A Review of Experimental Progress in Gluonia*

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1. Introduction

There has been considerable progress in gluonia investigations and their analysis. As requested by the Convenor, Rich Galik, I will cover the highlights of various conference papers and related work in an integrated manner which incorporates a review of the present state of glueballs (gluonia) to the extent space limitations allow.

There are four general methods of searching for glueballs:

1. J/ψ radiative decay [ι , θ , $\xi(2.2)$]
2. OZI violating (g_T , g_T' , g_T'')
3. Hadronic interaction pattern recognition of extra isosinglet states in addition to $q\bar{q}$ nonets, ι , G , S^{*1} , g_S .
4. Double Pomeron exchange.

2. Iota(1460) [$\eta(1460)$] Related Work

Cason et al., Paper 235C, Notre Dame/Brandeis/BNL/CCNY/Duke, studied 21.4 GeV/c $\pi^-p \rightarrow K_S^0 K_S^0 \pi^0 n$. A reaction for which $C = +1$ only. They found in contrast to similar experiments at lower energy where $C = \pm 1$ that their mass spectrum resembled that of the ι in the region of 1460. A fit to the mass spectrum and partial wave analysis with a $|t'| > 0.3$ cut revealed evidence for a $J^{PC} = 0^{-+}$ resonance with $M = 1453 \pm 7$, $\Gamma = 100 \pm 11$ while 1^{++} was structureless. The 0^{-+} $\eta(1420)$ appeared suppressed but consistent with other results (Fig. 1).

Paper 386, Ando et al., Sugiyama/Nagoya/KEK/Kyoto/Miyazaki/Nagoya Med. Tech/Kyoto U. of Ed., found that $8.06 \pi^-p \rightarrow K_S^+ K_S^- \pi^+ n$ gave mass spectrum and partial wave analysis results consistent with a 0^{-+} $\eta(1420)$ at $M = 1424$ MeV and $\Gamma = 35$ MeV. A hint of an $\eta(1280)$ was also observed.

In Paper 595c, Fukui et al., Sugiyama/Nagoya/KEK/Kyoto/Miyazaki/Nagoya Med. Tech./Kyoto U. of Ed., both the 0^{-+} $\eta(1275)$ and $\eta(1420)$ were clearly observed in the $\eta\pi^+\pi^-$ system (Fig. 1b).

Birman et al., (paper 657) performed a high statistics partial wave analysis of the $K^+K_S^0\pi^-$ system produced by 8 GeV/c π^- . They found a complicated situation

Fig. 1a $\pi^- p + K_S^0 K_S^0 \pi^0 n$

Fig. 1b $\eta(1275)$ and $\eta(1420)$

which needed many waves to fit, clearly showing that high statistics partial wave analyses are needed to draw critical conclusions.

They found at least one 0^-+ near 1.4 GeV or perhaps 2 resonances between 1.4-1.5 GeV, and an indication of a 0^-+ resonance at 1.28 GeV.

The SLAC $\eta(1460)$ has an asymmetrical shape which when analyzed also suggests more than one resonance in that region. Since only two 0^-+ resonances can be naturally accommodated as first $q\bar{q}$ radial excitations it is important to determine whether there is a third, which then could be a candidate for a glueball, multiquark or hybrid state. The complications due to the vacuum and its possible effects on the mass of higher radial excitations must also be considered in the 0^-+ spectroscopy.

3. $\theta(1720)$ [$f_2(1720)$] Related Work

Paper A498, B. Ratcliff et al., (LASS), found in the experiment $K^- p + K_S^0 K_S^0 \Lambda$ that while they clearly saw the f' peak there was no evidence for the θ (see Fig. 2) although this was expected from a prior coupled channel analysis.¹ This led Lindenbaum and Longacre to request from MK III the latest information on the status of the θ quantum numbers. The Bolton Thesis² which Walter Toki sent us made it clear that one could not distinguish between 0^{++} and 2^{++} or a mixture for the θ quantum numbers.

If the θ was 0^{++} then it would have the same mass width and quantum numbers of the S^{*1} (within the errors)³ discovered prior to the θ . In the scenario where the S^{*1} and θ are the same particle this modification of the coupled channel analysis was then found consistent with the LASS data.

Fig. 2a The comparison of the $K_S^0 K_L^0$ mass distribution from LASS and MK III with that from radiative J/ψ decay from threshold up to $1.9 \text{ GeV}/c^2$

Fig. 2b 300 GeV/c $p + p$ central production of $\pi^+ \pi^-$

Furthermore it should be noted that if the θ has 0^{++} and is assumed to be the same as the S^* the status of the $G(1590)$ [Alde et al., Nucl. Phys. B269, 485 (1986)] comes into question since the $G(1590)$ used an $\epsilon(1230 \pm 30)$ in its fitting whereas all other analyses used an $\epsilon(\sim 1450)$. Lindenbaum and Longacre⁴ have using the usual criterion of fitting the data with a minimum number of resonances found that the $0^{++} S^*$, g_S , ϵ and S^* fit the data reasonably, some of which is shown in Fig. 3, whereas the S^* , G , ϵ and S^* do not.

Obviously further work on this preliminary analysis which is still in progress is needed. DM2 does not see the narrow SLAC ξ but instead a broad enhancement.

LASS finds in the $\xi(2200)$ region a state which is likely $s\bar{s}$ and has $J^{PC} = 4^{++}$ or perhaps 2^{++} and could have a width which ranges from substantial to narrow. Thus the ξ does not appear to be a glueball candidate and instead appears to be an $s\bar{s}$ quark state.

4. Double Pomeron Exchange

Paper 521, Palano et al., Athens/Bari/Birmingham/CERN/College de France/LPNHE observed high statistics centrally produced $\pi^+ \pi^-$ in the reaction $300 \text{ GeV}/c \text{ } p + p \rightarrow p_f(\pi^+ \pi^-)p_s$. They found the main features of the S^* drop at KR (Fig. 2b)

Fig. 3a Fit⁴ to $K\bar{K}$ mass spectrum with $\theta = S^*$

Fig. 3b Fit⁴ to $\eta\eta$ mass spectrum with $\theta = S^*$

threshold best described as interference of the S^* with background. This explanation should also apply to this striking phenomenon previously observed at ISR. DPE seems to be a good 0^{++} selector but not likely an efficient glueball filter.

5. The OZI Violating $g_T(2010)$, $g_T'(2300)$ and $g_T''(2340)$ [$f_2(2010)$, $f_2(2300)$, $f_2(2340)$] and Related Work

Paper 706, Lindenbaum et al., BNL/CCNY. The statistics of the OZI forbidden $\pi^-p \rightarrow \phi\phi n$ have been $\approx$ doubled to a total 6658 analyzed events [Etkin et al., Phys. Lett. B201, 568 (1988)]. The characteristics of these data are very striking and unusual to a degree never seen in the uds spectroscopy in the > 1 -2 GeV mass region. The OZI suppression is completely broken down. A partial wave analysis confirms again that all $\phi\phi$ (within errors) are contained in three $1G_{JPC} = 0^+2^{++}$ resonances with no $\phi\phi$ continuum or other states. BNL/CCNY have found absolute Argand amplitude and phase behavior including speeds at resonance which very strongly establish these g_T , g_T' , g_T'' states as resonances. In contrast the ϕK^+K^- system shows $\approx 67\%$ featureless background $\approx 30\%$ 1^{--} which are the expected quantum numbers for s-wave ϕK^+K^- production via π -exchange, and only $\approx 3\%$ s-wave which shows no resonant behavior (see Fig. 4).

These striking phenomena are well explained as being produced by 1-3 primary glueballs whereas alternate published or conference proceedings explanations over

Fig. 4 (a) The acceptance corrected $\phi\phi$ mass spectrum, (b) intensity and (c) phase difference for the three $J^{PC} = 2^{++}$ waves. The curves show the fit by three Breit-Wigner resonances (i.e. K-matrix poles).

Fig. 4 (d) Argand plots for the three 2^{++} waves with the absolute phase based on the $1^{--} \phi K\bar{K}$ wave being a Breit-Wigner resonance (K-matrix), while (e) is based on the $1^{--} \phi K\bar{K}$ resulting from a deck mechanism, (f) The PWA of $\phi K^+ K^- n$.

the decade since our first $\phi\phi$ experiment have been shown to be incorrect, or do not fit the data or both.

The $d\sigma/d|t'|$ vs $|t'|$ curve shows the characteristic pion-exchange (i.e. $\pi^+\pi^-$ annihilation into gluons) exponential slope ≈ 10 for $|t'| < 0.3$ GeV/c accompanied by $M^0 = 0^-$ definitely establishing pion-exchange as the production process. For $|t'| > 0.3$ GeV/c the exponential slope decreases to ≈ 5 indicating A and other exchanges occur. These exchanges would allow exotic glueball production whereas pion-exchange does not.

However since only $\approx 5\%$ of the present is in this higher $|t'|$ range it is planned to change the experiment to enhance A-exchange by going to lower energies and search for an exotic 1^{--} , 3^{--} glueball if it should happen to occur in the mass range we have accessible.

It has traditionally taken a striking phenomenon such as that observed in the Δ , J/ψ , and Υ to establish a new type of particle in strong interaction physics. The g_T 's are the only glueball candidates which have this characteristic and thus are very likely due to production of 1-3 glueballs. At least one broad 2^{++} glueball is necessary to break the OZI suppression and select $J^{PC} = 2^{++}$ resonances only. However one could in principle then mix with one or two other conventional states in the mass region.

6. Other $\phi\phi$ Experiments

P.S. Booth et al., Nucl. Phys. B273 (1980) 687 and 689 in $\pi^- + Be \rightarrow \phi\phi + X$ conclude the $\phi\phi$ is mainly 2^{++} and are consistent with g_T^+ and g_T^0 . They do not expect to see g_T^- due to acceptance.

Mark III in $J/\psi \rightarrow \phi\phi$ found $\approx$ few hundred events. They are $\approx 75\%$ 0^{-+} with very little 2^{++} in the remainder. Since J/ψ radiative decay mainly sees 0^{-+} and is obviously an inefficient glueball filter since it sees mainly conventional objects such as η , η' , f , f' and continuum, it is not surprising they do not see g_T , g_T^+ and g_T^0 with their very low statistics $\phi\phi$. Secondly the width of the $J/\psi \rightarrow ggg$ and the branching ratio to radiative decay agrees with perturbative calculations. Therefore if J/ψ radiative decay were strongly coupled to glueballs one might expect that the process $J/\psi \rightarrow \gamma G$ would enhance the J/ψ radiative decay branching ratio and in the process increase the width of the J/ψ . In contrast in $\pi^-p \rightarrow \phi\phi n$, only the g_T 's are seen and no conventional objects or continuum appears. Not even a trace of the 4^{++} $n(2030)$ is seen even though we can easily detect it with the enormous analysis power of the $\phi\phi$ system. Thus there are huge factors in the filter action for glueballs in favor of the $\pi^-p \rightarrow \phi\phi n$ channel. Furthermore BNL/CCNY do not see 0^{-+} since π -exchange observes only 0^{++} , 2^{++} , 4^{++} etc. Thus I see no inconsistency.

References

1. Longacre et al., Phys. Lett. B177, 233 (1986).
2. T.A. Bolton, MK III Thesis. Radiative Decays of the J/ψ to Two Pseudoscalar Final States. MIT (April 1988).
3. Etkin et al., Phys. Rev. D25, 1786 (1982); D25, 2446 (1982).
4. Lindenbaum and Longacre (to be published)