Light D wave meson spectrum in a relativistic harmonic model with instanton induced interaction

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Introduction

The mass spectrum of the D wave mesons is considered in the frame work of relativistic harmonic model (RHM).[1] The full hamiltonian used in the investigation has Lorentz scalar + vector confinement potential, along with confined one-gluon-exchange potential (COGEP) [2] and the instanton-induced quark-antiquark interaction (III) [3]. To model the III we have used the form given in [4]. One of the aims of this study is to test whether strong coupling constant (α_s) can be treated as a perturbative effect and also to determine explicitly the role played by instantons in meson spectra, when used in the framework of the RHM.

Results and Discussions

To calculate the meson masses, the product of quark-antiquark oscillator wave functions is expressed in terms of oscillator wave functions corresponding to the relative and CM coordinates. The oscillator quantum number for the CM wave functions is restricted to N_{CM} = 0. The Hilbert space of relative wave functions is truncated at radial quantum number n_{max} = 4. The Hamiltonian matrix is constructed for each meson separately in the basis states of $\left| N_{CM} = 0, L_{CM} = 0;\ ^{2S+1}L_J \right\rangle$ and diagonalised. We have obtained the D wave meson spectra using the model described above. The masses of the singlet and triplet D wave mesons after diagonalisation in harmonic oscillator basis with n_{max}= 4 are listed in table 1. The results show that III potential along with COGEP is necessary to obtain the meson mass spectra. The inclusion of III diminishes the relative importance of COGEP for the hyperfine splitting. The important role played by III in obtaining the masses of these mesons can be well understood by examining the table 2. In table 2, we have given the calculated masses of triplet D wave mesons without the inclusion of III potential. The role of III is crucial in explaining the mass differences of D wave K mesons. In case of singlet D wave mesons, tensor and spin-orbit terms of COGEP and III do not contribute to the masses. In case of these singlet mesons the CE part of COGEP is attractive, whereas the CM part of COGEP is repulsive. The dominant contribution to the calculated masses comes from the confinement potential. In case of triplet D wave mesons the contribution of III potential is very significant. We note that the significant contribution to the masses of 1^3D_1 mesons arises from the tensor term of III which is attractive. The tensor term involves the parameters k_7 and k_8. It was necessary to tune k_7 and k_8 parameters to get a reasonably good agreement with the experimental masses. For 1^3D_1 mesons along with the tensor contribution of III, the spin orbit contribution of III is also significant and is attractive. The contribution of tensor term of III in case of 1^3D_2 is repulsive that significantly increases the value of calculated mass. It is to be noted that the anti-symmetric spin orbit potential of III contributes substantially to the mass difference between the 1^1D_2 and 1^3D_2 mesons in the K meson sector. The mass difference between K*(1680) and K_2(1820) mesons is due to the large difference in tensor part of III potential.

The tensor III potential is attractive for K*(1680) but is repulsive for K_2(1820). In case of 1^3D_3 mesons the contribution due to spin-orbit part of III potential is dominant compared to that of tensor part which is repulsive. From table 1 it is clear that the calculated meson masses are in good agreement with the experimental masses [5].

Conclusions

We have investigated the effect of the III on the masses of the D wave mesons in the frame work of RHM. We have shown that the computation of the masses using only COGEP is inadequate. The contribution of the III is found to be significant. To obtain the masses of D wave mesons, 5x5 Hamiltonian matrix was diagonalised. The contribution from the tensor and spin-orbit part of the III is found to be significant in case of triplet D wave mesons. To obtain the physical masse of mesons in the D wave K sector it is necessary to include the anti-symmetric part of III. There is a good agreement between the calculated and experimental masses of D wave mesons with the inclusion of III.

References

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Table 1. Masses of the singlet and triplet mesons (in MeV)

$N^{2S+1}L_J$	Meson	Exptl. Mass	Cal. Mass
1^1D_2	π_2 (1670)	1670±2	1673.8
	K_2 (1770)	1773±8	1768.8
1^3D_1	ω(1650)	1649 ± 2	1649.6
	K*(1680)	1717 ± 3	1718.9
1^3D_2	K_2(1820)	1816±1	1818.6
1^3D_3	ω_3 (1670)	1667 ± 4	1667.8
	K*(1780)	1776 ± 7	1778.3
	ϕ_3 (1850)	1854 ± 7	1855.9

Table 2. Masses of the triplet mesons without III (in MeV)

Meson	Experimental Mass	Calculated Mass without III
ω(1650)	1649 ± 24	1676.3
K*(1680)	1717 ± 27	1770.9
K_2(1820)	1816 ±13	1768.2
ω_3 (1670)	1667 ± 4	1670.4
K*(1780)	1776 ± 7	1765.9
ϕ_3 (1850)	1854 ± 7	1861.4