MUYSC: An end-to-end muography simulation framework

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MUography Simulation Code

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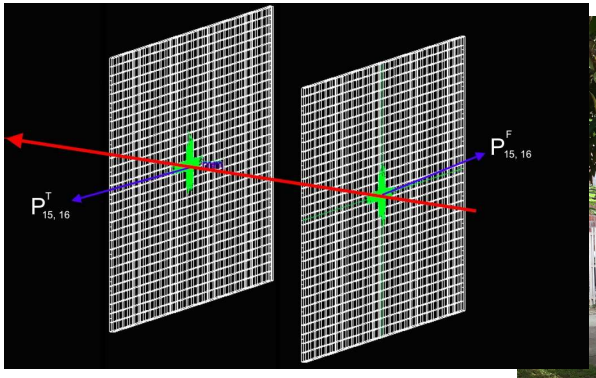
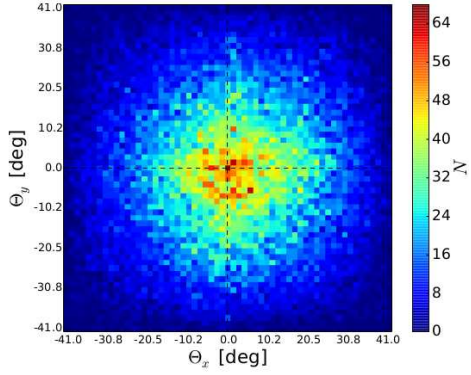
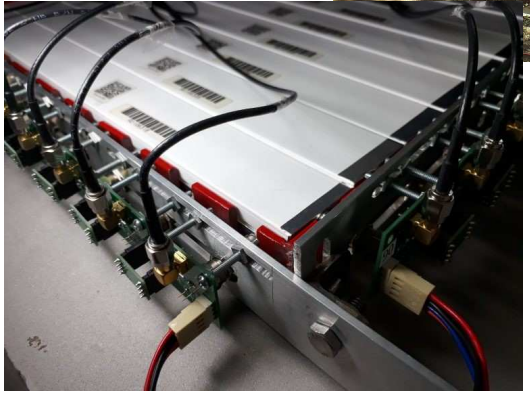
Outline

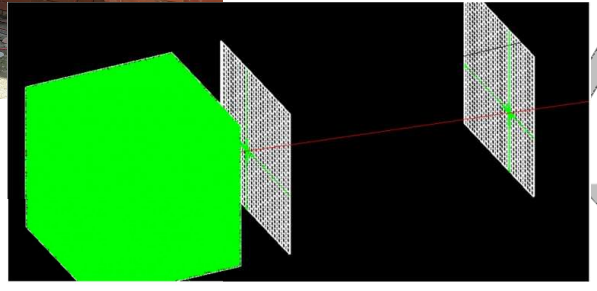
- Motivation
- MUYSC simulation framework
- Muon radiography simulation
- Muon tomography simulation
- Telescope parameterization
- Summary and outlook

A starting point









MuTe
The Muon Telescope

Muography simulation frameworks

Muon Generation

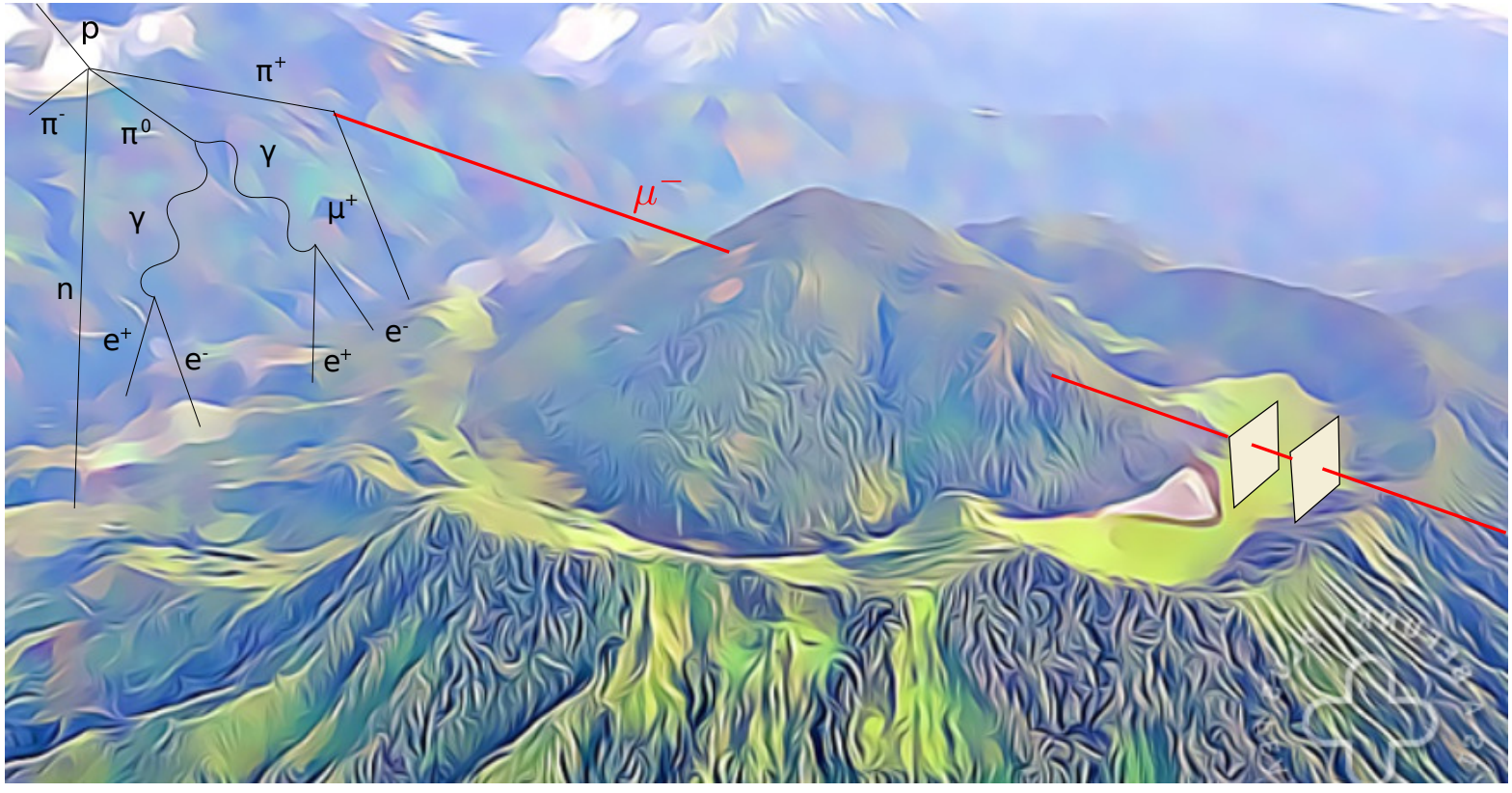
- CORSIKA
- CRY
- Parametric models

Muon Transport

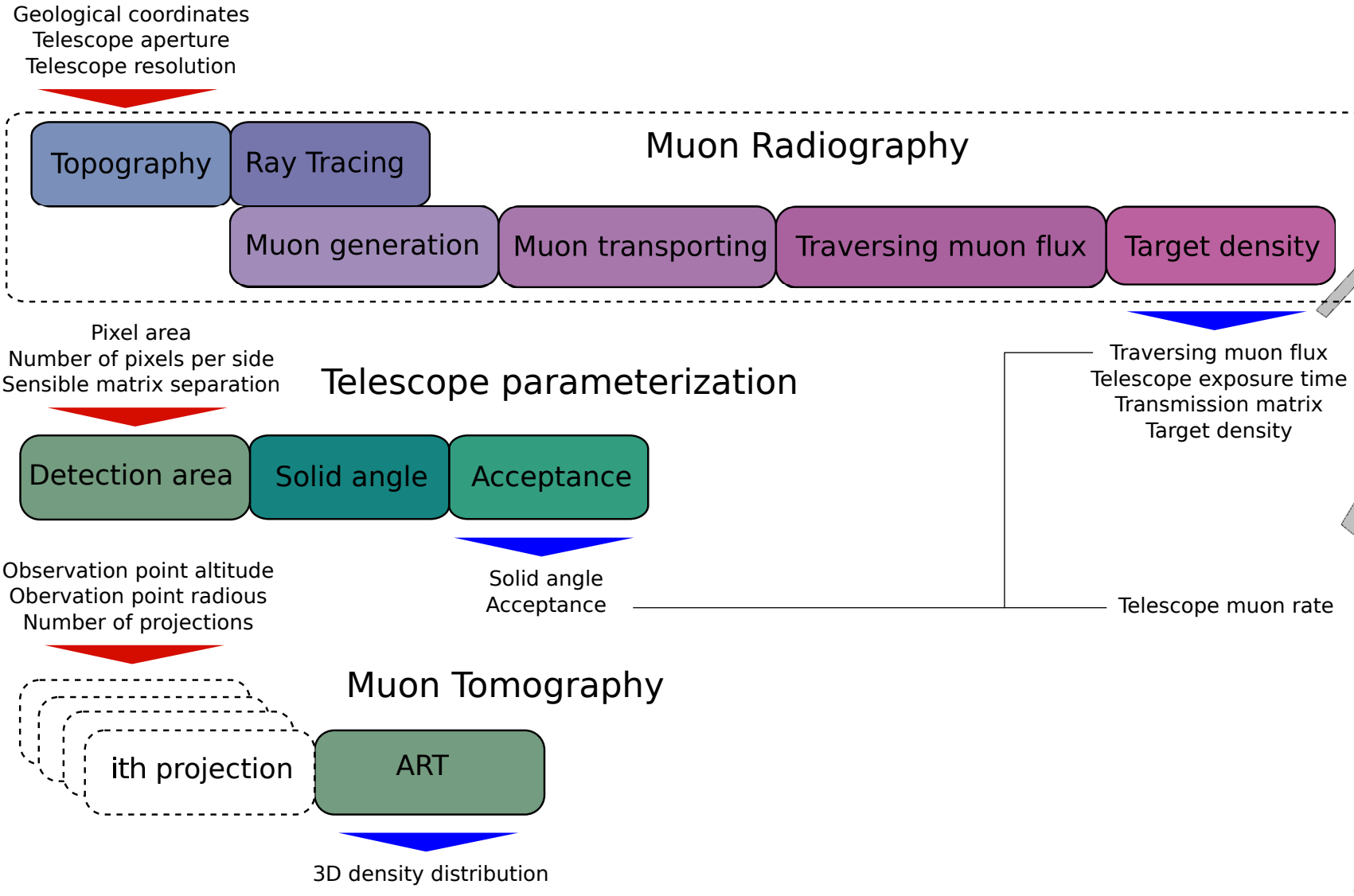
- GEANT4
- PHITS

Detector Simulation

- GEANT4
- PUMAS
- MUSIC



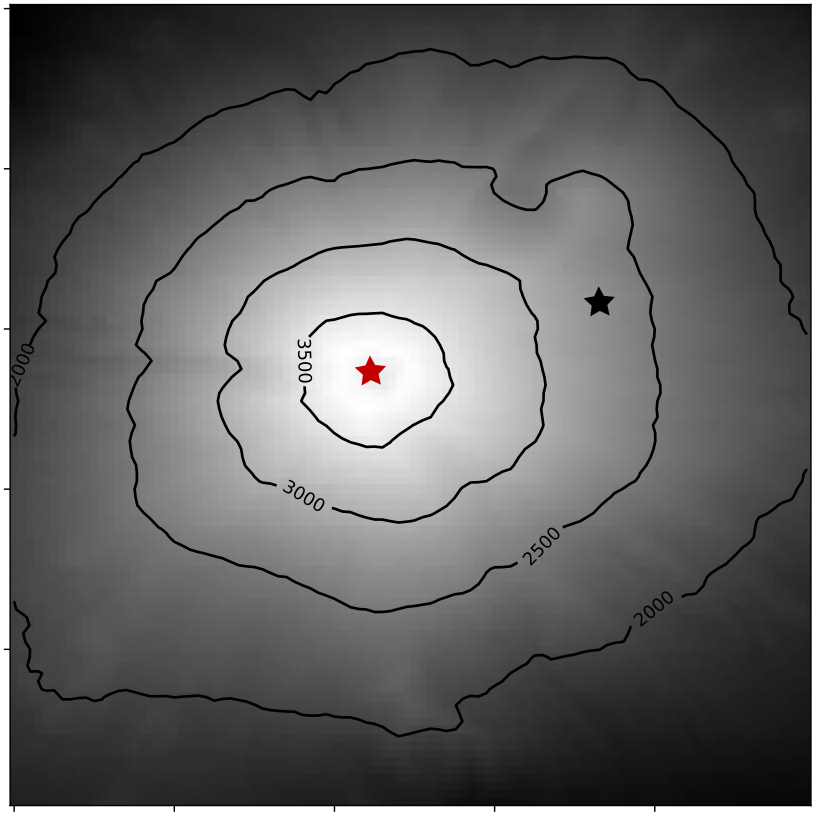
MUographY Simulation Code



MUYSC: Muon radiography

Topography

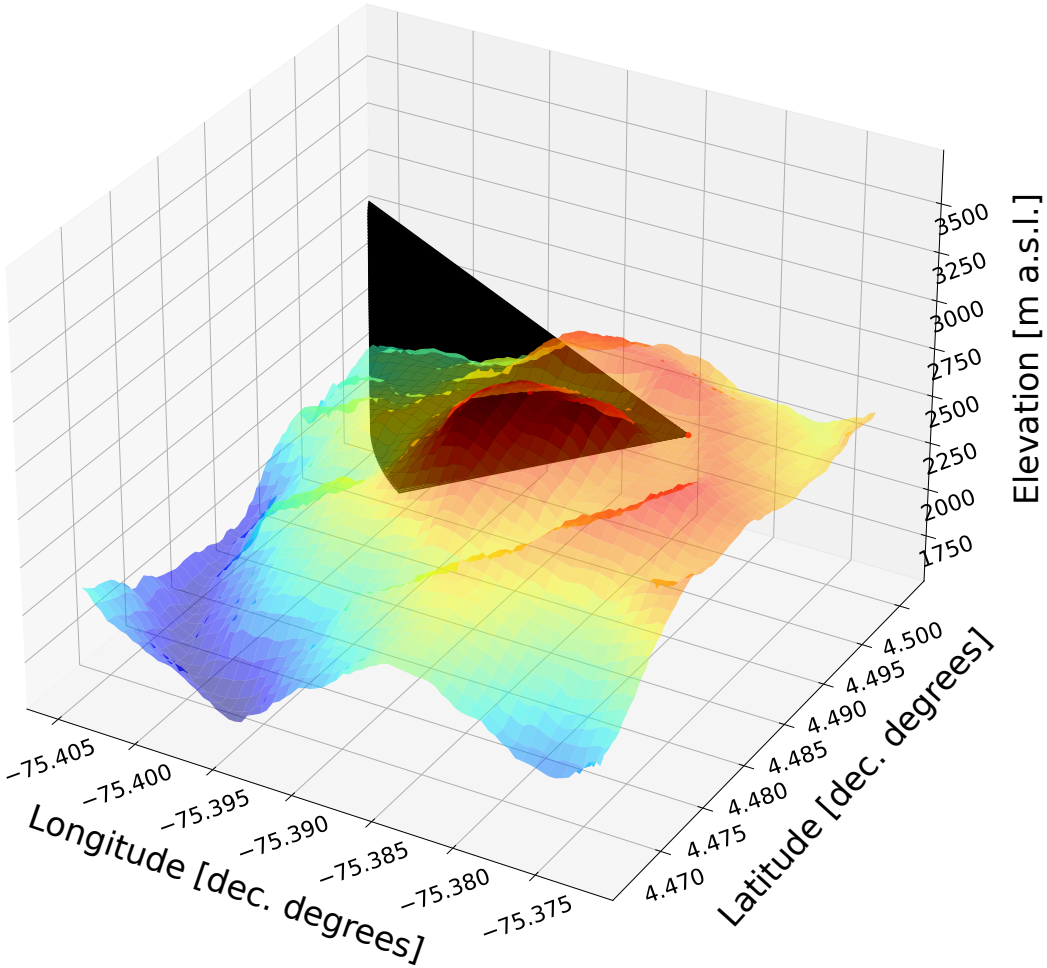
$(Long_{min}, Lat_{max})$ $(Long_{max}, Lat_{max})$



$(Long_{min}, Lat_{min})$ $(Long_{max}, Lat_{min})$

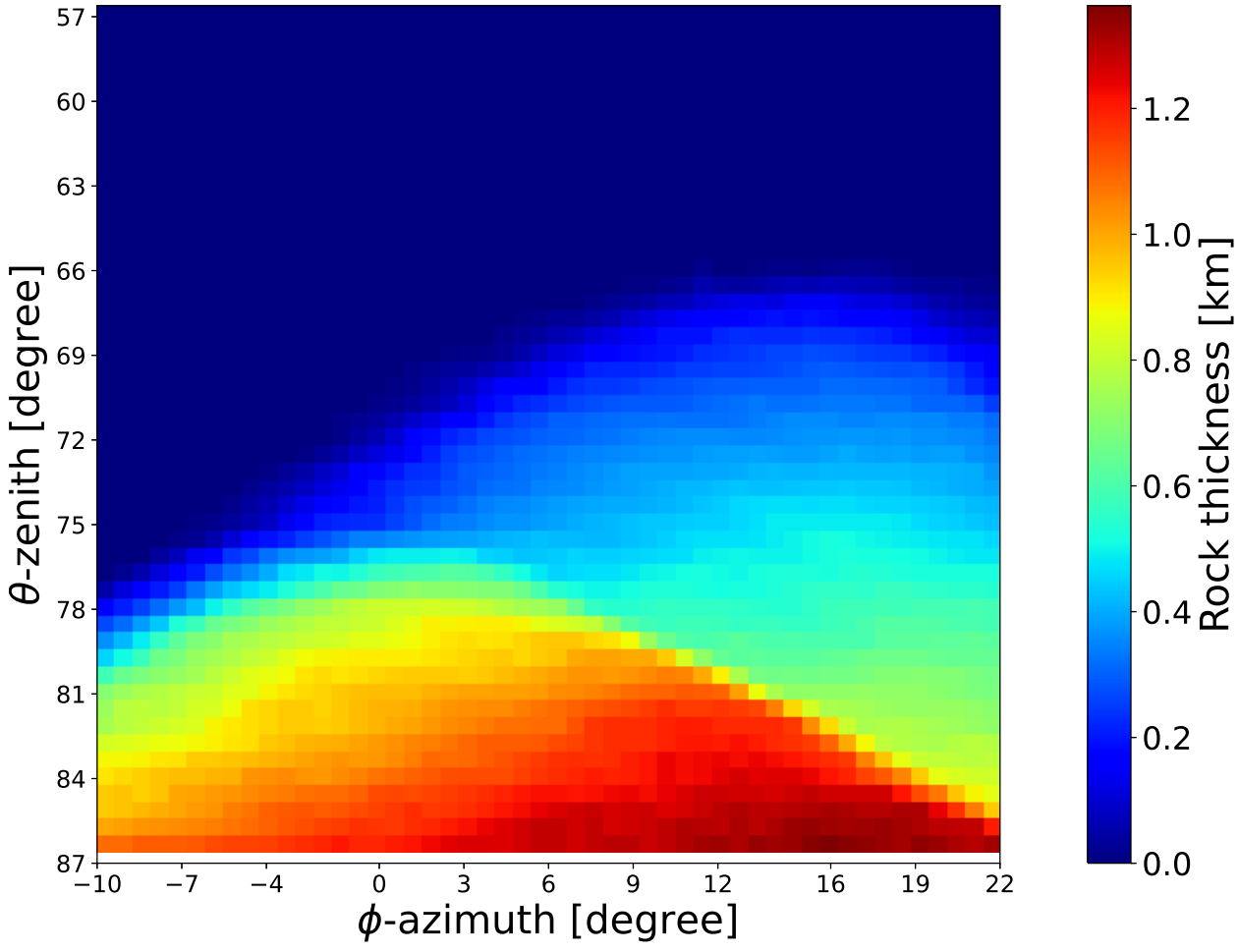
- SRTM (Shuttle Radar Topography Mission) NASA
- Point (Latitude, Longitude, Altitude)
- 30 m resolution

Ray tracing: Cerro Machín

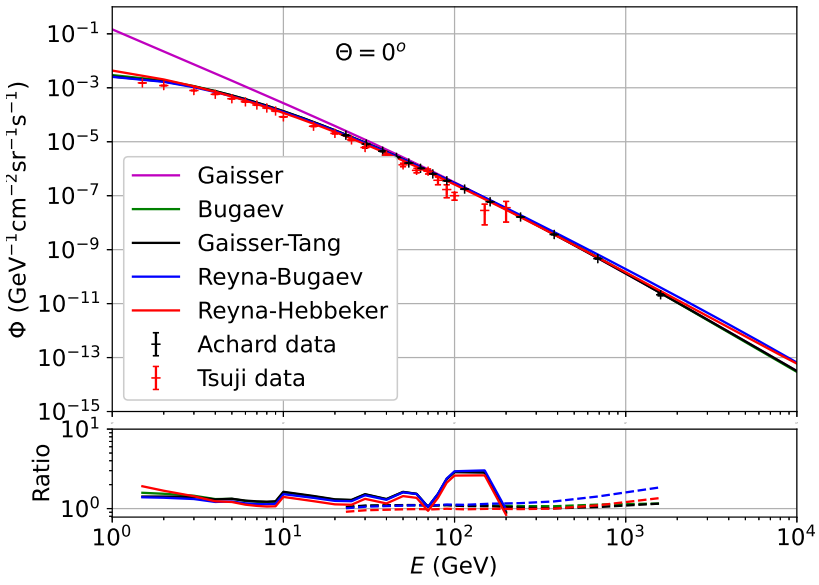


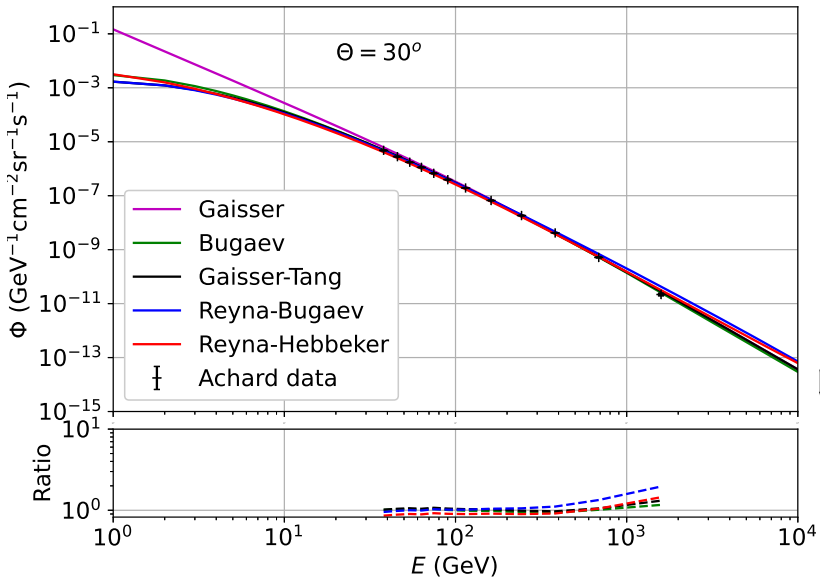
- Telescope angular aperture
- Telescope angular resolution
- Telescope position
- Telescope elevation angle

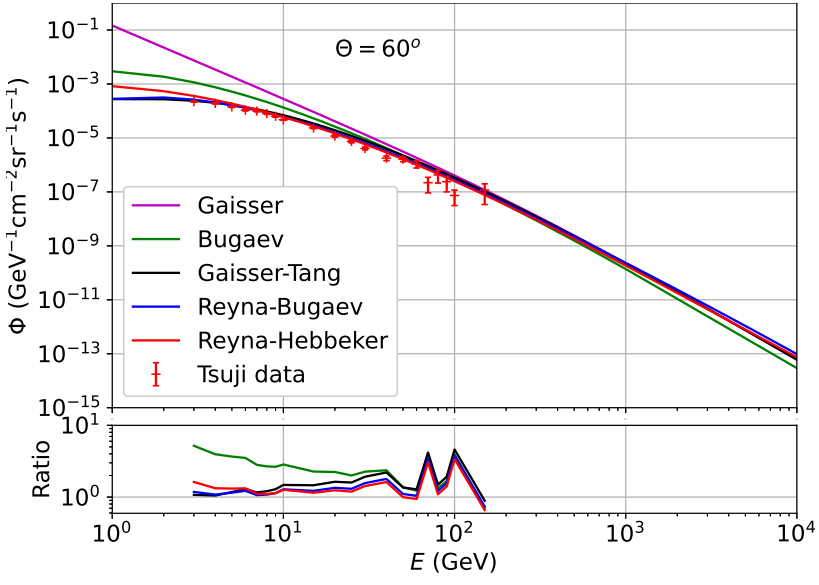
Rock thickness: Cerro Machín

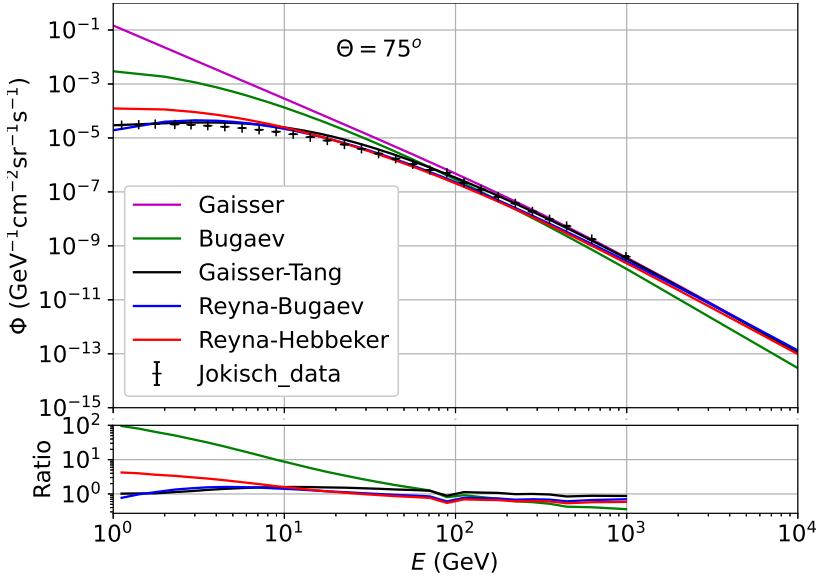


Muon generation: parametric models

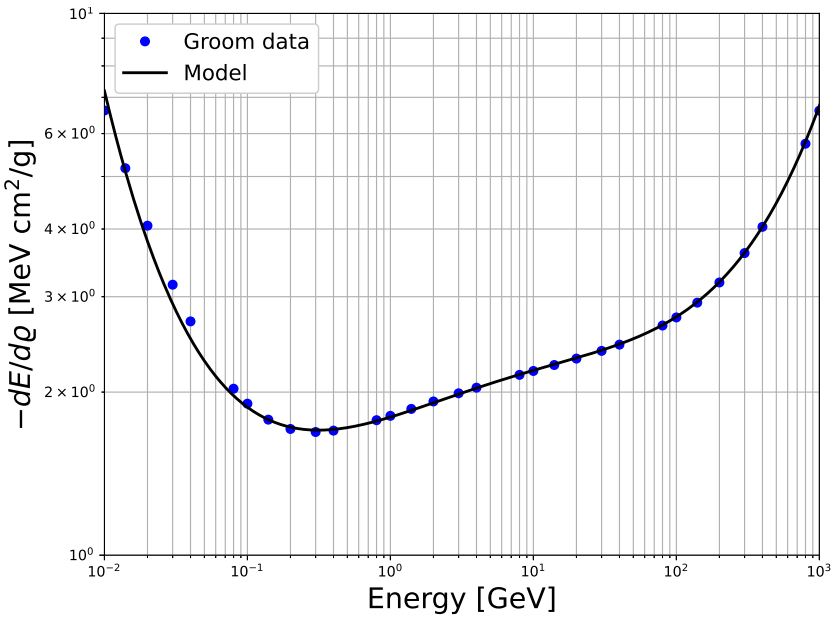


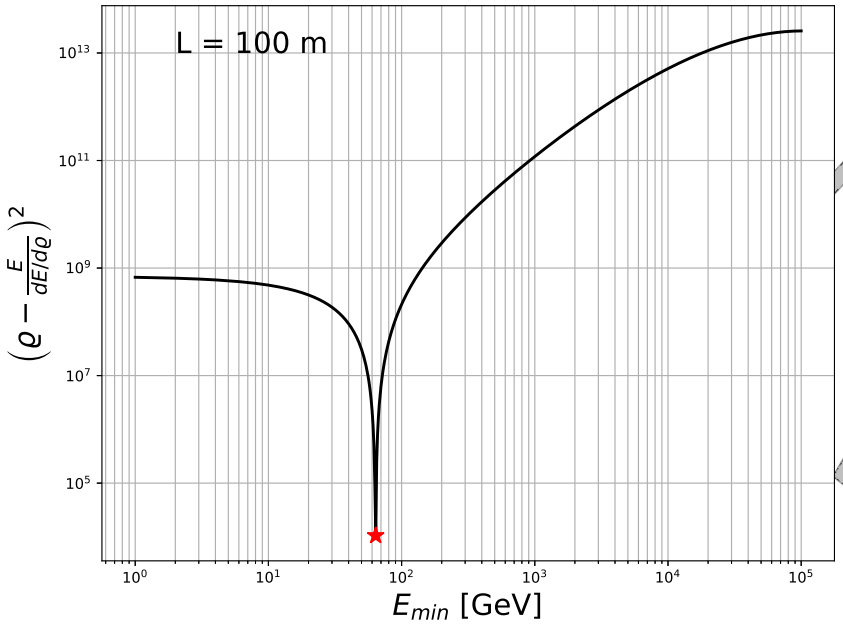






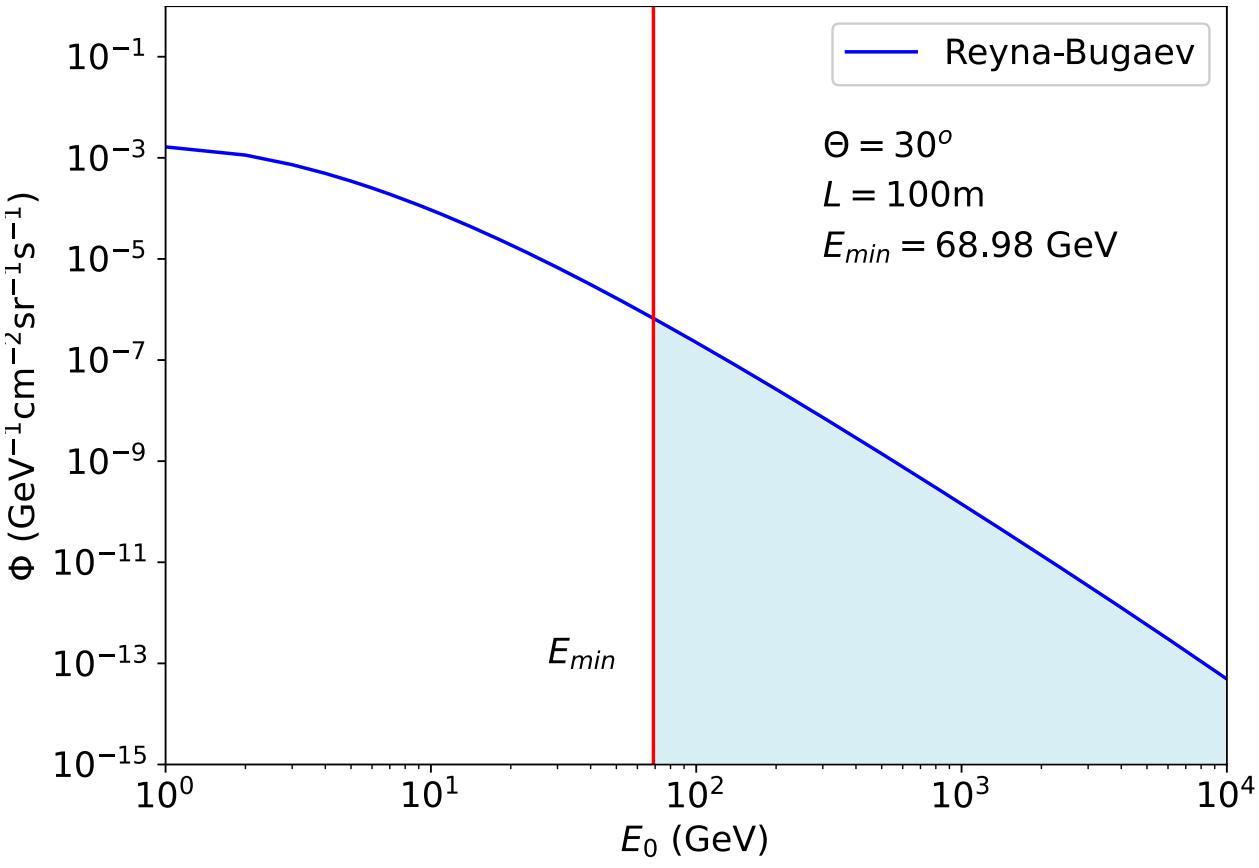
Muon transport: Muon energy loss in standard rock





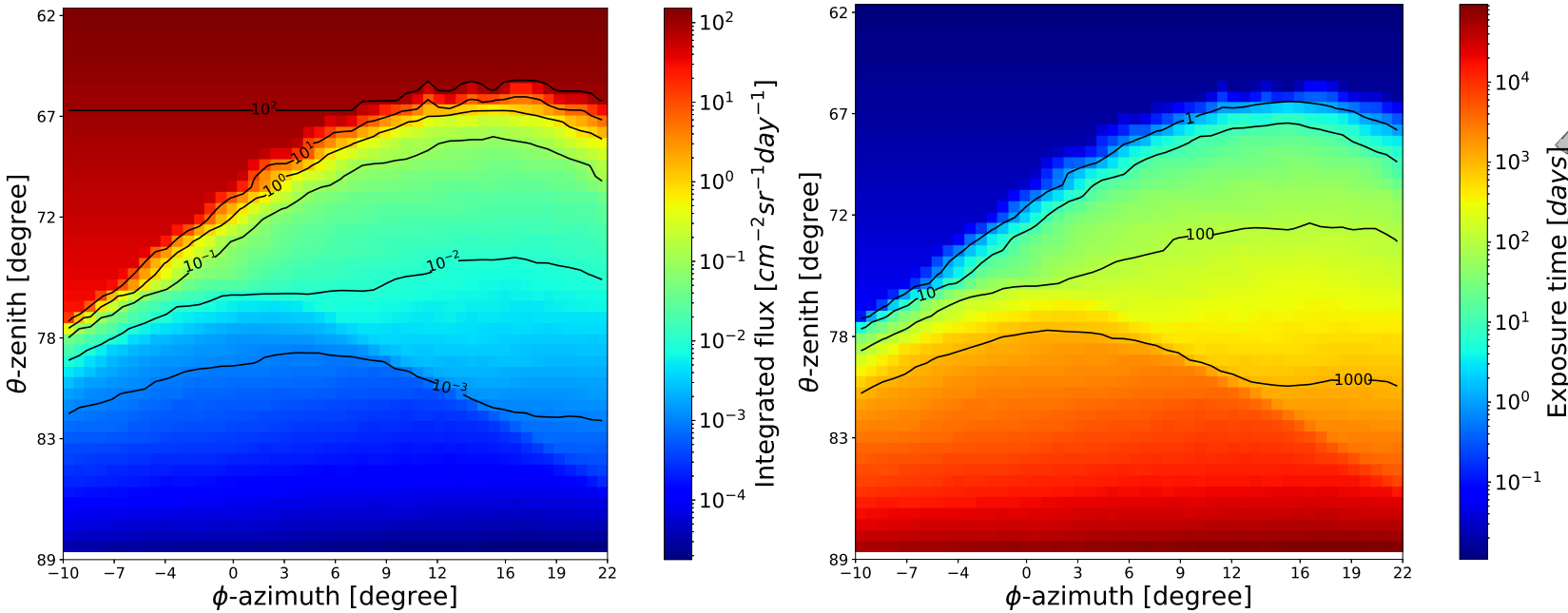
Function minimization obtains E_{min} for a given distance

Traversing muon flux: Estimation



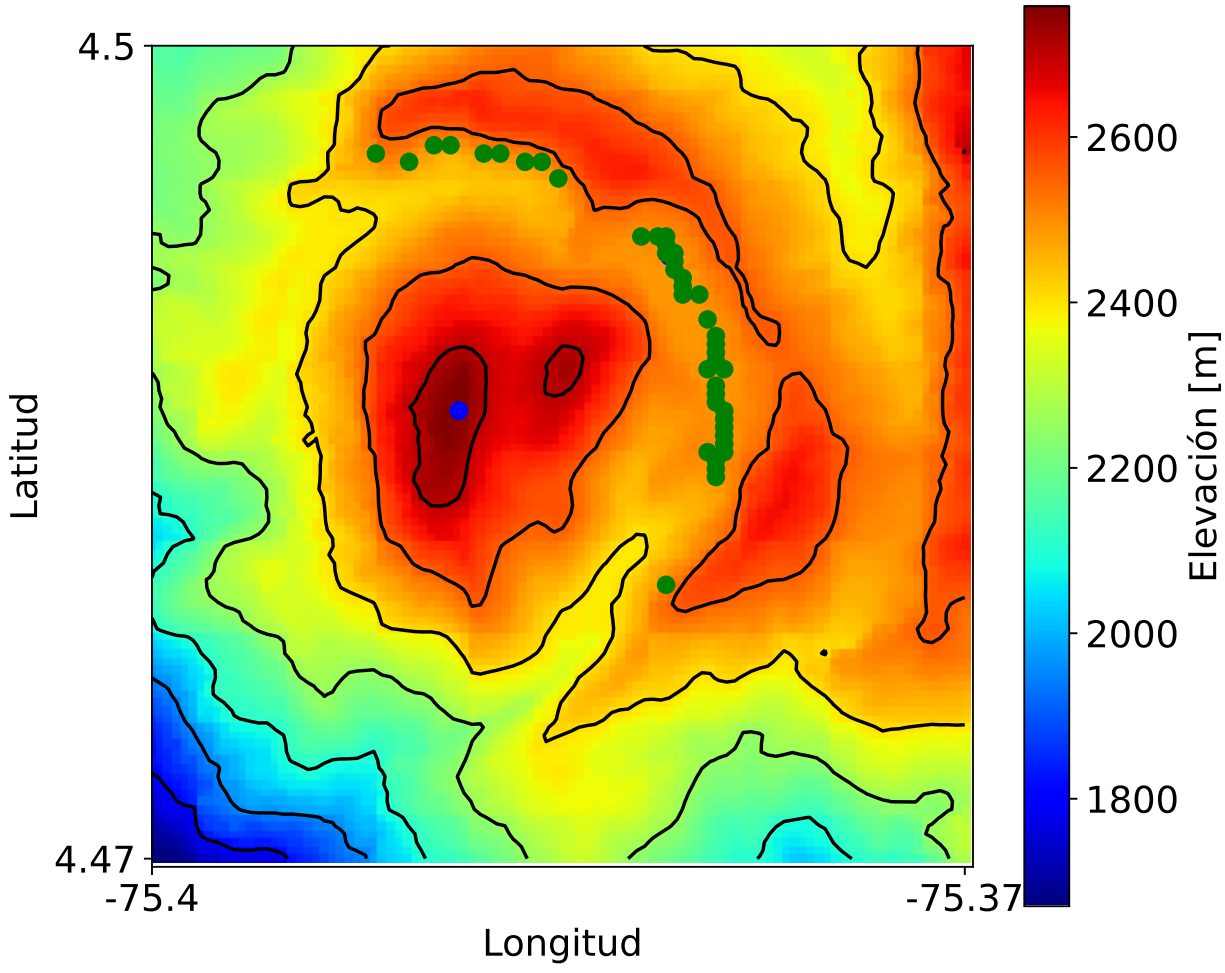
$$I(\varrho,\theta) = \sum_{E_{min}}^{\infty} \Phi(E_0,\theta)\Delta E_0 \ [cm^{-2}sr^{-1}s^{-1}]$$

Traversing muon flux: Cerro Machín



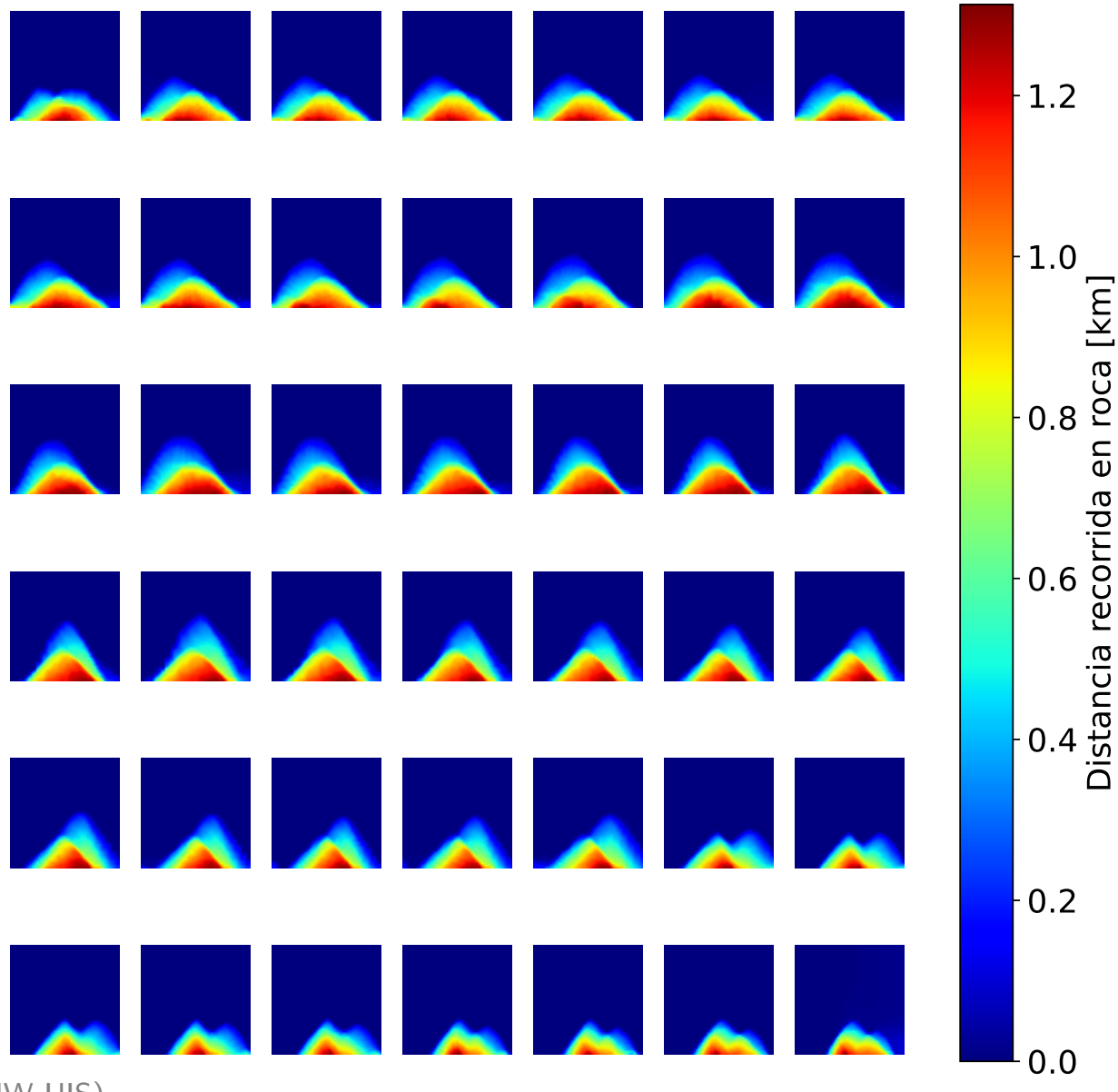
MUYSC: Muon tomography

Observation points: Cerro Machín

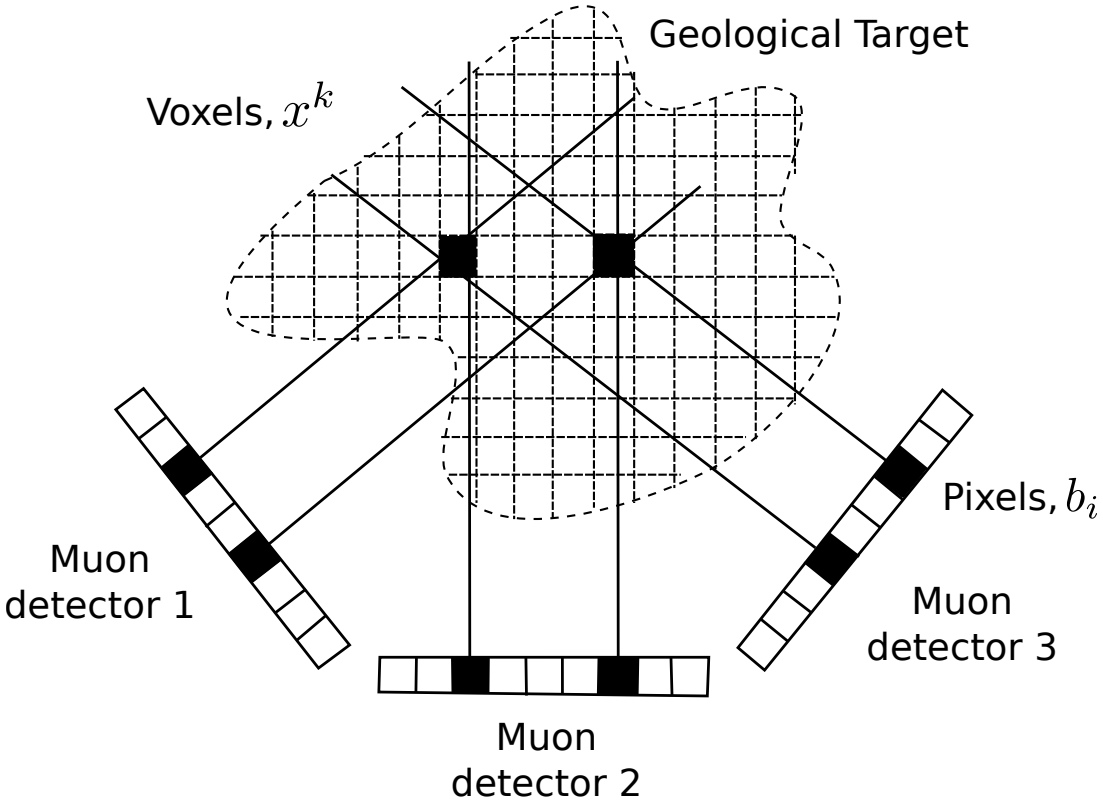


Equidistant points at same altitude

Observation projections: Cerro Machín

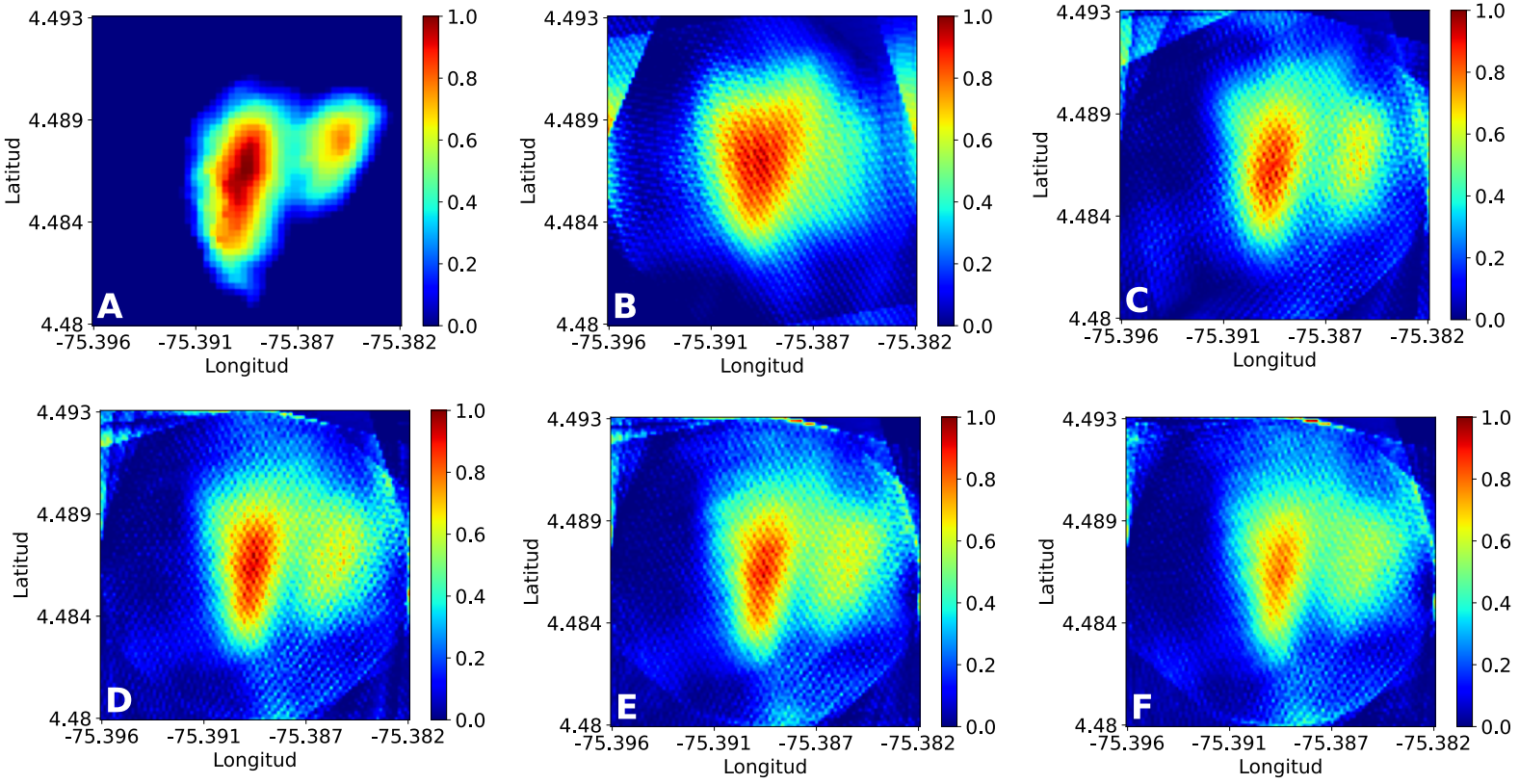


Reconstruction: Algebraic Reconstruction Technique



- Few projections
- No-equidistant between them

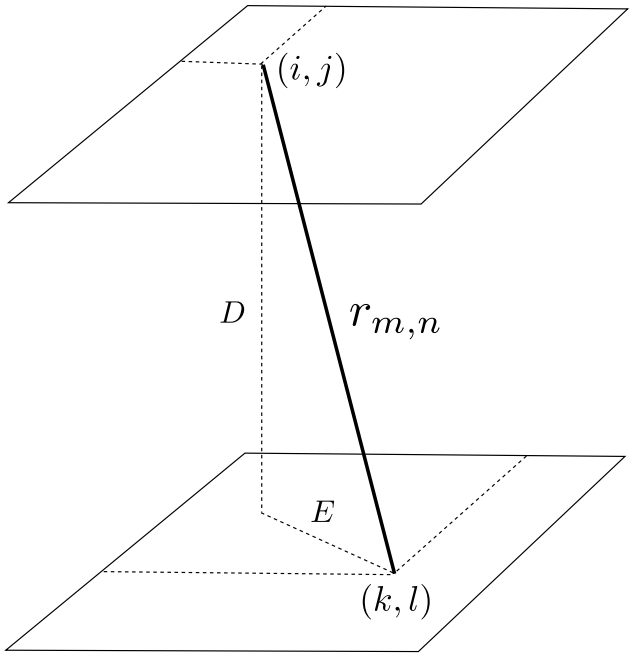
Reconstruction: Cerro Machín

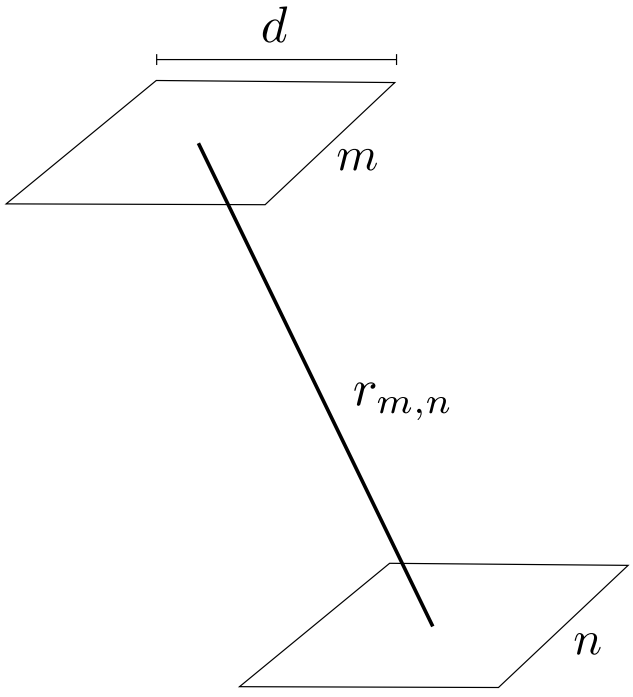


A) Original. B) 4 points. C) 8 points. D) 14 points. E) 21 points. F) 42 points.

MUYSC: Telescope parameterization

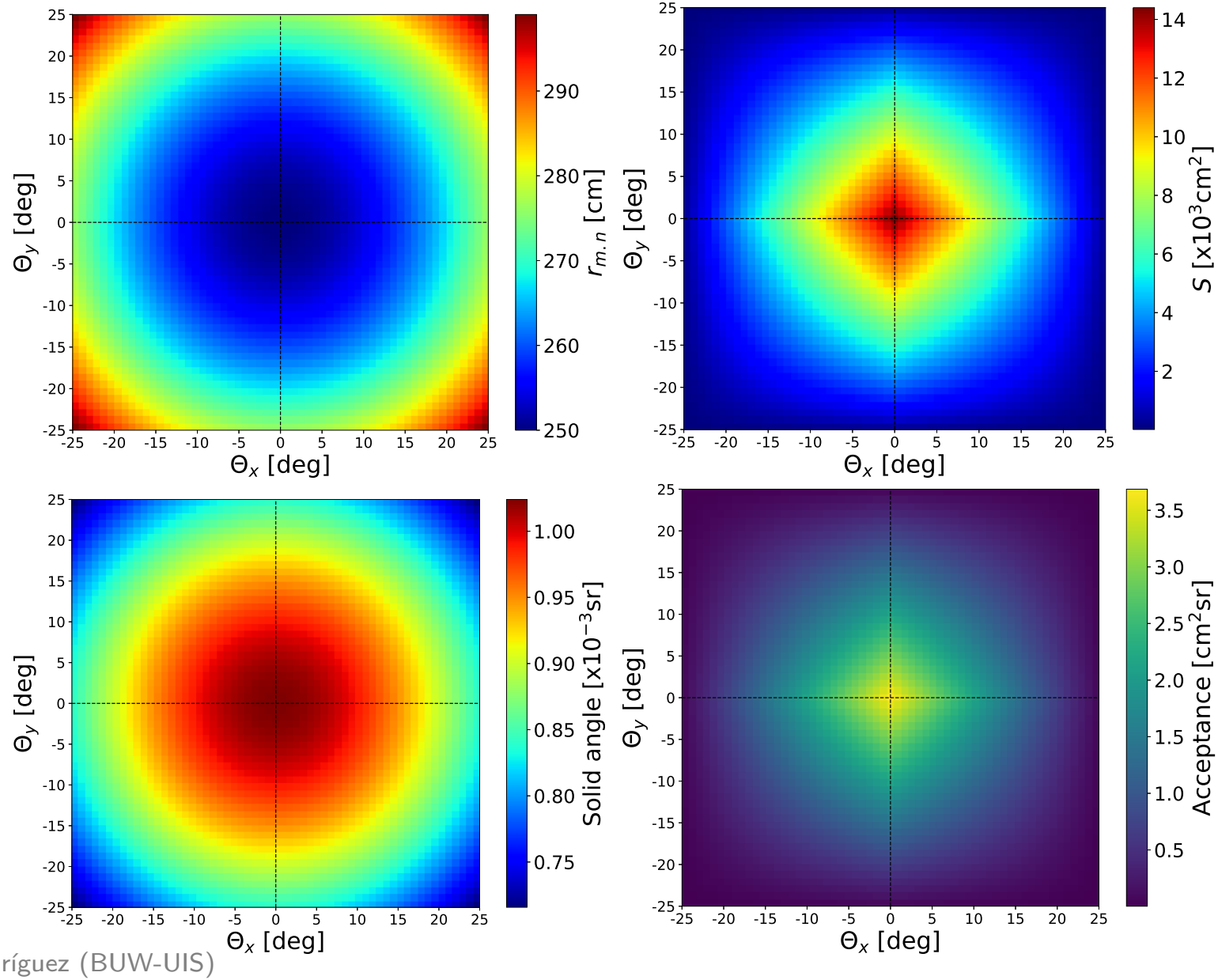
Solid angle and acceptance





$$\mathcal{T}(r_{m,n}) = S(r_{m,n}) \times \delta\Omega(r_{m,n}), \quad \text{where } \delta\Omega = \frac{4A}{r_{m,n}^2} \text{ and } S(r_{m,n}) = N_P A$$

MuTe parameterization



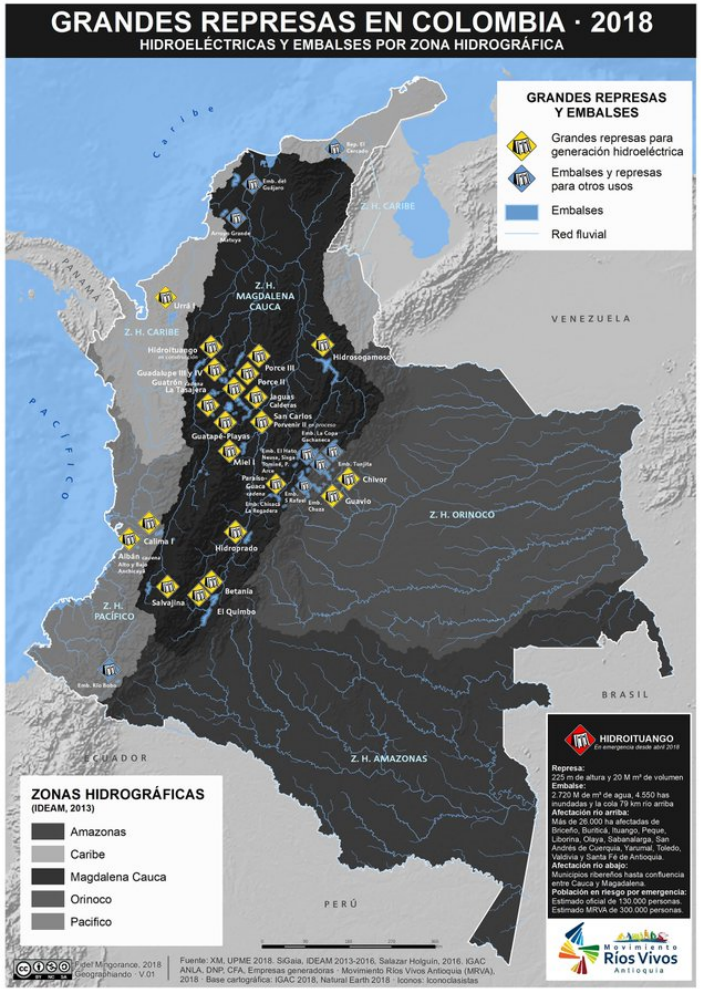
Summary & outlook

Python-based code for moun radiography and tomography

- Open source and easy to install
- Evaluates telescope design parameters: resolution, positioning ...
- Estimates traversing muon flux, observation time, transmission matrices, detector muon rate...
- Takes into account muon flux screening
- Optimizes minimum number of projections for muon tomography reconstruction
- Fast: 50×50 pixel muogram in $\sim 2\,\text{min}$

It doesn't pretend replace MonteCarlo codes as GEANT4, CORSIKA for detailed studies.

What's going on?



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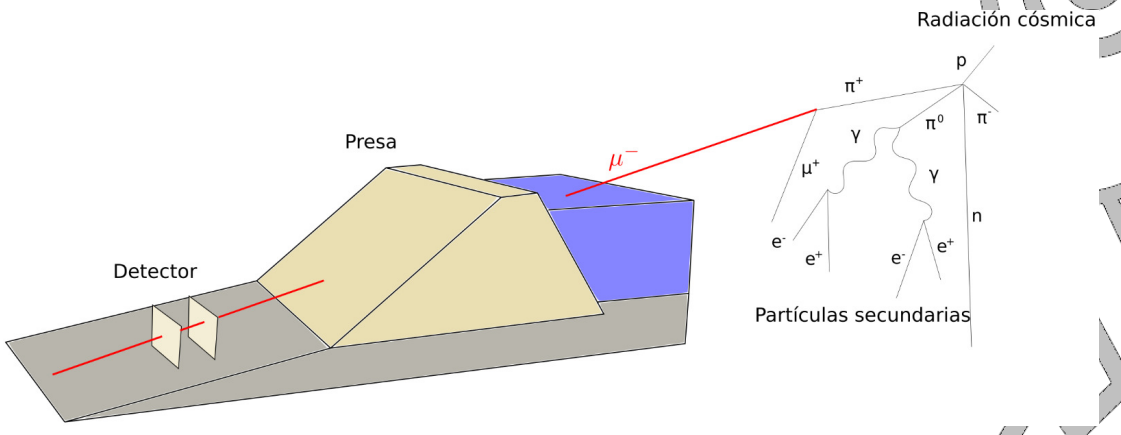
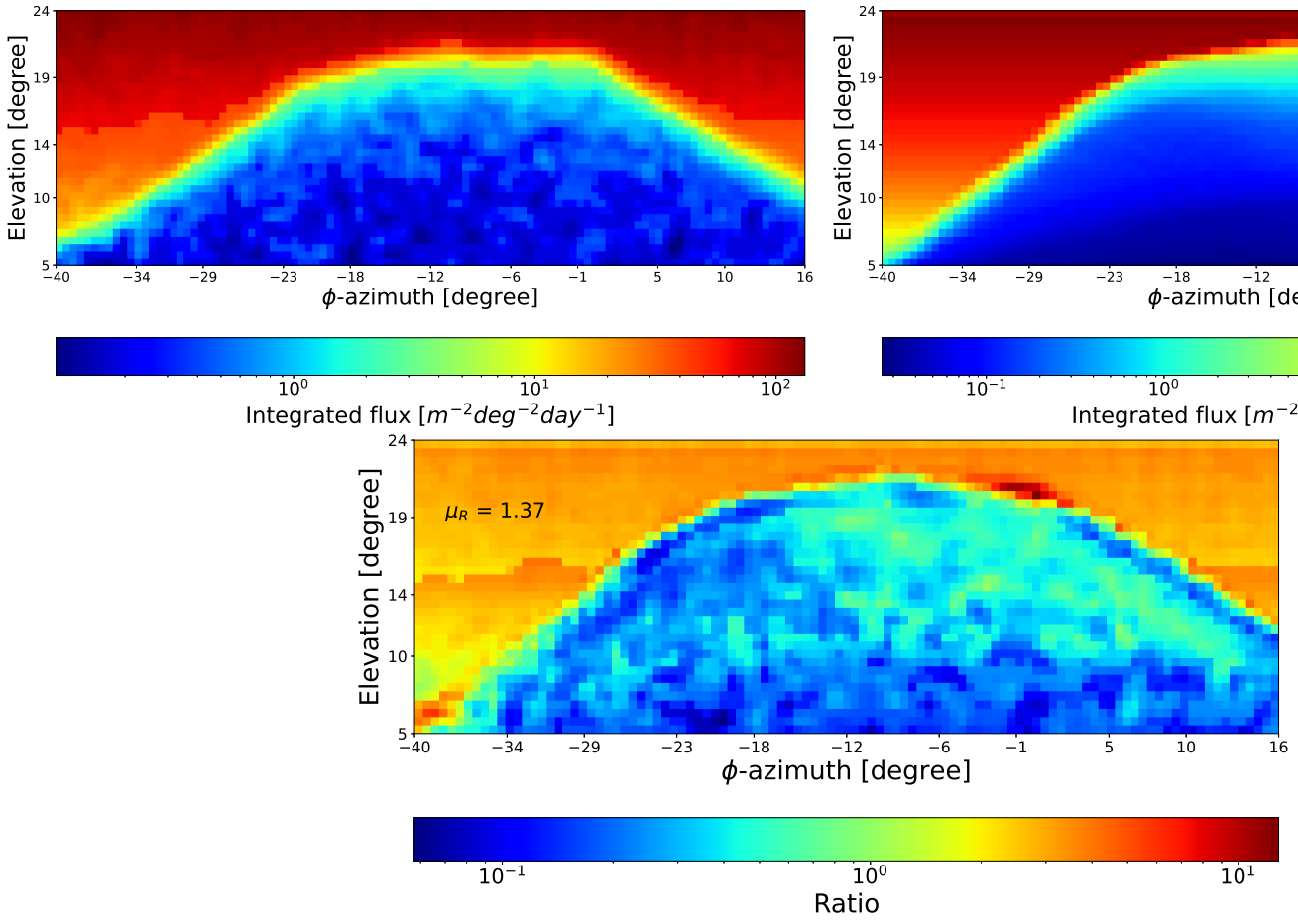


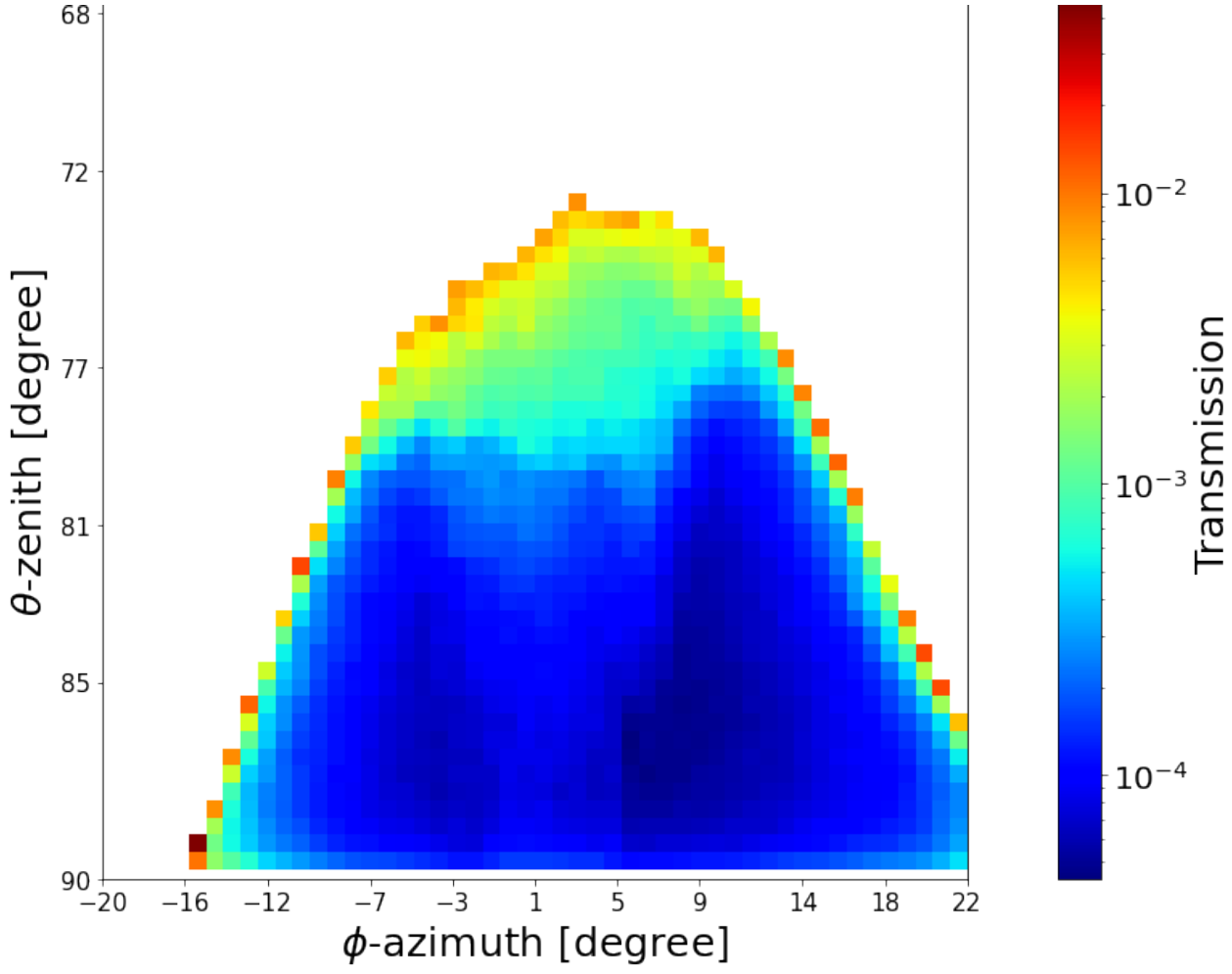
- Civil structures: Dams and water reservoirs
- Evaluate detector requirements for cracking, piping, and void inspection
- Standard STL 3D files

Gracias!

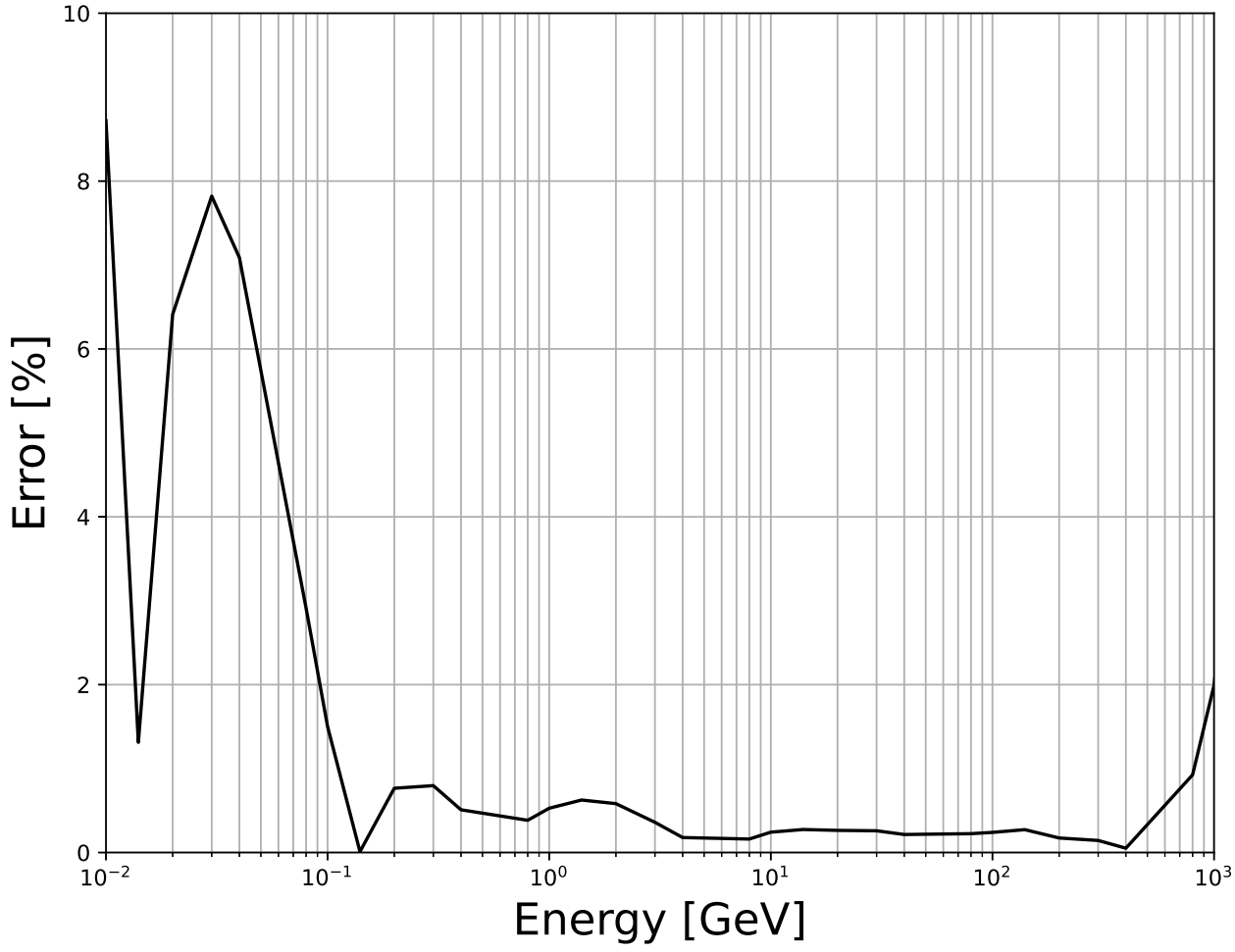
Validation


Elevation [degree]
ϕ-azimuth [degree]
Integrated flux [$m^{-2}deg^{-2}day^{-1}$]
Elevation [degree]
ϕ-azimuth [degree]
Integrated flux [$m^{-2}deg^{-2}day^{-1}$]
μ_R = 1.37
Elevation [degree]
ϕ-azimuth [degree]
Ratio

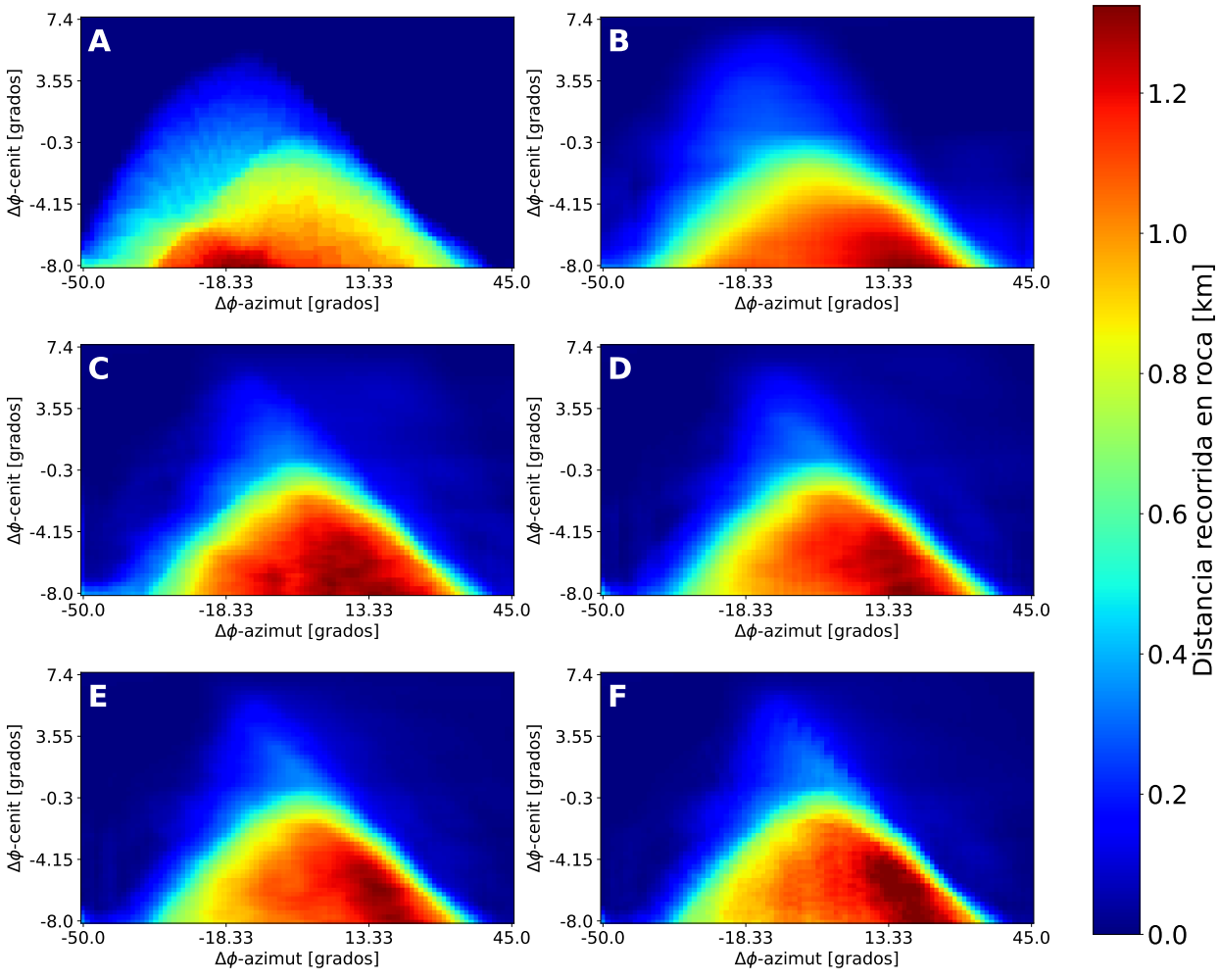
Muon transmission and observation time



Energy loss error



Reconstruction: Cerro Machín



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