Dihadron correlations in the ALICE experiment

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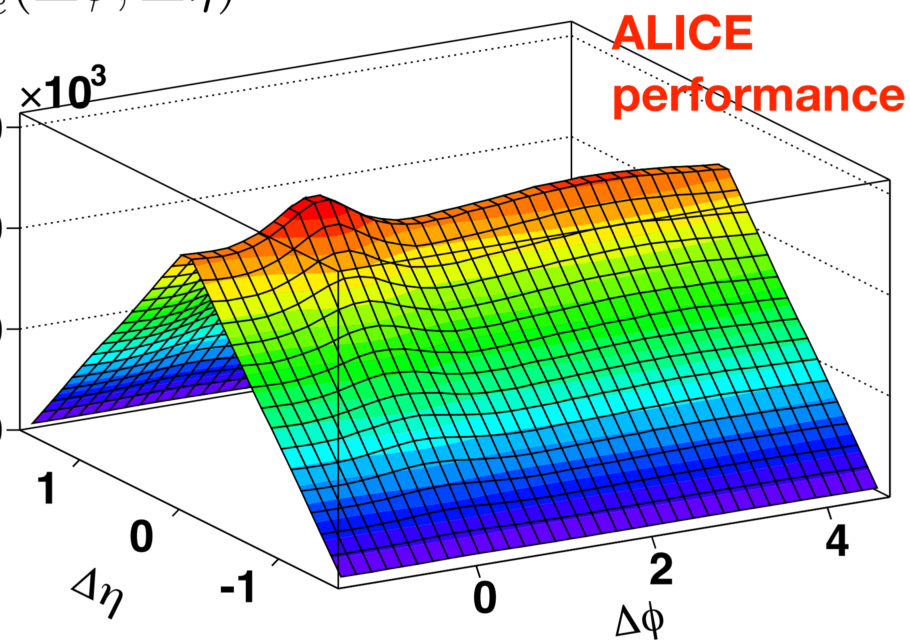
on behalf of
The ALICE collaboration

6th International Workshop on High-p_T physics at the LHC
Utrecht, NL - 4 April 2011

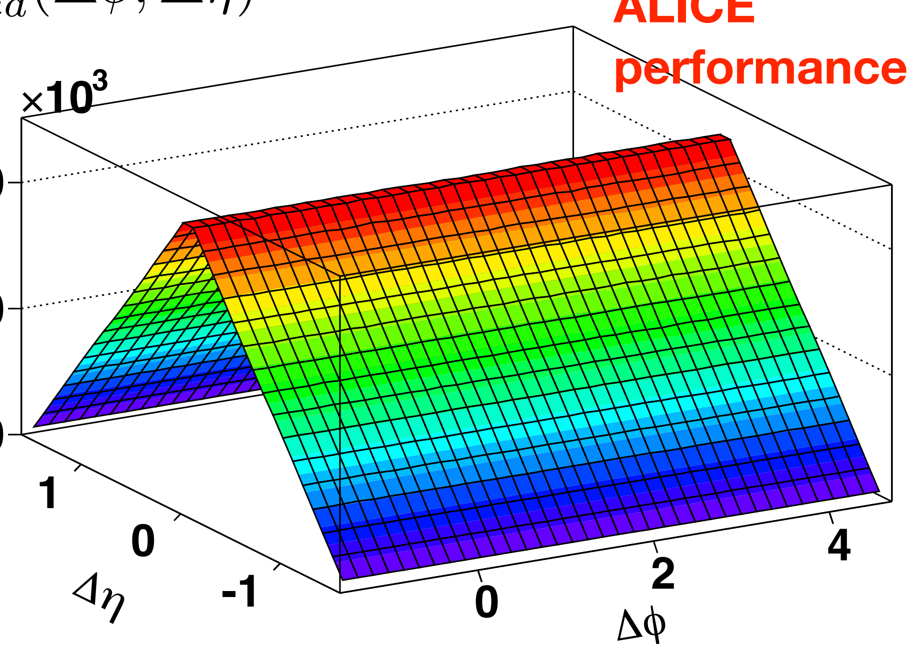
Two-particle correlations

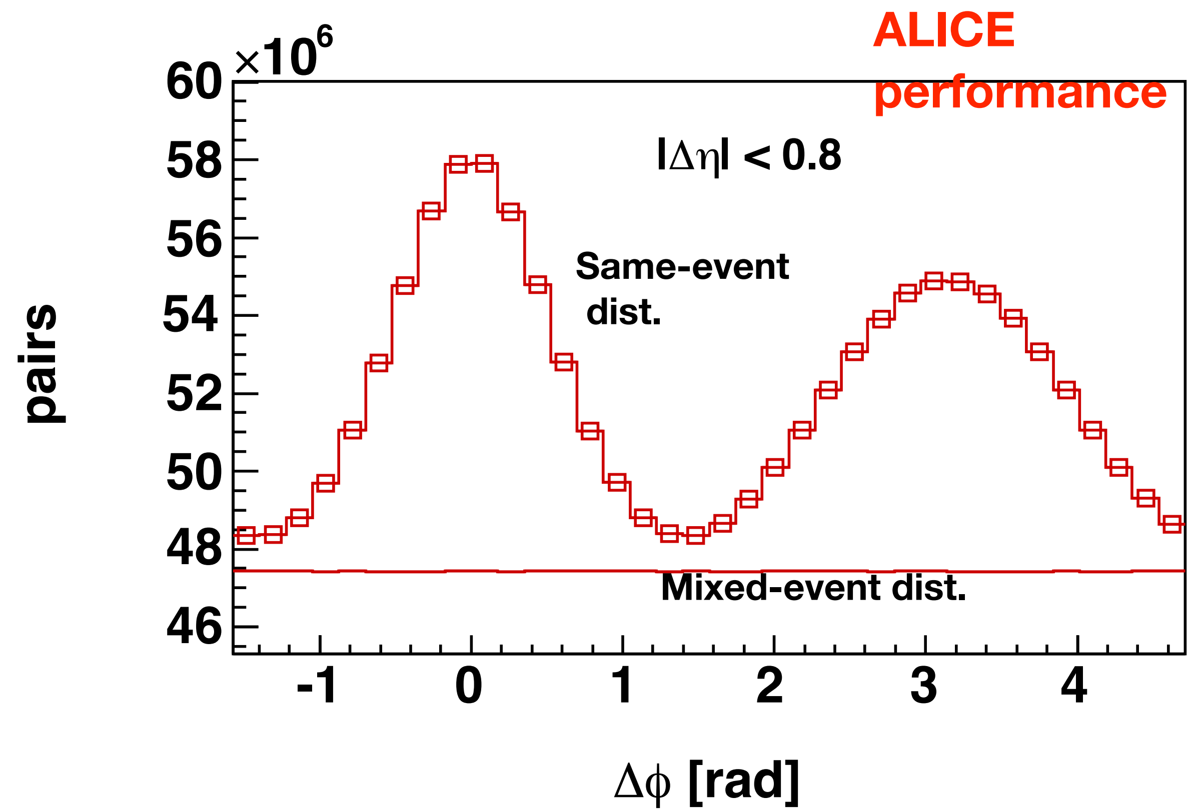
Same and mixed event pair distributions

$N^{AB}_{same}(\Delta\phi, \Delta\eta)$



$N^{AB}_{mixed}(\Delta\phi, \Delta\eta)$





$$\Delta\phi = \phi_A - \phi_B$$
$$\Delta\eta = \eta_A - \eta_B$$

Ratio is the correlation function:

$$C(\Delta\phi) \equiv \frac{N^{AB}_{mixed}}{N^{AB}_{same}} \cdot \frac{dN^{AB}_{same}/d\Delta\phi}{dN^{AB}_{mixed}/d\Delta\phi}$$

Tracking in time projection chamber

- Full azimuthal acceptance, $|\eta| < 1$ (but $|\eta| < 0.8$ for now)
- Excellent pair acceptance/efficiency

Centrality determination with V0 and SPD

Analysis (I): the data

12 million min-bias Pb+Pb events

High tracking efficiency

--> small correction, small systematics

High occupancy capability in TPC

Pair effects

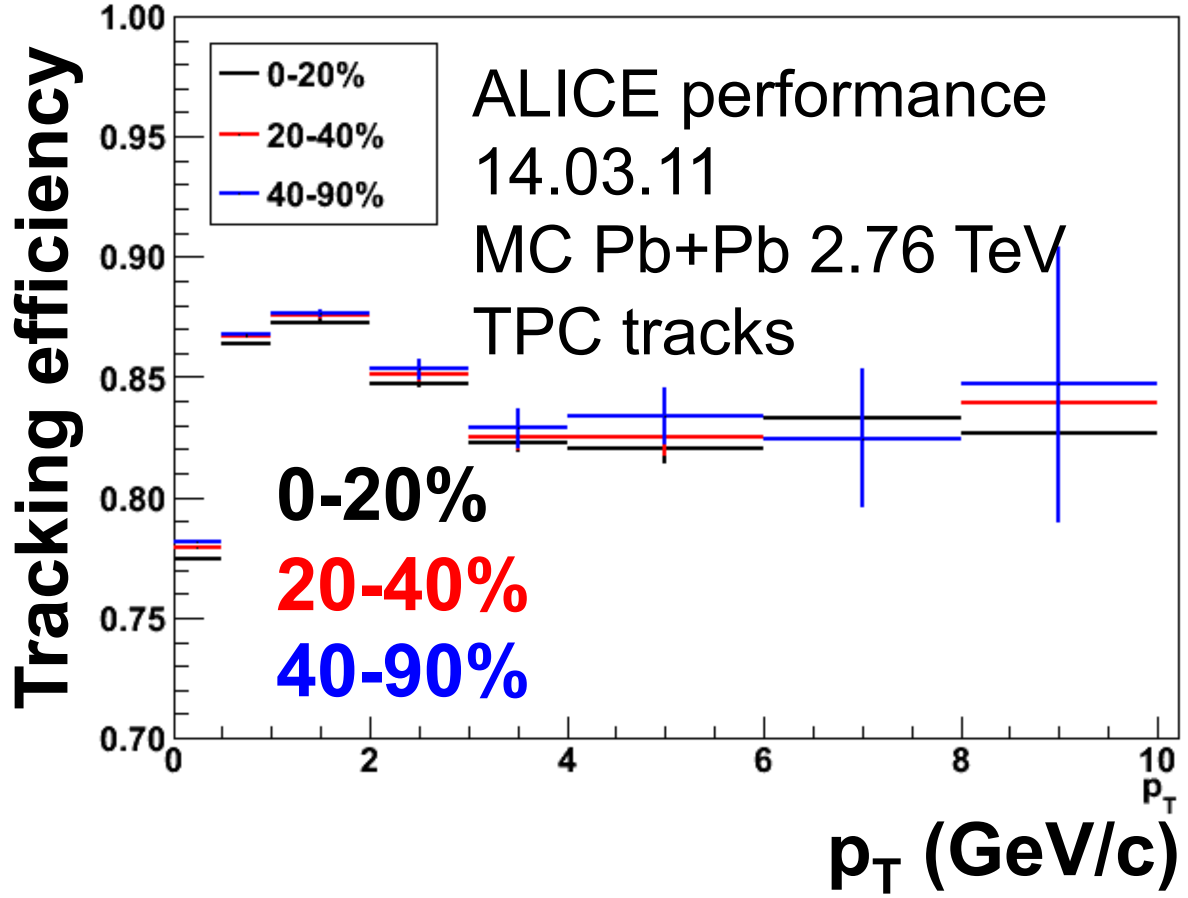
Contamination, two-track efficiencies, and merging were studied in Monte Carlo...negligible at high p_T

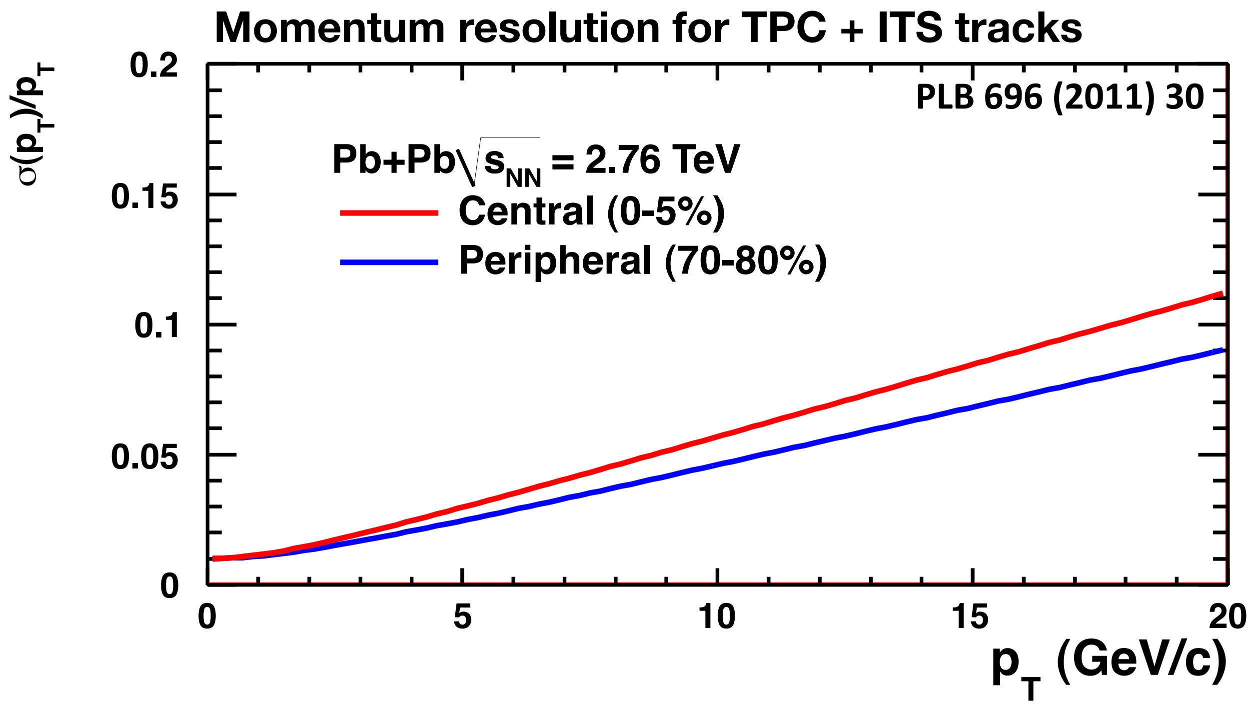
Momentum resolution

Shown right for global (TPC + ITS) tracks

TPC-only* tracks used in this analysis to improve acceptance (so $\sigma(p_T)$ somewhat worse than shown here)

Cross-check done using global tracks...consistent results found





*Silicon Pixel Detector was also included to constrain vertex

Δφ-Δη distributions - intermediate p_T

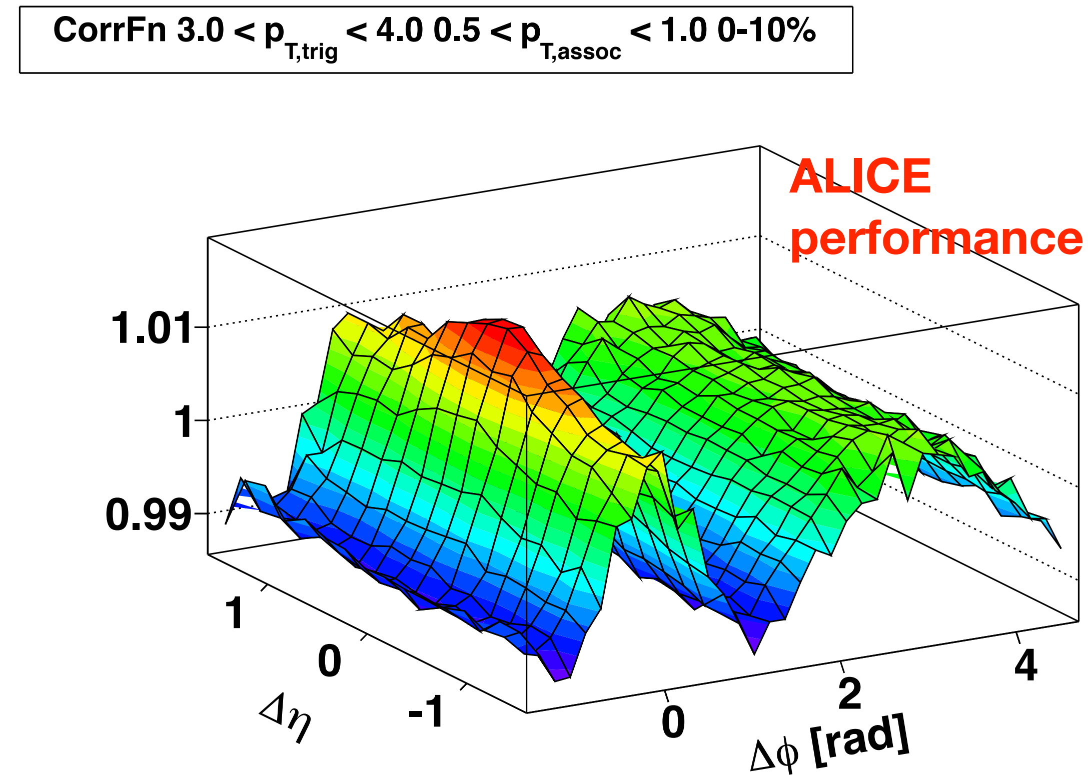
3-4 GeV/c triggers, central Pb+Pb:

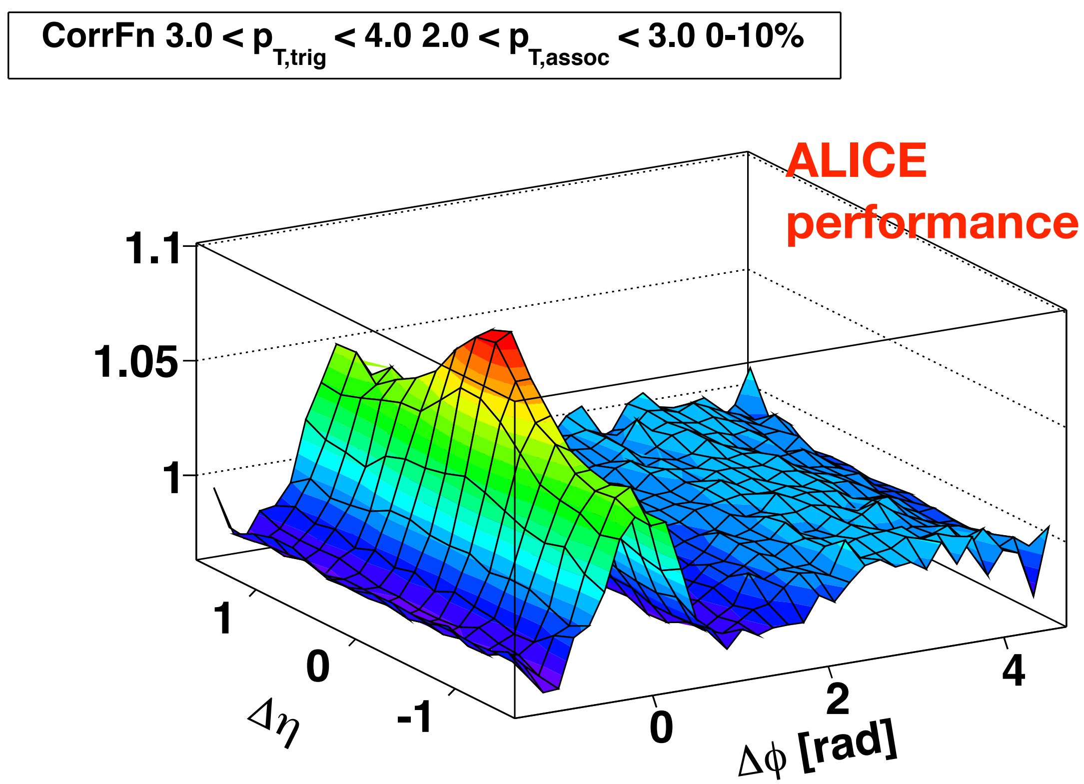
Prominent near-side ridge

- Near side jet emerges with rising associated p_T

Broad, flat away side

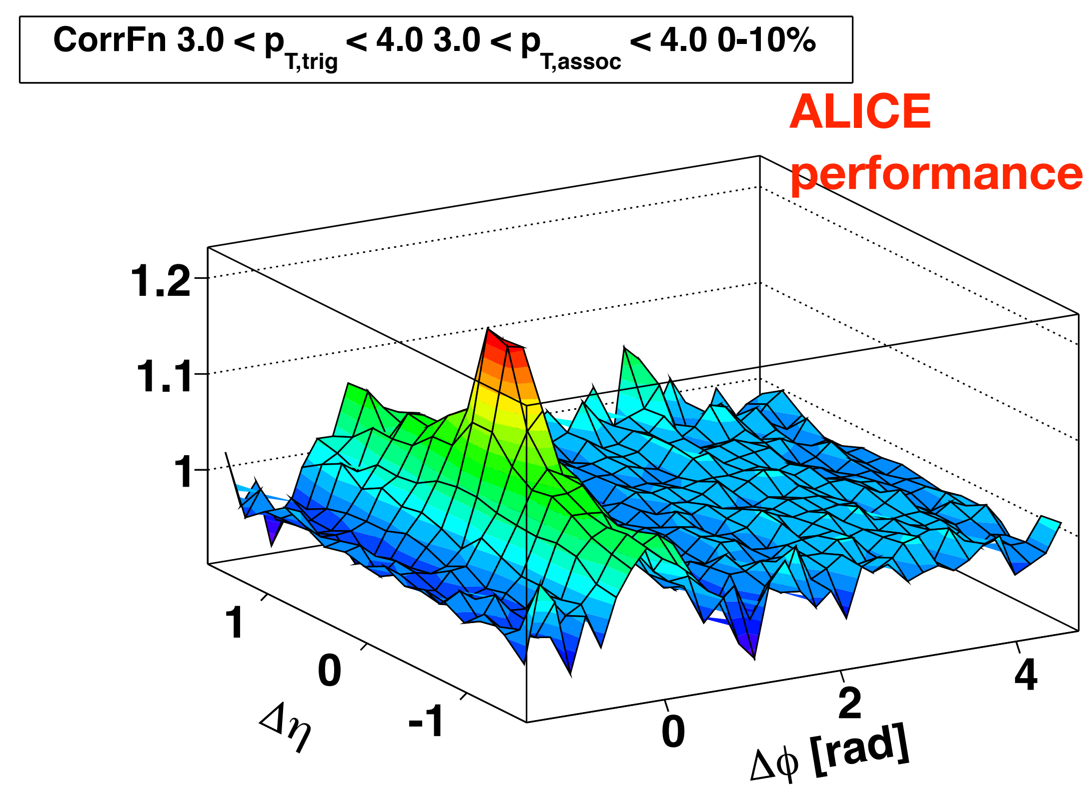
- correlation strength does not rise with assoc. p_T (compared to near side)





C(Δφ)

Not bkg. subtracted

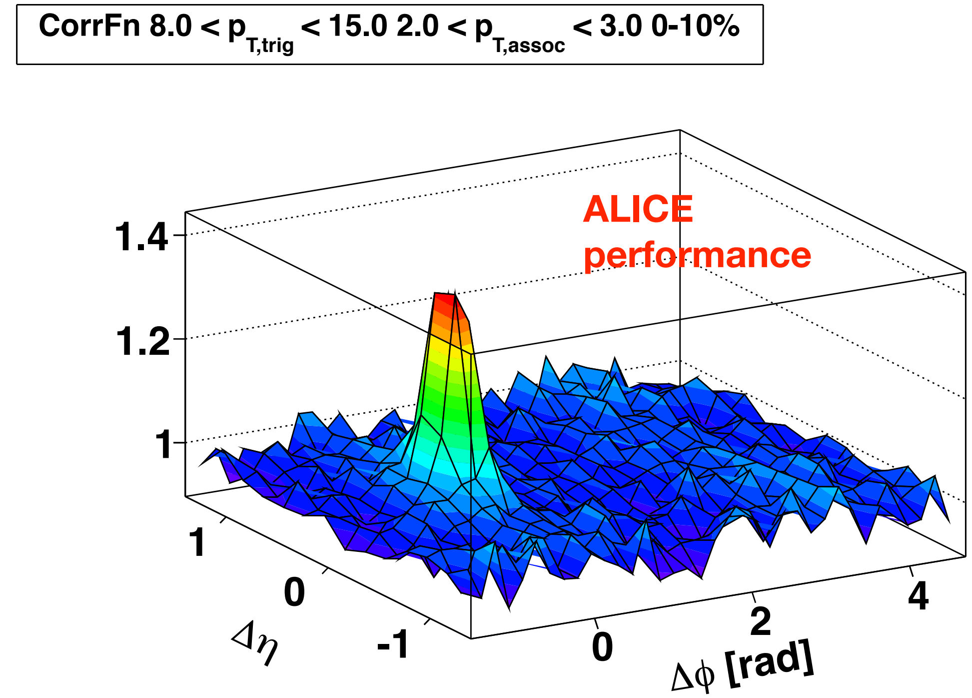


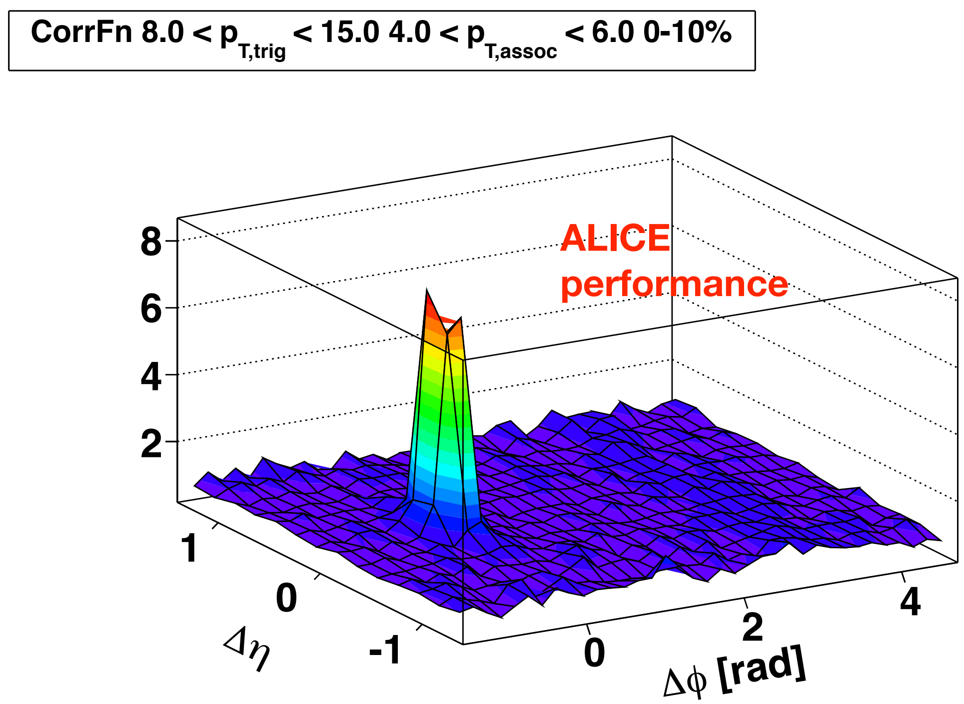
Δφ-Δη distributions - high p_T

8-15 GeV/c triggers, central Pb+Pb:

Near-side jet dominates

Ridge difficult to resolve at this scale





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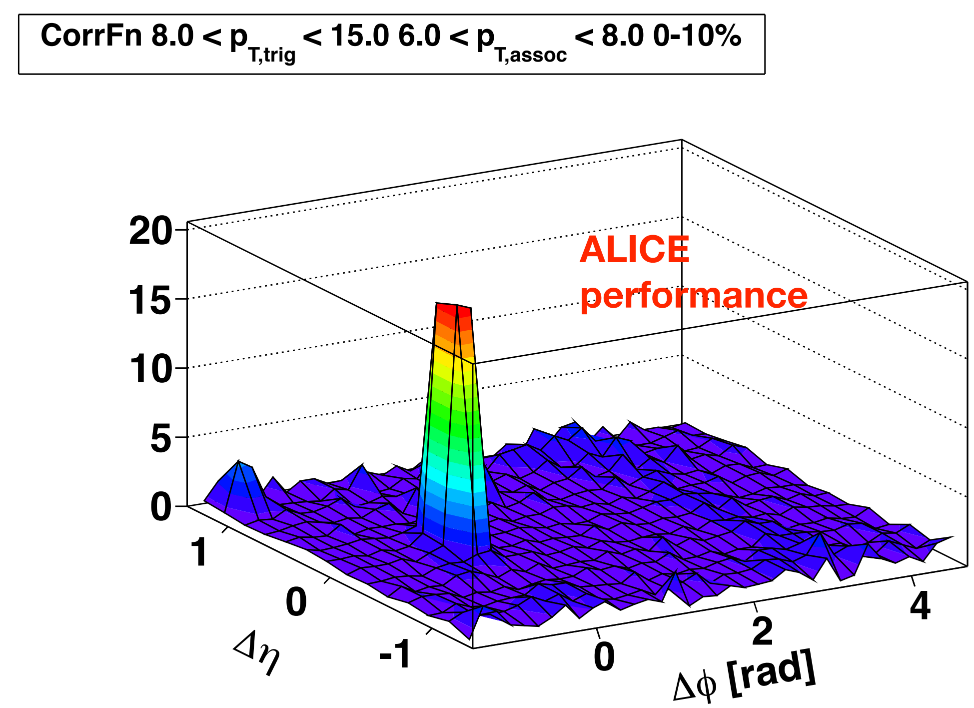
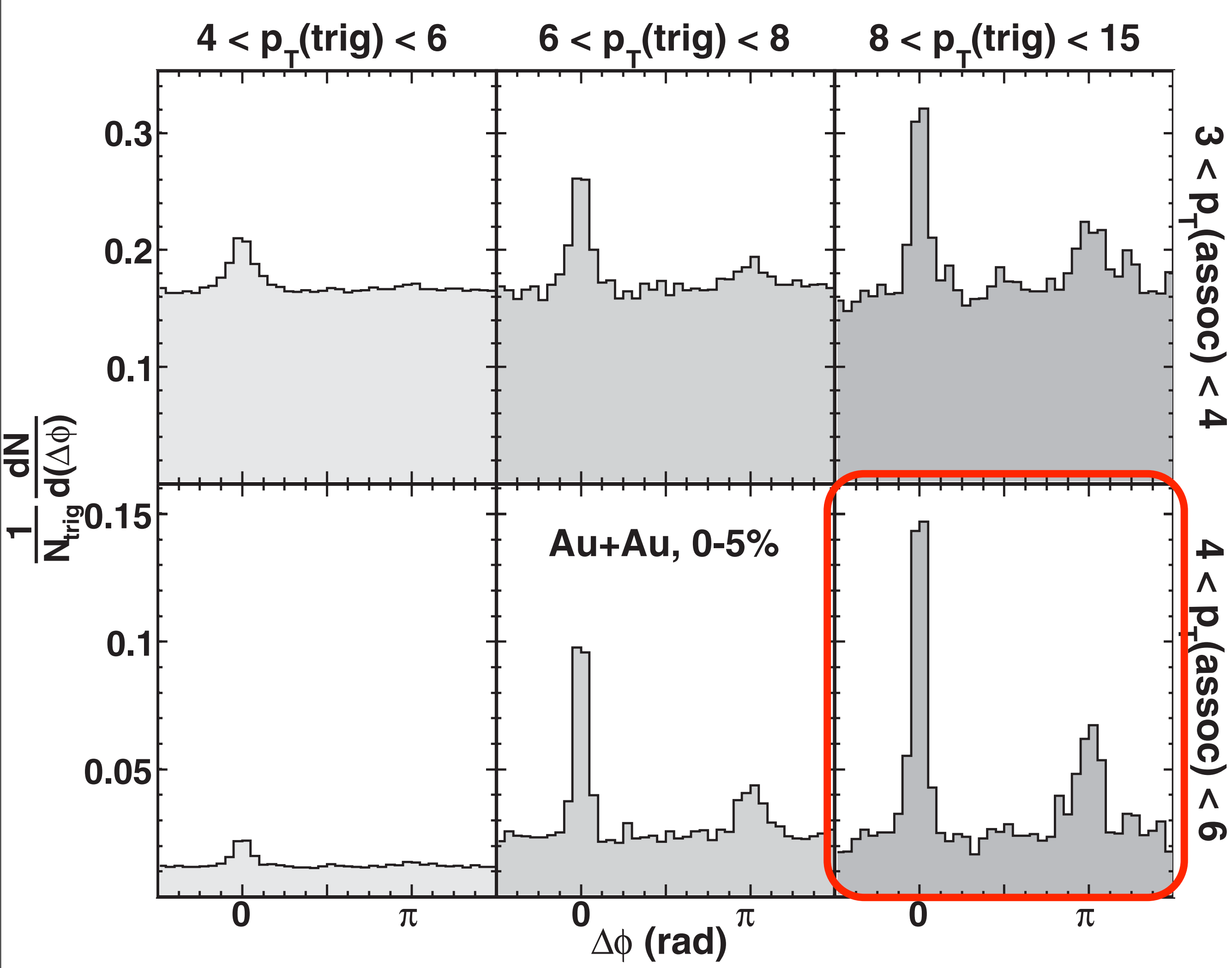


Away-side jet signal very weak!

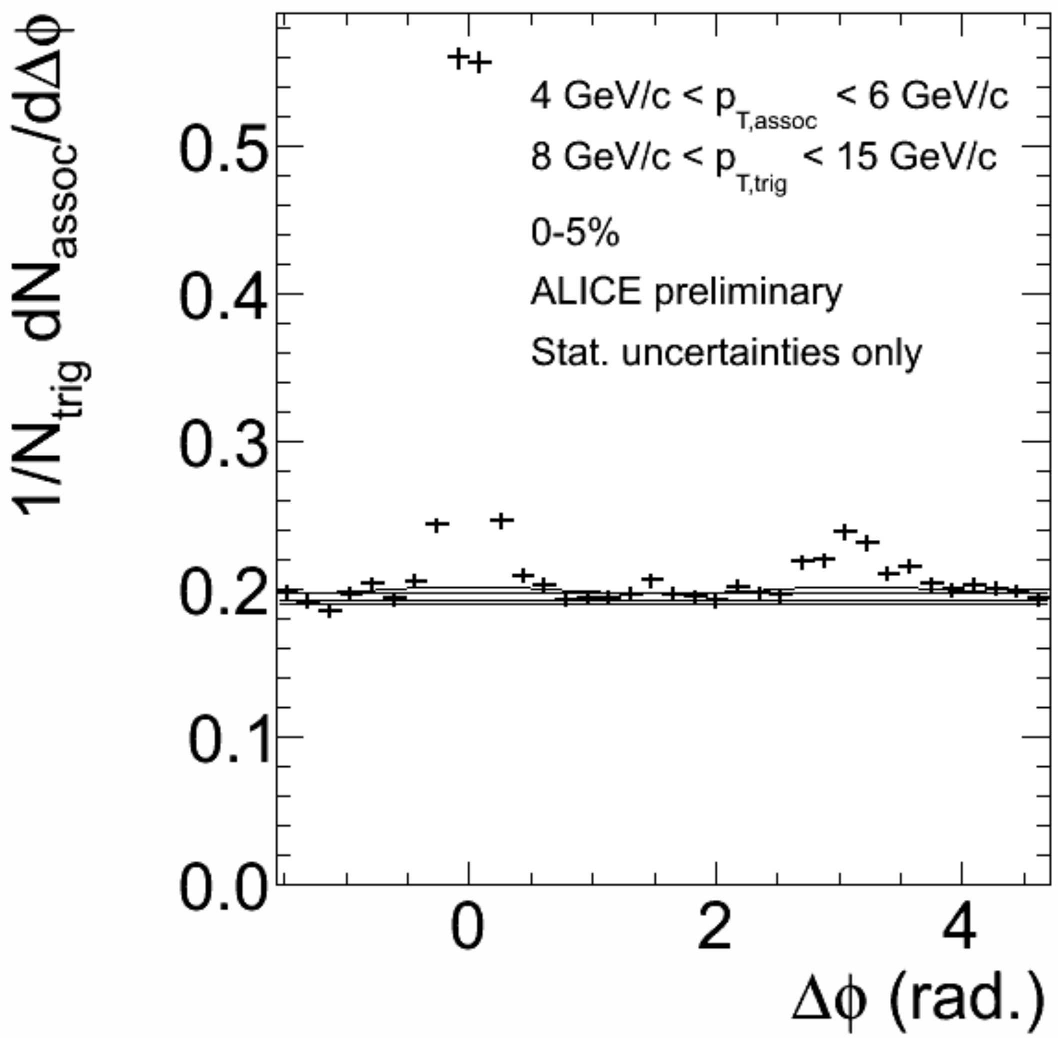
Does not strongly reappear (relative to near side) as assoc. p_T rises.

Δφ: ALICE vs. STAR at high p_T

STAR @ 200 GeV PRL 97, 162301 (2006)



ALICE @ 2.76 TeV



0-5% Pb+Pb @ 2.76 TeV:

Larger combinatoric background (no surprise)

Away side yield is ~comparable, while near side is 3-4x larger. Why?

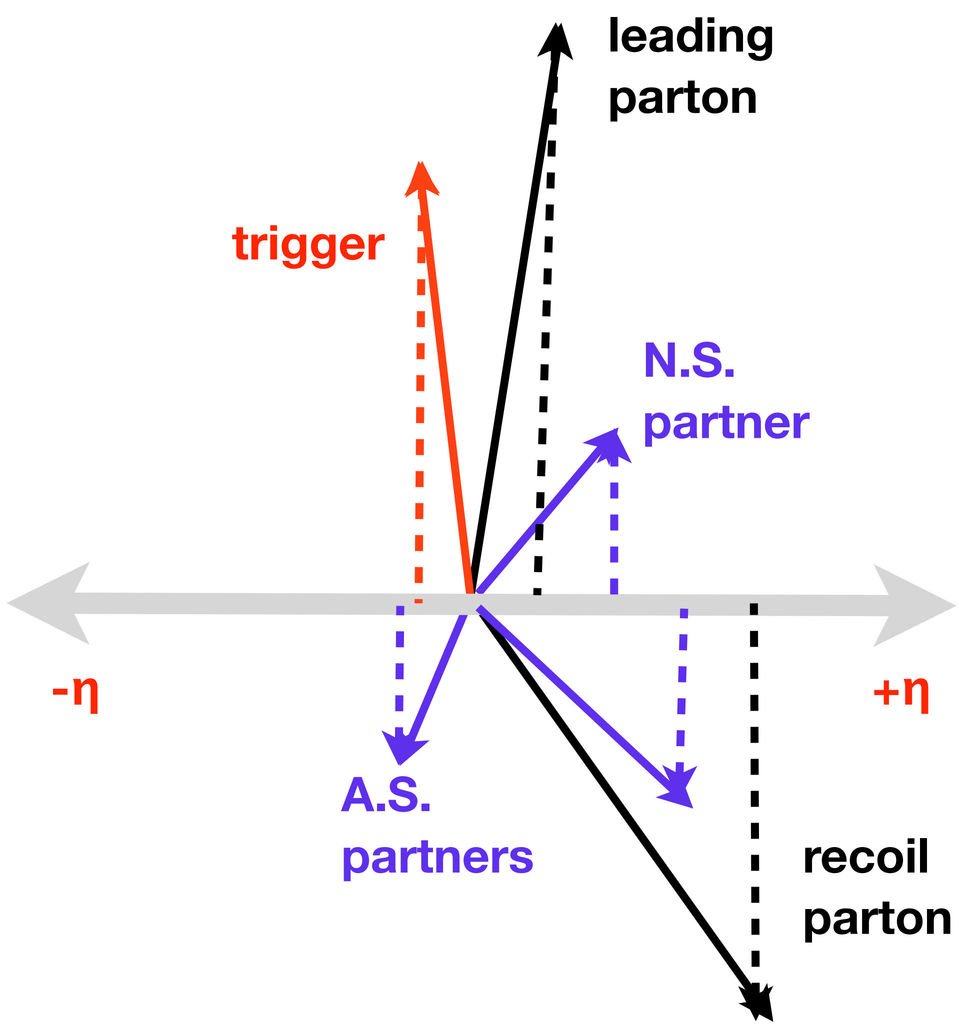
Kinematics at the LHC vs. RHIC

Near-side correlations

Requiring a trigger particle means $p_{T,parton} > p_{T,trig} + p_{T,assoc}$.

On the recoil side

No trigger: $p_{T,parton} > p_{T,assoc}$.



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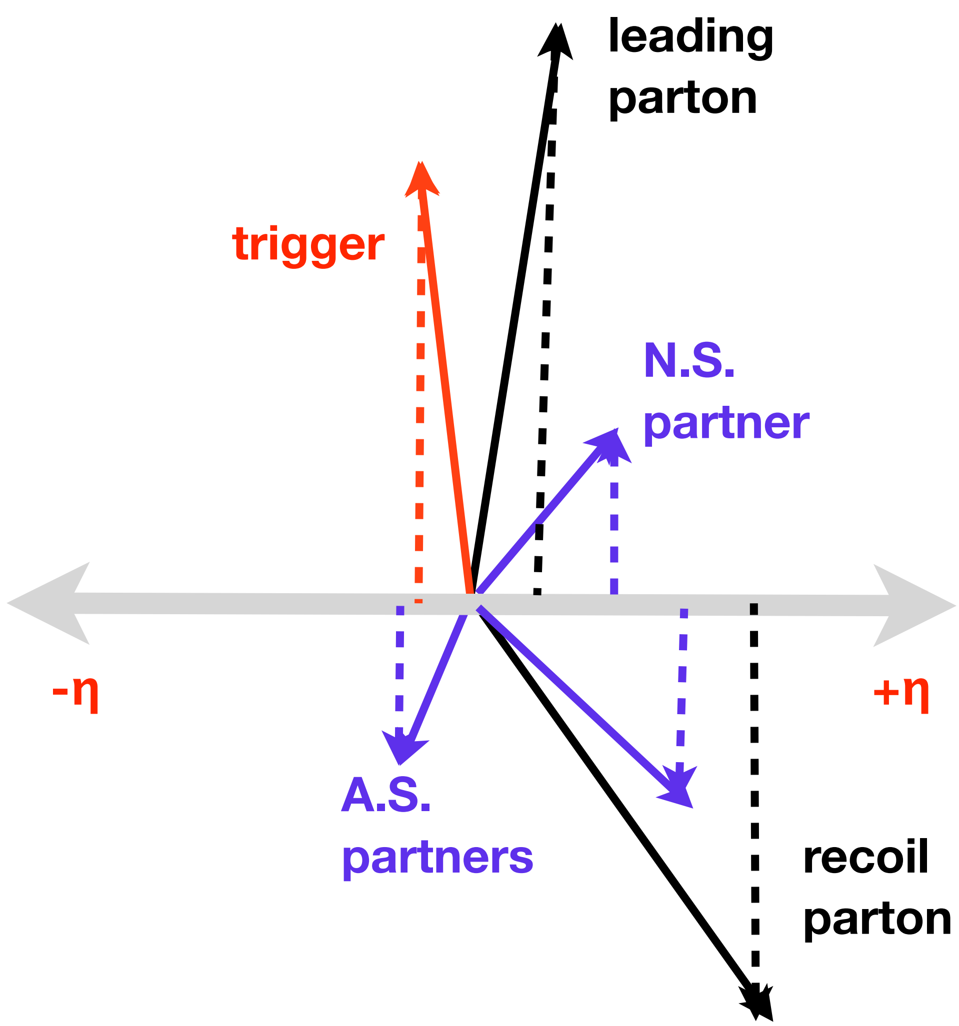
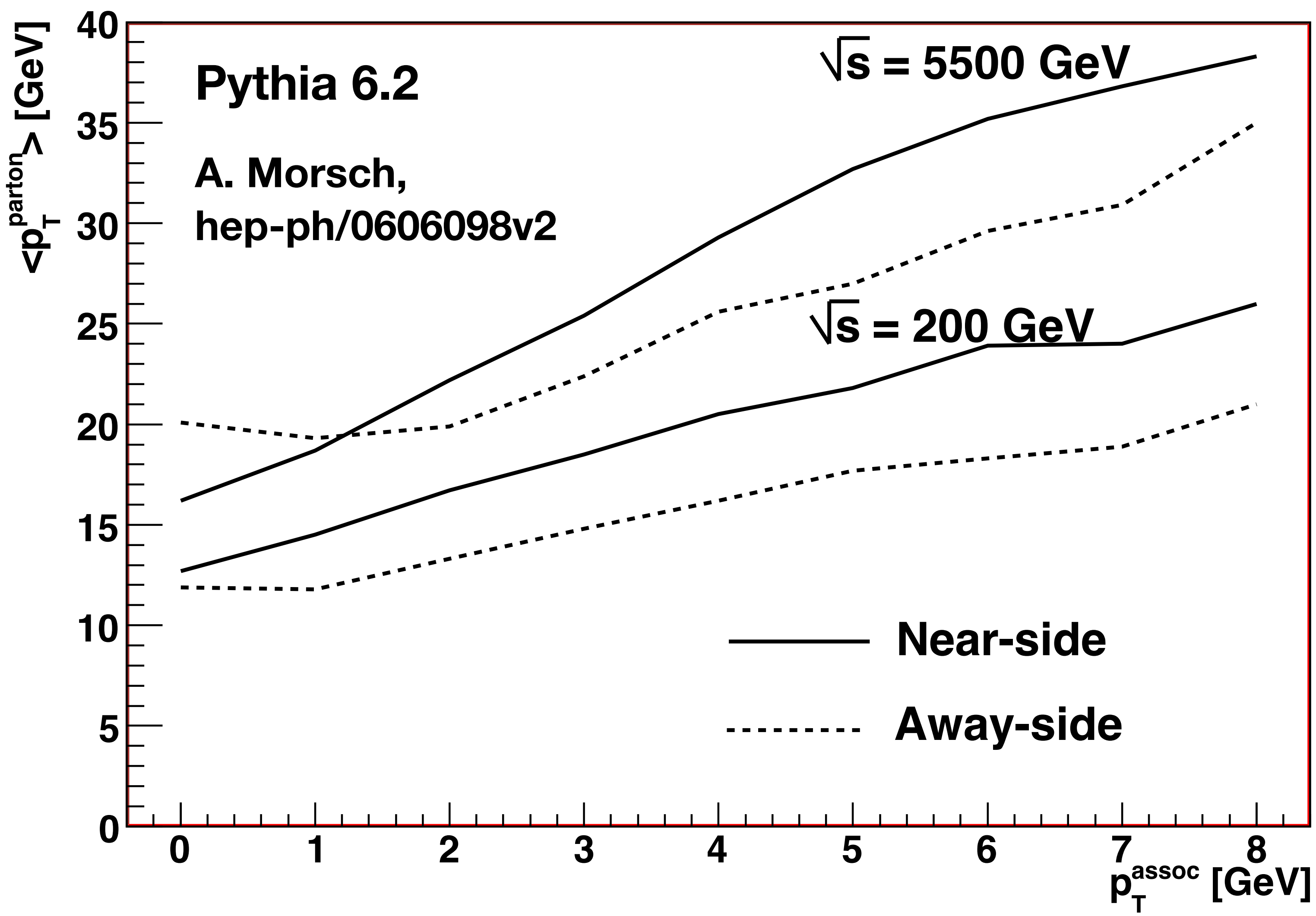


Parton p_T vs. associated p_T - $p_{T,trig}$ > 8 GeV/c:

- Near side samples higher $p_{T,parton}$ than away side
- At fixed $p_{T,trig}$ & $p_{T,assoc}$, much larger $p_{T,parton}$ at LHC



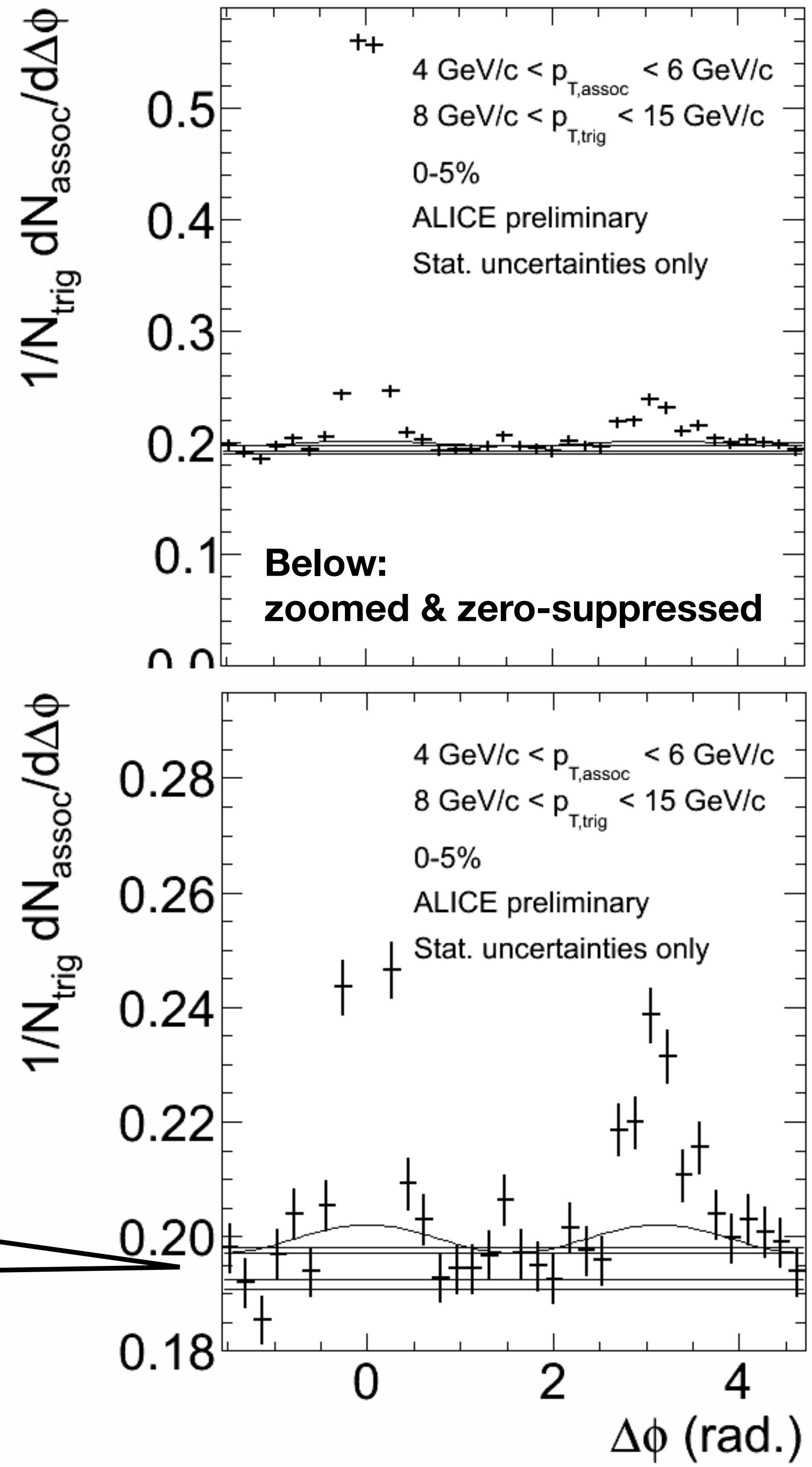
Analysis (II): yield extraction

Handling background

- The non-jet component must be characterized and removed
  - No known assumption-free methods...
- Go to high pt for reduced bias
  - Trigger pt 8-15 GeV/c
  - Associated pt > 4GeV/c, always with ptt > pta

Work with several bkg. shape/ normalization schemes, compare

- Differences gauge systematics
  - Ultimately ZYAM is used
  - Different “M” definitions --> sys. uncertainty



<u>Different bkg shape ansatzes:</u>
- v_2-only
- flat pedestal

<u>Different ZYAM levels:</u>
- n-lowest-bin averages
- const. fit over transverse region

Yield modification: I_{CP} and I_{AA}

Compare $1/N_{trig}\, dN/d\Delta\varphi$ in A+A to a reference

Integrate yields in selected Δφ range

Here, 0 (π) ± 0.7 for near (away) side

ICP reference:

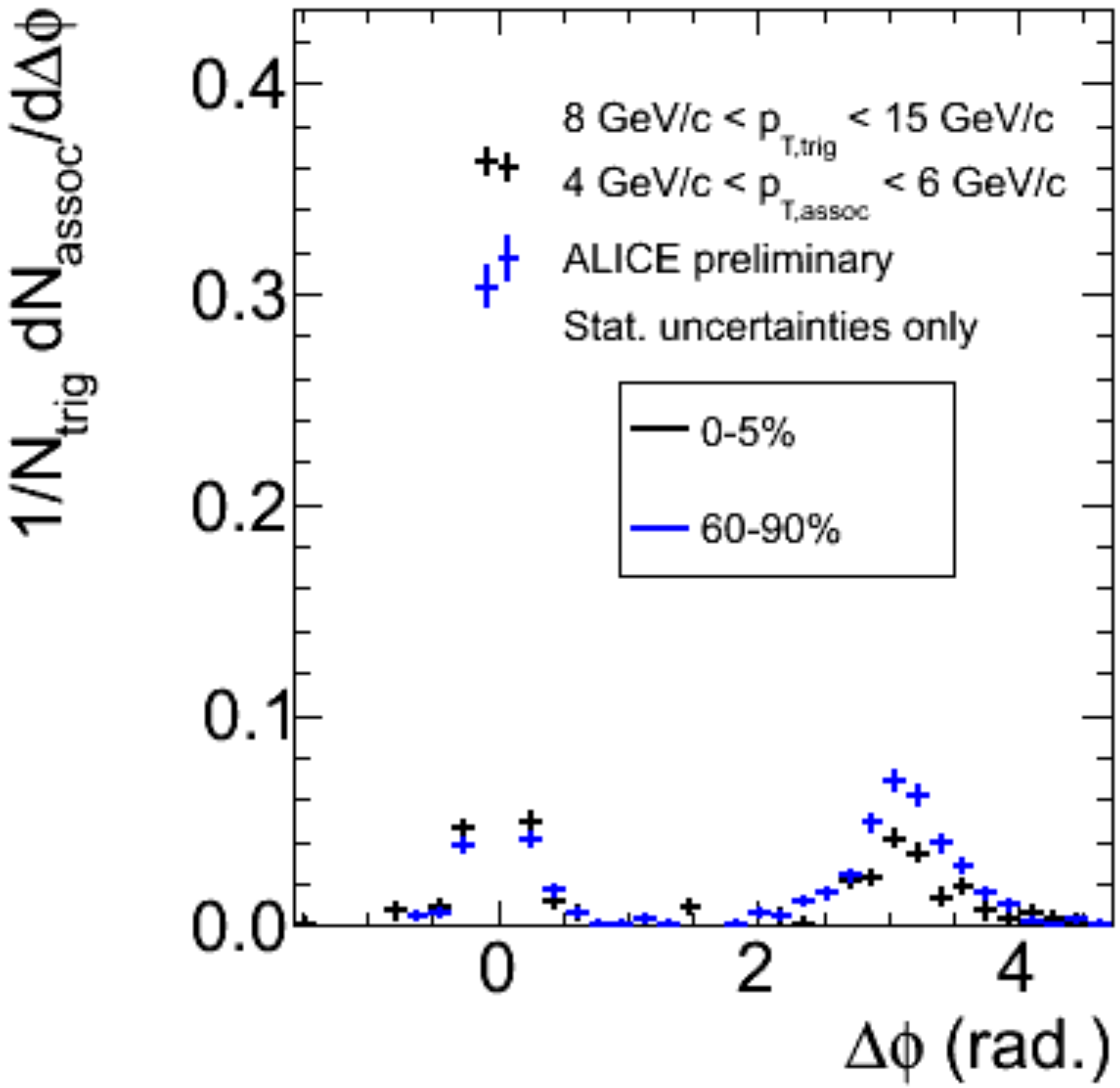
60-90% yield

IAA reference:

Normally p+p data, today I show pythia

$$I_{CP}(p_{T,trig};p_{T,assoc}) = \frac{Y^{AA}_{central}(p_{T,trig};p_{T,assoc})}{Y^{AA}_{peripheral}(p_{T,trig};p_{T,assoc})}$$

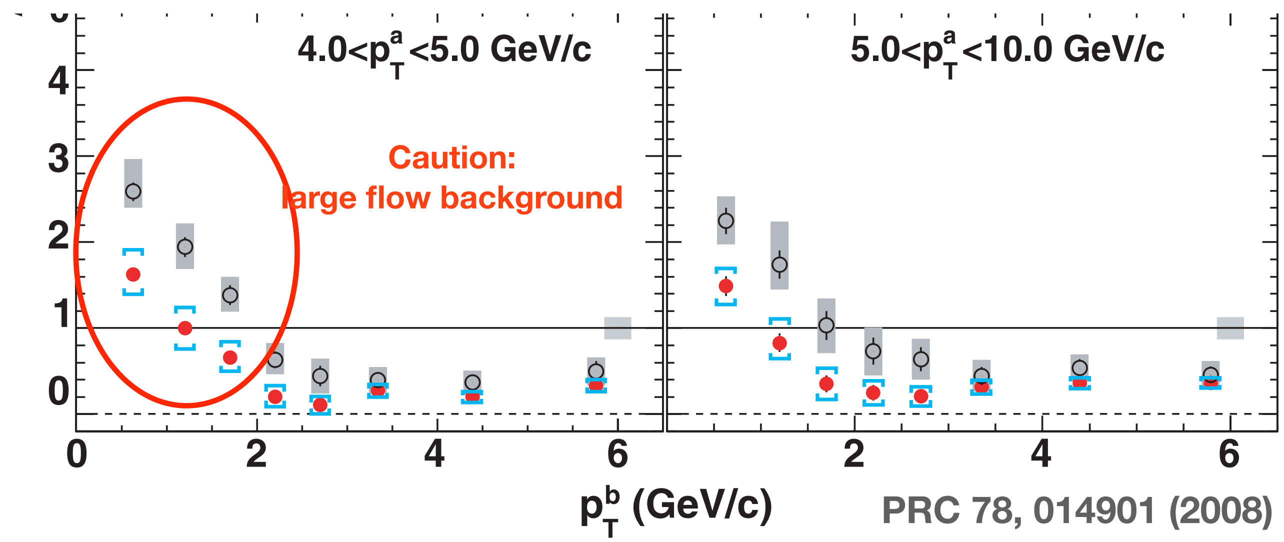
$$I_{AA}(p_{T,trig};p_{T,assoc}) = \frac{Y^{AA}(p_{T,trig};p_{T,assoc})}{Y^{pp}(p_{T,trig};p_{T,assoc})}$$



Benchmark 1: I_{AA} at PHENIX

PHENIX h-h:

Away-side I_{AA}: low-p_T enhancement, high-p_T suppression.



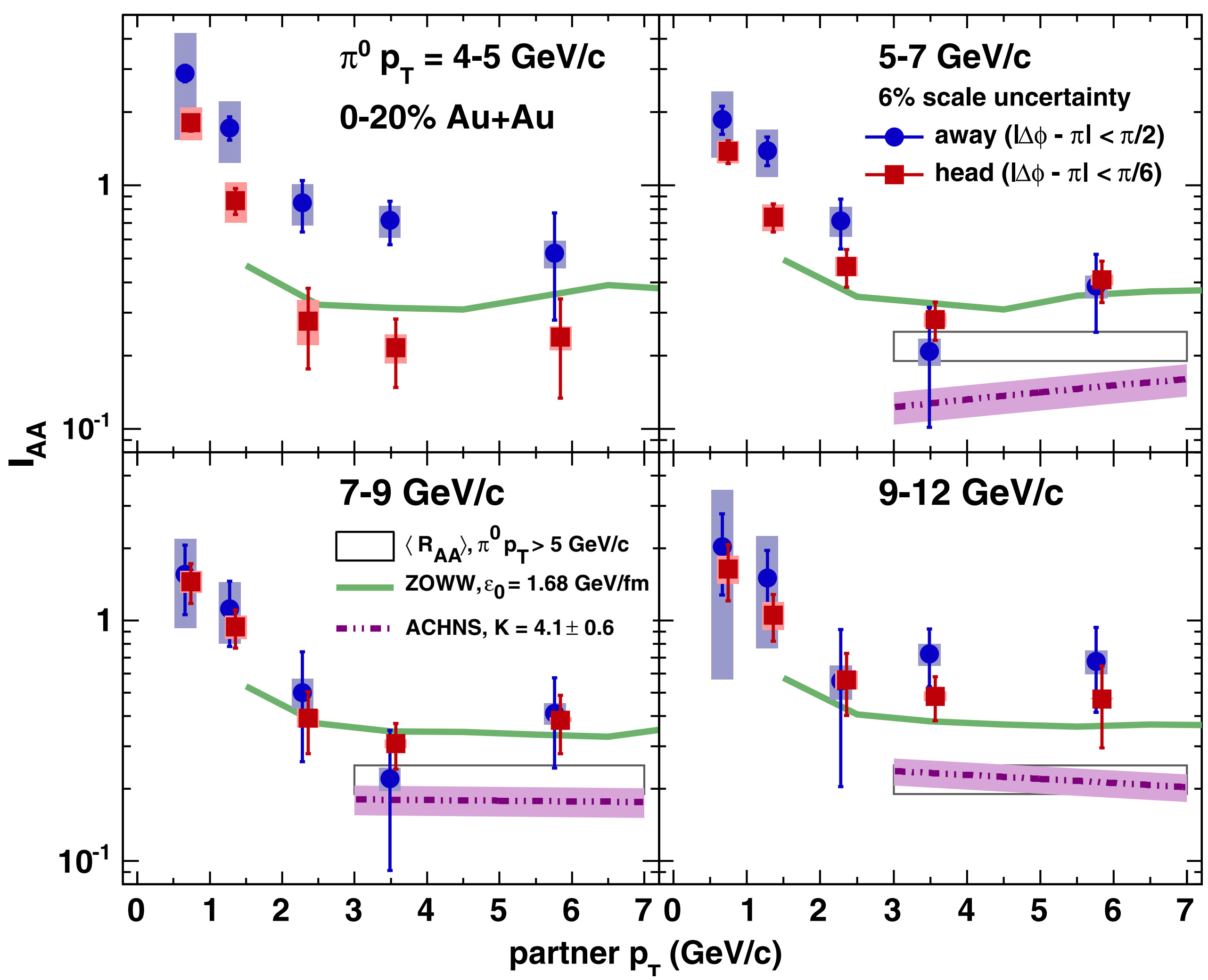
PRC 78, 014901 (2008)

PHENIX π^0-h:

High-p_T identified π^0 triggers

R_{AA} data, theory comparisons

PRL 104, 252301 (2010)



$$I_{AA}(p_T^a, p_T^b) = \frac{Y^{A+A}_{\text{jet\_ind}}(p_T^a, p_T^b)}{Y^{p+p}_{\text{jet\_ind}}(p_T^a, p_T^b)}.$$

Observations:

Focus on $p_{t,trig}$ > 5 and $p_{t,assc}$ > 2 GeV

- I_{AA} > R_{AA}
- I_{AA} ~ flat with $p_{T, assc}$
- I_{AA} increases with trigger p_T

Benchmark 2: D_{AuAu}/D_{dAu} from STAR

Plotted vs z_T

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

Near-side ratios consistent with 1 (with low statistical sensitivity).

Away-side ratios near 0.2-0.3 for 0-5%

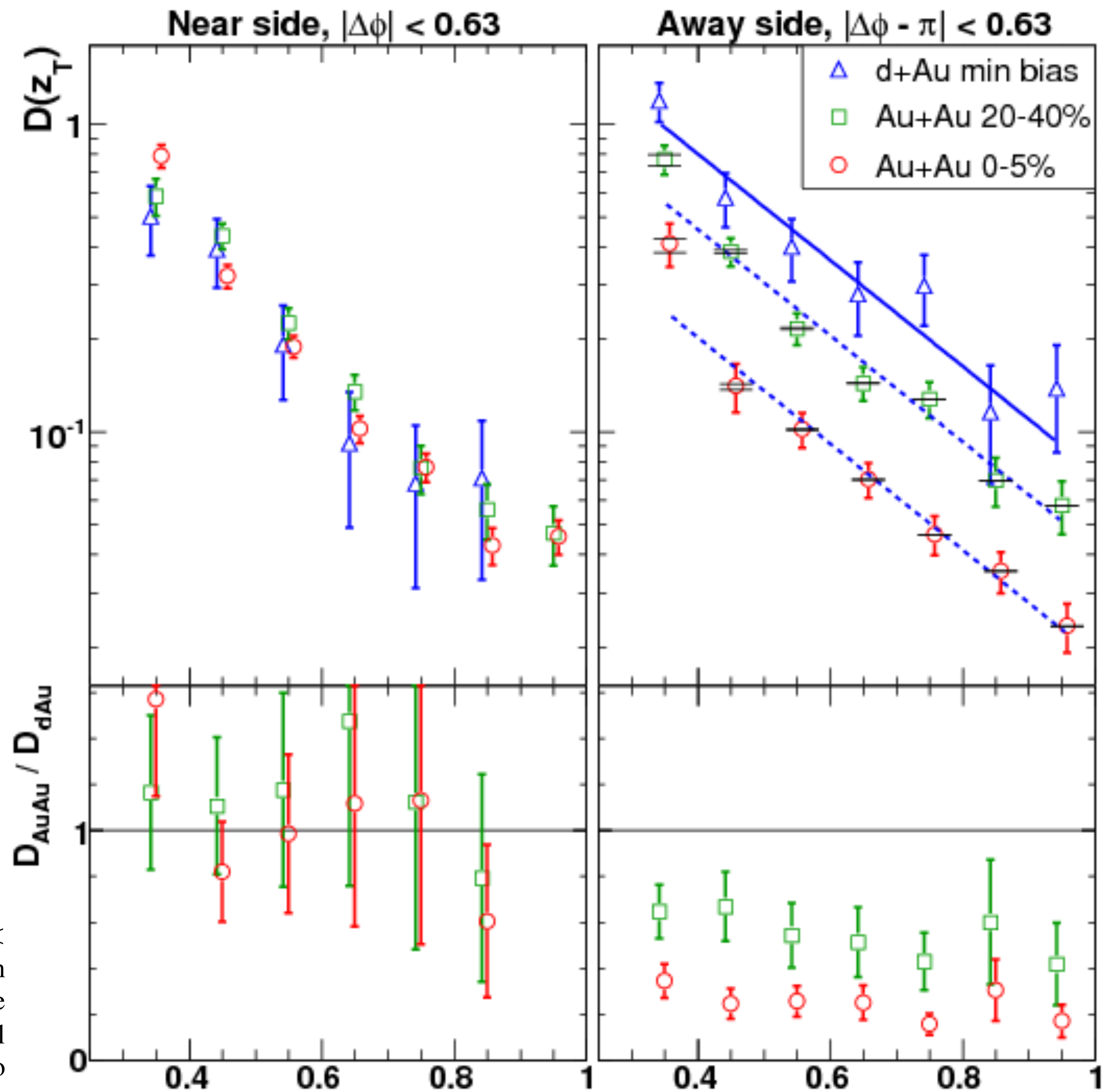


FIG. 4 (color online). Upper panels: $D(z_T)$ with $8 < p_T^{\rm trig} < 15$ GeV/c, for near- (left) and away-side (right) correlations in d + Au and Au + Au collisions at $\sqrt{s_{NN}} = 200$ GeV. The dashed and solid lines are described in text. The horizontal bars on the away side show systematic uncertainty due to background subtraction. Lower panels: Ratio of $D(z_T)$ for Au + Au relative to d + Au. The error bars are statistical in all panels.

STAR, PRL97,162301 (2006)

Near side I_{CP}

Shown for two background shape assumptions

1. v_2-only (line)

v_2 estimated as uniform extrapolation from data - thus probably an overestimate

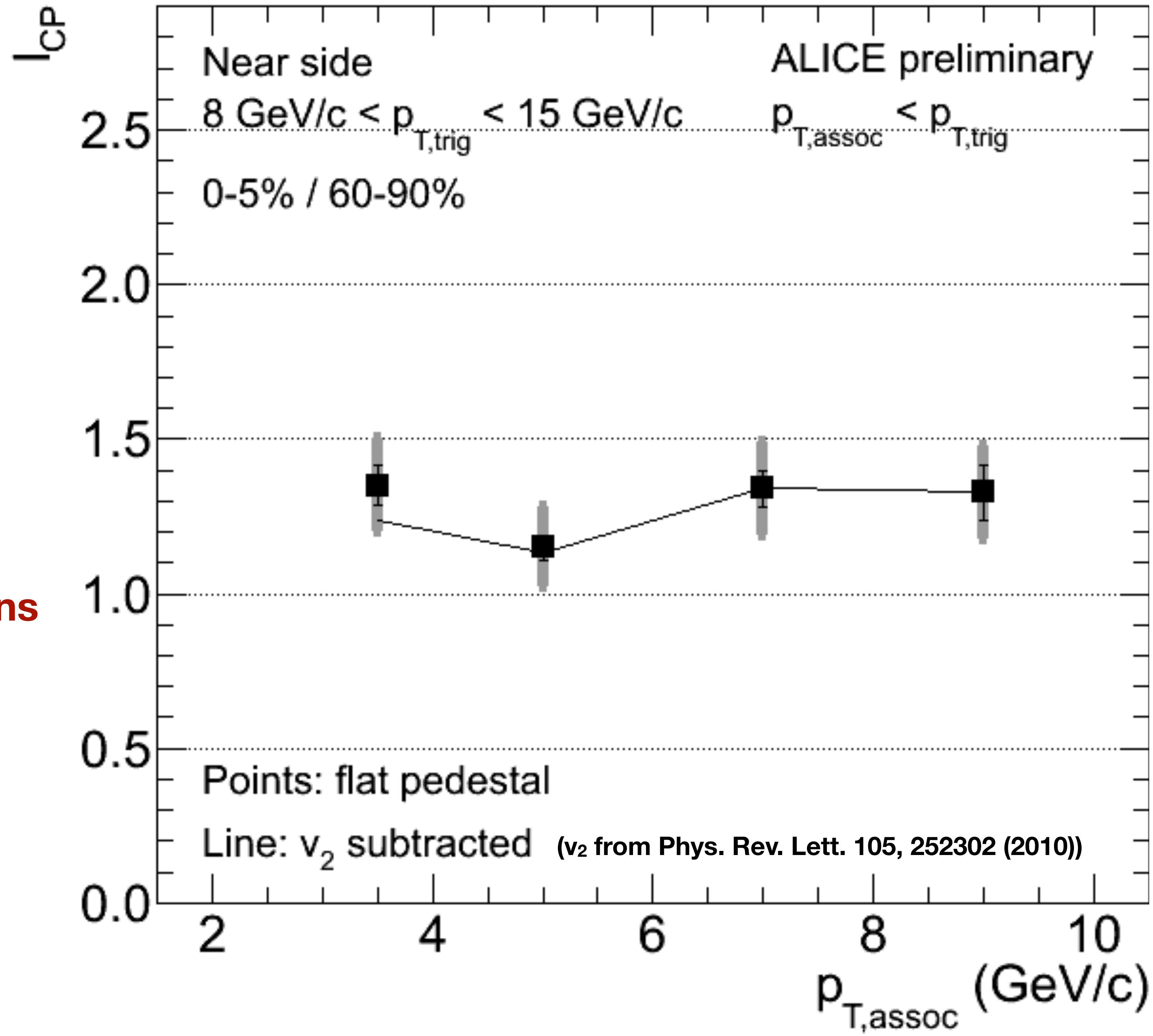
Useful especially for "historical" RHIC comparisons

2. Uniform bkg. (points)

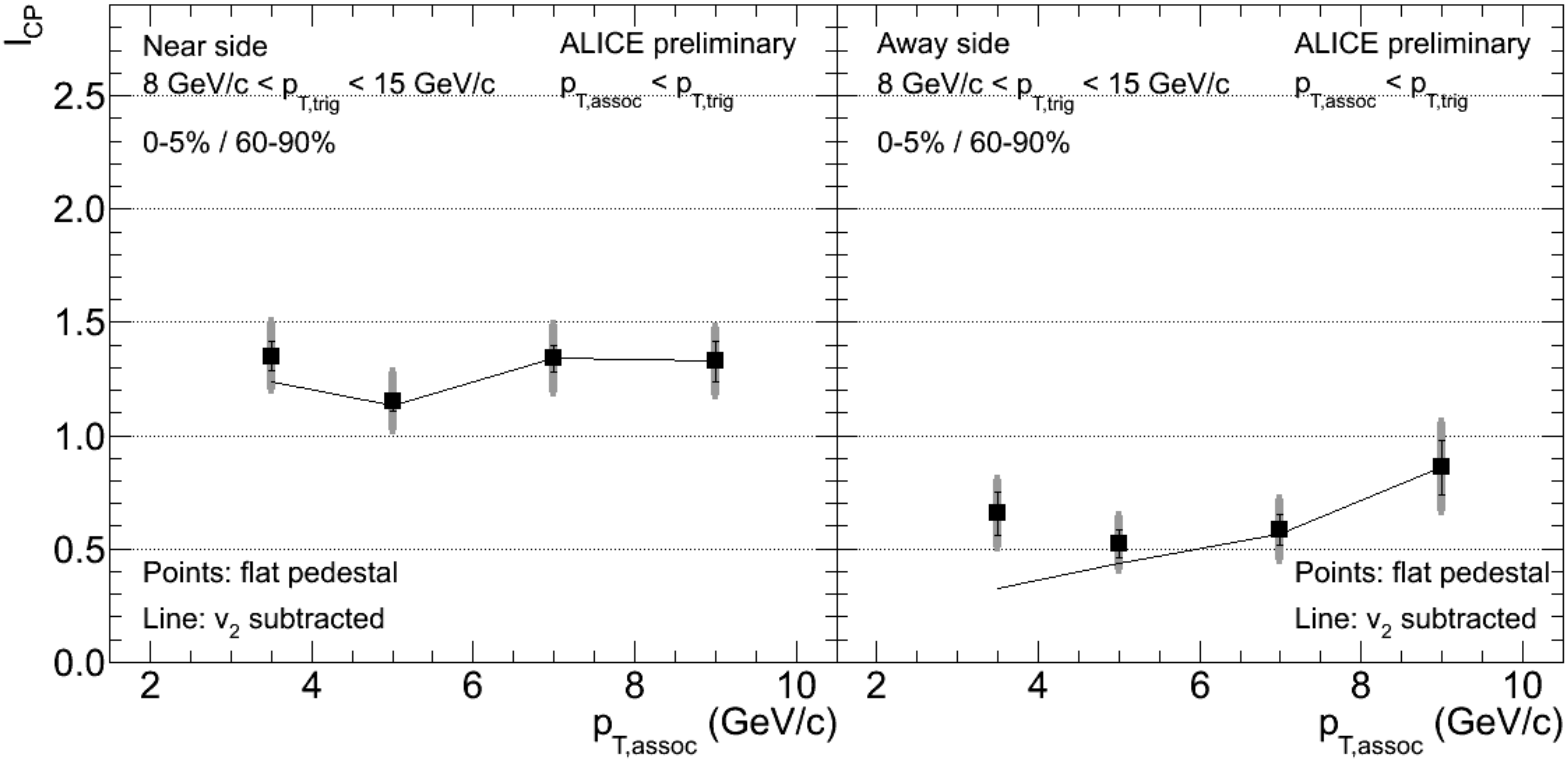
Result ~same as for (1): jet S/B is high enough that bkg. assumptions are not influential

I_{AA} ~ 1.2-1.3

Near side yield is enhanced! Interesting.



I_{CP} on near and away side



Enhancement on near side, suppression on away side

Flat or v_2-only bkg. assumptions give same results above 5 GeV

Away side I_{AA} ~ 0.6 at intermediate p_T

Note on rise at last point: $p_{T,\,trig} > p_{T,\,assoc}$ requirement in overlapping p_T bin influences kinematics: interpret with care.

Monte Carlo I_{AA} reference

In mid-March the LHC provided a few p+p days @ 2.76 TeV, but too late to use for today.

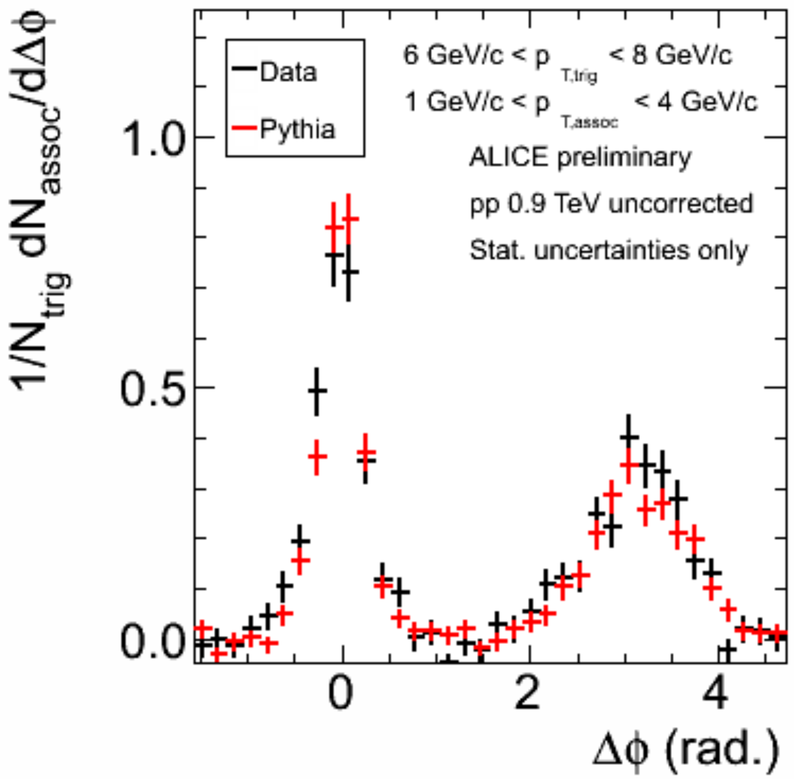
For now, we use pythia 6, Perugia-0 tune.

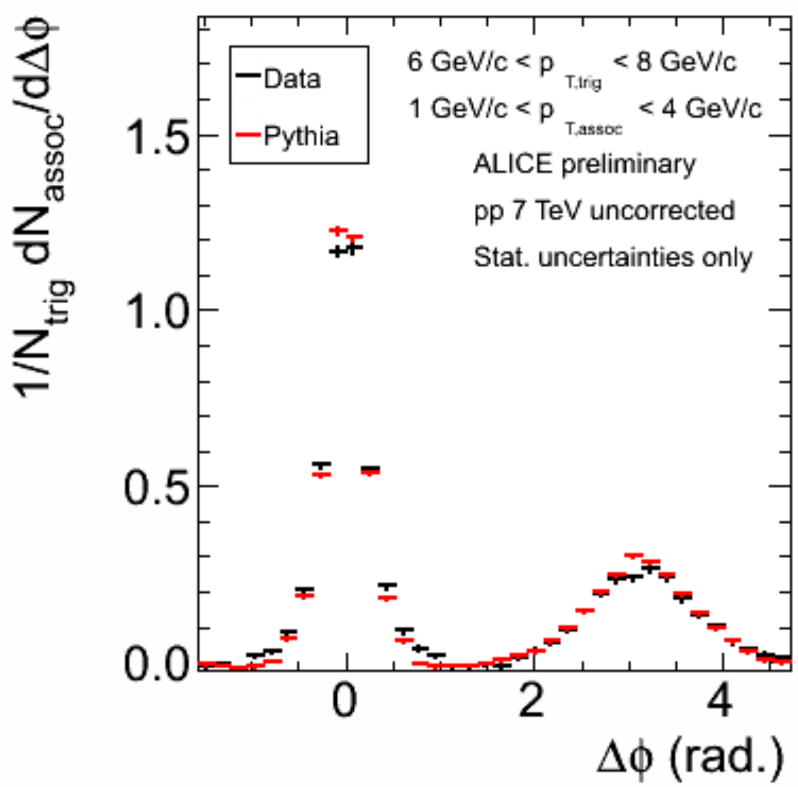
Shape agrees closely with ALICE data at 0.9 (top) and 7 TeV (below).

Normalization was slightly high; required scaling by 0.8 - 1.0 to match data.

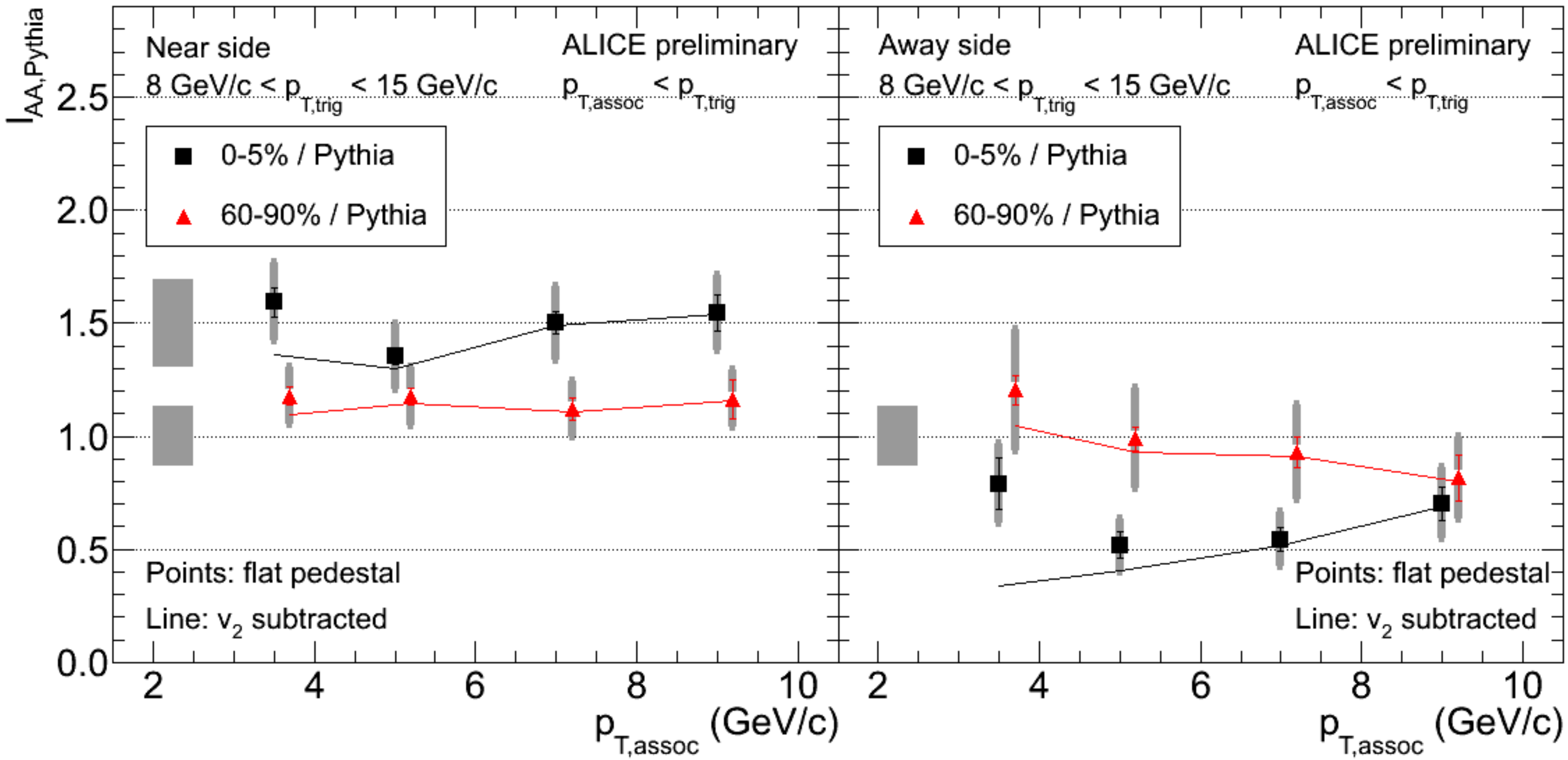
A single scaling factor was interpolated for 2.76 TeV: 0.93 ± 0.13

This is the dominant systematic for $I_{AA,\ Pythia}$





I_{AA} using pythia reference



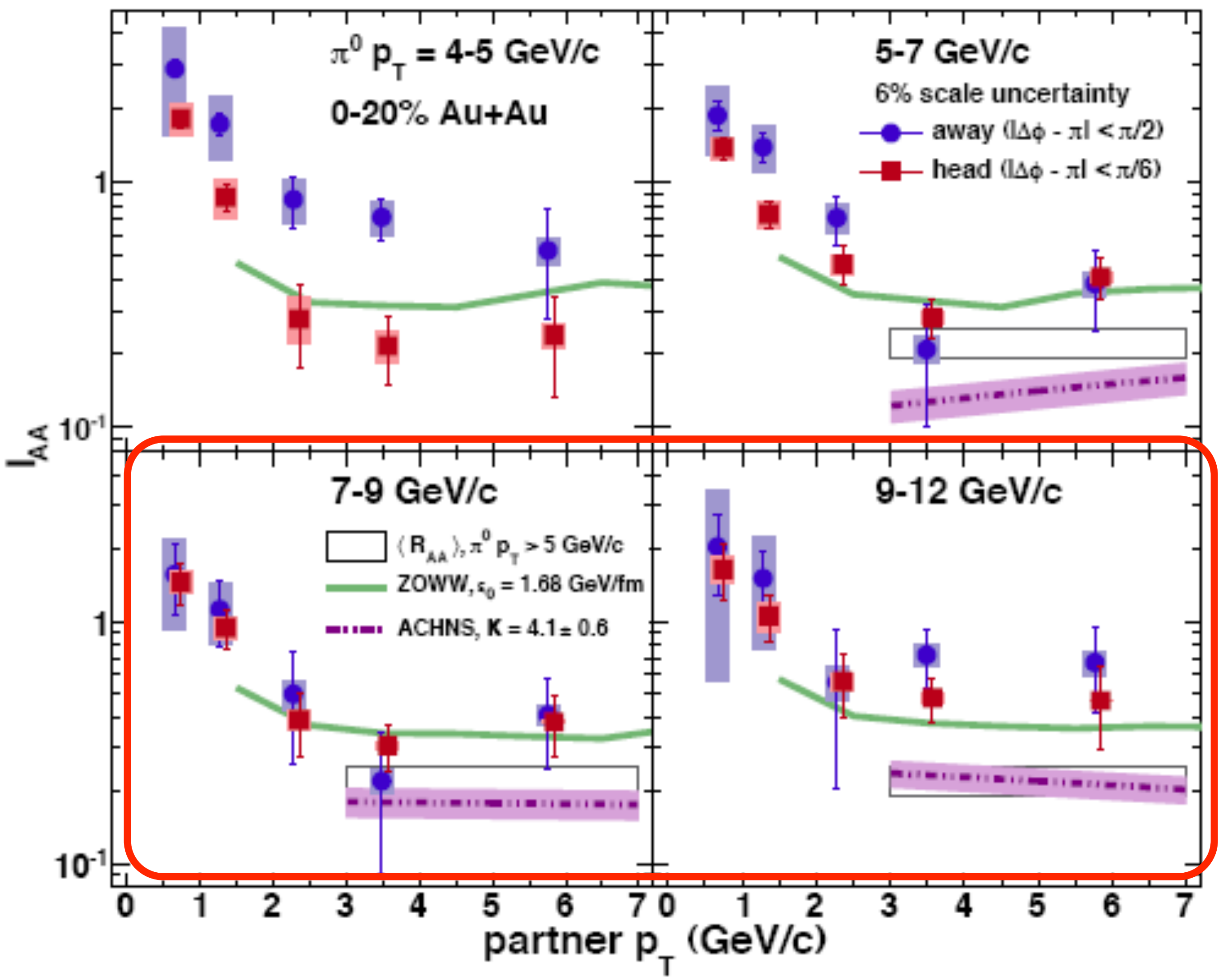
Observations

Near side yields enhanced by 1.3-1.5 for $p_{T,\,assoc}$ > 4 GeV/c in central events

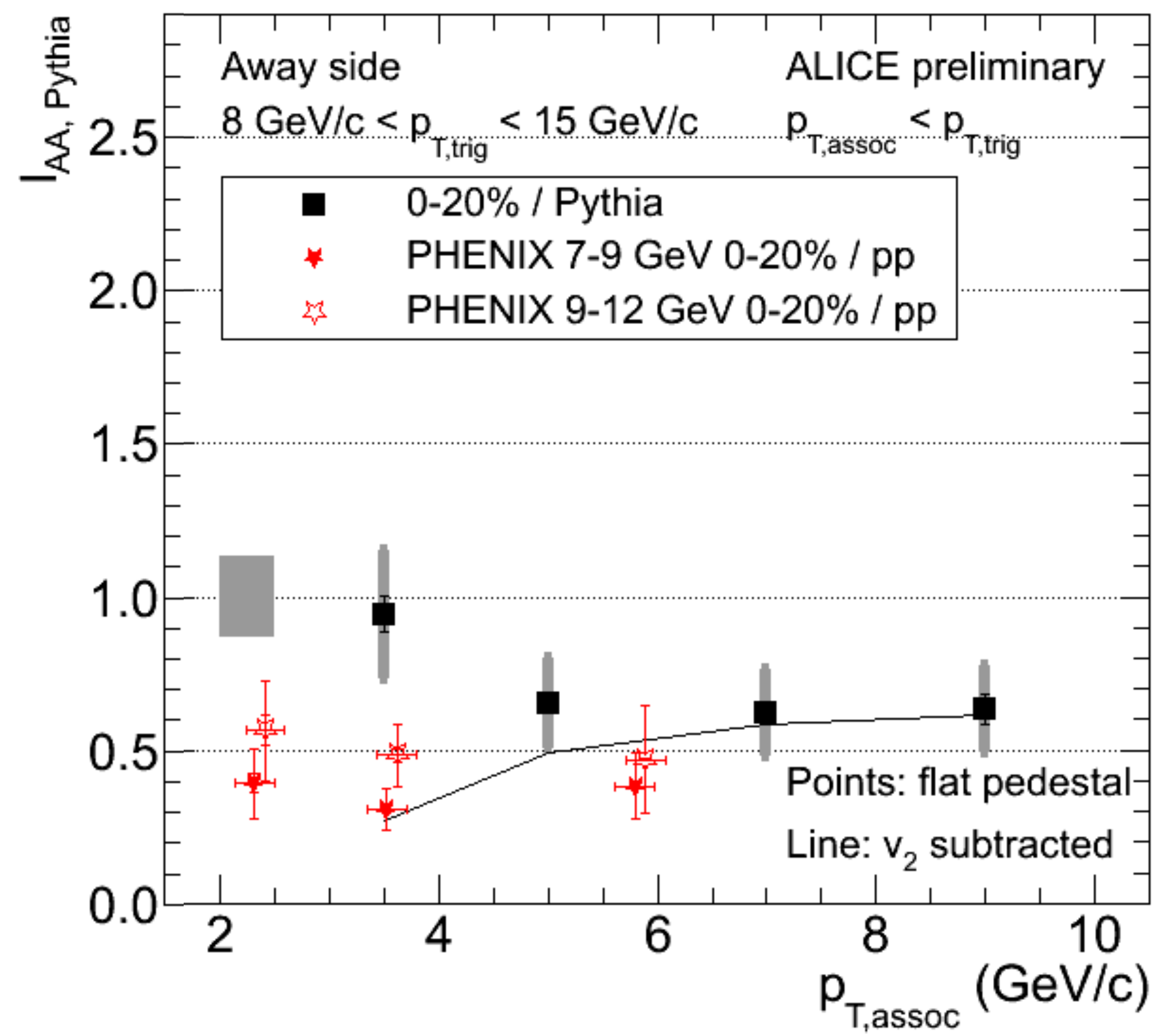
Some enhancement measured even in peripheral data

Away side 0.5-0.7 for central, ~1 for peripheral

I_{AA} vs. PHENIX I_{AA} result

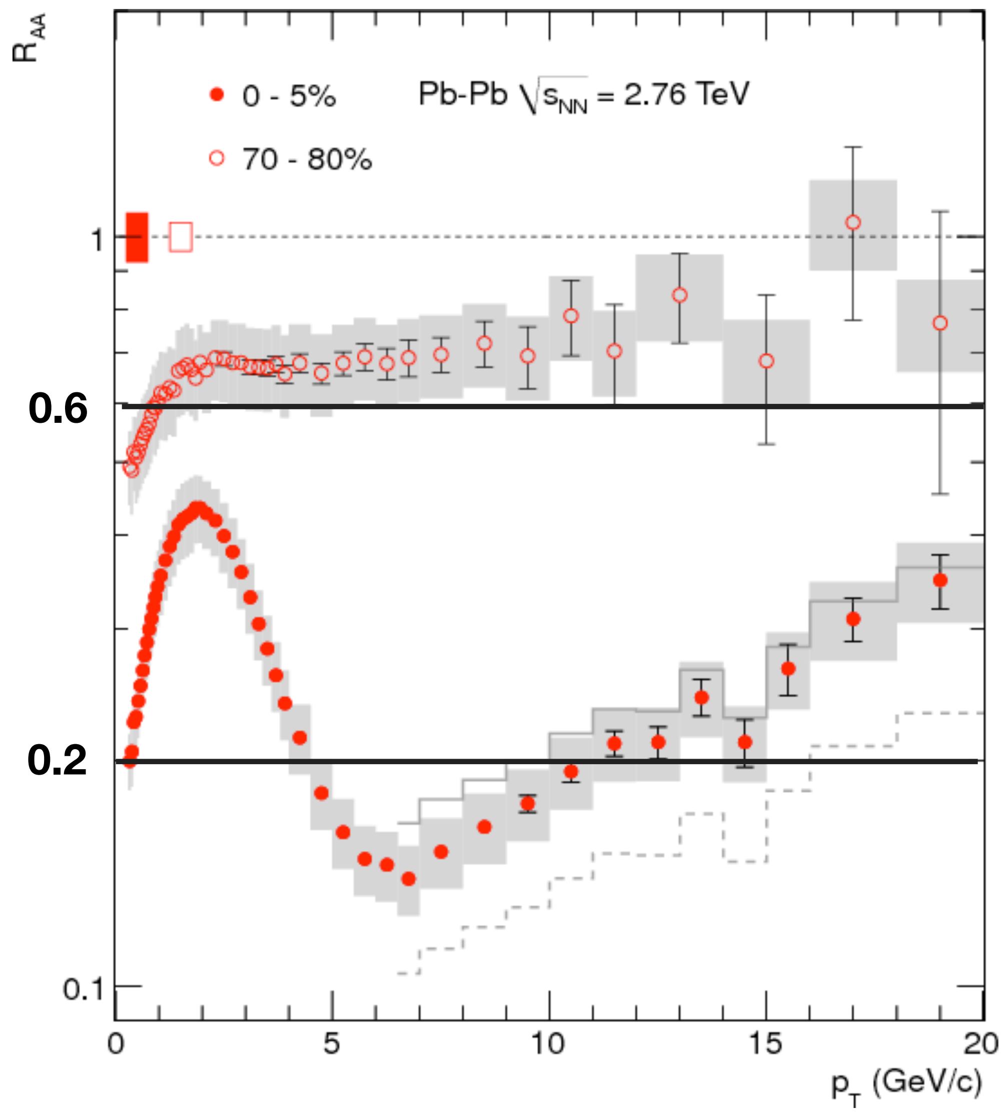


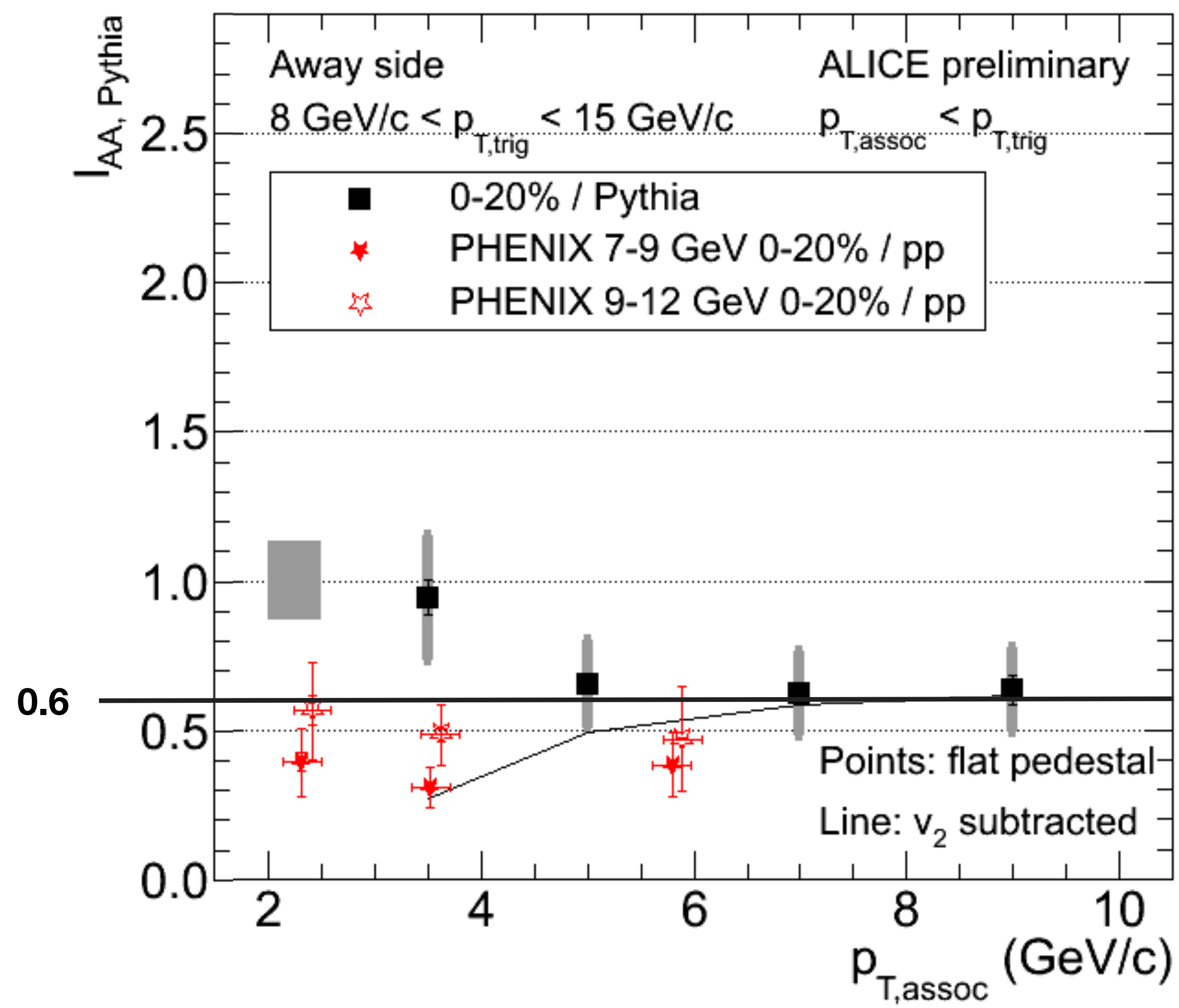
PHENIX, PRL 104, 252301 (2010)



ALICE I_{AA} is larger than PHENIX result.

I_{AA} vs. ALICE R_{AA} result





I_{AA}(0-20%) is much higher than R_{AA}(0-5%)

Looks in fact more like R_{AA}(70-80%)!

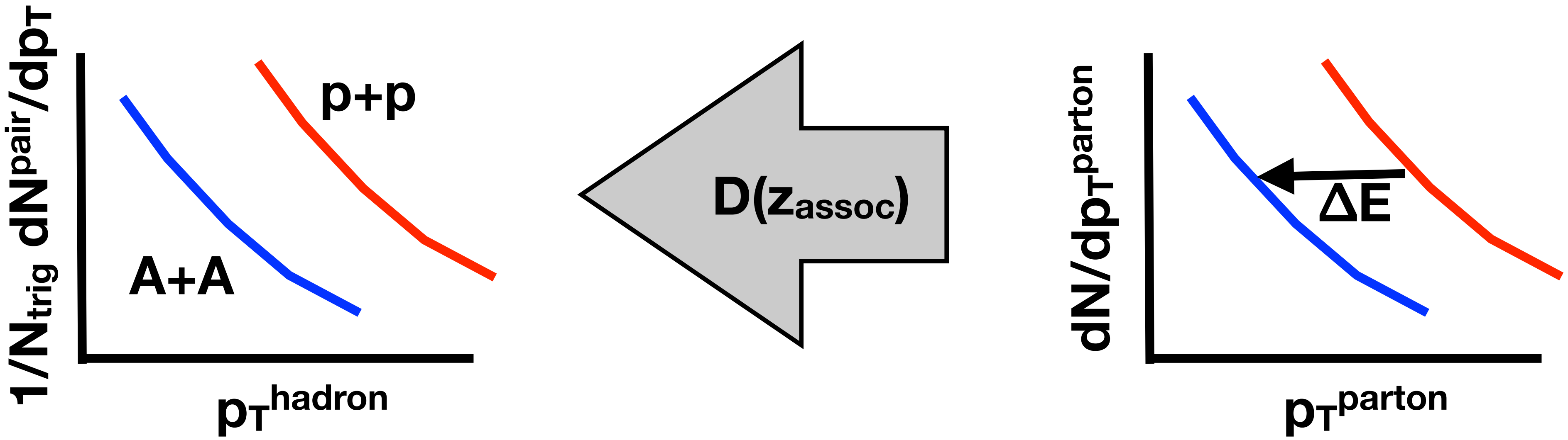
For 8-15 GeV triggers, the pT,assoc distribution is much harder than for min-bias.

Flatter spectra --> ratios closer to 1

Near-side vs. away-side I_{AA}

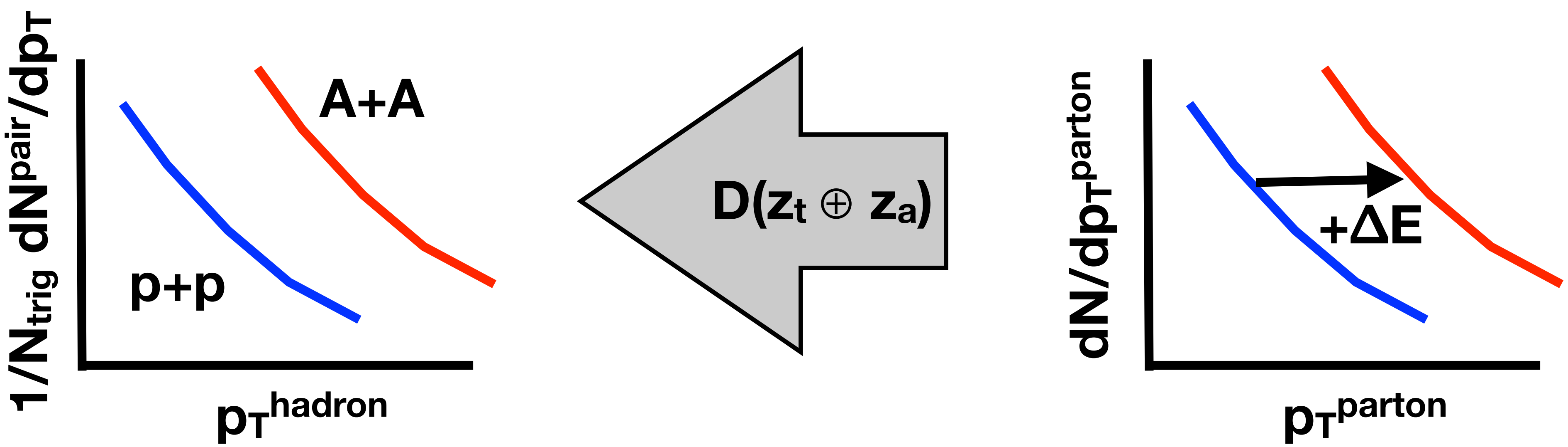
Consider partons losing ΔE, then fragmenting in vacuum.

Away side:



ΔE lowers parton <pt> ⇒ fewer pairs/trigger in A+A on away side.

Near side:



Including the trigger particle requires partons at higher initial energies.

The nontrivial near side*

If ΔE leads to $I_{AA}^{near} > 1$, then why wasn't this also seen at RHIC?

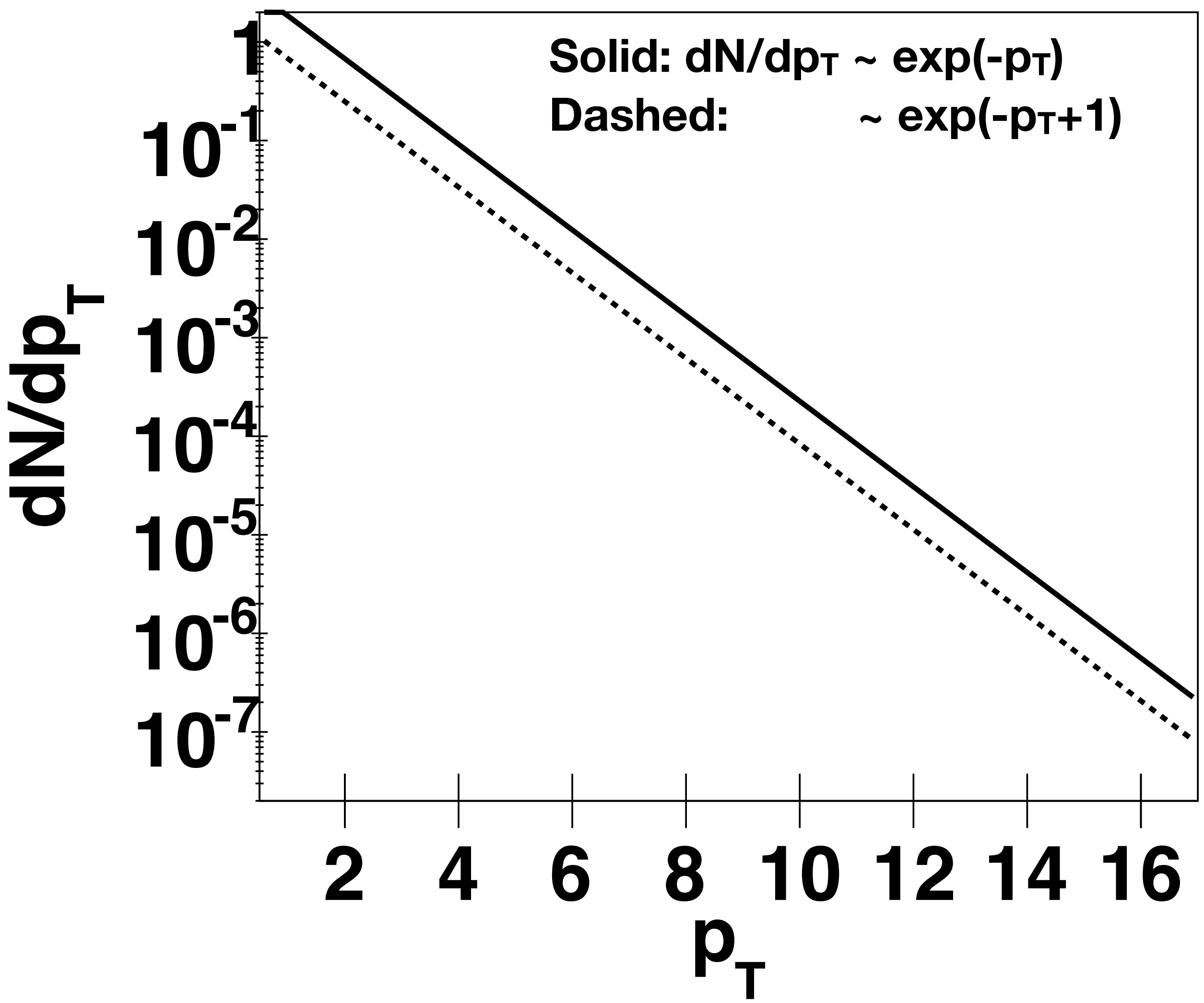
1. Phase space considerations

Steeper parton production at RHIC. There, high-pt triggers have larger z, lower assoc. yields.

2. Parton spectral shape:
Consider a fixed ΔE
(i.e. every parton loses 1 GeV)

For an exponential, the slope is unchanged. Energy loss is independent of E.

Probing different parton energy by requiring a trigger particle does not change the associated per-trigger yield.



Thus I_{AA} can be 1 even for large ΔE. Under these conditions, surface bias cannot be inferred from I_{AA}=1.

*Thanks to P. Jacobs for useful discussions on this topic

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1. Phase space considerations

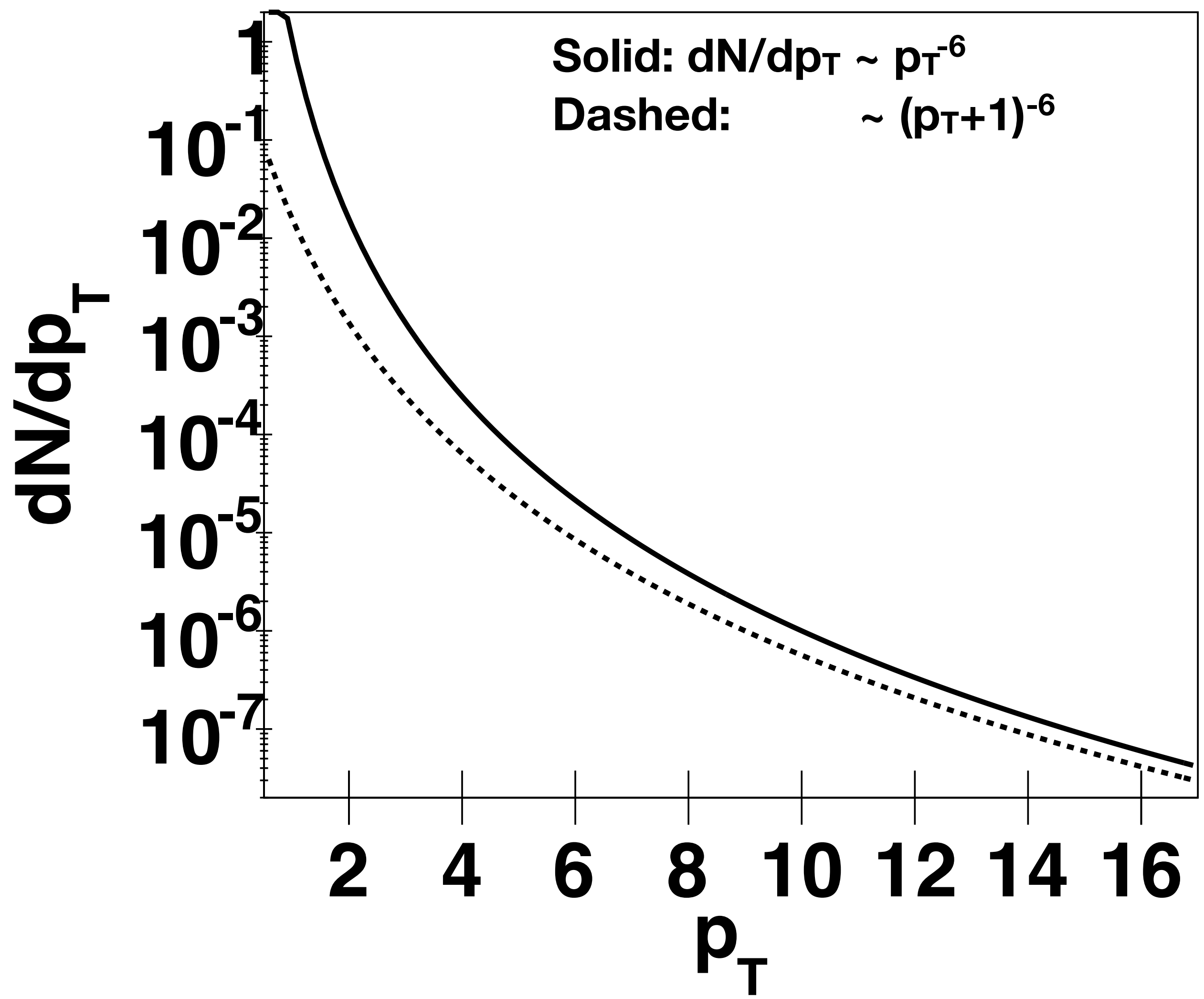
Steeper parton production at RHIC. There, high-pt triggers have larger z, lower assoc. yields.

2. Parton spectral shape:
Consider a fixed ΔE
(i.e. every parton loses 1 GeV)

For a power law, the slope becomes flatter.

If phase space permits, the trigger requirement can lead to increased per-trigger associated yield.

Thus I_{AA} can be > 1.



*Thanks to P. Jacobs for useful discussions on this topic

The nontrivial near side*

Near-side fragmentation

Shower evolution for two-hadron final state is difficult theoretically.

I know of no near side I_{AA} / I_{CP} calculations in the literature.

Perhaps some theorists are interested in taking this on?

*Thanks to P. Jacobs for useful discussions on this topic

Summary

Near side

Significant enhancement observed at LHC, but not RHIC - different parent parton distribution at LHC?

Away side

Significant quenching, but I_{AA} larger than at RHIC

Open questions

Can parton energy loss be accessed from near-side observables?

Near-side fragmentation complicated: can it be calculated?

More to come

Stay tuned for QM11

Thanks!

Extras

Energy loss and spectral ratios

Trends in IAA, RAA, ICP, etc. depend strongly on source shapes

A power-law example: use $A/(p_T - \Delta p_T)^n$ to check 3 scenarios:

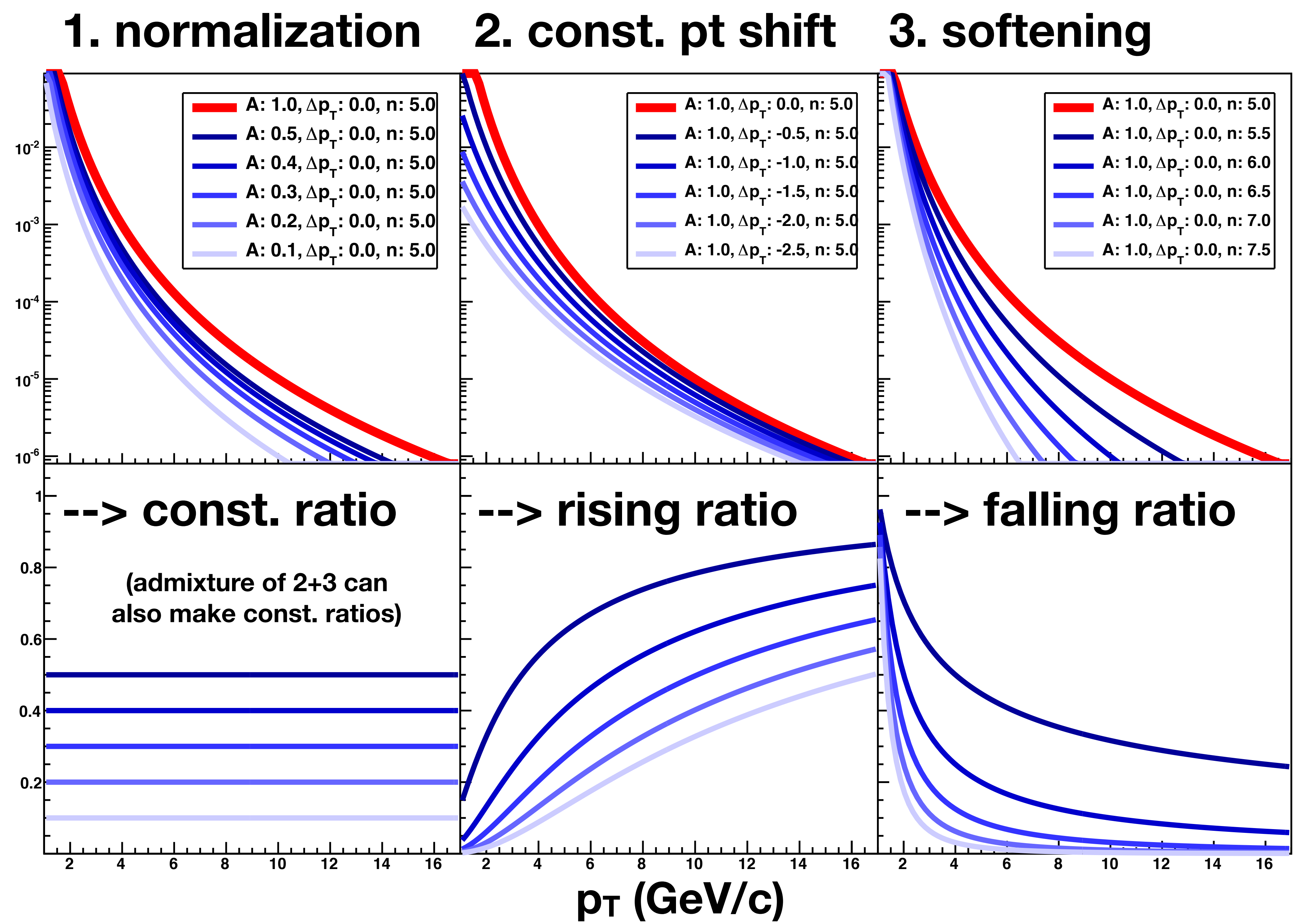
1. constant yield loss - reduce normalization A (i.e. all-or-nothing “punch-thru” E-loss fluctuations)
2. constant per-particle energy loss - leftward shift by Δp_T
3. softening of spectra - increase n

Top:
Red curve - “p+p” reference
Blue curves - “A+A” spectra

Bottom:
Ratio of blue/red

Ratio shape depends on nature of energy loss

IAA,RAA have different source shapes
comparison constrains models!
arXiv:1101.0290v1

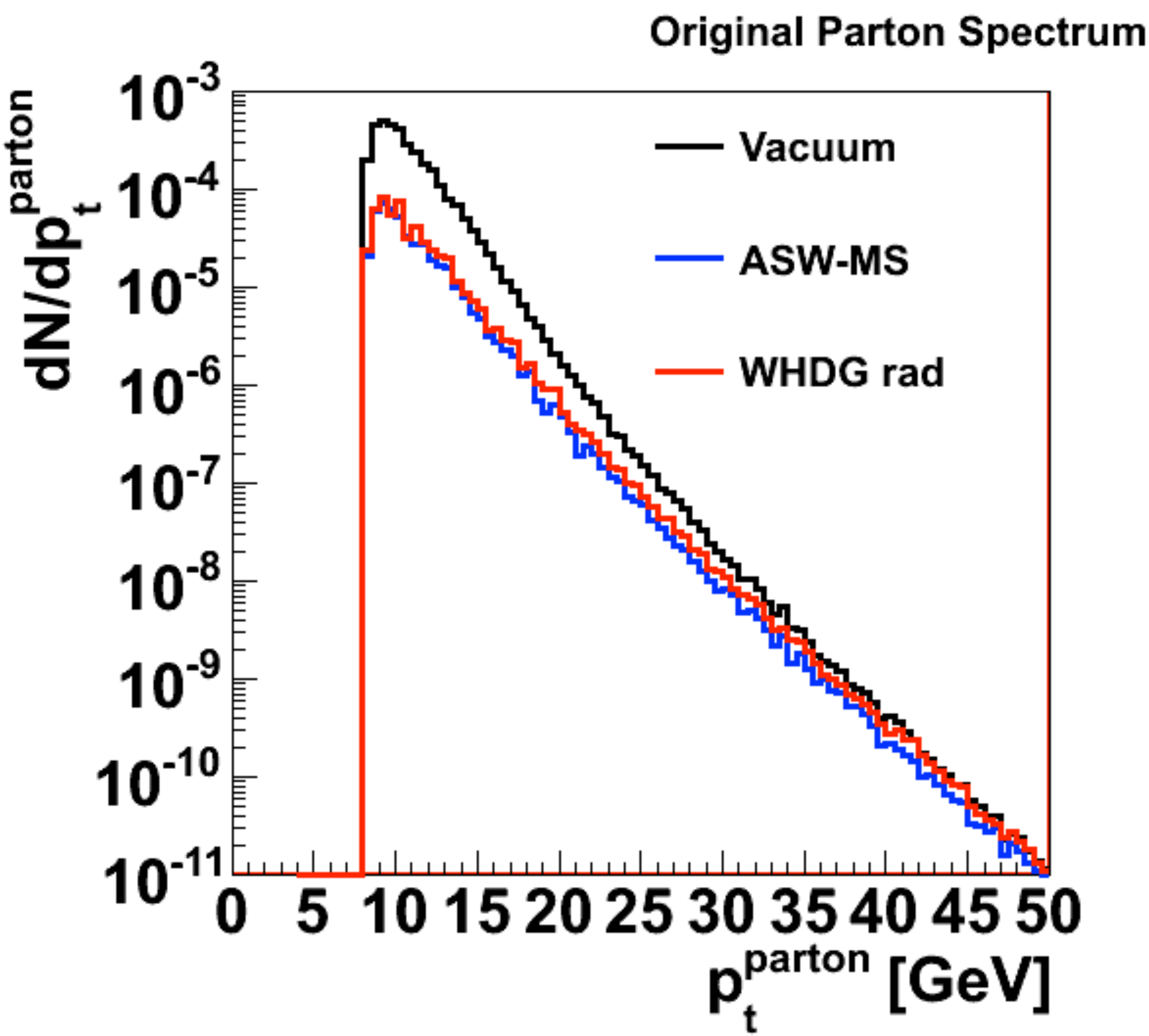


The slope of $I_{AA}^{away\text{-}side}$

Recoil-side parent parton distribution for leading hadrons

trigger p_T 8-15 GeV/c

M. Verweij - private communication



Systematic Uncertainties

- Detector efficiency and two-track effects
- Different detectors for centrality determination
- p_T resolution
  - Fold associated p_T distribution with momentum resolution
- Different pedestal determination schemes
- Integration window (between ±0.5 rad. and ±0.9 rad.)

Detector efficiency	5-8%
Centrality selection	2-8%
p_T resolution	3%
Pedestal calculation	7-20%
Integration window	0-3%

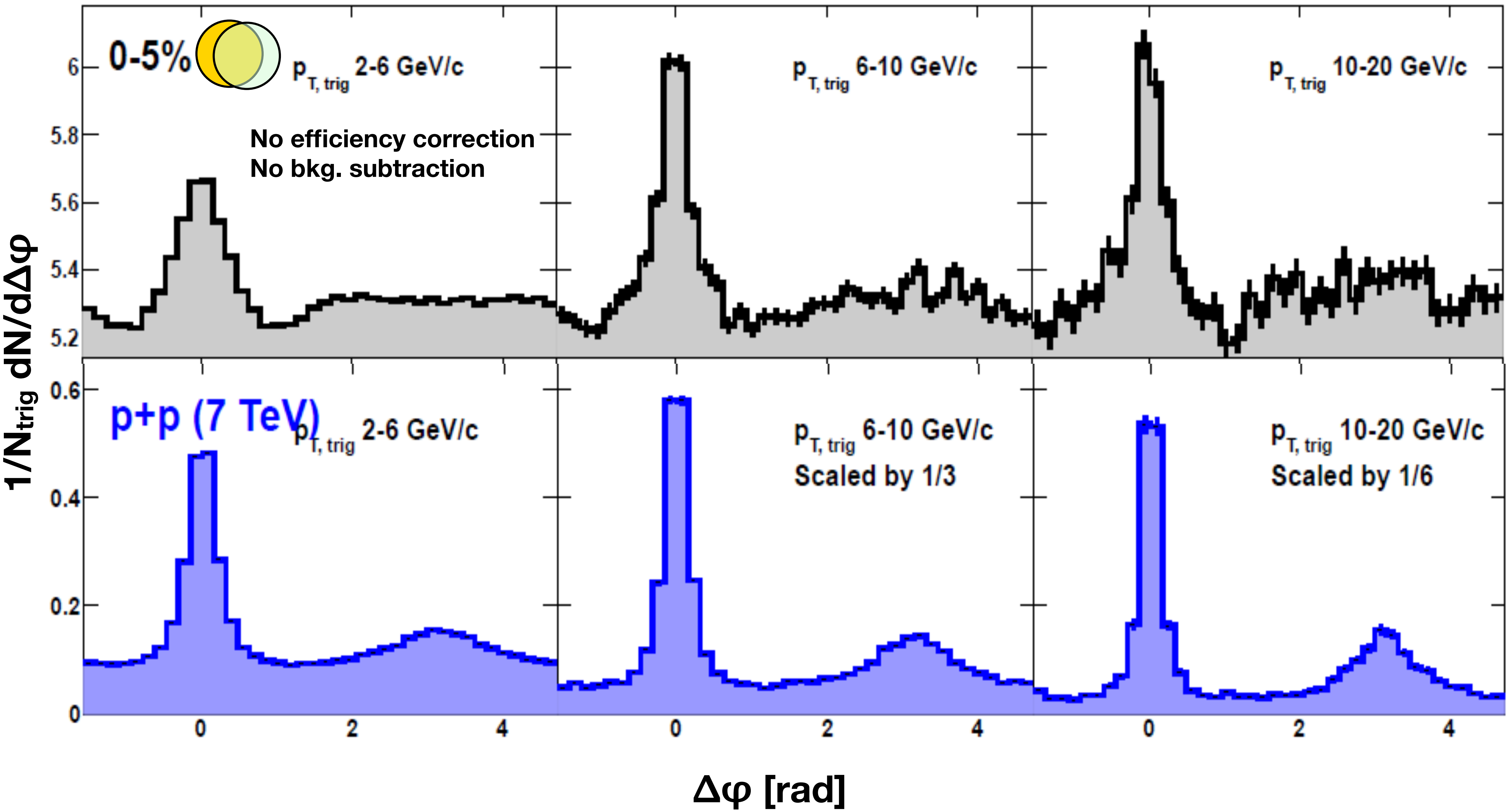
Ranges indicate different values for $I_{CP}/I_{AA,Pythia}$ and near/away side

Azimuthal projections

Central Pb+Pb and 7 TeV p+p ($p_{T,assoc.}$ 2-6 GeV/c)

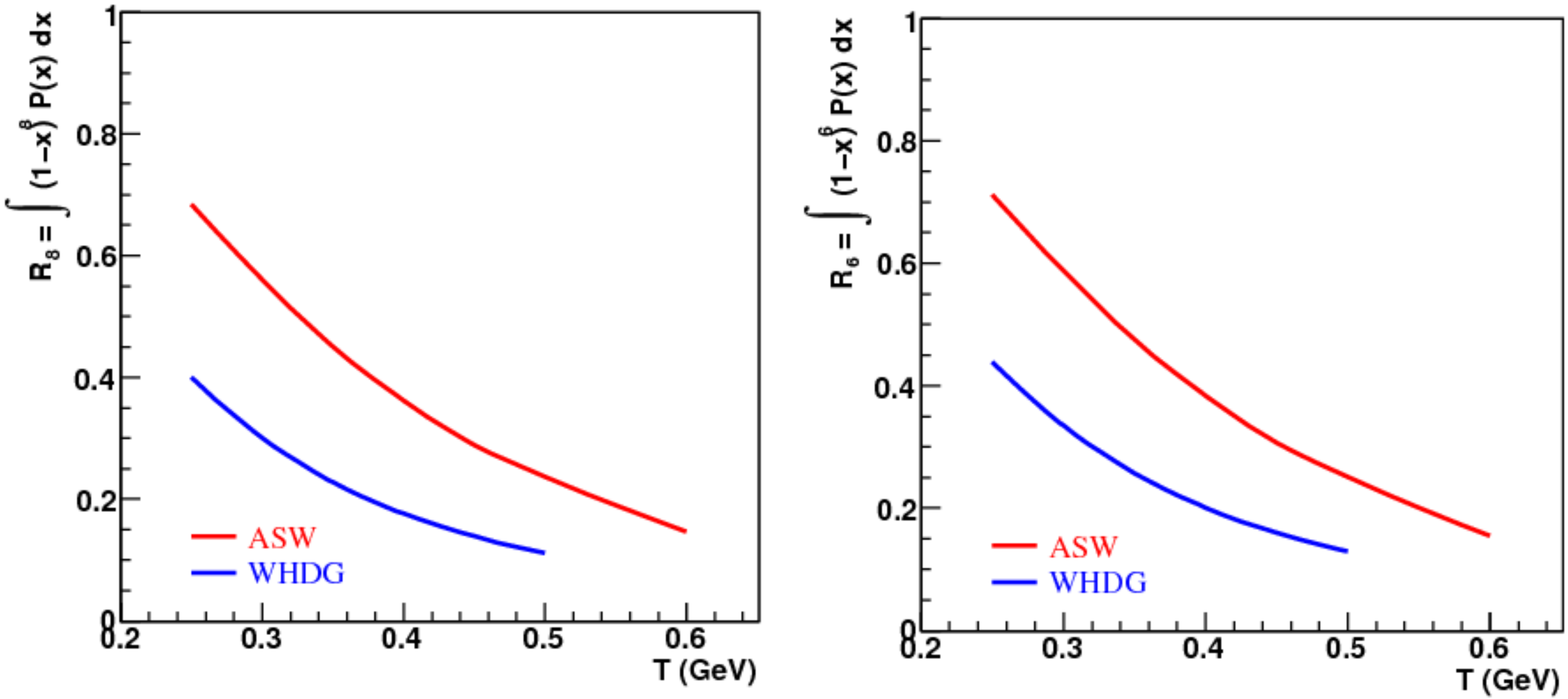
From an early subset of Pb+Pb data (~4M events)

Broadened away side at lower pt, indistinct away-side peak at high pt



R_{AA} insensitive to n

RHIC: n = 8 LHC: n = 6



p_T^{-6} instead of p_T^{-8} spectrum has only small effect on R_{AA}

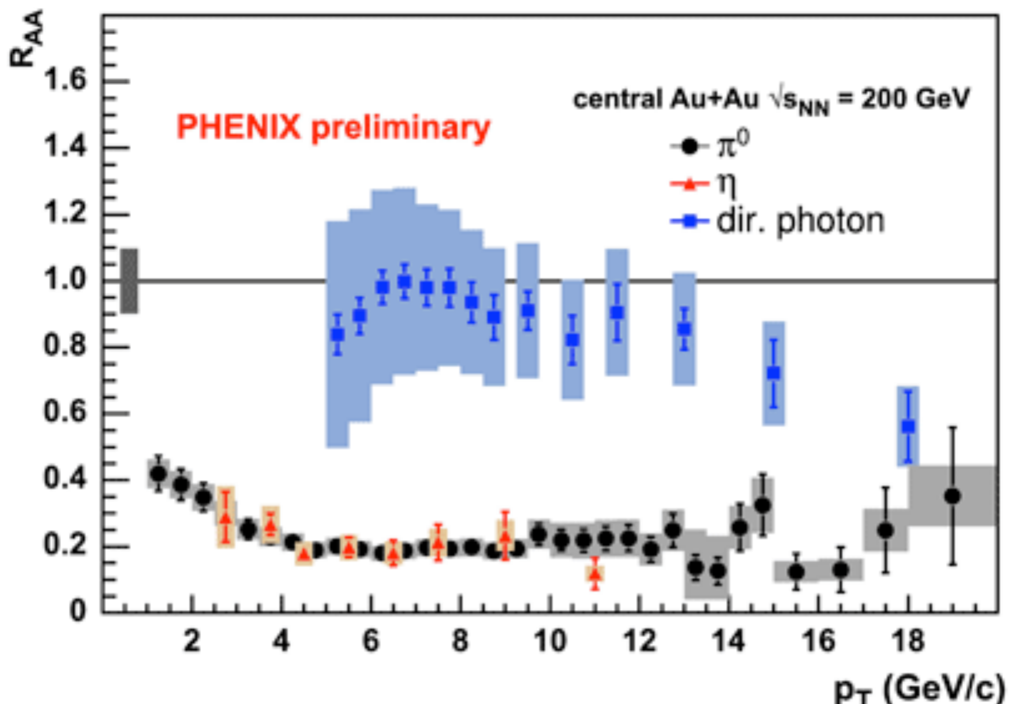
$R_8 \approx R_6$

Slide from M. Van Leeuwen

Suppression at RHIC vs. LHC

PHENIX RAA:

~flat at 0.2



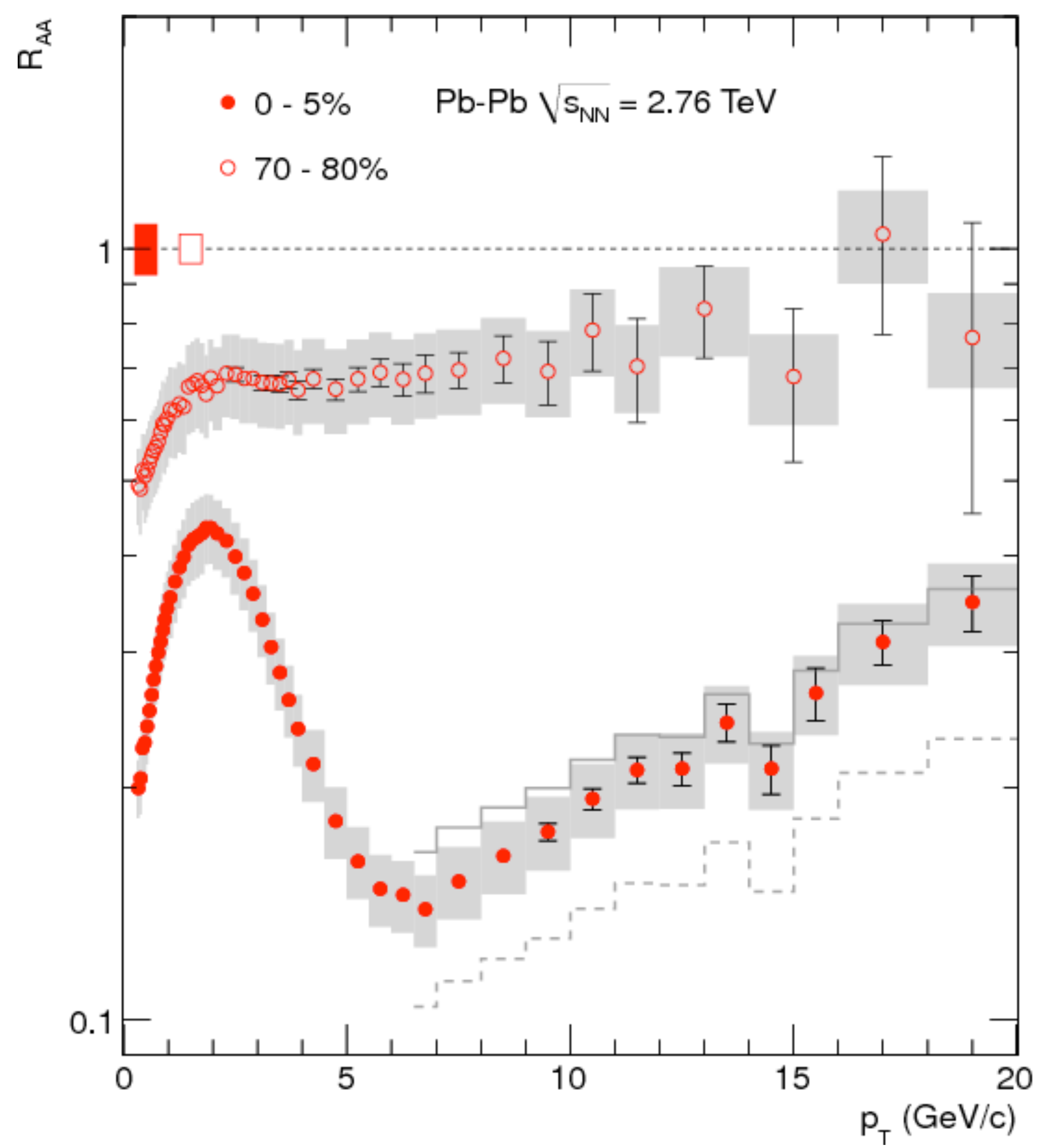
ALICE RAA:

sharp rise above 6 GeV

Caveat:

Identified mesons at PHENIX, non-PIDed hadrons in ALICE.

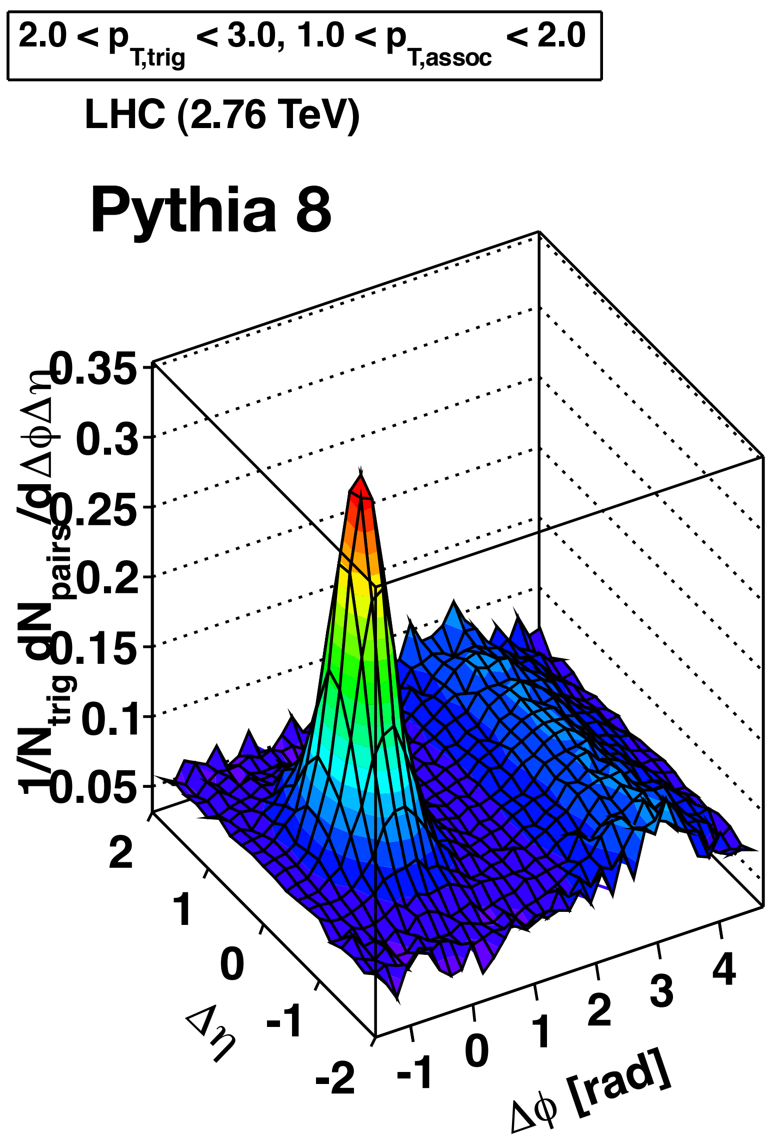
ALICE arXiv:1012.1004v1

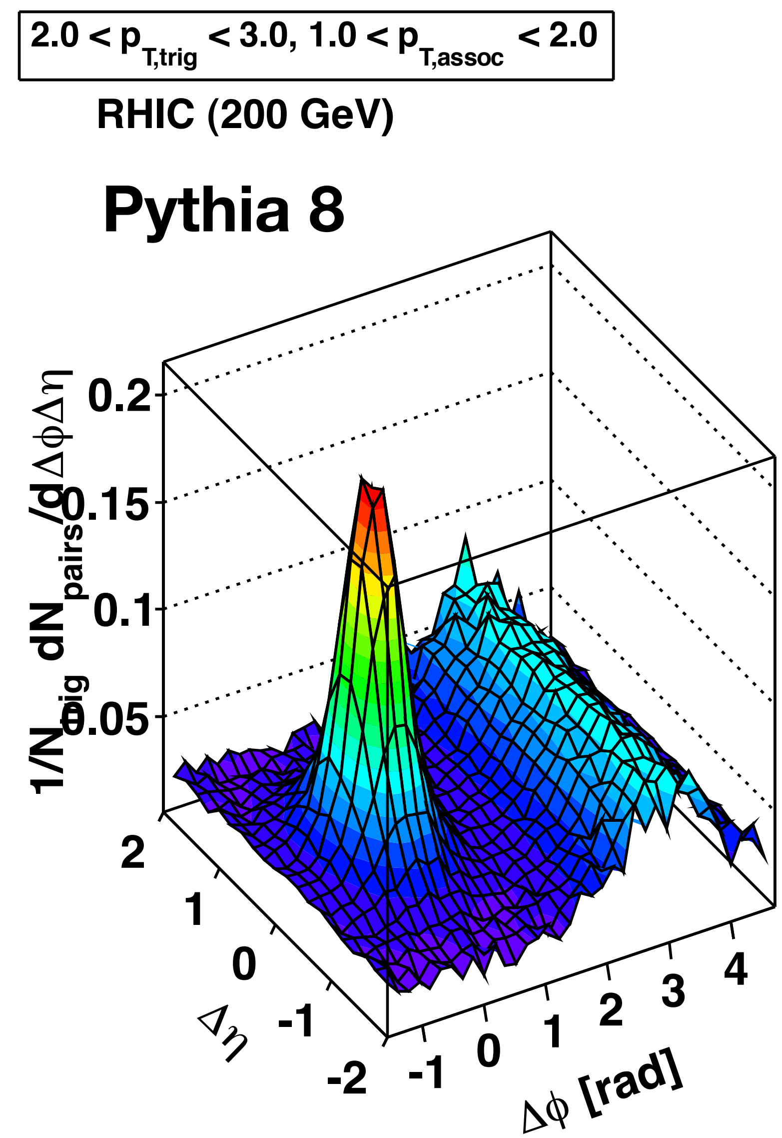


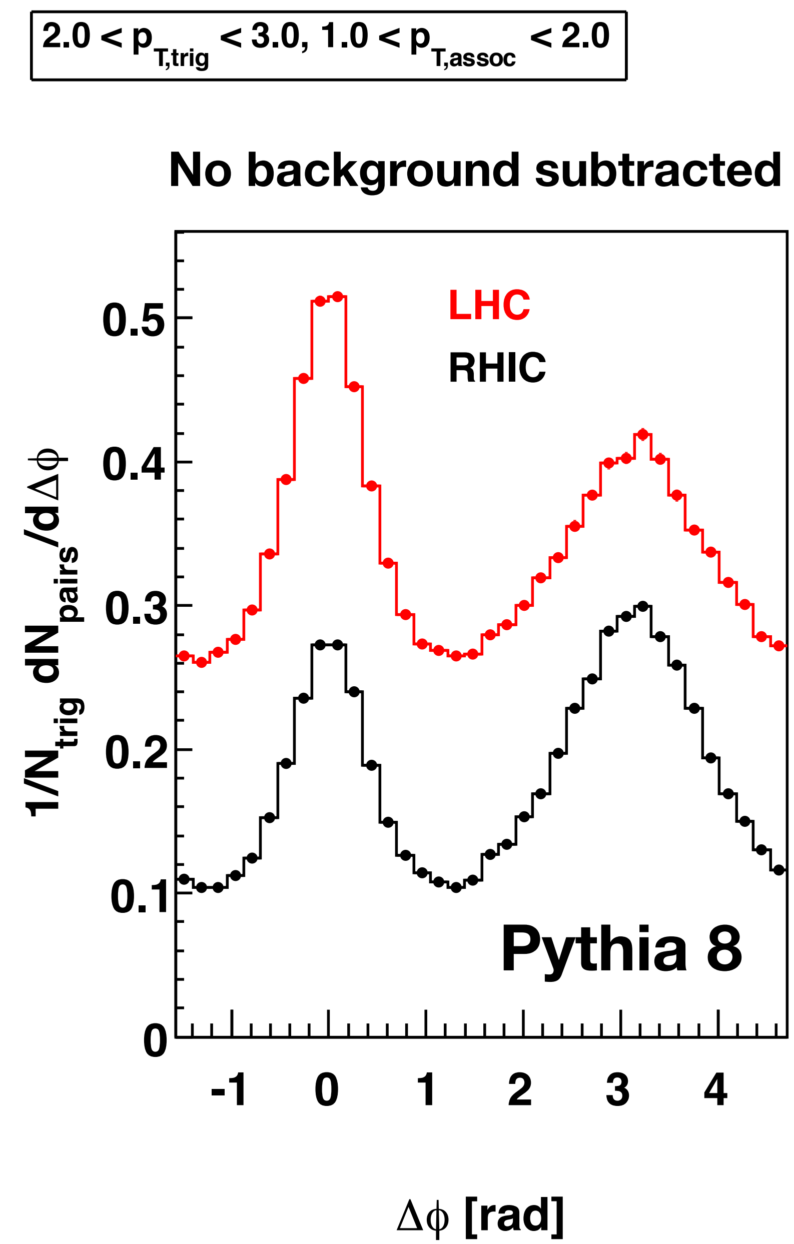
Low pt: large uncorrelated component

At Low pt, the LHC produces a much higher combinatorial background than at 200 GeV.

More independent hard scatterings per event, stronger NLO effects







Intermediate to high pt

The away side yield is comparable between the two energies, but the near side yield is much larger.

Also, away-side jet is broader (kt effects and radiation)