Particle production as a function of UE activity measured with ALICE at the LHC
At LHC high collision energies -> significant contributions from hard processes
  • pQCD precise calculations

Nevertheless particle production dominated by **soft-QCD** processes $p_T \sim \text{few GeV}$
  • non perturbative phenomenology
  • modelling
Introduction

At LHC high collision energies -> significant contributions from hard processes
- pQCD precise calculations

Nevertheless particle production dominated by **soft-QCD** processes $p_T \sim \text{few GeV}$
- non perturbative phenomenology
- modelling

**Underlying Event**
- Multiple parton interactions (MPI): more than one hard scattering
- semi-hard + soft interactions (ISR/FSR and beam remnants)

Figure adapted from Eur.Phys.J. C62 (2009) 237-242

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Motivation

\(p_T\) spectra versus multiplicity

Midrapidity multiplicity selection → particle production above 0.8 GeV/c increases with increasing multiplicity

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Motivation

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The effect is reduced using a forward multiplicity estimator → but still visible
Motivation

$\rho_T$ spectra versus multiplicity

Midrapidity multiplicity selection $\rightarrow$ particle production above 0.8 GeV/c increases with increasing multiplicity

The effect is reduced using a forward multiplicity estimator $\rightarrow$ but still visible

- Is it due to the presence of jets which bias the selection?

- Could a jet free multiplicity estimator help to understand the correlation between low and high $\rho_T$ particle production?
Motivation

Multiplicity dependence studies

Non-linear heavy-flavour and high-$p_T$ particle production increase with multiplicity

- effect of multiplicity saturation?
- interplay between multiplicity fluctuations of individual parton interactions and decrease of MPI?

Motivation

Multiplicity dependence studies

Non-linear heavy-flavour and high-$p_T$ particle production increase with multiplicity

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Could a jet free multiplicity estimator help to understand soft QCD dynamics?

ALICE
JHEP 1509 (2015) 148
arXiv:1905.07208

ALICE pp $\sqrt{s} = 13$ TeV
SPD tracklets mult. estimator

- $4 < p_T < 6$ GeV/c
- $6 < p_T < 10$ GeV/c

EPOS LHC

Stat. unc.
Uncorr. syst. unc.

ALICE pp $\sqrt{s} = 7$ TeV
$2 < p_T < 4$ GeV/c

$<0.5, 2 < p_T < 4$ GeV/c
$<10$ GeV/c

Data
PYTHIA 8
EPOS LHC

6.46 ± 0.19
6.87
6.85

The ALICE detector
A Large Ion Collider Experiment

- 18 different detector systems
- high-momentum resolution
- excellent PID

solenoidal magnet: 0.5 T

Trigger and event characterisation detectors

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Data-taking detectors

Tracking

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PID

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\langle p_T \rangle \ vs \ multiplicity
Unfolding of $p_T$ spectra

The correlation between $N_{\text{ch}}$ and $p_T$ is experimentally unknown (biased by acceptance and secondaries)
Unfolding of $p_T$ spectra

The correlation between $N_{ch}$ and $p_T$ is experimentally unknown (biased by acceptance and secondaries)

- high resolution response matrix available from MC
- benefit from unfolding application from Bayes’ theorem

Energy dependence of $<p_T>$ versus multiplicity in pp collisions

- $<p_T>$ increases with increasing multiplicity for higher energy
Energy and system–size dependence

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System-size dependence of $<p_T>$ versus multiplicity results

New Results

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Energy and system–size dependence

Energy dependence of $<p_T>$ versus multiplicity in pp collisions
- $<p_T>$ increases with increasing multiplicity for higher energy

System-size dependence of $<p_T>$ versus multiplicity results
- possibility to reach higher $N_{ch}$ to study the full shape thanks to unfolding

New Results

ALICE Preliminary
charged particles, $\sqrt{s_{NN}} = 5.02$ TeV
$|\eta| < 0.8, 0.15$ GeV/c $< p_T < 50$ GeV/c
$p_T$ spectra vs UE activity
A jet–free multiplicity estimator

What is $R_T$?

We look for a variable that

1. is not influenced by the initial hard parton scattering
2. can discriminate among soft and hard events
A jet–free multiplicity estimator

What is $R_T$?

We look for a variable that
1. is not influenced by the initial hard parton scattering
2. can discriminate among soft and hard events

- define the relative transverse activity classifier $R_T$ in the plateau region (jet pedestal)

$$R_T = \frac{N_{\text{inclusive}}}{\langle N_{\text{inclusive}} \rangle}$$

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A jet–free multiplicity estimator
$R_T$ distribution

Selection done in:

- transverse multiplicity
- plateau region $5 < p_T^{\text{leading}} < 40$ GeV/c
A jet–free multiplicity estimator

\( R_T \) distribution

Selection done in:

- transverse multiplicity
- plateau region \( 5 < p_T^{\text{leading}} < 40 \) \( \text{GeV/c} \)
- several \( R_T \) bins to allow to distinguish among low and high UE activity

\[ \frac{1}{N_{\text{ev}}} \frac{dN}{dR_T} \]
Transverse $p_T$ distributions

Comparison to inclusive transverse spectra

- clear $p_T$ hardening at high multiplicity in the transverse region → same trend observed for the midrapidity-based multiplicity estimator

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Transverse $p_T$ distributions

Comparison to inclusive transverse spectra

- clear $p_T$ hardening at high multiplicity in the transverse region $\rightarrow$ same trend observed for the midrapidity-based multiplicity estimator

- measurement ($p_T$) and selection (multiplicity) are done in the same pseudorapidity region

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Comparison to inclusive toward spectra

- If the multiplicity is determined in the transverse region, the spectra in the toward (jet) region clearly show the opposite trend.
Toward $\rho_T$ spectra distributions

Comparison to inclusive toward spectra

- If the multiplicity is determined in the transverse region, the spectra in the toward (jet) region clearly show the opposite trend

- we observe convergence to the jet:
  - complete separation among soft (UE) and hard (jet) part of the event at high $\rho_T$
  - correlation effects are significantly reduced
$R_T$ dependence for transverse and toward

ALICE Preliminary

$pp, \sqrt{s} = 13$ TeV

$|\eta| < 0.8, 2 < p_T < 4$ GeV/c

$5 < p_{T,\text{leading}} < 40$ GeV/c

- Transverse
- Toward
- PYTHIA 8 (Monash 2013)
\( R_T \) dependence

for transverse and toward

- yield in transverse vs \( R_T \)
- same behavior observed using the midrapidity–based multiplicity estimator

ALICE preliminary

\[ pp, \sqrt{s} = 13 \text{ TeV} \]

\[ |\eta| < 0.8, 2 < p_T < 4 \text{ GeV/c} \]

\[ 5 < p_{T, \text{leading}} < 40 \text{ GeV/c} \]

- Transverse
- Toward

PYTHIA 8 (Monash 2013)
yield in toward vs $R_T$

- does not converge to 0
  - at $R_T = 0$ we can have a jet
  - possibility to study hard object with almost no UE activity!

ALICE Preliminary

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  - it is linear
    - not the same as heavy flavours!

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Transverse
Toward

PYTHIA 8 (Monash 2013)
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    - Possibility to study hard object with almost no UE activity!
  - It is linear
    - Not the same as heavy flavours!
  - PYTHIA 8.2 reproduces very well the observed trends
<p><strong>Summary and outlook</strong></p>

- **<p><sub>T</sub> vs multiplicity:**
  - high resolution energy and system-size study capabilities due to unfolding

- **Transverse \( p_T \) spectra:**
  - hardening at high multiplicity  \( \rightarrow \) confirms the trend observed using the midrapidity multiplicity estimator

- **Toward \( p_T \) spectra:**
  - separation among soft (UE) and hard (jet) part of the event, at high \( p_T \)
  - no \( R_T \) saturation  \( \rightarrow \) no autocorrelation effects at play!
  - still possible to have a jet at \( \sim 0 \) UE activity
    \( \rightarrow \) unique opportunity to relate to elementary systems like \( e^+e^- \)
Summary and outlook

- $<p_T>$ vs multiplicity:
  - high resolution energy and system-size study capabilities due to unfolding

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  - still possible to have a jet at $\sim$ 0 UE activity
    $\rightarrow$ unique opportunity to relate to elementary systems like $e^+e^-$

$R_T$ is an effective instrument to disentangle jet and UE components of the spectra

$\rightarrow$ Promising for identified particle yields study, both for light and heavy flavours
Backup slides