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Tunka-133: Results of 3 year operation ☆

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ABSTRACT

The EAS Cherenkov light array Tunka-133, with ~3 km^2 geometric area, is taking data since 2009. The array permits a detailed study of cosmic ray energy spectrum and mass composition in the PeV energy range. After a short description of the methods of EAS parameter reconstruction, we present the all-particle energy spectrum and results of studying CR composition, based on 3 seasons of array operation. In the last part of the paper, we discuss possible interpretations of the obtained results.

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1. Introduction

The study of primary energy spectrum and mass composition in the energy range of 10^{15}–10^{18} eV is of crucial importance for understanding origin and propagation of cosmic rays (CR) in the Galaxy. An increasing dominance of heavy nuclei above the "knee" up to 10^{17} eV indicated the energy limit of CR acceleration in galactic sources. At higher energies, the composition becomes lighter again up to 2×10^{18}. This may indicate a transition to an extragalactic origin of CR.

To measure the primary energy spectrum and mass composition of cosmic rays in the mentioned energy range, the array Tunka-133 [1,2] with nearly 3 km^2 geometrical area has been deployed in the Tunka Valley, Siberia. It records EAS Cherenkov light using the atmosphere of the Earth as a huge calorimeter, resulting in a better energy resolution (~15%) than EAS arrays detecting only charged particles. The detectors are grouped into 25 clusters, each with 7 detectors – six hexagonally arranged detectors and one in the center. The distance between the detectors in the cluster is 85 m. 19 clusters are installed in an inner circle of 500 m radius – "inside" clusters, 6 clusters were placed at the distance of 700 – 1000 m from the center – "outside" clusters. Tunka-133 operates in clear moonless nights every year from October up to the beginning of April. Results presented in this paper are based on the data of the first three seasons of the array operation. The total time of data acquisition is 980 h. The number of recorded events is about 6×10^6.

2. EAS parameter reconstruction

The primary data record for each Cherenkov light detector contains 1024 amplitude values in steps of 5 ns [1]. Thus each pulse waveform is recorded over 5 μs. To derive the three main parameters of the pulse: pulse peak amplitude A_i, front delay t_i at a level 0.25 of A_i, and pulse area Q_i, each pulse is fitted with a specially developed smoothing curve [3]. A fourth pulse parameter is the effective width τ_{eff} equal $Q_i/(1.24\cdot A_i)$. The accuracy of this parameter is better than that of the pulse width (FWHM) used earlier. The additional coefficient (1.24) "normalizes" τ_{eff} to FWHM.

The reconstruction of the EAS core position is performed by fitting measured amplitudes A_i with an amplitude distance

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