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Interpretation of cosmic ray spectrum above the knee measured by the Tunka -133 array

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Abstract

A probable interpretation of the fine structure of all particle energy spectrum between the knee and the ankle (the sharp first knee at 3-4 PeV, the spectrum hardening at 20-30 PeV, the second knee at 200-300 PeV) as well as a <lnA> (E) dependence measured recently by the Tunka-133 experiment, is presented. We show that these features are compatible with the combined model where cosmic rays around the knee are produced by the group of dedicated sources and the extragalactic light component appears in the energy region of 10^{16} -10^{17} eV and reaches about 50% of all particles around (2-3)×10^{17} eV.

Keywords: Cherenkov light, EAS, Galactic and extragalactic cosmic rays, spectrum, mass composition

1. Introduction

The EAS Cherenkov light array Tunka-133, located in the Tunka Valley near Baikal lake in Siberia, with 3 km^2 geometric area, is taking date since 2009 [1,2]. Together with the earlier data obtained by the Tunka-25 array [3], predecessor of Tunka-133, both experiments permit a detailed study of cosmic ray energy spectrum and mass composition in the energy range 10^{15}-10^{18} eV. The most striking results obtained with this array is a remarkable fine structure of the all particle cosmic ray (CR) spectrum above the "classical" first knee at $E \sim 4$ PeV: the spectrum hardening around 2×10^{16} eV and steepening around (2-3)×10^{17} eV [4,5]. The same structures where measured by KASCADE Grande [6,7] experiments and recently confirmed by the IceTop-IceCube experiment [8]. In all three experiments the increasing ratio of heavy nuclei above the knee up to 10^{17} eV was determined. As a result the point 10^{17} eV looks like an indicator of the energy limit of CR iron nuclei accelerated in galactic sources at rigidity dependent position of the energy $E_{max}(Z)=ZE_{max}(Z=1)$, the position of the first knee, 4 PeV, as a limit for proton maximal energy in the galaxy. The behaviour of heavy and light components around the point 10^{17}eV is of crucial importance. If at higher energies the composition becomes lighter again up to 2× 10^{18}, this may indicate a direct transition to an extragalactic CR in this point.

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