RPC Tower for the Upgrade of the Pierre Auger Observatory

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WORKSHOP RENAFAE 2018

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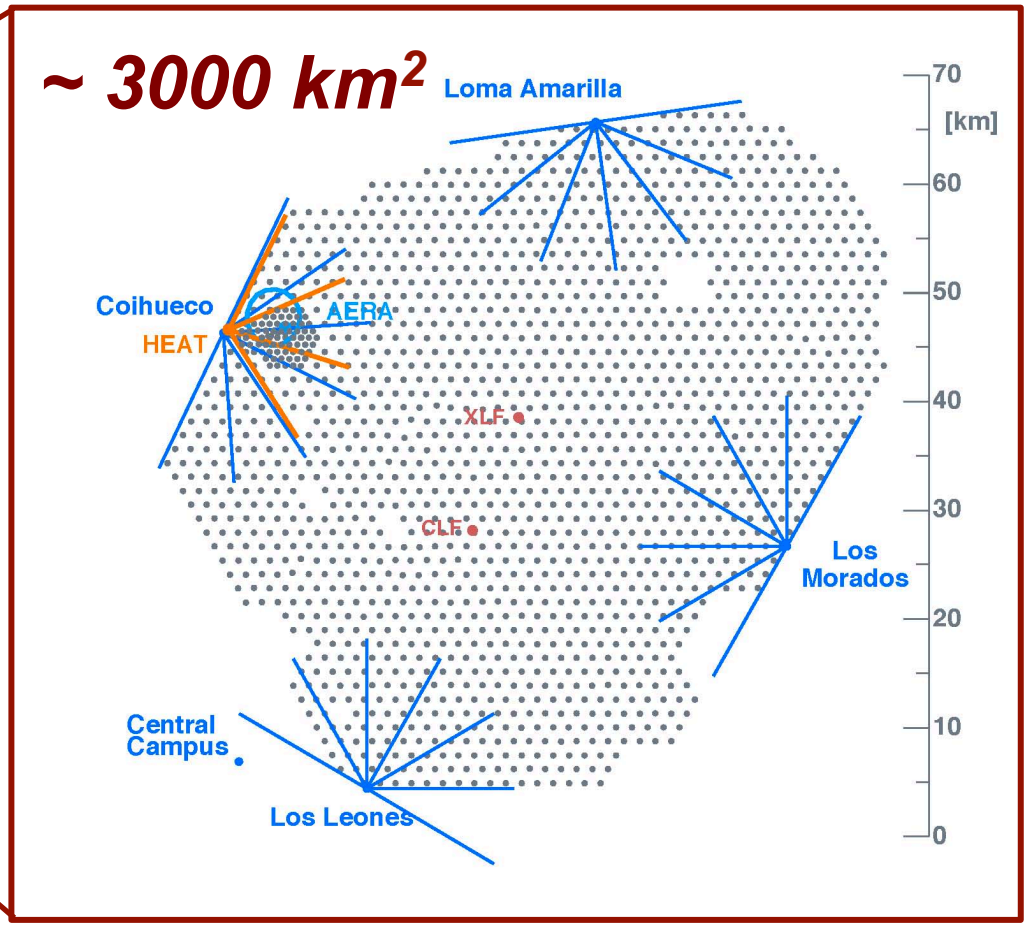
The Pierre Auger Observatory

the world's largest cosmic ray observatory

planned to operate until 2025 (Auger Upgrade Program)

~ 500 members from 17 countries

35.15° S, 69.2° W ~ 1400 m a.s.l.



probe origin and characteristics of cosmic rays above 10^{17} eV

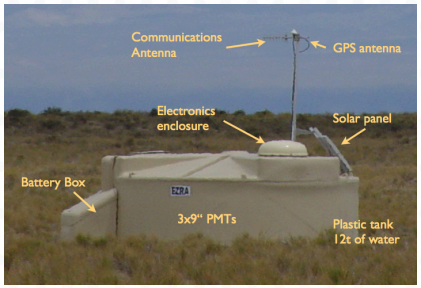
Hybrid Detector

....employing a giant array of particle counters and an optical fluorescence detector...is a "hybrid" ground detector...

- Surface Detector (SD)
  1660 Water Cherenkov detector
  grid of 1.5 km, 3000 km^2

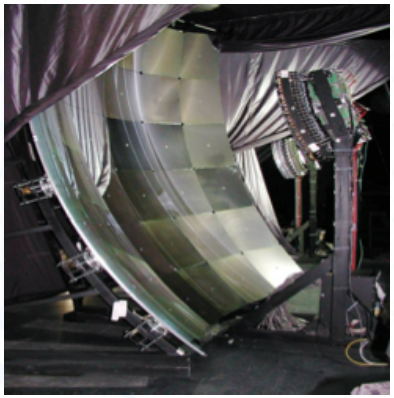
  61 Water Cherenkov detector
  grid of 0.75 km, 30 km^2

- Large statistic (24 h a day)
- Fully efficient above 3/0.3 EeV



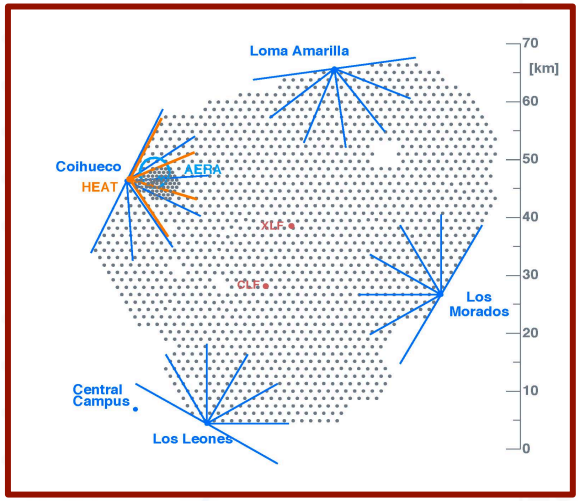
- Fluorescence Detector (FD)
  27 fluorescence (Schmidt) telescopes in 4 locations

- 15% duty cycle
- Particle ID
- calorimetric energy estimation



facility to test/implement new detection techniques

Parternship with Brazilian industries
- Surface Detector
- Fluorescence Detector



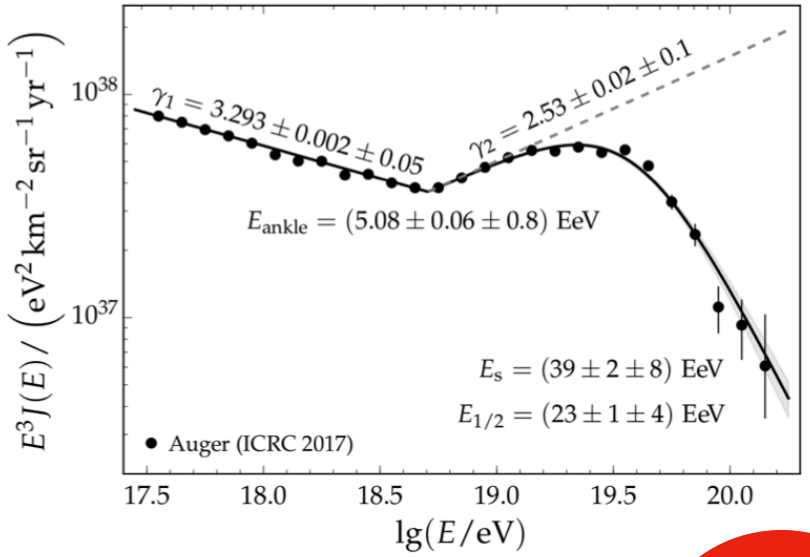
- Hybrid Detector (SD + FD)
  + high statistic from SD
  + energy calibration from FD

Energy resolution ~ 15%
Energy scale ~ 14%
Angular resolution < 1°

Key results of the Observatory (in 1 slide)

COMBINED (SD+FD) ENERGY SPECTRUM

flux suppression at ~ 4 × 10^{19} eV



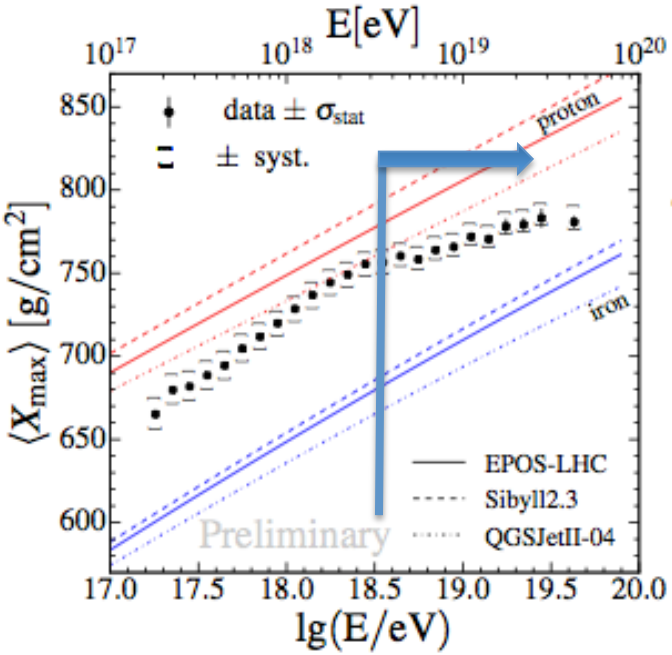
ICRC 2017
arXiv:1708.06592

MASS COMPOSITION (FD)

for E > $10^{18.5}$ eV <u>unexpected trend</u>

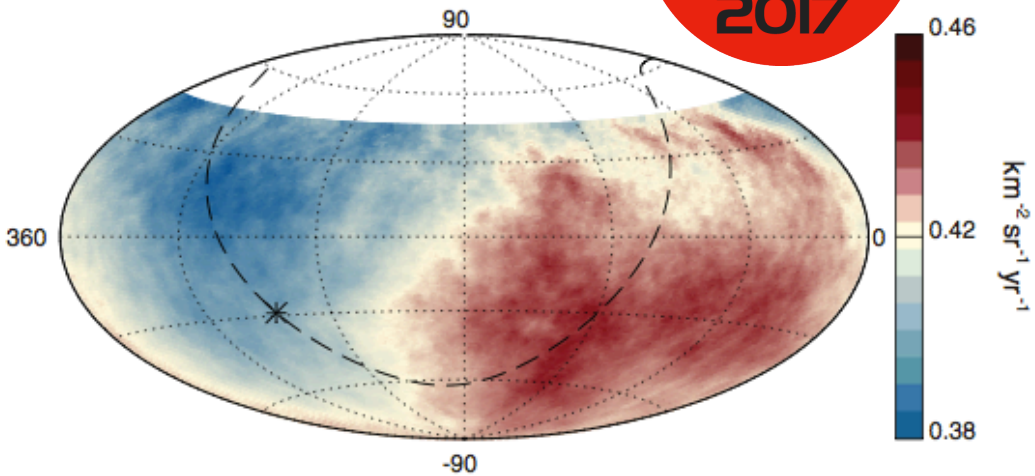
towards heavier elements

or change of hadronic interactions



Science 357 (2017)

physicsworld TOP 10 BREAKTHROUGH 2017



ARRIVAL DIRECTION (SD)

observation of large-scale anisotropy

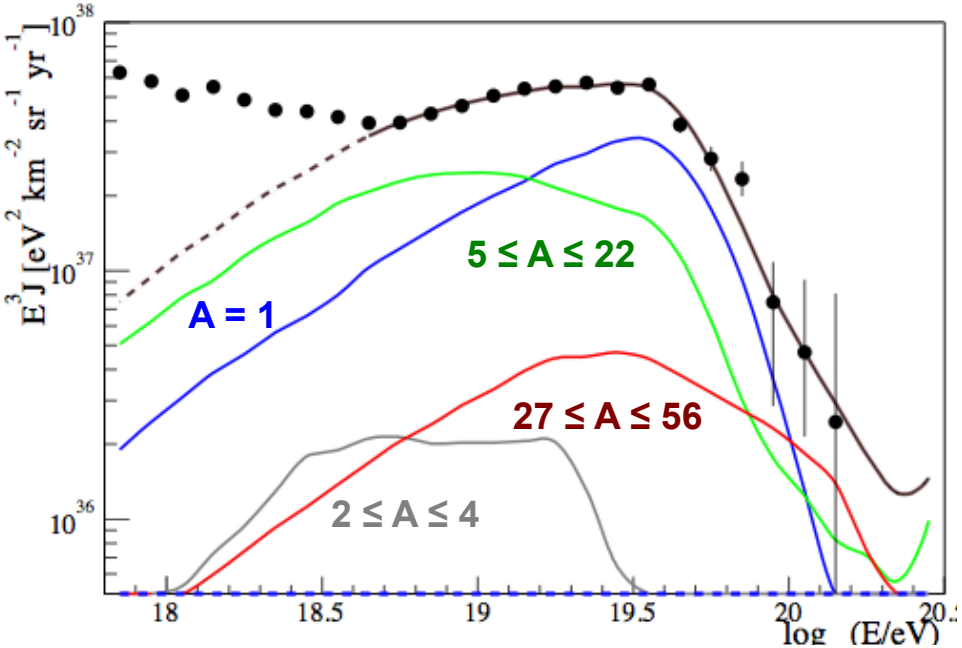
in the arrival directions above 8 × 10^{18} eV

@ Particle Physics results
(magn. monopole, hadr. Int.)
@ Auger Multimessanger program

What do spectrum and composition data tell us?

=> many way to fit the spectrum!

JCAP04(2017)038



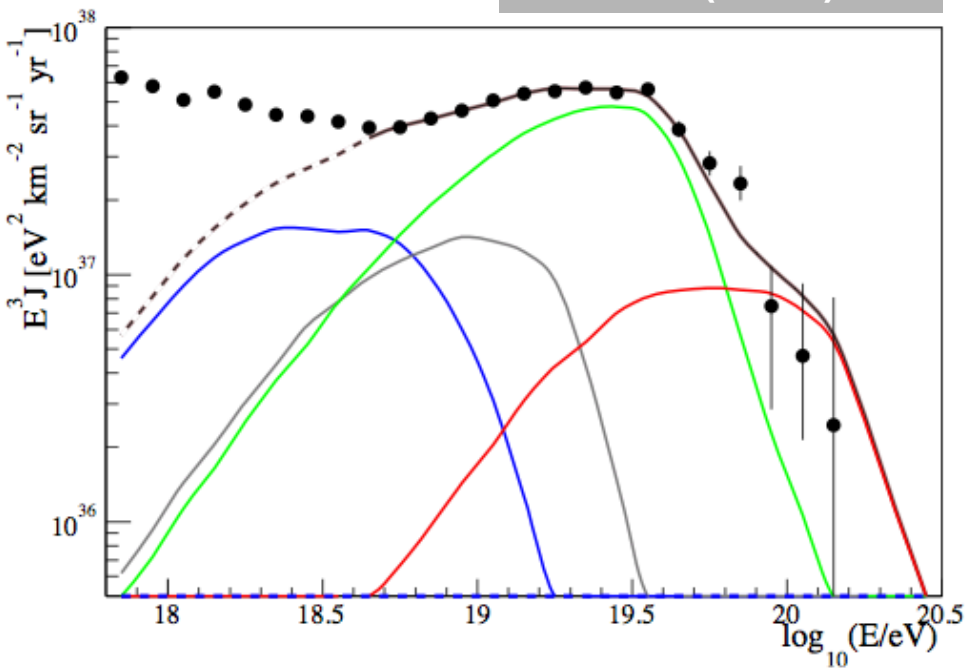


Photo-disintegration scenario

$A + \gamma_{CMB/IBR} \rightarrow (A - 1) + N$

Maximum rigidity scenario

$E_{MAX}^{Z} = Z \times E_{MAX}^{p}$

Origin of the suppression unresolved !!!

Data from Surface Detectors about mass composition in the suppression region needed to discriminate among different scenarios

The Pierre Auger Observatory Upgrade

"AugerPrime"

arXiv:1604.03637

Motivations

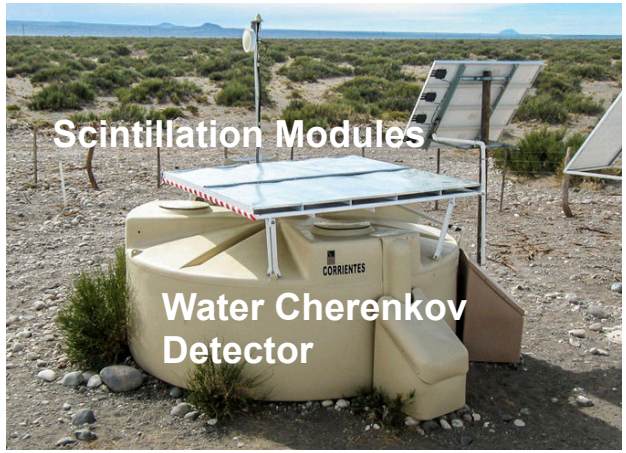
- Investigate mass composition in the suppression region on an event-by-event basis
- Reach the sensitivity to detect a small contribution (~10%) of protons in the suppression region
- Study hadronic interactions at center-of-mass energies above 100 TeV

Planned upgrades

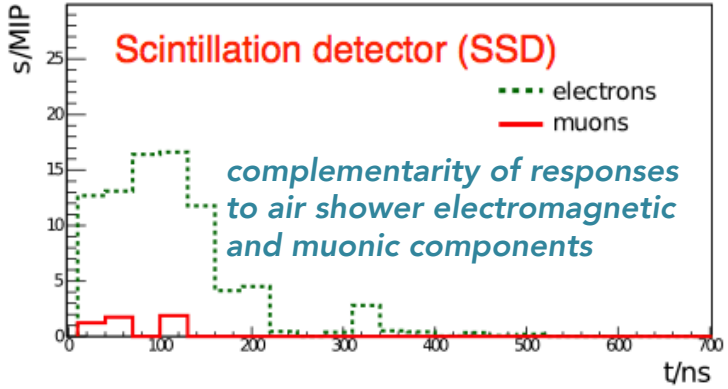
- Surface Scintillator Detectors (SSD) above the existing Water-Cherenkov-Detectors (WCD)
- New electronics for faster sampling of both WCD and SSD signals (better timing accuracy, increased dynamic range)
- Underground Muon Detectors in the SD area of 25 km^2 ("infill area")
- Extend Fluorescence Detector duty cycle from ≈ 15% to ≈ 20%

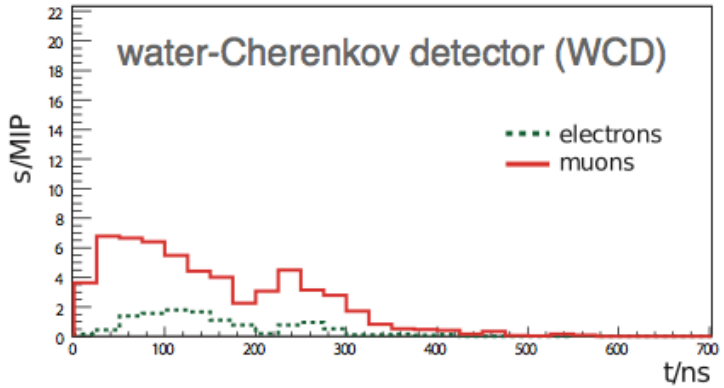
Surface Scintillator Detectors (SSDs)

Scintillators (SSD) on top of each Water Cherenkov Detector (WCD)

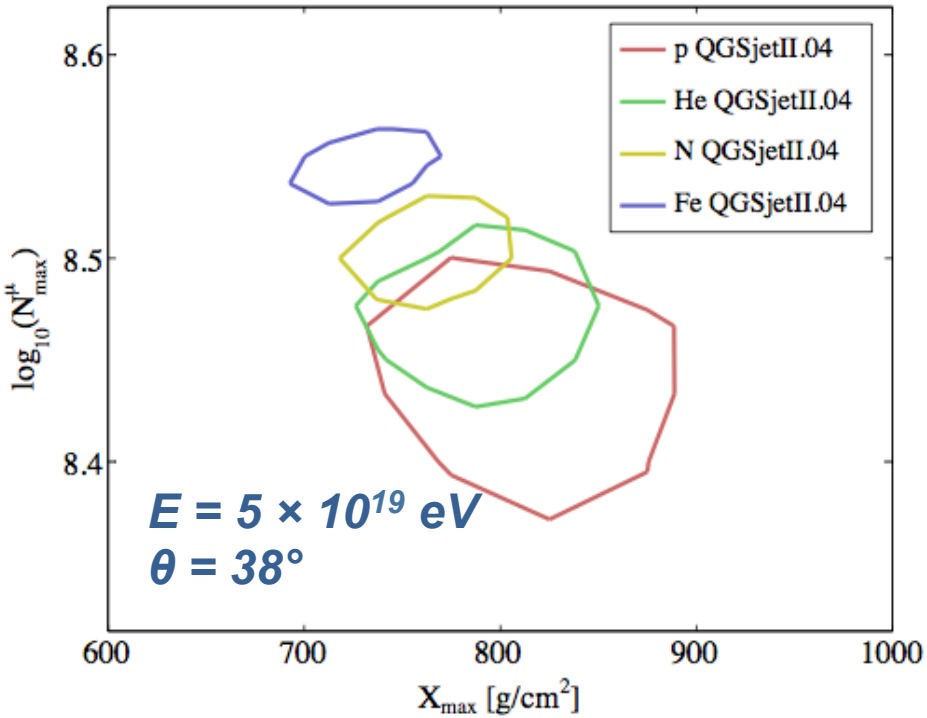


- two scintillation modules, each with 1.9m^2 and 1 cm thick
- light guided by optical fibers to a PMT
- deviations from uniformity < 5%
- SSD triggered by WCD
- **September 2016: Engineering Array**
- **First modules already in Malargüe**

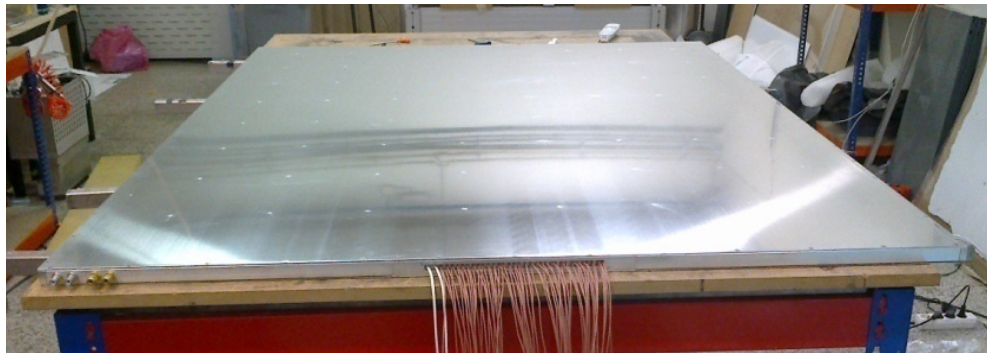




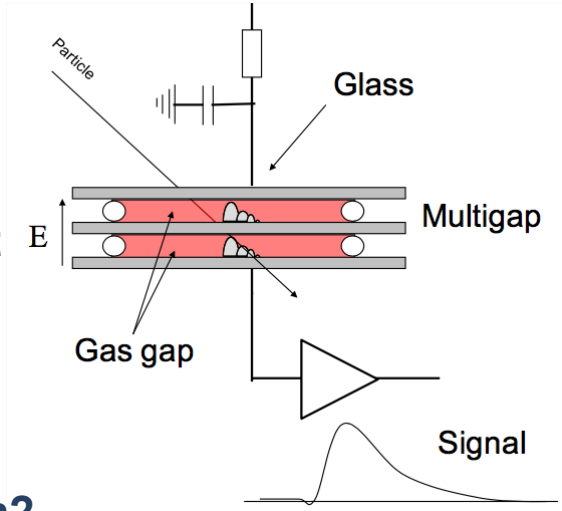
disentangle muonic and electromagnetic components of air showers



R&D of RPC for outdoor experiments

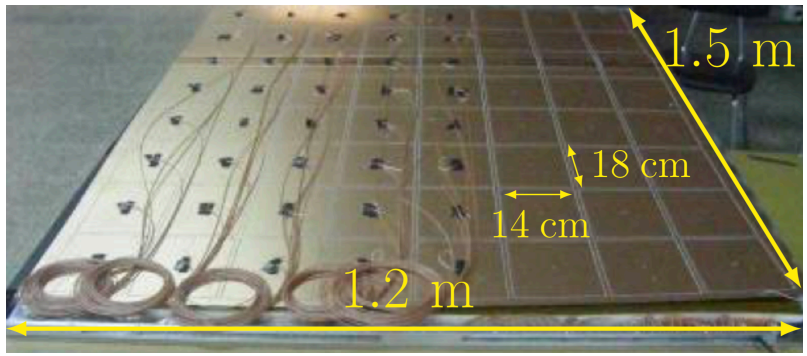


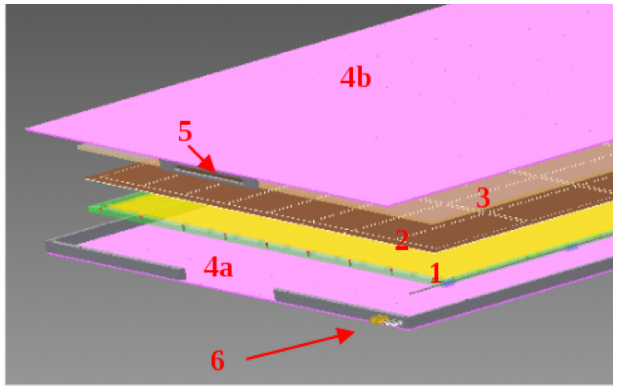
- **Electrodes** 2mm soda-lime glass
- **Gap thickness** 2 × 1 mm gaps
  "multi gap" construction



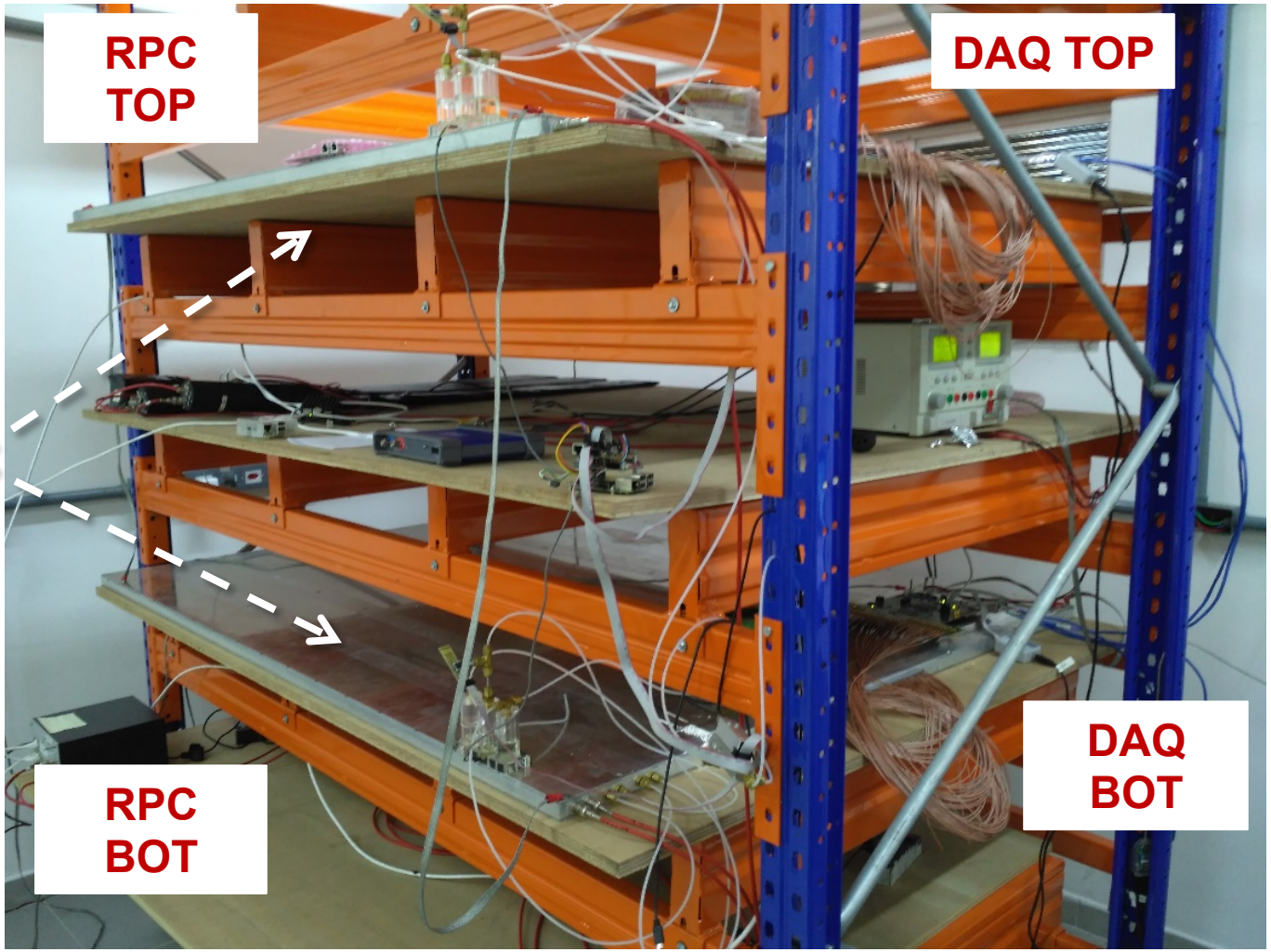
- **HV signal-transparent layer** controlled resistivity acrylic paint
- **Mono-component gas mixture** R-134a (tetrafluorethane)
- **Gas flow rate** 1cc/min, equivalent to 1 kg/year

- **Signal pick-up electrodes** 8 × 8 pad matrix, with 180 × 140 mm2
- **Electromagnetic shielding and structural case** Aluminium box





RPC Rio Hodoscope



2 RPC units

Developed and tested at CBPF

tracking atmospheric particles

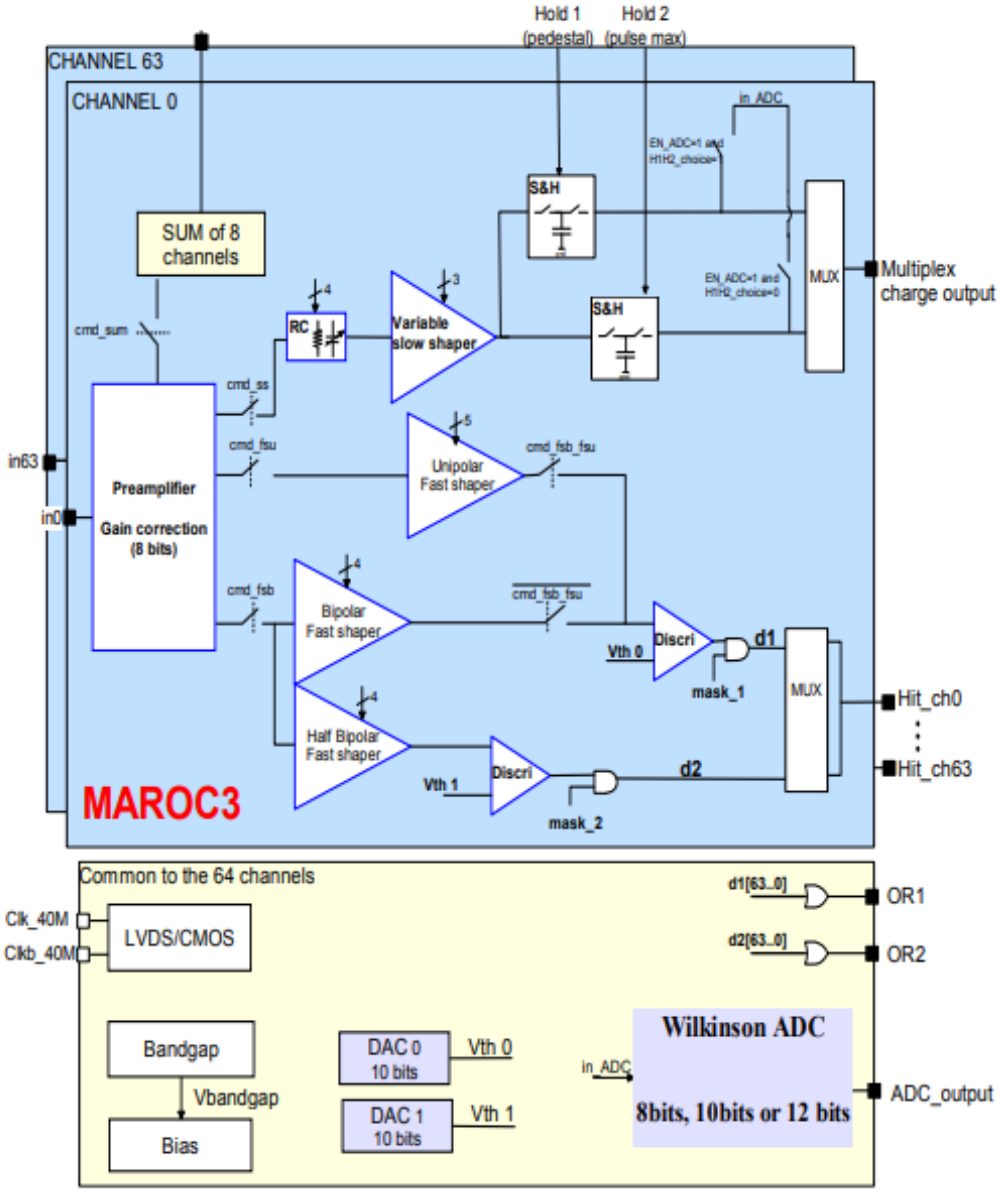
LVDS cables connecting the DAQs

MAROC-3 ASIC

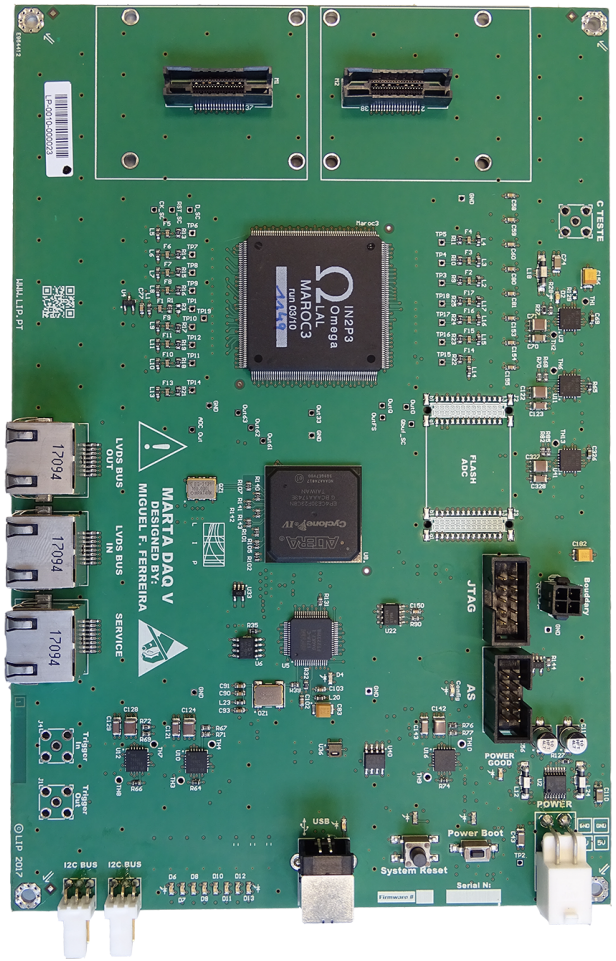
- 64 channel inputs:
  Variable gain current preamps (8 bits/ch.)
- 64 trigger outputs + 2 OR outputs
- 1 mux. analog charge output
- 1 digitized charge output
  (8, 10 or 12 bits ADC)

- Pw = 3 mW/ch
- Trigger efficiency= 5fC

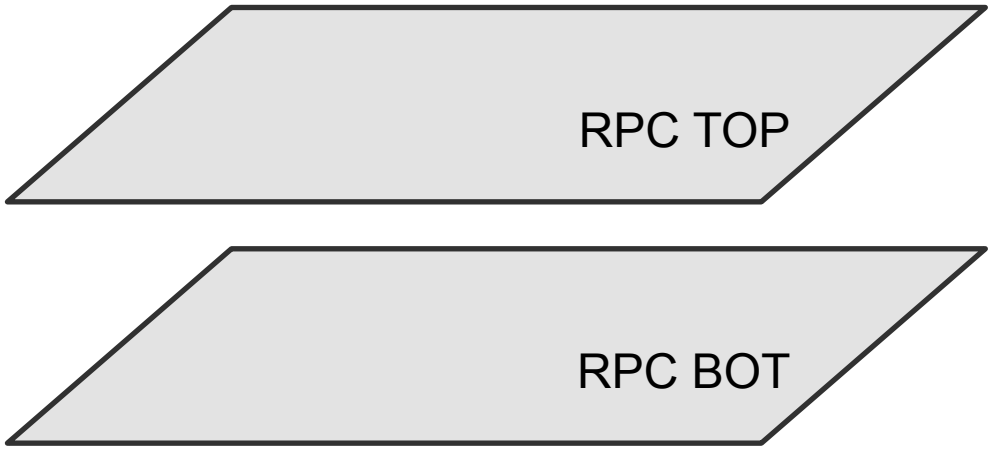
- Low input impedance (50-100 Ω)
- Variable slow shaper (20-100 ns)
- 2 T&H (baseline and max.)
- 10 bits DAC as threshold
- Internal bandgap for voltage references
- 828 slow control parameters

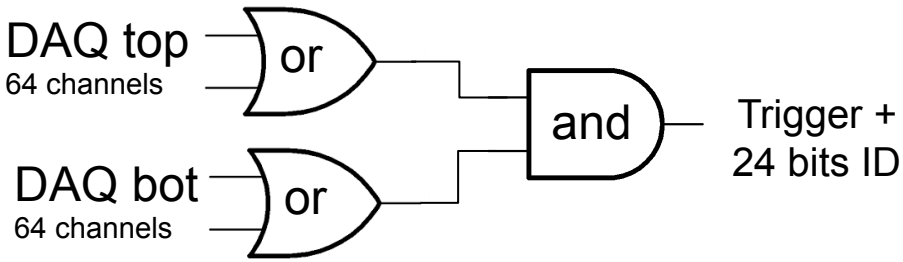


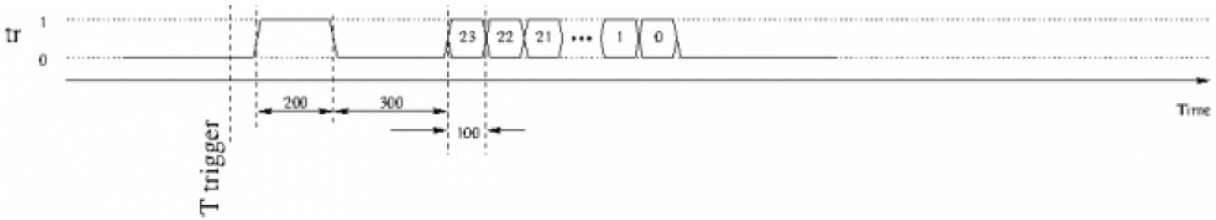
DAQ and trigger: Coincidence Trigger out with ID



Based on the MAROC ASIC





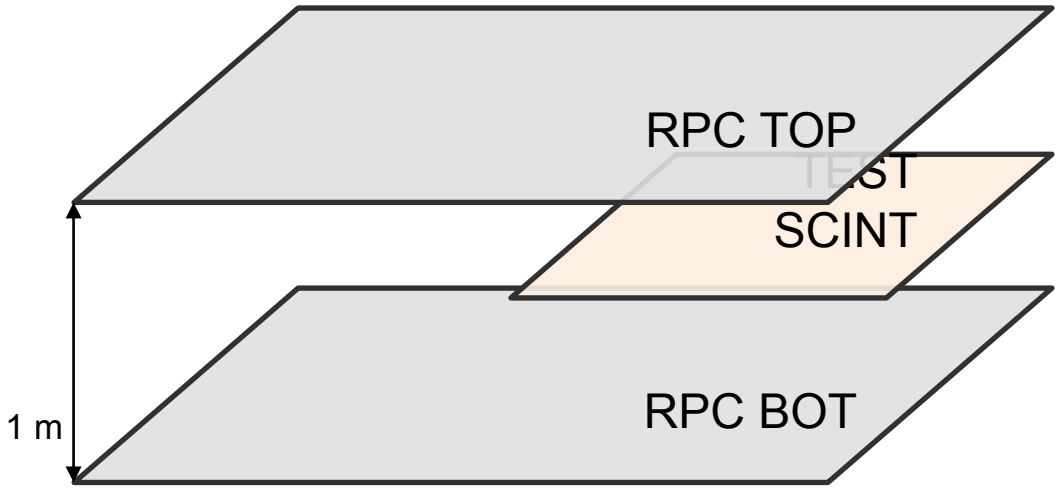


Output Trigger based on the Tr (Fast trigger of AUGER Front_end to AMIGA Project)

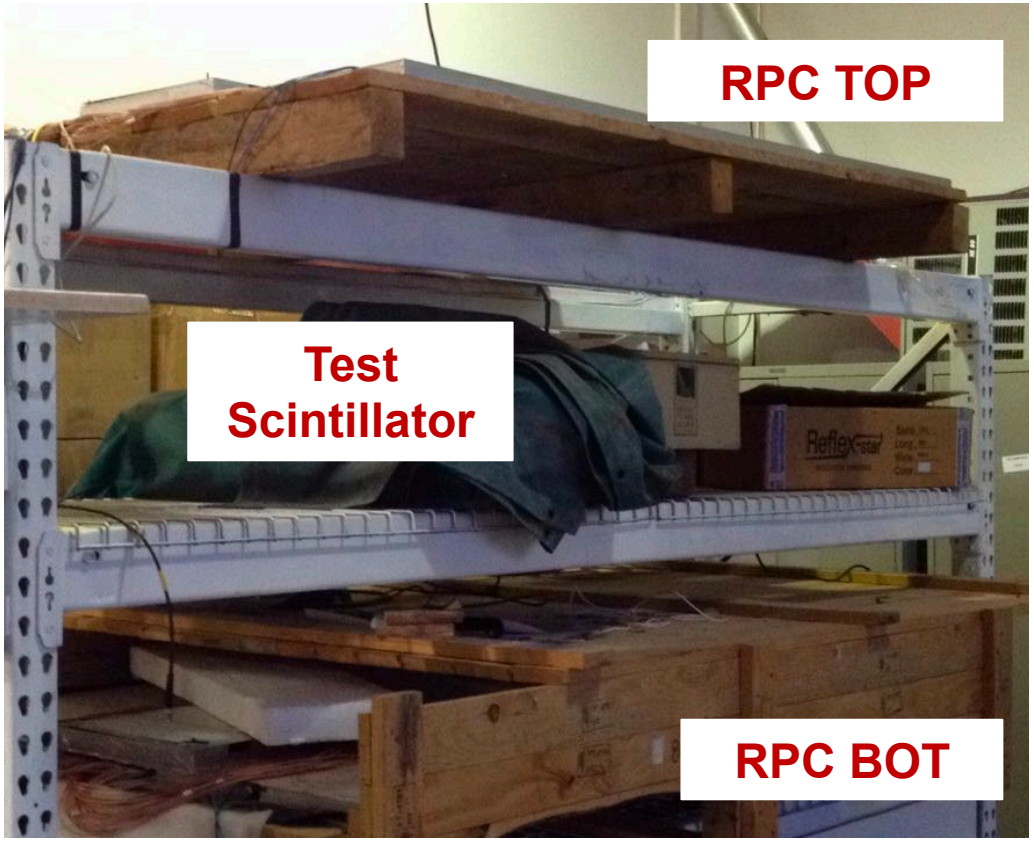
Acquisition of two FIFOs with ID of Coincidence and 256 BINs temporal each, read by central united for validation to trace reconstruction.

Test setup @ Malargüe

Setup at the Pierre Auger Observatory
Electronics migrated to Malargüe
2 RPCs in coincidence in "storage shell"
Probe scintillator (SSD)

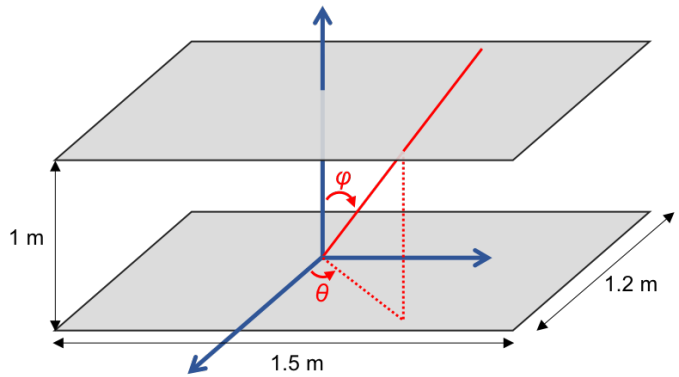


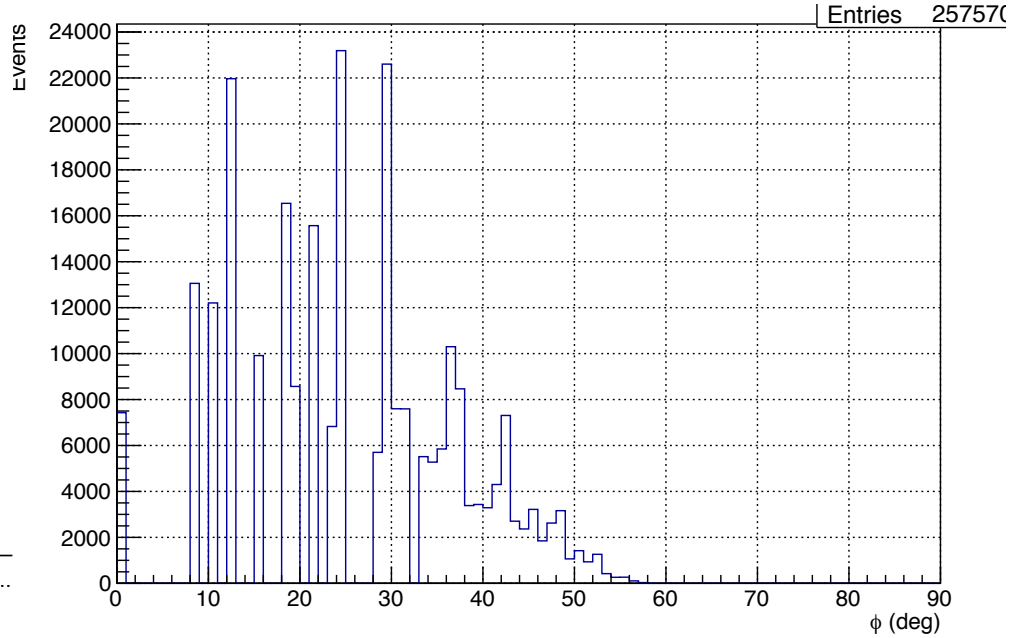
May 2018



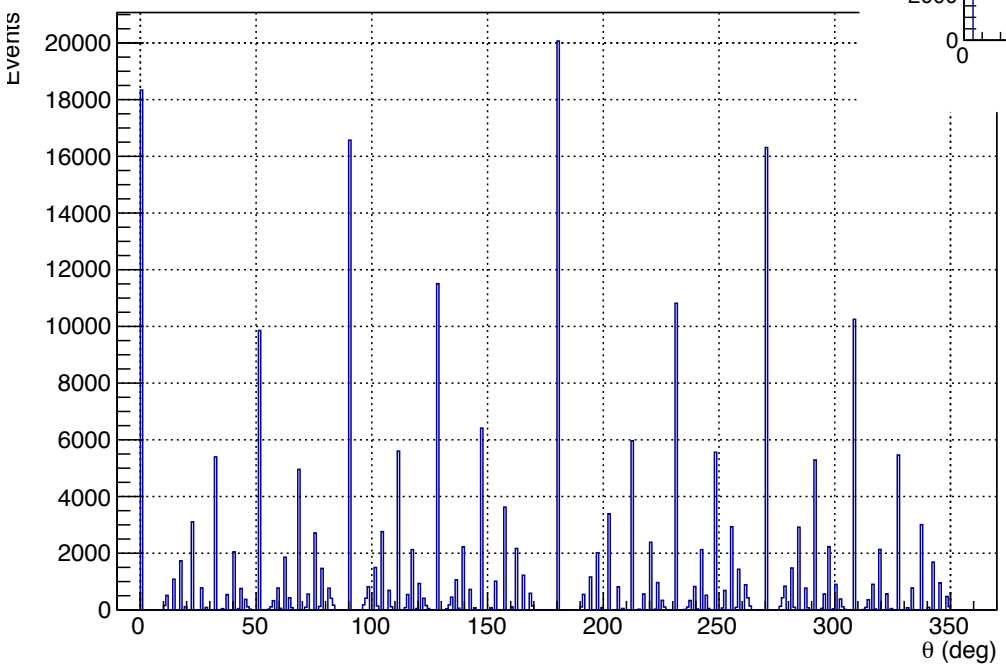
First tests with simple threshold on scintillator
→ input direct on FPGA

Typical measurements: angular distribution





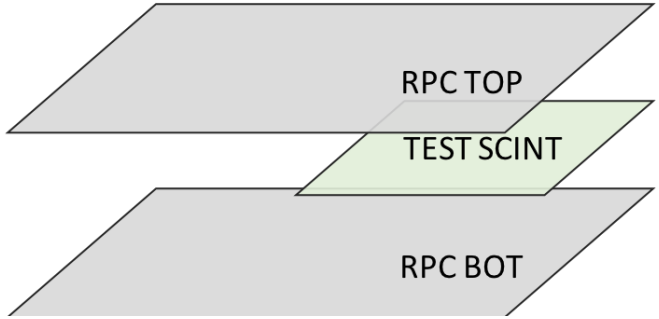
zenith/°

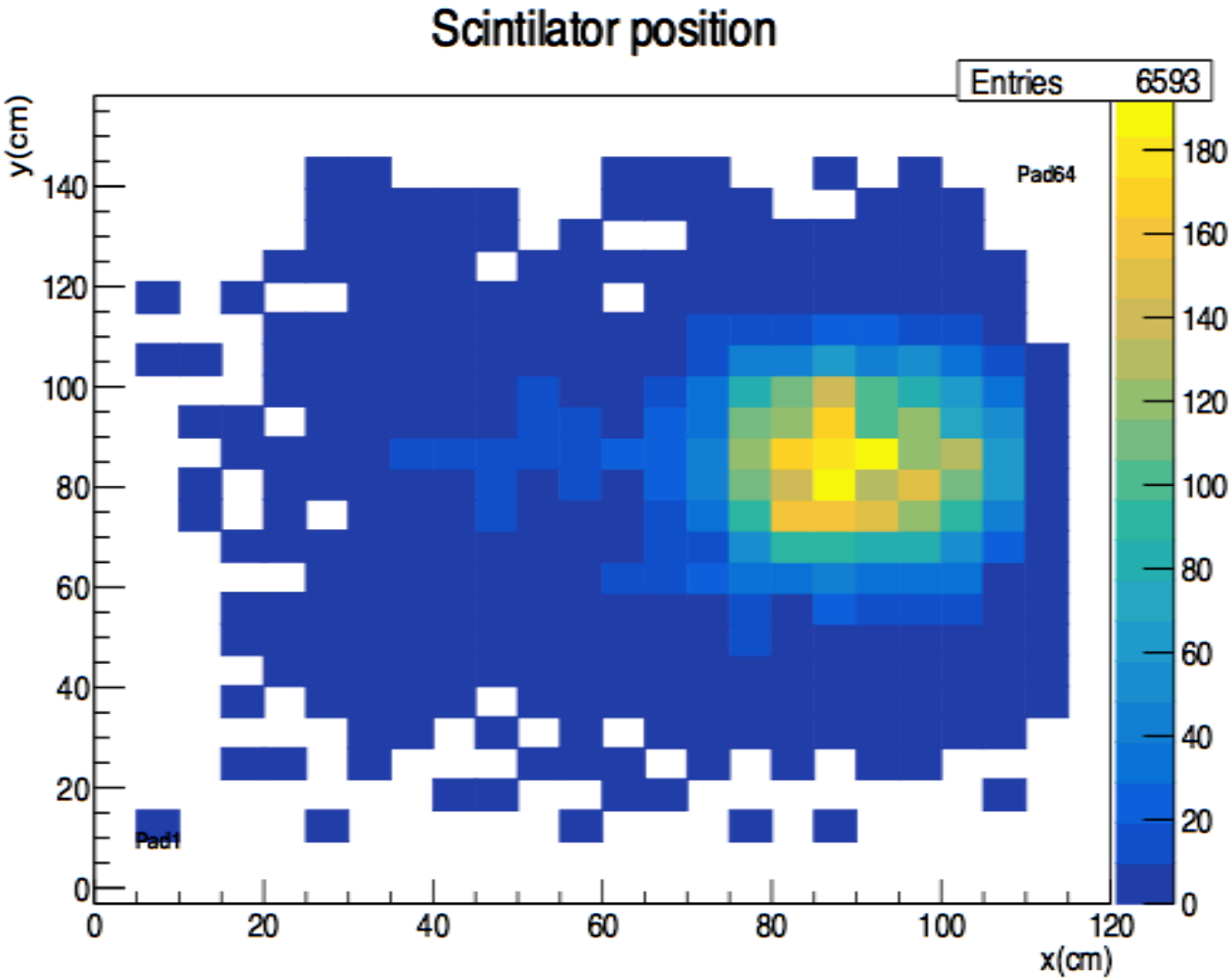


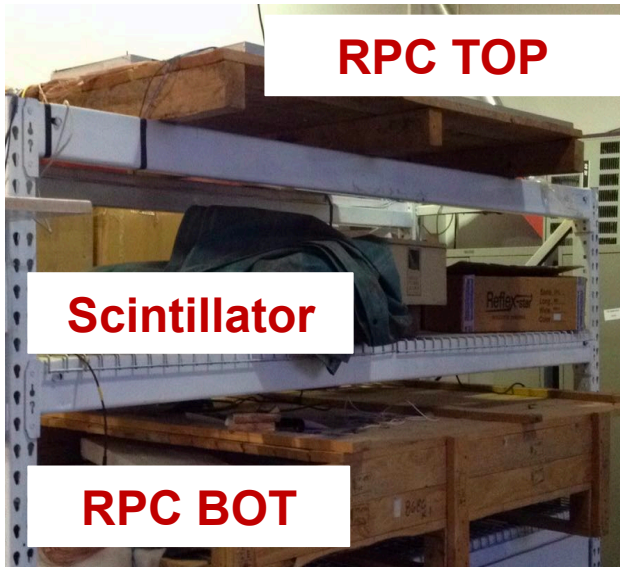
azimuth/°

Compatible with the simulations and with the results of the Rio Hodoscope

Scintillator.....







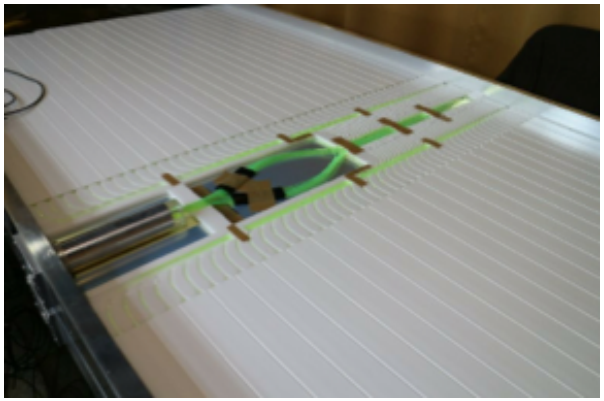
June 2018

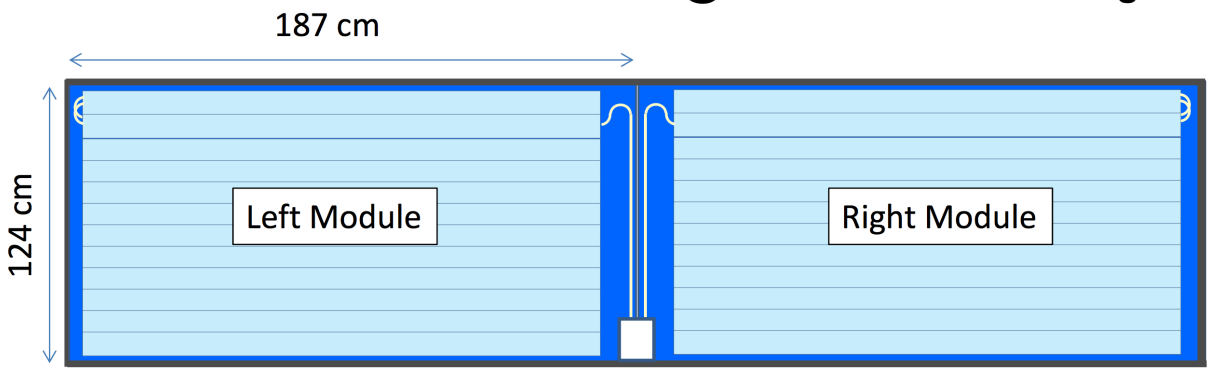
preliminary test presented at the Collaboration Meeting

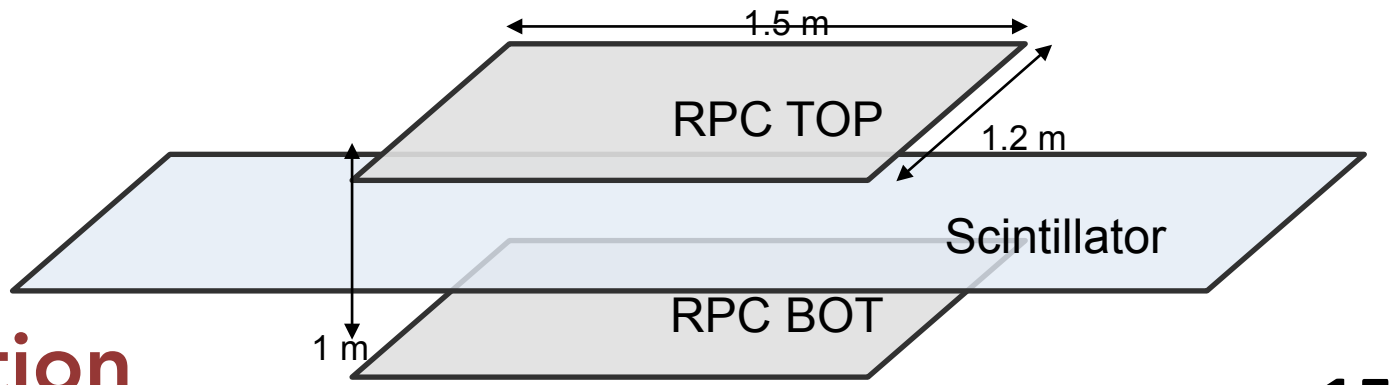
.....in the right position

RPCs Hodoscope to test SSD @Malargüe

@ObservatorioPierre Auger.Malargue



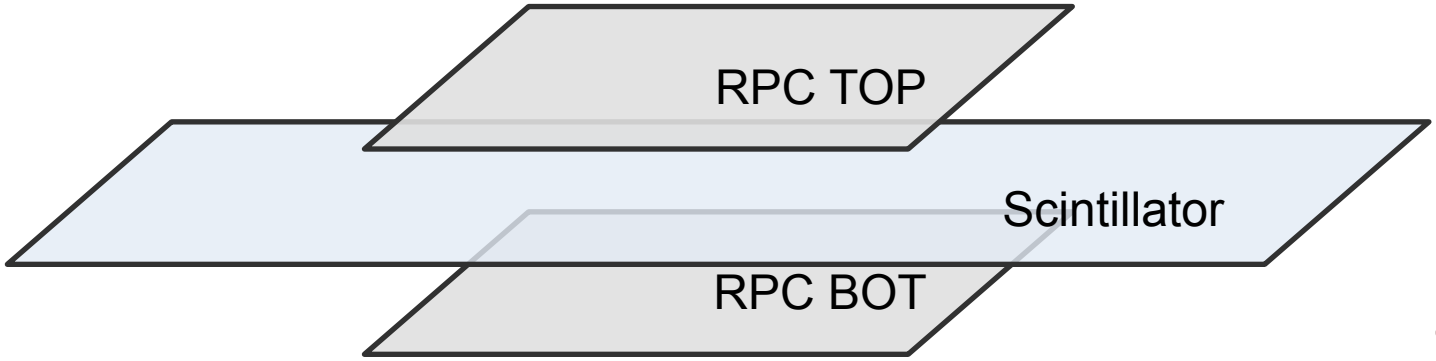




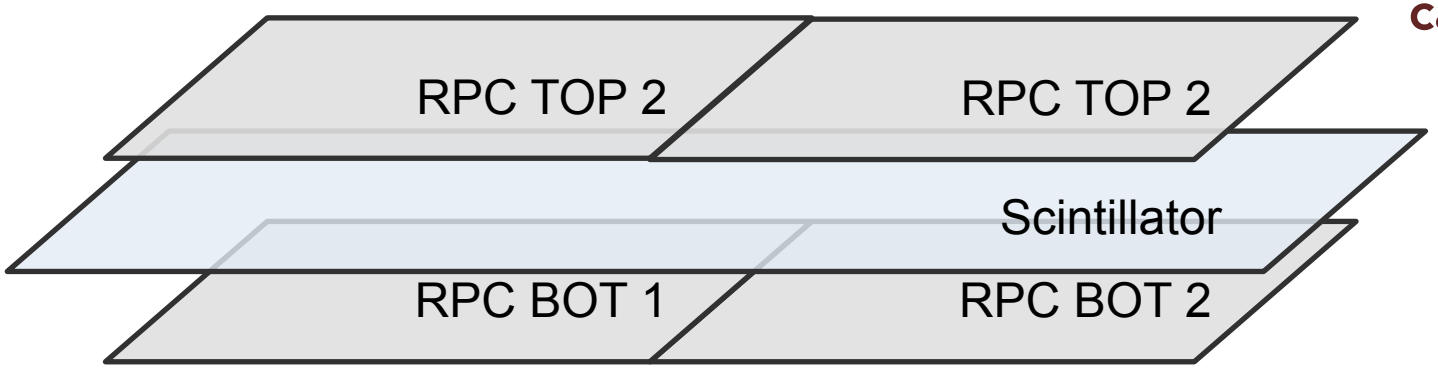
Debug and test after transportation

Possible Upgrades

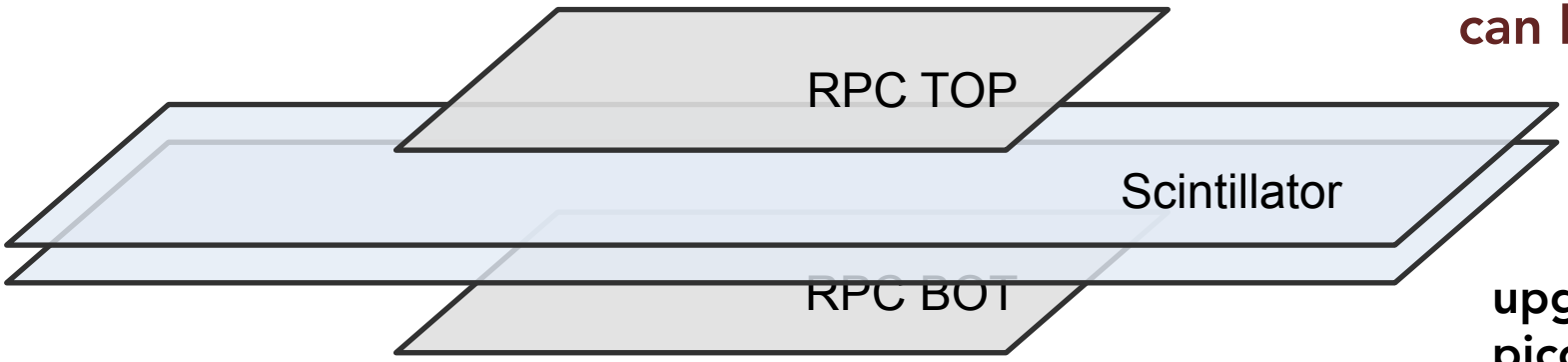
July 2018



different configurations can be assembled



different scintillators can be tested at once



upgraded to read by picoscope or -UUB

Conclusions

A hodoscope of RPCs has been build in Malargüe
based on the setup of the Rio Hodoscope

testing/debugging the Scintillators (SSD)
of the Pierre Auger Observatory after the transportation

preliminary test in May/June 08
setup works as expected

System being upgraded ongoing

final configuration and some mechanical adaptations to accommodate
the SSDs to be read by UUB or picoscope

Lattes concept