Status of the AFP Detector

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on behalf of
the ATLAS Collaboration

Institute of Nuclear Physics
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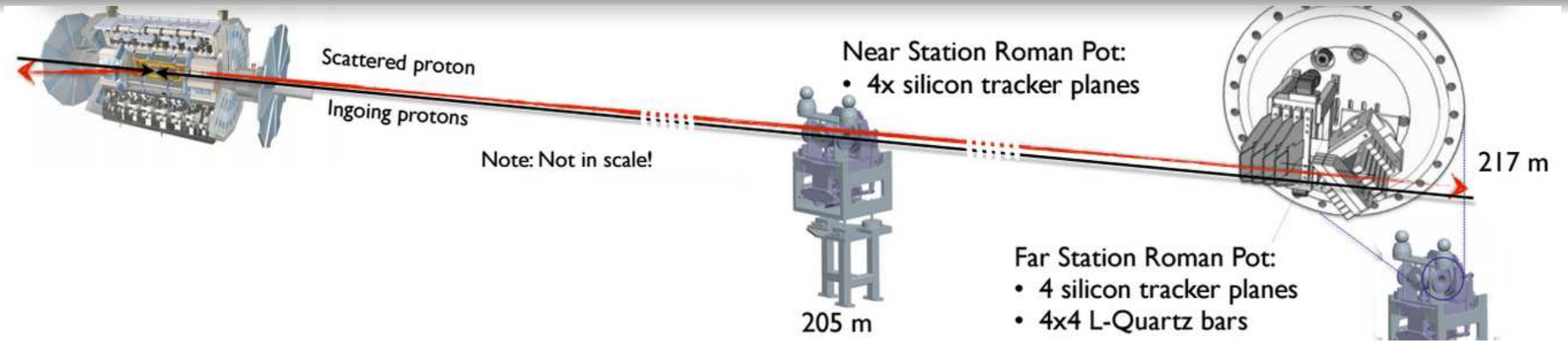
QCD at LHC: forward physics and UPC collisions of heavy ions

29th September 2016

ATLAS Forward Proton Project



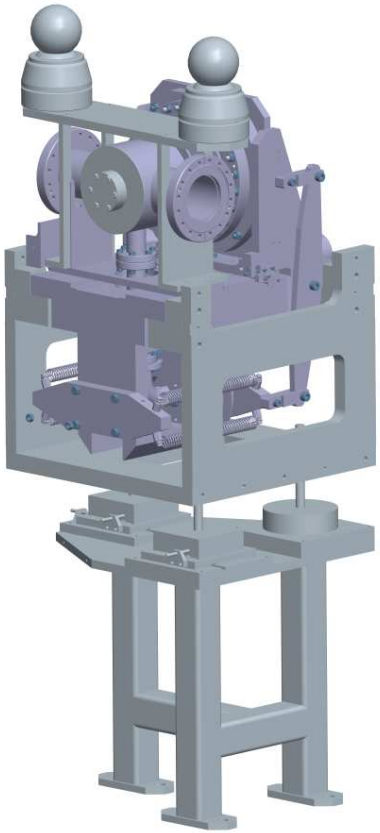
AFP TDR: CERN-LHCC-2015-009, ATLAS-TDR-024

Phase-1: AFP0+2 (2016)

- 2 horizontal Roman Pot stations at 205 (NEAR) and 217 m (FAR) in 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 trigger ATLAS)

Phase-2: AFP2+2 (2017+)

- add 2 horizontal RPs at 205 and 217 m on A side
- install time-of-flight detectors in far stations on both sides – new AFP trigger
- measure double tagged diffractive and exclusive events
- deliver diffractive triggers to ATLAS during standard runs



Physics of Interest

The AFP Detector for Run 2

Goals:

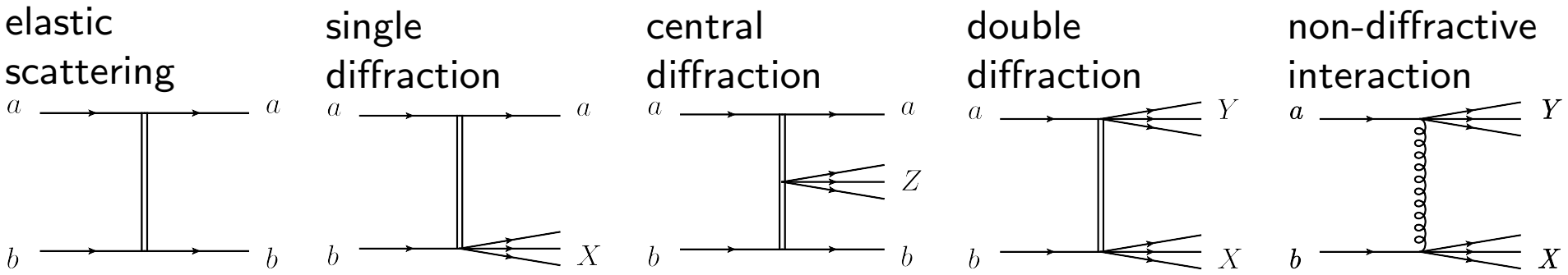
- commission the detector; explore the environment close to the LHC beam **DONE!**
- special runs at low-μ, focusing on high-rate diffractive physics processes **DONE!**
- staged installation:
  - Winter 2015-2016 shutdown – installation of a single AFP arm with two Roman pot stations, the 0+2 AFP configuration (AFP0+2) **DONE!**
  - Winter 2016-2017 shutdown – installation of the second detector arm

AFP 0+2:

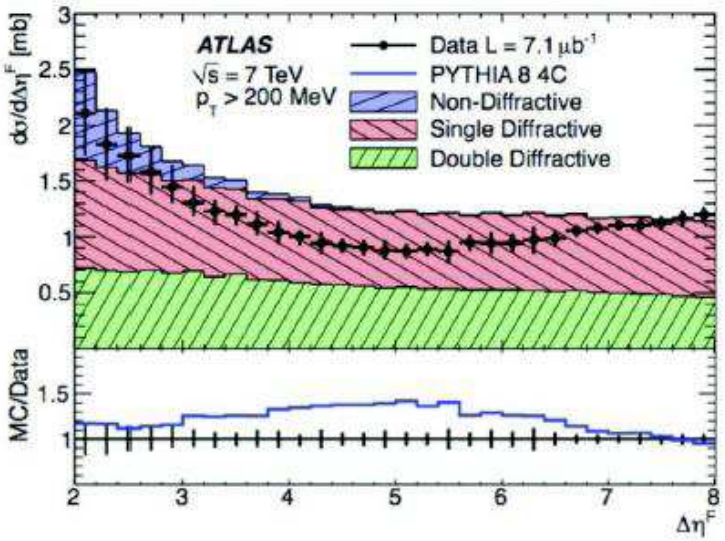
- two silicon tracking detectors and a Level-1 Track Hit trigger (hits in 2 out of 3 SiD planes)
- physics: **soft single diffraction**, **single diffractive jets**, W, jet-gap-jet, exclusive jet production (one tag)

AFP 2+2:

- two silicon tracking detectors on second arm and time-of-flight detectors on both far stations
- physics:
  - special runs: soft central diffraction, central diffractive jets, jet-gap-jet, γ+jet,
  - regular runs: exclusive jet production, anomalous couplings.



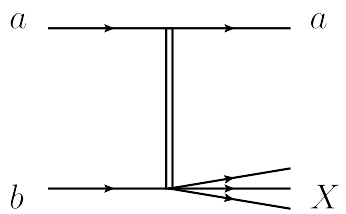
- Gap measurement in ATLAS does not distinguish SD from DD
- More information about events with forward proton tagging
- High cross sections → low lumi needed → possible with lowest pile-up
- AFP 0+2 – single diffraction
  AFP 2+2 – central diffraction



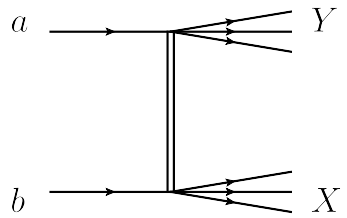
Eur. Phys. J. C72 (2012) 1926

Origin of forward protons

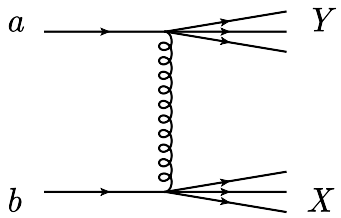
Single Diffraction



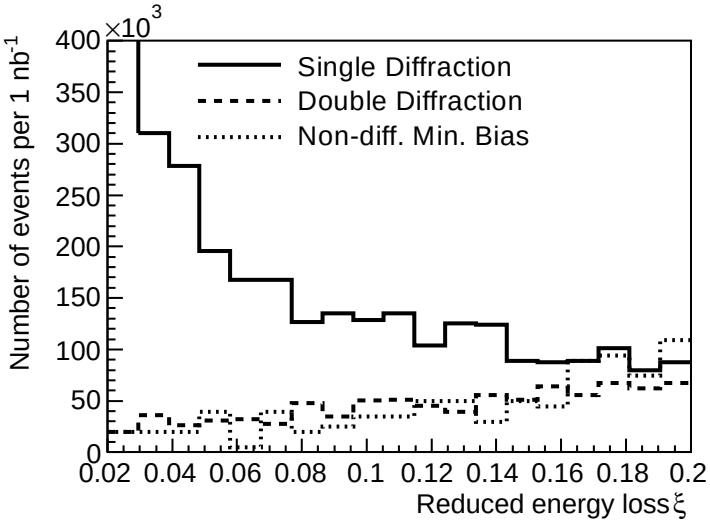
Double Diffraction



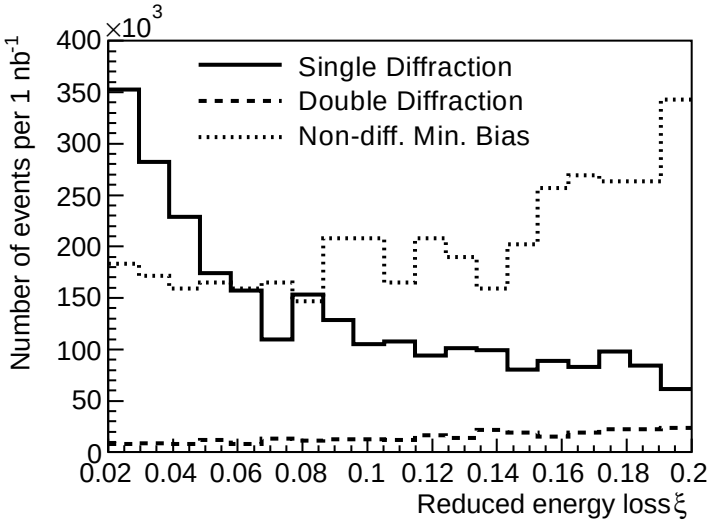
Non-diffractive



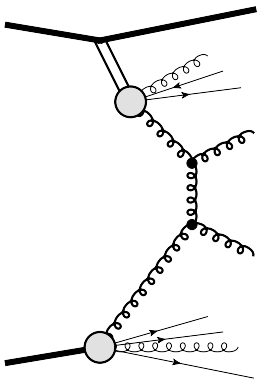
Pythia



Phojet

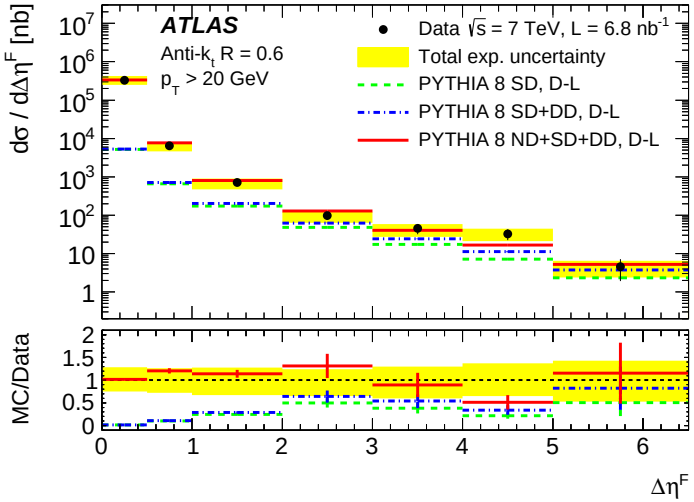


- High-ξ protons in ND and DD due to hadronisation
- Significant differences between MC generators
- Important also for simulating cosmic air showers

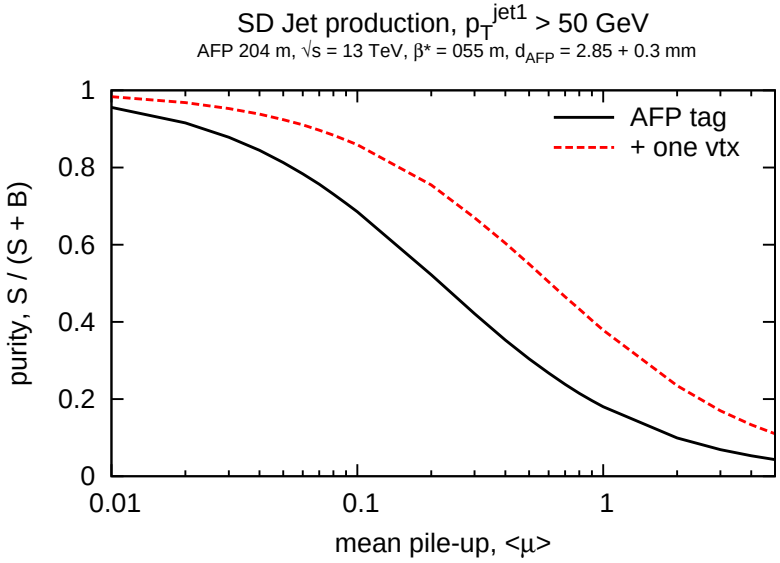


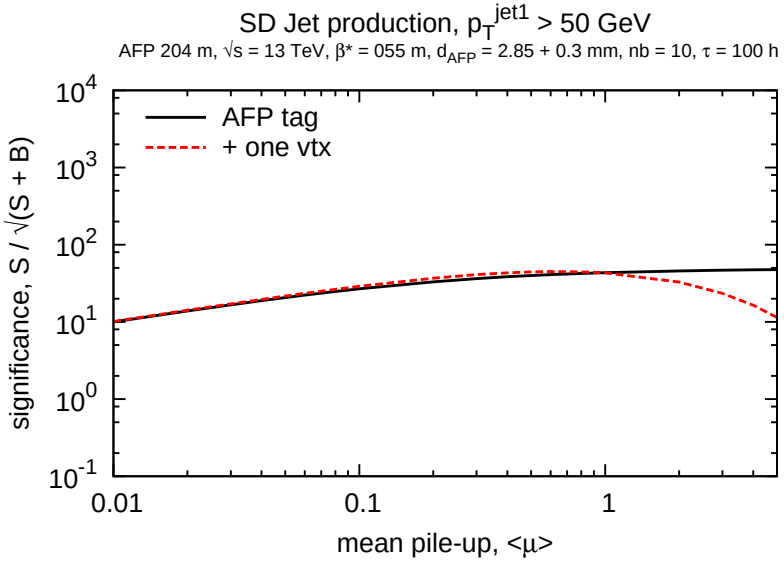
Motivation:

- cross section measurement
- gap survival probability
- Pomeron structure studies
- Reggeon contribution
- Pomeron universality between *ep* and *pp*

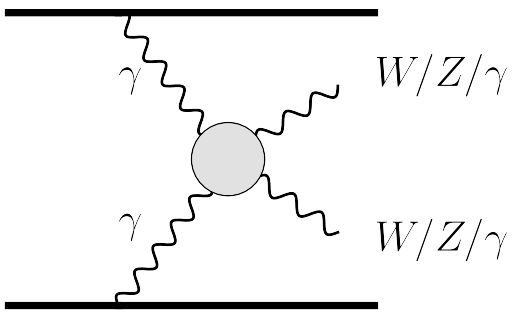


Dijet production in $\sqrt{s}$ TeV pp collisions with large rapidity gaps at the ATLAS experiment



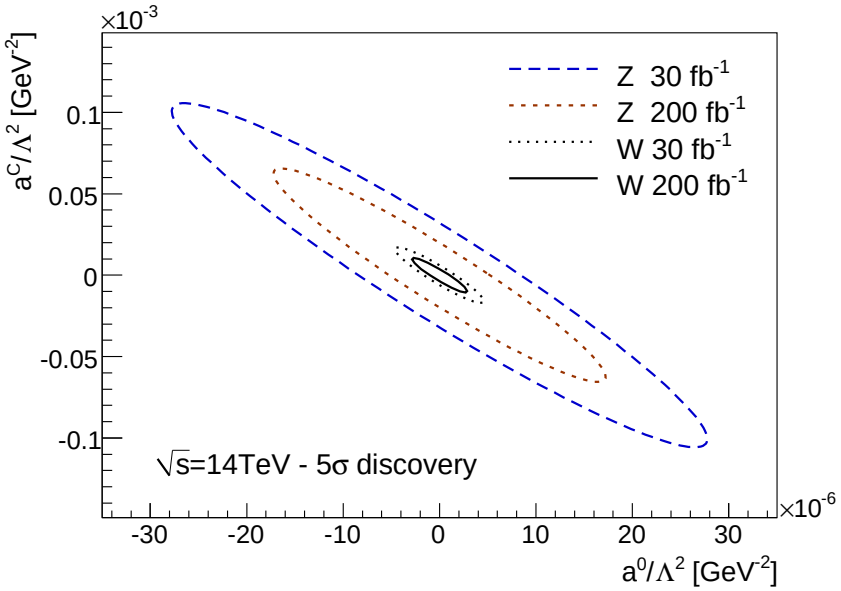


Details can be found in: CERN-PH-LPCC-2015-001



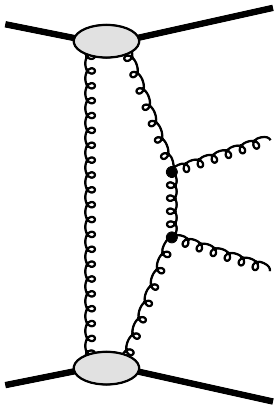
Motivation:

- measurement of W and Z boson pair production via the exchange of two photons allows to perform a stringent test of the electroweak symmetry breaking,
- tag in AFP results in gain in sensitivity of about two orders of magnitude over a standard ATLAS analysis.



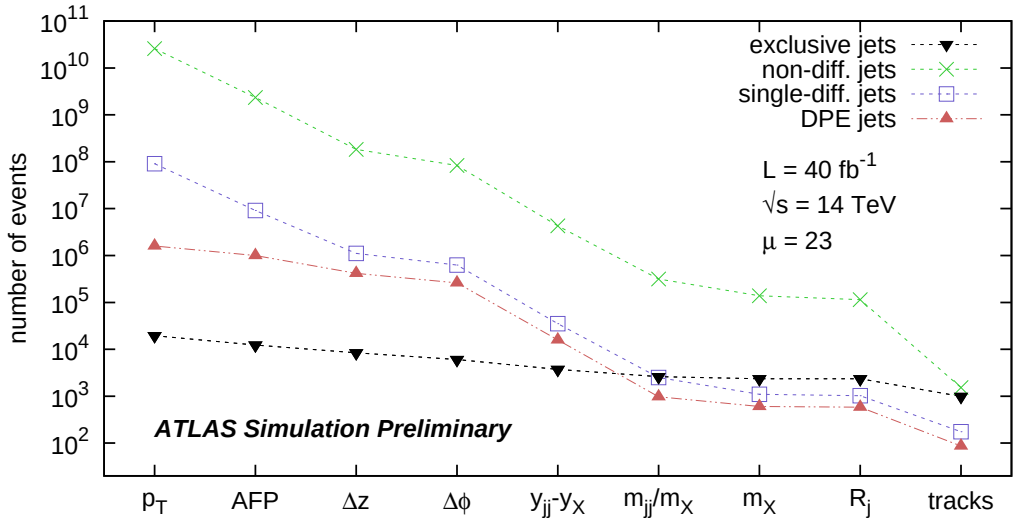
Details can be found in:

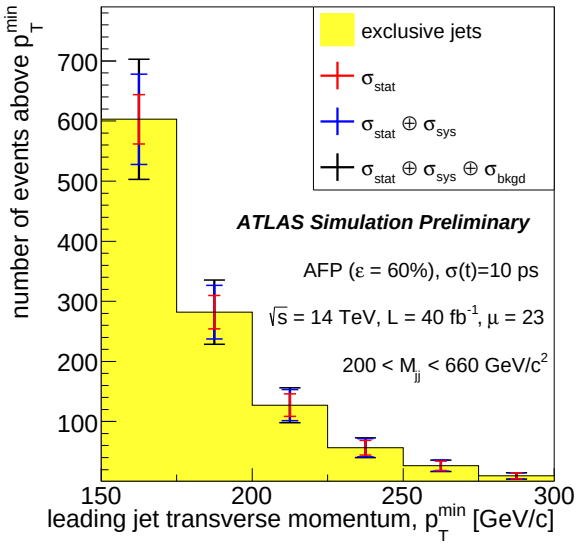
- http://arxiv.org/abs/0808.0322
- http://arxiv.org/abs/0912.5161



Motivation:

- shed a light on topics connected to gluon distributions in proton as such events are expected to be purely of gluonic nature,
- measurement of exclusive jets will set constraints on the exclusive Higgs production,
- without AFP measurement is not possible.



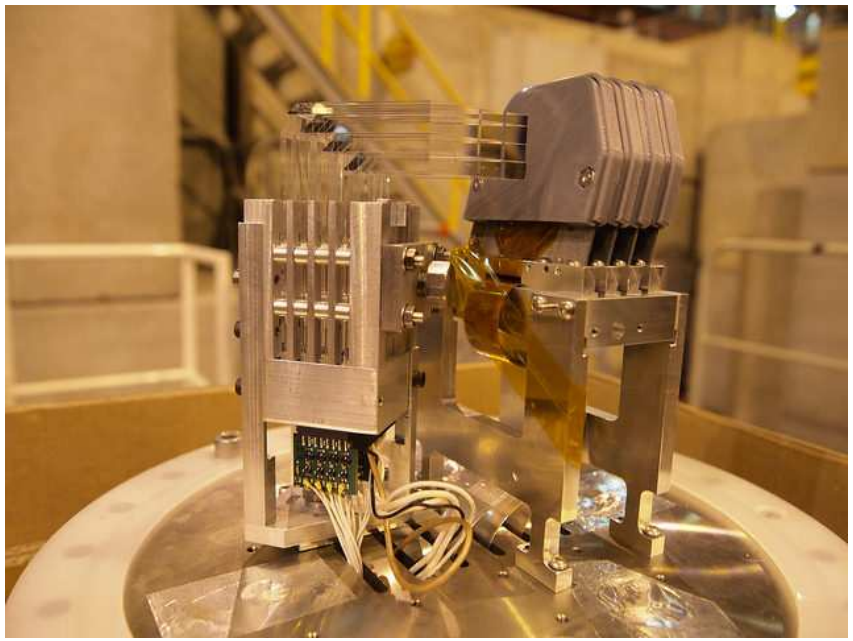


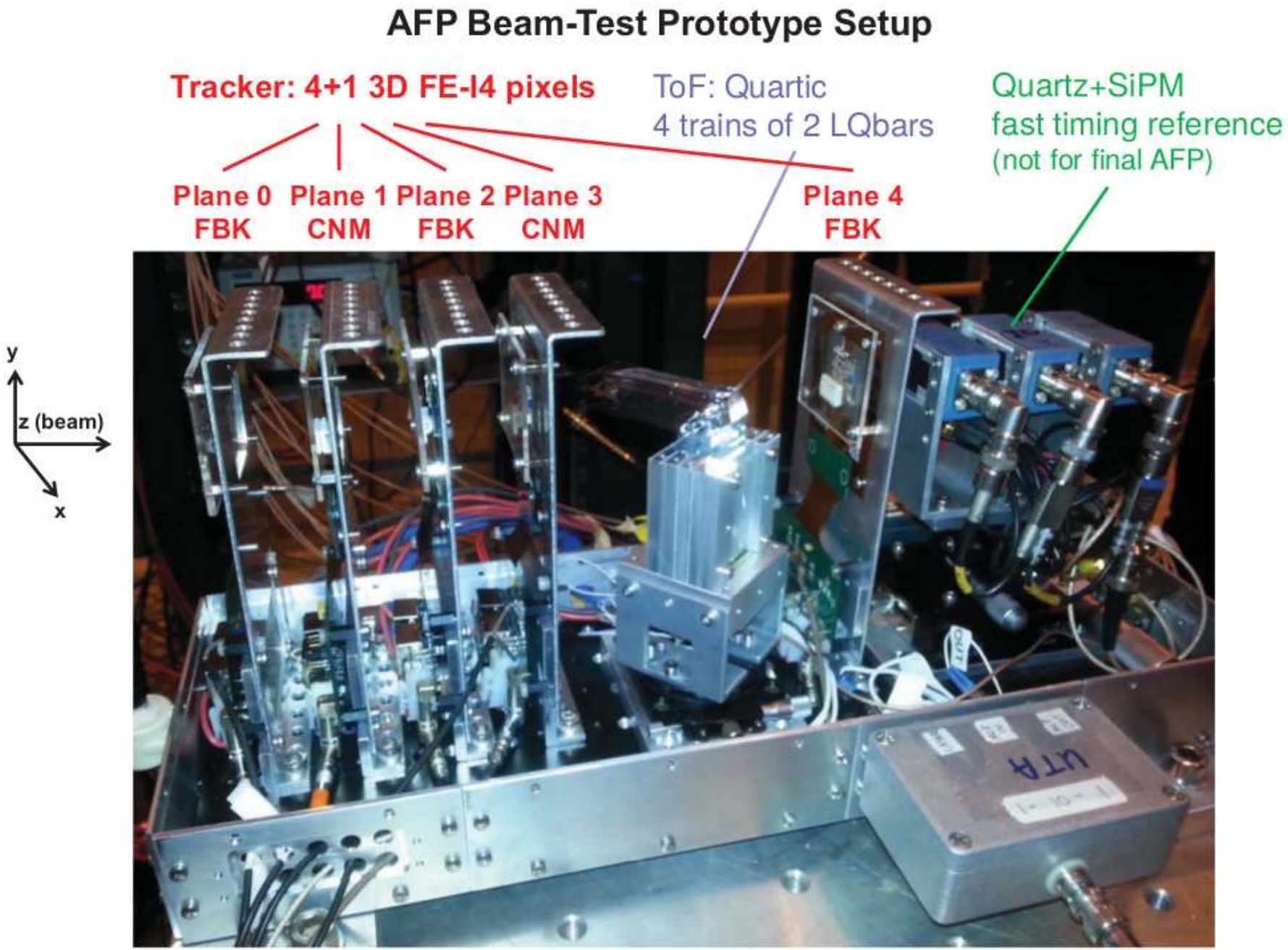
Details can be found in: https://cds.cern.ch/record/1993686

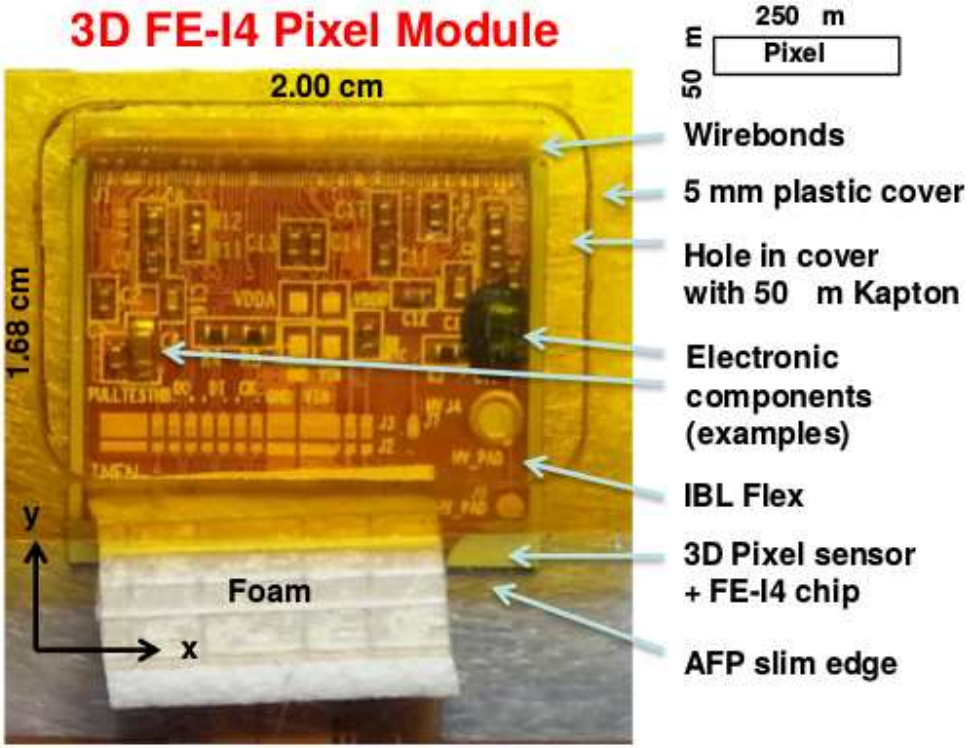
Test-beams

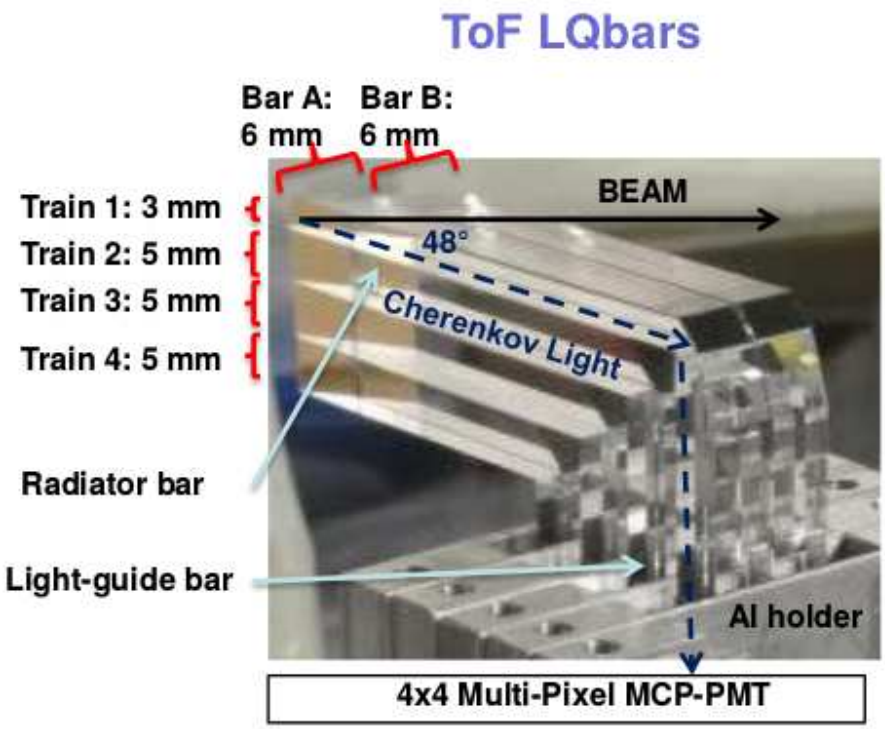
Schedule

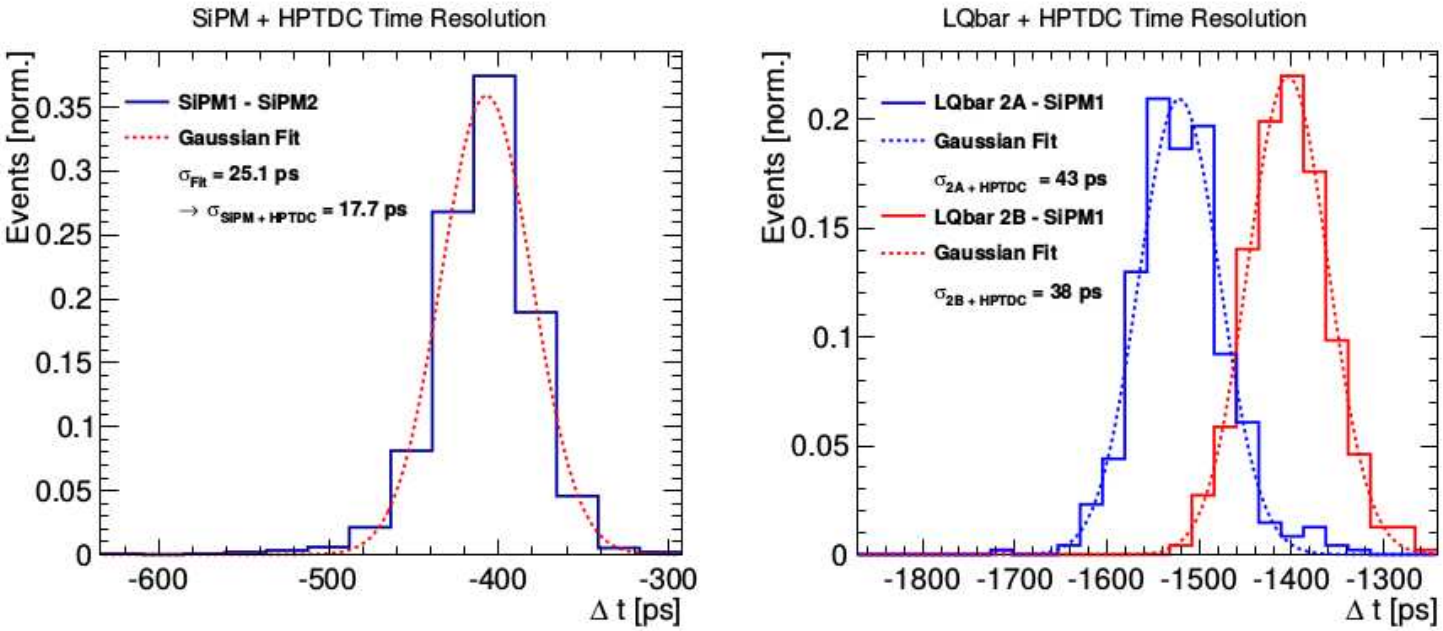
- Aug. 2012, CERN – 3D pixels
- Oct. 2012, CERN – 3D pixels
- Jul. 2014, FermiLab – ToF
- Nov. 2014, CERN – Integration
- Sep. 2015, CERN – Integration
- Apr. 2016, CERN – Tracker
- Jun. 2016, CERN – ToF
- Sep. 2016, CERN – ToF and Integration




AFP Beam-Test Prototype Setup
Tracker: 4+1 3D FE-I4 pixels
ToF: Quartic
4 trains of 2 LQbars
Quartz+SiPM
fast timing reference
(not for final AFP)
Plane 0
FBK
Plane 1
CNM
Plane 2
FBK
Plane 3
CNM
Plane 4
FBK
y
z (beam)
x
UTA


3D FE-I4 Pixel Module
2.00 cm
1.68 cm
y
x
Foam
250 m
50 m
Pixel
Wirebonds
5 mm plastic cover
Hole in cover
with 50 m Kapton
Electronic
components
(examples)
IBL Flex
3D Pixel sensor
+ FE-I4 chip
AFP slim edge


ToF LQbars
Bar A:
6 mm
Bar B:
6 mm
Train 1: 3 mm
Train 2: 5 mm
Train 3: 5 mm
Train 4: 5 mm
BEAM
48°
Cherenkov Light
Radiator bar
Light-guide bar
Al holder
4x4 Multi-Pixel MCP-PMT



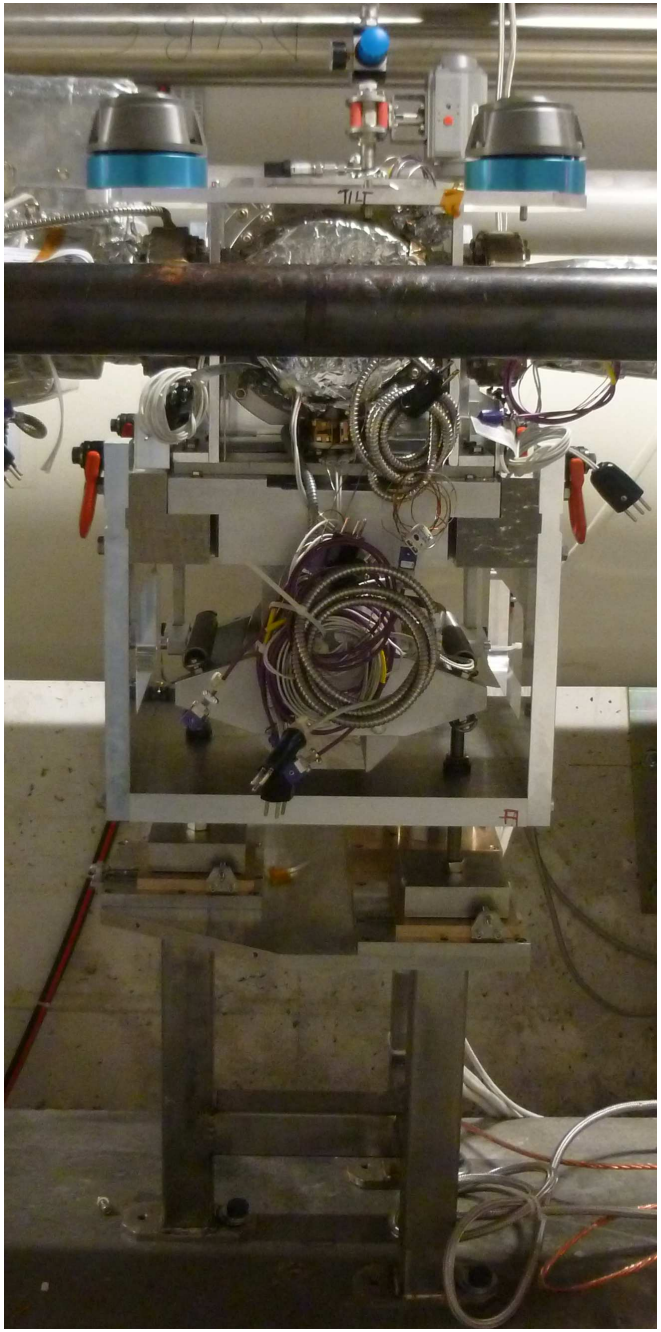
Left: time differences between the two SiPM reference
Right: time differences between the LQbars of the second train (2A and 2B) and SiPM1

Details can be found in: JINST **11** (2016) P09005, http://arxiv.org/abs/1608.01485

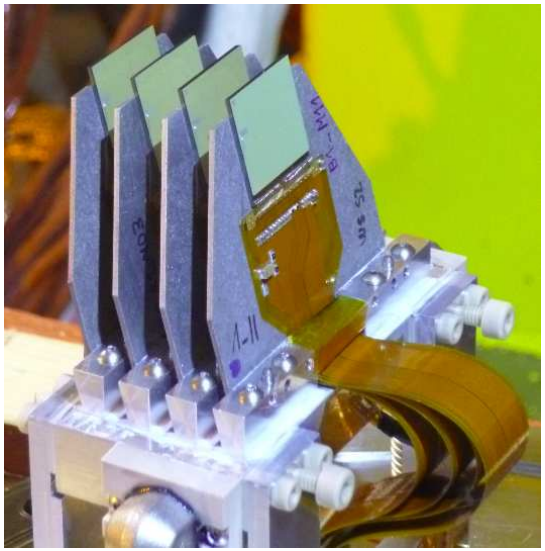
Infrastructure and Detectors

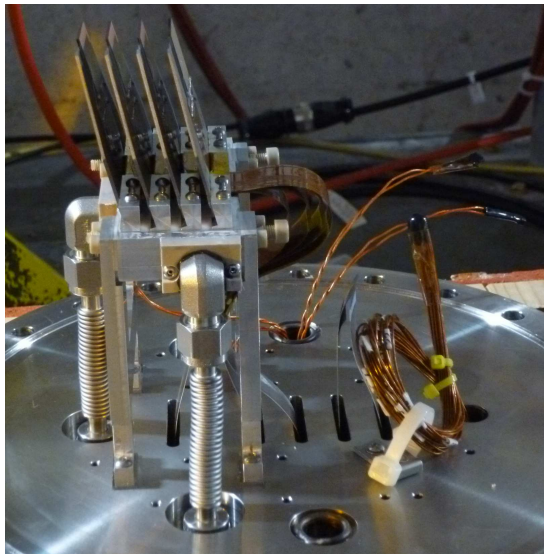
Station

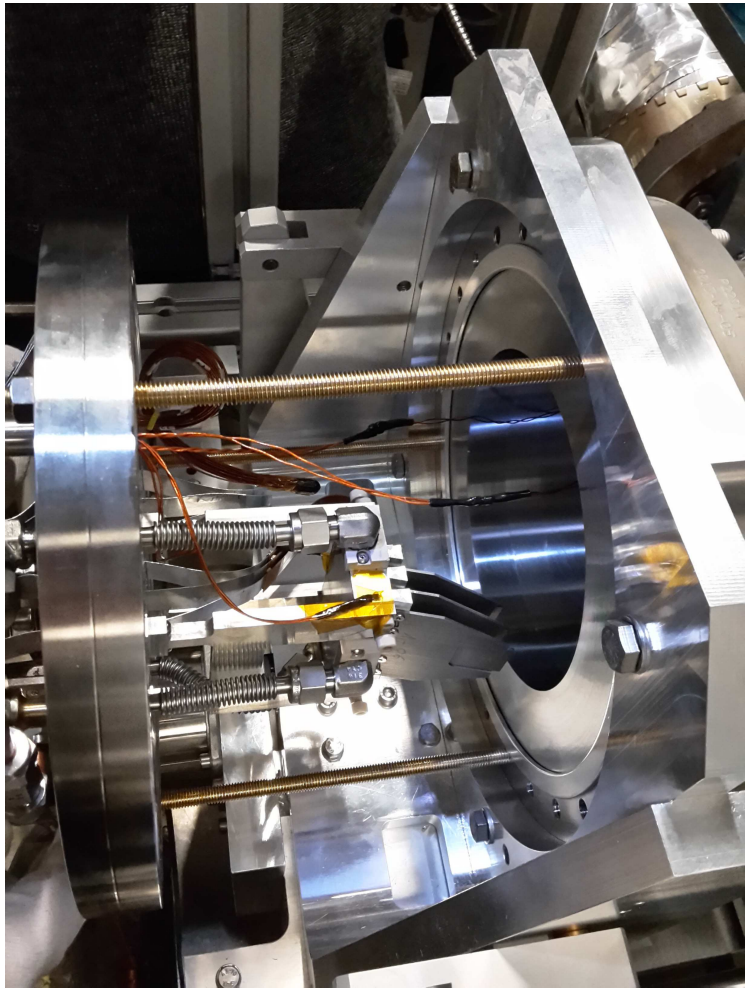
- based on the CMS-PPS/TOTEM horizontal stations
- two stations installed 18th Jan. on side C
- under LHC vacuum and baked-out since 3 Feb.
- **status: connected and fully operational**



Detectors



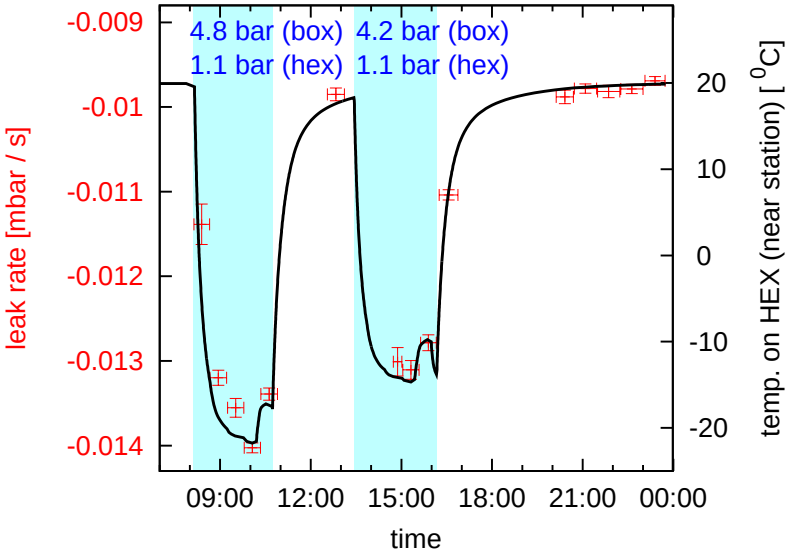




- technology: slim-edge 3D ATLAS IBL pixel sensors bonded with FE-I4 readout chips
- pixel size: $50x250\ \mu m^2$
- single layer resolution: $\sim$6 μm in x
- 3(4) detectors in NEAR(FAR) station
- trigger in 2016: majority vote (2 out of 3; two chips in FAR station are paired and vote as one)
- from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

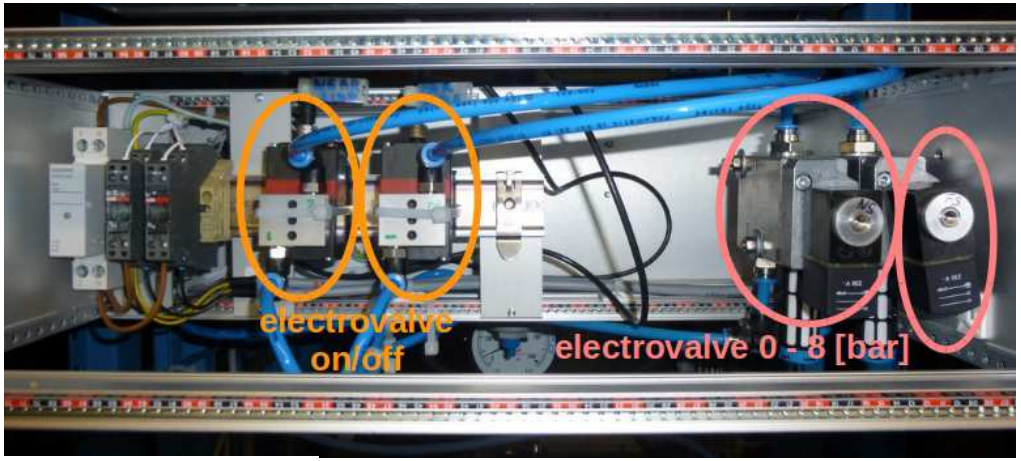
Vacuum System

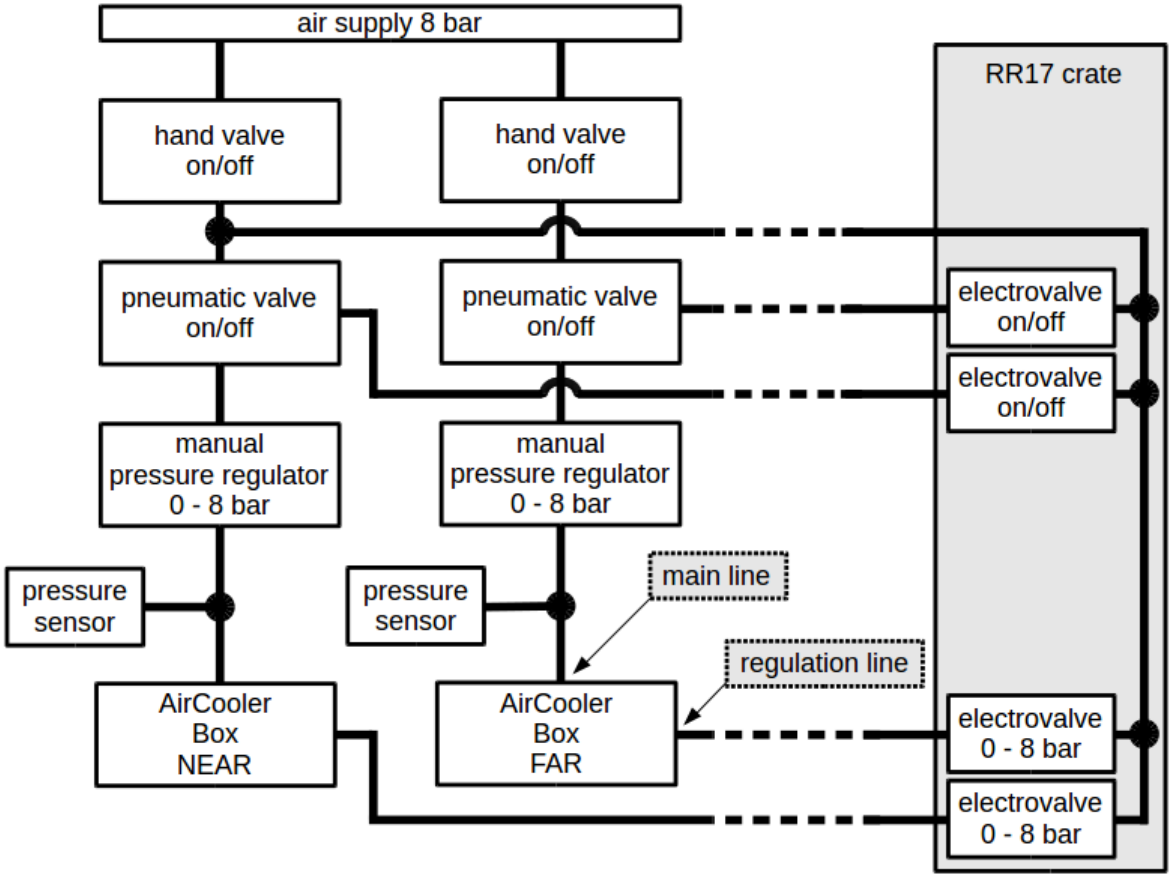
- Each RP is kept under secondary vacuum:
  - reduce stress and limit "bulge" of thin window,
  - allows cooling below 0 deg. (prevents icing of detectors).
- Two vacuum pumps (P1, P2) per arm located in RR17 alcove.
- Four operating modes:
  - mode 1: alternating between P1 and P2,
  - mode 2: use P1, if problem switch to P2,
  - mode 3: use P2, if problem switch to P1,
  - mode 4: use both pumps.
- Small leak observed in near station. Overall leak rate: ~ 0.01 mbar / s.

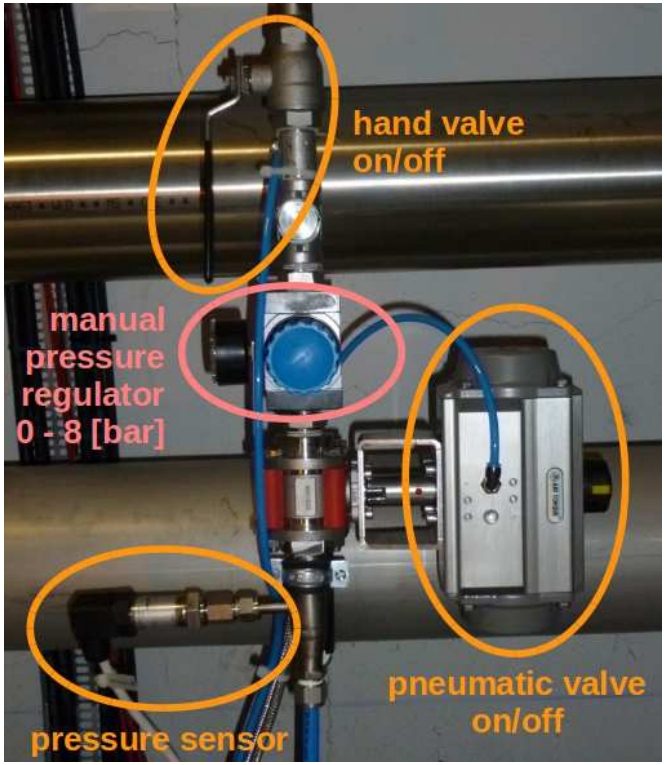


Cooling System – Connections

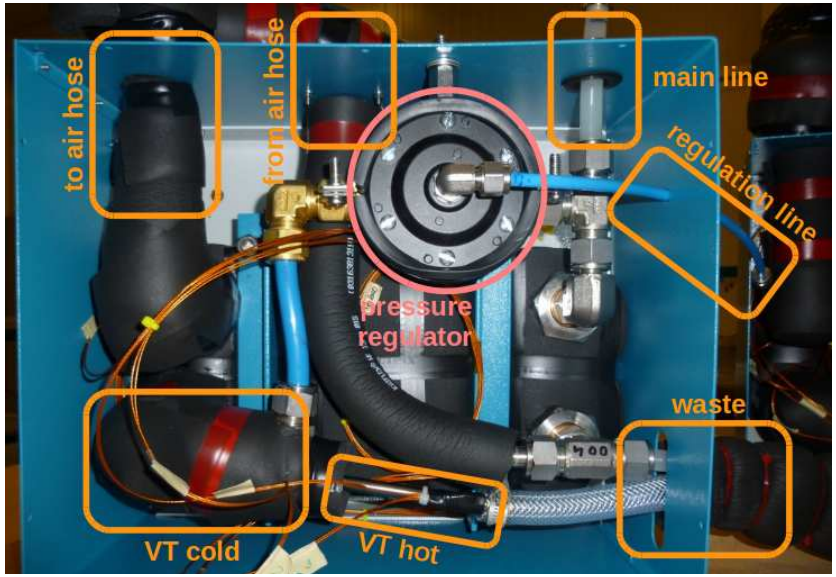
Vortex cooling technology – system runs purely on compressed air.

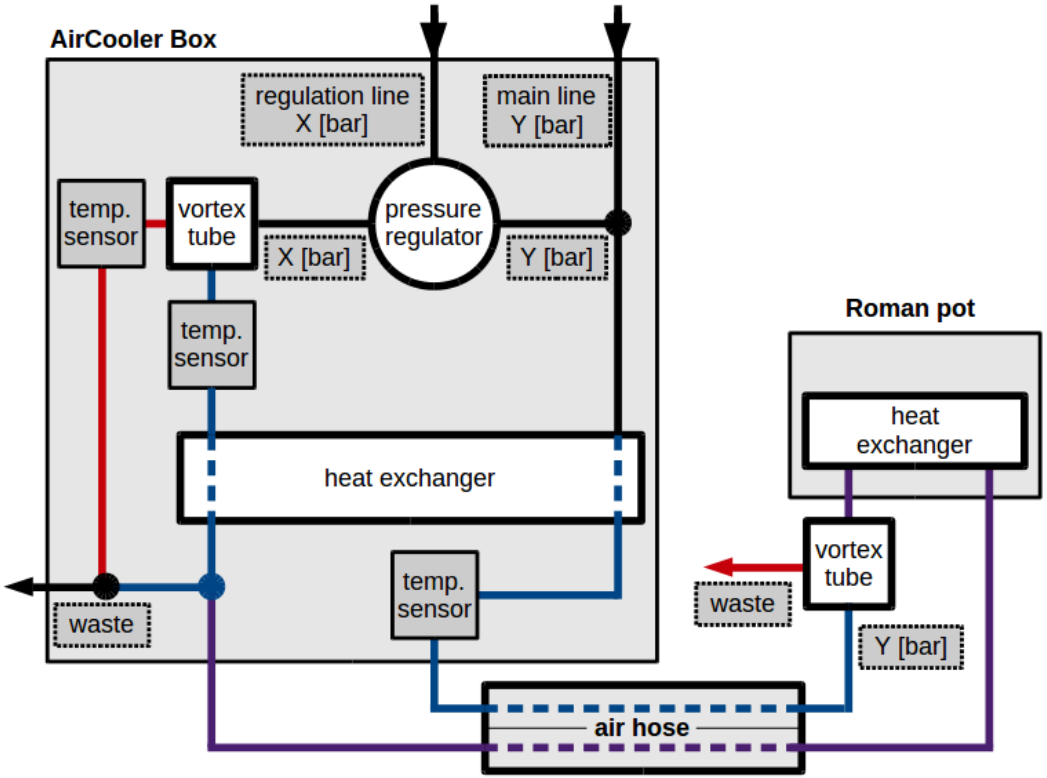






Cooling System – Station





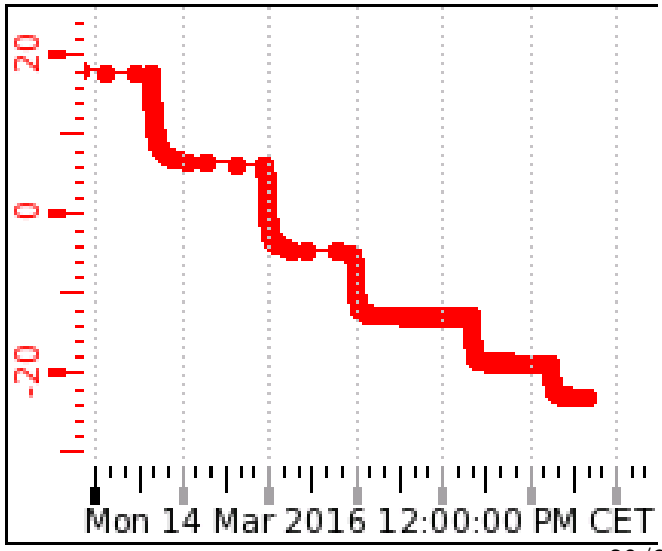
Staged approach:

- precooling of input air in AirCooler box,
- coooling with Vortex tube installed on RP.

Efficient cooling: temp. down to -30 ^{0}C with detectors powered on.

Operational requirements: -5 ^{0}C.

Online temperature regulation.

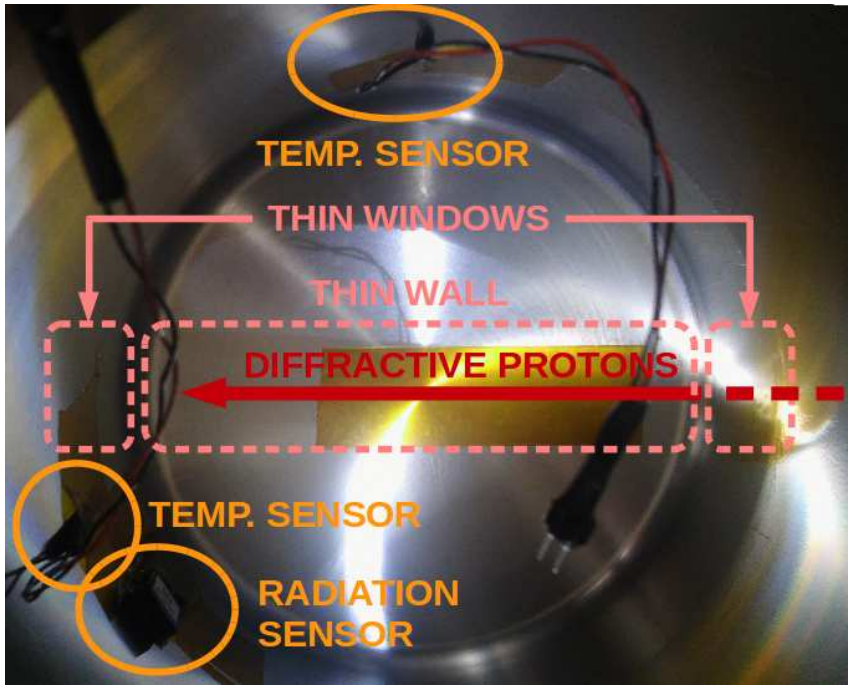


Temperature sensors (NTC):

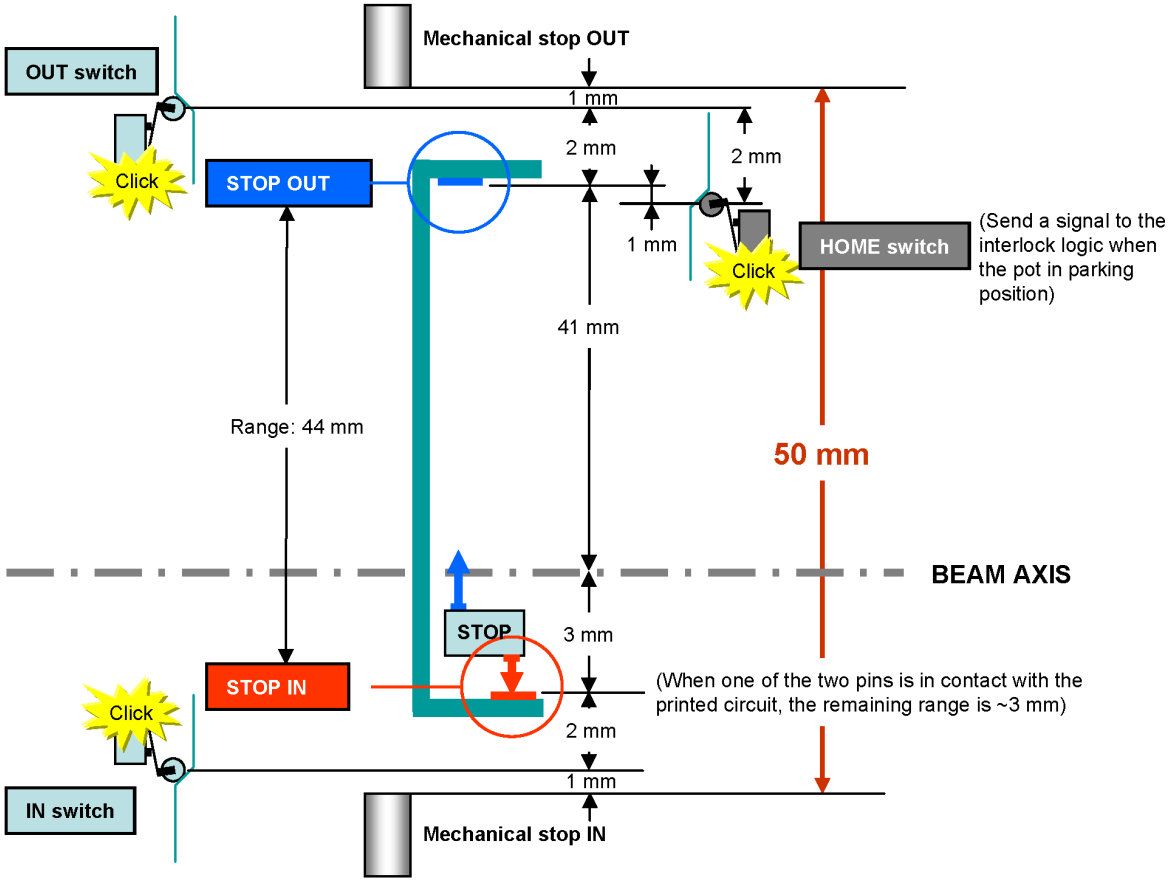
- each station:
  - each detector plate (on flex),
  - heat exchanger (NTC + PT1000),
  - pot wall (up + under second thin window),
  - flange (cold output of Vortex tube + HV for ToF),
  - LTB.
- VReg. crate.
- AirCooler box:
  - hot output of VT,
  - cold output of VT,
  - output of box.

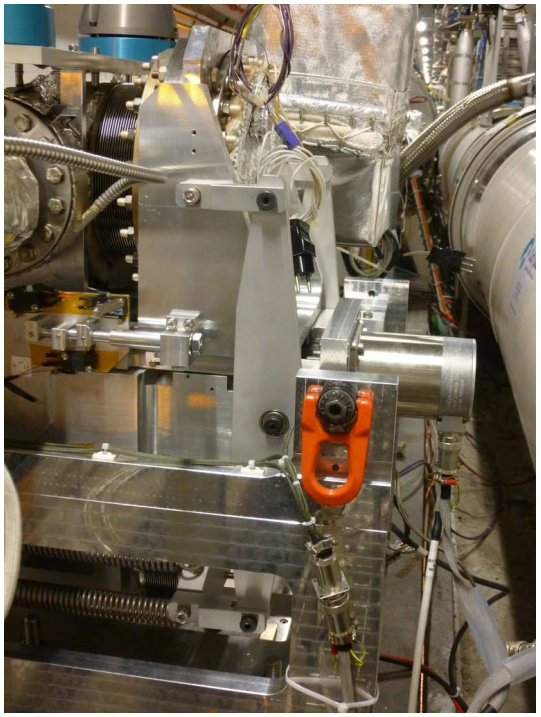
Radiation sensors:

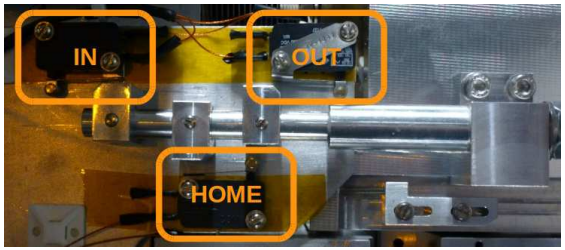
- bottom of each pot,
- VReg. crate,
- far station LTB,
- RR17 alcove.

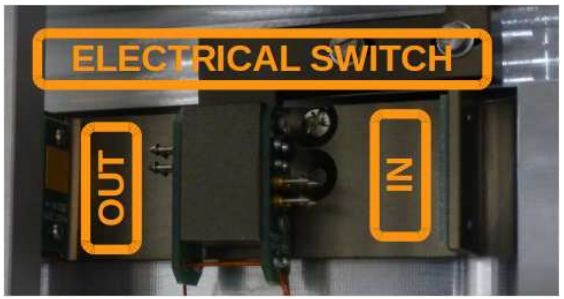


„Specification and Validation of the Motion Control System of the ATLAS Forward Proton Roman Pots"



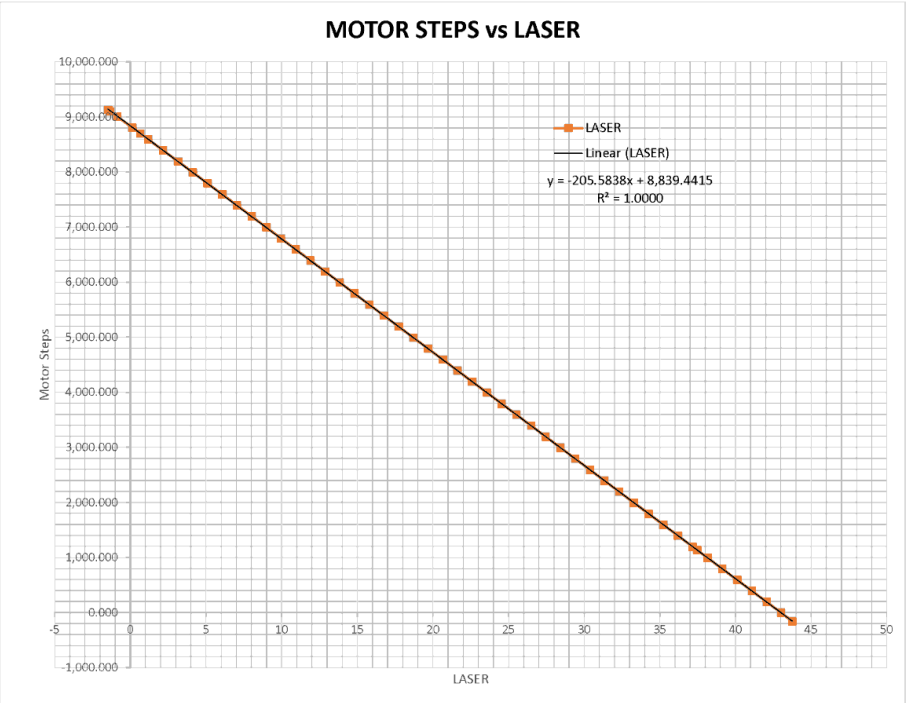


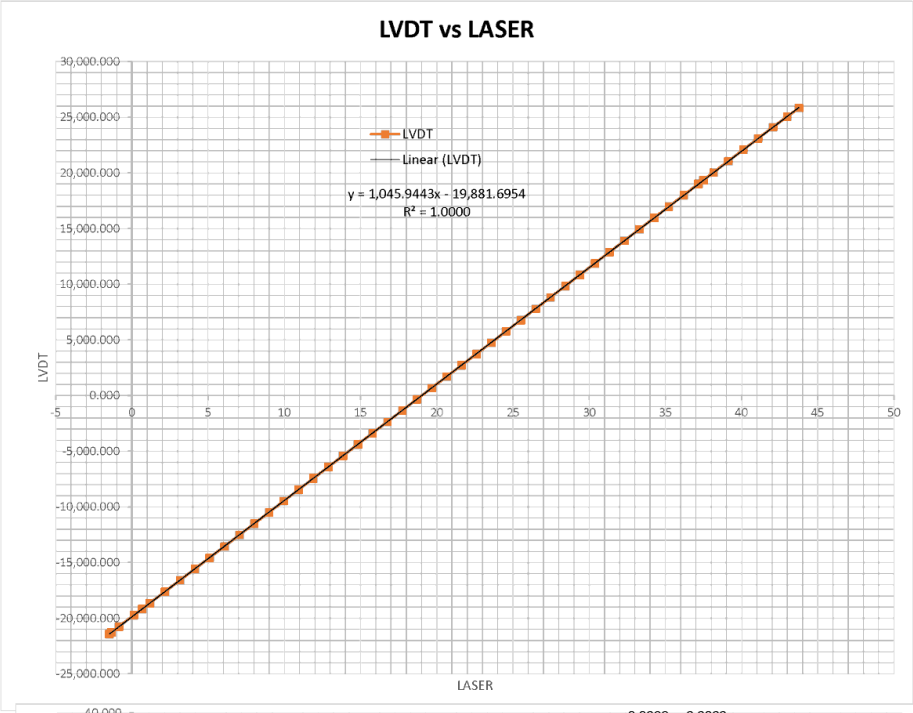


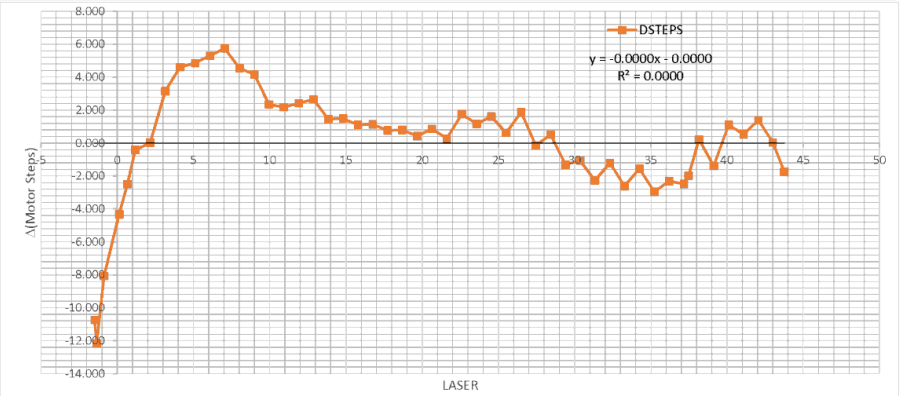


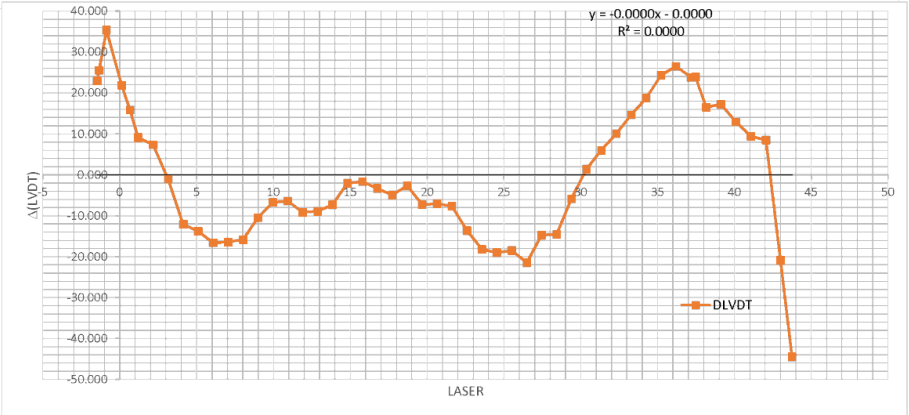
- mechanical stops installed to prevent damage of fragile electrical stop
- retraction with springs to the HOME position tested
- positions of IN, OUT, and HOME switch and Electrical Stop were set according to the laser measurements

Both stations calibrated (18 Feb.)



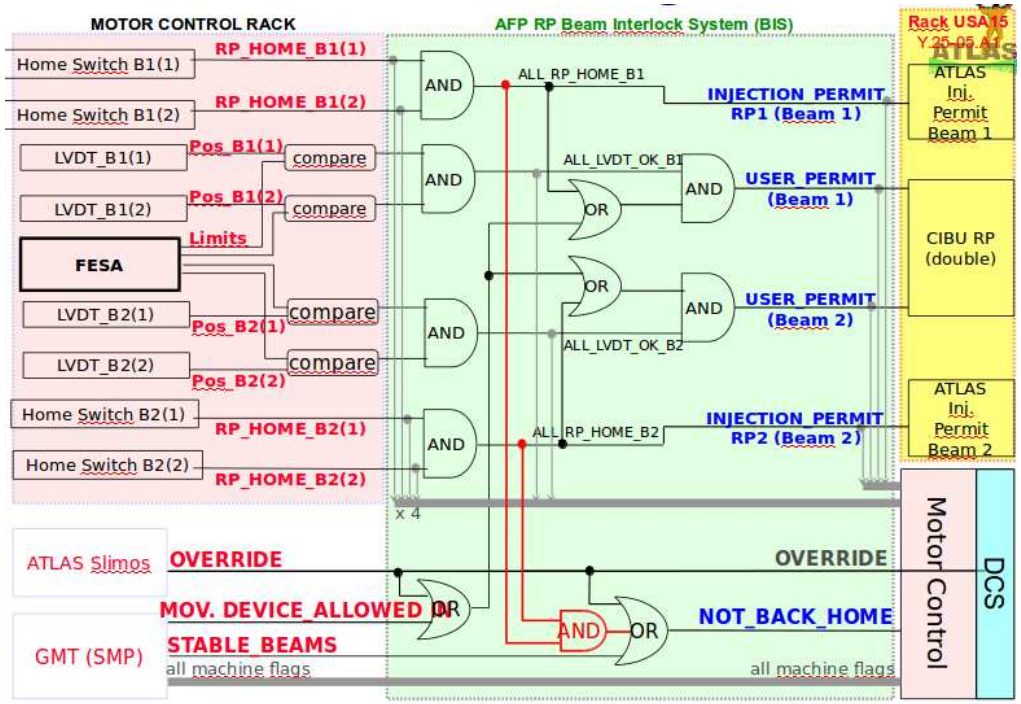






AFP Beam Interlock System

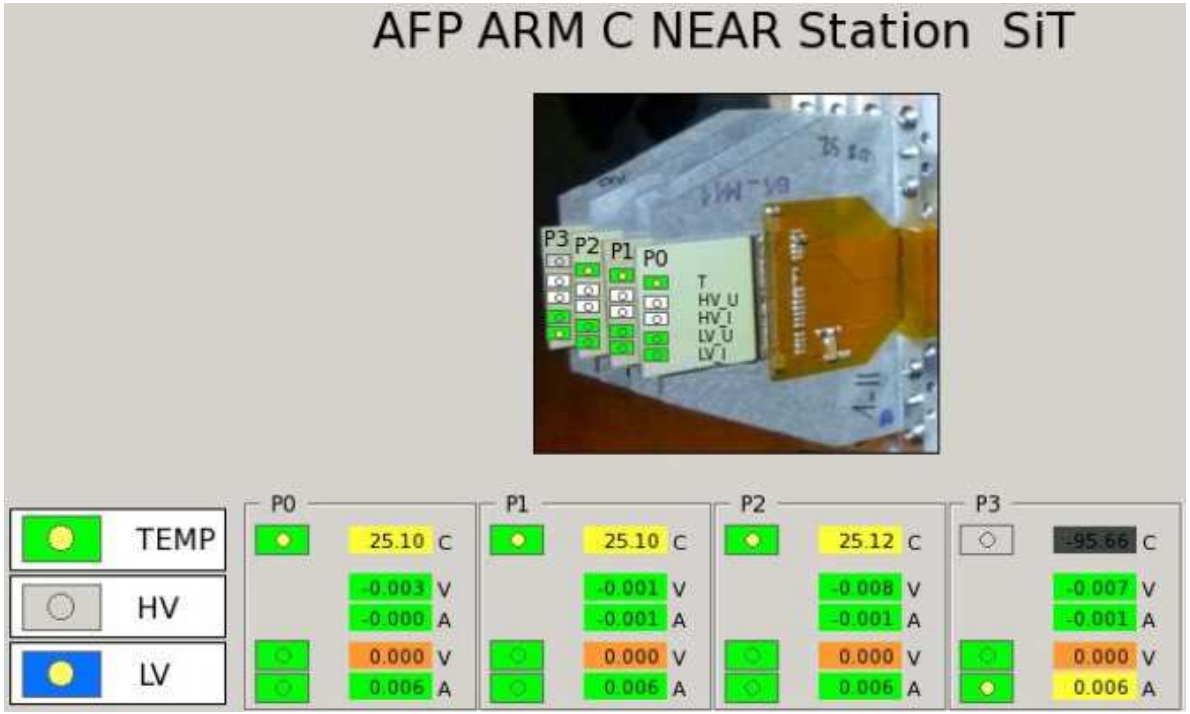
- copy of ALFA BIS
- AFP Beam Interlock System successfully commissioned from the central DCS up to the LHC interface (CIBU)



- hardware commissioning tests related to the position control of the 2 AFP Roman Pots done:
  - correct mapping and signal distribution of the LHC flags between the AFP Interlock and AFP position control system
  - signal integrity of the HOME SWITCH signal from RP station to AFP interlock and the transmission of the COPY HOME switch back to the PXI
  - EXTRACTION RP SWITCH and OVERRIDE signals from the ATLAS control room
  - HOLIDAY MODE KEY
- **status**: system is fully commissioned

DCS is responsible for coherent and safe operation of the detector:

- provides tools for bringing the detector into desired operational state, monitors its parameters, signals any abnormal behaviour and performs actions,
- defined subset of detector parameters is stored in data bases for later inspections,
- graphical user interfaces allow overall detector operation and visualisation.



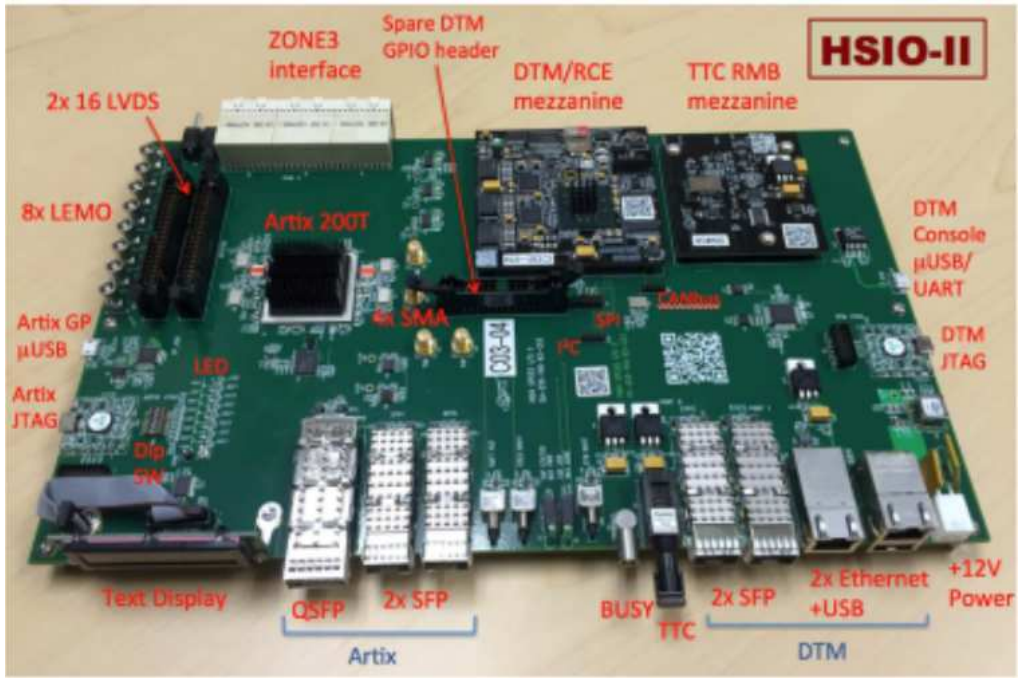
AFP is integrated with ATLAS DCS system.

Architecture of AFP TDAQ:

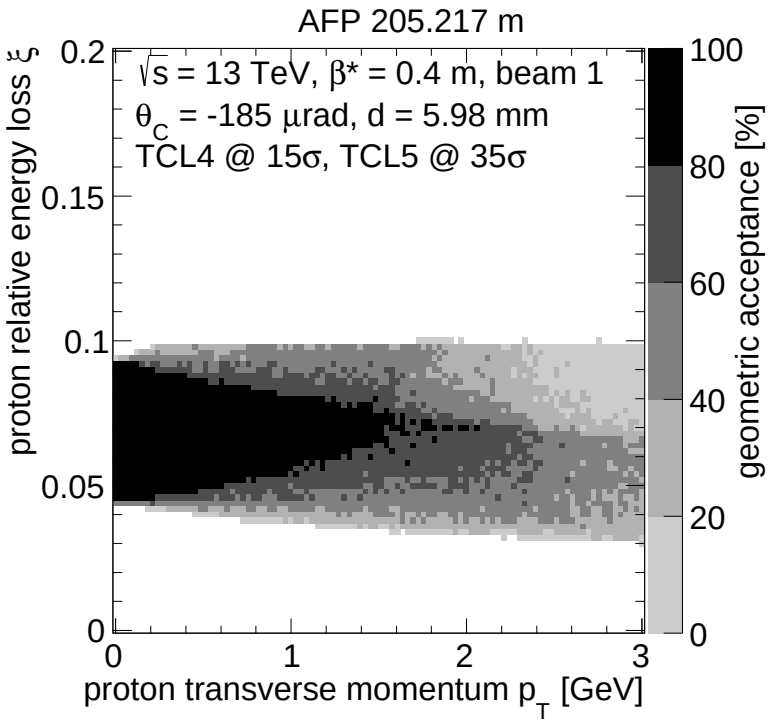
- High Speed Input Output board (HSIO): DAQ board with many high-speed and low-speed I/O channels, Xilinx Artix 200 FPGA, mezzanines with ATLAS TTC and RCE (Reconfigurable Cluster Element),
- frontends are configured at a 40 Mbps, the data is readout at 160 Mbps

AFP is fully integrated with ATLAS TDAQ system:

- AFP trigger signals are generated, combined (OR, AND, majority vote logics), synchronized with LHC clock and send to ATLAS Central Trigger Processor,
- trigger signals are sent via fast air-core cables and reach CTP within the standard ATLAS latency (85 BCXs),

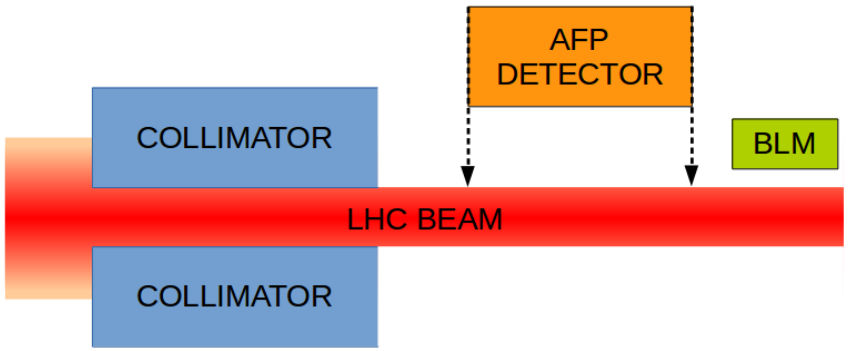


Alignment and Data Taking



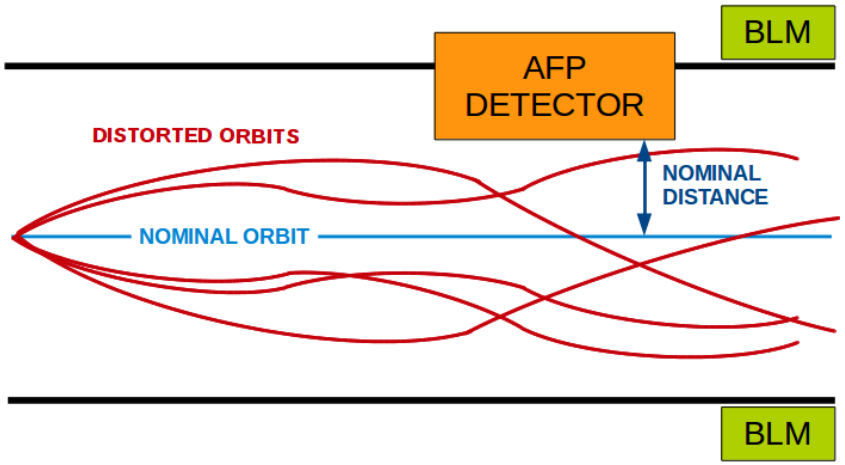
BBA procedure:

- scraping: close collimator to trim the beam,
- approach the beam with detector,
- monitor rates in BLMs and AFP – sudden increase marks the beam position.



Loss maps procedure:

- move detectors to the operational position (*e.g.* 20σ),
- distort beam trajectory,
- observe rates in BLMs and AFP – beam should not touch the Roman pot.



BBA and LM for AFP were done on:

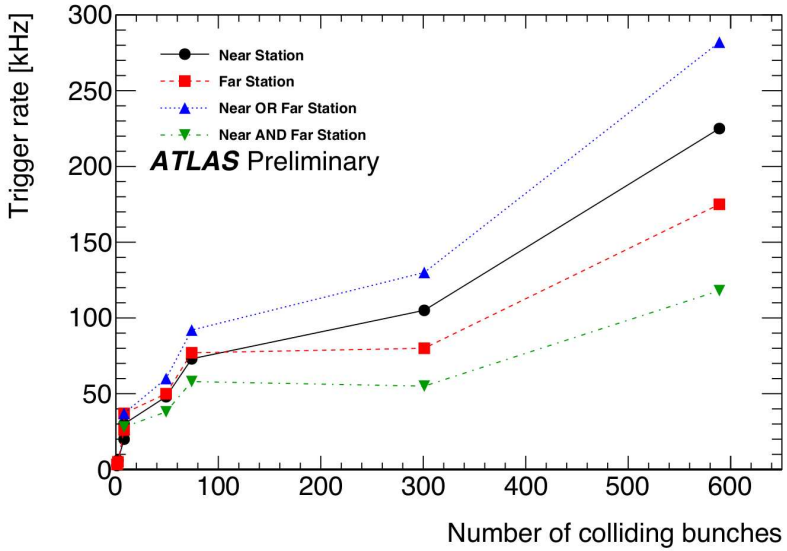
- 19-22 April,
- 23-24 September.

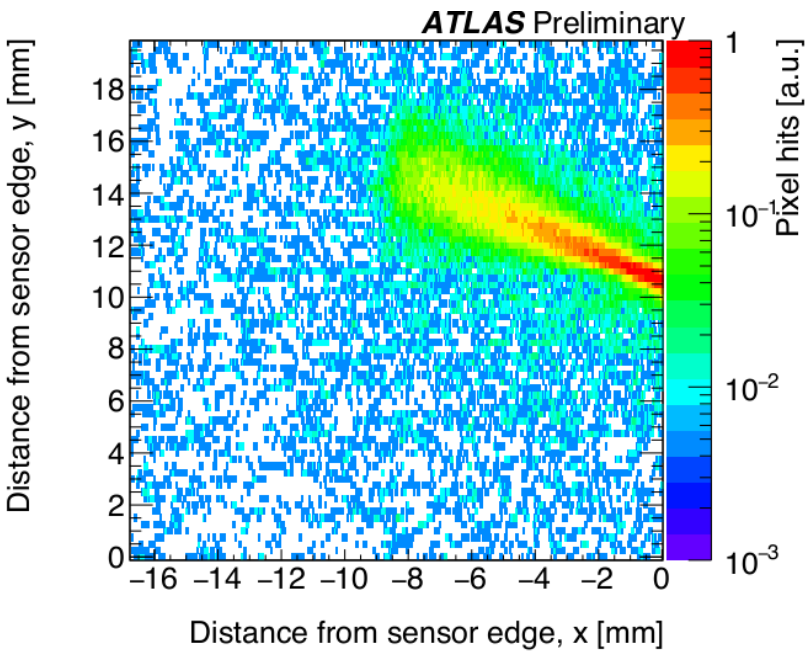
AFP detectors took high-μ data during LHC ramp-up:

- 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 $0.01 < \mu < 0.03$
- after MD4 (?)





AFP 0+2 was installed ...

... successfully took data ...

... and is ready for 2+2 phase!

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