improve the relative height of the 1.58-GeV peak.

In the framework of the SU(3)-symmetry model an $I=\frac{5}{2}$ N^* resonance may be classified in the 35 representation.[3] Recently it has been pointed out by Harari et al.[4] that in the extreme SU(12)-symmetry particle classification, where no orbital angular momentum between the quarks exists, the parity of an $I=\frac{5}{2}$ N^* resonance is negative if the decay mode $N_{5/2}^* \rightarrow N_{3/2}^*(1238)+\pi$ exists, and is a non-symmetry-breaking interaction. We have looked for the decay mode $N_{5/2}^*(1580) \rightarrow N_{3/2}^*(1238)+\pi$ in our data by plotting $m_{p\pi_1^+}{}^2$ versus $m_{p\pi_2^+}{}^2$ for events having $1.48 \leq m_{p\pi\pi} \leq 1.68$ GeV in the $p\pi^+\pi^+$ and $p\pi^+\pi^0$ configurations. Although there is some indication for the $N^*(1238)+\pi$ decay mode, the data is too meager for final conclusion.

We would like to express our gratitude to CERN and to the hydrogen bubble chamber crew for enabling us to have the p-p exposure.

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[2]By reflection effects we mean, for example, the contribution to the background in the $p\pi^+\pi^+$ invariant-mass distribution from the existence of the $N^*(1238)$ resonance in the $p\pi^-$ configuration in the reaction $p+p \rightarrow n+p+\pi^++\pi^++\pi^-$. These types of reflection effects were calculated through a Monte-Carlo-type phase-space calculation.

[3]H. Harari and H. J. Lipkin, Phys. Rev. Letters 13, 345 (1964).

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HIGH-ENERGY PHOTOPRODUCTION OF NEUTRAL RHO MESONS*†

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Measurements were made of the photoproduction of charged pion pairs in a mass range from 0.300 to 1.500 BeV using a 5.5-BeV bremsstrahlung beam produced by the Cambridge electron accelerator.[1] Copious production of neutral rho mesons was observed in the forward direction. The dependence of the rho photoproduction cross section on gamma-ray energy, production angle, and atomic number of the target nucleus indicates that a diffraction-like mechanism is dominant.

The spectrometer arms from the previously reported electron-pair experiment were modified and used to detect pion pairs.[2] The circular bending magnet was removed and the single-momentum counters were replaced by an array of angle and momentum counters. The total angular acceptance of each of the two channels on one arm was 1.5°, and the full width at half-maximum of the total momentum acceptance was 8.2%; these combine to give a total mass acceptance of 21%. The angle and momentum counters divided the total acceptance into angle bins of 0.21° and momentum bins of 1.4%; these combine to give mass bins with a full width of 2.8%. The outputs of the angle and momentum counters were fed on-line to a PDP-1 computer, which analyzed each event and calculated the invariant mass of the two-pion system. All charged particle pairs were assumed to be pion pairs; the electron-pair contamination was less than 0.1%. The mass of the dipion system was varied by keeping both the synchrotron energy and the opening angle between the spectrometer arms fixed and varying the momentum in each spectrometer.

Figure 1 shows the dipion mass spectra for dipions produced at 0° from hydrogen and carbon targets. Similar spectra were obtained at laboratory angles of 3.5° and 6°. The only significant structure observed was a peak around a mass of 740 MeV; it was assumed that this peak was due to the rho meson. An analysis of the data with fine mass resolution gave for the rho a full width of 150 ± 10 MeV and a mass of 740 ± 10 MeV. Excitation curves suggested that the rho production was due predominantly to elastic production in which the recoil particle was an unexcited proton.

The mass-spectra data were analyzed in the following manner. The cross section for pion-pair production outside the region of the rho meson was observed to decrease rapidly with the total energy of the dipion system and not to be a strong function of the direction of the two-pion system relative to the direction of the incident gamma ray. Since this behavior was different from that predicted by a simple phase-space model, and since no other model was available, the pair-production cross section outside the region of the rho meson was fitted to a single function which decreased rapidly as the energy of the dipion system increased and which was not a function of the direction of the two-pion system. The cross section for resonant production was determined by subtracting the nonresonant background from the measured cross section. This procedure (see Fig. 1) overestimates the nonresonant background for low-mass dipions which come off at 0°. The resultant error in the calculation of the cross section for rho production is at the worst comparable with the statistical uncertainty in the production cross section. A Monte-Carlo calculation was used to determine the detection efficiency for pion pairs from the decay of transversely polarized rhos.[3] The computer program assumed that the rho was produced with a Breit-Wigner mass distribution with a full width of 150 MeV and a central mass of 740 MeV; it then calculated the expected counting rate as a function of momentum. The cross section for rho production was determined by fitting the calculated acceptance to the data in the region of the rho peak. The acceptance calculations showed that the angular acceptance for rhos was plus or minus 0.5° about the nominal angle.

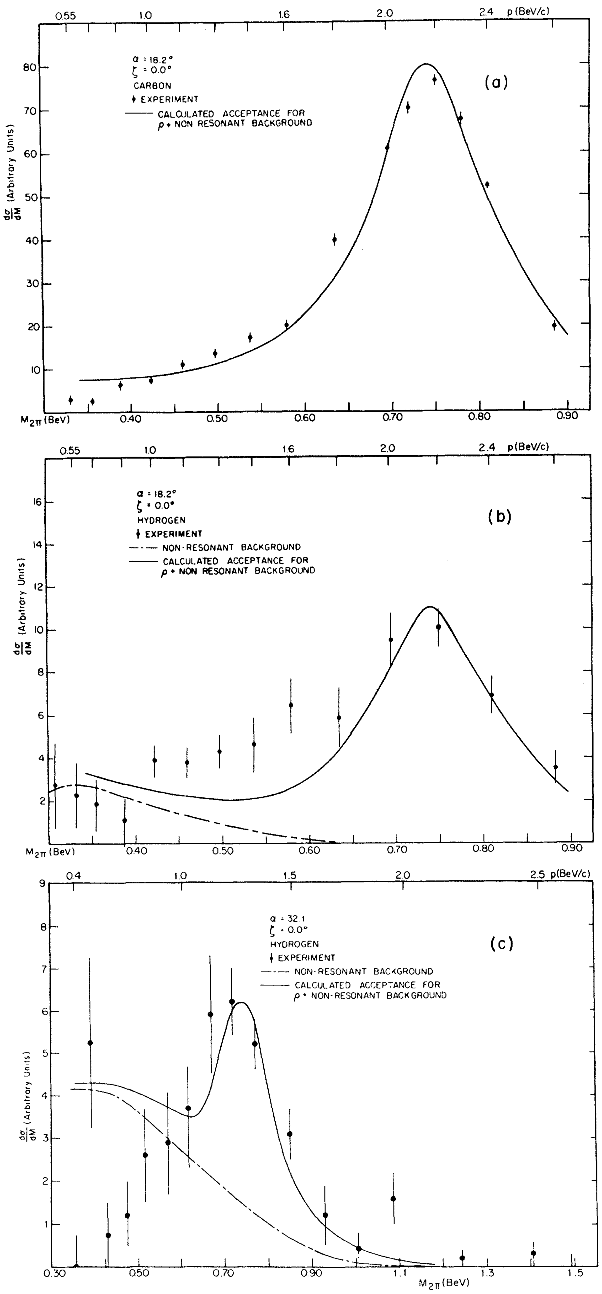

FIG. 1. This figure shows three mass spectra for dipions at 0°. The angle α is the opening angle between the two pions; the angle ζ is the angle the total momentum of the dipion system makes with the direction of the incident gamma ray. The spectra were taken by keeping the angle between the spectrometer arms fixed and varying the momentum. The dotted lines in (b) and (c) show the nonresonant background. The calculated acceptance for the rho is the result of a Monte-Carlo calculation of the detection efficiency. The program assumed that the rho is produced with a Breit-Wigner mass distribution with a full width of 150 MeV and a central mass of 740 MeV; it then calculated the expected counting rate as a function of momentum with a fixed angle between the spectrometer arms. The amplitude of the acceptance curve was adjusted to fit the measurements around the rho mass.

Figure 2 shows the rho-production cross section in the laboratory system for hydrogen as a function of energy and momentum transfer. Two models for rho photoproduction have been proposed by Berman and Drell–one-pion exchange and diffraction production.[3] If the one-pion exchange cross section for production of rhos at 0° is averaged over the apparatus acceptance, the ratio of the cross section

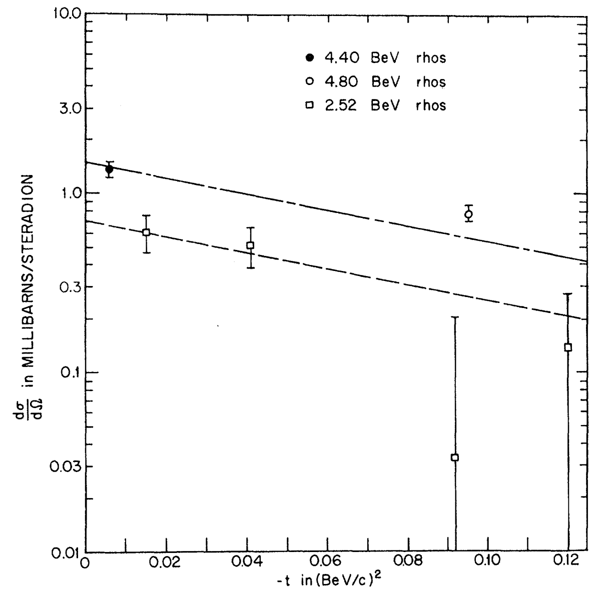

FIG. 2. A plot of the differential cross section for rho production from hydrogen versus t, the square of the invariant momentum transfer. The dotted lines show the variation with momentum transfer found for pion-proton scattering; they are plots of e^{10t}. This figure suggests that the dependence of the rho production cross section on momentum transfer is similar to that for pion-proton scattering.

for 4.40- and 2.52-BeV rhos is

$$\left.\frac{\langle d\sigma/d\Omega\rangle_{4.40\text{ BeV}}}{\langle d\sigma/d\Omega\rangle_{2.52\text{ BeV}}}\right|_{\text{one-pion exchange}} = 0.66. \quad (1)$$

The diffraction mechanism suggests that the differential cross section for rho photoproduction is proportional to the differential cross section for elastic pion-nucleon scattering at the same total energy and momentum transfer. If it is assumed that the differential cross section for elastic pion-nucleon scattering is given by the optical theorem, then

$$\left(\frac{d\sigma}{d\Omega}\right)_{\gamma+p\to\rho+p} = (\text{const})\left(\frac{k\sigma_{\pi N}}{4\pi}\right)^2 e^{Bt}. \quad (2)$$

Here k is the laboratory energy of the gamma ray, $\sigma_{\pi N}$ is the total cross section for pion-nucleon scattering, and t is the square of the invariant momentum transfer. For elastic pion-nucleon scattering in the range from 2 to 5 BeV,[4] $B = (9.5\pm 2.0)(\text{BeV}/c)^{-2}$. For this diffraction model and 0° photoproduction

$$\left.\frac{\langle d\sigma/d\Omega\rangle_{4.40\text{ BeV}}}{\langle d\sigma/d\Omega\rangle_{2.52\text{ BeV}}}\right|_{\text{diffraction}} = 3.15. \quad (3)$$

The ratio of the measured cross sections is

$$\left.\frac{\langle d\sigma/d\Omega\rangle_{4.40\text{ BeV}}}{\langle d\sigma/d\Omega\rangle_{2.52\text{ BeV}}}\right|_{\text{experimental}} = 2.2\pm 0.6. \quad (4)$$

Thus the data indicate that the photoproduction is dominated by the diffraction mechanism. If it is assumed that the photoproduction is due to a combination of the diffraction and one-pion-exchange mechanisms, one obtains for the average differential cross sections

$$\langle d\sigma/d\Omega\rangle_{4.40\text{ BeV}}^{\text{diffraction}} = 1.26\pm 0.17\text{ mb/sr}. \quad (5)$$

and

$$\langle d\sigma/d\Omega\rangle_{4.40\text{ BeV}}^{\text{one-pion exchange}} = 0.10\pm 0.10\text{ mb/sr}. \quad (6)$$

This one-pion-exchange cross section gives a value of (1.5 ± 1.5) MeV for $\Gamma_{\rho\pi\gamma}$.

Further evidence for diffraction production in hydrogen is given by the dependence of the observed cross section on momentum transfer. Figure 2 indicates that the parameter B for rho production is consistent with being the same as that for pion-nucleon scattering. The observed cross sections decrease more rapidly with momentum transfer than is predicted by the one-pion-exchange model corrected for absorption.[5]

Photoproduction from carbon, aluminum, and copper targets gave additional evidence for a diffraction mechanism. Figure 3 shows the variation with A of the cross section for 4.4-BeV rhos at 0°. Since the momentum transfer is not zero, a comparison with pion diffraction scattering[6] requires an extrapolation of the rho-photoproduction cross section to $t = 0$. It was assumed that the electron-scattering form factor at the same momentum transfer gives a measure of this correction.[7] The similarity of the A dependence of the rho cross section and the pion diffraction cross section is striking; this indicates that Eq. (2) gives

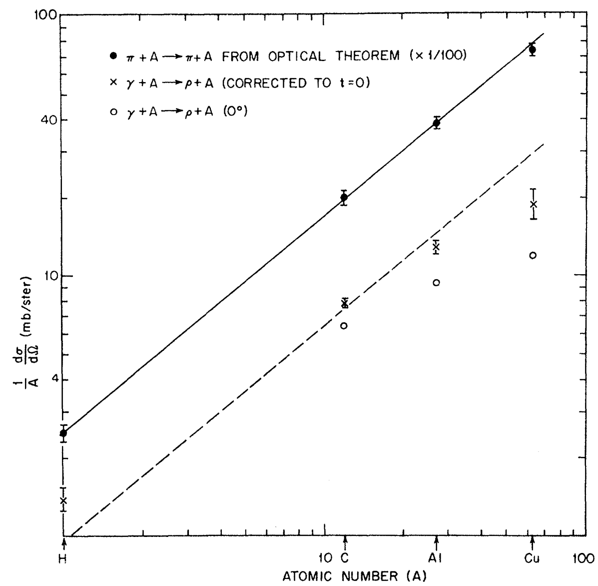

FIG. 3. A plot versus the atomic number, A, of the 0° 4.40-BeV rho photoproduction cross sections and the 0° cross sections for pion scattering. The optical theorem was used to calculate the pion-nucleus cross sections from measurements of the total cross sections. In order to compare the A dependence of the two cross sections, the rho cross sections were extrapolated to momentum transfer $t = 0$. The line drawn through the rho data has the same slope as the fit to the pion cross sections. This plot shows that there is coherent production, and it suggests that there is a simple relationship between the rho photoproduction and pion-nucleus scattering.

an excellent description of the rho photoproduction. Since isotopic-spin arguments predict a difference in the phase of the proton and neutron one-pion-exchange amplitudes, the observed A dependence cannot be accounted for by coherent one-pion exchange. On the basis of Fig. 3, a noncoherent mechanism in hydrogen with a cross section less than 30% of that of the diffraction production cannot be excluded.

The rho polarization was measured by observing the asymmetric decay of 2.52-BeV rhos produced at 0° from carbon. For a negative pion angle of 62° with respect to the forward direction in the rho center-of-mass system, the yield was 0.75 ± 0.16 times that for rhos decaying with the pions at 90°. For a negative pion angle of 118° the yield was 0.79 ± 0.17 times that for rhos decaying with the pions at 90°. If the rhos are transversely polarized, as is predicted by the diffraction and one-pion-exchange models, both ratios would be 0.78. It was concluded from this measurement that the rhos are transversely polarized. The ratio of the 62° and 118° yields is 0.96 ± 0.17. This result indicates that the large front-back asymmetry observed in the decay of rhos produced by π-p collisions does not occur in photoproduction.[8]

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