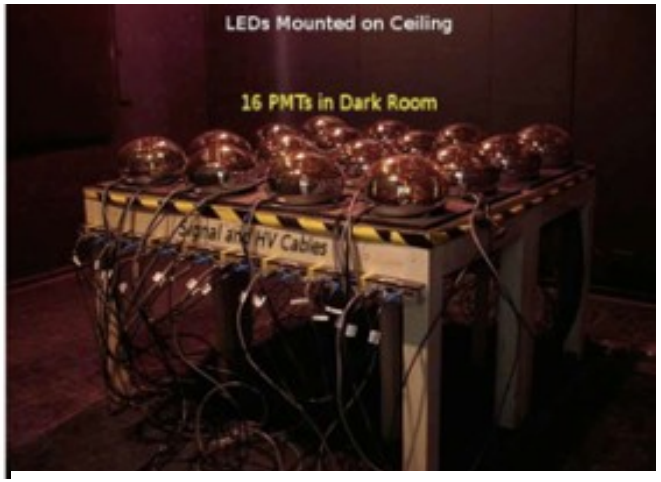
SiPM characterization and fully automated test facilities for astroparticle detection

PhD. Agustín Lucero

SiPM radiation workshop
Geneva, April 25th

Test lab @ Pierre Auger Observatory

Dark room

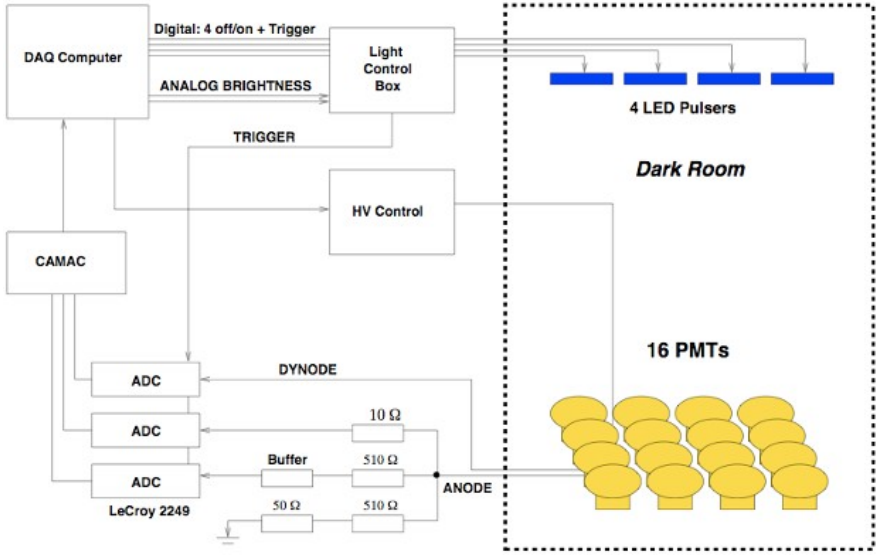


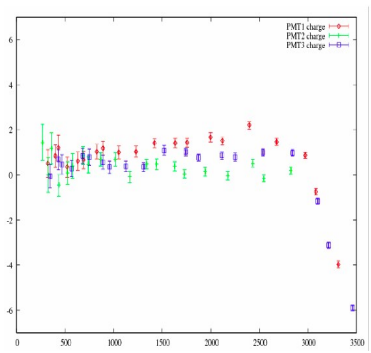
Control and Analysis

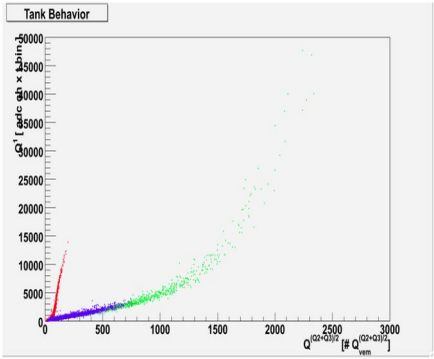
Testing Systems
- Darkrate and Cooldown
- SPE
- D/A ratio
- Gain vs Voltage
- Afterpulsing
- Linearity
- QE
- ENF

Data Analysis
- For ~5000 PMTs

Database
- Tests and production follow-up
- Web Accesing
- QA Plan



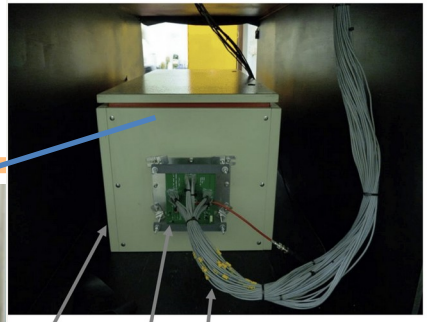


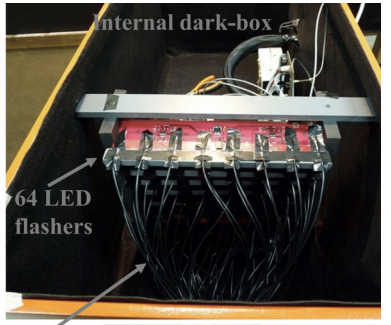


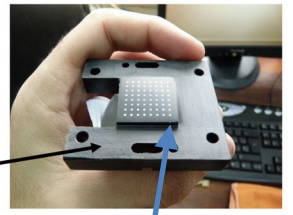
Linearity and dinamic range measurements in the SD

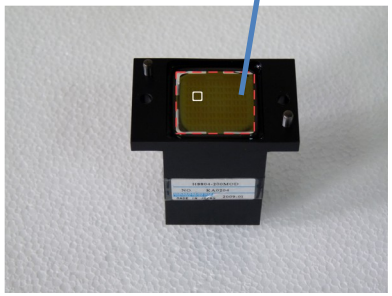
"Testing of Photomultiplier Tubes for Use in the Surface Detector of the Pierre Auger Observatory" D.Barnhill, F.Suarez, K. Arisaka,B. et al. Tripathi.NIM -Volume 591,July-2008.

Test facility for AMIGA







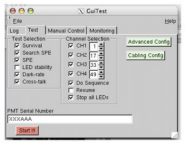


Internal Dark-box
64 signals
Socket board
64 fibers
Cookie with 64 fibers

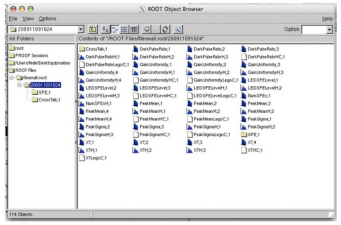
Testing Facility Characteristics

- Test of > 200 MaPMT with 64 channels each
  - Equivalent of 12800 Auger PMTs
  - Testing of 64 channels SiPM arrays
- Low systematic errors
- Low attenuation
- Low Crosstalk (cabling, mux)
- Good Electromagnetic Compatibility (EMC) SNR
- Stable system during testing
- Fully automated test Performed : SPE - DR – XT (and many others)
  - Requires complex multiplexing
  - Required unique test capacity and speed Database

Software (C++)



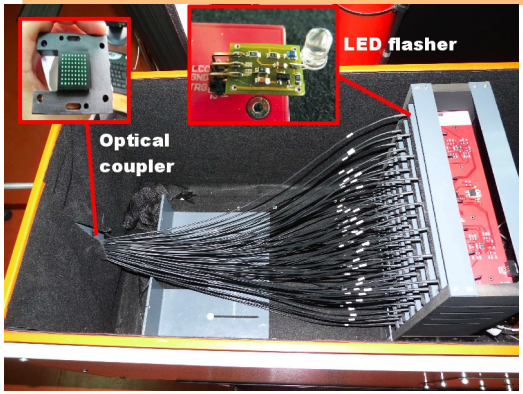
Graphical User Interface (batch-mode available)

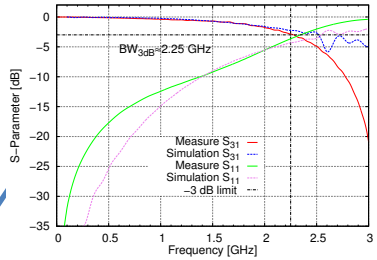


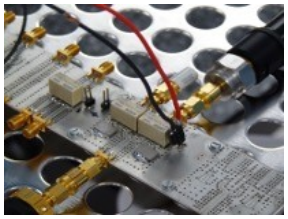
Results in a ROOT file

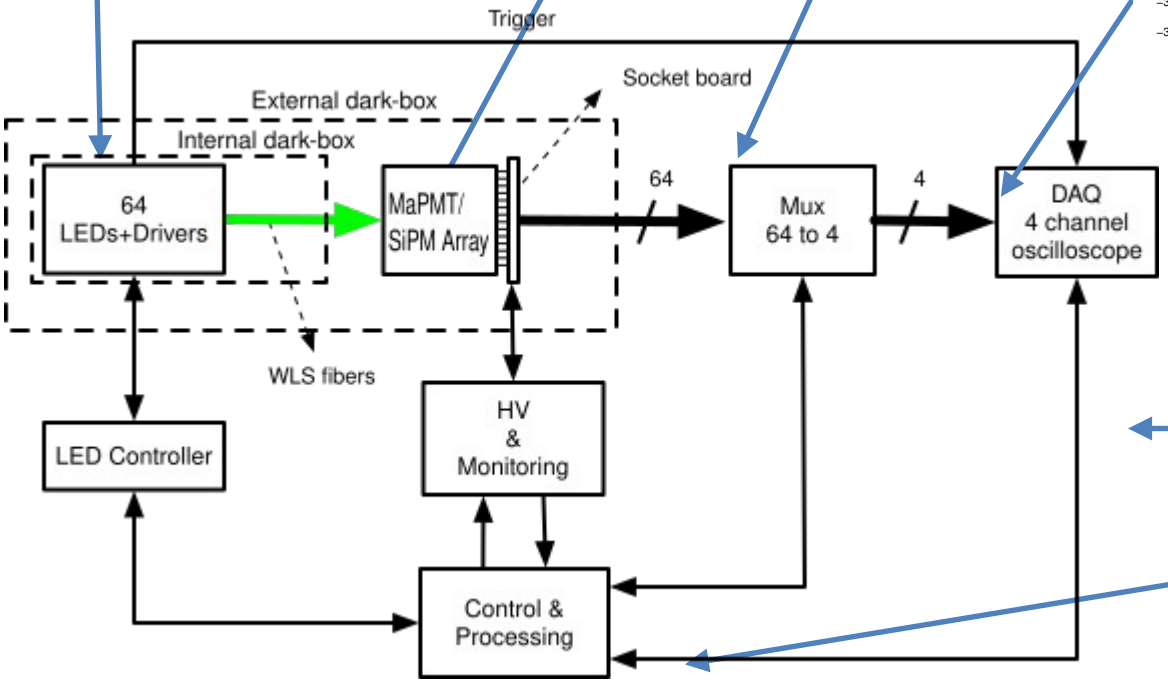
"Analog multiplexer for testing multianode photomultipliers used in AMIGA project of the Pierre Auger Observatory", A. Lucero, A. Almela, F. Suarez, et al. . JINST Volume 10, September 2015.

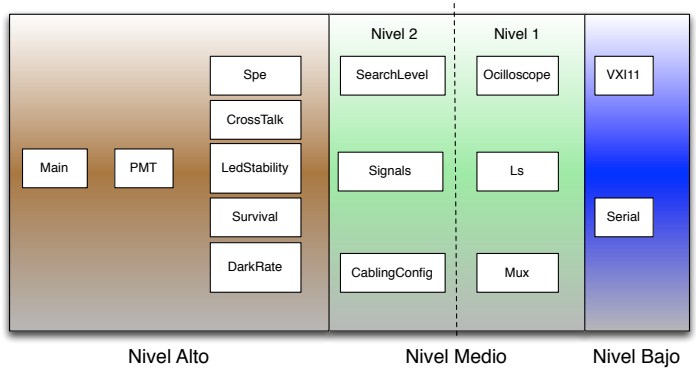
SiPM multi-parameter test bench





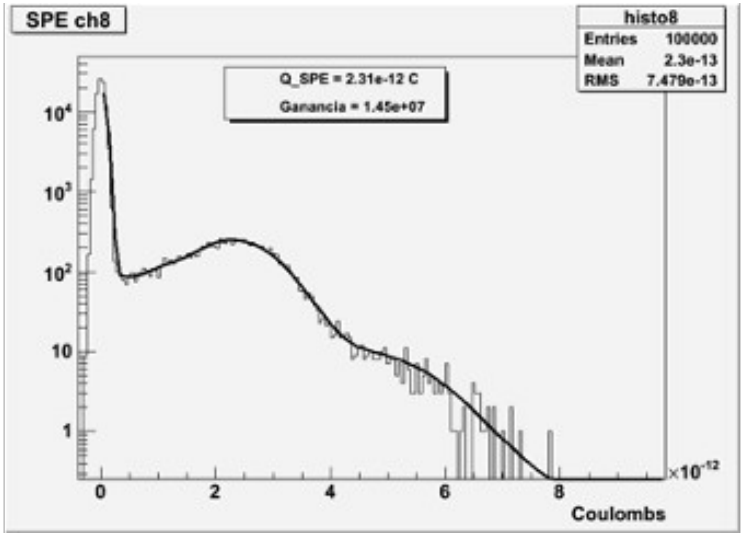


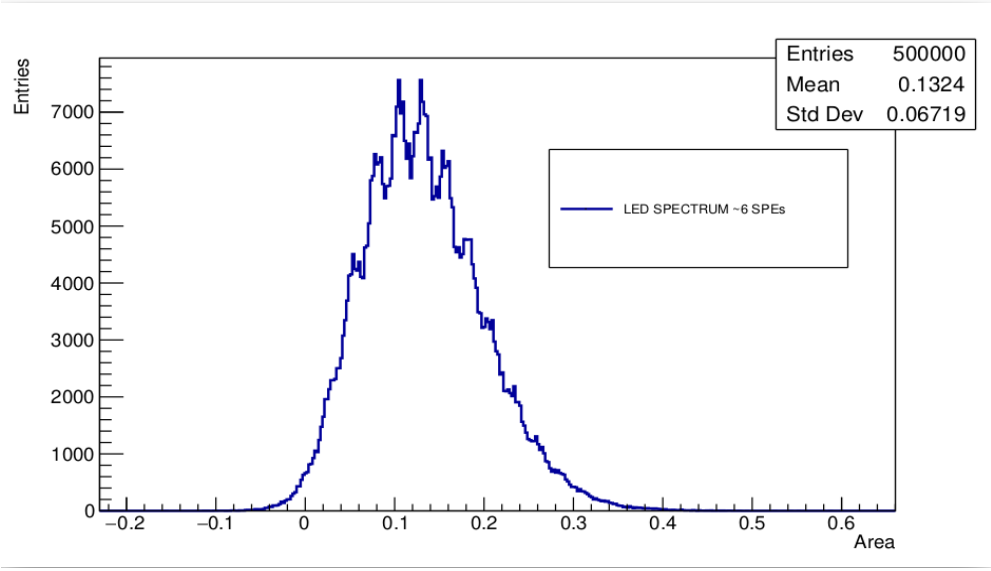


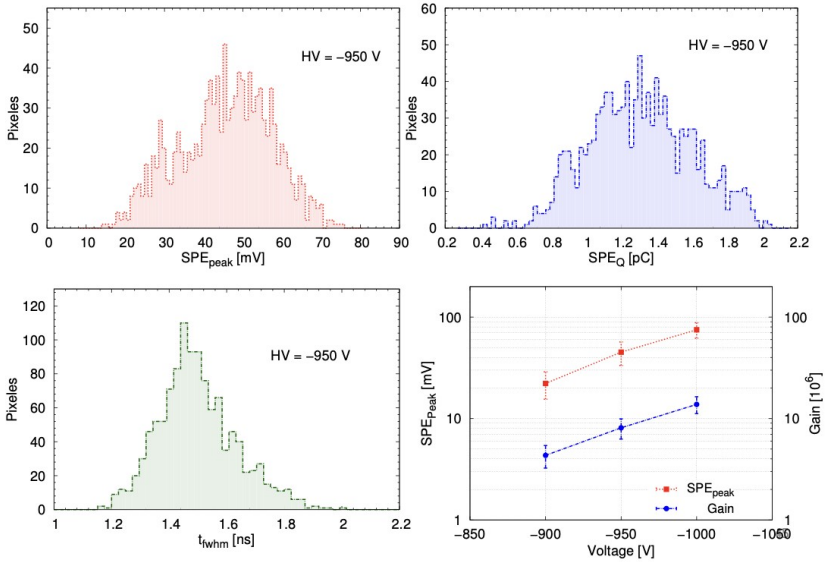


+ MySQL DB and Web interface

SPE spectrum: Gain vs. V







- Gain Measurements in PMTs and SiPMs

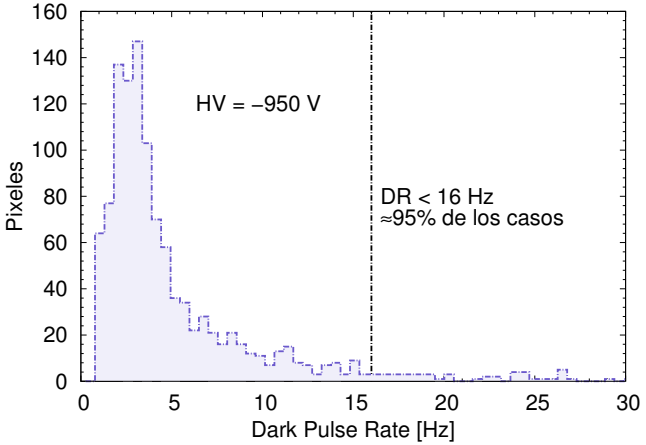
- PMTs requires a fitting method to get the Gain Value.

- Gain on SiPMs could be obtained by the difference between 2 resolved peaks (in charge histogram)

- MaPMTs Gain spread (Gain vs HV) for 1152 pixels

Noise:DCR & Darkcurrent

Noise in SiPMs is high but also useful



Dark Pulse Rate histogram for 18 MaPMTs (1152 pixels)

Measured as # of pulses in a time window.

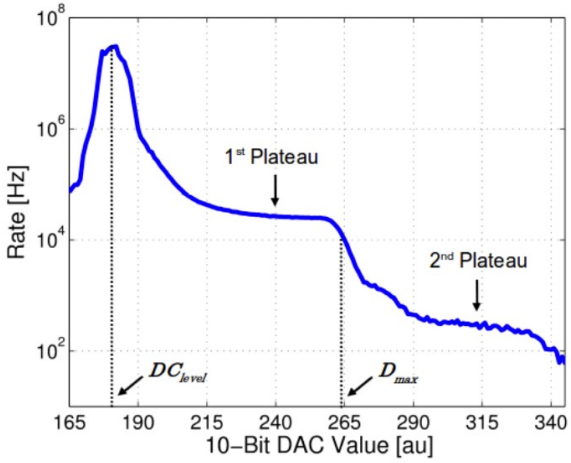
- For MaPMTs the DCR meausement sometimes requires too much time.

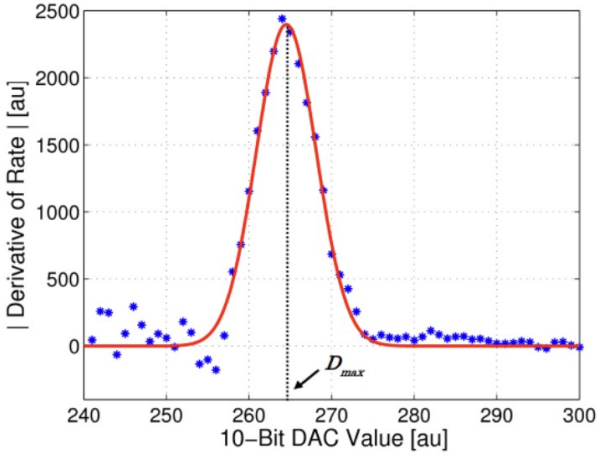
- DCR in SiPMs could be used for calibration purposes.

- Derivative used to get the “pulse height ”MaPMTs Gain spread (Gain vs HV)

Darkcurrent measurement using SMU & Prove Station

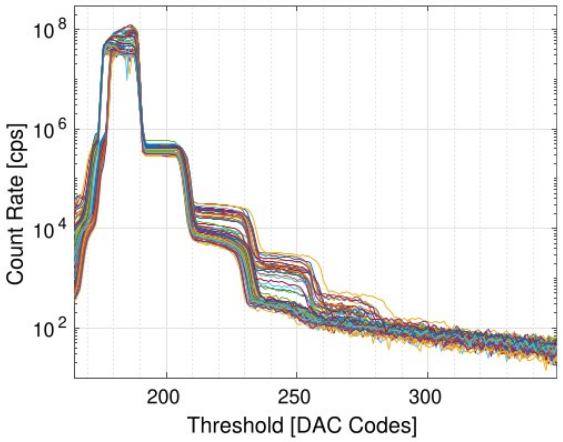
DCR vs Thr. level & Derivative

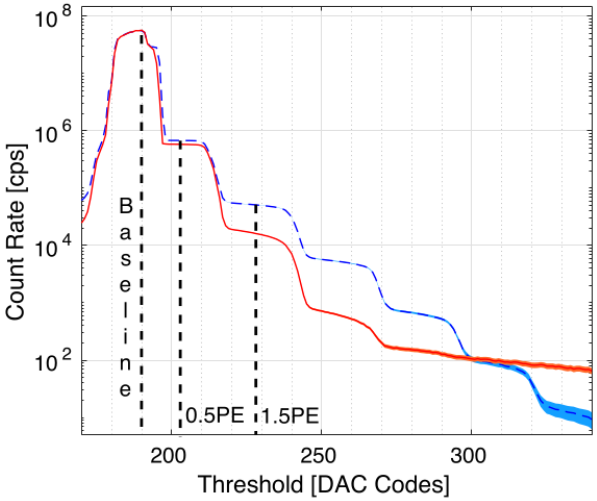




Cross-talk between cells

$$CT = \frac{CR_{>1.5PE}}{CR_{>0.5PE}}$$

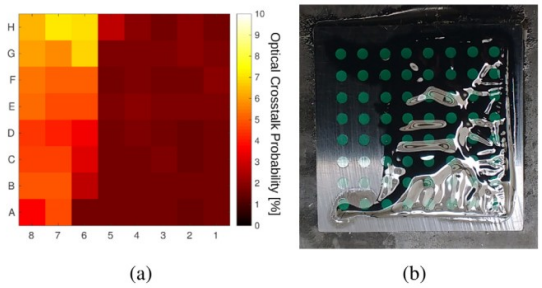


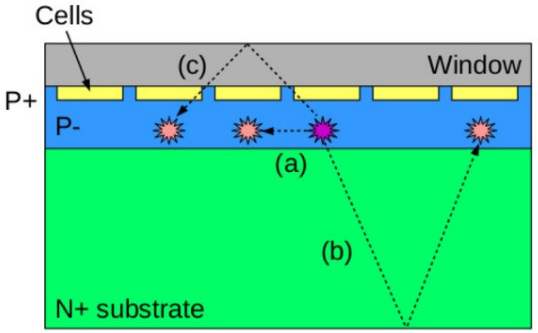


- Use Darkrate information to get %CT of cells

- Testing optical coupling between SiPM and Fibers.

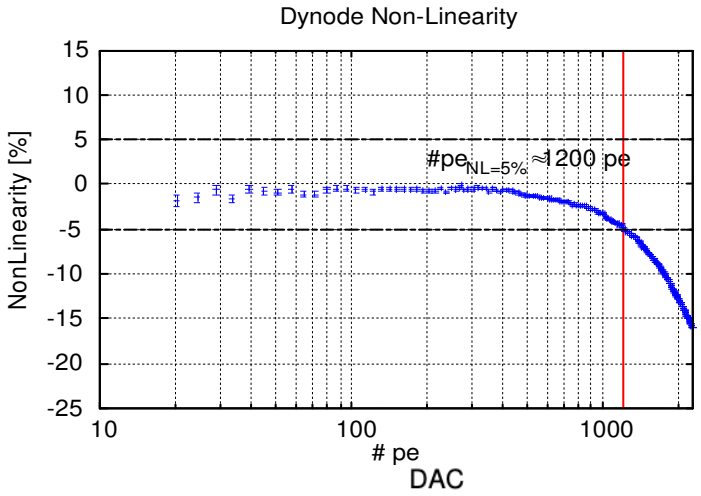
S13361-2050NE-08 SPL

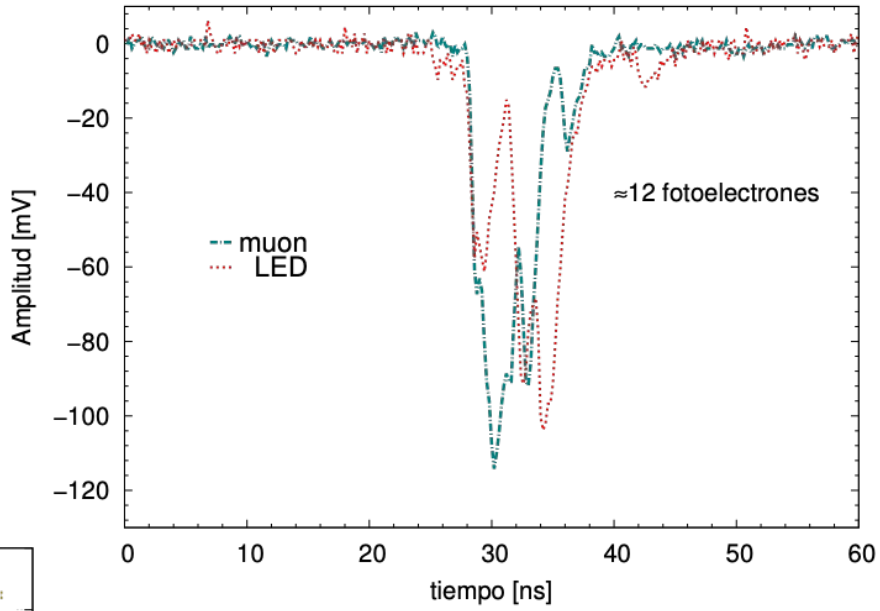


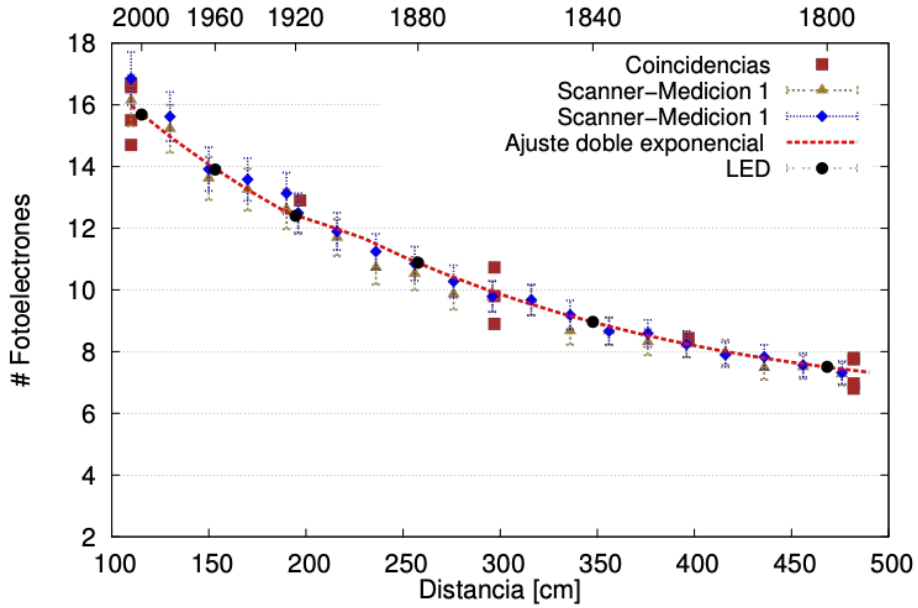


"Optical crosstalk in SiPMs" M.R. Hampel, A. Fuster, C. Varela, M. Platino, A. Almela, A. Lucero, B. Wundheiler, A. Etchegoyen. Nuclear Inst. and Methods in Physics Research, A 976 (2020) 16426.

Dynamic range, Non-linearity







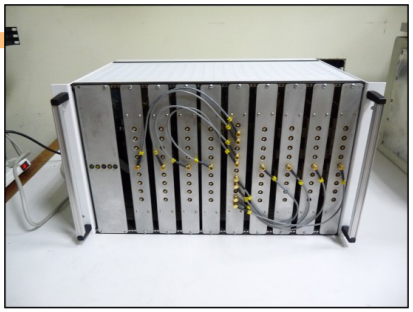
- Linearity Measurements for the MaPMT Dynode (Two pulse method)

- Emulate Muon Pulses

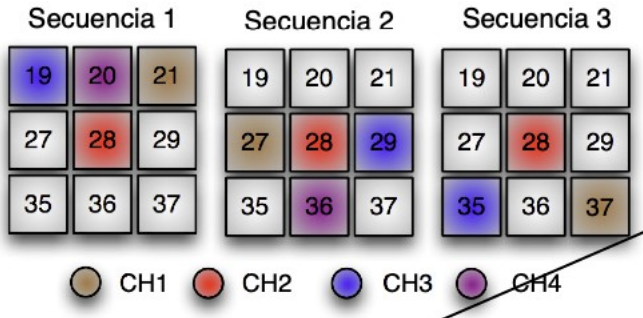
- Emulate scintillator light Levels

"Multichannel pulsed light source with LED for photomultiplier testing". A. Lucero, F. Suarez, C. Reyes, A. Etchegoyen. Nuclear Inst. and Methods in Physics Research, A 972 (2020) 164058.

Cross-talk between detector channels



Multiplexor 64 a 4

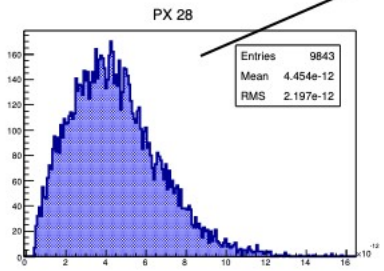


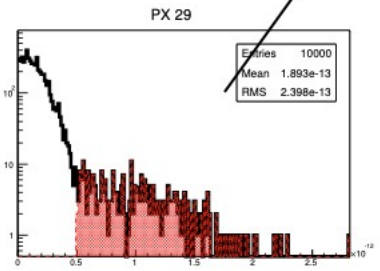
$$XT_{ij} = \frac{G_i}{Q_i}\frac{Q_j}{G_j}[\%]$$

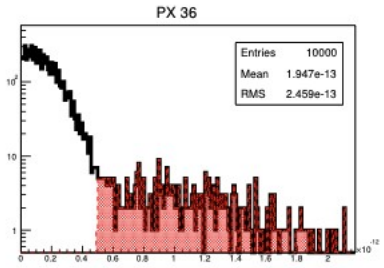
DATA FILE

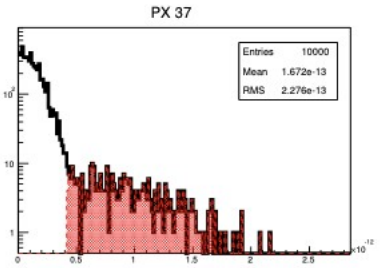
0.31	1.04	0.29
0.58	100	0.8
0.3	1.06	0.3

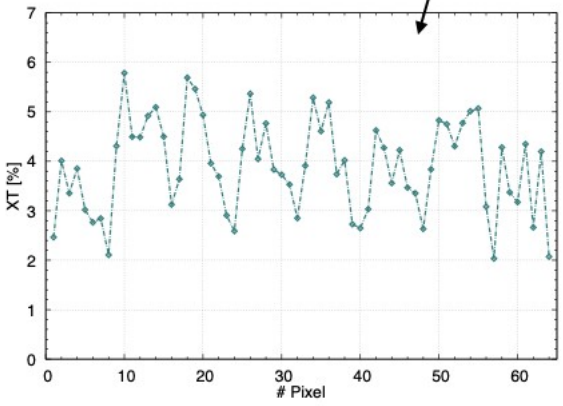
$$XT_i = \sum_j XT_{ij}$$



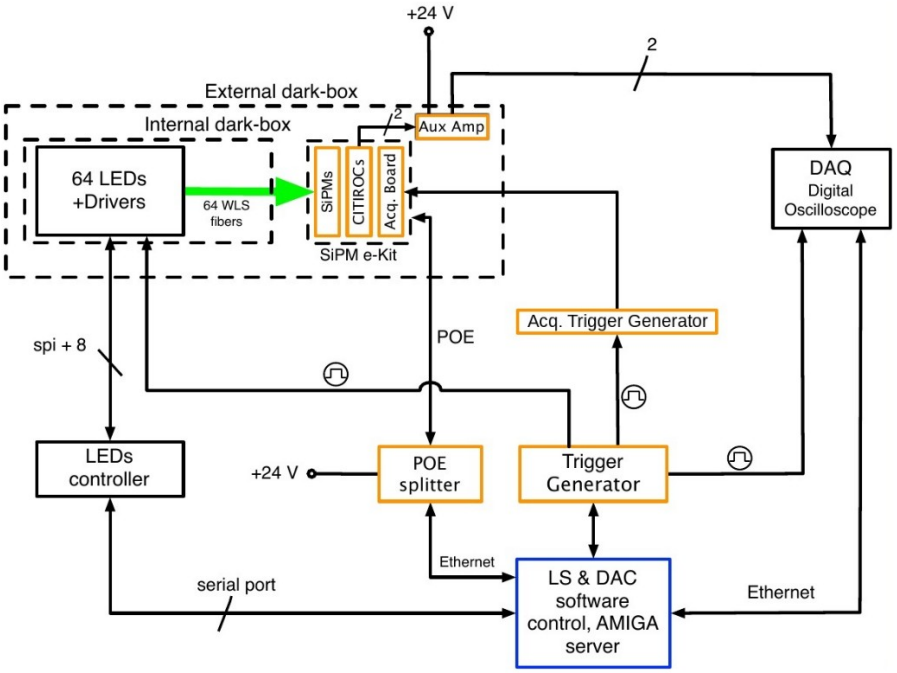


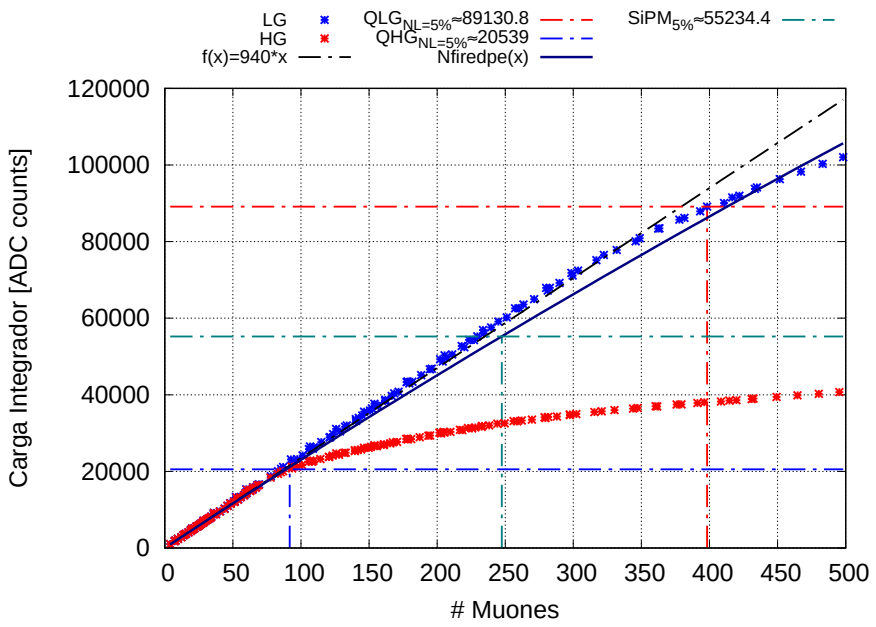


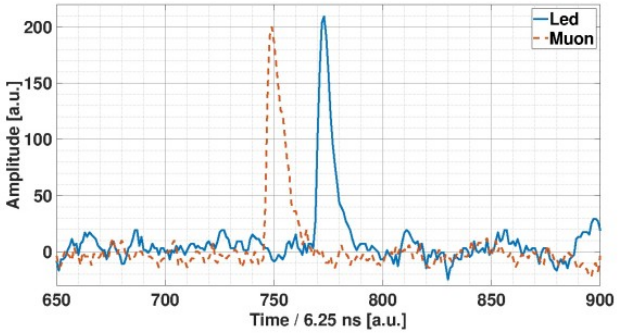




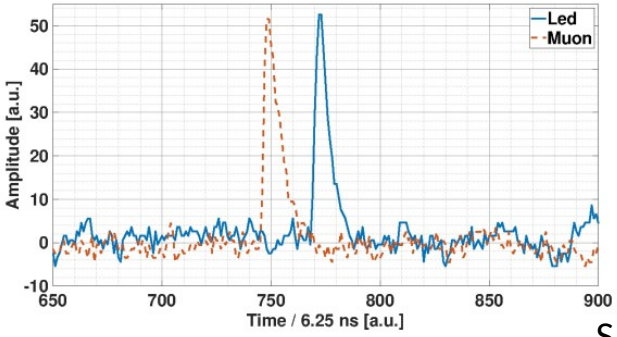
AMIGA Front-end Characterization







(a) HG channel.



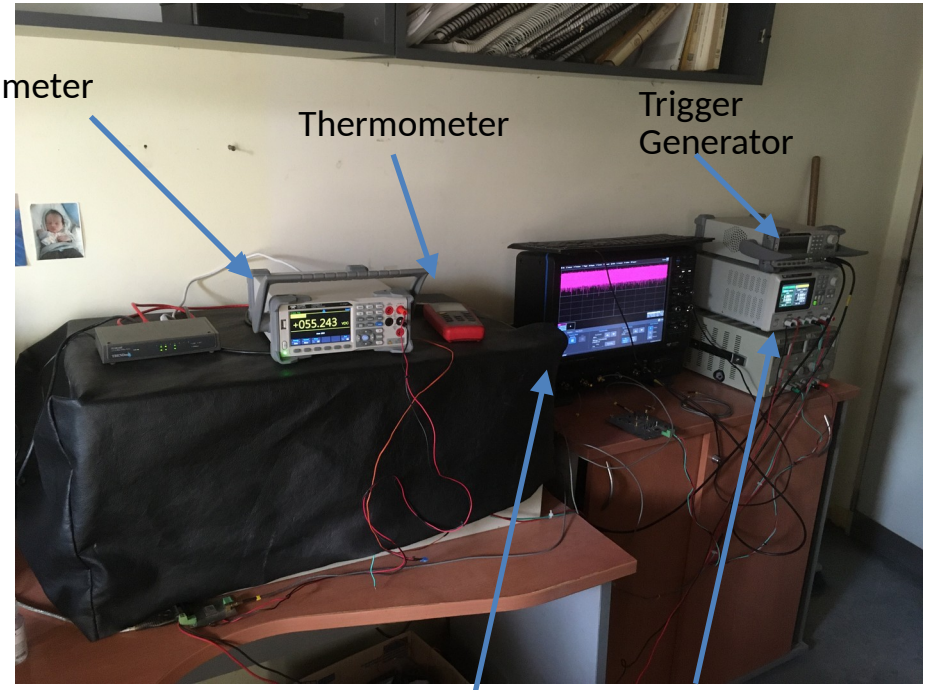
(b) LG channel.

- Linearity Measurements
- Events Emulation
- ADC Testing

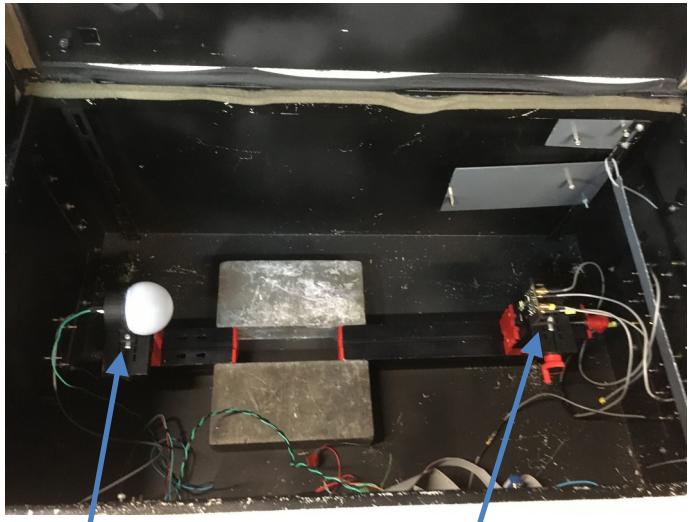
S13361-2050NE-08 SPL + CITIROC + Acq Board (FPGA + ADCs)

"Design, upgrade and characterization of the silicon photomultiplier front-end for the AMIGA detector at the Pierre Auger Observatory. J. Instrum., 16(P01026), 2021.

SiPM Testing Setup



SiPM testing Setup at CNEA



Many PMTLab Tools were used in this setup!!

More details and test results in F. Suares Talk (Thuesday)

Why SiPM full testing?

- Lack of useful information
  - Datasheets mostly incomplete
  - Information from literature normally not aplicable without deep understanding
- Understanding of the SiPM itself
  - Identification of parameters that may introduce systematic uncertainties
  - Characterization of parameters and spreads
    - In similar light-input conditions than final application (characteristics of pulsed light, intensity dynamic range, timing, wavelength)
    - Essential for instrument/detector calibration development
    - Help to develop techniques to mitigate systematics for event reconstructions
  - SiPM selection
    - Different brands
    - Different SiPM series/types
  - Quantification of effects in the SiPM under harsh conditions important for the project needs
    - Variation of parameters due to high thermal excursions
    - Quantification of radiation damage

Why a test lab?

Project Phase

- Several test benches
- The light-source simulates scintillator light-output
  - Full characterization of SiPM
  - End-to-end testing of electronic pack
  - Test/define calibration techniques
  - Reproduce abnormal events during operation

R&D

- Essential to better characterization of other components
  - Interaction between channels (cross-talk)
  - Testing of scintillators in different conditions
  - Aging of the photosensitive pack
  - Detection efficiency with or without acquisition front-end
  - Active stress tests

R&D + Integration + Critical design

- Specs setting for project needs
- QA for mass production
  - Verification that every devices fulfill specs (fast test bench)

System Acceptance + Production

- Operation
  - Aging monitoring
  - Diagnostics
  - Maintenance

Operations

Muchas Gracias