The Quantum Chromodynamics Theory Of Pentaquarks

Based on a generalized particle diagram of baryons and anti-baryons which, in turn, is based on symmetry principles, this theory predicts the existence of: (a) strange pentaquarks containing one, two, three and four strange quarks, (b) strange anti-pentaquarks containing one, two, three and four anti-strange quarks; and (c) a relatively large number of non-strange pentaquarks and their antiparticles. There are, however, other pentaquarks that this formulation does not cover.

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Contents

1. Introduction

Quantum Chromodynamics (QCD) [1, 2, 3, 4] is a quantum mechanical description of the strong nuclear force. The strong force is mediated by gluons [4, 5] which are spin $1\hbar$ bosons (spin is quoted in units of reduced Plank's constant: $\hbar = h/2\pi$). They act on quarks only (only quarks feel the strong force). Colour charge is a property of quarks (and gluons) which is a kind of electric charge (but of a totally different nature) associated with the strong nuclear interactions. There are three distinct types of colour charge: red, green and blue. It is very important to keep in mind that every quark carries a colour charge, while every antiquark carries an anticolour charge (antired, antigreen or antiblue). However colour charge has nothing to do with the real colour of things. The reason, this quark property, is called colour is because it behaves like colours: all known hadrons (baryons and mesons) are "colourless" (meaning colour neutral particles). Baryons, which are made of three quarks, are "colourless" because each quark has a different colour. Mesons, which are made of a quark and an antiquark, are "colourless" because antiquarks carry anticolour. Thus, a meson with a blue quark and a antiblue quark is a colour neutral particle.

An important point to observe is that the Pauli exclusion principle leads to the existence of colour. According to this principle, no two fermions can have all the same quantum numbers. The existence of colour was inferred from the omega-minus particle or Ω^- baryon because it seemed to challenge the above principle. This particle, which was discovered in 1964, is made up of three strange quarks (s quarks). Because quarks are fermions, they cannot exist with identical quantum numbers, or in other words, they cannot exist in identical quantum states. So that, the Ω^- particle needed a new quantum number to be able to satisfy the Pauli exclusion principle. Thus, physicists proposed the existence of a new quantum number which was called colour. Having a particle with a red strange quark, a green strange quark and a blue strange quark solved the problem: the Ω^- baryon had all its quarks in different quantum states. So that the property called colour was the one that distinguished each of the quarks of the Ω^- particle when all the other quantum numbers are identical.

Like the electric charge, colour charge is a conserved quantity. Thus, QCD introduced a new conservation law: the conservation of "colour charge". Both quarks and gluons carry colour charge. In contrast, photons which are the mediators or carriers of the electromagnetic force, do not carry electric charge. This is a very important difference between Quantum Electrodynamics (QED) [6] and QCD. Another property of gluons is that they can interact with other gluons.

The theory presented here is, in certain way, an extension of the QCD developed independently by Murray Gell-Mann and George Zweig in 1964. Gell-Mann read a James Joyce's novel entitled Finnegan's Wake, which contains the sentence "three quarks for Muster Mark", from where the word quark was taken and introduced into physics. Gell-Mann predicted the existence of the omega-minus particle from a particle diagram known as baryon decuplet (see page 25 of reference [2]). This diagram, which contains 10 baryons [4, 7, 8], is shown in blue on the right hand side of FIGURE 1. Although this theory is intended for experts, it is simple enough, so that, it is also suitable for those readers with basic knowledge of quarks and equations. Appendix 1 contains the nomenclature used throughout this paper. The expert may skip section 2 as it contains the basic properties of quarks and antiquarks.

2. Summary of the Properties of Quarks and

Antiquarks

Before I explain the details of this theory, we need to understand some of the properties of quarks and antiquarks. In order to do this I have included the following two tables. TABLE 1 is a summary of the properties of quarks while TABLE 2 is a summary of the properties of antiquarks. We shall define the elementary charge, e, as a positive the electric charge of $1.602\times10^{-19}C$, approximately. Thus the charge of the proton is e and that of the electron is $-e$.

QUARKS PROPERTIES (see note 1)							
QUARK NAME	SYMBOL	ELECTRIC CHARGE (times *e*)	SPIN	STRANGENESS	CHARMNESS	BOTTOMNESS	TOPNESS
up	u	$+\frac{2}{3}$	$\frac{1}{2}$	0	0	0	0
down	d	$-\frac{1}{3}$	$\frac{1}{2}$	0	0	0	0
strange	s	$-\frac{1}{3}$	$\frac{1}{2}$	-1	0	0	0
charm	c	$+\frac{2}{3}$	$\frac{1}{2}$	0	$+1$	0	0
bottom	b	$-\frac{1}{3}$	$\frac{1}{2}$	0	0	-1	0
top	t	$+\frac{2}{3}$	$\frac{1}{2}$	0	0	0	$+1$

TABLE 1: *Properties of quarks. The isospin and the isospin z-componet are not shown.*

ANTIQUARKS PROPERTIES (see note 1)							
QUARK NAME	SYMBOL	ELECTRIC CHARGE (times *e*)	SPIN	STRANGENESS	CHARMNESS	BOTTOMNESS	TOPNESS
Anti-up	$\bar{u}$	$-\frac{2}{3}$	$\frac{1}{2}$	0	0	0	0
Anti-down	$\bar{d}$	$+\frac{1}{3}$	$\frac{1}{2}$	0	0	0	0
Anti-strange	$\bar{s}$	$+\frac{1}{3}$	$\frac{1}{2}$	$+1$	0	0	0
Anti-charm	$\bar{c}$	$-\frac{2}{3}$	$\frac{1}{2}$	0	-1	0	0
Anti-bottom	$\bar{b}$	$+\frac{1}{3}$	$\frac{1}{2}$	0	0	$+1$	0
Anti-top	$\bar{t}$	$-\frac{2}{3}$	$\frac{1}{2}$	0	0	0	-1

TABLE 2: *Properties of antiquarks. The isospin and the isospin z-componet are not shown because are not used by this theory.*

3. The Incomplete Matter-Antimatter Way

The existence of pentaquarks was first postulated by three Russian physicists: Polyakov, Diakonov and Petrov in 1997. Using a different approach, I have hypothesized the existence of a wide spectrum of pentaquarks. My approach is based on a new diagram that I have called: *the matter antimatter way*. In this article we shall explore this diagram in detail starting form **the incomplete matter-antimatter way** showed below (FIGURE 1) which is, as the name suggests, an incomplete version of **the matter antimatter way**. The first thing we notice is that the diagram of FIGURE 1 is symmetrical about the vertical axis, which is called: the symmetry axis (the symmetry axis has no arrows and is shown in red). We also observe that the diagram may be considered as made up of two different diagrams:

(a) the **particles side** or **material side** (on the right hand size of the symmetry axis), and
(b) the **antiparticles side** or **anti-material side** (on the left hand side of the symmetry axis).

Thus, on the particles side we have 10 baryons, known as the baryon decuplet. This is the original decuplet discovered by Murray Gell-Mann. This decuplet is shown as blue circles. On the antiparticles side we have the anti-baryon decuplet containing the 10 corresponding anti-baryons. These anti-baryons are shown as red circles. The antiparticles side of the diagram can be obtained simply by placing a mirror along the symmetry axis (with the reflecting side facing the material side) and replacing the reflection of the particles by their corresponding antiparticles. Thus, our mirror is a kind of magical mirror because in addition to reflecting images (this is called parity or *P* symmetry) it has to do weirder tasks. Firstly, it must also be able to replace the reflected particles by their corresponding antiparticles (this is called charge conjugation or *C* symmetry). This means that the direction of the *Q* axis for antiparticles must point in the same direction to that of particles (in a normal reflected image it will point in the opposite direction). Secondly, it must reverse the direction of time so that if a particle moves forward in time, then its reflected image must be moving backward in time (this is called time reversal or *T* symmetry). Thirdly, it must change the strangeness of particles by the corresponding strangeness of antiparticles. This means that the direction of the *S* axis for antiparticles must point in the opposite direction to that of particles. This operation, as far as I know, has no name in physics. However because when dealing with strange particles, this operation is as important as the others, I shall give it the name of **strangeness conjugation** or ***S* parity**.

Thus, we have changed the direction of the reflected *Q* and *S* axes so that the *Q* axis for antiparticles will point in the same direction as the *Q* axis for particles, and the *S* axis for antiparticles will point in the opposite direction as *S* axis for particles. This is something that the literature normally does not tell you. Let us summarize the operations our "magical mirror" must be able to do:

(a) Parity operation (*P* symmetry).
(b) Charge conjugation (*C* symmetry),
(c) Time reversal (*T* symmetry),
(d) Strangeness conjugation (*S* symmetry, named proposed by the author, or whatever you would like to call it).

The first three operations are called *CPT* symmetry. However, using the name *CPT* symmetry will be inappropriate for two reasons. The first reason is physical. Because antiparticles have opposite properties to that of particles, and this includes (i) opposite charge, (ii) opposite flow of time and (iii) opposite strangeness (if strange quarks are involved) then to separate charge conjugation and time reversal as two distinct operations is, conceptually, a mistake. This is so because antiparticles will exhibit both time reversal and charge conjugation simultaneously, always. Secondly, if strange quarks are involved, to talk about a *CPT* operation would be part of the story but not the full story. This is because we would leave out the strangeness conjugation (which a strange antiparticle is forced to obey). Therefore, I shall use new acronyms: *PC+* or *CPTS*. Where *P* indicates a parity operation (operation 1) and *C+* indicates the following three operations:

(operation 2) Charge conjugation,
(operation 3) Time reversal, and
(operation 4) Strangeness conjugation.

It is worthwhile to observe that the order of the operations is not important. Having clarified this point about symmetry, let us return to FIGURE 1. Because I have introduced two modifications to the baryon decuplet, this decuplet is a special case of the incomplete matter-antimatter way shown on FIGURE 1. The first modification is that (a) the isospin axis has been replaced by an axis representing the electric charge of particles. This modification changes the layout of the 10 baryons. Thus, instead of having 10 baryons arranged in an equilateral triangle they are now arranged in a right triangle (see the blue circles on the particles side of FIGURE 1). I must clarify that the electric charge axis, *Q*, may be drawn diagonally on the original baryon decuplet diagram. This is shown in page 25 of reference [2]. The second modification is (b) the addition of the "magical mirror image" (*PC+ / CPTS* symmetry for the expert) of the 10 baryons represented by a right triangle on the left hand side of the symmetry axis (see the red circles on the antiparticles side of FIGURE 1).

The figure also shows 5 pairs of empty circles drawn on the symmetry axis. Despite the fact that every pair of empty circles overlap, they are shown as partially overlapped so that one can distinguish each pair. Each pair contains two points or empty circles. The fully visible empty circle correspond to particles (on the matter side) while the circle behind it, corresponds to antiparticles (on the antimmatter side). The 5 fully visible points or empty circles are denoted, from the lower vertex of FIGURE 1 up the page, with the letters *V, W, X, Y, Z,* respectively; and the 5 partially visible points or empty circles are denoted, in the same corresponding order, with the primed letters *V', W', X', Y', Z',* respectively. These 10 points are located on the symmetry axis. The coordinates of these 10 points are shown on TABLE 3. We have to keep in mind that these coordinates are fundamental to this theory.

(see next page)

QS COORDINATE SYSTEM	POINT	POINT COORDINATES	MEANING (The expert may leave out this column)
MATTER For particles. Right hand side coordinate system)	V (lower vertex)	$(-2,-4)$	$Q=-2$ and $S=-4$
	W (lower middle point)	$(-2,-3)$	$Q=-2$ and $S=-3$
	X (middle point)	$(-2,-2)$	$Q=-2$ and $S=-2$
	Y (upper middle point)	$(-2,-1)$	$Q=-2$ and $S=-1$
	Z (base point)	$(-2,\ 0)$	$Q=-2$ and $S=\ 0$
ANTIMATTER (For antiparticles. Left hand side coordinate system)	V' (lower vertex)	$(+2,+4)$	$Q=+2$ and $S=+4$
	W' (lower middle point)	$(+2,+3)$	$Q=+2$ and $S=+3$
	X' (middle point)	$(+2,+2)$	$Q=+2$ and $S=+2$
	Y' (upper middle point)	$(+2,+1)$	$Q=+2$ and $S=+1$
	Z' (base point)	$(+2,\ 0)$	$Q=+2$ and $S=\ 0$

TABLE 3: *Coordinates of the of points the triangle of FIGURE 1 (*particle *matter-antimatter way). These points are marked with empty circles.*

The main idea of this formulation is that every pair of empty circles (every pair of non-primed and primed points) of FIGURE 1 represents a set of particles and antiparticles. In fact, in the next sections, and based on the values of electric charge and strangeness given in TABLE 3, I shall find: (a) the exact nature of the particles and antiparticles (pentaquarks and antipentaquarks) of each pair of empty circles, and (b) the exact number of particles and antiparticles (pentaquarks and antipentaquarks) contained in every pair of empty circles. Thus, all the predictions of this theory are based on the incomplete matter-antimatter way shown below.

(see next page)

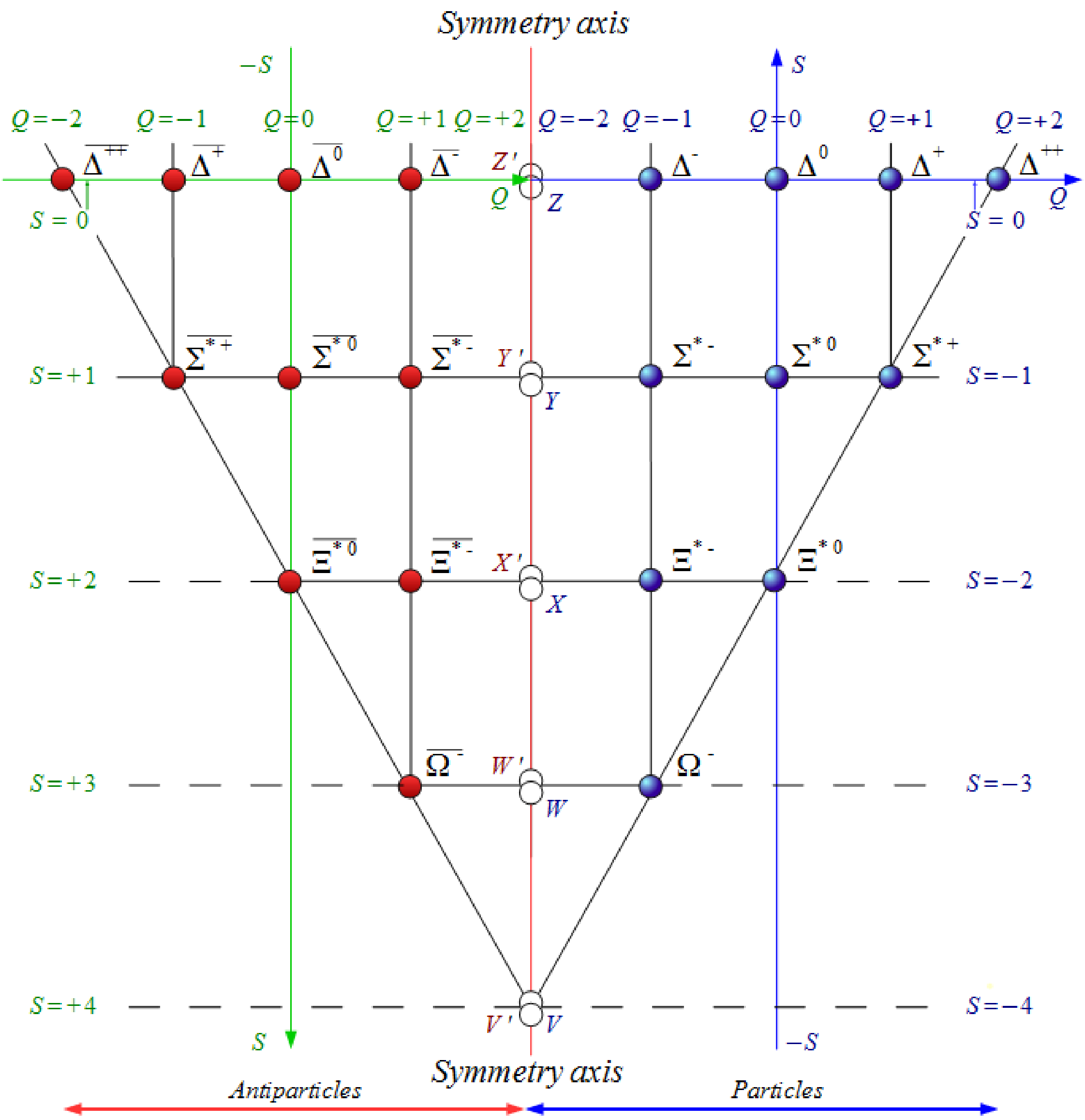

FIGURE 1: *The Incomplete Matter-Antimatter Way: a pattern of 10 baryons (blue circles), 10 anti-baryons (red circles) and 5 pairs of empty circles drawn on the symmetry axis. Despite the fact that every pair of empty circles overlap, they are shown as partially overlapped so that one can distinguish each pair. It is important to observe that two QS coordinate systems have been used. One QS coordinate system is for particles while the other one is for their antiparticles. Thus, one of the horizontal Q axes represents the electric charge of particles while the other one represents the electric charge of antiparticles. It is important to observe that Q=-2 belongs to the particles' Q axis while Q=+2 belongs to the antiparticles' Q axis (see TABLE 3 for the rest of the points). One of the vertical S axis represents the strangeness of particles while the other vertical S axis represents the strangeness of antiparticles. The isospin property of the particles and antiparticles is not used in this formulation, therefore is not shown in this diagram. The composition of all the particles and antiparticles shown in this diagram are given in Appendix 1. The particles whose names include an asterisk:* Σ^{*-} , Σ^{*0} , Σ^{*+} , Ξ^{*-} , Ξ^{*0} *are exited states of the corresponding particles:* Σ^{-} , Σ^{0} , Σ^{+} , Ξ^{-} , Ξ^{0} .

Later on, in section 10, I shall complete the diagram of FIGURE 1 by including all the pentaquarks and antipentaquarks there exist on the empty points. The final diagram will then be called: **the complete matter-antimatter way**, or simply: **the matter-antimatter way**.

Now, let us explore the diagram of FIGURE 1 in more detail. An innovative feature of this diagram is that contains two *QS* coordinate systems (charge-strangeness coordinate system which acts like an *xy* coordinate system). One *QS* coordinate system is for particles (shown in blue) while the other one is for their antiparticles (shown in red). Thus, one of the horizontal *Q* axes represents the electric charge of particles while the other one represents the electric charge of antiparticles. Similarly, one of the vertical *S* axis represents the strangeness of particles (+*S* points up the page) while the other vertical *S* axis represents the strangeness of antiparticles (+*S* points down the page).

It is important to observe that *Q*=-2 belongs to the particles' *Q* axis while *Q*=+2 belongs to the antiparticles' *Q* axis. Thus the points (-2, 0) and (+2,0) are *QS* points that overlap. We shall see that it is likely that there exist pentaquarks on the non-primed points: *V*, *W*, *X*, *Y* and *Z*; and antipentaquarks on the primed points: *V'*, *W'*, *X', Y'* and *Z'* of the diagram.

If pentaquarks were not real, no particles would occupy the empty circles. This would contradict our belief in symmetry. This believe states, in general terms, that nature is governed by symmetry principles (by the way, the standard model has been built on symmetry principles as well).

4. Analysis of Quadruply Strange Pentaquarks

Despite the fact I predicted the existence of quadruply strange pentaquarks in another article [9], I decided to include a similar analysis here because of three reasons. The first reason is completeness. The second reason is that the explanations of this section are more detailed. The third reason relates to graphics. The figure included in this section (FIGURE 2) is an improved version of the corresponding figure that appears in the previous article. While naive pentaquark diagrams are not included in this article, they are included in reference [9].

4.1. Analysis of the Electric Charge and Strangeness

Analysis for Particles (point *V*)

In this analysis we only consider the *QS* coordinate system for particles which is shown in blue colour on the right hand side of FIGURE 1. The predicted particles must satisfy the following two conditions:

(a) the first condition the unknown particle (pentaquark) must satisfy is that its electric charge should be equal to -2 ($Q=-2$) (meaning $-2e$, where *e* is the absolute value of the elementary charge).

(b) The second condition the unknown particle (pentaquark) must satisfy is that its strangeness should be equal to -4 ($S=-4$). Because strange quarks are the only particles which possess the strangeness property, and because the value of this property is -1 (see TABLE 1 of section 2), the only way a particle can have a strangeness of -4 is if 4 of the constituents of this particle were 4 strange quarks.

Taking into account these two conditions and the fact that each strange quark carries an electric charge of $-1/3$, the **electric charge equation** for this particle will be

$$Q=4\,q_s+q \tag{4.1.1}$$

Where

Q = total electric charge of the unknown particle (-2)

$q_s =$ electric charge of the strange quark ($-1/3$)
$q =$ electric charge of another quark (different from an *s* quark) so that the total charge of the unknown particle is -2 . This quark will be called the fifth quark.

We solve equation (4.1.1) for *q*. This gives

$$q = Q - 4 q_s \tag{4.1.2}$$

Then, the value of the electric charge, *q,* of the fifth quark should be

$$q = -2 - \left(-\frac{4}{3} \right) = -2 + \frac{4}{3} = -\frac{2}{3} \tag{4.1.3}$$

Looking at TABLE 2 of section 2 (antiquark properties) we see that there are only three antiquarks that have an electric charge equal to $-2/3$. These antiquarks are:

(i) the antiup quark, $\bar{u}$,
(ii) the anticharm quark, $\bar{c}$, and
(iii) the antitop quark, $\bar{t}$,

Because equation (4.1.2) is satisfied by three antiquarks, equation (4.1.1) must be written as three different equations

$$Q = 4 q_s + q_{\bar{u}} \tag{4.1.4}$$
$$Q = 4 q_s + q_{\bar{c}} \tag{4.1.5}$$
$$Q = 4 q_s + q_{\bar{t}} \tag{4.1.6}$$

Where

$q_{\bar{u}} =$ electric charge of the antiup quark = $-2/3$
$q_{\bar{c}} =$ electric charge of the anticharm quark = $-2/3$
$q_{\bar{t}} =$ electric charge of the antitop quark = $-2/3$

But having three different electric charge equations means that we must also have three different particles and, in addition, these particles must be pentaquarks. Thus we write

Pentaquark $P_{4s\bar{u}}$ $\quad (s\,s\,s\,s\,\bar{u})$ (4.1.7)

Pentaquark $P_{4s\bar{c}}$ $\quad (s\,s\,s\,s\,\bar{c})$ (4.1.8)

Pentaquark $P_{4s\bar{t}}$ $\quad (s\,s\,s\,s\,\bar{t})$ (4.1.9)

Analysis for Antiparticles (point *V'*)

In this analysis we only consider the *QS* coordinate system for antiparticles which is shown in green colour on the left hand side of FIGURE 1. The predicted particles must satisfy the following two conditions:

(a) the first condition the unknown particle (antipentaquark) must satisfy is that its electric charge should be equal to +2 (Q = +2) (meaning +2e, where e is the absolute value of the elementary charge).

(b) The second condition the unknown particle (antipentaquark) must satisfy is that its strangeness should be equal to +4 (S = +4). Because strange quarks are the only particles which possess the strangeness property, and because the value of this property for anti-strange quarks is +1 (see TABLE 2 of section 2), the only way a particle can have a strangeness of +4 is if 4 of the constituents of this particle were 4 anti-strange quarks.

Taking into account these two conditions and the fact that each anti-strange quark carries an electric charge of $+1/3$, the electric charge equation for this particle should be

$$Q = 4\, q_{\bar{s}} + q_5 \tag{4.1.10}$$

Where

Q = total electric charge of the unknown particle ($+2$)
$q_{\bar{s}}$ = electric charge of the anti-strange quark ($+1/3$)
q_5 = electric charge of another quark (different from a anti-strange quark) so that the total charge of the unknown particle is $+2$. This quark will be called the fifth quark.

We solve equation (4.1.11) for q. This gives

$$q_5 = Q - 4\, q_{\bar{s}} \tag{4.1.11}$$

Then, the value of the electric charge, q, of the fifth quark should be

$$q_5 = +2 - \left(+\frac{4}{3}\right) = +2 - \frac{4}{3} = +\frac{2}{3} \tag{4.1.12}$$

If we look at TABLE 1 of section 2 (quark properties) we shall see that there are only three quarks that have an electric charge equal to $+2/3$. These quarks are

(i) the up quark, u ,
(ii) the charm quark, c , and
(iii) the top quark, t

Because equation (4.1.11) is satisfied by three antiquarks, equation (4.1.10) must be written as three different equations

$$Q = 4\, q_{\bar{s}} + q_u \tag{4.1.13}$$
$$Q = 4\, q_{\bar{s}} + q_c \tag{4.1.14}$$
$$Q = 4\, q_{\bar{s}} + q_t \tag{4.1.15}$$

Where

q_u= electric charge of the up quark = $+2/3$
q_c= electric charge of the charm quark = $+2/3$

$q_t =$ electric charge of the top quark $= +2/3$

But having three different electric charge equations means that we must also have three different particles and, in addition, these particles must be pentaquarks (or antipentaquarks). Thus we write

antipentaquark $P_{4\bar{s}u}$ $\bar{s}\,\bar{s}\,\bar{s}\,\bar{s}\,u$ (4.1.16)

antipentaquark $P_{4\bar{s}c}$ $\bar{s}\,\bar{s}\,\bar{s}\,\bar{s}\,c$ (4.1.17)

antipentaquark $P_{4\bar{s}t}$ $\bar{s}\,\bar{s}\,\bar{s}\,\bar{s}\,t$ (4.1.18)

Thus based on the allowed electric charge and strangeness we have found the nature of the unknown particles. TABLE 4 summarizes the properties of the quadruply strange pentaquarks.

	PREDICTED PARTICLE (symbol)	PARTICLE COMPOSITION (quark contents)	ELECTRIC CHARGE (times the elementary charge: *e*	STRANGENESS
PARTICLES WITH 4 STRANGE QUARKS	$P_{4s\bar{u}}$	$(s\,s\,s\,s\,\bar{u})$	-2	-4
	$P_{4s\bar{c}}$	$(s\,s\,s\,s\,\bar{c})$	-2	-4
	$P_{4s\bar{t}}$	$(s\,s\,s\,s\,\bar{t})$	-2	-4
ANTI-PARTICLES WITH 4 STRANGE QUARKS	$P_{4\bar{s}u}$	$(\bar{s}\,\bar{s}\,\bar{s}\,\bar{s}\,u)$	$+2$	$+4$
	$P_{4\bar{s}c}$	$(\bar{s}\,\bar{s}\,\bar{s}\,\bar{s}\,c)$	$+2$	$+4$
	$P_{4\bar{s}t}$	$(\bar{s}\,\bar{s}\,\bar{s}\,\bar{s}\,t)$	$+2$	$+4$

TABLE 4: *Some of the properties of the quadruply strange pentaquarks.*

4.2. Analysis of the Colour Charge and Spin

Analysis for Particles

Because all known baryons and mesons are colourless, meaning they are neutral in terms of colour charge, the predicted pentaquarks should also be colourless. Also because of the Pauli exclusion principle there shouldn't be two quarks of the same type with all the same quantum numbers. This means that the two strange quarks of identical colour (because there are 4 strange quarks and because there are only three flavours of the colour charge, there must be two strange quarks of the same colour) should have opposite spins (one with spin up and the other one with spin down). For example the following pentaquark should be allowed by nature

$$s_R^{up}\; s_G^{up}\; s_B^{up}\; s_R^{down}\; \overline{u}_R^{up} \qquad (4.2.1)$$

It is worthwhile to observe that the anti-quark up could have spin up or down. Because the antiquark up is antired, the combination $s_R^{down}\,\overline{u_R}^{up}$ will be colourless. Also the combination $s_R^{up}\,s_G^{up}\,s_B^{up}$ will be colourless. This means that the entire pentaquark will be colourless. As an additional example, the following pentaquarks should be allowed

$$s_R^{down}\,s_G^{down}\,s_B^{down}\,s_R^{up}\,\overline{u_R}^{up} \tag{4.2.2}$$

$$s_R^{up}\,s_G^{up}\,s_B^{down}\,s_R^{down}\,\overline{u_R}^{up} \tag{4.2.3}$$

etc.

The interested reader could find more allowed combinations.

Analysis for Antiparticles

Carrying out a similar analysis we find that

$$\overline{s_B}^{up}\,\overline{s_G}^{up}\,\overline{s_B}^{up}\,\overline{s_R}^{down}\,u_R^{up} \tag{4.2.4}$$

Because this theory predicts that point V should contain 3 pentaquarks and that point V' should contain another 3 pentaquarks (remember that V and V' overlap), we may replace the visible empty circle of the lower vertex of FIGURE 1 by a blue circle representing the 3 new pentaquarks ($(s\,s\,s\,s\,\overline{u})$, $(s\,s\,s\,s\,\overline{c})$, $(s\,s\,s\,s\,\overline{t})$, and the partially visible empty circle of that figure by and a red circle representing the 3 new antipentaquarks ($\overline{s}\,\overline{s}\,\overline{s}\,\overline{s}\,u$, $\overline{s}\,\overline{s}\,\overline{s}\,\overline{s}\,c$, $\overline{s}\,\overline{s}\,\overline{s}\,\overline{s}\,t$). This is done in FIGURE 2.

(see next page)

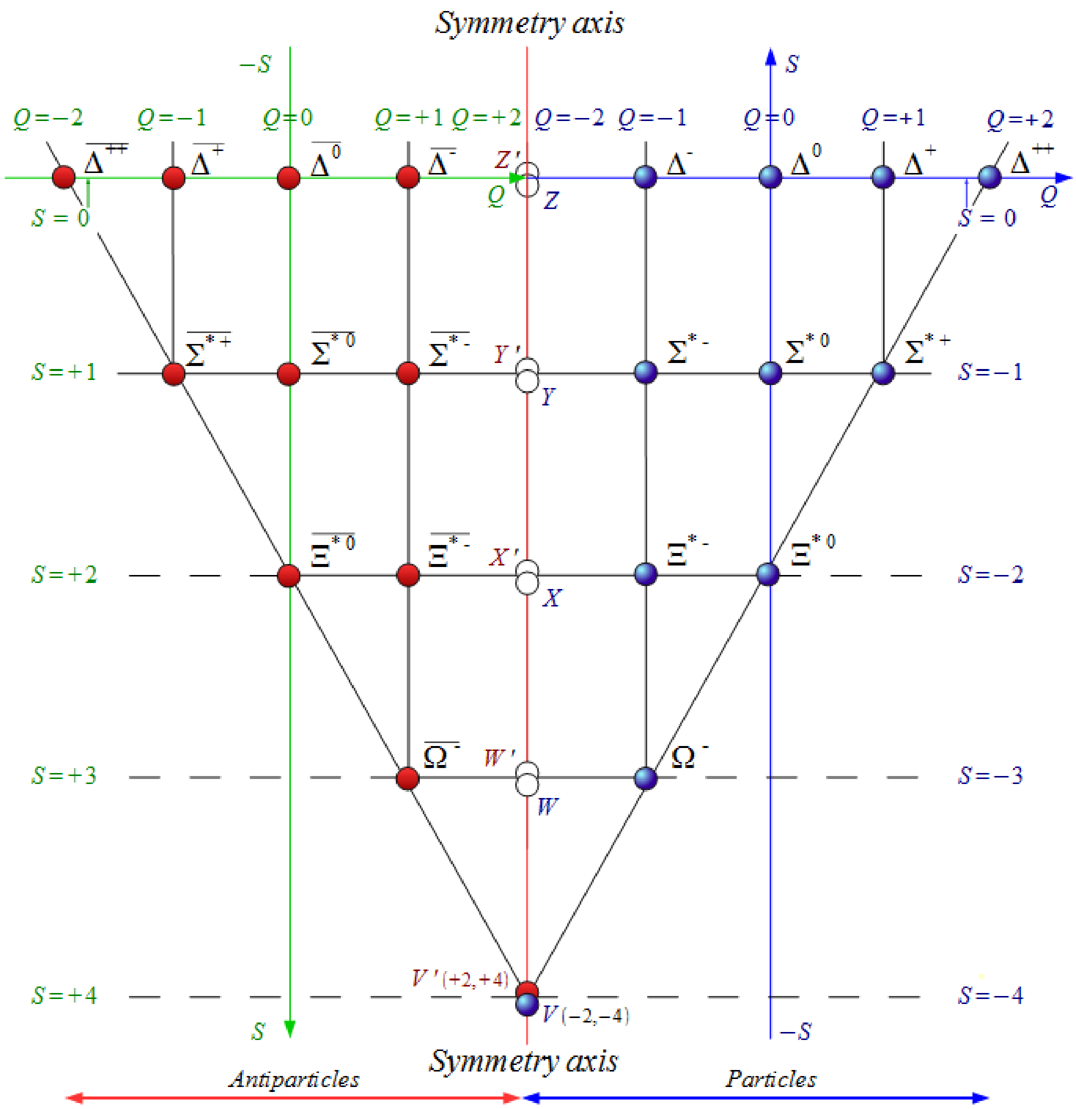

FIGURE 2: *The Incomplete Matter-Antimatter Way (including pentaquark level |4|): a pattern of 10 baryons (blue circles), 10 anti-baryons (red circles), 3 pentaquanks (blue circle at point V) and 3 antipentaquarks (red circle at point V').*

5. Analysis of Triply Strange Pentaquarks

5.1. Analysis of the Electric Charge and Strangeness

Analysis for Particles (point W)

In this analysis we only consider the QS coordinate system for particles which is shown in blue colour on the right hand side of FIGURE 1. The predicted particles must satisfy the following two conditions:

(a) the first condition the unknown particle (pentaquark) must satisfy is that its electric charge should be equal to -2 ($Q=-2$)

(b) The second condition the unknown particle (pentaquark) must satisfy is that its strangeness should be equal to -3 ($S=-3$). Because strange quarks are the only particles which possess the strangeness property, and because the value of this property is -1 (see TABLE 1 of section 2), the only way a particle can have a strangeness of -3 is if 3 of the constituents of this particle were 3 strange quarks.

Taking into account these two conditions and the fact that each strange quark carries an electric charge of $-1/3$, the electric charge equation for this particle should be

$$Q = 3 q_s + q_4 + q_5 \tag{5.1.1}$$

Where

Q = total electric charge of the unknown particle (-2)
q_s = electric charge of the strange quark ($-1/3$)
q_5 = electric charge of one of the constituents (quark) of the unknown particle (pentaquark) (cannot be an *s* quark). This quark will be called the fifth quark.
q_4 = electric charge of one of the constituents (quark) of the unknown particle (pentaquark) (cannot be an *s* quark). This quark will be called the forth quark.

We solve equation (5.1.1) for $q_4 + q_5$. This gives

$$q_4 + q_5 = Q - 3 q_s \tag{5.1.2}$$

Then, the value of the combined electric charge, $q_4 + q_5$, of the forth and fifth quarks should be

$$q_4 + q_5 = -2 - 3 \times \left(-\frac{1}{3} \right) = -2 + 1 = -1 \tag{5.1.3}$$

Therefore, the pentaquark must have the forth and the fifth quarks so that the addition of their electrical charges to be equal to -1 and, because of condition (b), none of these two quarks must be *s* quarks.

Looking at TABLE 2 of section 2 (antiquark properties) we see that

(i) the forth quark must be a *d* quark or a *b* quark, and
(ii) the fifth quark must be a $\bar{u}$ quark, a $\bar{c}$ quark or a $\bar{t}$ quark

These constrains will give us the following 6 pentaquarks

Pentaquark $P_{3sd\bar{u}}$ $(s\,s\,s\,d\,\bar{u})$ (5.1.4)

Pentaquark $P_{3sd\bar{c}}$ $(s\,s\,s\,d\,\bar{c})$ (5.1.5)

Pentaquark $P_{3sd\bar{t}}$ $(s\,s\,s\,d\,\bar{t})$ (5.1.6)

Pentaquark $P_{3sb\bar{u}}$ $(s\,s\,s\,b\,\bar{u})$ (5.1.7)

Pentaquark $P_{3sb\bar{c}}$ $(s\,s\,s\,b\,\bar{c})$ (5.1.8)

Pentaquark $P_{3sb\bar{t}}$ $(s\,s\,s\,b\,\bar{t})$ (5.1.9)

Analysis for Antiparticles (point *W'*)

A similar analysis shows that point W' should contain the following 6 antipentaquarks

antipentaquark $P_{3\bar{s}\,\bar{d}\,u}$ $\quad \bar{s}\,\bar{s}\,\bar{s}\,\bar{d}\,u \qquad$ (5.1.10)

antipentaquark $P_{3\bar{s}\,\bar{d}\,c}$ $\quad \bar{s}\,\bar{s}\,\bar{s}\,\bar{d}\,c \qquad$ (5.1.11)

antipentaquark $P_{4\bar{s}\,t}$ $\quad \bar{s}\,\bar{s}\,\bar{s}\,\bar{d}\,t \qquad$ (5.1.12)

antipentaquark $P_{3\bar{s}\,\bar{b}\,u}$ $\quad \bar{s}\,\bar{s}\,\bar{s}\,\bar{b}\,u \qquad$ (5.1.13)

antipentaquark $P_{3\bar{s}\,\bar{b}\,c}$ $\quad \bar{s}\,\bar{s}\,\bar{s}\,\bar{b}\,c \qquad$ (5.1.14)

antipentaquark $P_{3\bar{s}\,\bar{b}\,t}$ $\quad \bar{s}\,\bar{s}\,\bar{s}\,\bar{b}\,t \qquad$ (5.1.15)

Because this theory predicts that point W should contain 6 pentaquarks and that point W' should also contain 6 pentaquarks (remember that W and W' overlap), we may replace the visible empty circle of point W of FIGURE 1 by a blue circle representing the 6 new pentaquarks; and the partially visible empty circle of point W', by and a red circle representing the 6 new antipentaquarks. This is done in FIGURE 3. TABLE 5 summarizes the properties of the triply strange pentaquarks.

	PREDICTED PARTICLE (symbol)	PARTICLE COMPOSITION (quark contents)	ELECTRIC CHARGE (times the elementary charge: e	STRANGENESS
PARTICLES WITH 3 STRANGE QUARKS	$P^{--}_{3sd\bar{u}}$	$(s\,s\,s\,d\,\bar{u})$	-2	-3
	$P^{--}_{3sd\bar{c}}$	$(s\,s\,s\,d\,\bar{c})$	-2	-3
	$P^{--}_{3sd\bar{t}}$	$(s\,s\,s\,d\,\bar{t})$	-2	-3
	$P^{--}_{3sb\bar{u}}$	$(s\,s\,s\,b\,\bar{u})$	-2	-3
	$P^{--}_{3sb\bar{c}}$	$(s\,s\,s\,b\,\bar{c})$	-2	-3
	$P^{--}_{3sb\bar{t}}$	$(s\,s\,s\,b\,\bar{t})$	-2	-3
ANTI-PARTICLES WITH 3 ANTI-STRANGE QUARKS	$P^{--}_{3\bar{s}\,\bar{d}\,u}$	$(\bar{s}\,\bar{s}\,\bar{s}\,\bar{d}\,u)$	$+2$	$+3$
	$P^{--}_{3\bar{s}\,\bar{d}\,c}$	$(\bar{s}\,\bar{s}\,\bar{s}\,\bar{d}\,c)$	$+2$	$+3$
	$P^{--}_{3\bar{s}\,\bar{d}\,t}$	$(\bar{s}\,\bar{s}\,\bar{s}\,\bar{d}\,t)$	$+2$	$+3$
	$P^{--}_{3\bar{s}\bar{b}u}$	$(\bar{s}\,\bar{s}\,\bar{s}\,\bar{b}\,u)$	$+2$	$+3$
	$P^{--}_{3\bar{s}\bar{b}c}$	$(\bar{s}\,\bar{s}\,\bar{s}\,\bar{b}\,c)$	$+2$	$+3$
	$P^{--}_{3\bar{s}\bar{b}t}$	$(\bar{s}\,\bar{s}\,\bar{s}\,\bar{b}\,t)$	$+2$	$+3$

TABLE 5: *Some of the properties of the triply strange pentaquarks.*

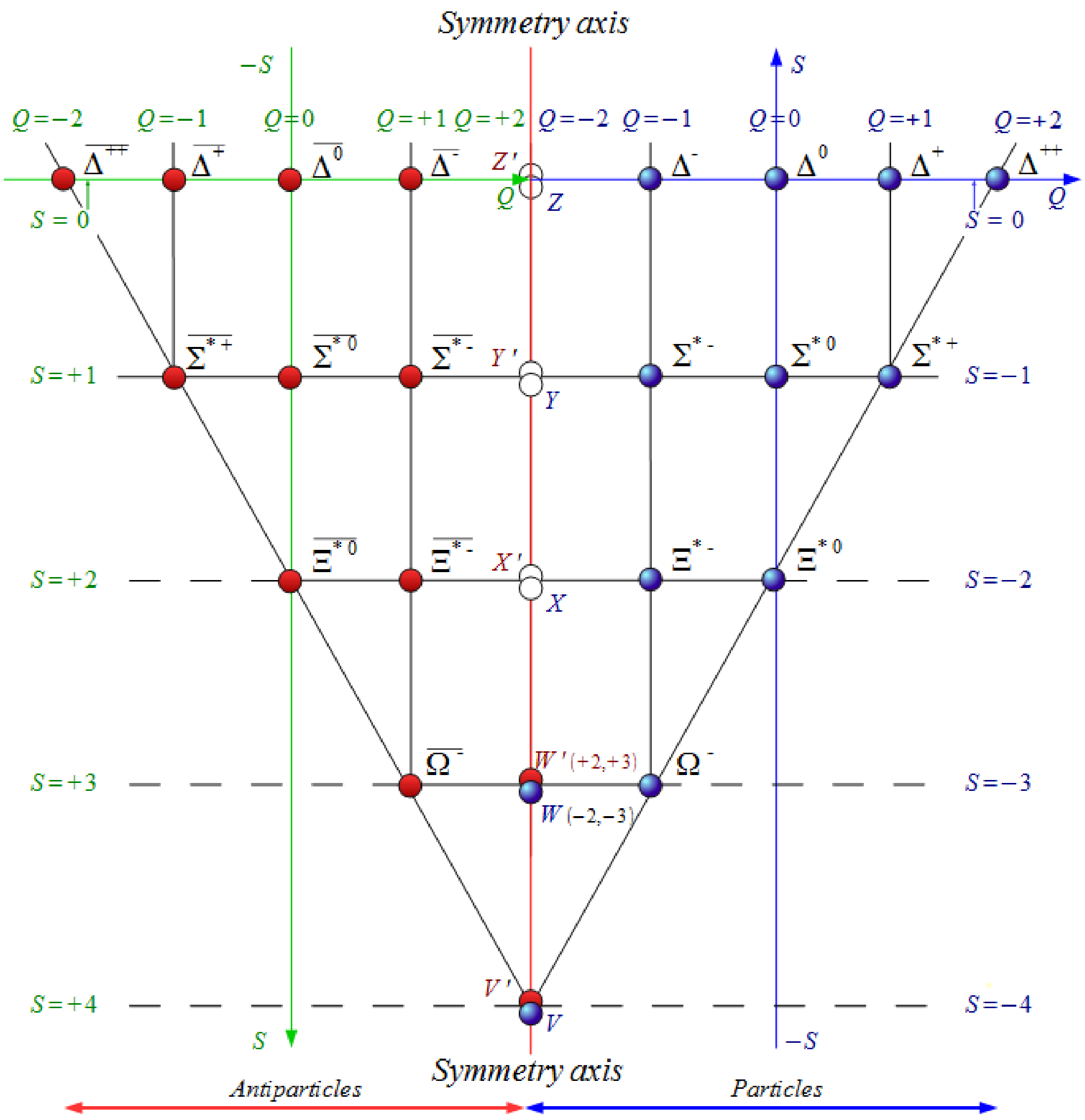

FIGURE 3: *The Incomplete Matter-Antimatter Way (including pentaquark levels* |3| and |4|)*: a pattern of 10 baryons (blue circles), 10 anti-baryons (red circles), 3 pentaquanks (blue circle at point V), 3 antipentaquarks (red circle at point V'), 6 pentaquanks (represented by a blue circle drawn at point W), 6 antipentaquarks (represented by a red circle drawn at point W').*

6. Analysis of Doubly Strange Pentaquarks

6.1. Analysis of the Electric Charge and Strangeness

Analysis for Particles (point *X*)

In this analysis we only consider the *QS* coordinate system for particles which is shown in blue colour on the right hand side of FIGURE 1. The predicted particles must satisfy the following two conditions:

(a) the first condition the unknown particle (pentaquark) must satisfy is that its electric charge should be equal to -2 ($Q=-2$)

(b) The second condition the unknown particle (pentaquark) must satisfy is that its strangeness should be equal to -2 ($S=-2$). Because strange quarks are the only particles which possess the strangeness property, and because the value of this property is -1 (see TABLE 1 of section 2), the only way a particle can have a strangeness of -2 is if 2 of the constituents of this particle were 2 strange quarks.

Taking into account these two conditions and the fact that each strange quark carries an electric charge of $-1/3$, the electric charge equation for this particle should be

$$Q=2q_s+q_3+q_4+q_5 \tag{6.1.1}$$

Where

$Q =$ total electric charge of the unknown particle (-2)
$q_s =$ electric charge of the strange quark ($-1/3$)
$q_5 =$ electric charge of one of the constituents (quark) of the unknown particle (pentaquark) (cannot be an *s* quark). This quark will be called the fifth quark.
$q_4 =$ electric charge of one of the constituents (quark) of the unknown particle (pentaquark) (cannot be an *s* quark). This quark will be called the forth quark.
$q_3 =$ electric charge of one of the constituents (quark) of the unknown particle (pentaquark) (cannot be an *s* quark). This quark will be called the third quark.

We solve equation (5.1.1) for $q_3+q_4+q_5$. This gives

$$q_3+q_4+q_5=Q-2q_s \tag{6.1.2}$$

Then, the value of the combined electric charge, $q_3+q_4+q_5$ of the third, forth and fifth quarks should be

$$q_3+q_4+q_5=-2-2\times\left(-\frac{1}{3}\right)=-2+\frac{2}{3}=-\frac{4}{3} \tag{6.1.3}$$

Therefore, the addition of the electrical charge of the third, forth and the fifth quarks must be to be equal to $-4/3$ and, because of condition (b), none of these two quarks must be *s* quarks. Looking at TABLE 1 (quark properties) and TABLE 2 (antiquark properties) of section 2 we see that the only way that 3 quarks can yield an electrical charge of $-4/3$

is if two of the 3 quarks have an electric charge of $-1/3$, and the other quark an electric charge of $-2/3$ so that the total charge of these 3 quarks is $-1/3-1/3-2/3=-4/3$

These constrains will give us the following 9 pentaquarks

Pentaquark $P_{2s2d\bar{u}}$ $(s\,s\,d\,d\,\bar{u})$ (6.1.4)

Pentaquark $P_{2s2d\bar{c}}$ $(s\,s\,d\,d\,\bar{c})$ (6.1.5)

Pentaquark $P_{2s2d\bar{t}}$ $(s\,s\,d\,d\,\bar{t})$ (6.1.6)

Pentaquark $P_{2sdb\bar{u}}$ $(s\,s\,d\,b\,\bar{u})$ (6.1.7)

Pentaquark $P_{2sdb\bar{c}}$ $(s\,s\,d\,b\,\bar{c})$ (6.1.8)

Pentaquark $P_{2sdb\bar{t}}$ $(s\,s\,d\,b\,\bar{t})$ (6.1.9)

Pentaquark $P_{2s2b\bar{u}}$ $(s\,s\,b\,b\,\bar{u})$ (6.1.10)

Pentaquark $P_{2s2b\bar{c}}$ $(s\,s\,b\,b\,\bar{c})$ (6.1.11)

Pentaquark $P_{2s2b\bar{t}}$ $(s\,s\,b\,b\,\bar{t})$ (6.1.12)

Analysis for Antiparticles (point *W′*)

A similar analysis shows that point *W′* should contain the following 9 antipentaquarks

Antipentaquark $P_{2\bar{s}2\bar{d}u}$ $(\bar{s}\,\bar{s}\,\bar{d}\,\bar{d}\,u)$ (6.1.13)

Antipentaquark $P_{2\bar{s}2\bar{d}c}$ $(\bar{s}\,\bar{s}\,\bar{d}\,\bar{d}\,c)$ (6.1.14)

Antipentaquark $P_{2\bar{s}2\bar{d}t}$ $(\bar{s}\,\bar{s}\,\bar{d}\,\bar{d}\,t)$ (6.1.15)

Antipentaquark $P_{2\bar{s}\bar{d}\bar{b}u}$ $(\bar{s}\,\bar{s}\,\bar{d}\,\bar{b}\,u)$ (6.1.16)

Antipentaquark $P_{2\bar{s}\bar{d}\bar{b}c}$ $(\bar{s}\,\bar{s}\,\bar{d}\,\bar{b}\,c)$ (6.1.17)

Antipentaquark $P_{2\bar{s}\bar{d}\bar{b}t}$ $(\bar{s}\,\bar{s}\,\bar{d}\,\bar{b}\,t)$ (6.1.18)

Antipentaquark $P_{2\bar{s}2\bar{b}u}$ $(\bar{s}\,\bar{s}\,\bar{b}\,\bar{b}\,u)$ (6.1.19)

Antipentaquark $P_{2\bar{s}2\bar{b}c}$ $(\bar{s}\,\bar{s}\,\bar{b}\,\bar{b}\,c)$ (6.1.20)

Antipentaquark $P_{2\bar{s}2\bar{b}t}$ $(\bar{s}\,\bar{s}\,\bar{b}\,\bar{b}\,t)$ (6.1.21)

Because this theory predicts that point *X* should contain 9 pentaquarks and that point *X′* should also contain 9 pentaquarks (remember that *X* and *X′* overlap), we may replace the visible empty circle of point *X* of FIGURE 1 by a blue circle representing the 9 new pentaquarks; and the partially visible empty circle of point *X′*, by and a red circle representing the 9 new antipentaquarks. This is done in FIGURE 4.

(see next page)

TABLE 6 summarizes the properties of the doubly strange pentaquarks.

	PREDICTED PARTICLE (symbol)	PARTICLE COMPOSITION (quark contents)	ELECTRIC CHARGE (times the elementary charge: *e*	STRANGENESS
PARTICLES WITH 2 STRANGE QUARKS	$P_{2s\,2d\,\bar{u}}$	$(s\,s\,d\,d\,\bar{u})$	-2	-3
	$P_{2s\,2d\,\bar{c}}$	$(s\,s\,d\,d\,\bar{c})$	-2	-3
	$P_{2s\,2d\,\bar{t}}$	$(s\,s\,d\,d\,\bar{t})$	-2	-3
	$P_{2s\,d\,b\,\bar{u}}$	$(s\,s\,d\,b\,\bar{u})$	-2	-3
	$P_{2s\,d\,b\,\bar{c}}$	$(s\,s\,d\,b\,\bar{c})$	-2	-3
	$P_{2s\,d\,b\,\bar{t}}$	$(s\,s\,d\,b\,\bar{t})$	-2	-3
	$P_{2s\,2b\,\bar{u}}$	$(s\,s\,b\,b\,\bar{u})$	-2	-3
	$P_{2s\,2b\,\bar{c}}$	$(s\,s\,b\,b\,\bar{c})$	-2	-3
	$P_{2s\,2b\,\bar{t}}$	$(s\,s\,b\,b\,\bar{t})$	-2	-3
ANTI-PARTICLES WITH 2 ANTI-STRANGE QUARKS	$P_{2\bar{s}\,2\bar{d}\,u}$	$(\bar{s}\,\bar{s}\,\bar{d}\,\bar{d}\,u)$	$+2$	$+3$
	$P_{2\bar{s}\,2\bar{d}\,c}$	$(\bar{s}\,\bar{s}\,\bar{d}\,\bar{d}\,c)$	$+2$	$+3$
	$P_{2\bar{s}\,2\bar{d}\,t}$	$(\bar{s}\,\bar{s}\,\bar{d}\,\bar{d}\,t)$	$+2$	$+3$
	$P_{2\bar{s}\,\bar{d}\,\bar{b}\,u}$	$(\bar{s}\,\bar{s}\,\bar{d}\,\bar{b}\,u)$	$+2$	$+3$
	$P_{2\bar{s}\,\bar{d}\,\bar{b}\,c}$	$(\bar{s}\,\bar{s}\,\bar{d}\,\bar{b}\,c)$	$+2$	$+3$
	$P_{2\bar{s}\,\bar{d}\,\bar{b}\,t}$	$(\bar{s}\,\bar{s}\,\bar{d}\,\bar{b}\,t)$	$+2$	$+3$
	$P_{2\bar{s}\,2\bar{b}\,u}$	$(\bar{s}\,\bar{s}\,\bar{b}\,\bar{b}\,u)$	$+2$	$+3$
	$P_{2\bar{s}\,2\bar{b}\,c}$	$(\bar{s}\,\bar{s}\,\bar{b}\,\bar{b}\,c)$	$+2$	$+3$
	$P_{2\bar{s}\,2\bar{b}\,t}$	$(\bar{s}\,\bar{s}\,\bar{b}\,\bar{b}\,t)$	$+2$	$+3$

TABLE 6: *Some of the properties of the doubly strange pentaquarks.*

(see next page)

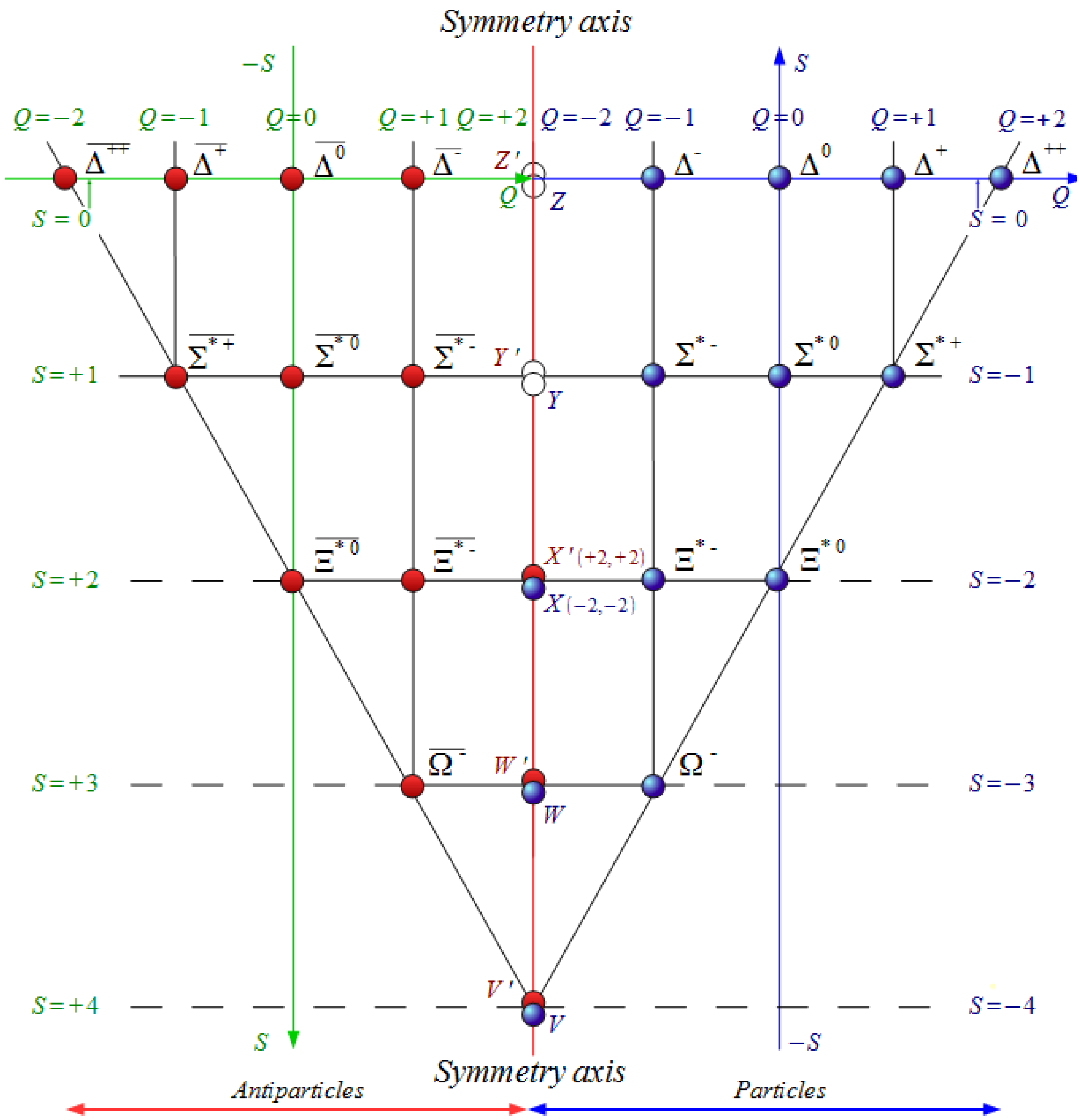

FIGURE 4: *The Incomplete Matter-Antimatter Way (including pentaquark levels |2|, |3| and |4|): a pattern of 10 baryons (blue circles), 10 anti-baryons (red circles), 3 pentaquanks (blue circle at point V), 3 antipentaquarks (red circle at point V'), 6 pentaquanks (represented by a blue circle drawn at point W), 6 antipentaquarks (represented by a red circle drawn at point W'), 9 pentaquanks (represented by a blue circle drawn at point X) and 9 antipentaquarks (represented by a red circle drawn at point X').*

7. Analysis of Singly Strange Pentaquarks

7.1. Analysis of the Electric Charge and Strangeness

Analysis for Particles (point *Y*)

In this analysis we only consider the *QS* coordinate system for particles which is shown in blue colour on the right hand side of FIGURE 1. The predicted particles must satisfy the following two conditions:

(a) the first condition the unknown particle (pentaquark) must satisfy is that its electric charge should be equal to -2 ($Q=-2$)

(b) The second condition the unknown particle (pentaquark) must satisfy is that its strangeness should be equal to -1 ($S=-1$). Because strange quarks are the only particles which possess the strangeness property, and because the value of this property is -1 (see TABLE 1 of section 2), the only way a particle can have a strangeness of -1 is if one of the constituents of this particle is a strange quark.

Taking into account these two conditions and the fact that each strange quark carries an electric charge of $-1/3$, the electric charge equation for this particle should be

$$Q=q_s+q_2+q_3+q_4+q_5 \tag{7.1.1}$$

Where

$Q=$ total electric charge of the unknown particle (-2)
$q_s=$ electric charge of the strange quark ($-1/3$)
$q_5=$ electric charge of one of the constituents (quark) of the unknown particle (pentaquark) (cannot be an *s* quark). This quark will be called the fifth quark.
$q_4=$ electric charge of one of the constituents (quark) of the unknown particle (pentaquark) (cannot be an *s* quark). This quark will be called the forth quark.
$q_3=$ electric charge of one of the constituents (quark) of the unknown particle (pentaquark) (cannot be an *s* quark). This quark will be called the third quark.
$q_2=$ electric charge of one of the constituents (quark) of the unknown particle (pentaquark) (cannot be an *s* quark). This quark will be called the second quark.

We solve equation (7.1.1) for $q_2+q_3+q_4+q_5$. This gives

$$q_2+q_3+q_4+q_5=Q-q_s \tag{7.1.2}$$

Then, the value of the combined electric charge, $q_2+q_3+q_4+q_5$, of the second, third, forth and fifth quarks should be

$$q_2+q_3+q_4+q_5=-2-\left(-\frac{1}{3}\right)=-2+\frac{1}{3}=-\frac{5}{3} \tag{7.1.3}$$

Therefore, the addition of the electrical charge of the second, third, forth and the fifth quarks must be to be equal to $-5/3$ and, because of condition (b), none of these four quarks must be *s* quarks. Looking at TABLE 1 (quark properties) and TABLE 2 (antiquark properties) of section 2 we see that the only way that 4 quarks (an additional *s* quark will complete the pentaquark) can yield an electrical charge of $-5/3$ is if one of the 4 quarks has an electric charge of $-2/3$ (which is the charge of either an $\bar{u}$ quark, or a $\bar{c}$ quark or a $\bar{t}$ quark) and the other 3 quarks have a charge of $-1/3$ each (which is the charge of either a *d* quark or a *b* quark). Thus, a combinations of these types of 4 quarks will produce a charge of

$$q_2+q_3+q_4+q_5=-\frac{2}{3}-\frac{1}{3}-\frac{1}{3}-\frac{1}{3}=-\frac{5}{3} \tag{7.1.4}$$

These constrains will give us the following 12 pentaquarks

Pentaquark $P_{s\,3\mathrm{d}\,\bar{u}}$ $(s\,d\,d\,d\,\bar{u})$ (7.1.5)

Pentaquark $P_{s\,2\mathrm{d}\,b\,\bar{u}}$ $(s\,d\,d\,b\,\bar{u})$ (7.1.6)

Pentaquark $P_{s\,d\,2\mathrm{b}\bar{u}}$ $(s\,d\,b\,b\,\bar{u})$ (7.1.7)

Pentaquark $P_{s\,3\mathrm{b}\,\bar{u}}$ $(s\,b\,b\,b\,\bar{u})$ (7.1.8)

Pentaquark $P_{s\,3\mathrm{d}\,\bar{c}}$ $(s\,d\,d\,d\,\bar{c})$ (7.1.9)

Pentaquark $P_{s\,2\mathrm{d}\,b\,\bar{c}}$ $(s\,d\,d\,b\,\bar{c})$ (7.1.10)

Pentaquark $P_{s\,d\,2\mathrm{b}\bar{c}}$ $(s\,d\,b\,b\,\bar{c})$ (7.1.11)

Pentaquark $P_{s\,3\mathrm{b}\,\bar{c}}$ $(s\,b\,b\,b\,\bar{c})$ (7.1.12)

Pentaquark $P_{s\,3\mathrm{d}\,\bar{t}}$ $(s\,d\,d\,d\,\bar{t})$ (7.1.13)

Pentaquark $P_{s\,2\mathrm{d}\,b\,\bar{t}}$ $(s\,d\,d\,b\,\bar{t})$ (7.1.14)

Pentaquark $P_{s\,d\,2\mathrm{b}\bar{t}}$ $(s\,d\,b\,b\,\bar{t})$ (7.1.15)

Pentaquark $P_{s\,3\mathrm{b}\,\bar{t}}$ $(s\,b\,b\,b\,\bar{t})$ (7.1.16)

Analysis for Antiparticles (point *Y′*)

A similar analysis shows that point Y' should contain the following 12 antipentaquarks

Pentaquark $P_{\bar{s}\,3\bar{d}\,u}$ $(\bar{s}\,\bar{d}\,\bar{d}\,\bar{d}\,u)$ (7.1.17)

Pentaquark $P_{\bar{s}\,2\bar{d}\,\bar{b}\,u}$ $(\bar{s}\,\bar{d}\,\bar{d}\,\bar{b}\,u)$ (7.1.18)

Pentaquark $P_{\bar{s}\,\bar{d}\,2\bar{b}\,u}$ $(\bar{s}\,\bar{d}\,\bar{b}\,\bar{b}\,u)$ (7.1.19)

Pentaquark $P_{\bar{s}\,3\bar{b}\,u}$ $(\bar{s}\,\bar{b}\,\bar{b}\,\bar{b}\,u)$ (7.1.20)

Pentaquark $P_{\bar{s}\,3\bar{d}\,c}$ $(\bar{s}\,\bar{d}\,\bar{d}\,\bar{d}\,c)$ (7.1.21)

Pentaquark $P_{\bar{s}\,2\bar{d}\,\bar{b}\,c}$ $(\bar{s}\,\bar{d}\,\bar{d}\,\bar{b}\,c)$ (7.1.22)

Pentaquark $P_{\bar{s}\,\bar{d}\,2\bar{b}\,c}$ $(\bar{s}\,\bar{d}\,\bar{b}\,\bar{b}\,c)$ (7.1.23)

Pentaquark $P_{\bar{s}\,3\bar{b}\,c}$ $(\bar{s}\,\bar{b}\,\bar{b}\,\bar{b}\,c)$ (7.1.24)

Pentaquark $P_{\bar{s}\,3\bar{d}\,t}$ $(\bar{s}\,\bar{d}\,\bar{d}\,\bar{d}\,t)$ (7.1.25)

Pentaquark $P_{\bar{s}\,2\bar{d}\,\bar{b}\,t}$ $(\bar{s}\,\bar{d}\,\bar{d}\,\bar{b}\,t)$ (7.1.26)

Pentaquark $P_{\bar{s}\,\bar{d}\,2\bar{b}\,t}$ $(\bar{s}\,\bar{d}\,\bar{b}\,\bar{b}\,t)$ (7.1.27)

Pentaquark $P_{\bar{s}\,3\bar{b}\,t}$ $(\bar{s}\,\bar{b}\,\bar{b}\,\bar{b}\,t)$ (7.1.28)

Because this theory predicts that point Y should contain 12 pentaquarks and that point Y' should also contain 12 pentaquarks (remember that Y and Y' overlap), we may replace the visible empty circle of point Y of FIGURE 1 by a blue circle representing the 12 new pentaquarks; and the partially visible empty circle of point Y', by and a red circle representing the 12 new antipentaquarks. This is done in FIGURE 5. TABLE 7 summarizes the properties of the singly strange pentaquarks.

	PREDICTED PARTICLE (symbol)	PARTICLE COMPOSITION (quark contents)	ELECTRIC CHARGE (times the elementary charge: *e*	STRANGENESS
PARTICLES WITH 1 STRANGE QUARK	$P_{s3d\bar{u}}$	$(s\,d\,d\,d\,\bar{u})$	-2	-3
	$P_{s2db\bar{u}}$	$(s\,d\,d\,b\,\bar{u})$	-2	-3
	$P_{sd2b\bar{u}}$	$(s\,d\,b\,b\,\bar{u})$	-2	-3
	$P_{s3b\bar{u}}$	$(s\,b\,b\,b\,\bar{u})$	-2	-3
	$P_{s3d\bar{c}}$	$(s\,d\,d\,d\,\bar{c})$	-2	-3
	$P_{s2db\bar{c}}$	$(s\,d\,d\,b\,\bar{c})$	-2	-3
	$P_{sd2b\bar{c}}$	$(s\,d\,b\,b\,\bar{c})$	-2	-3
	$P_{s3b\bar{c}}$	$(s\,b\,b\,b\,\bar{c})$	-2	-3
	$P_{s3d\bar{t}}$	$(s\,d\,d\,d\,\bar{t})$	-2	-3
	$P_{s2db\bar{t}}$	$(s\,d\,d\,b\,\bar{t})$	-2	-3
	$P_{sd2b\bar{t}}$	$(s\,d\,b\,b\,\bar{t})$	-2	-3
	$P_{s3b\bar{t}}$	$(s\,b\,b\,b\,\bar{t})$	-2	-3
ANTI-PARTICLES WITH 1 ANTI-STRANGE QUARK	$P_{\bar{s}3\bar{d}u}$	$(\bar{s}\,\bar{d}\,\bar{d}\,\bar{d}\,u)$	$+2$	$+3$
	$P_{\bar{s}2\bar{d}\bar{b}u}$	$(\bar{s}\,\bar{d}\,\bar{d}\,\bar{b}\,u)$	$+2$	$+3$
	$P_{\bar{s}\bar{d}2\bar{b}u}$	$(\bar{s}\,\bar{d}\,\bar{b}\,\bar{b}\,u)$	$+2$	$+3$
	$P_{\bar{s}3\bar{b}u}$	$(\bar{s}\,\bar{b}\,\bar{b}\,\bar{b}\,u)$	$+2$	$+3$
	$P_{\bar{s}3\bar{d}c}$	$(\bar{s}\,\bar{d}\,\bar{d}\,\bar{d}\,c)$	$+2$	$+3$
	$P_{\bar{s}2\bar{d}\bar{b}c}$	$(\bar{s}\,\bar{d}\,\bar{d}\,\bar{b}\,c)$	$+2$	$+3$
	$P_{\bar{s}\bar{d}2\bar{b}c}$	$(\bar{s}\,\bar{d}\,\bar{b}\,\bar{b}\,c)$	$+2$	$+3$
	$P_{\bar{s}3\bar{b}c}$	$(\bar{s}\,\bar{b}\,\bar{b}\,\bar{b}\,c)$	$+2$	$+3$
	$P_{\bar{s}3\bar{d}t}$	$(\bar{s}\,\bar{d}\,\bar{d}\,\bar{d}\,t)$	$+2$	$+3$
	$P_{\bar{s}2\bar{d}\bar{b}t}$	$(\bar{s}\,\bar{d}\,\bar{d}\,\bar{b}\,t)$	$+2$	$+3$
	$P_{\bar{s}\bar{d}2\bar{b}t}$	$(\bar{s}\,\bar{d}\,\bar{b}\,\bar{b}\,t)$	$+2$	$+3$
	$P_{\bar{s}3\bar{b}t}$	$(\bar{s}\,\bar{b}\,\bar{b}\,\bar{b}\,t)$	$+2$	$+3$

TABLE 7: *Some of the properties of the singly strange pentaquarks.*

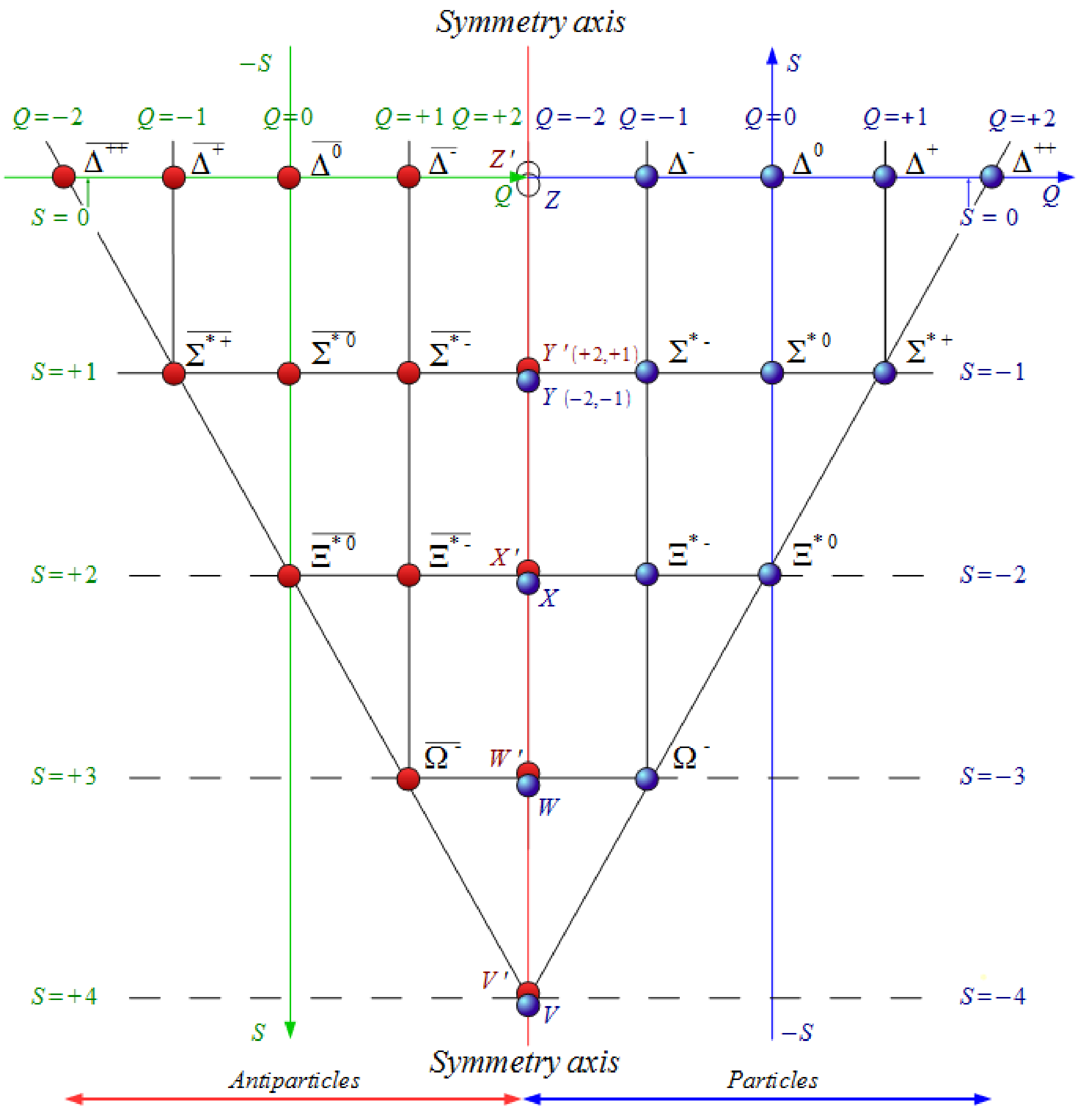

FIGURE 5: *The Incomplete Matter-Antimatter Way (including pentaquark levels* |*1*|, |*2*|, |*3*| and |*4*|)*: a pattern of 10 baryons (blue circles that are not on the symmetry axis), 10 anti-baryons (red circles that are not on the symmetry axis), 3 quadruply strange pentaquanks (represented by a blue circle at point V on the symmetry axis), 3 quadruply strange antipentaquarks (represented by a red circle at point V' on the symmetry axis), 6 triply strange pentaquanks (represented by a blue circle drawn at point W on the symmetry axis), 6 triply strange antipentaquarks (represented by a red circle drawn at point W' on the symmetry axis), 9 doubly strange pentaquanks (represented by a blue circle drawn at point X on the symmetry axis), 9 doubly strange antipentaquarks (represented by a red circle drawn at point X' on the symmetry axis), 12 singly strange pentaquanks (represented by a blue circle drawn at point Y on the symmetry axis), 12 singly strange antipentaquarks (represented by a red circle drawn at point Y' on the symmetry axis).*

8. Analysis of Non-Strange Pentaquarks

8.1. Analysis of the Electric Charge and Strangeness

Analysis for Particles (point *Z*)

In this analysis we only consider the *QS* coordinate system for particles which is shown in blue colour on the right hand side of FIGURE 1. The predicted particles must satisfy the following two conditions:

(a) the first condition the unknown particle (pentaquark) must satisfy is that its electric charge should be equal to -2 ($Q=-2$)

(b) The second condition the unknown particle (pentaquark) must satisfy is that its strangeness should be equal to 0 ($S=0$). In other words, this condition means that the unknown particle (pentaquark) can not contain any strange quarks.

Taking into account these two conditions and the fact that each strange quark carries an electric charge of $-1/3$, the electric charge equation for this particle should be

$$Q= q_1+q_2+q_3+q_4+q_5 \qquad (8.1.1)$$

Where

Q = total electric charge of the unknown particle (-2)
q_5 = electric charge of one of the constituents (quark) of the unknown particle (pentaquark) (cannot be an *s* quark). This quark will be called the fifth quark.
q_4 = electric charge of one of the constituents (quark) of the unknown particle (pentaquark) (cannot be an *s* quark). This quark will be called the forth quark.
q_3 = electric charge of one of the constituents (quark) of the unknown particle (pentaquark) (cannot be an *s* quark). This quark will be called the third quark.
q_2 = electric charge of one of the constituents (quark) of the unknown particle (pentaquark) (cannot be an *s* quark). This quark will be called the second quark.
q_1 = electric charge of one of the constituents (quark) of the unknown particle (pentaquark) (cannot be an *s* quark). This quark will be called the first quark.

The electric charge equation is

$$Q = q_1+q_2+q_3+q_4+q_5 = -2 \qquad (8.1.1)$$

Because this the addition of the electrical charge of the 5 quarks must be -2 , we shall consider two cases

Case 1

One way of satisfying equation (8.1.1) is as follows. One quark (let's say the first quark) must have an electric charge of $-2/3$ (which is the charge of either an $\bar{u}$ quark, or a $\bar{c}$ quark or a $\bar{t}$ quark) and the other 4 quarks must have an electric charge of $-1/3$ (which is the charge of either a *d* quark or a *b* quark). This way equation (8.1.1) yields the following value

$$Q = -\frac{2}{3}+4\times\left(-\frac{1}{3}\right) = -\frac{6}{3}=-2 \qquad (8.1.2)$$

These constrains will give us the following 15 pentaquarks

	PREDICTED PARTICLE (symbol)	PARTICLE COMPOSITION (quark contents)	ELECTRIC CHARGE (times the elementary charge: *e*	STRANGENESS	REF NUMBER
1	Pentaquark $P_{4d\bar{u}}$	$(d\,d\,d\,d\,\bar{u})$	-2	0	(8.1.3)
2	Pentaquark $P_{3db\bar{u}}$	$(d\,d\,d\,b\,\bar{u})$	-2	0	(8.1.4)
3	Pentaquark $P_{2d2b\bar{u}}$	$(d\,d\,b\,b\,\bar{u})$	-2	0	(8.1.5)
4	Pentaquark $P_{d3b\bar{u}}$	$(d\,b\,b\,b\,\bar{u})$	-2	0	(8.1.6)
5	Pentaquark $P_{4b\bar{u}}$	$(b\,b\,b\,b\,\bar{u})$	-2	0	(8.1.7)
6	Pentaquark $P_{4d\bar{c}}$	$(d\,d\,d\,d\,\bar{c})$	-2	0	(8.1.8)
7	Pentaquark $P_{3db\bar{c}}$	$(d\,d\,d\,b\,\bar{c})$	-2	0	(8.1.9)
8	Pentaquark $P_{2d2b\bar{c}}$	$(d\,d\,b\,b\,\bar{c})$	-2	0	(8.1.10)
9	Pentaquark $P_{d3b\bar{c}}$	$(d\,b\,b\,b\,\bar{c})$	-2	0	(8.1.11)
10	Pentaquark $P_{4b\bar{c}}$	$(b\,b\,b\,b\,\bar{c})$	-2	0	(8.1.12)
11	Pentaquark $P_{4d\bar{t}}$	$(d\,d\,d\,d\,\bar{t})$	-2	0	(8.1.13)
12	Pentaquark $P_{3db\bar{t}}$	$(d\,d\,d\,b\,\bar{t})$	-2	0	(8.1.14)
13	Pentaquark $P_{2d2b\bar{t}}$	$(d\,d\,b\,b\,\bar{t})$	-2	0	(8.1.15)
14	Pentaquark $P_{d3b\bar{t}}$	$(d\,b\,b\,b\,\bar{t})$	-2	0	(8.1.16)
15	Pentaquark $P_{4b\bar{t}}$	$(b\,b\,b\,b\,\bar{t})$	-2	0	(8.1.17)

Case 2

Another way of satisfying equation (8.1.1) is by having

(i) one quark with electric charge equal to $+2/3$ and another one with a charge of $-2/3$. Thus the total electrical charge of these two quarks will be 0.
(ii) The rest of the quarks (3 quarks) having and electric charge of $-2/3$ each. This makes a total charge, for these 3 quarks, equal to $-6/3=-2$.

Again, to find out which are the quarks with an electric charge of $+2/3$ we look into TABLE 1 of section 2 (quark properties). Then, we find that the answer is: quarks *u*, *c* and *t*. On the other hand, to find out which are the quarks with an electric charge of $-2/3$ we look into TABLE 2 of section 2 (antiquark properties). Then, we find that the answer is: quarks $\bar{u}$, $\bar{c}$ and $\bar{t}$. Then, with this knowledge we can "build" our non-strange pentaquarks. Thus, we get the following list

	PREDICTED PARTICLE (symbol)	PARTICLE COMPOSITION (quark contents)	ELECTRIC CHARGE (times the elementary charge: *e*	STRANGENESS	REF NUMBER
16	Pentaquark $P_{u4\bar{u}}$	$(u\,\bar{u}\,\bar{u}\,\bar{u}\,\bar{u})$	-2	0	(8.1.18)
17	Pentaquark $P_{u3\bar{u}\,\bar{c}}$	$(u\,\bar{u}\,\bar{u}\,\bar{u}\,\bar{c})$	-2	0	(8.1.19)
18	Pentaquark $P_{u\,2\bar{u}\,2\bar{c}}$	$(u\,\bar{u}\,\bar{u}\,\bar{c}\,\bar{c})$	-2	0	(8.1.20)
19	Pentaquark $P_{u\bar{u}\,3\bar{c}}$	$(u\,\bar{u}\,\bar{c}\,\bar{c}\,\bar{c})$	-2	0	(8.1.21)
20	Pentaquark $P_{u4\bar{c}}$	$(u\,\bar{c}\,\bar{c}\,\bar{c}\,\bar{c})$	-2	0	(8.1.22)
21	Pentaquark $P_{u4\bar{u}}$	$(u\,\bar{u}\,\bar{u}\,\bar{u}\,\bar{t})$	-2	0	(8.1.23)
22	Pentaquark $P_{u\,2\bar{u}\,2\bar{t}}$	$(u\,\bar{u}\,\bar{u}\,\bar{t}\,\bar{t})$	-2	0	(8.1.24)
23	Pentaquark $P_{u\bar{u}\,3\bar{t}}$	$(u\,\bar{u}\,\bar{t}\,\bar{t}\,\bar{t})$	-2	0	(8.1.25)
24	Pentaquark $P_{u\,4\bar{t}}$	$(u\,\bar{t}\,\bar{t}\,\bar{t}\,\bar{t})$	-2	0	(8.1.26)
25	Pentaquark $P_{c\,4\bar{u}}$	$(c\,\bar{u}\,\bar{u}\,\bar{u}\,\bar{u})$	-2	0	(8.1.27)
26	Pentaquark $P_{c\,3\bar{u}\,\bar{c}}$	$(c\,\bar{u}\,\bar{u}\,\bar{u}\,\bar{c})$	-2	0	(8.1.28)
27	Pentaquark $P_{c\,2\bar{u}\,2\bar{c}}$	$(c\,\bar{u}\,\bar{u}\,\bar{c}\,\bar{c})$	-2	0	(8.1.29)
28	Pentaquark $P_{c\,\bar{u}\,3\bar{c}}$	$(c\,\bar{u}\,\bar{c}\,\bar{c}\,\bar{c})$	-2	0	(8.1.30)
29	Pentaquark $P_{c4\bar{c}}$	$(c\,\bar{c}\,\bar{c}\,\bar{c}\,\bar{c})$	-2	0	(8.1.31)
30	Pentaquark $P_{c\,3\bar{u}\,\bar{c}}$	$(c\,\bar{u}\,\bar{u}\,\bar{u}\,\bar{t})$	-2	0	(8.1.28)
31	Pentaquark $P_{c\,2\bar{u}\,2\bar{c}}$	$(c\,\bar{u}\,\bar{u}\,\bar{t}\,\bar{t})$	-2	0	(8.1.29)
32	Pentaquark $P_{c\,\bar{u}\,3\bar{c}}$	$(c\,\bar{u}\,\bar{t}\,\bar{t}\,\bar{t})$	-2	0	(8.1.30)
33	Pentaquark $P_{c4\bar{c}}$	$(c\,\bar{t}\,\bar{t}\,\bar{t}\,\bar{t})$	-2	0	(8.1.31)
34	Pentaquark $P_{t\,4\bar{u}}$	$(t\,\bar{u}\,\bar{u}\,\bar{u}\,\bar{u})$	-2	0	(8.1.32)
35	Pentaquark $P_{t\,3\bar{u}\,\bar{c}}$	$(t\,\bar{u}\,\bar{u}\,\bar{u}\,\bar{c})$	-2	0	(8.1.33)
36	Pentaquark $P_{t\,2\bar{u}\,2\bar{c}}$	$(t\,\bar{u}\,\bar{u}\,\bar{c}\,\bar{c})$	-2	0	(8.1.34)
37	Pentaquark $P_{t\,\bar{u}\,3\bar{c}}$	$(t\,\bar{u}\,\bar{c}\,\bar{c}\,\bar{c})$	-2	0	(8.1.35)
38	Pentaquark $P_{t4\bar{c}}$	$(t\,\bar{c}\,\bar{c}\,\bar{c}\,\bar{c})$	-2	0	(8.1.36)
39	Pentaquark $P_{t\,3\bar{u}\,\bar{t}}$	$(t\,\bar{u}\,\bar{u}\,\bar{u}\,\bar{t})$	-2	0	(8.1.37)
40	Pentaquark $P_{t\,2\bar{u}\,2\bar{t}}$	$(t\,\bar{u}\,\bar{u}\,\bar{t}\,\bar{t})$	-2	0	(8.1.38)
41	Pentaquark $P_{t\,\bar{u}\,3\bar{t}}$	$(t\,\bar{u}\,\bar{t}\,\bar{t}\,\bar{t})$	-2	0	(8.1.39)
42	Pentaquark $P_{t4\bar{t}}$	$(t\,\bar{t}\,\bar{t}\,\bar{t}\,\bar{t})$	-2	0	(8.1.40)

	PREDICTED PARTICLE (symbol)	PARTICLE COMPOSITION (quark contents)	ELECTRIC CHARGE (times the elementary charge: *e*	STRANGENESS	REF NUMBER
43	Pentaquark $P_{u\,2\bar{u}\,2\bar{t}}$	$(u\,\bar{u}\,\bar{u}\,\bar{c}\,\bar{t})$	-2	0	(8.1.41)
44	Pentaquark $P_{u\bar{u}\,2\bar{c}\bar{t}}$	$(u\,\bar{u}\,\bar{c}\,\bar{c}\,\bar{t})$	-2	0	(8.1.42)
45	Pentaquark $P_{u\,3\bar{c}\,\bar{t}}$	$(u\,\bar{c}\,\bar{c}\,\bar{c}\,\bar{t})$	-2	0	(8.1.43)
46	Pentaquark $P_{u\bar{u}\,2\bar{t}\,\bar{c}}$	$(u\,\bar{u}\,\bar{t}\,\bar{t}\,\bar{c})$	-2	0	(8.1.44)
47	Pentaquark $P_{u\,3\bar{t}\,\bar{c}}$	$(u\,\bar{t}\,\bar{t}\,\bar{t}\,\bar{c})$	-2	0	(8.1.45)
48	Pentaquark $P_{c\,2\bar{u}\,\bar{c}\,\bar{t}}$	$(c\,\bar{u}\,\bar{u}\,\bar{c}\,\bar{t})$	-2	0	(8.1.46)
49	Pentaquark $P_{c\bar{u}\,2\bar{c}\,\bar{t}}$	$(c\,\bar{u}\,\bar{c}\,\bar{c}\,\bar{t})$	-2	0	(8.1.47)
50	Pentaquark $P_{c3\bar{c}\,\bar{t}}$	$(c\,\bar{c}\,\bar{c}\,\bar{c}\,\bar{t})$	-2	0	(8.1.48)
51	Pentaquark $P_{c\bar{u}\,2\bar{t}\,\bar{c}}$	$(c\,\bar{u}\,\bar{t}\,\bar{t}\,\bar{c})$	-2	0	(8.1.49)
52	Pentaquark $P_{c3\bar{t}\,\bar{c}}$	$(c\,\bar{t}\,\bar{t}\,\bar{t}\,\bar{c})$	-2	0	(8.1.50)
53	Pentaquark $P_{t2\bar{u}\,\bar{c}\bar{t}}$	$(t\,\bar{u}\,\bar{u}\,\bar{c}\,\bar{t})$	-2	0	(8.1.51)
54	Pentaquark $P_{t\bar{u}\,2\bar{c}\bar{t}}$	$(t\,\bar{u}\,\bar{c}\,\bar{c}\,\bar{t})$	-2	0	(8.1.52)
55	Pentaquark $P_{t\,3\bar{c}\bar{t}}$	$(t\,\bar{c}\,\bar{c}\,\bar{c}\,\bar{t})$	-2	0	(8.1.53)
56	Pentaquark $P_{t\bar{u}\,2\bar{t}\bar{c}}$	$(t\,\bar{u}\,\bar{t}\,\bar{t}\,\bar{c})$	-2	0	(8.1.54)
57	Pentaquark $P_{t3\bar{t}\,\bar{c}}$	$(t\,\bar{t}\,\bar{t}\,\bar{t}\,\bar{c})$	-2	0	(8.1.55)

Analysis for Antiparticles (point Z')

A similar analysis shows that point Z' should contain the following 57 antipentaquarks. Because of size considerations these antiparticles are not shown. However, the quark composition of the 57 antipentaquarks may be easily find by performing the anti operation on each and every quark shown on the above list. The following example illustrate this point:

Example 1
The antiparticle of the non-strange pentaquark: $(u\,\bar{u}\,\bar{u}\,\bar{u}\,\bar{u})$ is $(\bar{u}\,u\,u\,u\,u)$.

Example 2
The antiparticle of the non-strange pentaquark: $(u\,\bar{u}\,\bar{u}\,\bar{u}\,\bar{c})$ is $(\bar{u}\,u\,u\,u\,c)$.

Because this theory predicts that point Z should contain 57 pentaquarks and that point Y' should also contain 57 pentaquarks (remember that Z and Z' overlap), we may replace the visible empty circle of point Z of FIGURE 1 by a blue circle representing the 57 new pentaquarks; and the partially visible empty circle of point Z', by and a red circle representing the 57 new antipentaquarks. This is done in FIGURE 6. It is worthwhile to remarks that none of these pentaquarks (including their antiparticles) have any strange or antistrange quarks. Thus, all particles and antiparticles (including the baryons and the pentaquarks and their antiparticles) on the base of the triangle of FIGURE 6 (this is along both Q axes) have strangeness equal to zero (S= 0).

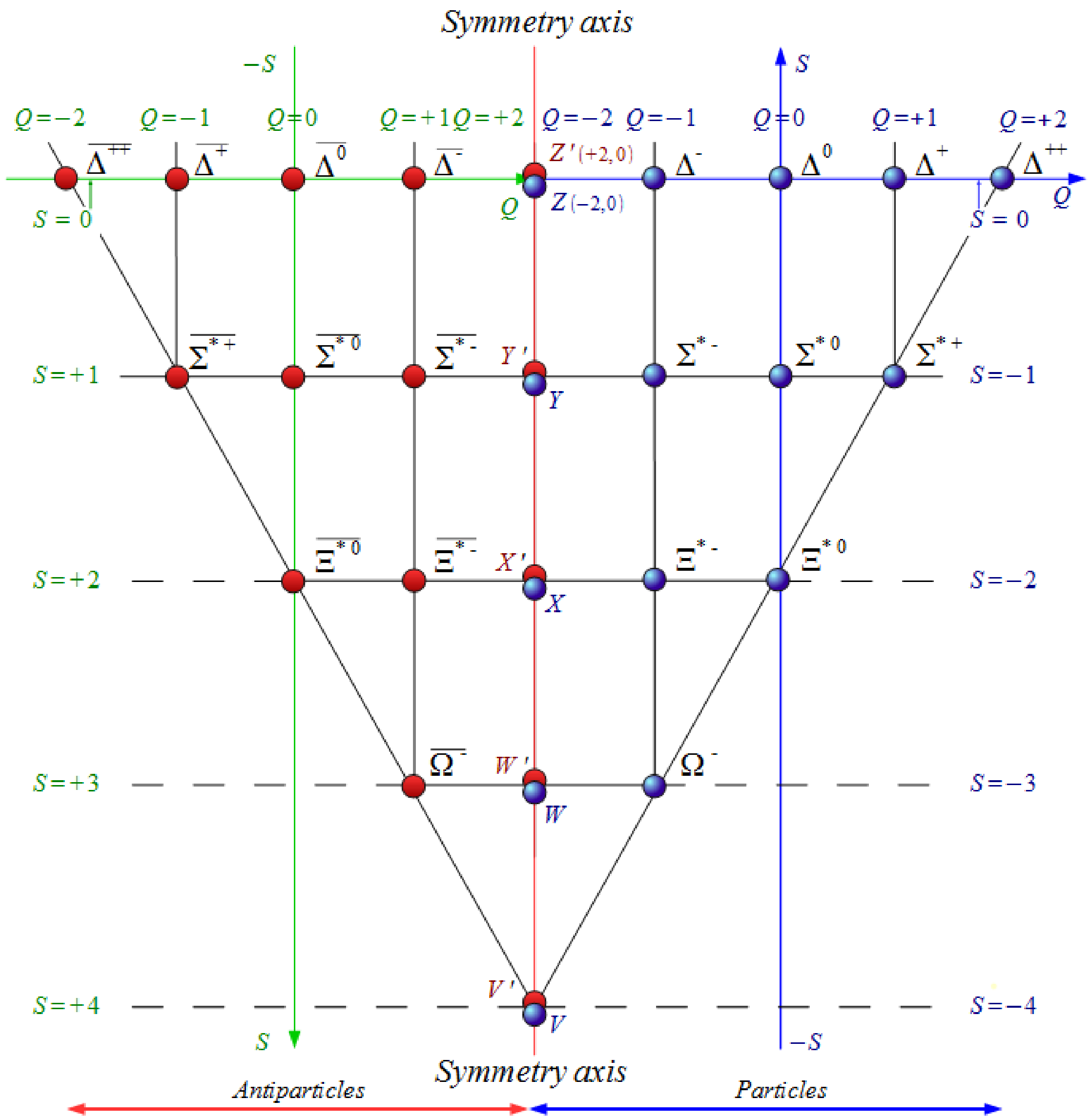

FIGURE 6: *The Matter-Antimatter Way (including non-strange pentaquarks)*

9. Do Pentaquarks, Which Contain Quark-Antiquark Pairs of the Same Flavour, Exit?

This theory predicts the existence not only of strange pentaquarks but also the existence of non-strange pentaquarks. Some of these non-strage pentaquarks contain quarks and anti-quarks of the same flavour. For example

Example 1) the $(u\bar{u}\bar{u}\bar{u}\bar{u})$ pentaquark contains the an $(u\bar{u})$ pair
Example 2) the $(t\bar{t}\bar{t}\bar{t}\bar{t})$ pentaquark contains the a $(t\bar{t})$ pair
Example 3) the $(c\bar{c}\bar{c}\bar{c}\bar{t})$ pentaquark contains the a $(c\bar{c})$ pair

It is reasonable to ask: do pentaquarks which contain quark/antiquark pairs of the same flavour (like the ones shown in the above examples), exit? To answer this question let's have a look at the neutral pi meson, which physicists have denoted with π^0 .

According to quantum mechanics, the π^0 meson is a particle made up by a superposition of two compositions:

1) $(u\,\bar{u})$ and
2) $(d\,\bar{d})$

These two compositions can be found in two different configurations:

$$\text{(configuration 1)} \quad \pi^0 = \frac{(u\,\bar{u} + d\,\bar{d})}{\sqrt{2}}$$

and

$$\text{(configuration 2)} \quad \pi^0 = \frac{(u\,\bar{u} - d\,\bar{d})}{\sqrt{2}}$$

By the way, the composition of the π^0 meson indicates that this meson is its own antiparticle (there is no distinction between the particle and the antiparticle, they are the same entity). Because of its composition, the lifetime of the π^0 meson is about $0.83\times 10^{-16}\,S$ which is much shorter than the lifetimes of the π^+ and π^- mesons, which is about $2.6\times 10^{-8}\,S$.

Let us consider configuration 1. If we were able to measure the composition of this particle by measuring the electric charge of its constituents, which of the two states would we observe? The answer is that we would observe 50% of the time the $(u\,\bar{u})$ state and the other 50% of the time the $(d\,\bar{d})$ state. (believe it or not we would obtain the same result with configuration 2).

Because the π^0 is real, and because it is made up of a superposition of two quark/antiquark pairs of the same flavour ($u\,\bar{u}$ and $d\,\bar{d}$), then it seems that pentaquarks which contain this type of pairs should be real as well. Therefore, if they really exist, their lifetimes must be extremely short, much shorter than that of the pentaquarks that do not contain quark/antiquark pairs of the same flavour.

10. The Complete Matter-Antimatter Way

The diagram shown on FIGURE 7 is the complete matter-antimatter way. It is worthwhile to observe that the number of non-strange pentaquarks and antipentaquarks on points *Z* and *Z'*, respectively, have been omitted in order to avoid cluttering the picture. Thus, the diagram of FIGURE 7 reflects the strange pentaquark and strange antipentaquark pattern of the triangle.

(see next page)

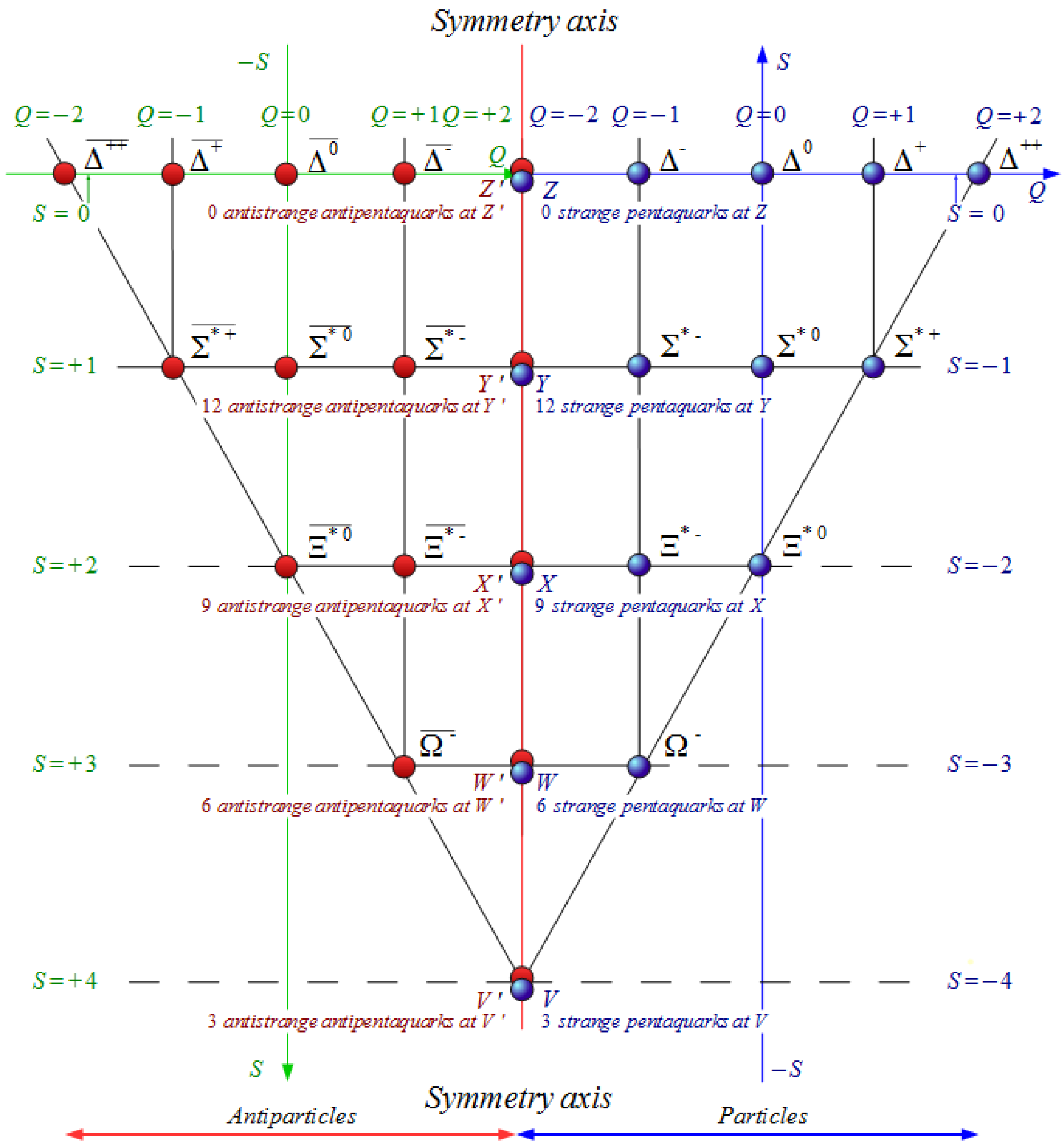

FIGURE 7: *The Complete Matter-Antimatter Way. The numbers of non-strange pentaquarks and non-strange antipentaquarks have been omitted to avoid cluttering the diagram.*

This diagram is complete because there are no empty circles in it. This means that we have found pentaquarks in each and every labelled point on the symmetry axis (these are the 10 points specified in TABLE 3, section 3)

11. Conclusions

This theory, which is based on a symmetry principle between matter and antimatter (the matter-antimatter way), suggests it's possible that there exist pentaquarks. In particular, this formulation predicts the existence of

(1) three quadruply strange pentaquarks and their antiparticles
(2) six triply strange pentaquarks and their antiparticles
(3) nine doubly strange pentaquarks and their antiparticles

(4) twelve singly strange pentaquarks, and their antiparticles; and
(5) 57 particles containing neither strange nor antistrange quarks and their antiparticles.

This theory, as all theories, have advantages and limitations. One advantage of this formulation is that it doesn't use the isospin property of particles, which by the way, is a weird concept (very difficult to explain). On the other hand, the limitation of this theory is that it does not predict the masses of the predicted particles. This, however, has nothing to do with the correctness or potential of this formulation (I shall expand the formulation if I can). The particles predicted by this theory are not the only pentaquarks there exist in nature. For example, the existence of quadruply bottom pentaquarks, which are not covered by this theory, were predicted in another formulation that I wrote and published earlier this year [10]. In summary, based on this formulation, I strongly believe that pentaquarks are real, which motivated me to write this article in the first place. I also believe that soon the LHC will confirm some of these findings.

Appendix 1
NOMENCLATURE

The following are the symbols used in this paper

LHC = large hadron collider
QED = quantum electrodynamics
QCD = quantum chomodynamics
Q = electric charge of the unknown particle (pentaquark). Also, in the diagram of FIGURE 1, Q is the electric charge of a baryon or the electric charge of an antibaryon
q_u = electric charge of the up quark
q_d = electric charge of the up quark
q_s = electric charge of the strange quark
q_c = electric charge of the charm quark
q_b = electric charge of the bottom quark
q_t = electric charge of the top quark
$q_{\bar{u}}$ = electric charge of the antiup quark
$q_{\bar{d}}$ = electric charge of the antidown quark
$q_{\bar{s}}$ = electric charge of the antistrange quark
$q_{\bar{c}}$ = electric charge of the anticharm quark
$q_{\bar{b}}$ = electric charge of the antibottom quark
$q_{\bar{t}}$ = electric charge of the antitop quark
q_5 = electric charge of one of the constituents (quark) of the unknown particle (pentaquark) (cannot be an s quark). This quark will be called the fifth quark.
q_4 = electric charge of one of the constituents (quark) of the unknown particle (pentaquark) (cannot be an s quark). This quark will be called the forth quark.
q_3 = electric charge of one of the constituents (quark) of the unknown particle (pentaquark) (cannot be an s quark). This quark will be called the third quark.
q_2 = electric charge of one of the constituents (quark) of the unknown particle (pentaquark) (cannot be an s quark). This quark will be called the second quark.
q_1 = electric charge of one of the constituents (quark) of the unknown particle (pentaquark) (cannot be an s quark). This quark will be called the first quark.

Δ^{-} = Delta-minus particle – composition: *ddd*

Δ^{0} = Delta-zero particle – composition: *udd*

Δ^{+} = Delta-plus particle – composition: *uud*

Δ^{++} = Delta-plus-plus particle – composition: *uuu*

Σ^{-} = Sigma-minus particle – composition: *dds*

Σ^{0} = Sigma-zero particle – composition: *uds*

Σ^{+} = Sigma-plus particle – composition: *uus*

Ξ^{-} = Xi-minus particle – composition: *dss*

Ξ^{0} = Xi-zero particle – composition: *uss*

Ω^{-} = Omega-minus particle – composition: *sss*

$\overline{\Delta^{-}}$ = Delta-minus antiparticle – composition: $\bar{d}\,\bar{d}\,\bar{d}$

$\overline{\Delta^{0}}$ = Delta-zero antiparticle – composition: $\bar{u}\,\bar{d}\,\bar{d}$

$\overline{\Delta^{+}}$ = Delta-plus antiparticle – composition: $\bar{u}\,\bar{u}\,\bar{d}$

$\overline{\Delta^{++}}$ = Delta-plus-plus antiparticle – composition: $\bar{u}\,\bar{u}\,\bar{u}$

$\overline{\Sigma^{-}}$ = Sigma-minus antiparticle – composition: $\bar{d}\,\bar{d}\,\bar{s}$

$\overline{\Sigma^{0}}$ = Sigma-zero antiparticle – composition: $\bar{u}\,\bar{d}\,\bar{s}$

$\overline{\Sigma^{+}}$ = Sigma-plus antiparticle – composition: $\bar{u}\,\bar{u}\,\bar{s}$

$\overline{\Xi^{-}}$ = Xi-minus antiparticle – composition: $\bar{d}\,\bar{s}\,\bar{s}$

$\overline{\Xi^{0}}$ = Xi- zero antiparticle – composition: $\bar{u}\,\bar{s}\,\bar{s}$

$\overline{\Omega^{-}}$ = Omega-minus antiparticle – composition: $\bar{s}\,\bar{s}\,\bar{s}$

Σ^{*-} = Excited state of the Sigma-minus particle – composition: *dds*

Σ^{*0} = Excited state of the Sigma-zero particle – composition: *uds*

Σ^{*+} = Excited state of the Sigma-plus particle – composition: *uus*

Ξ^{*-} = Excited state of the Xi-minus particle – composition: *dss*

Ξ^{*0} = Excited state of the Xi-zero particle – composition: *uss*

Σ^{*-} = Excited state of the Sigma-minus antiparticle – composition: $\bar{d}\,\bar{d}\,\bar{s}$

$\overline{\Sigma^{*0}}$ = Excited state of the Sigma-zero antiparticle – composition: $\bar{u}\,\bar{d}\,\bar{s}$

$\overline{\Sigma^{*+}}$ = Excited state of the Sigma-plus antiparticle – composition: $\bar{u}\,\bar{u}\,\bar{s}$

$\overline{\Xi^{*-}}$ = Excited state of the Xi-minus antiparticle – composition: $\bar{d}\,\bar{s}\,\bar{s}$

$\overline{\Xi^{*0}}$ = Excited state of the Xi-zero antiparticle – composition: $\bar{u}\,\bar{s}\,\bar{s}$

u = up quark

d = down quark

s = strange quark

c = charm quark

b = bottom quark

t = top quark

$\bar{u}$ = antiup quark or anti-up quark

$\bar{d}$ = antidown quark or anti-down quark

$\bar{s}$ = antistrange quark or anti-strange quark

$\bar{c}$ = anticharm quark or anti-charm quark

$\bar{b}$ = antibottom quark or anti-bottom quark

$\bar{t}$ = antitop quark or anti-top quark

u_R = up quark carrying red colour

u_G = up quark carrying green colour

u_B = up quark carrying blue colour

d_R = down quark carrying red colour

d_G = down quark carrying green colour

d_B = down quark carrying blue colour

$s_R =$ strange quark carrying red colour
$s_G =$ strange quark carrying green colour
$s_B =$ strange quark carrying blue colour
$c_R =$ charm quark carrying red colour
$c_G =$ charm quark carrying green colour
$c_B =$ charm quark carrying blue colour
$b_R =$ bottom quark carrying red colour
$b_G =$ bottom quark carrying green colour
$b_B =$ bottom quark carrying blue colour
$t_R =$ top quark carrying red colour
$t_G =$ top quark carrying green colour
$t_B =$ top quark carrying blue colour
$u_R^{up} =$ up quark carrying red colour and spin up
$u_G^{up} =$ up quark carrying green colour and spin up
$u_B^{up} =$ up quark carrying blue colour and spin up
$d_R^{up} =$ down quark carrying red colour and spin up
$d_G^{up} =$ down quark carrying green colour and spin up
$d_B^{up} =$ down quark carrying blue colour and spin up
$s_R^{up} =$ strange quark carrying red colour and spin up
$s_G^{up} =$ strange quark carrying green colour and spin up
$s_B^{up} =$ strange quark carrying blue colour and spin up
$c_R^{up} =$ charm quark carrying red colour and spin up
$c_G^{up} =$ charm quark carrying green colour and spin up
$c_B^{up} =$ charm quark carrying blue colour and spin up
$b_R^{up} =$ bottom quark carrying red colour and spin up
$b_G^{up} =$ bottom quark carrying green colour and spin up
$b_B^{up} =$ bottom quark carrying blue colour and spin up
$t_R^{up} =$ top quark carrying red colour and spin up
$t_G^{up} =$ top quark carrying green colour and spin up
$t_B^{up} =$ top quark carrying blue colour and spin up
$u_R^{down} =$ up quark carrying red colour and spin down
$u_G^{down} =$ up quark carrying green colour and spin down
$u_B^{down} =$ up quark carrying blue colour and spin down
$d_R^{down} =$ down quark carrying red colour and spin down
$d_G^{down} =$ down quark carrying green colour and spin down
$d_B^{down} =$ down quark carrying blue colour and spin down
$s_R^{down} =$ strange quark carrying red colour and spin down
$s_G^{down} =$ strange quark carrying green colour and spin down
$s_B^{down} =$ strange quark carrying blue colour and spin down
$c_R^{down} =$ charm quark carrying red colour and spin down
$c_G^{down} =$ charm quark carrying green colour and spin down
$c_B^{down} =$ charm quark carrying blue colour and spin down
$b_R^{down} =$ bottom quark carrying red colour and spin down
$b_G^{down} =$ bottom quark carrying green colour and spin down

$b_B^{down} =$ bottom quark carrying blue colour and spin down
$t_R^{down} =$ top quark carrying red colour and spin down
$t_G^{down} =$ top quark carrying green colour and spin down
$t_B^{down} =$ top quark carrying blue colour and spin down
$\overline{u_R} =$ antiup quark carrying antired colour
$\overline{u_G} =$ antiup quark carrying antigreen colour
$\overline{u_B} =$ antiup quark carrying antiblue colour
$\overline{d_R} =$ antidown quark carrying antired colour
$\overline{d_G} =$ antidown quark carrying antigreen colour
$\overline{d_B} =$ antidown quark carrying antiblue colour
$\overline{s_R} =$ antistrange quark carrying antired colour
$\overline{s_G} =$ antistrange quark carrying antigreen colour
$\overline{s_B} =$ antistrange quark carrying antiblue colour
$\overline{c_R} =$ anticharm quark carrying antired colour
$\overline{c_G} =$ anticharm quarkv carrying antigreen colour
$\overline{c_B} =$ anticharm quark carrying antiblue colour
$\overline{b_R} =$ antibottom quark carrying antired colour
$\overline{b_G} =$ antibottom quark carrying antigreen colour
$\overline{b_B} =$ antibottom quark carrying antiblue colour
$\overline{t_R} =$ antitop quark carrying antired colour
$\overline{t_G} =$ antitop quark carrying antigreen colour
$\overline{t_B} =$ antitop quark carrying antiblue colour
$\overline{u_R}^{up} =$ antiup quark carrying antired colour and spin up
$\overline{u_G}^{up} =$ antiup quark carrying antigreen colour and spin up
$\overline{u_B}^{up} =$ antiup quark carrying antiblue colour and spin up
$\overline{d_R}^{up} =$ antidown quark carrying antired colour and spin up
$\overline{d_G}^{up} =$ antidown quark carrying antigreen colour and spin up
$\overline{d_B}^{up} =$ antidown quark carrying antiblue colour and spin up
$\overline{s_R}^{up} =$ antistrange quark carrying antired colour and spin up
$\overline{s_G}^{up} =$ antistrange quark carrying antigreen colour and spin up
$\overline{s_B}^{up} =$ antistrange quark carrying antiblue colour and spin up
$\overline{c_R}^{up} =$ anticharm quark carrying antired colour and spin up
$\overline{c_G}^{up} =$ anticharm quark carrying antigreen colour and spin up
$\overline{c_B}^{up} =$ anticharm quark carrying antiblue colour and spin up
$\overline{b_R}^{up} =$ antibottom quark carrying antired colour and spin up
$\overline{b_G}^{up} =$ antibottom quark carrying antigreen colour and spin up
$\overline{b_B}^{up} =$ antibottom quark carrying antiblue colour and spin up
$\overline{t_R}^{up} =$ antitop quark with carrying antired colour and up
$\overline{t_G}^{up} =$ antitop quark with carrying antigreen colour and up
$\overline{t_B}^{up} =$ antitop quark with carrying antiblue colour and up
$\overline{u_R}^{down} =$ antiup quark carrying antired colour and spin down
$\overline{u_G}^{down} =$ antiup quark carrying antigreen colour and spin down
$\overline{u_B}^{down} =$ antiup quark carrying antiblue colour and spin down
$\overline{d_R}^{down} =$ antidown quark carrying antired colour and spin down
$\overline{d_G}^{down} =$ antidown quark carrying antigreen colour and spin down

$\overline{d}_B^{down}$ = antidown quark carrying antiblue colour and spin down
$\overline{s}_R^{down}$ = antistrange quark carrying antired colour and spin down
$\overline{s}_G^{down}$ = antistrange quark carrying antigreen colour and spin down
$\overline{s}_B^{down}$ = antistrange quark carrying antiblue colour and spin down
$\overline{c}_R^{down}$ = anticharm quark carrying antired colour and spin down
$\overline{c}_G^{down}$ = anticharm quark carrying antigreen colour and spin down
$\overline{c}_B^{down}$ = anticharm quark carrying antiblue colour and spin down
$\overline{b}_R^{down}$ = antibottom quark carrying antired colour and spin down
$\overline{b}_G^{down}$ = antibottom quark carrying antigreen colour and spin down
$\overline{b}_B^{down}$ = antibottom quark carrying antiblue colour and spin down
$\overline{t}_R^{down}$ = antitop quark carrying antired colour and spin down
$\overline{t}_G^{down}$ = antitop quark carrying antigreen colour and spin down
$\overline{t}_B^{down}$ = antitop quark carrying antiblue colour and spin down

Notes

Note 1

There are other properties that have been left out because they are not relevant to this paper.

Note 2

Some of the symbols shown on Appendix 1 are not used in this article. They are shown for completeness only.

Note 3

There are two conventions when referring to anti-quarks. The first convention is (1) anti-up quark, anti-down quark, anti-strange quark, anti-charm quark, anti-bottom quark and anti-top quark. The second convention is (2) up anti-quark, down anti-quark, strange anti-quark, charm anti-quark, bottom anti-quark and top anti-quark. In this article I use the first convention.

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