AFP - ATLAS FORWARD PROTON DETECTOR

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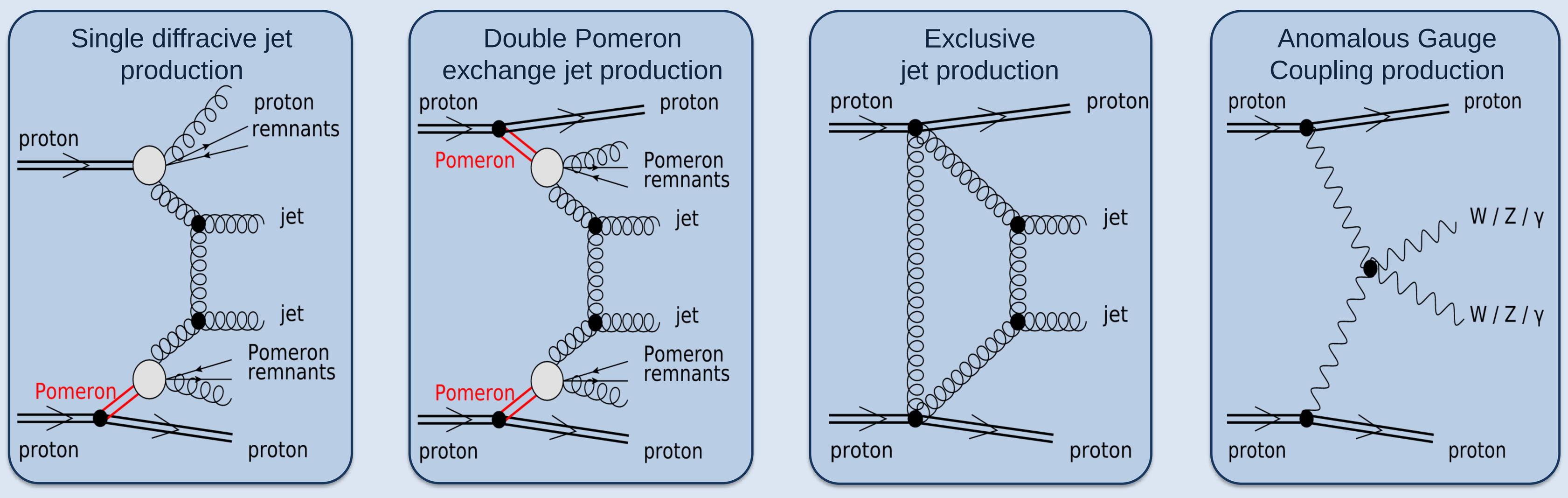
Physics Motivation

ATLAS **F**orward **P**roton (AFP) is a dedicated system for measurement of protons scattered at small angles. Such protons are predominantly produced when a colourless object – photon (in case of electromagnetic) or Pomeron (strong interaction) – is exchanged. AFP physics programme is focused on processes in which interacting protons stay intact – the so-called diffractive physics.

Examples of diffractive processes, described within the Standard Model, are: single diffractive, double Pomeron exchange and exclusive jet production. Measurements od the first two will shed a light on the details of the Pomeron structure. Precise estimation of the exclusive jet cross section is very interesting as it will set constraints for other exclusive processes including exclusive production of the Higgs boson. AFP can also be used as an effective tool for Beyond Standard Model studies, for example searches of Anomalous Quartic Gauge Coupling. Tagging the scattered protons in provides a powerful way to reduce backgrounds based on the exclusivity of the signal processes and the energy-momentum conservation.



Detector System

- Detectors are installed in the Roman pots.
- This technology allows movement w.r.t. the proton beam keeping detectors in a secondary vacuum (20 mbar).
- Precise movement system permits positioning of the pot ~2 mm from the beam centre (exact distance is due to the LHC beam conditions).
- Two stations, each containing a Roman pot, are installed on each side of ATLAS Interaction Point (IP).
- NEAR stations: ~205 m away from the IP, contain four layers of tracking detectors – Silicon Tracker.
- FAR stations: ~217 m away from the IP, contain a Silicon Tracker and a Time-of-Flight detector.

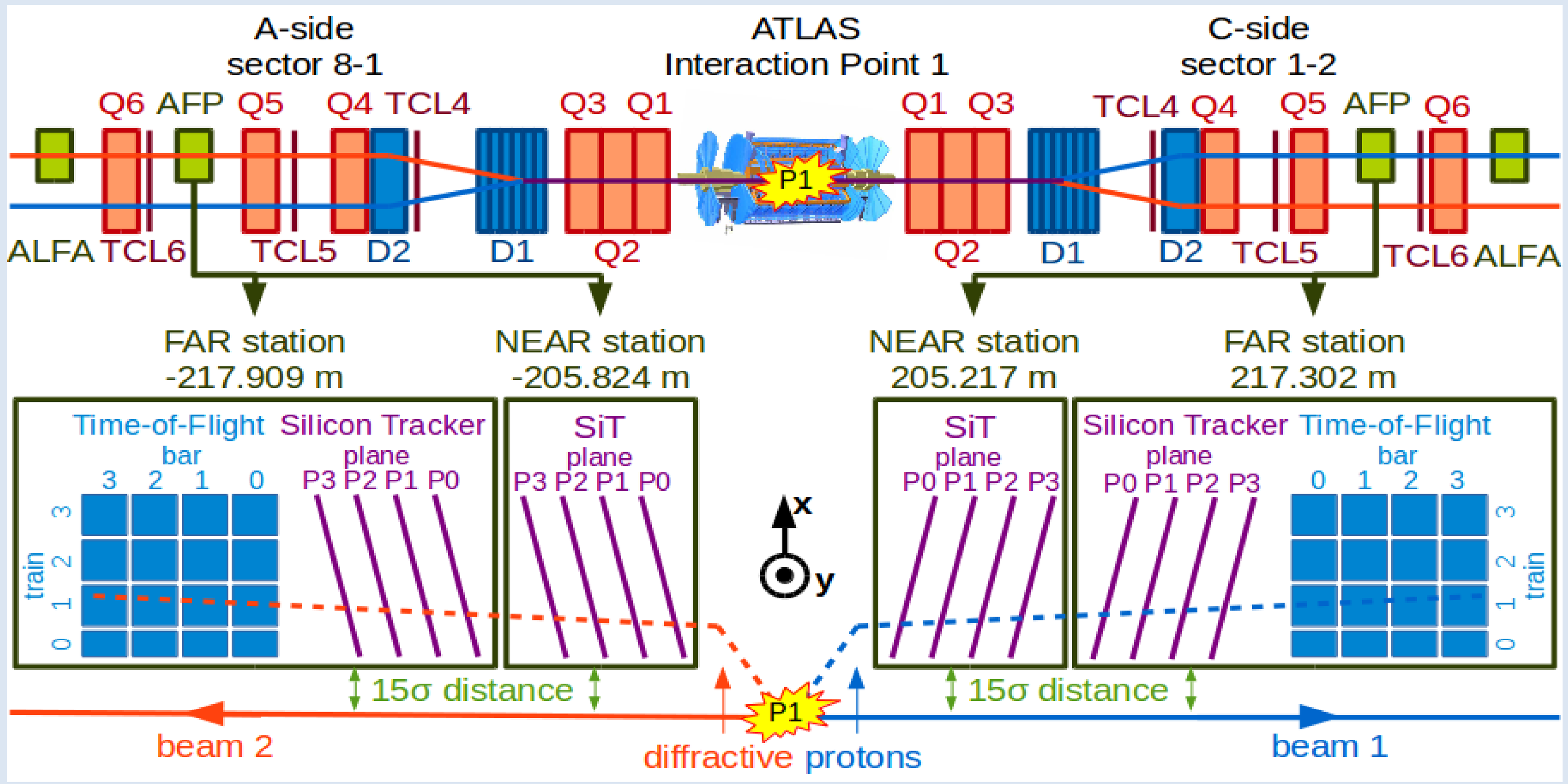


Figure: Position of AFP stations w.r.t. ATLAS detector.

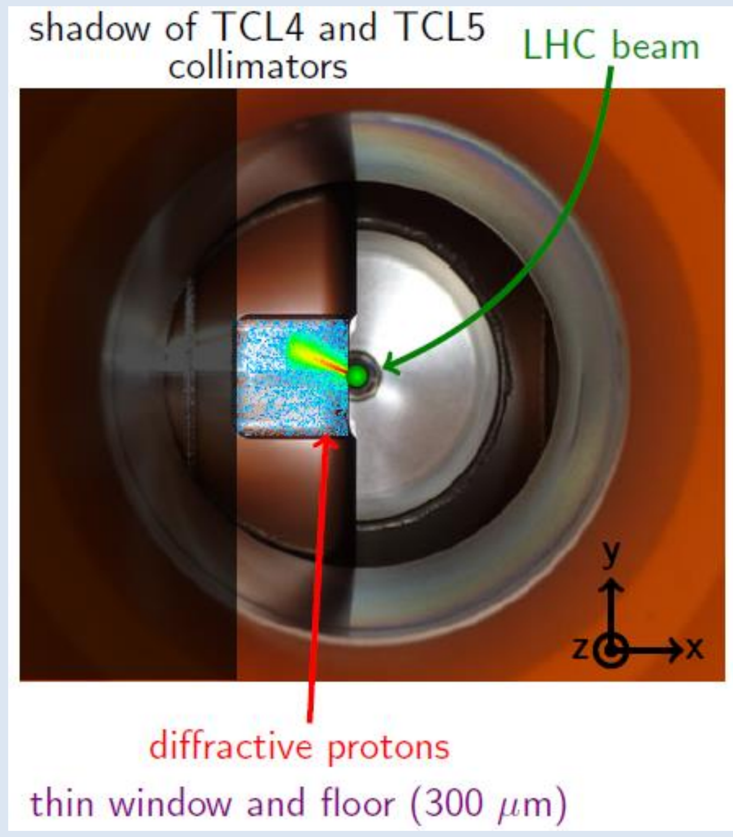


Figure: Diffractive protons as "seen" by AFP when pots are in data-taking position.

Silicon Tracker (SiT)

- Technology: 3D Silicon sensors (same as ATLAS **I**nsertable **B**eam **L**ayer).
- Each sensor accomodates 336 x 80 pixels with a dimensions of 50 μm and 250 μm.
- Overall chip size is 16.8 x 20 mm^2.
- Each station contains four sensors tilted by 14° w.r.t. the vertical direction (short pixel edge) to improve reconstruction resolution.
- Further resolution improvements are done by staggering sensors by several μm w.r.t. each others.
- Expected overall resolution: 6 μm along short and 70 μm along the long pixel edge.
- Provides the readout in high and low pile-up conditions and trigger for low pile-up runs.

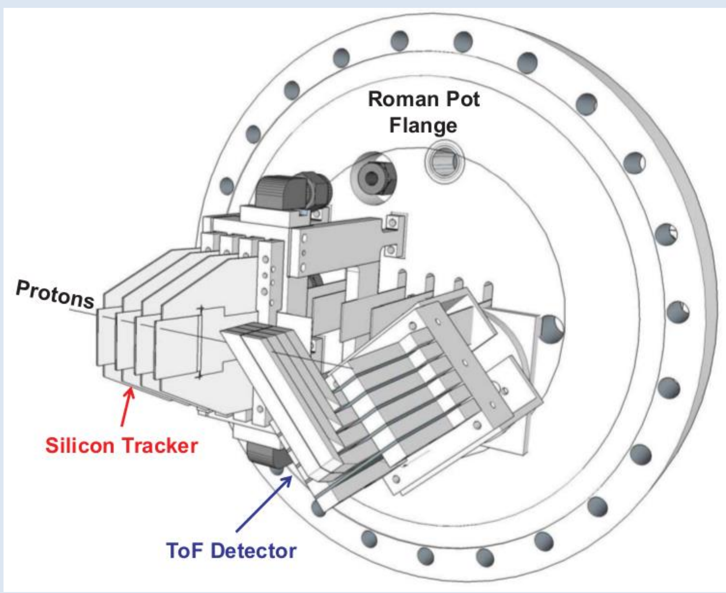


Figure: Sketch of Tracker and Time-of-Flight detectors mounted on Roman pots flange.

Time-of-Flight

- Matrix of 4 x 4 quartz bars mounted at the Cherenkov angle.
- Ultrafast photomultiplier (MCP-PMT) coverts light into an electric pulse which is further amplified by preamplifiers. Signals are readout by FPGA.
- Expected resolution: 25 ps per quatrz bar.
- Provides proton Time-of-Flight and proton trigger for low and high pile-up runs.

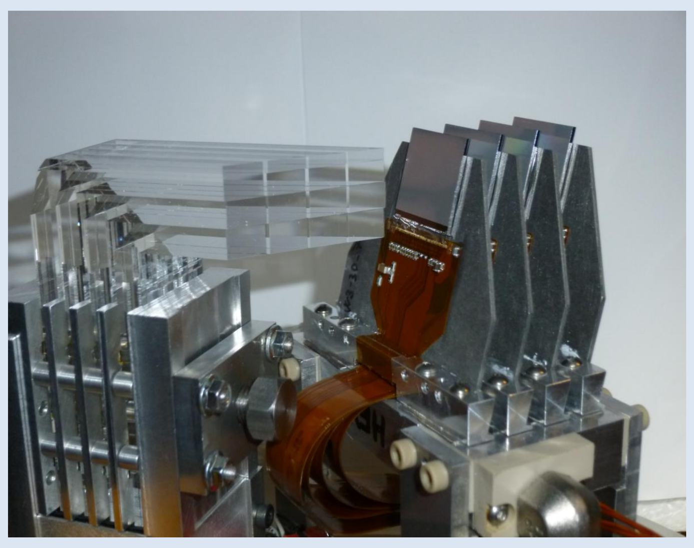


Figure: Time-of-Flight (left) and Silicon Tracker (right) detectors mounted on the AFP flange.

Roman Pot Depth Measurement

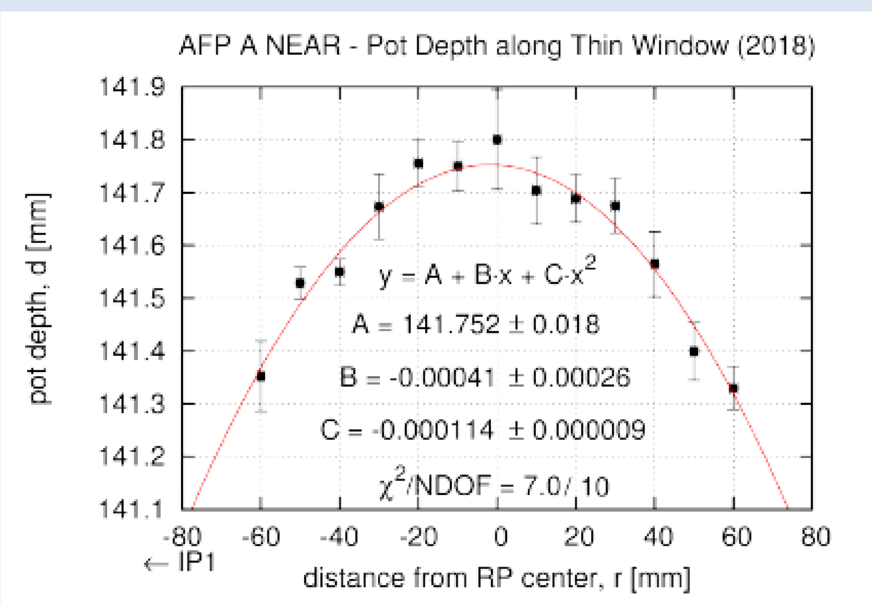


Figure: Depth measurements of AFP A NEAR station.

The acceptance for diffractive protons decrease drastically with increase of distance from the beam. For this reason the pot bottom was machined to be only 300 μm thick. Moreover, detectors take data as close to be beam as possible (constraints are set due to the safety reasons). Tracker and ToF detectors must be installed as close to the pot bottom as possible.

However, if they are so close that they may touch the pot bottom, there is a risk that they, or even the pot itself, may be damaged. The depth of the Roman pot was precisely estimated using the SICK laser. The result (see parameters in figure) was corrected for the thin window curvature, laser offset and thickness of the calibration plate. After corrections, the depth of the AFP NEAR station on ATLAS side A was calculated to be of 133.589 ± 0.123 mm. This procedure was used to determine the depth of all pots.

Evolution of LV Current in Tracker

Performance of SiT modules is affected by the radiation damage. This results in the increase of Low Voltage (LV) current w.r.t. irradiated modules (see plot). This increase is due to the increase of the dose deposited in the detector which is proportional to integrated luminosity. In the absence of the beams, the so-called annealing phenomena appear – the SiT modules recover which results in drop of the LV current.

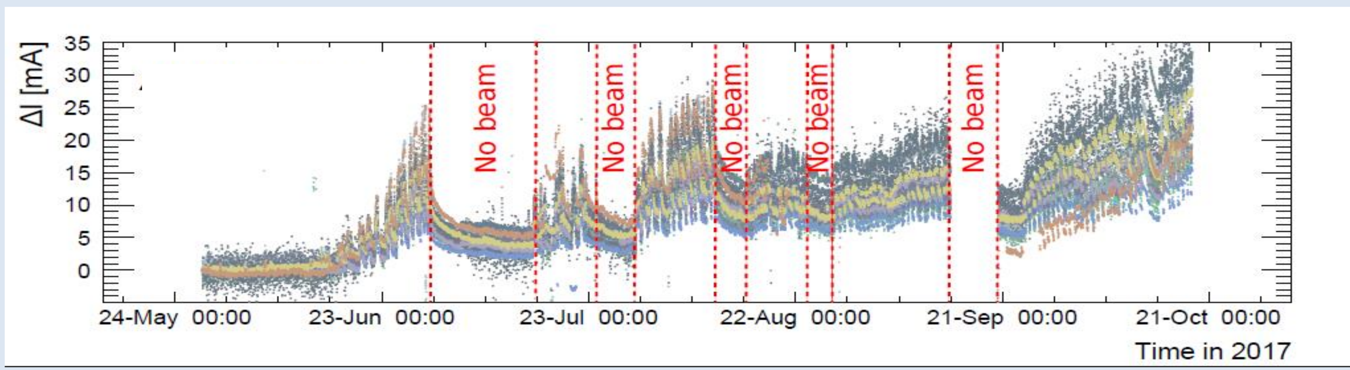


Figure: LV current for AFP modules in 2017.

Collected Data

2016:

- Only one arm with two tracker stations.
- Data taken during special, low pile-up (μ) runs.
- Collected luminosity: ~40nb^{-1} with μ of 0.03 and ~500nb^{-1} with μ of 0.3.

2017:

- Full system: two arms with two stations each.
- Data taken during special and standard runs.
- Luminosity collected during special runs: ~65nb^{-1} with μ of 0.05, ~640nb^{-1} with μ of 1 and ~ 150pb^{-1} with μ of 2.
- Luminosity collected during standard runs: ~ 29.6 fb^{-1} (see Figure).

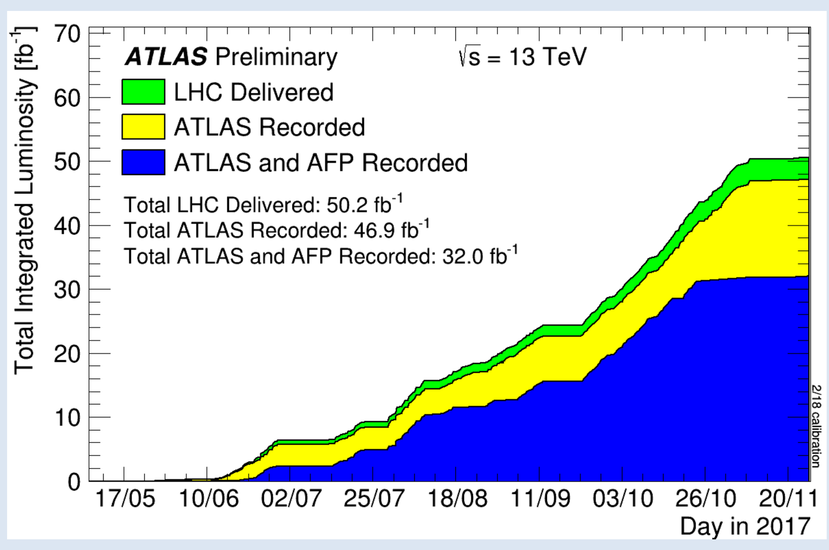


Figure: Amount of data recorded by ATLAS and AFP in 2017.