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EXPERIMENTAL RESULTS ON 600-1200 MeV ANTIPROTONS IN THE COSMIC RADIATION

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Abstract

The LEAP (Low Energy AntiProton) experiment results in the 600 - 1200 MeV kinetic energy range will be presented. The identification of events in this energy range depends primarily upon the particle mass determined from magnetic rigidity and the pulse height from a Cherenkov radiator having n=1.25 and yielding 70 photoelectrons for relativistic particles. The preliminary analysis has found 3 candidate events, which yields a 90 percent confidence upper limit on the antiproton/proton ratio at the top of the atmosphere of 2.3×10^{-4}.

Introduction Prior to the announced results of the Buffington group (Buffington et al., 1981) of a high flux of cosmic ray antiprotons below 320 MeV kinetic energy, the low energy flux of antiprotons was assumed to be of secondary origin, produced in high-energy nucleon-nucleon collisions of "ordinary matter" cosmic ray particles and nucleons of the interstellar medium. The curves in figure 2 show the expected secondary antiproton flux (Webber 1987) with the dashed line being the flux corrected for solar modulation (Perko 1987). Since the results of the Buffington group are at least an order of magnitude above the predicted secondary component, a source of primary antiprotons seemed to be necessary to reconcile theory with experiment. Many theories were proposed and with so little data, the need to confirm or expand the available data in this low energy regime was very apparent.

The LEAP Experiment The LEAP (Low Energy AntiProton) experiment was designed to do just that - measure the cosmic ray antiproton flux in the 120 - 1200 MeV kinetic energy range. This energy interval overlaps that of the Buffington group and adds to the spectral data above 320 MeV. A high-altitude balloon antiproton search, LEAP is a collaboration of groups at NASA/Goddard Space Flight Center, New Mexico State University, and the University of Arizona. The principal components of LEAP are the NMSU magnet spectrometer, GSFC time-of-flight counters, and a UA Cherenkov counter. A schematic of the experiment stack is shown in figure 1. The magnet spectrometer, described in detail elsewhere (Golden et al., 1978), measures the charge sign and rigidity of particles by tracing their trajectories using eight planes of x - y multiwire proportional counters (MWPC's) in a magnetic field produced by a superconducting magnet coil. The time-of-flight (TOF) system, also described elsewhere (Streimatter, et al., 1989), consists of four planes (two above the magnet, two below the magnet) of plastic scintillator slabs .

The Cherenkov counter, described in more detail in OG 10.5-11 in these proceedings, was designed and built by the Arizona group to extend the energy range of LEAP to 1.2 GeV, as well as identify spurious background events due to electrons, muons, or pions. With an index of refraction of 1.25, protons and antiprotons with less than 1.2 GeV kinetic energy radiate less than 1/2 of the maximum Cherenkov light intensity; in the same rigidity range lighter particles such as electrons, muons, and pions radiate nearly the maximum intensity. The Cherenkov counter could then effectively separate the heavier protons from the relatively light background particles. Thus, the counter was indispensable to the identification of antiprotons above 600 MeV, since the TOF system was not sufficiently accurate at those energies to separate antiprotons from the lighter cosmic ray cascade background particles. In addition, the Cherenkov counter served as a veto against electrons, muons, and pions for the analysis of the lower energy data.Two plastic scintillator counters (S1 and S2) recorded the exit of particles from the bottom of the Cherenkov counter and determined the magnitude of the particles' charge.

Results On August 21, 1987, LEAP was launched from Prince Albert, Canada, for a 20 hour flight at approximately 40,000 meters. The analysis of events in the 600 MeV to 1200 MeV range, where the Cherenkov counter was the primary means of particle separation (as opposed to the TOF system at lower energies), was performed at the University of Arizona and the results of that analysis are reported here.

To isolate the proton and antiproton candidate events, cuts were made to the flight data to weed out unwanted events. These cuts were overly strict, but since these cuts were applied equally to the positive and negative events, the antiproton/proton ratio would be unaffected. This caused us to lose many good events and will be corrected in a reanalysis being performed now. These cuts are the following. A good rigidity fit must have been achieved from the measured trajectory in the MWPC's of the magnet spectrometer. The chi-squared fit of the particle's trajectory through the MWPC's in the x and y axes is good, eliminated scattering events. The limits to chi-squared x and y were quite strict in this case. The pulse-height from the scintillating counter S2 indicates a particle exiting the bottom of the Cherenkov counter, eliminating particles that may range out in the Cherenkov medium (a liquid fluorocarbon-FC72) or miss the Cherenkov counter. The output of the scintillating counter S1 must fall within the peak for a single Z=1 particle (no multiple particles, no showers, no alphas) entering the top of the experimental stack. The particles' apparent rigidity must be within the range of interest to the UA analysis effort. The Cherenkov counter output must be consistent with a heavy particle. That is, the Cherenkov intensity should be less than approximately half the maximum intensity. This condition eliminated the electron, muon, and pion peaks in the rigidity range of interest. The particle's projected trajectory path, derived from the fitted MWPC trajectory, must pass through the body of the Cherenkov counter. The event

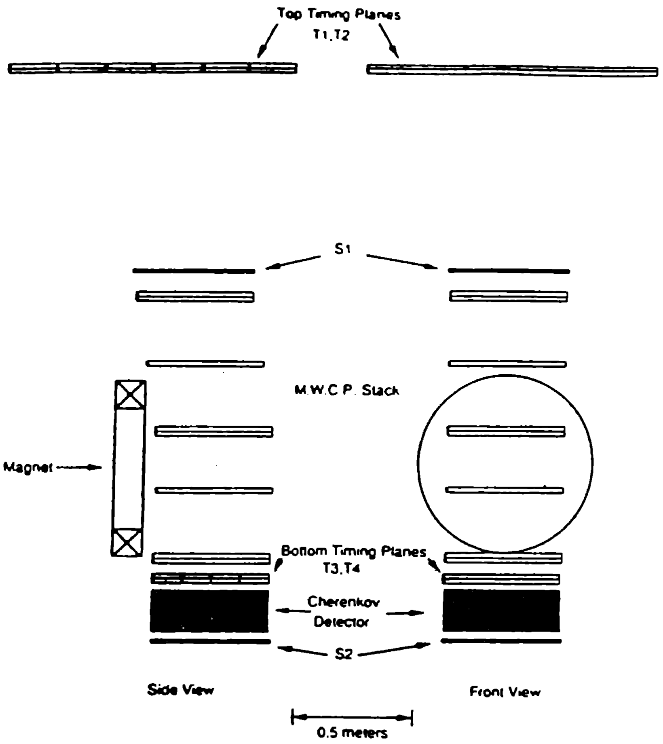

Fig. 1. The LEAP experiment, consisting of T1, T2, T3, T4 (the time-of-flight detector); S1, S2 (scintillation detectors); MWPC stack and magnet (the NMSU magnet spectrometer); and the Cherenkov detector.

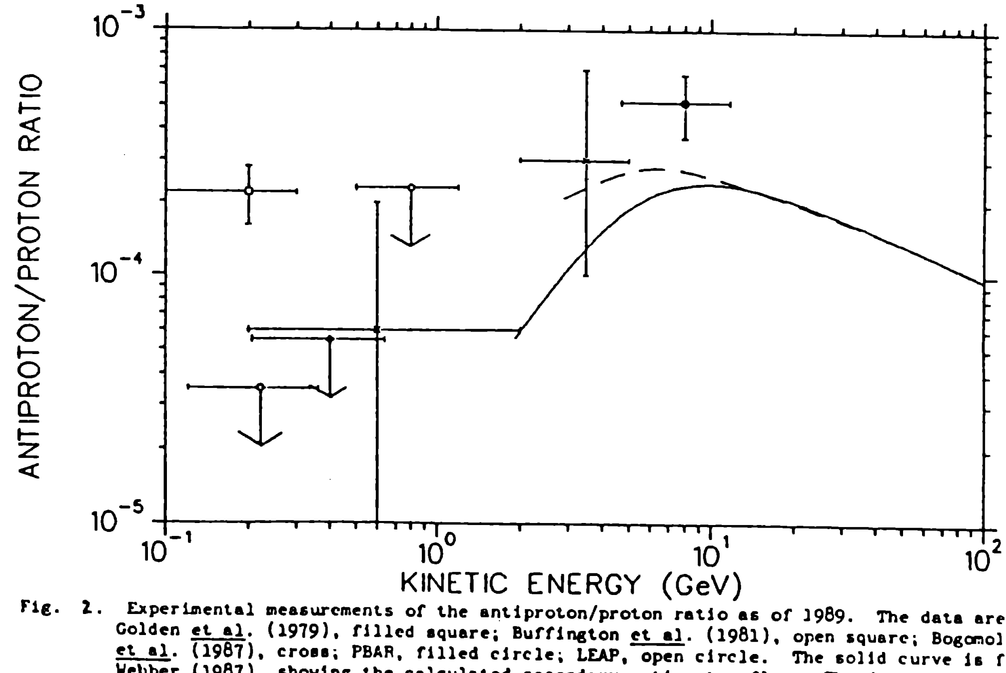

Fig. 2. Experimental measurements of the antiproton/proton ratio as of 1989. The data are from: Golden et al. (1979), filled square; Buffington et al. (1981), open square; Bogomolov et al. (1987), cross; PBAR, filled circle; LEAP, open circle. The solid curve is from Webber (1987), showing the calculated secondary antiproton flux. The dashed curve is from Perko (1987), showing the effect of solar modulation.

must be a downward-moving particle, eliminating albedo protons traveling upwards through the apparatus mimicking an antiproton. The direction of travel was determined from the TOF value of beta. Although the values of beta as calculated from the Goddard TOF system are not accurate enough to distinguish protons from pions at energies greater than 500 MeV, the overall sign of beta can be distinguished. The value of beta from the TOF system and the MWPC's (assuming a proton mass) must be broadly consistent with each other. The particle's mass, as calculated from the MWPC rigidity and the Cherenkov counter output, must lie within the loose limit of 400 MeV to 1.25 GeV. A stricter limit would be unwarranted because of the uncertainties in the rigidity and the inherent uncertainties associated with the low light level in the Cherenkov counter (70 photoelectrons for a relativistic particle). The TOF must be greater than 0.75, indicating an approximate lower limit of 480 MeV at the level of the LEAP gondola.

When these cuts were taken on the flight data, 3 possible antiproton candidates and an equivalent of 41,514 proton candidates were observed in the 600 MeV to 1200 MeV kinetic energy range corrected to the top of the atmosphere. It would require getting all systems calibrated to their utmost to positively identify these three events as antiprotons (in progress now). However, assuming these events to follow a Poisson distribution, the 90% confidence level upper limit is a possible 7 antiprotons giving an uncorrected antiproton/proton ratio of 7/41514 = 1.69 x 10^{-4}. To correct this figure for differential antiproton/proton absorption and antiproton annihilation in the upper atmosphere and gondola, a factor of 1.34 (Bowen and Moats 1986) was used. Thus, the final result is a 90% confidence level upper limit of 2.3 x 10^{-4}. Our calculations show that any contamination of our measurement from antiprotons produced in cosmic ray collisions with atmospheric nuclei is an order of magnitude below this upper limit.

Discussion This result, as well as the data analyzed by the Goddard group (Streitmatter et al., 1989), is shown as the open circles in figure 2. Also included are previously reported antiproton measurements. An upper limit is also shown for the PBAR collaboration (Ahlen et al., 1988), another antiproton search flown during the summer of 1987. Overall, the LEAP results are consistent with the PBAR limit and not consistent with the Buffington group's measurement. In the energy range reported in this paper, the LEAP result is also consistent with the Bogomolov group's data (Bogomolov et al., 1987). An extensive reanalysis of the data in the 600 MeV to 1200 MeV range is now under way to positively identify these antiproton candidates in order to gain a better understanding of the cosmic ray antiproton spectrum in this low energy region.

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