Dihadron Correlations in PbPb Collisions at $\sqrt{s_{NN}}$ = 2.76 TeV with CMS

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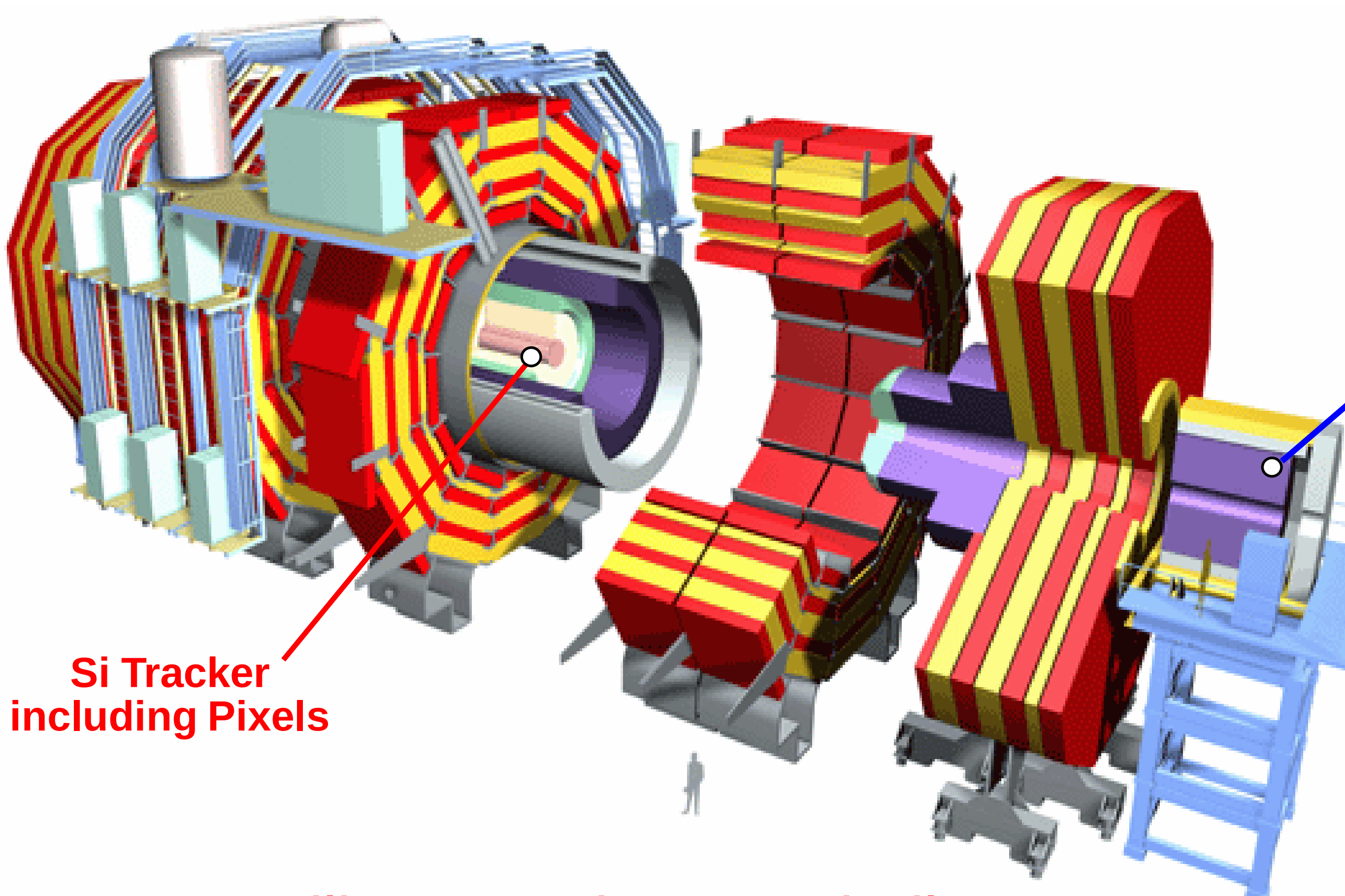
for the CMS Collaboration

Dihadron Correlations

- Features found in AA collisions at RHIC:
  - Broadened away side
  - Disappearance of back-to-back correlations
  - Near-side ridge
- Explanations of ridge include:
  - Connections to jet quenching
  - Higher order flow components (v_n | n>2)
- LHC and CMS provide:
  - Higher density system
  - Unprecedented pseudorapidity and p_T reach

CMS Detector



HF Utilized for Centrality Determination.

12 Centrality Classes

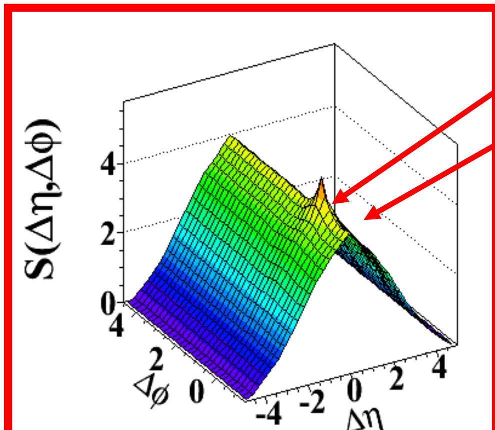
{0-5%}, {5-10%}, {10-15%}, {15-20%}, {20-25%}, {25-30%}, {30-35%}, {35-40%}, {40-50%}, {50-60%}, {60-70%}, {70-80%}

Largest Silicon Tracker ever built
Strips: 9.3M channels
Pixels: 66M channels
Extremely high granularity
Coverage over $|\Delta\eta| < 5$

Analysis Technique

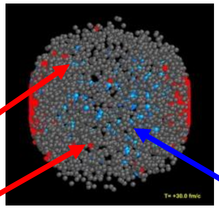
Signal distribution:

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

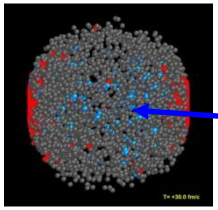


same event pairs

Event 1

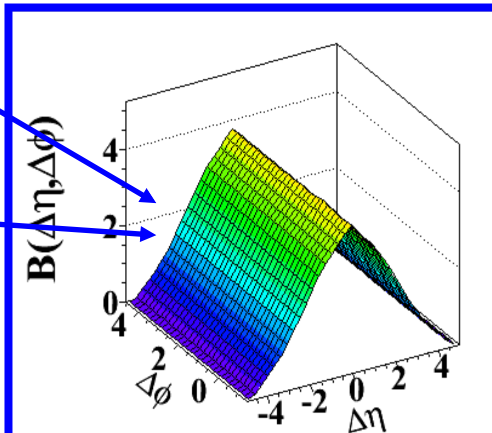


Event 2



Background distribution:

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



mixed event pairs

Analysis Technique

Signal distribution

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

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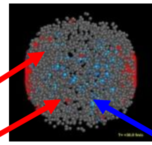
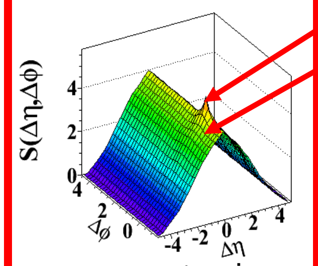
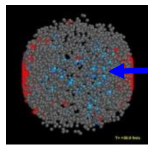
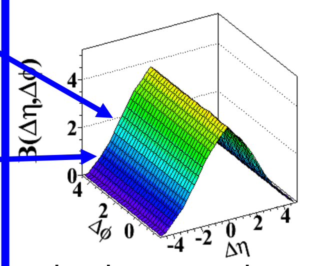




same event pairs

Event 2





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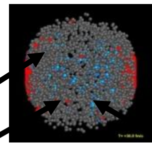

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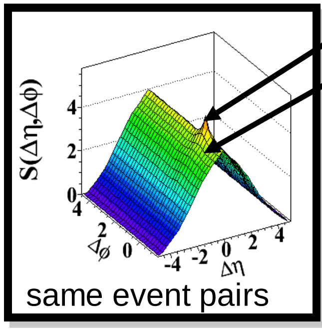
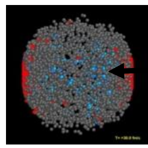
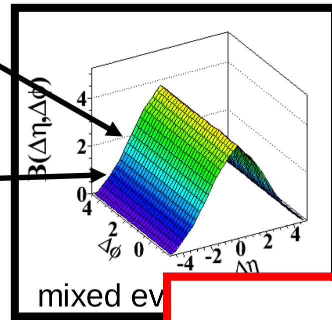
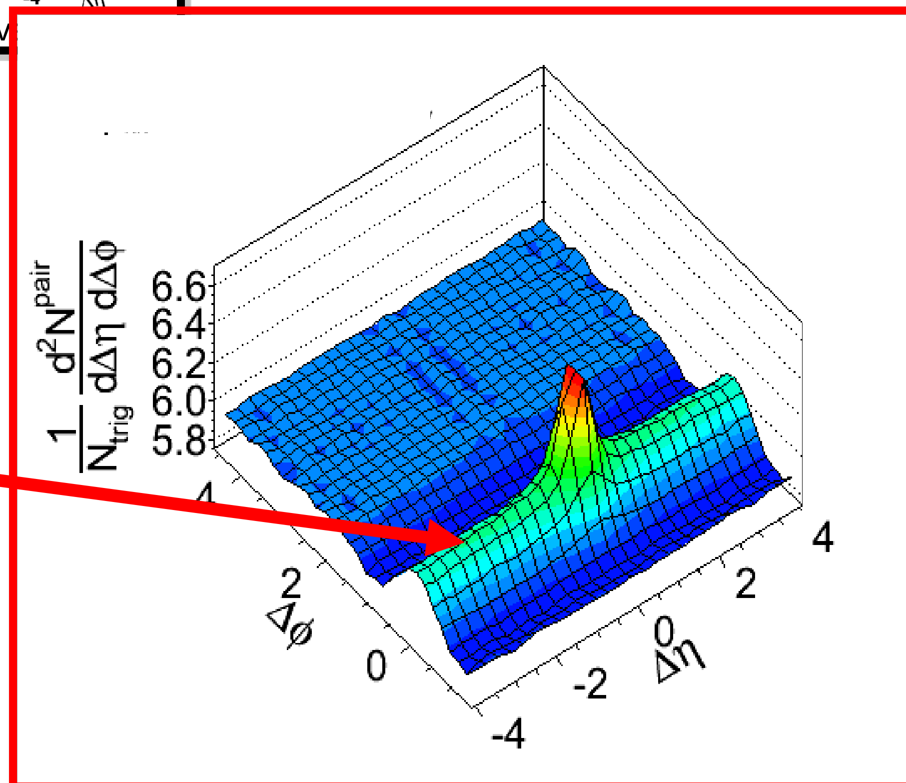


Event 2





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



0-5% central

$4 < p_T^{trig} < 6$ GeV/c

$2 < p_T^{assoc} < 4$ GeV/c

Ridge-like structure extends out to $|\Delta\eta| = 4$

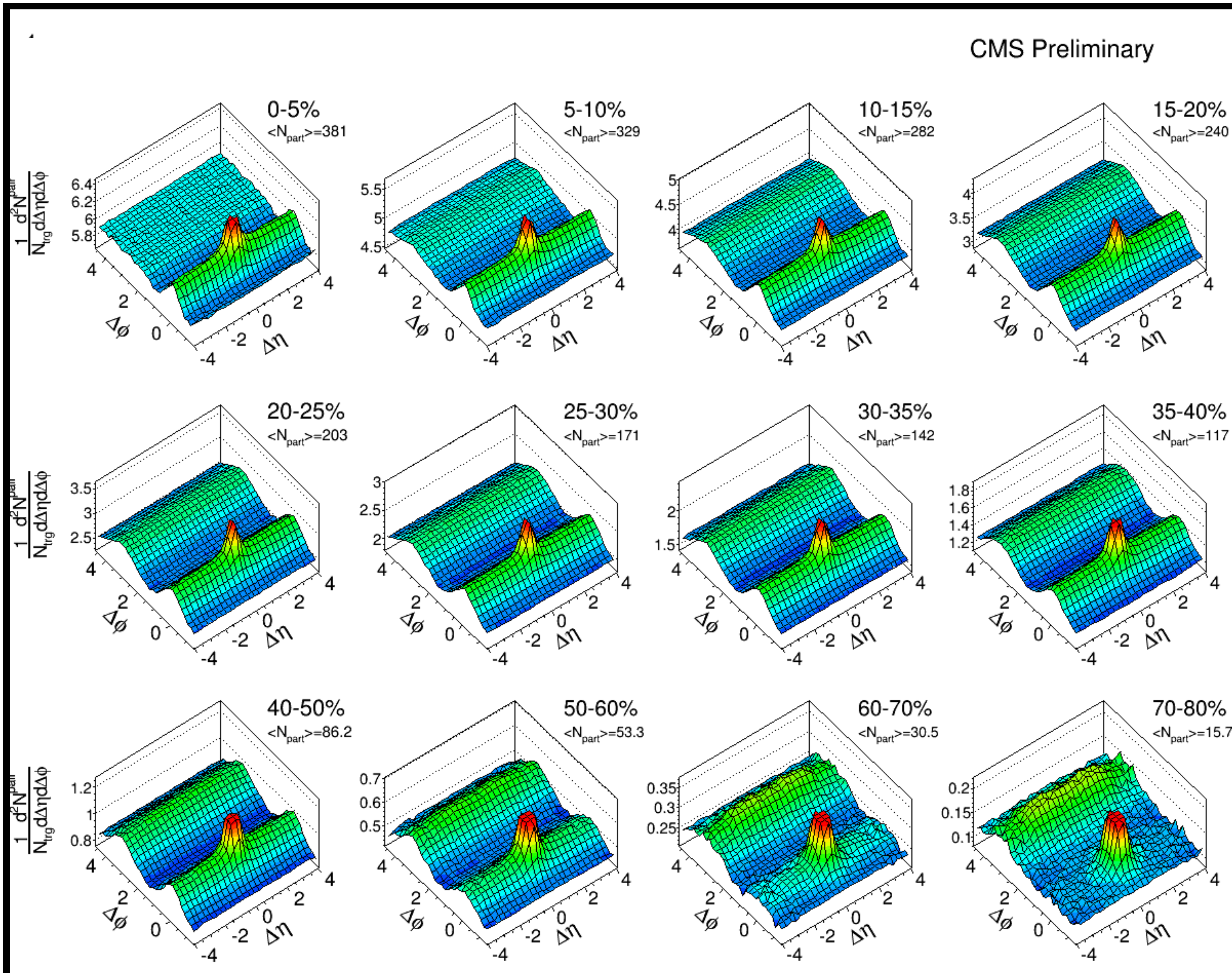
2D Correlation vs Centrality

$\int L\,dt = 3.1\mu b^{-1}$

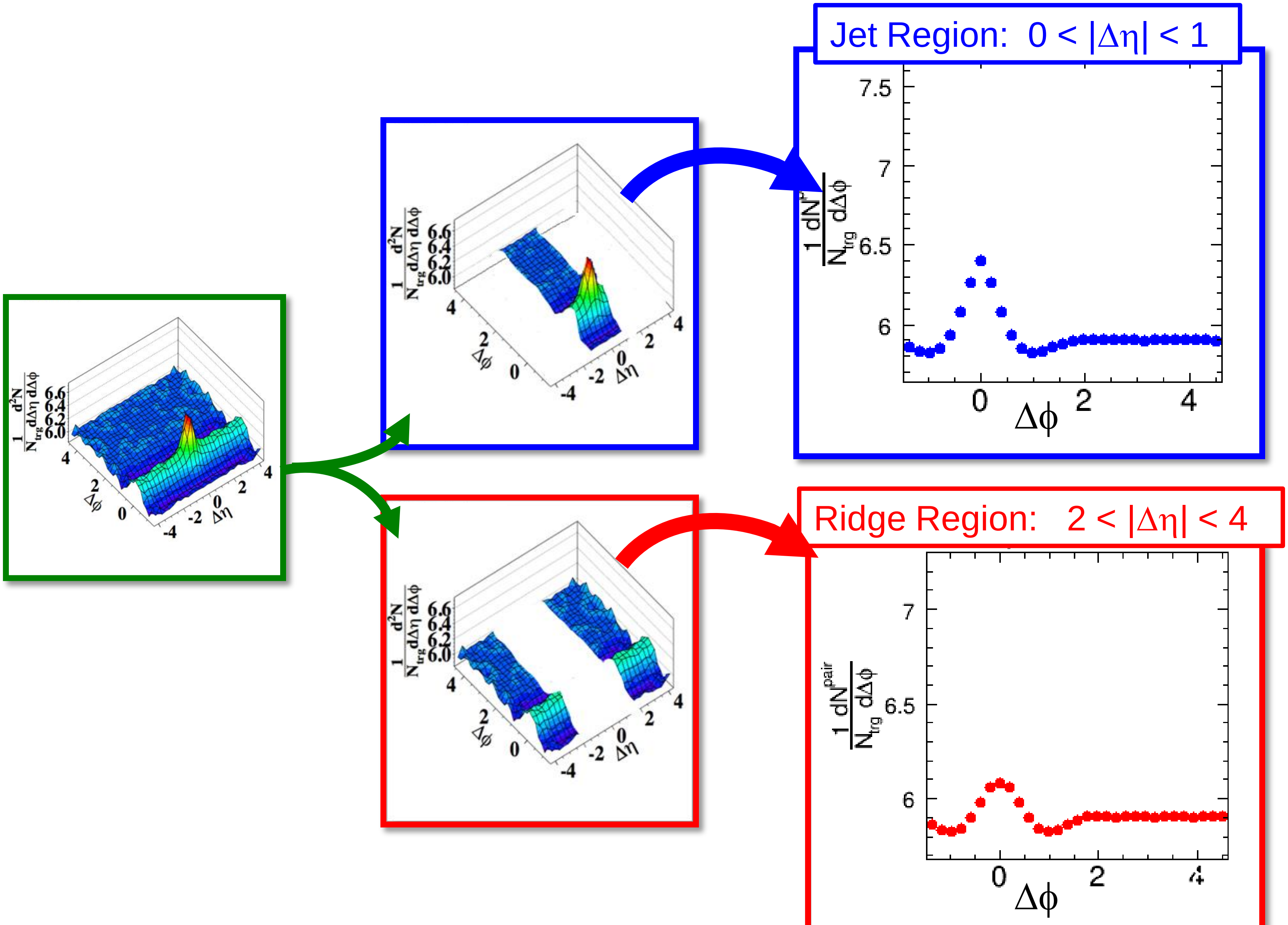
$4 < p_T^{trig} < 6$

$2 < p_T^{assoc} < 4$

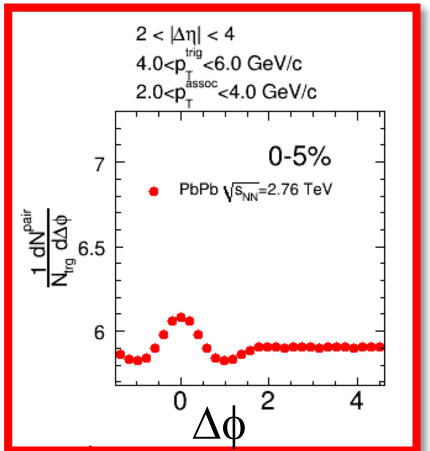
$\cos(2\Delta\phi)$ modulation visible



Jet and Ridge Regions



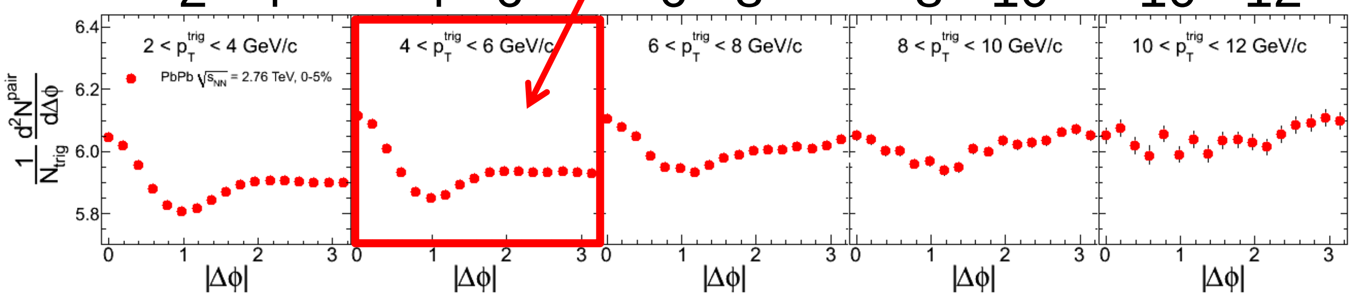
1D Correlation - Central 0-5% Ridge Region



"Long-range and short-range dihadron angular correlations in central PbPb collisions at a nucleon-nucleon center of mass energy of 2.76 TeV"
CMS arXiv:1105.2438

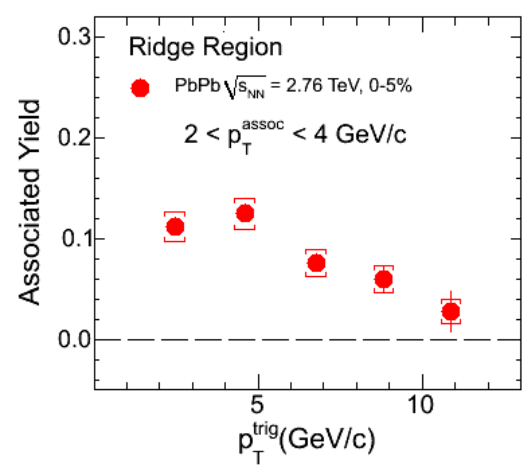
p_T^{trig} [GeV/c]:

2 - 4 4 - 6 6 - 8 8 - 10 10 - 12



p_T^{assoc} [GeV/c]: 2 - 4

Zero Yield At Minimum



1D Correlation – Ridge Region

PbPb $\sqrt{s_{NN}} = 2.76$ TeV

v_2 modulation
(EP + Cum{4}) / 2

v_2 uncertainty

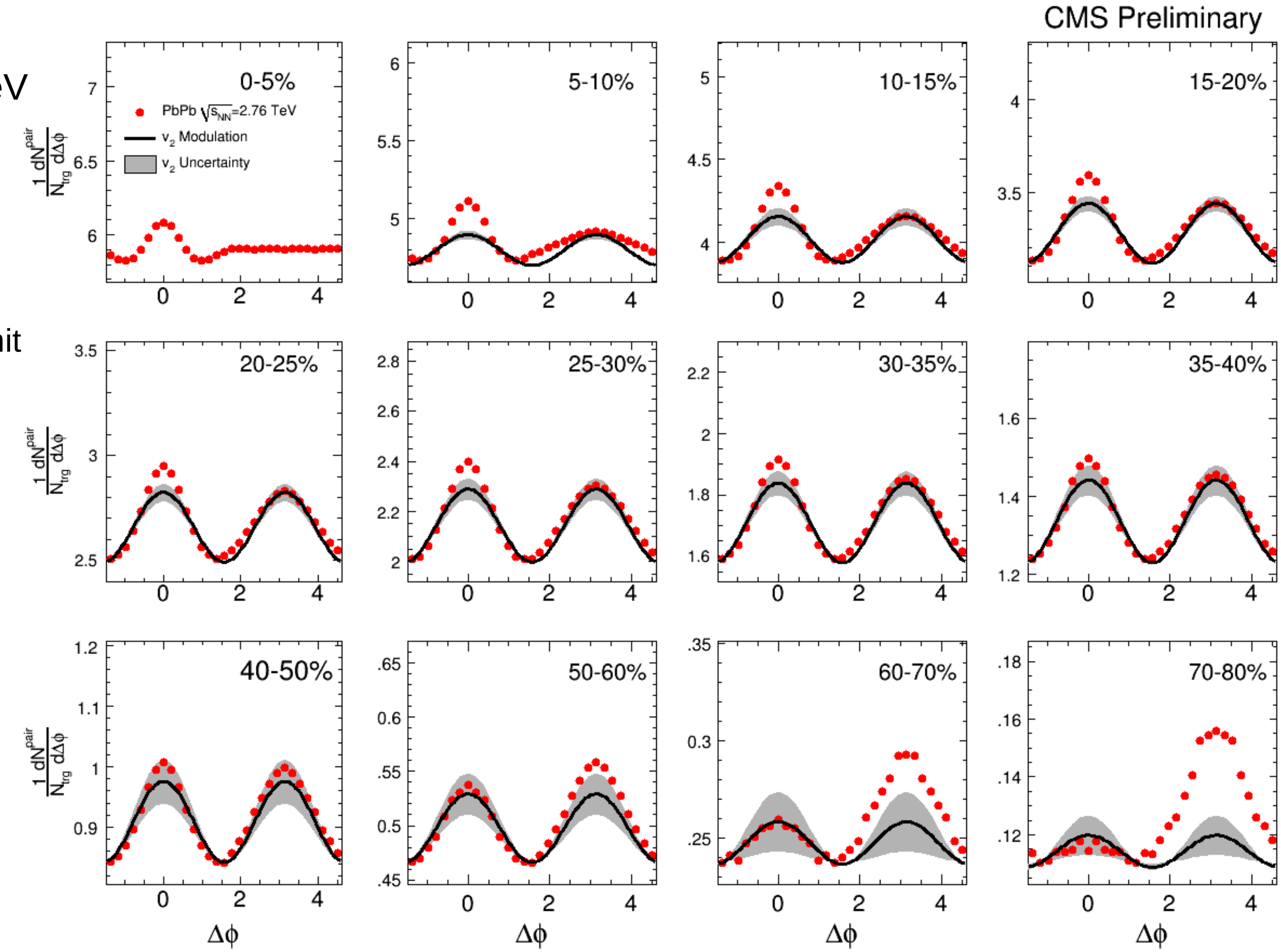
EP method = upper limit
Cum{4} = lower limit

$\int L\,dt = 3.1\mu b^{-1}$

$4 < p_T^{trig} < 6$

$2 < p_T^{assoc} < 4$

$2 < |\Delta\eta| < 4$



Flow at CMS:
Julia Velkovska (plenary, Tuesday) Victoria Zhukova (parallel, Monday)

1D Correlation – Jet Region

PbPb $\sqrt{s_{NN}} = 2.76$ TeV

v_2 modulation
(EP + Cum{4}) / 2

v_2 uncertainty

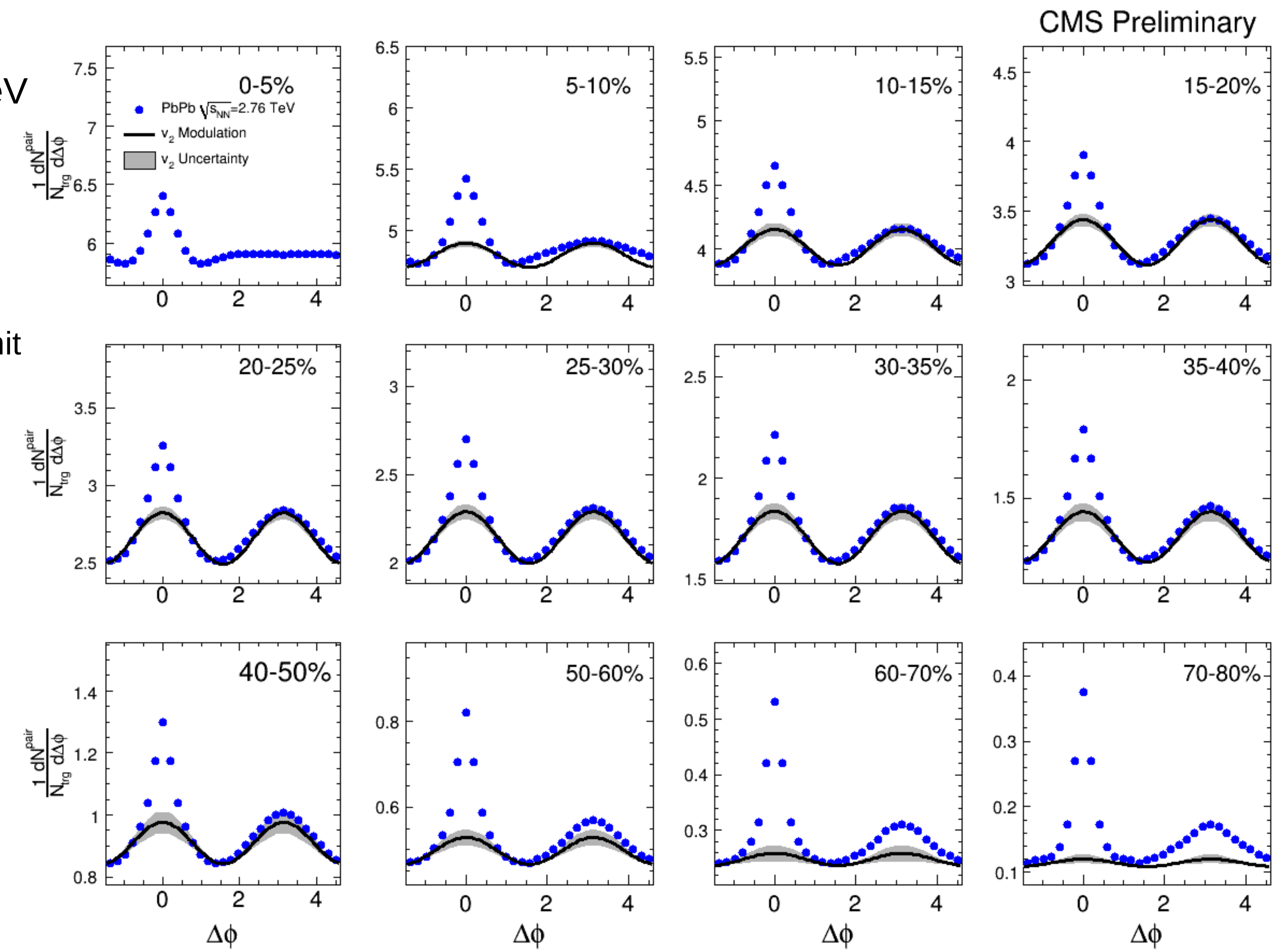
EP method = upper limit
Cum{4} = lower limit

$\int L\,dt = 3.1\mu b^{-1}$

$4 < p_T^{trig} < 6$

$2 < p_T^{assoc} < 4$

$0 < |\Delta\eta| < 1$



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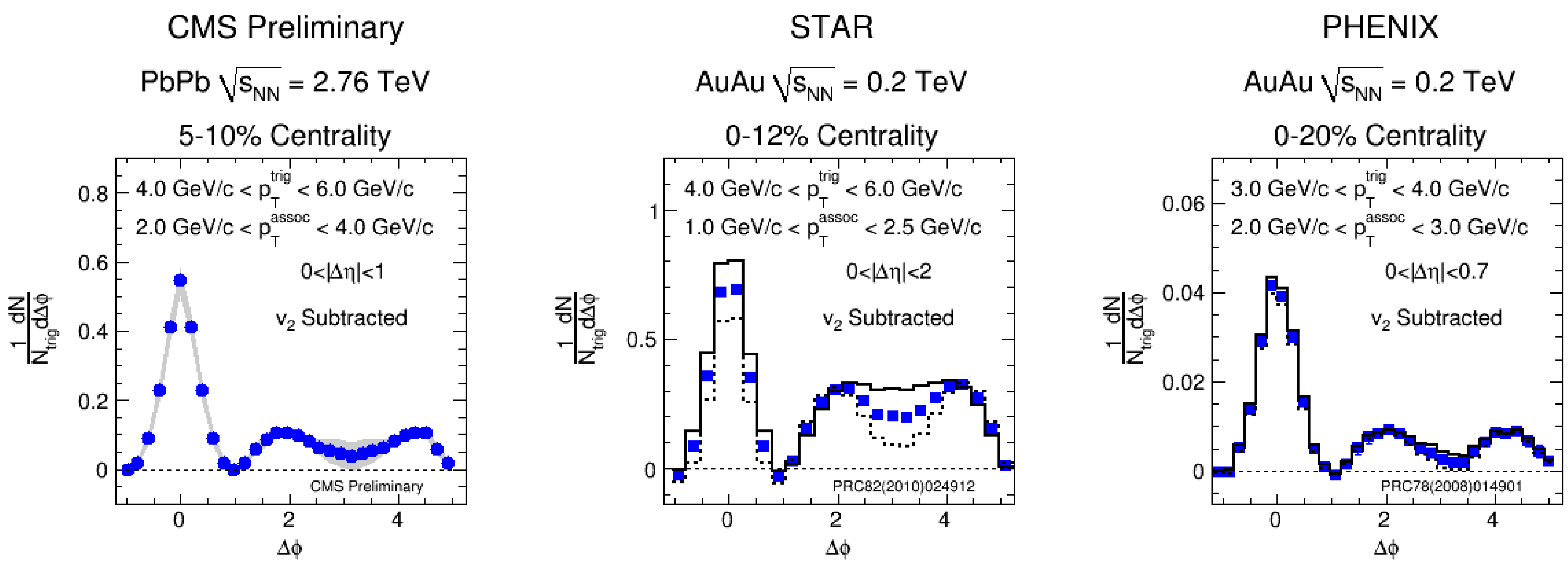
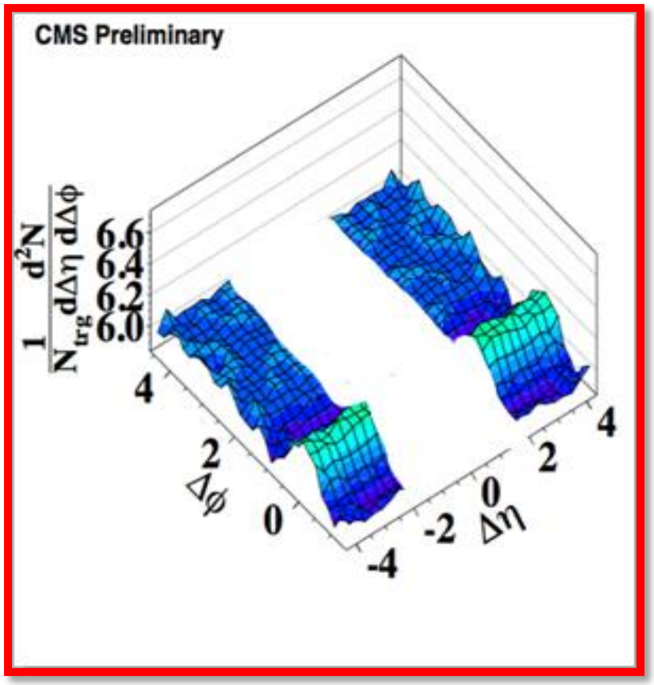
Comparison with RHIC

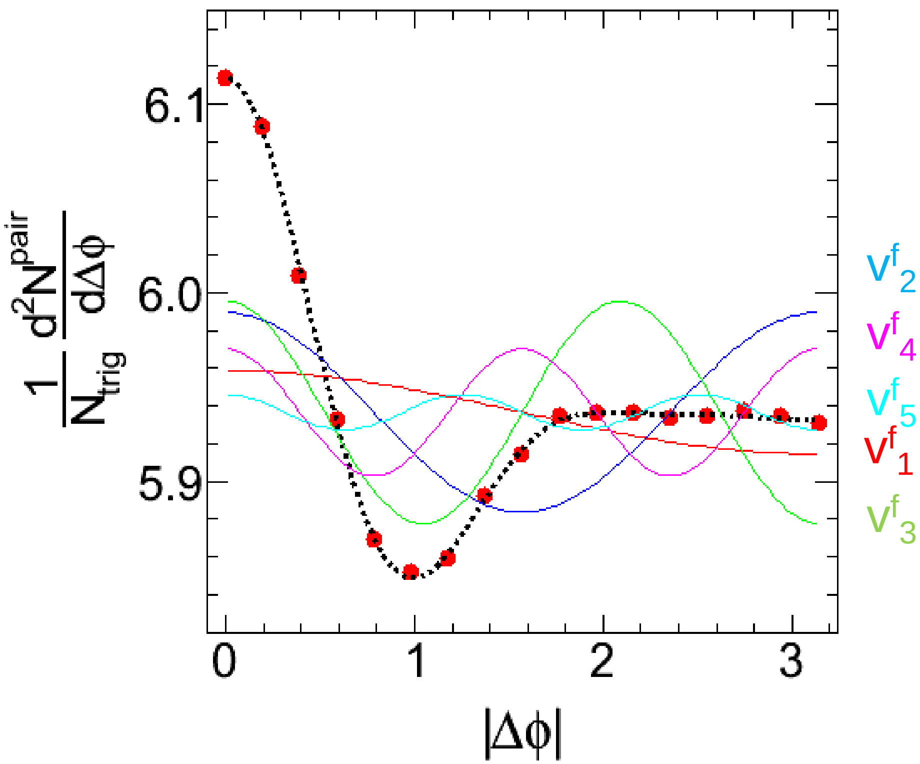


Good qualitative agreement

Alternative Approach: Fourier Analysis

$$\frac{1}{N_{trig}}\frac{dN^{pair}}{d\Delta\phi} = \frac{N_{assoc}}{2\pi}\left(1+2\sum_{n=1} V_n^f \cos(n\Delta\phi)\right)$$
$$= \frac{N_{assoc}}{2\pi}\left(1+2V_1^f \cos(\Delta\phi)+2V_2^f \cos(2\Delta\phi)+2V_3^f \cos(3\Delta\phi)+\ldots\right)$$





V_1^f vs p_T and Centrality

● PbPb $\sqrt{s_{NN}} = 2.76$ TeV

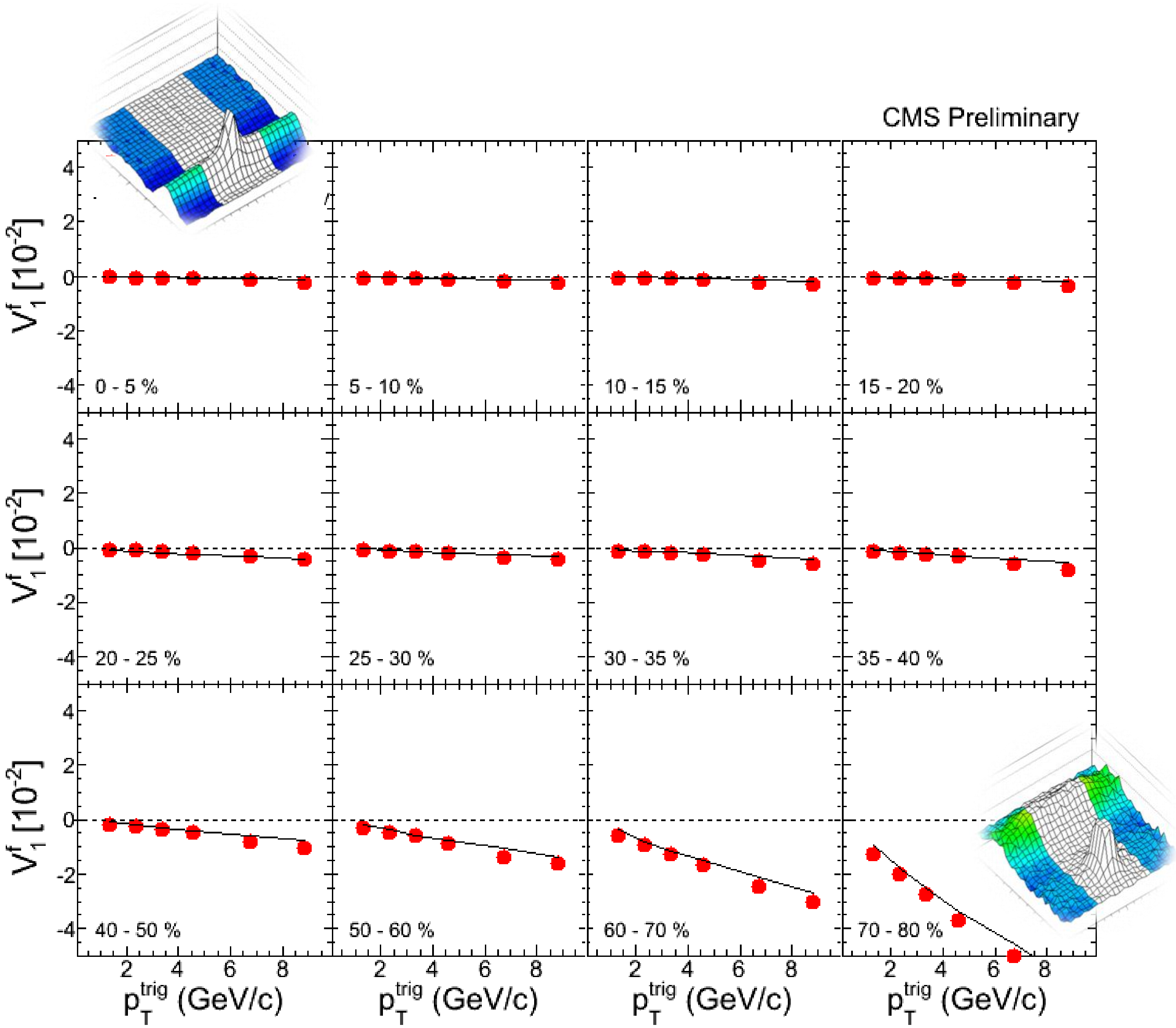
— 2.76 TeV pp (scaled by $N^{pp}_{assoc} / N^{PbPb}_{assoc}$)

$\int L\,dt = 3.1\mu b^{-1}$

$1 < p_T^{assoc} < 2$

$2 < |\Delta\eta| < 4$

Largely consistent with pp: dominated by momentum conservation



V_2^f vs p_T and Centrality

● PbPb $\sqrt{s_{NN}} = 2.76$ TeV

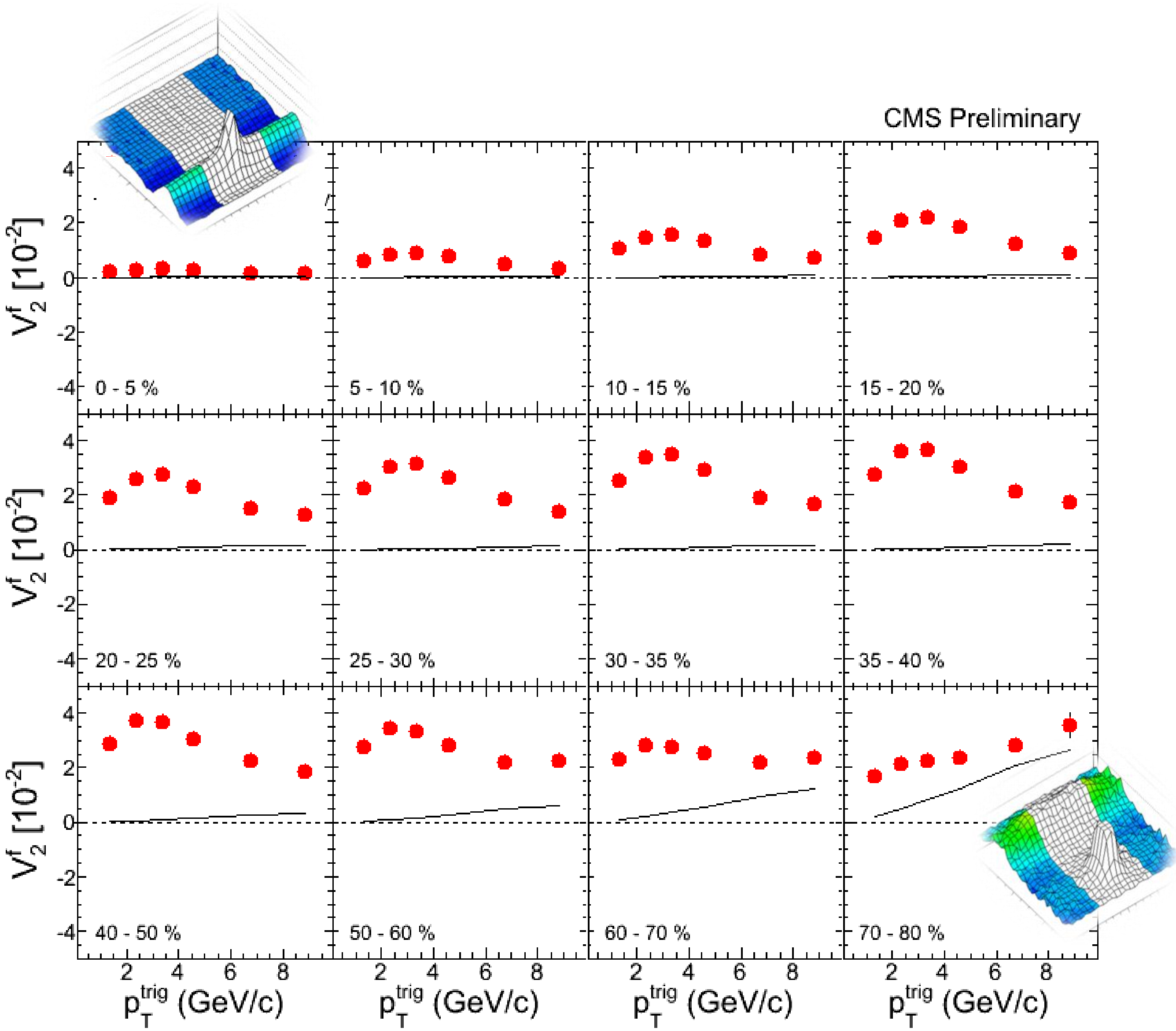
▬ 2.76 TeV pp (scaled by $N^{pp}_{assoc} / N^{PbPb}_{assoc}$)

$\int L\,dt = 3.1\mu b^{-1}$

$1 < p_T^{assoc} < 2$

$2 < |\Delta\eta| < 4$

Strong centrality dependence in PbPb



V_3^f vs p_T and Centrality

● PbPb $\sqrt{s_{NN}} = 2.76$ TeV

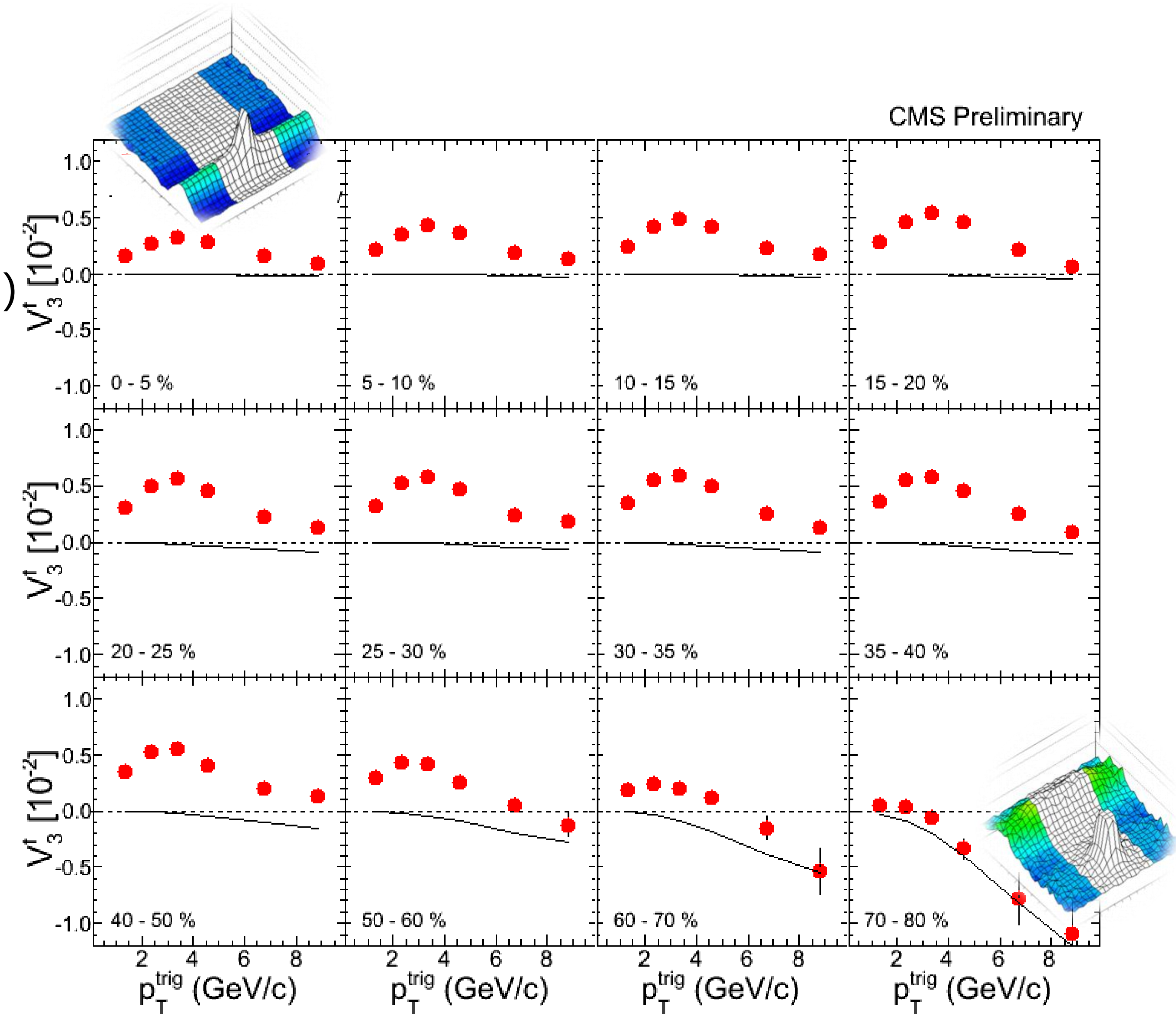
▬ 2.76 TeV pp (scaled by $N^{pp}_{assoc} / N^{PbPb}_{assoc}$)

$\int L\,dt = 3.1\mu b^{-1}$

$1 < p_T^{assoc} < 2$

$2 < |\Delta\eta| < 4$

Consistently above pp baseline, and smaller centrality dependence than v_2



Turning V_n^f into v_n

If we assume flow alone is responsible for the ridge and there is no away side jet contribution in the correlation, then

$$V_n^f(p_T^{trig}, p_T^{assoc}) = v_n(p_T^{trig}) \times v_n(p_T^{assoc})$$

We could then extract the flow coefficients v_n:

$$\frac{V_n^f(p_T^A, p_T^B)}{\sqrt{V_n^f(p_T^B, p_T^B)}} = \frac{v_n(p_T^A) \times v_n(p_T^B)}{\sqrt{v_n(p_T^B) \times v_n(p_T^B)}} = v_n(p_T^A)$$

Use $1 < p_T^B < 2$ GeV/c to minimize non-flow effects

How Does v_2^f Compare?

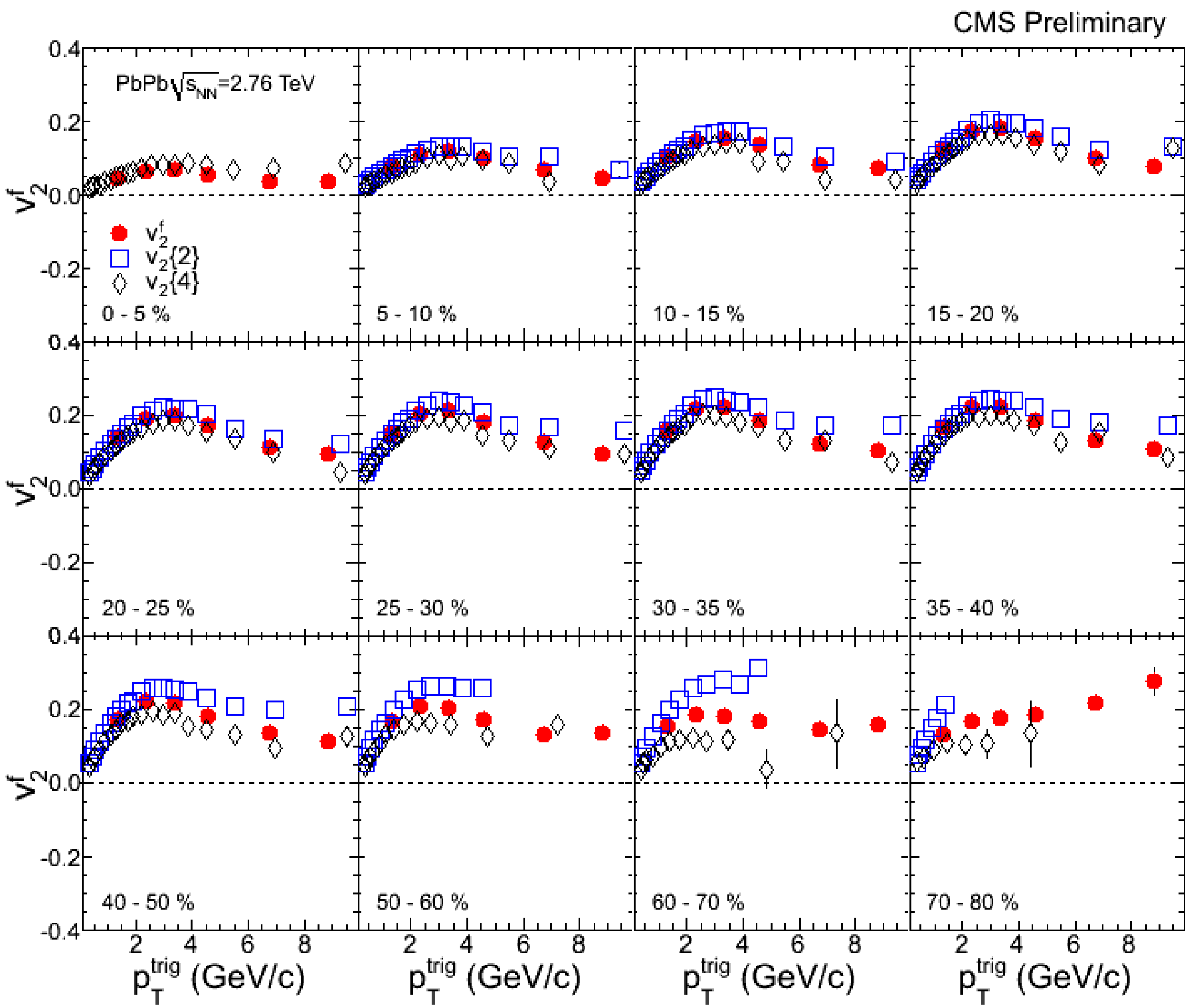
- v_2^f
- $v_2\{2\}$
- $v_2\{4\}$

$\int L\,dt = 3.1\mu b^{-1}$

$1 < p_T^{assoc} < 2$

$2 < |\Delta\eta| < 4$

Good agreement



Flow at CMS:

Julia Velkovska (plenary, Tuesday) Victoria Zhukova (parallel, Monday)

How Does v_3^f Compare?

● v_3^f

□ $v_3\{2\}$

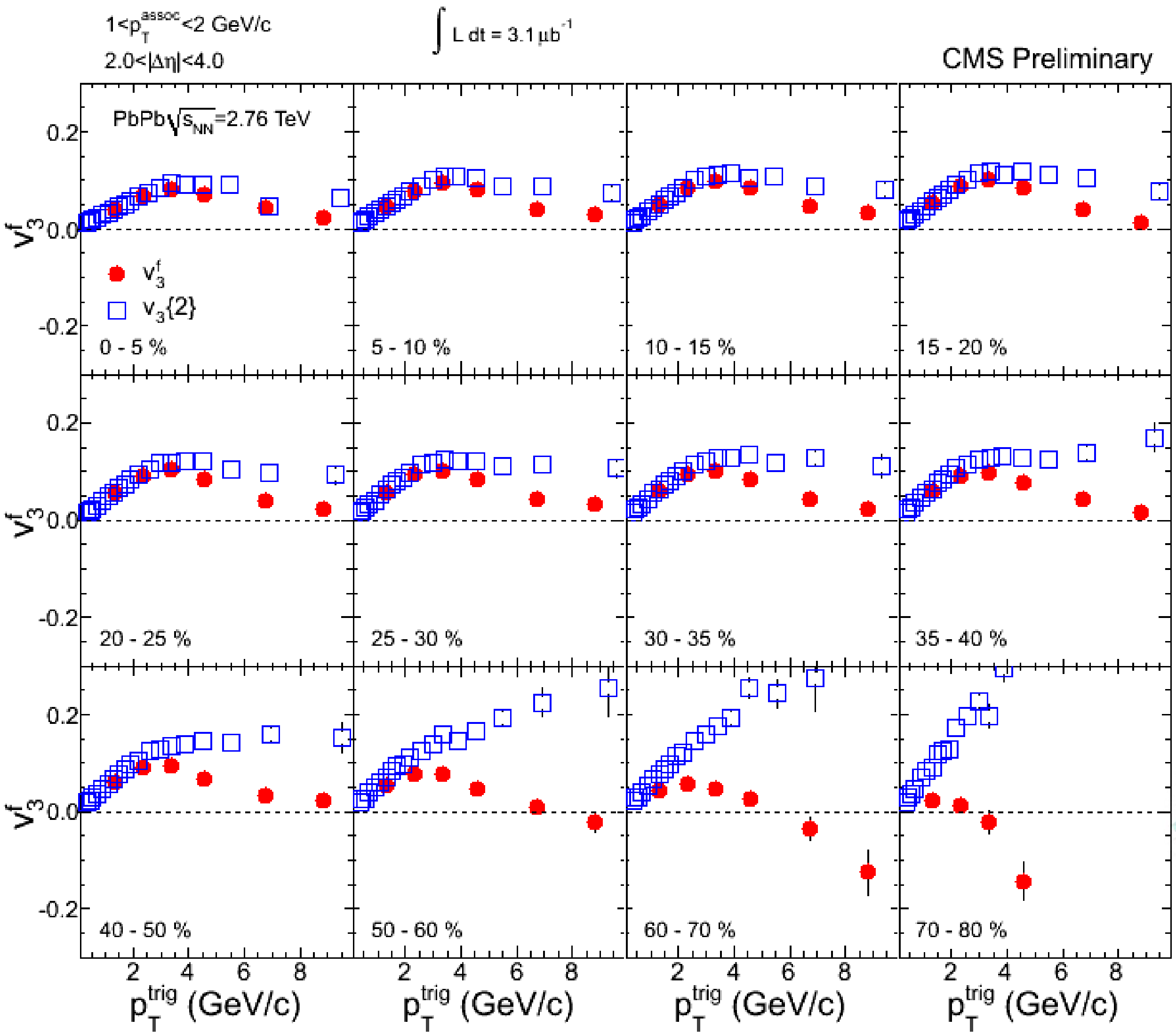
$\int L\,dt = 3.1\mu b^{-1}$

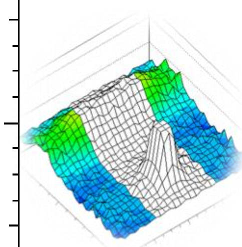
$1 < p_T^{assoc} < 2$

$2 < |\Delta\eta| < 4$

Good agreement for central

Deviation for high p_T peripheral





Flow at CMS:

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How Does v_4^f Compare?

● v_4^f

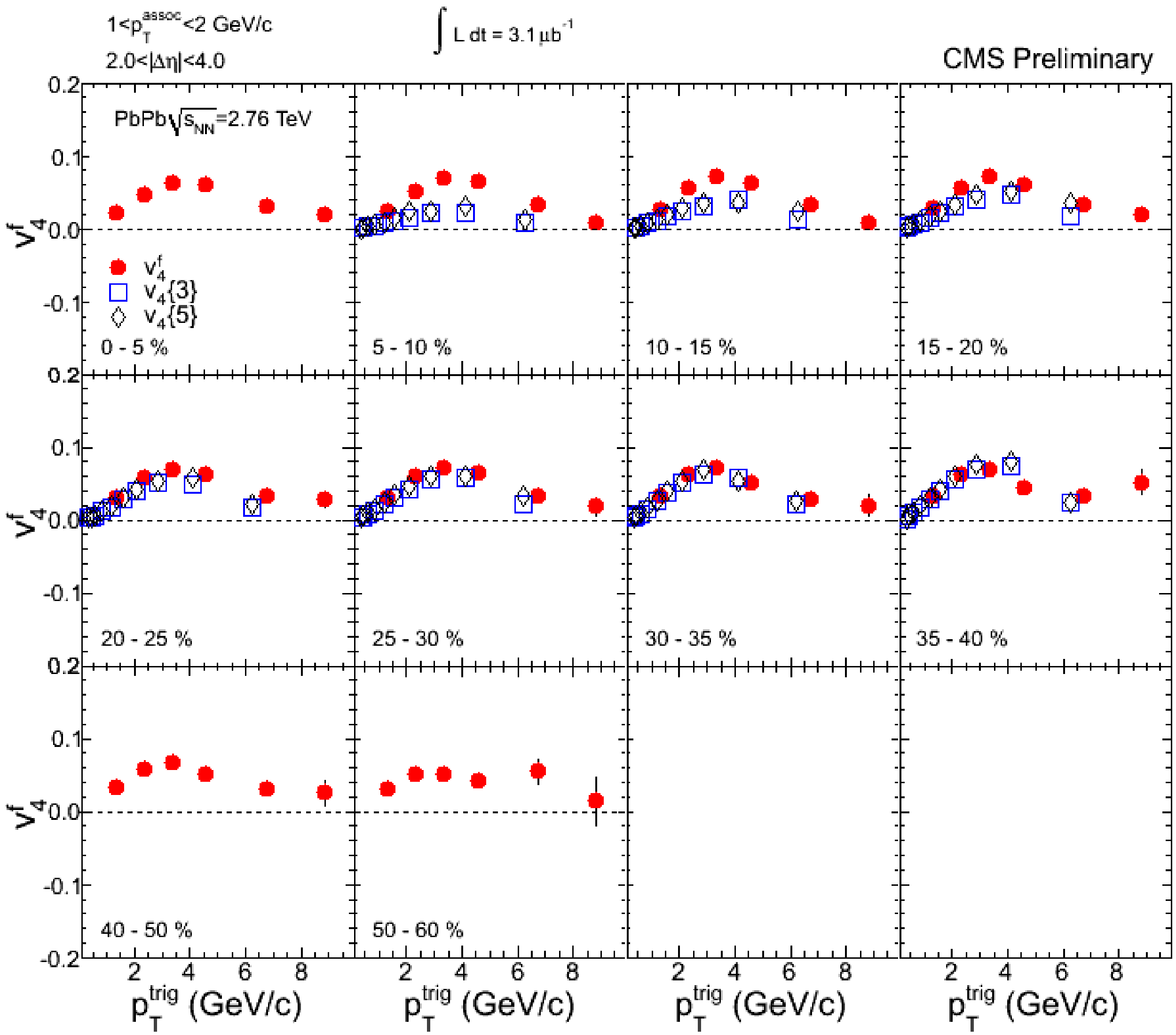
□ $v_4\{3\}$

◇ $v_4\{5\}$

$\int L\,dt = 3.1\mu b^{-1}$

$1 < p_T^{assoc} < 2$

$2 < |\Delta\eta| < 4$



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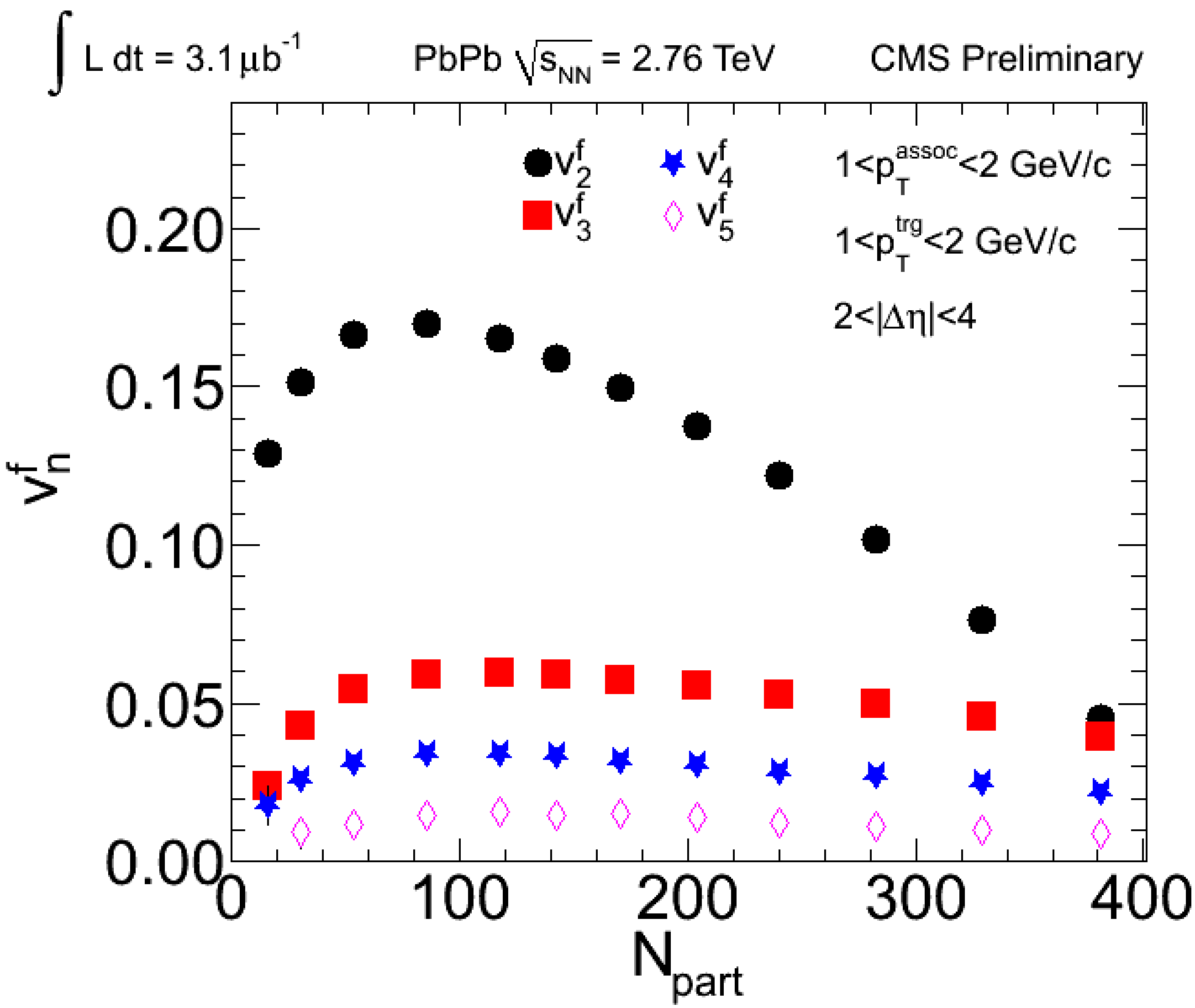
Fourier Analysis Results vs. Centrality



Summary

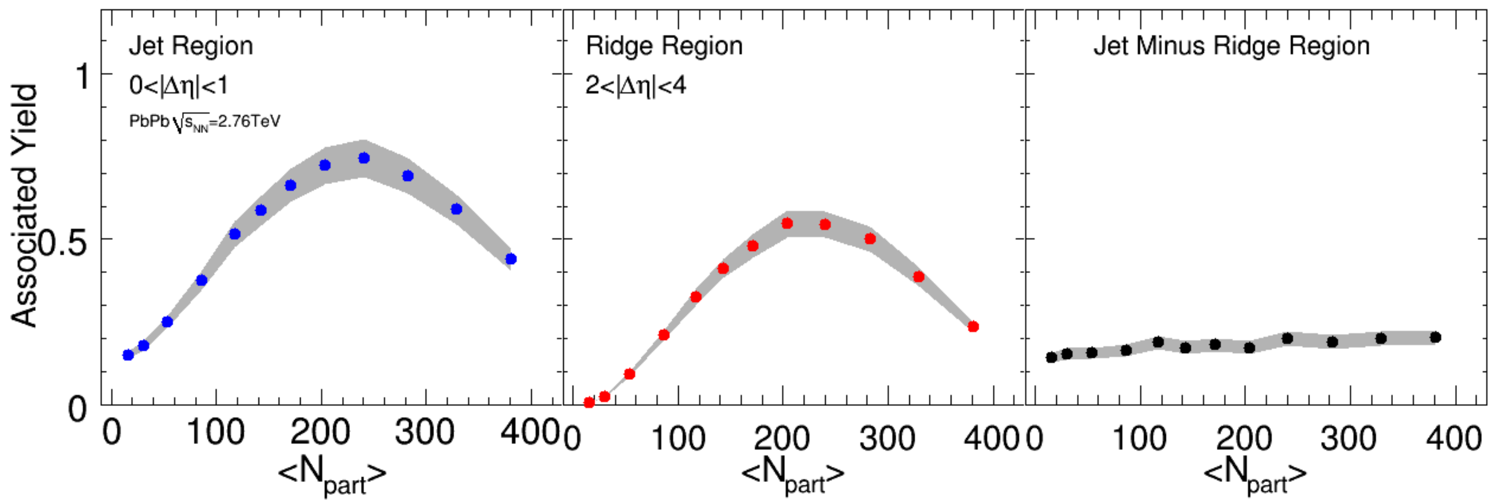
- Ridge-like structure extends out to $|\Delta\eta| < 4$ and tends to disappear with increasing p_T
- Standard v_2-subtracted ridge results are qualitatively consistent with RHIC
- First five Fourier terms are sufficient to describe the correlation function in the ridge region
- Results of Fourier analysis of the ridge region are consistent with standard flow measurements
- Learn more at Wei Li's plenary talk (Thursday)

BACKUP

Associated Yields (ZYAM)

Before v_2 subtraction

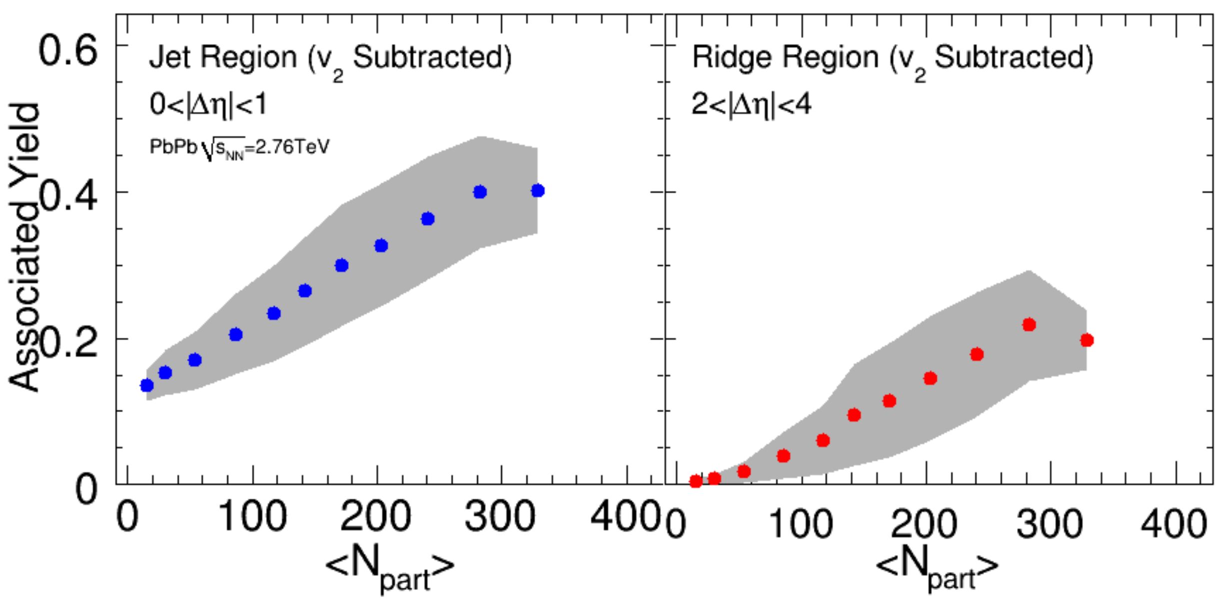
CMS Preliminary



$4 < p_T^{trig} < 6$ GeV/c
$2 < p_T^{assoc} < 4$ GeV/c

After v_2 subtraction

CMS Preliminary

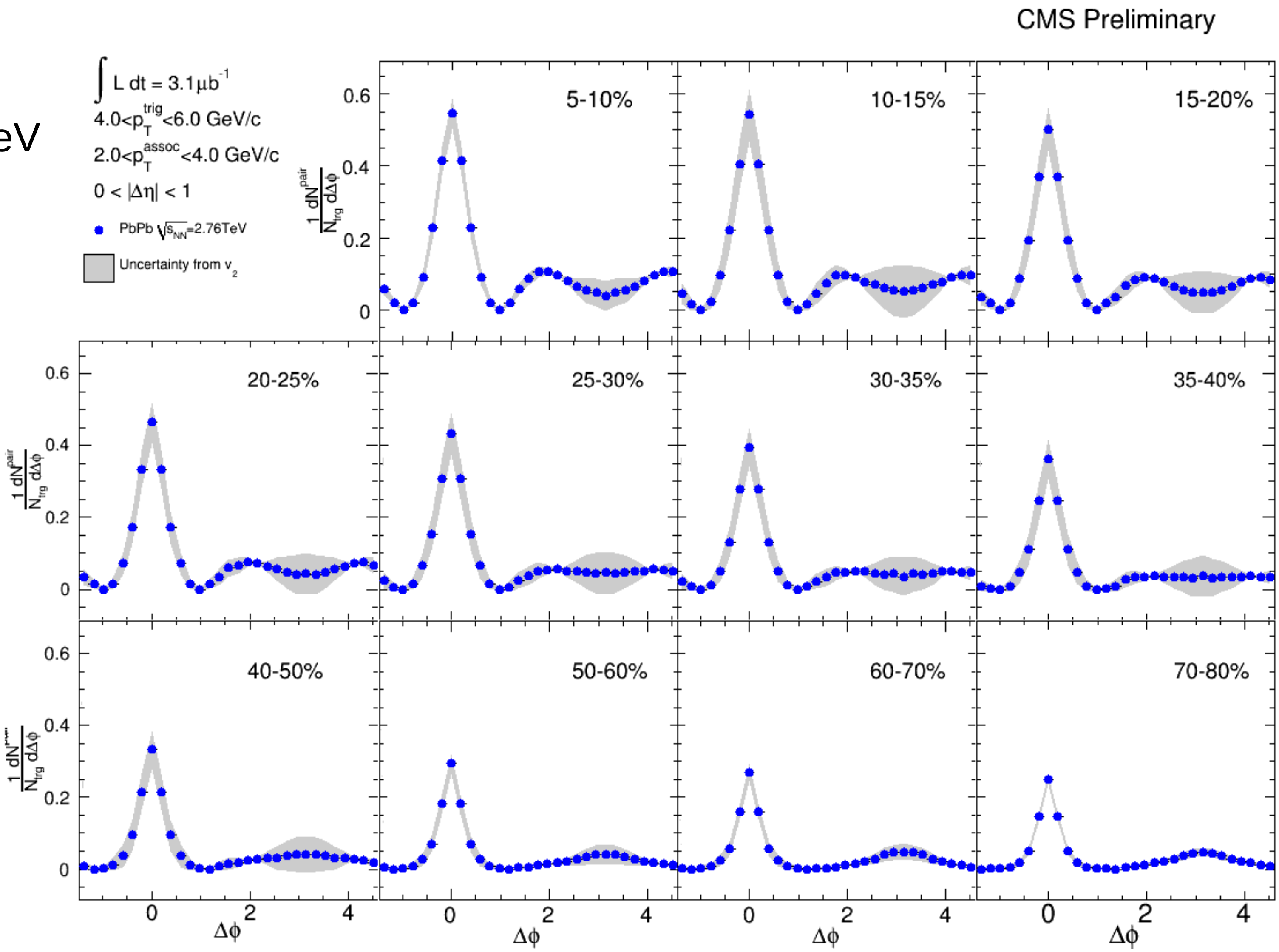


v_2 Subtracted Jet Region

- v_2 subtracted
  PbPb $\sqrt{s_{NN}}$ = 2.76 TeV
  Jet Region

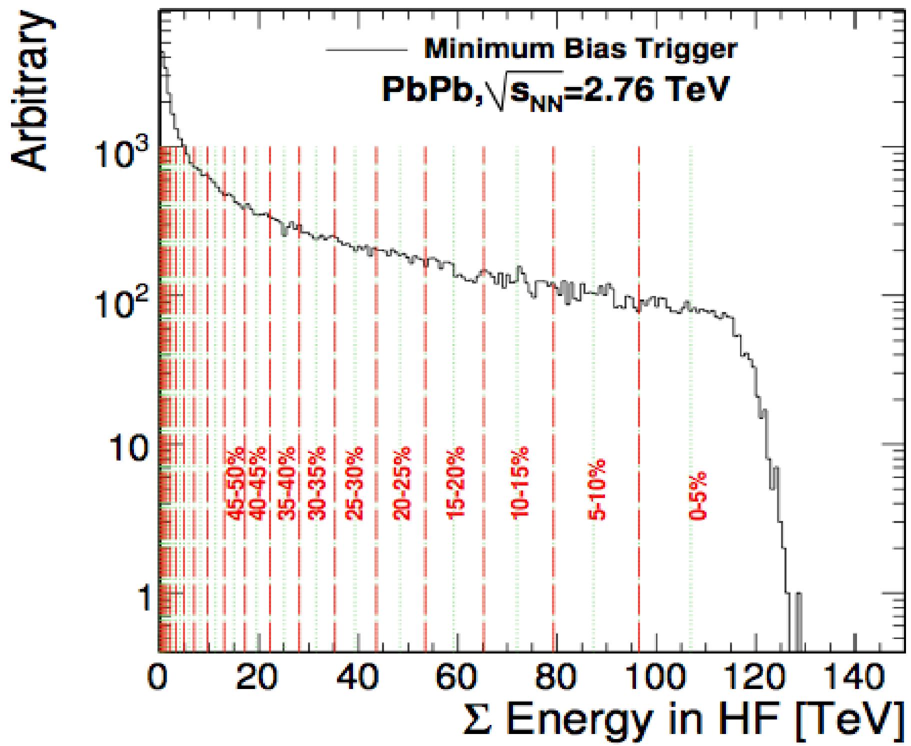
- Uncertainty from v_2

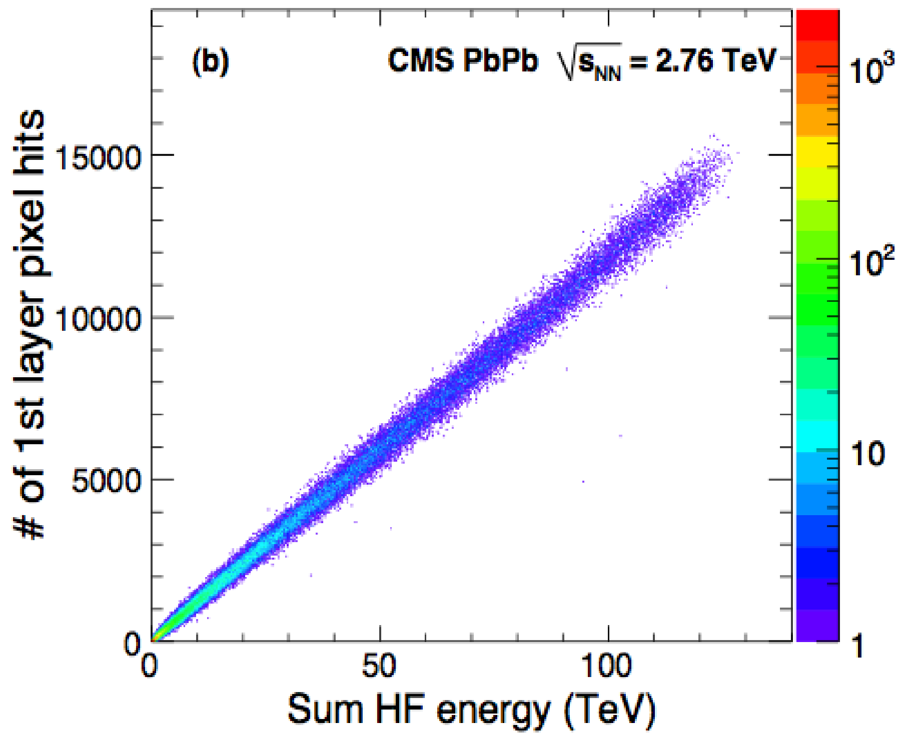
$4 < p_T^{trig} < 6$ GeV/c
$2 < p_T^{assoc} < 4$ GeV/c



Centrality Determination

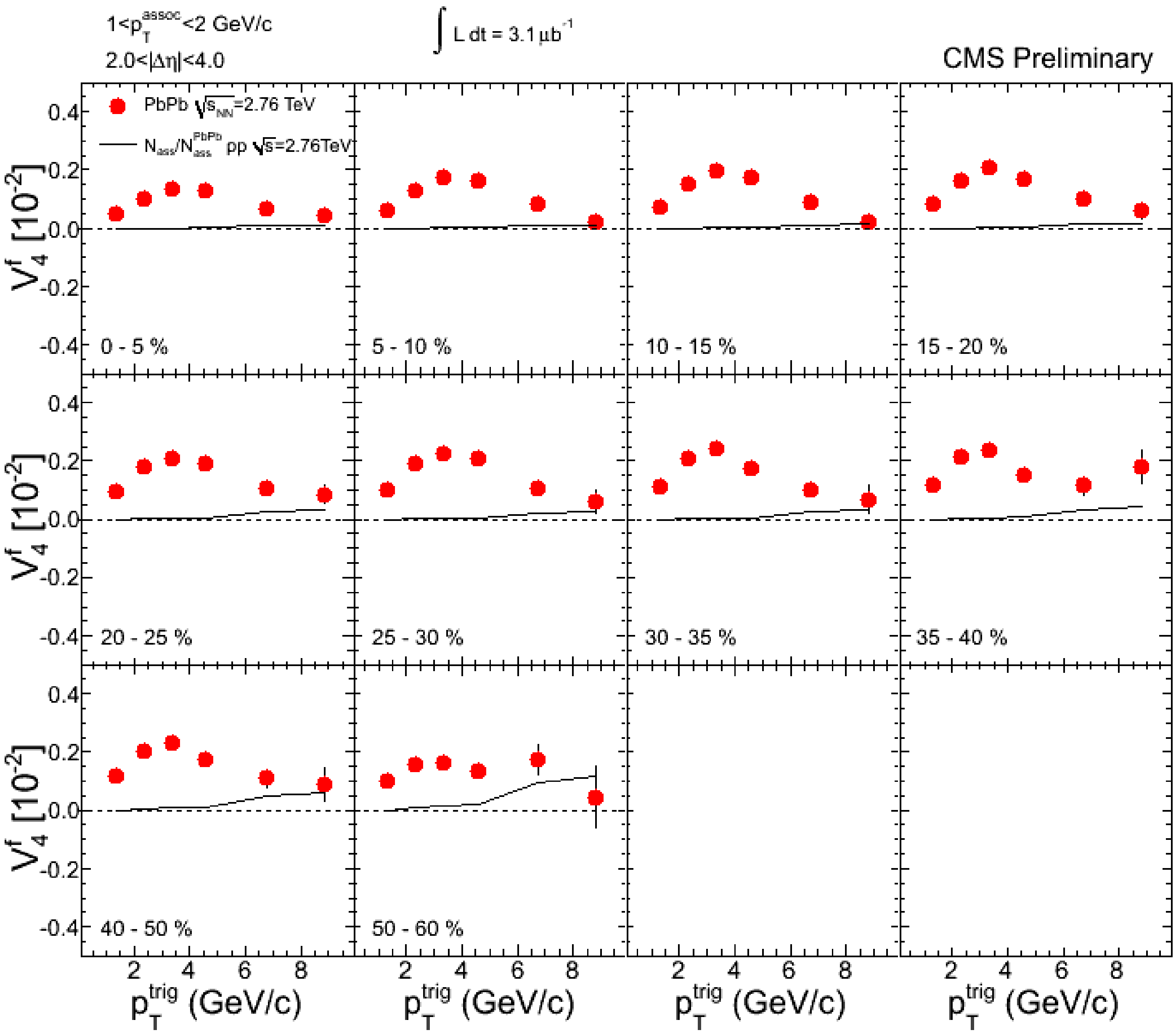
- Based on the total sum of the transverse energy in HF



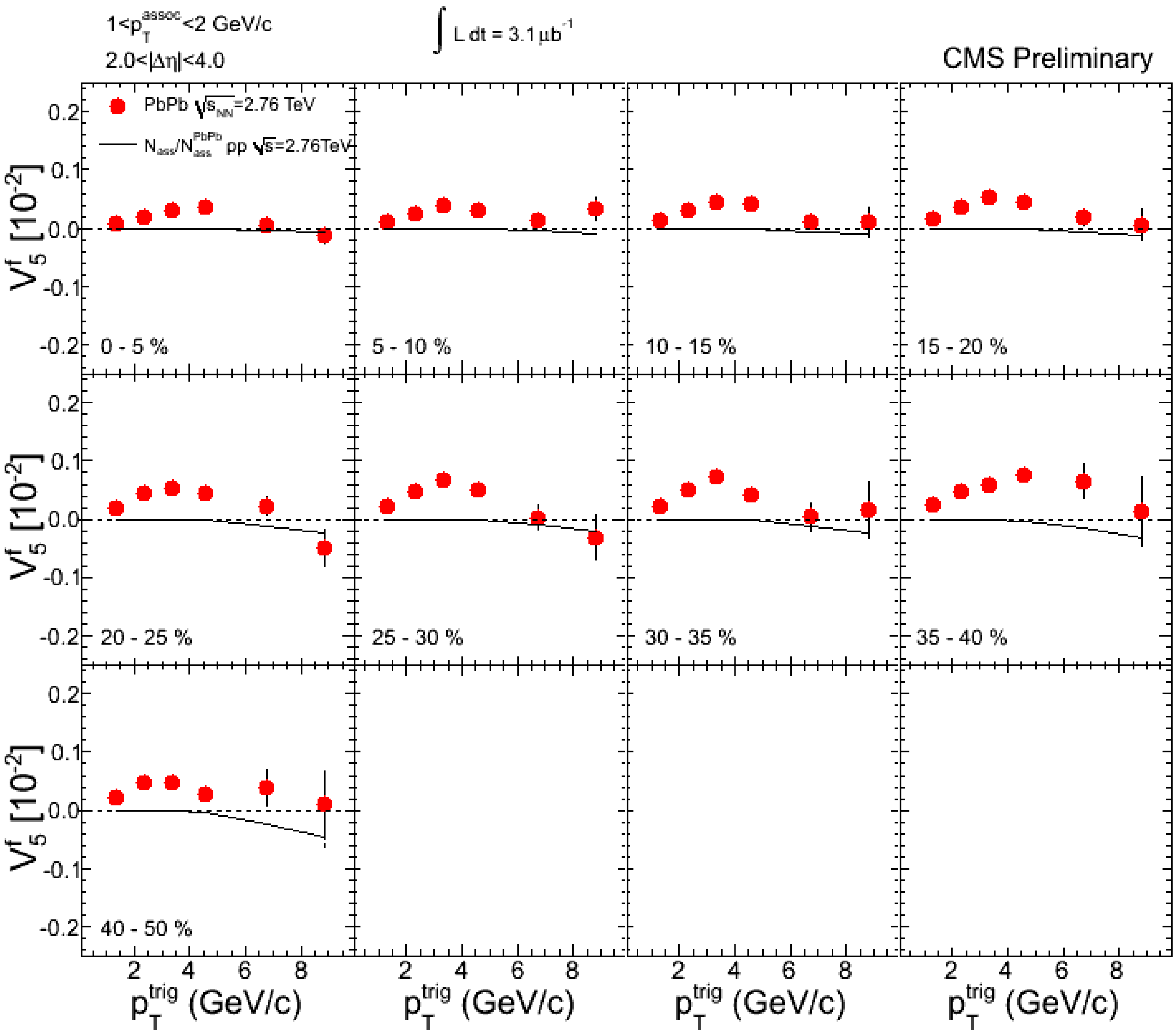


- 12 centrality classes:
{0-5%}, {5-10%}, {10-15%}, {15-20%}, {20-25%}, {25-30%}, {30-35%}, {35-40%}, {40-50%}, {50-60%}, {60-70%}, {70-80%}

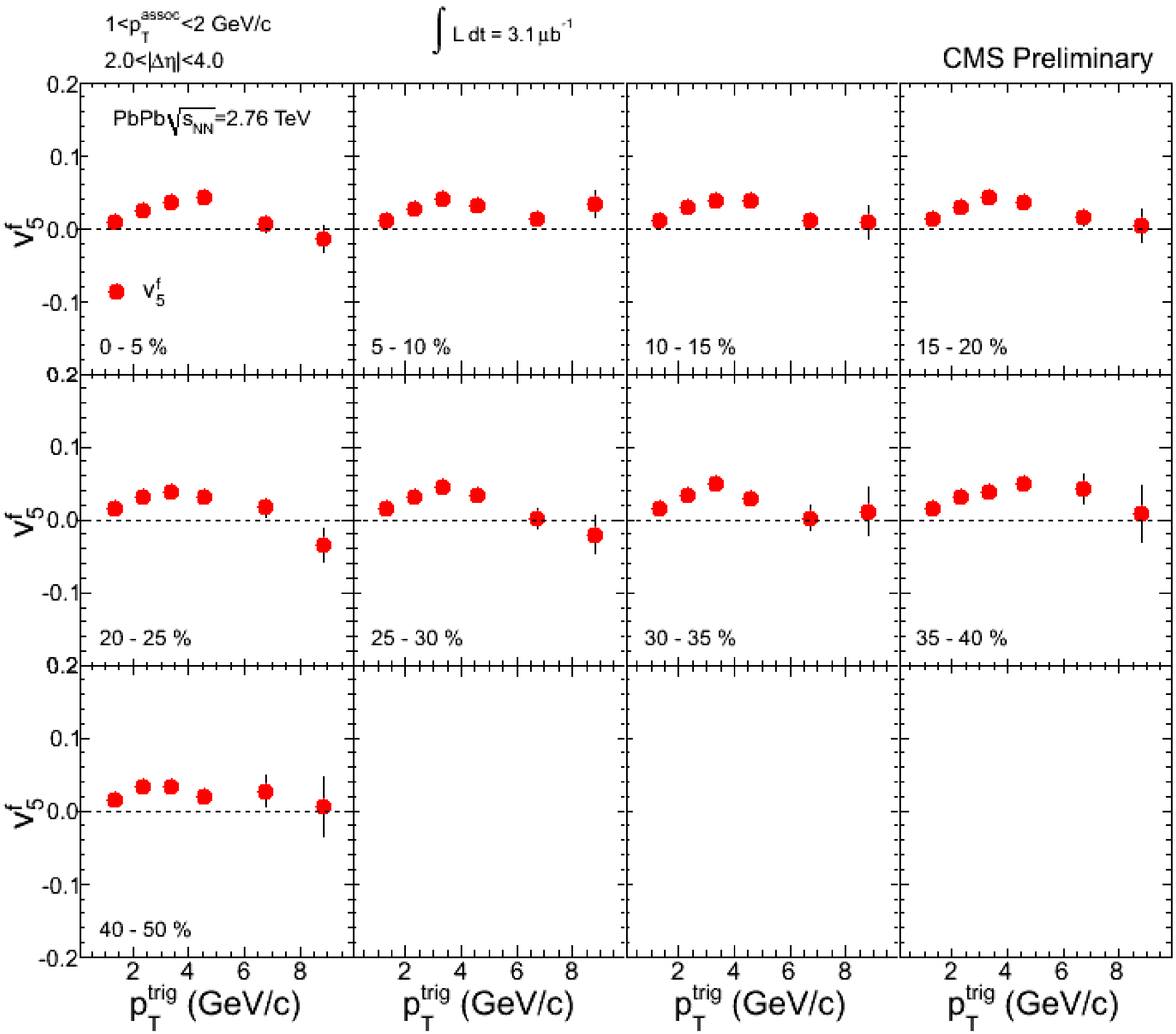
V_4^f vs p_T and Centrality



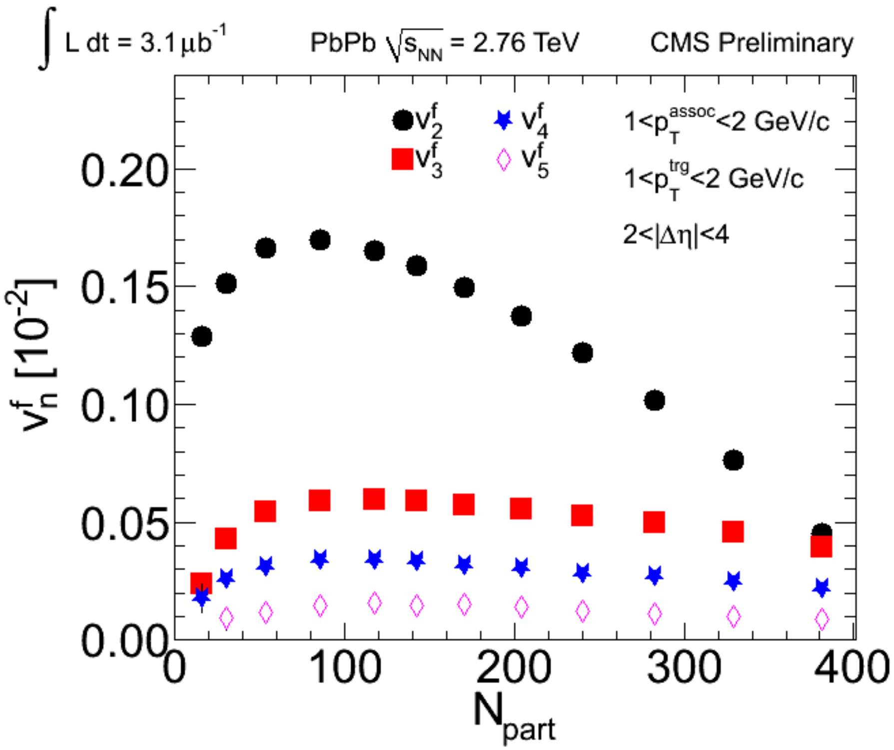
V_5^f vs p_T and Centrality



v_5^f vs p_T and Centrality

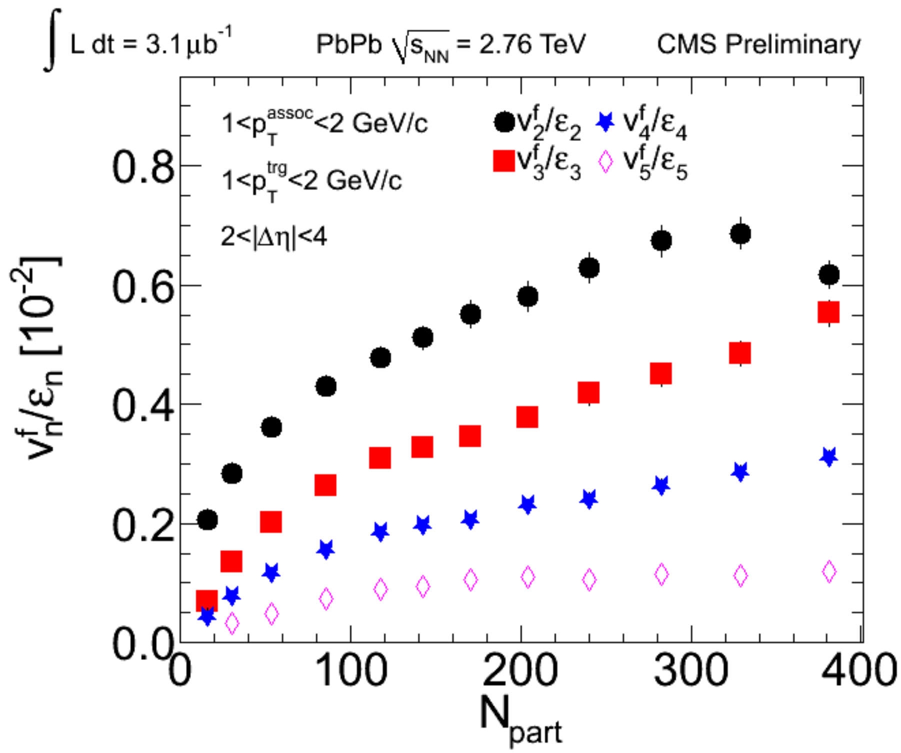


Fourier Analysis Results vs. Centrality

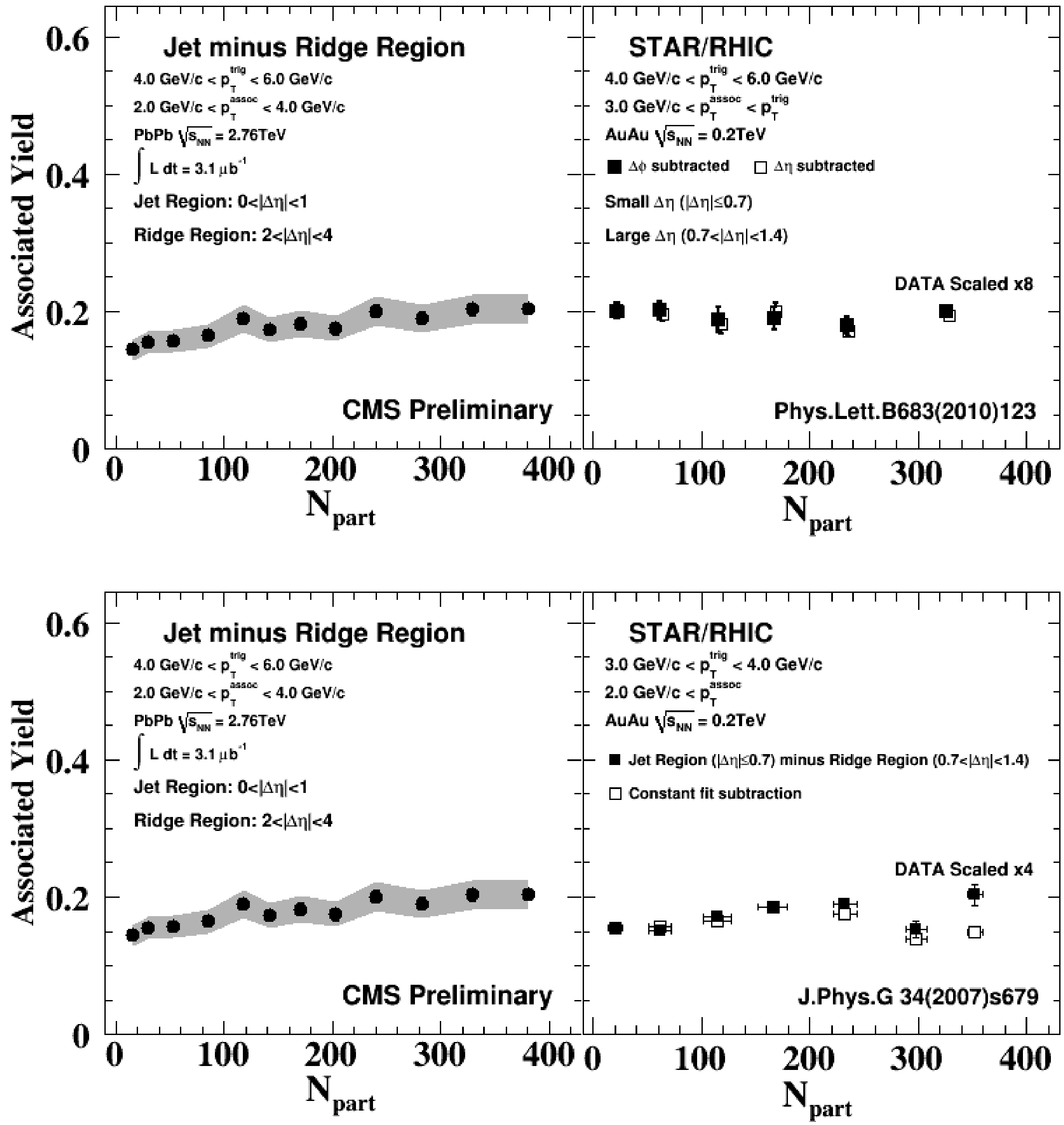


Normalize to Glauber-based calculation of eccentricity, triangularity, etc.

$$\epsilon_n = \frac{\sqrt{\langle r^2 \cos(n\phi_{\rm part})\rangle^2 + \langle r^2 \sin(n\phi_{\rm part})\rangle^2}}{\langle r^2 \rangle}$$



RHIC Comparisons: Jet minus Ridge Yields



RHIC Comparisons: v_2 subtracted Yields