ISCRA-2019

International Symposium on Cosmic Rays and Astrophysics

25–28 June 2019
National Research Nuclear University MEPhI, Moscow, Russia

Simulation of the NEVOD-EAS array detectors response using Geant4

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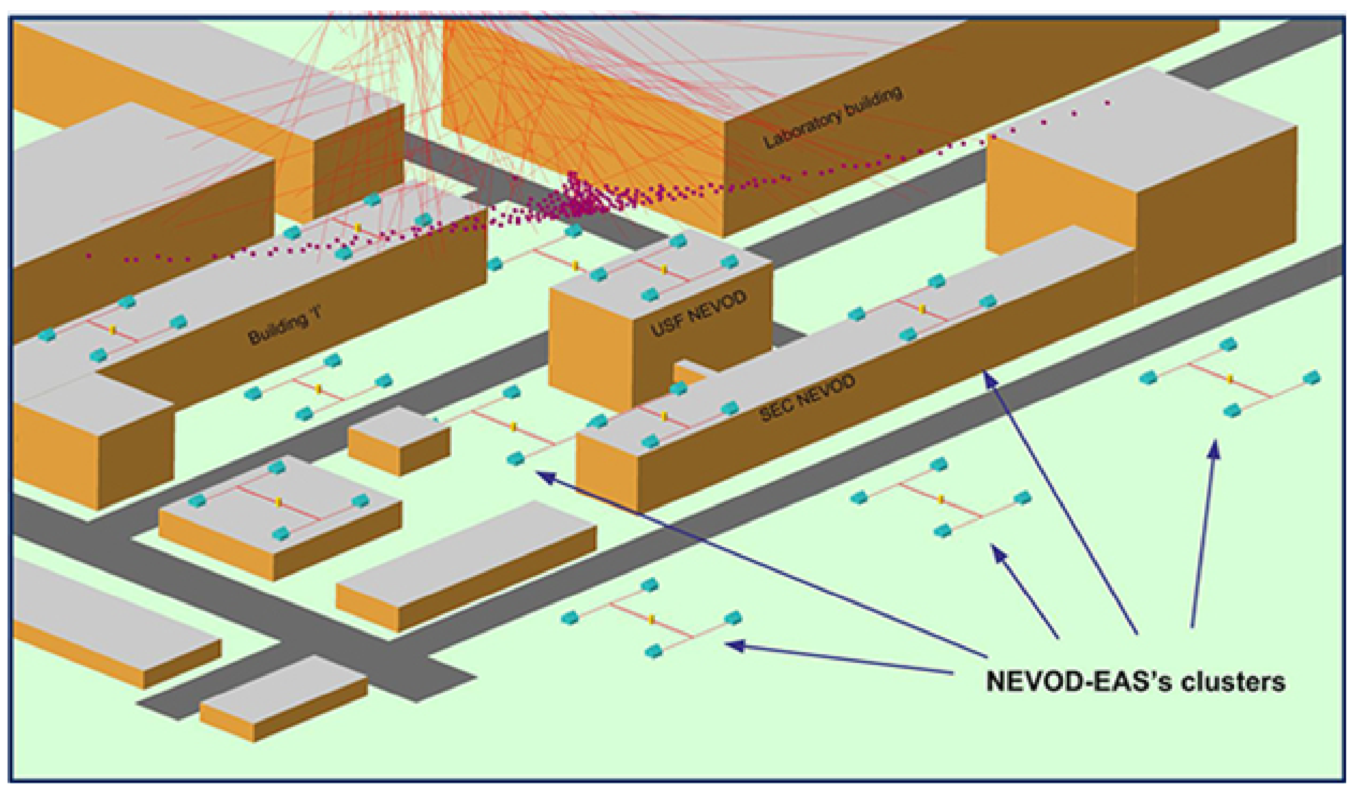
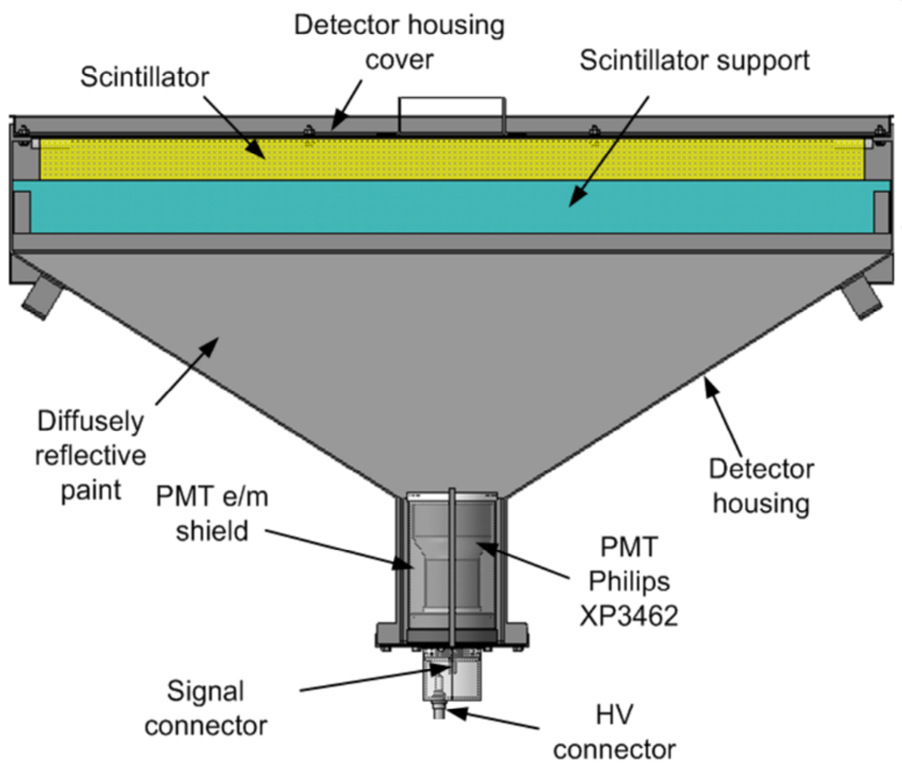
Introduction

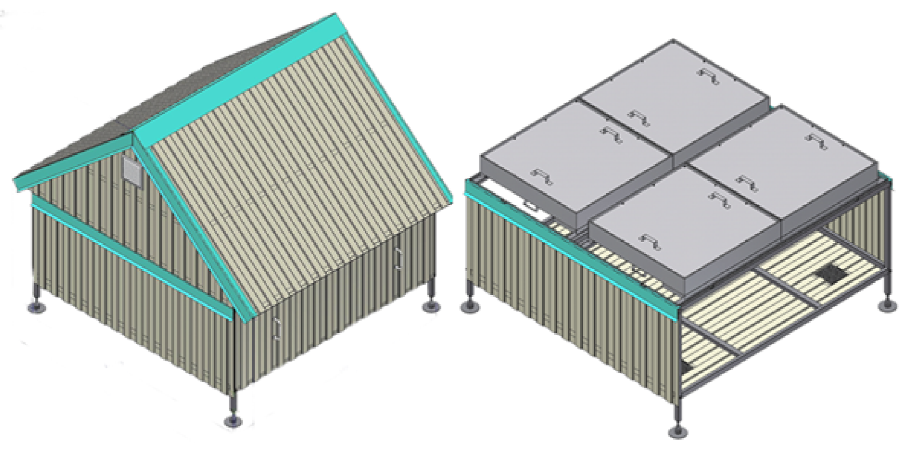
The **NEVOD-EAS array** (MEPhI, Moscow) is aimed at detection of extensive air showers (EAS) with energies of $\mathbf{10^{15} – 10^{17}}$ **eV**. It consists of clusters of scintillation counters of EAS electron-photon component particles. The central part of the array consists of 9 clusters. One cluster contains **16** scintillation counters, each **4** counters are combined in detector stations (DS). Each DS counter contains one photomultiplier tube (PMT) that is used for time and EAS particles density measurements. One of the DS counters is equipped with an additional PMT which has a lower gain than the others and extends the DS dynamic range up to ~ $\mathbf{10^5}$ **particles/m^2**.



NEVOD-EAS array



Construction of the scintillation counter



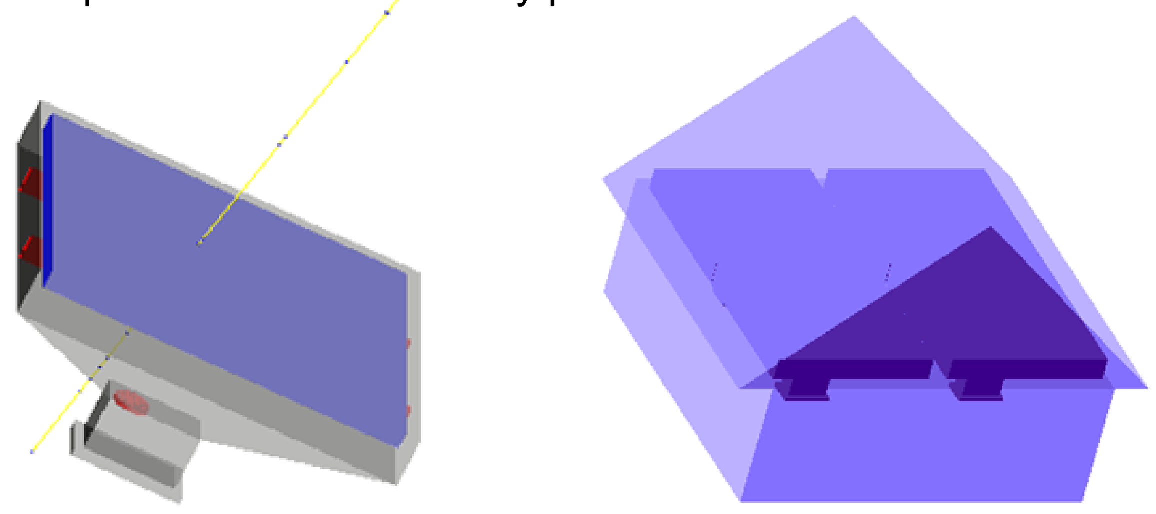
Detector station housing (left) and layout of counters inside the DS housing (right)

Purpose of the work

The work is aimed at creation of a model of the NEVOD-EAS detector station using the **Geant4** program package for the study of the characteristics of the detector response to the passage of particles and for the improvement of the quality of data processing and analysis, as well as for verification and enhancement of methods for reconstruction of EAS parameters.

Geometric model of the NEVOD-EAS array in the Geant4 toolkit

Using the Geant4 program package, the models of scintillation counter and DS were developed. These models account geometrical shape of particle counters and DS, physical and optical properties of used materials, geodesic data on the location of array DS. Photoelectric effect, processes of the PMT charge response and jitter formation were simulated. All the necessary physical processes for secondary particles were included.

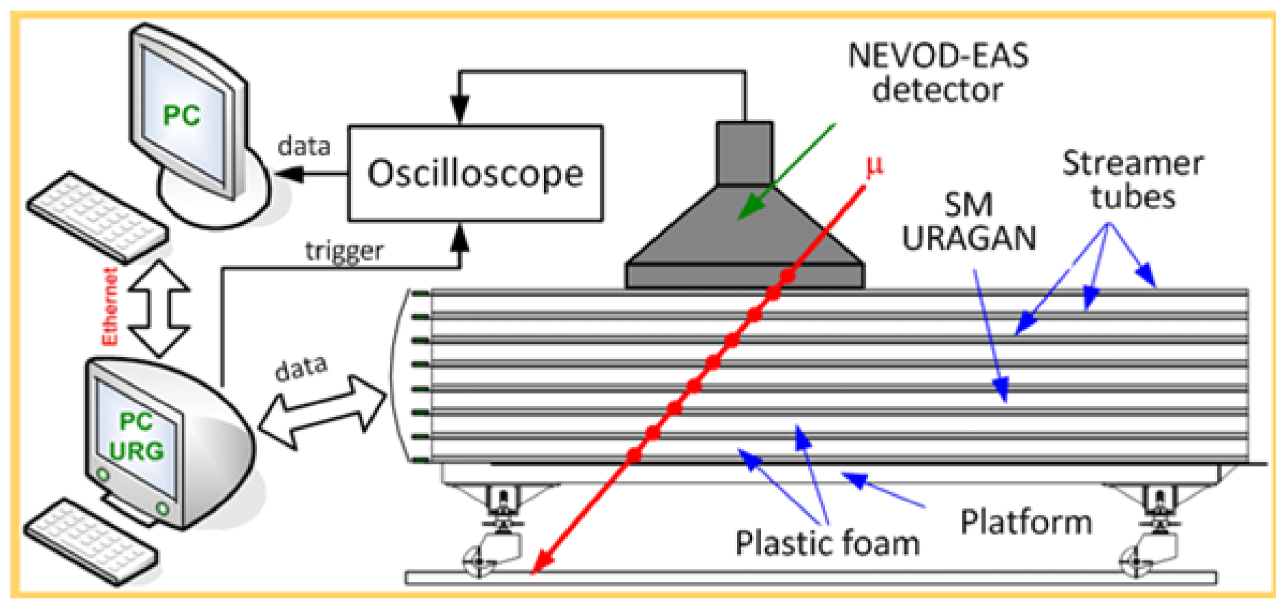


Geometric models of the NEVOD-EAS counter (left) and DS (right)

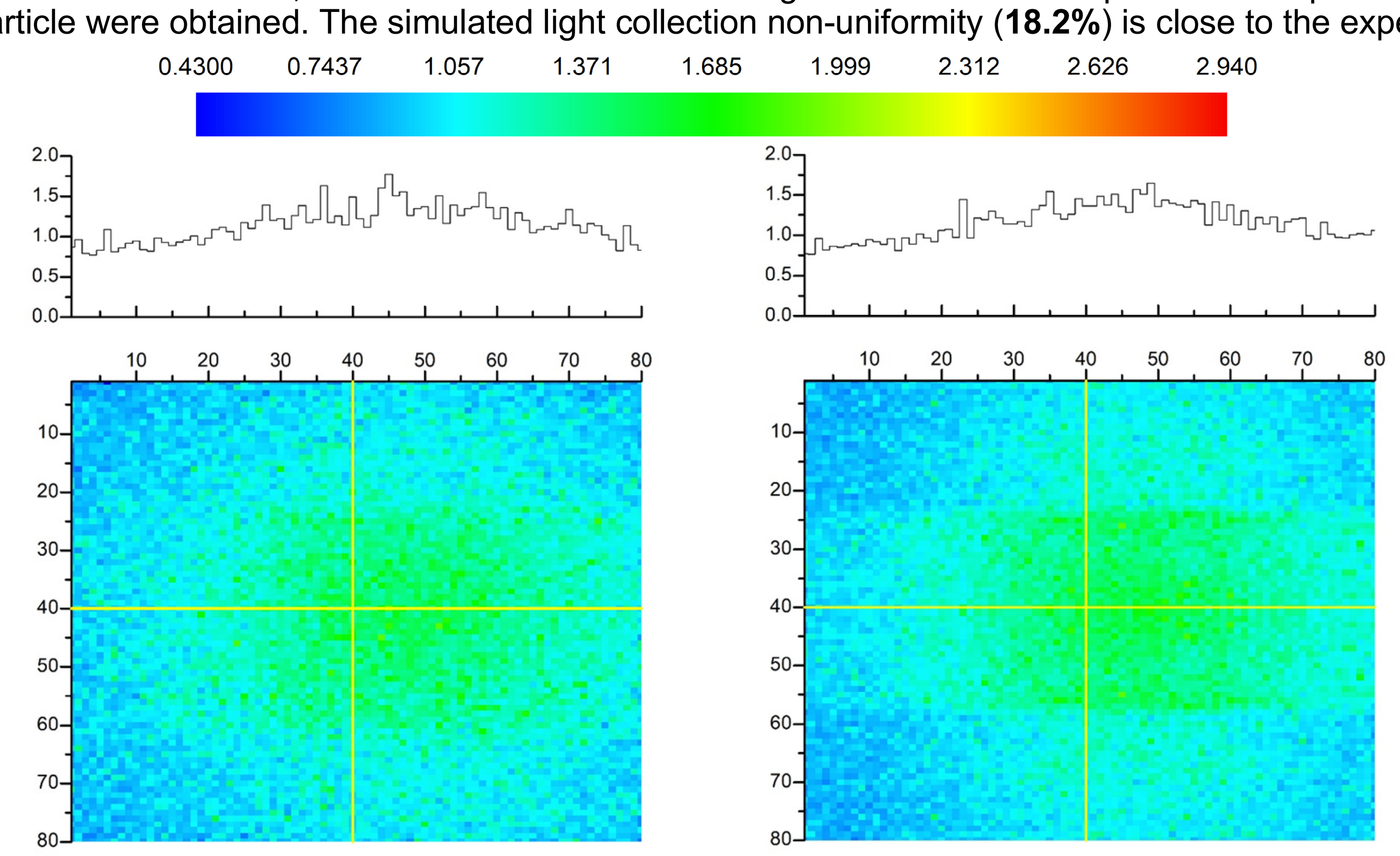
Calibration of the model

During the NEVOD-EAS creation, the characteristics of the scintillators were studied using the muon hodoscope (MH) URAGAN. It provides spatial and angular accuracies of muons track reconstruction better than 1 cm and 1º, respectively. This allows to study the light collection non-uniformity of the counters. The **light collection non-uniformity** of a set of studied counters is in range of **18–25%** and depends weakly on the light yield of the scintillators. It is determined only by the detector housing geometry.

To achieve a better accordance between the simulation and experimental results, the light collection non-uniformity of counters was modeled. For this purpose, the results of CORSIKA simulation were used to keep a good fit with the real spectrum of particles. To account the influence of the building roof over the MH, the value of particle energy threshold of 100 MeV was chosen. According to the experimental data, zenith angle was simulated in range of 0º - 15º. Using the simulation results, the matrices of the mean charge of the counter response to the passage of a single charged particle were obtained. The simulated light collection non-uniformity (**18.2%**) is close to the experimental value.



Experimental facility for studying of the light collection non-uniformity of the NEVOD-EAS scintillation counters



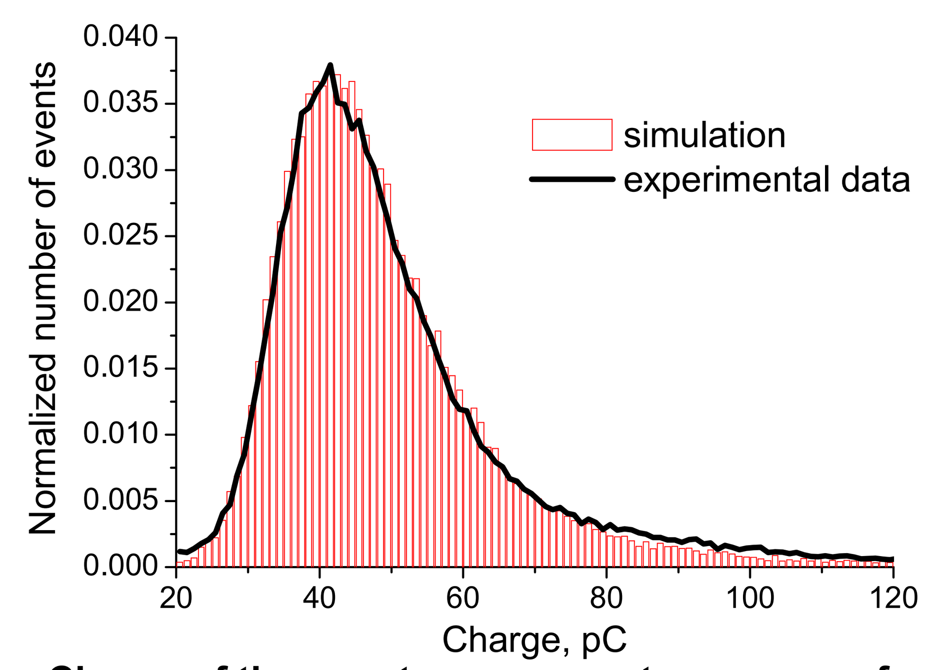
The matrices of the mean charge of the counter response to passage of a single muon

Experimental data (non-uniformity of the light collection is 18.4±0.1%)

Simulation (non-uniformity of the light collection is 18.2±0.1%)

The result of model

After accounting of the main detector properties and model calibration, the good fits have been achieved. The most probable **simulated charge** of the counter response is **49.6 pC**, while the **experimental** value is **51.6 pC**.



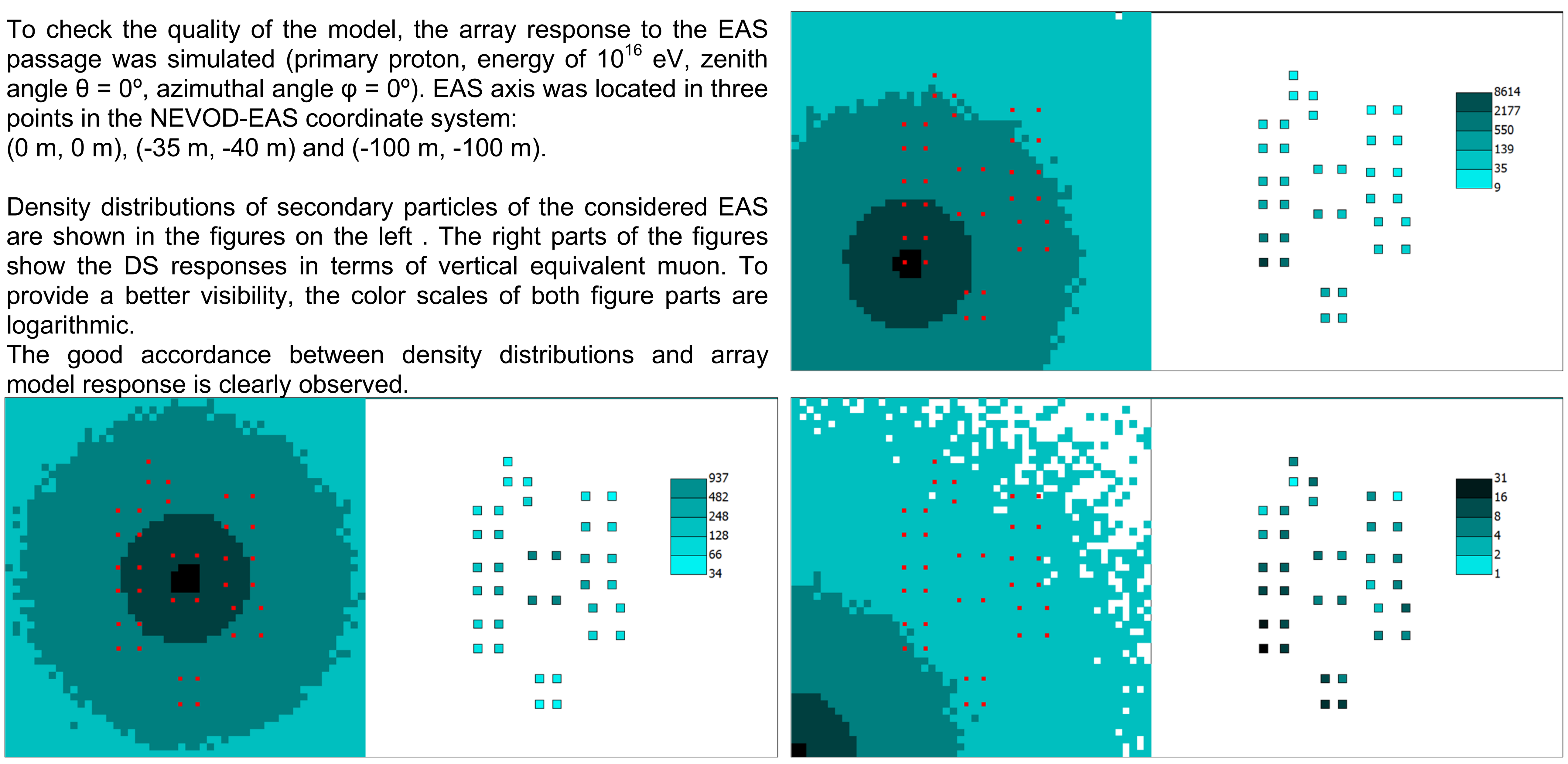
Charge of the counter response to passage of a single muon

Simulation of the NEVOD-EAS array response to extensive air showers

To check the quality of the model, the array response to the EAS passage was simulated (primary proton, energy of 10^{16} eV, zenith angle θ = 0º, azimuthal angle φ = 0º). EAS axis was located in three points in the NEVOD-EAS coordinate system: (0 m, 0 m), (-35 m, -40 m) and (-100 m, -100 m).

Density distributions of secondary particles of the considered EAS are shown in the figures on the left . The right parts of the figures show the DS responses in terms of vertical equivalent muon. To provide a better visibility, the color scales of both figure parts are logarithmic.

The good accordance between density distributions and array model response is clearly observed.



The simulation of the NEVOD-EAS array response to the passage of extensive air shower: the density of secondary particles (left) and DS responses in terms of vertical equivalent muon (right)

Conclusion

- a Geant4 model of the NEVOD-EAS air-shower array was created;
- the model was calibrated according to experimental data; based on calibration, a good agreement between the simulation and the experimental results was obtained;
- the response of the NEVOD-EAS array to the passage of the extensive air shower was simulated.

The developed model provides the opportunity to study the characteristics of the detector response to the passage of particles. It can be used for improving of the quality of applied data analysis and processing methods, as well as for testing the currently used techniques for the reconstruction of EAS parameters.

Acknowledgements

The work was performed at the Unique Scientific Facility "Experimental complex NEVOD" with the support of the Ministry of Science and Higher Education of the Russian Federation (State task 3.2432.2017/4.6 and MEPhI Academic Excellence Project of August 27, 2013, no. 02.a03.21.0005)