Performance of ATLAS Forward Proton Detector during LHC Run 2

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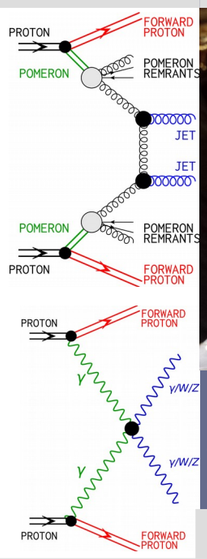
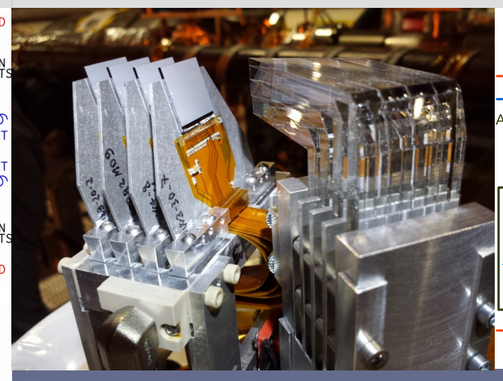
AFP Physics of Interest

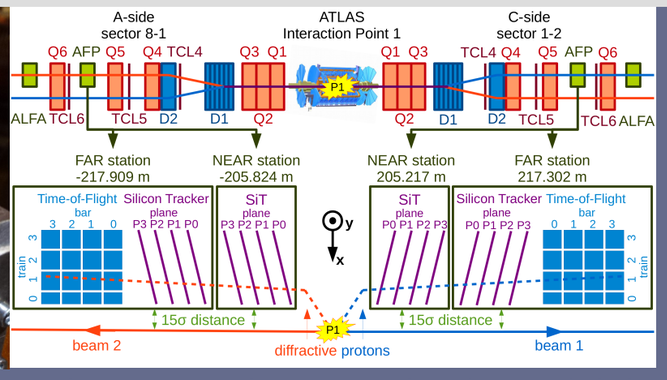
Hard diffractive processes:
- pertubative calculation methods,
- one or both interacting protons stay intact,
- e.g. double Pomeron Exchange Jet Production.

BSM processes:
- focus on processes with two intact protons,
- exclusivity – all produced particles are measured,
- e.g. anomalous quartic couplings.



Detectors Structure:

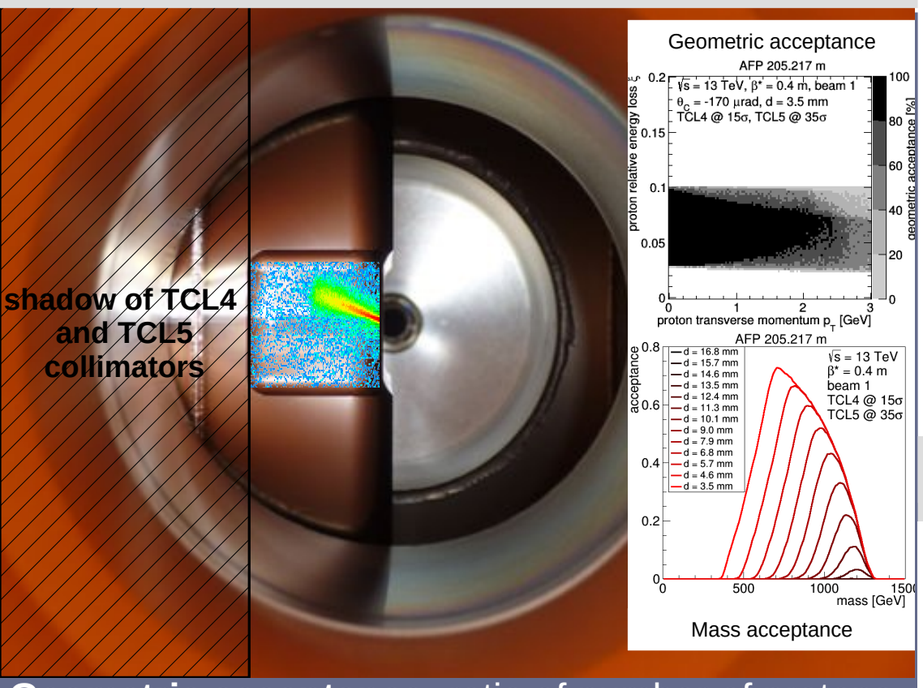




Layout: two AFP stations are placed on each side of ATLAS (~210 m from IP1) commonly called A/C Near/Far Stations.

Roman Pot Technology: used to move detectors in close vicinity to the beam. Once beam is stable, the detectors need to be very close to the beam in order to detect protons. In other cases AFP should be far away from the beam center.

AFP Acceptance



Geometric acceptance: ratio of number of protons of a given relative energy loss ($\xi=1-E_{proton}/E_{beam}$) and transverse momentum that reached the AFP detector to the total number of scattered protons having such ξ and momentum,
Black region on plot: more than 80% of protons hitting AFP for assumed optics settings,
Geometric acceptance limited by: beam-detector distance (small ξ) and collimators (large ξ).
Mass acceptance: probability that central system of a given mass will be visible in AFP (double proton tag),
Example: if a hypothetical particle of mass of 700 GeV is exclusively produced in the pp collision, there is a 70% chance to observe scattered protons in the AFP detector if they are inserted 3.5 mm from the beam.

Silicon Trackers (SiT)

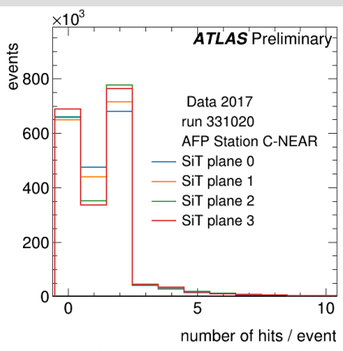
- 4 SiT planes are installed in each station.
- There are 336×80 pixels in plane with a pixel size of 50×250 μm^2.
- Edgeless: dead edge (beam side) of only ~100 μm.
- Radiation-hard technology.
- Planes are tilted by 14 degrees in order to increase the probability of hitting two or more pixels.

Time-of-Flight System (ToF)

Detector was designed to reduce combinatorial background from pile-up by factor of few.

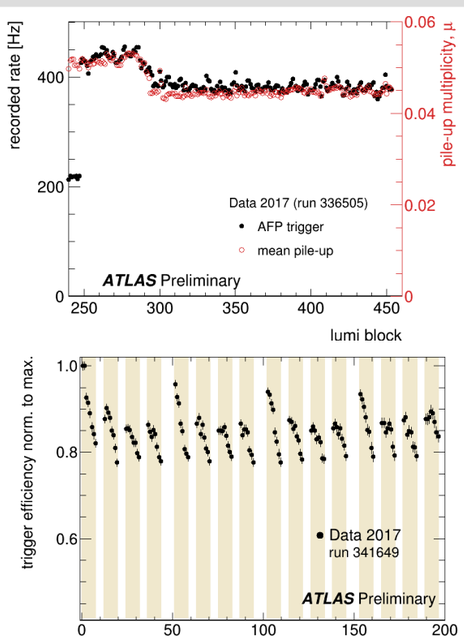
ToF components:
- 16 L-shaped quartz bars to guide Cherenkov light created by protons,
- radiated photons are detected by a Micro-Channel Plate Photo-Multiplier (MCP-PMT),
- after amplication, readout is done by radiation hard electronics.

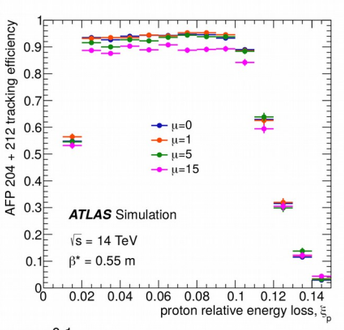
Run 2 SiT Performance



Distribution of the **number of hits per event** recorded by pixel layers in near station on C-side in AFP trigger.

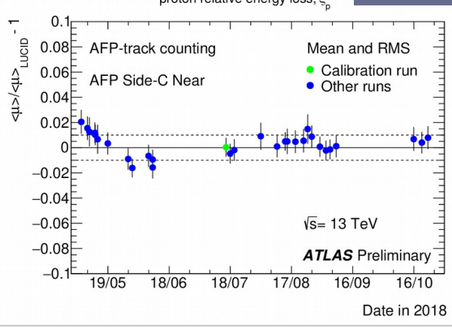
AFP **trigger rate** (black) pictured alongside the mean **pile-up** (μ, red) presented in dependence of Lumi Block.





Proton **track reco. efficiency** as a function of ξ. Events with NTrack ≤ 2 in inner and NTrack ≤ 5 in outer station are considered.

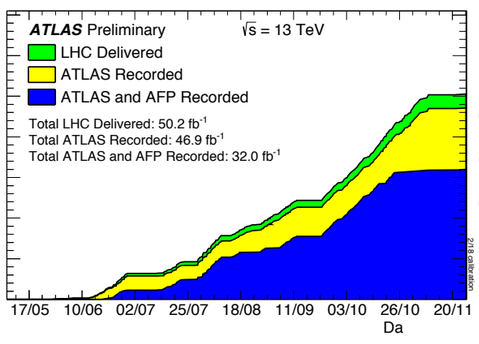
AFP relative **trigger efficiency** in function of LHC bunch structure. The data is normalized to the highest recorded efficiency



Relative difference between the values of estimated by AFP (track counting method) and LUCID, for the four AFP stations. The green point represents the calibration run, the blue points the other runs.

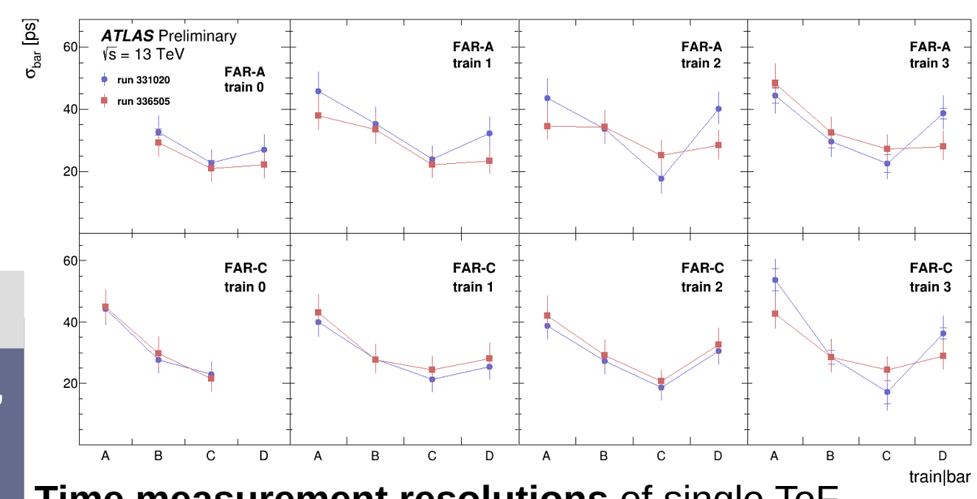
The agreement with LUCID is at better than 1% level.

AFP Cumulative luminosity 2017

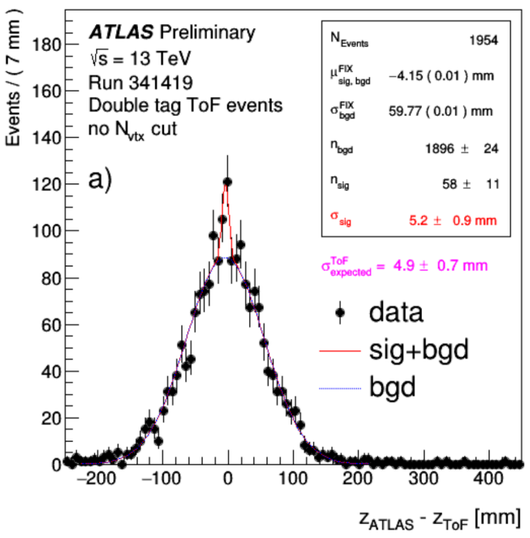


In 2017 AFP recorded 32 1/fb of data. After tight quality cuts 14.6 1/fb data was used for analysis.

Run 2 ToF Performance



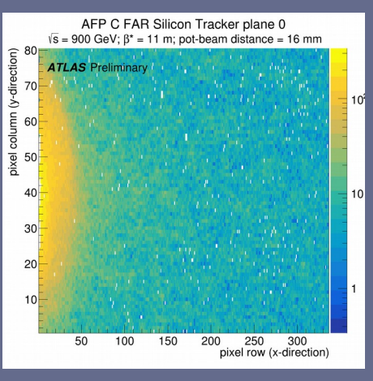
Time measurement resolutions of single ToF channels extracted from AFP calibration data. The time resolutions are extracted from the widths of the distributions of time differences within a single train, between different channels.
The time resolutions of the full ToF including the readout contributions were measured (at 1900 V) to be between:
38 ± 6 ps and 46 ± 5 ps per LQbar,
35 ± 6 ps and 37 ± 6 ps per train.



The distributions of z_{ATLAS} - z_{ToF} measured in events with ToF signals on both sides of the interaction region and primary vertex reconstructed by ATLAS.

After background subtraction, the measured vertex reconstruction precision is 5.2 ± 0.9 mm.

Pilot Beam 2021



Signal registered in AFP (C Far, layer 0) during pilot beam collisions. Data was taken at injection energy 900 GeV with β* = 11 m optics (no crossing angle). Stations were outside shadow of TCL4 and TCL5 collimators and beam aperture. Hits in rows 0-50 are mainly from diffractive protons whereas rest of the pattern is most probably due to showers. White areas are due to pixels masked in readout.

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