Vector Meson Spectroscopy

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While much is known about the meson spectrum, there are still open questions about the existence and characteristics of the excited $q\bar{q}$ states, especially $s\bar{s}$. Understanding this spectrum will aid the search for exotic, hybrid and glueball states which can decay into the same final state as a $q\bar{q}$ state. In addition, better knowledge of the meson spectrum will put constraints on potential models and QCD-inequality predictions. Recent vector meson production data has answered questions about the ρ meson spectrum, but questions still remain about the basic characteristics of the strangeonia states. In this paper the present data is reviewed and areas for further inquiry are identified.

The ρ meson radial and orbital excitations up to L=2 have been identified (except for the $^3D_2$ states) by several experiments. [BA96] What was once considered a single state – the ρ(1600) – has been shown to consist of two states – the ρ(1450) and ρ(1700) - by the DM2 analysis of e^+e^- data. [CA94] The ρ(1450) and ρ(1700) were also identified in $p\bar{p}$ collisions. [AB97, BE97]

A reanalysis of the DM2 data that includes resonance mixing, threshold effects, and energy dependent widths for the ρ,ω, and φ is consistent with the interpretation of the ρ(1450) and ρ(1700) as excitations of the vector meson ground state. [AC98] However, the authors caution that care must be taken drawing conclusions. Due to the poor quality of the data, their fits do not rule out alternative models that require fewer excited meson states.

The situation is even less clear for the phi meson excitation spectrum. There is only scant evidence for one radial and one orbital excitation.

DM2 reports that an excited φ meson is needed to provide a good fit to the charged kaon form factor. They also report an enhancement in the $K\bar{K}\pi$ final state consistent with a radial excitation of the phi with mass m~1680 MeV and width Γ~200 MeV.

This state is also reported in photoproduction where a K^+K^- pair is detected [AT85,BU89], consistent with the interpretation of a ϕ radial excitation. However, the mass (m=1.76 GeV) is much larger than that of e^+e^- annihilation while the width is much narrower (Γ=80 MeV). More data is needed to resolve this conflict between e^+e^- annihilation and photoproduction. There is no existing photoproduction data of $K\overline{K}\pi$ final state to compare with, for example.

Experiments at SLAC (LASS) produced a $K\overline{K}$ recoiling against a Λ hyperon in K^-p reactions at 11 GeV/c. By comparing the neutral channel (which only produces even spin states) with the charged kaon channel and performing an angular momentum analysis, they were able to identify the total angular momentum of the $\phi_3(1850)$ as $^3D_3$. This nonet is close to ideally mixed, lending credence to the interpretation that this state is an orbital excitation of $s\bar{s}$.

The 1^{++} and the 1^{+-} nonets are less well known than the 1^{--} nonet with most information used to study other states of the $s\bar{s}$ excitation spectrum coming through the final state $K\overline{K}\pi$. Note that the $K_SK^{\pm}\pi^{\mp}$ final state includes both C = ± 1, while the final state $K_LK_S\pi^{\circ}$ accesses only C = -1 states. Questions remain as to the existence of the $h_1'(1400)$. On the other hand, there are too many f meson candidates that can be assigned to the 1^{++} nonet.

Crystal Barrel measured the neutral products from the $K\overline{K}\pi$ final state recoiling against a π° in $p\bar{p}$ annihilation. In their analysis, a substantial improvement to the data fit was obtained when a $J^{PC} = 1^{+-}$ amplitude with mass ~1400 MeV was included. A BNL experiment produced the $K\overline{K}\pi$ final state (recoiling against a neutron) via π^-p and reports evidence of a 1^{+-} state with a mass around 1400 MeV, however, they saw no strong phase motion.[BI88] Additionally, in K-p->$K\overline{K}\pi\Lambda$, the LASS data analysis identified a 1^{+-} wave consistent with the $h'_1(1380)$.[AS89] While each experiment reports only slight evidence, taken together they provide a strong indication as to the existence of the last light quark member of the 1^1P_1 nonet.

These experiments also provide information on the 1^{++} nonet states. The LASS analysis identified a 1^{++} contribution from the

$f_1(1530)$. The MPS analysis also presents evidence for a pair of 1^{++} states, - the $f_1(1285)$ and its $s\bar{s}$ partner the $f_1(1510)$ - from the 1^3P_1 nonet. Their interpretation of the 1^{++} nonet as including the $f_1(1510)$ and the $f_1(1285)$ is accepted by the particle data group, although it is not certain. Close and Kirk argue that the $f_1(1285)$ should be partnered with the $f_1(1420)$ and that the $f_1(1510)$ existence is dubious at best. [CL97] This assignment is also more consistent with QCD inequalities.[NU98] Clearly more work is necessary to understand the structure of the 1^{++} nonet.

In summary, though the data are lacking statistics, there is little controversy over the excited states of the ρ and ω mesons. However, due to the paucity of data, the $s\bar{s}$ spectrum is still poorly known. Photoproduction data need to be reconciled with e^+e^- data in order to understand the radial excitation of the phi. Photoproduction of $K\bar{K}\pi$ final states would provide the necessary information. There is evidence for the $s\bar{s}$ state in the 1^{+-} nonet, but confirmation is needed. Finally, new data on the f mesons of the 1^{++} nonet is needed to settle the question of the $f_1(1510)$ vs. the $f_1(1420)$.

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