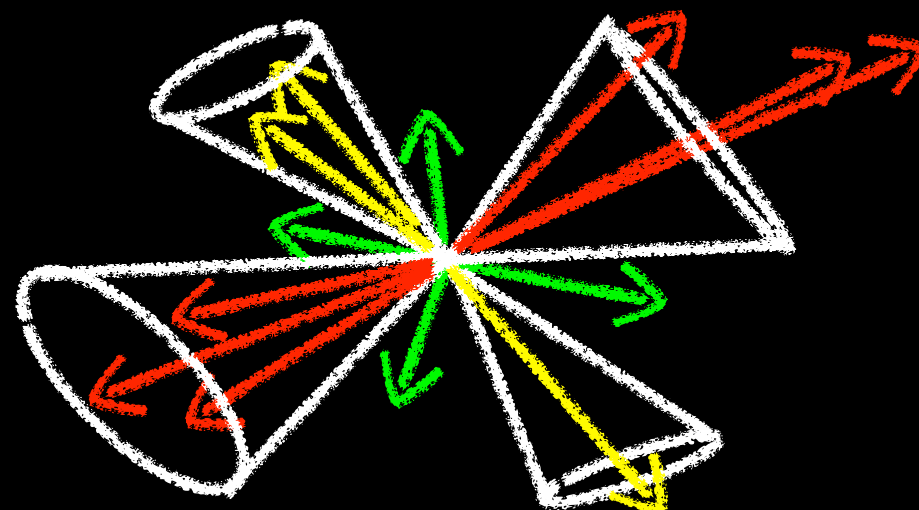
Jet-triggered dihadron correlations

Methodology, interpretation, results



Andrew Adare

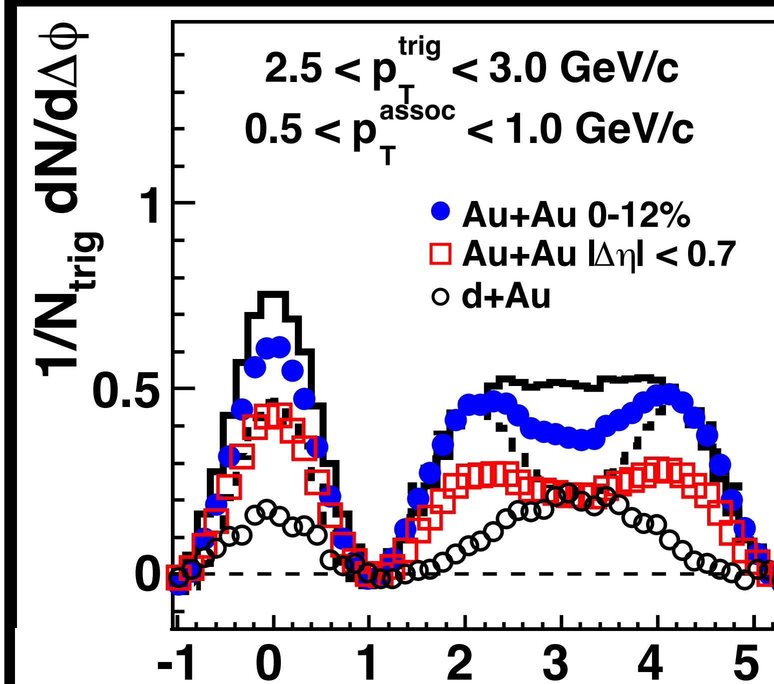
Yale University
for the
STAR collaboration

Hot Quarks 2010
La Londe les Maures,
France

Outline

- Correlations and jets
- Outstanding issues
    - correlation methodology & interpretation
    - background in correlations - simulations
- Dihadron and jet-hadron results

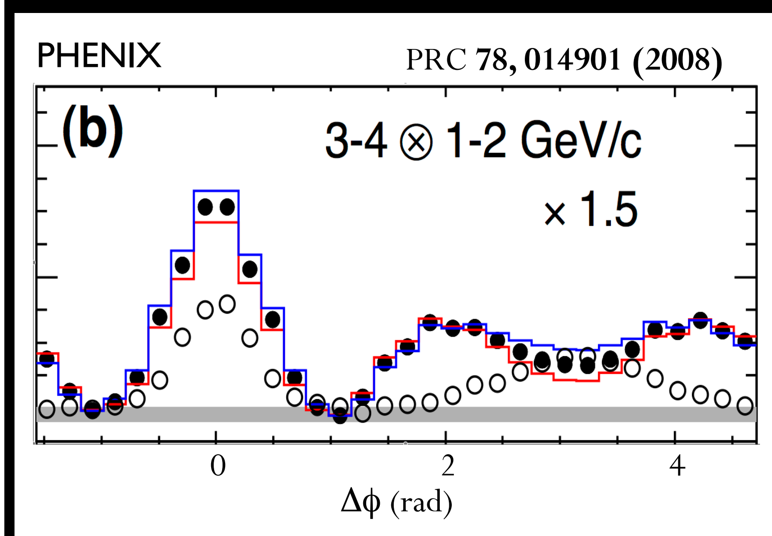
Angular correlations: current status

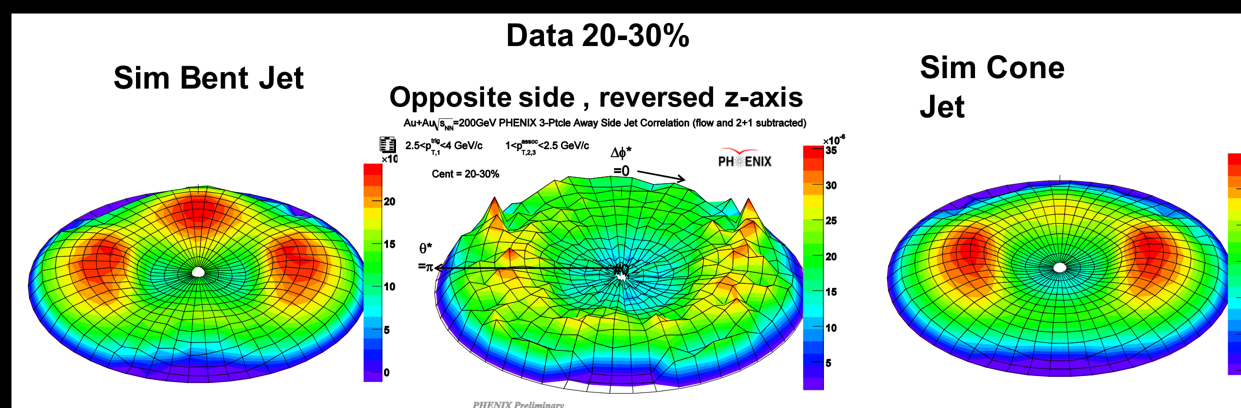


STAR - arXiV:1004.2377

- Away-side peaks are modified in A+A
- Dihadron double-peak structure observed in central events at lower p_T
- STAR and PHENIX 3-particle correlations suggest conical shape

e.g. STAR - PRL 102 (2009) 52302



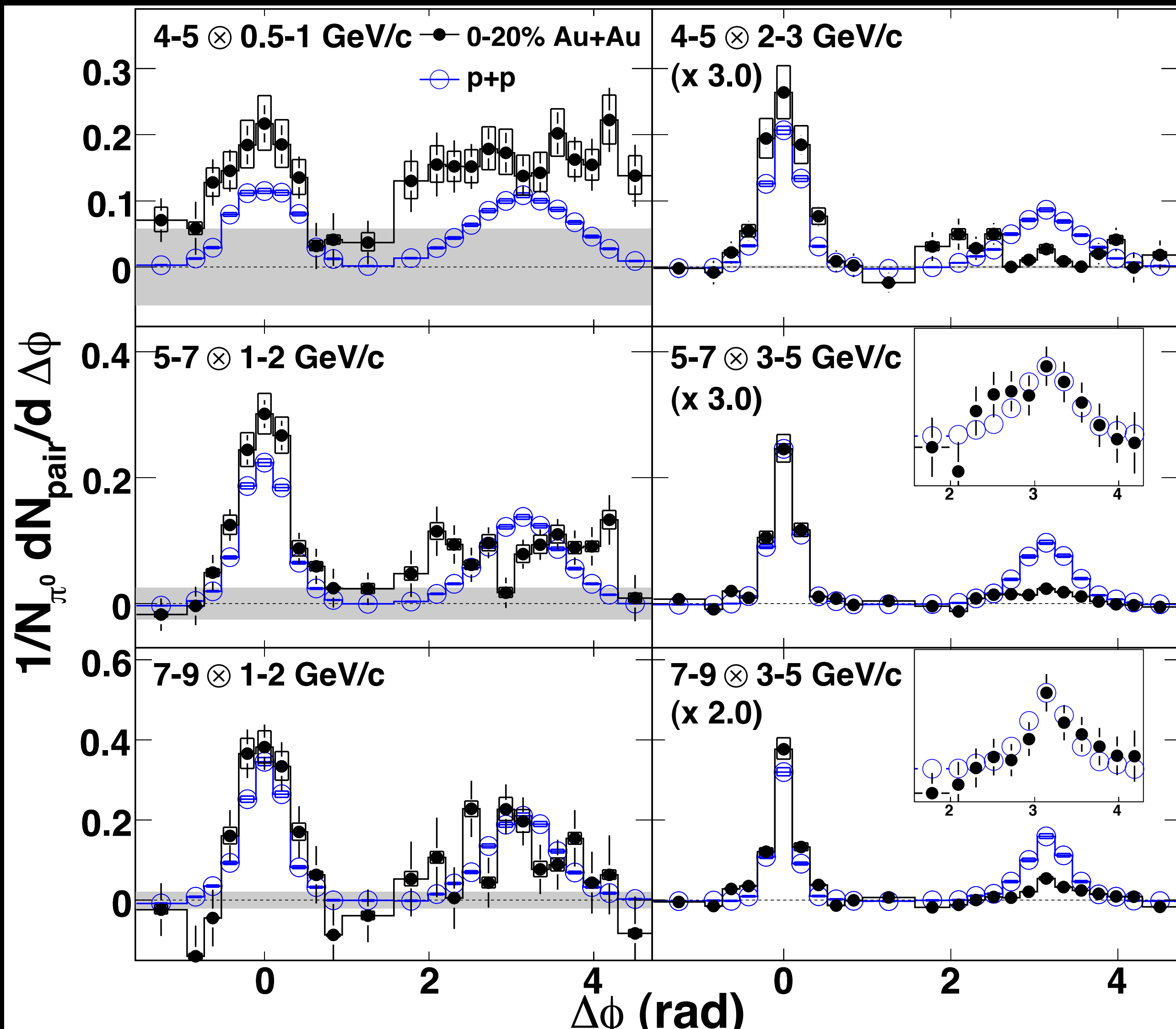


PHENIX - QM 2009

A. Adare

Higher p_T: peak shapes in π^0-$h^{\pm}$

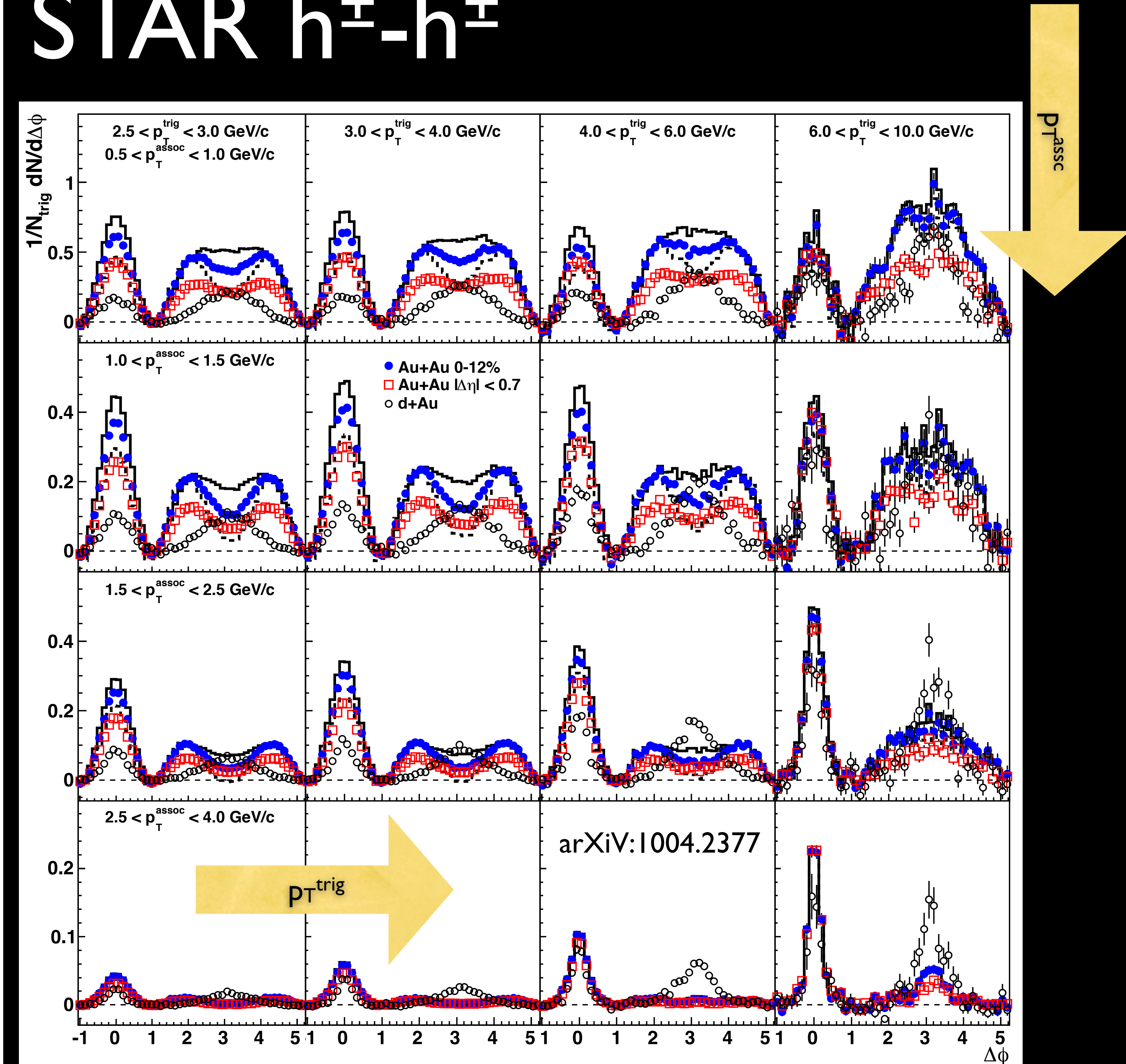
PHENIX - arXiv:1002.1077 (PRL in publication)



Au+Au shapes are broadened at lower p_T^{trig}, but consistent with p+p at high p_T^{trig}

2-peak away side structure not observed for p_T^{trig} > 7 GeV/c

STAR h±-h±

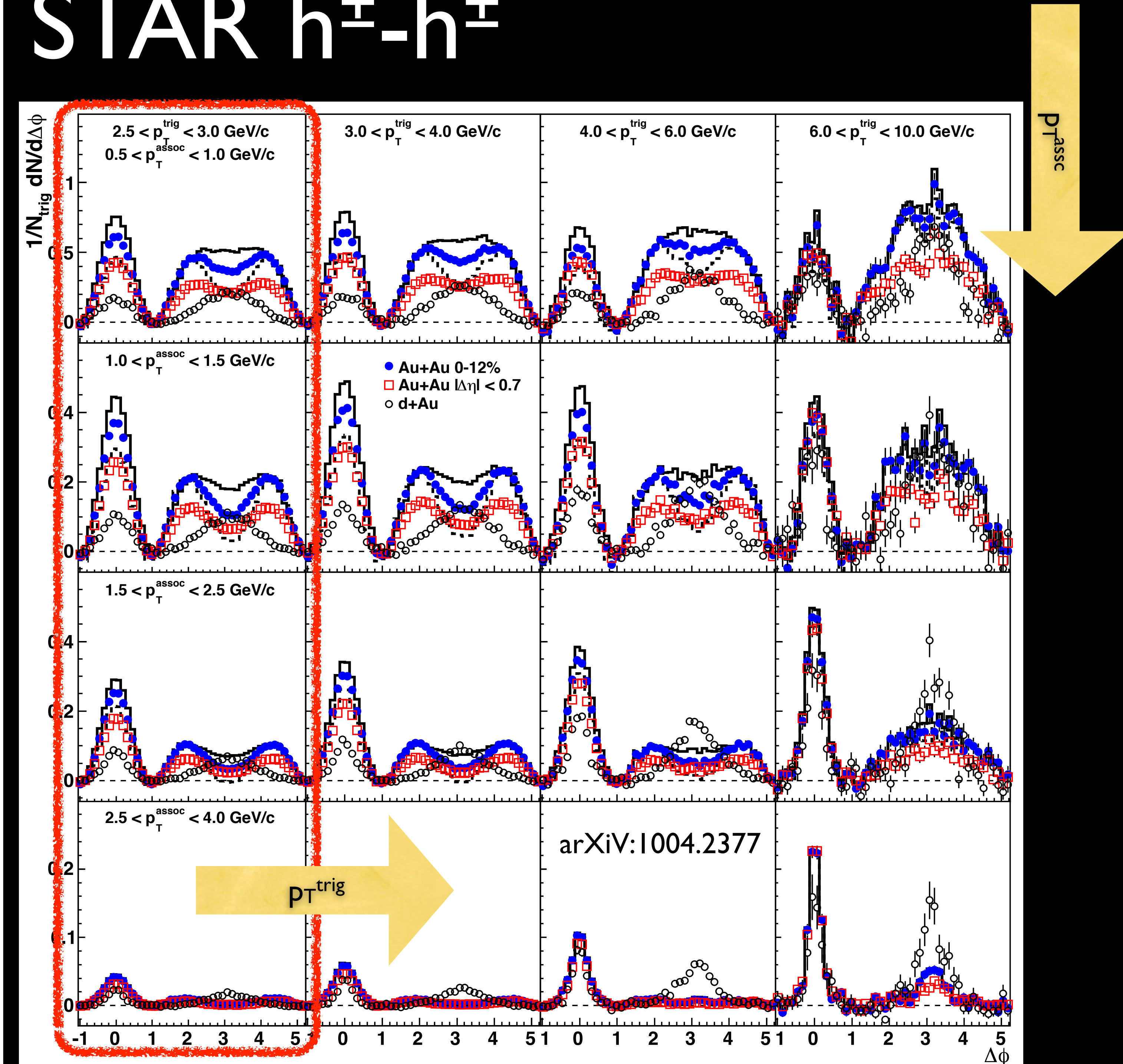


Strong shape transition!

"Shoulders" diminish with rising trigger p_T.

Seems to oppose expectations, if medium response scales with E_{parton}.

STAR h±-h±



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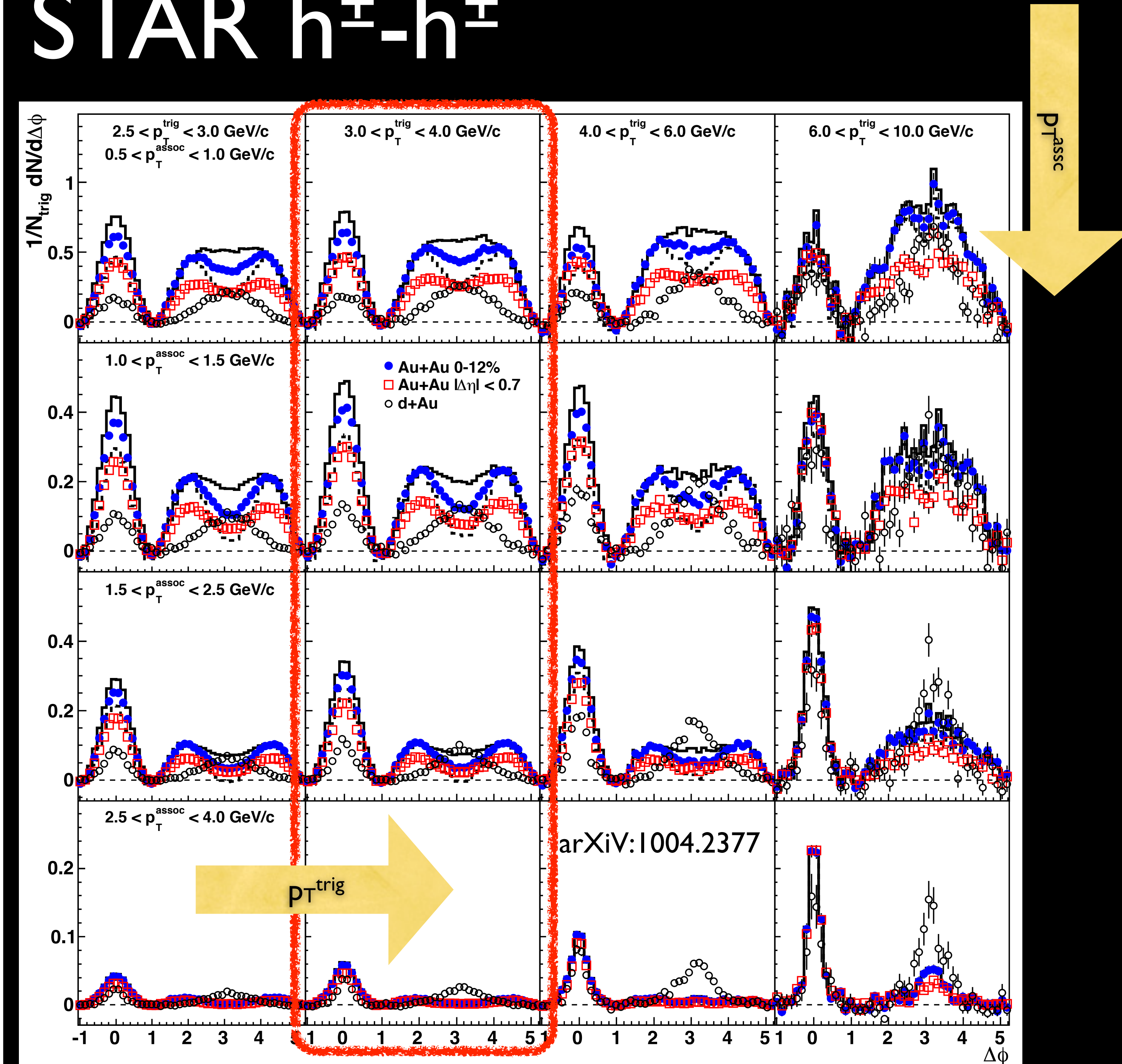

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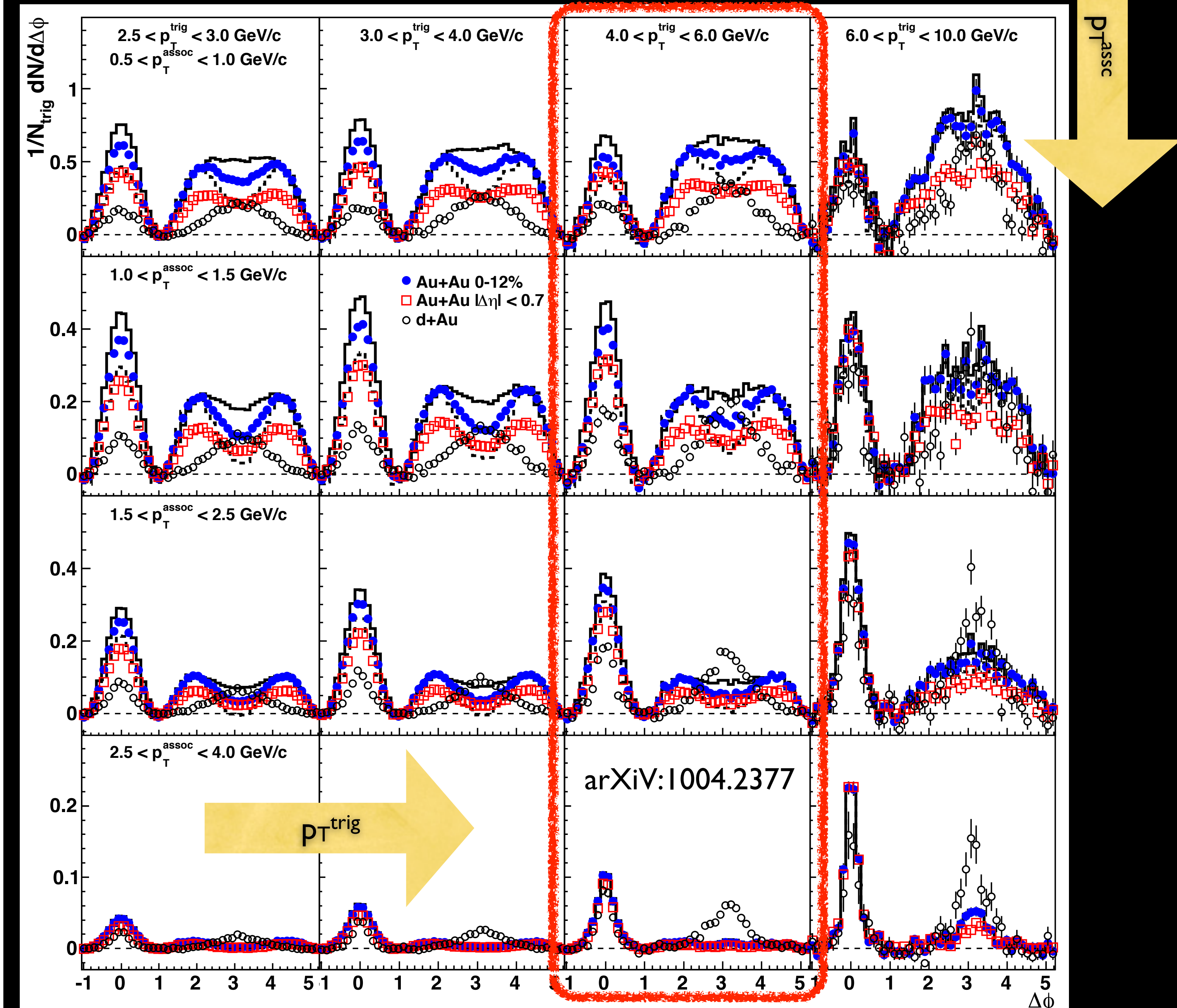

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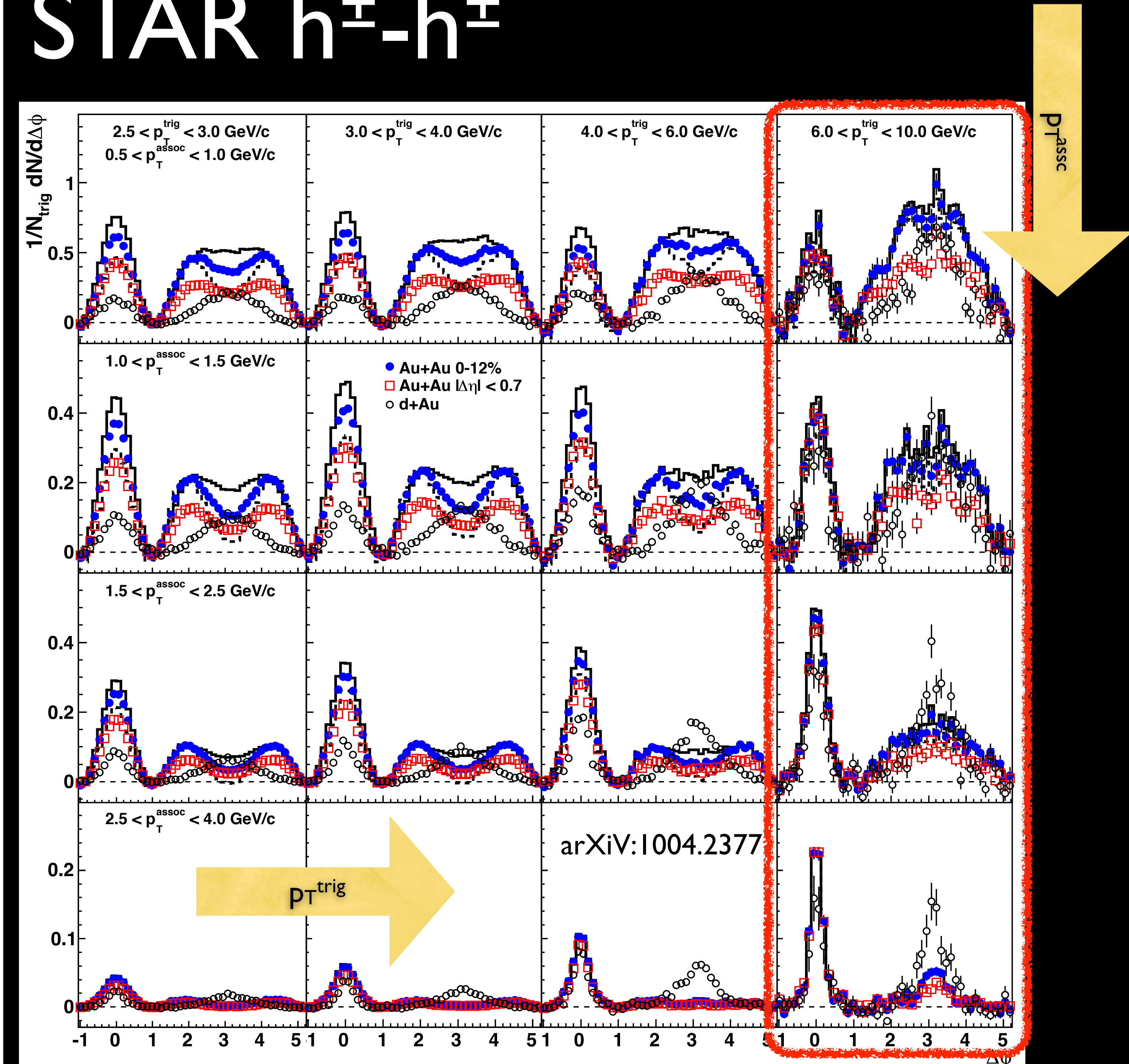
STAR $h^{\pm}$-$h^{\pm}$



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Seems to oppose expectations, if medium response scales with E_{parton}.

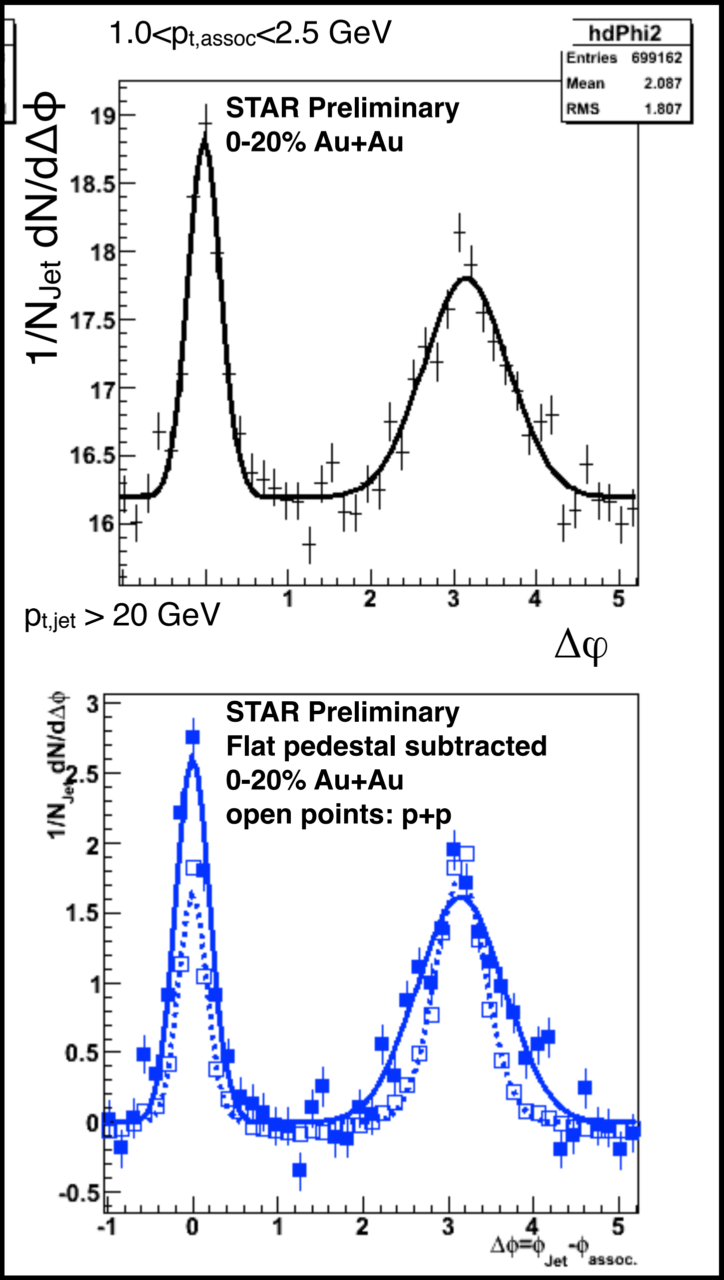
Jet-hadron correlations

Trigger on fully reconstructed jet; study away side in Au+Au and p+p to access D(z).

Jet energy scale, background handling in progress

FastJet anti-k_T with R_c = 0.4

Must know jet energy, fragmentation function...complicated to connect with h-h.



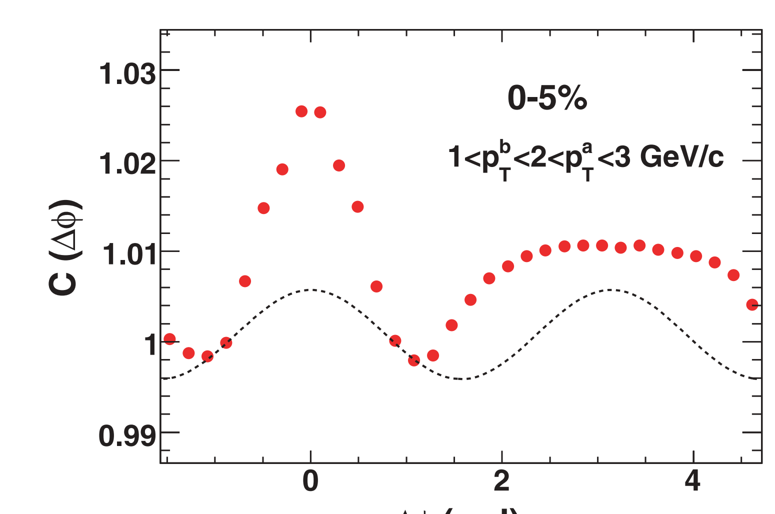
The two-source model

Jet-bkg. separation nontrivial

Are jets and UE independent? What about

- jet-medium interactions

- initial and final-state radiation

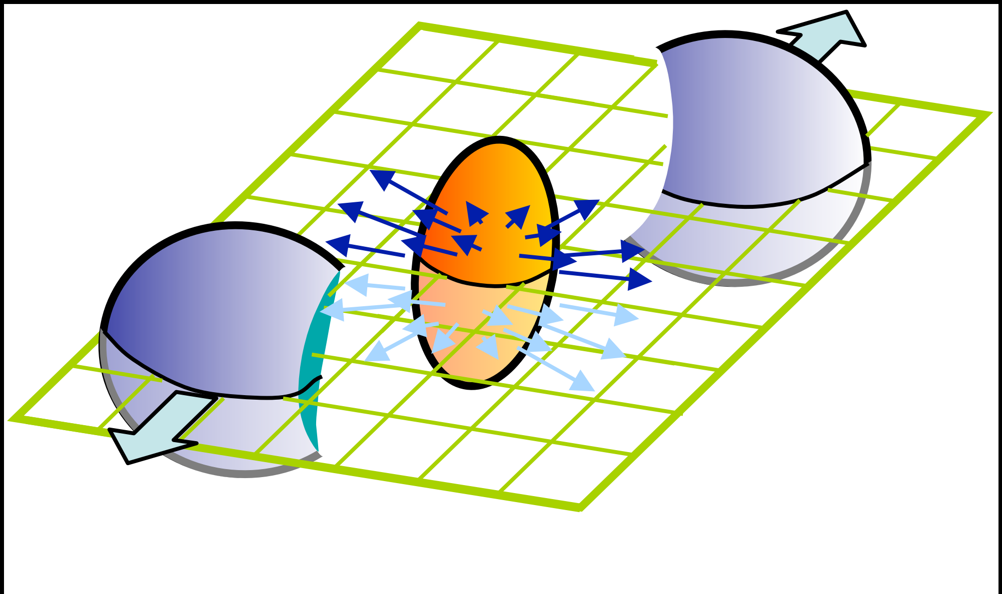


PRC 78 014901 (2008)

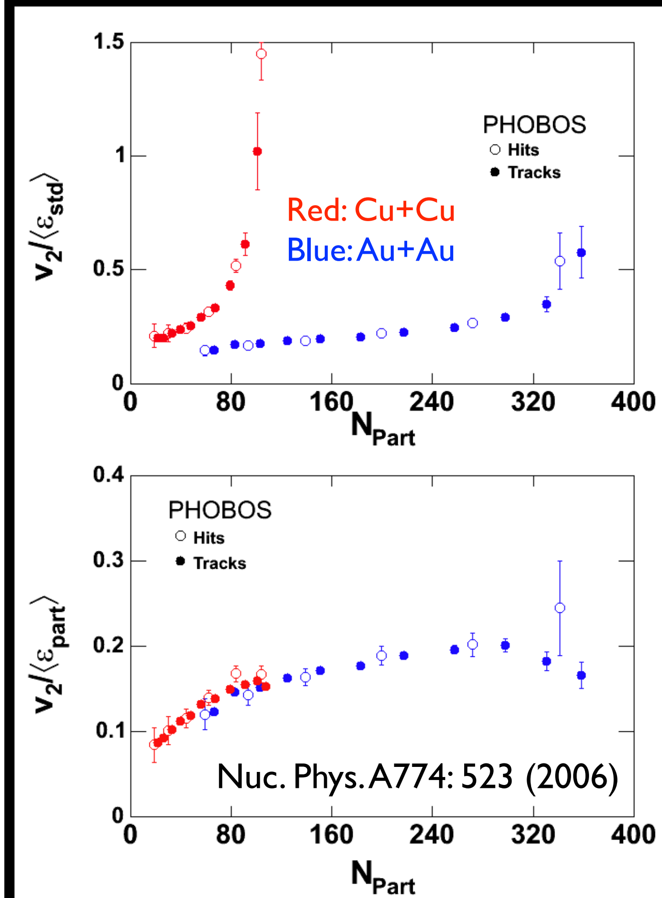
Background shape:

$B_0(1+2v_2^{AB}\cos 2\Delta\phi)$ is an approximation

A+A events are not this smooth...

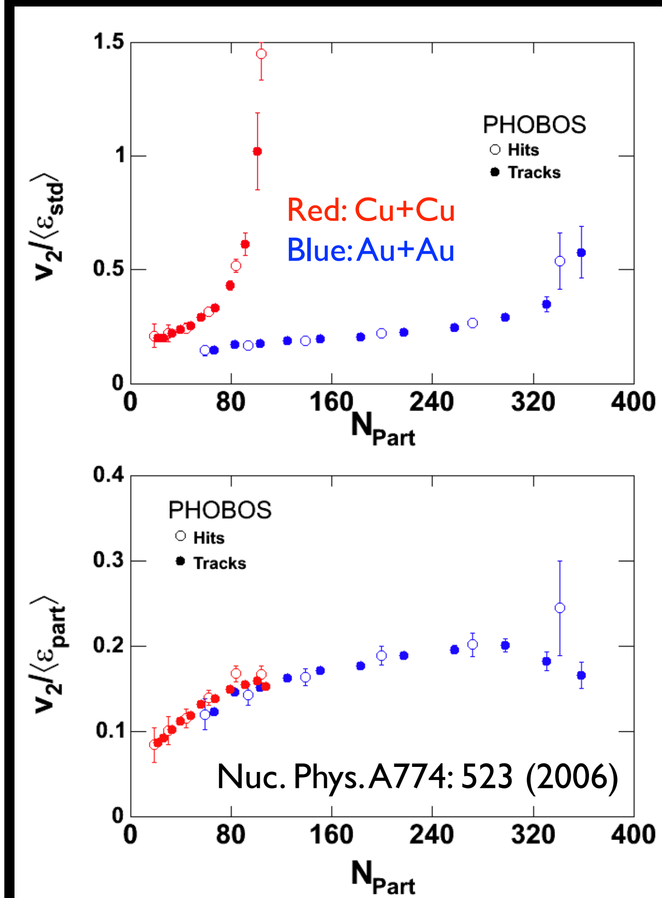


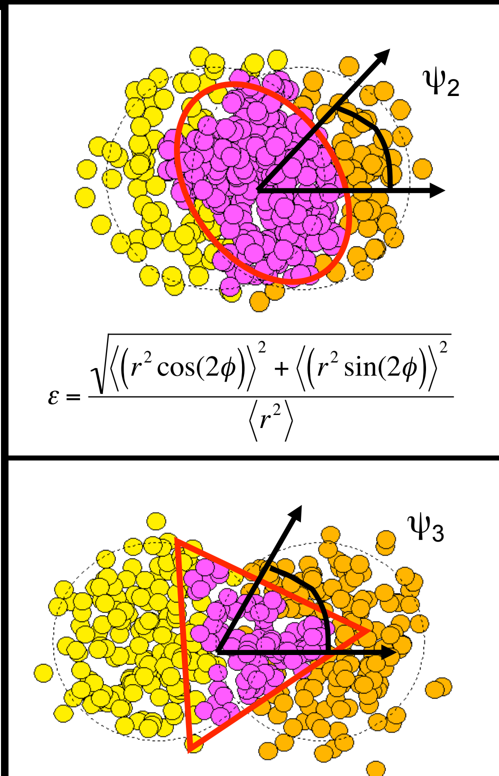
Event geometry and v_3



Accounting for fluctuations restores v_2/ε scaling

Event geometry and v_3





$$\varepsilon = \frac{\sqrt{\langle r^2\cos(2\phi)\rangle^2 + \langle r^2\sin(2\phi)\rangle^2}}{\langle r^2\rangle}$$

$$\varepsilon_3 = \frac{\sqrt{\langle r^2\cos(3\phi)\rangle^2 + \langle r^2\sin(3\phi)\rangle^2}}{\langle r^2\rangle}$$

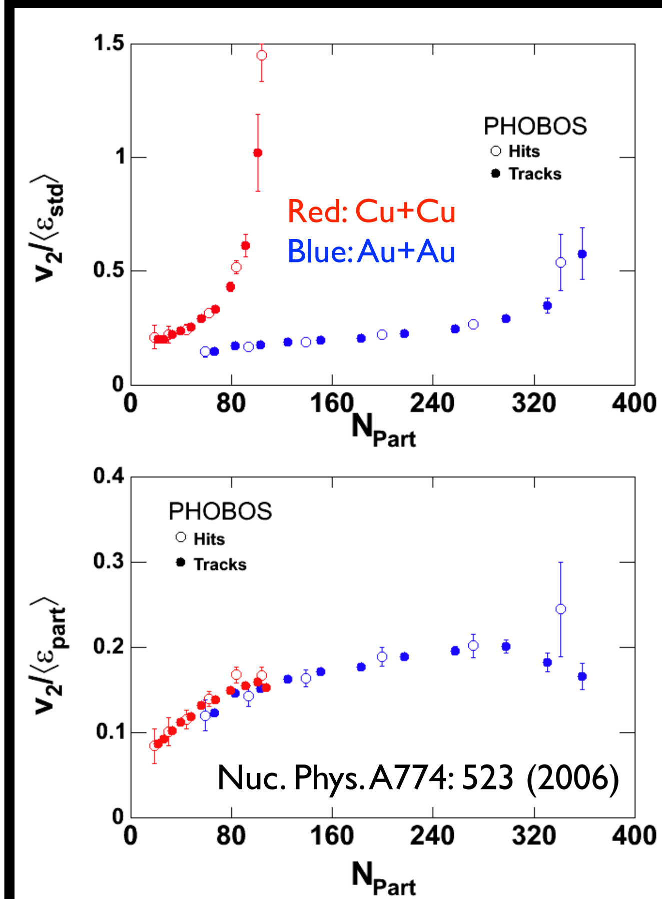
Accounting for fluctuations restores v_2/ε scaling

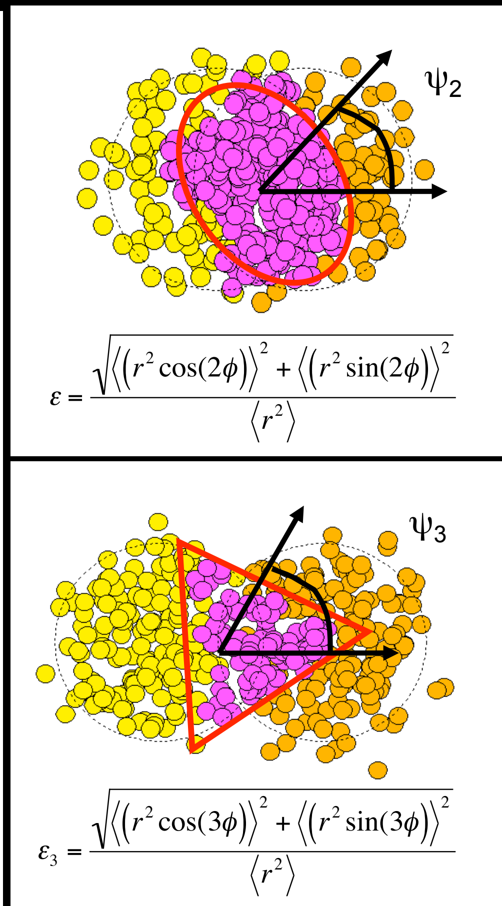
Fluctuations also affect event shape

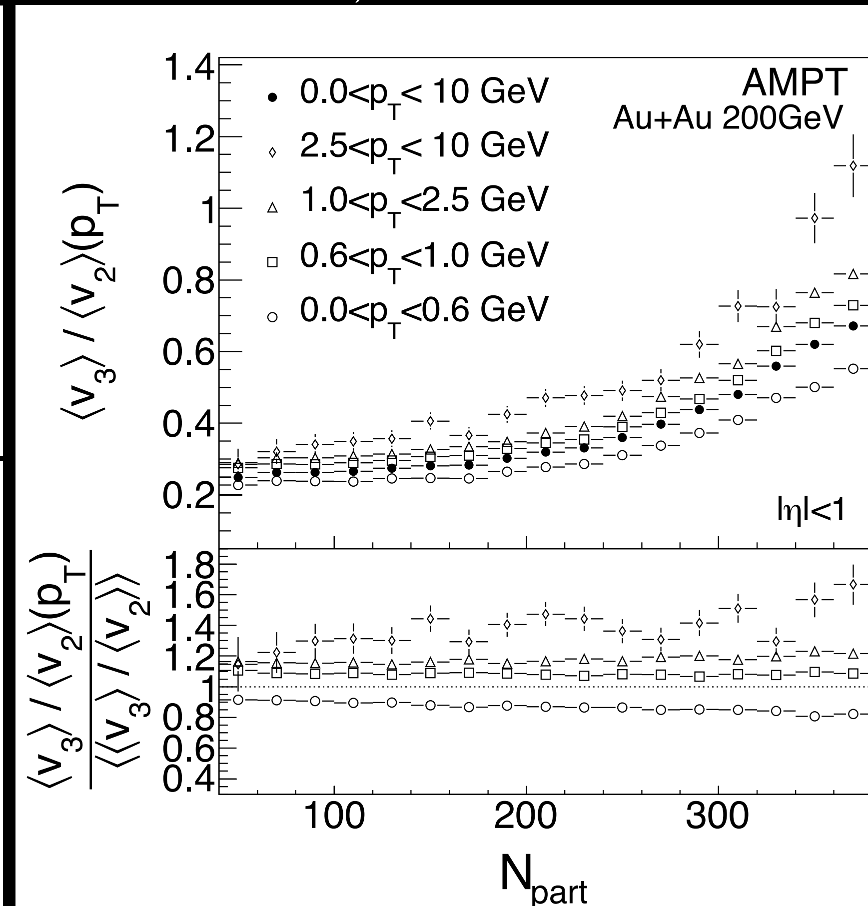
A. Adare

Event geometry and v_3

B. Alver, G. Roland arXiV:1003.0194







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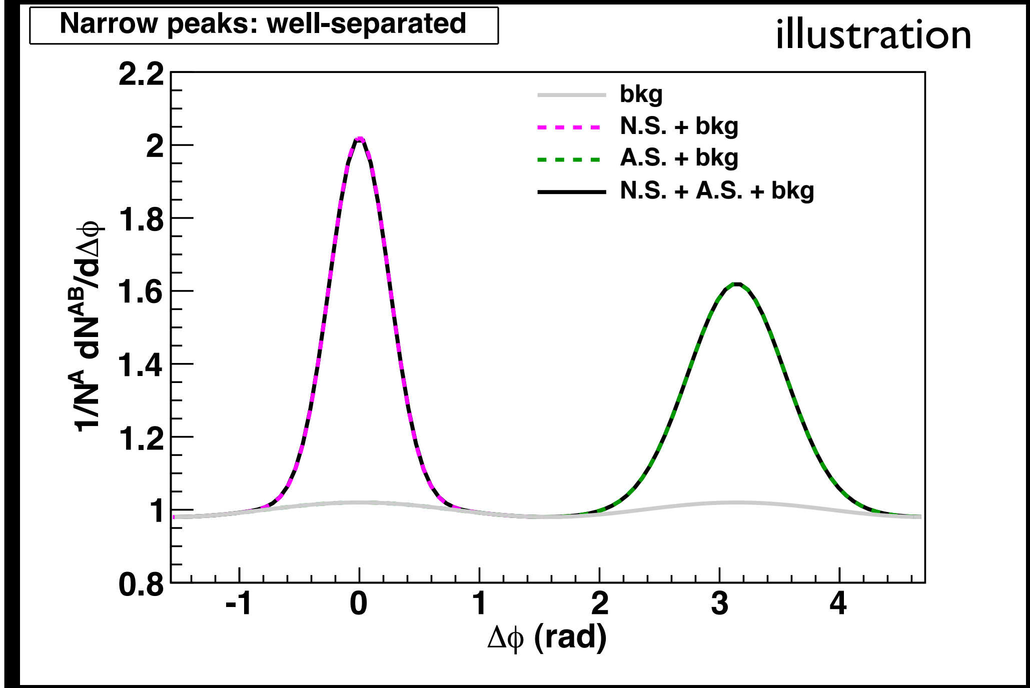
AMPT with HIJING ICs indicates a large v_3 component!

ZYAM and weak correlations



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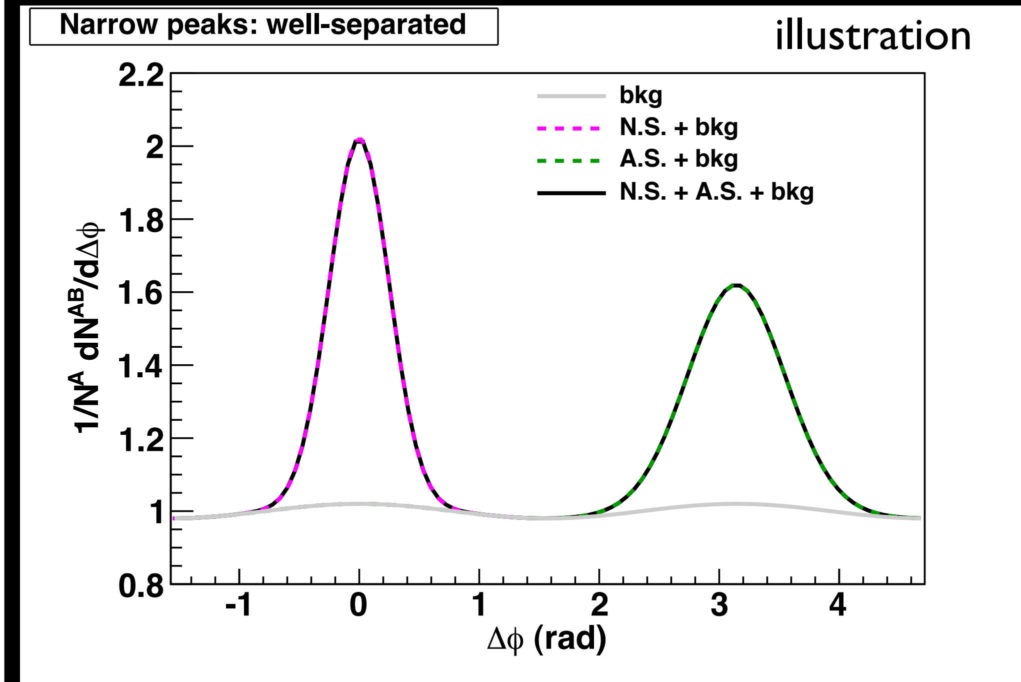

Relatively small bias where peaks are separated (peripheral, p+p, high p_T). N.B.: bkg. modulation also typically small.

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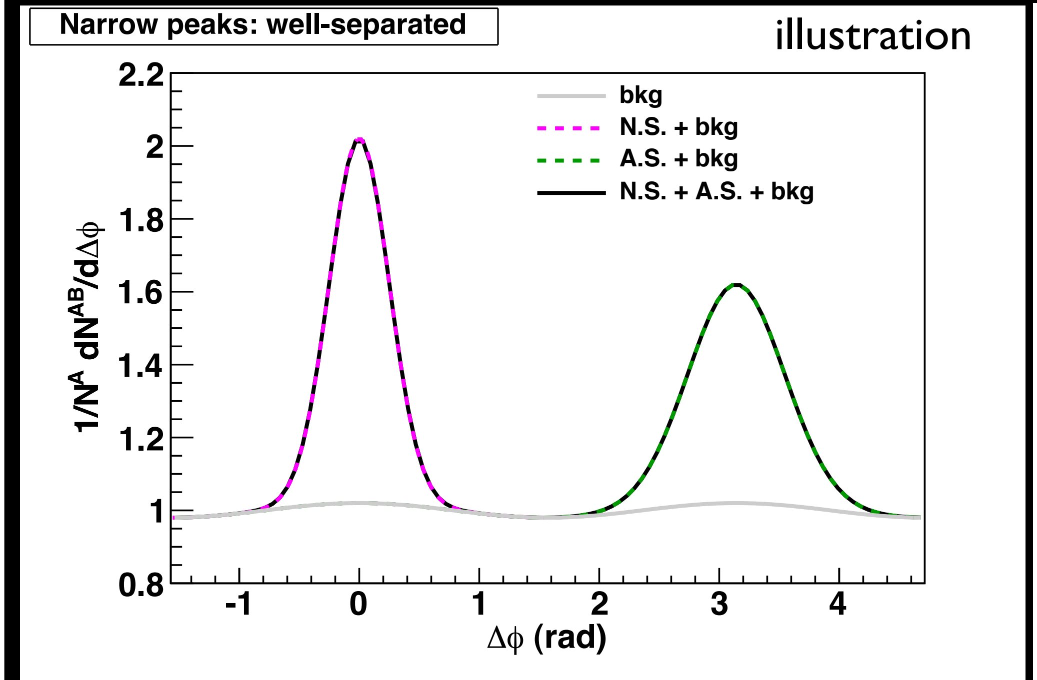
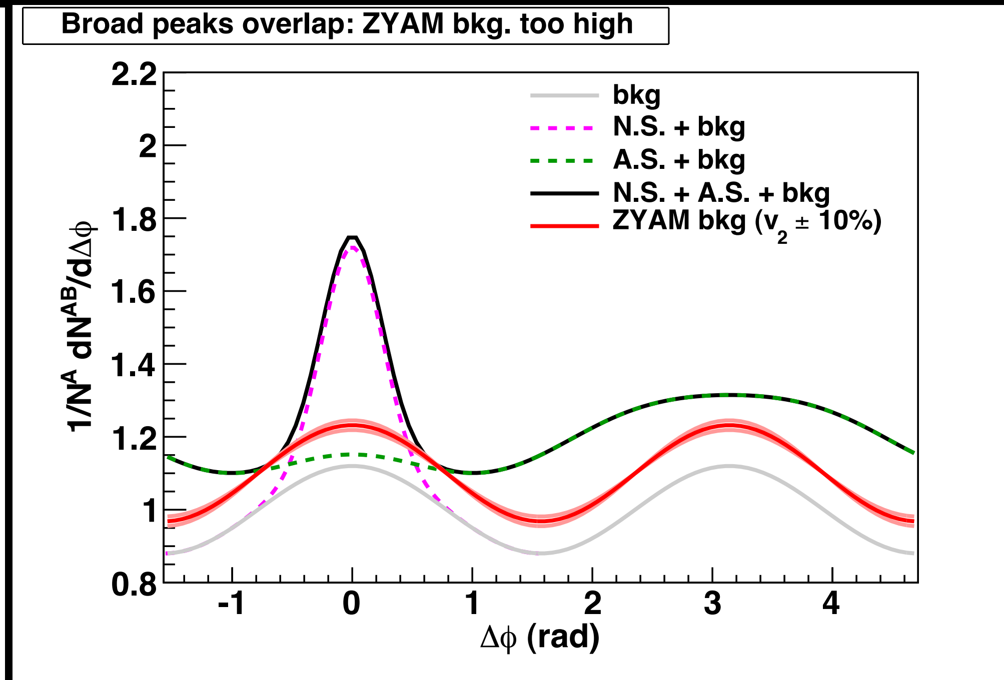
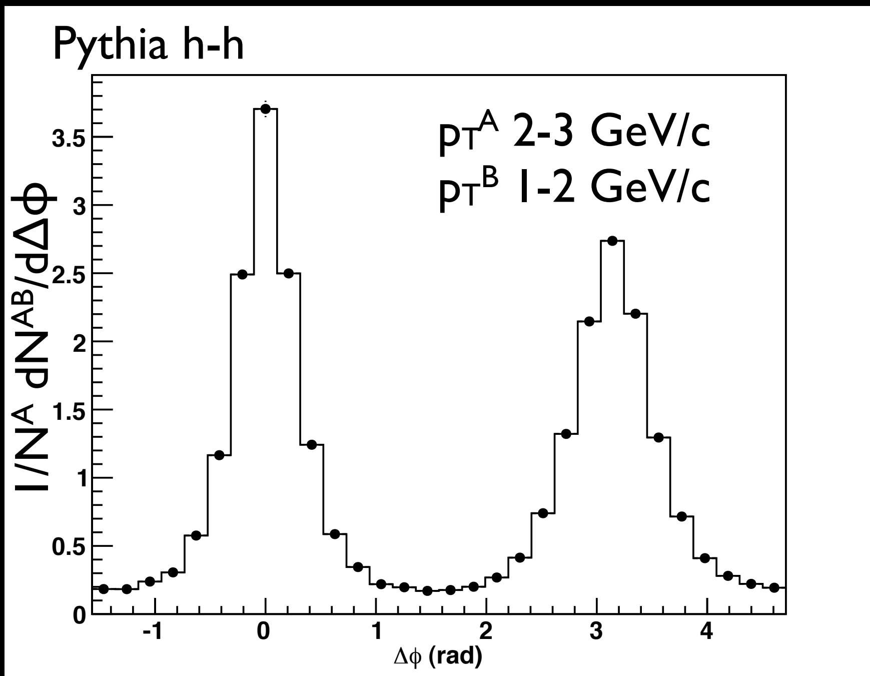


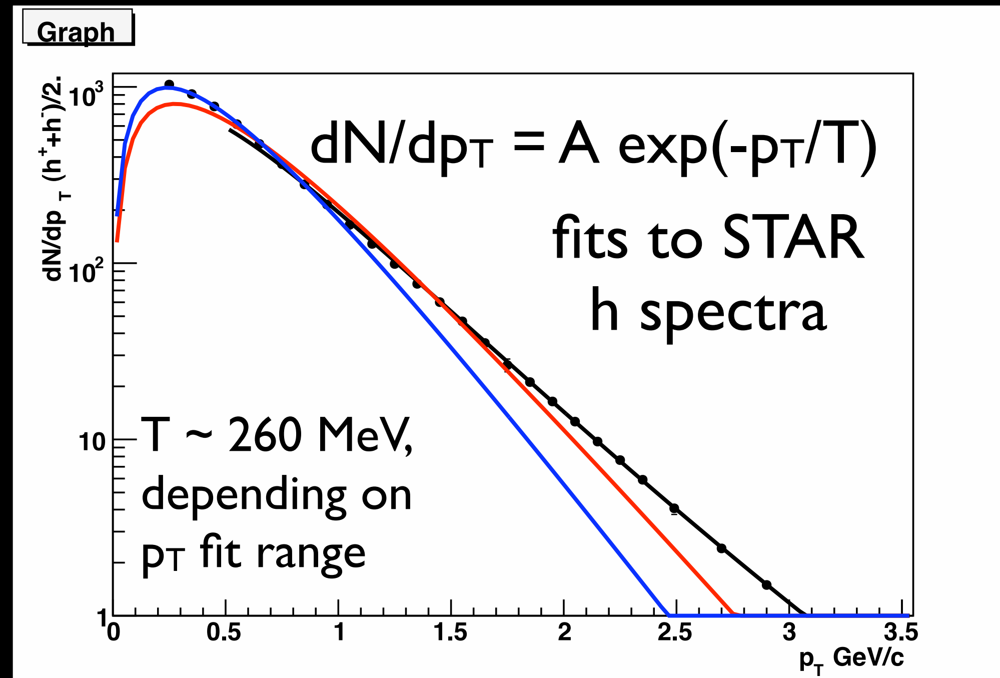


Relatively small bias where peaks are separated (peripheral, p+p, high p_T). N.B.: bkg. modulation also typically small.

Background overestimated where broad peaks merge, subtracted shape highly sensitive to v_2 uncertainty for weak correlations (central, low p_T)

Simulating background effects





<u>Pythia jets + thermal bkg.</u>

Generate ~20 GeV PYTHIA p+p jets for reference correlation

Embed jets in isotropic thermal background

Background multiplicity from STAR central $dN^{ch}/d\eta$

$$A = \frac{dN^{ch}}{d\eta}\frac{N^{all}}{N^{ch}}\Delta\eta \sim 2000$$

Background effects: expectations

Distinguish 2 particle sources: jet (J) and background (BG).

$N^{A,B}$ = total # triggers, partners. $n^{A,B} = N^{A,B}/N_{events}$.

If all triggers are from jets, background introduces an uncorrelated pedestal:

$$\int d\Delta\phi \frac{1}{N_J^A} \frac{dN_{J-BG}^{AB}}{d\Delta\phi} = \frac{n_{BG}^B}{2\pi}$$

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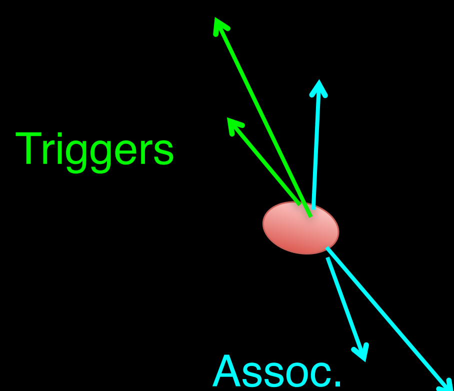
Example event:



2*3 / 2 pairs/trigger

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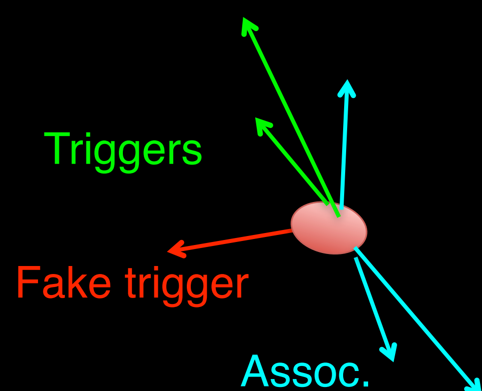

Add 1 fake trigger:

(2+1)*3 / (2+1) pairs/trigger

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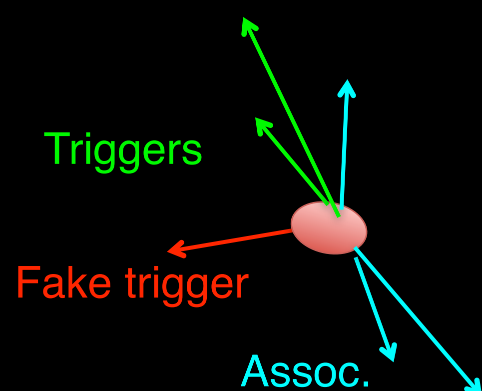

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(2+1)*3 / (2+1) pairs/trigger

But the correlation is weakened....

Adding BG triggers

Background-contaminated trigger particle sample:

$$N_J^A \to N_J^A + N_{BG}^A$$

A: trigger
B: partner

Trigger purity f:

$$f \equiv \frac{N_J^A}{N^A} = \frac{N^A - N_{BG}^A}{N^A}$$

Jet peaks are diluted by the factor f.

But the Δϕ-integrated yield is unchanged.

Fake trigger - true jet partner pairs add uncorrelated pedestal.

$$\int d\Delta\phi \frac{1}{N^A}\frac{dN^{AB}}{d\Delta\phi} = \frac{1}{2\pi}(n_{BG}^B + n_J^B)$$

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n_J^B → $f n_J^B$ suppressed peak

\+ $+$

$(1-f)n_J^B$ raised pedestal

h_{jet}-h correlations

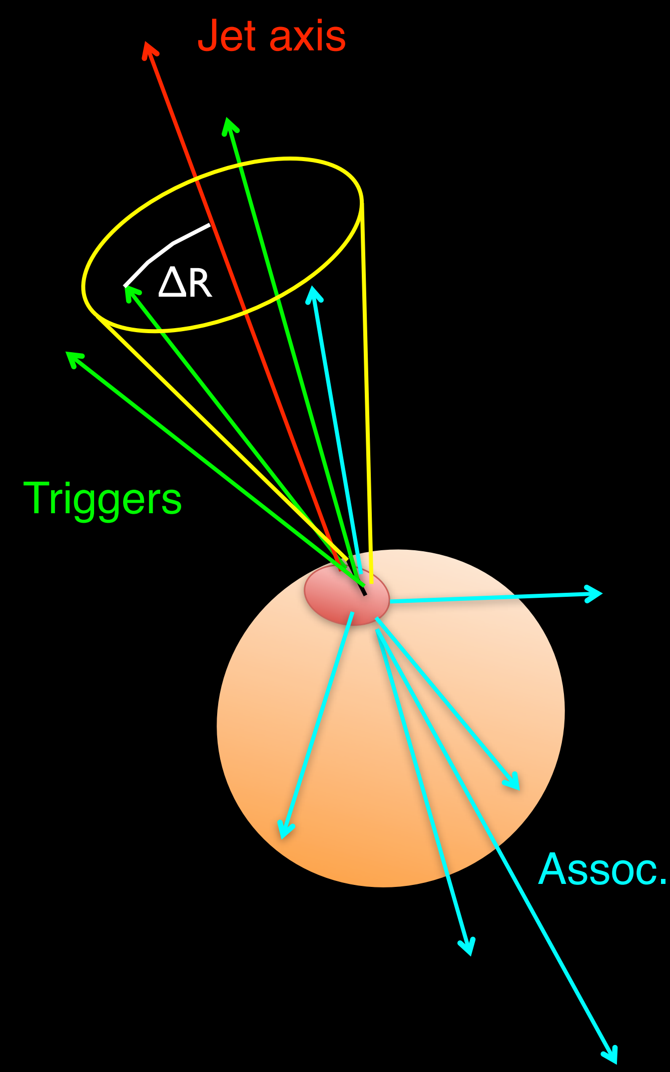
What if we require the trigger particle to be part of a reconstructed jet?

In each event, measure angular distance ΔR to nearest jet for each trigger particle *A*:

$$\Delta R \equiv \sqrt{(\phi_{jet} - \phi_A)^2 + (\eta_{jet} - \eta_A)^2}$$

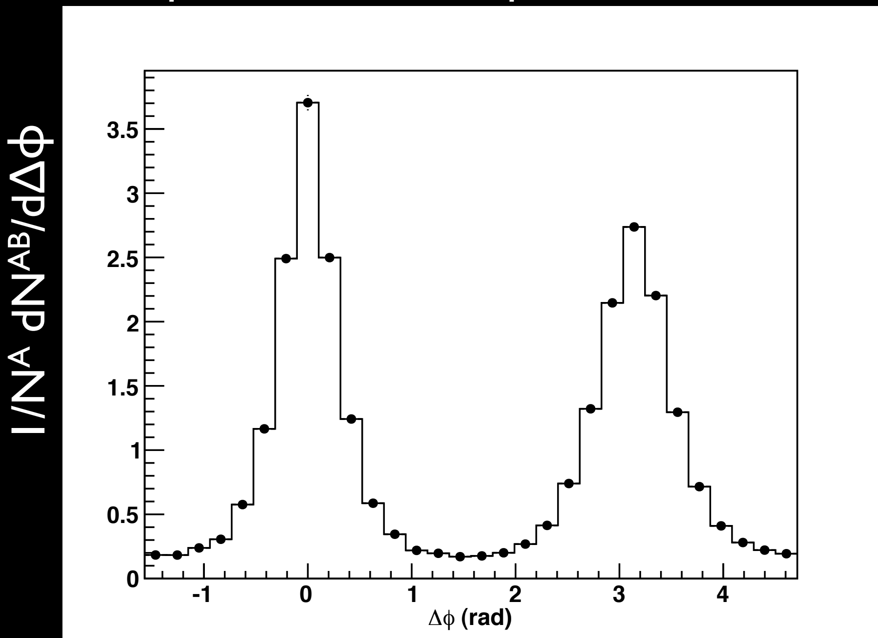
Require ΔR < R_C for h_{jet}-h.

How does shape, yield change vs. inclusive h-h?



h_{jet}-h correlations - MC

p_T^A 2-3 GeV/c p_T^B 1-2 GeV/c



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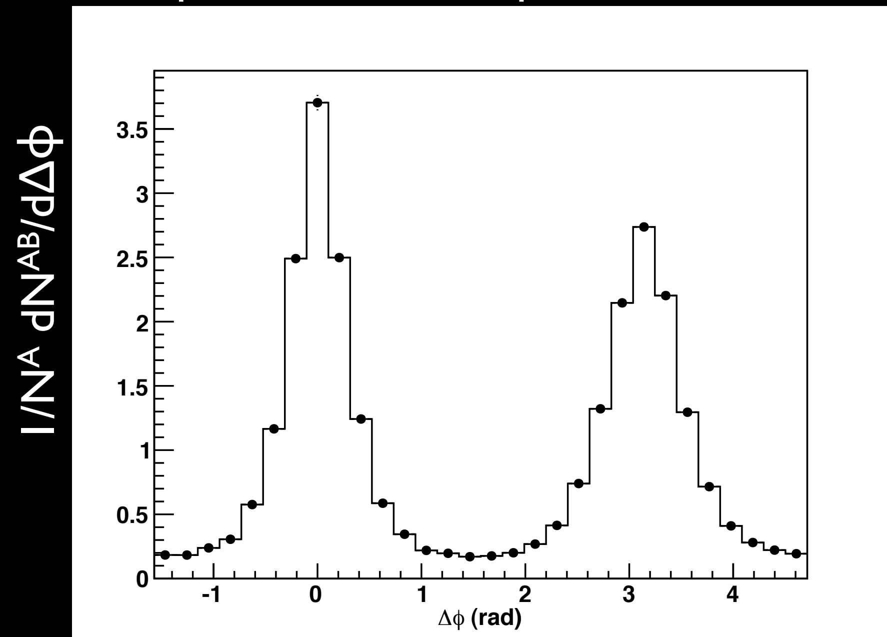

To start: produce h-h correlations in pythia.

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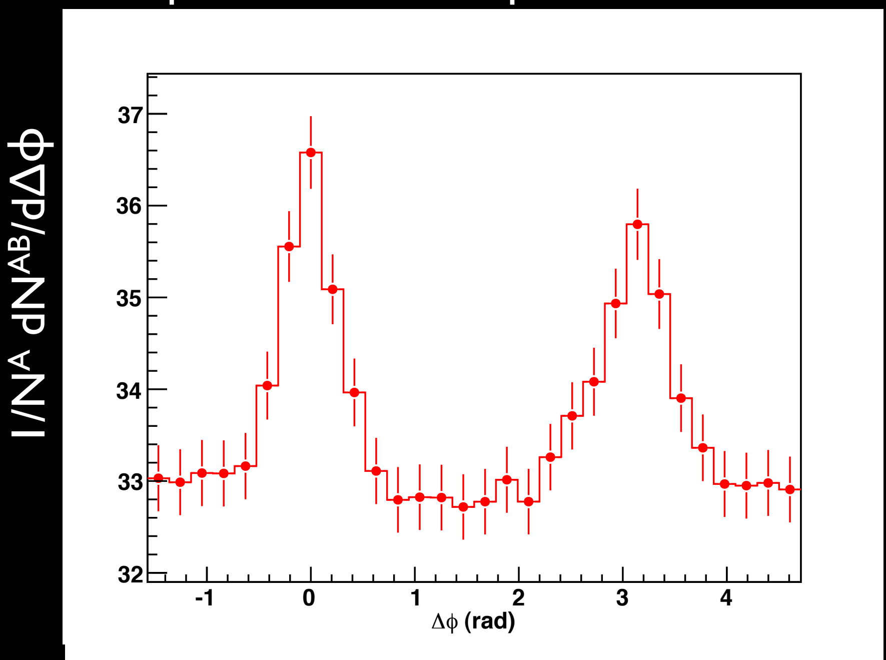

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Add isotropic thermal background; calculate h_{jet}-h. Trigger particles are inside $\Delta R = R_C = 0.4$.

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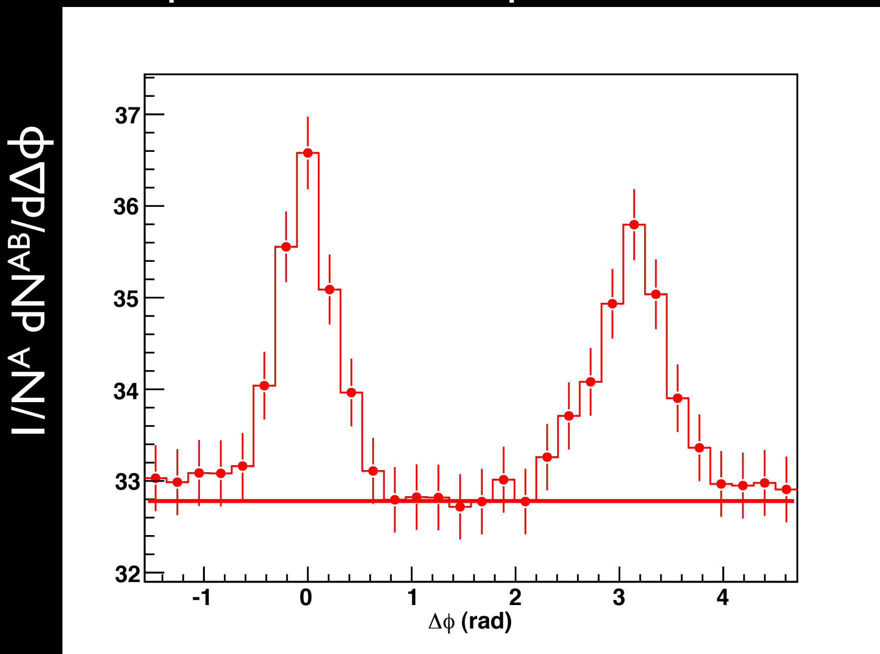

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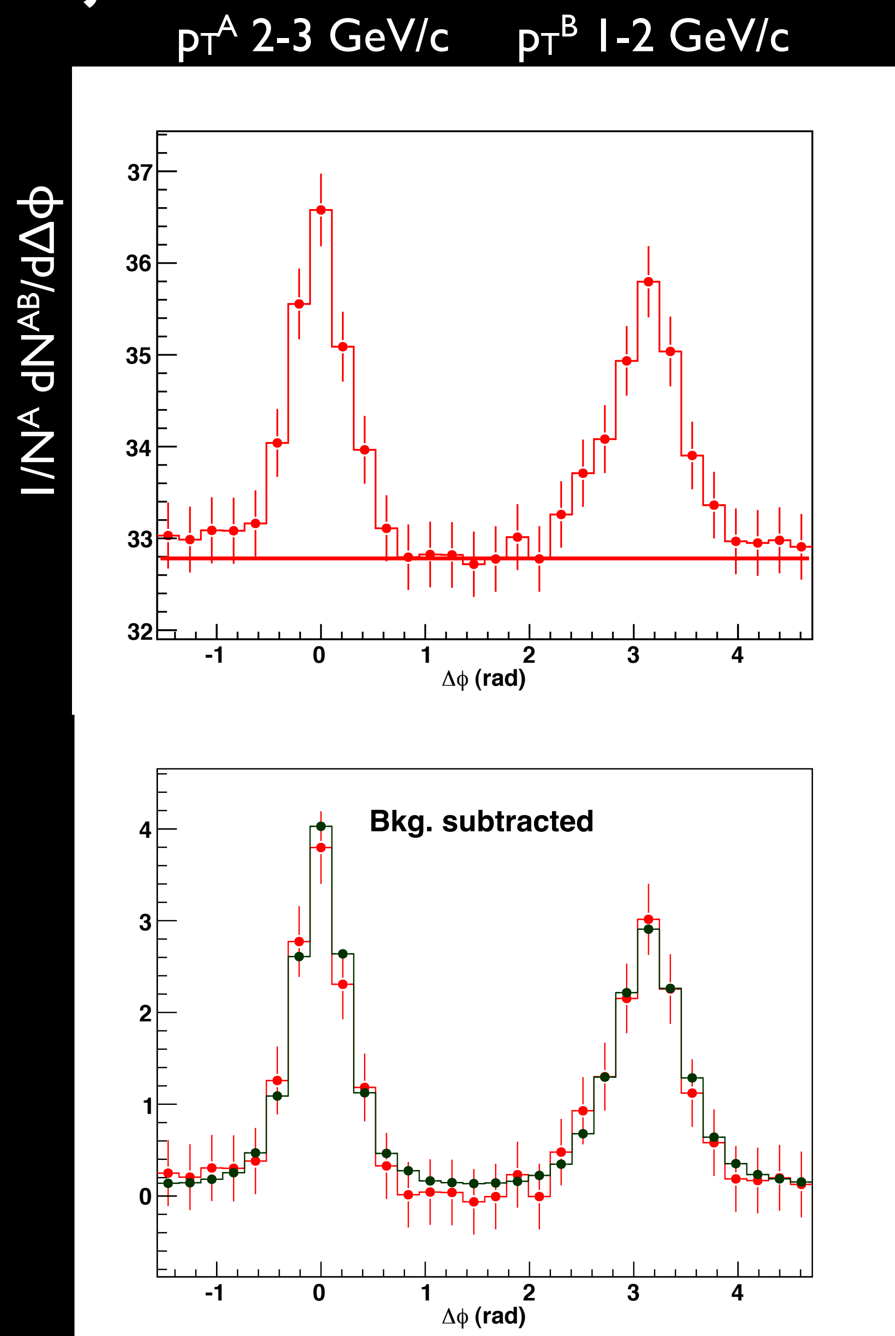
Background pedestal:

$$\frac{1}{2\pi}\frac{dN^{ch}}{d\eta}\Delta\eta\frac{N^{all}}{N^{ch}}\frac{N_{th}(1-2\,\mathrm{GeV})}{N_{th}(\mathrm{all}\,p_T)}$$

1/2π * 650 * 2 * 3/2 * 0.105 = 32.8

h_{jet}-h correlations - MC



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Pedestal subtraction recovers PYTHIA yield (dark points).

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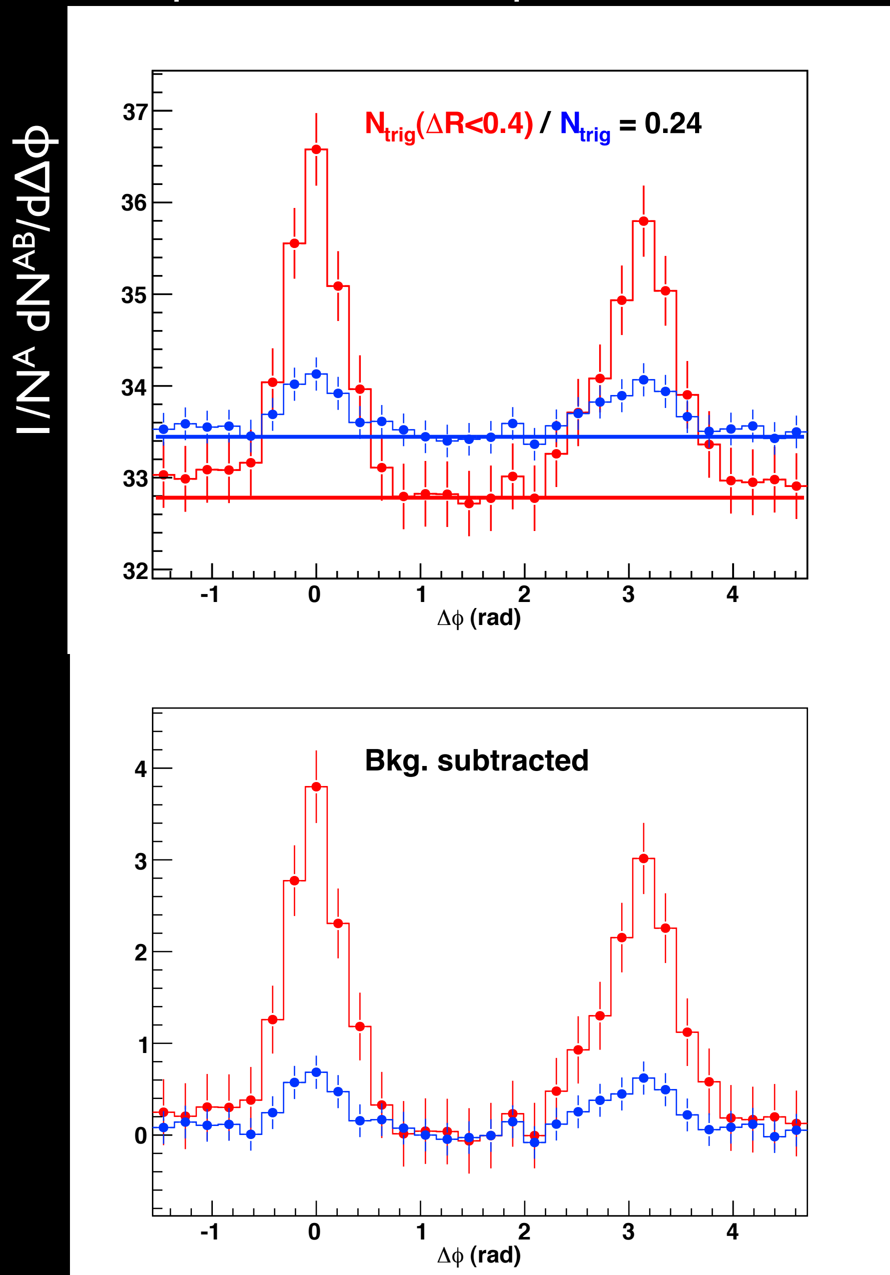

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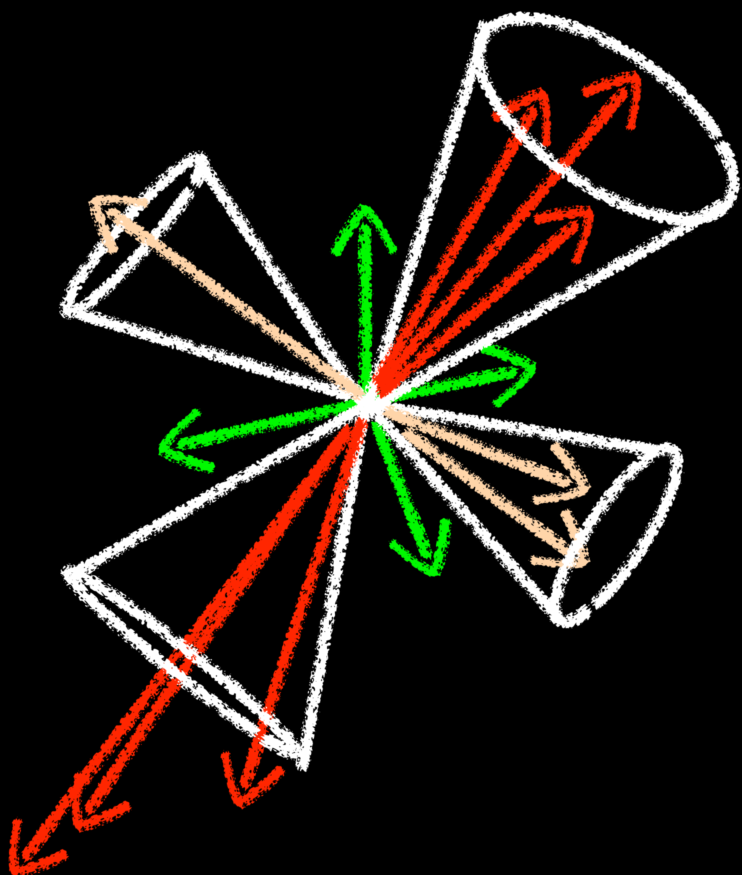
Inclusive h-h: many fake triggers

- peak yield is $f \approx 0.24$ x the h_{jet}-h yield

- pedestal raised by $1/2\pi *(1-f)n^B_{jet} = 0.67$

A. Adare

What is the real-world h-h bkg?



Uncorrelated sources at lower p_T:

- additional semi-hard scatterings or un-reconstructed jets
- recombination / coalescence
- thermal fluctuations
- radially boosted soft particles

....?

h-h interpretation complicated in A+A.

Enhancing the jet-like component adds valuable information.

h_{jet}-h vs. h-h

h_{jet}-h differs significantly from inclusive h-h:

(a) At given p_T^{trig}, h_{jet}-h samples harder collisions and lower-z hadrons

(b) Fewer triggers from soft bkg. sources: thermal, ReCo, hydro, etc.

(c) h_{jet}-h "misses" some jets from 2^{nd}, 3^{rd}, ..., n^{th} semi-hard scattering...not sampling minbias jet cross-section.

Also: h_{jet}-h results may depend sensitively on jet definition! Under investigation.

Trying h_{jet}-h in Au+Au data

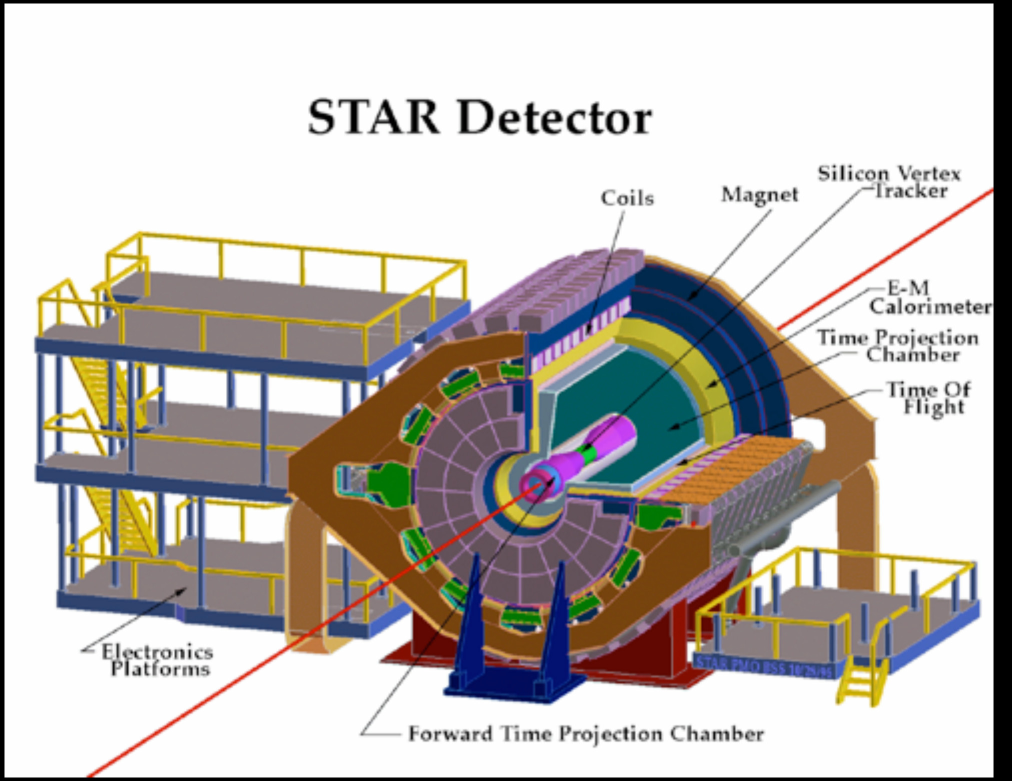
To maximize recoil parton L and ΔE, trigger on hadrons near energetic reconstructed jets.

FastJet anti-k_T with R_C = 0.4

$p_{T,jet}$ > 10 GeV/c, corrected for background:

$p_{T,jet} = p_{T,meas} - \rho A$

tower/particle p_T > 2 GeV/c



Use STAR high-tower triggered data.

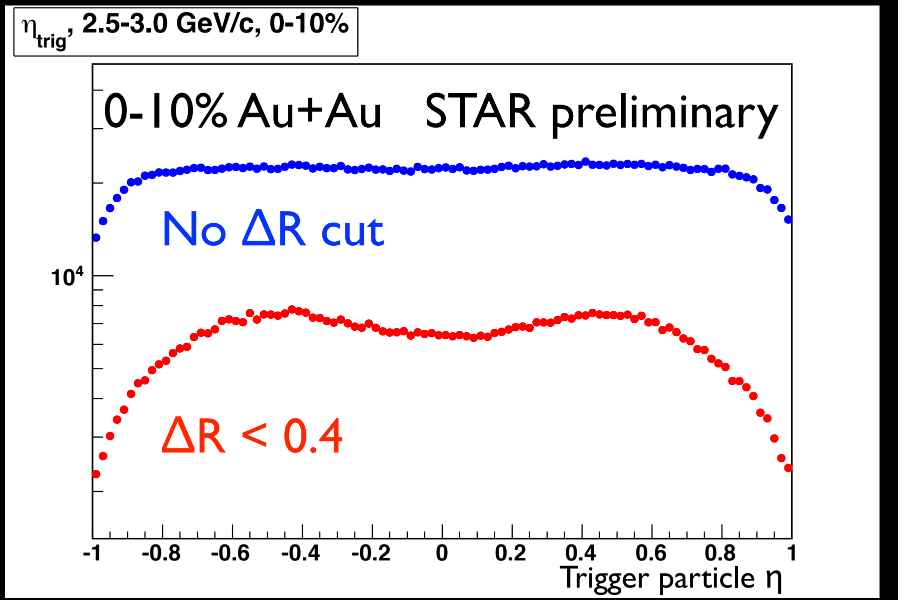
HT trigger requires > 5-6 GeV in one EMC tower

- High Tower trigger energy mostly neutral
- HT trigger, + using high p_T charged tracks, accesses hard jets

Additional considerations

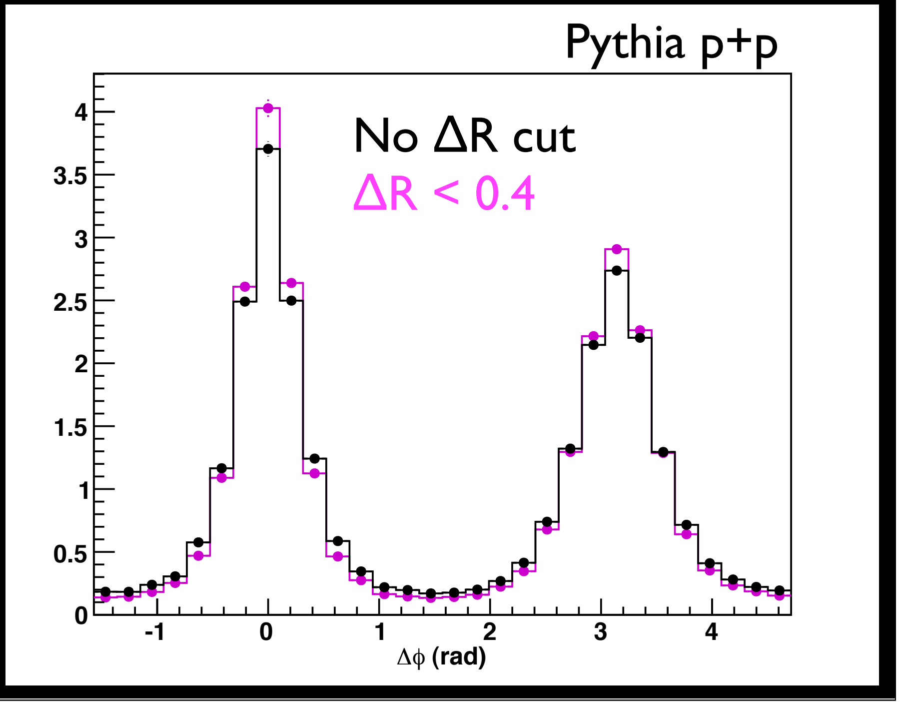
Event selection

Reject events with no reconstructed jets, even for inclusive trigger particles. Same events sampled for ΔR vs. inclusive correlations.



Acceptance effect

Requiring full jet cone in STAR η acceptance increases near-side assoc. yield. Thus some enhancement occurs even with no background. (Corrections are possible)



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h_{jet}-h in HT Au+Au, p+p

Blue: Event contains a 10+ GeV jet, but no ΔR cut

Red: Same events, with ΔR<0.4

Same v_2 currently used for both as initial estimation

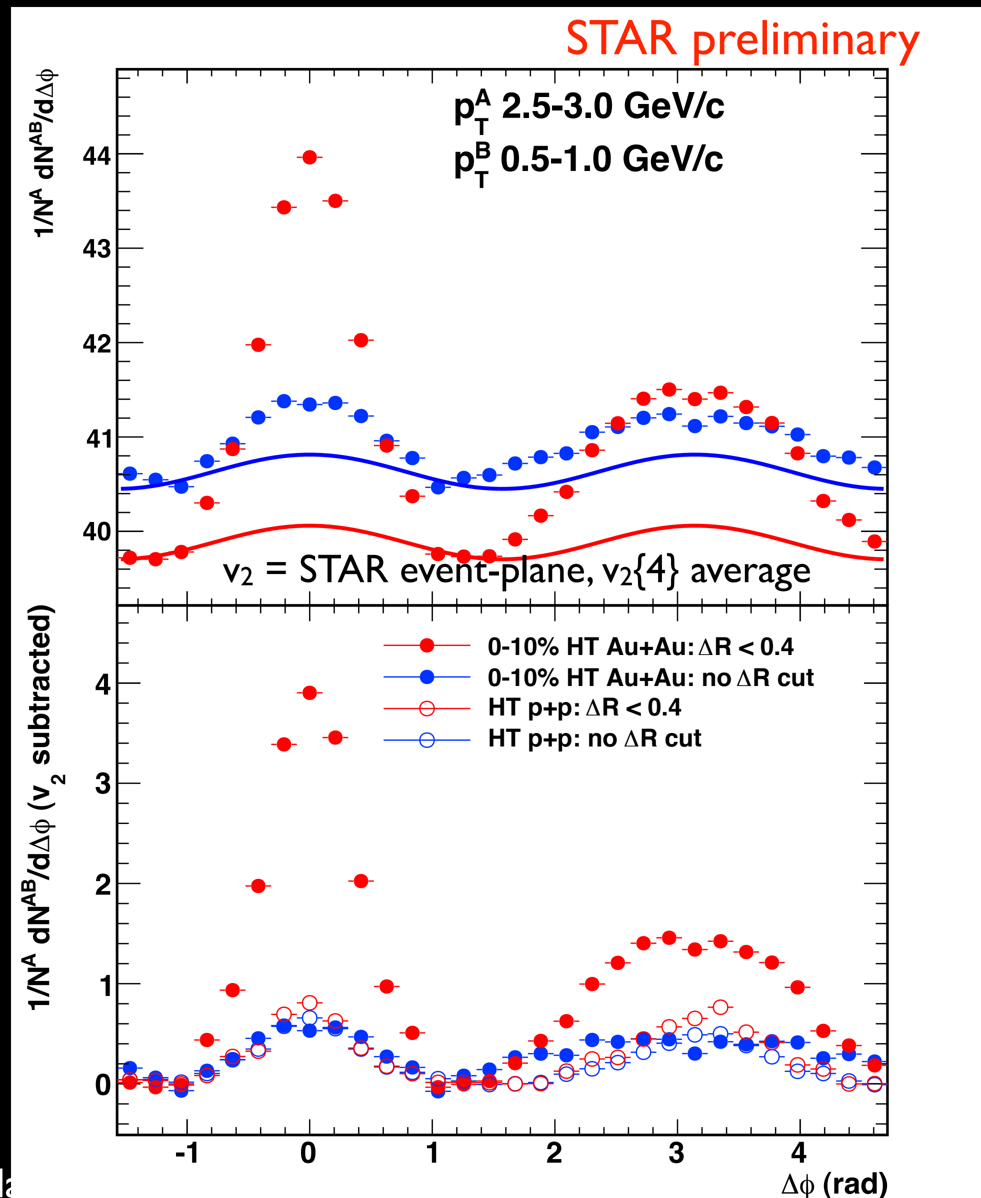
ZYAM applied for consistency with STAR h-h analyses

How to interpret enhanced correlation?

- sampling higher Q^2 events

- removing non-jet background?

Au+Au yields larger than p+p at low $p_T{}^B$...qualitatively consistent with measured h-h I_{AA}.



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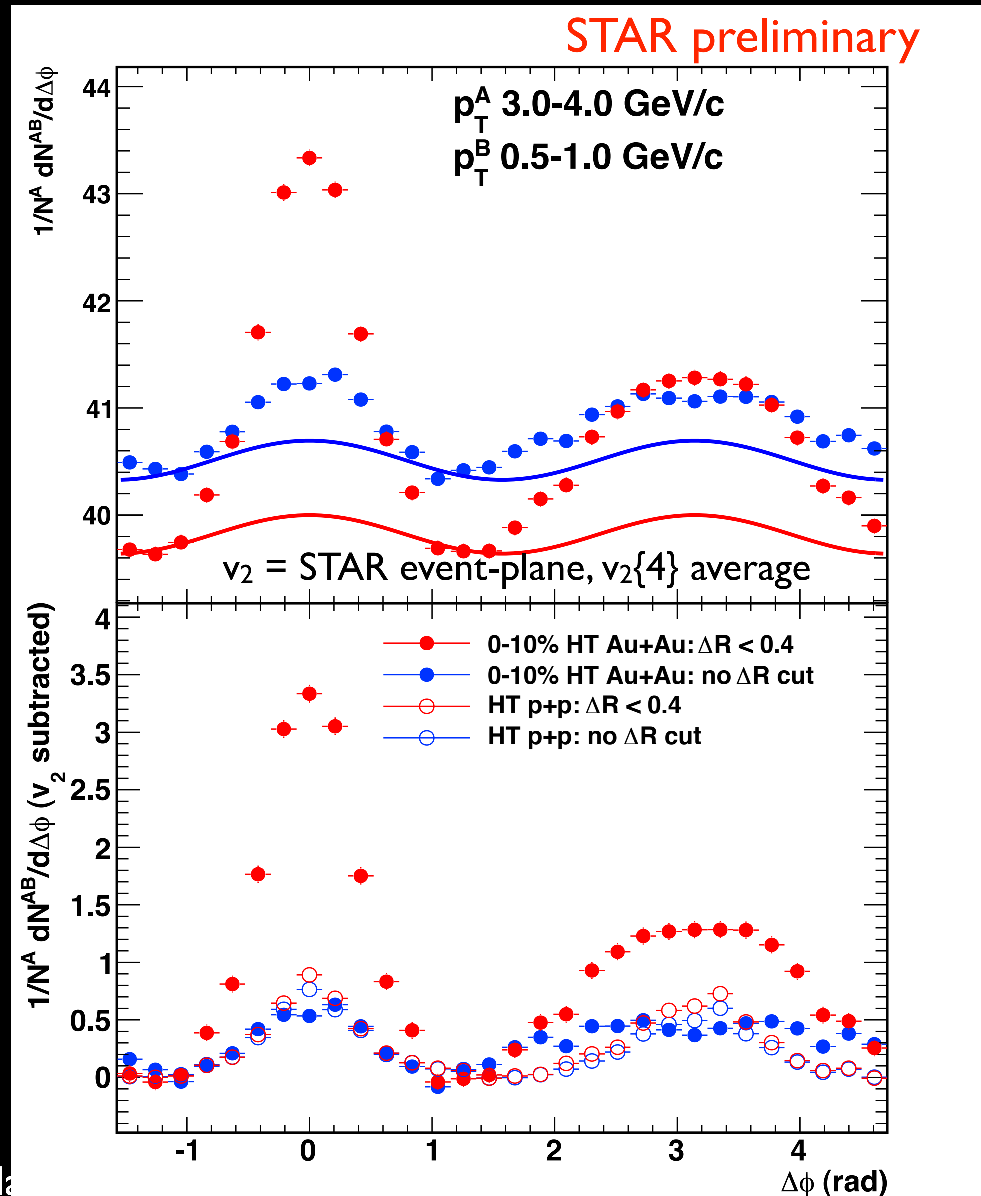

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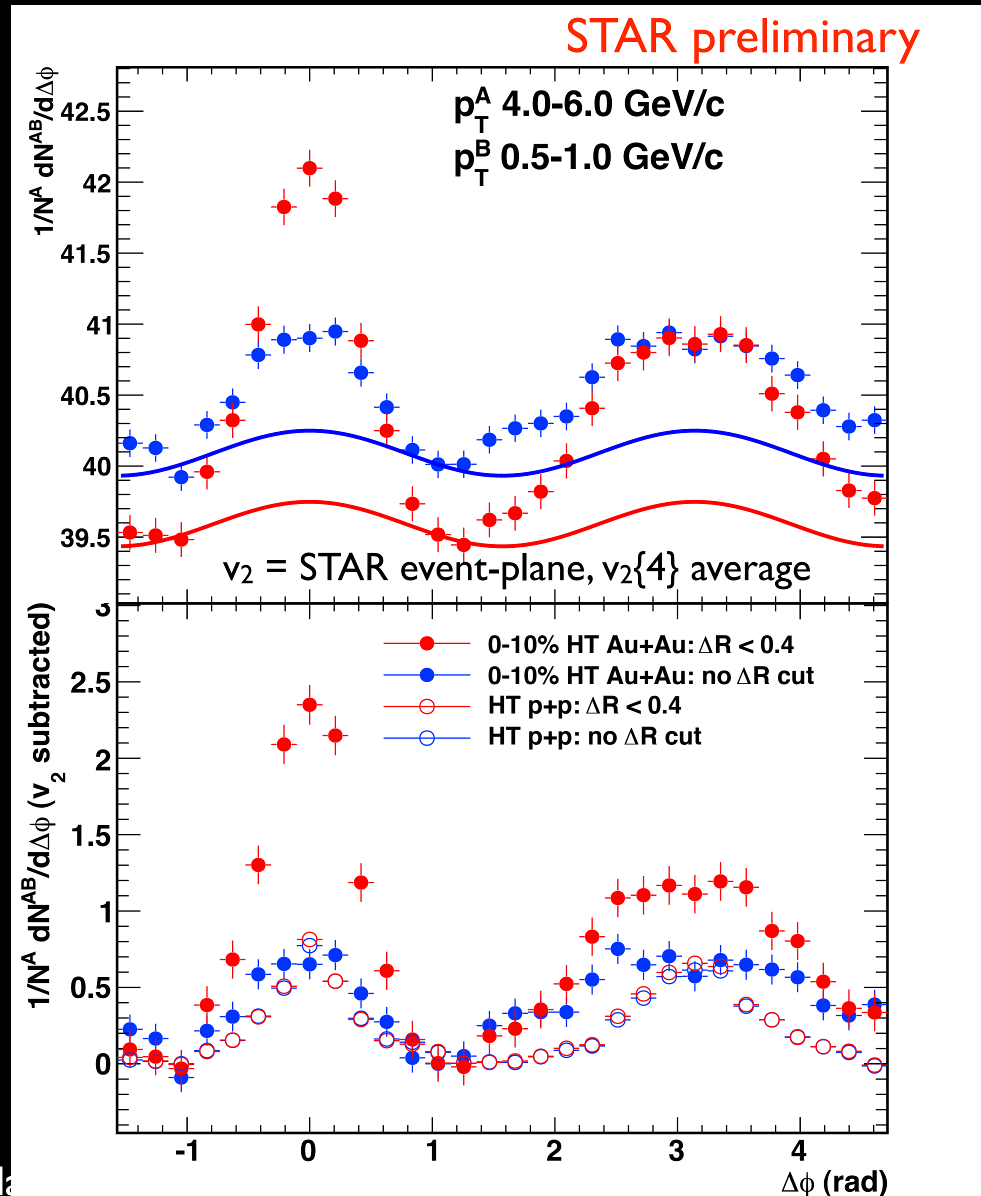
How to interpret enhanced correlation?

- sampling higher Q^2 events

- removing non-jet background?

Au+Au yields larger than p+p at low $p_T{}^B$...qualitatively consistent with measured h-h I_{AA}.



h_{jet}-h in HT Au+Au, p+p

Blue: Event contains a 10+ GeV jet, but no ΔR cut

Red: Same events, with ΔR<0.4

Same v_2 currently used for both as initial estimation

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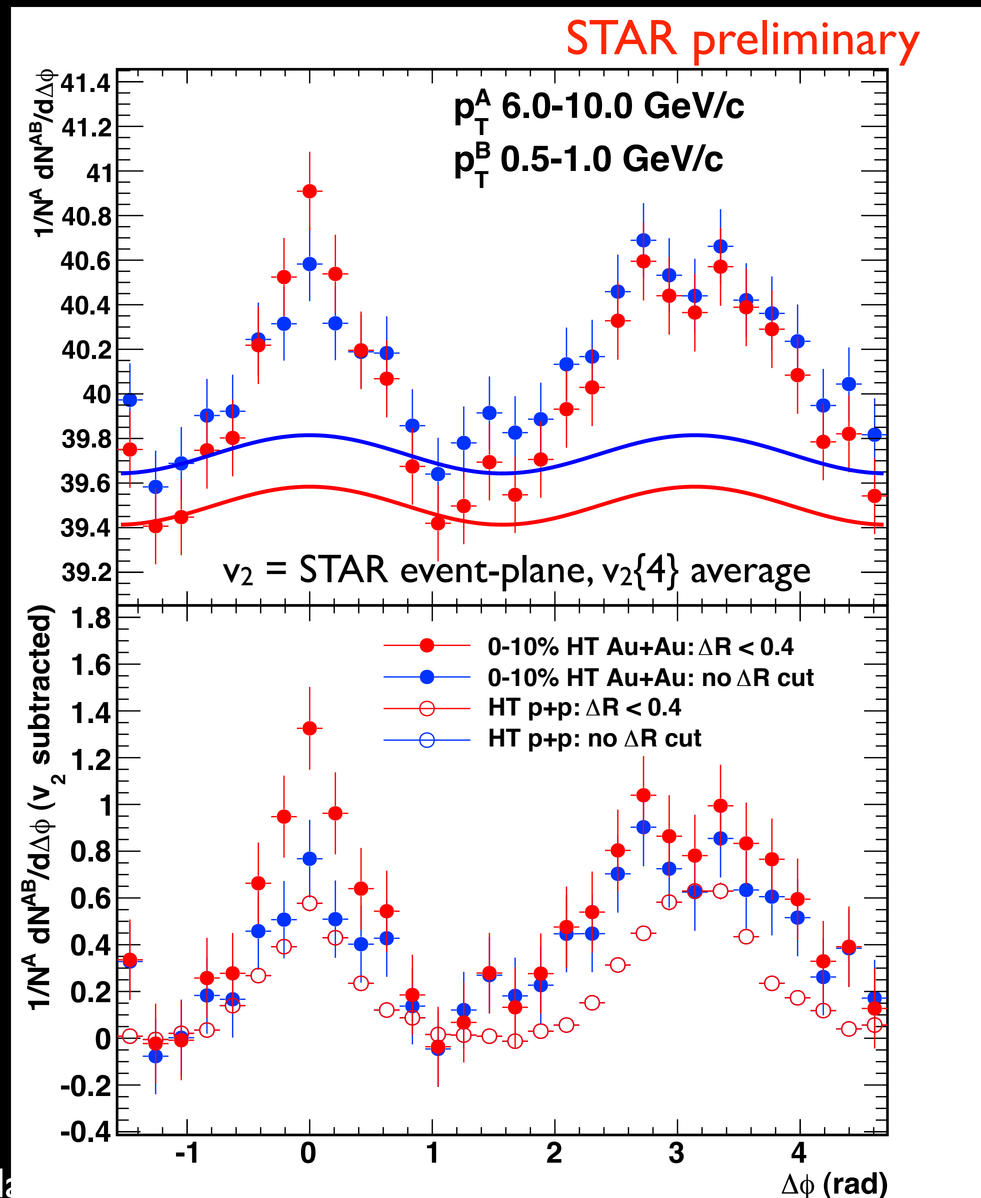


Understanding the results....

What, precisely, causes the peak enhancement in h_{jet}-h correlations?

- Selection of more energetic partons?
- Reduction of uncorrelated background?
- If both, what is the relative contribution of each effect?

What is the true v_2 of trigger hadrons inside jet cones?

These are topics of active investigation...many ideas to study effects more differentially.

Stay tuned!

Conclusions

Triggering on more jet-like particles

- strongly enhances the correlation strength

- diminishes evidence of 2-peak features, rather than enhancing them.

- accesses harder events (esp. in triggered data) and shouldn't be directly compared with MB h-h

- much of the "background" removed in h_{jet}-h may very well be from un-associated jet production...requires careful interpretation.

Backups

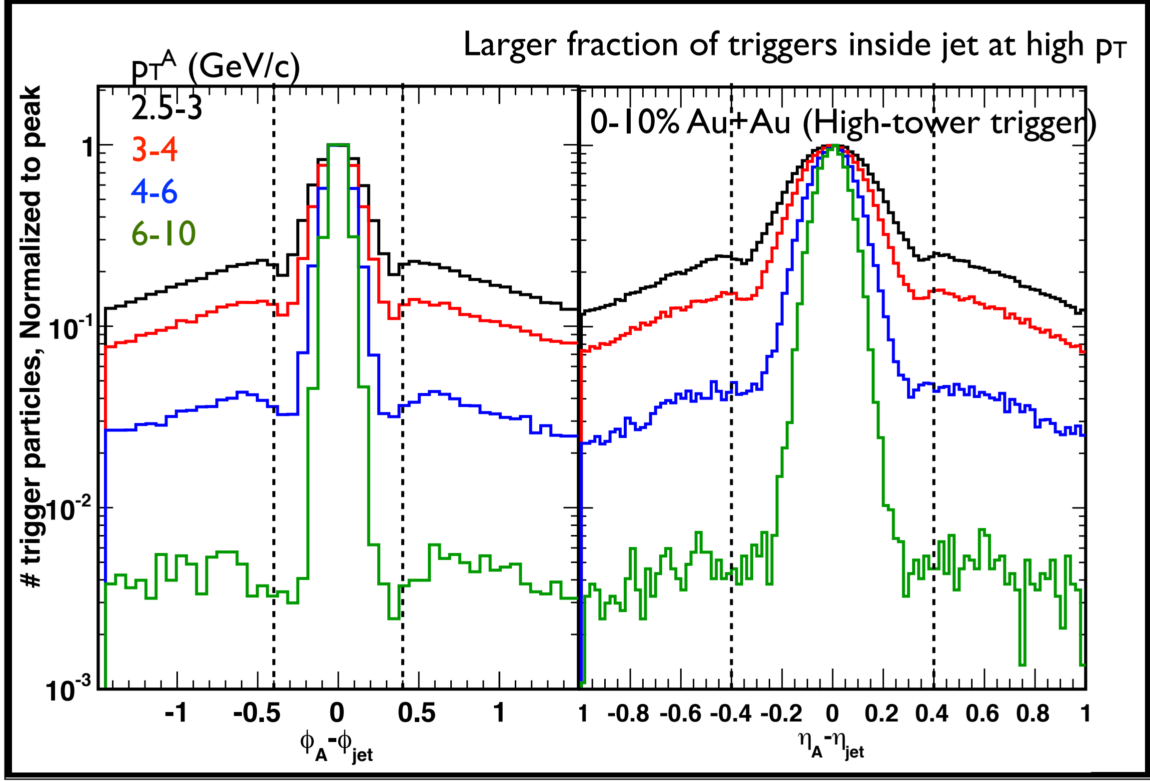
h_{jet}-h correlations

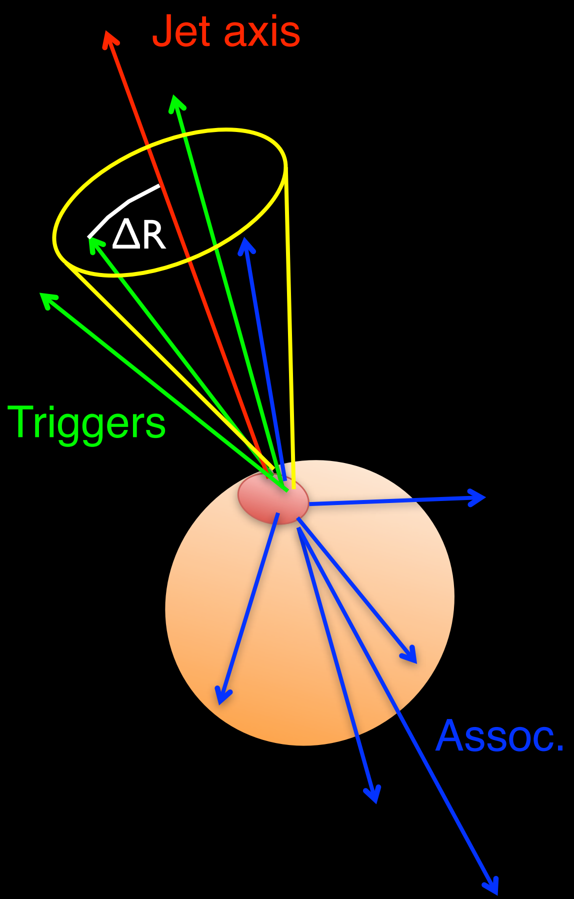
What if we require the trigger particle to be part of a reconstructed jet?

In each event, measure angular distance ΔR to nearest jet for each trigger particle *A*:

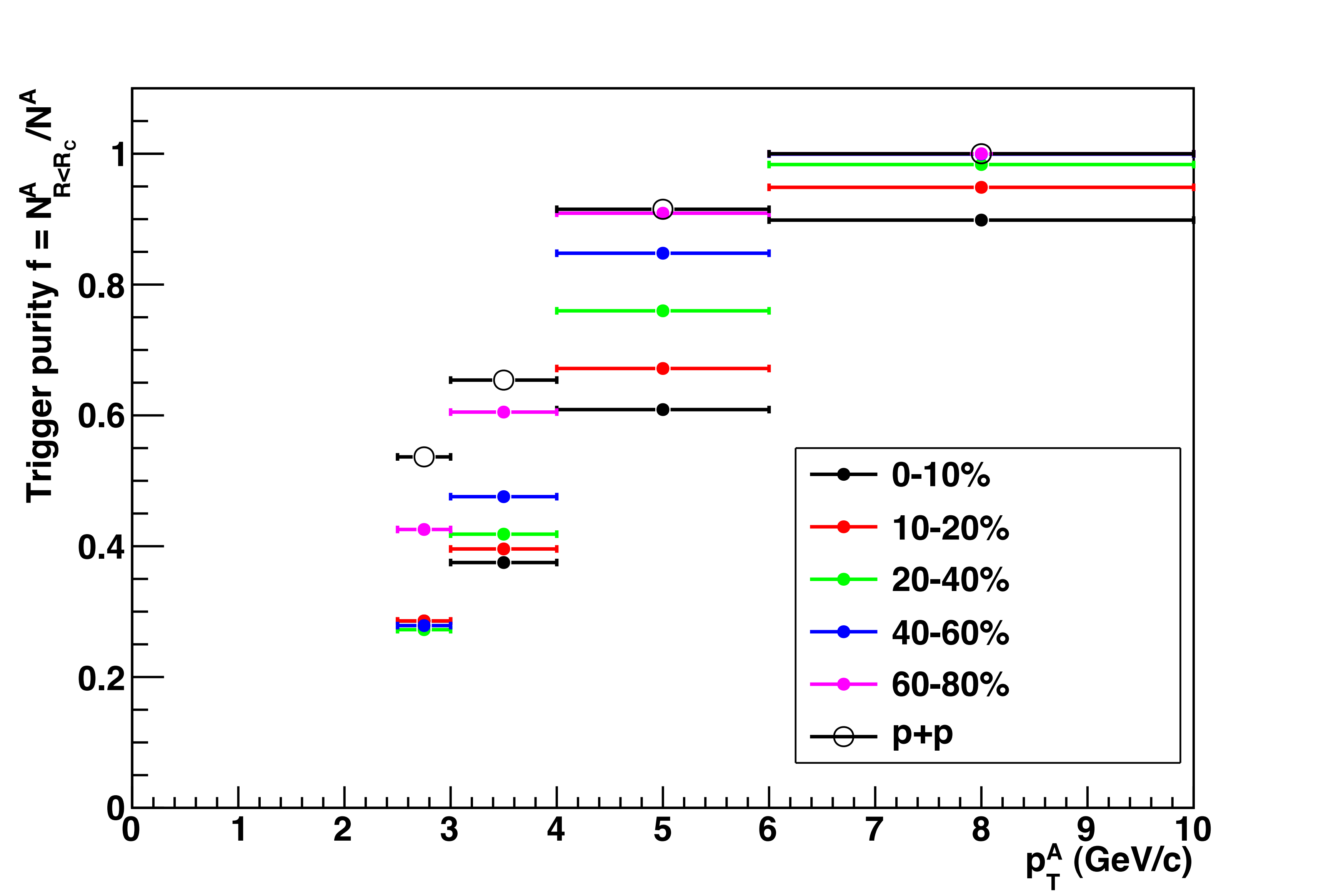
$$\Delta R \equiv \sqrt{(\phi_{jet} - \phi_A)^2 + (\eta_{jet} - \eta_A)^2}$$

Require $\Delta R < R_C$ for h_{jet}-h.

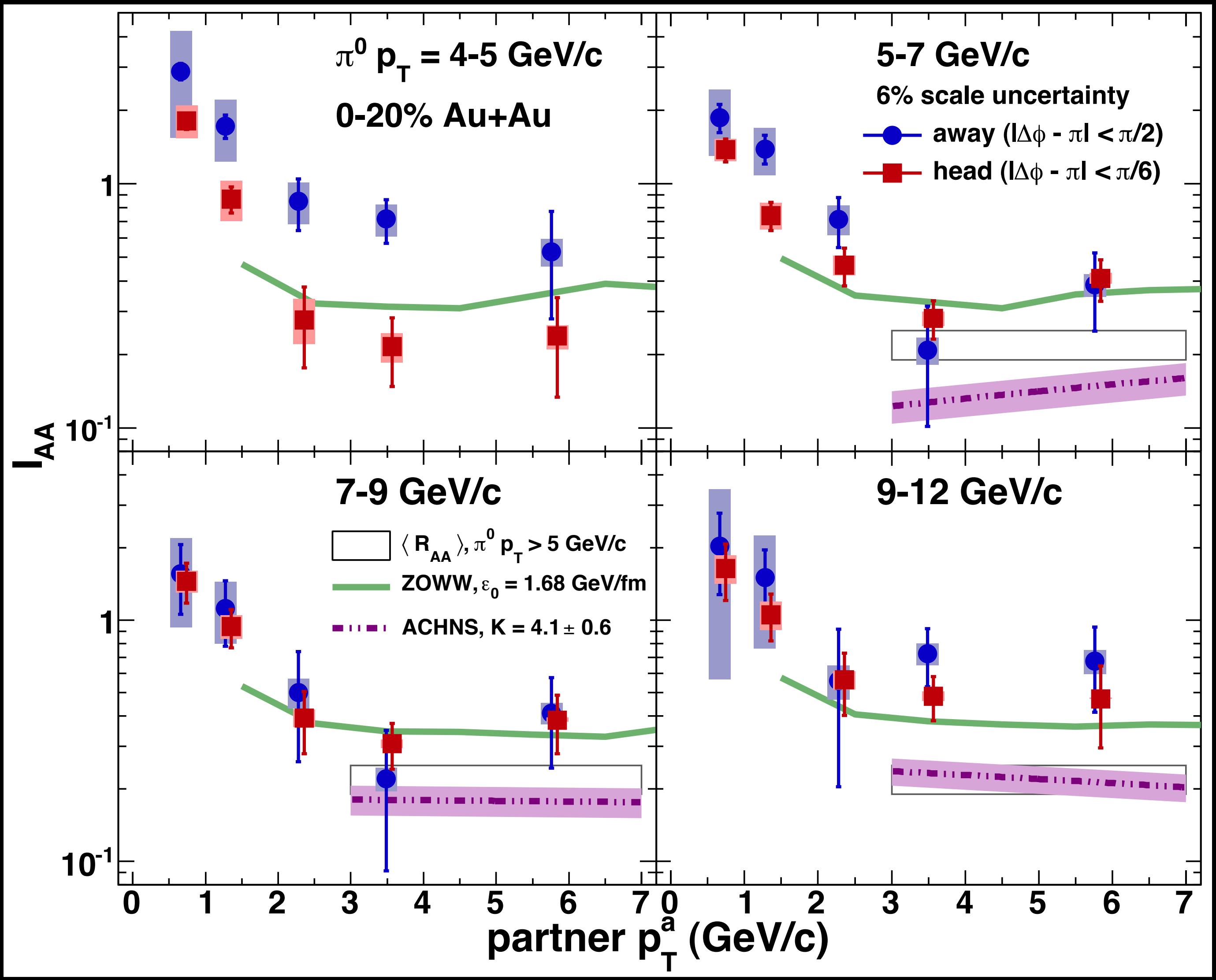




Trigger purity fraction in HT data



pi0-h IAA



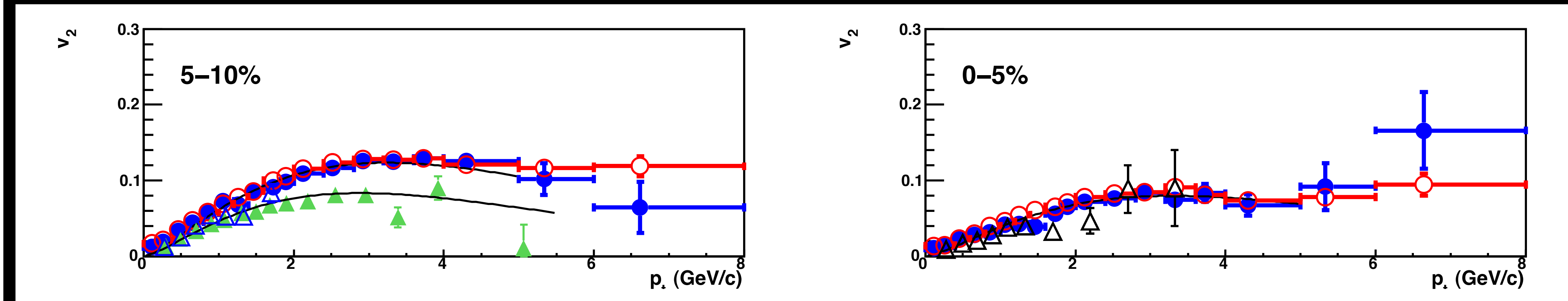
IAA > RAA, and rises with trigger pt

reflects hardening of spectra

Enhancement at low pTB

v2 input

Pair v2 from fit to STAR data



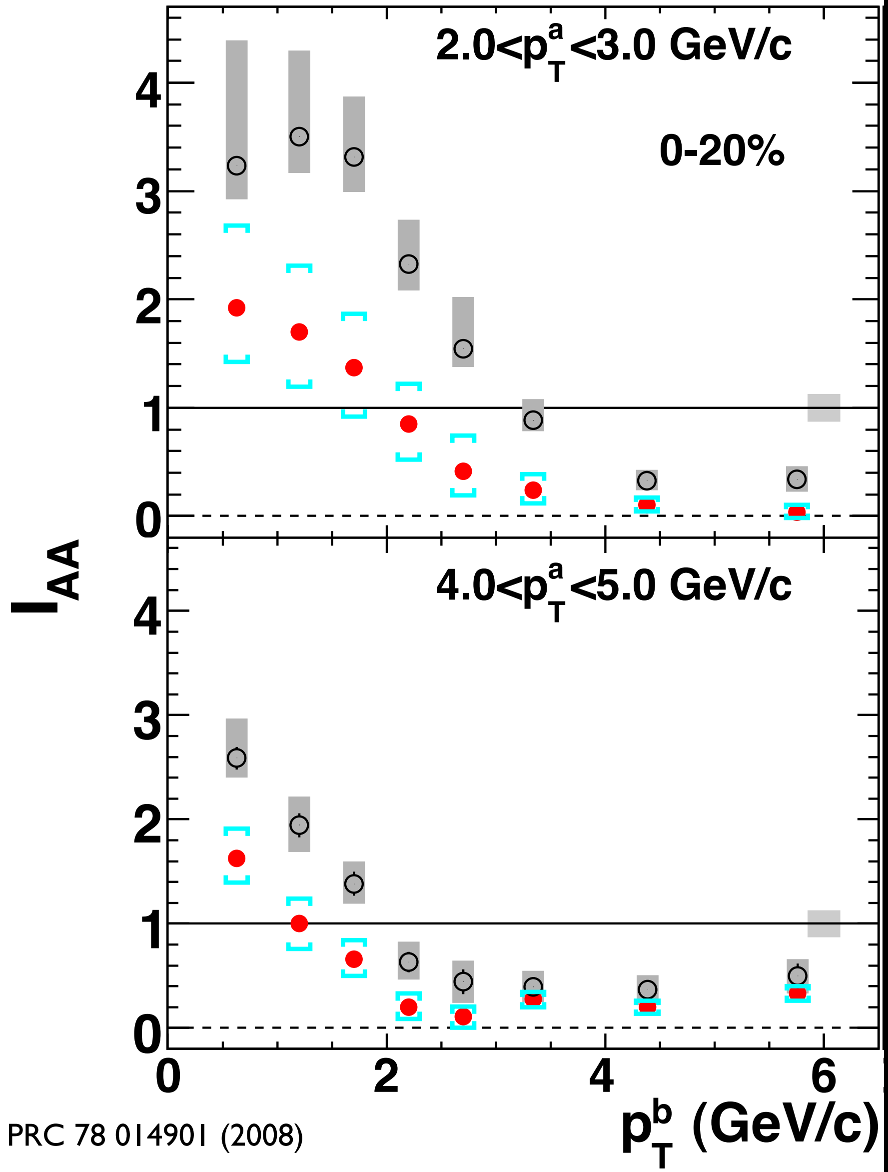
Mean of event-plane and v2{4} measurements used

Assume (as usual) v2AB = v2A*v2B

Important assumption: v2(DR < 0.4) = inclusive v2

However: v2 uncertainty is reduced in DR < 0.4 sample when propagated to subtracted result (larger peak yields).

PHENIX h-h away-side I_{AA}



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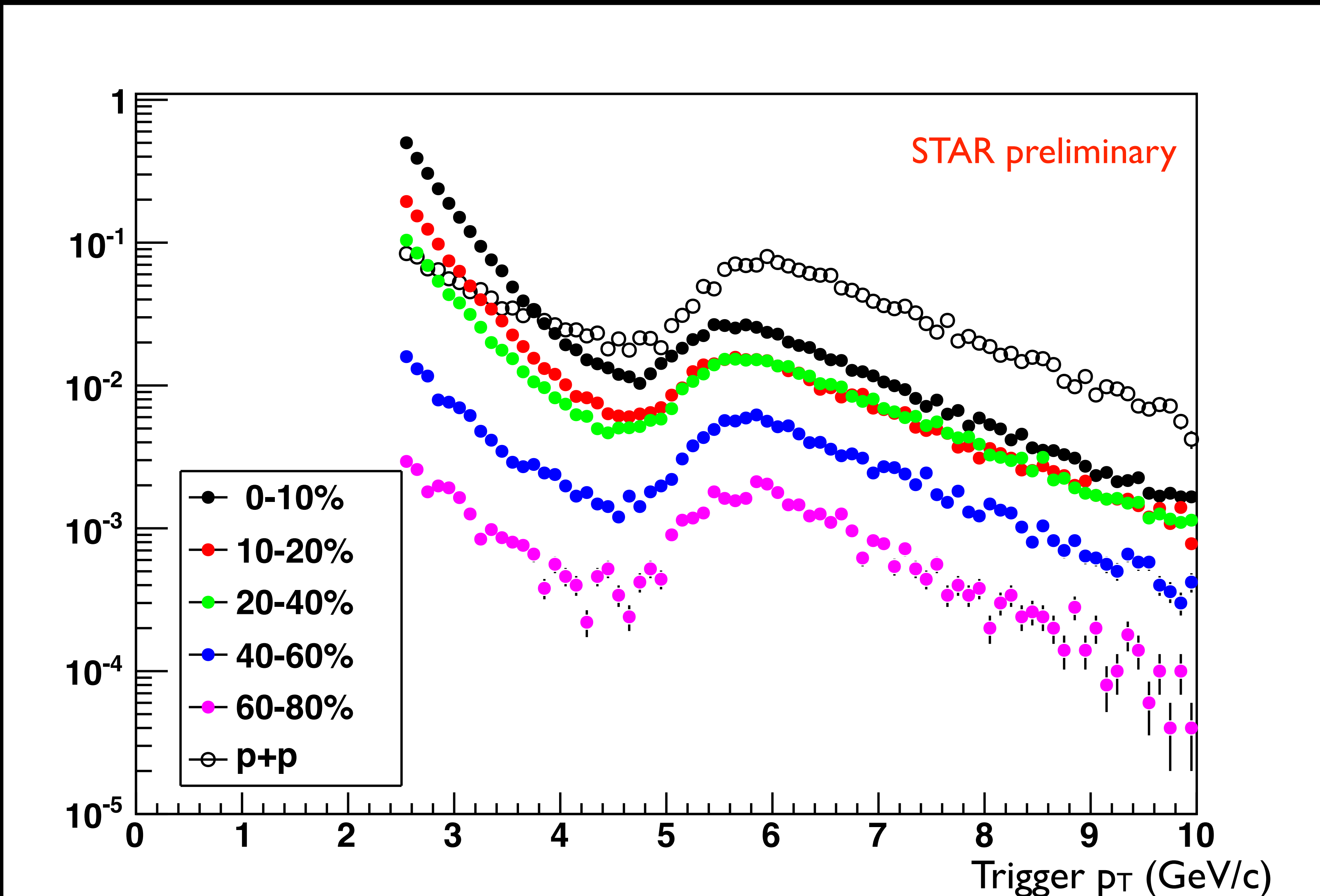
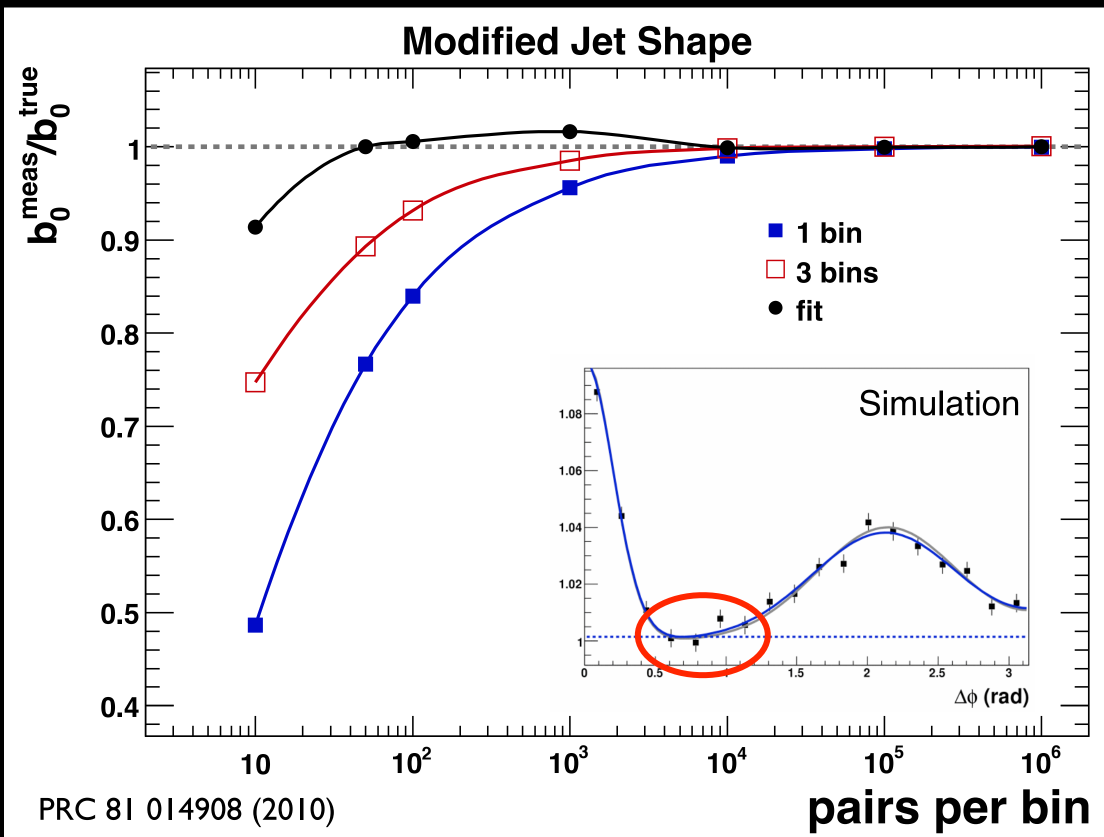
dN/dp$_{Ttrig}$, 2007 HT Au+Au data



Zero Yield At Minimum



ZYAM continues to be used in correlation analyses

Fluctuations at ZYAM point can underestimate background

Absolute background normalization avoids such biases....

However, any known bkg. normalization methods use 2-source factorization, requiring some bkg. shape assumption.