Lawrence Berkeley National Laboratory
Recent Work

Title
RECENT EXPERIMENTS ON THE ANTINUCLEON-NUCLEON INTERACTION

Permalink
https://escholarship.org/uc/item/0vh8z0b0

Author
Wenzel, W.A.

Publication Date
1960-08-01
DISCLAIMER

This document was prepared as an account of work sponsored by the United States Government. While this document is believed to contain correct information, neither the United States Government nor any agency thereof, nor the Regents of the University of California, nor any of their employees, makes any warranty, express or implied, or assumes any legal responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by its trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof, or the Regents of the University of California. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof or the Regents of the University of California.
RECENT EXPERIMENTS ON THE ANTINUCLEON-NUCLEON INTERACTION

W. A. Wenzel
Lawrence Radiation Laboratory, University of California, Berkeley, California

Although the subject upon which I will report concerns recent antinucleon work at Berkeley, no new antinucleon experiments have been begun during the past year. Nevertheless, owing to the complexity of the experiments in this field, much work on the analysis of older experiments is still in progress. And although much of what I have to say has been reported previously, most of it is presently unpublished.

\( \bar{p}-p \) CROSS SECTIONS

To begin with I would like to review the present situation in regard to the energy dependence of the total and inelastic cross sections and the elastic and charge-exchange scattering cross sections.

Fig. 1 shows the experimental arrangement used by our group \(^1\), for the measurement of these cross sections in the 1-2 BeV range. This kind of arrangement has been used before by our group \(^2\) and by the Segré Group \(^3\).

In this experiment the antiproton beam entered from the left. This beam of a selected momentum contained from \(2 \times 10^4\) to \(2 \times 10^5\) fast particles, mostly pions, per antiproton.

This background was rejected electronically by time of flight and by means of a gas Čerenkov counter. The electronically separated antiproton beam entered the liquid hydrogen target surrounded by a \(4\pi\) solid angle scintillation counter detector. Such a detector of large solid angle was required not only by the diversity of interactions which are possible, but also because of the low flux of antiprotons from the Bevatron, limited to a maximum of about 50 per minute. It was possible to determine the fate of each antiproton which entered the target, and accurate classification of interactions was possible. By two-body kinematics elastic scatterings were separated from annihilations and other inelastic processes. Charge exchange was identified by the apparent disappearance of the antiproton in the target. Addition of a lead converter inside the counter array permitted the detection of \(\gamma\) rays from \(\pi^0\)-decay.

The measured \(\bar{p}-p\) cross sections are shown in Fig. 2. This summarizes most of the work done at Berkeley. Not all measurements are included, but

---

**Fig. 1** Experimental arrangement for antiproton cross section measurements.

**Fig. 2** Measured \(\bar{p}-p\) cross sections.
only those in which a particular effort was made to obtain the energy dependence. The open symbols represent work of our group, including also results given in papers by Armenteros et al \(^1\) and Cork et al \(^2\). The solid symbols are from a paper by Elioff et al \(^3\). The new results show that the total cross section is falling at high energies but that it is still much larger than (about twice) the corresponding nucleon-nucleon cross sections. The elastic cross section is about one-third of the total, in agreement with the results of Elioff et al \(^3\). This is to be contrasted with the factor one-half, which we obtained at lower energies in agreement with the predictions of the Ball-Chew model \(^5\).

It is reasonable to associate this change with the additional inelastic channels due to pion production, since it is known from the high energy nucleon-nucleon measurements, where pion production is dominant, that the interaction can be characterized by a relatively low opacity \(^6\). In this experiment we were not able to separate directly the annihilation cross section from inelastic pion production without making some rather severe (and probably unrealistic) assumptions about the multiplicity of pion production. However if it is assumed that the pion production cross section is about the same at 2 BeV for \(\bar{p}p\) as for the nucleon-nucleon interaction, we find that this accounts for only half the measured inelastic cross section (49±6 mb) or that the annihilation process is still very important at this energy.

I will have some more to say later about the antinucleon-nucleon annihilation cross section at a somewhat lower energy, but meanwhile we may conclude that at 2 BeV we are still some distance below the energy range where Pomeranchuk's Theorem \(^7\) relating particle and antiparticle cross sections might apply to the two-nucleon system. At still higher energies there are some important new results from CERN which were discussed in the previous report.

In the Berkeley data there is still one area of disagreement between experiments, and that concerns the total cross section near 500 MeV. Although the question of the relative amount of elastic and inelastic scattering, which did such violence to our notions about the nature of forces between particles a few years ago, has been settled to the satisfaction of both experimentalist and theorist, there is still some question about just what the value of the cross section is at this energy. Perhaps the most important reason for knowing the cross section here is to gain knowledge of the pion production mechanism just above threshold.

### ELASTIC SCATTERING-ANGULAR DISTRIBUTIONS

Figs. 3, 4, 5 show the angular distribution of the \(\bar{p}p\) elastic scattering, measured \(^1\) at three energies, 1.0, 1.25, and 2.0 BeV respectively. The smooth curves represent efforts to fit the data with a simple optical model calculation. The solid curves represent a “gray disk” model in which the phase shift as a function of impact parameter is constant out to a fixed radius. A purely absorptive interaction is assumed so that two parameters, the radius and the opacity are completely determined by the elastic and the total cross sections. The predicted angular distributions show a characteristic sharp minimum which does not appear in the data. The dashed curves, which seem to fit the data somewhat better, include the effect of a gradual transition from a “black” region of complete attenuation (unit opacity) to zero attenuation. In this case the two parameters fitted
by the cross section data are the radii of these two regions. It should be noted that because of kinematic symmetry we cannot tell the proton from the anti-proton for scatterings in which the transverse momentum transfer is large, so that structure at angles greater than 30° c. of m. could be washed out if there were appreciable backward scattering of antiprotons. From the optical model calculations we conclude that in the 1-2 BeV energy range the \( p-p \) interaction is characterized by a range of about \( 1.5 \times 10^{-13} \) cm and an average opacity of about 0.89. In comparing this with corresponding parameters for \( p-p \) scattering, I think that the difference may be not so much in the range of the interaction as in the opacity. The much smaller \( p-p \) cross sections can also be fitted by an absorptive interaction of range corresponding to that of the pion Compton wavelength provided some potential scattering is included.

In our \( p-p \) angular distributions the points plotted at \( \theta = 0 \) were obtained from the total cross sections by means of the optical theorem and represent a purely imaginary scattering amplitude. Although our angular distributions extrapolated to zero angle are consistent with a purely imaginary scattering amplitude, we cannot rule out as much as a 15% contribution to the cross section from the real part of the scattering amplitude. On the other hand the large opacity required to fit the inelastic cross section would mask the effect of even a relatively large average real phase shift.

\( \bar{p}-n \) CROSS SECTIONS

Most of the work on the nucleon-antinucleon interaction concerns measurements of the \( p-p \) and \( p \)-nucleus interactions. Accurate measurements of \( \bar{p}-n \) (or equivalently \( n-p \)) have been difficult for several reasons. First only one of the particles is charged. Second, it is difficult to obtain a suitable \( n \) beam. Third, the neutron targets are usually bound in complicated nuclei. And fourth, because of the large interaction cross sections for antiprotons, the shadow corrections are large and uncertain even when deuterium is used as a neutron target.

Fig. 6 shows measurements made by the Segre group in the energy range 500-1100 MeV, using
Charge independence places additional constraints on the $\bar{p}$-$p$ and $\bar{p}$-$n$ cross sections. These are best expressed in a series of triangular inequalities \(11\), and it is readily shown that those involving the elastic and charge-exchange $\bar{p}$-$p$ scattering and the elastic $\bar{p}$-$n$ scattering are satisfied by the data of Fig. 6.

\[ \bar{n} \text{ EXPERIMENTS} \]

A study of the nucleon-antinucleon interaction which is charge symmetric to that discussed above has been made possible at one energy by the production of an antineutron beam. This experiment was done in the 72" hydrogen bubble chamber by the Moyer group \(12\) in collaboration with the Alvarez group. Antineutrons were produced by the charge exchange of 940 MeV antiprotons. These entered one end of the chamber after being purified in a momentum channel containing three 20ft parallel-plate electrostatic magnetic velocity selectors \(2,13\). The charge-exchange cross section was obtained from the number of antineutron production events each identified by the "disappearance" of an antiproton. Corrections were made for pion background in the primary beam, zero prong $\bar{p}$-$p$ annihilations, and inelastic neutral pion production. A preliminary value for the charge-exchange cross section is

\[ \sigma_c(\bar{p}p) = 8 \pm 1 \text{mb at } T_p = 940 \text{ MeV} \]

in fair agreement with the results of Armenteros et al \(1\) and Cork et al \(3\) shown in Fig. 2.

The subsequent production in the chamber of annihilation stars by some of the antineutrons (Fig. 7)
furnished a method for measuring the angular distribution of the charge-exchange cross section as well as the $\bar{n}-p$ annihilation cross section. Fig. 8 shows the momentum distribution of the antineutrons produced. The momentum in each case is determined from the angle of production with the assumption that the production is elastic.

The observed multiplicity distribution of charged pions from $\bar{n}-p$ annihilations is shown in Fig. 9. The theoretical distributions (histograms) were calculated by J. Lynch, using the Fermi statistical model with interaction volumes of 10 and $15\Omega_0$

$$\left(\Omega_0 = \frac{4\pi}{3} \left(\frac{\hbar}{m_pc}\right)^3\right)$$

which have been used to fit the annihilation data at lower energies. The theoretical distribution has been used to correct for an inability to distinguish the one-prong $\bar{n}-p$ annihilations. A preliminary value for the annihilation cross sections is

$$\sigma_{\text{ann}}(\bar{n}p) = 44 \pm 6\text{mb} \text{ at } 900\text{MeV}$$

Compared with the measurements of the $\bar{p}-n$ inelastic cross section at this energy $^3$, this suggests that the pion production cross section for $\bar{p}-n$ (or $\bar{n}-p$) is 20 $\pm$ 9 mb, comparable with the nucleon-nucleon inelastic cross section at this energy. The angular distribution of the charge exchange events is shown in Fig. 10. Compared with the data of Fig. 3 for the elastic scattering $^1$, it is seen that the forward scattering cross section for charge exchange is less by a factor of about 10, that the relative rate of fall-off of the cross section with angle is less for the charge-exchange by a factor of about $\frac{3}{2}$, and that at center-of-mass angles between 45° and 90° the charge exchange and elastic scattering cross sections are comparable.

The $\bar{p}-p$ charge-exchange forward scattering cross section is related to the total cross section for the $\bar{p}-p$ and the $\bar{p}-n$ interactions through the following optical theorem

$$\frac{d\sigma_{\bar{p}p}}{d\Omega}_{\theta=0^\circ} \geq \left\{k\left[\sigma_{\bar{n}(p)p} - \sigma_{\bar{n}(p)n}\right]\right\}^2$$

Compared with the measurements of the $\bar{p}-n$ inelastic cross section at this energy $^3$, this suggests that the pion production cross section for $\bar{p}-n$ (or $\bar{n}-p$) is 20 $\pm$ 9 mb, comparable with the nucleon-nucleon inelastic cross section at this energy. The angular distribution of the charge exchange events is shown in Fig. 10. Compared with the data of Fig. 3 for the elastic scattering $^1$, it is seen that the forward scattering cross section for charge exchange is less by a factor of about 10, that the relative rate of fall-off of the cross section with angle is less for the charge-exchange by a factor of about $\frac{3}{2}$, and that at center-of-mass angles between 45° and 90° the charge exchange and elastic scattering cross sections are comparable.

The $\bar{p}-p$ charge-exchange forward scattering cross section is related to the total cross section for the $\bar{p}-p$ and the $\bar{p}-n$ interactions through the following optical theorem

$$\frac{d\sigma_{\bar{p}p}}{d\Omega}_{\theta=0^\circ} \geq \left\{k\left[\sigma_{\bar{n}(p)p} - \sigma_{\bar{n}(p)n}\right]\right\}^2$$

Compared with the measurements of the $\bar{p}-n$ inelastic cross section at this energy $^3$, this suggests that the pion production cross section for $\bar{p}-n$ (or $\bar{n}-p$) is 20 $\pm$ 9 mb, comparable with the nucleon-nucleon inelastic cross section at this energy. The angular distribution of the charge exchange events is shown in Fig. 10. Compared with the data of Fig. 3 for the elastic scattering $^1$, it is seen that the forward scattering cross section for charge exchange is less by a factor of about 10, that the relative rate of fall-off of the cross section with angle is less for the charge-exchange by a factor of about $\frac{3}{2}$, and that at center-of-mass angles between 45° and 90° the charge exchange and elastic scattering cross sections are comparable.

The $\bar{p}-p$ charge-exchange forward scattering cross section is related to the total cross section for the $\bar{p}-p$ and the $\bar{p}-n$ interactions through the following optical theorem

$$\frac{d\sigma_{\bar{p}p}}{d\Omega}_{\theta=0^\circ} \geq \left\{k\left[\sigma_{\bar{n}(p)p} - \sigma_{\bar{n}(p)n}\right]\right\}^2$$

Compared with the measurements of the $\bar{p}-n$ inelastic cross section at this energy $^3$, this suggests that the pion production cross section for $\bar{p}-n$ (or $\bar{n}-p$) is 20 $\pm$ 9 mb, comparable with the nucleon-nucleon inelastic cross section at this energy. The angular distribution of the charge exchange events is shown in Fig. 10. Compared with the data of Fig. 3 for the elastic scattering $^1$, it is seen that the forward scattering cross section for charge exchange is less by a factor of about 10, that the relative rate of fall-off of the cross section with angle is less for the charge-exchange by a factor of about $\frac{3}{2}$, and that at center-of-mass angles between 45° and 90° the charge exchange and elastic scattering cross sections are comparable.

The $\bar{p}-p$ charge-exchange forward scattering cross section is related to the total cross section for the $\bar{p}-p$ and the $\bar{p}-n$ interactions through the following optical theorem

$$\frac{d\sigma_{\bar{p}p}}{d\Omega}_{\theta=0^\circ} \geq \left\{k\left[\sigma_{\bar{n}(p)p} - \sigma_{\bar{n}(p)n}\right]\right\}^2$$

Compared with the measurements of the $\bar{p}-n$ inelastic cross section at this energy $^3$, this suggests that the pion production cross section for $\bar{p}-n$ (or $\bar{n}-p$) is 20 $\pm$ 9 mb, comparable with the nucleon-nucleon inelastic cross section at this energy. The angular distribution of the charge exchange events is shown in Fig. 10. Compared with the data of Fig. 3 for the elastic scattering $^1$, it is seen that the forward scattering cross section for charge exchange is less by a factor of about 10, that the relative rate of fall-off of the cross section with angle is less for the charge-exchange by a factor of about $\frac{3}{2}$, and that at center-of-mass angles between 45° and 90° the charge exchange and elastic scattering cross sections are comparable.
where \( k \) is the wave number for the antiproton. Again, this relation is satisfied by the data of Figs. 6 and 10, supporting the hypothesis that the nucleon-anti-nucleon interaction obeys charge independence.

\[ \bar{p} \text{-NUCLEUS CROSS SECTIONS} \]

Using a modification of the experimental counter arrangement described in a paper by Coombes et al.\(^\text{2}\), Cork\(^\text{14}\) has measured the total, elastic, and charge-exchange cross sections for antiprotons on beryllium and carbon. The cross section results are summarized in Table 1. It should be noted that the charge-exchange cross section is about the same as that found for the \( \bar{p} - p \) interaction\(^\text{2}\). Figures 11 and 12 show the angular distributions of elastic scattering from beryllium and carbon. The curves were calculated\(^\text{15} \) with an optical model and the phase shifts calculated by Ball and Chew\(^\text{3}\) for antinucleon-nucleon scattering. The experimental values plotted at zero degrees were obtained from the total cross section with the help of the optical theorem. The absence of the predicted sharp minima near \( \theta_{CM} = 18^\circ \) may be a consequence of the large angular range of the counters.

Table 1. Total and elastic cross section measurements at 320 MeV antiprotons on Be and C

<table>
<thead>
<tr>
<th></th>
<th>Measured total cross section (mb)</th>
<th>Scattering cross section (5 to 38°) (mb)</th>
<th>Forward-scattering correction (mb)</th>
<th>Elastic cross section (0 to 38°) (mb)</th>
<th>Charge-exchange cross section (mb)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beryllium</td>
<td>670±30</td>
<td>170±10</td>
<td>100±20</td>
<td>270±23</td>
<td>11±4</td>
</tr>
<tr>
<td>Carbon</td>
<td>730±40</td>
<td>172±22</td>
<td>125±25</td>
<td>297±40</td>
<td>10±6</td>
</tr>
</tbody>
</table>

Fig. 11 Angular distribution of elastic \( \bar{p} \)-Be scatterings.

Fig. 12 Angular distribution of elastic \( \bar{p} \)-C scatterings.
STUDY OF THE ANNIHILATION PROCESS

With the data of the 1.05 BeV/c antiproton experiment in the 30° propane bubble chamber more detailed work has been done on several problems.

1. Pion multiplicity and momentum spectrum

The multiplicity is found to be 5.0 ± 0.2, or essentially the same as that which has been found for annihilations at rest (4.9 ± 0.2). The observed multiplicity and spectrum have been fit with the Fermi statistical model including a Lorentz-invariant phase space. The interaction volume required is large, consistent with the value $Q_\pi = 8Q_0$ required to fit the data for annihilations at rest. The statistical model predicts some increase in multiplicity with $p$ energy. This increase is reduced somewhat if a Lorentz contracted interaction volume is used.

The model of Koba and Takeda, on the other hand, predicts that the multiplicity is essentially independent of $p$ energy. While this model seems to fit the energy dependence best, the experimental errors are such that it is not possible to rule out the statistical model used.

2. $K$-production in nucleon-antinucleon annihilation

At 1.05 BeV/c $K$-pair production occurs in 8 ± 1% of all $\bar{p}p$ annihilations. Annihilations on carbon give about the same fraction. This is to be compared with a rate of 4 ± 1% for $K$-production in annihilations at rest. With the statistical model, these $K$-production rates are accounted for if $Q_K \approx 0.1Q_\pi$. This small volume for $K$-interaction, which also gives a rough fit to the observed energy dependence of $K$-production, may be a consequence of the smaller Compton wavelength of the $K$, or of a relatively weaker coupling or other dynamical effects.

3. Multiplicity and spectrum of pions produced with $K$'s in nucleon-antinucleon annihilations

With the above interaction volumes for $\pi$'s and $K$'s, the statistical model predicts a multiplicity $\langle N_\pi \rangle_K = 2.4$ for pions produced with a $K$-pair. This agrees with the observed value, 2.4 ± 0.5. In addition the statistical model predicts that $\langle N_\pi \rangle_K$ is a relatively sensitive function of available energy.

4. Pion-pion correlations

When the angular distribution of pairs of annihilation pions was measured, a difference was found between the distributions for like and unlike pairs. Specifically, pairs of like pions come off more nearly in the same direction than do unlike pairs. G. Goldhaber, S. Goldhaber, W. Lee and A. Pais have attempted to account for this in terms of the influence of Bose-Einstein statistics. A modification of the statistical model has been made by appropriate symmetrization of the pion wave function within the interaction volume. The results are summarized in Table II. $\gamma$ is the ratio of the number of pion pairs emitted in the backward hemisphere to those in the forward. $\rho$ is the radius of the interaction volume in units of the pion Compton wave length. The theoretical values of $\gamma$ have been averaged over four, five, and six pion distributions. $\gamma_{av}^{(mi)}$, predicted by the statistical model, is an average over like and unlike pairs. It is essentially determined by kinematics and agrees with the experi-

Table II. Predictions of modified statistical model for $\gamma$ (see text) for like and unlike pairs.

<table>
<thead>
<tr>
<th></th>
<th>$\gamma_{av}^{(mi)}$</th>
<th>$\gamma_{av}(0.5)$</th>
<th>$\gamma_{av}(0.75)$</th>
<th>$\gamma_{av}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Like</td>
<td>1.23 ± 0.10</td>
<td>1.41</td>
<td>1.38</td>
<td>1.80</td>
</tr>
<tr>
<td>Unlike</td>
<td>2.18 ± 0.12</td>
<td>1.95</td>
<td>1.91</td>
<td>1.80</td>
</tr>
</tbody>
</table>

Fig. 13 Angular distribution of like and unlike pairs of annihilation pions.
mental average. The predicted differences between like and unlike pairs are a consequence of the symmetrization of the pion wave function and can account for most of the observed difference. This effect is sensitive to the assumed interaction radius, $\rho$, and it may be significant that a physically reasonable interaction volume gives the best fit. A detailed angular distribution of the data is given in Fig. 13. The dashed curves are for the simple statistical model, while the solid curves include the effect of B-E symmetrization. It seems clear that continued attempts to understand the annihilation process must take into consideration the effect of B-E symmetries. Other weaknesses of the simple statistical model include failure to take angular momentum into proper consideration and the neglect of dynamical effects, such as pion-pion forces. A number of efforts have been and are being made to consider the effects of the pion-pion interaction in the annihilation process. At the moment I do not believe that any has been quantitatively successful.

LIST OF REFERENCES

8. Elioff, Chamberlain, Steiner, Wiegand and Ypsilantis. (Private communication.)
12. Hinrichs, Parker, Meyer, and Poirier. (Private communication.)
15. Bjorklund, Fernbach, Agnew and Fulco. (Private communications.)

DISCUSSION

Glauber: The weak point in the establishment of the antiproton-neutron cross section by means of subtraction from the antiproton-deuteron data is of course the shadowing or eclipsing effect. Within that term one should include the effect of double scattering, interference and the like. They are in fact all included in the correction as it has been used.

The calculations of this shadowing effect were rather model dependent in the form in which they were done originally and it may be worthwhile pointing out now that because you have angular distribution data of good accuracy, it will be possible to remove that model dependence. Where it was necessary to make explicit assumptions about the interaction between an antiproton and a nucleon (for example, to represent the interaction as a black sphere) it will be possible now to use the angular distributions directly, together with the form factor of the deuteron. Then by doing a simple integral, one evaluates the correction more directly.

Let me say that there is a similar correction in writing the expression for the real and imaginary parts of the optical potential in any optical model. That correction depends on the short range correlations in the positions of the nucleons, and presumably has been left out of the comparisons you describe. It will not be a small effect. Although it tends to be small for nucleon-nucleus encounters, it is proportional to the
squares of the elementary cross sections, and so is very much larger for incident antinucleons.

Wenzel: Are the details of the interaction required in order to make a good correction to the total cross section. It is obvious that they have to be included in the case of scattering angular distributions. To correct total cross sections do you have to know in detail how the interaction behaves in the sense of how much real and how much imaginary scattering there is?

Glauber: Well, as the calculations were done, the interactions were assumed to be black spheres.

Wenzel: Yes, but is that a sensitive thing for the total cross section correction, is that an important assumption?

Glauber: Yes, the correction will depend on whether or not the interaction regions are partially transparent and therefore larger in size. The dependence will be removed by using the angular distribution data directly, but I should say one requires the scattering amplitudes for this more general approach, rather than the scattered intensities that you have measured. The amplitudes can be found if one assumes, as the data indicates at least roughly, that they are purely imaginary.

Wenzel: I should mention in connection with the idea of using the experimental angular distributions here that the average opacity turns out to be, in the energy range we are interested in, about 89%. The interaction region is pretty nearly black.

Glauber: As far as the optical model is concerned, changing the depth of the potential clearly will not effect the more opaque volumes very much, but it will affect the fringes of the nucleus, and will certainly affect the light nuclei.

DOUBLE SCATTERING OF ANTIPROTONS IN HYDROGEN

J. Lannutti, G. Lynch, B. Maglic, M. L. Stevenson, and Nguyen-h-Xuong

University of California, Berkeley, California

(presented by L. Alvarez)

There have been no direct observations on the spin properties and the magnetic moments of antinucleons. An attempt to detect the polarization of antiprotons produced in the Bevatron at 5° in the laboratory has given an inconclusive result 1). To our knowledge, there has been no theory of antiproton polarization. Qualitative arguments, based on the theory of nucleon-antinucleon interaction of Ball and Chew 2) which is characterized by strongly spin-dependent absorption, suggested that an appreciable polarization could be produced in \( \bar{p}p \) scattering. However, the theory is valid only up to about 300 MeV.

The separated antiproton beam of the momentum of \( 1.61 \pm 0.03 \) BeV/c has been described elsewhere 3). The use of a large bubble chamber in the dual role of scatterer and detector presents features favorable for double scattering measurements: an attendant large available solid angle and a high angular resolution. The yield for double elastic \( \bar{p}p \) scattering in the chamber is \( 0.6 \times 10^{-2} \).

An integrated flux of \( 4.6 \times 10^{4} \) antiprotons entered the 72 inch bubble chamber during the exposure. Out of 465 measured 2-prong→2-prong events, 293 coplanar events were identified by KICK 4) as elastic