Experimental Results on Two & Three Particle Correlations

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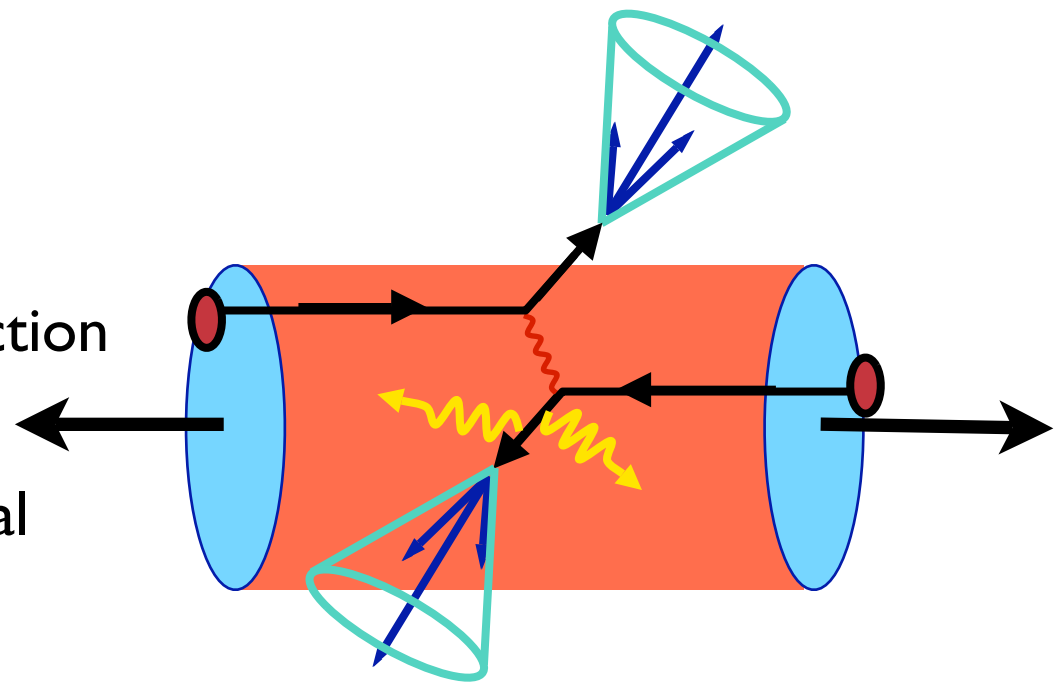
Brookhaven
June 9, 2008

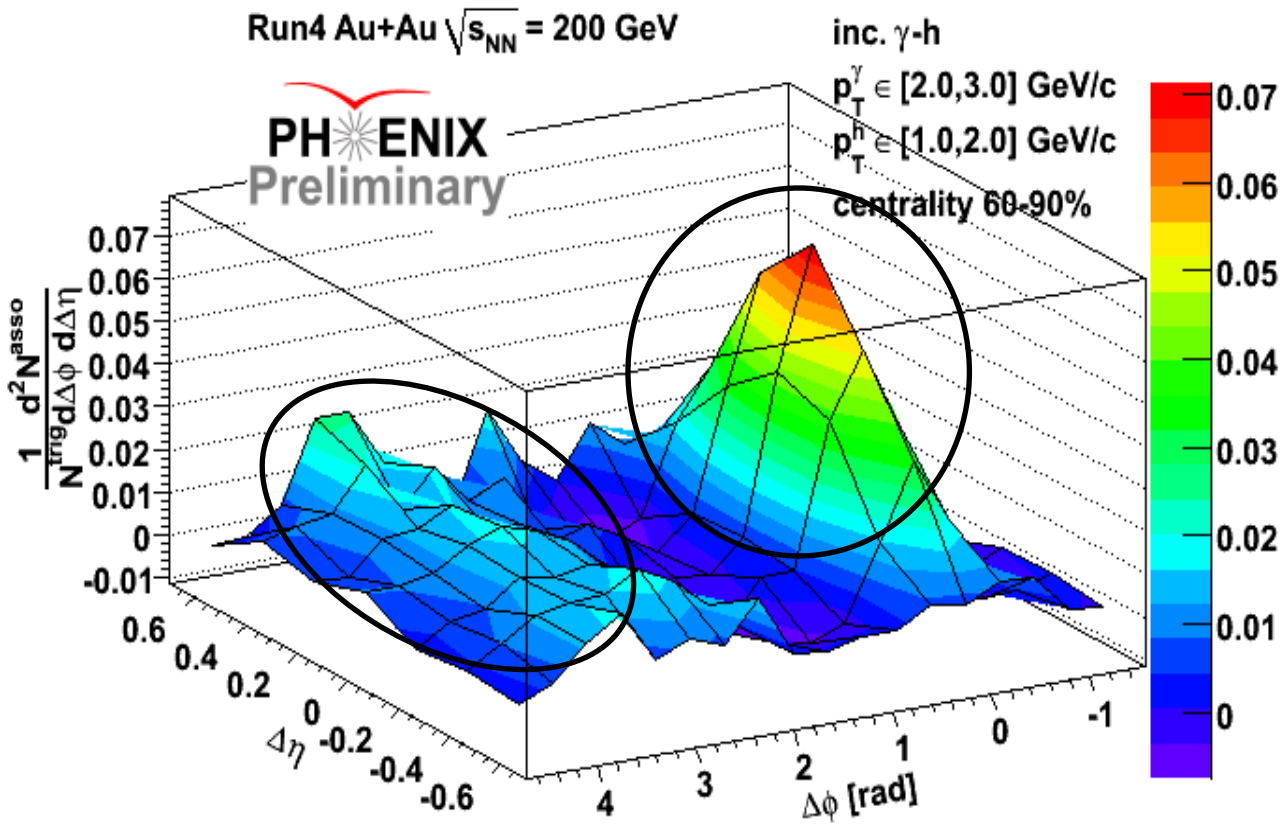
Goal: Jet Tomography

use a calibrated probe to study
matter created in heavy ion collisions

- we need to understand the probe, **jets**
  - p+p & d+Au collisions
- we need to understand the interaction of the probe and the matter
- we need to understand geometrical biases in the measurements



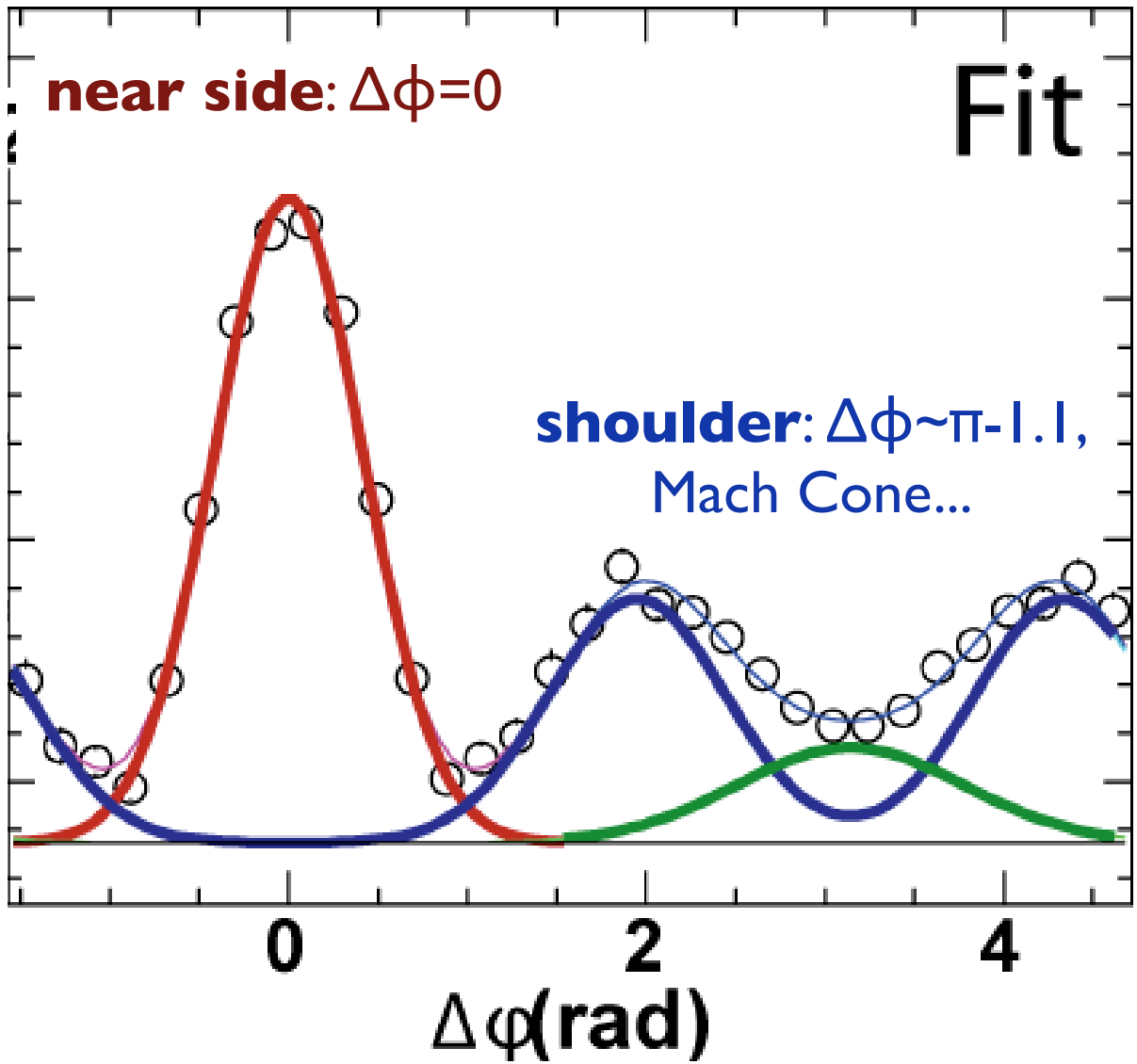
Unmodified Jets



near side jet: localized round jet in Δϕ & Δη

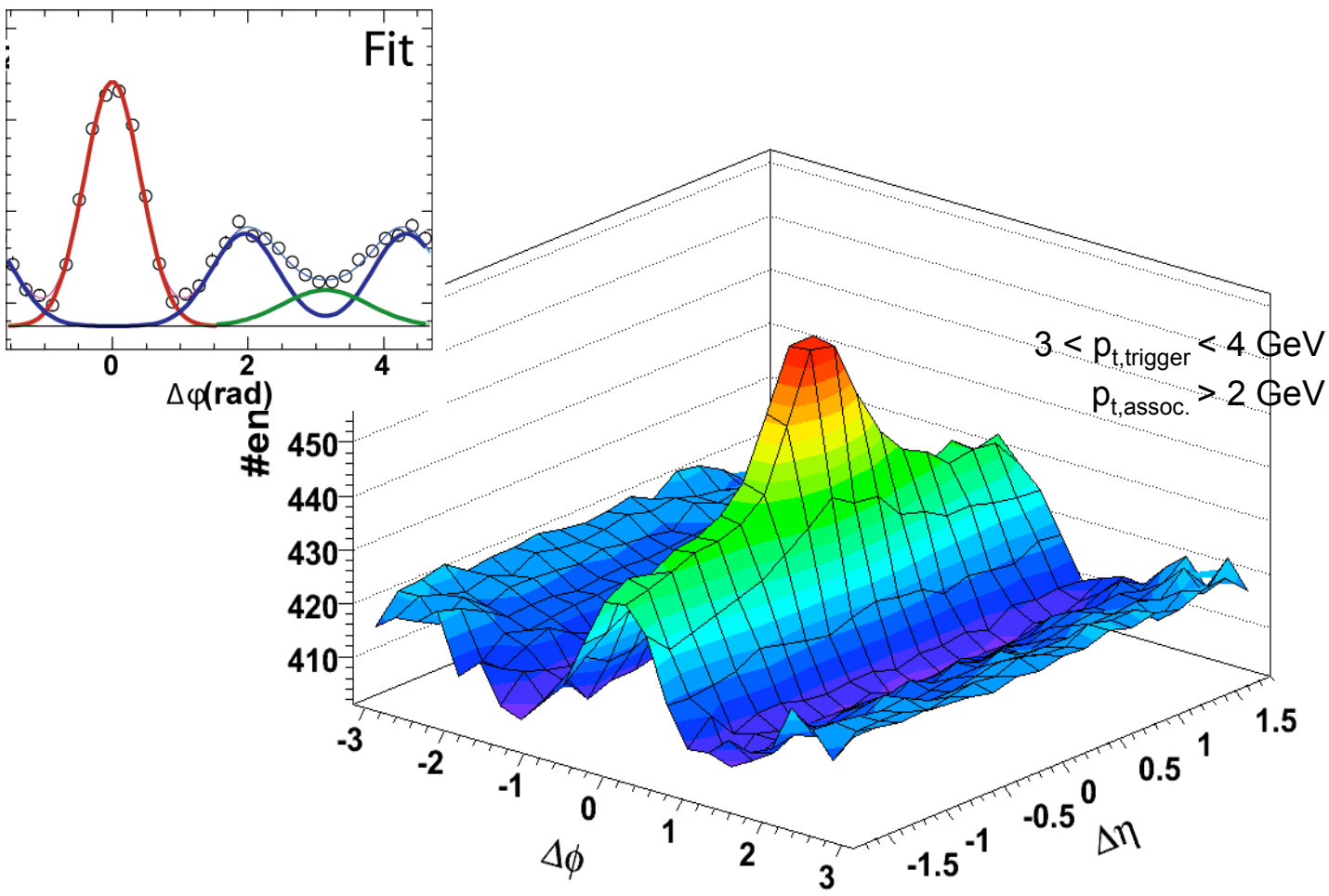
away side jet: smeared in Δη partonic kinematics

The Jet Landscape: Au+Au



di-jet: Δϕ=π

Focus on the Near Side



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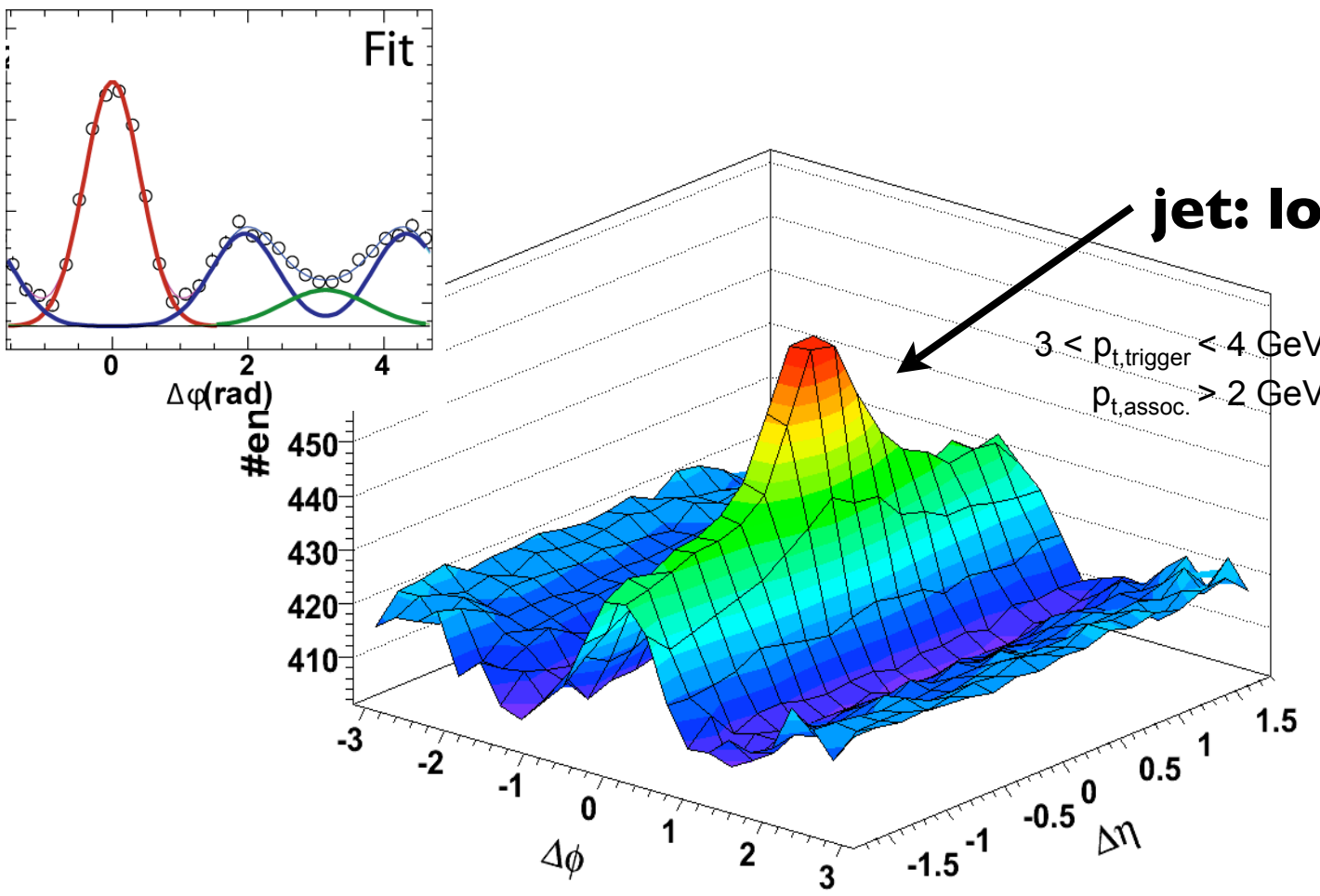
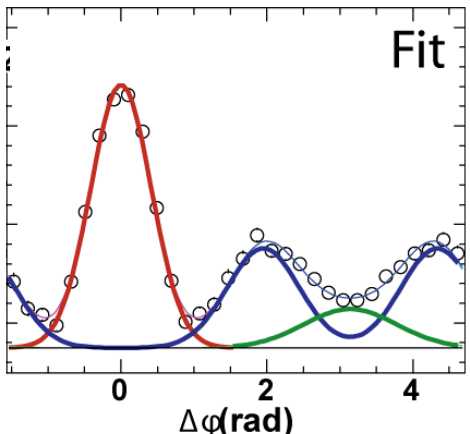
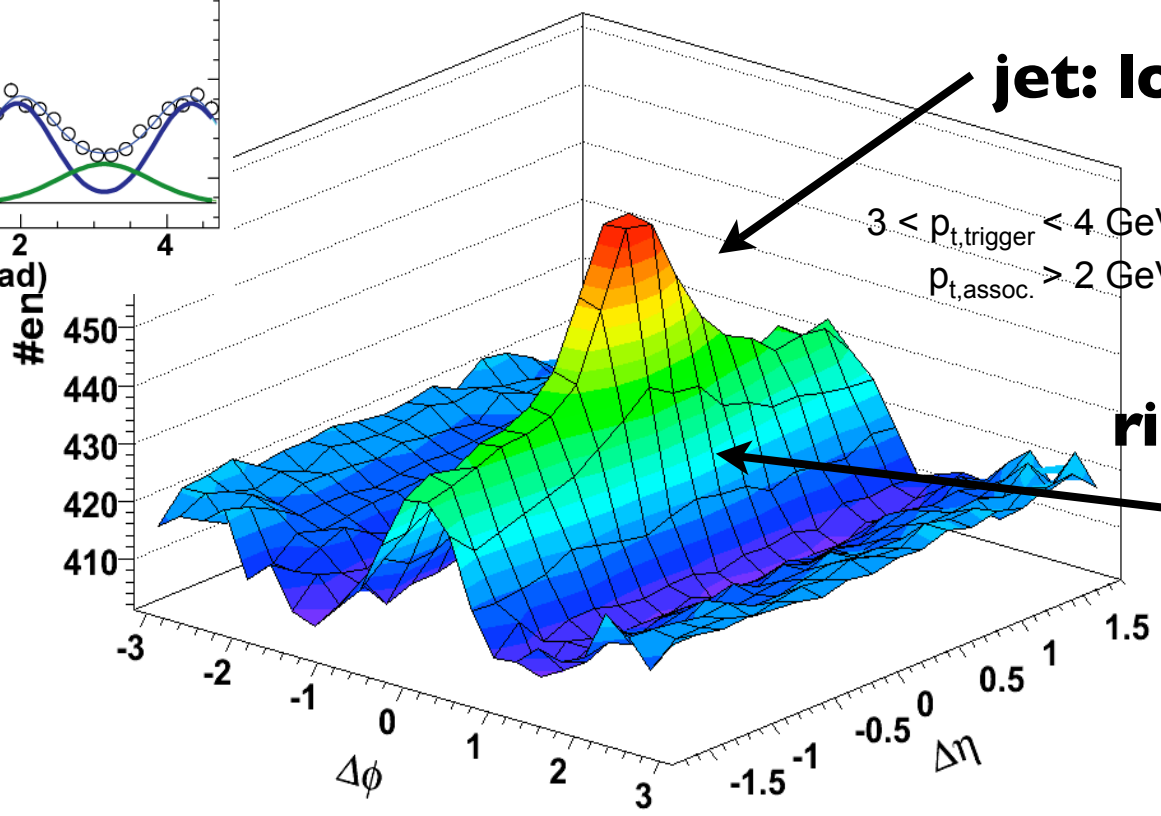


jet: localized in Δϕ & Δη

Focus on the Near Side

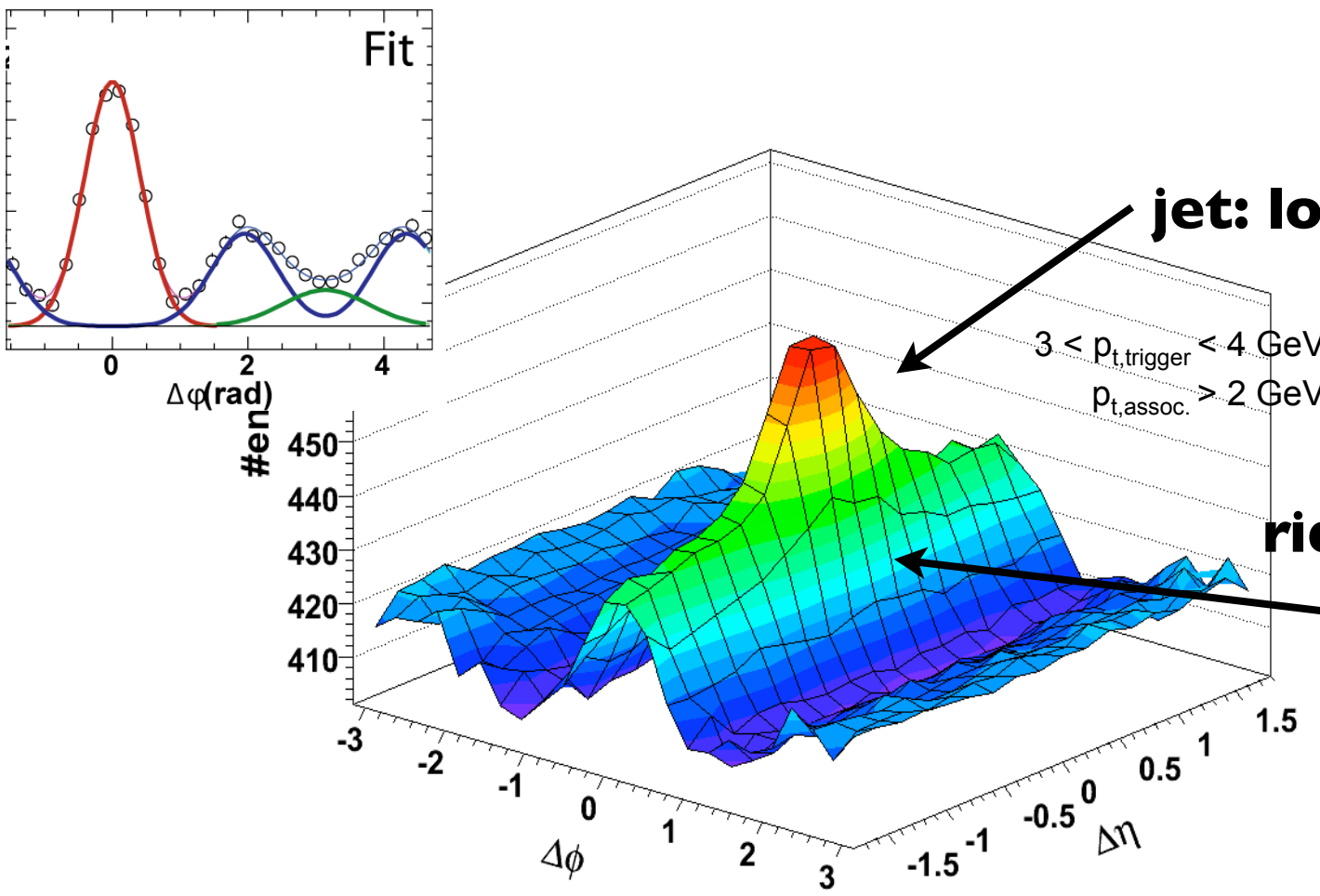




jet: localized in Δϕ & Δη

ridge: localized in Δϕ elongated in Δη

Focus on the Near Side



jet: localized in Δϕ & Δη

ridge: localized in Δϕ elongated in Δη

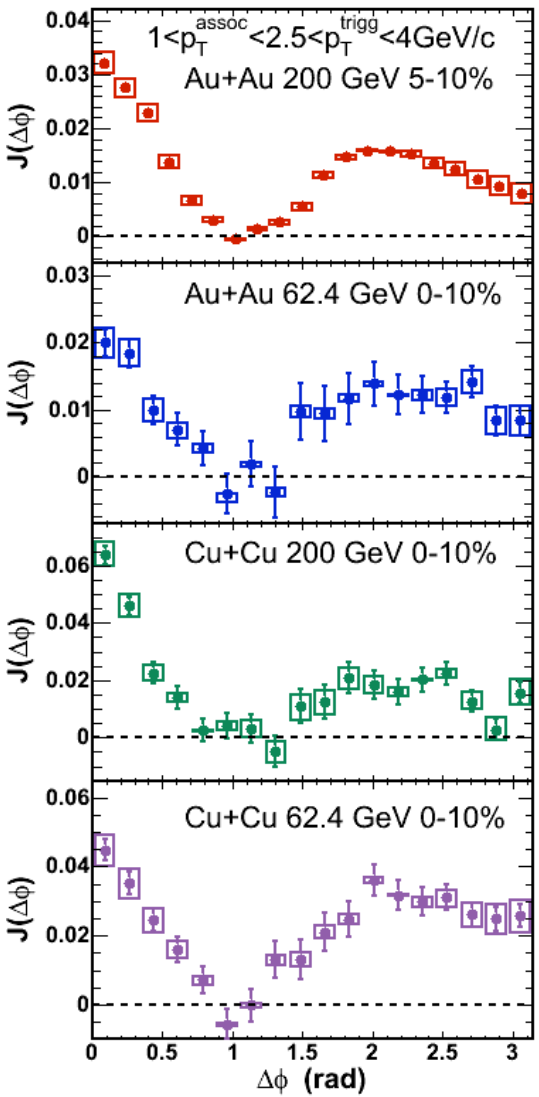
4 distinct structures: ridge & shoulder unique to heavy ion collisions

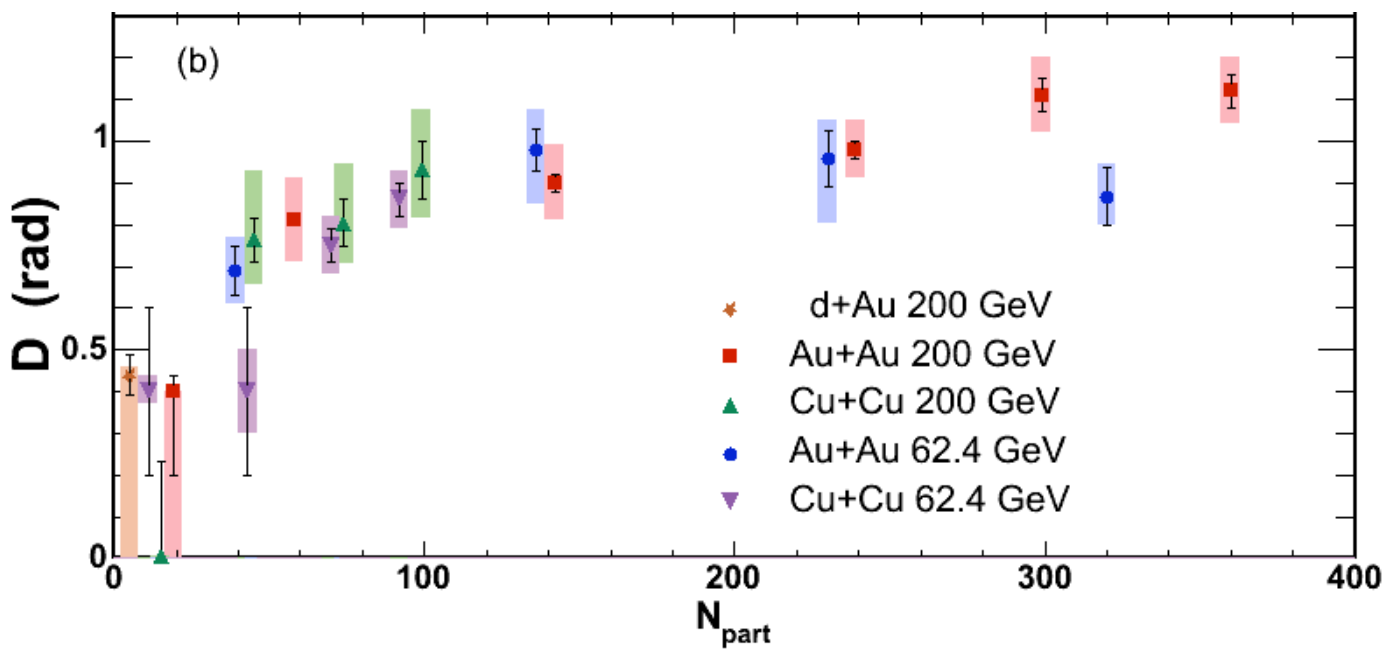
The Plan

- The Shoulder
- Comparing the Shoulder and the Ridge
- High p_T: Di-jets
- Particle Ratios and "Medium Response"
- Some New Measurements

Stability of the Shoulder

shoulder structure independent of system & energy



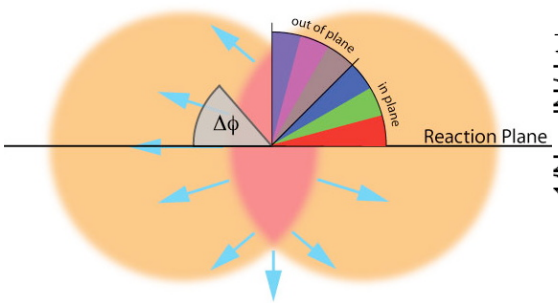


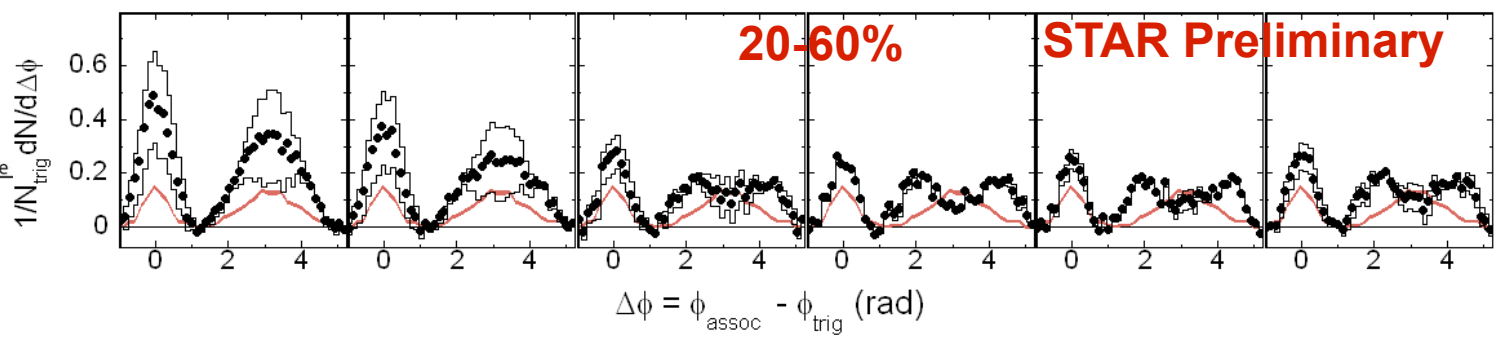
PHENIX, PRL 98 232302 (2007)

Stability of the Shoulder (II)

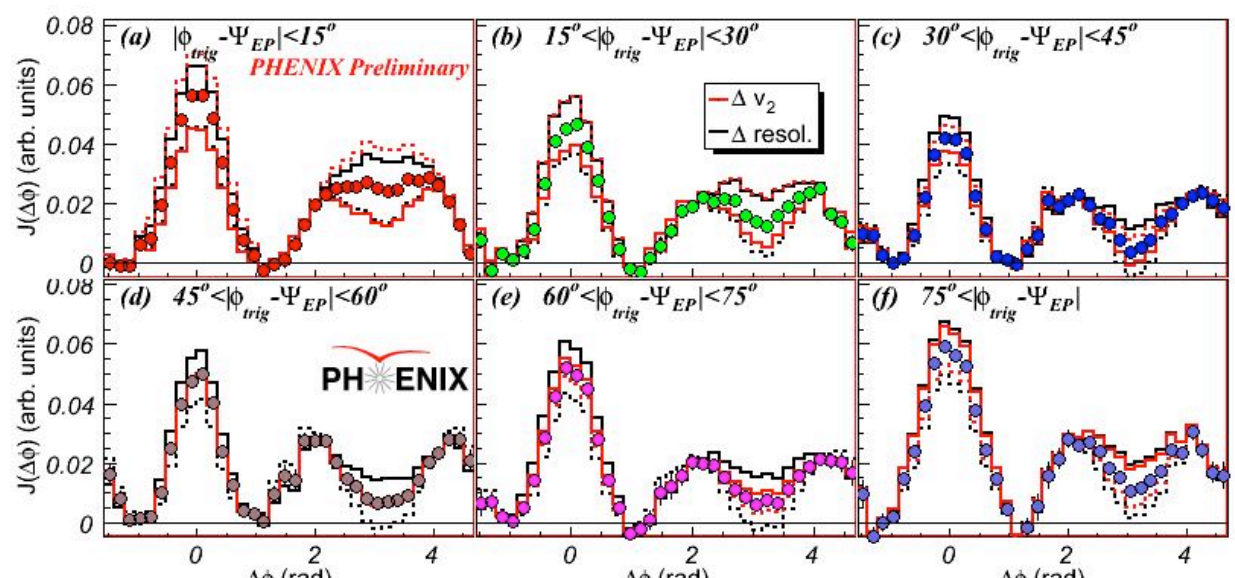
$3<p_T^{trig}<4$GeV/c & $1.0<p_T^{asso}<1.5$GeV/c

in-plane $\phi_S=0$ ⟶ out-of-plane $\phi_S=90^o$





Au+Au $\sqrt{s_{NN}}$=200GeV, Cent=30-40%, $1<p_{T,assoc}<2$ GeV/c, $2<p_{T,trig}<3$ GeV/c



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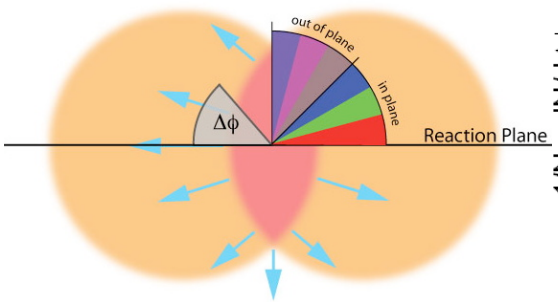

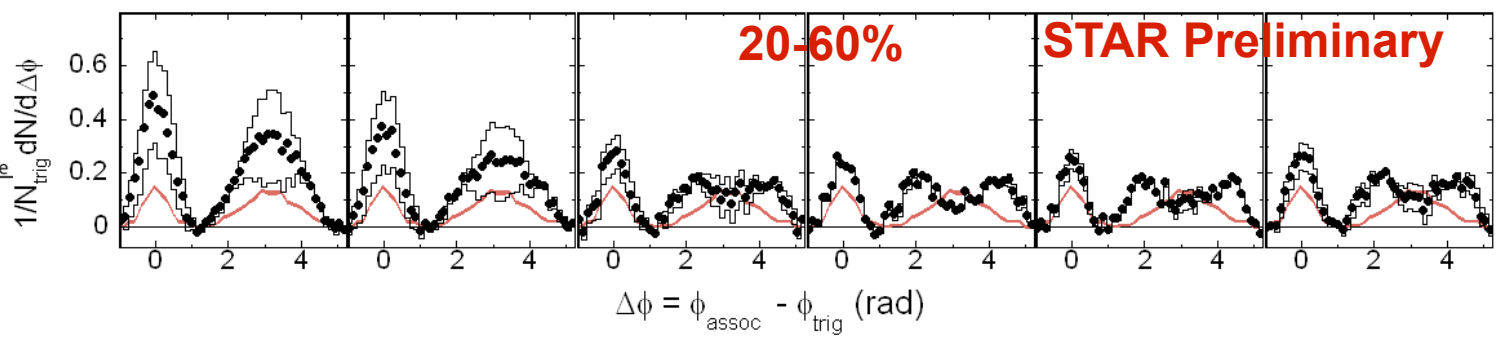

doesn't move with geometry

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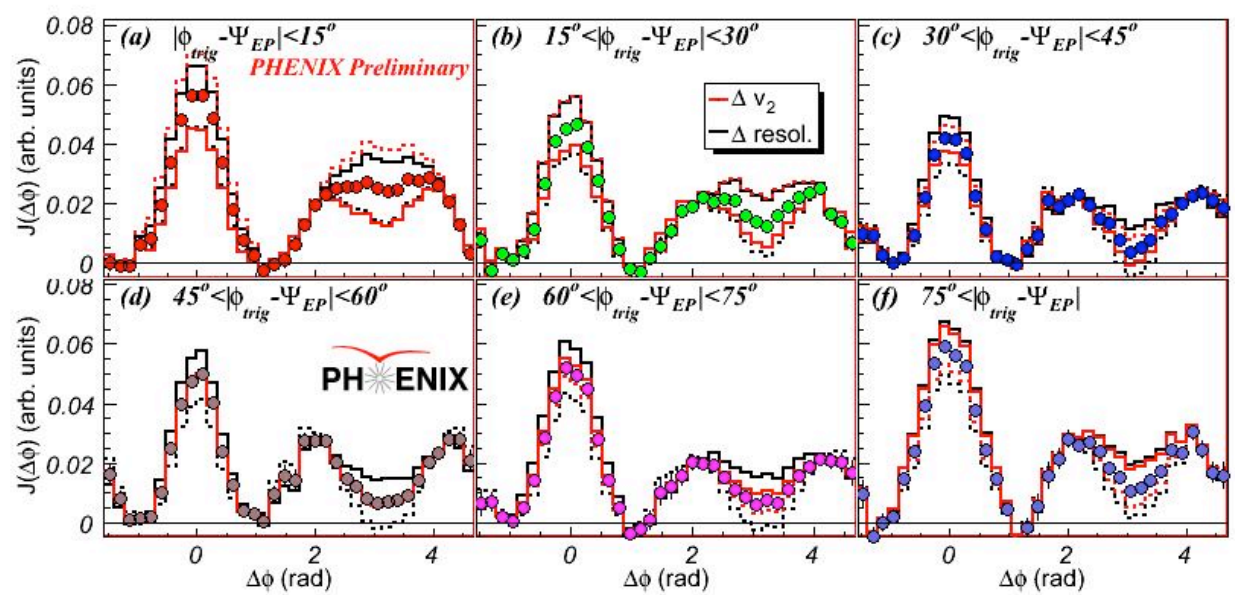

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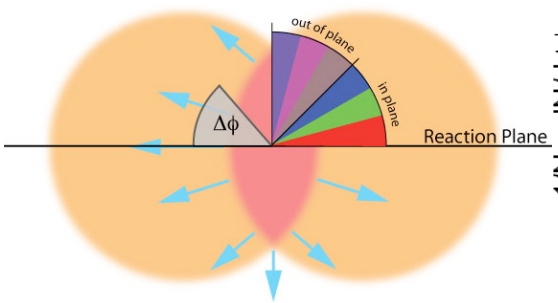
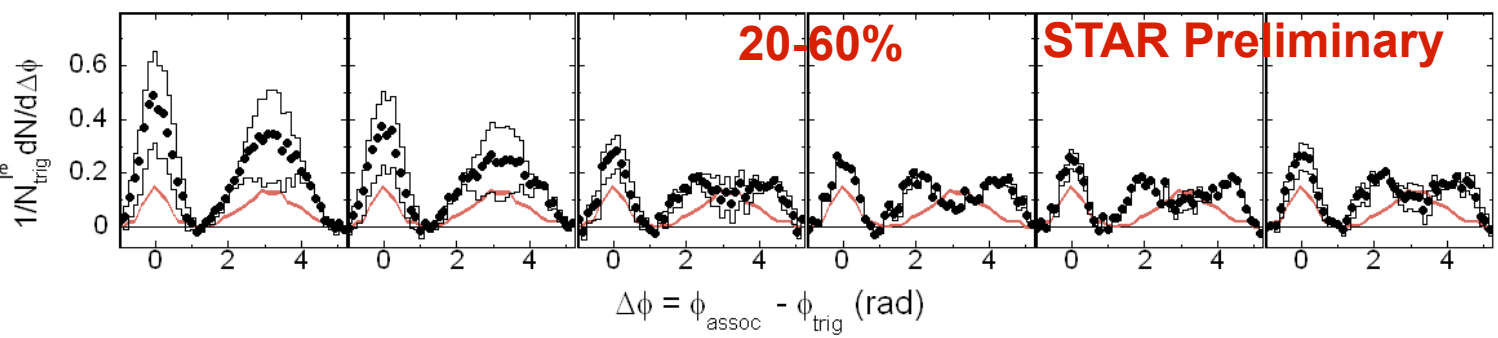
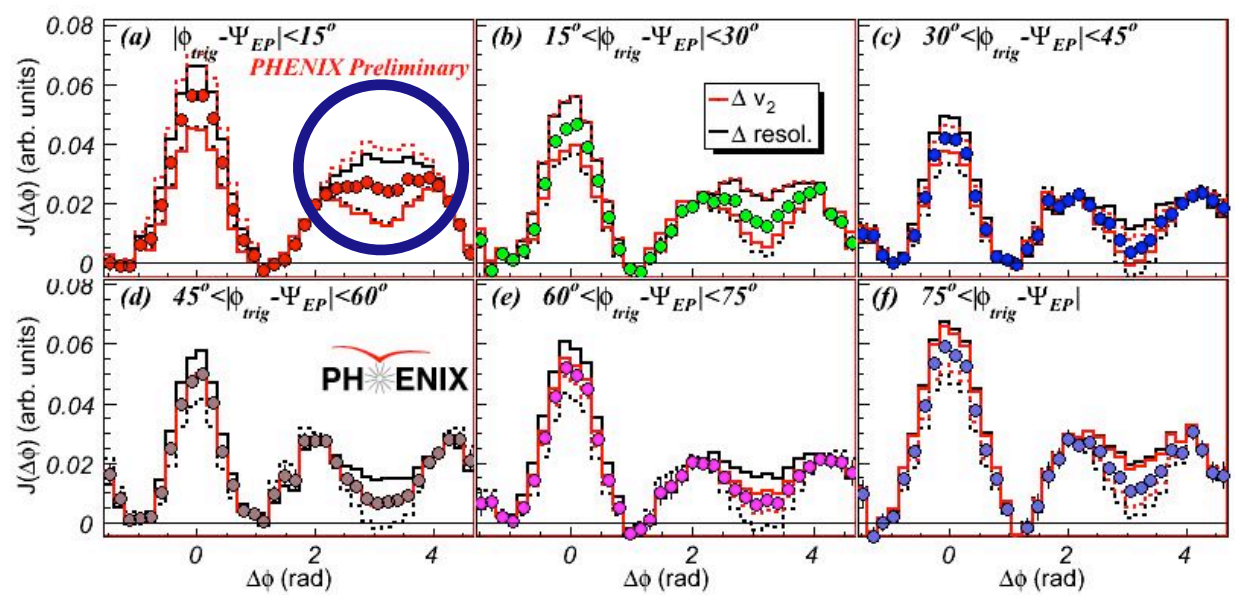




doesn't move with geometry

visible with only small matter path length

Au+Au $\sqrt{s_{NN}}$=200GeV, Cent=30-40%, $1<p_{T,assoc}<2$ GeV/c, $2<p_{T,trig}<3$ GeV/c



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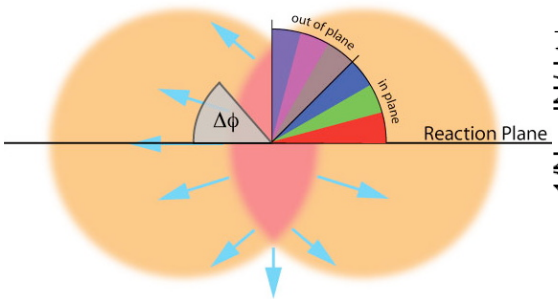
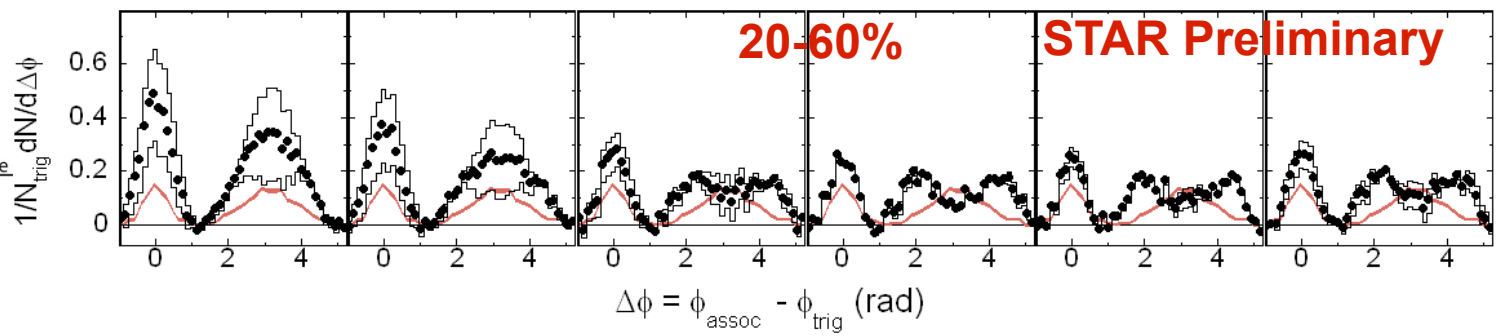
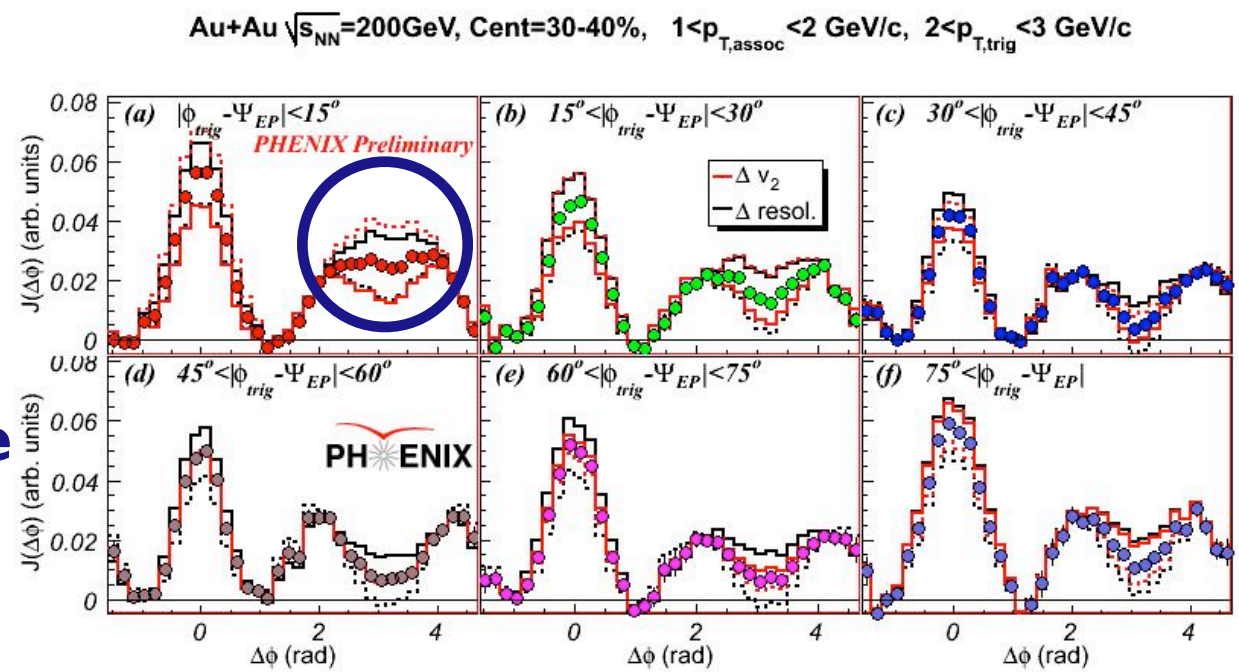




doesn't move with geometry

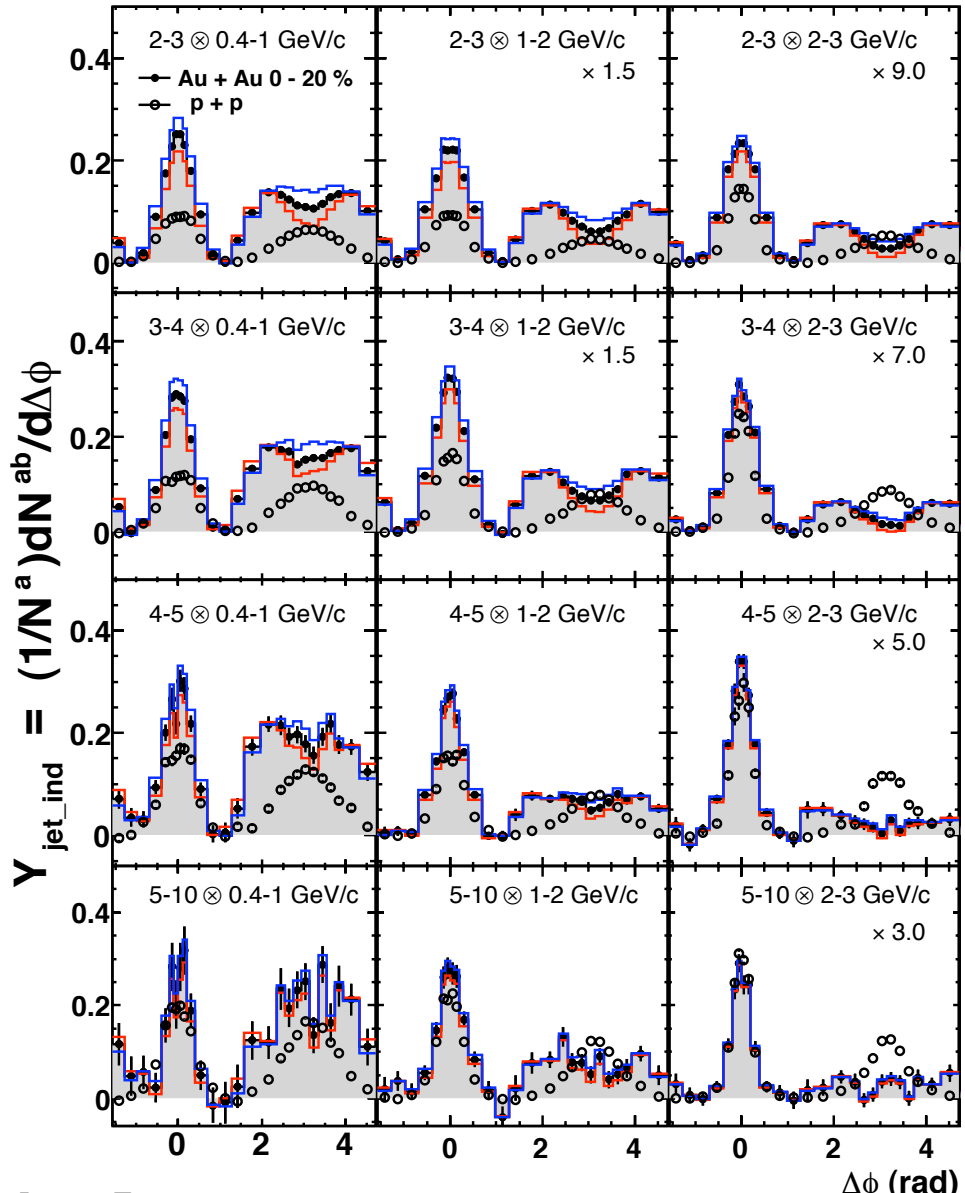
visible with only small matter path length

(does the reaction plane dependence change in more peripheral collisions?)



Stability of the Shoulder (III)

shoulder doesn't move or disappear with trigger p_T

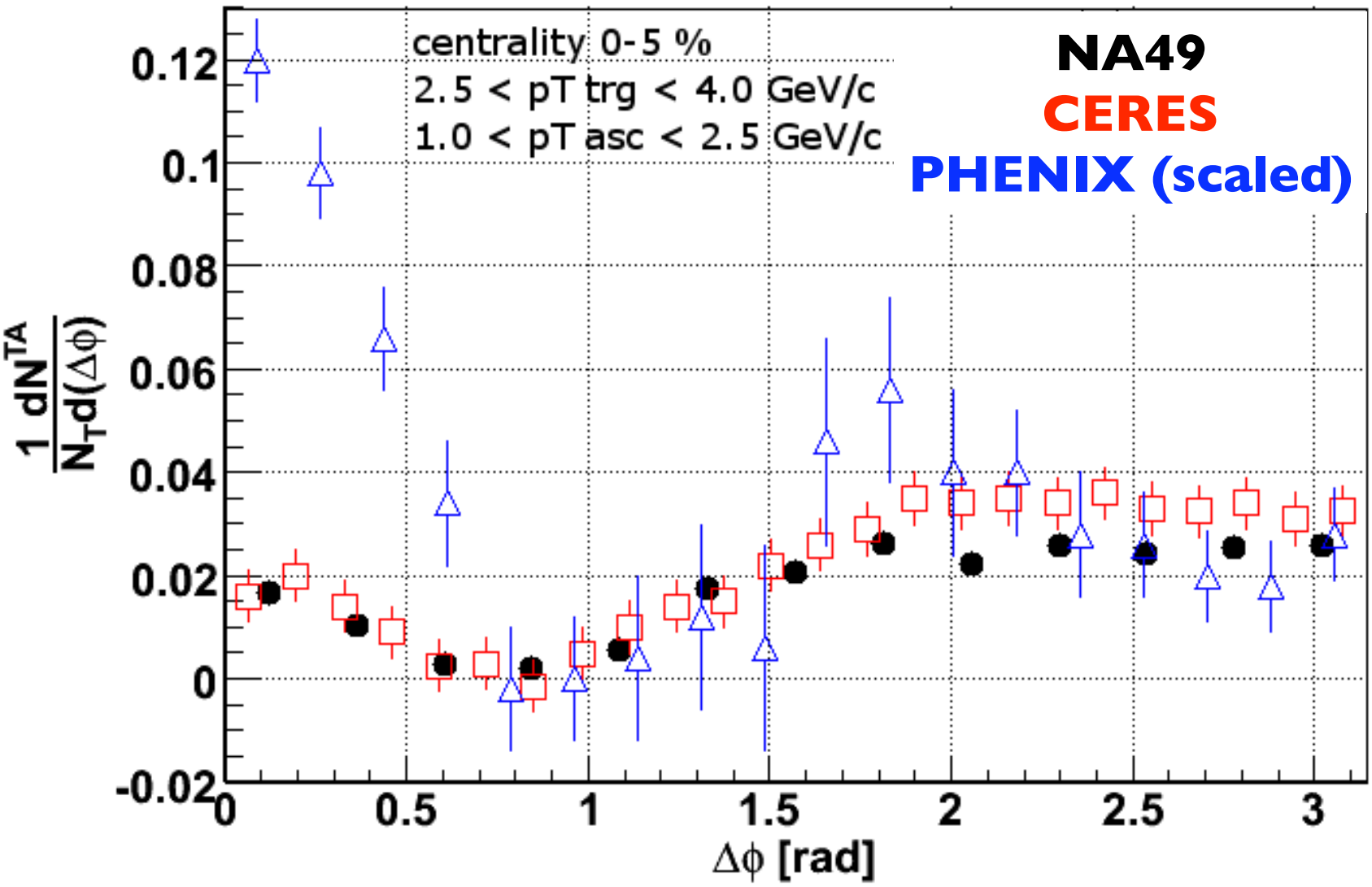


increasing trigger p_T

PHENIX, 0801.4545 [nucl-ex]

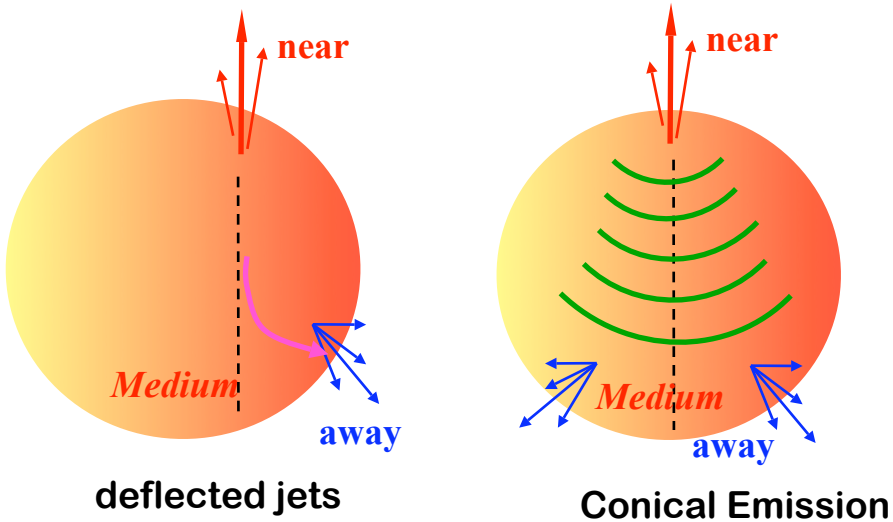
Stability of the Shoulder (IV)

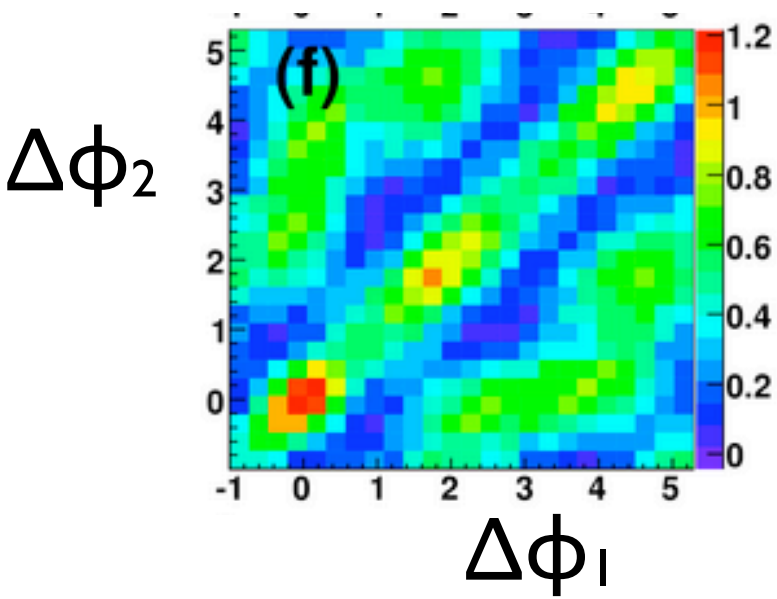
M. Szuba QM2008

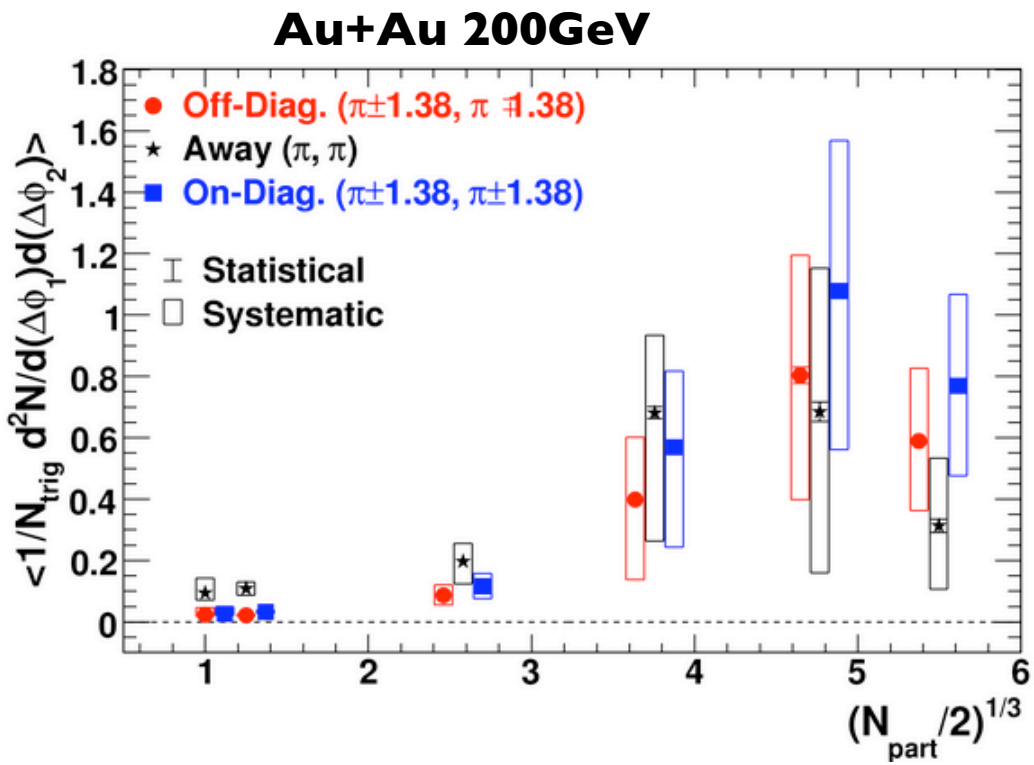


Shoulder is Conical

STAR 0805.0622 [nucl-ex], submitted to PRL





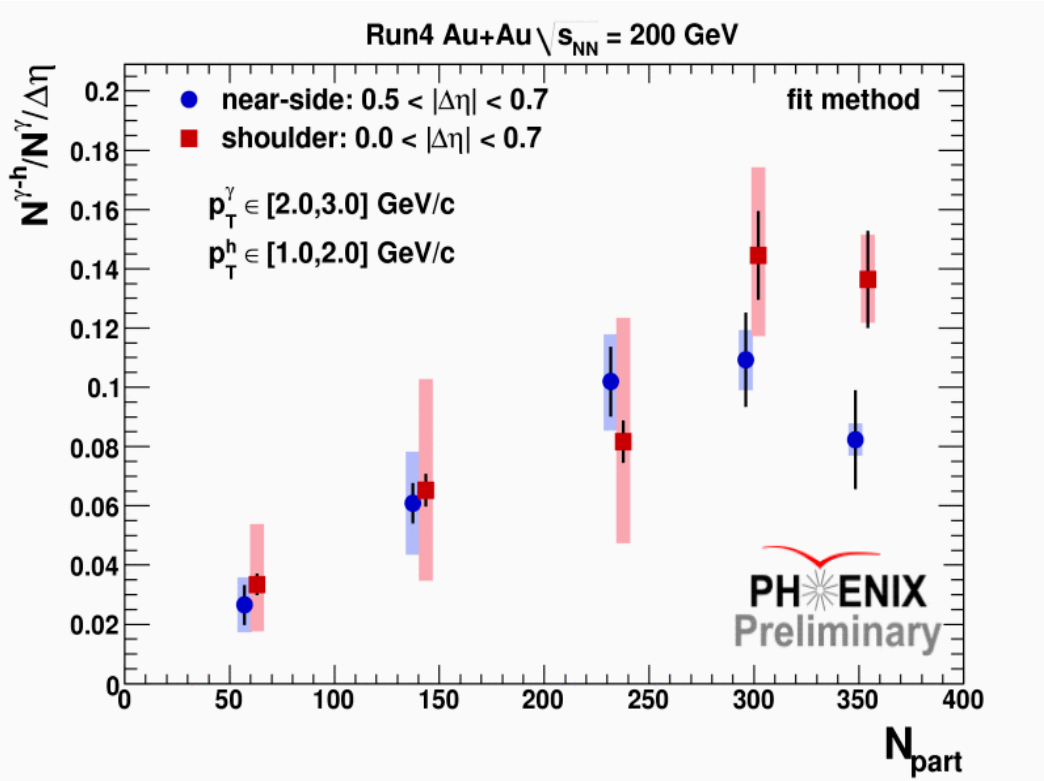


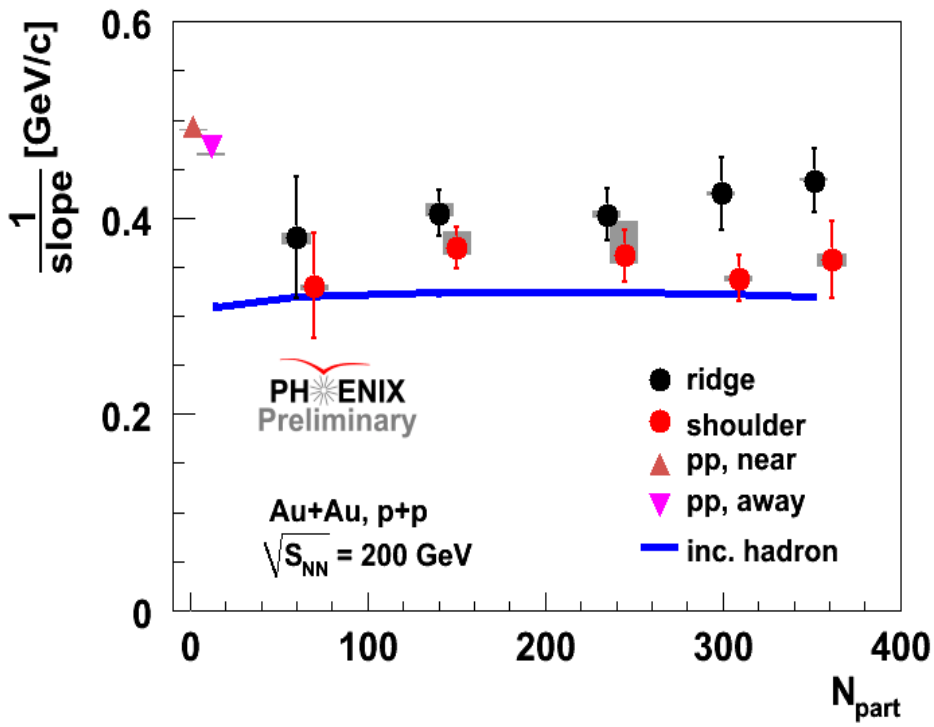
evidence for conical emission!
(CERES also sees evidence for a cone!
S. Kniege ISMD2007)

The Shoulder

- Shoulder is unlikely to be an artifact of the background subtraction, v_2 values or anything else, since those change radically from SPS to RHIC, as a function geometry, N_{part}, etc...
- What does it mean that this structure doesn't change from SPS energies to RHIC energies?
  - the data favor Mach Cone scenarios: is the speed of sound the same everywhere?
  - is there a ridge at the SPS?

Ridge vs Shoulder



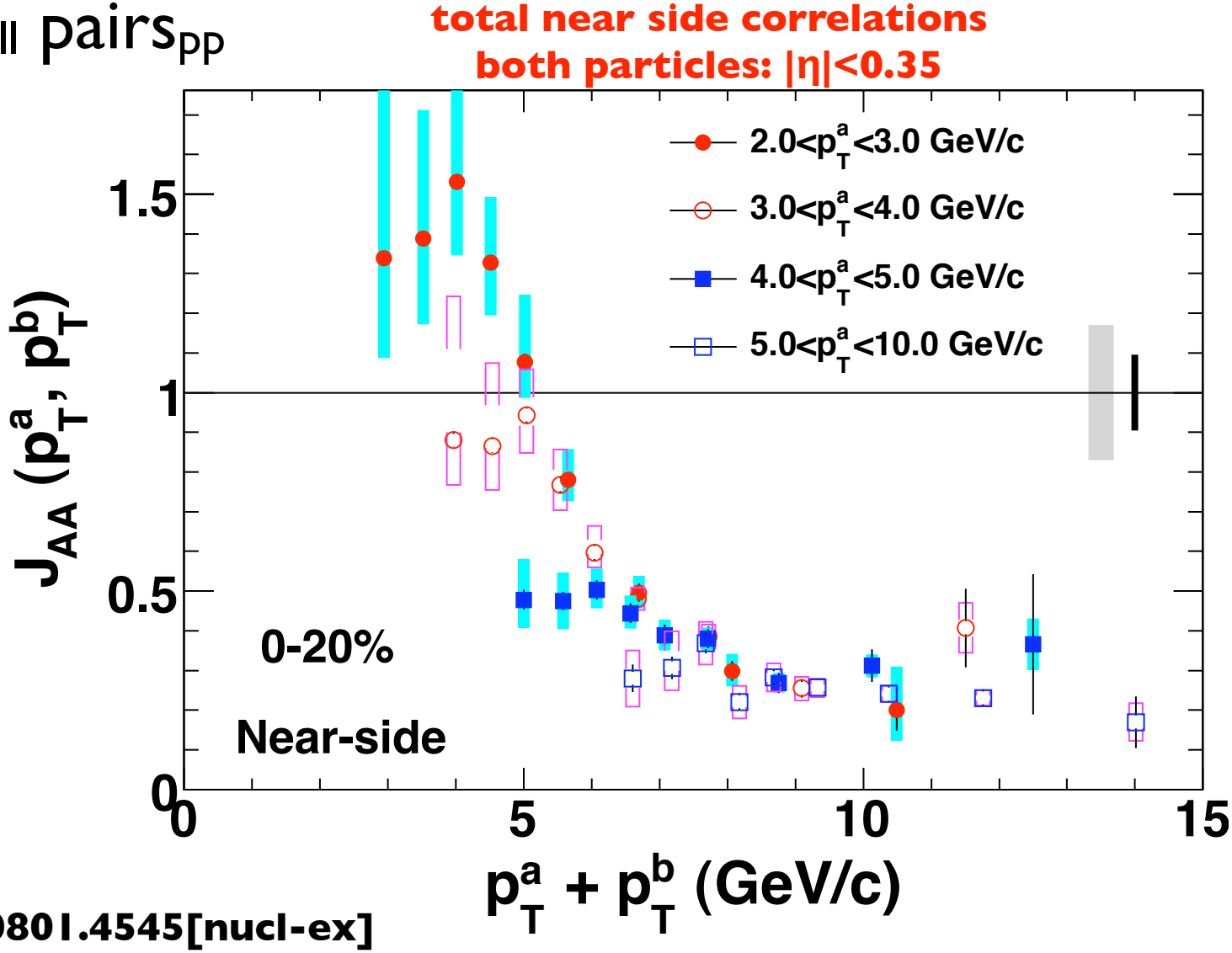


ridge & shoulder: similar centrality & p_T dependence -- both sensitive to medium properties?

J. Chen Tuesday parallel

Correlations are Softer at Low p_T

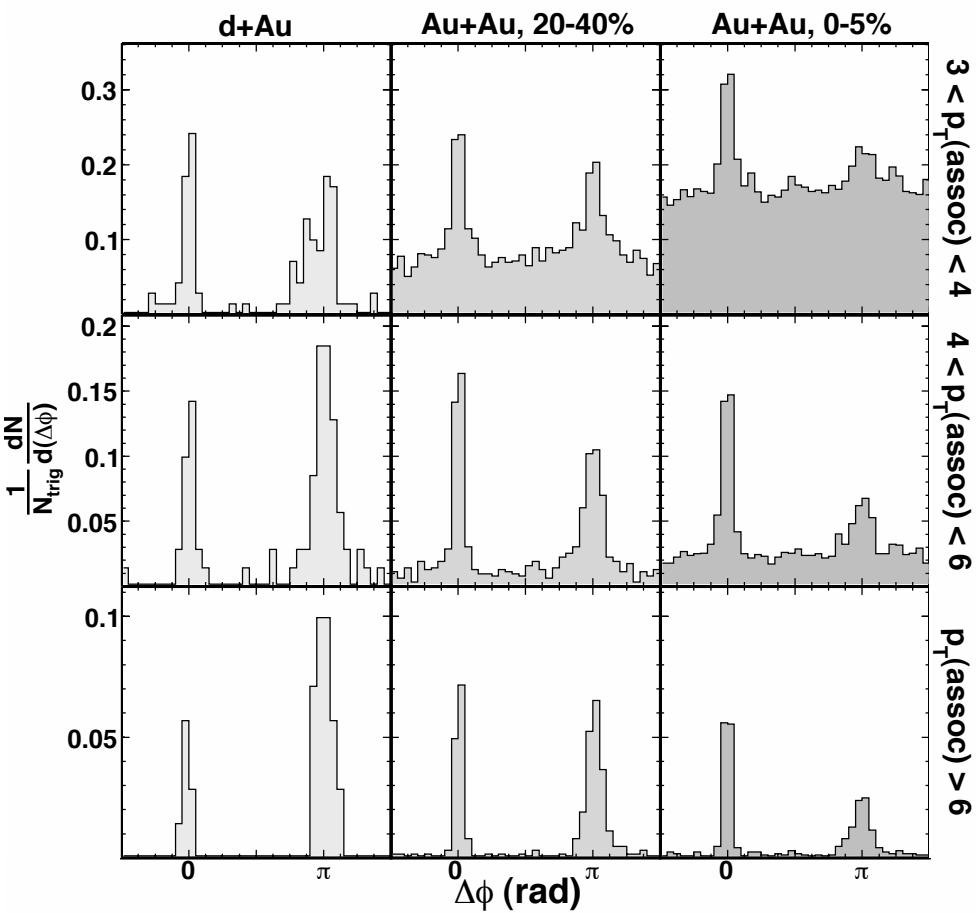
$$J_{AA} = \frac{\text{pairs}_{AA}}{N_{coll}\ \text{pairs}_{pp}}$$



PHENIX, 0801.4545[nucl-ex]

Di-jets at High p_T

$8 < p_{T,\,trig} < 15$GeV/c



STAR, PRL 97 162301 (2007)

Di-jets at High p_T

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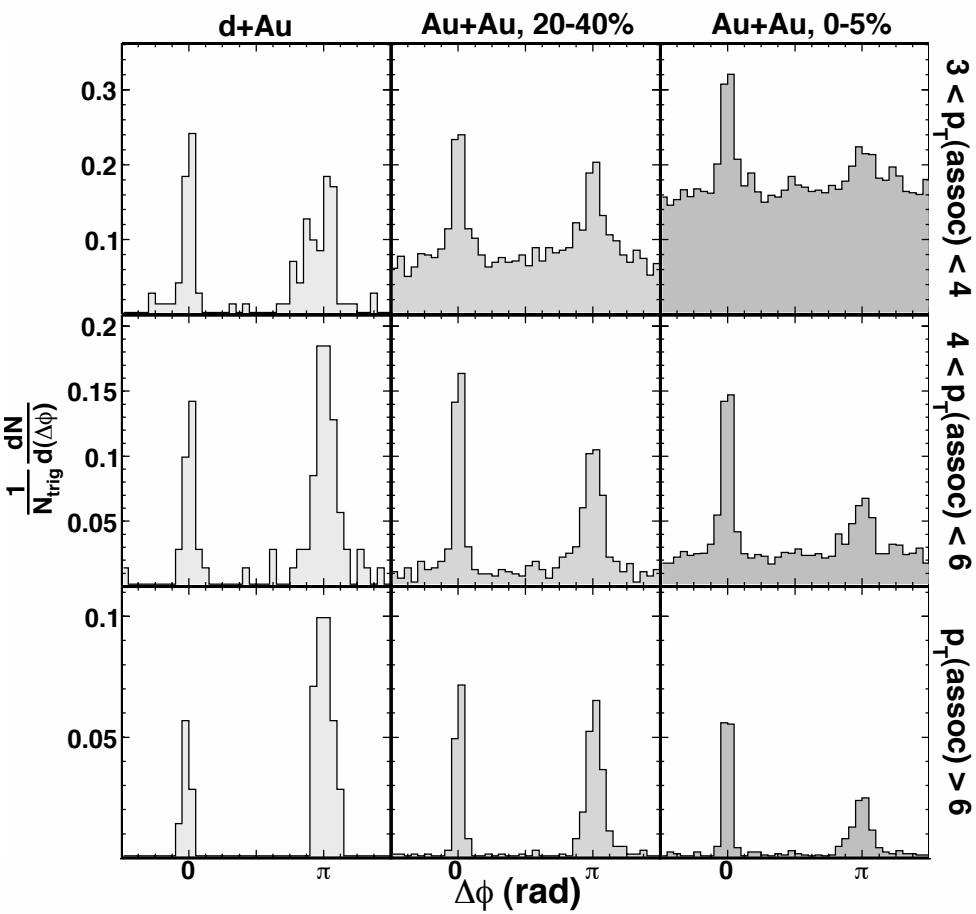

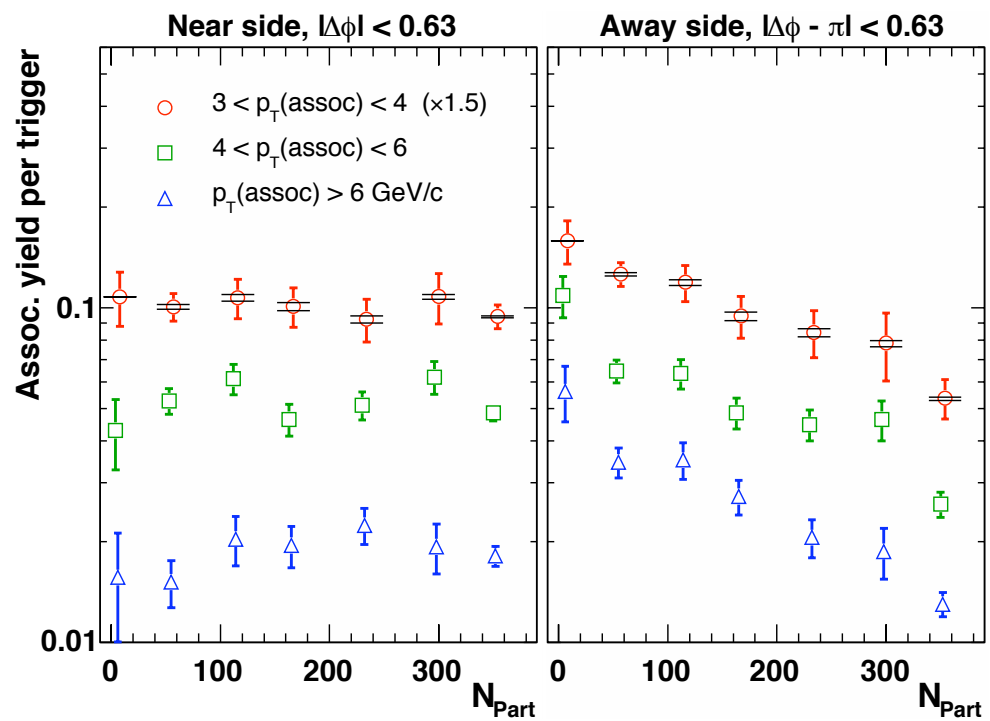

STAR, PRL 97 162301 (2007)

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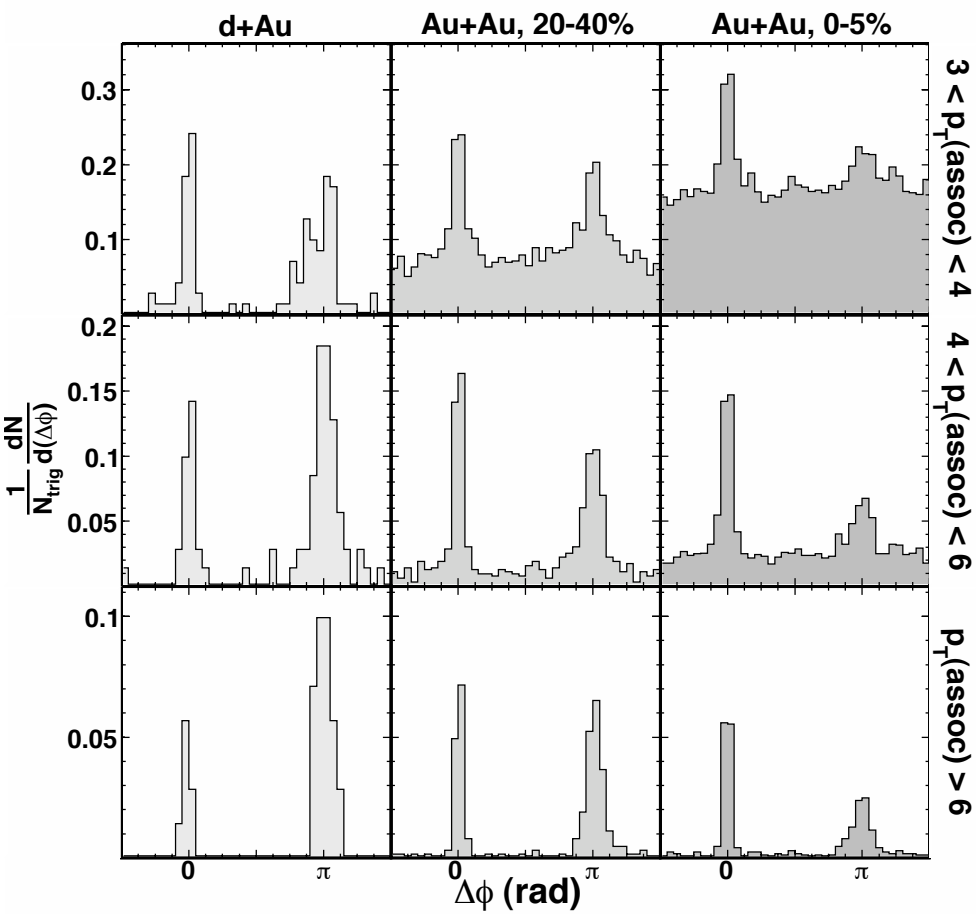
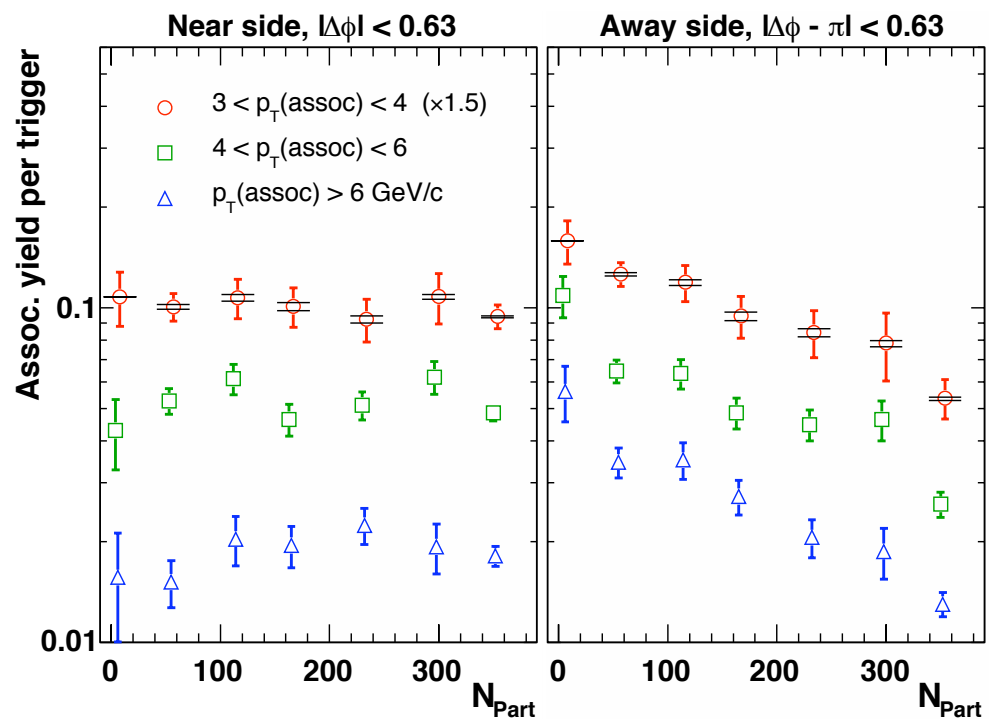


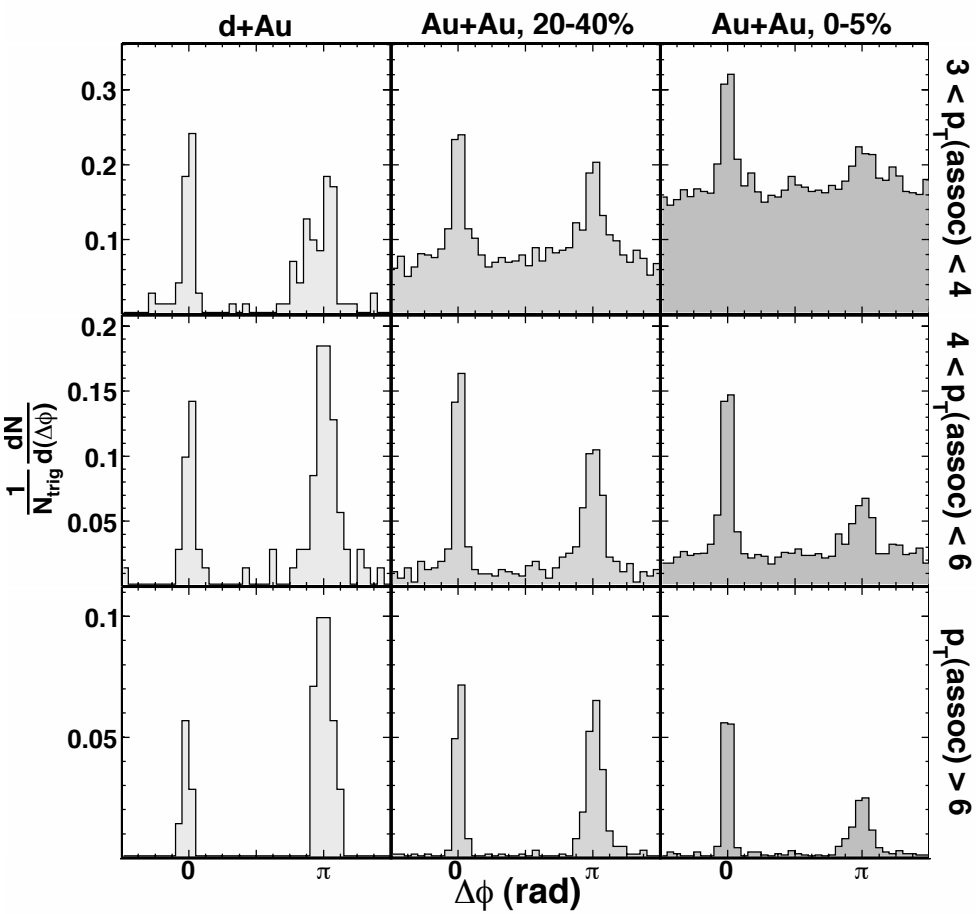


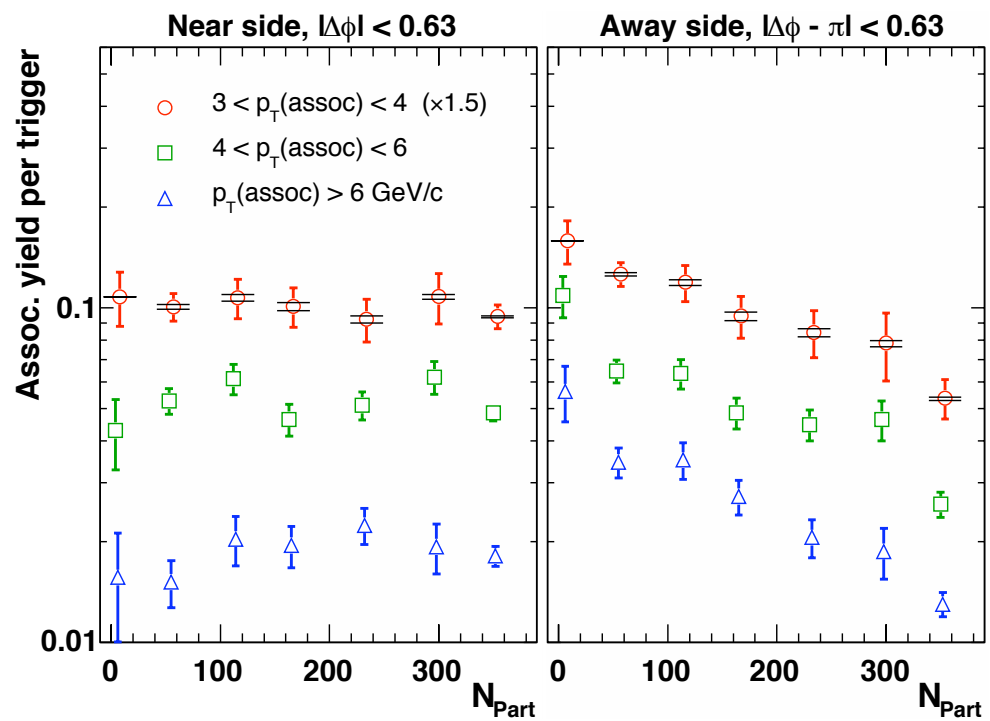
no significant centrality dependence on the near side

STAR, PRL 97 162301 (2007)

Di-jets at High p_T

$8 < p_{T,\,trig} < 15$ GeV/c



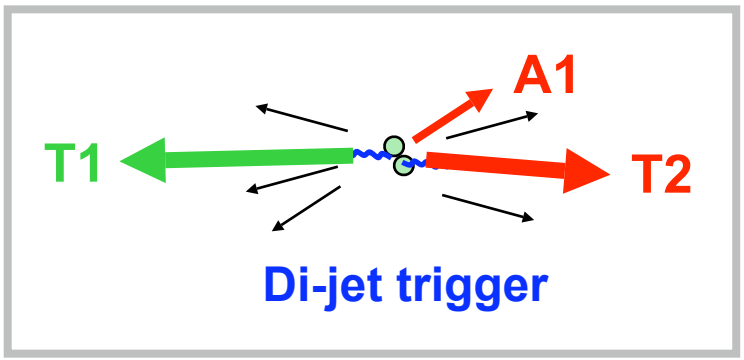


no significant centrality dependence on the near side

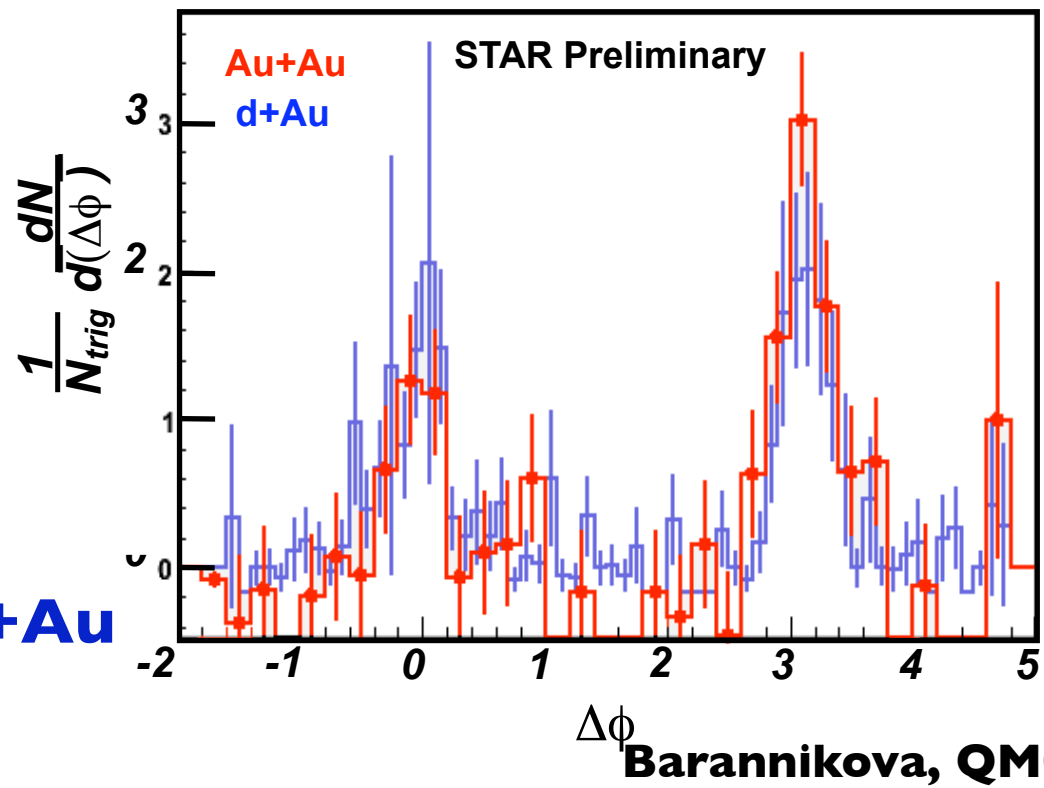
suppression with increasing centrality on the away side

STAR, PRL 97 162301 (2007)

2+1 Correlations



200 GeV Au+Au & d+Au



Barannikova, QM08

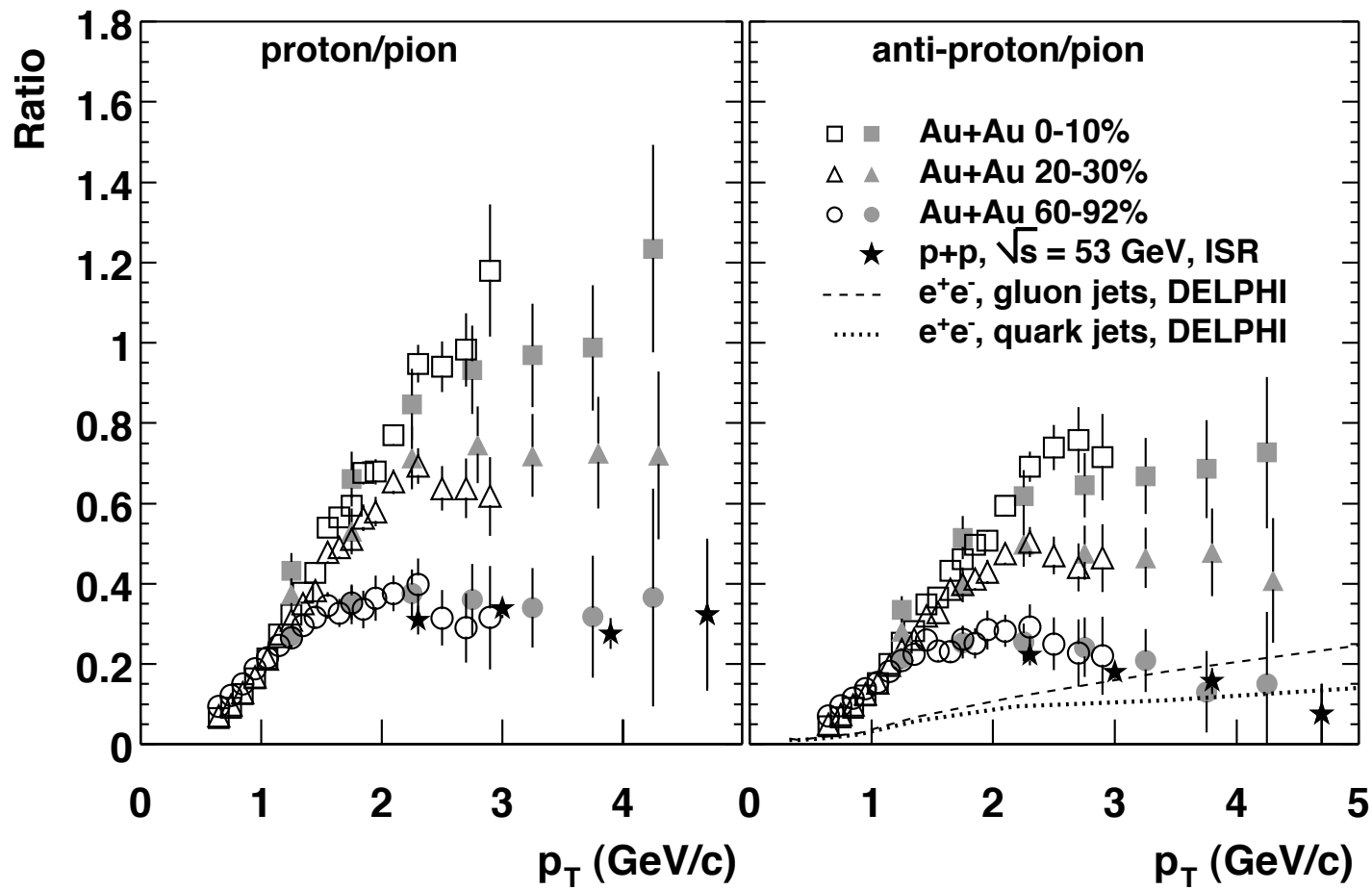
jet yields unmodified from d+Au to central Au+Au

T1: p_T>5 GeV/*c*, T2: p_T>4 GeV/*c*, A: p_T>1.5 GeV/*c*

next step: cone around di-jet axis, lower trigger p_T (or assoc. p_T), ridge? shoulder?

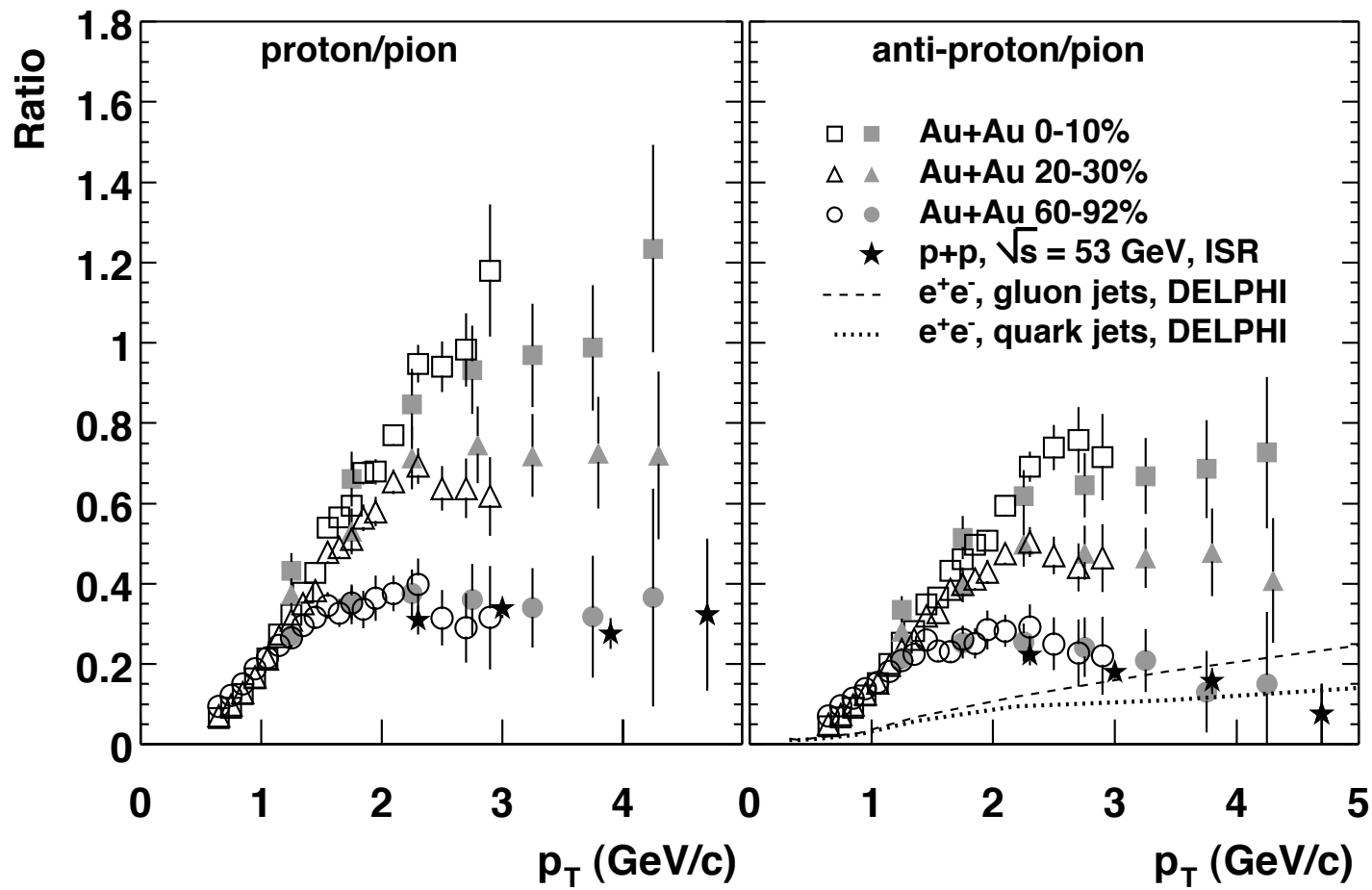
baryons

PRL 91 172301 (2003)



baryons

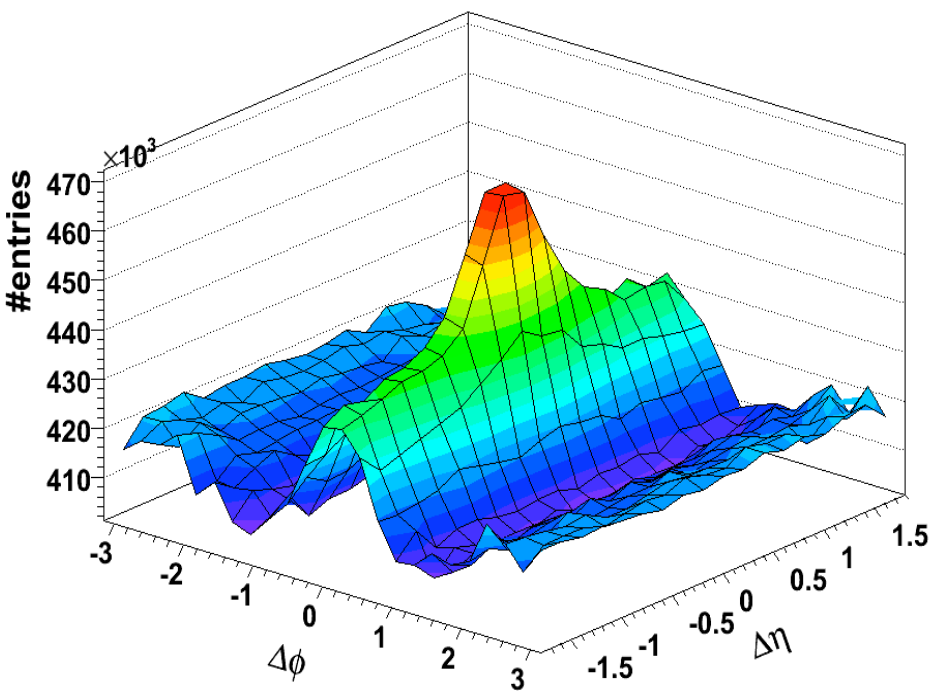
PRL 91 172301 (2003)

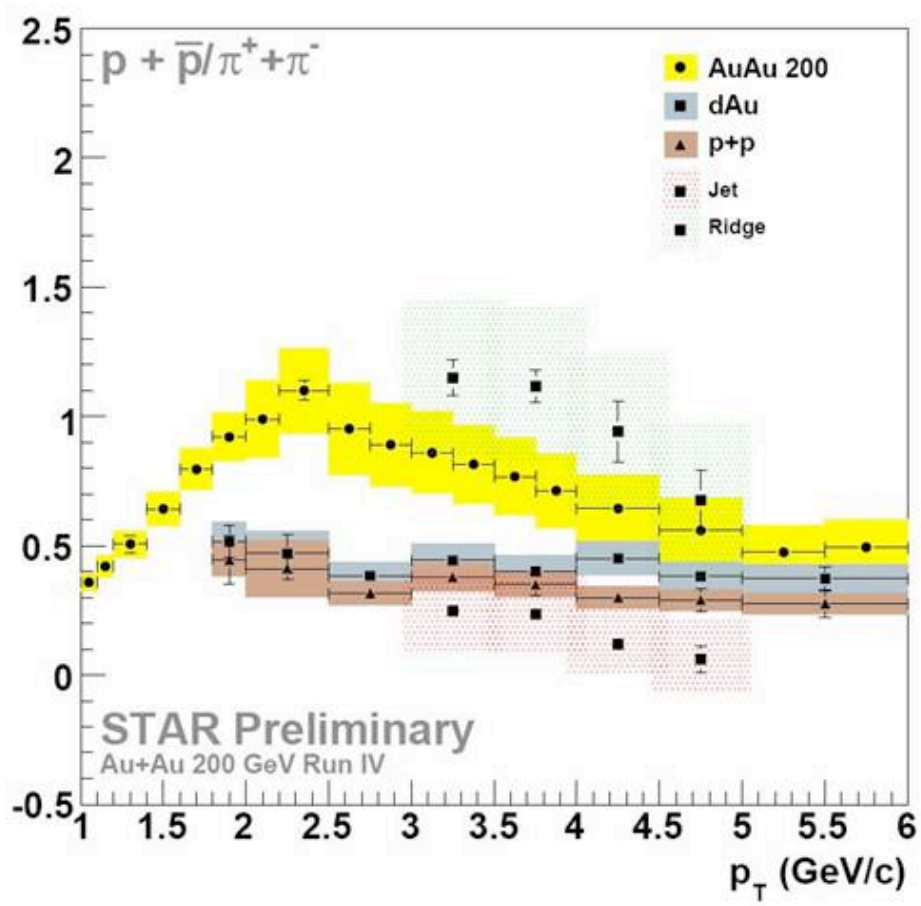


what does this have to do with hard scattering?

baryons in the ridge

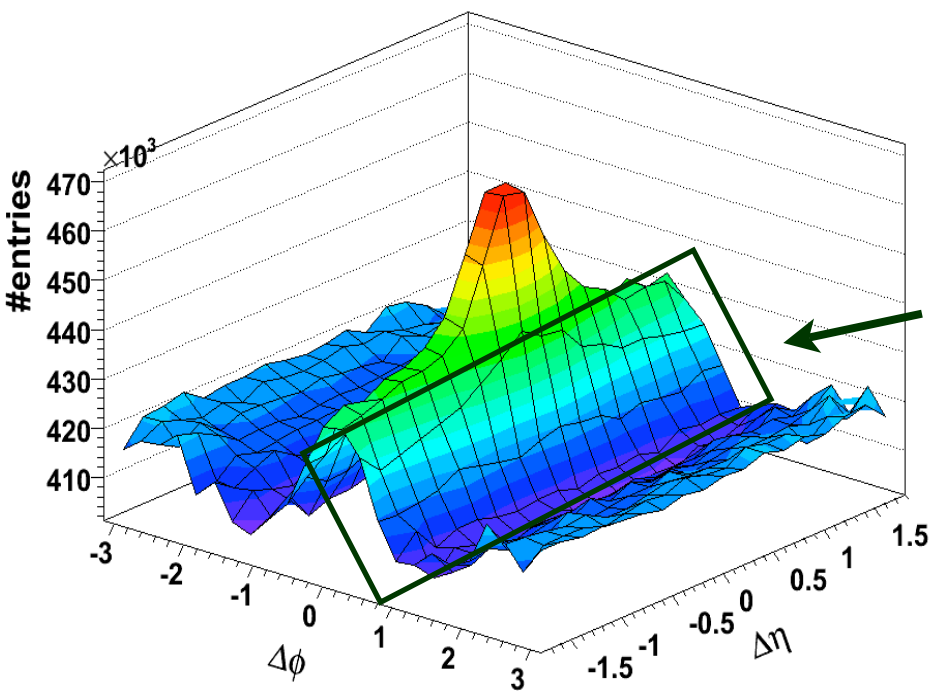
C. Suarez, QM08



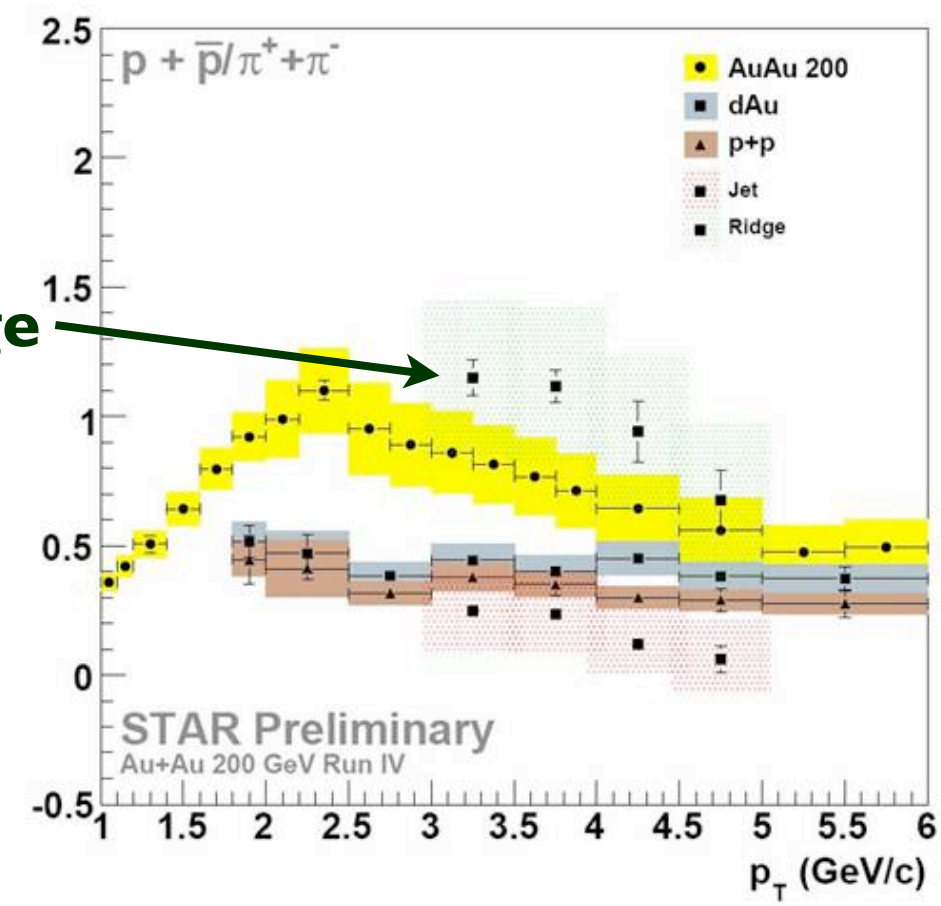


baryons in the ridge

C. Suarez, QM08

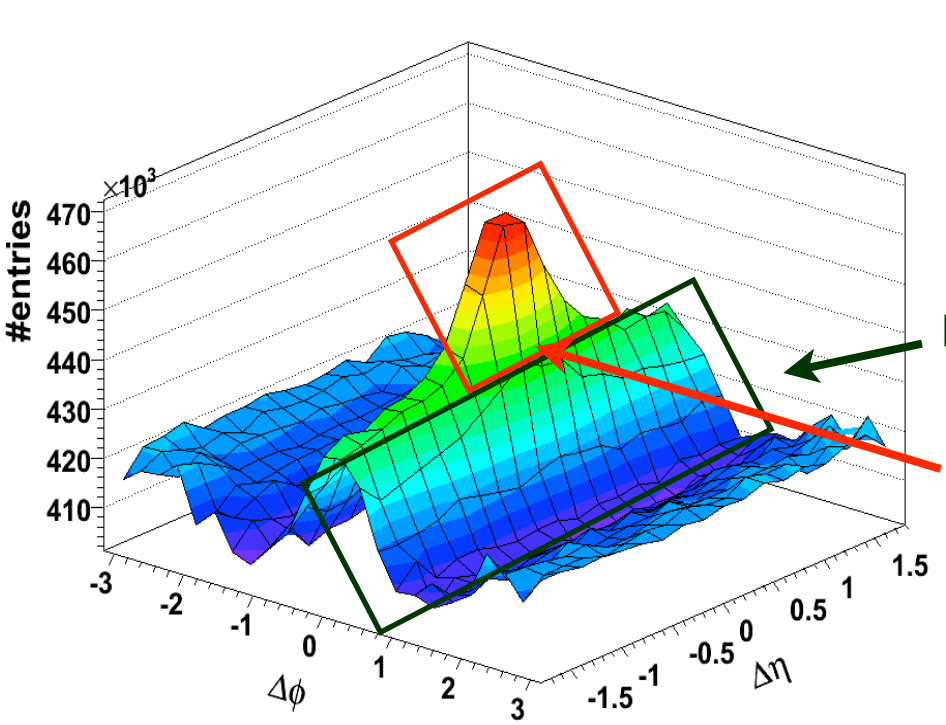


ridge



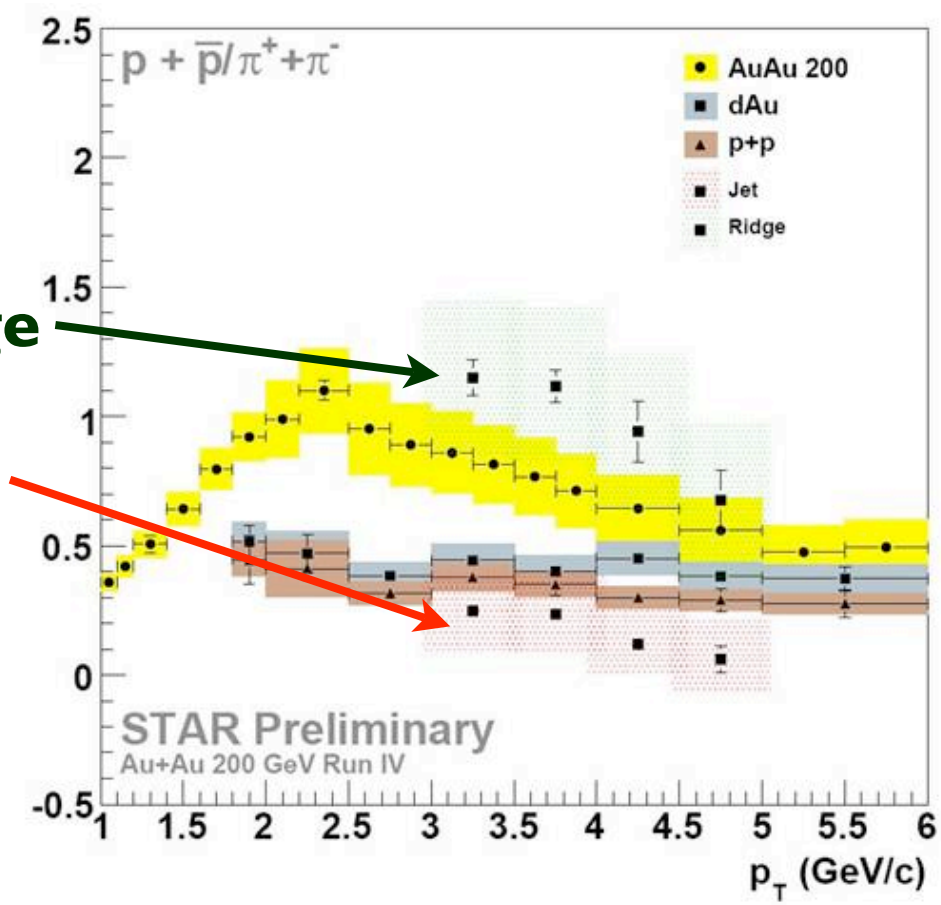
baryons in the ridge

C. Suarez, QM08



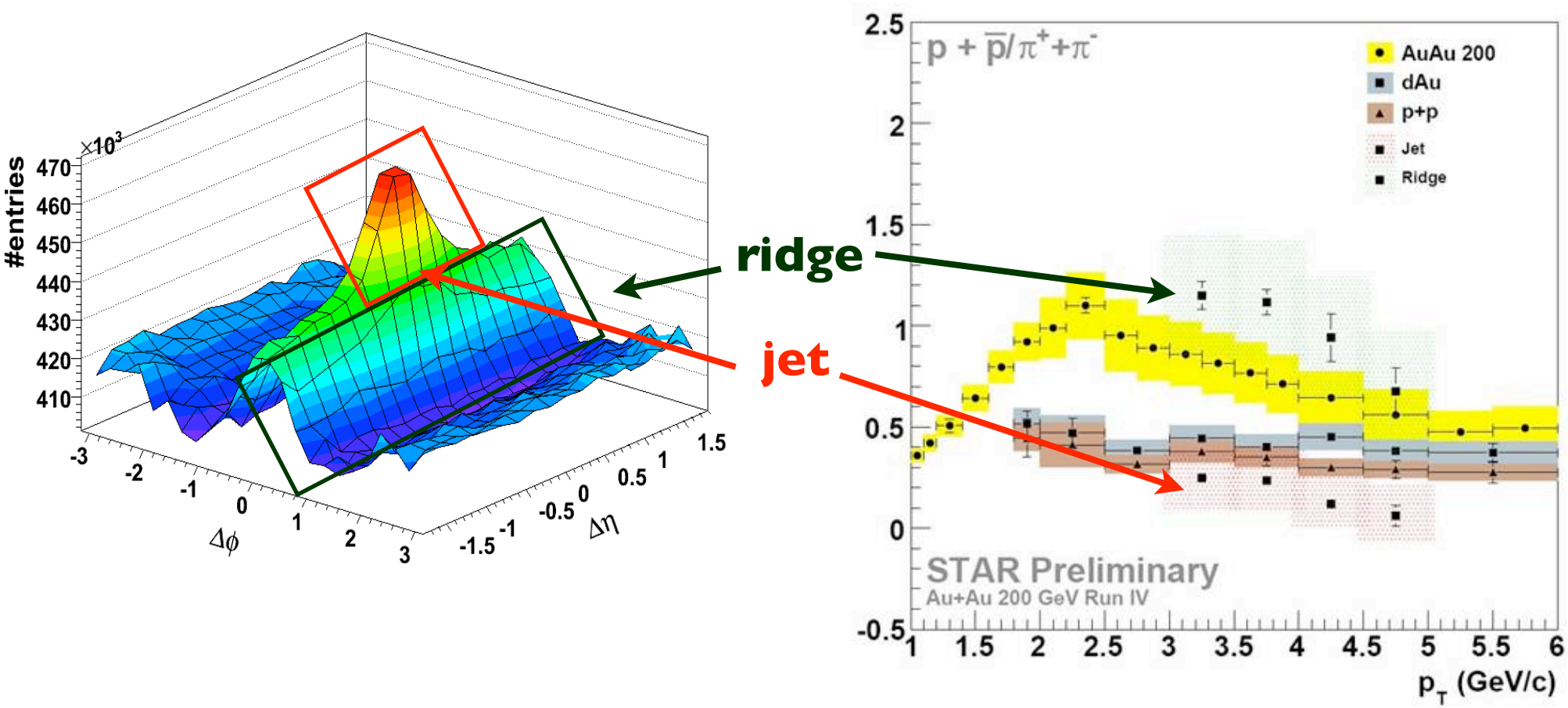
ridge

jet



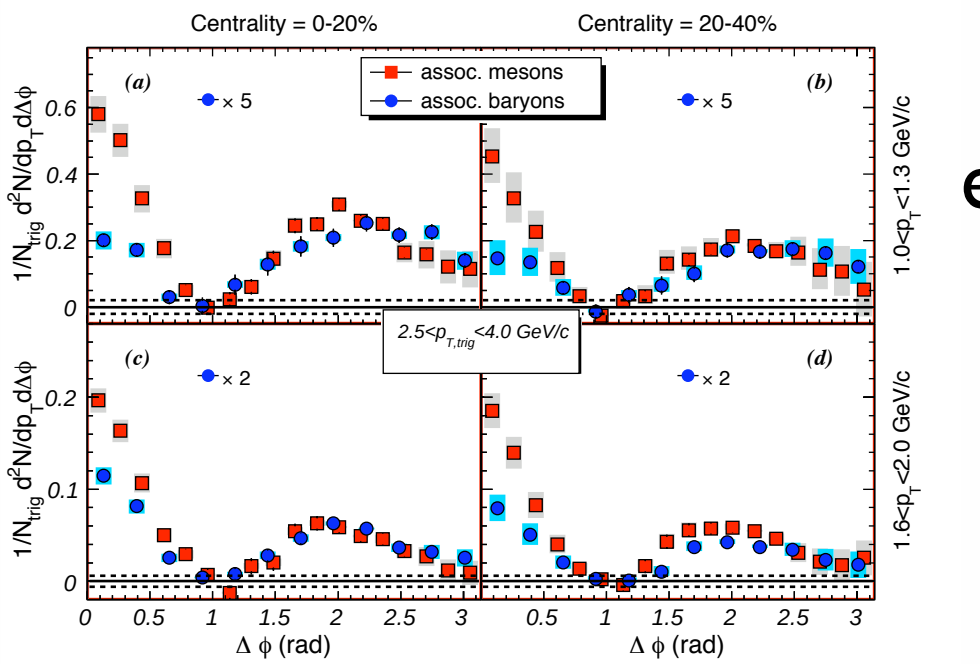
baryons in the ridge

C. Suarez, QM08



baryon excess in the ridge!

baryons in the away side

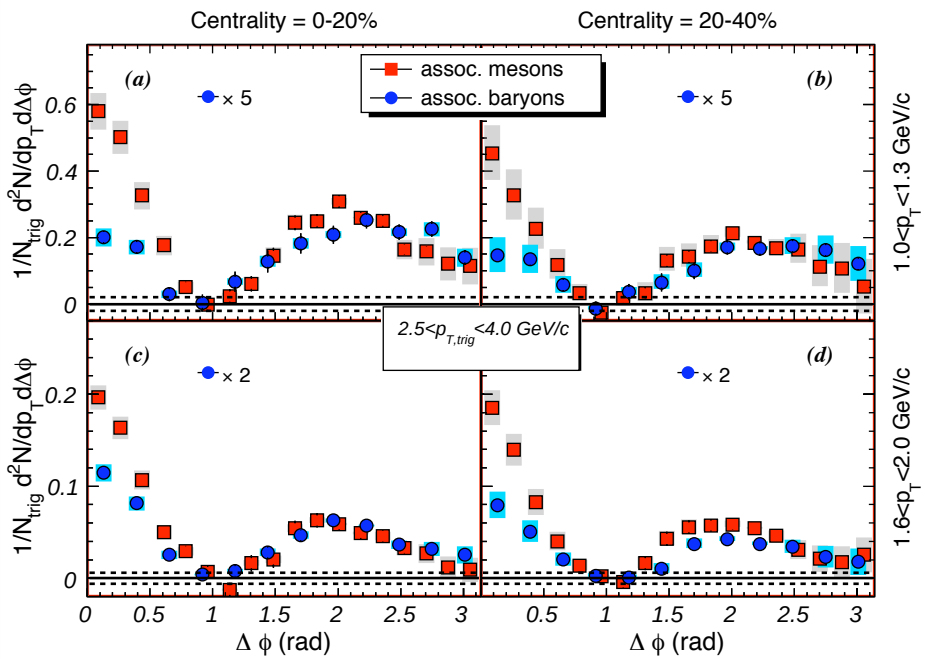


PHENIX, 0712.3033 [nucl-ex]

enhanced baryon/meson ratio in shoulder/di-jet region

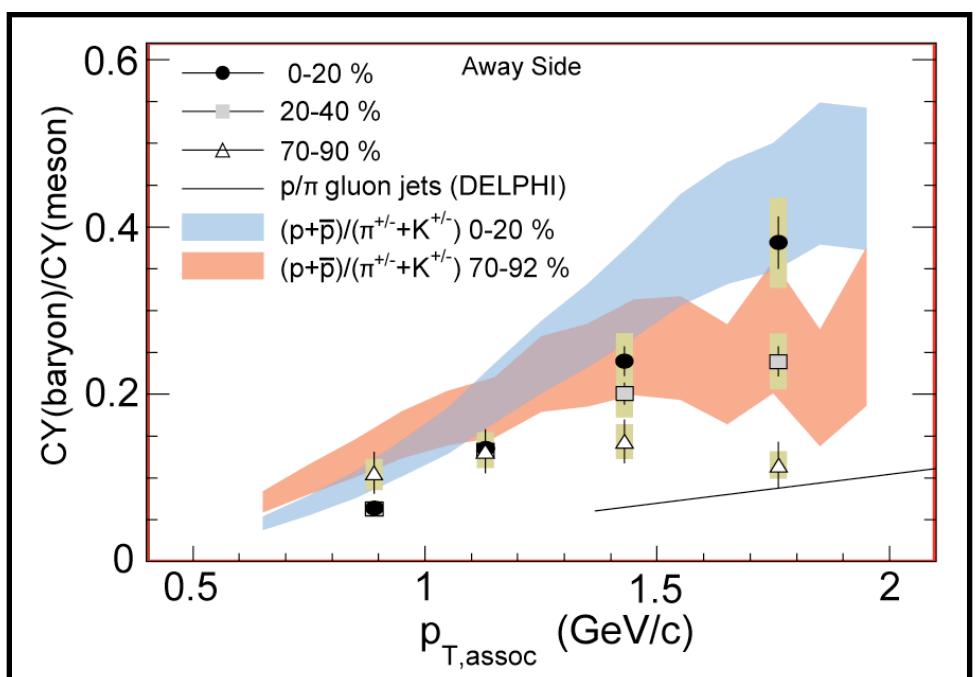
baryons in the away side

PHENIX, 0712.3033 [nucl-ex]



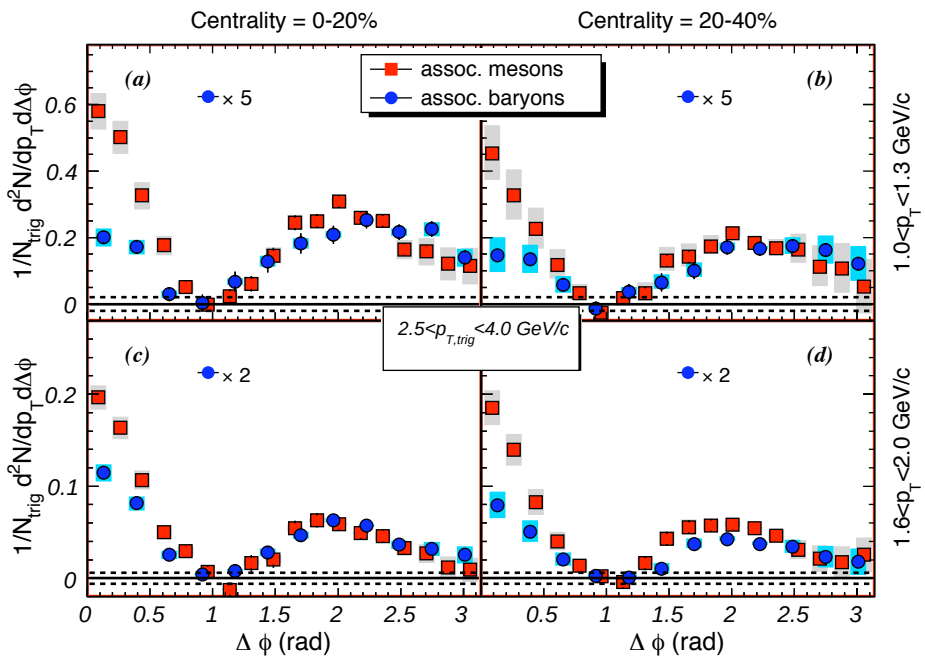
away side baryon/meson ratio approaches single particle ratio

enhanced baryon/meson ratio in shoulder/di-jet region

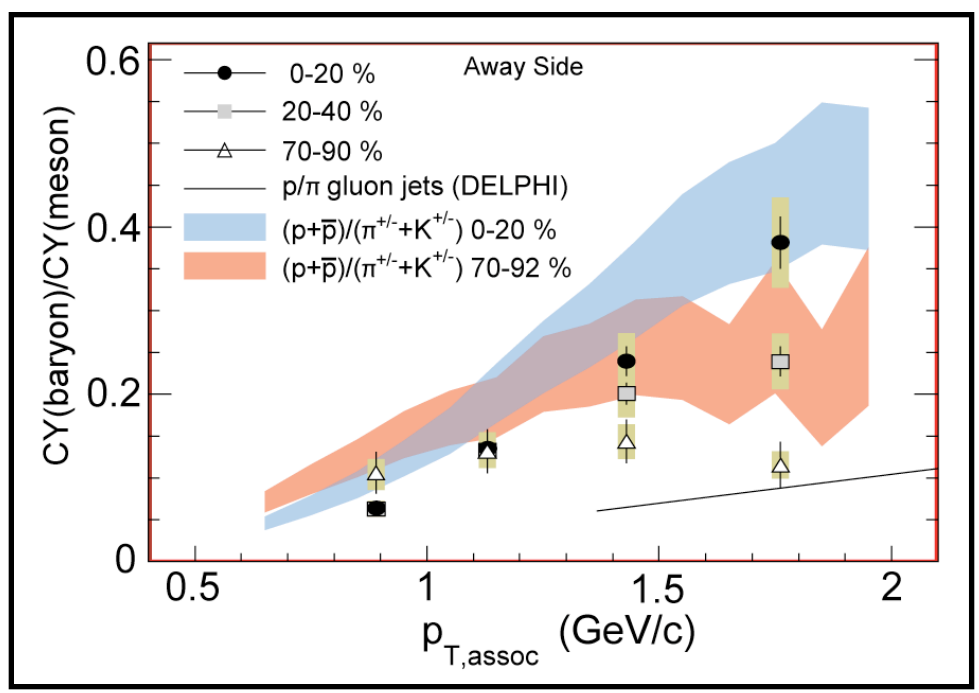


baryons in the away side

PHENIX, 0712.3033 [nucl-ex]



enhanced baryon/meson ratio in shoulder/di-jet region

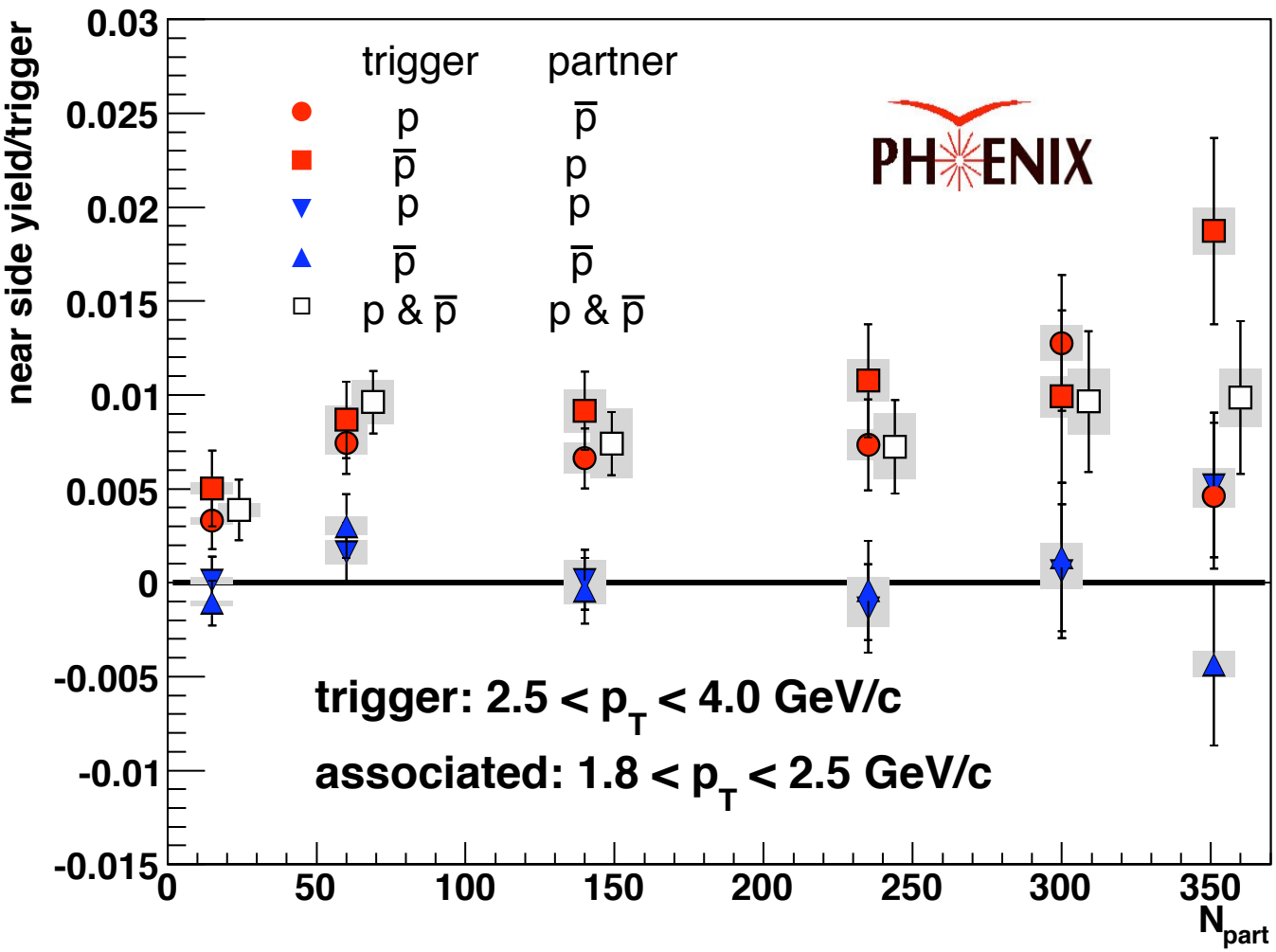


away side baryon/meson ratio approaches single particle ratio

another connection between ridge & shoulder!

p & $\bar{p}$ are correlated

PLB 649 (2007) 359-369



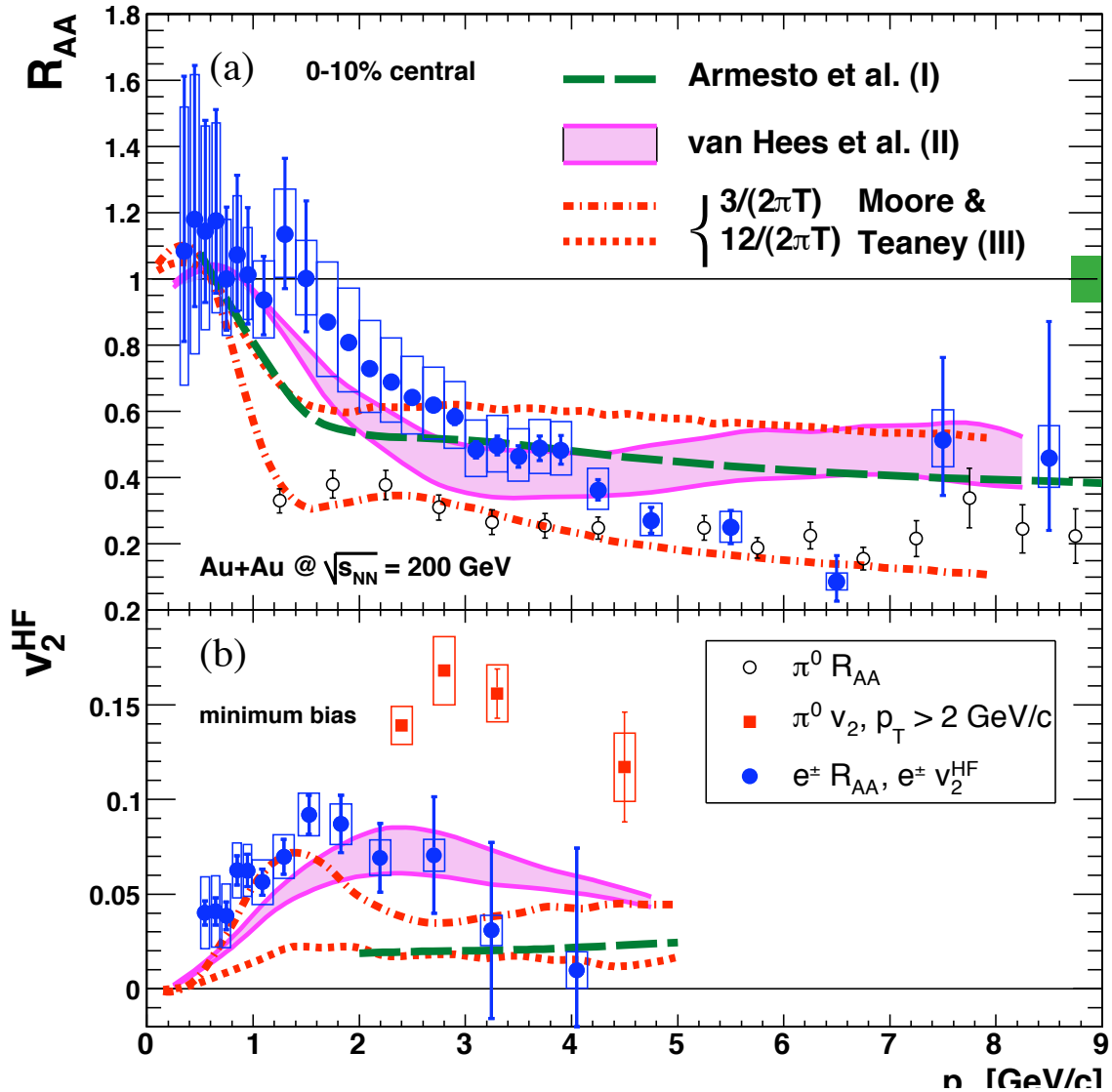
opposite sign pairs: CORRELATED

same sign pairs: NO CORRELATION

these correlations look pretty jet-like, how does this all fit together?

electrons from heavy flavor

- energy loss similar to that of π_0 for electrons from both D and B decay
- electrons from heavy flavor also flow
- what do the correlations look like?

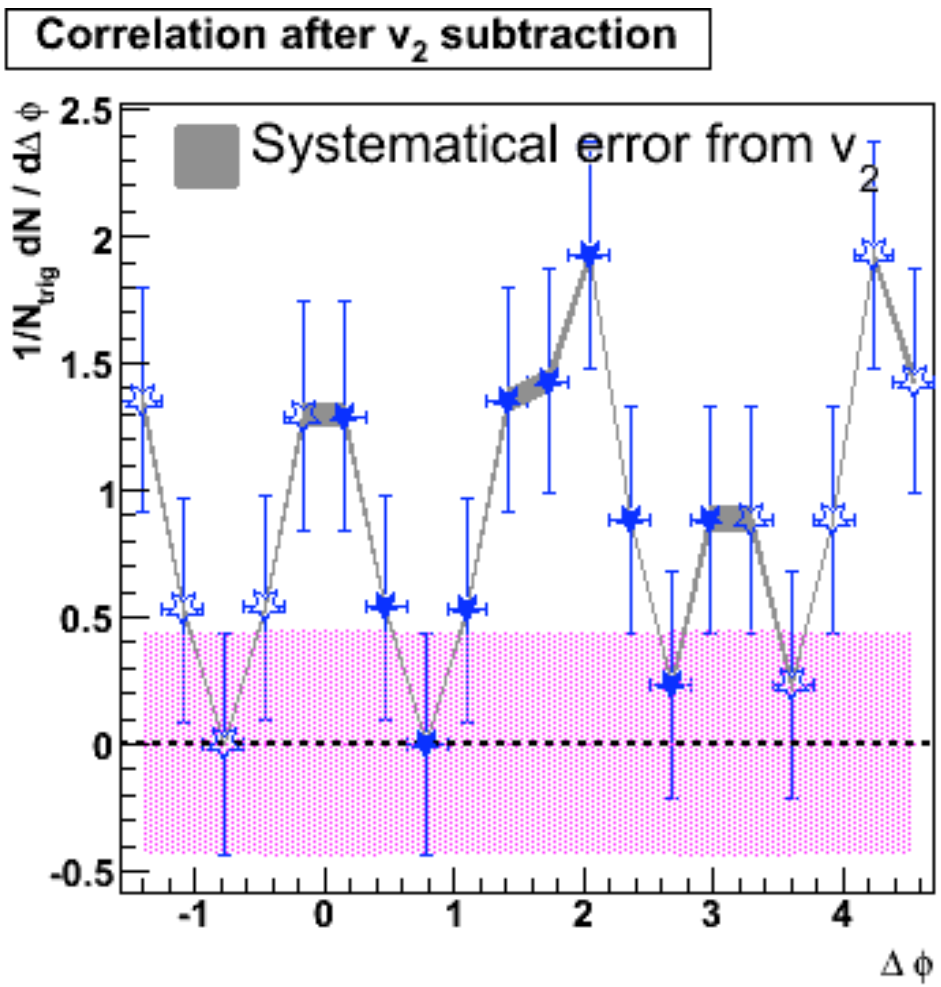


PHENIX, PRL 98172301 (2007)

correlations of heavy flavor

0 – 20%: 3 < p_T^{trig} < 6 GeV/*c* & 0.15 < p_T^{asso} < 0.5 GeV/*c*

Cu+Cu, 200GeV

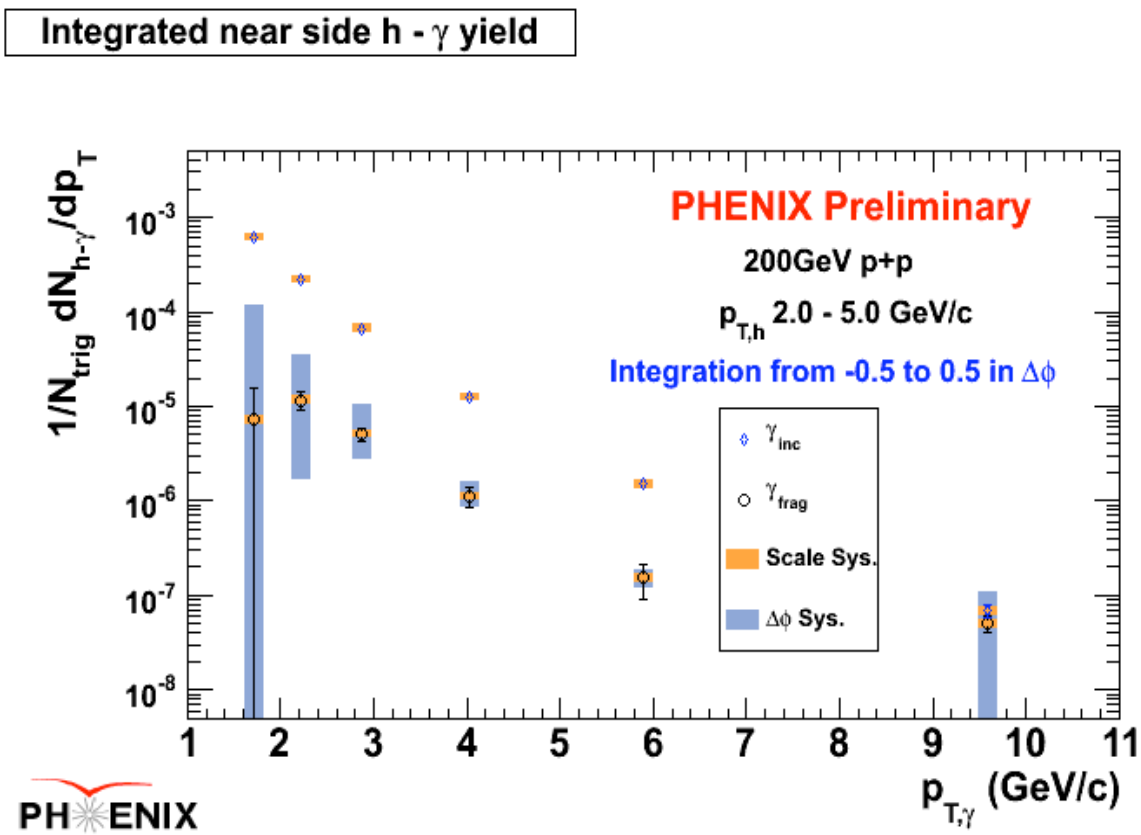


G. Wang QM08

- difficult measurement since electrons from conversions and Dalitz decays will carry the shoulder signal
- hadrons associated with electrons from D/B decay also show shoulder structure

fragmentation photons: p+p

- ask how many times you have a small angle hadron-photon correlation
- tag and subtract photons from π^0 & η decay



A. Hanks, Thursday

fragmentation photons: p+p

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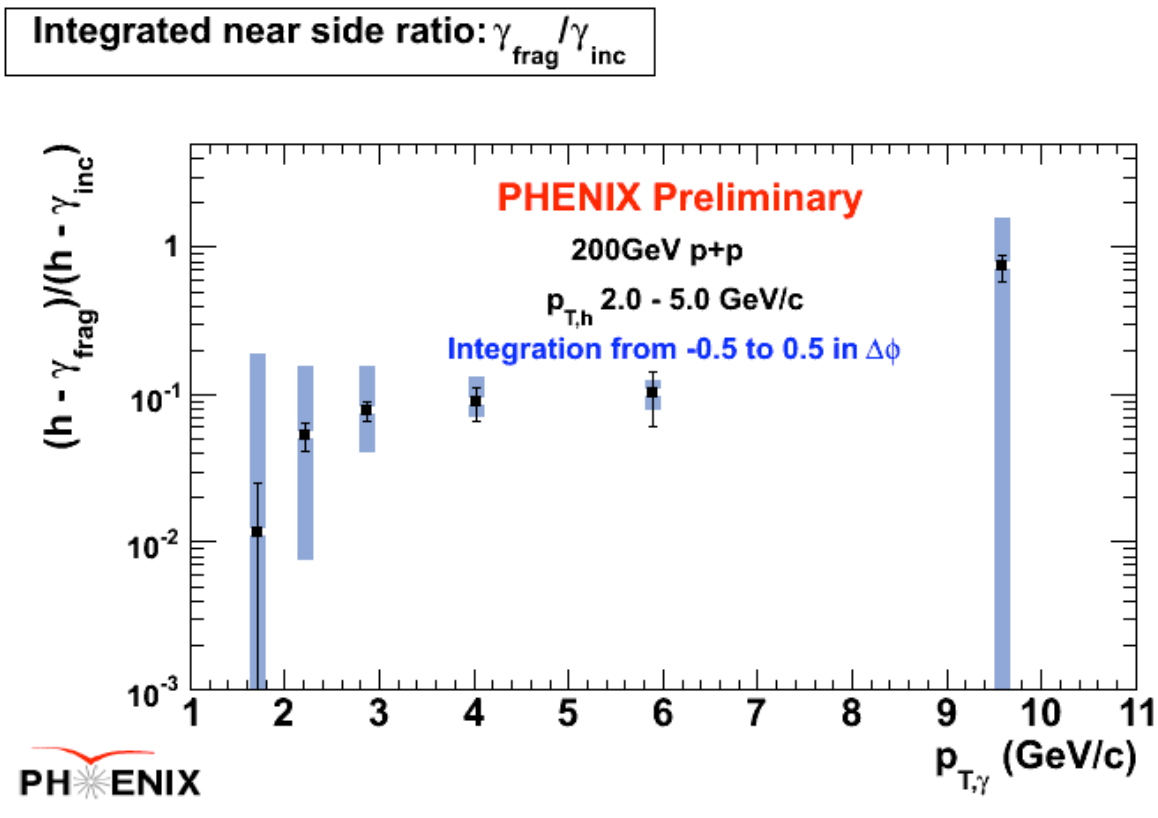

~5-10% of inclusive photons fragmentation!

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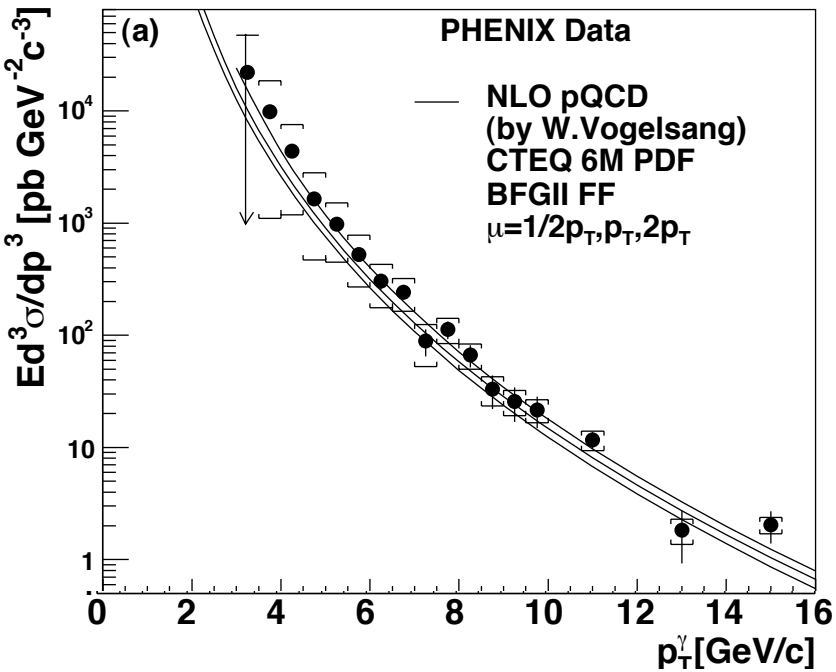
fragmentation photons (II)



PHENIX, PRL 98 012002 (2007)

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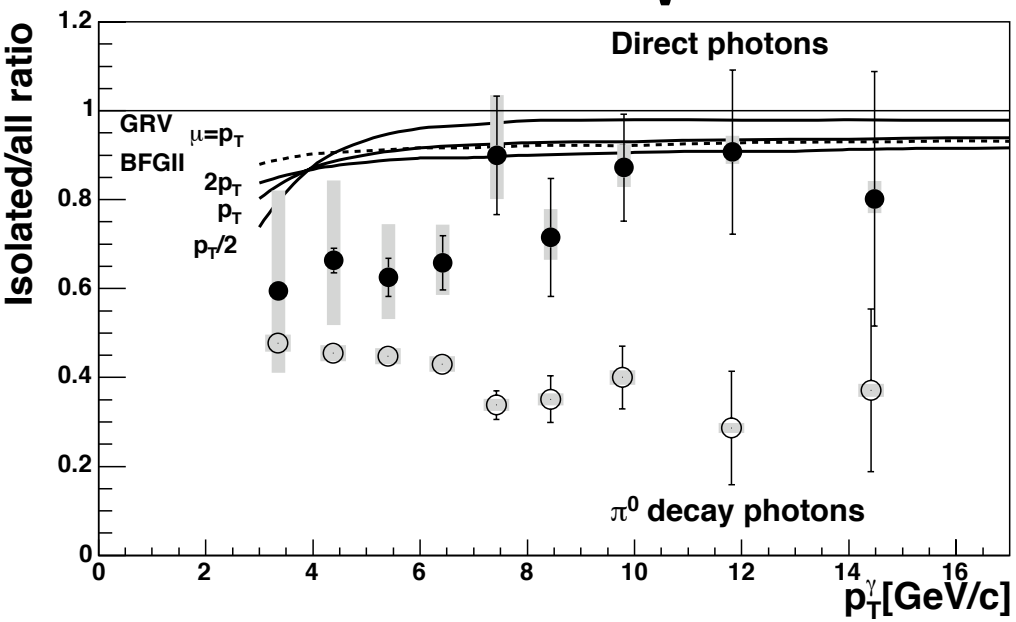
fragmentation photons (II)

fraction of direct γ isolated

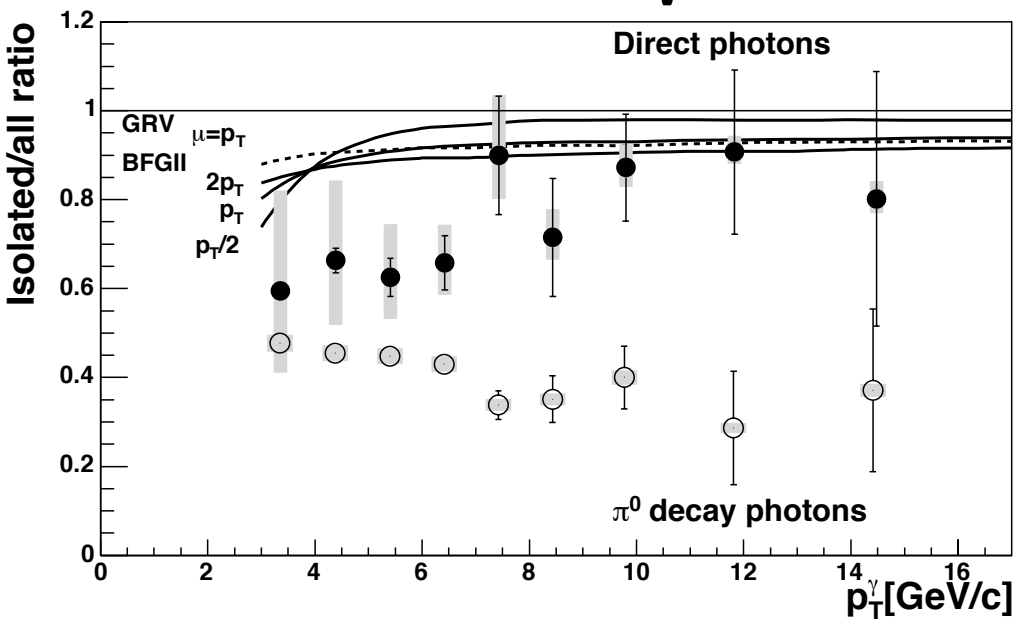


PHENIX, PRL 98 012002 (2007)

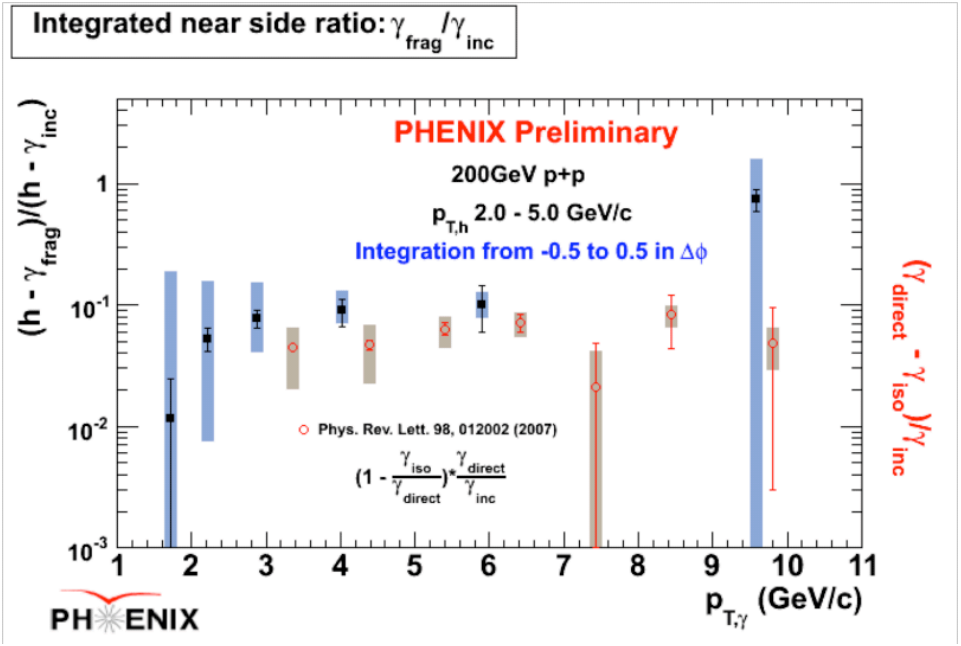
A. Hanks, Thursday parallel

fragmentation photons (II)

fraction of direct γ isolated



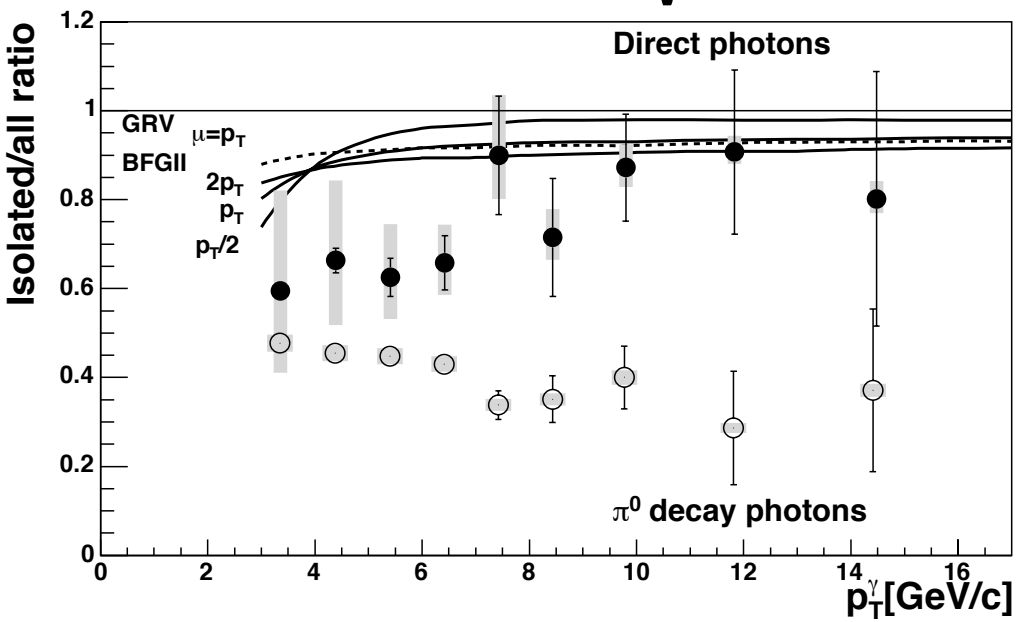
PHENIX, PRL 98 012002 (2007)



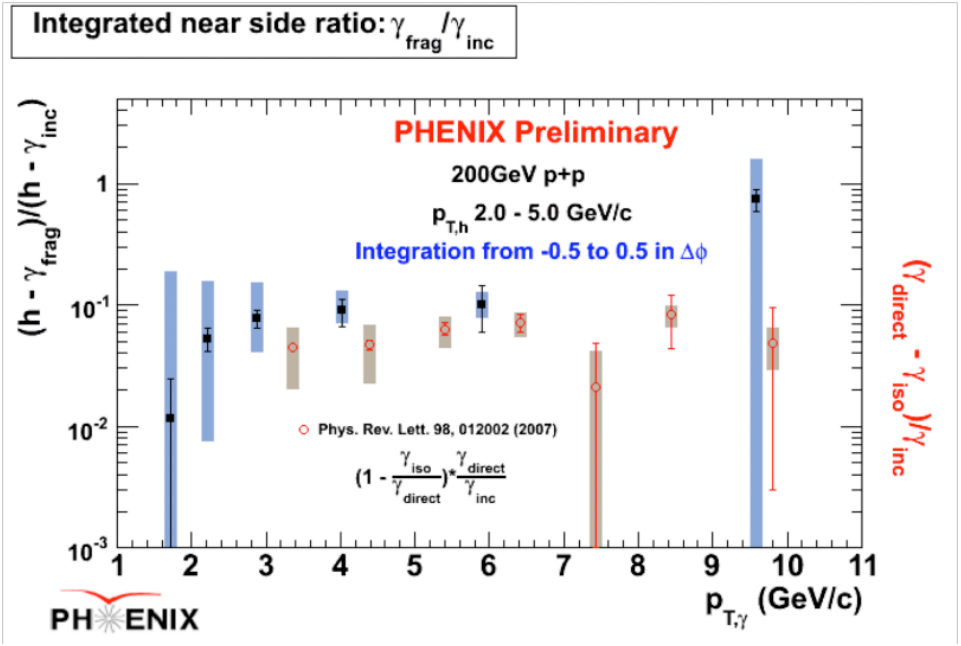
A. Hanks, Thursday parallel

fragmentation photons (II)

fraction of direct γ isolated



PHENIX, PRL 98 012002 (2007)



- consistent with fragmentation photon measurement via isolation cuts

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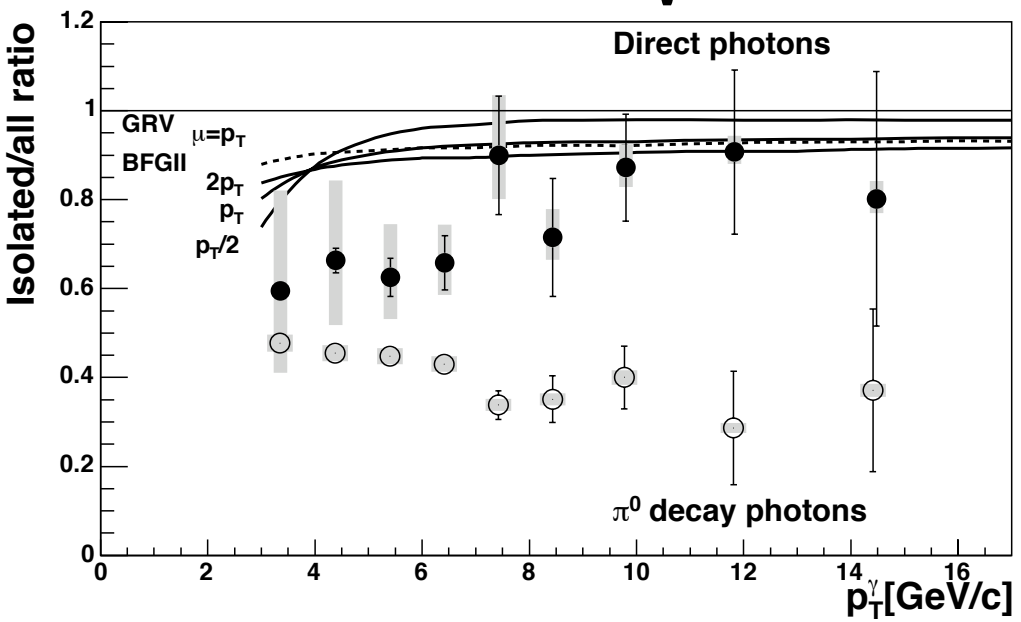
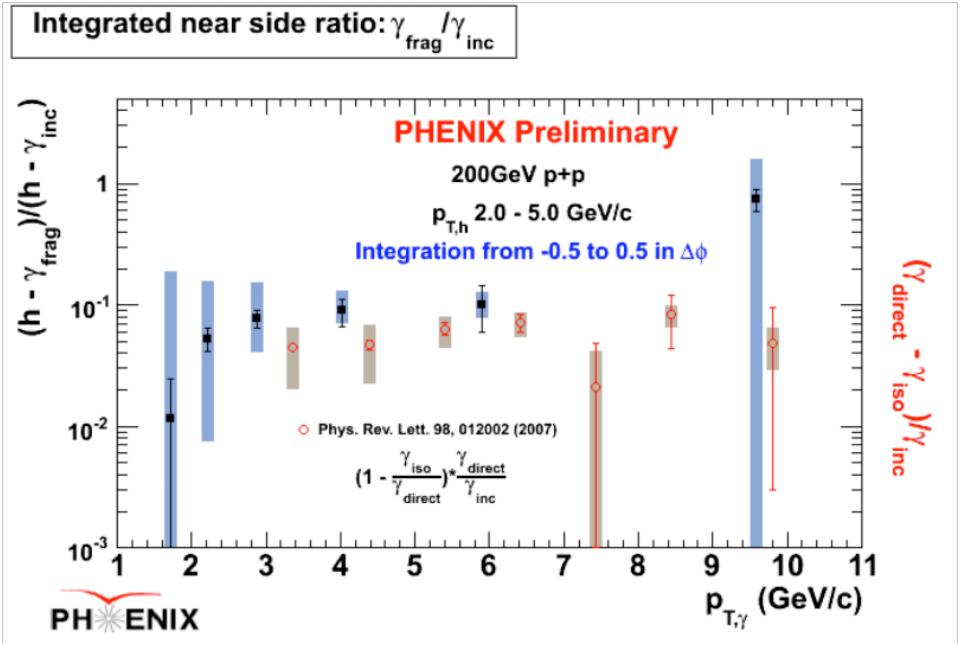
fragmentation photons (II)

fraction of direct γ isolated





PHENIX, PRL 98 012002 (2007)

- consistent with fragmentation photon measurement via isolation cuts
- establishes baseline for future Au+Au measurements

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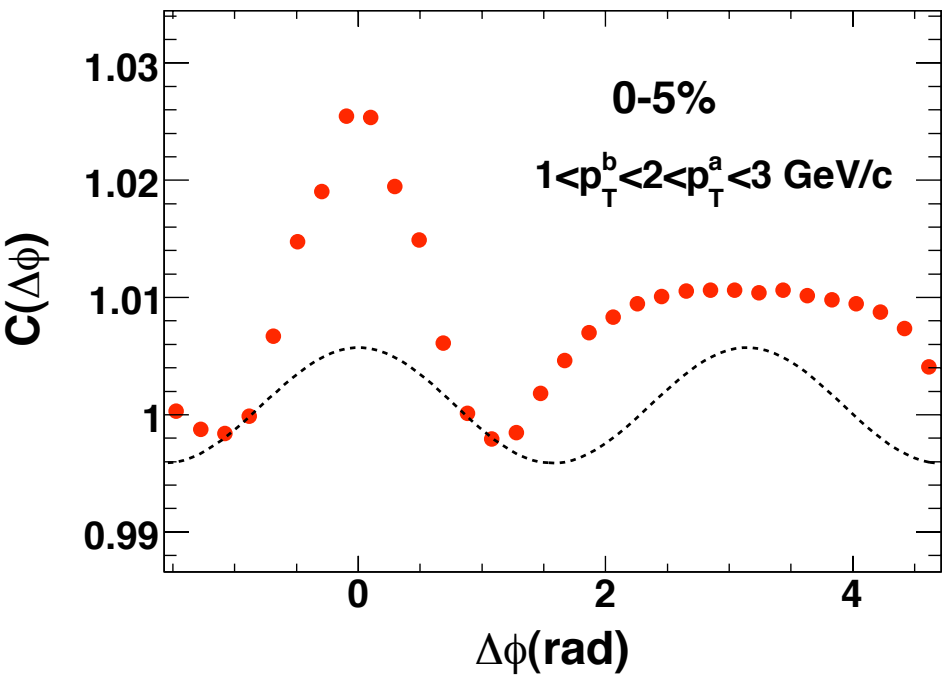
beyond ZYAM



- ZYAM: assume there is a $\Delta\phi$ region without signal:
  - over-subtracts, especially for:
    - wide jets
    - small signal/combinatoric background
- absolute subtraction: background from convolution of single particle rates nucl-ex/0702007)
  - background determination independent of signal shape
  - methods agree well (PHENIX, PRL98 232302 (2007)) with moderate statistics
  - with high precision measurements, ZYAM is a significant bias

Where Next?

- controlling the geometry:
  - more 2+1 correlations: can we see the shoulder and ridge grow?
  - reaction plane dependence: does the shoulder show a threshold with a given path length?
- connections between heavy and light quarks
- fragmentation functions: gamma-hadron, jet reconstruction
- what is the ridge?
- d+Au (new large data set on tape): saturation effects?