Masses of the Upsilon Mesons

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Abstract: Here, applying the Scale-Symmetric Everlasting Theory (S-SET), I described composition and calculated masses of the Upsilon mesons. This follows from the atom-like structure of baryons. Applying the modified quantum chromodynamics, within the S-SET, we can calculate the masses of quarks. This leads to conclusion that S-SET is the superior theory to the Standard Model in initial conditions. Calculated mass of b quark is 4190 MeV. Here, I showed that the Type 1S Upsilon meson is both a structure containing b-b(anti) quark pair (theoretical mass of such structure is 9460.1 MeV), or mesonic nucleus (theoretical mass of such nucleus is 9465.1 MeV). Due to the transformations/oscillations of these two different structures having practically the same mass and spin and parity, the full width of the Type 1S Upsilon meson is very small. Calculated masses of Types 1S, 2S, 3S, 4S, 10860 and 11020 Upsilon mesons are very close to experimental data. They all have unitary spin and negative parity.

1. Introduction and calculations

The Scale-Symmetric Everlasting Theory (S-SET) shows that the succeeding phase transitions of the modified Higgs field lead to the atom-like structure of baryons [1]. Within S-SET, we obtained hundreds theoretical results consistent with experimental data. They concern as well the physical constants. Mass of proton, its spin and radii are consistent with experimental results. Due to the atom-like structure, there appears the particle zoo [1]. For the strong interactions are responsible the large loops composed of entangled gluons – their mass is $m_{LL} = 67.54$ MeV ([1]: see the explanation below formula (8)). This mass is very close to the half of the mass of neutral pion, $m_{pion(o)} = 134.97$ MeV [1]. Outside the strong fields, the gluons transform into photons [1]. Mass of the charged pion calculated within S-SET is $m_{pion(+,-)} = 139.57$ MeV. Inside the strong fields, due to the atom-like structure of baryons, most numerous are the gluon loops carrying energy 67.54 MeV and gluons which energy follows from the transitions between the baryonic shells and relativistic effects: $m_B = 25.21$ MeV ([1]: formula (127)).

Gluon loops in strong fields behave as electrons in electromagnetic fields – it is not true that in the strong fields can be more than one boson loop in the same mass and spin-orientation state [1].

Because electrically neutral mesonic nuclei may consist of three different electrically neutral types of objects whereas only one of them contains the charged pions, the charged pions should, therefore, be two times less than the neutral pions. It is also obvious that there should be some analogy for mesonic and atomic nuclei. I will demonstrate this for the Upsilon meson and the Gallion. The Gal is composed of 31 protons and has an atomic mass equal to 69.72.

To try to build a meson having a mesonic mass equal to 69.5, we can use the following equation:

$$Y(1S) = {}^{69.5}\text{Upsilon} = 8\mathbf{a} + 14\mathbf{b} + 9\mathbf{b'} = 9465.1 \text{ MeV } (J^P = 1^-), \qquad (1)$$

where $a = m_{pion(o)} + m_{LL} = 202.5$ MeV, $b = m_{pion(o)} + (m_{pion(o)} + m_{LL}) = 337.5$ MeV and $b' = m_{pion(+)} + (m_{pion(-)} + m_{LL}) = 346.7$ MeV. The Type a objects have unitary angular momentum, J, and positive parity, P, i.e. $J^P = 1^+$, whereas for the Type b and b' objects is $J^P = 1^-$.

Such a mesonic nucleus contains 18 charged pions, 36 neutral pions (there indeed number of charged pions is two times smaller than neutral ones) and contains 31 objects. Applying the Hund law to $Y(1S)$ (i.e. $31 = (2) + (2 + 6) + (2 + 6 + 10) + (2 + \mathbf{1})$), we obtain that total angular momentum is unitary. On the other hand, there are $14 + 9 = 23$ objects with negative parity so the total parity is negative as well. Notice as well that total number of loops is 139 i.e. 69 pions plus loop (i.e. about a half of a pion) so the mass signature is 69.5.

In Table 1 are collected the Type $J^P = 0^+$ unstable neutral objects composed of the carriers of strong interactions i.e. of the pions (134.97 MeV, 139.57 MeV), gluon/large-loop (67.54 MeV) or the characteristic gluon (25.21 MeV), and virtual gluons g*.

Number of virtual gluons in an unstable neutral object we can calculate applying following rule. With each pion should be associated one virtual gluon plus one just exchanged virtual gluon. For example, the unstable neutral object, A, contains 3 pions so there should be 4 virtual gluons. But notice that if there is one pion then the additional just exchanged gluon is useless so there should be only one virtual gluon.

Table 1. *Unstable neutral objects, $J^P = 0^+$*

Symbol	Composition	Mass [MeV]
A	$m_{pion(+)} + (m_{pion(-)} + m_{LL}) + (m_{pion(o)} + m_{LL}) + 4g^*$	549.2
B	$m_{pion(+)} + (m_{pion(-)} + m_{LL}) + 3g^*$	346.7
C	$(m_{pion(o)} + m_{LL}) + 1g^*$	202.5
D	$m_{pion(+)} + (m_{pion(-)} + m_B) + 3g^*$	304.4
E	$(m_{pion(o)} + m_B) + 1g^*$	160.2

By the way, notice that the sum of the mass of η meson and its full width Γ is 549.2 MeV (Γ $\ll$ η; $J^P = 0^-$) [2]. On the other hand, it is as well the mass of the unstable neutral object, A, but to obtain the same spin and parity, the A should emit two virtual gluons

$$\eta + \Gamma = A - 2\,g^* = 549.2 \text{ MeV}, J^P = 0^-. \qquad (2)$$

Assume that there are preferred unstable neutral objects containing gluon loop or gluon carrying greater energy. If two objects contain the same gluon loop or gluon then there is preferred object carrying greater mass.

Assume that the $Y(1S)$ is the ground state of the Upsilon mesons. Composition and masses of the excited states of this meson are collected in Table 2.

Table 2. *Composition and theoretical masses of Upsilon mesons, $J^P = 1^-$*

Particle	Composition	PDG [2]	S-SET Theoretical mass [MeV]
Y(1S)	Y(1S)	9460.30 ± 0.26	9465.1
Y(2S)	Y(1S) + A	10023.26 ± 0.31	10014.3
Y(3S)	Y(1S) + A + B	10355.2 ± 0.5	10361.0
Y(4S)	Y(1S) + A + B + C	10579.4 ± 1.2	10563.5
Y(10860)	Y(1S) + A + B + C + D	10876 ± 11	10867.9
Y(11020)	Y(1S) + A + B + C + D + E	11019 ± 8	11028.1

Notice that there is not in existence some analog to A containing instead m_{LL} the m_B. It follows from the fact that neutral pion can decay to $2m_{LL}$ whereas there is not in existence a particle which can decay to $2m_B$. Notice as well that D is an analog to B whereas E is an analog to C.

We can see that the calculated masses of Types 1S, 2S, 3S, 4S, 10860 and 11020 Upsilon mesons are very close to experimental data. They all have unitary spin and negative parity.

Applying the modified quantum chromodynamics, within the S-SET, we can calculate the masses of quarks ([1]: Chapter "Reformulated Quantum Chromodynamics"). This leads to conclusion that S-SET is the superior theory to the Standard Model in initial conditions. Calculated mass of b quark is 4190 MeV. Composition of the Type 1S Upsilon meson containing the b-b_{anti} quark pair is as follows

$$Y(1S) = (b + b_{anti}) + (K^+ + m_{LL}) + (K^- + m_B) \rightarrow g\ g\ g = 9460.1 \text{ MeV}, J^P = 1^-. \text{ (3)}$$

We can see that $Y(1S)$ can decay to three gluons.

So we have the two different structures of the $Y(1S)$ i.e. one containing b-b_{anti} quark pair (theoretical mass of such structure is 9460 MeV) and the other which is the mesonic nucleus (theoretical mass of such nucleus is 9465.1 MeV). Due to the transformations/oscillations of these two different structures having practically the same mass and spin and parity, the full width of the Type 1S Upsilon meson is very small.

2. Summary

Here, applying the Scale-Symmetric Everlasting Theory (S-SET), I described composition and calculated masses of the Upsilon mesons. This follows from the atom-like structure of baryons.

Applying the modified quantum chromodynamics, within the S-SET, we can calculate the masses of quarks. This leads to conclusion that S-SET is the superior theory to the Standard Model in initial conditions. Calculated mass of b quark is 4190 MeV.

Here, I showed that the Type 1S Upsilon meson is both a structure containing b-b_{anti} quark pair (theoretical mass of such structure is 9460.1 MeV), or mesonic nucleus (theoretical mass

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References
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