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MARTA readout system

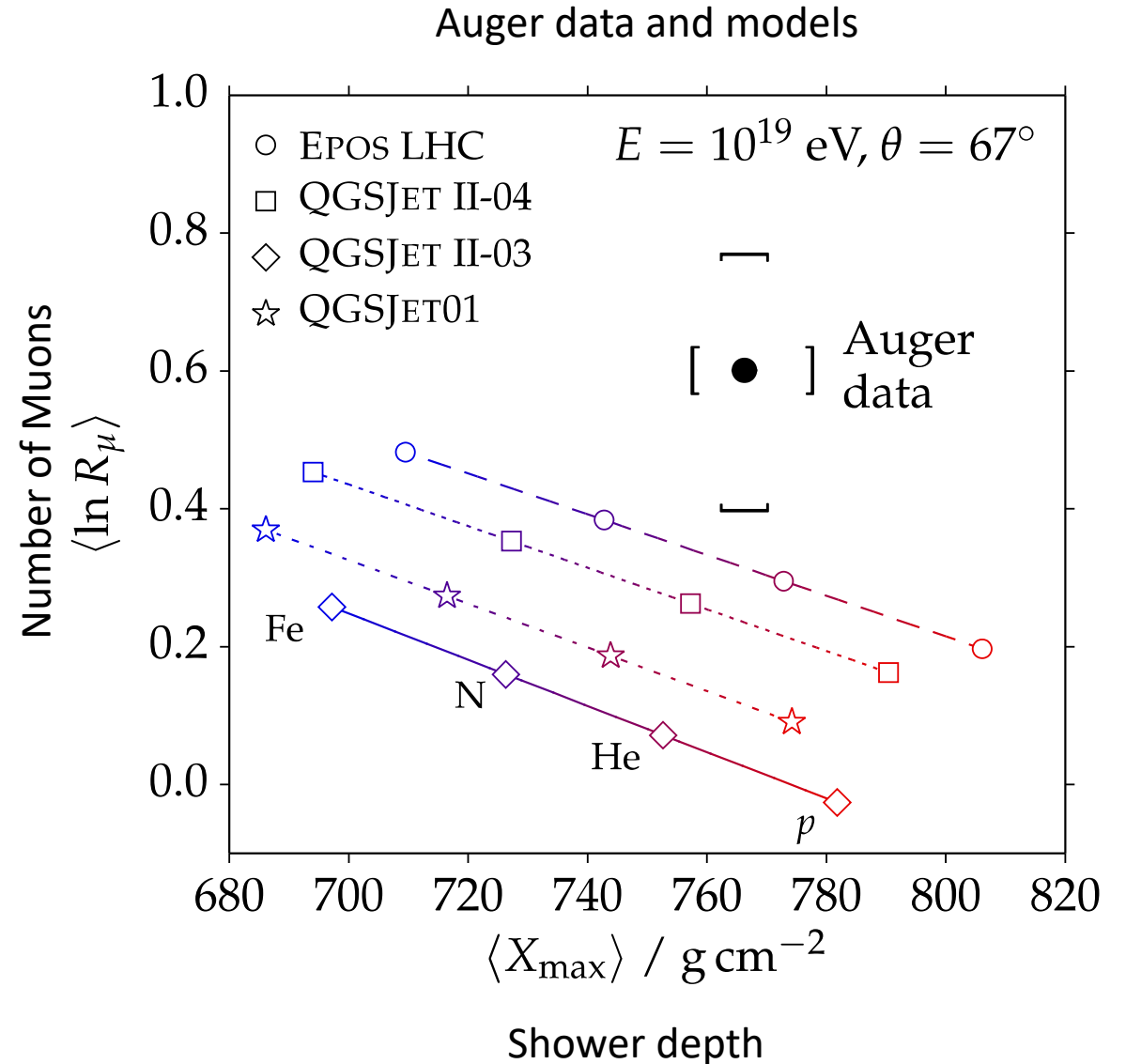
Ricardo Luz

4th IDPASC Students Workshop

Coimbra, June 2018

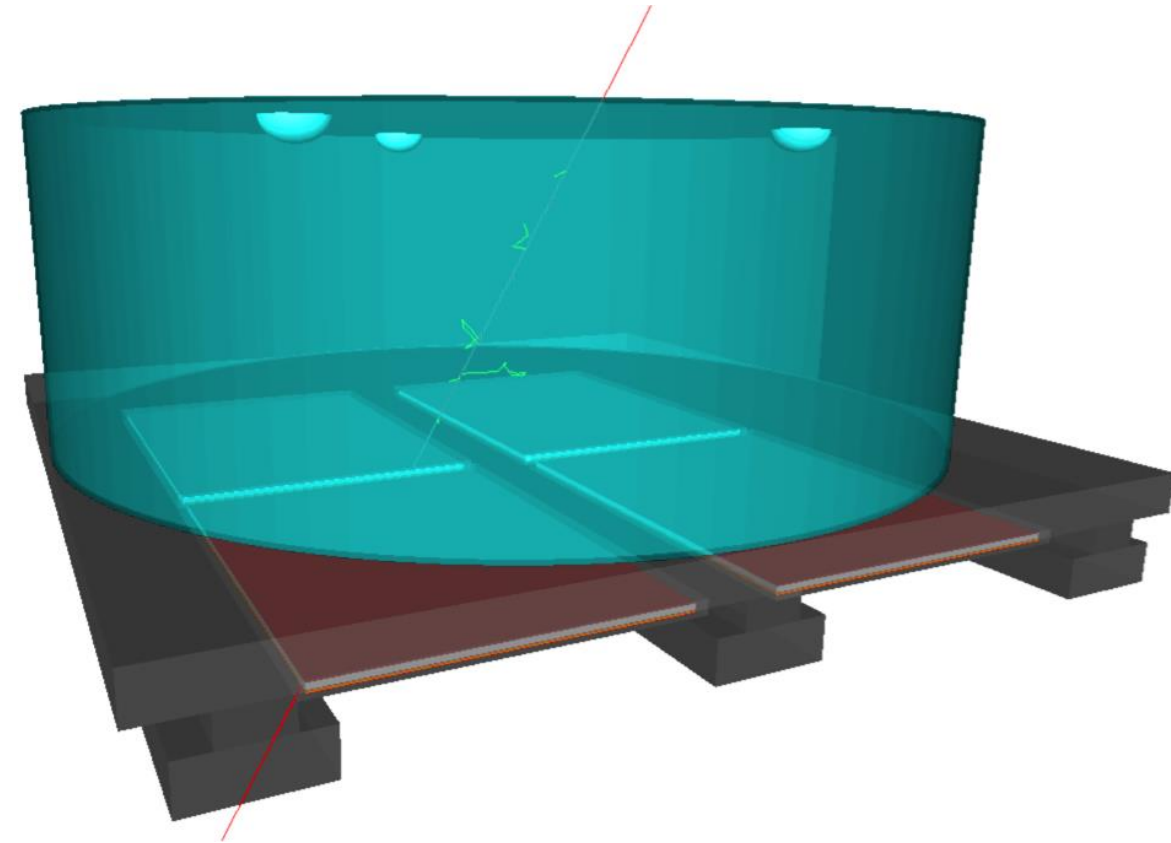
Motivation

- Auger's water Cherenkov detectors (WCD) measure a combination of the muonic and electromagnetic component of the air shower.
- A new and more precise and independent measurement of the air shower content would allow:
 - Understand the discrepancy between the muon models and data.
 - Help distinguish between iron and proton showers.



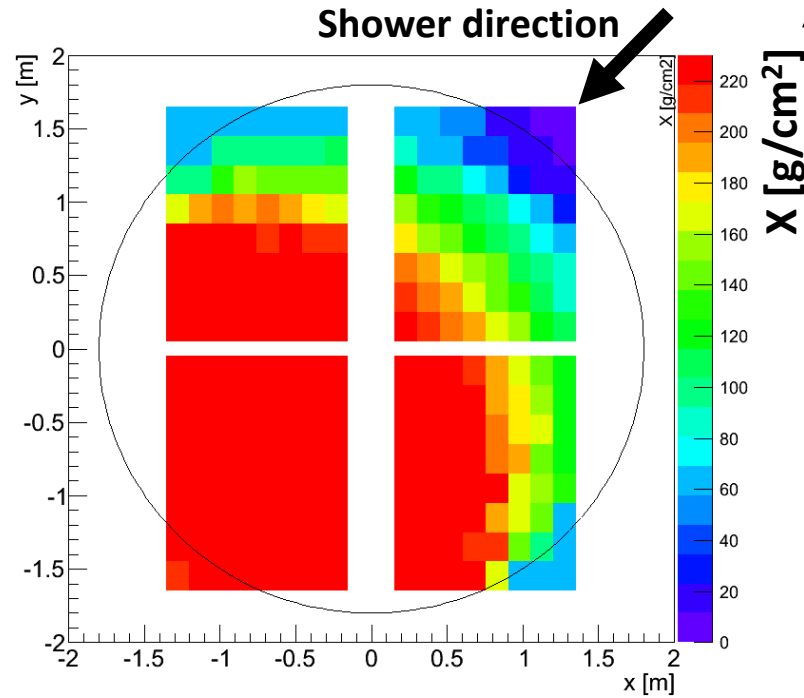
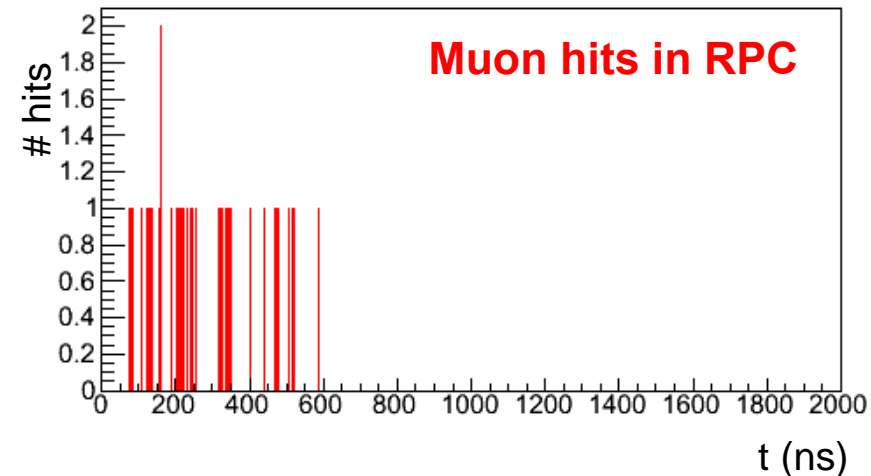
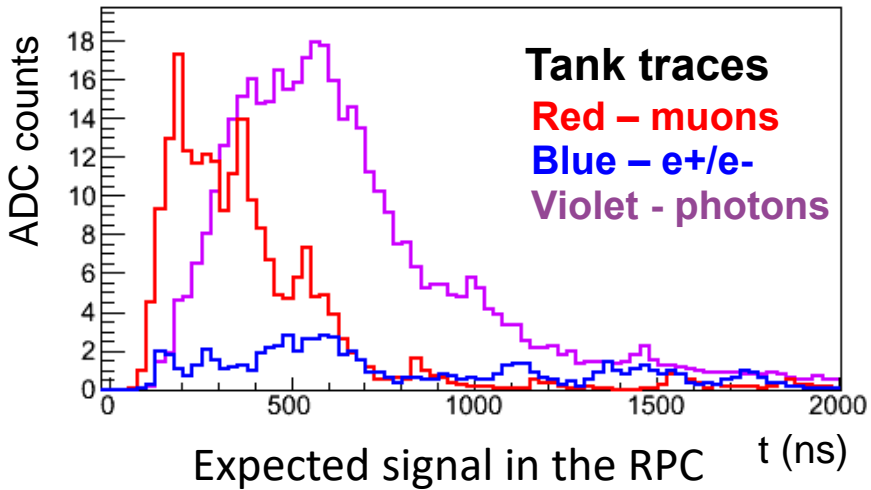
MARTA - Muon Array with RPCs for Tagging Air showers

- MARTA proposes to perform this measurement by adding RPCs detectors under the WCDs.
- The electromagnetic component of the shower will be strongly attenuated in the WCD and only the muons will reach the RPC.
- MARTA was designed with the requirements of Auger:
 - Low cost and low power stations.
 - Operate in harsh outdoors conditions.
 - Standalone with minimal maintenance.



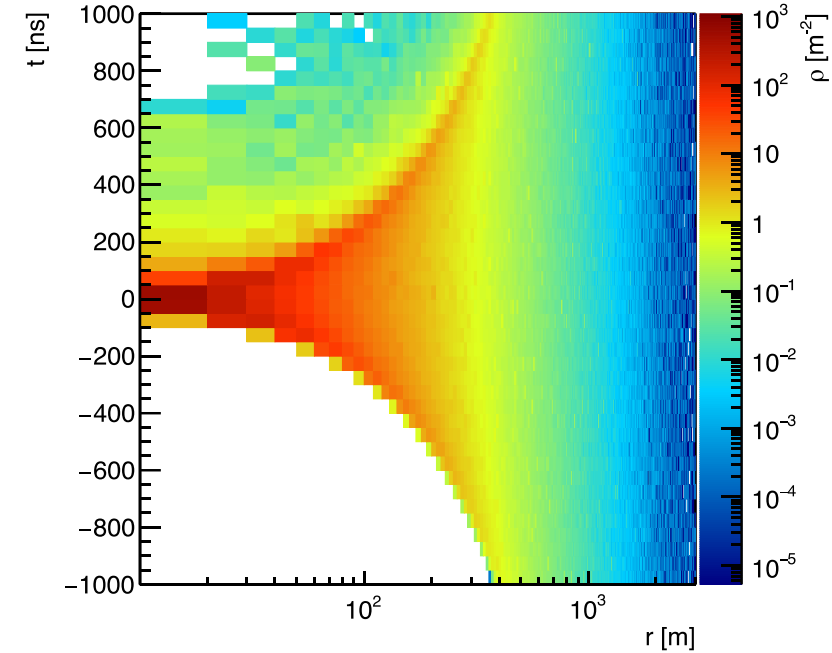
MARTA concept

Expected signal in the WCD



Mass overburden map

$\Delta t = 50$ ns



Particle density

Eur. Phys. J. C (2018) 78:333
<https://doi.org/10.1140/epjc/s10052-018-5820-2>

Regular Article - Experimental Physics

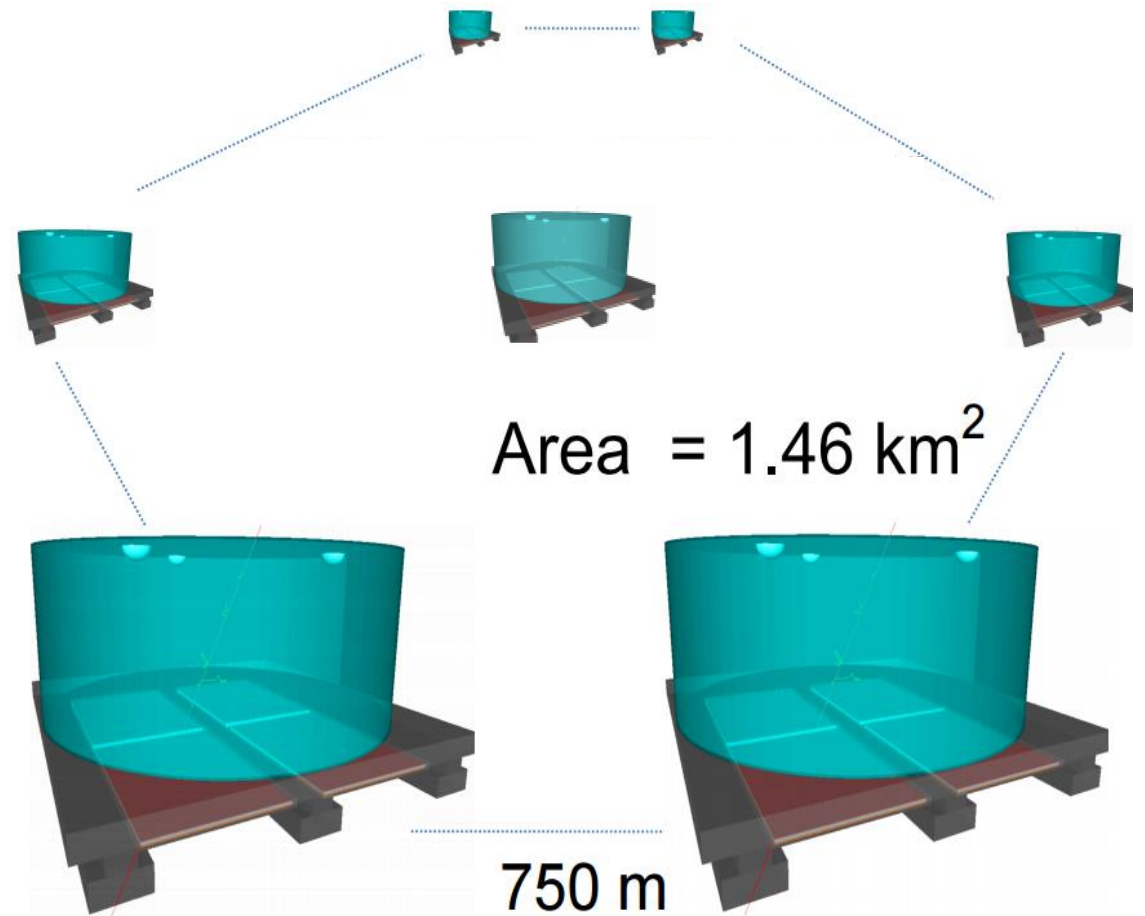
THE EUROPEAN
 PHYSICAL JOURNAL C



MARTA: a high-energy cosmic-ray detector concept for high-accuracy muon measurement

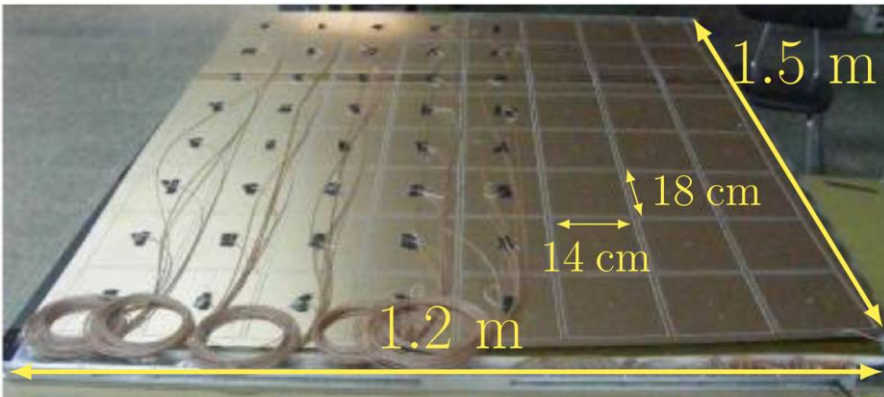
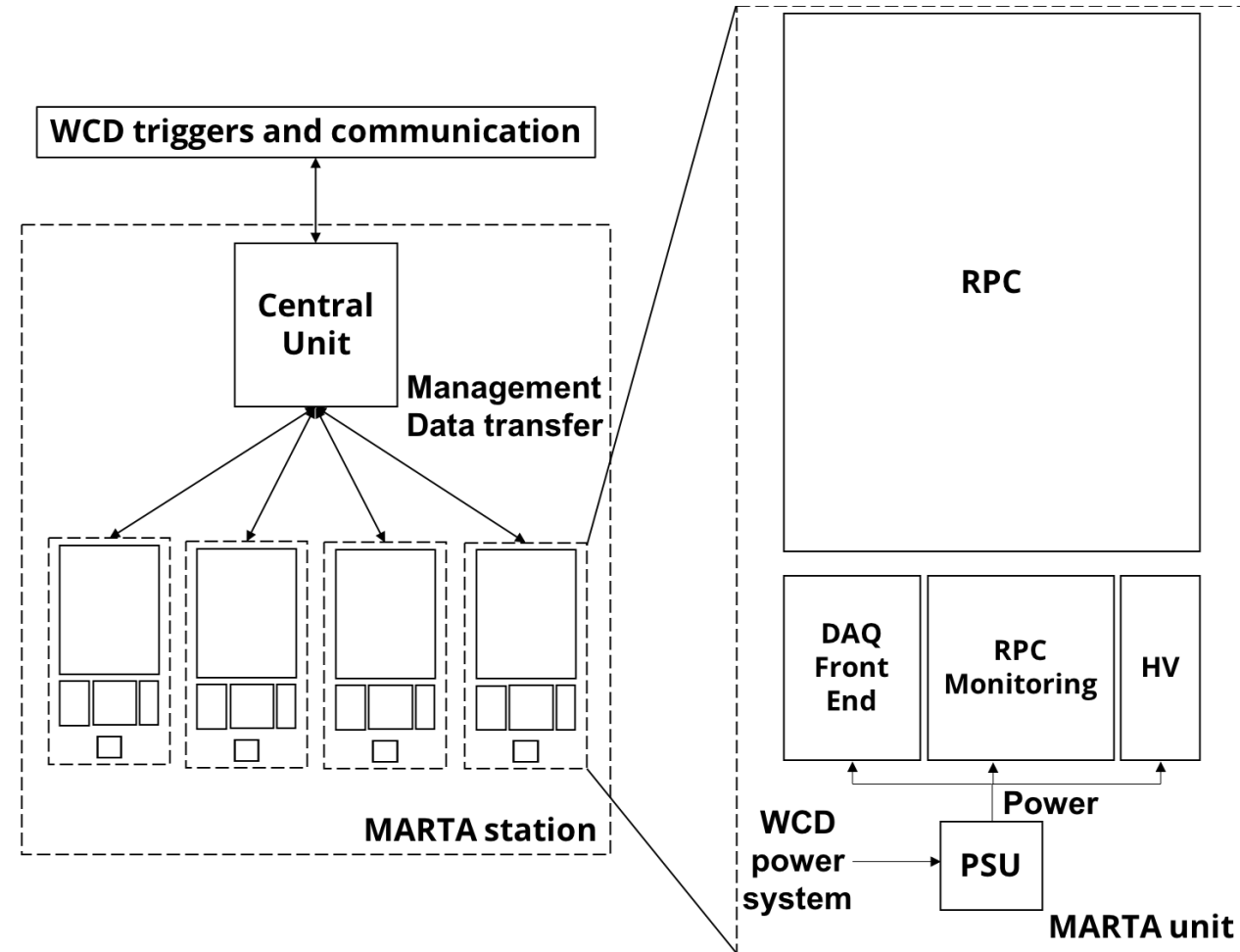
MARTA Engineering Array

- An EA of 7 MARTA stations have been approved by the collaboration and financed.
- It will serve as a proof of concept for the MARTA design and will help to cross calibrate new Auger detectors.
- The array will take advantage of Auger triggers - 100 Hz rate - and communication system - bidirectional radio frequency.



MARTA Station and Unit

- Each station has 4 MARTA Units.
- A Central Unit will concentrate the data of the 4 units and be the interface with the WCD.
- Each MARTA Unit is placed inside an aluminium box that contains:
 - RPC
 - RPC high voltage and monitoring
 - Power supply unit
 - **DAQ Front-End**

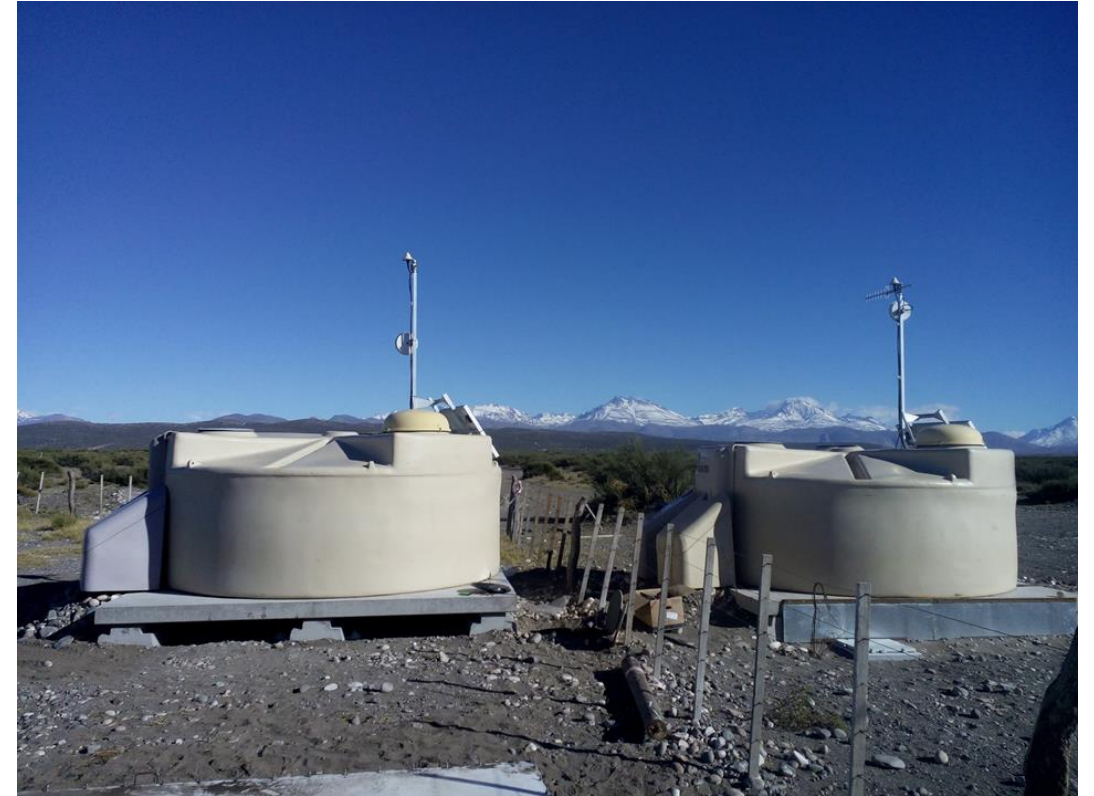


RPC:

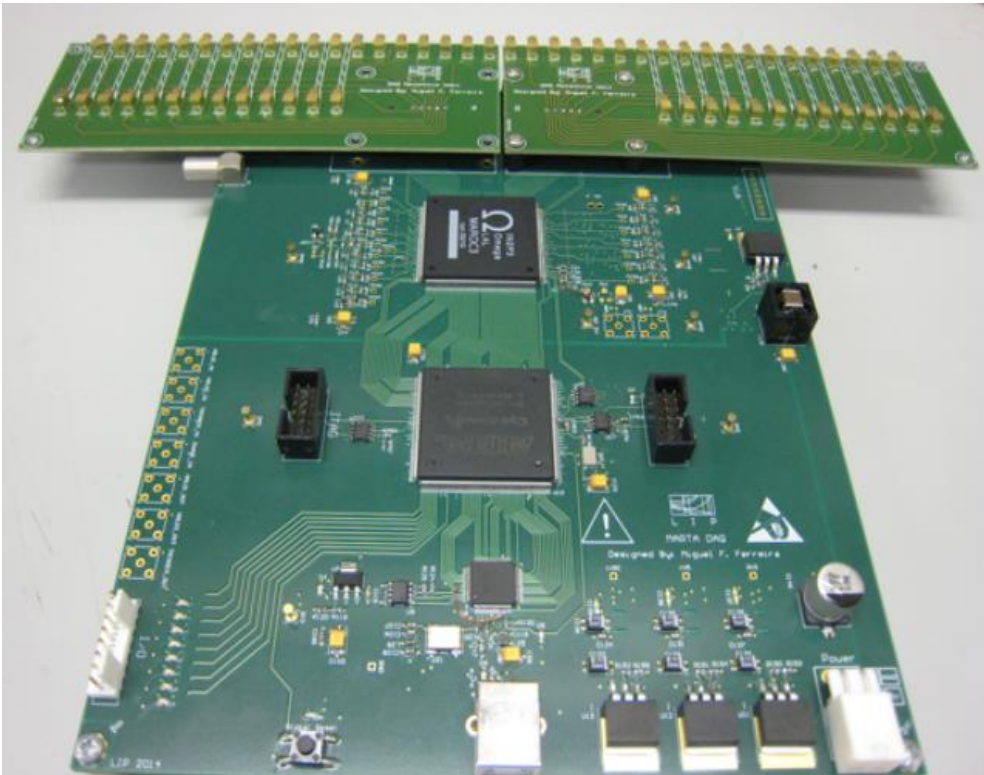
- Three 2mm glass plates
- Two 1 mm gas gaps
- HV applied to the outer glasses
- Area of $1.2 \times 1.5 \text{ m}^2$
- 8×8 pad grid
- Pads with $14 \times 18 \text{ cm}^2$
- Modest high voltage to work in the avalanche regime

Front-End - Challenge and requirements

- RPCs and existent DAQ systems have been mostly used in laboratory and are not prepared to work in field conditions.
- Requirements:
 - Estimate the number of particles in low and high density regions (up to 180 particles per RPC) using a charge measurement whenever necessary.
 - Fast signal digitalization to deal with the RPC pulses (about 8 ns)
 - Low power of a few watts per RPC
 - Stable and reliable for low maintenance operation
 - Compact design due to space limitation inside the aluminium box



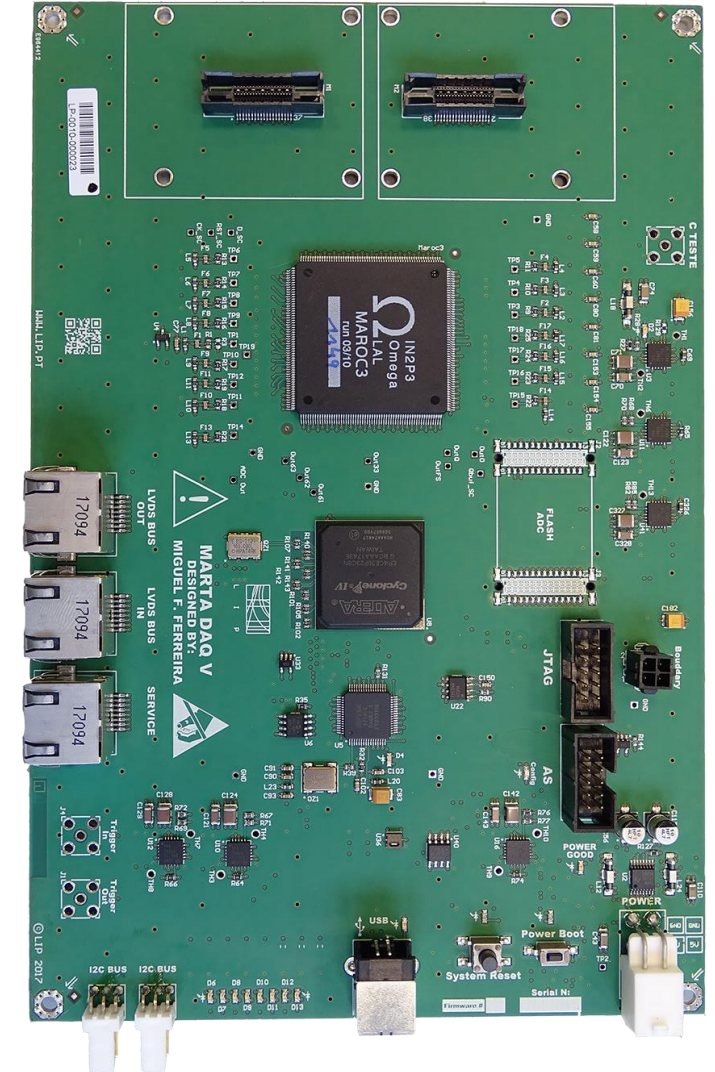
Front-End - Prototypes and final version



First Prototype – Mid 2014



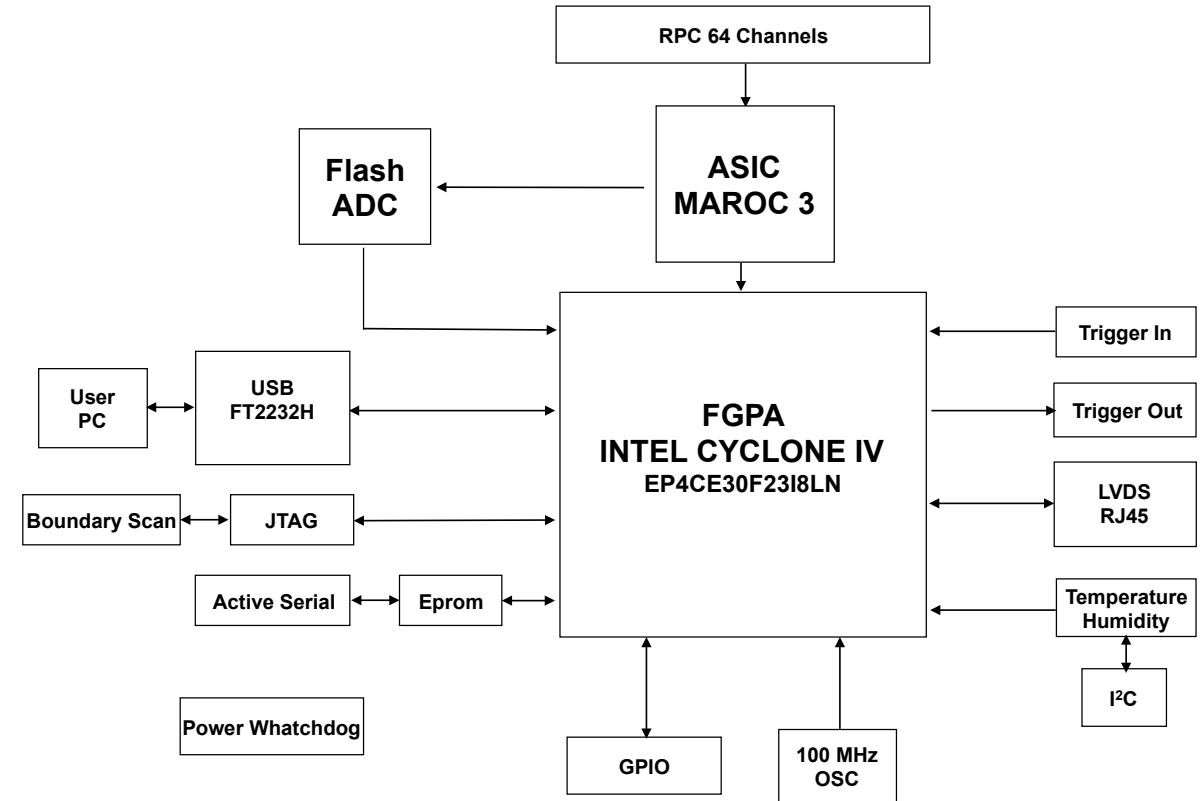
Second Prototype – End 2016



Final production – Early 2018

Front-End main components

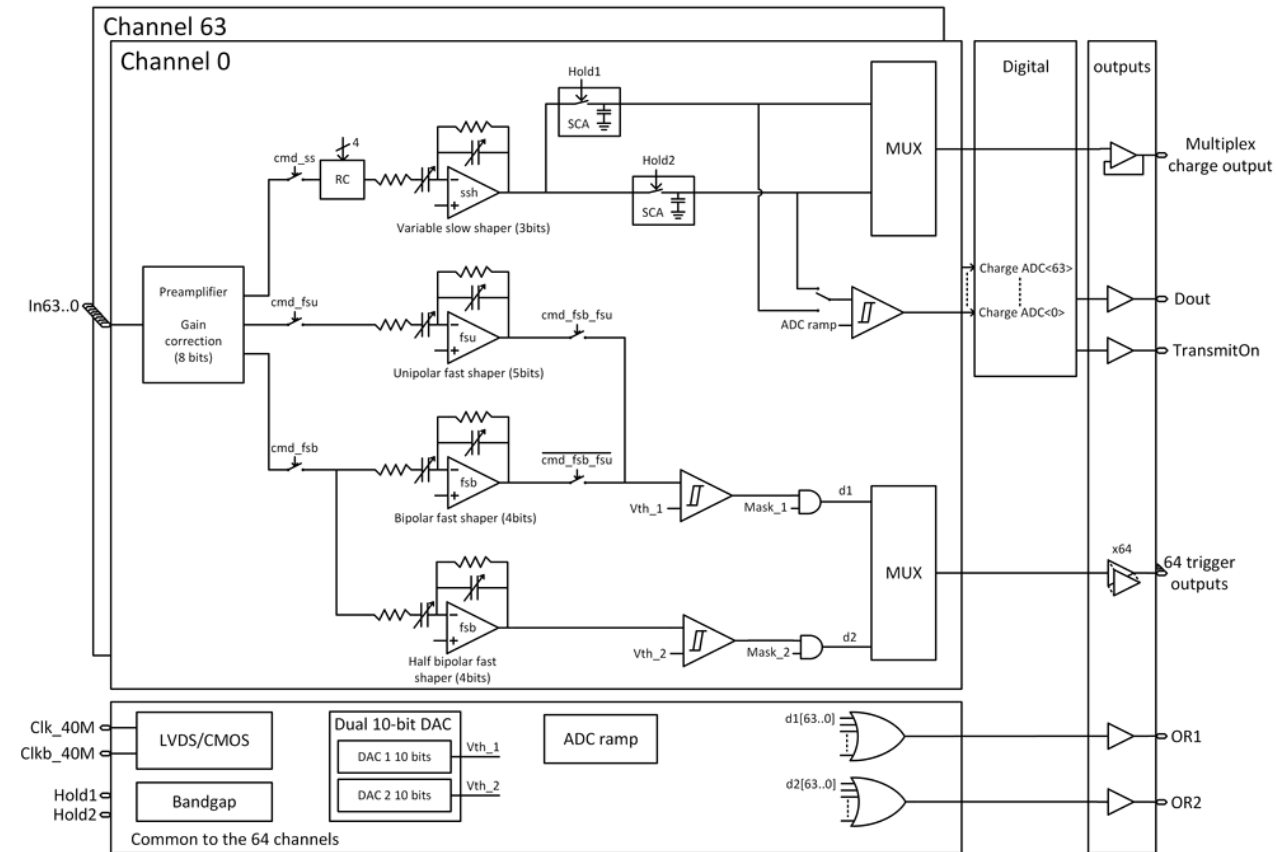
- MAROC 3 ASIC: Analog electronics. Low power and capable to count particles with a simple threshold. It can also measure the charge.
- FPGA: Digital electronics. Responsible for data management, data storage and interface with all the other components.
- LVDS lines: Data transfer, trigger synchronization and communications with the Central Unit.
- USB: Used for debug with a PC.



1 Front-End per RPC - 64 input channels
Area: $21.6 \times 14.4 \text{ cm}^2$
Power consumption: 1.43 W per board

Front-End measurements

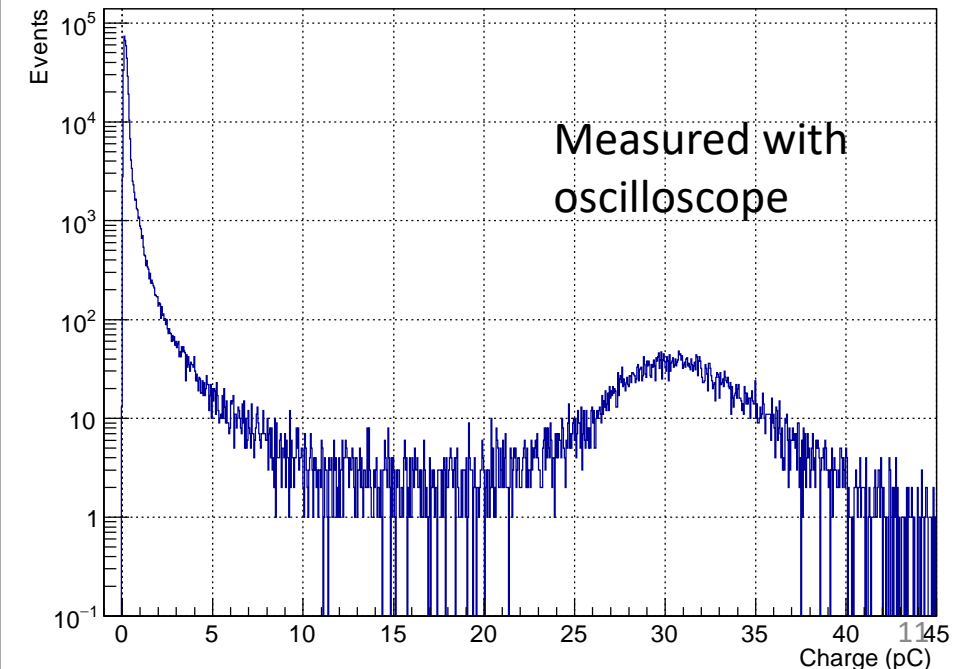
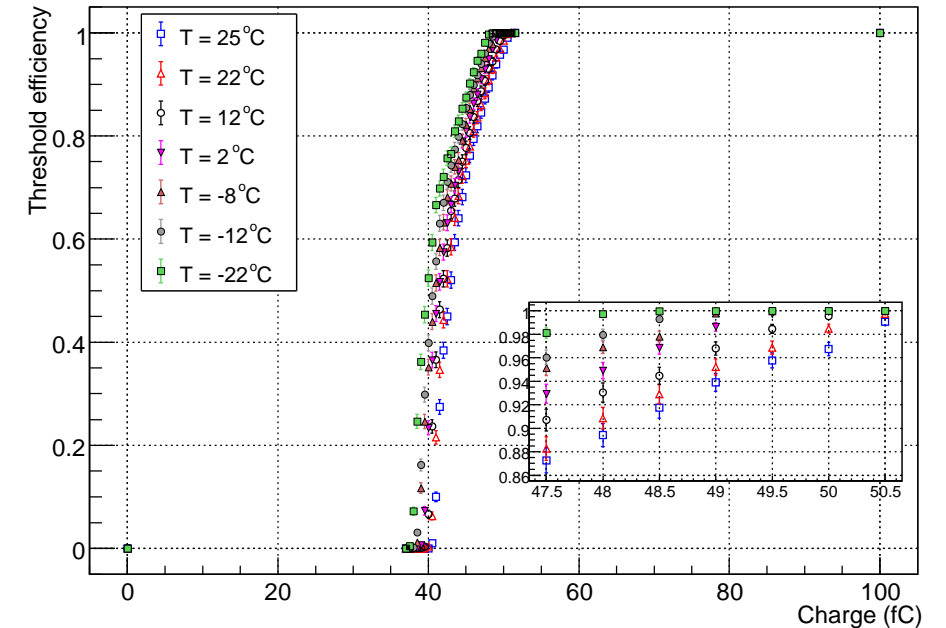
- All the signals are pre-amplified up to 4 times.
- Count measurement: A fast shaper (25 ns rising time) is applied to pre-amplified signal. After the threshold discriminates the signal. 128 “pictures” with an 80 MHz clock of this outputs are stored a total of (1.6 μ s).
- Charge measurement: A slow shaper (150 ns rising time) is applied to the pre-amplified signal. A delay is added to the count output to control a sample and hold that will hold the shaper peak (proportional to the induced charge in the pad). A 12 bits ADC converts this signal to digital.



Count reading dead time: 200 μ s
Charge conversion dead time: 100 μ s
Charge reading dead time: 20 μ s
Maximum measurement rate: 3.125 kHz
Auger trigger: 100 Hz

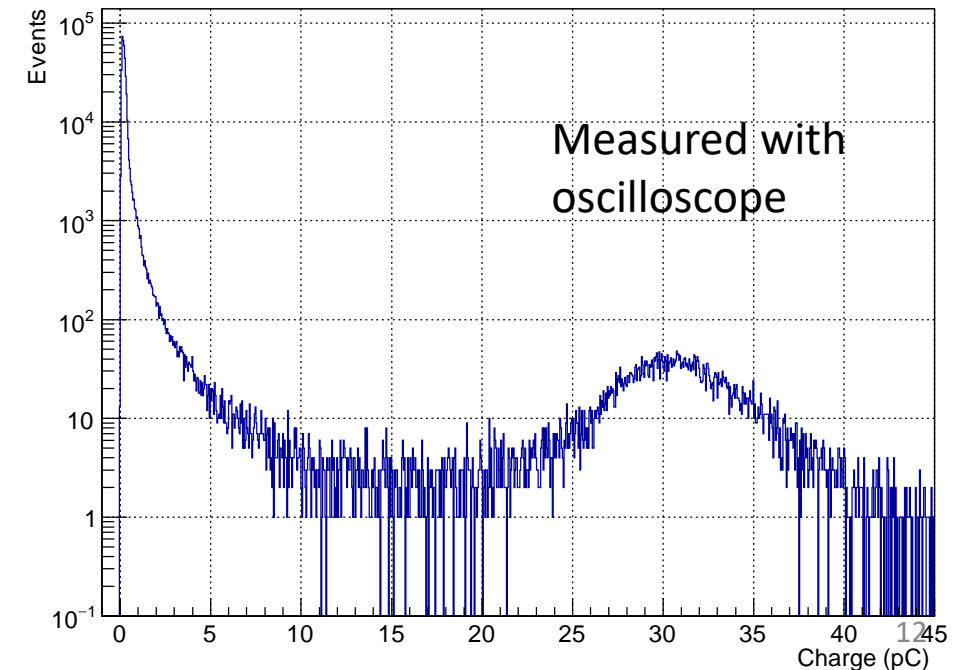
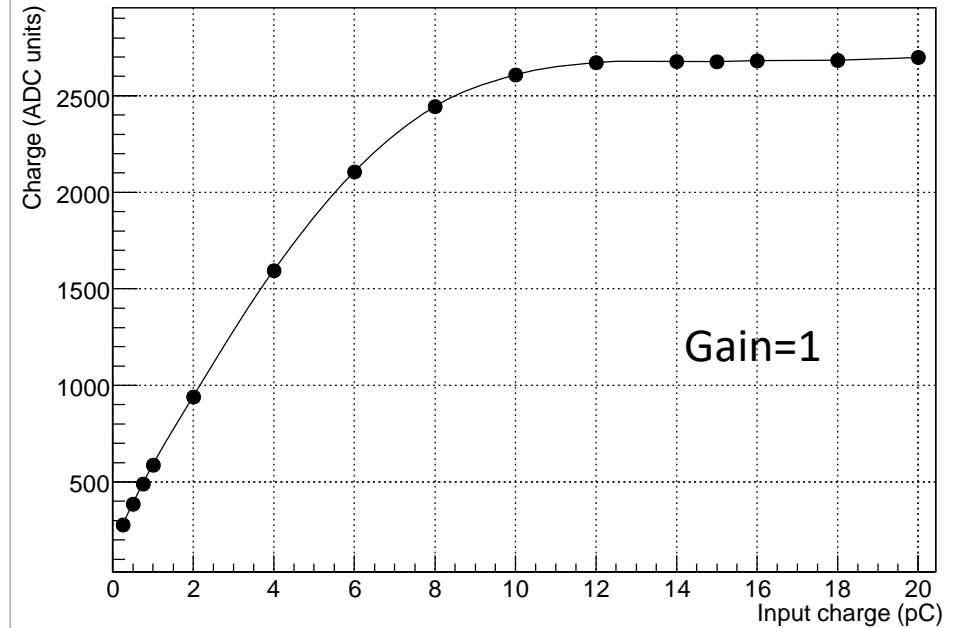
Front-End performance

- The threshold efficiency (s-curve) was studied for different temperature conditions.
- After 50 fC the threshold efficiency is 100 % for all conditions.
- The temperature effect shows a width of 3 fC in the s-curve between the lowest and highest temperature.
- Average charge of the RPC spectrum is 0.86 pC.



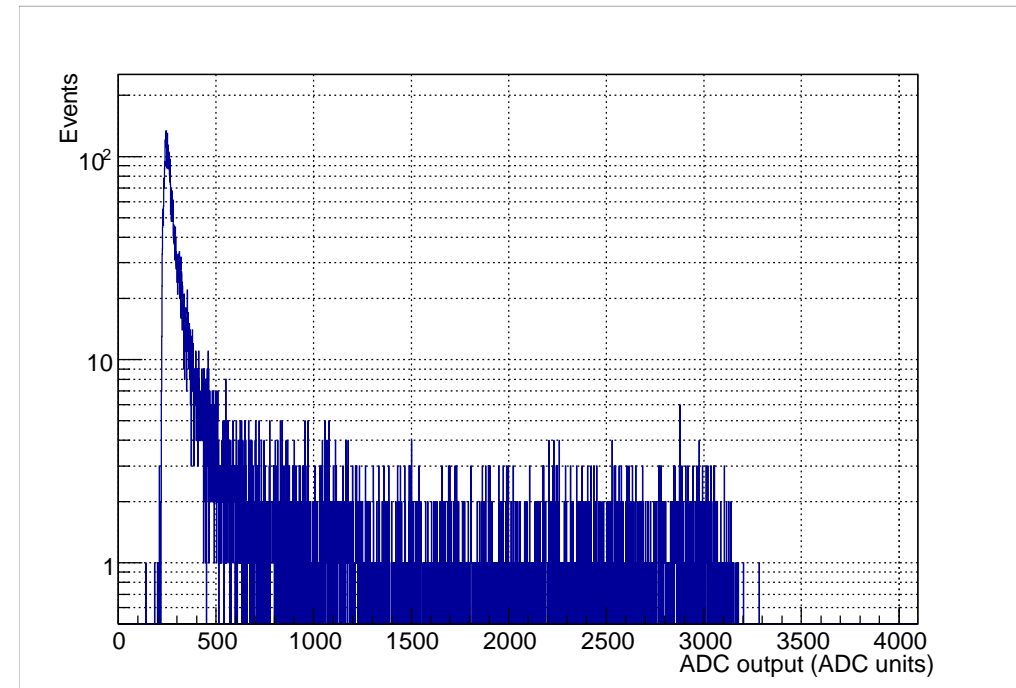
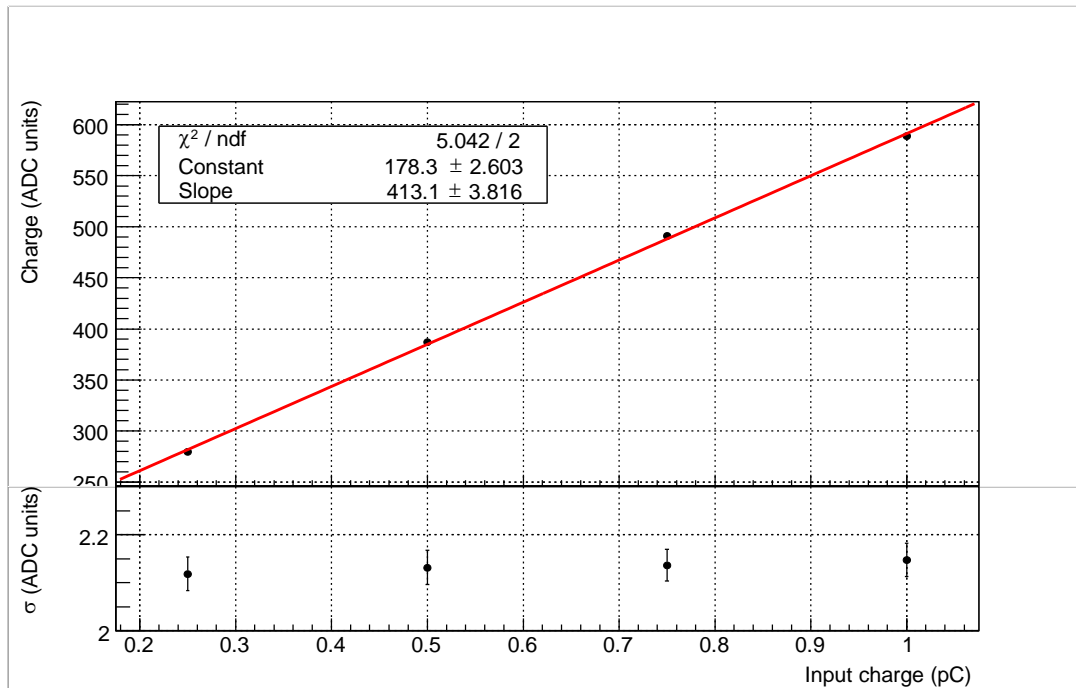
Front-End performance

- The ADC response to different charges was studied.
- Linear until about 6 pC.
- 95 % of the events of the spectrum are between 0 and 1 pC.
- Only 1.6% are in the streamer region (25 to 35 pC).
- By reducing the pre-amplifier gain higher charges can be achieved.



Front-End performance

- A linear dependency was obtained for the range 0 to 1 pC and taken as the calibration.
- A calibration needs to be performed for each channel for every board.
- Charge spectrum acquired with the MARTA Front-End

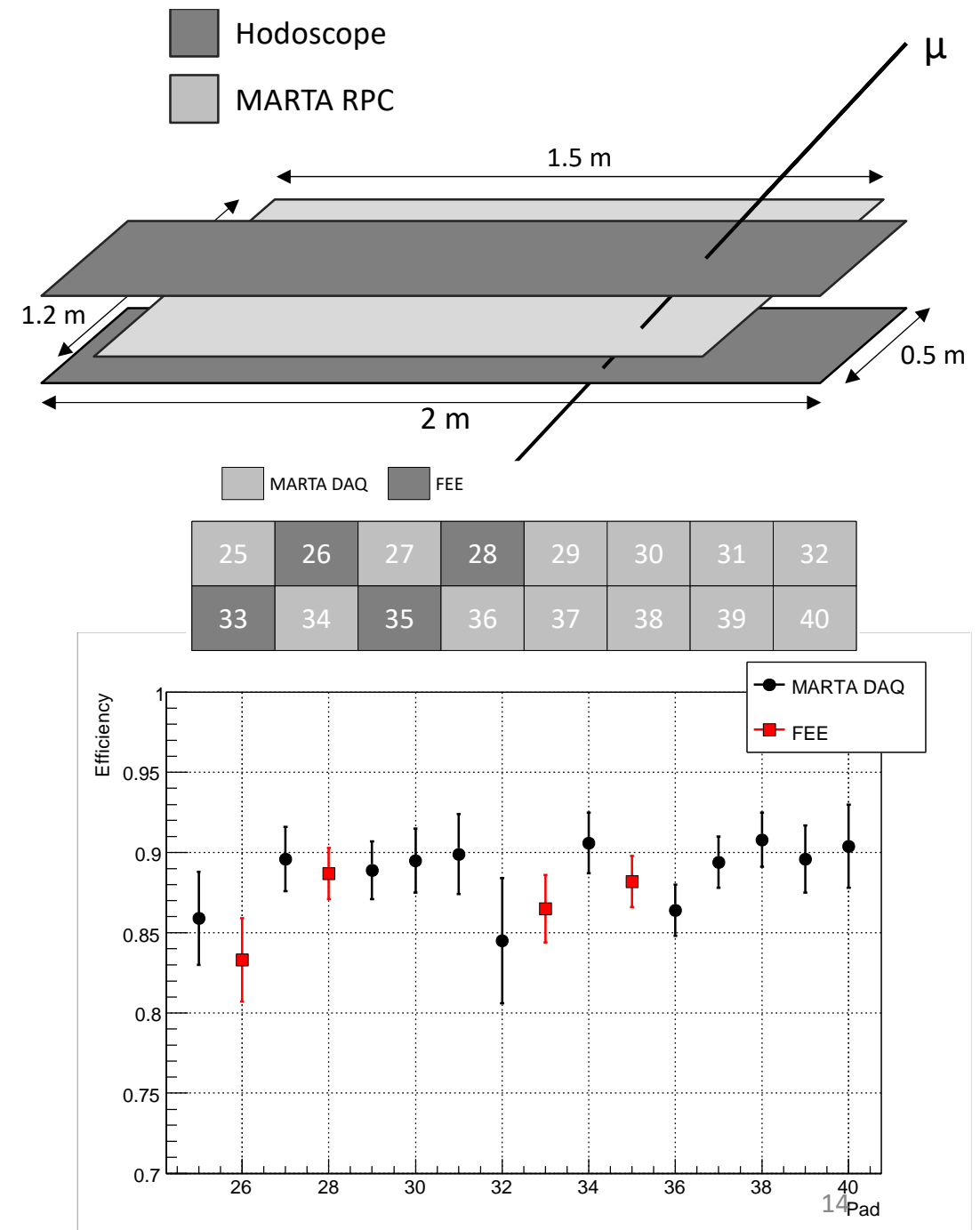


Avalanche peak well define

No streamer peak -> Low number of events

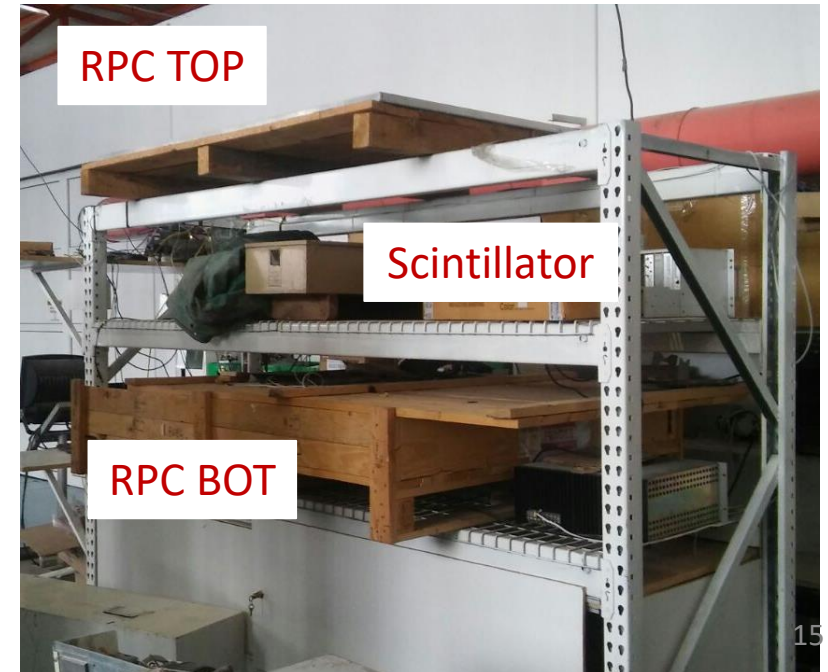
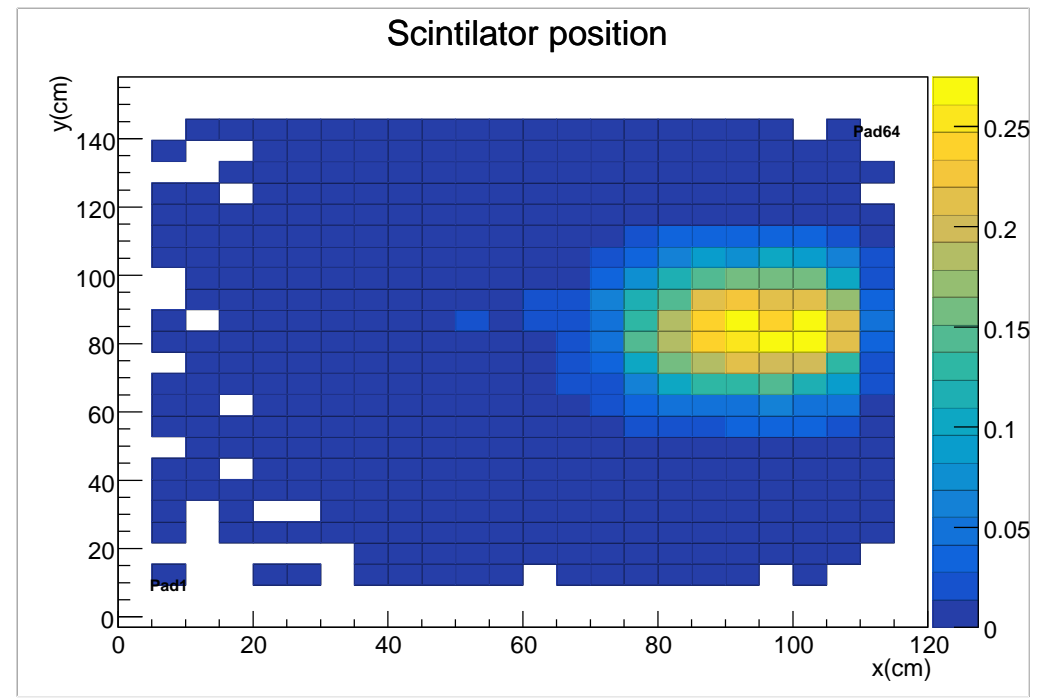
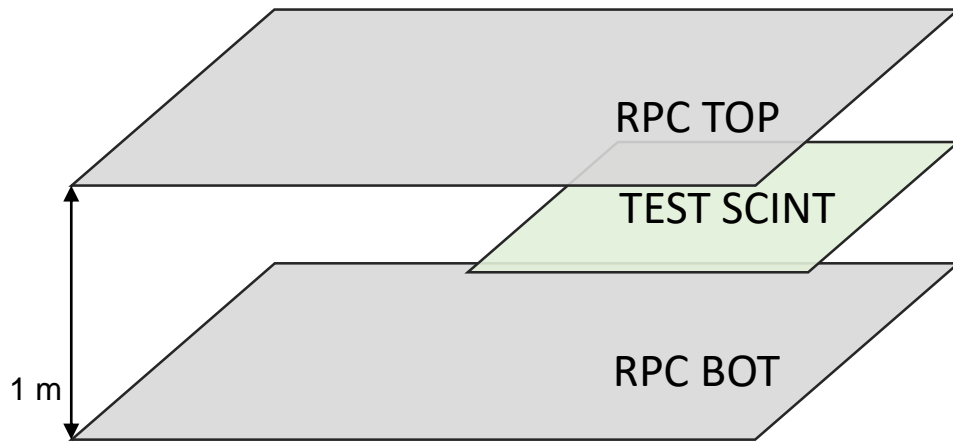
Front-End performance

- The overall performance to measure muons was tested using a hodoscope.
- 16 pads were instrumented: 12 with MARTA Front-End and 4 with another establish DAQ (HADES FEE).
- To minimize geometrical inefficiencies, the mean efficiency of pads 25,27,34 and 27 was compared with that of pads 26,28, 33 and 35, showing compatible results with a standard deviation between measurements of 2.1.
- Validating MARTA Front-End as a good acquisition system.



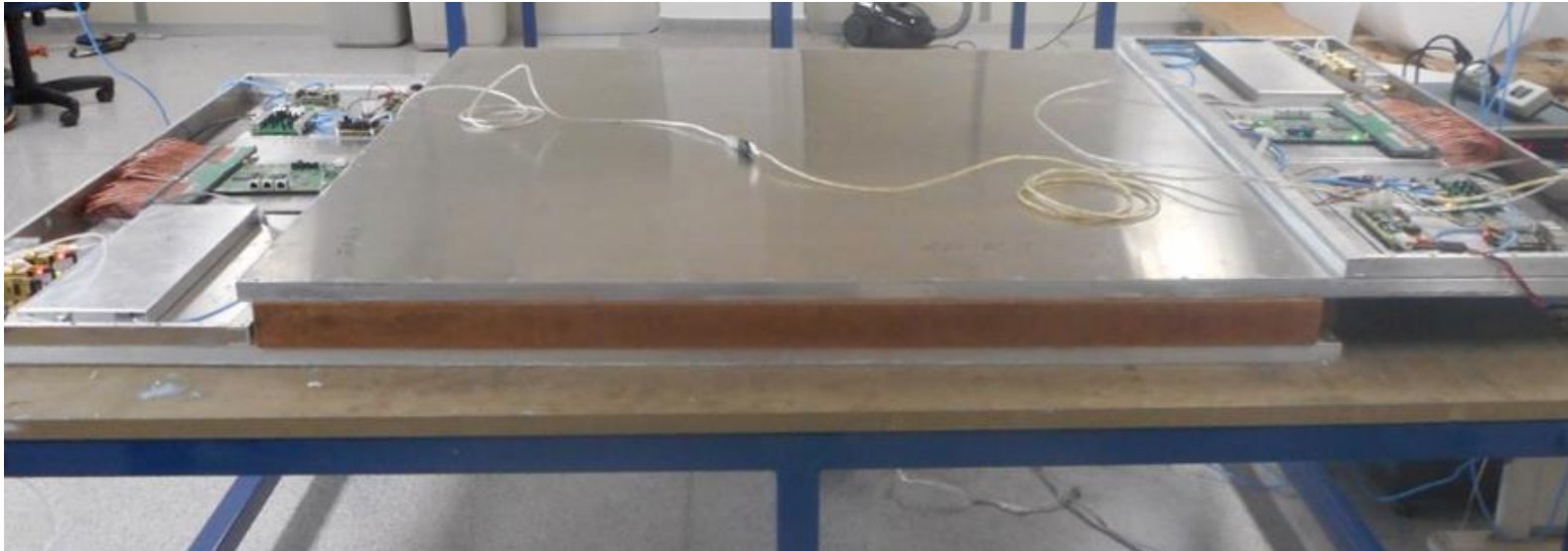
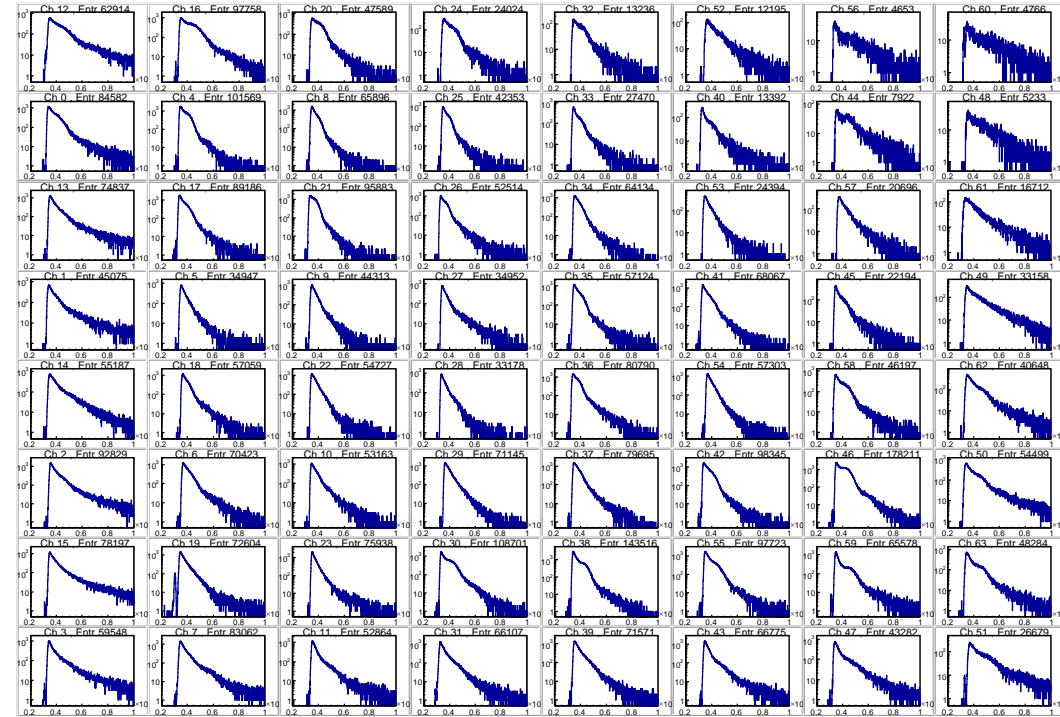
Front-End applications

- Two RPCs instrumented with the Front-End will be used to test new Auger's scintillators.
- Two Front-End work in coincidence.
- The coincidence is performed inside the FPGA of one of the Front-Ends
- The trigger created is send out to the other board and to scintillator DAQ.



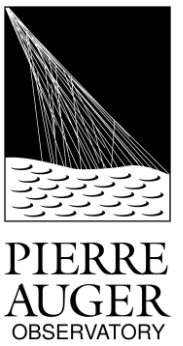
Front-End applications

- Bench to test newly build RPCs for the EA.
- By doing a quick measurement of the 64 channels charge spectrums.
- No external trigger needed.
- Used by the technicians by sampling pressing a button.
- This system detected problems in one of the RPCs



Summary and future

- We successfully design and build a small low power acquisition system for RPC detectors to measure the muons in the cosmic ray air showers.
- Final production is complete, boards will be debug in the next month.
- Main firmware and software are stable and working as intended but can still be improved (e.g. to reduce dead times).
- In all test benches the Front-End proved to be up to the task.
- Possibility to use the Front-End in some "spin-off" projects where some small software/firmware changes will be needed.
- Test new Auger's scintillators.
- Install the engineering array.
- Start tacking data!!



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