PROCEEDINGS OF SCIENCE

ATLAS Roman Pots at LHC Run 3 – Detector Status

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The ATLAS Roman pot detectors, ALFA and AFP, are being prepared to take data during LHC Run 3. The paper presents the design of these detectors and their main physics goals. The changes that the detectors have undergone during LHC Long Shutdown 2 (2018 — 2021) are discussed together with the commissioning procedures prior to operations.

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1. Introduction

The ATLAS Roman Pots (ARP) are subsystems of the ATLAS Experiment [1] at the LHC. ATLAS has two sets of such detectors: AFP and ALFA. Their goal is to extend the physics reach of the main detector by measurements of intact protons scattered at very small angles. Both these systems use the Roman pot technique to perform the measurements inside the LHC beam pipe and are installed between other elements of the LHC accelerator, see Figure 1.

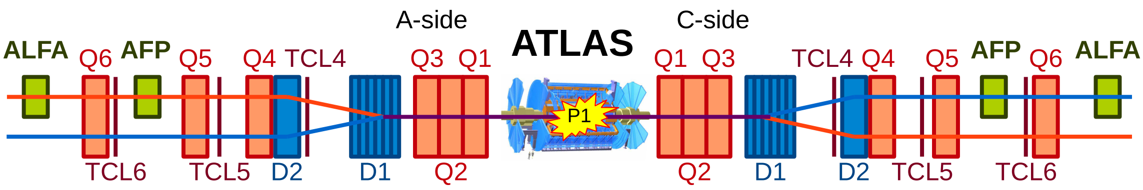

Figure 1: Overview of the ATLAS Roman pot system.

2. AFP Detectors

The AFP (ATLAS Forward Proton) detectors [2] are installed around 210 metres from the ATLAS interaction point, between the Q5 and Q6 quadrupole magnets. They use horizontally positioned Roman Pots, which allows them to register protons that lost some energy in the interaction and were deflected from the beam trajectory by the LHC magnets. AFP was designed to operate during standard LHC running to be able to study rare processes, for example photon–photon interactions.

The AFP system consists of four stations, two on each side of the interaction point (IP). Every station contains a tracking detector, which uses 3D silicon pixel sensors. Their goal is the measurement of the scattered proton trajectory. The information is then used for the kinematics reconstruction. The stations further away from the IP house also quartz-based Cherenkov time-of-flight (ToF) detectors. The time measurement can be used for the reconstruction of the longitudinal position of the interaction vertex, which helps to reduce the combinatorial background.

The AFP detectors were already operating during LHC Run 2 and allowed first measurements of photon-induced processes with proton tagging at the LHC [3]. However, the performance of the ToF detectors was not sufficient for a standard analysis [4] – their efficiency was below 5%. On the other hand, a very good time resolution of even 20 ps was achieved, and their usefulness for background reduction was proven.

During the LHC Long Shutdown 2, the AFP time-of-flight detectors underwent a major upgrade. Previously, they were fully placed inside the Roman pots within the so-called secondary vacuum. However, this caused problems with the operations of the photomultipliers, which were not designed to work under very low pressure. In the new out-of-vacuum solution, the radiators and light guides are placed in vacuum, inside the Roman pot, while the photomultiplier and all electronics are located outside. This is possible due to a quartz window installed on the Roman pot flange, see Figure 2. In addition, the photomultipliers were exchanged, and the quartz bars were replaced to new glue-less ones that will be able to withstand a higher radiation dose without efficiency loss. Also, the preamplifier system was changed from two-step to three-step.

Apart from the AFP ToF, all the AFP silicon sensors were replaced with new ones. The read-out system was also upgraded.

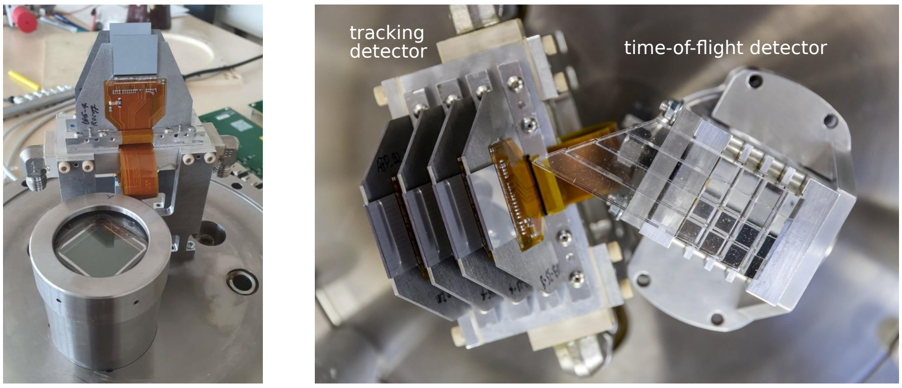

Figure 2: Photographs of the new ToF system with the out-of-vacuum solution. Left: photomultiplier behind the window is visible in the front, the silicon tracker in the back. Right: top view; the silicon tracker is on the left and the ToF detector on the right.

3. ALFA Detectors

The ALFA (Absolute Luminosity For ATLAS) detectors [5] are installed around 240 metres from the interaction point, behind the Q6 LHC magnets. The ALFA system consists of four stations located at 237 and 245 metres from the IP on either side. Each station consists of two Roman pots – one inserted from above and one from below the LHC ring plane. Each pot houses a detector built of 20 layers of scintillating fibres arranged in the UV geometry (consecutive layers are positioned at the alternating angles of ±45°).

Contrary to AFP, ALFA was designed to operate only during special LHC running, with reduced instantaneous luminosity and a dedicated setting of the magnetic fields of the accelerator magnets (machine optics). Special optics is characterised by a high value of the betatron function at the IP (β^*), which leads to a reduction of the angular divergence of the beams at the interaction point and an increase of their transverse size. Special optics allows detecting protons that were scattered at small angles, even if they did not loose any energy. In fact, the main goal of ALFA is the measurement of the elastic proton–proton scattering [6].

During Long Shutdown 2, no upgrades of the ALFA system were performed. However, the motherboards, responsible for reading out the photomultipliers, were suffering a large radiation damage accumulated over LHC Runs 1 and 2. In order to ensure smooth operations in future, the most damaged motherboards were replaced with spares.

4. Commissioning

There are several important points to consider when commissioning forward proton detectors. First, before any operation of the accelerator starts, calibration of the position of each station is performed so that they are properly positioned with respect to the centre of the LHC beam pipe. After the position calibration, the safety system (the so-called beam interlock) has to be tested.

The second crucial commissioning element is the calibration of the insertion of the Roman pots to ensure the safety of the accelerator. This is performed in a form of the beam-based alignment procedure. First, the beam is strongly trimmed to a pre-defined width using the LHC collimator system. Then, the Roman pots are slowly inserted towards the beam in small steps. The radiation behind the Roman pots, measured by the beam loss monitor (BLM) system, is carefully monitored. At some point, the BLM rates spike, indicating that the Roman pot bottom touched the trimmed beam. Since the width of the beam is known, the distance from the centre of the beam can be easily calculated.

Then, it is essential to ensure the proper timing of both the trigger signals and the detector readout. This is essential at the LHC, where only a small fraction of events is recorded. The timing-in procedure requires detectors to be inserted into the beam pipe, to be able to detect scattered protons, and the beams to contain isolated bunches, to be able to determine the necessary time shifts. Currently, both the ALFA and AFP detectors are ready for data collection in this respect.

At the time of writing these proceedings, the AFP detectors have already been commissioned and are taking data. It it planned that the ALFA system participates in special high-β^* runs in 2023.

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