Parameterizing cosmogenic neutron flux to measure soil moisture

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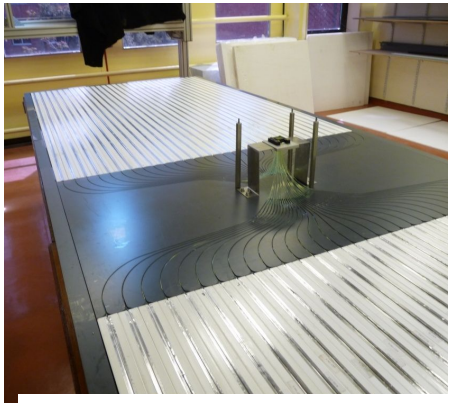
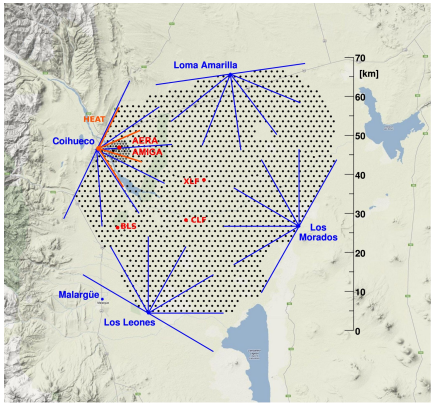
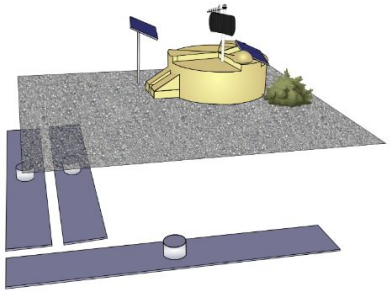
Background: LAGO, AMIGA and MuTe

AMIGA is a buried muon counter designed to study the UHECR composition at the Pierre Auger Observatory by measuring the EAS muon distribution density at ground





LAGO is a giant network of astroparticle WCD detectors, currently operating in 11 countries. The LAGO network measures the time-evolving flux of secondary particles produced by the modulated flux of GCR

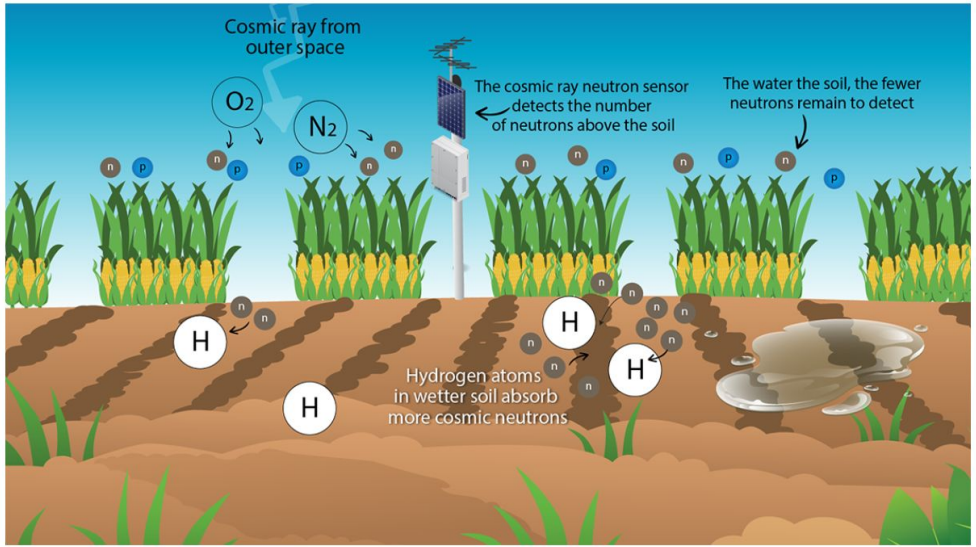


MuTe Project

MuTe is a two-panel, 900px and hybrid muographer, scintillators & WCD, designed, funded and built in Latin America

MuTe
The Muon Telescope

Measuring neutrons to estimate soil moisture



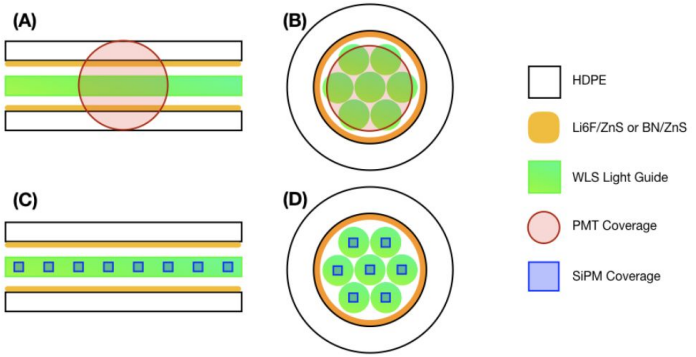
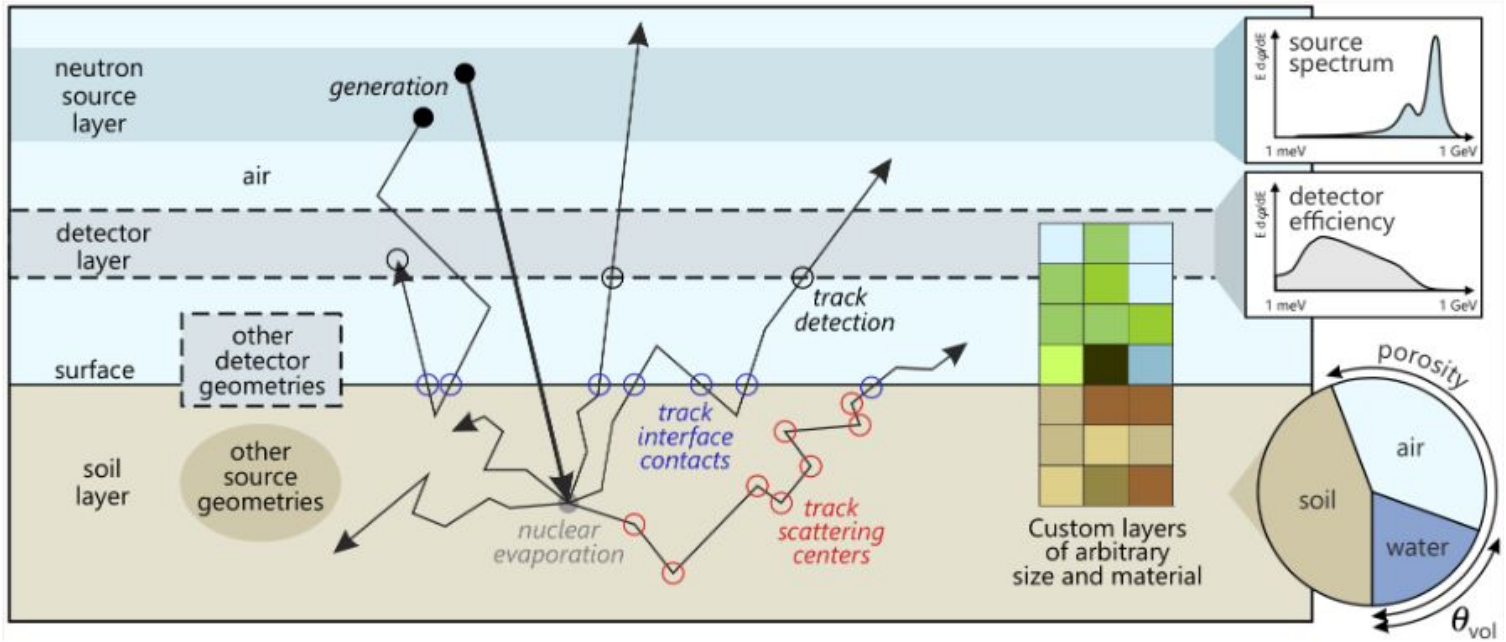


figure taken from IAEA bulletin

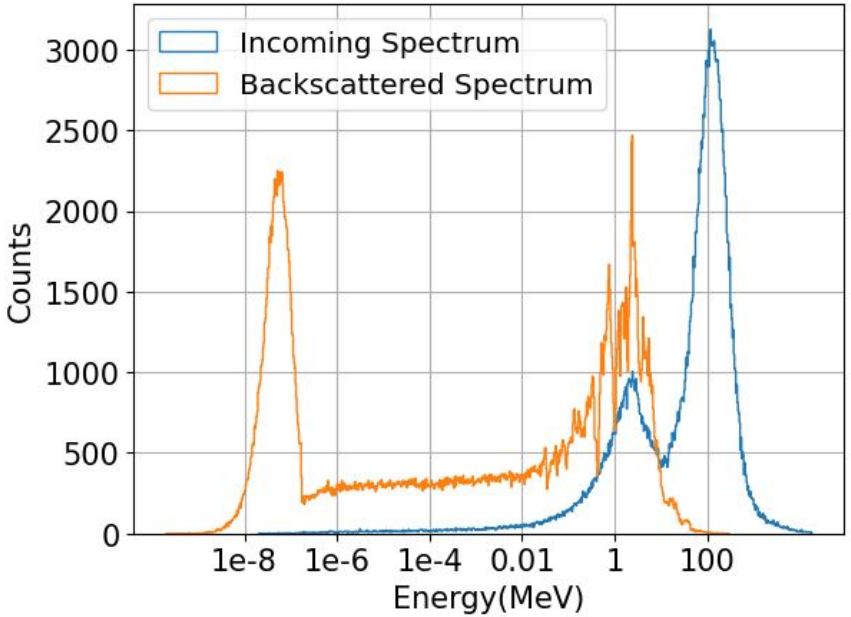
P. Stowell *et al* 2021 *JINST* **16** P11039
DOI 10.1088/1748-0221/16/11/P11039

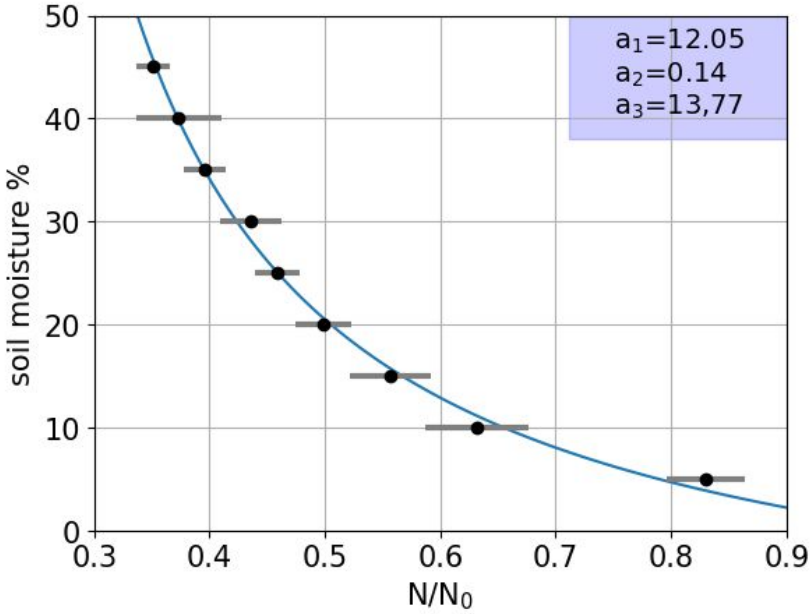
Ultra Rapid Neutron-Only Simulator, URANOS



Köhli et al., URANUS, 2022
https://doi.org/10.5194/gmd-16-449-2023

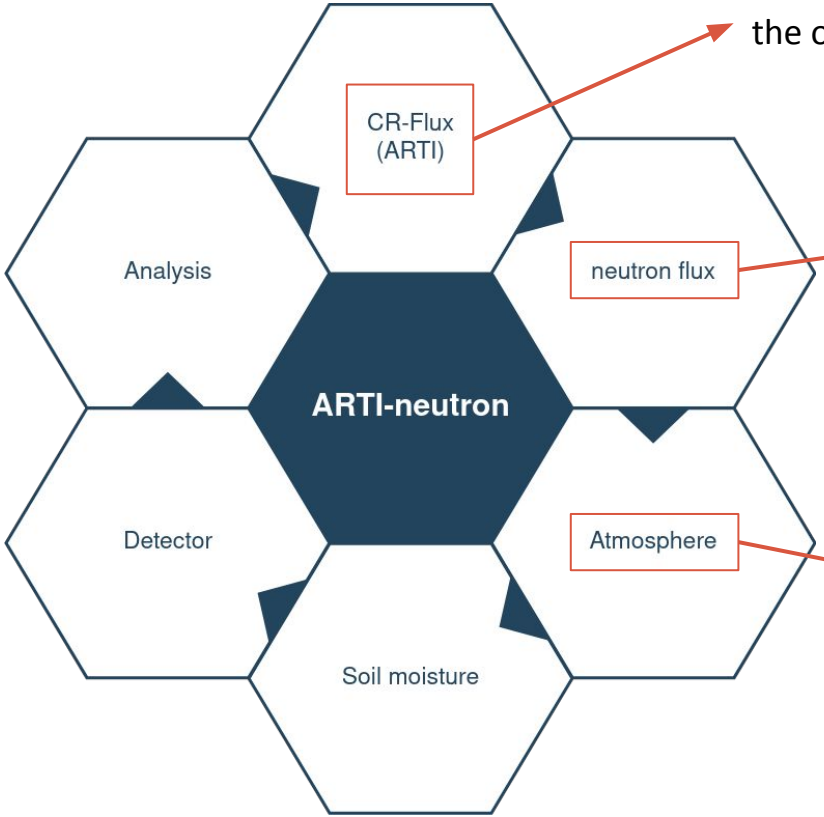
Results from URANOS





URANOS lacks consideration for both the duration of the simulation and the altitude of the observation level.

ARTI-neutron



Simulations of cosmic rays 2 km above the observation level using ARTI.

Parameterization of the neutron flux taking into account the dependence on height, atmosphere and geomagnetic field

Atmospheric profile related to the place of observation. Comparison of the flux in different atmospheres. Parameterize atmospheres by terrestrial zone

The ARTI Framework

A framework designed to simulate the signals produced by the secondary particles emerging from the interaction of the flux of primary cosmic ray with the atmosphere. These signals are simulated for any particle detector located at any place (latitude, longitude and altitude), including the real-time atmospheric, geomagnetic and detector conditions.

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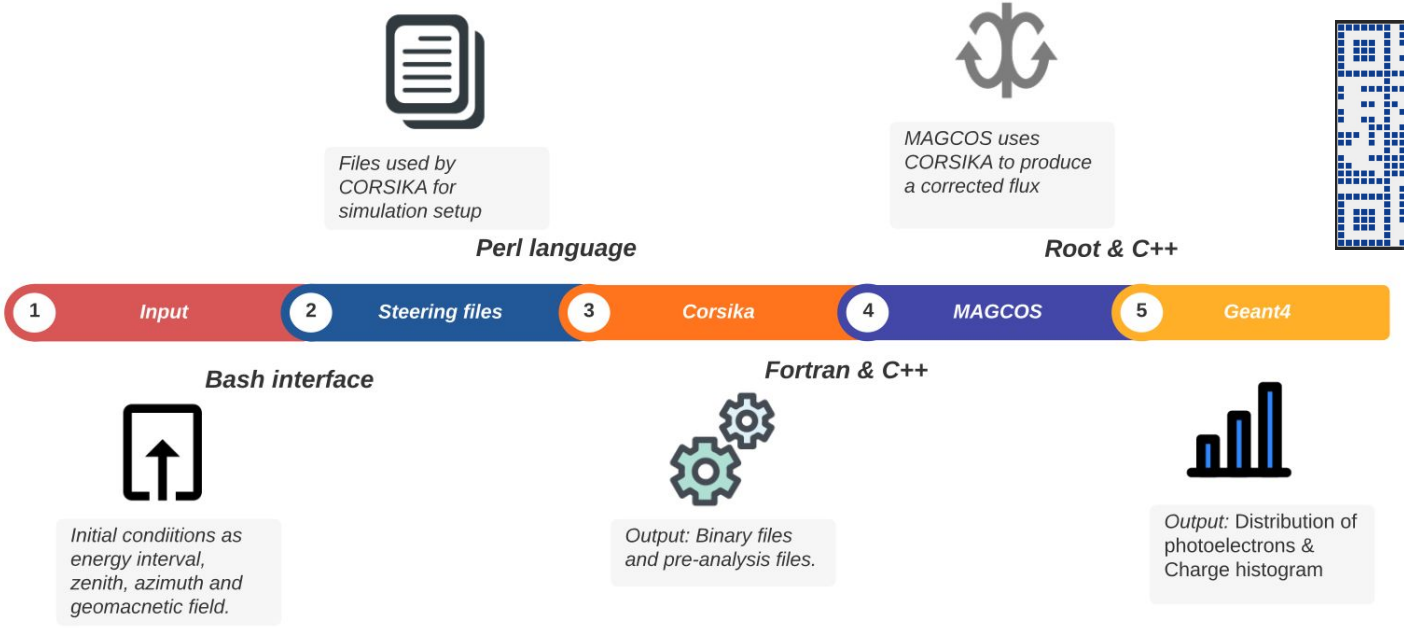
Github repository

Sarmiento-Cano et al., 2022
https://doi.org/10.1140/epjc/s10052-022-10883-z

Cosmic ray flux from Corsika -> ARTI

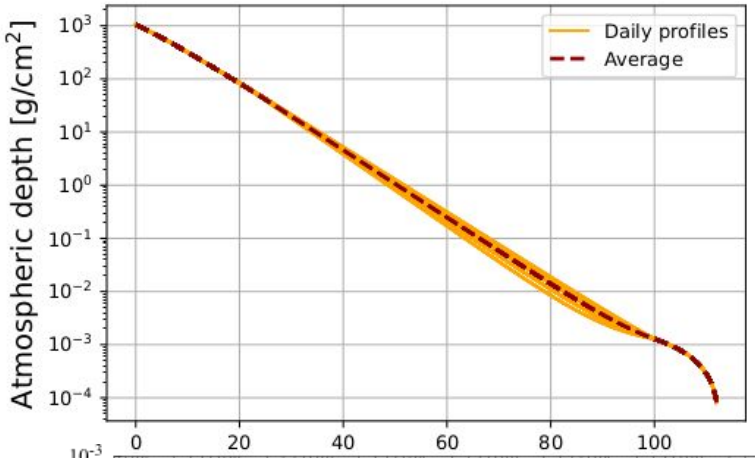
Github repository

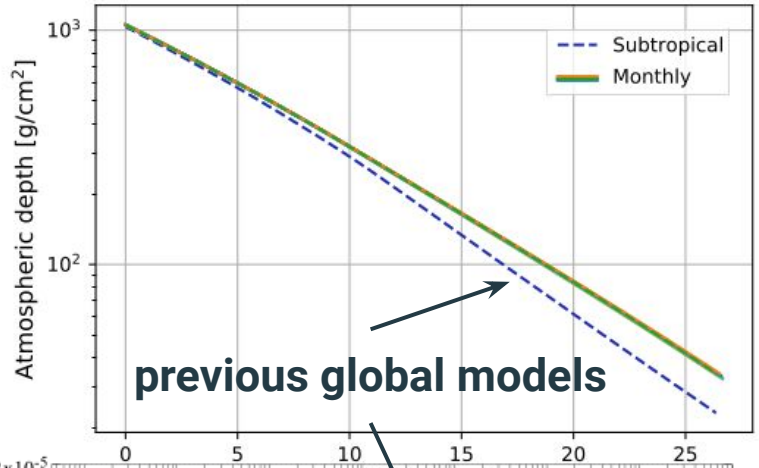


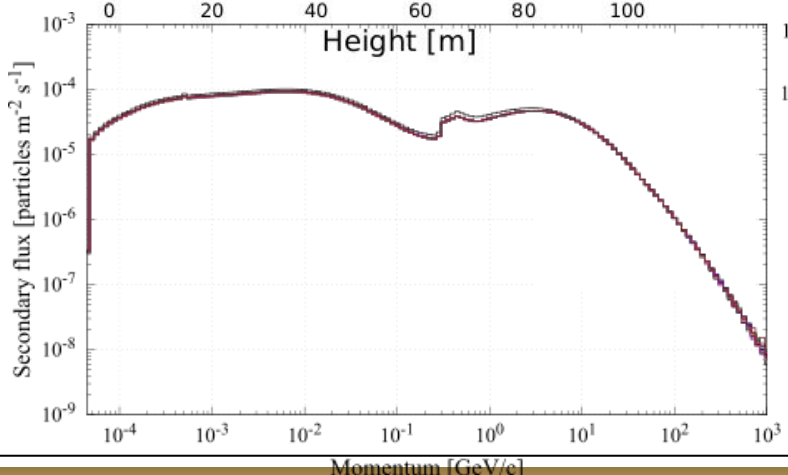
Sarmiento-Cano et al., 2022
https://doi.org/10.1140/epjc/s10052-022-10883-z

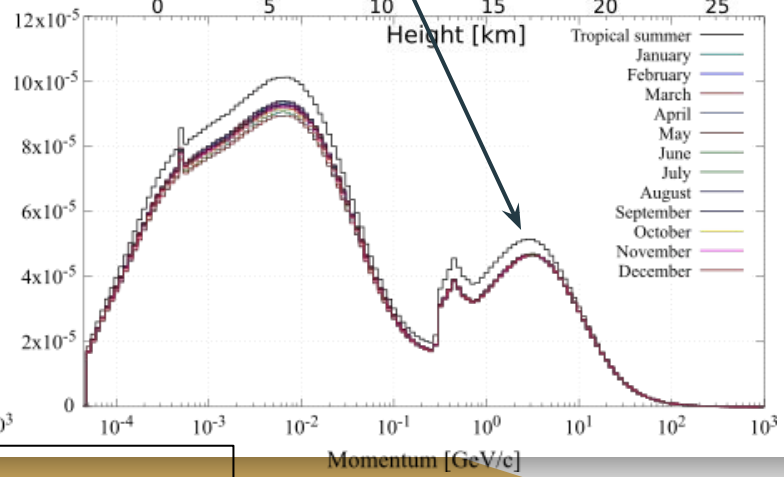
local atmospheric effects

Monthly-averaged or instantaneous local atmospheric profiles from GDAS



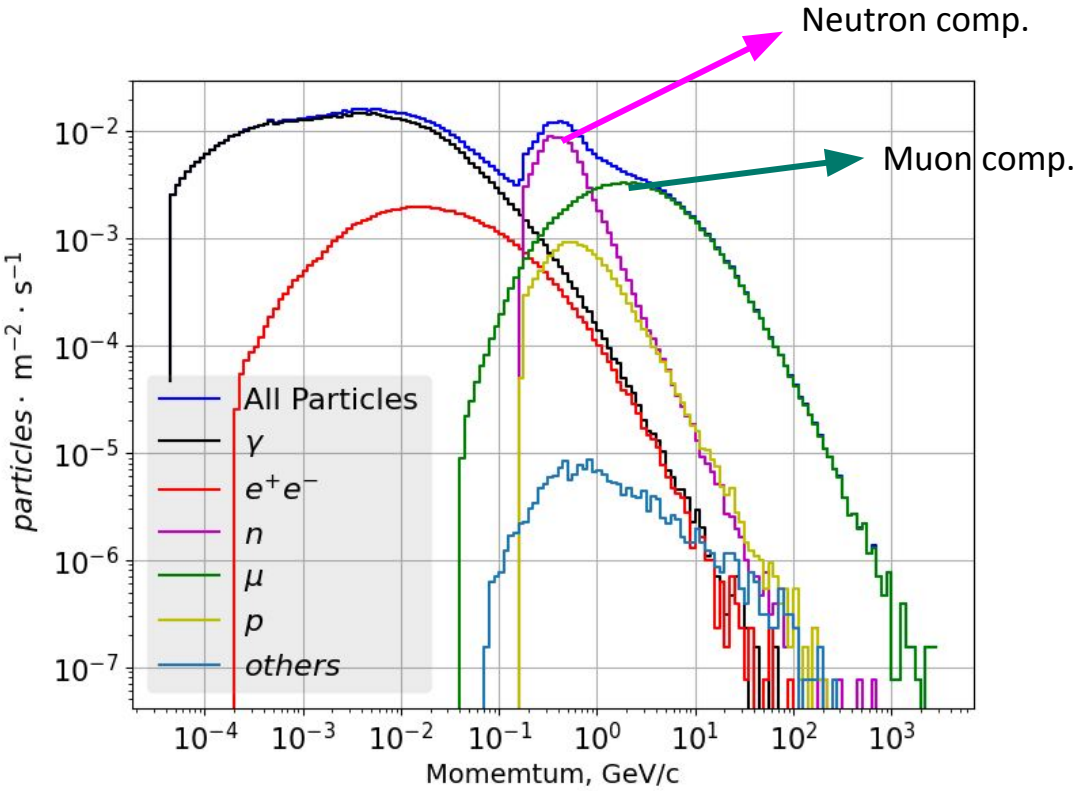




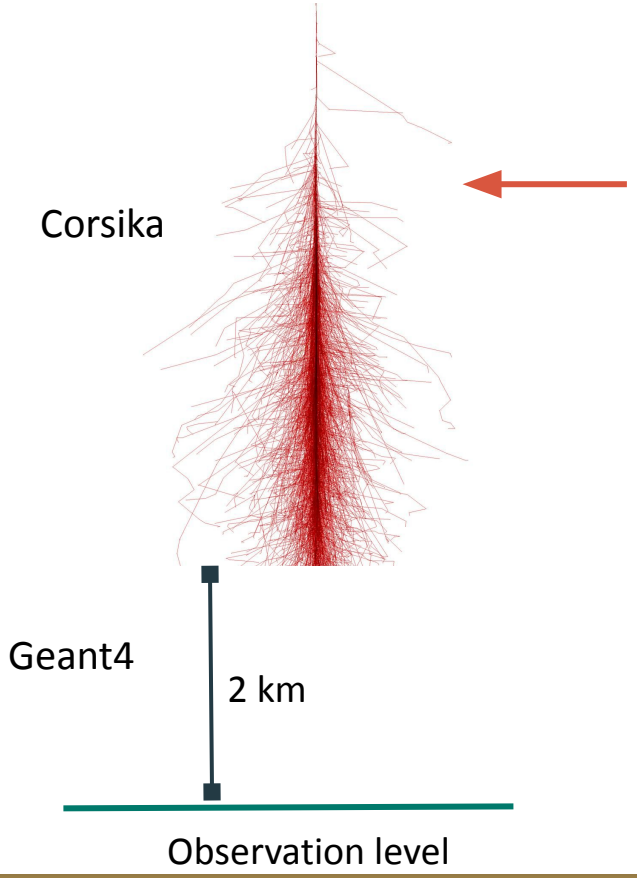


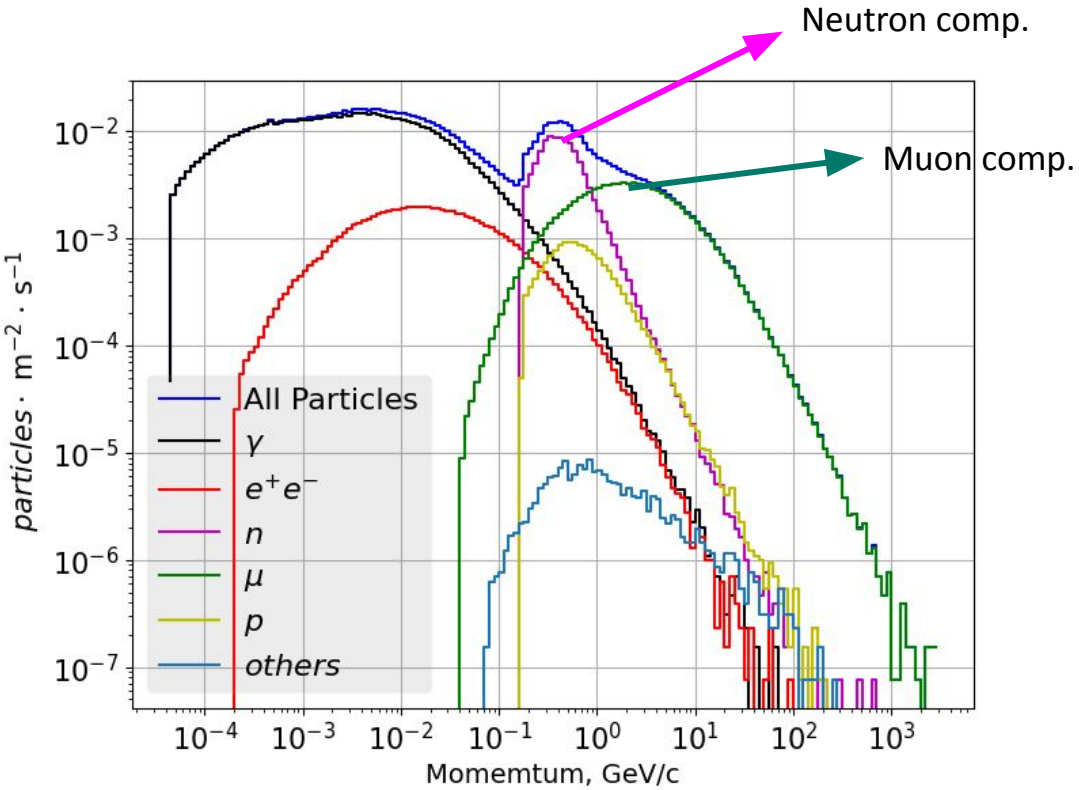
J. Grisales et al., CJP, 2021 https://doi.org/10.1139/cjp-2020-0561

Cosmic ray flux from ARTI(Corsika)

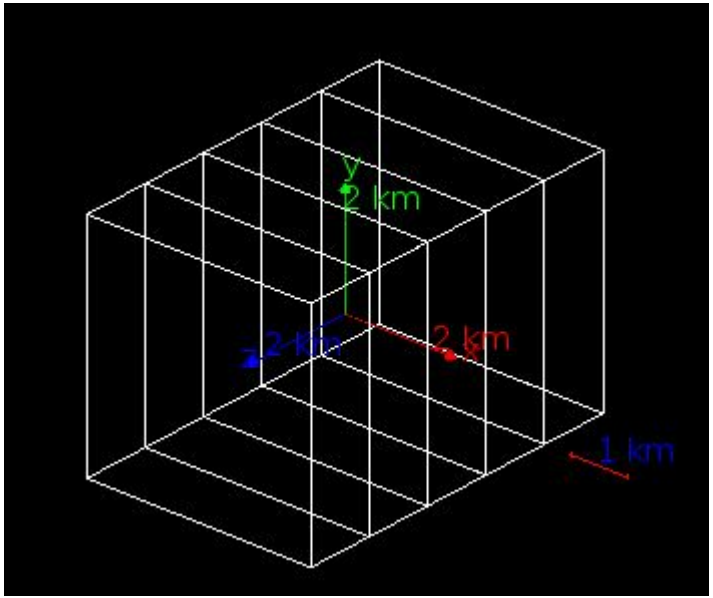


ARTI(Corsika) + Geant4 = ARTI-n

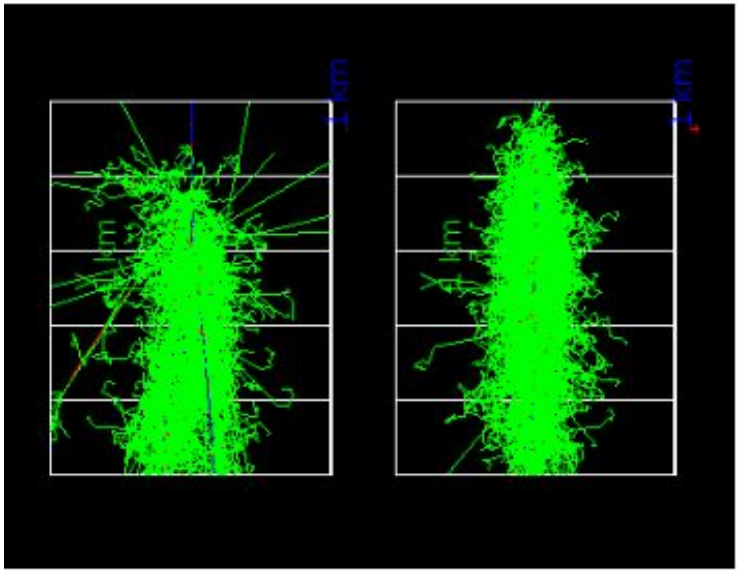




ARTI(Corsika) + Geant4 = ARTI-n

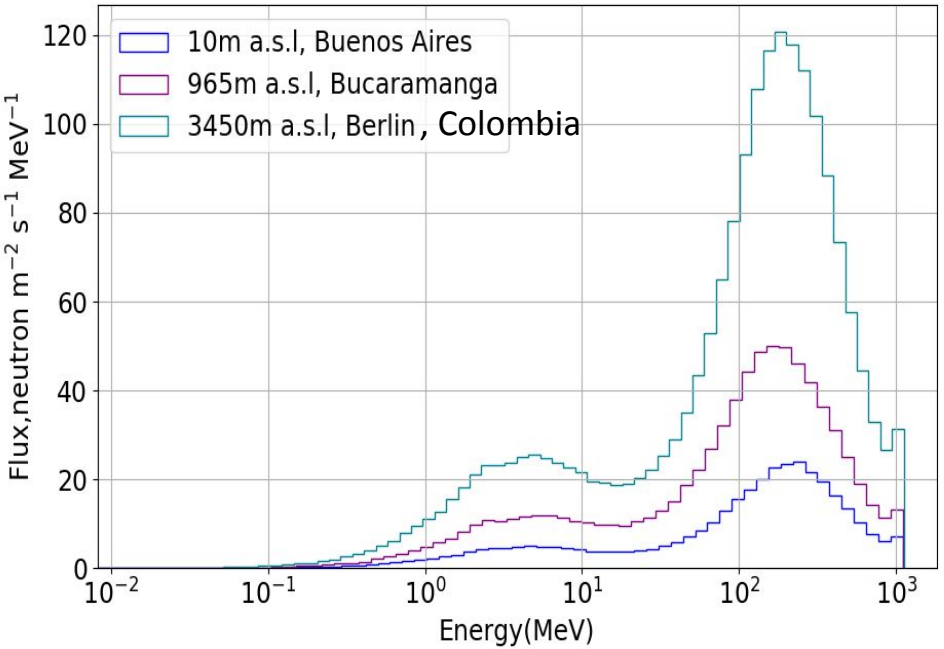


The world defined in Geant4 for this simulation is 2 km x 1 km x 2 km. In addition, it includes 5 layers of atmosphere that change with height.



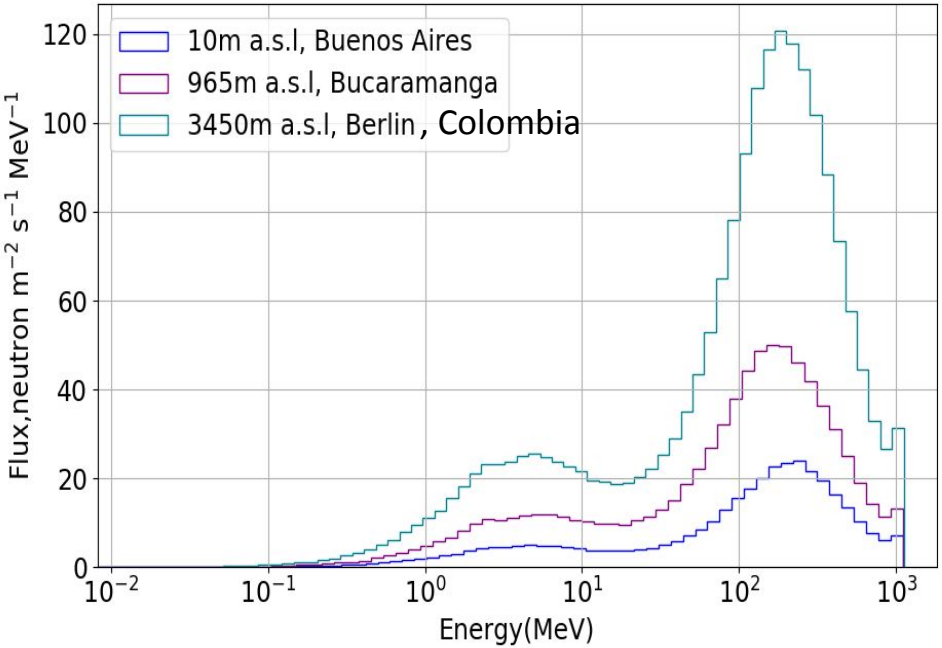
Photon and proton shower.

Results

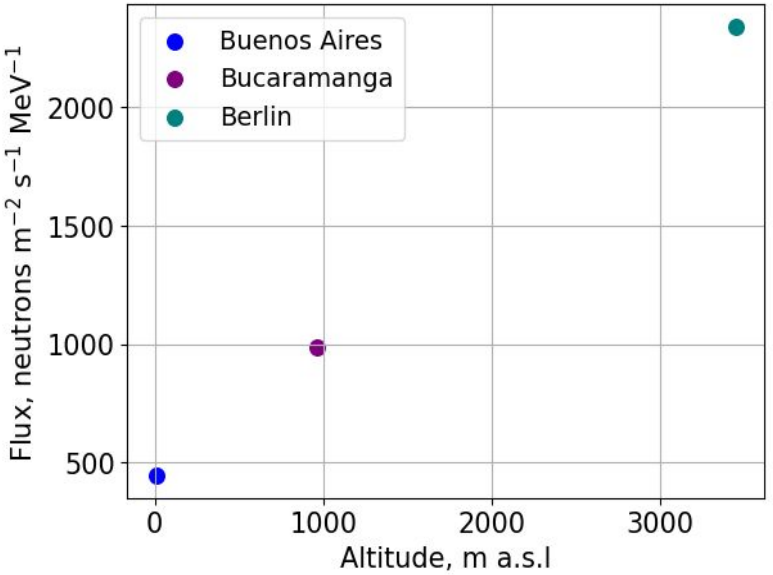


Neutron flux in three cities with different altitudes.

Results



Neutron flux in three cities with different altitudes.



The difference in neutron flux between a city near sea level and one at 3450 m a.s.l. is almost 5 times.

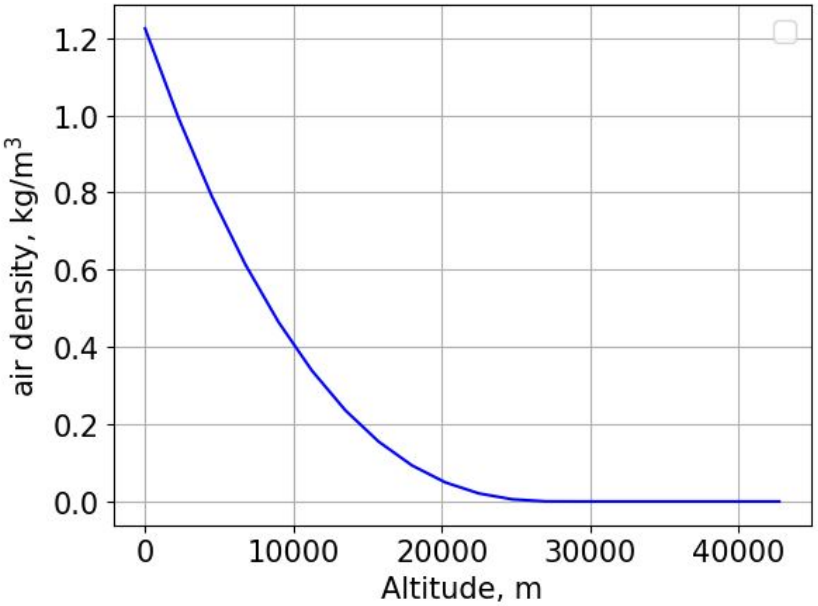
Conclusions

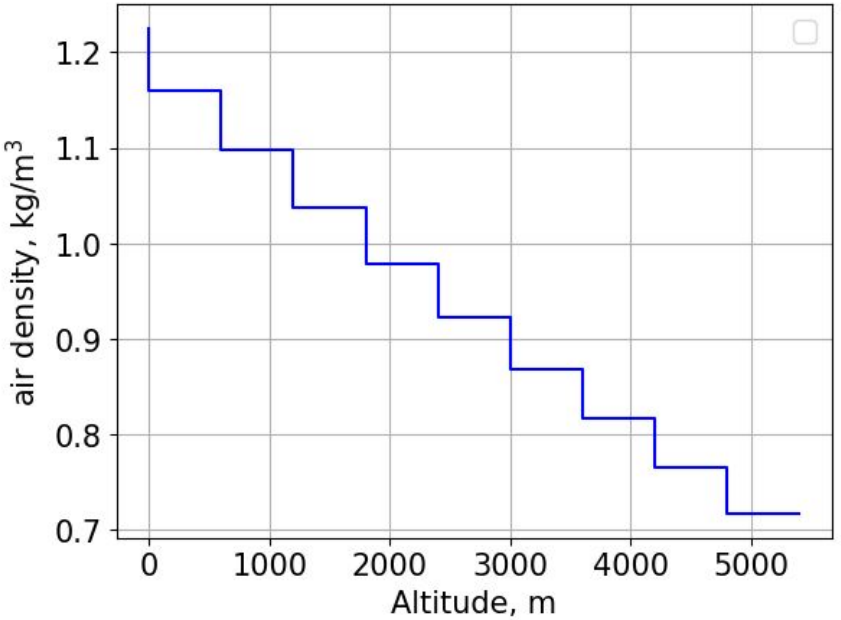
- We are currently developing a simulation framework to study various scenarios related to the use of neutron detectors for soil moisture detection in smart agriculture. Our goal is to explore the applications of neutron detectors in this context and gain a deeper understanding of their capabilities.
- During our research, we have a strong correlation between neutron flux and altitude. This dependency is crucial for calibrating the detectors accurately in field settings. By taking altitude into account, we can enhance the precision of the detectors and ensure reliable measurements of soil moisture.

Future work

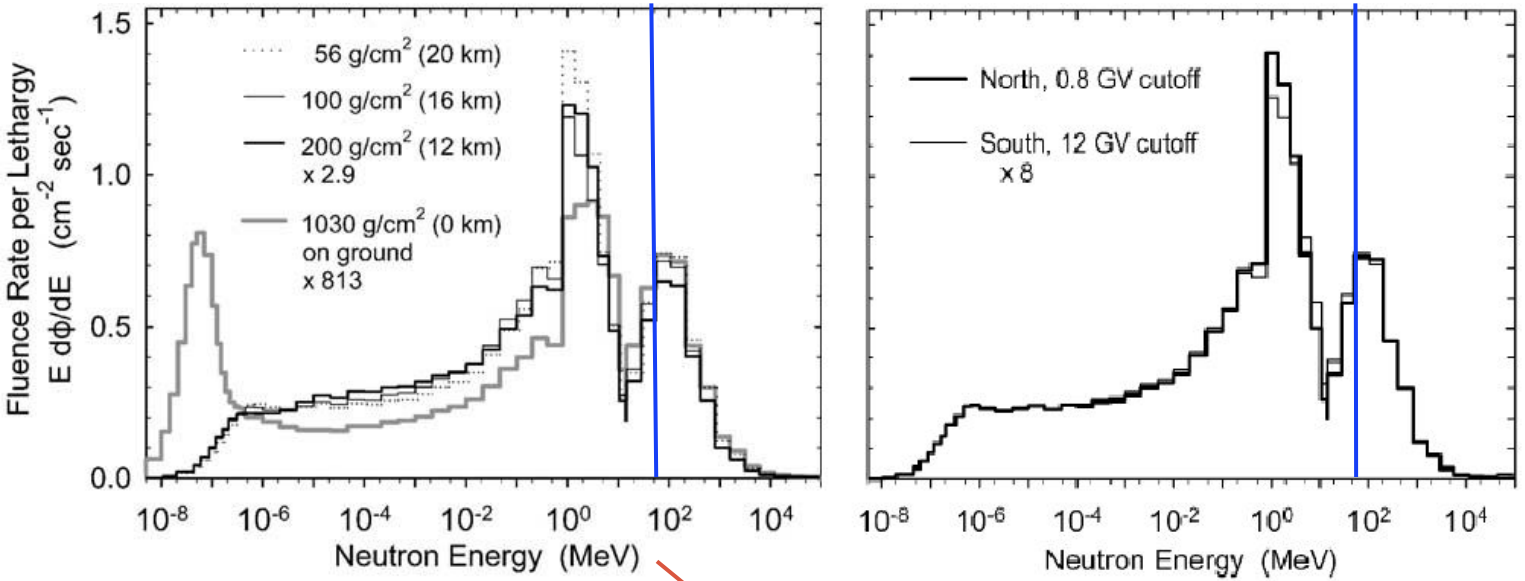
- Compare the simulation results with real data to validate the accuracy of the framework.
- Develop tools within the simulation framework to analyze the data generated by the simulations. Implement algorithms and statistical techniques like machine learning.

¡Gracias!


air density, kg/m^3
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0
10000
20000
30000
40000
Altitude, m


air density, kg/m^3
1.2
1.1
1.0
0.9
0.8
0.7
0
1000
2000
3000
4000
5000
Altitude, m

Cosmic neutron spectrum



Corsika limit

Goldhagen et al. (2002), ASR Volume 32, Issue 1, 2003, P35-40