Spectra of Ω Baryon

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Introduction

The strange baryon sector in octet and decuplet is not fully explored even through many experimental facilities worldwide. The presence of one or more strange quarks thus possess a great realm to study the underlying interactions. Hadron spectroscopy has been a tool towards such studies for heavy as well as light baryons with a target to obtain resonance masses of orbital and radial states as well as other baryonic properties. The present article is dedicated to Ω baryon in the decuplet family.

Ω^- baryon constituted of 3 strange quarks leading to isospin I=0 and strangeness S=-3. The small production cross-section in the experimental study of baryons with strange quarks posses difficulty. After the very early first observation of Ω ground state 1672 MeV [1], recent studies at Belle experiments have provided with some results as Ω(2012) through e^+e^- annihilations and into $\Xi^0 K^-$ as well as $\Xi^- \bar{K}^0$ decay channels [2]. BaBar collaboration attempted to study the spin of $\Omega^-(1672)$ for $J = \frac{3}{2}$ through the decay of Ω_c^0 and Ξ_c^0 [3].

Attempts have been made to exploit Ω baryon through various approaches. Few of them include the one using constituent quark model by Pervin *et al.* [4], Skyrme model by Y. Oh [5] as well as relativistic quark model by Faustov *et al.* [6]. Ω(2012), a three star state has been a matter of discussion as few studies point it to be a molecular state and other studies don't [7].

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Theoretical Background

The non-relativistic hypercentral Constituent Quark Model (hCQM) has been employed for obtaining resonance masses from light to heavy baryons [8–10]. The potential consists of a Coulomb-like term and a confining term which is of linear nature in the current study [11–13]. The model itself points that the potential is hypercentral i.e. depending only on hyperradius x, obtained using Jacobi coordinates. Jacobi coordinates takes care of the three body dynamics as given below.

$$\rho = \frac{1}{\sqrt{2}}(\mathbf{r_1} - \mathbf{r_2}); \;\; \lambda = \frac{1}{\sqrt{6}}(\mathbf{r_1} + \mathbf{r_2} - 2\mathbf{r_3})$$

$$x = \sqrt{\boldsymbol{\rho^2} + \boldsymbol{\lambda^2}}; \;\; \xi = arctan(\frac{\rho}{\lambda})$$

here x is hyperradius and ξ is hyperangle.

$$V(x) = -\frac{\tau}{x} + \alpha x + V_{SD}(x) + V^1(x)$$

Here, V_{SD} looks for the spin-dependent terms to include the possible distinction for a given state. The first order correction in the potential has been introduced as $\frac{1}{m}$ dependence of the form

$$V^1(x) = -\frac{{\alpha_s}^2}{mx^2}$$

α_s being the strong running coupling constant. Now, the complete Hamiltonian can be written as

$$H = \frac{P^2}{2m} + V^0(x) + V_{SD}(x) + V^1(x)$$

The Schrodinger equation has been numerically solved to obtain the resonance masses.

Results and Discussion

The earlier work on light, strange baryons of octet and decuplet has been extended here for Ω baryon [14]. The radial and orbital excited states have been as depicted in the table. The possible J^P values have been incorporated for spin $S = \frac{1}{2}$ and $S = \frac{3}{2}$.

TABLE I: Experimental state of Ω baryon [1]

State	J^P	Status
Ω(1672)	$\frac{3}{2}^+$	****
Ω(2012)	$?^-$	***
Ω(2250)		***
Ω(2380)		**
Ω(2470)		**

TABLE II: Resonance Mass (in MeV)

State	J^P	$Mass_{cal}1$	$Mass_{cal}2$
1S	$\frac{3}{2}^+$	1672	1672
2S	$\frac{3}{2}^+$	2057	2068
$1^2P_{1/2}$	$\frac{1}{2}^-$	1987	1996
$1^2P_{3/2}$	$\frac{3}{2}^-$	1978	1985
$1^4P_{1/2}$	$\frac{1}{2}^-$	1992	2001
$1^4P_{3/2}$	$\frac{3}{2}^-$	1983	1991
$1^4P_{5/2}$	$\frac{5}{2}^-$	1970	1997

The comparison of masses has been done for without and with first order correction in the potential term. As the Ω baryon is least explored experimentally, commenting on the calculated masses is difficult [15]. The upcoming experiments like PANDA [16, 17] shall be of great importance towards the study of light and strange sector where more experimental states shall be observed to reveal yet unknown properties of Ω baryon.

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