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GLUEBALL CANDIDATES

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ABSTRACT

Glueball candidates are reviewed. So far, candidates have been reported in $J^{PC} = 0^{++}$, 2^{++} and 0^{-+} but none in the exotic J^{PC} such as 1^{-+}.

I. INTRODUCTION

With introduction of the gluon degree of freedom in the hadron spectroscopy, it is becoming increasingly urgent that one searches for the expected gluon bound states in meson spectra. This review covers those states which can be interpreted as being glueballs, colorless and flavorless bound states with two or more gluons, produced in hadron-hadron collisions and in J/ψ radiative decays.

In order to give a framework for the order of presentations in this review, we follow the glueball spectrum resulting from the MIT bag model.[1] The first three lowest energy solutions for the gluons confined to a spherical cavity are the two TE (transverse electric modes TE_1 and TE_2 with $J^P = 1+$ and 2^-, followed by a TM (transverse magnetic) mode TM_1 with $J^P = 1^-$. Thus, two-gluon bound states resulting from these eigenmodes are $TE_1 \times TE_1$ ground states with $J^{PC} = (0, 2)^{++}$ and the first excited states $TE_1 \times TE_2$ with $J^{PC} = (1, 2, 3)^{-+}$ and $TE_1 \times TM_1$ with $J^{PC} = (0, 1, 2)^{-+}$.

So far, candidate states have been reported in $J^{PC} = 0^{++}$, 2^{++} and 0^{-+}, but none claimed in the remaining J^{PC}. Note, in particular, that the states with $J^{PC} = 1^{-+}$ and 3^{-+} have no $q\bar{q}$ mixing, making them unambiguous candidates for glueballs, if they should exist.

In sections II, III and IV are covered hadroproduced glueball candidates in $J^{PC} = 0^{++}$, 2^{++} and 0^{-+} states. Section V is reserved for possible glueball states seen in the J/ψ radiative decays. Section VI contains concluding remarks and acknowledgements.

II. CANDIDATES WITH $J^{PC} = 0^{++}$

Here one may cite three different experiments with data on possible 0^{++} glueballs.

In an amplitude analysis for K_SK_S system from the BNL data $\pi^-p \to K_SK_Sn$ at 23 GeV/c, A. Etkin, et al.[2] present evidence for a new state $g_S(1240)$ below the ε. Fig. 1 shows their I = 0 S-wave intensity, in which two states g_S and ε are clearly required to fit the data (a 7σ effect).

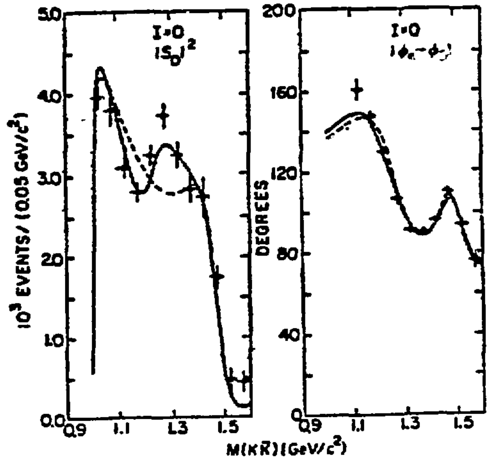


Fig. 1. I = 0 S-wave intensity and its phase difference from the D-wave (Ref. 2). The solid (dashed) curve shows the fit with (without) the g_S.

The fitted values for mass/width are (1240 ± 10)/(140 ± 10) MeV for g_S and (1470 ± 10)/(140 ± 10) MeV for ε. Together with the I = 0

$S^{*\prime}(1770)$ and $I = 1$ $\delta'(1400)$ also seen in the same experiment[3] and the $\kappa(1500)$, one has in fact ten 0^{++} members indicating a glueball mixing in the 0^{++} nonet. Based on a study of SU(3) mass assignments, one may surmise that the $g_S(1240)$ can be assigned the role of a glueball with the least amount of $q\bar{q}$ mixing.

The second experiment reporting a possible 0^{++} glueball is that of the GAMS-2000 Spectrometer at Serpukhov on the reaction $\pi^- p \to \eta\eta n$ at 38 GeV/c.[4] In a partial-wave analysis of the $\eta\eta$ system up to 1.9 GeV, they observe a structure in the S-wave intensity near 1600 MeV. They find for mass/width (1592 ± 25)/(210 ± 40) MeV (see Fig. 2).

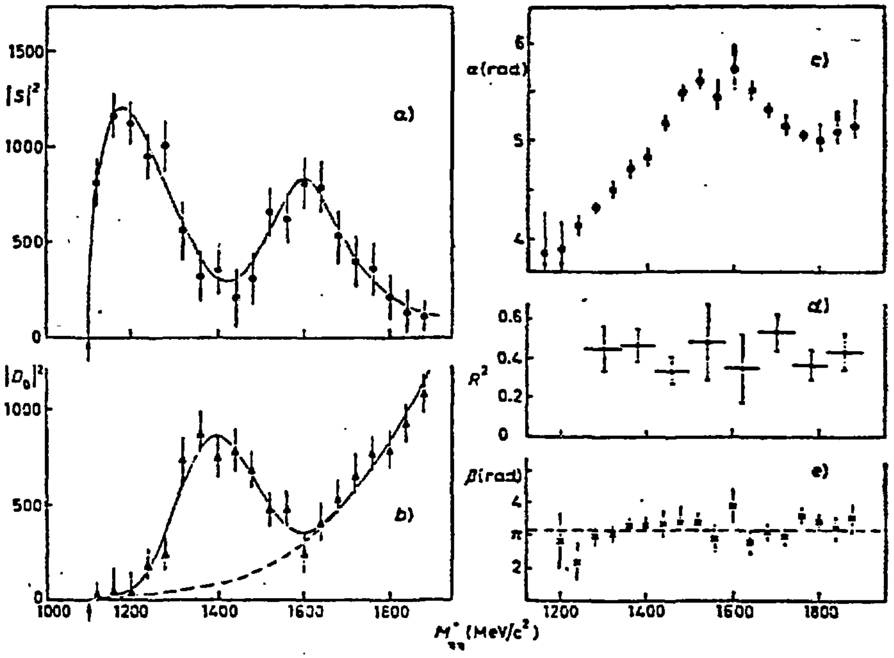


Fig. 2 (a,b) the S- and D-wave intensity and (c) the relative phase (see Ref. 4).

Since this state is not seen in $\pi^0\pi^0$ nor $K\bar{K}$, they argue that it is unlikely to be a $q\bar{q}$ or $q\bar{q}q\bar{q}$ state; hence a possible 0^{++} glueball candidate.

Finally, two recent CERN ISR experiments obtained results on $pp \to pp\pi^+\pi^-$ at $\sqrt{s} = 63$ GeV in the double-Pomeron exchange region. The data of the Axial-Field Spectrometer (AFS)[5] shows remarkable bump-dip structures in the $\pi^+\pi^-$ mass spectrum up to 2.6 GeV (see Fig. 3).

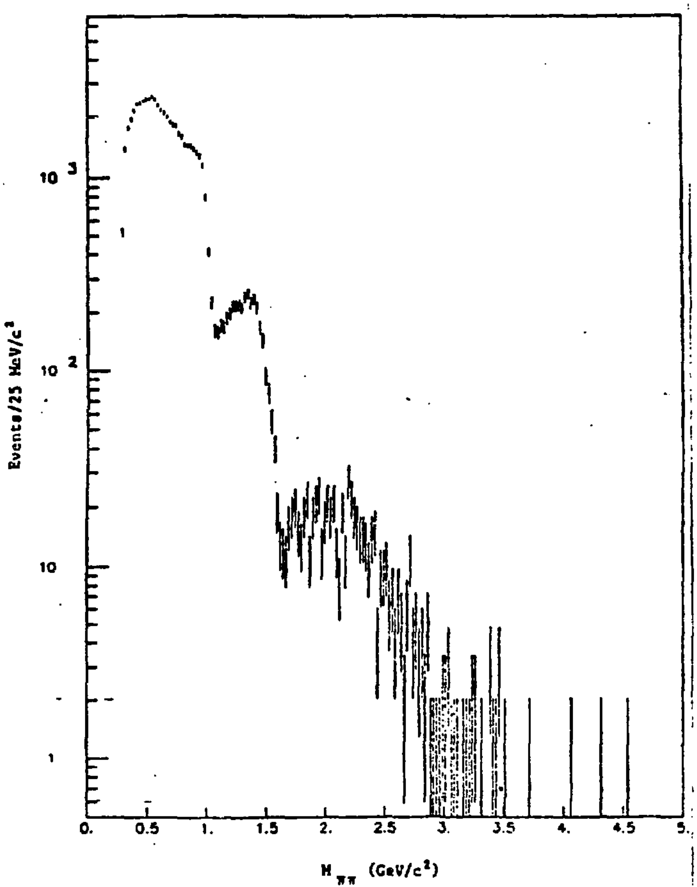


Fig. 3. $\pi\pi$ mass spectrum for $pp \to pp\,\pi^+\pi^-$ ($\approx$55,000 events at $\sqrt{s}$ = 63 GeV (Ref. 5).

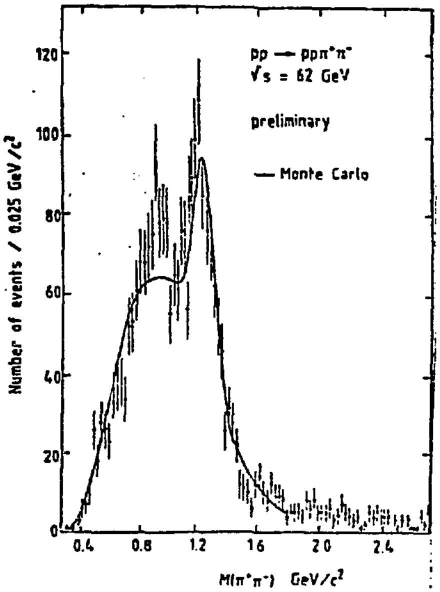


Fig. 4. $\pi\pi$ mass spectrum as in Fig. 3 but from Ref. 7.

A moment analysis shows that the region is mostly dominated by S-wave and no apparent bump at the f(1270) mass. It is known that the $\pi\pi$ structures up to 1.0 GeV (including the sharp dip at 1.0 GeV) can be deduced from the $\pi\pi$ elastic scattering amplitudes;[6] however, to the extent that the structures observed are from the quarkless double-Pomeron process, any of the bump-dip behavior may signal presence of 0^{++} glueballs. For further progress in this channel, one must await acceptance-corrected moments and a phase-shift analysis on the double-Pomeron process.

The data of the Split-field Magnet Spectrometer (SFM) at the same energy show, on the other hand, somewhat different $\pi\pi$ structures.[7] In particular, a prominent f(1270) is seen, as shown in Fig. 4. It should be noted, however, that the t range for the final protons are different; the AFS data are limited to $|t| \leq 0.05$ $(\mathrm{GeV}/c)^2$, while the SFM experiment is confined to $|t| > 0.1$ $(\mathrm{GeV}/c)^2$. One may speculate that the SFM data have a substantial contribution from the π-exchange process.

III. 2^{++} CANDIDATES

A number of experiments on $K\bar{K}$ system have observed a D-wave structure in the region between f(1270) and f'(1520), which cannot be explained by $A_2(1310)$ alone. The ACCMOR collaboration at the CERN SPS pointed out recently that a new state at $\approx$1410 MeV with a width 10-35 MeV is needed to explain their data[8] on the reaction $\pi^- p \to K_S K_S n$ at 63 GeV/c (see Fig. 5). In addition, the data of CERN-CRACOW-Munich collaboration[9] on $\pi^- p \to K\bar{K}n$ at 18 GeV/c show a D-wave structure with mass/width at $(1436^{+26}_{-16})/(81^{+51}_{-29})$ MeV. Finally, the BNL data of A. Etkin, et al.,[3] which represent the highest statistics for this reaction, also show a structure at 1450 MeV in the L = 4 moment. Such a state, being an additional member of the already-filled 2^{++} nonet, may very well be the glueball $f_T(1440)$ speculated previously by J.L. Rosner.[10]

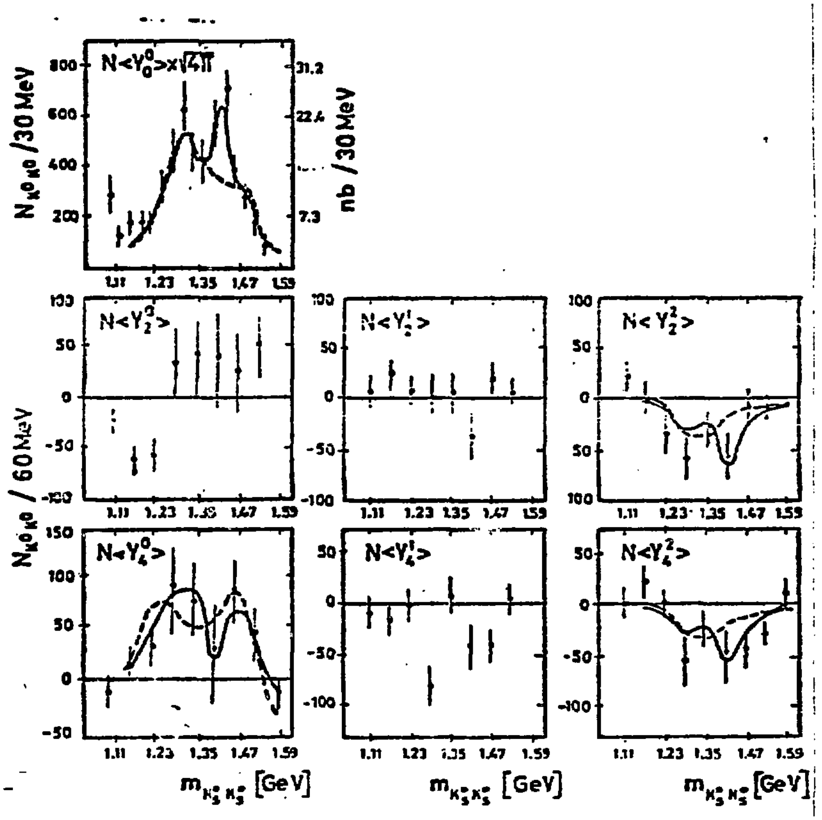


Fig. 5. Unnormalized t-channel moments (Ref. 8). The curve represents a fit with (without) f_T.

More persuasive candidates for 2^{++} glueballs come from a BNL multiparticle Spectrometer (MPS) experiment on the reaction $\pi^- p \rightarrow \phi\phi n$ at 22 GeV/c. Since a $\phi\phi$ system represents two pairs of $s\bar{s}$ and no s of $\bar{s}$ in the initial state, the only reasonable way to produce it has to involve two (or more) gluon mediations. Hence, the $\phi\phi$ system should be particularly rich in glueballs. They find from a partial-wave analysis[11] that the $\phi\phi$ system up to 2.6 GeV is dominated by a 2^{++} wave, but that its decomposition into L (orbital angular momentum) and S (total intrinsic spin) shows complex mass dependence, as shown in Fig. 6.

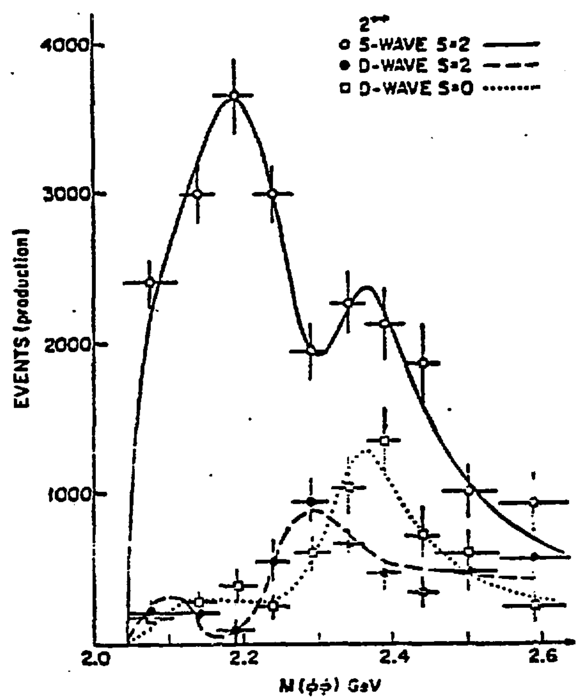


Fig. 6. Intensities for the partial waves with (L = 0, S = 2), (L = 2, S = 2) and (L = 2, S = 0) as solid, dashed and dotted curves, respectively (Ref. 11).

From a K-matrix analysis of partial waves, they deduce three 2^{++} resonances (denoted g_T) with mass/width at $(2120^{+20}_{-120})/(300^{+150}_{-50})$, $(2220^{+90}_{-20})/(200 \pm 50)$ and $(2360 \pm 20)/(150^{+150}_{-50})$ MeV.

If one accepts that the apparent violation of the OZI rule is due to resonances in two or more gluons, then one must regard these states as premier candidates for 2^{++} glueballs.

IV. 0^{-+} CANDIDATES

A possible 0^{-+} glueball called the i(1440) has been seen in the J/ψ radiative decay into a $K\bar{K}\pi$ system,[12] a channel considered the most likely source for hard-gluon productions (see next section). However, if one accepts the view that most if not all glueballs are mixed with ordinary $q\bar{q}$ states, such a state produced in a hadron-hadron collision is just as good a source for study of the glueball (but mixed $q\bar{q}$) as the J/ψ decay.

The E(1420) with $J^{PC} = 0^{-+}$ decaying into both K^*K and $\delta(1980)\pi$ has first been observed by P. Baillon, et al.[13] in the reaction $\bar{p}p$ (at rest) $\to E\pi\pi$. Subsequently, the E(1420) was seen in the reaction $\pi^- p \to En$ at 4 GeV/c and was found to be a $J^{PC} = 1^{++}$ state[14] decaying mostly to K^*K. In addition, a recent J^P analysis[15] on the centrally produced E in the reaction (π^+ or p)p $\to$ (π^+ or p)Ep at 85 GeV/c finds again a $J^{PC} = 1^{++}$ object at the E mass (see Fig. 7) with mass/width at (1425 ± 2)/(65 ± 5) MeV.

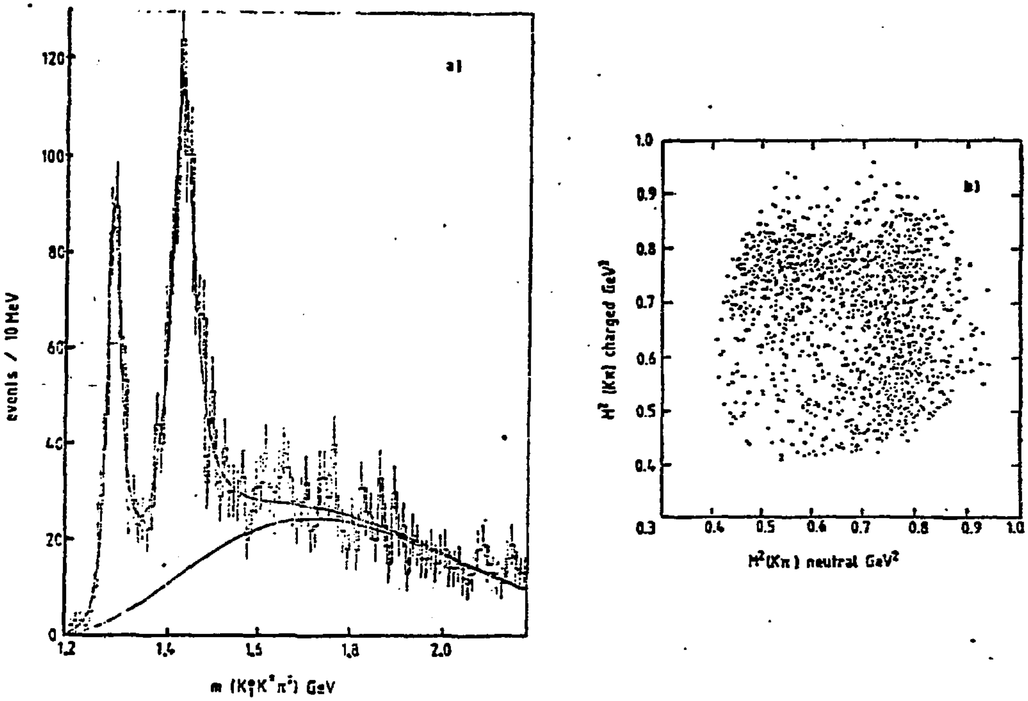


Fig. 7 (a,b) $K\bar{K}\pi$ mass spectrum and the Dalitz plot for $1.37 < M(K\bar{K}\pi) < 1.49$ GeV (Ref. 15).

It appears, therefore, that there exist indeed two states at the E/i mass with J^{PC} of 0^{-+} and 1^{++}. However, one needs to be cautious since the i spin-parity is determined on data with limited statistics and the E analysis on $\pi^- p$ data were limited to Dalitz-plot fits. Until further work is done, which includes the three production-angular correlations in the fit, one must reserve judgment on concluding that there exist two states with $J^P = 0^{-+}$ and 1^{++} at the E/i region. In particular, it is not at all clear that for the data with the central E's a fit of the E region with a single 1^{++} state and a flat background (≈34%) is adequate for an acceptable fit; for a pure 1^{++} state decaying into K^*K the density in the K^* region should increase fourfold in the region of two K^* overlap, and if the 1^{++} state accounts for 66% of the E region one must see the effect in the Dalitz plot! As seen in Fig. 7b, the K^* density seems constant throughout including the overlap region.

New data from a BNL MPS experiment[16] became available recently on the reactions $\pi^- p \rightarrow En$ at 8.0 GeV/c and $\bar{p}p \rightarrow E\ X^\bullet$ at 6.6 GeV/c. The $KK\pi$ mass spectra, with the prominent D and E peaks, are shown in Fig. 8.

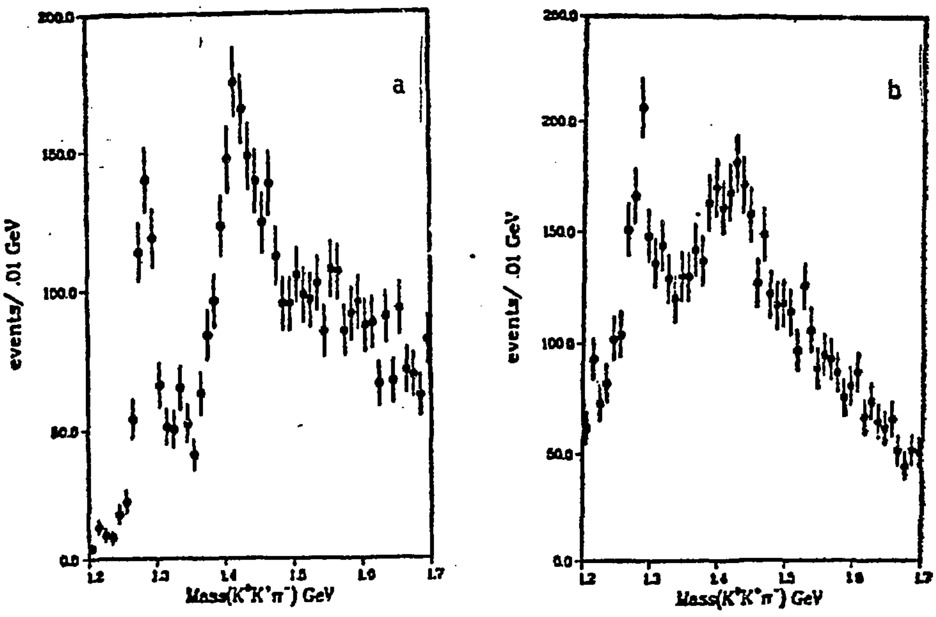
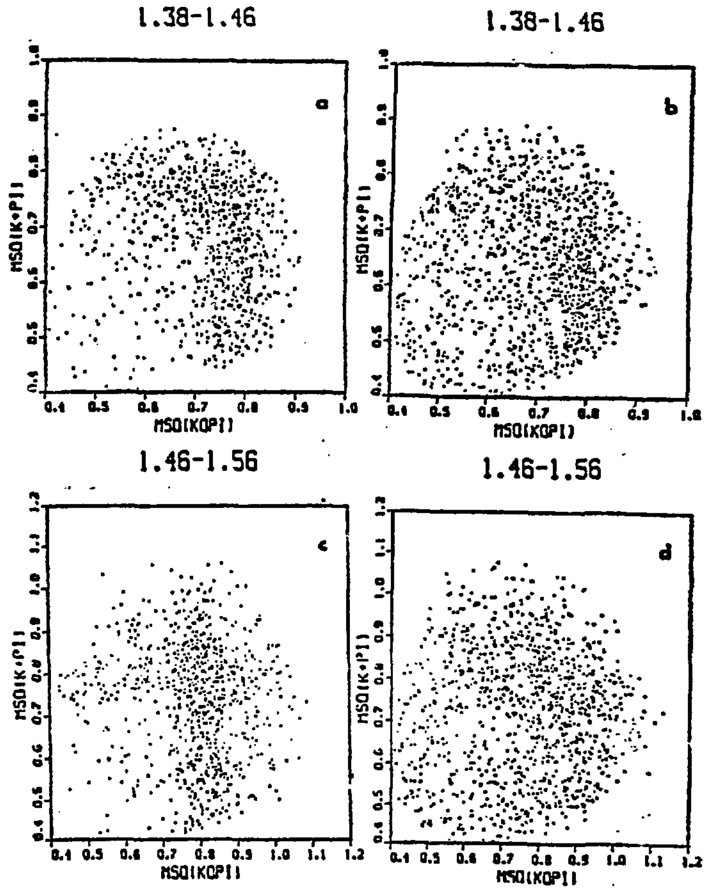


Fig. 8 (a) $K\bar{K}\pi$ mass spectrum for 40% of the π^- data;
(b) $K\bar{K}\pi$ mass spectrum for 30% of the $\bar{p}$ data (Ref. 16).

The fitted mass/width are (1421 ± 2)/(60 ± 10) MeV for the π beam and (1416 ± 5)/(80 ± 30) MeV for the $\bar{p}$ beam. The Dalitz plots for the E region and the region above are given in Figure 9.



1.38-1.46   1.38-1.46

1.46-1.56   1.46-1.56

Fig. 9 (a,c) Dalitz plots for $M(K\bar{K}\pi)$ in (1.38 → 1.46) and (1.46 → 1.56) GeV for the π^- data;
(b,d) Same as (a,c) for the $\bar{p}$ data (Ref. 16).

It is seen that the K^*'s are present in the E region, but the density along the K^* bands indicate complex interference behavior, requiring presence of more than one J^{PG} state in the E region.

Note, in particular, the two K^*'s for $\bar{p}$ data are highly asymmetric so that a strong interference of opposite G-parity states is required.

Recent ISR data[17] on proton diffractive dissociation $P \rightarrow pK\bar{K}\pi$, show two peaks at D and E (see Fig. 10); the data indicate the E/i decays into both K^*K and $\delta\pi$, but no results are given as yet on the spin-parity content.

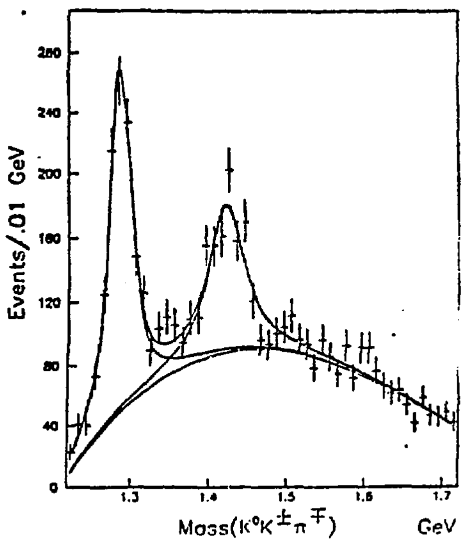


Fig. 10 $K\bar{K}\pi$ mass spectrum from the data on proton diffractive dissociation (Ref. 17).

The E data, at least in hadroproduction, suggest that the region is complex, probably indicating presence of states with both G = +1 and G = −1. It should be borne in mind that the $K\bar{K}\pi$ region between 1.5 to 2.0 GeV potentially harbors many overlapping and/or close-spaced states, such as the $1^{--}\rho'(1600)$, $1^{++}D'(1530)$ as well as the hitherto unobserved 1^{+-} $H'(1440)$ [partner of $B(1230)$] and $0^{-+}\eta_R'(1490)$ [partner of $\pi_R(1300)$]. In view of this, one must await results of more complete partial-wave analyses on the $K\bar{K}\pi$ system, from threshold up to 2 GeV, for progress in our understanding of the role gluons play in the isoscalar meson sector.

V. J/ψ RADIATIVE DECAYS

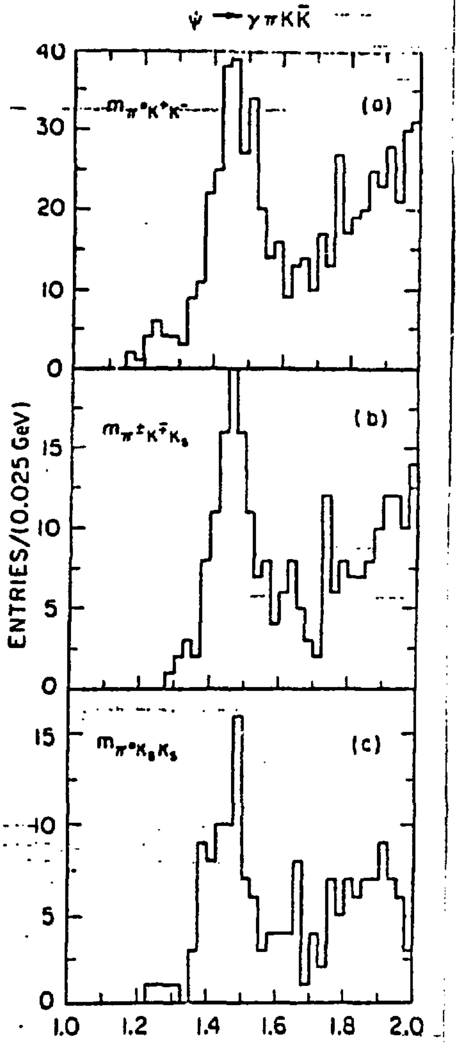
A review of possible glueball candidates in J/ψ radiative decays are given here. Since some states seen in this decay have as yet no J^P information, it seemed reasonable that all the possible candidates are treated collectively in a single section.

The J/ψ radiative decay proceeds via production of two gluons with a postive C-parity in the lowest-order QCD diagram. Therefore, this channel represents a prime source for C = +1 glueball productions. Glueballs are not the sole source for the enhanced radiative decay. One or both of the gluons can couple to $q\bar{q}$ within the boundary of an elementary particle, in which case a hybrid or four-quark state may be produced in the J/ψ decay. However, if such states do exist, they should eventually be identified in their changed states, to be distinguished from the glueballs.

The ι(1440) was seen in the Mark II and the Crystal Ball experiments[12] as a $K\bar{K}\pi$ enhancement with mass/width at ($1440\ ^{+10}_{-15}$) (50^{+30}_{-20}) MeV and (1440^{+20}_{-15})/(55^{+20}_{-30}) MeV, respectively. Recent Mark III data[18] have considerably more statistics in the $K\bar{K}\pi$ system and the mass/width is determined to be (1461 ± 5)/(105 ± 11) MeV, considerably higher than earlier determinations (see Fig. 11). It should be noted, however, that the Mark II and the Crystal Ball measurements were made with a low mass cut on $m(K\bar{K})$, while the Mark III measurements did not impose the cut.

A J^P analysis on the Crystal Ball data showed that the ι(1440) is a $J^{PC} = 0^{-+}$ state coupling predominatly to $\delta\pi$. Since $\delta \rightarrow \eta\pi$ is a predominant decay, one should also observe the decay $\iota(1440) \rightarrow \eta\pi\pi$, which is not observed in the Crystal ball nor in the Mark III data. Instead, the Mark III data show an enhancement with mass/width at (1378 ± 4)/(27 ± 18) MeV, considerably shifted down from that of the ι mass (see Fig. 12). Continued absence of the decay $\iota \rightarrow \eta\pi\pi$ and the status of the new $\eta\pi\pi$ state remain so far a mystery.

If ι(1440) is a pure glueball, it should be characterized by absence of the decay modes $\gamma\rho$ and $\gamma\gamma$, since gluons do not directly couple to photons. However, both Crystal Ball and Mark III experiments see a clear decay $\iota \rightarrow \gamma\rho$ with mass/width at (1434 ± 14)/(133 ± 32)MeV (see Fig. 13). Thus, it appears likely that the ι(1440) is not a pure glueball but has a substantial $q\bar{q}$ mixing.



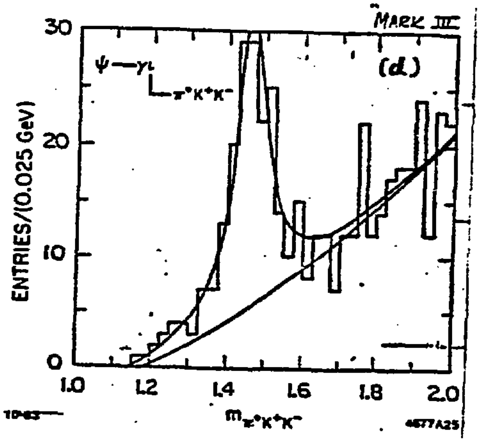


Fig. 11(a-c). $K\bar{K}\pi$ mass spectra; (d) Breit-Wigner fit to $K^+K^-\pi^\circ$ mass spectrum (Ref. 18).

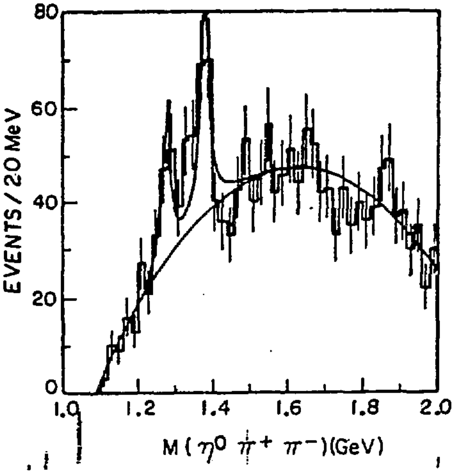


Fig. 12. $\eta\pi^+\pi^-$ mass spectrum. The curve is a fit with two Breit-Wigners over a guadratic background. The lower peak was fixed at the D values; M = 1280 MeV and Γ = 26 MeV (Ref. 18).

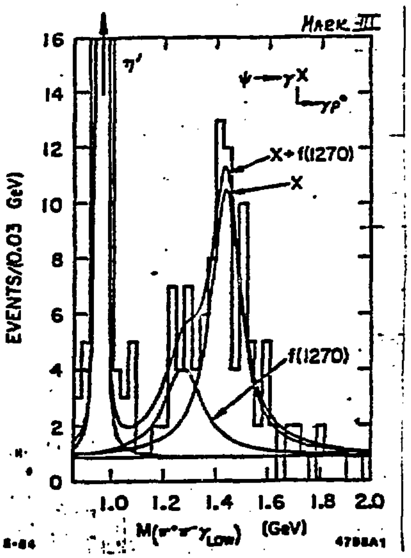


Fig. 13. $\gamma\rho^\circ$ mass spectrum. The best fit is obtained with an addition of some f(1370) (Ref. 18).

Another glueball candidate seen in J/ψ radiative decays is the θ(1700), seen by Crystal Ball in the ηη system, and by Mark II and Mark III in the $K\bar{K}$ systems. Taking into account the nearby f' resonance, the new mass/widths are (1719 ± 6 ± 10)/(117 ± 23 ± 10) MeV for the Mark III data (see Fig. 14).

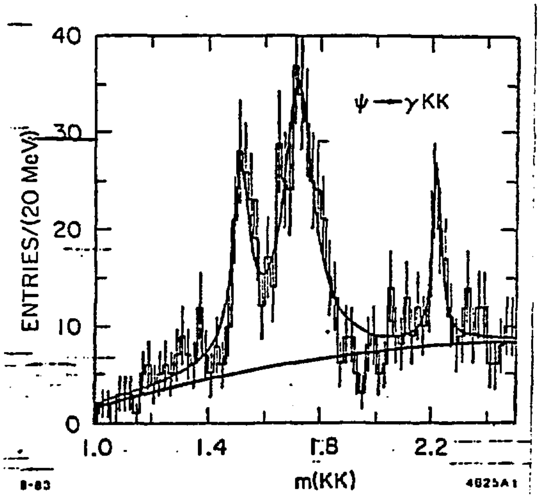


Fig. 14. K^+K^- mass spectrum, showing f', θ and ξ (Ref. 18).

In addition, the $\theta(1700)$ may have been seen in $\pi^+\pi^-$ mass spectrum as well by Mark III (see Fig. 15). Although there is no information on the J^{PC} from Mark III, an earlier analysis indicated that $J^{PC} = 2^{++}$ is favored for the $\theta(1700)$.

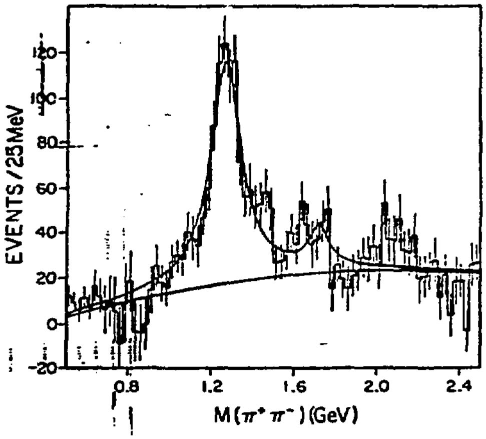


Fig. 15. $\pi^+\pi^-$ mass spectrum, showing f and a signal interpreted as an upper limit to the decay $\theta \to \pi\ \pi$ (Ref. 18).

Fig. 14 shows a sharp peak at (2218 ± 3 ± 10) MeV in both K^+K^- and K_SK_S mass spectra. This new state, called the $\xi(2200)$, is seen for the first time in the Mark III data. The interest in this state lies in the fact that the width is determined to be less than 40 MeV (at 95% confidence level), essentially consistent with a zero width. So far it has not been observed in any other decay channel, and no information yet on its spin-parity (due to limited statistics), except that it should belong to the series $J^{PC} = 0^{++}$, 2^{++}, 4^{++}, etc.

The nature of this resonance is not at all clear. This state could possibly be a Higgs particle, in which case the spin should be zero.[19] If it is a Higgs, it should also be seen in $\Upsilon \to \gamma\xi$, which is not observed.[20] In a recent preprint, Godfrey, Kokoski and Isgur[21] claimed that the ξ should be identified with an unusually narrow L = 3 $s\bar{s}$ state ($^3F_2$ or $^3F_4$), while Chanowitz and Sharpe would identify it with an ω-like hybrid state[22] in which a TM gluon combines with a $q\bar{q}$.

Finally, both Mark II and Mark III observe a structure in 1.5 - 1.9 GeV region in the $\rho^0\rho^0$ mass spectrum, which may represent a new state, possibly a glueball. In a spin-parity analysis performed on the Mark III data[18], it appears that the $\rho\rho$ enhancement is primarily in 0^- state (see Fig. 16). In addition, a similar structure is seen in the $\omega\omega$ spectrum[18] in the region 1.6 - 1.9 GeV, which may be a different decay mode of the $\rho\rho$ structure.

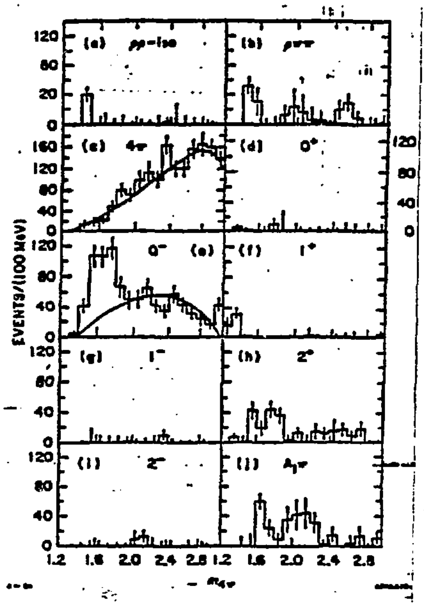


Fig. 16. Partial-wave decomposition of the $\rho^0\rho^0$ mass spectrum, showing an enhancement primarily in the 0^- wave (Ref. 18).

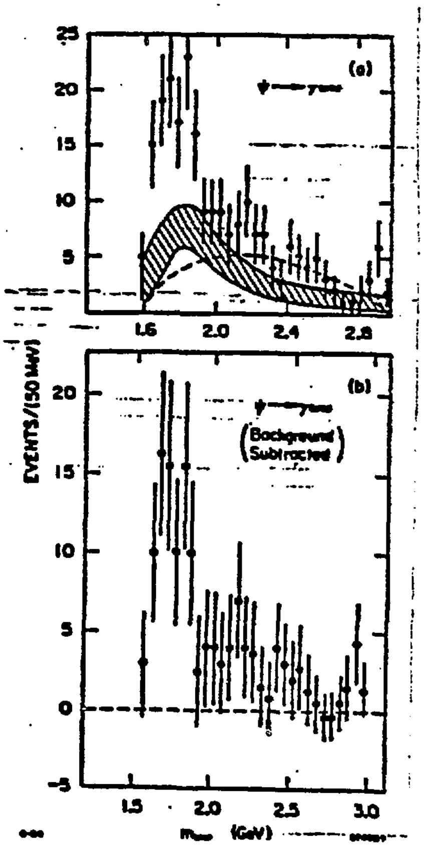


Fig. 17. $\omega\omega$ Mass Spectrum with and without background subtraction (Ref. 18).

VI. CONCLUDING REMARKS

A brief survey of glueball candidates with $J^{PC} = 0^{++}$, 2^{++} and 0^{-+} produced in hadron-hadron collisions as well as those from J/ψ radiative decays are given in the preceding sections and a summary given in Tables I and II.

It must be emphasized that all of the aforementioned states (with a single exception of the E/i) need independent experimental confirmation. Rather than concentrating on the states more firmly established experimentally, this review touched instead on those potential candidate states which may eventually turn out to be the glueballs. It must also be emphasized that so far no glueballs has been found which is universally accepted as such.

A part of the problem lies in the fact that most if not all the glueballs mix with $q\bar{q}$ states, making their identification phenomenologically difficult. M. Frank and P.J. O'Donnell[23], for example, consider η and η' and their first and second radial excitations mixing with a 0^{-+} glueball; in this scheme the i(1440) turns out to have 28% $q\bar{q}$ mixing. It is thus increasingly evident that a hunt for glueballs involve painstaking study of all of the isoscalar sectors of conventional $q\bar{q}$ states and their radial excitations.

Nevertheless, the i(1440) remains a favorite glueball candidate owing to its prominence in the J/ψ radiative decay, as has been repeatedly pointed out by M. Chanowitz.[24] There are problems to be sorted out, however. It is supposed to decay into $\delta\pi$ followed by $\delta \to K\bar{K}$. If so, why does one not observe it in the decay channel $i \to \delta\pi$ and $\delta \to \eta\pi$? Is it a pure glueball? If not, why is it not seen in $\pi^- p \to$ interactions? Indeed, some theorists find it difficult to accommodate it as a glueball, but instead they prefer to assign it as an $s\bar{s}$ radial excitation.[25]

Some consider the three $2^{++}\phi\phi$ resonances $g_T(2120)$, $g_T(2120)$, $g_T(2220)$ and $g_T(2360)$, as best glueball candidates,[25] inasmuch as they have been seen in an OZI-forbidden reaction where gluon mediation is the only possibility. However, H.J. Lipkin[26] points out the reaction $\pi^- p \rightarrow \phi\phi n$ is related to $\phi n \rightarrow \phi\, \pi^- p$ by crossing, which is certainly not OZI-forbidden, so that the enhanced $\phi\phi$ production does not necessarily indicate presence of glueballs. His view has subsequently been challenged by S.J. Lindenbaum.[27]

With the advent of quantum chromodynamics with flavorless, color-octet gluons as its carrier of force, the field of hadron spectroscopy has entered a new arena in which the gluon degree of freedom appears as an additional complexity. The hunt for glueballs, however, is hampered by our poor knowledge of isoscalar meson sector, pointing to an increased need for systematic experimental programs for study of neutral meson systems.

However laudable such an endeavor may be, a more direct approach might be to look for hybrid states with $J^{PC} = 1^{-+}$ or 2^{+-} which cannot be made out of simple $q\bar{q}$ systems. Another avenue for glueball hunt would simply involve looking for those states seen in J/ψ radiative decays but not in hadroproductions. Thus, the $\theta(1700)$ or the $\xi(2200)$ seen in the J/ψ decays may be considered perhaps the "purest glueball," for they have so far not been observed in any hadroproductions.

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Table I. Glueball Candidates in Hadroproduction

J^{PC}	Name	Mass/Width (MeV)	Decay Channel	Reaction[1]	Beam Momentum (GeV/c)	Ref.
0^{++}	$g_S(1240)$	$1240 \pm 10/140 \pm 10$	$K_S K_S$	$\pi^- p \to R\ n$	23.0	2
0^{++}	G (1590)	$1592 \pm 25/210 \pm 40$	$\eta\ \eta$	$\pi^- p \to R\ n$	38.0	4
0^{++}	--	Dips at 1.0 & 1.5 GeV	$\pi^+\pi^-$	$pp \to pRp$[2]	63.0[3]	5
2^{++}	$f_T(1440)$[4]	$1436^{+26}_{-10}/81^{+51}_{-29}$	K^+K^-	$\pi^- p \to R\ n$	18.0	9
2^{++}	$g_T(2120)$	$2120^{+20}_{-120}/300^{+150}_{-50}$	$\phi\ \phi$	$\pi^- p \to R\ n$	22.0	11
2^{++}	$g_T(2220)$	$2220^{+90}_{-20}/200 \pm 50$	$\phi\ \phi$	$\pi^- p \to R\ n$	22.0	11
2^{++}	$g_T(2360)$	$2360 \pm 20/150^{+150}_{-50}$	$\phi\ \phi$	$\pi^- p \to R\ n$	22.0	11
0^{-+}	E/i(1440)	$1425 \pm 2/65 \pm 5$	$K\bar{K}\pi$	$(\pi^+/p)p \to (\pi^+/p)R\ p$[2]	85.0	15
(or 1^{++})		$1421 \pm 2/60 \pm 10$	$K\bar{K}\pi$	$\pi^- p \to R\ n$	8.0	16
		$1416 \pm 5/80 \pm 30$	$K\bar{K}\pi$	$p\bar{p} \to R\ X^{\circ}$	6.6	16
		$1422 \pm 3/47 \pm 10$	$K\bar{K}\ \pi$	$p \to P\ R$[5]	63.0[3]	17

[1] R stands for the produced resonance.
[2] Central production of resonance.
[3] $\sqrt{s}$ for ISR.
[4] Ref. 8 calls this state G(1410); the name f_T is used here to distinguish it from the G of Ref. 4.
[5] Diffractive dissociation process.

Table II. Glueball Candidates in J/ψ Radiative Decays (Ref. 18)

J^{PC}	Name	Mass/Width (MeV)	Decay Channel	Branching Ratio	Experiment
0^{-+}	$\iota(1440)$	$(1440^{+10}_{-15})/(50^{+30}_{-20})$	$K_S K^{\pm} \pi^{\mp}$	$(4.3 \pm 1.7) \times 10^{-3}$	Mark II
		$(1440^{+20}_{-15})/(55^{+20}_{-30})$	$K^+K^-\pi^\circ$	$(4.0 \pm 1.2) \times 10^{-3}$	Crystal Ball[2]
		$(1461 \pm 5)/(105 \pm 11)$	$K \bar{K} \pi$	$(5.6 \pm 0.4 \pm 1.3) \times 10^{-3}$	Mark III[3]
		$(1434 \pm 14)/(133 \pm 32)$	$\gamma \rho^\circ$	$(1.10 \pm 0.24 \pm 0.25) \times 10^{-4}$	Mark III
2^{++}	$\theta(1770)$[4]	$(1708 \pm 30)/(156 \pm 60)$	K^+K^-	$(6.0 \pm 0.9 \pm 2.5) \times 10^{-4}$	Mark II
		$(1670 \pm 50)/(160 \pm 80)$	$\eta\ \eta$	$(3.8 \pm 1.6) \times 10^{-4}$	Crystal Ball
		$(1719 \pm 6 \pm 10)/$ $(117 \pm 23 \pm 10)$	K^+K^-	$(4.8 \pm 0.7 \pm 0.9) \times 10^{-4}$	Mark III
		--	$\pi^+\pi^-$	$< 3 \times 10^{-4}$ (at 90% CL)	Mark III
--	$\xi(2200)$[5]	$(2218 \pm 3 \pm 10/< 40$	K^+K^-	$(5.8 \pm 1.8 \pm 1.8) \times 10^{-5}$	Mark IV
0^-	--	1500 - 1900	$\rho^\circ \rho^\circ$	$(7.7 \pm 3.0) \times 10^{-4}$	Mark III[6]
		1600 - 1900	$\omega\ \omega$	$(6.7 \pm 1.7 \pm 2.4) \times 10^{-4}$	Mark III

[1] Branching Ratio = $B(J/\psi \to \gamma R)\ B(R \to \text{decay channel})$, R = resonance.

[2] J^P analysis finds $J^{PC} = 0^{-+}$ coupling mostly to $\delta\pi$; Branching Ratio into K^*K less than 25%.

[3] All charge combinations seen including $K_S K_S \pi^\circ$.

[4] J^P information from Crystal Ball data alone on limited statistic.

[5] ξ is also observed in $K_S K_S$ so that $J^{PC} = 0^{++}, 2^{++}, 4^{++}$, etc.

[6] Also observed in $\rho^+\rho^-$ with $J^P = 0^-$.