1. Introduction

- High-multiplicity pp collisions unveiled heavy-ion-like effects such as collectivity and strangeness enhancement. In PYTHIA 8, multiparton interactions (MPI) and color reconnection (CR) produce collective-like effects, therefore, it is pertinent to measure quantities sensitive to MPI.
- The underlying event (UE) [1] consists of particles from beam-beam remnants and MPI.
- The transverse region, relative to the track with the highest transverse momentum of the event ($P_T^{\text{trig}}$), is the most sensitive to UE [2], but it has contributions from initial- and final-state radiation (ISR and FSR).
- In this work, the multiplicity distributions in the transverse region measured in pp collisions at $\sqrt{s} = 2.76, 5.02, 7$ and $13$ TeV are reported. The transverse region is further subdivided into trans-max and trans-min regions corresponding to the sub-transverse region (I or II) with the largest and smallest charged-particle multiplicity which have an enhanced sensitivity to ISR-FSR and UE, respectively. Scaling properties are explored [3].
Datasets

<table>
<thead>
<tr>
<th>Energy</th>
<th>Year</th>
<th>Statistics</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.76 TeV</td>
<td>2011</td>
<td>22M</td>
</tr>
<tr>
<td>5.02 TeV</td>
<td>2015</td>
<td>176M</td>
</tr>
<tr>
<td>7 TeV</td>
<td>2010</td>
<td>171M</td>
</tr>
<tr>
<td>13 TeV</td>
<td>2016</td>
<td>199M</td>
</tr>
</tbody>
</table>

Event selection: $5 \leq p_T^{\text{trig}} \leq 40 \text{ GeV}/c$ in $|\eta| < 0.8$


Track selection for multiplicity: uniform distributions in azimuth

Correction method: bayesian unfolding

Systematic uncertainties: track selection, event selection, MC closure test, and model dependence

2. Analysis details

- Relevant detectors:
  - ITS: primary vertex reconstruction, pile up rejection, tracking
  - TPC: tracking
  - V0: triggering and beam background rejection

- Datasets

3. Results

- The charged-particle multiplicity distributions are energy dependent in the three topological regions

- Higher multiplicities are reached at higher energies.
In the three topological regions the KNO-like scaling holds for $0 < z(=N_{ch}/\langle N_{ch} \rangle) < 3.5$

MPI can explain the effect [5]

In the trans-min region, a higher $z$ reach is achieved, in particular for $z > 6$, a larger deviation is seen

For low $z$ values, EPOS LHC and PYTHIA 8 are consistent with data within two standard deviations

At high values of $z$, both models underestimate data

In the transverse region, a similar behavior was reported in Ref. [2]
Within uncertainties, both EPOS LHC and PYTHIA 8 are consistent with data and a better agreement is reached at higher energies.

In the transverse region, our results are consistent with the trend of existing measurements.

Data are consistent with an extrapolation of the CDF results to LHC energies, where the ISR-FSR component increases logarithmically, while the UE component increases like a power of the centre-of-mass energy.
4. Summary

- Average charged-particle densities as a function of the centre-of-mass energy:
  - The results for the transverse side can be described by a function of the form \( \propto s^{0.27} + 0.14 \log(s) \), where the first (second) term quantifies the MPI- (ISR-FSR-) sensitive topological region of the collision.
  - PYTHIA 8 and EPOS LHC, which incorporate MPI, are consistent with data, a better agreement is reached at higher energies.

- The KNO scaling:
  - KNO-like scaling holds for \( 0 < z < 3.5 \) and it is broken above 3.5. A higher \( z \) reach is achieved for the trans-min region, in particular for \( z > 6 \), a larger violation of the KNO scaling is observed.
  - PYTHIA 8 and EPOS LHC reproduce the distribution at low values of \( z \), and for higher \( z \) values they underestimate data.

5. Acknowledgement

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6. References