Fig. 1.

(3) The cross sections at 102 and 405 GeV for $M^2 < 10$ GeV^2 are, respectively, 4.5 ± 0.4 and 3.5 ± 0.5 mb (after multiplying by 2).[8] Taking into account differences in background we conclude that this low-mass diffraction-dissociation region contributes about half of the total "diffractive" component of 6–7 mb.

In Fig. 3 we show the invariant cross section versus x for various P_T^2 slices of the data. Where possible we have made comparison with the NAL[4] and IST[9] counter data and find good agreement within the limited statistical accuracy.

In Fig. 4 we show the invariant cross section versus P_T^2 for various x slices of the data. The P_T^2 dependences do not show any marked variation with x or s. In the P_T^2 region where our data overlap the ISR data the agreement is good. We see no evidence for turnovers or dips at small P_T^2.

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[1]See the reviews by J. C. Sens, in the Proceedings of the Conference on Recent Advances in Particle Physics, New York, New York, 15–17 March 1973 (to be published); and by P. Slattery, in *Experiments on High Energy Particle Collisions*, AIP Conference Proceedings No. 12, edited by R. S. Panvini (American Institute of Physics, New York, 1973).

[2]For 205-GeV/c $\pi^- p$ data, see F. C. Winkelmann *et al.*, Lawrence Berkeley Laboratory–NAL Report No. LBL-2113 (unpublished); G. S. Abrams *et al.*, Lawrence Berkeley Laboratory Report No. LBL-2112 (unpublished).

[3]We estimate the overall systematic uncertainties in the cross sections for the inelastic two-pronged channels in the region $x < -0.99$ to be $\pm 10\%$ at 102 GeV and $\pm 25\%$ at 405 GeV. The separation between elastic and inelastic events is particularly questionable for momentum transfers below 200 MeV/c. See C. Bromberg *et al.*, University of Michigan–University of Rochester Report No. UMBC 73-18 and UR-459 (to be published).

[4]K. Abe *et al.*, Phys. Rev. Lett. 31, 1527, 1530 (1973); F. Sannes *et al.*, Phys. Rev. Lett. 30, 766 (1973).

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Evidence for the $\omega\pi\pi$ Decay Modes of the A_2 and $\omega(1675)$

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We present evidence for the decay $A_2^0 \to \omega\pi^+\pi^-$ with a branching ratio $\Gamma(A_2 \to \omega\pi\pi)/\Gamma(A_2 \to \rho\pi) = 0.28 \pm 0.09$ and for the decay $\omega(1675) \to \omega\pi^+\pi^-$ with a branching ratio $\Gamma(\omega(1975) \to \omega\pi^+\pi^-)/\Gamma(\omega(1675) \to \rho\pi) = 0.47 \pm 0.18$. Evidence is given for an intermediate $B(1235)\pi$ state in the $\omega(1675)$ decay.

We present evidence for enhancements in the $\omega\pi^+\pi^-$ mass spectrum in the 1.3- and 1.65-GeV regions, which we identify as decay modes of the A_2 and the $\omega(1675)$, respectively. Enhancements in these regions have been reported in several experiments.[1-6] In addition, we give evidence

for the cascade decay of the $\omega(1675)$ through the $B(1235)$, i.e., $\omega(1675) \rightarrow B\pi$, $B \rightarrow \omega\pi$.

The data are from a 930 000-picture exposure of the Argonne National Laboratory 30-in deuterium bubble chamber to a 6.0-GeV/c π^+ beam at the zero-gradient synchrotron. The five- and six-prong and three- and four-prong events were fitted with

$$\pi^+ d \rightarrow p_s p \pi^+ \pi^- \pi^+ \pi^- \pi^0 \quad (1)$$

and

$$\pi^+ d \rightarrow p_s p \pi^+ \pi^- \pi^0, \quad (2)$$

respectively, where p_s refers to the spectator proton. Ionization information was used in selecting the fits. Ambiguities between fits with and without a neutral pion were resolved in favor of the latter. Ambiguities among fits with neutral particles were resolved in favor of the fit with the highest χ^2 probability. The data were subjected to the following cuts: specator momentum < 0.250 GeV/c, $-0.4 \leq (\mathrm{MM})^2 < 0.3$ GeV^2, χ^2 probability ≥ 0.01 for events with $(\mathrm{MM})^2 < M_{\pi^0}{}^2$, and χ^2 probability > 0.1 for events with $(\mathrm{MM})^2 > M_{\pi^0}{}^2$, where $(\mathrm{MM})^2$ is the square of the missing mass. After the above cuts the sample consists of 15 816 fits with Reaction (1) and 18 619 fits with Reaction (2). We have further selected events with $t' < 1.5$ (GeV/c)^2, where $t' = |t - t_{\min}|$, with t the square of the four-momentum transfer to the outgoing multipion system and $t_{\min}$ the minimum t for a given multipion effective mass. Cross sections have been calculated for this t' interval.

Figure 1(a) shows the $\pi^+\pi^-\pi^0$ mass distribution from the 5π channel (four combinations per event). A fit of a Gaussian function to this histogram for the ω meson with phase space modified by a polynomial yielded 2709 ± 110 ω events above background.[7] Figures 1(b) and 1(c) show the 5π mass distributions from Reaction (1) for the total sample and the six-prong subsample, respectively. There are suggestions of enhancements in the 1.3- and 1.65-GeV regions, which are seen more clearly in the more tightly constrained six-prong

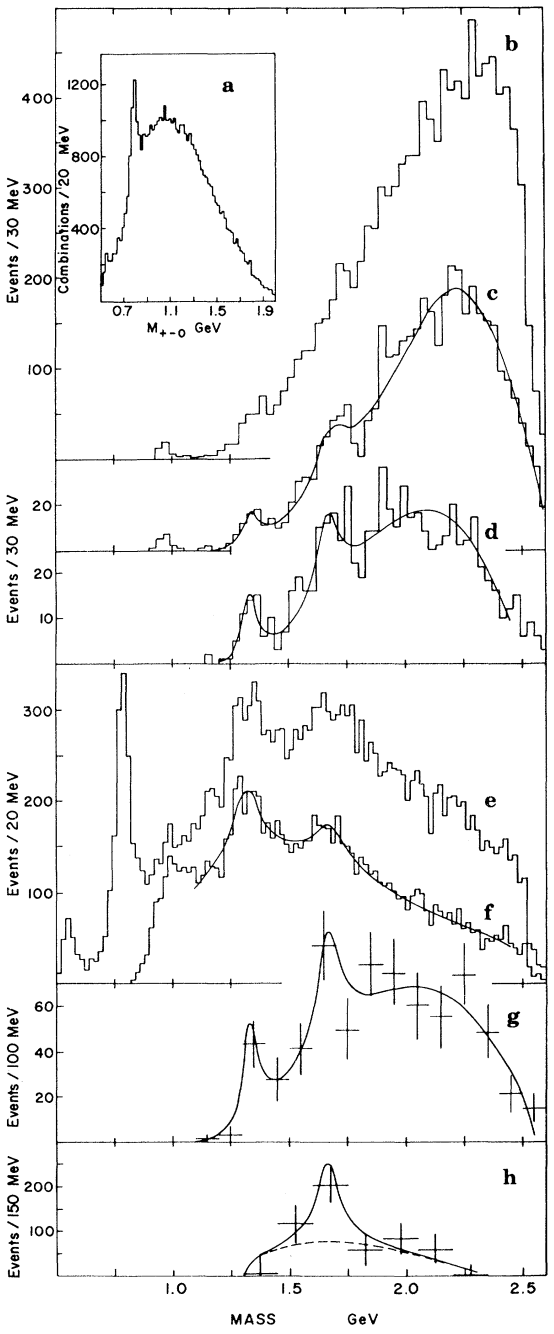

FIG. 1. (a) $\pi^+\pi^-\pi^0$ mass distribution from Reaction (1) (four combinations per event). (b) 5π mass distribution from Reaction (1). (c) Same as (b) but for six-prong data only. (d) 5π mass distribution from Reaction (1) for six-prong events having at least one neutral 3π combination in the ω region. (e) 3π mass distribution from Reaction (2). (f) 3π mass distribution from Reaction (2) for events having at least one 2π combination in the ρ region. (g) Fitted number of ω events above background as a function of the 5π mass for Reaction (1) (six-prong events). (h) Fitted number of B events above background as a function of the 5π mass from Reaction (1). The curves on (c), (d), (f), and (g) are fits to the data using an incoherent sum of two Breit-Wigner terms plus a modified phase-space background; in (c), (d), and (f) we used free mass and width parameters; in (g) the fit was obtained using masses and widths fixed at the values obtained in the fit to (d). The solid curve in (h) is a fit with one Breit-Wigner term plus modified background; the background is indicated by the dashed curve.

data. An η' signal is evident near 0.96 GeV. We then select events for which at least one neutral 3π mass combination is in the region $750 \leq M_{3\pi} < 825$ MeV and plot the resulting 5π mass distribution for the six-prong data in Fig. 1(d). Fits to the distributions in Fig. 1 are described in the caption. The enhancements at 1.3 and 1.65 GeV are again clearly visible, but this does not prove that the effects correspond to $\omega\pi\pi$ decays, since there is a high probability for any low-mass 5π system to have at least one 3π combination in the above-defined ω region. Therefore, we show in Fig. 1(g) the ω signal as a function of the 5π mass for the six-prong events.[8] There are distinct peaks in the spectrum in the 1.3- and 1.65-GeV regions. A fit to this spectrum using masses and widths fixed at values found in the fit to Fig. 1(d) gives our best estimates for the number of true $\omega\pi\pi$ decays for the two enhancements.

Figures 1(e) and 1(f) show for Reaction (2) the total $\pi^+\pi^-\pi^0$ mass distribution and the $\pi^+\pi^-\pi^0$ mass distribution for events with at least one dipion mass combination in the ρ mass region ($0.68 < M_{\pi\pi} < 0.84$ GeV).[9] Identification of the 1.3- and 1.65-GeV $\omega\pi\pi$ enhancements with decays of the A_2 and $\omega(1675)$ mesons is supported by the observation of strong A_2 and $\omega(1675)$ signals in these distributions. The A_2 and the $\omega(1675)$ signals in the separate ρ^+, ρ^-, and ρ^0 selections (not shown) are consistent with the expected branching ratios for the $I=1$ and $I=0$ states.

The fits in Figs. 1(c), 1(d), and 1(g) yield 57 ± 15, 62 ± 16, and 57 ± 17 A_2 events, consistent with the interpretation that this A_2 decay proceeds entirely through the $\omega\pi\pi$ channel. Masses and widths obtained from the fits to Figs. 1(c) and 1(d) are consistent with the values obtained from the fit to the 3π mass distribution of Fig. 1(f). Our best estimates of the masses and widths from fits to the A_2 peaks are listed in Table I. After a 10.4% correction for unobserved decay modes of the ω, we obtain the branching ratio $\Gamma(A_2 \to \omega\pi\pi)/\Gamma(A_2 \to \rho\pi) = 0.28 \pm 0.09$.[10] From Reaction (2) we obtain the cross section $\sigma(\pi^+ n \to A_2^0 p, A_2^0 \to \rho\pi) = 65 \pm 11$ μb.

In Figs. 2(a) and 2(c) we show the t' distributions for the $A_2 \to \rho\pi$ and $A_2 \to \omega\pi\pi$ events. The numbers of resonant events above background were obtained from fits to the mass plots for each t' interval. These distributions are compatible with two decay modes of the same state. Fits of the data in Figs. 2(a) and 2(c) with the form $Ae^{-bt'}$ give slopes $b = 2.0 \pm 0.6$ and $b = 2.7 \pm 0.5$, respectively. Studies of the decay angles and their moments gave no further information about the $\omega\pi\pi$ decay of the A_2.

TABLE I. Masses, widths, and branching ratios for decay modes of the A_2 and $\omega(1675)$. The A_2 branching ratio is normalized to the $\rho^\pm\pi^\mp$ mode; the $\omega(1675)$ branching ratios are normalized to the $\rho^{\pm,0}\pi^{\mp,0}$ mode. In the table the notation 5π means $\pi^+\pi^+\pi^-\pi^-\pi^0$.

Decay mode	M (MeV)	Γ (MeV)	Branching ratio (%)
$A_2 \to \omega\pi^+\pi^-$	1325 ± 9	74 ± 20	28 ± 9
$\to \rho^\pm\pi^\mp$	1313 ± 8	135 ± 21	...
$\omega(1675) \to 5\pi$	...	...	97 ± 28
$\to \omega\pi^+\pi^-$	1660 ± 13	122 ± 39	47 ± 18
$\to B^\pm\pi^\mp$	...	...	32 ± 16
$\to \rho^{\pm,0}\pi^{\mp,0}$	1678 ± 14	167 ± 40	...

In a previous experiment,[1] the $\omega\pi\pi$ decay of the A_2 was reported to be associated with an $\omega\pi$ resonance having a mass and width of 1040 ± 5 and ~ 55 MeV. We have studied the $\omega\pi^\pm$ mass plot [Fig. 2(e)] for events in the region $1.24 \leq M_{\omega\pi\pi} < 1.38$ GeV and observe no confirmation of this effect. Unmodified phase space (smooth curve) gives a good fit to the distribution ($\chi^2 = 4.2$ for 11 degrees of freedom).

We associate the 5π enhancement in the 1.65-GeV region [Figs. 1(b)–1(d)] with the $\omega(1675)$ meson.[11] The $\rho\pi$ decay modes of this state are clearly visible in the 3π mass plot of Fig. 1(e) and the ρ-selected distribution of Fig. 1(f). From the fits to the 3π and 5π mass distributions we obtain estimates for the mass and width of the resonance in the $\rho\pi$ and $\omega\pi\pi$ decay modes (see Table I). From the fits to the mass spectra of Figs. 1(c), 1(d), and 1(g) we obtain 204 ± 40, 115 ± 27, and 90 ± 31 as estimates for the number of events in the $\omega(1675)$ resonance. A comparison of the first and last of these numbers implies that there is a direct 5π decay of the $\omega(1675)$. We therefore list separately in Table I the $5\pi/\rho\pi$ and the $\omega\pi\pi/\rho\pi$ branching ratios, where the 5π mode includes submodes. Using the fits to Figs. 1(f) and 1(g), we find the branching ratio $\Gamma(\omega(1675) \to \omega\pi^+\pi^-)/\Gamma(\omega(1675) \to \rho\pi) = 0.47 \pm 0.18$. From Reaction (2) we obtain the cross section $\sigma(\pi^+ n \to \omega(1675)p, \omega(1675) \to \rho\pi) = 60 \pm 13$ μb. The t' distributions for the $\omega(1675)$ for the two decay channels [Figs. 2(b) and 2(d)] were fitted with the form $Ae^{-bt'}$ and yield slopes $b = 3.3 \pm 0.9$ and 2.8 ± 0.5. These distributions are consistent with alternative decay modes of the same state, as are the

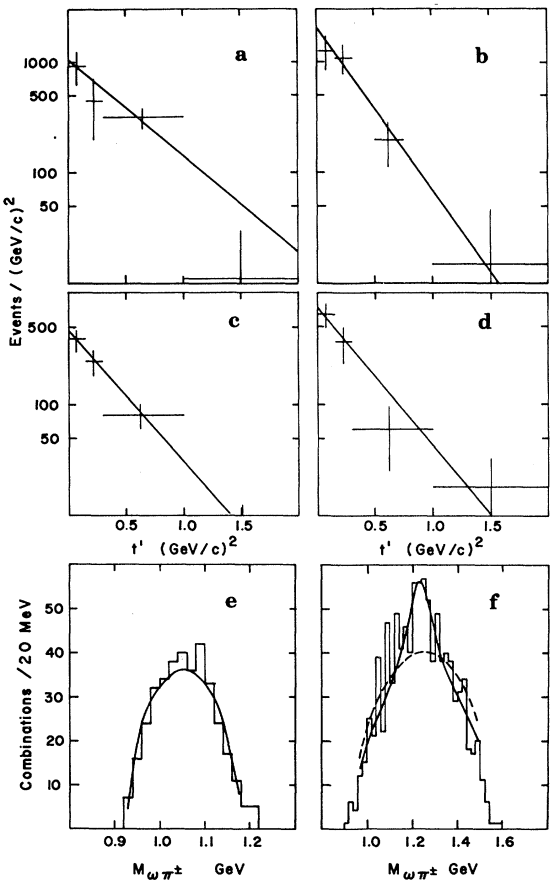

FIG. 2. (a) Background-subtracted t' distributions for the $A_2 \to \rho^\pm \pi^\mp$ events from Reaction (2). (b) Same as (a) but for $\omega(1675) \to \rho^{\pm,0}\pi^{\mp,0}$. (c) Background-subtracted t' distributions for the $A_2 \to \omega\pi^+\pi^-$ events from Reaction (1). (d) Same as (c) but for $\omega(1675) \to \omega\pi^+\pi^-$. (e) $\omega\pi^\pm$ mass distribution in the A_2 region from Reaction (1). (f) $\omega\pi^\pm$ mass distribution in the $\omega(1675)$ region from Reaction (1). The lines in (a)–(d) are fits to the data of the form $Ae^{-bt'}$ in the range $0 \leq t' \leq 2.0$ (GeV/c)^2. Curve in (e), fit with unmodified phase space. Solid curve in (f), fit with unmodified phase space plus one Breit-Wigner term having fixed mass and width; dashed curve in (f), fit with unmodified phase space.

masses and widths listed in Table I.

A study of the $\omega\pi^\pm$ mass plot [Fig. 2(f)] for the $\omega(1675)$ region ($1.60 < M_{\omega\pi\pi} < 1.75$ GeV) indicates that a fraction of the $\omega(1675)$ decays into $B^\pm\pi^\mp$. The possibility of this decay mode has been suggested by Matthews *et al.*[12] The solid and dashed curves in Fig. 2(f) correspond to fits of unmodified phase space with and without a Breit-Wigner resonance form for the $B(1235)$, and give $\chi^2 = 31$ for 25 degrees of freedom and $\chi^2 = 57$ for 26 degrees of freedom, respectively.[13] We show in Fig. 1(h) the number of $B\pi$ events above background as a function of $M_{5\pi}$. A fit to this plot gives 201 ± 91 events in the $\omega(1675)$ resonance, corresponding to a branching ratio[14] $\Gamma(\omega(1675) \to B^\pm\pi^\mp)/\Gamma(\omega(1675) \to \rho\pi) = 0.32 \pm 0.16$. A study of the decay angles and moments for the $B\pi$ and $\omega\pi\pi$ modes of the $\omega(1675)$ gave no further information. If $J^P = 1^+$ for the B meson, the observation of both a $\rho\pi$ and a $B\pi$ decay mode requires $J \geq 1$ for the $\omega(1675)$.

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[8]For each 100-MeV-wide 5π mass interval the 3π mass distribution was fitted with modified phase space plus Gaussian functions for the η and ω. The numbers of ω events from these fits are shown in Fig. 1(g).

[9]To remove $\pi n \to p\Delta$ events from Reaction (2), we exexclude events with $|t - t_{\min}| < 0.1$ (GeV/c)^2 and 1.16

$\leq M_{p\pi^-,0} < 1.32$ GeV, where t is the square of the momentum transfer between the beam pion and the outgoing di-pion system.

[10]Previous measurements (Refs. 1–3) of this branching ratio gave the values 0.23 ± 0.07, 0.08 ± 0.05, and 0.10 ± 0.05, where the first value (Ref. 1) was obtained from an assumed cascade decay $A_2 \rightarrow B_1(1040)\pi \rightarrow \omega\pi\pi$ and where $B_1(1040)$ is a new enhancement reported in Ref. 1. The weighted average of these three branching ratios is 0.11 ± 0.03. With our measurement the new weighted average is 0.14 ± 0.03.

[11]An A_3 interpretation is disfavored since the reactions considered in this report are charge exchange, whereas the A_3 is usually seen in non–charge-exchange reactions. Furthermore, we see no $A_3 \rightarrow f\pi$ in Reaction (2). To check for an $I=1$ interpretation for the 1.65-GeV $\omega\pi\pi$ state, we have looked for a $\rho^0\omega$ contribution by examining the ρ^0 signal as a function of $M_{\omega\pi\pi}$ (not shown). We find a smoothly varying $\rho^0\omega$ signal across the 1.65-GeV region consistent with no $\rho^0\omega$ contribution.

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[14]In Figs. 1(c), 1(d), and 1(g) we have used the high-resolution six-prong events only; in Figs. 1(h) and 2(c) through 2(f) we have used the five- and six-prong events. For the 3π channel, three- and four-prong events have been used throughout. Appropriate corrections have been applied to the branching ratios.

ERRATA

EXCITATION OF GIANT RESONANCES IN ^{58}Ni VIA INELASTIC SCATTERING OF POLARIZED PROTONS. D. C. Kocher, F. E. Bertrand, E. E. Gross, R. S. Lord, and E. Newman [Phys. Rev. Lett. 31, 1070 (1973)].

In Fig. 2, the DWBA predictions for the analyzing power were inadvertently plotted with the wrong sign. The data points are plotted correctly. Thus, we find that the analyzing power in the region $E_x \approx 14.6$–16.7 MeV gives better agreement with the $E0$ prediction than with the $E2$ prediction, while the cross section in the region $E_x \approx 12.7$–23.7 MeV (see Fig. 3) shows a preference for an $E2$ assignment. We are currently investigating possible causes of this ambiguity.

The authors are indebted to G. R. Satchler for bringing this error to our attention.

DIFFERENTIAL CROSS SECTIONS IN $\pi^- p \rightarrow K^0\Lambda^0$ AND $\pi^- p \rightarrow K^0\Sigma^0$ FROM 3 TO 6 GeV/c. C. E. W. Ward, I. Ambats, A. Lesnik, W. T. Meyer, D. R. Rust, and D. D. Yovanovitch [Phys. Rev. Lett. 31, 1149 (1973)].

In Ref. 5, read "A. Bashian *et al.* . . .," instead of "A. Abashian *et al.* . . . ."