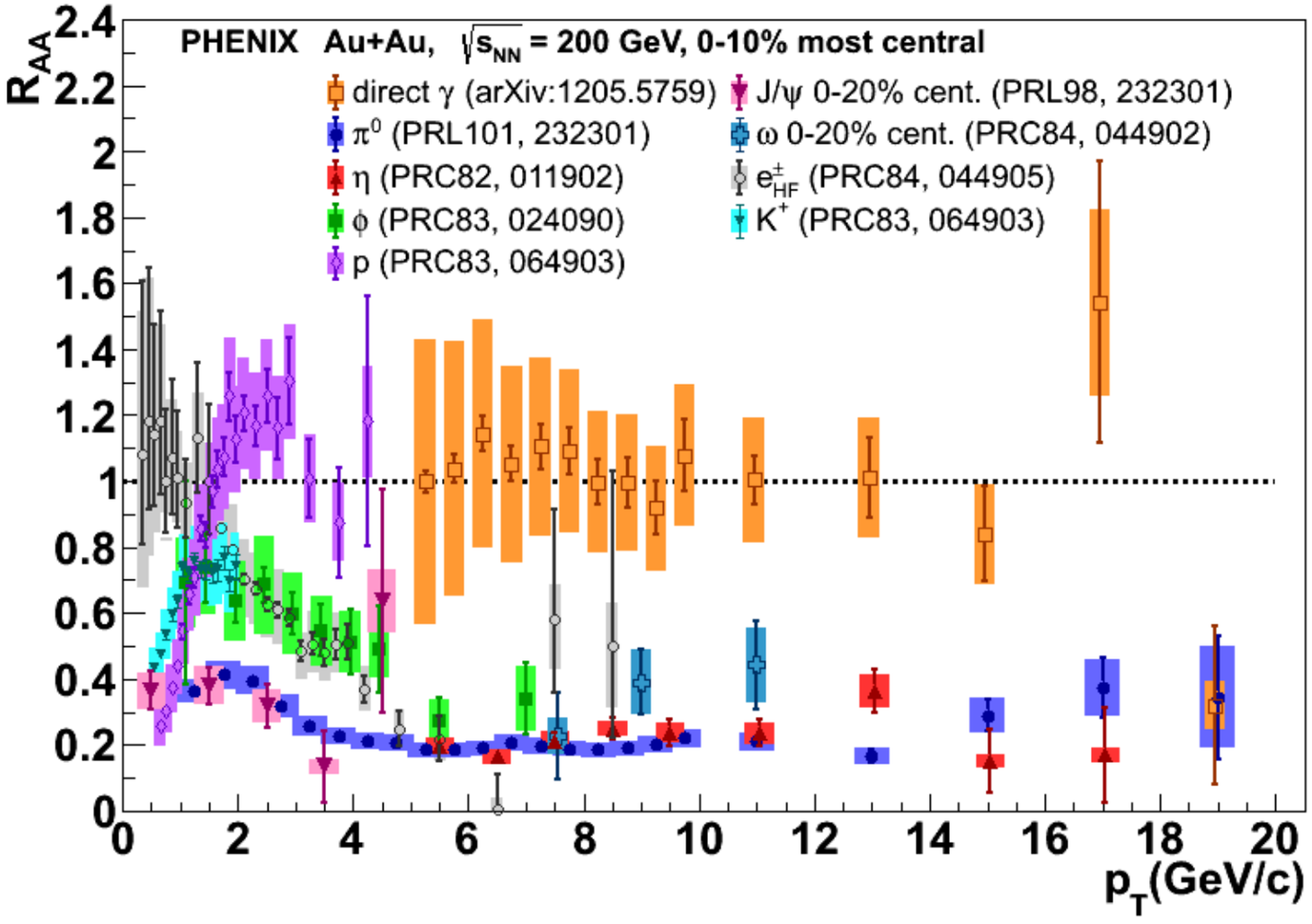
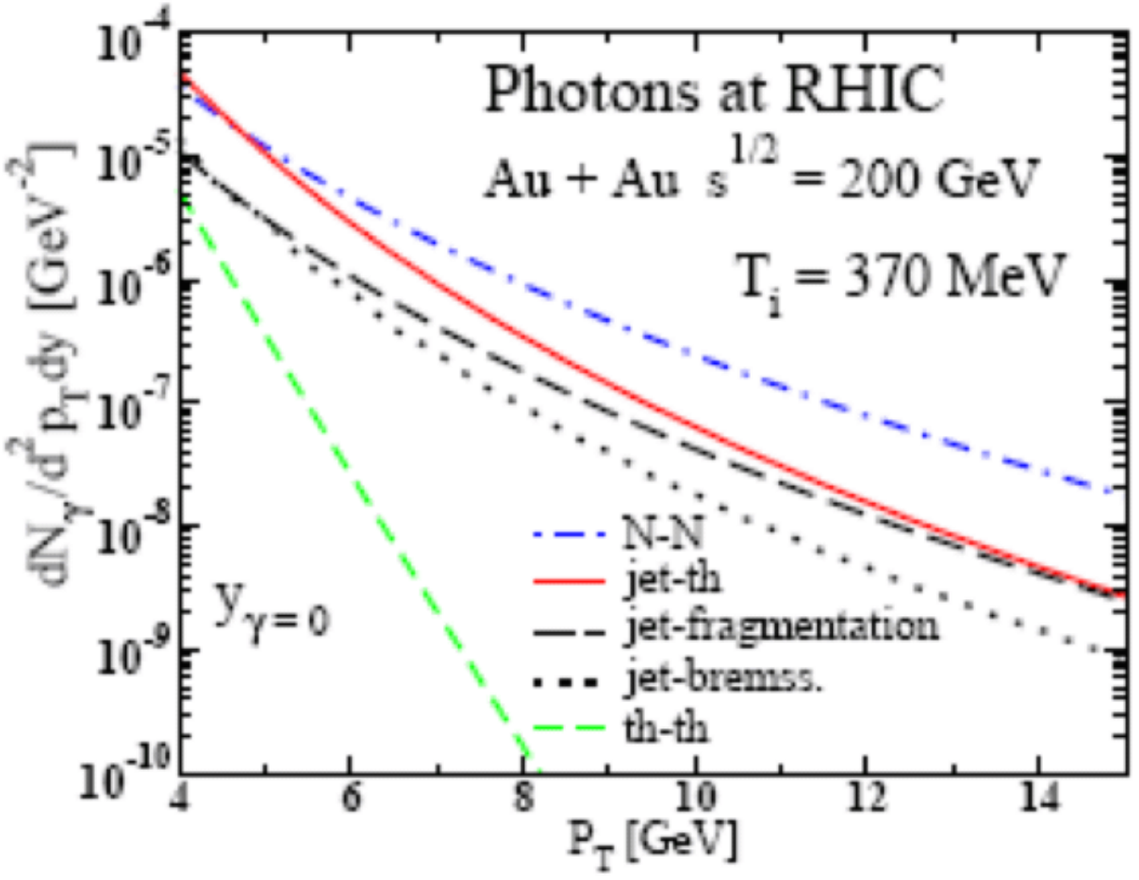
Photon-hadron correlations in PHENIX

Ali Hanks

ALICE Jet Workshop
January 15th, 2016

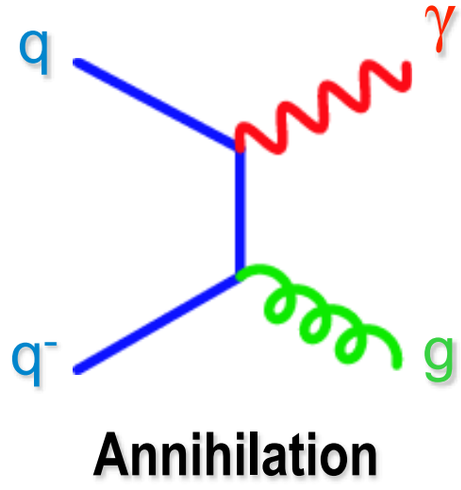
Why direct photons?



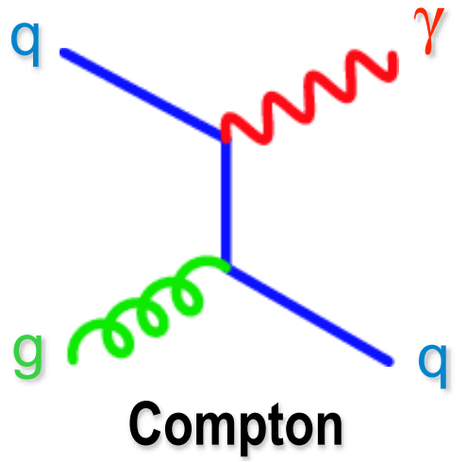


- Calibrated probe: largely insensitive to medium
  - photons do not interact strongly with the medium
  - at high p_T yield is dominated by hard processes
- Produced back-to-back with parton

$\Longrightarrow$ calibrated measure of initial parton energy

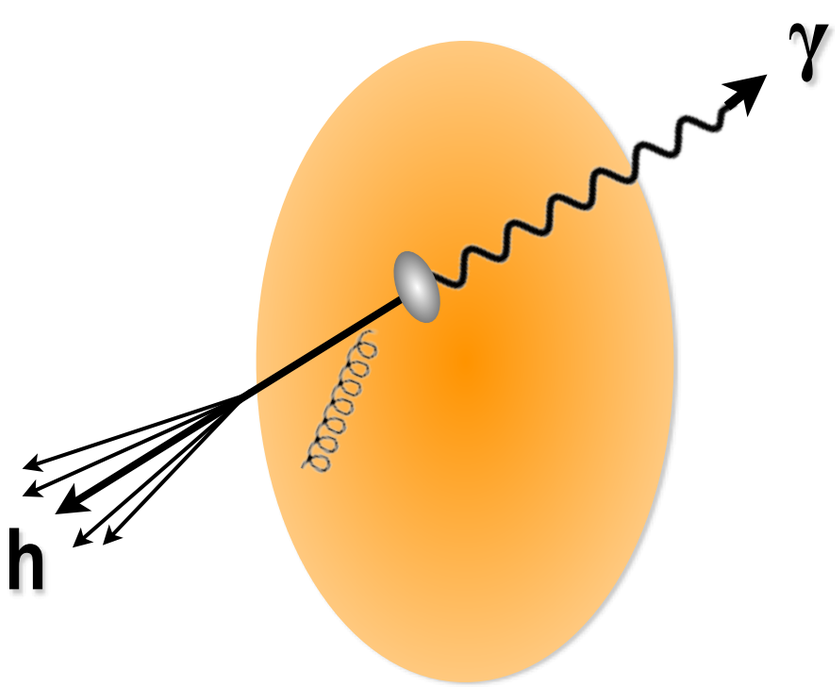


Annihilation



Compton

probing energy loss with γ-h correlations



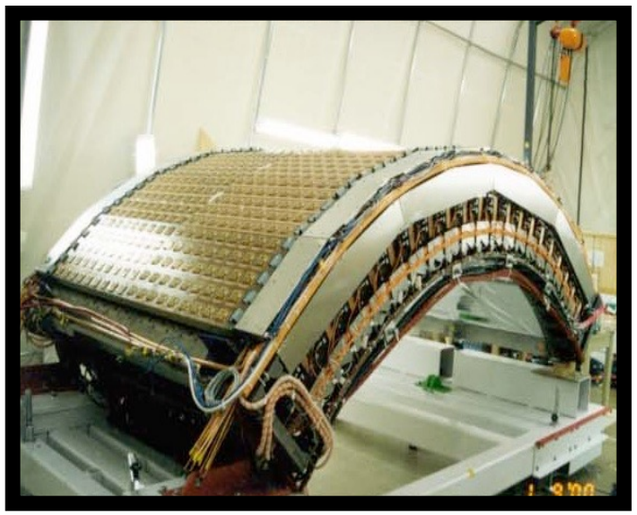
- **γ-h (and γ-jet):**
  - low signal rate
  - large decay background
- no trigger surface bias
- $p_{T,\gamma}$ most direct measure of **initial** parton p_T

dominated by quark jet

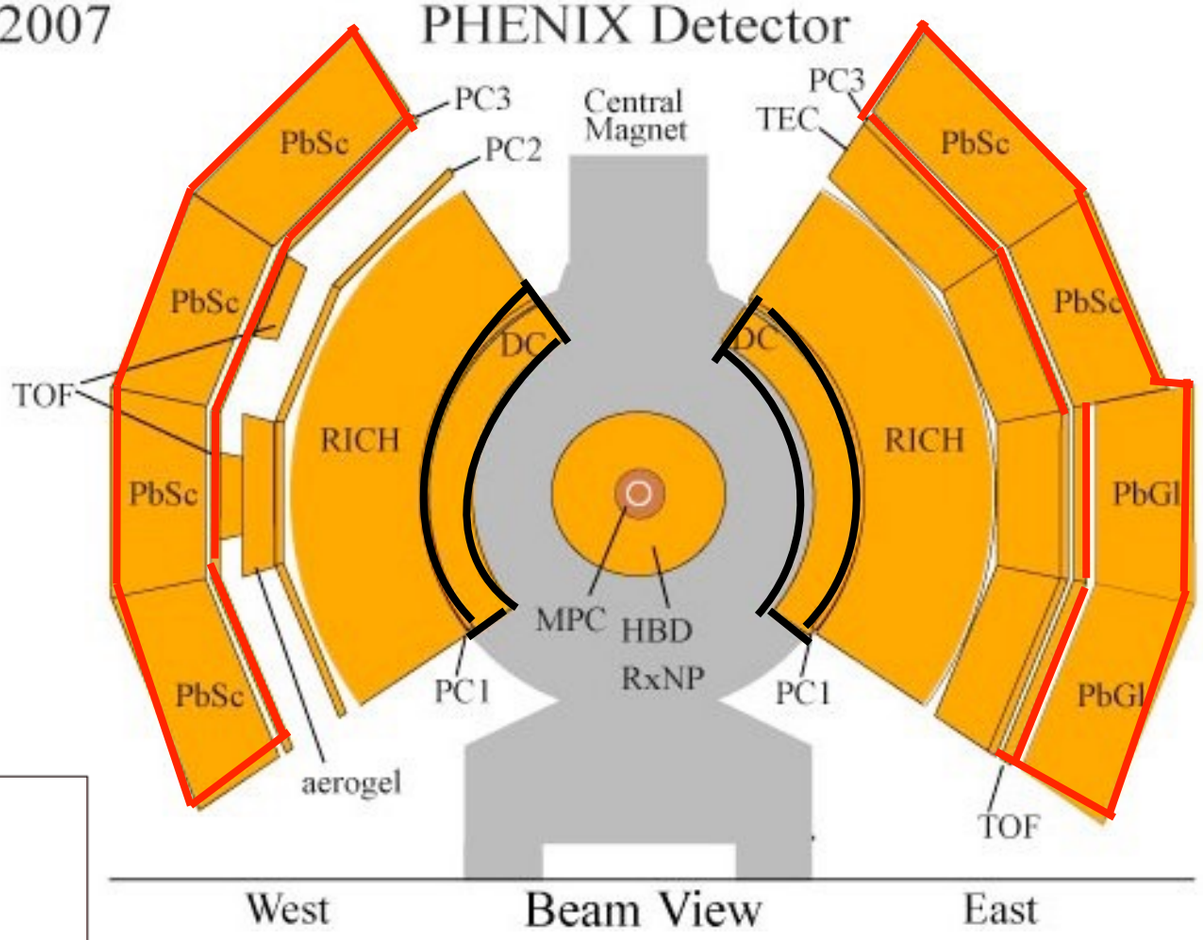
- **Important compliment to other jet measurements**
  - Different path-length dependence
  - Different relative contribution from quark vs gluon jets

γ-h correlations in PHENIX

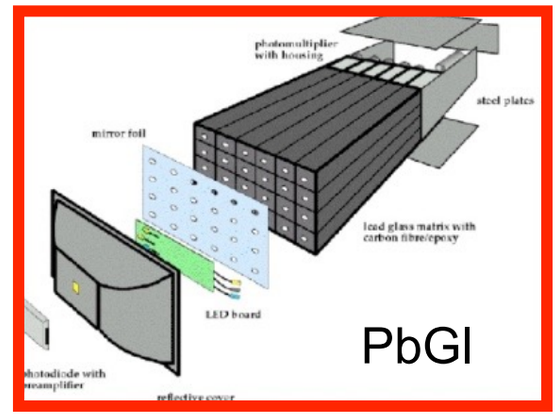
Drift Chamber

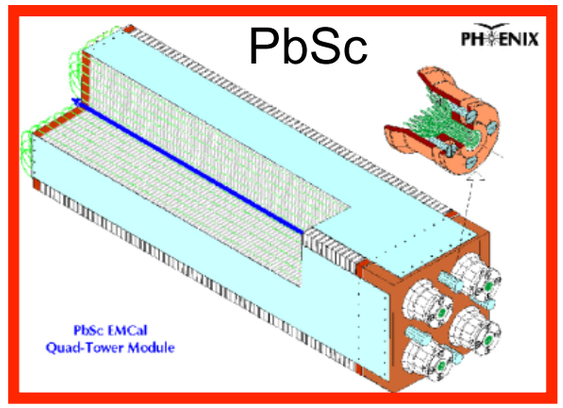


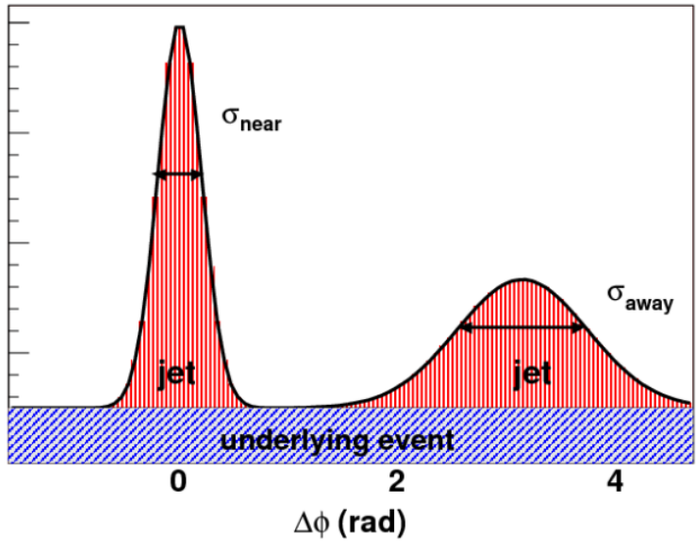
2007 PHENIX Detector

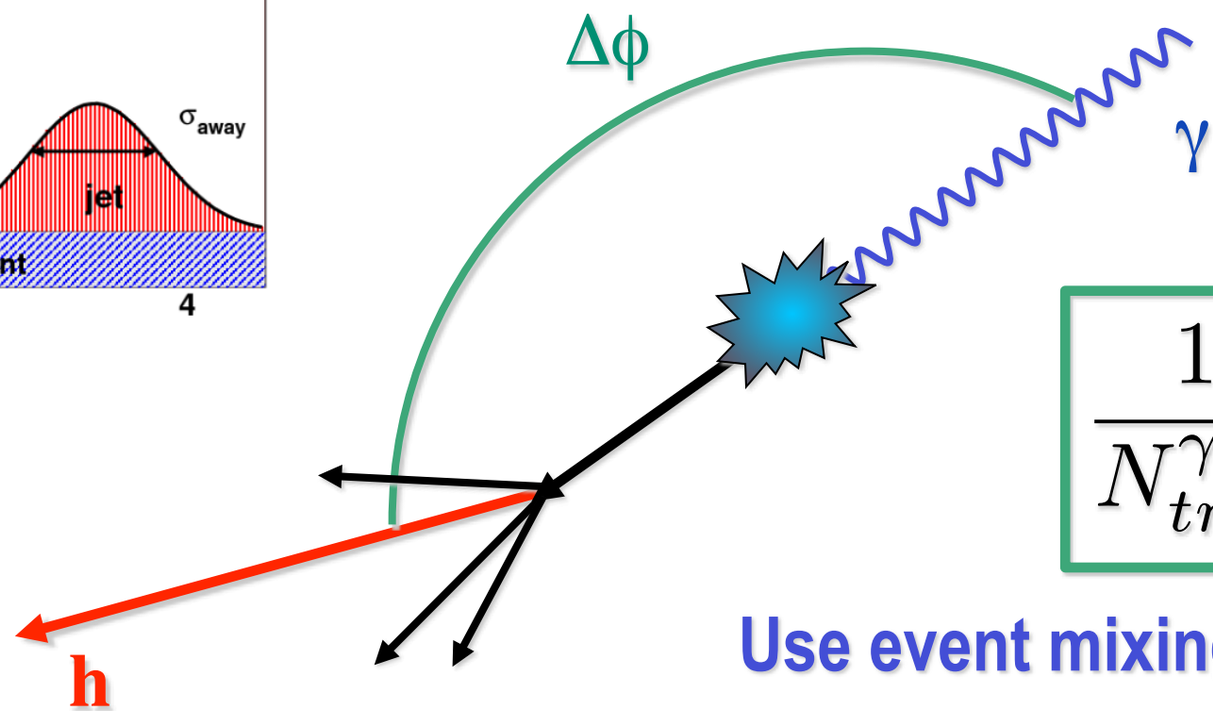


Electromagnetic Calorimeters







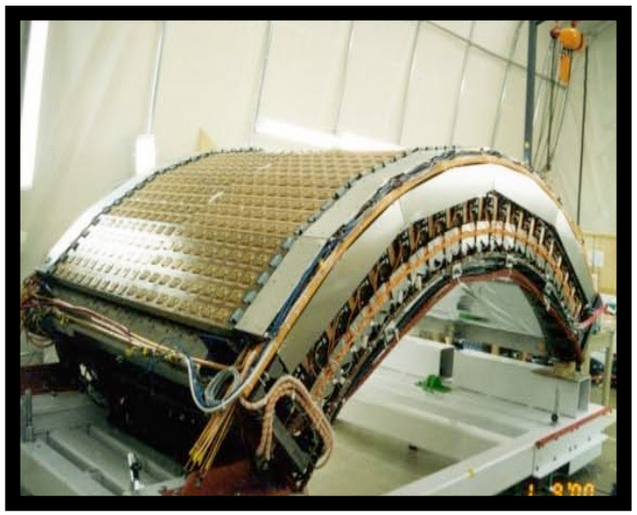


$$\frac{1}{N^{\gamma}_{trig}}\frac{dN^{\gamma-h}}{d\Delta\phi} = Y(\Delta\phi)$$

Use event mixing to correct for acceptance

γ-h correlations in PHENIX

Drift Chamber



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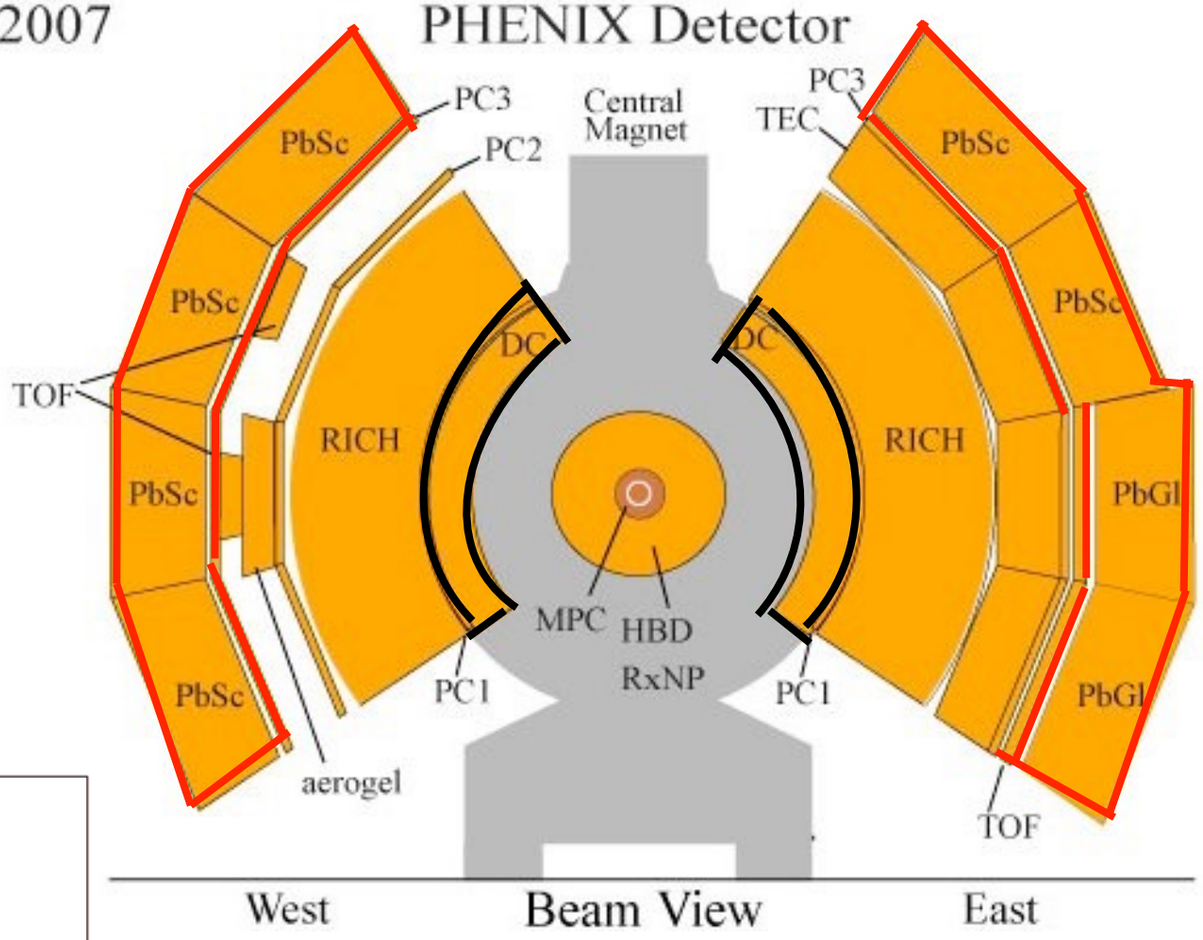

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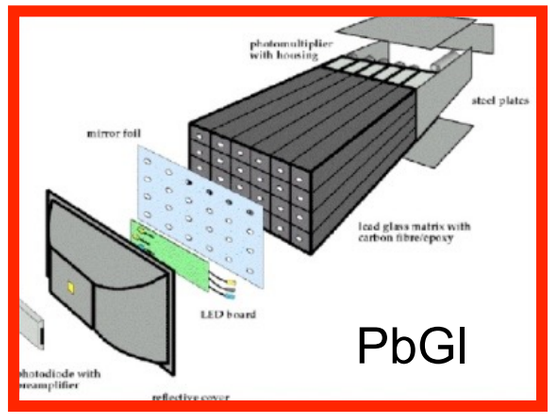
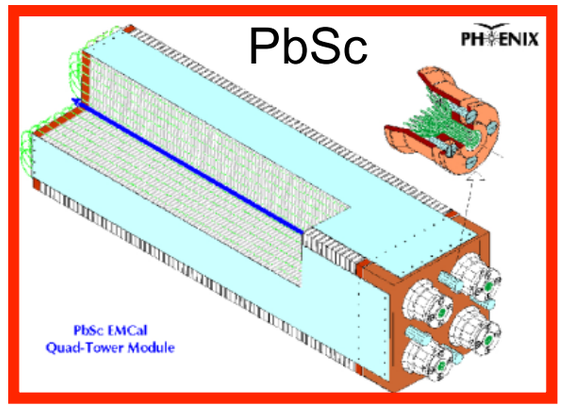
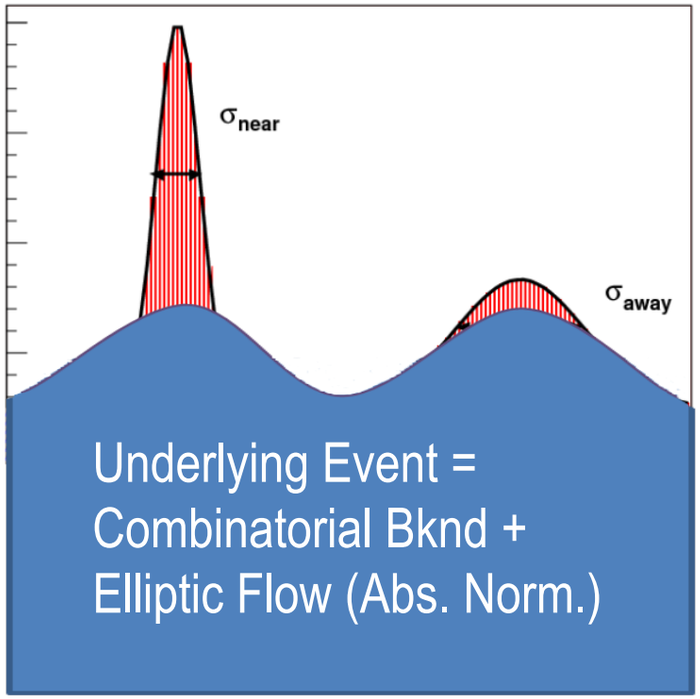
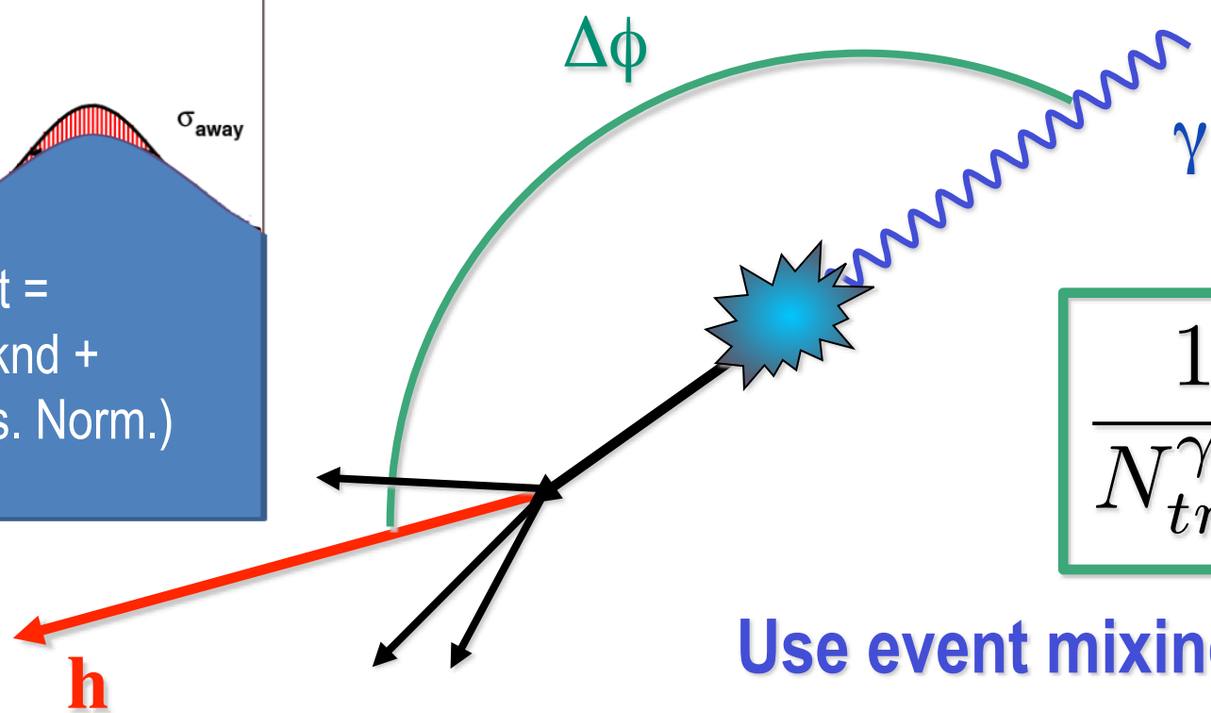








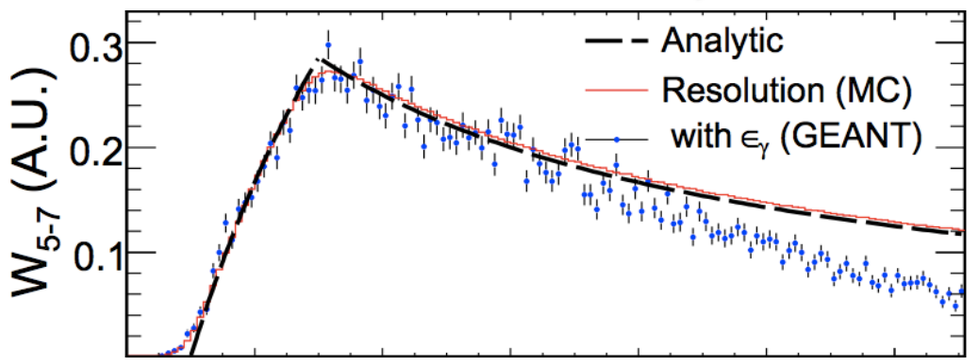
$$\frac{1}{N^{\gamma}_{trig}}\frac{dN^{\gamma-h}}{d\Delta\phi} = Y(\Delta\phi)$$

Use event mixing to correct for acceptance

The γ_{dir}-h signal in p+p

$$Y_{direct} = \frac{R_\gamma Y_{incl} - Y_{decay}}{R_\gamma - 1}$$

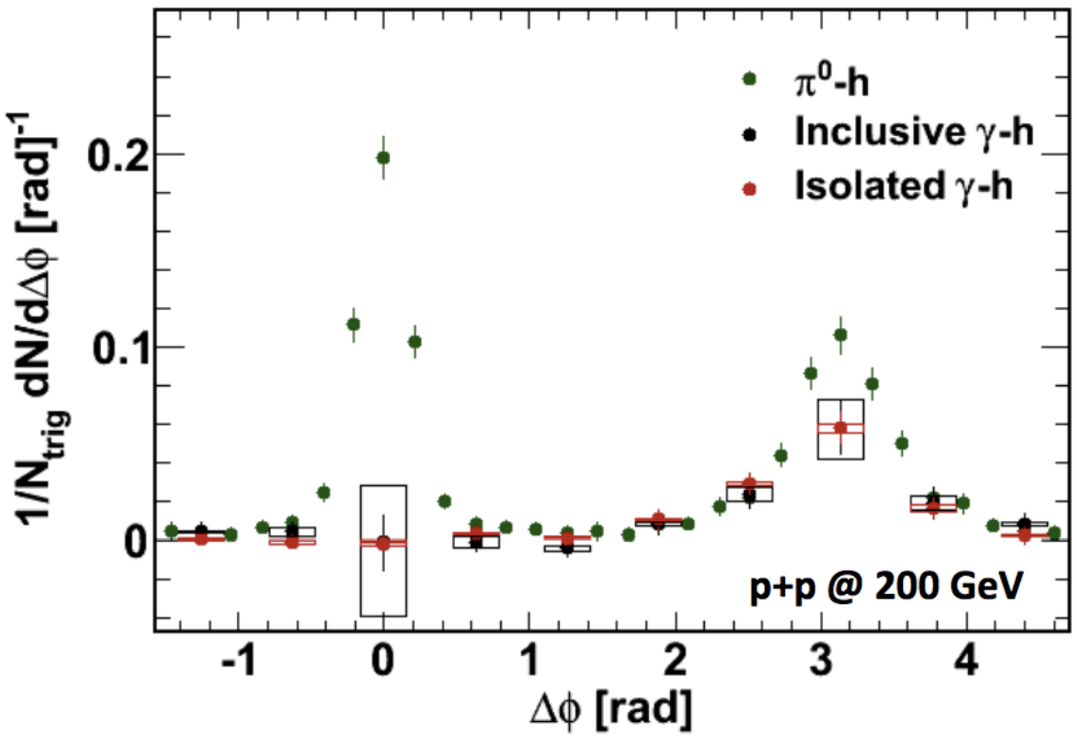
$$Y\pi_0 \rightarrow Y_{decay}$$

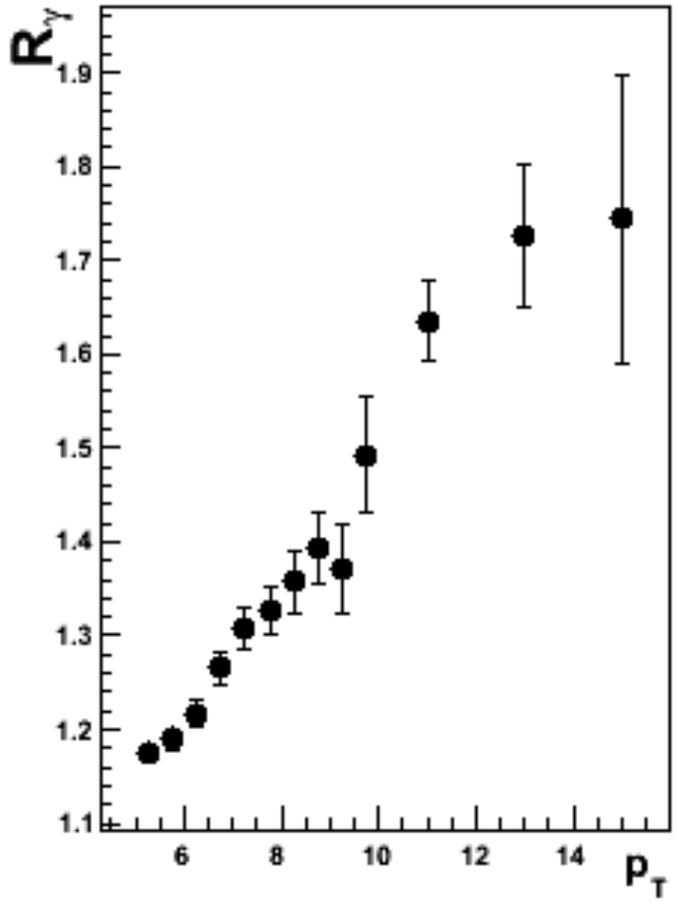


A. Adare et al, Phys. Rev. C 80, 024908 (2009)

- ZYAM subtraction of pedestal for Y_{inc} and Y_{decay}
  - only important for lowest p_T bins
- isolation cut to improve systematic uncertainties

$$R_\gamma = \frac{N_{incl}}{N_{decay}}$$





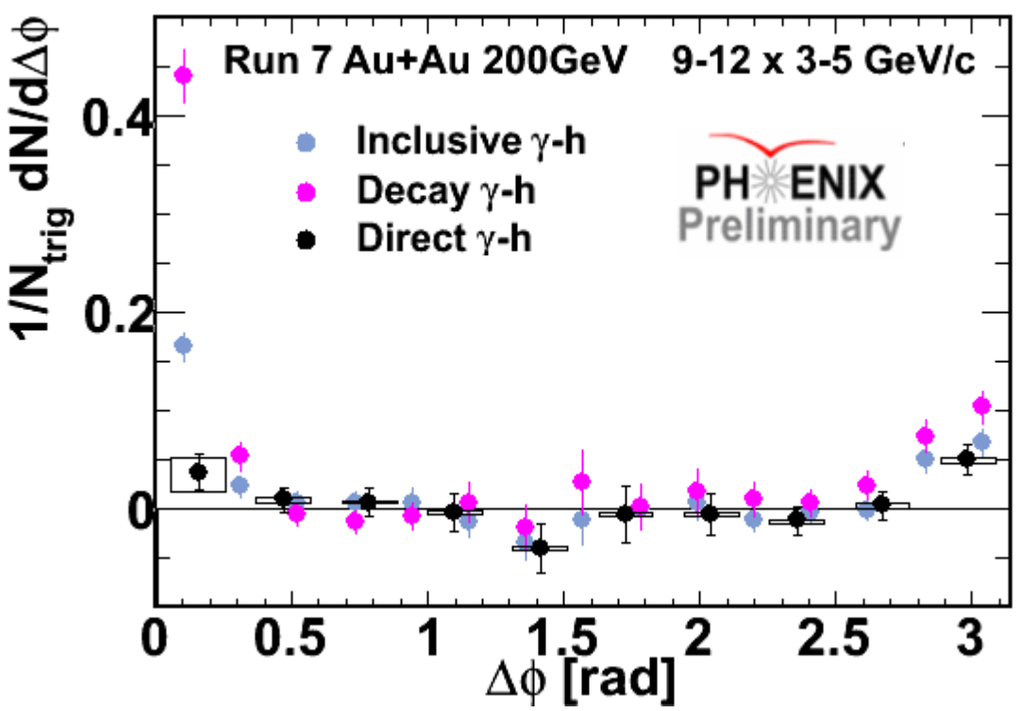
The γ_{dir}-h signal in Au+Au

$$Y_{direct} = \frac{R_\gamma Y_{incl} - Y_{decay}}{R_\gamma - 1}$$

$$Y_x \propto C(\Delta\phi) - \xi(1 + 2\langle v_2^\gamma \rangle \langle v_2^h \rangle \cos 2\Delta\phi)$$

Norm **Bkg(Flow)**

- UE (Abs. Norm.) and flow(v_2) subtracted from Y_{inc} and Y_{decay} separately



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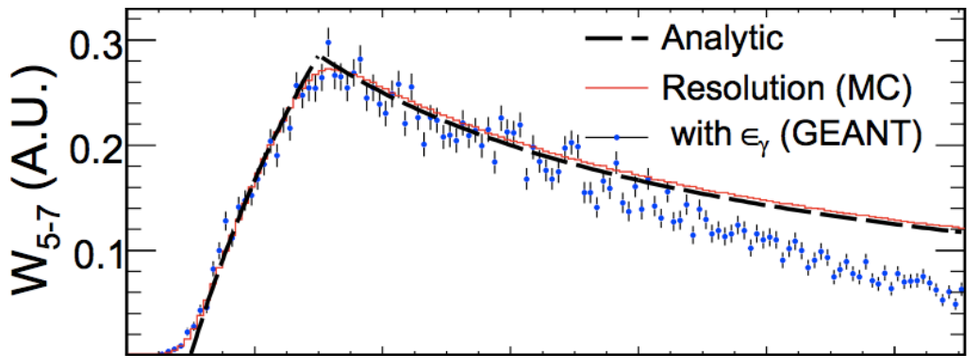

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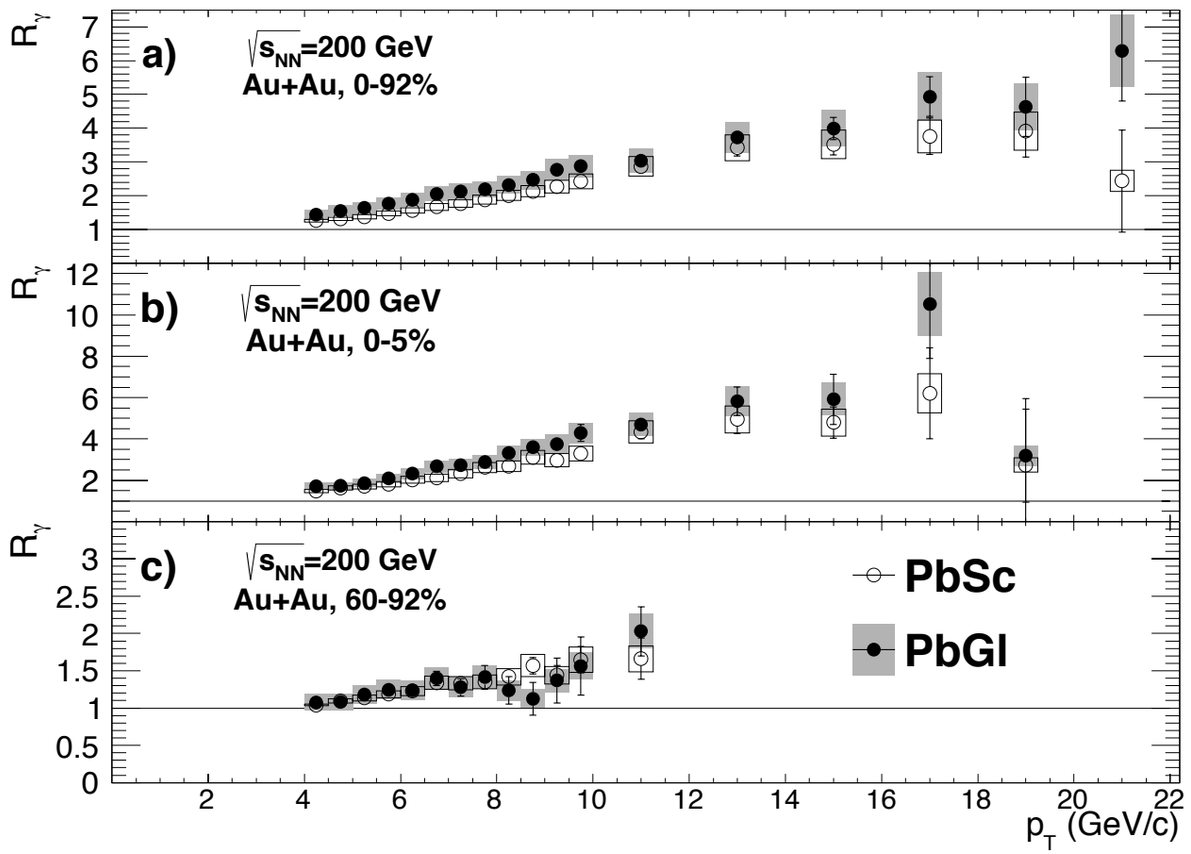
$$R_\gamma = \frac{N_{incl}}{N_{decay}}$$

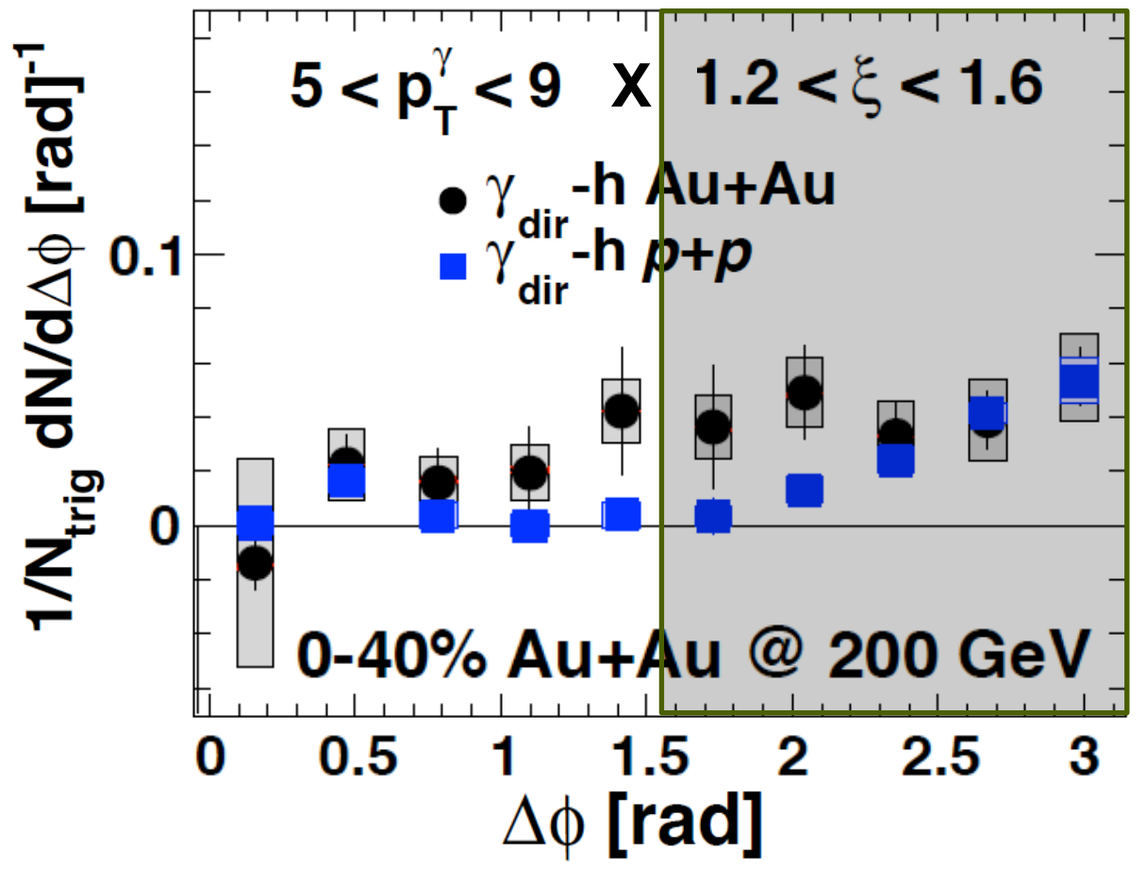


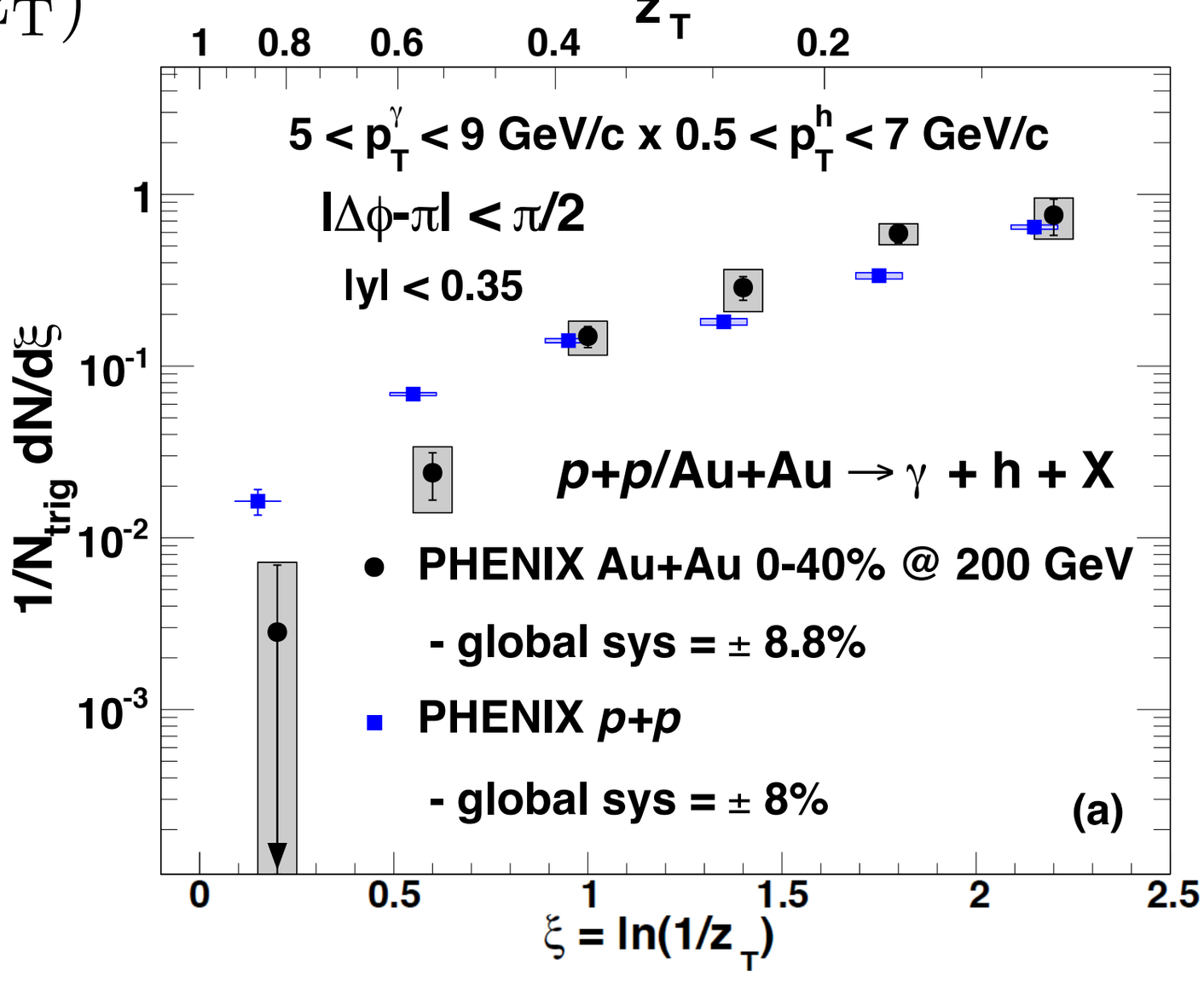
S. Afanaev et al, Phys. Rev. Lett. 109, 152302 (2012)

The effective fragmentation function

$$p_T^{\gamma} \approx p_T^{jet} \qquad z_T = \frac{p_T^h}{p_T^{\gamma}} \qquad \Longrightarrow \qquad D_q(z_T) = \frac{1}{N_{evt}} \frac{dN(z_T)}{dz_T}$$

- measure away-side yield to get effective fragmentation function
- focus on low $z_T \rightarrow \xi = \ln(1/z_T)$

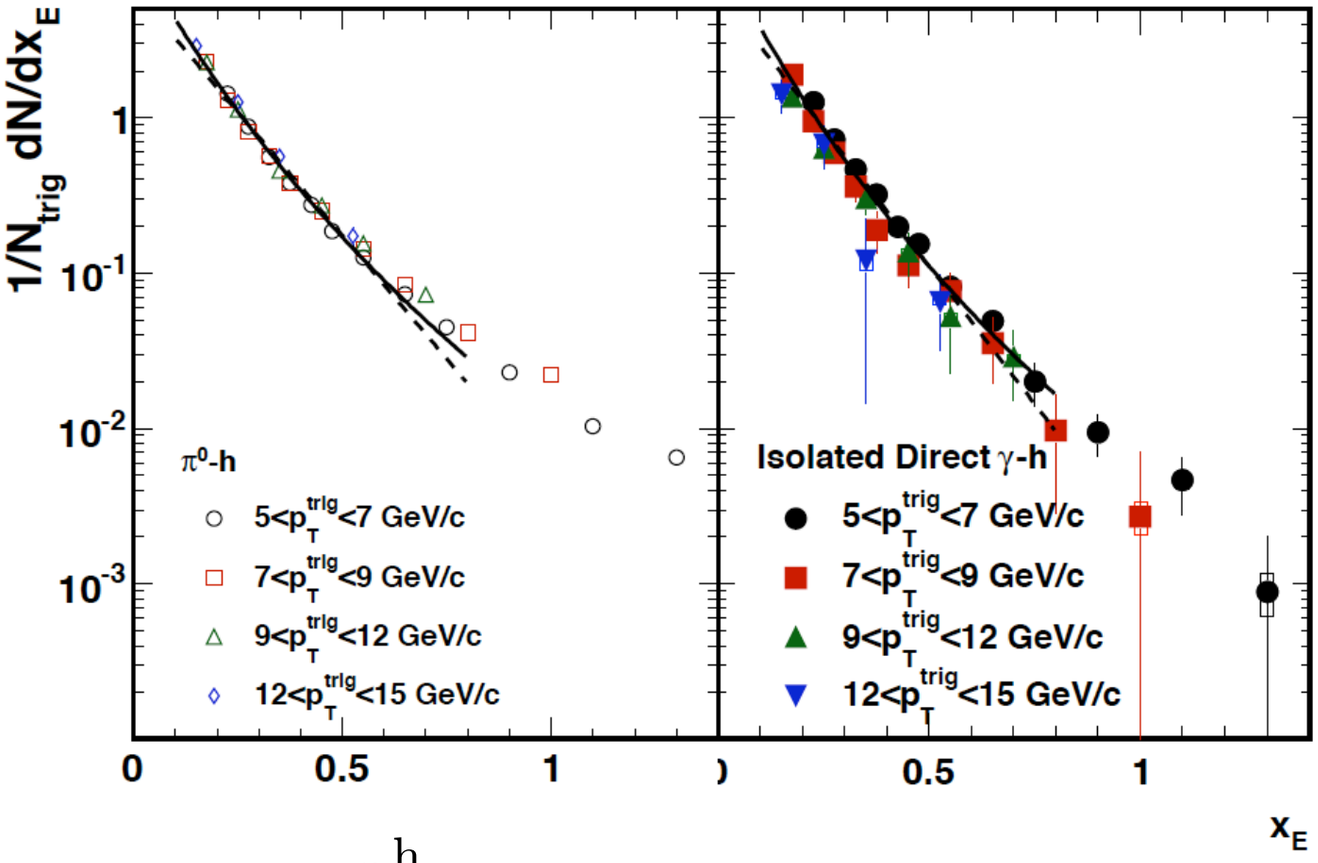


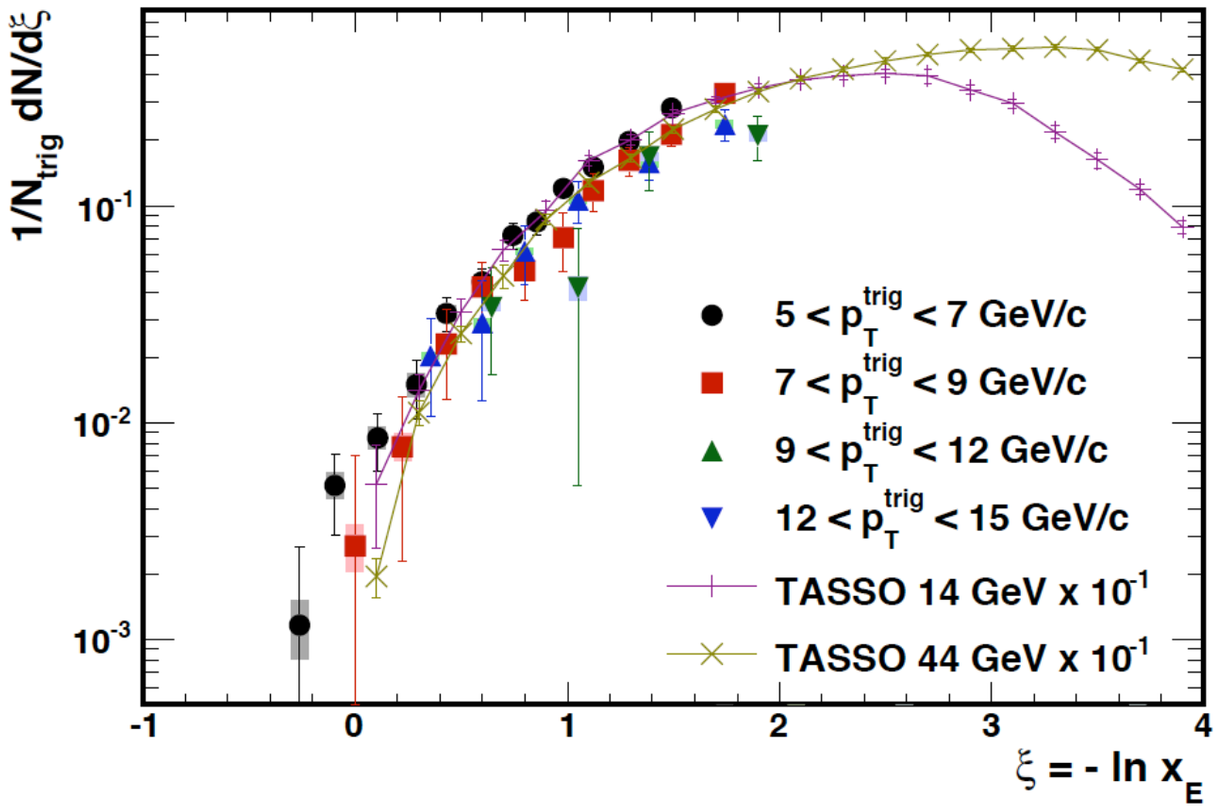


arXiv:1212.3323

Establishing the p+p baseline

A. Adare et al, Phys. Rev. D 82, 072001 (2010)



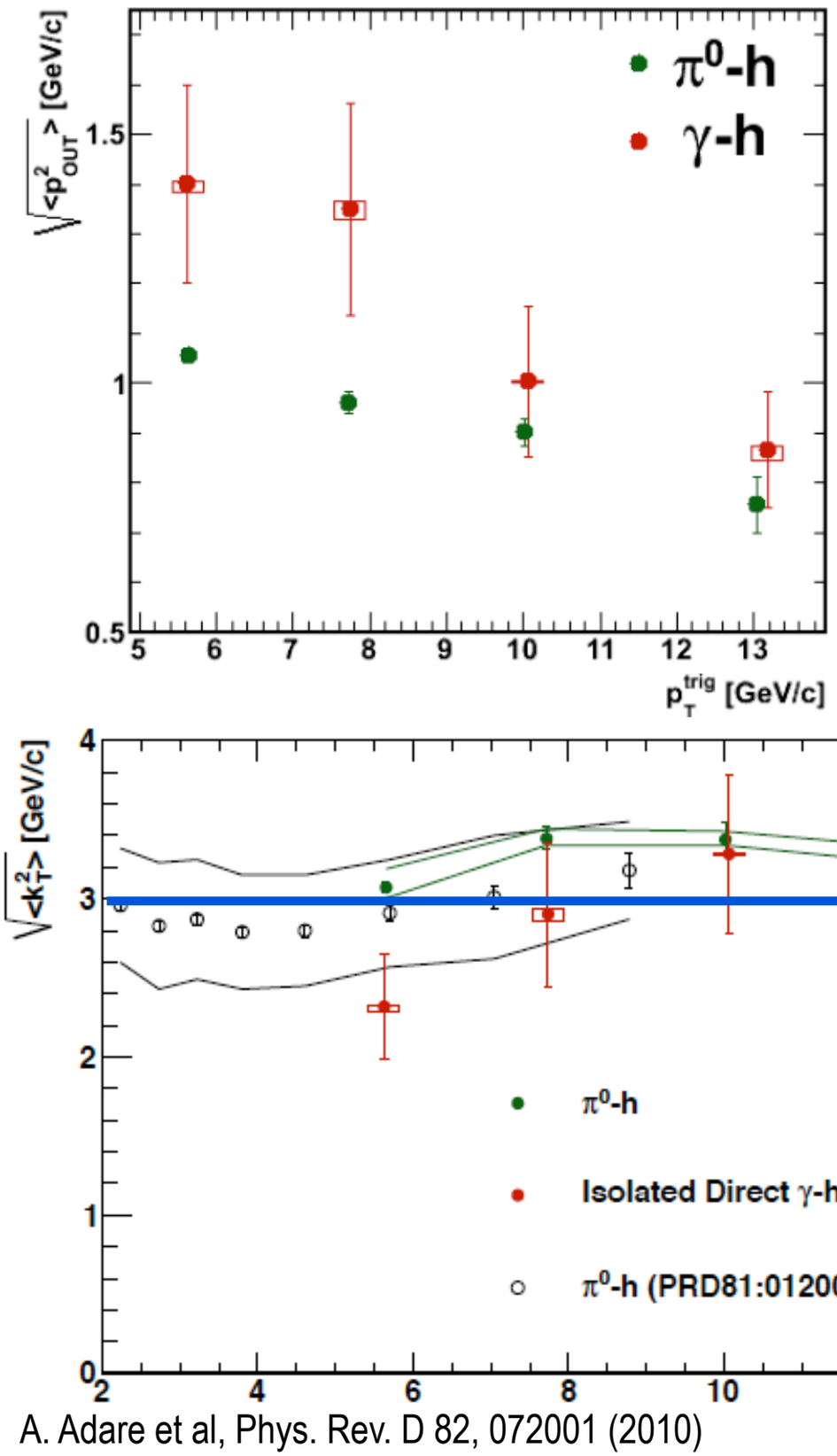


$$x_E = -\frac{p_T^h}{p_T^\gamma}\cos(\Delta\phi) \sim z_T$$

$$\frac{dN}{dx_E} = Ne^{-bx_E}$$

- approximate universal scaling
- b = 8.2 ± 0.3 → consistent with quark fragmentation
- good agreement with TASO measurement (e^+e^-)

How approximate is $p_{T,\gamma} \sim p_{T,q\text{-jet}}$



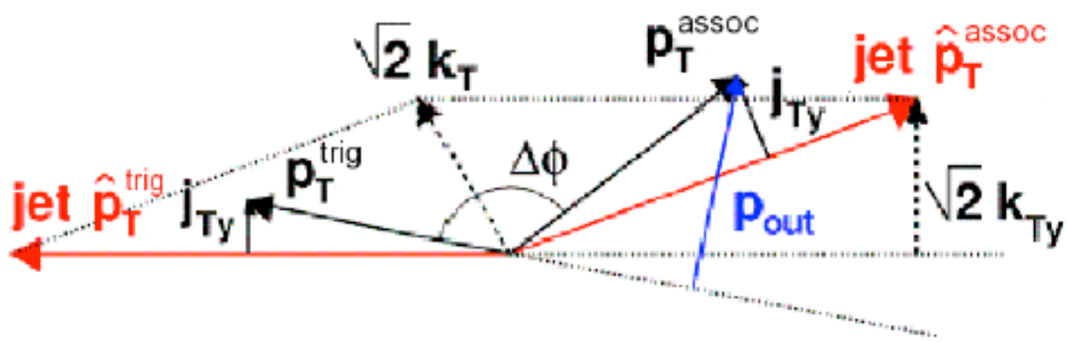
A. Adare et al, Phys. Rev. D 82, 072001 (2010)

- obtain p_{out} from $C(\Delta\phi)$
- extract k_T using LO+k_T smearing model
- consistent with other jet measurements
- no significant variation in k_T observed

(Adler et al, Phys.Rev.C73:054903,2006)

$$|p_{\rm out}| = |p_{\rm T}^{\rm assoc}|\sin\Delta\phi$$

$$|p_{\rm out}|^2 = x_{\rm E}^2[2\langle|k_{Ty}|\rangle^2 + \langle|j_{Ty}|\rangle^2] + \langle j_{Ty}\rangle^2$$



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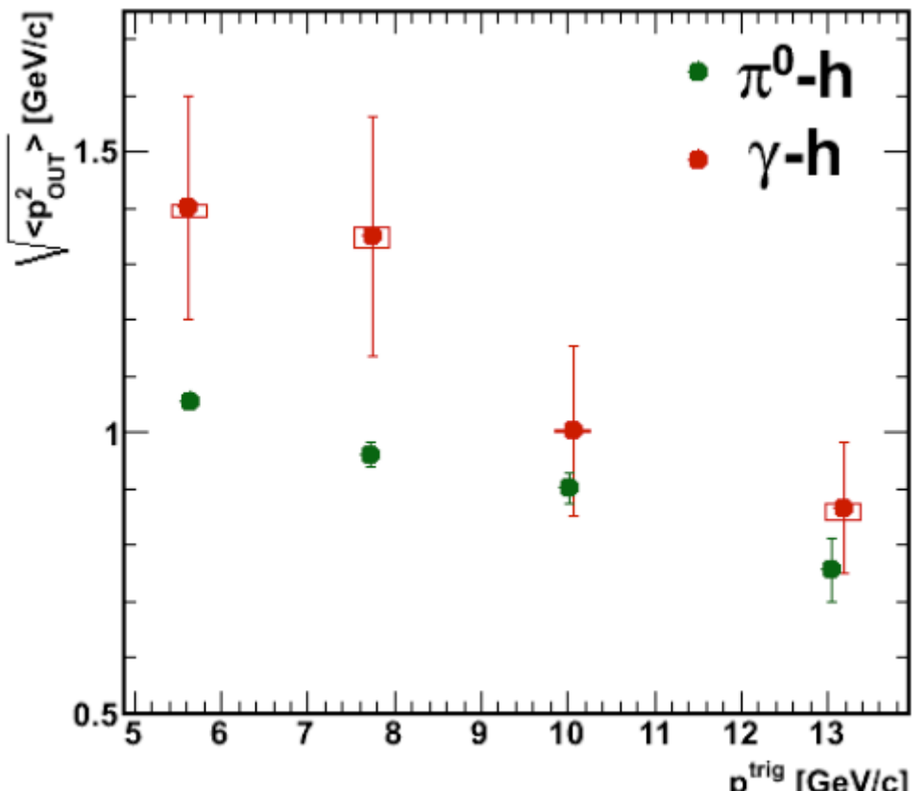

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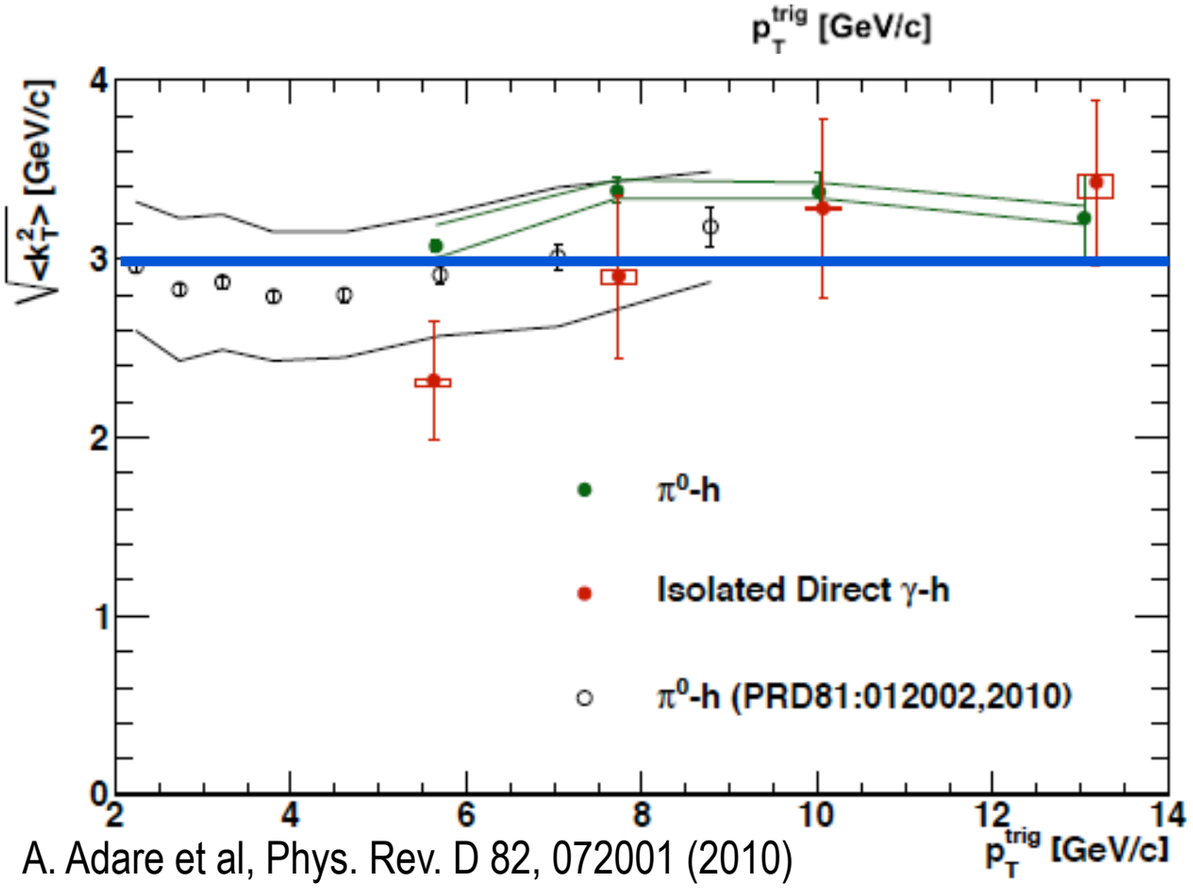

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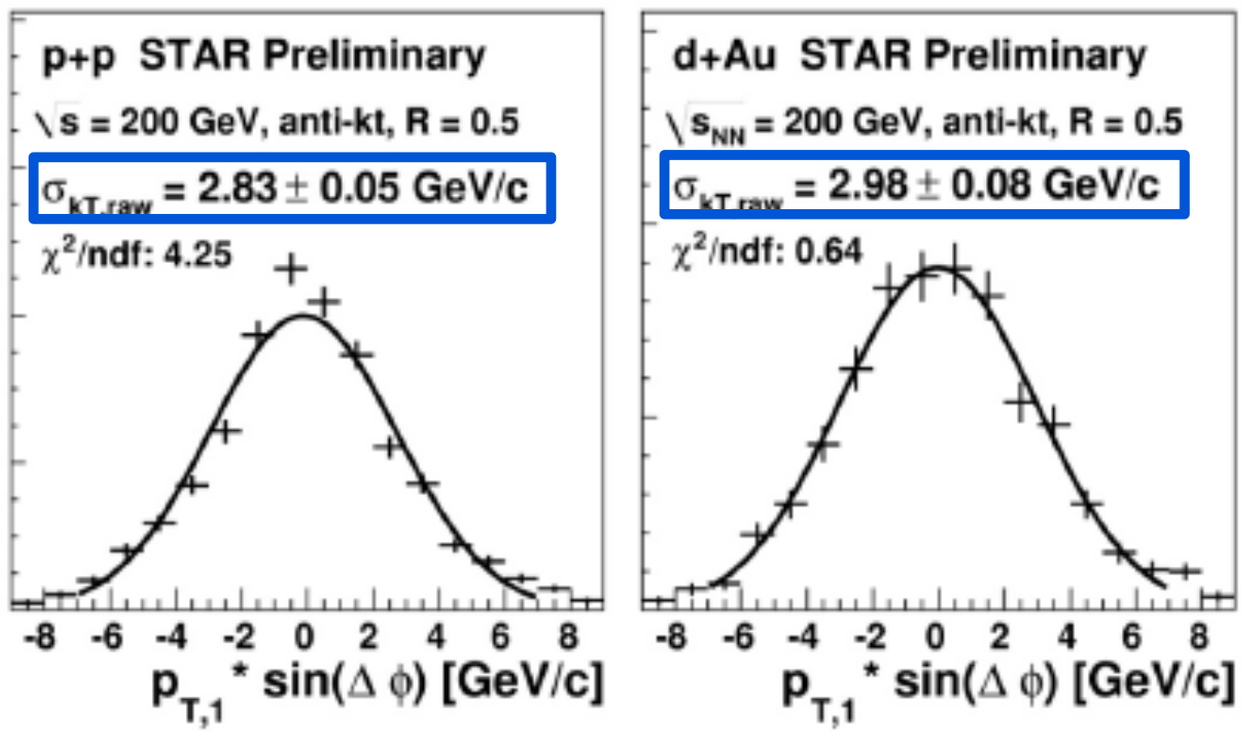
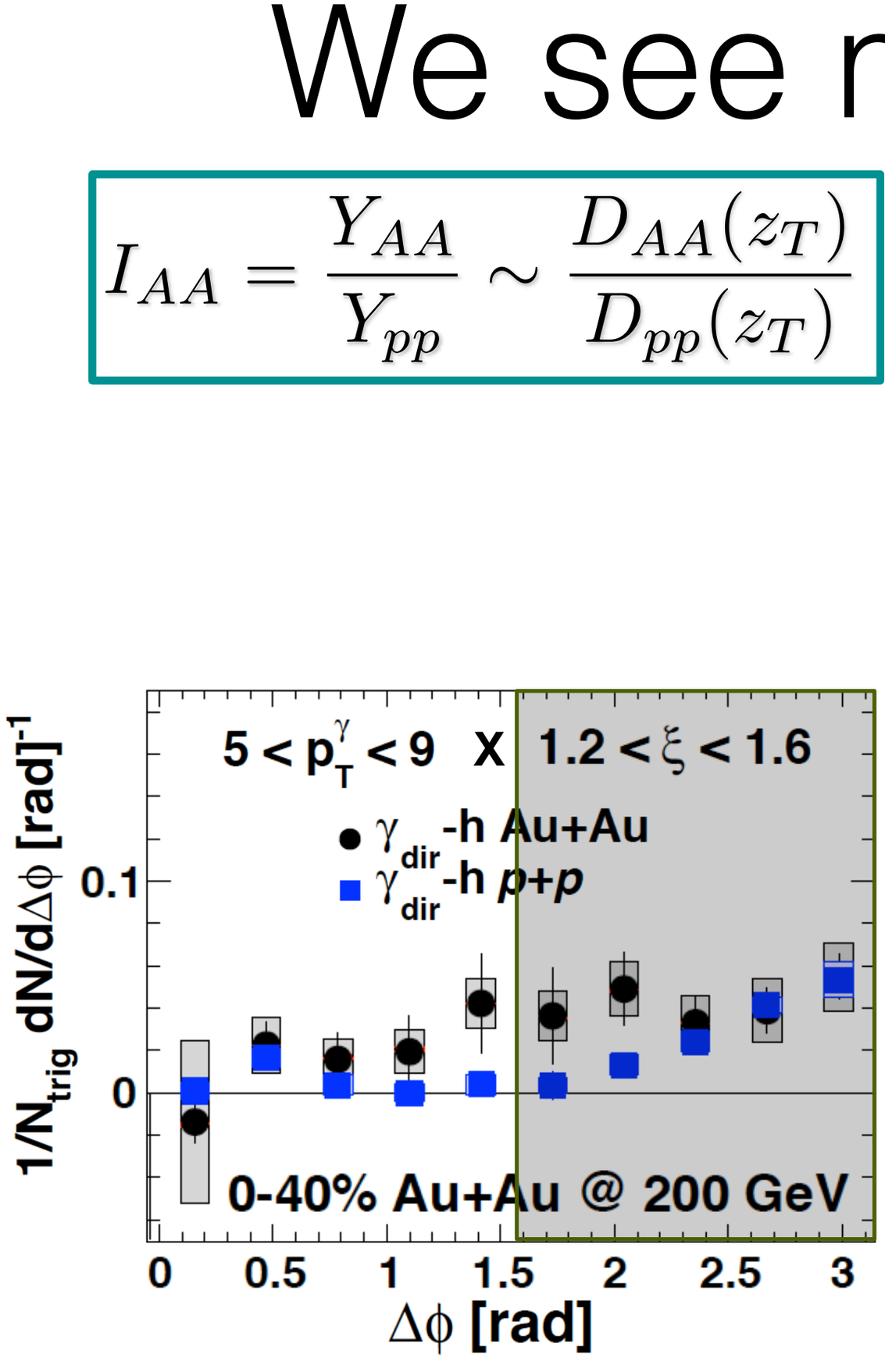
p_T(jet): 10-20 GeV/c

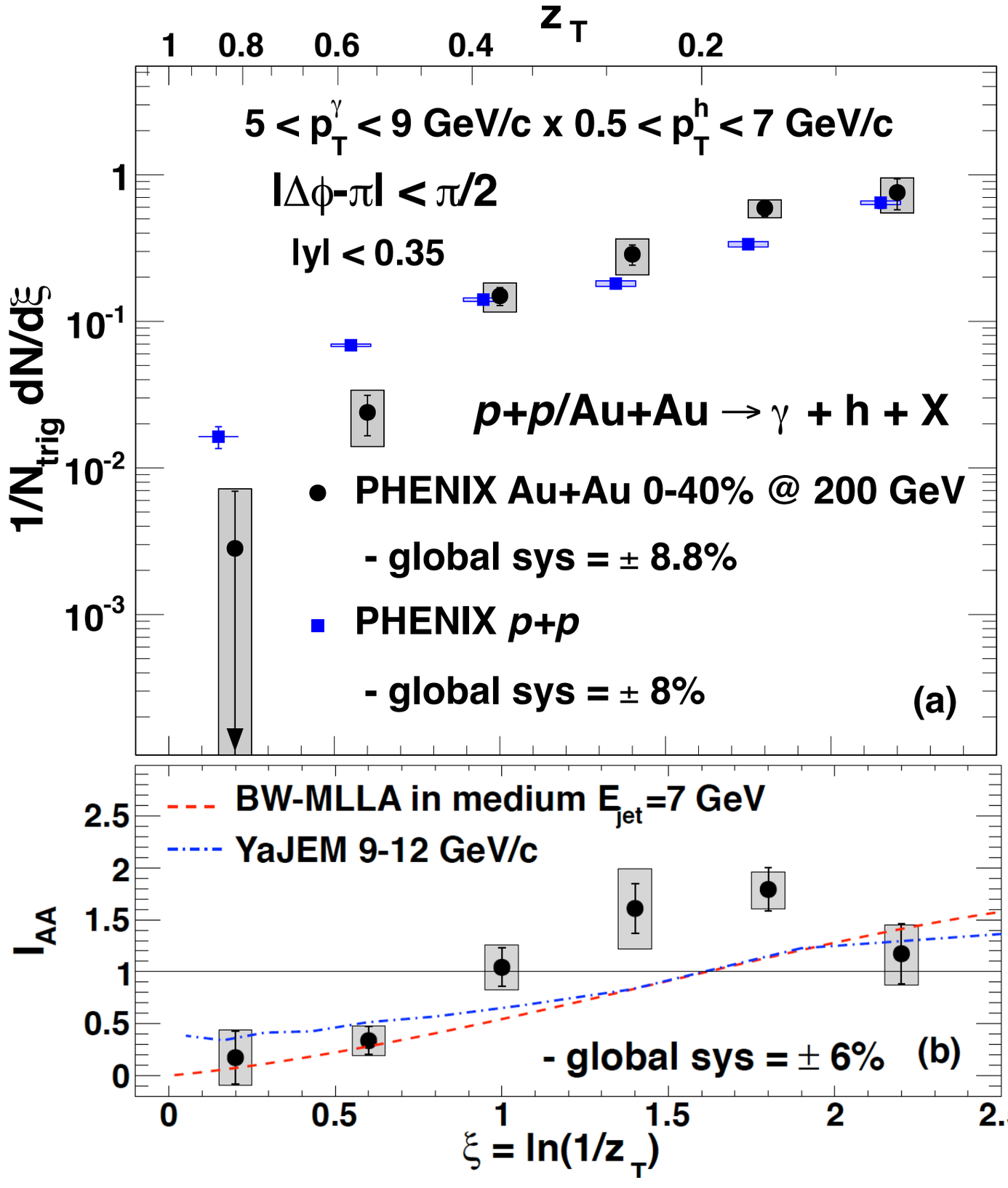


J.Kapitan (STAR),arXiv:1012.1804

We see modification!

$$I_{AA} = \frac{Y_{AA}}{Y_{pp}} \sim \frac{D_{AA}(z_T)}{D_{pp}(z_T)}$$





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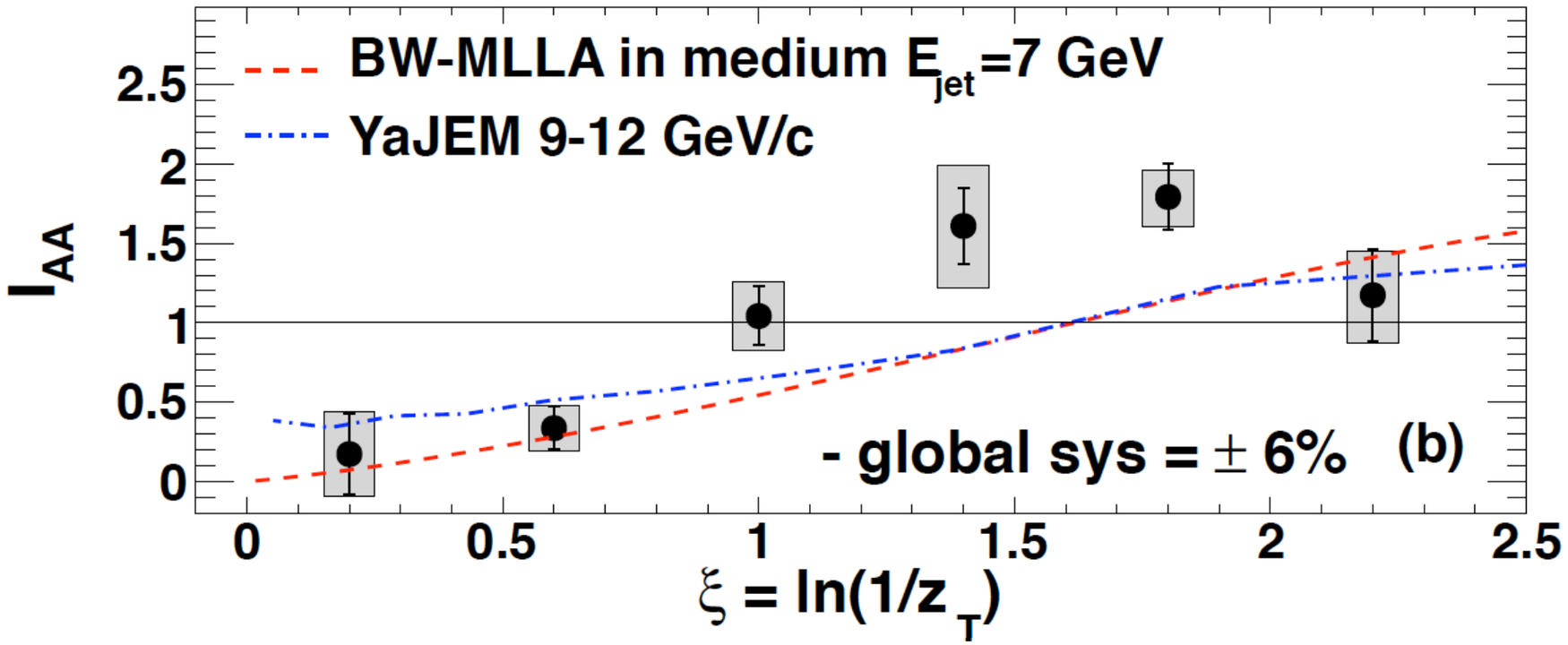
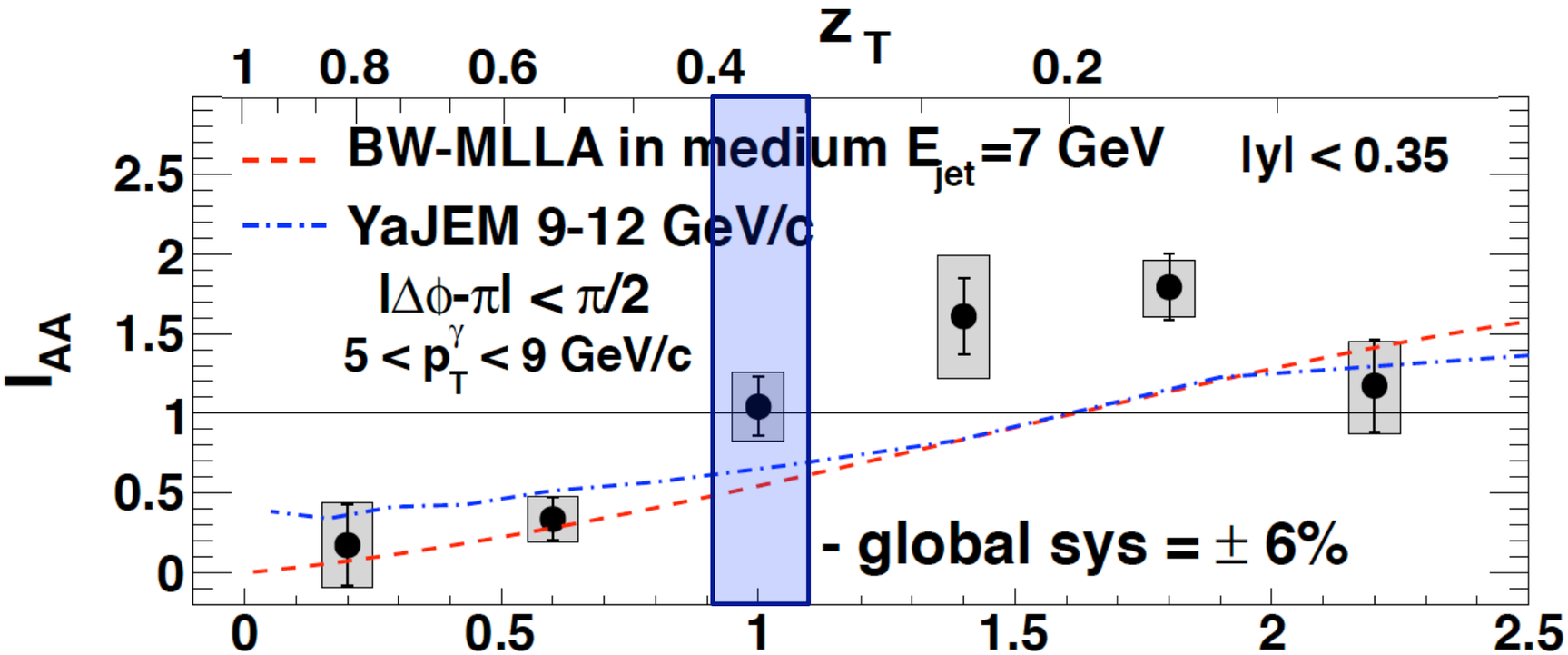
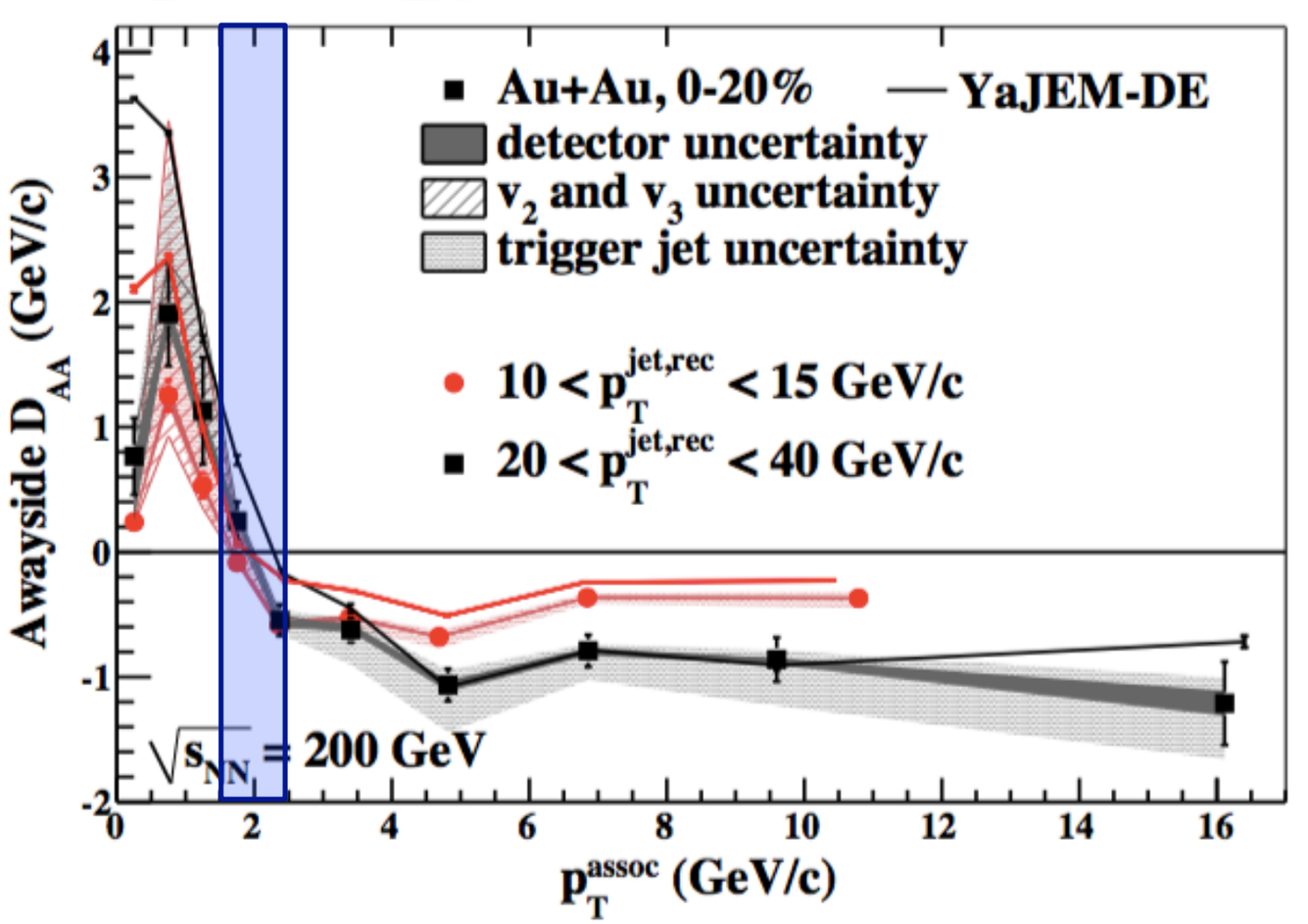


- See modification to effective fragmentation function (shape)
- Qualitative agreement with expectations from models that track the redistribution of energy from leading parton to soft particle production

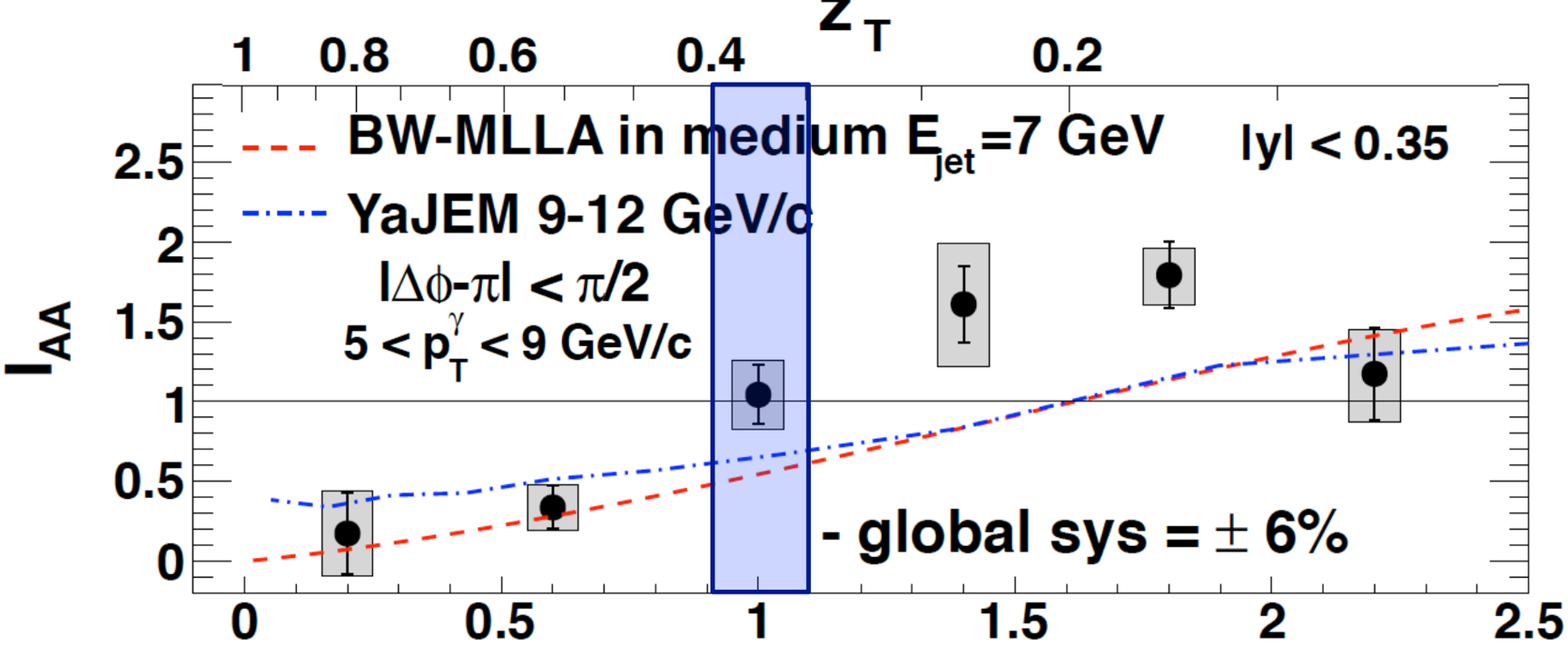
Comparison to other RHIC results



- Transition from suppression to enhancement at $p_{T,assoc}$ ~ 2 GeV/c

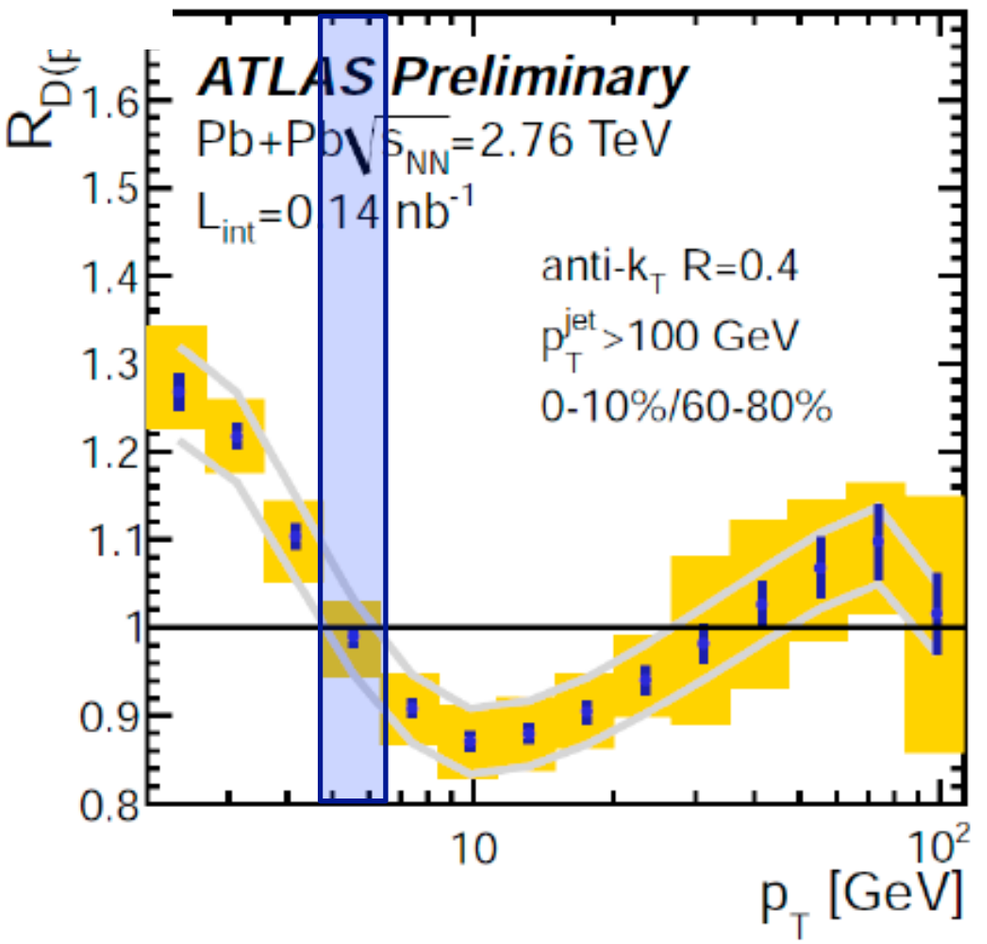


Comparison to other LHC results



- Transition from suppression to enhancement
  - ~ 2 GeV/c at RHIC
  - ~ 3-5 GeV/c at LHC

What determines the constituent p_T at which enhancement appears?



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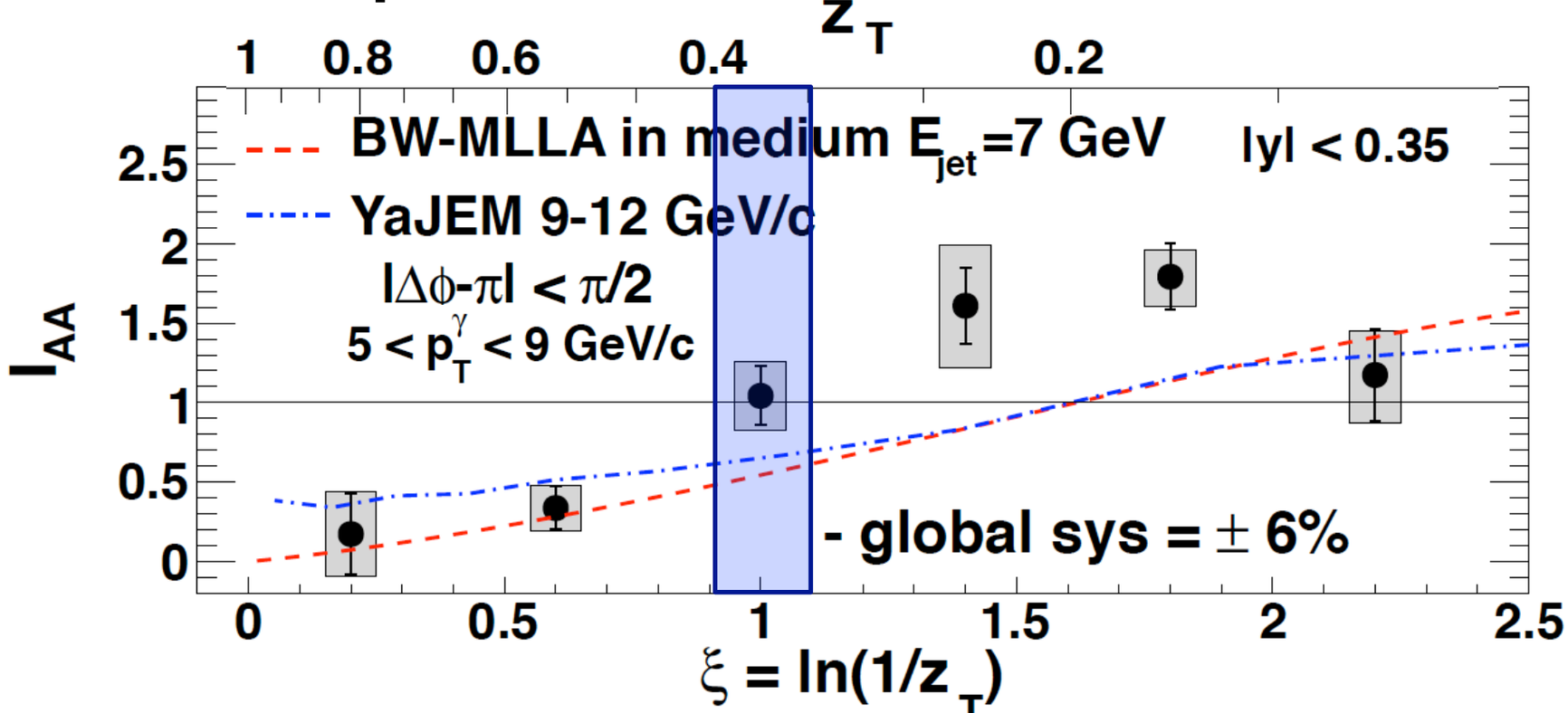

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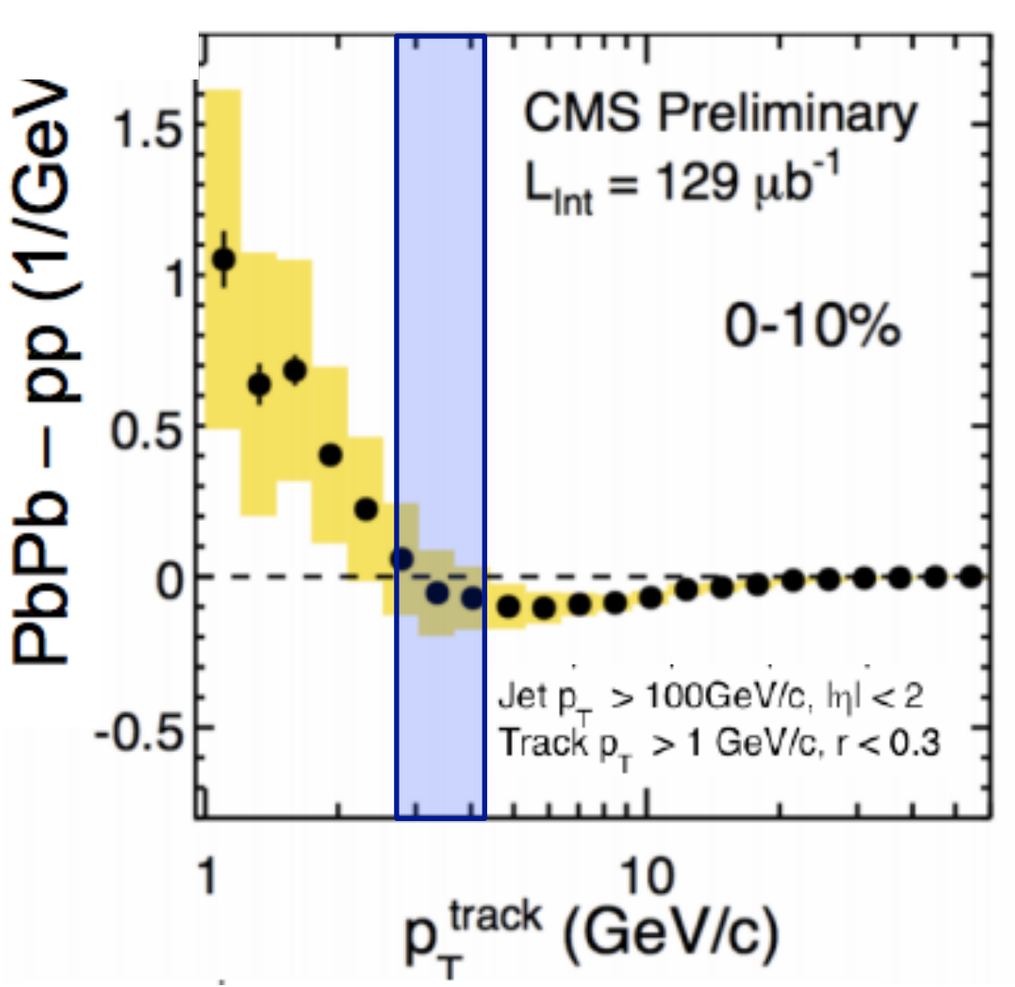
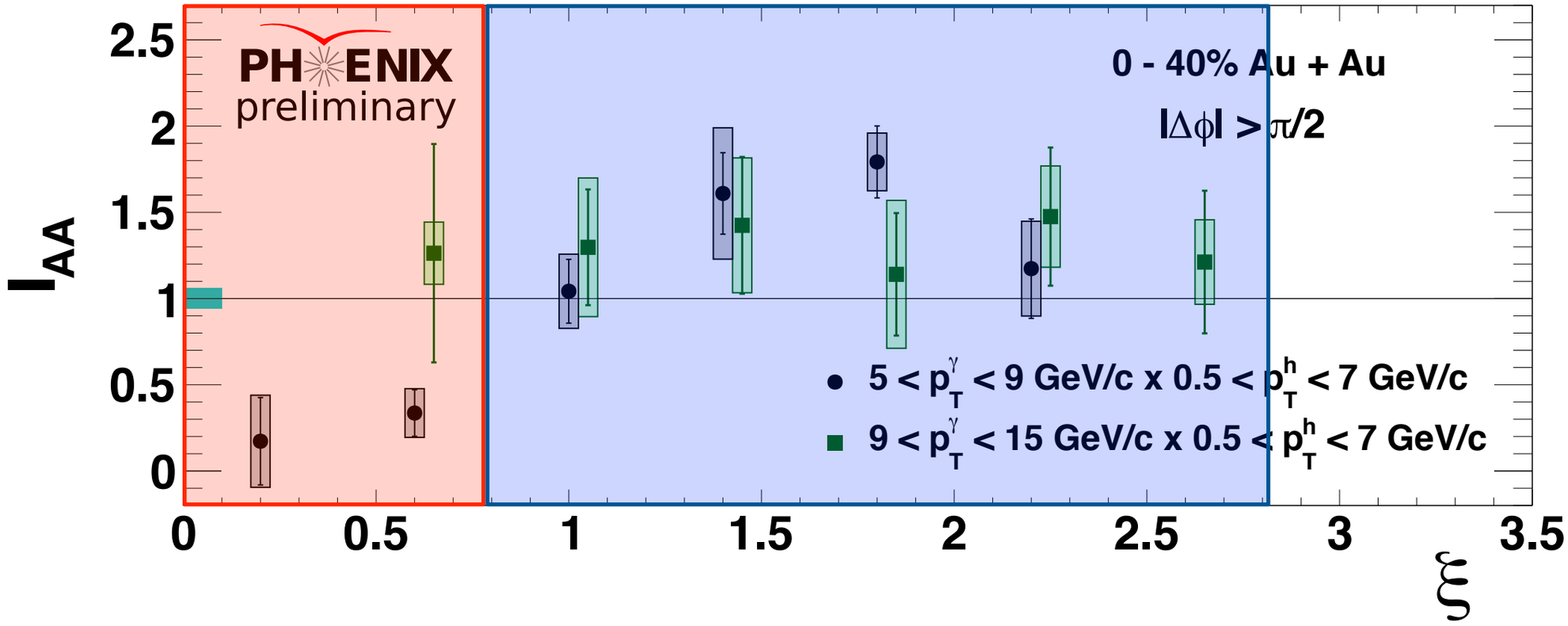
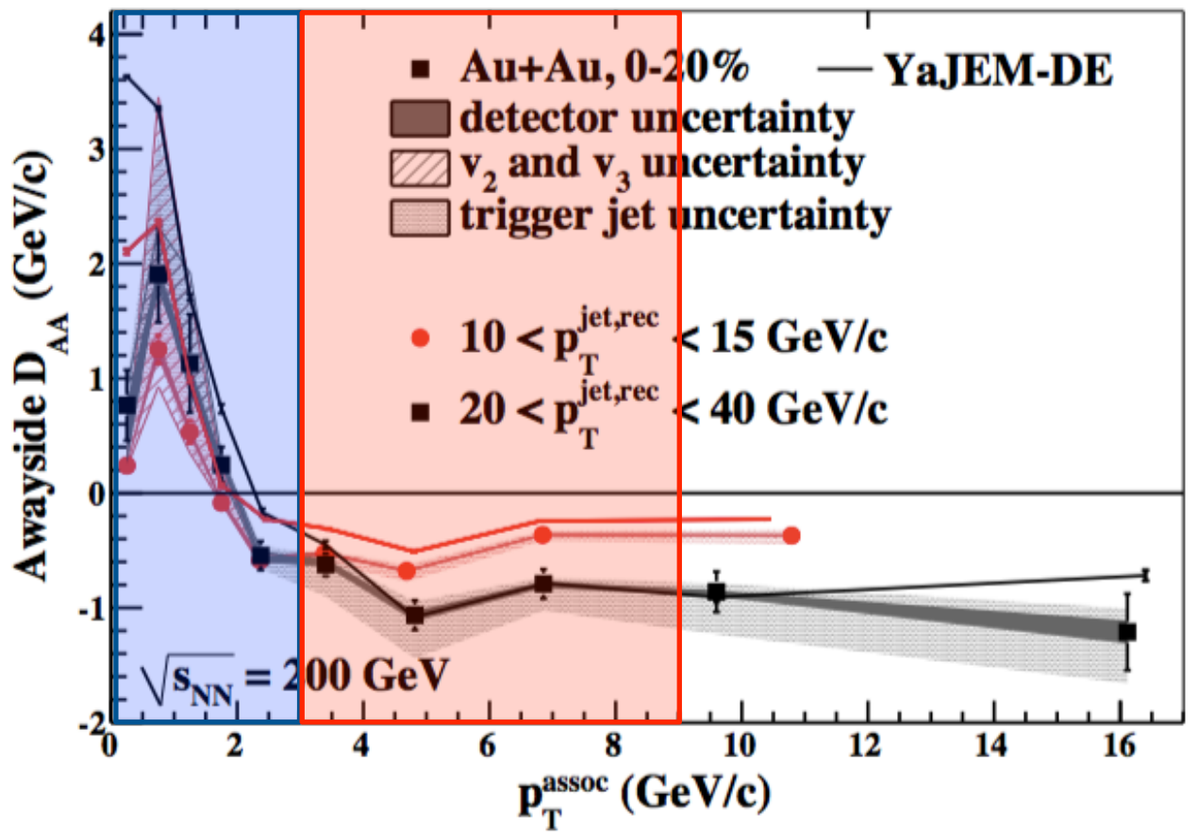


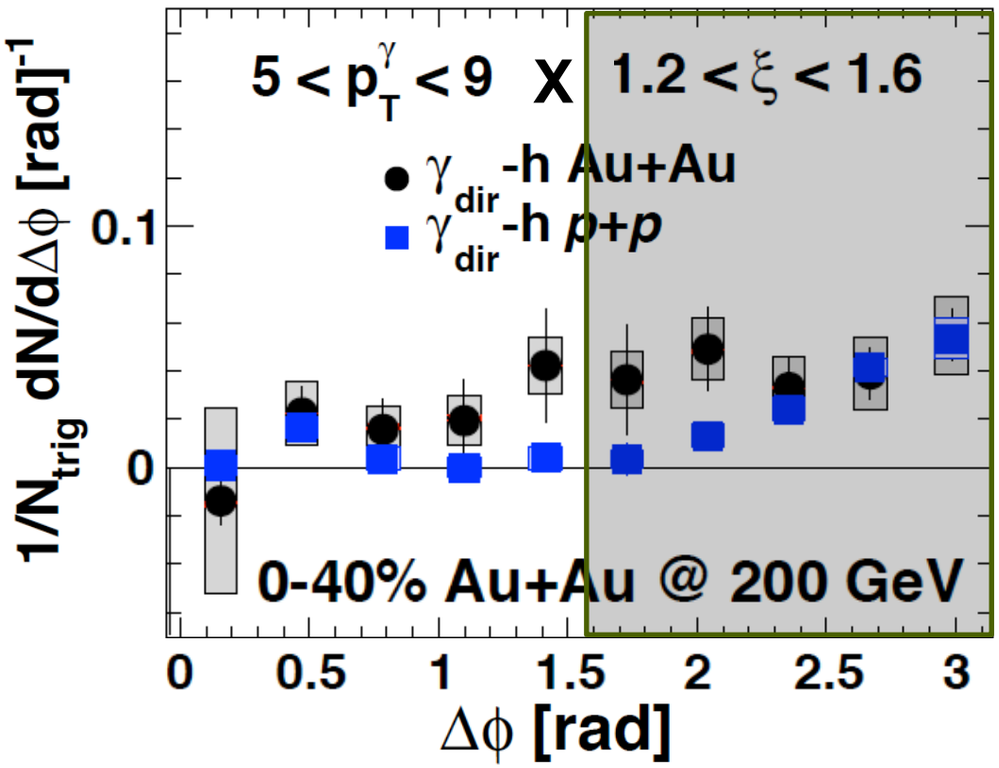
A look at trigger p_T dependence

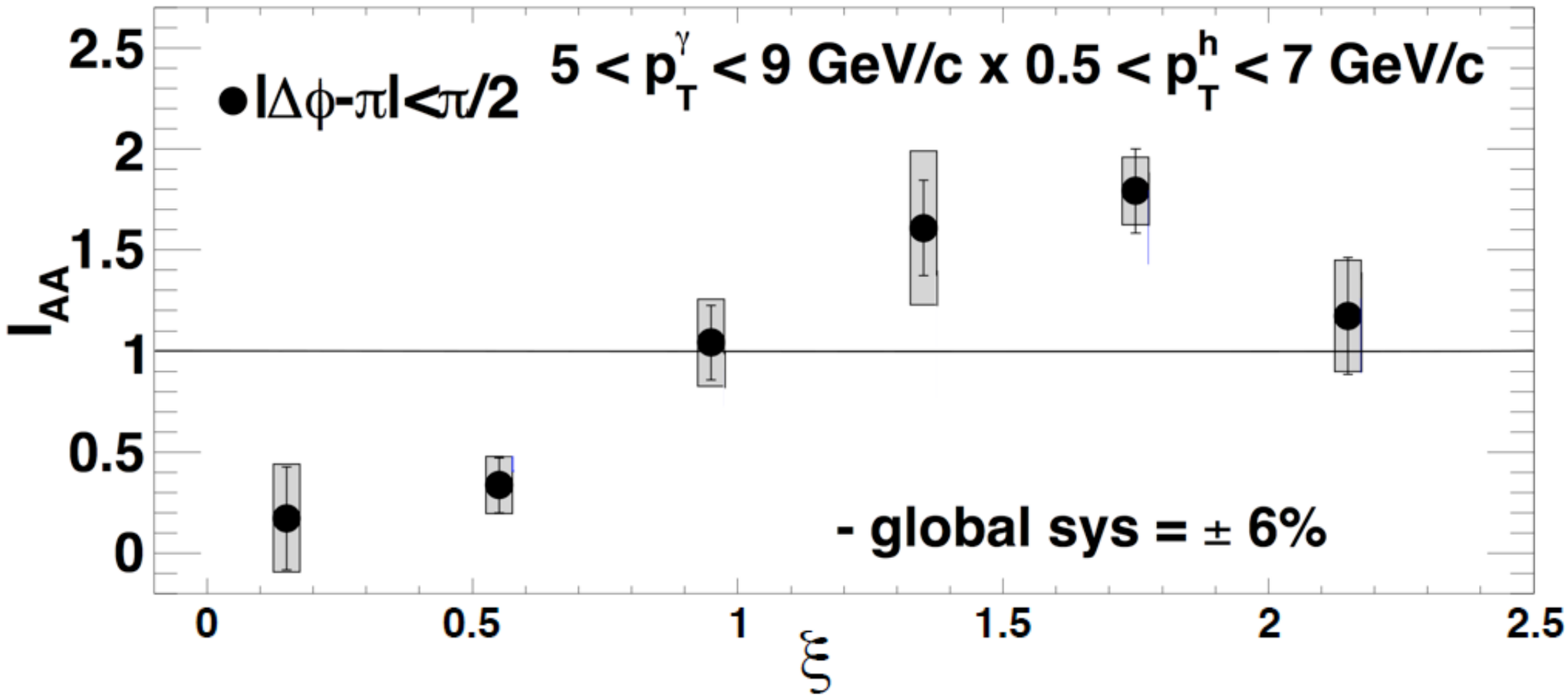


- **Low $p_{T,assoc}$:** lack of jet p_T dependence would show up as a shift in ξ
- **High $p_{T,assoc}$:** different path-length dependence → may see different effect



Do we see away-side broadening?





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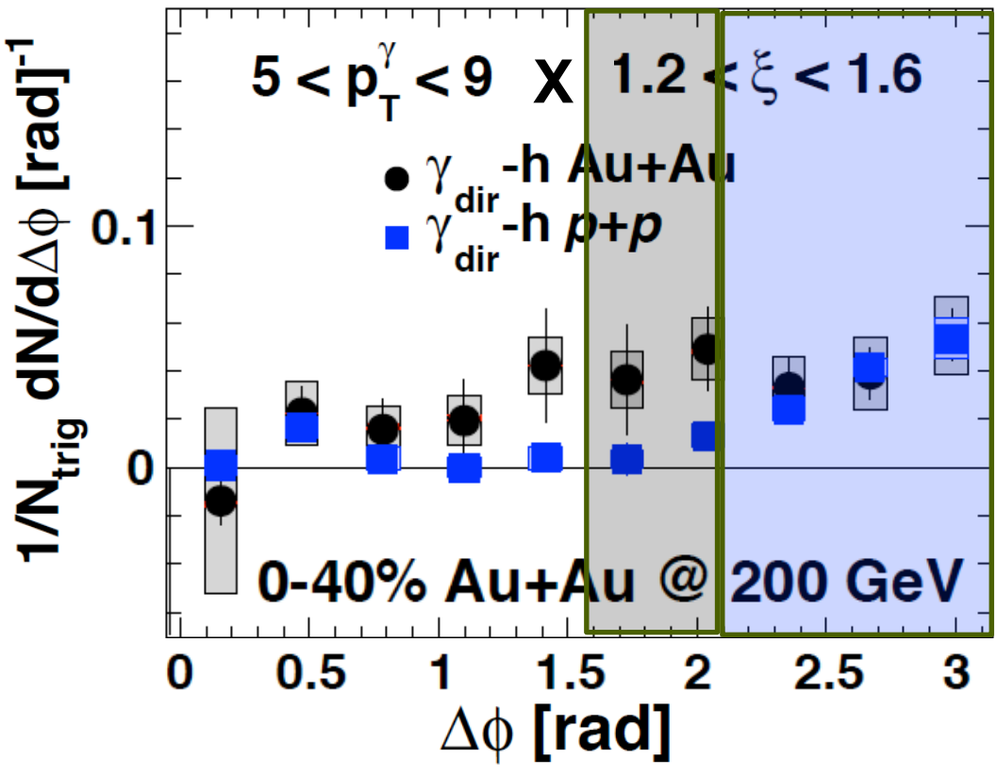
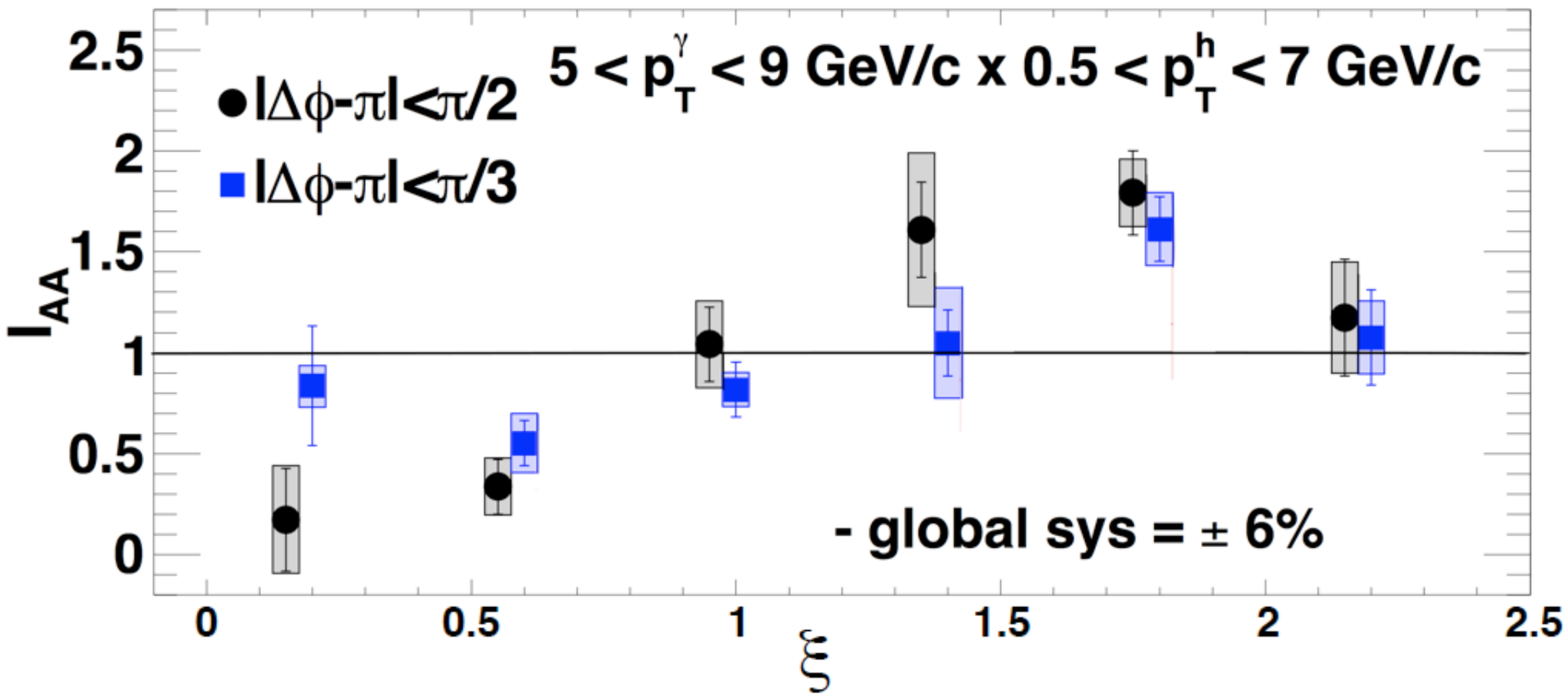
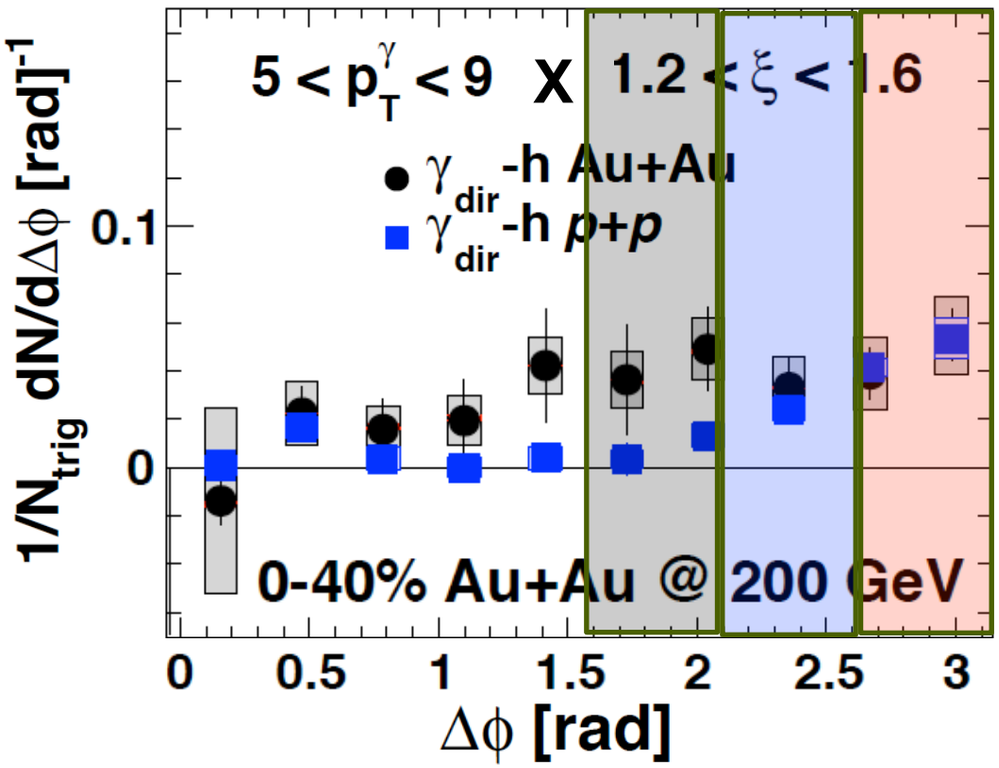
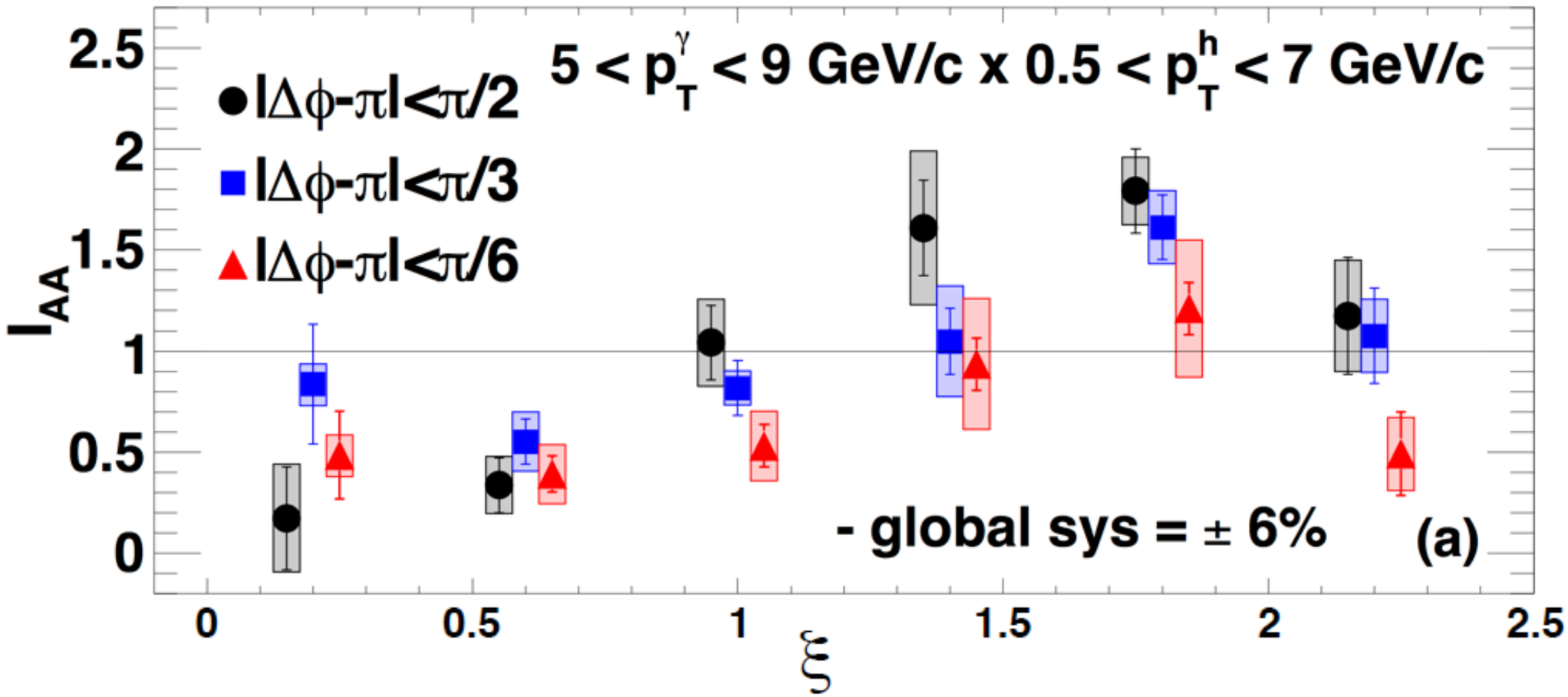




Do we see away-side broadening?





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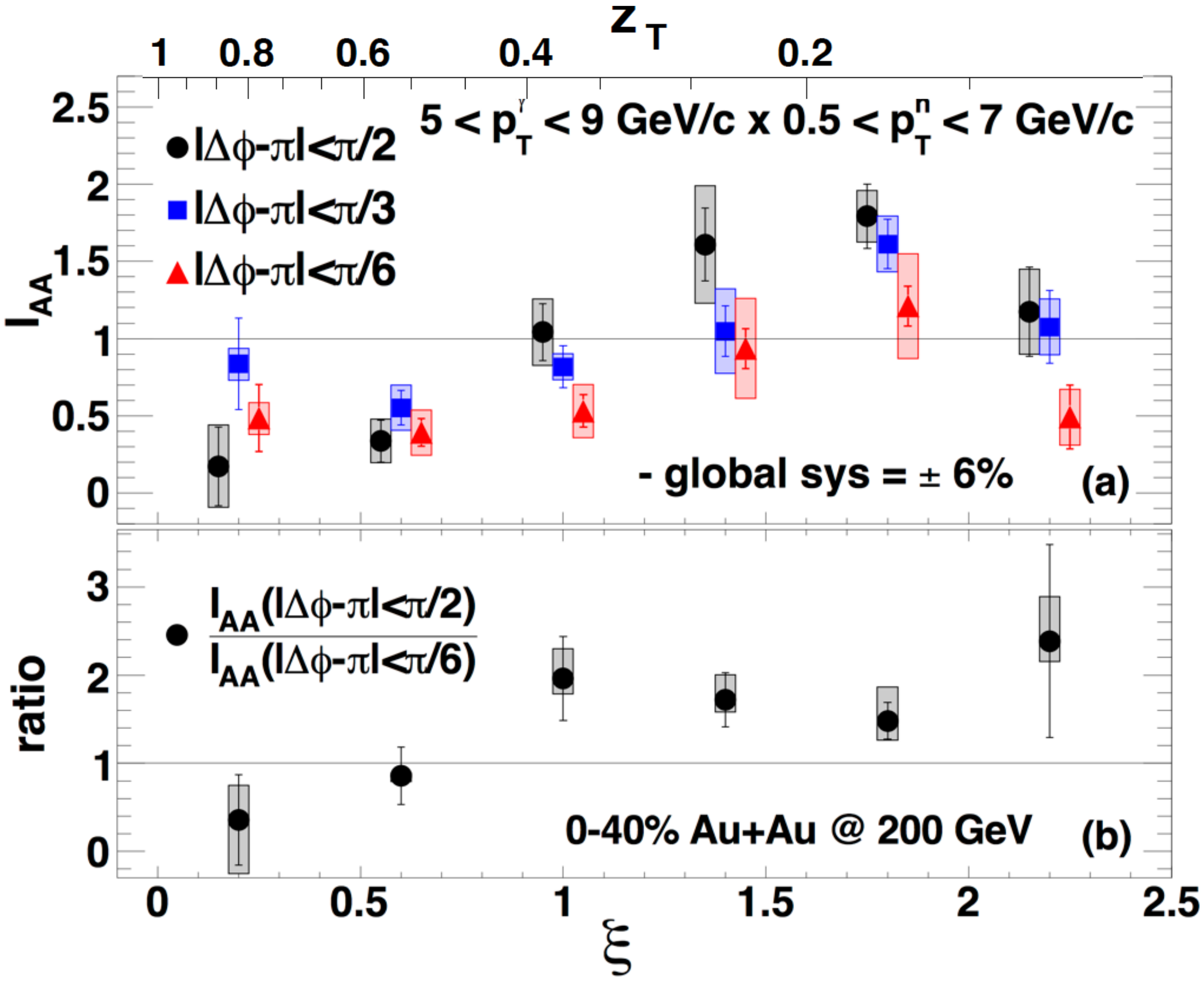
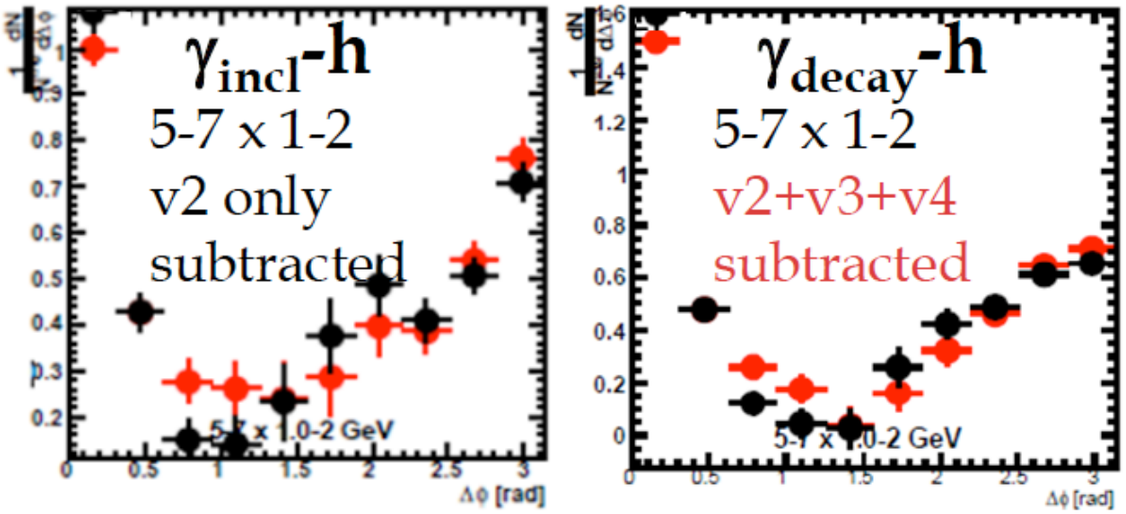
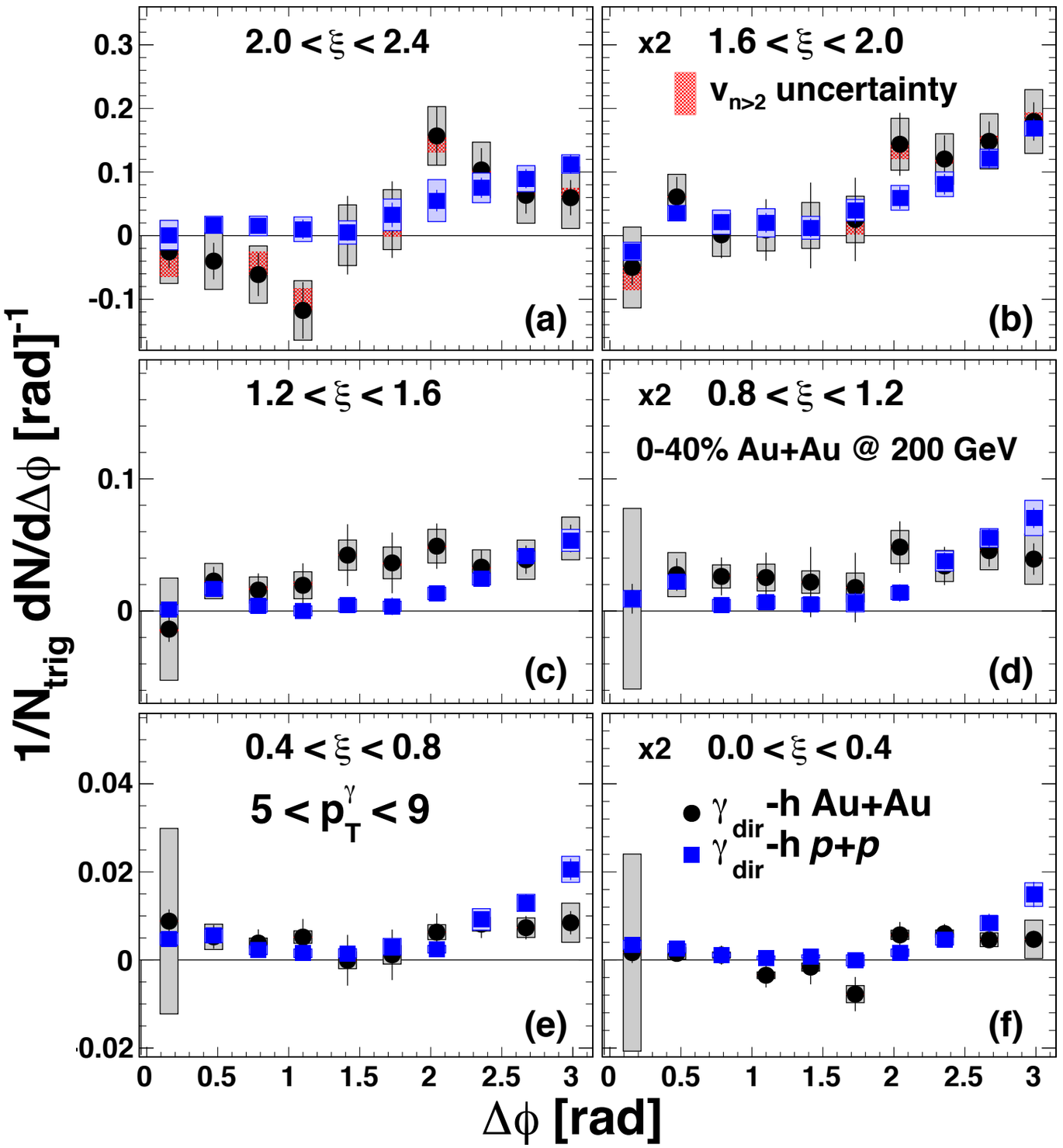


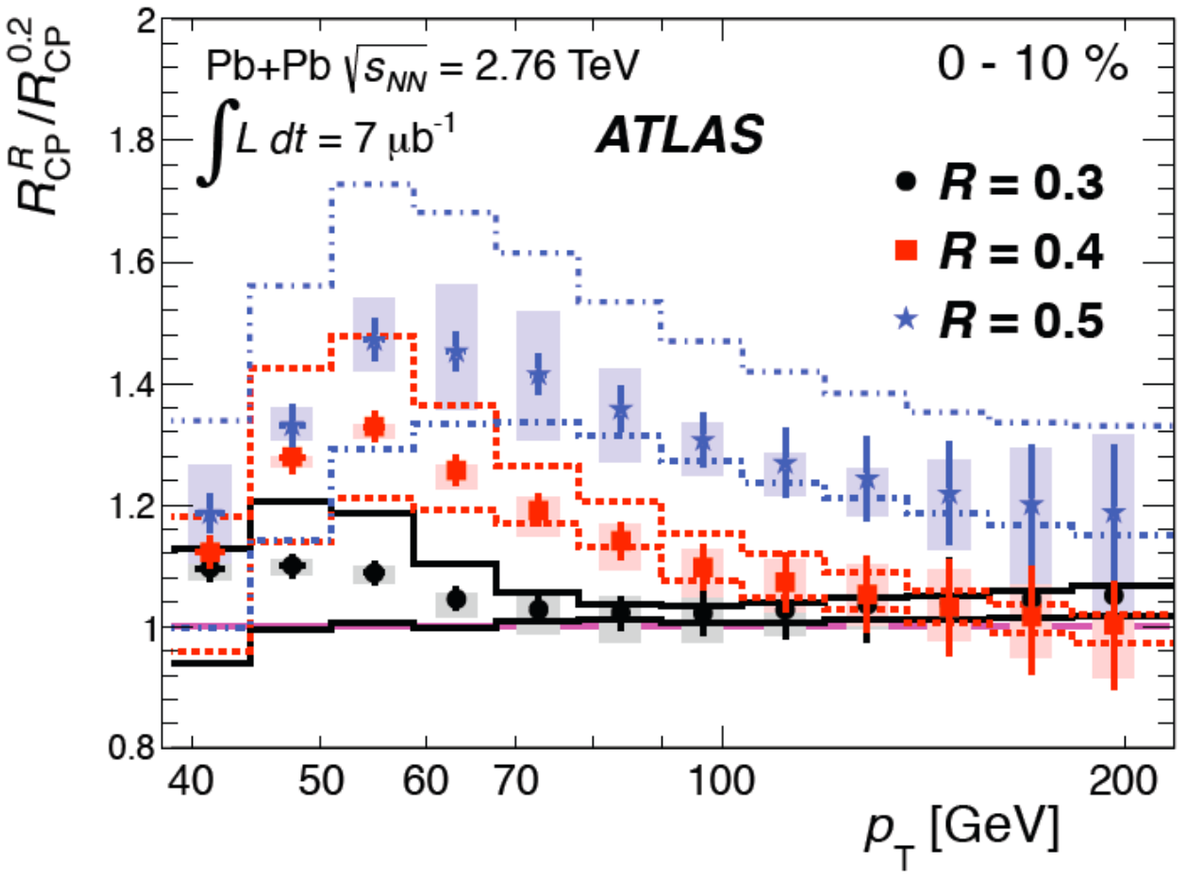
Could this be a trivial flow effect?

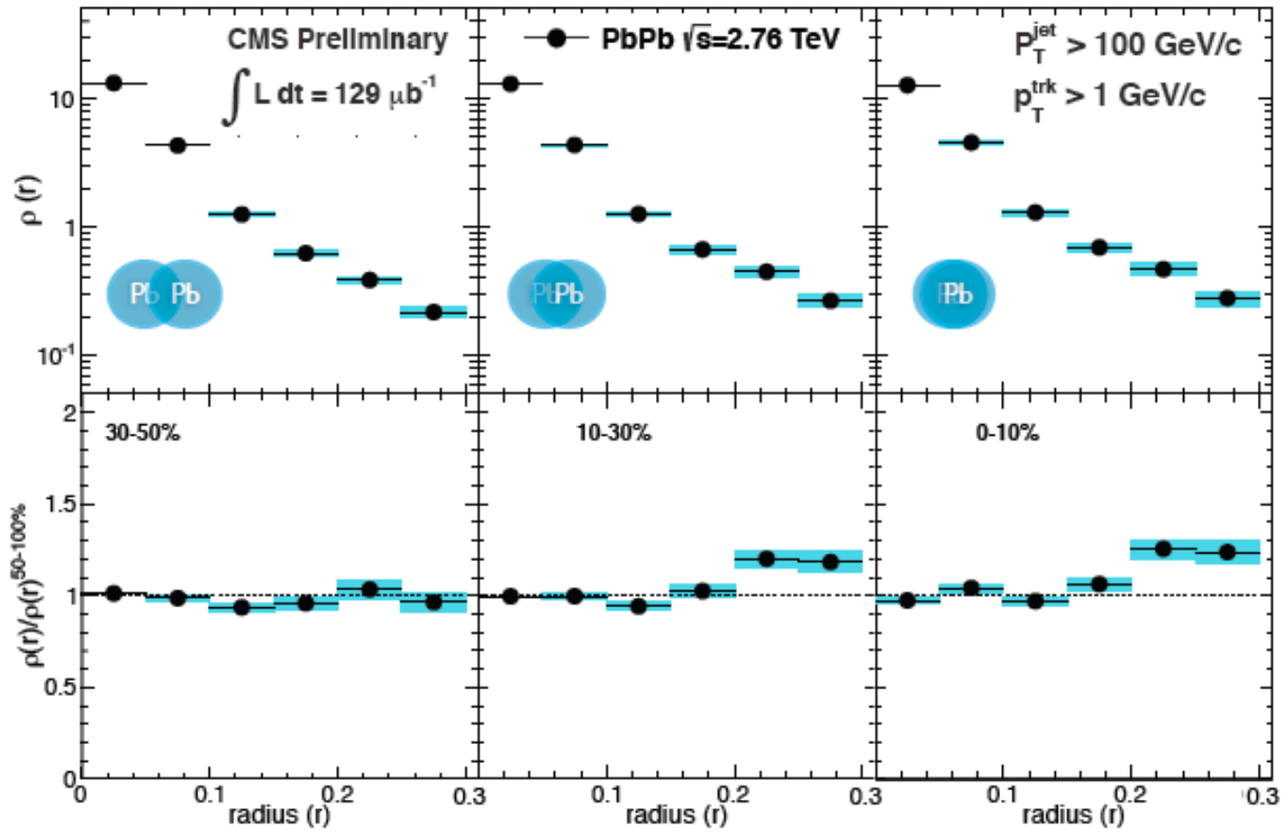


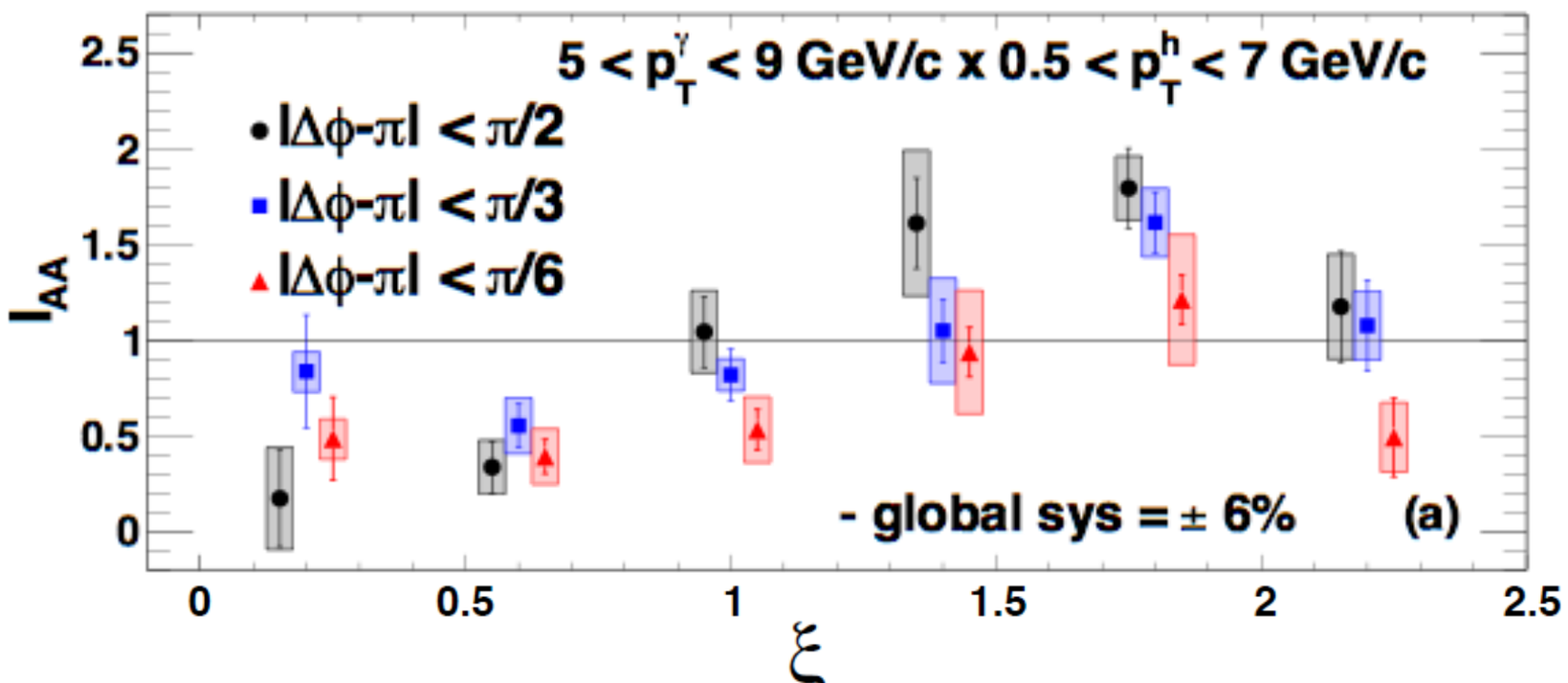
- No high p_T γ $v_{3,4}$ measurement
- Conservative estimate based on π^0
  - assume direct photon $v_n = 0.5 v_n^{\pi^0}$
- Uncertainties shown separately in Δϕ distributions
- Additional source of systematic uncertainty in I_{AA} measurement



Comparison to LHC results







Summary

- p+p baseline well established
- k_T effect seen but likely similar in p+p and Au+Au

- modification to effective fragmentation function observed using γ-h correlations
  - consistent with similar studies using fully reconstructed jets
  - similar effect seen at LHC looking at fragmentation function of reconstructed jets
- variation of away-side integration range suggests jet broadening in addition to enhancement at low $p_{T,h}$
  - similar effect seen at LHC
  - would be very interesting to see a real apples-to-apples comparison!
- Qualitatively consistent with expectations from models