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GALACTIC ANTIPROTONS OF 0.2-2 GEV ENERGY

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ABSTRACT

Balloon measurements of the galactic antiproton flux in the energy range 0.2-2 GeV are presented. The experiments were carried out in the summer of 1984 with magnet spectrometers flown at a residual pressure of $\sim 10\ g \cdot cm^{-2}$ and cut-off rigidity of ~ 0.6 GV. An upper limit for the antiproton to proton flux ratio has been obtained of

$$\bar{p}/p\ (0.2\text{-}2\ \text{GeV}) < 5 \times 10^{-4}.$$

1. Introduction. Detection of antiprotons in the primary cosmic radiation in the energy range $\sim$ 0.1-10 GeV [1,2,3] and subsequent analysis of the observational data showed that the experimental data cannot be accounted for in the context of ideas involving antiproton production in the interaction of high energy cosmic rays with the interstellar medium. As a result, hypotheses have appeared involving production of antiprotons in compact dense objects [4], in molecular hydrogen clouds [5], in the evaporation of primary black holes [6], and due to possible existence of antimatter in the Universe [7]. Since the largest discrepancy between experiment and theory is found to exist in the low energy region, it appeared reasonable to carry out measurements at a few hundred MeV energy by an independent method and to obtain data on the antiproton spectrum in the intermediate energy range up to $\sim$ 2 GeV. Our first experiments in this area have been carried out in the energy range 0.2-2 GeV with two magnet spectrometers in the summer of 1984 in two balloon flights made in the North at a cut-off rigidity of $\sim$ 0.6 GV.

2. Method and Instrumentation. Each magnet spectrometer (see Figure 1) consisted of a deflecting permanent magnet (M), a spark chamber assembly (SC1-SC4) with optical readout, and a telescope made up of scintillation counters (SC_1,$\overline{SC}_2$,$\overline{SC}_3$,$\overline{SC}_4$,SC_5) and a gas Čerenkov detector ($\bar{Č}$) to determine the direction of particle arrival and for the velocity and charge discrimination of particles. The background due to the electrons (both atmospheric and galactic) and atmospheric muons and pions (produced primarily in the top part of the instrument) which could simulate traversal of the instrument by antiprotons was supressed by the gas Čerenkov counter (with a threshold Lorentz factor $\gamma = 3.1$) with an efficiency > 99.9 %. The possible simulation of antiprotons by albedo protons was eliminated by a time-of-flight analysis of the incident particles. The expected background in the experiment could simulate antiprotons at a level of $\bar{p}/p < 3\times10^{-5}$. The geometry factor of the instrument for particle momenta > 0.4 GeV/c is 1.1 cm^{2}sr, the average line integral-0.68 kGm.

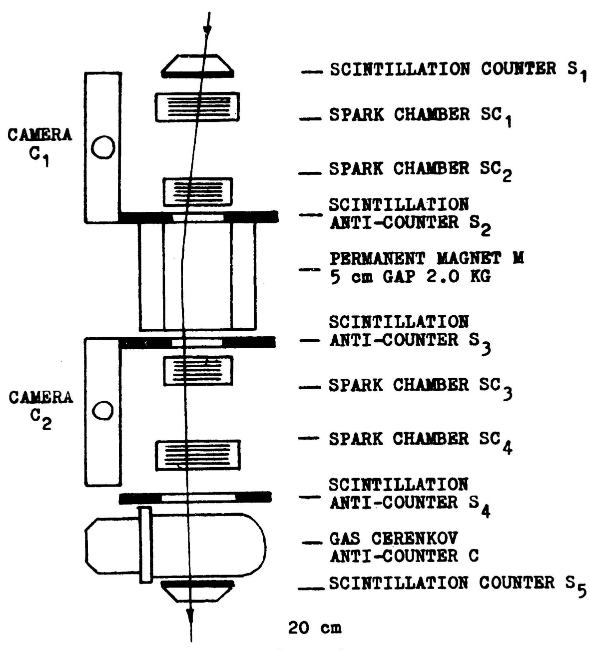

Fig.1. A schematic diagram of the IPTI Magnet Spectrometer.

3. Results. Two balloon flights of the two magnet spectrometers have been carried out in the summer of 1984. The flight on 28-30 June at a residual pressure of ~ 9 g$\cdot$cm^{-2} lasted for 26 hrs, and that on 30-31 June at a residual pressure of ~ 14 g$\cdot$cm^{-2}, for 5 hrs. About 16.500 events were recorded altogether. About 30 % of the information has been processed up to now by the selection criteria chosen [8]. Figure 2 shows the magnetic deflection distribution of singly-charged particles recorded in the flights.

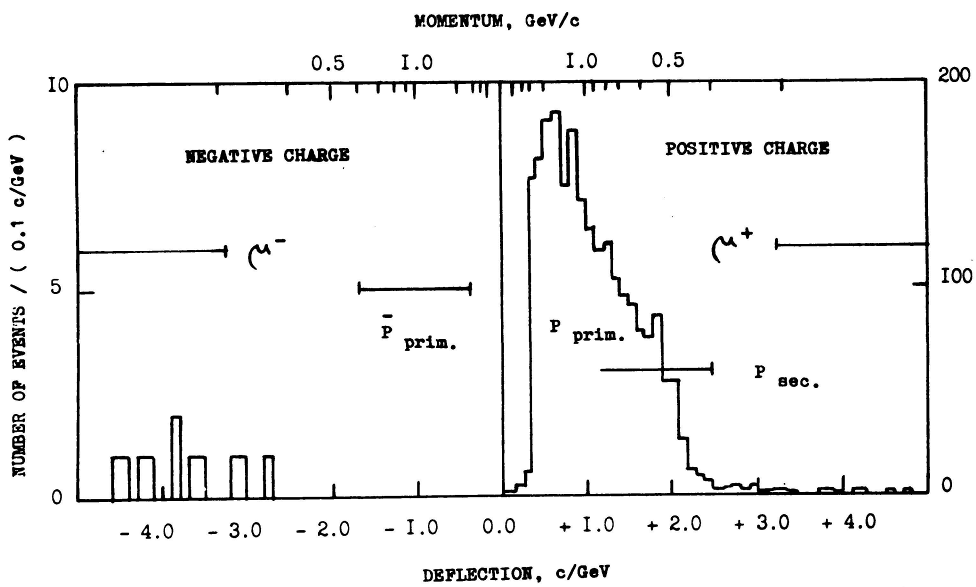

Fig.2. The deflection distribution of singly-charged particles recorded at $\sim 10\ g \cdot cm^{-2}$ of residual atmosphere and cut-off rigidity of ~ 0.6 GV in 1984.

The positive deflection region extending from + 0.3 to + 2.5 $(GeV/c)^{-1}$ corresponds to galactic protons of 2 to 0.2 GeV and secondary protons produced in the residual atmosphere. The upper energy limit for the primary protons is determined by the effective threshold of the Čerenkov counter, and the lower limit, by the actual cut-off rigidity. The expected region of detection of galactic and atmospherically-produced antiprotons corresponds to deflections ranging from - 0.3 to - 2.5 $(GeV/c)^{-1}$. The deflections in excess of $\pm$ 3.0 $(GeV/c)^{-1}$ are due to atmospherically-produced muons.

A total of $\sim$ 2000 protons were recorded in the energy range 0.2-2 GeV. Not a single event was observed in the antiproton deflection range. Thus only an upper limit for the $\bar{p}/p$ ratio has been found up to now, namely,

$$\bar{p}/p\ (0.2\text{-}2\ \text{GeV}) < 5\text{x}10^{-4}.$$

While the measured upper limit for the $\bar{p}/p$ ratio is close to the expected value $\bar{p}/p \simeq (2\text{-}4)\text{x}10^{-4}$ for the energy range 0.2-2 GeV [3,8], no definite conclusions can yet be drawn. Further analysis of the available data and new experiments planned for the summer of 1985 will hopefully improve the statistical significance of the results obtained.

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