

# Muography in Colombia: simulation framework and instrumentation

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<https://halley.uis.edu.co/fuego>



- Volcanoes in Latin-America and Colombia



- Muography in Latin-America



- The MuTe project



- Simulation framework



- Instrumentation



- Data analysis

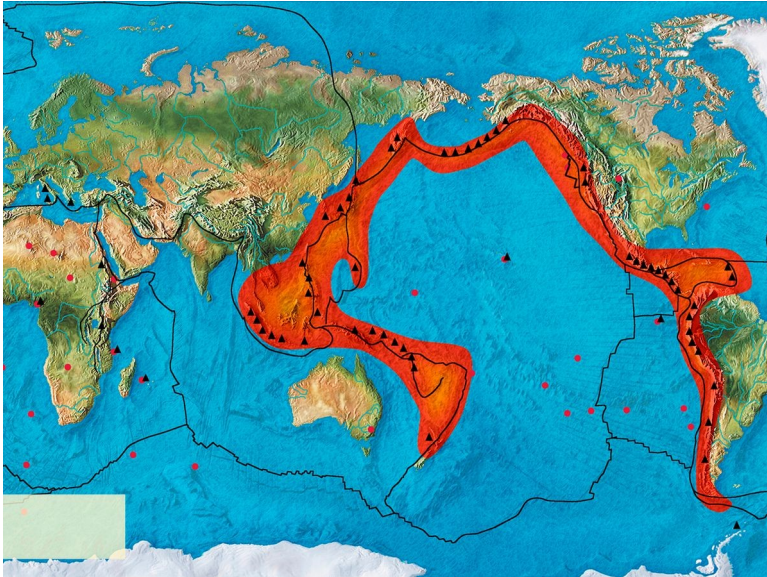


- Technology transfer



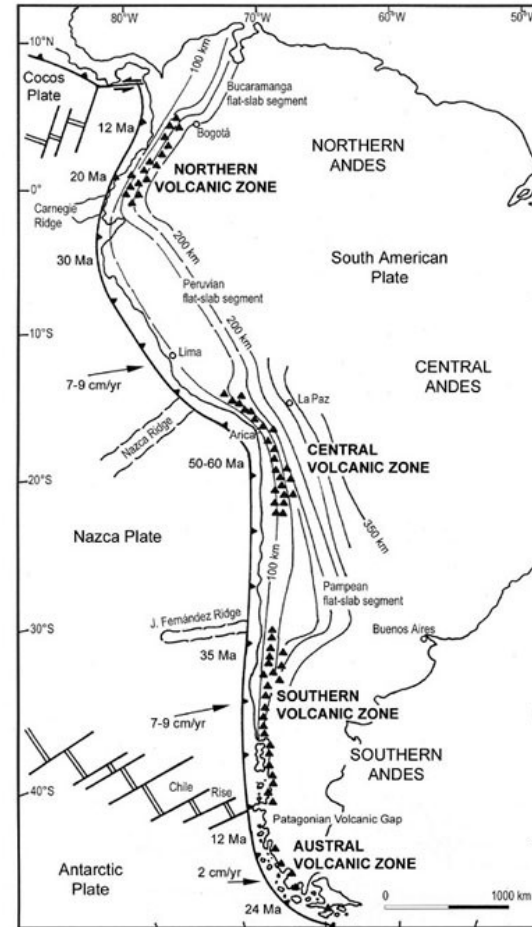
# Volcanoes in LA and Colombia

LA volcanoes are part of the **Pacific Ring of Fire**, most along the **Andes ~ 239**



Volcanoes in Latin America in the Ring of Fire. Mariandrea Miranda. 2020.

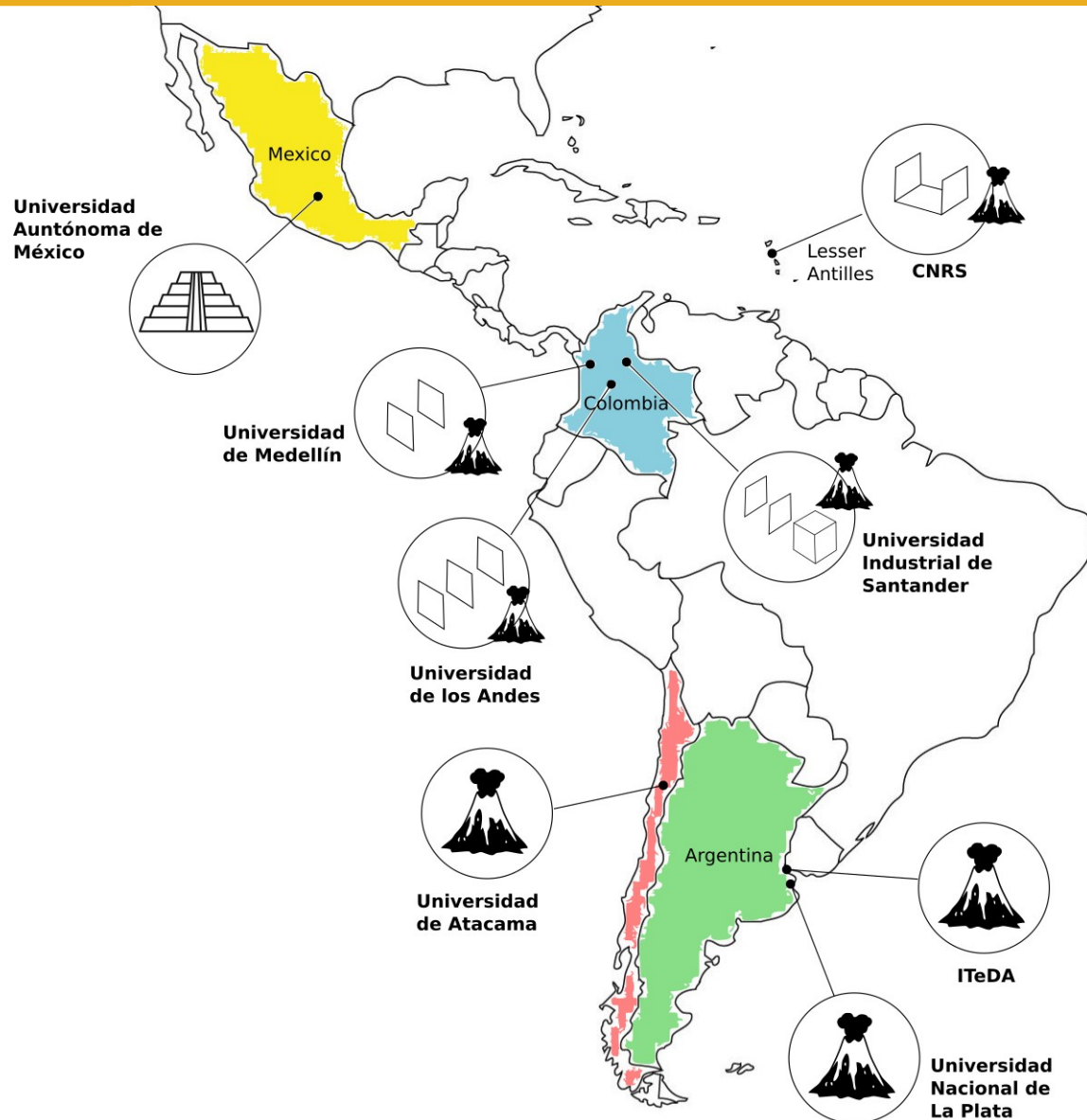
**Colombia ~ 19 volcanoes**



Charles R. Stern. Revista Geológica de Chile. 2004.



A. Vesga-Ramírez et al. Annals of Geophysics. 2020.



## Development of:

- Simulation tools
- Instrumentation
- New detection techniques
- Hybrid telescopes
- Data analysis
- Experimental Infrastructure
- Collaborative networking

# The Muon Telescope project

## Cerro Machín volcano



Volcano	Criterion 1:	Criterion 2:	Criterion 3:
Azufral	N	Y	N
Cerro Negro*	Y	Y	N
Chiles*	Y	Y	N
Cumbal	N	Y	N
Dona Juana	N	Y	N
Galeras	Y	N	Y
<b>Machín</b>	<b>Y</b>	<b>Y</b>	<b>Y</b>
Nevado del Huila	N	Y	N
Nevado del Ruíz	N	Y	Y
Nevado Santa Isabel	N	Y	Y
Nevado del Tolima	N	N	Y
Puracé	N	Y	Y
Sotará	N	Y	N



# The Muon Telescope project



Cerro Machín volcano → El Chichón volcano



**Eruption**  
**March 28, 1982**

**200** km ash fall

**2000** deaths

Displacement of **20000** people



# Simulation framework

<https://halley.uis.edu.co/fuego/en/simulation-framework/>

**MAGCOS**  
MAGnetoCOSmics

**CORSIKA**  
COsmic Ray SIMulations for KAscade



**GEANT4**  
A SIMULATION TOOLKIT

Cosmic Ray modulation

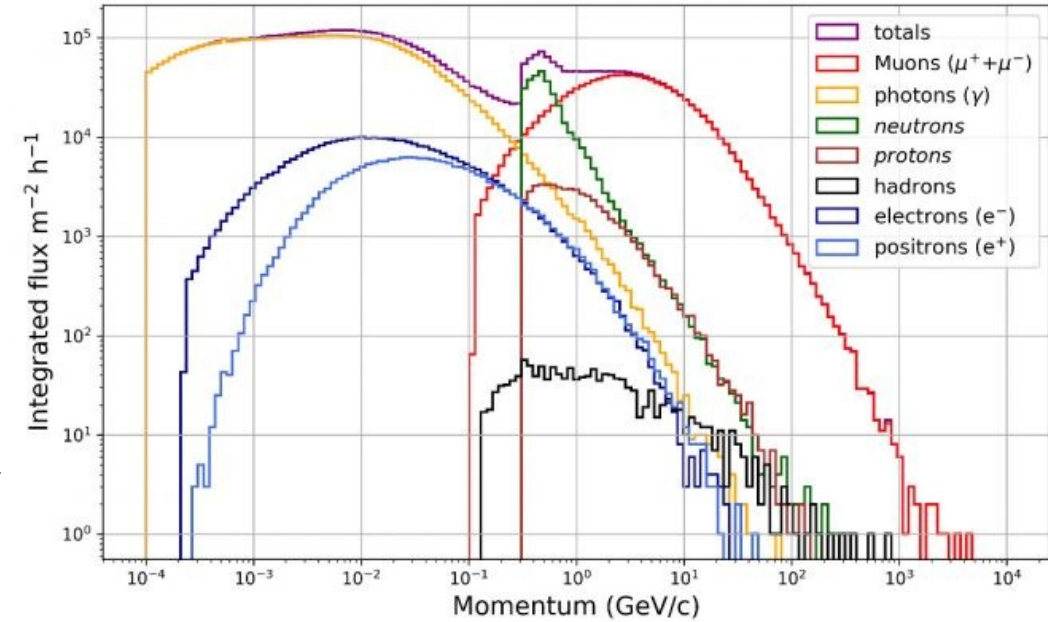
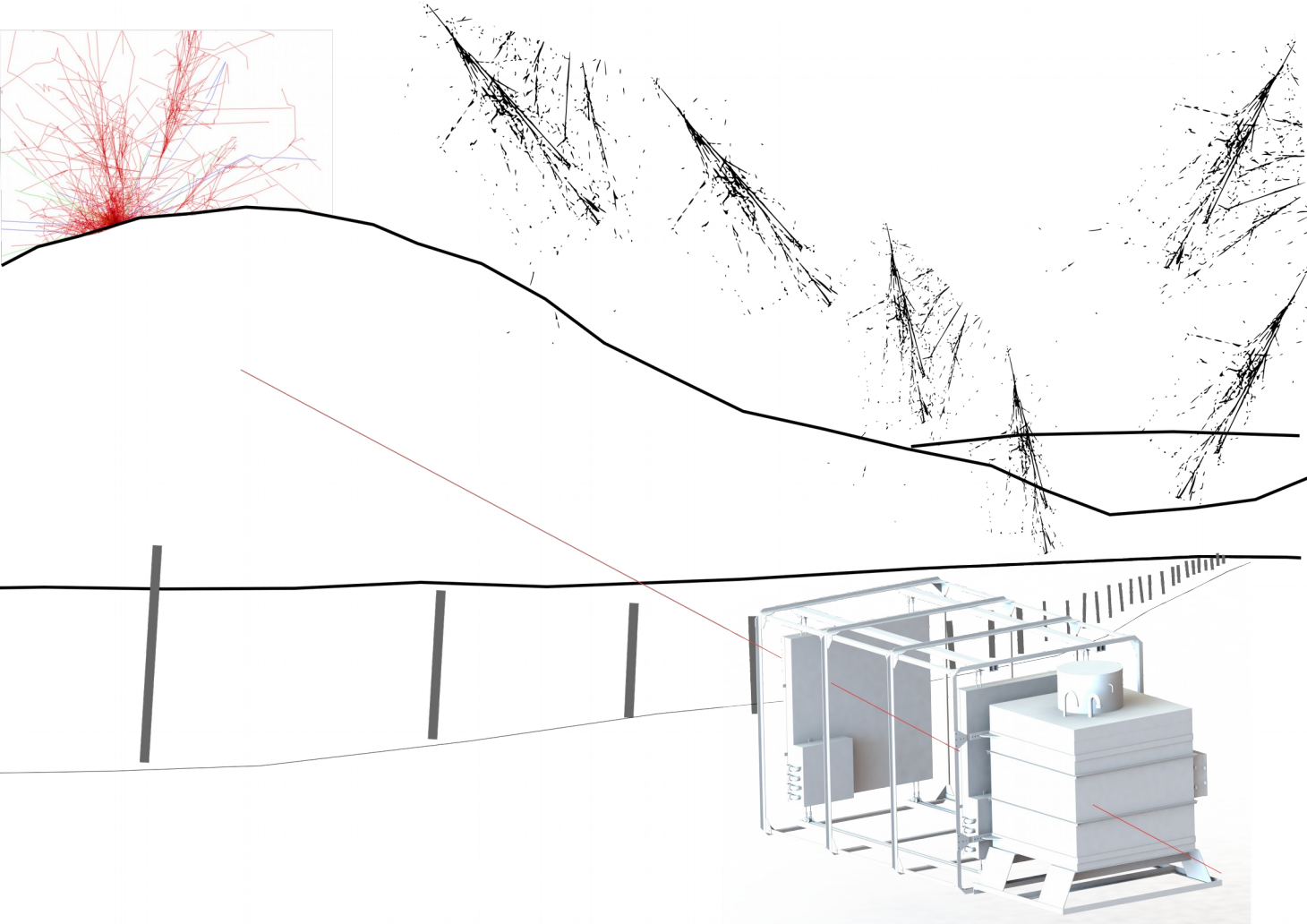
Atmospheric muon flux (EAS)

Traversing muon flux (python/MUSIC)

Detector response

next talk ... **H. Asorey (CNEA)**

# Muon flux – CORSIKA + MAGCOS



- Target coordinates
- Geomagnetic components
- Exposure time



- Integrated particle flux
- Flux components
- Energies



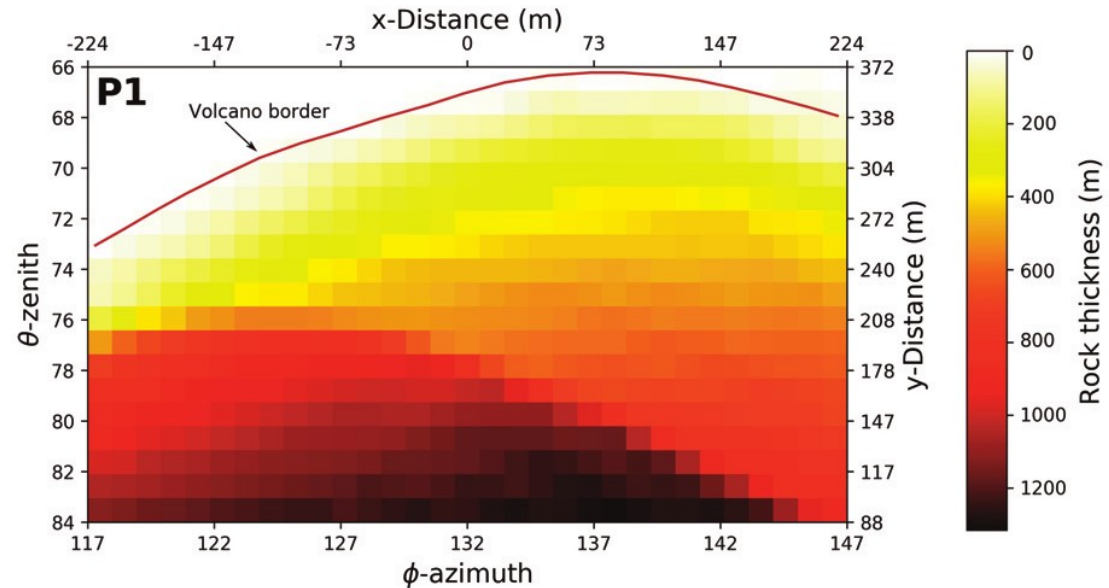
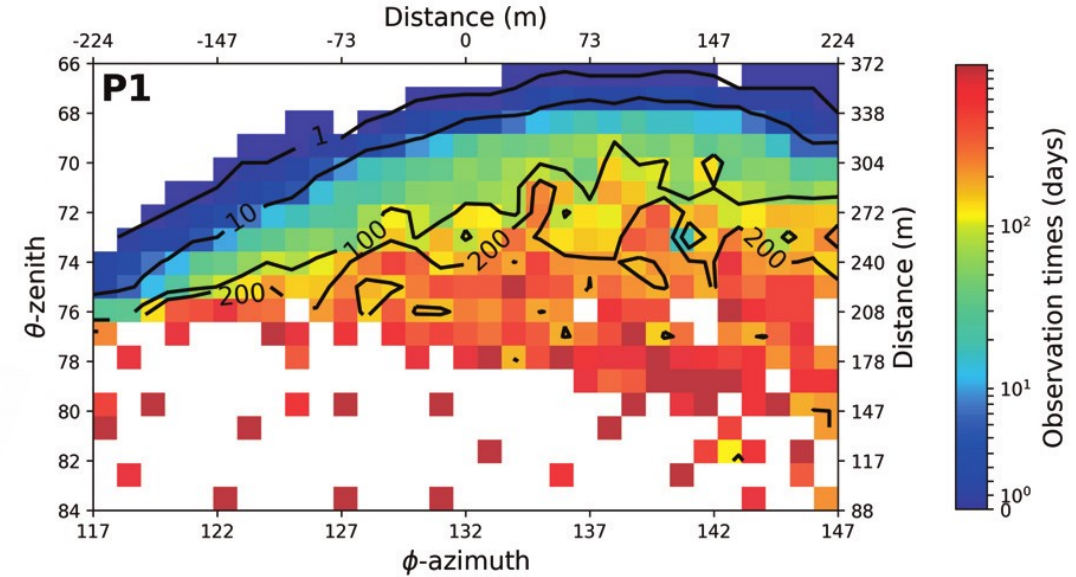
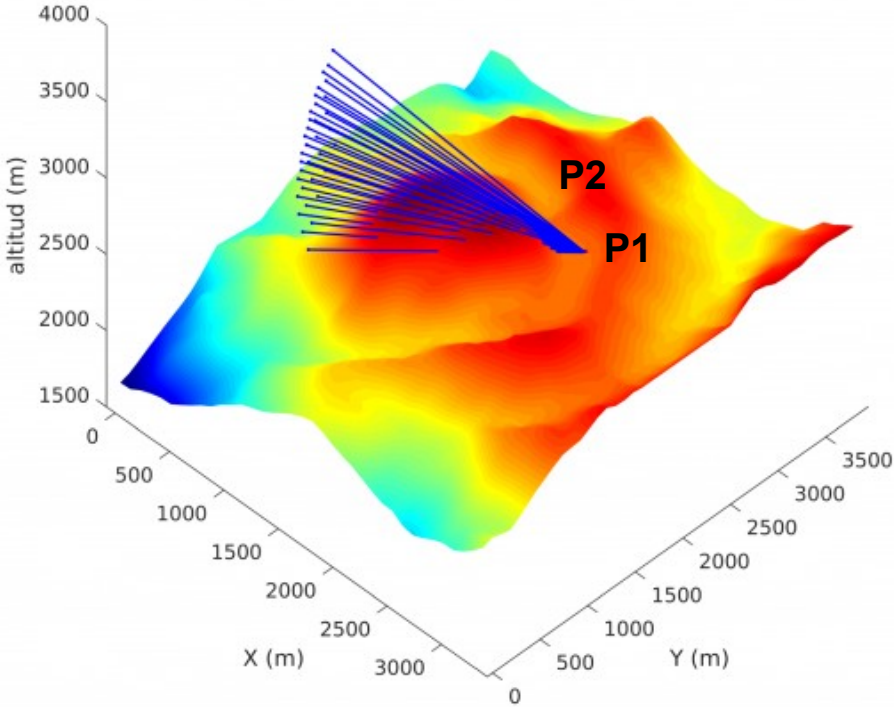
# Crossing distance and observation period

$$\rho(L) = \int \rho(\xi) d\xi L = \bar{\rho} \times L$$

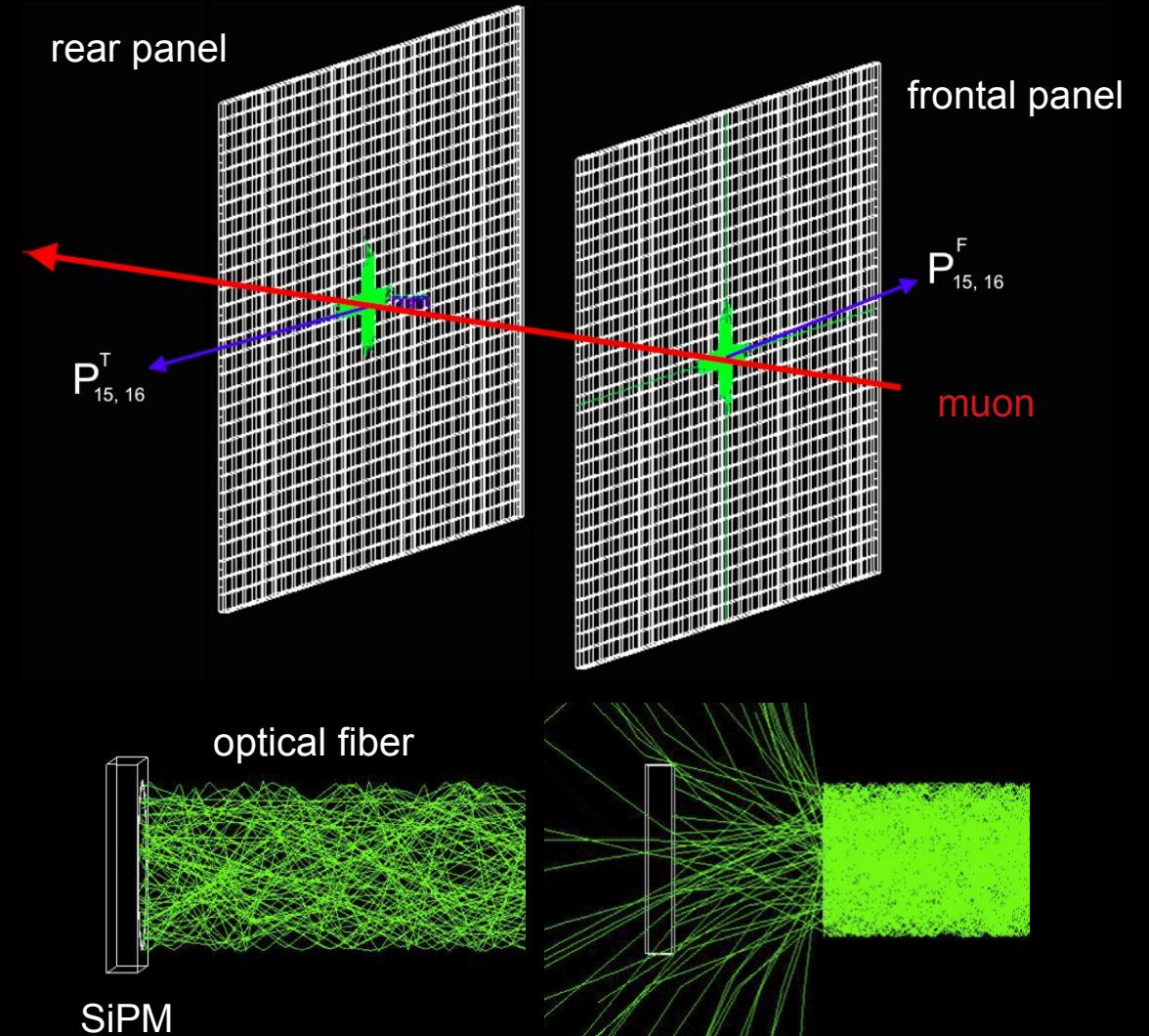
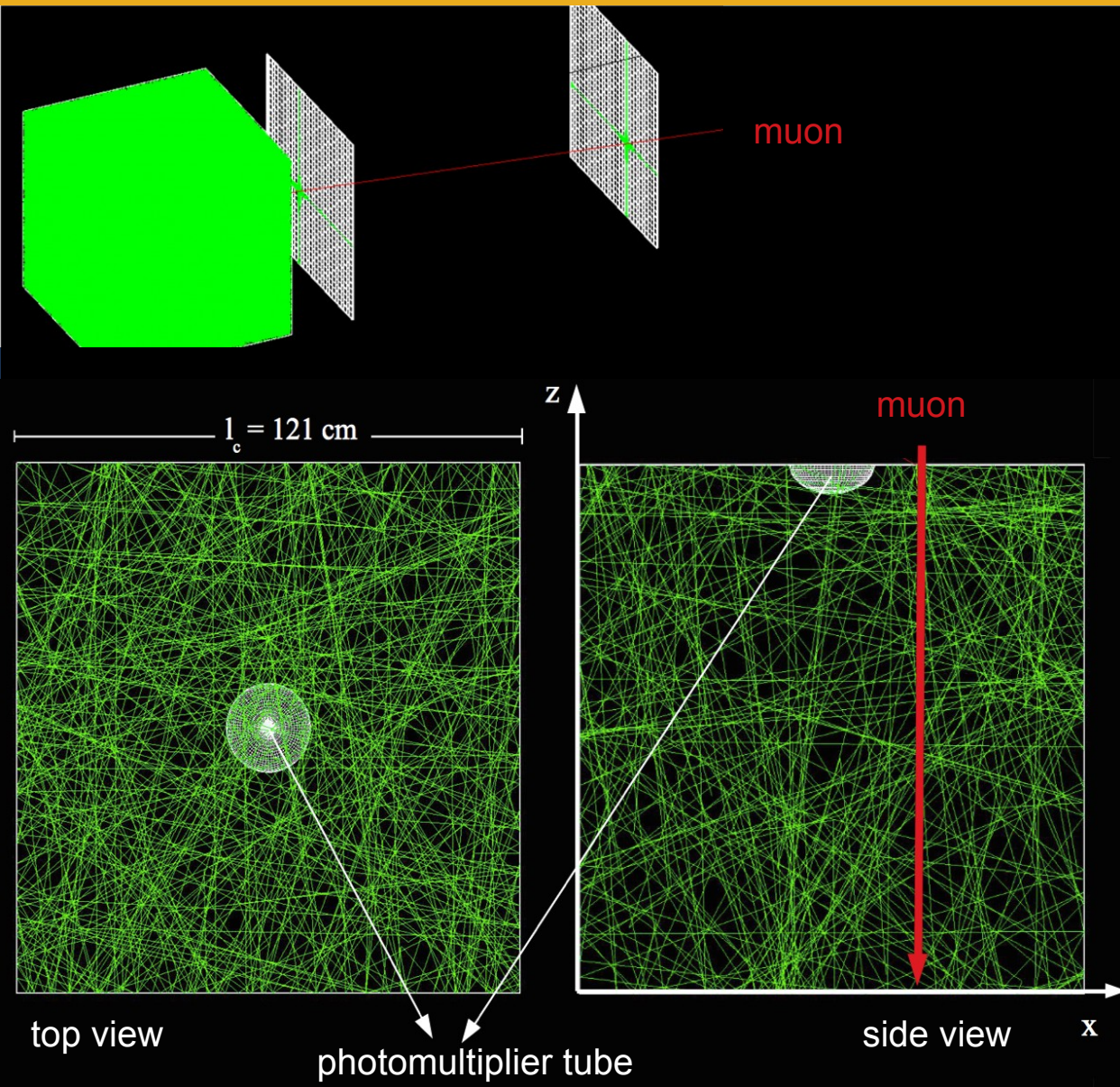
Topography +

$$-\frac{dE}{d\varrho} = a(E) + b(E)E$$

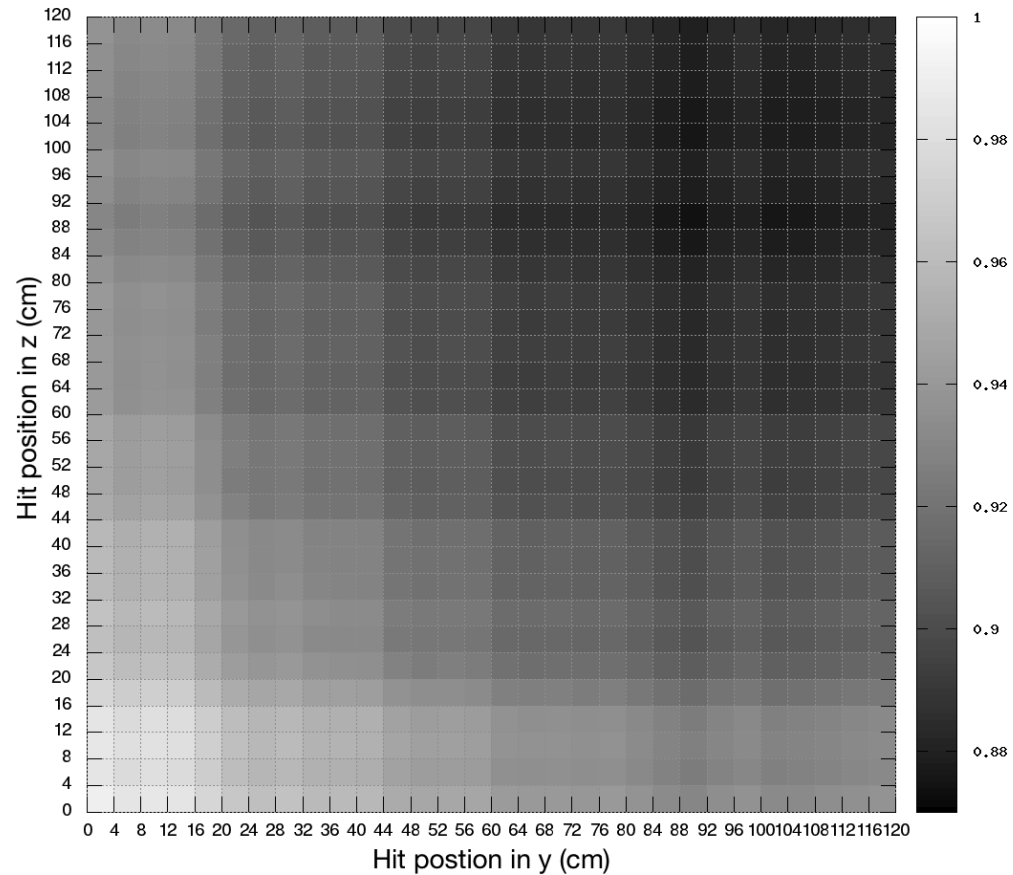
+ standard rock  
(2.65 g/cm<sup>3</sup>)



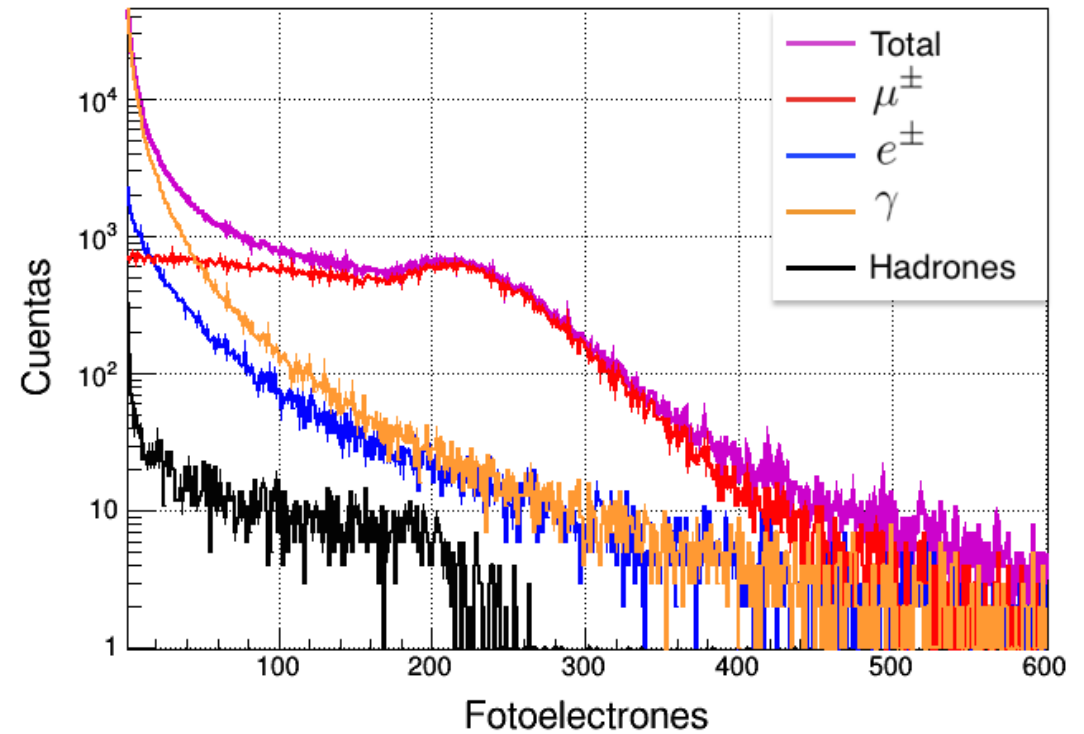
# Detector response - GEANT4



## panel signal attenuation

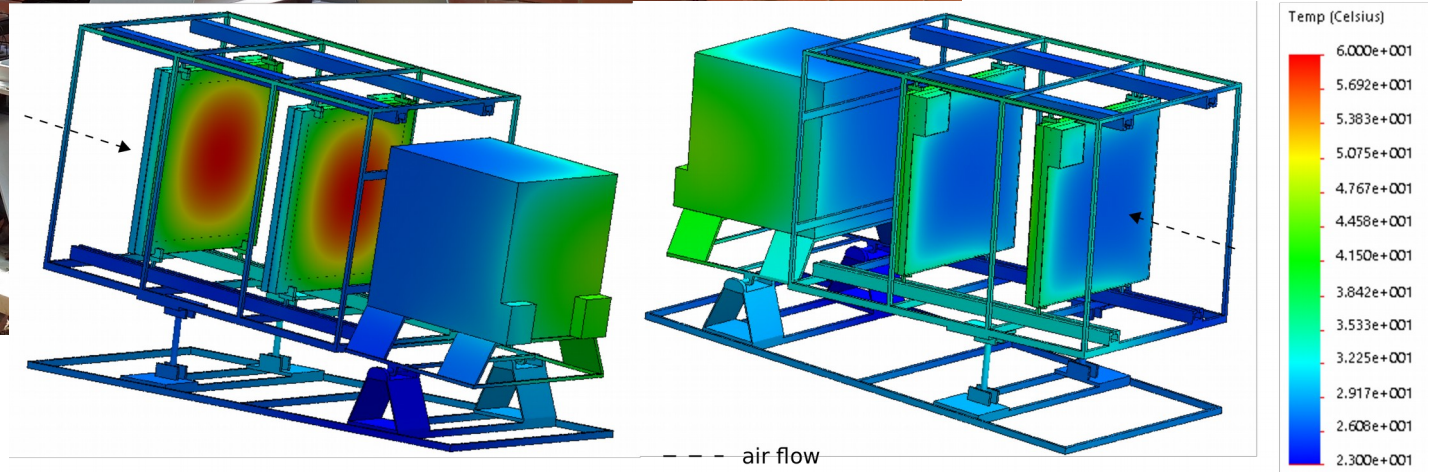
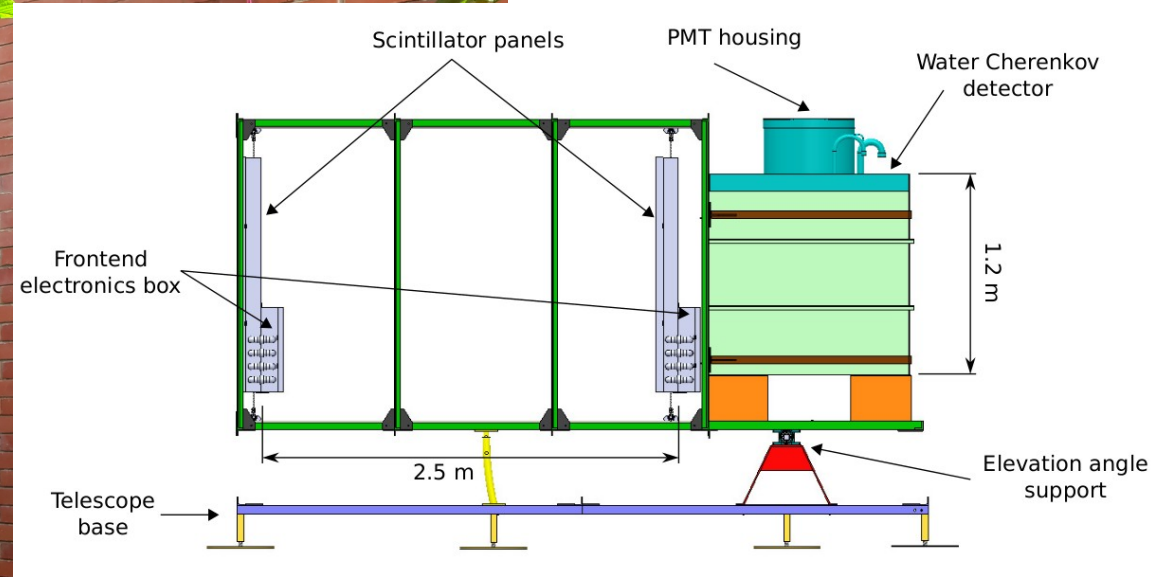


## WCD particle spectrum





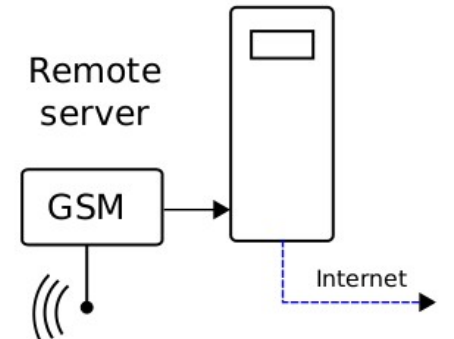
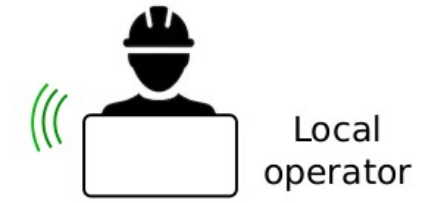
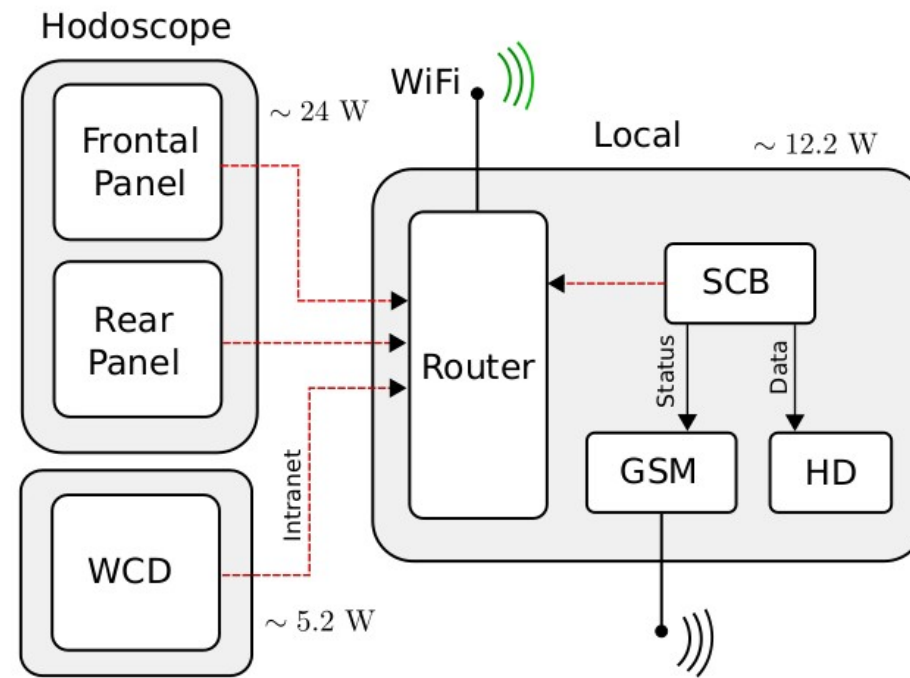
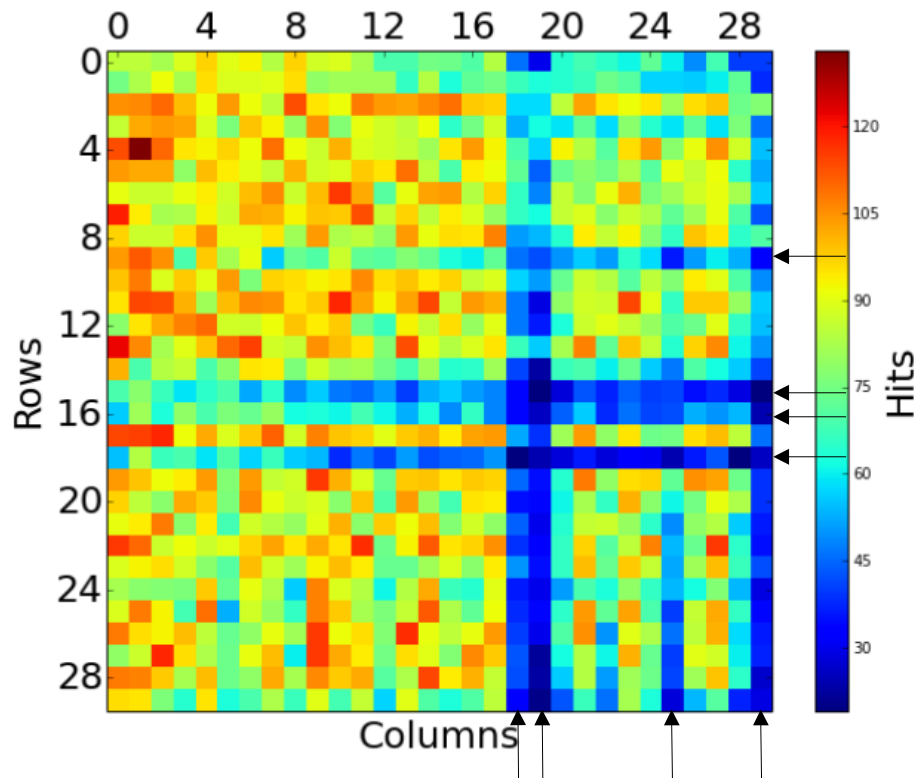
# Instrumentation → Mechanichs



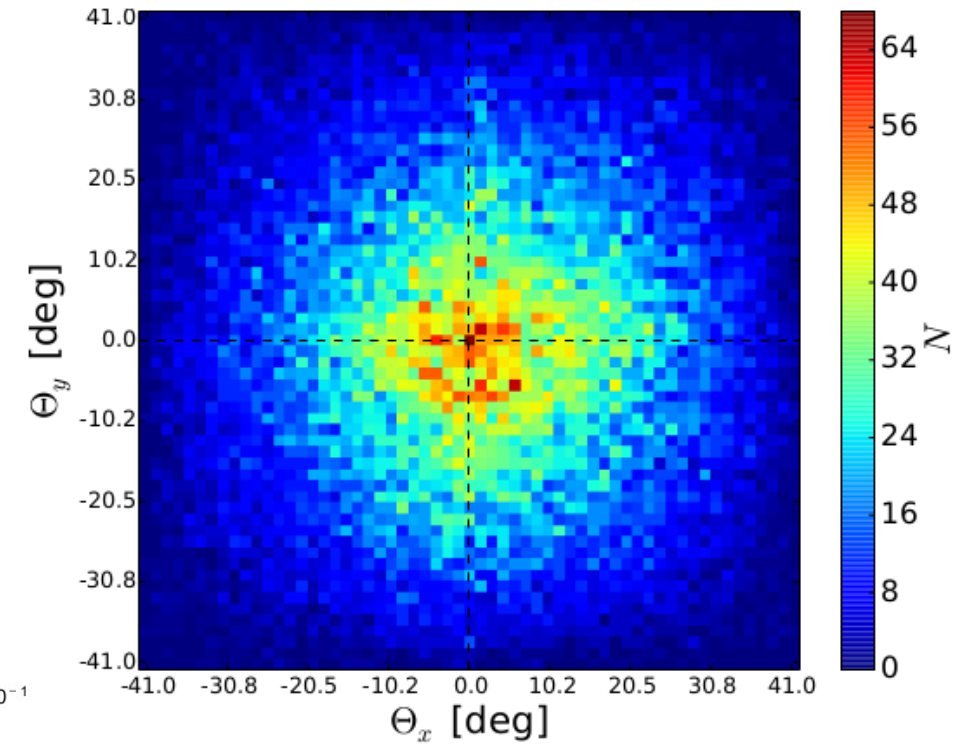
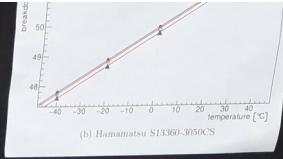
# Instrumentation → Programming

C/C++ and python based scripts

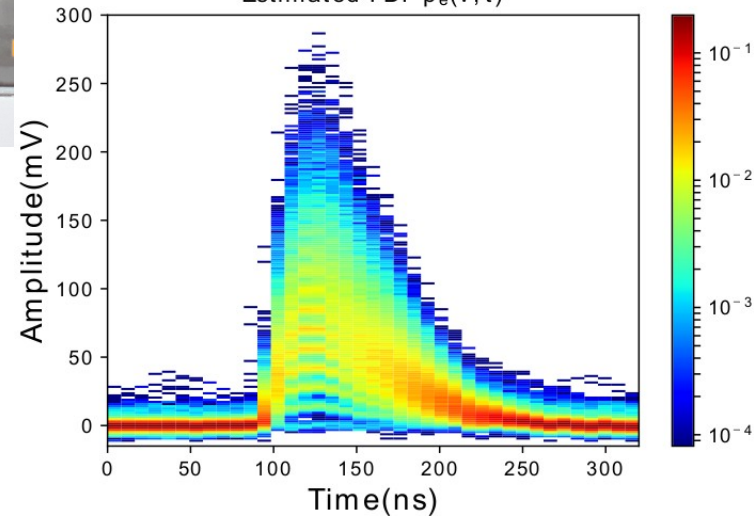
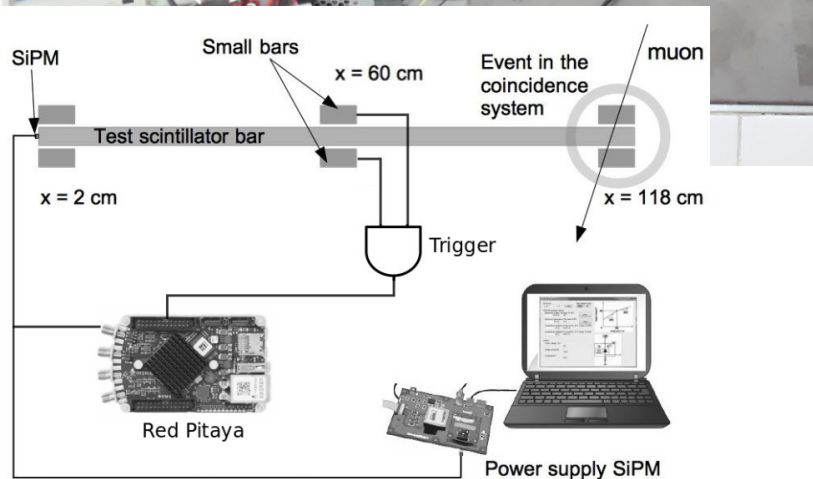
- Calibration
- Operation
- Diagnosis



# Instrumentation → Calibration

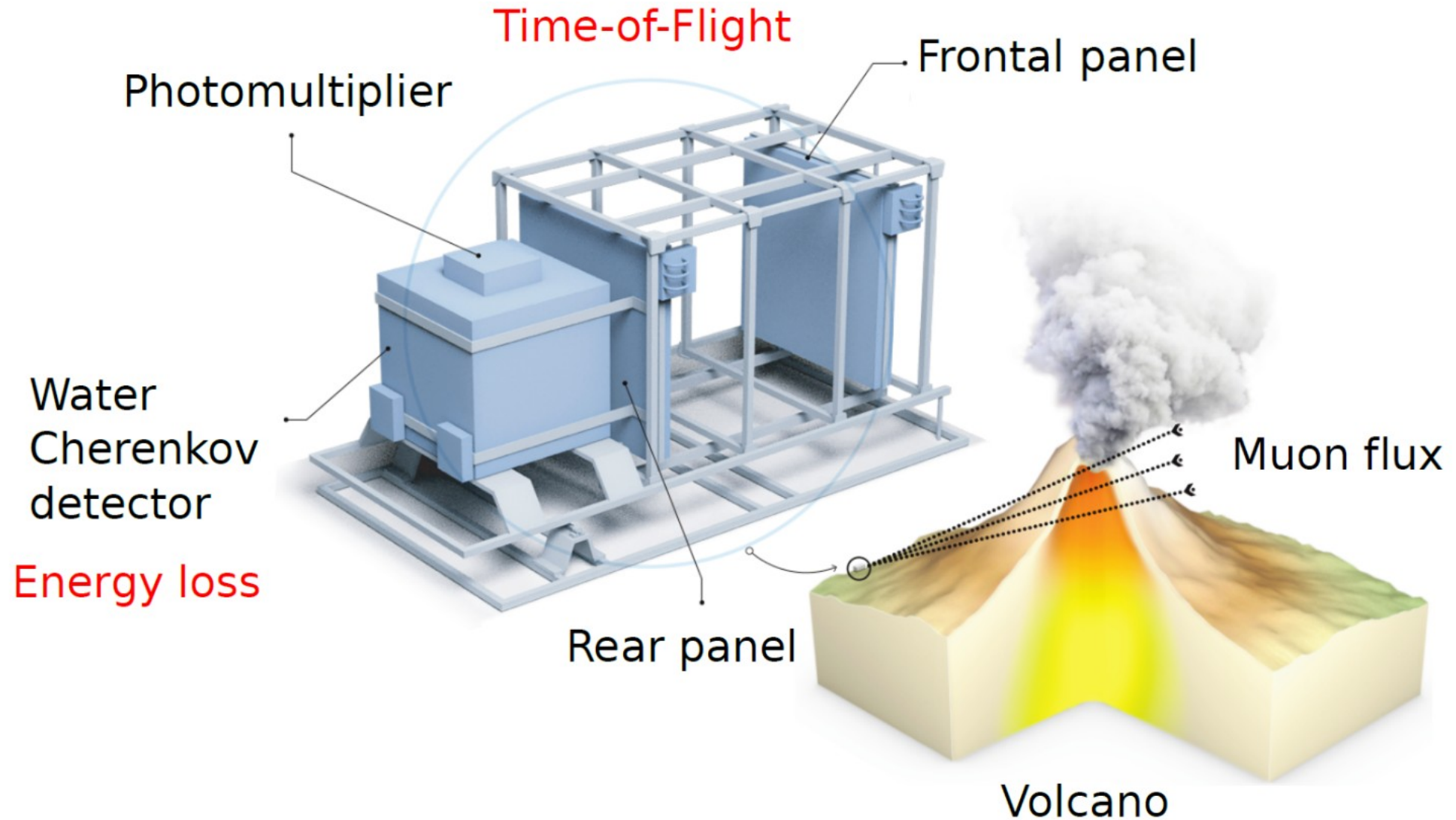


Estimated PDF  $\hat{p}_e(v, t)$



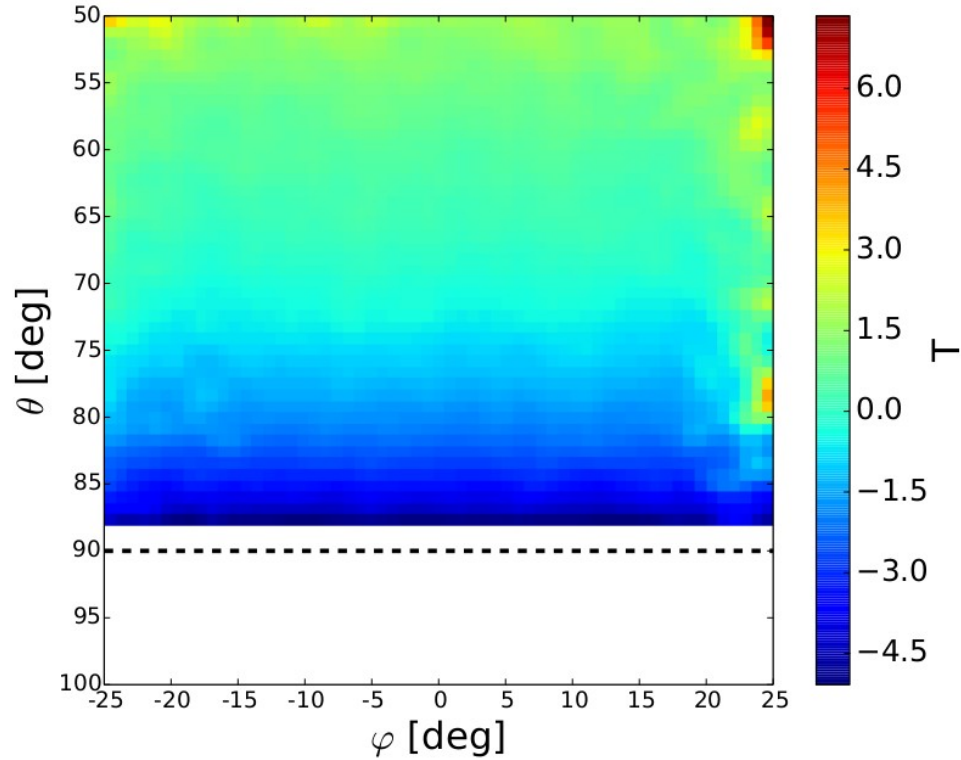
J. Peña-Rodríguez et al. Journal of Instrumentation. 2020.  
 A. Vásquez-Ramírez et al. Journal of Instrumentation. 2020  
 SiPM. <https://arxiv.org/abs/2102.01119>

# Hybrid detectors → PID techniques → Background reduction

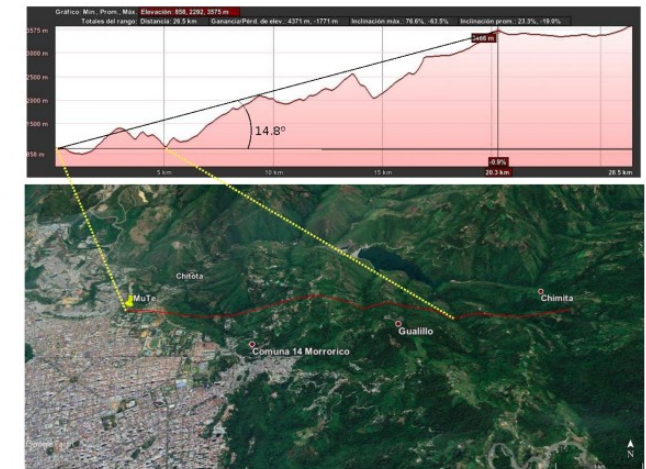
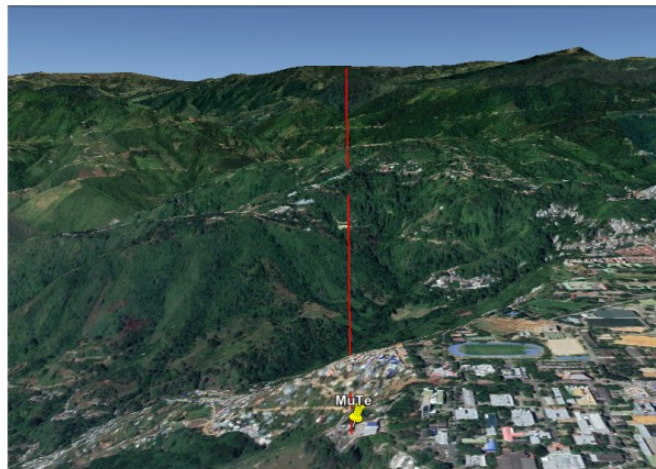
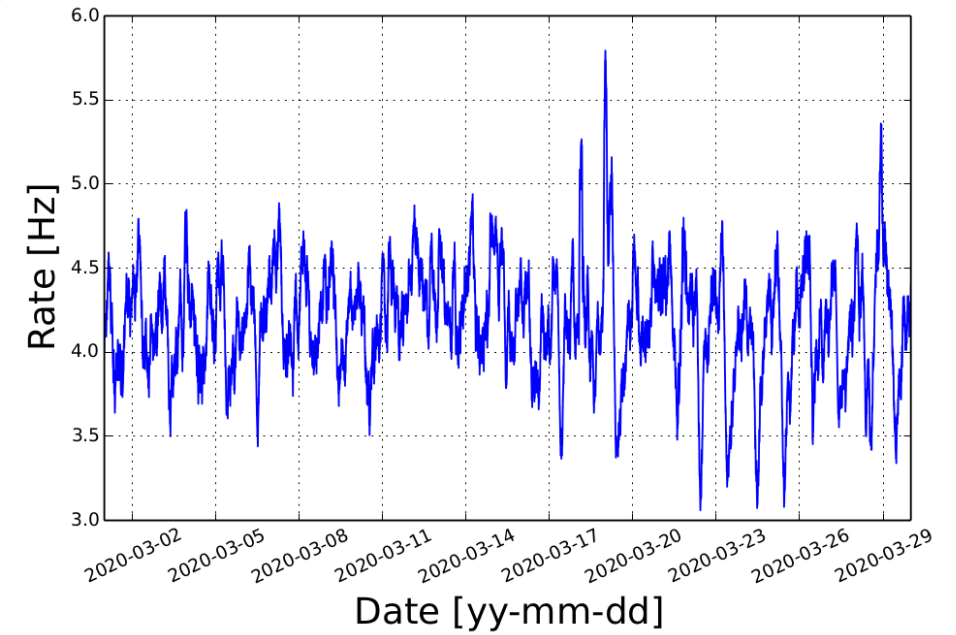




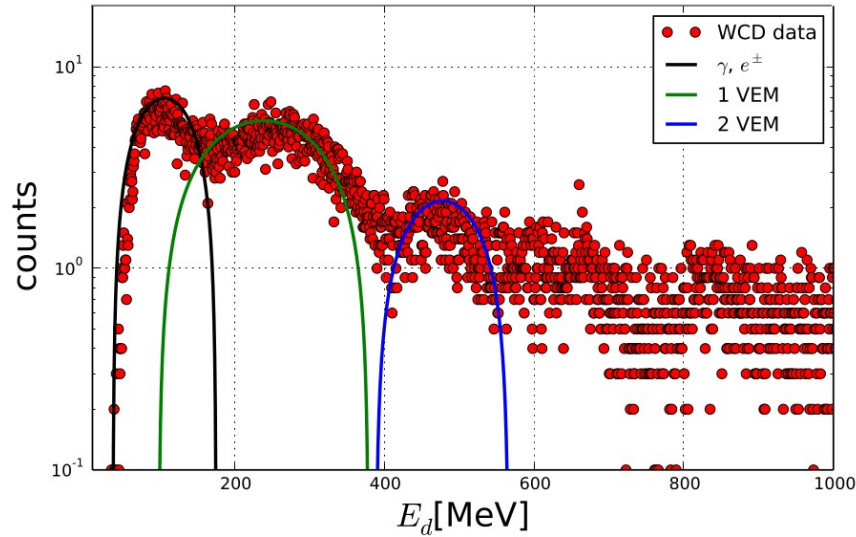
## Muogram



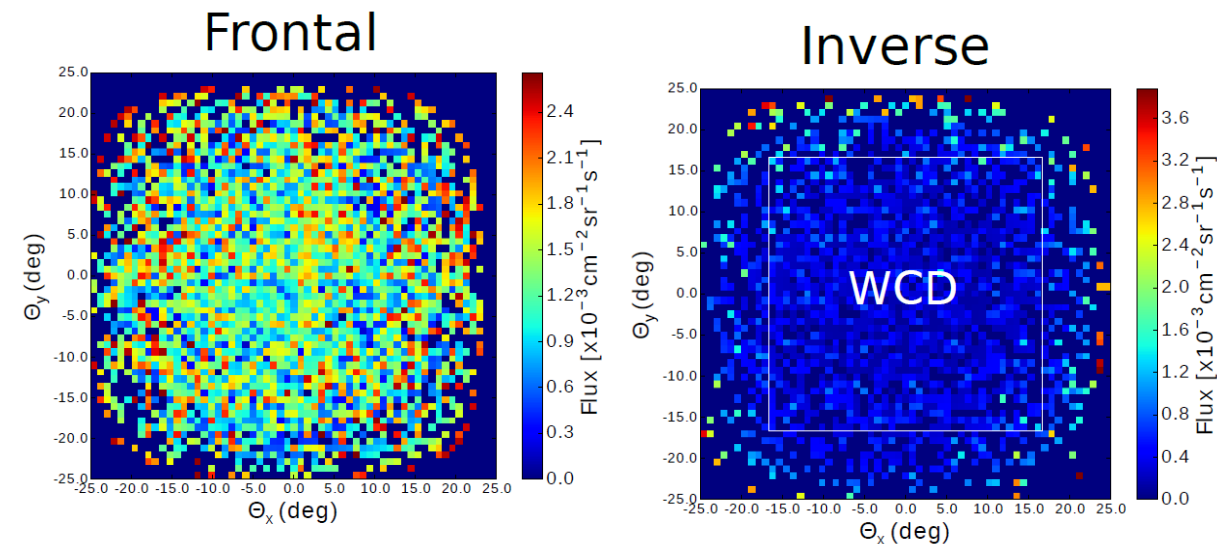
## Temperature dependency



# Data analysis → Background characterization

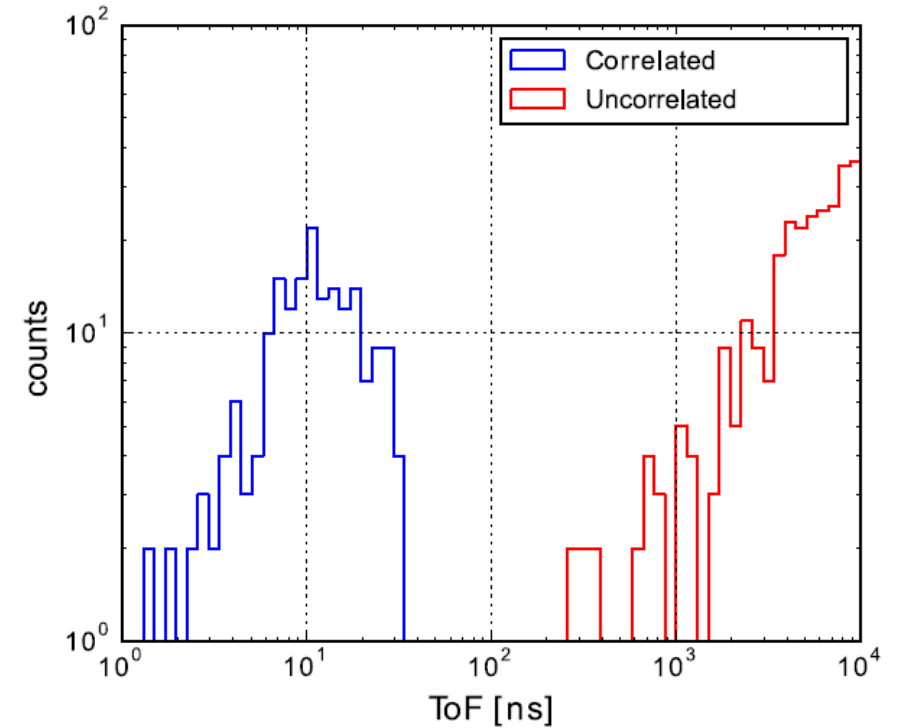


Particle spectrum

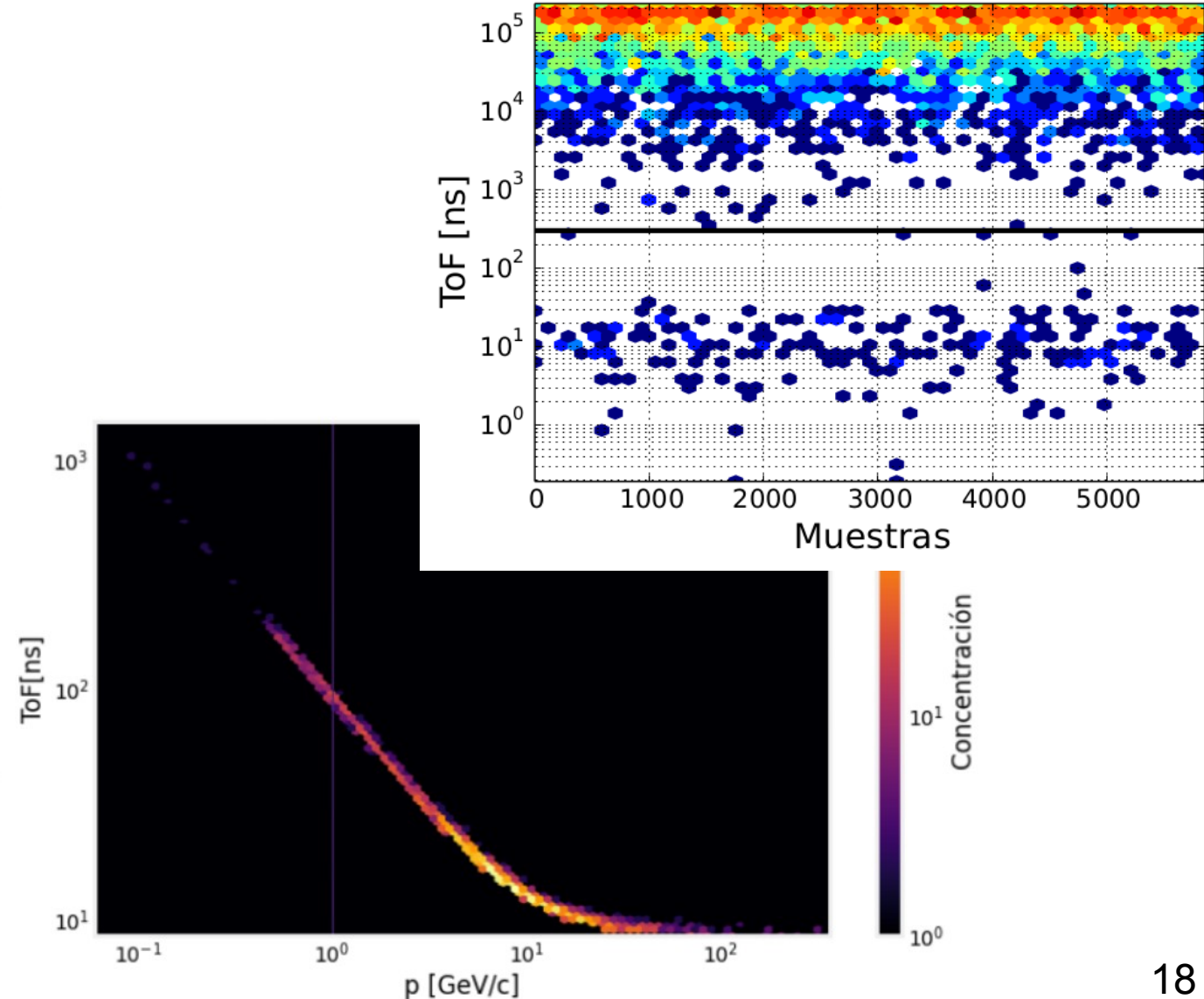
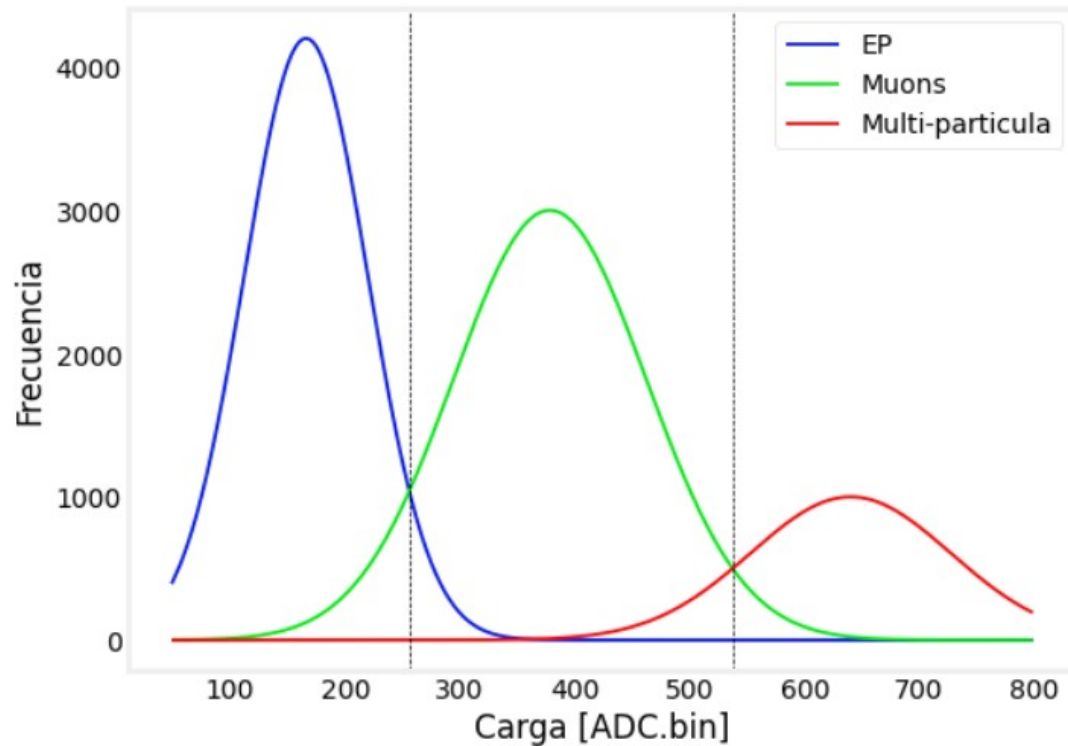


Direction

## Time-of-Flight

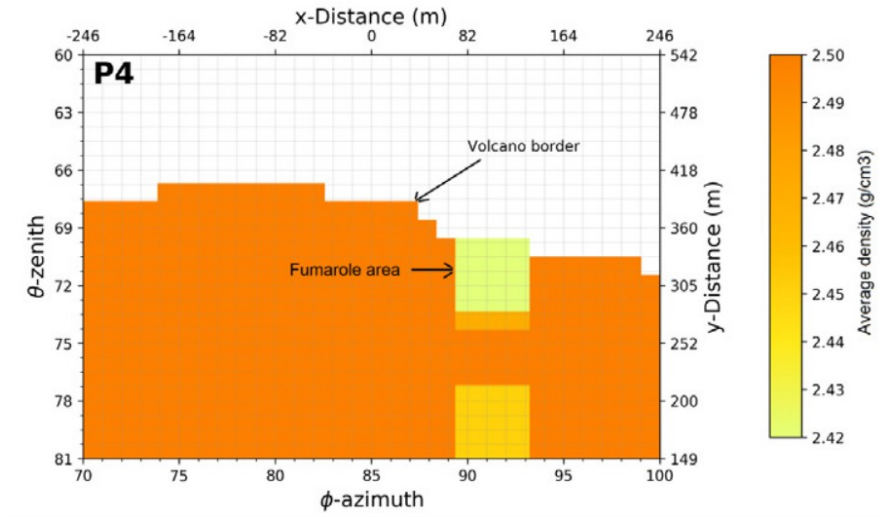
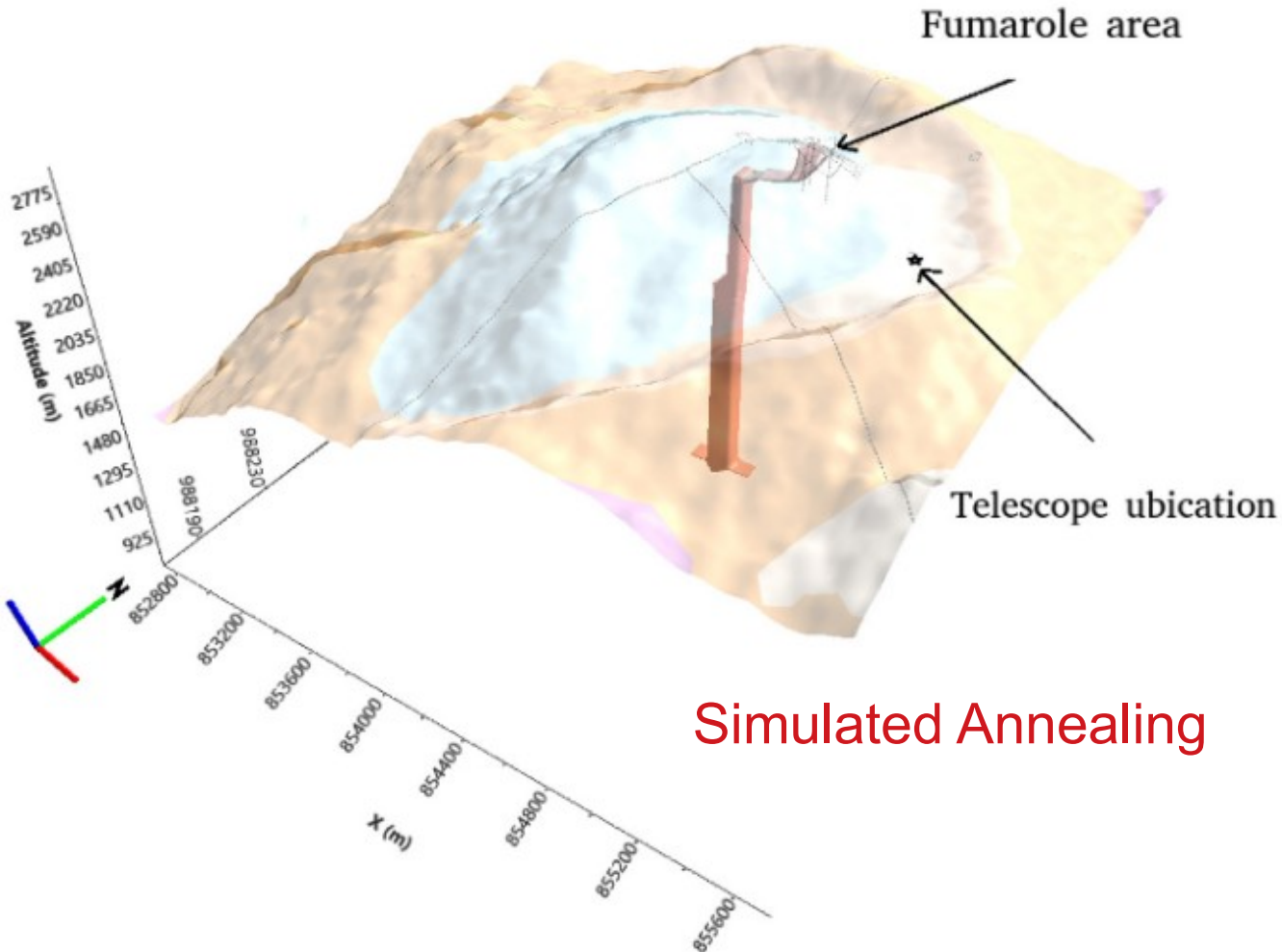


- PID using GMM
- ToF and momentum thresholding

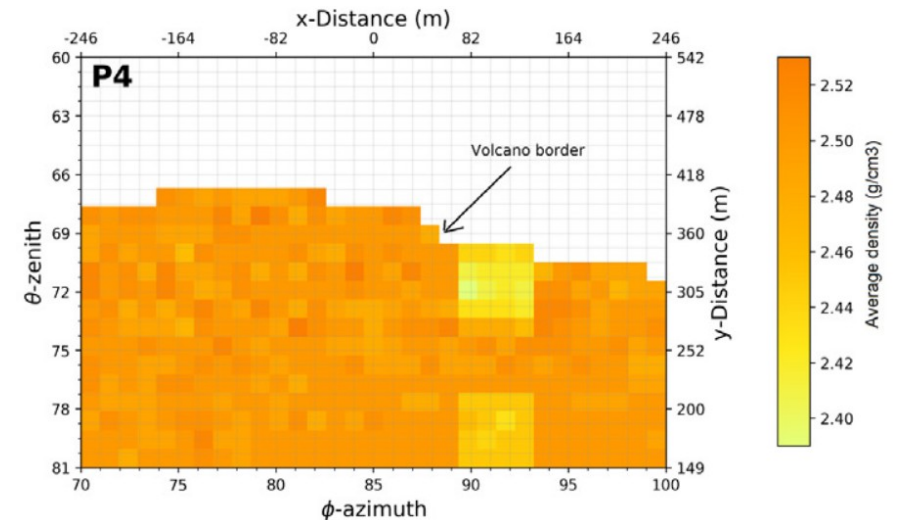


# Data analysis → Inverse problem

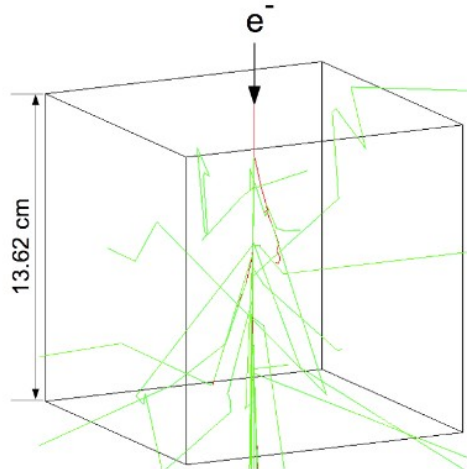
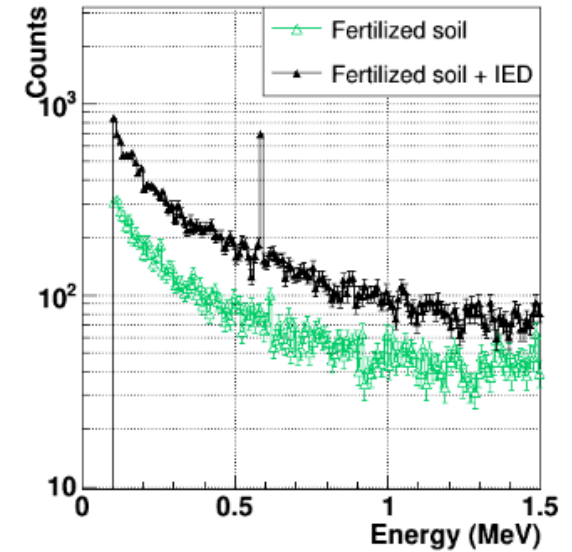
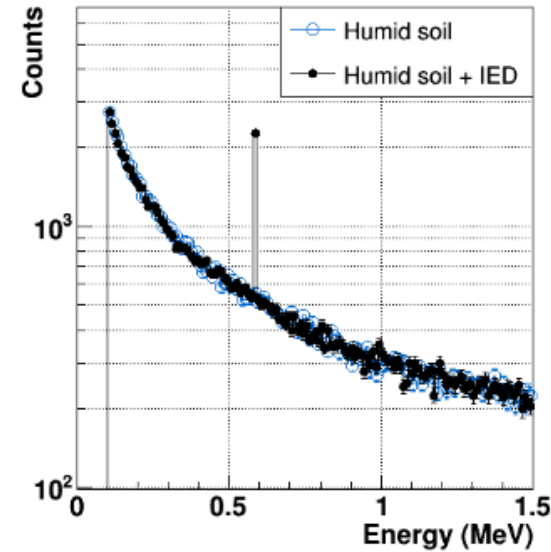
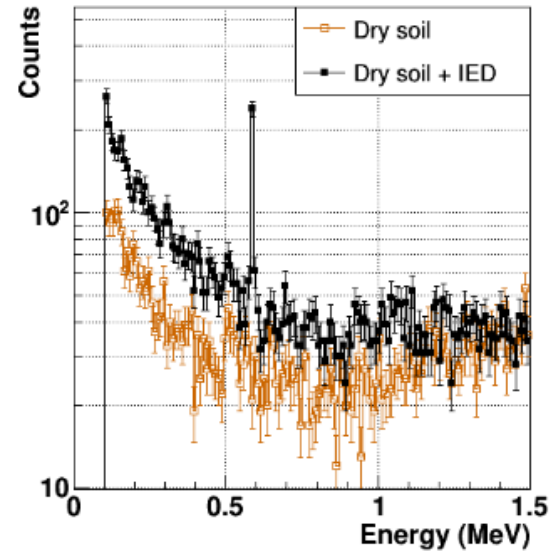
## Synthetic model



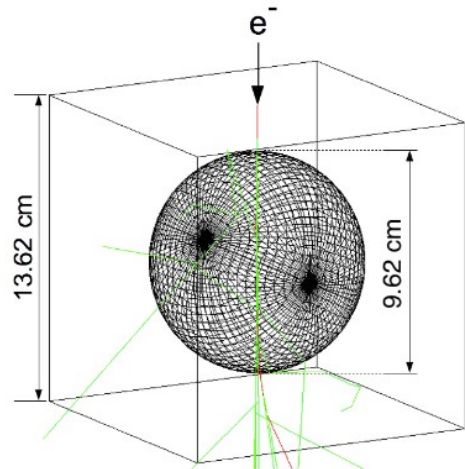
## Inversion result



# A Transitional Society: Improvised explosive devices detection

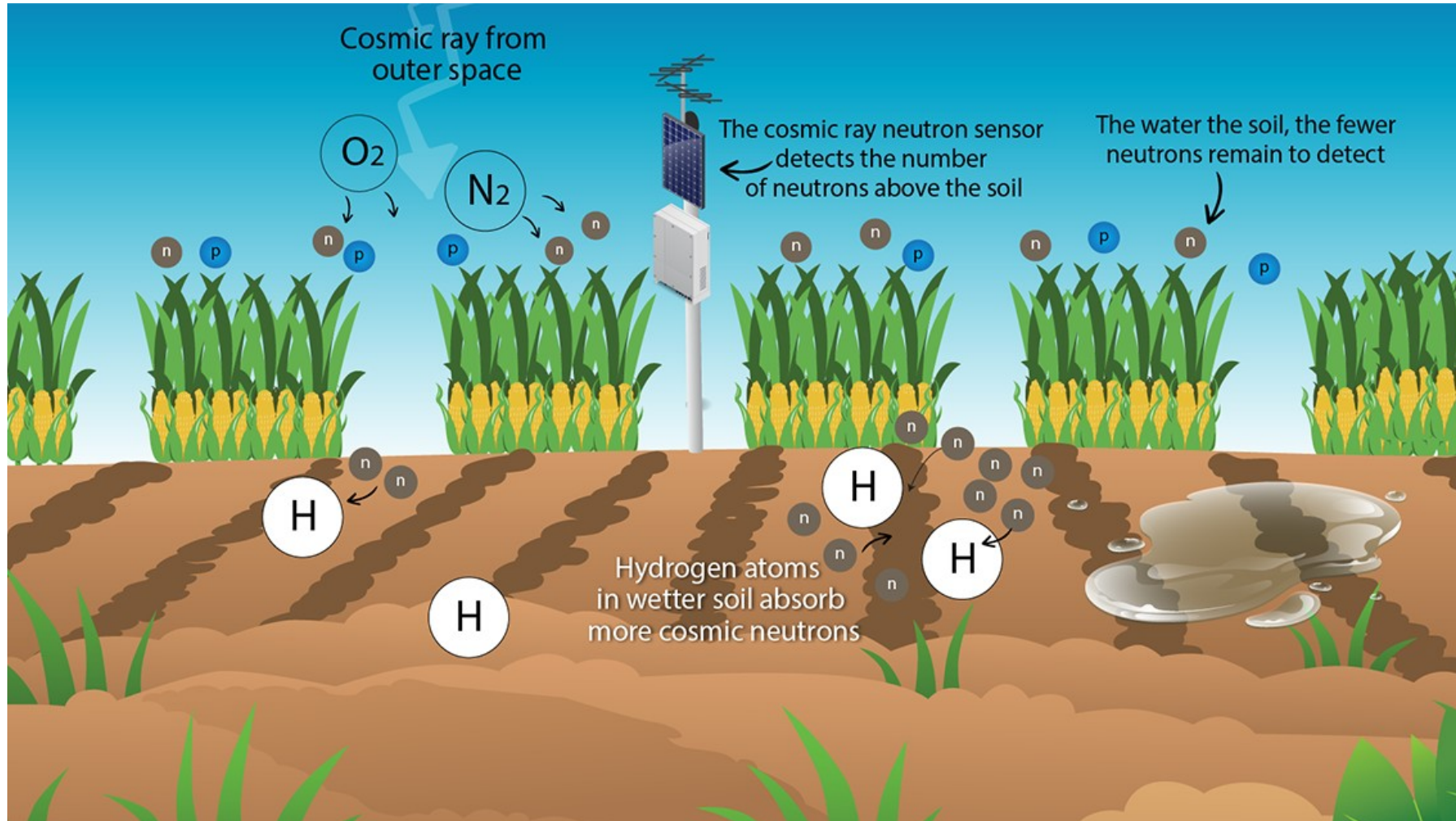


a) Dry soil model



b) Dry soil + IED

## Precision Agriculture: moisture measurement with CRs



<https://halley.uis.edu.co/fuego>

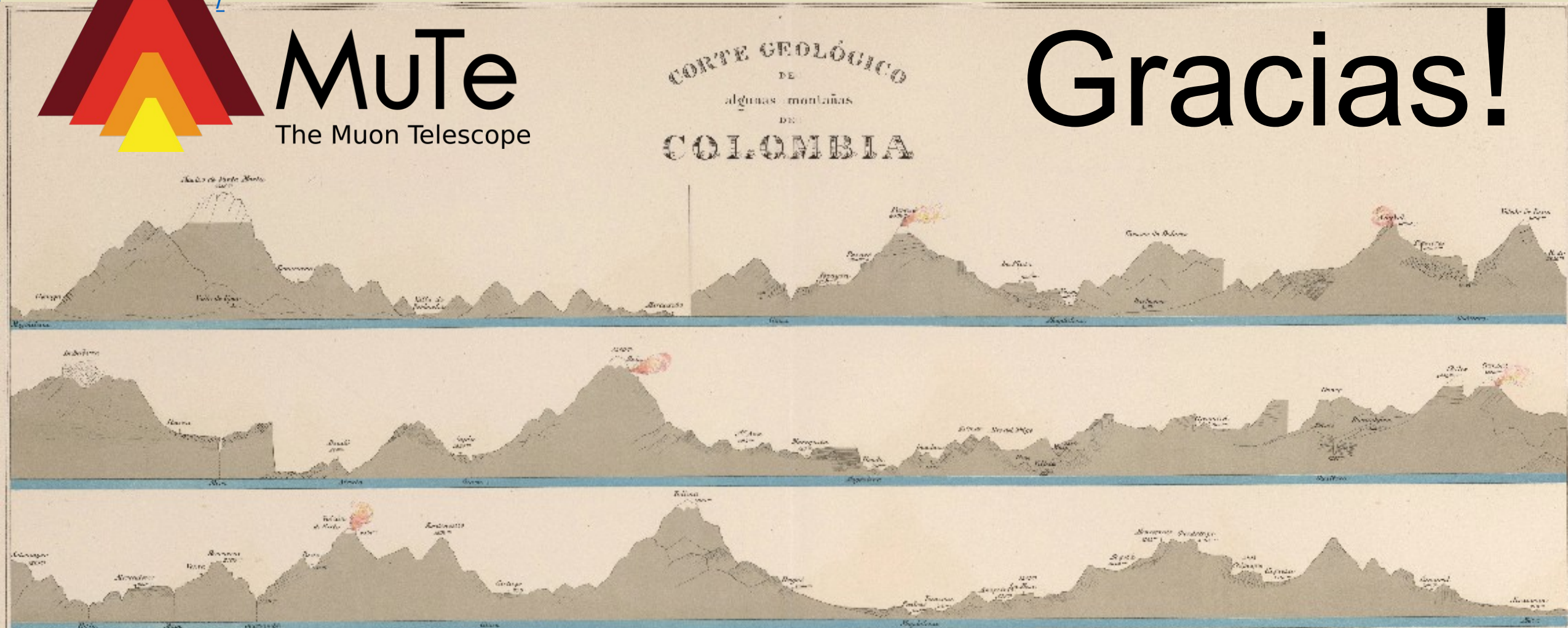


MuTe

The Muon Telescope

CORTE GEOLÓGICO  
DE  
algunas montañas  
DE  
COLOMBIA

Gracias!





**MUTE**  
The Muon Telescope



# Instrumentation

