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BACKWARD SCATTERING IN THE REACTION $\pi^+ n \rightarrow \Delta^{++}$ (1238) π^- FROM 1.9 TO 2.5 GeV/c*

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ABSTRACT

We have measured differential cross sections and decay distributions for the reaction $\pi^+ n \rightarrow \Delta^{++}(1238)\pi^-$ over a center of mass energy range 2.1 to 2.4 GeV. We have observed backward peaking in the differential cross section with a dip in the extreme backward direction. We observe decay distributions inconsistent with simple unmodified J = 1/2 baryon exchange in the u-channel. The dip is caused by strong helicity 3/2 amplitudes which must vanish in the extreme backward direction. Backward peaking has been observed in the charge symmetric reaction $\pi^- p \rightarrow \Delta^- \pi^+$ by Anthony et al.¹) at 2.15 GeV/c who examine the c.m. production angle cosine interval -0.999 <cospro (π^-, π^+_{out}) <-0.950. This group observes a dip in the production distribution in the backward direction -0.999 < cospro $(\pi^-_{in}, \pi^+_{out})$ <-0.990. Since this was a spark-chamber missing-mass experiment, this group does not have the extra constraint of the decay distributions available for analysis.

We report here on a sample of 13766 events of the reaction $\pi^+ D \rightarrow pp \pi^+ \pi^-$ obtained from the Alvarez Group 72-inch deuteriumfilled bubble chamber with c.m. energy of all outgoing particles except the lower momentum proton between 2.1 and 2.4 GeV and with the lower momentum proton < 300 MeV/c in the laboratory system (impulse approximation). A clear enhancement in the recoil proton- π^+ mass spectrum corresponding to the known mass and width of $\Delta(1238)$ is observed in both the forward and backward directions. The production differential cross section has been presented previously in fig. 2(c) of We note a clear dip in the backward direction -1.0 < cospro ref. 2. <-0.90 with a peak of 55µb/sr in the bin -0.9 < cospro < -0.8. Background under the \triangle^{++} (1238) peak typically averages 15% for the cospro bins that include the backward enhancement (-1.0 < cospro < -0.5). We have used Monte Carlo programs³) to investigate the possibility that the enhancements observed are kinematical reflections of resonances produced in other channels, e.g., backward-produced $\rho^0(765)$ such as seen in ref. 4; however, these reflections fail to give peaks with the mass and width of the $\Delta(1238)$.

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We also measure differential cross sections for the reaction $\pi^+n \rightarrow \Delta^0(1238)\pi^+$ and find differential cross sections in the backward direction $[-1.0 < \cos pro(\pi^+_{in}, \pi^+_{out}) < -0.5]$ with an upper limit of $7 \mu b/sr$ and statistically consistent with zero. Since only I = 3/2 exchange amplitudes can mediate backward peaking in this reaction and since by Clebsch-Gordan arguments I = 3/2 exchange contributes only 1/3 as much to backward peaking in $\pi^+n \rightarrow \Delta^{++}(1238)\pi^-$, we infer that the only significant backward production mechanisms for $\pi^+n \rightarrow \Delta^{++}(1238)\pi^-$ involve I = 1/2 exchange. An interpretation of the data (particularly the dip in the backward direction) on the basis of s-channel resonances as in ref. 1 is unlikely, since our data exhibit no rapid variation in c.m. energy(ECM) commonly associated with s-channel mechanisms over an ECM range of 300 MeV. The differential cross section retains the same shape throughout this ECM interval.

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In order to test production mechanisms it is of considerable help to know the decay distributions of a resonance. This report represents, to the best of the author's knowledge, the first experiment in which enough events exist in backward-produced inelastic resonance peaks to permit reliable measurement of the decay distributions. In a coordinate system with z-axis in the production plane (in the resonance rest frame) the normalized decay distribution of $\Delta(1238)$ can be described by the formula⁵)

 $D(\theta, \phi) = (1/4\pi) [\rho_{11}(1 + 3\cos^2\theta) + 3\rho_{33}\sin^2\theta - 4\sqrt{3} \operatorname{Re}(\rho_{31})\sin\theta\cos\theta\cos\phi - 2\sqrt{3} \operatorname{Re}(\rho_{3-1})\sin^2\theta\cos2\phi],$

where $\rho_{11} = 1/2 - \rho_{33}$ by the trace condition on the density matrix

elements. This formula can be rewritten in terms of the spherical harmonics $Y_{\ell}^{m}(\theta,\phi)$ as

$$\begin{split} \mathrm{D}(\theta,\phi) &= (1/4\pi) \{ 1 + \sqrt{4\pi/5} \, (1 - 4\rho_{33}) \mathrm{Y}_2^0(\theta,\phi) + 8\sqrt{2\pi/5} \, \mathrm{Re}(\rho_{31}) \mathrm{Re}[\mathrm{Y}_2^1(\theta,\phi)] \\ &- 8\sqrt{2\pi/5} \, \mathrm{Re}(\rho_{3-1}) \mathrm{Re}[\mathrm{Y}_2^2(\theta,\phi)] \}, \end{split}$$

from which arises the following relations between the density matrix elements and the moments $\langle Y_{\ell}^{m} \rangle$:

$$\langle Y_2^0 \rangle = 1/\sqrt{20\pi} (1 - 4\rho_{33}),$$

$$\langle \operatorname{Re}(Y_2^1) \rangle = 8\sqrt{1/40\pi} \operatorname{Re}(\rho_{31}),$$

$$\langle \operatorname{Re}(Y_2^2) \rangle = -8\sqrt{1/40\pi} \operatorname{Re}(\rho_{3-1})$$

and

In the Jackson coordinate system with z-axis along the incident π^+ direction (in the resonance rest frame) and y-axis along the normal to the production plane, we have evaluated the moments of the decay distribution for three intervals in $cospro(\pi_{in}^+, \pi_{out}^-)$. These are partially listed in table 1. All other moments are statistically consistent with zero. If the reaction is mediated by simple J = 1/2 nucleon exchange in the u-channel, we expect $\rho_{33} = \operatorname{Re}(\rho_{31}) = \operatorname{Re}(\rho_{3-1}) = 0.0$ and $\langle Y_2^0 \rangle$ =0.126(corresponding to $\rho_{11} = 1/2$) as the only non-vanishing $\ell = 2$ moment. We see from table 1, however, that for all intervals in cospro the $\langle Y_2^0 \rangle$ moments are inconsistent with the value 0.126 and there exist $\langle Y_2^2 \rangle$ moments inconsistent with zero. Therefore, explanation of the production mechanism in terms of simple unmodified nucleon exchange is ruled out. An interpretation based on the single Regge exchange amplitude N_{α} is ruled out, since there exists no dip in the differential cross section d σ /du at the value -u = 0.15 GeV²/c² where the N_{α} exchange amplitude goes to zero as a result of α passing through

the wrong signature nonsense point $\alpha = -1/2$.⁶)

In order to discuss reasons for the dip in the backward production direction it is convenient to use the helicity frame with z-axis along $-P_{m\pi}$ (in the resonance rest frame). Here the density matrix elements $\rho_{\mu\mu'}$ are directly proportional to the products of helicity amplitudes, i.e., $\rho_{\mu\mu'} ~ \langle \mu | + 1/2 \rangle \langle \mu' | + 1/2 \rangle^*$, where $\langle \mu | + 1/2 \rangle$ is the helicity amplitude with initial nucleon of helicity + 1/2 and final Δ (1238) of helicity μ . (There are four independent helicity amplitudes for this reaction: two with final Δ (1238) helicity | = 3/2 and two more with helicity = 1/2.) In fig. 1 we plot the polar decay angle in the helicity frame with superposed curves calculated from the measured moment $\langle Y_{2}^{0} \rangle$ for each interval in cospro. The relevant one-dimensional formula for the decay polar angle distribution is

 $D(\cos\theta) = D(\theta,\phi) d\phi = \frac{1}{2} + \sqrt{5\pi/4} \langle Y_2^0 \rangle (3\cos^2\theta - 1).$

We note strongly dominant production of the $\Delta^{++}(1238)$ in |helicity| = 3/2states which must vanish along the extreme backward direction (cospro = -1.0). This explains the dip in the differential cross section in the backward direction. However, the dynamical mechanism responsible for the dominant |helicity| = 3/2 production of the $\Delta^{++}(1238)$ (for cospro < -0.5) is still open to conjecture.

FOOTNOTES AND REFERENCES

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 1. R. Anthony, C. T. Coffin, E. Meanley, J. Rice, N. Stanton, and K. Terwilliger, Phys. Rev. Letters <u>21</u> (1968) 1605.
- 2. P. M. Dauber, P. Hoch, R. J. Manning, D. M. Siegel, M. A. Abolins, and G. A. Smith, Phys. Letters <u>29B</u> (1969) 609.
- J. Friedman, Lawrence Radiation Laboratory Report UCRL-19206, June 1969 (to be published). See also J. Friedman, "SAGE," Lawrence Radiation Laboratory Group A Programming Note P-189, July 1969 (unpublished).
- 4. P. B. Johnson et al., Phys. Rev. <u>176</u> (1968) 1651.
- 5. K. Gottfried and J. D. Jackson, Nuovo Cimento 33 (1964) 309.
- See V. Barger, Backward Peaks and Regge Phenomenology, in <u>Proceedings of the Coral Gables Conference on Symmetry Prin-</u> <u>ciples at High Energy</u>, 1968 (W. A. Benjamin, Inc., New York, 1968).

Table 1. Decay moments	for backward-produced $\Delta^{++}(1238)$
2.1 < ECM<2.4 GeV, coordinate system.	$1.35 < M^2_{p\pi^+} < 1.69 \text{ GeV}^2$ in Jackson

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Cospro interval	No. events	$\langle Y_2^0 \rangle$	$\langle \operatorname{Re}(\mathbb{Y}_2^2) \rangle$
-1.0 to -0.85	110	-0.050 ± 0.025	-0.072±0.019
- 0.85 to - 0.70	135	0.027±0.023	-0.062±0.016
- 0.70 to - 0.50	106	-0.034±0.026	-0.082±0.019

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FIGURE CAPTION

Fig. 1. Polar decay angle helicity frame cos(-π⁻, π⁺) distributions and corresponding values of (Y₂⁰) for (a) -1.0 <cospro <-0.85,
(b) -0.85 < cospro <-0.70, and (c) -0.70 < cospro <-0.50 for Δ⁺⁺(1238) events with ECM intervals and M²pπ⁺ cuts as in table 1.





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Fig. 1

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