THE DECAY OF THE $\rho'(1600)$ INTO $\pi^+\pi^-\pi^0\pi^0$

The Omega Photon Collaboration

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ABSTRACT

Measurements of the reaction $\gamma p \rightarrow \pi^+\pi^-\pi^0\pi^0 p$ are presented for the photon energy range 20 to 70 GeV. The 1.6 GeV peak in the mass spectrum of the $\pi^+\pi^-\pi^0\pi^0$ system is shown to decay dominantly to $\rho^\pm \pi^\mp \pi^0$. The ratio of $\rho^0\pi^0\pi^0$ to $\rho^\pm \pi^\mp \pi^0$ is less than 0.15, thus eliminating $\rho\pi$ as the dominant decay mode of $\rho'(1600)$.

Previous studies of the reaction $\gamma p \rightarrow \pi^+ \pi^- \pi^+ \pi^- p$ have shown evidence for a peak due to the $\rho'(1600)$ decaying strongly to $\rho^0 \pi^+ \pi^-$ (1,2). The study of $\gamma p \rightarrow \pi^+ \pi^- \pi^0 \pi^0 p$ is of interest since the ratio of $\rho^\pm$ to ρ^0 is predicted to be different for various models²⁾. In particular, decay via $\rho\pi$ (π signifies the low mass $\pi\pi$ s-wave interaction) can only occur through $\rho^0 \pi^0 \pi^0$, whilst a decay via an $A\pi$ mode (where A indicates an $I^G = 1^-$ state) will only occur in $\rho^\pm \pi^\mp \pi^0$. We show that $\rho^\pm \pi^\mp \pi^0$ decay dominates.

The data were taken using the Omega spectrometer [equipped with multi-wire proportional chambers (MWPCs) and drift chambers] together with the tagged photon beam and general layout previously described³⁾. The trigger required between two and five forward charged particles, and a signal from the lead-glass array which indicated the detection of at least 1 γ -ray. Event selection required 4 γ -rays to be reconstructed to form $2\pi^0$'s, and two or three charged particles consistent with being either $\pi^+ \pi^-$ or $\pi^+ \pi^- p$ respectively. Cuts on longitudinal momentum balance ensured that the contamination by events with additional undetected particles was $\leq 15\%$.

The 4π mass spectrum (Fig. 1) shows a two-peak structure. The data were divided into 100 MeV wide slices of 4π mass, and the 3π and 2π mass spectra for different charge combinations were studied. Figure 2 (for the 4π mass range 1.5 to 1.6 GeV) shows a typical series of mass plots. Generally the $\rho^\pm$ is visible for all 4π masses above ~ 1.4 GeV, whilst the ρ^0 is much less obvious. The ω meson is visible in all 4π mass slices and is strongest in the 4π mass region 1.1 to 1.3 GeV.

Simulated events for various final-state interaction models for the 4π system (as described in the appendix of Ref. 2) have been generated by the Monte Carlo method. The experimental incident photon energy distribution followed the standard bremsstrahlung form, so events were generated with this energy distribution and were weighted by a model of the experimental acceptance. The smoothed mass distributions from the Monte Carlo calculation

were then used in least squares fits to $\pi^{\pm}\pi^0\pi^0$, $\pi^+\pi^-\pi^0$, $\pi^{\pm}\pi^0$, and $\pi^+\pi^-$ mass spectra simultaneously, assuming linear sums of intensities of the following four models: i) 4π phase space; ii) $\rho^{\pm}\pi^{\mp}\pi^0$ phase space; iii) $\omega\pi^0$; and iv) $\rho^0\pi^0\pi^0$ phase space. Satisfactory fits (with $\chi^2/\text{degree of freedom} \leq 1.5$) need only the models i) + ii) + iii). An example of this fit for a typical 4π mass bin is shown as the curves in Fig. 2. In order to get estimates of the relative amounts of charged and neutral ρ production fits have been carried out with models i) + ii) + iii) + iv) constraining the contribution of each to be ≥ 0 . The numbers of events from each model given by these fits are shown on Fig. 3 where the errors are those given by the fitting programme MINUIT⁴⁾. The mass spectra are insensitive to the acceptance and the conclusions are unaffected by uncertainties in the acceptance calculation.

Figure 3 shows that the $\omega\pi$ channel is a major contributor to the peak in 4π mass at ~ 1.25 GeV. There is a peak at ~ 1.6 GeV in $\rho^{\pm}\pi^{\mp}\pi^0$ which may be identified with the $\rho'(1600)$. The evidence for ρ^0 production is not compelling and the ratio of ρ^0 to charged ρ production is ≤ 0.15 for all 4π mass bins. The possibility that charged ρ -mesons are produced in pairs has been investigated but there is no evidence for a strong $\rho^+\rho^-$ correlation in the data. We note the similarity in position and width of the peak in $\rho^{\pm}\pi^{\mp}\pi^0$ to that seen in $\pi^+\pi^-\pi^+\pi^-$ 2). Since the ratio of $\rho^0\pi^0\pi^0$ to $\rho^{\pm}\pi^{\mp}\pi^0$ is < 0.15 we rule out a dominant $\rho\epsilon$ decay mode for the $\rho'(1600)$.

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Figure Captions

Fig. 1 : Effective mass spectrum for $\pi^+ \pi^- \pi^0 \pi^0$.

Fig. 2 : Typical 3π and 2π effective mass spectra and fits assuming models i), ii) and iii) (discussed in the text), for a 100 MeV wide slice of 4π mass. The particular slice shown is $1.5 < M_{4\pi} < 1.6$ GeV.

Fig. 3 : Fitted yields of $\omega\pi^0$ (open circles), 4π phase space (squares), and $\rho^+ \pi^+ \pi^0$ phase space (solid circles) and $\rho^0 \pi^0 \pi^0$ phase space (triangles) as found by the minimization procedures assuming models i), ii), iii) and iv) (discussed in the text). The errors shown are those given by MINUIT.

Fig. 1

Fig. 2

Fig. 3