The Quantum Chromodynamics Theory Of Quadruply Bottom Pentaquarks

Based on a generalized particle diagram of baryons and antibaryons which, in turn, is based on symmetry principles, this theory predicts the existence of three quadruply bottom pentaquarks: $b\,b\,b\,b\,\bar{u}$, $b\,b\,b\,b\,\bar{c}$, *and* $b\,b\,b\,b\,\bar{t}$ *, and their antiparticles:* $\bar{b}\,\bar{b}\,\bar{b}\,\bar{b}\,u$, $\bar{b}\,\bar{b}\,\bar{b}\,\bar{b}\,c$, *and* $\bar{b}\,\bar{b}\,\bar{b}\,\bar{b}\,t$ *. Although this theory is intended for experts, it is simple enough, so that, it is also suitable for the general public.*

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Contents

1. Introduction

Quantum Chromodynamics (QCD) is a quantum mechanical description of the strong nuclear force. The strong force is mediated by gluons which are spin 1 bosons. 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.

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. 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. So that the property called colour is the one that distinguishes 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 force carriers of the electromagnetic force, do not carry electric charge. This is a very important difference between Quantum Electrodynamics (QED) 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. But instead of dealing with strange baryons, we shall deal with bottom baryons (baryons in which one of its constituents is a bottom quark, *b*, or a bottom antiquark, $\overline{b}$. Some of these baryons might have not been discovered yet). 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.

The “Gell-Mann's diagram” for bottomic particles (particles where at least one of their constituents is a bottom quark), which contains 10 baryons, including 6 bottomic baryons, is shown in blue on the right hand side of figure 1.

The “original” Gell-Mann's diagram (except that I replaced the original Isospin axis by a new *Q* axis) is shown in blue on the right hand side of figure 1 of another paper that I wrote recently and where I predicted the existence of 6 quadruply strange pentaquarks [1]. In this paper, on the other hand, I shall deal with the Ω^-_{bbb} (the bottomic omega-minus particle) and with the $\overline{\Omega^-_{bbb}}$ (the bottomic omega-minus antiparticle) baryons instead (and, of course, I shall also deal with other bottom baryons and with the delta particles which have zero bottomness). Appendix 1 contains the nomenclature used throughout this paper and the composition of all the particles and antiparticles shown in this paper.

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

QUARKS PROPERTIES							
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.*

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

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

3. The QCD Theory of Bottom Pentaquarks (The 26-Particles Matter-Antimatter Way)

The particle diagram showed below (figure 1), that I would like to call "the 26-particle Matter-AntiMatter Way", (The Matter-AntiMatter Way of 26 Particles, double decuplet+6 diagram or 26-particles triangle) suggests that pentaquarks are real physical entities. The reason is explained further below. But first, I would like to explain the diagram. The diagram contains two QB coordinate systems. One QB 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. For clarity reasons both QB coordinate axes are shown in green. One of the vertical B axis represents the bottomness of particles ($+B$ points up the page) while the other vertical B axis represents the bottomness of antiparticles ($+B$ 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 QB points that overlap. The only way of explaining this overlapping is if there are both pentaquarks and antipentaquarks on the lower vertex of the triangle.

This particle diagram is symmetrical about the vertical axis, which is called: the symmetry axis (shown in red). On the right hand size of the symmetry axis we have 10 baryons, known as the bottom baryon decuplet (the original strange decuplet was due to Gell-Mann). This decuplet is shown in blue. On the left hand side of the symmetry axis we have the antibaryon decuplet containing the 10 corresponding antibaryons. This decuplet is shown in red. The left hand side of the diagram (where antiparticles are placed) 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 magic mirror because in addition to reflecting images (mirror symmetry, parity (P) or P symmetry) it must also be able to replace the reflected particles by their corresponding antiparticles (charge conjugation (C) or C symmetry). If additionally, we consider, as Richard Feynman did [2], that antiparticles are particles moving backward in time[1], this is, if we consider time reversal (T, or T symmetry) as well, then our mirror would be even stranger: a "magical CPT mirror".

The "bottom Gell-Mann decuplet diagram", which comprises the 10 particles on the right, is part of the more general diagram shown below. This generalization allow us to predict the existence of pentaquarks of composition: (quark, quark, quark, quark, antiquark) and (antiquark, antiquark, antiquark, antiquark, quark). The coordinates of the lower vertex of the diagram of figure 1 are shown on table 3

(see next page)

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(1) "*the fundamental idea is that the "negative energy" states represent the state of electrons moving backward in time. In a classical equation of motion...reversing the direction of proper time s amounts to the same as reversing the sign of the charge so that the electron moving backward in time would look like a positron moving forward in time.*" [2]

QB COORDINATE SYSTEM	LOWER VERTEX COORDINATES	MEANING
MATERIAL (For particles. Right hand side coordinate system)	$(-2,0)$	$Q=-2$ and $B=-4$
ANTIMATERIAL (For antiparticles. Left hand side coordinate system)	$(+2,0)$	$Q=+2$ and $B=+4$

TABLE 3: *Coordinates of the lower vertex of the triangle of figure 1.*

If pentaquarks were not real, no particle would occupy the lower vertex of the diagram (e.g. there would be an empty circle). This would contradict our belief which states that, in general, nature is governed by symmetry principles (by the way, the standard model has been built around symmetry principles). Thus, we interpret the lower vertex of the triangle, as evidence of the existence of the following particles

(a) 3 pentaquarks: $bbbb\bar{u}$, $bbbb\bar{c}$, and $bbbb\bar{t}$.
(b) 3 antipentaquarks: $\bar{b}\bar{b}\bar{b}\bar{b}u$, $\bar{b}\bar{b}\bar{b}\bar{b}c$, and $\bar{b}\bar{b}\bar{b}\bar{b}t$

Consequently, the diagram shows 6 pentaquarks in the lower vertex instead of an empty circle. The reader should keep in mind that, for clarity reasons, these 6 pentaquarks are represented by a single particle (in green colour) in the diagram. These pentaquarks are labelled: $P_7, P_8, P_9, P_{10}, P_{11}$ and P_{12} the previous theory [1] uses P_1, P_2, P_3, P_4, P_5 and P_6 (the names are not important anyway). The reader who is interested in the composition of all the particles and antiparticles shown in figure 1 may find them in Appendix 1.

(see next page)

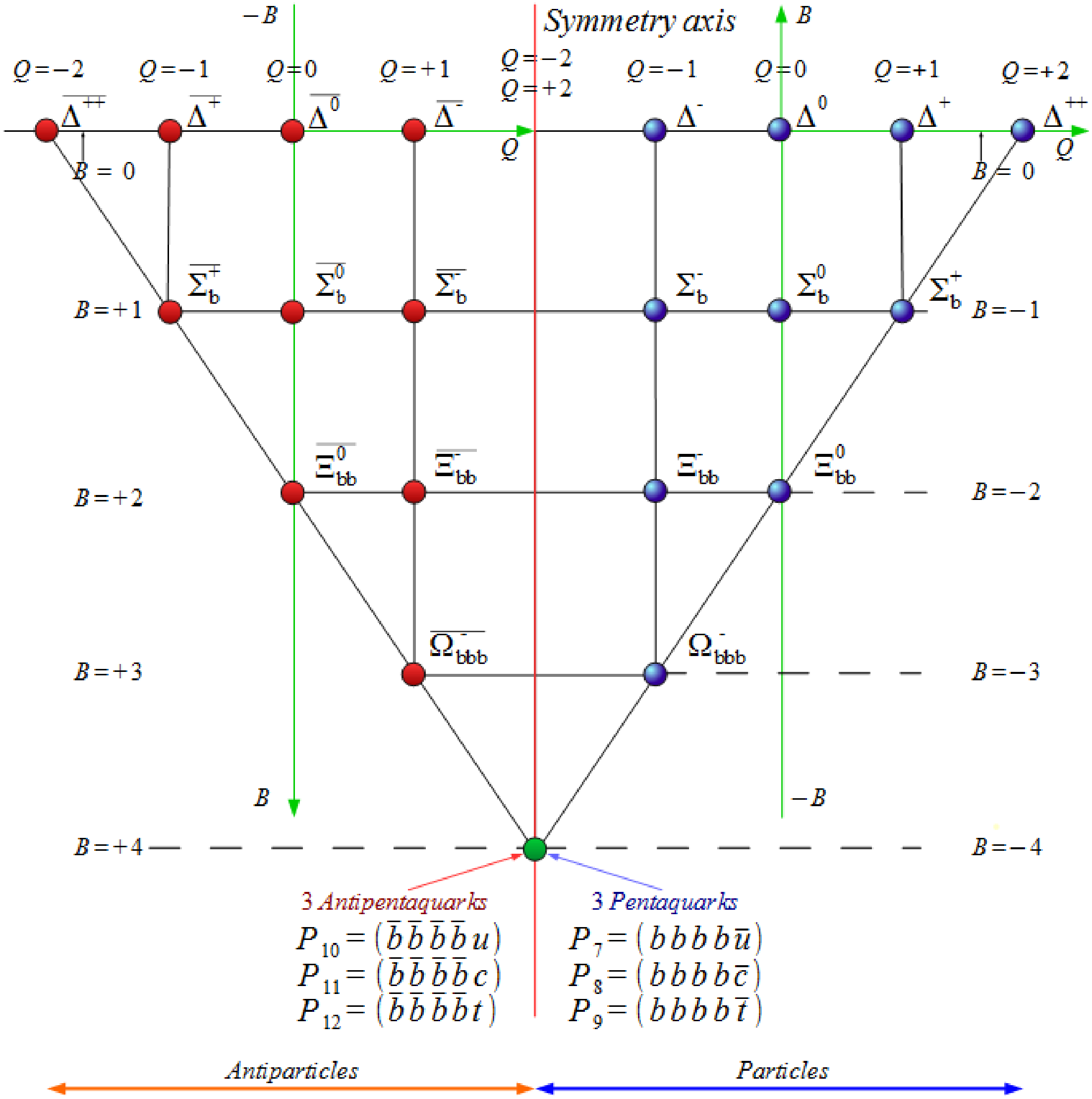

FIGURE 1: *The "Matter-Antimatter Way of 26 Particles": a pattern of 10 baryons (blue circles), 10 anti-baryons (red circles) and 6 pentaquanks and antipentaquarks (green circle). If the green circle in the lower vertex of the triangle wouldn't have been drawn, the vertex would be "empty" suggesting that there are new particles yet to be discovered (according to this formulation these particles must be pentaquarks). For this reason the vertex shows a green circle representing the six pentaquarks this formulation predicts. It is important to observe that two QB coordinate systems have been used. One QB 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. One of the vertical B axis represents the bottomness of particles while the other vertical B axis represents the bottomness of antiparticles. It is worthwhile to observe that I have used the particles with no exited states:* Σ_b^- , Σ_b^0 , Σ_b^+ , Ξ_{bb}^- , Ξ_{bb}^0 *instead of using the ones with exited states:* Σ_b^{*-} , Σ_b^{*0} , Σ_b^{*+} , Ξ_{bb}^{*-} , Ξ_{bb}^{*0} *(the asterisk denotes an exited state). This also applies to 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.*

3.1. Analysis of the Electric Charge

Analysis for Particles

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

(a) According to figure 1, the first condition the unknown particle (pentaquark) must satisfy is that its electric charge must be -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 bottomness must be -4 ($B=-4$). Because the bottom quark is the only particle which possesses the bottomness property, and because the value of this property is -1 (see table 1), the only way a particle can have a bottomness of -4 is if the particle were composed by 4 bottom quarks.

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

$$Q = 4q_b + q \qquad (3.1.1)$$

Where

Q = total electric charge of the unknown particle (-2)
q_b = electric charge of the bottom quark ($-1/3$)
q = electric charge of another quark (different from a *b* quark) so that the total charge of the unknown particle is -2 . This quark will be called the fifth quark.

We solve equation (3.1.1) for *q*. This gives

$$q = Q - 4q_b \qquad (3.1.2)$$

Because

$$4q_b = 4\times\left(-\frac{1}{3}\right) = -\frac{4}{3} \qquad (3.1.3)$$

Then, according to equation (3.1.2) the value of the electric charge, *q,* of the fifth quark should be

$$q = -2-\left(-\frac{4}{3}\right) = -2+\frac{4}{3} = -\frac{2}{3} \qquad (3.1.4)$$

So that the fifth quark must have an electric charge of $-2/3$. If we look at table 2 of section 2 (antiquark properties) we shall see that there are only three antiquarks that satisfy this condition. These antiquarks are:

(i) the antiup quark, $\bar{u}$, $q_{\bar{u}} = -2/3$
(ii) the anticharm quark, $\bar{c}$, $q_{\bar{c}} = -2/3$, and
(iii) the antitop quark, $\bar{t}$, $q_{\bar{t}} = -2/3$.

Because equation (3.1.1) is satisfied by three antiquarks we have three equations

$$Q = 4\, q_b + q_{\bar{u}} \tag{3.1.5}$$
$$Q = 4\, q_b + q_{\bar{c}} \tag{3.1.6}$$
$$Q = 4\, q_b + q_{\bar{t}} \tag{3.1.7}$$

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 = $-2/3$

This, in turn, means that the pentaquarks must have the following composition

Pentaquark P_7 $$(b\, b\, b\, b\, \bar{u}) \tag{3.1.8}$$

Pentaquark P_8 $$(b\, b\, b\, b\, \bar{c}) \tag{3.1.9}$$

Pentaquark P_9 $$(b\, b\, b\, b\, \bar{t}) \tag{3.1.10}$$

Analysis for Antiparticles

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

(a) According to figure 1, the first condition the unknown particle (pentaquark) must satisfy is that its electric charge must be +2 (*Q* = +2) (meaning +2*e*, where *e* is the absolute value of the elementary charge).

(b) The second condition the unknown particle (pentaquark) must satisfy is that its bottomness must be +4 (*B* = +4). Because the bottom quark is the only particle which possesses the bottomness property, and because the value of this property is +1 (see table 1), the only way a particle can have a bottomness of +4 is if the particle were composed by 4 antibottom quarks.

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

$$Q = 4\, q_{\bar{b}} + q \tag{3.1.11}$$

Where

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

quark.

We solve equation (3.1.11) for *q*. This gives

$$q = Q - 4\,q_{\bar{b}} \tag{3.1.12}$$

Because

$$4\,q_b = 4 \times \left(+\frac{1}{3}\right) = +\frac{4}{3} \tag{3.1.13}$$

Then, according to equation (3.1.12) the value of the electric charge, *q,* of the fifth quark should be

$$q = +2 - \left(+\frac{4}{3}\right) = +2 - \frac{4}{3} = +\frac{2}{3} \tag{3.1.14}$$

So that the fifth quark must have an electric charge of $+2/3$. If we look at table 1 of section 2 (quark properties) we shall see that there are only three quarks that satisfy this condition. These quarks are:

(i) the up quark, u , $q_u = +2/3$
(ii) the charm quark, c , $q_c = +2/3$ and
(iii) the top quark, t , $q_t = +2/3$

Because equation (3.1.11) is satisfied by three quarks we have three equations

$$Q = 4\,q_{\bar{b}} + q_u \tag{3.1.15}$$
$$Q = 4\,q_{\bar{b}} + q_c \tag{3.1.16}$$
$$Q = 4\,q_{\bar{b}} + q_t \tag{3.1.17}$$

Where

$q_u =$ electric charge of the antiup quark = $+2/3$
$q_c =$ electric charge of the anticharm quark = $+2/3$
$q_t =$ electric charge of the antitop quark = $+2/3$

This, in turn, means that the antipentaquarks must have the following composition

Pentaquark $P_{10} = \overline{P_7}$	$\bar{b}\bar{b}\bar{b}\bar{b}u\,,$	(3.1.18)
Pentaquark $P_{11} = \overline{P_8}$	$\bar{b}\bar{b}\bar{b}\bar{b}c\,,$	(3.1.19)
Pentaquark $P_{12} = \overline{P_9}$	$\bar{b}\bar{b}\bar{b}\bar{b}t\,,$	(3.1.20)

3.2. 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 bottom quarks of identical colour (because there are 4 bottom quarks and because there are only three flavours of the colour charge, there must be two bottom 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

$$b_R^{up}\, b_G^{up}\, b_B^{up}\, b_R^{down}\, \overline{u_R}^{up} \tag{3.2.1}$$

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

$$b_R^{down}\, b_G^{down}\, b_B^{down}\, b_R^{up}\, \overline{u_R}^{up} \tag{3.2.2}$$

$$b_R^{up}\, b_G^{up}\, b_B^{down}\, b_R^{down}\, \overline{u_R}^{up} \tag{3.2.3}$$

etc.

The interested reader could find more allowed combinations.

Analysis for Antiparticles

Carrying out a similar analysis we find that

$$\overline{b_B}^{up}\, \overline{b_G}^{up}\, \overline{b_B}^{up}\, \overline{b_R}^{down}\, u_R^{up} \tag{3.2.4}$$

3.3. Pentaquarks Naive Diagrams

In order to illustrate pentaquarks graphically, I have included a set of naive diagrams. The diagrams are naïve because they do not include all the constituents of the particles in question (such as quark-antiquark pairs and gluons). Although these graphics have limitations, they are good enough to illustrate the principles outlined in this paper.

The set (figures 2, 3 and 4) shows three bottom quarks on the left of the picture while the other bottom quark and the antiquark are shown on the right. The reason of having this set of drawings is to facilitate the visualisation of the colourless (neutral) nature of each particle. The diagrams shown on figure 2, 3 and 4 correspond to the $b_R^{up}\, b_G^{up}\, b_B^{up}\, b_R^{down}\, \overline{u_R}^{up}$ pentaquark, the $b_R^{up}\, b_G^{up}\, b_B^{up}\, b_R^{down}\, \overline{c_R}^{up}$ pentaquark, and the $b_R^{up}\, b_G^{up}\, b_B^{up}\, b_R^{down}\, \overline{t_R}^{up}$ pentaquark, respectively. The indices indicate the spin of the quark. The graphics for the corresponding antipentaquarks are not shown.

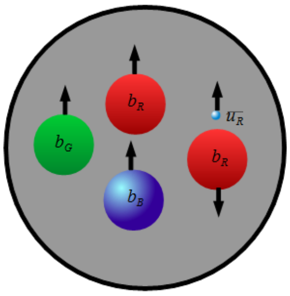

FIGURE 2: *The* $b_R^{up}\, b_G^{up}\, b_B^{up}\, b_R^{down}\, \overline{u_R}^{up}$ *pentaquark.*
Both quark-antiquark pairs and gluons are not shown.

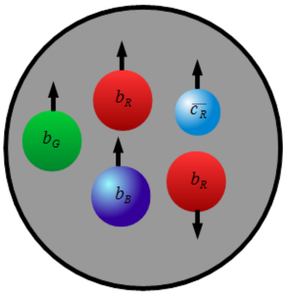

FIGURE 3: *The* $b_R^{up}\, b_G^{up}\, b_B^{up}\, b_R^{down}\, \overline{c_R}^{up}$ *pentaquark.*
Both quark-antiquark pairs and gluons are not shown.

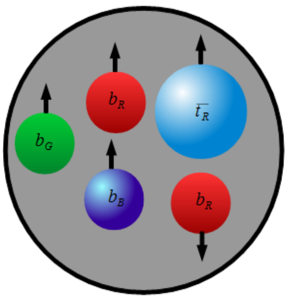

FIGURE 4: *The* $b_R^{up}\, b_G^{up}\, b_B^{up}\, b_R^{down}\, \overline{t_R}^{up}$ *pentaquark.*
Both quark-antiquark pairs and gluons are not shown.

4. Summary of the Properties of the Quadruply Bottom Pentaquarks

The following table shows some of the properties of the pentaquarks predicted by this theory

	PREDICTED PARTICLE (symbol)	PARTICLE COMPOSITION (quark contents)	ELECTRIC CHARGE (times the elementary charge: $\|e\|$)	BOTTOMNESS	SPIN
PARTICLES	P_7 or $P^{--}_{4b\bar{u}}$	$(b\,b\,b\,b\,\bar{u})$	-2	-4	$\frac{3}{2}$
	P_8 or $P^{--}_{4b\bar{c}}$	$(b\,b\,b\,b\,\bar{c})$	-2	-4	$\frac{3}{2}$
	P_9 or $P^{--}_{4b\bar{t}}$	$(b\,b\,b\,b\,\bar{t})$	-2	-4	$\frac{3}{2}$
ANTI PARTICLES	P_{10} or $P^{++}_{4\bar{b}u}$	$(\bar{b}\,\bar{b}\,\bar{b}\,\bar{b}\,u)$	$+2$	$+4$	$-\frac{3}{2}$
	P_{11} or $P^{++}_{4\bar{b}c}$	$(\bar{b}\,\bar{b}\,\bar{b}\,\bar{b}\,c)$	$+2$	$+4$	$-\frac{3}{2}$
	P_{12} or $P^{++}_{4\bar{b}t}$	$(\bar{b}\,\bar{b}\,\bar{b}\,\bar{b}\,t)$	$+2$	$+4$	$-\frac{3}{2}$

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

5. Conclusions

This theory (as the theory of my other paper [1]) which is based on a symmetry principle between matter and antimatter (translated into the 26-particles matter-antimatter way), suggests it's possible that there exist pentaquarks. In particular, this formulation predicts the existence of three quadruply bottom pentaquarks: $(b\,b\,b\,b\,\bar{u})$, $(b\,b\,b\,b\,\bar{c})$, $(b\,b\,b\,b\,\bar{t})$ and three quadruply bottom antipentaquarks: $(\bar{b}\,\bar{b}\,\bar{b}\,\bar{b}\,u)$, $(\bar{b}\,\bar{b}\,\bar{b}\,\bar{b}\,c)$, $(\bar{b}\,\bar{b}\,\bar{b}\,\bar{b}\,t)$. 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 hard to explain. Anyway this property is not necessary to predict the existence of new particles. On the other hand, the limitation is that the theory does not predict the masses of the six predicted pentaquarks. This, however, has nothing to do with the correctness or potential of this formulation. In summary, based on this formulation, I strongly believe that pentaquarks are real which impulsed me to write this article. I also believe that soon the LHC will confirm these findings.

Notes

Note 1

The composition of all the particles shown on figure 1 of this paper are included in Appendix 1

Appendix 1

NOMENCLATURE

The following are the symbols used in this paper

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_s = electric charge of the strange quark

$q_{\bar{u}}$ = electric charge of the antiup quark

$q_{\bar{c}}$ = electric charge of the anticharm quark

$q_{\bar{t}}$ = electric charge of the antitop quark

q = electric charge of another quark (different from an b quark) so that the total charge of the unknown particle is -2. This quark will be called the fifth quark

Ω^- = omega-minus particle (particle discovered by Murry Gell-Mann)

P_7 or $P^{--}_{4b\bar{u}} = (b\,b\,b\,b\,\bar{u})$ pentaquark

P_8 or $P^{--}_{4b\bar{c}} = (b\,b\,b\,b\,\bar{c})$ pentaquark

P_9 or $P^{--}_{4b\bar{t}} = (b\,b\,b\,b\,\bar{t})$ pentaquark

P_{10} or $P^{++}_{4\bar{b}u} = (\bar{b}\,\bar{b}\,\bar{b}\,\bar{b}\,u)$ antipentaquark

P_{11} or $P^{++}_{4\bar{b}c} = (\bar{b}\,\bar{b}\,\bar{b}\,\bar{b}\,c)$ antipentaquark

P_{12} or $P^{++}_{4\bar{b}t} = (\bar{b}\,\bar{b}\,\bar{b}\,\bar{b}\,t)$ antipentaquark

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_b^- = bottomic Sigma-minus particle – composition: *ddb*

Σ_b^0 = bottomic Sigma-zero particle – composition: *udb*

Σ_b^+ = bottomic Sigma-plus particle – composition: *uub*

Ξ_{bb}^- = bottomic Xi-minus particle – composition: *dbb*

Ξ_{bb}^0 = bottomic Xi-zero particle – composition: *ubb*

Ω_{bbb}^- = bottomic Omega-minus particle – composition: *bbb*. Note that this baryon does not contain any strange quark. However we still

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

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

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

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

$\overline{\Sigma_b^-}$ = bottomic Sigma-minus particle – composition: $\bar{d}\,\bar{d}\,\bar{b}$
$\overline{\Sigma_b^0}$ = bottomic Sigma-zero particle – composition: $\bar{u}\,\bar{d}\,\bar{b}$
$\overline{\Sigma_b^+}$ = bottomic Sigma-plus particle – composition: $\bar{u}\,\bar{u}\,\bar{b}$
$\overline{\Xi_{bb}^-}$ = bottomic Xi-minus particle – composition: $\bar{d}\,\bar{b}\,\bar{b}$
$\overline{\Xi_{bb}^0}$ = bottomic Xi-zero particle – composition: $\bar{u}\,\bar{b}\,\bar{b}$
$\overline{\Omega_{bbb}^-}$ = bottomic Omega-minus particle – composition: $\bar{b}\,\bar{b}\,\bar{b}$. Note that this baryon does not contain any antistrange quark.
u = up quark
d = down quark
s = strange quark
c = charm quark
b = bottom quark
t = top quark
$\bar{u}$ = antiup quark
$\bar{d}$ = antidown quark
$\bar{s}$ = antistrange quark
$\bar{c}$ = anticharm quark
$\bar{b}$ = antibottom quark
$\bar{t}$ = antitop 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

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