OBSERVATION OF A_1 MESON

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The problem of the existence of the A_1 meson and its detection in photo- and electroproduction is investigated. The absence of the A_1 meson in photoproduction is discussed and the cross section of its electroproduction is estimated.

Following the 1972 Batavia conference, the situation with the existence of the A_1 meson became exceedingly confused. As is well known, various theoretical approaches, e.g., current algebra or the quark model, call for the existence of a meson with quantum numbers $J^P = 1^+$ and

$I^G = 1^-$. Confidence in this increased after the SU(3) partner of A_1, the D meson, was observed [2]. Yet the A_1 meson has not been observed experimentally so far. Attempts were made recently, on the basis of large statistics, to find A_1 in the diffraction production $\pi N \to A_1 N$. The study of the 3π state by the method of Ascoli [1] in the A region ($m_{3\pi}$ = 1000 — 1400 MeV) has shown that the phase of the $\rho\pi$ state does not go through 90° in the region where the A_1 meson is expected to be ($\sim$ 1070 MeV), and reveals no rapid variation at all, whereas in the region of the A_2 meson one can clearly see a rapid variation of the phase shift, indicating the presence of a resonance. Since the background process, the Deck effect [3], makes a large contribution to $\pi N \to 3\pi N$ in the A region, the results of [1] signify that if the A_1 meson does exist at all, the cross section for its production is small in comparison with the background. Therefore diffraction production of the A_1 meson is not a suitable method of detecting it [2].

It might seem that the A_1 meson could be observed in photoproduction, since at small values of t the one-pion mechanism leads to its production with a sufficiently large cross section, $\sim$ 1 μb. In this case the dependence of the production on the phase shift of the $\rho\pi$ state takes, according to Watson's theory [2], the form $e^{i\delta} \sin\delta$ (δ is the phase shift of the elastic $\pi\rho$ scattering), unlike the $e^{i\delta}$ relation that holds in diffraction production. The $e^{i\delta} \sin\delta$ dependence should lead to a much sharper peak in the mass spectrum than in diffraction production, as is observed experimentally in the production of ρ, B, ω, etc. However, even in the photoproduction of the 3π state there is no enhancement whatever in the mass spectrum in the region of the A_1 meson [4]. This fact can be explained within the framework of a model based on the proportionality of the Pomeranchuk and f-meson trajectories, and the connection between the f meson and the conserved (tensor) current [5], a connection that explains successfully many features of diffraction production. In this model, the amplitude of the diffraction dissociation of the pion into an A_1 meson is proportional to $(t/m_A^2) g_{f\pi A_1}$, where t is the nucleon transfer, thus explaining the small cross section of A_1 production in comparison with the Deck background. On the other hand, the exchange ρ-f degeneracy in the $\pi \to A_1$ vertex causes the $A_1\pi\gamma$ residue in electroproduction to take the form $(q^2/m_A^2) g_{\rho\pi A_1}$ (here $\sqrt{q^2}$ is the photon mass). Thus, according to this model, there is no A_1 meson in photoproduction (in the one-pion approximation), but the model does make it possible to estimate the cross section at $q^2 \neq 0$.

For estimates at not very large q^2 we can use the vector-dominance model. In the one-pion approximation (see the figure) the amplitude takes the form

$$M = \frac{1}{(2\pi)^2} g_{\pi NN} \bar{u}(p_2) \gamma_5 u(p_1) \frac{q^2 m_\rho^2}{q^2 - m_\rho^2} \frac{g_{\rho\pi A_1} \epsilon^\mu(\rho) \epsilon_\mu(A_1) e}{(t - m_\pi^2) m_{A_1}^2 f_\rho} . \tag{1}$$

The notation is obvious. For the cross section we obtain

$$\frac{d\sigma}{dt} = \left(\frac{g_{\pi NN}^2}{4\pi}\right)\left(\frac{e^2}{4\pi} \frac{4\pi}{f_\rho^2}\right)\left(\frac{m_\rho^2}{m_\rho^2 - q^2}\right)^2 \left(\frac{q^2}{m_{A_1}^2}\right)^2 \frac{|t|}{(t - m_\pi^2)^2} \times \frac{4}{3} g_{\rho\pi A_1}^2 \frac{1}{8 I^2(s, q^2)} ; \tag{2}$$

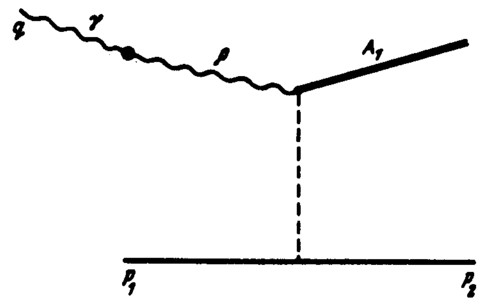
(in the estimate we have neglected the dependence of the $A_1\rho\pi$ vertex on q^2). I is the Moller invariant. For the width of the A_1 meson we use the mean value $\Gamma(A_1 \to \rho\pi)$ = 60 — 70 MeV. We estimate the cross section at $\sqrt{(p_1 + q)^2} = \sqrt{s}$ = 3 GeV, and at $|q|^2$ = 0.15, 0.5, and 1 GeV^2. The expression (2) is not suitable for estimates of the cross section, since it is well known that the one-pion approximation formulas lead to large overestimates. We must therefore take absorption into account in (2). In the simplest approximation this can be done by making in (2) the substitution $|t| \to m_\pi^2$.

We then obtain the values listed in the table. For comparison the table lists the A_2 production cross sections taken from [6]. The dependence of the A_2-meson production cross section on q^2 is also taken into account in the vector-dominance approximation.

At the present time, cross sections $\sim$ 0.1 b can be measured in principle at SLAC, but large statistics are needed for a better study of the A region in electroproduction of the 3π state.

q^2	A_1, μb	A_2, μb
0.15	0.02	0.52
0.5	0.04	0.25
1	0.08	0.11

The vector-dominance model [5] with ρ-f exchange degeneracy explains the absence of the A_1 meson in photoproduction and, at small q^2, in electro-production [4]. At $q^2 \sim -1\ GeV^2$ it predicts the splitting of the observed enhancement in the A region [7] into two closely-lying peaks of approximately equal intensity. In any case, the study of the 3π state in $\mu^-(e^-)p \to \mu^-(e^-)p + 3\pi$ is of great interest and can serve, together with the proposed nondiffraction reactions [2] $Kp \to A_1\Lambda$ and $\pi N \to NA_1$ (backward) as a convenient process for the observation of the A_1 meson. Common to most reactions with A_1 production is the suppression of the cross section due to the conservation of the vector [2, 8] or tensor [5] current, since the A_1 meson is connected with the pion via Regge trajectories (particles) with natural parity.



As to photoproduction of the Roper resonance $\gamma P \to N^* \to N\pi$ [9], owing to the exchange ω-f degeneracy, the tensor dominance leads to vanishing of the isoscalar transition $N^*(1470) \to N + \omega$. We are unable, however, to deduce from this any conclusions concerning the magnitude of the isovector transition $N^*(1470) \to N\rho$; it is possible that it is phenomenologically small.

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