

Review of ATLAS results on MPI, soft QCD and diffraction

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on behalf of the ATLAS Collaboration

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EDS Blois 2015
The 16th Conference on Elastic and Diffractive Scattering
29 June – 4 July, Borgo, Corsica

Recent ATLAS results on MPI, soft QCD and diffraction (from Run 1)

Review of
ATLAS results on
MPI, soft QCD
and diffraction

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Underlying event
studies

Total cross
section
measurement

Summary

- *Two-particle Bose-Einstein correlations in pp collisions at $\sqrt{s} = 0.9$ and 7 TeV measured with the ATLAS detector*
arXiv:1502.07947
- *Measurement of the transverse polarization of Λ and anti- Λ hyperons produced in proton-proton collisions at $\sqrt{s} = 7$ TeV using the ATLAS detector*
Phys.Rev. D91 (2015) 032004
- *The differential production cross section of the $\phi(1020)$ meson in $\sqrt{s} = 7$ TeV pp collisions measured with the ATLAS detector*
Eur. Phys. J. C (2014) 74:2895
- *Measurement of distributions sensitive to the underlying event in inclusive Z-boson production in pp collisions at $\sqrt{s} = 7$ TeV with the ATLAS detector*
Eur. Phys. J. C (2014) 74:3195
- *Measurement of the underlying event in jet events from 7 TeV proton-proton collisions with the ATLAS detector*
Eur.Phys.J. C74 (2014) 2965
- *Measurement of the total cross section from elastic scattering in pp collisions at $\sqrt{s} = 7$ TeV with the ATLAS detector*
Nucl.Phys. B889 (2014) 486-548

Introduction

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See talk on Monday by Elena:

Measurements of particle production and their correlations at the LHC with the ATLAS det.

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arXiv:1502.07947
- *Measurement of the transverse polarization of Λ and anti- Λ hyperons produced in proton-proton collisions at $\sqrt{s} = 7$ TeV using the ATLAS detector*
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This presentation

- *Measurement of distributions sensitive to the underlying event in inclusive Z-boson production in pp collisions at $\sqrt{s} = 7$ TeV with the ATLAS detector*
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- Complex structure of hadron-hadron interaction
- Underlying event – activity in addition to the hard interaction:
 - initial state radiation
 - final state radiation
 - multiple parton interaction
 - colour reconnections with beam remnants
- Non-perturbative effects
- No clear soft/hard separation
- Phenomenological model in MC generators
- A need for tuning to experimental data

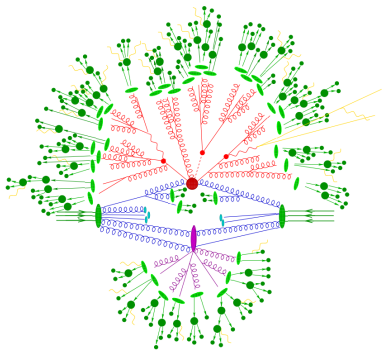


Figure from [arXiv:1411.4085]

Principle of the measurements

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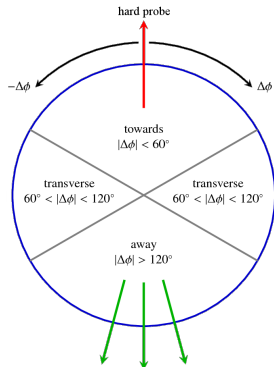
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- Regions in ϕ defined w.r.t. the direction of the hard object
- Transverse region – sensitive to UE
- Two transverse regions \rightarrow trans-min and trans-max (distinguished on the event-by-event basis according to $\sum p_T$)
- UE observables (unfolded to particle level):
 - $N_{\text{ch}}/\delta\eta\delta\phi$
 - $\sum p_T/\delta\eta\delta\phi$
 - Mean p_T
- Charged particles measured for $|\eta| < 2.5$ and $p_T > 0.5$ GeV



Event selection:

Jet events:

- anti- k_T algorithm with $R = 0.4$
- $p_T > 20$ GeV
- $|\eta| < 2.8$

Z boson events:

- $Z \rightarrow e^+e^-$ and $Z \rightarrow \mu^+\mu^-$
- $66 \text{ GeV} < m_{ll} < 116 \text{ GeV}$
- $|\eta_{ll}| < 2.4, p_T^l > 20 \text{ GeV}$

N_{ch} density distributions

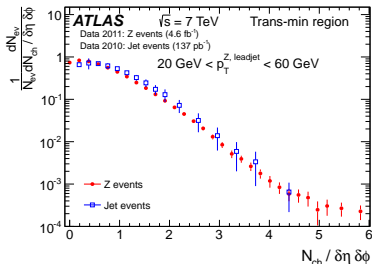
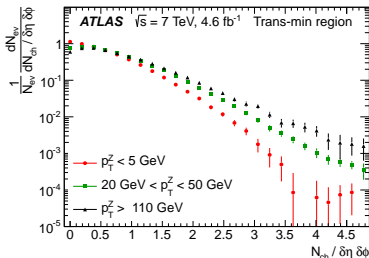
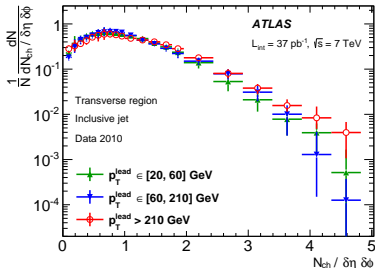
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- Measurements performed in different regions (toward, transverse, trans-min, trans-max) and p_T ranges
- Jets: inclusive and exclusive di-jet measurements
- UE universality – similar results for jet and Z events

Σp_T density distributions

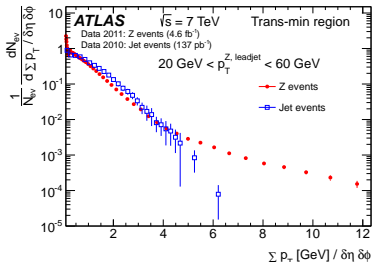
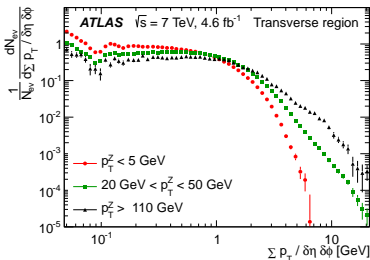
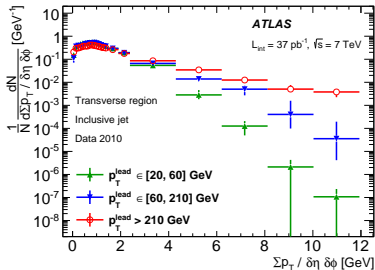
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Total cross section measurement

Summary



- Measurements performed in different regions and p_T ranges
- UE universality – similar results for jet and Z events
- Longer tail for Z events due to additional jets
- Better description by NLO and multi-leg generators

Scale (p_T) dependence

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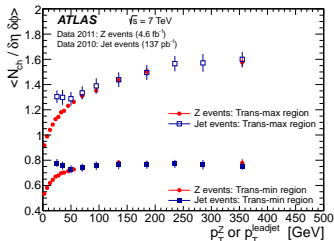
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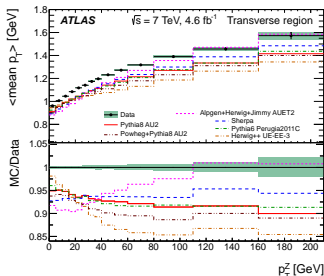
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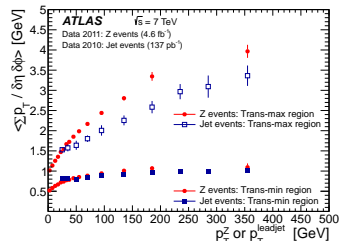
mean N_{ch} density:



mean p_T :



mean $\sum p_T$ density:



- Similar results for jet and Z events
- Differences for $\sum p_T$ in trans-max region – additional jet activity
- Difficulty of simultaneous description of N_{ch} and $\sum p_T$: $\langle p_T \rangle$ underestimated by all MC generators

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Measurement principle

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- Total hadronic cross section for $pp \rightarrow \text{anything}$
- Fundamental, but non-perturbative quantity
- Optical theorem

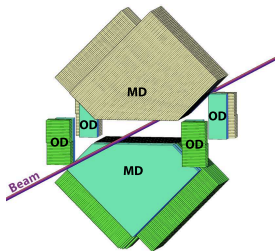
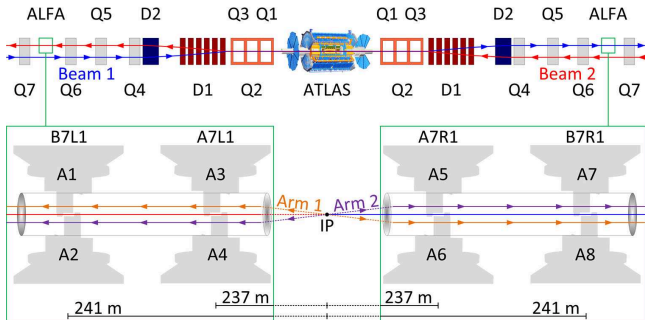
$$\sigma_{\text{tot}} = 4\pi \text{Im}f_{\text{el}}(t \rightarrow 0)$$

- Theory input: $\rho = \text{Re}f/\text{Im}f|_{t \rightarrow 0}$
- Measurement via elastic scattering extrapolated to $t = 0$

$$\sigma_{\text{tot}}^2 = \frac{16\pi(\hbar c)^2}{1 + \rho^2} \frac{d\sigma_{\text{el}}}{dt} \Big|_{t \rightarrow 0}$$

- $t \rightarrow 0 \Leftrightarrow$ very small angles
- Detectors close to the beam and far from the IP \rightarrow ALFA
- Dedicated LHC optics (high β^*)

ALFA detectors



- Located ~ 240 m from the IP
- Roman pot mechanism, 8 detectors
- Measurement 5 mm from the beam
- Detectors: scintillating fibres, UV geometry
- Resolution about $30 \mu\text{m}$ (3 – 12 % for t)
- Signature of elastic (golden) events: up-down (arm 1) or down-up (arm 2)

Elastic event selection

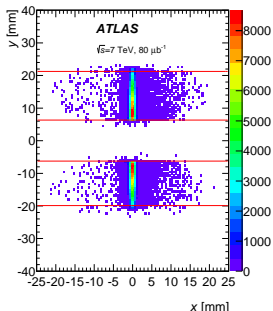
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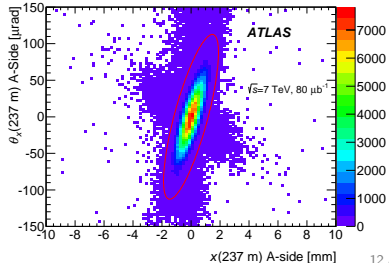
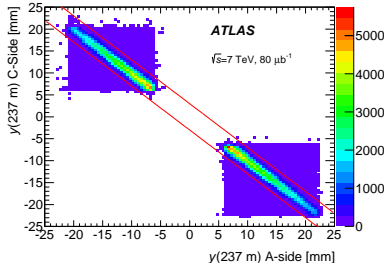
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- Elastic hit pattern in ALFA: elongated ellipse
- Selection based on constrained kinematics of elastic events:
 - golden event signature
 - left-right symmetry (in x and y)
 - fixed energy \rightarrow correlation between trajectory position and elevation angle



Background and corrections

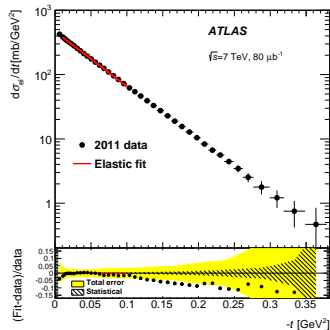
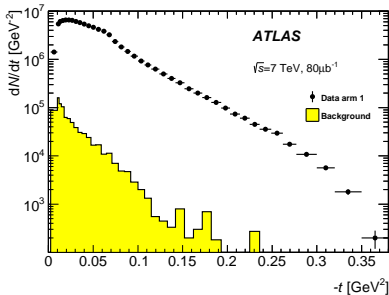
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- Background origin: coincidences of beam halo and single diffraction
- Background estimation: anti-golden events (up-up or down-down)
- Overall background contamination $\sim 0.5\%$
- The raw spectrum is unfolded and corrected for acceptance, efficiencies (event reconstruction, trigger, dead time) and luminosity
- Dominant sources of systematic uncertainties: luminosity, beam energy, event reconstruction efficiency

Results

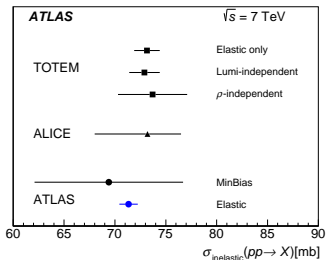
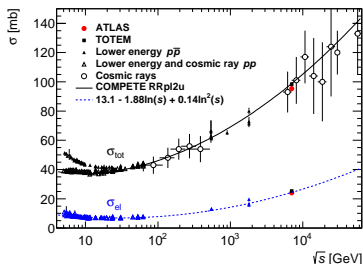
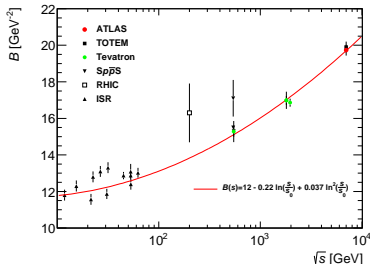
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Cross sections:

$$\sigma_{\text{tot}} = 95.35 \pm 1.36 \text{ mb}$$

$$\sigma_{\text{el}} = 24.00 \pm 0.60 \text{ mb}$$

$$\sigma_{\text{inel}} = 71.34 \pm 0.90 \text{ mb}$$

Elastic slope:

$$B = 19.73 \pm 0.24 \text{ GeV}^{-2}$$

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Underlying event measurements:

- Recent Run 1 ATLAS measurements of underlying event observables
- Large variety of data provided for jet and Z boson events
- Universality of UE (similar characteristics for jet and Z production)
- Importance of additional jet produced in hard processes
- Difficulty of MC models to simultaneously describe N_{ch} and $\sum p_T$

Total cross section measurements at $\sqrt{s} = 7$ TeV:

- Measurement via elastic scattering extrapolated to $t = 0$
- Dedicated detectors (ALFA) and LHC optics (high β^*)
- $\sigma_{\text{tot}} = 95.35 \pm 1.36$ mb
- Agreement with other measurements