

PHOTOPRODUCTION OF THE  $A_2$  MESON IN THE REACTION

$$\gamma p \rightarrow n \pi^+ \pi^+ \pi^- \text{ AND AN ESTIMATE OF THE } A_2 \text{ } \gamma\pi \text{ WIDTH}^*$$

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ABSTRACT

We observe production of the  $A_2$  meson in the reaction  $\gamma p \rightarrow n \pi^+ \pi^+ \pi^-$  at 4.3 and 5.25 GeV. The data is consistent with an OPE production mechanism and we give an estimate of  $\Gamma(A_2 \rightarrow \gamma\pi) \approx 0.5$  MeV. A similar value for  $\Gamma(A_2 \rightarrow \gamma\pi)$  is also obtained using a Vector Dominance Model.

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The  $A_2$  meson is known to decay mainly into  $\rho\pi$ . Since its spin-parity is believed to be  $J^P = 2^+$ , it should couple only to transversely polarized  $\rho$  mesons. Under the assumption of Vector Dominance<sup>1</sup> (VDM), it should also couple to photons and the decay mode  $A_2 \rightarrow \gamma\pi$  should be substantial. No direct observation of this decay mode so far has been reported. However, if indeed  $\Gamma(A_2\pi\gamma)$  is appreciable ( $\sim .5$  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:

$$\gamma p \rightarrow n A_2^+ \quad (1)$$

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

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

Indications of  $A_2$  production in the reaction  $\gamma p \rightarrow p \pi^+ \pi^+ \pi^- \pi^-$  have already been reported.<sup>2</sup>

The SLAC 40-inch HBC was exposed to 4.3 and 5.25 quasi-monochromatic 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/ $\mu$ b. Preliminary results and details of the analysis procedure have been presented separately by the SLAC group<sup>3</sup> at 5.25 GeV and by the Rehovoth group<sup>4</sup> at 4.3 GeV. Earlier bubble chamber experiments<sup>5</sup> 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 multi-neutral particle production which concealed the effect. In the present experiment the photon energy is known and thus the multi-neutral background is negligible.

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

In order to demonstrate that this resonance has a  $\rho\pi$  decay mode we display shaded in Fig. 1a the  $3\pi$  spectrum for events with no  $\pi^+\pi^-$  in the  $\rho^0$  band, and in Fig. 1b the same for events with a  $\pi^+\pi^-$  in the  $\rho^0$  (0.6 - 0.85 GeV). Essentially all events in the enhancement have a  $\pi^+\pi^-$  combination in the  $\rho^0$  band.

From Fig. 1 we estimate the branching ratio of the  $A_2$  to be:  $(A_2^+ \rightarrow \rho^0\pi^+)$  :  $(A_2^+ \rightarrow \text{all } \pi^+\pi^+\pi^-) = 1.0^{+0.0}_{-0.2}$  in agreement with the accepted value for  $A_2$  decay.

The best fit of our data to 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 sections for reaction (1) is:  $\sigma(\gamma p \rightarrow nA_2^+) = (1.2 \pm 0.4)$   $\mu\text{b}$  at 4.3 GeV and  $(0.6 \pm 0.3)$   $\mu\text{b}$  at 5.25 GeV.<sup>6</sup>

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<sup>7</sup>:

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

where  $k$  and  $s$  are the cms photon momentum and total energy squared,  $m_A$  is the  $A_2$  mass,  $\mu$  the pion mass,  $g_{\pi NN}^2$  and  $g_{A_2\pi\gamma}^2$  are the  $\pi NN$  and  $A_2\pi\gamma$  coupling constants squared respectively ( $g_{\pi NN}^2/4\pi = 14.6$ ). Absorption effects<sup>8</sup> may be introduced into Eq. (3) by standard methods used previously for the reactions  $\gamma p \rightarrow \omega^0 p$  and  $\gamma p \rightarrow \Delta^{++}\rho^-$ .<sup>4</sup> 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  $R \approx 1$  fermi, which is a reasonable value. The value of the coupling constant in Eq. (3) is then found to be  $g^2(A_2^+ \rightarrow \pi^+ \gamma)/4\pi \approx 0.13$ . The electromagnetic width may be deduced from the coupling constant using the relation<sup>7</sup>

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

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

The  $A\pi\gamma$  coupling constant can be related to the  $A_2 \rightarrow \rho\pi$  width using VDM.<sup>9</sup> If we assume VDM to hold in the  $A_2$  rest frame we can write<sup>10</sup>:

$$g_{A_2 \pi \gamma}^2 = \frac{\alpha}{4} \left( \frac{\gamma \rho}{4\pi} \right)^{-1} \cdot g_{A_2 \pi \rho^0}^2 \quad (5)$$

Now, using Eq. (4) for the  $\rho^0$  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,  $\Gamma(A_2 \rightarrow \gamma\pi) = 1.2$  MeV while for the case of a  $A_2$  split into two 25 MeV resonances  $\Gamma(A_2^H \rightarrow \gamma\pi) + \Gamma(A_2^L \rightarrow \gamma\pi) = 0.7$  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  $\Gamma(A_2^+ \rightarrow \gamma\pi^+)$  is estimated to be  $\sim 0.5$  MeV.

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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  $0.4 \pm 0.2$  was given.
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10. This is because in the  $A_2(J^P = 2^+)$  rest frame the  $\rho$  is purely transverse ( $\rho_{11} = 1/2$ ). If we believe VDM to hold in a different Lorentz frame obtained by a rotation of the quantization axis the r.h.s. side of (5) has to be multiplied by  $2\rho_{11}$ .

## LIST OF FIGURES

- $M(\pi^+ \pi^+ \pi^-)$  distribution for  $\gamma p \rightarrow n \pi^+ \pi^+ \pi^-$ . The shaded area represents the  $M(\pi^+ \pi^+ \pi^-)$  distribution for events with no  $\pi^+ \pi^-$  combination in the  $\rho^0$  band (.60 - .85 GeV). The curve is the best fit to an  $A_2$  resonance plus invariant phase space (see text).
  - $M(\pi^+ \pi^+ \pi^-)$  distribution for events having at least one  $\pi^+ \pi^-$  combination in the  $\rho^0$  band.
- $d\sigma/dt'$  for reaction (2) with  $M(3\pi) = (1.2 - 1.4 \text{ GeV})$ , 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  $\approx 1.0$  fermi and a width of  $\Gamma(A_2 \rightarrow \pi\gamma) = 0.55 \text{ MeV}$ .