MARTA readout system

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5th IDPASC Students Workshop

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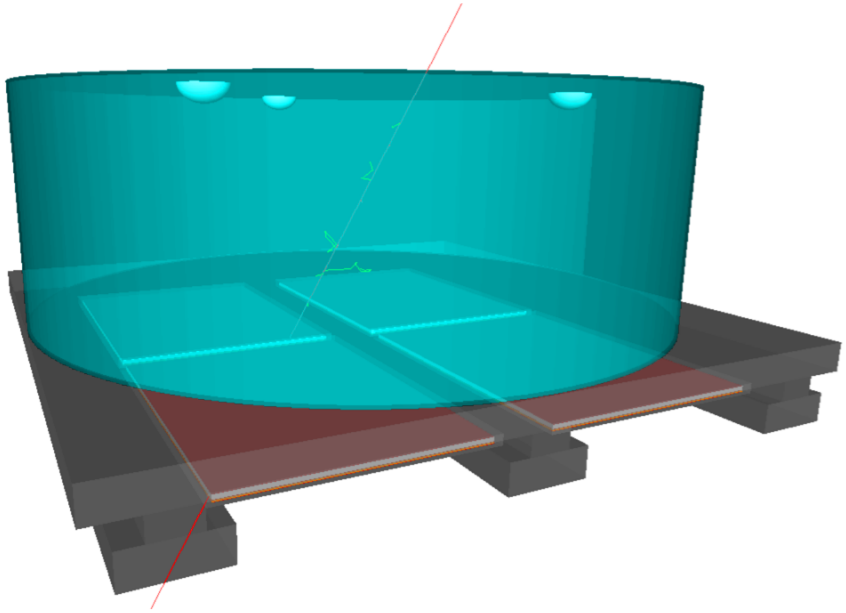
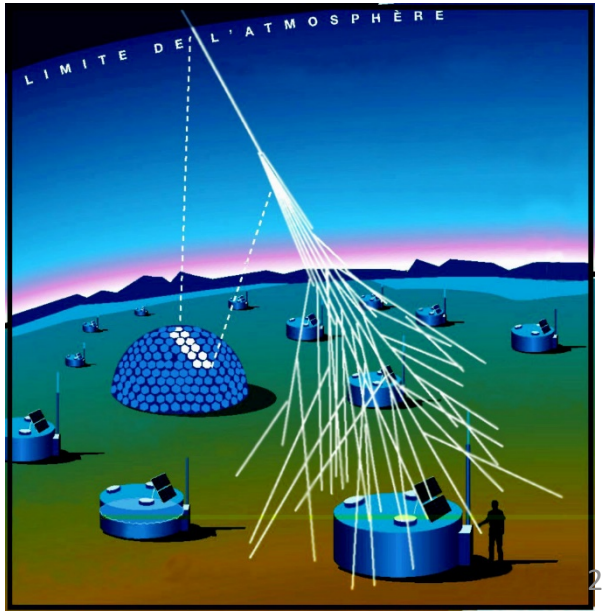
Motivation

- Build a muon detector for cosmic ray ground array experiments
- Placing Resistive Plate Chambers (RPC) detectors under Auger's water Cherenkov detectors (WCD)
- Help in the understanding of the muon number discrepancies between data and models





Challenges

- Instrument the RPCs:
  - Widely used gaseous detectors of charged particles
  - Avalanche mode: Fast pulses that need pre-amplification
  - Estimate the number of muons using both a simple threshold measurement and a charge measurement
- Comply with the strict demands of outdoor field operation:
  - Limited power and space
  - Harsh weather conditions
  - Low maintenance

PUBLISHED: *August 26, 2016*

TECHNICAL REPORT

Design and characterization of the PREC (Prototype Readout Electronics for Counting particles)

doi:10.1088/1748-0221/11/08/T08004

- Generic DAQ: used as a proof of concept without complying with the operation demands

2920 IEEE TRANSACTIONS ON NUCLEAR SCIENCE, VOL. 65, NO. 12, DECEMBER 2018

The MARTA (Muon Array With RPCs for Tagging Air Showers) Front-End Acquisition System

doi:10.1109/TNS.2018.2879089

- Final system to be used: the system is able to read the fast RPC signals while complying with the operation demands.

Charge distribution measurement of MARTA's RPCs

To be submitted

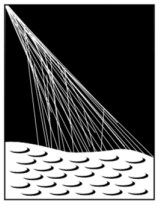
- RPC charge measurement description and analysis

RPC hodoscope for SSD quality control

GAP-2019-017

Collaboration internal gap note

- Application example: a test system for the new Auger's scintillators was successfully build



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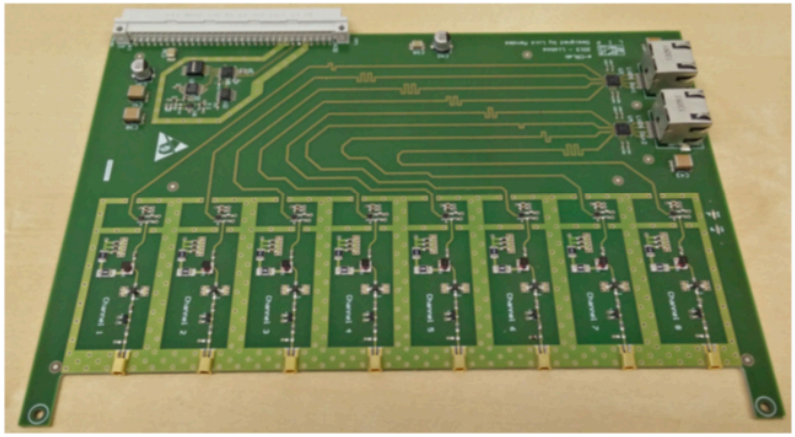
PUBLISHED: *August 26, 2016*

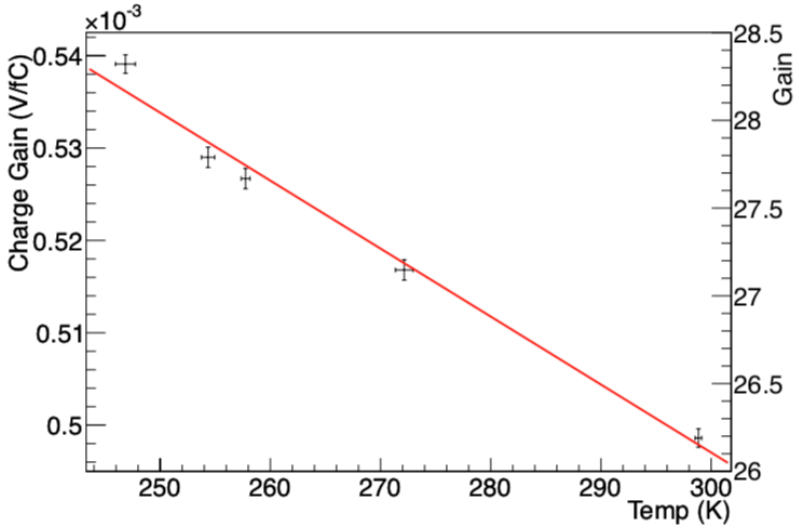
TECHNICAL REPORT

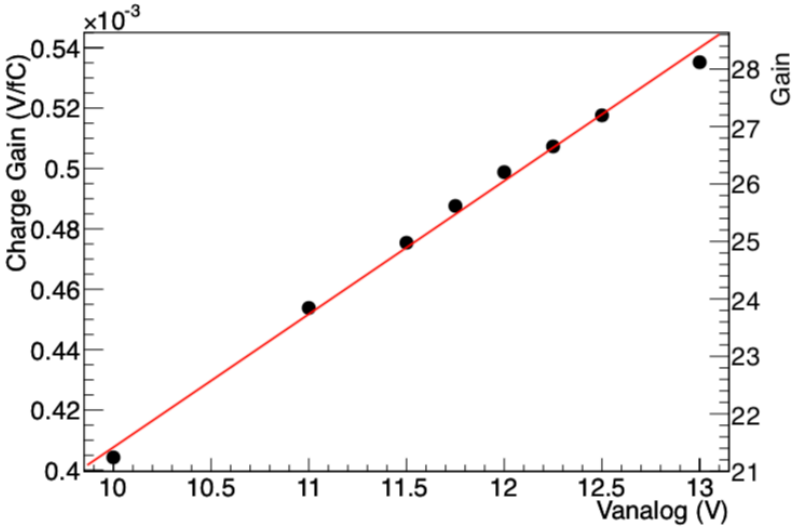
Design and characterization of the PREC (Prototype Readout Electronics for Counting particles)

- A proof of concept DAQ system was build using analogue electronics:
  - A simple amplifier followed by a comparator discriminate the RPC signals
- In this work a full characterization of the system performance was presented



- The charge gain was characterized for different temperatures and operation voltages

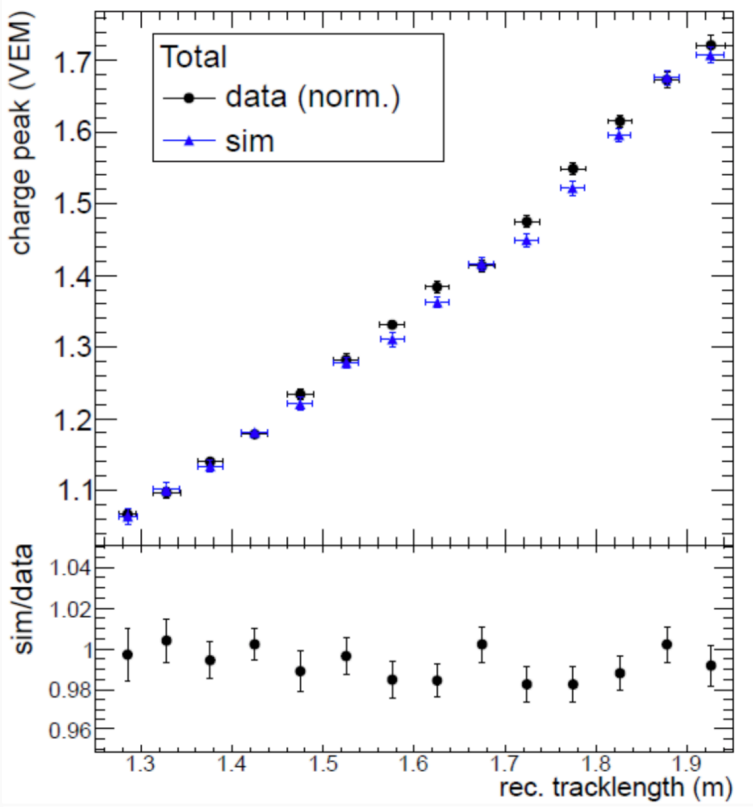




- No crosstalk was found above the noise level of 1.6 mV
- Trigger efficiency and signal propagation time in the board were studied
- Power consumption was found to be of about 1 Watt per channel

- The system was found to be a good fit for RPC signals
- However it occupies to much space and it draws to much power to be used in field operation

- It was used to study the water tank signals that were then compared with simulation
- This study helped validate the collaboration official simulation

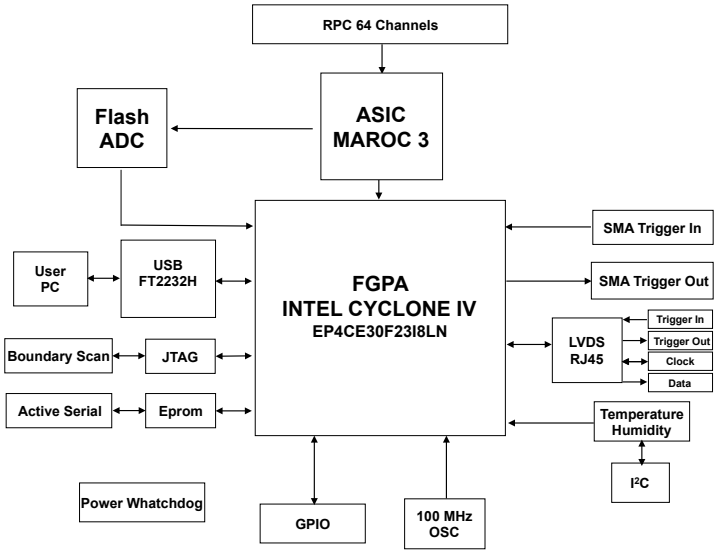


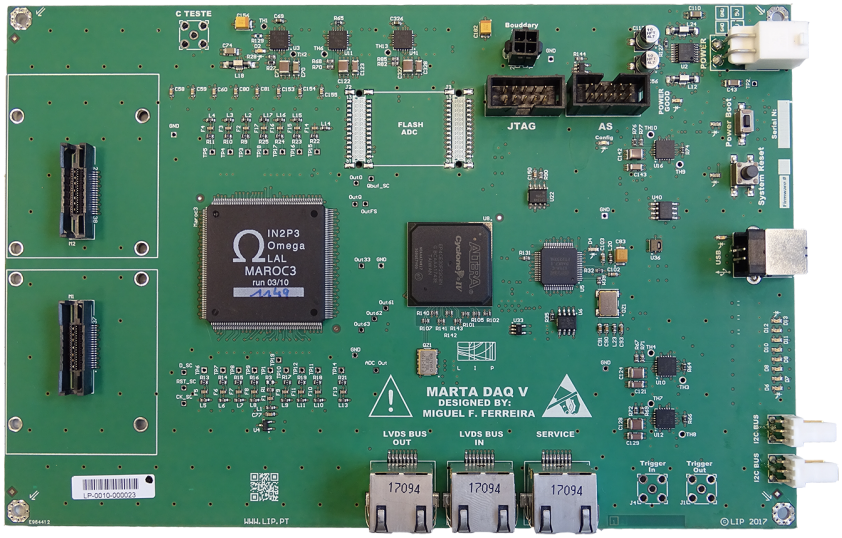
in P. Assis et al., Measurement of the water-Cherenkov detector response to inclined muons using an RPC hodoscope, ICRC 2015

The MARTA (Muon Array With RPCs for Tagging Air Showers) Front-End Acquisition System

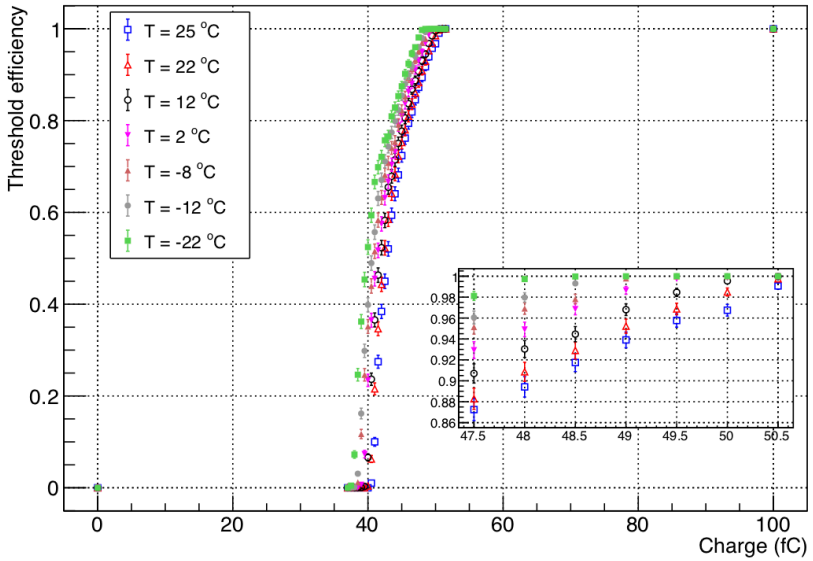
- A second acquisition system was developed
- It was designed to comply field operation:
  - Low power: 1.43 Watts per 64 channels
  - Compact: 22 x 14 cm^2
- Based on the MAROC ASIC: 64 input channels, pre-amplifier, threshold and charge measurement
- 2 prototypes and a final version were build
- In this work a detailed description of how the system works is given and validation tests are performed

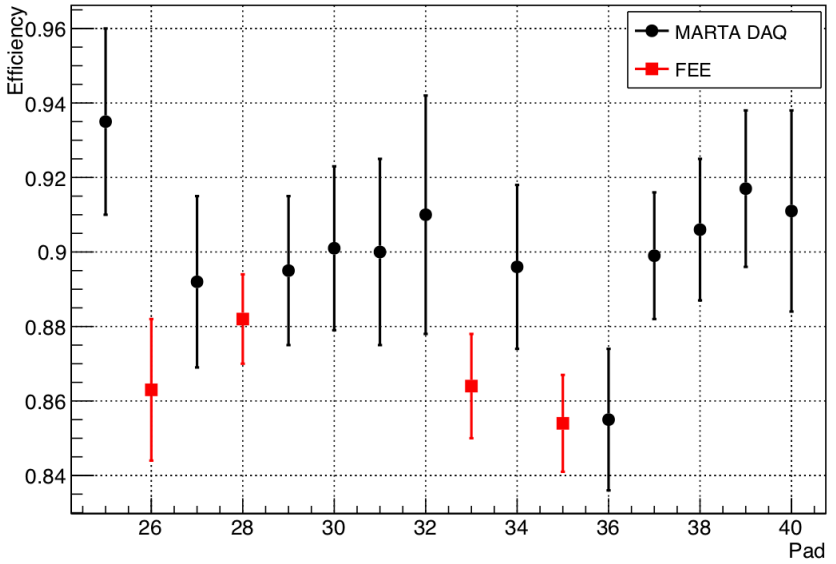
- The ASIC is responsible for the digitization of the RPC signals while the FPGA performs the digital electronics: measurement and data management and communications
- Responsible for the development of the firmware, software and test benches used to validate the design

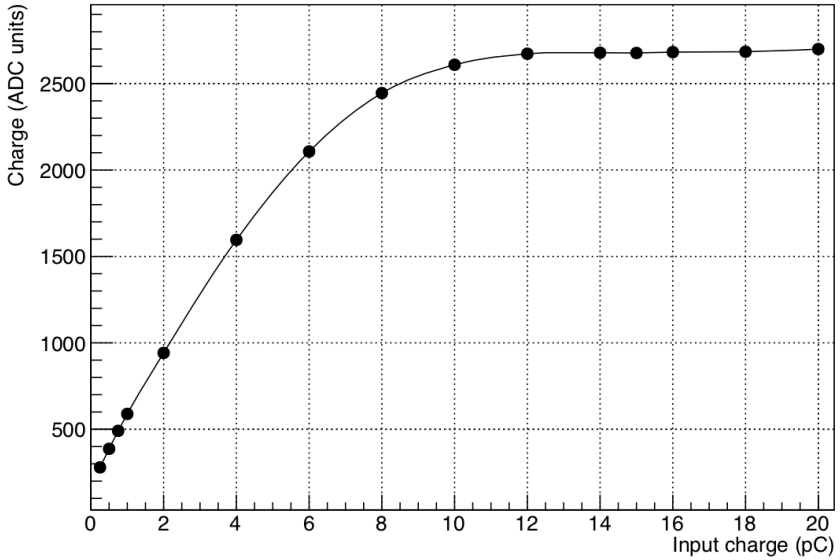


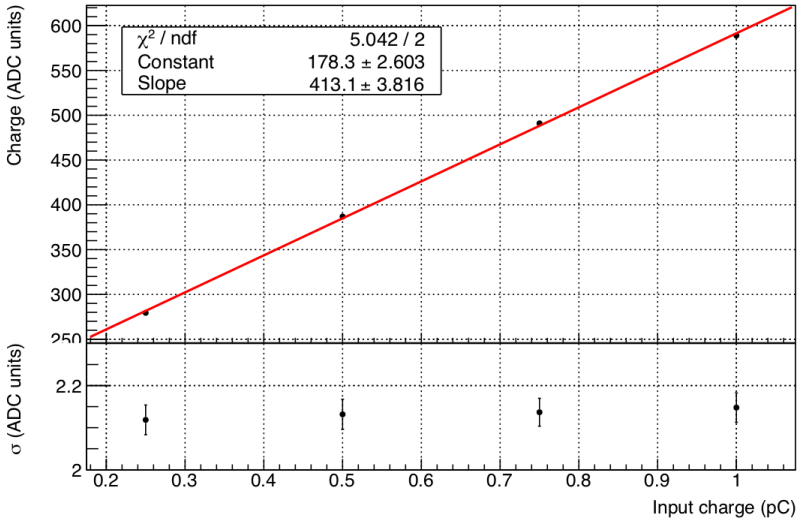


Validation results





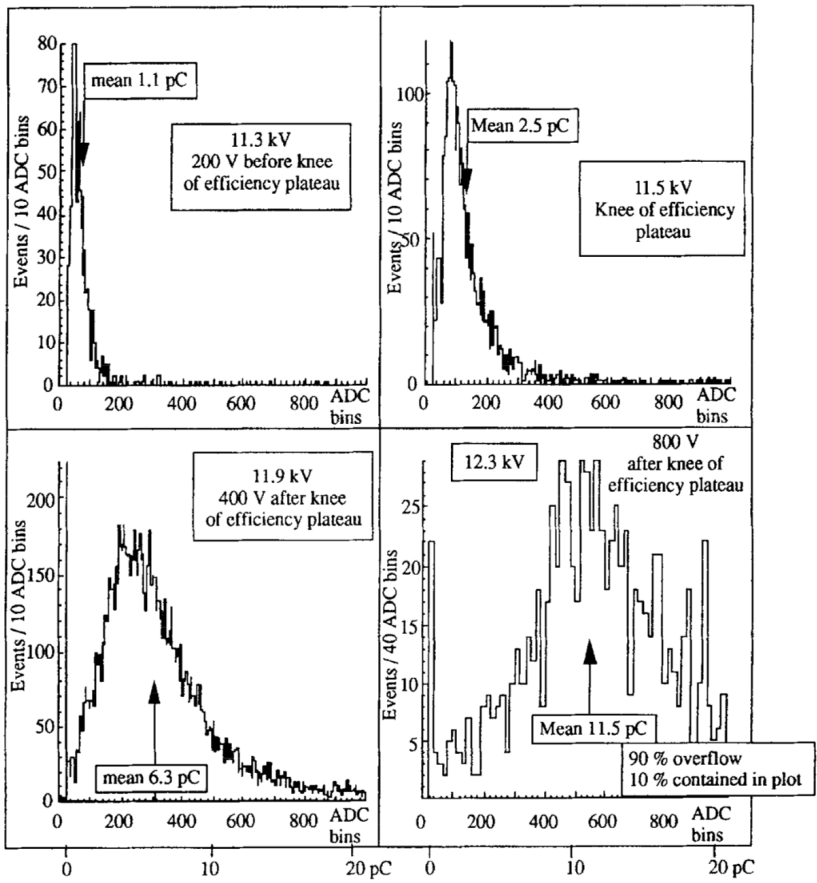




A low power RPC acquisition system was designed, debug and validated.

Charge distribution measurement of MARTA's RPCs

- The charge spectra of the RPC is a direct consequence of the avalanche that is developed inside the detector
- The expected shape of this spectra would be exponential (small avalanches)
- Several models have been proposed describing the avalanche evolution, but no model was able to describe it fully
- This spectra can give us good indications about the RPC behaviour and health

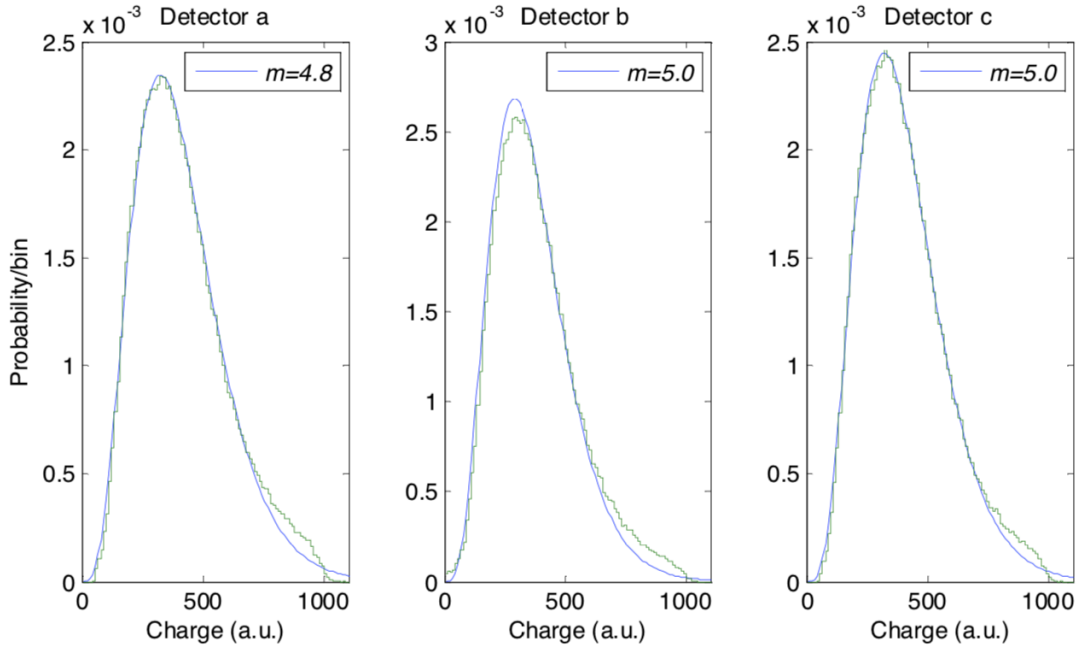


in E. C. Zeballos et al., Pure avalanche mode operation of a 2 mm gap resistive plate chamber, 1997

- One of the proposed models used a gamma distribution to describe the spectra

$$P(\mathcal{N}_e) = \frac{e^{\frac{\mathcal{N}_e}{G/r}} \mathcal{N}_e^{m-1} (G/r)^{-m}}{\Gamma(m)}$$

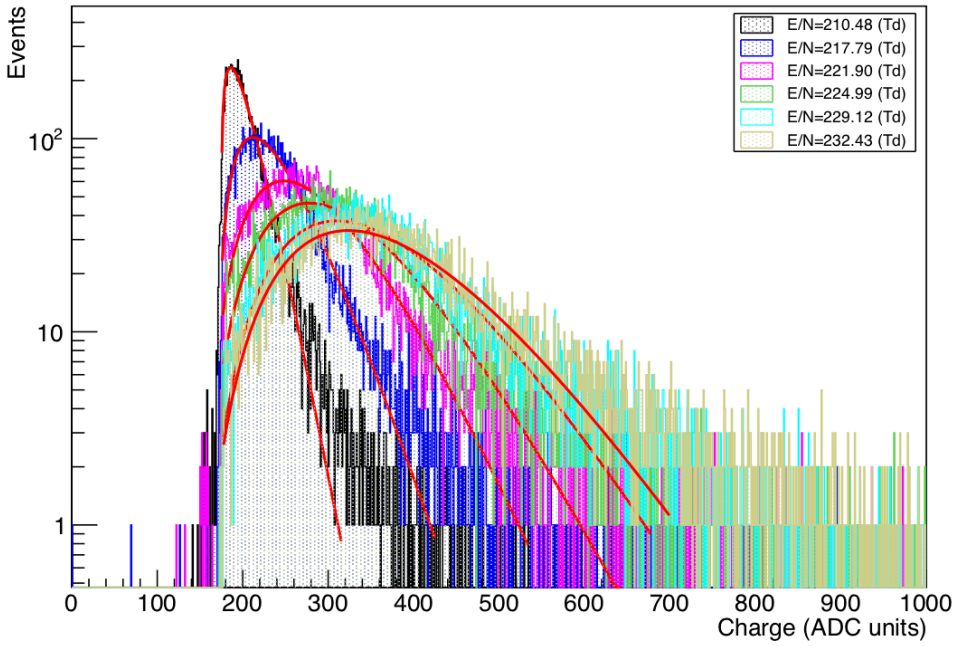
- This function was shown to fit data well

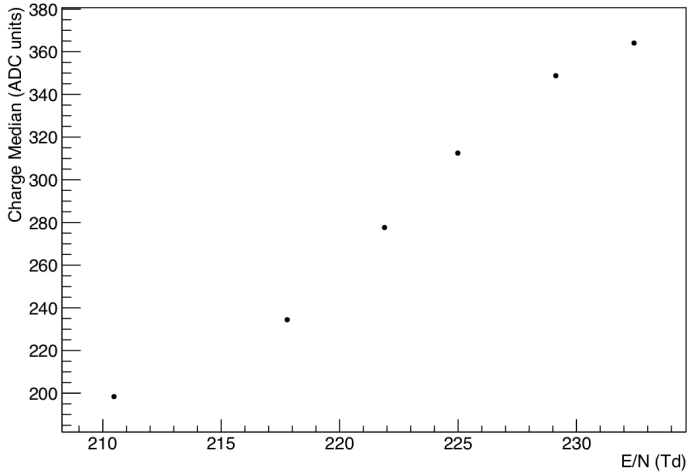


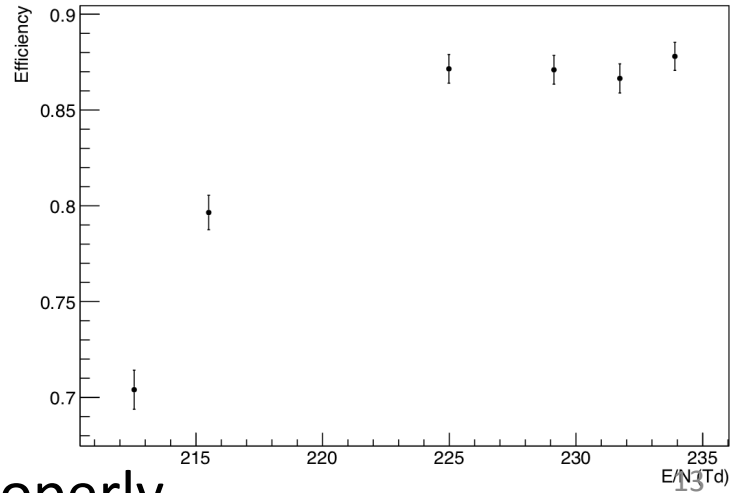
in P. Fonte, Analytical calculation of the charge spectrum generated by ionizing particles in Resistive Plate Chambers at low gas gain, 2013

- In this work, we described the measurement, optimize the measurement parameters and compared data obtained with the gamma distribution

E/N -> Reduced electric field





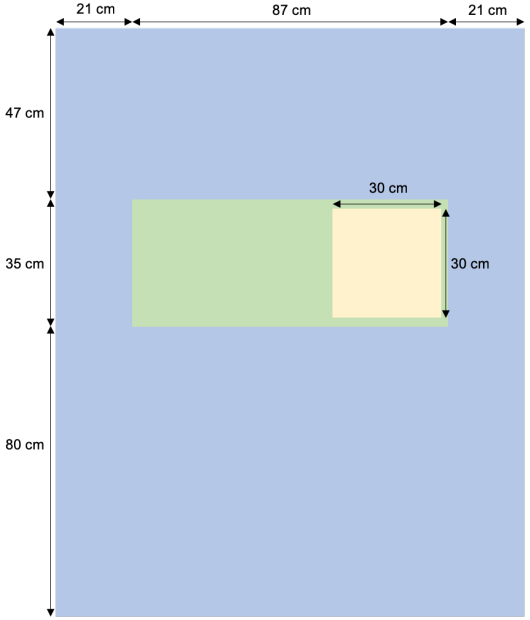


The system measures the RPC charge properly

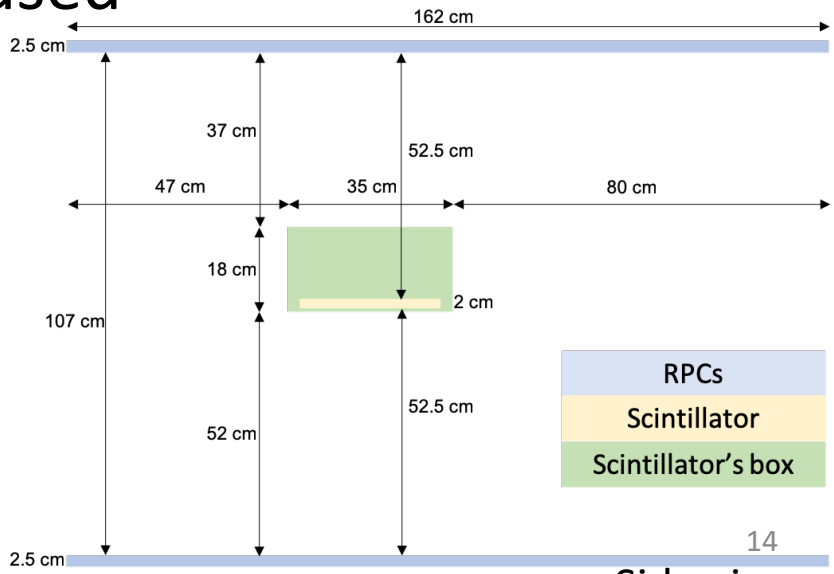
RPC hodoscope for SSD quality control

GAP-2019-017

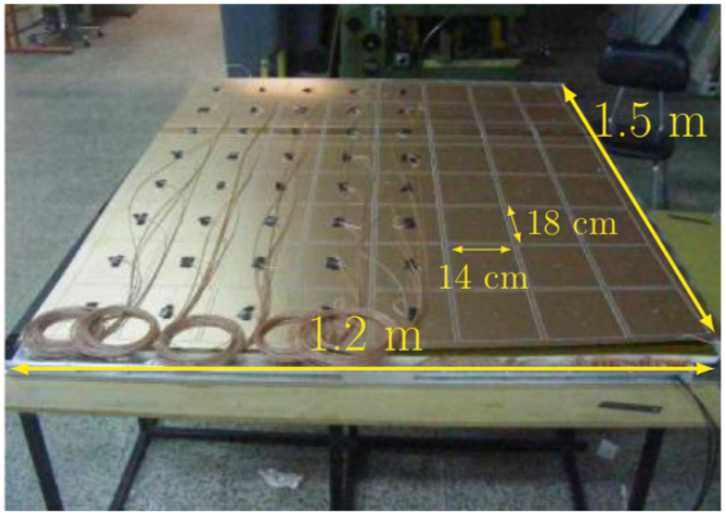
- We built an hodoscope, using MARTA's RPC unit to test the new scintillators that are being installed in the Auger array
- A smaller scintillator was used

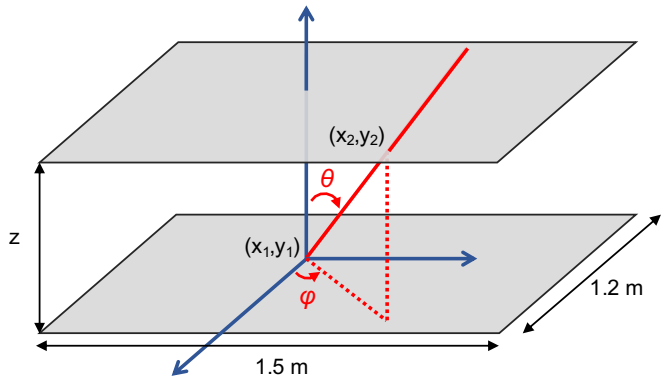


Top view

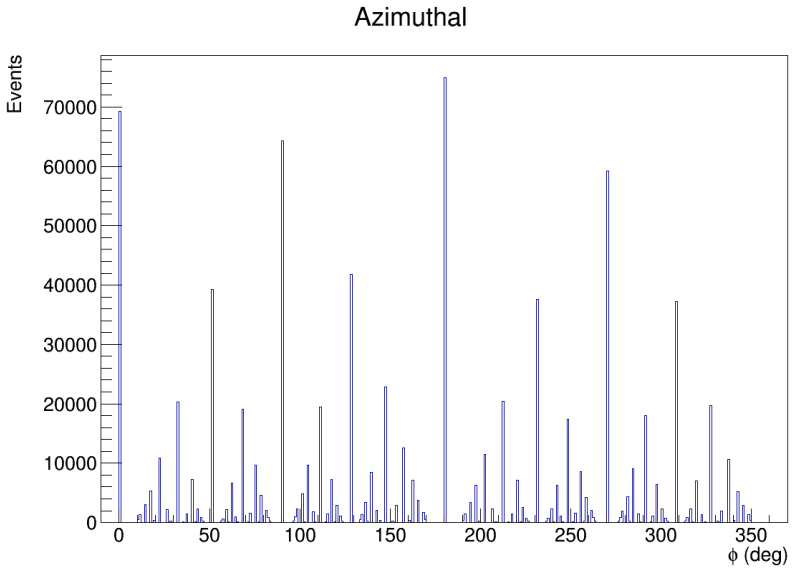


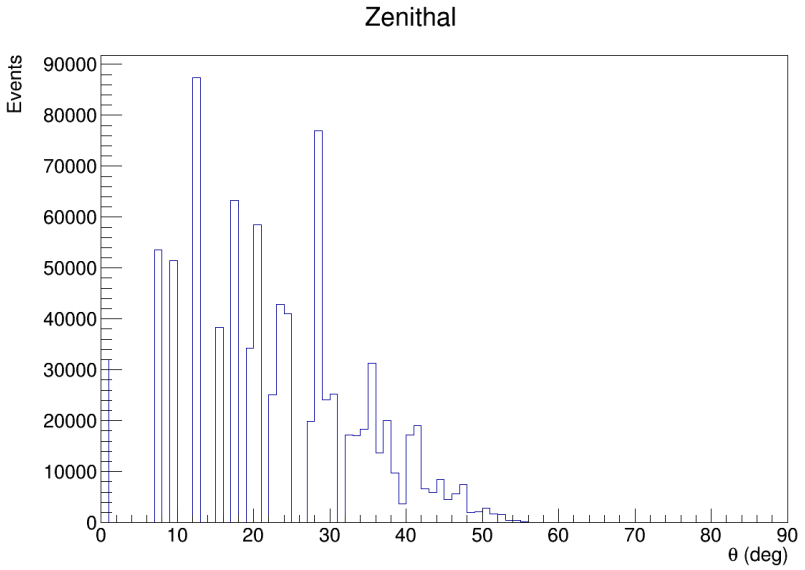
Side view



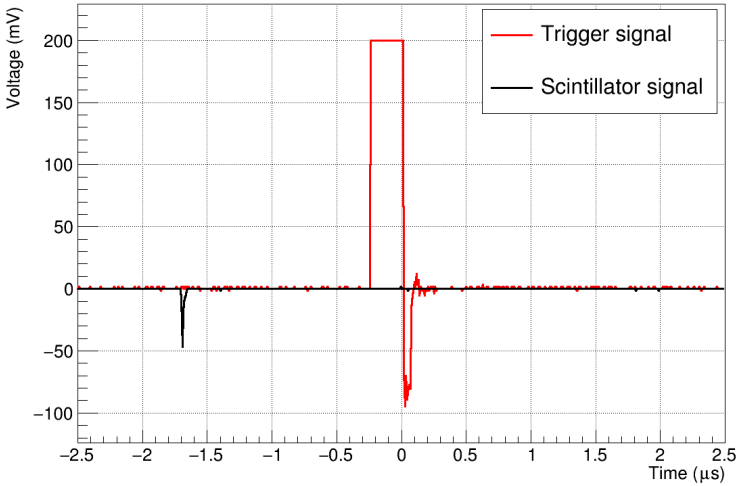


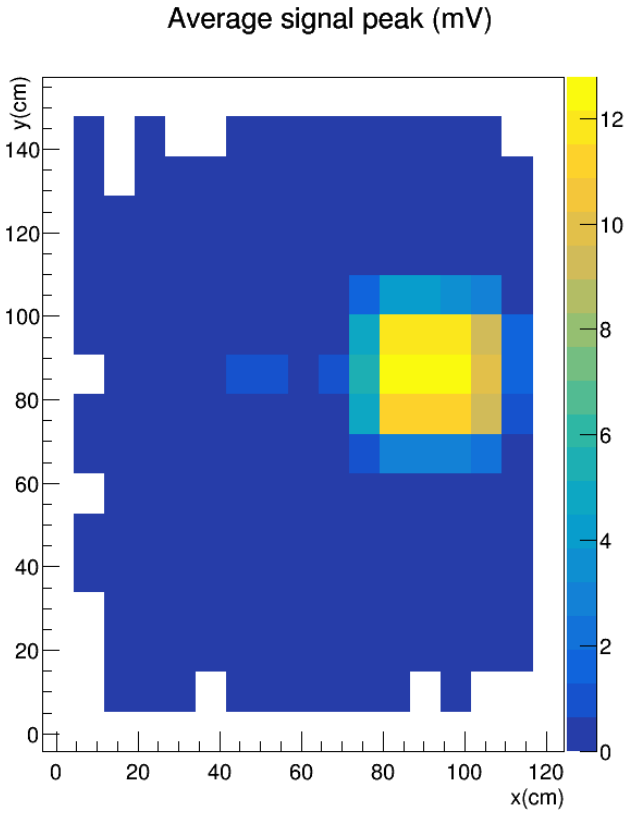
- Data angular distribution

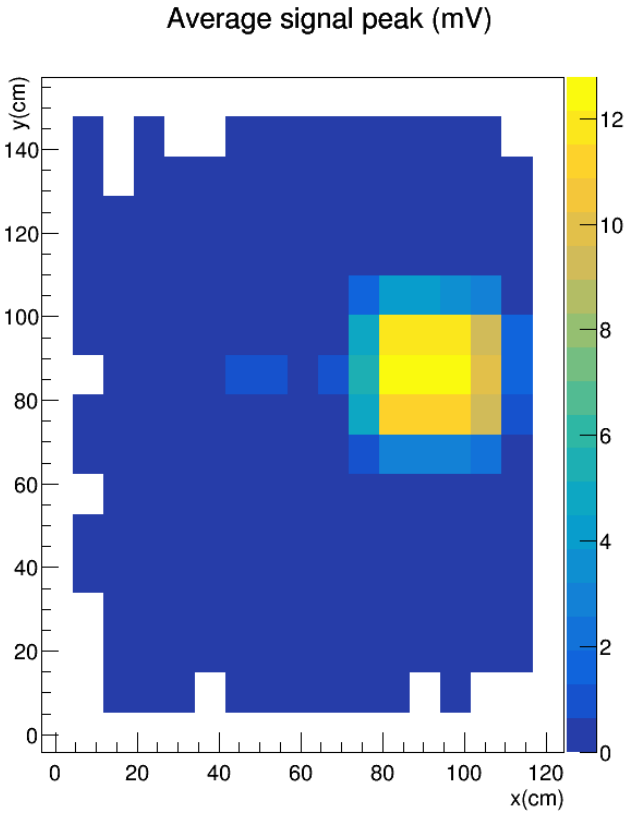


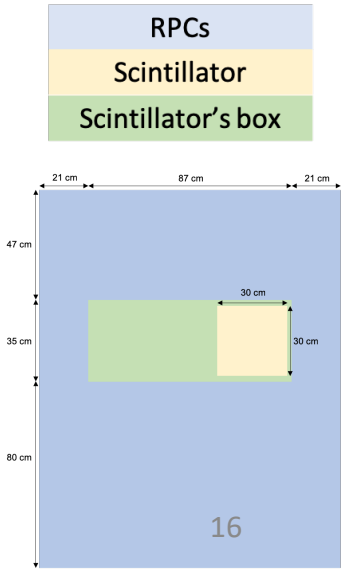


- The RPCs coincidence triggers a measurement in the test scintillator
- We were able to measure the signal vs the particle position

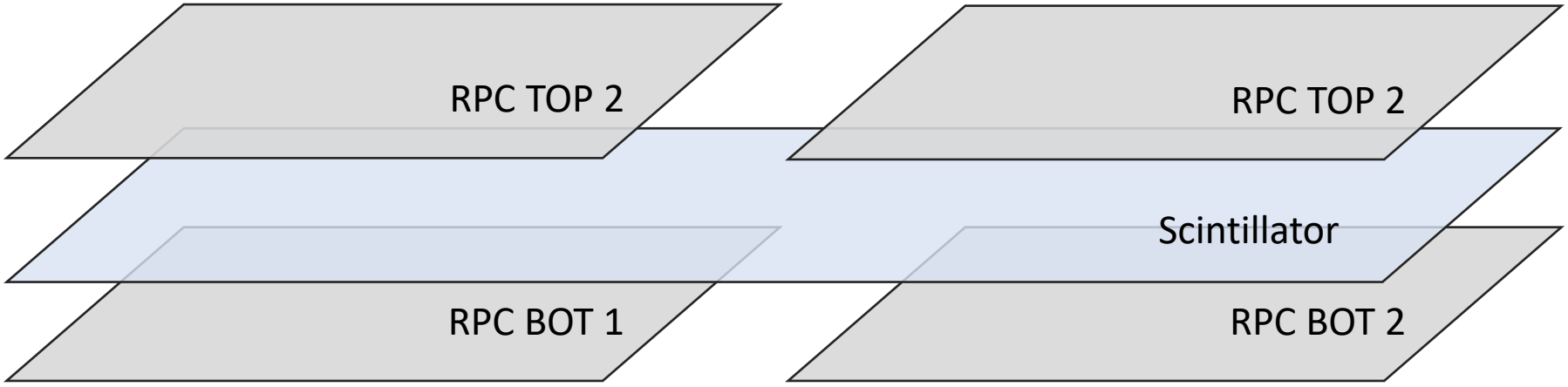








- We were able to build and debug the hodoscope using a test scintillator
- The next step is to make it work with Auger's scintillator and acquisition system
- The new stand was build where 4 RPCs will test the new detector for any broken fibbers or inefficiencies



Conclusions

- A proof of concept DAQ system based on analogue electronics was characterized
- A DAQ system for avalanche RPCs was build, tested, debugged and will be deploy
- It comply with the strict demands of field operation and is able to amplify and measure the fast RPC signals
- Can perform charge measurements with the spectrum following the expected distribution
- We built a test system for the new auger scintillators

Next

- Finish writing the presented work
- Write the thesis
- After:
  - Integrate the RPC hodoscope in the scintillators deployment process
  - Some field tests have already been performed, but more data is needed
  - Deploy a small engineering array of 30 RPCs, that will help determine a calibration point for the muonic component of the air showers
  - It will also be used to cross calibrate other detectors in the array e.g. AMIGA
  - This acquisition system is started to being used in other project like the tomography of the geological structure of the Lousal mine

Thank you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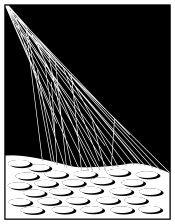
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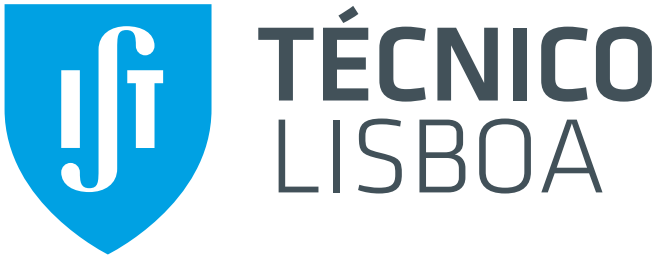
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Cosmic Rays and the Pierre Auger Observatory

- When a cosmic ray particle reaches the atmosphere creates a cascade of particles called Extensive Air Shower (EAS).
- There is a correlation between the particles sampled at ground and the primary cosmic particles.
- The Pierre Auger Observatory is a 3000 km^2 cosmic ray detector, located in Argentina.
- There is a need to get a more precise and independent measurement of the EAS' muon content.
- This measurement would allow to:
  - Distinguish FE and proton showers.
  - Understand the discrepancy between the muon models and data.