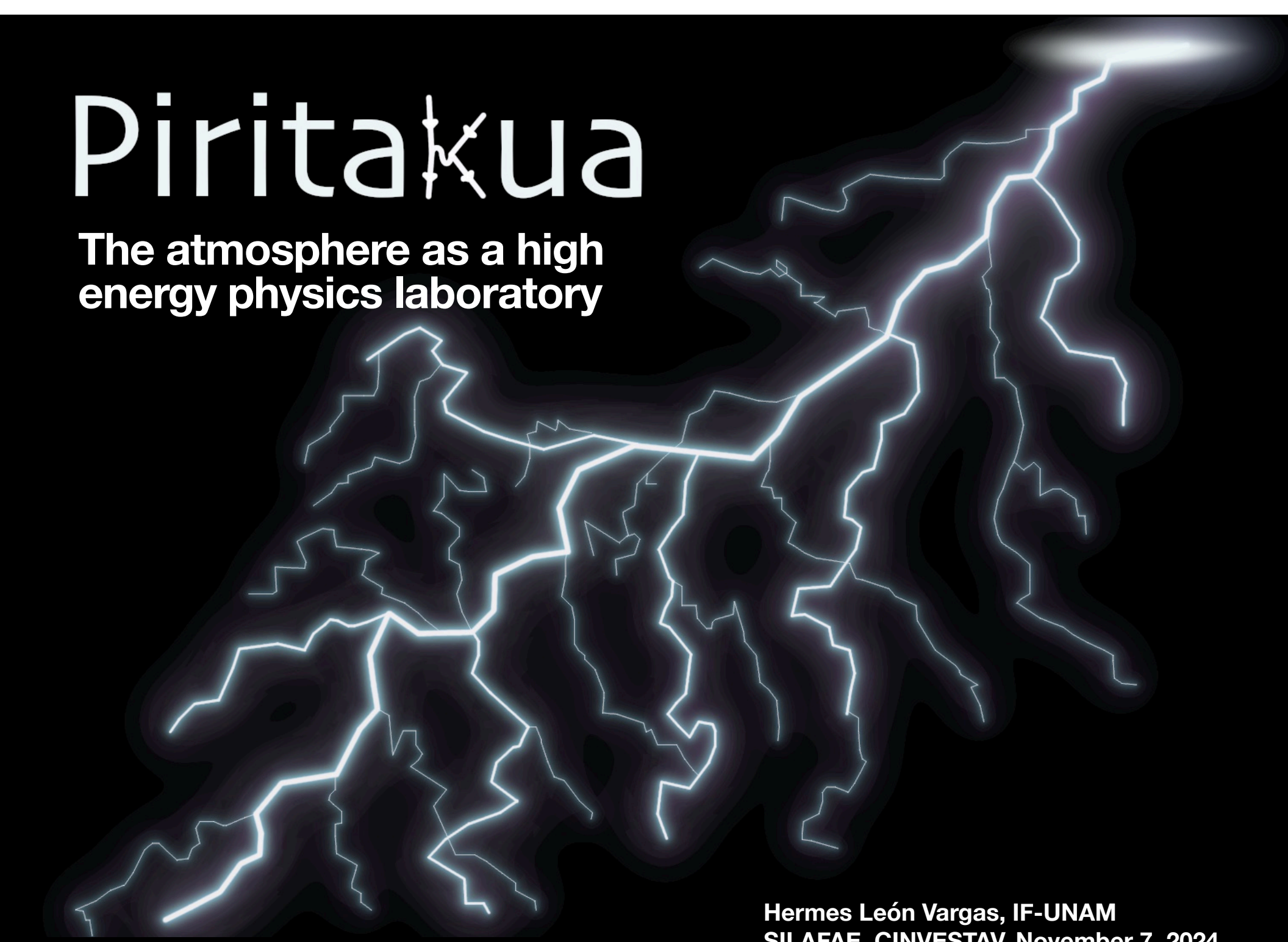
Piritakua

The atmosphere as a high energy physics laboratory

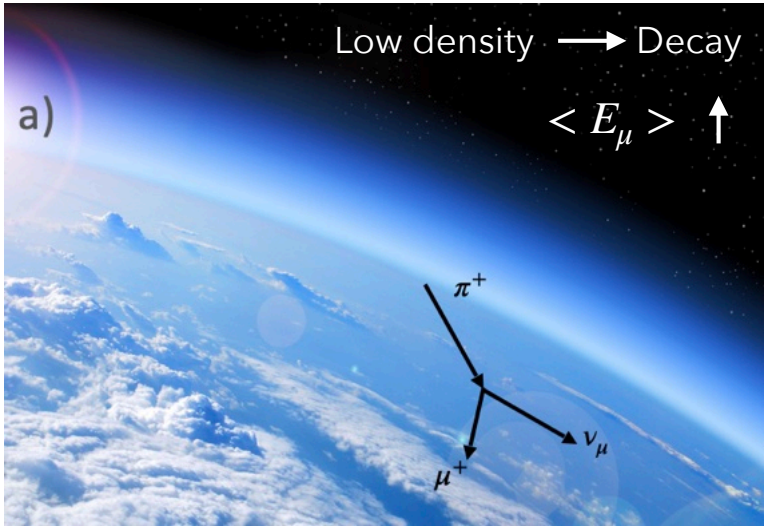


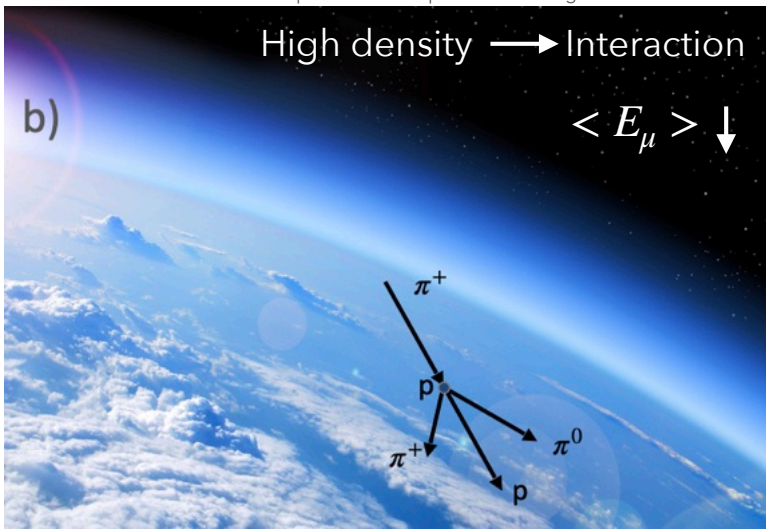
Hermes León Vargas, IF-UNAM
SILAFAE, CINVESTAV. November 7, 2024.

Effect of sudden transient changes in atmospheric properties in cosmic ray propagation

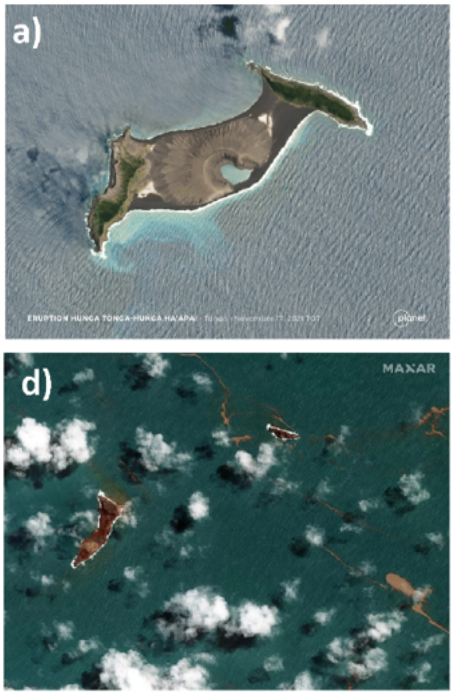
An example with density, effect on secondary particle energy

Copernicus Atmosphere Monitoring Service





Effect of sudden transient changes in atmospheric properties in cosmic ray propagation



Planet Labs PBC, Maxar Technologies, Brumfiel (NPR)

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NEWS | 18 January 2022

Tonga volcano eruption created puzzling ripples in Earth's atmosphere

Powerful waves ringing through the atmosphere after the eruption of Hunga Tonga–Hunga Ha'apai are unlike anything seen before.

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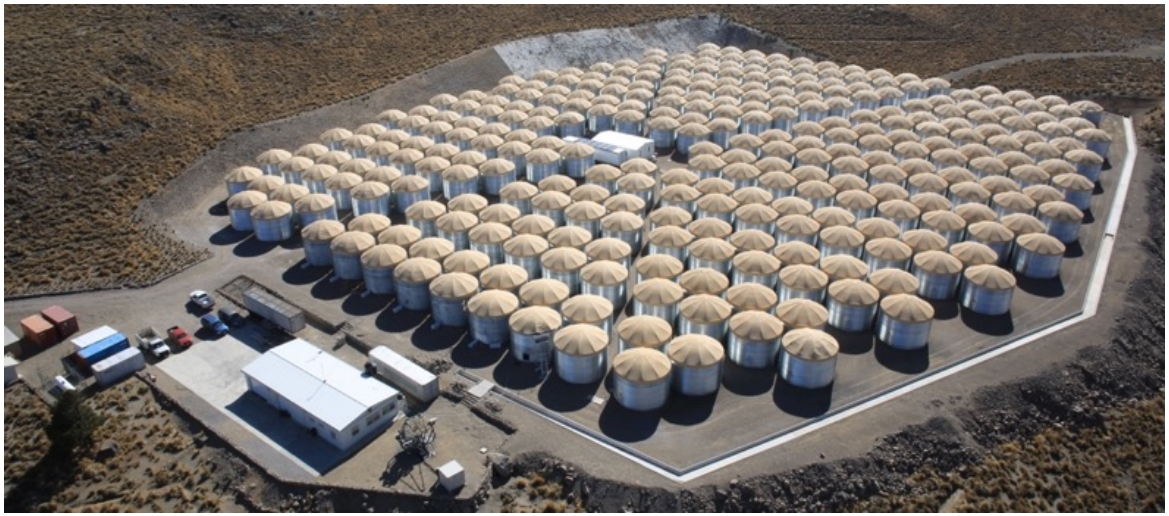
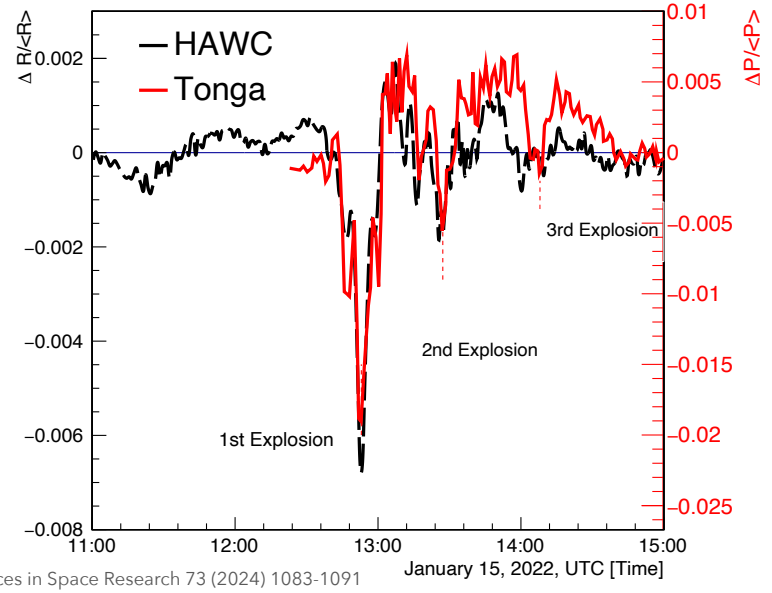
REPORT | NATURAL HAZARDS

Atmospheric waves and global seismoacoustic observations of the January 2022 Hunga eruption, Tonga

+67 authors | Authors Info & Affiliations

Going on the lamb





Advances in Space Research 73 (2024) 1083-1091
HAWC Collaboration

A lot going on in the atmosphere

Both periodic and aperiodic intensity variations in the secondary particle flux:

Changes:

- Barometric pressure
- Temperature
- Air density
- Humidity

} Produce variations in the column density [$g\ cm^{-2}$]

✦ Changes in density → lateral spread of particles (scattering)
mass above the detector → absorption

- Electromagnetic properties accelerate charged particles and deflects the particle trajectories

Important to control the systematic effects in order to do more precise studies using cosmic rays

A lot going on in the atmosphere

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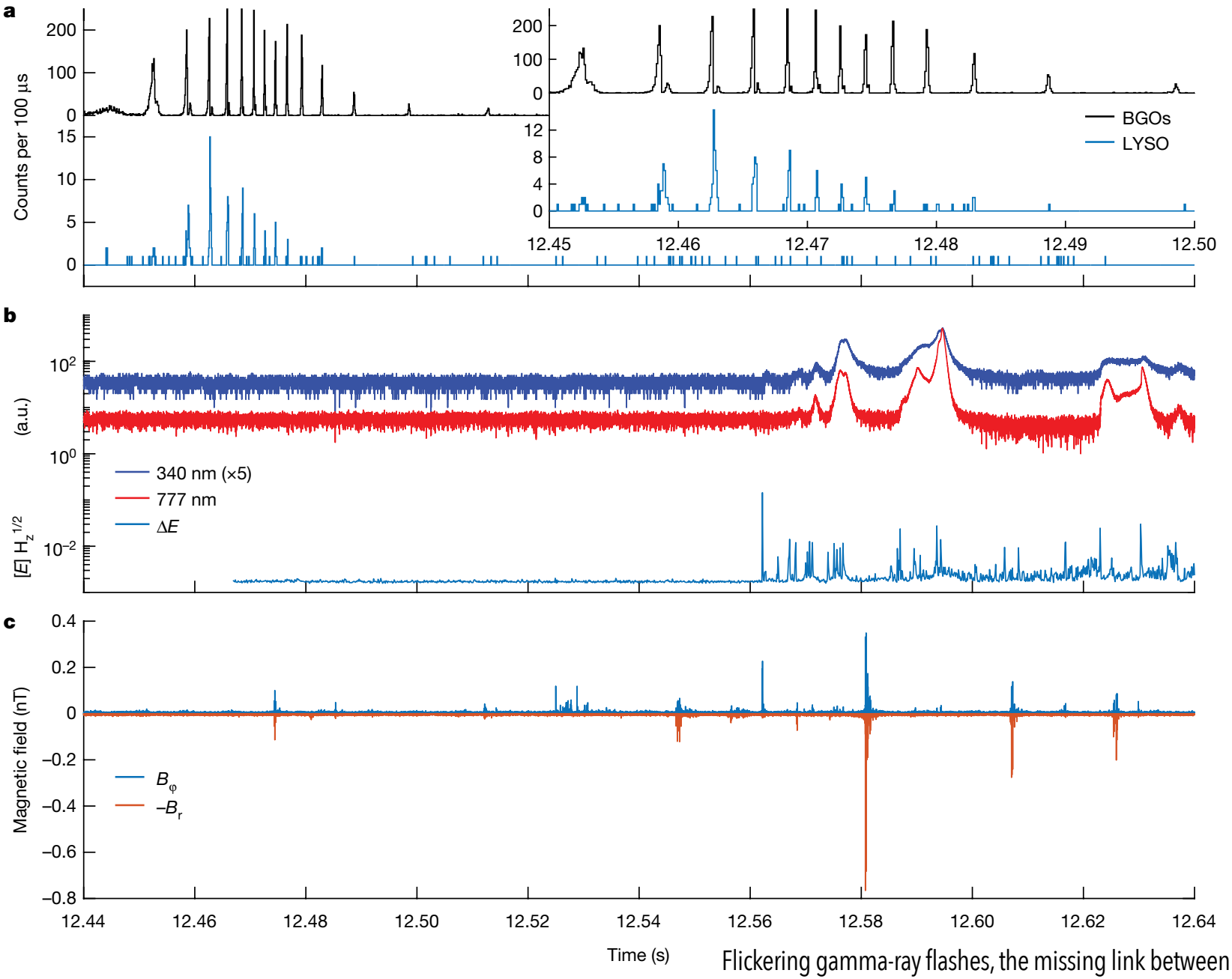
Important to control the systematic effects in order to do more precise studies using cosmic rays

Goals of the project

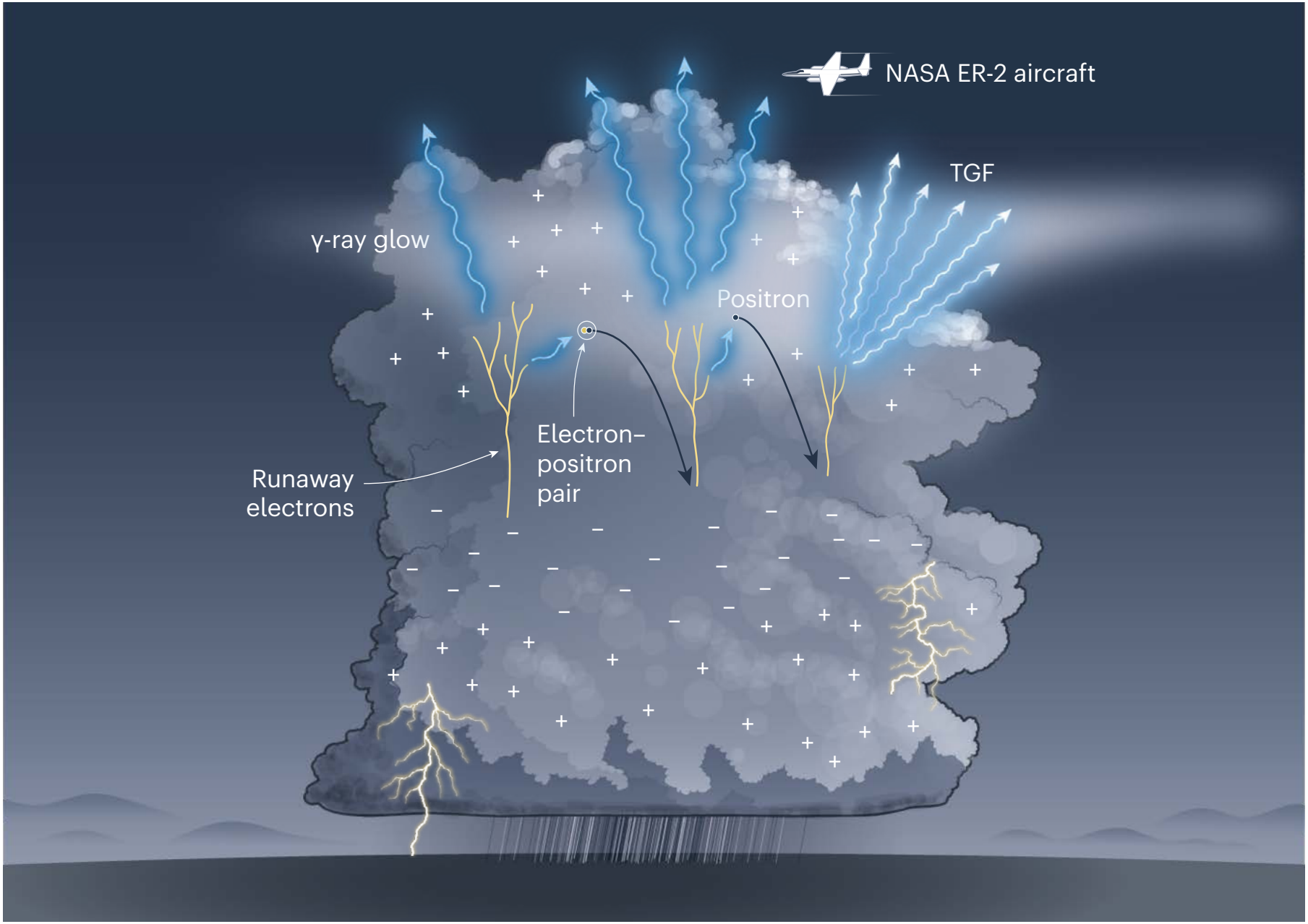
1. Systematic study of the effects of the atmospheric properties in the secondary particle propagation
2. Is it possible to measure hard radiation phenomena (avalanches of relativistic electrons) from thunderclouds at 2,200 m a.s.l.?
   - Gamma-ray glows (1-100's seconds)
   - Terrestrial gamma-Ray flashes (10's-100's μs, radio and optical signals)
   - Flickering gamma-ray flashes (20 to 250 ms, radio and optically silent) [*Nature 634 (October 2024)*]

High energy atmospheric physics



Flickering gamma-ray flashes, the missing link between gamma glows and TGFs
N. Østgaard et al. Nature 634 (2024)

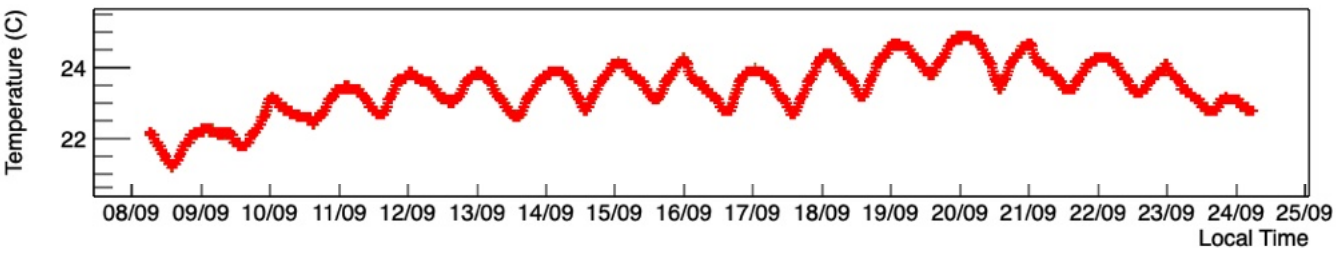
The experiments

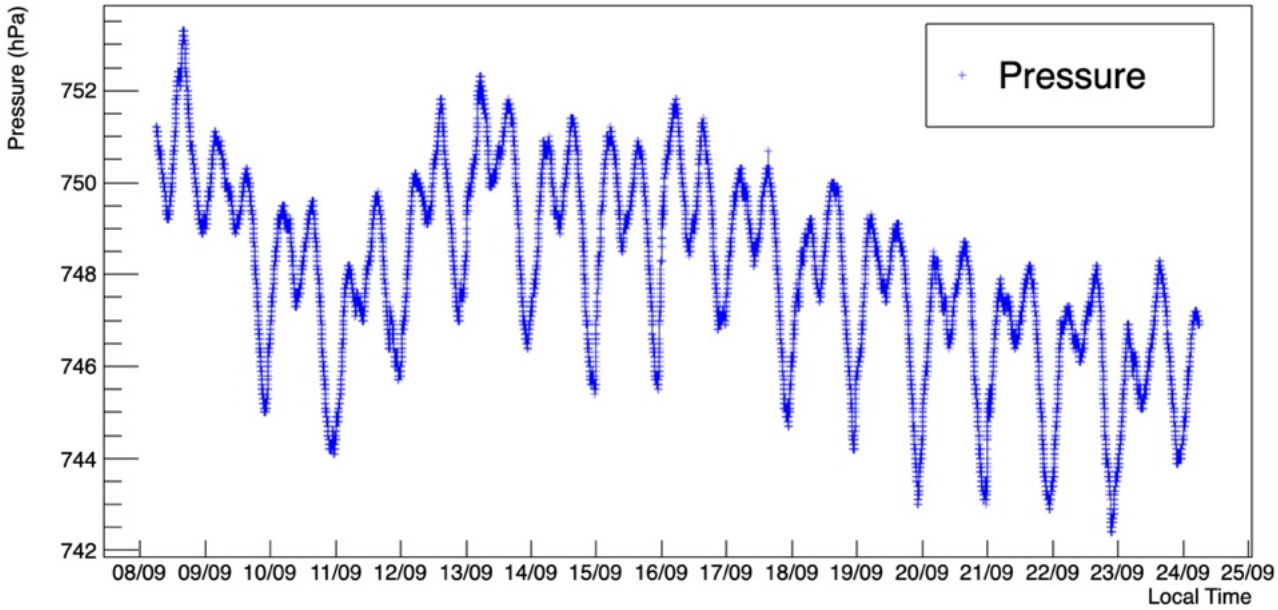


Glowing γ-rays solve thunderstorm conundrum
J. R. Dwyer. Nature 634 (2024)

Atmospheric monitoring (I)

Davis Vantage Pro 6323m



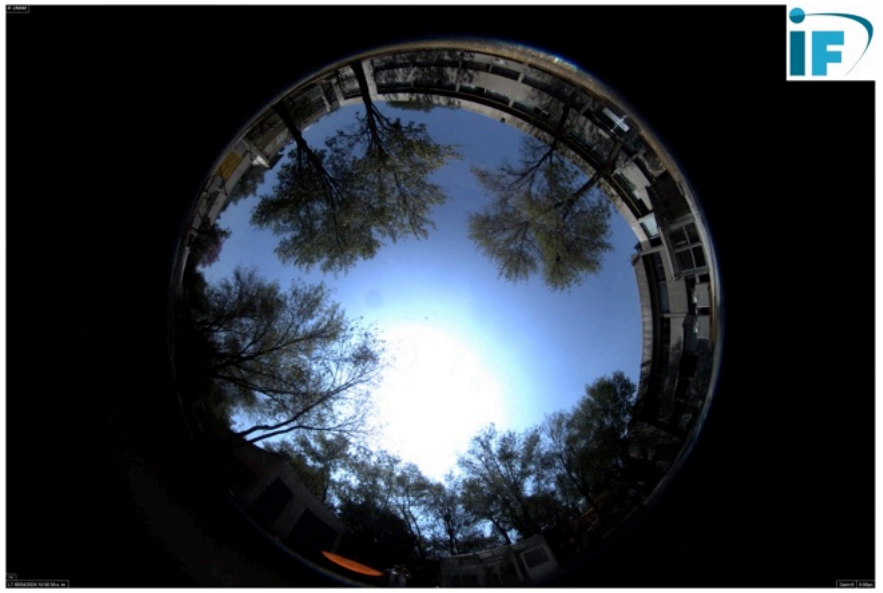


Work of Antonio Galván

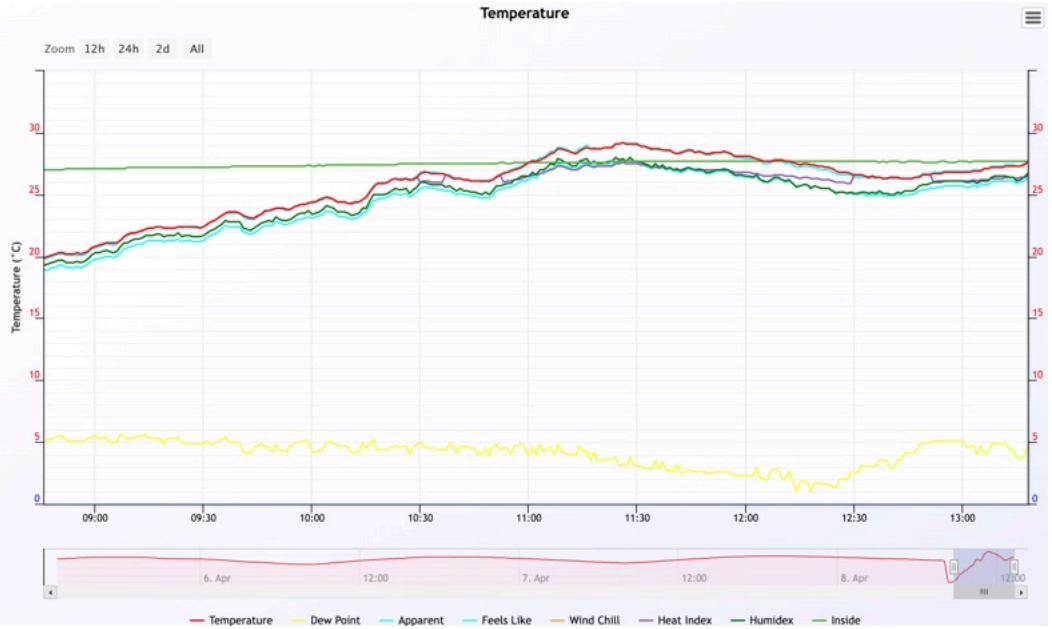
DAQ ready and recording data in ROOT format
First version of web monitoring also running

Atmospheric monitoring (II)

ALPHEA 6CW
180º × 180º FOV



Tested during the solar eclipse of last April

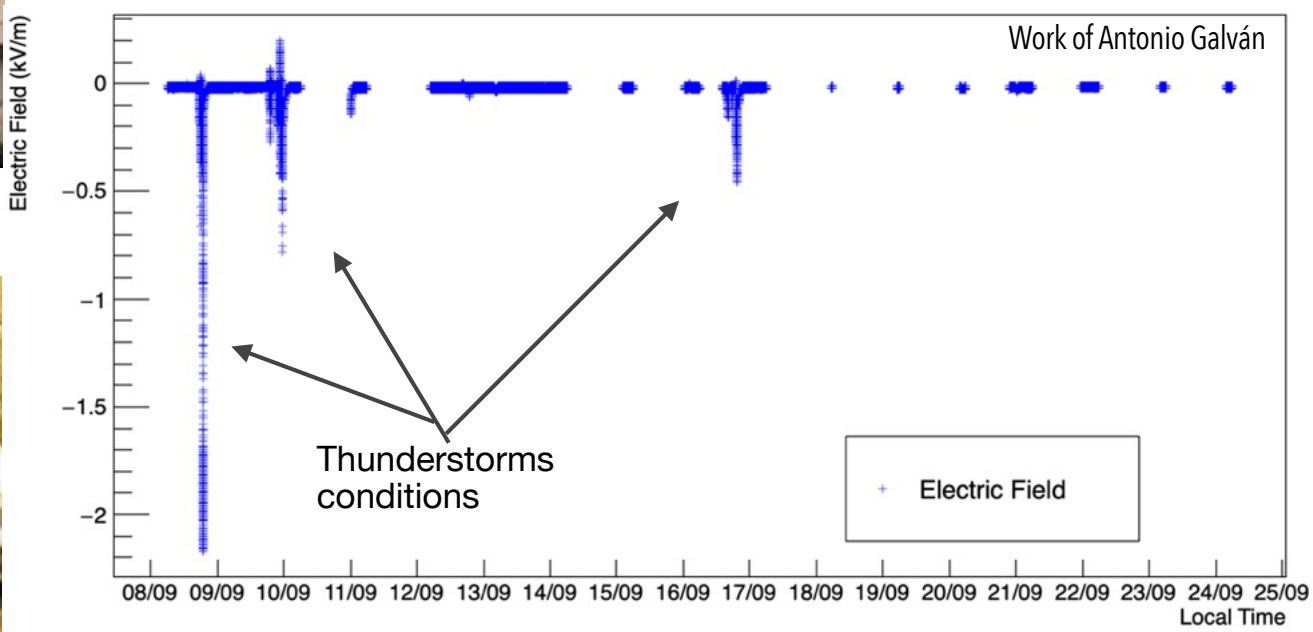


Atmospheric monitoring (III)

ERL 10-KIT2 Dual Sensor

Atmospheric Electric Field Monitor (Field Mill)
Max range: ~40 km

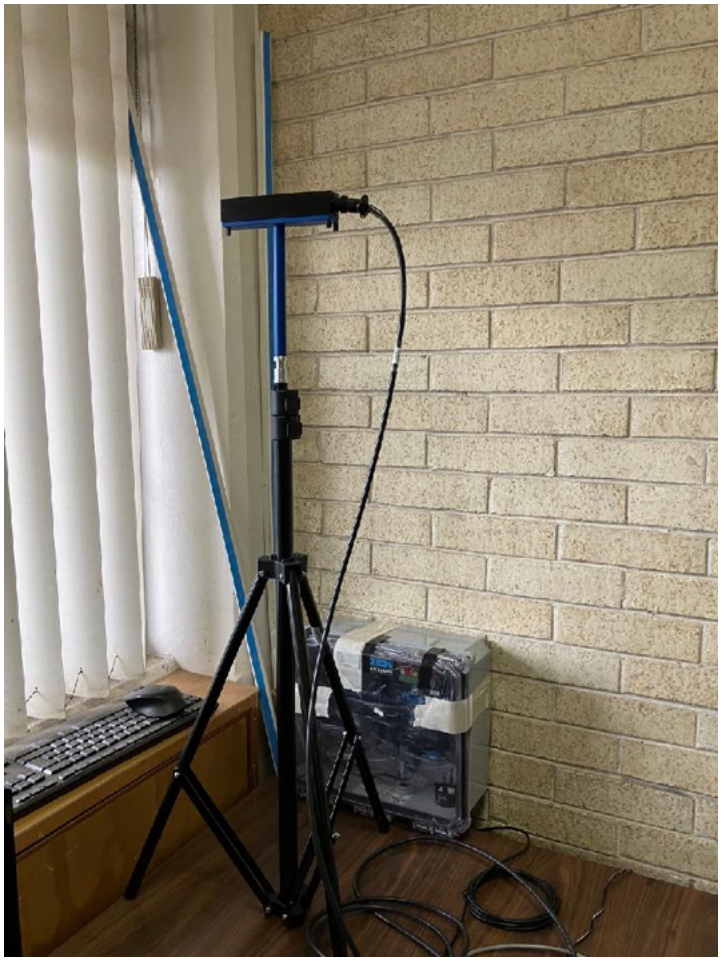
Lightning detector (radio antena)
Max range: ~480 km



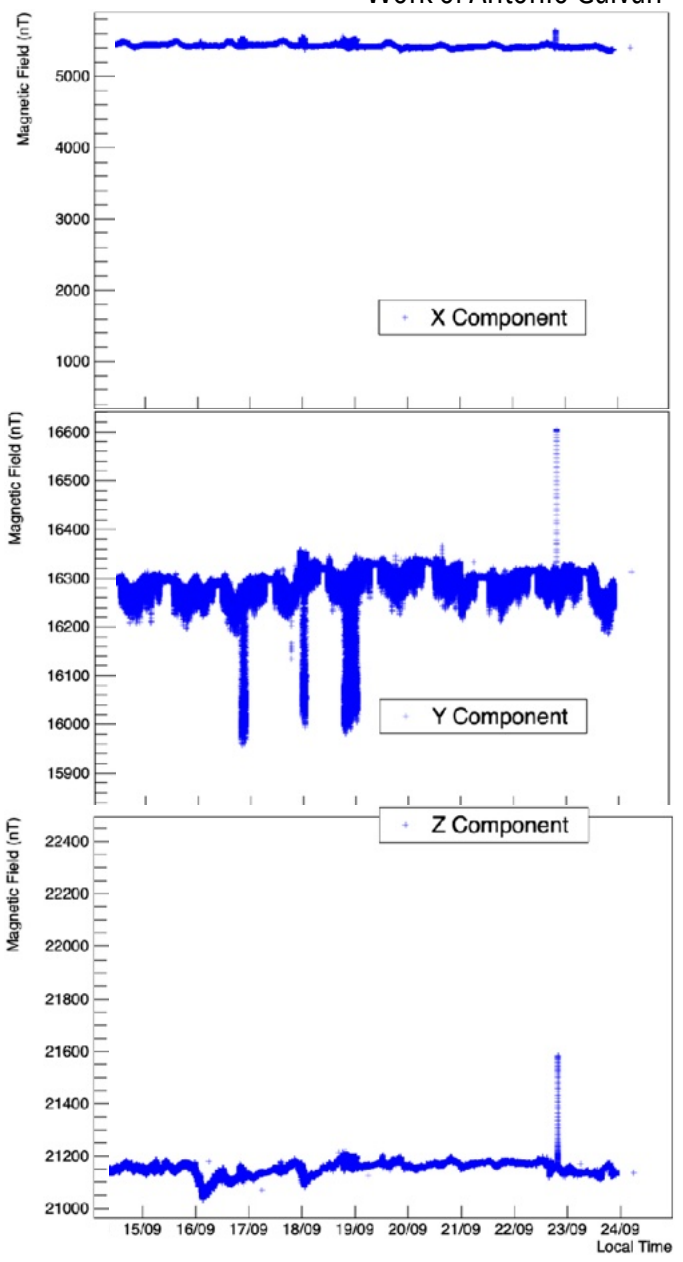
- DAQ ready, writing ROOT files
- Waiting for a cable to get an estimate of the distance to the electric discharge

Atmospheric monitoring (IV)

SENSYS FGM3D - magnetometer
Three-axis fluxgate magnetometer
Measuring range: $\pm$ 100 μT



Work of Antonio Galván

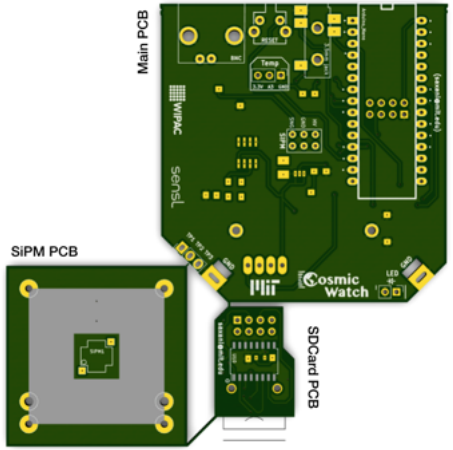


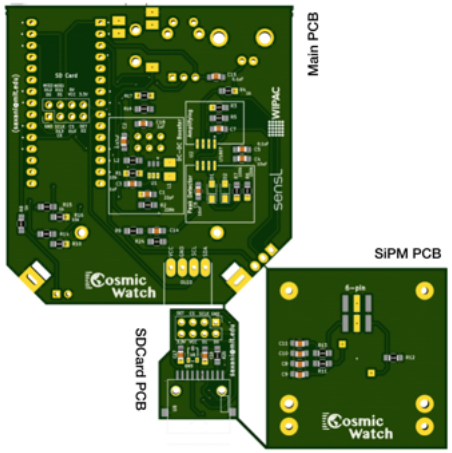
Designed to measure weak constant and alternating fields

- DAQ ready, writing ROOT files

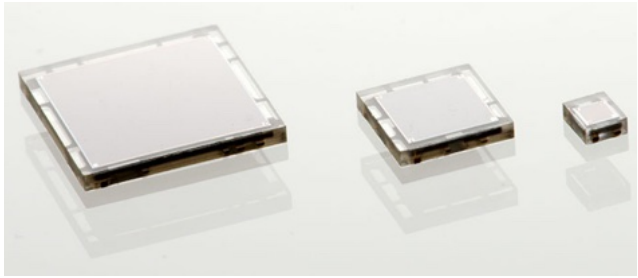
A scaler detector: Cosmic Watch

Will be based on the CosmicWatch project (http://www.cosmicwatch.lns.mit.edu/)





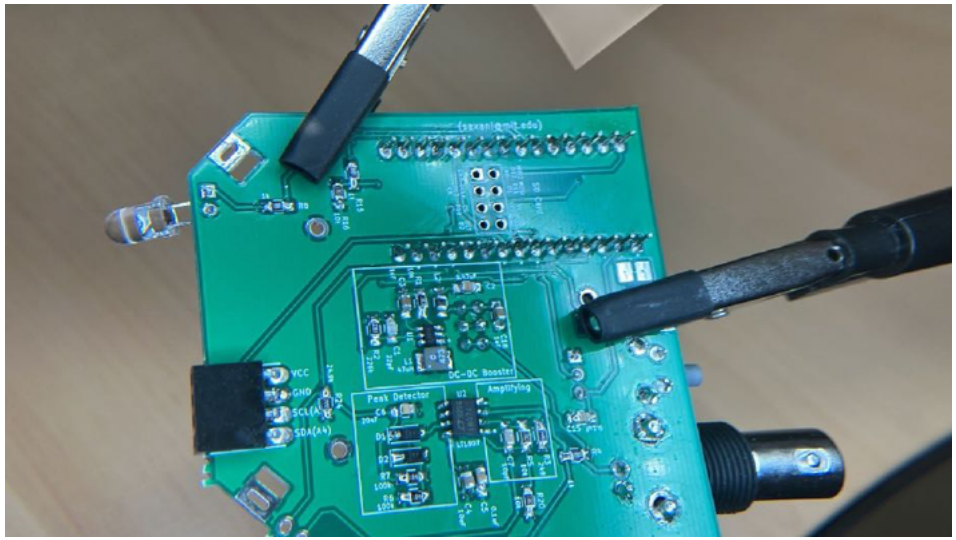
https://arxiv.org/abs/1801.03029
https://arxiv.org/abs/1908.00146

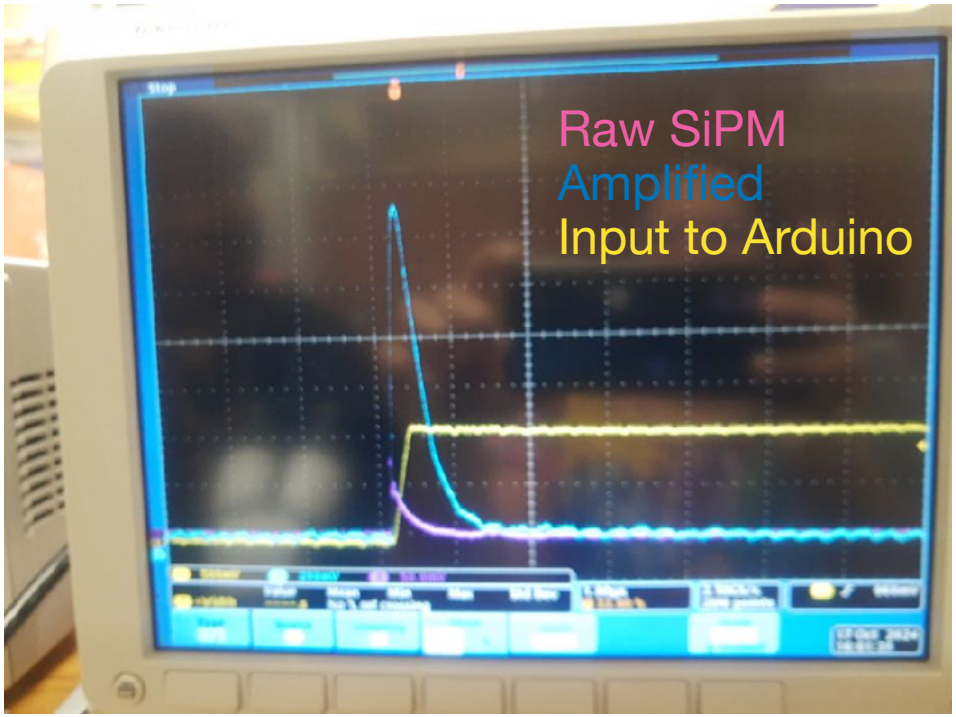


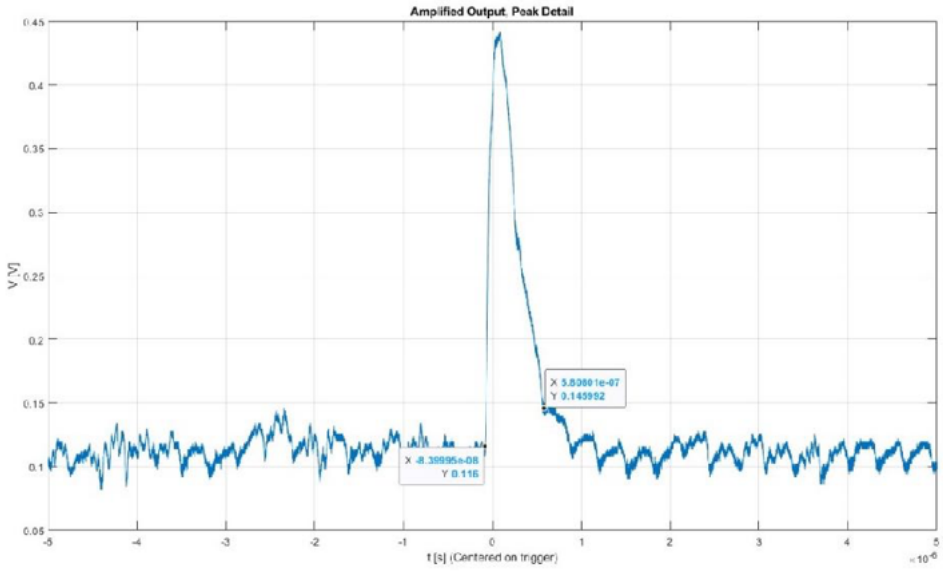
Excellent starting point!

First Cosmic Watch at IF-UNAM

After a long way to purchase all the components and debugging the first detector

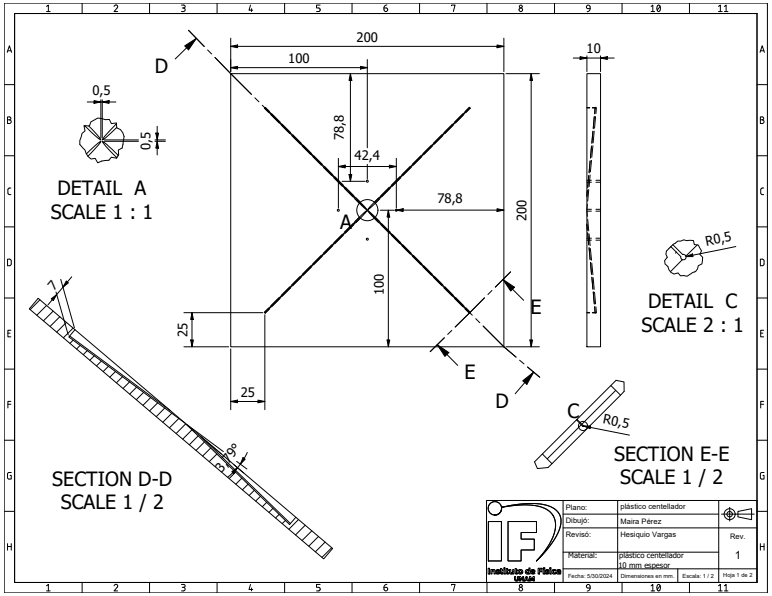




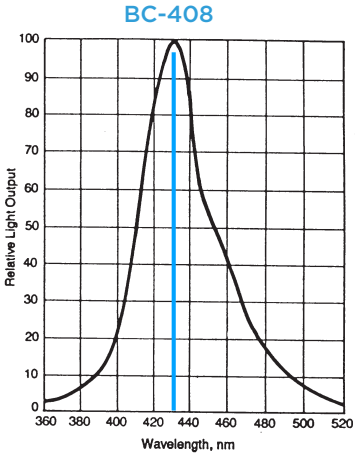


First pulses detected last October 17!

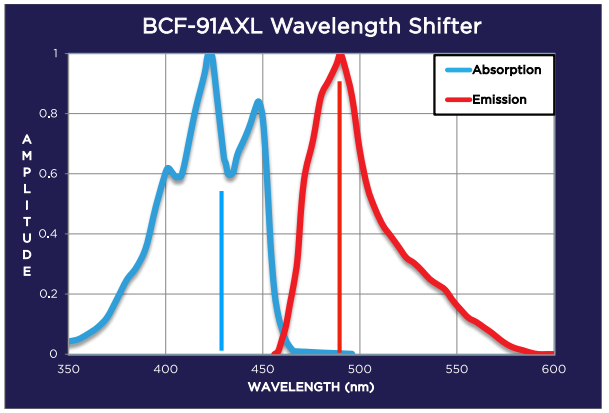
Plan to increase the sensitive volume



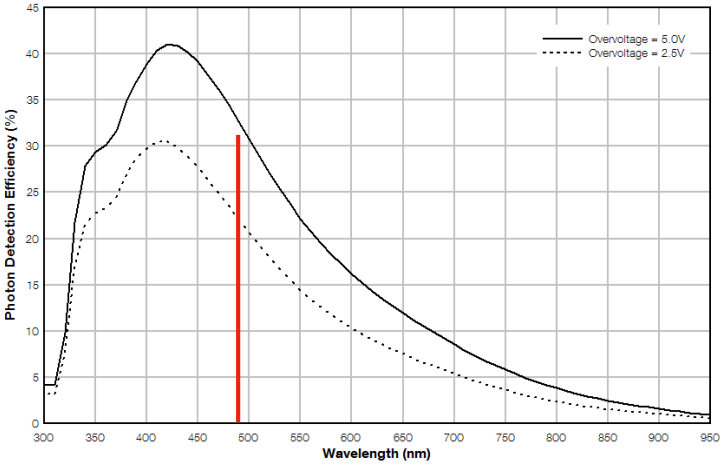
Use wavelength shifter fibers to collect light from a larger surface



Scintillator ~430 nm



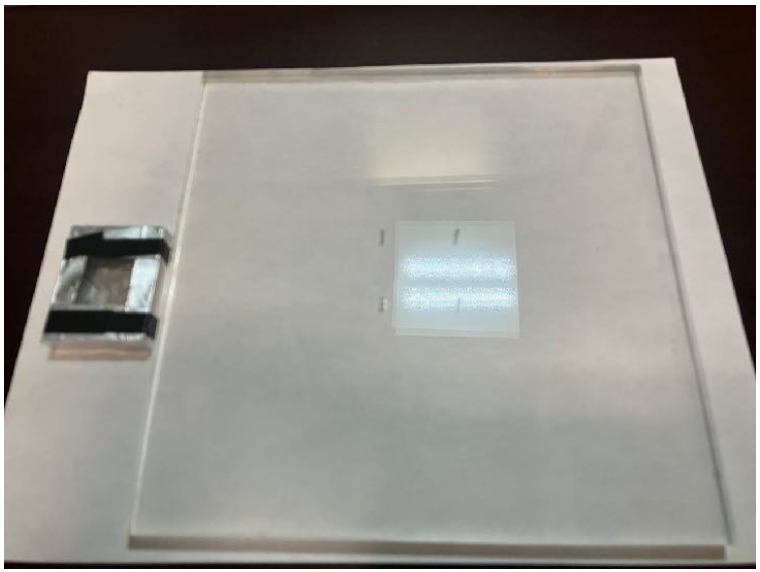
Emission: ~490 nm

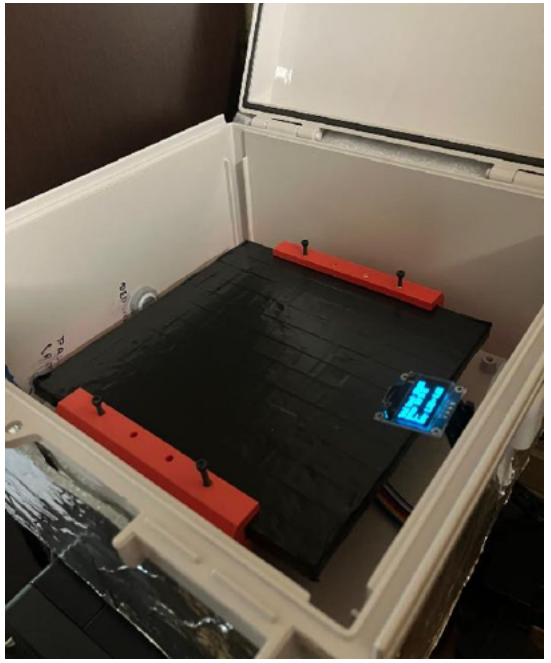


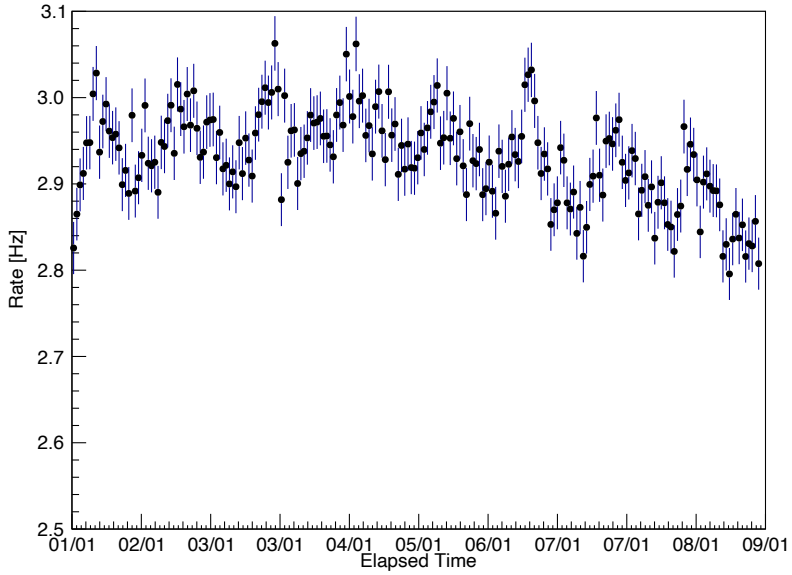
SiPM

First prototype of a larger detector

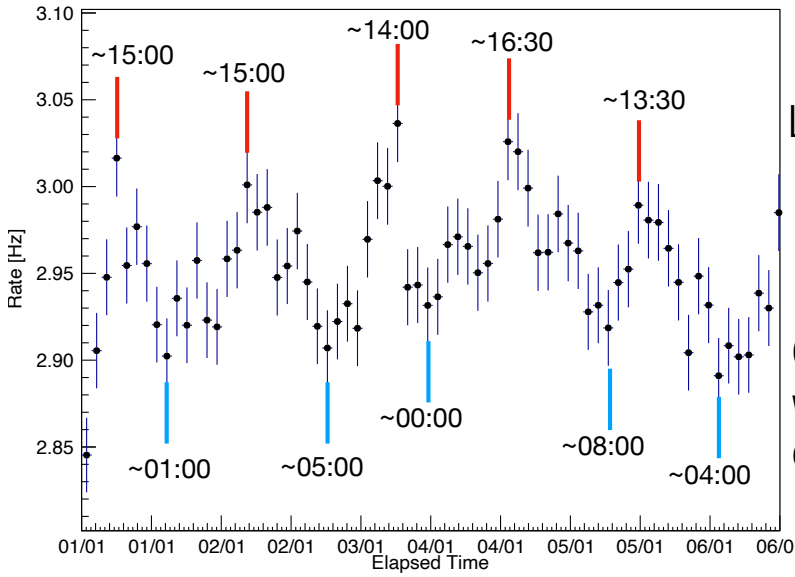
While waiting for the micro-milling tool to arrive, testing with a larger scintillator without fibers







First 9 days of data [21-10 9 am, 30-10, 9 am]

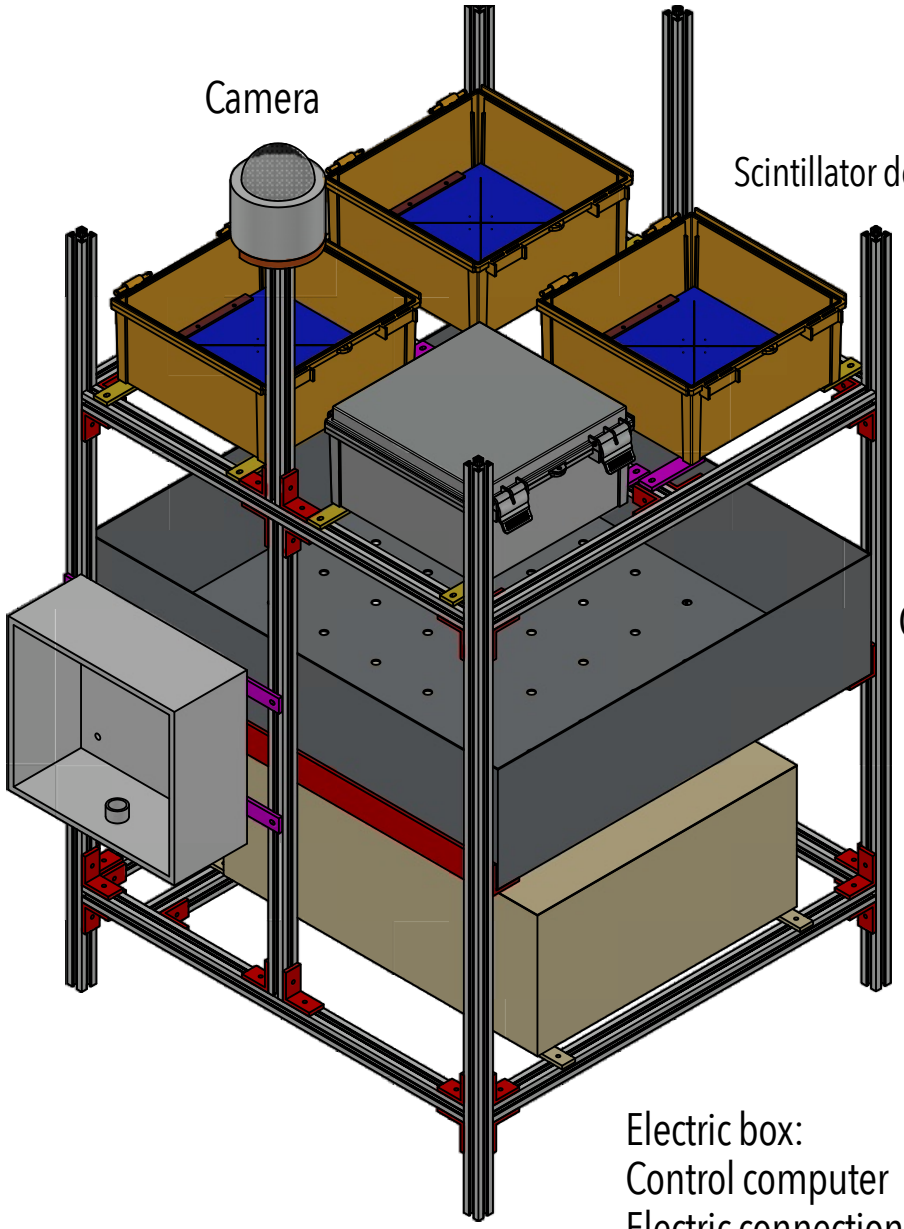


First 5 days of data

Local time

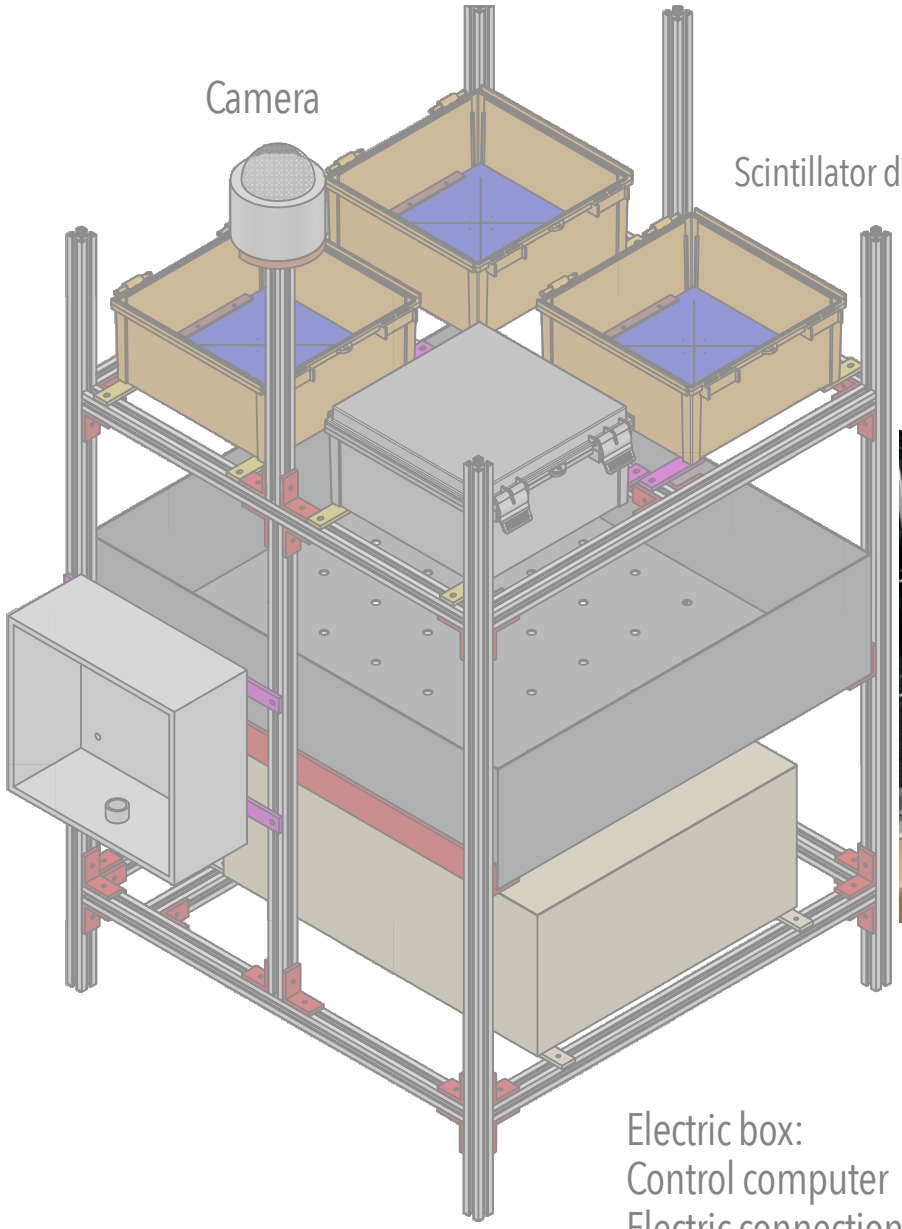
Clear daily modulation with a single (not yet optimized) detector!

Mechanical structures

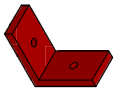


Electric box:
Control computer
Electric connections

Mechanical structures (current status)



Some missing pieces, almost there



Detector array

To be installed in the rooftop of the Experimental Physics building at IF-UNAM

Piritakua team

Dr. Antonio Galván (posdoc, IF-UNAM)
M. Sc. Cindy Castellón (PhD student, IF-UNAM)
Dr. Adiv Gonzalez (Instituto Tecnológico de Oaxaca)
Prof. Andrés Sandoval (IF-UNAM)
Dr. Ernesto Belmont (IF-UNAM)

Funding
CONAHCyT (CF-2023-I-645)
DGAPA-UNAM (PAPIIT IN102223)
IF-UNAM

Summary of the project, so far

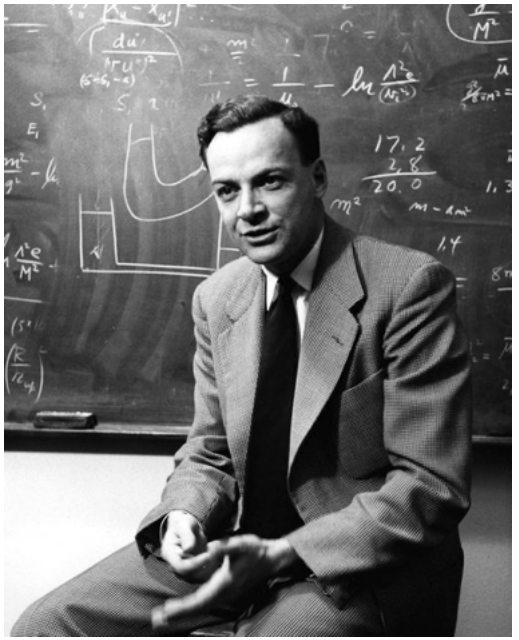
- ✦Funding started in September 2023
  - Very long delays to complete purchases abroad
- ✦Construction of the particle counters underway
  Second cosmic watch working just yesterday!
- ✦Working on the first prototype using wavelength shifter (hopefully before the end of the year)
- ✦The goal is to reach ~1 m^2 of active detector surface
  - Build a few "muon" modules using a metal plate as absorber
  - In 6 months: 8 scintillator detectors taking data simultaneously with the atmospheric sensors

Adiv González

Lighting in Mexico City

Piritakua (flash of lightning in Purépecha)

NASA



Caltech Archives

"Anyone who has been in a thunderstorm has enjoyed it, or has been frightened, or at least have had some emotion. And in those places in nature we get an emotion, we find that there is generally a corresponding complexity and mystery about it"