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Describing a Baryon as a Composition of Bound Stated and Unbound Stated Sea-Quarks

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Abstract

We propose the revised description of a baryon as a composition of bound stated sea-quarks and unbound stated sea-quarks from the previously proposed description of baryon as a meson pair. The purpose of this article is to show the following two possibilities. The first one shows the qualitative explanation to support our description of a nucleon as a pair of pions and the second one is that it gives an explanation of ALICE results that the p_T dependence of Λ_c^+/D^0 ratio is 0.5. Each isospin group is constructed of both baryons and antibaryons. This way of construction is consistent with that of mesons. The results obtained are listed in tables. This shows that the generalized Gell-Mann-Nishijima relation equation holds under the condition that the baryon number is 0.

Keywords

Baryon Description, Baryon Isospin, Baryon Mass

1. Introduction

The widely accepted theory of baryon composition is the SU(6) quark model [1] [2] based on the eightfold way proposed by Gell-Mann [3] and Ne'eman [4]. According to this theory, baryons are composed of three quarks and antibaryons are composed of three antiquarks. The isospin group is constructed of only baryons, and that of antibaryons is constructed of only antiquarks. This theory is well supported by evidence and seems to be a complete formalism under the condition that the intrinsic spin of composing quarks determines baryon spin. However, in 1987, The European Muon Collaboration discovered that proton spin is not determined by the intrinsic quark spin [5]. Presently, it is clear that the contribution of the intrinsic spin of quarks to proton spin is at most 30% [6]. In addition, H1

+ ZEUS collaboration has reported that proton structure is sea-quarks (quark and antiquark pairs) and glue-on ocean of which results is obtained by electron-proton collision at DESY [7], Recently ATLAS collaboration has taken proton-proton collision experiment for proton structure measurements at CERN and has reported that their results are agreeable to H1 and ZEUS results although several differences are appeared [8]. These results mean that proton structure is basically sea-quarks and glue-on ocean so that SU(6) quark model is not a satisfactory model anymore. In addition, ALICE collaboration has recently reported that the p_T dependence of Λ_c^+/D^0 ratio is 0.5 by measuring yields of Λ_c^+ for baryon and D^0 for mason [9]. Their experiment results are obtained by proton-proton collision at CERN. An alternated theory must explain these results also. In this paper, we propose the revised description of baryon from our previous paper [10] based on the H1+ZEUS and ATLAS results that proton structure is sea-quarks and on the fact that all baryons including neutron decay to proton as a final state.

2. Description of Properties

We consider that there are two types of sea-quarks. One type is quark and antiquark pair without being bound stated that is normal sea-quarks and the other type is quark and antiquark with being bound stated, namely, mesons. One of the most important ATLAS results is that stranges sea-quarks are not suppressed as different from most people's considering. Thus, a composition of proton must include $s\text{-}\bar{s}$ sea quarks that is not bound stated. This is the main difference from previous our description [10].

For meson state, we briefly describe our definition as follows in ref. [10].

The basic meson operator is defined by the Bethe-Salpeter–like amplitude of the hadronic operator as

$$\chi(1,2) = \langle 0|q(1,2)|P\rangle \tag{1}$$

where $|0\rangle$ and $|P\rangle$ denote a vacuum and physical state, respectively.

The gauge-invariant bi-local operator $q(1,2)$ is defined in the non-Abelian gauge field as

$$q(1,2) = T_r^c q_\beta^+(2) P \exp\left(ig\int_1^2 \mathrm{d}\vec{x}\overrightarrow{A^a}(x)\frac{\lambda_a}{2}\right) q_\alpha(1) \tag{2}$$

Here α and β denote the Dirac indices, P denotes the path ordering, and the $\frac{\lambda_a}{2}$ component generates the adjoint representation of the SU(N) color gauge group. The trace is calculated for color spin a. Suura first proposed this definition [11] [12], and later we applied it to the case of the t'Hoot model [13], the light meson mass spectra without quark mass and charged pion electromagnetic form factor (e.m. FF) [14] and neutral pion e.m. FF [15]. We also proposed that a nucleon can be described as a pair of pions and obtained the e.m. FFs and distribution functions of nucleon [16]. The results of ref. [16] encouraged us to extend this kind of description to the consideration that a baryon can be described as a pair of mesons. In ref. [14], a nucleon operator is defined as

$$\chi(1;2,3) = \langle 0 | q(1;,2,3) | P \rangle \tag{3}$$

where

$$q(1;2,3) = q(1,2) + q(1,3) \tag{4}$$

In the revised description, we describe a baryon as a bound stated sea-quarks pair, namely meson pair that is indicated by this operator and unbound stated sea-quarks, normal sea-quarks, that is not described by Eq. (1). Considered quark fields are extended to *u*, *d*, *s*, *c*, *b* quarks instead of *u* and *d* quarks in ref. [10]. For the case of anti-particles, it is easy to describe by using $\chi(1,2;3)$ instead of $\chi(1;2,3)$ for meson pair case.

We show baryons described by *u*, *d*, and *s* quarks including bound stated sea-quarks pair in **Table 4** (spin 1/2) and **Table 5** (spin 3/2). Baryons described by c and b quarks including bound stated sea-quarks pair are shown in **Tables 6** to **Tables 9** (**Table 6** and **7** for spin 1/2, **Table 8** and **Table 9** for spin 3/2). The terms listed in columns are composing state, isospin, the third component of isospin, strangeness *S*, *c*-value *C*, *b*-value *B*, binding quarks, binding energy, estimated mass and measured mass.

It is obvious to see that each baryon satisfies the generalized Gell-Mann-Nishijima relation equation [17] [18]. The generalized Gell-Mann-Nishijima relation equation is given as

$$Q = I_3 + \frac{1}{2}(S + B_a + C + B) \tag{5}$$

where *Q*: charge value;

I_3: the third component of isospin;

B_a: baryon number;

S: strangeness $s = -1$, $\bar{s} = +1$;

C: *c*-value $c = +1$, $\bar{c} = -1$;

B: *b*-value $b = -1$, $\bar{b} = +1$.

For determining isospin, we use different definition as follows. We consider that each quark has each intrinsic isospin as listed in **Table 1**. Then, baryon of isospin is determined by sum of composing quark isospin as following to angular moment algebra.

Table 1. Intrinsic isospin of quarks.

quark	u	$\bar{u}$	d	$\bar{d}$	s	$\bar{s}$	c	$\bar{c}$	b	$\bar{b}$
I	1/2	1/2	1/2	1/2	0	0	0	0	0	0
I_3	1/2	−1/2	−1/2	1/2	0	0	0	0	0	0

Because a composition of baryon includes a pair of mesons, we need the values of isospin, the third component of isospin, and strangeness and mass of each mesons. Table 2 shows the properties of mesons composed of *u*, *d*, and *s* quarks only for the spin 0 case.

Table 2. Properties of mesons (*u*, *d*, *s* quarks only).

meson	I	I_3	S	B_a	Mass (MeV)
π^+	1	1	0	0	139.57
π^0	1	0	0	0	134.98
π^-	1	−1	0	0	139.57
f^0	0	0	0	0	440.50
η^0	0	0	0	0	547.86
κ^+	$\frac{1}{2}$	$\frac{1}{2}$	1	0	493.68
κ^-	$\frac{1}{2}$	$-\frac{1}{2}$	−1	0	493.68
κ_s^0	0	0	0	0	497.61
κ_L^0	0	0	0	0	497.61
κ^0	$\frac{1}{2}$	$\frac{1}{2}$	1	0	497.61
$\overline{\kappa^0}$	$\frac{1}{2}$	$-\frac{1}{2}$	−1	0	497.61

Notes: The listed mass of f^0 is from ref [16]. All other mass are from Oliver *et al.* [19]. We use K_s^0 (short decay time of K^0) instead of $K^0, \overline{K^0}$ because $K^0, \overline{K^0}$ are strong eigenstates that are considered not to decay. Normally, K_s^0 is noted not to be eigenstates of strangeness, thus, we denote strangeness 0 for it because the quark representation of K_S^0 are $\frac{d\bar{s}+\bar{d}s}{\sqrt{2}}$ [19], and from these expression we can consider their strangeness to be 0. By setting this strangeness value, isospin of K_s^0 becomes 0 by our isosin definition.

Table 3 shows the properties of mesons with spin 0 composed by *c* and *b* quarks baryons.

Table 3. Properties of mesons (*c*, *b* quarks; spin 0).

meson	Composing quarks	I	I_3	S	C	B	Mass (MeV)
D^+	$c\bar{d}$	$\frac{1}{2}$	$\frac{1}{2}$	0	1	0	1869.61
D^-	$\bar{c}d$	$\frac{1}{2}$	$-\frac{1}{2}$	0	−1	0	1869.61

Continued

D^0	$c\overline{u}$	$\frac{1}{2}$	$-\frac{1}{2}$	0	1	0	1864.84
$\overline{D^0}$	$\overline{c}u$	$\frac{1}{2}$	$\frac{1}{2}$	0	−1	0	1864.84
D_s^+	$c\overline{s}$	0	0	1	1	0	1968.30
D_s^-	$\overline{c}s$	0	0	−1	−1	0	1968.30
B^+	$u\overline{b}$	$\frac{1}{2}$	$\frac{1}{2}$	0	0	1	5279.26
B^-	$\overline{u}b$	$\frac{1}{2}$	$-\frac{1}{2}$	0	0	−1	5279.26
B^0	$d\overline{b}$	$\frac{1}{2}$	$-\frac{1}{2}$	0	0	1	5279.58
$\overline{B^0}$	$\overline{d}b$	$\frac{1}{2}$	$\frac{1}{2}$	0	0	−1	5279.58
B_s^0	$s\overline{b}$	0	0	−1	0	1	5366.77
$\overline{B_s^0}$	$\overline{s}b$	0	0	1	0	−1	5366.77

Notes: The listed values are taken from ref. [19] including mass values. All baryon numbers are 0.

The listed isospin values are determined by our definition and all values are correspond to isospin values of ref. [19] except K_S^0. **Table 3** shows the properties of mesons with spin 1 composed by c and b quarks baryons.

Table 4. Properties of mesons (c, b quarks; spin 1).

meson	Composing quarks	I	I_3	S	C	B	Mass (MeV)
ρ^+	$u\overline{d}$	1	1	0	0	0	775.11
ρ^0	$u\overline{u}$, $d\overline{d}$	1	0	0	0	0	775.26
ρ^-	$\overline{u}d$	1	−1	0	0	0	775.11
ω^0	$u\overline{u}$, $d\overline{d}$	0	0	0	0	0	782.65
ϕ^0	$s\overline{s}$	0	0	0	0	0	1019.46
J/Ψ	$c\overline{c}$	0	0	0	0	0	3096.92
Υ	$b\overline{b}$	0	0	0	0	0	9460.30
D^{*+}	$c\overline{d}$	$\frac{1}{2}$	$\frac{1}{2}$	0	1	0	2010.26

Continued

D^{*-}	$\bar{c}d$	$\frac{1}{2}$	$-\frac{1}{2}$	0	−1	0	2010.26
D^{*0}	$c\bar{u}$	$\frac{1}{2}$	$-\frac{1}{2}$	0	1	0	2006.96
$\overline{D^{*0}}$	$\bar{c}u$	$\frac{1}{2}$	$\frac{1}{2}$	0	−1	0	2006.96
D_s^{*+}	$c\bar{s}$	0	0	1	1	0	2112.10
$\overline{D_s^{*-}}$	$\bar{c}s$	0	0	−1	−1	0	2112.10
B^{*+}	$u\bar{b}$	$\frac{1}{2}$	$\frac{1}{2}$	0	0	1	5325.20
B^{*-}	$\bar{u}b$	$\frac{1}{2}$	$-\frac{1}{2}$	0	0	−1	5325.20
B^{*0}	$d\bar{b}$	$\frac{1}{2}$	$-\frac{1}{2}$	0	0	1	5325.20
$\overline{B^{*0}}$	$\bar{d}b$	$\frac{1}{2}$	$\frac{1}{2}$	0	0	−1	5325.20
B_s^{*0}	$s\bar{b}$	0	0	−1	0	1	5415.40
$\overline{B_s^{*0}}$	$\bar{s}b$	0	0	1	0	−1	5415.40

Notes: The listed values are taken from ref. [19] including mass values. All baryon numbers are 0.

Using the values of Table 2, Table 3 and Table 4, we construct the isospin of a baryon and describe a baryon as composition of bound stated sea-quarks and unbounded sea-quarks. To construct the isospin, we regroup the baryons by including antibaryons. The composing sea-quarks are selected by their charge and composing quarks and mass. We show the results of light baryons with the spin $\frac{1}{2}$ case in Table 5. We use a baryon number of 0 for all baryons as proposed in ref. [16].

The definition of estimated mass is following.

$$\begin{aligned}\text{Estimated mass} &= \text{sum of mass of composing mesons and unbound stated sea-quarks} \\ &\quad + \text{binding energy}\end{aligned} \tag{6}$$

Binding energy is obtained as

$$\begin{aligned}&\text{Binding energy} = \text{setting mass}\left(\text{measured mass}\right) \\ &- \text{estimated mass of proton for light baryon and } \Xi_{cc}^{++} \text{ for } c \text{ quak baryon}\end{aligned} \tag{7}$$

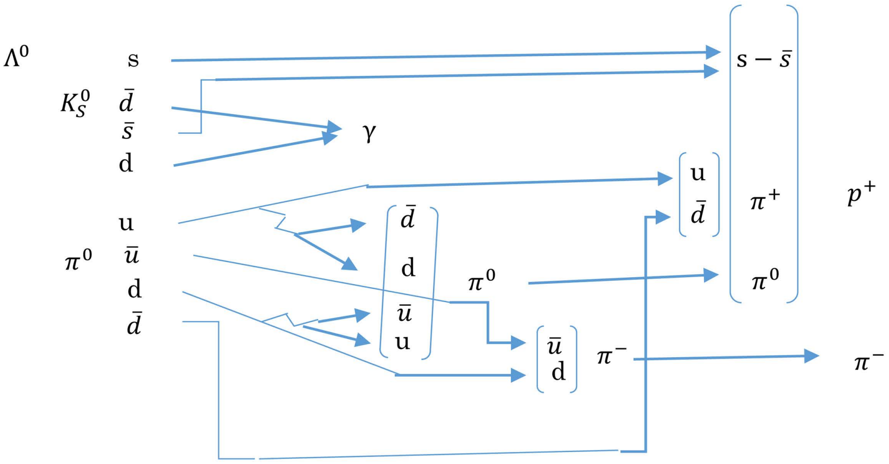
We use s quark mass of 93 (MeV) and c quark mass of 1273 (MeV) as following to Particle Data Group data [20] and ignore u and d quark masses.

Table 5. Properties of light baryons (spin 1/2).

baryon	Composing state	I	I_3	S	Binding quarks	Binding energy	Mass (estimated) (MeV)	Mass (measured) (MeV)
p	$\pi^+ + \pi^0$ s-$\bar{s}$	1	1	0	uu or $\bar{d}\,\bar{d}$	477.72	938.27 (setting)	938.27
n	$\pi^+ + \pi^-$ s-$\bar{s}$	1	0	0	ud or $\bar{u}\bar{d}$	477.72	942.86	939.57
p^-	$\pi^- + \pi^0$	1	−1	0	$\bar{u}\,\bar{u}$	477.72	938.27	-
Λ^0	$\pi^0 + K_S^0$	0	0	0	dd or $\bar{d}\,\bar{d}$	477.72	1110.97	1115.68
Σ^+	$\pi^+ + \eta^0$	1	1	0	uu or $\bar{d}\,\bar{d}$	477.72	1165.15	1189.37
Σ^0	$\pi^0 + \eta^0$	1	0	0	uu or $\bar{d}\,\bar{d}$	477.72	1160.56	1192.64
Σ^-	$\pi^- + \eta^0$	1	−1	0	$\bar{u}\,\bar{u}$ or dd	477.72	1165.15	1197.45
Ξ^+	$f^0 + K^+$	$\frac{1}{2}$	$\frac{1}{2}$	1	dd	477.72	1411.9	-
Ξ^-	$f^0 + K^-$	$\frac{1}{2}$	$-\frac{1}{2}$	−1	$\bar{d}\,\bar{d}$	477.72	1411.9	1321.71
Ξ^0	$f^0 + K_S^0$	0	0	0	dd or $\bar{d}\,\bar{d}$	477.72	1415.83	1314.86

Notes: All values of the baryon number B_a are 0.

All C and B values are 0. Our description of Λ^0 is probable to decay to $p^+ + \pi^-$ as follows.



γ denotes photons, however , it is also possible just becomes ejection energy. This shows decay mode of $\Lambda^0 \to p^+ + \pi^-$.

The measured mass in **Table 4** and in later tables is taken from Beringer *et al.* [21].

Table 6 shows the properties of light baryons with spin $\frac{3}{2}$.

Table 6. Properties of light baryons (spin 3/2).

baryon	Composing state	I	I_3	S	Binding quarks	Binding energy	Mass (estimated) (MeV)	Mass (measured) (MeV)
Δ^{++}	$\pi^+ + K^+$ $s\text{-}\bar{s}$	$\frac{3}{2}$	$\frac{3}{2}$	1	$\bar{d}\,\bar{d}$	477.72	1296.97	1232
Δ^{+}	$\pi^0 + K^+$ $s\text{-}\bar{s}$	$\frac{3}{2}$	$\frac{1}{2}$	1	$\bar{d}\,\bar{d}$	477.72	1292.38	1232
Δ^{-}	$\pi^0 + K^-$ $s\text{-}\bar{s}$	$\frac{3}{2}$	$-\frac{1}{2}$	-1	dd	477.72	1292.38	1232
Δ^{--}	$\pi^- + K^-$ $s\text{-}\bar{s}$	$\frac{3}{2}$	$-\frac{3}{2}$	-1	dd	477.72	1296.97	-
Δ^{0}	$\pi^0 + K_S^0$ $s\text{-}\bar{s}$	0	0	0	dd or $\bar{d}\,\bar{d}$	477.72	1296.31	1232
Σ'^{+}	$\pi^+ + \eta^0$ $s\text{-}\bar{s}$	1	1	0	uu or $\bar{d}\,\bar{d}$	477.72	1351.15	1382.8
Σ'^{0}	$\pi^0 + \eta^0$ $s\text{-}\bar{s}$	1	0	0	uu or $\bar{d}\,\bar{d}$	477.72	1346.56	1383..7
Σ'^{-}	$\pi^- + \eta^0$ $s\text{-}\bar{s}$	1	-1	0	dd or $\bar{u}\,\bar{u}$	477.72	1351.15	1387.2
Ξ'^{+}	$f^0 + K^+$ $s\text{-}\bar{s}$	$\frac{1}{2}$	$\frac{1}{2}$	1	$\bar{d}\,\bar{d}$	477.72	1597.40	-
Ξ'^{+}	$f^0 + K^-$ $s\text{-}\bar{s}$	$\frac{1}{2}$	$-\frac{1}{2}$	-1	dd	477.72	1597.40	-
Ξ'^{+}	$f^0 + K_S^0$ $s\text{-}\bar{s}$	0	0	0	dd or $\bar{d}\,\bar{d}$	477.72	1601.83	-
Ω^{+}	$\eta^0 + K^+$ $s\text{-}\bar{s}$	$\frac{1}{2}$	$\frac{1}{2}$	1	$\bar{d}\,\bar{d}$	477.72	1705.08	-
Ω^{-}	$\eta^0 + K^-$ $s\text{-}\bar{s}$	$\frac{1}{2}$	$-\frac{1}{2}$	-1	dd	477.72	1705.08	1672.45

Note: All values of the baryon number B_a are all 0.

Table 7 shows the properties of heavy baryons with spin $\frac{1}{2}$ composed by c quarks.

Table 7. Properties of heavy baryons (c quark; spin 1/2).

baryon	Composing state	I	I_3	S	C	Binding quarks	Binding energy	Mass (estimated) (MeV)	Mass (measured) (MeV)
Λ_c^+	$c\text{-}\bar{d}$, $c\text{-}\bar{u}$	0	0	0	2	cc	−216.51	2335.49	2286.46
Σ_c^{++}	$c\text{-}\bar{d}$, $c\text{-}\bar{d}$, $s\text{-}\bar{s}$	1	1	0	2	cc	−216.51	2523.49	2453.98
Σ_c^{+}	$c\text{-}\bar{d}$, $c\text{-}\bar{u}$, $s\text{-}\bar{s}$	1	0	0	2	cc	−216.51	2521.49	2452.9
Σ_c^{0}	$c\text{-}\bar{u}$, $c\text{-}\bar{u}$, $s\text{-}\bar{s}$	1	−1	0	2	cc	−216.51	2519.49	2453.74
$\overline{\Sigma_c^{0}}$	$u\text{-}\bar{c}$, $u\text{-}\bar{c}$, $s\text{-}\bar{s}$	1	1	0	−2	$\bar{c}\bar{c}$	−216.51	2519.49	-
Σ_c^{-}	$d\text{-}\bar{c}$, $u\text{-}\bar{c}$, $s\text{-}\bar{s}$	1	0	0	−2	$\bar{c}\bar{c}$	−216.51	2521.49	-
Σ_c^{--}	$d\text{-}\bar{c}$, $d\text{-}\bar{c}$, $s\text{-}\bar{s}$	1	−1	0	−2	$\bar{c}\bar{c}$	−216.51	2523.49	-
Ξ_c^{+}	$D^{+}+K_S^0$	$\frac{1}{2}$	$\frac{1}{2}$	0	1	-	0	2367.22	2467.8
Ξ_c^{-}	$D^{-}+K_S^0$	$\frac{1}{2}$	$-\frac{1}{2}$	0	−1	-	0	2367.22	-
Ξ_c^{0}	$D^{+}+K^{-}$	0	0	−1 Or 1	1 Or −1	-	0	2367.29	2470.88
$\Xi_c'^{+}$	$D^{+}+K_S^0$ $s\text{-}\bar{s}$	$\frac{1}{2}$	$\frac{1}{2}$	0	1	-	0	2553.22	2577.6
$\Xi_c'^{-}$	$D^{-}+K_S^0$ $s\text{-}\bar{s}$	$\frac{1}{2}$	$-\frac{1}{2}$	0	−1	-	0	2553.22	-
$\Xi_c'^{0}$	$D^{+}+K^{-}$ $s\text{-}\bar{s}$	0	0	−1 Or 1	1 Or −1	-	0	2553.29	2577.9
Ω_c^{0}	$D^{0}+\eta^{0}$ $s\text{-}\bar{s}$	$\frac{1}{2}$	$-\frac{1}{2}$	0	1	-	0	2597.86	2695.2

Continued

$\overline{\Omega_c^0}$	$\overline{D^0}+\eta^0$ s-$\overline{s}$	$\frac{1}{2}$	$\frac{1}{2}$	0	-1	-	0	2597.86	-
Ξ_{cc}^{++}	$D^+ + D_s^+$	$\frac{1}{2}$	$\frac{1}{2}$	1	2	cc	-216.51	3621.40 (setting)	3621.40
Ξ_{cc}^{--}	$D^- + D_s^-$	$\frac{1}{2}$	$-\frac{1}{2}$	-1	-2	cc		3621.40	-

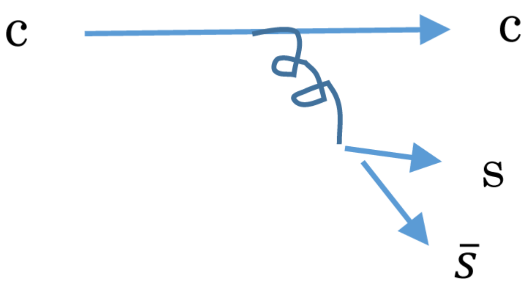
From Table 7, our description of Λ_c^+ looks like probable, but we need to check this description is possible to decay to $p+K^-+\pi^+$. Our explanation is following.

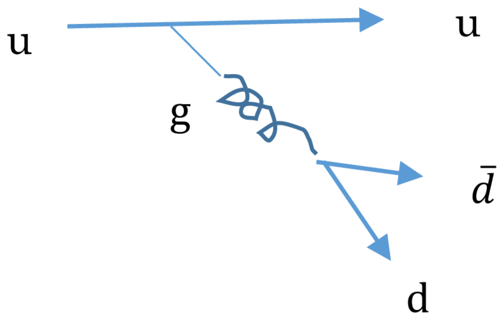
Because D^0 is bound stated c-$\overline{u}$ and its mass is 1864.84 (MeV) as shown in Table 2, c-$\overline{u}$ sea-quark state becomes D^0 by using a part of mass of Λ_c^+ that is 2286.46 (MeV) and energy of 421.6 (MeV) is remained. Main decay mode of D^0 is $D^0 \to K_S^0 + \pi^0$ and ejecting energy is 1226 MeV. Composing state of K_S^0 is bound stated d-$\overline{s}$, s-$\overline{d}$ with mass energy 497.61 (MeV). When s-$\overline{s}$ sea-quark state is kept, energy of 311 (MeV) is remained.

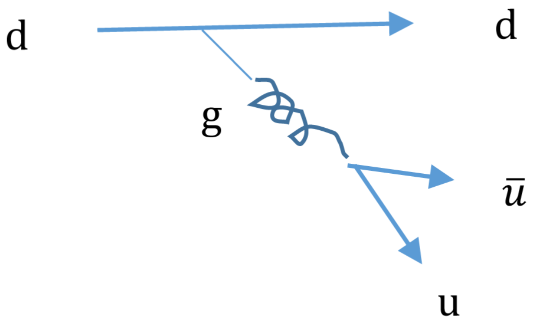
Therefore c-$\overline{d}$ sea-quark state becomes D^+ by using remained energy of $421.6+1226+311=1958.6(\text{MeV})$. Main decay mode of D^+ is $K^-+2\pi^+$ and ejecting energy is 1091 (MeV). Recalling that s-$\overline{s}$ sea-quark state is kept, $\pi^+ + \pi^0 + s$-$\overline{s}$ becomes p (proton) by using ejecting energy of 1091 (MeV) because energy of 1091 (MeV) is larger than proton mass of 938.27 (MeV). Then Λ_c^+ decays to $p+K^-+\pi^+$. We consider that $d+\overline{d}$ becomes either photons or ejecting energy. Alternative explanation is as follows. Recalling of strong and weak decay of c quark, c-$\overline{u}$ becomes $K^-+\pi^++s$-$\overline{s}$. Ejecting energy is $1273-(493.7+140+186)=453.3(\text{MeV})$. Recalling of weak decay of c quark and strong decay of u and d quarks, c-$\overline{d}$ becomes $\pi^++\pi^0$. Ejecting energy is $1273-(140+135)=998(\text{MeV})$. Recalling that mass of two c quarks is 2546 (MeV) and mass of Λ_c^+ is 2286.46 (MeV) and difference is −259.54 (MeV), total ejecting energy is 1191.76 (MeV) that is larger than proton mass 939 (MeV). Thus it is possible that $\pi^++\pi^0+s$-$\overline{s}$ becomes p^+.

Schematic description is:

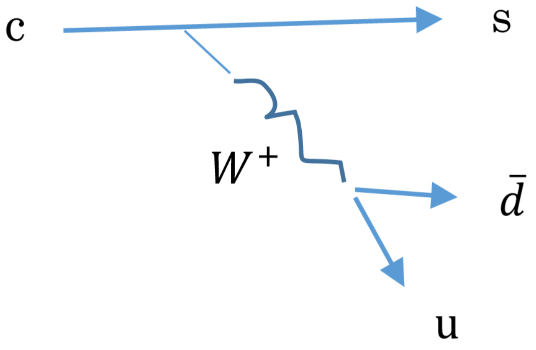
Examples of the strong decay are:

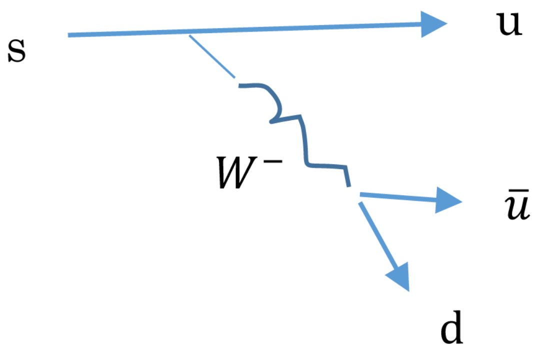




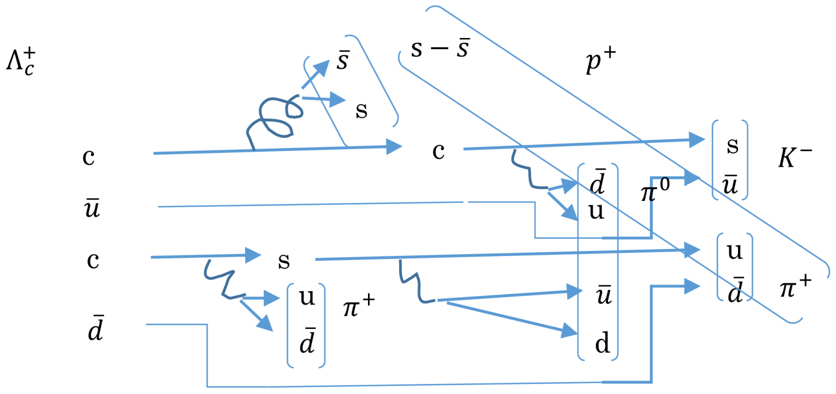


Examples of weak decay of are:





Using above strong decay and weak decay, decay mode of Λ_c^+ is shown as follows:



This shows $\Lambda_c^+ \to p^+ + K^- + \pi^+$ because there is enough energy for composing p^+ as mentioned in above.

Thus, our description of Λ_c^+ is probable. In our understanding, the p_T dependence of differential cross section of ALICE experiment tells hadronization of c quarks to Λ_c^+ baryon and that to D^0 mesons. In our description of Λ_c^+ and D^0, number of c quarks of Λ_c^+ is twice as much as that of D^0. Thus, hadronization probability of Λ_c^+ becomes $\frac{1}{2}$ of that of D^0 because two c quarks are needed to hadronize to Λ_c^+, while one c quark is needed to hadronize to D^0. Thus, our description of Λ_c^+ and D^0 gives p_T dependence of Λ_c^+/D^0 ratio of 0.5.

Table 8 shows the properties of heavy baryons with spin $\frac{1}{2}$ composed by *b* quarks.

Table 8. Properties of heavy baryons (*b* quark; spin 1/2).

baryon	Composing state	I	I_3	S	B	Binding quark	Binding energy	Mass (estimated) (MeV)	Mass (measured) (MeV)
Λ_b^0	$B^+ + \pi^-$	$\frac{1}{2}$	$-\frac{1}{2}$	0	1	-	0	5418.83	5619.4
$\overline{\Lambda_b^0}$	$B^- + \pi^+$	$\frac{1}{2}$	$\frac{1}{2}$	0	−1	-	0	5418.83	5619.4
Σ_b^+	$B^+ + \pi^0$ s-$\bar{s}$	$\frac{1}{2}$	$\frac{1}{2}$	0	1	-	0	5600.56	5811.3
Σ_b^-	$B^- + \pi^0$ s-$\bar{s}$	$\frac{1}{2}$	$-\frac{1}{2}$	0	−1	-	0	5600.56	5815.5
Σ_b^0	$B^+ + \pi^-$ s-$\bar{s}$	$\frac{1}{2}$	$-\frac{1}{2}$	0	1	-	0	5605.15	-
$\overline{\Sigma_b^0}$	$B^- + \pi^+$ s-$\bar{s}$	$\frac{1}{2}$	$\frac{1}{2}$	0	−1	-	0	5605.15	-

Continued

Ξ_b^+	$B^+ + K_S^0$ Or $B^+ + K_L^0$	$\frac{1}{2}$	$\frac{1}{2}$	0	1	-	0	5776.87	-
Ξ_b^-	$B^- + K_S^0$ Or $B^- + K_L^0$	$\frac{1}{2}$	$-\frac{1}{2}$	0	-1	-	0	5776.87	5791.1
Ξ_b^0	$B^+ + K^-$	0	0	-1	1	-	0	5772.87	5787.8
$\Xi_b'^+$	$B^+ + K_S^0$ Or $B^+ + K_L^0$ $s\text{-}\bar{s}$	$\frac{1}{2}$	$\frac{1}{2}$	0	1	-	0	5962.87	-
$\Xi_b'^-$	$B^- + K_S^0$ Or $B^- + K_L^0$ $s\text{-}\bar{s}$	$\frac{1}{2}$	$-\frac{1}{2}$	0	-1	-	0	5962.87	-
$\Xi_b'^0$	$B^+ + K^-$ $s\text{-}\bar{s}$	0	0	-1	1	-	0	5958.87	-
Ω_b^+	$B_s^0 + K^+$ $s\text{-}\bar{s}$	$\frac{1}{2}$	$\frac{1}{2}$	0	1	-	0	6046.45	-
Ω_b^-	$B_s^0 + K^-$ $s\text{-}\bar{s}$	$\frac{1}{2}$	$-\frac{1}{2}$	0	-1	-	0	6046.45	6071

Note: All values of the baryon number B_a are all 0 and all C value are 0.

The determination of binding energy is based on the same considerations used in the charm baryon case.

The reason that the strangeness of Ω_b^- (Ω_b^+) is 0 is that the strangeness of $\overline{B_s^0}$ (B_s^0) is +1 (−1) and that of K^- (K^+) is −1 (+1) so that the total of strangeness becomes 0.

Table 9 shows the properties of heavy baryons with spin $\frac{3}{2}$ composed by c quarks.

Table 9. Properties of heavy baryons (c quark; spin 3/2).

baryon	Pair of mesons	I	I_3	S	C	Binding quarks	Binding energy (MeV)	Mass (estimated) (MeV)	Mass (measured) (MeV)
Σ_c^{*++}	$D^{*+} + K^+$	1	1	1	1	-	0	2503.94	2517.9
Σ_c^{*+}	$D^{*0} + K^+$ $s\text{-}\bar{s}$	1	0	1	1	-	0	2500.64	2517.5

Continued

Σ_c^{*0}	$D^{*+}+K^-$ s-$\bar{s}$	1	−1	1	1	-	0	2503.94	2518.8
$\overline{\Sigma_c^{*0}}$	$D^{*-}+K^+$ s-$\bar{s}$	1	1	−1	−1	-	0	2503.94	-
Σ_c^{*-}	$D^{*0}+K^-$	1	0	−1	−1	-	0	2500.64	-
Σ_c^{*--}	$D^{*-}+K^-$	1	−1	−1	−1	-	0	2503.94	-
Ξ_c^{*+}	$D_s^{+}+K_s^0$	$\frac{1}{2}$	$\frac{1}{2}$	0	1	-	0	2609.71	2645.9
Ξ_c^{*-}	$D_s^{*-}+K_s^0$	$\frac{1}{2}$	$-\frac{1}{2}$	0	−1	-	0	2609.71	-
Ξ_c^{*0}	$D_s^{*+}+K^-$	$\frac{1}{2}$	$-\frac{1}{2}$	0	1	-	0	2605.78	2645.9
$\overline{\Xi_c^{*0}}$	$D_s^{*-}+K^+$	$\frac{1}{2}$	$\frac{1}{2}$	0	−1	-	0	2605.78	-
Ξ_c^{*++}	$D^{*+}+D_s^{*+}$	$\frac{1}{2}$	$\frac{1}{2}$	1	2	cc	−216.5	3905.86	-
Ξ_{cc}^{*--}	$D^{*-}+D_s^{*+}$	$\frac{1}{2}$	$-\frac{1}{2}$	−1	−2	$\bar{c}\,\bar{c}$	−216.5	3905.86	-
Ω_c^{*0}	$D_s^{*+}+K^-$ s-$\bar{s}$	$\frac{1}{2}$	$-\frac{1}{2}$	0	1	-	0	2791.78	2765.9
$\overline{\Omega_c^{*0}}$	$D_s^{*-}+K^+$ s-$\bar{s}$	$\frac{1}{2}$	$\frac{1}{2}$	0	−1	-	0	2791.78	-

Note: All values of the baryon number B_a are all 0 and all B value are 0.

Table 10 shows the properties of heavy baryons with spin $\frac{3}{2}$ composed by b quarks.

Table 10. Properties of heavy baryons (b quark; spin 3/2)

Baryon	Pair of mesons	I	I_3	S	B	Binding quarks	Binding energy (MeV)	Mass (estimated) (MeV)	Mass (measured) (MeV)
Σ_b^{*+}	$B_s^0+\pi^+$ s-$\bar{s}$	1	1	−1	1	-	0	5740.67	5835.1
Σ_b^{*0}	$B_s^0+\pi^0$ s-$\bar{s}$	1	0	−1	1	-	0	5736.38	-

Continued

Σ_b^{*-}	$B_s^0+\pi^-$ s-$\overline{s}$	1	−1	−1	1	-	0	5740.67	5835.1
Ξ_b^{*+}	$B_s^{*0}+K^+$ or	$\frac{1}{2}$	$\frac{1}{2}$	0	1	-	0	5909.08	-
Ξ_b^{*-}	$B_s^{*0}+K^-$	$\frac{1}{2}$	$-\frac{1}{2}$	0	−1	-	0	5909.08	-
Ξ_b^{*0}	$B_s^{*0}+K_S^0$	0	0	−1	1	-	0	5913.01	5945.5
Ω_b^{*+}	$B_s^{*0}+\kappa^+$ s-$\overline{s}$	$\frac{1}{2}$	$\frac{1}{2}$	0	1	-	0	6095.08	-
Ω_b^{*-}	$\overline{B_s^{+0}}+\kappa^-$ s-$\overline{s}$	$\frac{1}{2}$	$-\frac{1}{2}$	0	−1	-	0	6095.08	-

Note: All values of the baryon number B_a are all 0 and all C value are 0.

For baryons lists, unbound stated sea-quarks of composition system are s-$\overline{s}$, c-$\overline{u}$, c-$\overline{d}$, $\overline{c}$-u and $\overline{c}$-d.

3. Conclusions and Discussions

In Section 2 and 3, we show the qualitative aspects of baryons composed by bound stated sea-quarks (mesons) and unbound stated sea-quarks (normal sea-quarks). From Tables 5 to Tables 10, we can demonstrate that all baryons satisfy the generalized Gell-Mann-Nishijima relation equation (5) with baryon number 0. The estimate mass also shows fairly good under using two fixed parameters, namely binding energy of which one is for light baryons and the other one is for c quark baryons. We would like to emphasize that both parameters is fixed values for each cases. As mass spectra, our estimated masses are meaningless because of using these parameters, although these are fixed. However, goodness of these estimated masses gives a suggestion that our description of baryons is meaningful. We consider that pion pairs, bound state sea-quarks, become unbound stated sea-quarks inside proton. Thus proton does not decay. Furthermore unbound stated sea-quarks may go back to bound stated sea-quarks that is pion pairs. These processes may occur repeatedly inside proton. Because we obtain fairly good light baryon mass spectra by very simple estimation based on our model and , we consider above mentioned process may happen from the results of H1+ZEUS and ATLAS experiment.

In addition, our description of Λ_c^+ may explain the ALICE results that the p_T dependence of Λ_c^+/D^0 is 0.5 as shown in Sec. 3. The example calculation based on our model is proton and neutron em. FF is described by pion pair as shown in ref. [16]. In this case we ignored contribution of s-$\overline{\text{s}}$ sea quarks because we considered that nucleon does not have s-$\overline{s}$ sea quarks. We describe Λ_c and Σ_c as *c* sea-quarks pair. Other baryons are described as a meson pair with or without s sea-quarks. This looks like a little bit questionable. However, using binding energy, the obtained estimated mass is fairly good although estimation method is quite simple. In addition, the determination of this binding energy seems plausible because only Ξ_{cc}^{++} case shows that sum of composing meson masses overwhelms to measured mass among all cases. Thus, we consider that our description of Λ_c and Σ_c is very probable.

Conflicts of Interest

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

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