Very High-p_T Triggered Dihadron Correlations in PbPb Collisions at 2.76 TeV with CMS

Rylan Conway
(UC Davis)
for the CMS Collaboration

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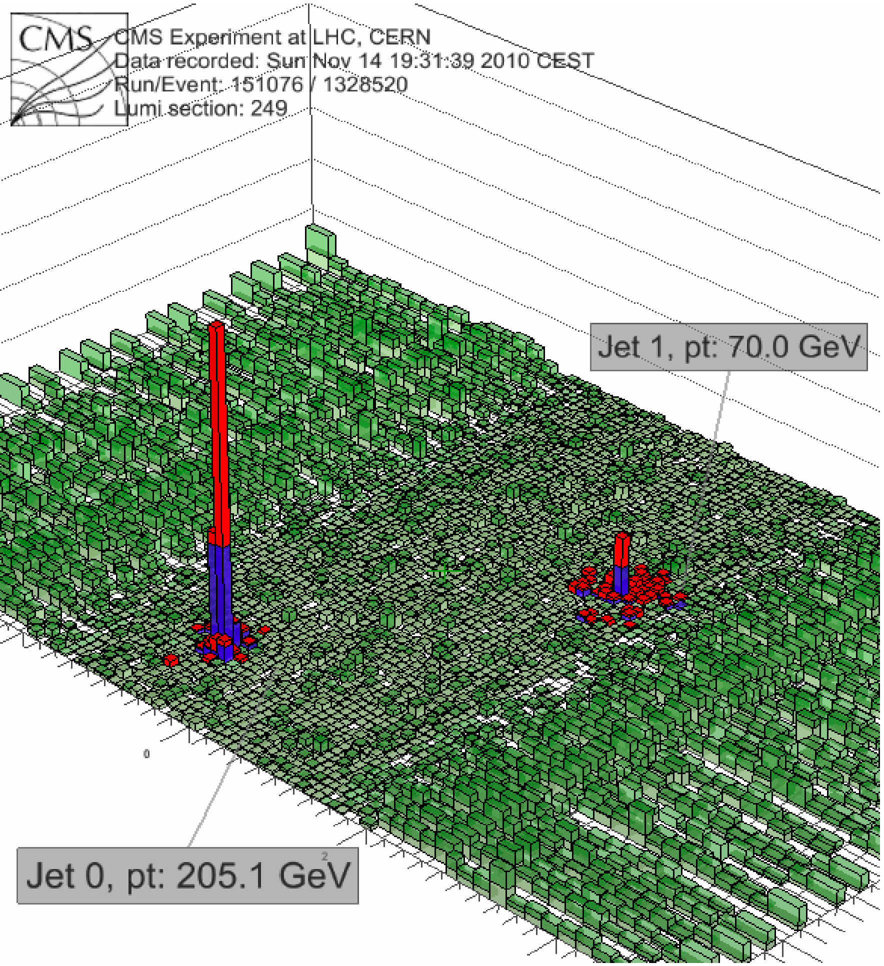
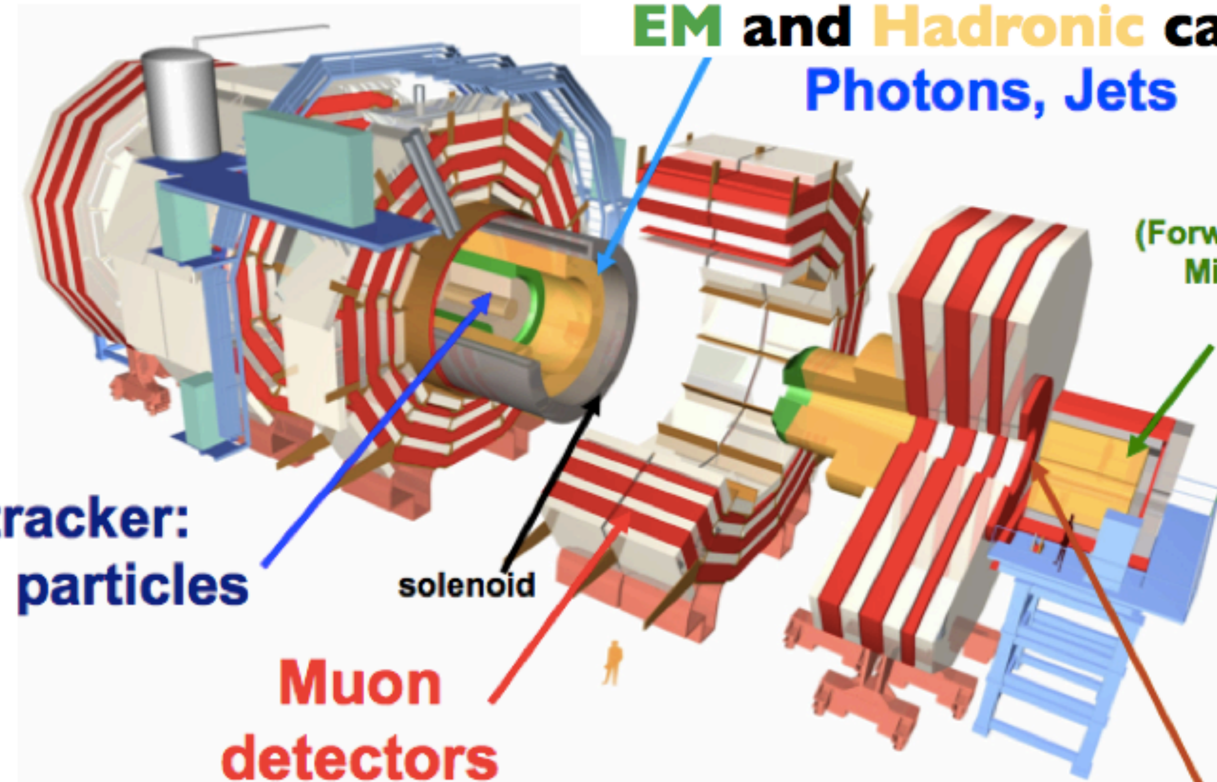
Motivation



- Measuring the effects of jet quenching can give us important information about energy loss mechanisms in a QGP medium.
- Using high-p_T track correlations we can study jet quenching over a large kinematic range from very low p_T to high p_T
  - Associated particle: $0.5 < p_T < 15$ GeV/c
  - Trigger particle: $20 < p_T < 50$ GeV/c
- Provides quantitative constraints on jet quenching models.

CMS Detector

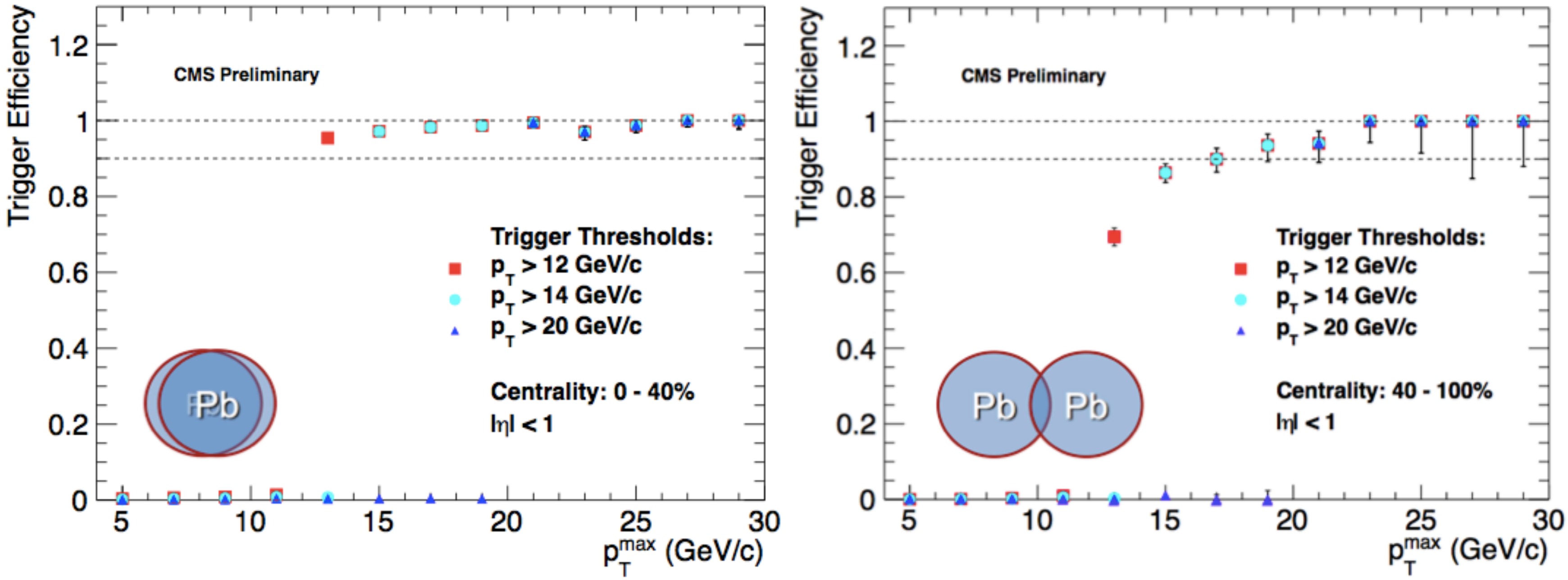


Muon Chambers	$\lvert\eta\rvert < 2.4$
Hadronic Calorimeter	$\lvert\eta\rvert < 5.2$
EM Calorimeter	$\lvert\eta\rvert < 3.0$
Tracker	$\lvert\eta\rvert < 2.5$

High p_T Single-Track Trigger

- Full 2011 HI Data Set: $\mathcal{L}_{int}$ = 150 μb^{-1}
- High p_T Triggers
  - Full track reconstruction is used in HLT
  - Single-Track High-p_T Triggers (Total #events: ~1.55M with p_T>20 GeV/c)

All triggers used in this analysis are at least 95% effective for central events



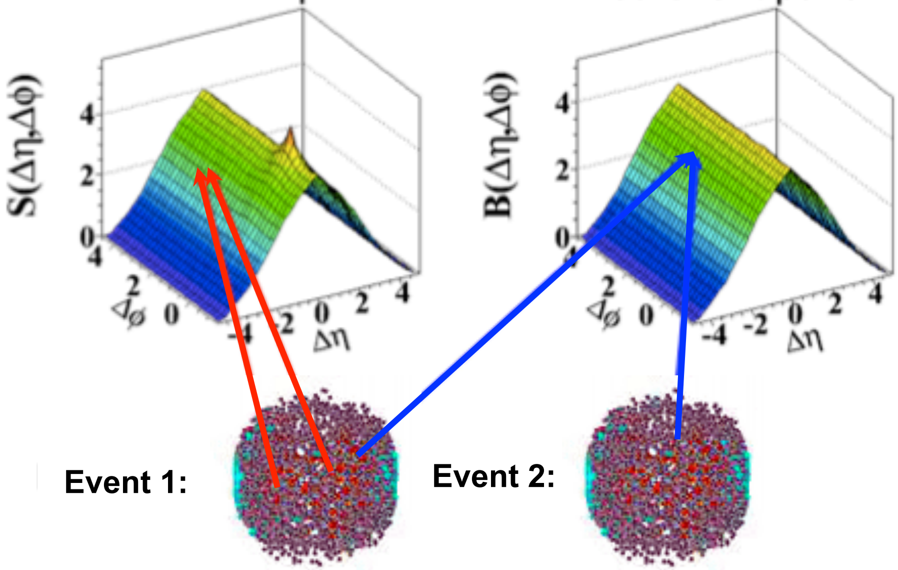
Two Particle Correlations

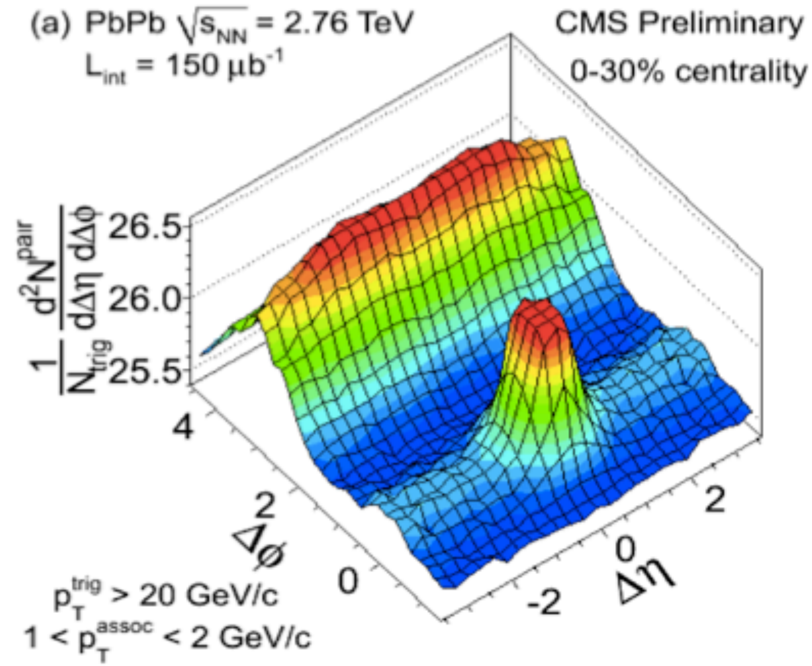
Signal pair distribution:

$$S(\Delta\eta,\Delta\varphi) = \frac{1}{N_{trig}} \frac{d^2N^{same}}{d\Delta\eta d\Delta\varphi}$$

Background pair distribution:

$$B(\Delta\eta,\Delta\varphi) = \frac{1}{N_{trig}} \frac{d^2N^{mix}}{d\Delta\eta d\Delta\varphi}$$





Note: Peak at $\Delta\eta=0$ and $\Delta\phi=0$ is truncated

$\Delta\eta = \eta^{assoc} - \eta^{trig}$

$\Delta\phi = \phi^{assoc} - \phi^{trig}$

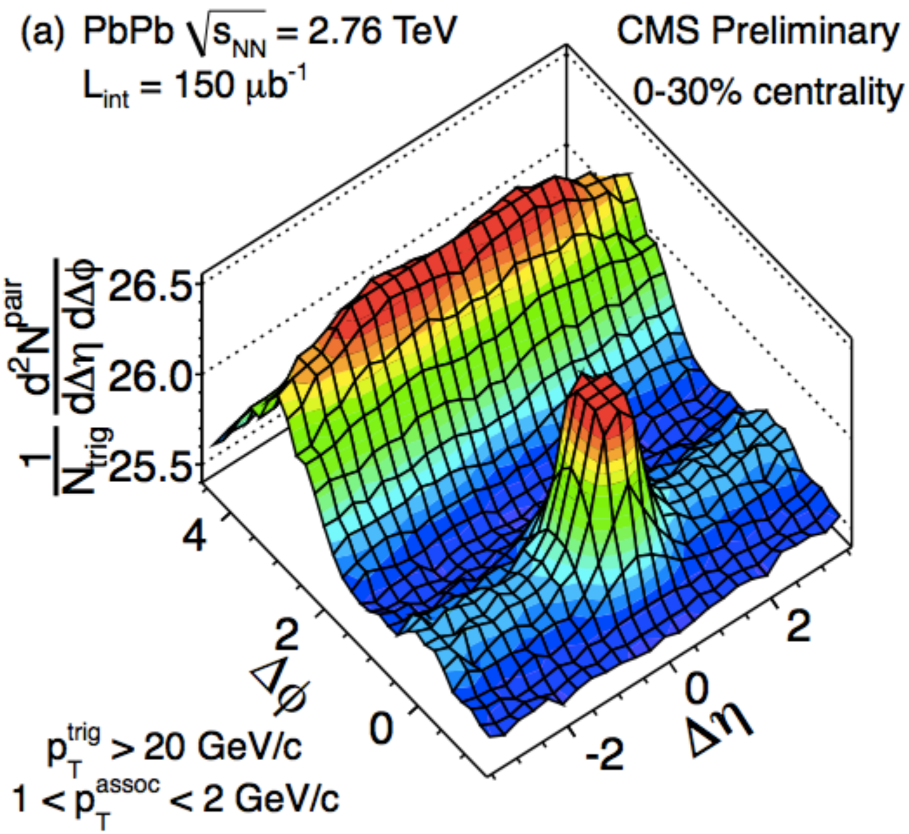
Events are mixed within 0.5 cm
In z_{vtx} and 2.5% in centrality

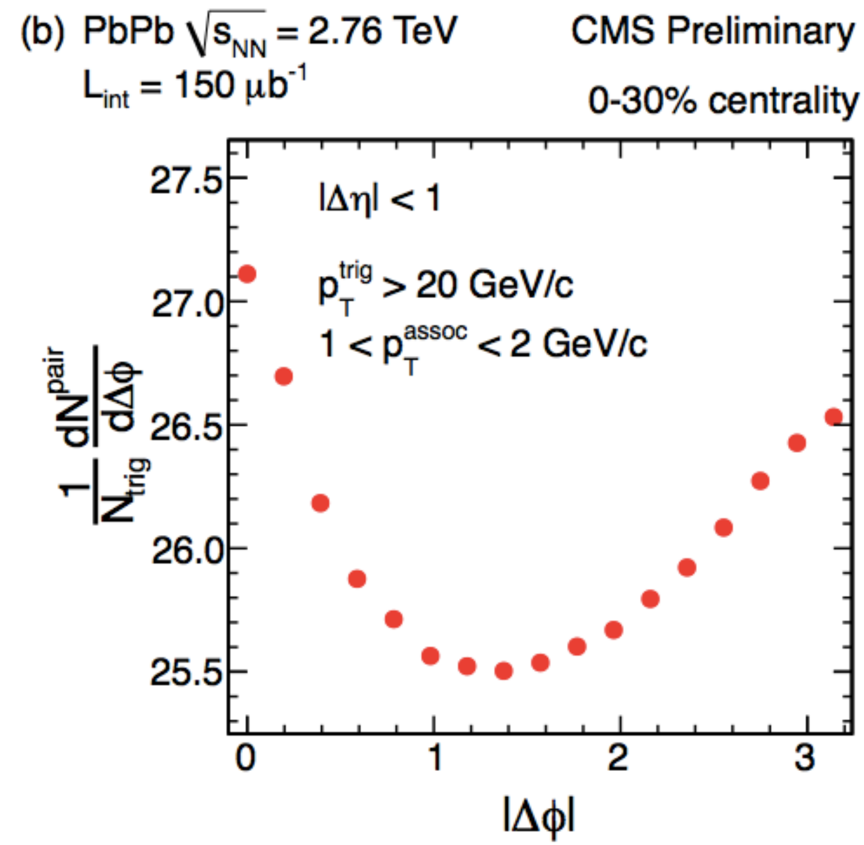
Associated hadron yield per trigger:

$$\frac{1}{N_{trig}} \frac{d^2N^{pair}}{d\Delta\eta d\Delta\phi} = B(0,0) \times \frac{S(\Delta\eta,\Delta\phi)}{B(\Delta\eta,\Delta\phi)}$$

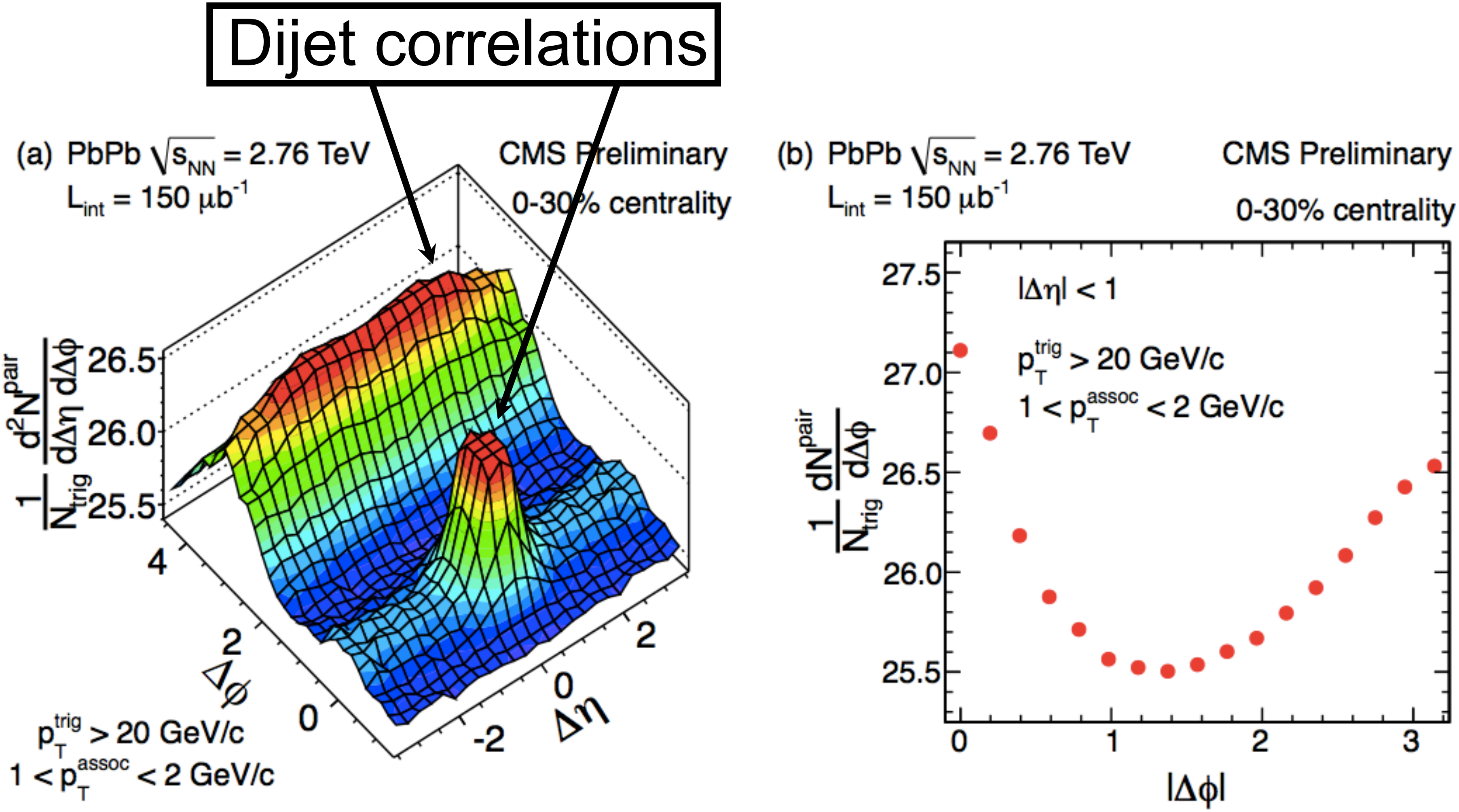
High-p_T Dihadron Correlations

Project onto the $\Delta\emptyset$-axis

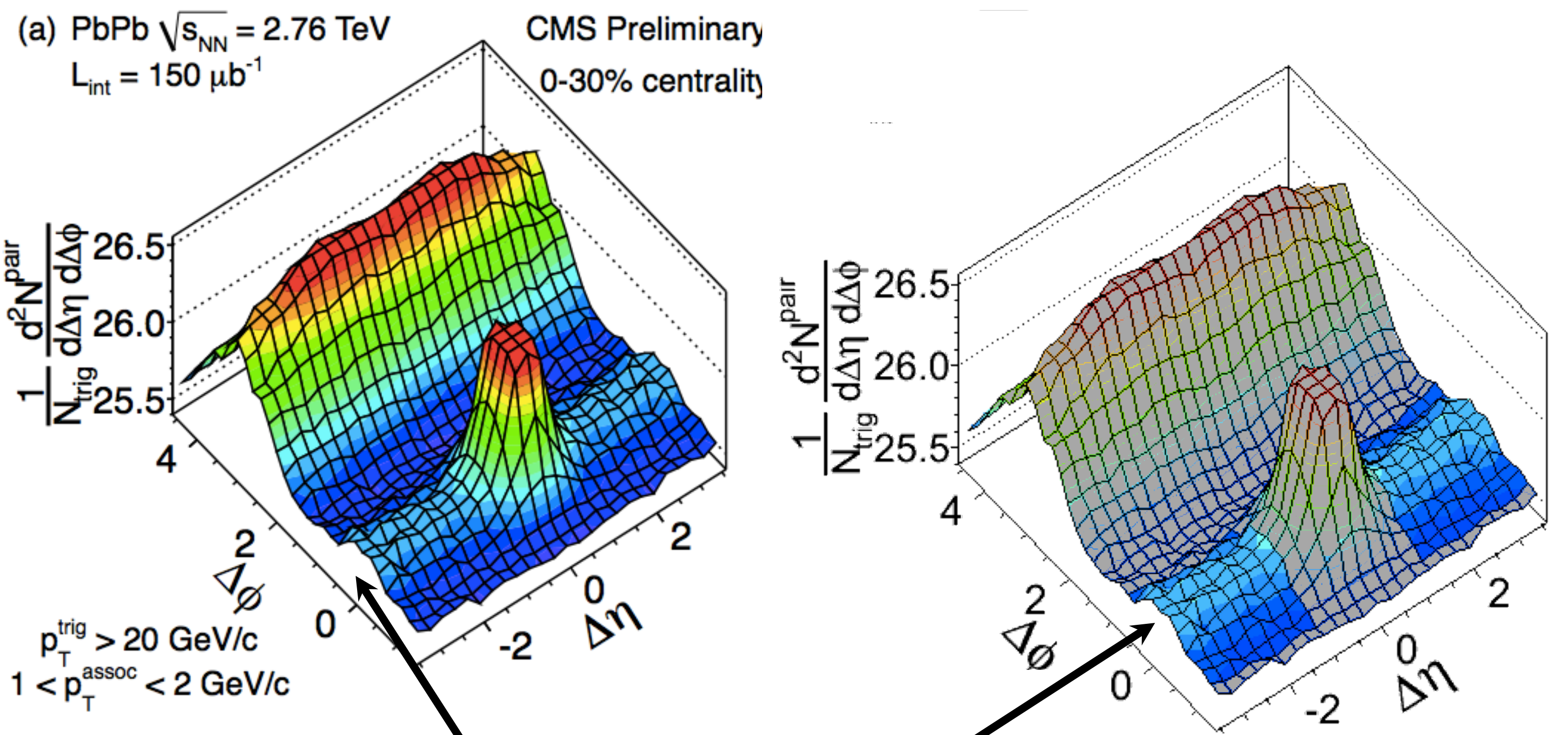




High-p_T Dihadron Correlations



High-p_T Dihadron Correlations

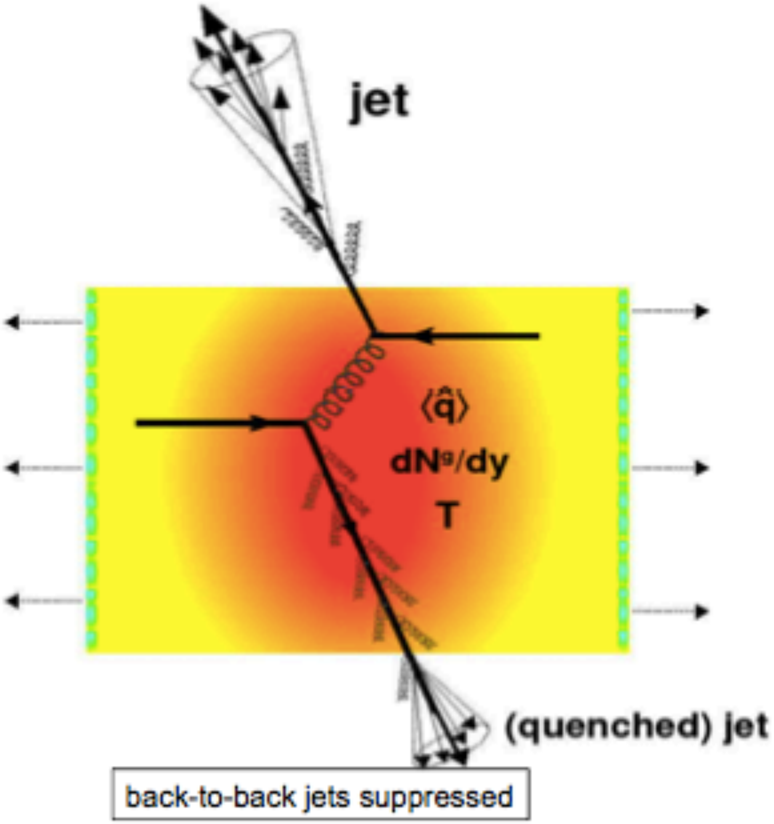


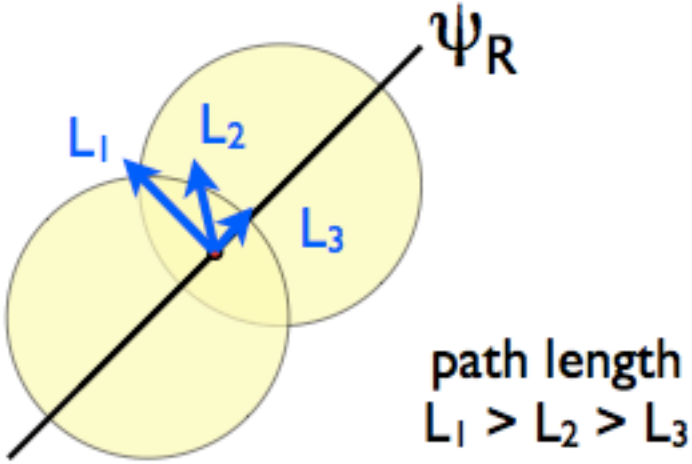
Azimuthal anisotropy contribution

Characterized by Fourier components: ($v_2 - v_4$).

Needs to be subtracted in order to study dijet correlations

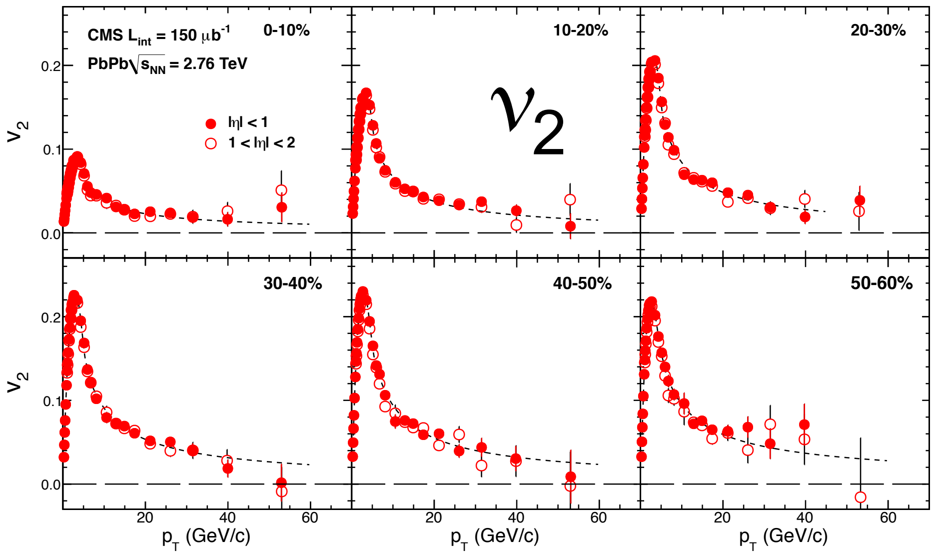
Azimuthal Anisotropy Background

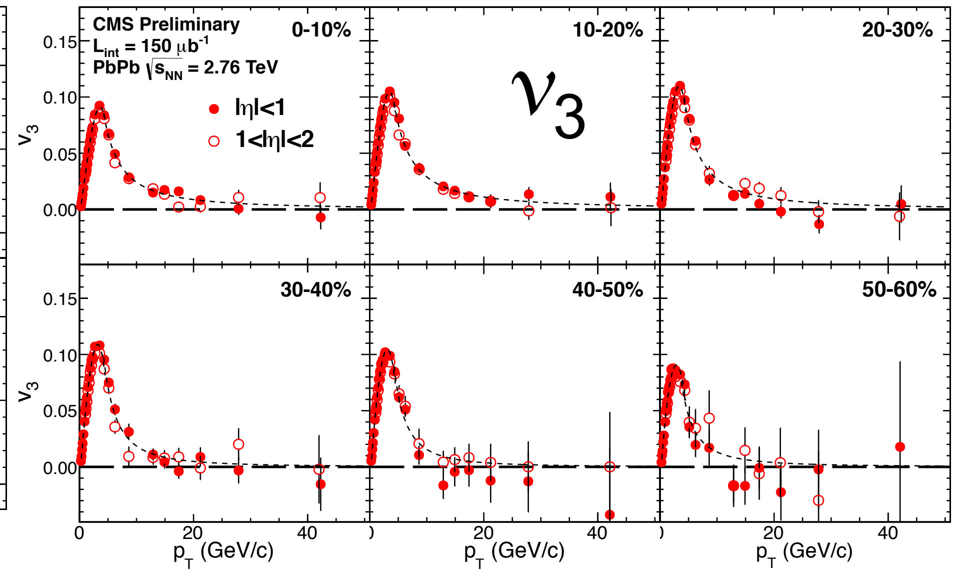


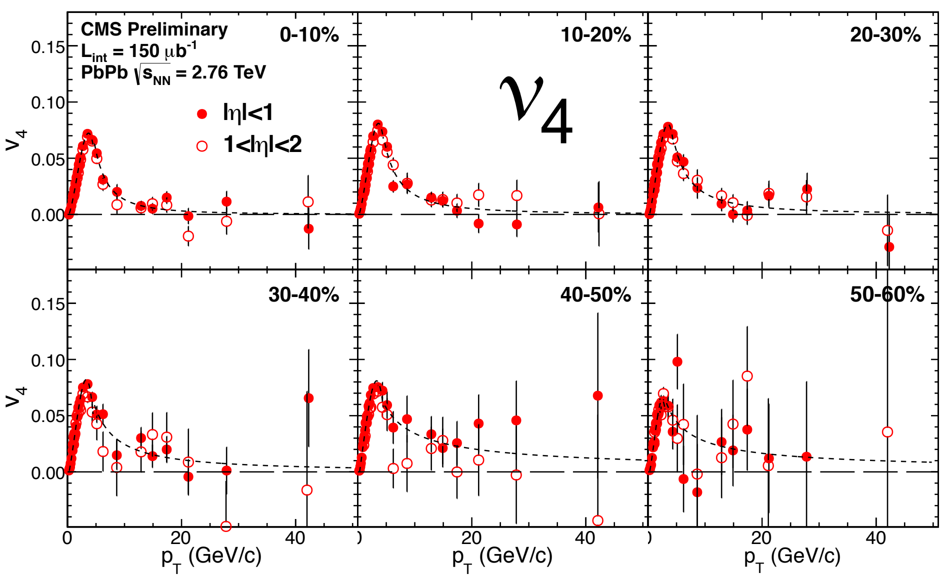


Note: the v_n background does not come from hydrodynamic flow but the path length dependence of energy loss of high p_T particles in a QGP medium.

High-p_T v_n Measurements







High-p_T v_n coefficients used in the flow background subtraction were measured using the HF event plane method

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The ZYAM Procedure

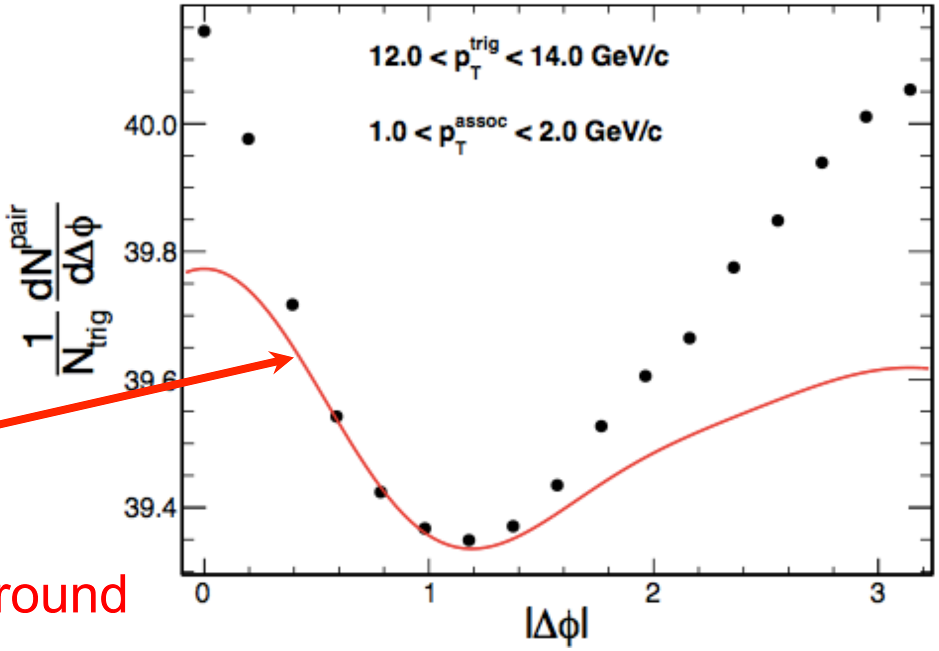
The 2D correlations are averaged over Δη and projected onto the Δ∅-axis to get 1D correlations.

v_n Subtraction via the Zero-Yield-At-Minimum procedure

$$\frac{1}{N_{trig}}\frac{dN^{pair}_{sub}}{d\Delta\phi} = \frac{1}{N_{trig}}\frac{dN^{pair}}{d\Delta\phi} - a\left(1+2\sum_n v_n(p_T^{trig})v_n(p_T^{assoc})\cos(n\Delta\phi)\right)$$

- Find "a" such that the minimum of the difference is around 0 at $\Delta\phi=\Delta\phi_{ZYAM}$

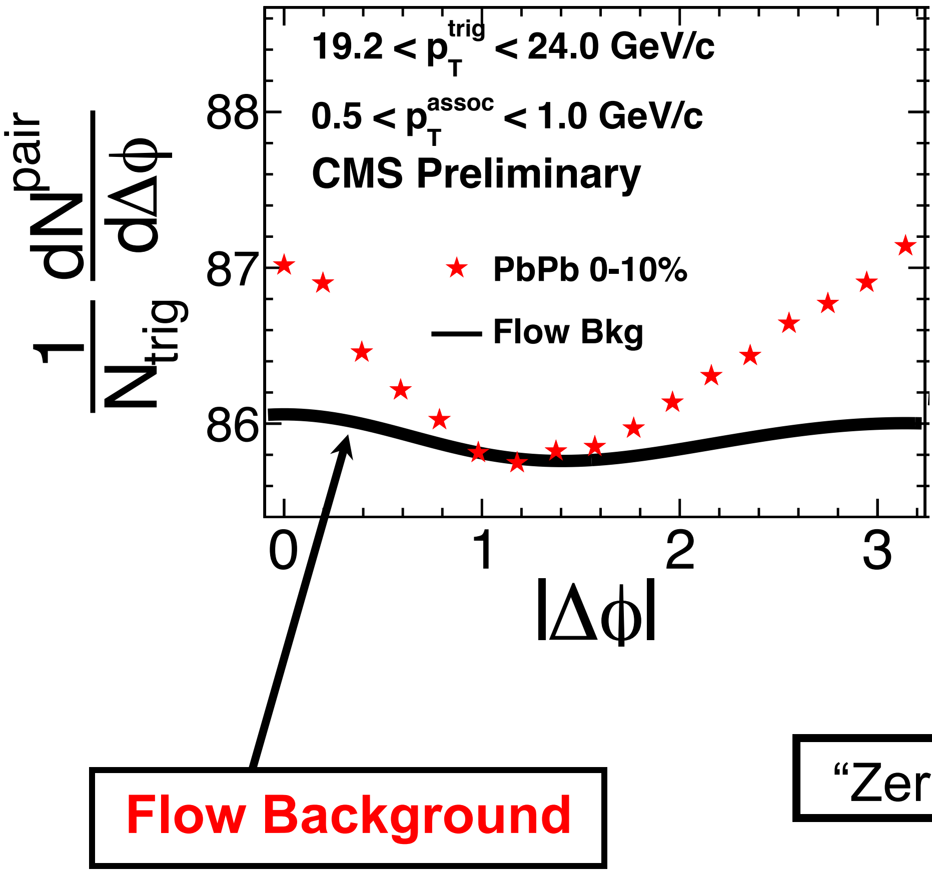
"Flow" Background expressed as a Fourier expansion and scaled by the ZYAM procedure

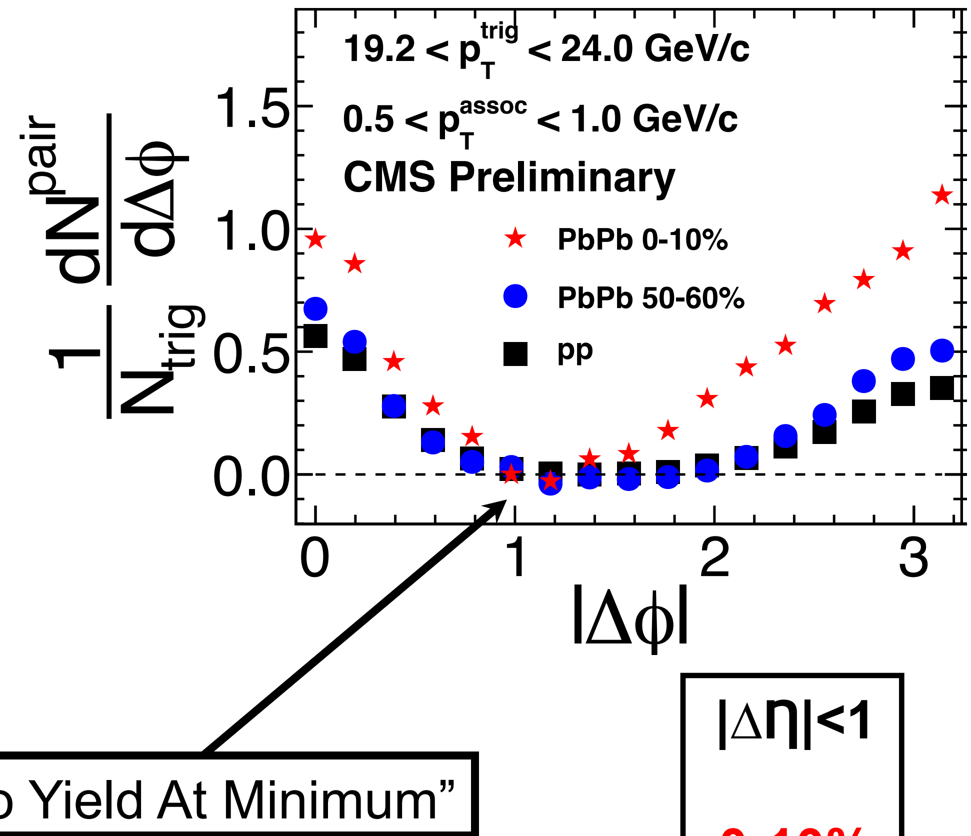


Note: v_1 is not included in flow background

1D Projected Correlation Functions

Before ZYAM Subtraction → **After ZYAM Subtraction**





$|\Delta\eta|<1$

0-10%
50-60%
pp

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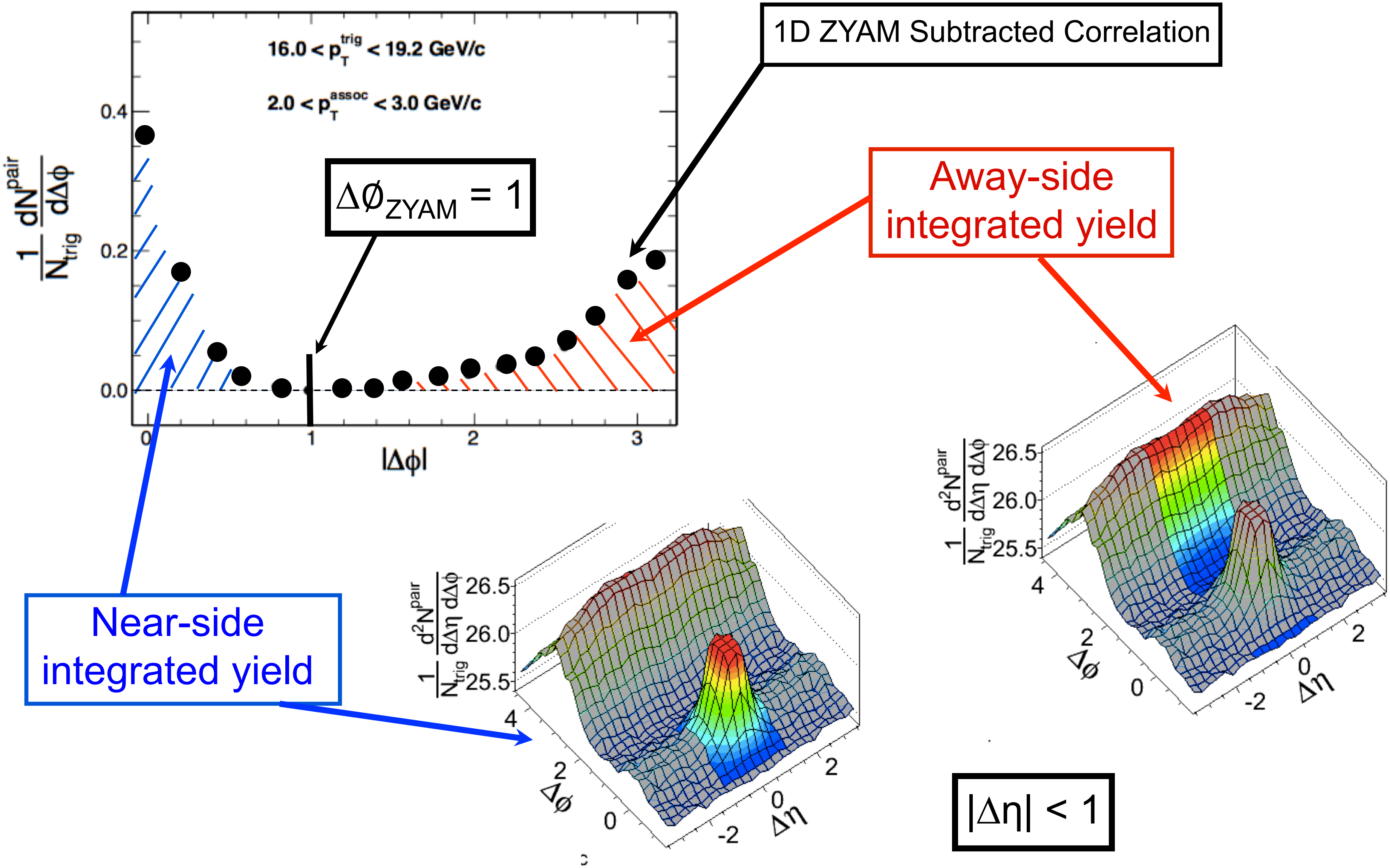
Calculating the Integrated Yield



Integrated Yields

Differences at low associated particle p_T are clearly visible on the near and away-side

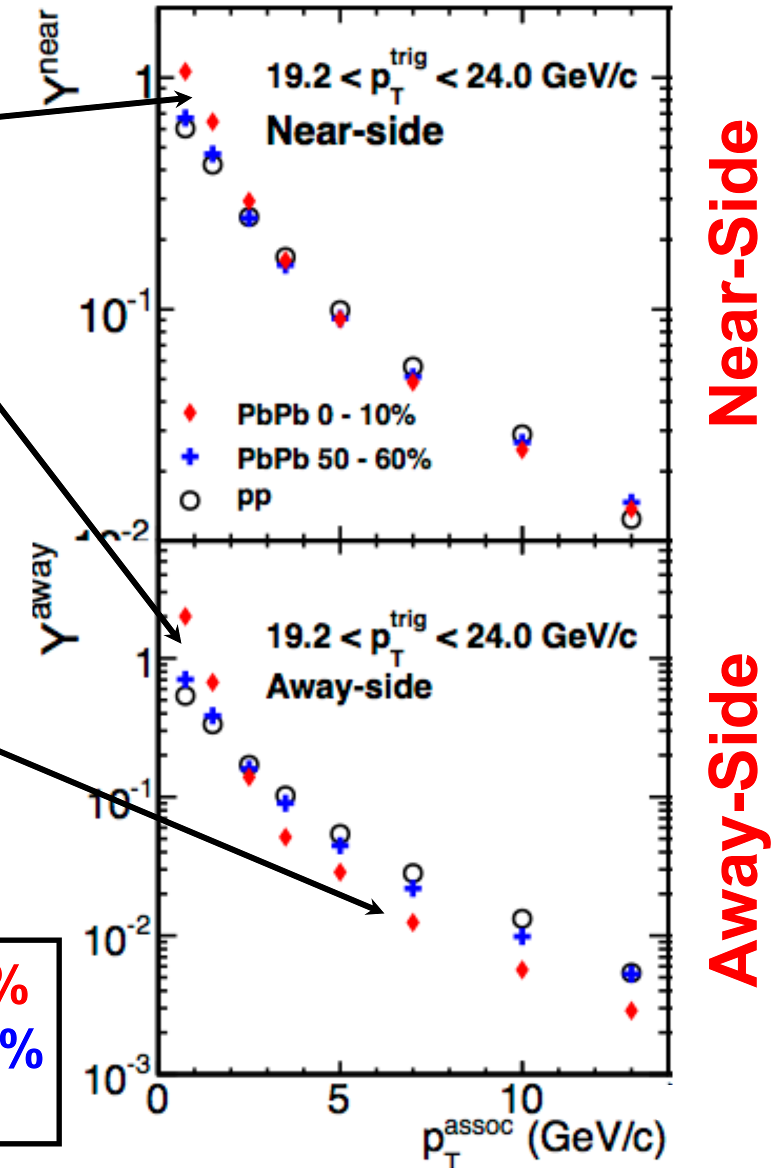
The away-side also shows large discrepancies at high associated particle p_T

We use I_{AA} ratios to quantify any modifications from pp reference:

$$I_{AA}^{near} = \frac{Y_{PbPb}^{near}}{Y_{pp}^{near}}$$

$$I_{AA}^{away} = \frac{Y_{PbPb}^{away}}{Y_{pp}^{away}}$$

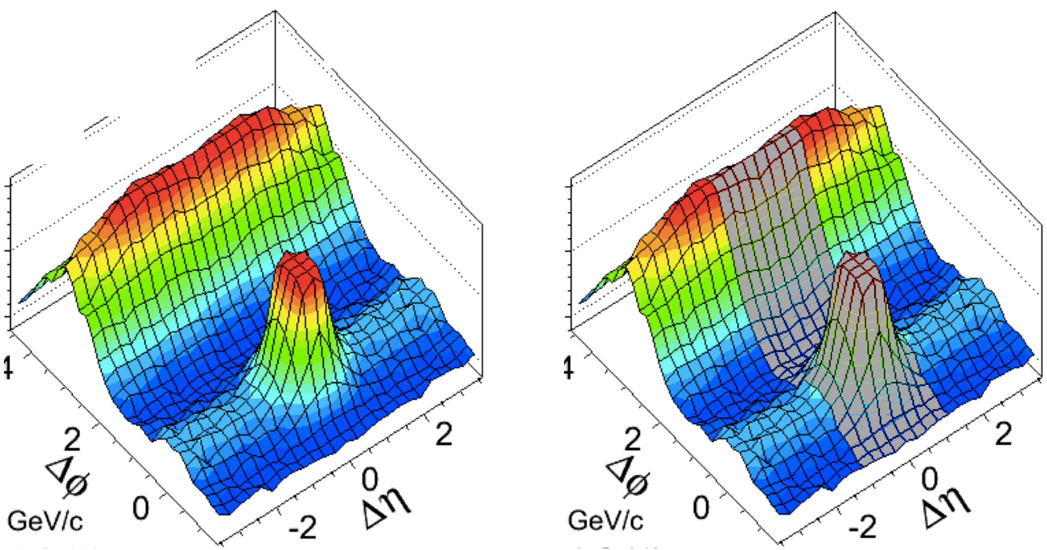
0-10%
50-60%
PP

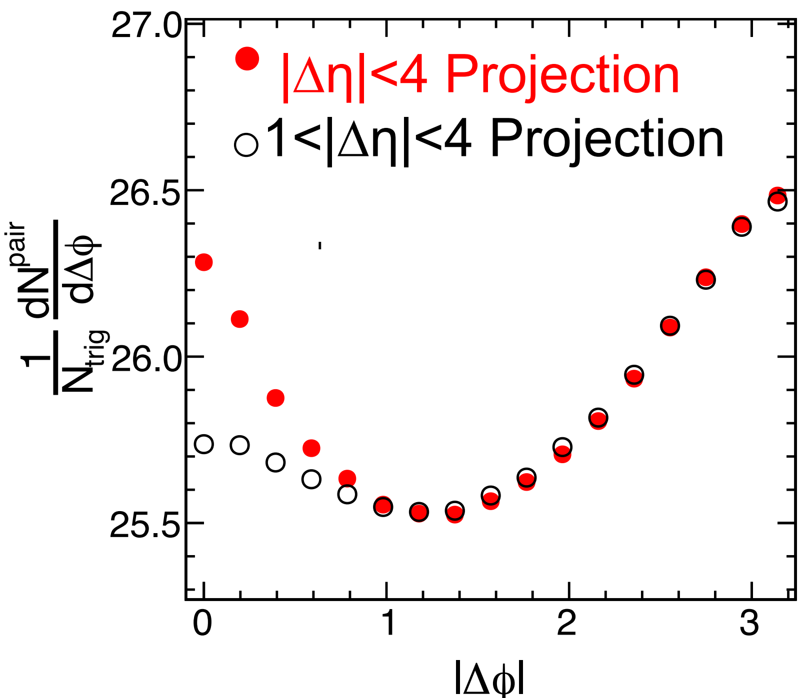


Long-Range Δη Subtraction

An alternate method is to use the long-range region to estimate the full flow background (including v_1)

Full Range $|\Delta\eta| < 4$ — Long Range $1 < |\Delta\eta| < 4$

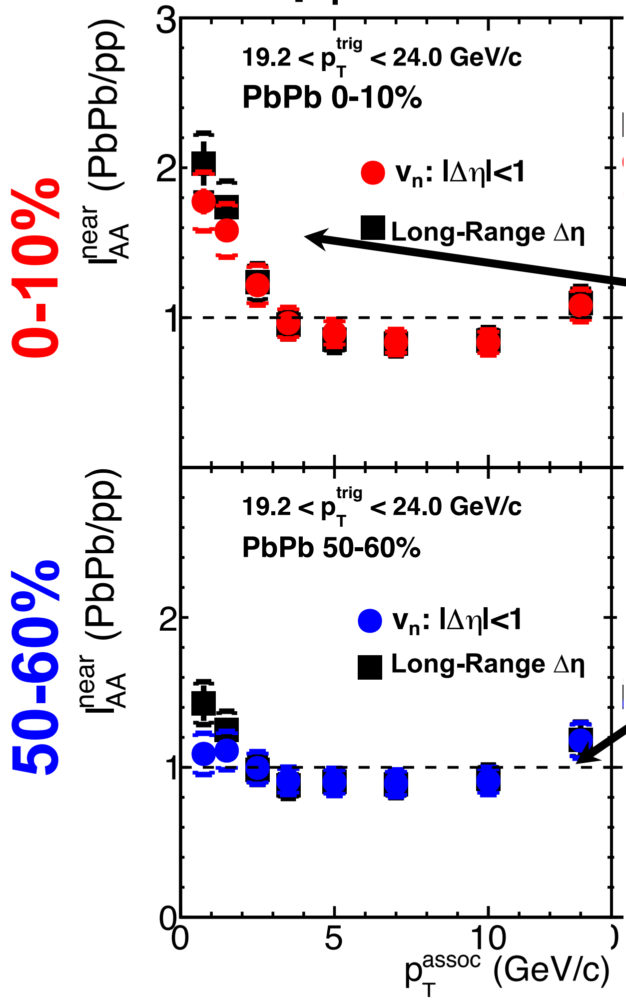




Note: This method can only be applied to the near-side

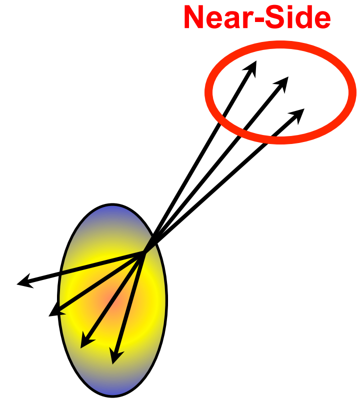
Near-Side I_{AA}

$19.2 < p_T^{trig} < 24$ GeV/c



We can compare the near-side I_{AA} results from the ZYAM and the Long-Range Δη subtraction methods

Significant enhancement of low p_T particles



No significant suppression/ enhancement at high p_T

There is a slight difference between the two methods at low p_T, possibly due to a long-range cos(ΔØ) background term

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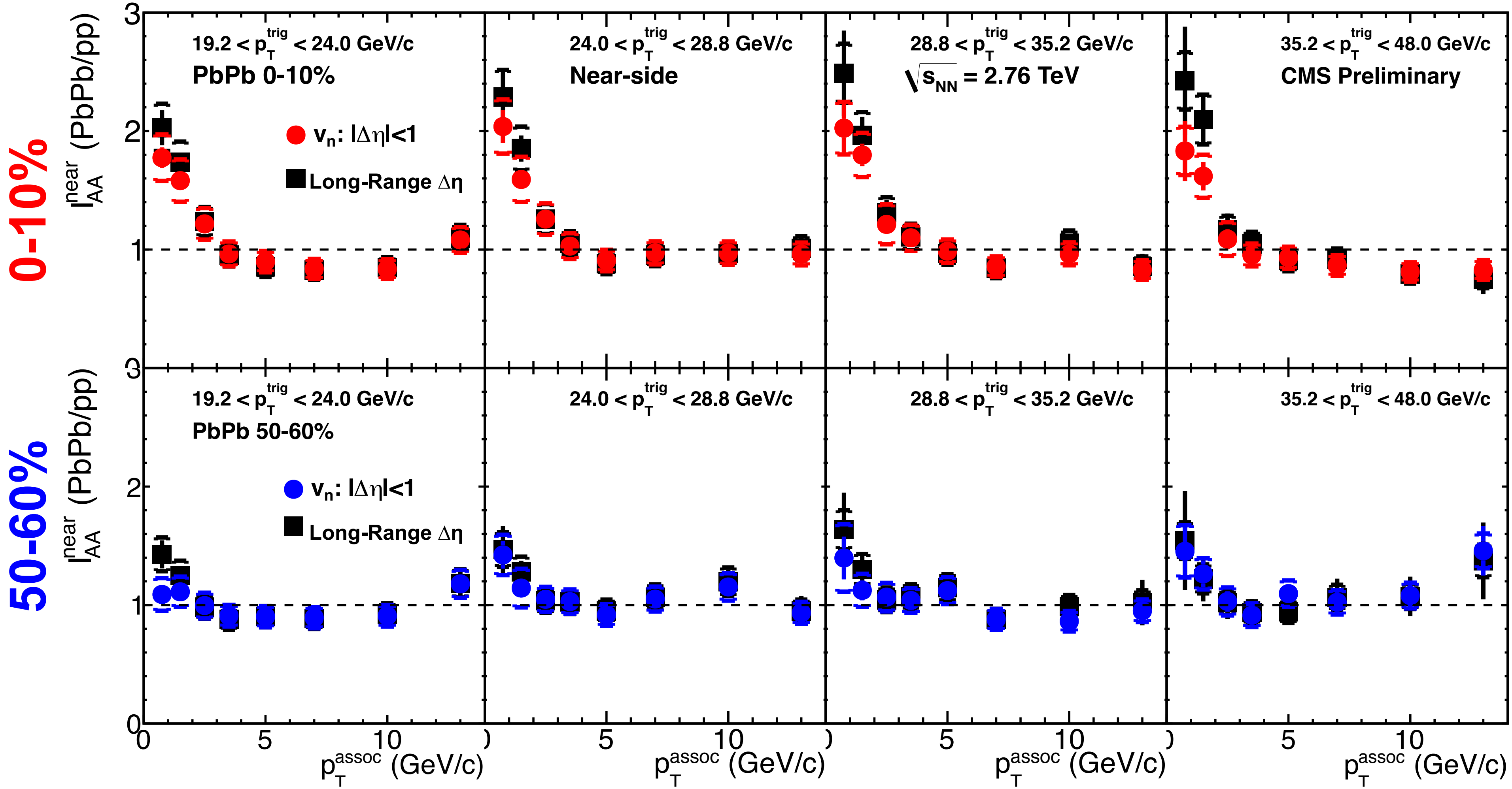
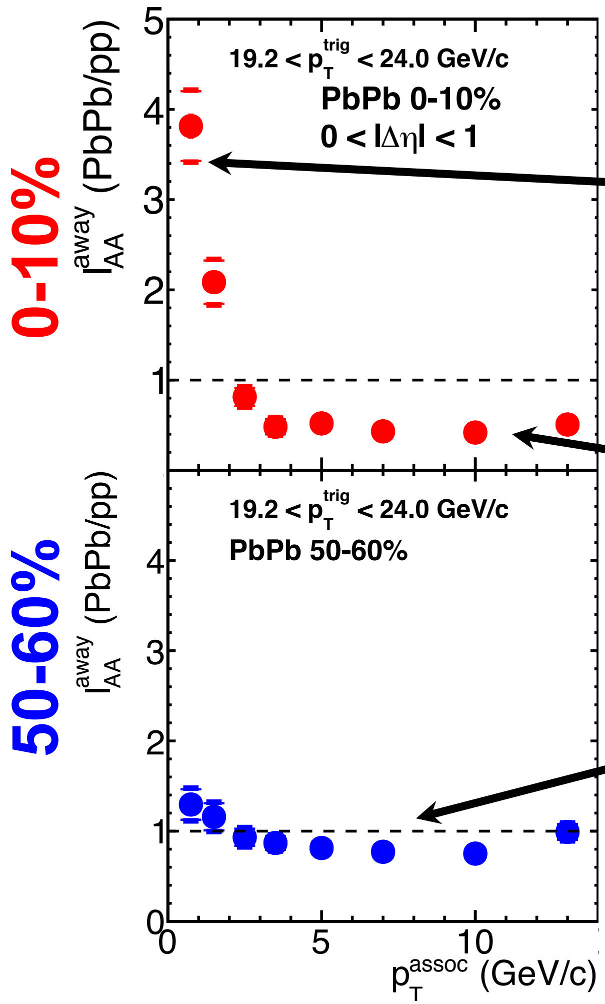
Near-Side I_{AA}



Independent of trigger particle p_T for p_T > 20 GeV/c

Away-Side I_{AA}

$19.2 < p_T^{trig} < 24$ GeV/c

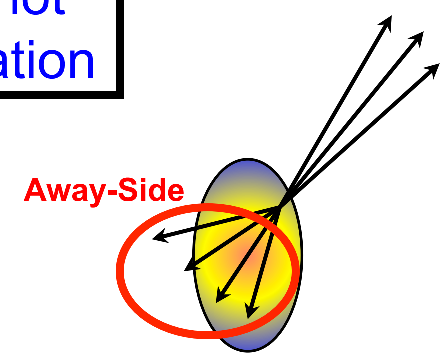


Factor of ~4 enhancement of low p_T particles in central collisions

Factor of ~2 suppression at high p_T in central collisions

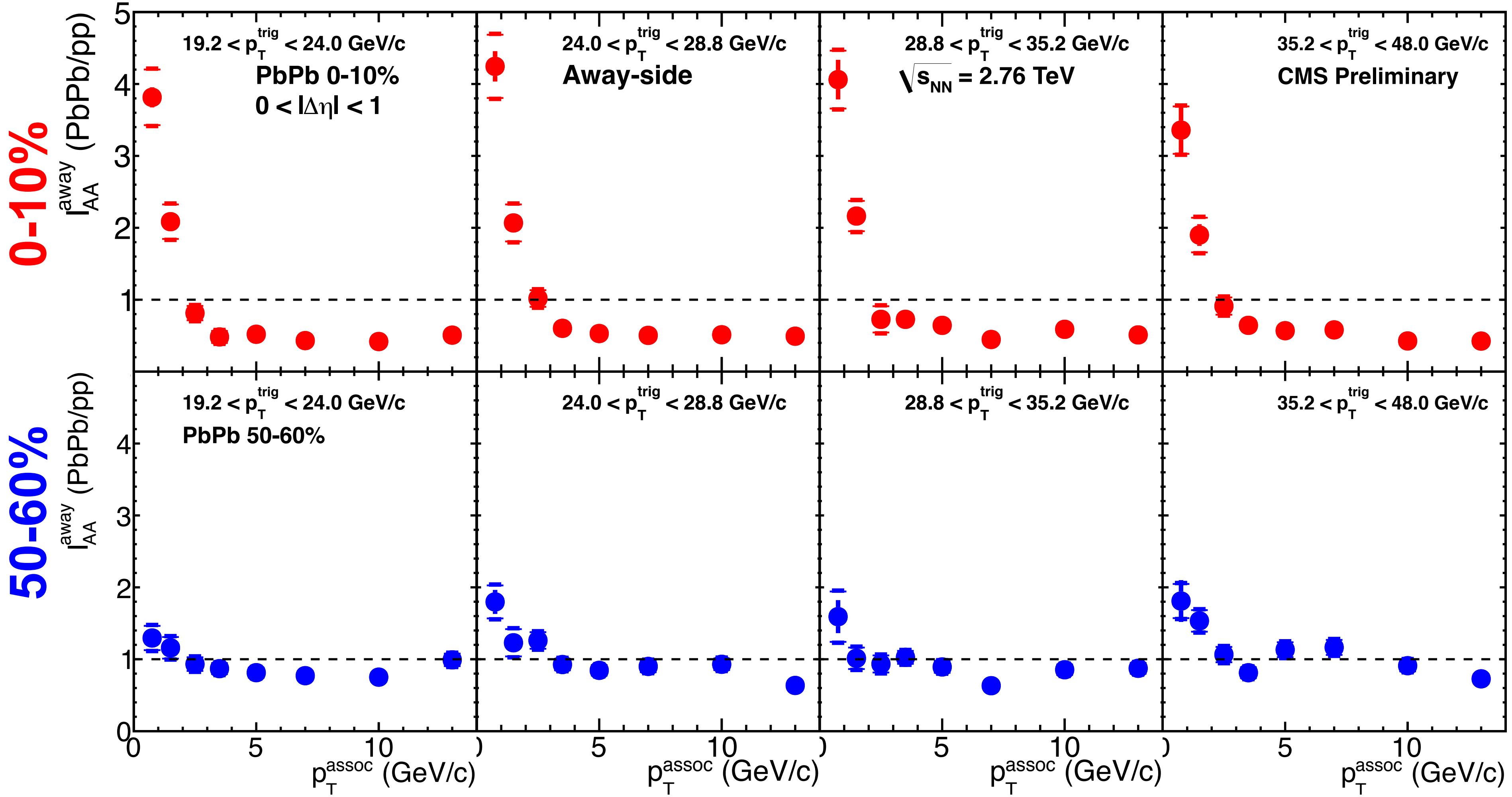
Peripheral events do not show as much modification

Consistent with the jet quenching picture



Note: the long-range $\Delta\eta$ method can only be applied to the near-side

Away-Side I_{AA}



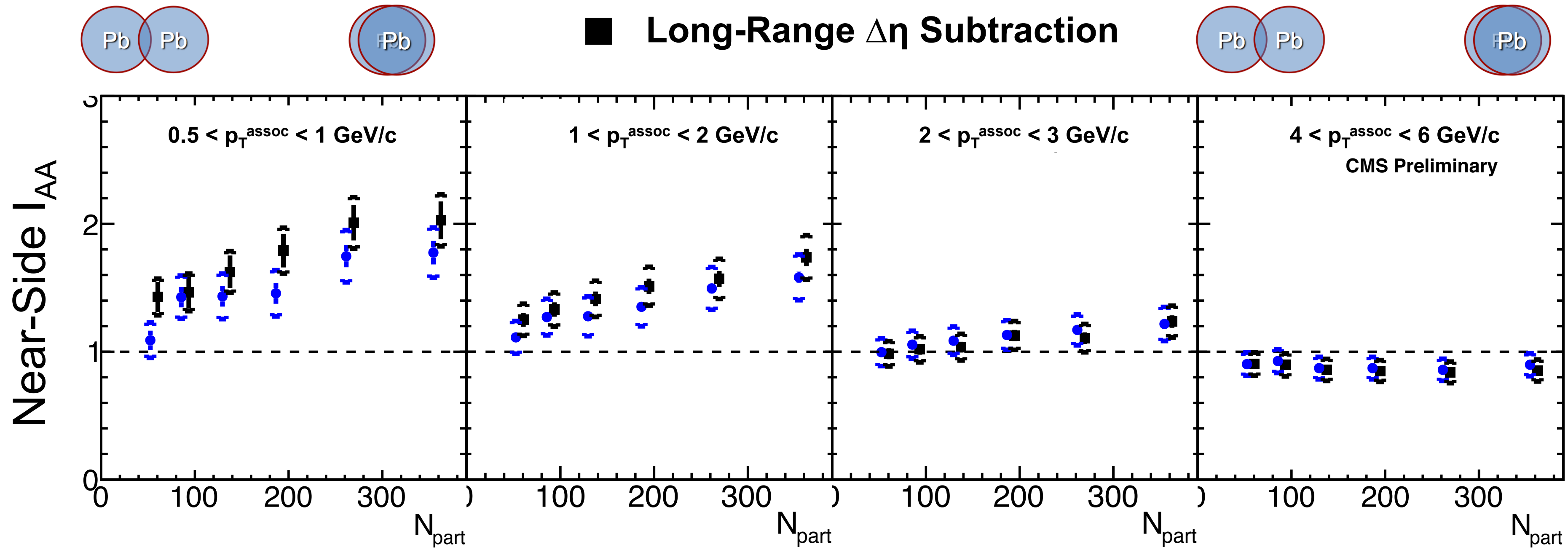
Away-side is also independent of trigger particle p_T

Near-Side I_{AA} Centrality Dependence

$19.2 < p_T^{trig} < 24$ GeV/c

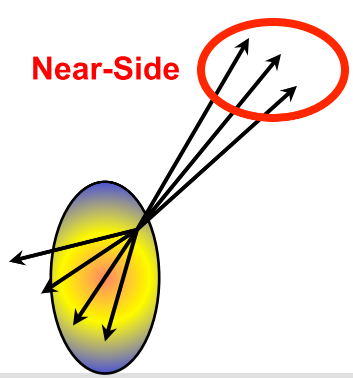
● v_n Subtraction: $|\Delta\eta| < 1$

■ Long-Range $\Delta\eta$ Subtraction



Enhancement at low p_T^{assoc}

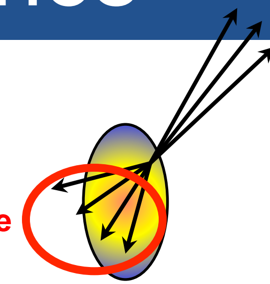
Increases with N_{part}



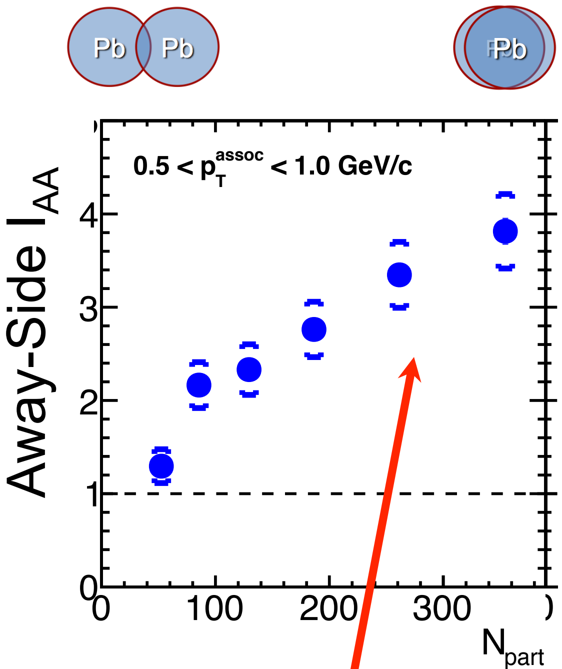
No enhancement for $p_T^{assoc} \sim 5$ GeV/c

Constant with N_{part}

Away-Side I_{AA} Centrality Dependence



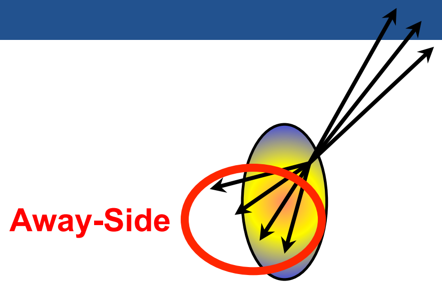
19.2 < p_T^{trig} < 24 GeV/c

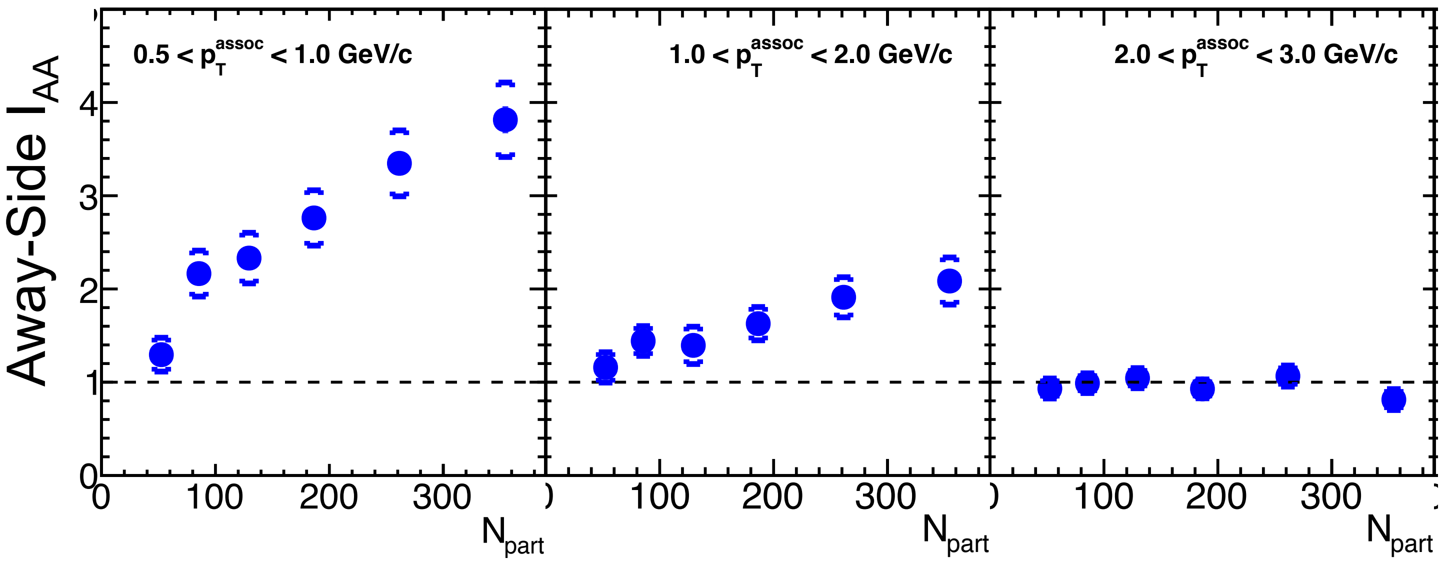


Enhancement

Away-Side I_{AA} vs. N_{part}

$19.2 < p_T^{trig} < 24$ GeV/c

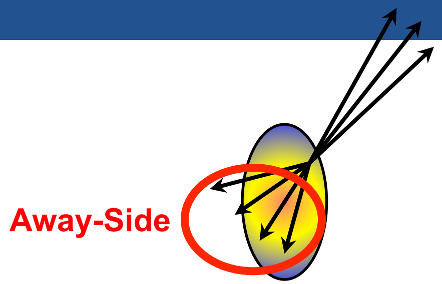


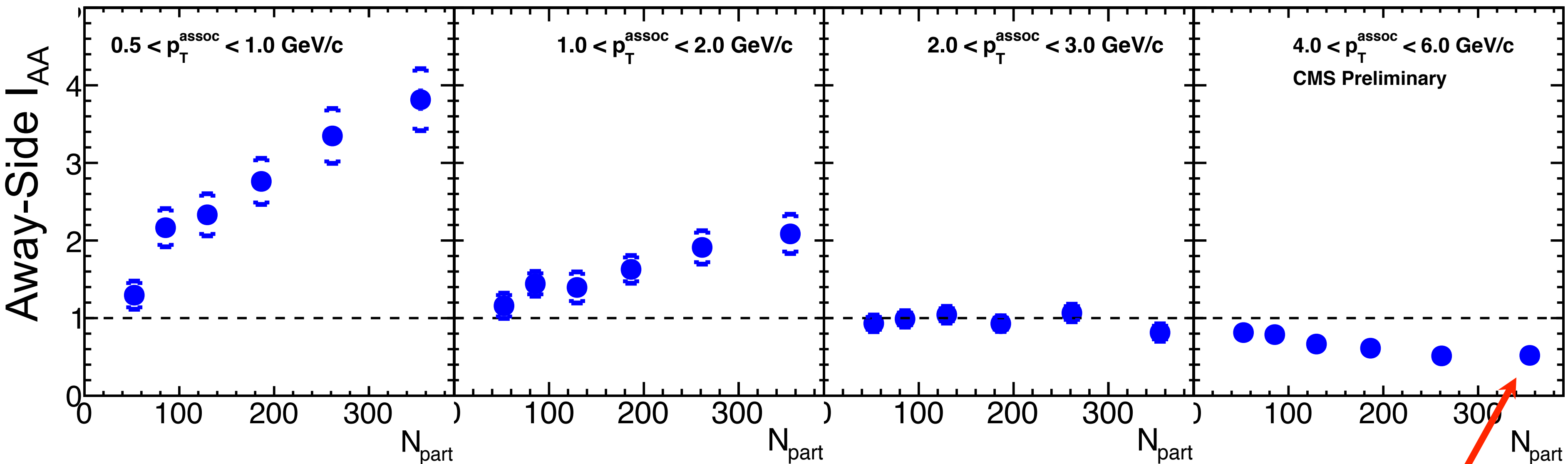


Enhancement Evolves with increasing p_T^{assoc}

Away-Side I_{AA} vs. N_{part}

19.2 < p_T^{trig} < 24 GeV/c

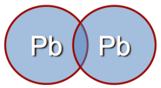




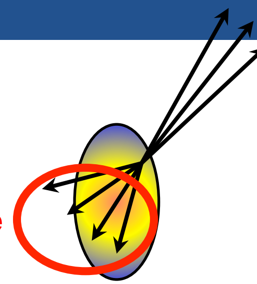
Enhancement Evolves with increasing p_T^{assoc} **Suppresion**

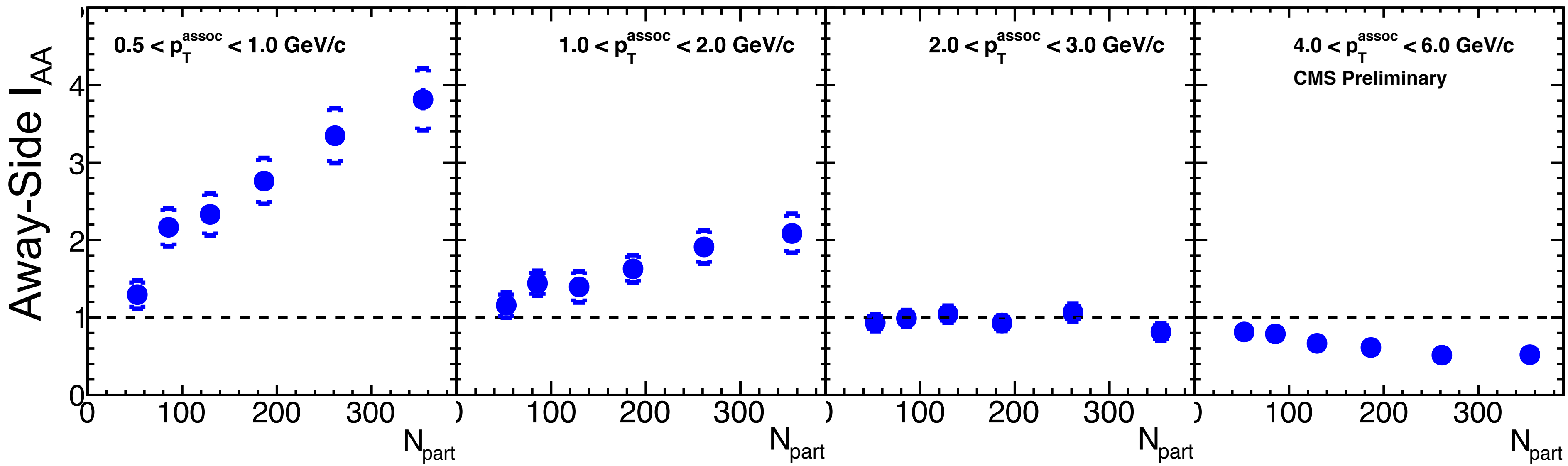
Away-Side I_{AA} vs. N_{part}

$19.2 < p_T^{trig} < 24$ GeV/c



Away-Side





Enhancement Evolves with increasing p_T^{assoc} **Suppresion**

There is a clear correlation between N_{part} and I_{AA} at different p_T^{assoc} consistent with the jet quenching picture

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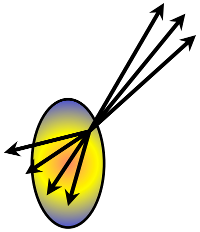
Summary

- Dihadron correlations over a wide kinematic range and high p_T
- Contributions from v_2-v_4 were subtracted
  - Access to jet-like correlations.
- Integrated yields from the near and away-side were extracted:
  - Near-Side:
    - No modification above 3-4 GeV/c for the associated particle.
    - Enhancement up to factor of 2 is seen at low associated particle p_T.
  - Away-Side:
    - Above 4 GeV/c a suppression of ~50% is seen for all centralities up to trigger particle p_T ~ 50 GeV/c.
    - Below 4 GeV/c: suppression changes to enhancement of a factor ~4 at the lowest measured associated particle p_T ~ 0.5 GeV/c
- Observations consistent with jet quenching and provide quantitative constraints on the models.



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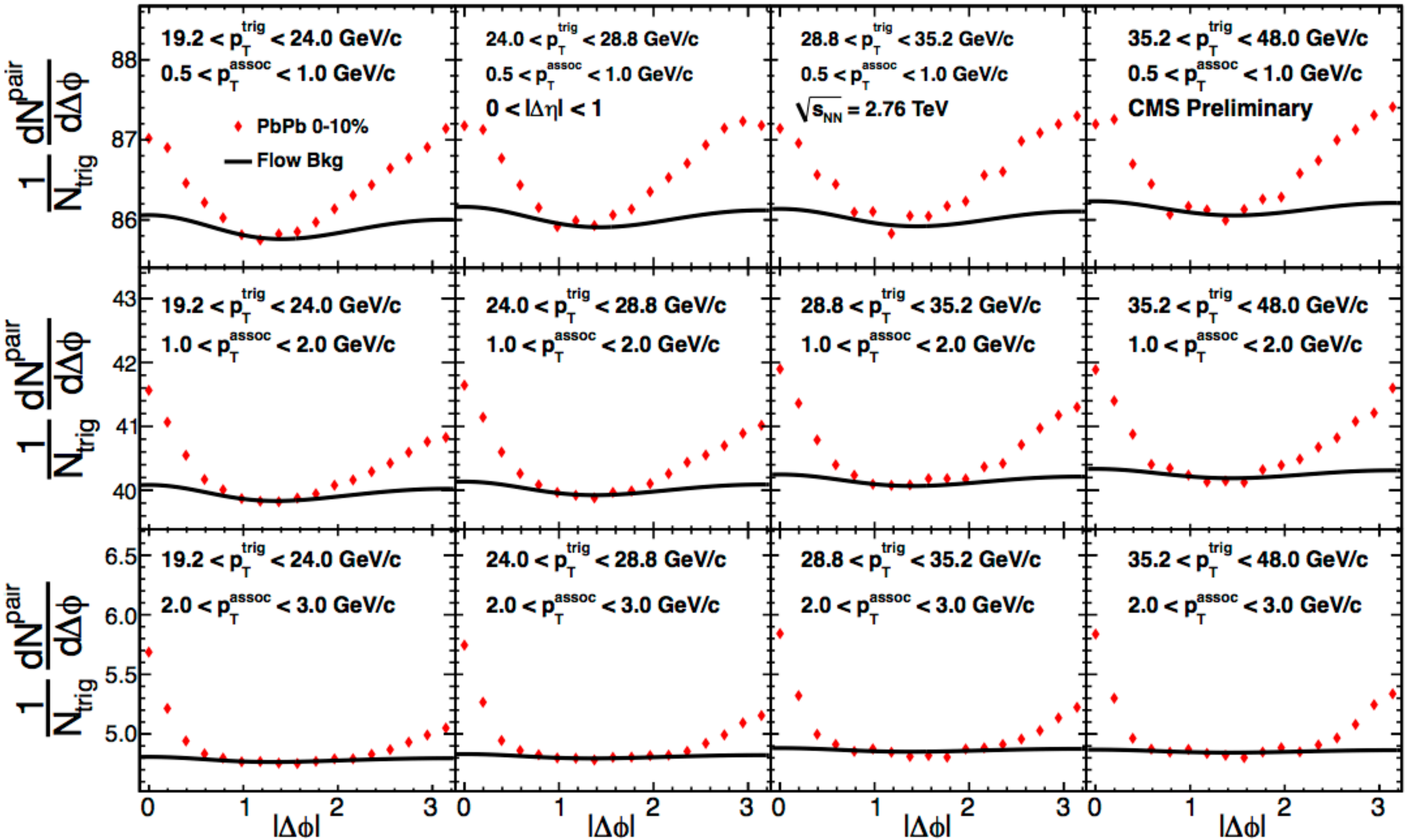
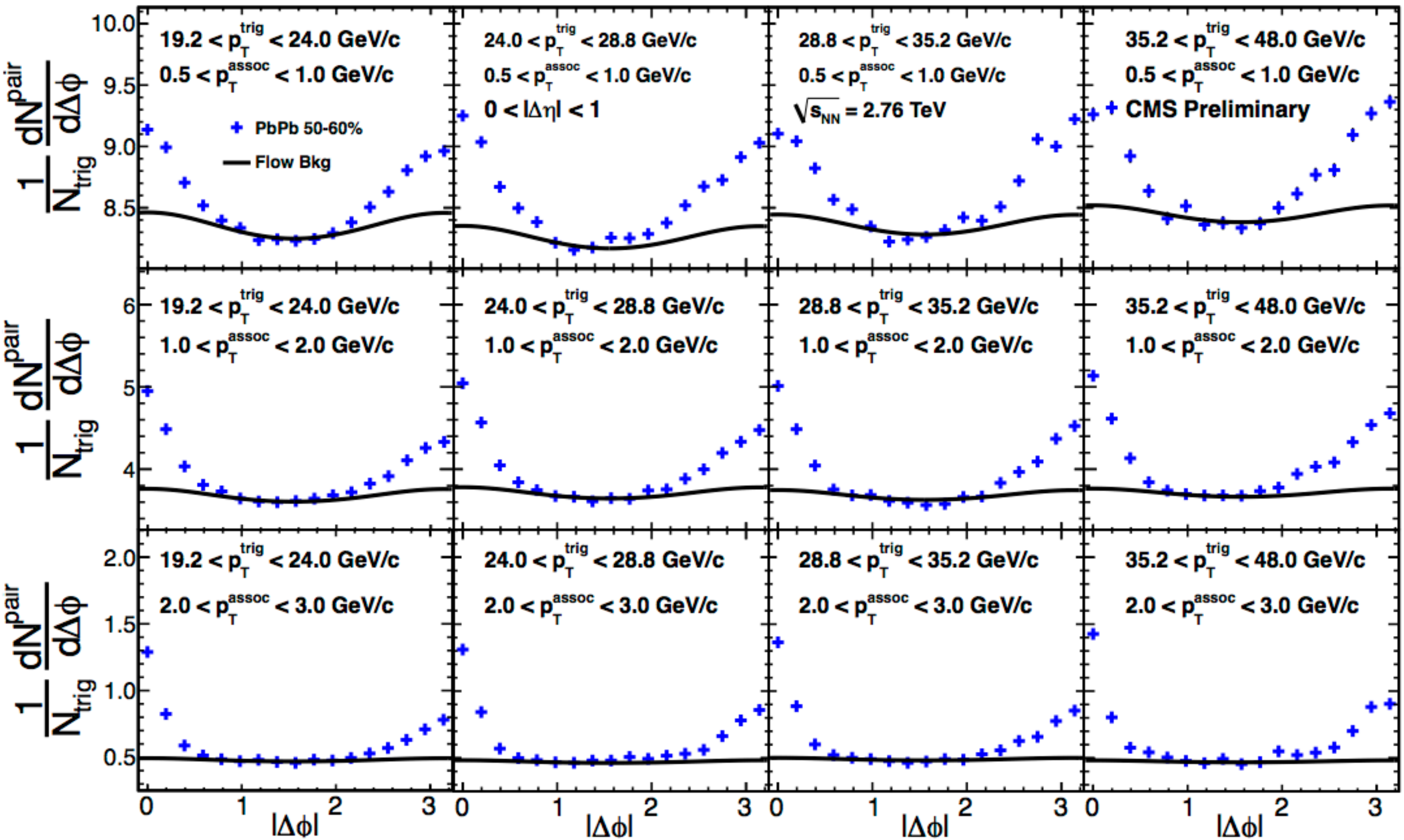
Backup Slides

0-10% PbPb Correlation Functions



50-60% PbPb Correlation Functions



pp Correlation Functions