Geomagnetic Cutoff Effect on Atmospheric Muon Spectra at Ground Level

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Abstract

We observed ground level atmospheric muon fluxes at Ft. Sumner, New Mexico in September 2001. We have obtained an absolute flux and a charge ratio of muon in a momentum range from 0.6 to 10 GeV/c . In this report, we compare the observed results of the flux and charge dependence with those previous measured at different locations, and discuss the geomagnetic cutoff effect on the atmospheric muon fluxes.

1. Introduction

Atmospheric muons convey information of primary cosmic rays and interaction processes inside the atmosphere. The temporal and locational variations of the muon spectrum measured at sea level, for example, reflects the changes of the spectrum of primary protons and helium nuclei[1]. Aside from the local change in the density profile of the atmosphere, the annual variation can be explained by the solar modulation and the locational variation by the geomagnetic cut off, which is 11.4 GV at Tsukuba in Japan and 0.4 GV at Lynn Lake in northern Canada. The difference is clearly seen in the charge ratio of muons for two different geomagnetic latitudes, Tsukuba and Lynn Lake[10]. This observation means that the primary cosmic rays below median energy of the parent particles have an observable effect on low energy muons measured at sea level. The flux of the atmospheric muons has close connection with the flux of atmospheric neutrino. Muons produced through decay processes of π and other mesons are

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also measured at Ft. Sumner. The difference is as large as about 20 % around 1 GeV/c . Since the atmospheric conditions are similar in both observations, it may be considered that the difference is attributed to the effect of solar modulation. The annual variation of muon flux at sea level has been studied in our previous work using the data collected at Lynn Lake in 1997 through 1999[10]. During this period, the flux of primary protons changed about 10 % at 10 GeV and the flux of muons at 1 GeV/c changed by about 5 %. The proton flux measured by BESS in 2000, just after the solar-field reversal, is much lower than the previous years. After the polarity reversal of solar magnetic field, we entered the negative-polarity cycle in which positive particles suffer large modulation effect. It is therefore expected that the proton flux in 2001 is lower than 1999 and the muon flux is also lower. Also shown in Fig.1(left) are the predicted spectra calculated by [8] under the same experimental conditions of atmospheric profile and geomagnetic cut off. The primary spectrum was tuned to reproduce a measured proton spectrum[1] at a balloon altitude by BESS in 2001. The prediction is in good agreement with our result. The flux of both μ^+ and μ^- are higher than the flux observed at Lynn Lake in 1997 through 1999 and at Tsukuba in 1995. The major part of this difference arises from the difference in the altitude of the experimental site; $\sim$ 1000 g/cm^2 at both Lynn Lake and Tsukuba, 892 g/cm^2 at Ft. Sumner. For a comparison with these data, energy loss and decay during the last $\sim$1200 m between the altitudes of 892 g/cm^2 and 1000 g/cm^2 should be properly corrected for. In Fig.1(right), the charge ratio of muons observed each location is also presented.

We observed atmospheric muon fluxes on the ground level at Ft. Sumner, New Mexico, USA in a momentum range of 0.6 - 10 GeV/c. The corresponding atmospheric depth was 892 g/cm^2 during the measurement. The observed result has good agreement with the results obtained by a theoretical calculation, based on the hadronic interaction model developed for the evaluation of the atmospheric neutrino fluxes[7]. The atmospheric depth dependence on the muon flux was clearly observed in the lower energy region. The geomagnetic cutoff effect was observed in μ^+/μ^- ratio. Some details of the analysis on the atmospheric depth dependence and the geomagnetic cut off effect to the muon flux and charge ratio will be presented at the conference.

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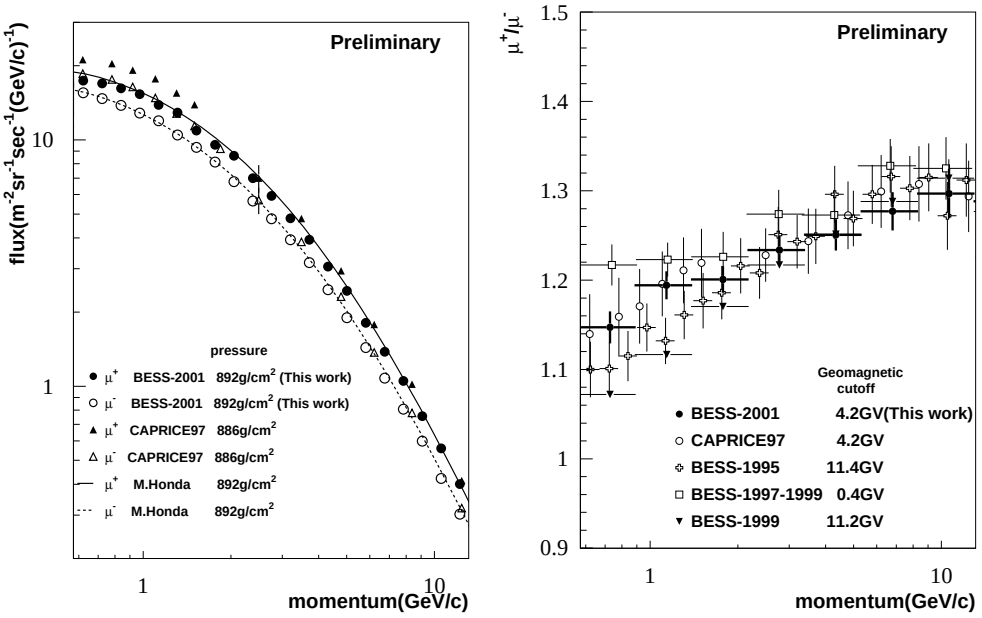

Fig. 1. (left):Result for momentum spectra of the positive and negative muons at Ft. Sumner. (right):μ^+/μ^- ratios at different geomagnetic locations, BESS-1999[11]

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