ATLAS Forward Proton Detectors
Status and Upgrades

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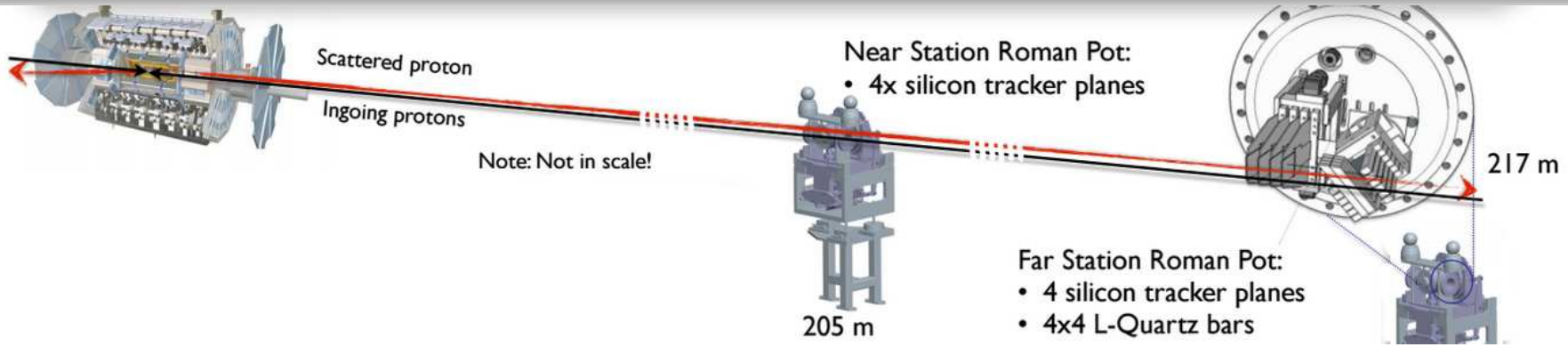
ATLAS Forward Proton Project



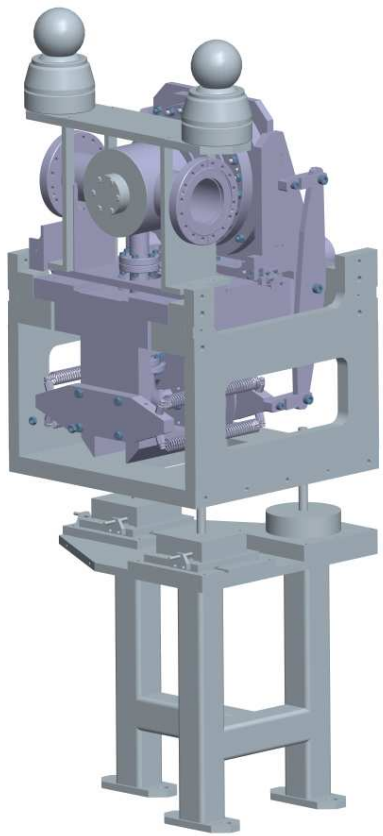
AFP TDR: CERN-LHCC-2015-009, ATLAS-TDR-024
ECR: LHC-XAFP-EC-0002, LHC-XAFP-EC-0003

Phase-1: AFP0+2 (2016)

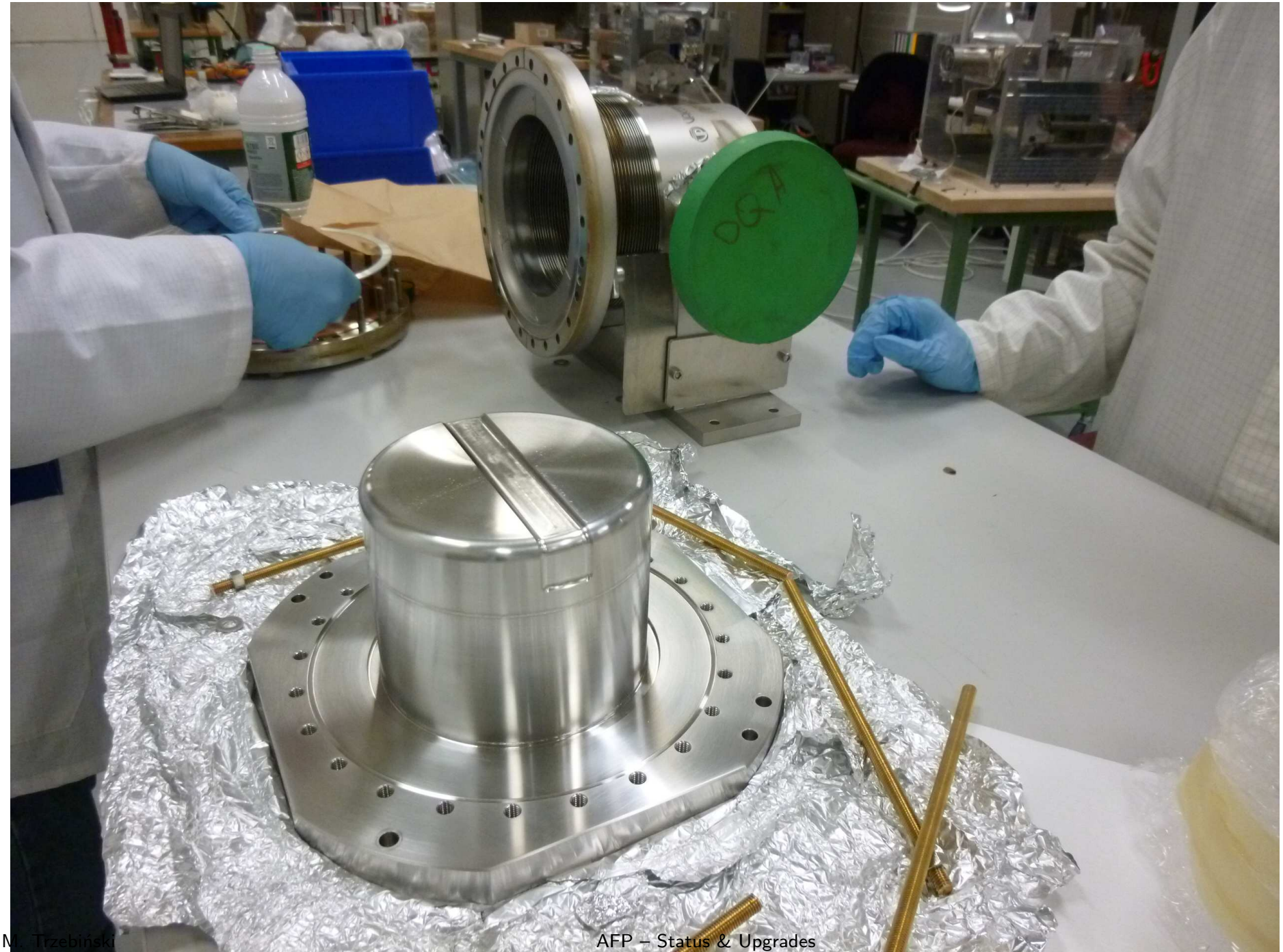
- 2 horizontal Roman Pot stations at 205 (NEAR) and 217 m (FAR) on ATLAS C side – **installed!**
- study beam background in low and high intensity runs
- measure diffractive and exclusive events with one tag in a special low-μ runs (AFP triggers ATLAS)

Phase-2: AFP2+2 (2017+)

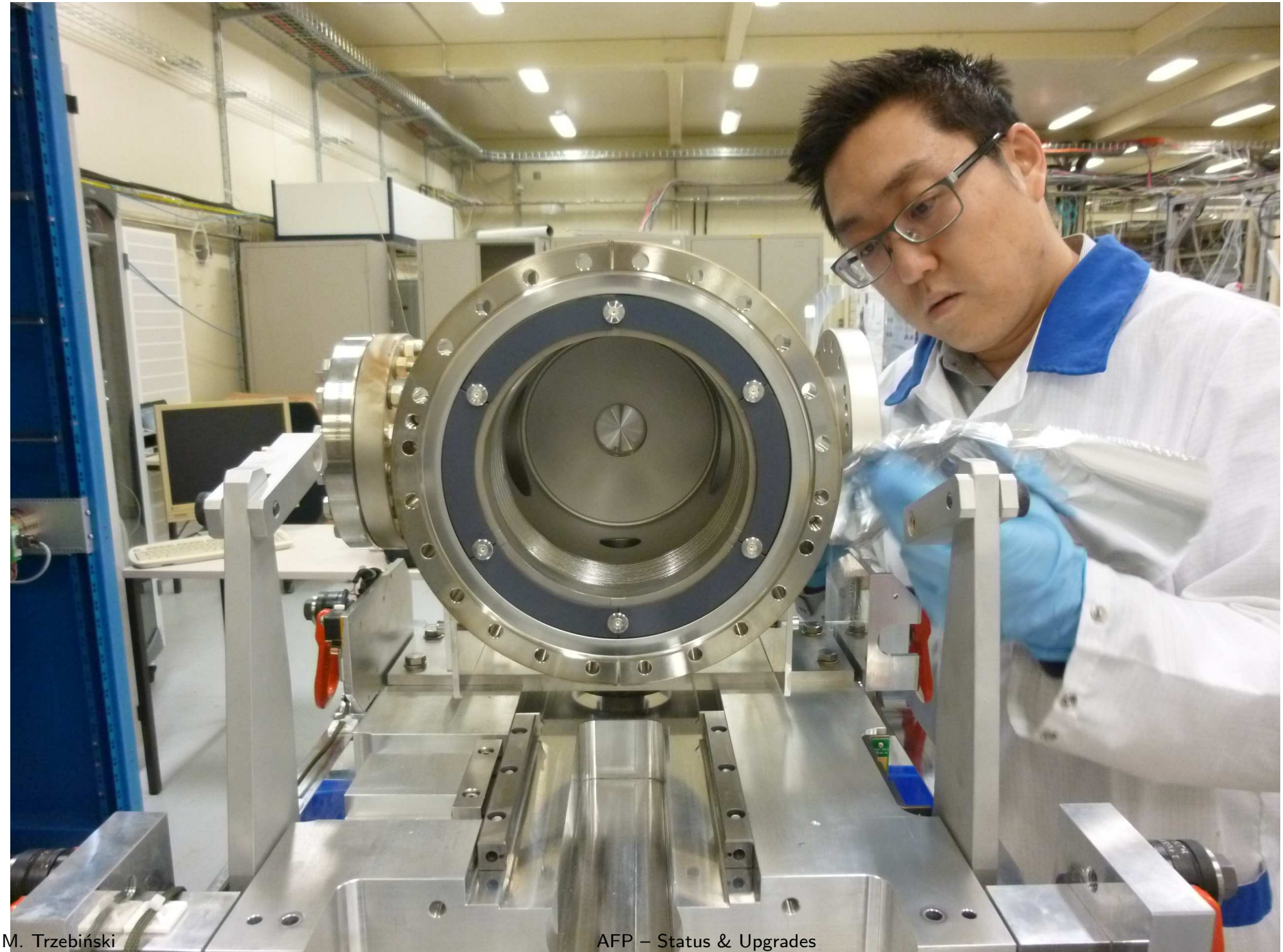
- 2 horizontal RPs on A side – **installed!**
- install time-of-flight detectors in far stations on both sides – new AFP trigger system
- measure double tagged diffractive and exclusive events
- deliver diffractive triggers to ATLAS during:
  - special (low pile-up) and
  - standard (high pile-up) runs



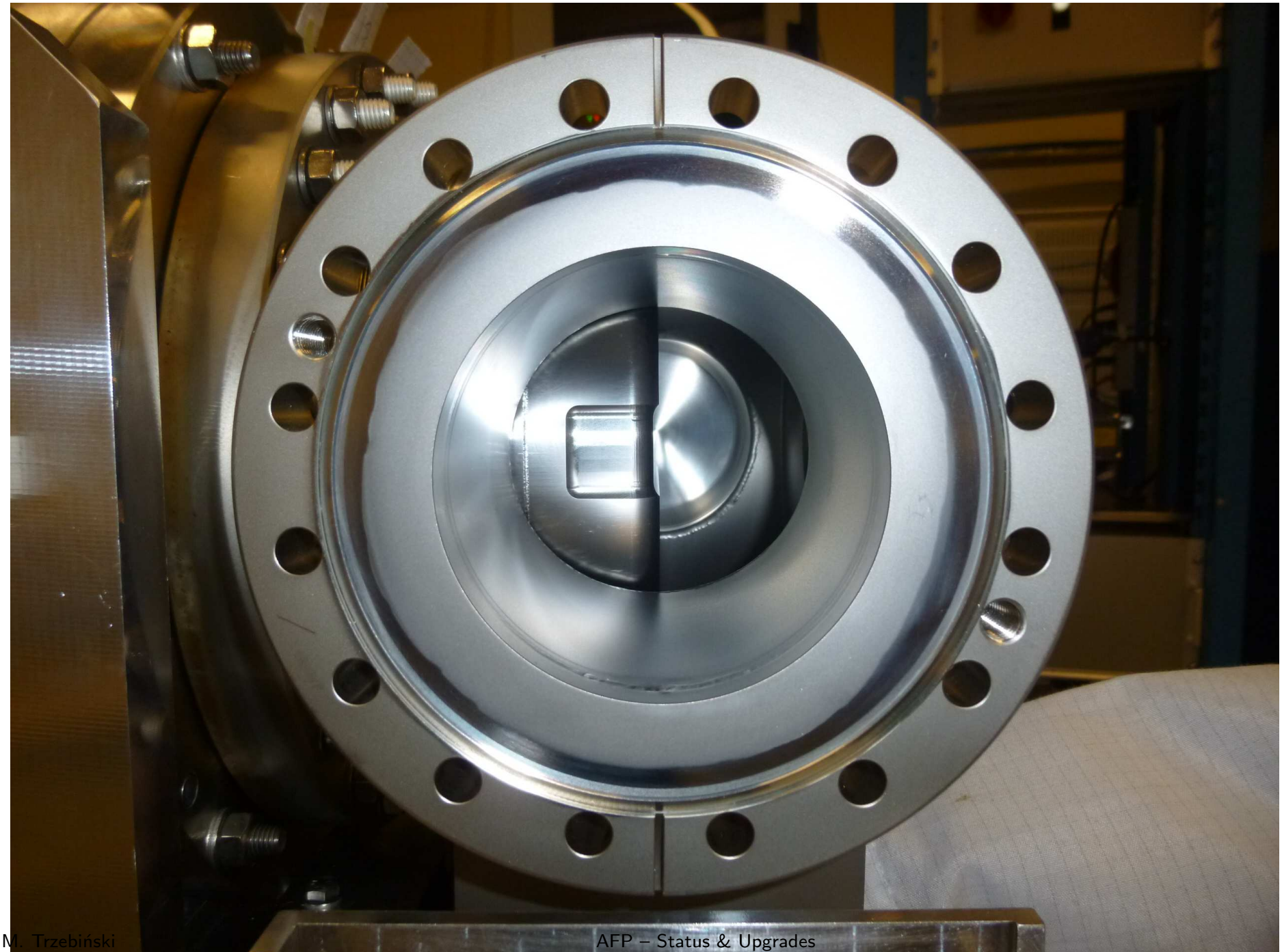
Station Assembly (I)



Station Assembly (II)

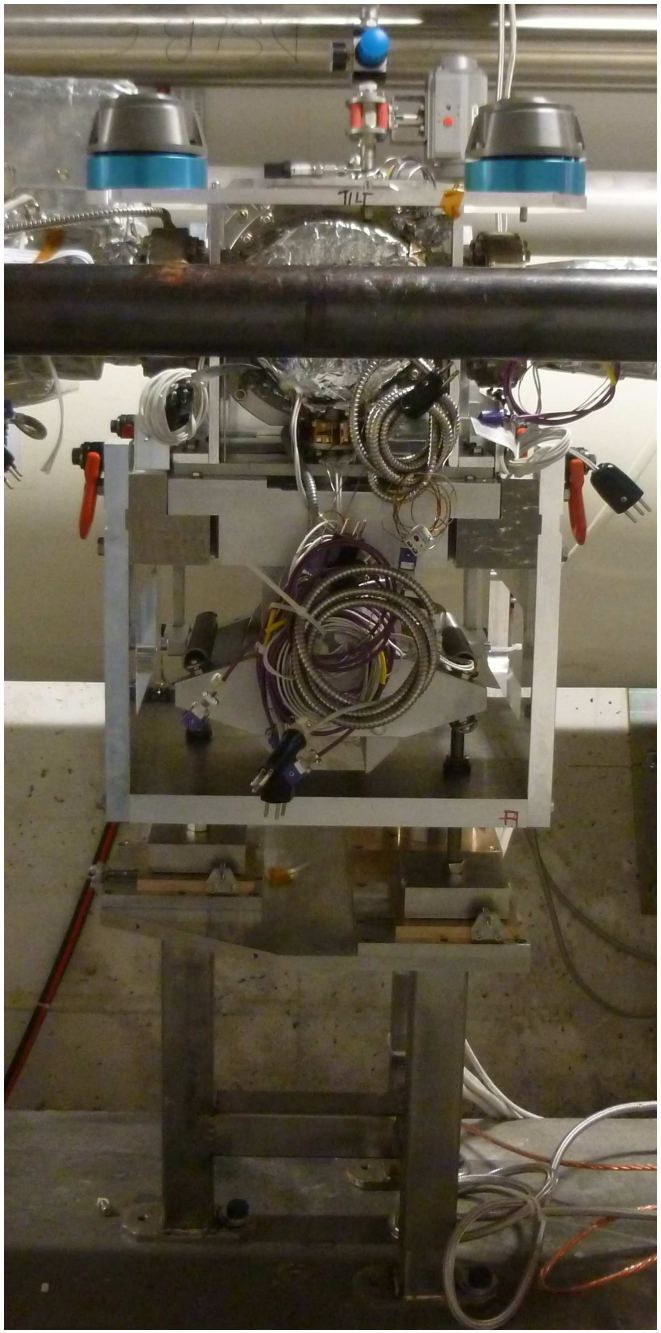


Station Assembly (III)

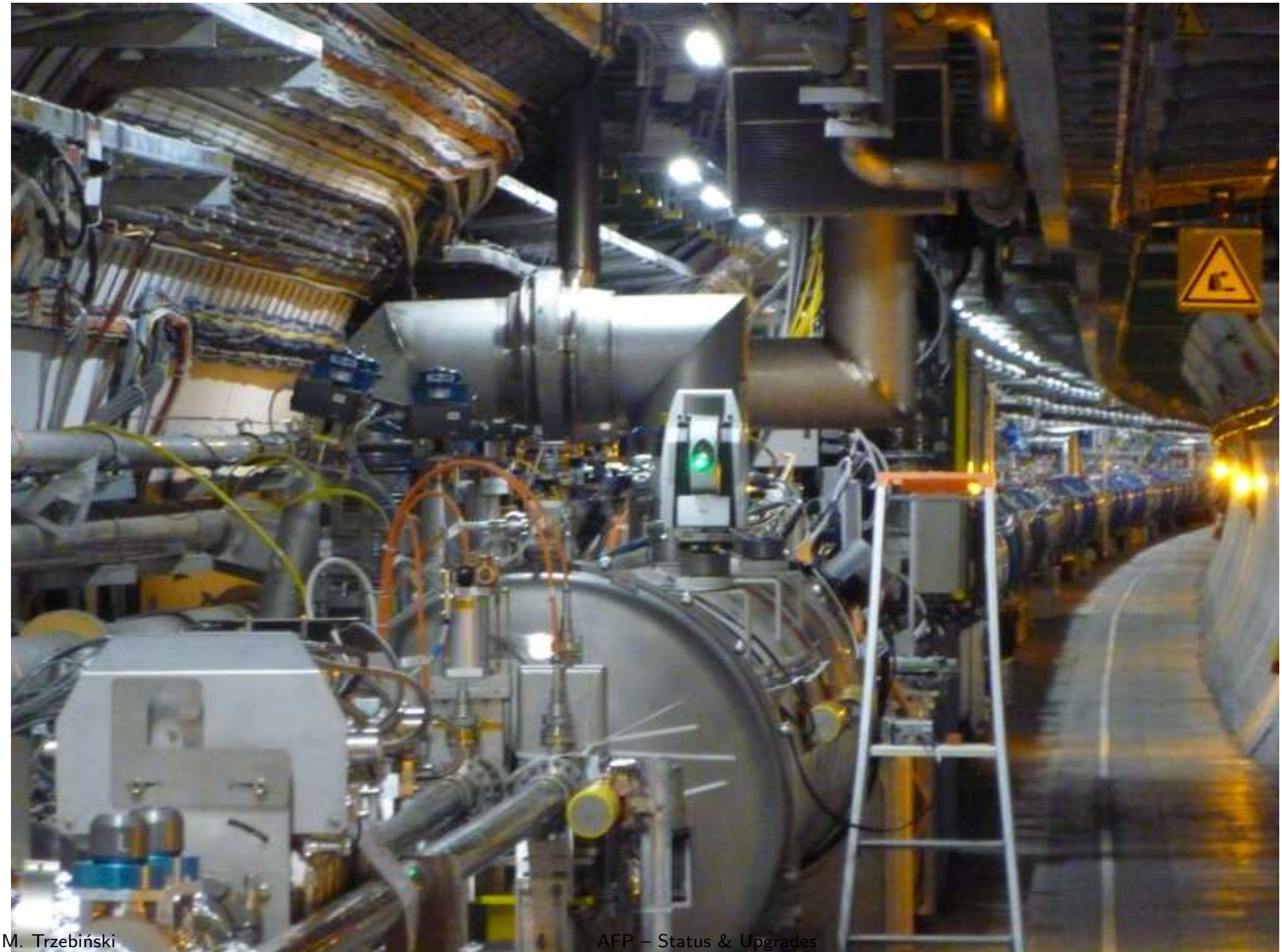


Station

- based on the CMS-PPS/TOTEM horizontal stations
- all four stations installed in tunnel
- under LHC vacuum and baked-out
- **status: connected and fully operational**

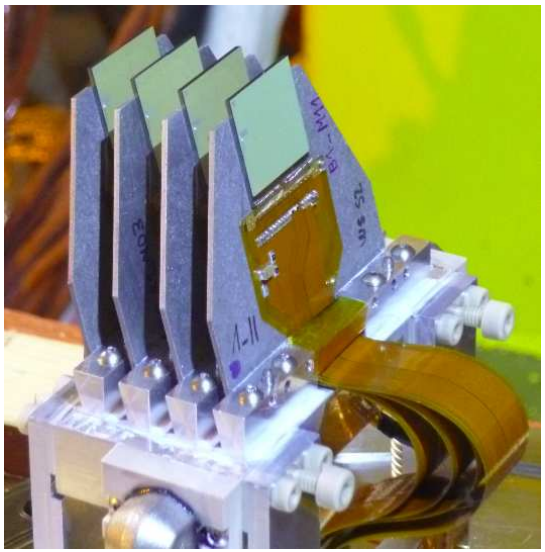


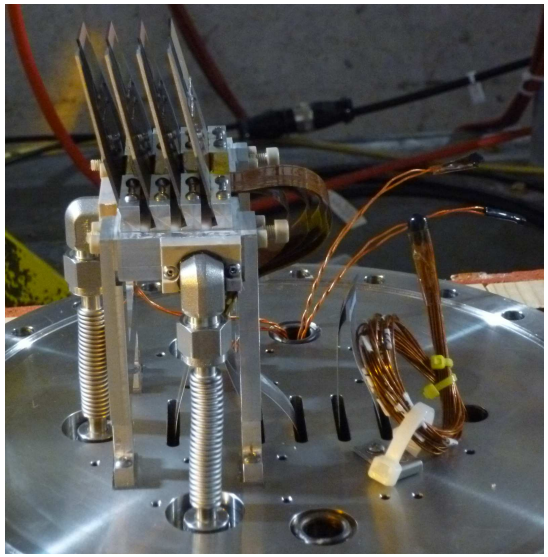
Positioning in Tunnel (I)

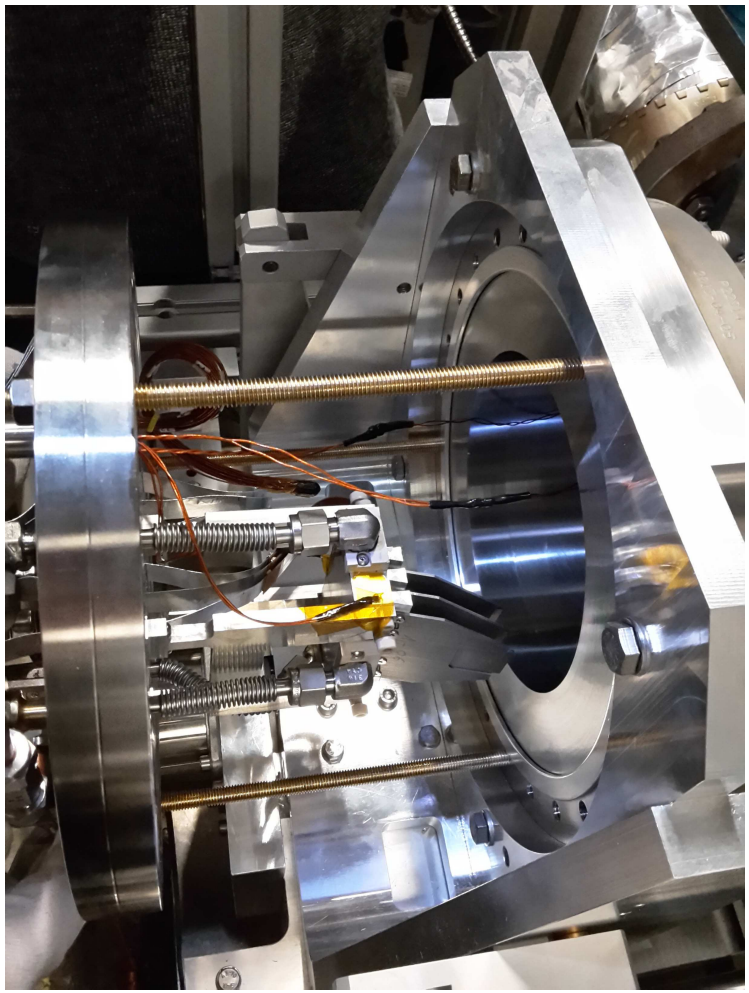


Positioning in Tunnel (II)

Detectors

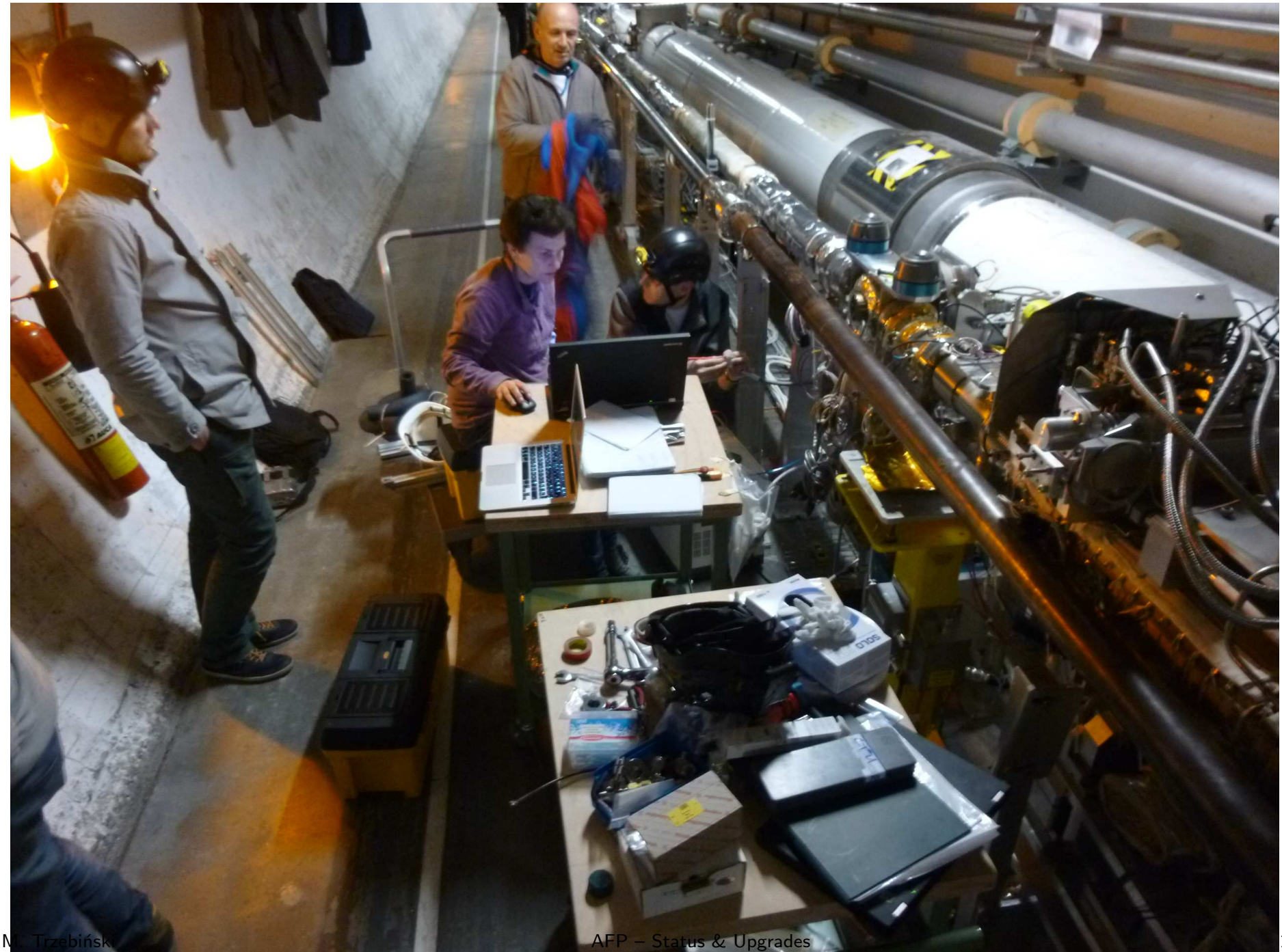






- technology: slim-edge 3D ATLAS IBL pixel sensors bonded with FE-I4 readout chips
- pixel size: $50x250\ \mu\text{m}^2$
- single layer resolution: $\sim$6 μm in x
- 4 detectors in station
- trigger in 2016: majority vote (2 out of 3; two chips in FAR station are paired and vote as one)
- from 2017 our trigger will be based on ToF detectors (A and C side); our trigger menu will change

Detectors – Installation

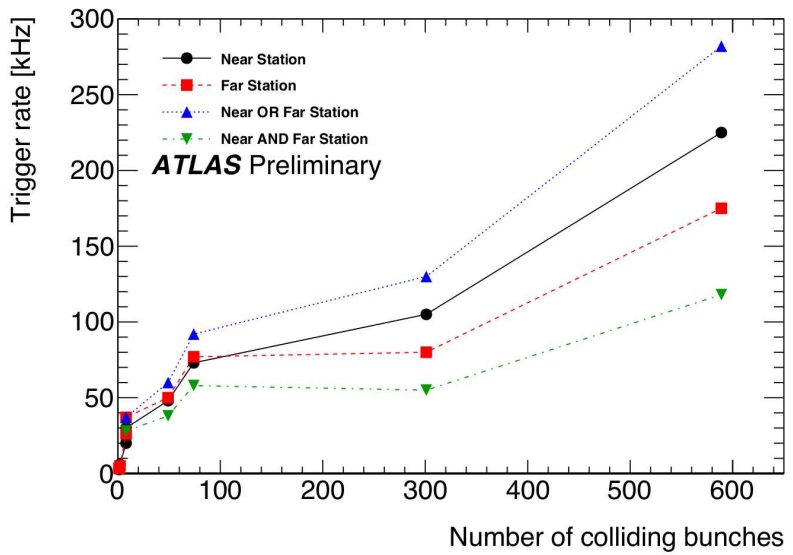


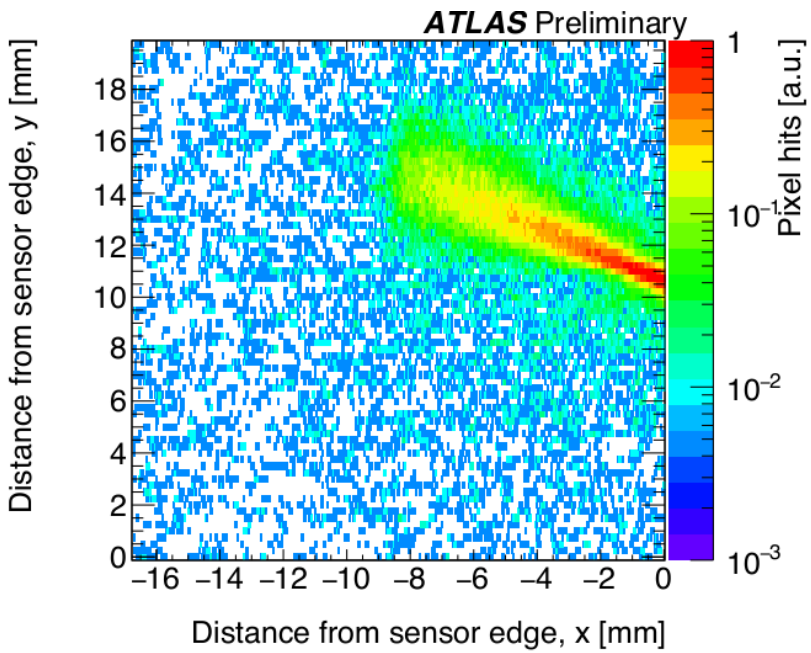
AFP detectors took high-μ data during LHC ramp-up:

- 23/04 – 3 bunch fill – 2.2 nb^{-1} of data collected
- 24/04 – 12b – 0.46 pb^{-1}
- 25/04 – 12b – 0.71 pb^{-1}
- 7/05 – 49 and 86 b – 8.1 pb^{-1}
- 10/05 – 300 b – 7.9 pb^{-1}
- 13/05 – 600 b – 8.0 pb^{-1}
- 10/06 – 3 b – 3.8 nb^{-1}
- 1/08 – 3 b – 23 nb^{-1}
- 25/09 – 3 b – 21 nb^{-1}
- 25/09 – 3 b – 21 nb^{-1}
- 25/09 – 157 b – 17.6 nb^{-1}
- 25/09 – 589 b – 35.6 nb^{-1} (only far station)

and during special low-μ runs:

- 1/08 – 600 b – 39 nb^{-1} with $0.01 < \mu < 0.03$
- 08/10 – 600 b – 490 nb^{-1} with $0.25 < \mu < 0.3$





AFP Installation and Operation

Installation:

- all four stations are installed in the LHC tunnel,
- cables, cooling and vacuum infrastructures are prepared,
- new sets of silicon trackers (SiT) are prepared to be installed in March,
- Time-of-Flight (ToF) detectors and electronics will be installed in March / April.

Commissioning:

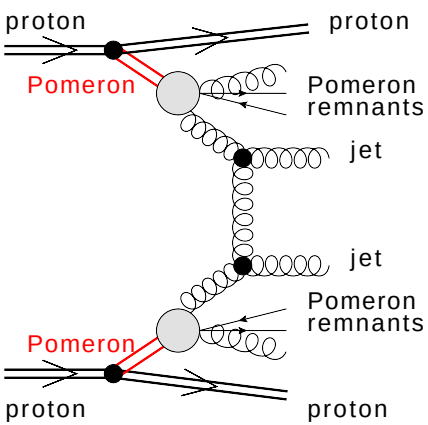
- calibration of the AFP movement system in April,
- AFP Beam Interlock System tests in April / May,
- followed by the Beam Based Alignment and Loss Maps,
- Detector Control System – integration of arm A and ToF system,
- Trigger Data AcQuisition – new trigger system (ToF instead of SiT).

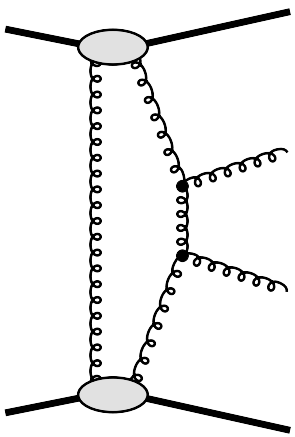
Data taking:

- take data at about 15 σ distance from the beam, using nominal optics ($\beta^* = 0.4$ m); low pile-up will be achieved by the beam separation,
- at least two special runs in 2017: $\mu \sim 0.01$ (integrated luminosity of about 100 nb^{-1}) and $\mu \sim 1$ (int. lumi. ~ 1 pb^{-1}),
- plan to collect ~ 10 pb^{-1} in several low luminosity runs in 2017 and 2018,
- **participate in all ATLAS physics runs.**

Special, low-μ runs

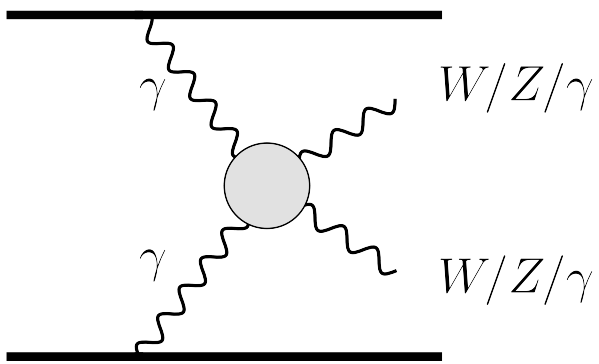
- diffractive physics:
  - soft diffraction (particle, gap, ξ spectra, *etc.*)
  - diffractive jets, jet-gap-jet, W, *etc.*
  - exclusive jets (low-p_T, single tagged)
- AFP can trigger ATLAS for presence of proton in:
  - one side (single difraction)
  - both sides (double Pomeron exch.)
- **special trigger menu based on AFP**
- as in 2016, we expect to have a few low-μ runs (bunch separation)
- we would like to have a majority of bandwidth on L1 and HLT dedicated to AFP items (min-bias stream)





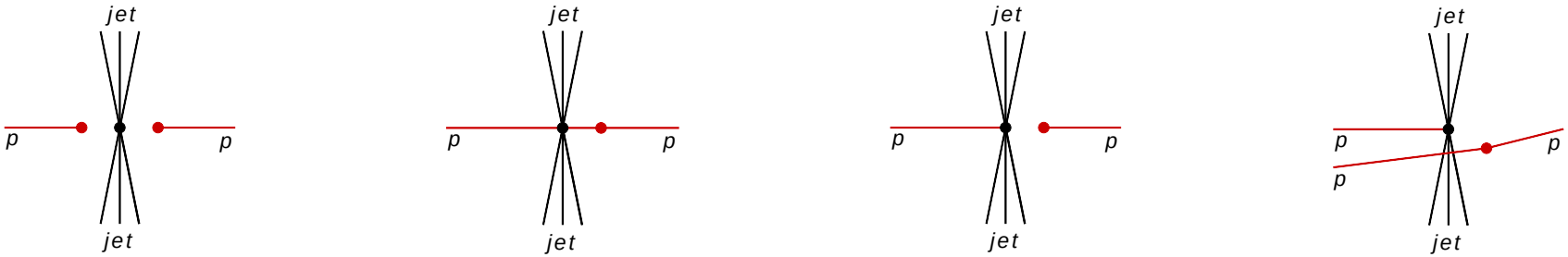
Standard, high-μ runs

- exclusive events (Pomeron and photon induced), new physics
- double tag can decrease the rates by factor 10 – 100 (depending on the mass of central system)
- in the case of jets a lower p_T threshold can be achieved (see *e.g.* ATL-PHYS-PUB-2015-003)
- in the case of new, heavy resonances or anomalous couplings the prescale can be reduced
- **AFP triggers (L1 and HLT) present in physics stream**
- for now, one unique item requested: the exclusive jet trigger

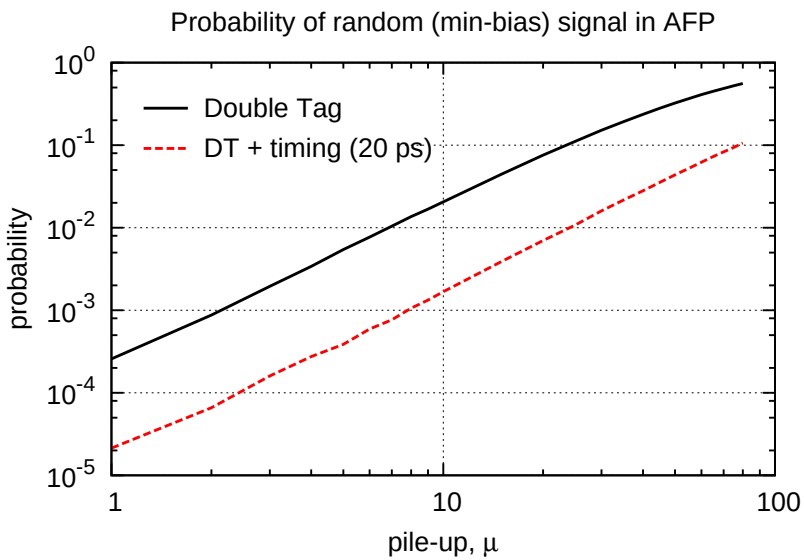


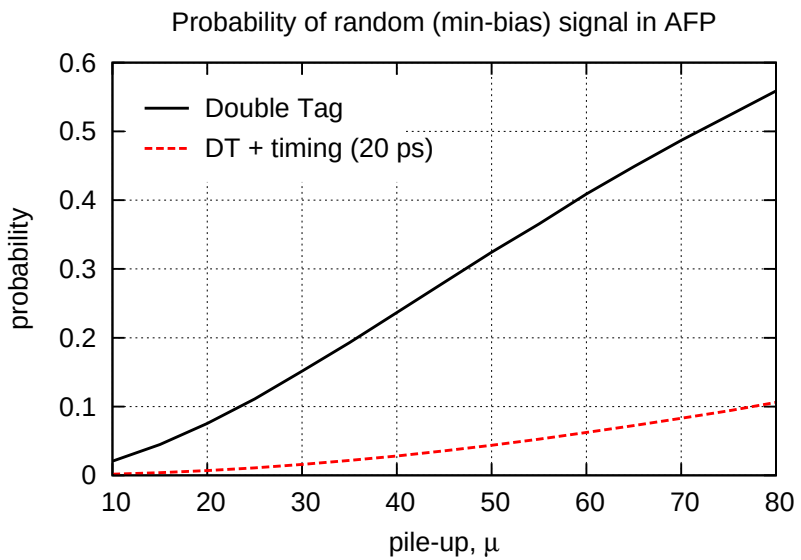
Usual background for the hard diffractive processes: a non-diffractive process + ,,soft" protons from pile-up.

Example: backgrounds for the double Pomeron exchange jet production (2 jets + 2 protons from the same proton-proton interaction):

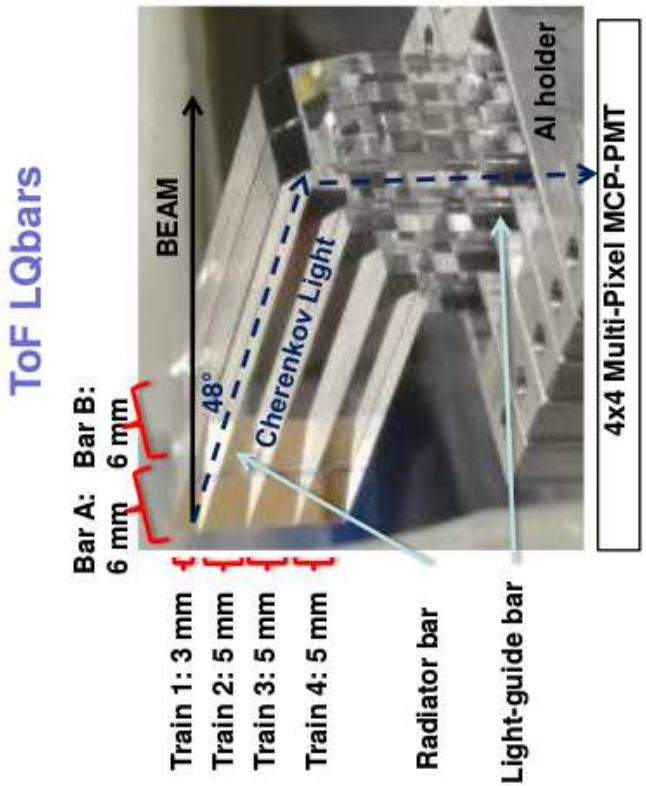


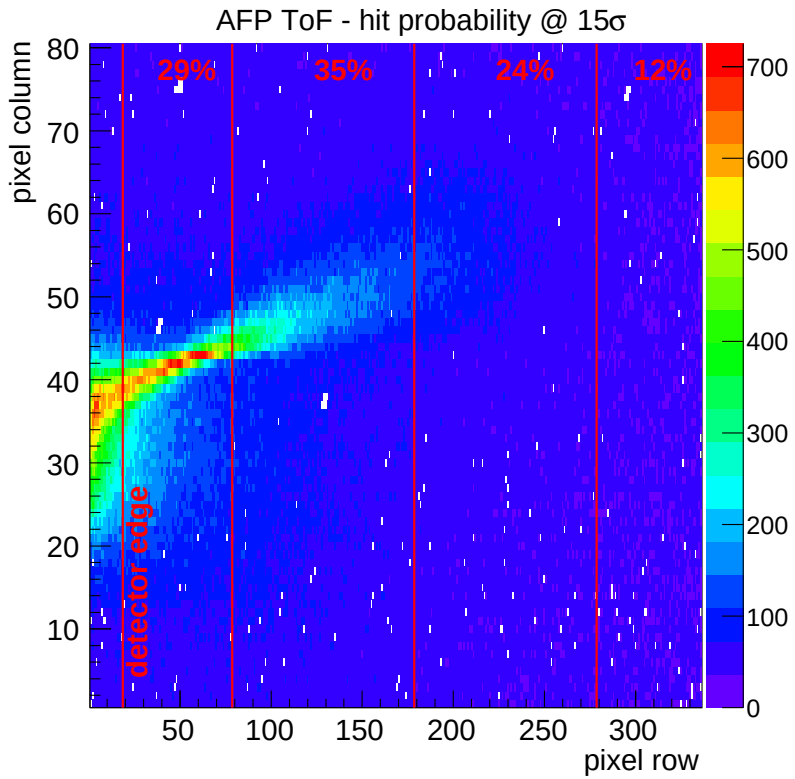
Amount of ,,soft" protons strongly depends on pile-up:





Requirement of proton presence in both AFP arms (double tag) can significantly reduce such background.





Trigger idea:

- use the second AFP trigger cable to specify which part of ToF triggered,
- for the exclusive jets we expect majority of events to be in the first train,
- in this way the rate on Level 1 can be reduced by a factor:
  - 2.5 when first two trains on each side are used,
  - 10 when only the first train on each side is used,
- this reduction is independent of the double proton tag requirement, *e.g.* for $\mu \sim 23$ a total reduction of factor 100 (10×10) can be expected.

Summary

- All AFP stations are installed in the LHC tunnel. New sets of silicon trackers, Time-of-Flight detectors and electronics will be installed in March / April.
- After commissioning phase in April / May, AFP will take data during:
  - dedicated, low-μ runs (~ 100 nb^{-1} at $\mu \sim 0.01$ and ~ 10 pb^{-1} $\mu \sim 1$),
  - all standard, high-μ runs.
- In all cases AFP will deliver triggers to ATLAS.

- **Various data taking strategies:**
  - very low pile-up ($\mu \sim 0.05$): measure properties of soft diffraction,
  - low pile-up ($\mu \sim 1$): measure properties of hard diffraction:
    SD JJ, SD JGJ, SD W, SD Z, DPE JJ, DPE JGJ, DPE γ+jet, exclusive jets (single tag),
  - high pile-up ($\mu \sim 50$): measure exclusive production and discovery physics:
    exclusive jets, anomalous couplings: $\gamma\gamma WW$, $\gamma\gamma ZZ$, $\gamma\gamma\gamma\gamma$.

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