Measurements of particle production, Bose-Einstein correlations and Underlying Event properties with the ATLAS detector

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On behalf of the ATLAS collaboration
Introduction

- Tracking system ideal for the measurement of track based particles properties

- Multi purpose detector:
  - Can measure events with different detector technologies
  - Possibility to measure soft-QCD with complementary methods
  - First comparisons with 13 TeV data will be shown in the talk
Publications

New 7 TeV results for Bose Einstein Correlations and Lamda polarisation:

- Two-particle Bose-Einstein correlations in pp collisions at $\sqrt{s}= 0.9$ and 7 TeV measured with the ATLAS detector (arXiv:1502.07947, submitted to EPJC)
- Measurement of the transverse polarization of $\Lambda$ and anti-$\Lambda$ hyperons produced in proton-proton collisions at $\sqrt{s}=7$ TeV using the ATLAS detector (arXiv:1412.1692; submitted to PRD)

7 TeV underlying event results:

- Underlying event characteristics and their dependence on jet size of charged-particle jet events in pp collisions at $\sqrt{s} = 7$ TeV with the ATLAS detector (Phys. Rev. D 86 (2012) 072004)

Brand new: 13 TeV comparisons for underlying-event using charged particles

- Detector Level plots for UE with leading track: PUB-STDM-2015-03
Bose Einstein Correlations (BEC)

- **BEC**: higher emission probability of two mesons with very similar momentum

- **Two particle correlation** $C_2$ of same sign particles:
  
  \[ C_2(Q^2) = \rho(++)/\rho(+-) \] with \( Q^2 = - (P_1 - P_2)^2 \)

- \( R_2(Q^2) = C_2(Q^2)_{\text{data}} / C_2(Q^2)_{\text{MC}} \)

- **MC := MC without BEC**

- **Fit to extract BEC**, two possible parametrisations:
  - $\lambda \cdot \exp(-R^2 Q^2)$, gauss
  - $\lambda \cdot \exp(-R Q)$, exponential
  - $\lambda$ := strength of BEC
  - $R$: effective radius

![Graph showing data and fits for BEC](image)
**Bose Einstein Correlations**

- **$\lambda$:** strength
  - $0 \rightarrow$ fully correlated, $1 \rightarrow$ chaotic
  - Depends on centre of mass energy and charged multiplicity $n_{ch}$

- **$R$:** effective radius of the BEC
  - Saturation at $n_{ch} \sim 70$
  - Proton overlap, expect for a decreases at very high $n_{ch}$
Lambda Polarisation in the transverse plane

- Huge $\Lambda$ sample allows to measure $\Lambda$ polarisation $P$ by measuring the decay angle $\cos \theta^*$ between the decay proton and $\Lambda$ flight directions
  - $P(\Lambda) = (1 + \alpha P \cos \theta^*)$; Decay asymmetry: $\alpha = 0.642 \pm 0.013$

Results:
- $P(\Lambda) = -0.010 \pm 0.005\text{(stat)} \pm 0.004\text{(syst)}$
- $P(\bar{\Lambda}) = 0.002 \pm 0.006 \text{(stat)} \pm 0.004\text{(syst)}$

- Consistent to previous measurement which expect a degradation of the $\Lambda$ polarisation at high energy
Underlying event

- Looking for activity in an event in addition of the hard interaction:
  - Initial/final state radiation
  - Multi parton interactions

- These soft interaction cannot be calculated:
  - Free parameters to be tuned using data

- Usual approach, split event in three regions:
  - Towards region: close to leading object
  - Transverse region: sensitive to UE and MPI
  - Away region: recoil of the leading object

- Leading object can be defined variously:
  - Leading jet
  - $Z - p_T$
  - Leading track in Minimum Bias like events
Underlying events with jets / Z: $\Sigma p_T$

> Sum $p_T$ for UE vs leading jet and $p_T(Z)$:

- Agreement is in the 10% level but different for both analyses
- LO vs NLO Matrix element: Powheg+Pythia looks different than Pythia
Compatibility of the different analyses

Track density for different leading objects:

- Data are compatible between the different definitions
- Transition between leading track and jet
- Z and jet agree well at high $p_T$ (selection bias in the Z at low $p_T$)
Underlying events comparisons at 13 TeV

- Underlying events with leading track with $p_T > 1$ GeV
- Spin off of Minimum Bias analyses
  (15:30, Anthony Morley):
  - Minimum Bias scintillator trigger
  - Pile up veto
  - Track $p_T > 500$ MeV and $|\eta| < 2.5$
  - Event selection is ~99.5% efficient for at least 2 selected tracks

- Uncorrected performance plots:
  - Systematic shown is for tracking efficiency using Monte Carlo

- Comparisons to:
  - Pythia8 Monash (Author tune)
  - Pythia8 A2 (Atlas MinBias tune)
  - Pythia8 A14 (Atlas UE tune)
  - Herwig++ UEEE5 (Author tune)
  - EPOS (Astrop. physics model)
MinBias Tune (A2) agrees well at $p_T$-lead $> 1$ GeV

Underlying event Tunes (Herwig++, Monash, A14) better at $p_T$-lead $> 5$ GeV
From 10 GeV decent description for the UE Tunes
A2 describes only toward region well
EPOS 15% off in the plateau
A2 (MinBias Tune) agrees well at $p_T$-lead $> 1$ GeV

Underlying event Tunes better at $p_T$-lead $> 5$ GeV

Epos off in the Plateau
Summary

- Atlas is a good place to study soft-QCD

- Particle production studies:
  - Bose Einstein-Correlations correlation of same sign particles
    - saturation effect in the effective radius observed for large $n_{ch}$
  - Lambda polarisation:
    - no polarisation for $\Lambda$ and $\bar{\Lambda}$ at high energies

- Underlying event analysis:
  - Needed for tuning of the soft part of Monte Carlo simulation
  - Diverse studies done at 7 TeV: leading track, leading jet and $Z$

- New comparisons for Underlying Event with 13 TeV data are shown:
  - Reasonable agreement of tunes used in Atlas Monte Carlo with new data
  → looking forward to future unfolded results