Masses and decay rates of Charmonia

Zalak Marfatia[1*] and Ajay Kumar Rai[1]
[1]*Department of Applied Physics, SVNIT, Surat - 395 007, INDIA*

Introduction

The heavy flavored mesons spectroscopy is now interesting and challenging due to number states observed experimentally [1] and their possible theoretical explanation as mesons, baryons and exotic states [2]. Charmonia are charmed quark and its anti-quark ($c\bar{c}$) system belong to a heavy flavor mesons. Properties like mass spectra and radiative decays are influenced by relativistic effects. The mass spectra of charmonia (such as η_c, J/ψ or ψ) are calculated in the framework of quark model using relativistic correction to the kinetic energy term. We also calculate the decay widths with in nonrelativistic QCD (NRQCD) approach [3].

Theoritical framework

We consider a Hamiltonian given by[4],

$$H = \sqrt{p^2 + m_Q^2} + \sqrt{p^2 + m_{\bar{Q}}^2} + V(r) \quad (1)$$

where, p is the relative momentum of two quarks and V(r) is quark anti-quark potential.We have taken the quark mass parameters m_c =1.45 GeV. We use potential of the form

$$V(r) = -\frac{\alpha_c}{r} + Ar^v + V_0 \quad (2)$$

where $\alpha_c = \frac{4}{3}\alpha_s$, α_s is the strong running coupling constant, A is the potential parameter with constant value and ν is power index,which varies from 0.7 to 1.3. We solve

$$H\psi = E\psi \quad (3)$$

*Electronic address: raiajayk@gmail.com

TABLE I: Spin average masses(in GeV) of the S-wave $c\bar{c}$ mesons.

State	ν	$\bar{\mu}$ GeV	$\|R(0)\|$ $GeV^{\frac{3}{2}}$	$E(\bar{\mu})$ (GeV)	Exp. [1] (GeV)
1S	0.7	1.1	0.8516	3.068	
	0.9	1.216	0.948	3.068	
	1.0	1.270	1.012	3.068	3.068
	1.1	1.324	1.077	3.068	3.067[5]
	1.2	1.376	1.141	3.068	
	1.3	1.428	1.207	3.068	
2S	0.7	1.613	0.362	3.383	
	0.9	1.801	0.427	3.466	
	1.0	1.890	0.460	3.508	3.674
	1.1	1.981	0.492	3.551	3.673[5]
	1.2	2.070	0.526	3.595	
	1.3	2.155	0.559	3.639	
3S	0.7	1.913	0.103	3.623	
	0.9	2.165	0.125	3.787	
	1.0	2.288	0.136	3.873	
	1.1	2.410	0.147	3.963	4.027 [5]
	1.2	2.530	0.158	4.056	
	1.3	1.647	0.169	4.151	
4S	0.7	2.127	0.022	3.817	
	0.9	2.432	0.027	4.060	
	1.0	2.583	0.0306	4.191	4.421 [5]
	1.1	2.733	0.0332	4.330	
	1.2	2.880	0.0332	4.475	
	1.3	3.024	0.0387	4.627	

using Hydrogenic radial wave function.

$$R(r) = \sqrt{\frac{\mu^3(n-l-1)!}{2n(n+l)!}}(\mu r)^l e^{-\mu r/2} L_{n-l-1}^{2l+1}(\mu r) \quad (4)$$

Here, μ is the variational parameter and L_{n-l-1}^{2l+1} is Laguerre polynomial.

$$M_{SA} = M_P + \frac{3}{4}(M_V - M_P) \quad (5)$$

TABLE II: Di-gamma decay rates(in keV) of $\eta_c(0^{-+} \rightarrow \gamma\gamma)$

Models	Γ_0	Γ_B	Γ_C	Γ_R	Γ_T	Γ_{NRQCD}	Γ Expt.[1]
0.7	8.912	0.6283	-0.8377	-2.948	5.755	5.441	5.0±0.4
0.9	12.005	0.6866	-0.9154	-3.972	7.807	7.487	
1.0	13.676	0.6854	-0.9139	-4.523	8.924	8.617	
1.1	15.483	0.6588	-0.8784	-5.121	10.142	9.860	
1.2	17.355	0.6030	-.8040	-5.741	11.414	11.166	
1.3	19.364	0.5116	-0.6822	-6.405	12.788	12.589	

TABLE III: Di-leptonic decay rates (in keV) of J/$\psi(1^{--} \rightarrow l^+l^-)$

Models	Γ_{VW}	Γ_{rad}	Γ_{Corr}	Γ_T	Γ_{NRQCD}	Γ Expt.[1]
0.7	6.695	-3.497	0.275	3.472	3.613	5.55±0.14 ± 0.02
0.9	9.032	-4.719	0.384	4.698	4.981	
1.0	10.297	-5.379	0.447	5.365	5.747	
1.1	11.670	-6.097	0.518	6.091	6.599	
1.2	13.098	-6.843	0.593	6.849	7.507	
1.3	14.637	-7.647	0.679	7.670	8.511	

Using equation(5), we calculate the spin average mass of $c\bar{c}$. The spin average charmonium mass spectrum is given in Table-(I).
As an attempt to improve the theoretical predictions involving the phenomenological description of the meson,using the radial wave function and other model parameters of the potential model we study the decay of $^1S_0$ quarkonium into di-γ and the decay $^3S_1$ into lepton pairs using the NRQCD formalism[3].The computed decay widths for pseudoscalar are presented in Table II and for vector mesons are listed in Table III.

Results and disscussions

The pseudoscalar and vector mesons masses are computed using the relativistic corrections of kinetic energy term. The decay rates of pseudoscalar mesons ($0^{-+} \rightarrow \gamma\gamma$) and vector mesons ($1^{--} \rightarrow l^+l^-$) are computed using the Van Royen-Weisskopf formula as well as in NRQCD formalism. The obtain results are in good agreement with experimental results, listed in Table-(II-III). Details of these studies will be presented in the conference.

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