MARTA's DAQ system

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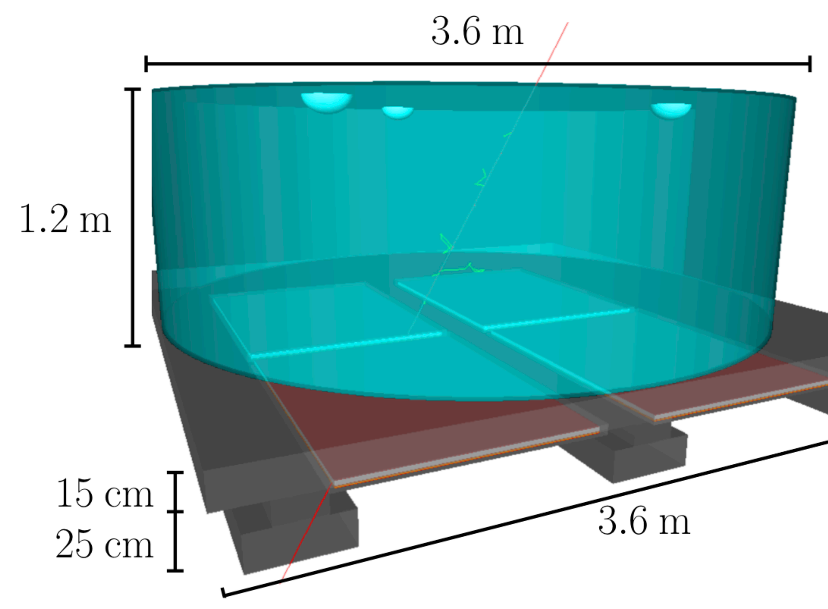
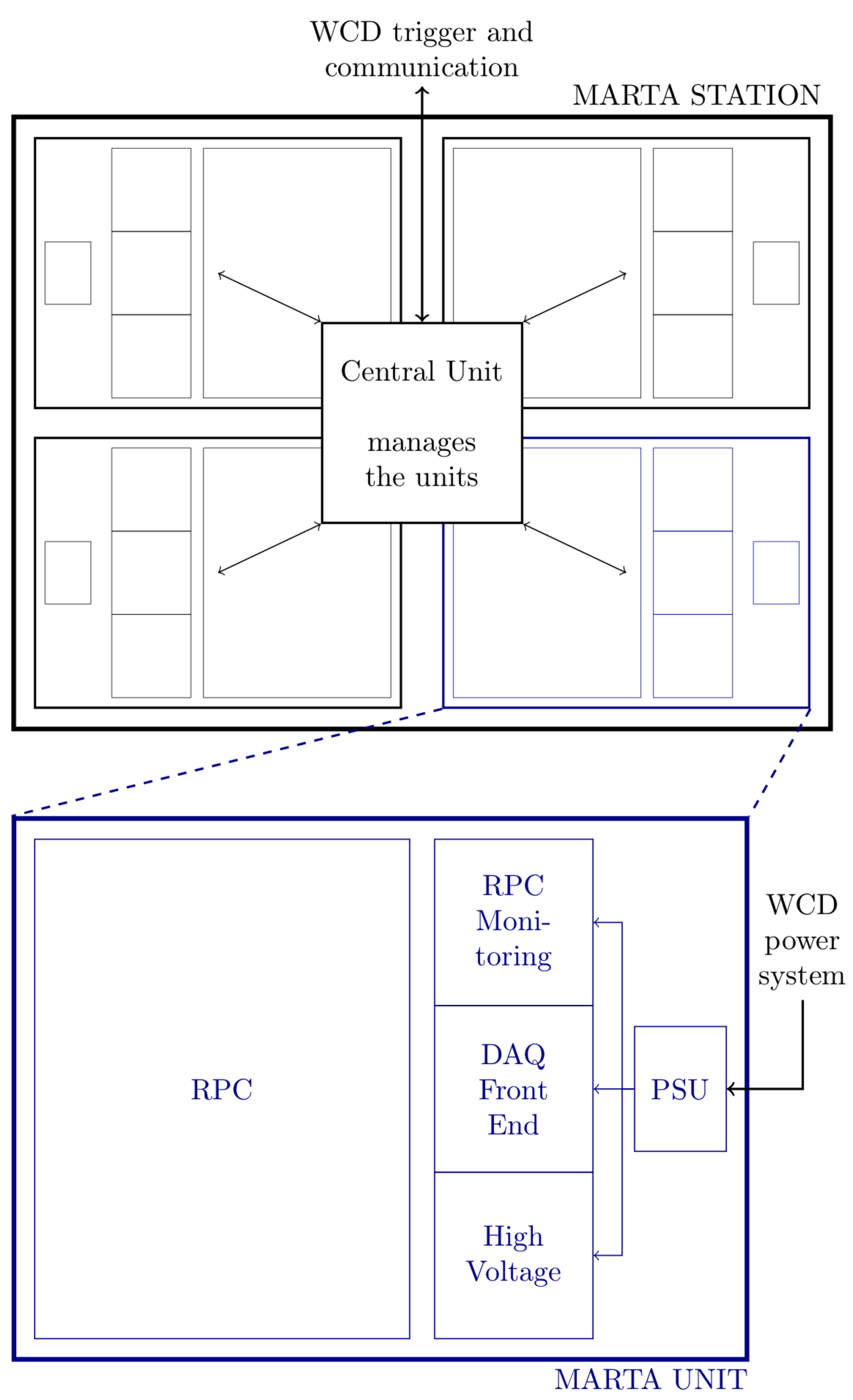
Muon Array with RPCs for Tagging Air showers (MARTA) was designed to measure directly the muonic component of the extensive air showers (EAS) that are created when a high energy cosmic ray interacts at the top of the atmosphere. It was proposed in the framework of the Pierre Auger Observatory to **enhance its capabilities to discriminate the muons** that are part of the EAS. Having an independent measurement of the number of muons at ground level will allow for a **better understanding of the shower development** in particular the high-energy hadronic interaction properties. An **Engineering Array** will be installed at seven of the **surface detector stations of the Pierre Auger Observatory**. MARTA is a **collaboration between Portugal and Brazil**.

MARTA's design

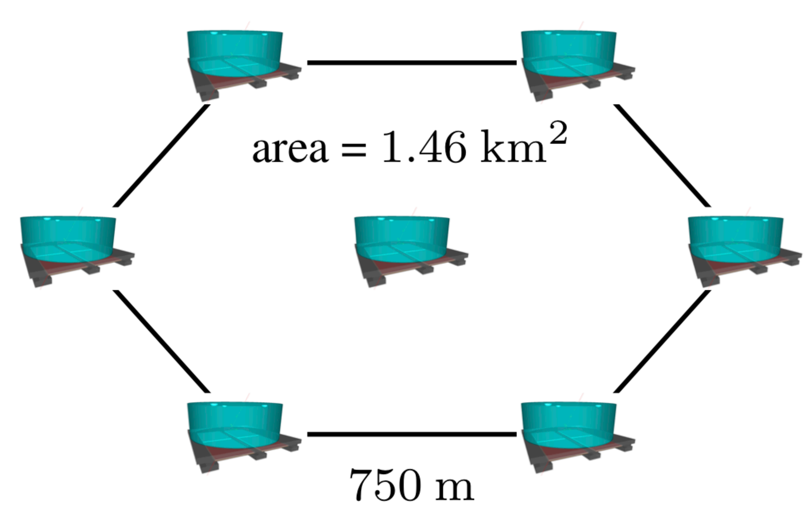
Four **Resistive Plate Chamber (RPC)** detectors are placed below the Water Cherenkov detector (WCD) which will act as an absorber for the lighter particles of the shower ensuring that **only the muonic component of the EAS reaches the RPCs**.



MARTA station. 1.2×1.5 m^2 RPCs are placed under the WCD (3.6 m diameter and 1.2 m height). Each RPC has a 8×8 readout pad grid (pad size 14×18 cm^2). The detectors will be installed inside a concrete structure with a total height of 40 cm that will support the WCD. MARTA RPCs were designed to work in avalanche mode, generating fast and small negative pulses when the gas inside is ionized by particles.



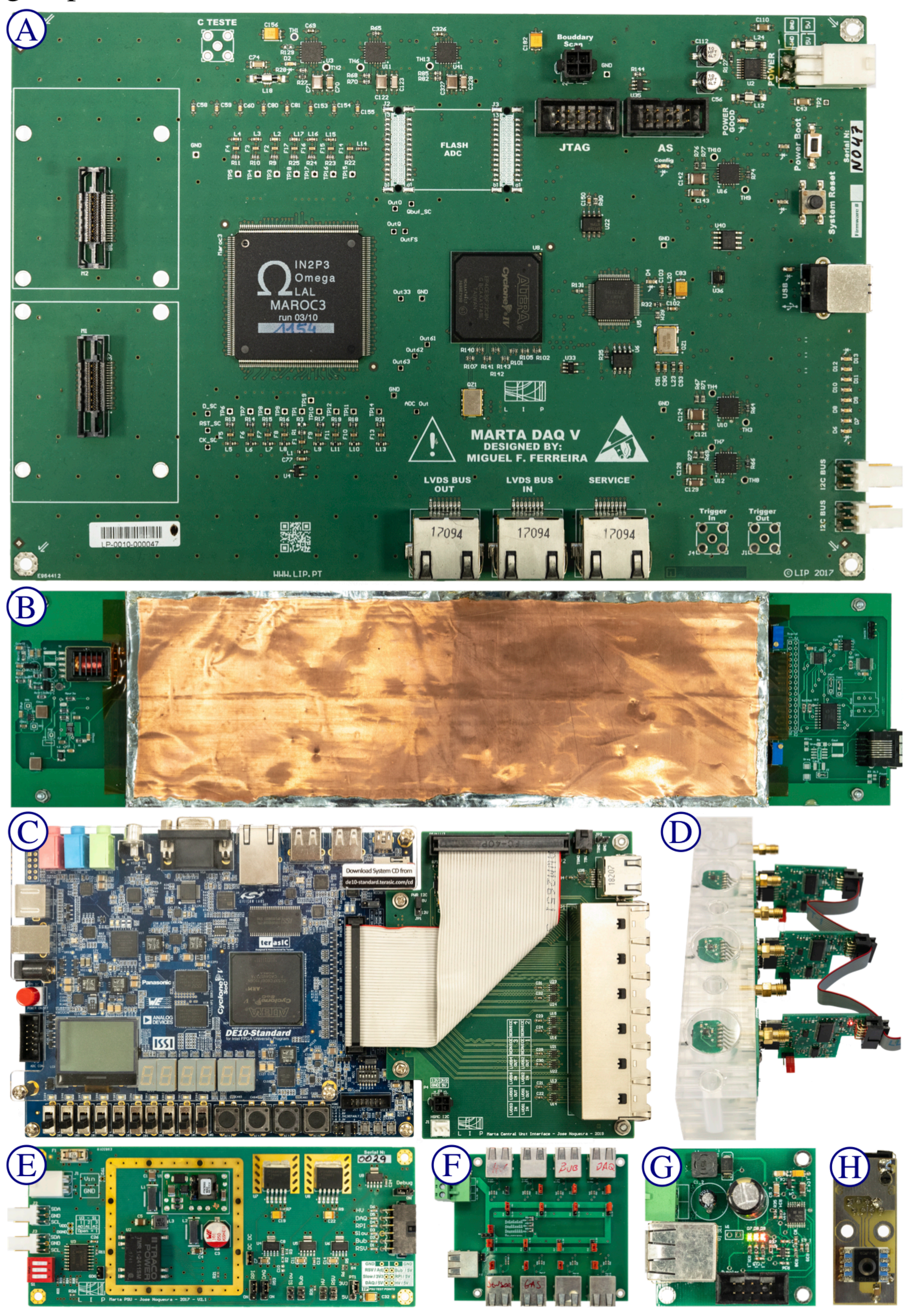
MARTA station and unit diagram. Each MARTA unit is composed of the RPC sensitive volume, DAQ front-end, high voltage, detector monitoring and a Power Supply Unit. All these components are enclosed inside an aluminium box. A Central Unit is responsible for communications, trigger, data transfer and power distribution of station. MARTA will take advantage of Auger's trigger, power and communications systems.



Engineering array. Seven MARTA stations will be installed at Auger. Due to the limitations that come with field operation, all the components of the system were designed to be low power and compact, while also being able to sustain the harsh weather conditions expected in the Auger site.

Electronics

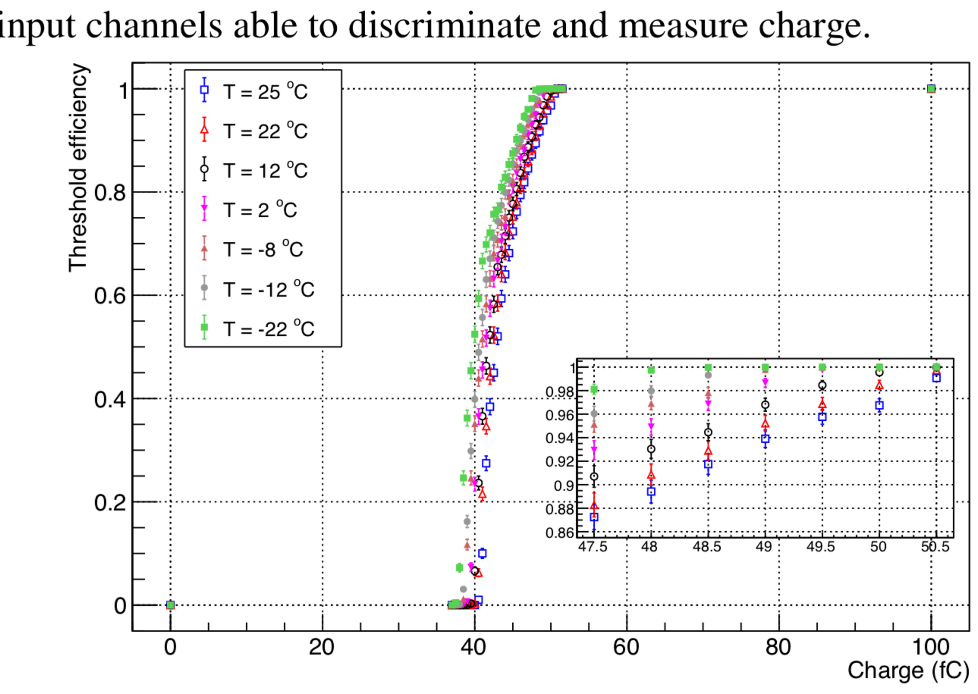
The electronics part of MARTA were designed to **comply with the strict demand of field operation**. All the components, except for the central unit, are placed inside the **aluminium box along with the detector's sensitive volume**, creating a closed structure with gas, power and communication connections.



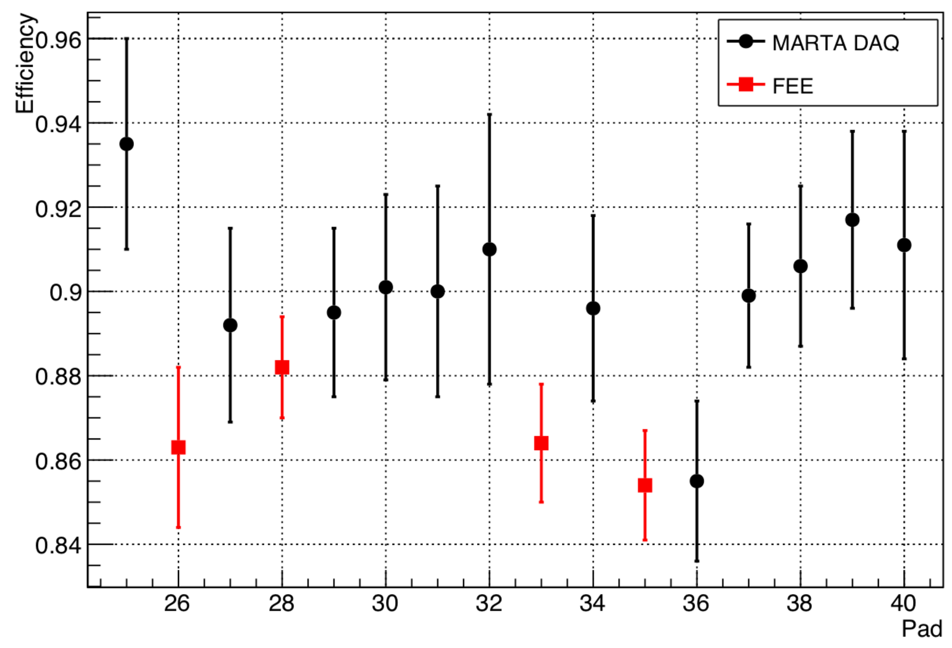
Front-end (A). Based on the MAROC ASIC. The ASIC is responsible for the digitization of the RPC signals while an Intel Cyclone IV FPGA performs all the digital electronics: measurement and data management as well as communications. **High Voltage (B).** Creates the high voltage that applies the strong electric field in the detector's gas gaps. The voltage applied and the current are monitored via I^{2}C. **Central Unit (C).** It controls all the electronics of a station, acts as a data concentrator and communicates with the WCD. It is based on a development board containing a Intel Cyclone V SoC FPGA with a dual-core ARM processor. An adaptor board was design to communicate via LVDS and I^{2}C with each unit of a station. **Gas Monitoring (D, G and H).** Monitors the gas flux inside the bubblers that are placed in the gas input and output. A pressure sensor is also placed at the gas input. **Power Supply Unit (E).** Inputs the 24 V given by the WCD power system and converts it to the required voltage of each element inside the aluminium box. **I^{2}C Multiplexer (F).** Routes the I^{2}C lines to all the systems. This includes the gas and environmental monitoring as well as high voltage. Environmental monitoring is performed by pressure, humidity and temperature sensors inside the detector.

Front-end

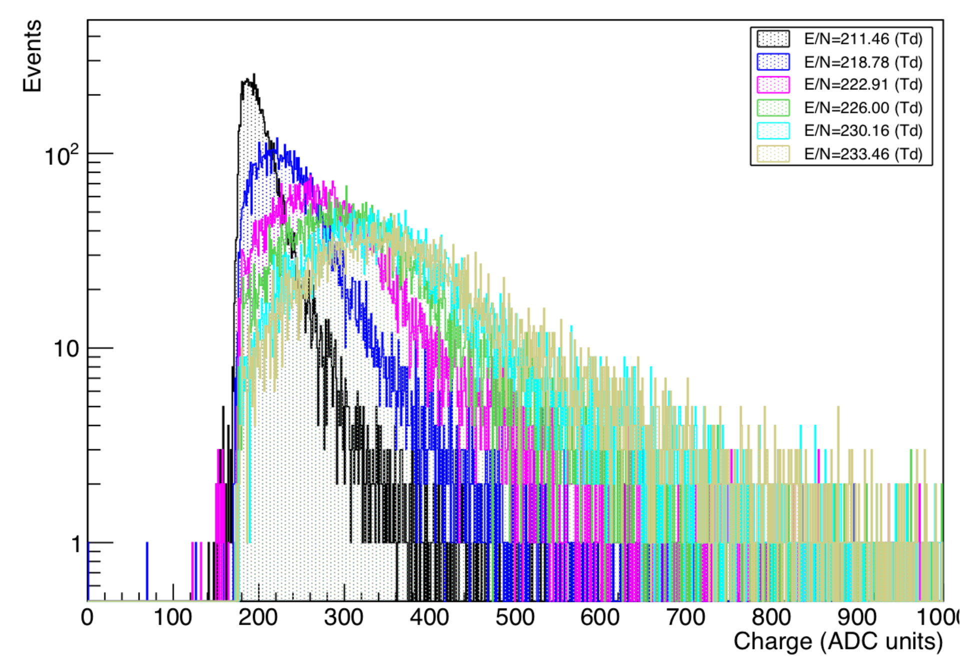
The front-end is the main component of the MARTA's DAQ. Its main requirement, other than to be low power and compact, was to be able to **discriminate** and measure the **charge** of the negative RPC signals created when a particle crosses the detector. The **MAROC** was found to fit the job being a low power ASIC with 64 input channels able to discriminate and measure charge.



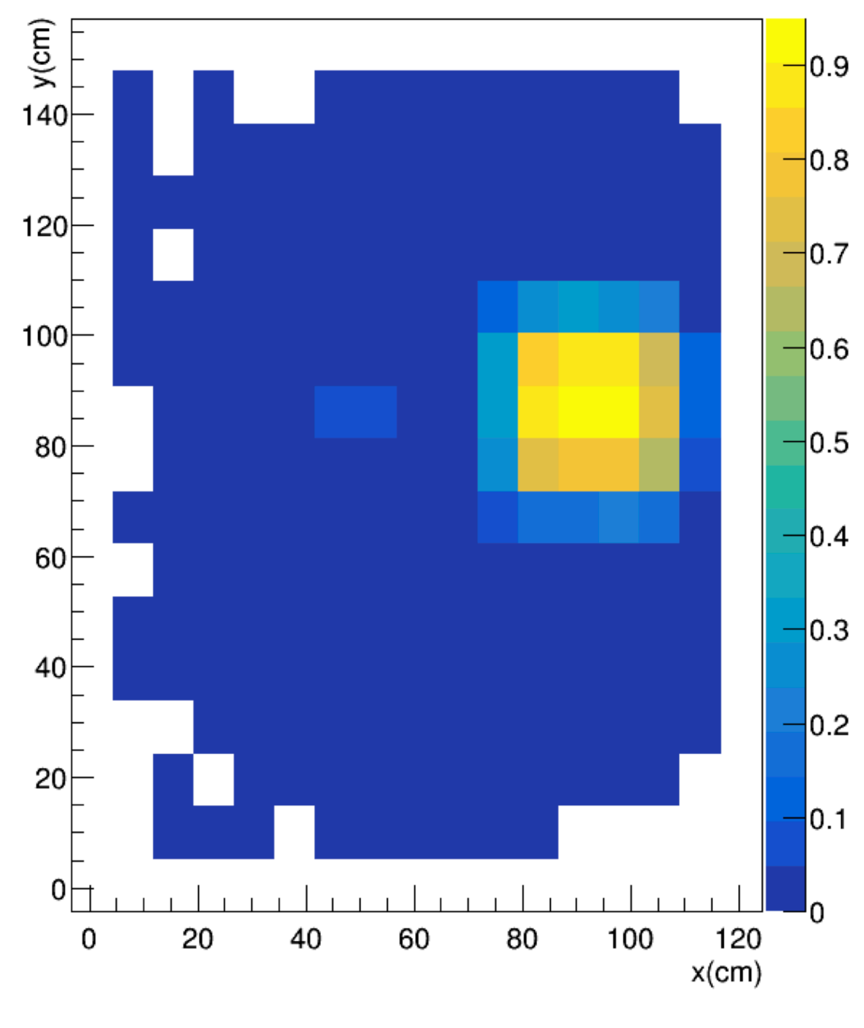
Threshold efficiency. The threshold efficiency of the system was studied for different temperatures in the expected range of operation. In all cases, for charge values above 52 fC the efficiency is 100 %. The temperature effect shows a width of 3 fC in the s-curve between the lowest and highest values studied.



RPC efficiency. The RPC efficiency was studied for 16 channels of the detector simultaneously using the front-end and another establish RPC DAQ. The results validate the front-end, showing that it is able to read the fast RPC signals without introducing any unwanted inefficiencies into the system.



Charge measurement. Six charge spectra of the RPC signals were obtained for different values of Reduced Electric Field (E/N). The spectra present the expected shape and as the electric field is increased so does the average charge of each spectra, validating the charge measurement.



RPC hodoscope used to validate scintillators. An hodoscope of MARTA RPC was built. The RPCs are instrumented using the front-end. Preliminary tests have been performed using a small 30×30 cm^2 scintillator, that validate the hodoscope and all the components of the system.

The first MARTA station is expected to be installed in the near future, as all production and debugging is nearly complete.

References

A. Aab et al. *Nucl. Instrum. Methods A*, 798:172, 2015.

P. Abreu et al. *The European Physical Journal C*, 78(4):333, 2018.

P. Assis et al. *IEEE Transactions on Nuclear Science*, 65(12):2920, 2018.

S. Blin et al. *Journal of Instrumentation*, 5(12):C12007, 2010.

L. Lopes et al. *Journal of Instrumentation*, 14(07):C07002, 2019.

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