Title
SEARCH FOR AUTIPROTONS

Authors
Stork, Donald H.
Birge, Robert W.
Haddock, Roy P.
et al.

Publication Date
1956-09-18

UNIVERSITY OF CALIFORNIA

Radiation Laboratory

BERKELEY, CALIFORNIA

DISCLAIMER

UCRL-3505

UNIVERSITY OF CALIFORNIA
Radiation Laboratory
Berkeley, California

Contract No. W-7405-eng-48

SEARCH FOR ANTIPROTONS

Donald H. Stork, Robert W. Birge, Roy P. Haddock, Leroy T. Kerth,
Jack Sandweiss, and Marian N. Whitehead

September 18, 1956

Printed for the U. S. Atomic Energy Commission

SEARCH FOR ANTIPROTONS

Donald H. Stork, Robert W. Birge, Roy P. Haddock, Leroy T. Kerth, Jack Sandweiss, and Marian N. Whitehead

Radiation Laboratory, University of California
Berkeley, California

September 18, 1956

ABSTRACT

Two examples of antiproton annihilation have been observed in an emulsion stack exposed at the Bevatron. The experimental arrangement was designed to affect a partial separation of antiproton and pion fluxes. From the yield of antiprotons, we estimate the total cross section for antiprotons in beryllium to be $1^{+0.2}_{-0.1}$ barns. The average energy of the antiprotons in the beryllium was 315 Mev.

SEARCH FOR ANTIPROTONS*

Donald H. Stork, Robert W. Birge, Roy P. Haddock, Leroy T. Kerth, Jack Sandweiss, and Marian N. Whitehead

Radiation Laboratory, University of California
Berkeley, California

September 18, 1956

I. INTRODUCTION

We have calculated the energy spectrum (in the laboratory system) of antiprotons produced by bombarding complex nuclei with 6.2-Bev protons. This calculation employed the Fermi statistical model[1] for nucleon-nucleon encounters and averaged the results over a Gaussian momentum distribution[2] of target nucleons.[3] Because this experiment was planned prior to the discovery of the antiproton,[4] it was necessary to carry out the work on the basis of various theoretical calculations. As we expected, our calculations indicate that even in the most favorable case, the antiprotons would have to be detected in the midst of a very large background of negative pions. We therefore decided to make a partial separation of the antiproton and pion fluxes. The method employed was that of placing an absorber between two momentum-analyzing magnets; the antiprotons and pions impinging on the absorber with equal momenta had different rates of energy loss and left the absorber with different momenta. The second analyzing magnet then caused a spatial separation between the pions and antiprotons. Assuming the total cross section for antiprotons in Be to be the same as that of positive protons, we estimated an improvement in the antiproton-to-pion ratio by a factor of 30, and an antiproton flux sufficient to put about 150 antiprotons into our emulsion stack in several days of Bevatron operation. However, substantially no improvement in the antiproton-to-pion ratio was found. This result is a consequence of the anomalously large cross sections for antiproton interactions.[5]

*This work was done under the auspices of the U. S. Atomic Energy Commission.

II. EXPERIMENTAL METHOD

A. Production Energy and Degrader

The system accepted antiprotons that had been produced at 0° with a mean energy of 430 Mev (a momentum of 1 Bev/c). The beam particles passed through 12 g/cm^2 of stainless steel and 6 g/cm^2 of lucite in leaving the Bevatron tank. After they had passed through 70 g/cm^2 Be absorber, the average antiproton energy was 200 Mev. The choice of production energy and final energy was made on the basis of the theoretical production spectrum mentioned above and an assumption that the total cross section for antiprotons in Be was equal to that of positive protons.

B. Arrangement of Magnets

Figure 1 shows the arrangement of the focusing magnets, degrader, and final analyzing magnet. The magnetic field of the Bevatron served as the first analyzing magnet. The first quadrupole set formed an image of the target at the degrader, and the second quadrupole set (together with the final analyzing magnet) formed an image of the degrader at the stack location. The aperture of the second quadrupole set was large enough so that the loss caused by multiple scattering in the Be degrader was not severe.

C. Bevatron Operation

The proton beam was operated at full energy (6.2 Bev). The copper target was located 5° upstream in the southwest curved section as shown in Fig. 1.

D. Exposure

The limiting factor in the exposure was thought to be the flux of background pions, and the stack (one hundred and eighty 6-by 9-inch pellicles of 600μ G 5 emulsion) was exposed to as large a flux of pions as was consistent with efficient scanning for tracks of twice-minimum ionization (the antiprotons). The exposure was monitored by 50-μ test plates located at the beryllium and at the stack. In actual scanning of the stack, the most troublesome background was found to be the flux of positive protons produced by pions striking the pole tips of the analyzing magnet. The scanning efficiency for twice-minimum tracks has been checked by rescanning parts of the stack, and is essentially 100%.

III. RESULTS

Approximately 50% of the stack has been scanned, yielding two examples of antiproton annihilation.[6] Because the yield of antiprotons in this experiment is dependent upon the total cross sections for antiprotons in beryllium, stainless steel, and lucite, the low yield can be understood in terms of anomalously large cross sections in these materials. The experimental setup is of the "good-geometry" type and thus provides a rough measurement of the total cross sections. Table I shows the number of antiprotons expected in the scanned portion of the stack, for different ratios of total cross section σ_T to nuclear area σ_o equal to $\pi(1.4 \times 10^{-13} A^{1/3})^2 cm^2$, where the antiproton-to-pion ratio at production is 1/48,000.[4]

Table I

Expected number of antiprotons in the scanned portion of the stack for different ratios of total cross section σ_T to nuclear area σ_o equal to $\pi(1.4 \times 10^{-13} A^{1/3})^2 cm^2$.

$\frac{\sigma_T}{\sigma_o}$	Number of antiprotons expected
1.0	125
2.0	30
3.0	7
3.5	3
4.0	1.5
4.5	0.7

Because two antiprotons were found, the total cross sections in the materials mentioned above, are very probably between 3 and 4.5 nuclear areas. In Be, this is a cross section of 0.9 to 1.2 barns. This result can not be compared directly with the previously reported attenuation experiment,[5] because in that experiment scatterings less than 19° were not counted as attenuation events, whereas in this experiment scatterings greater than 2.5° would be counted as attenuation events. However, if those results are corrected for small-angle scattering by assuming that the small-angle scattering is determined solely by "black-sphere" diffraction, a total cross section of 0.7 ± 0.1 barn is obtained.

IV. ACKNOWLEDGMENTS

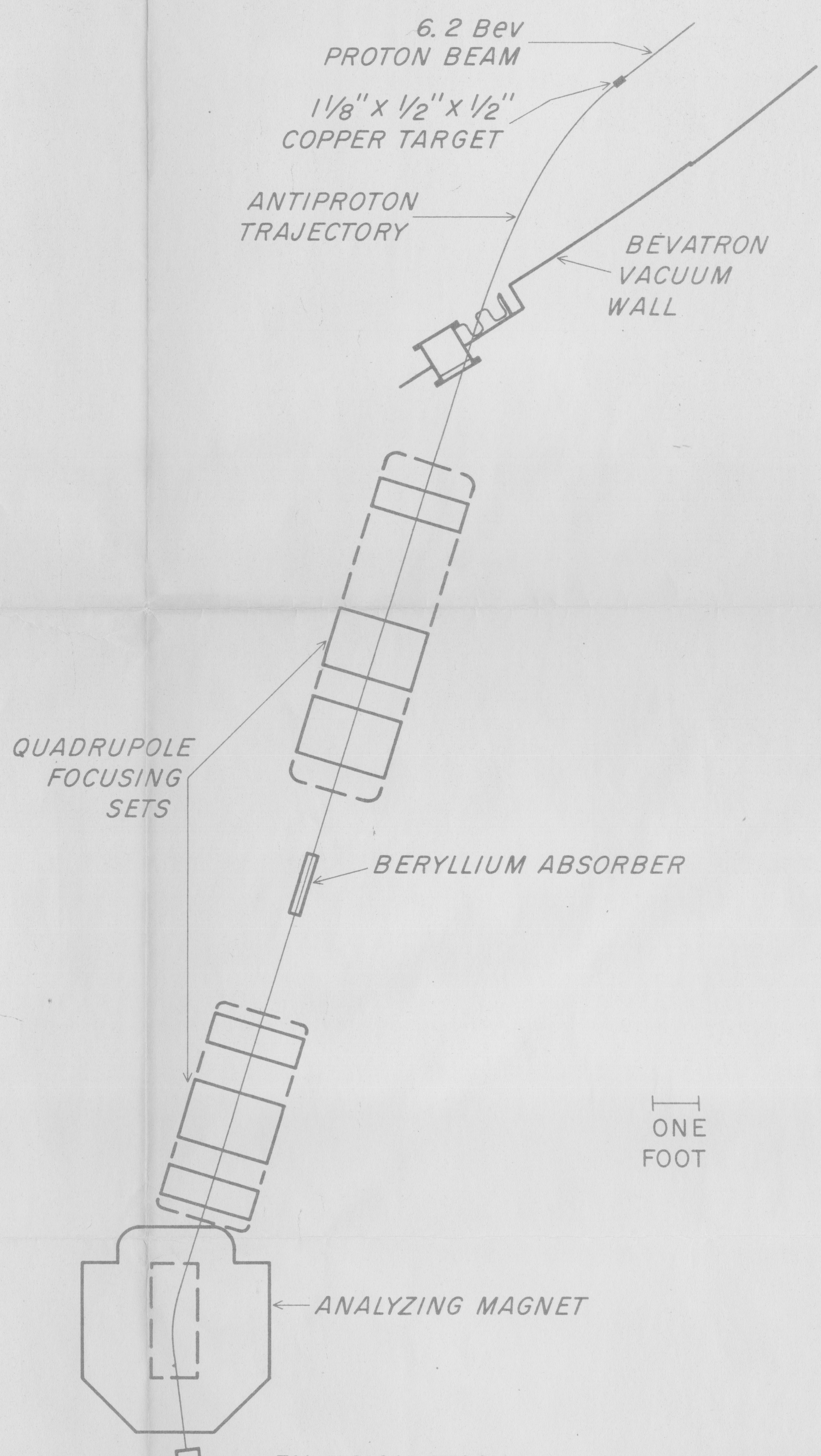
We wish to thank Dr. Edward J. Lofgren and the crew of the Bevatron for their assistance and for the successful operation of the Bevatron.

REFERENCES

1. Enrico Fermi, Progr. Theoret. Phys. (Japan) 5, 570 (1950).
2. Peter A. Wolff, Phys. Rev. 87, 434 (1952).
3. A similar calculation employing a Fermi gas distribution for the target nucleons is reported in Nuovo Cimento X, Vol. III, p. 447 (1956) by Chamberlain, Chupp, Goldhaber, Segrè, Wiegand, Amaldi, Baroni, Castagnoli, Franzinetti, and Manfredini.
4. Chamberlain, Segrè, Wiegand, and Ypsilantis, Phys. Rev. 100, 947 (1955).
5. Chamberlain, Keller, Segrè, Steiner, Wiegand, and Ypsilantis, Phys. Rev. 102, 1637 (1956).
6. The data on the annihilation stars of one of these have been included in the antiproton collaboration experiment, to be published.

FIGURE CAPTION

Fig. 1. The arrangement of quadrupole focusing magnets, degrader, and final analyzing magnet. For clarity the shielding is not shown.


6.2 Bev
PROTON BEAM
1 1/8" x 1/2" x 1/2"
COPPER TARGET
ANTIPROTON
TRAJECTORY
BEVATRON
VACUUM
WALL
QUADRUPOLE
FOCUSING
SETS
BERYLLIUM ABSORBER
ONE
FOOT
ANALYZING MAGNET
EMULSION STACK

25417-3