PHENIX Measurement of Direct Photon-Triggered Two-Particle Correlations in Heavy Ion Collisions and its Implication for Medium-Induced Energy Loss

PHENIX

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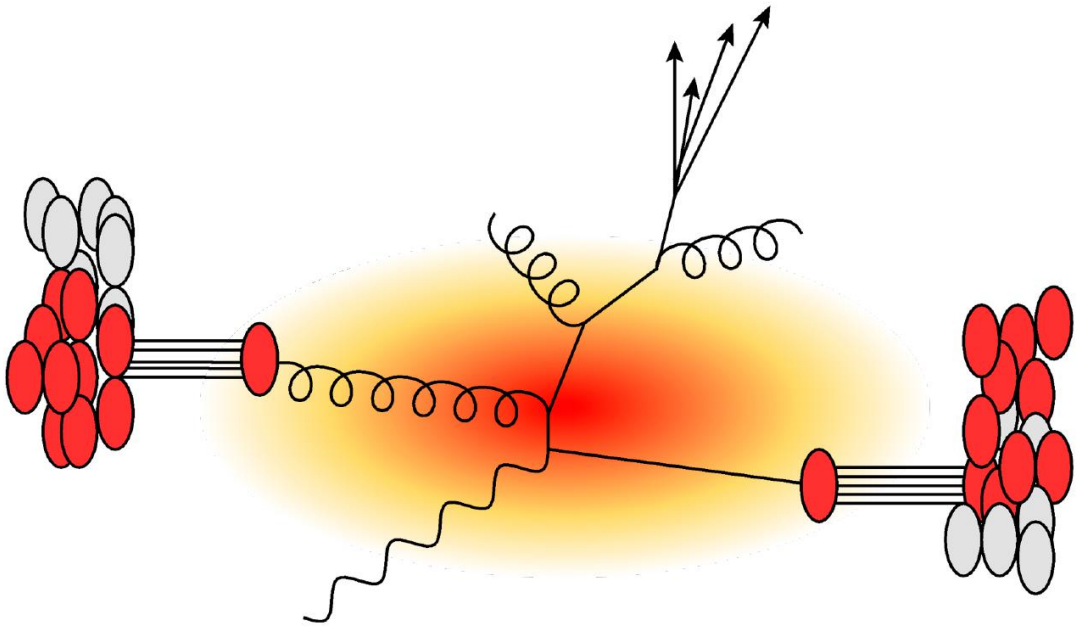
Two-Particle Correlations

Two-particle correlations provide the opportunity to study QGP properties.
A proxy for jet correlation measurement.

Di-hadron correlations are sensitive to near and away-side QCD interactions.

Direct photon-hadron correlations provide additional benefits:

- Photons are colorless – most direct measure of the parton energy. No trigger surface bias.
- Important complement to other jet measurement:
  - *Different path length dependence.*
  - *Different relative contribution from quark vs gluon jets.*



New PHENIX results on γ-$h^{\pm}$ correlations at $\sqrt{s_{NN}}$ = 200 GeV in d+Au, and Au+Au collisions.

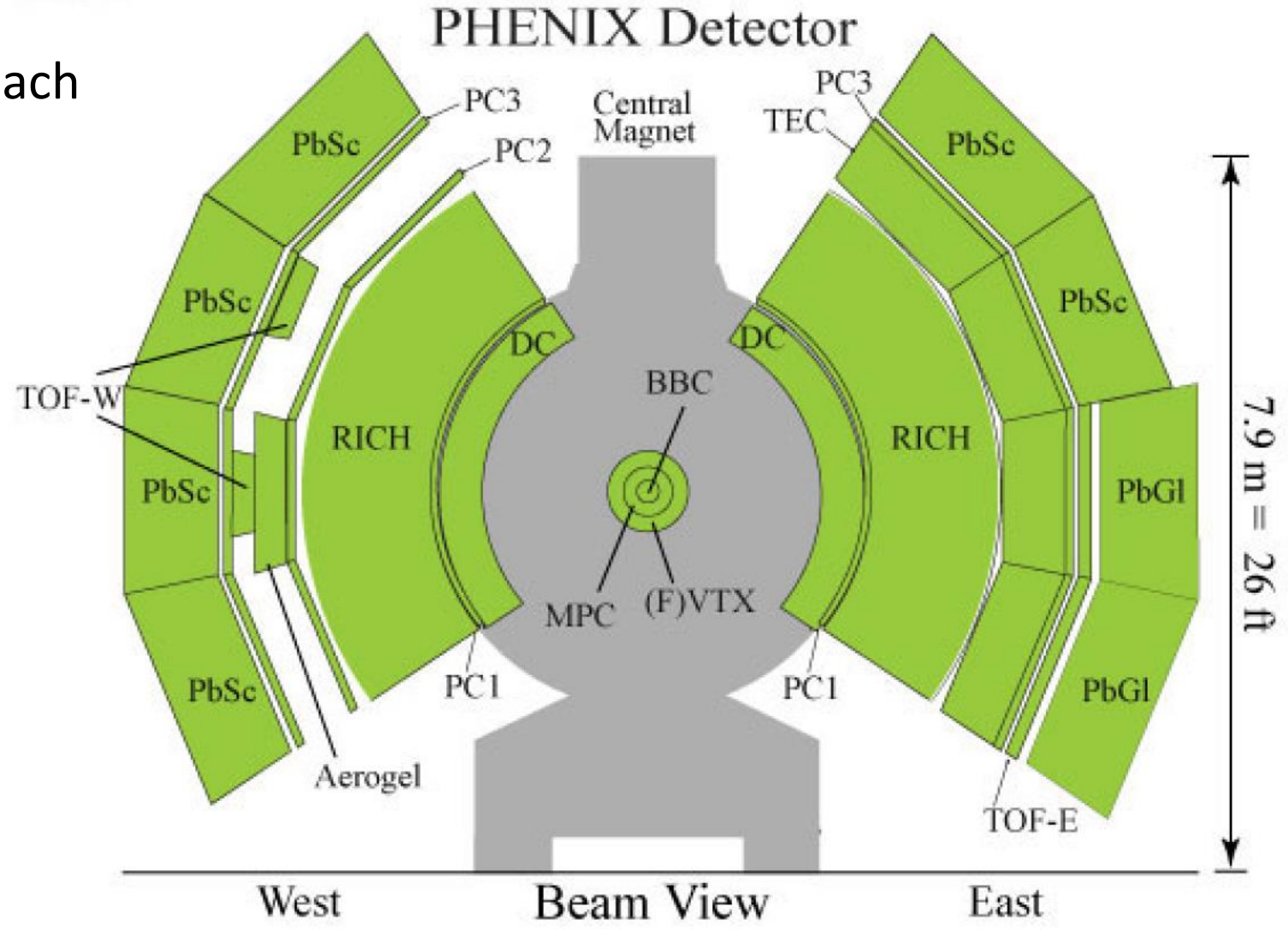
The PHENIX Detector

Two central arms covering $\varphi \sim \pi/2$ each and $|\eta| < 0.35$

EMCal measures γ and $\pi^0 \rightarrow \gamma\gamma$

Drift Chamber (DC) and Pad Chamber (PC) tracking system measures charged hadrons

Forward Beam-Beam-Counter (BBC) and Zero-Degree-Calorimeter (ZDC) measure centrality classes in p+A and A+A



Direct Photon Measurement in PHENIX

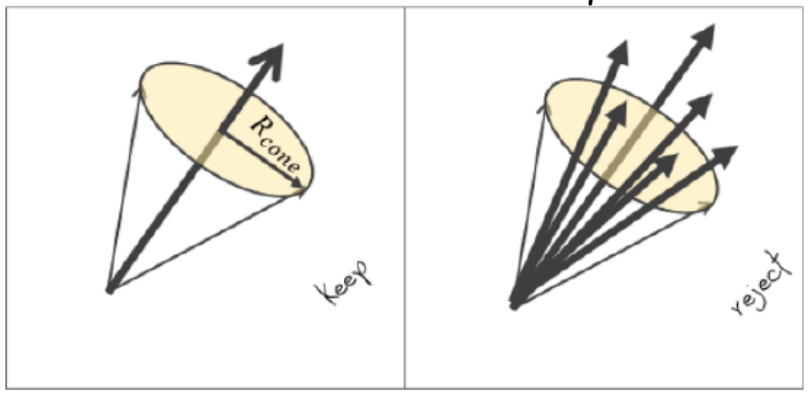
Statistical subtraction

- Used in older Au+Au analyses.
- Subtract decay photons from all photon sample: $Y_{DIR} = (R_\gamma Y_{INC} - Y_{DEC})/(R_\gamma - 1)$
  See ***Phys. Rev. C80 024908*** for details.

Isolation cone method

- Provides better uncertainty.
- Used in p+p and d+Au
- New Au+Au vs centrality results use this method.

$R_{cone} = 0.4$; $E_{cone} < 0.1E_\gamma$ (in p+p)

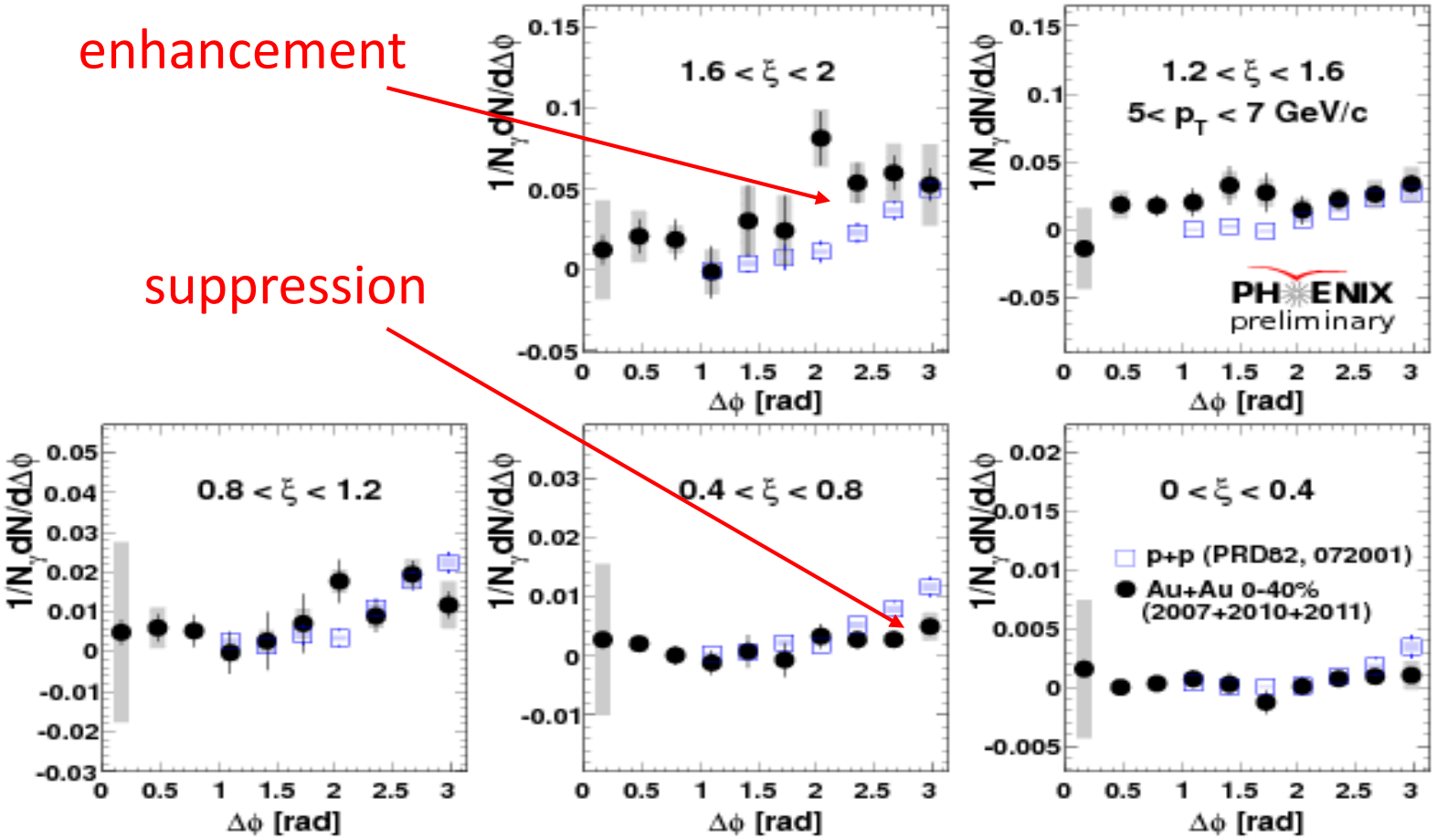


- *Subtract background (mixed events)*
- *In d+Au we assume no flow, use ZYAM normalization.*
- *In Au+Au measured flow is also subtracted.*

Per-trigger yields of hadrons

enhancement

suppression



Proxy for the fraction of the quark's original moment carried by hadrons

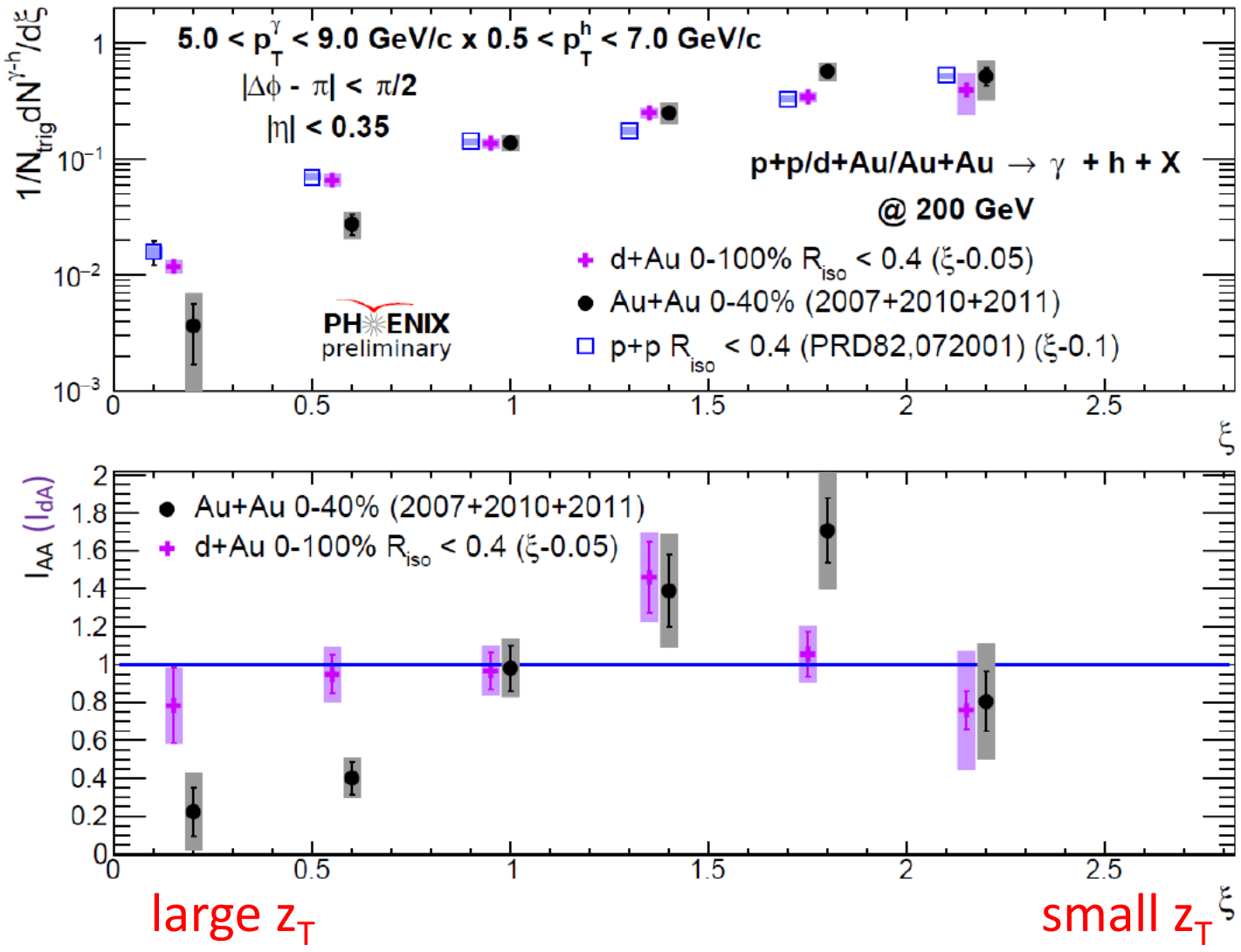
$$z_T = \frac{p_T^h}{p_T^\gamma}$$

For better look at low z_T region we use

$$\xi = \ln(1/z_T)$$

Integrate over ϕ in away-side region to obtain fragmentation function vs ξ

Fragmentation function



Effective jet fragmentation function

$$D_q(z_T) = \frac{1}{N_{evt}} \frac{dN(z_T)}{dz_T}$$

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

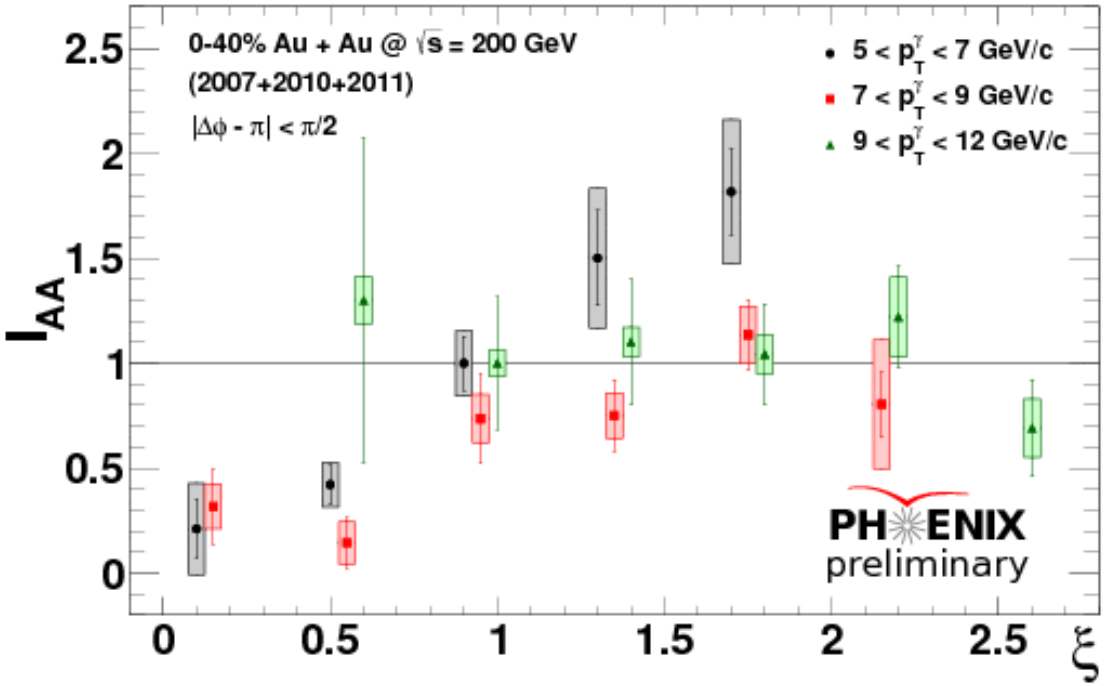
In d+Au no significant modification compared to p+p

In Au+Au suppression at small ξ and enhancement at large ξ

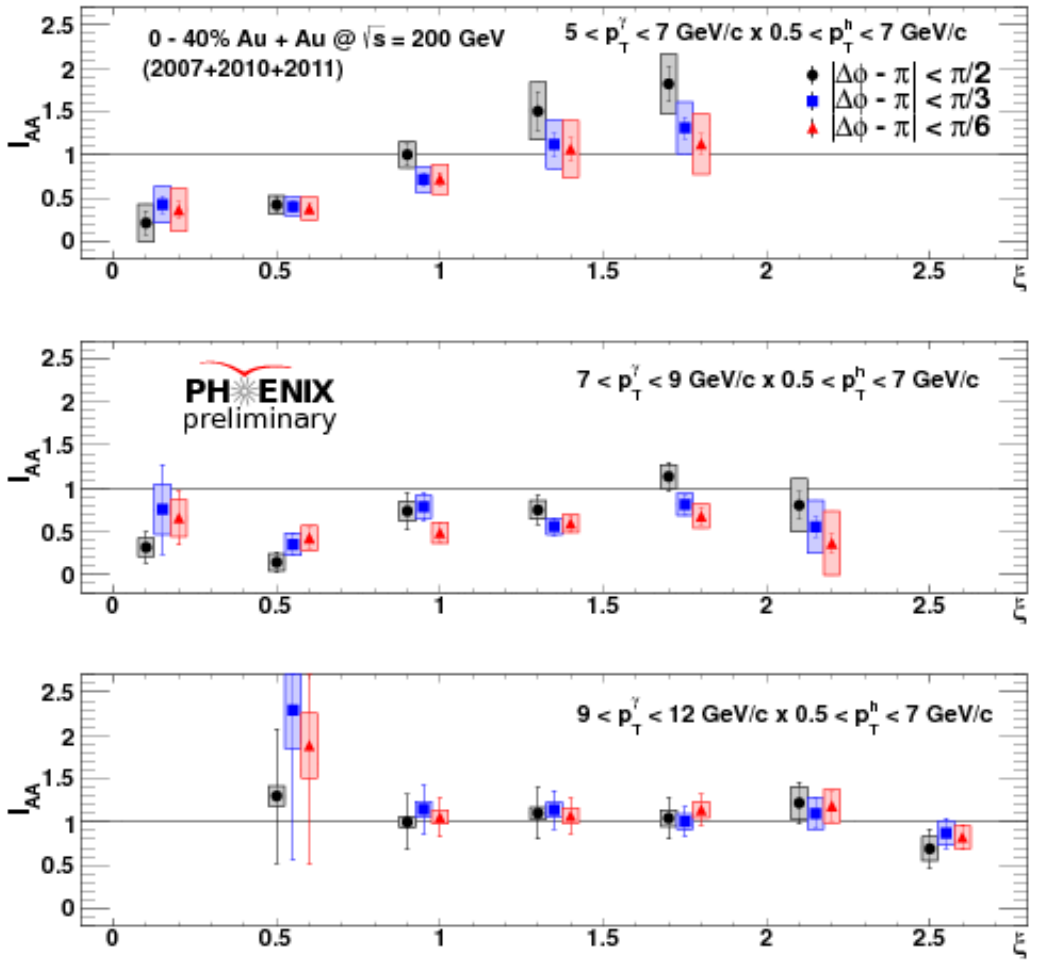
Transition at $\xi \sim 1.2$

Trigger p_T dependence

Trigger p_T is a proxy for parton p_T

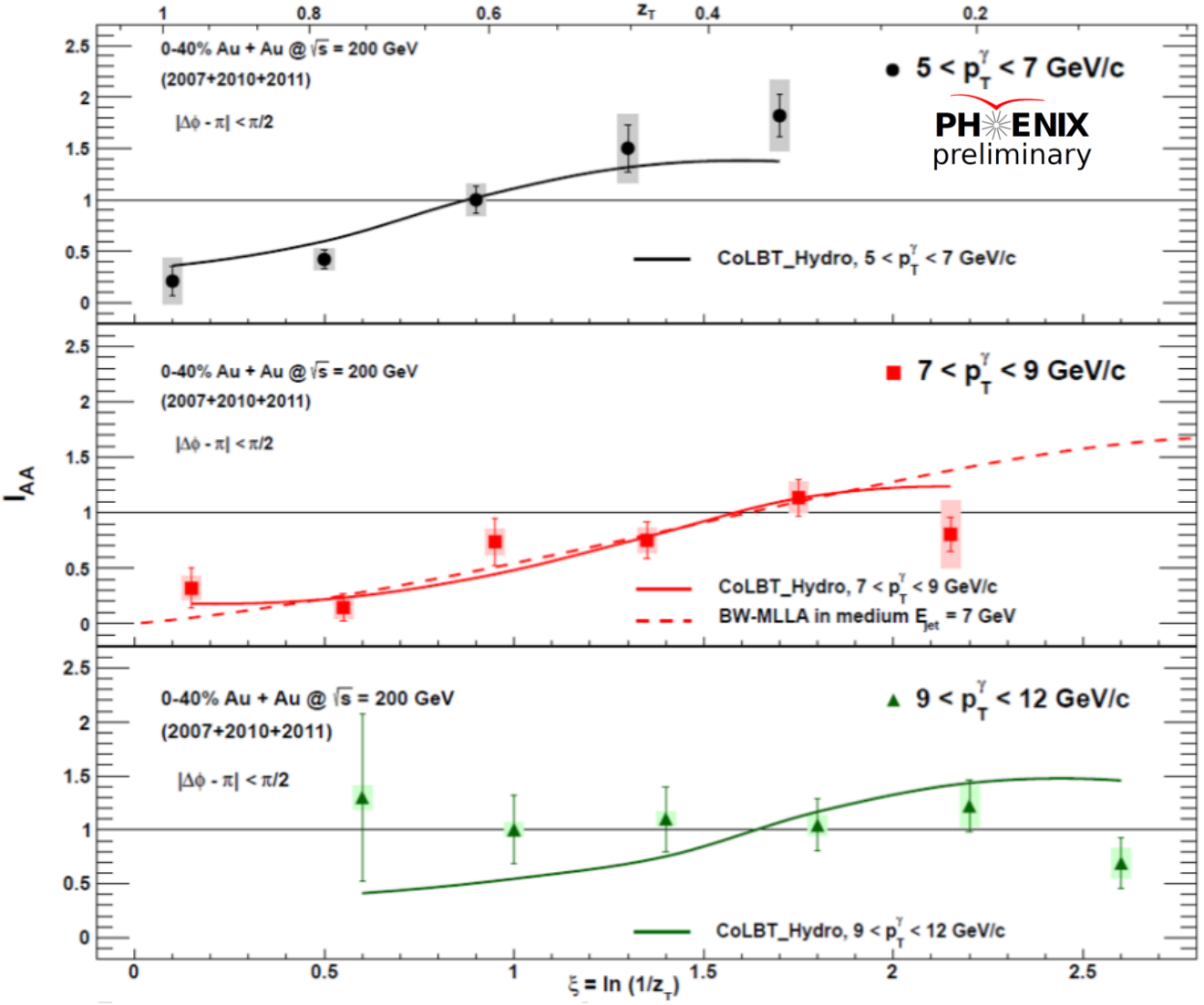


Enhancement is seen only at low p_T
Qualitatively similar increase of I_{AA} with ξ is seen in intermediate p_T bin.



Enhancement is seen only for broad integration range at large angles.

Where does the transition occurs?



Transition from suppression to enhancement occurs not at fixed z_T

Models suggest transition at fixed p_T

Medium response in addition to redistribution of lost energy from high p_T hadrons?

Where does the lost energy go?

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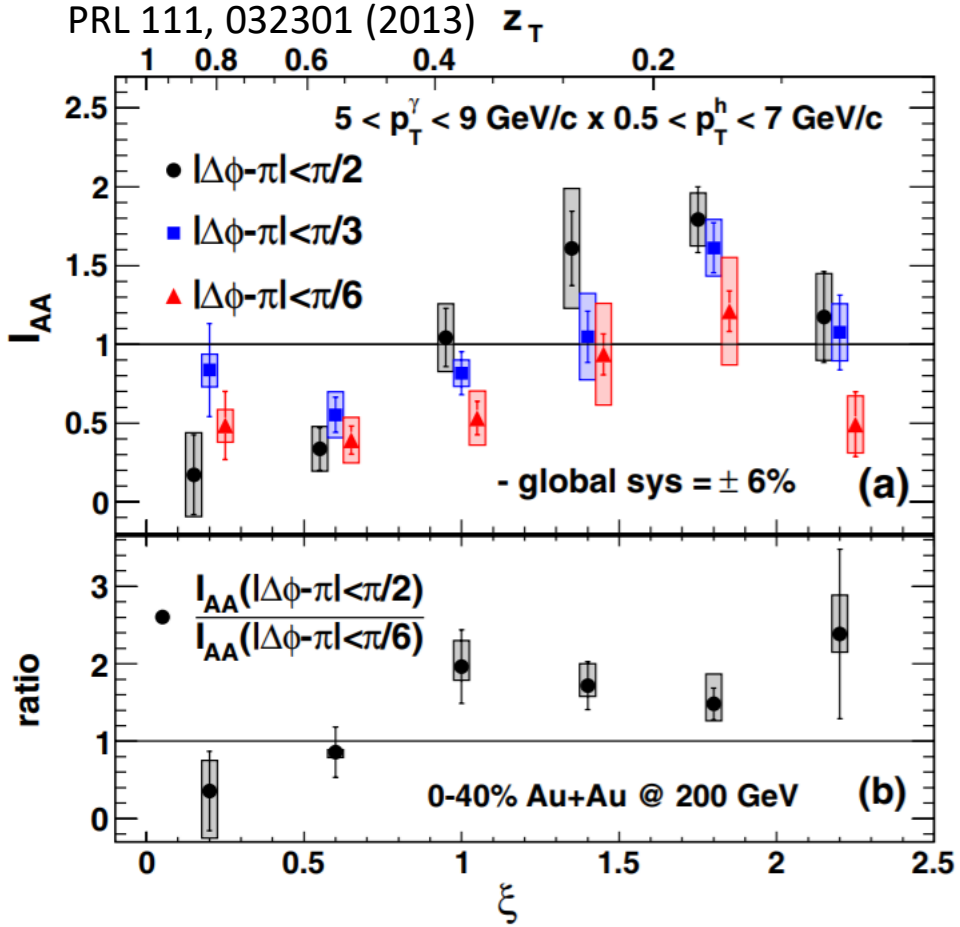
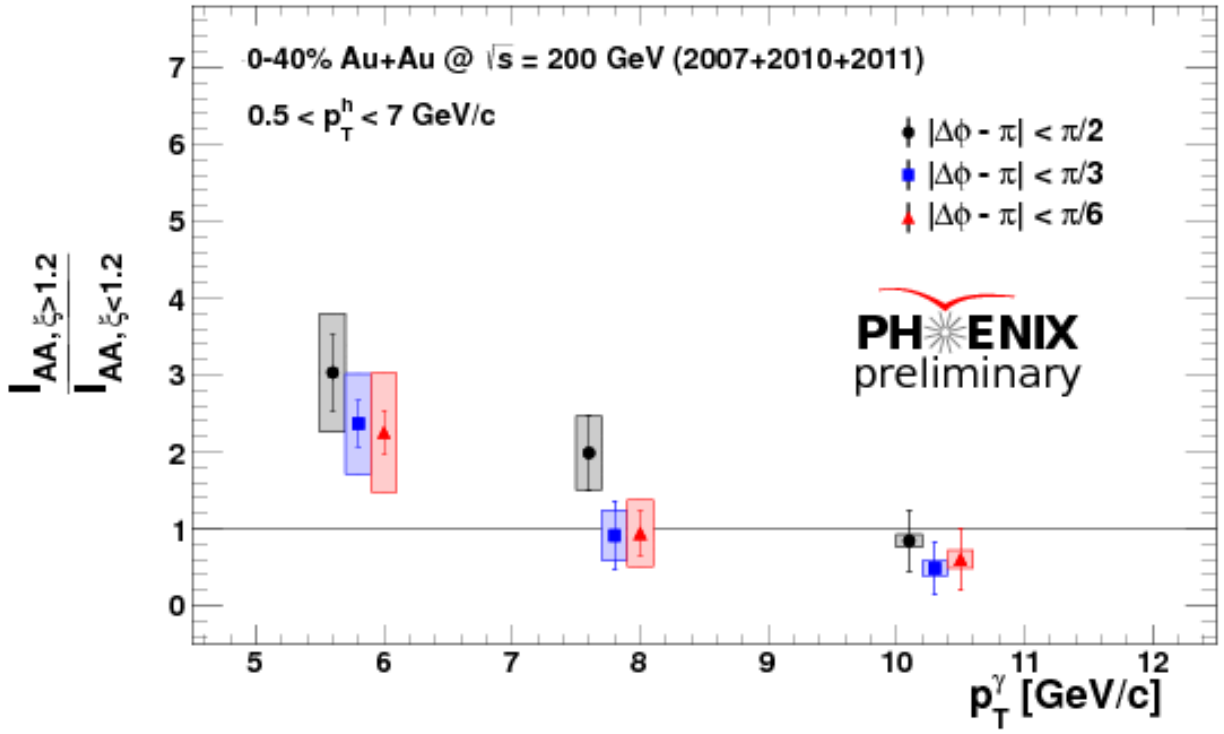


Enhancement disappears with narrow integration range.
Suppression stays the same.
Monotonic increase of enhancement over suppression vs ξ.



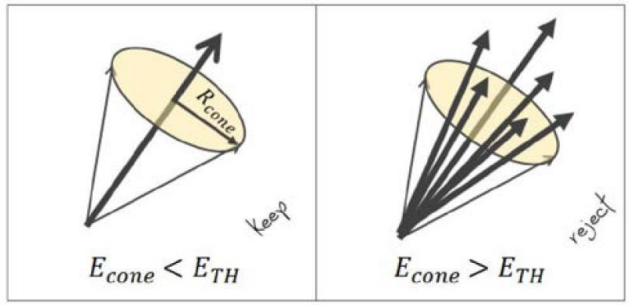
Soft hadrons are enhanced more.

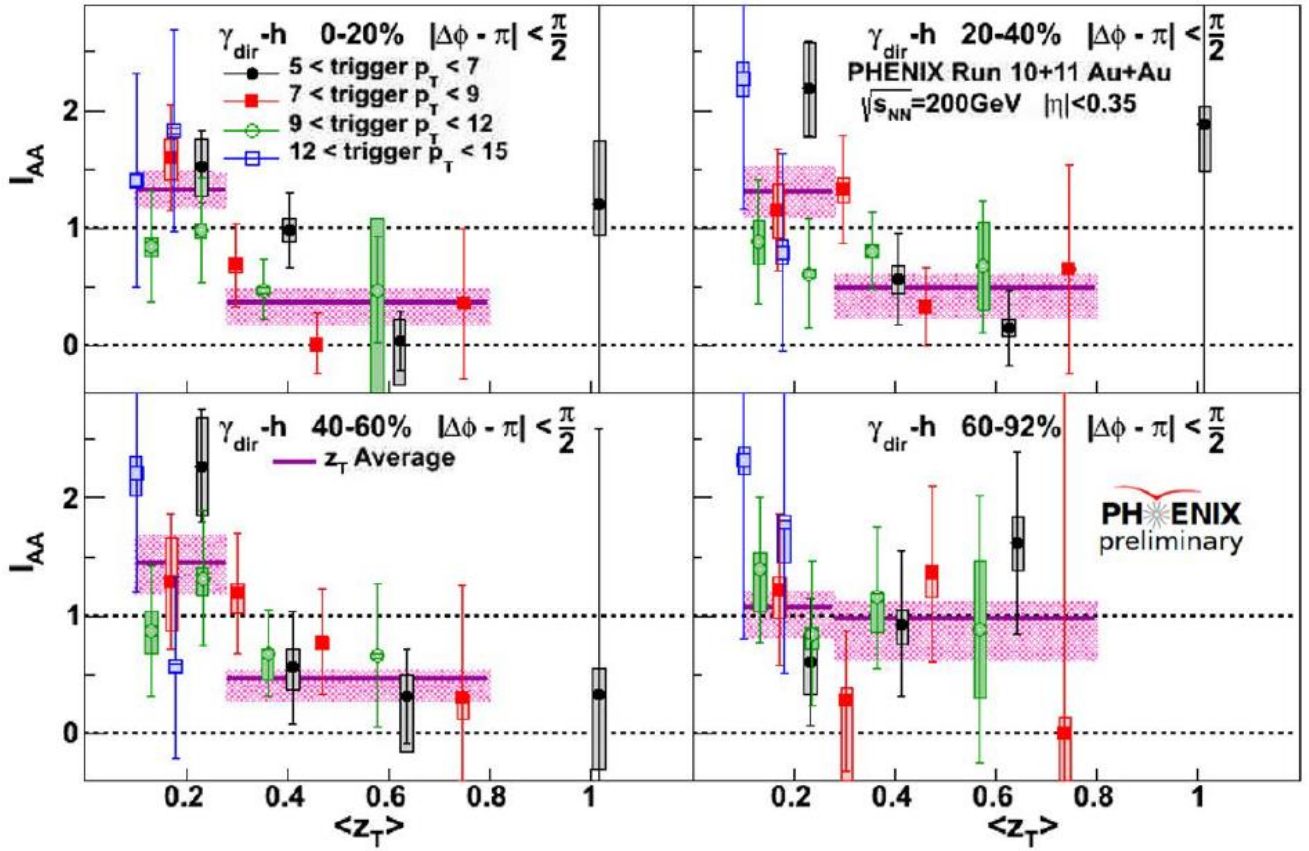
Both plots suggest medium response dominated process.

Centrality dependence

Using isolation cone method in Au+Au allowed detailed look at centrality dependence.

$$R_{cone} = \sqrt{(\Delta\phi)^2 + (\Delta\eta)^2}$$
$$E_{TH} = aE_{\gamma} + b.$$





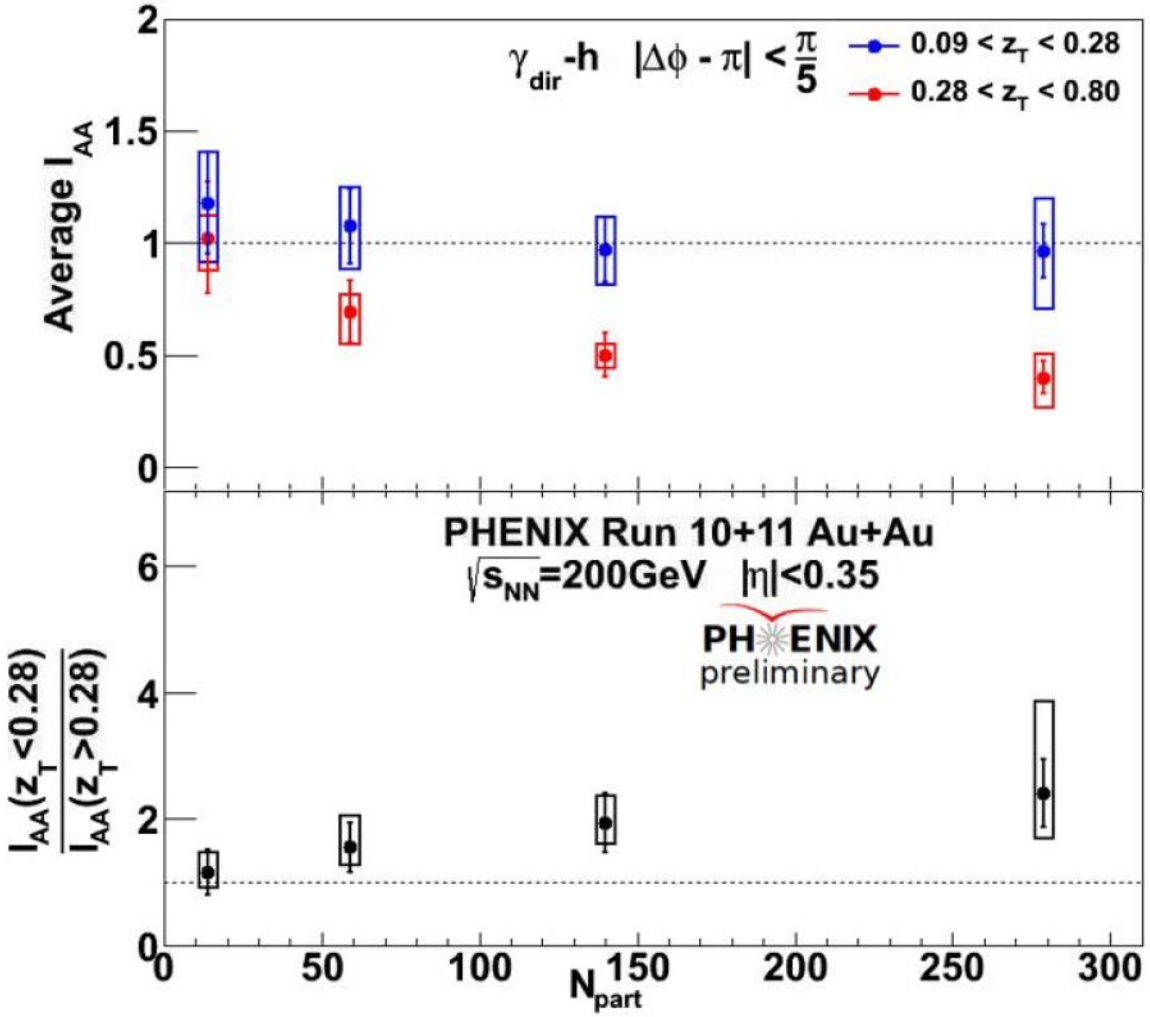
Measure $I_{AA} = Y_{AA} / Y_{pp}$ as a function of z_T, for different p_T and centrality.

Purple bands show integration range and mean I_{AA}

$z_T \approx 0.3$ is $\xi \approx 1.2$

Study suppression/enhancement with these averages

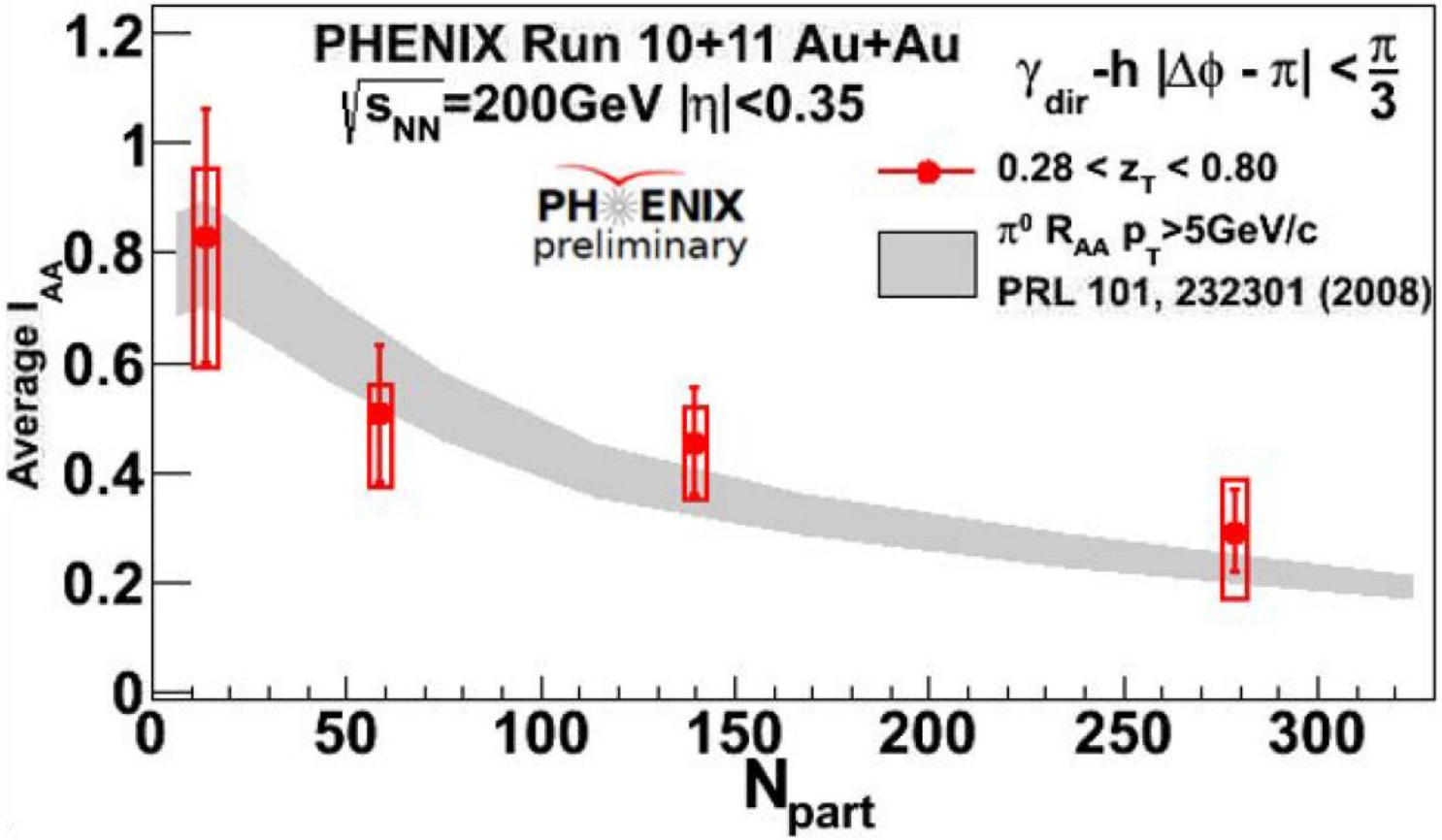
Average I_{AA} vs centrality



With narrow integration range enhancement is not pronounced.

High z_T range shows statistically significant monotonic increase in suppression with centrality.

Comparison to π^0



Good agreement with single π^0 suppression

New result gives better constraint on suppression of high p_T hadrons vs centrality

Conclusions

- γ-h correlations are a powerful tool for studying QCD.
- d+Au collisions show no significant modification of fragmentation function compared to p+p
  - *Possible CNM effects are small*
- In AuAu enhancement at low z_T (high ξ) and suppression at high z_T (low ξ) is observed.
  - *Suppression increases monotonically with centrality*
  - *Enhancement is largest for broad integration region and for soft hadrons*
  - *Transition from suppression to enhancement occurs at fixed hadron p_T*
  - *All this suggests medium response dominated processes.*
- More measurements to come from PHENIX: large Au+Au data sets in 2014 and 2016 are currently being analyzed!