PRECISE MEASUREMENT OF ATMOSPHERIC GAMMA RAYS AT HIGH ALTITUDE

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Atmospheric gamma rays at high altitude of several g/cm^2 are almost produced by a single interaction of primary cosmic rays, and useful to interpret the various cosmic-ray phenomena inside the atmosphere. More conclusive understanding for the cosmic-ray transport inside the atmosphere is desirable to estimate the absolute flux of atmospheric neutrinos. This estimation is important for the detailed analysis of neutrino oscillation experiments particularly at high energy side. In this paper, we present a precise measurement of atmospheric gamma rays from 30 GeV to 8 TeV at high altitude with emulsion chambers. These chambers have been successfully used to observe the primary electrons in the energy range from 30 GeV to 3 TeV at balloon altitude 14 times from 1968 to 1998. The total exposure factor is 6.42 m^2·day·sr. In the course of these electron observations, we picked up simultaneously gamma-ray events to check a consistency of the observed data.
For the accurate determination of atmospheric gamma-ray spectrum, we took into account of the following factors: detection efficiency, zenith angle distribution of gamma rays, correction for the enhancement of the spectrum due to energy resolution, contribution from the bremsstrahlung of primary electrons. Finally, we obtain the atmospheric gamma-ray spectrum normalized at an altitudes to 4 g/cm^2. It is important to reduce the systematic errors of energy determination in the case of such steep spectrum as power-law form. Although we performed the calibration of energy determination by using FNAL electron beams of 50 GeV, 100 GeV and 300 GeV, the chamber structure is slightly different at each flight. Monte Carlo simulations were performed to calculate the shower development for each chamber, in which the code was confirmed by the FNAL electron calibration experiments within a precision of 5 %.
Assuming that charged pions are produced almost twice neutral pions, we estimate the muon flux at high altitude reliably from our observed gamma-ray spectrum without referring to the primary cosmic-ray flux or hadronic interaction models. We also estimate the primary flux of cosmic rays, referring to an appropriate hadronic interaction model. Proton spectrum estimated by our observed gamma-ray spectrum covers the energy range from 400 GeV to 15 TeV filling a gap in the currently observed proton spectrum.