Masses of the Five New Narrow States of Neutral Charmed Omega Baryon Calculated Within the Atom-Like Structure of Baryons

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Abstract: The phase transitions of the inflation field, which are described within the Scale-Symmetric Theory (SST), lead to the atom-like structure of baryons. Here, within such a model, we calculated mass of the charged charmed Xi baryon (2467.89 MeV) and mass of neutral one (2468.51 MeV). We calculated also mass of ground state of the neutral charmed Omega baryon (2949.02 MeV) - it is below the threshold mass (2961.61 MeV) for the decay to charged charmed Xi (2467.93) and charged kaon (493.68 MeV), and we calculated masses of the five new narrow states of the neutral charmed Omega baryon with a mass of 2949.02 MeV: 3000 MeV (it is the ground state above the threshold mass), 3051 MeV, 3067 MeV, 3084 MeV, and 3118 MeV. We showed as well that there should be a structure around 3186 MeV. Within presented here model, we calculated mass of the charm quark (1276.4 MeV).

1. Introduction

Recently, the LHCb collaboration have reported the discovery of the five new narrow states of neutral charmed Omega baryons $\Omega*_c^o$ [1]. Here, applying the Scale-Symmetric Theory (SST), we showed the origin of such resonances and we calculated mass of the charm quark.

Table 1 *Masses of neutral loops,* $\mathbf{m_{S(o)}}$*, and relativistic masses of neutral pion,* $\mathbf{m_{W(o)}}$*, in d states in baryons* [2]

d	$\mathbf{m_{S(o)}}$ [MeV]	$\mathbf{m_{W(o)}}$ [MeV]
1	421.494	208.643
2	297.151	175.709
4	186.886	156.668

The phase transitions of the inflation/Higgs field, which are described within SST, lead to the atom-like structure of baryons [2]. There appear the d shells. Calculated masses of neutral loops (they are composed of the entangled Einstein-spacetime (ES) components [2]) and relativistic masses of neutral pion in the d states are collected in Table 1. The shells lead to the origin of the charmed baryons and mass of the charm quark.

2. Calculations

At higher energies of collisions of protons, there is created a structure S^o composed of the three different $S(o)$ loops which interact electromagnetically with proton – it causes that due to the emitted electromagnetic energy, mass of the S^o structure is lower than the ordinary sum. To obtain the correct mass of S^o, we must multiply the ordinary sum by $(1 - \alpha_{em})$, where $\alpha_{em} = 1 / 137.036$ is the fine structure constant [2], [3]

$$S^o(899) \equiv \Sigma_{d=1,2,4}\, S(o)_d \equiv (421.49 + 297.15 + 186.89)(1 - \alpha_{em}) = 898.92 \text{ MeV}. \quad (1)$$

SST shows that in $\Xi_c^{\ +} \equiv [p\ S^o(899)\ K^-\ \pi^+$ or $p\ S^o(899)\ K^o\ \pi^o]$, besides the S^o structure, there is a pair $K^-\ \pi^+$ or $K^o\ \pi^o$ – when the constituents are charged then, due to the electromagnetic interaction, there as well appears the factor $(1 - \alpha_{em})$. Masses of kaons and pions are calculated within SST also [2]. We obtain

$$K^-\ \pi^+ \equiv (493.73 + 139.57)(1 - \alpha_{em}) = 628.68 \text{ MeV}. \quad (2a)$$
$$K^o\ \pi^o \equiv (497.76 + 134.98) = 632.74 \text{ MeV}. \quad (2b)$$

We know that probability is inversely proportional to mass so for $K^-\ \pi^+$ is 0.50161 whereas for $K^o\ \pi^o$ is 0.49839. It leads to the mean value for $K\ \pi$

$$K\ \pi \equiv 630.70 \text{ MeV}. \quad (3)$$

SST leads to following central value for $\Xi_c^{\ +}$

$$\Xi_c^{\ +} \equiv [p\ S^o(899)\ K\ \pi] = 2467.89 \text{ MeV}, \quad (4)$$

where $p \equiv 938.27$ MeV is calculated within SST [2].This value is very close to the central value of the world-average mass 2467.85 MeV [3]!

SST show that in $\Xi_c^{\ o} \equiv [p\ S^o(899)\ K^-\ \pi^o$ or $p\ S^o(899)\ K^o\ \pi^-]$, besides the S^o structure, there is a pair $K^-\ \pi^o$ or $K^o\ \pi^-$ – when a constituent is charged then, due to the electromagnetic interaction, there as well appears the factor $(1 - \alpha_{em})$. We obtain

$$K^-\ \pi^o \equiv 493.73\ (1 - \alpha_{em}) + 134.98 = 625.11 \text{ MeV}. \quad (5a)$$
$$K^o\ \pi^- \equiv 497.76 + 139.57\ (1 - \alpha_{em}) = 636.31 \text{ MeV}. \quad (5b)$$

We know that probability is inversely proportional to mass so for $K^-\ \pi^o$ is 0.50444 whereas for $K^o\ \pi^-$ is 0.49556. It leads to the mean value for $K\ \pi$

$$K\ \pi \equiv 630.66 \text{ MeV}. \quad (6)$$

We obtain

$$\Xi_c^o(p) \equiv [p\ S^o(899)\ K\ \pi] = 2467.85\ \text{MeV}. \quad (7)$$

Notice that there can be $\Xi_c^o(n) \equiv [n\ S^o(899)\ K^o\ \pi^o$ or $n\ S^o(899)\ K^-\ \pi^+] = 2469.16$ MeV. Mean value is $\Xi_c^o = (\Xi_c^o(p) + \Xi_c^o(n)) / 2 = 2468.51$ MeV.

The next less massive structure S^o has mass

$$S^o(481) \equiv \Sigma_{d=2,4}\ S(o)_d \equiv (297.15 + 186.89)(1 - \alpha_{em}) = 480.51\ \text{MeV}. \quad (8)$$

SST suggests that the ground state of the neutral charmed Omega baryon Ω_c^o consists of

$$\Omega_c^o \equiv [\Xi_c^o\ S^o(481)] = 2949.02\ \text{MeV}. \quad (9)$$

We can assume that mass of the charm quark, $m_{q(c)}$, should be close to the mass distance between Ω_c^o and Ω^- which mass is calculated within SST (1672.575 MeV [4])

$$m_{q(c)} \approx \Omega_c^o - \Omega^- = 1276.4\ \text{MeV}. \quad (10)$$

This value is consistent with the PDG result [3].

The mass of $\Omega_c^o(2949)$ is below the energy threshold, $E_{threshold}$, for decay of Ω_c^o to Ξ_c^+ and K^-

$$E_{threshold} = 2467.89 + 493.73 = 2961.62\ \text{MeV}. \quad (11)$$

To obtain the ground state for decay of Ω_c^o to Ξ_c^+ and K^-, we must find the excited states of Ω_c^o which we denote by $\Omega*_{c,n}^o$.

During the energetic collisions of protons, there, first of all, are produced the S^o loops and the loops inside the core of baryons that are responsible for the nuclear strong interactions (their mass is $m_{LL} = 67.54$ MeV – the neutral pions are the binary systems of such loops [2]). The transitions of the relativistic pions W^o from the $d = 1$ state to $d = 2$ state cause that there appear masses $m_{\Delta W} = 32.93$ MeV (see Table 1) – relativistic mass of them in $d = 1$ state is $m_{\Delta W,rel} = 50.91$ MeV [2].

The masses $m_{\Delta W,rel} = 50.91$ MeV and $m_{LL} = 67.54$ MeV can lead to the excited states of $\Omega_c^o(2949.02)$

$$\Omega*_{c,n=1,ground}^o = \Omega_c^o + m_{\Delta W,rel} = 2999.93\ \text{MeV} \approx 3000\ \text{MeV}, \quad (12a)$$
$$\Omega*_{c,n=2}^o = \Omega*_{c,n=1,ground}^o + m_{\Delta W,rel} = 3050.84\ \text{MeV} \approx 3051\ \text{MeV}, \quad (12b)$$
$$\Omega*_{c,n=3}^o = \Omega*_{c,n=1,ground}^o + m_{LL} = 3067.47\ \text{MeV} \approx 3067\ \text{MeV}, \quad (12c)$$
$$\Omega*_{c,n=4}^o = \Omega*_{c,n=3}^o + m_{\Delta W,rel} = 3118.38\ \text{MeV} \approx 3118\ \text{MeV} \quad (12d)$$

or

$$\Omega*_{c,n=4}^o = \Omega*_{c,n=2}^o + m_{LL} = 3118.38\ \text{MeV} \approx 3118\ \text{MeV}, \quad (12e)$$
$$\Omega*_{c,n=5}^o\ \text{(broadened)} = \Omega_c^o + 2\ m_{LL} = 3084.10\ \text{MeV} \approx 3084\ \text{MeV}, \quad (12f)$$
$$\Omega*_{c,n=6}^o\ \text{(broadened)} = \Omega_c^o + 2\ m_{\Delta W,rel} + 2\ m_{LL} = 3185.92\ \text{MeV} \approx 3186\ \text{MeV}. \quad (12g)$$

Masses of the excited states, $\Omega*_{c,n}^o$, are consistent with experimental data [1]. Due to the binary systems with masses of $2m_{\Delta W,rel}$ and $2m_{LL}$, which can transform into the pion-like particles, which can be exchanged between the colliding protons (so there appear the nuclear strong interactions), the excited states $\Omega^*{}_{c,n=5}{}^o$ and $\Omega^*{}_{c,n=6}{}^o$ are more broadened. Due to the masses, the width Γ_6 is higher than Γ_5.

3. Summary

Here, applying the atom-like structure of baryons described within SST, we calculated following masses: $\Xi_c{}^+$(2467.89), $\Xi_c{}^o$(2468.51), $\Omega_c{}^o$(2949.02), $m_{q(c)}$(1276.4), and the masses of excited states of $\Omega_c{}^o$: $\Omega^*{}_c{}^o$(3000) (it is the ground state for the decay to $\Xi_c{}^+$(2467.89) K^-), $\Omega^*{}_c{}^o$(3051), $\Omega^*{}_c{}^o$(3067), $\Omega^*{}_c{}^o$(3118), $\Omega^*{}_c{}^o$(3084) (broadened), and $\Omega^*{}_c{}^o$(3186) (broadened). Obtained results are consistent or very close to experimental data.

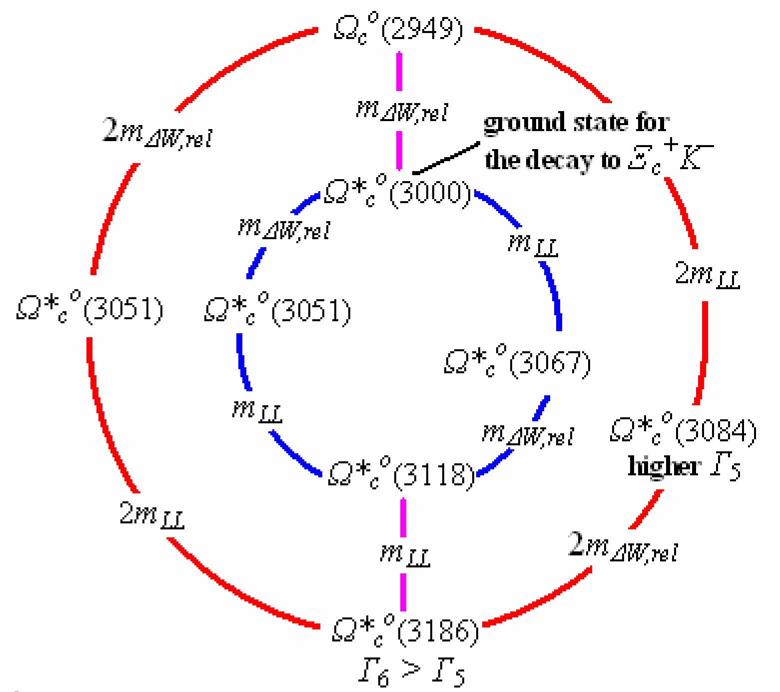

Fig.1
The excited states of neutral charmed Omega baryon

References

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