

Are protons still dominant at the knee of the cosmic-ray energy spectrum?

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A hybrid experiment of emulsion chamber and air-shower array was successfully done at Yangbajing in Tibet to study the primary cosmic rays around the knee energy region. Using the events observed simultaneously in the emulsion chamber and the air-shower array, and applying a neural network analysis to this data set, we obtained the energy spectrum of primary protons in the energy range from 4×10^{14} eV to 10^{16} eV as shown in Fig. 1. The spectrum observed can be represented by the power-law fit and the power indexes are estimated to be -3.01 ± 0.11 and -3.05 ± 0.12 for the spectra obtained using the ANN trained by the QGSJET+HD and SIBYLL+HD events, respectively, which are steeper than that extrapolated from the direct observations of -2.74 ± 0.01 in the energy range below 10^{14} eV. The absolute fluxes of protons was derived within 30% systematic errors depending on the hadronic interaction models adopted in the Monte Carlo simulation. We further obtained the result that the fraction of the nuclei heavier than helium in the primary cosmic rays around the knee region as shown in Fig. 2, which was estimated using the proton+helium spectrum and the all-particle spectrum observed with the Tibet experiment, increases with increasing primary energy. This strongly suggests that the main component responsible for making the knee structure in the all-particle energy spectrum is the nuclei heavier than the helium component. This is the first measurement of the differential energy spectra of primary protons and heliums by selecting them event by event (8).

References

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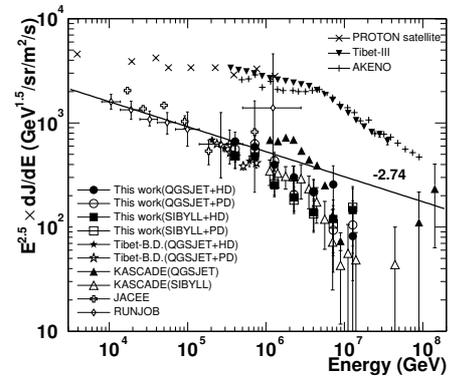


Fig. 1. The primary protons spectra obtained by the present experiment. This work is compared with results from other experiments: Tibet-B.D. (1), KASCADE (2), JACEE (3) and RUNJOB (4). The all-particle spectra are from the experiments : PROTON satellite (5), Tibet-III (6) and AKENO (7).

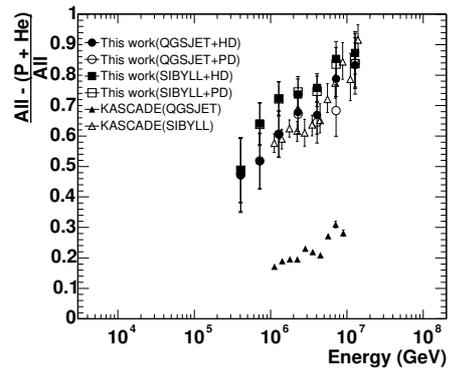


Fig. 2. Fraction of the primary cosmic-rays heavier than helium nuclei obtained by assuming the QGSJET and SIBYLL interaction models. Our results are compared with those by the KASCADE experiment (2).