Production and test of BI-RPC detectors for ATLAS Phase-2 upgrade

M. F. Perrone on behalf of ATLAS Muon Community[a,b]

[a]*Physics Department of Unical, Via Pietro Bucci, 87036, Rende, Italy*
[b]*Gruppo Collegato INFN di Cosenza, Via Pietro Bucci, 87036, Rende, Italy*

Abstract

The current Resistive Plate Chamber (RPC) system is undergoing a major upgrade [1], consisting in the installation of approximately 1000 RPC detector units in the innermost barrel layer of the ATLAS Muon Spectrometer. The goal of the project is to increase the detector coverage, currently limited to approximately 80%, and improve the trigger robustness and efficiency. The production of the gas volumes takes place in Italy, in Germany and China, while the readout panels in Cosenza and Hefei (China). The Italian collaboration is taking care of the construction and test of the chambers located in the large sectors of the ATLAS barrel (BIL). Here we present the state of the art of the production, certification and logistics related to all the components produced at the Italian sites, as well as the assembly line and characterization of the BIL chambers at CERN with cosmic rays. The certification results of the components produced are analyzed and discussed.

Keywords: RPC, Trigger, ATLAS

1. PURPOSE OF THE BI-RPC PROJECT

The main purposes of the project is to improve the performance of the stand-alone muon trigger, increase the acceptance (up to 96%) with a better coverage of the regions around the coils and supports of the barrel muon spectrometer magnet system (fig. 1), increase the selectivity (the distance between the innermost and the outermost chamber goes from about 2.3 m to about 5 m) and improve the temporal and spatial resolution allowing a more precise selection on muon momentum. The project foresees the installation of 130 BIL (Barrel Inner Large for the odd sectors), 96 BIS (Barrel Inner Small for the even sectors) and 80 BOM/BOR chambers (barrel outer chambers in sector 11 and 15) for a total of 65184 read out channels. All BIS RPC detectors will be coupled with monitored drift tube chambers made of 15mm diameter tubes (sMDT). This enhances the redundancy (9 layers instead of 6) and will make possible to reduce the HV of the legacy chambers (this reduce the charge integrated by the detectors, enhancing the longevity) without significantly loosing trigger efficiency.

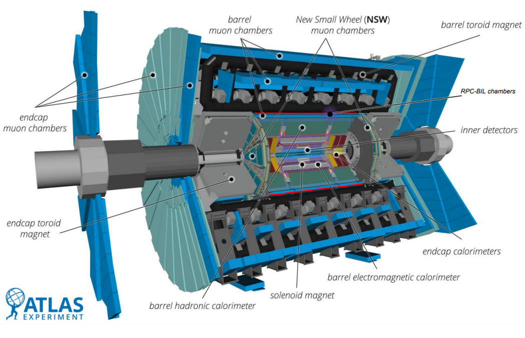

Figure 1: ATLAS experiment [2]. In red the new barrel RPC layer.

2. THE DETECTOR

These new generation RPC detectors [1] consist of a gas gap sandwiched between two readout (RO) panels. Each RO panel consists of two halogen-free single-sided copper-clad FR4 plate, 0.435 mm thick, which enclose a 3 mm thick aramid paper honeycomb foil. One of the two plates is photo-engraved to form the design of the strips. The orientation of the strips on the two panels is identical, and the signal is read only from one edge of the strip but on the two FR4 plates from opposite

Email address: `mattia.francesco.perrone@cern.ch`; `mattia.perrone1996@libero.it` (M. F. Perrone on behalf of ATLAS Muon Community)

edges. In this way, when an ionizing particle passes through the gas inside the gap and an electric field is applied to the electrodes, a multiplication is triggered and the strips pick up an electrical signal whose amplitude depends greatly on the distance between the strip and the avalanche. This system of equal strips oriented on both sides of the gas gap is able to reconstruct the position of the avalanche in the plane at the center of the gas gap with a spatial resolution better than 1 cm in both directions. In the ATLAS coordinate system these coordinates are called η and ϕ. The last one is obtained from the difference in the arrival time of the signal at the front-end electronics. The gas gap has a 1 mm thick gas volume and 1.4 mm thick high pressure laminate (HPL) resistivity plates ($1.5 \div 6 \cdot 10^{10}\Omega$ resistivity).

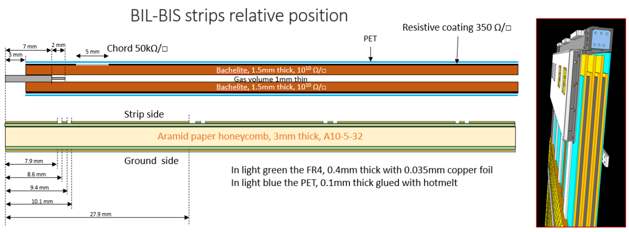

Figure 2: On the left, the transverse section of a gas gap (top) and a strip panel (bottom); on the right a 3D drawing of the RPC chamber.

2.1. THE GAS GAP

The BIL and BIS gas gaps are produced at the General Tecnica Engineering (Frosinone, It) company which receives and tests the HPL foils produced by Teknemika (Milano, It), add a graphite layer on both sides of the HPL planes, glues the internal gas volume spacers, internal frames and internal gas distribution system. Once the detector is assembled, the gas tightness and the insulation of the polaritazion electrodes are checked. The conditioning of the gaps with standard gas mixture and the amperometric test follow. The gap is accepted if the gap current is less than 2 μA at 6100 V. The BOM/BOR gas gaps (240) are aimed to be produced in Germany in the incoming year. Prototypes and several test beams are underway to validate the production technique and performance of these gas gaps. Few gas gaps for the special chambers in sector 9 and 7 will be produced in China.

2.2. THE READOUT PANEL

The assembly of the BIL strip panels (fig. 3, left) is taking place at Cosenza University (It). It involves 5 phases. Quality control of the received material (FR4, PCB and honeycomb), gluing in an unique step strip plate, honeycomb and ground plate, dimensional tests, taping the edges with copper tape with conductive acrylic adhesive and soldering the SMD termination resistors. There are 12 different BIL chamber geometries, all with the same 2 cm strip pitch. The assembly of the BIS strip panels is under the responsibility of Hefei University (China). Panel gluing is done by an outside company, while QAQC and resistor soldering are done in USTC's physics department. There are 2 different BIS chamber geometries, all with the same 2.6 cm strip pitch. Finally the assembly of BOM/BOR RO panels is under the responsibility of INFN and USTC.

2.3. THE ELECTRONICS

The Front-End (FE) electronics [3] is realized in a mixed technology of Silicon BJT for the discrete component preamplifier and a full custom ASIC in SiGe BiCMOS technology. This ASIC will be connected to the FE PCB board through the wire bonding method, and it will be interfaced on the board with the preamplifier. The output of the ASIC will be interfaced with a Data Collector and Transmitter through a differential serial transmission Manchester encoded.

3. ASSEMBLY OF THE CHAMBERS

The assembly of the BIL and a fraction of BOM/BOR chambers is taking place at CERN. First the gas gaps and strip panels are tested (gas tightness, HV current leak, electrical continuity of strips). Then a gas gap and a pair of RO panels are assembled to create a singlet. The dimensional checks of the singlet follow. Then the soldering of the FE cards follows with the noise test of each strip. The singlets that pass the test go to the cosmic ray stand (fig. 3, right) where tests with ionized particles are performed. Three qualified singlets are inserted inside the aluminium box to create a chamber and the services are assembled. BIS triplets will be built at MPI with similar procedures.

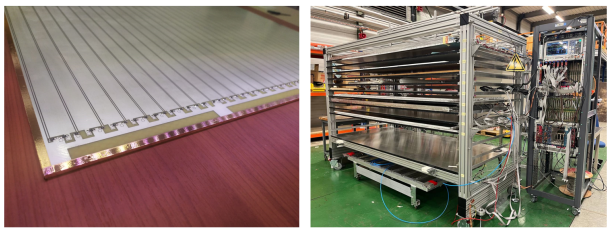

Figure 3: Left: A BIL readout panel, with copper tape end matching resistors in evidence. Right: Cosmic rays test stand.

4. QUALIFICATION OF THE CHAMBERS

The test station at CERN (fig. 3, right) consists of four RPC detectors used in coincidence to select cosmic rays. Both the singlets and chambers will undergo a series of meticulous tests immediately after assembly by placing these detectors inside the test station. A complete tomography of the objects is performed to identify inefficient areas in the detectors. Furthermore, before installing the chambers in ATLAS a simplified version of the tower is used.

References

[1] Technical Design Report for the Phase-II Upgrade of the ATLAS Muon Spectrometer, CERN-LHCC-2017-017 (2017).

[2] The ATLAS experiment at CERN Large Hadron Collider, Journal of Instrumentation 3 (2008). doi:`doi:10.1088/1748-0221/3/08/`.

[3] L. Pizzimento, On novel front-end electronics for the ATLAS BI RPC upgrade at HL-LHC developed in SiGe BiCMOS technology with a high-resolution rad-hard Time-To-Digital converter embedded , to be published in Nuclear Instruments and Methods in Physics Research (2024).