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THE MASS SPECTRA OF THE OLD NEUTRAL VECTOR MESONS

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ABSTRACT

We use Dirac's equation with a harmonic potential to obtain the mass spectra of the neutral vector mesons ρ^{o}, ω, ϕ and K^{o*}. Our predictions are in fairly good agreement with the experimental results.

In a preceeding paper$^{(1)}$ we have established the mass spectrum for the charmed ψ mesons. We have used Dirac's equation to obtain the masses of the resonances.

In a general way the agreement with the experimental results was reasonable, giving us confidence to apply the same formalism to the spectra of other families of mesons.

We will consider now the vector meson multiplet, calculating the masses of the neutral particles (ρ^o, ϕ, ω and K^{o*}) with their radial excitations since the charged states are not relevant in our formalism.

In reference (1) it was assumed that the quarks interact mainly via a static harmonic potential $V(r) = Kr^2/2$. The contributions of the remaining interactions were incorporated in the effective mass of the quarks. This works reasonably for an almost non relativistic case as occurs in charmonia$^{(1)}$. Now, where relativistic effects are relevant, this approximation, as expected, gives unsatisfactory results and must be modified. Therefore, we assume that $V(r) = \frac{K}{2} r^2 - \Delta$, where the constant Δ takes into account, in a simple way, the remaining interactions$^{(2,3)}$.

According to reference (1), the mass $M^{(n)}$ of the $n^{\underline{th}}$ excited state is now given by:

$$M^{(n)} = \left(\eta^*_{(n)} \frac{\varepsilon^2}{2} + \frac{m_1 + m_2}{2\mu} \right) 2\mu - \Delta$$

where m_1 and m_2 are the masses of the interacting quarks, $\mu = m_1 m_2/(m_1 + m_2)$ is the reduced mass of the system and $\eta^*_{(n)}$

and ε are defined in our previous paper$^{(1)}$.

Taking into account the experimental values obtained for the mixing angle in the vector meson multiplet we can put, in a fairly good approximation, the physical states of the mesons as being:

$$\rho^o = \frac{1}{\sqrt{2}}\left[d\bar{d} - u\bar{u}\right] , \quad \phi = s\bar{s} , \quad \omega = \frac{1}{\sqrt{2}}\left[u\bar{u} + d\bar{d}\right] \quad \text{and}$$

$$K^{o*} = d\bar{s}$$

in a spin triplet configuration.

In our simple model the quarks u and d are similar, so it is not possible to distinguish ρ^o from ω. In this case ρ^o and ω would be formed by $u\bar{u}$ or by the equivalent pair $d\bar{d}$. Furthermore, we put $m_u = m_{\bar{u}} = m_d = m_{\bar{d}} = 0.340$ GeV and $m_s = m_{\bar{s}} = 0.540$ GeV $^{(4)}$.

It must be remarked that in our scheme it is not possible to distinguish the triplet state $^3\ell_J$ from the singlet state $^1\ell_J$.

(a) ρ^o, ω mesons

We assume that the ρ^o, ω mass at the fundamental state is $M_\omega^{(0)} = M_\rho^{(0)} \simeq 0.778$ GeV $^{(5)}$. There is a well established excitation at 1.600 GeV $^{(5)}$. If we consider that the resonance near to 1.250 GeV $^{(5)}$ is a possible excited state of ρ^o we can try to put $M_{\rho,\omega}^{(2)} = 1.600$ GeV. With this choice we obtain for $\ell = 1$ and $\ell = 2$ several resonant masses smaller than 1.300 GeV that are not observed experimentally. This seems to corroborate the hypothesis that the resonance at 1.250 GeV does not correspond to an excited state of ρ^{o} (6) .

The next possibility is to take $M^{(1)}_{\rho,\omega} = 1.600$ GeV . In this case we obtain, following ref. (1), $\varepsilon = 2.86$ and $\Delta = 1.327$ GeV , as unique solutions. The predicted masses for the ρ^{o} , ω and experimental results are shown in Figure 1.

Insert Figure 1

(b) ϕ mesons

Here, assuming that $M^{(0)}_{\phi} = 1.020$ GeV (5) and that $M^{(1)}_{\phi} = 1.820$ GeV (5) we get $\varepsilon = 1.82$ and $\Delta = 1.164$ GeV as unique solutions. The predicted masses for the resonances and experimental results are seen in Figure 2.

Insert Figure 2

We note that if the resonance at 1.820 GeV were taken as the second excitation, several masses not observed experimentally would appear.

(c) K^{o*} mesons

We take $M^{(0)}_{K^*} = 0.890$ GeV (5) and $M^{(1)}_{K^*} = 1.650$ GeV (9) obtaining $\varepsilon = 2.20$ and $\Delta = 1.155$ GeV , as unique solutions. The mass spectrum and the experimental results are seen in Figure 3.

Insert Figure 3

Also in this case the choice $M^{(2)}_{K^*} = 1.650$ GeV would give spurious resonances.

We can conclude, from Figures 1, 2 and 3, that there is a reasonable agreement between theory and experiment. We believe that this agreement could be improved by taking into account a more elaborate spin-orbit coupling to display in a more correct way the mass splitting for $\ell = 1$ and $\ell = 2$.

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FIGURE CAPTIONS

Figure 1 - The mass spectrum for ρ^{o}, ω mesons. Our theoretical predictions are indicated by (——) and the experimental results by (— — —). The levels $n = 0,1,2,\ldots$ correspond to the fundamental state, to the first excited state, and so on. In our notation ω_1 refers to $\omega(1675)$ and ω_2 refers to $\omega(1780)$(7) which we interpret as having $\ell = 2$.

Figure 2 - The mass spectrum for ϕ mesons. (Conventions as in Figure 1)

Figure 3 - The mass spectrum for K^{o*} mesons. (Conventions as in Figure 1). In our notation Q_1 refers to Q (1200) and Q_2 refers to Q (1400) .

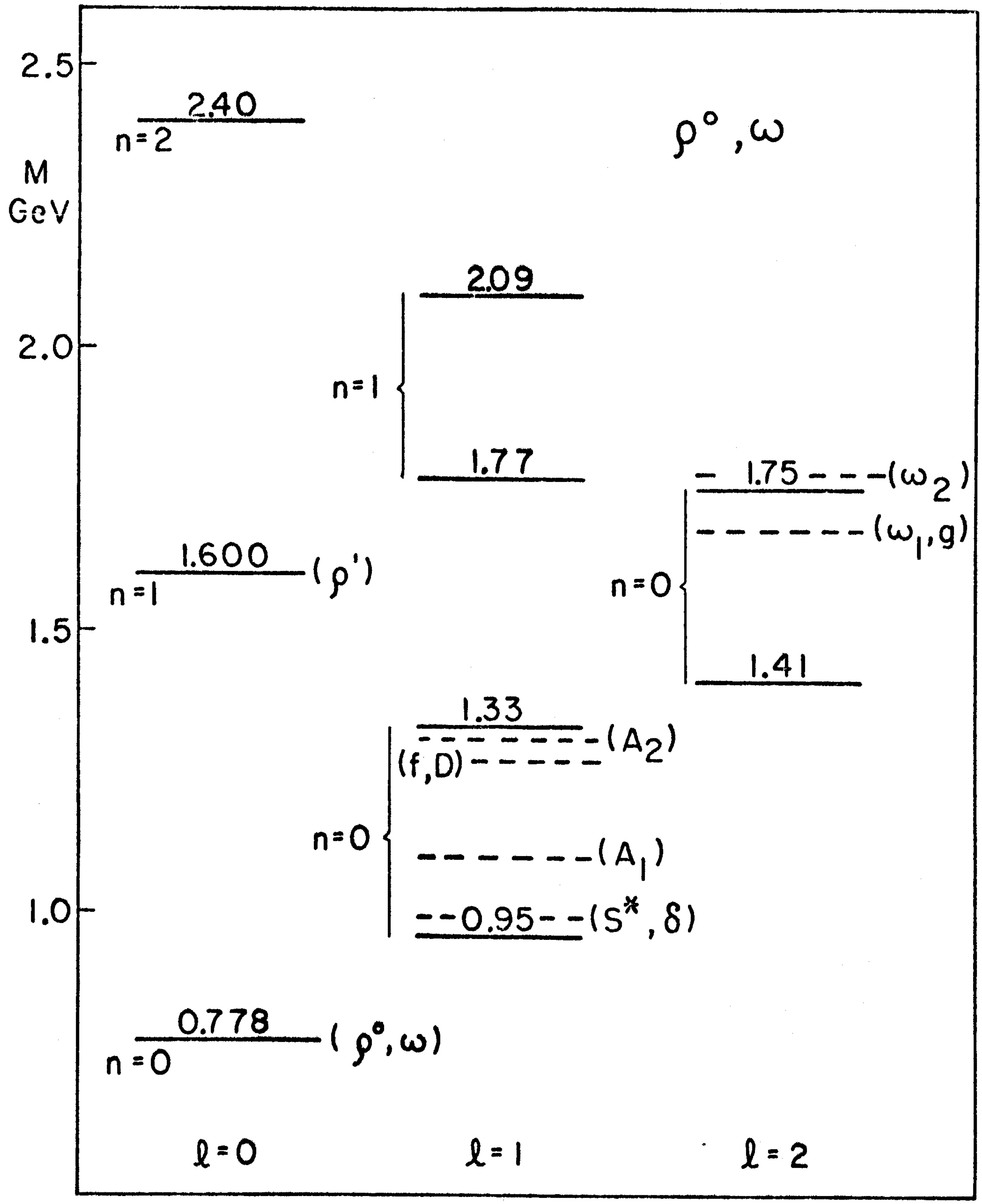
2.5
2.0
1.5
1.0
M
GeV
ρ°, ω
2.40
n=2
1.600
n=1
(ρ')
0.778
n=0
(ρ°, ω)
2.09
n=1
1.77
1.33
(A₂)
(f, D)
n=0
(A₁)
0.95
(S*, δ)
1.75
(ω₂)
(ω₁, g)
n=0
1.41
ℓ=0
ℓ=1
ℓ=2

fig: 1

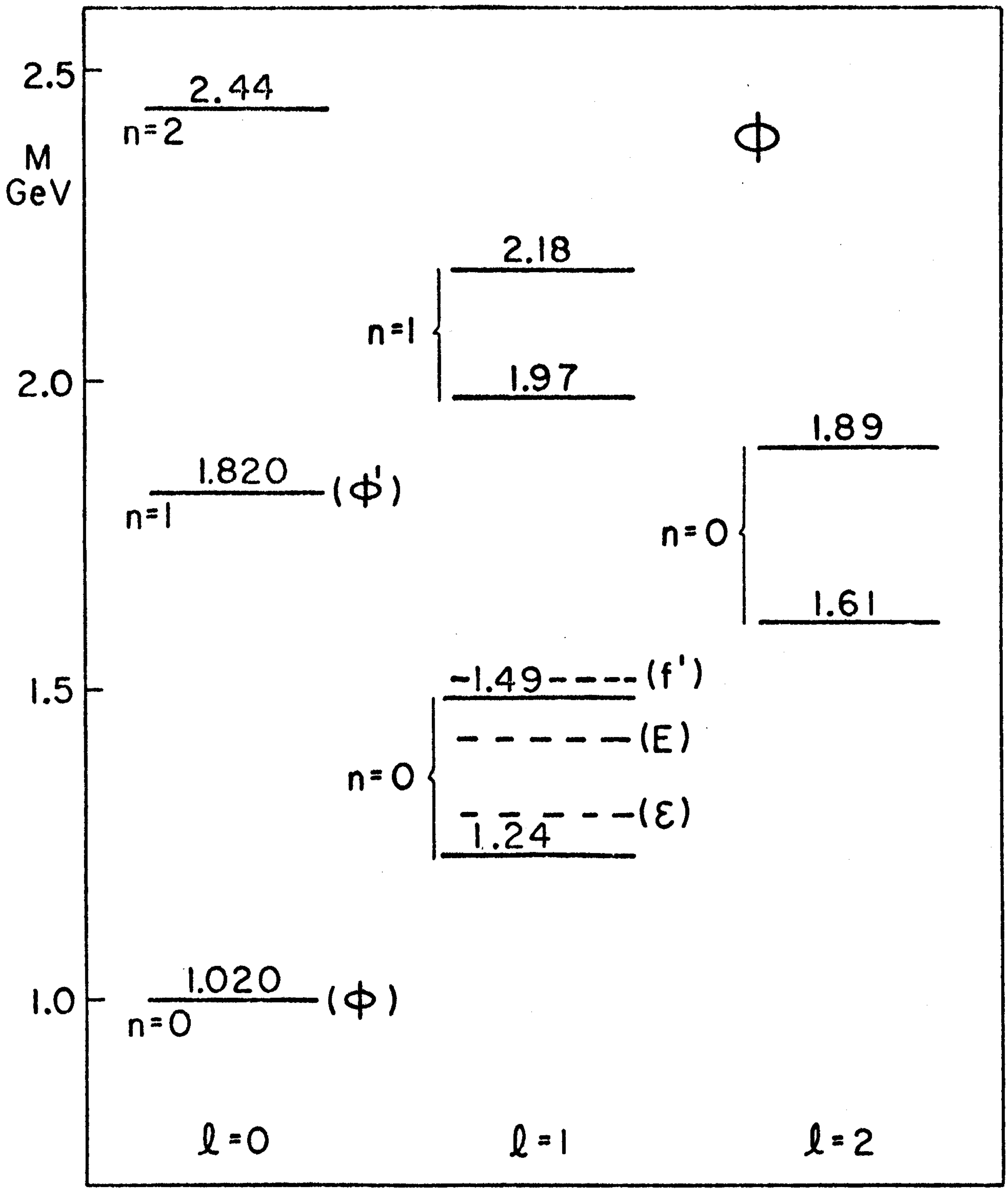
2.5
2.0
1.5
1.0
M
GeV
2.44
n=2
1.820
(ϕ')
n=1
1.020
(ϕ)
n=0
2.18
n=1
1.97
1.49
(f')
(E)
(ε)
n=0
1.24
ϕ
1.89
n=0
1.61
ℓ=0
ℓ=1
ℓ=2

fig. 2

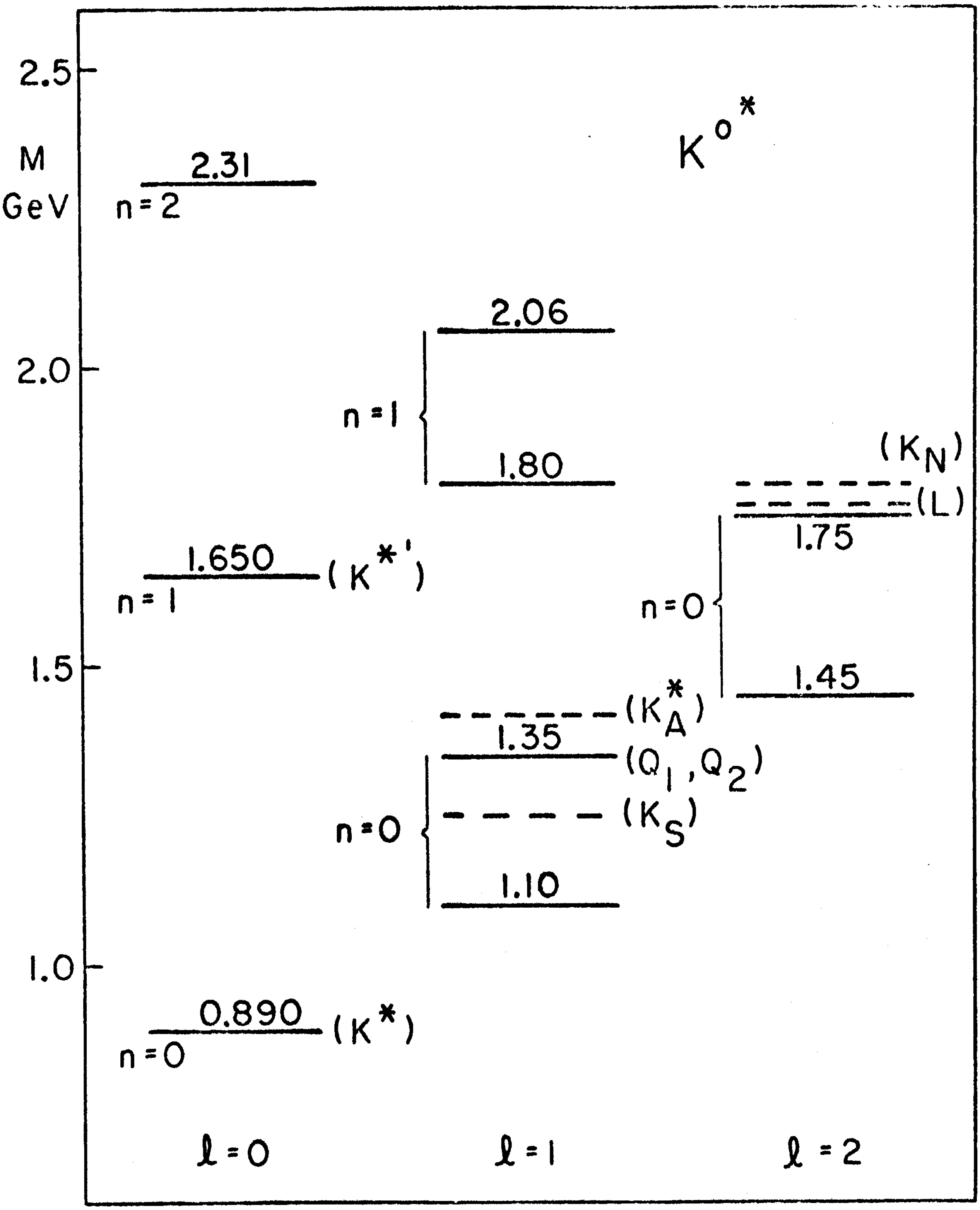
2.5
2.0
1.5
1.0
M GeV
K^{o*}
2.31
n=2
1.650 ($K^{*'}$)
n=1
0.890 (K^*)
n=0
2.06
1.80
n=1
(K_A^*)
1.35 (Q_1, Q_2)
(K_S)
n=0
1.10
(K_N)
(L)
1.75
n=0
1.45
ℓ=0
ℓ=1
ℓ=2

fig. 3