Preliminary results of the AMIGA engineering array at the Pierre Auger Observatory

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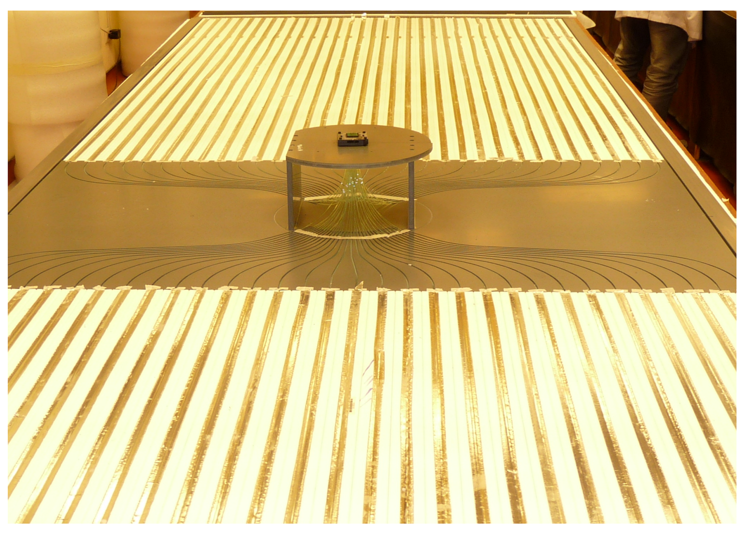
PIERRE AUGER OBSERVATORY

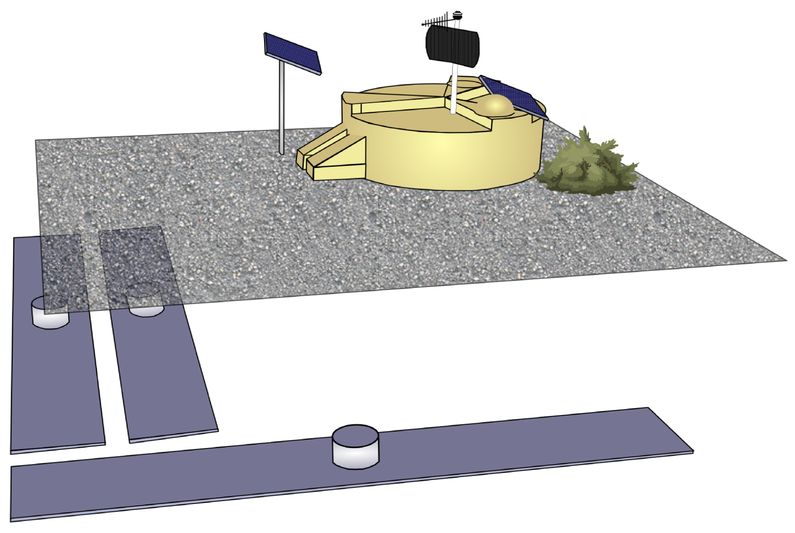
1. The AMIGA Engineering Array

The AMIGA muon detector array (MD) will provide Muon Counters for the whole SD-750 m spacing array. Between March 2015 - November 2017, an engineering array (EA) of the MD was operating as a proof of concept of the detector and to optimize the design, where the main upgrade was the change of PMTs by SiPMs and the introduction of an specific channel to measure high muon densities close to the shower core. Each station on the array is composed by a pair of Water-Cherenkov Detector and a 30 m^2 Muon Counter buried at 2.3 m depth. The Muon Counters at the EA were a combination of 5 m^2 and 10 m^2 modules, each filled with 64 scintillator bars and wavelength-shifting fibers which guide the scintillation light to a SiPM array. The AMIGA The deployment of the AMIGA MD array with SiPMs started in January 2018. So far, 7 stations were installed. The production rate is 10 m^2/week.

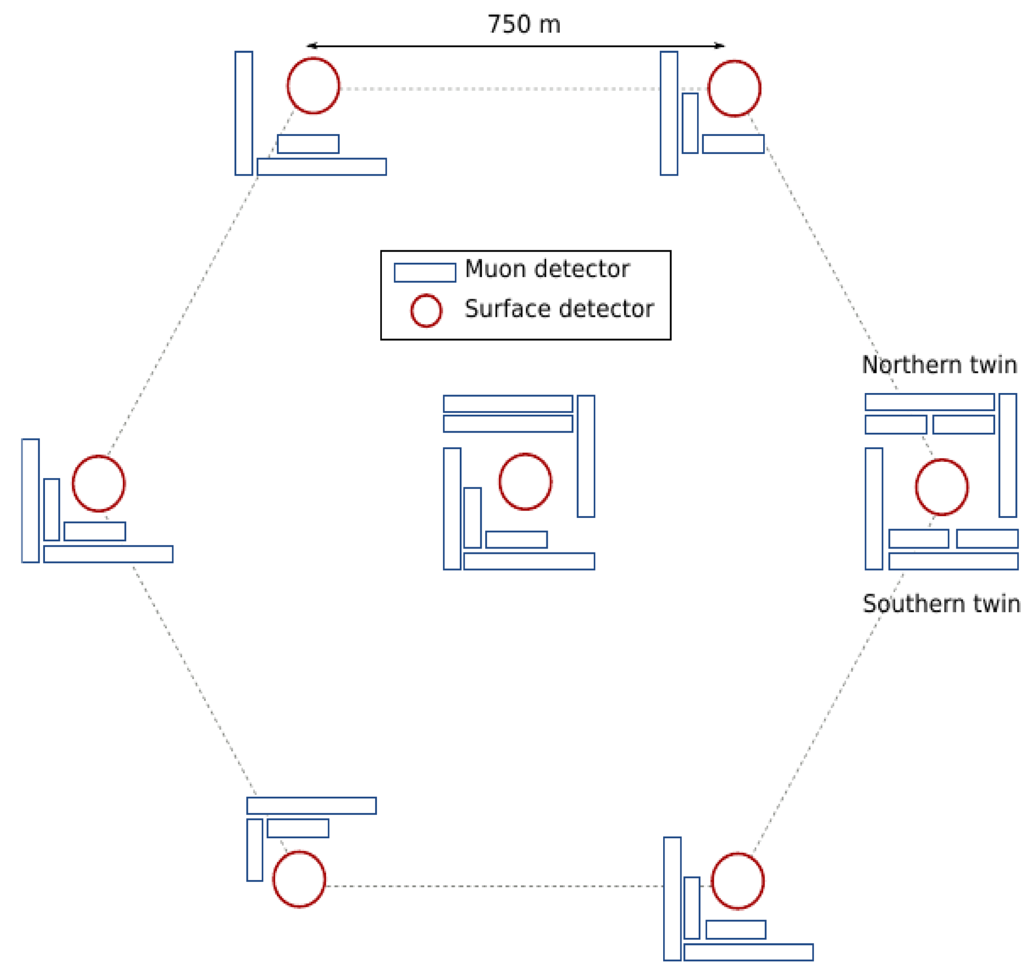


64 scintillator bars and fibers per module

Deployment of AMIGA module



Sketch of the 30 m^2 AMIGA station



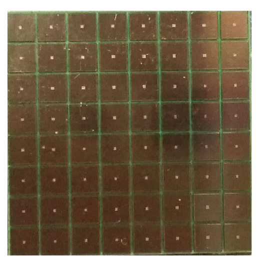
Map of the AMIGA Engineering Array

2. SiPMs

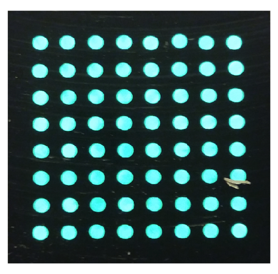
64 SiPMs array coupled to WLS fibers.

Sources of uncertainty

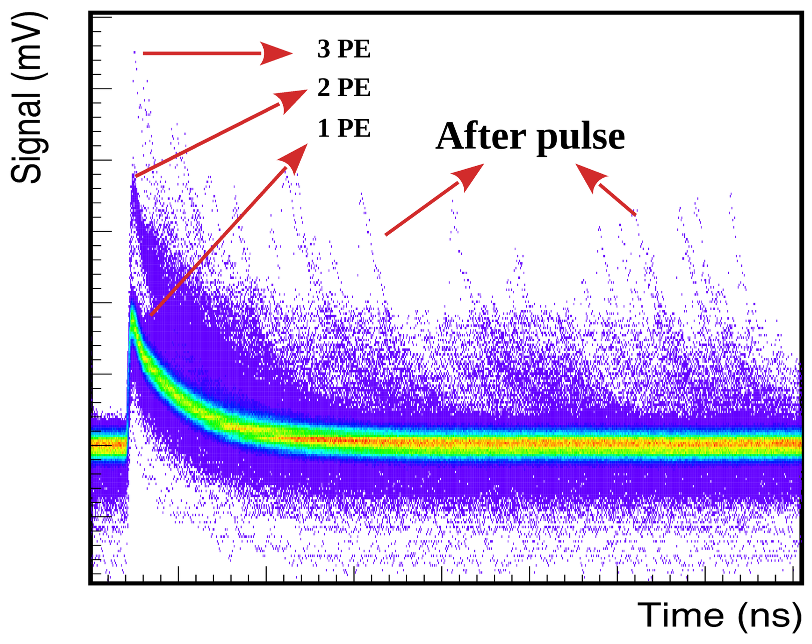
- Dark Rate
- Cross-Talk
- Temperature Dependency



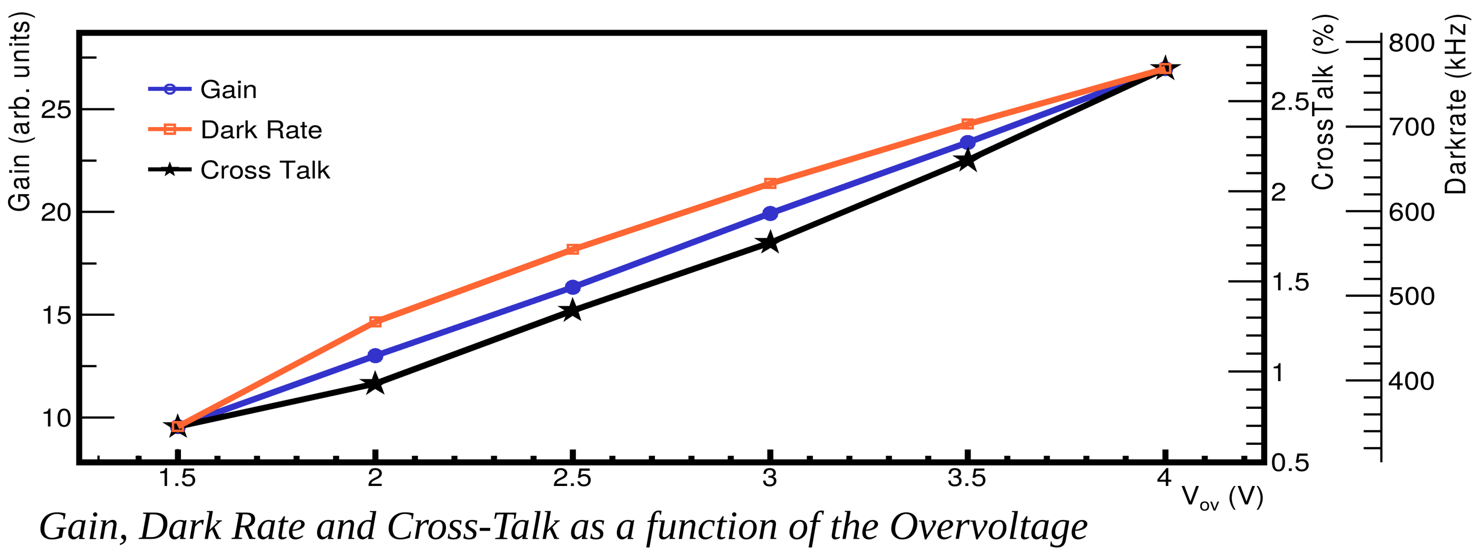
Array of SiPMs



Optical coupling

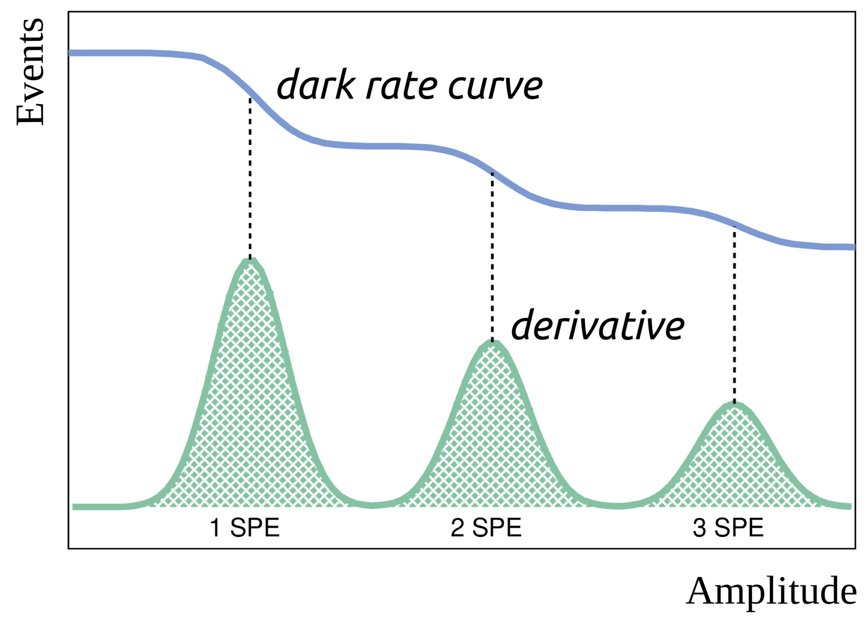


Dark rate pulses



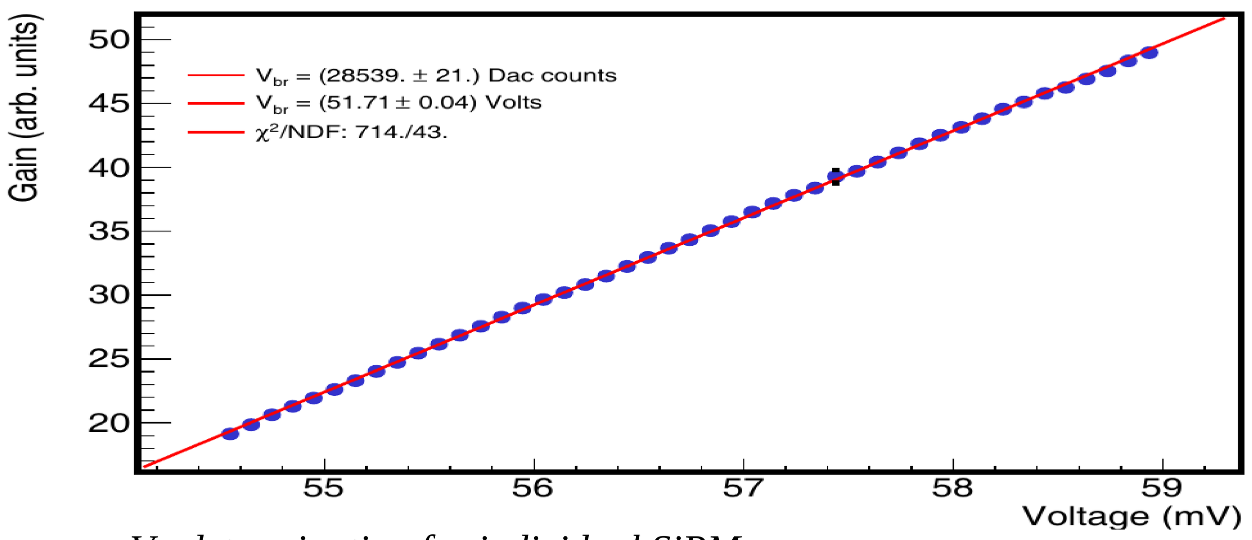
Gain, Dark Rate and Cross-Talk as a function of the Overvoltage

3. Calibration



The curve of dark rate is obtained varying the threshold level and its derivative gives the amplitude of PE. This is used to calibrate the SiPM. As the Gain depends on the *Overvoltage* (V_{Ov}), in order to achieve a uniform gain over the array of SiPMs, the *Breakdown voltage* (V_{Br}) is calculated for each channel and the V_{Ov} is set as:

$$V_{Ov} = V_{BIAS} - V_{Br}$$



V_{Br} determination for individual SiPM

4. Event Reconstruction

The muon density ρ_μ is estimated via two different ways: **counter** & **integrator**

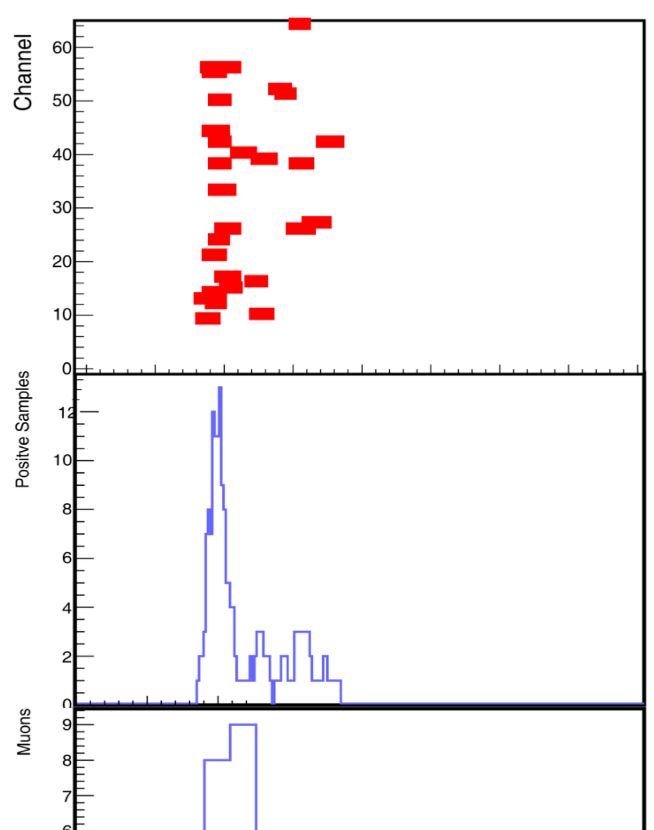
1. Counter

SiPMs signal consists in a trace of bits. When signal is above some discrimination threshold muons are counted. The counter is useful to measure **low densities** with minimal fluctuations.

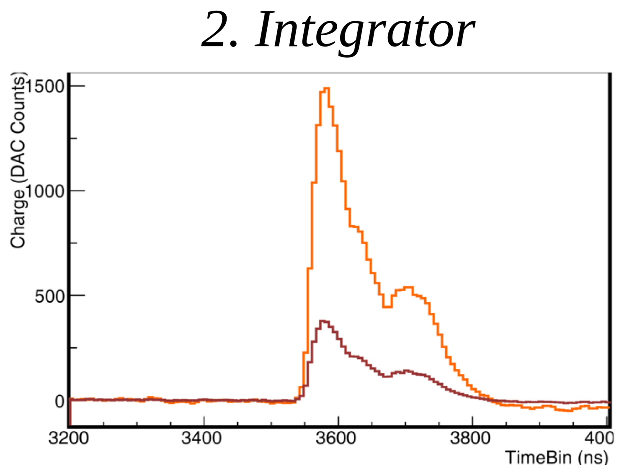
2. Integrator

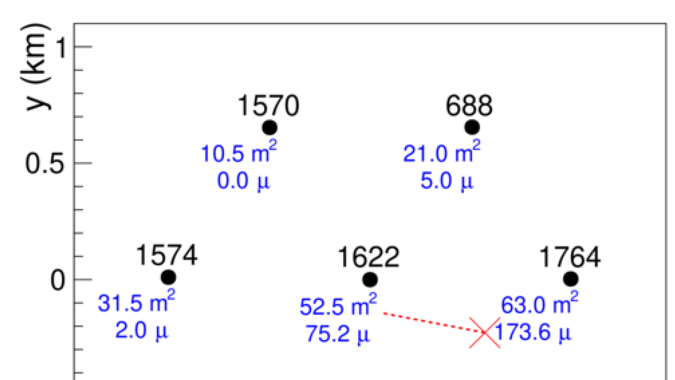
Signal is obtained by integrating the

1. Counter



2. Integrator





The **event reconstruction** procedure consists in **fitting** the **muon density** as a function of the distance to the shower core of the form:

$$\rho_\mu(r,E,\theta) \propto \left(\frac{r}{r*}\right)^{-\alpha}\left(1+\frac{r}{r*}\right)^{-\beta(E,\theta)}\left(1+\left(\frac{r}{10r*}\right)^2\right)^{-\gamma}$$