Towards a Total Cross Section Measurement with the ALFA Detector at ATLAS

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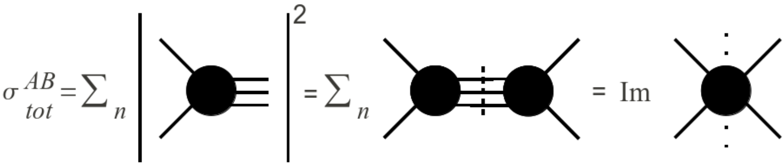
How to Measure Total Cross Section

Optical theorem

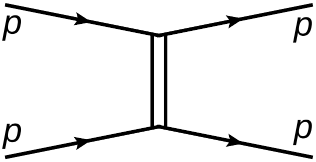
Total cross section is directly proportional to the imaginary part of the forward **elastic scattering** *amplitude extrapolated to* **zero momentum transfer***:*

$$\sigma_{tot} = 4\pi \cdot Im[f_{el}(t=0)]$$



Elastic scattering:

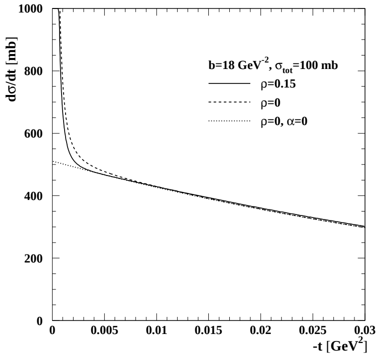
- both protons stay intact,
- described by the four momentum transfer, t,
- protons are scattered at very small angles.

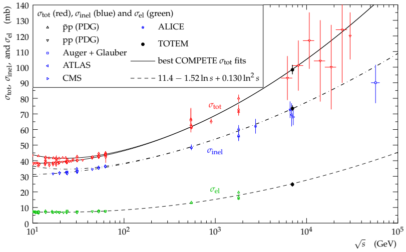


How to Measure Total Cross Section

$$\left.\frac{dN}{dt}\right|_{t=0} = L\pi |f_C + f_N|^2 \approx L\pi \left| -\frac{2\alpha_{EM}}{|t|} + \frac{\sigma_{tot}}{4\pi}(i+\rho)\exp\left(\frac{-b|t|}{2}\right)\right|^2$$

$$\rho = \left.\frac{Re\ f_{el}}{Im\ f_{el}}\right|_{t\to 0}$$

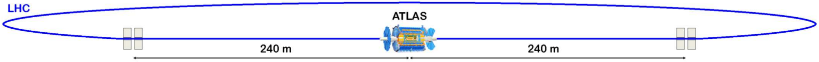


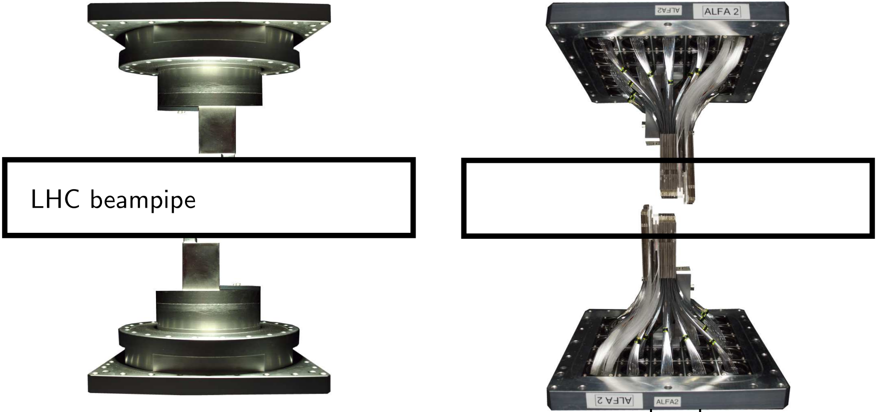


ALFA Detectors

ALFA – Absolute Luminosity For ATLAS:

- two stations at each ATLAS side, 240 m far from the IP1,
- scintillating fibres – position measurement with precision of 30 μm,
- *Roman Pot* technology – detectors can move in vertical (y) direction



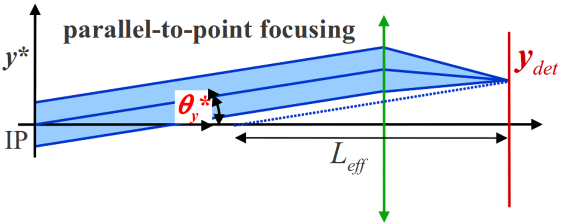


open closed

LHC Special High β^* Optic

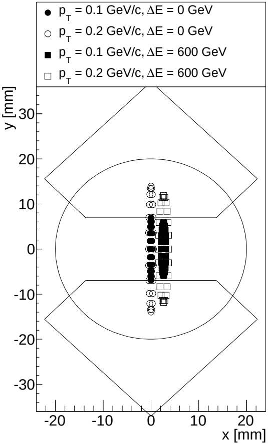
LHC high β^* optic (special runs):

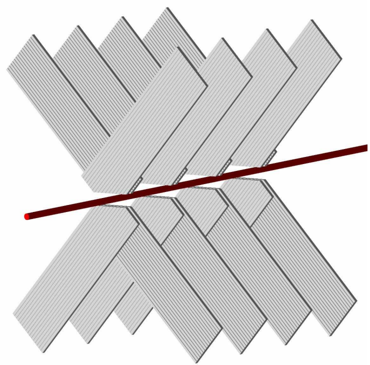
- access to low t values for elastically scattered protons,
- high betatron function – beam is almost parallel in IP (small divergence),
- low intensity bunches – less interactions within a bunch,
- parallel-to-point focusing – all protons with the same p_y momentum are focused in one point at ALFA station (y_{det}):



- phase advance $\psi = \pi/2$

Protons in ALFA





- $\beta^* = 90$ m
- elastic protons ($\Delta E = 0$) are going centrally ($x \sim 0$)
- diffractive protons ($\Delta E \neq 0$) are going inside the LHC ring ($x > 0$)

Principle of a scintillating fibre detector with 4 planes in *UV* geometry.

Four-momentum Transfer Reconstruction

Transport matrix:

$$\begin{pmatrix} y \\ y' \end{pmatrix} = \begin{pmatrix} \sqrt{\frac{\beta}{\beta^*}}(\cos\psi + \alpha^* \sin\psi) & L_y = \sqrt{\beta\beta^*}\sin\psi \\ \frac{(\alpha^*-\alpha)\cos\psi-(1+\alpha\alpha^*)\sin\psi}{\sqrt{\beta\beta^*}} & \sqrt{\frac{\beta}{\beta^*}}(\cos\psi - \alpha\sin\psi) \end{pmatrix} \begin{pmatrix} y^* \\ {y^*}' \end{pmatrix}$$

Four-momentum transfer:

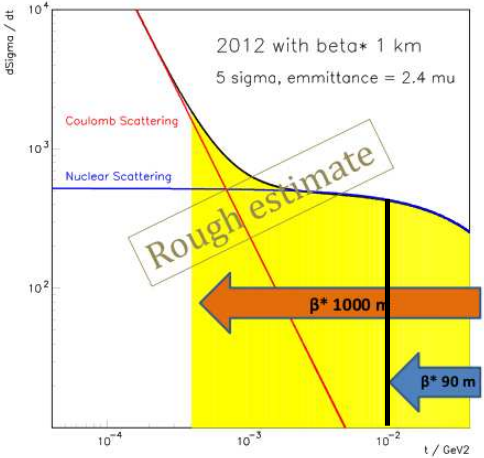
$$t \approx -(p\theta^*)^2$$

$$\theta^*_y = \frac{y_{left} - y_{right}}{L_y^{left} - L_y^{right}}$$

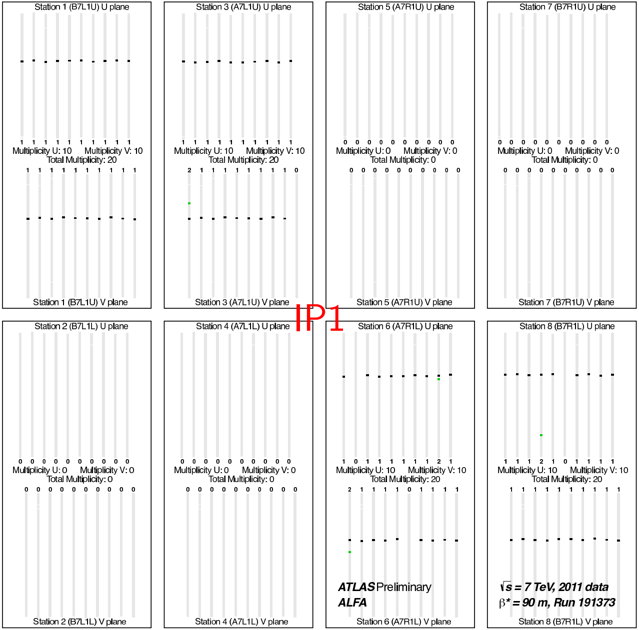
Collected Data

Collected data:

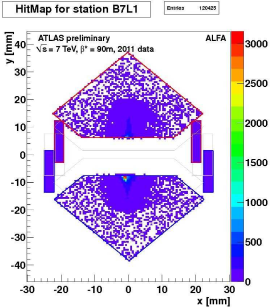
- 2011, $\sqrt{s} = 7$ TeV, $\beta^* = 90$ m, $\int L \sim 0.1$ nb^{-1},
- 2012, $\sqrt{s} = 8$ TeV, $\beta^* = 90$ m, $\int L \sim 25$ nb^{-1},
- 2012, $\sqrt{s} = 8$ TeV, $\beta^* = 1000$ m, $\int L \sim 0.1$ nb^{-1}.



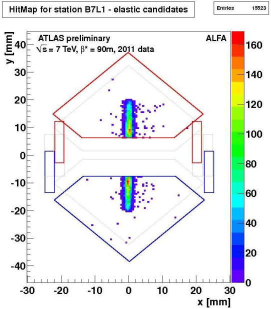
Elastic Candidate



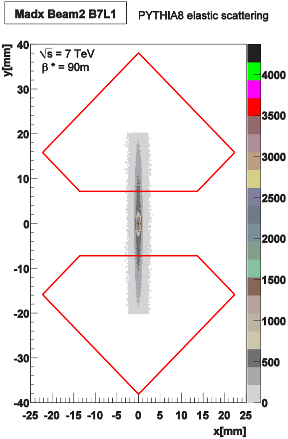
Data and Monte Carlo



all particles passing the ALFA detectors in station B7L1

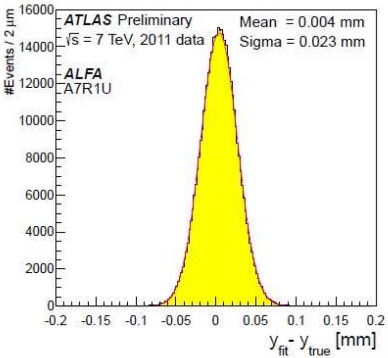


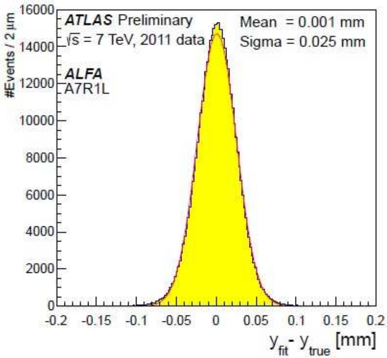
golden elastic events



simulated track maps of elastic events

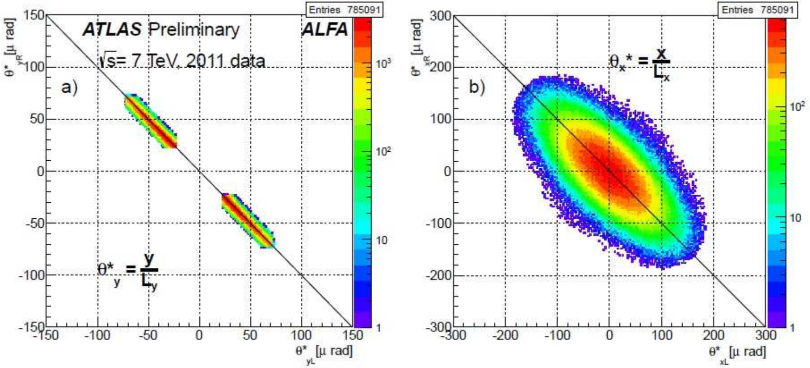
Detector Alignment





The mean value of the Gaussian fit shows the precision of the relative alignment between all detectors. The precision is consequently better than 5 μm.

Angle Reconstruction



Reconstructed scattering angle correlation between left and right side for elastic candidates after background rejection cuts in the vertical and horizontal plane.

Summary

- ALFA detectors successfully took data during the runs in years 2011 and 2012.
- Detectors are aligned and data is understood and under control.
- Runs with $\beta^* = 90$ m allow to measure total cross section – systematic effects are being considered.
- Runs with $\beta^* = 1000$ m probably allow investigation of Coulomb-nuclear Interference region.