Difference in Energy Dependence for A_2^- and A_2^0 Production

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We present a comparison of A_2^- and A_2^0 production. The cross section for the production of A_2^0 falls much more rapidly with increasing energy than the A_2^- cross section. The characteristics of the production processes seem to be very similar in other respects. These facts are hard to understand in terms of a Regge picture of the production process.

We wish to report on three experiments which give results on the production of the A_2 meson.[1,2] We present results from 7-BeV/c π^-p and π^+d exposures in the 30-in. Argonne National Laboratory–Midwestern Universities Research Association chamber and a 25 BeV/c π^-p experiment in the 80-in. Brookhaven National Laboratory chamber.

The production characteristics of the A_2 are similar in each of the three experiments. The A_2^- is produced in a large $J^P=1^+$ background coming from diffractive processes. In Figs. 1(a) and 1(c) we see that the A_2^- signal is greatly enhanced relative to the background by requiring that the momentum transfer to the recoil proton be larger than 0.1 (BeV/c)^2 [0.15 in Fig. 1(a)]. The diffractive background is not present for the A_2^0 in Fig. 1(b) and the Δ^2 cut does little to improve the signal. We have drawn on the mass plots the fitted Breit-Wigner (BW) curves. The error bars show the level of background obtained from a Zemach[3] analysis of the 2^+ signal and the mass range considered in the analysis, respectively. The background assumed in making the BW fit is shown as a cross line. The mass values obtained in the fits were 1.29, 1.31, and 1.305 BeV/c^2 with widths of 0.102, 0.122, and 0.085 BeV/c^2 for the charged and neutral 7-BeV/c data and the 25-BeV/c data, respectively.

All three experiments yield a t distribution for

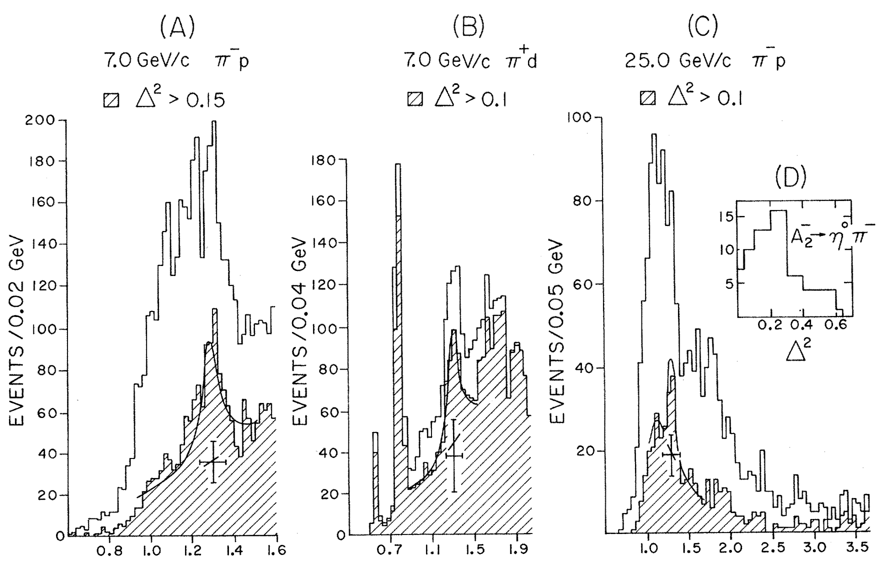

FIG. 1. (a) $M(3\pi)$ distribution from the reactions $\pi^-p\to p\pi^+\pi^-\pi^-$ and $\pi^-p\to p\pi^-\pi^0\pi^0$ at 7 BeV/c, 2.6 events/μb. (b) $M(\pi^+\pi^-\pi^0)$ from the reaction $\pi^+d\to p_s p\pi^+\pi^-\pi^0$ at 7 BeV/c, 5.6 events/μb. This plot has $|\vec{p}_s|<0.3$ BeV/c and includes three-prong events. (c) $M(\pi^+\pi^-\pi^-)$ from the reaction $\pi^-p\to p\pi^+\pi^-\pi^-$ at 25 BeV/c, 3.3 events/μb. All of the mass plots have $N^*(1238)$ removed. (d) $\Delta_{pp}{}^2$ distribution from the reaction $\pi^-p\to pA_2^-$ at 7 BeV/c with $A_2^-\to\eta^0\pi^-$ (see Morse in Ref. 1).

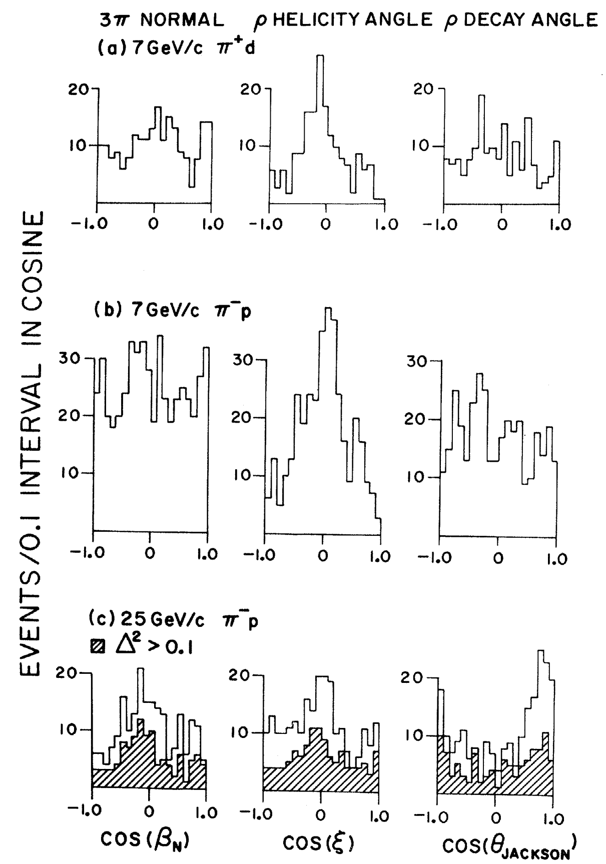

FIG. 2. (a)-(c) Angular distributions for the A_2 as seen in 7-BeV/c π^+d, 7-BeV/c π^-p, and 25-BeV/c π^-p. The angles plotted are the 3π normal ($\cos\beta$), the p helicity angle ($\cos\xi$), and the ρ decay angle ($\cos\theta$).

the A_2 (together with background) which falls as $\sim e^{4.5t}$. In Fig. 1(d) we show the momentum-transfer spectrum from the process $\pi^-p \to pA_2^-$ at 7 BeV with $A_2^- \to \eta^0\pi^-$,[4] which process has little background.

Next we consider the angular correlations associated with the decay of the A_2. The decay mode $A_2 \to \rho\pi$ is such that the ρ has helicity ± 1 and the π and ρ are in a relative d wave. This means that we should see ρ's with helicity 1, as we do when we look at the distribution of the helicity angle ξ in the decay of the ρ in Fig. 2. The Jackson angle (θ), i.e., the decay angle of the ρ relative to the beam direction, is more or less flat, which is completely different from the background of diffractively produced ρ's which have helicity 0. The distribution in $\cos\beta$, the normal to the 3π decay plane, relative to the incident beam direction, is also similar for the three experiments. In the 7-BeV/c data we see the $\cos^2(\beta)+\cos^2(2\beta)$ behavior with a $\sin^2\beta$ from

Table I. Ratio of neutral to charged A_2 cross section.

P_L (BeV/c)	$\sigma(A_2^-)^a$ (μb)	$\sigma(A_2^0)$ (μb)	$R(A_2^0/A_2^-)$
3.65	180 ± 60	190 ± 50	1.06 ± 0.45
7.0	130 ± 30	50 ± 15	0.38 ± 0.14

[a]See Ref. 6.

the 1^+ background yielding a three-peaked structure.[5] The angular distributions from the 25-BeV/c experiment show a stronger 1^+ background although the helicity angle does show the peaking at $\cos\xi = 0$ characteristic of a ρ with helicity 1 from the A_2. We conclude that the helicity states are populated in similar ways in the three experiments and, in fact, are characteristic of ρ exchange for the production process.

As was pointed out by the Michigan group,[2] the ratio of $\sigma(A_2^0)/\sigma(A_2^-)$ should be 2:1 if the production mechanism were simple ρ exchange. In Table I, we give the ratio of cross sections for A_2 production at 3.65 BeV/c from the Michigan group and at 7.0 BeV/c. From these results it is clear that A_2 production is not dominated by ρ exchange. Also apparent is the fact that the energy dependence is different for A_2^- and A_2^0 production. In Fig. 3 we give the cross section for A_2^- and A_2^0 production. The cross section for A_2^0 production falls like P_L^{-2} and A_2^- like $\sim P_L^{-1}$.[7] Other aspects of the production of these particles seem to be very much as expected. We have measured $A_2^- \to \rho^0\pi^-$ and $A_2^- \to \rho^-\pi^0$ at 7

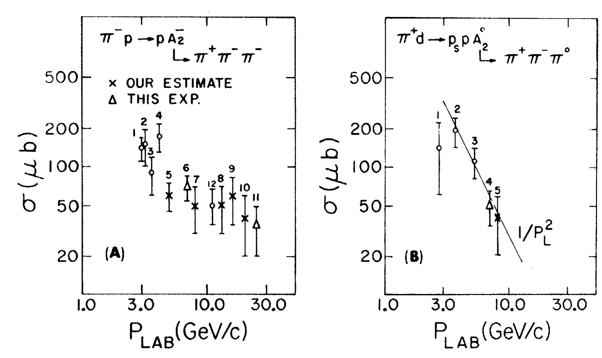

FIG. 3. Cross section for A_2^- and A_2^0 production versus laboratory beam momentum. Points indicated by X are our estimates from published data; see Refs. 1 and 2. (a) 1, Key *et al.*; 2,4, Chung *et al.*; 3, Benson *et al.*; 5, Ascoli *et al.*; 7, Cason *et al.*; 8, 10, Ioffredo *et al.*; 9, Ballam *et al.*; 12, Conte *et al.*; all of these references are listed under Ref. 1. (b) 1, Miller *et al.*; 2, Benson *et al.*; 3, Armenise *et al.*; 5, Kenyon *et al.*; all of these references are listed under Ref. 2.

BeV/c. This has been done by reconstructing the π^0 trajectories by measuring the direction of the γ rays. We find the ratio of the two modes is 1:1 with about 20% uncertainty. The helicity distributions of the produced A_2's seem to be as expected for ρ exchange. The usual explanation of the production process is that both ρ and f^0 exchange occur. The energy dependence of the charged A_2^- cross section might be consistent with ρ and f^0 (or P') exchange but the A_2^0 cross section is not consistent, as it seems to fall off too rapidly with energy.

These results appear difficult to understand in the framework of Regge models. The ρ and P' trajectories should be close to each other, yet the energy dependences are grossly different. The A_2^0 should be produced solely by ρ exchange yet the energy dependence seems also to be inconsistent with the ρ trajectory, though this is not the main point of our argument.

We would propose that the production process for the A_2^- is quite closely related to the A_1 production process, or so called "Deck" mechanism. In the "Deck" mechanism either a π or a ρ comes from the $\pi \rightarrow \pi$-ρ vertex and subsequently scatters from the nucleon or nucleus. The result is that the ρ's so produced tend to have their spins perpendicular to the beam direction. In the mechanism proposed the ρ from the $\pi \rightarrow \pi\rho$ vertex is scattered and has its spin flipped to a helicity ± 1 in the process. The A_2 is formed as a result of a final-state interaction. In the neutral A production, the spin-flipped ρ must also be charge exchanged in the scattering process. Thus, it is not surprising to find that the energy dependence of the two processes are different, yet the angular correlations are nearly the same. This sort of two-step process was discussed in outline at least by Byers and Frautschi.[8]

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[2]R. J. Miller *et al.*, Phys. Rev. 178, 2061 (1969); G. Benson *et al.*, Phys. Rev. Lett. 16, 1177 (1966); N. Armenise *et al.*, Phys. Lett. 25B, 53 (1967); I. R. Kenyon *et al.*, Phys. Rev. Lett. 23, 146 (1969).

[3]C. Zemach, Phys. Rev. 133, B1201 (1964).

[4]For the events plotted in Fig. 1(d) we have measured and fit the gammas for $\eta^0 \rightarrow \gamma\gamma$ in the 7 BeV/c π^-p data.

[5]This angular dependence is obtained if we take $\rho_{11} = 0.5$ and neglect all off-diagonal density-matrix elements.

[6]These cross sections are corrected for $A_2^- \rightarrow \rho^-\pi^0$. For the 3.65-BeV/$c$ data see Benson *et al.*, in Ref. 2.

[7]If $\sigma(A_2^0)$ were to fall as $1/P_L$ one would expect to see this in $\sigma(K^0\bar{K}^0)$. Instead, the $K_0\bar{K}_0$ cross section is observed to fall as $1/P_L^2$ out to at least 12 BeV/c; this is quite consistent with our result. It is difficult to disentangle $A_2^0 \rightarrow K_1^0K_1^0$ from $f^0 \rightarrow K_1^0K_1^0$ but there is no part which falls with energy much less rapidly than $1/p^2$. See K. W. Lai, in *Proceedings of an Informal Meeting on Experimental Meson Spectroscopy, Philadelphia, 1968*, edited by C. Baltay and A. H. Rosenfeld (Benjamin, New York, 1968).

[8]N. Byers and S. Frautschi, "Diffraction Dissociation in the Chou-Yang Model" (to be published).