Understanding jet shapes with π^0-$h^\pm$ correlations

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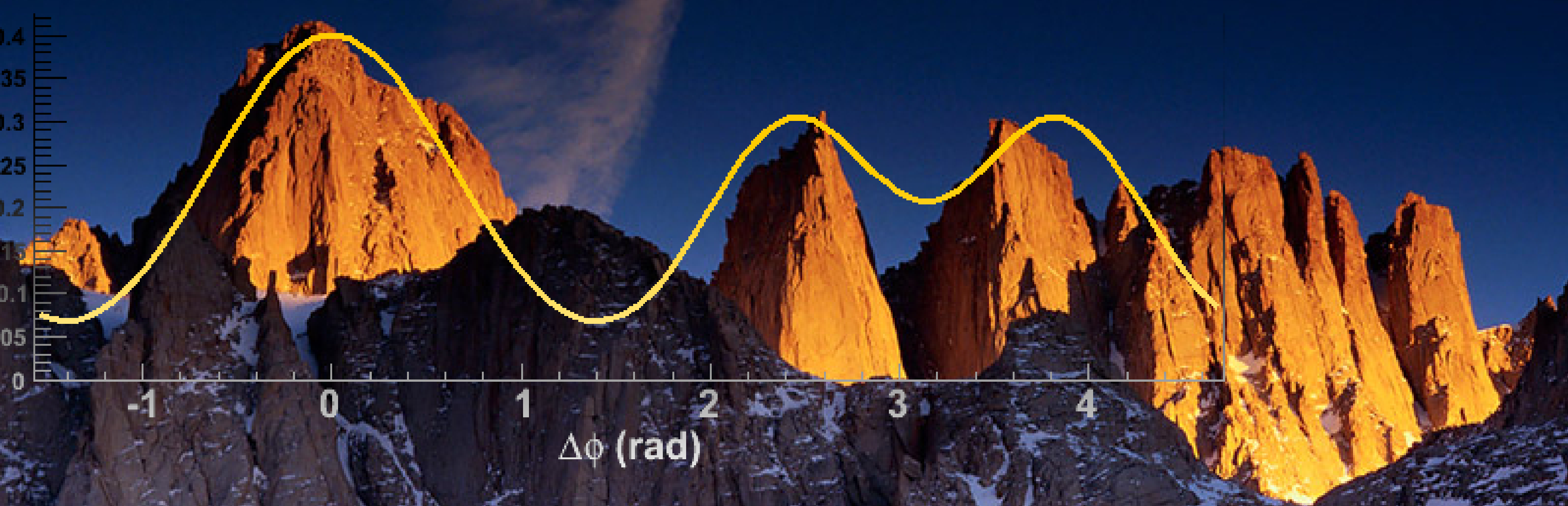
for the
PHENIX collaboration
Hot Quarks 2008



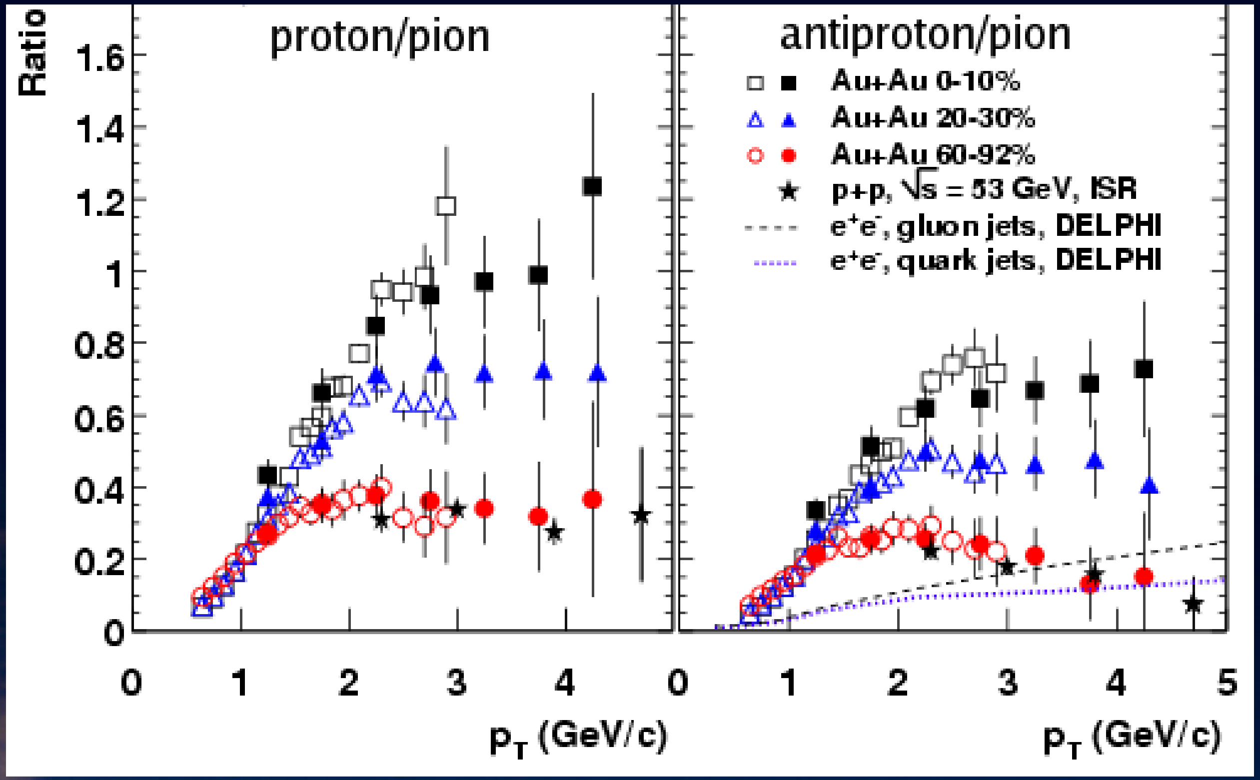
Questions addressed (raised?) by 2-particle correlations:

- *Partons lose energy in the medium...where does it go?*
- *Is there a mach cone at low p_T? If so, what happens to it at higher p_T?*
- *Are observed high-energy partons passing through the bulk of the medium, or just being emitted near the surface?*

Motivation: why π^0-$h^\pm$?

To date, most jet correlations results have been $h^\pm$-$h^\pm$. But triggering on one kind of particle can simplify the picture.

At p_T ~ 2-5 GeV, unidentified $h^\pm$ triggers may be 50% baryons in central Au+Au!

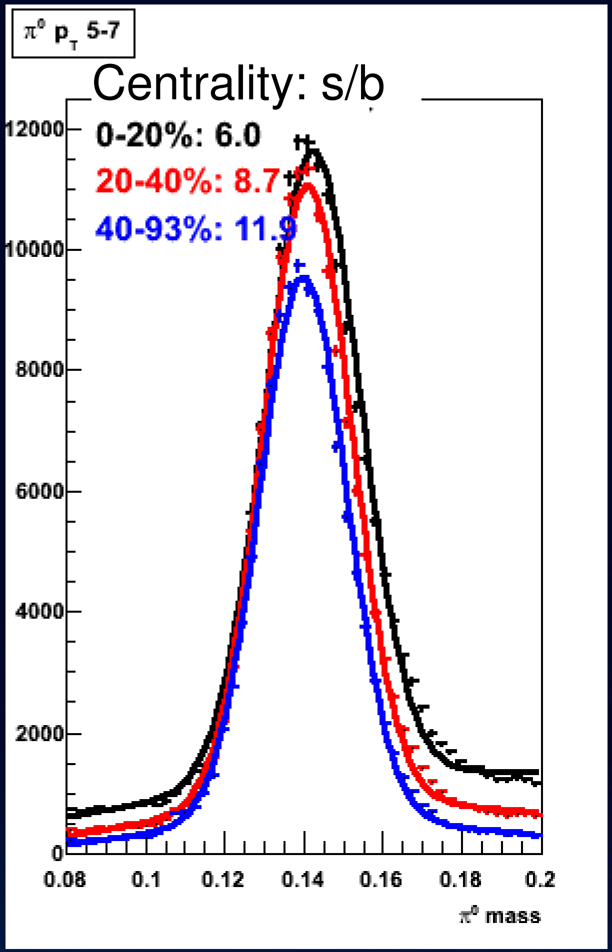


PRL 91, 172301 (2003)

Motivation: why π^0-$h^\pm$?

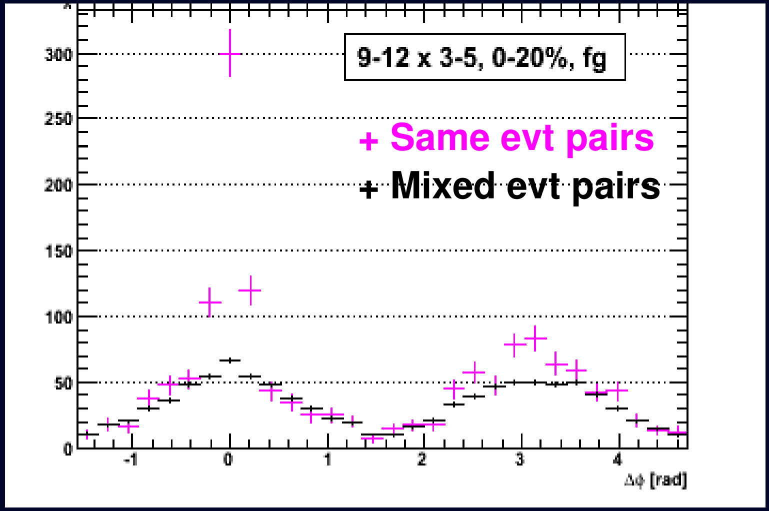
π^0s are a clean trigger at high p_T.

- 2γ reconstruction in PHENIX: kinematic constraints improve PID
- Combinatoric background drops with increasing p_T
- Not so with $h^\pm$
- Can make p_T / centrality-dependent E_γ^{min} cuts



Producing π^0-$h^{\pm}$ correlations

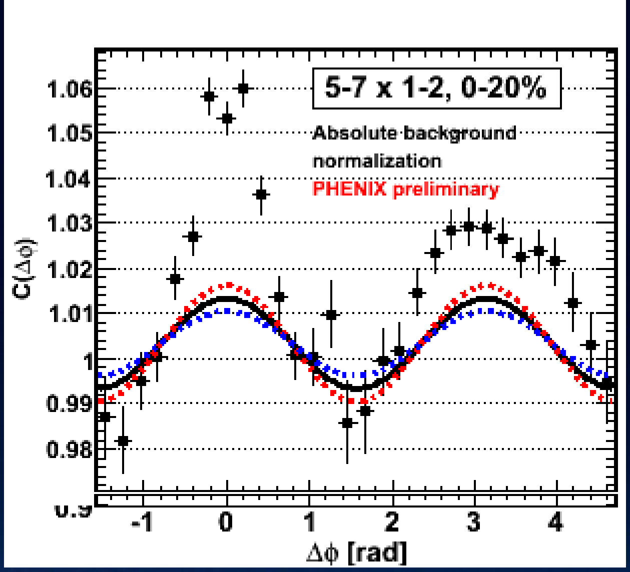
Imperfect detector acceptance.
Correct with event mixing:
generate $N^{AB}_{same}(\Delta\phi)$, $N^{AB}_{mixed}(\Delta\phi)$.



Correlation function:

$$C(\Delta\phi) = N^{AB}_{same}(\Delta\phi) / N^{AB}_{mixed}(\Delta\phi)$$
$$= Jet(\Delta\phi) + b_0(1+2v_2^{pair}\cos(2\Delta\phi))$$

$$C(\Delta\phi) \rightarrow Jet(\Delta\phi) \rightarrow Y(\Delta\phi)$$



Jet background

What is the background level?

- The number of flow/combinatoric pairs ($/2\pi$):

$$N_{BG}(\Delta\phi) = \int d\Delta\phi \, b_0(1 + 2v_2^{pair}\cos 2\Delta\phi) = 2\pi b_0$$

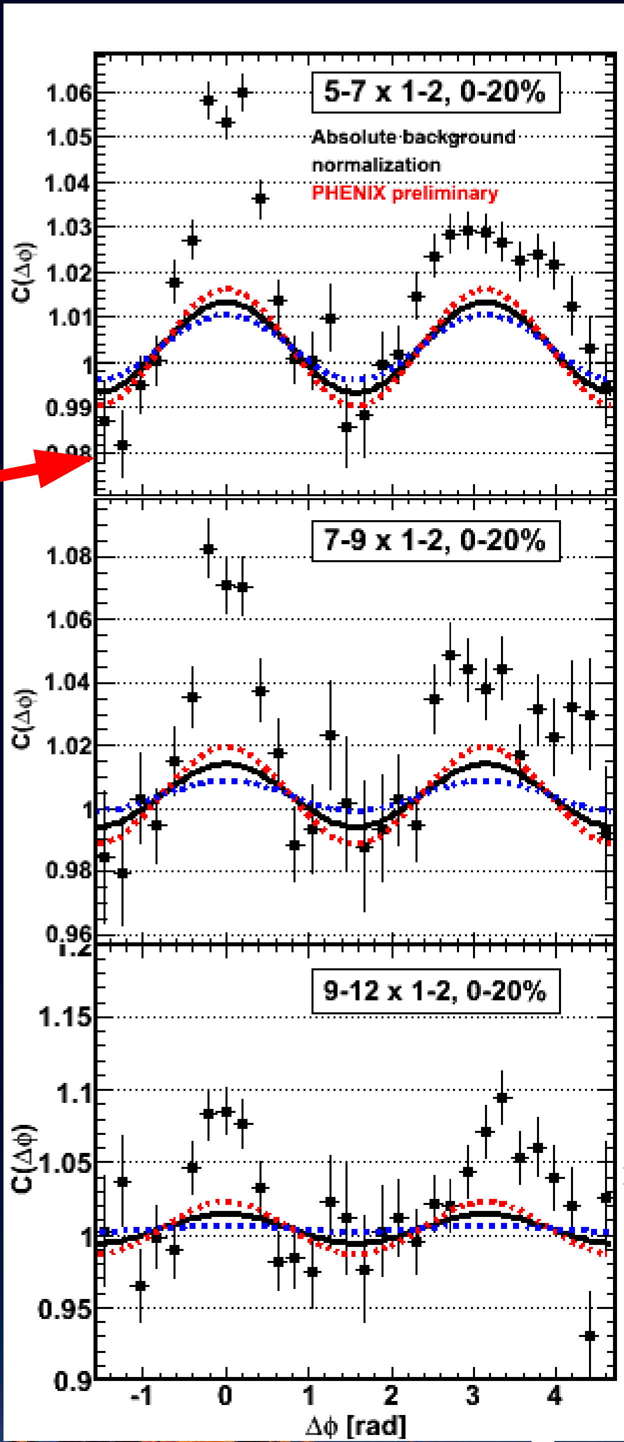
- But $N_{comb}^{AB} \neq N_{mixed}^{AB}$ because
  - Uncertainty in mapping N_{part} or N_{coll} to centrality
  - Must mix in finite centrality categories
  - Finite multiplicity resolution

So, how is the background determined?

Option 1: ZYAM

Zero Yield At *which* Minimum?
Could be:

- Min. = lowest data point
  - Bad procedure for low statistics
  - Can severely miscalculate jet yield
- Min. = “bottom” of fit curve
  - Relies on functional form
  - What about wide jets?
    - When tails merge, minimum is pushed up
    - Must choose to enforce ZYAM or not in this case



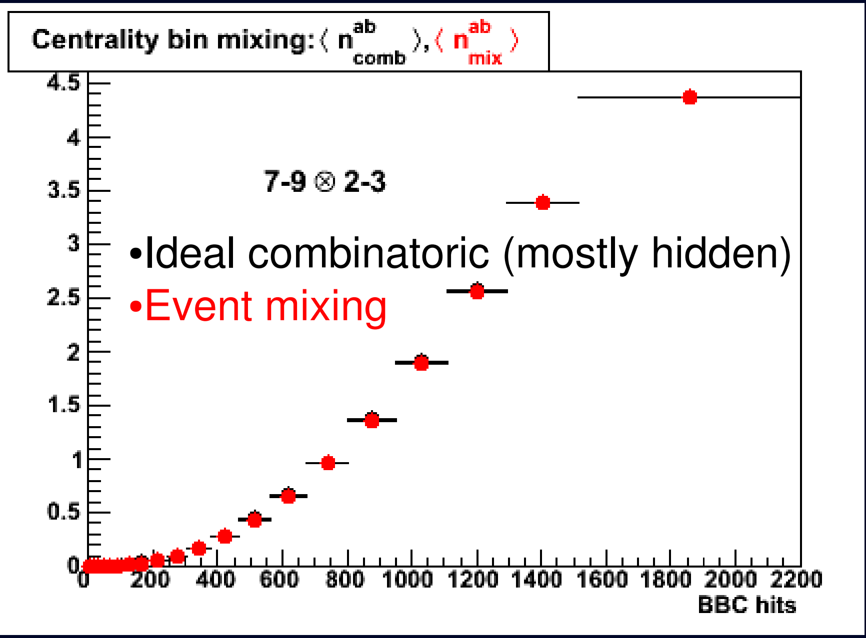
Option 2: Absolute Normalization

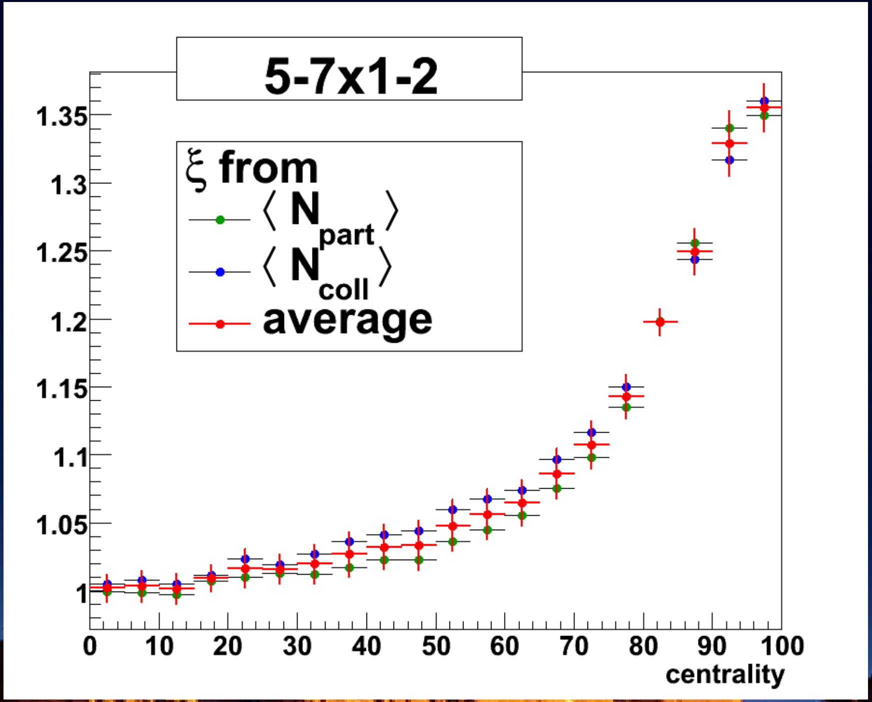
Background $\approx N^{AB}_{mixed}$,
but needs a correction:

$$\langle n^{AB}_{comb} \rangle = \langle n^A \rangle \langle n^B \rangle$$

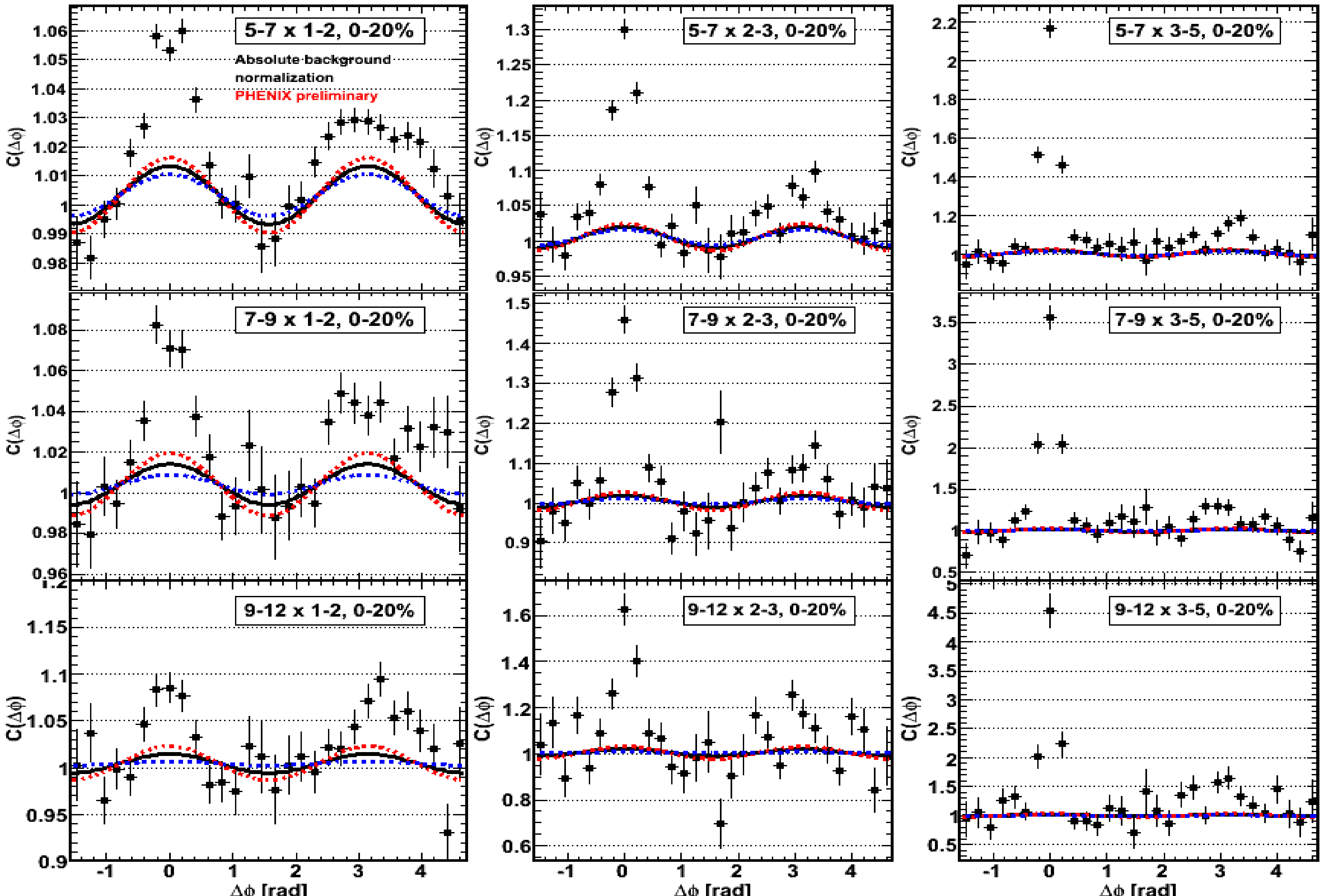
$$\xi = \frac{\langle n^{AB}_{comb} \rangle}{\langle n^{AB}_{mixed} \rangle}$$

Model ideal
&
mixed-event
pair rates. The ratio is the correction!

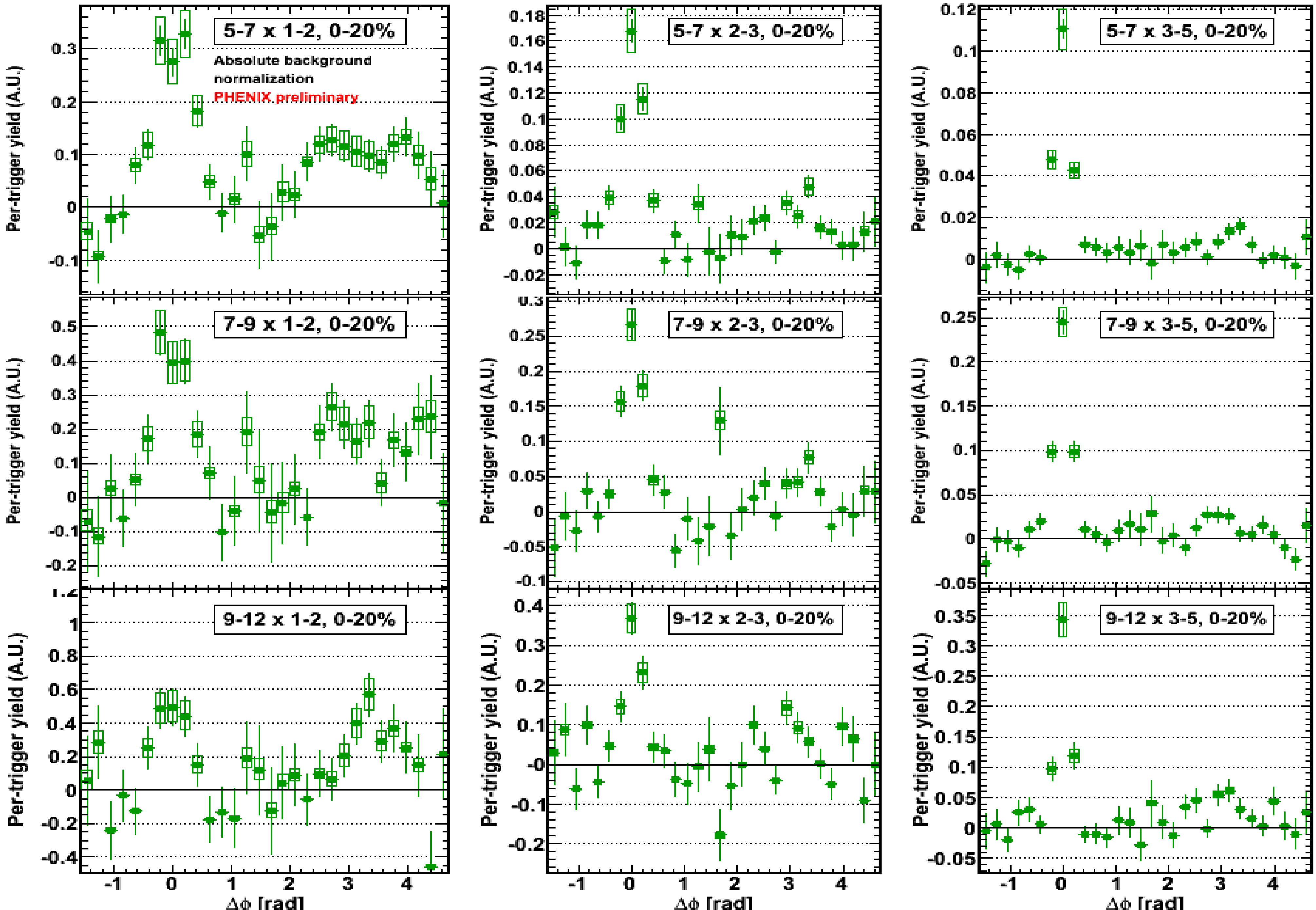




Au+Au Correlation functions



Au+Au Jet(Δϕ)


5-7 x 1-2, 0-20%
Absolute background
normalization
PHENIX preliminary
5-7 x 2-3, 0-20%
5-7 x 3-5, 0-20%
7-9 x 1-2, 0-20%
7-9 x 2-3, 0-20%
7-9 x 3-5, 0-20%
9-12 x 1-2, 0-20%
9-12 x 2-3, 0-20%
9-12 x 3-5, 0-20%
Per-trigger yield (A.U.)
Δϕ [rad]

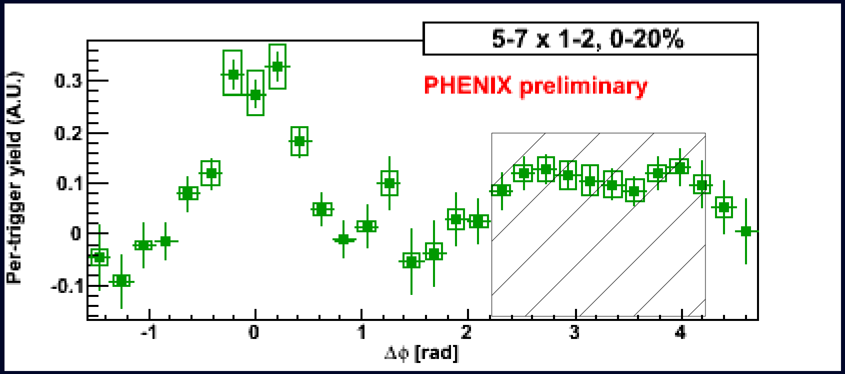
Quantitative peak shape studies

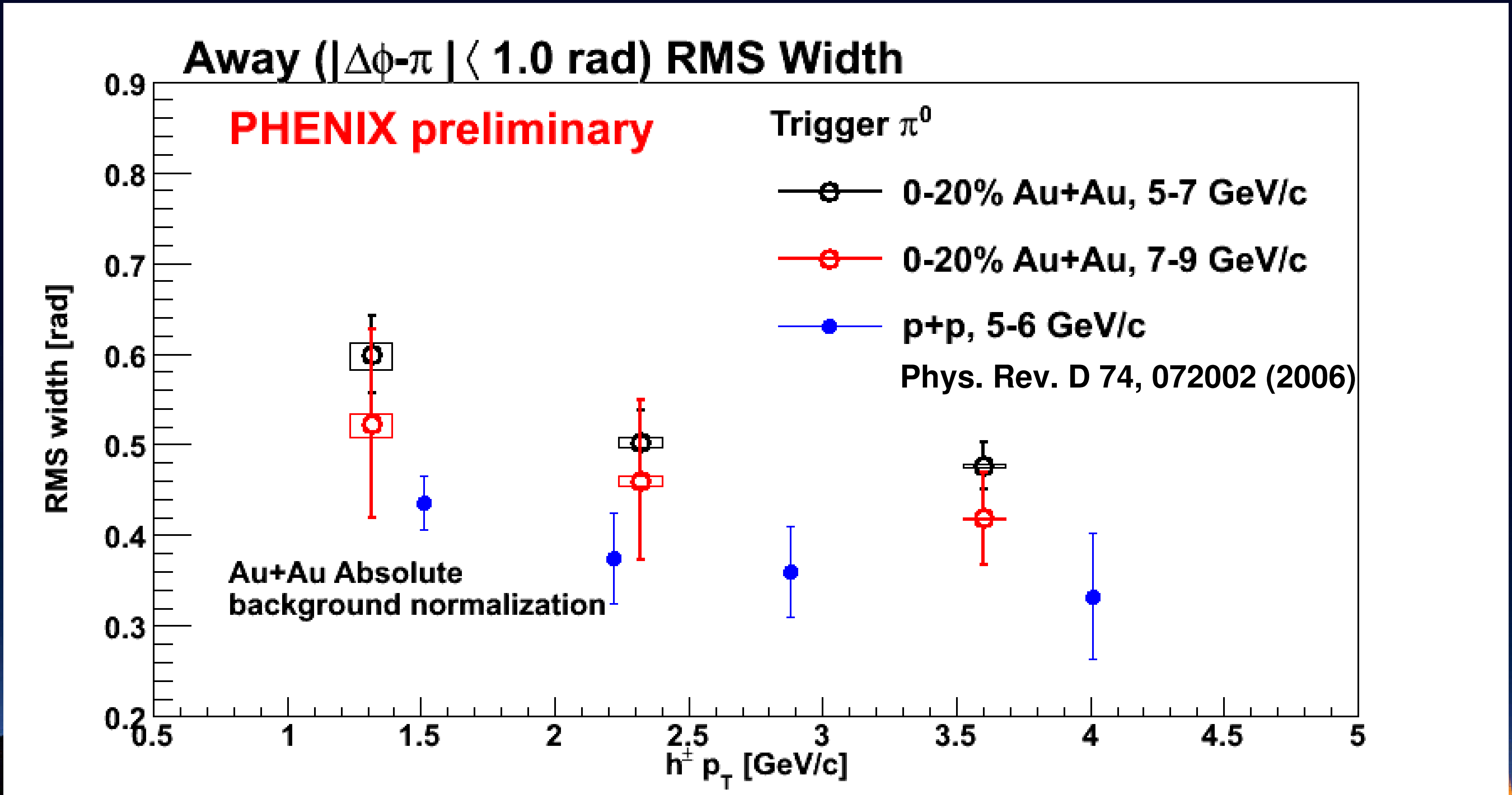
Focus on three derived jet shape observables:

1. RMS jet peak widths:
   - How do they evolve with p_T?
   - How do they compare to p+p?
2. Away-side “head” / “shoulder” jet yield ratio R_{HS}:
   - Can be a measure of concavity. Do we see this?
3. Split Gaussian 2-peak fit ansatz:
   - is the offset parameter D significant?

Away-side RMS width

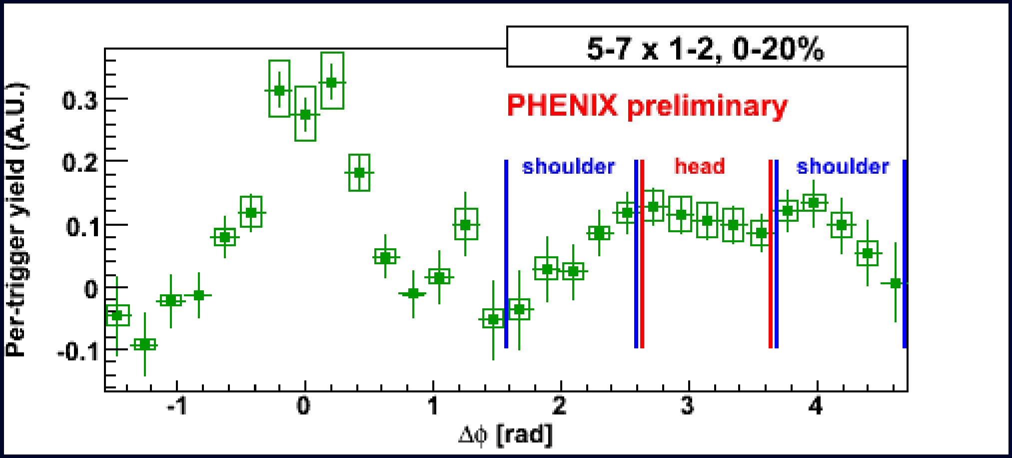
With increasing partner p_T,
peak becomes narrower,
but remains wider than in p+p.

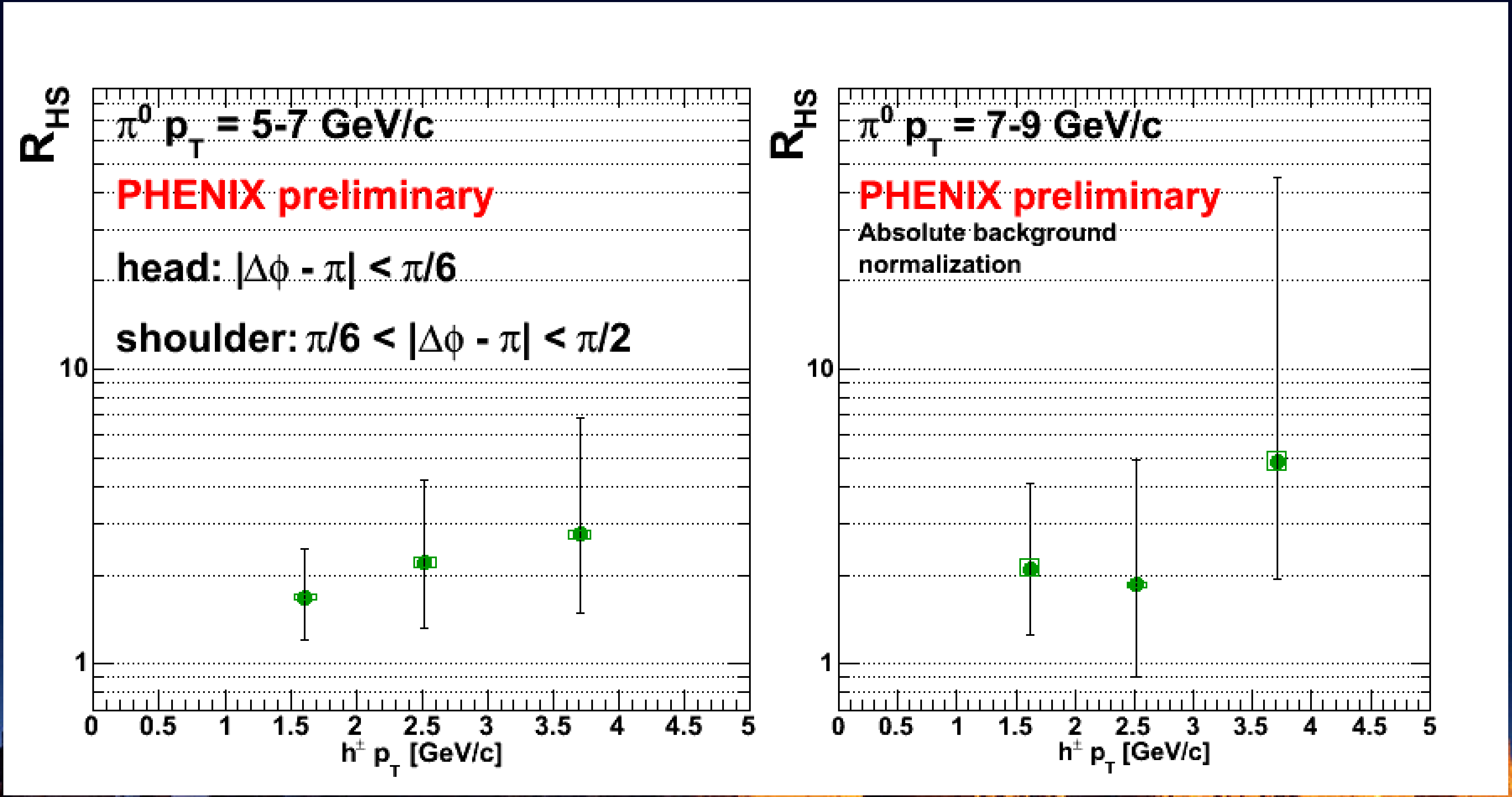




Peak shape: R_{HS}

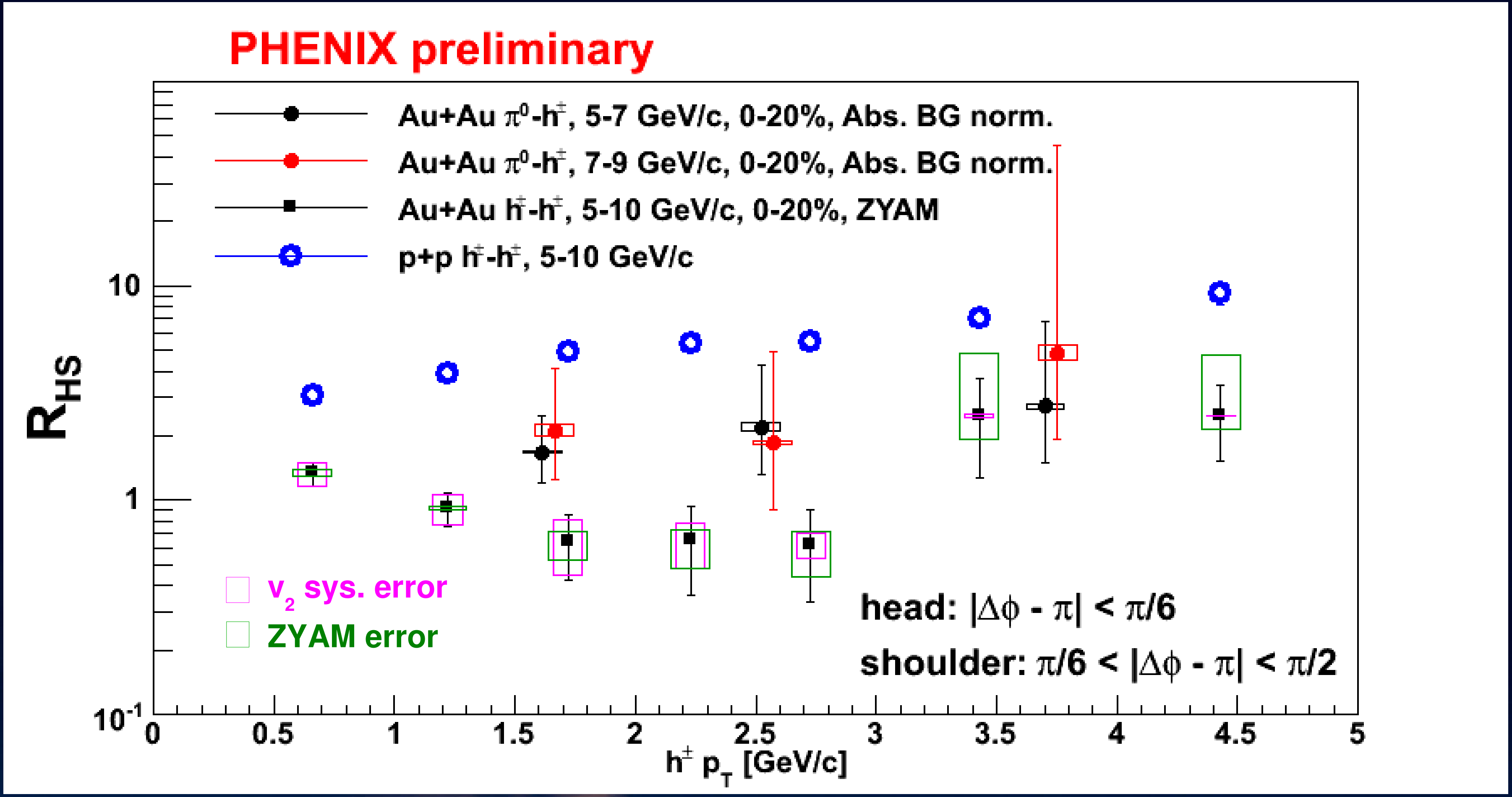
R_{HS} =
2x (integrated head)/
integrated shoulder
yields.





R_{HS}: π^0-$h^\pm$ vs. $h^\pm$-$h^\pm$

R_{HS} is higher in π^0-$h^\pm$ than in $h^\pm$-$h^\pm$ for comparable p_T ranges.

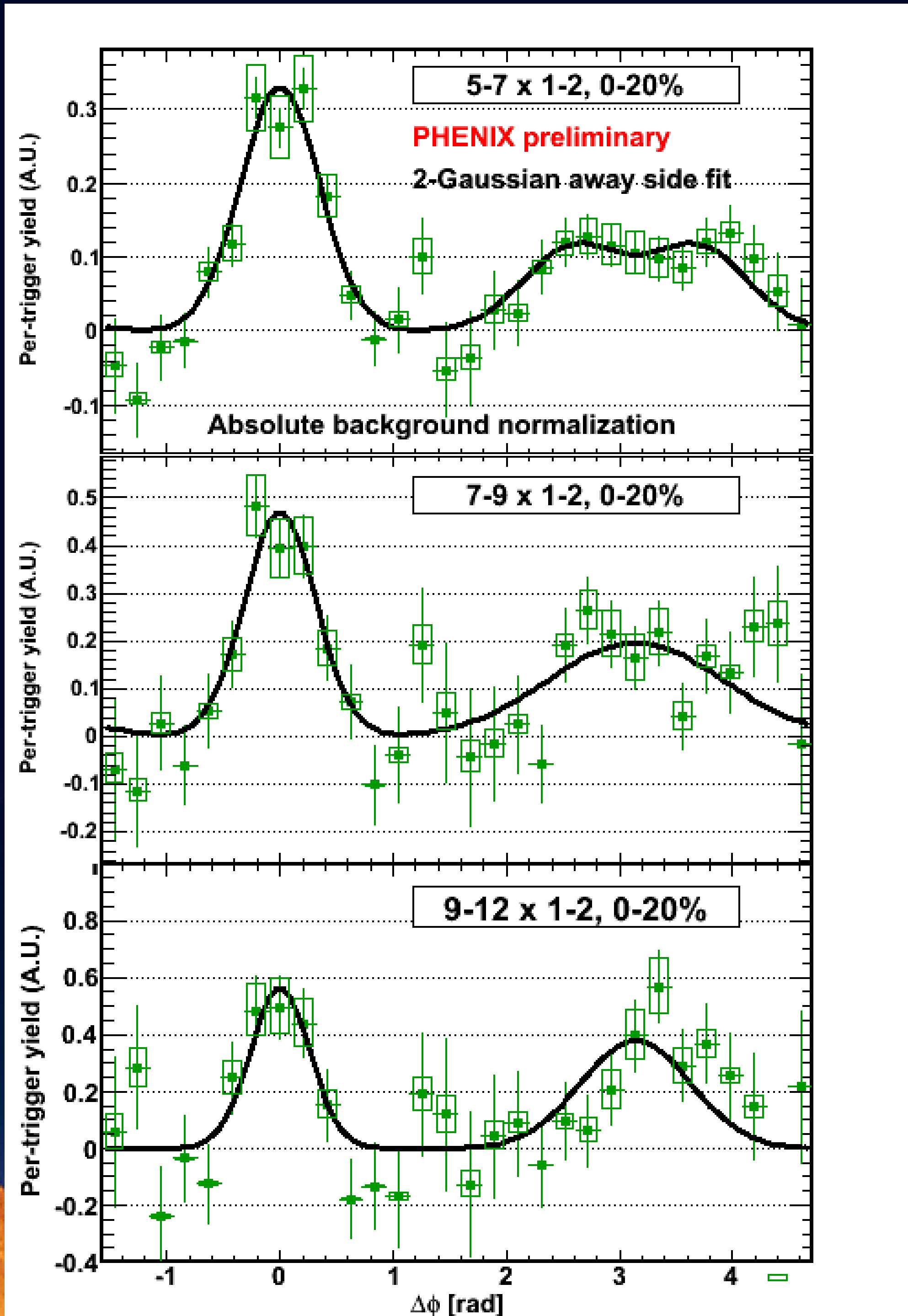


h-h data: Phys. Rev. C 78, 014901 (2008)

2-peak fit & the "D" parameter

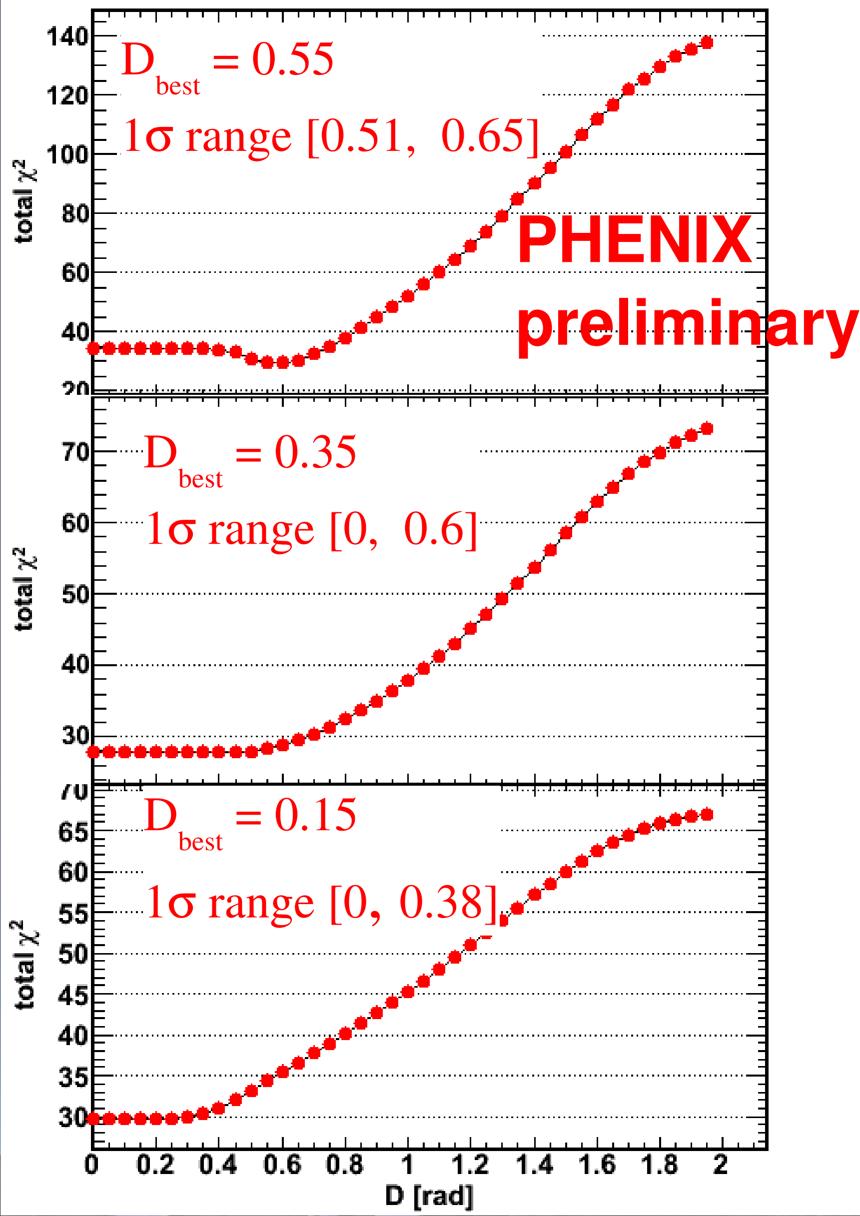
χ^2 minimization study:

- Step through fit parameter space to find best width, amplitude, and D offset from π.
- Store χ^2_{min} for each (σ, amplitude, D) and plot vs. D.
- The best fits are shown here.



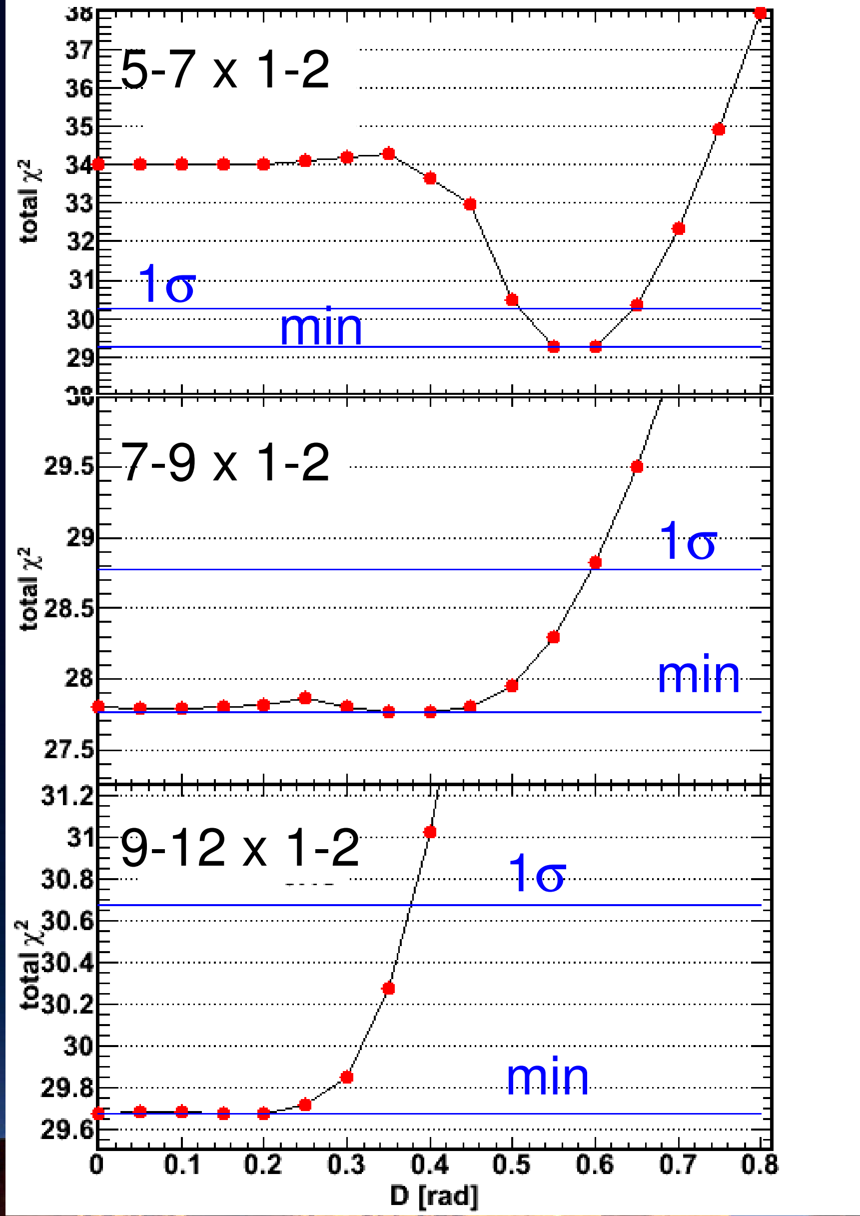
χ^2_{min} vs. D

Significant offset for $p_{T,trig}$ = 5-7 GeV, but D is consistent with 0 at 1σ for $p_{T,trig}$ = 7-9, 9-12



Zoom!

⇒

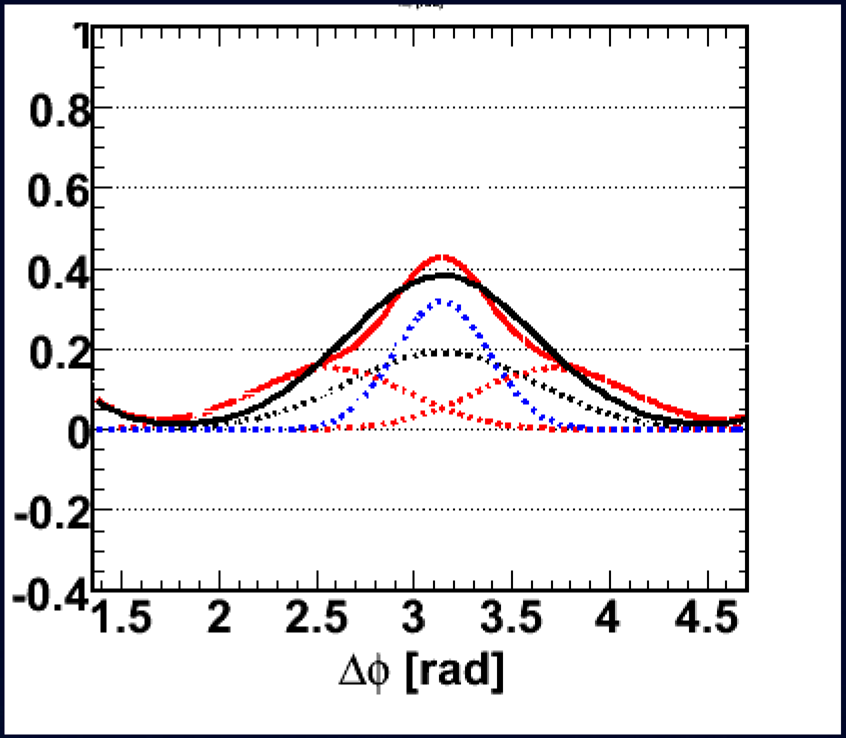


How many peaks?

At high p_T, the away side could be well-described by:

- a single Gaussian,
- 2 mostly merged Gaussians,
- 2 separated Gaussians + "punchthru" component.

Separating these scenarios will require more statistical tests.



Summary

Good progress...

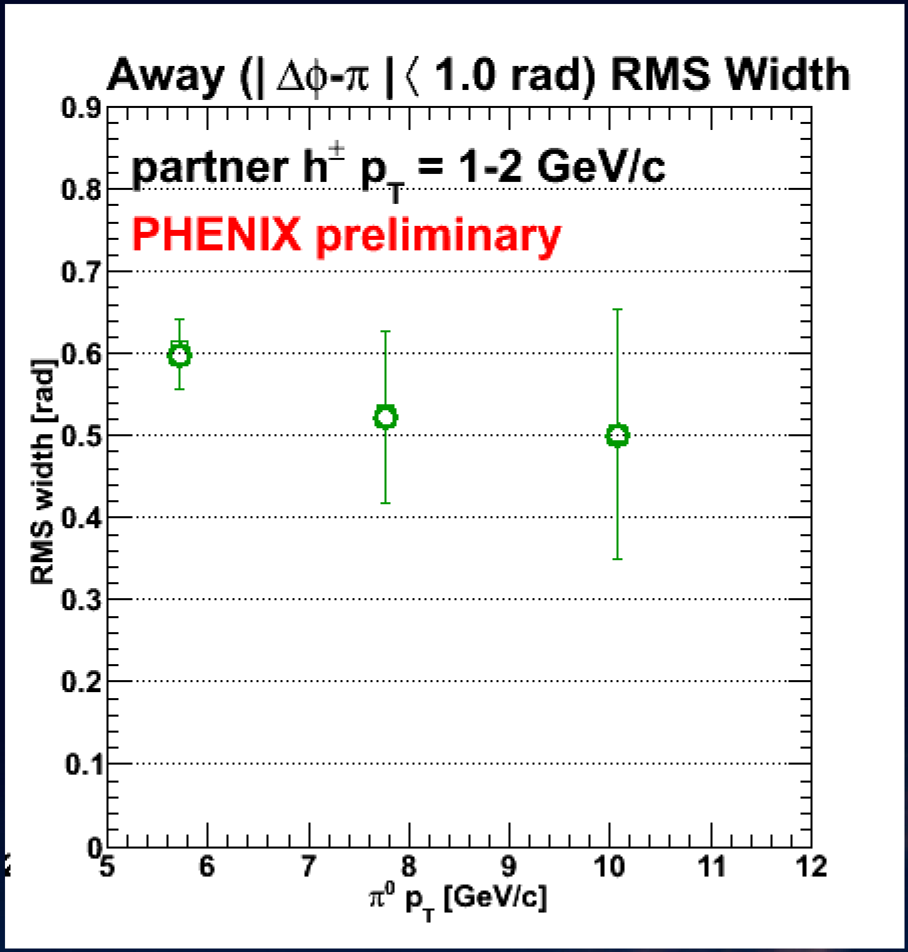
- New correlations using identified trigger particles and absolute background normalization
- Applied quantitative peak shape studies:
  - See significant offset using 2-peak ansatz for lowest p_T bin
  - But the head/shoulder yield is still larger than for h-h

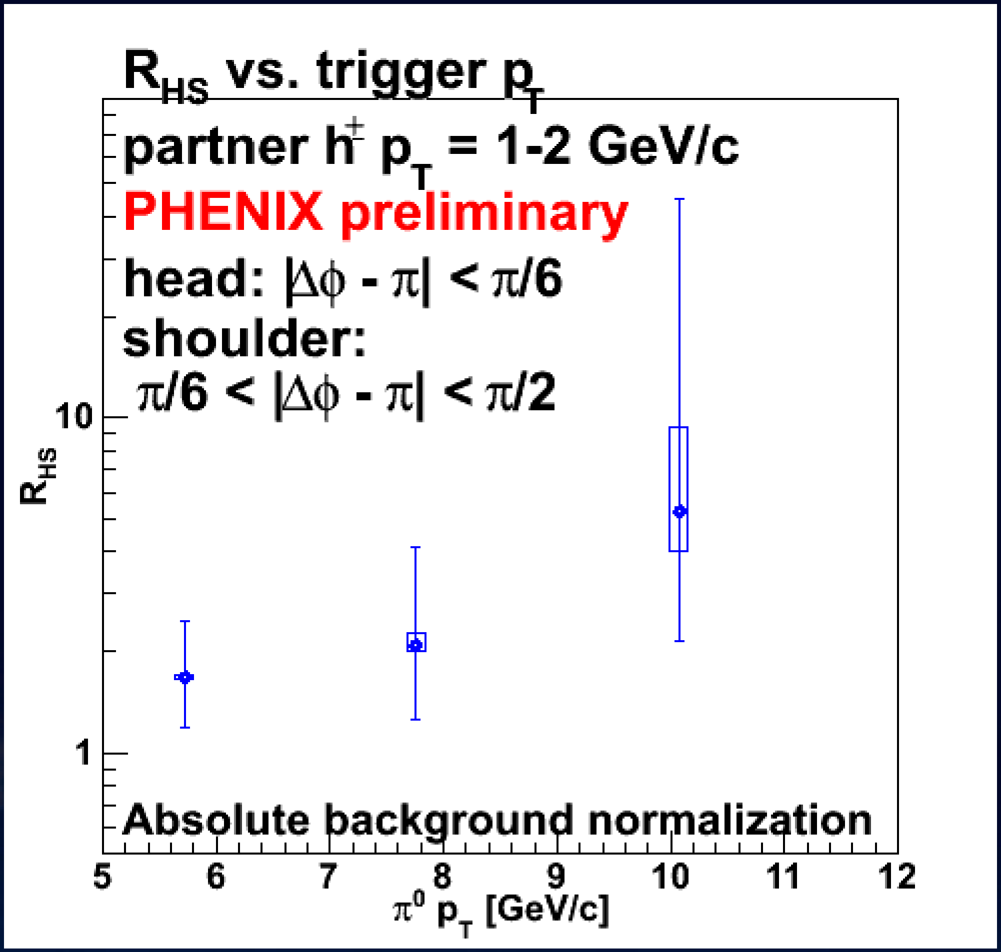
What's next?

- Push to lower trigger p_T...does mach cone structure grow?
- Partner efficienty correction → Yields, I_{AA}, etc.
- Working towards publication, stay tuned.

Backups

Trigger p_T evolution



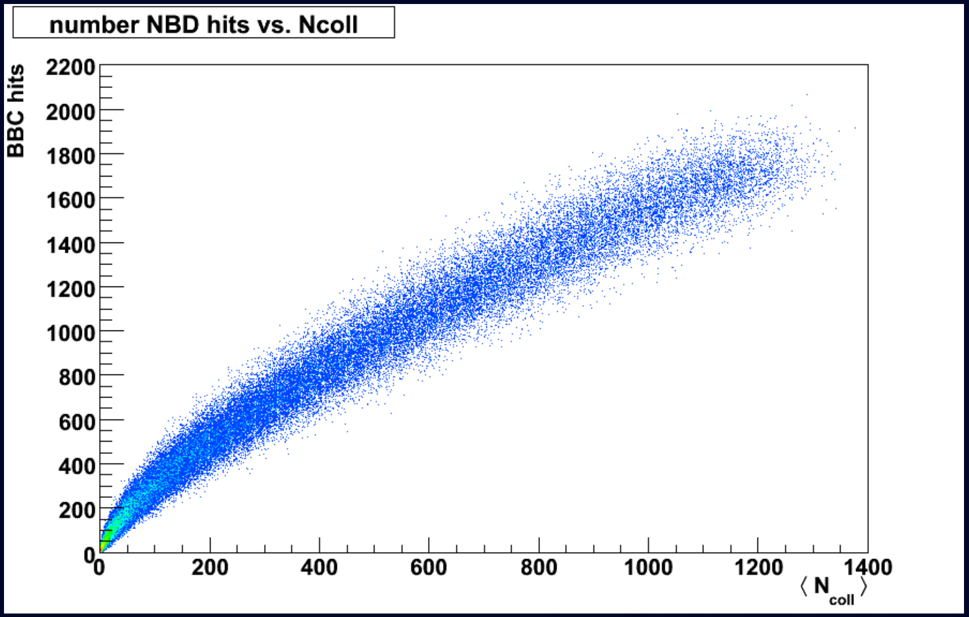


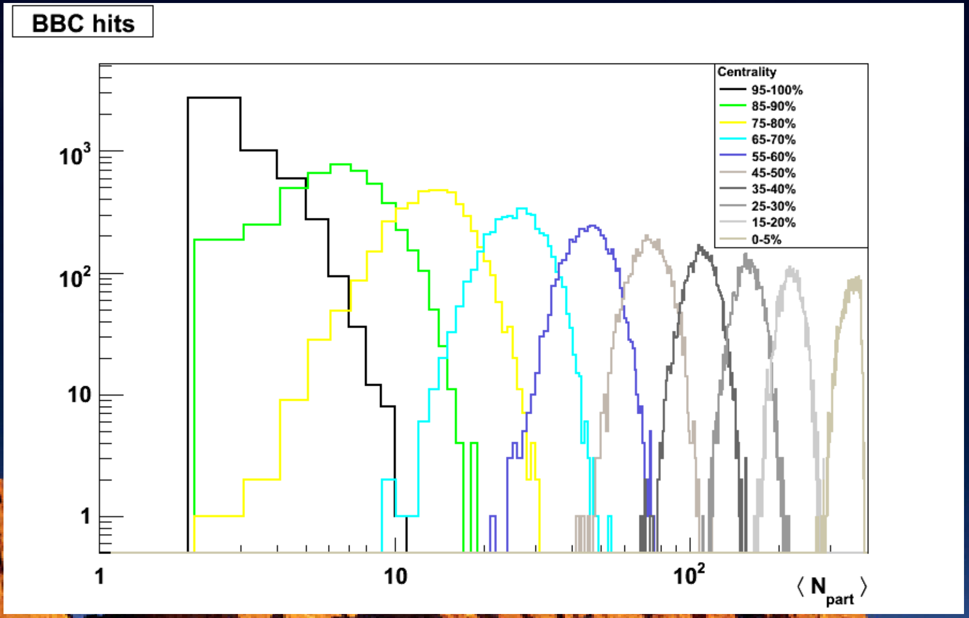
Absolute Normalization

Calculate from event mixing, then correct.

1. Start with a Glauber Monte Carlo simulation. Let the number of BBC hits follow a negative binomial distribution. This maps a physical parameter $\langle N_{\text{part or coll}} \rangle$ to an observable (BBC hits).

2. Divide the BBC hits distribution into percentile bins. The finite width in $\langle N \rangle$ introduces a smearing when ξ is calculated, simulating a real uncertainty.

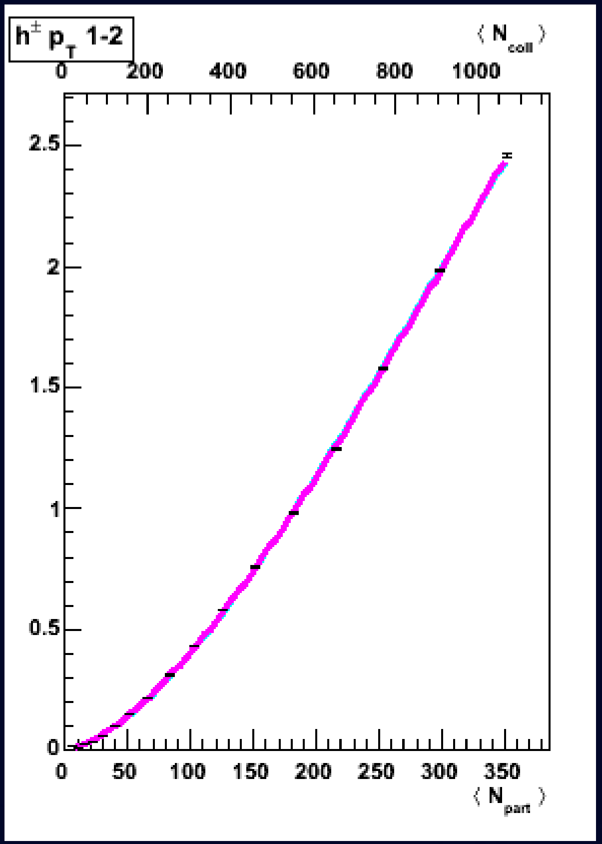




Determining ξ

Triggers

Partners



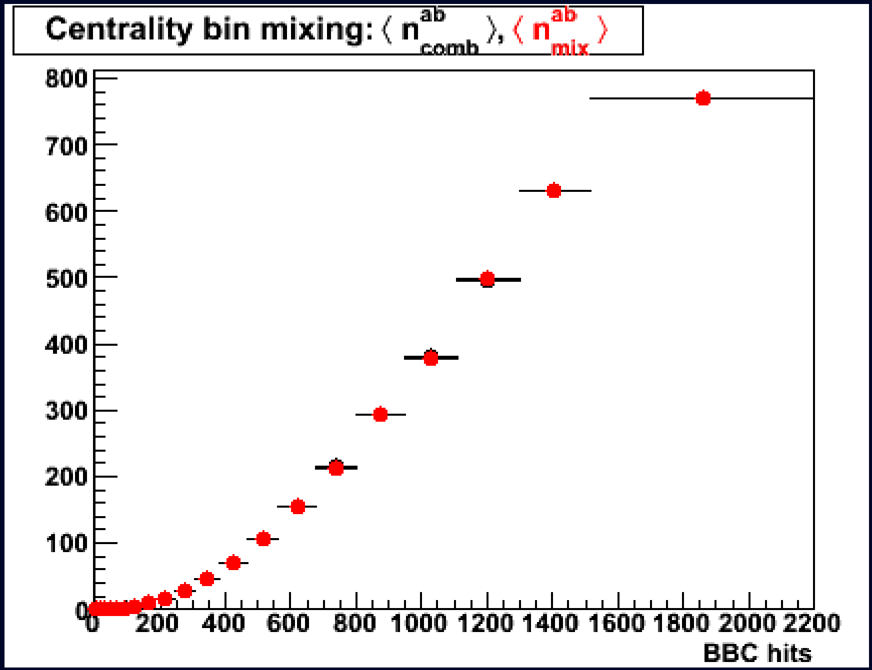
3. Single-particle unconditional per-event yields are measured in data. All cuts are identical to those applied in the correlations. The mapping between centrality bins and N comes from Glauber.
4. The yields are fit with a smooth function of N. Two different functions are used, and the differences help estimate the systematic error.

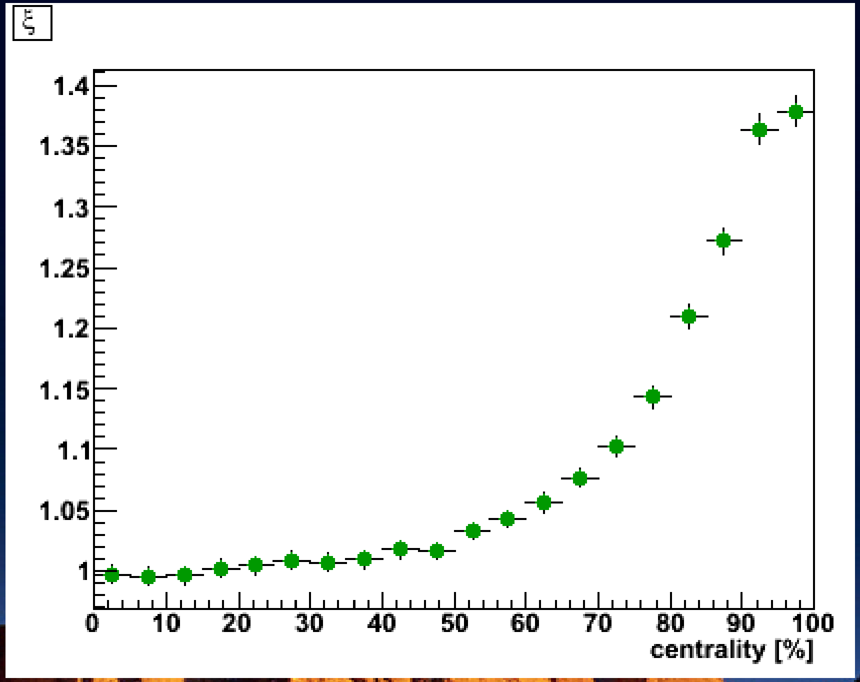
   The fits are done vs. Npart and vs. Ncoll. Again, any differences go into the systematics.

Determining ξ

5. The pair yields are calculated 2 ways in MC:
   1. <u>Ideal.</u> For each pair
      (a) Sample N randomly from Glauber distribution
      (b) Evaluate the $<n^A>$, $<n^B>$ fit curves at this exact N.
      (c) Sample n^A, n^B from Poissons, $\mu = <n^A>$, $<n^B>$. Then $n^{AB} = n^A n^B$.
   2. <u>Real</u>: add cent. bin mixing.
      (a) Sample N. Same as 1(a).
      (b) $<n^A>$ same as 1(a)., but $<n^B>$ comes randomly from the trigger centrality bin.
      (c) Same as 1(c)

The pair distributions are binned in BBC hit percentiles (top). The ideal/real ratio (bottom) is the residual multiplicity correction ξ.





Jet mathematics

Correct for detector acceptance by event mixing: $C(\Delta\phi) = N^{AB}_{same}(\Delta\phi)/N^{AB}_{mixed}(\Delta\phi)$.
It is implicit that the mixing depth is normalized out. Count pairs from the mixed events:

$$\int d\Delta\phi N^{AB}_{mixed}(\Delta\phi) = N^{AB}_{comb} = N_{events}\langle n^A\rangle\langle n^B\rangle \tag{1}$$

Use the "sum rule for angular correlations" to obtain[a]

$$\frac{1}{N^A}\frac{dN^{AB}_{jet}}{d\Delta\phi} = \frac{\langle n^B\rangle}{2\pi}\left[C(\Delta\phi) - \xi(1 + 2v_2^A v_2^B \cos 2\Delta\phi)\right]$$

Rewrite normalization factor using (1) , remembering the single particle efficiency:

$$\boxed{\frac{1}{N^A}\frac{dN^{AB}_{jet}}{d\Delta\phi} = \frac{\int d\Delta\phi N^{AB,obs}_{mix}(\Delta\phi)}{\epsilon^B 2\pi N^A}\left[C(\Delta\phi) - \xi(1 + 2v_2^A v_2^B \cos 2\Delta\phi)\right]}$$

This is the operational equation, consistent with e.g. ppg083 eq. 17.

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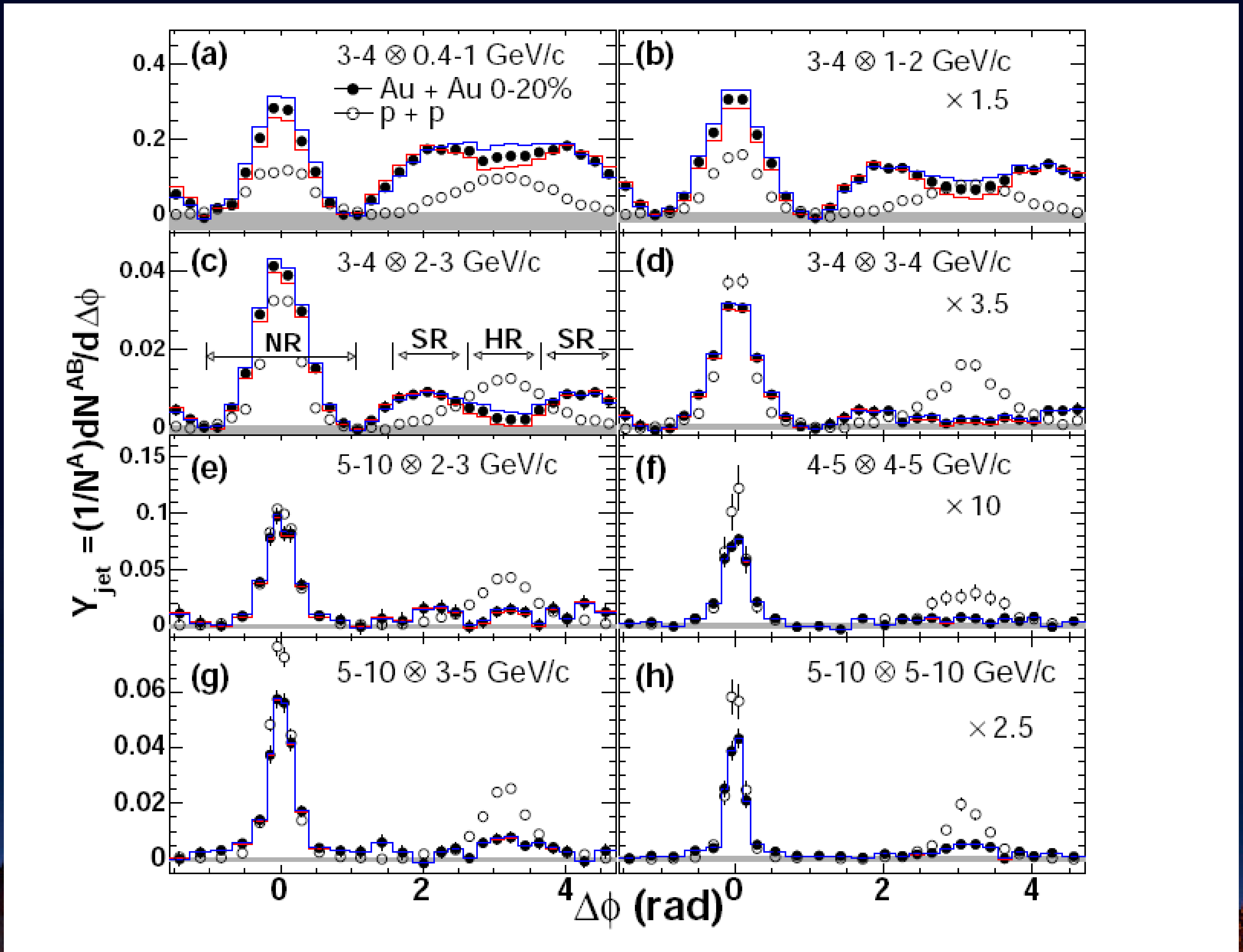
[a] $\frac{1}{N^A}\frac{dN^{AB}}{d\Delta\phi} = \frac{\langle n^B\rangle}{2\pi}C(\Delta\phi)$ PHENIX TN 412, eq. (49)

Au+Au h-h per-trigger yields

Phys. Rev. C 78, 014901 (2008)



Photon energy cut for π^0 PID