Technical Physics, 2024, Vol. 69, No. 12

# Studies of near-vertical muons in extensive air shower using a detector on multi-wire drift chambers

© I.Yu. Troshin, E.A. Zadeba, V.S. Vorobev

National Research Nuclear University „MEPhI",
115409 Moscow, Russia
e-mail: IYTroshin@mephi.ru

Received April 25, 2024
Revised August 11, 2024
Accepted October 30, 2024

The configuration of a detector with an absorber on multi-wire drift chambers for studying near-vertical muons of high-energy cosmic rays is considered..

**Keywords:** muons, drift chambers, atmospheric showers, cosmic rays.

DOI: 10.61011/TP.2024.12.60403.349-24

To study near-vertical muons extensive air showers (EAS), a multipurpose muon detector (MMD) is being created at National Research Nuclear University "MEPhI". The detector is an array of multiwire drift chambers shielded by absorber layers. The detector is designed to study muons in the zenith angle range from 0 to 60° and to review near-vertical EAS using the local muon density spectra (LMDS) methods [1]. Together with other HEVOD detectors [2,3], a spatial muon distribution function in EAS will be plotted.

A detector with absorber was simulated to determine threshold energies of charged particles. The MMD detector (Figure 1) contains four drift chamber layers with a sensitive volume of 3700 × 3700 × 250 mm and four steel absorber layers: top layer 4500 × 4500 × 210 mm, other layers 4500 × 4500 × 105 mm.

Particle detection process was simulated for particles with energies in the range from 100 MeV to 100 TeV with the constant logarithmic step $E_i + 1/E_i = 1.2$. For each energy, 1000 single events were simulated. Charged particles (including secondary ones) that passed throughout the sensitive volume of the drift chambers were reviewed.

The number of particles detected in the second plane of the drift chambers with respect to the initial number of particles is shown in Figure 2. Threshold detection energies are determined using these distributions: $E_{\min}$ is the minimum energy at which a particle will pass through absorbers and will be detected by the drift chambers, $E_{\max}$ is the maximum energy at which the number of secondary particles is max. 200 on any of the planes, restriction is based on the capability of drift chambers.

For two and for four absorber layers, $E_{\min}$ and $E_{\max}$ were determined and listed in the table. The findings suggest that the chosen detector configuration makes it possible to detect primarily muon events in a wide energy range. Upper energy detection threshold $E_{\max}$ is defined as energy at which there are max. 200 particles in an event on each

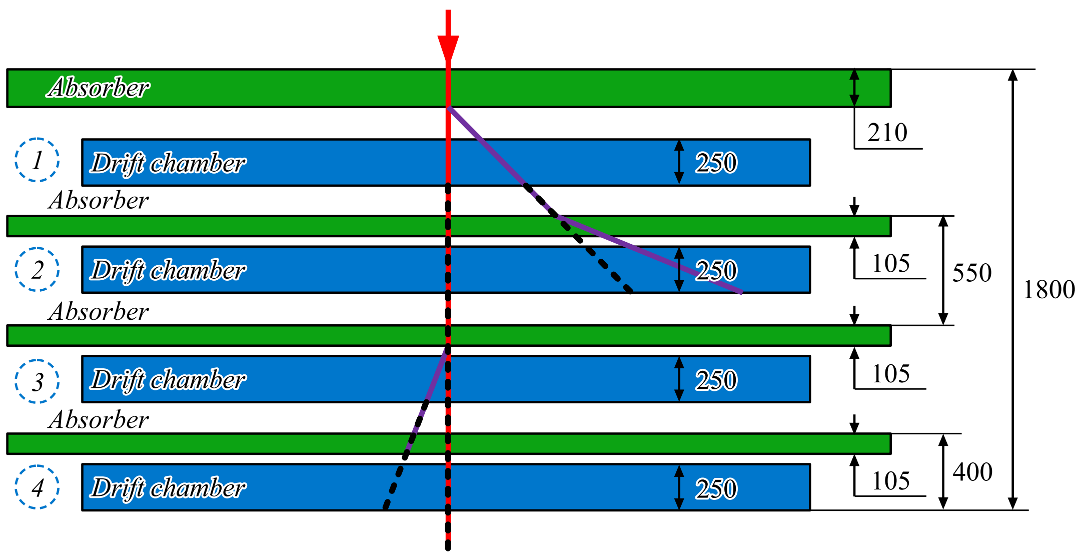


**Figure 1.** MMD detector model in Geant4 with typical sizes and event reconstruction example: red track — muon, violet tracks — other particles.

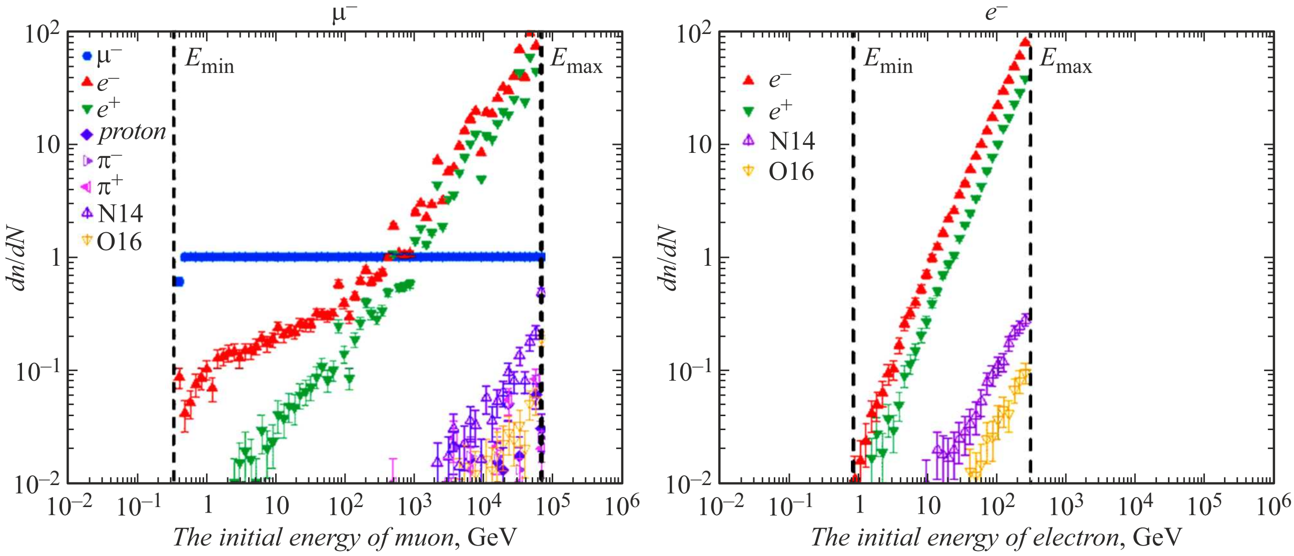


**Figure 2.** Number of charged particles $(dn/dN)$ that passed through the second drift chamber layer with respect to the initial number of particles depending on the energy of the initial particle: muon and electron.

Threshold energies for muon and electron

| Particle | $E_{min}$ two layers, GeV | $E_{min}$ four layers, GeV | $E_{max}$, GeV |
|---|---|---|---|
| Muon | $0.34 \pm 0.03$ | $0.59 \pm 0.06$ | $(6.9 \pm 0.5) \cdot 10^4$ |
| Electron | $0.79 \pm 0.02$ | $1.1 \pm 0.1$ | $(2.9 \pm 0.3) \cdot 10^2$ |

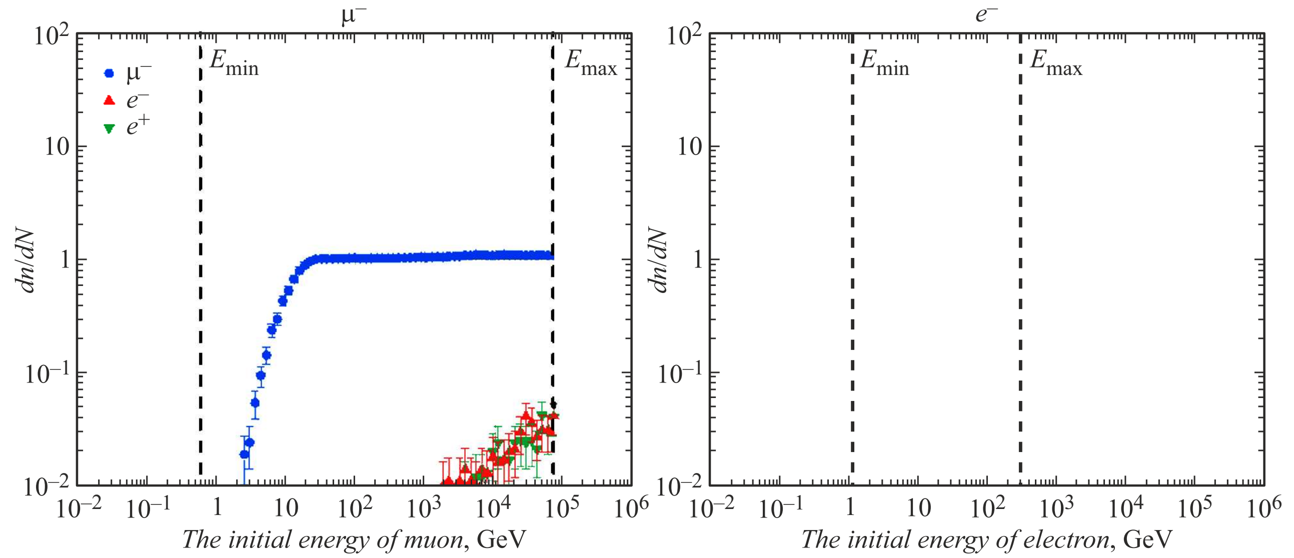


**Figure 3.** Number of particles reconstructed as a muon $(dn/dN)$ with respect to the initial number of particles depending on the energy of the initial particle: muon and electron on four drift chamber layers.

of the planes. Considering that most particles exist on the upper planes, then $E_{max}$ will be the same both for a two-layer and four-layer detector.

Configuration of a detector consisting of drift chamber layers separated by absorber makes it possible to distinguish secondary particle tracks when processing detected events. For this, a reconstruction method (Figure 1) is used that identifies muons by the identical response of drift chambers in several layers simultaneously. However, secondary particles are either absorbed between the layers or deviate from the initial direction. Criteria for muon detection among secondary particles: difference in zenith angle max. 5°, difference in coordinate max. 5 mm, spacing between tracks is more than 3 mm, max. 200 particles per plane in the event. Criterion of difference in zenith angle within 5° was chosen because the groups of quasi parallel muons in EAS deviate within this range; deviation in coordinate within 5 mm is associated with potential shifts induced by angular distribution of particles, and restriction to the number of particles (max. 200 per plane) is defined by the characteristics of drift chambers.

According to the data of the first two drift chamber layers, a large part of secondary particles is filtered out by the screening method. In the range from 3 GeV to 1 TeV, single muons are reconstructed unambiguously, the mixture of secondary particles is max. 1%. The reconstruction method transmits some secondary particles only to the regions higher than 1 TeV. When using four drift chamber and absorber layers (Figure 3), this region moves up to 2 TeV, however,muons in the low energy region may be erroneously screened out due to scattering. Electrons on four layers are screened out completely.

Simulation has established that the detector configuration will allow detecting high energy muons and separating them from secondary particles in the energy range from 3 GeV to 2 TeV. Steel absorber with this configuration will reduce the flux of low-energy EAS component and will make it possible to use the LMDS method for a near-vertical direction.

### Funding

The study was carried out on the Unique Research Unit „NEVOD Experimental System“ and supported by the Russian Science Foundation, 23-72-10067, https://rscf.ru/project/ 23-72-10067/.

### Conflict of interest

The authors declare no conflict of interest.

## References

[1] A.G. Bogdanov, D.M. Gromushkin, R.P. Kokoulin, J. Mannokkii, A.A. Petrukhin, O. Saavedra, J. Trinkero, D.V. Tchernov, V.V. Shutenko, I.I. Yashin. Yadernaya fizika, **73** (11), 1904 (2010) (in Russian).

[2] I.I. Yashin, M.B. Amelchakov, I.I. Astapov, N.S. Barbashina, A.G. Bogdanov, F.A. Bogdanov, V.V. Borog, A. Chiavassa, A.N. Dmitrieva, D.M. Gromushkin, S.S. Khokhlov, V.V. Kindin, R.P. Kokoulin, K.G. Kompaniets, A.Yu. Konovalova, A.A. Kovylyaeva, G. Mannocchi, Yu.N. Mishutina, V.V. Ovchinnikov, A.A. Petrukhin, I.A. Shulzhenko, V.V. Shutenko, Yu.V. Stenkin, G. Trinchero, V.S. Vorobiev, K.O. Yurin, E.A. Yurina, E.A. Zadeba. J. Instrumentation, **16**, 112 (2021). DOI: 10.1088/1748-0221/16/08/T08014

[3] V.S. Vorobev, E.A. Zadeba, R.V. Nikolaenko, I.Yu. Troshin. Bull. Russ. Acad. Sci.: Phys., **87**, 918 (2023). DOI: 10.3103/S1062873823702702

*Translated by E.Ilinskaya*