Measurement of the Cosmic-Ray Antiproton Energy Spectrum with HEAT-pbar

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Abstract

The absolute intensities of cosmic-ray antiprotons have been measured in the energy range between 4.5 and 50 GeV. The data were obtained by the HEAT-pbar instrument, a balloon borne superconducting magnet spectrometer with precise rigidity and multiple energy loss measurement capability. The instrument was flown in the Spring 2000 from Ft. Sumner, NM, at an average atmospheric depth of 7.2 g/cm^2. Here we briefly describe the instrument and the measurement and outline the analysis of the data which is still ongoing at this time. We will present the result of our analysis and discuss the implications for cosmic-ray propagation models at the conference.

1. Introduction

Antiprotons are produced as secondary particles in the interaction of high energy cosmic rays with the interstellar medium (ISM). For proton-proton collisions, kinematics suppress production of protons with energies less than 1 GeV. Interactions of protons with heavier nuclei in the ISM have lower kinematic cutoffs. The kinematics of the antiproton production results in a distinguishing shape of the energy spectrum, namely a peak at around 2 GeV. This unique spectral shape and their large mean free path makes them important probes of galactic propagation. In addition to this secondary antiproton component several authors have pointed out the possibility of a small primary antiproton component, for instance through the annihilation of dark matter particles [3] or from such sources as evaporating primordial black holes [4]. The search for a primary antiproton component requires a good understanding of the secondary pbar "background" flux. In this contribution we will present the measurement of the antiproton flux

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above a geomagnetic cut-off rigidity of 4.5 GV based on a total of 78 antiprotons detected during the flight of the HEAT (High Energy Antimatter Telescope) experiment in the spring of the year 2000.

2. Instrument

The HEAT-pbar experiment utilizes a unique combination of particle detectors allowing redundant particle identification, and thus can unambiguously identify antiproton particles. The instrument consists of a superconducting magnet with a drift-tube hodoscope (DTH) at its center combined with a stack of multiwire proportional chambers (MWPC) above and below the magnet. The magnet spectrometer is used to determine a particle's rigidity as well as its charge sign which, combined with the energy loss information from the proportional chambers, is used to provide particle identification. Two layers of scintillators at the very top and at the very bottom of the instrument provide the time-of-flight (ToF) information and, together with a scintillator at roughly the center, form the event trigger. A more detailed description of the instrument can be found in [5].

The measurement reported here was carried out during the 2000 HEAT-pbar balloon flight launched on June 3rd from Ft. Sumner, NM. Data were taken during 68611 sec of integrated livetime at a residual atmospheric pressure between 4.5 – 8.6 mbar (corresponding to an average residual overburden of 7.2 g/cm^2.) The vertical geomagnetic cut-off rigidity along the flight path varied little and averaged to 4.2 GV.

3. Analysis and Results

For this analysis we restricted data selection to the rigidity range 4.5 – 50 GV divided in four intervals. This selects data unaffected by the geomagnetic cut-off and provides reliable rigidity measurement by the drift tube hodoscope. The combined information from the three detector systems (ToF, DTH, MWPC) is used to identify the particle species and kinetic energy [4,5]. Several criteria were imposed on the data to select singly charged events with clean trajectory and to remove upward moving albedo particles. The event selection is described in [2,5].

From the observed number of antiprotons (and protons) we calculate the antiproton (and proton) flux at the top of the atmosphere (ToA) in a sequence of steps. Corrections are applied for particle production in the atmosphere above the instrument and for interaction and annihilation losses of protons and antiprotons in the atmosphere and in the instrument. From the number of antiprotons and protons at the top of the atmosphere we then calculate the flux at ToA from

$$\Phi(E) = \frac{1}{t_{live} \times \Delta E \times \epsilon \times G} \times N^{ToA}(E) \tag{1}$$

where E is the kinetic energy, t_{live} is the live time, ΔE is the ToA energy bin, G is the geometric factor (acceptance), ϵ is the (total) efficiency factor, and $N^{ToA}(E)$ is the number of antiprotons (or protons) at the top of the atmosphere.

The complete analysis and the obtained proton and antiproton fluxes will be presented at the conference.

4. References

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