Measurements of the elastic, inelastic and total cross sections in pp collisions with ATLAS subdetectors

Per Grafstrom
University of Bologna and CERN

On behalf of the ATLAS collaboration
Introduction

- This presentation summarizes the ATLAS results at 7 TeV on $\sigma_{\text{tot}}$, $\sigma_{\text{el}}$ and $\sigma_{\text{inel}}$ using the Roman Pot technique


- The results are compared with results from other experiments

- The results are also discussed in relation to previous ATLAS measurements based upon "minimum bias" data

- Unfortunately no data from 13 TeV is available at this point
The quantities $\sigma_{\text{tot}}$, $\sigma_{\text{el}}$ and $\sigma_{\text{inel}}$ can all be determined from a single measurement of the differential elastic cross section.

- The $\sigma_{\text{tot}}$, is extracted using the optical theorem:
  \[
  \sigma_{\text{tot}} \propto 4\pi \cdot \text{Im}(f_{\text{el}})_{t\rightarrow 0}
  \]

- The $\sigma_{\text{el}}$ is obtained by integration
  \[
  \sigma_{\text{el}} = \int d\sigma_{\text{el}}/dt
  \]

- The $\sigma_{\text{inel}}$ is derived by a simple subtraction
  \[
  \sigma_{\text{inel}} = \sigma_{\text{tot}} - \sigma_{\text{el}}
  \]
Elastic scattering is measured in a dedicated run of the LHC with special high $\beta^*=90\text{m}$ optics with the ALFA Roman Pot sub-detector.

The ALFA detector is at 240m from the IP, the detector was placed at $\sim5\text{mm}$ from the beam, 800k elastic events were recorded.
Event Selection

- first level elastic trigger
- data quality cuts
- apply geometrical acceptance cuts
- apply elastic selection based on back-to-back topology and background selection cut
The differential elastic cross section

Corrected t-spectrum in the two arms are combined and divided by luminosity

\[
\left( \frac{d\sigma}{dt} \right)_i = \frac{1}{t_i} \cdot \frac{M^{-1}[N_i - B_i]}{A_i \cdot \varepsilon^{\text{reco}} \cdot \varepsilon^{\text{trig}} \cdot \varepsilon^{\text{DAQ}} \cdot L_{\text{int}}}
\]

A: acceptance(t)
M: unfolding procedure (symbolic)
N: selected events
B: estimated background
\(\varepsilon^{\text{reco}}\): reconstruction efficiency
\(\varepsilon^{\text{trig}}\): trigger efficiency
\(\varepsilon^{\text{DAQ}}\): dead-time correction

L\(_{\text{int}}\): luminosity

Main systematic uncertainties
• luminosity
• nominal beam energy
Extracting $\sigma_{tot}$ and B

\[ \sigma_{tot} \propto 4\pi \cdot \text{Im}(f_{el})_{t \to 0} \]

\[ \sigma_{tot} = 95.4 \pm 1.3 \text{ mb} \]

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

The fit includes experimental systematic uncertainties in the $\chi$.

The fit quality is good: $\chi^2$/N dof = 7.4/16.

The fit range is set to $-t[0.01, 0.1]$ GeV$^2$, where possible deviations from exponential form are small.

Further uncertainty arise from the extrapolation $t \to 0$, probed by a variation of the fit range from 0.1 to 0.15 resp. to 0.058.

Extrapolation error $\Delta \sigma_{tot} = \pm 0.4$ mb, $\Delta B = \pm 0.17$ GeV$^2$
The total cross section and the elastic cross section

From the fit; $\sigma_{\text{tot}} = 95.4 \pm 1.4$ mb

From the integral $\int d\sigma_{\text{el}}/dt$; $\sigma_{\text{el}} = 24.0 \pm 0.6$ mb
The inelastic cross section

$$\sigma_{\text{inel}} = \sigma_{\text{tot}} - \sigma_{\text{el}} = 71.3 \pm 0.9 \text{ mb}$$

Recent compilation from LHCb

ATLAS Roman Pots
The slope parameter

\[ B = B_0 + 2\alpha_p^{\text{eff}} \ln\left(\frac{s}{s_0}\right) \]

\[ \alpha_p^{\text{eff}} = 0.25 \text{ GeV}^{-2} \]

\[ B(s)=12 - 0.22 \ln\left(\frac{S}{S_0}\right) + 0.037 \ln^2\left(\frac{S}{S_0}\right) \]

Previous ATLAS measurement of $\sigma_{\text{inel}}$


Used “minimum bias” sample to extract $\sigma_{\text{inel}}$

Limited acceptance for diffractive events in terms of the mass of the dissociated system

\[ \xi \geq 5 \times 10^{-6} \quad \Rightarrow \quad M_X \geq 15 \text{ GeV} \]

$\sigma_{\text{inel}} = 60.3 \pm 2.1 \text{ mb}$ in the fiducial region

$\sigma_{\text{inel}} = 71.3. \pm 0.9 \text{ mb}$ from Roman Pot measurement

$\sigma_{\text{inel}} = 11.0. \pm 2.3 \text{ mb}$ for $M_X < 15 \text{ GeV}$

Pythia and Phojet predicts: 3-6 mb

e.g models of Khoze Martin and Ryskin (KMR) better description: 11-14 mb
Conclusions

• $\sigma_{\text{tot}}$, $\sigma_{\text{el}}$ and $\sigma_{\text{inel}}$ have been measured using the Roman Pot technique. Results are in agreement with TOTEM measurements but with slightly better precision. Concerning $\sigma_{\text{inel}}$ the results are in agreement with all other LHC experiments but again with the better precision.

• Comparing $\sigma_{\text{inel}}$ with a previous minimum biased based measurement from ATLAS yield a cross section of $11 \pm 2.3$ mb for diffractive masses below 15 GeV.

• The slope parameter B increases with $s$ faster than the “standard” $2 \alpha'_p \ln (s/s_0)$ behavior normally assumed.

• Looking forward to 13 TeV data
BACK-UP
Background

Two ways to estimate the background

- Use «anti-golden « configuration
- Reconstruct the vertex distribution in x

Background fraction ~0.5 % dominated by halo protons
Luminosity and beam optics

\( L = 78.7 \pm 1.9 \ \mu \text{b}^{-1} \)

Luminosity uncertainty 2.3%

Small correction to optics model, 3% to inner triplet magnet strength.