Certification of a new generation of Resistive Plate Chambers for the Phase-1 BIS78 upgrade of the ATLAS Muon Spectrometer

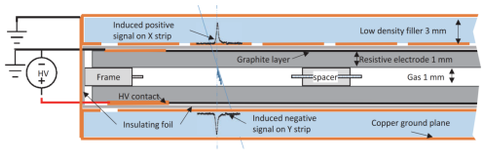
G. Proto (Università degli studi di Roma Tor Vergata and INFN) on behalf the ATLAS Muon Collaboration

Introduction to the BIS78 project for the Phase-I upgrade

The Resistive Plate Chambers detectors

The Resistive Plate Chambers (RPC) are planar gaseous detectors working with a uniform electric field generated by two parallel plates of high-bulk resistivity electrodes. The uniform field makes them very fast detectors with an excellent time resolution.

In the ATLAS experiment the RPCs are used to trigger muons in the barrel



(I)

Scheme of a Resistive Plate Chamber detector

The Resistive Plate Chambers in the ATLAS experiment

The present RPC system consists in three concentric layers of doublet chambers around the beam axis, two in the Middle region of the Muon Spectrometer and one in the Outer region, in order to select muons with both low-p_t (4 GeV < p_t < 10 GeV) and high p_t threshold (11 GeV < p_t < 20 GeV). The detector characteristics are summarized in table.

Gap width	2 mm
Electrode thickness	1.8 mm
Gas Mixture	ATLAS Standard
Time resolution	1 ns
Gaps per chamber	2
Readout	2D orthogonal

In view of operation at High Luminosity LHC, where a higher rate of particles is expected, an improvement of the RPC system is required in order to maintain a high efficiency for muons, while keeping the rate of fake triggers at low level like now.

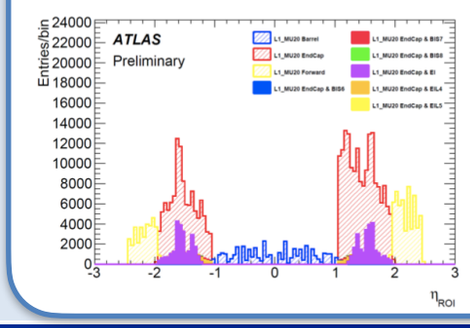
For this reason the present system will be completed during Phase-II upgrade with an **additional layer of RPC** in the Barrel-Inner region to improve the acceptance, redundancy and p_t selectivity of the trigger.

The materials, readout electronics and chambers layout of this **new generation of RPCs** have been optimized to operate at higher rates.

(II)

BIS78 project for the Phase-I upgrade: Motivations

The BIS78 is the pilot project of the BI Phase-II upgrade and consists in the installation of an additional layer of RPC in the transition region between barrel and end cap, where the highest rate of fake triggers is expected. The installation of the BIS78 will complete the geometrical coverage of the trigger and will reduce both rate and background fraction, without loosing efficiency.

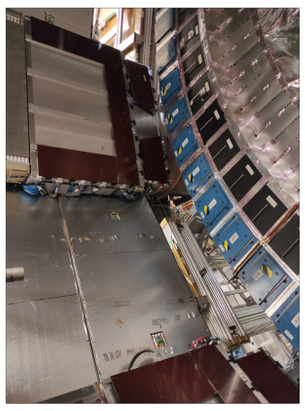


Simulation of η distribution of ROIs (p_t > 20 GeV) in runs with 25 ns of bunch crossing interval. The hatched distribution is obtained with the current End Cap trigger, while the fully colored one is obtained requiring the passage through the BIS chambers

(III)

BIS78 project: Overview

The BIS78 project consists in the installation of 32 stations of BIS78-RPC coupled with sMDT (total number of gas gaps=192). Each RPC-BIS78 station is a "triplet" of three independent RPC detectors, integrated in the same mechanical structure.



BIS78 station in the ATLAS MS

Due to the 2/3 trigger logic, the BIS stations have already some tracking capability

The total thickness of the system is strongly limited by the space available for the installation, therefore it has been reduced.

16 BIS78 triplets have been installed in the side A of the ATLAS experiment. The installation of side C is planned

Before the installation the detectors undergo some certification tests at CERN:

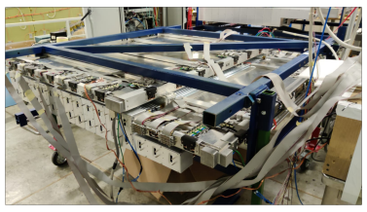
1. Conditioning at Gamma Irradiation Facility (GIF++)
2. Test with cosmic rays in the BB5 area

(IV)

Detector description

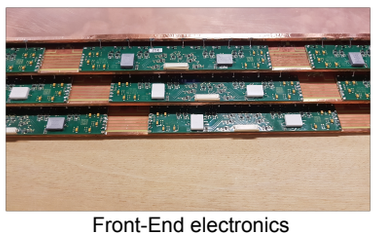
BIS 78 singlets

- **2D read out** (orthogonal strips in η direction and Φ direction)
- The new **Front-end electronics** with a lower threshold allows to reduce the operating high voltage and therefore the charge delivered inside the gas, resulting in an improvement of the rate capability at fixed current, therefore with no aging increase (~500 Hz/cm2 for 10 years of LHC operation)



BIS 78 triplet coupled with sMDTs

- **New generation** of Resistive Plate Chambers
- **1 mm** gas gap width : the reduced gas gap allows to work at lower high voltage working point and lower average current per count, and improves the time resolution (0.4 ns)
- **1.2 mm** electrode thick. The reduction of both gas gap and electrode thickness reduce the total dimensions of the system



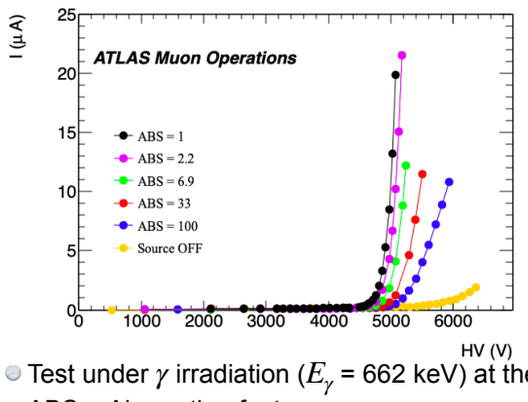
Front-End electronics

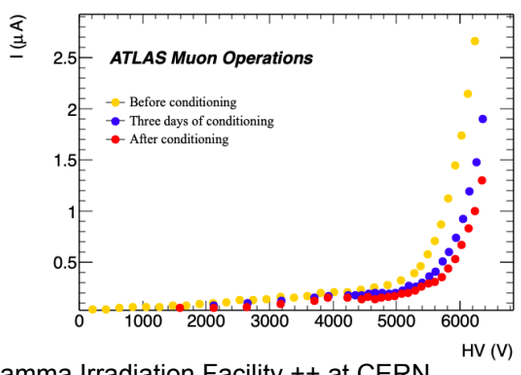
- The **new discriminator** technology (SiGe) allows to correct the timing for time walk effects
- The **Faraday cage** has been redesigned in order to reinforce the electromagnetic shielding and operate with a low noise system

(V)

Validation test for the RPC-BIS78

Conditioning at Gamma Irradiation Facility at CERN (GIF++)

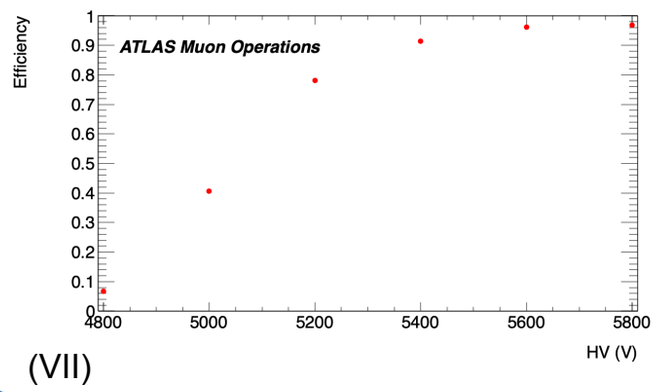




- Test under γ irradiation (E_γ = 662 keV) at the Gamma Irradiation Facility ++ at CERN
- ABS = Absorption factor

(VI)

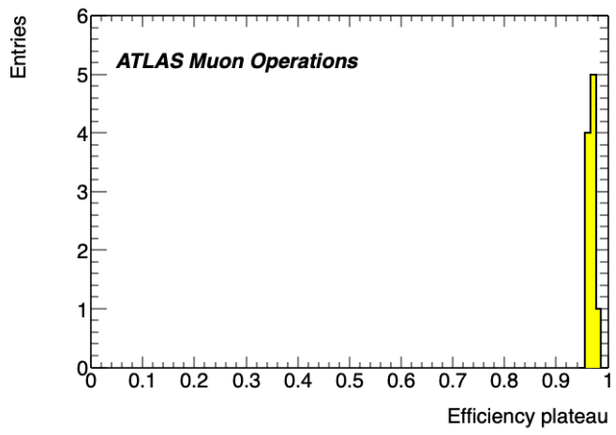
Efficiency measurement



(VII)

- (η OR ϕ) singlet efficiency curve of a BIS7 module obtained with cosmic rays.
- The chamber is operated with the PAD in broad self-trigger mode (just time coincidence without tracking).
- The curve is obtained considering the logical OR of the two read-out planes.
- A conservative Front end threshold has been set. This threshold corresponds to 6 pC of average charge per count delivered inside the gas

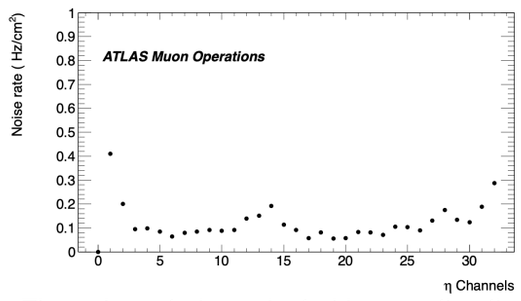
Efficiency plateau



- (η OR ϕ) efficiency of a sample of 10 gas gaps at 5.8 kV (efficiency plateau).
- The efficiency plateau value is uniform over the production (at the level of 3 per mille)

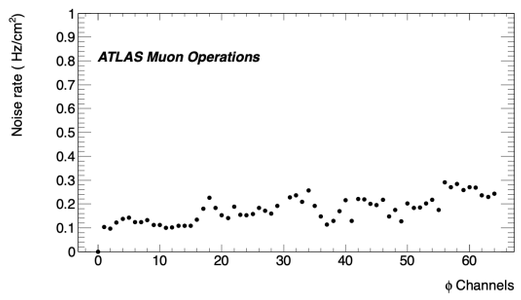
(VIII)

Noise map



- The noise rate is evaluated by counting the number of the efficient events in a given time window. The total counted events are normalized channel by channel to the whole time window acquired and to the strip surface.

- Noise rate map at the 5.8 kV for a BIS7 singlet. The noise rate is measured by using a random trigger and keeping the detector at fixed voltage

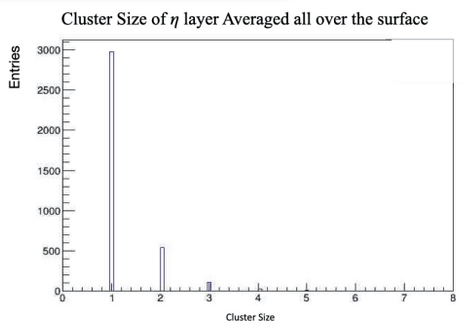


Noise rate < 1 Hz/cm^2

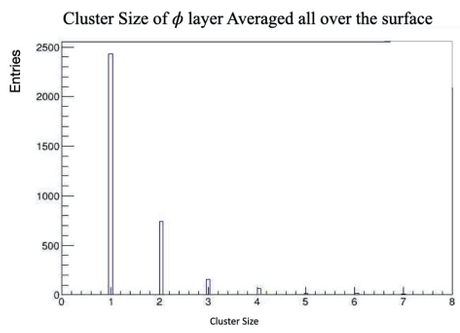
(IX)

Cluster size

(X)

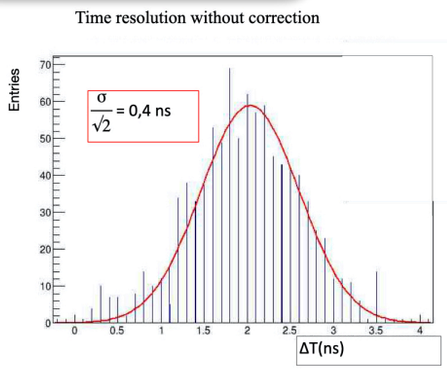


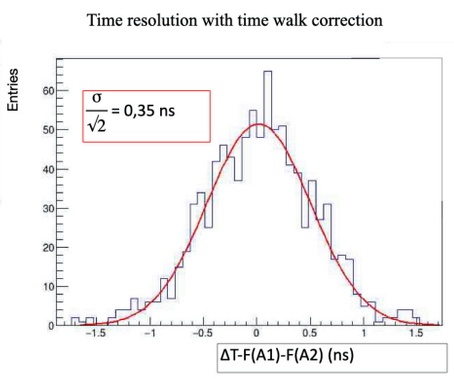
Average cluster size η = 1.3-1.5



Average cluster size ϕ = 1.4-1.8

Time resolution

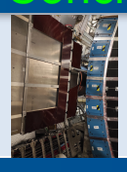




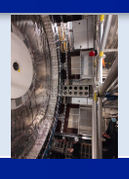
- Time resolution from the Time of Flight measurement
- Single gap resolution= **0.35 ns**, confirming the excellent time resolution of the Resistive Plate Chambers

(XI)

Conclusions



The detectors have been successfully installed and the commissioning is on going



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L. Pizzimento on behalf of the ATLAS Collaboration, "Performance of the BIS78 RPC detectors: a new concept of electronics and detector integration for high-rate and fast timing large size RPCs", 2020, cds.cern.ch/record/2720934

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