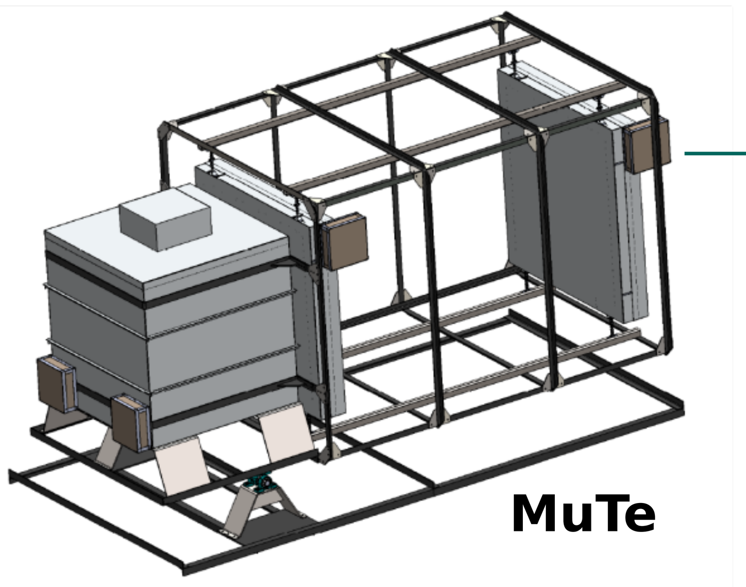
Study of the System response, Plastic Scintillator - Optical fiber - SIPM for the MuTe Project

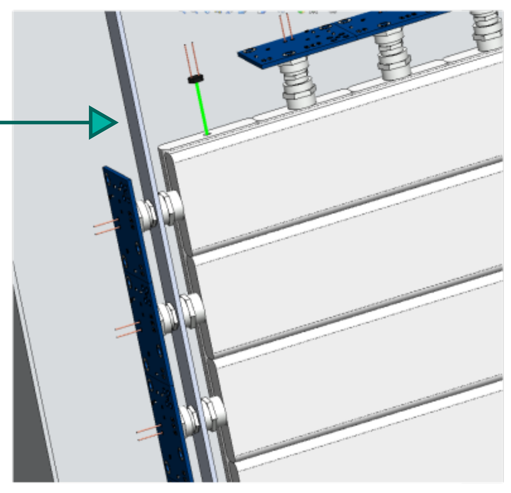
R. Calderón-Ardila*[1], H. Asorey[2], L.A. Nuñez[1], J. Peña-Rodríguez[1], J. Sanchez-Villafrades[1], J. Salamanca-Coy[1], J. Pisco-Guayabe[1], D. Sierra-Porta[1], M. Suarez-Durán[1], for the MuTe collaboration[3].

1-Universidad Industrial de Santander , 2-Instituto de Tecnologias en Detección y Astropartículas (ITeDA) , 3- http://halley.uis.edu.co/fuego/

Introduction

The MuTe project (Muon Telescope) seeks to design, build, calibrate and operate a telescope to detect the flux of the atmospheric muons that go through a volcanic structure in Colombia.
Part of the development of the instrument is the study and interpretation of the response of the scintillator bars that make up the Hodoscope, each bar has an optical fiber embedded and a SiPM (Silicon Photomultiplier) that transforms light guided by fiber in analog pulses..





Scintillator Bars

The scintillator bars used in MuTe are made of a plastic material doped with two different organic scintillators so that they produce a shift in the wavelength of photons. (Wavelength Shifter).

Experimental setup

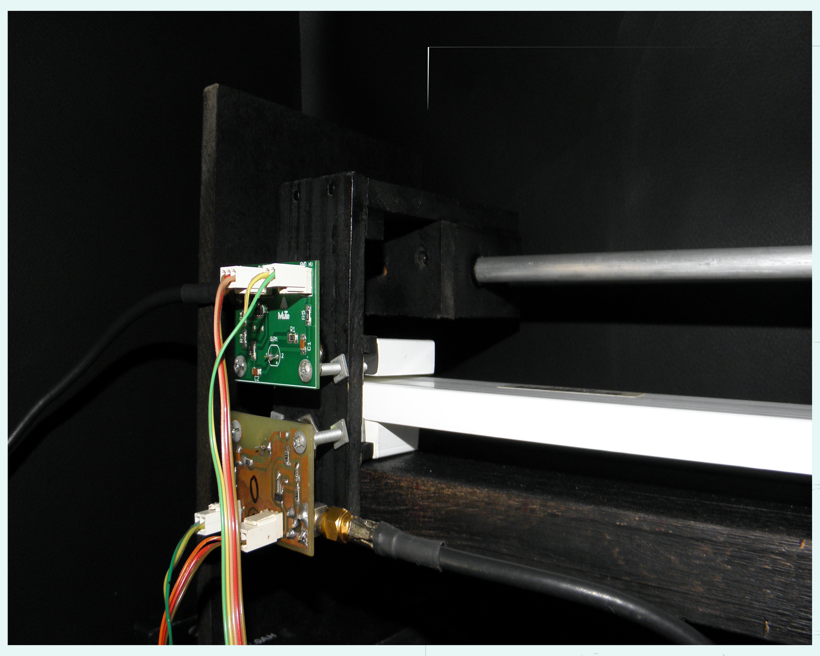


Fig. 1: To make the measurements in the laboratory we use a dark box to avoid light pollution and only measure the light produced by fluorescence in the scintillator.

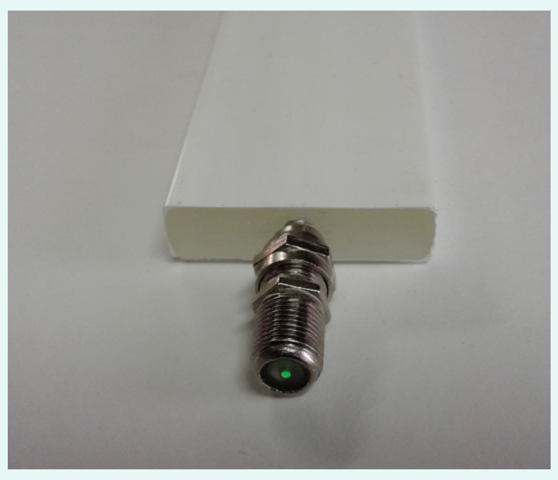
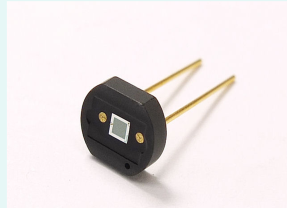


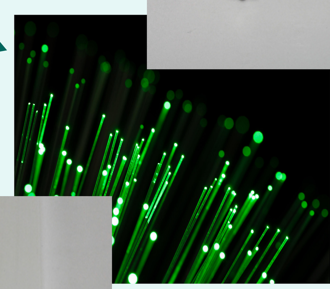
Fig. 2: MuTE employs scintillator material bars with rectangular cross-section (4cmx1cm) and 120 cm length.

Fig. 3: The bar-fiber system transports light to the SiPM that communicates with the acquisition electronics.

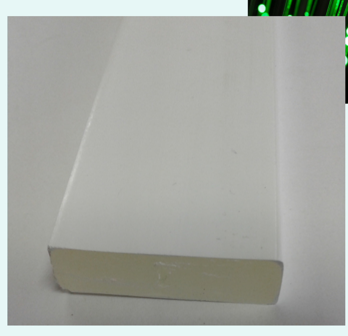


SiPM

couplings



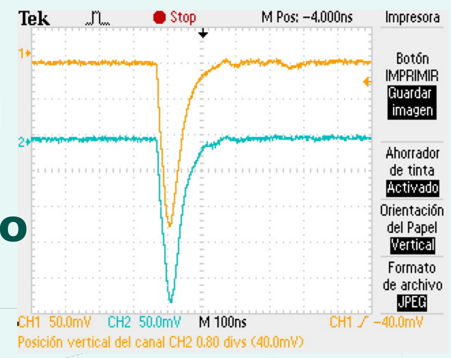
Optical fiber



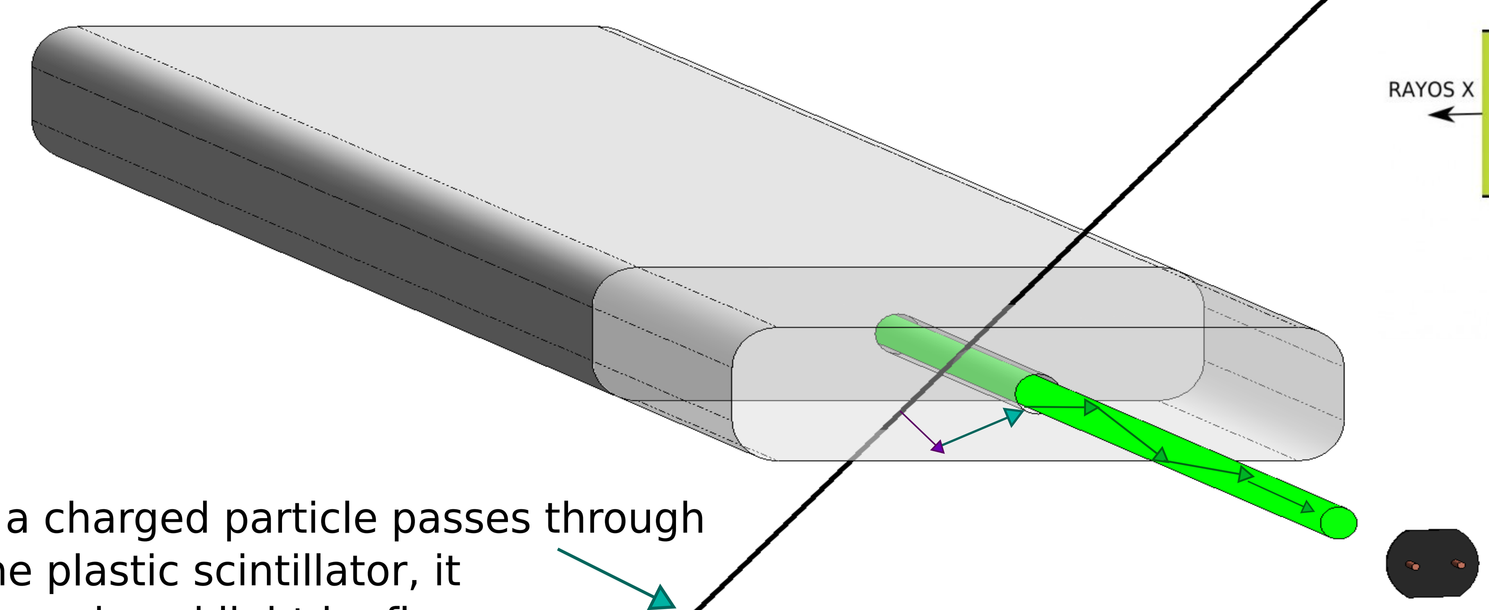
scintillator bars

SiPM

A silicon photomultiplier or SiPM is a light detector formed by a matrix of avalanche photodiodes (APDs) on a silicon substrate. MuTe uses SIPM manufactured by Hamamatsu ref: S13360-1350CS.



The SiPM transforms photons into pulses.



If a charged particle passes through the plastic scintillator, it is produced light by fluorescence

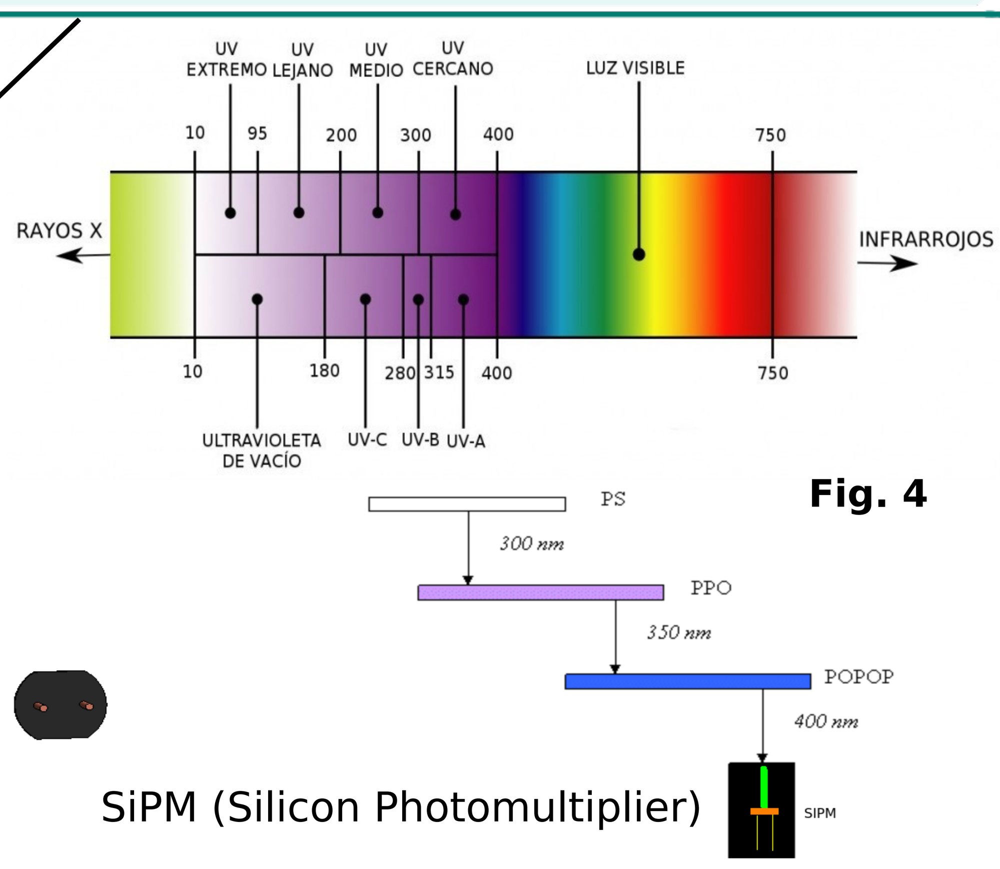


Fig. 4

SiPM (Silicon Photomultiplier)

How are the particles detected?

In Fig. 4 we observe what happens when a charged particle passes through the scintillator bar, this produces light by fluorescence in the bar, those photons are absorbed and emitted increasing its wavelength, then they are transported by optical fiber up to the SiPM and produce pulses that depend on photons numer, then they are saved and digitized with a development card, finally, the data is analyzed.

Results:

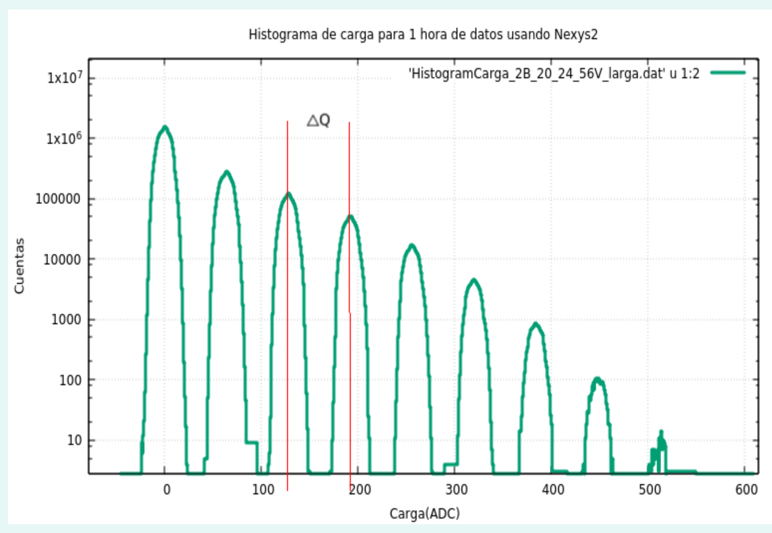


Fig. 5: A charge histogram for one hour of pulses is presented, the humps correspond to several Spe (Single particle equivalent)

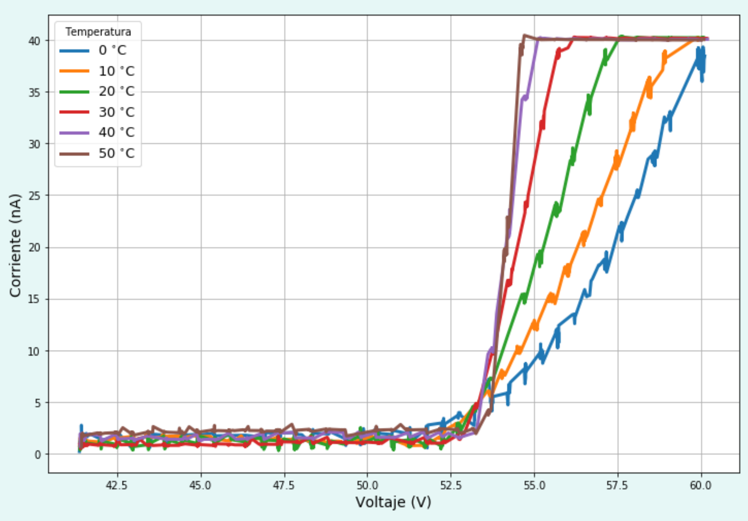


Fig. 6: Measurements of the dark current of the SIPM were took at different voltages, in each set of measurements the temperature was adjusted to keep it constant, in the graph we can observe how the slope changes in relation to each measured temperature, thus obtaining the breaking voltage.

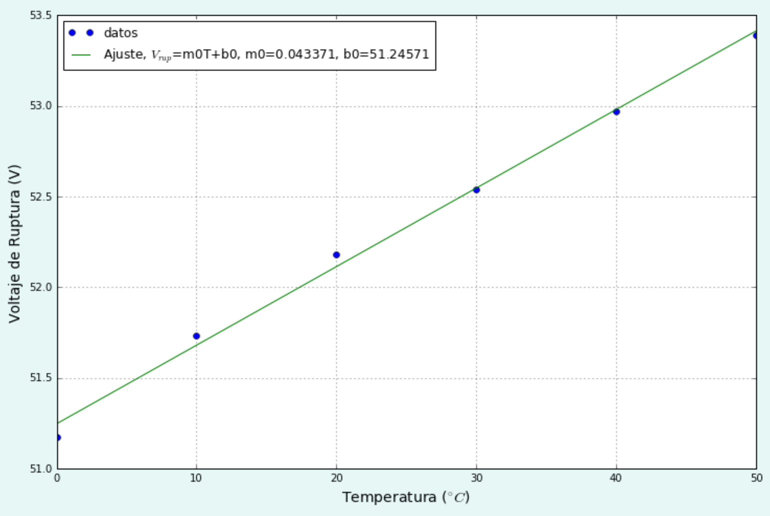
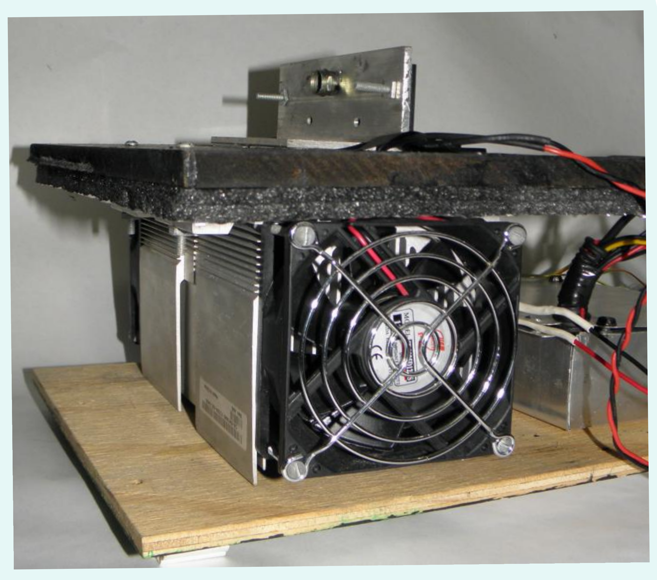


Fig. 7: After identifying the breaking voltage for different temperatures, a plot that relates the two previous variables was made, this is useful because we must guarantee that the SIPM is in operation at all times, knowing this will allow to correct the voltage for different temperatures in the site near the volcano.

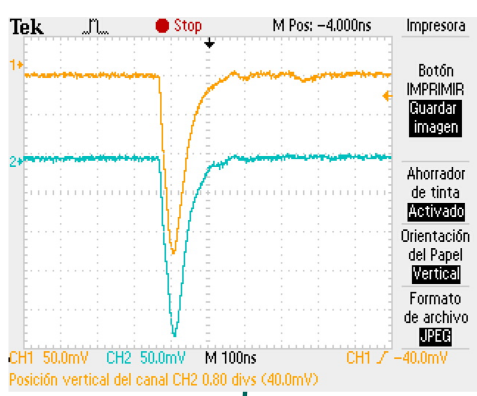
To take the measurements we use a box with temperature control

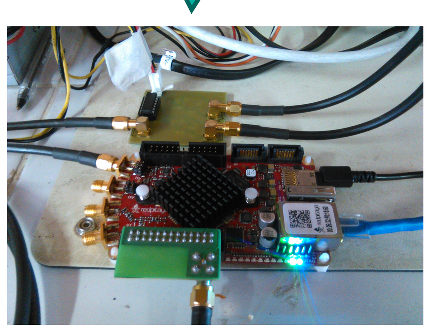


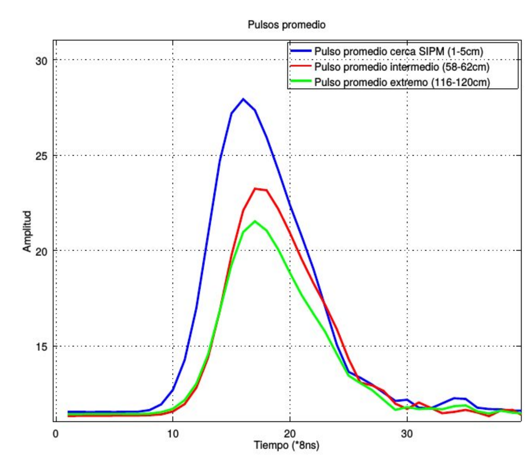
In conclusion :

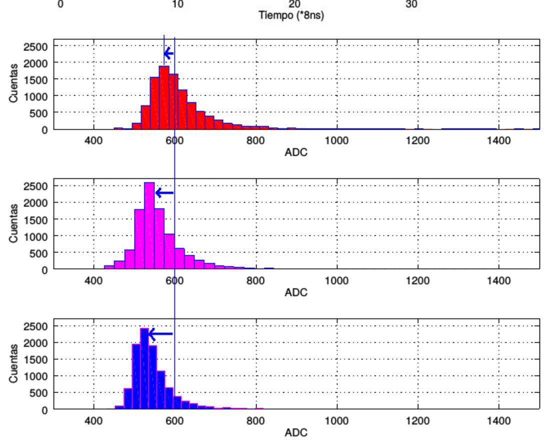
- Pulses were taken to verify the behavior of the SIPM identifying the SPEs, this served to know the Single particle equivalent, this will be useful to identify the noise level, and establish an adequate threshold.
- The dark current and its dependence with the temperature were measured, this allowed to find the rupture voltage as a function of temperature, this is necessary to decide the operating voltage suitable for the instrument such that the SIPM always works in Geiger mode.
- Finally, pulses were acquired with coinciding bars; this allowed determining the existence of attenuation in terms of the average energy deposited. We are currently working on this.

The average deposited charge differs in pulses measured at opposite ends, attenuation.









The project advances

- To know and interpret the response of the bar-fiber-SIPM system before the installation of MuTe in the volcano is of vital importance for the project, this will allow defining limits of operation during the calibration. Additionally, knowing its impulse response will be useful for the development of simulations of the Hodoscope, which will allow modeling for the study during the offline analysis.

Bibliography

[1] Anna Pla-Dalmau, Alan D Bross, and Victor V Rykalin. Extruding plastic scintillator at fermilab. In Nuclear Science Symposium Conference Record, 2003 IEEE.
[2] The Pierre Auger Collaboration. Prototype muon detectors for the amiga component of the pierre auger observatory, JINST, 2016.
[3] Adam N.Otte, D. Garcia et al. Characterization of Three High Efficiency and Blue Sensitive Silicon Photomultipliers, Nuclear Instruments and Methods in Physics Research 2017 - Elsevier.

* rolando.calderon@correo.uis.edu.com