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Measurements of $f_1(1285) \to \pi^+\pi^-\pi^+\pi^-$, $\eta_c \to \rho^0\rho^0$ and $\eta_c \to f_2(1270)f_2(1270)$ in Radiative J/ψ Decays†

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Abstract

A measurement of $J/\psi \to \gamma\pi^+\pi^-\pi^+\pi^-$ is presented. The $f_1(1285)$ is observed and its spin and parity are investigated. The η_c is observed to decay to $\rho^0\rho^0$, and the first observation of η_c decays to $f_2(1270)f_2(1270)$ is presented.

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The radiative decay $J/\psi \to \gamma\pi^+\pi^-\pi^+\pi^-$ has been studied previously by Mark III, with a smaller data sample.[1] The present analysis is still in progress, and is therefore **preliminary**. Our data, taken with the Mark III detector at the SLAC e^+e^- storage ring SPEAR, consist of 5.8×10^6 produced J/ψ 's. Events are selected with four charged tracks and one or more photon candidates. The events are kinematically fitted to the $J/\psi \to \gamma\pi^+\pi^-\pi^+\pi^-$ hypothesis, looping over all photon candidates (up to five, ordered in decreasing energy). The fit with the highest probability is kept. Selection criteria on kinematic quantities are imposed. The invariant mass distribution of the $\pi^+\pi^-\pi^+\pi^-$ system is shown in Figure 1a. A peak at 1.285 GeV/c^2 is seen, consistent with the $f_1(1285)$ mass and width. A prominent resonance at 2.98 GeV/c^2, consistent with the $\eta_c(2980)$ mass and width, is also seen. To study the first enhancement we look at the angular distributions for masses between 1.25 and 1.30 GeV/c^2. Figure 2a shows the distribution of χ, the angle between the decay planes of the $\pi^+\pi^-$ systems in the $\pi^+\pi^-\pi^+\pi^-$ rest frame. This distribution is expected to be zero at 0°, rising to its maximum above 45° if the 4π state has $J^P = 0^-$. In contrast for $J^P = 1^+$, this distribution is expected to be nearly flat. In Figure 2b the distribution of $\cos\theta_{\pi^+}$ is shown, where θ_{π^+} is the polar angle of the π^+ in the $\pi^+\pi^-$ rest frame. A $\sin^2\theta_{\pi^+}$ distribution is expected if the 4π state has $J^P = 0^-$, while a nearly flat distribution is expected for $J^P = 1^+$. Our data rules out the pseudoscalar assignment, and is consistent with the $f_1(1285)$ being an axial vector. The branching ratio is given in Table I.

To study the η_c region we select the invariant mass of the $\pi^+\pi^-\pi^+\pi^-$ system from 2.95 to 3.00 GeV/c^2, and plot one $\pi^+\pi^-$ invariant mass versus the other in Figure 3 (there are two entries for each event). An enhancement is seen in the $\rho^0\rho^0$ and $f_2(1270)$ $f_2(1270)$ regions. Such enhancements are not seen in nearby control regions of $M_{\pi^+\pi^-\pi^+\pi^-}$. Motivated by this, we define: $\delta^2_{\rho^0} = (M_{(\pi^+\pi^-)_1} - 0.77)^2 + (M_{(\pi^+\pi^-)_2} - 0.77)^2$ and $\delta^2_{f_2} = (M_{(\pi^+\pi^-)_1} - 1.27)^2 + (M_{(\pi^+\pi^-)_2} - 1.27)^2$. We restrict $\delta_{\rho^0} < 0.15$ and $\delta_{f_2} > 0.30$ GeV/c^2 and plot $M_{\pi^+\pi^-\pi^+\pi^-}$ in Figure 1b. A clear η_c signal is seen. The angular distributions in the η_c region are currently

being investigated. We restrict $\delta_{f_2} < 0.175$ and $\delta_{\rho^0} > 0.26$ GeV/c^2 and plot $M_{\pi^+\pi^-\pi^+\pi^-}$ in Figure 1c. A clear η_c signal is seen providing the first evidence of a tensor-tensor decay of the η_c. The angular distributions in the η_c region and the f_2 helicities are currently being studied. The branching ratios are given in Table I, where the first error is statistical and the second systematic.

Table I. $J/\psi \to \gamma\pi^+\pi^-\pi^+\pi^-$ **Preliminary Branching Ratios.**

Process	Product branching ratio (10^{-4})
$(J/\psi \to \gamma f_1(1285))(f_1 \to \pi^+\pi^-\pi^+\pi^-)$	$0.55 \pm 0.11 \pm 0.10$
$(J/\psi \to \gamma\eta_c)(\eta_c \to \pi^+\pi^-\pi^+\pi^-)$	$1.50 \pm 0.13 \pm 0.30$
$(J/\psi \to \gamma\eta_c)(\eta_c \to \rho^0\rho^0)$	$0.96 \pm 0.15 \pm 0.22$
$(J/\psi \to \gamma\eta_c)(\eta_c \to f_2(1270)f_2(1270))$	$1.2 \pm 0.3 \pm 0.4$

Conclusions

A measurement of $J/\psi \to \gamma\pi^+\pi^-\pi^+\pi^-$ is presented. The $f_1(1285)$ is observed and its spin and parity are found to be consistent with an axial vector. The η_c is observed to decay to $\rho^0\rho^0$. The first observation of η_c decays to $f_2 f_2$ is presented.

References

1. R.M. Baltrusaitis et al., Phys. Rev. D **33**, 1222 (1986).

FIGURE CAPTIONS

1. The $\pi^+\pi^-\pi^+\pi^-$ invariant mass distribution for events of the type: (a) $J/\psi \rightarrow \gamma\pi^+\pi^-\pi^+\pi^-$; (b) $J/\psi \rightarrow \gamma\rho^0\rho^0$, $\rho^0 \rightarrow \pi^+\pi^-$; (c) $J/\psi \rightarrow \gamma f_2(1270) f_2(1270)$, $f_2 \rightarrow \pi^+\pi^-$.

2. (a) χ and (b) $\cos\theta_{\pi^+}$ distributions for events of the type: $J/\psi \rightarrow \gamma f_1(1285)$; $f_1 \rightarrow \pi^+\pi^-\pi^+\pi^-$.

3. Scatter plot of $M_{\pi^+\pi^-}$ *vs.* $M_{\pi^+\pi^-}$ for events of the type $J/\psi \rightarrow \gamma\pi^+\pi^-\pi^+\pi^-$ where $2.95 < M_{\pi^+\pi^-\pi^+\pi^-} < 3.00$ GeV/c^2 (η_c region).

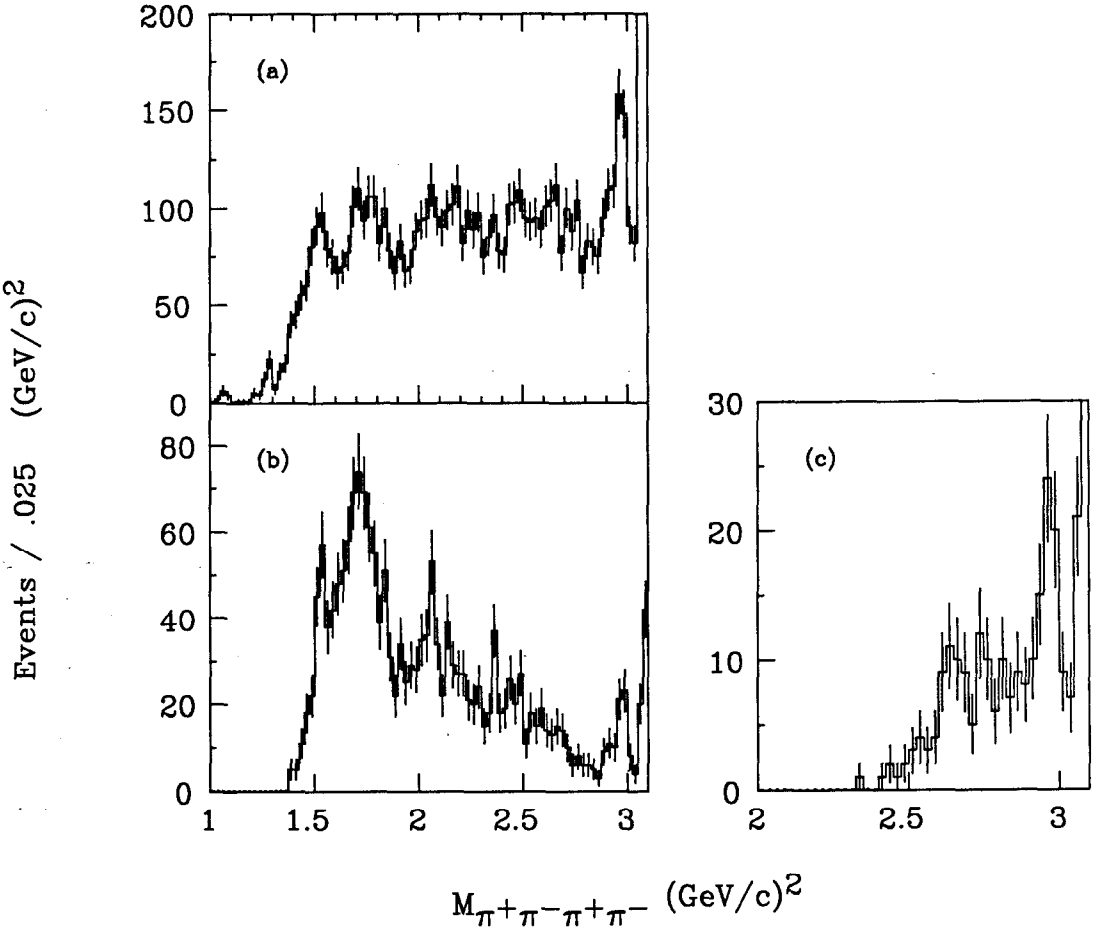

Figure 1

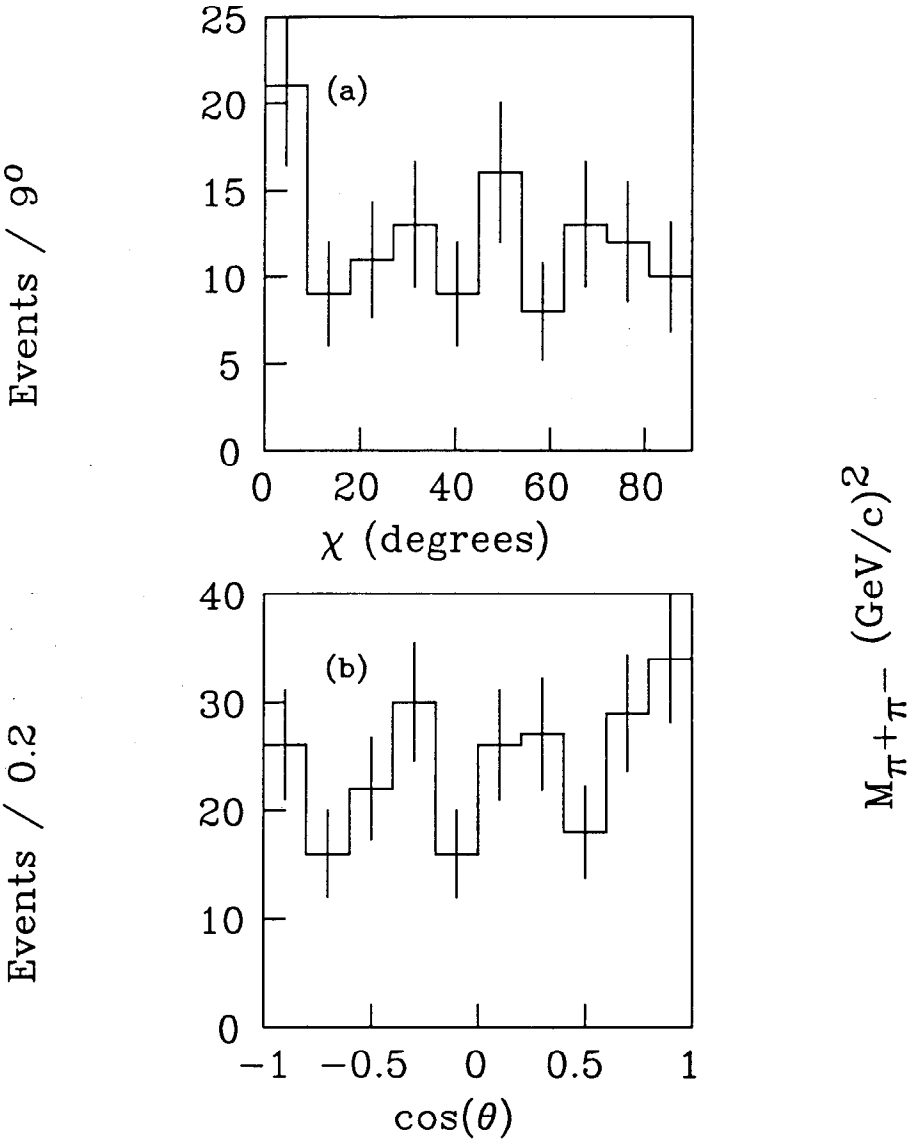
Events / 9°
25
20
15
10
5
0
(a)
0
20
40
60
80
χ (degrees)
Events / 0.2
40
30
20
10
0
(b)
−1
−0.5
0
0.5
1
cos(θ)
$M_{\pi^+\pi^-}$ (GeV/c)^2

Figure 2

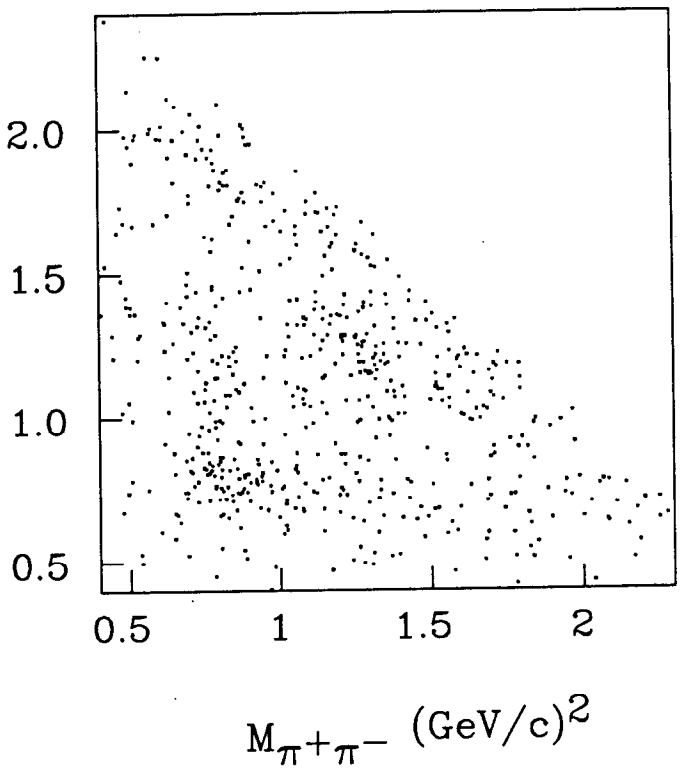

Figure 3