Recent soft QCD and jet physics results from ATLAS
Lake Louise Winter Institute - 2015

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Introduction

Select highlights from the 21 ATLAS Standard Model papers published in 2014, focusing on topics of Soft QCD and Jet physics.
Topics Covered

- Soft QCD: $\Lambda$ & $\bar{\Lambda}$ transverse polarisation.
- Soft QCD: The total $pp$ cross section.
- Soft QCD: The Underlying Event in inclusive $Z$-boson production.

- Jet Physics: Inclusive jet cross sections.
- Jet Physics: Three-jet cross sections.
- Jet Physics: Jet vetoes & azimuthal decorrelation in di-jet events.
Transverse Polarisation of $\Lambda$ and $\bar{\Lambda}$ \textbf{arXiv:1412.1692 [hep-ex]}

- Past experiments have measured large (up to 30%) $\Lambda$ transverse polarisation w.r.t. the production plane in $p$-$p$ and $p$-Ion collisions.
- ATLAS measure the transverse polarisation differential in Feynman-$x$ ($x_F = p_z/p_{beam}$) and $p_T$ with respect to the beam line.
- Polarisation extracted from the angular distribution of $\Lambda$ & $\bar{\Lambda}$ decay products via method of moments.
  - For any polarisation $P$, the first moment of the angular distribution may be written as a linear combination of the un-polarised $E(0)$ and fully-polarised $E(1)$ moments: $E(0) + [E(1) - E(0)]P$. 

![Diagram of transverse polarisation](image-url)
Transverse Polarisation of $\Lambda$ and $\bar{\Lambda}$ arXiv:1412.1692 [hep-ex]

- Results, presented in the fiducial volume of $0.8 < p_T < 15$ GeV, $5 \times 10^{-5} < x_F < 0.01$ and $|\eta| < 2.5$

$$P_\Lambda = -0.010 \pm 0.005\,(\text{stat.}) \pm 0.004\,(\text{syst.})$$

are compatible with zero polarisation. Equivalently for $P_{\bar{\Lambda}} = 0.002$.

- Reconstruction efficiencies are provided as a function of $p_T$ and $x_F$ to allow model builders to weight their $\Lambda$ baryons for comparison with ATLAS data.
ALFA consists of dedicated tracking detectors in the beam line at $z = \pm 238 \, \text{m} \text{ and } 241 \, \text{m}$ from ATLAS.

Data taking in special runs with high-$\beta^*$ optics ($* = \text{at IP}$) and parallel-to-point focusing in the vertical plane.

- Elastic scattering angle at IP maps to a $y$ displacement in ALFA.

Allows the reconstruction of the 4-mom transfer: $-t = (\theta^* \times p)^2$
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Total Cross Section with ALFA Nuc. Phys B (2014), 486-548

- The (predominantly) exponential $-t$ slope is fitted in the region of high ALFA acceptance ($> 10\%$) yielding slope parameter

$$B = 19.73 \pm 0.14\text{(stat.)} \pm 0.26\text{(syst.)} \text{ GeV}^{-2}$$

- The total cross section is obtained via the optical theorem:

$$\sigma_{\text{tot}}(pp \rightarrow X) = \frac{16\pi}{1 + \rho^2} \frac{1}{L} \frac{dN_{\text{el}}}{dt} \bigg|_{t=0} = 95.35 \pm 0.38\text{(stat.)} \pm 1.30\text{(sys.)} \text{ mb}$$
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- Underlying Event measurements probe everything *but* the hard scatter: multi parton interactions, colour reconnection, wide angle radiation...
- Traditionally measured *transverse* to the hard axis.
- With $Z$-events: the *towards* region can also be probed.

Left Sum-$p_T$ density of charged particles in the transverse region for three bins of $p_T^Z$.

Right Average transverse charged particle multiplicity density as a function $p_{T,\text{lead}}$ for $Z$, jet and minimum bias data.

At high-$p_T$ the $<N>$ UE looks to be a universal quantity. Disagreement at low-$p_T$ due to the hard scale ($m_Z$) in $Z$ events.
• Model description for the average sum-$p_T$ density in the transverse and towards regions as a function of $p_T^Z$.
• The high-$p_T^Z$ transverse region rises faster due to a greater contribution from the hadronic recoil.
• Shapes driven by perturbative radiation at high $p_T^Z$. 

- The inclusive jet cross section is measured with 4.5 fb\(^{-1}\) data.
- In general, both NLO pQCD matrix elements, parton shower matched and with EW corrections are in good agreement with data up to 2 TeV.
- ABM11 and HERAPDF1.5 NLO underestimate \(\sigma\) at low \(|y|\).
- Data & theory compared quantitatively w. correlated uncertainties.
- ATLAS has in addition the two-jet cross section JHEP05(2014)059.
Three Jet Cross Section  

- Probe the $2 \rightarrow 3$ scattering process as a function of 3-jet mass and $|Y^*| = |y_1 - y_2| + |y_2 - y_3| + |y_1 - y_3|$.
- NLO QCD calculations show a correlated sensitivity to the choice of anti-$k_t R$ parameter.
- Data are described over $0.4 M_{jjj} < 5$ TeV. The ABM11 PDF are observed to be systematically low compared to other PDF sets.

$R = 0.4$
Three Jet Cross Section arXiv:1411.1855 [hep-ex]

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- Use large-$y$ separated di-jets along with veto on a third in-between jet to probe parton evolutions.
- The ratio of the 1\textsuperscript{st} and 2\textsuperscript{nd} moments of the cosine of the $\phi$ separation of the di-jets is particularly sensitive to BFKL effects.
- POWHEG (BFKL-like) underestimates whereas HEJ (DGLAP-like) overestimates $\phi$ correlation.

Image: D. Diakonov, CERN Courier

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Conclusion

ATLAS continuing to publish measurements on various variables sensitive to non-perturbative \( pp \) modelling effects such as hadronisation, small \( |t| \) scattering and multi parton interactions.

Analysis fiducial volumes are chosen to give greatest model discrimination power.

Jet data are compared to a variety of PDF sets as a function of the mass and \( y \) of the jet system for two values of the jet size parameter.

Correlations between all ATLAS jet cross sections are treated in a common framework to allow for future correlated PDF constraints.

Azimuthal decorrelations are studied in extreme phase spaces with the addition of a veto on additional jets to maximise sensitivity to BFKL evolution effects.