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PROPERTIES OF THE ωp RESONANCE AT 1.8 GeV OBSERVED IN $p_{\uparrow}p \to p\omega p$ AT 11.75 GeV/c

by

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Properties of the ωp Resonance at 1.8 GeV Observed in $p_{\uparrow}p \to p\omega p$ at 11.75 GeV/c

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Abstract: Preliminary results from a sample of $\sim$ 20, 000 events of the reaction $pp \to p\omega p$ obtained using the ZGS 11.75 GeV/c polarized proton beam and the Effective Mass Spectrometer are presented. An enhancement in the ωp mass distribution with mass 1.810 ± 0.025 GeV and width 0.140 ± 0.040 GeV is observed. The t distribution of this enhancement shows a pronounced dip near $-t = 0.2$ GeV^2, suggesting that the production mechanism is mostly ω-exchange. The decay angular distributions are consistent with a spin-parity of $\frac{3}{2}^-$.

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We report preliminary results from a sample of ~20,000 events of the reaction $pp \rightarrow p\omega p$ at 11.75 GeV/c obtained using the Effective Mass Spectrometer at the ZGS. A number of previous experiments have examined the ωp system[1], but except for the experiment of Nagy[2], which had ~5000 events, they have all been of low statistical sensitivity. The principal feature of the ωp system, which is confirmed in the present experiment, is an enhancement of width ~100 MeV at a mass near 1.8 GeV.

These data were obtained using the 11.75 GeV/c polarized proton beam from the ZGS incident on a 25 cm long liquid hydrogen target. About half the data were taken with transverse beam polarization, and half with longitudinally polarized beam; the sense of the polarization was reversed on alternate ZGS pulses. Events of the final state $p\pi^+\pi^-\pi^0p$ were measured by the Effective Mass Spectrometer[3], a large aperture magnetic spectrometer, which used magnetostrictive readout wire spark chambers to measure the momenta of the forward produced p, π^+ and π^-. The recoil proton detector[4], consisting of two cylindrical multiwire proportional chambers coaxial with the target, measured the directi- of the recoil proton. The π^0 was not detected. The trigger, which was primarily intended to select events of the reaction $pp \rightarrow p\pi^+\pi^-p$, required a good beam track, no count in a small beam veto counter, exactly 3 hits in the 40-counter hodoscope just downstream of the magnet and at most one hit in the box of veto counters surrounding the target on four sides. The large downstream Cerenkov counter was used offline to distinguish the π^+ from the proton, but was not required in the trigger. The integrated beam flux was 6.3×10^9 protons, corresponding to a cross section sensitivity of ($\sigma \times$ acceptance) = 6.8 events/nb.

After track reconstruction events with the desired topology of two positive and one negative track through the spectrometer and one (or more) tracks in the recoil detector were selected. Events of the final state $p\pi^+\pi^-p$ were removed from the sample by cuts on the (missing mass)^2 calculated from the momenta of the forward tracks and the differences of the angles of the recoil measured by the recoil detector from the values expected from the $pp \rightarrow p\pi^+\pi^-p$ kinematics. The remaining events were subjected to zero constraint (0 - C) calculations for the reaction $pp \rightarrow p\pi^+\pi^-\pi^o p$. For those events with acceptable 0 - C solutions we attempted to resolve the quadratic kinematic ambiguity (and also ambiguities arising from more than one measured recoil track) by examining the calculated momentum and direction of the recoil proton. The recoil proton was required to have sufficient energy to escape from the hydrogen target and pass through the recoil detector. If the recoil should have reached one of the veto counters around the target that counter was required to have fired, otherwise no veto counter was allowed to have fired. After these cuts about half the events have unambiguous solutions, with the remaining events ambiguous between the two kinematic solutions. For events that remained ambiguous both solutions were retained.

Further cuts were made on the Dalitz-plot distribution of the $\pi^+\pi^-\pi^o$ system to clean up the sample. The ω decay populates preferentially the center of the Dalitz plot, while the background was found to be more concentrated near the edges of the plot. A cut removing events more than

0.2 units from the center was applied (where in the non-relativistic limit the boundary of the plot is a circle of radius 1/3 units).

Figure 1 shows the final $\pi^+\pi^-\pi^o$ mass distribution for events with momentum transfer -t less than 0.5 GeV^2. The background under the ω peak has a much more gradual t dependence than does the signal, resulting in an especially clean ω peak at small t. A fit to the distribution of Fig. 1 using a Gaussian on top of a polynomial background gives a σ of 34 MeV. To improve resolution on the ωp mass and t the events were subjected to fits constraining the $\pi^+\pi^-\pi^o$ mass to the ω mass. To obtain the ωp mass distribution the data were binned in the fitted ωp mass and the raw $\pi^-\pi^+\pi^o$ mass distributions for each bin were fitted with a Gaussian of fixed mass and width and a cubic polynomial background to determine the number of ω events. The same procedure was followed to obtain the t distribution.

The distribution of the effective mass of the ω and the forward proton is shown in Figure 2. The acceptance, calculated by Monte-Carlo, is rather flat out to about 2.4 GeV, above which it falls off rapidly. An obvious mass peak occurs at about 1.8 GeV. A fit to this distribution with an S-wave Breit-Wigner shape smeared by a mass resolution of 0.010 GeV (as calculated from the fitted errors of the 1-C fit to the ω mass) and a polynomial background gives a mass of 1.810 GeV and a width of 0.140 GeV for the resonance. These values are in reasonable agreement with those obtained by previous experiments[1,2]. We estimate that the errors on the mass and width are 0.025 and 0.040 GeV respectively. These errors are dominated by systematics.

Figure 3 shows the distribution in momentum transfer t from the incoming proton to the outgoing ωp system for all events, and Figure 4 for those events with $M_{\omega p} < 1.9$ GeV. The acceptance in t is rather flat out to $-t$ of $\sim 1.0\ GeV^2$. The turnover at small t in the uncorrected data is due to the requirement that the recoil proton escape from the target. The t distributions of Figure 3 and Figure 4 are quite steep ($\sim e^{14t}$) at small t. The distribution for all the data exhibits a break near $-t$ of $0.2\ GeV^2$; for the data in the resonance region a pronounced dip near $-t = 0.2\ GeV^2$ is apparent. The imaginary part of the C odd exchange amplitude (deduced from $K^+ - K^-$ and $p-\bar{p}$ elastic cross section differences)[5] is known to have a structure that would produce such a dip. This suggests that ω-exchange is the primary production mechanism for the resonance.

Based on earlier low statistics experiments Lednicky[6] has argued that the resonance has spin-parity $J^P = \frac{3}{2}^-$; in other words the ω and p have total spin $\frac{3}{2}$ and are in an orbital S-wave. We are in the process of doing an analysis of the angular distribution moments and also the moments of the polarization correlations to examine this question. This analysis will also allow us to unfold the acceptance and determine the production cross section. Here we make only the following qualitative remarks about the angular distributions, these results are also consistent with those of Nagy[2]. The angular distribution of the $N^* \to \omega p$ decay in the t-channel (Jackson) frame is flat in $\cos\theta$, consistent with an S-wave decay, and flat in φ, consistent with a t-channel helicity conserving production process. The $\cos\theta$ distribution of the $\omega \to 3\pi$ decay in the s-channel helicity frame is isotropic. Such a distribution is consistent with the decay of either a $\frac{3}{2}^-$ or $\frac{1}{2}^-$ state. The φ distribution shows some $\cos 2\varphi$ dependence (corresponding to a non-zero $\rho_{1\,-1}$ density matrix element). Such a dependence is allowed for $\frac{3}{2}^-$ but not for $\frac{1}{2}^-$. Thus the decay distributions are qualitatively consistent with a $\frac{3}{2}^-$ state.

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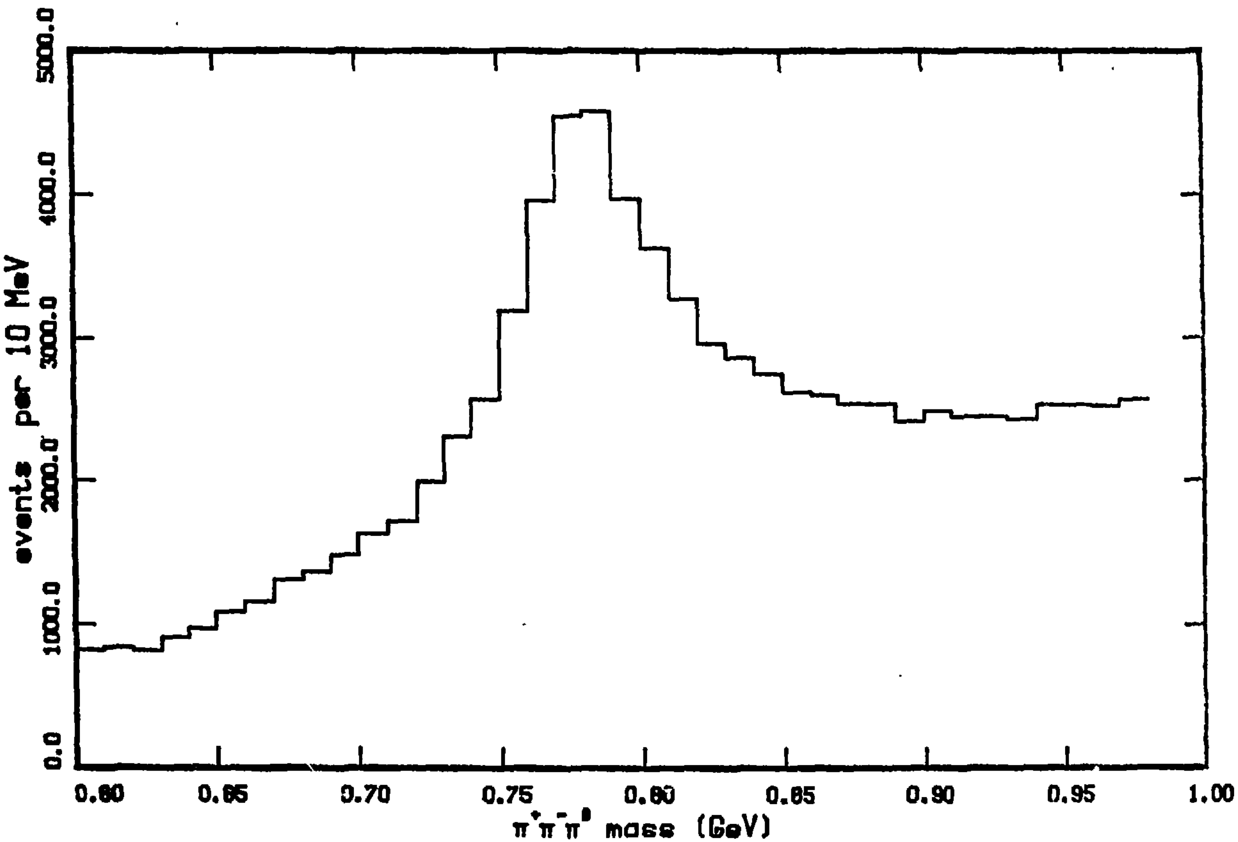

Fig. 1. $\pi^+\pi^-\pi^0$ mass distribution for the reaction $pp \rightarrow p\pi^+\pi^-\pi^0 p$. For events where there are more than one acceptable kinematic solution, both solutions are plotted.

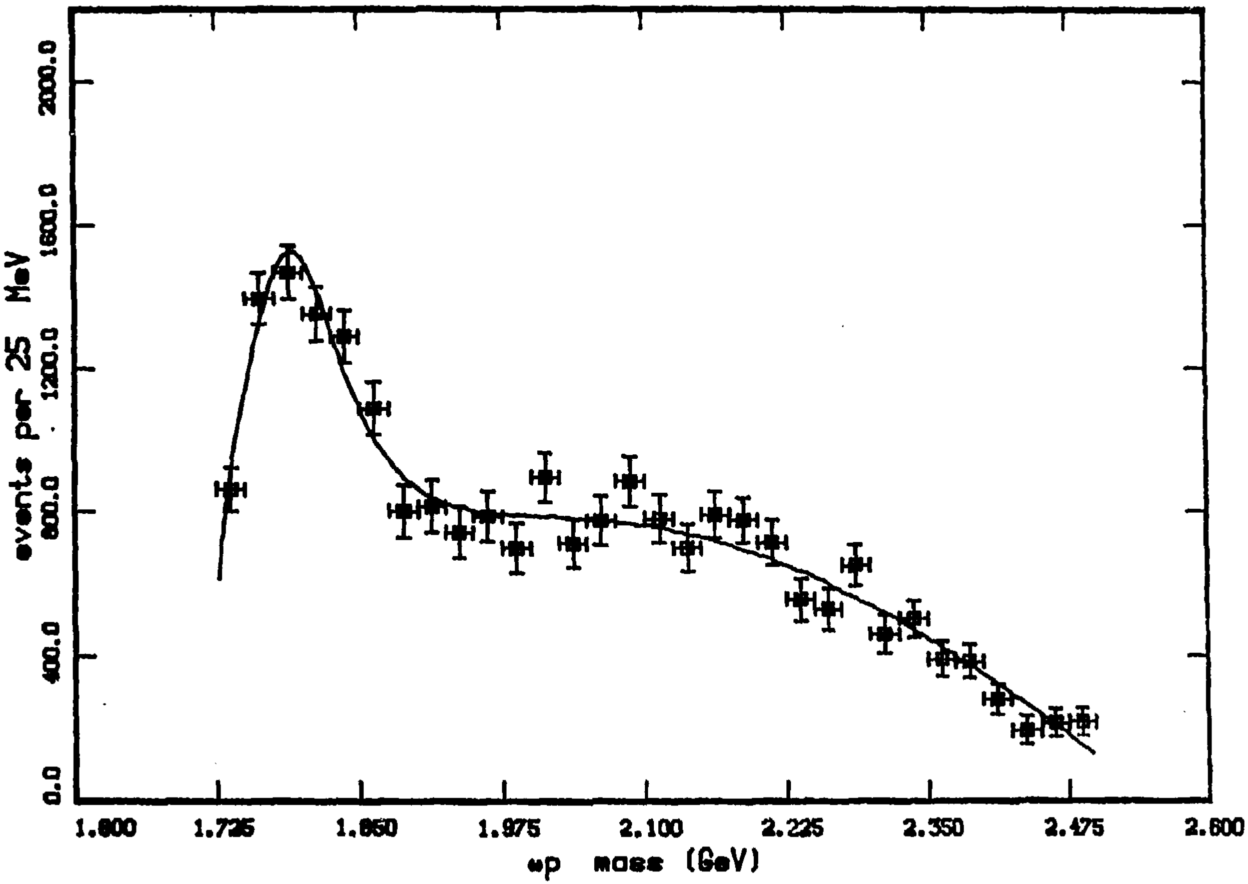

Fig. 2. The ωp mass distribution after fits to the ω mass. The curve is the result of the fit to an S-wave Breit-Wigner shape and a polynomial background.

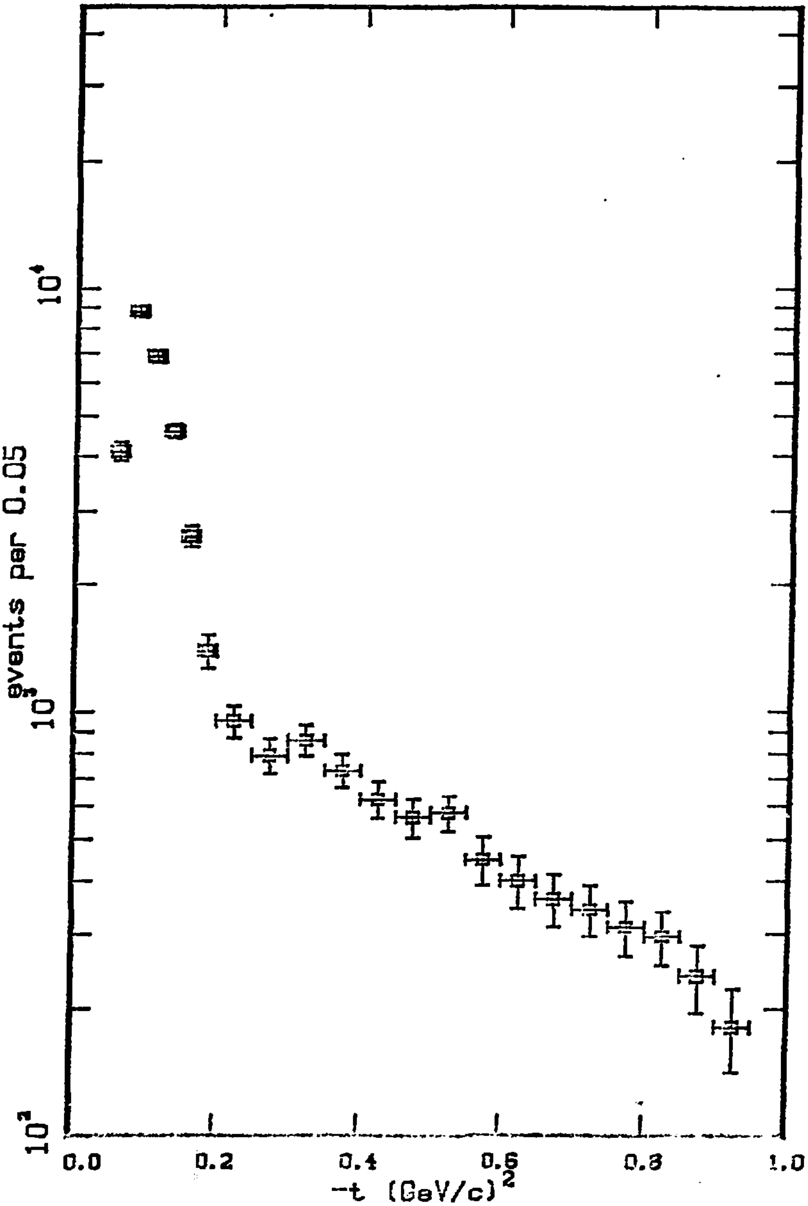

Fig. 3. The t distribution for all ωp masses after fits to the ω mass.

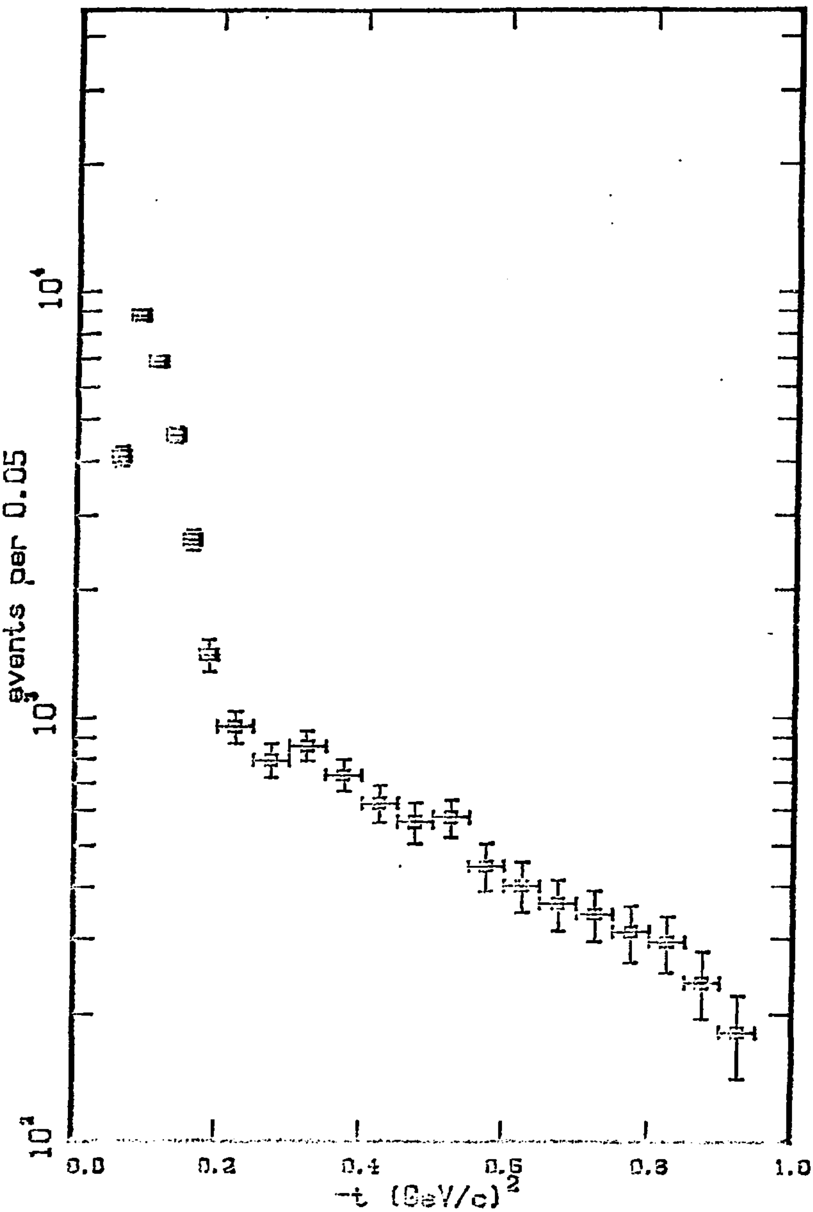

Fig. 4. The t distribution for events with ωp mass less than 1.9 GeV.