ALFA detector before LHC Run 2

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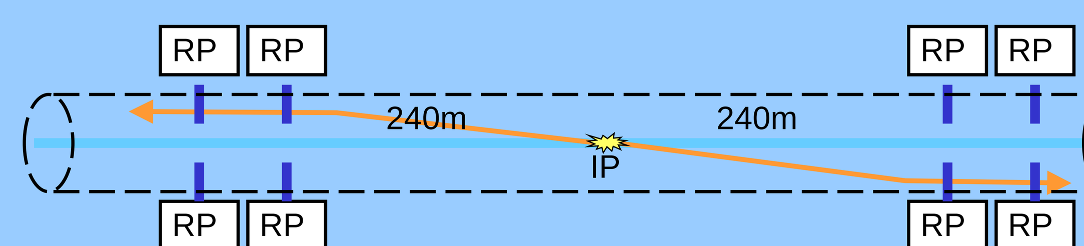
The ALFA detector system (Absolute Luminosity For ATLAS) is part of the ATLAS experiment at the LHC. The ALFA is a tracking detector designed to register protons which are scattered in the very forward direction – scattering angle of order μrad. This allows investigation of elastic scattering in the region of Coulomb-Nuclear interference and to some extent also diffraction processes.

ALFA system

The system consists of four stations with detectors in an upper and lower Roman Pots (RP). In total, 8 ALFA detectors are used in the system. Two stations are placed on each side of the ATLAS interaction point at a distance about 240 m. The distance between two stations was approximately 4 m during Run 1.



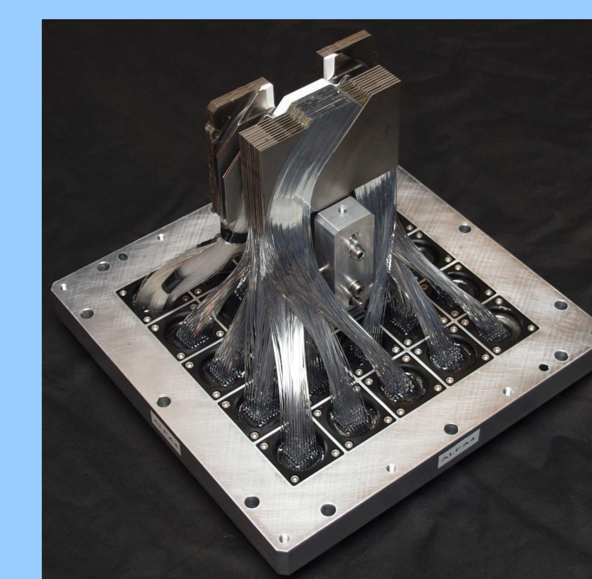
ALFA tracking detectors

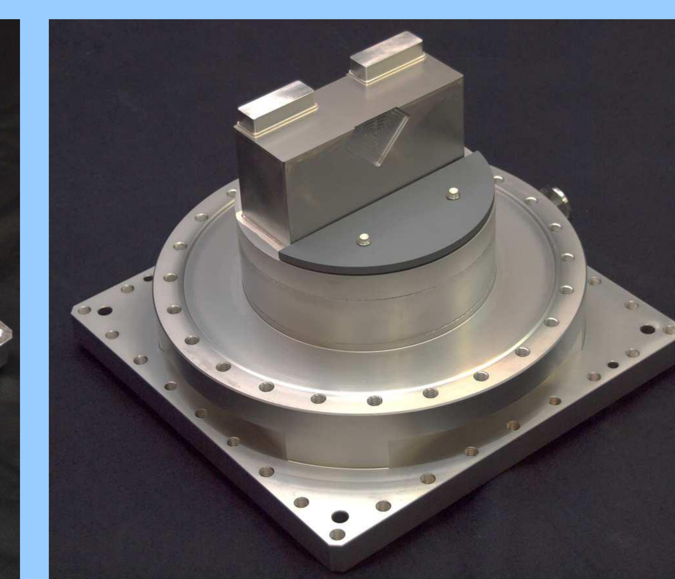
Main Detector: 20 staggered layers of square-shaped 0.5mm thick scintillating fibres, 64 fibres in each layer. Fibres inclined by +45° (10 layers) and -45° (10 layers) with respect to vertical direction. Resolution of MD of about 30μm thanks to staggering of the layers.

Overlap Detector: fibres arranged horizontally measuring the vertical coordinate only with a precision of 100μm.

MD and OD readout by Multi-Anode Photo-Multiplier Tubes.

Triggers: 3mm thick plastic scintillator trigger tiles have the shapes of the corresponding sensitive areas of MD and OD.





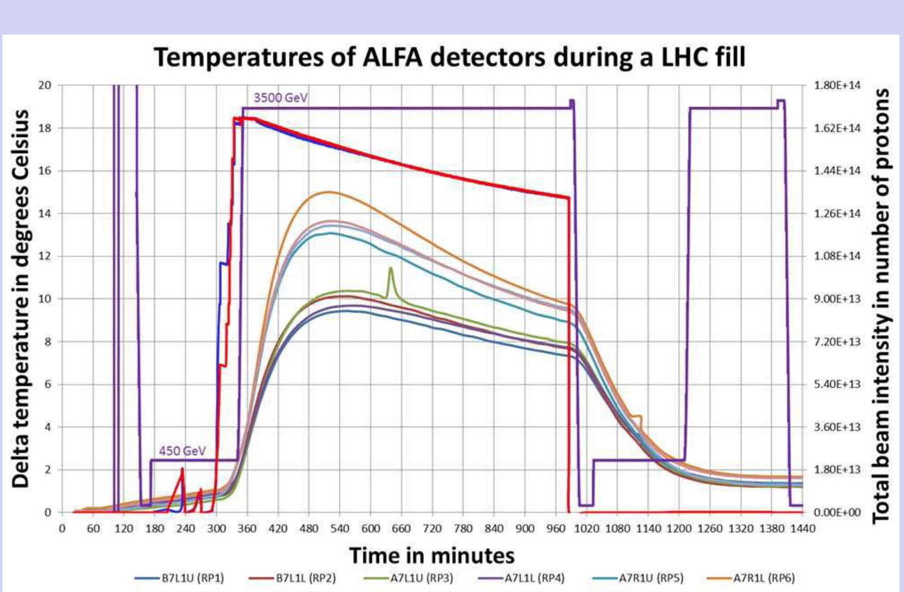
Roman Pot in Run 1

The ALFA detectors are installed in a secondary vacuum inside the RP for safe separation from the ultra-high vacuum of LHC. The RP, see the photo on the left, consists of a cylindrical pot, a cavern for the detector and two flanges. The cylindrical flange is connected to the bellow and allows the movement of RP. The squared flange is used to fix the detector base plate. The RP is made of stainless steel. The side walls are 500μm, bottom window is 200μm thick. The RP can approach vertically the LHC beam to milimeter distance. Semi-circular ferrite tile attached to the bottom of the cylindrical part.

Detector heating in Run 1

There is a semi-circular ferrite tile attached to the bottom of the cylindrical part of RP – see the above panel figure. It aims to absorb the electro-magnetic power of the RF wake field caused by repetitive passing of the proton bunches by the RP. The field resonates in the cavity where the RP are installed. The resonances are origin of the RF losses and the power deposition to the RP and heating up the detector.

During LHC Run 1 fill the estimated power deposit was 10 W and the detectors were heated up to 45°C. The titanium substrates and the fibres glued on them have different thermal expansion coefficients and the resulting stress can destroy the assembly. Extrapolations to Run 2 indicated a power deposit of up to 80 W in case of extreme beam conditions. Therefore the main effort between Run 1 and Run 2 was dedicated to the heat protection.



Roman Pot in Run 2

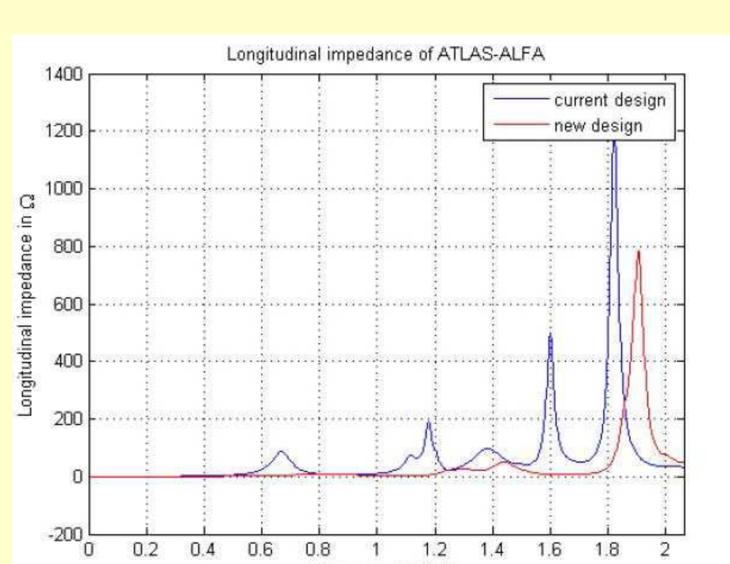
Measures to minimize the RF impact on the temperature:

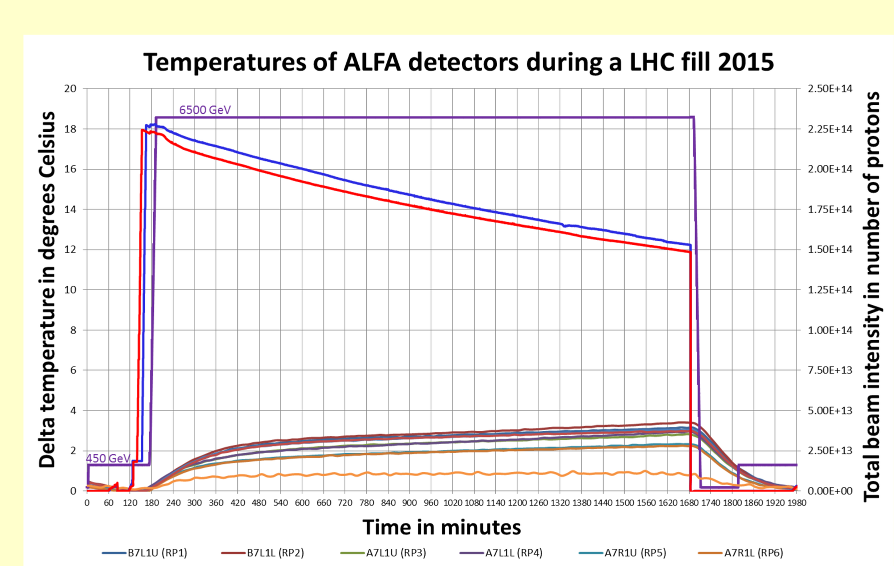
1. Reduce the cavity volume and RF power deposit by extending the RP by the RP-filler
2. Ferrites mounted at positions where the wake field is absorbed in more efficient way, location of the ferrites far from detectors reduce the heat transfer to the detectors
3. Heat distribution system made of thin copper installed inside the RP
4. Air cooling intensified by additional fans and a better streaming to the RP flanges

RP-filler

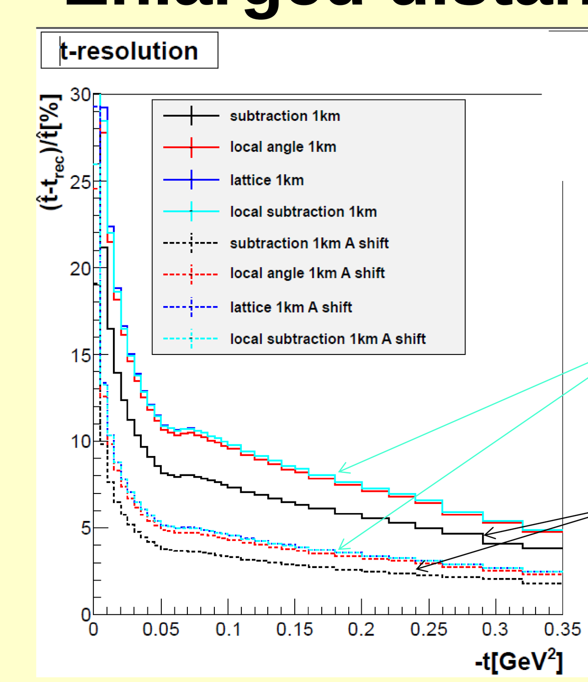
The RP-filler is made of titanium and connected by conductive copper-beryllium springs to the original RP. Thanks to the RP-filler all resonance lines between 0.6 GHz and 1.8 GHz are strongly reduced. Those below 1 GHz, which have the strongest coupling to the beam spectrum and are most dangerous for heating, disappeared completely.

The semi-circular ferrite tile at the RP bottom has been replaced by ring of six individual pieces located on the flange. At the new positions the heat is emitted to the flanges where the air stream for cooling is circulating. After extensive lab tests, the stations were reinstalled in the LHC tunnel. The temperature increase in a high intensity fill is below 5°, far from the destructive range.





Enlarged distance between inner and outer stations



The outer stations were displaced downstream from their original positions. In this way the distance between inner and outer station was enlarged from 4 m to 8 m. The **angular resolution was improved by a factor two** what results in a higher precision of the derived proton momentum transfer.

Local angle methods resolution improved by a factor of 2, reason: larger distance (+6m) between stations, better local angle resolution.

Subtraction method resolution improved by by 80%, reason : larger Leffx.
(may be different for a different optics)

Trigger upgrade

Dead time reduced from 550 ns to 88 ns thanks to upgrades in the firmware of the MAROC chip of the front end electronics. It allows triggering and data taking with a bunch spacing down to 100 ns.
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Upgrade of the ATLAS Central Trigger Processor (CTP) brought a latency penalty 75 ns what increased the ALFA latency beyond the limits of the first level trigger (L1) budget. For compensation a new back-end trigger board was produced. It allows to bypass the standard trigger input stages and injects signals directly to CTP core. In addition, it replaces the NIM electronics used in the past for separation od MD and OD trigger signals and allows the monitoring of rates per bunch crossing.