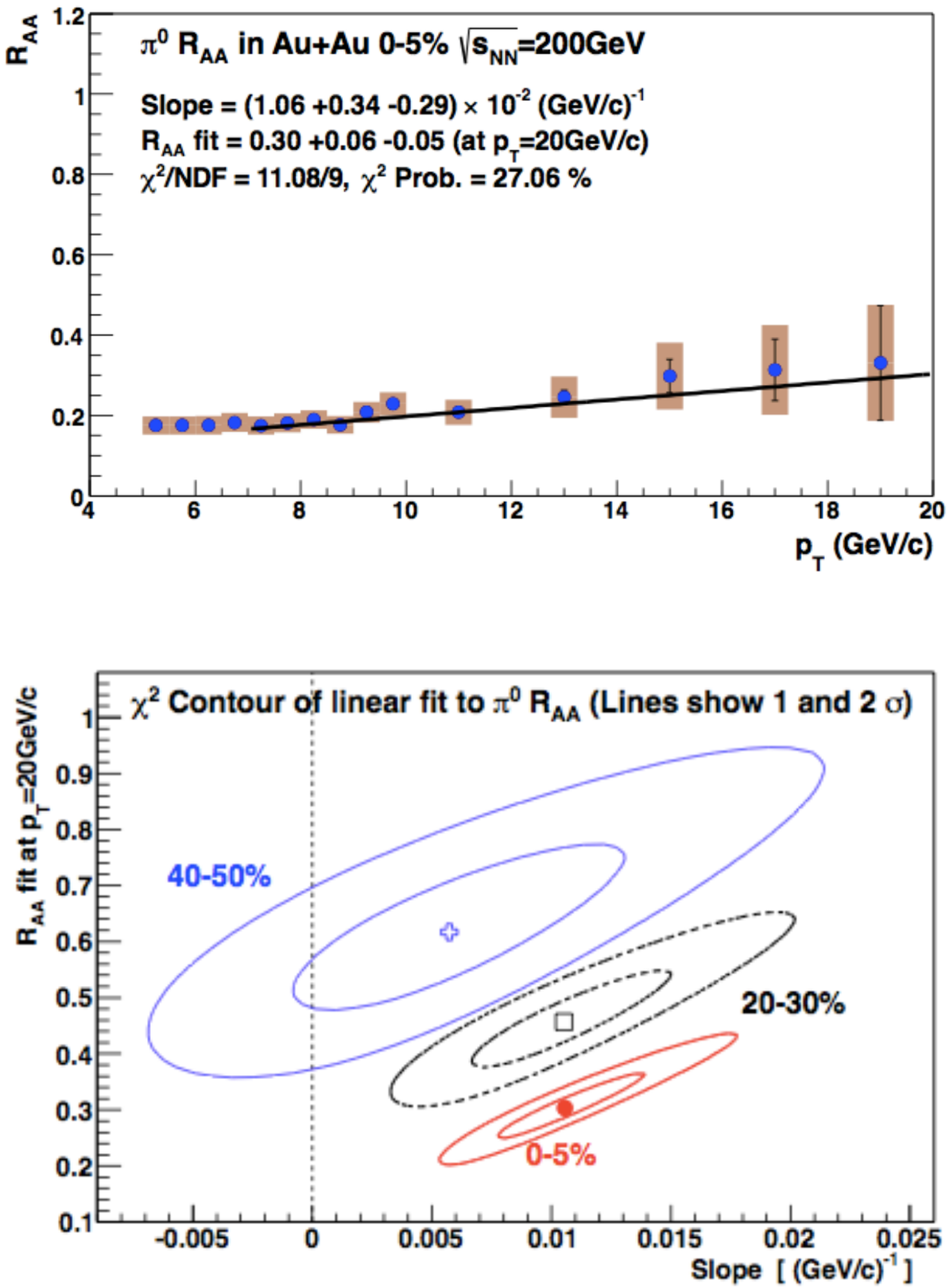
Direct Photon Backup

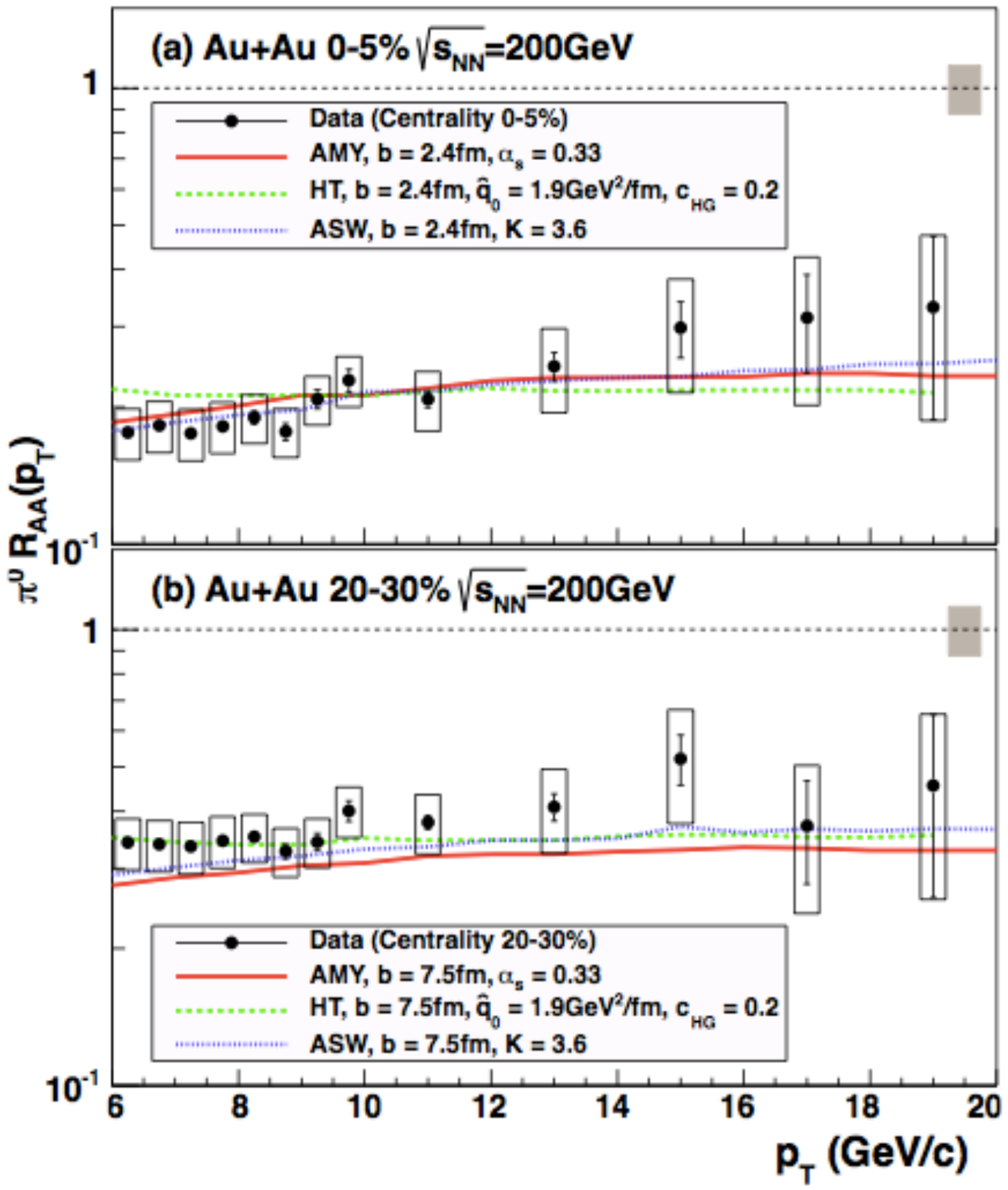


Nuclear Suppression Backup I

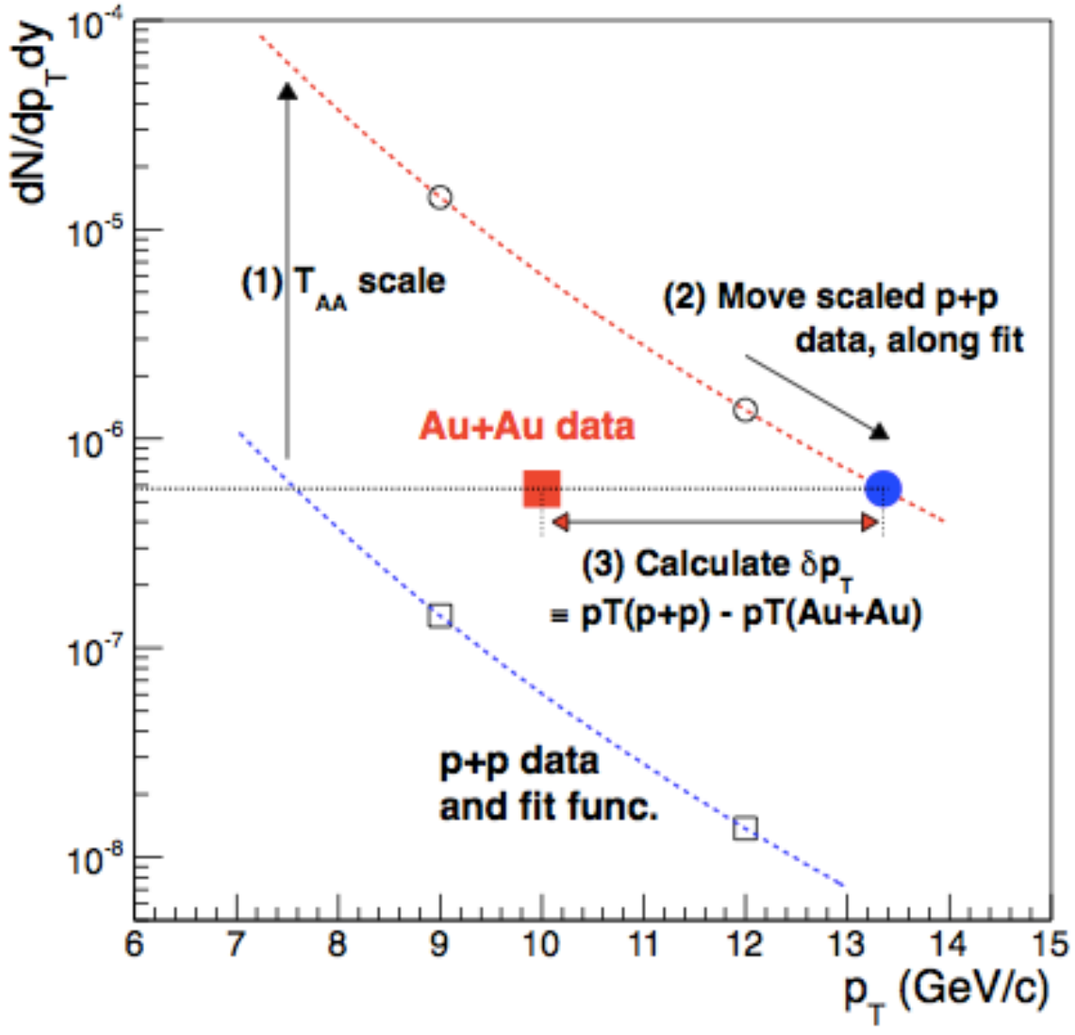


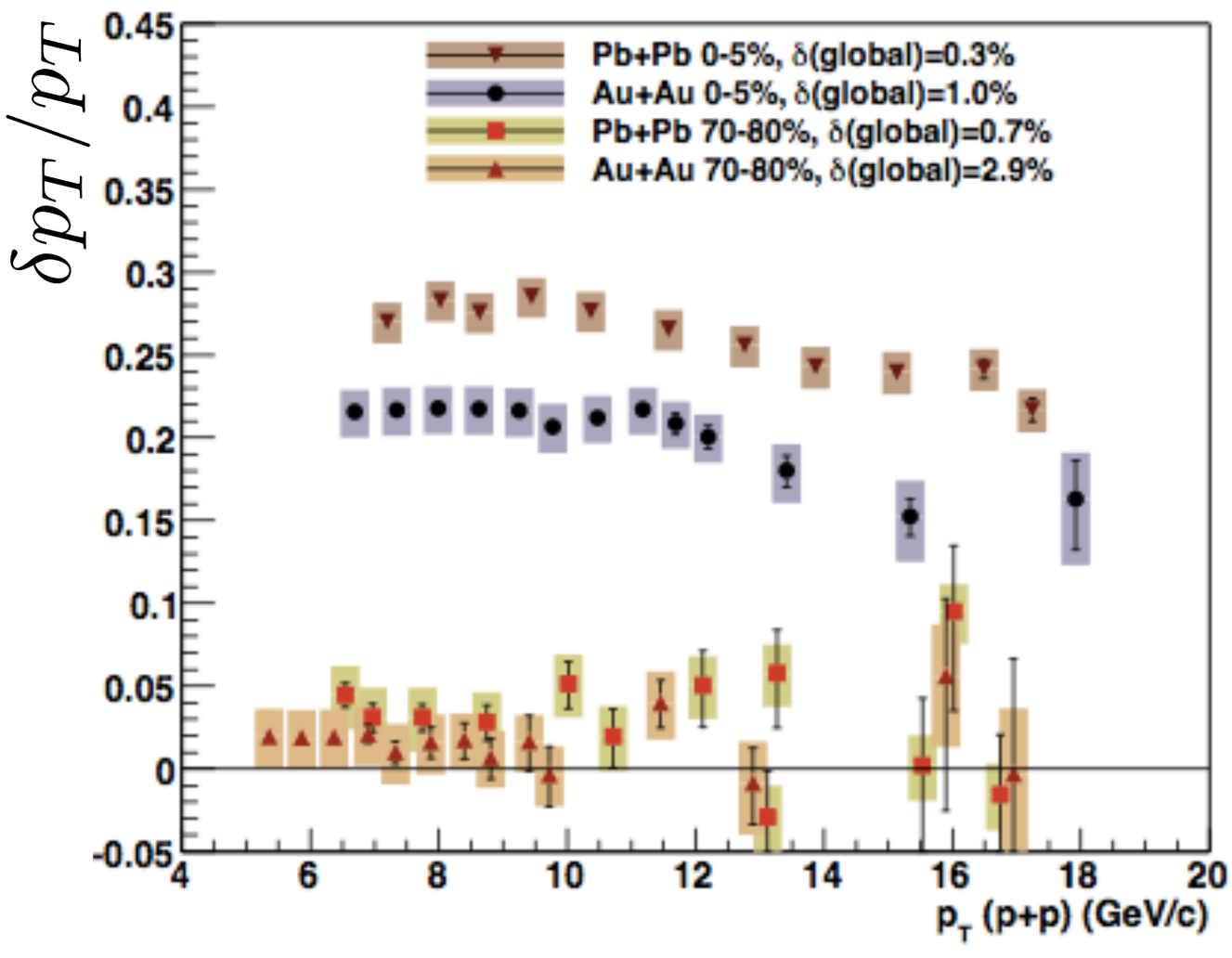
Nuclear Suppression Backup II



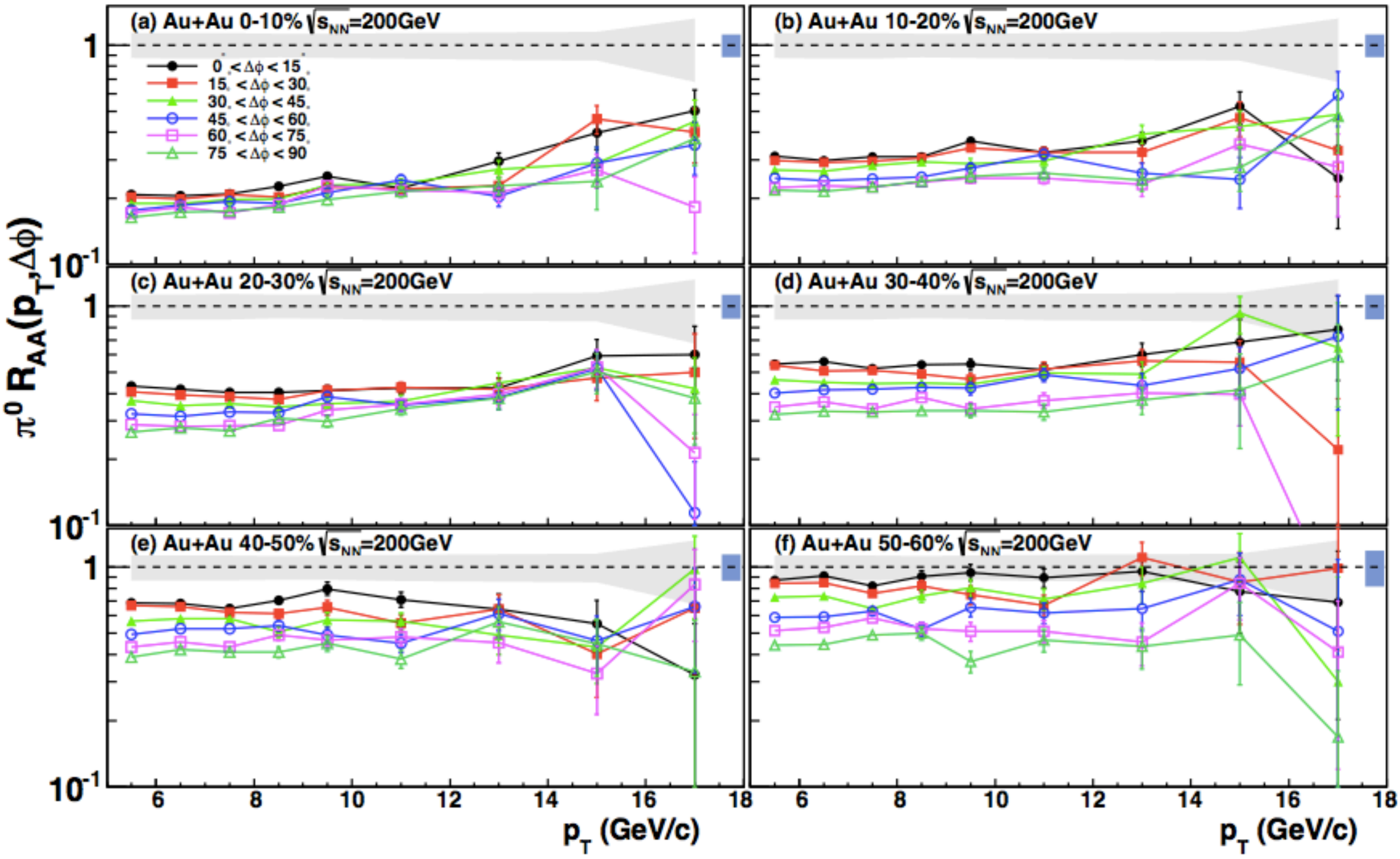


Fractional Energy Loss Backup

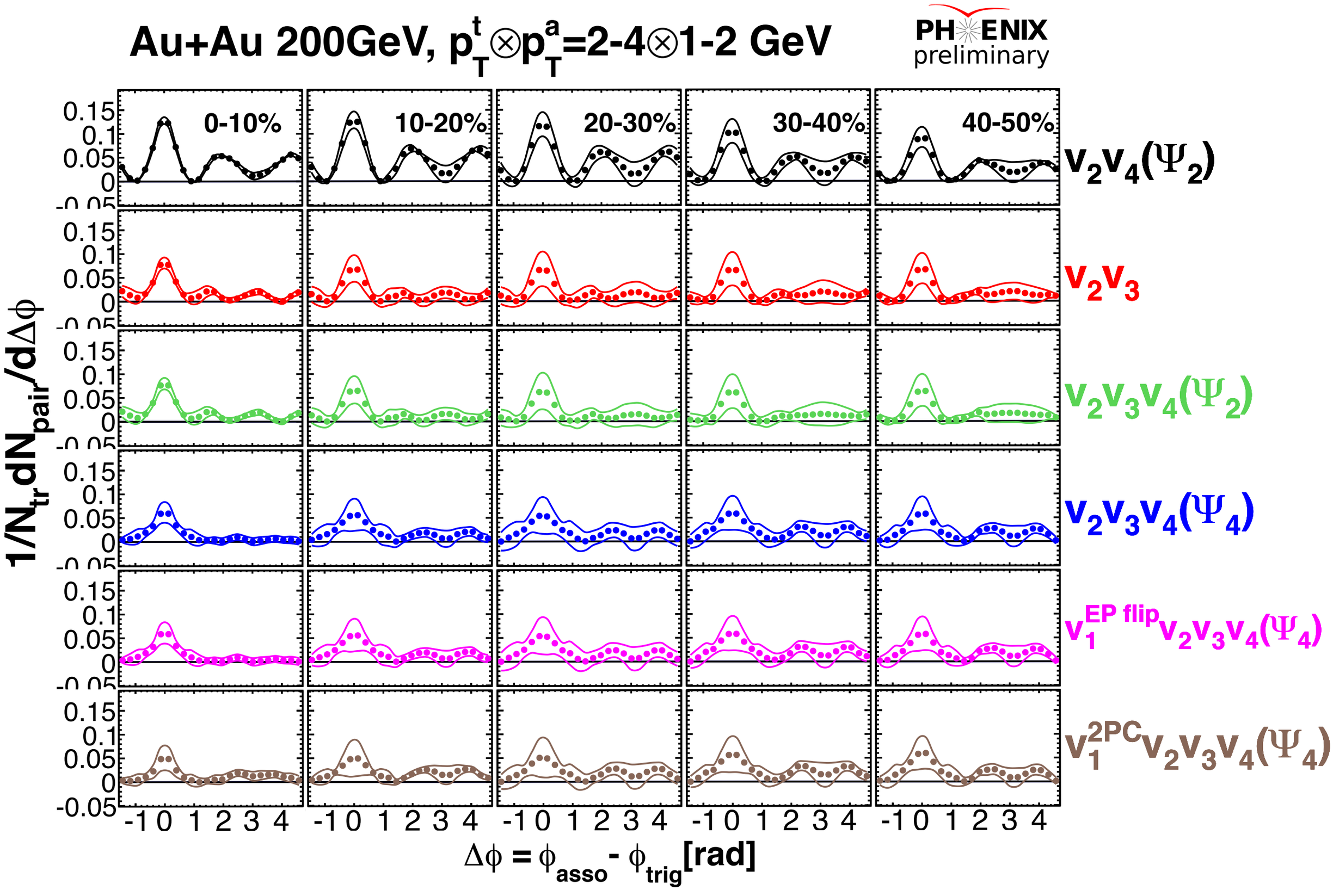




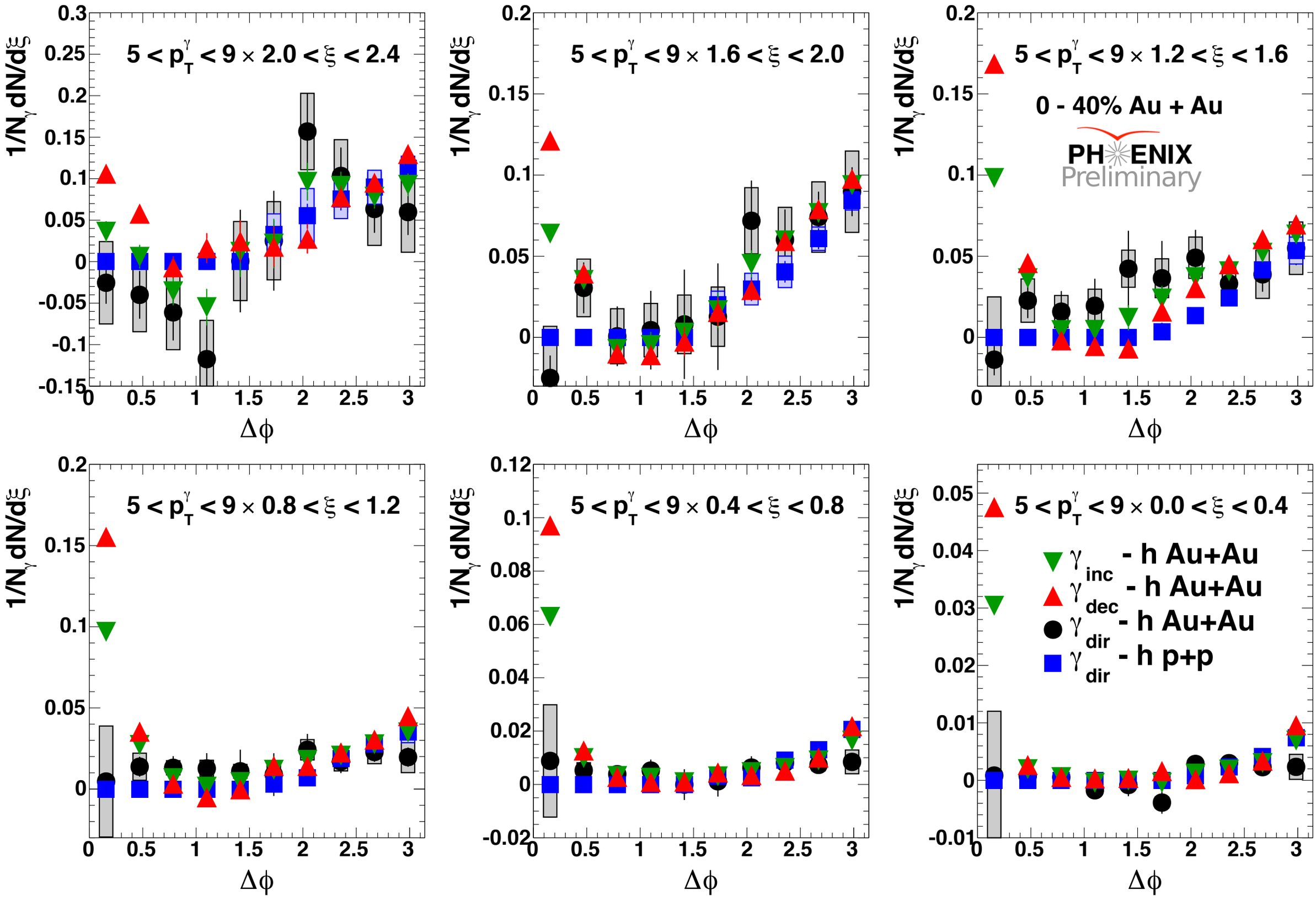
Path-Length Dependence Backup



Flow Subtraction Backup



Direct Photon Backup I



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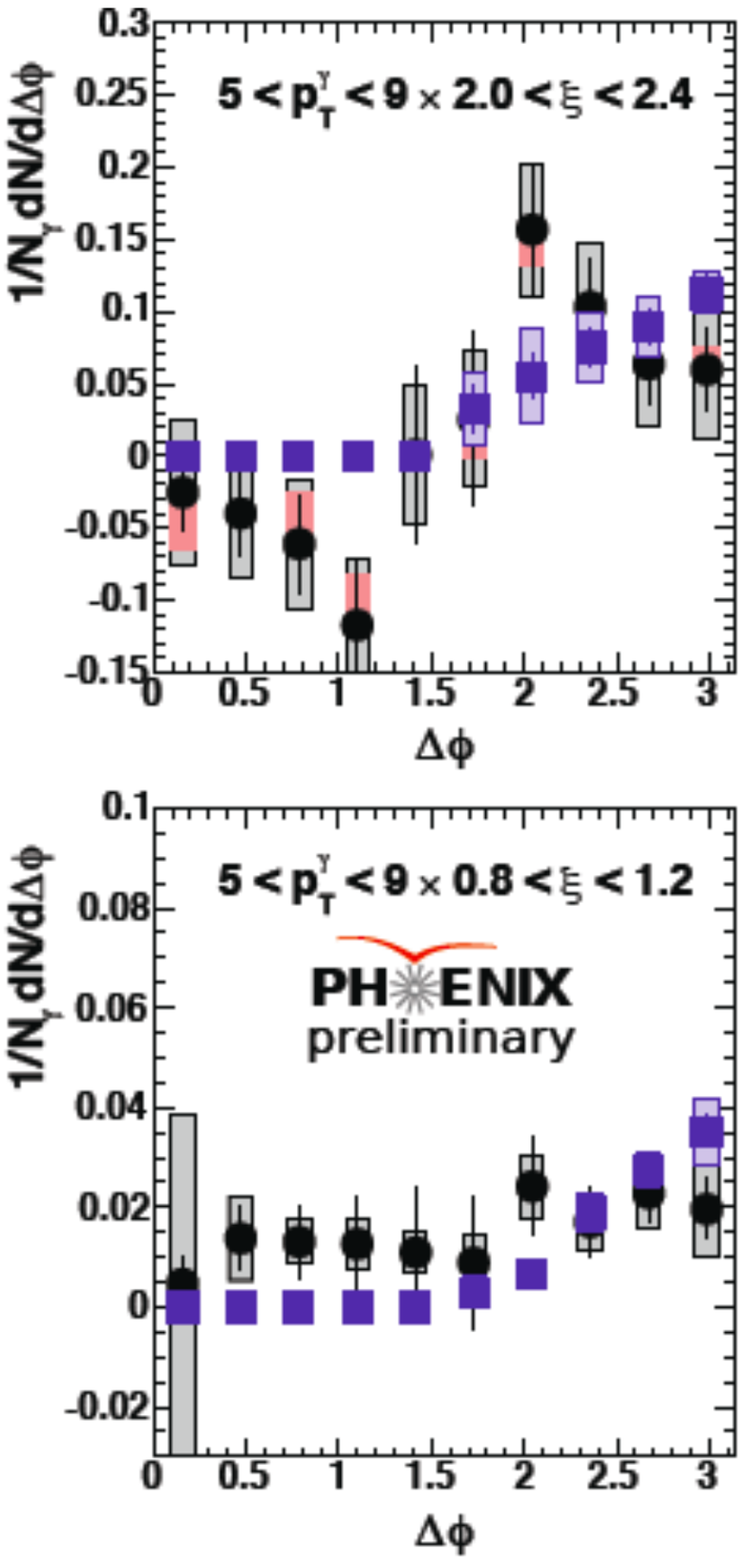
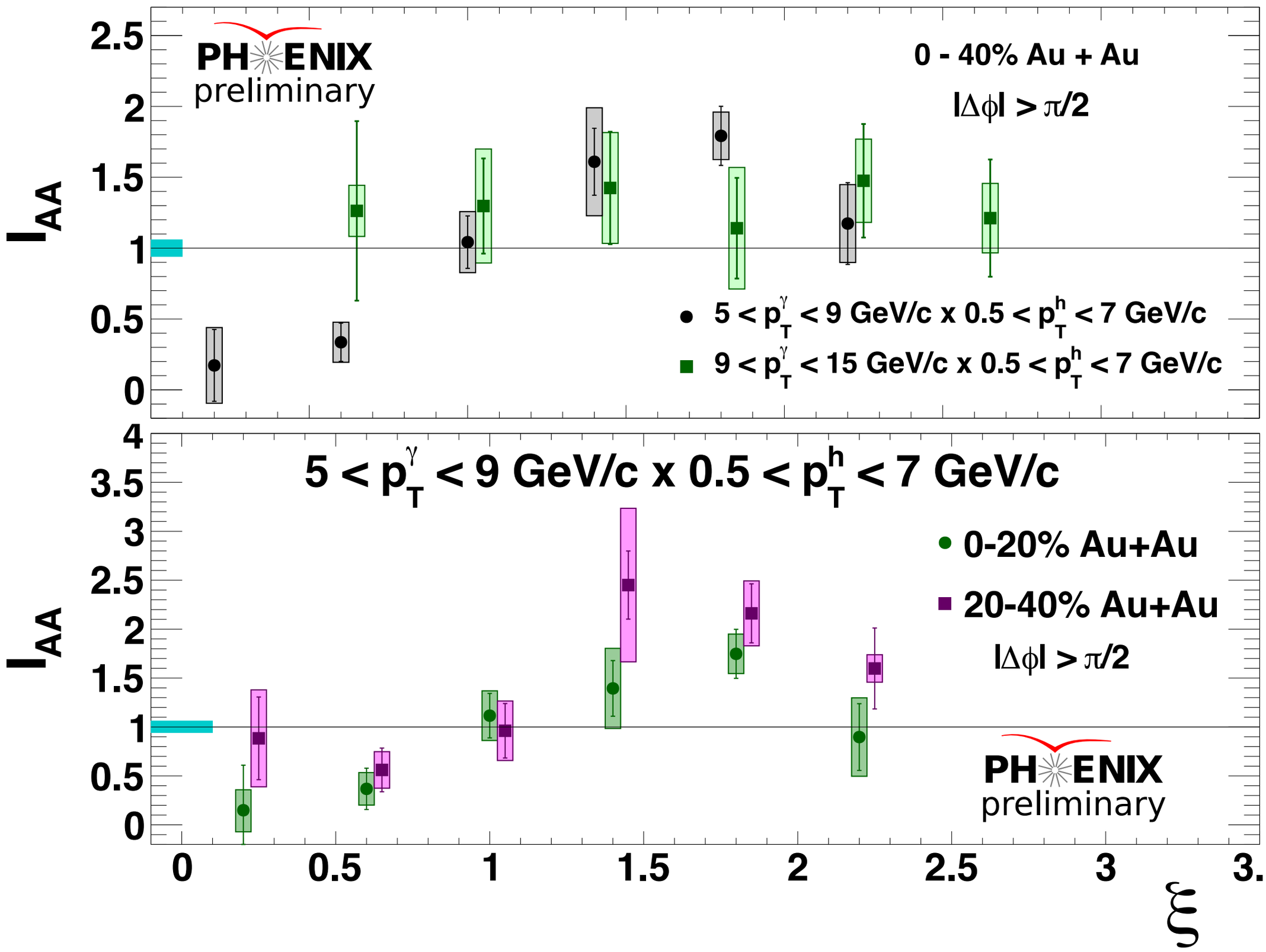
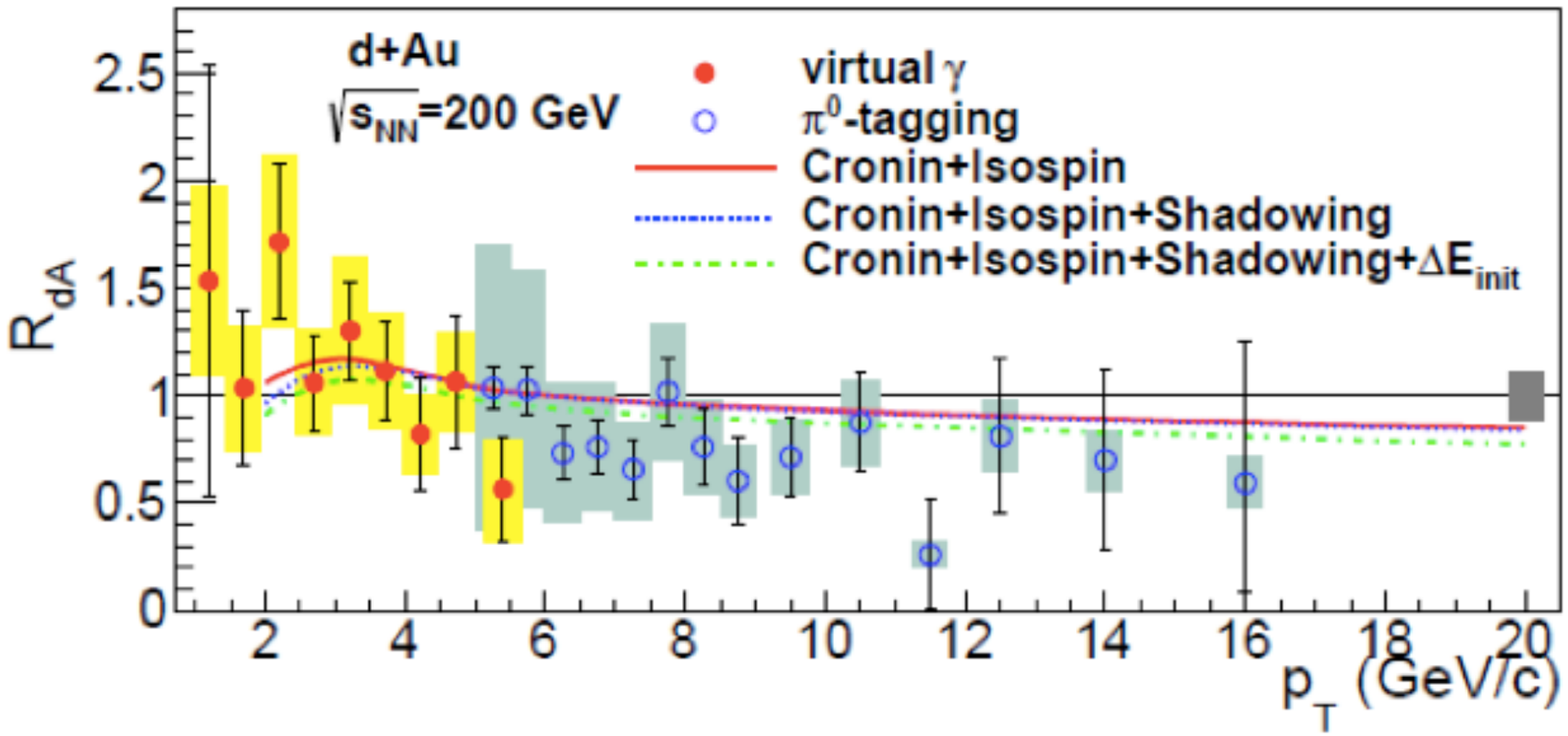
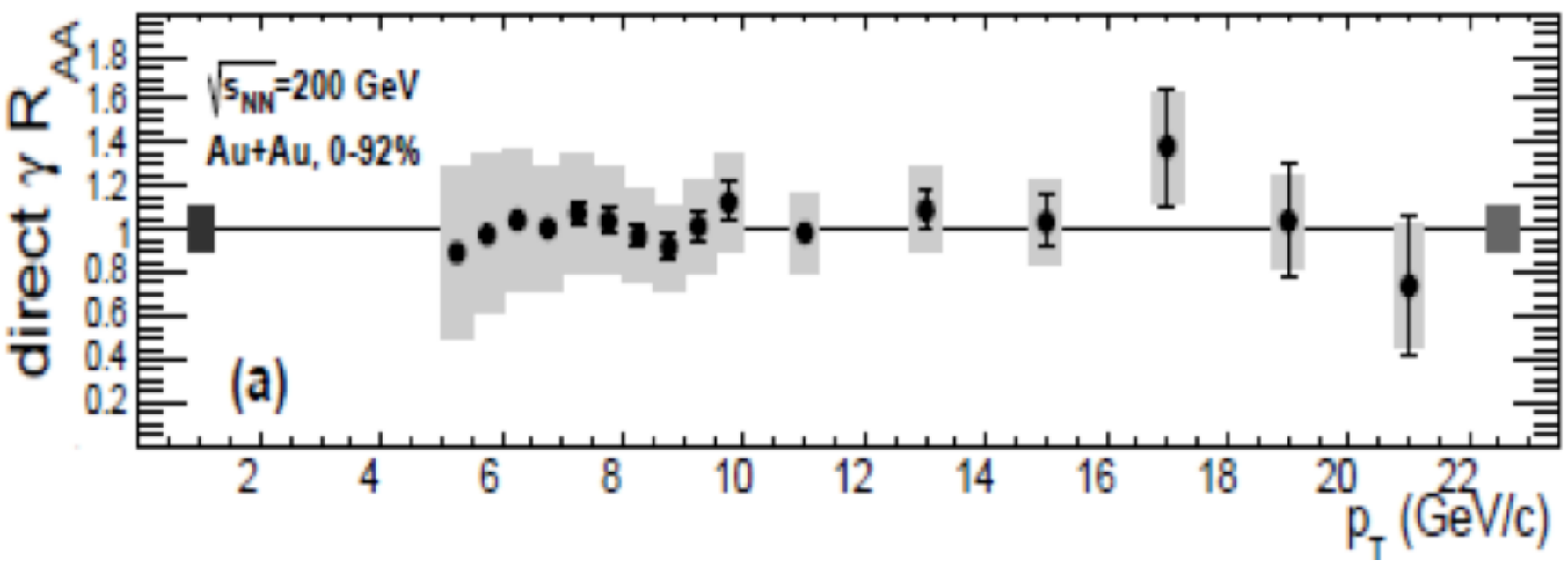


Direct Photon Backup III

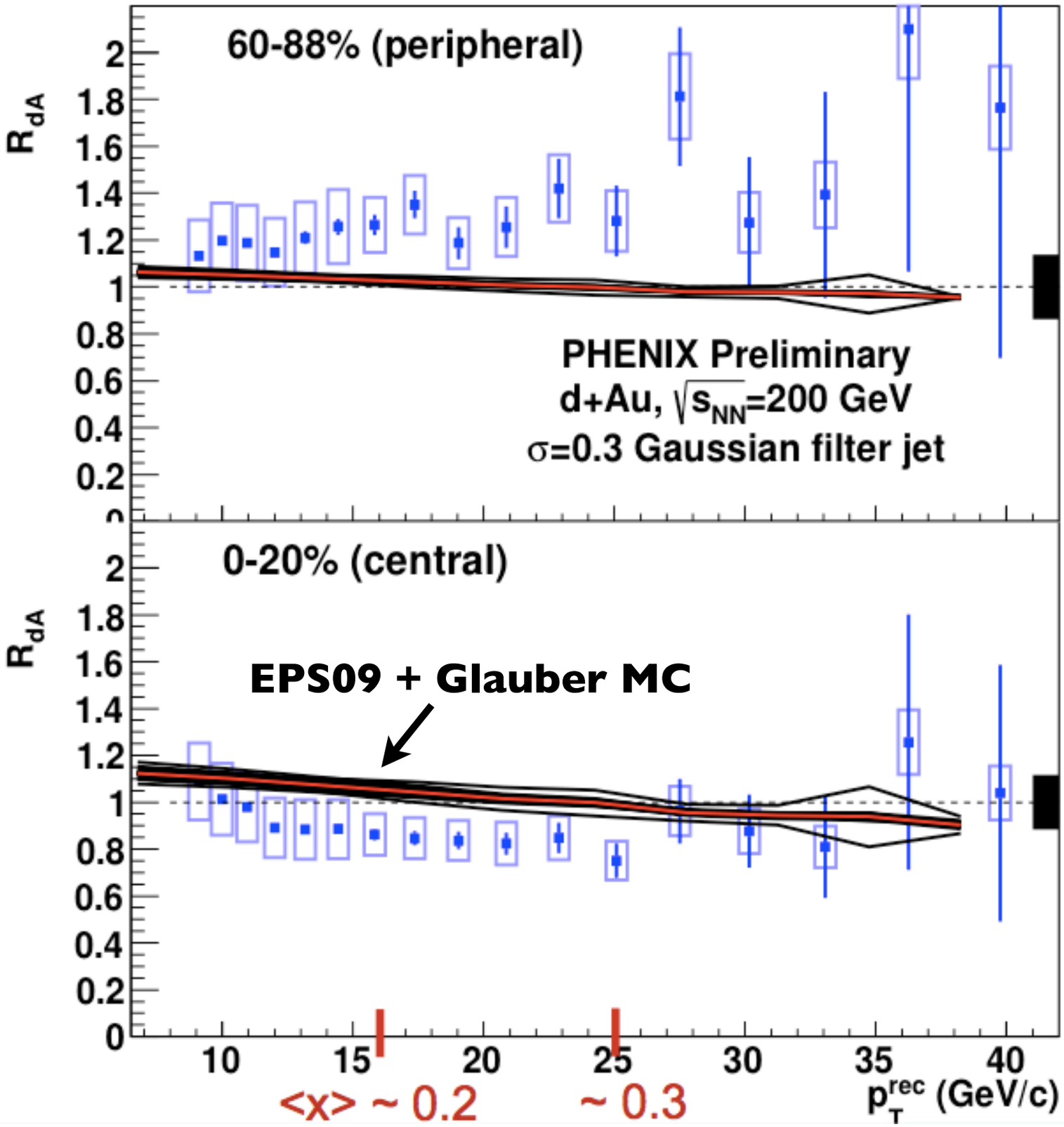


Direct Photon Backup IV

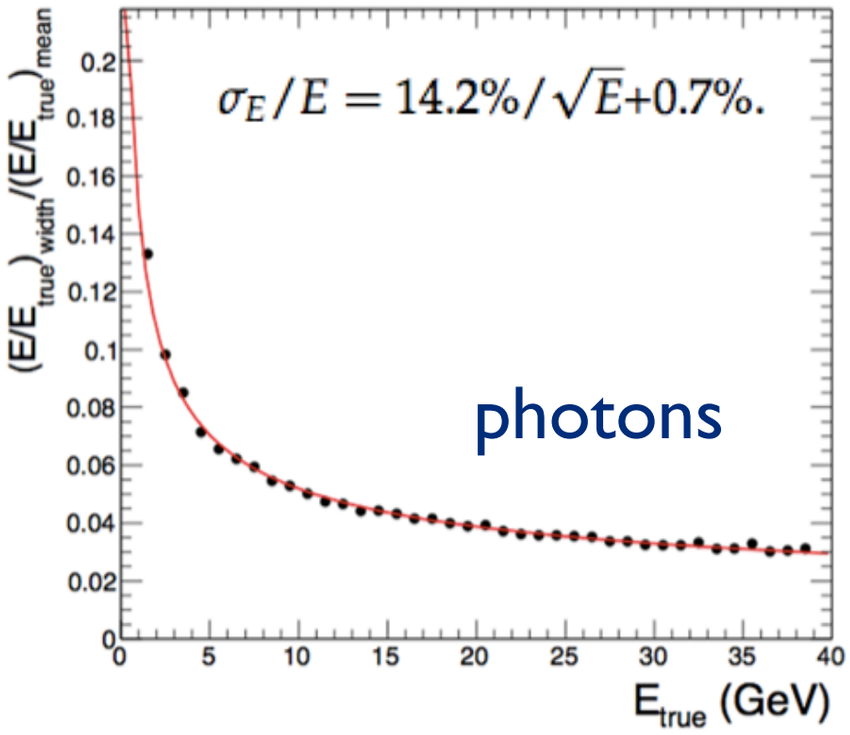


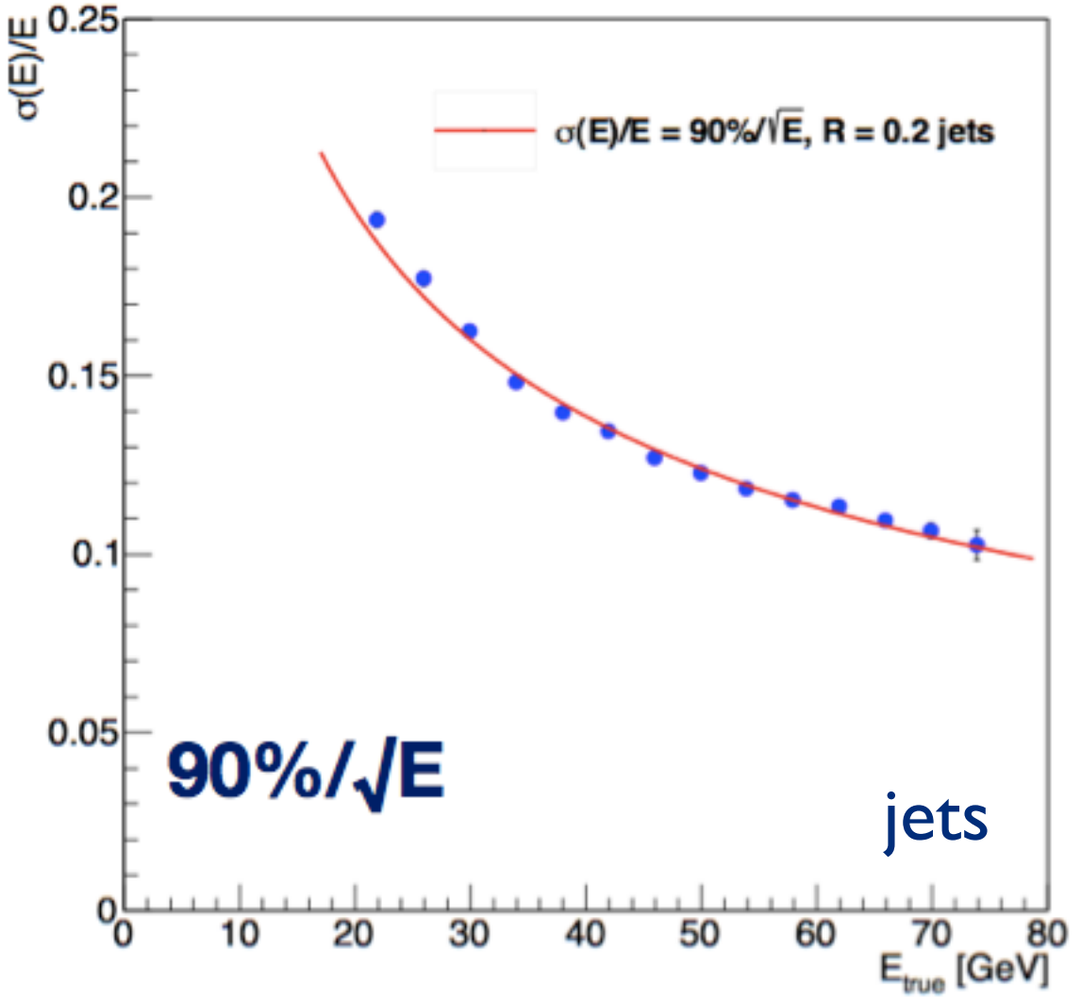


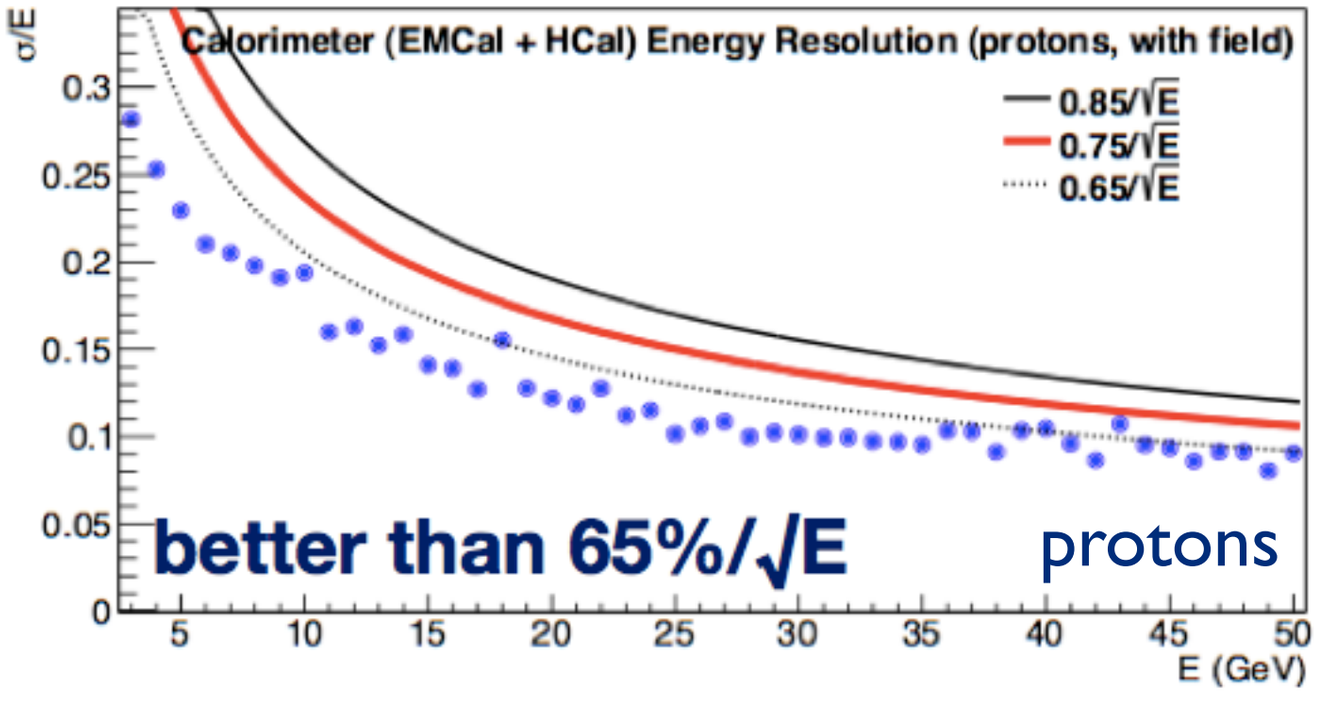
CNM Jets Backup



sPHENIX Backup I







sPHENIX Backup II