The ATLAS Forward Proton Time-of-Flight detector: use and projected performance for LHC Run3

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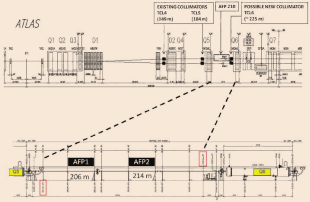
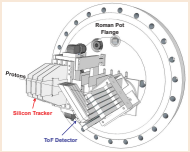
The AFP project

AFP stations

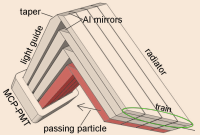
- **A**TLAS **F**orward **P**roton
- Forward detector focused on diffractive protons
- Detector packages placed in four Roman Pot stations located on both sides, $\sim 210\,\mathrm{m}$ from ATLAS collision point
- 3D silicon tracker + ToF (only far stations)

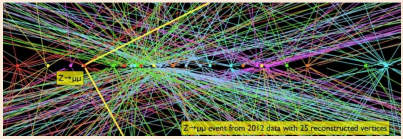




ToF detector

- A fast Cherenkov timing detector
- 4x4 channel matrix, 4 bars form a train
- Purpose:
  - reduce background by mathing vertex reconstructed by central ATLAS detector with one computed from proton arrival time difference
  - provide fast trigger

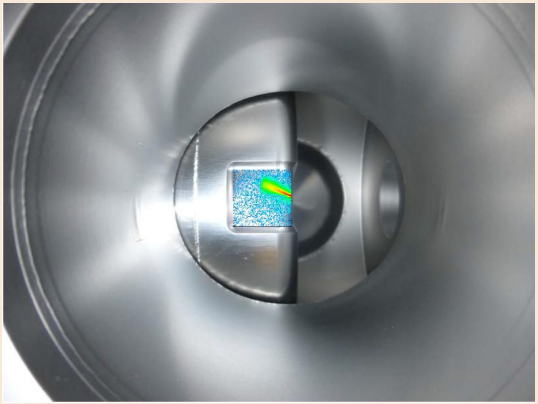




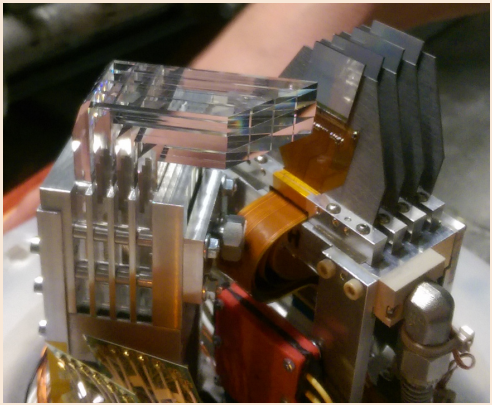
- Expected background reduction: factor of 10 for $20\,\mathrm{ps}$ detector.

AFP – how the real thing looks like

Roman Pot as seen by the beam, with diffractive pattern



AFP detector package ready for installation



Timing resolution results

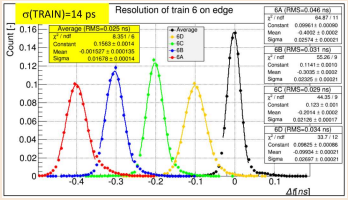
Beam test

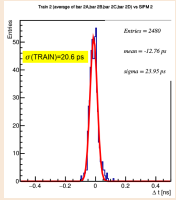
Results obtained at SPS NA beam test (140 GeV pions)

Raw PMT signal (oscilloscope):
20 ps single channel, 14 ps train combined

After passing High Performance Time to Digital Converter (HPTDC):
20.6 ps train combined

Timing resolution distributions (raw left, HPTDC right)



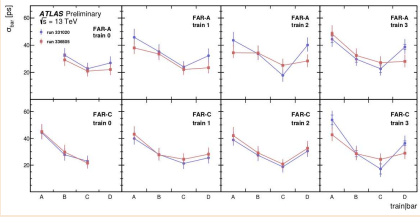


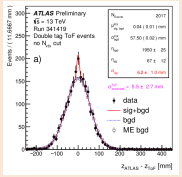
Note: fits in raw plots without timing reference resolution subtraction (9 ps)

Performance analysis of 2017 data

- Poor efficiency of few percent (PMT degraded fast)
- Good timing resolution (21 ps) nonetheless!

Timing resolution of individual channels, vertex matching distribution



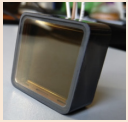


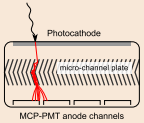
Performance of the ATLAS Forward Proton Time-of-Flight Detector in 2017, ATL-FWD-PUB-2021-002

Upgrades and summary

Photomultipliers

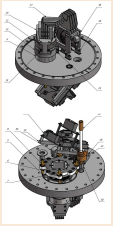
Long life tubes with low MCP resistance, operated at low gain (performance would deteriorate at high rates)

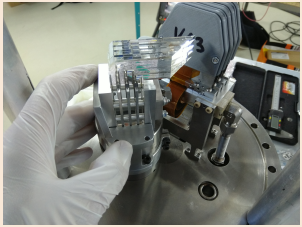




Out of Vacuum solution

Out of vacuum redesign – PMT moved out of the pot → easier access to electrochemistry, new alignment system





Glueless ToF bars

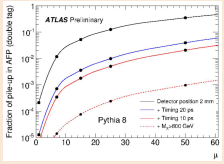
Glue absorbed some deeper UV signal, was a radiation hardness weak point

Electronics

- Faster read-out: PicoTDC instead of HPTDC
- Remotely controlled amplifiers
- Better PMT interference shielding
- Modified HV divider – improved timing and efficiency at low PMT gain

Expected timing and background suppression

- $25 - 30\,\mathrm{ps}$ single bar
- $20 - 25\,\mathrm{ps}$ train combined
- Without PicoTDC a bit worse ($\sim 16\,\mathrm{ps}$ HPTDC contribution)



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