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Trigger Topologies for Hybrids and Glueballs

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Abstract

This note contains various triggers possibilities aimed at searching for the $J^{PC} = 1^{-+}$ exotic mesons as well as the scalar glueball candidate $f_0(1500)$.

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1 Introduction

This note is a condensed and updated version of the preprint BNL-QGS94-01 written by me in 1994. It appears that a separate compendium could be useful which contains various trigger topologies of interest for E852—in particular in the *new notation* which I advocate.

The PDG advocates a naming scheme in which a new notation involving a caret be introduced[1]. However, one must point out that it is *not* necessary to introduce a new naming scheme; the present conventions for the nomenclature are sufficient for *all* possible J^{PC}-exotic mesons. Denoting particle names within parentheses preceded by exotic J^{PC}'s, one may write 0^{--} $(\rho_0, \omega_0, \phi_0, \psi_0)$, 0^{+-} (b_0, h_0, h'_0, h_{0c}), 1^{-+} $(\pi_1, \eta_1, \eta'_1, \eta_{1c})$, 2^{+-} (b_2, h_2, h'_2, h_{2c}), 3^{-+} $(\pi_3, \eta_3, \eta'_3, \eta_{3c})$ and so on. Finally, we shall use the word 'quarkonium' for any $q\bar{q}$ system; however, it is convenient to give different names for each class of quark mass. Hence we use the word 'isospinium' to indicate $n\bar{n}$ where $n = u$ or d (these are the only quarks which impart strong isospin flavor to hadronic matter), 'strangeonium' for $s\bar{s}$ and 'charmonium' for $c\bar{c}$.

An updated version of the current status of hybrids and glueballs will be forthcoming soon.

2 Possible Triggers for π_1 search

The two states, $\pi_1(1600)$ and $\pi_1(1900)$, as well as the state $\pi_1(1400)$, can be searched for in BNL-E852. Possible trigger modes are summarized in Tables I and II for production of π_1, and Table III for η_1. Trigger modes in these tables follow the convention:

$$[TCYL]^{n_1} \cdot [TPX1]^{n_2} \cdot [TPX2]^{n_3} \cdot [LGD]^{n_4} \;\Rightarrow\; n_1 - n_2 - n_3 - n_4 \tag{1}$$

where the exponents denote multiplicities. One has assumed, somewhat arbitrarily, that $n_1 \leq 1$, $n_2 \leq 5$, $n_3 \leq 5$ and $n_4 \leq 7$. For secondary and tertiary decay modes, only major decays with branching ratios greater than 10% have been included, but with two exceptions: $\eta' \to \gamma\gamma$ (2%) and $\omega \to \pi^0\gamma$ (9%).

3 Observation of the $J^{PC} = 0^{++}$ glueball candidate

The Crystal Barrel Collaboration reported at the 29th Rencontres de Moriond in France that they have found a scalar glueball candidate at mass 1500 MeV with width around 150 MeV. Their main argument is that this state seems to have nearly equal couplings to the final states $\pi^0\pi^0$, $\eta\eta$ and $\eta\eta'$—suggestive of the flavor-neutral coupling of a glueball. Table IV shows possible triggers appropriate for this glueball search.

4 Additional Exotic-Meson Searches

One prime candidate for the $J^{PC} = 2^{++}$ glueball is the three states $f_2(2000 - 2200)$ seen in the $\phi\phi$ decay channel[1]. From $SU(3)$ there must be a finite decay into $\omega\omega$ as well. Bose symmetry requires that $\ell + S =$even, where ℓ is the orbital angular momentum between the two ω's and S is the total intrinsic spin. Note that $\ell = S = 1$ induces a $J^{PC} = 1^{-+}$ glueball, which cannot couple to quarkonia.

Another intriguing isoscalar channel is $\omega\eta$. The allowed quantum numbers are $J^{PC} = 1^{+-}$ for an S-wave decay and $J^{PC} = 0^{--}$ or 2^{--} for a P-wave decay. Note that 0^{--} is an exotic or a non-quakonium. In addition, a 0^{--} state is not allowed for a ground-state hybrid meson according to the flux-tube model[2], whereas it is one of the allowed states for a glueball (the predicted mass at around 2.8 GeV). The channel $\omega\eta'$ is similar. A $J^{PC} = 0^{--}$ glueball may couple predominantly to the final state containing a P-wave quarkonium. In this case, the final states $\omega\eta$ or $\omega\eta'$ may not be the favored decay channels. Distinctive decay modes with a P-wave quakonium are $a_2(1320)\rho$ or $f_2(1270)\omega$. However, a 0^{--} state couples to these final states via D-wave orbital angular momentum; the barrier factor may then suppress these dacay modes. It should be noted that very little is known about the 2^{--} quarkonium states, and the channels $\omega\eta$, $\omega\eta'$, $a_2(1320)\rho$, and $f_2(1270)\omega$ are natural decay modes for a 2^{--} state.

Tables Va, Vb and Vc summarize the trigger modes relevant for these states.

References

[1] Review of Particle Properties, Particle Data Group, Phys. Rev. **D50**, Part I (1994).

[2] N. Isgur and J. Paton, Phys. Rev. **D31**, 2910 (1985).

TABLES

Table I. Reaction $\pi^- p \to \pi_1^- \, p$

primary decay	secondary decay	B(%)	tertiary decay	B(%)	trigger mode
$\pi^-\eta$	$\eta \to \gamma\gamma$	39			$1-1-1-2$
$\pi^-\eta$	$\eta \to \pi^0\pi^0\pi^0$	32			$1-1-1-6$
$\pi^-\eta$	$\eta \to \pi^+\pi^0\pi^-$	24			$1-3-3-2$
$\pi^-\rho^0$	$\rho^0 \to \pi^+\pi^-$	100			$1-3-3-0$
$\pi^0\rho^-$	$\rho^- \to \pi^0\pi^-$	100			$1-1-1-4$
$\pi^-\eta'$	$\eta' \to \gamma\gamma$	2			$1-1-1-2$
$\pi^-\eta'$	$\eta' \to \rho^0\gamma$	30	$\rho^0 \to \pi^+\pi^-$	100	$1-3-3-1$
$\pi^-\eta'$	$\eta' \to \pi^+\pi^-\eta$	44	$\eta \to \gamma\gamma$	39	$1-3-3-2$
$\pi^-\eta'$	$\eta' \to \pi^0\pi^0\eta$	21	$\eta \to \gamma\gamma$	39	$1-1-1-6$
$\pi^- f_1(1285)$	$f_1(1285) \to \pi^\pm\pi^0\rho^\mp$	26	$\rho^\mp \to \pi^\mp\pi^0$	100	$1-3-3-4$
$\pi^- f_1(1285)$	$f_1(1285) \to \pi^+\pi^-\rho^0$	13	$\rho^0 \to \pi^+\pi^-$	100	$1-5-5-0$
$\pi^- f_1(1285)$	$f_1(1285) \to \pi^+\pi^-\eta$	33	$\eta \to \gamma\gamma$	39	$1-3-3-2$
$\pi^- f_1(1285)$	$f_1(1285) \to \pi^+\pi^-\eta$	33	$\eta \to \pi^0\pi^0\pi^0$	32	$1-3-3-6$
$\pi^- f_1(1285)$	$f_1(1285) \to \pi^0\pi^0\eta$	17	$\eta \to \gamma\gamma$	39	$1-1-1-6$
$\pi^- f_1(1285)$	$f_1(1285) \to \pi^0\pi^0\eta$	17	$\eta \to \pi^+\pi^0\pi^-$	24	$1-3-3-6$
$[\pi b_1(1235)]^-$	$\to \pi^-\pi^0\omega$	100	$\omega \to \pi^0\gamma$	9	$1-1-1-5$
$[\pi b_1(1235)]^-$	$\to \pi^-\pi^0\omega$	100	$\omega \to \pi^+\pi^0\pi^-$	89	$1-3-3-4$

Note: B(%) is the branching ratio in percent.
One has assumed $\pi^0 \to \gamma\gamma$, with B($\pi^0 \to \gamma\gamma$)= 99%.

Table II. Reaction $\pi^- p \to \pi_1^0 n$

primary decay	secondary decay	B(%)	tertiary decay	B(%)	trigger mode
$\pi^0\eta$	$\eta \to \gamma\gamma$	39			$0-0-0-4$
$\pi^0\eta$	$\eta \to \pi^+\pi^0\pi^-$	24			$0-2-2-4$
$\pi^\pm\rho^\mp$	$\to \pi^0\pi^+\pi^-$	100			$0-2-2-2$
$\pi^0\eta'$	$\eta' \to \gamma\gamma$	2			$0-0-0-4$
$\pi^0\eta'$	$\eta' \to \rho^0\gamma$	30	$\rho^0 \to \pi^+\pi^-$	100	$0-2-2-3$
$\pi^0\eta'$	$\eta' \to \pi^+\pi^-\eta$	44	$\eta \to \gamma\gamma$	39	$0-2-2-4$
$\pi^0\eta'$	$\eta' \to \pi^+\pi^-\eta$	44	$\eta \to \pi^+\pi^0\pi^-$	24	$0-4-4-4$
$\pi^0 f_1(1285)$	$f_1(1285) \to \pi^\pm\pi^0\rho^\mp$	26	$\rho^\mp \to \pi^\mp\pi^0$	100	$0-2-2-6$
$\pi^0 f_1(1285)$	$f_1(1285) \to \pi^+\pi^-\rho^0$	13	$\rho^0 \to \pi^+\pi^-$	100	$0-4-4-2$
$\pi^0 f_1(1285)$	$f_1(1285) \to \pi^+\pi^-\eta$	33	$\eta \to \gamma\gamma$	39	$0-2-2-4$
$\pi^0 f_1(1285)$	$f_1(1285) \to \pi^+\pi^-\eta$	33	$\eta \to \pi^+\pi^0\pi^-$	24	$0-4-4-4$
$\pi^\pm b_1^\mp(1235)$	$\to \pi^+\pi^-\omega$	100	$\omega \to \pi^0\gamma$	9	$0-2-2-3$
$\pi^\pm b_1^\mp(1235)$	$\to \pi^+\pi^-\omega$	100	$\omega \to \pi^+\pi^-\pi^0$	89	$0-4-4-2$

Note: B(%) is the branching ratio in percent.
One has assumed $\pi^0 \to \gamma\gamma$, with B($\pi^0 \to \gamma\gamma$)= 99%.

Table III. Reaction $\pi^- p \to \eta_1\, n$

primary decay	secondary decay	B(%)	tertiary decay	B(%)	trigger mode
$\eta f_1(1285)$	$f_1(1285) \to \pi^\pm \pi^0 \rho^\mp$	26	$\rho^\mp \to \pi^\mp \pi^0$	100	
	$\eta \to \gamma\gamma$	39			$0-2-2-6$
$\eta f_1(1285)$	$f_1(1285) \to \pi^\pm \pi^0 \rho^\mp$	26	$\rho^\mp \to \pi^\mp \pi^0$	100	
	$\eta \to \pi^+ \pi^0 \pi^-$	24			$0-4-4-6$
$\eta f_1(1285)$	$f_1(1285) \to \pi^+ \pi^- \rho^0$	13	$\rho^0 \to \pi^+ \pi^-$	100	
	$\eta \to \gamma\gamma$	39			$0-4-4-2$
$\eta f_1(1285)$	$f_1(1285) \to \pi^+ \pi^- \rho^0$	13	$\rho^0 \to \pi^+ \pi^-$	100	
	$\eta \to \pi^0 \pi^0 \pi^0$	32			$0-4-4-6$
$\eta f_1(1285)$	$f_1(1285) \to \pi^+ \pi^- \eta$	33	$\eta \to \gamma\gamma$	39	
	$\eta \to \gamma\gamma$	39			$0-2-2-4$
$\eta f_1(1285)$	$f_1(1285) \to \pi^+ \pi^- \eta$	33	$\eta \to \pi^+ \pi^0 \pi^-$	24	
	$\eta \to \gamma\gamma$	39			$0-4-4-4$
$\pi^0 b_1^0(1235)$	$\to \pi^0 \pi^0 \omega$	100	$\omega \to \pi^0 \gamma$	9	$0-0-0-7$
$\pi^0 b_1^0(1235)$	$\to \pi^0 \pi^0 \omega$	100	$\omega \to \pi^0 \pi^+ \pi^-$	89	$0-2-2-6$
$\pi^\pm b_1^\mp(1235)$	$\to \pi^+ \pi^- \omega$	100	$\omega \to \pi^0 \gamma$	9	$0-2-2-3$
$\pi^\pm b_1^\mp(1235)$	$\to \pi^+ \pi^- \omega$	100	$\omega \to \pi^0 \pi^+ \pi^-$	89	$0-4-4-2$
$\pi^0 \rho^0$	$\rho^0 \to \pi^+ \pi^-$	100			$0-2-2-2$

Note: B(%) is the branching ratio in percent.
One has assumed $\pi^0 \to \gamma\gamma$, with $B(\pi^0 \to \gamma\gamma)= 99\%$.

Table IV. Reaction $\pi^- p \to f_0(1500)\, n$

primary decay	secondary decay	B(%)	tertiary decay	B(%)	trigger mode
$\pi^0\pi^0$					$0-0-0-4$
$\pi^\pm\pi^\mp$					$0-2-2-0$
$\eta\eta$	$\eta \to \gamma\gamma$	39			
	$\eta \to \gamma\gamma$	39			$0-0-0-4$
$\eta\eta$	$\eta \to \gamma\gamma$	39			
	$\eta \to \pi^+\pi^0\pi^-$	24			$0-2-2-4$
$\eta\eta$	$\eta \to \pi^+\pi^0\pi^-$	24			
	$\eta \to \pi^+\pi^0\pi^-$	24			$0-4-4-4$
$\eta\eta'$	$\eta \to \gamma\gamma$	39			
	$\eta' \to \gamma\gamma$	2			$0-2-2-4$
$\eta\eta'$	$\eta \to \pi^+\pi^0\pi^-$	24			
	$\eta' \to \gamma\gamma$	2			$0-0-0-4$
$\eta\eta'$	$\eta' \to \rho^0\gamma$	30	$\rho^0 \to \pi^+\pi^-$	100	
	$\eta \to \gamma\gamma$	39			$0-2-2-3$
$\eta\eta'$	$\eta' \to \pi^+\pi^-\eta$	44	$\eta \to \gamma\gamma$	39	
	$\eta \to \gamma\gamma$	39			$0-2-2-4$
$K_S K_S$	$K_S \to \pi^+\pi^-$	69			
	$K_S \to \pi^+\pi^-$	69			$0-4-4-0$
$K_S K_S$	$K_S \to \pi^+\pi^-$	69			
	$K_S \to \pi^0\pi^0$	32			$0-2-2-4$

Note: B(%) is the branching ratio in percent.
One has assumed $\pi^0 \to \gamma\gamma$, with B($\pi^0 \to \gamma\gamma$)= 99%.

Table Va. Additional Isoscalar Exotics—$\omega\omega$ and $\omega\eta$

primary decay	secondary decay	B(%)	tertiary decay	B(%)	trigger mode
$\omega\omega$	$\omega \to \pi^0\gamma$	9			
	$\omega \to \pi^0\gamma$	9			$0-0-0-6$
$\omega\omega$	$\omega \to \pi^+\pi^0\pi^-$	89			
	$\omega \to \pi^+\pi^0\pi^-$	89			$0-4-4-4$
$\omega\omega$	$\omega \to \pi^0\gamma$	9			
	$\omega \to \pi^+\pi^0\pi^-$	89			$0-2-2-5$
$\omega\eta$	$\omega \to \pi^0\gamma$	9			
	$\eta \to \gamma\gamma$	39			$0-0-0-5$
$\omega\eta$	$\omega \to \pi^+\pi^0\pi^-$	89			
	$\eta \to \pi^+\pi^0\pi^-$	24			$0-4-4-4$
$\omega\eta$	$\omega \to \pi^0\gamma$	9			
	$\eta \to \pi^+\pi^0\pi^-$	24			$0-2-2-5$
$\omega\eta$	$\omega \to \pi^+\pi^0\pi^-$	89			
	$\eta \to \gamma\gamma$	39			$0-2-2-4$

Note: B(%) is the branching ratio in percent.
One has assumed $\pi^0 \to \gamma\gamma$, with B($\pi^0 \to \gamma\gamma$)= 99%.

Table Vb. Additional Isoscalar Exotics—$\omega\eta'$

primary decay	secondary decay	B(%)	tertiary decay	B(%)	trigger mode
$\omega\eta'$	$\omega \to \pi^0\gamma$	9			
	$\eta' \to \gamma\gamma$	2			$0-0-0-5$
$\omega\eta'$	$\omega \to \pi^+\pi^0\pi^-$	89			
	$\eta' \to \pi^+\pi^-\eta$	44	$\eta \to \gamma\gamma$	39	$0-4-4-4$
$\omega\eta'$	$\omega \to \pi^0\gamma$	9			
	$\eta' \to \rho^0\gamma$	30	$\rho^0 \to \pi^+\pi^-$	100	$0-2-2-5$
$\omega\eta'$	$\omega \to \pi^0\gamma$	9			
	$\eta' \to \pi^+\pi^-\eta$	44	$\eta \to \gamma\gamma$	39	$0-2-2-5$
$\omega\eta'$	$\omega \to \pi^+\pi^0\pi^-$	89			
	$\eta' \to \rho^0\gamma$	30	$\rho^0 \to \pi^+\pi^-$	100	$0-4-4-3$
$\omega\eta'$	$\omega \to \pi^+\pi^0\pi^-$	89			
	$\eta' \to \gamma\gamma$	2			$0-2-2-4$
$\omega\eta'$	$\omega \to \pi^0\gamma$	9			
	$\eta' \to \pi^+\pi^-\eta$	44	$\eta \to \pi^+\pi^0\pi^-$	24	$0-4-4-5$

Note: B(%) is the branching ratio in percent.
One has assumed $\pi^0 \to \gamma\gamma$, with B($\pi^0 \to \gamma\gamma$)= 99%.

Table Vc. Additional Isoscalar Exotics—$a_2(1320)\rho$ and $f_2(1270)\omega$

primary decay	secondary decay	B(%)	tertiary decay	B(%)	trigger mode
$a_2^\pm(1320)\rho^\mp$	$a_2^\pm(1320) \rightarrow \rho^0\pi^\pm$	70	$\rho^0 \rightarrow \pi^+\pi^-$	100	
	$\rho^\mp \rightarrow \pi^0\pi^\mp$	100			$0-4-4-2$
$a_2^\pm(1320)\rho^\mp$	$a_2^\pm(1320) \rightarrow \rho^\pm\pi^0$	70	$\rho^\pm \rightarrow \pi^\pm\pi^0$	100	
	$\rho^\mp \rightarrow \pi^0\pi^\mp$	100			$0-2-2-6$
$a_2^0(1320)\rho^0$	$a_2^0(1320) \rightarrow \rho^\pm\pi^\mp$	70	$\rho^\pm \rightarrow \pi^\pm\pi^0$	100	
	$\rho^0 \rightarrow \pi^+\pi^-$	100			$0-4-4-2$
$a_2^\pm(1320)\rho^\mp$	$a_2^\pm(1320) \rightarrow \pi^\pm\eta$	15	$\eta \rightarrow \gamma\gamma$	39	
	$\rho^\mp \rightarrow \pi^0\pi^\mp$	100			$0-2-2-4$
$a_2^0(1320)\rho^0$	$a_2^0(1320) \rightarrow \pi^0\eta$	15	$\eta \rightarrow \gamma\gamma$	39	
	$\rho^0 \rightarrow \pi^+\pi^-$	100			$0-2-2-4$
$a_2^\pm(1320)\rho^\mp$	$a_2^\pm(1320) \rightarrow \pi^\pm\pi^0\omega$	11	$\omega \rightarrow \pi^0\gamma$	9	
	$\rho^\mp \rightarrow \pi^0\pi^\mp$	100			$0-2-2-7$
$a_2^\pm(1320)\rho^\mp$	$a_2^\pm(1320) \rightarrow \pi^\pm\pi^0\omega$	11	$\omega \rightarrow \pi^+\pi^0\pi^-$	89	
	$\rho^\mp \rightarrow \pi^0\pi^\mp$	100			$0-4-4-6$
$a_2^0(1320)\rho^0$	$a_2^0(1320) \rightarrow \pi^+\pi^-\omega$	11	$\omega \rightarrow \pi^0\gamma$	9	
	$\rho^0 \rightarrow \pi^+\pi^-$	100			$0-4-4-3$
$f_2(1270)\omega$	$f_2(1270) \rightarrow \pi^+\pi^-$	57			
	$\omega \rightarrow \pi^+\pi^0\pi^-$	89			$0-4-4-2$
$f_2(1270)\omega$	$f_2(1270) \rightarrow \pi^0\pi^0$	28			
	$\omega \rightarrow \pi^+\pi^0\pi^-$	89			$0-2-2-6$
$f_2(1270)\omega$	$f_2(1270) \rightarrow \pi^+\pi^-$	57			
	$\omega \rightarrow \pi^0\gamma$	9			$0-2-2-3$
$f_2(1270)\omega$	$f_2(1270) \rightarrow \pi^0\pi^0$	28			
	$\omega \rightarrow \pi^0\gamma$	9			$0-0-0-7$