The 5th International Symposium on Cosmic Rays and Astrophysics (ISCRA-2025)

Separation of Muon Component of Extensive Air Showers in Multipurpose Detector of Muons

24-26 June, 2025

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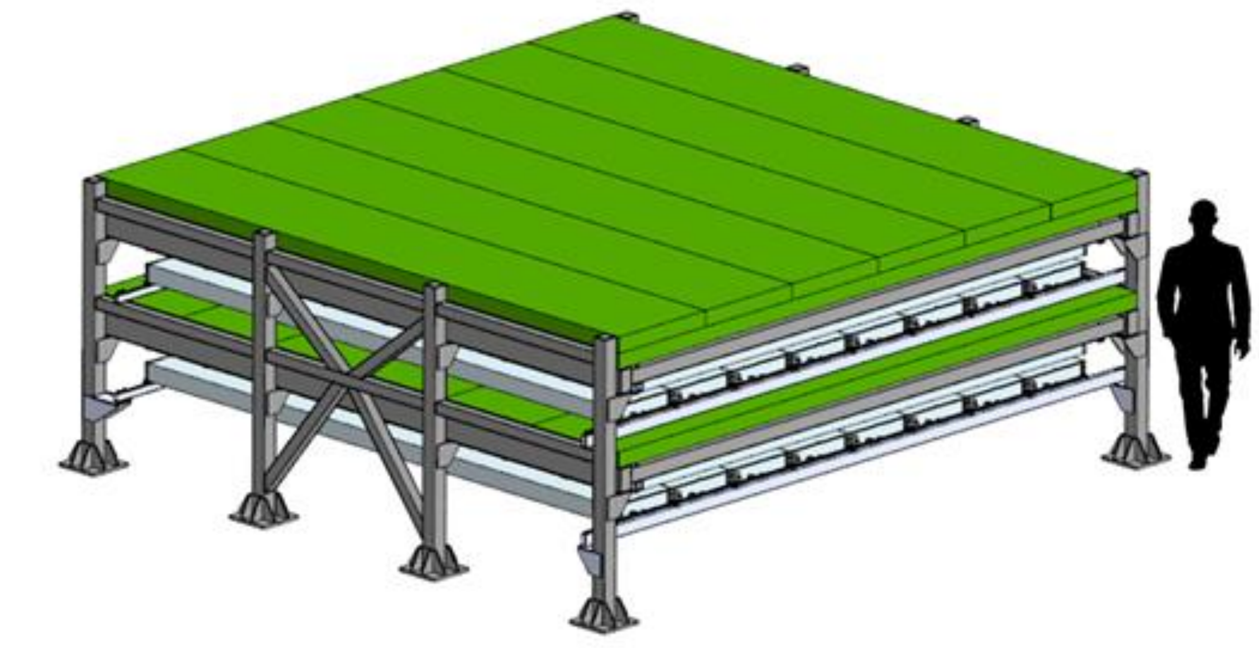
Multipurpose Detector of Muons (MDM)

The MDM detector [1] is designed to study high energy muons in Extensive Air Showers (EAS) generated by Primary Cosmic Rays (PCR) in the atmosphere.



Model of MDM detector

The detector consists of an array of the multiwire Drift Chambers (DC) forming two coordinate planes interpolated with a thick upper and a thin lower absorber layers.

There are 16 drift chambers in each coordinate plane, eight per X-projection and eight per Y-projection.

Such configuration allows distinguishing muons from electrons and studying EAS using the method of Local Muon Density Spectra (LMDS) [2] in 0°-60° range of zenith angles. The installation has good spatial accuracy of 1 mm.

This detector can be operated with the trigger from scintillation counters or in self-triggering mode with the GPS-timestamp for each event. That allows matching events with the responses of other detectors of the Experimental Complex (EC) NEVOD.

Objectives of the MDM detector

- Obtaining local muon density spectra for the near-vertical muons bundles.
- Determining muon densities at different distances from the axis of the extensive air showers.
- Calculating lateral distribution function of muons in joint operation with the NEVOD-EAS, PRISMA, URAN [3].
- Studying anisotropy of single and multi-muon events.
- Searching events from gamma-rays in joint operation with all detectors of the EC NEVOD.
- Operating as a test-bench for studying spatial response of other particle detectors.

Detectors of the EC NEVOD

The EC NEVOD combines detectors designed to study various components of EAS.

DECOR and **TREK**: near-horizontal muon component of EAS.

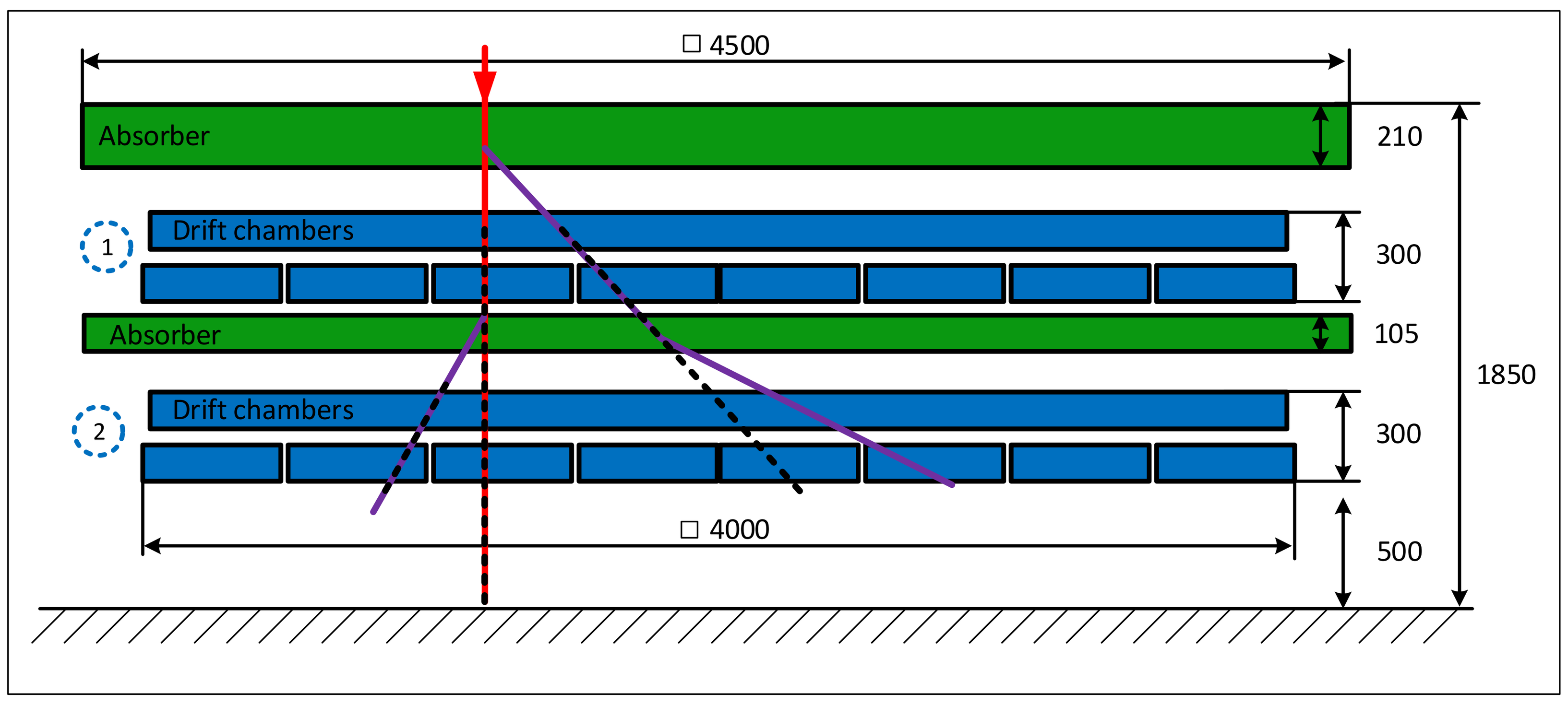
MDM: near-vertical muon component of EAS.

CWD NEVOD: Cherenkov water detector (2000 m^3), that estimates the energy deposit of particles.

NEVOD-EAS: electron-photon component in the EAS energy range from 10^{15} to 10^{17} eV.

URAN and **PRISMA-36**: analyzes the neutron component of EAS.

Geant4 model of MDM detector



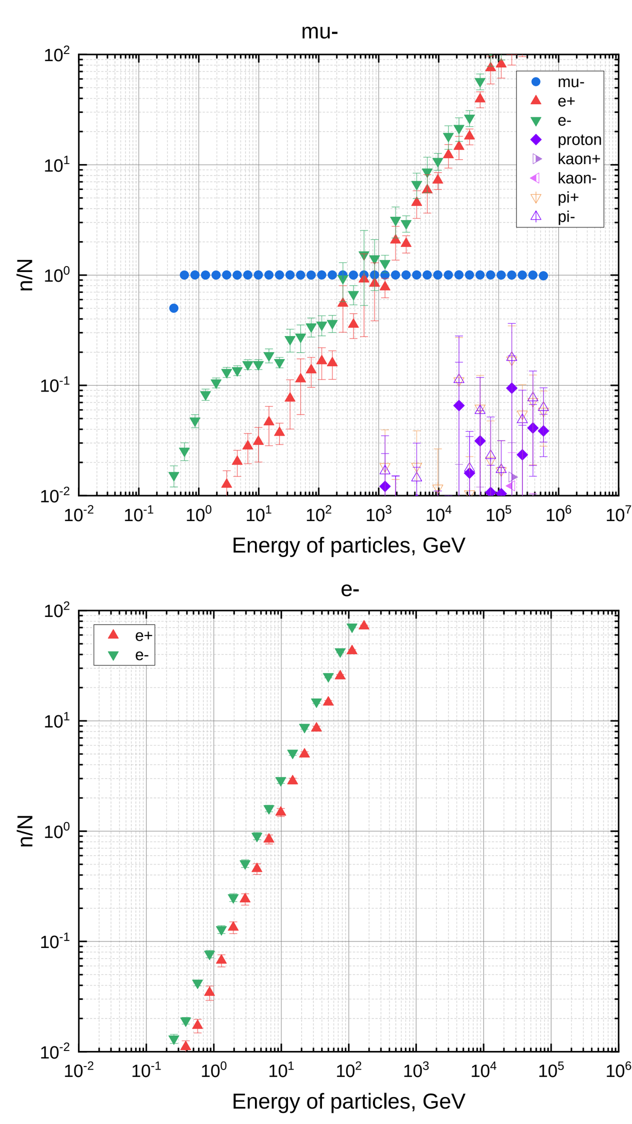
The model of the MDM detector in Geant4 with the characteristic dimensions of **steel absorbers** and **drift chambers** and an example of event reconstruction: **the red line** shows muon track, **the purple lines** denote tracks of secondary particles, and the **dotted lines** demonstrate rectilinear extrapolation of the tracks.

Simulation of passage of vertical particles through the detector

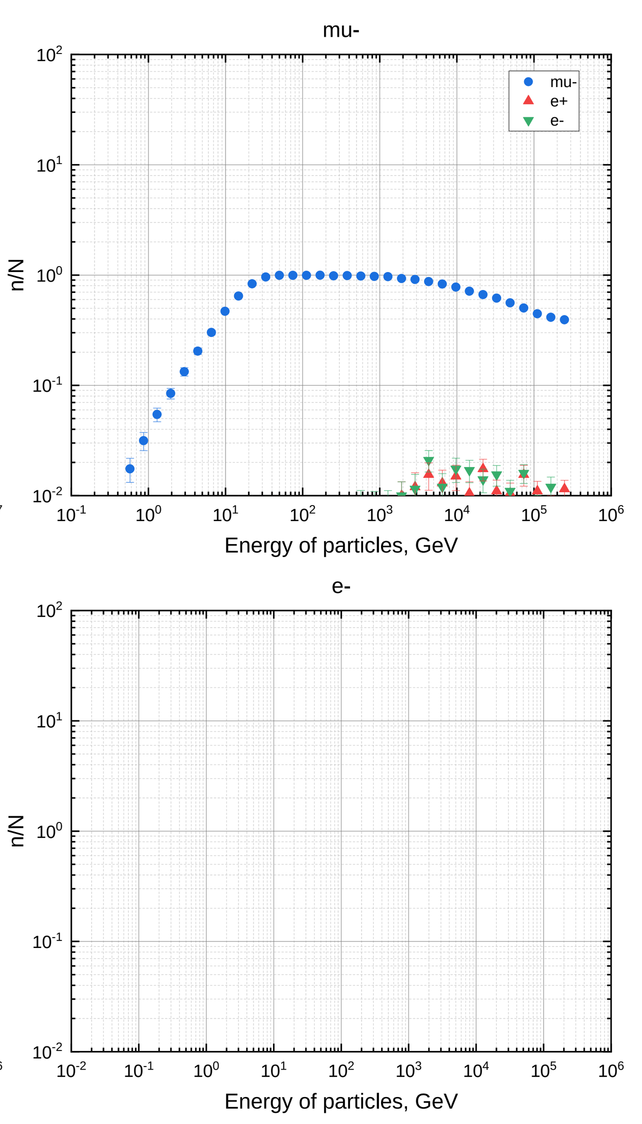
In order to specify the detector design and to estimate the thickness of the absorbers, a detector model in Geant4 was developed and a simulation of the detection of single muons and electrons in a wide energy range was performed.

The MDM detector model consists of an upper 210 mm thick steel absorber, four DC planes and a 105 mm thick steel absorber between the planes of the drift chambers. In reality, the thickness of the absorbers may be changed.

An initial incident particle was simulated and launched above the detector. Most of the particles in EAS have energy in the range from 10 MeV to 10 TeV. Therefore, in the simulation the first initiate particles were muons and electrons, with energies from 1 MeV to 100 TeV and with a constant logarithmic step $E_{i+1}/E_i = 1.2$.

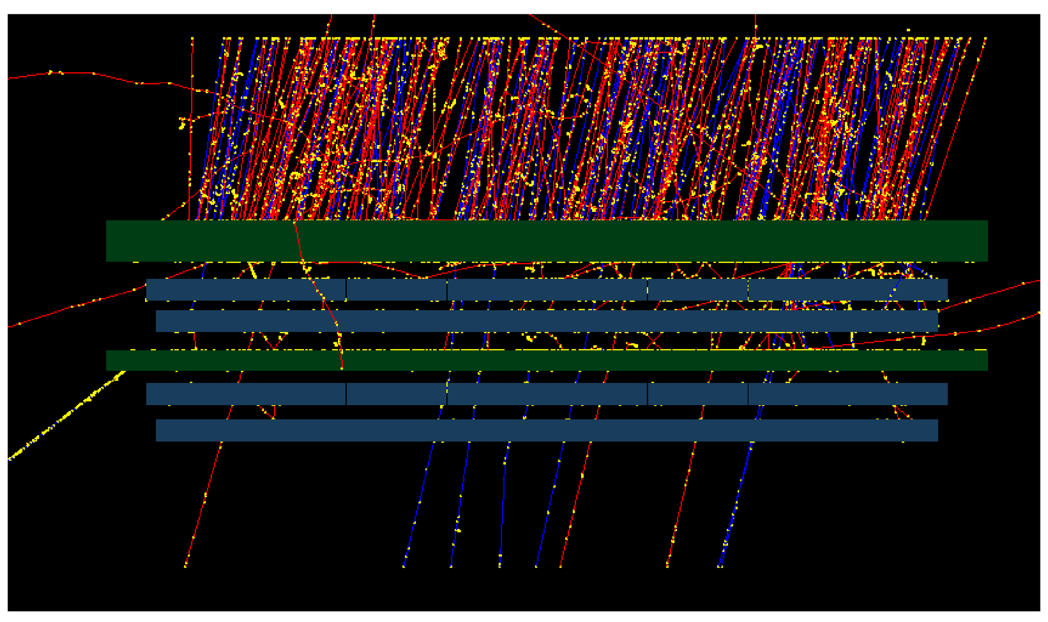


*The dependence of relative number of **charged** particles passed through the drift chambers on the energy of the initial particle.*

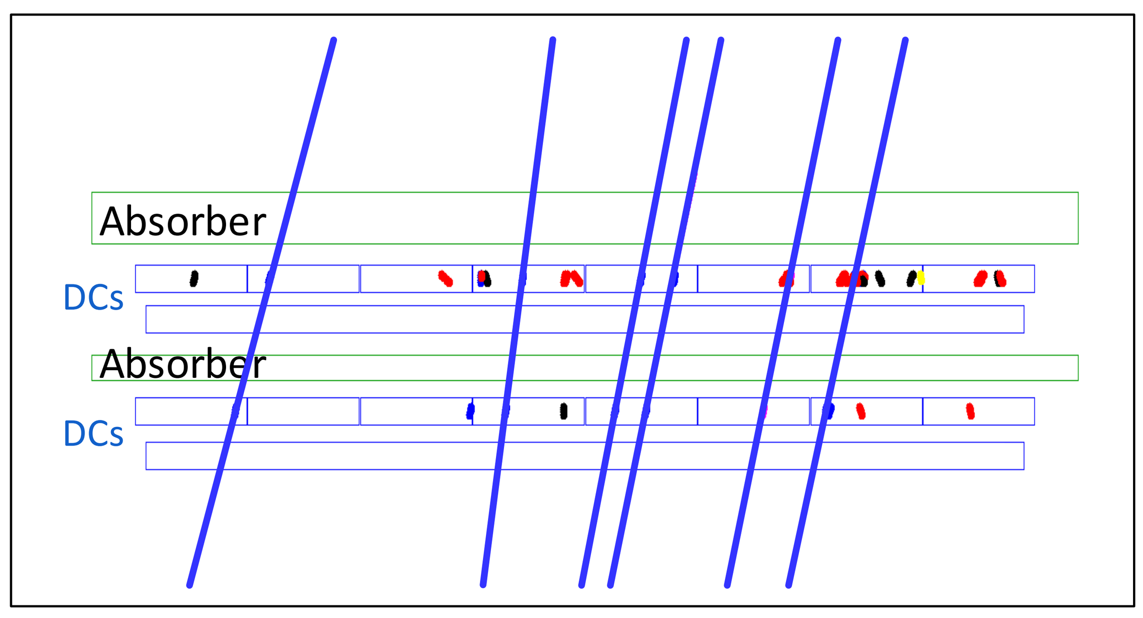


*The dependence of relative number of **reconstructed** particles passed through the drift chambers on the energy of the initial particle.*

To determine the energy range of muon detection, the air-showers were modeled in CORSIKA for primary cosmic rays with energies from 10^{14} to 10^{18} eV. The simulated EAS events generated in CORSIKA were imported into the Geant4 environment to simulate the passage of particles through the MDM detector. Subsequently, the response of the MDM model was reconstructed to obtain the tracks of muon bundles.

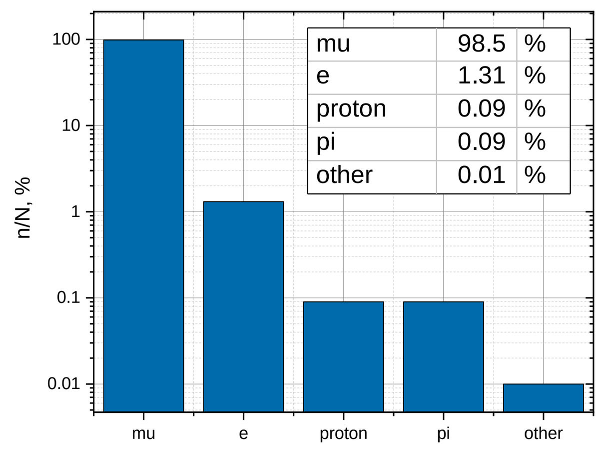


Simulation of EAS particles passing through the MDM detector in Geant4.
($\gamma - 168$, $e - 261$, $\mu - 6$, $\pi - 6$, $n - 1$)



Reconstruction of EAS muons passed through the MDM detector, in the corresponding event.

Particle	Threshold energy of signal registration, GeV	Threshold energy of reconstruction, GeV
Muon	0.44 ± 0.06	24 ± 2
Electron	4.7 ± 0.5	-
Gamma quantum	4.0 ± 0.4	-
Proton	6.9 ± 0.6	-
Pion	9.9 ± 0.8	-
Neutron	12 ± 1	-



The developed algorithm reconstructs the tracks of particles, 98.5% of which are muons, while the remaining 1.5% are attributed to electrons, protons and pions.

Conclusion

The design of the MDM detector makes it possible to reject electrons and secondary particles and to study muon bundles in EAS. Also, this detector configuration makes it possible to distinguish single muons with energies from 5 GeV to 20 TeV.

Thus, Multipurpose Detector of Muons will allow for the first time to study near-vertical muons using the LMDS method.

References

[1] Troshin I.Yu. at al., Simulation of a detector based on multi-wire drift chambers for identifying the muon component of EAS // Physics of Particles and Nuclei, 2025, V.56, pp.219–222.

[2] Bogdanov A. G., et al., Investigation of the properties of the flux and interaction of ultrahigh-energy cosmic rays by the method of local-muon-density spectra // Elementary Particles and Fields, 2010, V.73, pp.1852–1869.

[3] Yashin I.I. et al., NEVOD — An experimental complex for multicomponent investigations of cosmic rays and their interactions in the energy range 1–10^{10} GeV // Journal of Instrumentation, 2021, V.16, T08014.