Apparent modification of the jet-like yield in proton-proton collisions with large underlying event

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Motivation

-> High-multiplicity proton-proton collisions show collective behavior

$$\frac{dn}{d\phi} \propto 1 + \sum_{n} 2v_n(p_T) \cos[n(\phi - \Psi_n)]$$

-> Good agreement with relativistic viscous hydrodynamic calculations

Figure: Elliptic (v2), triangular (v3) and quadrupolar (v4) flow coefficients, PLB 774 (2017) 351-356

Figure: Uncorrected acoplanarity distributions for ALICE data (left) and PYTHIA 8 Monash (right), Nucl.Phys.A 1005 (2021) 121924

No jet quenching found so far -> searches warranted: first measurement from ALICE collaboration: Search for jet quenching effects in high multiplicity pp collisions at 13 TeV (preliminary)

- Event activity classes based on average multiplicities
- broadening of recoil jet acoplanarity -> characteristic of jet quenching
- similar effect observed in the PYTHIA model (which lacks the mechanism of jet-quenching)

Goal:
Study high-multiplicity pp events in PYTHIA to understand the potential biases
Methods - Observable and Event activity classifier $R_T$

**Standard two-particle azimuthal correlation analysis to study jet-quenching effects**

$I_{AA}^\gamma$: ratio of jet-like yield from AA to the one from pp collisions

- interplay between the parton production spectrum and energy loss in the medium
- Towards (away) region: enhancement (suppression)

**PYTHIA 8 model**: 2->2 process + parton shower (Initial- and Final state radiation), Color Reconnection, MPI

- primary charged particles in $|\eta|<0.8$, $\sqrt{s} = 5.02$ TeV
- trigger particle: $8 \text{ GeV/c} < p_T < 15 \text{ GeV/c}$

**Study Underlying Event activity** (semi-hard and multi-parton interactions)

**Use relative transverse activity classifier $R_T$**

$$R_T = \frac{N_{\text{trans.}}}{N_{\text{ch}}}$$

- Goal: study how event selection based on $R_T$ biases towards and away regions

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Methods - jet-like signal $C(\Delta\eta, \Delta\phi)$ extraction

- correlations at partonic level (due to gluon radiation or colour reconnection) are turned **on and off**: Initial- and Final state radiation, CR
- **Monash tune**: above given $R_T$ value $\langle N_{MPI} \rangle$ saturates -> towards region “picks up” particles from jet fragments -> **activity biased**

<table>
<thead>
<tr>
<th>$R_T$ bin</th>
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<th>2</th>
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<th>4</th>
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$\langle N_{MPI} \rangle$ vs $R_T$

-> selection on $R_T$, a **third structure in the transverse region** ($\pi/3 < |\Delta\phi| < 2\pi/3$): associated yield increases with $R_T$
-> **contribution** to the towards and the away regions has to be **removed**: using **mixed event technique**
-> Underlying event subtracted using Zero Yield at Minimum method

-> **evolution of jet signal with $R_T$ is studied**

$C(\Delta\eta, \Delta\phi) = \frac{S(\Delta\eta, \Delta\phi)}{B(\Delta\eta, \Delta\phi)}$

**Figure. Average number of multi-parton interactions as a function of $R_T$**
Results - I.

- $R_T > 2.5$: distributions have peak at $\Delta \phi \sim 2$ rad
  
  - region where NMPI saturates: presence of a third jet
  
  - experimentally also observed ArXiv 1910.04457: particle production strong increase with $R_T$

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- Quantify the effect:
  - calculate the ratio of yields from different $R_T$ classes to the $R_T$-integrated one -> $I_{pp}$

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Results - II.

- $I_{pp} = 1$: in the absence of selection bias
- Selection bias reduced: integrate the $\Delta \varphi$ distribution around the towards/away regions

$\Rightarrow I_{pp} = 1$ w/o radiations
$\Rightarrow$ negl. difference w/ UE subtraction
$\Rightarrow I_{pp}$ increase with $R_T$ incl. radiations: similar to heavy-ion results
$\Rightarrow$ Radiation plays significant role

$\Rightarrow I_{pp} = 1$ w/o radiations
$\Rightarrow$ w/ UE subtraction: different behavior w.r.t. towards region
$\Rightarrow I_{pp} = 1$ after UE subtraction: event selection bias negligible

Takeaway message

High-multiplcity pp events can be made bias-free using event classification based on $R_T$ and study observables in the away region