ATLAS Forward Detectors

Workshop on Forward Physics and QCD at the LHC, the Future Electron-Ion Collider and Cosmic Ray Physics

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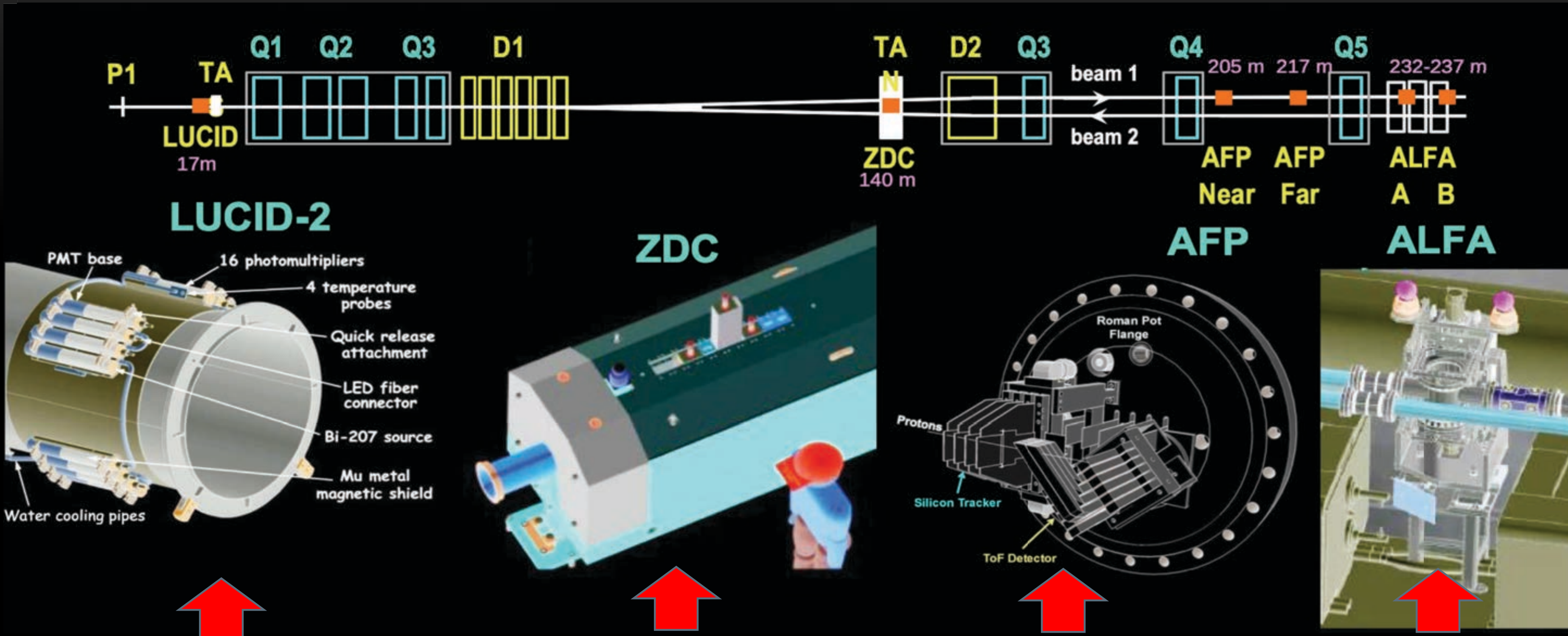
The ATLAS Forward Detector System



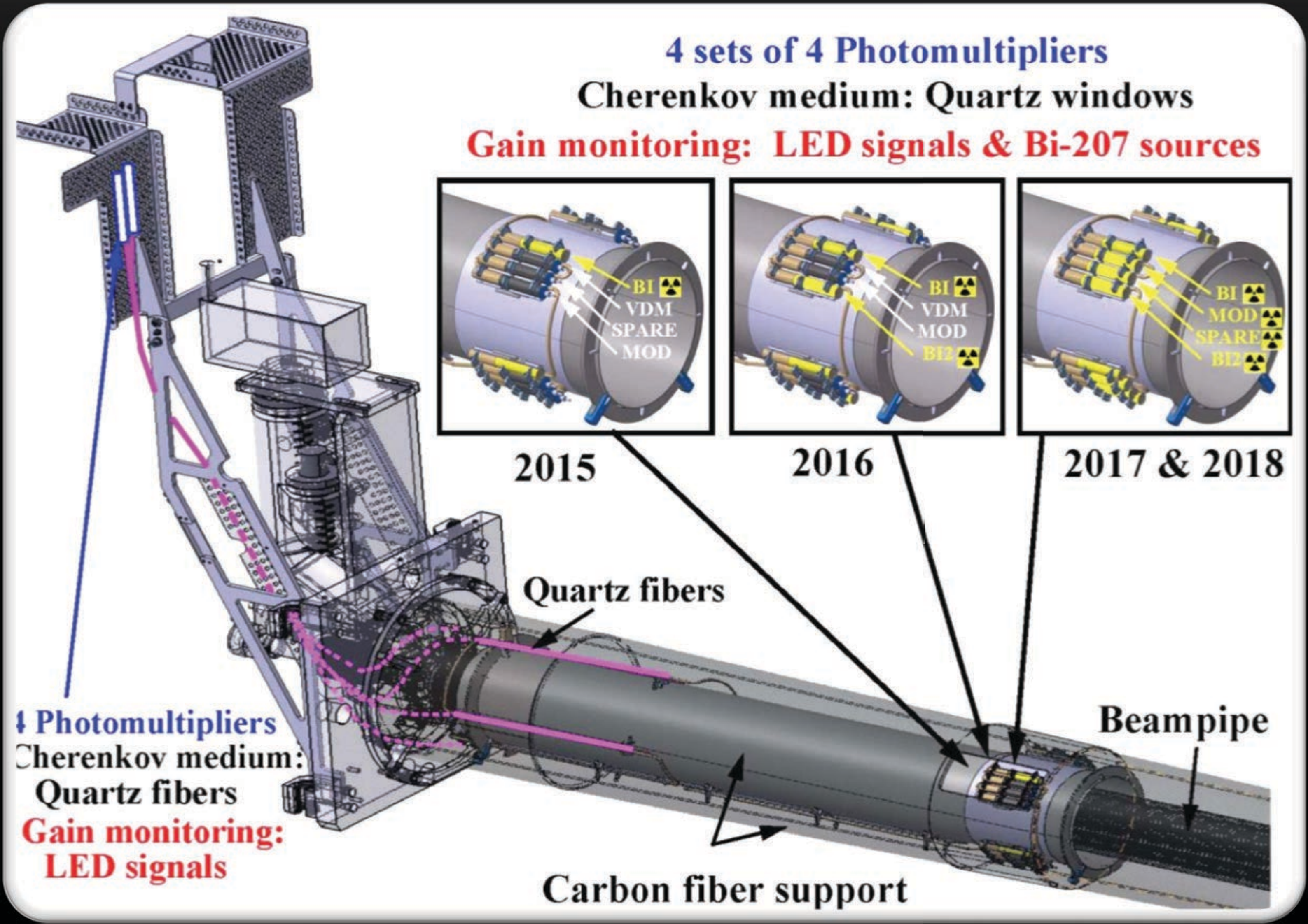
- *Offline lumi monitor*
- *Online lumi monitor*
- *Bunch-by-bunch luminosity*

- *Very forward neutral detection*
- *HI Centrality*
- *Ultra Per. trigger*
- *Lumi monitor*
- *Etc.*

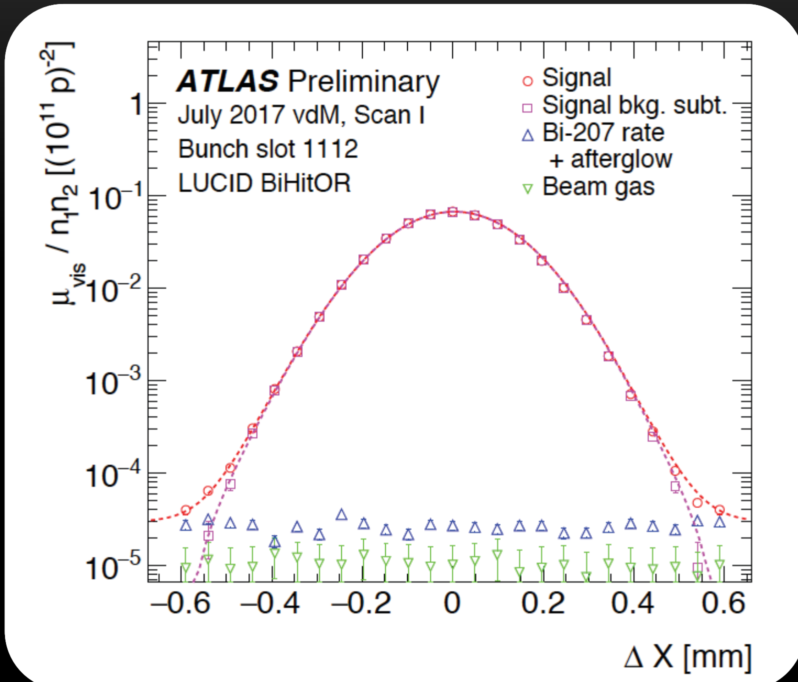
- *Central excl. production*
- *Anom. quartic gauge couplings*
- *Single diff.*
- *BSM, etc.*

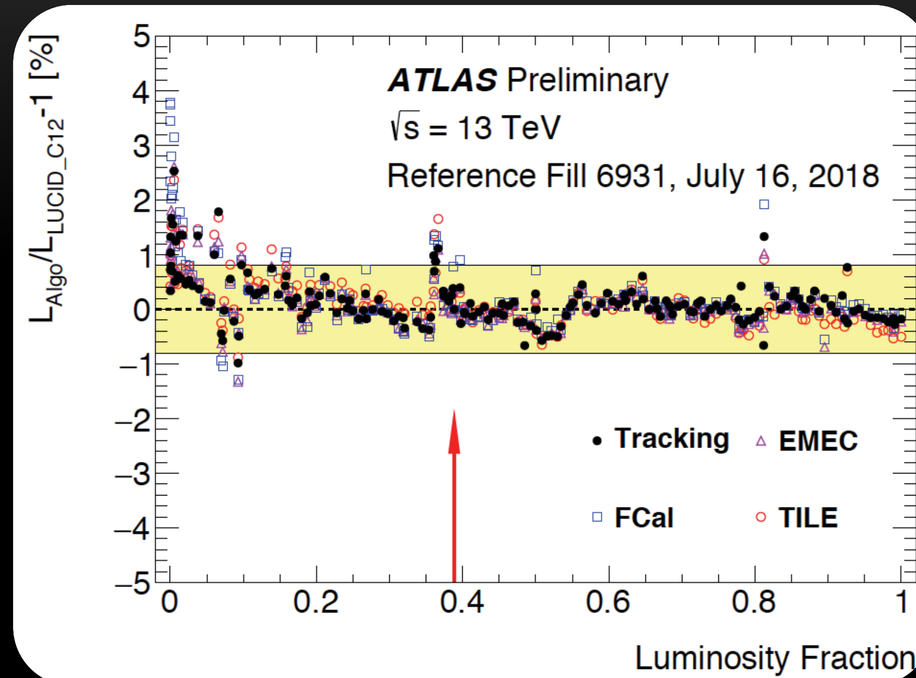
- *Elastic p-p x-sec.*
  - σ_{tot},
  - *B (diff x-sec slp)*
  - ρ *(Re/Im el. Sct x-sec in fwd dir.)*
- *Diff. physics*
- *BSM, Etc.*

LUCID-2 (JINST. 13 PO7017 2018)



LUCID Luminosity Measurement

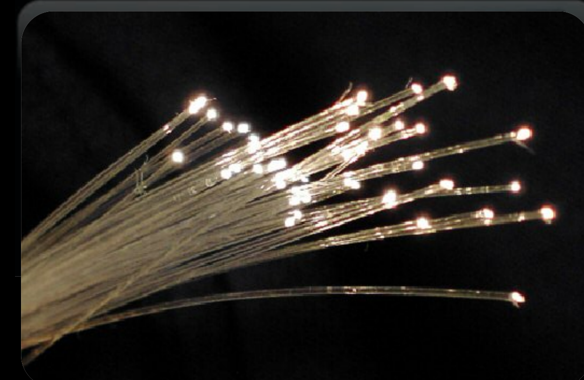


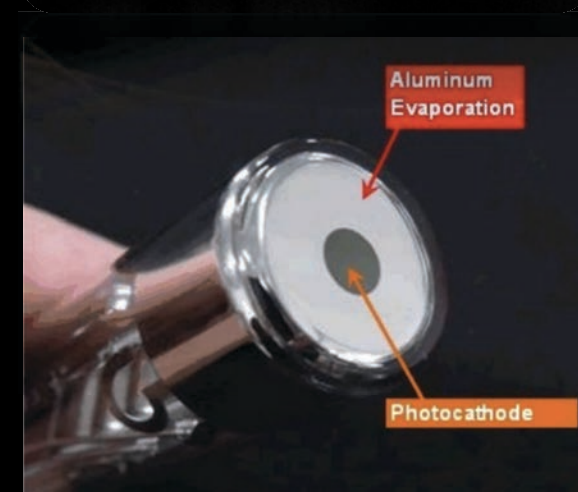


- *Absolute calibrations via yearly Van de Meer scans*
- *Total luminosity uncertainty (RUN-2)*
  - *2.1% (2015+2016) - (BiEventORA & BiHitOR)*
  - *2.4% (2017) – (BiHitOR)*
  - *2.0% (2018) – (C12 single PMT)*

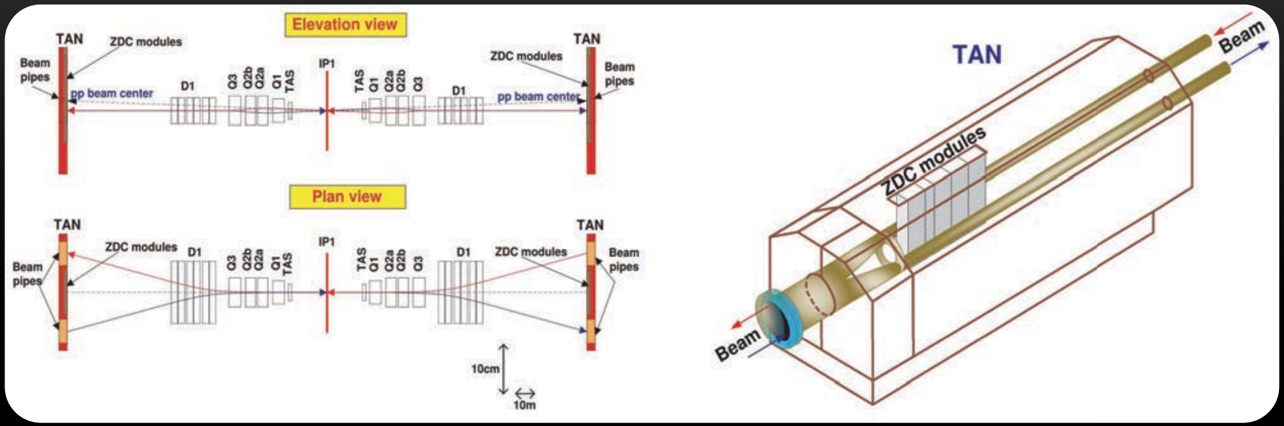
LUCID Run-3 & Beyond

- *RUN-3 –radiation damaged PMTs + bases replaced*
  - *New PMTs and bases will be inserted for RUN-3*
- *LUCID at HL LHC (Run-4)*
  - *For the HL- LHC (run 4) the present standard PMTs will saturate (have HITS in every bunch crossing) and cannot be used.*
- *New detector being developed (LUCID-3) for Run-4. Two options being pursued*
  - *Quartz fibre bundle "calorimeters"*
  - *Modified PMTs with a smaller acceptance*

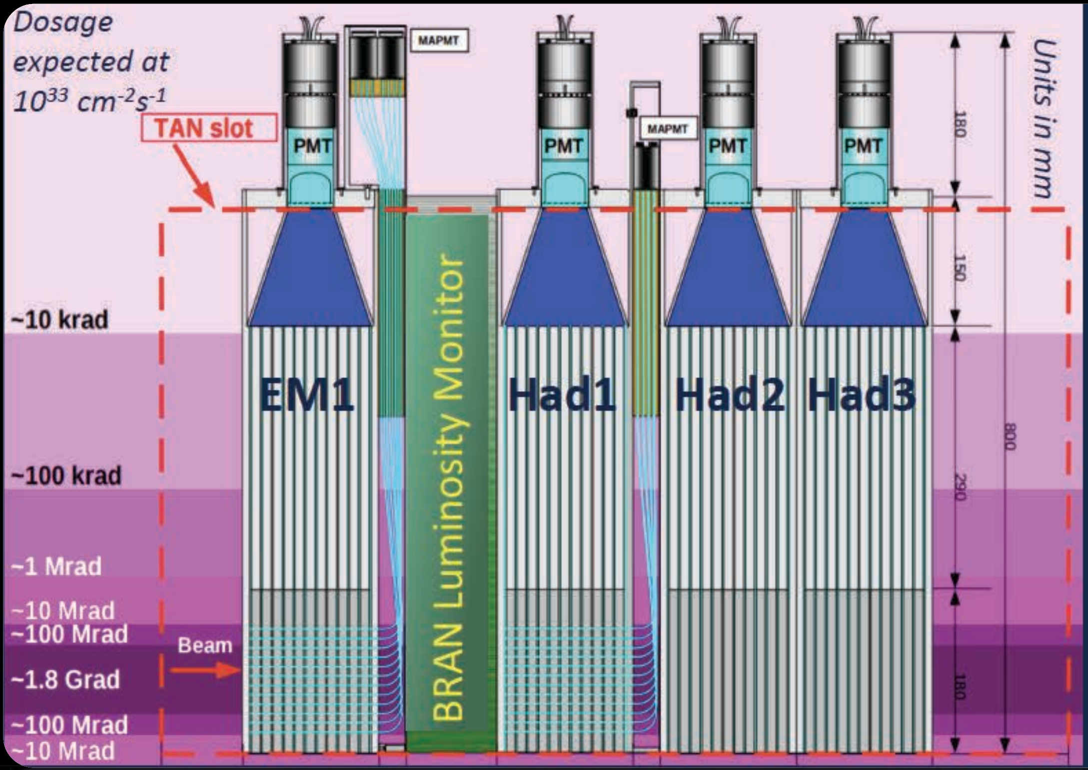




The ZDC



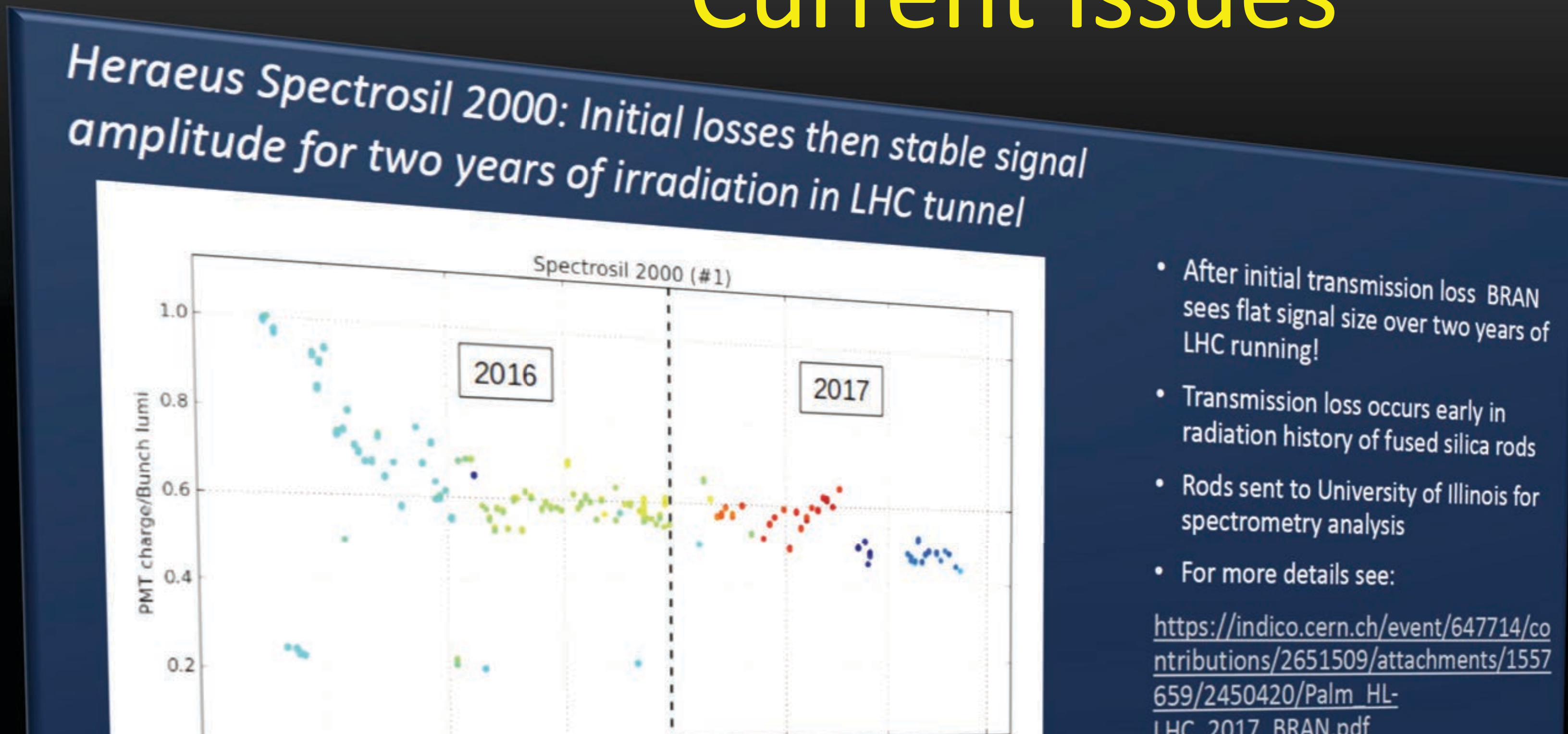
± 141 m
from IP
$\eta > 8.3$



- Tungsten absorbing, fused quartz sampling calorimeter
- Four independently read out modules along each ATLAS arm
- 1.1 λ_{int}/module
- Only used during heavy ion running
  - Measures event-by-event impact parameter for Pb+Pb collisions
  - Provides triggers for ultra peripheral collisions
- Resolution for single spectator neutrons: ~ 14-17%
- Sits in extremely high radiation area
  - Shower max: ~18 Grad/year (*pp* running)

Slides from Peter Steinberg's Talk at CALOR 2018, May 21st 2018

Current Issues

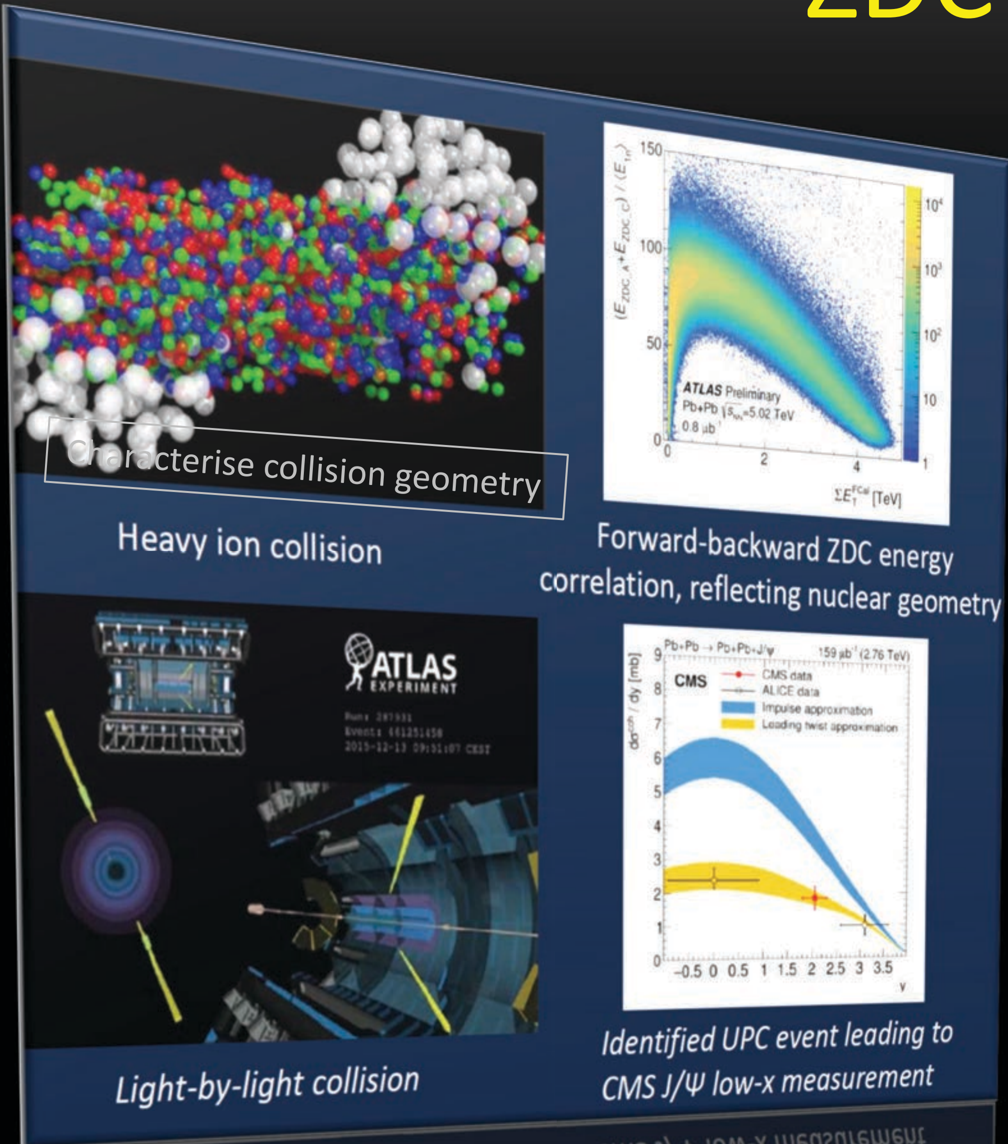


2010-12 pp, pPb, PbPb running

- *Radiation levels experienced by ZDC are challenging ~ 18GRads/yr in p-p running! Irradiation studies continue.*

Slides from Peter Steinberg's Talk at CALOR 2018, May 21st 2018

ZDC the Future



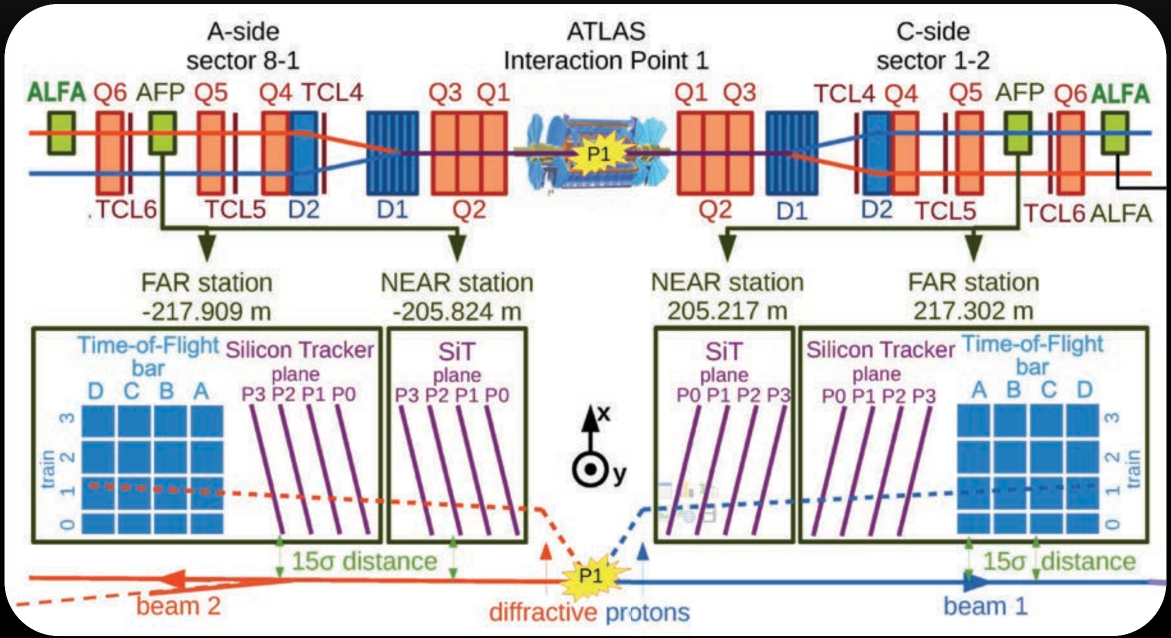
- *pp* luminosity (10^{34} cm^{-2} s^{-1})
  - Run 3: Increases by 2 x
  - Run 4: Increases by 5-7 x
- Heavy ion luminosity increases similarly:
  - Nominal *p*+Pb: 10^{31} cm^{-2} s^{-1}
  - Nominal Pb+Pb: 10^{28} cm^{-2} s^{-1}
- Crossing angle change during Run 4 (HL-LHC) causes:
  - ZDC to move closer to the IP (141 m to 126 m)
  - ZDC transverse width to shrink from 100 mm to 60 mm

The Physics

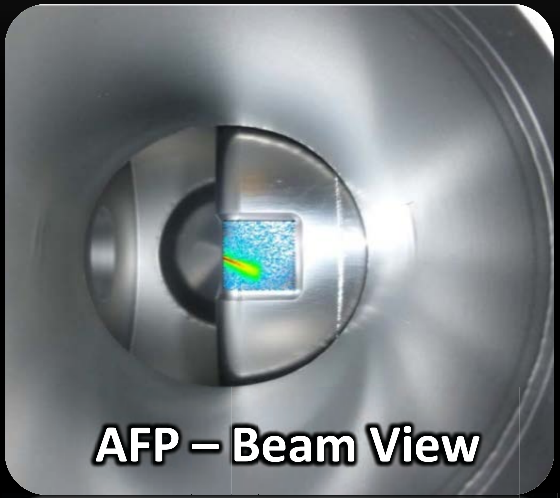
The Changes

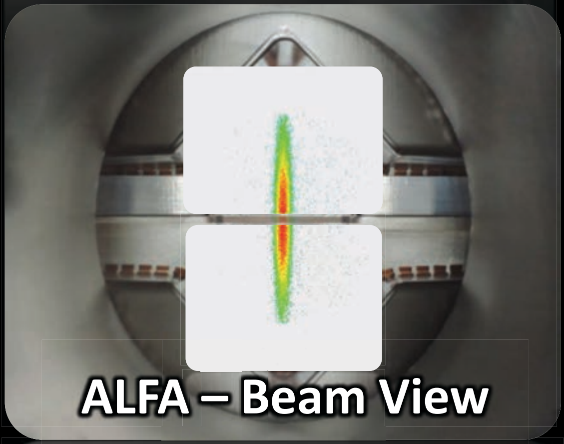
Slides from Peter Steinberg's Talk at CALOR 2018, May 21st 2018

ATLAS Roman Pots (ARP) – AFP + ALFA (Special Runs)

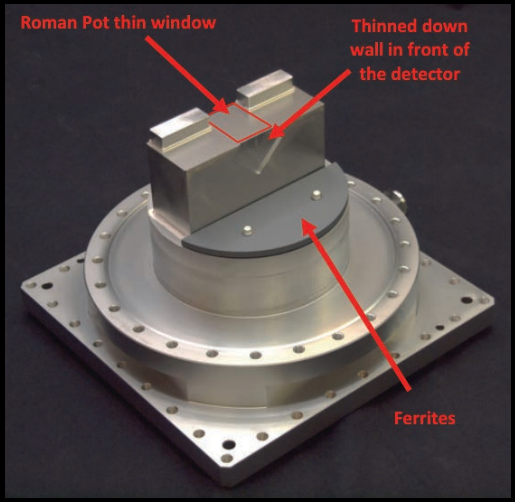


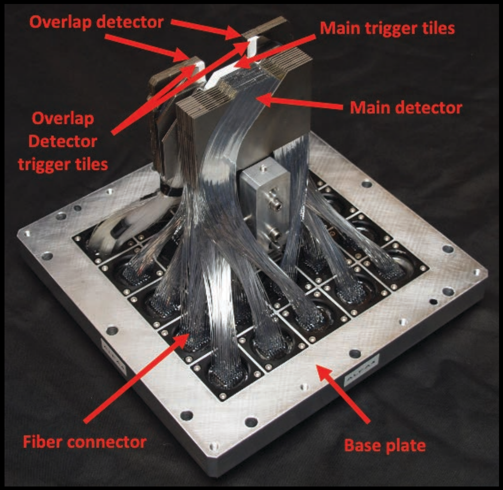
- *ALFA (p-p total cross-section + abs. lumi) – stations at ±237m & ±245m needs special (low-μ) highβ* beam optics- vertical RP motion*
- *AFP (Exclusive diffractive physics) – stations at ±205m & ±217m – data taking in standard ATLAS running – horizontal RP motion.*

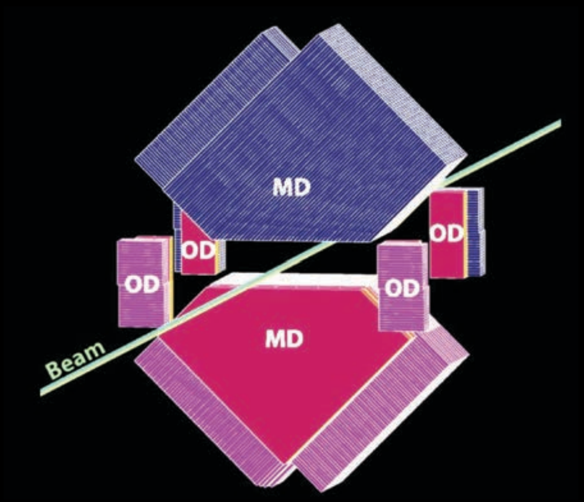




ALFA - Detector



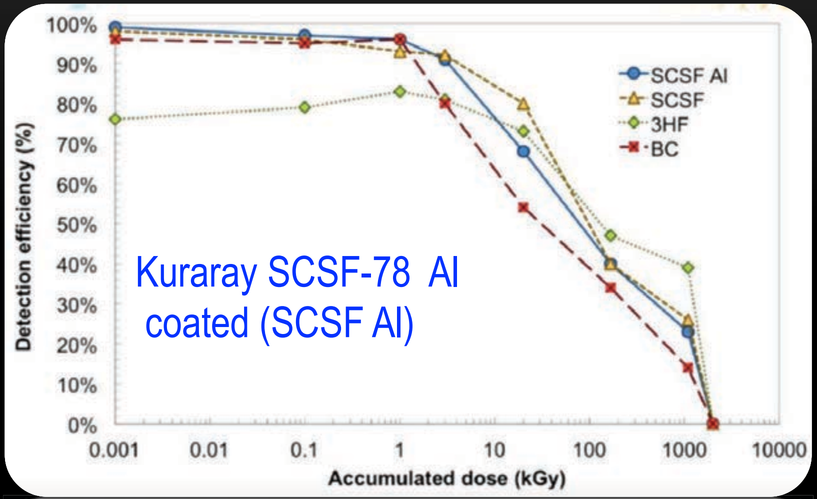


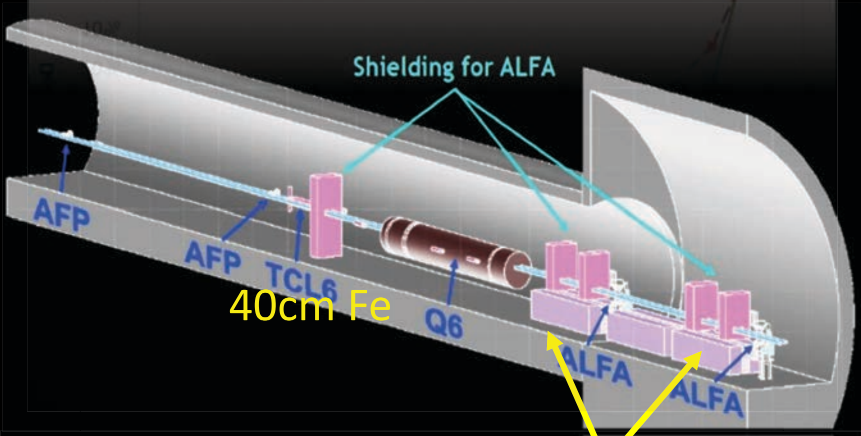


- *ALFA's tracking detector is designed to measure elastic proton scattering in the very forward region (10.6 <|η|<13.5) at very small angles(~μ-rad) down to Coulomb-Nuclear Interference region*
- *The tracking detector:*
  - *Main detectors (MD) 2 x 10 layers of 0.5 x 05 mm^2 square fibres*
  - *Read out by Multi-Anode-Photomultiplier with 64 channels*
  - *Light Yield 4-5 photoelectrons/fibre, measured resolution ~35 μm*
  - *Special overlap detectors (OD) to measure precisely the distance between the upper and lower scintillator detectors.*

Key ALFA Challenge- Radiation Damage

- *The ATLAS RP rad. environment is made of a wide spectrum of particles from the interaction of off-momentum protons.*
  - *During normal operation, ALFA ScjFis are exposed to doses of ~100 Gy/yr.*
  - *AFP's installation (2016) & TCL6'* consequent closure made it worse.*
- *Rad. hardness of ALFA components was the main RUN-2 issue*
  - *5 shield walls were installed in each arm to reduce expected dose rise.*
  - *Rad. tests of SciFi (PS IRRAD1 fac.) and electronics (CHARM fac.) were made*
  - *The acquired rad. damage in Run-2 indicate a max. dose of ~20 Gy in the electronics & ~2.5 kGy in the SciFis*

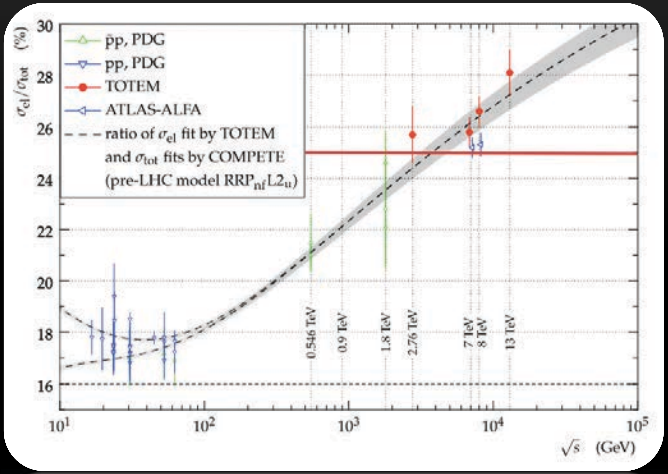


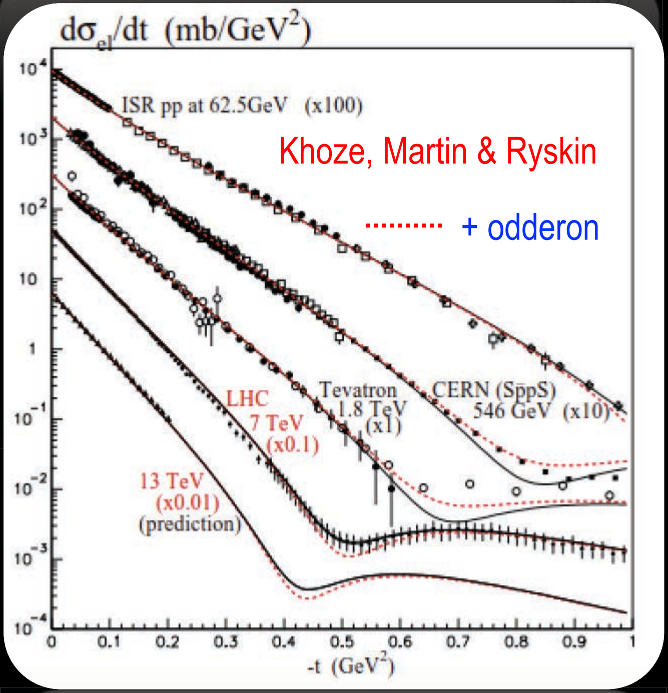


*Target Collimator Long 6

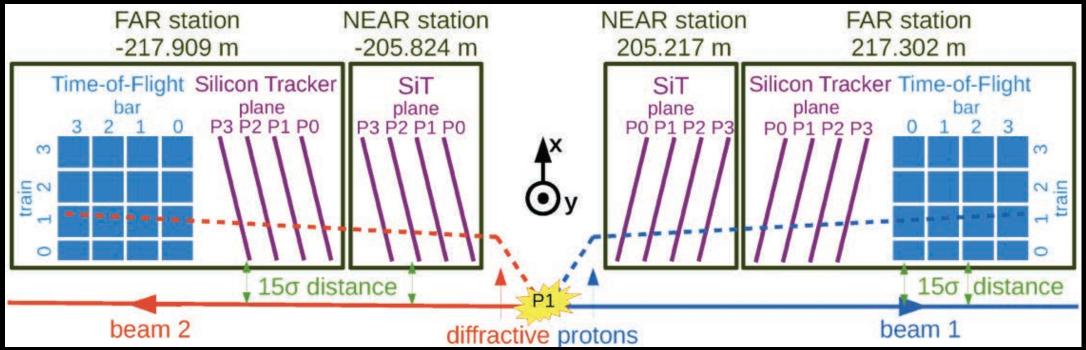
ALFA Run-3 Physics Program

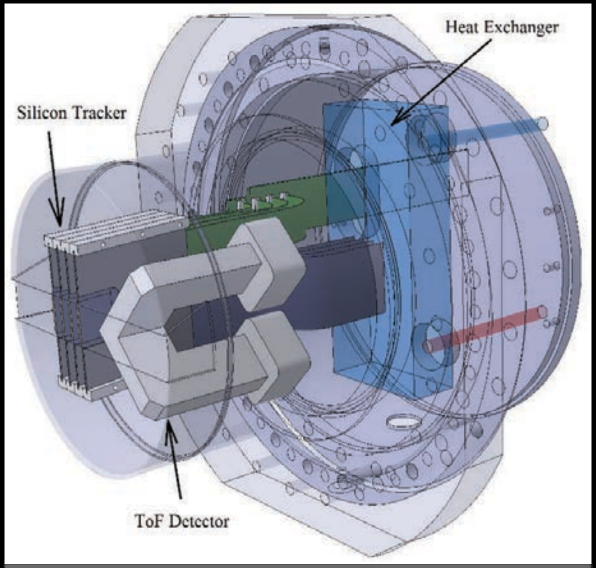
- *Measurement of total cross- section at 14 TeV*
- *Measurement of rho at 1 more energy: a lot of interest on this after TOTEM recent 13 TeV results*
- *Measuring in the "dip" region of the differential elastic scattering*
- *Diffractive physics at beta*=90m (search for exotics, Glueball, Odderon)*
- *AFP alignment (to be better investigated/quantified)*
- *HL- LHC – will beta* runs be possible?*

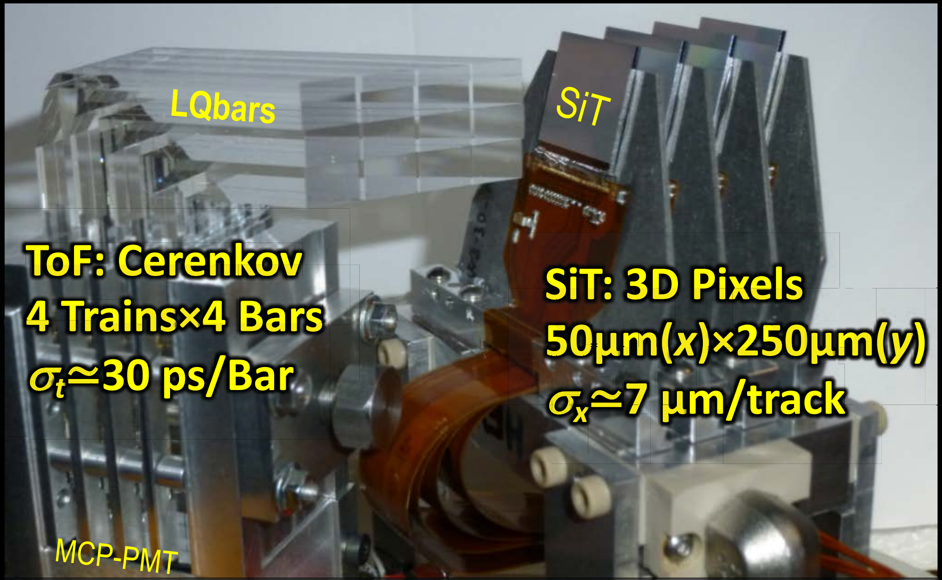




AFP- Status



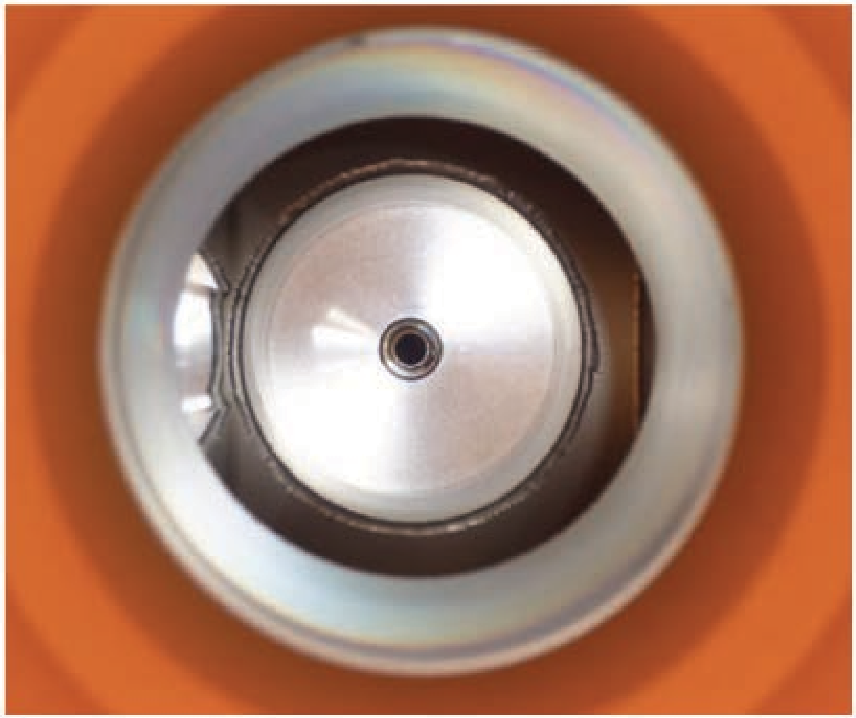


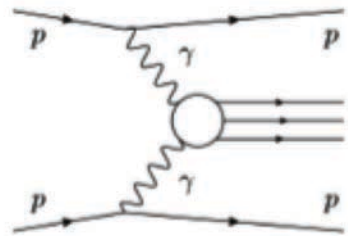


- *AFP fully integrated into ATLAS TDAQ system and able to deliver first level triggers within the 85 bunch crossing latency (fast air-core cables) according to field-programmable criteria.*

Acceptance

Advantages of Roman Pot Technology





$$m = \sqrt{s\xi_1\xi_2}$$

ξ *is fractional momentum loss of Scattered proton*

Acceptance

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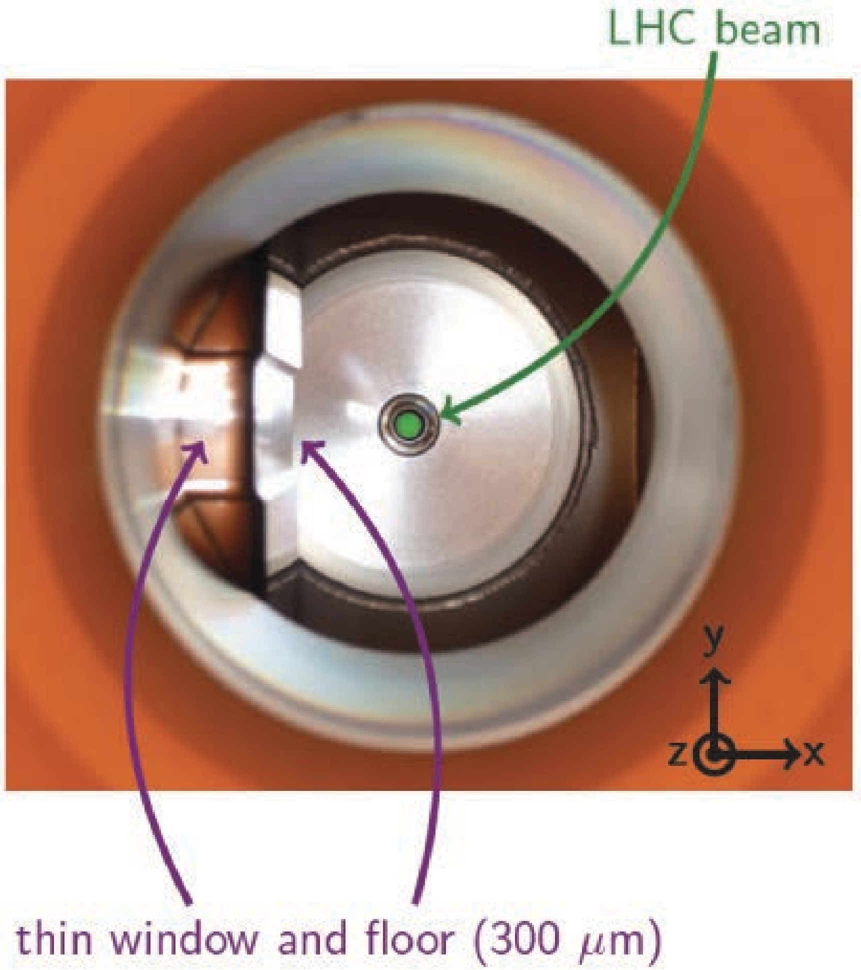
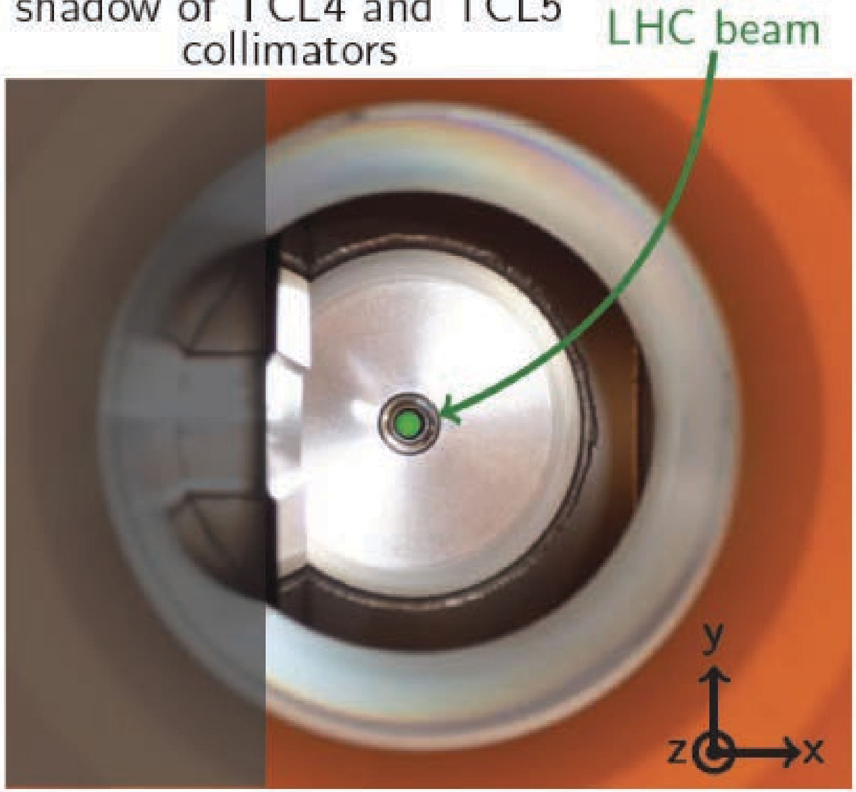


Acceptance

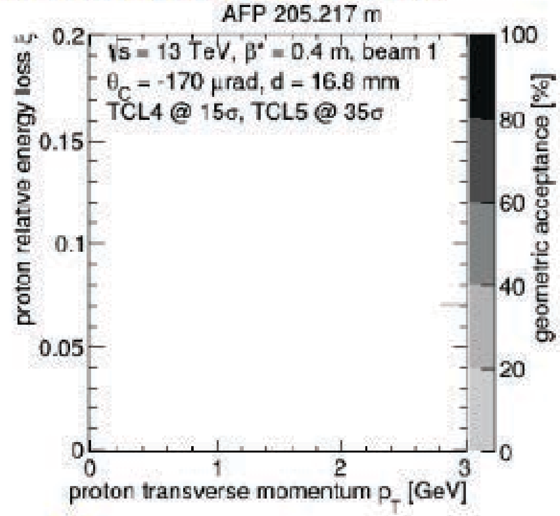
Advantages of Roman Pot Technology

shadow of TCL4 and TCL5 collimators

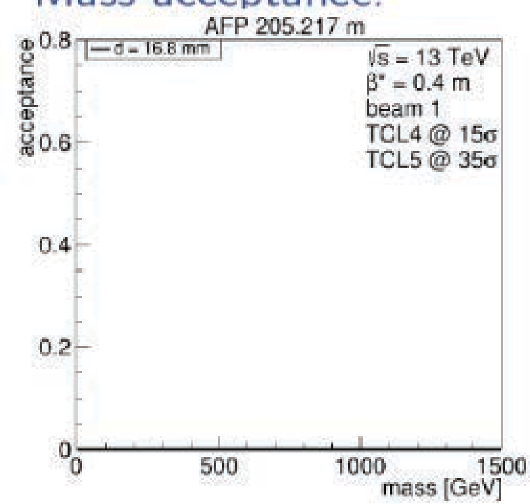


thin window and floor (300 μm)

Geometric acceptance:



Mass acceptance:

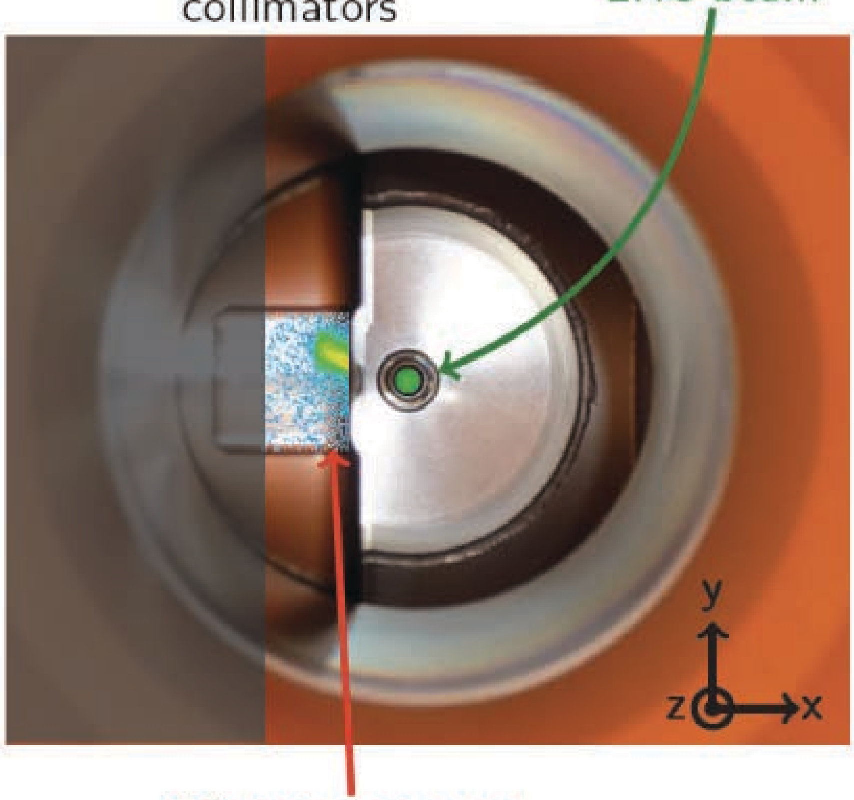


Acceptance

Advantages of Roman Pot Technology

shadow of TCL4 and TCL5 collimators

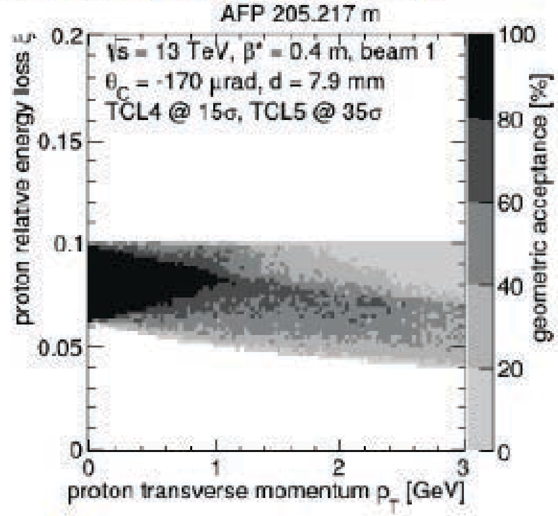
LHC beam



diffractive protons

thin window and floor (300 μm)

Geometric acceptance:



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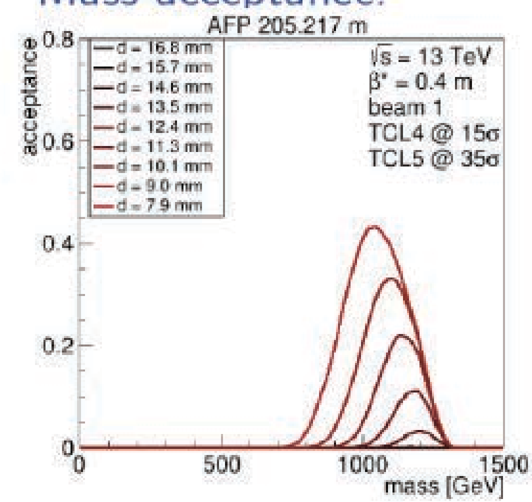

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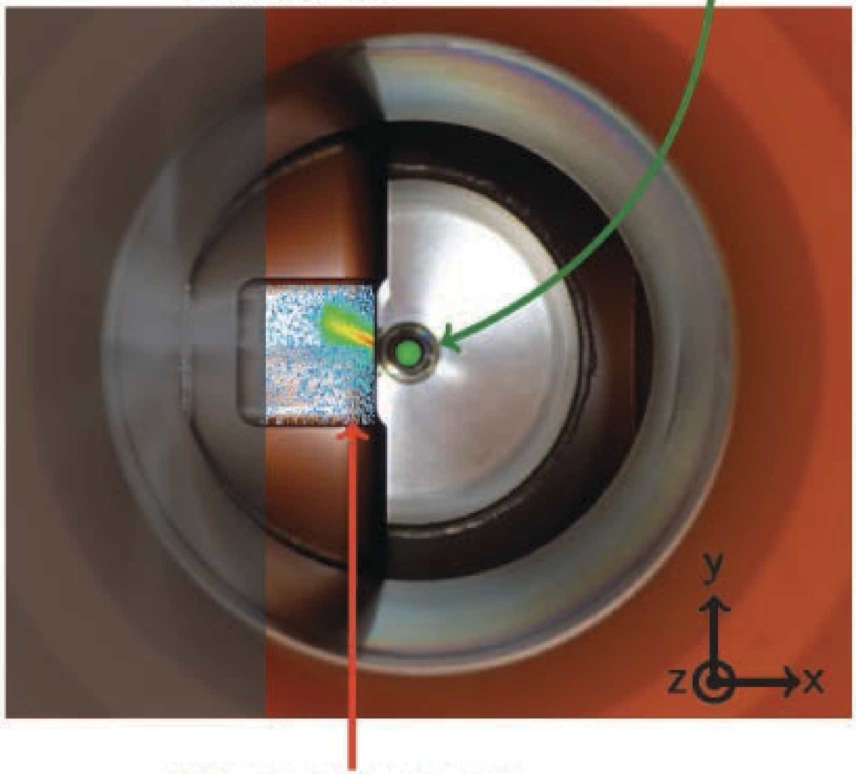
Advantages of Roman Pot Technology

shadow of TCL4 and TCL5 collimators



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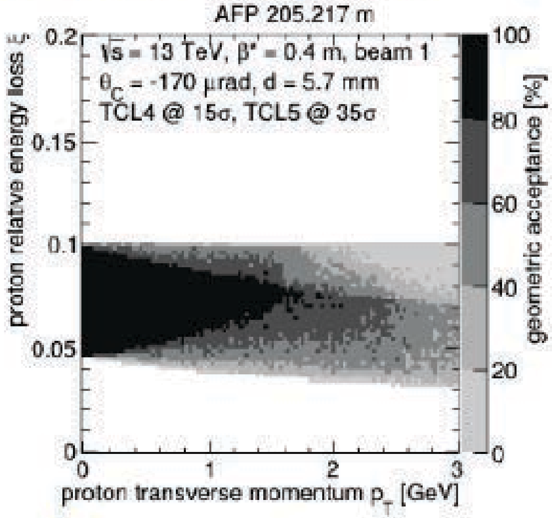

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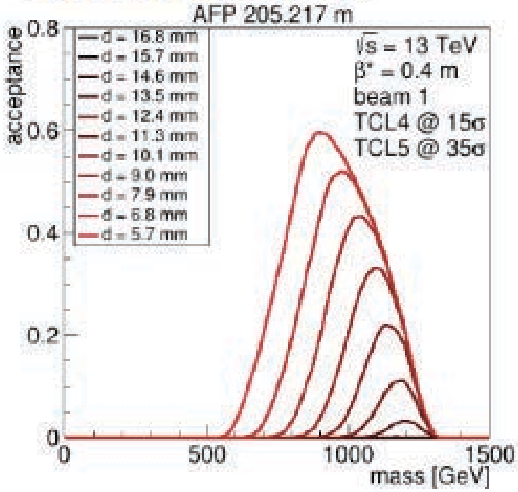
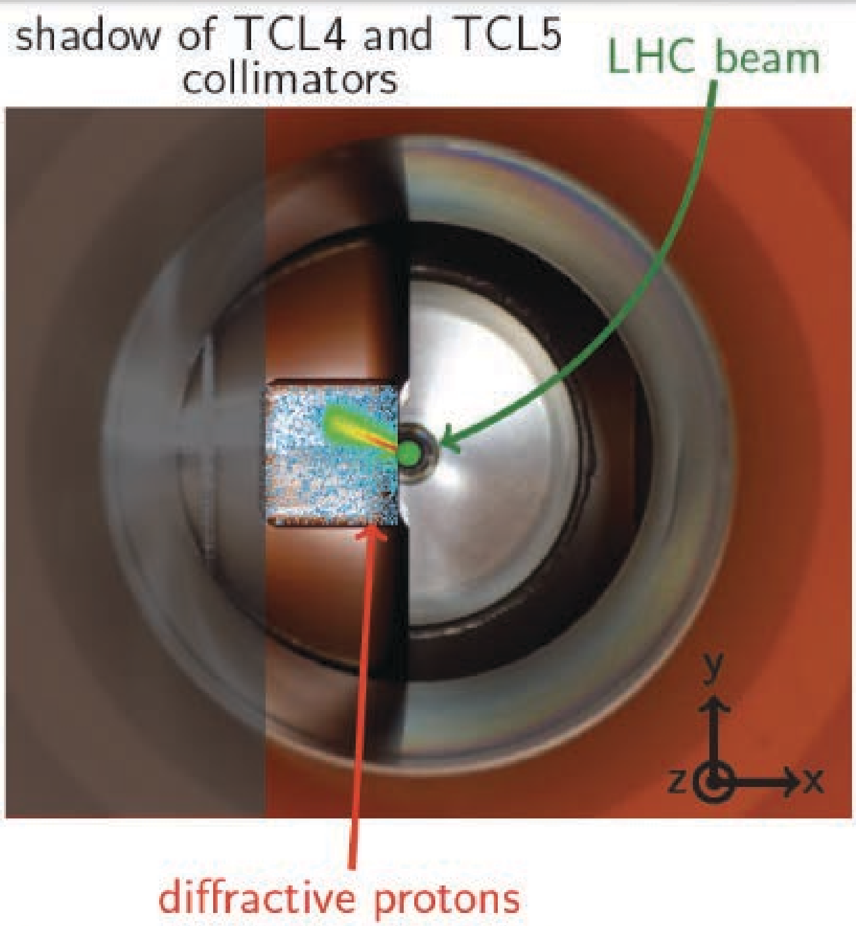


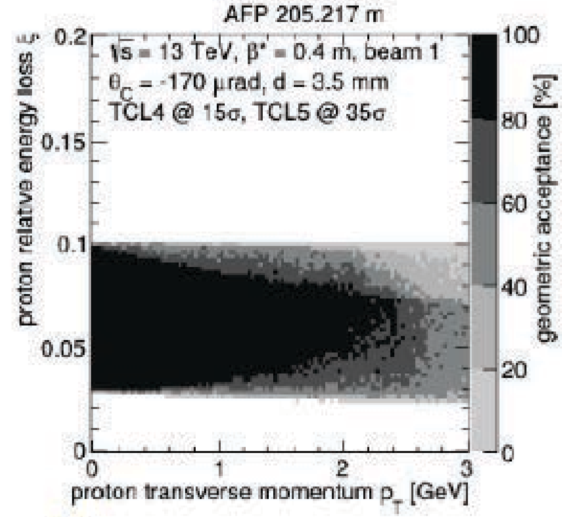
Acceptance

Advantages of Roman Pot Technology

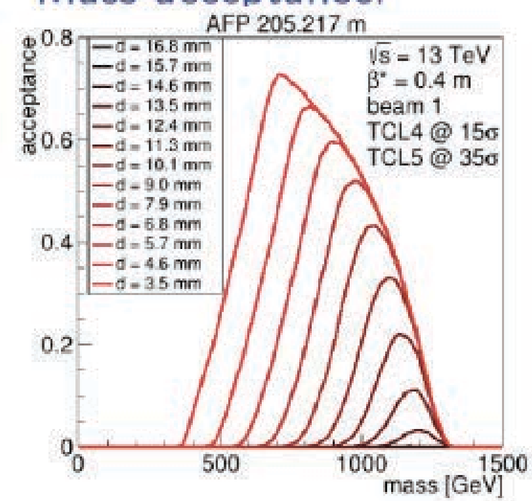


thin window and floor (300 μm)

Geometric acceptance:



Mass acceptance:

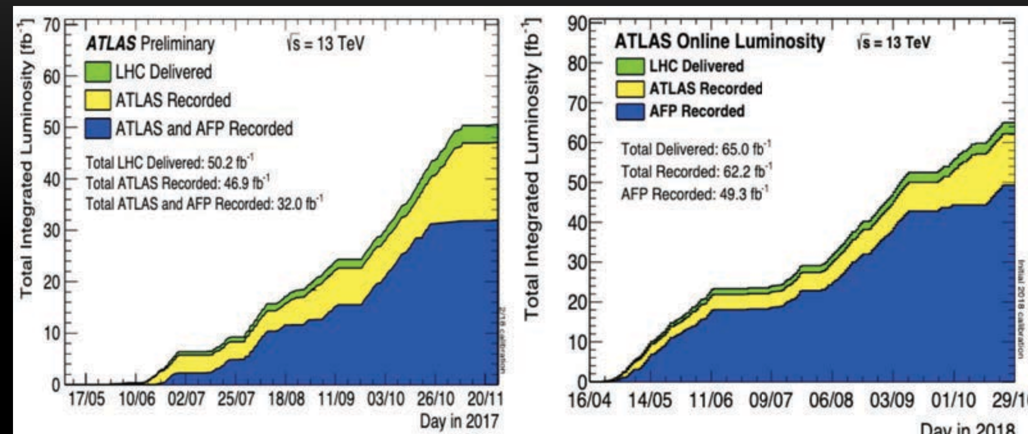


Run-2 Operation of AFP Detector

2017

- $\sqrt{s} = 13$ TeV, $\beta^* = 0.3$ and 0.4 m
- Full system ready
- Single and double tagged events
- Data taken during BBA*:
  - two runs
- Data taken during special runs:
  - $\mu \sim 0.05$:
    - int. lumi.:~65 nb^{-1}
    - main goal: soft diffraction
  - $\mu \sim 1$:
    - int. lumi.:~640 nb^{-1}
    - main goal: low-p_T jets
  - $\mu \sim 2$:
    - int. lumi.:~150 pb^{-1}
    - goals: hard diffraction
- Data taken during standard runs:
  AFP was inserted on regular basis, usually few minutes after stable beams were declared

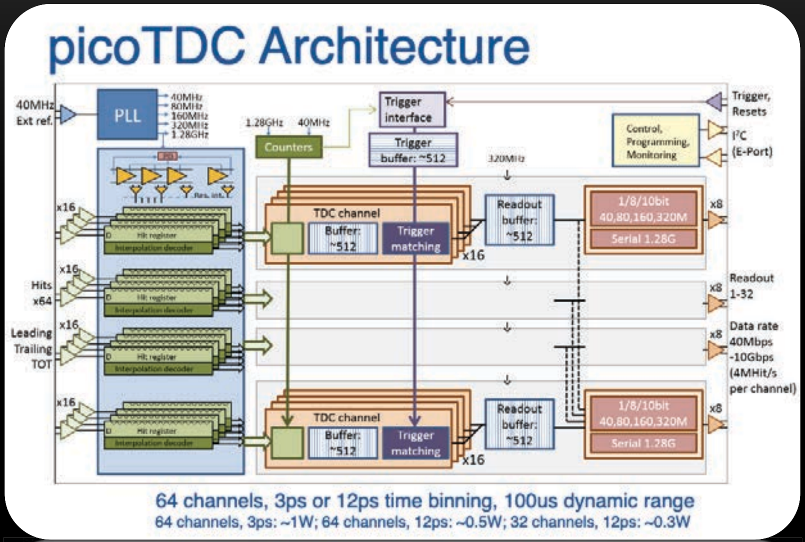
* Beam based alignment

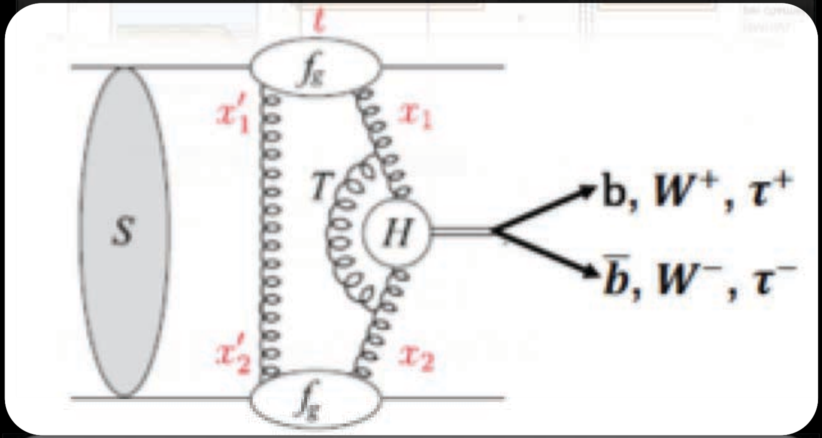


- *In 2016 AFP one arm installed, only inserted during special low lumi runs*
- *AFP took data at full lumi In 2017 & 2018 – DAQ problem nixed 2018 data.*
- *OPs at high-lumi caused rad. damage to Si sensors (annealing with no beam)*
- *ToF system (to reduce pileup bckgrnd) 2017: low eff. but good resolution (σ_t =20-25 ps/p)– HV problems in 2018*

AFP in LS2 and the Future

- *LS2 work for Run-3*
  - *SiT Refurbishment*
  - *TDAQ upgrades – to avoid data loss of 2018, etc.*
  - *ToF improvements: glue-less LQbars, long lived MCPs (ALD coating), picoTDC (σ_{TDC} from 14ps → ~1ps)*
- *AFP at HL-LHC – 3000 fb^{-1} by late 2030s?*
- *Physics motivation – eg exclusive higgs production*
  - *High mass resolution*
  - *B-bbar mode*
  - *0++ confirmation + CP structure*
  - *Needs stations at ±420m*





Summary

- ***LUCID:***
  - *Cause of “dying Lumi PMTs” found and remediation in progress for Run3*
    - *Bi sources give superbly monitored Lumi performance*
  - *Planning for HL-LHC …*
- ***ALFA:***
  - *Preparing for special runs at RUN-3*
    - *14 TeV elastics at large-β* & Odderon related studies , etc.*
  - *No showstoppers; but worries about rad-hardness*
- ***AFP:***
  - *On track for run 3*
    - *Several items have to be monitored - ToF: LQbars, MCP-PMTs etc.*
    - *Significant work on SiT, Trigger, DAQ, DQ, check-lists*
  - *Planning for HL-LHC*
- ***ZDC:***
  - *No showstoppers; solution at hand to rad-hardness concerns*
  - *Refurbishment for RUN-3, planning for Run-4*