ALFA – Absolute Luminosity Calibration for ATLAS.

Elastic scattering in the Coulomb-nuclear interference region.

PHYSICS AT THE TERA SCALE
Helmholtz Alliance

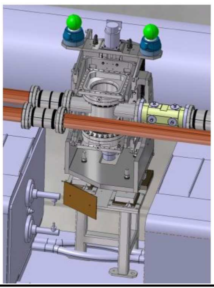
JUSTUS-LIEBIG-UNIVERSITÄT GIESSEN

DESY

HUMBOLDT-UNIVERSITÄT ZU BERLIN

The ALFA Roman Pot detector for ATLAS

•Two Roman pot stations at 240m from ATLAS at each side in the LHC tunnel
• Each station housing two vertically moveable ALFA detectors
• Each Roman Pot is instrumented by 1500 scintillating fibres
•The entire ALFA set-up consists of eight Roman Pot detectors



The German ALFA community

DESY:

• Metrology measurements
• MAPMT photomultipliers
• HV power supplies
• Trigger detectors
• Testbeam coordination

JLU Giessen:

• Module production
• Detector assembly
• Mechanical structures & MAPMT
• Software & Simulation

HUB Berlin:

• Production of titanium substrates

The scintillating fibre tracker

• Squared scintillating fibres 0.5x0.5mm^2

• Double-sided modules with 64 fibres on each side arranged in U/V geometry

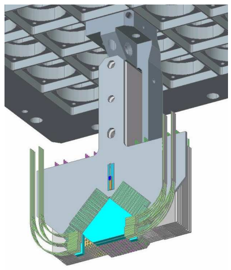
•Ten staggered modules per detector provide accurate space point measurement

• Fibres are positioned and glued on precisely machined titanium substrates

• Fibre positions are measured by optical metrology

• Special overlap modules with horizontally arranged fibres enable precise vertical alignment of upper and lower detectors in beam position

• Scintillating tiles covering the fibre crossing and overlap area provide a first level trigger signal



Impact of the alliance

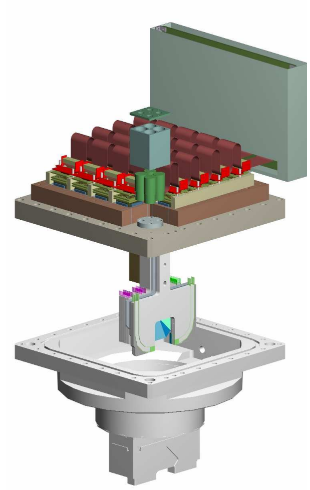
Successful kick-off funding

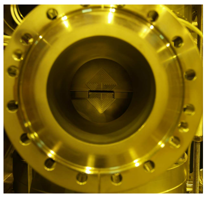
The support from the Alliance "Physics at the Terascale" has allowed the ALFA project to move from its R&D phase into production.

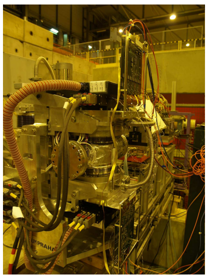
Upon completion of the prototyping the technical design was finalized and the series production launched.

The project was significantly substantiated, more collaborators joined and ALFA is funded by the BMBF since 2009.

ALFA components – from design to production







Running conditions

Challenging measurement in the vicinity of the LHC beam requires dedicated beam conditions.

• High β* optics (2600m)
• Parallel-to-point focusing
• Phase advance at ALFA close to 90°
• Low emittance beam
• Low instantaneous luminosity

Under these conditions the detector can approach the beam to 1.5 mm distance and the *t*-spectrum can be measured in the Coulomb-nuclear interference region.

For a run of 100 hours sufficient statistics is accumulated to determine the absolute luminosity and calibrate ATLAS relative luminosity monitor LUCID

Prototyping and testbeam results

Various prototypes ranging from small test modules to full-scale detectors have been produced and exposed to testbeams at DESY and CERN.

• The anticipated performance of the detector was verified to be adequate for the LHC conditions.

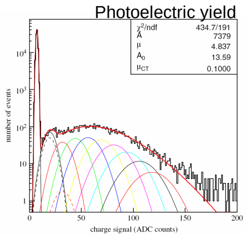
• A good light yield of 4-5 photoelectrons per fibre

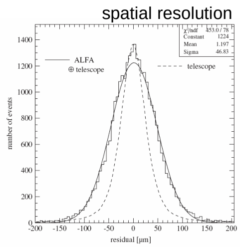
• A spatial resolution of +/- 30 µm was obtained

• The track reconstruction efficiency is above 95%

• "Edgeless detector": no insensitive region at edge towards the beam

• Overlap concept validated, enables vertical alignment precision of 10 µm





Luminosity determination

Reconstruction of the scattering angles from the impact positions

$$u = \sqrt{\beta\beta^*}\,\sin\Psi\,\theta_u^*,\; u = (x,y)$$

Calculate *t* from scattering angle and LHC beam momentum

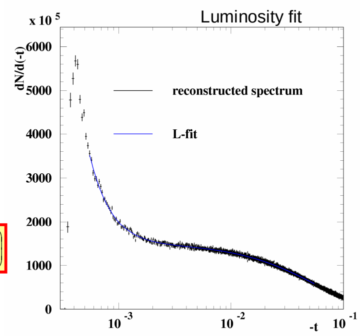
$$-t = (p\theta^*)^2$$

Fit t-spectrum to extract the luminosity and forward physics parameter

$$\frac{dN}{dt} = L\left(\frac{4\pi\alpha^2(\hbar c)^2}{|t|^2} - \frac{\alpha\rho\sigma_{tot}e^{-B|t|/2}}{|t|} + \frac{\sigma_{tot}^2(1+\rho^2)e^{-B|t|}}{16\pi(\hbar c)^2}\right)$$

Expected precision of the method:

$$\Delta L/L \approx 3\%$$



HELMHOLTZ GEMEINSCHAFT

The ATLAS Experiment
ALFA - absolute luminosity for ATLAS