by putting in the first member the experimental results on reaction $\gamma p \rightarrow p\pi^0$ and $\gamma n \rightarrow p\pi^-$, and in the second member the BDW multipoles, leaving only $\mathrm{Re}M_1^{(0)}$ and $\mathrm{Re}M_{1-}^{(1)}$ to be determined. However, this analysis is not free of ambiguities for the following two reasons: (1) The BDW multipoles are not in good agreement with the Bonn results on $d\sigma/d\Omega$, as previously mentioned; (2) There is a big cancellation when performing the sum $M_{1-}^{(0)}+\frac{1}{3}M_{1-}^{(1)}$ because of the isospin decomposition (4) in the π^0 case. This fact makes it very hard to detect P_{11} effect in π^0 photoproduction.

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Scattering of Antineutrons by Protons*

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The total and elastic cross sections for antineutrons on protons have been measured for antineutron momenta from 0.5 to 2.5 GeV/c. The results are in agreement with previous $\bar{p}p$ data at these momenta.

THE scattering of antineutrons by protons has been investigated using antineutrons obtained from a previously analyzed[1] sample of 841 events fitting the hypothesis

$$\bar{p}p \rightarrow \bar{n}p\pi^- \tag{1}$$

from a 2.7-GeV/c exposure in the Brookhaven 20-in. hydrogen bubble chamber. The momentum spectrum and effective pathlength of the antineutrons are shown in Fig. 1. The values of antineutron momentum ranged from approximately 0.3 GeV/c to 2.5 GeV/c and peaked near 2.2 GeV/c.

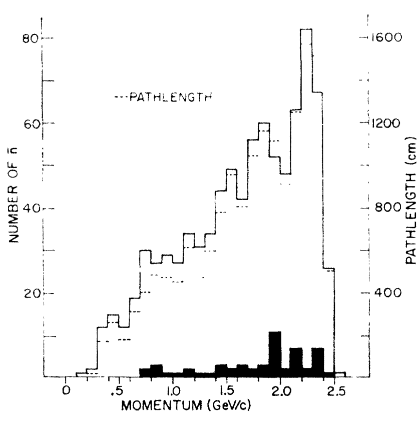

FIG. 1. The solid curve is the momentum spectrum for antineutrons from $\bar{p}p \rightarrow \bar{n}p\pi^-$. The dashed lines indicate the effective pathlength. Events which fit a three-constraint hypothesis are shown by the shaded area.

For each event satisfying reaction (1), a three-view scan was done by two physicists to search for possible interactions along the computed antineutron direction. All interactions within a 5° half-angle cone of the computed antineutron direction were accepted for measurement. No minimum-tracklength criterion was applied during scanning. A total of 277 events were found which had at least one possible antineutron interaction. Each event including the recoil track(s) was measured in three views and processed through TVGP and SQUAW.

A total of 54 events fitted the three-constraint hypothesis to $\bar{p}p \rightarrow \bar{n}p\pi^-$ with a χ^2 probability greater than 1%. In these fits, the antineutron was constrained to pass through the proposed point of interaction. The momentum distribution of these events is shown by the shaded area in Fig. 1. The breakdown of the 54 events includes 36 single recoil tracks, 11 three-prong stars, and 7 five-prong stars. Fits to the various possible final states were tried and the results of these fits are given in Table I. Unique ionization-consistent fits to the $\bar{n}p$ interaction were made for 45 of the events.

The antineutron pathlength was calculated by computing the distance from the antineutron production vertex to the visible edge of the chamber for each event satisfying reaction (1). Corrections were made for the antineutrons which interacted before reaching the visible edge of the chamber. It was found that 19 of the 277 measured events which originally fitted reaction (1) when analyzed by DATPRO-GUTS did not give a fit with probability greater than 1% when analyzed by TVGP-

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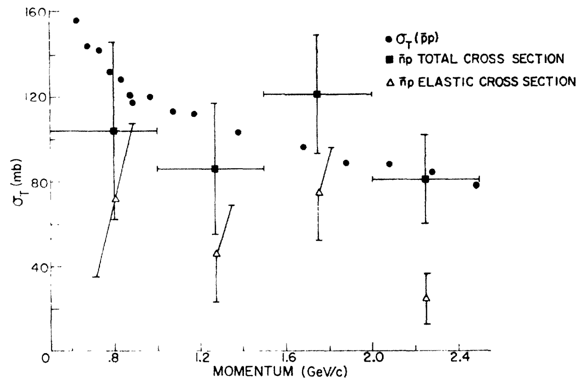

FIG. 2. The $\bar{n}p$ total (solid squares) and elastic (open triangles) cross section as a function of momentum. The total cross section for $\bar{p}p$ obtained by Amaldi *et al.* (Ref. 4) is shown for comparison.

TABLE I. Final results for total and elastic cross sections for antineutron-proton interactions. Final states obtained for $\bar{n}p$ interactions are given below.

Momentum range (GeV/c)	Weighted center (GeV/c)	Number of events	σ_T (mb) (no t cut)	σ_T (mb) (t cut included)	σ (mb) Elastic
0.5–1.0	0.8	6	96±39	104±42	72±36
1.0–1.5	1.27	8	81±29	86±31	46±23
1.5–2.0	1.75	21	125±27	121±28	74±22
2.0–2.5	2.25	19	99±23	81±21	24±12

Final state	Number of events
$\bar{n}p$	29
π^++missing mass	5
p+missing mass	2
$\bar{p}p\pi^+$	1
$\pi^+\pi^+\pi^-\pi^0$	8
$\pi^+\pi^+\pi^-$+missing mass	2
$\pi^+\pi^+\pi^+\pi^-\pi^-\pi^0$	6
$\pi^+\pi^+\pi^+\pi^-\pi^-$	1

SQUAW. The momentum distribution of the antineutrons for these events was consistent with the total spectrum so a statistical correction was applied to the data by decreasing the pathlength by 6.9%. The cross section was corrected for the 1% probability requirement on the three-constraint fits and the results for the total antineutron-proton cross section are given in Table I. No correction has been made for scanning efficiency.

As a check on the number of events lost because of invisible recoils produced by elastic $\bar{n}p$ scattering and because of scanning bias against very short recoils, the four-momentum transfer for all events fitting elastic scattering was examined. A cut was made by requiring that $|t|>0.01$ (GeV/c)^2. This eliminated six events whose recoil tracks were less than 0.4 mm in length. The remaining events had recoil tracks which were sufficiently long to allow precise momentum and direction determination. Based on the total number of recoil tracks with length greater than 0.4 mm observed in our experiment, we estimate an upper limit of 1.5 elastic events and 0.2 multiprong stars due to accidental fitting.[2]

The elastic cross section was corrected by assuming the four-momentum transfer dependence of the elastic scattering to be of the form $e^{\lambda t}$ with a value of $\lambda=12$ (GeV/c)$^{-2}$ consistent with results obtained in $\bar{p}p$ and $\bar{p}n$ elastic scattering.[3,4] The correction to the elastic cross section was 12.7% and this was applied separately to each momentum interval. In all cases the cross sections obtained with and without the four-momentum transfer cut were consistent and both are given in Table I. All errors given are purely statistical. Figure 2 shows the momentum dependence of the $\bar{n}p$ total cross section using the results obtained with the four-momentum transfer cut. The data are plotted at the pathlength-weighted center of each bin. The $\bar{p}p$ total cross section obtained by Amaldi *et al.*[5] is shown for comparison. A χ^2 probability of 73% was obtained for the hypothesis that the $\bar{n}p$ total cross section is equal to the $\bar{p}p$ total cross section, indicating that within our statistics the $T=0$ amplitude is about the same as the $T=1$ amplitude in the $\bar{p}p$ interaction at these energies.

For each momentum interval, the elastic $\bar{n}p$ cross section was calculated using the correction obtained with the four-momentum transfer cut. The results are given in Table I and Fig. 2. These results are consistent with those obtained by Amaldi *et al.*,[5] for $\bar{p}p$ scattering.

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[2] The estimate of possible accidental elastic fits was obtained as follows. A total of 175 recoil tracks with length greater than 0.4 mm were found in the scanning volume. The mean scanning volume is a 5° half-angle cone of height 20 cm which is 0.004 of the effective bubble chamber volume. The actual volume obtained for three-constraint fits was a 2.5° half-angle cone or 0.001 of the effective bubble chamber volume which leaves a total of 44 recoils in this volume. The probability of an accidental fit is determined by requiring that the recoil track lies in the appropriate volume for an elastic scatter. This reduces the probability for an accidental fit by a factor of approximately 30 and gives an upper limit of 1.5 elastic events due to accidental fitting. We note that no requirement has been made on the recoil momentum. Requiring that this momentum be consistent with an elastic scatter would further reduce the accidental probability. A similar calculation for multiprong stars gives an upper limit of 0.2 accidental events.

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