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MUOGRAPHY APPLICATIONS at IFIN-HH

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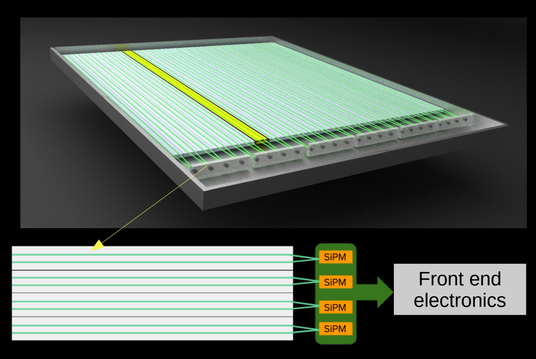
Cosmic rays have been studied in the Astroparticle Physics Group of IFIN-HH for the last 20 years and what firstly began as fundamental research is continued to the present day by the development of muon detectors to be used in transmission muography applications. In our group, we focus on two main cases: scanning dense objects at ground level in order to determine their inner characteristics, as well as imaging underground structures such as tunnels or mines. For this purpose, we have developed a detector capable of muon tracking - SiRO (SiPM ReadOut muon detector).

SiRO - SiPM ReadOut muon detector

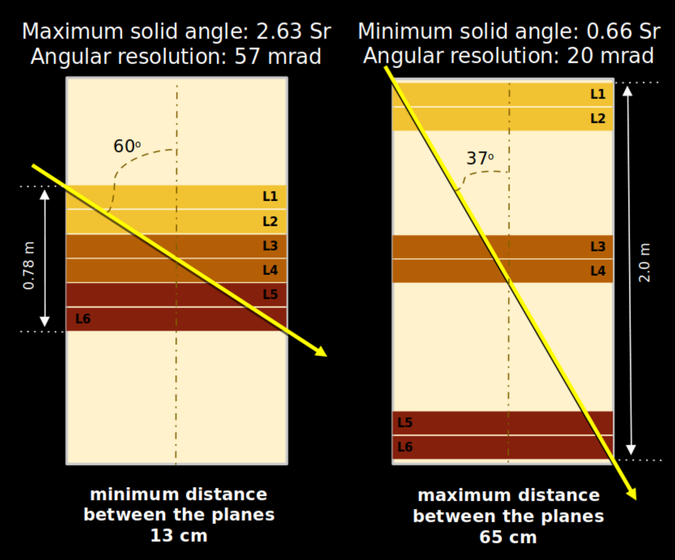
DETECTOR CONFIGURATION

SiRO is used for transmission muography applications, with plastic scintillators as active volume and SiPM devices to convert the optical signal into electric signal. It has 6 detection layers grouped two by two, in order to extract the information of trajectory for the incident muon. This picture shows the detector in its final configuration, the active medium being enclosed in light-tight metallic boxes.



- 1 m² active surface per layer
- 24 plastic scint. strips optically delimited
- 2 optic fibers on each plastic scintillator
- the collected light is readout by a SiPM device for each plastic bar

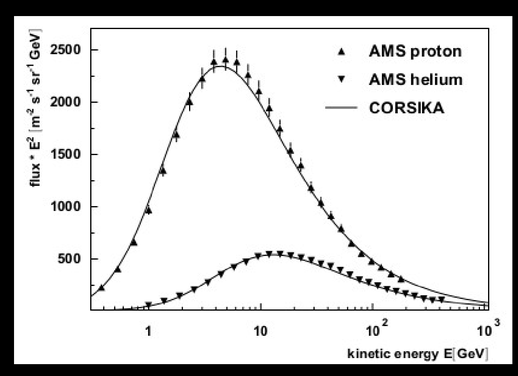
ANGULAR RESOLUTION



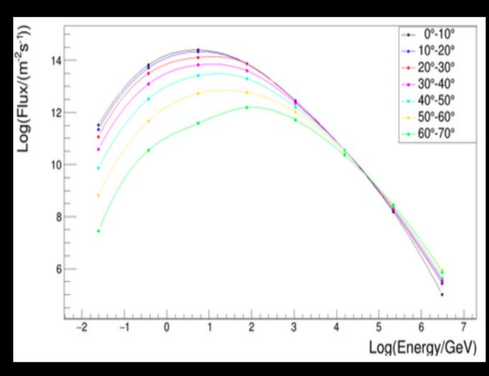
The 3 planes of detection must be mounted on a metallic frame, but their spatial configuration can be customized.
Therefore, the distance between them can be minimal, of 13 cm, and the detector could see muons with trajectories inclined at a maximum of 60°. For the maximum distance between the planes - 65 cm, the maximum angle of the muons trajectory is of only 60°.

SIMULATIONS

MUON FLUX PARAMETRIZATION

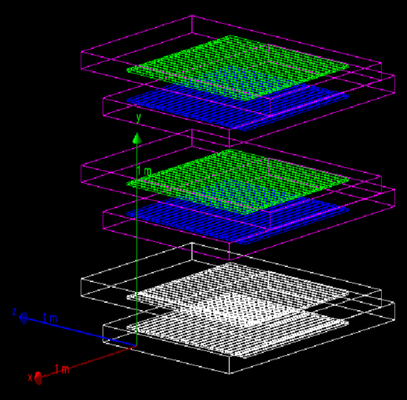


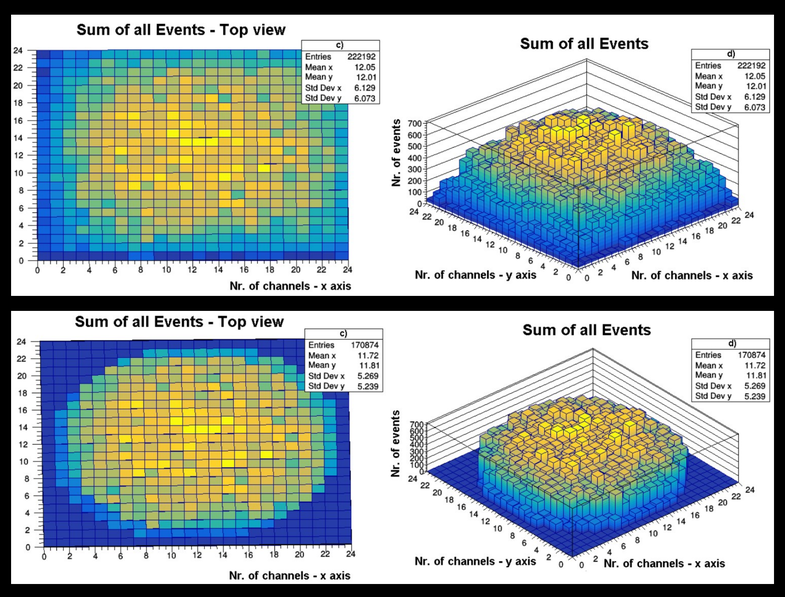
a) The primary cosmic rays spectra for protons and helium, used as input of the Corsika simulations [1]



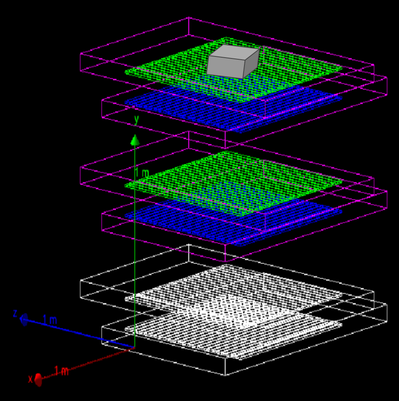
b) Parametrization of muon flux from CORSIKA simulations

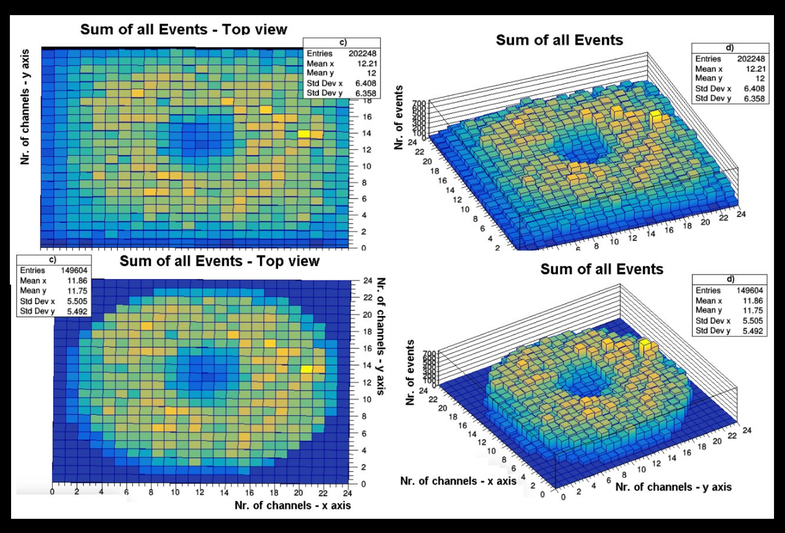
DETECTOR RESPONSE SIMULATION





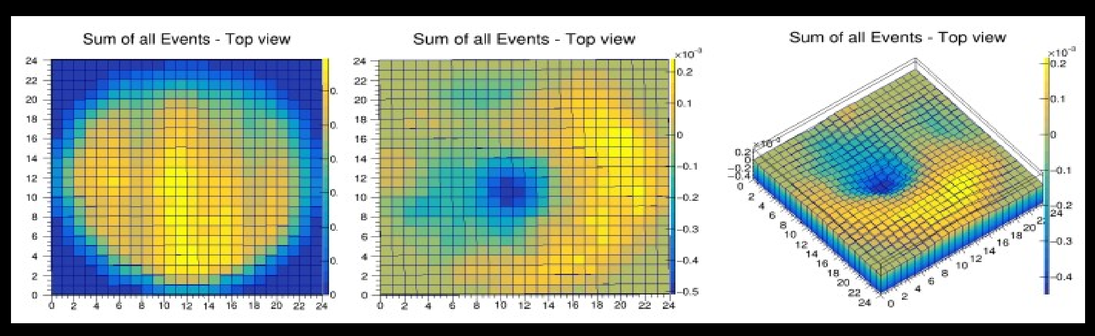
Left: SiRO detector simulated in GEANT4; *Right*: Density map from the simulation of the vertical muon flux in laboratory conditions



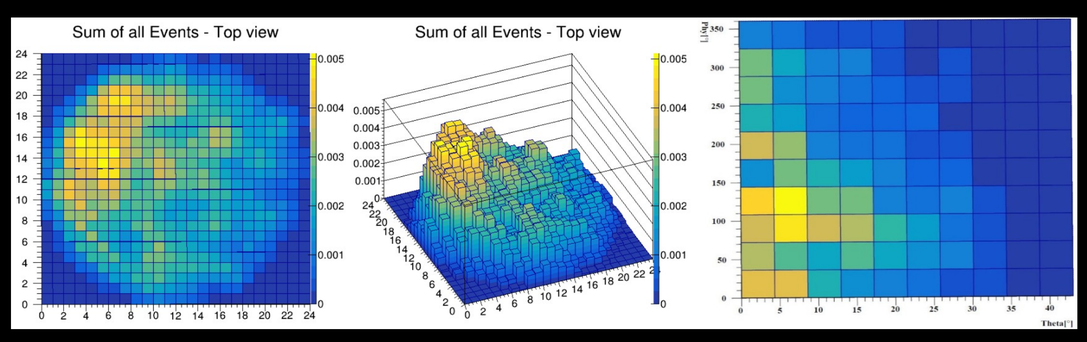


Left: Lead brick placed above the first layer of the detector; *Right:* Density map from the simulation of the vertical muon flux in laboratory conditions, lead brick placed above the first layer

MEASUREMENTS



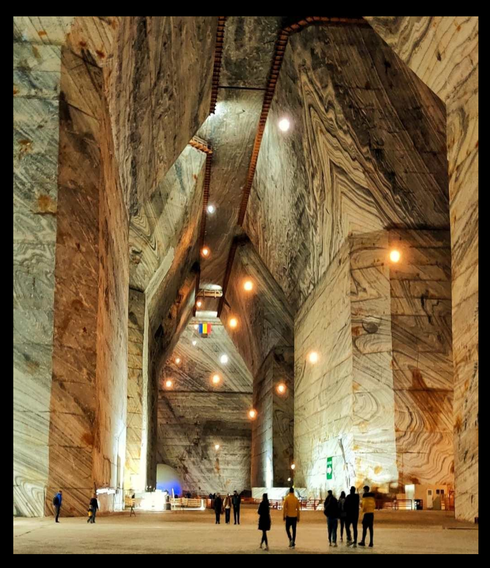
a) Left: Density map for the measured vertical muon flux in laboratory at IFIN-HH for the truncated sensitive volume; *Center & Right*: Density map of the muon flux measured with a lead object above the first layer.



b) *Left*: Density map of the muon flux measured in Slanic Prahova salt mine; *Right*: Distribution of incident muon directions for zenith and azimuth

For an additional set of measurements, we assembled and prepared to run the SiRO detector in the underground Laboratory of IFIN-HH in Unirea salt mine, situated in Slanic – Prahova.
It can be easily observed in b) how the presence of the wall dramatically decreases the number of incident muons, the cavity on the opposite side bringing a cosistent contribution to to the flux. A strong anisotropy is observed in the angular distribution, also generated by the presence of the wall – the muon flux is mainly coming from a direction of 0 to 200 degrees azimuth, with zenith angles of 0 to 10 degrees, as can be seen in the right b) picture.

The underground low-background radiation laboratory
- 408 m above sea level
- 208 m depth (610 m.w.e.)
- temperature: 12 - 13 C
- Muon flux: 0.18 ± 0.01 $m^{-2} s^{-1}$ [1]
- **Ultra low radiation background 1.3 ± 0.3 nSv h^{-1}** [2]



PROSPECTS

- upgrading the detection system in both hardware and software in order to improve the angular, spatial and timing resolution
- automatic temperature stabilization of SiPM response
- new detector systems under development (scintillating fibers/bars)
- extensive measurement campaigns
- apply various reconstruction methods for 2D and 3D data representation

BIBLIOGRAPHY

1. B.Mitrica et al. Nucl. Inst. and Meth. A 654 (2011) 176-183
2. Margineanu, R. M., et al. "External dose rate in Unirea salt mine, Slanic-Prahova, Romania."

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