PHOTOPRODUCTION OF THE A_2 MESON IN THE REACTION $\gamma p \to n\pi^+\pi^+\pi^-$ AND AN ESTIMATE OF THE A_2 $\gamma\pi$ WIDTH*†

Y. Eisenberg, B. Haber, B. Horovitz, E. Peleg, E. E. Ronat, A. Shapira, G. Vishinsky, and G. Yekutieli
The Weizmann Institute of Science, Rehovoth, Israel

and

J. Ballam, G. B. Chadwick, Z. G. T. Guiragossián, A. Levy,‡ M. Menke, P. Seyboth,§ and G. Wolf‖
Stanford Linear Accelerator Center, Stanford University, Stanford, California 94305
(Received 17 November 1969)

We observe production of the A_2 meson in the reaction $\gamma p \to n\pi^+\pi^+\pi^-$ at 4.3 and 5.25 GeV. The data are consistent with a one-pion-exchange production mechanism and we give an estimate of $\Gamma(A_2 \to \gamma\pi) \approx 0.5$ MeV. A similar value for $\Gamma(A_2 \to \gamma\pi)$ is also obtained using a vector dominance model.

The A_2 meson is known to decay mainly into $\rho\pi$. Since its spin and parity are believed to be $J^P = 2^+$, it should couple only to transversely polarized ρ mesons. Under the assumption of vector dominance[1] (VDM), it should also couple to photons and the decay mode $A_2 \to \gamma\pi$ should be substantial. No direct observation of this decay mode so far has been reported. However, if indeed $\Gamma(A_2 \to \pi\gamma)$ is appreciable (~0.5 MeV) one should be able to observe the photoproduction of A_2 mesons via a one-pion exchange mechanism (OPE), for example in the reaction

$$\gamma p \to nA_2^+. \quad (1)$$

In this Letter we wish to report evidence for this process in the final state

$$\gamma p \to n\pi^+\pi^+\pi^-. \quad (2)$$

Indications of A_2 production in the reaction $\gamma p \to p\pi^+\pi^+\pi^-\pi^-$ have already been reported.[2]

The Stanford Linear Accelerator Center (SLAC) 40-in. hydrogen bubble chamber was exposed to 4.3 and 5.25 quasimonochromatic photon beams, obtained by the annihilation of 8.5- and 10-GeV positrons in a liquid-H_2 target. The number of photographs analyzed was 400 000 at 4.3 GeV and 260 000 at 5.25 GeV. The event yield in the combined data was 60 events/μb. Preliminary results and details of the analysis procedure have been presented separately by the SLAC group[3] at 5.25 GeV and by the Rehovoth group[4] at 4.3 GeV. Earlier bubble-chamber experiments[5] did not report A_2 production in Reaction (2). We believe that the lack of knowledge of the photon energy in these bremsstrahlung experiments resulted in contamination of the channel with multineutral particle production which concealed the effect. In the present experiment the photon energy is known and thus the multineutral background is negligible.

In Fig. 1(a) we show the $M(\pi^+\pi^+\pi^-)$ distribution unshaded for Reaction (2) with the two incident energies combined. A clear signal at the A_2

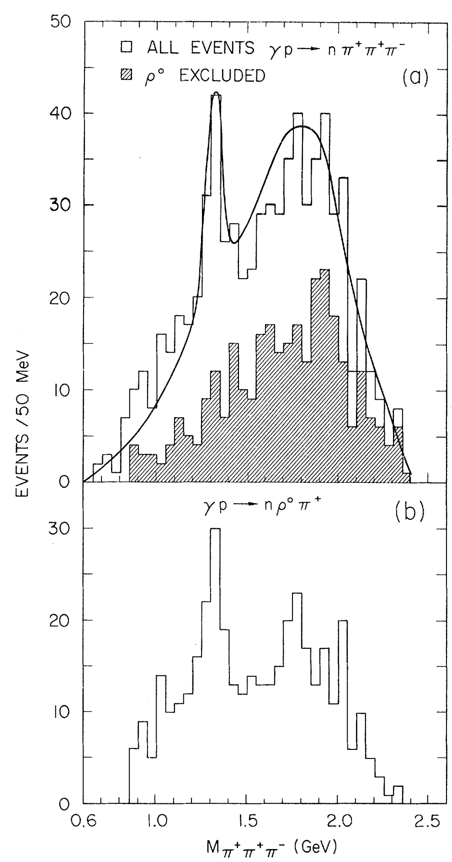

FIG. 1. (a) $M(\pi^+\pi^+\pi^-)$ distribution for $\gamma p \to n\pi^+\pi^+\pi^-$. The shaded area represents the $M(\pi^+\pi^+\pi^-)$ distribution for events with no $\pi^+\pi^-$ combination in the ρ^0 band (0.60-0.85 GeV). The curve is the best fit by an A_2 resonance plus invariant phase space (see text). (b) $M(\pi^+\pi^+\pi^-)$ distribution for events having at least one $\pi^+\pi^-$ combination in the ρ^0 band.

mass is visible. In order to demonstrate that this resonance has a $\rho\pi$ decay mode we display shaded in Fig. 1(a) the 3π spectrum for events with no $\pi^+\pi^-$ in the ρ^0 band, and in Fig. 1(b) the same for events with a $\pi^+\pi^-$ in the ρ^0 (0.06-0.85 GeV). Essentially all events in the enhancement have a $\pi^+\pi^-$ combination in the ρ^0 band. From Fig. 1 we estimate the branching ratio of the A_2 to be $(A_2^+ \to \rho^0\pi^+):(A_2^+ \to \text{all } \pi^+\pi^+\pi^-) = 1.0_{-0.2}^{+0.0}$ in agreement with the accepted value for A_2 decay. The best fit of our data by an A_2 resonance plus phase space yields $M(A_2) = (1310 \pm 14)$ MeV and $\Gamma(A_2) = (80 \pm 30)$ MeV. The errors do not allow a conclusion as to whether we observe A_2^H, A_2^L, or both. The cross section for Reaction (1) is $\sigma(\gamma p \to nA_2^+) = (1.2 \pm 0.4)$ μb at 4.3 GeV and (0.6 $\pm$ 0.3) μb at 5.25 GeV.[6]

As mentioned above, an attractive possibility is that the A_2 in Reaction (1) is produced via OPE. In the OPE model without absorption the differential cross section $d\sigma/dt$ for Reaction (1) is given by[7]

$$\frac{d\sigma}{dt}(\gamma p \to A_2^+ n) = \frac{\pi}{64}\frac{g_{\pi NN}^2}{4\pi}\frac{g_{A\pi\gamma}^2}{4\pi} \times \frac{1}{m_A^6 k^2 s}\frac{|t|(t-m_A^2)^4}{(t-\mu^2)^2}, \quad (3)$$

where k and s are the c.m.-system photon momentum and total energy squared, m_A is the A_2 mass, μ the pion mass, $g_{\pi NN}^2$ and $g_{A\pi\gamma}^2$ are the πNN and $A_2\pi\gamma$ coupling constants squared, respectively ($g_{\pi NN}^2/4\pi = 14.6$). Absorption effects[8] may be introduced into Eq. (3) by standard methods used previously for the reactions $\gamma p \to \omega^0 p$ and $\gamma p \to \Delta^{++}\rho^-$.[4] In Fig. 2 the momentum transfer distribution to the three pions in the A_2 region is shown, where $t' = |t - t_{\min}|$ and $t_{\min}$ is the minimum momentum transfer squared to the A_2 for a given A_2 mass. $d\sigma/dt'$ is normalized to the A_2 cross section. The solid line is the distribution calculated using a sharp cutoff model. The shape is best fitted with an absorption radius of $R \approx 1$ F, which is a reasonable value. The value of the coupling constant in Eq. (3) is then found to be $g^2(A_2^+ \to \pi^+\gamma)/4\pi \approx 0.13$. The electromagnetic width may be deduced from the coupling constand using the relation[7]

$$\Gamma(A_2^+ \to \gamma\pi^+) = \frac{1}{10}\frac{g_{A_2\gamma\pi}^2}{4\pi}\frac{q^5}{m_A^4} \approx 0.5 \text{ MeV}, \quad (4)$$

where q is the photon momentum in the A_2 rest frame.

The $A\pi\gamma$ coupling constant can be related to the $A_2 \to \rho\pi$ width using VDM.[9] If we assume VDM to

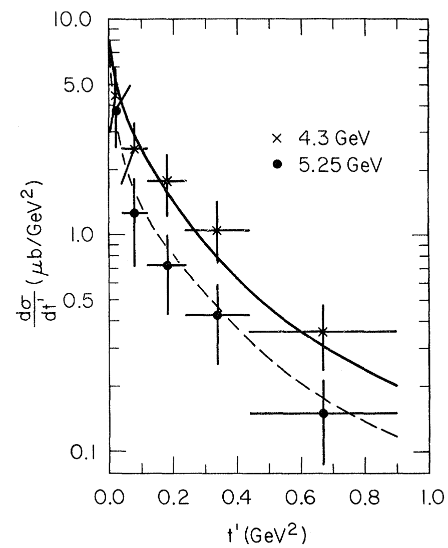

FIG. 2. $d\sigma/dt'$ for Reaction (2) with $M(3\pi) = 1.2$-1.4 GeV, normalized to $\sigma(A_2)$. The curves are the calculated A_2 cross sections using an OPE plus strong absorption model and correspond to an absorption radius of ≈ 1.0 F and a width of $\Gamma(A_2 \to \pi\gamma) = 0.55$ MeV.

hold in the A_2 rest frame we can write[10]

$$g_{A_2\pi\gamma}^2 = \frac{\alpha}{4}\left(\frac{\gamma_\rho^2}{4\pi}\right)^{-1} g_{A_2\pi\rho}^2. \quad (5)$$

Now, using Eq. (4) for the ρ^0 decay of the A_2 and $\gamma^2/4\pi = 0.52$ (see Ref. 1) we find, for a total A_2 width of 80 MeV, $\Gamma(A_2 \to \gamma\pi) = 1.2$ MeV while for the case of an A_2 split into two 25-MeV resonances $\Gamma(A_2^H \to \gamma\pi) + \Gamma(A_2^L \to \gamma\pi) = 0.7$ MeV. The agreement between this VDM prediction and our estimate from the data is within errors in each case.

The A_2 decay correlations could in principle serve as further tests for its production mechanism. Within our limited statistics we get agreement between the OPE calculations and experiment. Much more data are required before the decay distribution could test significantly the production mechanism.

In conclusion, we observe A_2 production via Reaction (1) but it is not clear if we observe A_2^H, A_2^L, or both. The t distribution for the produced A_2 is consistent with OPE with absorption corrections. The width $\Gamma(A_2^+ \to \gamma\pi^+)$ is estimated to be ~0.5 MeV.

We wish to thank the SLAC Bubble Chamber Operations crew and the SLAC Research Area Division personnel for help in obtaining the exposure, and the scanning teams of both institu-

tions for their excellent work.

---

*Accepted without review under policy announced in Editorial of 20 July 1964 [Phys. Rev. Letters 13, 79 (1964)].

†Work supported in part by the U. S. Atomic Energy Commission.

‡Present address: Physics Department, Tel-Aviv University, Tel-Aviv, Israel.

§On leave from Max-Planck Institute, Munich, Germany.

‖On leave from Deutsches Elektronen-Synchrotron, Hamburg, Germany.

[1]For references on VDM and γ-vector-meson couplings see, H. Harari, Phys. Rev. 155, 1565 (1967); S. C. C. Ting, in Proceedings of the Fourteenth International Conference on High Energy Physics, Vienna, Austria, September 1968, edited by J. Prentki and J. Steinberger (CERN Scientific Information Service, Geneva, Switzerland, 1968). J. E. Augustin et al., Phys. Letters 28B, 508 (1969).

[2]J. Ballam et al., Stanford Linear Accelerator Center, Stanford University, Stanford, California Report No. SLAC-PUB-625, 1969 (to be published).

[3]J. Ballam et al., Phys. Rev. Letters 21, 1541, 1544 (1968).

[4]Y. Eisenberg et al., Phys. Rev. Letters 22, 669 (1969).

[5]Cambridge Bubble Chamber Group, Phys. Rev. 169, 1081 (1968); Aachen-Berlin-Bonn-Hamburg-Heidelberg-München Collaboration, Deutsches Elektronen-Synchrotron Report No. DESY 69/19, 1969 (unpublished).

[6]The errors include an uncertainty due to the A_2 width assumed. For the 5.25-GeV data a 30 MeV width was assumed in Ref. 2 and consequently a cross section of (0.4 ± 0.2) μb was given.

[7]H. Högaasen, J. Högaasen, R. Keyser, and B. E. Y. Svensson, Nuovo Cimento 42A, 323 (1966).

[8]J. D. Jackson, J. T. Donohue, K. Gottfried, R. Keyser, and B. E. Y. Svensson, Phys. Rev. 139, B428 (1965); B. Haber and G. Yekutieli, Phys. Rev. 160, 1410 (1967).

[9]F. J. Gilman and H. J. Schnitzer, Phys. Rev. 150, 1362 (1966).

[10]This is because in the A_2 ($J^P = 2^+$) rest frame the ρ is purely transverse ($\rho_{11} = \frac{1}{2}$). If we believe VDM to hold in a different Lorentz frame obtained by a rotation of the quantization axis the right-hand side of (5) has to be multiplied by $2\rho_{11}$.