Upgrade of TAIGA–Muon scintillation counters

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In 2019, in addition to the operating Tunka-Grande array, the construction of the TAIGA–Muon scintillation array began. Both experiments are part of the TAIGA astrophysical complex aimed at solving fundamental problems in the field of cosmic ray physics and gamma-ray astronomy. The paper provides a description of the TAIGA–Muon array and the results of test operation. A new configuration of clusters and a project for an updated design of scintillation counters are also presented.

Keywords: cosmic rays, extensive air shower, TAIGA–Muon scintillation array, TAIGA astrophysical complex.

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Introduction

The purpose of the TAIGA–Muon scintillation facility is to study in detail the energy spectrum and mass composition of primary cosmic rays together with the existing Tunka-Grande [1] facility, as well as to search for diffuse gamma radiation in the energy range $10^{15}-10^{18}$ eV by the method of registration of the components of extensive air showers (EAS). Both experiments are part of the astrophysical complex TAIGA (Tunka Advanced Instrument for cosmic ray physics and Gamma Astronomy) [2], located in the Tunkinskaya Valley (Republic of Buryatia, Russia), 50 km from Lake Baikal. Currently 3 of the 10 TAIGA–Muon clusters have been deployed in the first phase of construction. For the period 2019–2022 test measurement sessions were carried out, based on the results of which a new

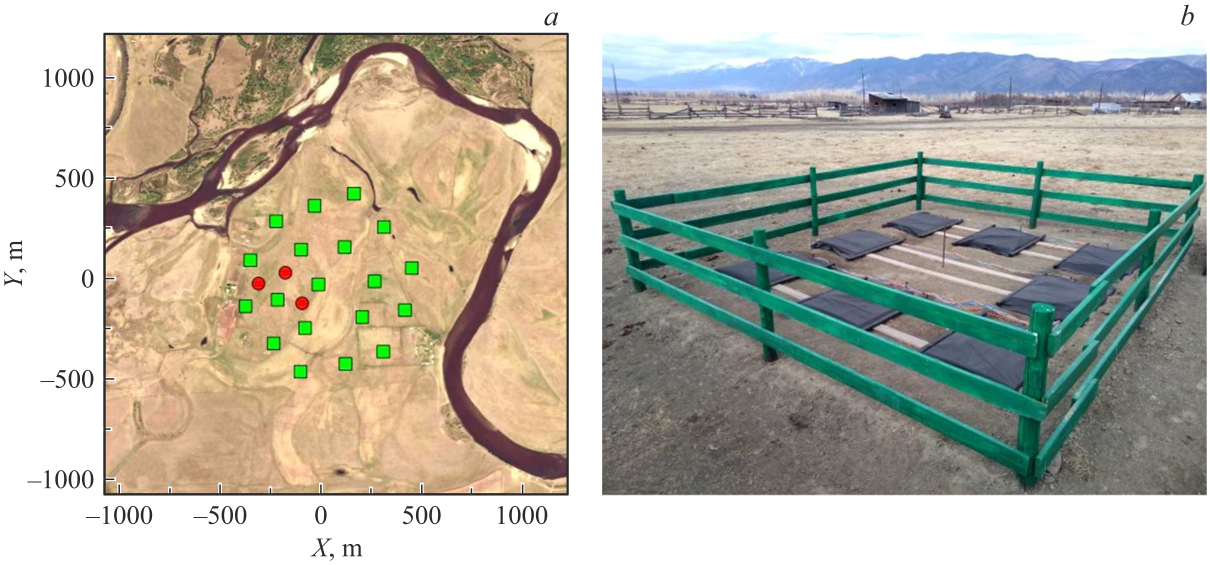

Figure 1. Facility TAIGA–Muon: *a* — Cluster location relative to Tunka-Grande installation stations (green squares (in online version) — stations, red circles (in online version) — clusters), *b* — cluster appearance.

configuration of clusters and a project for modernizing the design of scintillation counters were formed.

1. Cluster configuration

The location and configuration of the TAIGA–Muon clusters are based on the model calculations given in the paper [3]. At this point in time, the three clusters are located at the centers of the triangles, the vertices of which are the stations of the Tunka-Grande installation (Fig. 1). The two clusters have 8 ground scintillation counters to record all charged EAS particles at the facility level and 8 underground ones to isolate the muon component of the EAS. The meters are geometrically arranged in pairs: the above-ground ones are strictly above the underground ones. All 8 pairs are placed around the perimeter of the square with side 5 m. Distance between adjacent pairs — 1 m. It should be noted that the design of the clusters does not provide for direct access to the underground part, the soil thickness above which is ~ 1.7 m. The configuration of the third cluster was upgraded in 2022 in order to increase the effective detection area of the muon component of the EAS without making changes to the existing data acquisition system. The number of above-ground meters has been reduced to 4, the number of underground meters — increased to 16. It is assumed that this configuration will be applied to all clusters in the first phase of the TAIGA–Muon installation construction.

2. Scintillation Counter Design

The scintillation counter [4] consists of a stainless casing inside which there are prefabricated scintillation plates of variable thickness (10 mm in the center of the detector and 20 mm on its periphery) based on polystyrene with the addition of 1.5% p-terphenyl and 0.01% POPOP (1,4-bibenzene), plates –light guides with a cross-section of $5 \cdot 20\,\text{mm}^2$ (acrylic glass with re-emitting additive BBQ), diffuse reflectors and photomultiplier PMT-85-4. Increasing the thickness of the plates towards the periphery of the counters and the use of plates– light guides made it possible to achieve an acceptable homogeneity of the amplitudes of signals from different parts of the detector (heterogeneity of light collection $\sim 25\%$). Total counter area $\sim 1\,\text{m}^2$.

After conducting test measurement sessions on three clusters of the TAIGA–Muon installation, it was determined that, firstly, the meter housings were not sufficiently sealed. The TAIGA experimental complex is located within the floodplain and the floodplain terrace of the Irkut River. And this area, depending on the time of year, the groundwater level is high. Secondly, PMT-85-4 has a trough-shaped dynode system, which has a relatively low linearity of anode current (from 1 to 10 mA). This leads to distortion of counter signals when registering events with a particle count greater than 20. At the same time, the required linear range of registration for each counter is from 1 to 100 particles.

To protect the meters from the effects of precipitation, accidental and groundwater, an additional sealed plastic box with a size of $120 \times 110 \times 12$ cm was designed and implemented. The box is made of polypropylene sheets with an operating ambient temperature range from -25 to $+85^\circ$C, gray color, thickness 3, 8 and 10 mm. The sheets are connected to each other on the basis of extrusion welding. To eliminate the effect of nonlinearity, a PMT anode preamplifier (buffer amplifier) was developed and tested. The test measurements were carried out by the standard method of paired illuminations, in which at each step the PMT photocathode was illuminated first by one pulsed light source with a given intensity taken as the equivalent of the number of EAS particles, then by the

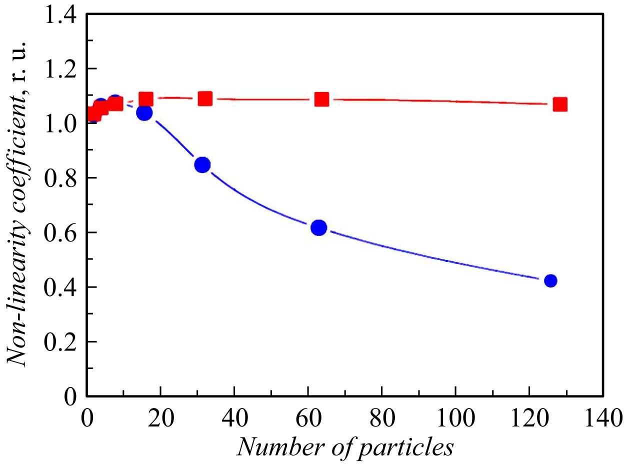

Figure 2. Linearity range PMT-85-4. Blue circles (in online version) show measurement results without a signal preamplifier, red squares (in online version) — when using a signal preamplifier.

second, and then by two sources simultaneously. The main idea of the method is the assumption that in the field of linearity, the response of PMT to illumination by two sources should be equal to the sum of the backlight responses of only the first and only the second source. The measurement results showed that the modified switching scheme allows to increase the linearity range of PMT to ~ 120 EAS particles (Fig. 2).

Conclusion

The design of a sealed plastic box has been developed to protect the scintillation meters of the TAIGA–Muon installation from the effects of precipitation, accidental and groundwater. A signal preamplifier for PMT-85-4 has been developed and tested, which makes it possible to reliably record from 1 to ~ 120 EAS particles with a scintillation counter. The use of a new configuration of clusters and modernized counters will increase the informative value of the experimental data obtained and will make it possible to start a detailed study of cosmic radiation in the energy range $10^{15}-10^{18}$ eV.

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Conflict of interest

The authors declare that they have no conflict of interest.

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