Lepton electric charge swap at the 10 TeV energy scale

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Abstract: In this paper, the solution of 6-dimensional Dirac equation suggests that the third family of leptons, and the W gauge bosons, propagates to the six-dimensional bulk at the 10 TeV energy scale. We investigate the possibility that the W boson decays to a neutral non regular lepton, of zero mass mode 1784 MeV, and a charge non regular lepton, of zero mass mode 35 MeV. We show that the proposed process of electric charge swap between leptons respects the conservation of all quantum numbers and W, Z decay rates. This proposition provides for global rotational symmetry between the ordinary lepton and the new non regular leptons. The electric charge swap produces heavy neutral non regular leptons of zero mass mode 1784 MeV, which may form cold dark matter. The existence of these proposed leptons can be tested once the Large Hadron Collider (LHC) becomes operative at the 10 TeV energy-scales. This proposition may have far reaching applications in astrophysics and cosmology.

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1. Introduction

The nature of dark matter, proposed in 1933 to explain why galaxies in some clusters move faster than their predicted speed if they contained only baryonic matter [1], remains one of the open questions of modern physics. Several models of dark matter have been suggested, such as Light Supersymmetric Particles ([2], [3], [4], [5], [6], [7]); heavy fourth generation neutrinos ([8], [9]); Q-Balls ([10], [11]); mirror particles ([12], [13], [14], [15], [16]); and axion particles, introduced in an attempt to solve the Charge-Parity (CP) violation problem in particle physics ([17], [18)

Recently, the Brane world ideal has been used to furnish new solutions to old problems in particle physics and cosmology([19],[20],[21],[22],[23],[24],[25],[26],[27],[28],[29],[30],[31] [32], [33]). Scenaria in which all fields are allowed to propagate in the bulk are called Universal Extra Dimensions (UED) models ([34], [35]). UED models provide a viable dark matter candidate, namely the Lightest Kaluza Klein particle (LKP) ([36], [37]).

The main goal of the present paper is to investigate the possibility that, at the 10 TeV energy scale, the $W^{\pm}$ boson decays to a neutral non regular lepton, of zero mass mode 1784 MeV, and a charge non regular lepton, of zero mass mode 35 MeV. In doing so, this paper formulates a new rotational symmetry between the ordinary lepton and proposed new leptons, with many potential applications in astrophysics and cosmology. The existence of these proposed leptons can be tested once the Large Hadron Collider (LHC) becomes operative at the 10 TeV energy-scales.

2. The set-up of the electric charge swap (ECS) symmetry

To formulate the electric charge of swapped particles, we have to look for symmetry that characterizes swap processes in the framework of 2- extra dimensions with compactification scale 10 TeV.

Let us consider the 6-dimensional spacetime with signature $(+,-,-,-,-,-)$. Einstein's equations in this spacetime have the form

$$R_{AB}-\frac{1}{2}g_{AB}R=\frac{1}{M^4}(g_{AB}\Lambda+T_{AB}) \tag{1}$$

where M the 6-dimensional fundamental is scale and Λ is the cosmological constant. Capital indices $A,B=0,1,2,3,4,5$.

To split the 6-dimensional space-time into 4-dimensional and 2-dimensional parts we use the metric ansatz [38]

$$\begin{aligned} &ds^2=\phi^2(\theta)g_{\mu\nu}(x^a)dx^\mu dx^\nu-\varepsilon^2(d\theta^2+b^2\sin^2\theta d\varphi^2),\\ &\phi(\theta)=1-\sin^2(\frac{\theta}{2})=\cos^2(\frac{\theta}{2}) \end{aligned} \tag{2}$$

where ε and b are constants and $\phi(\theta)$ is the wrap factor. This warp factor equals one at brane location $(\theta=0)$ and decreases to zero in the asymptotic region $(\theta=\pi)$, at the south pole of the extra 2-dimensional sphere. Here the metric of the ordinary 4–dimensional $g_{\mu\nu}(x^a)$ has signature $(+,-,-,-)$, with $\alpha,\mu,\nu=0,1,2,3$. The extra compact 2-manifold is parameterized by the spherical angles θ,ϕ ($0\le\theta\le\pi, 0\le\phi\le 2\pi$). This 2-surface is attached to the brane at point $\theta=0$. When θ changes from 0 to π, therefore, the geodesic distance into the extra dimensions shifts from the north to the south pole of the 2-spheroid. For $b=1$in equation (2), the extra 2-surface is exactly a 2-sphere with radius ε (0.1TeV^{-1}).

The six dimensional massless Dirac equation in the 2-spheroid becomes a system of first order partial differential equations [38], [39], [40].

$$\left(\frac{1}{\varphi}\Gamma^{\mu}\frac{\partial}{\partial x_{\mu}}+\frac{\sin\theta}{4\varepsilon\varphi}\Gamma^{\mu}\Gamma_{\theta}\Gamma_{\varphi}+\frac{1}{\varepsilon}\Gamma^{\theta}\frac{\partial}{\partial\theta}+\frac{1}{b\varepsilon\sin\theta}\Gamma^{\varphi}\frac{\partial}{\partial\varphi}-\frac{\cot\theta}{2\varepsilon}\Gamma^{\varphi}\Gamma_{\theta}\Gamma_{\varphi}\right)\Psi(x^{A})$$
$$=\left[\frac{1}{\varphi}\Gamma^{\mu}\frac{\partial}{\partial x_{\mu}}+\frac{1}{\varepsilon}\Gamma^{\theta}\left(\frac{\partial}{\partial\theta}-\frac{\sin\theta}{\varphi}+\frac{\cot\theta}{2}\right)+\frac{1}{b\varepsilon\sin\theta}\Gamma^{\varphi}\frac{\partial}{\partial\varphi}\right]\Psi(x^{A}) \quad (3)$$

For $b=1$ in equation (2) the internal 2-surface is a sphere S^2. For this case there exists only one zero mode with angular quantum number ($l=0$). This zero mode corresponds to a massless lepton of the third family, of either ordinary or swapped electric charge. This suggests that only the third lepton family propagates in the six dimensional bulk, while the second and first families of leptons are confined to the 3-brane. The normalizable solution of 6-dimensional Dirac equation (3) is given by

$$\Psi_0(x^A)=\frac{1}{\sqrt{2\pi\sin\theta\phi^2(\theta)}}\begin{pmatrix}A_0\\B_0\end{pmatrix}\psi_0(x^{\nu})\ ([38]) \quad (4)$$

where A_0 and B_0 are integration constants with the dimensions of mass, and $\psi_0(x^{\nu})$ is the one lepton zero mode . The expression for the determinant of our ansatz (2), which will be used often in what follows, is given by

$$\sqrt{-g}=\sqrt{-g^{(4)}}\varepsilon^2\phi^4(\theta)\sin\theta \quad (5)$$

where $\sqrt{-g^{(4)}}$ is the determinant of 4-dimensional space-time.

This can be understood from the point of view that this state has a non-zero effective wave function on the brane $(\theta=0)$, and this has an overlap with the scalar field. (By effective wave function we mean the combination from (4) and the square root of the determinant from (5). In this way the singular $\sin\theta$ term cancels out).

We consider the 2-sphere S^2 as a quotient space $S^2\equiv SU(2)_L/U(1)_{\Upsilon}$, we can express the 2-extra dimensional sphere S^2 in terms of the new symmetry between the original lepton and the new, massless ECS lepton doublets.

This is achieved in the following steps.

First, let all electric charge swaps ECS leptons have lepton number $L_s=-1$, and all ECS antileptons have lepton number $\bar{L}_s=1$. Furthermore, all ECS leptons of are either positively charged or neutral, and ECS antileptons are either negatively charged or neutral. Therefore, we consider all the ECS leptons as non regular lepton.

We observe that both the massless ordinary lepton doublet $l_0(x^\nu) = (\tau_L^-, \nu_\tau)$ and the ECS lepton doublet $\tilde{l}_0(x^{\nu'}) = (\tilde{\tau}_L^0, \tilde{\nu}_\tau^+)$ can form the fundamental representation of $SU(2)_L$ [39]. This fundamental representation is given by

$$[I_j, I_k] = i\varepsilon_{jkl} I_l \tag{6}$$

The generators are denoted as

$$I_i = \frac{1}{2}\tau_i \tag{7}$$

where

$$\tau_1 = \begin{pmatrix} 1 & 0 \\ 0 & 1 \end{pmatrix}, \tau_2 = \begin{pmatrix} 0 & -i \\ i & 0 \end{pmatrix}, \tau_3 = \begin{pmatrix} 1 & 0 \\ 0 & -1 \end{pmatrix} \tag{8}$$

are the isospin versions of Pauli matrices.

The latter act to the new leptons states represented by

$$\tilde{\tau}_L^0 = \begin{pmatrix} 1 \\ 0 \end{pmatrix}, \tilde{\nu}_\tau^+ = \begin{pmatrix} 0 \\ 1 \end{pmatrix} \tag{9}$$

To link the two distinct sectors, the ordinary and ECS leptons, we assume that neither ordinary L nor ECS L_{swap} lepton numbers are conserved, while the overall lepton number must be conserved.

$$L_{overall} = L_{swap} + L = 0 \tag{10}$$

$$L_{swap} = \bar{L}, \qquad L_{swap}(\nu_\tau^+) = \bar{L}(\tau^+) = -1 \tag{11}$$

$$\bar{L}_{swap} = L, \qquad \bar{L}_{swap}(\bar{\tilde{\tau}}^0) = L(\nu_\tau) = 1 \tag{12}$$

The next step is to define the group transformation responsible for the swap of electric charges between the tau and neutrino of tau particles. The ECS transformation must given by a transformation from $SU(2)_L / U(1)_Y$, in which the fundamental representation of $SU(2)_L$ is $l_0(x^\nu) = (\tau_L^-, \nu_\tau)$ and $U(1)_Y$ is the symmetric group generated by hypercharge $Y = -1$, to $SU(2)_L / U(1)_{Y_S}$, in which the fundamental representation of $SU(2)_L$ is $\tilde{l}_0(x^{\nu'}) = (\tilde{\tau}_L^0, \tilde{\nu}_\tau^+)$ and $U(1)_{Y_S}$ is the symmetric group generated by swap hypercharge $Y_S = 1$. The quotient space *SU (2)/U (1)* is diffeomorphic to the unit 2-sphere S^2. Consequently, the swap of the electric charges between the tau and neutrino of tau particles must be an automorphism of the 2-sphere to itself.

Here, since the two extra dimensions are endowed with the Fubini-Study[1] metric [46], [47], then not all Möbius transformations (e.g. dilations and translations) are isometries. Therefore the automorphism from the $S^2 \equiv SU(2)/U(1)$ to itself, which brings the electric charge swap between the tau and neutrino of tau particles, is given by the isometries that form a proper subgroup of the group of projective linear transformations $PGL_2(\hat{C})_{(Charge)}$,namely $PSU_{2(Charge)}$. Subgroup $PSU_{2(Charge)}$ is isomorphic to the rotation group $SO(3)^{(ECS)}$ [46], [47], which is the isometric group of the unit sphere in three-dimensional real space R^3. The automophism of the Riemann sphere $\hat{C}$[2] is given by:

$$Rot_{(ECS)}(\hat{C}) = PSU_{2(Charge)} = SO(3)^{(ECS)}, \tag{13}$$

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where $\hat{C}$ is the extended complex plane, $PSU_{2(Charge)}$ is the proper subgroup of the projective linear transformations, and swap symmetry, $SO(3)^{(ECS)}$, is the group of rotations in three-dimensional vector space R^3.

The universal cover of $SO(3)^{(ECS)}$ is the special unitary group $SU(2)^{(ECS)}$. This group it is also differomorphic to the unit 3-sphere S^3.

We regard ordinary and ECS leptons as different electric charge states of the same particle– analogous, that is, to the proton-neutron isotopic pair.

Finally, in terms of rotational symmetry between the original lepton and the proposed ECS leptons, the 2-extra dimensional sphere S^2 is given by

$$S^2 \equiv \frac{SU(2)^{(ECS)}}{U(1)_{Y(Y_s)}} \tag{14}$$

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[1] The round metric of the 2-extra dimensional sphere can be expressed in stereographic coordinates as

$g = \frac{dy_1^2 + dy_2^2}{(1+\varepsilon^2)^2}$, where $\varepsilon = \sqrt{y_1^2 + y_2^2}$. The metric g is Fubini-Study metric of the 2-sphere and [46], [47].

[2] Recall that stereographic projection is a conformal bijection from the round sphere S^2 to the Riemann sphere $\hat{C}$.

An automorphism of $\hat{C}$ that corresponds under stereographic projection to a rotation of S^2 is called a rotation of $\hat{C}$. The group of rotation of $\hat{C}$ is denoted $Rot(\hat{C})$. Thus under stereographic projection, $Rot(S^2) = Rot(\hat{C})$.

where $SU(2)^{(ECS)}$ is the special unitary group, and $U(1)_{Y(Y_s)}$ is the symmetric group generated by hypercharge $Y(Y_S)$.

In terms of the new rotational symmetry, the zero mode $\psi_0(x^\nu)$ in equation (4a) can be expressed as either a massless ordinary lepton doublet of the third family, $l_0(x^\nu) = (\tau_L^-, \nu_\tau)$, or a massless electric charge swap (ECS) lepton doublet of the third family, $\tilde{l}_0(x^{\nu\prime}) = (\tilde{\tau}_L^0, \tilde{\nu}_\tau^+)$.

Hence the normalizable combine solution of 6-dimensional Dirac equation (3) becomes

$$\Psi_0(x^A) = \frac{\delta_0(x^\nu)}{\sqrt{2\pi \sin\theta \phi^2(\theta)}}, \tag{15}$$

where

$$\delta_0(x^\nu) = A_0 l(x^\nu) + B_0 \tilde{l}(x^{\nu\prime}), \tag{16}$$

A_0 and B_0 are integrating constants (for details see [38]), $\delta_0(x^\nu)$ is the one zero mode which combining the third family massless ordinary lepton doublet $l_0(x^\nu)$ and the massless electric charge swap (ECS) lepton doublet $\tilde{l}_0(x^{\nu\prime})$ respectively.

2.1. The ECS leptons quantum numbers

Brane solutions with different gauge fields and fermions localization mechanisms have been investigated in the literature ([38], [40], [41], [42], [43]). The zero mass modes are given mass via the Higgs mechanism ([38], [44], [45]).

The Higgs fields propagate in the bulk, the Vacuum Expectation Value (VEV) of the Higgs zero-mode, the lowest lying KK state, generates spontaneous symmetry breaking and gives mass to charge ECS lepton (for details see [38]) .

Extra dimensions allow one to reduce the fundamental scale of the theory down to $M_c^* = 10TeV$ [58-60]. The left handed neutral ECS-$\tilde{\tau}_L^0$ leptons is localized on the brane, whereas the right handed ECS-$\tilde{\tau}_R^0$ leptons (being the singlet of the $SU(2)^{(ECS)}$ group) propagates in the bulk. Since the right handed component $\tilde{\tau}_R^0$ is not localized. Essentially *φ(θ)* gives the overlap factor and the Dirac mass on the brane equals

$$m_{\tilde{\tau}_L^0} = \lambda u_{EW} \varphi(\theta), \tag{17}$$

where

$$\varphi(\theta) = \cos^2\left(\frac{\theta}{2}\right) = \frac{1}{2}(1+\cos\theta) = \frac{M^*_{L_S}}{M_{L_S}}, \tag{18}$$

the corresponds warp factor. Brane is localized in different points of extra dimension with different values of warp factor are given in (Table.1)

Table.1. Brane is localized in different points of extra dimension with different values of warp factor

θ-angle (degrees)	cos(θ)	warp factor.
0	1	1
90	0	0.5
168	-0.98	0.0065
180	-1	0

Brane is localized in the specific point of extra dimension, the mass of neutral ECS and the corresponds warp factor are given in (Table.2)

Table.2. Brane is localized in the specific point of extra dimension, the mass of neutral ECS and the corresponds warp factor

$\tilde{\tau}^0_R$ mass (GeV)	Fundamental scale (TeV)	Effective-scale (TeV)	cos(θ)	warp factor.	θ-brane
1.7	10	1529	-0.98	0.0065	168

The quantum numbers of the new non regular leptons, of zero-mode mass 1784 MeV and $35 MeV$ respectively, are given in (Table 3).

Table.3. Quantum numbers (zero mass mode M, weak isospin I, charge Q, Swap-hypercharge Y_{Swap}, Swap-Lepton number L_{Swap}) of the ECS leptons $\tilde{\tau}^0_L$, $\tilde{\nu}^+_\tau$.

New lepton	M	I	I-z	Q	Y_{Swap} L_{Swap}
$\tilde{\nu}^+_\tau$	35MeV	½	1/2	1	1 -1
$\tilde{\tau}^0_L$	1784MeV	½	-1/2	0	1 -1

Although ECS leptons have the same zero mode mass as the ordinary third family charge and neutral leptons, they are distinguished from the latter by their different lepton numbers ($L_s = 1$ for ordinary leptons and $\bar{L}_s = -1$ for ordinary antileptons, respectively) and their electric charges (positive or neutral for ordinary leptons and negative or neutral for ordinary antileptons, respectively).

2.2. The W^+ decays to ECS leptons

In this paper, we investigate the particular category of (W, Z) decay processes that have additional ECS leptons as daughter particles Let us call this process *electric charge swap*. We are beginning with a familiar decay process:

$$W^+ \to \tau^+ \nu_\tau \tag{19}$$

where W^+ is the positive charged boson, and (τ^+, ν_τ) are the positive charged tau and neutral tau neutrino. In this particular decay, mass and energy, momentum and angular momentum, electric charge and the overall leptonic number $L_{overall}$ (equation (10)) are always conserved. Neither ordinary leptonic number L, nor ECS leptonic number L_s are conserved, in the presence of ECS symmetry. The ordinary leptonic number pair is given by

$$L(W^+) = \bar{L}(\tau^+) + L(\nu_\tau) \tag{20}$$

By substituting (10), (11) and (12) for the ordinary pair of leptonic numbers (20) we obtain the ECS pair of leptonic numbers:

$$L(W^+) = L_s(\tilde{\nu}_\tau^+) + \bar{L}_s(\bar{\tilde{\tau}}^0) \tag{21}$$

In the presence of W^+ decays, the electric charge swap rotation in the 3-dimensional vector space V_3 is given by:

$$Q(\tau^+)\hat{e}_1 + Q(\nu_\tau)\hat{e}_2 + Q(W^+)\hat{e}_1 = Q(\bar{\tilde{\tau}}^0)\hat{e}'_1 + Q(\tilde{\nu}_\tau^+)\hat{e}'_2 + Q(\tilde{W}^+)\hat{e}'_1 \tag{22}$$

Since electric charge is conserved, there is a particle with non-swapped electric charge W^+

$$\begin{gathered} Q(W^+) = Q(\tilde{W}^+ \ ) \\ \hat{e}_3 = \hat{e}'_3 \end{gathered} \tag{23}$$

This yields the electric charge swap rotation with respect to the z-axis

$$\begin{gathered} \hat{e}_1 = \cos\theta \hat{e}'_1 + \sin\theta \hat{e}'_2 \\ \hat{e}_2 = \cos\theta \hat{e}'_1 - \sin\theta \hat{e}'_2 \end{gathered} \tag{24}$$

The electric charge of ECS particles can be derived as a linear combination of the electric charge of the ordinary particles:

$$Q(\bar{\tilde{\tau}}^0) = Q(\tau^+)\cos\theta - Q(\nu_\tau)\sin\theta$$

$$Q(\tilde{\nu}_\tau^+) = Q(\tau^+)\sin\theta + Q(\nu_\tau)\cos\theta \qquad (25)$$

$$Q(\tilde{W}^+) = Q(W^+)$$

by substituting the series of angles

$\theta = \frac{\pi}{2}, \frac{3\pi}{2}, \frac{5\pi}{2}, ...$ For simplicity, here we only investigate the case of $\theta = \frac{\pi}{2}$. In this case equation (25) becomes:

$$Q(\bar{\tilde{\tau}}^0) = -Q(\nu_\tau) = 0, \quad Q(\tilde{\nu}_\tau^+) = Q(\tau^+) = 1, Q(\tilde{W}^+) = Q(W^+) = 1, \qquad (26)$$

The conservation of electric charge then becomes

$$1_{W^+} \rightarrow (+1)_{\tilde{\nu}_\tau^+} + 0_{\bar{\tilde{\tau}}^0} \qquad (27)$$

corresponding to a swap of electric charge between the tau and the tau neutrino during decay Equations (21), (26) yields to the variation of the ordinary decay process (equation (19)) to the following decay :

$$W^+ \rightarrow \bar{\tilde{\tau}}^0 \tilde{\nu}_\tau^+ \qquad (28)$$

In which the products are a hypothetical particle - a zero-charged version of the tau, $\bar{\tilde{\tau}}^0$ (swap-antilepton) - and a positive charged version of the tau neutrino, $\tilde{\nu}_\tau^+$ (swap-lepton).

3. The process of electric charge swap at the 10TeV energy scale

In addition to zero mass modes, there are massive KK modes, with mass at the order $1/\varepsilon = 10TeV$. With mass of these values, these massive KK modes lie above the (W, Z) zero mass modes. In this model, the internal space ($S^2 = SU(2)^{(ECS)} / U(1)_{Y(Y_s)}$) must be small enough to permite. Therefore, assuming that the standard Model (SM) remains valid up to a cut-off of order the LHC centra -of- mass energy 10TeV. However, the SM with a cut-off of order the LHC energy would be 10% fine tuned, and so we should expect to see new physics at the LHC. The search for new physics involves measuring the deviation from the SM. Here, this deviation is small and a precise measurement may be needed. For this reason will assume a ECS physics program when LHC running at 14 TeV center -of- mass energy, and integrated luminosity of $10fb^{-1}$ per year.

The SM prediction:

$$\frac{G_F}{\sqrt{2}} = \frac{\pi}{M_W^2(1 - M_W^2 / M_Z^2)}(1 + \Delta r) \tag{29}$$

where

$$\Delta r = \Delta a - \frac{c^2}{s^2}\Delta\rho + \Delta r_{rem} , \tag{30}$$

The $\Delta\rho$ term arises from the (t,b) contribution to the W and Z self-energies and can be written to one loop:

$$\Delta\rho = \frac{3a}{16s^2c^2}\frac{M_t^2}{M_Z^2} = \frac{3G_F M_t^2}{8\sqrt{2}\pi^2} \tag{31}$$

The Δr_{rem} term contains the remaining contributions which are generally not including those due to Higg boson. The $\Delta a = 2(\delta e / e)$ and $\Delta\rho$ terms gives the largest contribution to Δr: For $M_t = 175 GeV$ and light Higgs they taken on the values 0.05 and -0.03 respectively, while the 0.005.

3.1. The ECS invariant

This swap of electric charge does not violate any conservation law. In addition, the electric charge swap does not affect the transition rates of neither ordinary (19), nor electric charge swapping processes (28). The rate dΓ for the electric charge swapping processes (28) is given by

$$d\Gamma(W^+ \to \bar{\tilde{\tau}}^0 \tilde{\nu}_\tau^+) = G^2 \sum_{spin} |\bar{u}(p_{\tilde{\nu}_\tau^+})\gamma^0(1-\gamma^5)\upsilon(p_{\bar{\tilde{\tau}}^0})|^2 \frac{d^3 p_{\tilde{\nu}_\tau^+}}{(2\pi)^3 2E_{\tilde{\nu}_\tau^+}} \times \frac{d^3 p_{\bar{\tilde{\tau}}^0}}{(2\pi)^3 2E_{\bar{\tilde{\tau}}^0}} 2\pi\delta(E_{W^+} - E_{\bar{\tilde{\tau}}^0} - E_{\tilde{\nu}_\tau^+}) \tag{32}$$

$$\sum_{spin} |\bar{u}(p_{\tilde{\nu}_\tau^+})\gamma^0(1-\gamma^5)\upsilon(p_{\tilde{\tau}^0})|^2 = 8E_{\tilde{\tau}^0}E_{\tilde{\nu}_\tau^+}(1 + u_s\cos\theta) , \tag{33}$$

where E_W is the energy released to the swap lepton pair and θ is the opening angle between the two leptons and the swap-antilepton velocity u_s in our approximation.

Substituting (33) to (32), the transition rate becomes

$$d\Gamma(W^+ \to \bar{\tilde{\tau}}^0 \tilde{\nu}_\tau^+) = \frac{2G^2}{(2\pi)^5}(1+\cos\theta)[(2\pi d\cos\theta\, p_{\bar{\tilde{\tau}}^0}^2 dp_{\bar{\tilde{\tau}}^0})(4\pi E_{\tilde{\nu}_\tau^+}^2 dE_{\tilde{\nu}_\tau^+})] \delta(E_{W^+} - E_{\bar{\tilde{\tau}}^0} - E_{\tilde{\nu}_\tau^+}) \tag{34}$$

The rate dΓ for the ordinary processes (19) is given by

$$d\Gamma(W^+ \to \tau^+\nu_\tau) = G^2 \sum_{spin} |\bar{u}(p_{\tau^+})\gamma^0(1-\gamma^5)\upsilon(p_{\nu_\tau})|^2 \frac{d^3 p_{\tau^+}}{(2\pi)^3 2E_{\tau^+}}$$
$$\times \frac{d^3 p_{\nu_\tau}}{(2\pi)^3 2E_{\nu_\tau}} 2\pi\delta(E_W - E_{\tau^+} - E_{\nu_\tau}) \quad (35)$$

$$\sum_{spin} |\bar{u}(p_{\tau^+})\gamma^0(1-\gamma^5)\upsilon(p_{\nu_\tau})|^2 = 8E_{\tau^+}E_{\nu_\tau}(1+u\cos\theta), \quad (36)$$

where E_W is the energy released to the lepton pair and θ is the opening angle between the two leptons and the antitau velocity u in our approximation. Substituting (36) to (35) the transition rate becomes

$$d\Gamma(W^+ \to \tau^+\nu_\tau) = \frac{2G^2}{(2\pi)^5}(1+\cos\theta)[(2\pi d\cos\theta\, p_{\tau^+}^2 dp_{\tau^+})(4\pi E_{\nu_\tau}^2 dE_{\nu_\tau})]$$
$$\delta(E_W - E_{\tau^+} - E_{\nu_\tau}) \quad (37)$$

By comparing equations (33), (34), (36) and (37) we conclude that there is an electric charge swapping invariant ($d\Gamma(W^+ \to \tau^+\nu_\tau) = d\Gamma(W^+ \to \bar{\tilde{\tau}}^0\tilde{\nu}_\tau^+)$). The electric charge swapping invariant with at the 10TeV energy scale is given by

$$\Gamma(W^+ \to \tau^+\nu_\tau) = \Gamma(W^+ \to \bar{\tilde{\tau}}^0\tilde{\nu}_\tau^+) = \frac{G_F}{6\pi\sqrt{2}} M_W^3 \quad (38)$$

In the presence of electric charge swap symmetry, the rate of Z decays to ECS leptons is given by

$$\Gamma(Z^0 \to \tilde{l}\bar{\tilde{l}}) = \frac{g^2}{8\cos^2\theta_w} M_Z(\tilde{c}_V^2 + \tilde{c}_A^2) \quad (39)$$

where $\tilde{l} = (\tilde{\tau}^0, \tilde{\nu}_\tau^+)$ the swap flavor indices, and the $\tilde{c}_V$, $\tilde{c}_A$ .are the swap axial and vector coupling. In Table.4, we calculate the axial ($\tilde{c}_A = I_3$) and vector ($\tilde{c}_V = I_3 - 2Q_{\tilde{l}}\sin^2\theta_W$) swap couplings by using the values of Q and I-z, given in Table. 3.

Table. 4 Electric charge, axial and vector couplings of ECS leptons

ECS leptons	$\tilde{c}_A$	$\tilde{c}_V$
$\tilde{\tau}^0$	$-1/2$	$-1/2$
$\tilde{\nu}_\tau^+$	$1/2$	$1/2 - 2\sin^2\theta_W$

Using equation (39) and the values given in Table.4, we calculate the Z decay to ECS lepton partial widths:

$$\Gamma(Z^0 \to \tilde{\tau}^0\bar{\tilde{\tau}}^0) = 2\Gamma(Z^0 \to \nu_\tau\bar{\nu}_\tau),\ \Gamma(Z^0 \to \tau^+\tau^-) = 2\Gamma(Z^0 \to \tilde{\nu}_\tau^+\tilde{\nu}_\tau^-) \tag{40}$$

Taken together, equations (38) and (40) predict that ordinary third family leptons and ECS leptons couple equally with (W, Z) bosons at collision energy at the scale of $M_C \approx 10TeV$. This prediction can be tested when LHC becomes operative at such energy scales.

The invariant energy- averaged annihilation cross- section at 10 TeV scale of energy is given by

$$<\sigma_{ann}(\tilde{\tau}_L^0\bar{\tilde{\tau}}_L \to Z^0)>_s = <\sigma_{ann}(\nu_\tau\bar{\nu}_\tau \to Z^0)>_{SM} = \int \frac{ds}{M_Z^2}\sigma_{ann}(s) = \frac{4\pi G_F}{\sqrt{2}} \tag{41}$$

the invariant energy-averaged annihilation cross-section defined by the following integral over the z-pole:

with s the square of the energy in the center of momentum frame. The SM value of this cross-section is: ($<\sigma_{ann}(\nu_\tau\bar{\nu}_\tau \to Z^0)>_{SM} = 4.62\times10^{-32} cm^2$) for each neutral lepton type (flavor or mass basis) independent of any flavor mixing since the annihilation mechanism is a neutral current process.

3.2. The ECS leptons in the LHC detectors

These propositions can only be tested at a higher energy linear collider with high integrated luminosity >> >50 fb^{-1}, such as the LHC when it becomes operative at 10TeV energy scale.

Since the proposed non regular ($\tilde{\tau}^0$) lepton is neutral, it will not be detectable by the LHC detectors. This lepton could still be detected indirectly: if leptons escape the accelerator, they will manifest as missing energy. In a toroidal LHC apparatus (ATLAS) inner detector experiment [61] the charged non regular lepton ($\tilde{\nu}_\tau^\pm$) with zero mass mode of 35 MeV carries the electric charge. Its orbit must, therefore, be different from that of ordinary tau neutrinos (ν_τ). The deviation of this orbit will have a significant value ([48], [49]). This signature track is unexplainable by any of the observed particles, as it streaks across the LHC's detectors.

4. Current collider signatures of ECS leptons

At the collision scale of energy below the compactification scale $(M_s < 10TeV)$, the ordinary third family of leptons can decay to the second and first leptons families. Therefore the overall lepton number given by equation (10) is not conserved ($L_{swap} + L \neq 0$), $L_{swap} \neq \bar{L}$ while the ordinary lepton number L and ECS lepton number L_{swap} can be conserved.

The solution of the six-dimensional Dirac equation (15) suggests that first and second lepton families of swap electric charge do not exist. ECS lepton number L_{swap} is conserved since there is no mixing between ordinary leptons and ECS leptons at energy scales below the compactification scale $(M_c = 10TeV)$. Therefore, ECS leptons can be stuck to the scale of energy close to compactification scale $(M_c = 10TeV)$, while the ordinary third family of leptons is at the collision scale of energy $(M_s < 10TeV)$.

The contribution of ECS leptons at collision energy scale $M_s \leq 10$ TeV is given by the mixing between the compactification and the current collision scale of energies. This mixing is proportional to $1-\left(\frac{M_s}{M_c}\right)^4$. The Fermi constant ($G_F = 10^{-6} GeV^{-2}$) is modified

$$G'_F = G_F - G_F \left(\frac{M_s}{M_c}\right)^4 . \tag{42}$$

The above equation yields to changes of Fermi constant:

$$\Delta G_F = | G'_F - G_F | = G_F \left(\frac{M_s}{M_c}\right)^4 . \tag{43}$$

The ordinary leptons coupling to (W, Z) gauge bosons by G_F, and the ECS leptons coupling to (W, Z) gauge bosons by the changes of ΔG_F.

Being with the relation:

$$\rho(G_F / \sqrt{2}) = g^2 / 8M_Z^2 \cos^2 \theta_W , \tag{44}$$

where (experimentally ρ≈1), we obtain a change of g^2 .

$$\delta\rho \frac{G_F}{\sqrt{2}} + \rho \frac{\delta G_F}{\sqrt{2}} = \frac{\delta g^2}{8M_Z} \cos\theta_w \tag{45}$$

Substituted equations (43) and (44) to equation (45) we obtain

$$\delta\rho \frac{G_F}{\sqrt{2}} + \left(\frac{M_s}{M_c}\right)^4 \frac{g^2}{8M_Z} \cos\theta_w = \frac{\delta g^2}{8M_Z} \cos\theta_w \tag{46}$$

Here, because of the small deviation from SM ($\delta\rho \leq$ -0.03) at scale of energy close to $(M_c = 10TeV)$, the equation (46) becomes

$$\left(\frac{M_s}{M_c}\right)^4 \frac{g^2}{8M_Z} \cos\theta_w = \frac{\delta g^2}{8M_Z} \cos\theta_w \tag{47}$$

where

$$\delta g^2 = g^2\left(\frac{M_s}{M_c}\right)^4 \tag{48}$$

The contribution of ECS leptons to the (W, Z) decays at the collision scale of energies of ($0.1\text{TeV}\le M_s\le 10\text{TeV}$) is given by

$$\frac{\Gamma(W^+\to \bar{\tilde{\tau}}^0\tilde{\nu}_\tau^+)_s}{\Gamma(W^+\to \tau^+\nu_\tau)_{SM}} = \frac{\Delta G_F}{G_F} = \left(\frac{M_s}{M_c}\right)^4,\ \frac{\Gamma(Z^0\to \tilde{l}\bar{\tilde{l}})_s}{\Gamma(Z^0\to l\bar{l})_{SM}} = \frac{\Delta g^2}{g^2} = \left(\frac{M_s}{M_c}\right)^4 \tag{49}$$

Calculations of the contribution of ECS leptons at collision energy scale ($0.1\text{TeV}\le M_s\le 10\text{TeV}$) are given in Table.5.

Table.5 The rate of (W, Z) decays to the ECS leptons at collision energy scale ($0.1\text{TeV}\le M_s\le 10\text{TeV}$)

$M_S(TeV)$	$(M_S / M_c)^4$
0.1	10^{-8}
1	10^{-4}
2	1.6×10^{-3}
3	8×10^{-3}
4	0.025
5	0.062
6	0.12
7	0.2
8	0.4
9	0.6
10	1

By the values given in Table.5, we conclude that the ECS invariant is broken at collision scale of energies below the compactification scale ($M_s<10\text{TeV}$), and that the ECS lepton does not break the Z pole observables at LEP.2 ($M_s\approx 0.1\text{TeV}$-1TeV) [50], [51]. However we find that the contribution of ECS at current collision energy scales (e.g.$M_s\approx 7\text{TeV}$ at the LHC [52]) and LEP.2 measurements at electroweak scale of energy is very small.

The predicted non regular neutral lepton zero mass mode (1.7GeV) is lighter than $M_Z/2$ contributed to the invisible Z width

$$\Delta\Gamma_Z = \left(\frac{M_s}{M_C}\right)^4 \frac{\Gamma_\nu}{2}\left[1-\left(\frac{2m_{\tilde{\tau}^0}}{M_Z}\right)^2\right]^{3/2} \theta\left(2m_{\tilde{\tau}^0} - M_Z\right) \tag{50}$$

where $\Gamma_\nu = 167 MeV$ is the Z invisible decay into one neutrino species [51]. We find that the contribution of the non regular neutral lepton $\Delta\Gamma_Z \approx 3.1$eV, at LEP.2 collision energy scale is required to be ($\tilde{\tau}^0$) – that is a dark matter particle.

Since ECS lepton number L_s is conserved, ECS leptons can be created or annihilated in pairs through (Z, γ). Here, we study the process $(e^+e^- \to \tilde{\nu}_\tau^+\tilde{\nu}_\tau^-)$ and $(\bar{\tilde{\tau}}^0\tilde{\tau}^0 \to e^+e^-)$ at the collision energy scale (0.1TeV≤M_s≤10TeV). The cross section of the process $(\tilde{\tau}^0\bar{\tilde{\tau}}^0 \to e^+e^-)$ is given by

$$< \sigma_{ann}(\tilde{\tau}^0\bar{\tilde{\tau}}^0 \to e^+e^-) >_s = 4\pi\frac{\Delta G_F}{\sqrt{2}} \tag{51}$$

substituting equation (43) to equation (51):

$$\frac{< \sigma_{ann}(\tilde{\tau}^0\bar{\tilde{\tau}}^0 \to e^+e^-) >_s}{< \sigma_{ann}(\tilde{\tau}^0\bar{\tilde{\tau}}^0 \to e^+e^-) >_{SM}} = \left(\frac{M_s}{M_c}\right)^4 \tag{52}$$

where $< \sigma_{ann}(\tilde{\tau}^0\bar{\tilde{\tau}}^0 \to e^+e^-) >_{SM} = 4\pi\frac{G_F}{\sqrt{2}}$ the SM neutrino cross section of the process. The cross section of the process $(e^+e^- \to \tilde{\nu}_\tau^-\tilde{\nu}_\tau^+)$ is given by

$$\sigma_s(e^+e^- \to \tilde{\nu}_\tau^-\tilde{\nu}_\tau^+) = R_{\tilde{\nu}_\tau^+}\sigma_s(e^+e^- \to \tilde{\nu}_\tau^-\tilde{\nu}_\tau^+)_{QED} \tag{53}$$

where $R_{\tilde{\nu}_\tau^+} = \frac{1}{8}\left(\frac{\Delta G_F M_Z^3}{\Gamma_Z e^2}\right)^2$ is the ($\tilde{\nu}_\tau^+$) cross section ratio. Substituting equation (43) to equation (53):

$$\frac{R_{\tilde{\nu}_\tau^+}}{R_{\mu^-}} = \left(\frac{M_s}{M_c}\right)^8 \tag{54}$$

where $R_{\mu^-} = \frac{1}{8}\left(\frac{G_F M_Z^3}{\Gamma_Z e^2}\right)^2$ the SM muon cross section ration of the process $(e^+e^- \to \mu^-\mu^+)$

Calculations of the contribution of ECS leptons at collision energy scale ($0.1TeV \le M_s \le 10TeV$) are given in Table. 6.

Table.6. The contribution of ECS leptons at collision energy scale ($0.1TeV \le M_s \le 10TeV$)

$M_S(TeV)$	$\frac{<\sigma_{ann}(\bar{\tilde{\tau}}^0\tilde{\tau}^0 \to e^+e^-)>_s}{<\sigma_{ann}(\nu\bar{\nu} \to e^+e^-)>_{SM}}$	$\frac{R_{\tilde{\nu}_\tau^+}}{R_\mu}$
0.1	10^{-8}	10^{-16}
1	10^{-4}	10^{-8}
2	1.6×10^{-4}	2.5×10^{-8}
3	8.1×10^{-3}	6.5×10^{-5}
4	2.5×10^{-2}	4×10^{-4}
5	0.062	3×10^{-3}
6	0.12	0.010
7	0.24	0,05
8	0.40	0.16
9	0.65	0.42
10	1	1

By the values given in Table.6, we conclude that the contribution of ECS leptons (equations (52), (54)), at the current LHC collision energy scale ($M_s \approx 7TeV$) [52] and LEP.2 measurements of cross-section for electron-positron annihilation [50], [51] is too small to be detected. The E821 experiment at the Brookhaven National Laboratory (BNL) studied the precession of muon and anti-muon in a constant external magnetic field as they circulated in a confining storage ring [50], [51]. For two extra dimensions of radius (1/10TeV), the additional contribution of the proposed non regular charge lepton with zero mass mode of $35MeV$ to anomalous magnetic moments:

$$a^{add} = O(1)\frac{m_{\tilde{\nu}_\tau^+}^2}{M_C{}^2} = 10^{-11} \tag{55}$$

which is too small to be detected by this experiment ([51], [53], [54], [55], [56], [57]). For this reason, neither the current LHC [52] collision scale of energy nor the LEP2 measurements of the cross-section for electron-positron annihilation [50], [51] and of anomalous magnetic moments of the electron and muon [50], [51] can prove the existence of the proposed ECS lepton with a zero mass mode of 35 MeV. The energy scale we propose here is large compared to the electroweak energy scale. These propositions, and the predicted level of the standard model (SM) loop corrections, can only be tested at a higher energy linear collider with high integrated luminosity >>> 50 fb^{-1}, such as the LHC.

5. Discussion

The proposition of electric charge swap predicts the occurrence of a non regular neutral leptons ($\tilde{\tau}^0$), with zero mass mode of 1784 MeV. It follows that the predicted lepton ($\tilde{\tau}^0$) is a stable particle that contributes to the dark matter of the Universe.The ESC - $\tilde{\tau}^0$ leptons could be produced in the early Universe through reactions such that $(e^+e^- \to \tilde{\tau}^0\bar{\tilde{\tau}}^0)$,the ESC - $\tilde{\tau}^0$ leptons can be annihilated through the backreaction $(\tilde{\tau}^0\bar{\tilde{\tau}}^0 \to e^+e^-)$. As longs T≥ $M_c/10$ where ($M_c \approx$10TeV) is the compactification energy scale.

However, one the temperature drops below $M_c/10$ the ESC - $\tilde{\tau}^0$ leptons abundance begins to drop. The ESC - $\tilde{\tau}^0$ leptons freeze-out temperature of ($T_F=M_c/10=1$TeV) occurs at ESC - $\tilde{\tau}^0$ leptons relic density determined by the ESC - $\tilde{\tau}^0$ leptons annihilation cross-section impels that[3]:

$$\Omega_{\tilde{\tau}^0} h^2 = \frac{10^{-37} cm^2}{<\sigma_{ann}(\tilde{\tau}^0\bar{\tilde{\tau}}^0 \to e^+e^-)>_s} = 0.1 \qquad (56)$$

The interactions of the predicted non regular lepton ($\tilde{\tau}^0$) freeze out at a temperature such that ($x_{\tau^0} = m_{\tau^0}/T_F \approx 1.7\times10^{-3}$) is much smaller than one. Therefore, the ($\tilde{\tau}^0$) leptons cannot have significant relic abundance today.

However we do not have enough information on the detailed nature of Cold Dark Matter (CDM), except that $\Omega_{DM} h^2 = 0.1$. More information for direct and indirect dark matter searches and colliders are indispensable for us to diagnose the particle identity of the CDM, namely its mass and spin and other internal quantum number(s) [61].

Recently, (PAMELA) reported a sharp increase of positron fraction $e^+/(e^+ + e^-)$ in the cosmic radiation for the energy range 10 GeV to 100 GeV [62], [63] and no excess in p^-/p^+ from the theoretical calculations. And also very recently, (Fermi- LAT) [64] and (HESS) [65] data showed clear excess of $(e^+ + e^-)$ spectra in the multi-hundred GeV range above the convential model [66], although they do not confirm the previous (ATIC) [67] peak. The phenomenology of ECS dark matter at PAMEL/FERMI is under investigation.

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[3] At the freeze out temperature of $(T_F = 1TeV)$:

$$<\sigma_{ann}(\tilde{\tau}^0\bar{\tilde{\tau}}^0 \to e^+e^-)>_s = (T_F/M_c)^4 <\sigma_{ann}(\nu\bar{\nu} \to e^+e^-)>_{SM} = 10^{-36} cm^2$$

where $(T_F/M_c)^4 = 10^{-4}$, $<\sigma_{ann}(\nu\bar{\nu} \to e^+e^-)>_{SM} = 10^{-36} cm^2$.

The success of the Standart Big Bang Nucleosynthesis The success of the Standart Big Bang Nucleosynthesis (SBBN) model notwithstanding, an outstanding issue is SBBN's ability to correctly predict elemental abundance in the Universe.

The amount of $^{7}\mathrm{Li}$ predicted by the SBBN, for instance, is about 2-3 times larger than the observational value from stellar atmospheres of the low metalisity halo stars ([68], [69], [70]). This statistically significant discrepancy is known as the 'Lithium problem'.

The proposed charge ECS lepton is a heavy electron. In analogy with the muon, the charge lepton could catalyze high temperature fusion of lithium and beryllium nuclei. The proposed charge lepton could thus provide an explanation for the missing lithium in the SBBN model [68].

6. Conclusions

The ($W^{\pm}$, Z) decay to neutral non regular lepton (zero mass mode 1784 MeV) and charge non regular lepton (zero mass mode 35 MeV) proposed here is strictly a phenomenon of the $10TeV$ energy scale. Its proposition is formulated by reference to a 2-extra dimensional sphere with a global isometric group, the electric charges-swapping group, $SO(3)^{ECS}$ **.** Instead of introducing *ad hoc* new particles, our proposition introduces new particles from ordinary ones, using an alternative interpretation of the distribution of lepton electrical charge.

We suggest that (W, Z) decay beyond SM comes from the proposed new leptons. The existence of these non regular leptons is testable once the LHC becomes operative. The neutral non regular lepton (zero mass mode 1784 MeV) is a possible cold dark matter candidate.

Furthermore, we find that the contribution of the proposes non regular leptons on scale of energies below the compactification scale is suppressed. Therefore the new non regular leptons are not subject of bounds comes from both current colliders: Large Electron Positron (LEP) 2, which reached a central of mass energy of 209 GeV [50], [51] and current LHC, which reached a central of mass energy of 7 TeV [52] and from the E821 experiment at Brookhaven National Laboratory reported a measurement of the muon's magnetic moment [50], [51].

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