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

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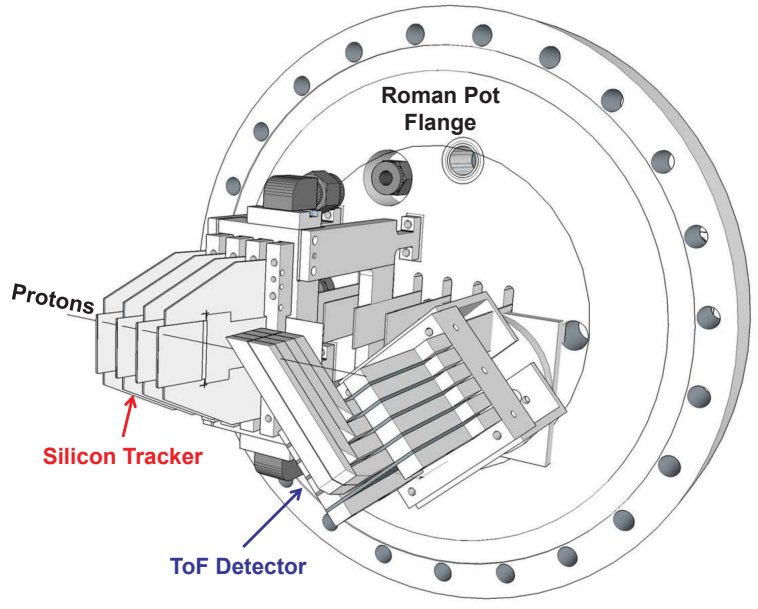
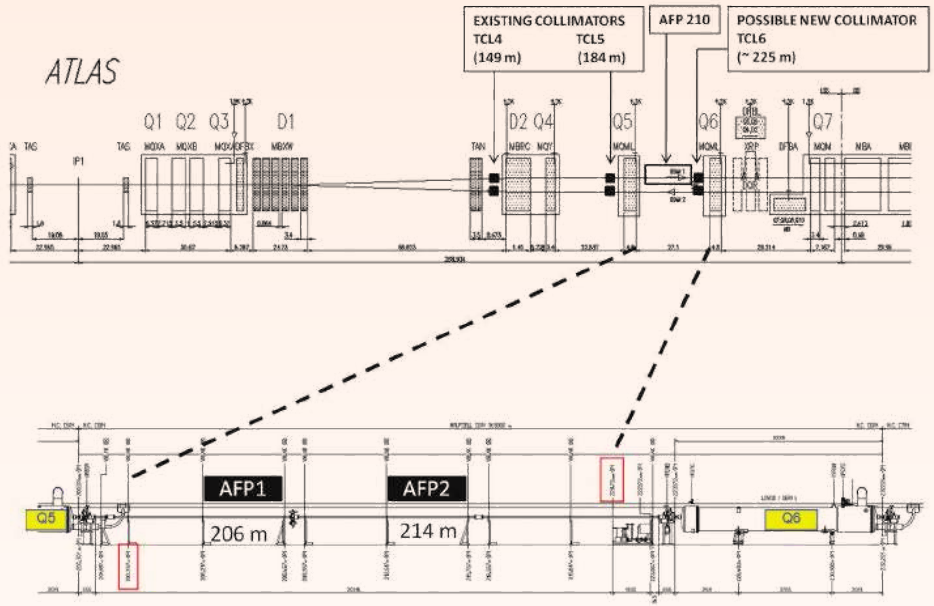
The AFP project

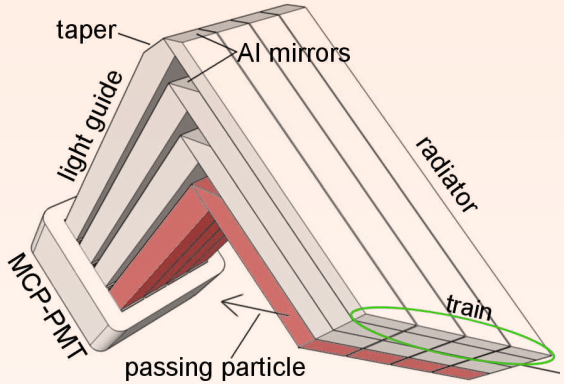
- **A**TLAS **F**orward **P**roton
- Forward detector focused on diffractive protons
- Placed in Roman Pots (RP) $\sim 210\,\mathrm{m}$ from the ATLAS IP
- 3D silicon tracker + ToF (only far stations)

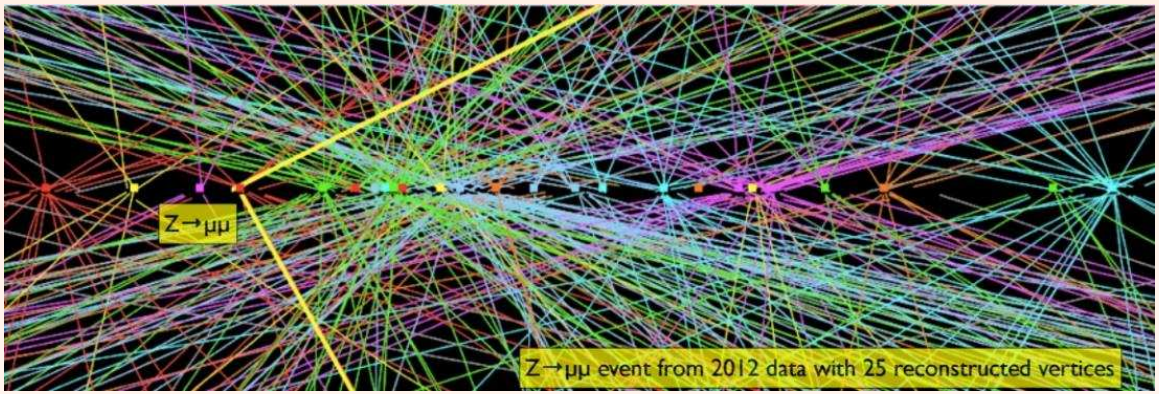




ToF detector

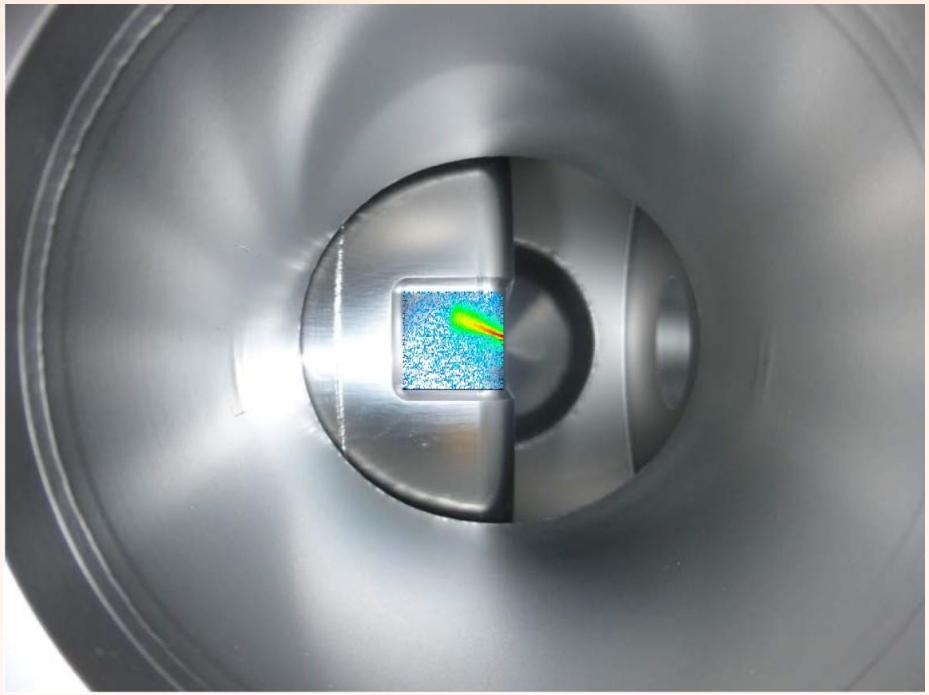
- A fast Cherenkov timing detector
- Purpose:
  - assign protons detected by AFP to individual collisions in IP1
    $\rightarrow$ timing measurement determines vertex position to match

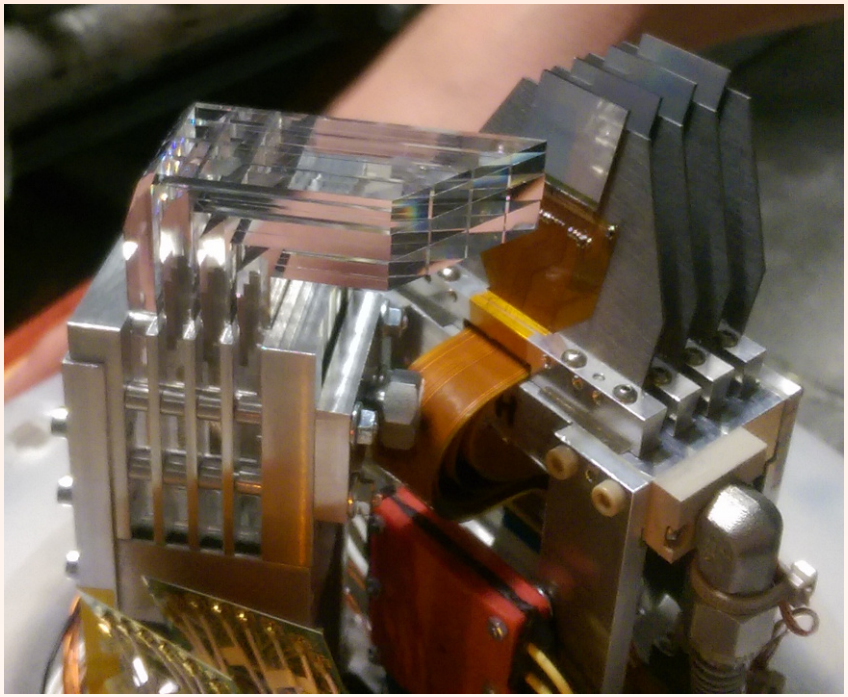




- Reduces background in high pileup situations
- Expected performance few tens of ps, strong impact on background suppression!

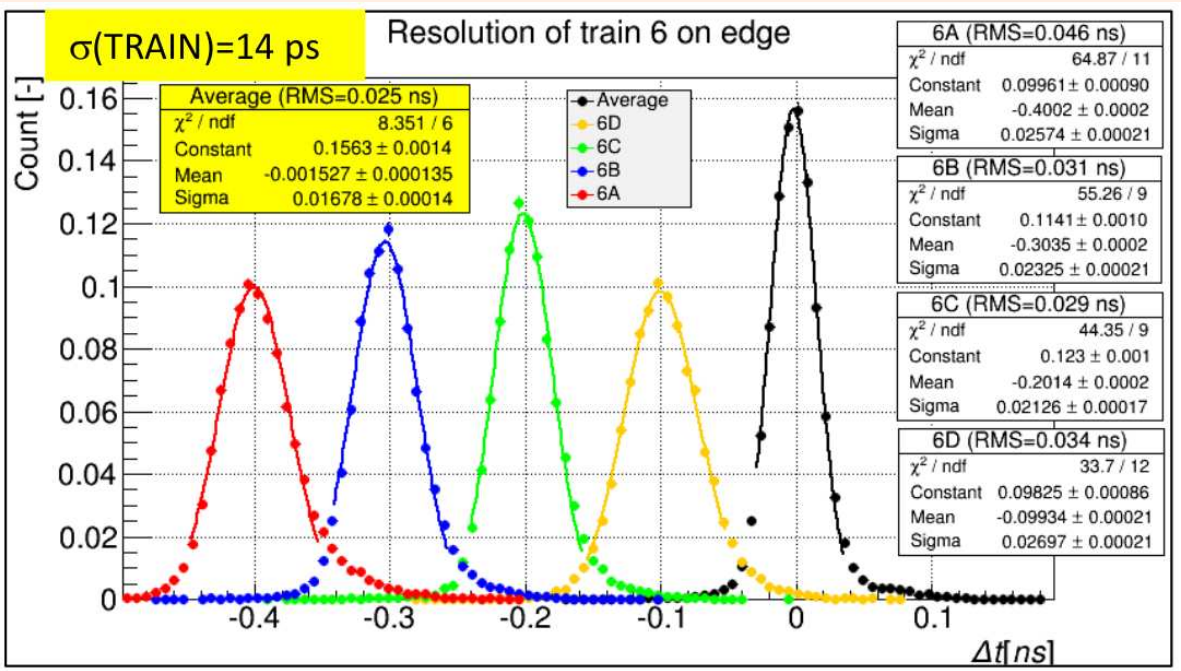
AFP – how the real thing looks like

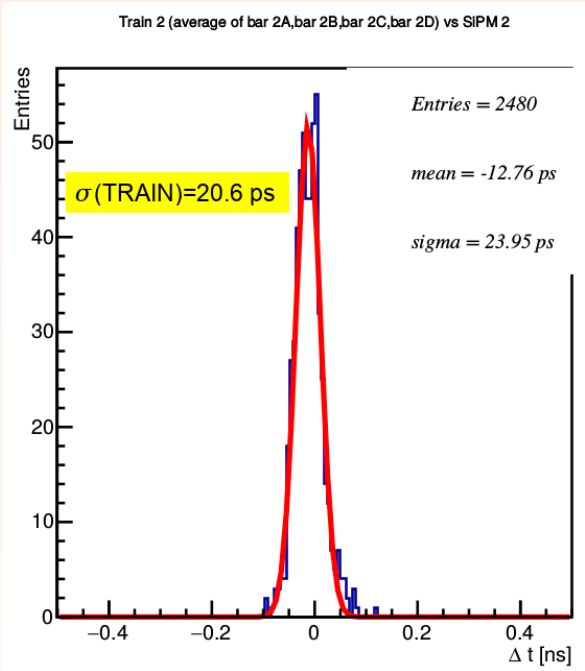




Beam tests – timing resolution

Best results so far obtained at SPS NA beam test (140 GeV pions)
Raw signal: 20 ps single channel, 14 ps train combination
HPTDC: 20.6 ps train combination

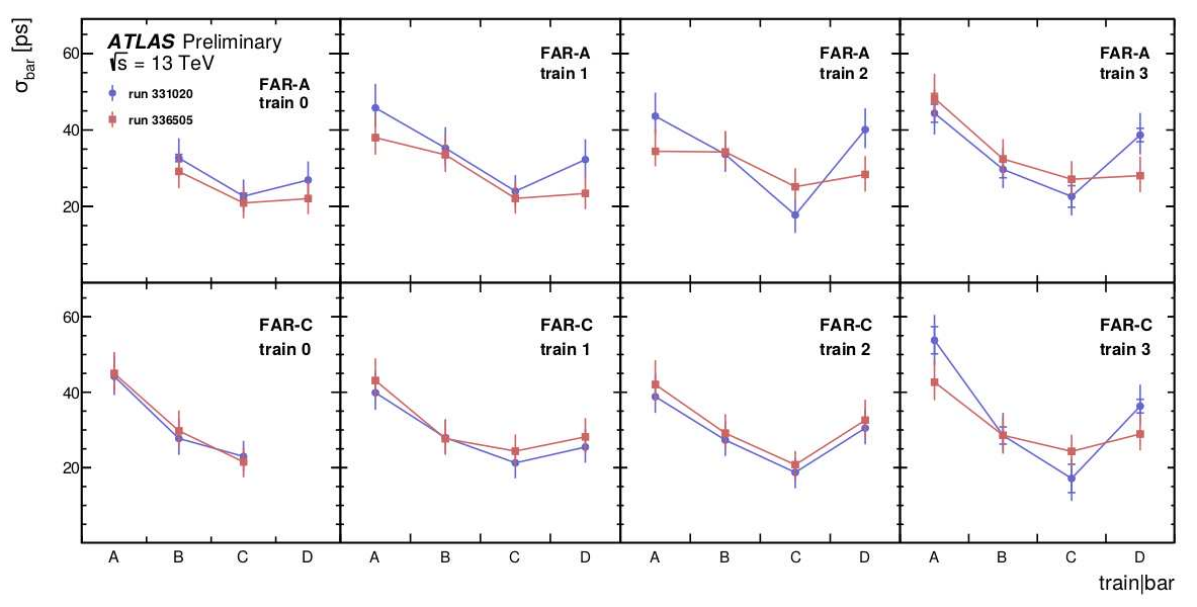


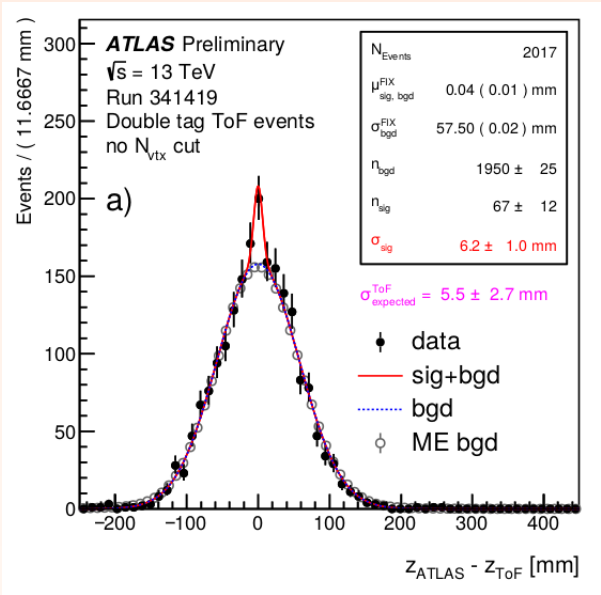


Note: fits in raw plot (left) without timing reference resolution subtraction (9 ps)

ToF detector performance analysis

- Performance analysis of 2017 data
- Poor efficiency of few percent (fast PMT degradation)
- Good timing resolution nonetheless!

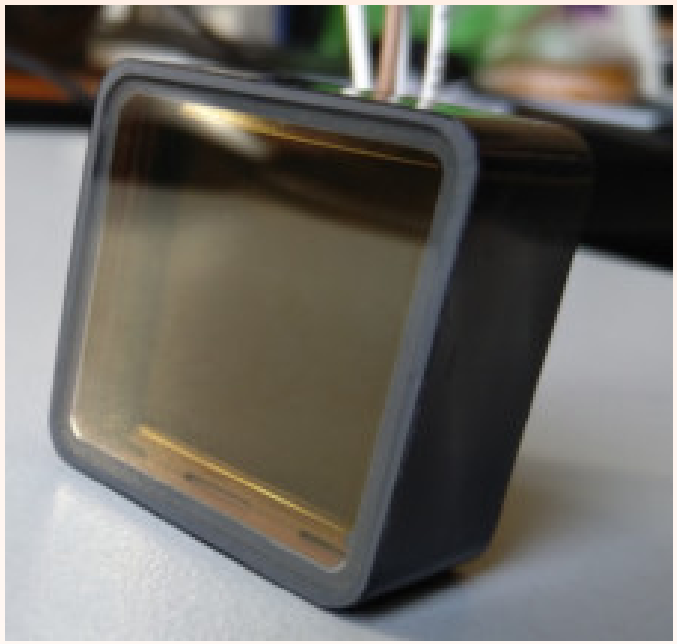


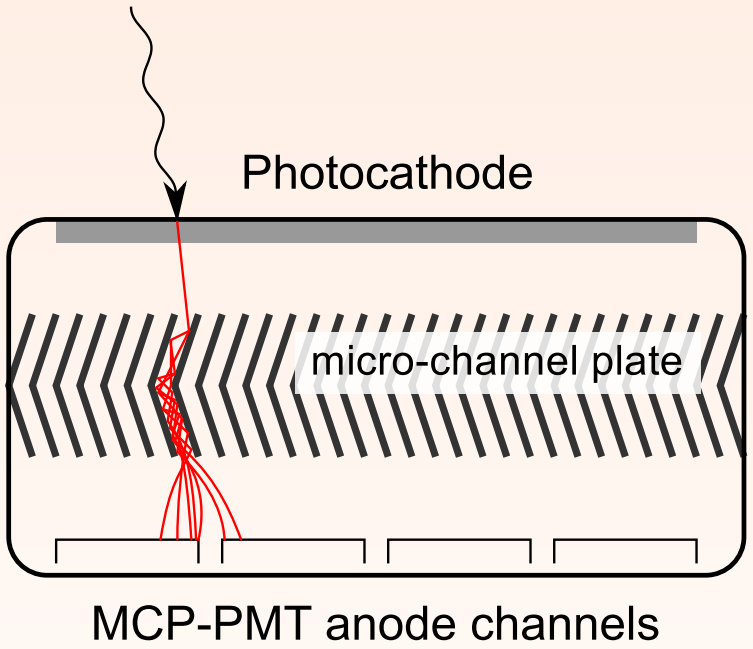


Performance of the ATLAS Forward Proton Time-of-Flight Detector in 2017, ATL-FWD-PUB-2021-002

Photomultipliers

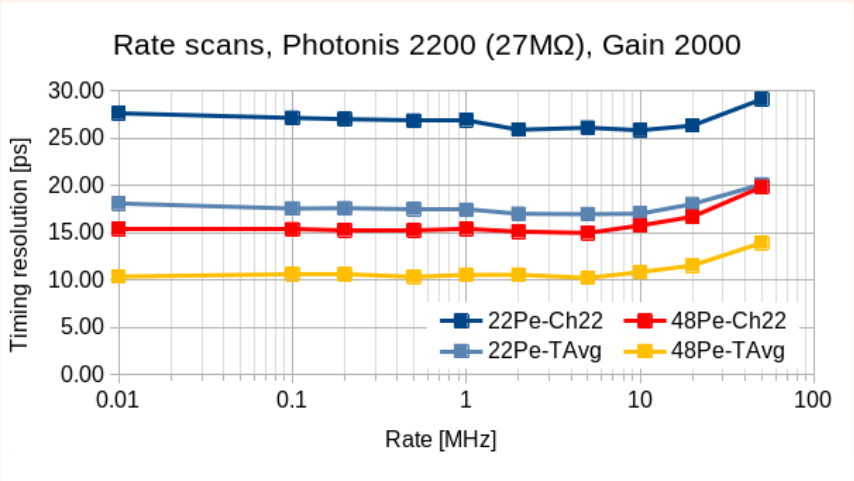
- Need for long-life tubes with relatively low MCP R ($\sim 20 - 30\,\mathrm{M}\Omega$)
- Low target PMT gain 2×10^3 to further improve rate capability (previously $\sim 10^5$), requires additional amplification stage

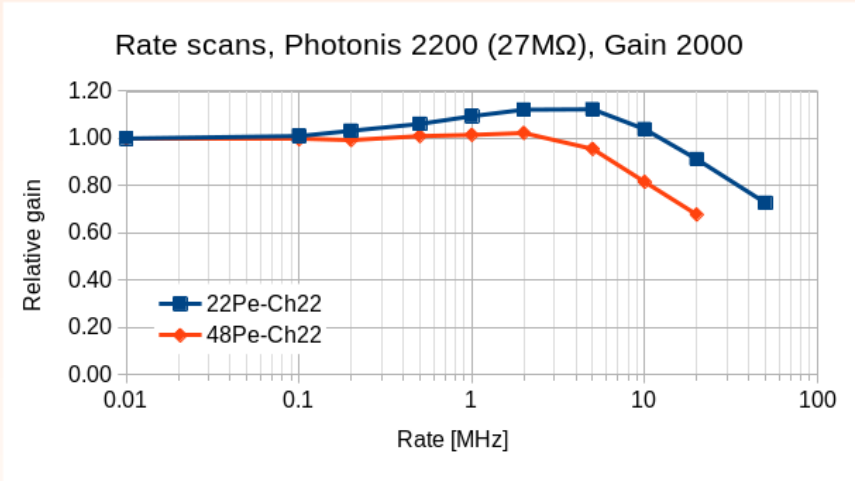




PMT performance at high rates

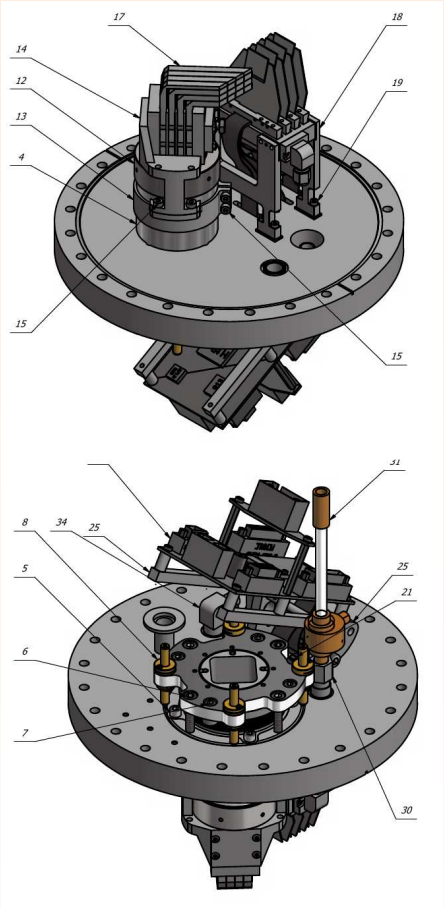
- Gain deteriorates at very high event rates (charge depletion from MCP), influencing timing and efficiency
- Tested using laser, scanning through different event rates

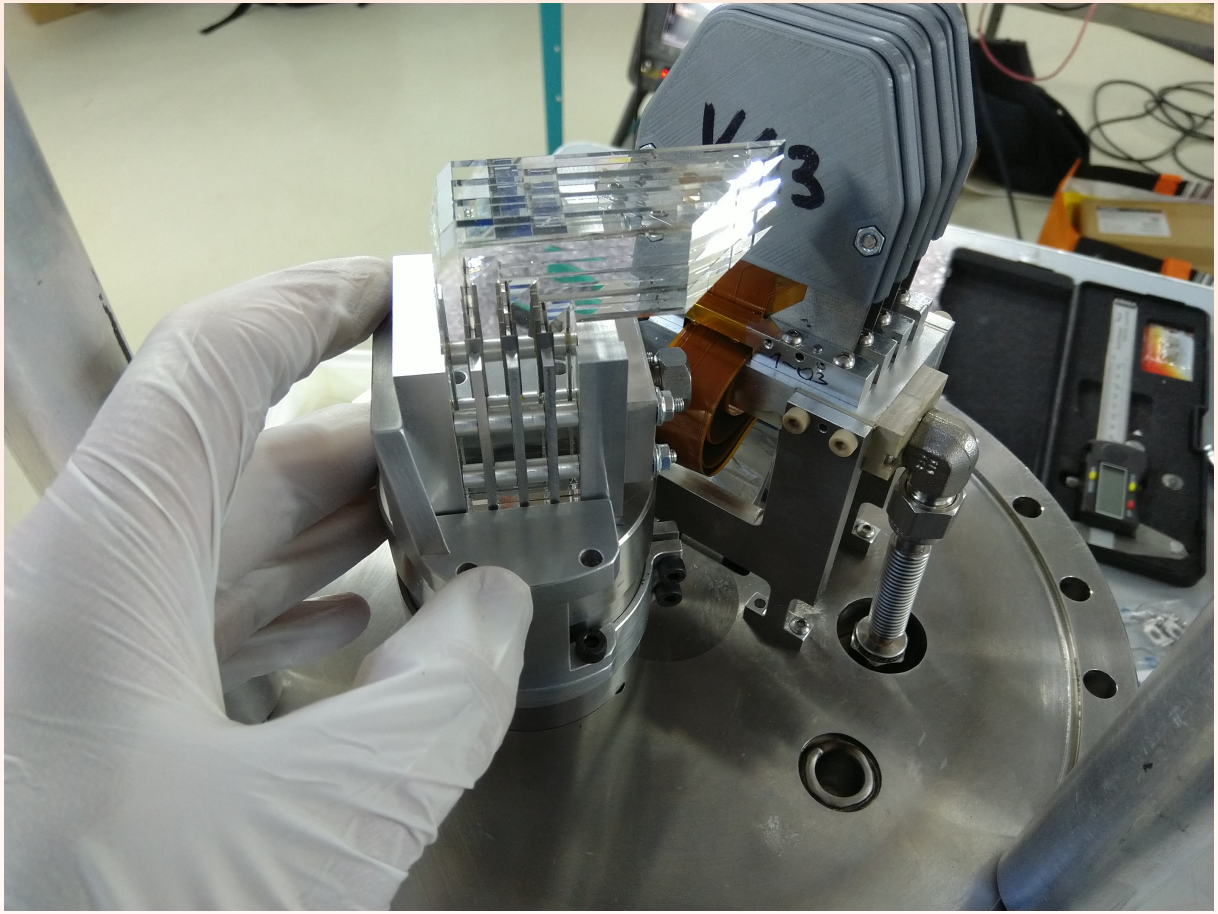




Out of Vacuum solution

Out of vacuum redesign – PMT moved out of the pot, behind window





Other upgrades

- Glueless bars production
  - more light, removed radiation weak point
- PicoTDC to replace ageing HPTDC
- Integration of 2. and 3. stage amplifier, remotely controlled
- Better PMT interference shielding
- Evaluating new experimental HV divider
- Integration of light pulse generator for in-situ tests

Summary

Many upgrades were or are being implemented

- Out of vacuum
- Glueless bars
- More suitable PMTs, divider and their shielding
- PicoTDC in progress

Expected timing

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

Thank you for your attention!