Observation of Atmospheric Antiproton with BESS

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Abstract

We have observed cosmic-ray antiprotons at an atmospheric depth of 4 to 26 g/cm^2 with a balloon flight of the BESS Spectrometer, launched at Ft. Sumner, New Mexico, in 2001. The atmospheric antiprotons were directly detected for the first time, at balloon altitude under a geomagnetic cut-off condition. We report here the atmospheric antiproton flux in a kinetic energy region of 0.2 - 3.4 GeV.

1. Introduction

In a measurement of cosmic-ray antiproton flux at the top of the atmosphere, subtraction of atmospheric antiprotons is inevitable and a major source of systematic errors. Although several theoretical calculations predicted energy spectra of the atmospheric antiprotons at various altitudes [3,5,7], there have been no direct measurements to verify these predictions. We report here a measurement of the atmospheric antiproton flux by using the BESS spectrometer [1,2,4,6].

2. Balloon Observation

The BESS-2001 flight was carried out in 2001 at Ft.Sumner, NM, where the cut-off kinetic energy is 3.4 GeV for the cosmic-ray protons and antiprotons.

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Thus the observed cosmic-rays below 3.4 GeV were not primary cosmic rays, but were produced inside the atmosphere. It enabled us to perform the direct measurements of the atmospheric antiprotons as well as protons. During the observation time of 14 hours, the payload were slowly descending from 4 to 26 g/cm^2. Fig. 1 shows the change in atmospheric depth during the flight.

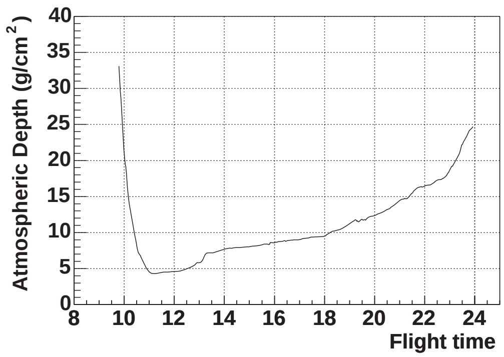

Fig. 1. Atmospheric depth v.s. flight time

3. Analysis and the Results

We first selected events (i) with no interactions inside the BESS detector, (ii) with good quality of the measurement, and (iii) with dE/dx consistent with a singly charged particles and no signal from silica-aerogel Čerenkov counter. We then selected events (iv) with mass consistent with antiprotons. In Fig. 2 ($1/\beta$ v.s. rigidity), events inside the β-band were identified as antiprotons. In whole observation, about two hundred antiprotons were detected in a kinetic energy range between 0.2 and 4.2 GeV. The upper energy of the detectable range is due to a threshold of silica-aerogel Čerenkov counter.

In order to obtain the absolute flux of $\overline{p}$'s, we estimated the detection efficiencies and background. The energy loss in the detector was corrected to derive the kinetic energy at the top of instrument. The interaction probability of the incident particles with detector components, and geometrical acceptance were calculated by using M.C. simulation. The efficiencies of event selection, trigger and silica-aerogel Čerenkov veto were obtained by using real data, which consists mainly of protons. The background contamination due to the inefficiency of silica-aerogel Čerenkov counter was estimated by using the number of negative particles in the antiproton band. It was found to be 5% in an energy range between 1.9 and 3.4 GeV and 0.2% between 1.0 and 1.9 GeV. Below 1.0 GeV it can be neglected. The antiproton flux obtained for an atmospheric depth range of 4 - 26 g/cm^2 is shown in Fig. 3 together with the an expectation , based on the prediction given by Stephens [7]. The measured result is generally consistent with the prediction.

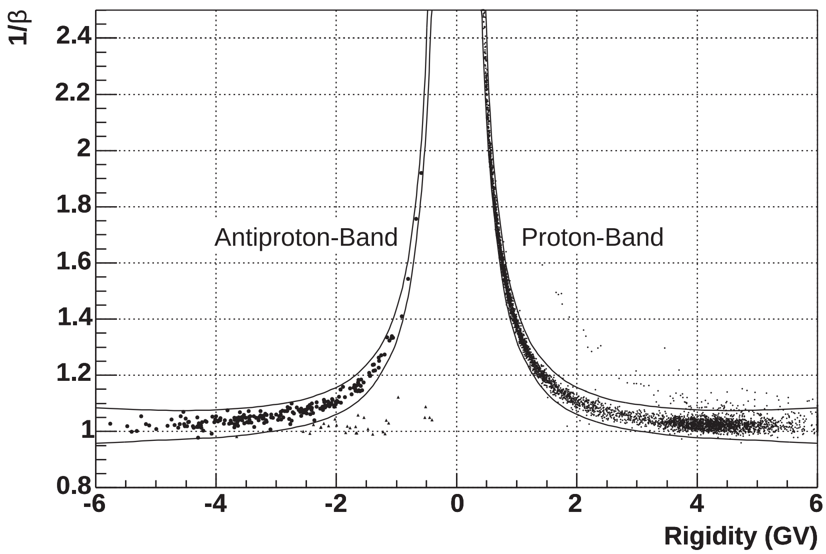

Fig. 2. β^{-1} v.s. rigidity plot. The solid lines represent boundaries of β. The $\overline{p}$'s can be seen at the exact mirror position of protons. Small number of events below antiproton-band are background (i.e. $\mu^-/e^-/\pi^-$). The events of the positive region are sampled, and the events above proton-band are deuterons and tritons.

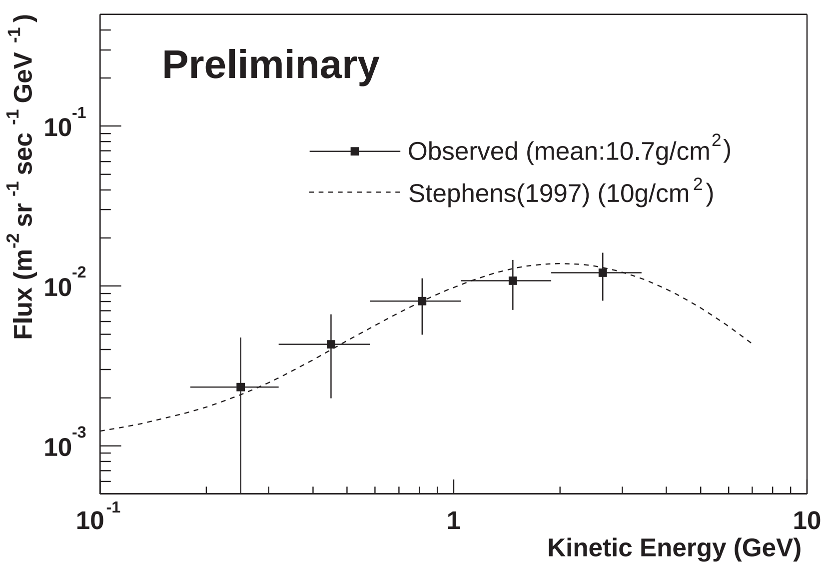

Fig. 3. The atmospheric antiproton flux (preliminarily). The plots with error bars are observed result, and the dashed curve is the theoretical calculations by Stephens [7].

This flux is obtained by using 140 antiprotons in a kinetic energy region of 0.2 to 3.4 GeV corresponding to the cut-off rigidity of 4.2 GV at Ft. Sumner.

4. Summary

Atmospheric antiprotons were clearly observed, for the first time, at an atmospheric depth region of 4 to 26 g/cm^2. We obtain the atmospheric antiproton flux using 140 antiprotons in an energy range between 0.2 and 3.4 GeV.

The atmospheric antiprotons are a major background for precise measurements of cosmic-ray antiprotons. A long duration balloon-borne experiment, the BESS-Polar experiment [8, 9], is being prepared to investigate origin of the cosmic-ray antiprotons by very high statistical observation of the cosmic-ray antiprotons. Understanding the atmospheric antiproton flux will be very important because it enables to minimize the systematic error from this major background.

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