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Radial trajectories of light phi mesons

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Surveys have shown the validity of Veneziano trajectories [1] for light diquark mesons ($q\bar{q}$). Here "light" means $(m/M)^2 << 1$, where m is a quark restmass and M is a meson mass in a chain of radial excitations. The formula for this chain is of ultimate simplicity:

$$M^2 = AN + B \quad [1]$$

where N=1.2.3.... are integers representing successive radial excitations. There is no other direct measure of N, since all external variables - such as C, I, J, L, P, S... - are identical.

The strength of Eq.(1) lies in the assertion that A is a universal constant so long as $(m/M)^2 << 1$. This assumption has been tested until now only by mesons with S = 1 and J = L +/- 1.. These were states [2] for J^{PC} = (even)++: namely, $^3P_0$ $^3P_2$ $^3F_0$. These included all 4 varieties of mesons, according to I=1, ½, 0 and 0' ($s\bar{s}$). The slopes for all cases averaged to:

$$A = 1.04 \pm 0.01 \text{ GeV}^2 \quad [2]$$

An additional test was made on states [3] with J^{PC} = (odd)−−, only for I =1. The states observed were $\rho(^3S_1)$ and $\rho(^3D_1)$ with an error-weighted average:

$$A = 1.046 \pm 0.006 \text{ GeV}^2 \quad [3]$$

Universality of A leaves only the intercept B at N = 0 to distinguish among trajectories.

In the present exercise we attempt to extend the (odd) −− trajectories to $s\bar{s}$ states: the φ mesons, which have been particularly difficult to identify (see Fig. 1). We look for resonances with significant decay modes of $K\bar{K}, K^*\bar{K}$, ...These are shown in Tables 1 and 2; the slopes of the respective trajectories are

$$A(\varphi_S) = 1.040 \pm 0.016 \text{ GeV}^2, \qquad A(\varphi_D) = 1.067 \pm 0.047 \text{ GeV}^2 \quad [4]$$

with an error-weighted average (EWA) of

$$A(\varphi) = 1.043 \pm 0.015 \text{ GeV}^2 \quad [5]$$

In both trajectories J^{PC} = 1−− has been directly observed for N = 1,2.

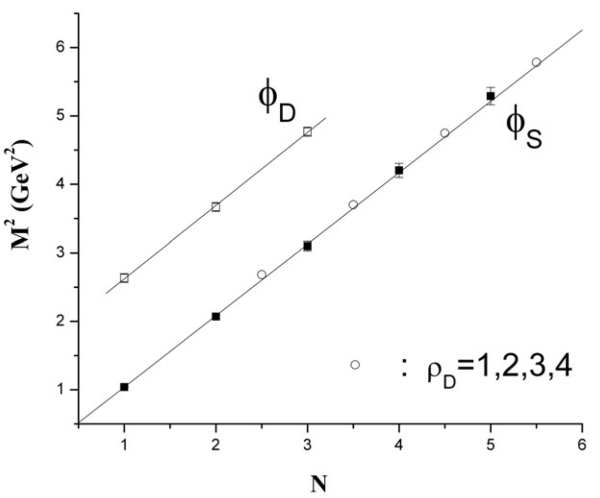

Figure 1. φ_S and φ_D trajectories. Since A is universal, intercept B (N=0) specifies each trajectory: leading to occasional overlap and confusion. Here ρ_D [3] overlays φ_S, impeding its extraction.

Table 1. φ_S

N	M(MeV)	M²(GeV²)	Ref.
1	1019.3	1.039 ± 0.001	4
2	1439 ± 6	2.070 ± 0.017	5
3	1760 ± 20	3.098 ± 0.070	6
4	2050 ± 25	4.203 ± 0.103	7
5	2300 ± 44	5.290 ± 0.127	8

Table 2. φ_D

N	M(MeV)	M²(GeV²)	Ref.
1	1623 ± 20	2.634 ± 0.056	9
2	1915 ± 17	3.667 ± 0.065	10
3	2130 ± 35	4.537 ± 0.149	11
	2192 ± 17	4.827 ± 0.075	12
	<2184 ± 15>	<4.769 ± 0.069>	13,14

Because light meson resonances in the 1-2 GeV region have become so numerous, the Particle Data Group (PDG) tends to group many data points in clusters that display some internal similarities. They are most often summarized by notations $f_0(x)$, $f_2(x)$,.... We take the liberty of extracting from these groups individual reactions that best yield our criteria of $K\overline{K}, K^*\overline{K}, K\overline{K}\pi$, etc. When the PDG average of a single cluster is acceptable, it is referenced simply as PDGAvg.

References

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[13] <M²> is the EWA of [11] and [12]
[14] <M> is the square root of [13}