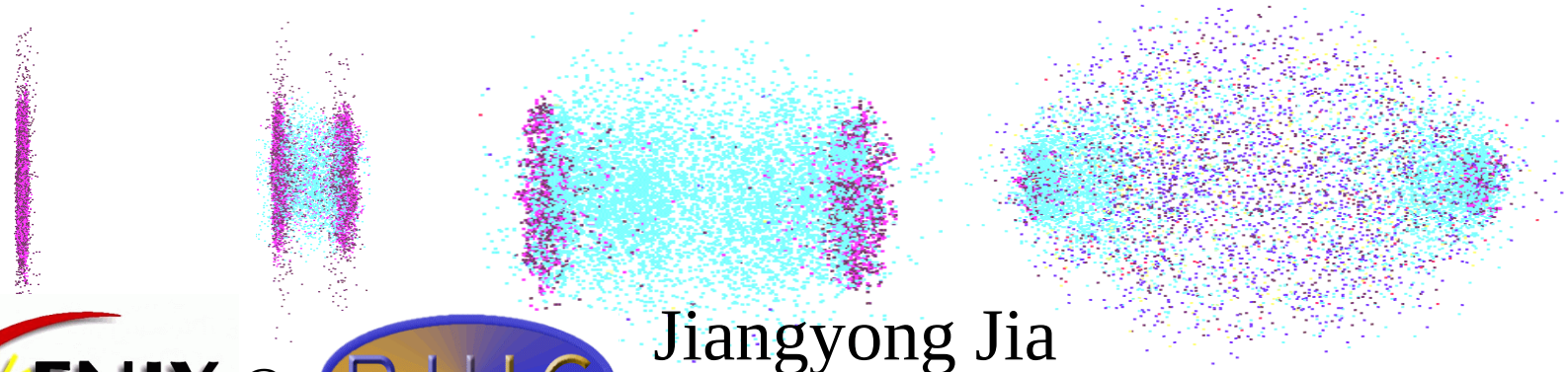
High p_T $\pi^{\pm}$ production and correlation in d+Au/p+p collisions at $\sqrt{s}$ = 200 GeV



Jiangyong Jia

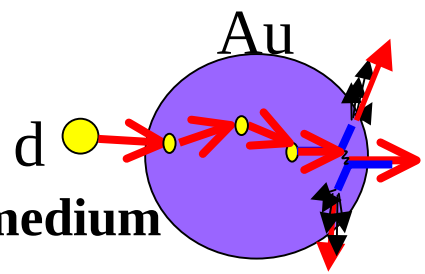
Columbia University

For the **PHENIX** Collaboration

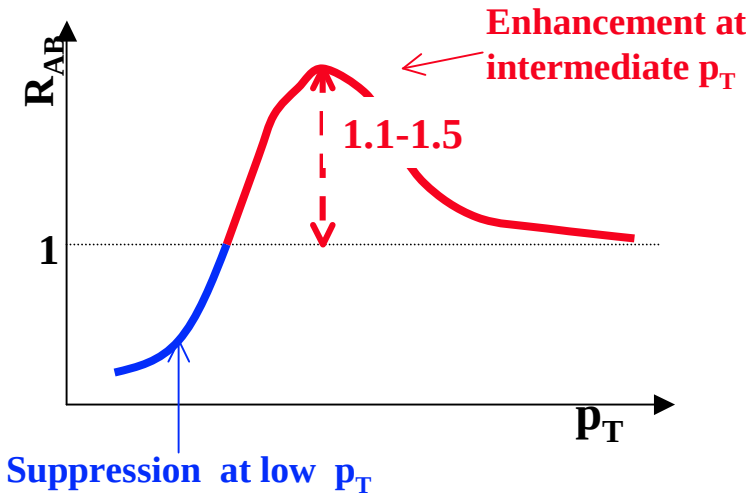
- Motivation
- Experiment setup and analysis
- Result on R_{CP}.
- Result on $\pi^{\pm}$ - $h^{\pm}$ correlation.

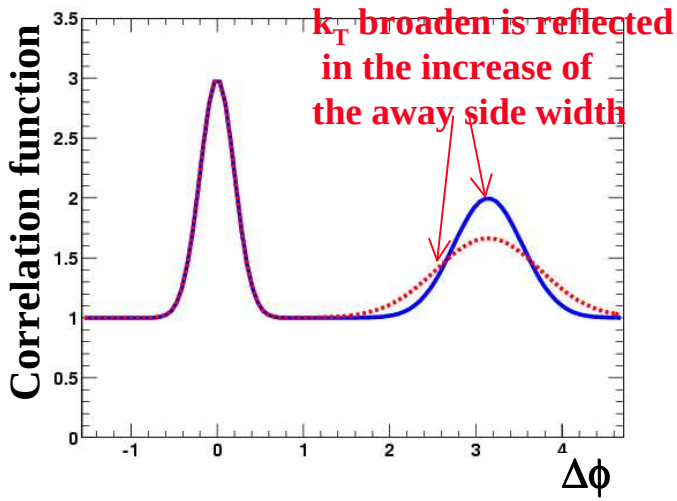
Motivation

- **Jet production in d+Au(pA type) collisions**
  - **Multiple collisions before the hard scattering broaden high pT spectrum,which modify the back-to-back correlation strength.**
  - **This initial state medium effect can be studied by comparing with pp data.**



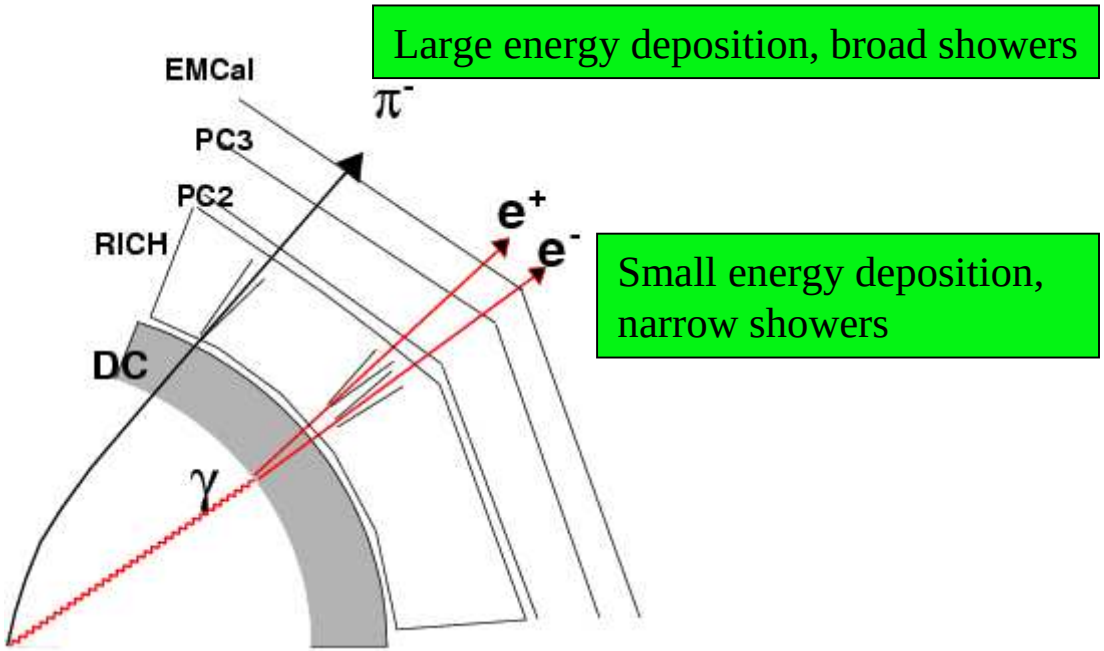
- **Two methods to study the jet modification in cold medium**
  - **Study of inclusive yield: R_{dAu} or R_{CP}**
  - **Study directly the characteristics of jet fragmentation**





High p_T pion identification at PHENIX

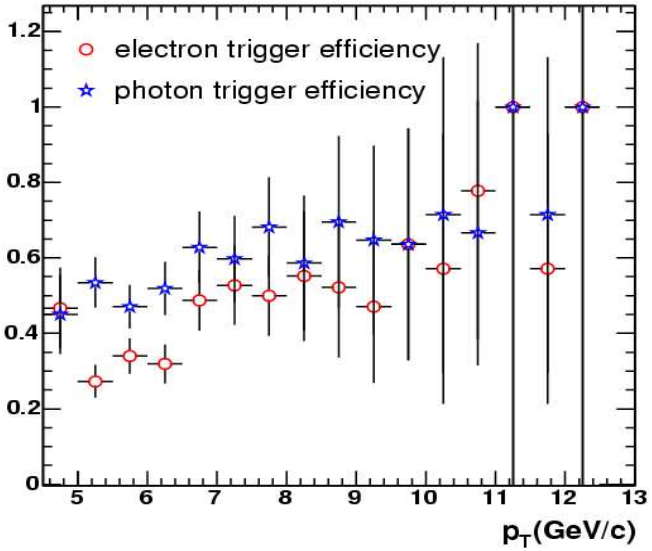
- **Ring Cherekov detector threshold $\gamma \sim 35 \rightarrow$**
  - **4.5 GeV/c for $\pi^{\pm}$, 16 GeV/c for $k^{\pm}$ s.**
- **In principle e/p $<10^{-3}$ for primary particles. However, photon conversions close to the DC can be falsely reconstructed at high p_T.**
- **Background electrons have intrinsically low p_T and the shower shapes in EMCAL are different from hadrons.**
- **Thus these background tracks can be rejected by applying an appropriate energy and shower shape cut.**

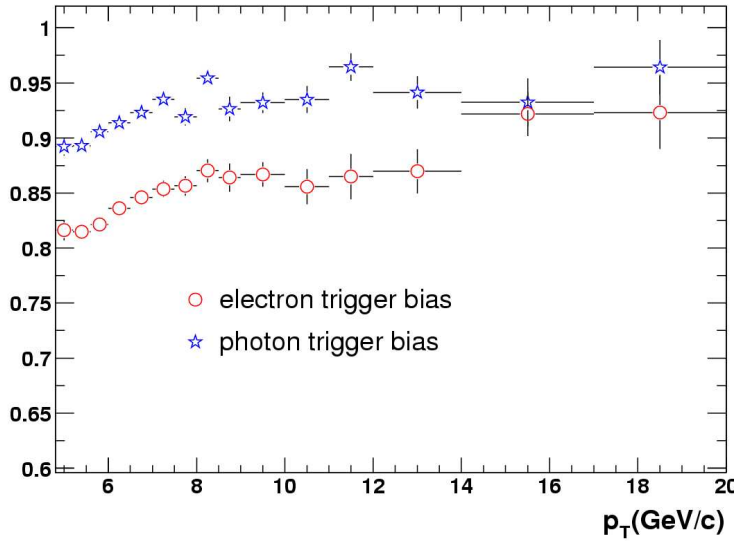


Level 1 triggers for high p_T pions

- **PHENIX have two Level1 triggers that triggers on charge pions.**
  - **ERT electron trigger and ERT photon trigger(F. Kajihara poster)**
  - **Trigger efficiency is p_T dependent.**
  - **Most of the events that containing high p_T pions are fired by the pion(>90% for electron trigger and >80% for photon trigger)**

	Minimum bias	ERT electron trigger	ERT photon trigger
evts(M)	87.14	95.27	48.51
sampled evts(M)	87.14	4359.5	
pions candidates	1651	38280	39627

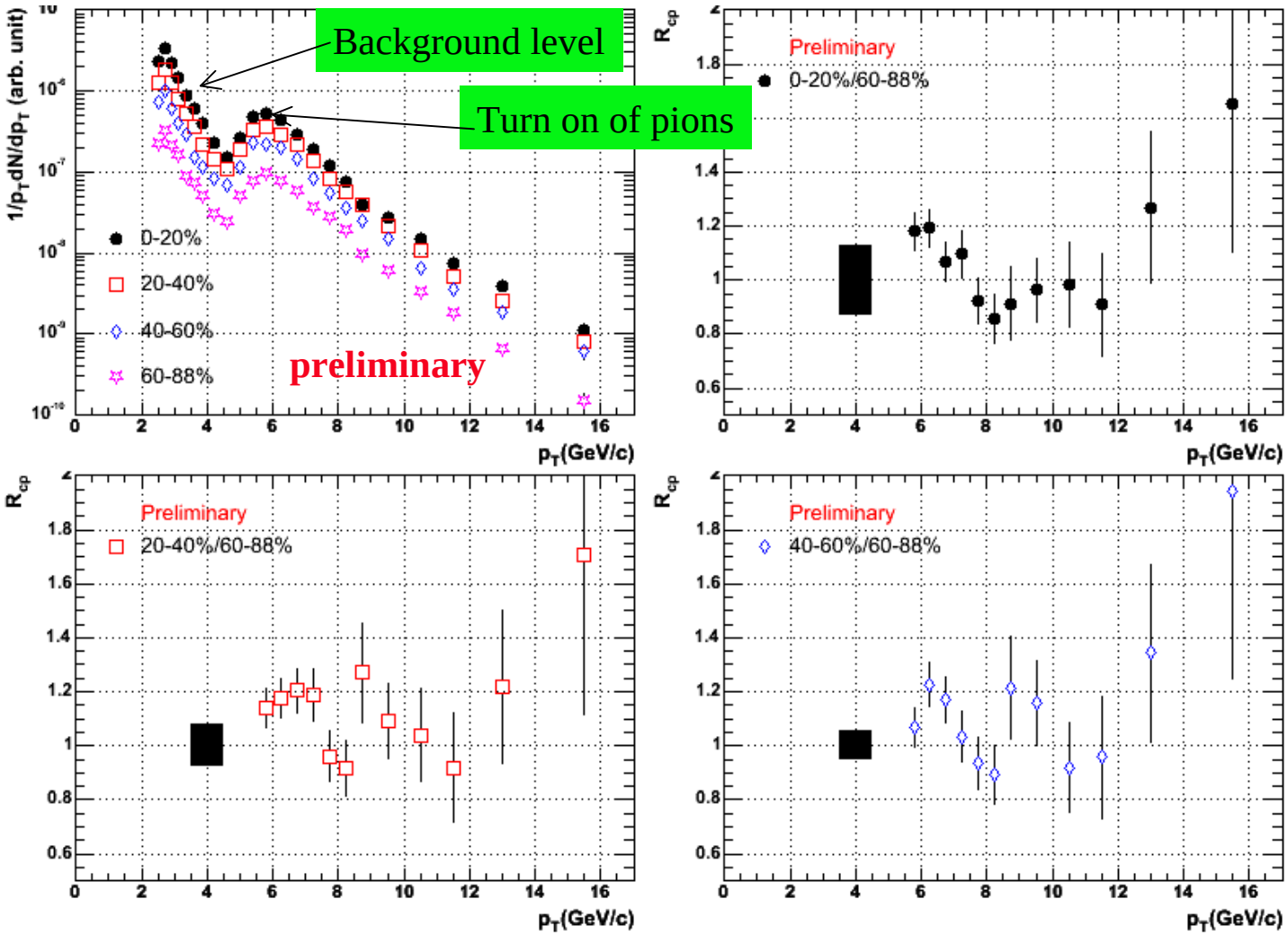




- **We use electron trigger only for the inclusive yield.**
- **We use both triggers for the correlation analysis.**
  - **50% of the pions in photon trigger are not included in electron trigger.**
  - **Total number of high p_T pion candidates : 63795**

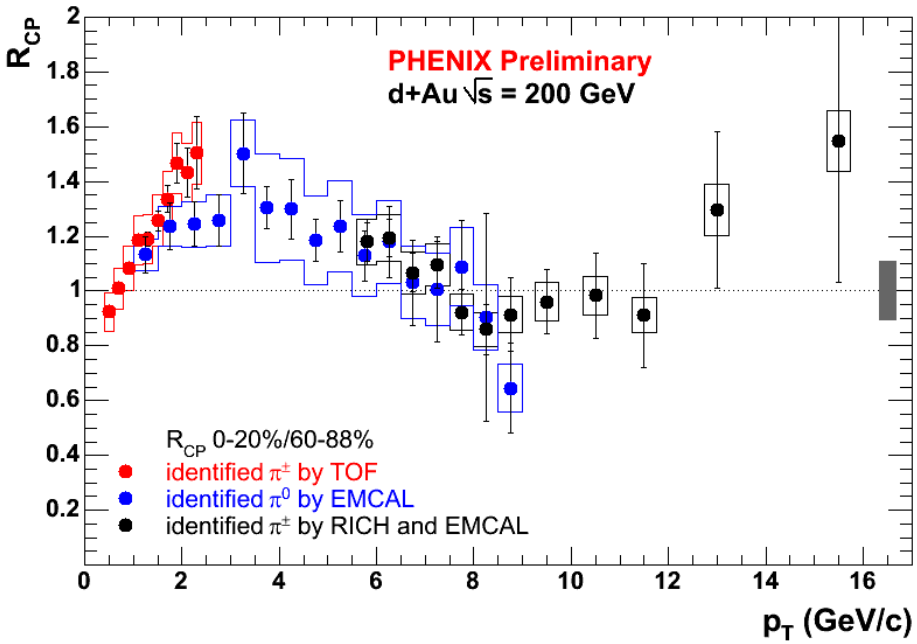
Raw yield and R_{CP}

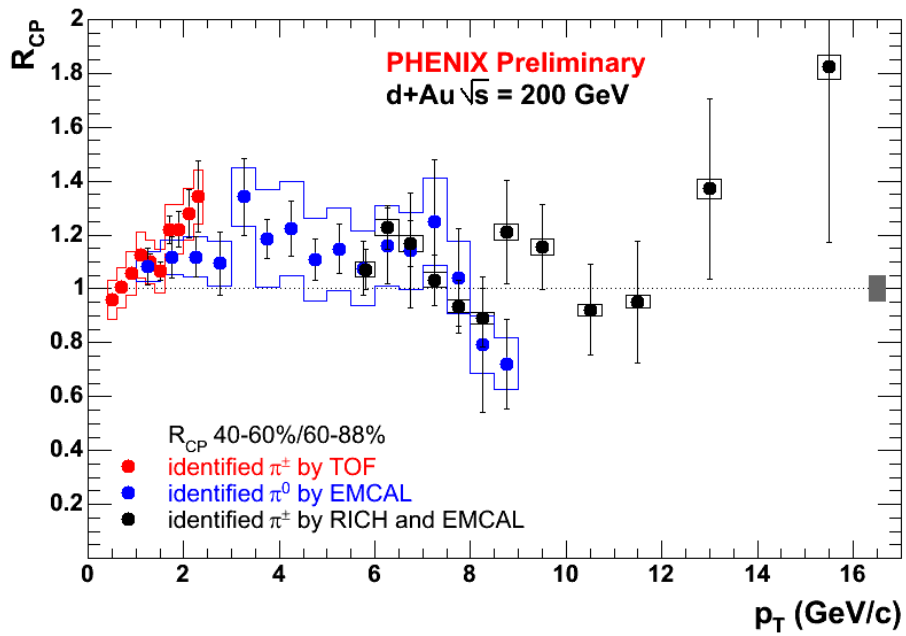
- **Raw yield for several centrality bins.**
  - **Background level is <5% at 6 GeV/c, and <10% for p_T>8 GeV/c.**
- **R_{CP} for 0-20%/60-88%, 20-40%/60-88%, 40-60%/60-88%**
- **Left black bar is the systematic errors(overall scale error)**



Compilation of d+Au pion R_{cp} in mid-rapidity

- **Error are:**
  - **Solid marker(data)**
  - **box (stat error and point to point systematic error)**
  - **Bar at right band (error on ratio of Ncoll)**
- **For the first time, we have mapped out the p_T and centrality dependence of Cronin effect in d+Au by combining results from three independent analysis.**
- **Croning enhancement peaks around 2-4 GeV/c and become negligible around 6-8 GeV/c.**

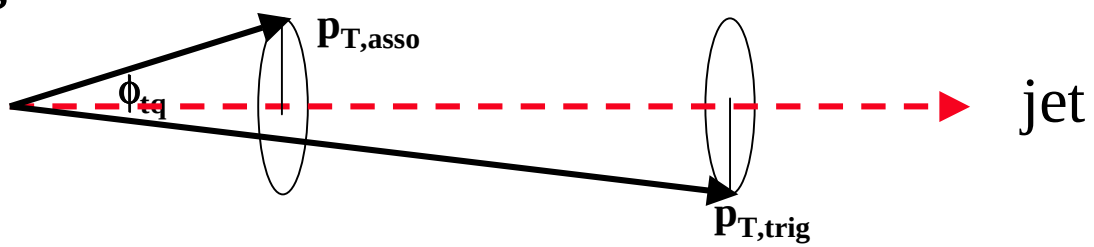




Kinematics of jet fragmentation

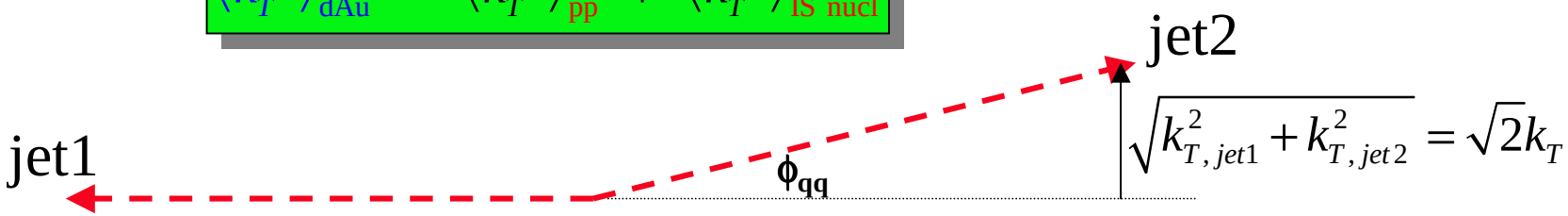
Partons have to fragments into colorless fragments.

- $\vec{j}_T$ **is the transverse momentum of jet fragments, it is connected to the width $\sigma \sim j_T/p_T$. It is constant independent of fragment p_T, characteristic of jet fragmentation.**



- $\vec{k}_T$ **is the transverse momentum carried by the partons before hard scattering. It is responsible for the acoplanarity of back-to-back correlation. And it carries the information on the parton interaction with QCD medium.**
  - **Since fragment only carry a fraction z of the jet momentum, the fragment is sensitive only to z k_T.**

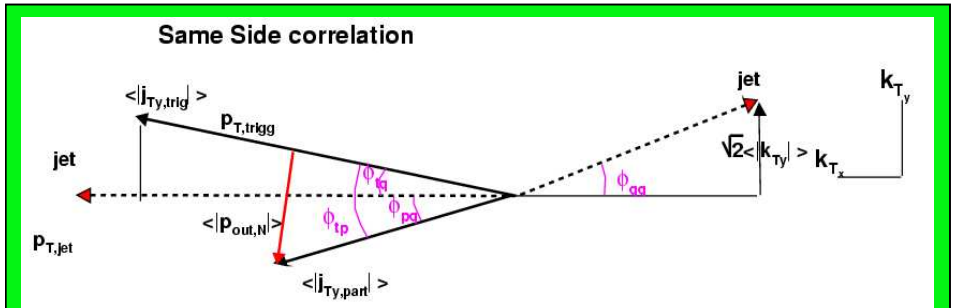
$$\langle k_T^2 \rangle_{dAu} = \langle k_T^2 \rangle_{pp} + \langle k_T^2 \rangle_{IS\ nucl}$$



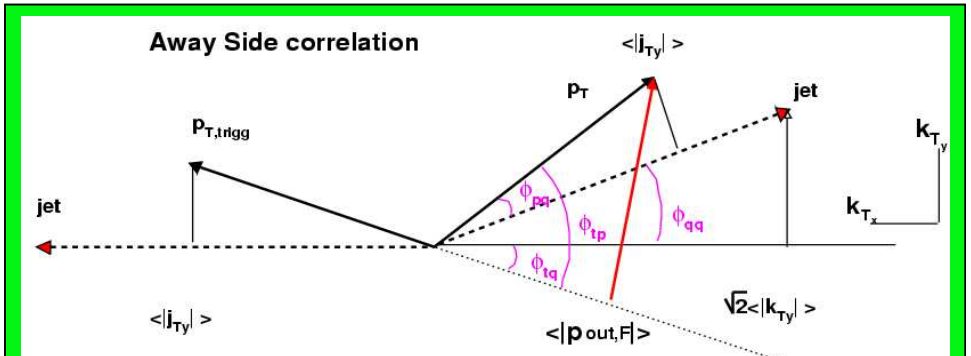
- **j_T and k_T are 2D vectors. We measure the mean value of its projection into the transverse plane $\langle |j_{Ty}| \rangle$ and $\langle |k_{Ty}| \rangle$**

Extraction of j_T and k_T

- **Define angle between: jet–jet(ϕ_{qq}), leading–jet(ϕ_{tq}), fragment –jet(ϕ_{pq})**
  - **ϕ_{tq} and ϕ_{pq} are sensitive to j_T, ϕ_{qq} is sensitive to k_T.**
  - **same side: $\phi_{tp} = \phi_{tq} \oplus \phi_{pq}$ away side: $\phi_{tp} = \phi_{tq} \oplus \phi_{pq} \oplus \phi_{qq}$.**



$$\langle | p_{out,N} | \rangle^2 \approx \langle j_{Ty} \rangle^2 + \langle x_h \rangle^2 \langle j_{Ty} \rangle^2$$



$$\langle | p_{out,F} | \rangle^2 \approx \langle j_{Ty} \rangle^2 + \langle x_h \rangle^2 [\langle j_{Ty} \rangle^2 + 2 z_{trig}^2 \langle k_{Ty} \rangle^2]$$

$$x_h = \frac{p_{T,part}}{p_{T,trig}}$$

- **We measure the two particle correlations width σ for ϕ_{tp}, which is directly related to the projection of fragment p_T onto leading particle $p_{out}=p_T \sin\phi_{tp}$,**

$$\langle p_{out} \rangle^2 = \langle p_T^2 \sin^2 \phi_{tp} \rangle \simeq \langle p_T^2 \rangle (\sin \sigma^2 - \sigma^4 + 19/6\sigma^6)$$ Good for σ<1 rad

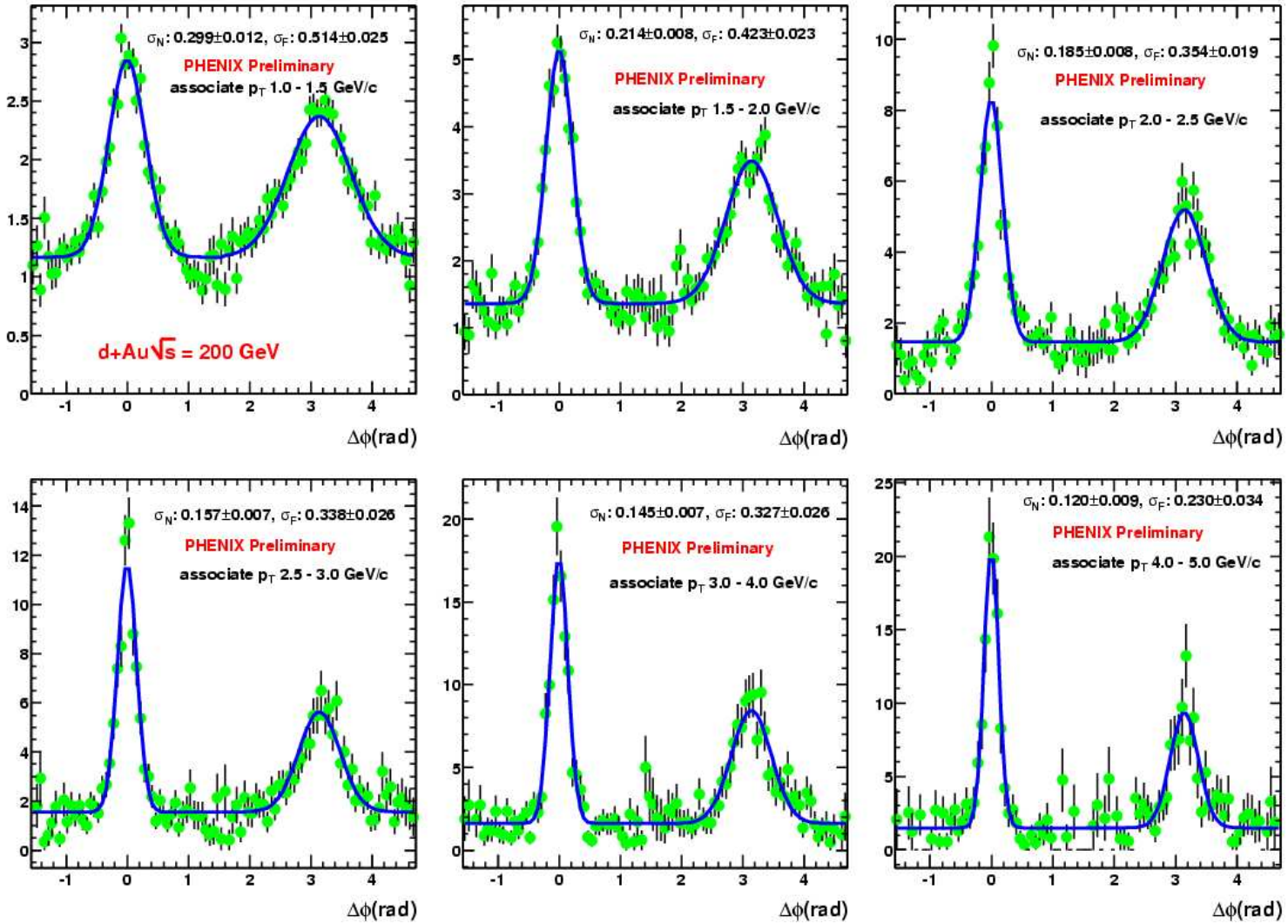
- **The j_T and $z\ k_T$ are directly related to p_{out}.**

$$\langle | j_{Ty} | \rangle = \frac{\langle | p_{out,N} | \rangle}{\sqrt{1 + x_h^2}}$$

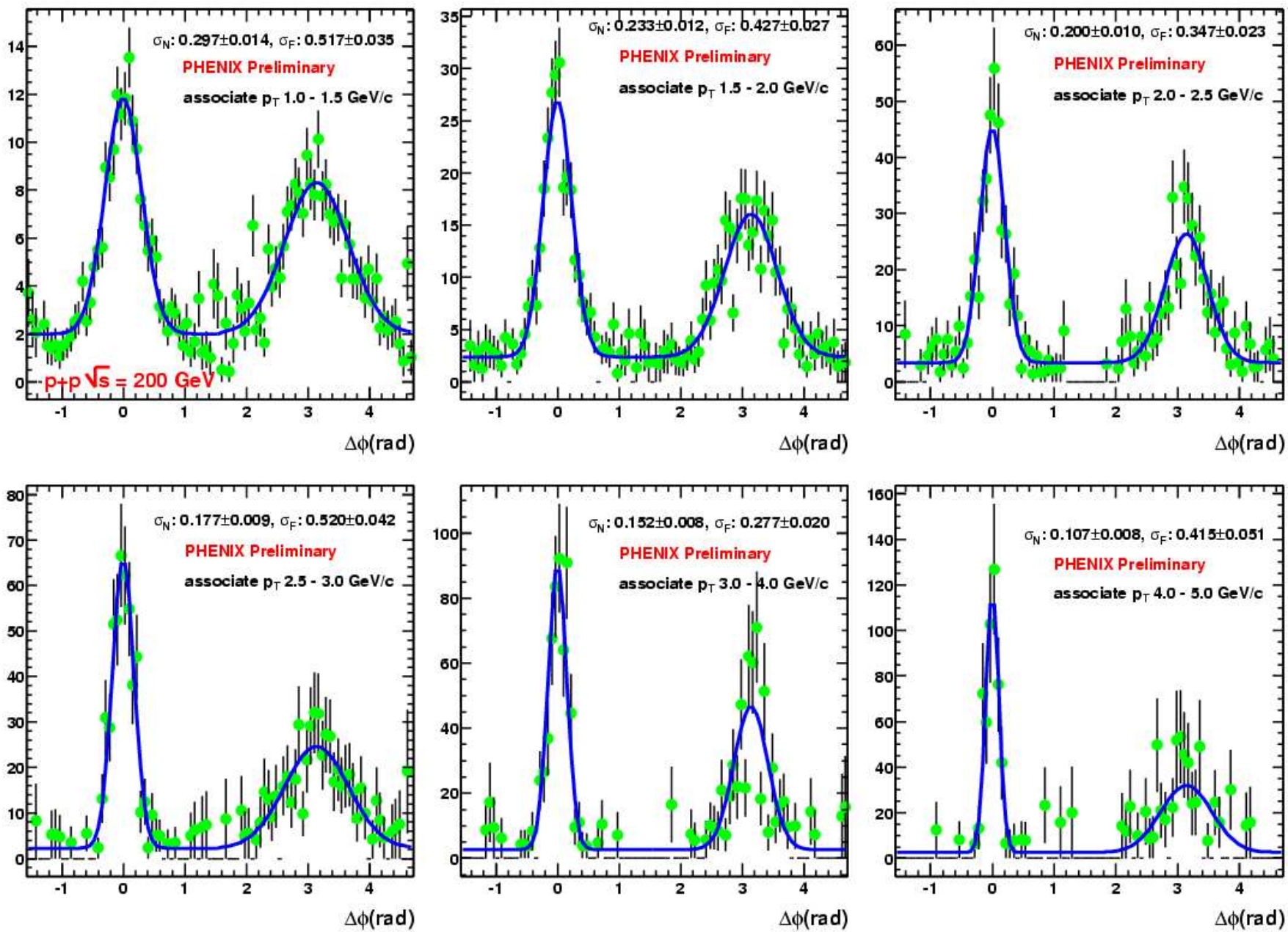
$$z_{trig} \langle | k_{Ty} | \rangle = \sqrt{\frac{\langle | p_{out,F} | \rangle^2 - \langle | p_{out,N} | \rangle^2}{2 x_h^2}}$$

$\pi^{\pm}$ - $h^{\pm}$ Correlation

- **Correlating $\pi^{\pm}$ (5<pt<16 GeV/c) with low p_T charged hadrons (1-5 GeV/c).**
- **The advantage is:**
  - **very good signal/background ratio.**
  - **acceptance effect is small.**

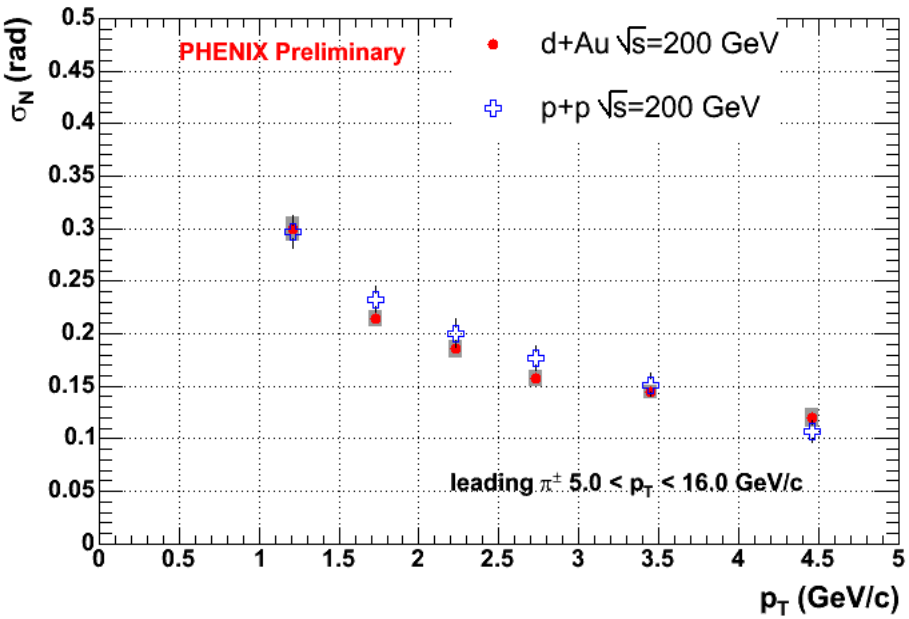


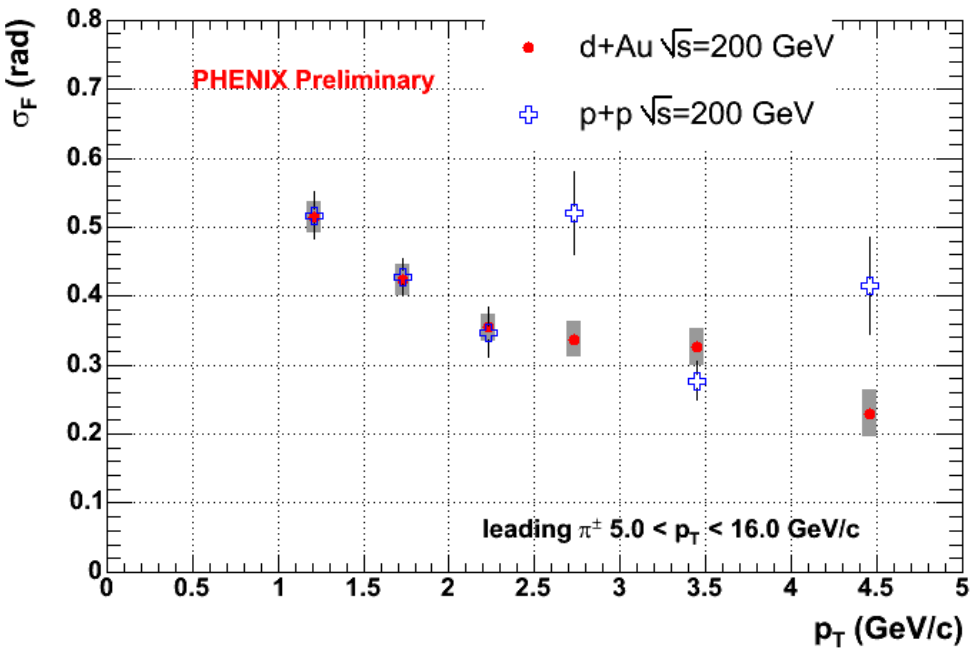
$\pi^{\pm}$ - $h^{\pm}$ Correlation in p+p



Width for d+Au and p+p

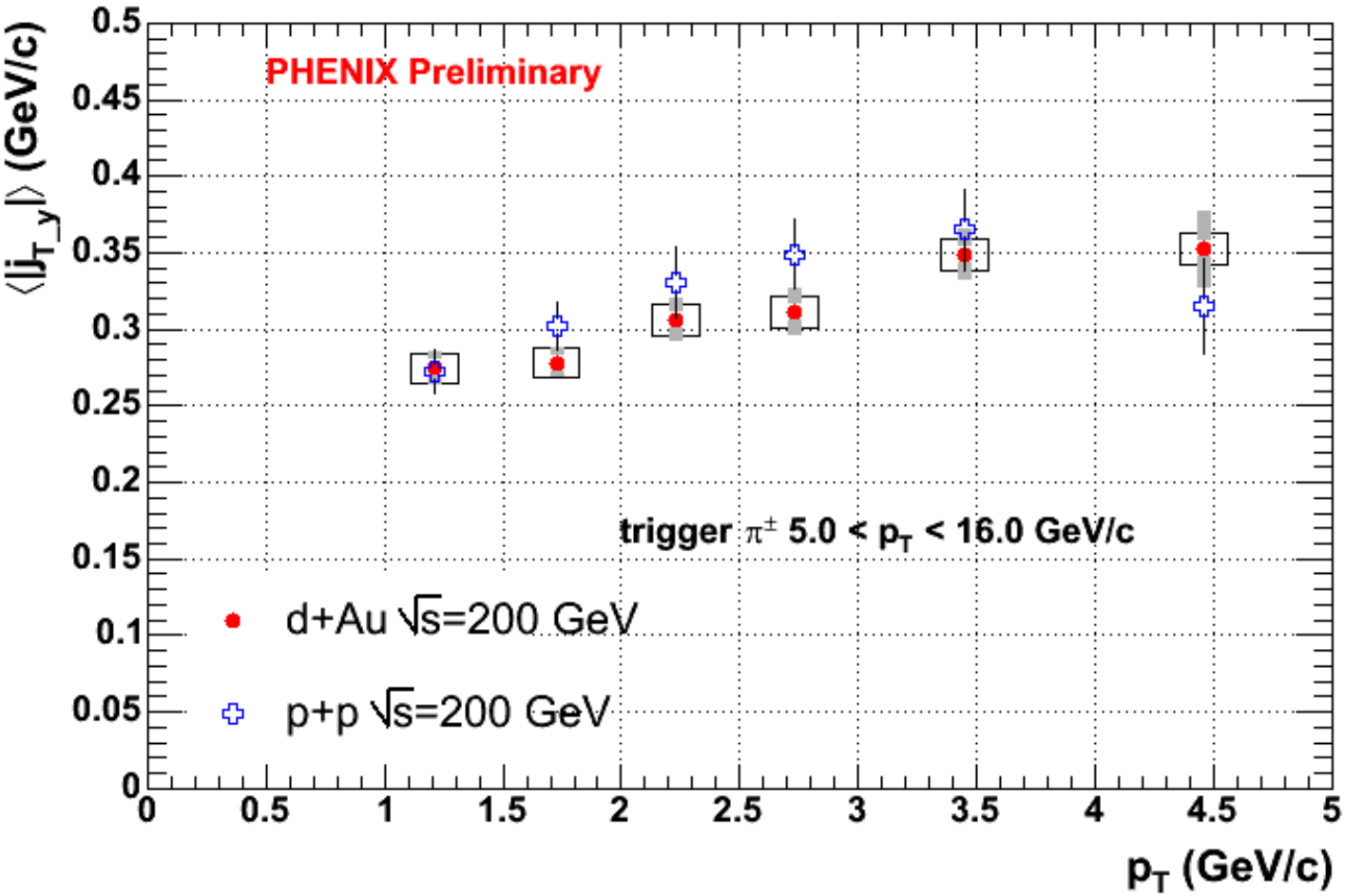
- **Width of the correlation function for 5-16 GeV/c trigger particle to various low p_T associated particles**
- **Both near side and far side width drops as function of associated particle p_T.**





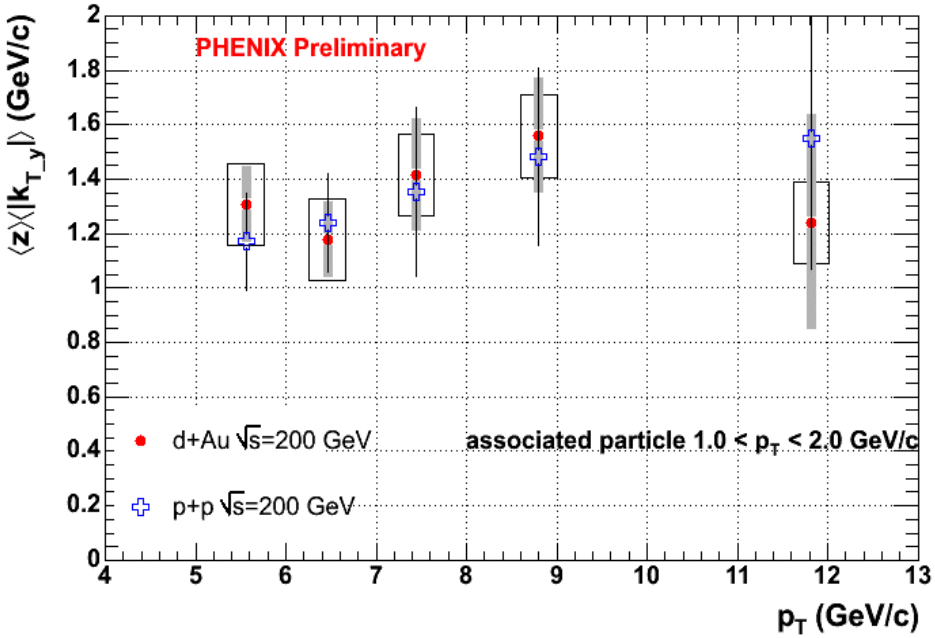
j_T results in d+Au and p+p

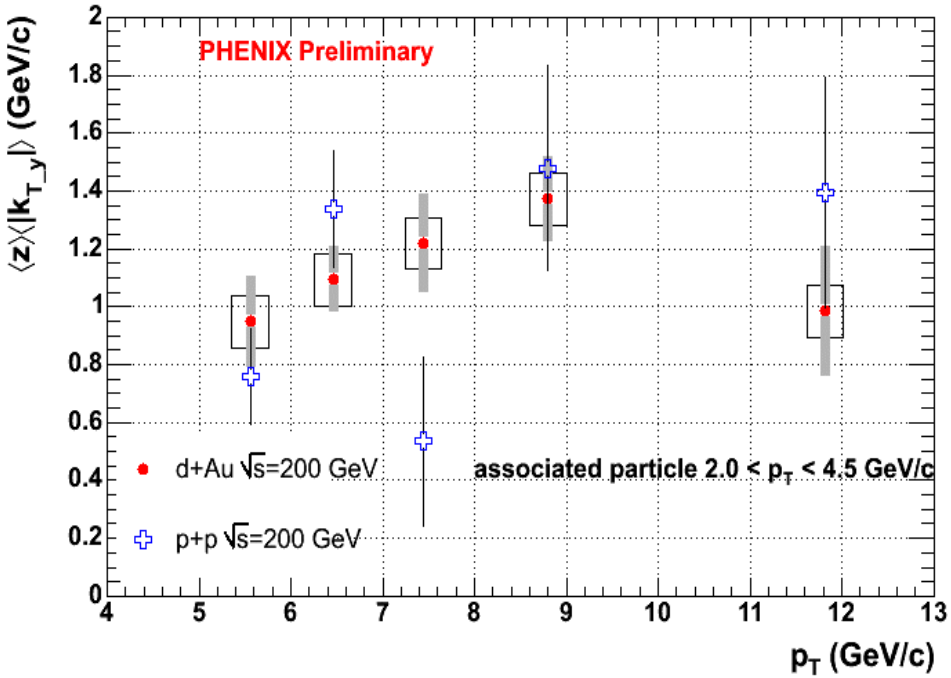
- Calculated j_T width for associated $h^{\pm}$.
- We assumed j_T follows gauss distribution. Physically, since j_T can not exceed p_T of the fragment. This leads to a truncation of the gauss tail, this effect leads to a slight drop at low p_T.
- No difference between d+Au and p+p



$\langle z \rangle \langle |k_{Ty}| \rangle$ in d+Au and p+p

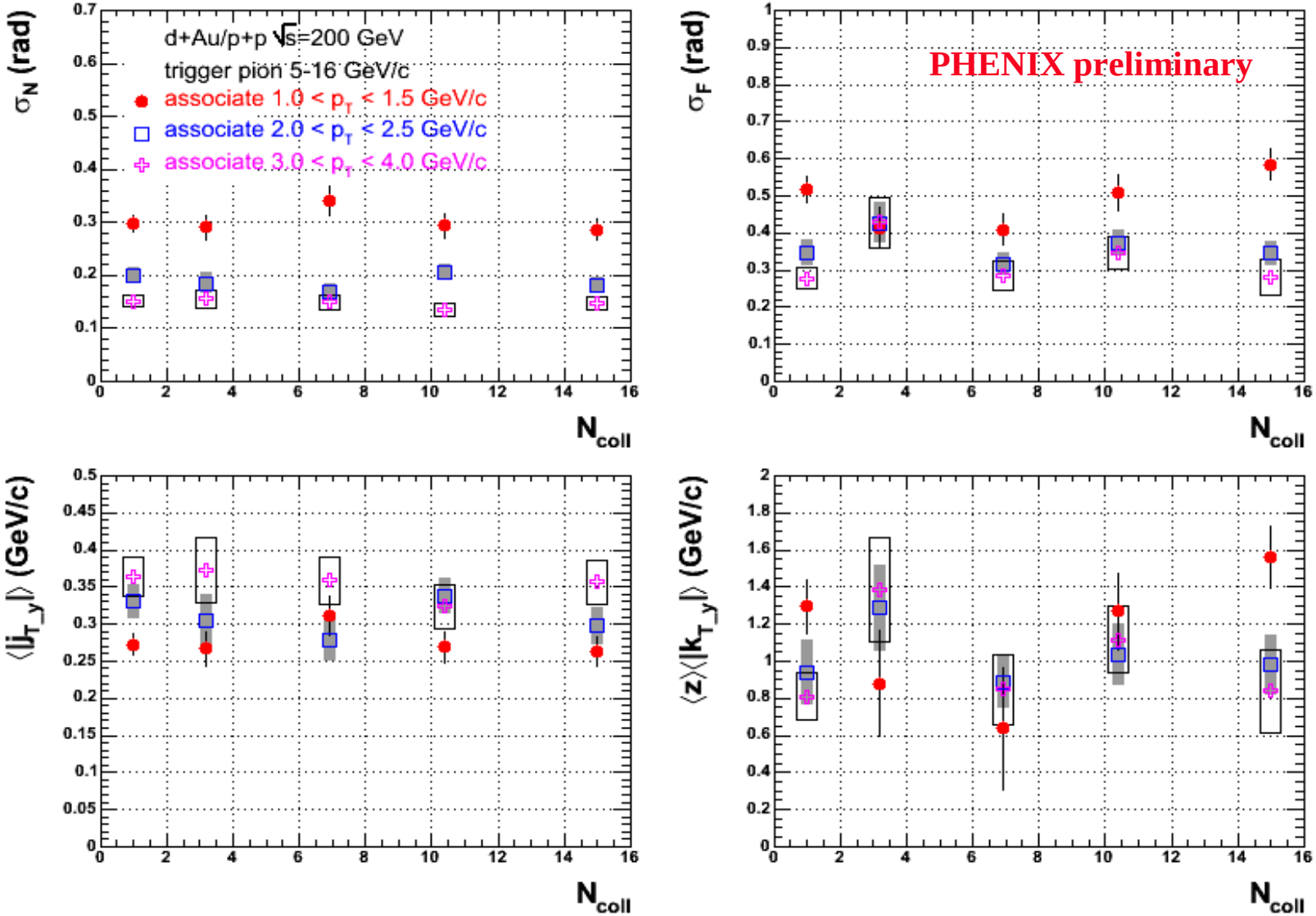
- We measures the $\langle z \rangle \langle |k_{Ty}| \rangle$ for trigger high p_T pions for different associated particle p_T range.
- For a simple power law spectra $\frac{dN}{p_T\, dp_T} = \left(\frac{p_0}{p_T}\right)^n$, assuming fragmentation function have the form $D(z) = e^{-6z}$, one find that $\langle z \rangle \approx 0.76$ independent of p_T. So one can get the $\langle |k_{Ty}| \rangle$ by dividing $\langle z \rangle \langle |k_{Ty}| \rangle$ by 0.76
- d+Au and p+p are consistent.





Centrality dependence

- Plot the σ_N, σ_F , $\langle|j_{Ty}|\rangle$ and $\langle z\rangle\langle|k_{Ty}|\rangle$ as function of centrality for different associated particle p_T ranges.
- No apparent centrality dependence is observed.



Summary

- **We have presented high p_T charged pion R_{CP} and it's centrality dependence in d+Au collisions.**
  - **Slight drop as function of p_T for p_T<8 GeV/c.**
  - **Consistent with 1 at p_T>8 GeV/c.**
  - **Complete picture of the p_T and centrality dependence of Cronin effect**

- **We have studied the characteristics of jet fragmentation and back-to-back correlation through $\pi^{\pm}$ - $h^{\pm}$ correlation in d+Au and p+p collisions.**
  - **σ_N, σ_F , $\langle|j_{Ty}|\rangle$ and $\langle z\rangle \langle|k_{Ty}|\rangle$ have no apparent centrality dependence.**
  - **No apparent difference between d+Au and p+p**
  - **$\langle|j_{Ty}|\rangle \approx 350 \pm 30$MeV/c.**
  - **$\langle z\rangle \langle|k_{Ty}|\rangle \approx 1.2 \pm 0.2(\text{stat}) \pm 0.2(\text{sys})$ GeV/c**