Measurement of underlying event characteristics using charged particles in pp collisions at $\sqrt{s}$ =13TeV with the PYTHIA event generator.

Project Group D[1]

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I. ABSTRACT

The "underlying event" (UE) is defined as those aspects of a hadronic interaction attributed not to the hard scattering process, but rather to the accompanying interactions of the rest of the proton. The analysis of the UE is what helps us understand the process better. Here, we plot the relative azimuthal angle distributions and divide each event into three distinct regions based on the azimuthal angle of the leading track. Furthermore, we plot the average number density and the scalar p_T sum density as a function of the p_T of the leading track for each of the three regions.

II. INTRODUCTION

The data provided for analysis has been generated with Pythia 8 Monte Carlo event generator.
Number of events : 2 million
Collisions System : p + p at centre of mass energy 13 TeV.

For a single collision event, we define the following observables

Observables	Definition
$\mathrm{p_T}$	Transverse momentum of the particle (component of momentum perpendicular to z axis)
θ	Angle between momentum vector and z axis
ϕ	Azimuthal angle
η	Pseudo-rapidity of the particle defined as $\ln(\cot(\theta/2))$
$\mathrm{p_T^{lead}}$	Transverse momentum of the stable charged particle with maximum $\mathrm{p_T}$ in the event
$\langle d^2N_{ch}/d\eta d\phi\rangle$	Mean number of stable charged particles per unit $\eta - \phi$
$\langle d^2 \sum \mathrm{p_T}/d\eta d\phi\rangle$	Mean scalar $\mathrm{p_T}$ sum of stable charged particles per unit $\eta - \phi$

$|\Delta\phi|$ is defined as $|\phi - \phi_{leading\ track}|$, where $\phi_{leading\ track}$ is the azimuthal angle of the stable charged particle with highest transverse momentum (also called leading track). This is used to define three azimuthal regions with respect to the leading track:

- $|\Delta\phi| <60°$, towards region.
- $60°<|\Delta\phi| <120°$, the transverse region, and
- $|\Delta\phi| >120°$, the away region.

Now, the density of particles, $\langle d^2N_{ch}/d\eta d\phi\rangle$ is obtained by dividing the number of particles that lie in the region of interest (towards, transvere or away) by the area of the region in $\eta - \phi$ space.

$$\left\langle \frac{d^2\mathrm{N}_{ch}}{d\eta d\phi} \right\rangle = \frac{\mathrm{N}}{\Delta\eta\Delta\phi} \tag{1}$$

where N is the number of particles/tracks that lie in the region of interest. Similarly, the transverse momentum sum, $\langle d^2 \sum \mathrm{p_T}/d\eta d\phi\rangle$ is obtained by summing over the transverse momentum values of the particles that lie in the region of interest and dividing by the area of the region in $\eta - \phi$ space.

$$\left\langle \frac{d^2 \sum \mathrm{p_T}}{d\eta d\phi} \right\rangle = \frac{\sum \mathrm{p_T}}{\Delta\eta\Delta\phi} \tag{2}$$

As the maximum $\Delta\phi$ in a region is $\pi/3$ and because we select only those particles that have $|\eta| < 2.5$, we take the area, $\Delta\phi\Delta\eta = 5\pi/3$.

III. EXPERIMENTAL OBSERVATIONS

A. $\mid \Delta\phi \mid$ plots

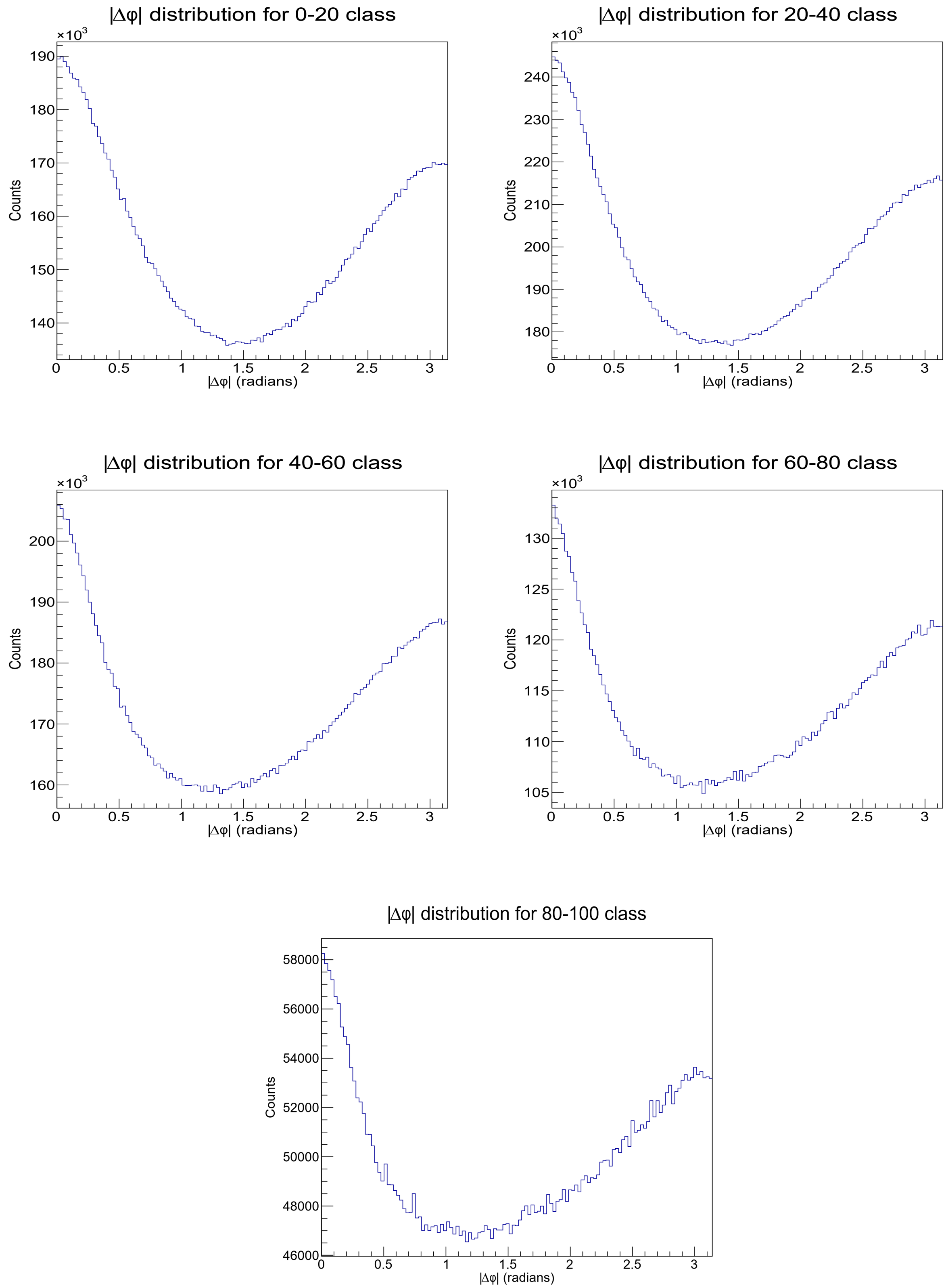

FIG. 1: Difference in ϕ between the leading particle and all other particles in an event ($|\phi_{leading\ track} - \phi|$).

B. For multiplicity class 20-40

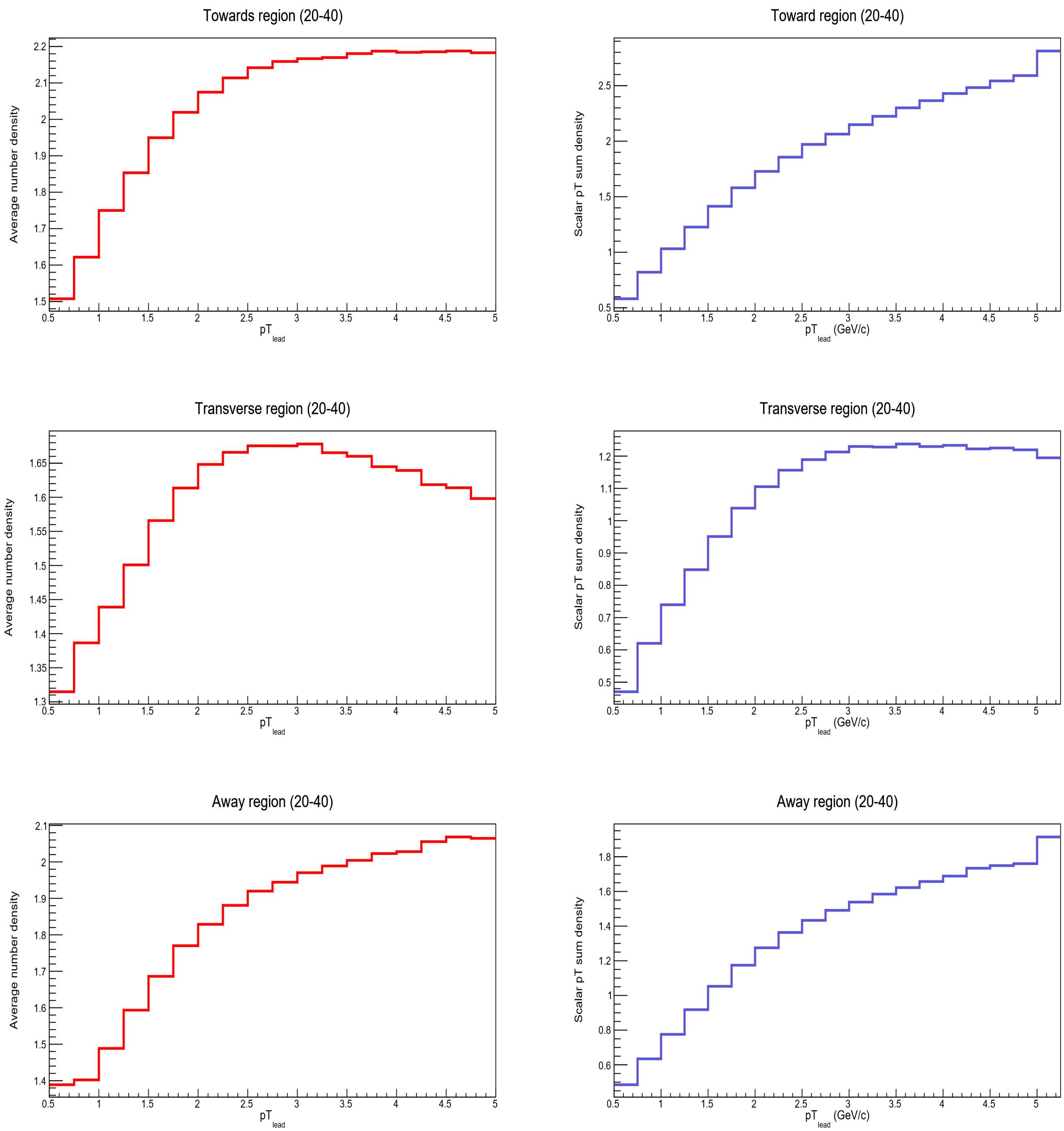

FIG. 2: Plots for average track multiplicity density, (left column) and average scalar p_T sum density (GeV/c) of tracks, (right column) as a function of leading track transverse momentum, p_T^{lead} (GeV/c), in the three relevant regions.

C. For multiplicity class 40-60

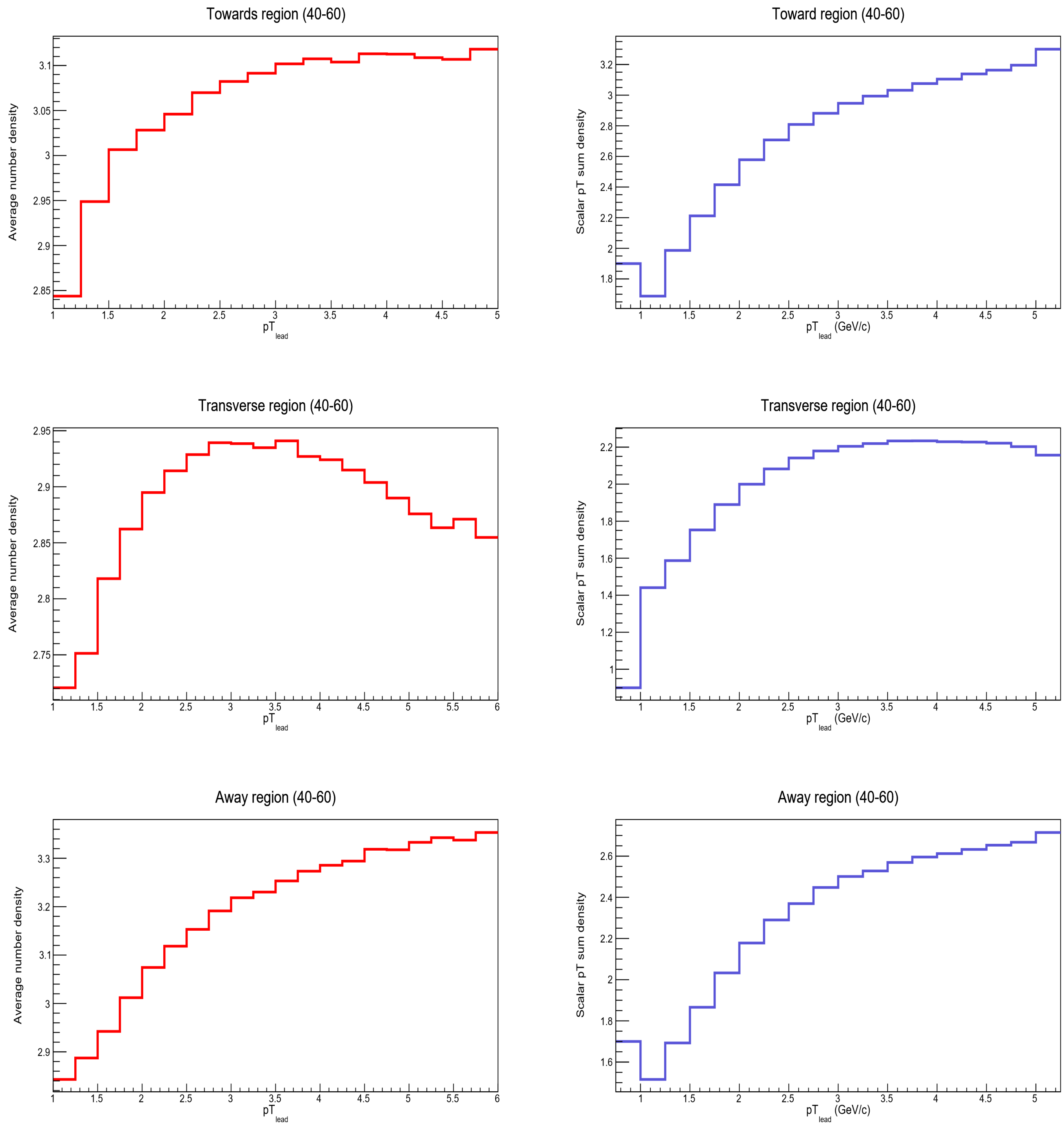

FIG. 3: Plots for average track multiplicity density, (left column) and average scalar p_T sum density (GeV/c) of tracks, (right column) as a function of leading track transverse momentum, p_T^{lead} (GeV/c), in the three relevant regions.

D. For multiplicity class 60-80

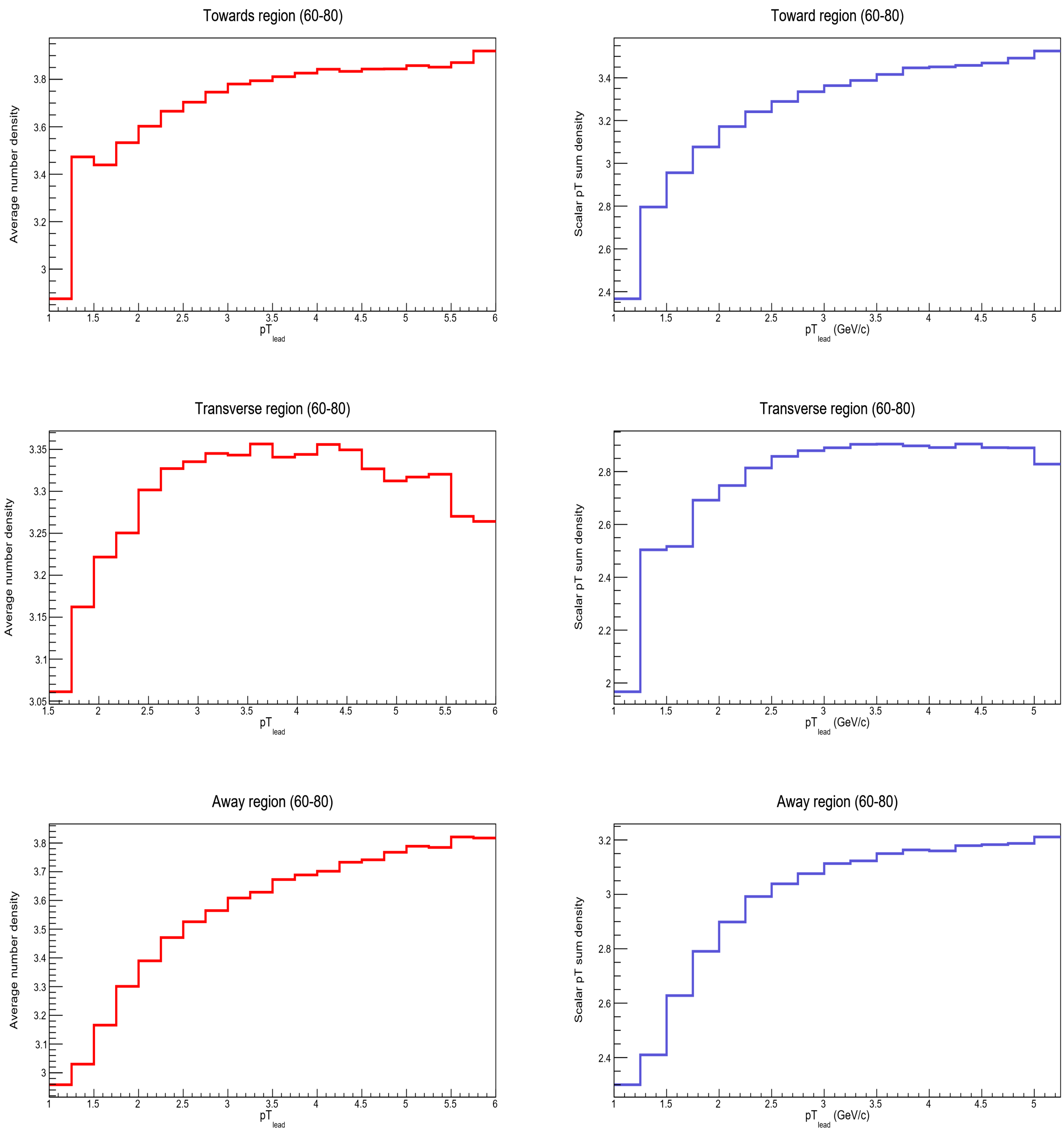

FIG. 4: Plots for average track multiplicity density, (left column) and average scalar p_T sum density (GeV/c) of tracks, (right column) as a function of leading track transverse momentum, p_T^{lead} (GeV/c), in the three relevant regions.

E. Additional plots

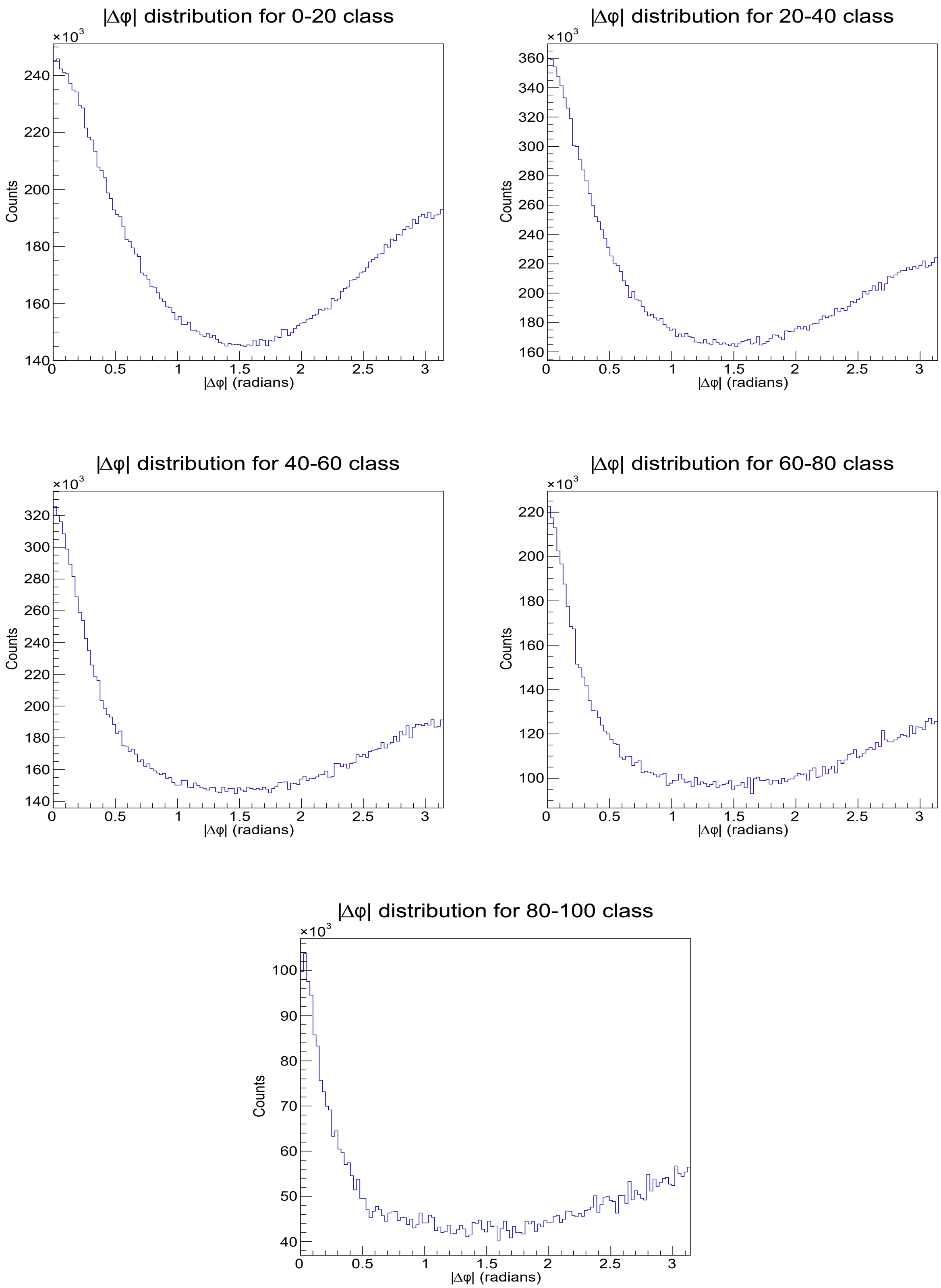

FIG. 5: Difference in ϕ between the leading track and sub-leading track in an event ($|\phi_{leading\ track} - \phi_{sub-leading\ track}|$).

IV. SUMMARY

We plotted the $\Delta\phi$ frequency histogram, and divided the events into three distinct angular regions. We then constructed the UE-sensitive observables $\langle d^2N_{ch}/d\eta d\phi\rangle$ and $\langle d^2\sum \mathrm{p_T}/d\eta d\phi\rangle$ and plotted them as functions of leading transverse momentum. These plots are indicative of the nature of the underlying pp collision.
The codes for generating the plots and the plots themselves can be found here.

[1] G. A. *et al.* (ATLAS Collaboration), Phys. Rev. D **83**, 112001 (2011).