Possible Hints and Search for Glueballs in Charmless Rare B Decays

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We suggest possibility for glueball search in 3-body charmless B decays, and compare hints in these channels with other possibilities, such as $p\bar{p}$ annihilation, pp central production, and Υ decay.

1. HINT FOR ξ IN B DECAY?

With 30 fb^{-1} of data, the Belle experiment has reported the observation of various 3-body charmless $B \rightarrow Kh^+h^-$ decays, where h is π , K [1] or p [5]. We point out [3], as shown in Fig. 1(a), (c) and (e), possible hints of some structure at $m_{hh} \sim 2.2\text{--}2.3 \text{ GeV}$, or the “ ξ ” candidate for a 2^{++} glueball. Admittedly, the “evidence”, if at all, are rather weak. We shall discuss in Sec. 2 the underlying curve for the $B \rightarrow p\bar{p}K$ decay, giving some support for a “bump” structure at $2.2\text{--}2.4 \text{ GeV}$ bin. Fig. 1(c) for the $K_S\pi^+\pi^-$ mode is very low in statistics, and there is no indication in the corresponding $K^+\pi^+\pi^-$ and $K_S K^+K^-$ modes, as shown in Fig. 1(b) and (d). Fig. 1(e) and (f) are the high mass $m_{K^+K^-}$ spectra of the $B \rightarrow K^+K^+K^-$ transition, where $B \rightarrow K\phi$ is observed, with a broad K^+K^- spectrum at $1.2\text{--}1.6 \text{ GeV}$. These spectra, complicated by identical particle effects, are not yet understood.

We give some reasoning in Sec. 3 for why glueball production in charmless B decays may be interesting, and in Sec. 4 we gather a few other processes where a hint for ξ production can be entertained.

2. UNDERLYING 3-BODY DYNAMICS

Stimulated by observation of $\bar{B} \rightarrow D^*p\bar{n}$ decay, we proposed to account for the process by factorized currents. The current induced $\bar{B} \rightarrow D^*$ transition is standard, but for the “current-produced”

$p\bar{n}$ pair, we invoke isospin relations to tap into proton and neutron EM form factor data. Although axial vector current data is lacking, we find [4] that the vector current alone accounts for 60% of $\bar{B} \rightarrow D^*p\bar{n}$ rate.

Armed with this success, when Belle reported the first ever charmless baryonic B decay, $B \rightarrow p\bar{p}K$ [2], we etried understand it (and other modes) within the factorization framework. The extension [5] seemed to work, giving rise to *threshold enhancement* in $m_{p\bar{p}}$ spectra, in agreement with experiment. Such threshold enhancement is

Figure 1. Spectra for $B \rightarrow$ (a) $p\bar{p}K$; (b) $K\pi\pi$ ($m_{K\pi} > 2 \text{ GeV}$); (c) $K_S\pi\pi$; (d) $K_SK\bar{K}$; and (e), (f) for $KK\bar{K}$ vs. $m_{K\bar{K}}^{\min}$, $m_{K\bar{K}}^{\max}$ ($m_{K\bar{K}}^{\min} > 1.1 \text{ GeV}$).

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rooted in the baryon form factor structure. The idea is further confirmed by the recent Belle observation of $\overline{B} \rightarrow D^{(*)}K^-K^{0(*)}$, where one utilizes [6] kaon EM form factor data.

3. CHARMLESS B DECAYS & GLUEBALL SEARCH

Why are charmless B decays potentially interesting for glueball search?

First, glueballs turn out to be relatively heavy, probably > 1.5 GeV. Thus, for flavored meson decays, they are only accessible in the B system. Lattice calculations give [7] the 0^{++} and 2^{++} glueball masses at 1.5–1.7 GeV and ~ 2.2 GeV, respectively, with the latter coinciding well with the “ ξ ” particle hinted by BES data [8].

Second, it has always been a curiosity, at least to this author, why the gluonic penguin, $b \rightarrow sg^*$, i.e. a QCD-induced $b \rightarrow s$ weak “loop” transition, evolves only into $sq\bar{q}$ final states. The parton level sgg final state suffers cancellation via “Low’s low energy theorem” and becomes considerably smaller. This is in contrast to the equivalent presence of quarks and gluons in hadrons, or the equivalence of $N_C = 3$ vs. the number of light quarks. On the other hand, we were quite surprised in 1997 to learn the enormous strength of $B \rightarrow \eta'K$, and especially $B \rightarrow \eta'X_s$, decays. The latter, at 10^{-3} level, is a sizable fraction of the expected $b \rightarrow sq\bar{q}$ which is at 10^{-2} level.

It was pointed out in this context that the large inclusive $B \rightarrow \eta'X_s$ rate is likely related to the glue-rich nature of the η' . An intriguing possibility is that η' is radiated preferentially from the virtual g^* in the $b \rightarrow sg^*$ transition via $g^* \rightarrow g\eta'$, which is an extension of the QCD gluon anomaly. This picture [9] is so far the only one that can give the effective 3-body m_{X_s} spectrum first observed by CLEO, which is now confirmed by BaBar. Caution has to be taken, however, that a straightforward application of the $g^* \rightarrow g\eta'$ idea would lead to energetic η' mesons from $\Upsilon \rightarrow ggg + \eta'$ decay, another glue rich environment, which does not seem [10] to be observed by experiment.

Keeping the caution in mind, let us visualize ξ production in analogy with η' , i.e. $g^* \rightarrow g\xi$ (or, via $(c\bar{c})_8 \rightarrow g\xi$, where $c\bar{c}$ is in color octet).

How the $sg\bar{q}$ system evolves into a kaon is of no concern, for we now consider an effective $B \rightarrow \xi K$ transition, much in analogy with $B \rightarrow \eta'K$. A numeric exercise shows that, if $\xi \rightarrow p\bar{p}$ is of order $\sim \%$, and $B \rightarrow \xi K$ is comparable to $B \rightarrow \eta'K \sim 10^{-4}$, then $B \rightarrow p\bar{p}K$ could be at 10^{-6} order and could show up in the spectrum of Fig. 1(a). Whether and how ξ would show up in the $\pi\pi$ or $K\bar{K}$ spectra of the remainder of Fig. 1 depends on $\xi \rightarrow \pi\pi$, $K\bar{K}$ branching ratios, which are controversial, like the existence of ξ itself.

We suggest the B factories to combine modes in their analysis.

4. OTHER EVIDENCE FOR ξ AND POSSIBLE COMPETITION

The ξ state has a rather checkered history, to say the least. Early on, it was seen by MARK III, but not DM2. In the 1990’s, the BES experiment claimed [8] observation in quite a few channels. In particular, the $p\bar{p}$ channel stimulated a lot of interest in experiments at LEAR. But a multitude of null search results made $p\bar{p}$ and pp experiments very skeptic of the very existence of ξ itself. Note that the null results could simply be explained by ξ having many open channels to decay to, with each channel having branching ratio considerably below $\%$ level.

In the course of our studies, however, we encountered a few curiosities, which could be counted as possible hints for ξ .

4.1. Glueball-filtered Central Production?

An empirical “glueball filter” [11] has been argued and applied to centrally produced $pp \rightarrow p(\pi^+\pi^-\pi^+\pi^-)p$ by the WA102 collaboration, to data with proton beams at 450 GeV. The glueball filter works as a “ dP_T ” cut. For $dP_T > 0.5$ GeV, the $\pi^+\pi^-\pi^+\pi^-$ invariant mass spectrum shows a prominent $f_1(1285)$ peak, which is definitely $q\bar{q}$. One sees a small bump at 1500 MeV. As dP_T is lowered, i.e. for $0.2 \text{ GeV} < dP_T < 0.5 \text{ GeV}$, the significance of $f_1(1285)$ drops while the 1500 MeV structure is enhanced. For $dP_T < 0.2 \text{ GeV}$, the $f_1(1285)$ state becomes less significant than the 1500 MeV structure, which is a possible candidate for the 0^{++} glueball.

In the plot [11] that demonstrates this “glueball filter” phenomenon, we note one curiosity. For $dP_T < 0.2$ GeV, in contrast to the other two regions, a one bin *spike* pops up at ~ 2400 MeV, with statistical significance $> 5.5\sigma$! The claimed ξ width is very narrow, of order 20 MeV, and the WA102 experiment has sufficient resolution. The mass may seem high, but it may in part be due to the plots in Ref. [11] are perhaps based on raw data. A similar spike in a published WA102 paper [12] appears at ~ 2200 MeV.

4.2. $p\bar{p} \rightarrow \phi\phi$?

As stated, the strongest doubt for ξ comes from LEAR experiments, which claim nonobservation in $p\bar{p} \rightarrow K_S K_S$, $\phi\phi$, $\pi^0\pi^0$ and $\eta\eta$ channels. It has come to our attention, however, that some hint may exist in the $\phi\phi$ channel.

In an unpublished work [13], a partial wave analysis of $p\bar{p} \rightarrow \phi\phi$ finds evidence for a 70 MeV “resonance”, in both the cross section *and* the phase (relative to other channels) for the 2_{00}^+ channel. It appears to us that there may be some underlying structure in addition to the Breit-Wigner resonance. If so, the resonance part could be narrower. To my eye, it could well be 30 MeV. Reanalysis seems to be in progress.

4.3. $\Upsilon \rightarrow \gamma p\bar{p}$?

The CLEO experiment has searched [14] for $\Upsilon \rightarrow \gamma\pi^+\pi^-$, γK^+K^- , $\gamma p\bar{p}$. Using 61.3 fb^{-1} data, 1, 1, 2 events were found in the ξ window, respectively, against estimated background of 0.12, 0.21, 0.28 events. CLEO allowed for larger background and stopped short of claiming evidence. But it now has 1.3 fb^{-1} data on the Υ , a factor of 20 increase. This means that 10–40 events (scaling up from BES branching ratios) could pop up in these channels once the data is analyzed, and could establish the ξ state.

4.4. Disappearance of $J/\psi \rightarrow \gamma\xi \rightarrow \gamma p\bar{p}$?

If ξ becomes established in $\Upsilon \rightarrow \gamma p\bar{p}$ by CLEO would be rather cute. But the rug seems pulled from under the original source . . .

The BES experiment has just shown [15] its new result on $J/\psi \rightarrow \gamma p\bar{p}$, with 7 times the data of Ref. [8]. The ξ state has all but disappeared, but one has a sizable peak right at threshold.

Glueball search is a hazardous occupation . . .

5. Conclusion

We have pointed out that charmless B decays could be a hunting ground for glueballs, because i) the B meson is heavy enough; ii) strong penguins are gluon induced; iii) glue-rich channels such as the η' modes seem rather enhanced.

A possible hint is pointed out for the ξ , or 2^{++} glueball candidate, in the $B \rightarrow Kh^+h^-$ spectra; but it is far from conclusive. We have further collected a few other possible hints. Alas, the rug seems pulled from underneath: BES no longer seems to see ξ in $J/\psi \rightarrow \gamma p\bar{p}$.

Still, with luck, glueballs may (or may not!) emerge in some of these channels within a year.

REFERENCES

1. A. Garmash *et al.* (Belle Collab.), Phys. Rev. D **65**, 092005 (2002).
2. K. Abe *et al.* (Belle Collab.), Phys. Rev. Lett. **88**, 181803 (2002).
3. C.K. Chua, W.S. Hou and S.Y. Tsai, Phys. Lett. **B544**, 139 (2002).
4. C.K. Chua, W.S. Hou and S.Y. Tsai, Phys. Rev. D **65**, 034003 (2002).
5. C.K. Chua, W.S. Hou and S.Y. Tsai, Phys. Rev. D **66**, 054004 (2002).
6. C.K. Chua *et al.*, hep-ph/0209164.
7. C.J. Morningstar and M.J. Peardon, Phys. Rev. D **60**, 034509 (1999).
8. J.Z. Bai *et al.* (BES Collab.), Phys. Rev. Lett. **76**, 3502 (1996).
9. W.S. Hou and B. Tseng, Phys. Rev. Lett. **80**, 434 (1998).
10. A.L. Kagan, AIP Conf. Proc. **618**, 310 (2002).
11. F.E. Close and A. Kirk, Phys. Lett. **B397**, 333 (1997).
12. D. Barberis *et al.* (WA102 Collab.), Phys. Lett. **B471**, 440 (2000).
13. A. Palano, talk at *Workshop on Hadron Spectroscopy*, Frascati, 1999.
14. G. Masek *et al.* (CLEO Collab.), Phys. Rev. D **65**, 072002 (2002).
15. S. Jin, following article, this proceedings.