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

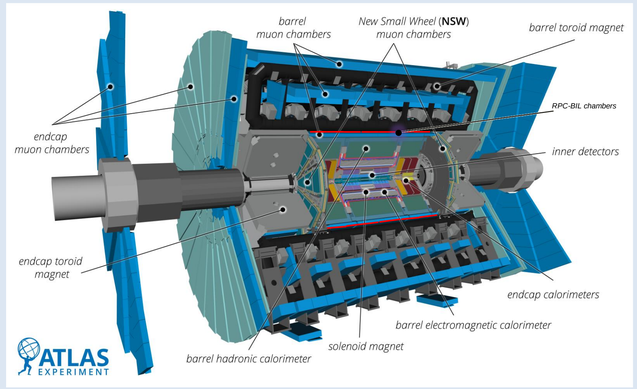
M. F. Perrone (INFN and Unical) on behalf of ATLAS Muon community

mattia.perrone1996@libero.it; mattia.francesco.perrone@cern.ch

The current Resistive Plate Chamber (RPC) system is undergoing a major upgrade (1), consisting in the installation of approximately 1000 RPC detector units of new generation 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 a factory 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. In particular, we describe the protocols defined and the instrumentation created for the certification of gas volumes at the Italian production factory, for the construction and certification of the read-out panels in Cosenza and for the assembly and certification with cosmic rays of the detectors at CERN. The certification results of the components produced are analyzed and discussed.

PURPOSE OF THE BI-RPC PROJECT

- *Improve the performance of the stand-alone muon trigger*
- *Increase the **acceptance**; better cover the regions around the torus support structures (up to 96%)*
- *Increase the **selectivity** (the distance between the innermost and the outermost chamber goes from 2.3 m to 4-5 m) and improve the temporal and spatial resolution allowing cuts at more precise momentum*
- *Enhance the redundancy (9 layers instead of 6)*
- *Enhance the **longevity** (lowering the HV of the RPCs it is possible to reduce the charge integrated by the detectors without significantly losing efficiency).*



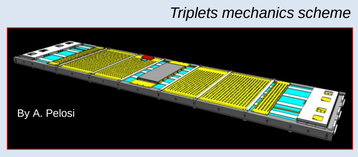
130 BIL, 96 BIS and 80 BOM/BOR chambers for a total of 8148 front-end boards x 8 channels=65184 read out channels.

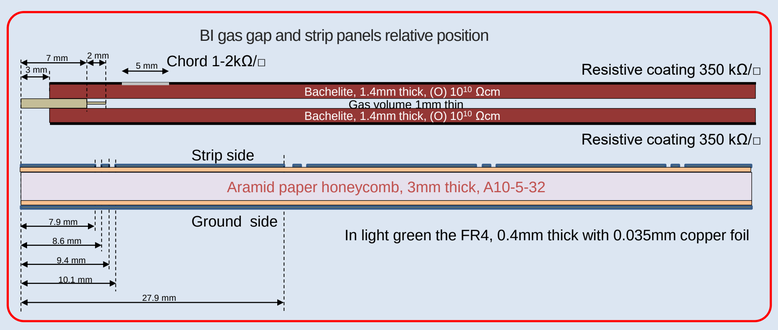
- BIS (Barrel Inner Small)
- BIL (Barrel Inner Large)
- BOM/BOR (Barrel Outer)

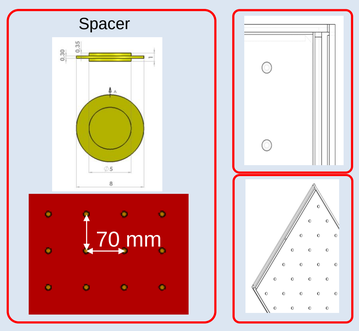
THE DETECTOR

- *Gas volume thickness 1mm*
- *High Pressure Laminated (HPL) Resistive plates 1.5 mm thick*
- *Resistive electrodes resistivity* $1.5 \times 10^{10} - 6 \times 10^{10} \boldsymbol{\Omega}\ cm$
- *Strip panels in FR4 and aramid paper honeycomb with copper strips on both side of the gas gap oriented in the same direction (to measure η coordinate).*

Triplets mechanics scheme







THE GAS GAP

The BIL and BIS gas gaps are produced at the General Tecnica (Frosinone, It) company which:

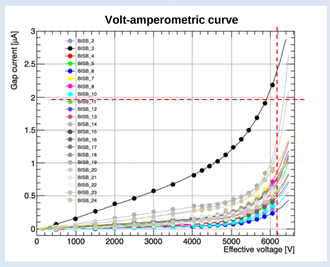
- *Receives and tests the HPL sheets produced by Teknemika (Milano, It)*
- *Add a graphite layer on the HPL planes, glues the internal gas volume spacers, internal frames and internal gas distribution system*

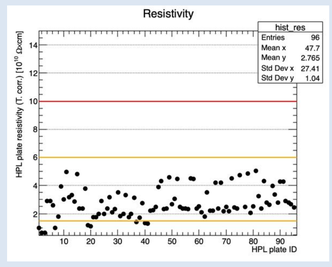
Once the detector is assembled, the gas tightness and the insulation of the polaritazion electrodes are checked.

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.

Gas gap test at GTE

The BOM/BOR gas gaps (240) are supposed to be produced in Germany in the incoming year. Prototypes and several test beams are underway to validate the production technique and performances.
Few gas gaps for the special chamber in sector 9 will be produced in China.





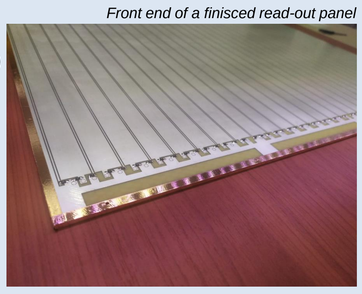
THE READOUT PANEL

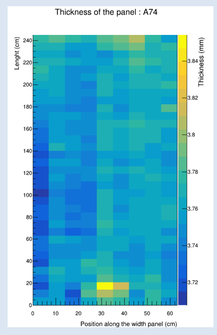
The assembly of the BIL strip panel is taking place in Cosenza (UNICAL, physics department). It involves 5 phases in this order:

- *Quality control of the received material (FR4, Honey Comb)*
- *Gluing with epoxy glue (Araldite 2011)*
- *Dimensional tests*
- *Taping the eges with conductive copper adhesive tape*
- *Soldering the SMD termination resistors*

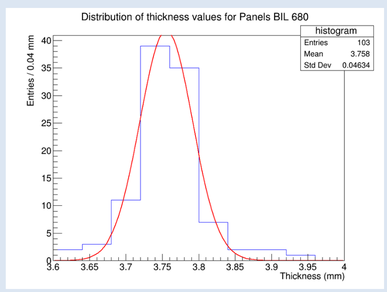
The assembly of the BIS strip panels is under the responsibility of Hefei University (China). The gluing of the PCBs with honeycomb is done by an external company, while the QAQC and the welding of the termination resistors will be done in the physics department of USTC.

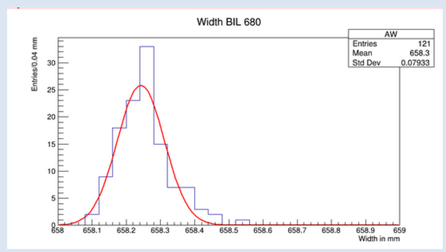
Front end of a finisced read-out panel





Single-sided, halogen-free, copper-clad FR4 plates, 0.435 mm thick, enclosing a 3 mm thick aramid paper honeycomb sheet. One of the two plates is photo-etched to form the strip design.



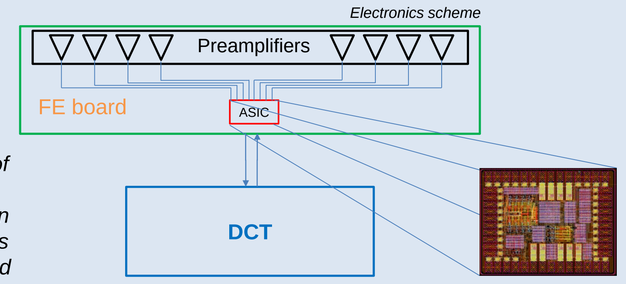


Mass production started on November 2023, and after 6 months 30% of the BIL was produced.
The number of strip panels to be produced at UNICAL are 672 BIL and 420 BOM/BOR + some spares for all the types.

THE ELECTRONICS

The Front-End (FE) electronics (2) is realized in a mixed technology of Silicon BJT for the discrete component preamplifier and a full custom ASIC in IHP 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 (DCT) through a differential serial transmission Manchester encoded. The preamplifier that will be used as interface for this FE is similar to the one already developed and used for the phase 1 (BIS 78 project) RPC upgrade.

Electronics scheme



Preamplifier

- *Amplification factor: 0.3-0.4 mV/fC*
- *Max equivalent input noise → min=1000; max=2000 (electrons RMS)*
- *gain (min, nom, max) → (4;4.5;5.5)*
- *gain dispersion → 1%*
- *Band Width: 100 MHz*
- *Power consumption: 2 mW/ch*
- *Maximum input rate= 100 MHz*
- *Peaking time (min, nom, max) →* max=2 ns

ASIC

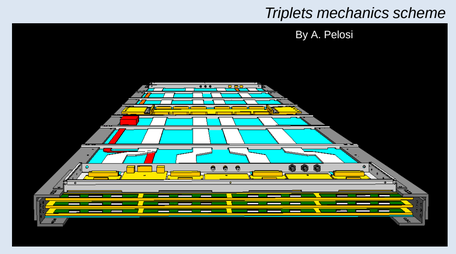
- ***Discriminator**: upgraded version of BIS 78 one (min threshold 1-2 fC)*
- ***TDC**: Voltage Controlled Oscillator (VCO) (the ring oscillator which defines the TDC time resolution driving the scaler); scaler 8-bits synchronous counter; Flip Flop (FF) & Registers (memories which save the status of the TDC scaler when the latch signal is provided); Time resolution achieved 90ps RMS*
- ***Transmission logic, serializer and transmission protocol:** The data communication to the DCT is performed with a serial line for each channel which transmits, in the given latency budget, all the information to allow for the reconstruction of the event and a possible trigger candidate. The transmission is Manchester encoded.*

ASSEMBLY OF THE CHAMBERS

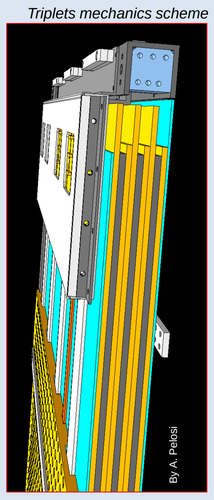
The assembly of the BIL chambers is taking place at CERN. The assembly phases are:

- *Test of the gas gaps and strip panels before assembly (gas tightness, volt-amperometric curve)*
- *Assembly of a gas gap and a pair of strip panels to create a singlet*
- *Dimensional checks of the singlet*
- *Soldering of the FE Boards and noise testing via pulse generator (resolve problems that occurred before qualifying the singlet)*
- *Cosmic rays test of a singlet*
- *Inserting three qualified singlets inside the aluminium box*
- *Mounting the services on the aluminium box.*

Triplets mechanics scheme

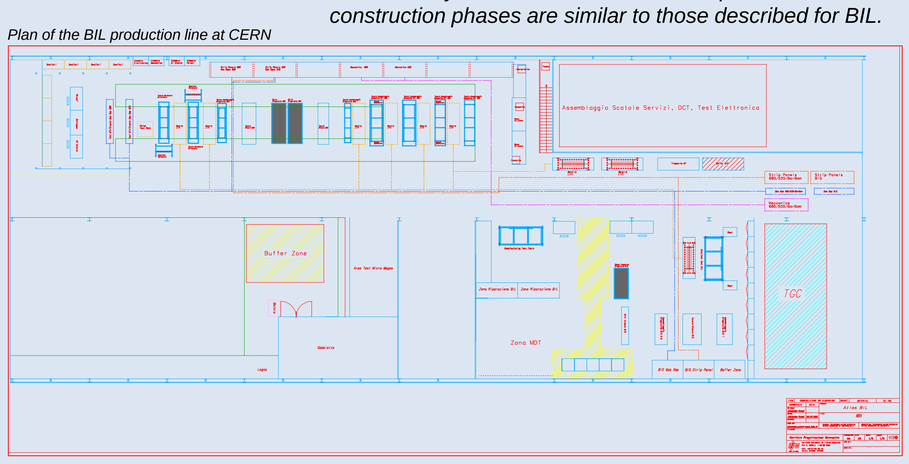


Triplets mechanics scheme



The assembly of BOM/BOR has foreseen at CERN, and the assembly of the BIS chambers takes place at MPI. The construction phases are similar to those described for BIL.

Plan of the BIL production line at CERN



QUALIFICATION OF THE CHAMBERS

The test station at CERN consists of four (4) RPC-BOL detectors used in coincidence to select cosmic rays. Both the triplets and singlets will undergo a series of meticulous tests immediately after assembly by placing these objects inside the test station. We measure:

- *Detection efficiency*
- *Volt-amperometric curve*
- *Streamer rate*

A complete tomography of the objects is performed to identify holes and/or inefficient areas in the detectors.

The test station, using both RPC-BIL and Legacy RPC-BOL simulate a trigger tower and allow us to test the integration of the new DCT reading electronic that will be mounted in ATLAS.

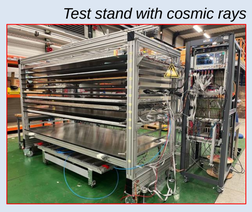
Validation/commissioning station at CERN

- *This station has two functions :*

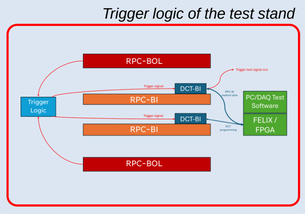
1. *Define the test protocol for the RPC-BI detectors and the chambers*
2. *Commission the chambers before installing in ATLAS*

- *This station uses an RPC-BI(L, S, O) chamber as a trigger above which the chamber to be commissioned is placed.*

Test stand with cosmic rays



Trigger logic of the test stand



TIME SCHEDULE AND CONCLUSIONS

- *Production of the RPC singlets will begin in June. These detectors will be stored in special containers awaiting the arrival of the electronics, scheduled for the end of 2024. Immediately afterwards the electronic boards will be soldered on the detectors. The singlets will be subjected to a series of checks and assembly of the chamber will begin. Once validated, the chamber will be stored in a storage cart. Completion of the BIL chambers is expected to be in early 2026*
- *The BOM/BOR chamber's assembly will start soon after.*

References

1. ATLAS Collaboration, CERN-LHCC-97-022, https://cds.cern.ch/record/331068
2. *See the talk "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 " by L. Pizzimento to this Conference*

16th Pisa Meeting on Advanced Detectors
La Biodola, Isola d'Elba, May 27th - June 1st, 2024