Journal of High Energy Physics, Gravitation and Cosmology, 2023, 9, 1161-1180
https://www.scirp.org/journal/jhepgc
ISSN Online: 2380-4335
ISSN Print: 2380-4327

The QCD Ground State Chiral Tetrahedron Symmetry

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How to cite this paper: Rom, R. (2023) The QCD Ground State Chiral Tetrahedron Symmetry. *Journal of High Energy Physics, Gravitation and Cosmology*, **9**, 1161-1180.
https://doi.org/10.4236/jhepgc.2023.94082

Received: June 27, 2023
Accepted: October 14, 2023
Published: October 17, 2023

Abstract

We propose that the exotic meson tetraquark $u\tilde{d}d\tilde{u}$ introduced in previous papers, may be a pseudo-Goldstone boson having a tetrahedron geometry and symmetry. The transition from the neutral pion superposition of two free mesons, $d\tilde{d}$ and $u\tilde{u}$, to the tetrahedron geometry with optional two chiral states may be the symmetry breaking of the QCD ground state. The $u\tilde{d}d\tilde{u}$ tetrahedron mass may be calculated by measuring the β decay rate variability. We assume that electrons and positrons are composite particle exotic tetraquarks, $d\tilde{u}u\tilde{d}$ for the electrons and $u\tilde{d}d\tilde{d}$ for the positrons and confined by the strong force. We propose that the QCD tetrahedrons play a central role in electron pairing mechanism in both chemical bond forming and superconductor Cooper pairs. We propose a hypothesis where the QCD ground state tetrahedrons play a central role in low energy physics where quark exchange reactions between particles and the QCD tetrahedrons via gluon junctions transfer all the forces. The QCD ground state $u\tilde{d}d\tilde{u}$ tetrahedrons hypothesis provides a symmetry breaking and a mass gap may be created by the ground state QCD tetrahedrons Bose-Einstein condensate.

Keywords

QCD Vacuum, Pseudo-Goldstone Boson, Bose Einstein Condensate (BEC), Lattice QCD, Gluon Junctions, Tetrahedrons, Cooper Pairs, Isotope Effect, Superconductor, Dirac Equation, Klein Paradox, Cosmic Web Voids, Doppler Redshift, Black Hole Laser

1. Electrons, Positrons and the QCD Tetrahedrons

Inspired by the theory of Loop Quantum Gravity (LQG), which introduces a spin foam and assumes that on a small scale there should be a quantum of space and no non-dynamical spacetime "stage" background [1], we propose that the

QCD exotic meson tetraquarks $u\tilde{d}d\tilde{u}$ introduced in previous papers [2] [3] [4] [5] may have a tetrahedron geometry and may populate the QCD ground state. We note that pion π^0 comprised of a superposition of $d\tilde{d}$ and $u\tilde{u}$ mesons, which are the same four quarks and antiquarks of the proposed exotic teraquark, $u\tilde{d}d\tilde{u}$, may condense to a tetrahedron geometry that may be a pseudo-Goldstone boson [6] and may have two chiral symmetry states as shown in **Figure 1**.

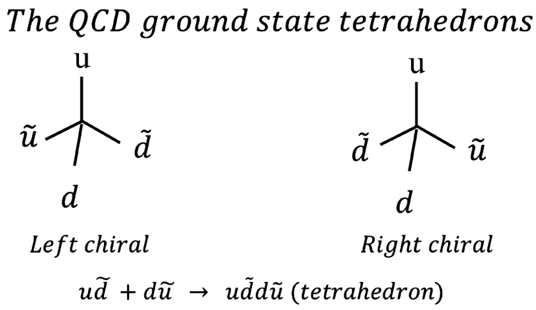

Figure 1. The proposed QCD tetrahedron pseudo-Goldstone boson with possible left or right chirality. The QCD tetrahedron linear strings are connected by a gluon junction in the tetrahedron center.

$$d\tilde{d} + u\tilde{u} \rightarrow u\tilde{d}d\tilde{u}\left(\text{tetrahedron}\right) \tag{1}$$

A gluon junction may be created in the tetrahedron center that confines the quarks and stabilize the tetrahedron structure as illustrated below. The tetrahedron pseudo-Goldstone bosons are assumed to have a small volume comparing to protons and neutrons and to fill space with high density.

The QCD tetrahedrons may be rotated/twisted into a plane where all four quarks and anti-quarks collapse to the XY or the YZ planes for example as shown in **Figure 2**.

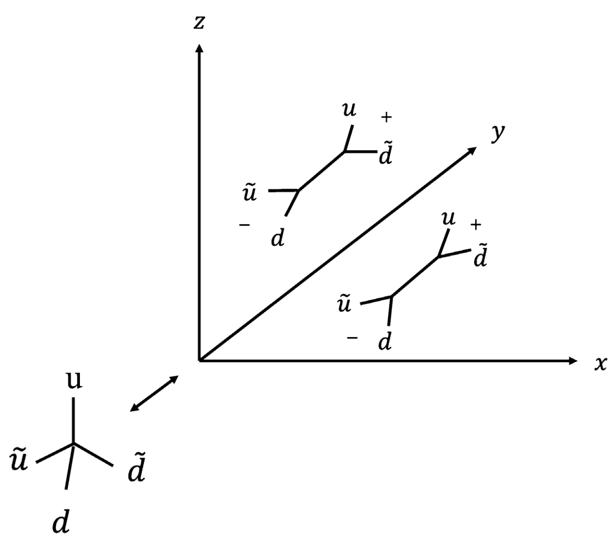

Figure 2. The proposed QCD tetrahedron pseudo-Goldstone boson and two planar orthogonal polarizations where all four quarks and antiquarks collapse to the XY or the YZ planes.

In a previous paper we suggested that the tetraquark may be a peculiar positronium (see Crater and Wong TBDE solution) [7] [8]. We further propose here that a $u\tilde{d}d\tilde{d}$ charged exotic tetraquark tetrahedron may be the positron and a $d\tilde{u}d\tilde{d}$ charged exotic tetraquark tetrahedron may be the electron. The electrons and positrons sub-quark charges are stabilized by the $d\tilde{d}$ quark and antiquark and the gluon junction in the center of the tetrahedron such that they are confined by the strong force like the proton and neutron. Accordingly, we assume that electrons and positrons are composite multiquark tetrahedrons having a left and right chirality that can spin around their center of mass and polarize their surrounding QCD tetrahedrons of the vacuum as shown in **Figure 3**.

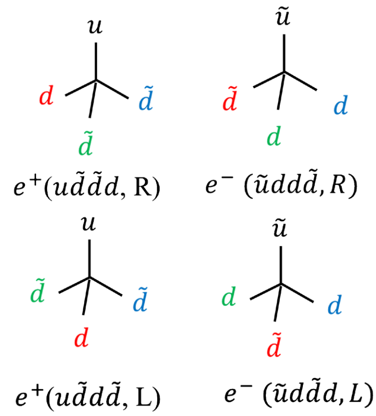

Figure 3. The electrons and positrons are comprised of exotic tetraquarks having left and right chirality and a gluon junction in the center of the tetrahedron. The two chirality's are obtained by exchanging two quark and antiquark creating two enantiomers. Note that the colors are used to illustrate the chirality and are not the QCD charge colors.

Another hint for the leptons and quarks interaction is the electroweak theory, where the electron mass is found to be proportional to the QCD vacuum pion condensate expectation value $m_e \sim \langle 0|\varphi^0|0\rangle$ [9].

Dirac's Hamiltonian couples the electron and positron spinor components; accordingly, matter and antimatter are mixed and cannot be separated [10]. The exchange of an electron with a virtual electron-positron pair described by a Feynman diagram [11] mix matter and antimatter components, however, if the exchange reaction is written in terms of quarks, it adds an interaction with the QCD ground state. The electron exchange reaction exchanges a charged meson with the QCD tetrahedron as described by the following reaction:

$$d\tilde{u}\tilde{d}d_{(e^1)} + \left[u\tilde{d}d\tilde{u}\right]_{\text{tetrahedron}} \to \left[u\tilde{d}d\tilde{u}\right]_{\text{tetrahedron}} + d\tilde{u}\tilde{d}d_{(e^2)} \quad (2)$$

According to Equation (2) electrons are not created nor destroyed from the vacuum state like assumed by QFT, electrons exchange their positron partners interacting with the QCD ground state tetrahedrons.

Studying the Dirac equation, Klein found that electrons can cross a potential barrier without the exponential damping expected from non-relativistic quantum tunneling [12]. Brito wrote that the creation of particle-antiparticle pairs at the potential barrier explains the undamped transmitted part solving the Klein paradox [13]. The solution of Klein paradox suggests that nucleus take part in electron pairing dynamics by exciting electron-positron pairs from the vacuum.

The fine and hyperfine structure of the hydrogen atom energy levels can be derived from Dirac equation [14]. The magnetic hyperfine spin-spin interaction is attractive and singular at short distances:

$$W_{hyperfine} = -\frac{8\pi}{3}\mu_e \cdot \mu_p \delta(R) \tag{3}$$

The positron magnetic moment is about 2000 times bigger than the proton magnetic moment μ_p and hence the hydrogen atom fine and hyperfine perturbative solution is not justified for the positronium. Crater and Wong solved the Two Body Dirac Equation (TBDE) system with constraint dynamics approximation for the positronium and found a new ground state significantly more strongly binding than the more familiar positronium solution of about 6.8 eV. The condensed peculiar positronium binding energy is about 300 KeV and its bond length is three orders of magnitude shorter than the hydrogen atom bond length (Bohr radius). The main attraction term in Crater and Wong TBDE approximate solution is the magnetic spin-spin attraction term of Equation (3). The peculiar positronium existence and its expected decay via 4 photons were not verified yet and a non-radiative decay channel to the QCD ground state may exist.

In the next section we propose that the QCD tetraquarks take part in electron pairing in chemical bonds.

2. Electron Pairing in Molecules and the QCD Ground State Tetrahedrons

Herzberg studied the dissociation energies of the hydrogen molecule (H_2) and its isotopes HD and deuterium (D_2) molecules [15]. The dissociation energies in the ground electronic state of the three molecule isotopes are 36118.3 cm^{-1}, 36406.2 cm^{-1} and 36748.9 cm^{-1}. The heavier molecular isotopes, HD and D_2, have bigger dissociation energy than the hydrogen molecule. The non-adiabatic corrections to rovibrational levels of the hydrogen molecule were studied by Puchalski and Komasa that concluded that the non-adiabatic corrections adds to the moving ions an electron coat that changes the effective mass carried by the ions [16]. Puchalski *et al.* studied the relativistic corrections for the ground electronic state of molecular hydrogen and concluded that the ions relativistic recoil corrections might be larger than previously anticipated [17]. The outcome of the isotope effect in molecules is different from the isotope effect in superconductors but their source is similar. In both cases the isotope effect couples the ions motion to the electrons affecting the electron pairing mechanism.

The ground state polarized QCD tetraquarks, $u\tilde{d}d\tilde{u}$, may create an effective attractive force between electrons for example in the hydrogen molecule. The polarized QCD tetrahedrons due to two electrons with opposite spins may create an effective attraction between the electron pair and the two hydrogen ions as shown in Figure 4.

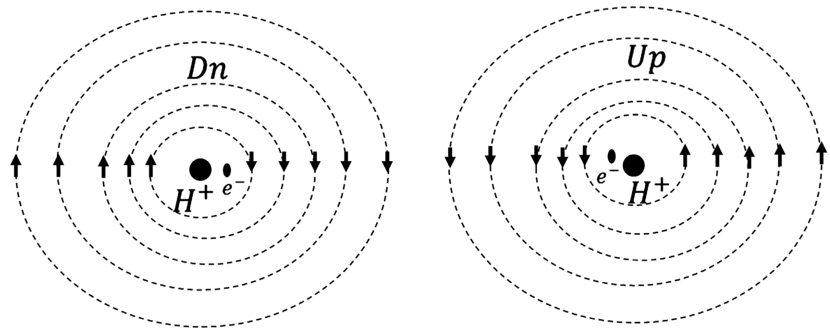

Figure 4. The QCD tetrahedrons polarization due to pair of electrons with opposite spins in a Hydrogen molecule.

A coherent double exchange reaction with two electron-positron pairs may occur for example at the elliptic turning point as shown below due to the interaction with the Hydrogen nuclei. A first electron-positron pair may pop up on the right-side hydrogen nucleus, the positron creates a peculiar positronium tetraquark tetrahedron with the first electron and the second electron may be released at the elliptic turning point. Same sequence of events may occur coherently at the left-hand side hydrogen nucleus. The double exchange reactions may occur coherently and the electrons of the two hydrogens exchange of nuclei form the chemical bond as shown in Figure 5.

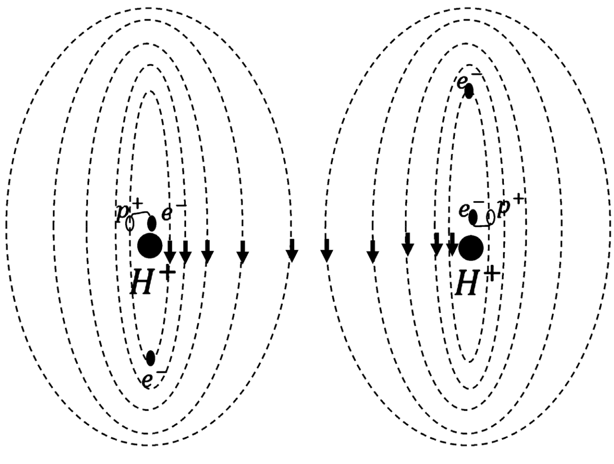

Figure 5. The proposed QCD ground state tetrahedron polarization creating an effective attraction between electron pair via coherent double exchange reactions of two electrons with two electron-positron pairs excited by the two hydrogen nuclei.

The Feynman diagram as shown in Figure 6 below illustrates the coherent double exchange reactions of two electrons with two electron-positron pairs excited by the two hydrogen nuclei forming a chemical bond.

The spin polarization effect of the QCD ground state tetrahedrons may be analogous to the Casimir force between two neutral plates in the vacuum. If a quantum system is confined between walls (here the two ions) the QCD ground state energy reduction will lead to a net force between the walls [18].

The isotope effect in the dissociation energy of the hydrogen, HD and deuterium molecules and the superconductor isotope effect described below [19] hint that the QCD ground state plays a role in the electron pairing mechanism in both cases.

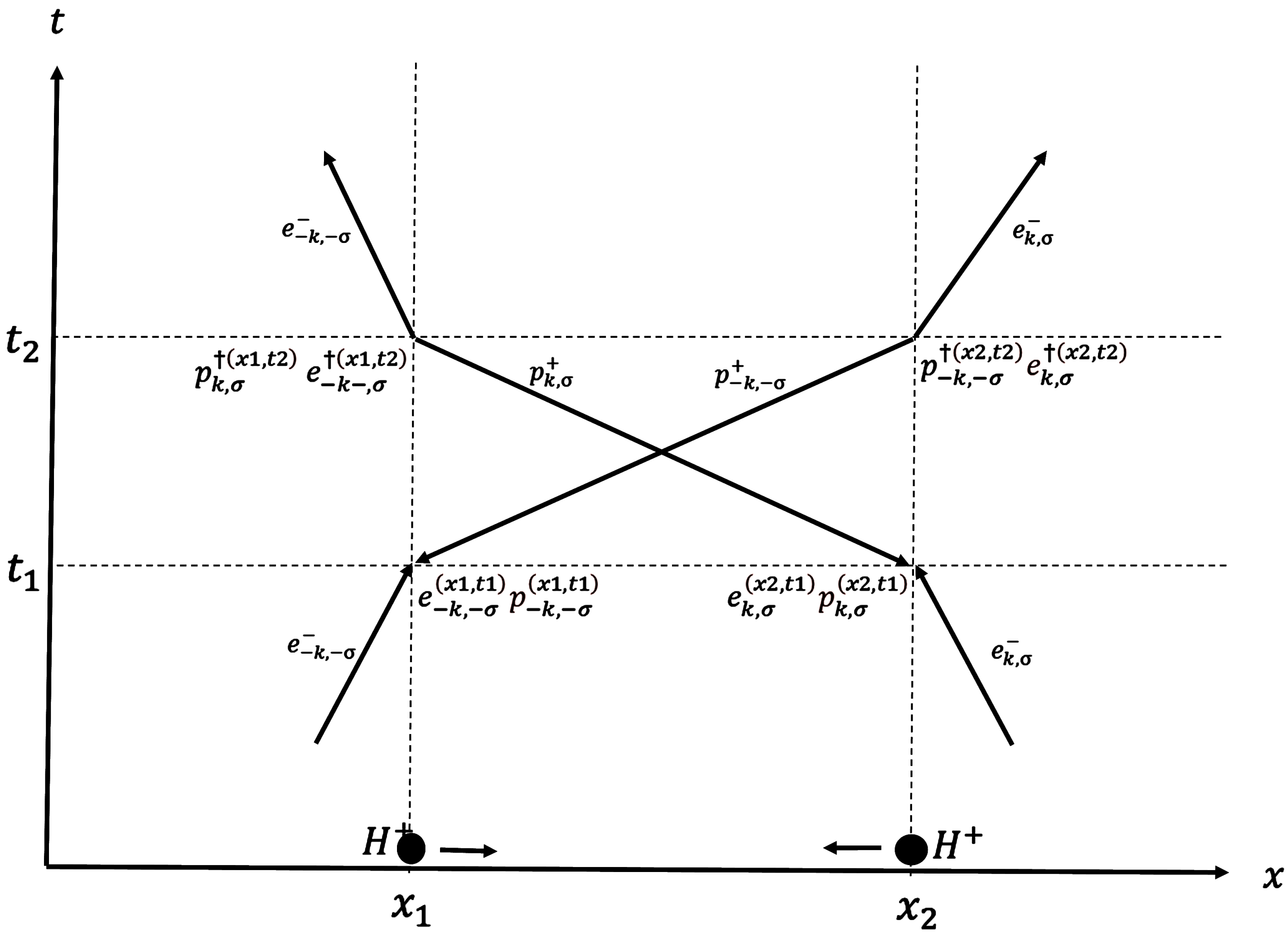

Figure 6. The coherent double exchange reactions of two electrons with opposite spins with two electron-positron pairs tetrahedrons excited by the two hydrogen ions.

3. Electron Pairing in Superconductors and the QCD Ground State Tetrahedrons

The Superconductor electron pairing mechanism forming Cooper pairs [20], especially in the high temperature superconductors (HTSC) is not fully understood. The Bardeen-Cooper-Schrieffer (BCS) theory [21] assumes that the interaction between electrons becomes attractive and dominates the repulsive Coulomb interaction in the vicinity of the Femi energy level. The ground state of a superconductor, formed by electrons virtually excited in pairs of opposite spin and momentum, is assumed to be lower in energy than the normal electron ground state. BCS noted that the discovery of the isotope effect was a breakthrough that indicated that electron-phonon interactions are primarily responsible for superconductivity. According to BCS theory due to the isotope effect, $T_c\sqrt{M}$ is expected to be a constant, where T_c is the superconductor phase transition temperature and M is the lattice ions mass. The superconductor isotope effect proves that the lattice ions motion plays dynamic part in the electron pairing mechanism. Eliashberg included time-dependent phonon dynamics to the electron pairing mechanism [22].

In previous papers, we suggested that quark and antiquark pair exchange reactions between particles and the QCD ground state tetrahedrons accelerate or decelerate particles and that the quarks and antiquarks numbers are strictly conserved. We suggested that antimatter plays a principal role in the universe and is inseparable from matter, via Dirac' spinor, and space, via the quarks and antiquarks pair exchange reactions with the QCD ground state tetrahedrons [2] [3] [4] [5]. In this paper we propose that the QCD tetrahedrons play a role in the electron pairing mechanism in both molecules and superconductors. We suggest that the electron spins polarize the QCD tetrahedrons and that ions motion in both molecules and superconductors create coherent electron-positron excitations and double electron exchange reaction with the QCD tetrahedrons according to Equation (2) and **Figure 6** above (with heavier ions of superconductors replacing the hydrogen ions) that reduce the system energy in the vicinity of the Fermi energy and create the collapse to the lower energy superconducting ground state [23] [24]. The effects of the electron pairing in molecules and superconductors are different, in molecules electron pairs with opposite spins create chemical bonds and in superconductors the electron pairs enable the collapse to the lower energy superconducting state, however, the underlying electron pairing mechanism may be similar involving ion motion that creates electron-positron pair excitations from the QCD tetrahedrons in the non-empty ground state. The electron pairing is related to electron-hadron interaction via the QCD ground state tetrahedrons.

In the next section we show that the QCD ground state tetrahedrons may create a cosmological redshift alternative or in addition to the Doppler redshift.

4. Redshift and the QCD Ground State Tetrahedrons

Gray and Dunning-Davies reviewed the interpretation of redshift in cosmology and astrophysics, discussed the history and origin of the traditional accepted idea of Doppler redshift and described other possible mechanisms for the redshift [25]. For example, the tired light theory was first proposed in 1929 by Fritz Zwicky, who suggested that photons lose energy over time via interaction with matter or by some other novel physical mechanism [26]. Gray and Dunning-Davies noted that the Doppler and/or space-expansion effects will yield similar photon and neutrino redshifts, whereas a non-Doppler mechanism arising from an energy-loss interaction with intervening matter will result in different redshifts for the two cases [27].

In previous paper we assumed that the QCD tetraquarks density varies in space according to the gravitational field like atmospheric density [2]. The cosmic web is built from filaments of galactic walls and great voids. We suggest that the light that travels from far away galaxies and reach for example the Webb telescope pass some of these great voids where the QCD tetrahedrons density is low causing the redshift. Light that comes from galaxies that are further away cross more great voids on their path and accumulate more redshift proportional to their distance. The combination of the QCD ground state tetrahedron density variations in space and the cosmic web great voids may be an alternative mechanism for the cosmological redshift that depends also on the distance between the emitting sources.

5. Is the QCD Ground State Empty?

QFT solved the long-standing problem of Dirac negative energy states. QFT creation and destruction operators create and destroy both particles and antiparticles and both have positive energies [28], however, QFT description of the non-empty ground state, the quantum vacuum, using free fields operators based on the quantum harmonic oscillator is not consistent [29]. The quantum harmonic oscillator model assumes that a harmonic potential exists of the general form $V(q)=\frac{1}{2}mw^2q^2$ and the result is the harmonic oscillator bound state spectrum $H|n\rangle=\left(n+\frac{1}{2}\right)\hbar\omega|n\rangle$. The quantum harmonic oscillator zero-level is an "empty" state, $E_0=\frac{1}{2}\hbar\omega$, however, the quantum field excitations electrons and quarks are stable particles and do not decay to a lower zero-level "empty" ground state. There is no physical process that takes stable particles and destroy them to an empty lower energy ground state without creating other particles.

The creation and destruction operator of the quantum harmonic oscillator model raises or reduces the Hamiltonian energy as follows:

$$Ha^{\dagger}|n\rangle=(E+\omega)|n\rangle \tag{4a}$$

$$Ha|n\rangle=(E-\omega)|n\rangle \tag{4b}$$

$$Ha|0\rangle=0 \tag{5}$$

However, Equations ((4a), (4b)) and particularly Equation (5) do not describe complete physical processes. The physical processes described by Feynman diagrams destroy for example an electron and a positron in a vertex but a high energy photon is created. Particles may be transformed to other particles by QFT but an all-empty physical ground state cannot be produced by any physical process that must conserve total momentum, energy, charge, spin, QCD color etc. The QCD tetrahedrons compact exotic tetraquarks may be a better description of the QCD ground state.

In 1936 Yukawa proposed that the exchange of heavy meson particles of about 100 MeV between protons and neutrons inside the nucleus mediates the attractive nuclear strong force [30]. The first mesons were discovered in 1947 by Lattes *et al.* [31]. Gel-Mann proposed the quark model in 1964 [32]. The quark model includes 3 light flavor quarks (u, d and s) and 3 heavy flavor quarks (c, b and t). Colorless combinations of three quarks create hadrons (protons and neutrons) and of two quarks create mesons (pions, kaons and etas). According to the standard model, the mass of the quarks is due to the broken symmetry by the non-empty QCD ground state populated by pions [33].

$$\langle 0|\pi^0|0\rangle = \langle 0|d\tilde{d} + u\tilde{u}|0\rangle > 0 \tag{6}$$

The standard model QCD ground state must not be empty since the mass of the quarks is due to the non-zero overlap integral in the non-empty QCD ground state, however, a more specific description of the non-empty QCD ground state and its broken symmetry is not given.

6. What Are the Masses of the Quarks?

At low energies, and particularly for the QCD ground state, only the two light valence quarks, u and d, and their antiquark, $\tilde{d}$ and $\tilde{u}$, are significant. The chiral perturbation theory (CHPT) allows calculating only quark mass ratios $\frac{m_u}{m_d} \sim 0.65$ and $\frac{m_s}{m_d} \sim 21.5$ [34]. The quarks mass absolute values were calculated by the $\overline{MS}$ renormalization scheme [35] and lattice QCD with a renormalization scale parameter μ of 2 GeV. The lattice QCD simulations were performed with assumed degenerate u and d quark mass, $m_u = m_d$, and the average mass obtained was $\overline{m}_{ud} = \frac{1}{2}(m_u + m_d) = 3.364\ \text{MeV}$. The individual masses of the two light quarks are estimated to be not equal $\overline{m}_u = 2.32\ \text{MeV}$ and $\overline{m}_d = 4.71\ \text{MeV}$ [36].

In a previous paper we provided a formula for calculating the QCD $u\tilde{d}d\tilde{u}$ mass using the β decay rate variability measurements [2]. We estimated that if the QCD $u\tilde{d}d\tilde{u}$ mass is on the order of the electron mass, 0.5109 MeV, which is in the same order of magnitude of the u quark mass, the β decay rate variability may be about 10% and may be measurable.

7. Is the QCD $u\tilde{d}d\tilde{u}$ Tetrahedron Stable?

QCD meson-meson bound states were reviewed by Hoyer [37] and by Faria-da-Veiga and O'Carroll using Lattice QCD models. A meson-meson bound state was found below the two-particle threshold and two sources of the meson-meson attraction were pointed out. A quark-antiquark exchange and a gauge field correlation of four overlapping bonds, two positively oriented and two of opposite orientation. Fariada-Veiga and O'Carroll noted that the main mechanism for the formation of the meson-meson bound state comes from the gauge contribution field correlation of the four overlapping bonds [38].

Cheung *et al.* studied tetraquark operators and constructed compact tetraquark interpolating operators by combining a diquark with an anti-diquark operator [39]. The diquark operator is built from two quark fields coupled together to obtain appropriate color, flavor, and spin quantum numbers and, analogously, the anti-diquark operator is built from two antiquarks. The diquark and anti-diquark operators are then combined to form a color singlet with the desired flavor and spin.

Bicudo recent review of tetraquarks and pentaquarks in lattice QCD with light and heavy quarks specify three types of tetraquark systems: molecular tetraquarks, diquark tetraquarks and s-pole tetraquarks, where the three mechanisms may act conjointly to produce tetraquarks [40]. Okiharu *et al.* studied the tetraquark 4Q potential, *i.e.*, the interaction between quarks in the 4Q system and investigated the hypothetical fluxtube picture and flip-flop for the multi-quark system [41]. Okiharu noted that the inter-quark force in the exotic multi-quark system is not known, however, lattice QCD simulations show that the compact twisted tetraquark tetrahedral structure is stable and energetically favorable.

The QCD tetrahedron may be energetically favorable since it minimizes the length of the linear confining tension terms $V(r) = -\frac{\alpha_s}{r} + \sigma r$ and creates a gluon junction that connects the quarks by QCD strings [42] [43] [44] [45]. The QCD string tension σ is estimated to be about 1 GeV/fm.

8. The Gluon Junction Role

Ferreres and Sjostrand described the Lund string model and confinement by string breaking creating jets of hadrons in high energy proton-proton and electron-proton collisions [46] [47]. The quark exchange reactions of matter with the QCD ground state tetrahedrons may be equivalent description to the Lund string breaking. We assume that the QCD ground state may be a $u\tilde{d}d\tilde{u}$ tetrahedrons Bose-Einstein condensate [48] (BEC). Lattice QCD computations may confirm its stability by initially constructing the tetraquark interpolating operators with mixed diquark and antiquark charged meson operators, e.g. the two charged pions $u\tilde{d}$ and $d\tilde{u}$, that will be strongly attracted by both electromagnetic and QCD forces.

$$u\tilde{d}\left(\pi^{+}\right) + d\tilde{u}\left(\pi^{-}\right) \to u\tilde{d}d\tilde{u}(\text{tetrahedron}) \tag{7}$$

For example, we assume that the β decay is triggered by the QCD ground state tetrahedron. The QCD tetrahedron may exchange a d quark of the neutron with a u quark of the tetrahedron and an exotic charged tetraquark $d\tilde{u}d\tilde{d}$ is obtained that decays to an electron and an antielectron neutrino.

$$udd(n) + u\tilde{d}d\tilde{u}(\text{tetrahedron}, *) \to udu\left(p^{+}\right) + d\tilde{u}d\tilde{d}(*) \tag{8a}$$

$$d\tilde{u}d\tilde{d}(*) \to e^{-} + \tilde{\nu}_e \tag{8b}$$

The strong force confinement may also be triggered by quark exchange reactions with the QCD ground state tetrahedrons. The QCD tetrahedron performs the breaking of the Lund string by exchanging a u quark with a proton u quark and absorbing its extra momentum when it gets separated a bit from the other two hadron's quarks cooling the proton and transferring its extra momentum to the QCD tetrahedron ground state condensate.

$$udu\left(p^{+,*}\right)+u\tilde{d}d\tilde{u}\left(\text{tetrahedron}\right)\rightarrow udu\left(p^{+}\right)+u\tilde{d}d\tilde{u}\left(\text{tetrahedron},*\right) \tag{9}$$

The interaction between the baryons and the QCD tetrahedrons occur via the baryon gluon junction that connects the quarks with linear Y shape string and hence the gluon junction may act as the connecting channel of matter quarks and the QCD tetrahedron ground state condensate.

The non-empty QCD ground state plays a central role in various low energy processes, the β decay, the electron pairing in chemical bonds and superconductors for example, and hence QCD forces are relevant not only in the high energy physics. Quark exchange reactions transfer force via gluon junction dynamics interacting with the QCD ground state populated by quarks and antiquarks in equal portions and having a tetrahedron geometry.

Note that the QCD $u\tilde{d}d\tilde{u}$ tetrahedrons may have left and right chiral states. The QCD ground state may be a Bose-Einstein condensate that includes only one chiral tetrahedron or both. The QCD ground state may have a broken chiral symmetry and a mass gap may be created by the BEC energy matching the requirements of the Yang-Mills theory millennium problem [49].

9. Matter and Antimatter Symmetry Breaking

What may happen to the QCD ground state $u\tilde{d}d\tilde{u}$ tetrahedrons at the event horizon of a black hole? We hypothesize that the following symmetry breaking reaction may occur where matter may be ejected to space and antimatter may be trapped under the black hole horizon surface.

A first matter and antimatter symmetry breaking reaction may take three $u\tilde{d}d\tilde{u}$ tetrahedrons and creates a proton and a neutron that are ejected to space where their pairs anti-proton and anti-neutron falls in and remain trapped under the black hole event horizon surface.

$$u\tilde{d}d\tilde{u}+u\tilde{d}d\tilde{u}+u\tilde{d}d\tilde{u}\rightarrow udd+uud+\tilde{u}\tilde{d}\tilde{d}+\tilde{u}\tilde{u}\tilde{d} \tag{10}$$

A second matter and antimatter symmetry breaking reaction that may occur takes two $u\tilde{d}d\tilde{u}$ tetrahedrons and split them to two charged tetraquarks where the $d\tilde{u}d\tilde{d}$ is ejected to space and may be the negatively charged electron and the second positively charged tetraquark falls in and remain trapped under the black hole event horizon.

$$u\tilde{d}d\tilde{u}+u\tilde{d}d\tilde{u}\rightarrow d\tilde{u}d\tilde{d}+u\tilde{d}u\tilde{u} \tag{11}$$

Neutrons, protons and electrons may be created from the QCD ground state tetrahedrons and ejected to space while their antiquark pairs remain trapped under the black hole horizon surfaces. Accordingly, matter and antimatter symmetry breaking may be generated by the black holes.

10. The QCD Ground State Broken Symmetry

The QCD ground state structure and symmetry may be determined by the requirement that the QCD tetrahedrons fill space as Hill tetrahedrons [50]. A space cube can be dissected into six 3-orthoscheme tetrahedrons, three left-handed and three right-handed 3-orthoscheme tetrahedrons. The 3-orthoscheme is a tetrahedron having two right angles at each of two vertices and overall, it contains four right angles. Note that the division to right-handed and left-handed 3-orthoscheme tetrahedrons allows having two chiral states such that the QCD ground state may have both right and left chiral tetrahedron broken symmetry. Note that by mirroring the positions of the two antiquarks in the tetrahedron as shown below on four rotated vertices of a cube, the chirality may be switched/mirrored/twisted. An electromagnetic radiation may be emitted by the QCD ground state tetrahedron twists since the quarks and the anti-quarks have electric charge. Hence the proposed quantum of space QCD tetrahedron may also have a quantum of time determined by the tetrahedron electromagnetic radiation frequency [1]. The frequency and intensity may depend on the QCD ground state tetrahedron density in the source galaxy or cluster of galaxies. The QCD ground state tetrahedrons may have a single chirality or both chirality's and chirality domains may be formed in space. Theoretical and experimental research is needed to explore the proposal that the QCD ground state is a $u\tilde{d}d\tilde{u}$ tetrahedron BEC with a single or both chirality tetrahedron symmetry.

11. The Hypothesis Summary

The hypothesis proposed in this and previous papers [2] [3] [4] [5] is:

(1) The QCD $u\tilde{d}d\tilde{u}$ tetrahedrons are pseudo-Goldstone bosons that fill space and condense to the QCD ground state. The QCD $u\tilde{d}d\tilde{u}$ tetrahedron mass may be calculated directly by measuring the β decay rate variability [2] and a mass gap may be created by condensation to a Bose-Einstein Condensate (BEC).

(2) The QCD $u\tilde{d}d\tilde{u}$ tetrahedrons have two chiral states and may flip between the chiral state with a characteristic frequency that may be observed as shown in **Figure A1** in the **Appendix**. The tetrahedrons may fill a cube cell with 6 3-orthoschemes, three left-handed and three right-handed chirality or with a simpler cube symmetry with a single gluon junction per cube.

(3) The QCD ground state tetrahedrons transfer forces by quark exchange reactions. The quark exchange reactions may be the underlying processes that connect matter and the QCD ground state tetrahedrons via gluon junctions as shown in **Figures A2-A7** in the **Appendix**.

(4) The stable particles are the light $u, d, \tilde{d}$ and $\tilde{u}$ quarks and antiquarks.

(5) There are a equal number of quarks and antiquarks in the universe, the missing antimatter particles may be hidden under the event horizon surfaces of black holes. The neutrons, protons and electrons may be created from the QCD tetrahedrons and ejected to space at the black hole event horizons.

(6) Leptons like hadrons are composite particles confined by the strong force,

$d\tilde{u}d\tilde{d}$ may be the electron, $u\tilde{d}d\tilde{d}$ may be the positron for example. Other unstable transition state particles may be comprised of various combinations and geometries of the $u, d, \tilde{d}, \tilde{u}$ quarks and antiquarks, for example the unstable heavy quark flavors may be: $s = du\tilde{d}d\tilde{u}$, $c = u\tilde{u}d\tilde{d}u$, $b = du\tilde{d}d\tilde{u}u\tilde{d}d\tilde{u}$, $t = u\tilde{u}d\tilde{d}uu\tilde{d}d\tilde{u}$ as shown in **Figure A8** and **Figure A9** in the **Appendix**.

(7) The QCD tetrahedrons density in space vary according to the gravitational field. The gravitational force is transferred by the QCD tetrahedrons density gradients via quark exchange reactions.

(8) The electron pairing mechanism in atoms and molecules forming chemical bonds and in superconductors forming Cooper pairs is enabled by the QCD ground state tetrahedrons. The ion motion induces coherent exchange reactions of electron pairs with the polarized QCD tetrahedrons.

(9) Active AGNs act as matter reactors [3] that increase the density of the QCD tetrahedrons by duplicating the $u\tilde{d}d\tilde{u}$ pseudo-Goldstone bosons in their ergoregions that act as laser cavities. The expansion of the universe may also be triggered by this black hole laser effect [51].

(10) Theoretical and experimental research is needed to explore the proposal that the QCD ground state is a $u\tilde{d}d\tilde{u}$ tetrahedrons BEC with a single or both chirality tetrahedron symmetry.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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Appendix

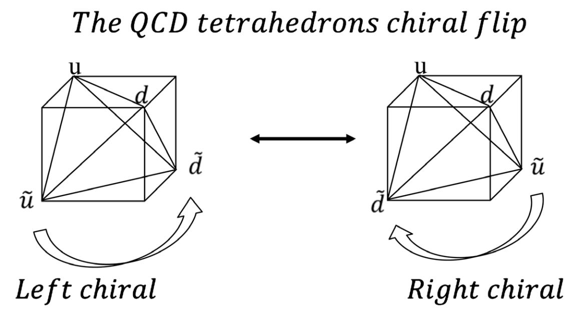

Figure A1. The proposed QCD tetrahedron enantiomers. A chiral flip may occur by exchanging the $\tilde{d}$ and $\tilde{u}$ antiquarks. Note that small rotations around the gluon junction center will not flip the chirality but may generate electromagnetic radiation and that space may be filled with the QCD tetrahedrons with a cubic symmetry where all vertices of the cubes are occupied by the *u*, *d*, $\tilde{d}$ and $\tilde{u}$ quarks.

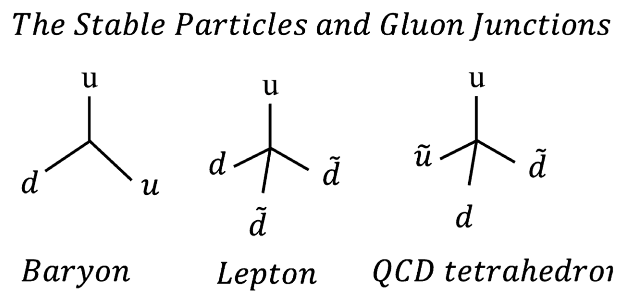

Figure A2. Proposes that hadrons have in their center a gluon junction that keeps them stable and confined.

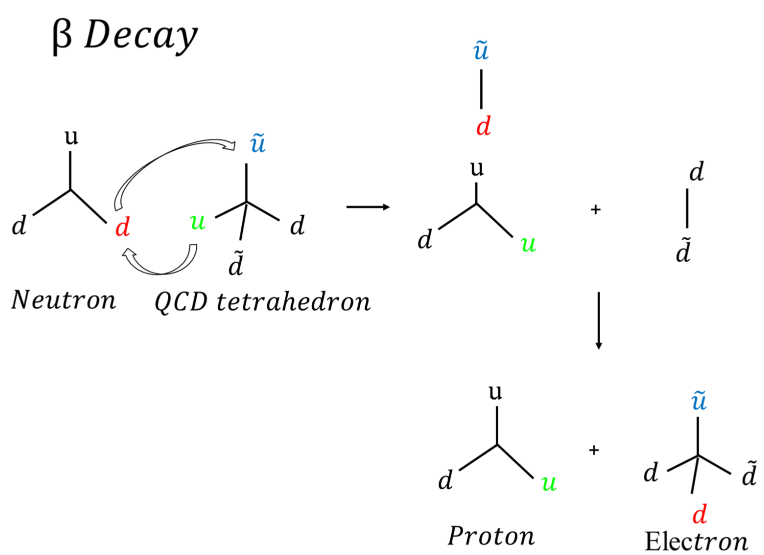

Figure A3. The beta decay reaction enabled by the QCD tetrahedron. Note that the colors are not the QCD charge colors and are used above to illustrate the quark exchanges.

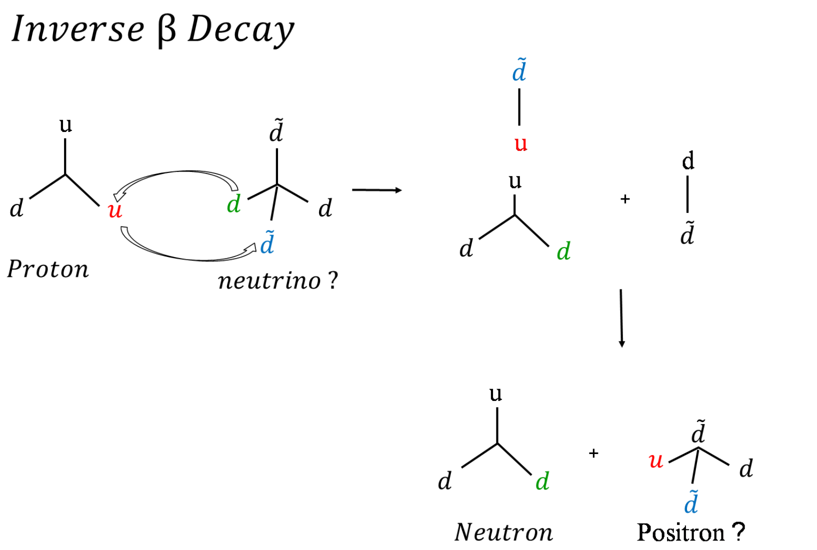

Figure A4. The inverse beta decay reaction may be enabled by a $d\tilde{d}d\tilde{d}$ tetrahedrons, which may be a neutrino. Note that the colors are not the QCD charge colors and are used above to illustrate the quark exchanges.

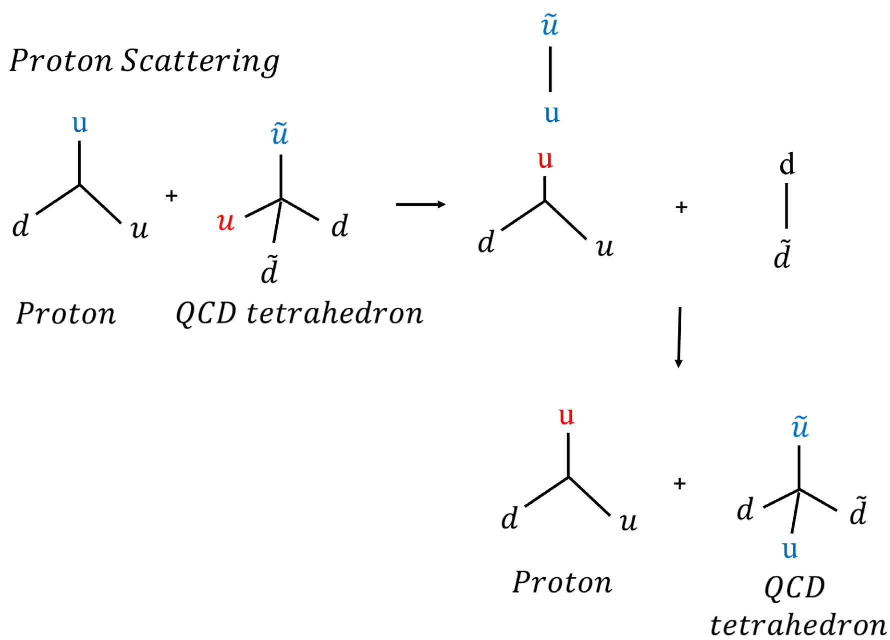

Figure A5. A quark exchange reaction between a proton and a QCD tetrahedron transfers momentum from the proton to the QCD tetrahedron. Note that the colors are not the QCD charge colors and are used above to illustrate the quark exchanges.

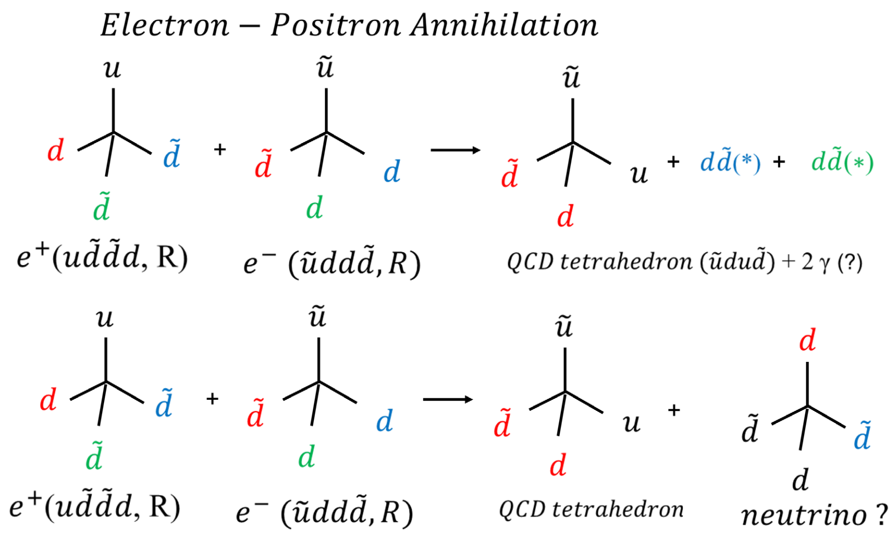

Figure A6. The electron-positron annihilation reaction is described by a quark exchange reaction that generates a QCD tetrahedron that further condense to the QCD ground state and two $d\tilde{d}$ mesons that may further create two γ rays. Alternatively, in the second quark exchange reaction, a $d\tilde{d}d\tilde{d}$ tetraquark is generated that may be the neutrino particle in addition to the QCD tetrahedron. Note that the colors are not the QCD charge colors and are used above to illustrate the quark exchanges.

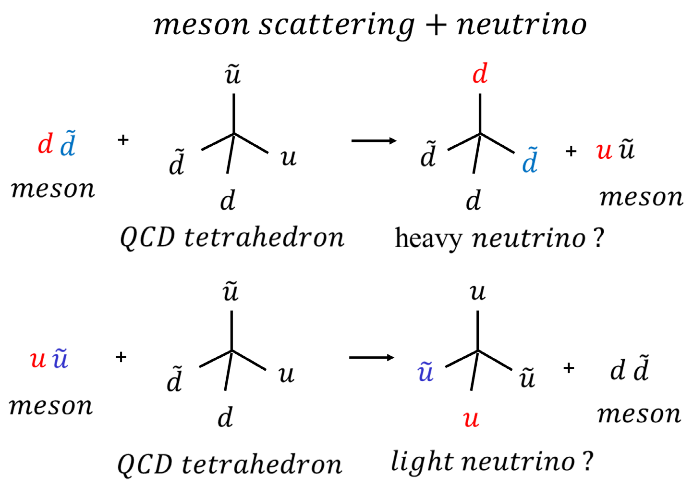

Figure A7. The meson exchange with the QCD ground state tetrahedron. Mesons are exchanged and a new tetraquark are formed that may be neutrinos with different flavor. Note that the meson exchange reactions above may occur in the vacuum with the QCD tetrahedrons and may explain the neutrino flavor oscillations. Note that the colors are not the QCD charge colors and are used above to illustrate the quark exchanges.

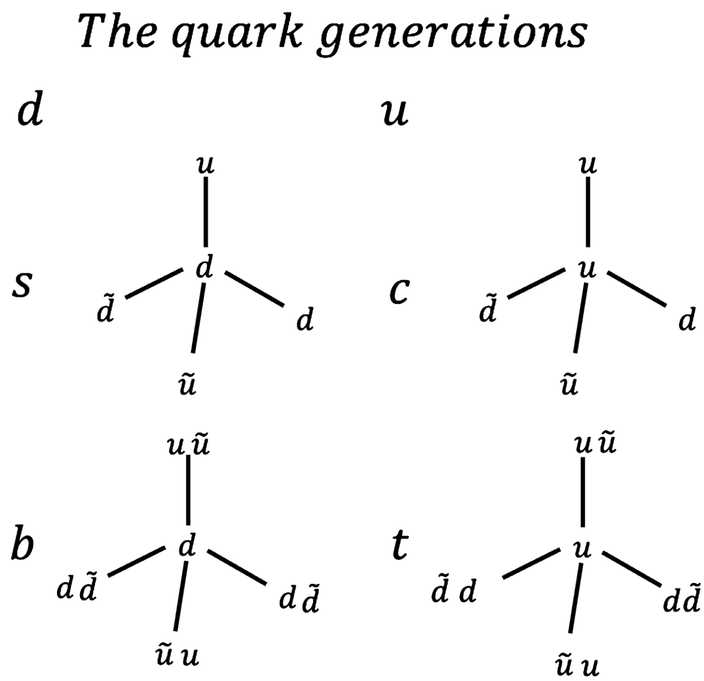

Figure A8. The quark generations composites where the heavy quarks, *s*, *c*, *b* and *t*, are assumed to be multi-quarks tetrahedrons comprised of the light quarks *d*, *u*, $\tilde{d}$ and $\tilde{u}$.

The lepton generations

$e^- = d\tilde{u}\tilde{d}d$ (π^-) $e^+ = u\tilde{d}\tilde{d}d$ (π^+)

$\mu^- = d\,\tilde{c} = d\tilde{u}u\tilde{d}d\tilde{u}$ (K^-) $\mu^+ = u\,\tilde{s} = u\tilde{d}u\tilde{d}d\tilde{u}$ (K^+)

$\tau^- = d\,\tilde{t} = d\tilde{u}u\tilde{d}d\tilde{u}u\tilde{d}d\tilde{u}$ $\tau^+ = u\,\tilde{b} = u\tilde{d}u\tilde{d}d\tilde{u}\,\tilde{u}u\tilde{d}d$

Figure A9. The lepton generations as multiquark composites comprised of the light quarks *d*, *u*, $\tilde{d}$ and $\tilde{u}$. The electron and positron may be stabilized and confined by the additional $\tilde{d}$ and $\tilde{u}$ quarks.