S-wave masses of the D_s meson

Virendrasinh Kher[1*] and Nayneshkumar Devlani[1†]
Applied Physics Department, Polytechnic, The MS University of Baroda, Vadodara, INDIA 390 002

Ajay Kumar Rai[2‡]
Department of Applied Physics, SV National Institute of Technology, Surat, INDIA 395 007

Introduction

The S-wave masses of the ground states 1^3S_1 and 1^1S_0 as well as one of the radially excited states 2^3S_1 of the D_S mesons are very well established experimentally[1]. Since D_s meson is a heavy-light quark system, study of this meson provides insight into the quark dynamics.

In this article some of the S-wave state masses of the D_s meson are obtained using phenomenological potential model including $\mathcal{O}(1/m)$ correction to the potential. Since this is a heavy-light quark system due to the presence of light quark, kinematic relativistic corrections play an important role.

Methodology

For the present study we employ the hamiltonian[2]

$$H = \sqrt{\mathbf{p}^2 + m_Q^2} + \sqrt{\mathbf{p}^2 + m_Q^2} + V(r); \quad (1)$$

where m_i are the quark masses and the potential $V(r)$ is given by[3, 4],

$$V(r) = -\frac{4\alpha_S}{3r} + Ar - \left(\frac{1}{m_Q} + \frac{1}{m_{\bar{q}}}\right) + V_0, \quad (2)$$

here α_S is the running strong coupling constant, A is a potential parameter and V_0 is a constant. We expand the hamiltonian up to order $\mathbf{p}^6$. The value of the QCD coupling constant α_S is determined as in ref. [5].

In the present calculation we have employed $A = 0.135$, GeV^2, $\alpha_S = 0.640$, $m_c = 1.35$ GeV and $m_{\bar{s}} = 0.55$ GeV. We use variational method in which the trial wave function is a Gaussian. The position space wave function is given by

$$R_{nl}(\mu, r) = \mu^{3/2}\left(\frac{2\,(n-1)!}{\Gamma\,(n+l+1/2)}\right)^{1/2} \times (\mu r)^l\, e^{-\mu^2 r^2/2} L_{n-1}^{l+1/2}(\mu^2 r^2); \quad (3)$$

and in the momentum space it is

$$R_{nl}(\mu, p) = \frac{(-1)^n}{\mu^{3/2}}\left(\frac{2\,(n-1)!}{\Gamma(n+l+1/2)}\right)^{1/2} \times \left(\frac{p}{\mu}\right)^l e^{-p^2/2\mu^2} L_{n-1}^{l+1/2}\left(\frac{p^2}{\mu^2}\right) \quad (4)$$

μ is a variational parameter and L is Laguerre polynomial. The variational parameter μ is determined by making use of the virial theorem[6]

$$\langle K.E. \rangle = \left\langle \frac{dV}{rdr} \right\rangle. \quad (5)$$

The kinetic energy part is evaluated by making use of the wave function in momentum space whereas the potential energy part is evaluated with the help of wave function in position space. With this value of μ spin-averaged(SA) mass of D_s meson is obtained by using

$$H\psi = E\psi. \quad (6)$$

The ground state spin-averaged mass is matched with the experimental spin-averaged mass in order to determine the constant V_0.

*Electronic address: vhkher@yahoo.com
†Electronic address: nayneshdev@gmail.com
‡Electronic address: raiajayk@gmail.com

State	Present work	Expt.[1]	Ref. [7]	Ref. [8]	Ref. [9]	Ref. [10]
1^1S_0	1.962	1.968	1.969	1.975	1.940	1.965
1^3S_1	2.108	2.112	2.111	2.108	2.130	2.113
2^1S_0	2.684		2.688	2.659	2.610	2.700
2^3S_1	2.722	2.710^{+12}_{-7}	2.731	2.722	2.730	2.806
3^1S_0	3.265		3.219	3.044	3.090	3.259
3^3S_1	3.283		3.242	3.087	3.190	3.345
4^1S_0	3.798		3.652	3.331		
4^3S_1	3.809		3.669	3.364		

TABLE I: S-wave masses of the D_s meson(in GeV).

Fitted value of constant $V_0 = -0.123$ GeV. By making use of the fitted ground state parameters further radially excited state masses are obtained. The calculated values of the masses of the various S-wave states are listed in table I.

Summary and conclusions

Mass spectra of the S-wave states of the D_s meson are obtained by making use of a phenomenological potential model within variational scheme. Kinematic relativistic corrections as well as $\mathcal{O}(1/m)$ corrections are employed within the interquark potential.

From the table I it is observed that the ground state masses are in fairly good agreement with the experimentally observed masses as well as predictions from the other theoretical schemes. Our results for the experimentally observed state 2^3S_1 are also in fairly good agreement with experimental measurement as well as other theoretical predictions. Due to the unavailability of sufficient experimental data it is difficult to single out any model.

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