Now μ^*, the N^*-N transition magnetic moment, can be written in terms of $g_{\gamma NN^*}$:

$$\mu^* = \frac{\sqrt{2}}{3} \frac{2m_N g_{\gamma NN^*}}{m_\pi}. \tag{13}$$

Using $g^* = 2.2$ we get

$$\mu^* = (\tfrac{2}{3}\sqrt{2})1.44\mu_p \tag{14}$$

to be compared with the value

$$\mu^* = \tfrac{2}{3}\sqrt{2}\,(1.28 \pm 0.02)\mu_p \tag{15}$$

obtained by Dalitz and Sutherland.[10] Here we ignored the problem of parity doublet for the N^* trajectory. Since no parity partner of N^* exists in nature, we have simply put its residue equal to zero.

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$\bar{p}p$ BACKWARD ELASTIC SCATTERING FROM 0.7 TO 2.16 GeV/c*

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Elastic scattering of $\bar{p}$ on p has been studied for $\cos\theta_{\text{c.m.}}$ between -0.88 and -1.0 and $P_{\text{lab}}(\bar{p})$ between 0.70 and 2.16 GeV/c. The momentum dependence of the cross section shows a sharp dip at 0.9 GeV/c and a broad peaking around 1.4 GeV/c. The possibility of the peak resulting from direct formation of boson resonances has been studied. Alternatively, a diffraction model agrees qualitatively with our data and other elastic data at different angles.

A survey of the backward elastic $\bar{p}p$ scattering has been performed with good statistical accuracy between 0.70 and 2.16 GeV/c at approximately 100-MeV/c intervals. This experiment, along with $\bar{p}p$ annihilation into two charged mesons which was run simultaneously, used much of the same apparatus as the Brookhaven National Laboratory (BNL)–Rochester K^+p backward-scattering experiments.[1]

Previous experiments indicate the possilbe existence of several boson resonances with masses >2 GeV. In particular, a CERN missing-mass experiment[2] gives evidence for the T ($M=2.2$ GeV, $\Gamma=13$ MeV) and U mesons ($M=2.38$ GeV, $\Gamma=30$ MeV) with $I\geq 1$, while a BNL $\bar{p}p$ total-cross-section experiment[3] shows structure interpretable as $I=1$ resonances ($M=2.19$ and 2.34 GeV, $\Gamma=85$ and 140 MeV) and one $I=0$ resonance ($M=2.38$ GeV, $\Gamma=140$ MeV). These two experiments agree fairly well on masses of the $I=1$ resonances, but the widths are in disagreement.

Backward $\bar{p}p$ elastic scattering should be very sensitive to the abovementioned resonances since it is far away from the forward diffraction peak which dominates elastic scattering and no u-channel exchange is expected (no $B=2$ and $Q=2$ particle is known to exist). Thus, if these resonances do exist, we expect to see sharp structures in the 180° cross section as a function of momentum; one may also expect sharp backward peaking since the J of these resonances is expected to be large.

A partially separated beam at the BNL alternating-gradient synchrotron was used to obtain from 500 to 40 000 antiprotons per pulse with a $\pi/\bar{p}$ ratio varying from 1 to 15. A beam particle was identified as a $\bar{p}$ using the information from a liquid differential Cherenkov counter as well as from time of flight at lower momenta (pion contamination was checked often and was always less than 1 %.) The beam-momentum spread was about ±2 %; however, a counter hodoscope was used to improve the beam-momentum resolution so that the final uncertainty in the beam momentum was about ±1 %.

The apparatus, a missing-mass spectrometer using digitized wire spark chambers with magnetostrictive readout,[4] differs from that used in the K^+p experiment[1] only in the following ways: (a) A new 15-in. liquid-hydrogen target was used. (b) A counter hodoscope was used to measure the beam time of flight and also improve momentum resolution. (c) Smaller counters were used to reduce the aperture for triggering. (d) A time-of-flight system was used on the outgoing particle with ±1-nsec resolution. (e) An 8-ft.-wide gas (Freon-12) threshold Cherenkov counter with a threshold of 1.1 GeV/c for pions was added downstream of the last set of wire chambers.

Pion contamination of our backward elastic peak in the square of the missing mass [$(\mathrm{MM})^2$] was reduced by a factor of about 8 using the information from the gas Cherenkov counter and the outgoing-particle time-of-flight system while only about 2 % of the backward elastic events were lost. Figure 1 shows the distribution of events satisfying and failing our criteria for protons.

The data were analyzed in two stages on the BNL CDC-6600 computer. The first-stage program reconstructed the tracks from the wire-chamber spark positions, eliminated events which had an insufficient number of tracks, and provided preliminary results. The second-stage program processed the events which passed the first stage and obtained $d\sigma/d\Omega^*$ in $\cos\theta_{\mathrm{c.m.}}$ bins of 0.02 by applying various kinematic and other cuts.

We have subtracted the background assuming that the background is a linear function of $(\mathrm{MM})^2$ (see dashed line in Fig. 1) and is independent of $\cos\theta_{\mathrm{c.m.}}$ (which had been verified by bin-by-bin subtraction). Typical background levels, as shown in Fig. 1, are about 10 %. The acceptance of our apparatus was calculated using a Monte Carlo program which includes multiple scattering and beam characteristics. The error quoted for $d\sigma/d\Omega^*$ includes statistical errors (10-20%)

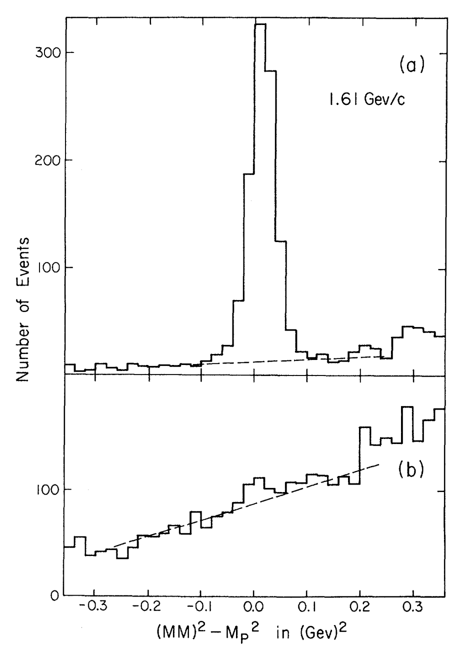

FIG. 1. Number of events plotted against $(\mathrm{MM})^2-M_p^2$. (a) Events satisfying gas-Cherenkov-counter and outgoing-particle time-of-flight criteria for proton. (b) Events failing these criteria and therefore discarded. The dashed line represents the linear background.

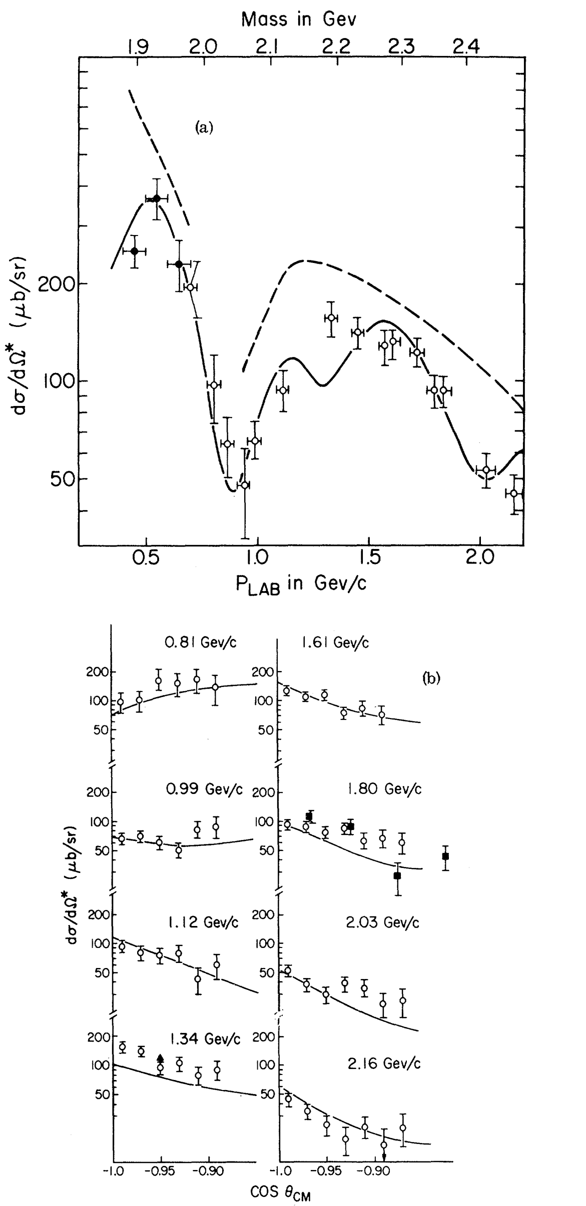

FIG. 2. (a) $d\sigma/d\Omega^*$ for $-0.98 \geq \cos\theta_{c.m.} \geq -1.0$ plotted as a function of momentum is shown by open circles. Data from Ref. 5 ($-0.95 \geq \cos\theta_{c.m.} \geq -1.0$) at lower momenta are shown as closed circles. 90° data based on Ref. 5 (low momentum) and Ref. 7 (0.9-2.2 GeV/c) are shown by dashed line. The solid line is a theoretical diffraction-model curve (see test for model and parameters used). (b) The angular $d\sigma/d\Omega^*$ for representative momenta showing backward peaking above 0.9 GeV/c. Data from J. Lys, J. W. Chapman, and D. G. Falconer, C. T. Murphy, and J. C. Vander Velde [Phys. Rev. Letters 21, 1116 (1968)] (closed triangles) and W. A. Cooper, L. G. Hyman, W. Manner, B. Musgrave, and L. Voyvodic [Phys. Rev. Letters 20, 1059 (1968)] (closed squares) have been included for comparison. The solid line is the result of our diffraction model. Open circles refer to our experiment.

and estimated errors (about 8%) primarily due to uncertainties in the beam distribution and in the approximations used in the Monte Carlo program.

We have studied and applied the corrections to the normalization due to counter inefficiency ($\frac{1}{2}$%), wire-chamber inefficiency (1-5%), beam absorption (8-15%), beam contamination (1%), event-reconstruction ineffeciency (5-12%), and losses due to various kinematic and other cuts (2%). We believe that error in these corrections and any remaining systematic error in the normalization total less than 5%.

Figure 2(a) shows the momentum dependence of $d\sigma/d\Omega^*$ (for $-0.98 \geq \cos\theta_{c.m.} \geq -1.0$) from this experiment. The prominant features include (a) a sharp dip at 0.9 GeV/c and (b) a broad maximum centered at approximately 1.4 GeV/c. It is interesting to note that the 90° $d\sigma/d\Omega^*$, as shown in Fig. 2(a), exhibits the same behavior. Figure 2(b) shows the $d\sigma/d\Omega^*$ in $\cos\theta_{c.m.}$ bins of 0.02 for eight representative momenta. Below 0.9 GeV/c there are indications of a slight backward dip (in agreement with Wisconsin $\bar{p}p$ data below 0.7 GeV/c [5]). Above 0.9 GeV/c, backward peaking is present with a factor-of-2 decrease over a $\cos\theta_{c.m.}$ range of 0.1; this behavior remains in evidence up to our highest momentum.

No evidence for the sharp peaks found in the CERN missing-mass experiment[2] was observed. However, our energy resolution may not be sufficient to resolve them. Also, it should be noted that these mesons may not couple strongly to the $\bar{p}p$ system if they belong to the leading trajectories and thus have J higher than $kr+1$, the maximum angular momentum obtainable from the $\bar{p}p$ system (k = c.m.-system momentum and r = radius, which is about 1.0 F). Barger and Cline also suggest that the absence of sharp peaks may be due to the overlapping of many resonances.[6]

To see if our results are compatible with the broad resonances found in the $\bar{p}p$ total cross section, it is possible to obtain the 180° $d\sigma/d\Omega^*$ using only the values of σ_R (the enhancement to the total cross section due to each resonance)[3] if we assume that the resonances are all in the singlet state (amplitude is pure P_J^0). For the triplet states, the amplitudes are a combination of P_J^0, P_J^1, and P_J^2's, and σ_R alone is insufficient to determine the 180° $d\sigma/d\Omega^*$ although it is expected to be less than if pure P_J^0 exists since P_J^1 and P_J^2 do not contribute at 180°.

For the singlet state, one can obtain the analog of the optical theorem for 180°, $f(180°) = i(-1)^J \times k\sigma_R/4\pi$, at the peak of the resonance by using

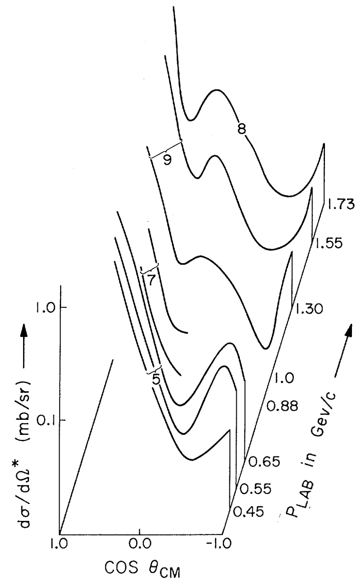

FIG. 3. A three-dimensional compilation of $\bar{p}p$ elastic data between 0.45 and 1.73 GeV/c from other data (the number in the figure refers to the number of the reference from which the data are taken). For the 1.73-GeV/c data, our data have been used to supplement the data of Ref. 8 for which $\cos\theta_{\text{c.m.}} > -0.727$. Note the two valleys which exist; t values for each valley become smaller with decreasing momentum (which agrees with our diffraction model).

Breit-Wigner resonance form and assuming no background. One can thus obtain the amplitude for each of the resonances and combine them. Above 1.1 GeV/c, we are able to obtain a 180° $d\sigma/d\Omega^*$ of approximately the same shape and slightly larger magnitude as our data using only these three resonances. Hence, resonance interpretation is in agreement with our data.

An alternative interpretation for our data which qualitatively agrees with $\bar{p}p$ elastic-scattering data over the full angular range in our energy region is a diffraction picture. Figure 3, a compilation of $\bar{p}p$ elastic data in our energy region,[5,7-9] shows clear indications of the existence of two valleys each appearing at approximately constant t values (t slightly lower at lower momenta); these valleys could be interpreted as diffraction minima. The existence of a very strong annihilation channel from threshold through our energy region gives theoretical incentive and justification for this view.

We have calculated preliminary results of a diffraction model using a black sphere in which the individual partial-wave scattering amplitude is parametrized, following Daum et al.[8] Spin-orbit terms are included but spin-spin terms are neglected.

The equations in our model are the following:

$$d\sigma/d\Omega^* = f_i^2 + f_r^2 + g_r^2, \tag{1a}$$

$$f_i = k^{-1}\sum_{L=0}^{\infty}(L+\tfrac{1}{2})P_L(\cos\theta)/(1+A), \tag{1b}$$

$$f_r = k^{-1}\sum_{L=0}^{\infty}[(L+\tfrac{1}{2})\mu + \tfrac{1}{2}\mu'](A/kD) \times (1+A)^{-2}P_L(\cos\theta), \tag{1c}$$

$$g_r = k^{-1}\sum_{L=0}^{\infty}\tfrac{1}{2}\mu'(A/kD)(1+A)^{-2} \times P_L^{1}(\cos\theta), \tag{1d}$$

$$A = \exp[(L-kR)/kD], \tag{1e}$$

where R = radius, D = skin depth, k = c.m.-system momentum, and μ and μ' are the spin-orbit parameters [related to μ^+ and μ^- of Ref. 8 by $\mu = \frac{1}{2}(\mu^+ + \mu^-)$ and $\mu' = \frac{1}{2}(\mu^+ - \mu^-)$]. Note that complete absorption of lower partial waves is assumed (i.e., a black sphere). f_i, f_r, and g_r are the imaginary and real part of the usual f and g amplitudes.

The solid lines in Figs. 2(a) and 2(b) are the prediction of the model for the values $R = 0.88$ F, $D = 0.03$ F + (0.065 F GeV/c)/k, $\mu' = 0.5$ and $\mu = 0.09$ for $P_{\text{lab}} \leq 1.25$ GeV/c, and $\mu = 0.40$ for $P_{\text{lab}} > 1.25$ GeV/c. Away from 180°, this model with the given values of the parameters still gives qualitative agreement with all the data in Fig. 3. The positions of the two diffraction minima are fairly closely reproduced where data exist. Thus the diffraction picture does give an overall view in agreement with data.

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†Currently at University of Madagascar, Tananarive, Malagasy Republic.

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ERRATA

THEORY OF ITINERANT FERROMAGNETS EXHIBITING LOCALIZED-MOMENT BEHAVIOR ABOVE THE CURIE POINT. S. Q. Wang, W. E. Evenson, and J. R. Schrieffer [Phys. Rev. Letters 23, 92 (1969)].

The bracket in Eq. (9a) should be taken to the -1 power. In the line immediately following Eq. (10), the expression for R should read

$$R = [1 + (c\,\xi_0/\beta\Gamma)^2]^{-1}.$$

The first term on the right-hand side of Eq. (11) should be deleted. Equation (11) should read

$$\chi = (\mu_B{}^2/U)[2\pi\langle\xi_0{}^2\rangle - 1] + \chi_{\text{band}}.$$

THREE-BODY PARTIAL-WAVE ANALYSIS FOR THE FINAL-STATE SCATTERING OF (π^-, NN) FROM ^{12}C AND ^{16}O. H. J. Weber [Phys. Rev. Letters 23, 178 (1969)].

On p. 178 in the third sentence of the Letter, "hence low excitation of the residual nucleus" should be replaced by "hence leaving a clean two-hole state of the target as excited residual nucleus."