S-Wave spectroscopy of Ω baryon in a relativistic Dirac formalism using the independent Quark model

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Abstract: Ω_c^0 baryon is the center of attraction for many researchers after the discovery of different states all together in the single decay $\Omega_c^0 \rightarrow \Xi_c^+ K^-$. These states are $\Omega_c^0(2695)$, $\Omega_c^0(2770)$, $\Omega_c^0(3000)$, $\Omega_c^0(3050)$, $\Omega_c^0(3067)$, $\Omega_c^0(3090)$ & $\Omega_c^0(3120)$. Thus, we investigate the S-wave of Ω_{tssc} in the relativistic Dirac formalism. The spectroscopy is performed using the independent quark model in which the spin-average masses are obtained by summing the individual Dirac energy of the constituent quarks under the mean field confinement of Martin-like potential with a parametric center of mass correction. We find the spin-average masses of low lying S-wave. the spin degeneracy is removed by considering the spin-spin$(j \cdot j)$ interaction. The best-fitted potential parameters yielded the estimation of the ground state masses in very good agreement with experimental data. The computed masses of $1S(\frac{3}{2}^+)$, 2768.84 MeV and $1S(\frac{1}{2}^+)$, 2698.14 MeV are very close to the experimentally observed states $\Omega_c^0(2770)$ and $\Omega_c^0(2695)$ respectively. We also predict the experimentally observed state $\Omega_c^0(3120)$ is 3119 MeV as 2S$(\frac{3}{2}^+)$ state and the 2S$(\frac{1}{2}^+)$ at 3047 MeV which is identified here as $\Omega_c^0(3050)$. Higher S state doublets are also predicted which will be useful for the identification of future experimental data. Other states may be related to the orbital excited states and will be estimated by incorporating the spin orbit and tensor interactions among the confined quarks.

Methodology:

- The Independent Confinement of Quarks in Baryon

$$V(r) = \frac{1}{2}(1+\gamma_0)(\lambda r^{0.1} + V_0)$$

- The Spin-Average Mass of a Baryon

$$M_{SA}^{Qqq} = E_Q^D + 2E_q^D - E_{CM}$$

[1] M. Shah et al. Phys. Rev. D 90, no.1, 014009 (2014).

[2] M. Shah et al. Eur. Phys. J. C 76, no.1, 36 (2016).

[3] M. Shah et al. Phys. Rev. D 93, no.9, 094028 (2016).

$$[\gamma^0 E_q - \vec{\gamma}\vec{P} - m_q - V(r)]\psi_q(\vec{r}) = 0$$

[4] N. Barik and S. n. Jena, Phys. Rev. D 26, 24202429 (1982).

$$\frac{d^2 U^{\mathrm{Sch}}(\rho)}{d\rho^2} + \left[\epsilon^{\mathrm{Sch}} - \rho^{v} - \frac{l(l+1)}{\rho^2}\right] U^{\mathrm{Sch}}(\rho) = 0$$

$$\frac{d^2 U^{\mathrm{Dir}}(\rho)}{d\rho^2} + \left[\epsilon^{\mathrm{Dir}} - \rho^{v} - \frac{l(l+1)}{\rho^2}\right] U^{\mathrm{Dir}}(\rho) = 0$$

- The Spin-Spin (j · j) Interaction

$$\langle V^{jj}_{Qqq}(r)\rangle = \sum_{i=1,i<k}^{i,k=3} \frac{\sigma\langle j_i j_k JM|\hat{j}_i\hat{j}_k|j_i j_k JM\rangle}{(E_{q_i}+m_{q_i})(E_{q_k}+m_{q_k})}$$

TABLE I : S state of Ω_c^0 in GeV

$n^{2S+1}S_J$	M_{SA}^{Qqq}	$\langle V_{Qqq}^{jj}(r)\rangle$	Our	Experiment[5]	[6]	[7]	[8]
$1^2S_{\frac{1}{2}}$	2.742	-0.044	2.698	2.695	2.699	2.698	2.695
$1^4S_{\frac{3}{2}}$	2.742	0.026	2.769	2.766	2.762	2.768	2.767
$2^2S_{\frac{1}{2}}$	3.081	-0.034	3.047	-	3.15	3.088	3.1
$2^4S_{\frac{3}{2}}$	3.081	0.021	3.102	3.119	3.197	3.123	3.126
$3^2S_{\frac{1}{2}}$	3.278	-0.030	3.248	-	3.308	3.489	3.436
$3^4S_{\frac{3}{2}}$	3.278	0.018	3.296	-	3.346	3.51	3.45
$4^2S_{\frac{1}{2}}$	3.419	-0.027	3.392	-	3.557	3.814	3.737
$4^4S_{\frac{3}{2}}$	3.419	0.016	3.436	-	3.526	3.83	3.745
$5^2S_{\frac{1}{2}}$	3.530	-0.026	3.504	-	-	4.114	4.015
$5^4S_{\frac{3}{2}}$	3.530	0.015	3.546	-	-	4.102	4.021

[5] R. Aaij et al. [LHCb], Phys. Rev. Lett. 124, no.8, 082002 (2020).
[6] G. L. Yu, et al. [arXiv:2206.08128 [hep-ph]].
[7] D. Ebert, et al. Phys. Rev. D 84, 014025 (2011).
[8] Z. Shah, K. Thakkar, A. K. Rai and P. C. Vinodkumar, Chin. Phys. C 40, No.12, 123102 (2016).

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Thank You