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# EXPERIMENTAL LIMIT ON LOW ENERGY ANTIPROTONS IN THE COSMIC RADIATION

R. E. Streitmatter[1], S. J. Stochaj[1,2], J. F. Ormes[1], R. L. Golden[3], S. A. Stephens[3],
T. Bowen[4], A. Moats[4], J. Lloyd-Evans[5], L. Barbier[1,6], E. S. Seo[1,7]

1. NASA/Goddard Space Flight Center, Greenbelt, MD 20771, U.S.A.
2. Dept. of Physics, University of Maryland, College Park, MD, U. S. A.
3. Particle Astrophysics Laboratory, New Mexico State University,Las Cruces, NM 88003, U.S.A.,
4. Department of Physics, University of Arizona, Tucson, AZ, 85721, U.S.A.
5. Department of Physics, University of South Hampton, South Hampton, SZ09-5NH, United Kingdom
6. NAS/NRC Resident Research Associate
7. Dept. Physics and Astronomy, Louisiana State U., Baton Rouge, LA 70803, U.S.A.

## ABSTRACT

We report results from the Low Energy Antiproton Experiment (LEAP), a balloon-borne instrument which was flown in August, 1987. We find no evidence of antiproton fluxes in the kinetic energy range 120 MeV to 860 MeV, top of the atmosphere. The 86 percent confidence upper limit on the antiproton/proton ratio in this energy range is 1.8 x $10^{-5}$. In particular, this experiment places an upper limit on the flux almost an order of magnitude below the reported flux of Buffington et al. /1/. Results from a final pass through the data will be reported at the conference.

**INTRODUCTION** - The reported observation by Buffington et al. /1/ of a high flux of antiprotons at energies below 1 GeV in the cosmic radiation stimulated a number of intriguing theoretical ideas. Among these theoretical ideas were the decay of primordial black holes or PBHs /2/ and photinos /3/ or other weakly interacting Majorana Fermions (WIMPs) /4/. Ahlen et al. /5/ have reported limits on the antiproton to proton ratio in the cosmic rays which have begun to challenge Buffington's result and place constraints on these hypotheses. Here, we report results from the balloon flight of the Low Energy Antiproton Experiment (LEAP), a collaborative effort by the Goddard Space Flight Center (GSFC), the New Mexico State University (NMSU), and the University of Arizona (UA)

**THE LEAP INSTRUMENT** - The instrument consists of three principal components: a superconducting magnetic spectrometer, a time of flight system (TOF), and a Cherenkov detector. At low energies, proton mass particles are identified by simultaneous measurement of rigidity (R=pc/Ze: momentum per unit charge) and TOF. At higher energies, all three detectors contribute to identification of proton mass particles. The arrangement of detectors is shown schematically in Figure 1. A superconducting magnet and eight planes of Multiwire Proportional Counters (MWPC's) /6/ constitute the spectrometer. The rigidity of each particle is determined by the spectrometer. The geometric factor of the spectrometer telescope in the configuration flown was energy dependent, but of order 200 $cm^2$-sr.

The time of flight system was developed at Goddard Space Flight Center /7/. It consists of twenty Bicron 404 one centimeter thick plastic scintillating paddles, each viewed end-on by one Hamamatsu R2490-1 photomultiplier tube. The paddles are grouped into four planes (T1-T4), two above the spectrometer and two below. See Figure 1. For planes T3 and T4, the tubes are operated in the ambient magnetic field (1400 gauss), without shielding, but aligned with the field so as to minimize gain reduction effects. For the T1 and T2 planes, the photomultipliers are shielded, but not aligned with the small 80 gauss ambient field. The centerlines of the entrance and exit planes are vertically separated by 180 cm, 6 nanoseconds at lightspeed. The time of flight between planes is determined with a resolution of 200 to 270 picoseconds, depending upon which particular paddles are involved.

In addition to the TOF system, the two other scintillators shown in Figure 1, S1 and S2, determine incident charge and make a redundant TOF measurement sufficient to separate upward from downward moving particles.

The Cherenkov detector for the LEAP instrument was developed by the University of Arizona, and uses FC72, a liquid fluorocarbon with an index of refraction of 1.25. This Cherenkov detector will be used to extend the antiproton search up to one GeV.

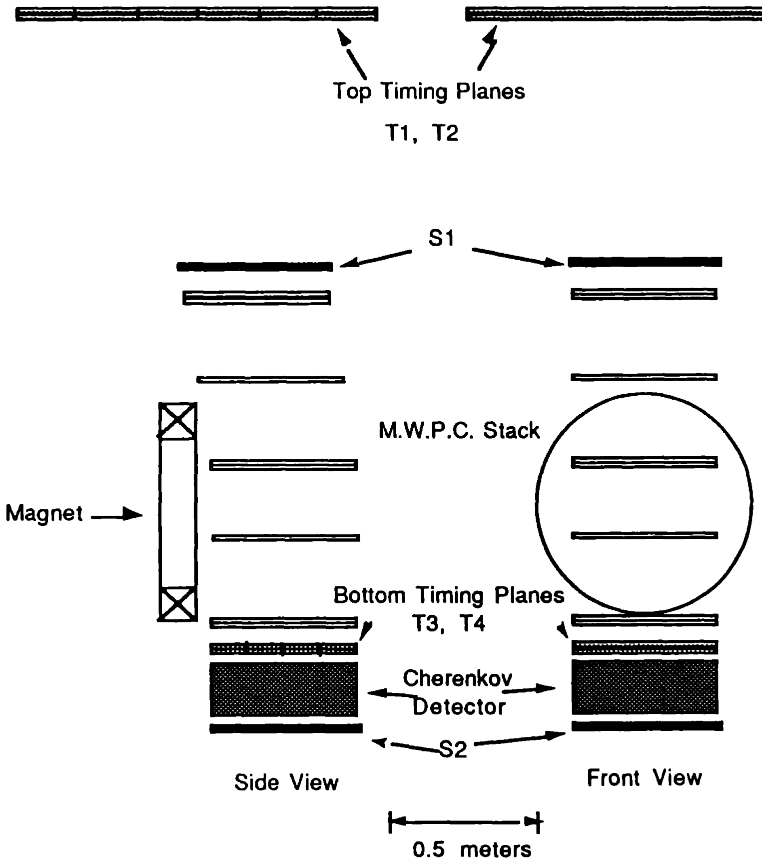

Figure 1. The LEAP Instrument

**FLIGHT** - The LEAP experiment balloon was launched from Prince Albert, Saskatchewan, Canada at 8 p.m. local time on August 21, 1987, and 3 hours later reached float (long. 255.7, lat. 52.7) at an altitude of 119,000 ft., with a residual atmospheric overburden of 4.7 g/cm$^2$. The flight followed a southwesterly trajectory. Using the tables of Shea and Smart /8/, the nominal geomagnetic vertical cutoff rigidity at initial float was 0.65 GV, but as the experiment drifted towards the southwest the nominal cutoff increased throughout the flight. LEAP spent more than 20 hours at float altitude. The experiment landed (long. 250.2, lat. 49.9) near Medicine Hat, Alberta with a nominal cutoff of 1.09 GV.

**ANALYSIS** - During the flight, approximately $10^7$ triggers were recorded. These include not only good events, but nascent air showers and other background events. The following selection criteria were imposed on the data : MWPC tracks met goodness of fit parameters: energy loss in the scintillators was consistent with that expected from a singly charged particle with proton mass and $\beta$ measured by the TOF; timing paddle hit pattern was that of a single particle and not that of an air shower; timing position along a paddle was in agreement with the position determined by the MWPC's; the particle was moving downward with a speed $\leq 0.85 * c$, corresponding to a proton rigidity of less than 1.52 GV. Effects of the geomagnetic cutoff were observed in measured spectra; see paper by E. Seo et al., this conference. The effect of increasing cutoff throughout the flight is to decrease the number of primary protons relative to atmospheric secondary protons in our energy range. At initial float the calculated fraction of proton events in our energy range which are atmospheric secondaries is 0.13, while at the end of the flight this has risen to 0.17.

**RESULTS** - The current processed data contains a sample which represents 159,439 positive curvature proton events in the range corresponding to particles below 860 MeV, corrected to the top of the atmosphere. We find no negative curvature candidate antiprotons. Our uncorrected 86 percent confidence upper limit in the antiproton/proton ratio is then $2/159439 = 1.3 \times 10^{-5}$. The following correction factors are then applied to this ratio: proton atmospheric loss, 0.96; secondary proton atmospheric production /9/, 1.15; proton loss in instrument, 0.93; antiproton atmospheric loss, 1.10; antiproton loss in instrument, including annihilation backprongs, 1.26. This gives an 86 percent confidence upper limit of $1.8 \times 10^{-5}$ for the antiproton to proton ratio in the energy range 120 - 860 MeV, top of the atmosphere. The upper limit from this experiment, the limit from Ahlen et al. /5/, and the finite fluxes previously reported (/1, 10, 11, 12, 13/) are all shown in Figure 2. These results and the results of Ahlen et al. /5/ are in conflict with that of Buffington et al. /1/. These observations together strongly suggest the presence of the low energy cutoff in the antiproton to proton ratio which is expected from kinematic considerations.

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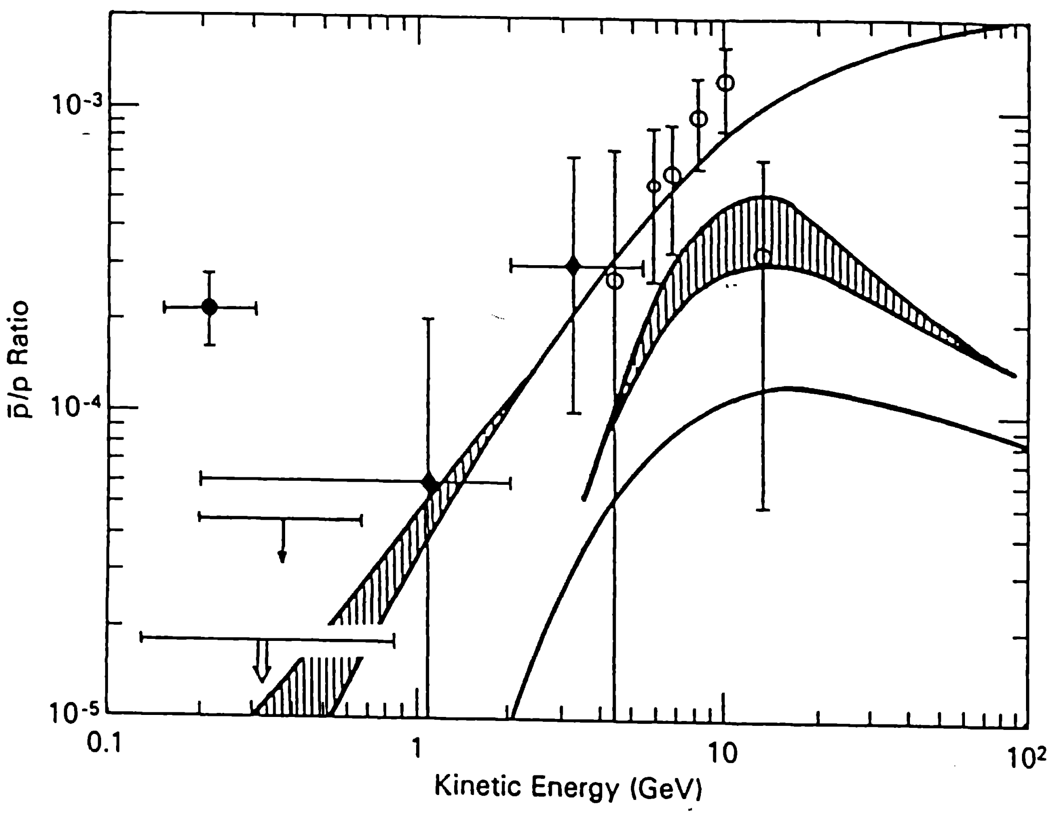

Figure 2 Antiproton/Proton Ratio vs Energy. The data shown are: Golden et al./11/,open circle; Bogomolov et al. /13/, diamonds; Buffington et al. /1/, filled circle, Ahlen et al. /5/, upper limit at 4.6 x $10^{-5}$; this work , upper limit at 1.8 x $10^{-5}$. The three curves are, top to bottom: the closed galaxy model /14/ as calculated by Protheroe /15/; calculation by Simon et al. /16/ with a range of reaccelerartion parameters; leaky box as calculated by Protheroe /15/.