QUARK-QUARK OF SWAP ELECTRIC CHARGE BOUND STATES

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In loving memory of Zella, my brightest cat

Quark–quark of swap electric charge bound state

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Abstract: We test the Electric Charged Swap (ECS) symmetry in the case of quarks. We propose a quark (q)- and an ECS-quark (q˜)-bound state, qq˜. We explain the electric charged charmonium Z^{+}_{c} (3, 9) meson as a charm quark (c)- and charm ECS-quark (c˜)- bound state (cc˜). We predict that J/ψ and π^{+} mesons are the decay products of a Z^{+}_{c} (3, 9), as it has been recently observed at the Beijing Electron Positron Collider (BES) III. Furthermore, from the charm ECS-quark (c˜) of mass 2,3GeV we predict two new mesons, an electric charged charmed meson $\bar{D}^{*+(zm)}$ and a neutral charmed meson $D^{*0(zm)}$.

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1. Introduction

The Y(4260) particle was originally discovered by the BaBar collaboration[25]. Other particles of similar characteristics — called "*charmonium*" — are composed of a charm quark and an anti-charm quark held together by the strong force. Yet the Y(4260) doesn't seem to fit this model and its building blocks remain unclear.

To gain a better understanding of *Y*(4260), the Beijing Electron Positron Collider (BES)III and Belle teams created large numbers of Y(4260) by colliding electrons and positrons [1-3].

While the $Y(4260)$ is so short-lived that it cannot be detected directly, its signature turns up in the energy spectrum of pions and J/ψ particles produced in the collision[1-3].

Both teams, however, found more than they bargained for: evidence for an unexpected particle, $Z_c(3900)$, with a mass around 3.9 GeV/c^2[1-3]. This new particle is even more mysterious than $Y(4260)$, since it appears to decay to an electrically charged pion plus an electrically neutral J/ψ. This means that $Z_c(3900)$ must carry electric charge; therefore it does not consist simply of charm and anti-charm quarks [1-3].

Following M.B Voloshin, the models so far proposed to explain Z(3900) can be classified as follows [4]:

Hadronic molecules[5]:
Heavy-light quark-antiquark pairs form heavy mesons; the resulting meson-antimeson pairs move at distances longer than the typical size of mesons. Mesons interact through exchange of light quarks and gluons, similar to the nuclear force.

Hadro-quarkonium[6, 7]:
The $Q\bar{Q}$ pair forms a tightly bound system whose wave function is close to that of one of the heavy quarkonium states. The heavy quark pair is embedded in a spatially large excited state of light mesonic matter and interacts with it by a QCD analog of Van der Waals force.

Tetraquarks[8]:
The pairs Qq and $Q\bar{q}$ form relatively tightly bound diquark and antidiquark, which interact by means of the gluonic color force.

In principle, quantum chromodynamics (QCD) could be used to determine the properties of these more exotic configurations. The problem is that when QCD is applied to situations like these, the equations that ensue unsolvable, through 'conventional' techniques. Some progress has been made recently using numerical methods with very high-powered computers to solve the applicable QCD. We refer to these methods, as "lattice QCD"'[26-27].

Electric Charged Swap (ECS) symmetry for the case of leptons has been proposed by the author [9]. A family of particular transformations may be *continuous* (such as rotation of a circle) or discrete (e.g. reflexion of a bilaterally symmetric figure, or rotation of a regular polygon) [9], [10]. ECS-transformation between ordinary families of leptons produces heavy neutral non-regular leptons of masses of order O (1TeV). These particles may form cold dark matter [9]. Furthermore, certain properties of lepton families may be explained from this symmetry, within the framework of superstring theories [11-15].

Recently, A-Wollmann Kleinert and F. Bulnes considered the Higgs mechanism to re-combine gauge fields of $SU(2)$ and $U(1)$, through three classes of bosons, W, Z, and A [10]. Based on ECS symmetry (in this case of leptons), we obtain a possible representation of the electrical charge associated with the electromagnetism for any particle in the space-time M[10].

In the present paper we test the ECS symmetry in the case of quarks. We propose a quark (q) and an ECS-quark ($\tilde{q}$) bound state ($q\tilde{q}$). We explain the electric charged charmonium Z^+_c (3, 9) meson as a charm quark (c) and charm ECS-quark ($\tilde{c}$) bound state ($c\tilde{c}$). We predict that J/ψ and π^+ mesons are the decay products of a Z^+_c (3, 9), as it has been recently observed at BES III. Furthermore, we use the charm ECS-quark ($\tilde{c}$) of mass 2,3GeV to predict an electric charged charmed $\bar{D}^{*+(zm)}$ and neutral charmed $D^{*0(zm)}$ new mesons.

2. Quark of swap electric charges

Hypothetical non-regular leptons are, a) a 1/3-electric charged version of the up (α) quark types, $\tilde{\alpha}$ and, b) a -2/3-electric charged version of the down (κ) quark types, $\tilde{\kappa}$ ... Non-regular quarks may, therefore, be obtained by the swap of electric charges between up and down quark types. We call these proposed non-regular quarks *electric charge swap* (ECS) quarks [9].

Topologically, the dispersed surplus of energy in the weak decay comprises remnants of energy of the rotations of particles like the topological sphere [10] (Figure 1). Such automorphisms are rotations of $S^2 = SU(2)/U(1)$ [9]. Being remnants of energy, therefore these non-regular quarks can be expressed as ECS-transformations from $S^2 = SU(2)_{B_s}/U(1)_{Y_s}$ whose declarations has been gauged in [9], and where, B_s is the non-regular quark (*non-ordinary*) baryonic number, and, Y_s is the swap hypercharge.

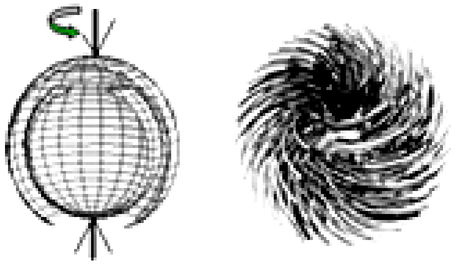

Fig.1 Isospin from the inner of quarks. This model can be applied in the isomorphism obtained with the field in $SO(3)^{(ECS)}$. According to Chern-Simons theory, this ball degenerates in many Calabi-Yau manifolds [10].

If follows that the automorphism from the $S^2 = SU(2)/U(1)$ to itself, which brings the electric charge swap between the up (α) and down (κ) quark types, is derived from the isometries that form a proper subgroup of the group of projective linear transformations $PGL_2(\tilde{C})_{(charge)}$, $PSU_2(\tilde{C})$. Subgroup $PSU_2(\tilde{C})$ is isomorphic to the rotation group $SO(3)^{(ECS)}$ [9, 10,16], which is the isometric group of the unit sphere in three-dimensional real space R^3 . The automophism of the Riemann sphere C˜, is given by:

$$rot_{ECS}^{(charge)} = PSU_2^{(charge)} = SO(3)^{charge}, \tag{1}$$

where C˜, is the extended complex plane, $PSU_2^{(charge)}$ is the proper subgroup of the projective linear transformations, and swap symmetry, $SO(3)^{(charge)}$, is the group of rotations in 3-dimensional vector space R^3 . This can be consigned in the double fibration on a vector bundle of lines $\Im^2$, in the extended space-time (*ad infinitum*), that is to say, $\tilde{C} = C \cup \infty$. The universal cover of $SO(3)^{(ECS)}$, is the special unitary group $SU(2)^{(ECS)}$ [9]. This group is also differomorphic to the unit 3-sphere S^3.

Non-regular quarks obtained by the swap of electric charges between up (α) and down (κ) quark types, are given by equation (1). We regard ordinary and ECS quarks as different electric charge states of the same particle – analogous, that is, to the proton-neutron isotopic pair [9].

Some quantum numbers of the new ECS quarks are given in Table 1.

Table 1: Quantum numbers of the proposed ECS-quarks.

ECS-quarks	Q-electric charge	Iz-isospin, component	B_s-Baryonic number
u˜,c˜,t˜	1/3	-1/2	-1/3
d˜,s˜,b˜	-2/3	1/2	-1/3

3. Quark-quark of swap electric charges bound states: Zella-Mesons

Quarks are strongly interacting fermions with spin 1/2 and, by convention, positive parity. ECS-quarks have negative parity. Quarks have the additive baryon number 1/3; ECS-quarks -1/3. Table 2 gives the other additive quantum numbers (flavors) for the two generations of ECS-quarks.

These are related to the charge Q (in units of the elementary charge e) through the generalized Gell-Mann-Nishijima formula [17]

$$Q = I_z + \frac{B_s + S + C}{2}, \qquad (2)$$

where B_s is the non-regular baryonic number. The convention is that the flavor of an ECS-quark (I_z, S, C,) has the same sign as their charges Q. ECS-quarks have the opposite flavor signs of quarks.

Table 2: Additive quantum numbers of the proposed ECS-quarks.

ECS-quark	d˜	u˜	s˜	c˜
Q-electric charge	-2/3	1/3	-2/3	1/3
I-isospin	1/2	1/2	0	0
Iz-isospin, component	1/2	-1/2	0	0
S-strangeness	0	0	1	0
C-charm	0	0	0	-1

In the proposed quark model, mesons are identified as bound states of a quark and an ECS-quark. We call such mesons Zella-Mesons (ZM).

This leads to the direct product $4\otimes 4^*$. With quarks and the ECS-quarks denoted by q^α and $\tilde{q}_\beta$ respectively, the direct product may be represented by $q^\alpha\tilde{q}_\beta$. As in ordinary mesons [17-19], this direct product is reducible. The irreducible decomposition can be obtained as follows:

$$q^\alpha\tilde{q}_\beta = q^\alpha\tilde{q}_\beta - \frac{1}{4}\delta^\alpha_\beta q^r\tilde{q}_r + \frac{1}{4}\delta^\alpha_\beta q^r\tilde{q}_r = (15)^\alpha_\beta + \frac{1}{2}\delta^\alpha_\beta(1), \tag{3}$$

Or,

$$4\otimes 4^* = 15 + 1, \tag{4}$$

where

$$(15)^\alpha_\beta = q^\alpha\tilde{q}_\beta - \frac{1}{4}\delta^\alpha_\beta q^r\tilde{q}_r \tag{5}$$

and

$$1 = \frac{1}{2}q^r\tilde{q}_r = \frac{1}{2}\left(u\tilde{u} + d\tilde{d} + s\tilde{s} + c\tilde{c}\right). \tag{6}$$

From these it follows that ZM transform like singlets or 15-plets under the special unitary group SU(4). Recall that in SU(4) there are 15 independent generators. Therefore ZM is a regular representation of SU(4) in 15 form. If the spins of quarks and ECS-quarks are antiparallel, we obtain pseudoscalar ZM. If they are parallel, we obtain vector ZM.

We first consider the case of pseudoscalar ZM. The singlet is given by

$$\eta_1^{(zm)} = \frac{1}{2}\left(u\tilde{u} + d\tilde{d} + s\tilde{s} + c\tilde{c}\right). \tag{7}$$

The diagonal elements of the 15-plet satisfy the following relation:

$$(15)^1_1 + (12)^2_2 + (15)^3_3 + (15)^4_4 = 0. \tag{8}$$

Consequently, only three of them are linearly independent. A possible choice of the three independent states is:

$$\pi^{(zm)} = \frac{1}{\sqrt{2}}\left(u\tilde{u} - d\tilde{d}\right) = \frac{1}{\sqrt{2}}\left[(15)^1_1 - (15)^2_2\right] \tag{9}$$

$$\eta^{(zm)} = \frac{1}{\sqrt{6}}\left(u\tilde{u} + d\tilde{d} + s\tilde{s} + 2c\tilde{c}\right) = \frac{1}{\sqrt{6}}\left[(15)^1_1 + (15)^2_2 - 2(15)^3_3\right] \tag{10}$$

$$\eta_{15}^{(zm)} = \frac{1}{\sqrt{12}}\left(u\tilde{u} + d\tilde{d} + s\tilde{s} - 3c\tilde{c}\right) = -\frac{2}{\sqrt{3}}(15)^4_4, \tag{11}$$

where $\pi^{(zm)}$ and $\eta^{(zm)}$ are chosen to be physical states known previously in SU(3), and $\eta_{15}^{(zm)}$, is obtained by requiring it to be orthogonal to $\pi^{(zm)}$, $\eta^{(zm)}$ and $\eta_{1}^{(zm)}$. Equations (9)-(11) can be easily inverted to obtain

$$
\begin{aligned}
(15)_1^1 &= \frac{1}{\sqrt{2}}\pi^{(zm)} + \frac{1}{\sqrt{6}}\eta^{(zm)} + \frac{1}{\sqrt{12}}\eta_{15}^{(zm)} \\
(15)_2^2 &= -\frac{1}{\sqrt{2}}\pi^{(zm)} + \frac{1}{\sqrt{6}}\eta^{(zm)} + \frac{1}{\sqrt{12}}\eta_{15}^{(zm)} \\
(15)_3^3 &= -\frac{2}{\sqrt{6}}\eta^{(zm)} + \frac{1}{\sqrt{12}}\eta_{15}^{(zm)} \\
(15)_4^4 &= -\frac{3}{\sqrt{12}}\eta_{15}^{(zm)} .
\end{aligned}
\tag{12}
$$

With the help of the above equations, the pseudoscalar ZM of the 15-plet can be written in the following matrix form:

$$
\begin{matrix}
(1/\sqrt{2})\pi^{0(zm)}+(1/\sqrt{6})\eta^{(zm)}+(1/\sqrt{12})\eta_{15}^{(zm)} & \pi^{0(zm)} & K^{0(zm)} & \bar{D}^{+(zm)} \\
\pi^{0(zm)} & (1/\sqrt{2})\pi^{(zm)}+(1/\sqrt{6})\eta^{(zm)}+(1/\sqrt{12})\eta_{15}^{(zm)} & K^{+(zm)} & D^{0(zm)} \\
K^{0(zm)} & \bar{K}^{-(zm)} & (1/\sqrt{6})\eta^{(zm)}+(1/\sqrt{12})\eta_{15}^{(zm)} & F^{0(zm)} \\
D^{+(zm)} & D^{0(zm)} & F^{0(zm)} & (1/\sqrt{12})\eta_{15}^{(zm)}
\end{matrix}
\tag{A}
$$

Similar results may be obtained for vector ZM. Denoting the singlet by $W_1^{(zm)}$, it is

$$W_1^{(zm)} = \frac{1}{2}\left(u\tilde{u} + d\tilde{d} + s\tilde{s} + c\tilde{c}\right). \tag{13}$$

In the 15-plet, only three independent states can be obtained from linear combinations of the diagonal elements. A possible choice is given by:

$$\rho^{(zm)} = \frac{1}{\sqrt{2}}\left(u\tilde{u} - d\tilde{d}\right) \tag{14}$$

$$W^{(zm)} = \frac{1}{\sqrt{6}}\left(u\tilde{u} + d\tilde{d} - 2s\tilde{s}\right) \tag{15}$$

$$W_{15}^{(zm)} = \frac{1}{\sqrt{12}}\left(u\tilde{u} + d\tilde{d} + s\tilde{s} - 3c\tilde{c}\right). \tag{16}$$

The vector ZM in the 15-plet may then be written in the following matrix form:

$$\begin{matrix} (1/\sqrt{2})\rho^{0(zm)}+(1/\sqrt{6})W^{(zm)}+(1/\sqrt{12})W_{15}^{(zm)} & \rho^{0(zm)} & K^{*0(zm)} & \bar{D}^{*+(zm)} \\ \rho^{0(zm)} & (1/\sqrt{2})\rho^{0(zm)}+(1/\sqrt{6})W^{(zm)}+(1/\sqrt{12})W_{15}^{(zm)} & K^{*+(zm)} & D^{*0(zm)} \\ K^{*0(zm)} & \bar{K}^{*+(zm)} & (1/\sqrt{6})W^{(zm)}+(1/\sqrt{12})W_{15}^{(zm)} & F^{*0(zm)} \\ D^{*-(zm)} & D^{*(zm)} & F^{*0(zm)} & (1/\sqrt{12})W_{15}^{(zm)} \end{matrix} \quad \text{(B)}$$

The singlet and neutral members of the 15-plet are mixed. Moreover, the mixing should be more effective than the case of pseudoscalar ZM as observed at BES III [1]. Consequently, the $Z_c^{+(zm)}$ particle turns out to be the bound state of pure $(c\tilde{c})$.

The quark contents and the quantum numbers of pseudoscalar (O$^-$) and vector (1$^-$) ZM are given in Table 3.

The SU(3) subcontents of the 15-plet are given by

$$15 \supset \{8\}_{0+}\{1\}_{0+}\{3^*\}_{1}+\{3\}_{-1}, \quad (17)$$

where the subscripts denote the eigenvalues of charm ECS-quark c$^\sim$.

Table.3. Quark contents and quantum numbers (Q, S, C, I, I_z) of pseudoscalar (O$^-$) and vector (1$^-$) ZM.

ZM O$^-$	ZM 1$^-$	Quark contents	Q	S	C	I	I_z
$\pi_1^{0(zm)}$	$\rho_1^{0(zm)}$	$u\tilde{d}$	0	0	0	1	-1
$\pi_2^{0(zm)}$	$\rho_2^{0(zm)}$	$(u\tilde{u}-d\tilde{d})/\sqrt{2}$	0	0	0	1	0
$\pi_3^{0(zm)}$	$\rho_3^{0(zm)}$	$d\tilde{u}$	0	0	0	1	+1
$\eta^{0(zm)}$	$\omega^{0(zm)}$	$(u\tilde{u}+d\tilde{d}-2s\tilde{s})/\sqrt{6}$	0	0	0	0	0
$\eta'^{+3(zm)}$	$\varphi^{+3(zm)}$	$(u\tilde{u}+d\tilde{d}+s\tilde{s})/\sqrt{2}$	0	0	0	0	0
$K_1^{0(zm)}$	$K_1^{*0(zm)}$	$u\tilde{s}$	0	-1	0	1/2	-1/2
$K_2^{0(zm)}$	$K_2^{*0(zm)}$	$s\tilde{u}$	0	+1	0	1/2	+1/2
$K^{-(zm)}$	$K^{*-(zm)}$	$d\tilde{s}$	-1	-1	0	1/2	-1/2
$\bar{K}^{-(zm)}$	$\bar{K}^{*-(zm)}$	$s\tilde{d}$	-1	+1	0	1/2	+1/2
$\eta_c^{+(zm)}$	$Z_c^{+(zm)}$	$c\tilde{c}$	+1	0	0	0	0
$D^{0(zm)}$	$D^{*0(zm)}$	$c\tilde{d}$	0	0	-1	1/2	-1/2
$D^{+(zm)}$	$D^{*+(zm)}$	$c\tilde{u}$	+1	0	-1	1/2	+1/2
$F^{0(zm)}$	$F^{*0(zm)}$	$c\tilde{s}$	0	-1	-1	0	0
$\bar{D}^{+(zm)}$	$\bar{D}^{*+(zm)}$	$u\tilde{c}$	+1	0	+1	1/2	-1/2
$D^{0(zm)}$	$\bar{D}^{*0(zm)}$	$d\tilde{c}$	0	0	+1	1/2	+1/2
$F^{0(zm)}$	$F^{*0(zm)}$	$s\tilde{c}$	0	+1	+1	0	0

4. ECS-gauge fields masses

The most general Lagrangian consistent with $SU(2)_{ECS} \times U(1)_{Y(Y_S)}$ [9] gauge invariance, Lorentz invariance, and with renormalizability is:

$$\Im_\phi = -\frac{1}{2} | (\partial_\mu - iA_\mu \cdot t^{(\phi)} - iB_\mu y^{(\phi)})\phi |^2 - \frac{\mu^2}{2}\phi^*\phi - \frac{\lambda}{4}(\phi^*\phi)^2, \qquad (18)$$

where

$$t^{(\phi)} = \frac{\tilde{g}_1}{2}\left\{ \begin{pmatrix} 0 & 1 \\ 1 & 0 \end{pmatrix}, \begin{pmatrix} 0 & -i \\ i & 0 \end{pmatrix}, \begin{pmatrix} 1 & 0 \\ 0 & -1 \end{pmatrix} \right\}, \quad y^{(\phi)} = -\frac{\tilde{g}_1'}{2}\begin{pmatrix} 1 & 0 \\ 0 & 1 \end{pmatrix} \qquad (19)$$

generators of the (ϕ^+, ϕ^0), $\lambda > 0$, and

$$\phi = \begin{pmatrix} \phi^+ \\ \phi^0 \end{pmatrix} \qquad (20)$$

For $\mu^2 < 0$, there is a tree-approximation vacuum expectation value at the stationary point of the Lagrangian

$$\langle \phi \rangle^* \langle \phi \rangle = v^2 = | \mu^2 | / \lambda \quad . \qquad (21)$$

We can always perform an $SU(2)_{ECS} \times U(1)_{Y(Y_S)}$ gauge transformation to a unitary gauge, in which $\phi^+ = 0$ and ϕ^0 is Hermitian, with positive vacuum expectation value. In unitarily gauge the vacuum expectation values of the components of ϕ are

$$\langle \phi^+ \rangle = 0, \qquad \langle \phi^0 \rangle = v > 0 \quad . \qquad (22)$$

The scalar Lagrangian (18) then yields an ECS vector boson mass term:

$$-\frac{1}{2} | (\partial_\mu - iA_\mu \cdot \tau^{(\phi)} - iB_\mu y^{(\phi)})\phi |^2 = -\frac{1}{2}\left| \left(\frac{\tilde{g}_1}{2} A_\mu T^a - \frac{\tilde{g}_1'}{2} B_\mu \right) \begin{pmatrix} 0 \\ v \end{pmatrix} \right|^2$$
$$= -\frac{v^2 \tilde{g}_1^2}{4} \tilde{W}_\mu^* \tilde{W}^\mu - \frac{v^2}{8}(\tilde{g}_1^2 + \tilde{g}_1'^2)\tilde{Z}_\mu \tilde{Z}^\mu \quad , \qquad (23)$$

where $\tilde{g}_1, \tilde{g}_1'$ are the ECS coupling constants. The masses are given as follows

$$M_A = 0, M_{\tilde{W}} = \frac{1}{2}\tilde{g}_1 v, M_{\tilde{Z}} = \frac{1}{2}\sqrt{\tilde{g}_1^2 + \tilde{g}_1'^2}\, v \quad . \qquad (24)$$

The ECS gauge fields masses and electric charges predicted by this model are summarized in Table.4.

Table.4. The ECS gauge fields masses and electric charges predicted by the proposed model.

Gauge fields	Masses (M)-MeV	Electric Charges (e)
$\tilde{W}^{\pm}$ (New)	120	$\pm$
$\tilde{Z}^{0}$ (New)	500	0

5. ECS-quark masses

The masses and mixings of ECS-quarks have a common origin, as suggested in the Standard Model (SM) [20-23]. They arise from the Yukawa interactions with the Higgs condensate,

$$L_Y = -Y_{ij}^{\tilde{d}} \bar{\tilde{Q}}_{Li}^{I} \phi \tilde{d}_{Rj}^{I} - Y_{ij}^{\tilde{u}} \bar{\tilde{Q}}_{Li}^{I} \varepsilon \phi^{*} \tilde{u}_{Rj}^{I} + h.c, \tag{25}$$

where $Y^{\tilde{u},\tilde{d}}$ are 3×3 complex matrices, ϕ is the Higgs field, i, j are generation labels, and ε is the 2 × 2 antisymmetric tensor. $\tilde{Q}_L^I$ are left-handed ECS-quark doublets, and $\tilde{d}_R^I$ and $\tilde{u}_R^I$ are right-handed down- and up-type ECS-quark singlets, respectively, in the weak-eigenstate basis. When φ acquires a vacuum expectation value, $\langle\phi\rangle = \left(0, u/\sqrt{2}\right)$, equation (25) yields mass terms for the ECS-quarks, as follows:

$$L_Y = -\bar{\tilde{Q}}_{Li}^{I} m_{ij}^{\tilde{d}} \tilde{d}_{Rj}^{I} - \bar{\tilde{Q}}_{Li}^{I} m_{ij}^{\tilde{u}} \tilde{u}_{Rj}^{I} + h.c\,, \tag{26}$$

where

$$m_{ij}^{\tilde{d}} = \sum_n Y_{ij}^{\tilde{d}} \left\langle \phi_n^0 \right\rangle_{vac},\; m_{ij}^{\tilde{u}} = \sum_n Y_{ij}^{\tilde{u}} \left\langle \phi_n^0 \right\rangle_{vac}^{*}. \tag{27}$$

The ECS-quarks masses depend on the arbitrary couplings $Y^{\tilde{u},\tilde{d}}$ and cannot be predicted. Furthermore, we do not observe ECS-quarks in isolation, so their masses are not precisely defined. Indeed, if we attribute the mass of a ZM to simply the sum of the masses of the constituent quarks, then the mass of ECS-c˜ quark quoted here is 0, 6 times the mass of Z^{+}_{c} particle interpreted as a c-c˜ bound state: ZM-state. For c-quark and Z^{+}_{c} particle masses of 1,6GeV and 3,9GeV respectively, the mass of ECS-c˜ quark should be 2,3GeV.

We thus predict an electrically charged charmed ZM ($D^{*+(zm)}$) and a neutral charmed ZM ($D^{*0(zm)}$), by the charm ECS-quark (c˜) of mass 2,69GeV.

6 Discussion

The ECS- scheme we propose here is similar to the Cabibbo-scheme [19], [24], which allows weak transitions between $u \leftrightarrow d$ and weak ECS-transitions $\tilde{c} \leftrightarrow c$.

Instead of introducing new couplings, let us try to keep universality while modifying both the quark and ECS-quark doublets. We assume that the charged current couples are "rotated" ECS-quark states

$$\begin{pmatrix} u \\ d' \end{pmatrix}, \begin{pmatrix} c \\ \tilde{c}' \end{pmatrix}, \tag{28}$$

where

$$\begin{aligned} d' &= d\cos\theta_s + c\sin\theta_s, \\ \tilde{c}' &= -d\sin\theta_s + c\cos\theta_s \end{aligned} \quad . \tag{29}$$

This introduces an arbitrary parameter θ_s, which represents the ECS-quark mixing angle. What we have done is to change our mind about the charged current. We now have ECS "favored" transitions (proportional to $\sin\theta_s$).

We can summarize this by writing down the explicit form of the matrix element, which describes the charged current weak interactions of the ECS-quarks:

$$M^{(ECS)} = \frac{4\tilde{G}}{\sqrt{2}} J^{\mu(ECS)} J_{\mu}^{+(ECS)}, \tag{30}$$

with

$$J^{\mu(ECS)} = (\bar{u}, \bar{c}) \frac{\gamma^{\mu}(1-\gamma^5)}{2} U_{ECS} \begin{pmatrix} d \\ \tilde{c} \end{pmatrix}. \tag{31}$$

The unitary matrix U_{ECS} performs the rotation (29) of the d and $\tilde{c}$ quark states:

$$U_{ECS} = \begin{pmatrix} \cos\theta_s & \sin\theta_s \\ -\sin\theta_s & \cos\theta_s \end{pmatrix} . \tag{32}$$

All this has implications for our previous calculations. For instance, we can now replace $\tilde{G}$ in the formula for the ECS weak -decay rate by:

$$\tilde{G}_{wk} = \tilde{G}\sin\theta_s . \tag{33}$$

In this model the Z_c meson is a ZM state, consisting of a $\tilde{c}$ and c quark (see Table.3). Hence the $c, \tilde{c}$ weak current is responsible for the weak decay of Z_c particle.

Assuming that $\sin^2\theta_s \gg \cos^2\theta_s$, it follows from (28) and (29) that the "favored" ECS-quark decay pattern is that shown in Fig.2, with amplitude

$$M^{(ECS)}(\tilde{c} \to cu\bar{d}) \sim \sin^2\theta_s . \tag{34}$$

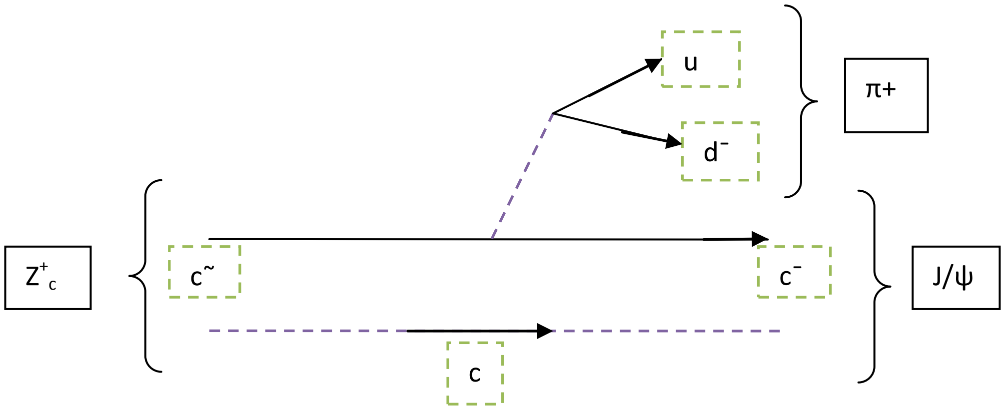

Fig.2 An ECS-quark description of Z^+_c decay. The ECS-favored process is $\tilde{c} \to \bar{c}u\bar{d}$ with a spectator *c* quark.

That is, J/ψ and π^+ mesons should be the decay products of a Z^+_c.

The present phenomenological support to the earlier suggested generalized symmetry scheme [9], including the hypothetical charged "swap" quarks, through the interpretation of the recently observed Z^+(3.9GeV) meson resonance as the bound state of the standard charmed quark and hypothetical (q˜)-quark providing the charged mode of the Z^+(3.9GeV) - resonance decay: $Z^+ \to \pi^+ J/psi$.

According to quantum numbers of the c˜-quark(s) as given in Table 2 and in Fig. 2, the decay $Z^+ \to \pi^+ J/psi$ should be the ECS isospin-breaking one and having characteristic lifetime or width for the ECS-weak interactions.

The probability of emitting an ECS-wake boson $\tilde{W}^+$ is then essentially the same as that for emitting a photon, namely, α=10^{-2}. The slow rate of ECS-weak decays is achieved instead by giving the ECS-$\tilde{W}^+$ a large mass. The probability of exchanging an ECS-$\tilde{W}^+$ is small compared to that for exchanging a photon, not because it is less likely to be emitted, but because it is massive. The probability of emitting an ECS-$\tilde{W}^+$ is given by

$$\tilde{a}_W = \frac{a}{\left(M_{\tilde{W}} / m_p\right)}, \tag{35}$$

where $M_{\tilde{W}^+}$ is the ECS-wake boson mass, α is the ECS the coupling strength. Here, for dimensional reasons, $M_{\tilde{W}^+}$ has to be expressed in terms of some reference mass; our choice is the proton mass $m_p = 1000 MeV$.

The qualitative statement expressed by (35) is already clear. The large mass $M_{\tilde{W}^+}$ suppresses the coupling strength α of the ECS-weak bosons to a given "effective" ECS coupling strength $\alpha^{\sim}_{W}$. For an ECS-weak bosons mass of $M_{\tilde{W}^+} = 120 MeV$ as is given in Table 4 and ECS coupling strength $\alpha=10^{-2}$, we calculate an effective" ECS coupling strength $\alpha_{\tilde{W}} = 8.3\times10^{-2}$.

A minimum energy $M_{\tilde{W}^+}c^2$ is necessary to emit a virtual ECS-$\tilde{W}^+$. It can therefore only live a time $\Delta t = \hbar / M_{\tilde{W}^+}c^2 = 10^{-23}\sec$, after which it has to be reabsorbed. During that time, it can travel at most distance $c\Delta t = \hbar / M_{\tilde{W}^+}c = 1F$. This range is the same with the range of a strong interaction.

The experimental width of the $Z^+ \to \pi^+ J / psi$-decay is of the order $\Gamma_{Z_C(3.9)} = 46 \pm 10 \pm 4.9 MeV / c^2$ [1-3], which is reasonable for the ECS-weak interaction effective coupling constant $\alpha^{\sim}_{W}$.

7. Conclusion

We propose a quark (q) and an ECS-quark (q˜) bound state (qq˜). We explain the electric charged charmonium Z^+_c (3, 9) meson as a charm quark (c) and charm ECS-quark (c˜) bound state (cc˜). We predict that J/ψ and π^+ mesons are the decay products of a Z^+_c (3, 9), as it has been recently observed at BES III. Furthermore, by the charm ECS-quark (c˜) of mass 2,3GeV, we predict an electric charged charmed $\bar{D}^{*+(zm)}$ and neutral charmed $D^{*0(zm)}$ new mesons.

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