Proposal of a compact particle detector with commercial embedded systems

The first Visegrad Cosmic Ray Extremely Distributed Observatory (CREDO) Worshop 2024

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Benemérita Universidad Autónoma de Puebla
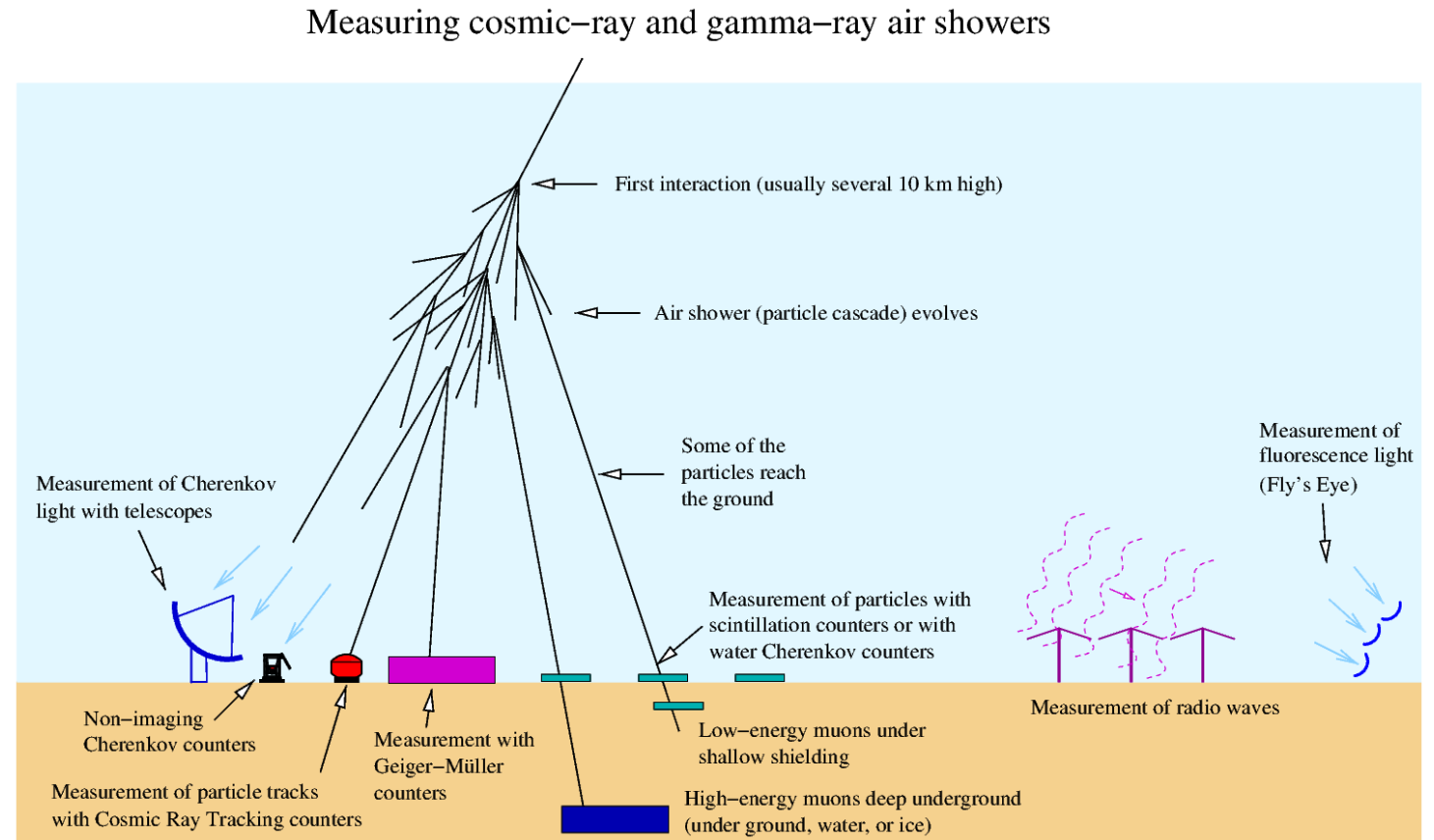
Cosmic Rays

Measuring cosmic–ray and gamma–ray air showers

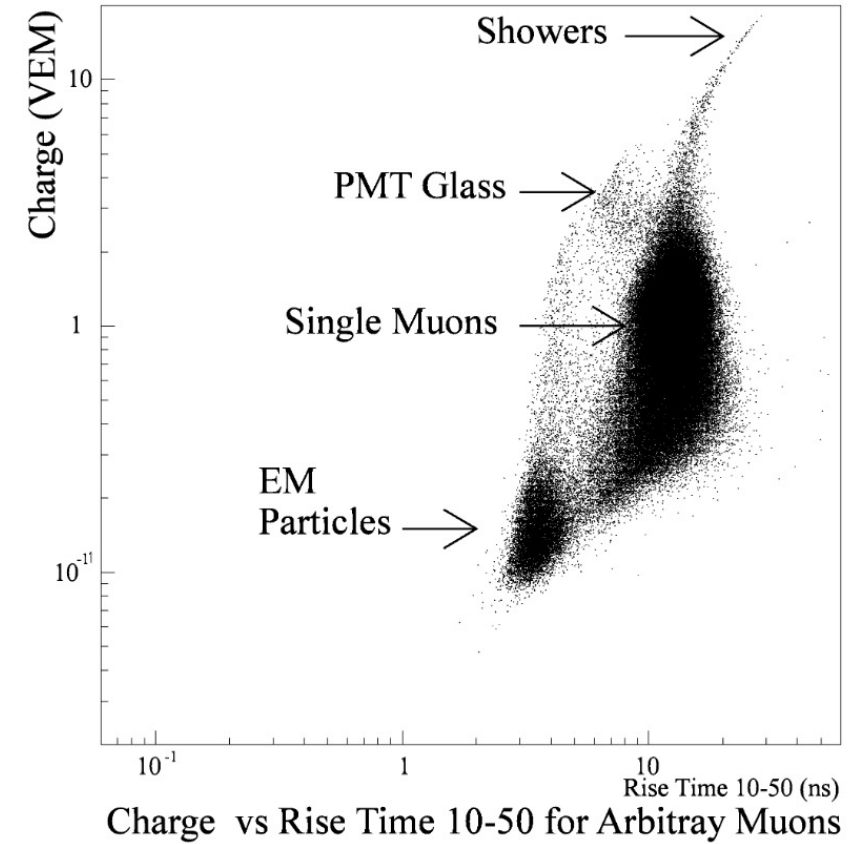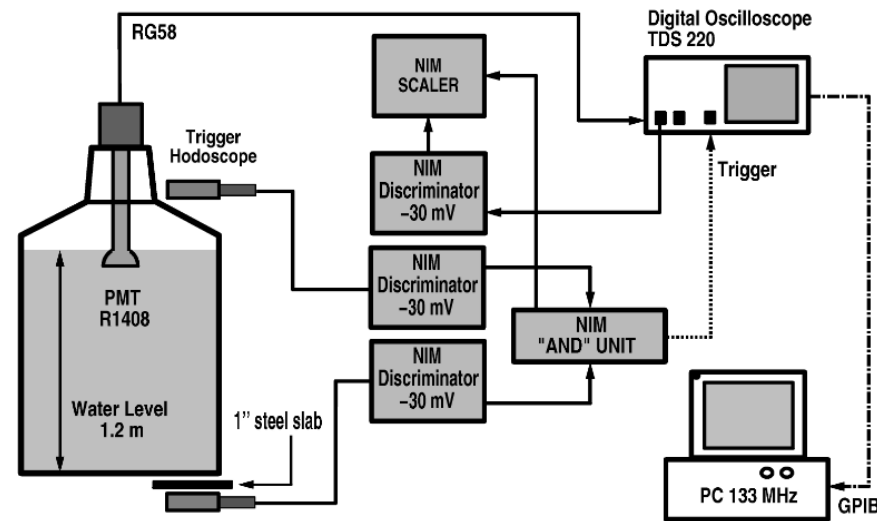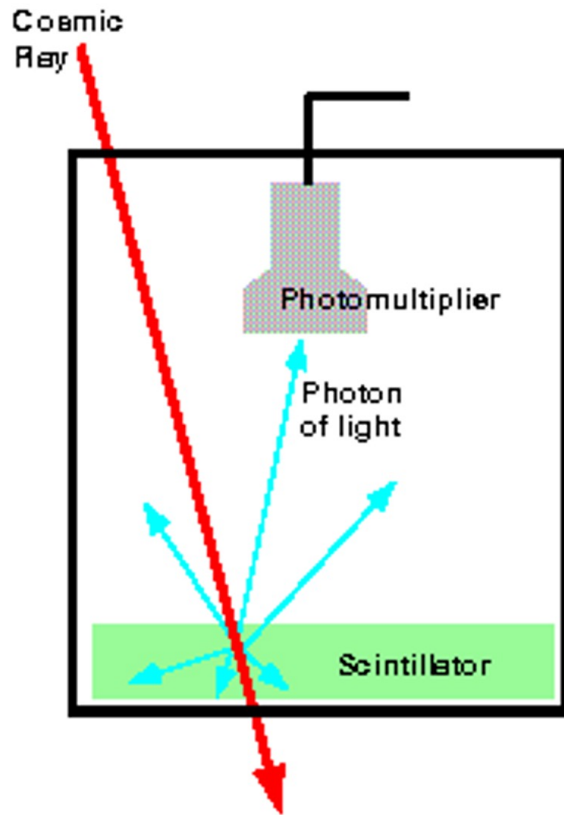Figure adapted from https://www.mpi-hd.mpg.de/hfm/CosmicRay/ShowerDetection.html

Cosmic Rays

J. Cotzomi et al., Air shower array at the university of Puebla for the study of cosmic rays, RMF, 51 (1) 38–46

Water Cherenkov detector (WCD)

Ph. D. Thesis

- Calibration of a large water-Cherenkov detector at the Sierra Negra site of LAGO
  - It consists of a cylindrical water tank with a diameter of 7.3 m and a height of 1 m and a total detection area of 40 m^2
    - Simulation
    - Calibration of Tube photomultipliers
    - Installation at 4500 masl
    - Segmented tank
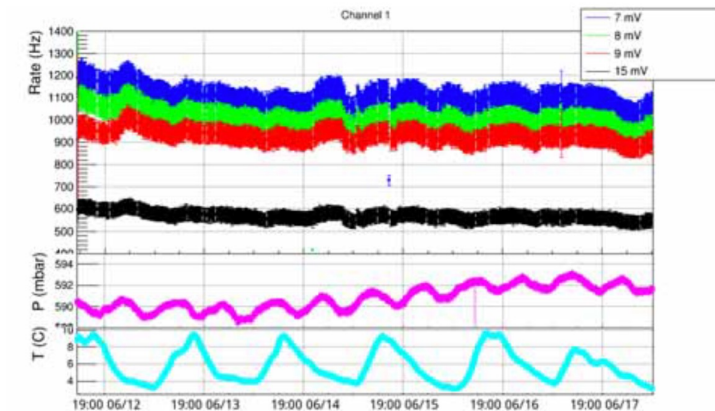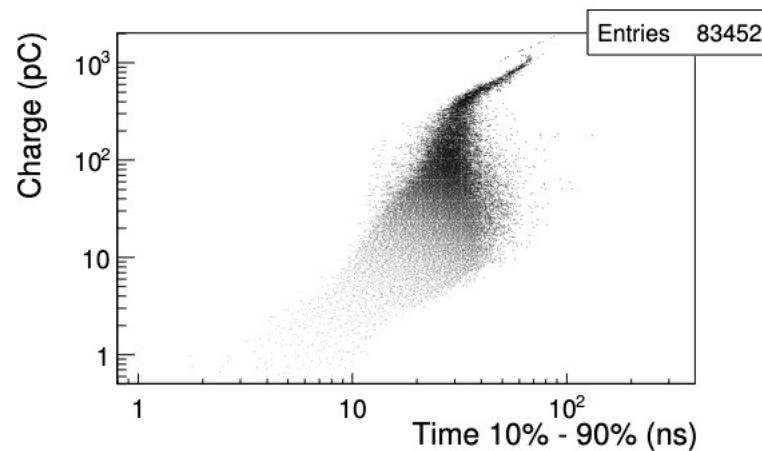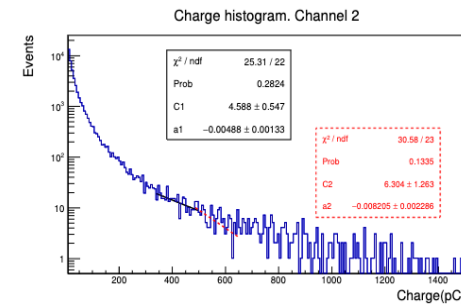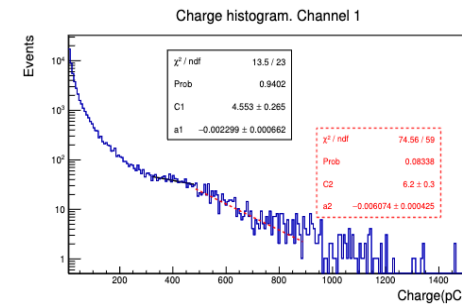
Water Cherenkov detector (WCD)

- ## Simulation
  - ### Geant4

- ## Calibration
  - ### CAEN electronics

- ## Acquisition data
  - ### CAEN electronics

- ## Monitoring
  - ### ADC/Nexys 2 – rate mode

- ## 4500 masl
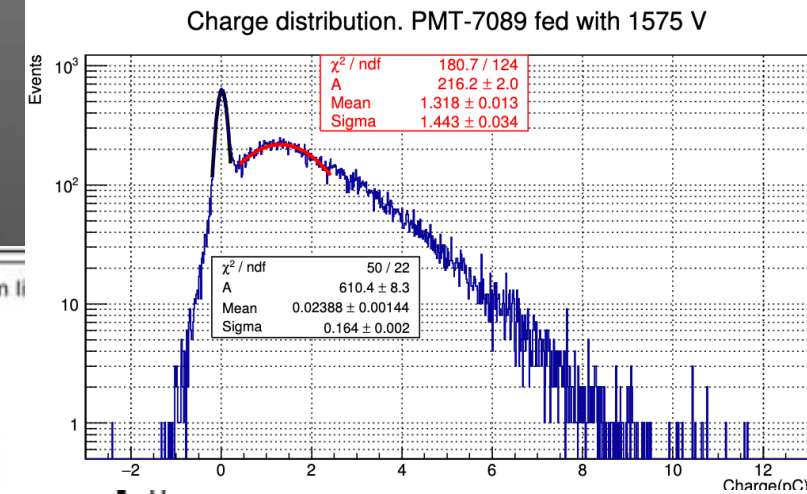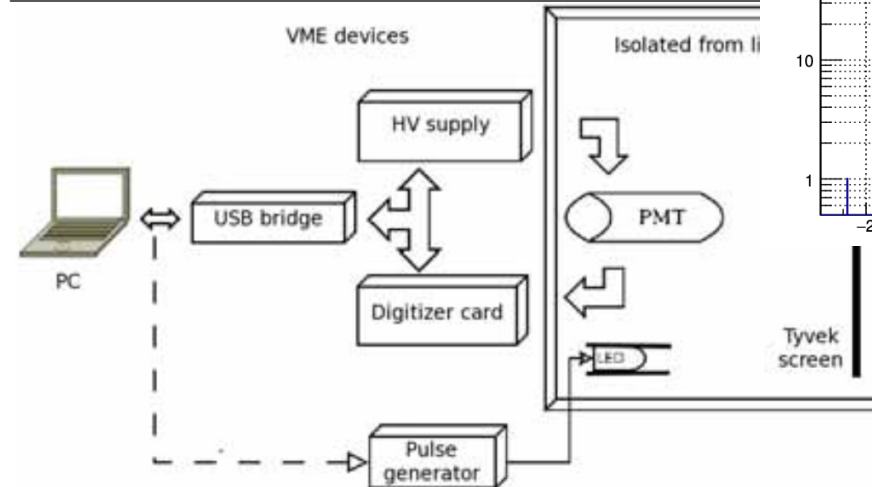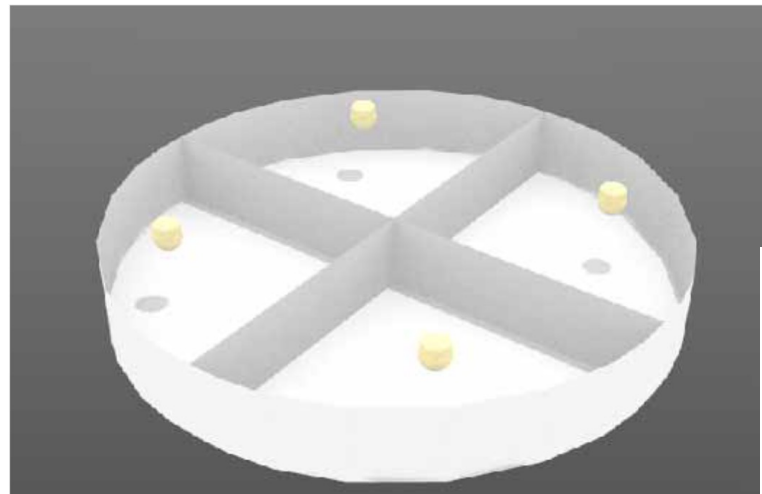
A Galindo et al. Calibration of a large water-Cherenkov detector at the Sierra Negra site of LAGO, NIMA, 2017

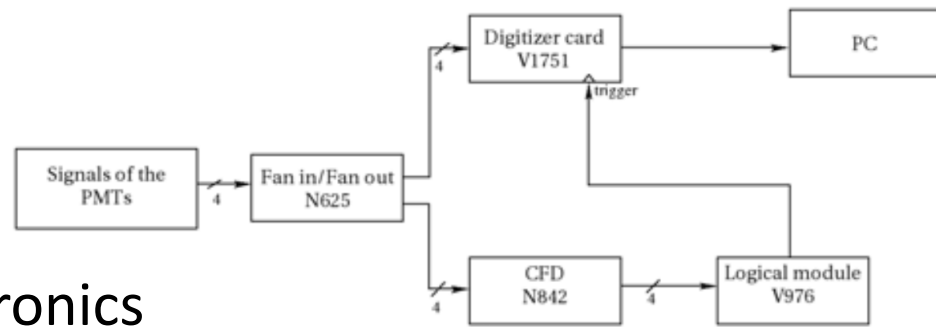# Water Cherenkov detector (WCD)

- ## Simulation
  - Geant4

- ## Calibration
  - CAEN electronics

- ## Acquisition data
  - CAEN electronics

- ## Monitoring
  - ADC/Nexys 2 – rate mode

- ## 4500 masl

A Galindo et al. Calibration of a large water-Cherenkov detector at the Sierra Negra site of LAGO, NIMA, 2017

Background

- A first attempt at a detector consisting of
  - scintillator bar (MINOS Project)
  - wavelength shifter fiber
  - Tube photomultiplier
  - 10-bit ADC
  - Spartan 3 FPGA card (Xilinx).
  - Sensor of temperature/pressure
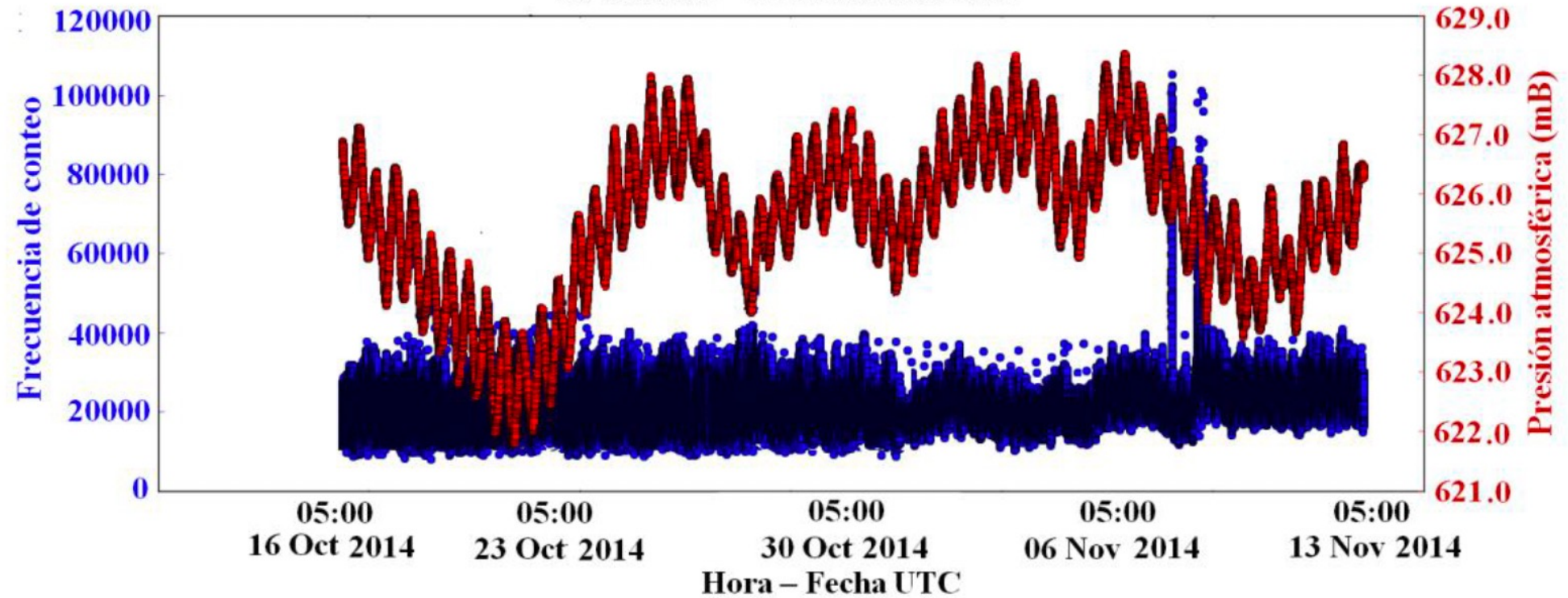 - GPS system
- 4100 masl

Bachelor Thesys: Characterization of a particle detector with respect to atmospheric variables
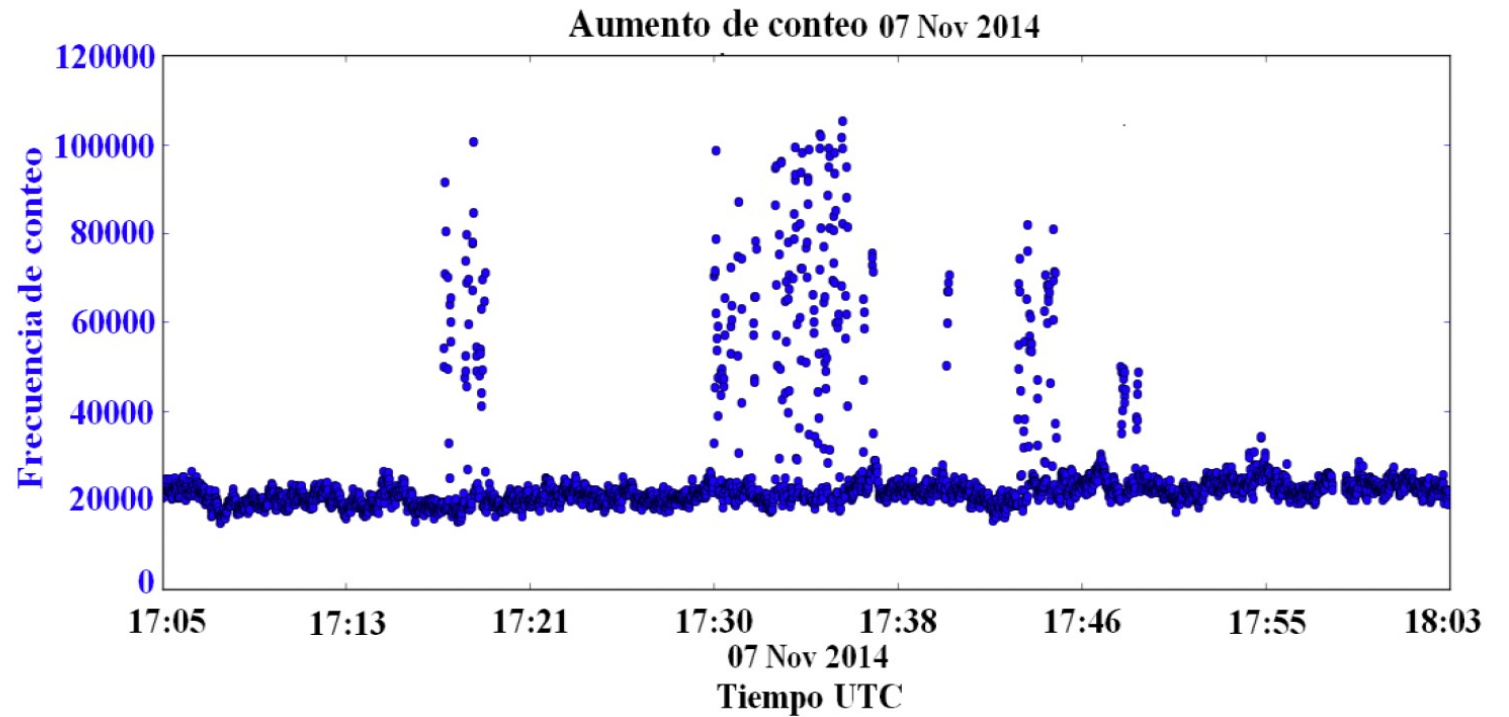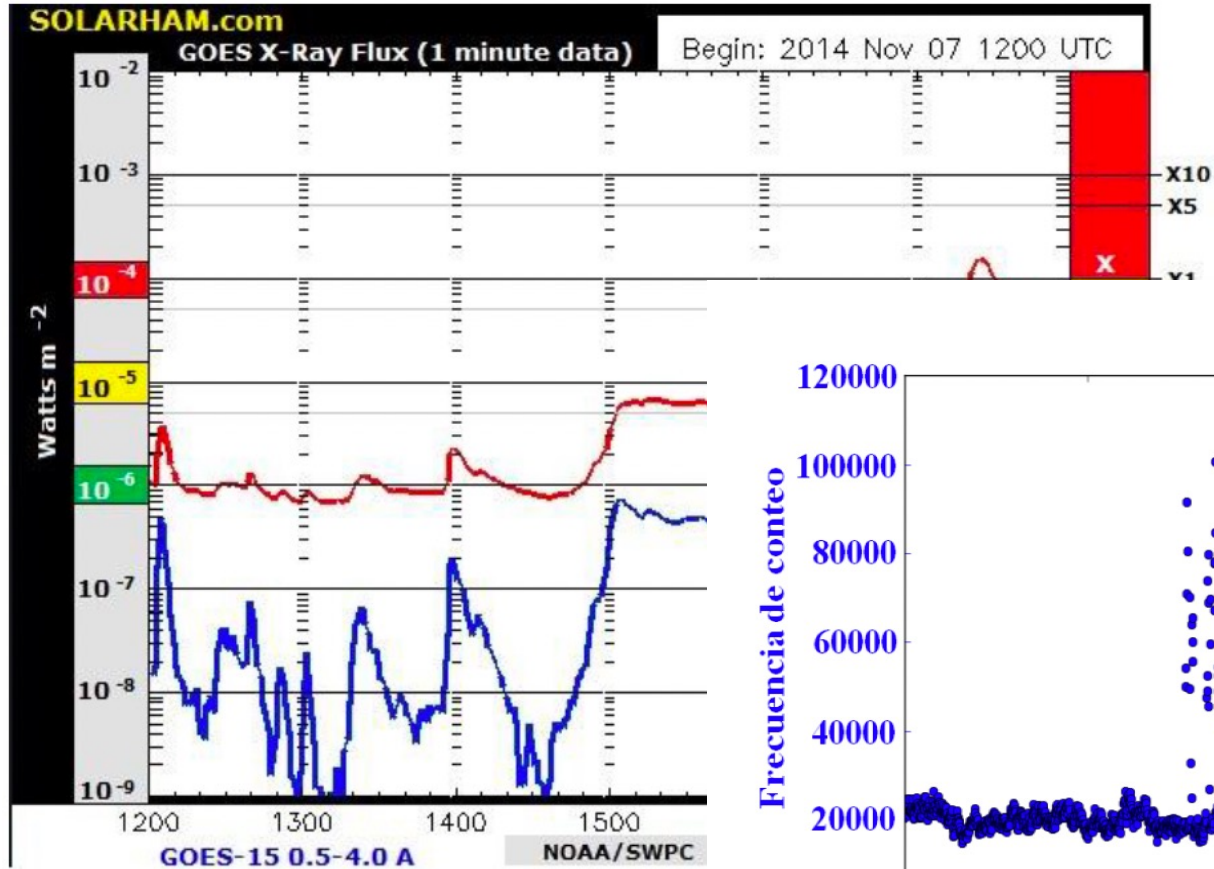
Results

Frecuencia de conteo con respecto a Presión
14 Junio – 11 Julio 2014
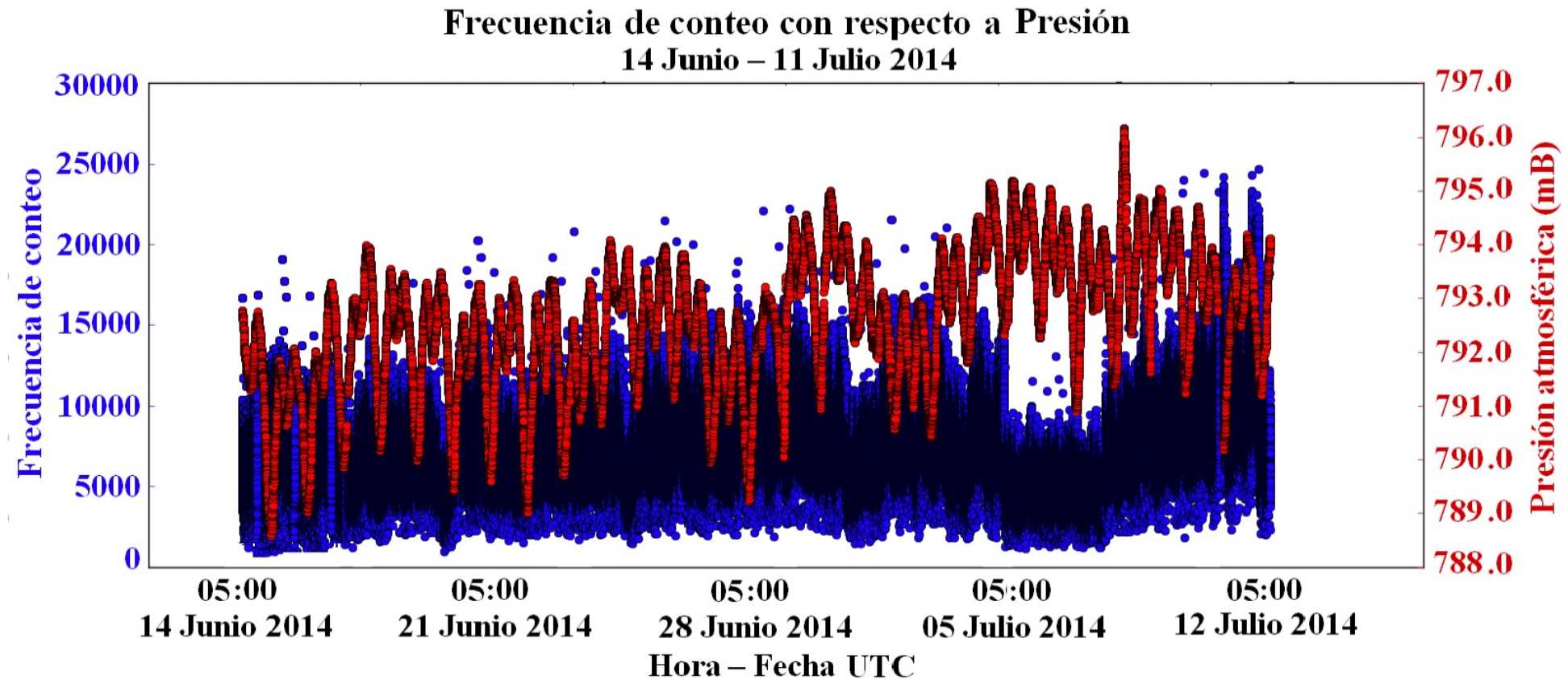
Frecuencia de conteo con respecto a Presión
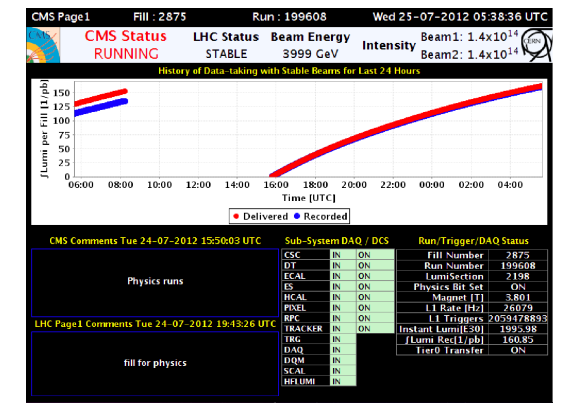16 Octubre – 12 Noviembre 2014

Solar physics

Detector proposal

- Embedded system
- Micro computer
- IoT sensors
- Wi-Fi/wired connectivity
  - App for phone/tablet/pc
- Web development
  - Monitoring/control
- Processing/data analysis
  - Introductory/advanced

Figures adapted from internet and https://lss.fnal.gov/archive/2014/pub/fermilab-pub-14-293-cms.pdf

Proposal Portable

Scintillator plastic	Front-End	Embedded system	Slow control & weather parameters	Connectivity
• 15 X 15 X 1 cm3	• SiPM • 50 • Gain 2x, 5x	• Red pitaya • Digilent	• Temperature • Pressure • Humidity	• Wireless • wired • network
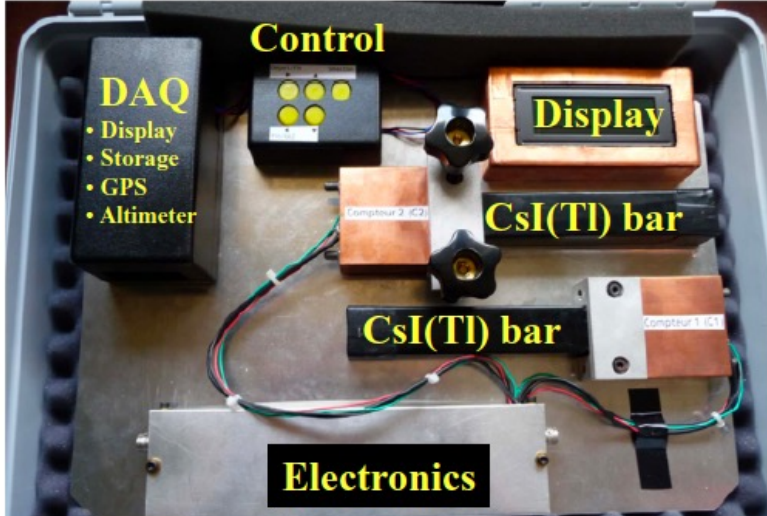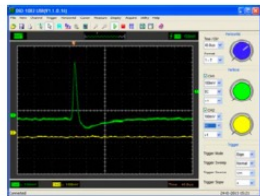
Portable detectors
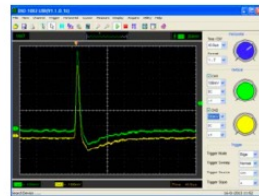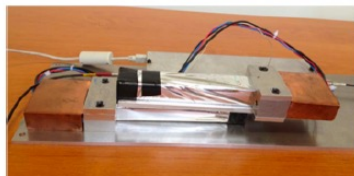
Cherenkov radiator in a light guide

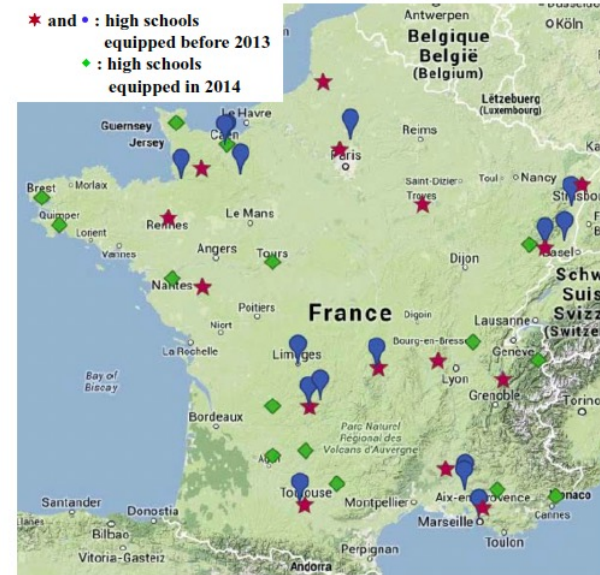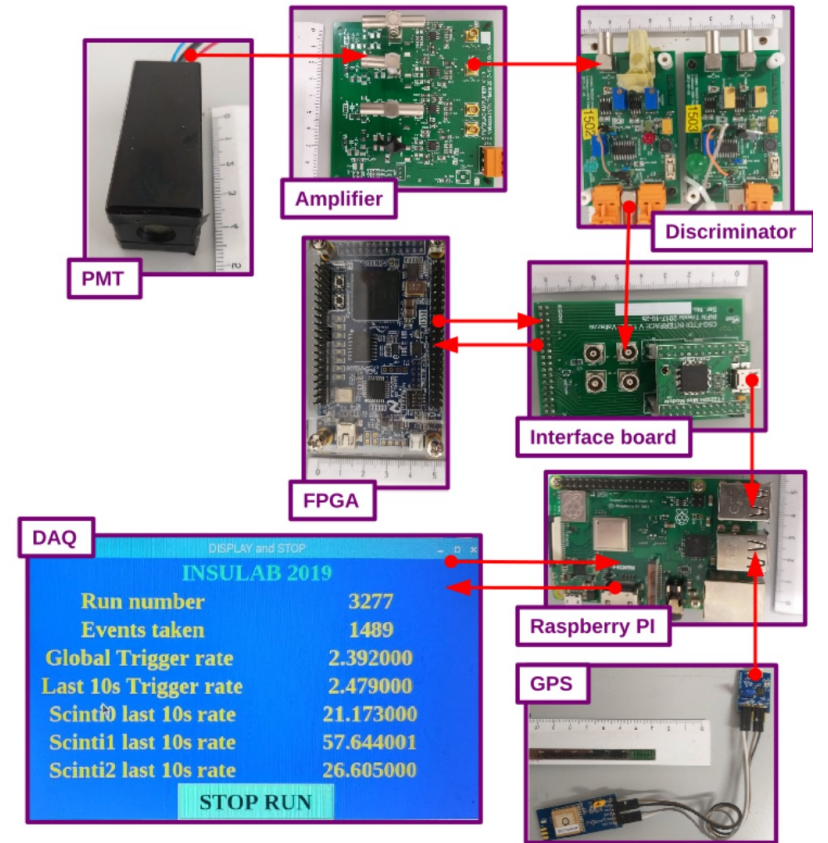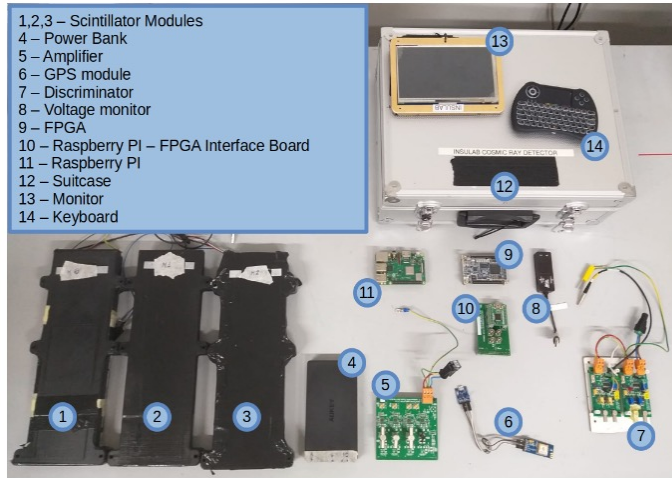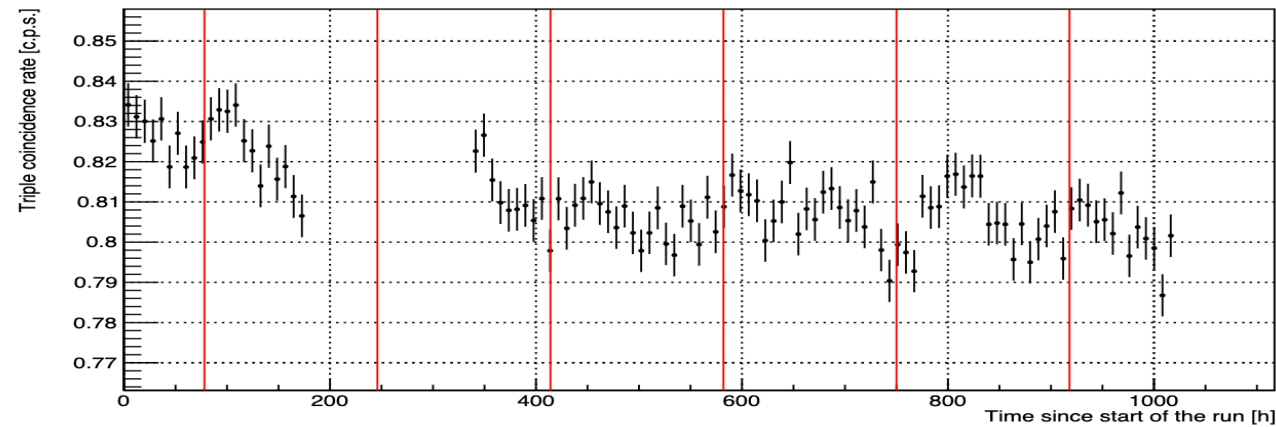
Thick scintillator

Nicolas Arnauda et al., Cosmic ray detectors for high schools in France, Nuclear and Particle Physics Proceedings 273–275 (2016) 1233–1238

Portable detectors

1,2,3 – Scintillator Modules
4 – Power Bank
5 – Amplifier
6 – GPS module
7 – Discriminator
8 – Voltage monitor
9 – FPGA
10 – Raspberry PI – FPGA Interface Board
11 – Raspberry PI
12 – Suitcase
13 – Monitor
14 – Keyboard

L. Bomben et al., A Portable Cosmic Ray Detector for School Education, arXiv:2111.10151v1 [physics.ins-det] 19 Nov 2021
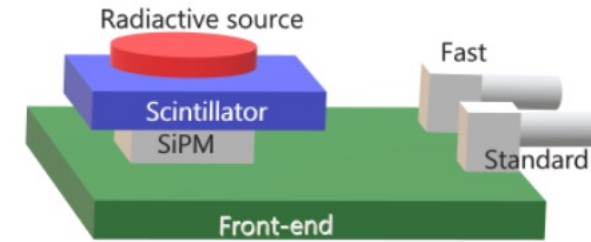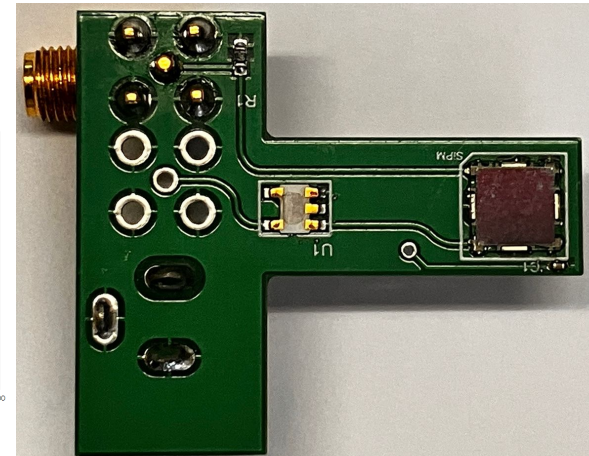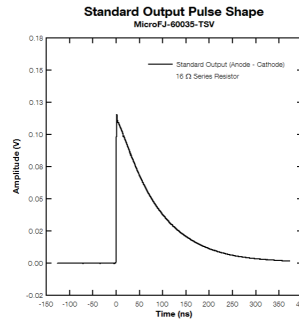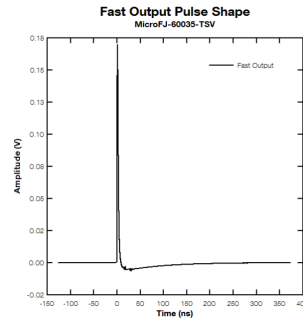
Current work

- Select SiPM
  - SensL
- Simulation
  - Geant 4
- Digital development of Time to Digital Convert
- Low-cost Field programmable Gate Array
- Altera -> Xilinx

Silicon photomultiplier (SiPM)

- SensL (Onsemi)

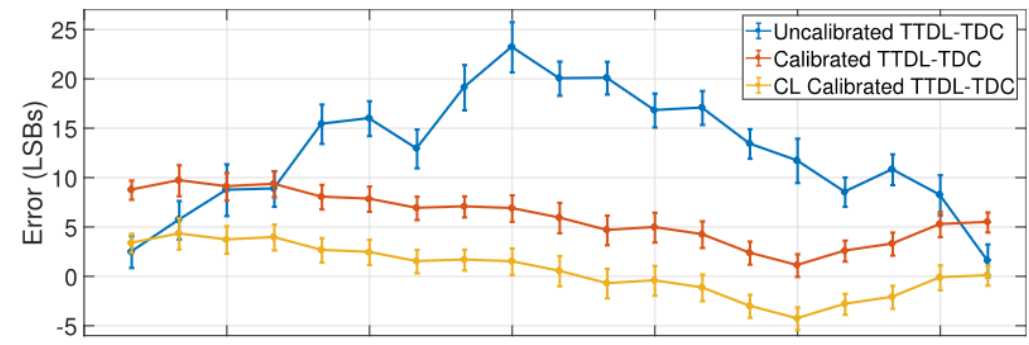- 2 output
  - Slow (us)
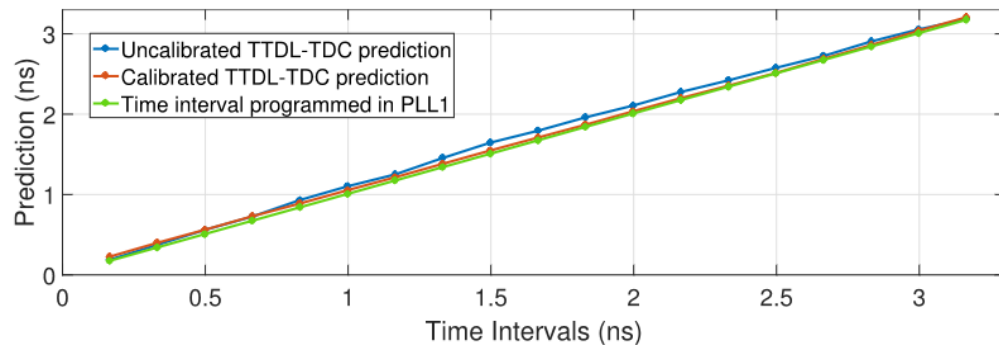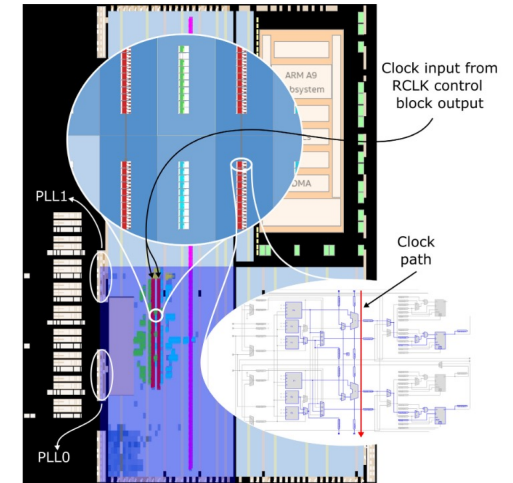 - Fast (ns)

- Characterization of electric charge
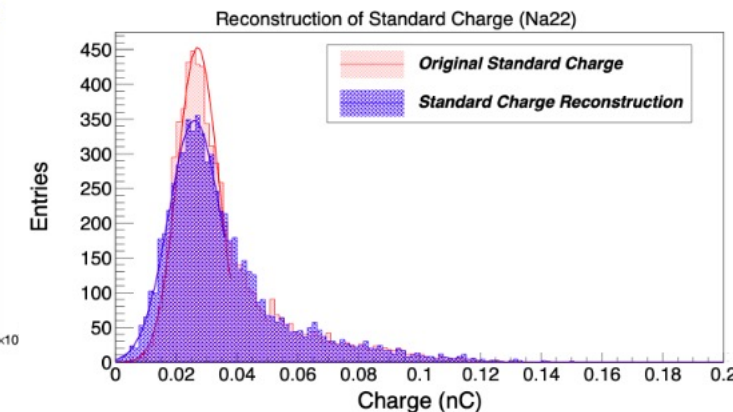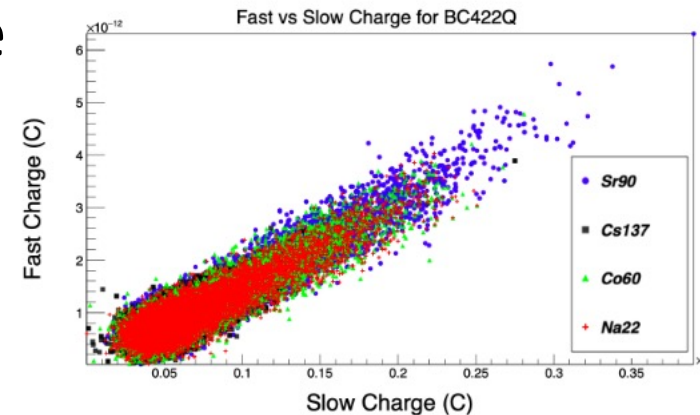
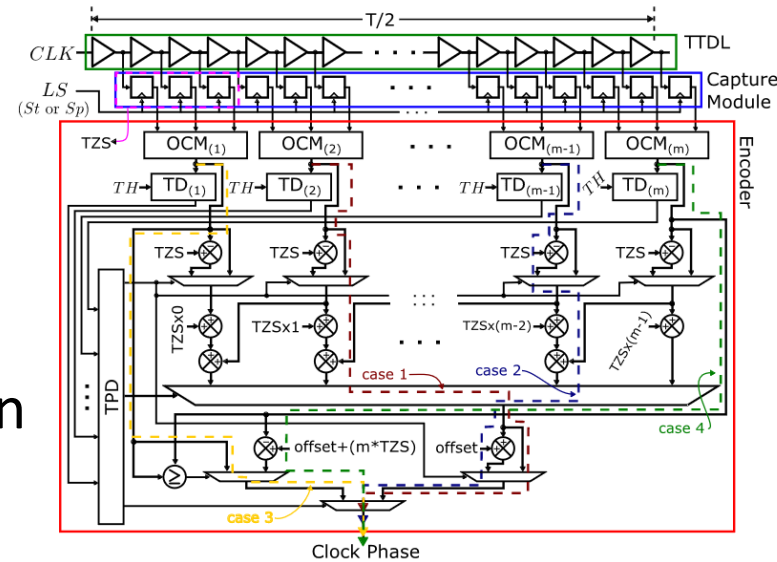C.H. Zepeda-Fernández et al 2020 JINST 15 P09008

Time to digital Convert (TDC)

- Field Programmable Gate Array (FPGA)
- Resolution (LSB) of 5.98 ps
- multichannel measurement systems in low-end devices

Moisés Arredondo-Velázquez et al., Trimmed-TDL-Based TDC Architecture for Time-of-Flight Measurements Tested on a Cyclone V FPGA, IEEE TRANSACTIONS ON INSTRUMENTATION AND MEASUREMENT, VOL. 72, 2023

Work Group
Laboratory of scientific instrumentation and medical physics Faculty of Sciences Physics and Mathematics

- Dr. Lucio Fidel Rebolledo
  - Expert in analog electronics

- Dr. Juan Moises Arredondo Velazquez
  - Expert in digital electronics

- Dr. Cristian Heber Zepeda Fernández
  - Expert in Simulation and data analysis

- Dr. Eduardo Moreno Barbosa
  - Expert in instrumentation and characterization.

Thank you

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