A Large Ion Collider Experiment

European Organisation for Nuclear Research

Yale University

Dihadron correlations at RHIC and the LHC
with an update from
the ALICE experiment

Andrew Adare

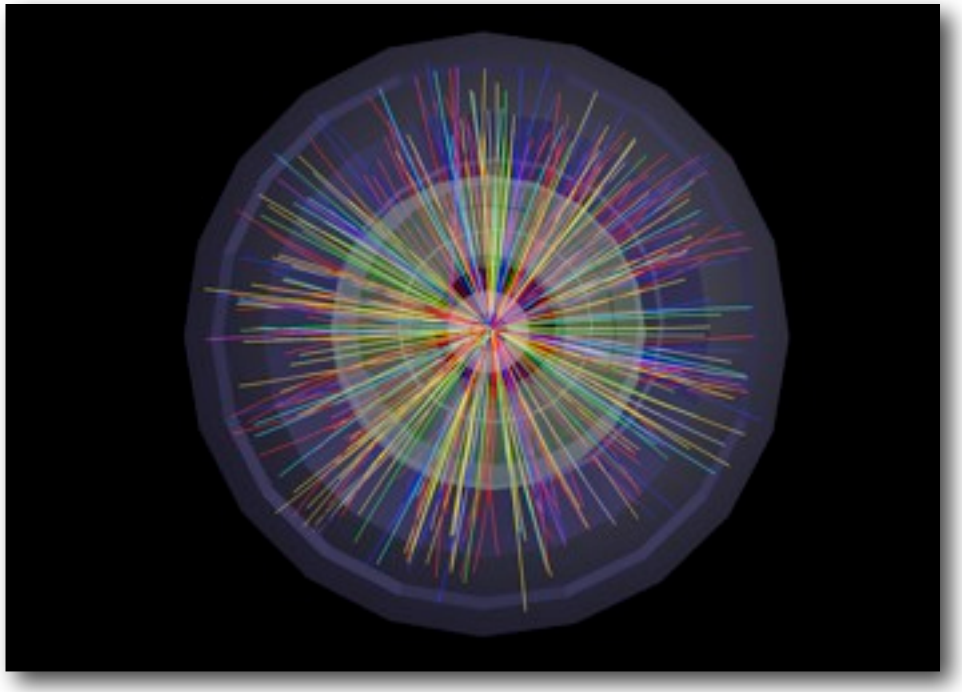
Yale University

on behalf of

The ALICE collaboration

27th Winter Workshop on Nuclear Dynamics

Tuesday, 8 February 2011

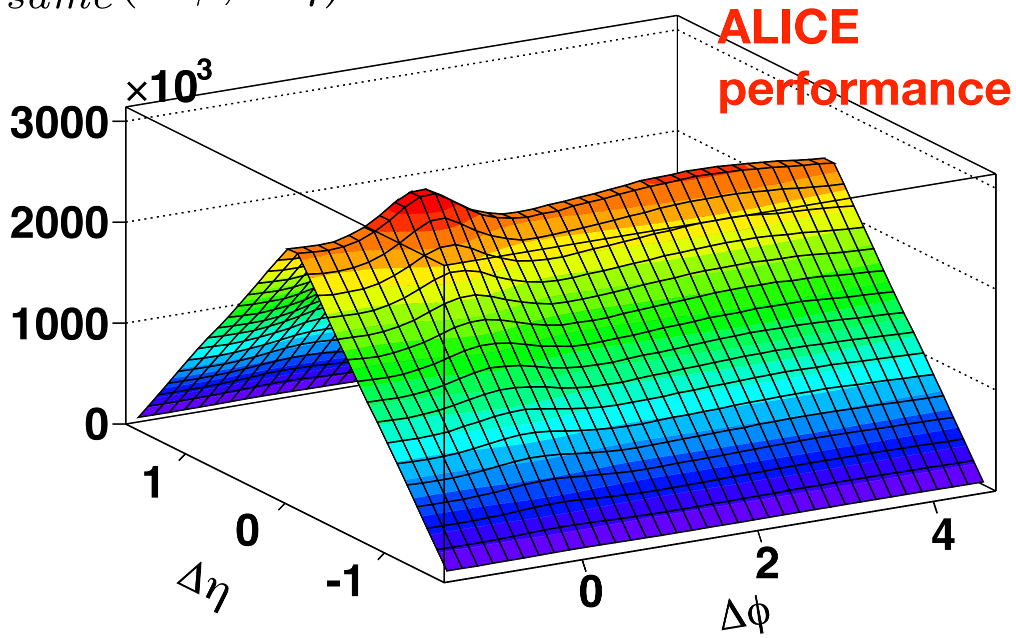


Two-particle correlations

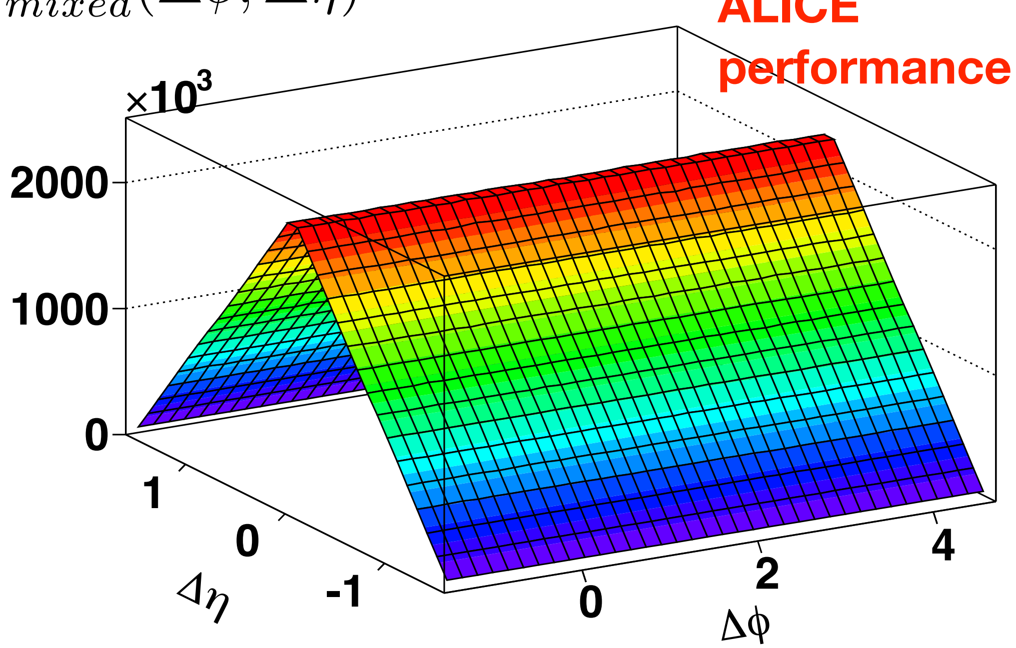
Finding patterns in violent nuclear collisions

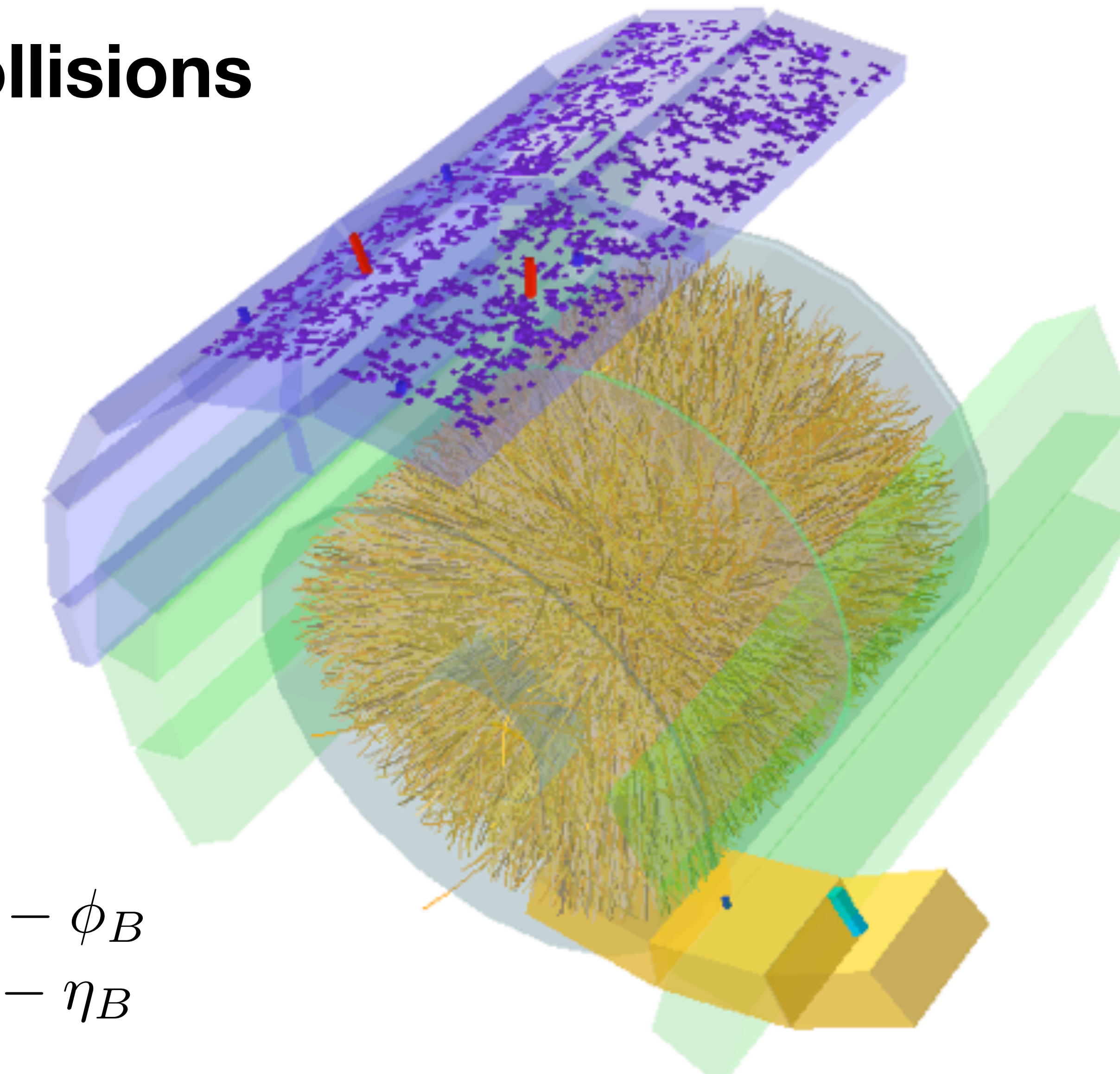
This talk: triggered correlations

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



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





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

Ratio is the correlation function:

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

Primary physics topics

Diverse range of accessible physics

High momentum

Radiative and collisional parton energy loss

Di-jets in a new kinematic frontier: broadening, suppression

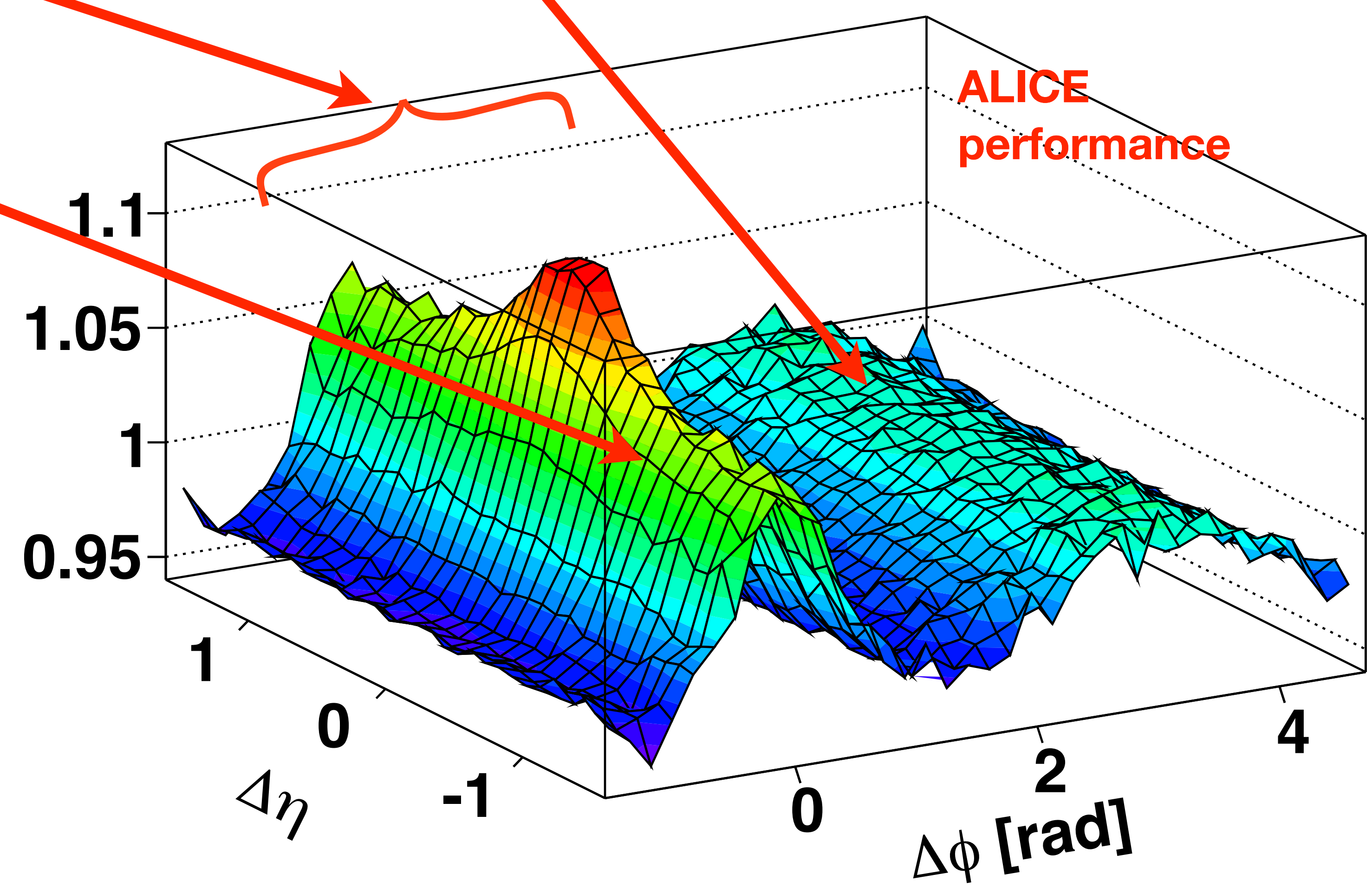
Intermediate and low momentum

Bulk and transport properties

Initial-state conditions

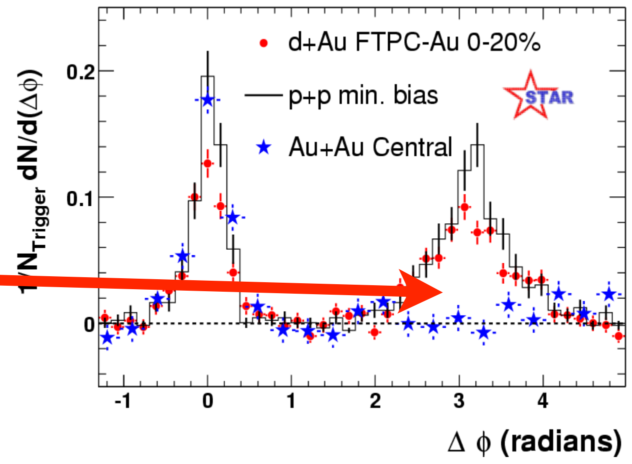
Ridge properties & evolution

Hydrodynamics vs. quenching

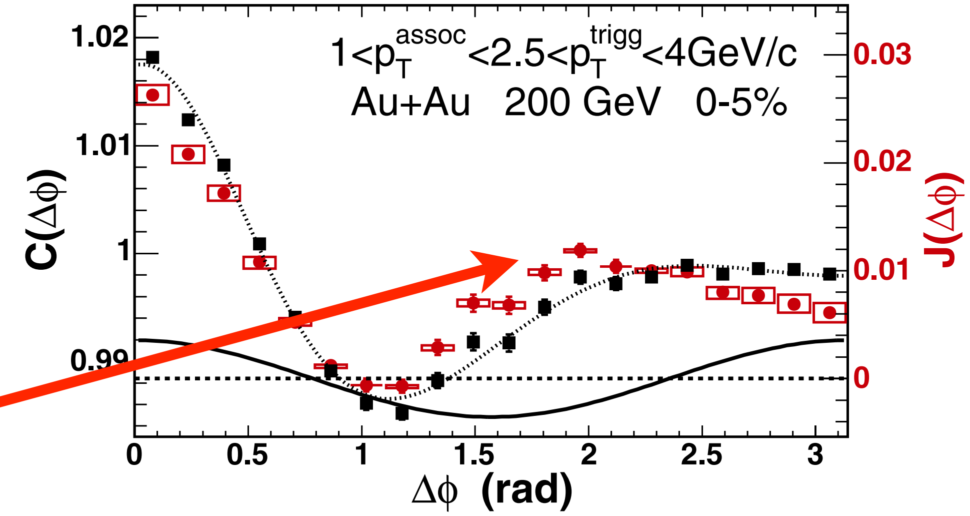


Triggered Correlations at RHIC

A few milestones*



PRL 97, 052301 (2006), PRL 98, 232302 (2007)



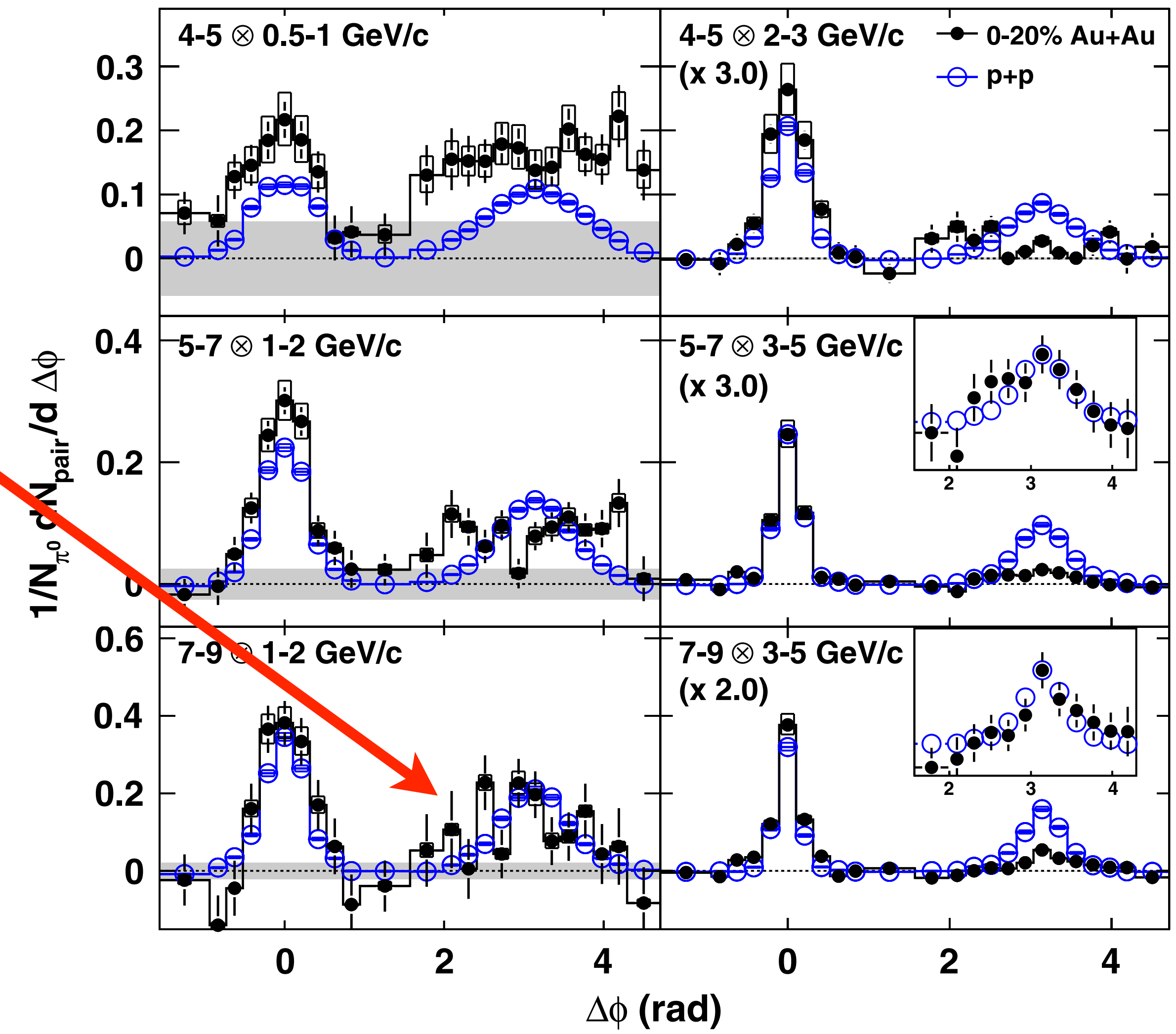
2001 - Jet quenching!

Unexpectedly large suppression

2004 - Away-side shape modification

v_2 + ZYAM paradigm: the "Mach cone era"

PRL 104, 252301 (2010)



2008-10 - Pushing to higher pt

No obvious mach cone for high $p_{T,trig}$ x low $p_{T,assoc}$?

2010 - The v_n revolution (?)

Flow/nonflow decomposition remains an unsolved problem

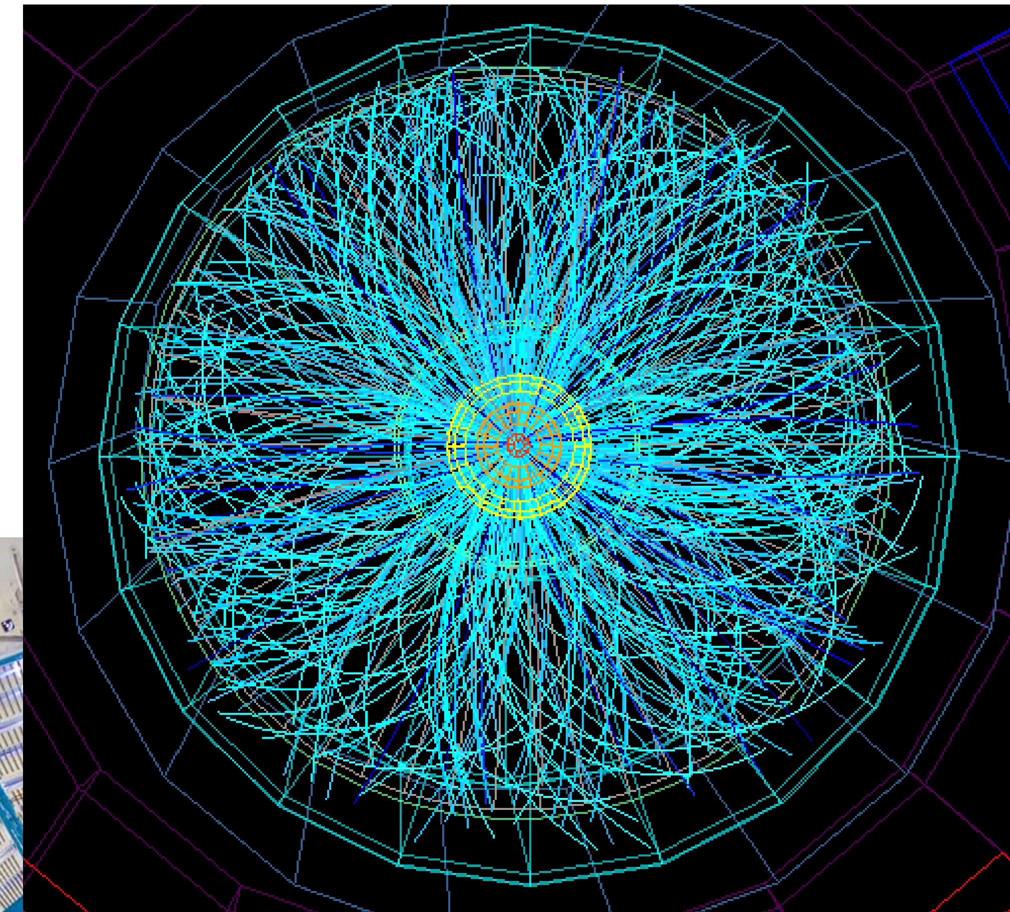
*unapologetically biased & incomplete.

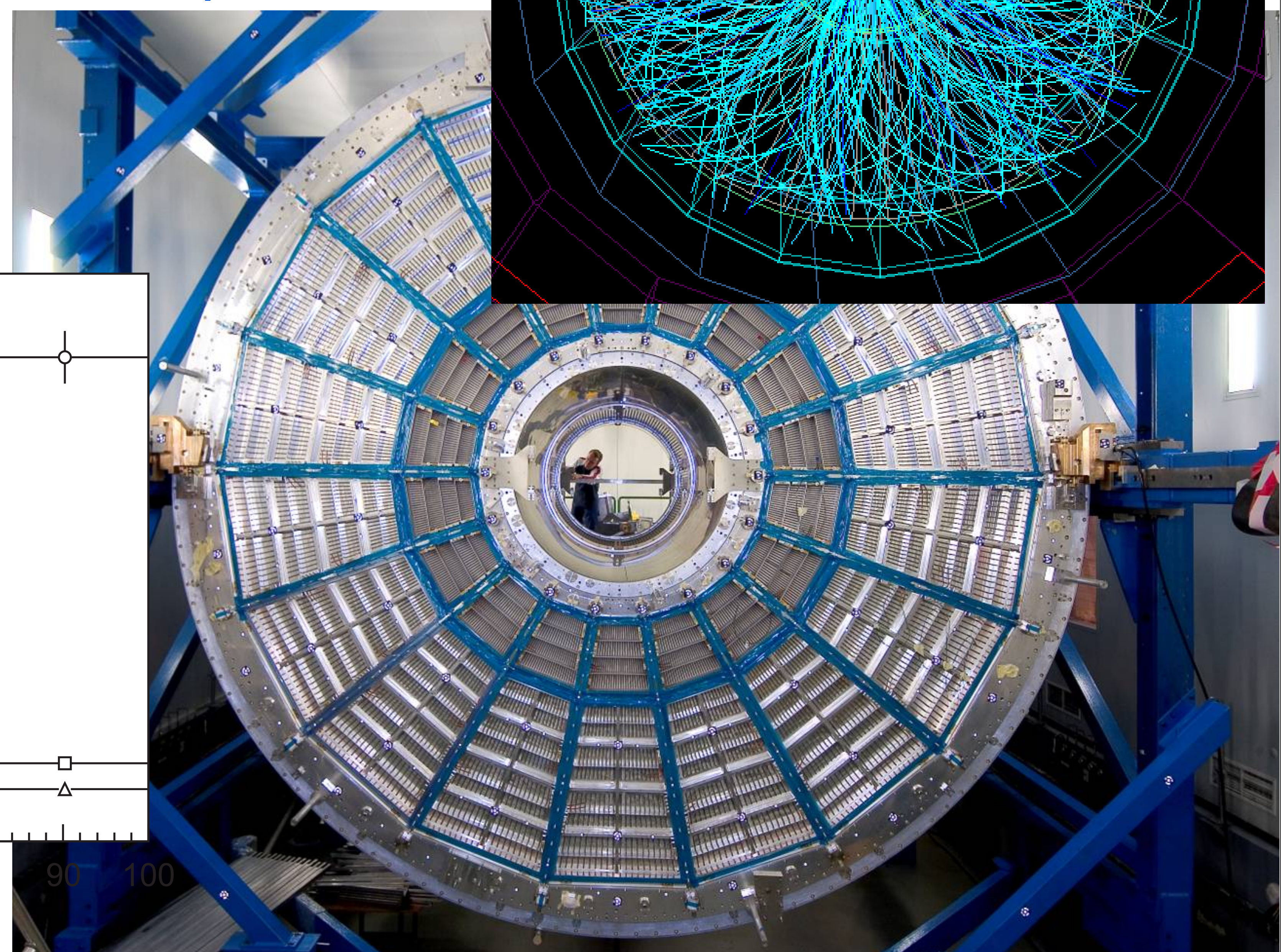
Charged hadrons in the ALICE TPC

TPC ideal for tracking in Pb+Pb

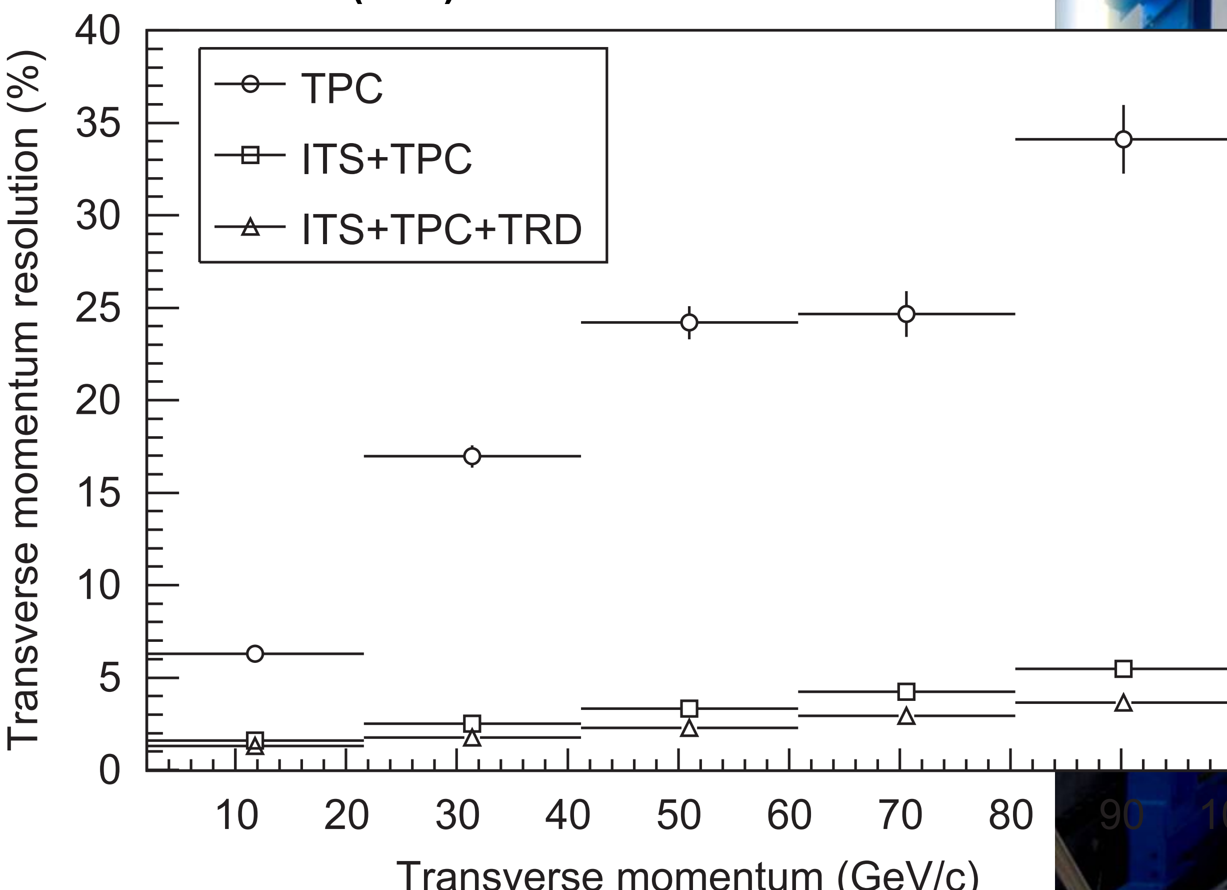
- high occupancy capability
- good momentum resolution
- excellent pair acceptance

potential to measure $|\Delta\eta|<2.0$, even beyond (although only $|\eta|<0.8$ currently reconstructed)





NIM A 572 (2007) 64–66



Status update from ALICE

Triggered Correlations in Pb+Pb

Trigger pt 1-15 GeV/c, assoc. p_T < trigger p_T

Data

(Almost) full 2.76 TeV dataset used (~8 Million events after physics selection)

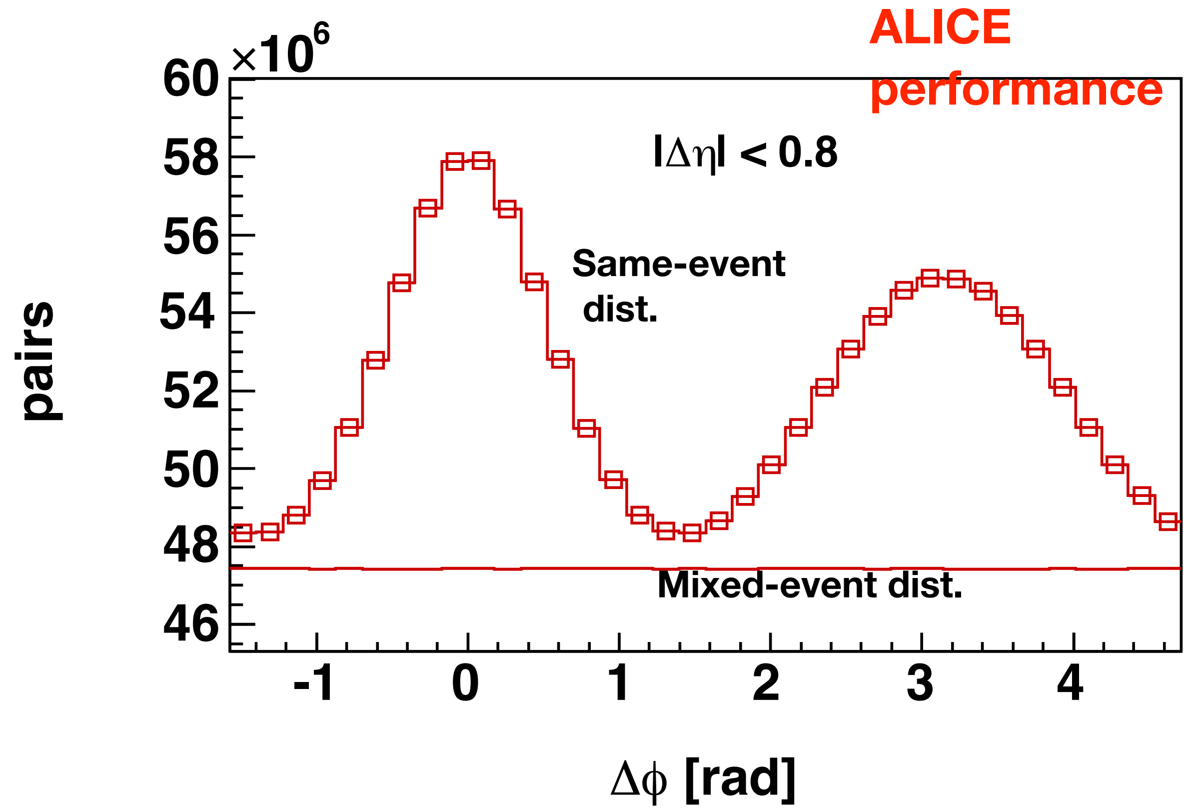
TPC-only tracks, also use ITS info to improve vertex resolution

- Current offline reconstruction requires $|\eta| < 0.8$
- Soon hope to have $|\eta| < 1.0$

Correlation function

Pair-wise (vs. event-wise) normalization:

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



Δφ-Δη distributions - intermediate p_T

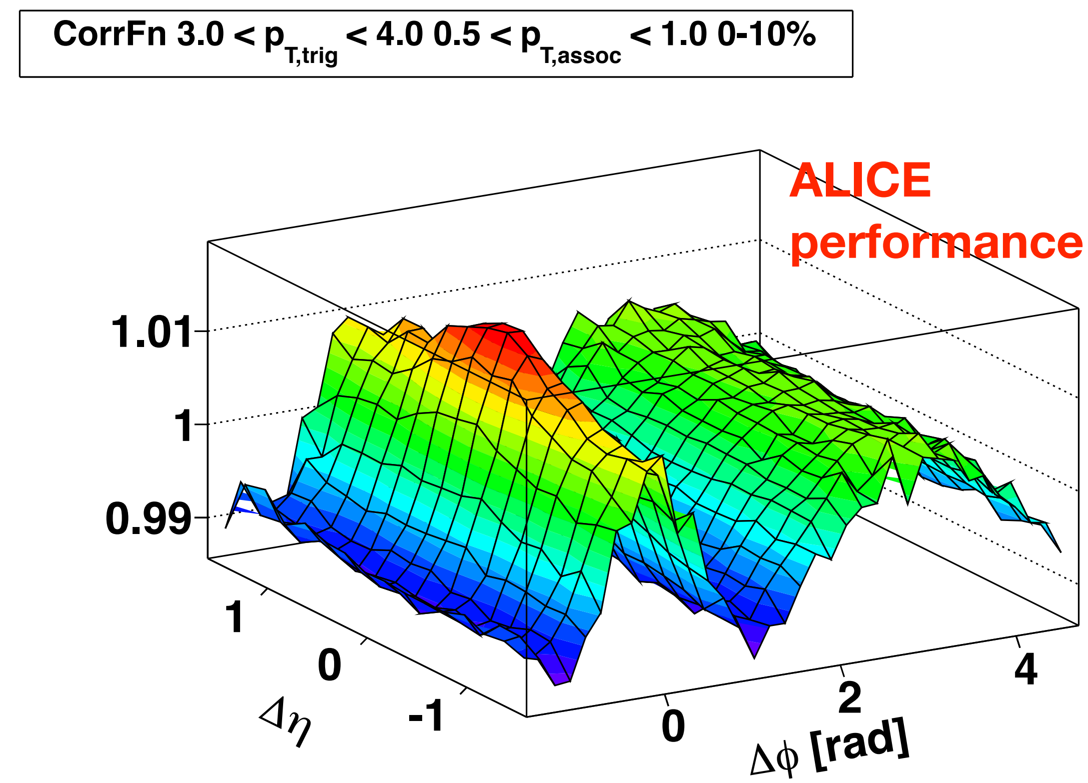
3-4 GeV/c triggers, central Pb+Pb:

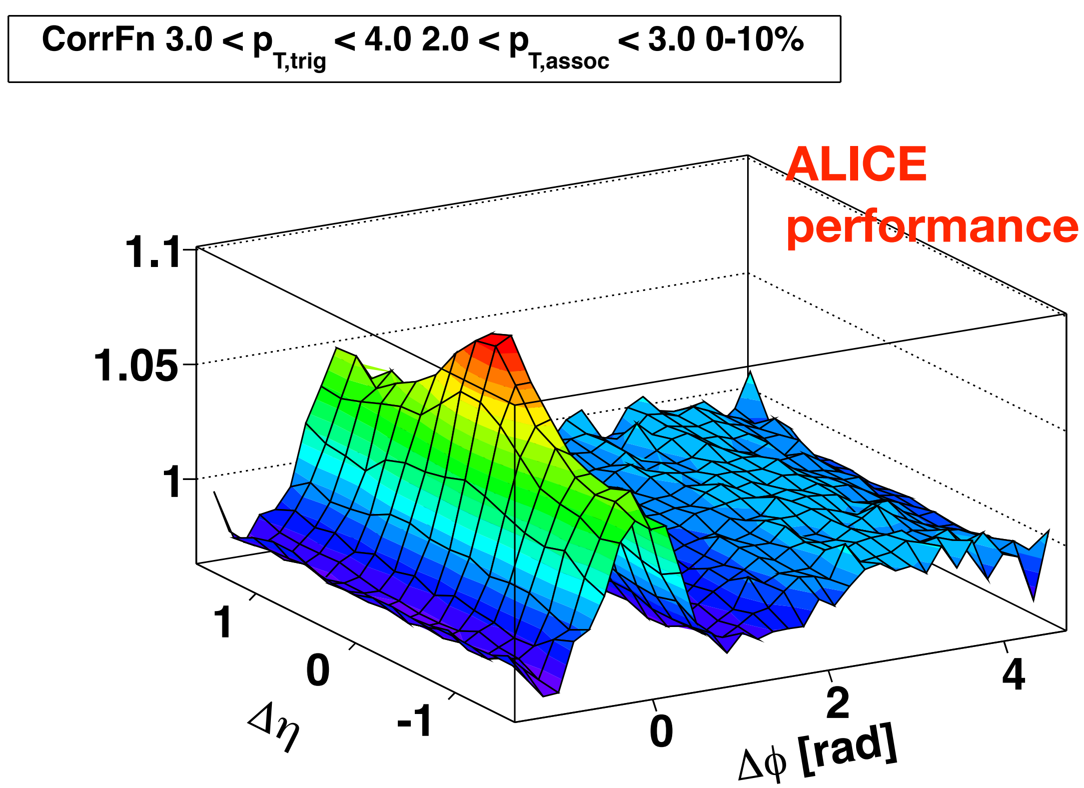
Prominent near-side ridge

- Near side jet emerges with rising associated p_T

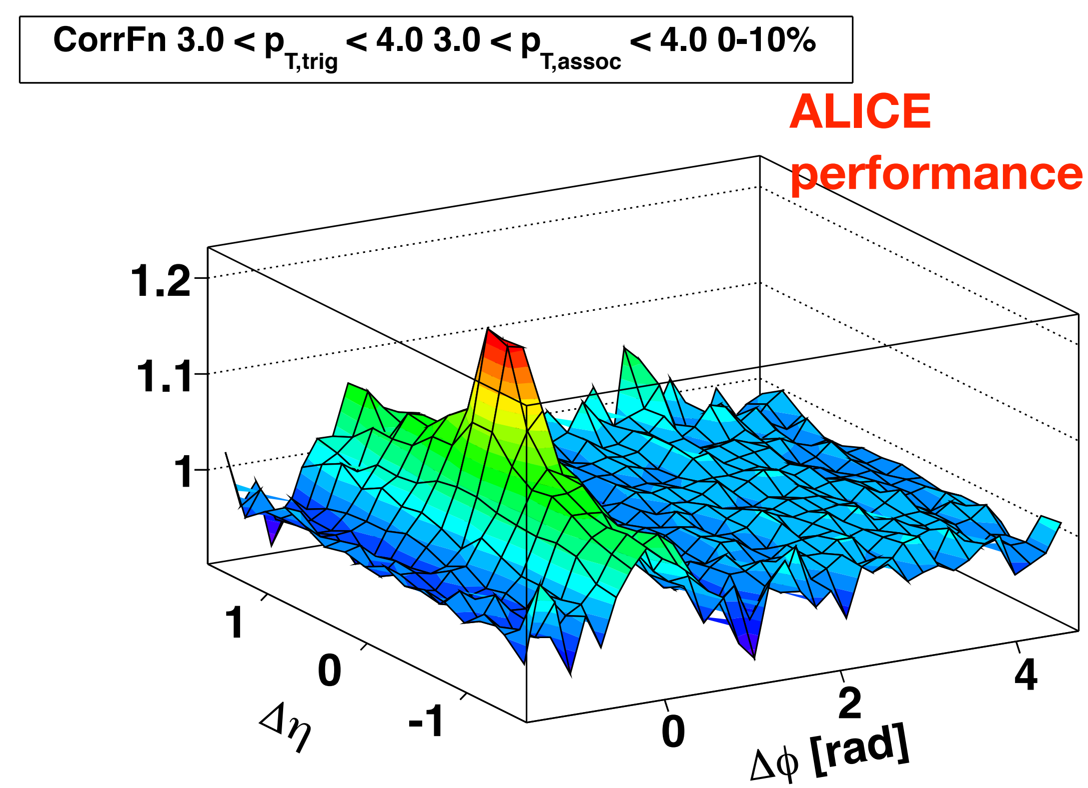
Broad, flat away side

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





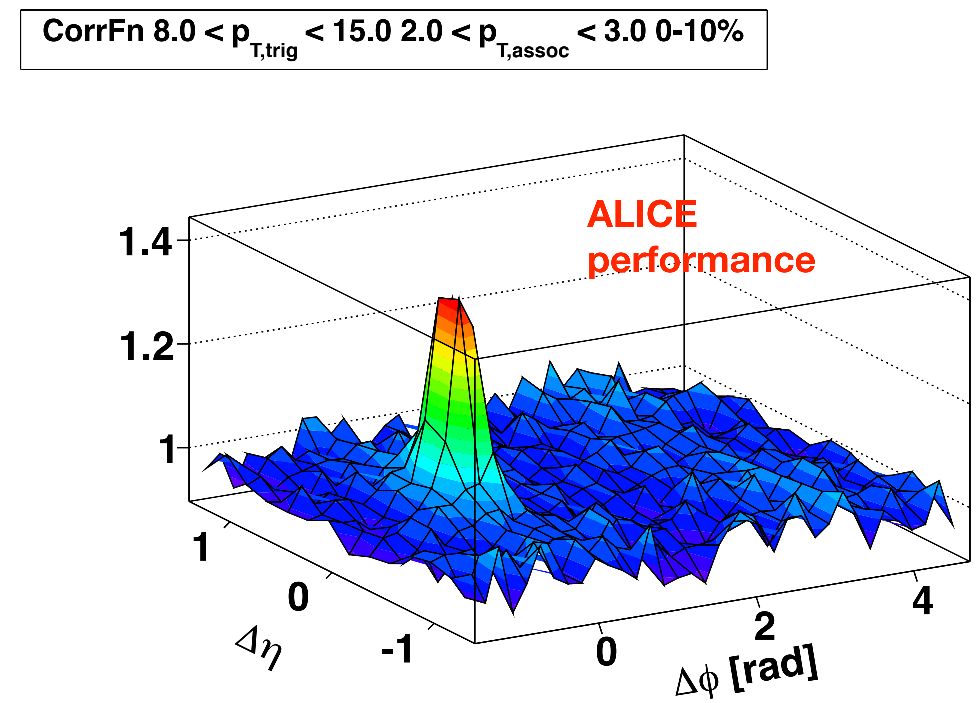
C(Δφ)
Not bkg. subtracted

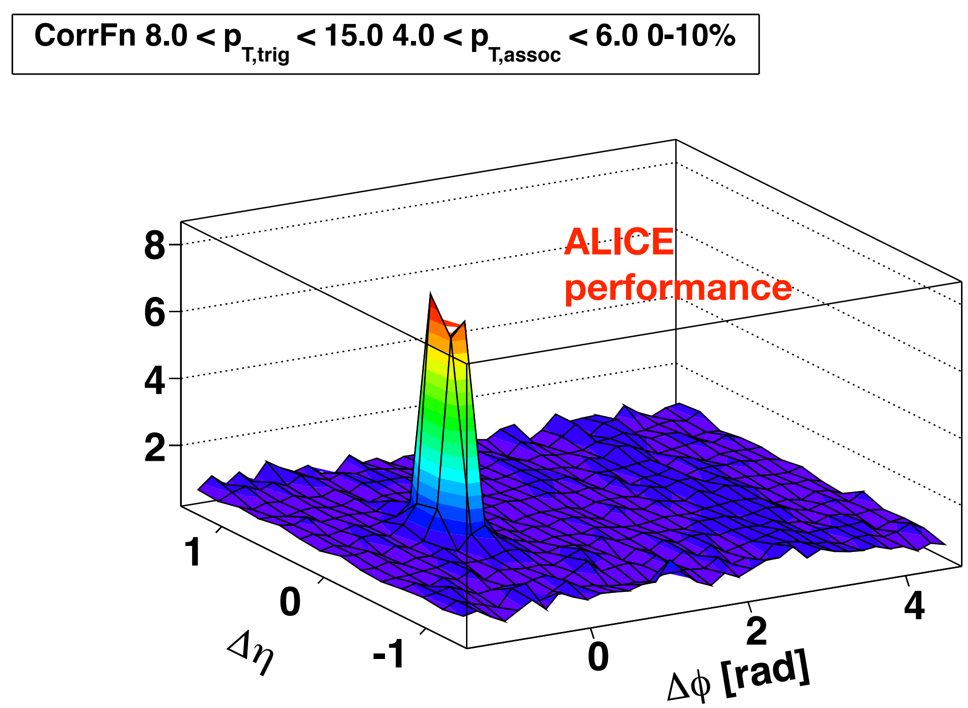


Δφ-Δη distributions - high p_T

8-15 GeV/c triggers, central Pb+Pb: Near-side jet dominates

Ridge difficult to resolve at this scale





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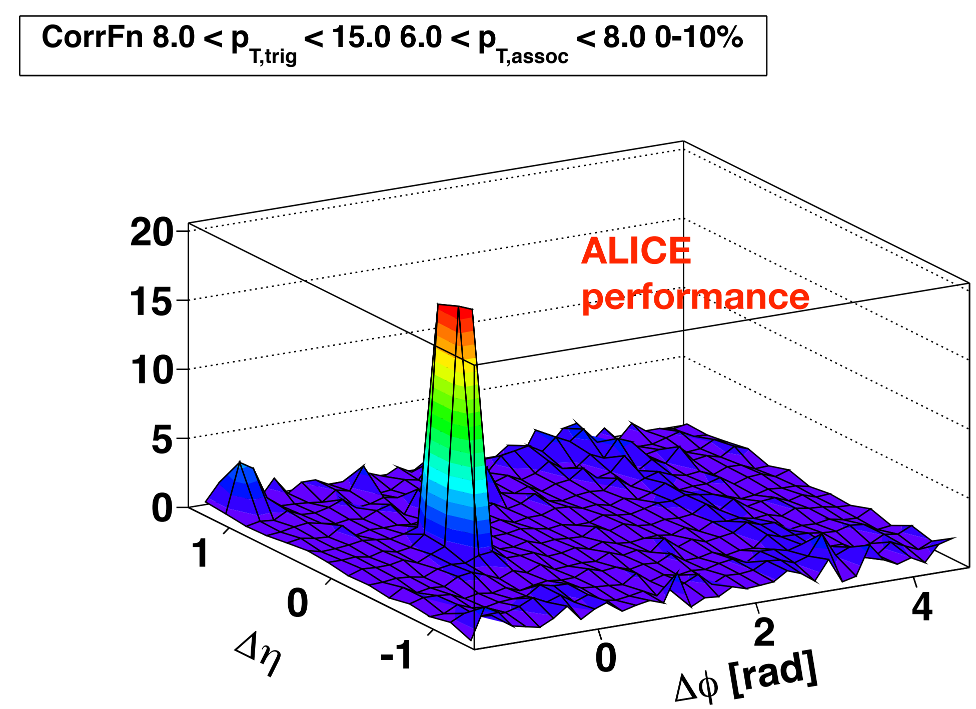


Away-side jet signal very weak!

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

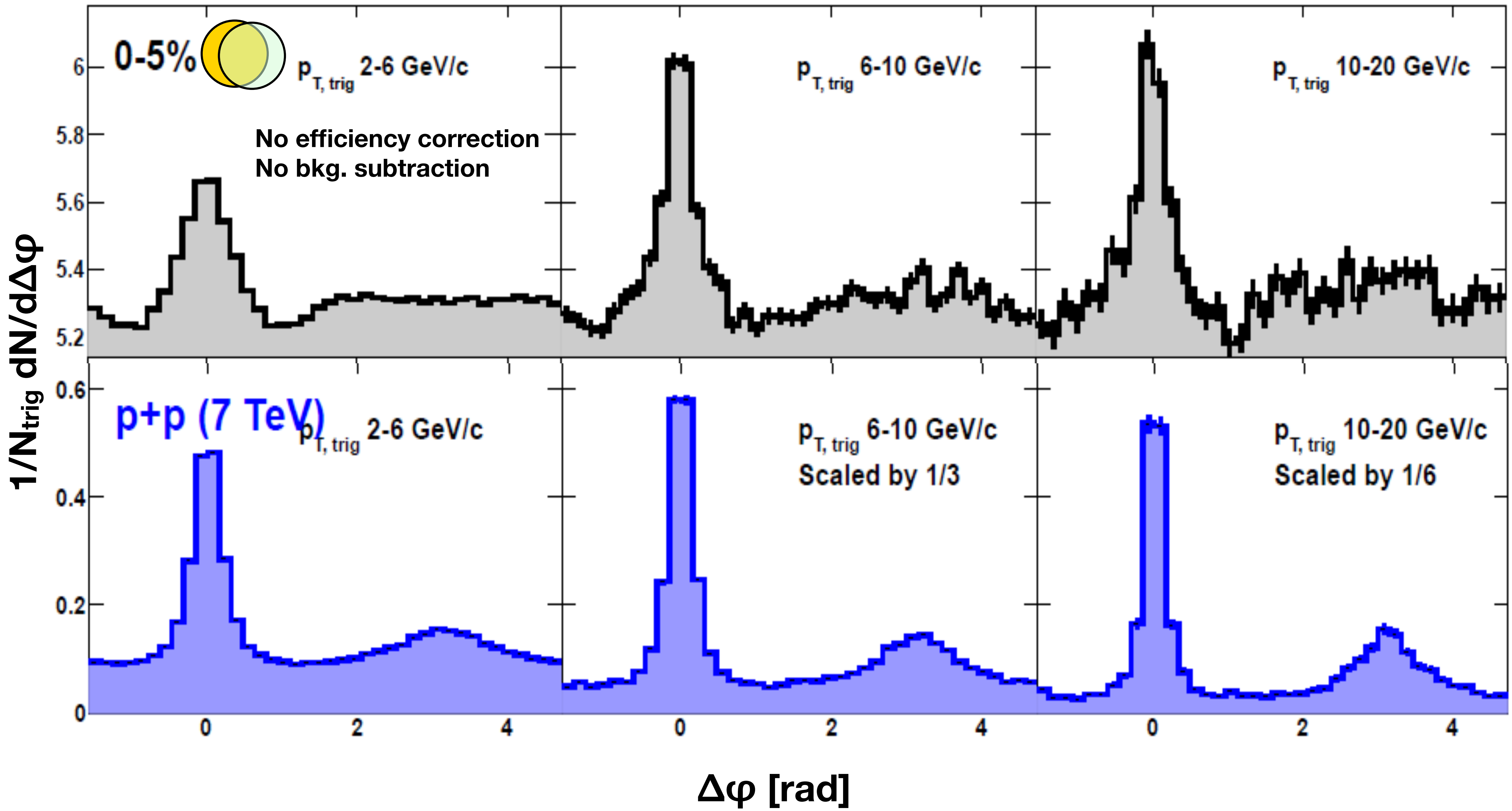
Azimuthal projections

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)

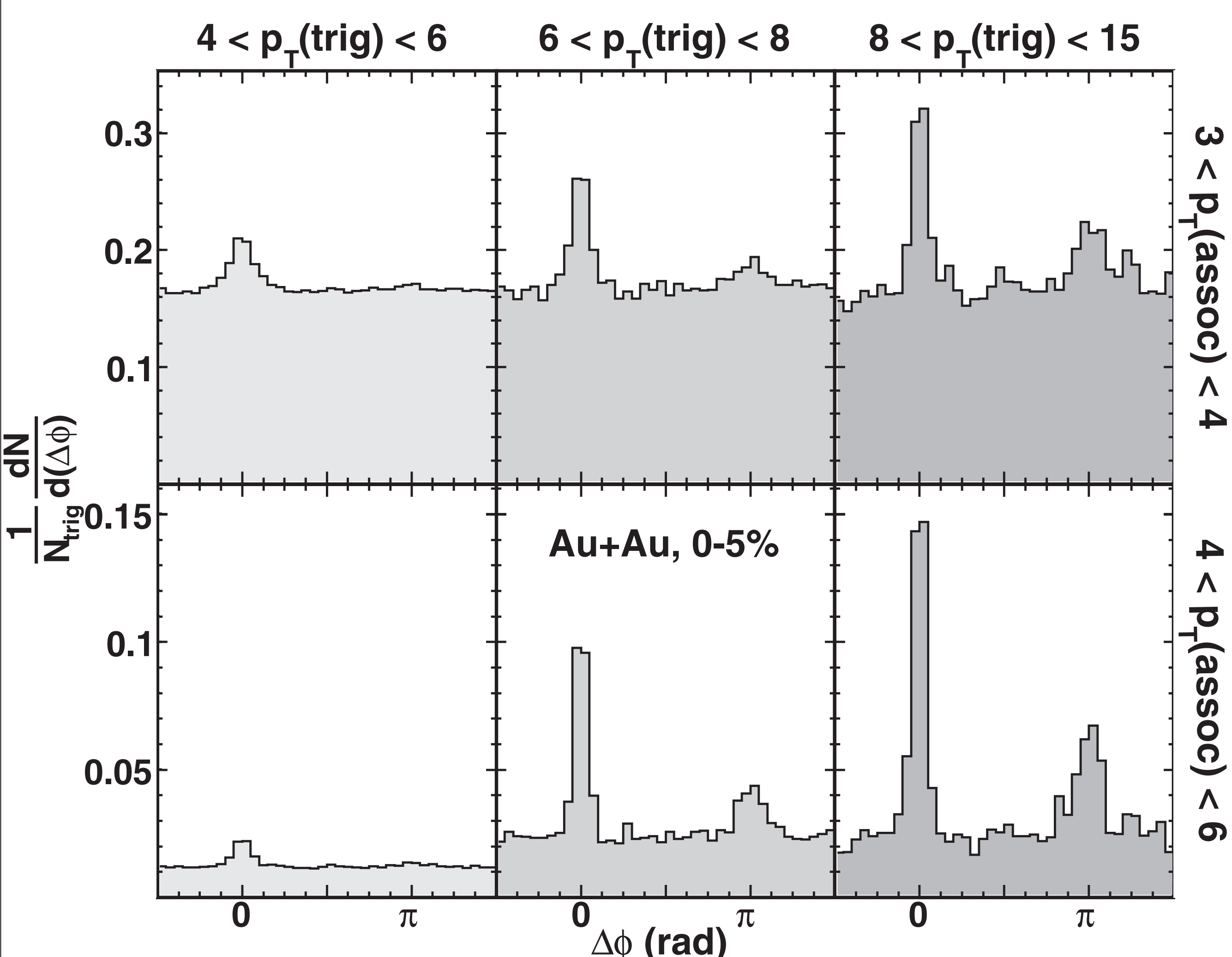
Broadened away side at lower pt, indistinct away-side peak at high pt

Note - Pb+Pb background not removed

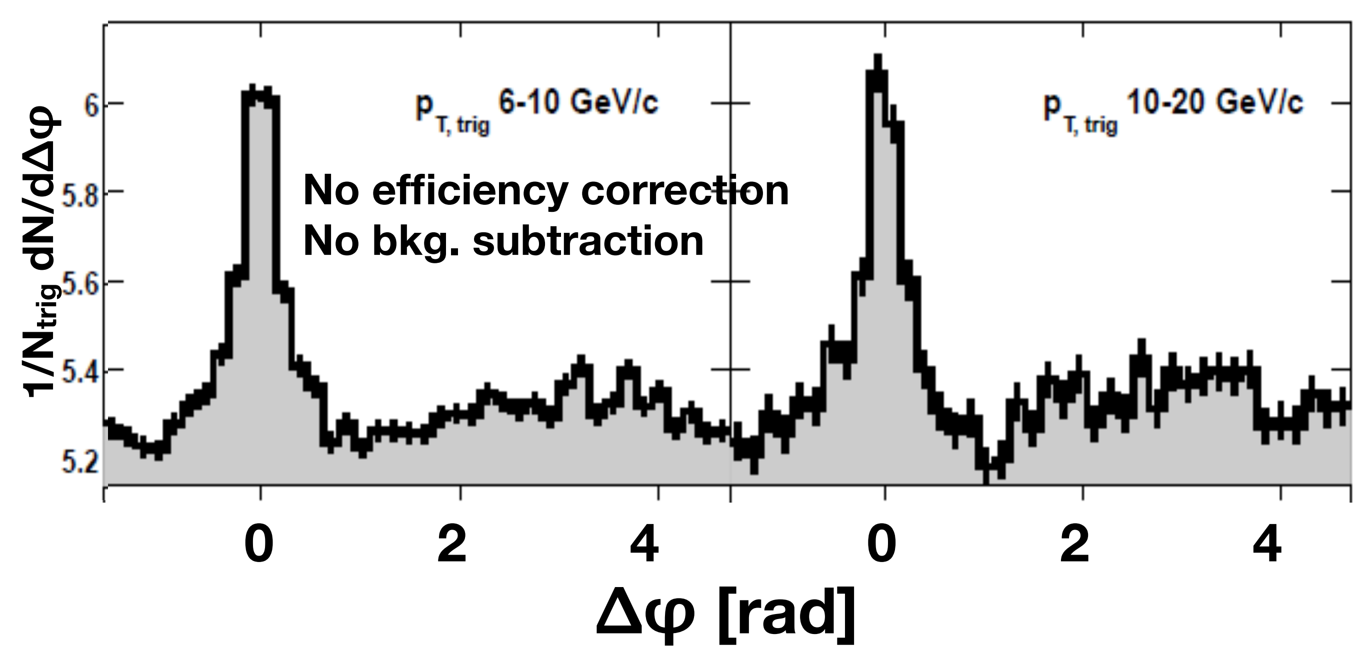


ALICE vs. STAR at high p_T

STAR @ 200 GeV PRL 97, 162301 (2006)



ALICE
(performance plot)



No strong emergence of away-side peak compared to RHIC

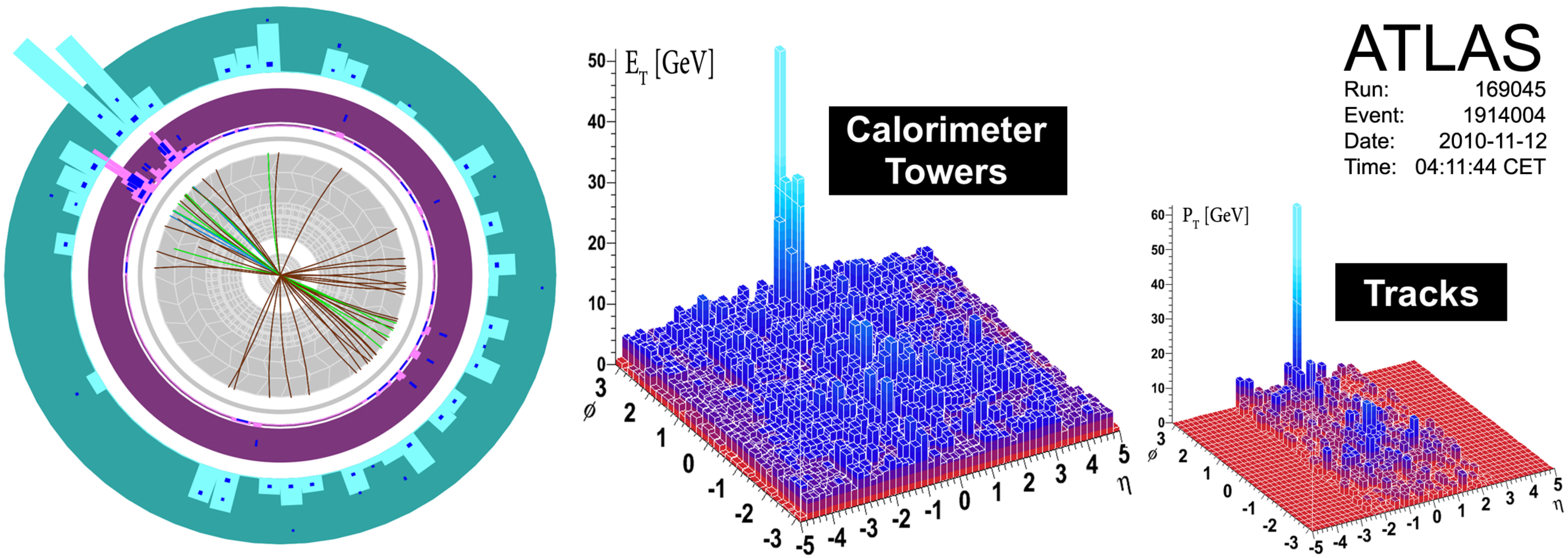
Many caveats: non-identical pt bins, no acceptance or efficiency correction, partial statistics...

Even so, away-side / near-side ratio appears smaller for 2.76 TeV Pb+Pb! Why?

Quenching vs. kinematics

ATLAS

Direct observation of quenched recoil jet in Pb+Pb



arXiv:1011.6182v2

But also:

Beam rapidity gaps differ at LHC vs. RHIC

For fixed hadron pt, different parton energies are sampled, different z represented

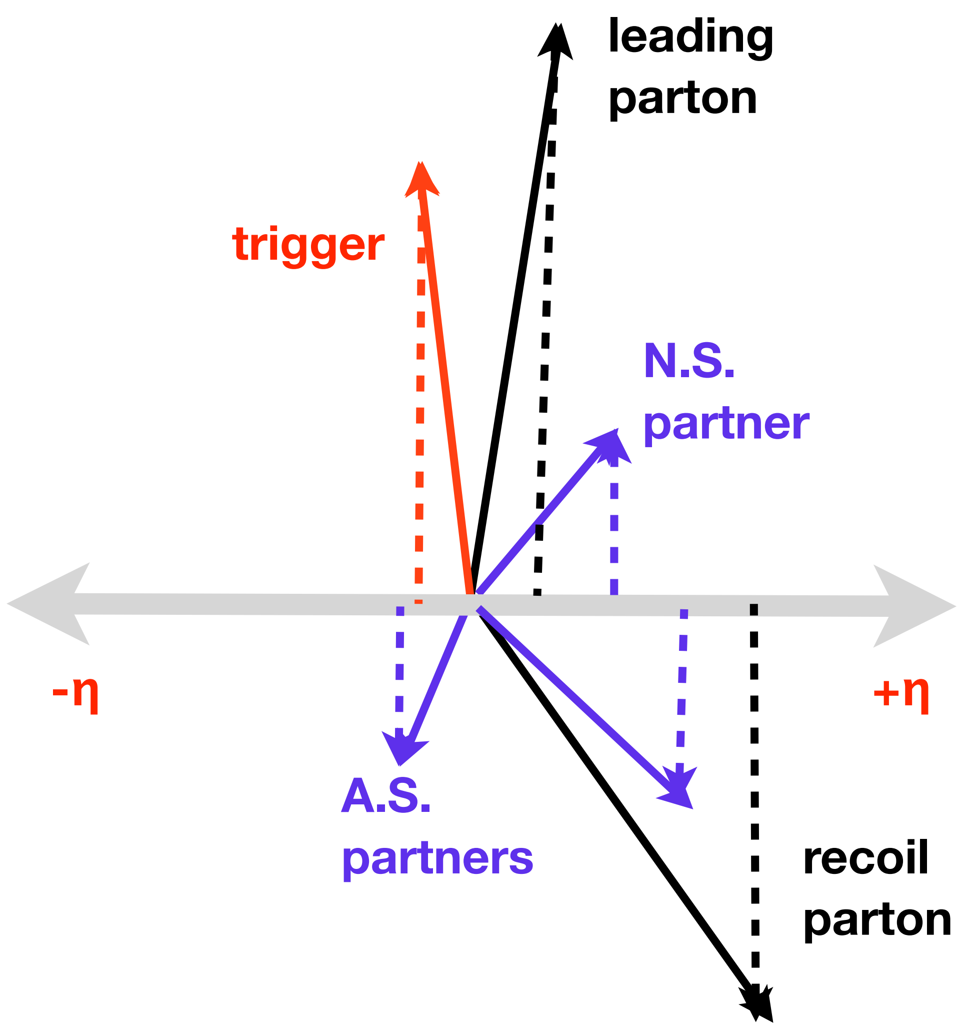
Kinematics at the LHC vs. RHIC

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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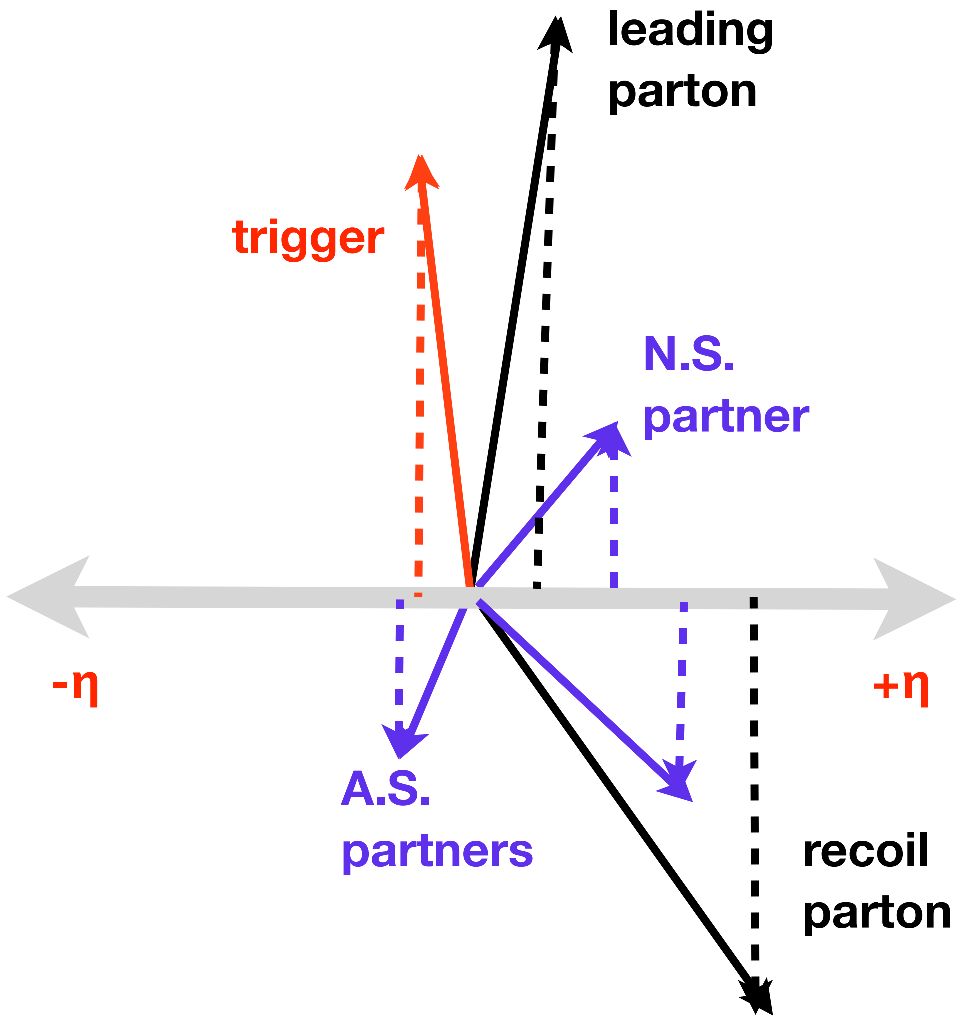
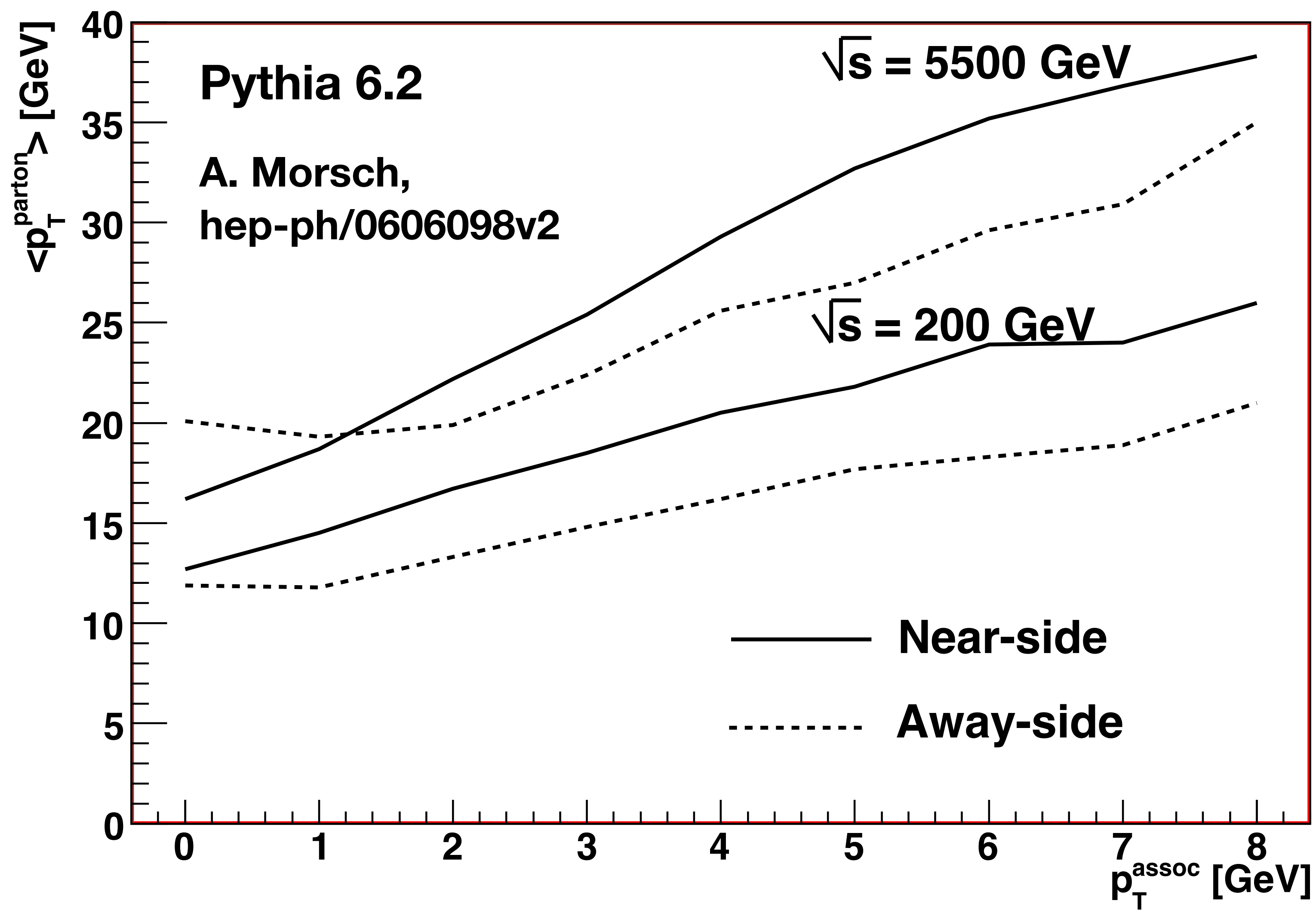


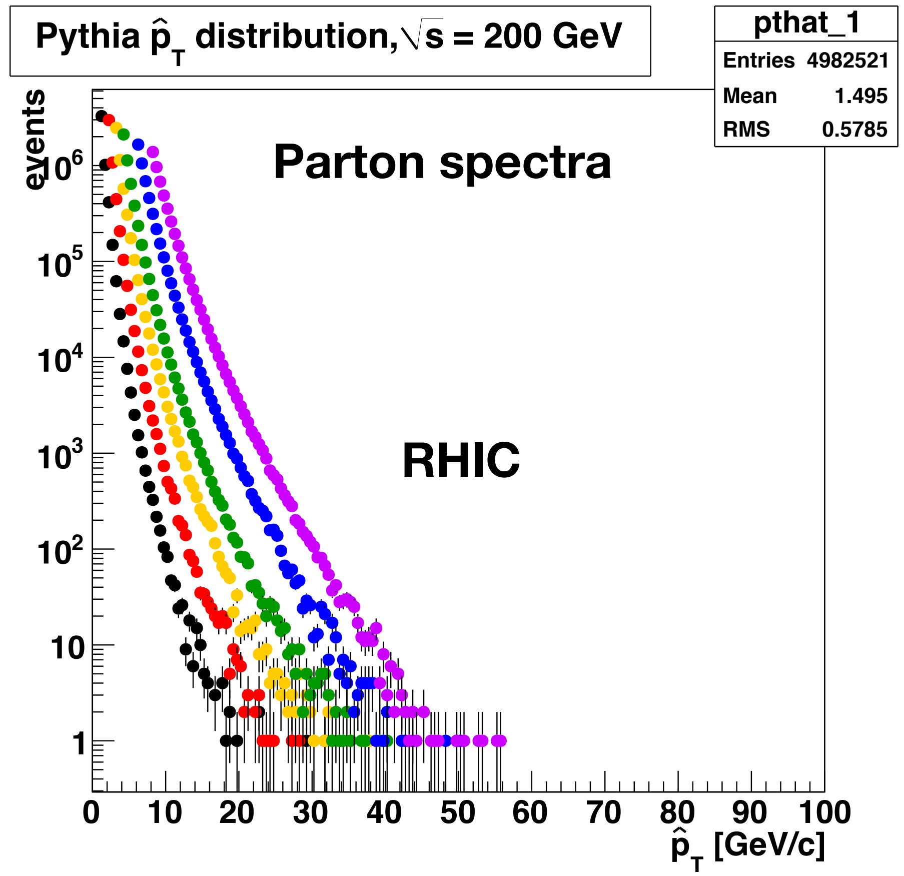
Parton p_T vs. associated p_T - $p_{T,trig}$ > 8 GeV/c:

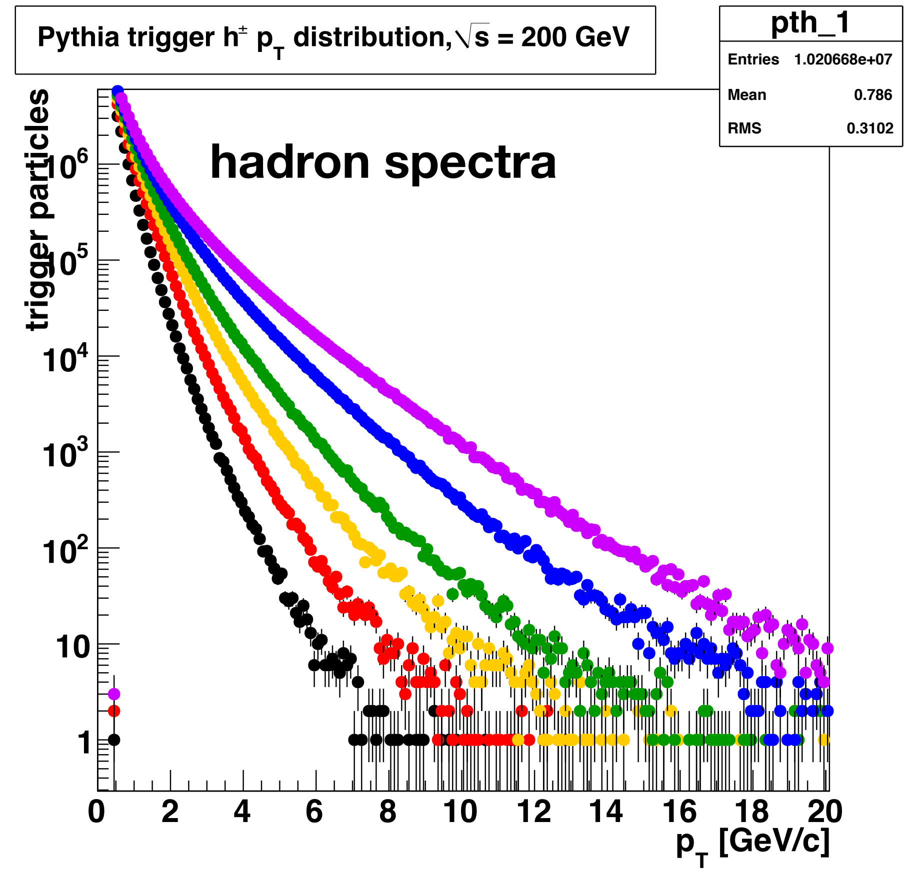
- Near side samples higher $p_{T,parton}$ than away side
- At fixed $p_{T,trig}$ & $p_{T,assoc}$, much larger $p_{T,parton}$ at LHC



Pythia acceptance study

Compare dihadron correlations between RHIC and LHC





Want to understand differences due to kinematics in absence of quenching.

Generated events in several pT,hard bins

Combine results, weighted by cross section.

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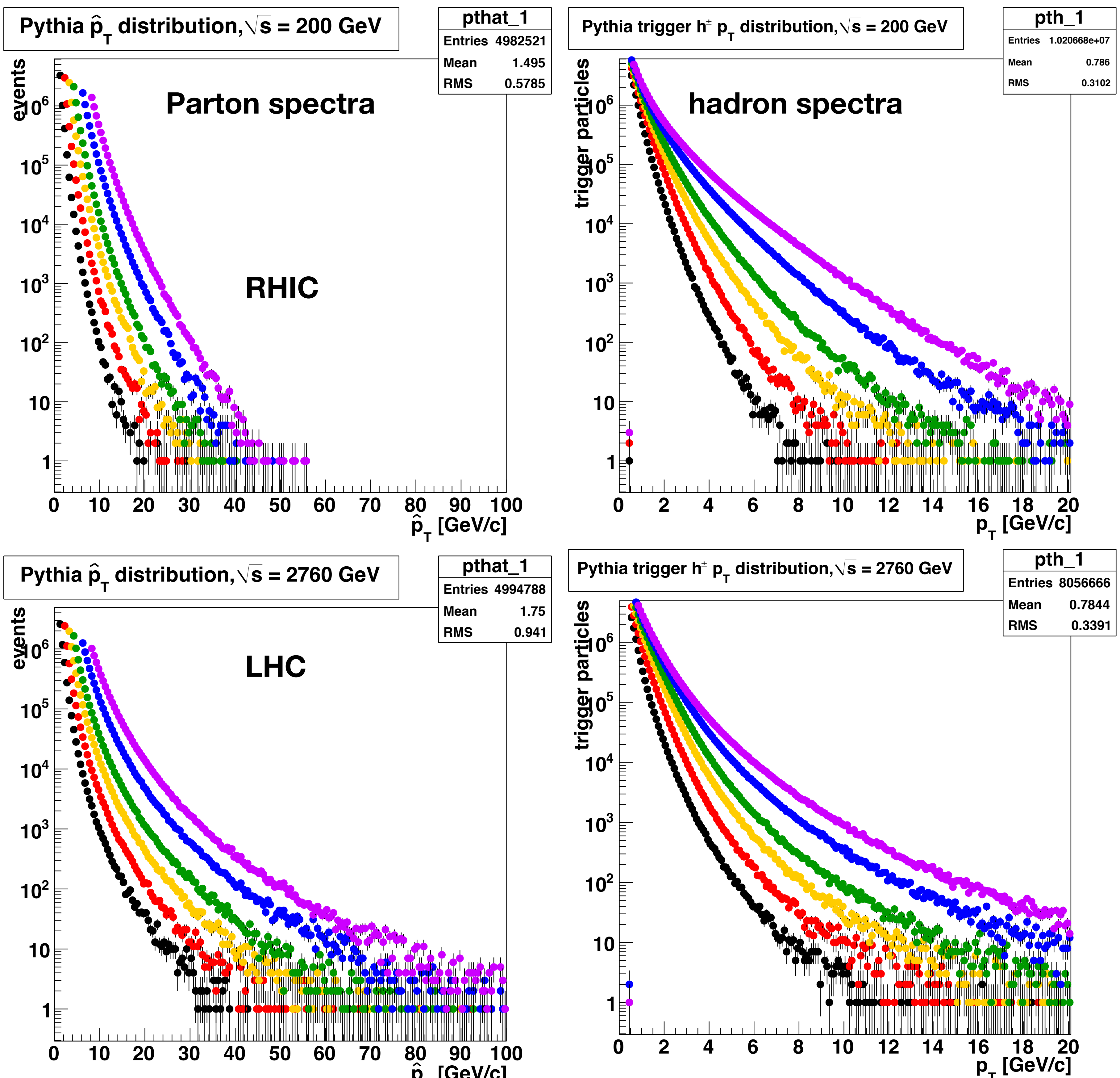
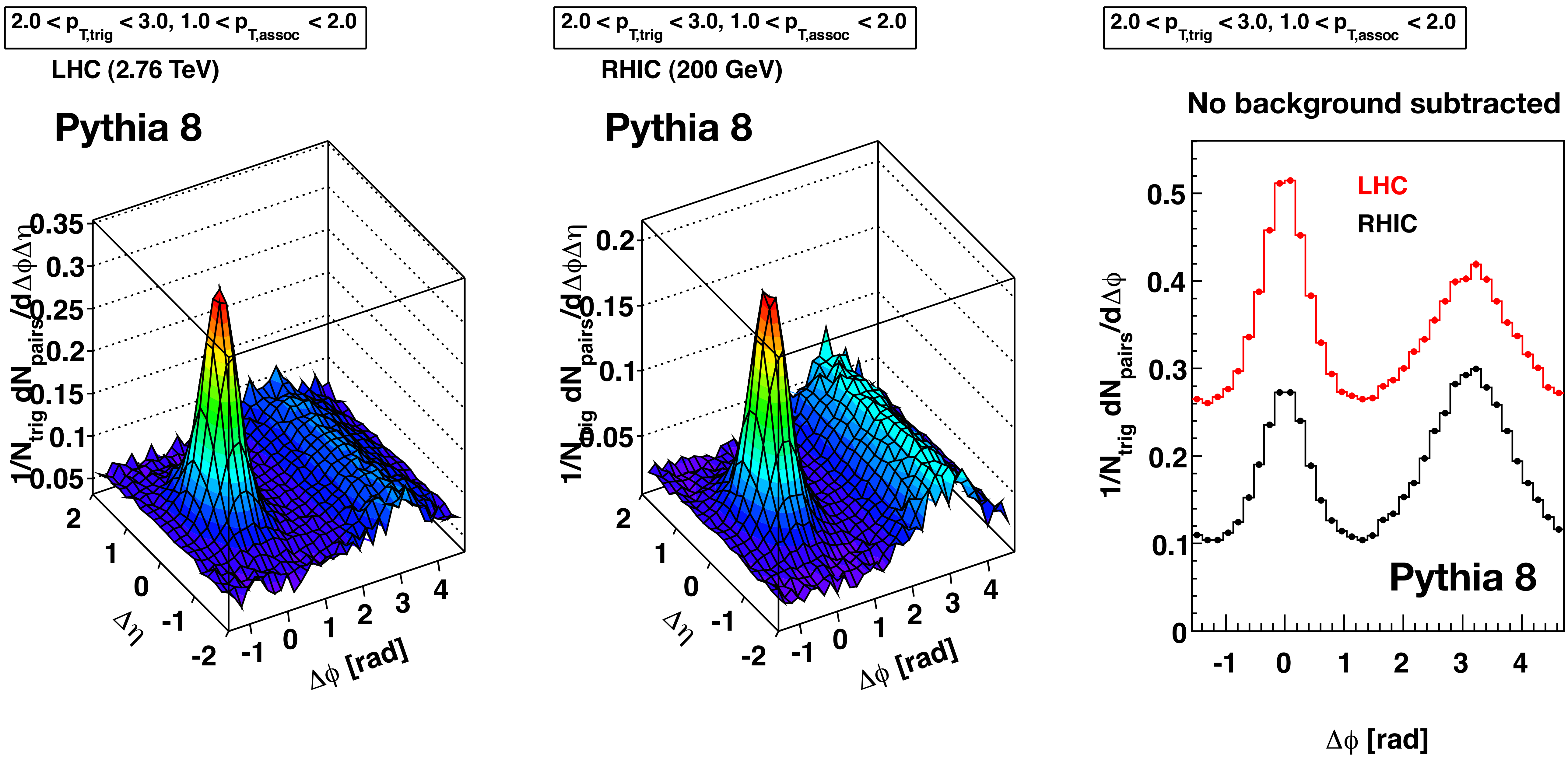
Combine results, weighted by cross section.



Low pt: large uncorrelated component

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

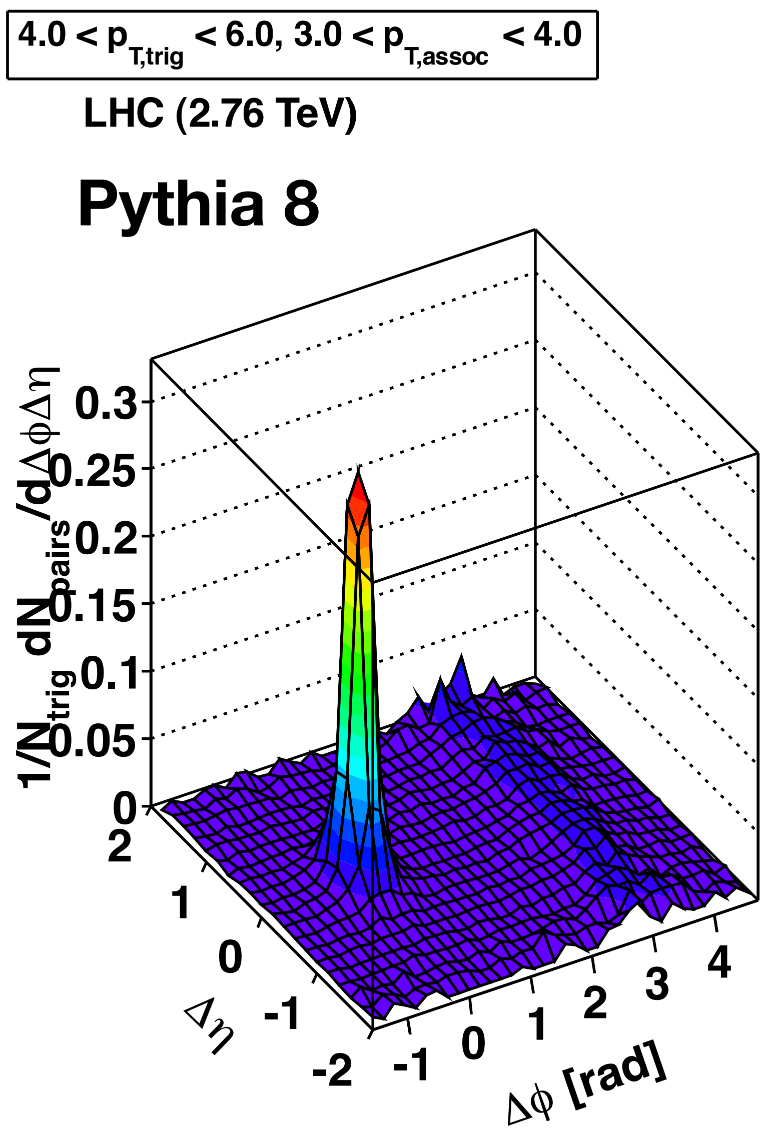
More independent hard scatterings per event, stronger NLO effects

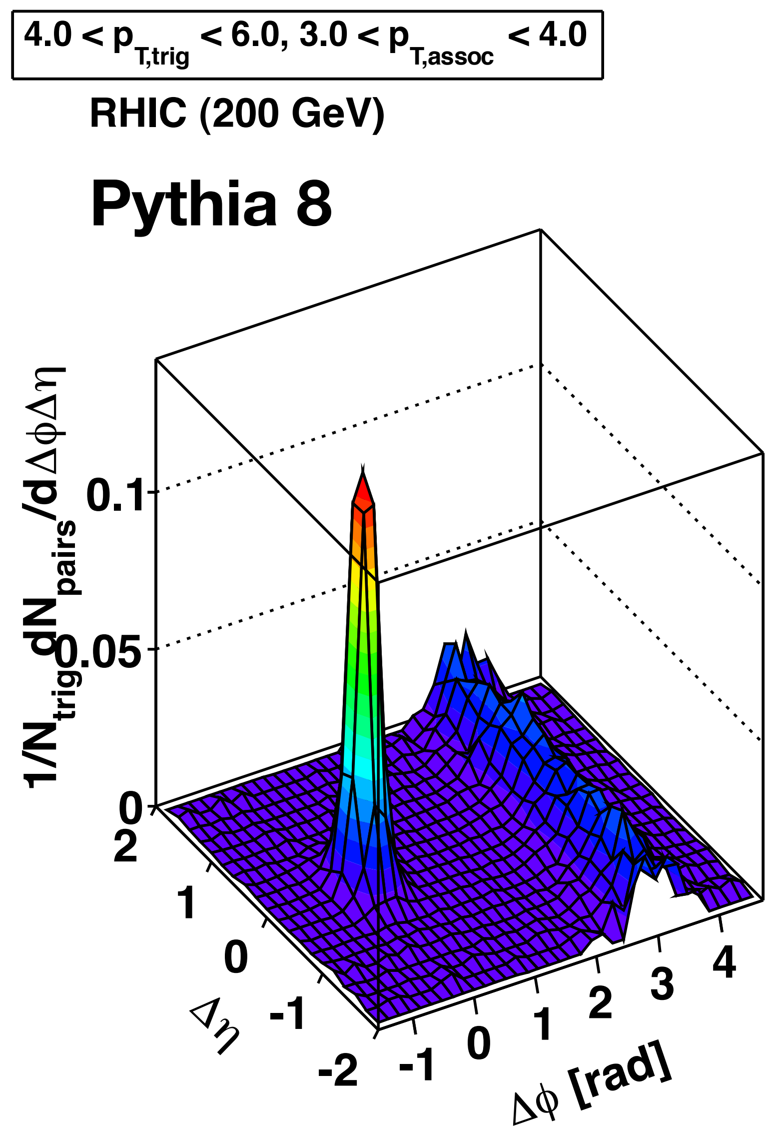


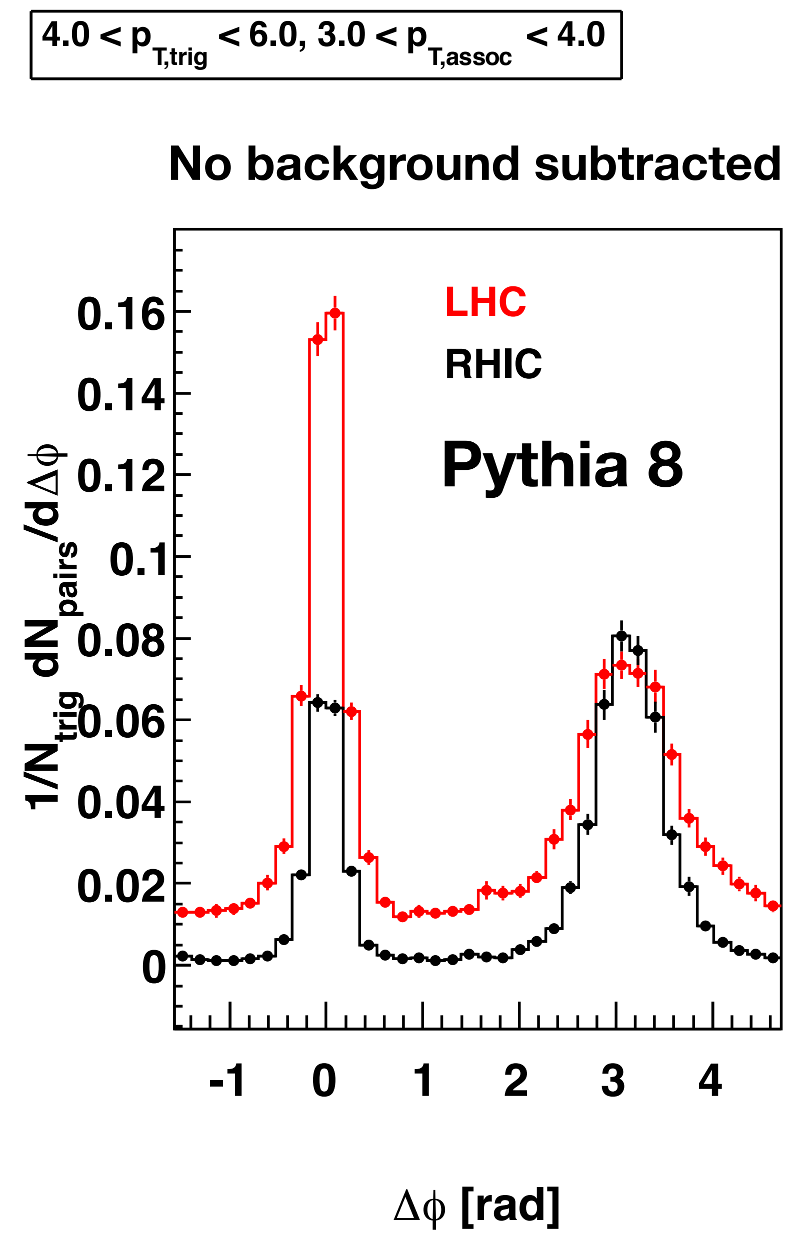
Intermediate to high pt

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)

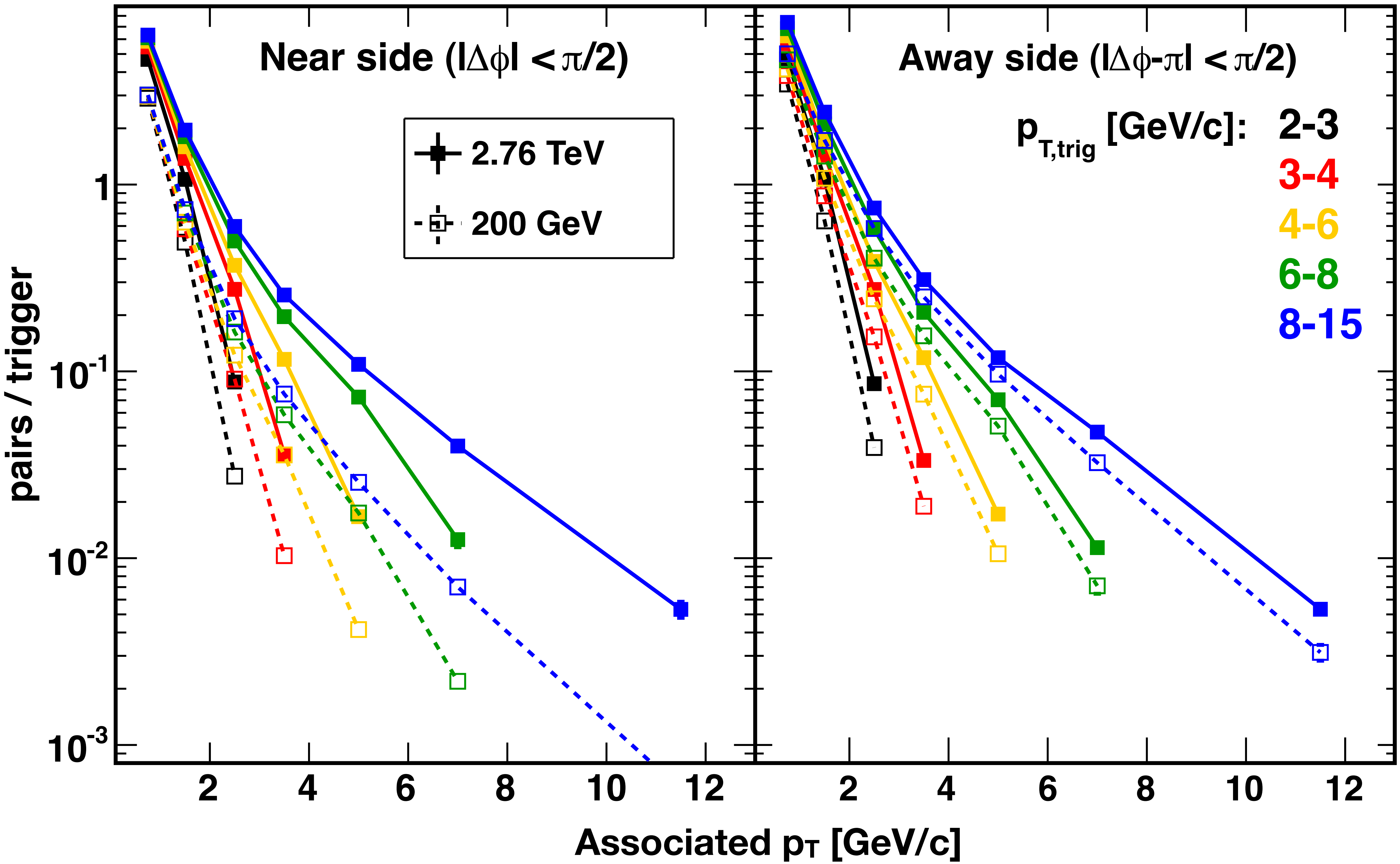






Pythia conditional yields

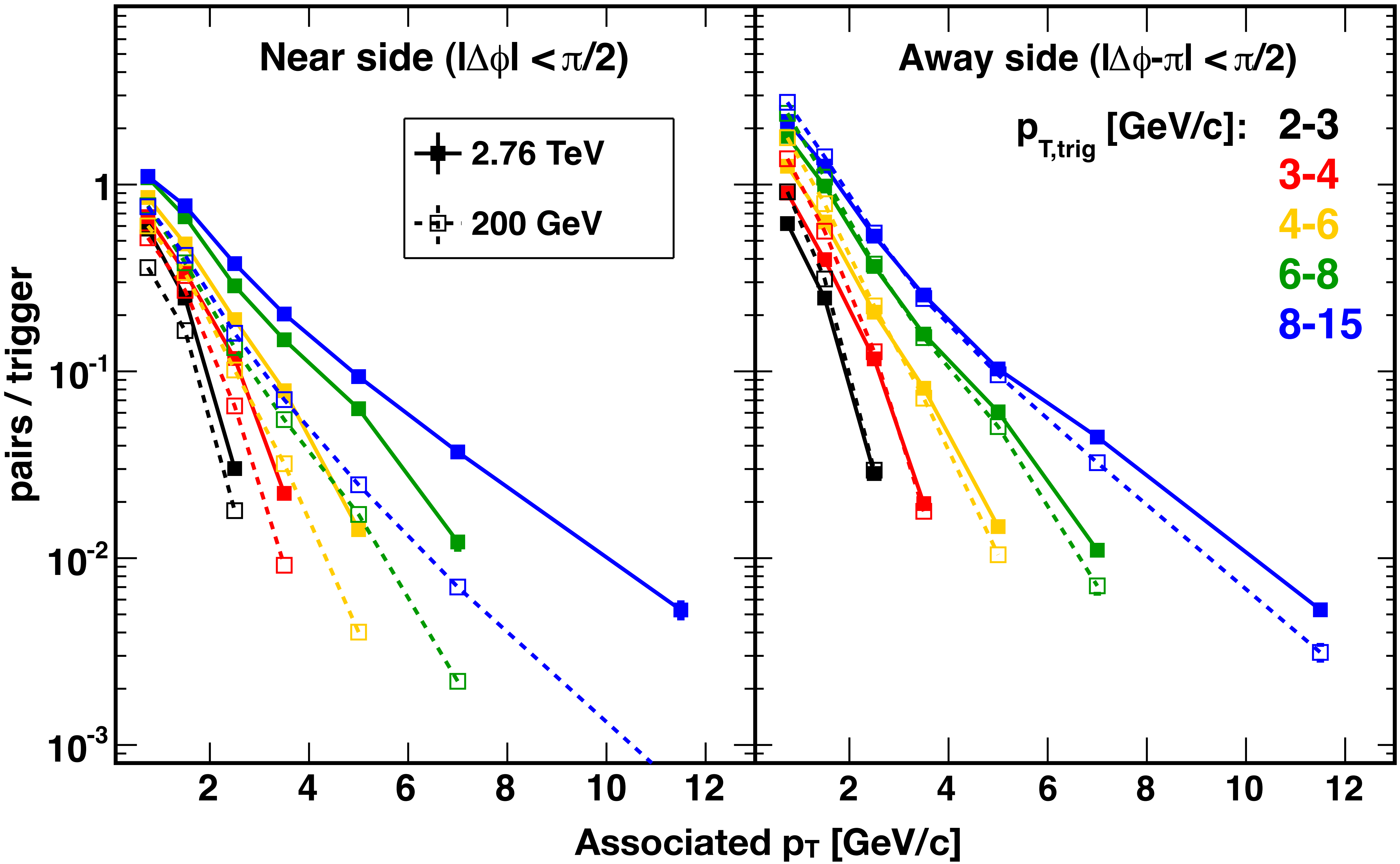
Full PYTHIA correlations (no bkg. subtraction)



Pythia conditional yields

Zero-yield-at-minimum applied to PYTHIA correlations

Affects yields at low-int. pt. Brings away-side yields to closer agreement.



Next steps

Near side analysis

After subtracting the ridge, what does the near side look like?

In STAR, vacuum-like fragmentation is recovered.

Away-side: what to subtract

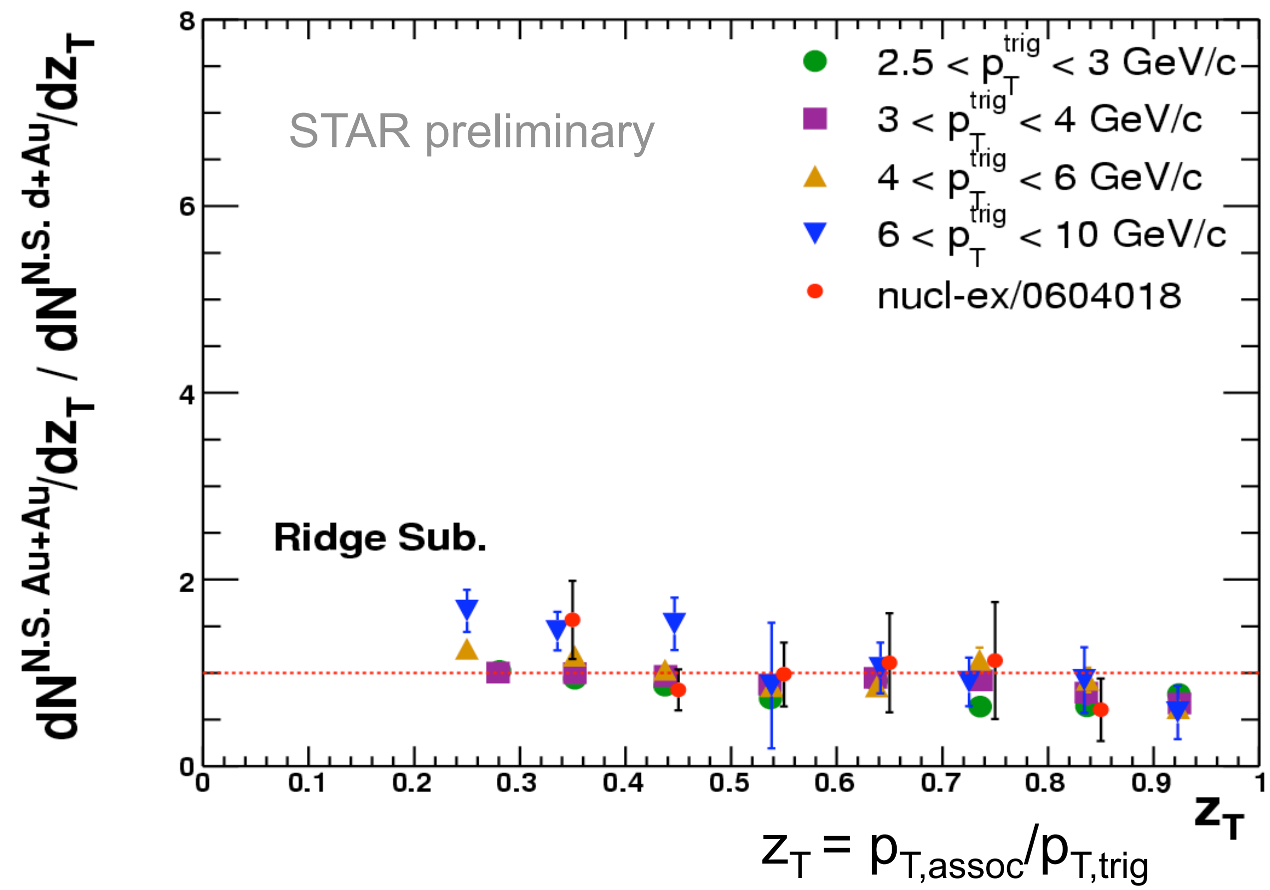
We are trying several scenarios. In any case we plan to make the un-subtracted yield information available.

- flat background
- v2 only (traditional)
- v2+v3+v4 (under study, how to avoid removing the away-side jet?)

The Different ansatzes strongly affect the shape and yield at low pt

At high pt, results are less sensitive (jet signal dominates over Vn)

M. Horner (STAR), QM'2006 and arXiv:1004.2377v2



STAR Au+Au / d+Au yield ratio: Ridge-subtracted peak matches vacuum-like fragmentation

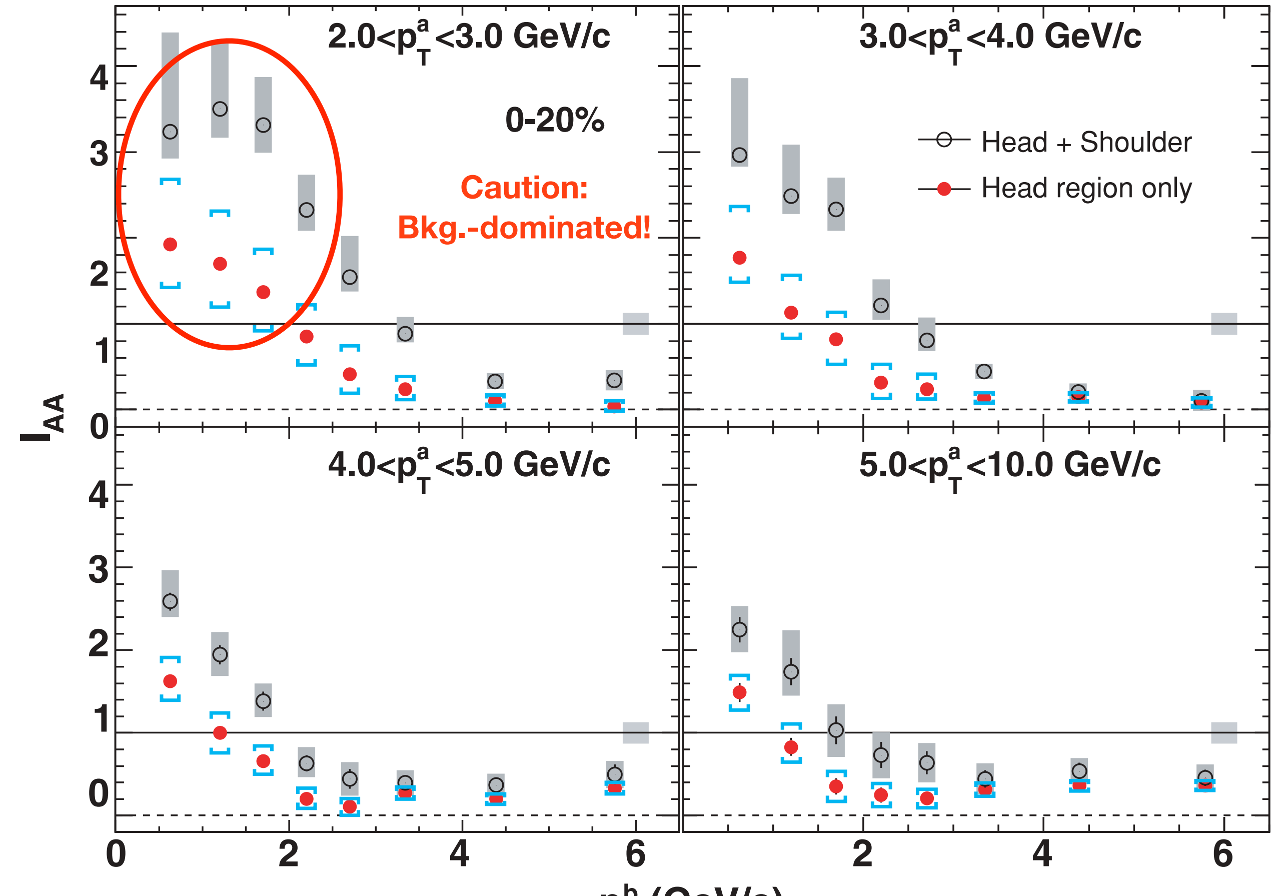
Benchmark: IAA at RHIC

PHENIX h-h:

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

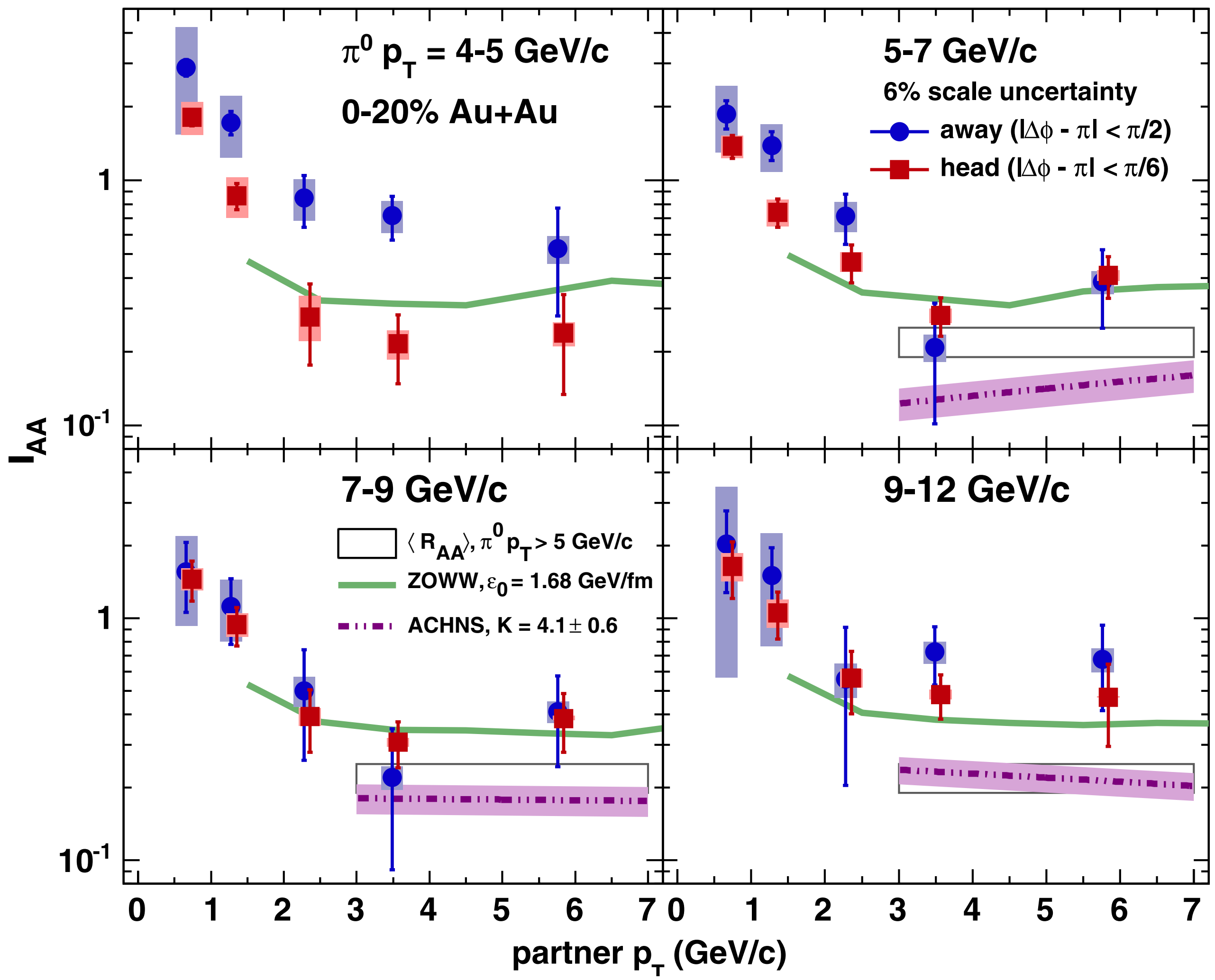
PHENIX π^0-h:

High-pt identified pi0 triggers
R_{AA} data, theory comparisons



PRC 78, 014901 (2008)

PRL 104, 252301 (2010)



$$I_{AA}(p_T^a, p_T^b) = \frac{Y^{A+A}_{\text{jet\_ind}}(p_T^a, p_T^b)}{Y^{p+p}_{\text{jet\_ind}}(p_T^a, p_T^b)}. \qquad (5)$$

Conclusions:

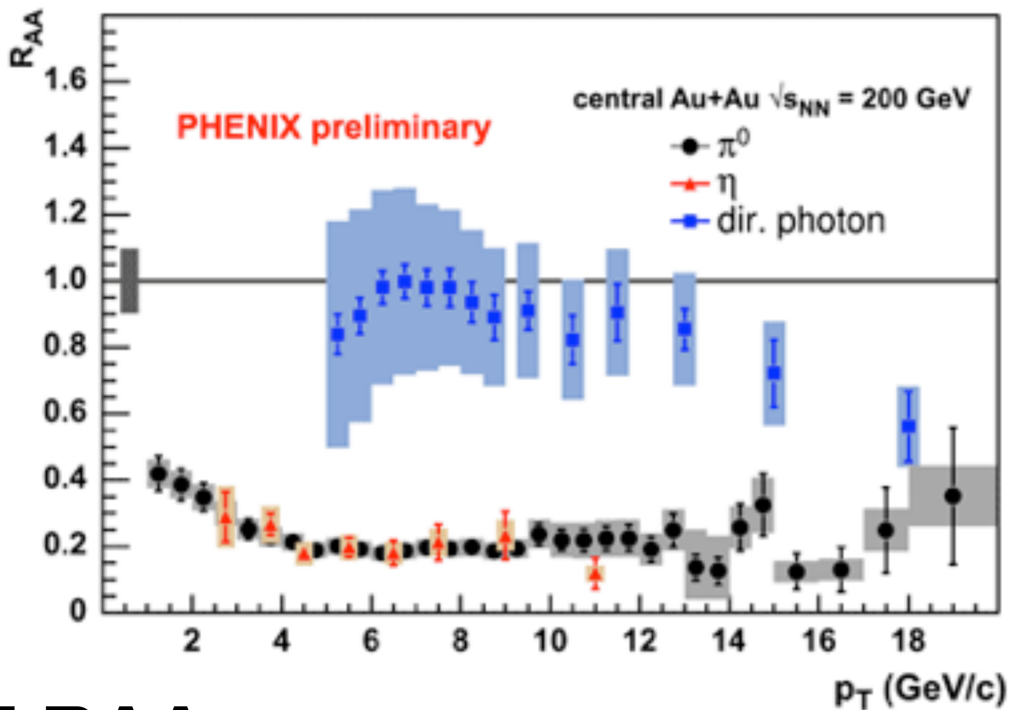
Focus on $p_{t,trig}$ > 5 and $p_{t,assc}$ > 2 GeV

- I_{AA} > R_{AA}
- I_{AA} ~ flat with $p_{t,\,assc}$
- I_{AA} increases with trigger p_t

Suppression at RHIC vs. LHC

PHENIX RAA:

~flat at 0.2



ALICE RAA:

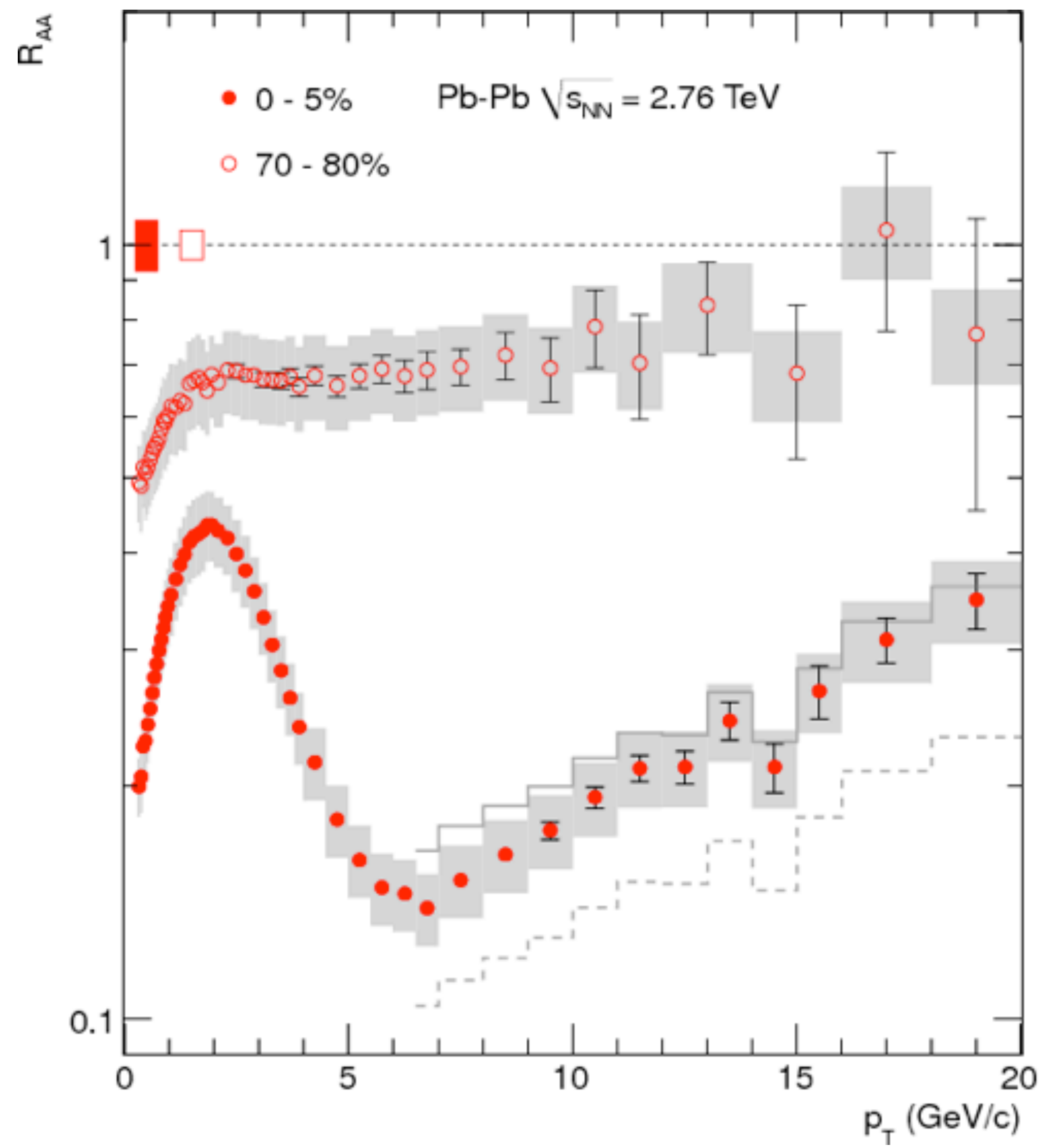
sharp rise above 6 GeV

Caveat:

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

Anticipating I_{AA}, I_{CP} measurements to see if trend persists in triggered correlations as well….

ALICE arXiv:1012.1004v1



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:

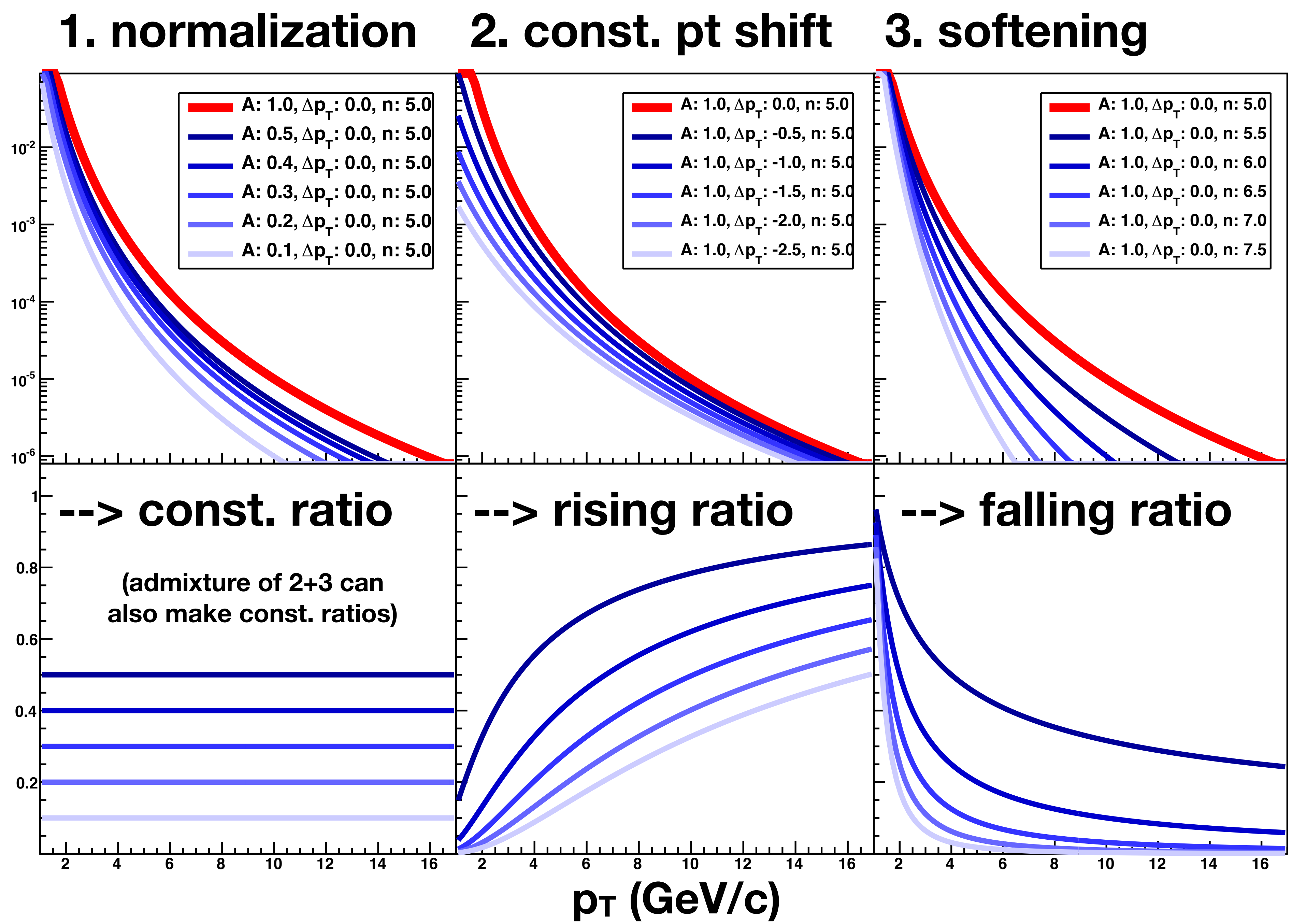
Ratio of blue/red

Ratio shape depends on nature of energy loss

IAA,RAA have different source shapes

comparison constrains models!

arXiv:1101.0290v1



Summary

ALICE in ideal position to push understanding of QGP state to the next stage from RHIC

Early look at correlation fns. shows qualitatively that the away side correlation strength is weaker than at RHIC

Some of this is expected due to kinematics at LHC

Much work in progress for quantitative measurements - stay tuned!