Development of Mudulus, a Muography detector based on double-synchronized electronics for Geophysical applications

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This work presents a prototype detectors use different modules of plastic scintillators with embedded optical fibres and 64 channel multi-anode photomultiplier tubes (PMT) with a common dynode. The improvement in performance obtained with Mudulus is achieved by the combination of its modular design and the double synchronised detection at the end of each scintillator bar. We take advantage of the photomultiplier at each end to determine the muon flux using a model to account signal attenuation in each anode, and then determine the position of the incoming muons with a better discrimination and sub-pixel spatial resolution.

1) Detection principle

- Our prototypes use plastic scintillators with embedded optical fibers.
- This work is a technology transfer from experiments: AMIGA (at the Pierre Auger Observatory) and muon detection within the LAGO project.
- The detection principle is based on scintillators to produce light and then to transport it through optical fibers to a photomultiplier (PMT or SiPM).
- The main goal is to design modular detectors for different configurations.

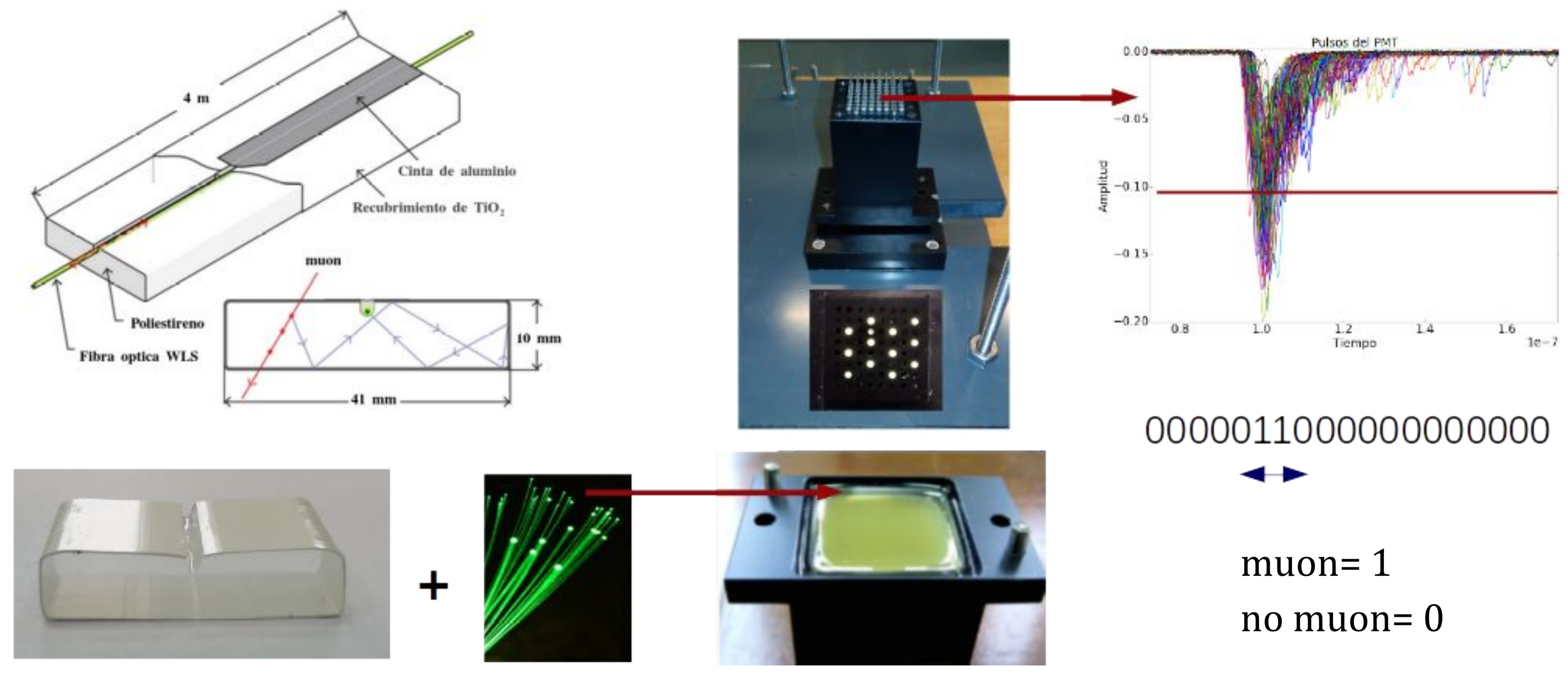


Fig 1. Muon Detection: Muon -> Scintillator + WLS Fiber -> PMT -> SIgnal (Pulses) -> Event

2) Detection strategy

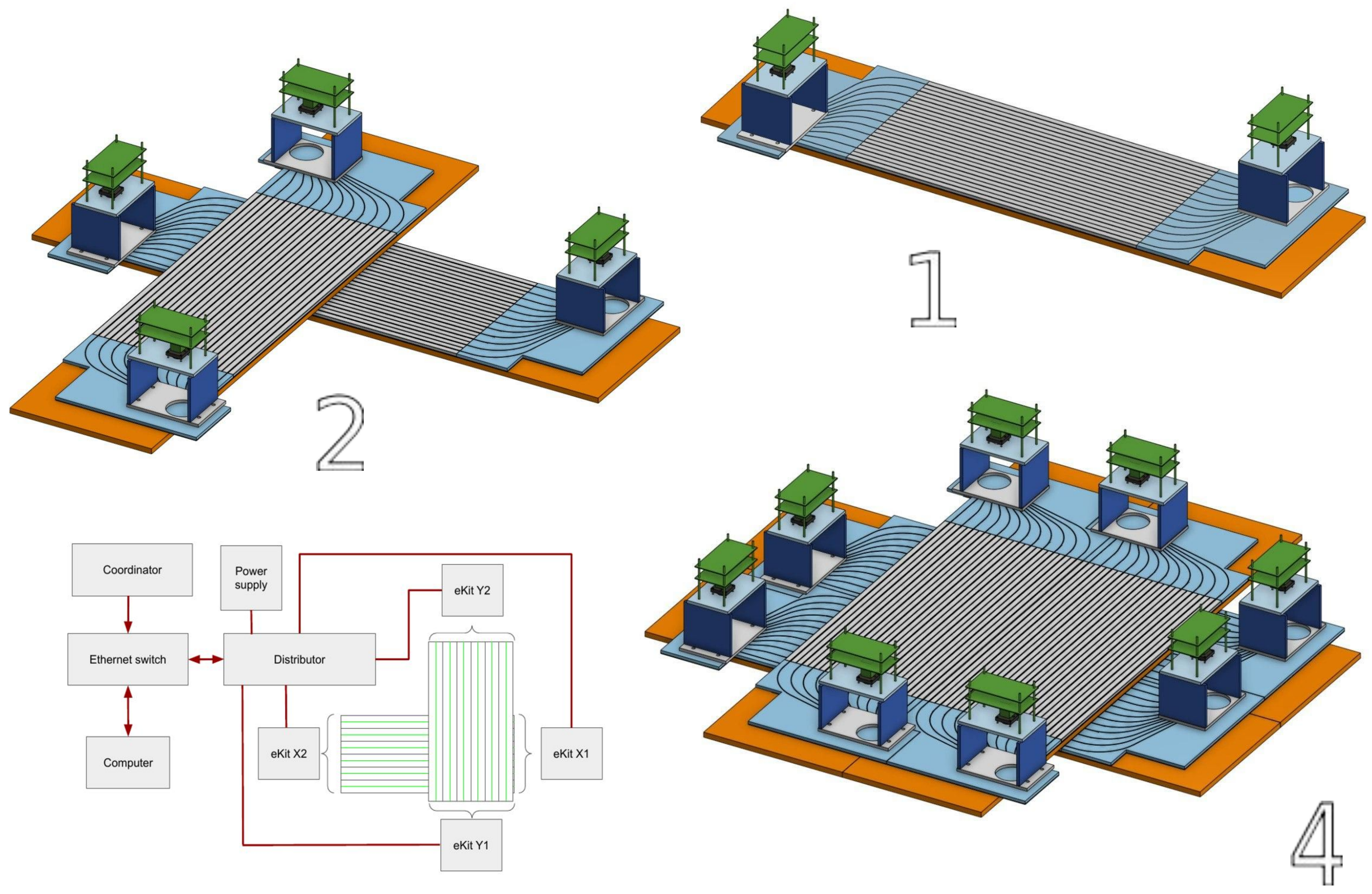


Fig 2. Modules: The goal is to built modular arrays of scintillators for each plane of detector.

3) Calibration

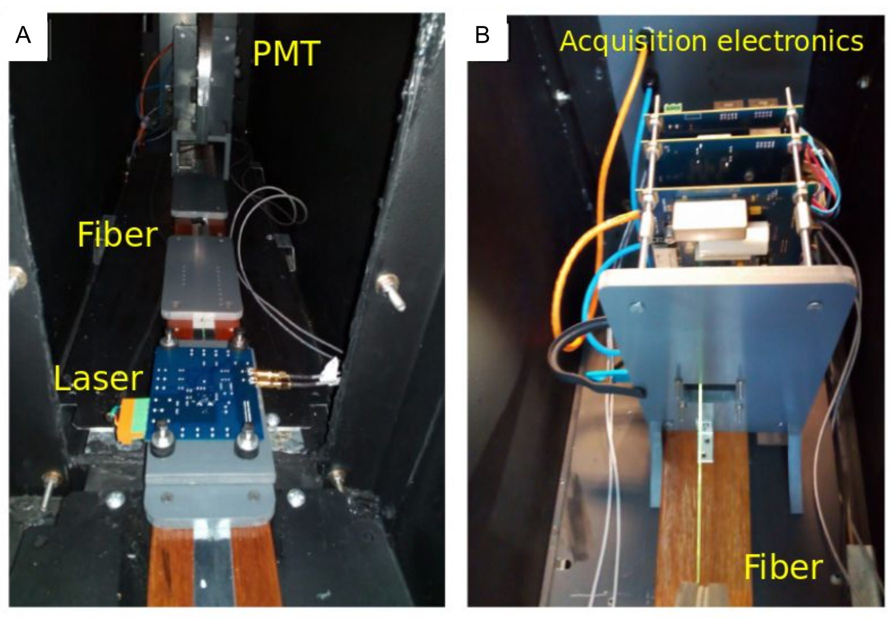


Fig 3. A) Laser and B) Electronic inside dark box.

- We used a dark box to calibrate PMTs
- We measured with a calibrated laser
- Calibrated the PMT with an analytical model
- Measured in different positions
- Measured using anode and dynode
- Synchronize extreme measurements
- Determine the average <u> value
- Used <u> subtraction - reference for localization

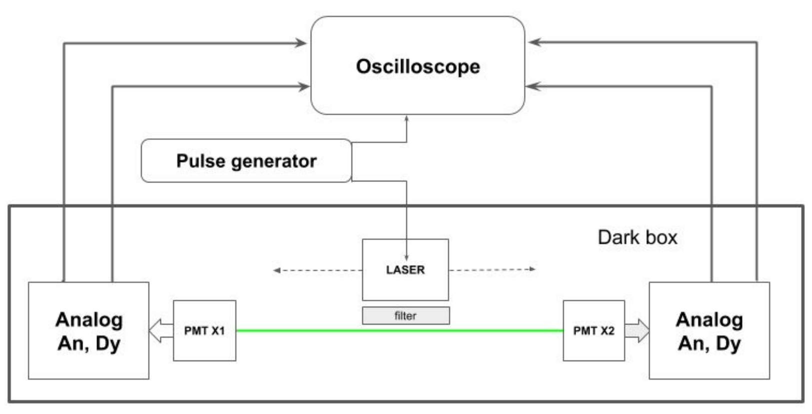


Fig 4. Diagram representing the setup for calibration.

$$S_{real}(x) = S_{ideal}(x) \otimes N(x)$$

$$S_{ideal}(x) = \sum_{n=0}^{\infty} \frac{u^n \cdot e^{-u}}{n!} \cdot \frac{1}{\sigma\sqrt{2\pi}} \cdot e^{-\frac{(x-n\cdot q)^2}{2n\sigma^2}}$$

Eq 1. Model: Ideal PMT model + Noise model.

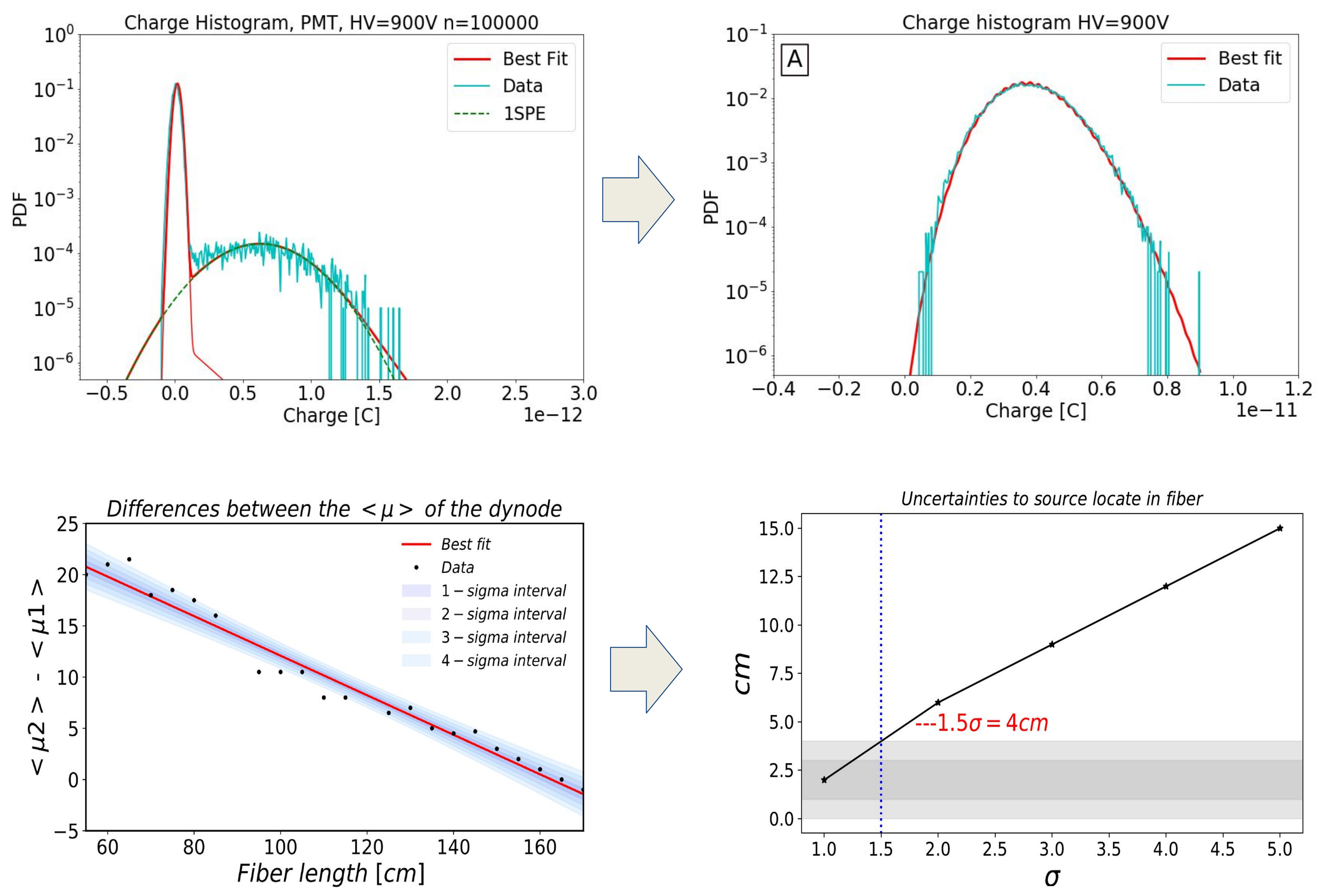


Fig 5. With the model, we determine parameters to find the signal source location. This method improves resolution and is good for studying background noise

4) Prototype modular detectors

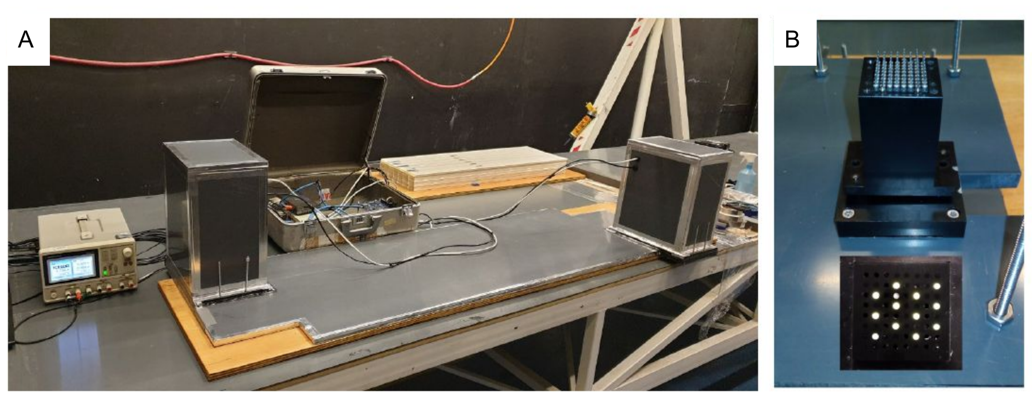
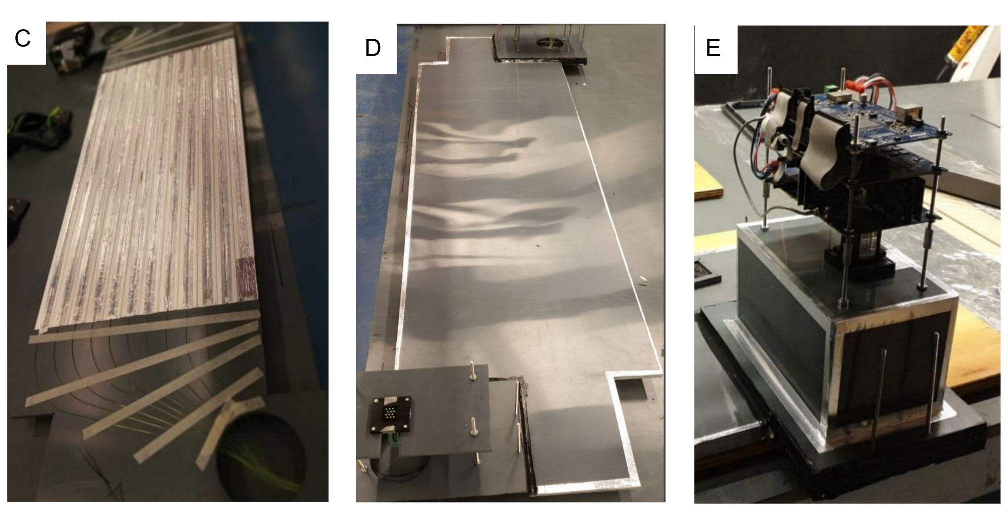
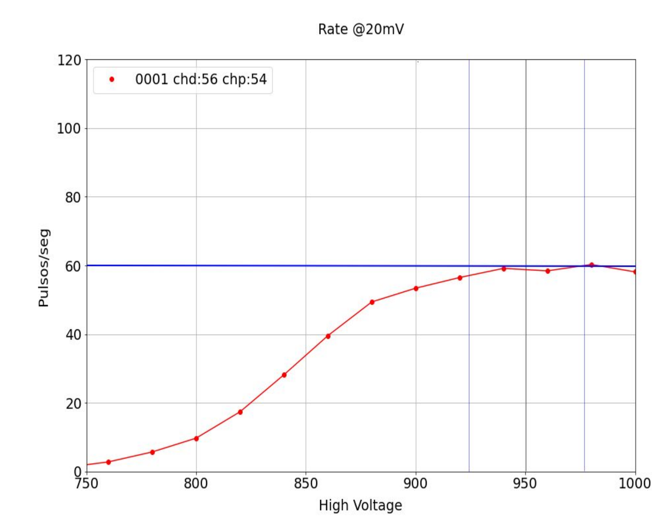


Fig 6. A) Module (12 bars) with PMT on each end B) PMT with a couple. C) Scintillators D)PVC Casing E) Readout electronics.





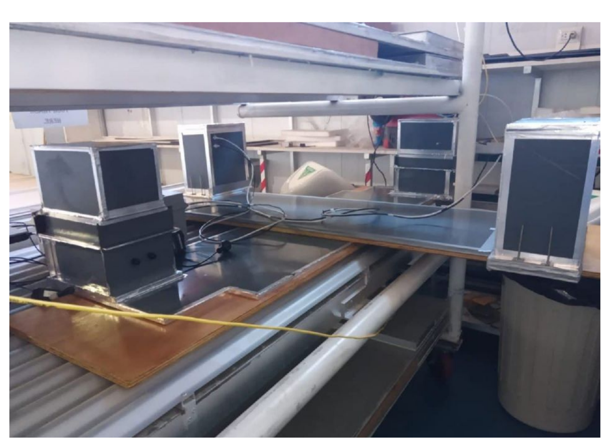


Fig 7. Top, Counts for one channel with different voltage, each PMT have 64 Channels with one dinode. Down, two modules.

Summary and outlook

- We built 3 prototypes for muography.
- We are considering 4 geophysical targets.
- We are studying the possibility of portable detectors.
- Synchronization of different detectors (Arrays).
- Possibility of joint detection.

References

[1] M. Platino et al., JINST 06 P06006 (2011)
[2] A. Aab, et al. [Pierre Auger Coll.], JINST 11 P02012 (2016)
[3] A. Vesga-Ramírez et al., Ann. Geophys. 63661 (2020)
[4] R. Calderón-Ardila et al., arXiv:2006.03165 (2020)
[4] A. Vásquez-Ramírez et al., JINST 15 P08004 (2020)
[5] J. Peña-Rodríguez et al., JINST 15 P09006 (2020)
[6] A. Vesga-Ramírez et al., SAMES 109 103248 (2021)

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