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J/ψ Results from Mark III[†]

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ABSTRACT

Measurements of the two-body decays of the J/ψ into vector and pseudoscalar meson pairs are presented. Using the measured branching ratios, a phenomenological model of J/ψ decays indicates that the η and η' are composed only of light and strange quarks, without a gluonium contribution in the η' wavefunction. A measurement of $J/\psi \rightarrow \gamma\pi^+\pi^-\pi^+\pi^-$ 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 first indications of η_c decays to f_2f_2 are presented. The spin and parity of the η_c are investigated.

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J/ψ Decays to Vector Pseudoscalar Meson Pairs.^[1]

The $J/\psi(3097)$ is the lowest lying $c\bar{c}$ vector meson. The narrow width (63 keV) of the J/ψ is a consequence of disconnected quark lines in its decay (OZI rule). A full set of measurements of $J/\psi \rightarrow VP$ decays enables us to study the contributions of the different processes to the decay rates, the mixing angle in the pseudoscalar meson nonet, and the quark content of the η and η' mesons.

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. All $J/\psi \rightarrow VP$ decays are analyzed. Most processes are observed in more than one decay mode of the pseudoscalar, thus enabling us to cross-check our measurements. Our results are summarized in Table I, where the first error is statistical and the second systematic.

Table I. $J/\psi \rightarrow VP$ branching ratios.

$J/\psi \rightarrow$	Branching ratio (10^{-3})	$J/\psi \rightarrow$	Branching ratio (10^{-3})
$K^{*+}K^- + c.c.$	$5.26 \pm 0.13 \pm 0.53$	$\omega\pi^0$	$0.482 \pm 0.019 \pm 0.064$
$K^{*0}\bar{K}^0 + c.c.$	$4.33 \pm 0.12 \pm 0.45$	$\omega\eta$	$1.71 \pm 0.08 \pm 0.20$
$\rho\pi$	$14.2 \pm 0.1 \pm 1.9$	$\omega\eta'$	$0.166 \pm 0.017 \pm 0.019$
$\rho\eta$	$0.193 \pm 0.013 \pm 0.029$	$\phi\pi^0$	<0.0068 (90% CL)
$\rho\eta'$	$0.114 \pm 0.014 \pm 0.016$	$\phi\eta$	$0.661 \pm 0.045 \pm 0.078$
		$\phi\eta'$	$0.308 \pm 0.034 \pm 0.036$

The widths of J/ψ into the VP meson pairs are equal to $|A_i|^2 \times p_{V_i}^3$, where p_{V_i} is the momentum of the vector meson in the rest frame of the J/ψ . In a recent phenomenological model^[2] the amplitudes A_i are composed of strong, SU(3) violating and electromagnetic processes as well as processes with more than one disconnected quark line (DOZI processes). The η and η' mesons can be parametrized by: $|\eta\rangle = X_\eta \frac{1}{\sqrt{2}} |u\bar{u} + d\bar{d}\rangle + Y_\eta |s\bar{s}\rangle$, $|\eta'\rangle = X_{\eta'} \frac{1}{\sqrt{2}} |u\bar{u} + d\bar{d}\rangle + Y_{\eta'} |s\bar{s}\rangle$. We fit the phenomenological model to the ten reduced branching ratios with the constraints $X_i^2 + Y_i^2 = 1$ and $X_{\eta'} = -Y_\eta$. The fit yields $Y_\eta = -0.581$ from which we calculate the mixing angle in the pseudoscalar nonet to be: $\theta_p = (-19.2 \pm 1.4)^\circ$. The result for θ_p is in good agreement with recent two-photon results.^[3] A fit to the data, without the above constraints on X_i and Y_i yields $X_\eta^2 + Y_\eta^2 = 1.00 \pm 0.16$ and $X_{\eta'}^2 + Y_{\eta'}^2 = 1.44 \pm 0.26$. The results of the unconstrained fit indicate that the model where the η and η' consist of only u , d and s quarks, with no contribution from gluonium, is consistent with the data.

J/ψ Decays to $\gamma\pi^+\pi^-\pi^+\pi^-$

The radiative decay $J/\psi \rightarrow \gamma\pi^+\pi^-\pi^+\pi^-$ has been studied previously by Mark III, with a smaller data sample.^[4] 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 $J/\psi \rightarrow \gamma\pi^+\pi^-\pi^+\pi^-$ 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 $1.285 \text{ GeV}/c^2$ is seen, consistent with the $f_1(1285)$ mass and width. A prominent resonance at $2.98 \text{ GeV}/c^2$, 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 $1.30 \text{ GeV}/c^2$. Figure 3a 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° for a particle with $J^P = 0^-$. In contrast, for $J^P = 1^+$, this distribution is expected to be flat. In Figure 3b 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 for a particle with $J^P = 0^-$, while a 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 II.

To study the η_c region we constrain the invariant mass of the $\pi^+\pi^-\pi^+\pi^-$ system from 2.95 to $3.00 \text{ GeV}/c^2$, and plot one $\pi^+\pi^-$ invariant mass versus the other in Figure 2 (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: $\delta_{\rho^0}^2 = (M_{(\pi^+\pi^-)_1} - 0.77)^2 + (M_{(\pi^+\pi^-)_2} - 0.77)^2$ and $\delta_{f_2}^2 = (M_{(\pi^+\pi^-)_1} - 1.27)^2 + (M_{(\pi^+\pi^-)_2} - 1.27)^2$. We restrict $\delta_{\rho^0} < 0.15$ and $\delta_{f_2} > 0.30 \text{ GeV}/c^2$ and plot $M_{\pi^+\pi^-\pi^+\pi^-}$ in Figure 1b. A clear η_c signal is seen, and the angular distributions in the η_c region (Figures 3c and 3d) identify it as a $J^P = 0^-$ state, in agreement with the DM2 measurement.^[5] We restrict $\delta_{f_2} < 0.175$ and $\delta_{\rho^0} > 0.26 \text{ GeV}/c^2$ 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 are shown in Figures 3e and 3f, providing further evidence for the pseudoscalar assignment of the η_c . The branching ratios are given in Table II, where the first error is statistical and the second systematic.

Table II. $J/\psi \rightarrow \gamma\pi^+\pi^-\pi^+\pi^-$ Preliminary Branching Ratios.

Process	Product branching ratio (10^{-4})
$(J/\psi \rightarrow \gamma f_1)(f_1 \rightarrow \pi^+\pi^-\pi^+\pi^-)$	$0.55 \pm 0.11 \pm 0.10$
$(J/\psi \rightarrow \gamma \eta_c)(\eta_c \rightarrow \pi^+\pi^-\pi^+\pi^-)$	$1.50 \pm 0.13 \pm 0.30$
$(J/\psi \rightarrow \gamma \eta_c)(\eta_c \rightarrow \rho^0\rho^0)$	$0.96 \pm 0.15 \pm 0.22$
$(J/\psi \rightarrow \gamma \eta_c)(\eta_c \rightarrow f_2f_2)$	$1.2 \pm 0.3 \pm 0.4$

Conclusions

New measurements for J/ψ decays to vector pseudoscalar meson pairs are presented. Using the model of Ref. 2 the η and η' are found to be composed of light and strange quarks only, without a gluonium contribution in the η' wavefunction. Using the results of the model the pseudoscalar mixing angle is found to be $\theta_p = (-19.2 \pm 1.4)^\circ$ in agreement with $\gamma\gamma$ results. A measurement of $J/\psi \rightarrow \gamma\pi^+\pi^-\pi^+\pi^-$ 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 $\rho^0\rho^0$. First indications of η_c decays to f_2f_2 are presented. Angular distributions show that the η_c is a pseudoscalar.

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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) $J/\psi \rightarrow \gamma f_2 f_2$, $f_2 \rightarrow \pi^+\pi^-$.
2. Scatter plot of $M_{\pi^+\pi^-}$ vs. $M_{\pi^+\pi^-\pi^+\pi^-}$ 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).
3. The χ and $\cos\theta_{\pi^+}$ angular distributions for events of the type: (a)(b) $J/\psi \rightarrow \gamma f_1$; $f_1 \rightarrow \pi^+\pi^-\pi^+\pi^-$; (c)(d) $J/\psi \rightarrow \gamma\eta_c$; $\eta_c \rightarrow \rho^0\rho^0$; the curves are the Monte Carlo simulation for a pseudoscalar η_c ; (e)(f) $J/\psi \rightarrow \gamma\eta_c$; $\eta_c \rightarrow f_2 f_2$.

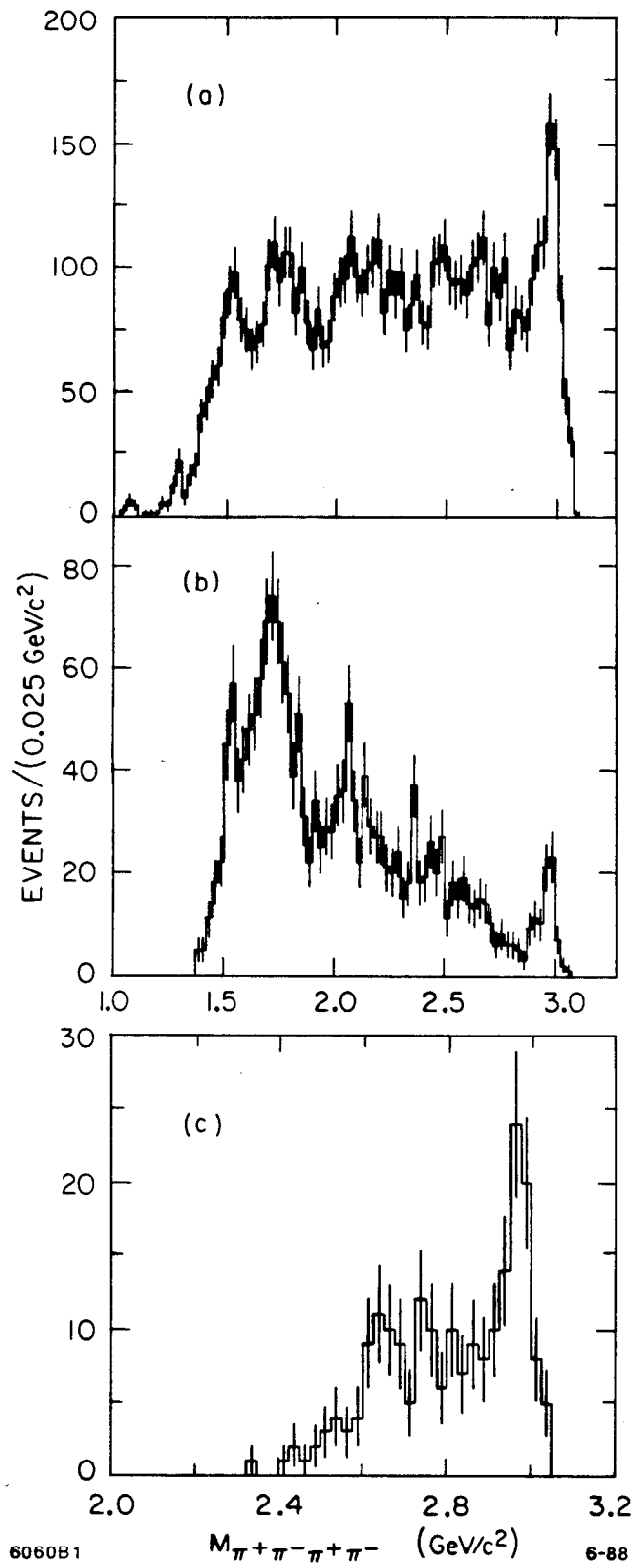


Fig. 1

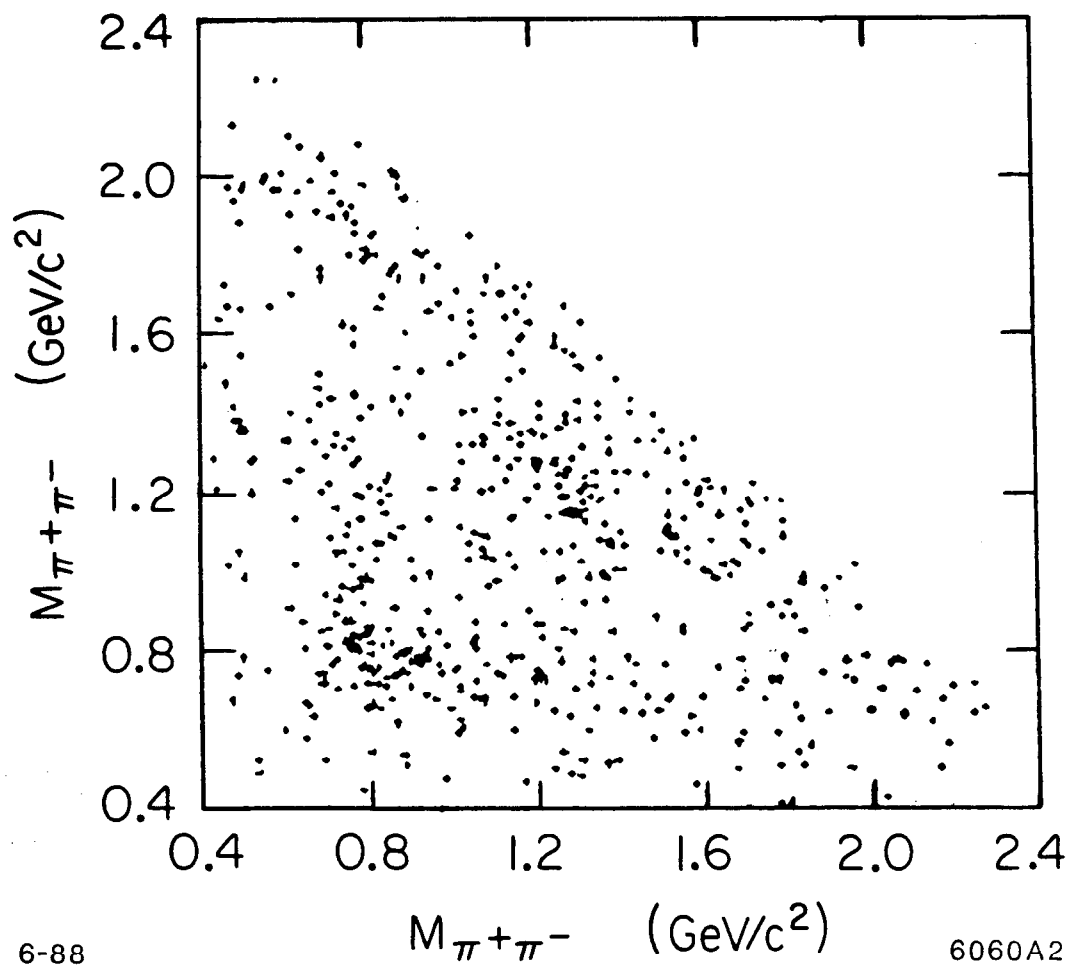
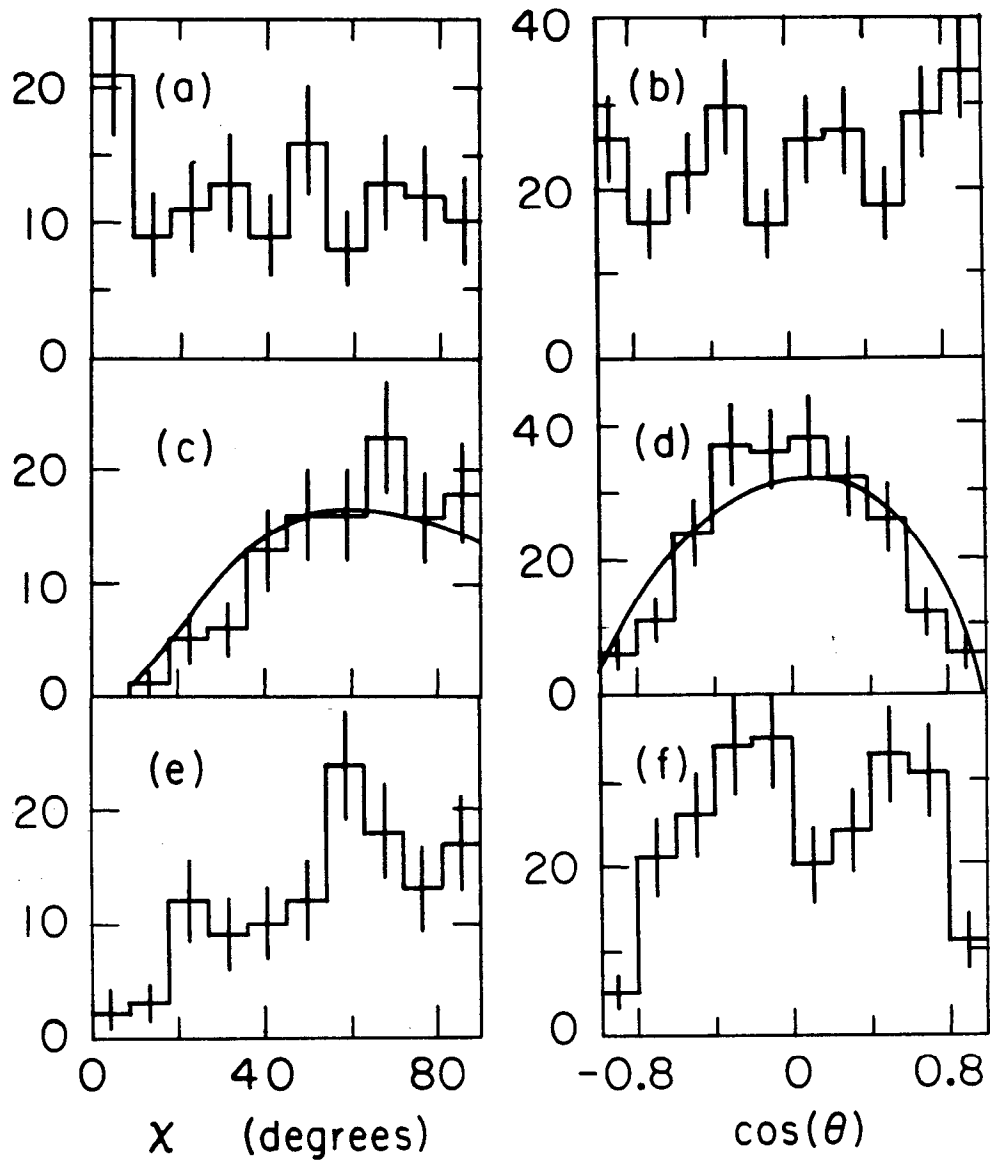


Fig. 2



6-88

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Fig. 3