

## Testing of the high-energy $\pi$ and K meson production by the primary cosmic protons and helium nuclei

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The primary cosmic particles with very high energies are initiating huge cascades of various secondary particles in the atmosphere. The atmospheric muon spectrum at energies from 100 up to  $10^5$  GeV is formed in decays of the most energetic  $\pi$  and K mesons produced by the primary protons and more heavy nuclei with energies above the threshold and up to  $10^7$  GeV. The primary nuclei may be regarded as a flux of nucleons. A sophisticated scheme of simulations of the atmospheric vertical muon flux has been elaborated. The partial differential energy spectra of the atmospheric vertical muons in the air shower cascades initiated by primary cosmic nucleons with different fixed energies had been simulated with the help of the program package CORSIKA with statistics of  $10^6$ . The suggested scheme of simulations provides a reasonable accuracy at high energies. The eight most popular hadronic interactions models QGSJET-01, QGSJET-II-03, QGSJET-II-04, DPMJET 2.55, VENUS 4.12, EPOS LHC, SIBYLL 2.1 and SIBYLL 2.3 had been used to estimate these partial spectra. These partial spectra of muons have been convolved with the energy spectrum of the primary nucleons to estimate the atmospheric vertical muon flux. The known calculations of the primary cosmic proton and helium nuclei spectra produced in the supernova remnants had been normalized on the AMS-02 data and tested by PAMELA, ATIC-2, CREAM, ARGO-YBJ, ARGO-YBJ & FWCTA, KASCADE, KASCADE-Grande, Tunka, Ice Cube and Telescope Array TALE data. The energy spectrum of the primary nucleons had been estimated with the help of these spectra. At last, the simulated spectrum of the atmospheric vertical muons had been compared with the rather accurate measurements of the atmospheric vertical muon spectra at energies above 100 GeV (e.g., L3+Cosmic, MACRO, LVD, Ice Cube data). This comparison had demonstrated that all tested models failed to reproduce the atmospheric vertical muon flux correctly. The calculated muon fluxes happened to be below data by factors of  $1.5 \div 2$ . Therefore, all tested models underestimate the production of the most energetic charged  $\pi$  and K mesons by the primary cosmic nucleons by the same factors at energies from  $10^2$  up to  $10^7$  GeV.

### The speaker is a student or young scientist

Yes

### Section

1. Neutrino physics and nuclear astrophysics

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