Recent High-p_T Results from *STAR*

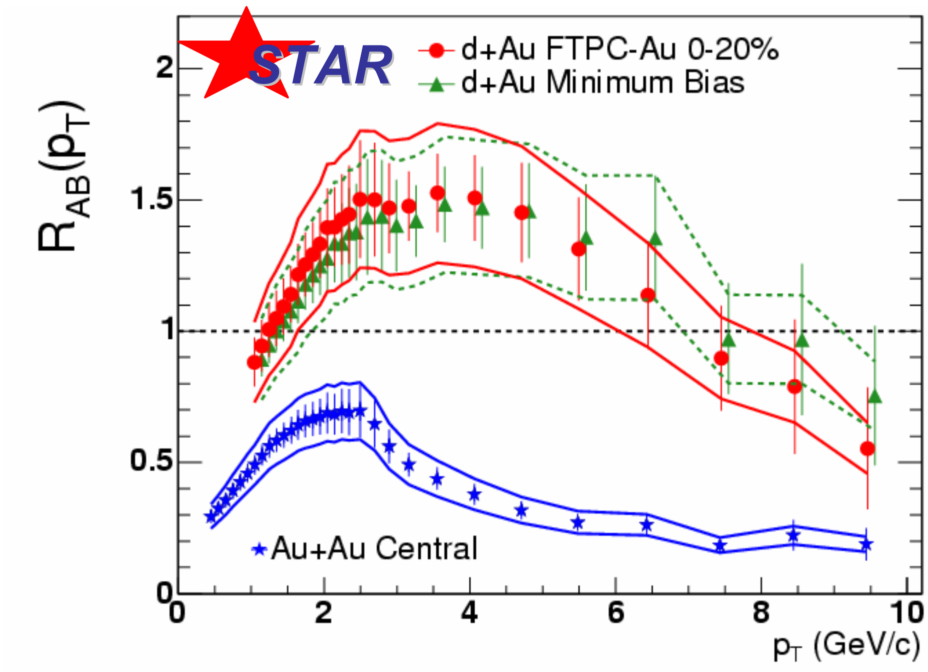
Carl A. Gagliardi

Texas A&M University

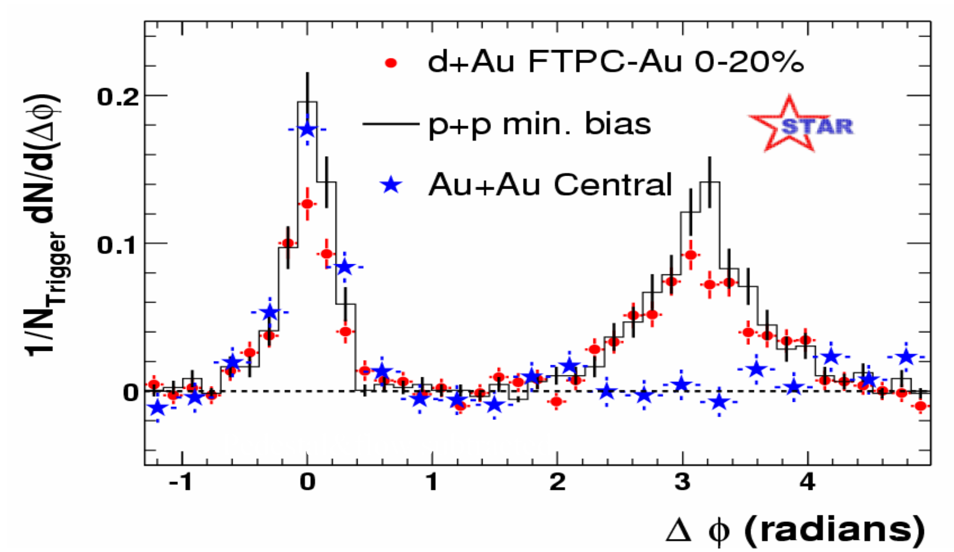
for the *STAR* **Collaboration**

- Introduction
- Spectra
- Elliptic flow
- Correlations
- Forward physics

What We Know – Jet Quenching



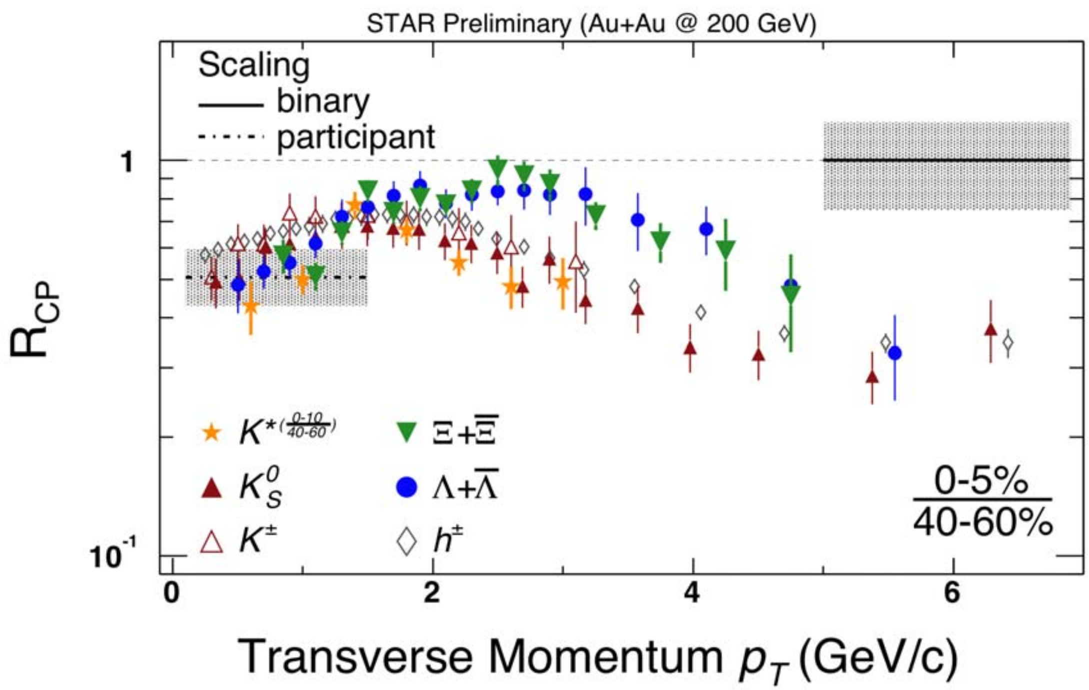
Phys. Rev. Lett. 91, 072304 (2003).

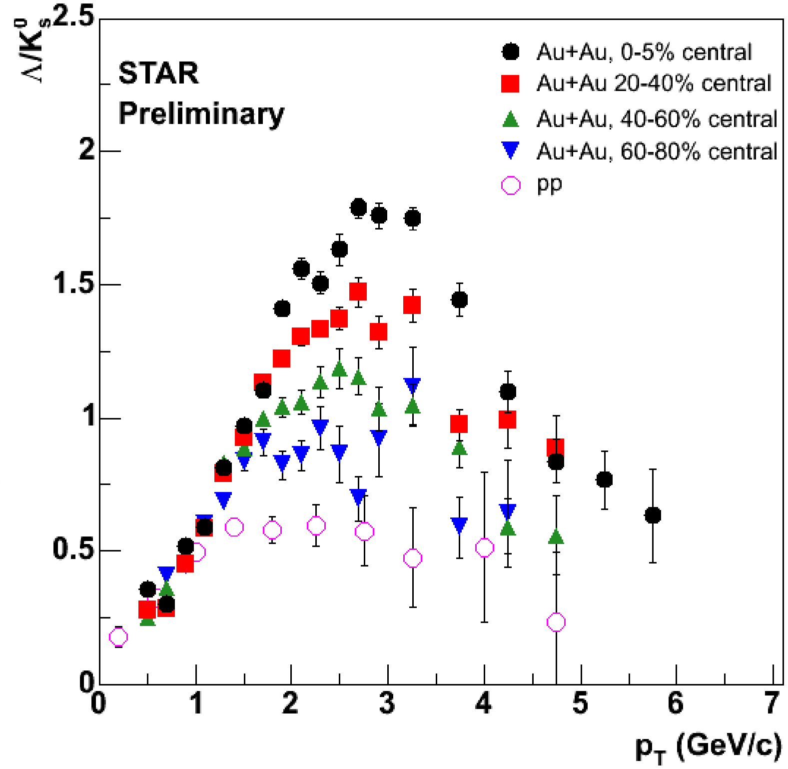


Inclusive yields and back-to-back di-hadron correlations are very similar in p+p and d+Au collisions

Both are strongly suppressed in central Au+Au collisions at 200 GeV

What We Know – Baryon Enhancement

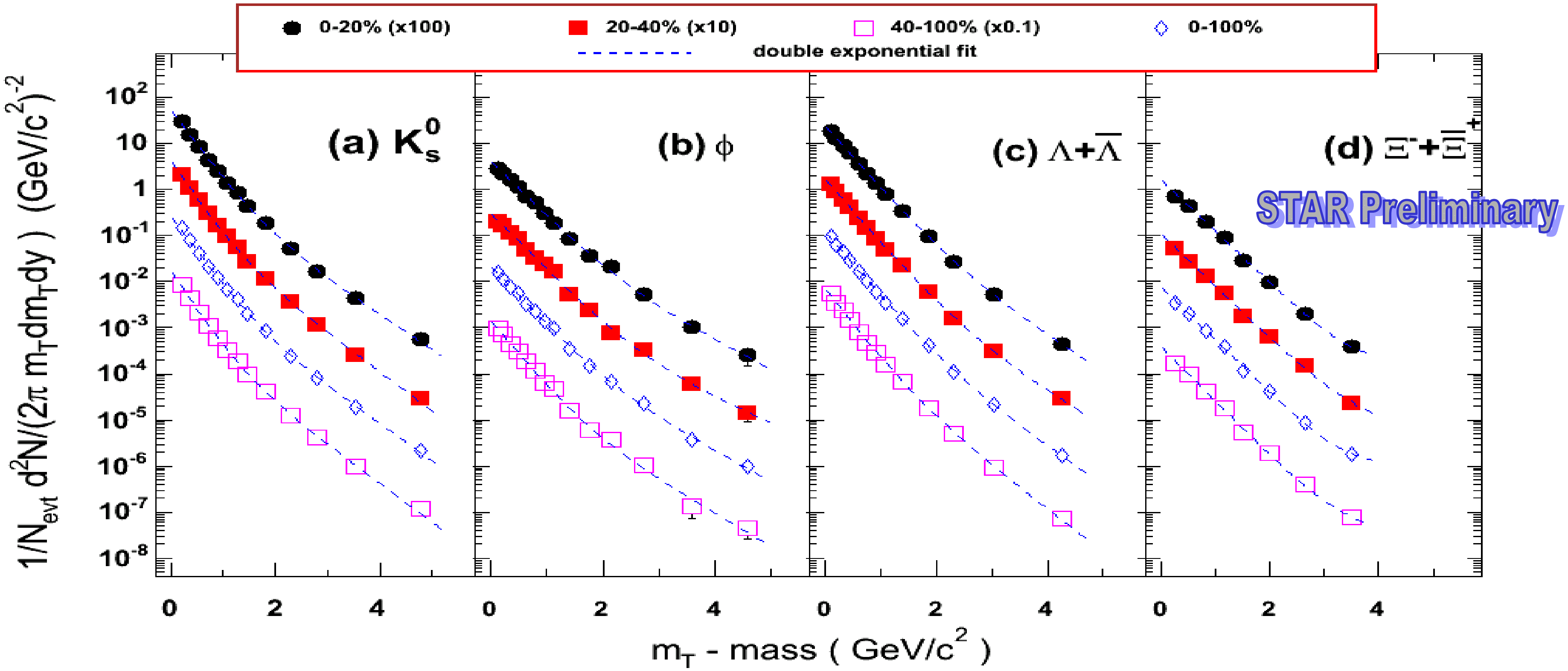




Clear meson-baryon yield differences at intermediate p_T

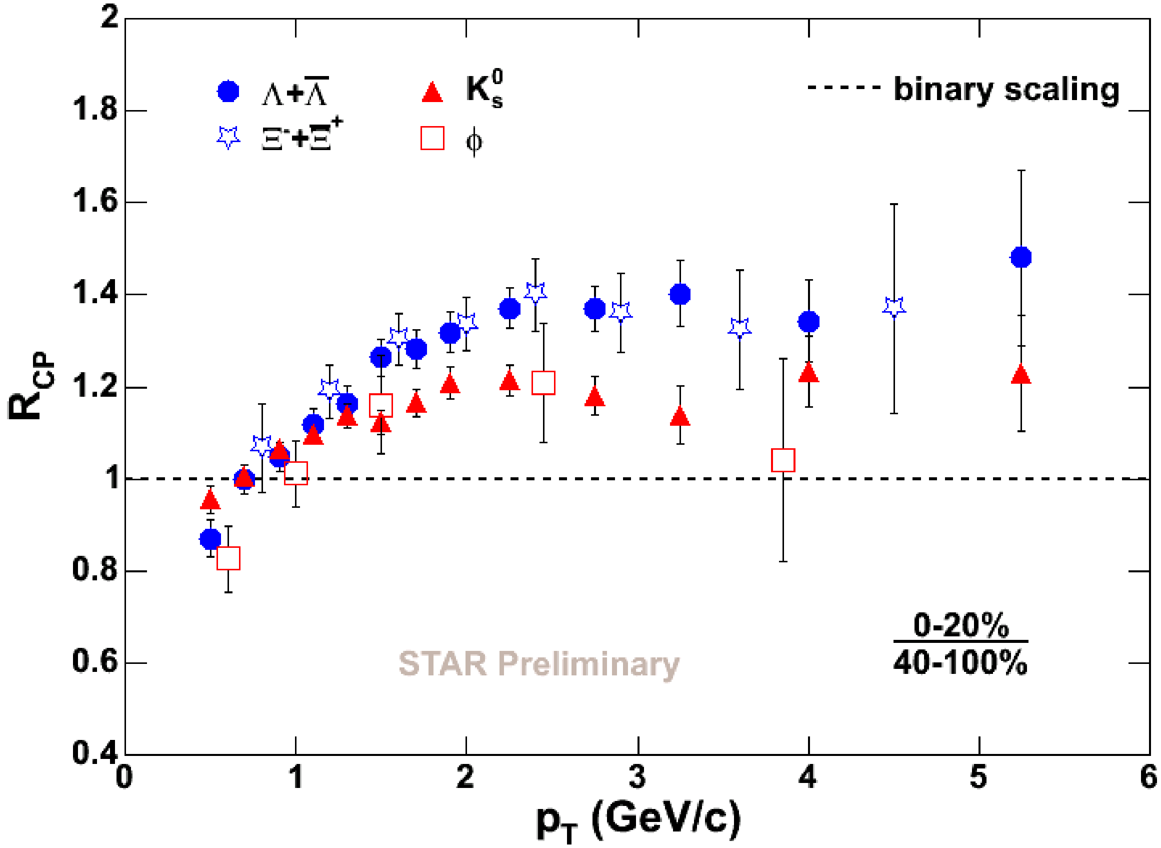
They seem to come together at $p_T \sim$ 5-6 GeV/c

Identified Strange Particles in 200 GeV d+Au



Yields to ~ 5 GeV/c measured vs centrality

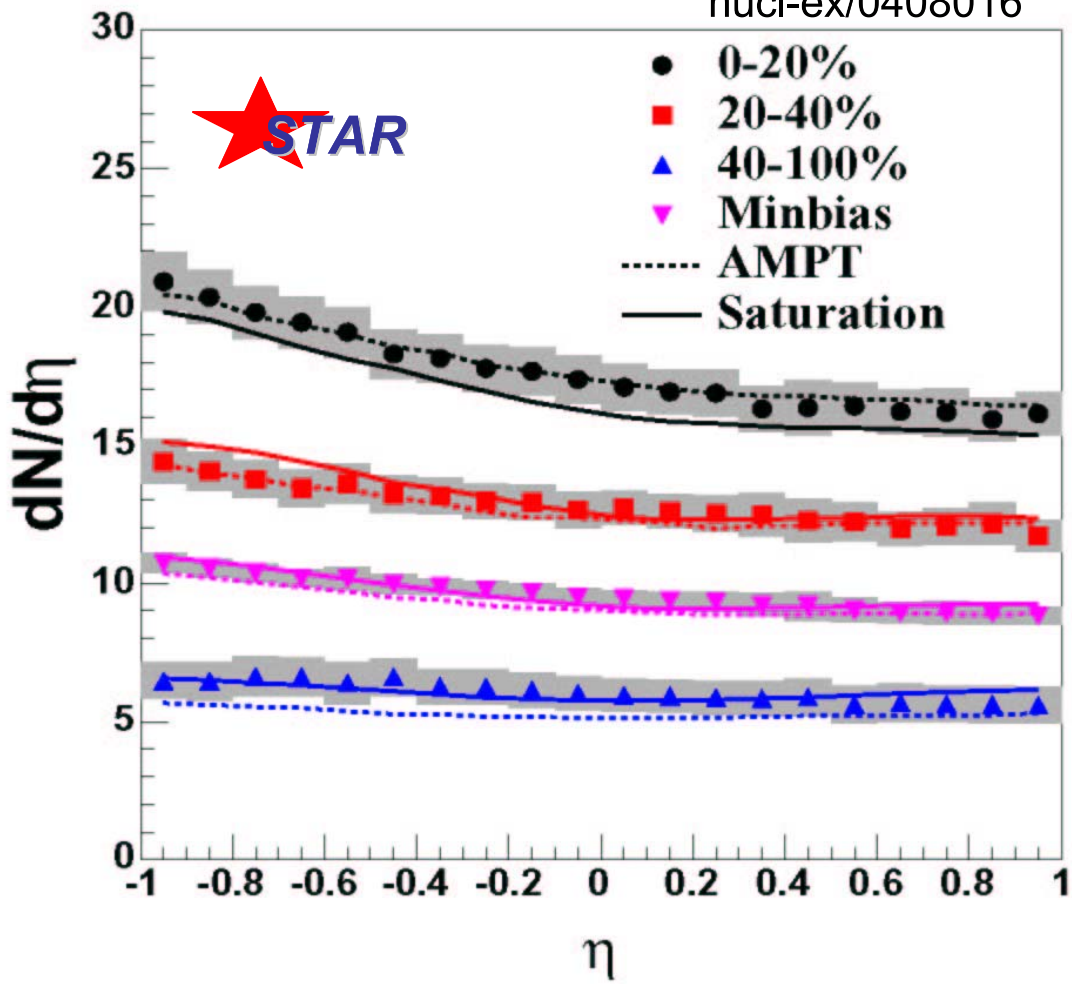
Meson-Baryon Difference in d+Au 200 GeV



R_{CP} also shows a clear meson-baryon pattern in d+Au

Pseudo-rapidity Density in d+Au

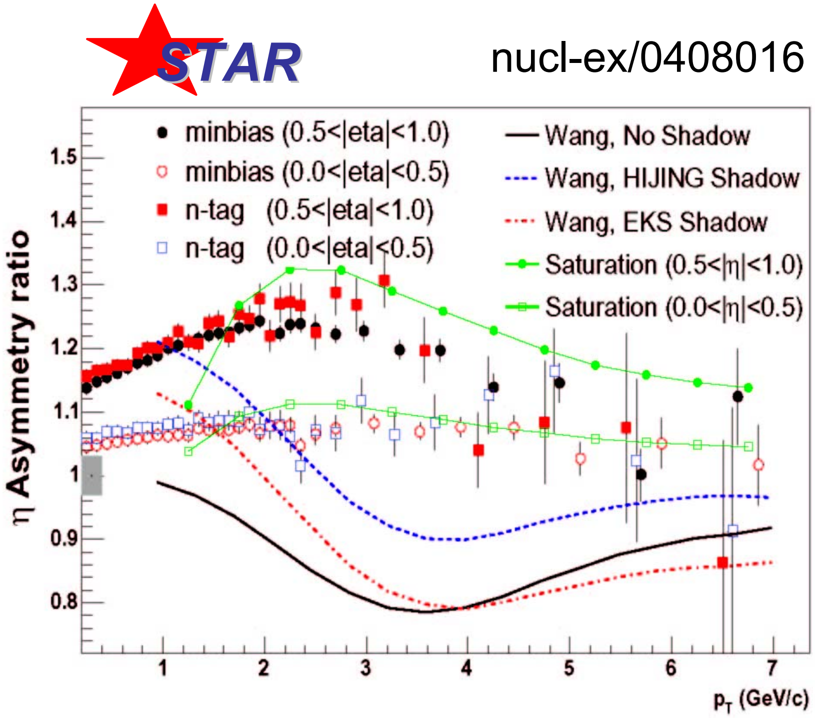
nucl-ex/0408016

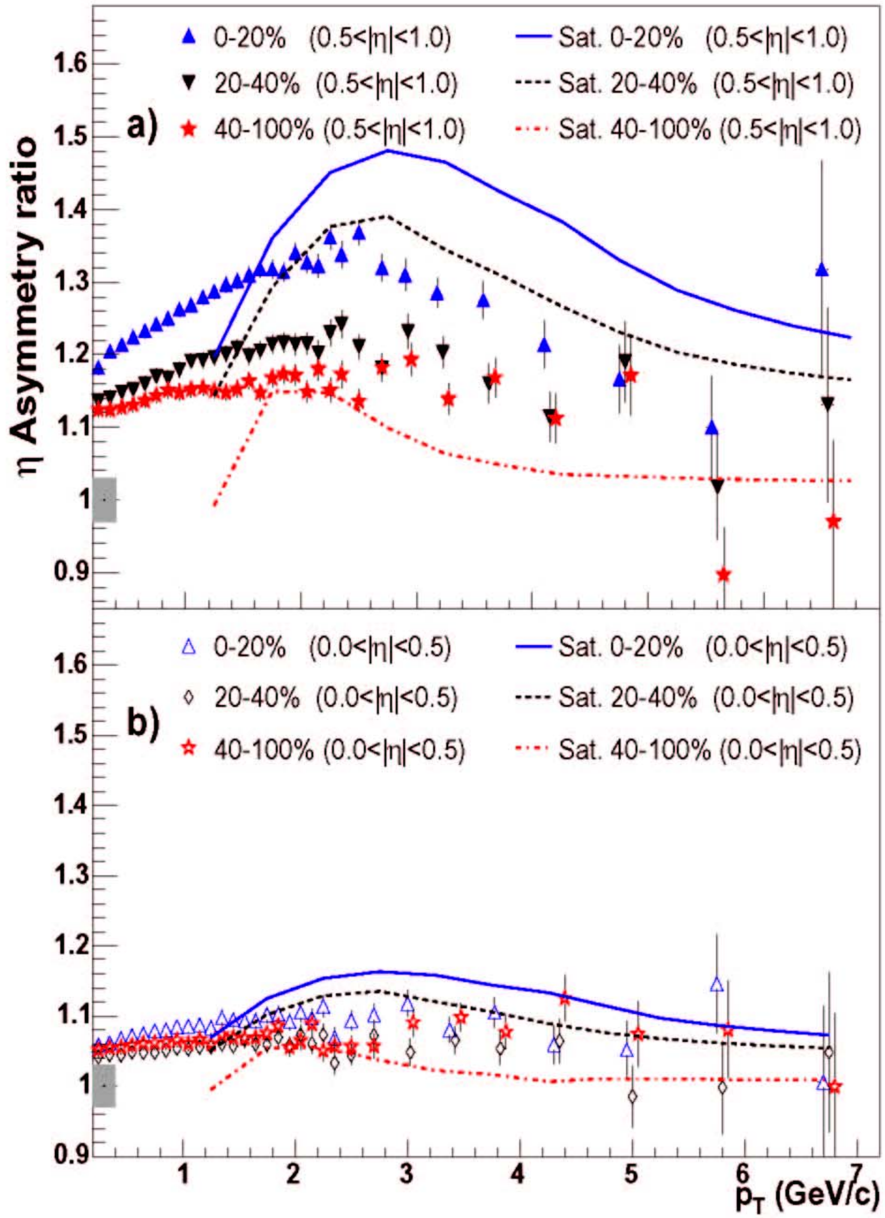


Particle yields are consistent with a range of models

Pseudo-rapidity Yield Asymmetry vs p_T

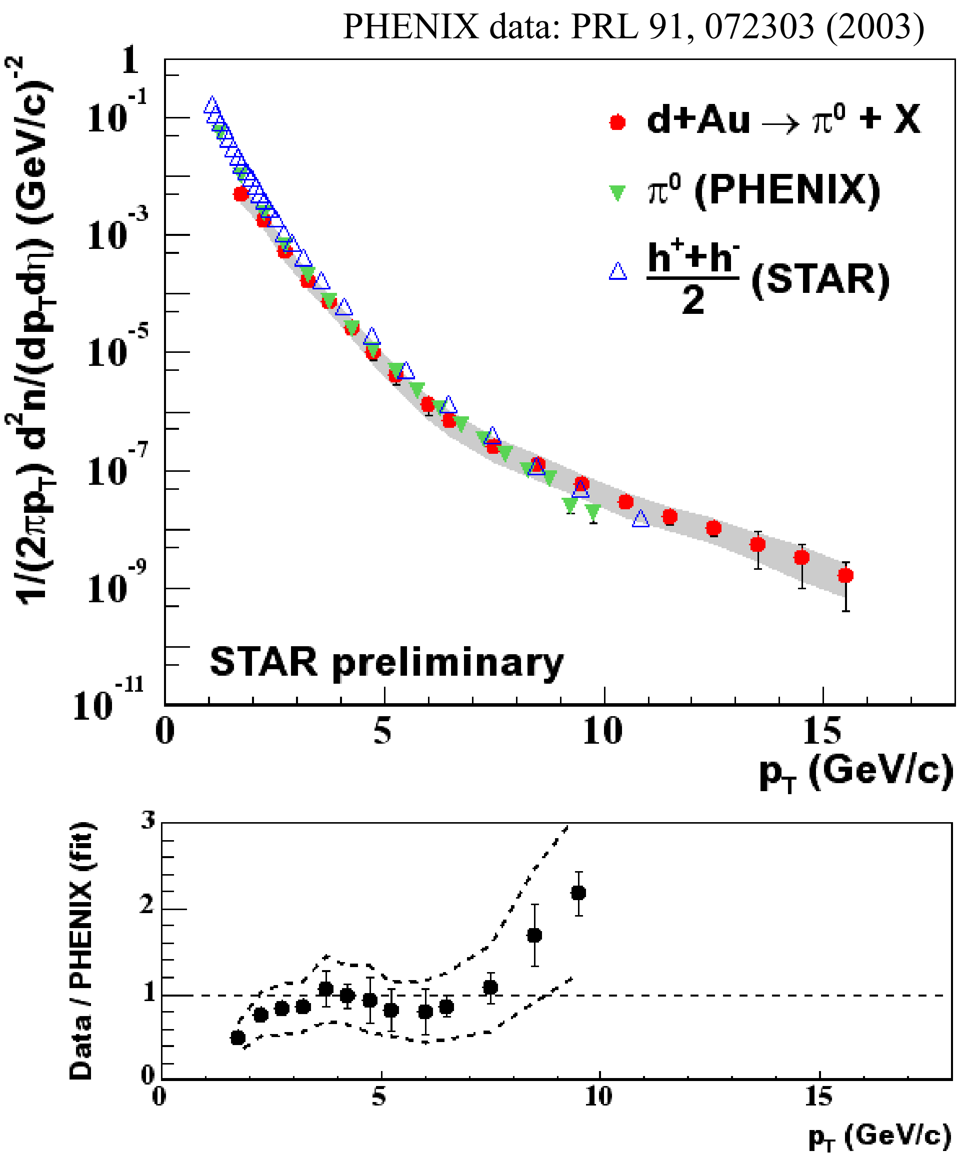
Au direction / d direction





Back/front asymmetry in 200 GeV d+Au consistent with general expectations of saturation or coalescence; doesn't match pQCD prediction.

π^0 p_T Spectrum in 200 GeV d+Au

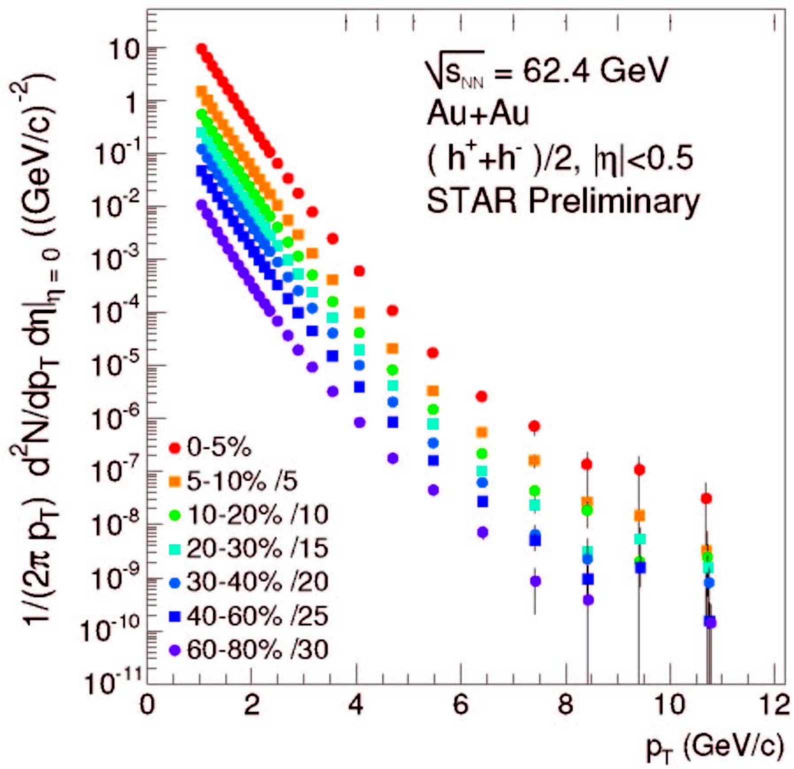


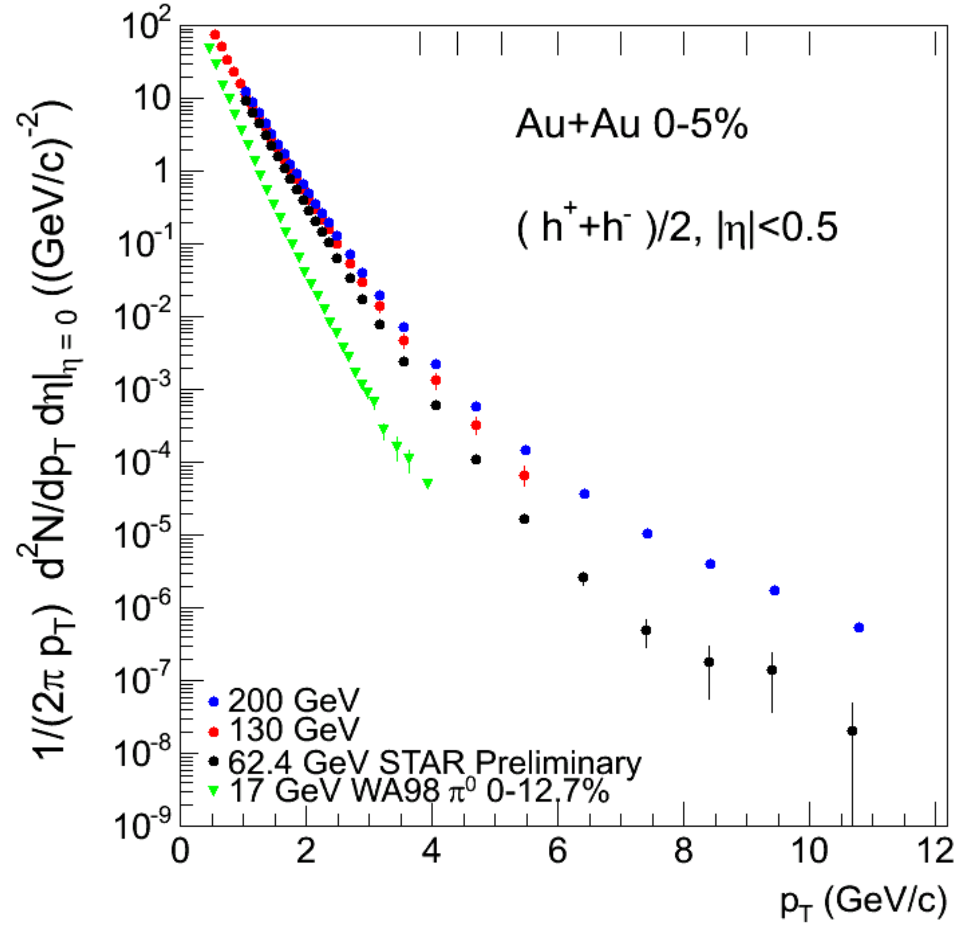
Neutral pion p_T spectrum to 13-16 GeV/c

Reasonable agreement with pQCD calculation, STAR charged-hadrons, and PHENIX neutral pions

See talk by Andre Mischke, Mon pm

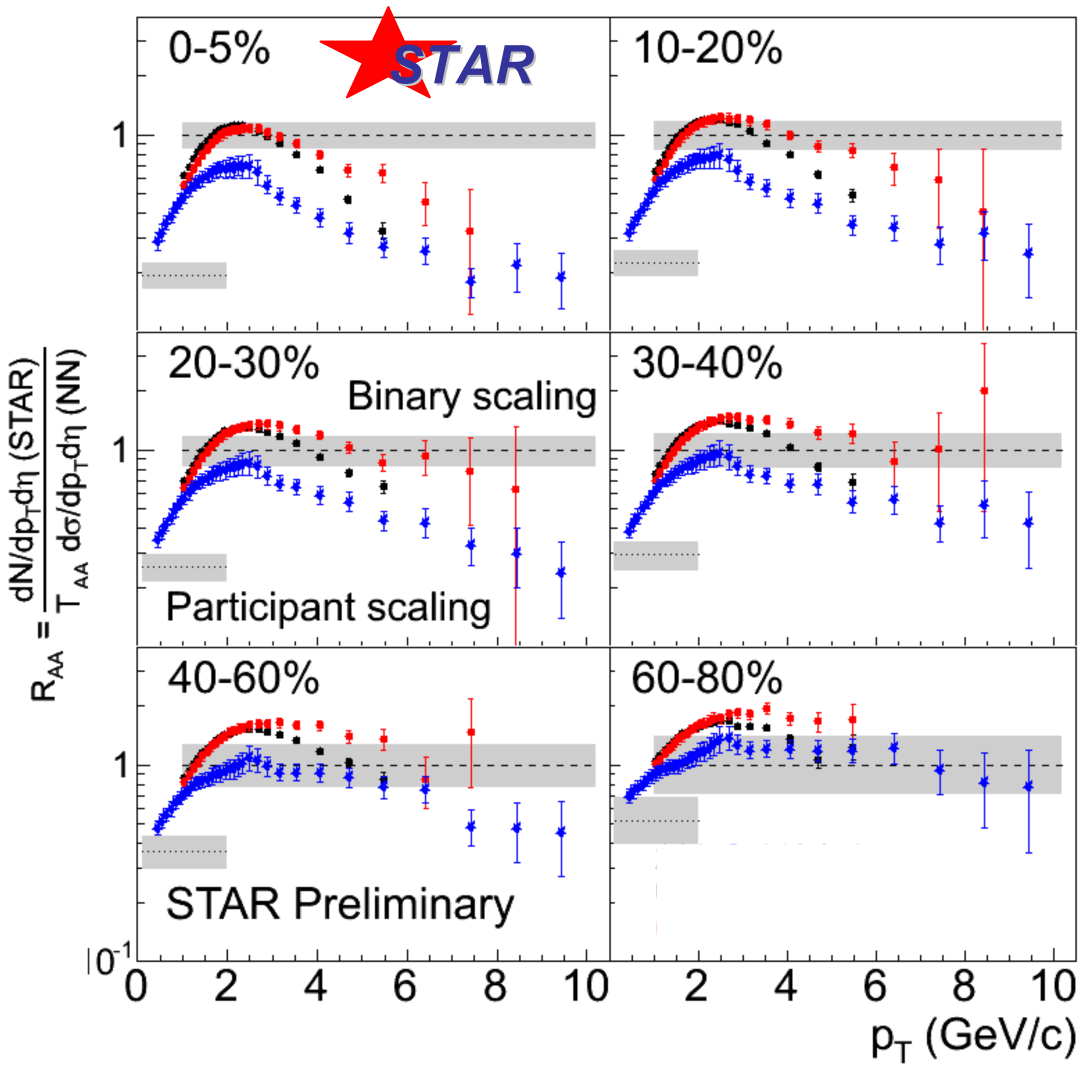
Au+Au at 62 GeV: Charged-Particle Yields





Spectrum shapes similar, but high-p_T absolute yield down over an order of magnitude at 62 GeV relative to 200 GeV

Inclusive Hadron Suppression



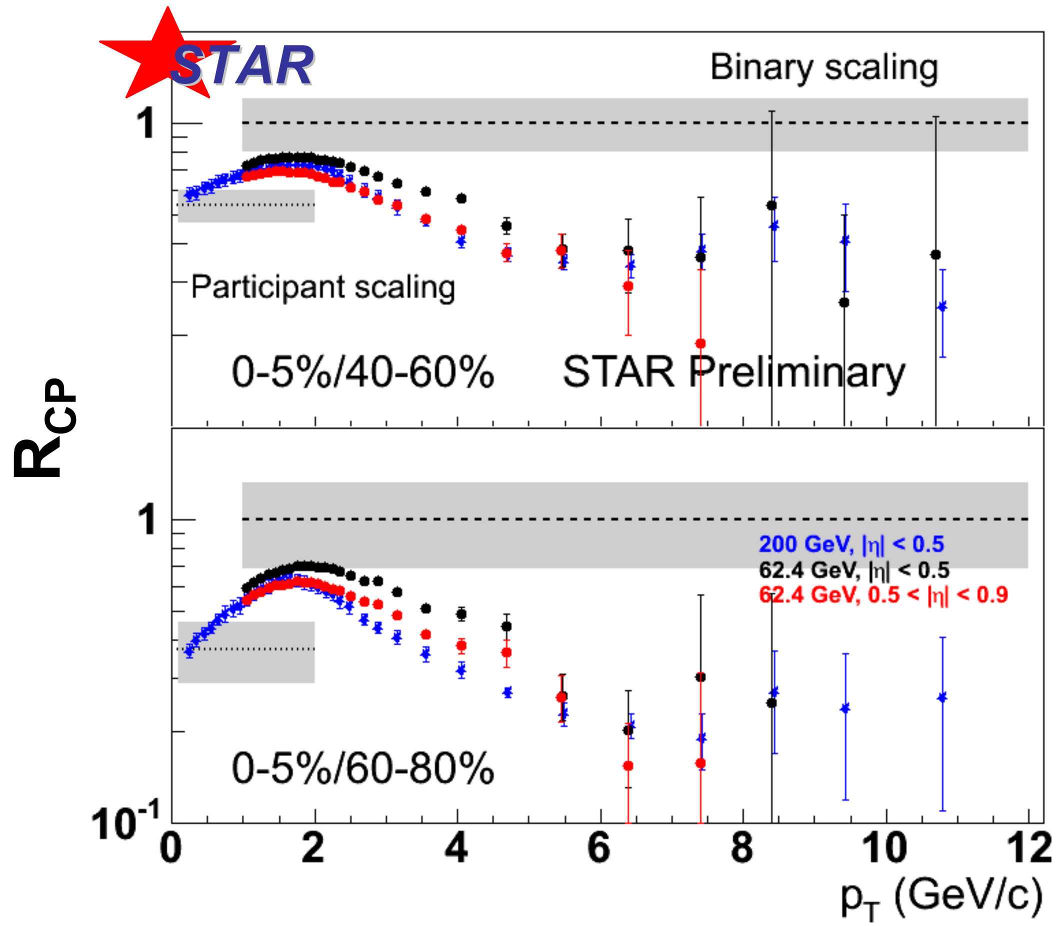
- 2 η bins, driven by p+p
  - η = 0: p_T <~6 GeV
  - η = 0.7: p_T <~10 GeV
- Significant suppression seen at 62 and 200 GeV

200 GeV |η| < 0.5

62 GeV |η| < 0.5

62 GeV 0.5 < |η| < 0.9

R_{CP}: Centrality Dependence



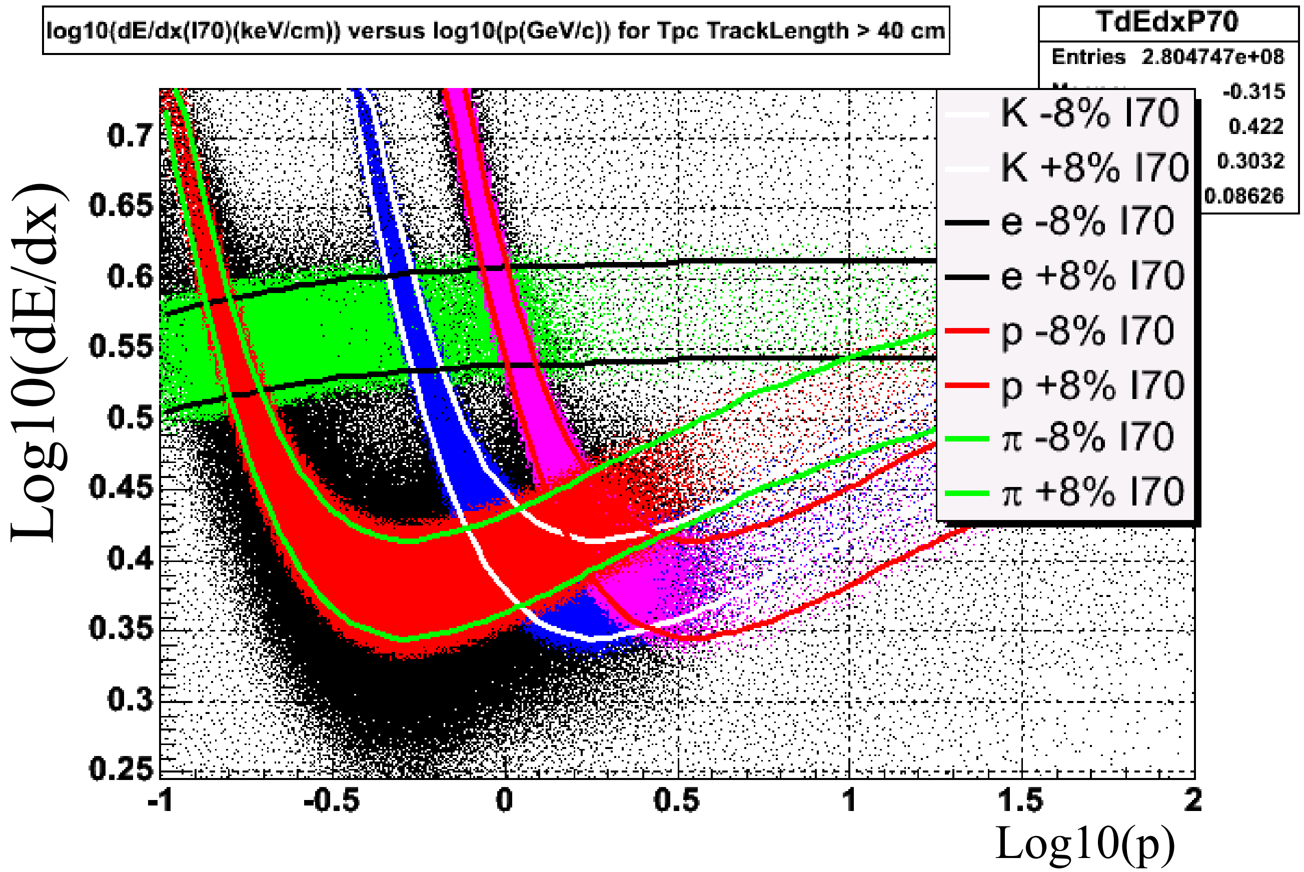
62 GeV |η| < 0.5

62 GeV 0.5 < |η| < 0.9

200 GeV |η| < 0.5

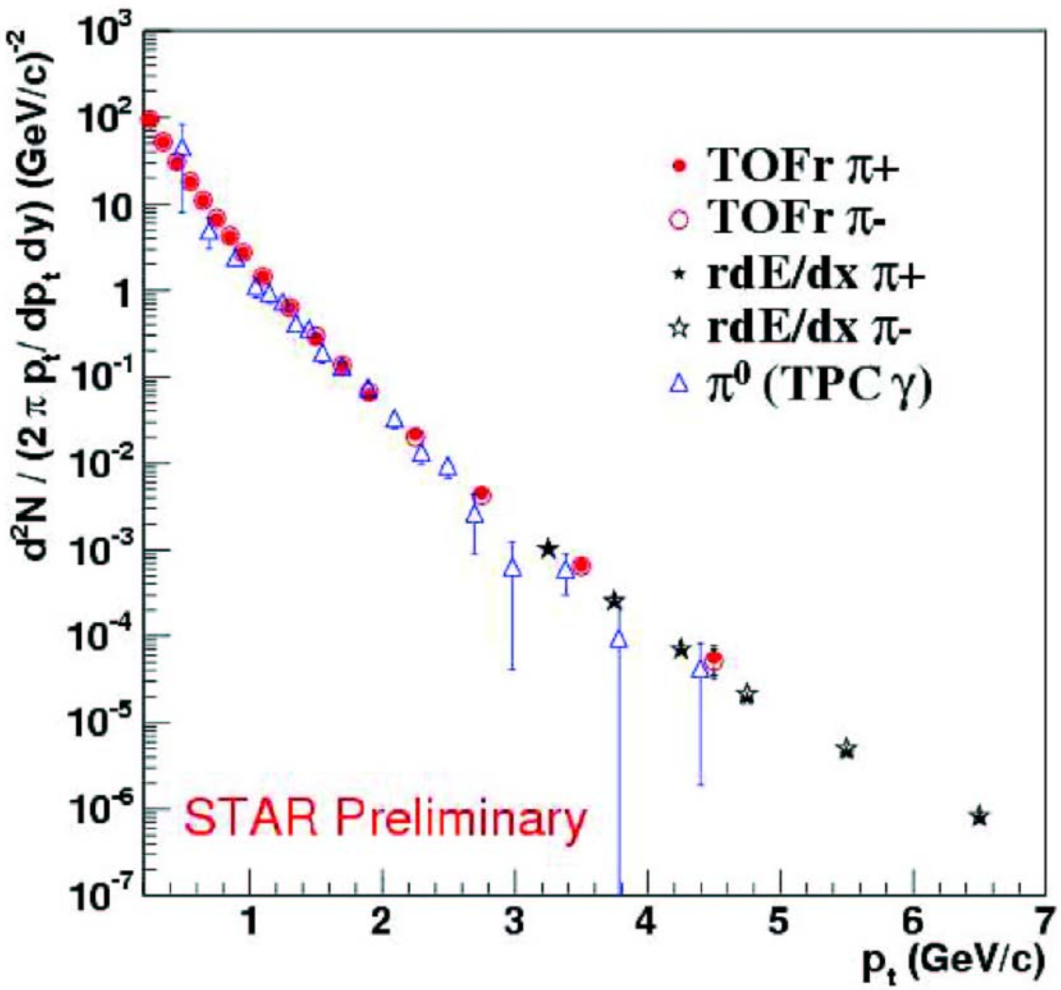
- Significant suppression in both η regions
- 62 GeV η ~ 0.7 very similar to 200 GeV η ~ 0

Additional Particle Identification Techniques



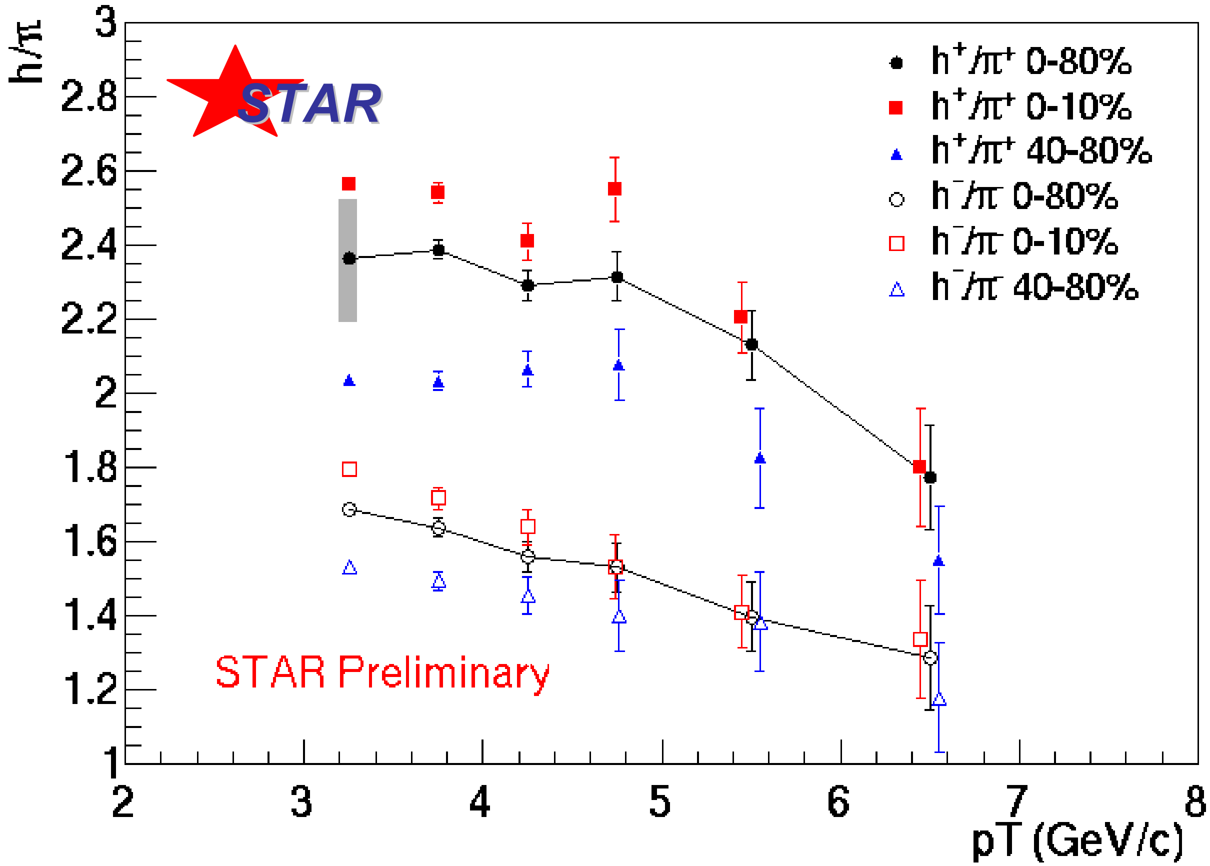
- TOF using MRPC chambers
- π^0 conversion into $e^+e^-e^+e^-$
- dE/dx relativistic rise

Charged and Neutral Pions in 62 GeV Au+Au



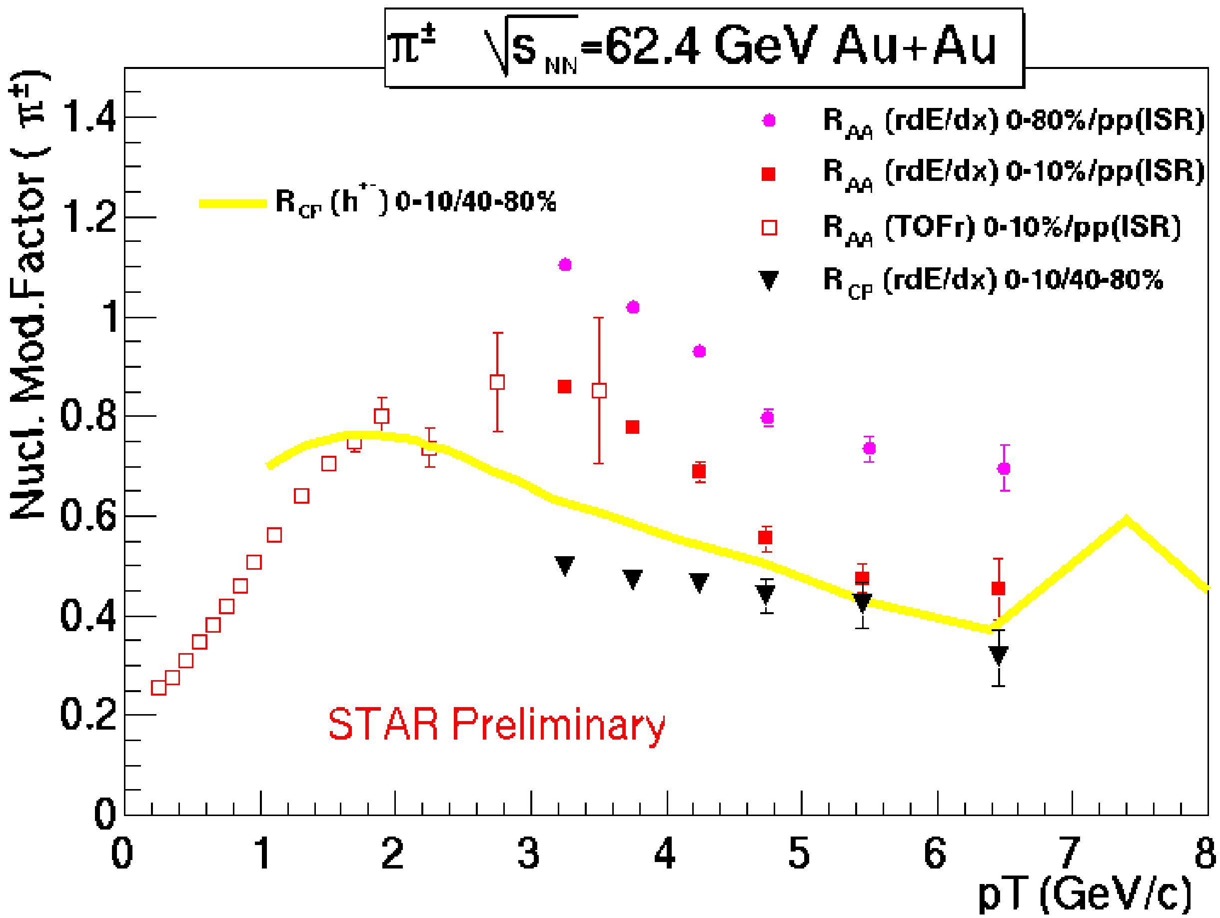
Three different techniques – good agreement

h/π Ratios in 62 GeV Au+Au



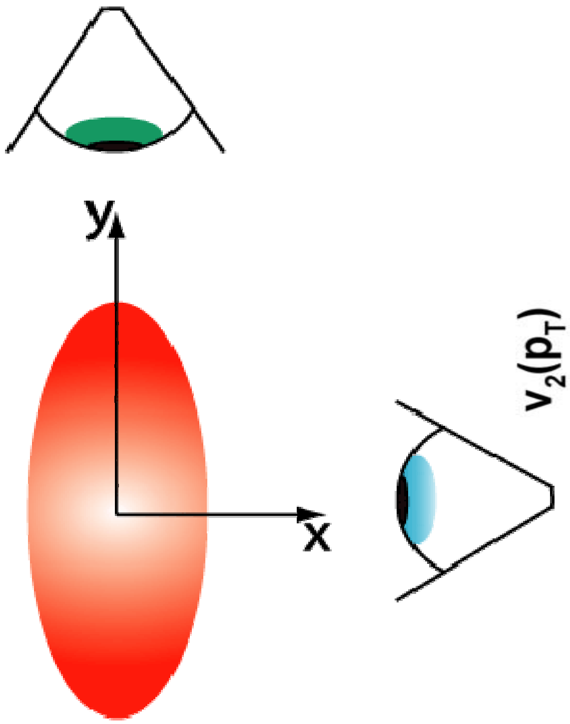
h/π higher in central Au+Au than peripheral.
Ratios approach at $p_T \sim 6$ GeV/c

$\pi^{\pm}$ Nuclear Modification Factor

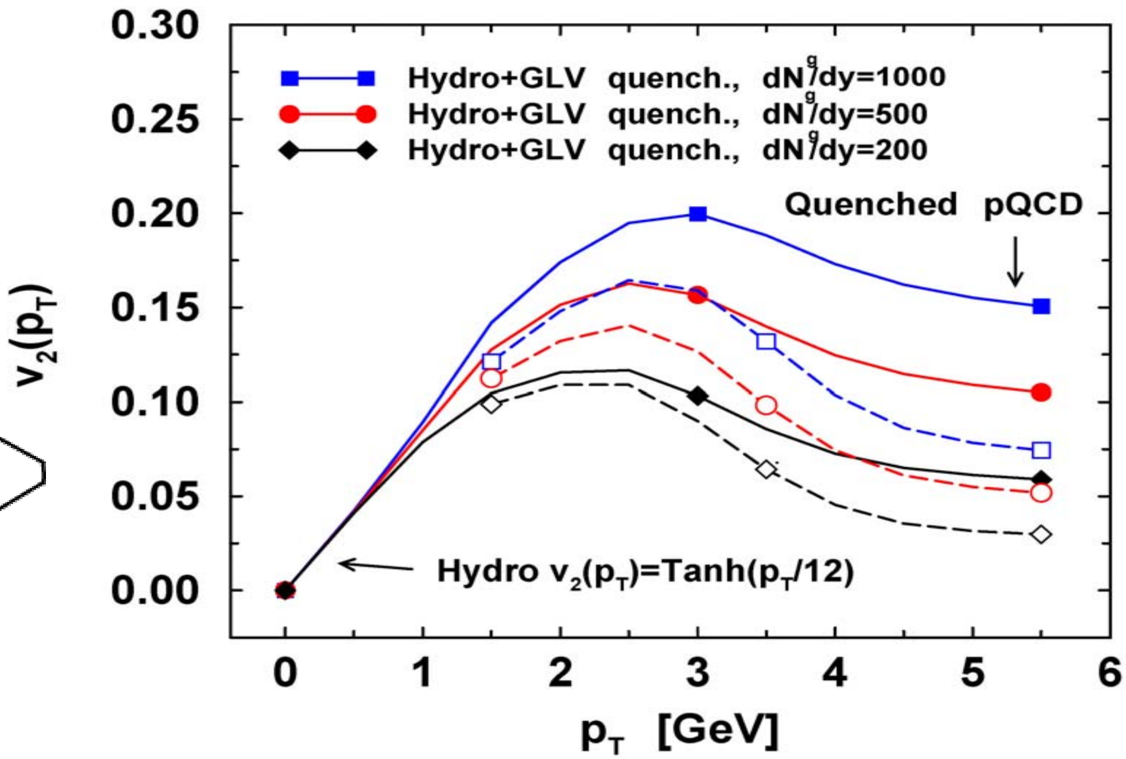


- R_{CP} for h+- 20% higher than π+- for p_T = 3-4 GeV/c
- R_{CP} for h+- and π+- merge at p_T = 5~6 GeV/c
- Consistent with h/π ratio

Azimuthal Anisotropy and Partonic Energy Loss



M. Gyulassy, I. Vitev and X.N. Wang

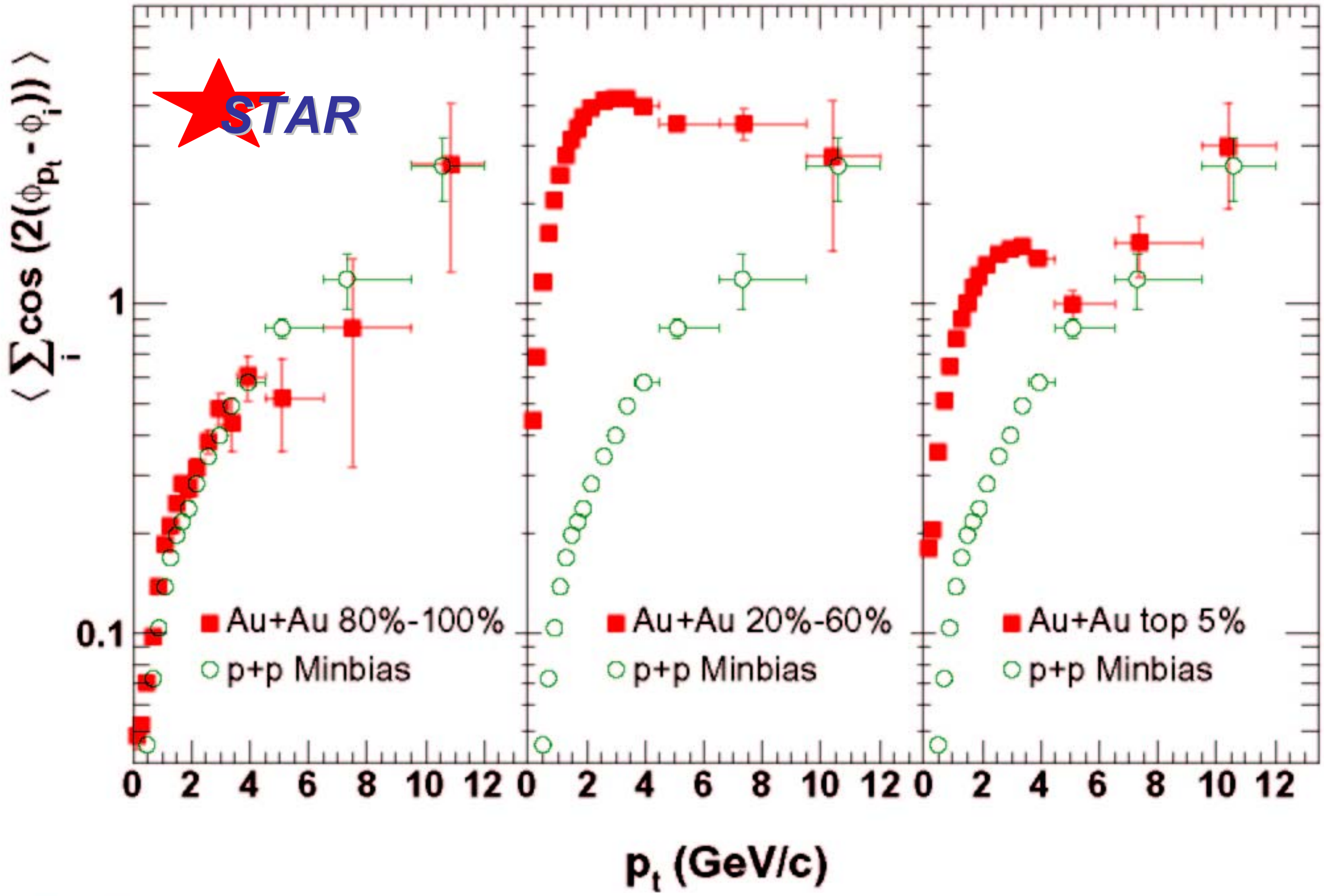


$$\frac{dN}{d\phi} \propto 1 + 2v_2(p_T)\cos[2(\phi - \Psi_R)]$$

Anisotropy at high p_T is sensitive to the gluon density of the medium.

Separating Flow from Non-Flow at 200 GeV

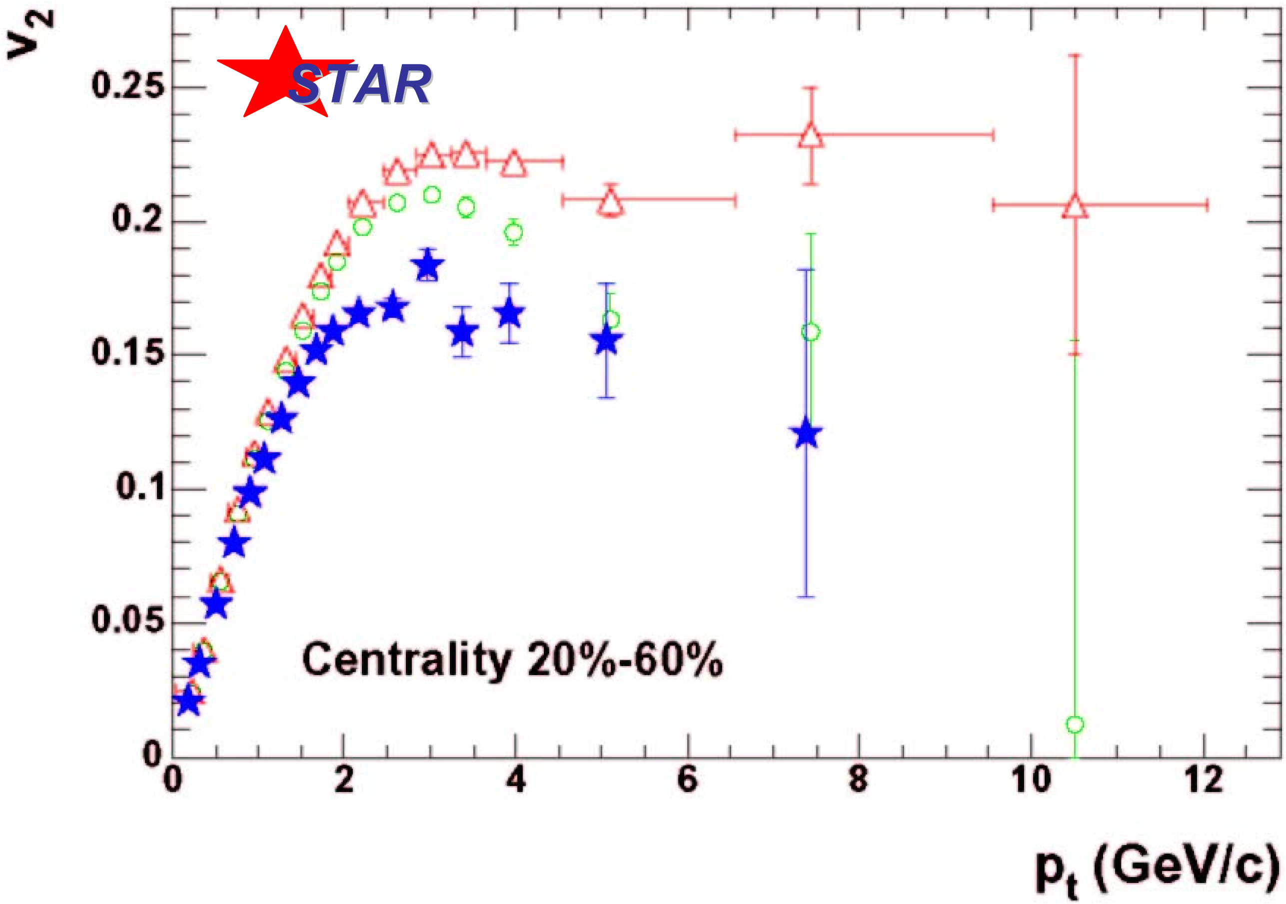
nucl-ex/0407007



$$\langle \sum_i \cos 2(\phi_{p_t} - \phi_i) \rangle = M\, v_2(p_t)\, \bar{v}_2 + \{\text{non-flow}\}$$

Flow at High p_T in 200 GeV Au+Au

nucl-ex/0407007



v_2 {2-particle}

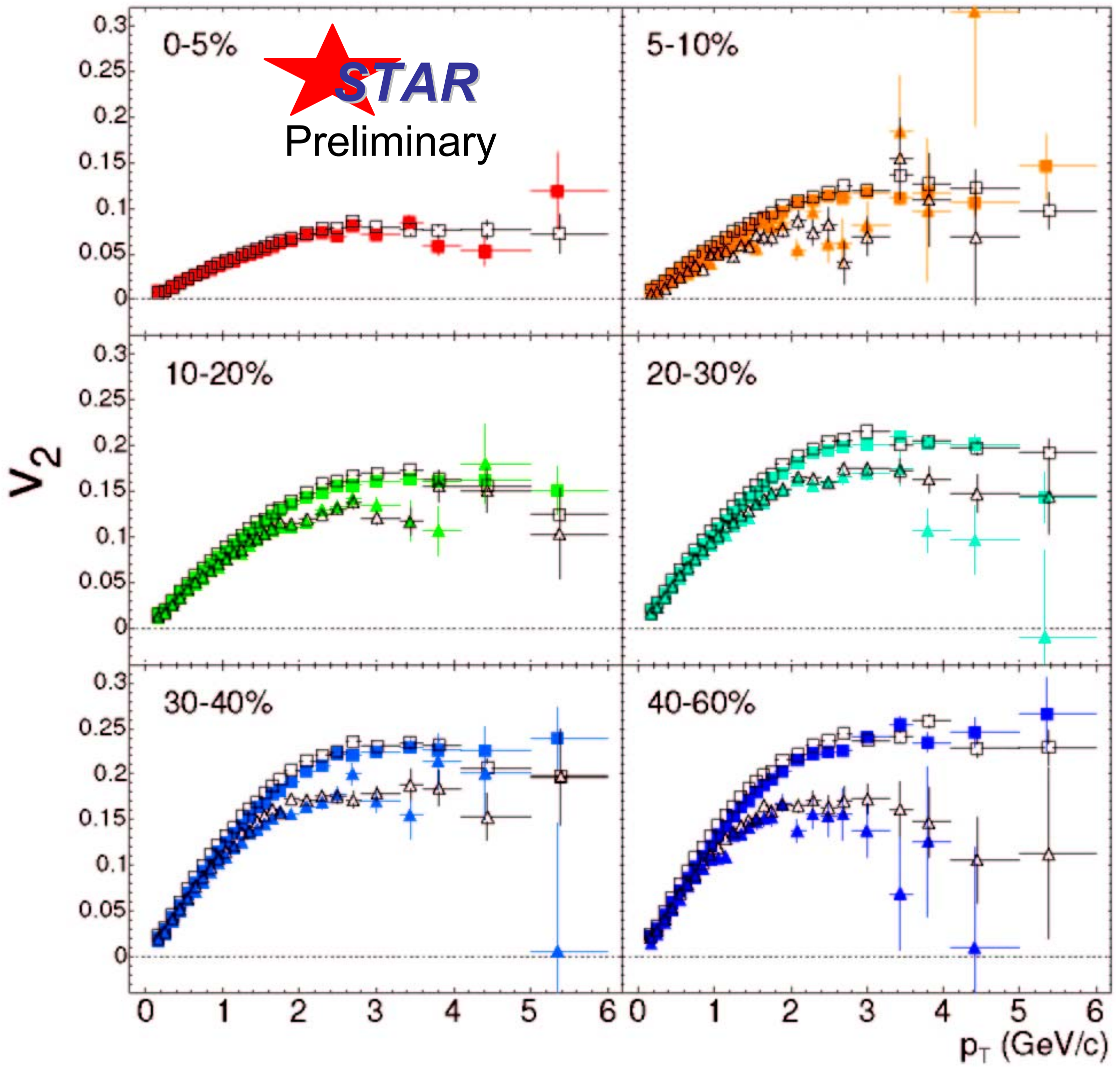
v_2 {AuAu – pp}

v_2 {4-particle}

Flow reaches a maximum ~3 GeV/c, then decreases slowly

Sizable real flow to ~8 GeV/c in mid-central collisions

Flow in 62 GeV vs 200 GeV Au+Au



Upper curves: v_2 {2-particle}

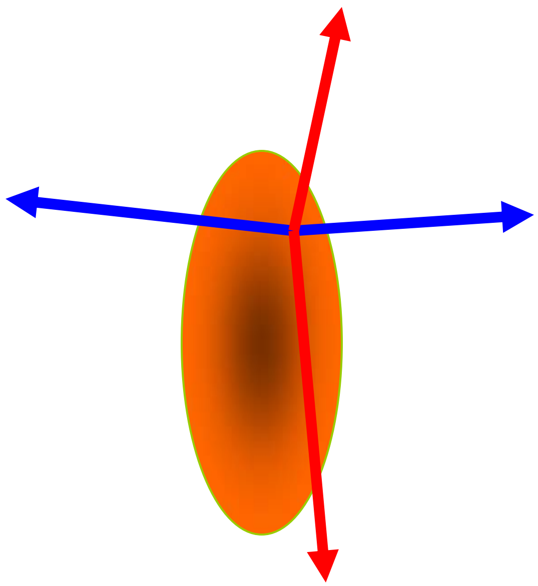
Lower curves: v_2 {4-particle}

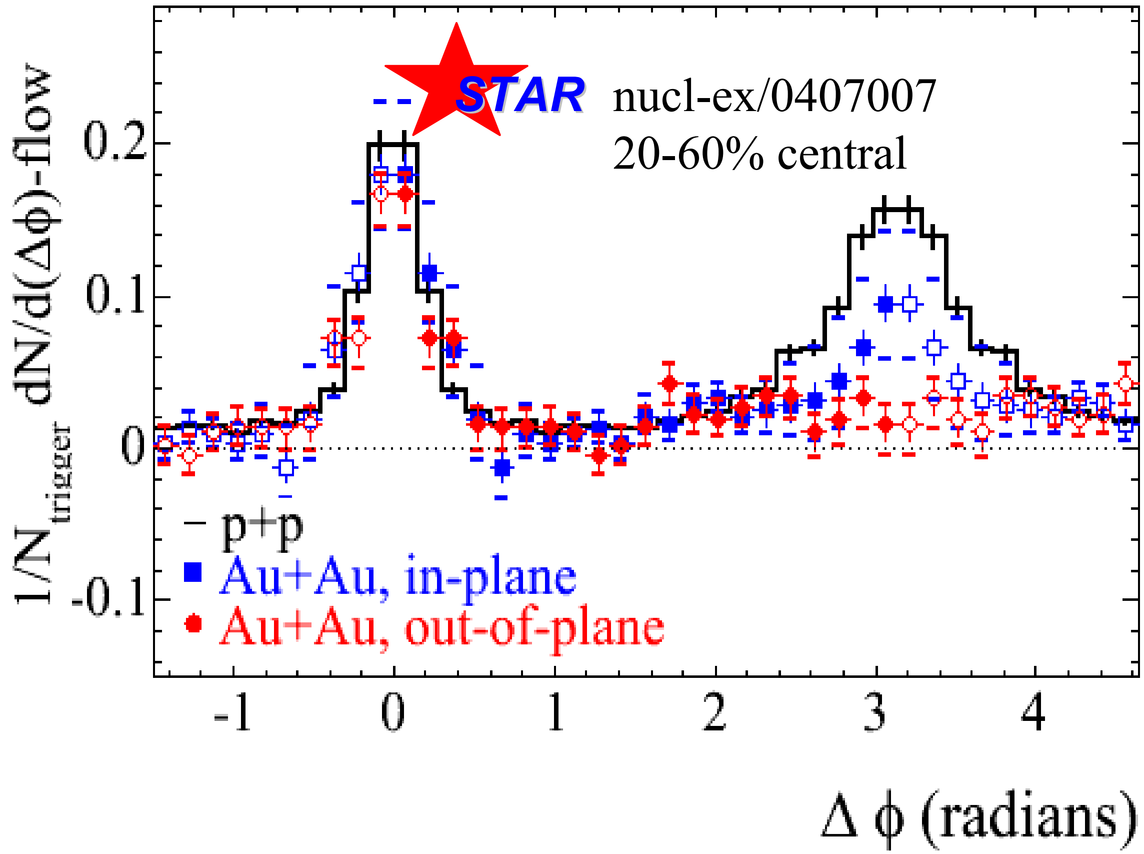
Solid points: 62 GeV

Open points: 200 GeV

$v_2(p_T)$ is very similar for 62 GeV to 200 GeV

Back-to-Back Correlations vs. Reaction Plane

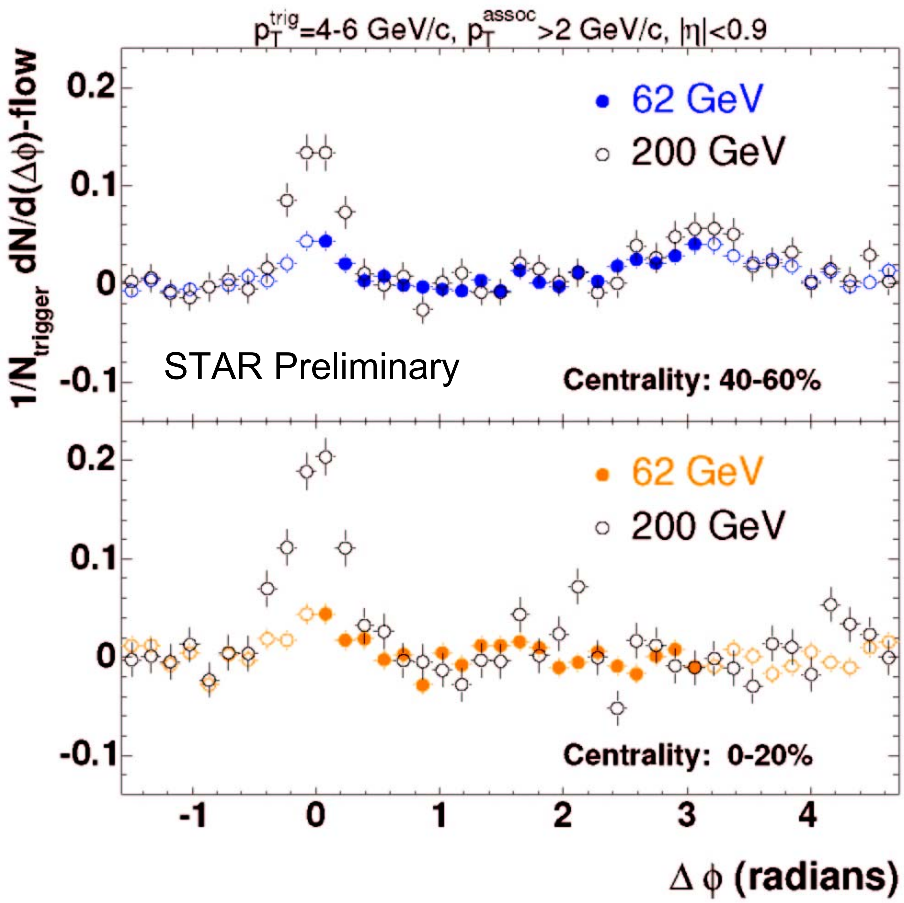




Near-side correlations: independent of orientation

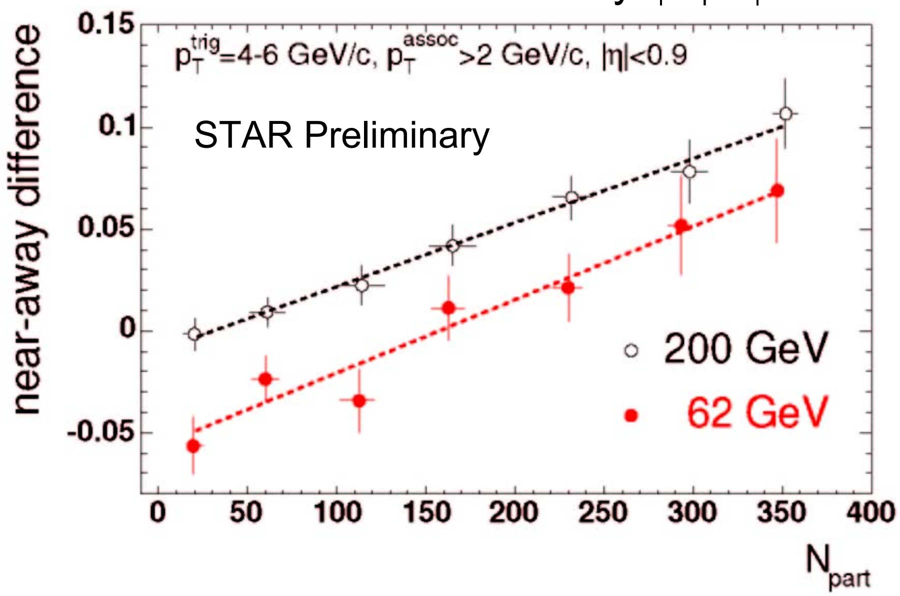
Back-to-back correlations: suppressed more strongly when the path length is longer

Di-Hadron Angular Distributions: 62 GeV vs 200 GeV Au+Au



STAR

Near: $|\Delta\varphi| < 0.8$
Away: $|\Delta\varphi-\pi| < 0.8$

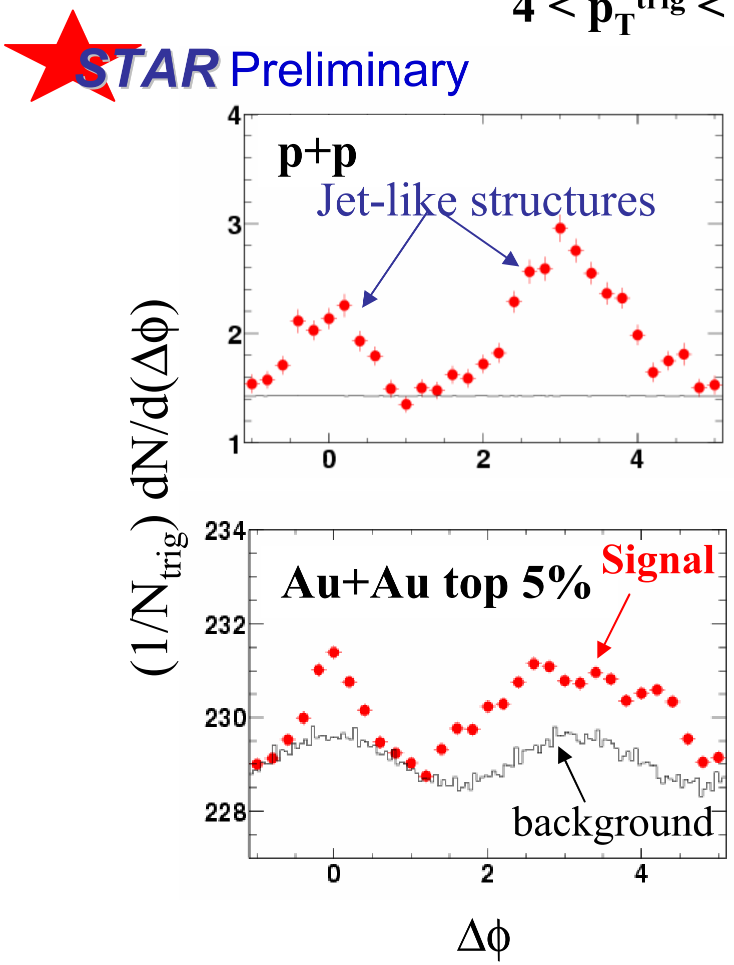


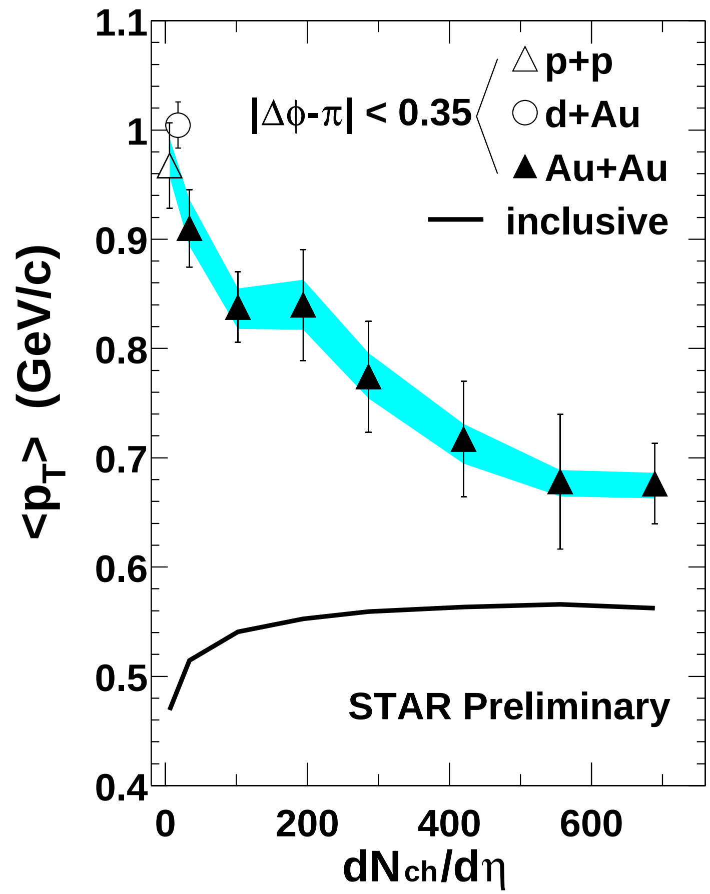
Near-side correlated yields are much reduced at 62 GeV

Away-side angular distribution is very similar

Finding the Associated Hadrons

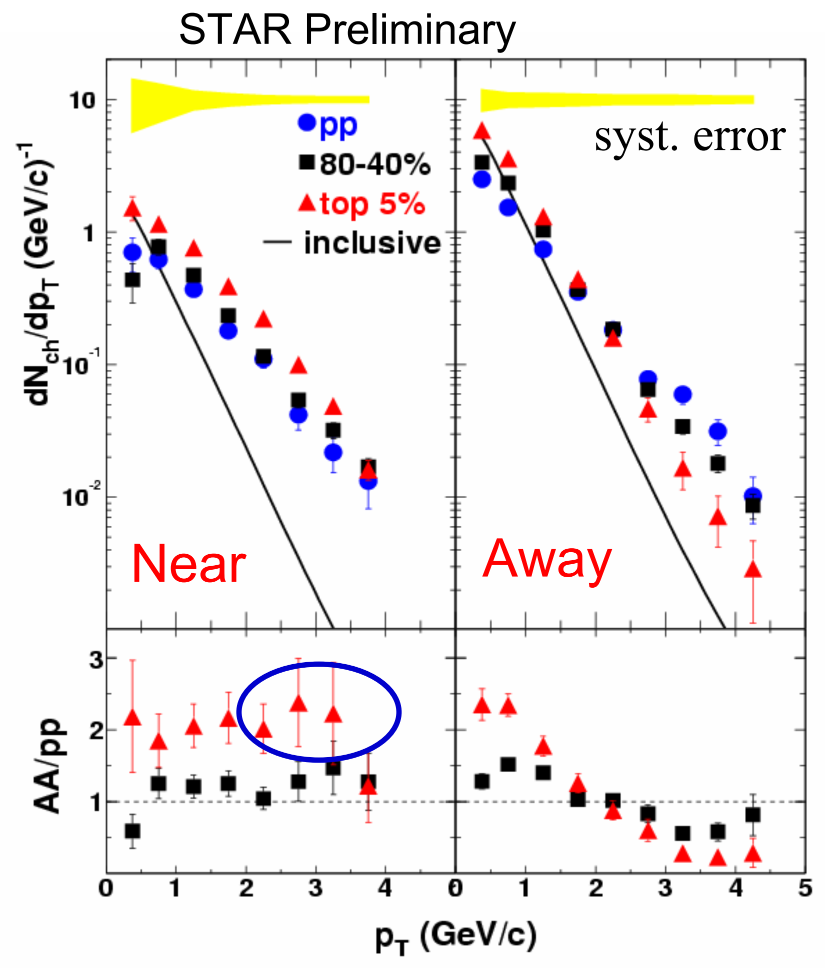
$4 < p_T^{trig} < 6$ GeV/c , $0.15 < p_T^{assoc} < 4$ GeV/c

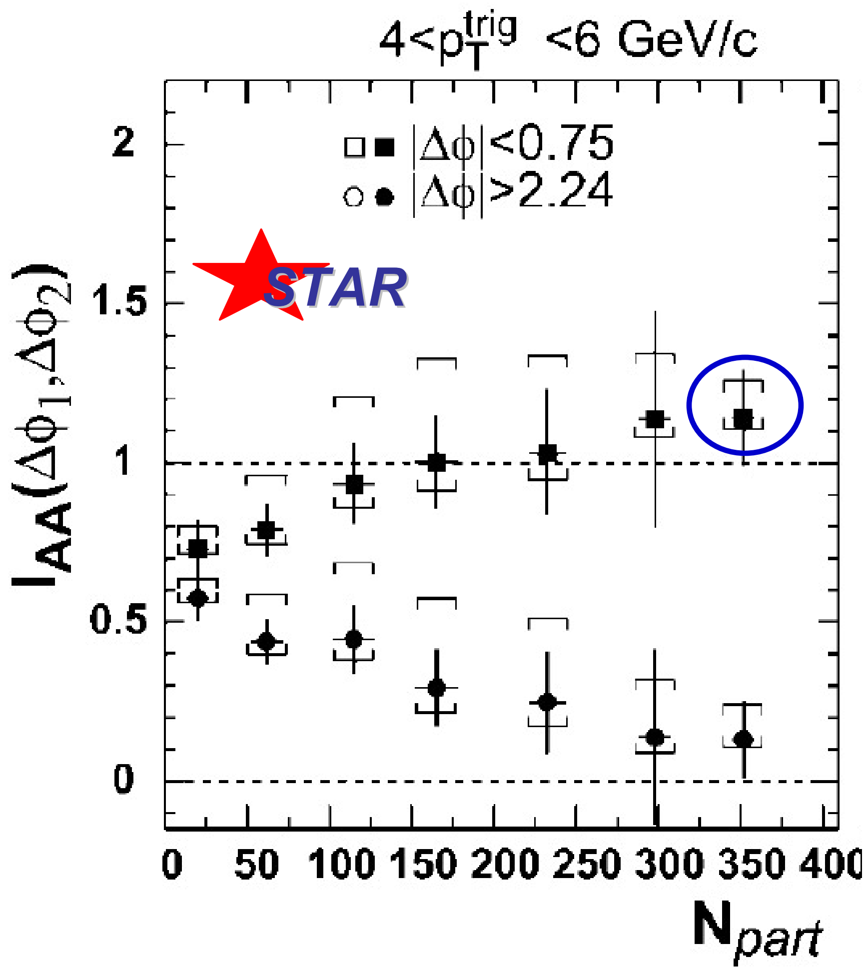




Explores the interaction of an energetic parton with the dense medium

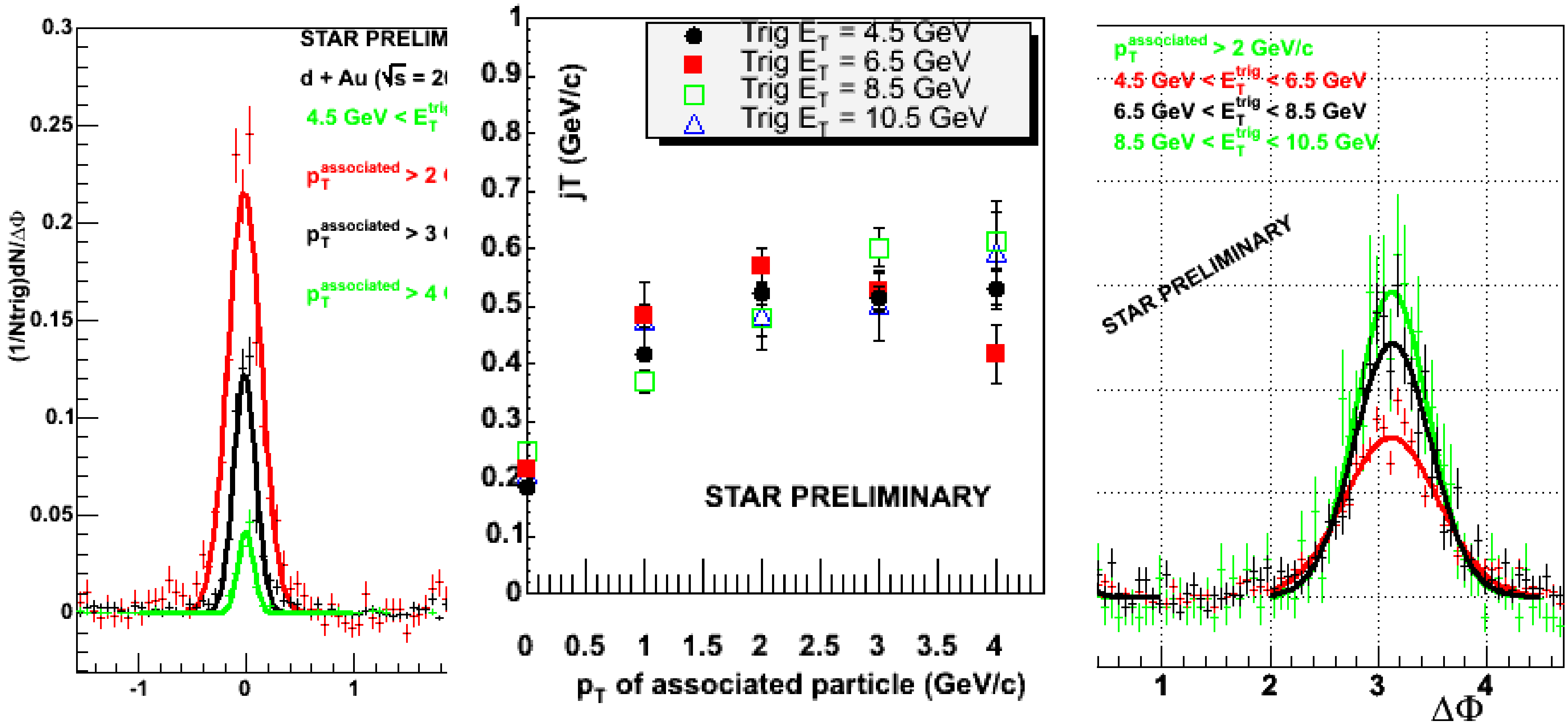
What about the near-side yield?





A discrepancy? See Dan Magestro's talk, Mon am!

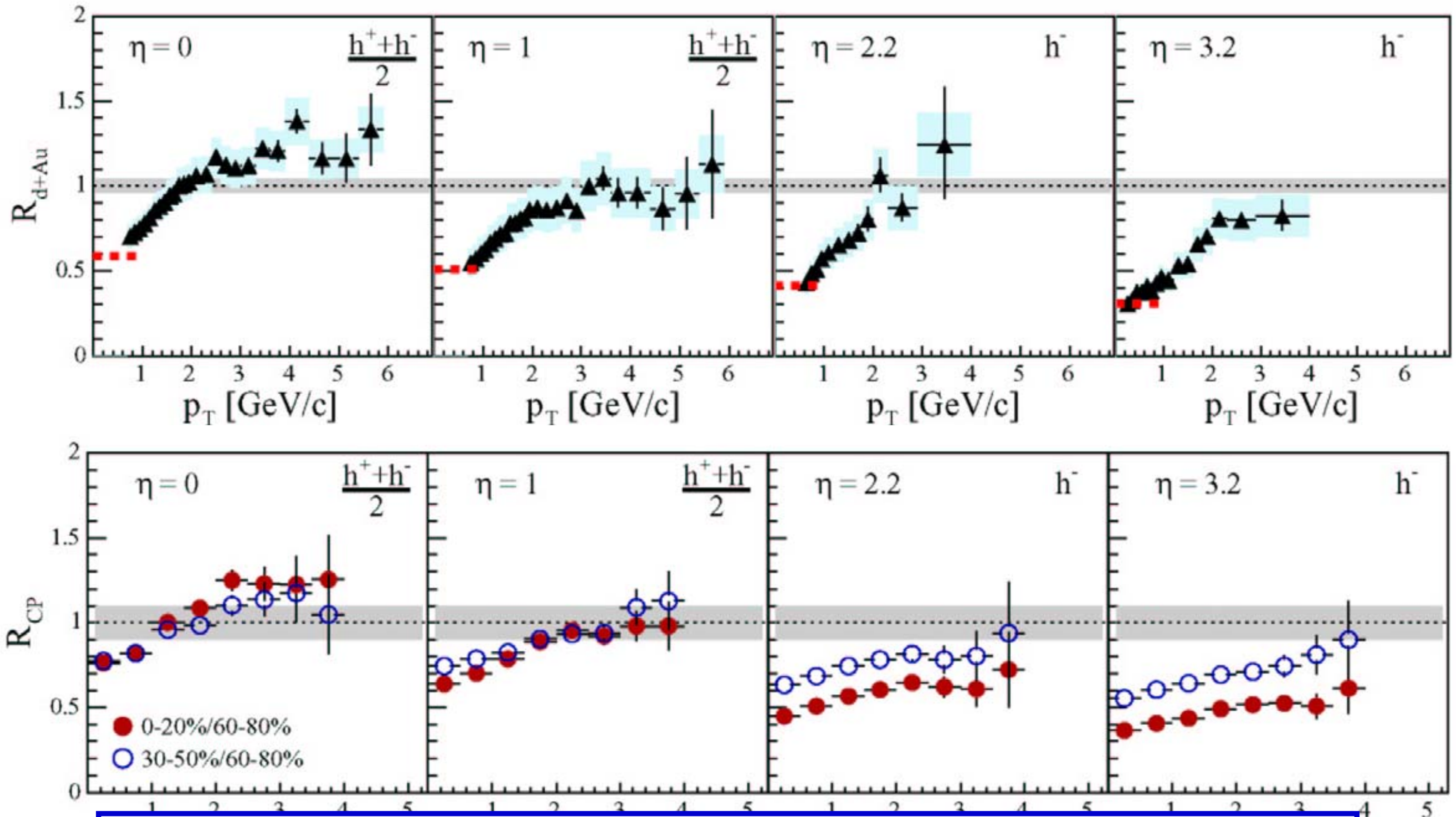
Extending Two-Particle Correlations to Higher p_T



Triggering with the STAR barrel and endcap EMC's gives extended reach for correlation studies with high E_T photons

Forward Particle Production in d+Au Collisions

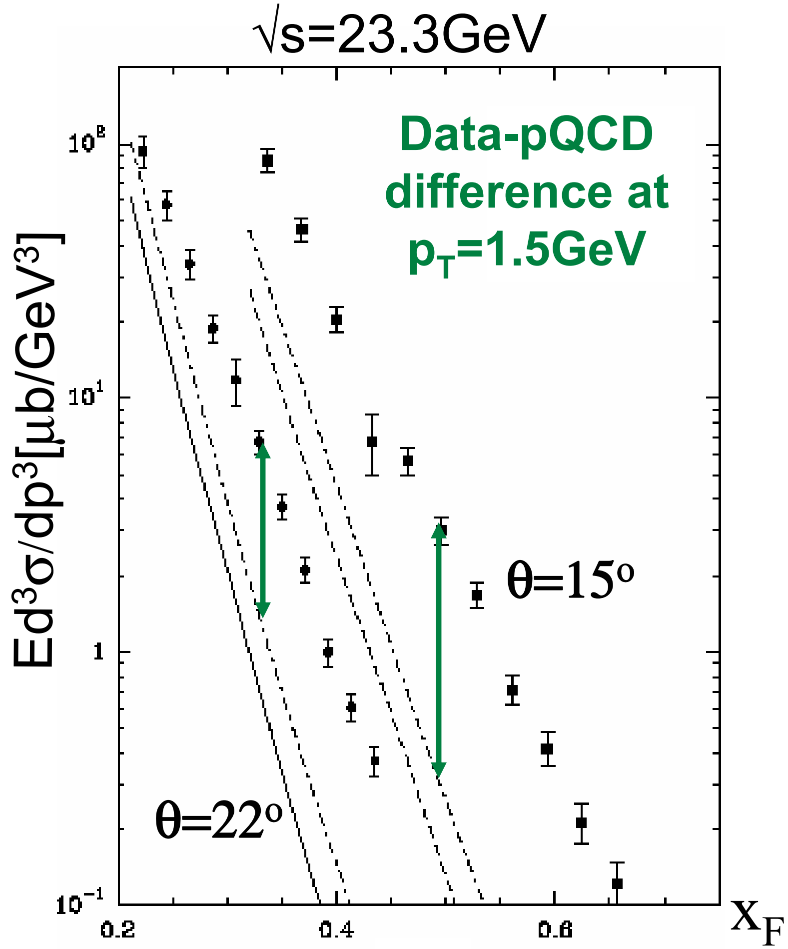
BRAHMS, nucl-ex/0403005

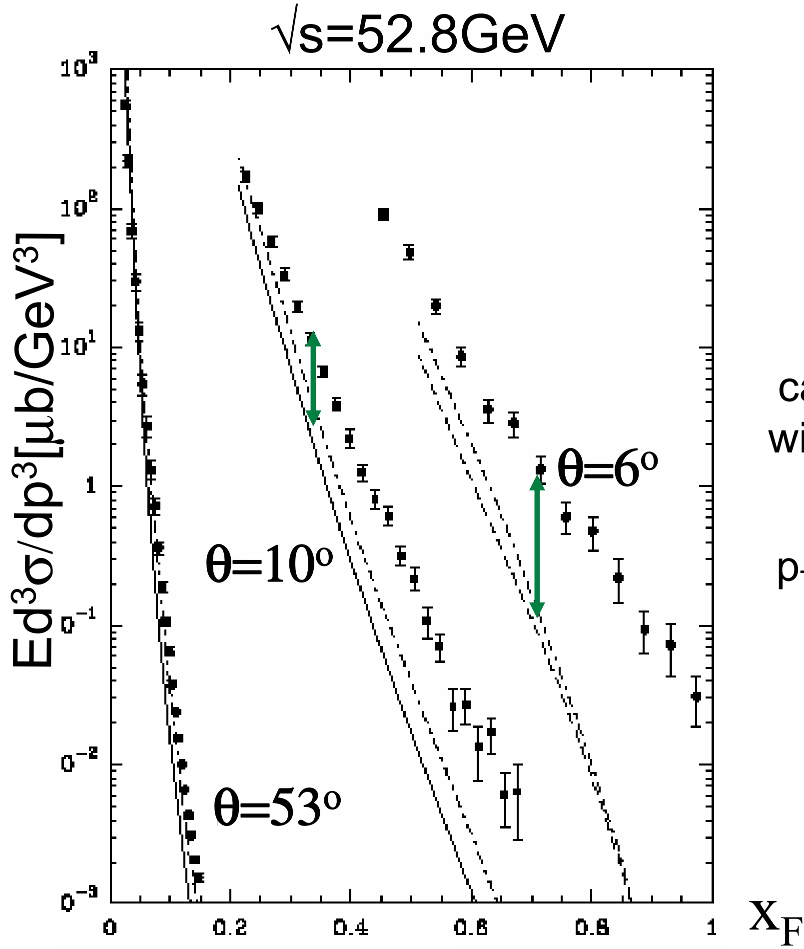


Sizabl ... n
d+Au (... apidity

Difficult to explain with standard shadowing, but $<x_g>$~0.02 for the BRAHMS data is not that small in NLO pQCD
(Guzey, Strikman, and Vogelsang, hep-ph/0407201)

Do we understand forward π^0 production in p + p?





2 NLO calculations with different scale:

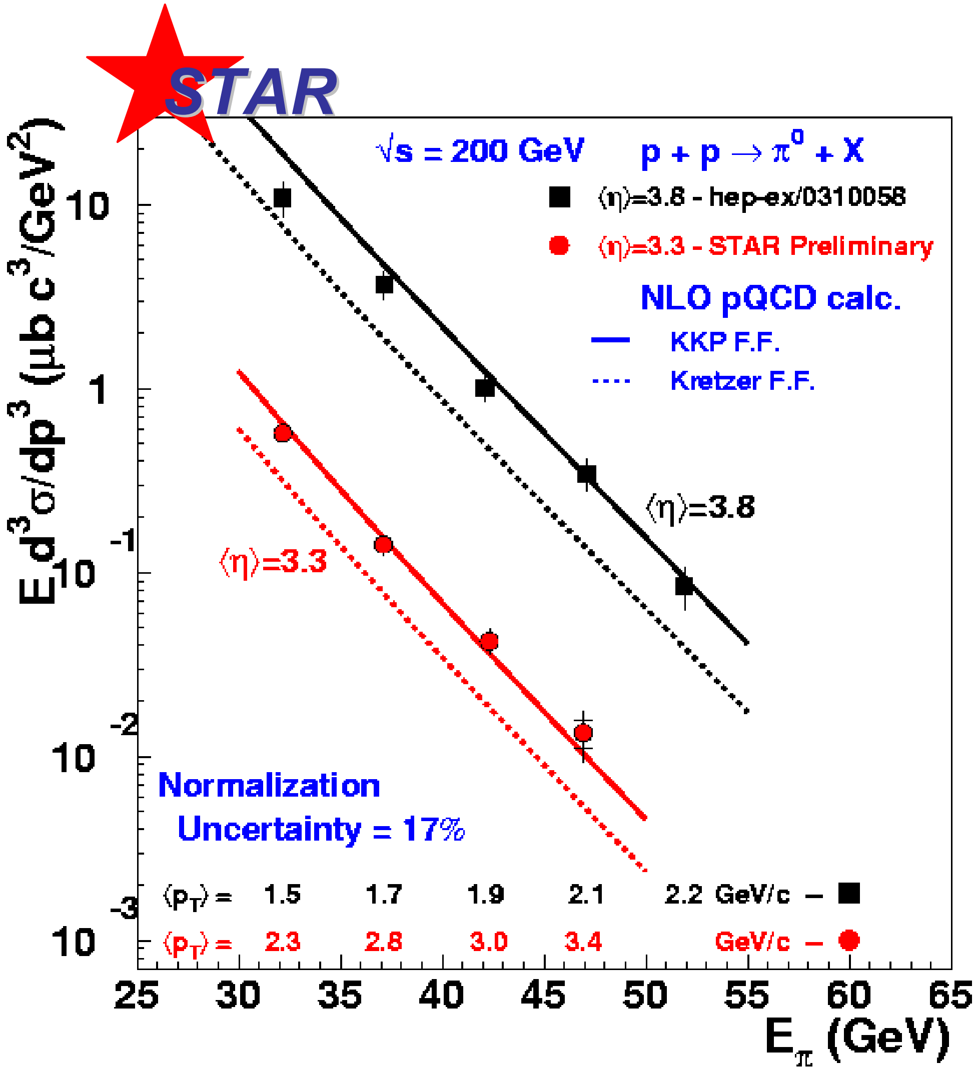
p_T and $p_T/2$

Bourelly and Soffer (hep-ph/0311110):

NLO pQCD calculations underpredict the data at low √s from ISR

$\sigma_{data}/\sigma_{pQCD}$ appears to be function of θ, √s in addition to p_T

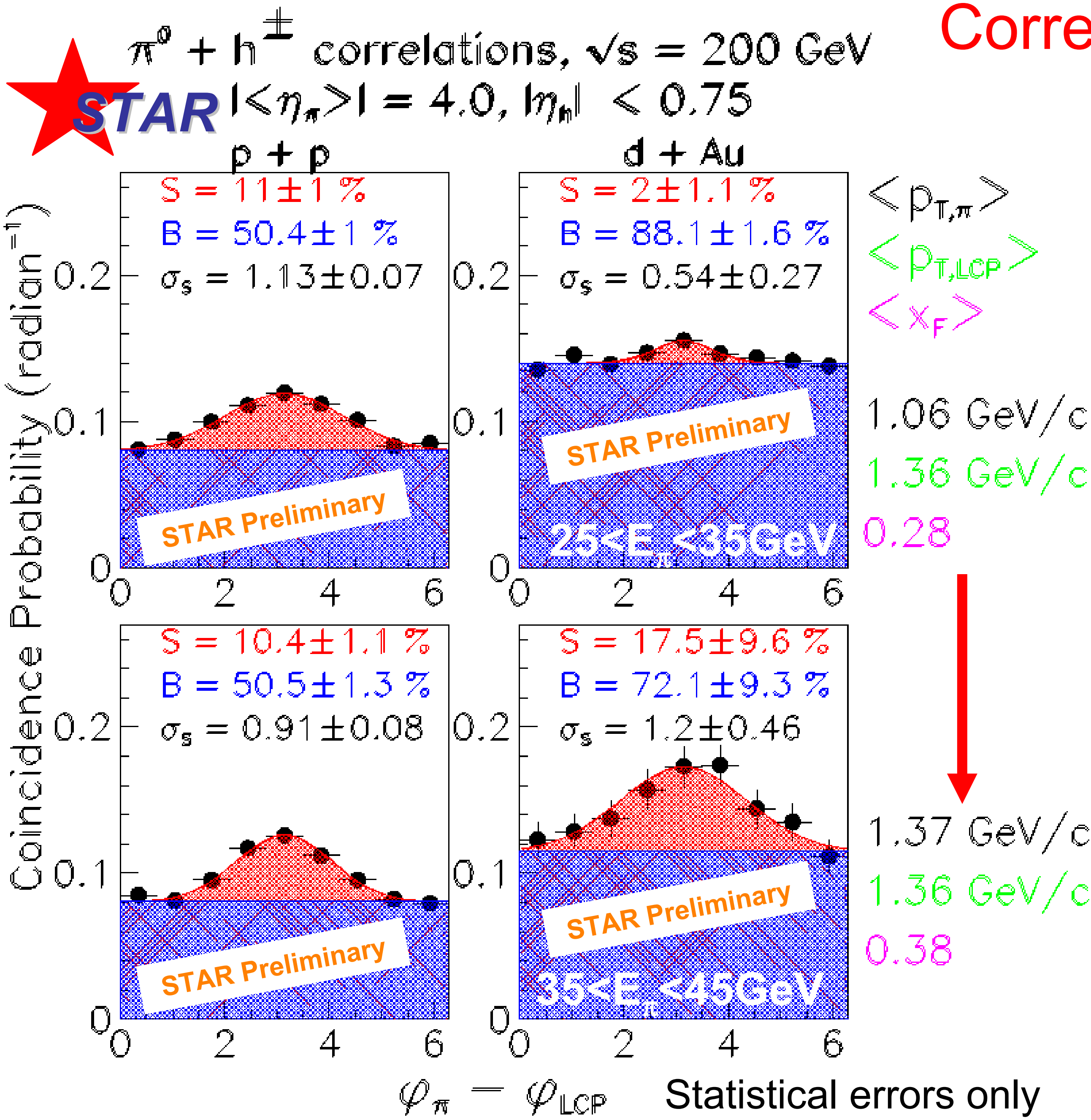
Forward π^0 Inclusive Cross Section



- STAR data at
  - $\langle\eta\rangle$= 3.8 (PRL 92, 171801)
  - $\langle\eta\rangle$= 3.3 (hep-ex/0403012, Preliminary)
- NLO pQCD calculations at fixed η with equal factorization and renormalization scales = p_T
- Solid and dashed curves differ primarily in the $g \rightarrow \pi$ fragmentation function

STAR data **consistent with Next-to-Leading Order pQCD calculations** in contrast to data at lower $\sqrt{s}$

Correlations in d+Au

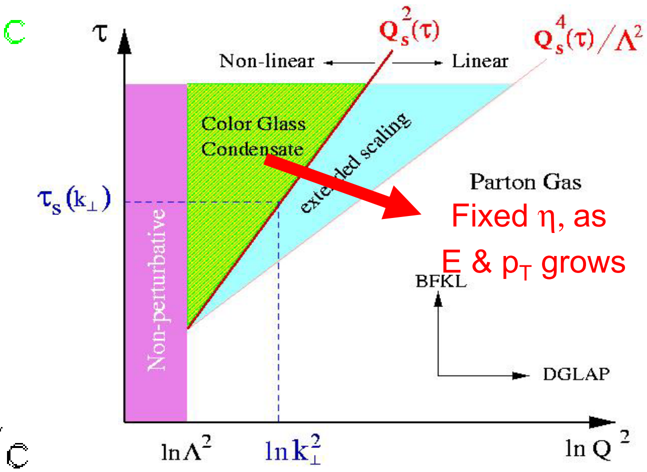


Statistical errors only

- are suppressed at small $\langle x_F\rangle$ and $\langle p_{T,\pi}\rangle$

S_{pp}-S_{dAu}= (9.0 ± 1.5) %

Consistent with CGC picture

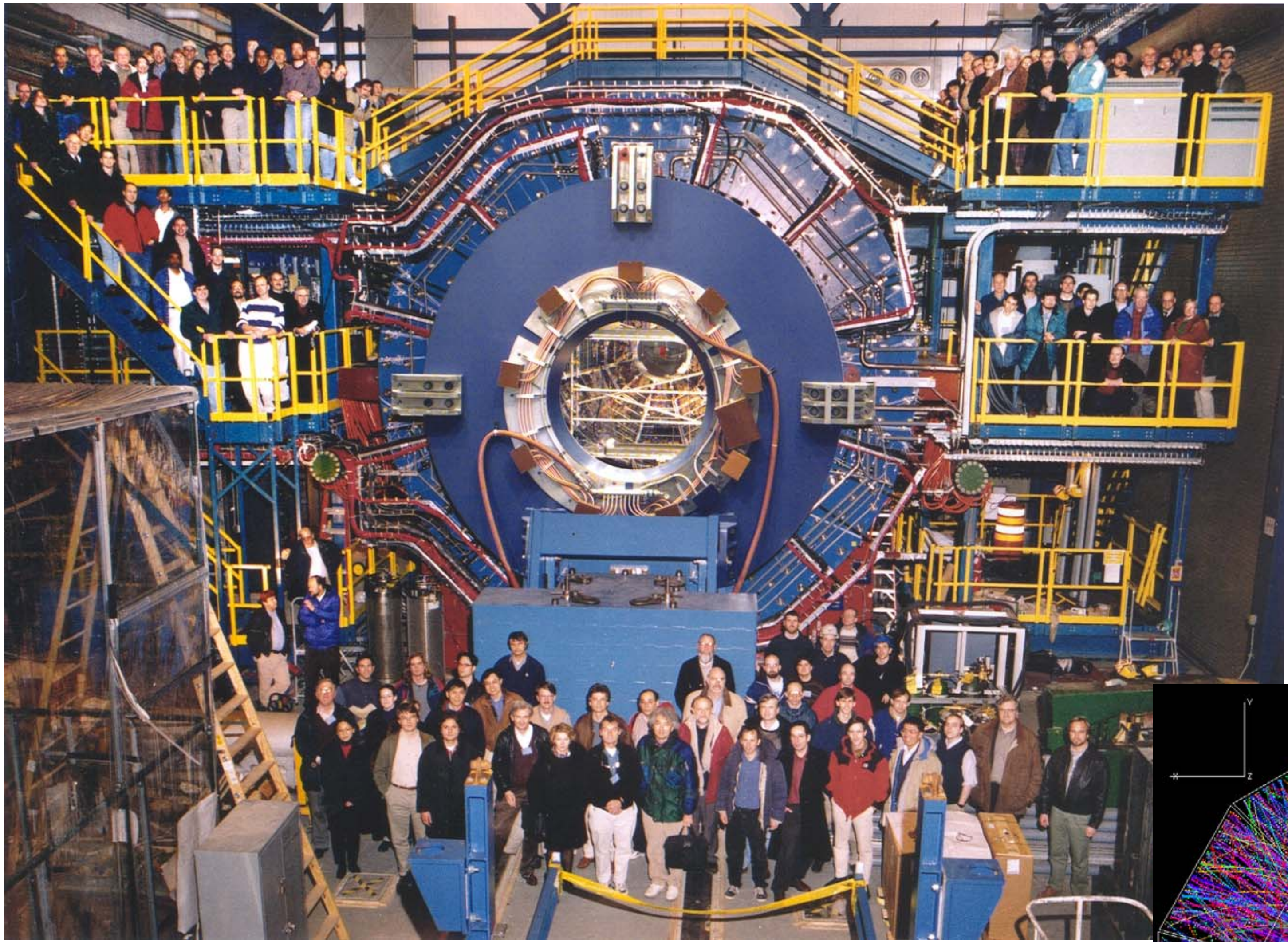


- are consistent in d+Au and p+p at larger $\langle x_F\rangle$ and $\langle p_{T,\pi}\rangle$

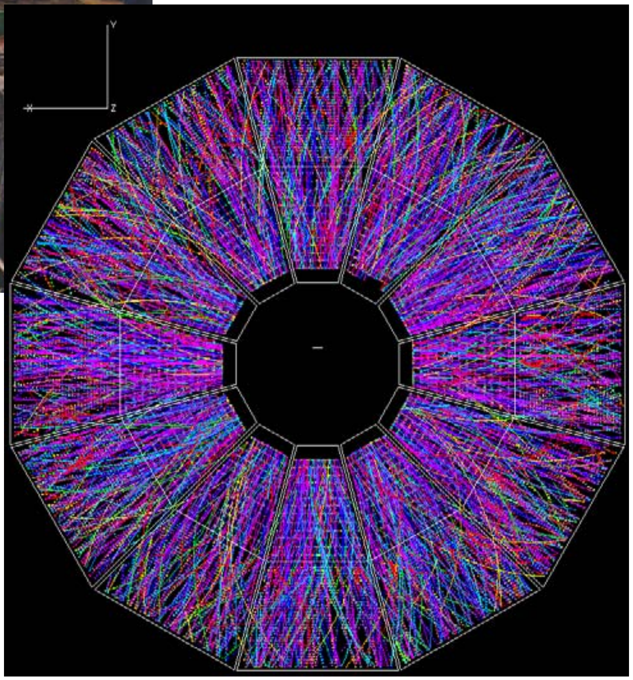
as expected by HIJING

Conclusions

- **Jet quenching, elliptic flow, and di-hadron correlations** are all very similar in 62 GeV Au+Au to the results from 200 GeV Au+Au
- **Meson-baryon differences** are also present in d+Au and 62 GeV Au+Au at intermediate p_T
- The **saturation picture** is consistent with back-front asymmetries and forward-midrapidity correlations in d+Au
- Lots more about *STAR* high-p_T correlations tomorrow morning



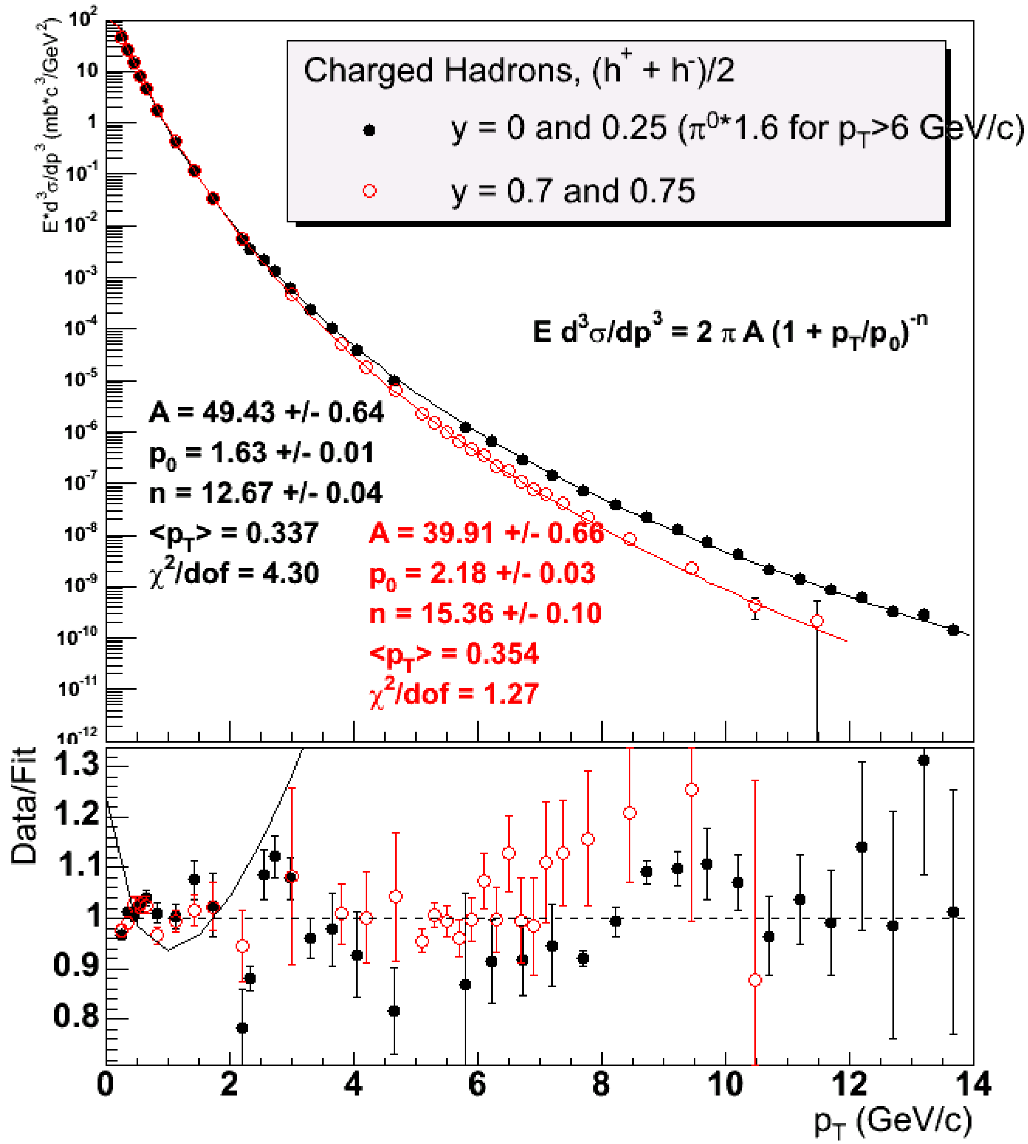
The STAR Collaboration



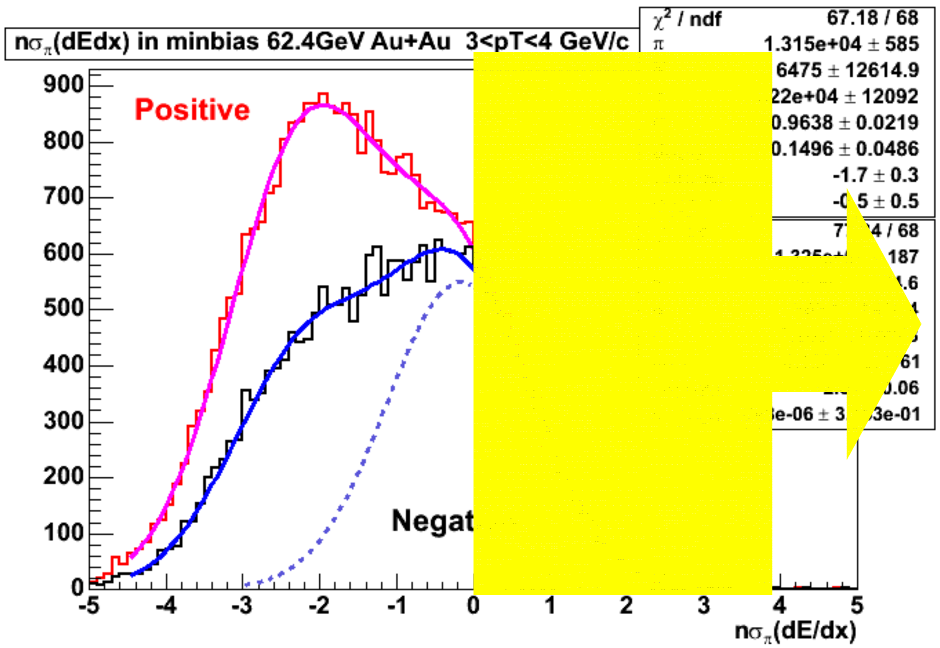
Solenoid Tracker At RHIC

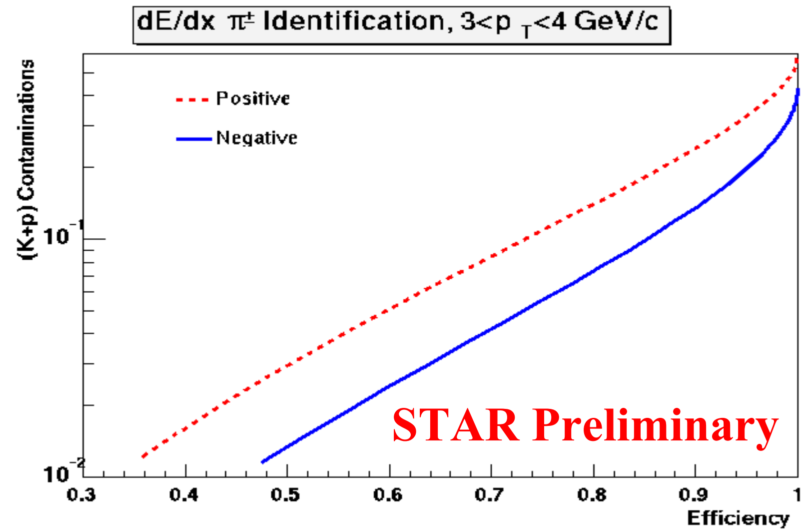
522 collaborators
51 institutions
12 countries

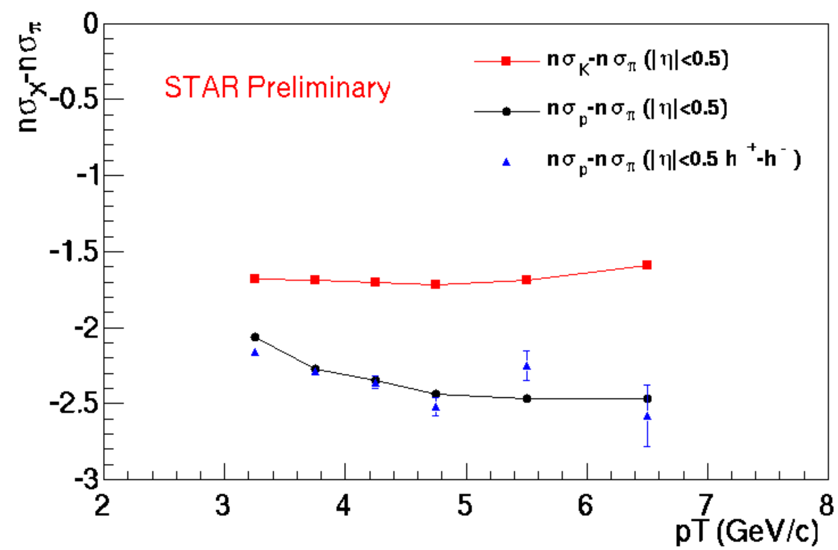
The 62 GeV Reference Spectrum Problem



π-(K+p) Separation

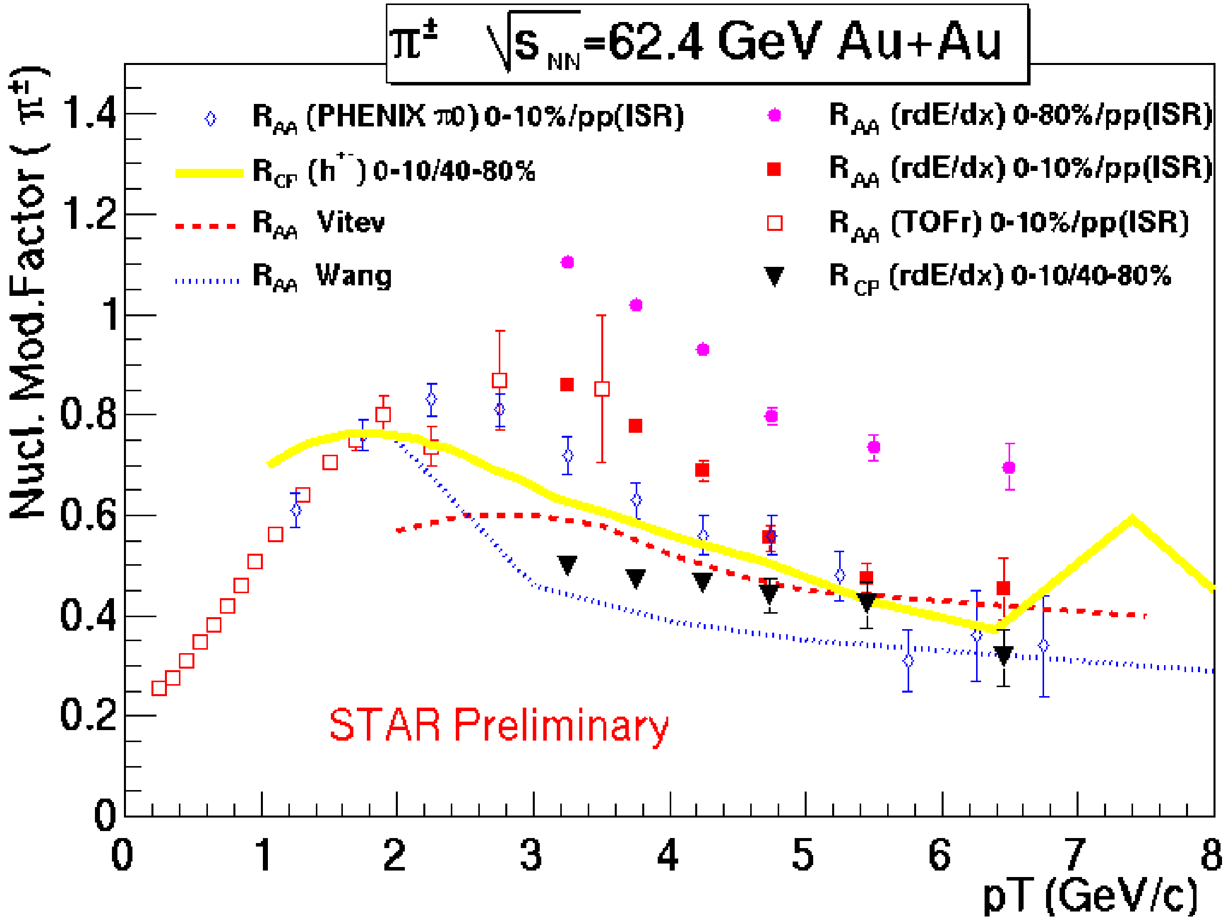






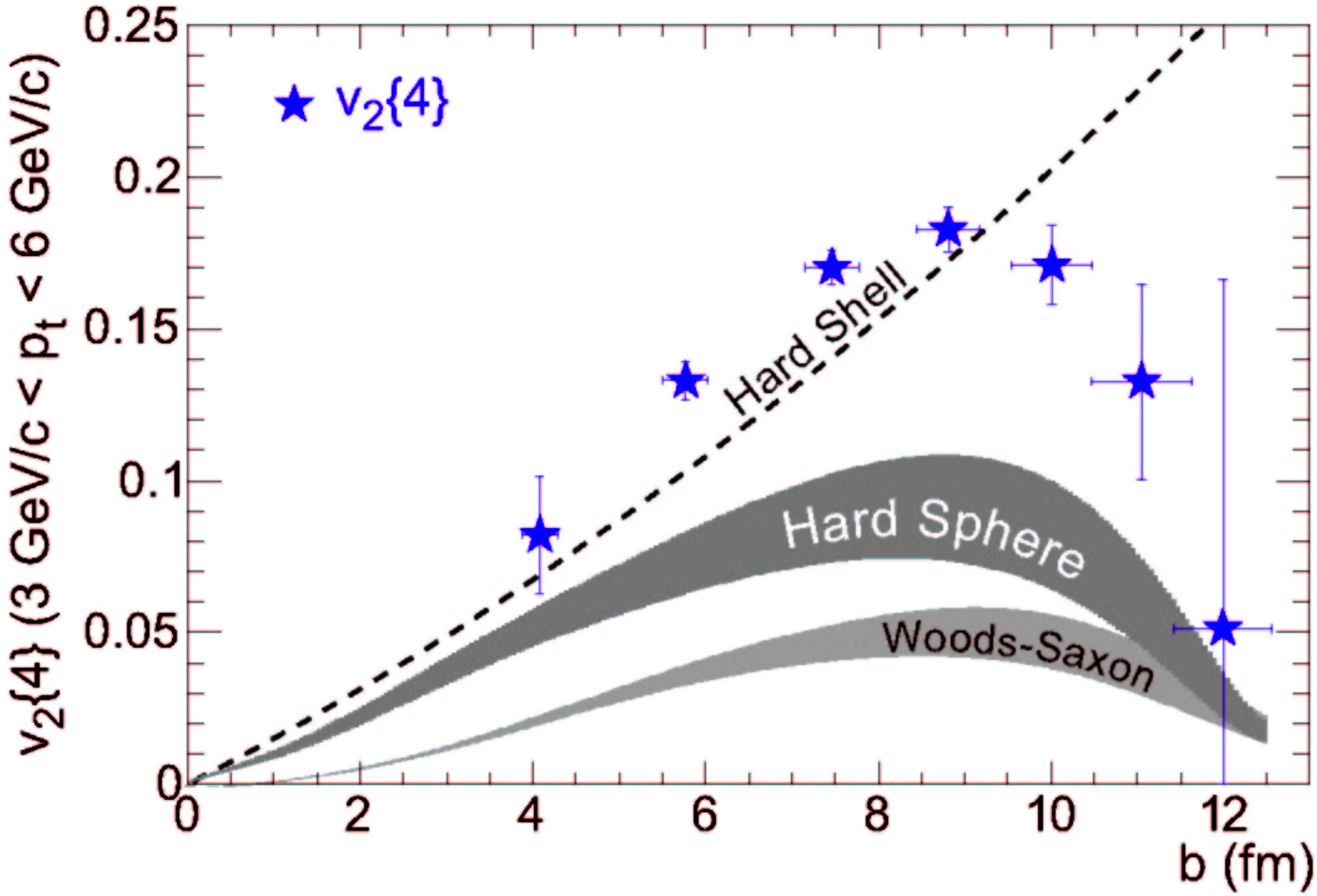
- 3 Gauss fits: dE/dx(π)>1.3*dE/dx(K)
dE/dx(π) as normal Gauss: σ=1, mean=0
- π-(K+p) Separation: ~1.5-2σ
- Worst Contamination:
1-3% at 50% Eff , 10% at 70-90% Eff

$\pi^{\pm}$ Nuclear Modification Factor



- R_{CP} h+- 20% higher than π+- p_T=3-4 GeV/c; consistent with h/π ratio
- Vitev prediction at dN/dy=650
- ISR pp parametrization same as PHENIX

v_2 vs. Geometry in 200 GeV Au+Au

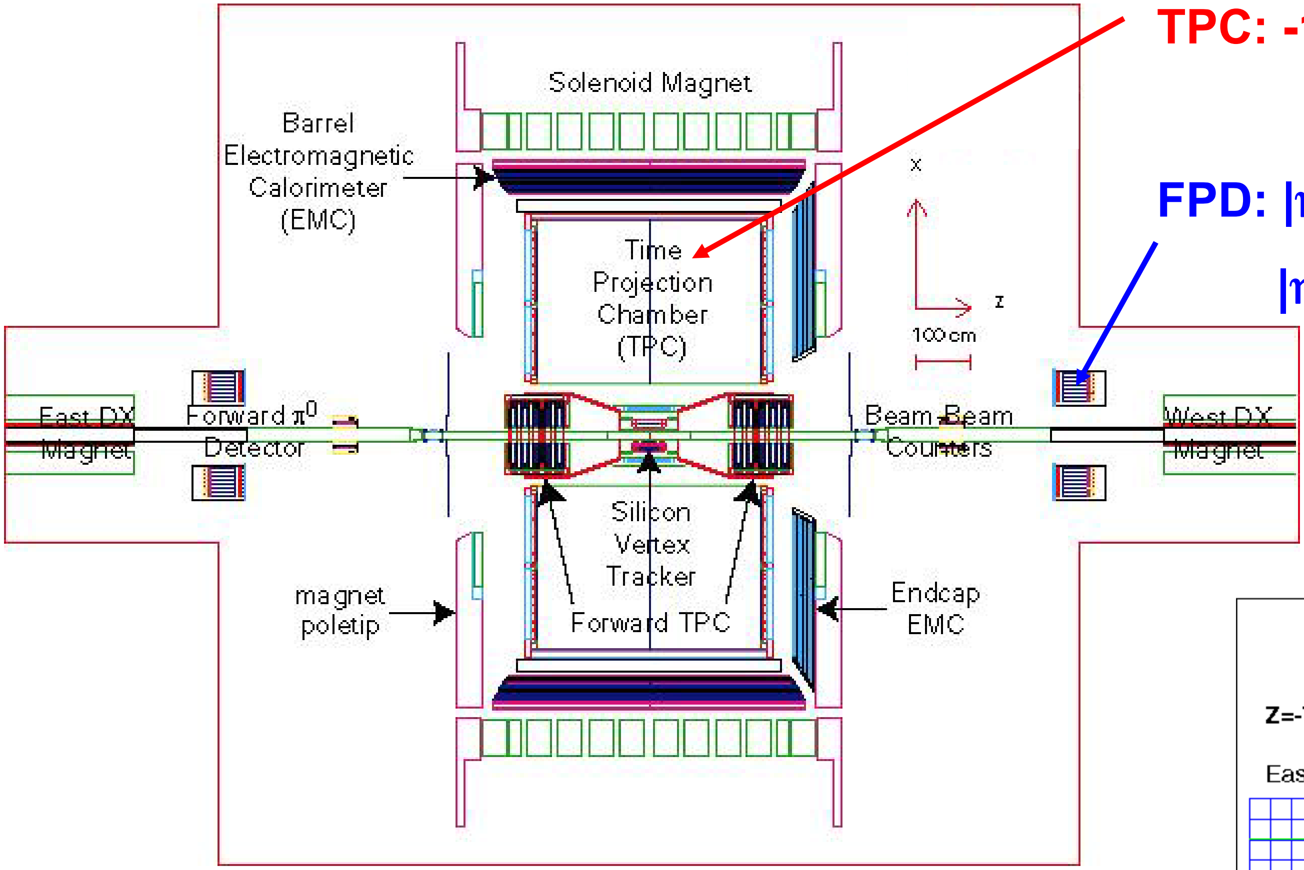


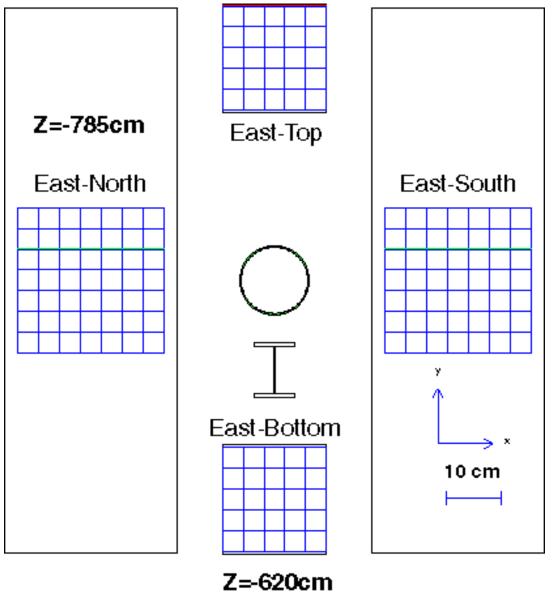
STAR Detector

TPC: -1.0 < η < 1.0

FPD: |η| ~ 3.8 (p + p)

|η| ~ 4.0 (p + p and d + Au)



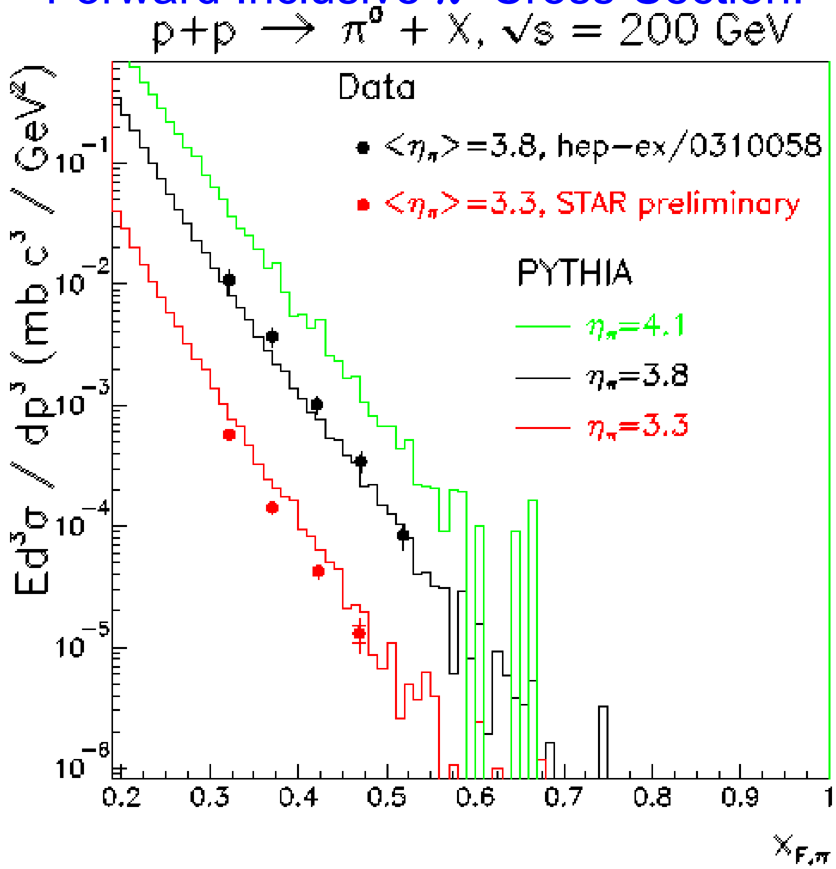


Forward π^0 Detector (FPD)

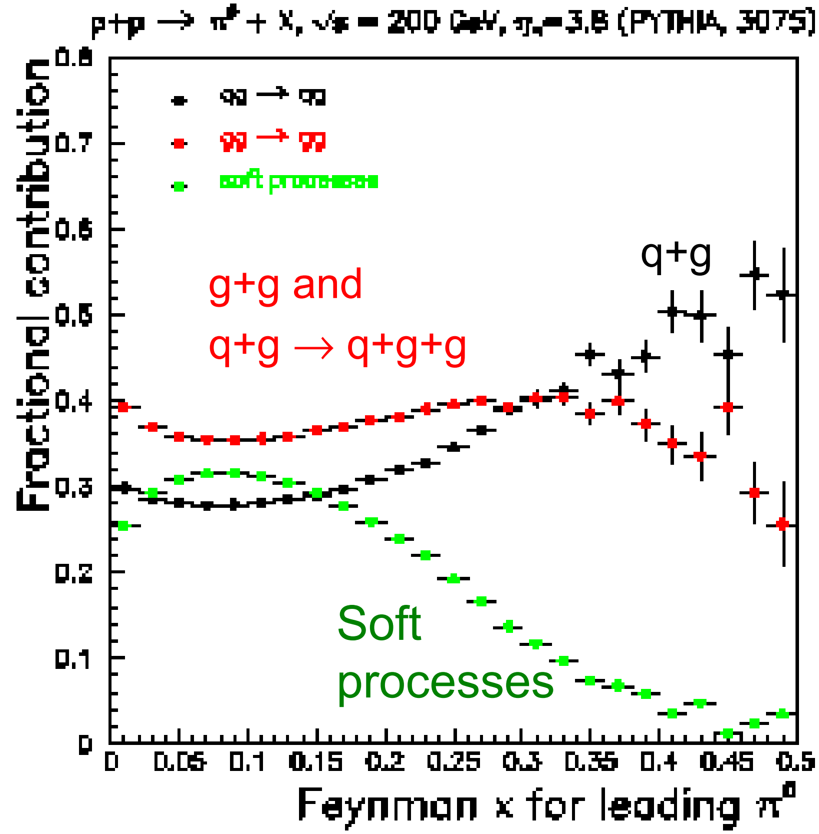
- **Pb-glass EM calorimeter**
- **Shower-Maximum Detector (SMD)**
- **Preshower**

PYTHIA: a Guide to the Physics

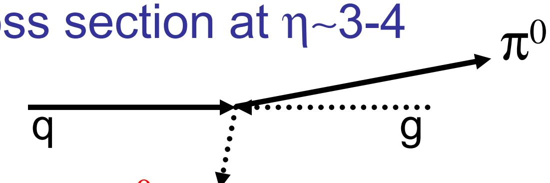
Forward Inclusive π^0 Cross-Section:



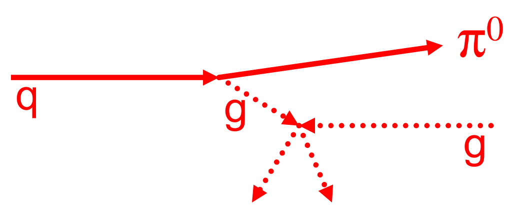
Subprocesses involved:



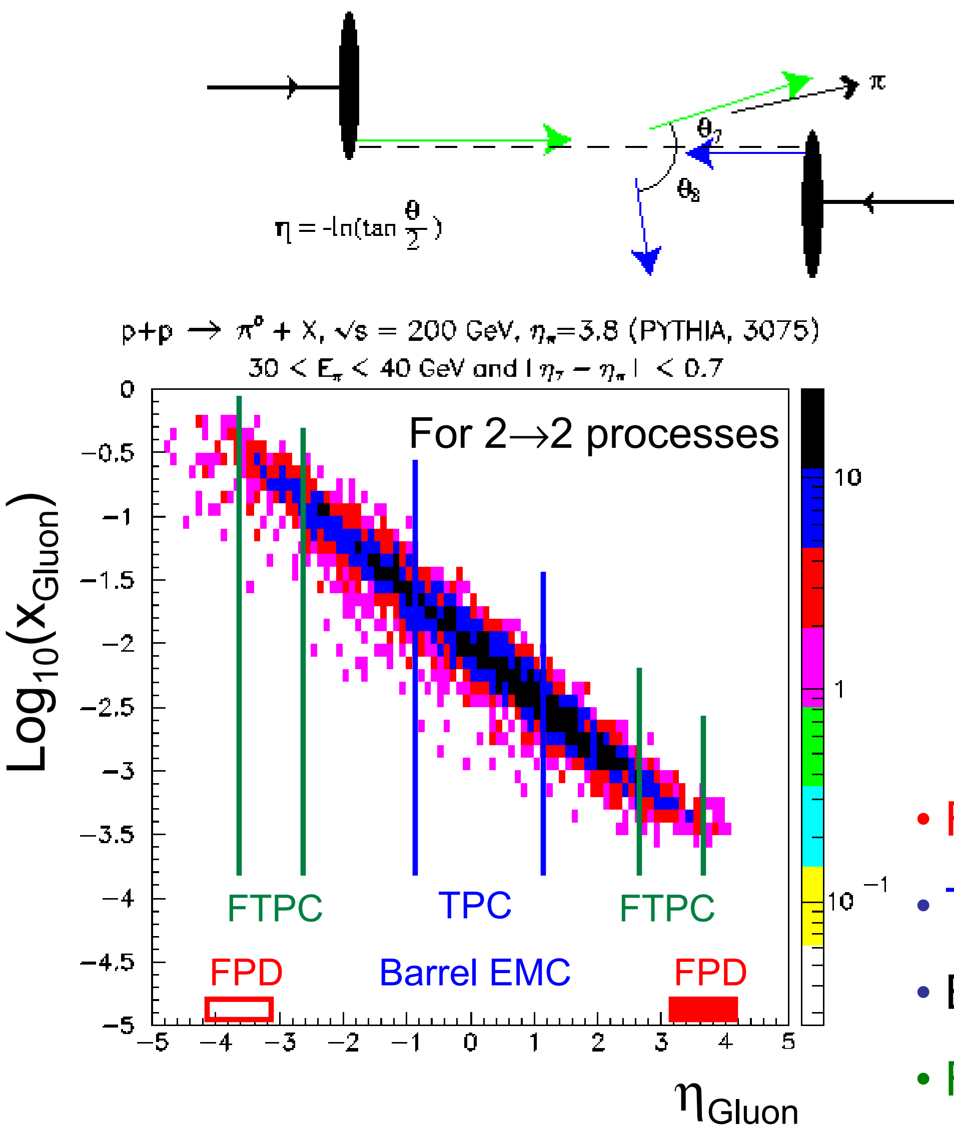
- PYTHIA ***prediction*** agrees well with the inclusive π^0 cross section at η~3-4
- Dominant sources of large x_F π^0 production from:



- q + g → q + g **(2→2)** → π^0 + X
- q + g → q + g + g **(2→3)** → π^0 + X



Forward – Mid-Rapidity Correlations



Final state correlations allow **reconstruction of parton kinematics…**

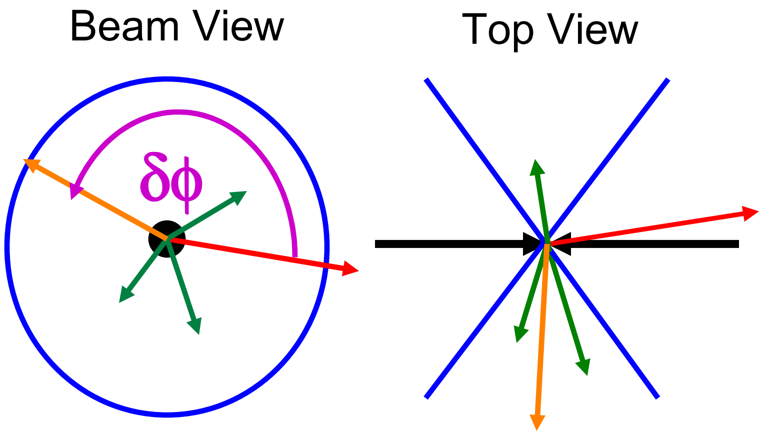
Broad rapidity range at STAR enables broad coverage of parton kinematics

Nuclear enhancement of gluon field : $A^{1/3}x$ ~ 6x (Au case)?

- FPD: $|\eta| \sim 4.0$
- TPC and Barrel EMC: $|\eta| < 1.0$
- Endcap EMC: $1.0 < \eta < 2.0$
- FTPC: $2.8 < |\eta| < 3.8$

Back-to-Back Azimuthal Correlations

over a large rapidity interval



Trigger by forward π^0

- **$E_p > 25$ GeV**
- **$\langle \eta_\pi \rangle = 3.8$**

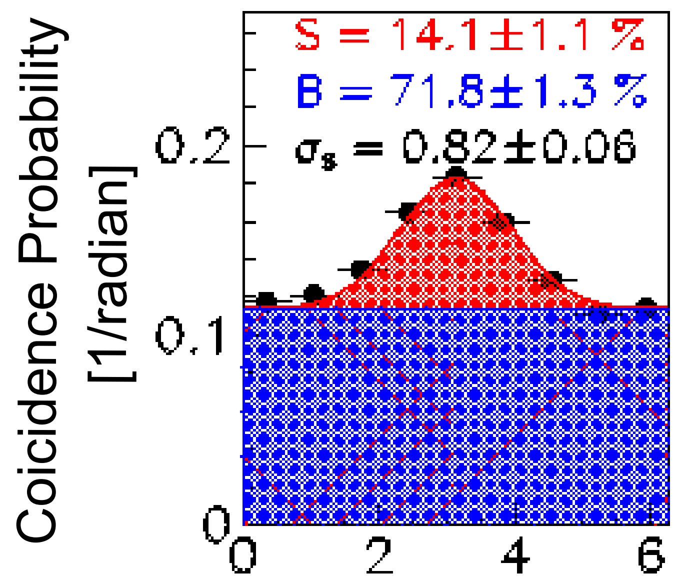
Midrapidity $h^{\pm}$ tracks in TPC

- **$-0.75 < \eta < +0.75$**

Leading Charged Particle(LCP)

- **$p_T > 0.5$ GeV/c**

Fit $\delta\phi = \phi_\pi - \phi_{LCP}$ normalized distributions and with Gaussian+constant



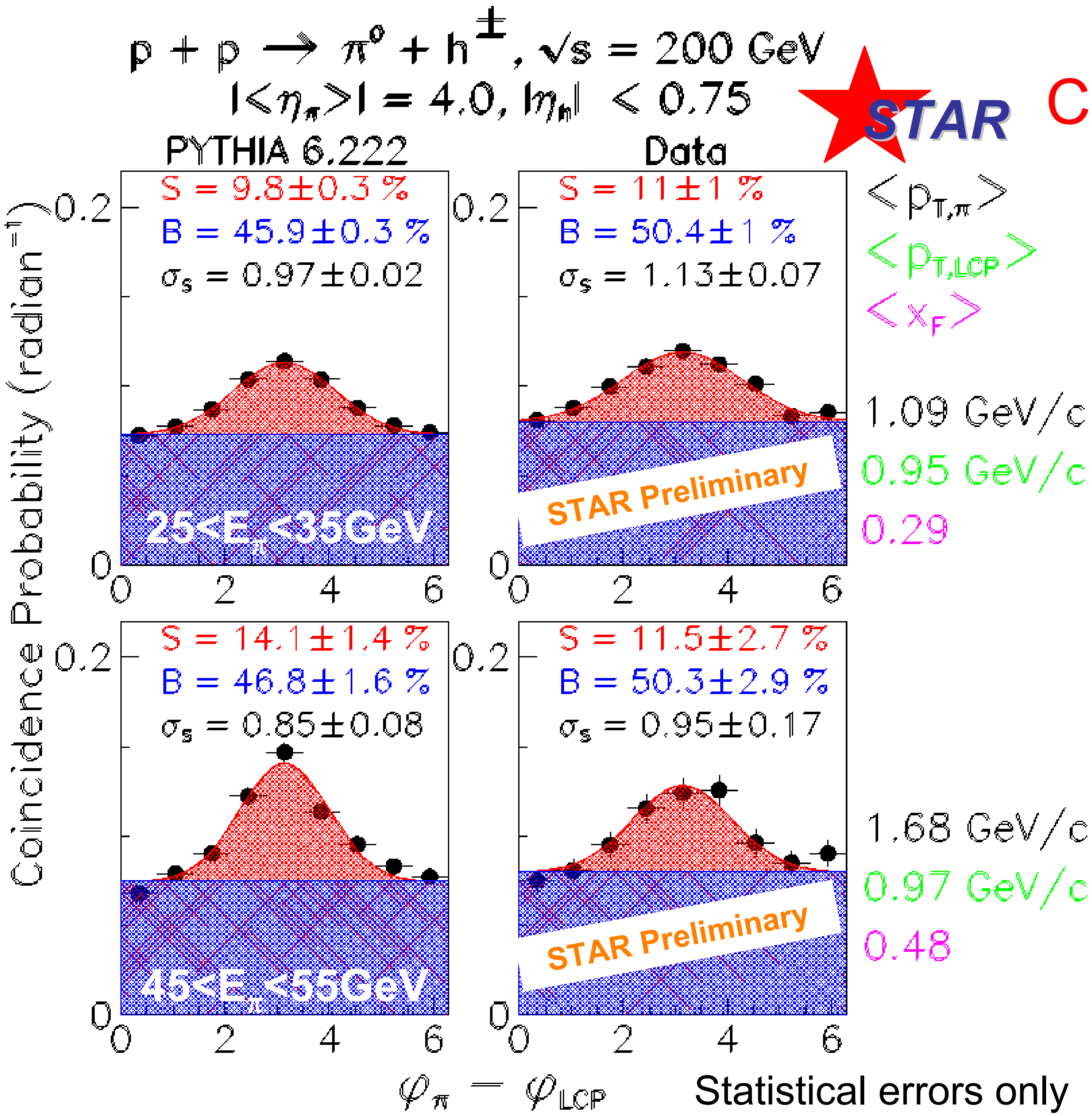
$\delta\phi = \phi_\pi - \phi_{LCP}$

S = Probability of “correlated” event under Gaussian

B = Probability of “un-correlated” event under constant

σ_s = Width of Gaussian

FPD-TPC Correlations in p+p



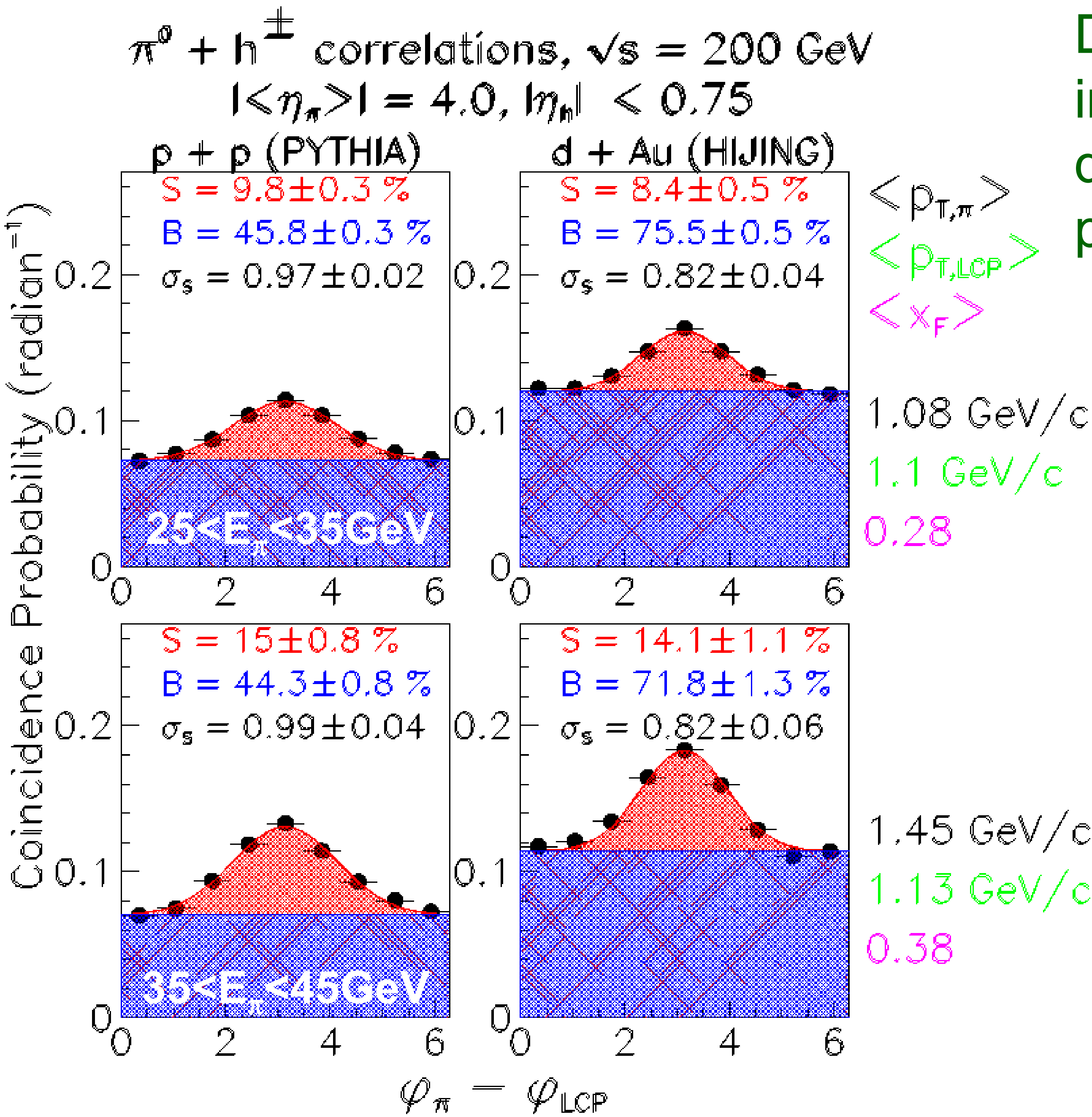
Statistical errors only

PYTHIA (with detector effects) predicts

- **"S" grows with $<x_F>$ and $<p_{T,\pi}>$**
- **"σ_s" decrease with $<x_F>$ and $<p_{T,\pi}>$**

PYTHIA prediction agrees with data

Larger intrinsic k_T required to fit data



Does multiplicity introduce “trivial” differences between p+p and d+Au?

HIJING predicts **similar effects in d+Au** as seen in p+p