New Physics Resulting from Far Too Large a Mass Distance between the Doubly Charmed Baryons Ξ_{cc}

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Abstract: The Standard Model (SM) and experimental data show that the change of the up quark for down quark increases the mass of nucleon by about 1 MeV. On the other hand, SM and experimental results show that the same change in the doubly charmed baryons Ξ_{cc} decreases the mass by about 100 MeV. Within the SM we cannot explain such two major inconsistencies (i.e. 100 MeV instead 1 MeV and the increase-decrease asymmetry) so such problems suggest new physics. To save the SM, some scientists suggest that the first doubly charmed $\Xi^{+}{}_{cc}$, detected by the SELEX collaboration based at Fermilab, should disappear! Here, applying the atom-like structure of baryons that follows from the Scale-Symmetric Theory (SST), we calculated masses and I, J and P of baryon Δ, of many charmed and bottom baryons and masses of the two doubly charmed baryons Ξ_{cc}. Calculated mass of $\Xi^{+}{}_{cc}$ is 3519.08 MeV whereas of $\Xi^{++}{}_{cc}$ is 3621.90 MeV - the results are consistent with experimental data. The other theoretical masses obtained here are very close to experimental results. We present a generalized scheme that is very helpful in calculating masses and other physical quantities that characterize baryons. Charmed baryons contain relativistic, positively charged pion in the d = 0 state which mass is 1256.6 MeV - this mass is close to the mass of the charm quark (in SST it is 1267 MeV) so the quark model can mimic presented here the atom-like theory of baryons. On the other hand, relativistic mass of charged kaon in the d = 0 state is 4444.9 MeV so it can mimic the mass of the bottom quark (in SST it is 4190 MeV).

1. Introduction

According to the Scale-Symmetric Theory (SST), the phase transitions of the initial inflation field lead to five different energy/size scales in Nature and to the atom-like structure of baryons [1], [2]. Within SST, we calculated the initial parameters applied in the Standard Model (SM) [3].

In baryons there is the core and the four states $d = 0, 1, 2, 4$ [2]. In the d states can be relativistic pions denoted by W_d (orbital angular momentums of W_d are equal to zero) and the expanding spin-1 gluon loops denoted by $S^{+,-,o}{}_d$. Masses of the gluon loops, m_S, depend on their spin speed, v_{spin}, that via the speed of light in "vacuum" c fixes the radial speed of expanding gluon loop, v_{radial}. Knowing mass of a gluon loop, we can calculate initial spin speed from following formula: $m_S\, v_{spin}\, r_S = \hbar$, where r_S denotes the initial radius of gluon loop defined by d. Next, via $v_{spin}^{\,2} + v_{radial}^{\,2} = c^2$, we can calculate v_{radial} and next the time required to leave the strong field of a baryon. Gluon loop with antiparallel spin (APS) to the half-integral spin of the core of baryons has negative parity $P = -1$ whereas with parallel spin (PS) has positive parity $P = +1$. Applying such model, we calculated masses, isospins I, spins J and parities P of hyperons [4], [2] and of selected baryon resonances [2].

Generally, the $I(J^P)$ of charmed and bottom baryons have not been measured or need confirmation – cited here values are the quark model predictions [5] but we showed that they, in general, are consistent with SST.

In Table 1 are collected calculated masses of the $S^{+,-,o}{}_d$ gluon loops, the W_d pions and. The relativistic kaons $K_{d=0}$. Table 1 is taken from [2]. Relativistic mass of the charged pion and charged kaon in the $d = 0$ state is $f = 9.0036$ times higher than their rest masses [2]. It means that mass of the charged pion in the $d = 0$ state is $m_{W(+,-),d=0} = 1256.633$ MeV. This mass is close to the mass of the charm quark, which in SST is $q_{charm,SST} = 1267$ MeV [2], so the quark model can mimic presented here the atom-like theory of baryons. Relativistic mass of charged kaon in the $d = 0$ state is $m_{K(+,-),d=0} = 4444.9$ MeV so it can mimic the mass of the bottom quark, which in SST is $q_{bottom,SST} = 4190$ MeV [2].

Table 1 *Masses of* $S^{+,-,o}{}_d$, W_d *and* $K_{d=0}$

d	$m_{S(+,-),d}$ [MeV]	$m_{S(o),d}$ [MeV]	$m_{W(+,-),d}$ [MeV]	$m_{W(o),d}$ [MeV]	$m_{K(+,-),d}$ [MeV]	$m_{K(o),d}$ [MeV]
0	727.440123	724.776800	1256.633	1215.275	4444.90	4480.29
1	423.043	421.494	215.760	208.643		
2	298.243	297.151	181.704	175.709		
4	187.573	186.886	162.013	156.668		

Mass of the spin-0 condensate in centre of muon, which is responsible for the weak interaction of an object in the $d = 0$ state with the core of baryons, is $m_{C,muon} = 17.775 - 0.498 = 17.277$ MeV (see formulae (79) – (81) in [2]).

2. Masses and $I(J^P)$ of charmed baryon resonances Ξ_c

Within SST, we described the selection rules that lead to the charge states of hyperons and baryon resonances [2].

Mass of the lightest $\Xi^+{}_c$ is

$$\Xi^+{}_c \equiv \Sigma^o\,[5] + m_{W(+),d=0} + m_{C,muon} = 2466.55 \text{ MeV and } I(J^P) = 1/2(1/2^+). \quad (1)$$

Experimental mass is 2467.87 ± 0.30 MeV and $I(J^P) = 1/2(1/2^+)$ [5].

The $m_{W(+),d=0}$ dominates because it has the same internal helicity as the core of proton in the Σ hyperon [2].

Mass of the lightest $\Xi^o{}_c$ is

$$\Xi^o{}_c \equiv \Sigma^-\,[5] + m_{W(+),d=0} + m_{C,muon} = 2471.36 \text{ MeV and } I(J^P) = 1/2(1/2^+). \quad (2)$$

Experimental mass is $2470.87^{+0.28}{}_{-0.31}$ MeV and $I(J^P) = 1/2(1/2^+)$ [5].

The Ξ_c resonances are created because of presence of the $S^o{}_d$ gluon loops.

By adding the $S^o{}_{d=4}$ gluon loop (see Table 1) with parallel spin (PS) to the results obtained in (1) and (2), we obtain respectively 2653.44 MeV and 2658.25 MeV and $1/2(3/2^+)$. We identify them as the $\Xi_c(2645)$ [5].

By adding the $S^o{}_{d=2}$ gluon loop with antiparallel spin (APS) to the results obtained in (1) and (2), we obtain respectively 2763.70 MeV and 2768.51 MeV and $1/2(1/2^-)$. We identify them as the $\Xi_c(2790)$ [5].

By adding the $S^o{}_{d=4}$ (PS) and $S^o{}_{d=2}$ (APS) gluon loops to the results obtained in (1) and (2), we obtain respectively 2950.59 MeV and 2955.40 MeV and $1/2(1/2^-)$. But due to the two gluon loops, we can observe the other spins and parities as well. We identify such particles as the $\Xi_c(2970)$ [5].

By adding the $S^o{}_{d=4}$ (PS) and $S^o{}_{d=1}$ (APS) gluon loops to the results obtained in (1) and (2), we obtain respectively 3074.93 MeV and 3079.74 MeV and $1/2(1/2^-)$. But due to the two gluon loops, we can observe the other spins and parities as well. We identify such particles as the $\Xi_c(3080)$ [5].

Presented here a generalized scheme, that is very helpful in calculating masses and other physical quantities that characterize baryons, we can apply to all baryons.

3. Masses of doubly charmed baryons Ξ_{cc}

In the doubly charmed baryons are two pions in the $d = 0$ state. These relativistic pions must interact with each other and with the core of the baryons. It can be done via exchanged the large gluon loop with a mass of $m_{LL} = 67.54441$ MeV – neutral pions are the binary systems of such loops [2].

Mass of the $\Xi^+{}_{cc}$ is

$$\Xi^+{}_{cc} \equiv p\ [5] + m_{W(+),d=0} + m_{W(-),d=0} + m_{LL} = 3519.08 \text{ MeV}\,. \qquad (3)$$

Experimental mass is 3518.7 ± 1.7 MeV [6].

In the $\Xi^{++}{}_{cc}$, instead $m_{W(-),d=0}$ there is $M^- \equiv (\pi^o\ e\ \nu_{e,anti})_{d=0} = 1219.876$ MeV i.e. there are the products of decay of $W^-{}_{d=0}$ but the resultant particles are entangled and are still in the $d = 0$ state. There as well appears charged pion in the rest with a mass of $m_{pion(+)}$ = 139.57013 MeV which is entangled with the modified $\Xi^+{}_{cc}$.

Mass of the $\Xi^{++}{}_{cc}$ is

$$\Xi^{++}{}_{cc} \equiv p\ [5] + m_{W(+),d=0} + M^- + m_{LL} + m_{pion(+)} = 3621.90 \text{ MeV}\,. \qquad (4)$$

Experimental mass is 3621.40 ± 1.13 MeV [7].

Notice that lifetime of $\Xi^+{}_{cc}$ should be shorter than $\Xi^{++}{}_{cc}$ because in $\Xi^+{}_{cc}$ there in the same state is particle and its antiparticle, i.e. $W^+{}_{d=0}$ and $W^-{}_{d=0}$.

4. Masses and $I(J^P)$ of bottom baryons and other charmed baryons

$$\Lambda_b(5620)^o \text{ and } I(J^P) = 0(1/2^+) \text{ in SM [5]} \equiv$$
$$\equiv \Lambda^o\ [5] + K^o{}_{d=0} + m_{C,muon} \approx$$
$$\approx 5613.3 \text{ MeV and } I(J^P) = 0(1/2^+) \text{ in SST.} \qquad (5)$$

$$\Lambda_b(5912)^o \text{ and } J^P = 1/2^- \text{ in SM [5]} \equiv$$
$$\equiv \Lambda_b(5619.58)^o \text{ [5]} + S^{,o}_{d=2} \text{ (APS)} \approx$$
$$\approx 5916.7 \text{ MeV and } J^P = 1/2^- \text{ in SST.} \tag{6}$$

$$\Lambda_b(5920)^o \text{ and } J^P = 3/2^- \text{ in SM [5]} \equiv$$
$$\equiv \Lambda_b(5619.58)^o \text{ [5]} + S^{,o}_{d=2} \text{ (PS)} \approx$$
$$\approx 5916.7 \text{ MeV and } J^P = 3/2^+ \text{ in SST.} \tag{7}$$

From expressions (6) and (7) follows that mass of baryon depends slightly on orientation of spin of the gluon loops.

$$\Sigma_b^*(\sim 5833)^{+,\, o,\, -} \text{ and } I(J^P) = 1(3/2^+) \text{ in SM [5]} \equiv$$
$$\equiv \Lambda_b(5619.58)^o \text{ [5]} + S^{+,-,o}_{d=4} \text{ (PS)} \approx$$
$$\approx 5807 \text{ MeV and } I(J^P) = 1(3/2^+) \text{ in SST.} \tag{8}$$

$$\Lambda_c(2286.5)^+ \text{ and } I(J^P) = 0(1/2^+) \text{ in SM [5]} \equiv$$
$$\equiv p + m_{W(o),d=0} + m_{pion(o)} \approx$$
$$\approx 2288.5 \text{ MeV and } I(J^P) = 0(1/2^+) \text{ in SST.} \tag{9}$$

$$\Sigma_c(2455)^{++,\, +,\, o} \text{ and } I(J^P) = 1(1/2^+) \text{ in SM [5]} \equiv$$
$$\equiv \Lambda_c(2286.5)^+ \text{ [5]} + S^{+,-,o}_{d=4} \text{ (APS) or (PS)} \approx$$
$$\approx 2473 \text{ MeV and } I(J^P) = 1(1/2^-) \text{ or } 1(3/2^+) \text{ in SST.} \tag{10}$$

$$\Lambda_c(2595)^+ \text{ and } I(J^P) = 0(1/2^-) \text{ in SM [5]} \equiv$$
$$\equiv \Lambda_c(2286.5)^+ \text{ [5]} + S^o_{d=2} \text{ (APS)} \approx$$
$$\approx 2583 \text{ MeV and } I(J^P) = 0(1/2^-) \text{ in SST.} \tag{11}$$

$$\Lambda_c(2880)^+ \text{ and } I(J^P) = 0(5/2^+) \text{ in SM [5]} \equiv$$
$$\equiv \Lambda_c(2286.5)^+ \text{ [5]} + S^o_{d=4} \text{ (PS)} + S^o_{d=1} \text{ (PS)} \approx$$
$$\approx 2894 \text{ MeV and } I(J^P) = 0(5/2^+) \text{ in SST.} \tag{12}$$

5. Mass and $I(J^P)$ of baryon Δ

The first not occupied state in nucleons is the $d = 2$ state so the lightest baryon resonance should contain gluon loop in it.

$$\Delta(1232)^{++,\, +,\, o,\, -} \text{ and } I(J^P) = 3/2(3/2^+) \text{ in SM [5]} \equiv$$
$$\equiv n \text{ or } p + S^{+,-,o}_{d=2} \text{ (PS)} \approx$$
$$\approx \text{from } 1235.4 \text{ to } 1237.8 \text{ MeV and } I(J^P) = 3/2(3/2^+) \text{ in SST.} \tag{13}$$

6. Summary

The mass distance about 103 MeV between the two doubly charmed baryons Ξ^{++}_{cc} and Ξ^{+}_{cc} instead the expected mass distance 1.3 MeV and the increase-decrease asymmetry suggest new physics.

Here, applying the atom-like structure of baryons that follows from the Scale-Symmetric Theory (SST), we calculated masses and I, J and P of Δ baryon and many charmed and bottom baryons. Obtained results are consistent or very close to experimental data. Charmed baryons contain in the $d = 0$ state charged pion(s) (there can be as well a neutral pion plus electron plus electron-antineutrino which are entangled) whereas bottom baryons contain in the $d = 0$ state kaon.

The quark model mimics presented here model based on the SST but contrary to the quark model, the SST model does not lead to new unsolved problems.

We showed a generalized scheme that is very helpful in calculating masses and other physical quantities that characterize baryons.

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