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J/ψ Radiative Decay to Two Pseudoscalar Mesons from Mark III [1]

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Abstract. The results of amplitude analyses of the Mark III data on the $K_s^0 K_s^0$, K^+K^- and $\pi^+\pi^-$ systems produced in J/ψ radiative decay are shown for the mass range 1 - 2 GeV. The intensity distributions for the amplitudes having J^{PC} values 0^{++} and 2^{++} are presented and discussed. The observed strong production of the $f_0(1700)$ in J/ψ radiative decay suggests that this state may consist primarily of the lightest scalar glueball state. No significant production of spin 2 is observed in the 1.7 GeV mass region.

INTRODUCTION

The radiative decay of the J/ψ to a hadronic final state is believed to proceed via an intermediate state consisting of two gluons. Such gluonic states are expected to give rise to a rich isoscalar meson spectroscopy, and Lattice Gauge Theory calculations predict, in particular, that the lowest-lying such state should occur in the mass range 1.4-1.8 GeV, and have $J^{PC} = 0^{++}$. If the hadronic final state consists of two pseudoscalar mesons, only J^{PC} values in the series 0^{++}, 2^{++}, ... are possible, and it follows that such states provide a very clean, if low statistics (to date), laboratory in which to search for the lowest mass scalar glueball. One difficulty is that this state is expected to mix with the $q\overline{q}$ ground state isospin zero scalar mesons, so that, even if a signal is obtained, its interpretation in terms of gluonium spectroscopy may not be straightforward.

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The present analysis summarizes and updates results which have been shown previously [1–3].

DATA AND AMPLITUDE ANALYSES

The Mark III data sample contains 5.8 x $10^6 J/\psi$ events. Analysis samples corresponding to radiative decay to $K_s^0 K_s^0$, K^+K^- and $\pi^+\pi^-$ contain 582, 1755 and 12212 evnts, respectively; the $\pi^+\pi^-$ sample is corrected for feedthrough from the $\pi^+\pi^-\pi^0$ final state [2]. Each data sample is analyzed independently in each mass interval in terms of the joint production and decay angular distribution of the pseudoscalar meson system. These analyses are confined to masses less than 2 GeV in order that a description in terms of only 0^{++} and 2^{++} amplitudes be appropriate.

The angular correlations are expressed in terms of moments, and the measured moments are corrected for acceptance losses by means of a model-independent Monte Carlo procedure [1–3]. The acceptance- and isospin- corrected $K\overline{K}$ ($K_s^0 K_s^0$ and K^+K^- combined) and $\pi\pi$ mass distributions are shown in Figs.1(a) and 1(b) respectively. The $K\overline{K}$ distribution shows a peak at the $f_2'(1525)$, a second peak at $\sim$ 1.7 GeV, and a shoulder at 1.25-1.45 GeV; the $\pi\pi$ distribution has a peak at the $f_2(1270)$, a shoulder at $\sim$ 1.4 GeV, and a small bump at $\sim$ 1.7 GeV.

In each mass interval, the 10 measured moments are expressed as quadratic functions of the complex amplitudes $a_{0,0}$, $a_{2,0}$, $a_{2,1}$ and $a_{2,2}$ (i.e. 7 parameters, since e.g. $a_{2,0}$ may be chosen real), where the first subscript represents angular momentum, and the second helicity. The program MINUIT is used to search for all possible solutions, where a solution corresponds to a fit to the data with confidence level greater than 0.01; error estimates are obtained using MINOS, and in an interval

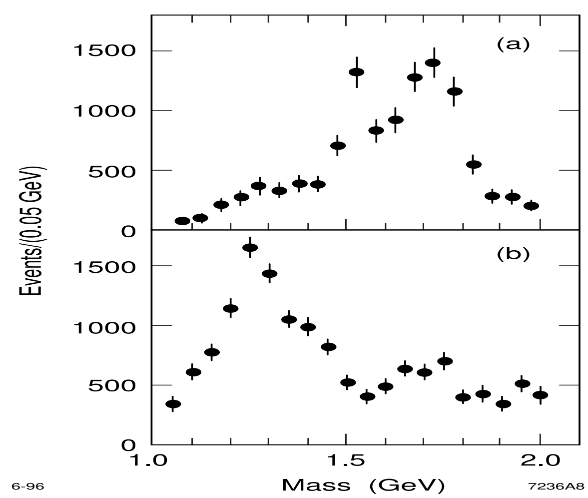

FIGURE 1. (a) The $K\overline{K}$ and, (b), $\pi\pi$ mass distributions from J/ψ radiative decay after all acceptance and isospin corrections.

with more than one solution, the solutions are averaged and errors corresponding to the extrema of the individual errors are assigned.

In the past there has been some question as to the need for a significant S-wave amplitude (i.e. $a_{0,0}$) in order to describe the data. This issue tends to be further clouded due to the possibility of solution ambiguities. It is not possible to simply calculate the S-wave intensity from the measured moments. However, the moments can be combined to isolate the quantity $|a_{0,0}|^2 + \sqrt{5}\ \mathrm{Re}(a_{0,0}\ a^*_{2,0})$, which is zero if there is no S-wave. This quantity is plotted in Fig. 2, and is clearly large near 1.7 GeV for $K\overline{K}$, and in the range 1.4-1.8 GeV for $\pi\pi$. The need for significant S-wave in these regions is unambiguously demonstrated.

DISCUSSION OF THE RESULTS

The D- and S-wave intensity distributions resulting from the analyses are shown as a function of mass in Figs. 3 and 4 respectively. It should be noted that the results for $K^0_s K^0_s$ and K^+K^- were obtained independently, but that in the fits represented by the curves, the fit normalization was constrained to be the same in order to test the consistency of the analyses.

The D-wave distributions show clear signals corresponding to the $f_2'(1525)$ in $K\overline{K}$ and the $f_2(1270)$ in $\pi\pi$. The curves represent fits to squared Breit-Wigner (BW) amplitudes using PDG mass and width values [4]. There is no evidence for significant structure in the vicinity of 1.7 GeV, although, within the present uncertainties, the existence of small contributions cannot be excluded. The branching

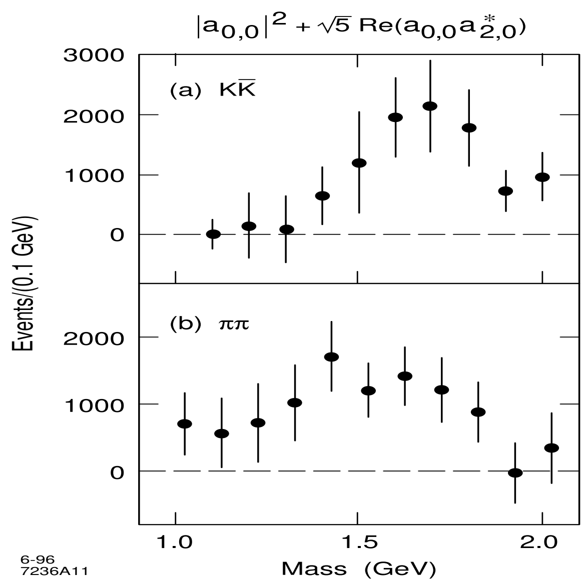

FIGURE 2. The mass dependence of the moments combination whose value is zero in the absence of any S-wave contribution (a), for $K\overline{K}$ and, (b), for $\pi\pi$.

fractions (b.f.s) for J/ψ radiative decay to $f_2'(1525)$ and to $f_2(1270)$ are found to be (4.0 ± 0.8) x 10^{-4} and (15.6 ± 1.4) x 10^{-4} respectively.

Both S-wave $K\overline{K}$ distributions exhibit a large signal at ~ 1.7 GeV, and there is also evidence of a much smaller bump at ~ 1.4 GeV. In contrast, the $\pi\pi$ distribution

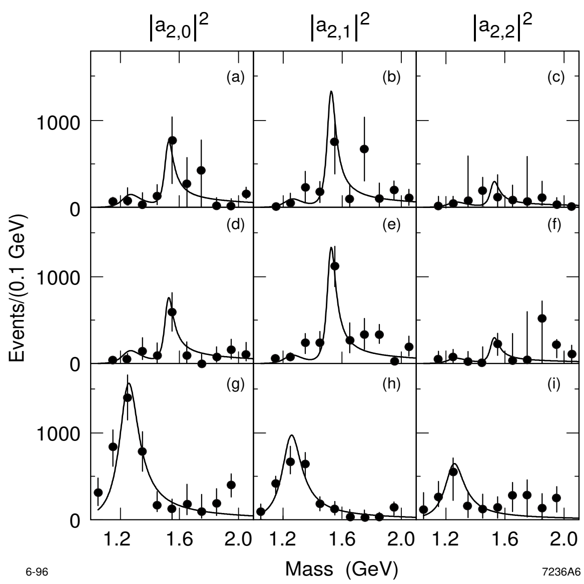

FIGURE 3. The mass dependence of the D-wave intensity for $K\overline{K}$ ((a)-(c) from $K_s^0K_s^0$, (d)-(f) from K^+K^-) and, (g)-(i), for $\pi\pi$; the curves are described in the text.

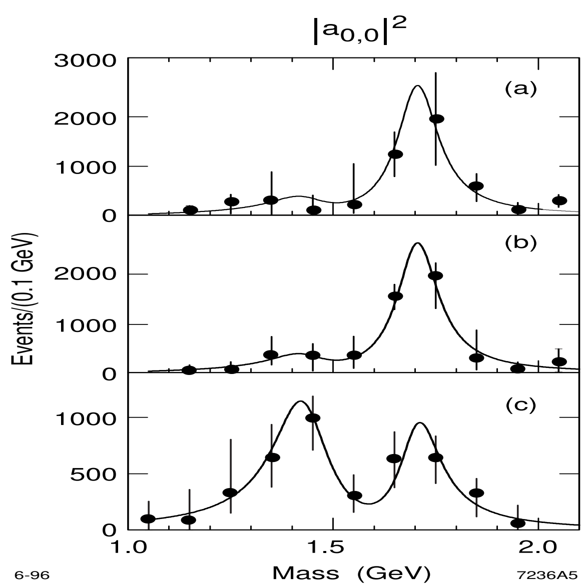

FIGURE 4. The mass dependence of the S-wave intensity for $K\overline{K}$ ((a) from $K_s^0K_s^0$, (b) from K^+K^-) and, (c), for $\pi\pi$; the curves are described in the text.

shows a very large signal at ~ 1.4 GeV, and in addition a significant signal at ~ 1.7 GeV. The curves result from the simultaneous fit of the square of the superposition of two coherent BW amplitudes to the data; the mass and width values are required to be the same in all three distributions, and the fitted relative phase is ~ 0 degrees. The mass and width of the lower mass state are 1429 $^{+43}_{-37}$ and 169 $^{+111}_{-76}$ MeV, the $K\overline{K}$ to $\pi\pi$ branching ratio (b.r.) is 0.149 $^{+0.215}_{-0.133}$, and the b.f. for J/ψ radiative decay to the combined modes is (4.3 $^{+2.7}_{-1.7}$) x 10^{-4}. For the higher mass state, the mass and width are 1704 $^{+16}_{-23}$ and 124 $^{+52}_{-44}$ MeV, the $\pi\pi$ to $K\overline{K}$ b.r. is 0.268 $^{+0.169}_{-0.120}$, and the b.f. for J/ψ radiative decay to the combined modes is (9.5 $^{+2.5}_{-2.0}$) x 10^{-4}. To the extent that both states appear to couple to $\pi\pi$, they are both isoscalar.

The mass, width and b.r. of the lower mass state agree very well with those obtained in an analysis of $\pi\pi$ scattering to the $K\overline{K}$ final state [5], with the signals observed in D_s decay to three pions in E791 [6], and in the $\pi\pi$ system recoiling against the $\phi(1020)$ in J/ψ decay [7]. It seems reasonable to interpret this state as being mainly the $n\overline{n}$ isoscalar $J^{PC} = 0^{++}$ ground state, since none of these production contexts is expected to be rich in gluon pairs.

The higher mass state does not appear to have significant $s\overline{s}$ content, since it is not observed in an $s\overline{s}$ rich fixed target context [8] , nor in the K^+K^- system recoiling against the $\phi(1020)$ in J/ψ decay [7]. It is clearly observed when this system recoils against the $\omega(782)$ [7], and it is claimed that such a state is also produced in an $n\overline{n}$ rich fixed target experiment [9]. This suggests that it has significant $n\overline{n}$ content; however, its dominant production in the gluon rich context of J/ψ radiative decay suggests that it is composed primarily of the lowest mass scalar gluonium state. That it is observed to have a rather small $\pi\pi$ to $K\overline{K}$ branching ratio may be due to its decaying preferentially to four pions [10]; the $K\overline{K}$ mode could be due mainly to an initial $n\overline{n}$ configuration dressing itself with an $s\overline{s}$ pair, as is the case in e.g. the decay of the $f_2(1270)$.

In summary, it is conjectured that:

- the $f_0(1430)$ observed in this experiment consists mainly of the $n\overline{n}$ ground state, with some significant admixture of the scalar gluonium ground state in order to account for its high mass relative to the $f_2(1270)$;

- the $f_0(1700)$ has very little $s\overline{s}$ content, has significant $n\overline{n}$ content, but consists mainly of the scalar gluonium ground state.

REFERENCES

1. L.-P. Chen et al.,*Nucl. Phys.* **B21**, *Proc. Suppl.*, 80 (1990); *SLAC-PUB-5378* (1990).
2. L.-P. Chen et al., *SLAC-PUB-5669* (1991).
3. L.-P. Chen, *Ph.D Thesis*, Vanderbilt Univ. (1991); *SLAC-Report-386* (1991).
4. R. M Barnett et al., *Phys. Rev.* **D54**, 1 (1991).
5. D. Cohen et al., *Phys. Rev.* **D22**, 2595 (1980).
6. M. Sokoloff, private communication.

7. U. Mallik, *SLAC-PUB-3946* (1986).
8. D. Aston et al., *Nucl. Phys.* **B301**, 525 (1988).
9. A. Etkin et al., *Phys. Rev.* **D25**, 1786 (1982).
10. D. Bugg et al., *Phys. Lett.* **B353**, 378 (1995).