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Review of J/Ψ Decays*

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Abstract

Recent results from the Mark III collaboration in radiative J/Ψ decays are presented. This includes a study of iota/E decays in $J/\Psi \to \gamma\eta\pi\pi$ and $\gamma\gamma\rho$, two pseudoscalar decays near threshold in $J/\Psi \to \gamma\pi\pi$ and $\gamma \bar{K}K$ and two vector decays in $J/\Psi \to \gamma \bar{K}^{o*} K^{o*}$.

Recent results in J/Ψ radiative decays from the Mark III collaboration are presented in this brief summary. Many are new and preliminary. The topics include a study of iota/E decays in the channels $J/\Psi \to \gamma\eta\pi\pi$ and $\gamma\gamma\rho$, a study of two pseudoscalar decays to search for scalar decays in the channels $J/\Psi \to \gamma\pi\pi$ and γKK and a study of the two vector decays in the channel $J/\Psi \to \gamma K^* K^*$. Background material for these topics can be found elsewhere.[1]

1.1 Study of $J/\Psi \to \gamma\eta\pi\pi$

The iota or η(1440), seen in $J/\Psi \to \gamma KK\pi$, is a leading glueball candidate. It has a large branching ratio, it appears to be pseudoscalar, it has not been seen in $\gamma\gamma$ production and possibly it is the same state seen in $\pi^- p$ production from MPS group at BNL.[2] Among the states that have been seen in this mass region in hadronic and J/Ψ production are the $D/f_1(1285)$, η(1275), iota/η(1440), $E/f_1(1420)$, and $D'/f_1(1530)$. In this paper we will call the 1.38-1.45 GeV mass region the "E" region and the 1.25-1.38 GeV area the "D" region.

The mode $J/\Psi \to \gamma\eta\pi\pi$ is important because if iota→δπ as published by the Crystal Ball group, it should be seen in ηππ since δ→ηπ.[3] There are however models developed to predict a low mass KK enhancement but no δ decay.[4] The Mark III analysis of this mode begins with a 5-C constraint fit to $J/\Psi \to \gamma\gamma\gamma\pi\pi$ and $\eta \to \gamma\gamma$. The raw ηππ spectrum has a complex structure. A very clear δ→ηπ signal is seen in the quasi-two body decays. After cutting on the δ signal, $.93 < m(\eta\pi) < 1.03$ GeV, structures at the "E" region with $m = 1382 \pm 6$ and $\Gamma = 69 \pm 23$ MeV and in the "D" region but there appears to be no evidence for the iota/E at 1440 MeV.[5-7] This is shown in Figure 1. The branching ratios for these two peaks are

$$B(J/\Psi \to \gamma\text{"E"})\,B(\text{"E"} \to \delta\pi)\,B(\delta \to \eta\pi) =$$

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$$(5.2 \pm 1.2 \pm .5) \times 10^{-4}$$

$$B(J/\Psi \to \gamma \text{“}D\text{”})\, B(\text{“}D\text{”} \to \delta\pi)\, B(\delta \to \eta\pi) =$$
$$(2.7 \pm .8 \pm .2) \times 10^{-4}$$

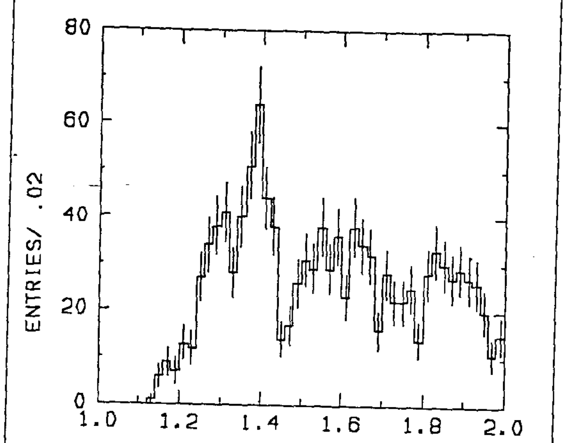


Fig. 1

We can determine the spin using isobar spin-parity tests. For spin 0 the matrix elements are

$$\text{p. s.} + |A^{j=0}(\varepsilon\eta) + A^{j=0}(\delta\pi)|^2$$

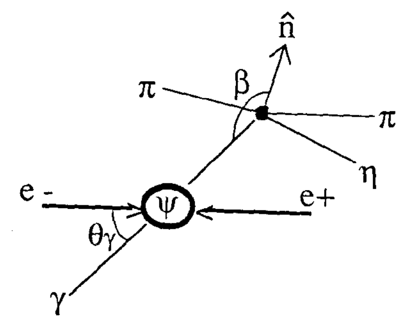
and for the spin 1 case,

$$\text{p.s.} + |A^{j=0}(\varepsilon\eta) + A^{j=1}(\delta\pi, m=0) + A^{j=1}(\delta\pi, m=1)|^2$$

where p.s. is the phase space contribution and the $\varepsilon\eta$ and $\delta\pi$ are the isobars. The angular distributions for these cases are shown in the following chart;

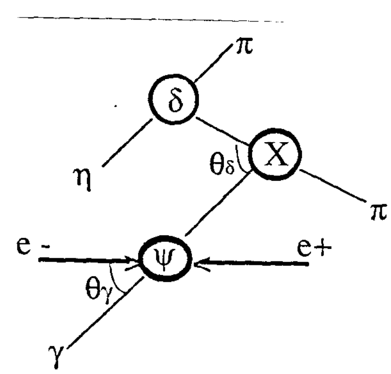
hypothesis	θ_γ	θ_δ	β
spin 0	$1+\cos^2\theta$	flat	flat
spin 1 (m=0)	$1+\cos^2\theta$	$\cos^2\theta$	$\sin^2\beta$
spin 1 (m=1)	$\sin^2\theta$	$\sin^2\theta$	$1+\cos^2\beta$

The decays angles are shown for the angle β in Figure 2 and for the isobar angle in Figure 3. Applying a maximum likelihood test on the lower mass region, 1.26-1.30 GeV, yields a preference of $J^{PC}=1^{++}$ over $J^{PC}=0^{-+}$ by 3.3 σ and the upper mass region, 1.37-1.41 GeV, prefers 0^{-+} by 3.8 σ.



DECAY PLANE NORMAL β

Fig. 2



ISOBAR ANGLE θδ

Fig. 3

1.2 Study of $J/\Psi \to \gamma\gamma\rho^\circ$

The study of the reaction $J/\Psi \to \gamma\gamma\rho^\circ$ is of great interest to find a radiative decay of the iota/E. If the decay is found then this would provide evidence for quark content in the iota/E. A signal in the iota/E region has been previously seen in the Mark III[8], Crystal Ball[9] and DM2 groups.[10] In this new result from Mark III a spin-parity analysis is done. This analysis begins with a fit to $J/\Psi \to \gamma\gamma\pi^+\pi^-$ with the photons near the pions removed. In addition cuts are applied to remove the $J/\Psi \to \rho\pi$ and ωf backgrounds that feed into this channel. A clear $\rho^\circ \to \pi^+\pi^-$ is observed in a scatter plot against structures in the "E" and "D" regions of the $\gamma\pi^+\pi^-$ masses as shown in Figure 4.

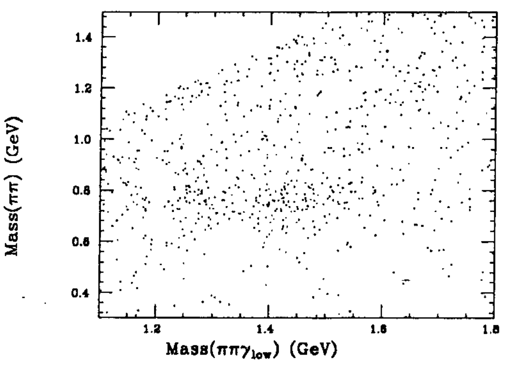


Fig. 4

Cutting on the $\gamma\rho^\circ$ masses, $0.6 < m(\gamma\pi^+\pi^-) < 0.9$ GeV yields two separated structures shown in Figure 5.

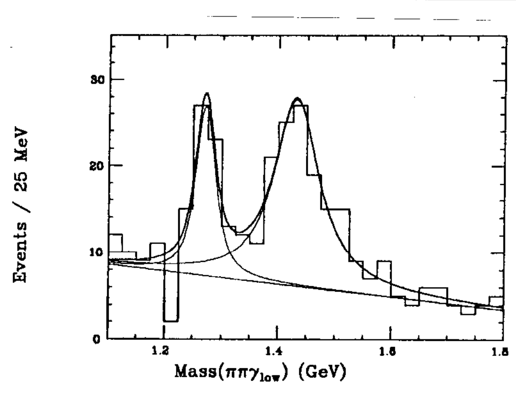


Fig. 5

The masses and widths are m=1271±7 and Γ=31±14 MeV and m=1432±8 and Γ=90±26 MeV and the branching ratios are

$$B(J/\Psi \to \gamma\text{"E"})\,B(\text{"E"} \to \gamma\rho^\circ) =$$

$$(.25 \pm .07 \pm .03) \times 10^{-4}$$

$$B(J/\Psi \to \gamma\text{"D"})\,B(\text{"D"} \to \gamma\rho^\circ) =$$

$$(.64 \pm .12 \pm .07) \times 10^{-4}$$

A spin parity test has been applied to these regions, 1.2-1.35 and 1.35-1.6 GeV. The lower mass region prefers $J^{PC} = 1^{++}$ by 3.9 σ and the upper mass region prefers $J^{PC} = 0^{-+}$ by 2.0 σ.

1.3 Discussion

In the "D" region, both DM2 and Mark III groups have observed a peak in the mode $J/\to \gamma\pi\pi\pi\pi$. Using the particle data tables values, this predicts that the observed $\delta\pi$ rate is too big by a factor 3. Possibly the $\eta(1275)$ is underneath or the PDT values are too small. Future analysis will attempt to separate out the 0^- and 1^+ components. In addition the $D \to \gamma\rho^\circ$ rate is much larger than prediction in a model by Rosner.[11] Again in this case the $\eta(1275)$ may be contributing.

In the "E" region the $\eta\pi\pi$ peak is well below the iota/ $\eta(1440)$ or $E/f_1(1420)$. A KEK experiment[12] observed a similiar peak in $\pi^- p \to \eta\pi\pi n$ at 1390±10 MeV and their signal has been found to be 0^{-+}. The $\gamma\rho^\circ$ signal has a mass and width consistent with the and the spin-parity prefers 0^{-+} but the significance is meager.

2. Study of $J/\Psi \to \gamma\pi\pi$ and γKK

The lowest lying scalar glueball has been predicted by Lattice Gauge Theories to be near 1 GeV. A search for a narrow and broad peak in the mass spectrum in the mode $J/\Psi \to \gamma\pi\pi$ has been performed.[13] The search for a narrow peak in the raw mass distributions yields upper limits of,

$$B(J/\Psi \to \gamma X)B(X \to \pi^+\pi^-) < 2.1\times10^{-5}$$
at 90% CL

$$B(J/\Psi \to \gamma f_0(975)) < 1.4\times10^{-5}$$
at 90% CL

The search for a broad scalar $\pi\pi$ resonance in the ρ° region (.5-.9 GeV) has been performed using a moments analysis. The upper limit is obtained by using the 00 moments after a subtraction of the ρ° background and this is shown in Figure 6

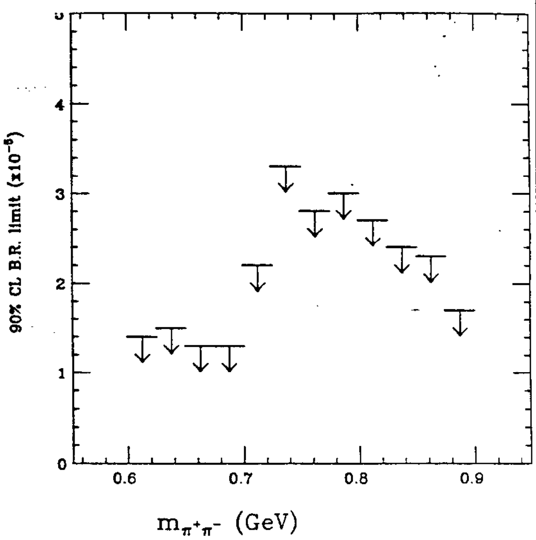


Fig. 6

and yields an upper limit of

$$B(J/\Psi \to \gamma X)B(X \to \pi^+\pi^-) < 3\times10^{-5}$$
at 90% CL

There is however evidence for scalar production near threshold in $J/\Psi \to \gamma\pi^+\pi^-$, γK^+K^- and $\gamma K_S K_S$. The pseudoscalar pairs are produced in an s-wave. The mass distribution for the $\bar{K}K$ modes near threshold is shown in the following Figure 7. The mass distributions are flat and featureless. The $\pi\pi$ rate in the .3-.5 GeV region is

$$B(J/\Psi \to \gamma\pi^+\pi^-) = (4.7\pm.5\pm.6)\times10^{-5}$$

and in the KK region 1.1-1.4 GeV, there is a rate of

$$B(J/\Psi \to \gamma K^+K^-) = (1.7\pm.1)\times10^{-4}$$

$$B(J/\Psi \to \gamma K_S K_S) = (1.7\pm.3)\times10^{-4}$$

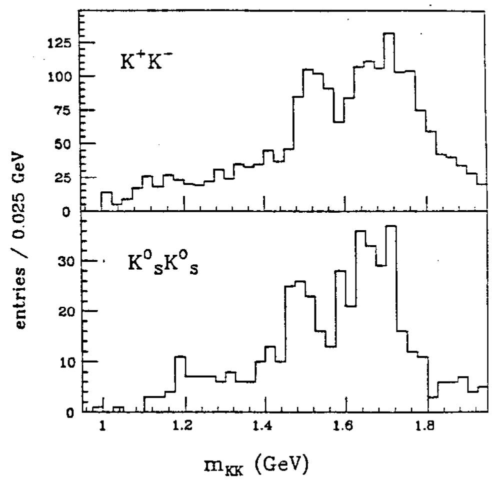


Fig. 7

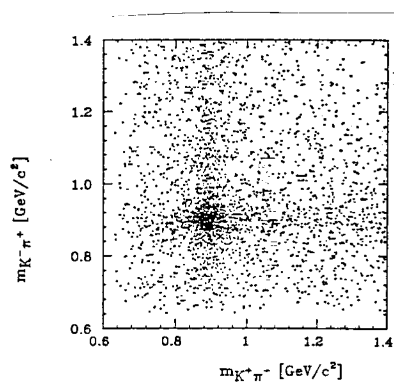


Fig. 8

3. Study of $J/\Psi \to \gamma$+two vectors

The radiative decays to two vectors has been extensively studied by the Mark III and DM2 groups. Originally the decays into $\rho^\circ\rho^\circ$, $\rho^+\rho^-$ and $\omega\omega$ were seen with a large structure near threshold.[14-16] This search was extended to $\phi\phi$[17] and now as shown in this paper to $\bar{K}^{o*} K^{o*}$. All of the modes have been measured to be pseudoscalar. This is unexpected as the vectors must be in a p-wave to have negative parity. One of the motivations was to search for the g_T tensor glueball candidates from BNL.[18] Not observing tensor $\phi\phi$ decays in radiative J/Ψ decays would tend to cast doubt on a glueball interpretation for the g_T. One suggestion has been that these are part of a large and broad pseudoscalar multichannel resonance that includes the iota.[19]

The $\bar{K}^{o*} K^{o*}$ analysis begins with a 4-C fit to $J/\Psi \to \gamma K^+ \pi^- K^- \pi^+$. The quasi-two body masses of the $K\pi$ pairs show a definite peak of radiative decays to two K^{*o} as shown in the scatter plot in Figure 8. The radiative $\bar{K}^{o*} K^{o*}$ events are further selected by requiring the $K\pi$ masses to be near the $K^{*o}(890)$ mass. The resulting $\bar{K}^{o*} K^{o*}$ mass distribution is shown in the following mass plot in Figure 9.

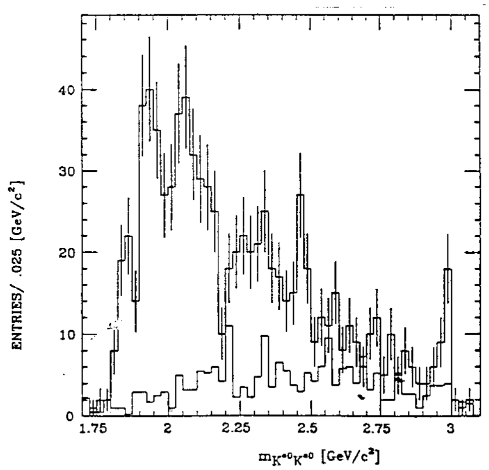


Fig. 9

The lower mass threshold enhancement has been spin-parity analyzed with the chi angle distribution and is found to be pseudoscalar.[20] We now have observed the radiative decays to all pairs of vectors $\rho\rho$, $\omega\omega$, $\phi\phi$ and $K^* \bar{K}^*$. They all have an enhancement near threshold and they appear to all pseudoscalar.

4. Summary

The results shown in this report demonstrate that the physics is still very much in flux. The iota/E region still has many surprises. There appear to be more resonances or structures than predicted. The lack of scalars is also very puzzling. The basic prediction Lattice Gauge Theories of the lowest lying s-wave gluon pair resonance so far has not been verified in J/ψ radiative decays. The observation of pseudoscalar resonances near threshold from two vectors in radiative decays is also unexpected and as yet does not have any compelling reason.

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