A New Measurement of the ω (784) Width*

by

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Abstract

A measurement of the ω (784) decay width has been performed using a neutron counter missing mass spectrometer. A value of $\Gamma_{\omega} = (7.7 \pm 1.0)$ MeV is obtained. The quoted error does not include systematic errors of ± 0.3 , ± 0.2 and ± 0.15 MeV due to uncertainties in background, angular resolution, and beam momentum resolution, respectively. Our value of Γ_{ω} is significantly lower than the current world average of $\Gamma_{\omega} = (10.0 \pm 0.6)$ MeV.

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We report here a new measurement of the decay width of the ω meson. The experiment was performed at the Argonne National Laboratory Zero Gradient Synchrotron. A neutron counter hodoscope, used as a high-resolution missing-mass spectrometer, detected recoil neutrons from the reaction $\pi^- p \rightarrow n + (\text{missing mass})$. A missing-mass spectrum showing a strong ω signal was obtained. The decay width of the ω has been found by unfolding the experimental resolution from the observed signal. Our result is $\Gamma_\omega = 7.7 \pm 1.0$ MeV. This value is significantly smaller than the current world average of $\Gamma_\omega = (10.0 \pm 0.6)$ MeV.^{1/}

Fig. 1 shows a plan view of the apparatus. A 2.5 GeV/c π^- beam produced from an internal ZGS target was focused on a momentum slit. Fifteen scintillation counters, each 0.2" wide, determined the position of beam particles at the momentum slit. Two multi-wire proportional counters (MWPC) upstream of the target measured the horizontal angles of beam particles as they entered the 30-cm-long liquid hydrogen target. Additional scintillation counters defined the beam as it entered the target. Downstream of the target a 25-element scintillation counter hodoscope (PI) detected charged particles from interactions in the target, and a beam anti-coincidence counter detected non-interacting beam particles. Additional anti-coincidence counters were placed around the sides, top, and bottom of the target to exclude interactions with charged particles at wide angles to the beam. A 12-gap thin foil optical spark chamber immediately followed the PI hodoscope and anti-coincidence counter. A neutron counter hodoscope (NCH) was placed 20 meters from the target at an angle of 50° with respect to the beam. The total angle subtended was $\pm 5^\circ$. This NCH served to measure the momenta (time-of-flight) and angles of the neutrons recoiling from interactions in the target. The NCH consisted of 52 separate counters placed in an array 13 counters wide by 4 counters high. Each counter consisted of a 11-cm-wide x 25-cm-high x 30-cm-long block of scintillating plastic viewed by a 5" 58AVP photomultiplier. A large anti-coincidence counter was used to reduce extraneous counts in the NCH originating from secondary scattering in the spark chamber and target area.

An event trigger consisted of a count in the momentum hodoscope, the appropriate counts in the beam defining counters, two and only two counts in the PI hodoscope, no count in any of the anti-coincidence counters, and a count in the NCH 70 to 200 ns after the beam entered the target. The optical spark chambers were then fired and photographed in 90° stereo. Information which described the status of the counter hodoscopes, the MWPC's, the neutron time-of-flight, and the neutron counter pulse height was recorded on magnetic tape by a Σ -2 on-line computer. The photographs were later measured on the University of Illinois DOLLY film-measuring system.^{2/} The output of DOLLY was processed on an IBM 7094 computer for recognition and geometric reconstruction of the two secondary particle tracks. Extrapolation of these tracks into the target yielded the interaction vertex. Accepted events were required to:

- (1) have a unique pair of reconstructed tracks passing through the proper PI hodoscope elements, (2) have an interaction point located inside the target consistent with the extrapolation of the incident beam particle as determined from the MWPC's, (3) be inconsistent with reaction $\pi^- p \rightarrow \pi^- \pi^+ n$, as determined from the kinematic constraints, and (4) be consistent with the reaction $\pi^- p \rightarrow \pi^+ \pi^- \pi^0 n$.^{3/}

The value of the missing mass in reactions of the type $\pi^- p \rightarrow n + (\text{missing mass})$ can be determined from a knowledge of the incoming beam momentum and the recoil neutron momentum. The resolution can be expressed in terms of the uncertainties in (1) the magnitude of the beam momentum, (2) the angle between the neutron and the beam, and (3) the neutron time-of-flight. Table 1 shows the contributions to the mass resolution from each of these terms for various values of momentum transfer to the neutron. The ω^0 width inferred from this experiment depends on these uncertainties, and a discussion of each is warranted.

The magnitude of the momentum of the incident beam particle is determined by correlating the position and angle at the target with the hodoscope element through

which the particle passed at the first beam focus. The momentum is also corrected for energy loss in the target. The accuracy of this procedure is limited by counter sizes to 0.15% of the average incident momentum; we take $(0.20 \pm 0.05)\%$ to be a realistic rms error.

The angle between the neutron and the incoming beam particle is determined by taking the difference of the two measured angles. The neutron angle is fixed by the location of the interaction vertex and the particular neutron counter involved. Each counter subtends a polar angle of 5.6 mr at the target. The error due to uncertainty in the vertex location is an order of magnitude smaller than that due to the counters; consequently, the rms angular error for the neutron is $2.8/\sqrt{3}$ mr. The beam horizontal angle is measured by the MWPC's spaced 1 meter apart with wire separations of 2 mm. The geometric rms angular error is 0.8 mr. A comparable contribution to the angular error results from multiple scattering of the beam, principally in the hydrogen target. The projected rms multiple scattering angle is taken to be $3.6/\sqrt{x}$ mr, where x is the fraction of a radiation length penetrated by the beam particle.^{4/} This contributes a 0.6 mr rms angular error at the center of the target. Thus, the rms error on the relative neutron-beam angle is 1.75 mr for an interaction at the center of the target. The uncertainty in this figure is estimated to be ± 0.1 mr.

We take the rms error in the measurement of the neutron time-of-flight to be 0.85 ns. We determine this value by requiring consistency in Γ_w , as obtained in high- and low-momentum transfer data samples. In the high- $|t|$ sample, $0.50 \leq -t \leq 0.75 (\text{GeV}/c)^2$, the resolution is dominated by the time-of-flight uncertainty, whereas, in the low- $|t|$ sample, $0.175 \leq -t \leq 0.50 (\text{GeV}/c)^2$, the resolution is relatively insensitive to the time-of-flight uncertainty (See Table I). Statistical fluctuations in the data limit the accuracy obtained to 0.1 ns. This corresponds to changes in Γ_w of 3.0 and 0.5 MeV for the high- $|t|$ and low- $|t|$ regions respectively.

The decay width is unfolded from the observed signal by fitting the data to a quadratic polynomial background plus a modified Breit-Wigner line shape^{5/} folded with a resolution function. The resolution function for a given sample is obtained by summing the resolution function for each event in the sample. In order to account for differences in resolution between the signal and background due to differences in $|t|$ dependence, the final ω^0 resolution function is found by subtracting background functions in control regions (747.5 to 765.0 MeV and 800.0 to 817.5 MeV) from that in the signal region (765.0 to 800.0 MeV).

The missing mass spectra for two momentum transfer intervals are shown in Fig. 2. Also shown are the respective resolution functions. The curves show the fitted quadratic polynomial background and folded Breit-Wigner obtained in each interval. The significant parameters are given in Table 2. It is important to keep in mind that the high- $|t|$ interval is used only to obtain an accurate estimate of the time-of-flight resolution; no independent measurement of the ω^0 width is obtained in this sample. Our result is

$$\Gamma_{\omega} = (7.7 \pm 1.0) \text{ MeV.}$$

The quoted error in the width includes 0.9 MeV due to statistical uncertainties, and 0.5 MeV due to an uncertainty of 0.1 ns in the rms time-of-flight error. Effects of other errors of a more systematic nature are not included in the above value. These are ± 0.2 MeV and ± 0.15 MeV due to uncertainties of 0.1 mr and 0.05% in the angular and momentum rms errors, respectively. Also not included are systematic uncertainties of ± 0.3 MeV due to assumptions about the background and the shape of the resonance curve. Our value for the ω^0 decay width is small in comparison with previous measurements. As has been noted recently, however, some of these widths are obtained using potentially inaccurate approximations.^{6/}

We wish to acknowledge the assistance of the ZGS staff, and to thank Argonne National Laboratory for the use of the neutron-counter hodoscope and Σ -2 computer.

References and Footnotes

1. Particle Data Group, "Review of Particle Properties", Physics Letters, 39B No. 1, (1972).
2. R. M. Brown & R. W. Downing, Proc. International Conf. on Advanced Data Processing for Bubble and Spark Chambers, Argonne Nat'l Laboratory, ANL-7515, October 1968 (unpublished).
3. The kinematics for this reaction are underconstrained; however, many background events can be rejected because they violate certain kinematic inequalities.
4. We thank R. Diebold for information concerning multiple-Coulomb scattering.

5. The line shape used was

$$f(m) = (1+\alpha m)/[(m-m_\omega)^2 + \Gamma_\omega^2/4],$$

where m is the missing mass, m_ω and Γ_ω are the mass and width of the ω , respectively, and $\alpha = 0.016 \text{ (GeV/c}^2\text{)}^{-1}$. This expression corresponds to a Breit-Wigner modified by a linear approximation of the effects of phase space and a ρ propagator in the ω decay matrix element.

6. D. G. Coyne, W. R. Butler, G. Fang-Landau, J. MacNaughton, Nucl. Phys. B32, 333 (1971).

TABLE 1

Contributions to the mass resolution function at various values of the momentum transfer.

The entries in the column Δm_θ are given by

$$\Delta m_\theta = \left| \frac{\partial m}{\partial \theta} \Delta \theta \right| \text{ where } \Delta \theta \text{ is the rms error in the relative beam-neutron angle.}$$

Similar

expressions are evaluated for Δm_{PBEAM} and Δm_{TOF}

which are the contributions from uncertainties

in the beam momentum and time-of-flight respec-

tively. The total rms resolution is given by

$$(\Delta m_{\text{TOT}})^2 = (\Delta m_\theta)^2 + (\Delta m_{\text{PBEAM}})^2 + (\Delta m_{\text{TOF}})^2.$$

-t (GeV/c) ²	Δm_θ (MeV)	Δm_{PBEAM} (MeV)	Δm_{TOF} (MeV)	Δm_{TOT} (MeV)
0.2	2.1	1.0	0.3	2.4
0.3	2.6	1.1	2.0	3.4
0.4	2.9	1.3	4.2	5.3
0.5	3.2	1.4	7.0	7.8
0.6	3.5	1.6	10.2	10.9
0.7	3.7	1.7	13.8	14.4

TABLE 2

Results of fitting high- and low- momentum transfer data samples as defined in the text. The fitted ω^0 mass is subject to a systematic uncertainty of $\pm 2\text{MeV}$.

	χ^2/NDF	Resolution FWHM(MeV)	Events above background	M_ω (MeV)	Γ_ω (MeV)
High-t region	77/54	25.0	532	784.0	7.5
Low-t region	50/54	9.0	940	783.1	7.7 $\pm$ 1.0

Figure Captions

1. Plan view of experimental apparatus. The neutron counter hodoscope and upstream momentum hodoscope are not shown.
2. The missing mass spectra for (a) low- t and (b) high- t samples. The curves show the fits to the signal and background. Also shown are the resolution functions for the two samples and the observed widths of the signals.

Fig. 1. Plan view of experimental apparatus. The neutron counter hodoscope and upstream momentum hodoscope are not shown.

Fig. 2. The missing mass spectra for (a) low- t and (b) high- t samples. The curves show the fits to the signal and background. Also shown are the resolution functions for the two samples and the observed widths of the signals.