Probing Low x in d+Au and p+p Collisions in PHENIX

Zvi Citron for PHENIX

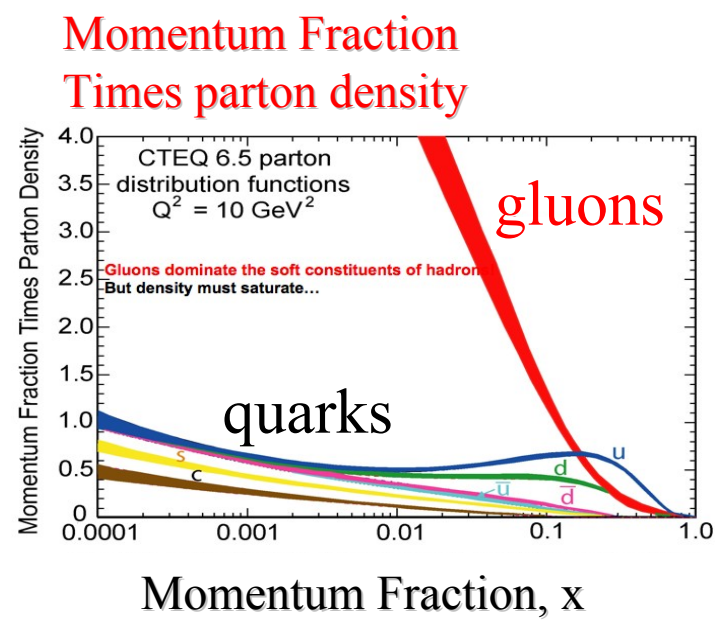
19 March 2010

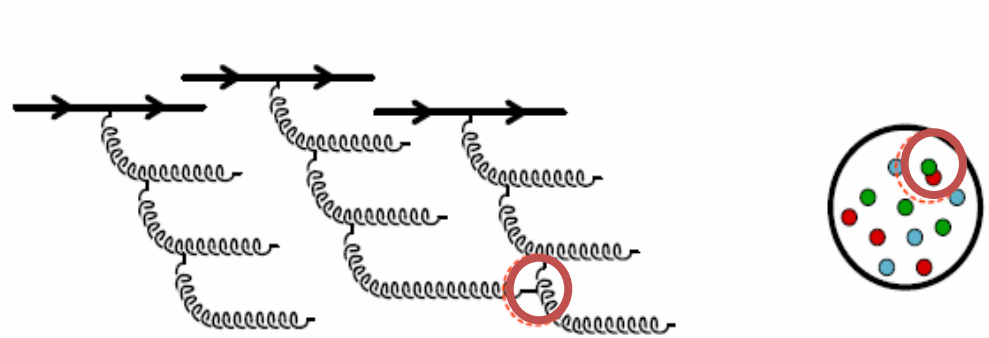
"Progress in High-P_T Physics at RHIC"

Riken-BNL Workshop

Why d+Au?

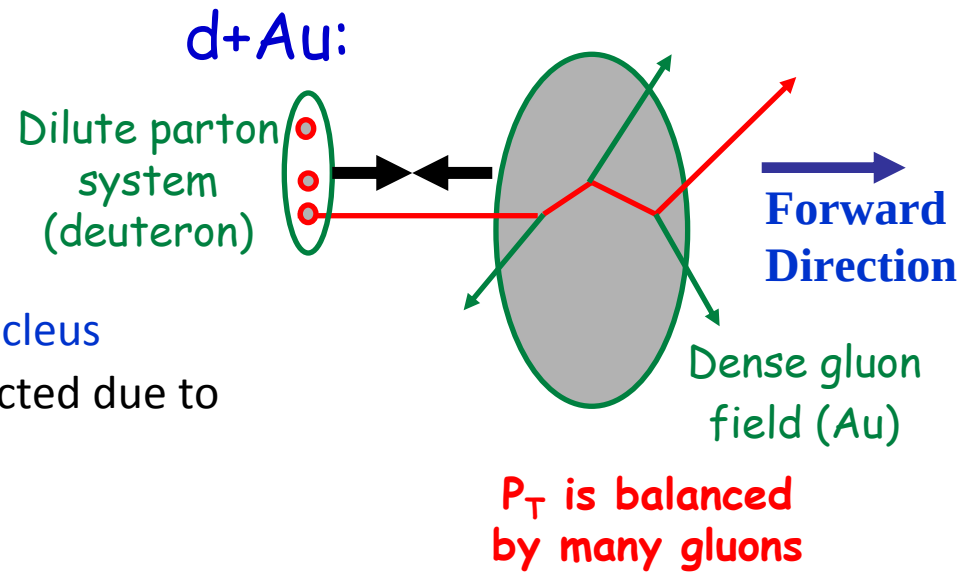
- Understanding nucleon structure in nuclei using deuteron+gold (d+Au) collisions
  - The initial state in Au+Au collisions (necessary for model calculations)
  - Cold nuclear effects
  - Understand gluon distribution at low x and high parton densities
- How the gluon distribution saturates at low x is of active theoretical interest



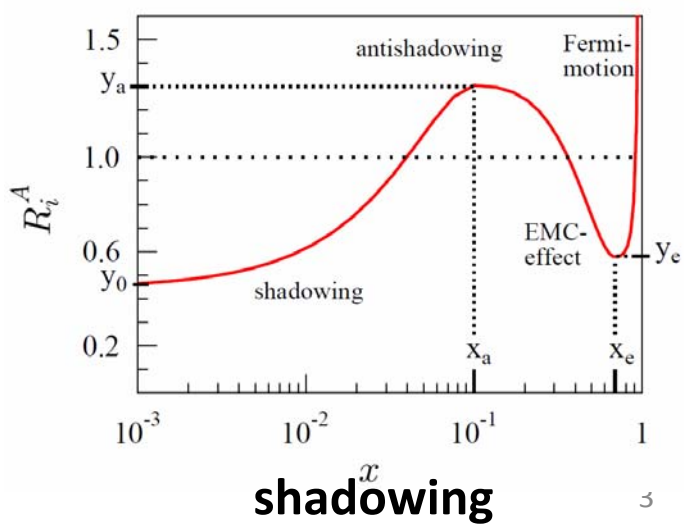


Why Probe Rapidity?

- Forward → Low x

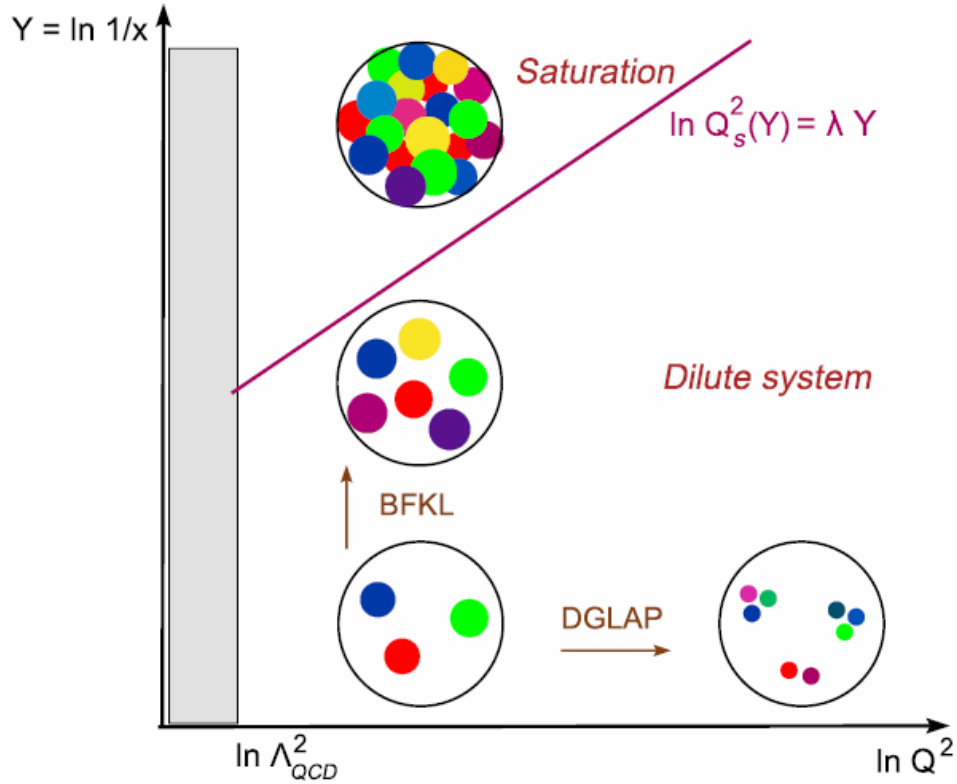


- Probe low-*x* gluon distribution in Au nucleus
  - Suppression of particle yields expected due to extremely high gluon density
  - Gluon saturation
  - Shadowing effects
  - Decorrelation in 2 particle $\Delta\phi$ distribution
- Rapidity Separated Jets
  - Mueller-Navelet Jets
    - Larger rapidity gap between jets → larger probability for emitting gluons →decorrelation in 2 particle $\Delta\phi$distribution
    - d+Au*and* p+p



The Color Glass Condensate

see for example, F. Gelis, E. Iancu, J. Jalilian-Marian, R. Venugopalan, arXiv:1002.0333



gluon density $n(Y, k_T)$ saturates for large densities at small x :

Non-linear evolution eqn.

$$\frac{\partial n}{\partial Y} \cong \underbrace{\lambda \alpha_S n}_{\text{g emission}} + \nu \alpha_S \partial_t^2 n - \underbrace{\mu \alpha_S^2 n^2}_{\text{g-g merging}}$$

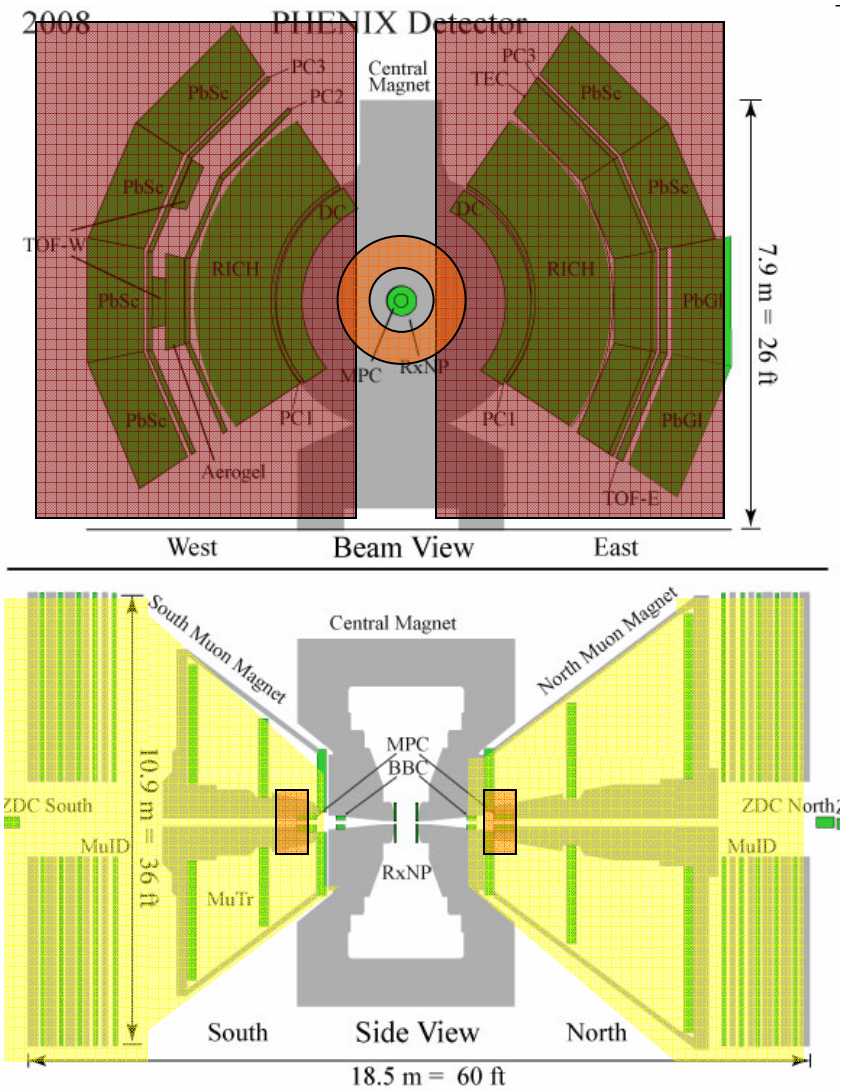
diffusion

g-g merging large if $\alpha_S n \propto 1$

➔saturation scale

Q_S, nuclear enhancement ~ $A^{1/3}$

PHENIX Detector at RHIC



Central Arms $|\eta| < 0.35$

- Charged hadrons
- Neutral pions / η
- Direct Photon
- J/Psi
- Heavy Flavor

Muon Arms $1.2 < |\eta| < 2.4$

- J/Psi
- Unidentified charged hadrons
- Heavy Flavor

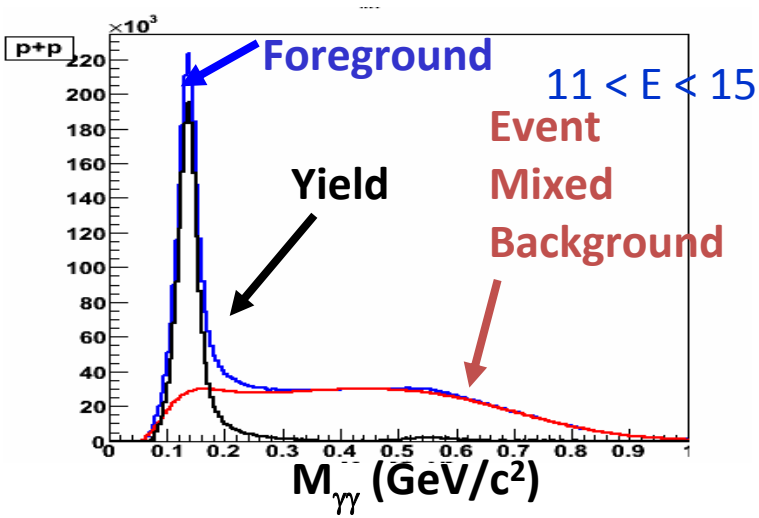
Muon Piston Calorimeter

$3.1 < |\eta| < 3.9$

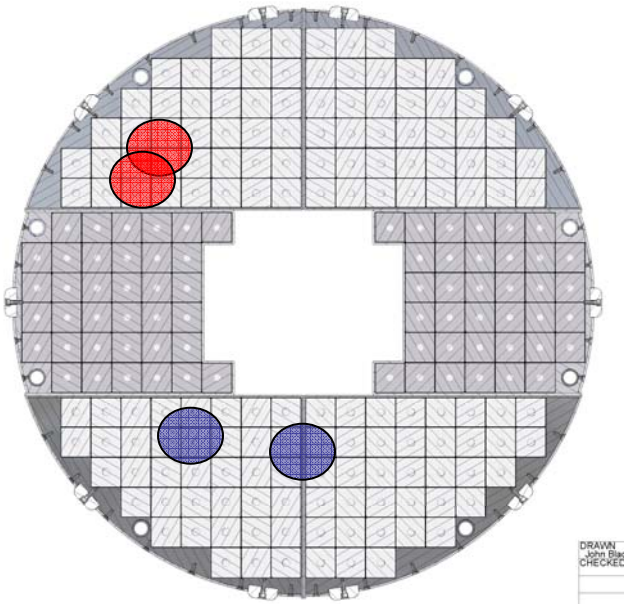
- Neutral pions / η

PHENIX forward EMCs (MPCs)

- Forward and backward Muon Piston Calorimeters have rapidity $3.1<|\eta|<3.9$
- 2.2 x 2.2 x 18 cm^3 $PbWO_4$ scintillating crystals
- 220 cm from nominal interaction point
- Detect pions (via $\pi^0 \rightarrow \gamma\,\gamma$) up to ~ *20GeV*
- Limitations are the tower separation and merging effects (p_T max ~ *2*GeV/c)
- To go to higher p_T, use single clusters
  - Use π^0s for *7*GeV< *E* < *17*GeV
  - Use clusters for *E* > *20*GeV

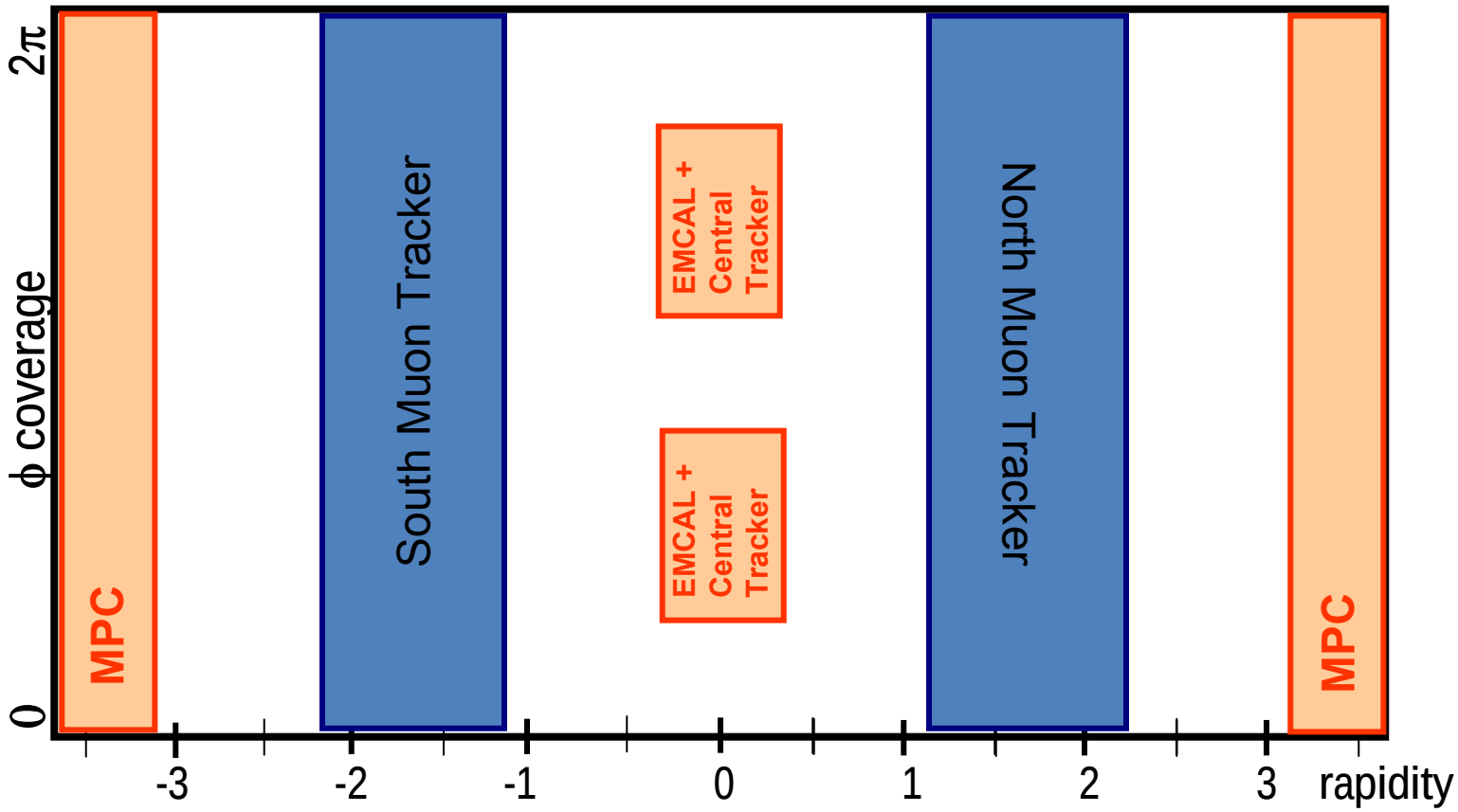


North MPC



Decay photon impact positions for **low** and **high** energy π^0s

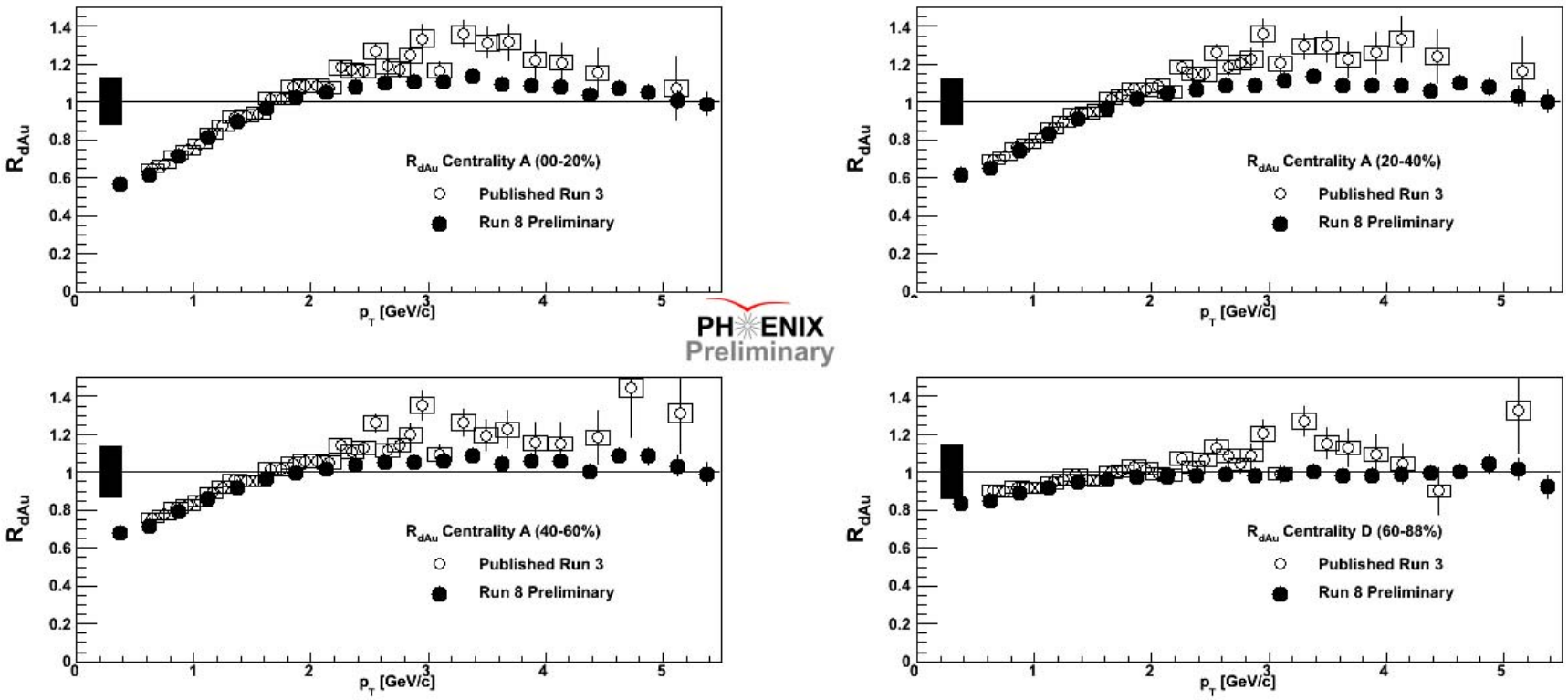
PHENIX Acceptance



- Use rapidity as the lever arm to access different x regions
- Map as much of the phase space as possible with single particle and two particle correlation measurements

Nuclear Modification in d+Au at Mid-Rapidity

$$R_{dAu} \equiv \frac{1}{\langle N_{coll} \rangle} \frac{d^2 N^{d+Au}/dp_T d\eta}{d^2 N^{p+p}_{inel}/dp_T d\eta}$$

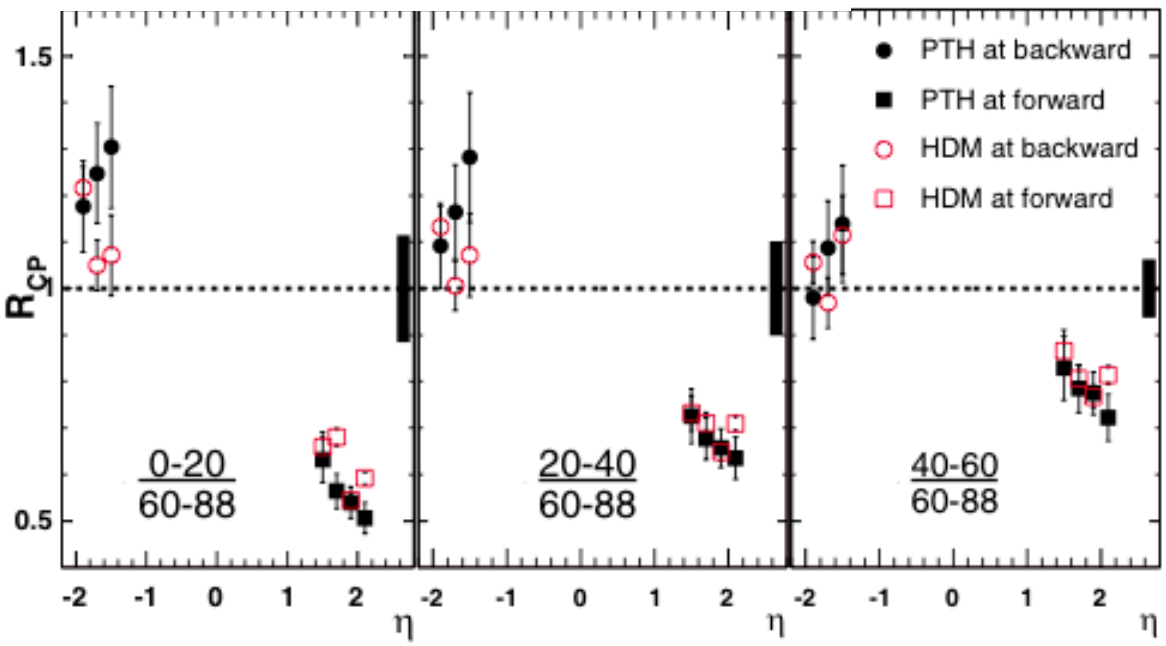


Cronin effect leads to enhancement of d+Au yield compared to p+p, for |η|<.35

Phys. Rev. C 77, 014905 (2008)

Nuclear Modification in d+Au at Forward(Backward) Rapidity

$$R_{cp} = \frac{\langle (\frac{dN}{d\eta dp_T})^{\text{central}} \rangle / \langle N_{\text{coll}}^{\text{central}} \rangle}{\langle (\frac{dN}{d\eta dp_T})^{\text{peripheral}} \rangle / \langle N_{\text{coll}}^{\text{peripheral}} \rangle}$$



- At forward η suppression is seen, but not in the backward direction
- Gluon Saturation?
- Cronin + Shadowing + E-loss?
- Look at 2 particle correlations …

Phys. Rev. Lett. 94, 082302 (2005)

Correlation Function, CY, and I_{dA}

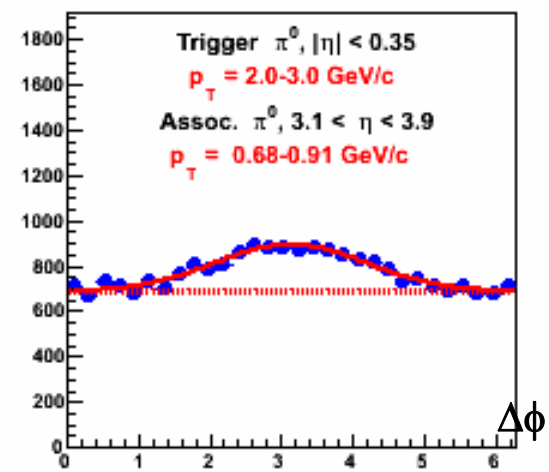
- Use two-particle azimuthal angle correlation technique to probe di-jet structure of d+Au and p+p
  - Define trigger, associated particles in different η, p_T configurations
  - Probe the available phase space

$$N_{pair} = \int \left(\frac{dN_{fg}(\phi)/d\phi}{\text{acceptance}} - Background \right) d\varphi$$

$$CY = \frac{N_{pair}}{N_{trig}\,\varepsilon_{assoc}} \qquad I_{dA} = \frac{CY_{dA}}{CY_{pp}}$$

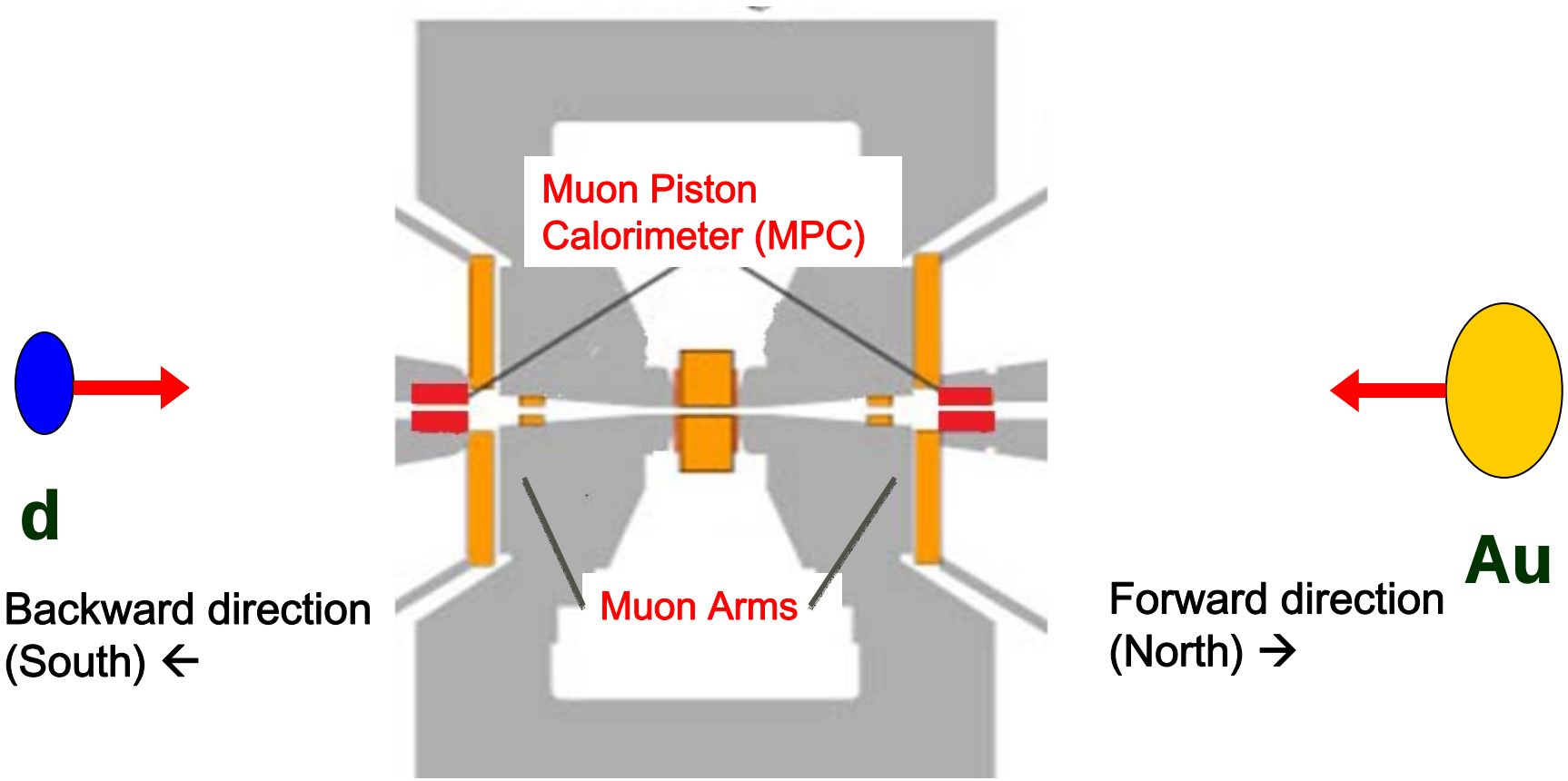
Associated particle efficiency

Peripheral d+Au
Correlation Function



$\sqrt{s_{NN}}$ = *200* GeV d+Au Collision

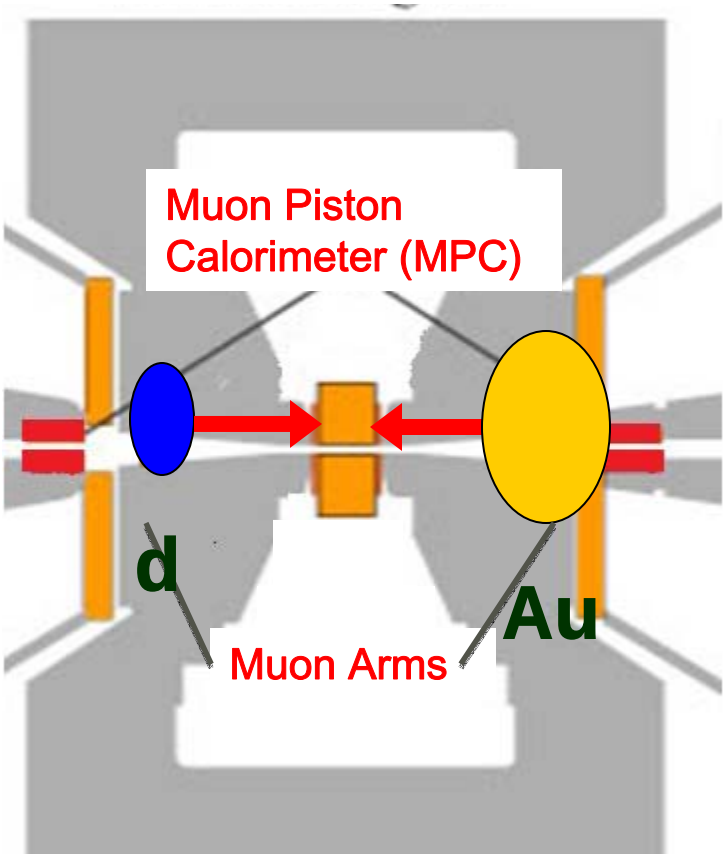
PHENIX central spectrometer magnet



Side View

$\sqrt{s_{NN}}$ = *200* GeV d+Au Collision

PHENIX central spectrometer magnet

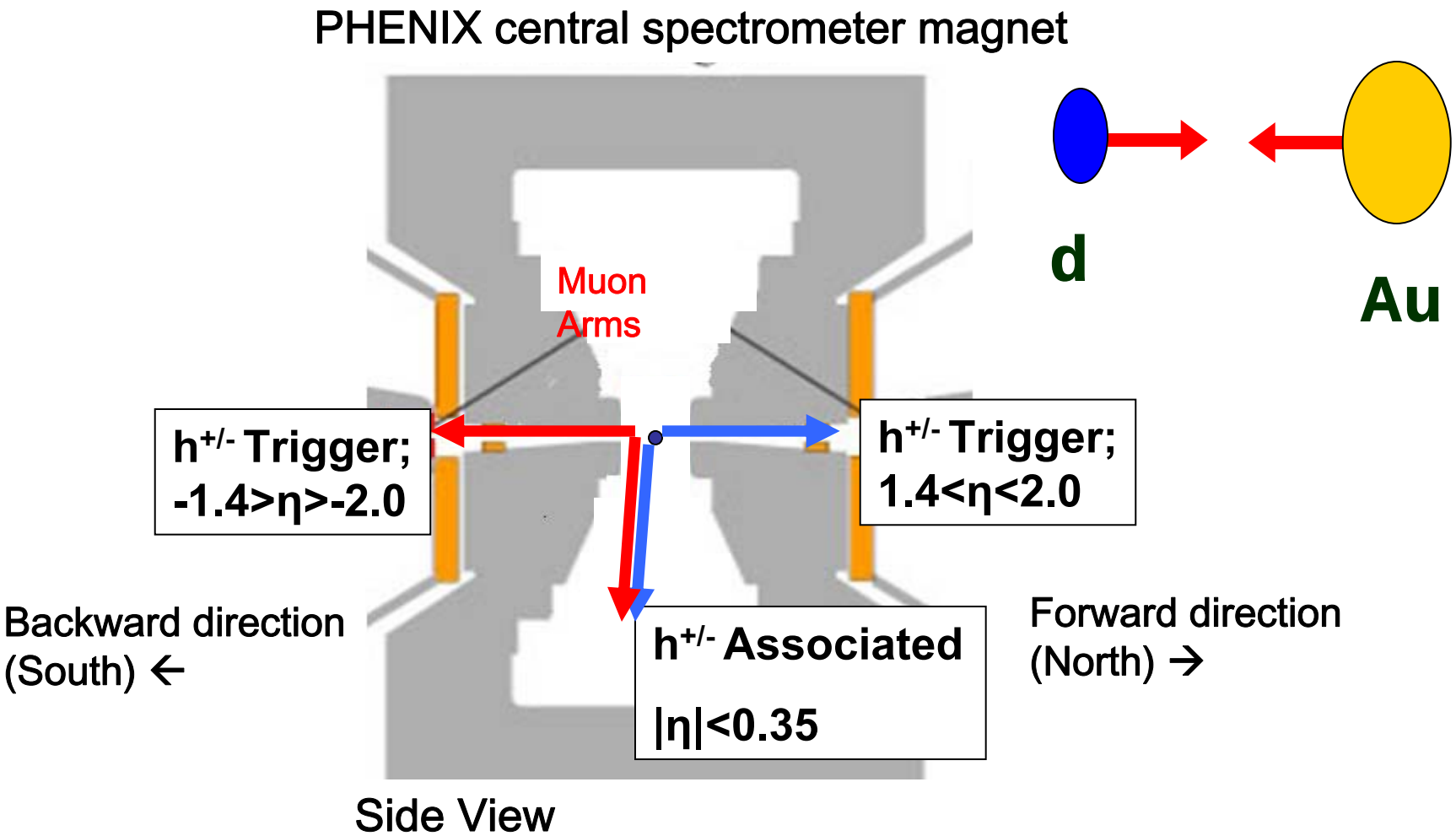


Backward direction
(South) ←

Forward direction
(North) →

Side View

Forward Di-jet Signal with Moderate $\Delta\eta$



I_{dAu} from the PHENIX Muon Arms

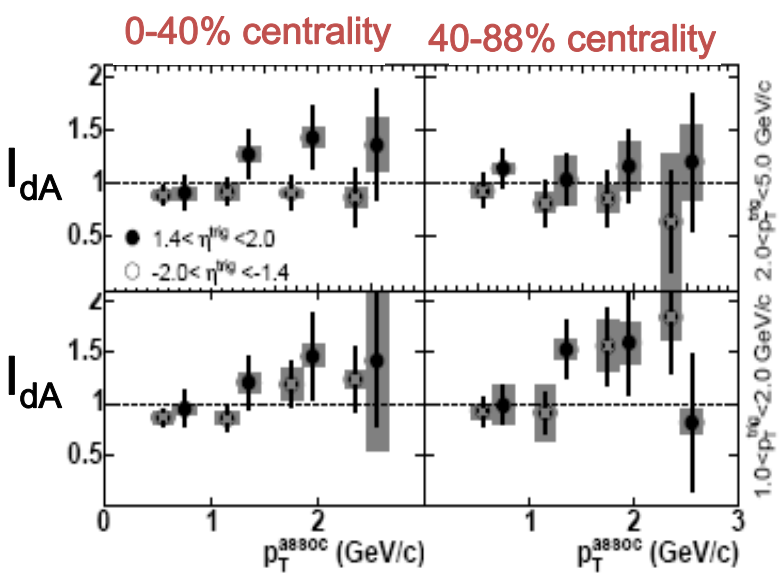
Observations at PHENIX using the 2003 d+Audata:

- Left: I_{dA} for hadrons $1.4 < |\eta| < 2.0$, PHENIX muon arms.

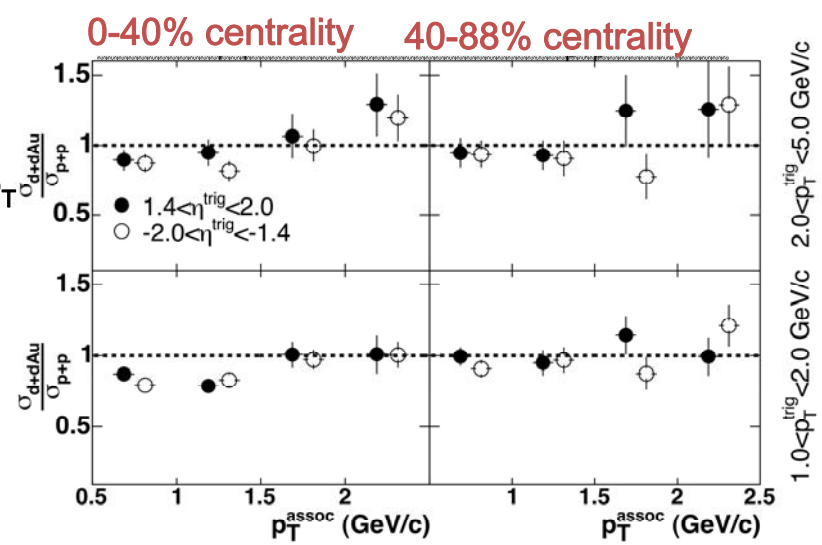
correlated with $h^{+/-}$ in $|\eta| < 0.35$, *central arms.*

- Right: Comparison of conditional yields with different trigger particle pseudo-rapidities and different collision centralities

➔No significant suppression or widening seen within large uncertainties !



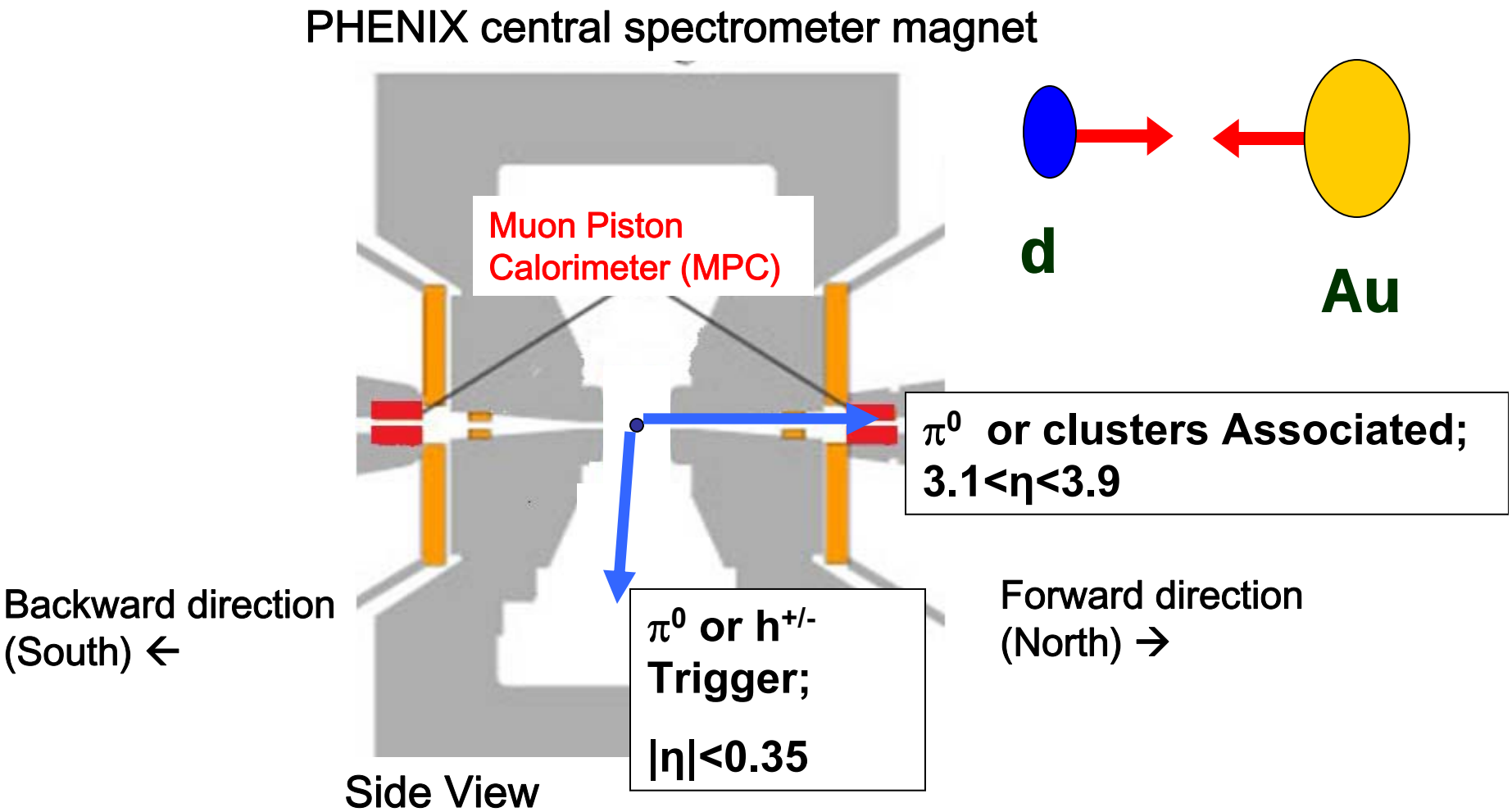
Trigger p_T range



Ratio of d+Au width/pp width

PRL 96 (2006) 222301

Forward Di-jet Signal with Large Λn



π^0 (trigger,central)/π^0 (associate,forward)

2.0 <p_T^t< 3.0GeV/c

for all plots

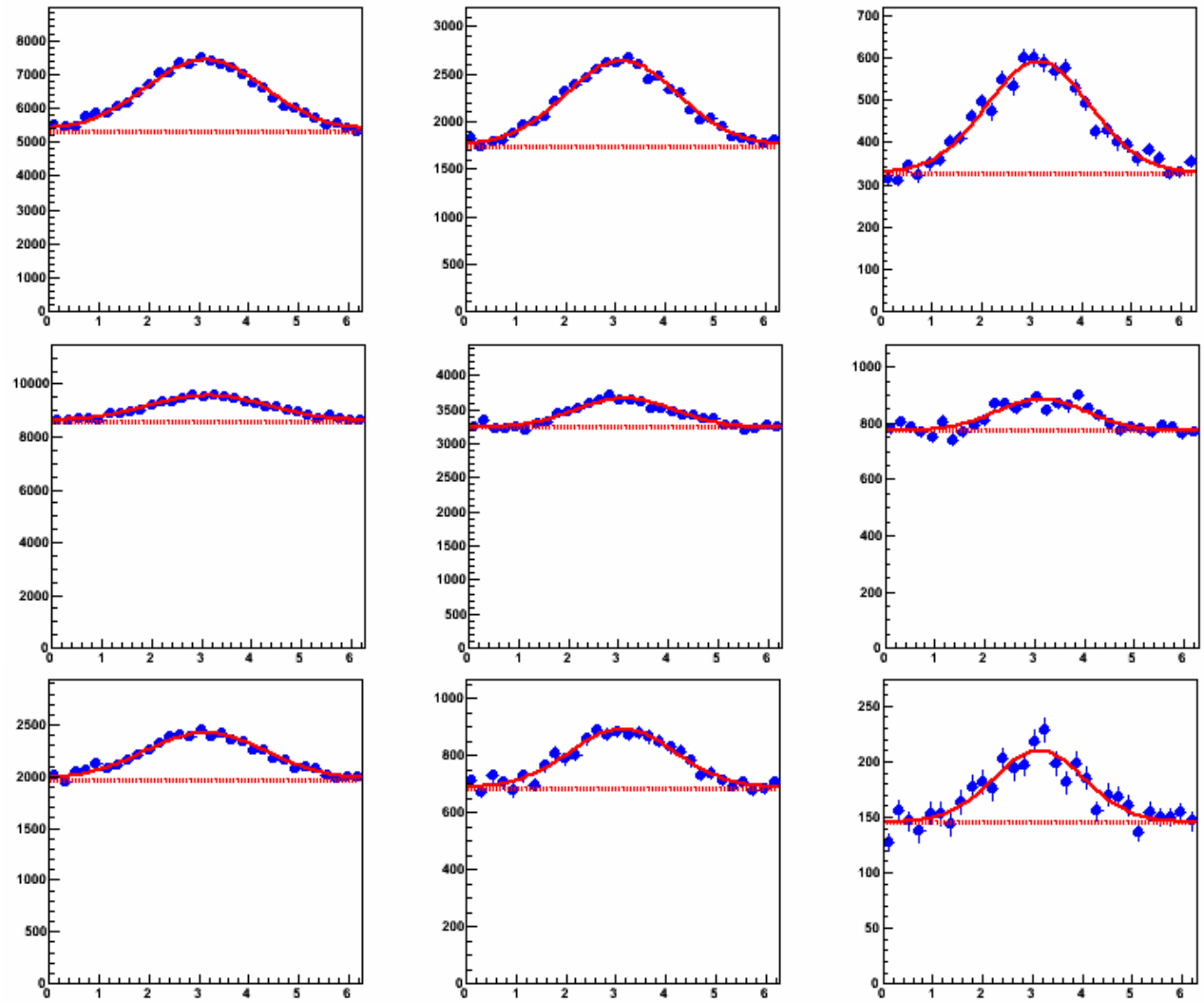
pp

dAu 0-20%

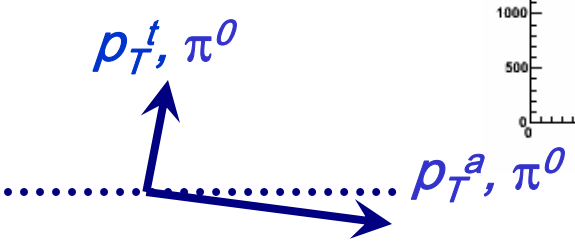
dAu 60-88%

Correlation Function

<p_T^a>=0.55 GeV/c ***<p_T^a>=0.77 GeV/c*** ***<p_T^a>=1.00 GeV/c***



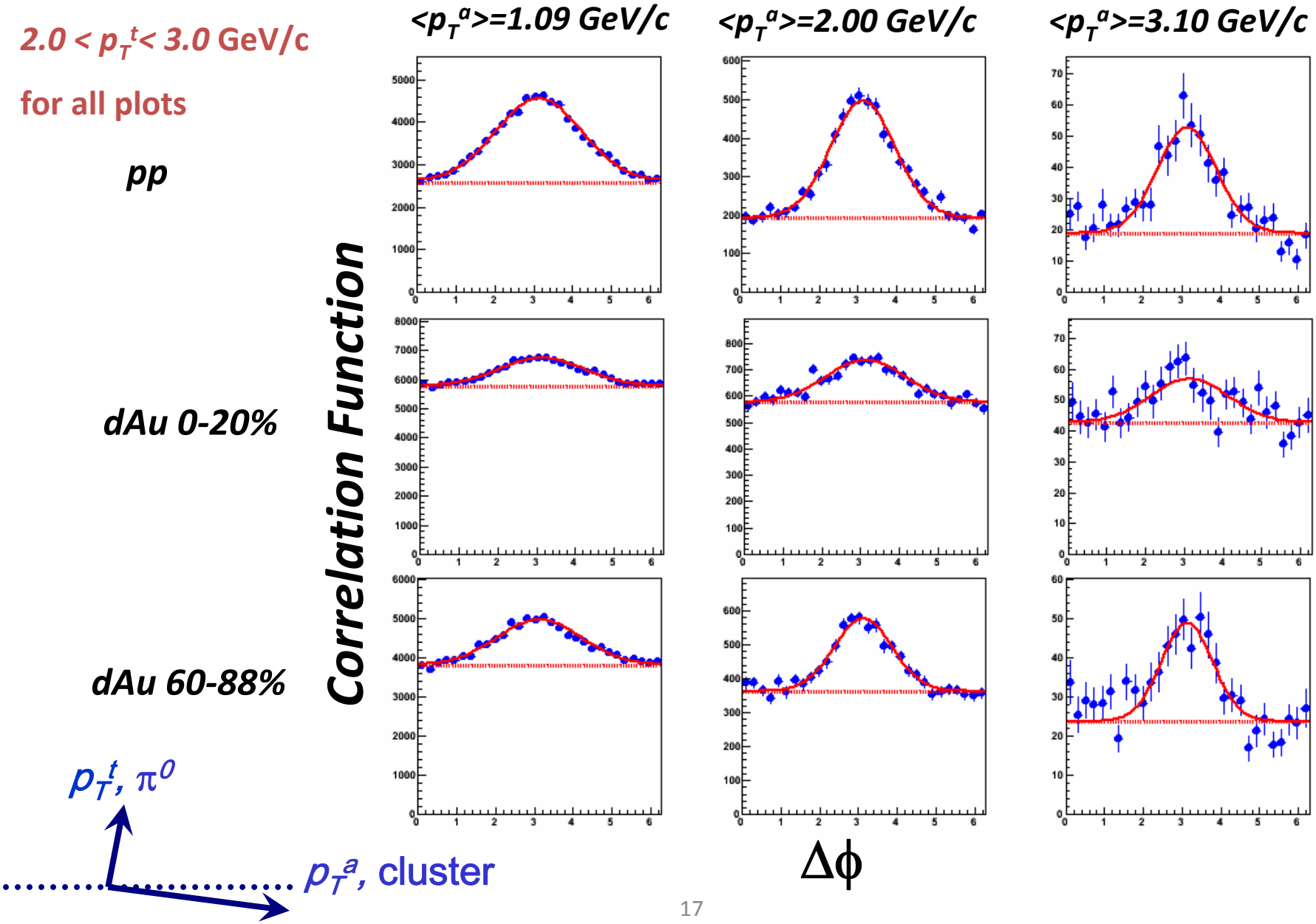
$\Delta\phi$



π^0(trigger,central)/cluster (associate,forward)

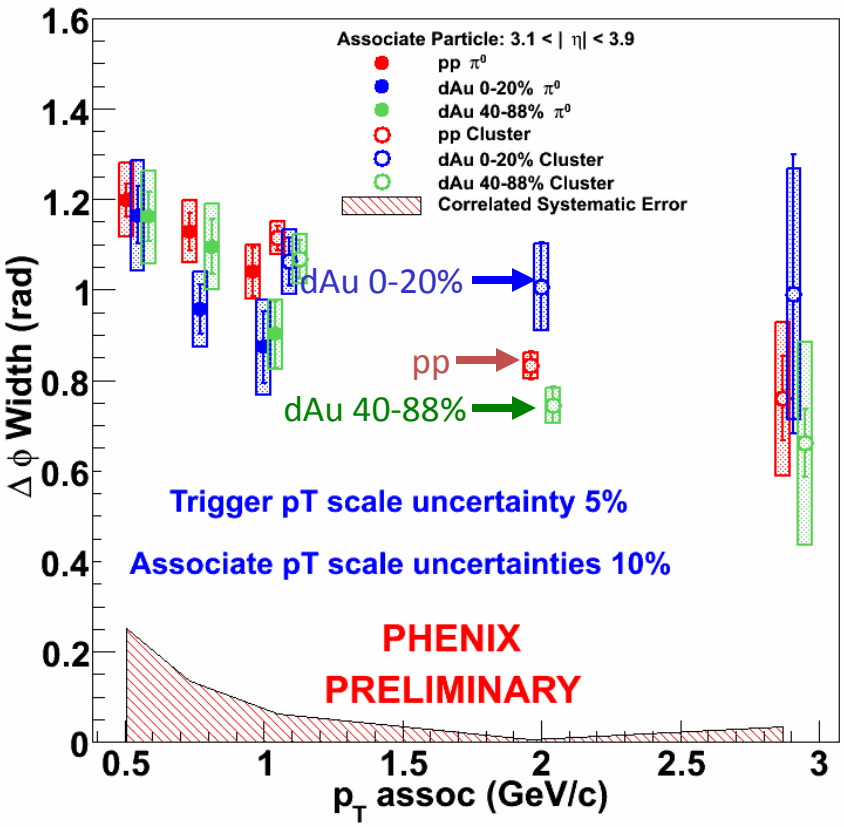
2.0 < p_T^t< 3.0 GeV/c

for all plots

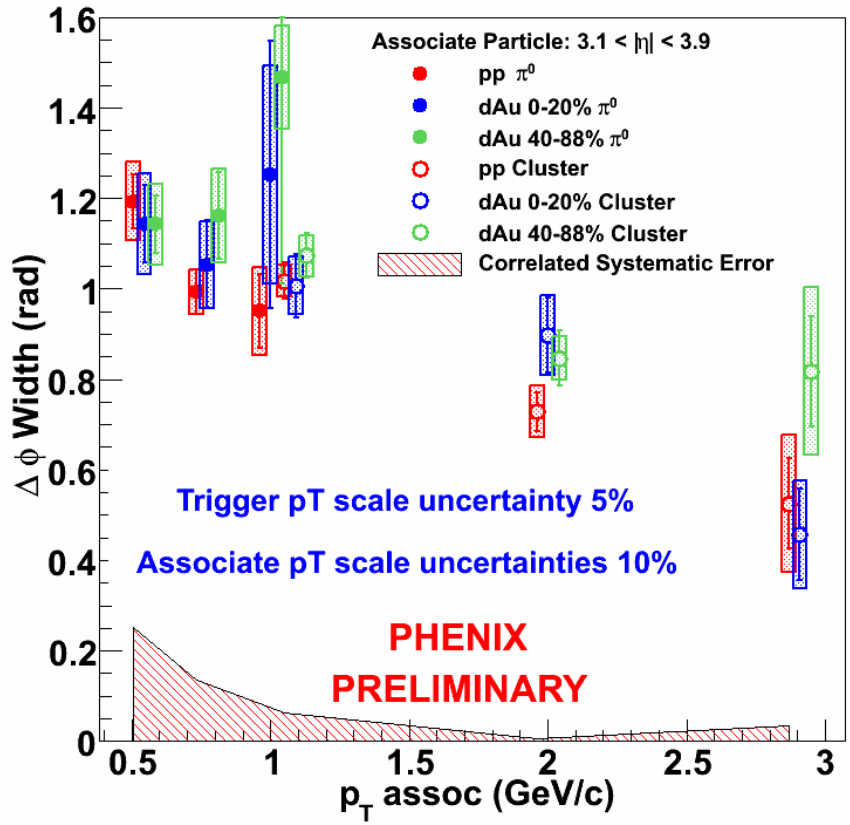


Correlation Widths, d+Au, $\sqrt{s_{NN}}$= *200*GeV

Trigger π^0: $|\eta| < 0.35$, $2.0 < p_T < 3.0$ GeV/c

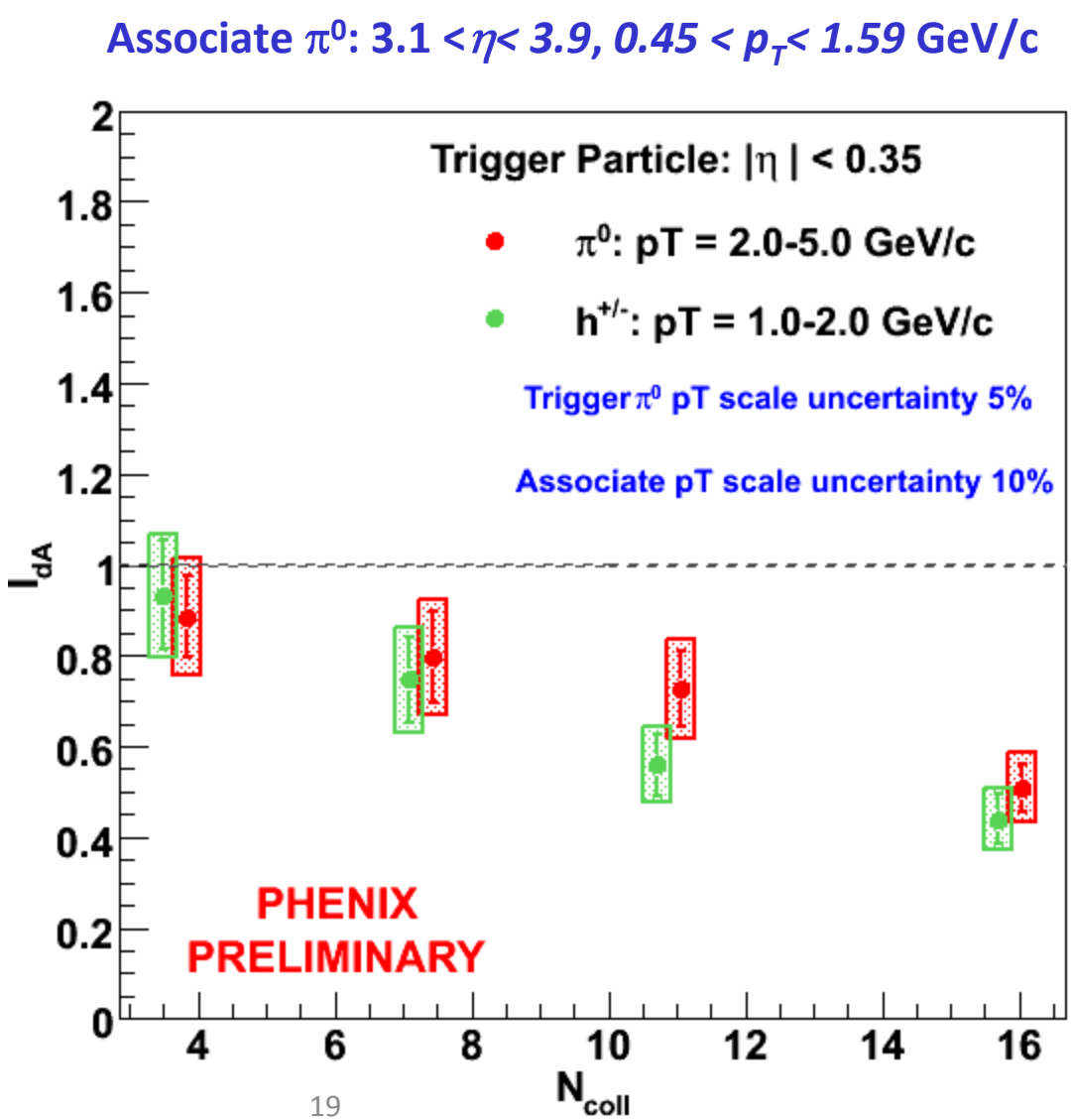


Trigger π^0: $|\eta| < 0.35$, $3.0 < p_T < 5.0$ GeV/c

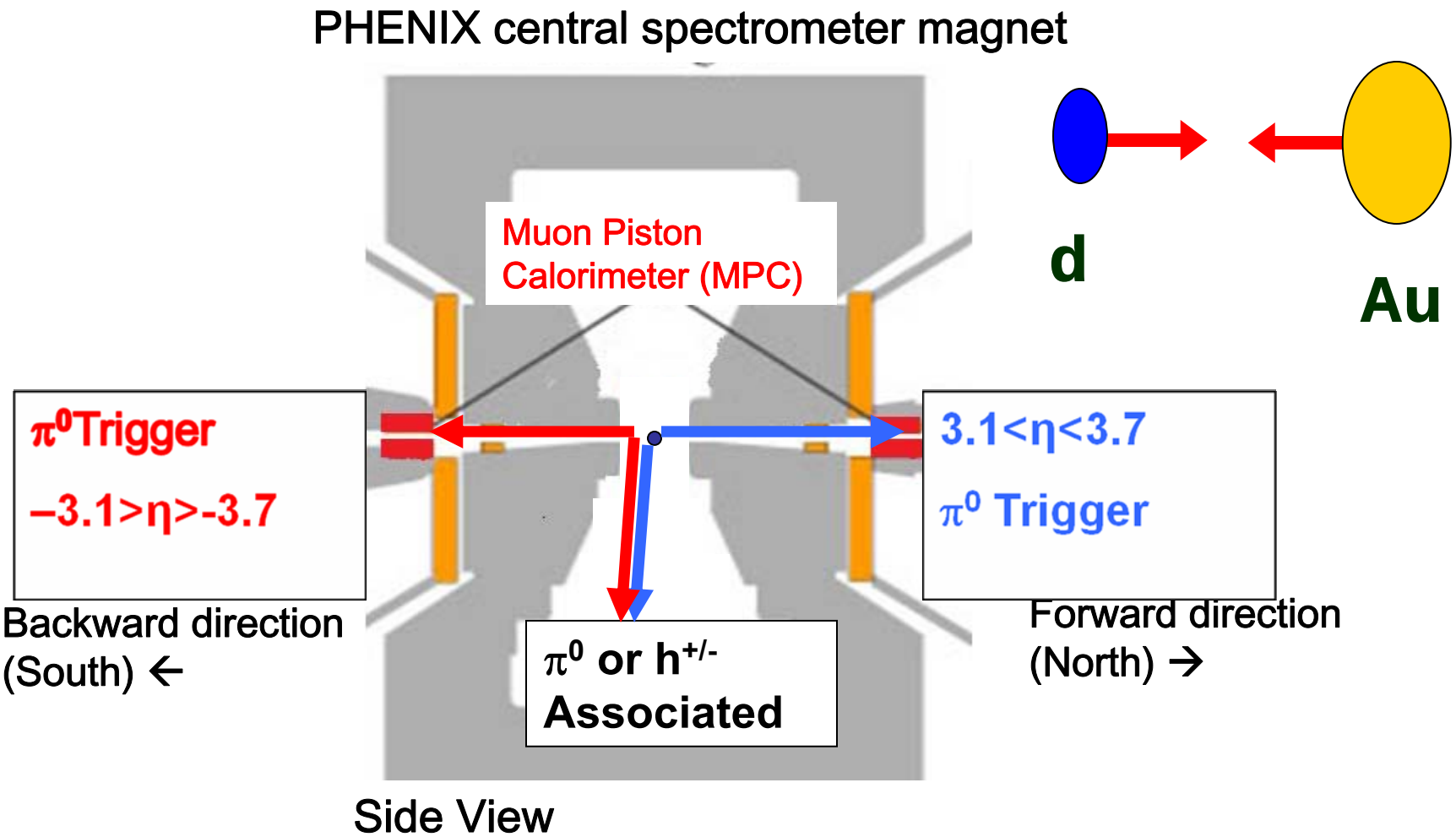


Forward/Central I_{dA} vs N_{coll}

- Increasing suppression of I_{dA} reaches a factor 2 for central events
- Indicates di-jet suppression
- More model calculations are needed
  - Saturation (Color Glass Condensate)
  - Shadowing
  - Others?

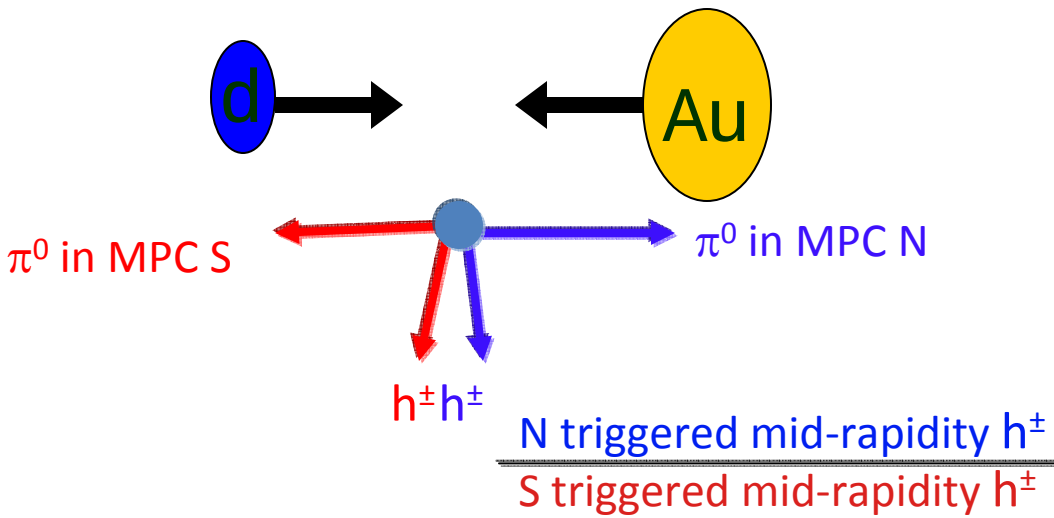


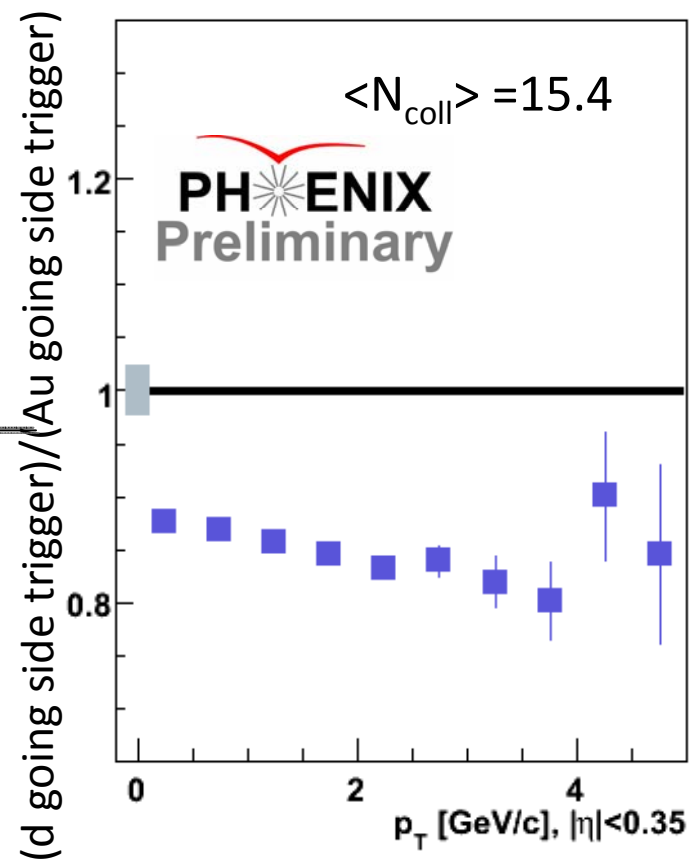
Comparing Forward to Backward



Ratio of d Going Side to Au Going Side Triggered Mid-Rapidity Yields

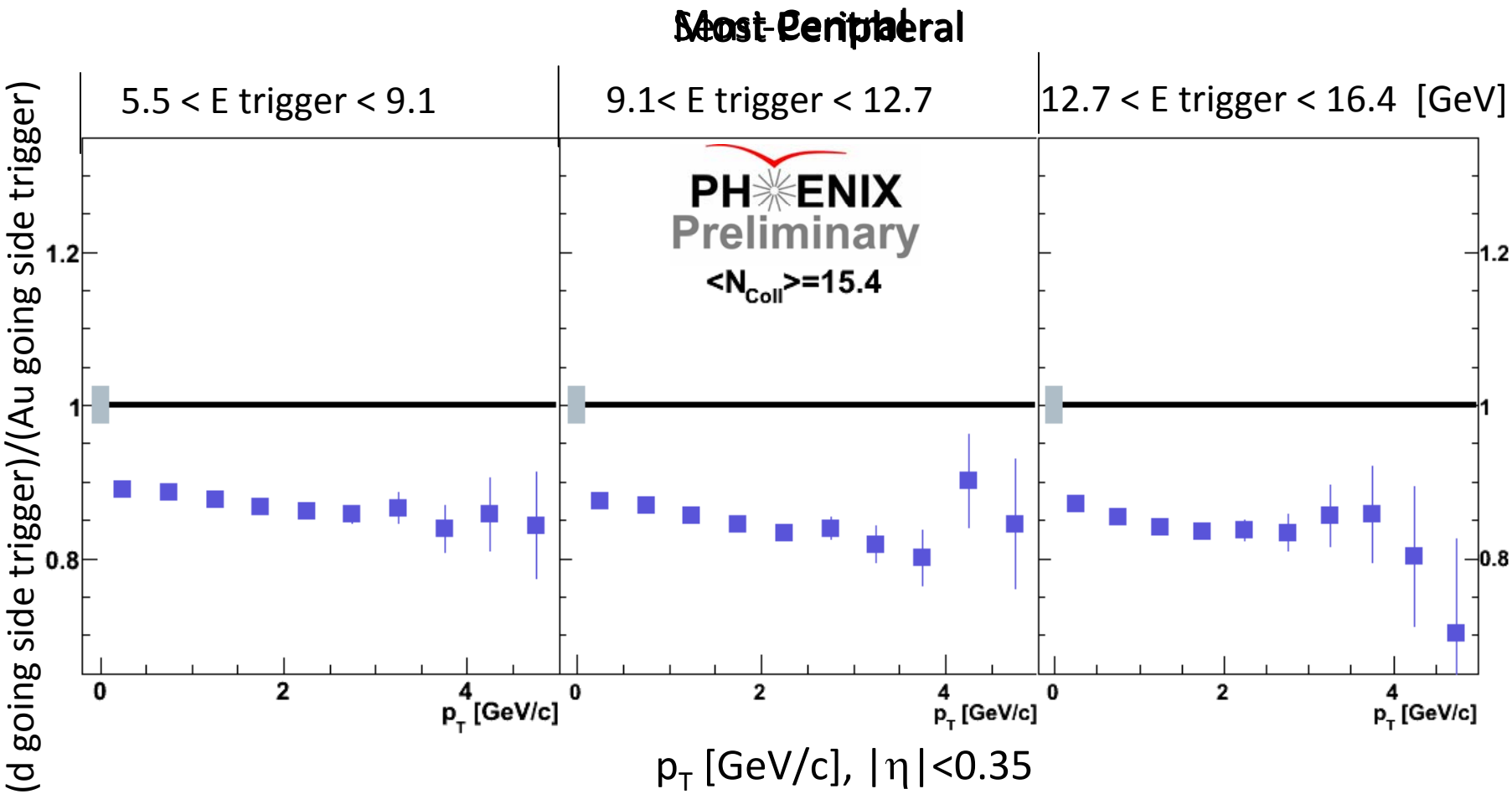
- Most central bin, $\langle N_{coll} \rangle = 15.4$
- π^0 Trigger in MPC with 9.1<E<12.7 GeV





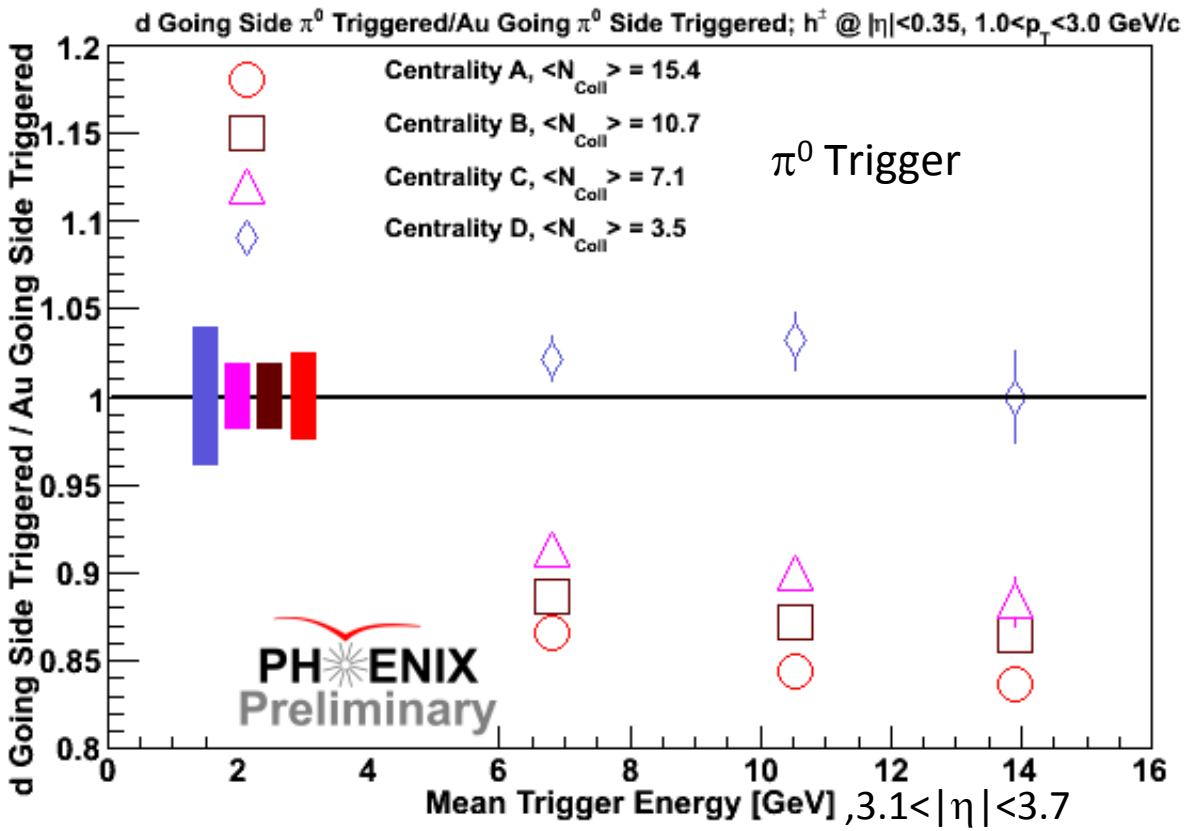
Shadowing, saturation, or other effects may lead to non unity ratio in mid-rapidity trigger associated spectra.

Centrality Dependence of the Ratio



The ratio of d going side to Au going side π^0 triggered inclusive mid-rapidity spectra.

(d side triggered)/(Au side triggered) Ratio Trends

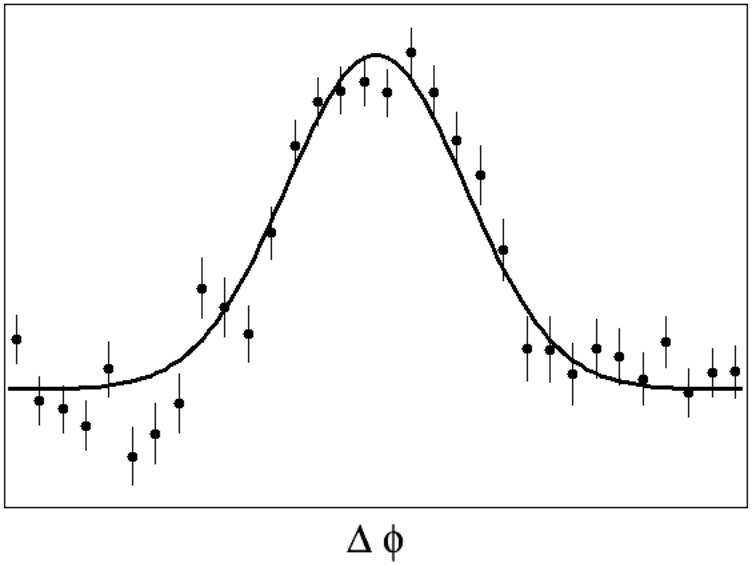


The suppression of the d going side triggered yield relative to the Au going side triggered yield as a function of the trigger energy. (Bands indicate systematic uncertainties from the centrality bias associated with the trigger requirement and possible asymmetries stemming from the higher multiplicity in the Au going side MPC.)

Compare Forward and Backward Triggered Correlated Yields

- Interpretation of the previous ratio is clouded by the uncorrelated part of the yield
- Make similar ratio using correlated yields of forward(backward) – mid-rapidity correlations
- This work is in progress

$1<p_T^{trigger}<2$ GeV/c, $-3.1>\eta^{trigger}>-3.9$
$1<p_T^{associated}<2$ GeV/c, $-0.35<\eta^{associated}<0.35$



Summary and a Look Forward

- Azimuthal angle correlations for rapidity separated hadronpairs: $|\eta| < 0.35$, $1.4<|\eta|<2.0$ and $|\eta|<0.35$, $3.1<\eta<3.9$
  - No significant broadening between d+Auvs pp within experimental precision
  - Suppression of I_{dA} is observed as one goes to more central collisions for larger $\Delta\eta$ correlations
- Comparison of integrated mid-rapidity yields between forward and backward trigger
  - Suppression of yield in d going side trigger compared to Au going side trigger
  - Comparison of correlated yield coming soon…
- Upcoming
  - Scan different $\Delta\eta$ gaps within PHENIX acceptance
  - Forward-Forward correlations to probe the lowest x