Composite Model and CP Violation

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Abstract

In an axiomatic way we propose a fermion-boson-type Composite Model for quarks and leptons based on the gauge theory equipped with Cartan connections. Elementary fields are only one kind of spin-1/2 and spin-0 preon. Both are in the global supersymmetric pair with the common electric charge of "e/6" and belong to the fundamental representations of \( (3, 2, 2) \) under the spontaneously unbroken \( SU(3)_C \otimes SU(2)_L^h \otimes SU(2)_R^h \) gauge symmetry (\( h \) means hyper-color gauge). Preons are composed into subquarks which are intermediate clusters towards quarks and leptons. Weak interactions are residual ones of hyper-color gauge interactions. \( W \)-and \( Z \)-boson are also composite objects of subquarks, which introduces the idea of existence of their scalar partners (\( S \)) by hyper-fine-splitting whose masses would be around 110 \( \sim \) 120 GeV. The mechanism of making higher generations is obtained by adding neutral scalar subquark (\( y \)) composed of a preon-antipreon pair. Creation or annihilation of \( y \) inside quarks induces the coupling constants of flavor-mixing weak interactions which are all complex numbers (contrary to CKM-matrix elements) and then they all become sources of direct and mixing-induced CP violations. Exchange of \( y \) between quark and anti-quark inside neutral pseudo-scalar meson \( (P^0) \) gives indirect CP violation and mass-difference of \( P^0 \) and \( \bar{P}^0 \). Current experimental results of CP violation (Belle, BaBar, CLEO, KTeV and NA48) are inspected by this Composite Model. This model suggests the candidates for "Dark Energy" and "Dark Matter".

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1 Introduction

The discovery of the top-quark[1] has finally confirmed the existence of three quark-lepton symmetric generations. So far the standard $SU(2)_L \otimes U(1)$ model (denoted by the SM) has successfully explained various experimental evidences. Nevertheless, as is well known, the SM is not regarded as the final theory because it has many arbitrary parameters, e.g., quark and lepton masses, quark-mixing parameters, etc.

Therefore it is meaningful to investigate the origins of these parameters and the relationship among them. In order to overcome such problems some attempts have done, e.g., Grand Unification Theory (GUT), Supersymmetry, Super String Theory, Composite model, etc. In the theory except Composite model quarks and leptons are elementary fields in general. On the contrary in the composite scenario they are literally the composite objects constructed from the elementary fields (so called “preon”). The lists of various Composite model are in Ref.[2].

If quarks and leptons are elementary, in order to solve the above problems it is necessary to introduce some external relationship or symmetries among them. On the other hand the composite models have ability to explain the origin of these parameters in terms of the substructure dynamics of quarks and leptons. Further, the composite scenario naturally leads us to the thought that the intermediate vector bosons of weak interactions ($W, Z$) are not elementary gauge fields (which is so in the SM) but composite objects constructed from preons (same as $\rho$-meson from quarks). Many studies based on such conception have done after Bjorken’s[3] and Hung and Sakurai’s[4] suggestions of the alternative way to unified weak-electromagnetic gauge theory[5~11]. In this scheme the weak interactions are regarded as the effective residual interactions among preons. The fundamental fields for intermediate forces are massless gauge fields belonging to some gauge groups and they confine preons into singlet states to build quarks and leptons and $W, Z$.

The conception of our model is that the fundamental interacting forces are all originated from massless gauge fields belonging to the adjoint representations of some gauge groups which have nothing to do with the spontaneous breakdown and that the elementary matter fields are only one kind of spin-1/2 preon and spin-0 preon carrying common “$e/6$” electric charge ($e > 0$). Quarks, leptons and $W, Z$ are all composites of them and usual weak interactions are regarded as effective residual interactions.

Based on such scenario various CP-violating phenomena are investigated. The most outstanding point is that CP-violations originate from interactions among subquarks
inside quarks.

The outline of this article is as follows. In Section 2 we introduce brief presentation about the gauge theory inspiring composite quarks and leptons. In Section 3 we discuss the composite model naturally inherited from above mentioned gauge theory. In Section 4 we give the definition of the flavor-mixing matrix elements, which come from subquark dynamics. These correspond to CKM-matrix elements in the SM. In Section 5 we discuss the mass difference (denoted by $\Delta M_P$) by $P^0-\overline{P^0}$ mixing ($P^0$ is pseudo scalar meson). This originates from $y$-subquark-exchange between quark and anti-quark inside $P^0$. In Section 6 indirect CP-violations are investigated. This is also caused by $y$-subquark-exchange between quark and anti-quark inside $P^0$. In Section 7 we study direct and mixing-induced CP-violations which originate from flavor-mixing interactions caused by subquark dynamics. Lastly we give conclusions in Section 8.

2 Gauge theory inspiring quark-lepton composite scenario

In our model the existence of fundamental matter fields (preon) are inspired by the gauge theory with Cartan connections[14]. Let us briefly summarize the basic features of that.

Generally gauge fields, including gravity, are considered as geometrical objects, that is, connection coefficients of principal fiber bundles. It is said that there exist some different points between Yang-Mills gauge theories and gravitationary theory, though both theories commonly possess the fiber bundle structures. Namely the latter is equipped with the fiber bundle essentially related to 4-dimensional space-time freedoms but the former with the fiber bundle belonging to the internal space which has nothing to do with the space-time coordinates.

In case of gravity it is usually considered that there exist ten gauge fields, that is, six spin connection fields in $SO(1,3)$ gauge group and four vierbein fields in $GL(4, R)$ gauge group from which the metric tensor $g^{\mu\nu}$ is constructed in a bilinear function of them. Both altogether belong to Poincaré group $ISO(1,3) = SO(1,3) \otimes R^4$ which is semi-direct product. In this scheme spin connection fields and vierbein fields are independent but only if there is no torsion, both come to have some relationship. Seeing this, $ISO(1,3)$ gauge theory seems to have the logical weak point not to answer how two kinds of gravity fields are related to each other intrinsically.
In the theory of Differential Geometry, S. Kobayashi has investigated the theory of "Cartan connection" [15]. This theory, in fact, has ability to reinforce the above weak point. The brief recapitulation is as follows. Let \( E(B_n, F, G, P) \) be a fiber bundle (which we call Cartan-type bundle) associated with a principal fiber bundle \( P(B_n, G) \) where \( B_n \) is a base manifold with dimension "\( n \)", \( G \) is a structure group, \( F \) is a fiber space which is homogeneous and diffeomorphic with \( G/G' \) where \( G' \) is a subgroup of \( G \). Let \( P' = P'(B_n, G') \) be a principal fiber bundle, then \( P' \) is a subbundle of \( P \). Here let it be possible to decompose the Lie algebra \( g \) of \( G \) into the subalgebra \( g' \) of \( G' \) and a vector space \( f \) such as :

\[
g = g' + f, \quad g' \cap f = 0, \quad (2.1)
\]

\[
[g', g'] \subset g', \quad (2.2)
\]

\[
[g', f] \subset f, \quad (2.3)
\]

\[
[f, f] \subset g', \quad (2.4)
\]

where \( \text{dim} f = \text{dim} F = \text{dim} G - \text{dim} G' = \text{dim} B_n = n \). The homogeneous space \( F = G/G' \) is said to be "weakly reductive" if there exists a vector space \( f \) satisfying (2.1) and (2.3). Further \( F \) satisfying (2.4) is called "symmetric space". Let \( \omega \) denote the connection form of \( P \) and \( \bar{\omega} \) be the restriction of \( \omega \) to \( P' \). Then \( \bar{\omega} \) is a \( g \)-valued linear differential 1-form and we have :

\[
\omega = g^{-1}\bar{\omega}g + g^{-1}dg, \quad (2.5)
\]

where \( g \in G, \ dg \in T_g(G) \). \( \omega \) is called the form of "Cartan connection" in \( P \).

Let the homogeneous space \( F = G/G' \) be weakly reductive. The tangent space \( T_O(F) \) at \( o \in F \) is isomorphic with \( f \) and then \( T_O(F) \) can be identified with \( f \) and also there exists a linear \( f \)-valued differential 1-form (denoted by \( \theta \)) which we call the "form of soldering". Let \( \omega' \) denote a \( g' \)-valued 1-form in \( P' \), we have :

\[
\bar{\omega} = \omega' + \theta. \quad (2.6)
\]

The dimension of vector space \( f \) and the dimension of base manifold \( B_n \) is the same "\( n \)", and then \( f \) can be identified with the tangent space of \( B_n \) at the same point in
$B_n$ and $\theta$s work as $n$-bein fields. In this case $\omega'$ and $\theta$ unifyingly belong to group $G$. Here let us call such a mechanism “Soldering Mechanism”.

Drechsler has found out the useful aspects of this theory and investigated a gravitational gauge theory based on the concept of the Cartan-type bundle equipped with the Soldering Mechanism[16]. He considered $F = SO(1,4)/SO(1,3)$ model. Homogeneous space $F$ with $dim = 4$ solders 4-dimensional real space-time. The Lie algebra of $SO(1,4)$ corresponds to $g$ in (2.1), that of $SO(1,3)$ corresponds to $g'$ and $f$ is 4-dimensional vector space. The 6-dimensional spin connection fields are $g'$-valued objects and vierbein fields are $f$-valued, both of which are unified into the members of $SO(1,4)$ gauge group. We can make the metric tensor $g'^{\mu\nu}$ as a bilinear function of $f$-valued vierbein fields.

Inheriting Drechsler’s study, the author has investigated the quantum theory of gravity which has already appeared in Ref.[14]. The most important ingredient of this investigation is that $F$ is a “symmetric space” and then $f$s are satisfied with (2.4). Using this symmetric nature we can pursue making a quantum gauge theory, that is, constructing $g'$-valued Faddeev-Popov ghost (denoted by $C$), anti-ghost (denoted by $\overline{C}$), gauge fixing (denoted by $B$), anti-gauge fixing (denoted by $\overline{B}$), gaugeon (denoted by $G_1$) and its pair field (denoted by $G_2$) as composite fusion fields of $f$-valued gauge fields “$\theta$” by use of (2.4) and also naturally inducing BRS-invariance among them. In this way these six kinds of fusion fields are made of $f$-valued vierbein fields. Here let us call these six fields together “six-fields-set” : \{ $C, \overline{C}, B, \overline{B}, G_1, G_2$ \}

Comparing with such a scheme of gravity, let us consider the Yang-Mills gauge theories. Usually when we make the Lagrangian density $\mathcal{L} = tr(\mathcal{F} \wedge \mathcal{F}^*)$ ($\mathcal{F}$ is a field strength of the Yang-Mills fields), we must borrow a metric tensor $g'^{\mu\nu}$ from gravity to get $\mathcal{F}^*$ and also for Yang-Mills gauge fields to propagate in the 4-dimensional real space-time. This fact seems to mean that “there is a hierarchy between gravity and other three gauge fields (electromagnetic, strong, and weak) and gravity has the outstanding position compared with others”. But is it really the case? As an alternative thought let us think that all kinds of gauge fields are “equal”. Then it would be natural for the question to arise : “What kind of equality is that?” In other words, it is the question that “What is the minimum structure of the gauge mechanism which four kinds of forces are commonly equipped with?”. For answering this question, let us begin from making an assumption :

“Gauge fields are Cartan connections equipped with Soldering Mechanism.”
In this meaning four gauge fields are all equal. In this scheme three gauge fields except gravity are also able to have their own metric tensors “$g^a_{\mu\nu}$” (where $a$ means electromagnetic, strong and weak.) and to propagate in the real space-time without the help of gravity. Such a model has already investigated in Ref.[14].

Let us discuss them briefly. It is found that there are four types of sets of classical groups with small dimensions which admit (2.1~4), that is, $F = SO(1,4)/SO(1,3)$, $SU(3)/U(2)$, $SL(2,C)/GL(1,C)$ and $SO(5)/SO(4)$ with $dim F = 4[17]$. Note that the quality of “dimension : 4” is very important because it guarantees $F$ to solder to 4-dimensional real space-time and all gauge fields to work in it. The model of $F = SO(1,4)/SO(1,3)$ for gravity is already mentioned. Concerning other gauge fields, it seems to be appropriate to assign $F = SU(3)/U(2)$ to QCD gauge fields, $F = SL(2,C)/GL(1,C)$ to QED gauge fields and $F = SO(5)/SO(4)$ to weak interacting gauge fields (as is well known, $SO(4)$ is locally isomorphic with $SU(2) \otimes SU(2)$, which we set as $SU(2)_L \otimes SU(2)_R$). It is noted that four kinds of $g'$-valued gauge fields have each six-fields-set of their own, with the help of which and also with $g^a_{\mu\nu}$ ($i = gravitational$, electromagnetic, strong, and weak) they can propagate all over the universe. And also it is memorable that our model expects that the six-fields-set is not merely the mathematical tool for BRS-invariance but really exist at every point of the universe (speculatively in the cube of (Plank length)$^3$). Then massless scalar fields such as $\{ C, C\bar{C}, B, \bar{B}, G_1, G_2 \}$ cause the “repulsive forces” at every points of the universe. Especially fermionic scalars of $C$ and $\overline{C}$ may be thought to have generated huge short distant repulsive forces at the very early Universe by Pauli Exclusion Principle. Therefore they are possibly candidates for “Dark Energy”.

Concerning matter fields, they couple to $g'$-valued gauge fields. As for QCD, matter fields couple to the gauge fields of $U(2)$ subgroup but $SU(3)$ contains, as is well known, three types of $SU(2)$ subgroups and then after all they couple to all members of $SU(3)$ gauge fields. In case of QED, $GL(1,C)$ is locally isomorphic with $C^4 \cong U(1) \otimes R$. Then usual Abelian gauge fields are assigned to $U(1)$ subgroup of $GL(1,C)$. Georgi and Glashow suggested that the reason why the electric charge is quantized comes from the fact that $U(1)$ electromagnetic gauge group is a unfactorized subgroup of $SU(5)[18]$. Our model is in the same situation because $GL(1,C)$ is an unfactorized subgroup of $SL(2,C)$. For usual electromagnetic $U(1)$ gauge group, the electric charge unit “$e$”($e > 0$) is for one generator of $U(1)$ but in case of $SL(2,C)$ which has six generators, the minimal unit of electric charge shared per one generator must be
"\textit{e/6}". This suggests that quarks and leptons might have the substructure simply because \(e, 2e/3, e/3 > e/6\). Finally as for weak interactions we adopt \(F = SO(5)/SO(4)\). As is stated above, \(SO(4)\) is locally isomorphic with \(SU(2) \otimes SU(2)\). Therefore it is reasonable to think it the left-right symmetric gauge group: \(SU(2)_L \otimes SU(2)_R\). As two \(SU(2)\)s are direct product, they are able to have coupling constants \((g_L, g_R)\) independently. This is convenient to explain the fact of the disappearance of right-handed weak interactions in the low-energy region. Possibility of composite structure of quarks and leptons suggested by above mentioned \(SL(2,C)\)-QED would introduce the thought that the usual left-handed weak interactions are intermediated by massive composite vector bosons (usually denoted by \(W, Z\)) same as \(\rho\)-meson in QCD and that they are residual interactions due to substructure dynamics of quarks and leptons. The elementary massless gauge fields, as "\textit{connection fields}" , relate intrinsically to the structure of the four dimensional real space-time but on the other hand the composite vector bosons have nothing to do with it. Considering these discussions, we set the assumption:

"All kinds of gauge fields are elementary massless fields, belonging to spontaneously unbroken \(SU(3)_C \otimes SU(2)^h_L \otimes SU(2)^h_R \otimes U(1)_{e.m}\) gauge group and quarks and leptons and \(W, Z\) are all composite objects of the elementary matter fields."

3 Composite model

As discussing in Section 2, the assumption: "The minimal unit of electric charge is \(e/6\)" leads us to think of compositeness of quarks and leptons. However, other several phenomenological facts tempt us to consider a composite model, e.g., repetition of generations, quark-lepton parallelism of weak isospin doublet structure, quark-flavor-mixings, etc. Especially Bjorken[3]'s and Hung and Sakurai[4]'s suggestion of an alternative to usual unified electro-weak gauge theories have invoked many studies of composite models including composite weak bosons[5~11]. Our model stands on the line of those studies. There are two ways to make composite models, that is, "Preons are all fermions." or "Preons are both fermions and bosons," which is denoted by FB-model. The merit of the former is that it can avoid the problem of a quadratically divergent self-mass of elementary scalar fields. However, even in the latter case it is found that such a disease is overcome if both fermions and bosons are the supersymmetric pairs, both of which carry the same quantum numbers except the nature of
Lorentz transformation (spin-1/2 or spin-0)[19]. Pati and Salam have suggested that the construction of a neutral fermionic composite object (neutrino in practice) needs both kinds of preons: fermionic and bosonic, if they carry the same charge for the Abelian gauge or belong to the same fundamental representation for the non-Abelian gauge[20]. This is a very attractive idea for constructing the minimal model. Further, according to the representation theory of Poincaré group both integer and half-integer spin angular momentum occur equally for massless particles[21], and then equal existence of fermionic and bosonic elementary particle may be naturally acceptable. But on the contrary, if nature chooses “fermionic monism”, there must exist the additional special reason to select it. Therefore in this point also, the thought of the FB-model is minimal without any special conditions. Based on such considerations we propose a FB-model:

“Primaldial elementary particles are (spin 1/2)-fermion (denoted by Λ) and (spin 0)-boson (denoted by Θ).”

(Preliminary version of this model has appeared in Ref.[14]). Both have the same electric charge of “e/6” (Maki has first proposed the FB-model with the minimal electric charge e/6.[22]) \(^1\) and admit the same transformation properties of the fundamental representation (3, 2, 2) under the spontaneously unbroken gauge symmetry of $SU(3)_C \otimes SU(2)_L^h \otimes SU(2)_R^h$ (let us call $SU(2)_L^h \otimes SU(2)_R^h$ “hypercolor gauge symmetry”). Then Λ and Θ come into the supersymmetric pair which guarantees ’tHooft’s naturalness condition[23]. The $SU(3)_C$, $SU(2)_L^h$ and $SU(2)_R^h$ gauge fields cause the confining forces with confining energy scales of Λ\(_c\) << Λ\(_L\) < (or \(\cong\)) Λ\(_R\) (Schrempp and Schrempp discussed this issue elaborately in Ref.[11]). Here we call positive-charged primons (Λ, Θ) “matter” and negative-charged primons (Λ, Θ) “antimatter”. Our final goal is to build quarks, leptons and W, Z from Λ (Λ) and Θ (Θ). Let us discuss that scenario next. At the very early stage of the development of the universe, the matter fields (Λ, Θ) and their antimatter fields (Λ, Θ) must have been created from the vacuum. After that they would have combined with each other as the universe was expanding. That would be the first step of the existence of composite objects, which we call “subquark”. There are ten types of them:

\(^1\)The notations of Λ and Θ are inherited from those in Ref.[22]. After this we call Λ and Θ “Primon” named by Maki which means “primordial particle”[22].
In this step the confining forces are, in kind, in $SU(3) \otimes SU(2)_L^h \otimes SU(2)_R^h$ gauge symmetry but the $SU(2)_L^h \otimes SU(2)_R^h$ confining forces must be main because of the energy scale of $\Lambda_L, \Lambda_R >> \Lambda_c$ and then the color gauge coupling $\alpha_s$ and e.m. coupling constant $\alpha$ are negligible. As is well known, the coupling constant of $SU(2)$ confining force are generally characterized by $\varepsilon_i = \sum_a \sigma_p^a \sigma_q^a$, where $\sigma$s are $2 \times 2$ matrices of $SU(2)$, $a = 1, 2, 3$, $p, q = \Lambda, \bar{\Lambda}, \Theta, \bar{\Theta}$, $i = 0$ for singlet and $i = 3$ for triplet. They are calculated as $\varepsilon_0 = -3/4$ which causes the attractive force and and $\varepsilon_3 = 1/4$ causing the repulsive force. Next, $SU(3)_C$ octet and sextet states are repulsive but singlet, triplet and antitriplet states are attractive and then the formers are disregarded. Like this, two primons are confined into composite objects in more than one singlet state of any $SU(3)_C, SU(2)_L, SU(2)_R$ as appeared in (3.1∼3.3). Note that three primon systems cannot make the singlet states of $SU(2)$ and we omit them. In (3.2), the $(1, 1, 1)$-state is the “most attractive channel”. Therefore $(\Lambda \bar{\Theta}), (\bar{\Lambda} \Theta), (\Lambda \Lambda)$ and $(\Theta \bar{\Theta})$ of $(1, 1, 1)$-states with neutral e.m. charge must have been most abundant in the universe. Further $(\bar{3}, 1, 1)$- and $(3, 1, 1)$-states in (3.1) and (3.3) are next attractive. They presumably go into $\{((\Lambda \Theta)(\bar{\Lambda} \bar{\Theta}))\}, \{((\Lambda \Lambda)(\bar{\Lambda} \bar{\Theta}))\}$, etc. of $(1, 1, 1)$-states with neutral e.m. charge. Then these objects may be the candidates for the “Cold Dark Matter” if they have tiny masses. Namely it may be said that “Dark Matter is subquark.” It is presumable that the ratio of the quantities between the ordinary matters and the dark matters firstly depends on the color and hypercolor charges and the quantity of dark matter greatly surpasses that of the ordinary matter (maybe the ratio is around $1/(2 \times 3)$).

Finally the $(*, 3, 1)$-and $(*, 1, 3)$-states are remained $(*$ is $1, 3, \bar{3})$. They are also stable because $|\varepsilon_0| > |\varepsilon_3|$. These subquarks are, so to say, the “intermediate clusters” towards constructing ordinary matters (quarks, leptons and $W, Z$) \(^2\) and are denoted as follows:

$\alpha = (\Lambda \Theta)$

$\alpha_L : (\bar{3}, 3, 1) \quad \alpha_R : (\bar{3}, 1, 3)$

$$\begin{align*}
\text{spin} & \quad \text{spin}0 & \quad \text{e.m.charge} & \quad \text{Y.M.representation} \\
\Lambda \Theta & \quad \Lambda \Lambda, \Theta \Theta & \quad \frac{1}{3}e & \quad (\bar{3}, 1, 1) \quad (\bar{3}, 3, 1) \quad (\bar{3}, 1, 3), & \quad (3.1) \\
\Lambda \bar{\Theta}, \bar{\Lambda} \Theta & \quad \Lambda \bar{\Lambda}, \Theta \bar{\Theta} & \quad 0 & \quad (1, 1, 1) \quad (1, 3, 1) \quad (1, 1, 3), & \quad (3.2) \\
\Lambda \bar{\Theta} & \quad \Lambda \bar{\Lambda}, \Theta \bar{\Theta} & \quad -\frac{1}{3}e & \quad (3, 1, 1) \quad (3, 3, 1) \quad (3, 1, 3). & \quad (3.3)
\end{align*}$$

\(^2\)Such thoughts have been first proposed by Maki in Ref.[22].
\( \beta = (\Lambda \overline{\Theta}) \quad \beta_L : (1, 3, 1) \quad \beta_R : (1, 1, 3) \quad \frac{1}{2} \quad 0 \)  
(3.5)

\[ x = (\Lambda \Lambda, \Theta \Theta) \quad x_L : (3, 3, 1) \quad x_R : (3, 1, 3) \quad 0 \quad \frac{1}{3} e \]  
(3.6)

\[ y = (\Lambda \overline{\Lambda}, \Theta \overline{\Theta}) \quad y_L : (1, 3, 1) \quad y_R : (1, 1, 3) \quad 0 \quad 0 \]  
(3.7)

and there are also their anti-subquarks\(^3\).

Now we come to the step to build quarks, leptons and \( W, Z \). The gauge symmetry of the confining forces in this step is also \( SU(2)_L^h \otimes SU(2)_R^h \) because the subquarks are in the triplet states of \( SU(2)_L^h \) and then they are combined into singlet states by the decomposition of \( 3 \otimes 3 = 1 \oplus 3 \oplus 5 \) in \( SU(2) \). We make the first generation of quarks and leptons as follows:

| e.m.charge | Y.M.representation |
|------------|-------------------|
| \(< u_l | = < \alpha_l x_l | \) | \( \frac{2}{3} e \) | \( (3, 1, 1) \) |
| \(< d_l | = < \overline{\alpha_l} \overline{x_l} | \) | \( -\frac{1}{3} e \) | \( (3, 1, 1) \) |
| \(< \nu_l | = < \alpha_l x_l | \) | 0 | \( (1, 1, 1) \) |
| \(< e_l | = < \overline{\alpha_l} \overline{x_l} | \) | \( -e \) | \( (1, 1, 1) \) |

where \( l \) stands for \( L \) (left handed) or \( R \) (right handed).\(^4\) Here we note that \( \beta \) and \( y \) do not appear. In practice \( (\beta y) : (1, 1, 1) \)-particle is a candidate for neutrino. But as Bjorken has pointed out\(^3\), non-vanishing charge radius of neutrino is necessary for obtaining the correct low-energy effective weak interaction Lagrangian\(^1\). Therefore \( \beta \) is assumed not to contribute to forming ordinary quarks and leptons. However \( (\beta y) \)-particle may be a candidate for “sterile neutrino”. Presumably composite \( (\beta \overline{\beta}) \); \( (\beta \overline{\beta}) \); -; \( (\overline{\beta} \overline{\beta}) \)-states may go into the dark matters. It is also noticeable that in this model the leptons have finite color charge radius and then \( SU(3) \) gluons interact directly with the leptons at energies of the order of, or larger than \( \Lambda_L \) or \( \Lambda_R \).\(^4\)

Concerning the confinement of primon-level or subquark-level, the confining forces of these levels are controled by the same spontaneously “unbroken” \( SU(2)_L^h \otimes SU(2)_R^h \) gauge symmetry. It is known that the running coupling constant of the \( SU(2) \) gauge symmetry

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\(^3\)The notations of \( \alpha, \beta, x \) and \( y \) are inherited from those in Ref.[9] written by Fritzsch and Mandelbaum, because ours is, in the subquark level, similar to theirs with two fermions and two bosons. R. Barbieri, R. Mohapatra and A. Masiero proposed the similar model\([9]\).

\(^4\)Subquark configurations in (3.8;9;10;11) are essentially the same as those in Ref.[5] written by Królickowski, who proposed the model of one fermion and one boson with the same e.m. charge \( e/3 \).
theory satisfies the following equation:

\[
\frac{1}{\alpha_W(Q_1^2)} = \frac{1}{\alpha_W(Q_2^2)} + b_a \ln \left( \frac{Q_1^2}{Q_2^2} \right),
\]

(3.12)

\[
b_a = \frac{1}{4\pi} \left( \frac{22}{3} - \frac{2}{3} \cdot N_f - \frac{1}{12} \cdot N_s \right),
\]

(3.13)

where \( N_f \) and \( N_s \) are the numbers of fermions and scalars contributing to the vacuum polarizations, \((a = q)\) for the confined subquarks in quark and \((a = sq)\) for confined primons in subquark and \(Q_{1,2}^2\) is the effective four momentum square of \( g_b \)-exchange.

We calculate \( b_q = 0.35 \) which comes from that the number of confined fermionic sub-quarks are 4 \((\alpha_i, i = 1, 2, 3)\) for color freedom, \( \beta \) and 4 for bosons \((x_i, y)\) contributing to the vacuum polarization, and \( b_{sq} = 0.41 \) which is calculated with three kinds of \( \Lambda \) and \( \Theta \) owing to three color freedoms. Experimentally it is reported that \( \Lambda_q > 1.8 \) TeV (CDF exp.) or \( \Lambda_q > 2.4 \) TeV (DØ exp.) [12]. Extrapolations of \( \alpha_W^q \) and \( \alpha_W^{sq} \) to near Plank scale are expected to converge to the same point and then tentatively, setting \( \Lambda_q = 5 \) TeV, \( \alpha_W^q(\Lambda_q) = \alpha_W^{sq}(\Lambda_{sq}) = \infty \), we get \( \Lambda_{sq} = 10^3 \Lambda_q \).

Next let us see the higher generations. Harari and Seiberg have stated that the orbital and radial excitations seem to have the wrong energy scale (order of \( \Lambda_{L,R} \)) and then the most likely type of excitations is the addition of primon-antiprimon pairs [6,25]. In our model the essence of generation is like “isotope” in case of atoms. Then using neutral \( y_{L,R} \) in (3.7) we construct them as follows:

\[
\begin{align*}
\{ <c| &= <\alpha xy| \\
< s| &= <\alpha xxy| \\
< t| &= <\alpha xyy| \\
< b| &= <\alpha xyy|
\end{align*}
\]

2nd generation

\[
\begin{align*}
\{ <\nu| &= <\alpha xy| \\
< \mu| &= <\alpha xxy| \\
< \tau| &= <\alpha xyy|
\end{align*}
\]

3rd generation

where the suffix \( L,R \)s are omitted for brevity. We can also make vector and scalar particles with \((1,1,1)\):

\[
\begin{align*}
\{ <W^+| &= <\alpha^+\alpha^+x| \\
< W^-| &= <\alpha^+\alpha^+\bar{x}| \\
< S^+| &= <\alpha^+\alpha^+x| \\
< S^-| &= <\alpha^+\alpha^+\bar{x}|
\end{align*}
\]

Vector

\[
\begin{align*}
\{ <\!\!\!\!\!\!\!\!\!\!\!\!\!\!(Z^0_1 | &= <\alpha^+\alpha^+| \\
<\!\!\!\!\!\!\!\!\!\!\!\!\!\!(Z^0_2 | &= <\alpha^+\alpha^+x| \\
<\!\!\!\!\!\!\!\!\!\!\!\!\!\!(S^0_1 | &= <\alpha^+\alpha^+| \\
<\!\!\!\!\!\!\!\!\!\!\!\!\!\!(S^0_2 | &= <\alpha^+\alpha^+x|
\end{align*}
\]

Scalar

where the suffix \( L,R \)s are omitted for brevity and \( \uparrow, \downarrow \) indicate spin up, spin down states. They play the role of intermediate bosons same as \( \pi, \rho \) in the strong interactions. As (3.8~11) and (3.16;17) contain only \( \alpha \) and \( x \) subquarks, we can draw the “line diagram” of weak interactions as seen in Fig (1). Equation (3.11) shows that
the electron is constructed from antimatters only. Therefore electrons are totally not matters but antimatters. Actually we don't know the exact reason why “ electron is matter ” and this is merely the assumption. We know, phenomenologically, that this universe is mainly made of protons, electrons, neutrinos, antineutrinos and unknown dark matters. It is said that the universe contains almost the same number of protons and electrons. Our model show that one proton has the configuration of \((uuu) : (2\alpha, \pi, 3\pi, \bar{x})\); electron: \((\bar{\pi}, 2\pi)\); neutrino: \((\alpha, \bar{x})\); antineutrino: \((\bar{\pi}, \bar{x})\) and the dark matters are constructed from the same amount of matters and antimatters because of their neutral charges. Note that proton is a mixture of matters and anti-matters and electrons is composed of anti-matters only. These ideas may lead the thought that

“The universe is the matter-antimatter-even object.” And then there exists a conception-leap between “proton-electron abundance” and “matter abundance” if our composite scenario is admitted (as for the possible way to realize the proton-electron excess universe, see Ref.[14]). This idea is different from the current thought that the universe is made of matters only. Then in our model the problem about CP violation in the early universe does not occur.

Our composite model contains two steps, namely the first is “subquarks made of primons” and the second is “quarks and leptons made of subquarks”. Here let us discuss about the mass generation mechanism of quarks and leptons as composite objects. Our model has only one kind of fermion : \(\Lambda\) and boson : \(\Theta\). The first step of “subquarks made of primons” seems to have nothing to do with 'tHooft’s anomaly matching condition[23] because there is no global symmetry with \(\Lambda\) and \(\Theta\). Therefore from this line of thought it is impossible to say anything about that \(\alpha, \beta, x\) and \(y\) are massless or massive. However, if it is the case that the neutral \((1,1,1)\)-states of primon-antiprimon composites (as is stated above) construct the dark matters, the masses of them are presumably less than the order of MeV from the phenomenological aspects of astrophysics. Then we may assume that these subquarks are massless or almost massless compared with \(\Lambda_{L,R}\) in practice, that is, utmost a few MeV. In the second step, the arguments of 'tHooft’s anomaly matching condition are meaningful. The confining of subquarks must occur at the energy scale of \(\Lambda_{L,R} >> \Lambda_{c}\) and then it is natural that \(\alpha_s, \alpha \to 0\) and that the gauge symmetry group is the spontaneously unbroken \(SU(2)_L \otimes SU(2)_R\) gauge group. Seeing (3.8∼11), we find quarks and leptons are composed of the mixtures of subquarks and antisuquarks. Therefore it is proper to regard subquarks and antisubquarks as different kinds of particles. From (3.4;5) we find eight kinds of fermionic subquarks (3 for \(\alpha, \bar{\pi}\) and 1 for \(\beta, \bar{\beta}\)). So the global
symmetry concerned is $SU(8)_L \otimes SU(8)_R$.

Then we arrange:

$$\left( \beta, \overline{\beta}, \alpha_i, \overline{\alpha}_i \right)_{L,R} \in (SU(8)_L \otimes SU(8)_R)_{global}, \quad (3.18)$$

where $i$ is color freedom. Next, the fermions in (3.18) are confined into the singlet states of the local $SU(2)_L \otimes SU(2)_R$ gauge symmetry and make up quarks and leptons as seen in (3.8~11) (eight fermions).

Then we arrange:

$$\left( \nu_e, e, u, d \right)_{L,R} \in (SU(8)_L \otimes SU(8)_R)_{global}, \quad (3.19)$$

where $i$ is color freedom. From (3.18) and (3.19) the anomalies of the subquark level and the quark-lepton level are matched and then all composite quarks and leptons (in the 1st generation) are remained massless or almost massless. Note again that presumably, $\beta$ and $\overline{\beta}$ in (3.18) are composed into “bosonic” $(\beta\beta)$, $(\beta\overline{\beta})$ and $(\overline{\beta}\overline{\beta})$, which vapour out to the dark matters. Schrempp and Schrempp have discussed about a confining $SU(2)_L \otimes SU(2)_R$ gauge model with three fermionic preons and stated that it is possible that not only the left-handed quarks and leptons are composite but also the right-handed ones are so on the condition that $\Lambda_R/\Lambda_L \sim O(10^3)$[11]. As seen in (3.16) the existence of composite $W_R, Z_R$ is predicted. As concerning, the fact that they are not observed yet means that the masses of $W_R, Z_R$ are larger than those of $W_L, Z_L$ because of $\Lambda_R > \Lambda_L$. Owing to 'tHooft’s anomaly matching condition the small mass nature of the 1st generation comparing to $\Lambda_L$ is guaranteed but the evidence that the quark masses of the 2nd and the 3rd generations become larger as the generation numbers increase seems to have nothing to do with the anomaly matching mechanism in our model, because, as seen in (3.11;12), these generations are obtained by just adding neutral scalar y-particles. This is different from Abott and Farhi’s model in which all fermions of three generations are equally embedded in $SU(12)$ global symmetry group and all members take part in the anomaly matching mechanism[8,26]. Equation (3.16;17) shows that the difference in $Z^0$ and $S^0$ essentially originates from the combination of two spins (up-spin and down-spin) of $\alpha$- and $\overline{\alpha}$-subquark. $S^0$ has the combination of up- and down-spin and $Z^0$ has that of up- and up-spin. This situation is similar to hadronic mesons. They are the composite objects of a quark($q$) and a anti-quark($\overline{q}$). namely, $\rho-\pi$, $K^*-K$, $D^*-D$, $B^*-B$. Each vector meson mass (denoted by $M(V)$) is larger than the mass (denoted by $M(Ps)$) of its pseudo-scalar partner. The mass differences between $M(V)$ and $M(Ps)$ are qualitatively explained.
by the hyperfine spin-spin interaction in Breit-Fermi Hamiltonian[28]. As the model of the hadronic mass spectra by the Breit-Fermi Hamiltonian is described by use of the semi-relativistical approach, it has some defects in the quantitative estimations, especially in the small mass mesons (such as $\rho$-$\pi$ and $K^*$-$K$) but qualitatively it is not so bad, namely the explanation of the fact that: $M(V) > M(Ps)$(and else $M(J = 3/2 \text{ baryon}) > M(J = 1/2 \text{ baryon})$). The hyperfine interaction Hamiltonian(denoted by $H_{q\bar{q}}^l$) causing mass split between $M(V)$ and $M(Ps)$ is described as:

$$H_{q\bar{q}}^l = -\frac{8\pi}{3m_qm_{\bar{q}}} \vec{S}_q \vec{S}_{\bar{q}} \delta(|\vec{r}'|),$$

where $\vec{S}_{q(\bar{q})}$ is a operator of $q(\bar{q})$'s spin with its eigenvalue of $1/2$ or $-1/2$, $m_q$($m_{\bar{q}}$) is quark (anti-quark) mass, $l$ is the orbital angular momentum between $q$ and $\bar{q}$ and $|\vec{r}'| = |\vec{r}'_q - \vec{r}'_{\bar{q}}|[28].$

In QCD theory eight gluons are intermediate gauge bosons belonging to 8 representation which is real adjoint representation. Quarks(anti-quarks) belong to $3(\bar{3})$ representation which is complex fundamental representation. Therefore gluons can discriminate between quarks and anti-quarks and couple to them in the "opposite sign". The strength of their couplings to different color quarks and anti-quarks is described as:

$$+\frac{g\lambda^a_{ij}}{2} : \text{ for quark}$$

$$-\frac{g\lambda^a_{ij}}{2} : \text{ for anti - quark},$$

where $a(=1 \sim 8)$ : gluon indices; $i, j(=1, 2, 3)$ : quark indices; $\lambda$'s : SU(3) matrices and $g$ : the coupling constant of gluons to quarks and anti-quarks(See Fig.(3)). The wave function of a color singlet $q\bar{q}$(meson) system is $\delta_{ij}/\sqrt{3}$, corresponding to:

$$|q\bar{q} > = (1/\sqrt{3})\sum_{i=1}^{3} |q_i\bar{q}_i >.$$

By use of (3.22) the effective coupling for the $q\bar{q}$ system(denoted by $\alpha_s$) is given by:

$$\alpha_s = \sum_{a,b} \sum_{i,j,k,l} \frac{1}{\sqrt{3}} \delta_{ij} \left( \frac{g}{2} \lambda^a_{ik} \right) \left( -\frac{g}{2} \lambda^b_{lj} \right) \frac{1}{\sqrt{3}} \delta_{kl} = -\frac{g^2}{12} \sum_{a,b,j,l} \lambda^a_{ij} \lambda^b_{lj}$$

$$= -\frac{g^2}{12} \sum_{a,b} \text{Tr} \left( \lambda^a \lambda^b \right) = -\frac{g^2}{6} \sum_{ab} \delta_{ab}$$

$$= -\frac{4}{3} g^2.$$
Making use of (3.22) and (3.23) let us write the quasi-static Hamiltonian for a bound state of a quark and an anti-quark is given as:

\[ H = H_0 + \alpha_s H_{q\bar{q}}^{\text{iso}}. \]  

(3.24)

Calculating the eigenvalue of \( H \) in (3.24) we have:

\[ M(\text{VorS}) = M_0 + \xi_q < \bar{S}_q S_{\bar{q}} >, \]  

(3.25)

where \( \xi_q \) is a positive constant which includes the calculation of \( \alpha_s \). In (3.25) it is found that \( < \bar{S}_q S_{\bar{q}} > = -3/4 \) for pseudoscalar mesons and \( < \bar{S}_q S_{\bar{q}} > = 1/4 \) for vector mesons and then we have:

\[ M(\text{Ps}) = M_0 - \frac{3}{4} \xi_q \]
\[ M(\text{V}) = M_0 + \frac{1}{4} \xi_q. \]  

(3.26)

By (3.26) it is resulted that:

\[ M(\text{V}) > M(\text{Ps}). \]  

(3.27)

Here let us turn discussions to “intermediate weak bosons”. As seen in (3.16;17) \( Z^0 \) weak boson has its scalar partner \( S^0 \) and both of them contain “fermionic” \( \alpha_L \) and \( \bar{\alpha}_L \) as subquark elements. Referring(3.4) we find that both of \( \alpha_L \) and \( \bar{\alpha}_L \) belong to “adjoint 3” state of \( SU(2)_L \) (which is the real representation) and then \( SU(2)_L \)-hypercicolor gluons cannot distinguish \( \alpha_L \) from \( \bar{\alpha}_L \). Therefore the hypercolor gluons couple to \( \alpha_L \) and \( \bar{\alpha}_L \) in the “same sign”. This point is distinguishably different from hadronic mesons (Refer (3.21)). The wave function of a hypercolor singlet \((\alpha\bar{\alpha})\)-system is \( \delta_{ij}/\sqrt{3} \), corresponding to \( |\alpha_i\bar{\alpha}_i> = (1/\sqrt{3})\sum_{i=1}^{3}|\alpha_i\bar{\alpha}_i> \) where \( i = 1, 2, 3 \) are different three states of the triplet of \( SU(2)_L \). The strength of their couplings to different hypercolor subquarks and anti-subquarks is described as:

\[ +g_h \frac{\tau_{ij}}{2} : \] for subquark
\[ +g_h \frac{\tau_{ij}}{2} : \] for anti-subquark,

(3.28)

where \( a(=1,2,3) \) : hypercolor gluon indices; \( i,j(=1,2,3) \) : subquark and anti-subquark indices and \( \tau : SU(2) \) matrices and \( g_h \) : the coupling constant of hyper- gluons to the subquarks and anti-subquarks(See Fig.(3)). By use of (3.28) the effective
coupling (denoted by $\alpha_W$) is given by:

$$\alpha_W = \sum_{a,b} \sum_{i,j,k,l} \frac{1}{\sqrt{3}} \delta_{ij} \left( \frac{g_h}{2} \tau^a_{ik} \right) \left( \frac{g_h}{2} \tau^b_{lj} \right) \frac{1}{\sqrt{3}} \delta_{kl} = \frac{g^2}{12} \sum_{a,b} \sum_{j,l} \tau^a_{jl} \tau^b_{lj}$$

$$= \frac{1}{2} \sqrt{\frac{2}{g_h}}, \quad (3.29)$$

where $a, b = 1, 2, 3; i, j, k, l = 1, 2, 3$. Note that $\alpha_s$ (in (3.23)) is “negative” but $\alpha_W$ (in (3.29)) “positive”. Through the same procedure as hadronic mesons the masses of $Z^0$ and $S^0$ are described as:

$$M(Z^0 \text{ or } S^0) = M_0 - \xi_{sq} < \overline{S}_\alpha \overline{S}_\pi >,$$  \hspace{1cm} (3.30)

where $\xi_{sq}$ is a positive constant which includes the calculation of $\alpha_W$ and $\overline{S}_\alpha(\pi)$ is the spin operator of $\alpha(\pi)$. In (3.30) it is calculated that $< \overline{S}_\alpha \overline{S}_\pi > = -3/4$ for scalar : $S^0$ and $< \overline{S}_\alpha \overline{S}_\pi > = 1/4$ for vector : $Z^0$ and then we get:

$$M(S^0) = M_0 + \frac{3}{4} \xi_{sq}$$

$$M(Z^0) = M_0 - \frac{1}{4} \xi_{sq}. \quad (3.31)$$

From this it follows that:

$$M(S^0) > M(Z^0). \quad (3.32)$$

Here let us define:

$$\bar{M} = \frac{1}{2} \left( M(S^0) + M(Z^0) \right),$$

$$\Delta = M(S^0) - M(Z^0),$$

$$R = \frac{\Delta}{\bar{M}}. \quad (3.33)$$

Experimentally it is reported : $M(Z^0) = 91$GeV[24], with which by use of (3.33) we obtain:

$$R = 0.2 \quad M(S^0) \approx 110 \text{ GeV},$$

$$R = 0.3 \quad M(S^0) \approx 120 \text{ GeV}. \quad (3.34)$$

Therefore if the existence of the scalar particle whose mass is a little above $Z^0$‘s mass is confirmed in future it may be a scalar partner of $Z^0$ and that might suggest the possibility of the subquark structure.
One of the experimental evidences inspiring the SM is the “universality” of the coupling strength among the weak interactions. Of course if the intermediate bosons are gauge fields, they couple to the matter fields universally. But the inverse of this statement is not always true, namely the quantitative equality of the coupling strength of the interactions does not necessarily imply that the intermediate bosons are elementary gauge bosons. In practice the interactions of $\rho$ and $\omega$ are regarded as indirect manifestations of QCD. In case of chiral $SU(2) \otimes SU(2)$ the pole dominance works very well and the predictions of current algebra and PCAC seem to be fulfilled within about 5%[19]. Fritzsch and Mandelbaum[9][19] and Gounaris, Kögerler and Schildknecht[10][27] have elaborately discussed about universality of weak interactions appearing as a consequence of current algebra and W-pole dominance of the weak spectral functions from the stand point of the composite model. Extracting the essential points from their arguments we mention our case as follows. In the first generation let the weak charged currents be written in terms of the subquark fields as:

$$
J^+_{\mu} = \mathcal{U} h_{\mu} D, \quad J^-_{\mu} = \mathcal{D} h_{\mu} U,
$$

(3.35)

where $U = (\alpha x)$, $D = (\overline{\alpha x})$ and $h_{\mu} = \gamma_{\mu}(1 - \gamma_5)$. Reasonableness of (3.35) may given by the fact that $M_W << \Lambda_{L,R}$ (where $M_W$ is W-boson mass). Further, let $U$ and $D$ belong to the doublet of the global weak isospin $SU(2)$ group and $W^+, W^-$, $(1/\sqrt{2})(Z_1^0 - Z_2^0)$ be in the triplet and $(1/\sqrt{2})(Z_1^0 + Z_2^0)$ be in the singlet of $SU(2)$. These descriptions seem to be natural if we refer the diagrams in Fig.(1). The universality of the weak interactions are inherited from the universal coupling strength of the algebra of the global weak isospin $SU(2)$ group with the assumption of $W^-, Z$-pole dominance. The universality including the 2nd and the 3rd generations are investigated in the next section based on the above assumptions and in terms of the flavor-mixings.

4 Flavor-mixing matrix element by subquark dynamics

The quark-flavor-mixings in the weak interactions are usually expressed by Cabbibo-Kobayashi-Maskawa (CKM) matrix based on the SM. Its nine matrix elements (in case of three generations) are ”free” parameters (in practice four parameters with the unitarity) and this point is said to be one of the drawbacks of the SM along with the origins of the quark-lepton mass spectrum and generations. In the SM, the quarks
and leptons are elementary and then we are able to investigate, at the utmost, the external relationship among them. On the other hand if quarks are the composites of substructure constituents, the quark-flavor-mixing phenomena must be understood by the substructure dynamics and the values of CKM matrix elements become materials for studying these. Terazawa and Akama have investigated quark-flavor-mixings in a three spinor subquark model with higher generations of radially excited state of the up (down) quark and stated that a quark-flavor-mixing matrix element is given by an overlapping integral of two radial wave functions of the subquarks which depends on the momentum transfer between quarks[13][31].

In our model we set the assumption:

*The quark-flavor-mixings occur by creation (or annihilation) of y-particles from(or into) vacuum inside quarks.*

The y-particle is a neutral scalar subquark in the 3-state of SU(2)$_L$ group (as seen in(3.7)). and then couples to two hypercolor gluons (denoted by $g_h$) (see Fig.(2)). This is analogous to $\pi^0 \rightarrow 2\gamma$.

Here we propose the another important assumption:

*The (y → 2$g_h$)-process is factorized from the net W$^\pm$ exchange interactions.*

This assumption is plausible because the effective energy of this process may be in a few TeV energy region comparing to a hundred GeV energy region of W-exchange processes. Let us write the contribution of (y → 2$g_h$)-process to charged weak interactions as:

$$A_i = \alpha_W^2 (Q_i^2)^2 \cdot B \quad \quad i = s,c,b,t,$$

where $\alpha_W$ is a running coupling constant of the hypercolor gauge theory appearing in (3.12) , $Q_i$ is the effective four momentum of $g_h$-exchange among subquarks inside the i-quark and $B$ is a dimensionless “complex” free parameter originated from the unknown prion dynamics and may depend on $< 0|f(\LambdaΩ\Lambda, and/or, \overline{Ω}Ω)|y >$ (Ω is some operator).

The weak charged currents of quarks are taken as the matrix elements of subquark currents between quarks which are not the eigenstates of the weak isospin[13]. Using
(3.14;15), (3.18) and (4.1) with the above assumption we have:

\[
\begin{align*}
V_{ud} \bar{u}h_\mu d &= <u|\bar{U}h_\mu D|d>, \\
V_{us} \bar{u}h_\mu s &= <u|\bar{U}h_\mu (Dy)|s> \geq <u|\bar{U}h_\mu D|s> \cdot A_s, \\
V_{ub} \bar{u}h_\mu b &= <u|\bar{U}h_\mu (Dyy)|b> \geq <u|\bar{U}h_\mu D|b> \cdot 2A_b^2, \\
V_{cd} \bar{c}h_\mu d &= <c|\bar{U}h_\mu D|d> \geq <c|\bar{U}h_\mu D|d> \cdot A_c, \\
V_{cs} \bar{c}h_\mu s &= <c|\bar{U}h_\mu (Dy)|s>, \\
V_{cb} \bar{c}h_\mu b &= <c|\bar{U}h_\mu (Dyy)|b> \geq <c|\bar{U}h_\mu (Dy)|b> \cdot A_b, \\
V_{td} \bar{t}h_\mu d &= <t|\bar{U}y h_\mu (Dy)|d> \geq <t|\bar{U}h_\mu D|d> \cdot 2A_t^2, \\
V_{ts} \bar{t}h_\mu s &= <t|\bar{U}y h_\mu (Dy)|s> \geq <t|\bar{U}h_\mu (Dy)|s> \cdot A_t, \\
V_{tb} \bar{t}h_\mu b &= <t|\bar{U}y h_\mu (Dyy)|b>,
\end{align*}
\]

where \(V_{ij}\)s are flavor-mixing coupling constants (complex number in general), which correspond to CKM-matrices in the SM and \(\{u, d, s, \text{etc.}\}\) in the left sides of the equations are quark-mass eigenstates. Here we need some explanations. In transitions from the 3rd to the 1st generation in (4.4;8) there are two types: One is that two \((y \rightarrow 2\epsilon_h)\)-processes occur simultaneously and the other is that \(y\) annihilates into \(2\epsilon_h\) in a cascade way. Then let us describe the case of (4.4) as:

\[
< u|\bar{U}h_\mu (Dyy)|b> \geq < u|\bar{U}h_\mu (Dy)|b> \cdot A_b + < u|\bar{U}h_\mu (Dy)|b> \cdot A_b \\
\geq < u|\bar{U}h_\mu D|b> \cdot A_b + < u|\bar{U}h_\mu D|b> \cdot A_b \\
= < u|\bar{U}h_\mu D|b> \cdot 2A_b^2.
\]

The case of (4.8) is also same as (4.11). If we admit the assumption of factorizability of \((y \rightarrow 2\epsilon_h)\)-process, it is natural that the universality of the net weak interactions among three generations are realized. The net weak interactions are essentially same as \((u \rightarrow d)\)-transitions(Fig.(1)). Then we may think that:

\[
\begin{align*}
|<u|\bar{U}h_\mu D|d>| &= |<u|\bar{U}h_\mu D|s>| \geq |<u|\bar{U}h_\mu D|b>| \\
&\geq |<c|\bar{U}h_\mu D|d>| \geq |<t|\bar{U}h_\mu D|d>|, \\
|<c|\bar{U}y h_\mu (Dy)|s>| &= |<c|\bar{U}y h_\mu (Dy)|b>| \\
&\geq |<t|\bar{U}y h_\mu (Dy)|s>|.
\end{align*}
\]
and additionally we may assume:

\[ |<u|\bar{U}h_\mu D|d>| \cong |<c|((\bar{U}y)h_\mu (Dy)|s>| \]
\[ \cong |<t|((\bar{U}yy)h_\mu (Dyy)|b>| \]. \tag{4.14} \]

In (4.13) and (4.14) \( y \)-particles are the "spectators" for the weak interactions.

Concerning the left sides of (4.2~4.10), \{ \( \bar{u}h_\mu d, \bar{u}h_\mu s, \) etc. \} operate as the current operators coupling to the \( W \)-boson current when only weak interactions switch on. In our subquark model we think that weak interactions occur as the residual ones among subquarks inside any kinds of quarks. Therefore in this scenario, \{ \( \bar{u}h_\mu d, \bar{u}h_\mu s, \) etc. \} act identically in the weak interactions. Then it seems natural to assume:

\[ \bar{u}h_\mu d = \bar{u}h_\mu s = \bar{u}h_\mu b = \bar{c}h_\mu d = \cdots \]. \tag{4.15} \]

Namely they make equal operations as current operators because \( y \)-particles work as spectators.

Using (4.1~4.10) and (4.12~4.15) we find:

\[ \frac{|V_{us}|}{|V_{ud}|} = |A_s| = \alpha_W^2 (Q_s^2)^2 \cdot |B|, \]
\[ \frac{|V_{cd}|}{|V_{ud}|} = |A_c| = \alpha_W^2 (Q_c^2)^2 \cdot |B|, \]
\[ \frac{|V_{cb}|}{|V_{cs}|} = |A_b| = \alpha_W^2 (Q_b^2)^2 \cdot |B|, \]
\[ \frac{|V_{ts}|}{|V_{cs}|} = |A_t| = \alpha_W^2 (Q_t^2)^2 \cdot |B|, \]
\[ \frac{|V_{tb}|}{|V_{ud}|} = 2|A_b|^2 = 2\{ \alpha_W^2 (Q_b^2)^2 \cdot |B| \}^2, \]
\[ \frac{|V_{td}|}{|V_{ud}|} = 2|A_t|^2 = 2\{ \alpha_W^2 (Q_t^2)^2 \cdot |B| \}^2. \]

Here let us discuss how the substructure dynamics inside quarks generate quark masses. In our composite model quarks are composed of \( \alpha, \mathbf{x}, \mathbf{y} \). As seen in (3.14;15) \( \mathbf{c} \)-quark is composed of three subquarks; \( \mathbf{t} \)-quark : four subquarks; \( \mathbf{s} \)-quarks : four subquarks; \( \mathbf{b} \)-quark : five subquarks. As discussing in Section 3, subquark masses are expected to be almost massless and then it may be thought that quark masses are proportional to the sum of the average kinetic energies of the subquarks (denoted by \( <T_i>, i = \mathbf{s, c, b, t} \)). The proportional constants (denoted by \( K_s \) (\( s = up, down \)), which may depend on details of subquark dynamics) are assumed common in the up
(down)-quark sector and different between the up- and the down-quark sector from the hierarchical pattern of quark masses. According to “Uncertainty Principle” the kinetic energies of the constituent particles moving inside the composite particle are, in general, inversely proportional to the radius of that composite particle. The radii of quarks may be around $1/\Lambda_{L,R}$. So the kinetic energies of subquarks may be more than hundreds GeV. Therefore the masses of quarks may essentially depend on two parts, namely the kinetic energies of subquarks and such a large binding energies as counterbalance them. The $< T_i >$ may be considered in inverse proportion to the average interaction length among subquarks (denoted by $< r_i >$). Further, it is presumable that $\sqrt{Q_i^2}$ ($Q_i$ is the effective four momentum of $g_i$-exchange among subquarks inside the $i$-quark seen in (4.1)) is inversely proportional to $< r_i >$.

Then we have:

$$m_b/m_s = \frac{5K_{down}}{4K_{down}} < T_b > = \frac{5}{4} \cdot \frac{< r_s >}{< r_b >}$$

$$m_t/m_c = \frac{4K_{up}}{3K_{up}} < T_t > = \frac{4}{3} \cdot \frac{< r_c >}{< r_t >}$$

where $m_i$ is the mass of $i$-quark. In the Review of Particle Physics[29] we find: $m_s = 0.095$ GeV; $m_b = 4.2$ GeV; $m_c = 1.25$ GeV; $m_t = 174.2$ GeV, by which we obtain $m_b/m_s = 44.2$ and $m_t/m_c = 139.4$. Using them we get by (4.22;23):

$$\frac{Q_b^2}{Q_s^2} \cong (35.4)^2,$$

$$\frac{Q_t^2}{Q_c^2} \cong (104.5)^2.$$  

Note again that it seems to be meaningless to estimate $Q_s^2/Q_t^2$ or $Q_c^2/Q_b^2$ because the up-quark sector and the down-quark sector possibly have the different aspects of substructure dynamics (that is $K_{up} \neq K_{down}$).

Review of Particle Physics [29] has reported that:

$$|V_{ud}| = 0.9735 \pm 0.0008, \quad |V_{us}| = 0.2196 \pm 0.0023,$$

$$|V_{cd}| = 0.224 \pm 0.016, \quad |V_{ub}| = (41.6 \pm 0.6) \times 10^{-3},$$

$$|V_{cs}| = 1.04 \pm 0.16, \quad |V_{ub}| = (3.84_{-0.19}^{+0.67}) \times 10^{-3},$$

(4.26)
which are “experimental” results without unitarity assumption.

Relating these data to the scheme of our composite model, let us investigate the quark-flavor-mixing phenomena in terms of the subquark dynamics. Using (4.16;18) and $|V_{us}|$, $|V_{cb}|$ in (4.26) we get:

$$\frac{\alpha^q_W(Q_s^2)}{\alpha^q_W(Q_b^2)} = 2.30,$$

where we assume $|V_{ud}| = |V_{cs}|$. Applying $N_f = N_s = 4$ (as is stated in Section 3) to (3.13) we have:

$$b_q = 0.35.$$  

(4.28)

Here we rewrite (3.12) as:

$$\alpha^q_W(Q_1^2) = 1 - \frac{\alpha^q_W(Q_1^2)}{\alpha^q_W(Q_2^2)}.$$  

(4.29)

Inserting the values of (4.24;27;28), into (4.29) we have:

$$\alpha^q_W(Q_s^2) = 0.520,$$

(4.30)

where $Q_s, (Q_b)$ corresponds to $Q_1, (Q_2)$ in (4.29). Combining $|V_{ud}|$, $|V_{us}|$ in (4.26) and (4.30) with (4.16) we obtain:

$$|B| = 0.835,$$

(4.31)

and using (4.30) to (4.27) we get:

$$\alpha^q_W(Q_b^2) = 0.226.$$  

(4.32)

By use of $|V_{ud}|$, $|V_{cd}|$ in (4.26) and (4.31) to (4.17) we have:

$$\alpha^q_W(Q_c^2) = 0.525.$$  

(4.33)

Using (4.25; 28; 33) and setting $t \rightarrow (c)$ to 1 (2) in (4.29) we obtain:

$$\alpha^q_W(Q_t^2) = 0.197.$$  

(4.34)
Inserting (4.31;32), to the right side of (4.20) we have:

$$|V_{ub}| = 3.54 \times 10^{-3}. \quad (4.35)$$

Comparing this with the experimental value of $|V_{ub}|$ in (4.26) the consistency between them seems good.

Finally using (4.31;34) to (4.19;21) we predict:

$$|V_{ts}| = 3.06 \times 10^{-2}, \quad |V_{td}| = 1.92 \times 10^{-3}, \quad (4.36)$$

where we adopt $|V_{ud}| = |V_{cs}| = 0.974$ from (4.26).

Comparing the values of (4.36) with $|V_{ts}| = 0.039 \pm 0.004$ and $|V_{td}| = 0.0085 \pm 0.0045$ [29] obtained by assuming unitarity with three generations, we find that our results are rather smaller than them. The origin of these results is presumably in the fact that "the top-quark mass is heavy." We wish the direct measurements of $(t \rightarrow d, s)$ transitions in leptonic and/or semileptonic decays of top-quark mesons.

So far we have discussed absolute values of $V_{qq'}$ but they are "complex" in principle because $B$ (in (4.1)) is originated from $y$-subquark annihilation(creation) to(from) vacuum. Therefore let us make the definition:

$$< 0 | f(\Lambda\mathcal{O}\overline{\Lambda}, \text{and/or}, \Theta\mathcal{O}\overline{\Theta}) | y > \equiv |B|e^{i\theta}, \quad (4.37)$$

where $\mathcal{O}$ is some operator. Then preparing for discussions in following sections, let the generation-changing flavor-mixing-coupling-constants of $V_{qq'}$ in (4.3~5) and (4.7~9) be parametrized as:

$$V_{us} = \lambda e^{i\delta} \quad V_{cb} = \lambda^2 e^{i\delta} \quad V_{ub} = \lambda^3 e^{i\delta'}, \quad V_{cd} = \lambda e^{-i\delta} \quad V_{ts} = \lambda^2 e^{-i\delta} \quad V_{td} = \lambda^3 e^{-i\delta'}. \quad (4.38)$$

here $\delta(\delta')$corresponds to one(two) $y$- subquark(s) creation from vacuum and $-\delta(-\delta')$ one(two) $y$-subquark(s) annihilation to vacuum and we use $\lambda = 0.22$ from Wolfenstein’s parametrization[70]. In case of (4.2;6;10) $y$-subquark is a “spectator” and then $V_{qq'}$ are real, which we set for simplicity:

$$V_{ud} = V_{cs} = V_{tb} = 1. \quad (4.39)$$

It is important to note that $V_{qq'}$s are different from the CKM matrix elements. They do not necessarily satisfy the strict unitarity-condition with three generations because
in our composite model the generating-mechanism of "generation" originates from subquark dynamics (adding $y$-subquarks). The seeming disappearance of the forth generation may be caused by imbalance of kinetic and binding energies of internal subquark system inside quarks.

5 Mass difference $\Delta M_P$ by $P^0 - \bar{P}^0$ mixing

5.1 Historical summary

Mass difference $\Delta M_P$ originates from the mixing between a neutral pseudo scalar meson ($P^0$) and its antimeson ($\bar{P}^0$). There are six types of mixing, e.g., $K^0 - \bar{K}^0$, $D^0 - \bar{D}^0$, $B^0_d - \bar{B}^0_d$, $B^0_s - \bar{B}^0_s$, $T^0_u - \bar{T}^0_u$ and $T^0_c - \bar{T}^0_c$ mixings. Theoretically they have been considered to be one of the most sensitive probes of higher-order effects of the weak interactions in the SM. The basic tool to investigate them is the "box diagram". By using this diagram to the $K_L-K_S$ mass difference, Gaillard and Lee predicted the mass of the charm quark[37]. Later, Wolfenstein suggested that the contribution of the box diagram which is called the short-distance (SD) contribution cannot supply the whole of the mass difference $\Delta M_K$ and there are significant contributions arising from the long-distance (LD) contributions associated with low-energy intermediate hadronic states[38]. As concerns, the LD-phenomena occur in the energy range of few hundred MeV and the SD-phenomena around 100 GeV region. Historically there are various investigations for $P^0-\bar{P}^0$ mixing problems[36][39~48] and many authors have examined them by use of LD- and SD-contributions.

In summary, the comparison between the theoretical results and the experiments about $\Delta M_P$ ($P = K, D$ and $B_d$) are as follows :

\[
\begin{align*}
\Delta M^{LD}_K & \approx \Delta M^{SD}_K \approx \Delta M^{exp}_K, \\
\Delta M^{SD}_D & \ll \Delta M^{LD}_D (\ll \Delta M^{exp}_D, 	ext{upper bound}), \\
\Delta M^{LD}_{B_d} & \ll \Delta M^{SD}_{B_d} \approx \Delta M^{exp}_{B_d}.
\end{align*}
\]

Concerning (5.1) it is explain that $\Delta M_K = \Delta M^{SD}_K + m\Delta M^{LD}_K$ where " $m$ " is a numerical value of order $O(1)$. As for (5.3), they found that $\Delta M^{LD}_{B_d} \approx 10^{-16}$ GeV and $\Delta M^{SD}_{B_d} \approx 10^{-13}$ GeV, then the box diagram is the most important for $B_d^0-\bar{B}_d^0$ mixing.
Computations of $\Delta M_{B_d}^{SD}$ and $\Delta M_{B_s}^{SD}$ from the box diagrams in the SM give:

$$\frac{\Delta M_{B_d}^{SD}}{\Delta M_{B_d}^{SD}} \simeq \left| \frac{V_{ts}}{V_{td}} \right|^2 \frac{B_{B_d} f_{B_d}^2}{B_{B_s} f_{B_s}^2} \frac{M_{B_d}}{M_{B_d}} \zeta,$$

(5.4)

where $V_{ij}$s stand for CKM matrix elements; $M_P$ : P-meson mass; $\zeta$ : a QCD correction of order $O(1)$; $B_B$ : Bag factor of B-meson and $f_B$ : decay constant of B-meson.

Measurements of $\Delta M_{B_d}^{exp}$ and $\Delta M_{B_s}^{exp}$ are, therefore, said to be useful to determine $|V_{ts}/V_{td}|$.[49][50]. Concerning (5.2), they found that $\Delta M_{D}^{LD} \approx 10^{-15}$ GeV and $\Delta M_{D}^{SD} \approx 10^{-17}$ GeV[36][44] but the experimental measurement is $\Delta M_{D}^{exp} < 4.6 \times 10^{-14}$ GeV with CL=90%. Further there is also a study that $\Delta M_{D}^{LD}$ is smaller than $10^{-15}$ GeV by using the heavy quark effective theory[45]. Then many people state that it would be a signal of new physics beyond the SM if the future experiments confirm that $\Delta M_{D}^{exp} \approx 10^{-14} \sim 10^{-13}$ GeV[39-45][60].

On the other hand some researchers have studied these phenomena in the context of the theory explained by the single dynamical origin. Cheng and Sher[68], Liu and Wolfenstein[47], and Gérard and Nakada[48] have thought that all $P^0-\overline{P}^0$ mixings occur only by the dynamics of the TeV energy region which is essentially the same as the idea of Super-Weak (denoted by SW) originated by Wolfenstein[35]. They extended the original SW-theory (which explains indirect CP violation in the $K$-meson system) to other flavors by setting the assumption that some neutral spin 0 particle with a few TeV mass (denoted by $H$) contributes to the “real part” of $M_{ij}$ which determines $\Delta M_P$ and also the “imaginary part” of $M_{ij}$ which causes the indirect CP violation. The ways of extensions are that $H$-particles couple to quarks by the coupling proportional to $\sqrt{m_i m_j}$[47][68], $(m_i/m_j)^n$ $n = 0, 1, 2$[47] and $(m_i + m_j)$[48] where $i, j$ are flavors of quarks coupling to $H$. It is suggestive that the SW-couplings depend on quark masses (this idea of “mass-dependence” is adopted in our model discussed below). Cheng and Sher[68] and Liu and Wolfenstein[47] obtained that $\Delta M_D = (m_c/m_s) \Delta M_K^{exp} \approx 10^{-14}$ GeV with the assumption that $H$-exchange mechanism saturates the $\Delta M_K^{exp}$ bound, which is comparable to $\Delta M_D^{exp} < 4.6 \times 10^{-14}$ GeV[29].

Concerning $B$-meson systems they found that $\Delta M_{B_s}/\Delta M_{B_d} = m_s/m_d \simeq 20$. But from the experimental data we have $(\Delta M_{B_s}/\Delta M_{B_d})_{exp} = 36.8$[29][62]. Further using their scheme it is calculated that:

$$\frac{\Delta M_{B_d}}{\Delta M_K} = \frac{B_{B_d} f_{B_d}^2 M_{B_d}}{B_K f_K^2 M_K} \frac{m_b}{m_s} \simeq 300,$$

(5.5)

where we use $m_b = 4.3$ GeV, $m_s = 0.2$ GeV, $M_{B_d} = 5.279$ GeV, $M_K = 0.498$ GeV,
\[ B_{B_d} f_{B_d}^2 = (0.22 \text{GeV})^2, \quad B_K f_K^2 = (0.17 \text{GeV})^2. \] This is larger than \((\Delta M_{B_d}/\Delta M_{K})_{\text{exp}} = 89 \) [29] and is caused by large b-quark mass value.

### 5.2 \( P^0 - \overline{P^0} \) mixing by subquark dynamics

Various ideas discussed in former subsection seem to be hard to explain all mass differences as a whole. So in order to overcome this difficulty let us discuss \( P^0 - \overline{P^0} \) mixings by using our subquark model. The discussions start from the assumption: Mass mixing matrix \( M_{ij}(P) \) \((i(j) = 1(2) \) denotes \( P^0(\overline{P^0}) \) \) is described only by the "\( y \)-exchange" interactions causing \( P^0 - \overline{P^0} \) transitions. We calculate \( \Delta M_P \) as:

\[
M_{12}(P) = \langle \overline{P^0} \mid \mathcal{H}^y \mid P^0 \rangle, \quad \tag{5.6}
\]

\[
\Delta M_P = M_H - M_L \simeq 2| M_{12}(P) |, \quad \tag{5.7}
\]

where \( \mathcal{H}^y \) is Hamiltonian for \( P^0 - \overline{P^0} \) transition interaction by \( y \)-exchange and we assume \( \text{Im} M_{12} \ll \text{Re} M_{12} \) which is experimentally acceptable[36][52] and \( M_H(L) \) stands for heavier (lighter) \( P^0(\overline{P^0}) \)-meson mass.

Applying the vacuum-insertion calculation to the hadronic matrix element as:

\[
\langle \overline{P^0} | [\overline{\psi} \gamma_\mu (1 - \gamma_5) \psi] | P^0 \rangle \sim B_P f_P^2 M_P^2 \] \[36\]
we get:

\[
M_{12}(P) = \frac{1}{12\pi^2} B_P f_P^2 M_P M_P, \quad \tag{5.8}
\]

Here \( M_P \) is a matrix element contributed by \( y \)-exchange diagram (which is seen in Fig.(3)). \( P^0 - \overline{P^0} \) mixings occur due to "\( y \)-exchange" between two quarks inside the present \( P^0(\overline{P^0}) \)-meson. This is a kind of the realizations of Wolfenstein’s SW-idea [35].

The schematic illustration is as follows: two particles (that is, quarks) with radius order of \( 1/\Lambda_q \) (maybe a few \( \text{TeV}^{-1} \)) are moving inside a sphere (that is, meson) with radius order of \( \text{GeV}^{-1} \). The \( y \)-exchange interactions would occur when two quarks inside \( P^0(\overline{P^0}) \)-meson interact in contact with each other because \( y \)-particles are confined inside quarks. As seen in Fig.(3), the contributions of \( y \)-exchanges are common among various \( P^0(\overline{P^0}) \)-mesons.

Then we set the assumption:

**Universality of the \( y \)-exchange interactions,**

which means that these interactions are independent of a variety of quarks.
Further let us describe $\mathcal{M}_P$ as:

$$\mathcal{M}_P = n_P \eta(P) \tilde{\mathcal{M}}_l(P), \quad \text{(5.9)}$$

where $n_P = 1$ for $P = K, D, B_d, T_u$; $n_P = 2$ for $P = B_s, T_c$, $l = 1$ for $K, D, B_s, T_u$; $l = 2$ for $B_d, T_c$ and $\tilde{\mathcal{M}}_l(P)$ is the “net” matrix element of $y$-exchange interaction.

“Universality” means explicitly that:

$$\tilde{\mathcal{M}}_1(K) = \tilde{\mathcal{M}}_1(D) = \tilde{\mathcal{M}}_1(B_s) = \tilde{\mathcal{M}}_1(T_c), \quad (5.10)$$

The explanation of $n_P$ is such that $K$ and $D$ have one $y$-particle and one $y$-particle exchanges; $B_d$ and $T_u$ have two $y$-particles and both of them exchange simultaneously, so we set $n_P = 1$ for them. On the other hand $B_s$ and $T_c$ have two $y$-particles but one of them exchanges, so they have $n_P = 2$ because the probability becomes double. The “$l$” means the number of exchanging $y$-particles in the present diagram.

Concerning $\eta(P)$, we explain as follows: In our FB-model $P^0\overline{P^0}$ mixing occurs by the “contact interaction” of two quarks colliding inside $P^0(\overline{P^0})$-meson. Therefore the probability of this interaction may be considered inverse proportional to the volume of the present $P^0(\overline{P^0})$-meson, e.g., the larger radius $K$-meson gains the less-valued probability of the colliding than the smaller radius $D$-(or $B_s$-) meson. The various aspects of hadron dynamics seem to be successfully illustrated by the semi-relativistic picture with “Breit-Fermi Hamiltonian” [28]. Assuming the power-law potential $V(r) \sim r^\nu$ ($\nu$ is a real number), the radius of $P^0(\overline{P^0})$-meson (denoted by $r_p$) is proportional to $\mu_p^{-1/(2+\nu)}$, where $\mu_p$ is the reduced mass of two quark-masses inside $P^0(\overline{P^0})$-meson [28]. Then the volume of $P^0(\overline{P^0})$-meson is proportional to $r_p^3 \sim \mu_p^{-3/(2+\nu)}$. After all we could assume for $\eta(P)$ in (5.9) as:

$$\eta(P) = \xi \left( \frac{\mu_p}{\mu_K} \right)^{1.0} \quad \text{for linear potential} \quad \text{(5.11)}$$

$$\eta(P) = \xi \left( \frac{\mu_p}{\mu_K} \right)^{1.5} \quad \text{for log potential} \quad \text{(5.12)}$$

where $\xi$ is a dimensionless numerical factor depending on the details of the dynamics of the quark-level. The $\eta(P)$ is normalized by $\mu_K$ (reduced mass of s- and d-quark in $K$ meson) for convenience.

The present experimental results of $\Delta M_P$ are as follows [29][51][62]:

$$\Delta M^{\text{exp}}_K = (3.489 \pm 0.008) \times 10^{-15} \quad \text{GeV}, \quad \text{(5.13)}$$
\[ \Delta M_D^{\exp} < 4.6 \times 10^{-14} \text{ GeV,} \quad (5.14) \]
\[ \Delta M_{B_d}^{\exp} = (3.12 \pm 0.11) \times 10^{-13} \text{ GeV,} \quad (5.15) \]
\[ \Delta M_{B_s}^{\exp} = 11.47 \times 10^{-12} \text{ GeV.} \quad (5.16) \]

Using (5.7;8) and (5.13~16), we have:

\[ |\mathcal{M}_D| < 1.4 |\mathcal{M}_K|, \quad (5.17) \]
\[ |\mathcal{M}_{B_d}| = 4.92 |\mathcal{M}_K|, \quad (5.18) \]
\[ |\mathcal{M}_{B_s}| = 142 |\mathcal{M}_K|. \quad (5.19) \]

At the level of \( M_P \), it seems that:

\[ \frac{|\mathcal{M}_P|}{|\mathcal{M}_K|} \approx O(1) \sim O(100), \quad (5.20) \]

where \( P = D, B_d, B_s \).

Here adopting “ \( \hat{N}_i(P) \) ” instead of \( \mathcal{M}_P \), let us make following discussions. By use of (5.9~12) and (5.18) we obtain:

\[ \mu_{B_d} = 4.91 \mu_K \quad \text{for linear – potential,} \quad (5.21) \]
\[ \mu_{B_d} = 2.88 \mu_K \quad \text{for log – potential,} \quad (5.22) \]

where \( B_d \mathcal{B}_d = (0.22 \text{GeV})^2, B_K \mathcal{B}_K = (0.17 \text{GeV})^2 \) are used. This result does not seem “unnatural”. Comparing with the case of (5.5), we can evade the large enhancement by \( b \)-quark mass effect. This is because the quark mass dependence is introduced through the “reduced mass” (in which the effect of heavier mass decreases). Some discussions are as follows: If we adopt the pure non-relativistic picture it may be that \( \mu_K \approx \mu_{B_d} \approx m_d \approx (\mu_D \approx \mu_{T_u}) \) but from the semi-relativistic standpoint it seems preferable that \( \mu_K (< \mu_D) < \mu_{B_d} (< \mu_{T_u}) \) because the effective mass value of “\( d \)-quark” in \( B_d \)-meson is considered larger than that in \( K \)-meson, which may be caused by that the kinetic energy of “\( d \)-quark” in \( B_d \)-meson is larger than that in \( K \)-meson (Refer to the discussion in Section 3). Then we can expect the plausibility of (5.21;22).

Next, let us discuss \( \Delta M_D \). Here we write \( \Delta M_P^\gamma \) as the mass difference of \( P^0 \) and \( \overline{P}^0 \) by \( \gamma \)-exchange interaction.

Using (5.7~10) we obtain:

\[ \Delta M_D^\gamma = \frac{B_D f_D^2}{B_K f_K^2} \frac{M_D}{M_K} \frac{\eta(B_d)}{\eta(K)} \Delta M_K^\gamma, \quad (5.23) \]
If we set $\mu_D = \mu_K$ tentatively in (5.11;12) we obtain:

$$\Delta M_D^\gamma = 4.67 \times \Delta M_K^{\exp} = 1.6 \times 10^{-14} \text{ GeV},$$

(5.24)

where we assume $\Delta M_K = \Delta M_K^{\exp}$ in (5.13) and use $B_df_D^2 = (0.19\text{GeV})^2$. In the same way, assuming $\mu_D = 1.5 \times \mu_K$ for example we have:

$$\Delta M_D^\gamma = (2.9 \sim 5.4) \times 10^{-14} \text{ GeV},$$

(5.25)

where the parenthesis means that (linear-potential $\sim$ log-potential). This result is consistent and comparable with (5.14). These values are similar to the results by Cheng and Sher [68] and Liu and Wolfenstein [47]. Concerning compilation of various studies about $\Delta M_D$, see Ref.[53].

The study of $\Delta M_{B_s}$ is as follows. Both $s$- and $b$-quark in $B_s$-meson are rather massive and then supposing availability of the non-relativistic scheme we have:

$$\mu_{B_s} = \frac{m_sm_b}{m_s + m_b} = 0.19 \text{ GeV},$$

(5.26)

where $m_s = 0.2 \text{ GeV}$ and $m_b = 4.3 \text{ GeV}$ are used. If we adopt $\mu_K = 0.01 \text{GeV}(\simeq m_d)$ for example we obtain:

$$\eta(B_s) = 19.0\xi \text{ for linear - potential},$$

(5.27)

$$= 82.8\xi \text{ for log - potential},$$

(5.28)

By using (5.7~10) we have:

$$\Delta M_{B_s}^\gamma = \frac{2B_{B_s}f_{B_s}^2 M_{B_s} \eta(B_s)}{B_Kf_K^2 M_K \eta(K)} \Delta M_K^\gamma,$$

(5.29)

where factor 2 comes from $n_{B_s} = 2$ in (5.9). Assuming that $\Delta M_K^\gamma = \Delta M_K^{\exp}$ in (5.13) and using (5.26;27) we obtain:

$$\Delta M_{B_s}^\gamma = (3.1 \sim 14) \times 10^{-12} \text{ GeV},$$

(5.30)

where we use $B_{B_s}f_{B_s}^2 = (0.25\text{GeV})^2$[49] (the parenthesis means the same as (5.25)).

This estimation is consistent with (5.16) and note that it is obtained by inputting the information of $\Delta M_K^{\exp}$.

Finally let us estimate $\Delta M_{T_u}^\gamma$ and $\Delta M_{T_c}^\gamma$. Setting $\mu_{T_u} = \mu_{B_d}$ (though $\mu_{T_u} > \mu_{B_d}$ in practice) and using (5.7~10) we find:

$$\Delta M_{T_u}^\gamma = \frac{B_{T_u}f_{T_u}^2 M_{T_u}}{B_{B_d}f_{B_d}^2 M_{B_d}} \Delta M_{B_d}^\gamma = 7.3 \times 10^{-10} \text{ GeV},$$

(5.31)
where we use $B_{T_u}f_{T_u}^2 = (1.9\text{GeV})^2$ [36], $M_{B_d} = 5.279 \text{ GeV}$, $M_{T_u} = 171 \text{ GeV}$ and set $\Delta M_{B_d}^\gamma = \Delta M_{B_d}^{\text{exp}}$ in (5,15).

For evaluating $\Delta M_{T_c}$, we calculate:

$$\mu_{T_c} = \frac{m_c m_t}{m_c + m_t} = 1.34 \text{ GeV},$$  \hspace{1cm} (5.32)

where $m_c = 1.35 \text{ GeV}$ and $m_t = 170 \text{ GeV}$ are used.

Then from (5.11;12) we get:

$$\eta(T_c) = \begin{cases} 134\xi & \text{for linear potential}, \\ 1551\xi & \text{for log potential}, \end{cases}$$  \hspace{1cm} (5.33-34)

where we set $\mu_K = 0.01 \text{ GeV}$.

With (5.7~10) and (5.31;32) we obtain:

$$\Delta M_{T_c}^\gamma = \frac{2B_{T_c}f_{T_c}^2}{B_K f_K} \frac{M_{T_c} \eta(T_c)}{M_K \eta(K)} \Delta M_{K}^\gamma = (4 \sim 47) \times 10^{-8} \text{ GeV},$$  \hspace{1cm} (5.35)

where we adopt $n_{T_c} = 2, B_{T_c}f_{T_c}^2 = (1.9\text{GeV})^2[36], M_{T_u} = 171 \text{ GeV}$ and $\Delta M_{K}^\gamma = \Delta M_{K}^{\text{exp}}$ in (5.13) and the parenthesis means the same as (5.24).

## 6 Indirect CP violation in $P^0-\bar{P}^0$ mixing

Here we discuss indirect CP violation by mass-mixings which is assumed to be saturated by the “$y$-exchange interactions”. In the CP-conserving limit in the $P^0(\bar{P}^0)$-meson systems, $M_{12}(P)$s are supposed to be real positive. Note that $CP|P_H >= -|P_H >$ and $CP|P_L >= |P_L >$ where $H$ ($L$) means heavy (light). If the CP-violating $y$-exchange interactions are switched on, $M_{12}(P)$ becomes complex.

Following Gérard and Nakada’s notation [48][52], we write as:

$$M_{12} = |M_{12}| \exp(i\theta_P),$$  \hspace{1cm} (6.1)

where $\theta_P$ is defined by:

$$\tan \theta _P = \frac{\text{Im}M_{12}(P)}{\text{Re}M_{12}(P)}.$$  \hspace{1cm} (6.2)

As we assume that the $y$-exchange interaction saturates indirect CP violation, we can write:

$$\text{Im} < \bar{P}^0|\mathcal{H}^y|P > = \text{Im}M_{12}(P).$$  \hspace{1cm} (6.3)
From (5.6;8;9) we obtain:

\[ \text{Im} M_{12}(P) = \mathcal{C} \cdot \text{Im} \tilde{M}_l(P), \quad (6.4) \]

where \( \mathcal{C} = \frac{1}{12\pi^2} B_p f_P^2 M_P \eta(P) \). Therefore the origin of indirect CP violation of \( P^0(T^0) \)-meson system is only in \( \tilde{M}_l(P) \). The Factor “ \( \mathcal{C} \)” in (6.4) is common also in \( \text{Re} M_{12}(P) \) and then we have:

\[ \frac{\text{Im} M_{12}(P)}{\text{Re} M_{12}(P)} = \frac{\text{Im} \tilde{M}_l(P)}{\text{Re} \tilde{M}_l(P)}. \quad (6.5) \]

If the universality of (5.10) is admitted, we obtain:

\[ \theta_K = \theta_D = \theta_{B_d} = \theta_{B_s} = \theta_{T_c} = \theta_{T_u}. \quad (6.6) \]

These are the predictions about indirect CP violation from the standpoint of our subquark-model. As for the experimental result it is reported that\[47\] :

\[ \theta_K = (6.5 \pm 0.2) \times 10^{-3}. \quad (6.7) \]

### 7 Direct and mixing-induced CP Violation by Subquark Dynamics

In our model direct and mixing-induced CP violations occur by subquark dynamics same as indirect CP violations discussed in Section 6 and essentially originate from the phases : “ \( \delta \)” and “ \( \delta' \)” which appeared in (4.38). Recently experimental measurements of various CP- asymmetries are already available, which are \( B_d \)-meson decays at KEK and SLAC and \( B_s \)-meson decays at Fermilab. By use of these experiments we can get the informations about \( \delta \) and \( \delta' \).

#### 7.1 Preliminaries

First we denote the amplitude of \( P^0(T^0) \)-meson decaying into some final state (denoted by \( f \)) as \( A(P^0 \to f) \) and \( A(T^0 \to f) \). In order to calculate direct CP violation (denoted by \( A_{cp}^{dir}(P^0 \to f) \)) and mixing-induced CP violation (denoted by \( A_{cp}^{mix}(P^0 \to f) \)) we introduce “ \( \xi(P^0 \to f) \)” , which is defined as :

\[ \xi(P^0 \to f) \equiv \pm e^{-i\theta_P} \frac{A(T^0 \to f)}{A(P^0 \to f)}, \quad (7.1) \]
where \( e^{-i\theta_p} = \sqrt{M_{12}/M_{12}} \) (\( M_{12} \) and \( \theta_p \) appeared in (6.1)); \((-\)-sign for \( f = (P_S, P_S) \) CP-even final state and \((+\)-sign for \( f = (P_S, V) \) CP-odd final state.

By use of (7.1) we obtain:

\[
A^{\text{dir}}_{\text{cp}}(P^0 \to f) = \frac{1 - |\xi(P^0 \to f)|^2}{1 + |\xi(P^0 \to f)|^2},
\]

\[
A^{\text{mix}}_{\text{cp}}(P^0 \to f) = \frac{2 \text{Im}\xi(P^0 \to f)}{1 + |\xi(P^0 \to f)|^2}.
\]

### 7.2 CP violation through \( B_d \to J/\psi K_s \)

We write \((B_d \to J/\psi K_s)\)-decay amplitude as:

\[
A(B_d \to J/\psi K_s) = V_{cb}^\ast V_{us} A_T + V_{ub}^\ast V_{us} A_P + V_{tb}^\ast V_{ts} A_P
\]

\[
= \lambda^2 e^{-i\delta} A_T + \lambda^2 e^{-i\delta} A_P + \lambda^2 e^{i(\delta - \delta')} A_P,
\]

where \( A_i^T (i = T : \text{tree}; P : \text{penguin}; q : \text{quark name}) \) is the amplitude of strong interaction and the equations of (4.38) and (4.39) are used.

Here let us abbreviate (7.4) and obtain:

\[
A(B_d \to J/\psi K_s) \propto e^{-i\delta} \{1 + \gamma_1 \lambda^2 e^{i(2\delta - \delta')} \cdot e^{i\theta_1}\},
\]

where \( \gamma_1 e^{i\theta_1} \equiv A_P^u/(A_T + A_P + A_P^t) \); \( \theta_1 \) is CP invariant strong phase.

For \((\bar{B}_d \to J/\psi K_s)\)-process we have:

\[
\overline{A}(ar{B}_d \to J/\psi K_s) \propto e^{i\delta} \{1 + \gamma_1 \lambda^2 e^{-i(2\delta - \delta')} \cdot e^{i\theta_1}\}.
\]

The application of (7.5) and (7.6) to (7.1) yields:

\[
\xi(B_d \to J/\psi K_s) = +e^{-i(2\delta + \theta_B_d)} \cdot \frac{1 + \gamma_1 \lambda^2 e^{-i(2\delta - \delta')} \cdot e^{i\theta_1}}{1 + \gamma_1 \lambda^2 e^{i(2\delta - \delta')} \cdot e^{i\theta_1}}.
\]

Putting (7.7) into (7.2;3) we obtain:

\[
A^{\text{dir}}_{\text{cp}}(B_d \to J/\psi K_s) = \frac{-2\gamma_1 \lambda^2 \sin(2\delta - \delta') \sin\theta_1}{1 + 2\gamma_1 \lambda^2 \cos(2\delta - \delta') \cos\theta_1},
\]

and

\[
A^{\text{mix}}_{\text{cp}}(B_d \to J/\psi K_s) = \frac{\sin(2\delta - \theta_{B_d}) + 2\gamma_1 \lambda^2 \sin(\delta') \cdot \cos\theta_1}{1 + 2\gamma_1 \lambda^2 \cos(2\delta - \delta') \cos\theta_1}.
\]
Taking $\gamma_1 \lambda^2 \sim O(10^{-2}) \ll 1$ ($\gamma_1 \sim 0.3$ : QCD calculation) into account for (7.8) and (7.9) we have :

$$A_{cp}^{dir}(B_d \rightarrow J/\psi K_s) \cong 0 + O(\gamma_1 \lambda^2),$$  \hspace{1cm} (7.10)

and

$$A_{cp}^{mix}(B_d \rightarrow J/\psi K_s) \cong \sin(2\delta - \theta_{B_d}) + O(\gamma_1 \lambda^2).$$  \hspace{1cm} (7.11)

The Belle and Babar recently reported that :

$$A_{cp}^{mix}(B_d \rightarrow J/\psi K_s) = \begin{cases} 
0.642 \pm 0.030 \text{(stat.)} \pm 0.017 \text{(syst.)} & \text{(Belle [32])} \\
0.715 \pm 0.034 \text{(stat.)} \pm 0.019 \text{(syst.)} & \text{(BaBar [33])} 
\end{cases}$$  \hspace{1cm} (7.12)

Putting the numerical values of (7.12) into the left side of (7.11) we obtain :

$$\delta \cong \begin{cases} 
(20 \pm 2)^{\circ} \text{ or } (70 \pm 2)^{\circ} & \text{(Belle)} \\
(23 \pm 2)^{\circ} \text{ or } (67 \pm 2)^{\circ} & \text{(BaBar)} 
\end{cases}$$  \hspace{1cm} (7.13)

where $\theta_{B_d} \ll 1^{\circ}$ is neglected.

We see a two-fold ambiguity in (7.13). The Babar Collaboration has showed the interesting information about the value of “$\cos 2\delta$” in $B_d \rightarrow D^{*0} h^0$ (where $h^0$ is $\pi^0, \eta, \eta'$ or $\omega$) and claimed that $\delta = (23 \pm 2)^{\circ}$ is preferable to $\delta = (67 \pm 2)^{\circ}$ [33].

### 7.3 CP violation through $B_d \rightarrow \pi^+\pi^-$

With the help of (4.39~41) we obtain :

$$A(B_d \rightarrow \pi^+\pi^-) = V_{ub}^* V_{ud} A_T + V_{ub}^* V_{ud} A_P + V_{cb}^* V_{cd} A_T + V_{cb}^* V_{cd} A_P$$

$$\propto e^{-i\delta'} \{1 + \gamma_2 e^{-i(2\delta - \delta')} \cdot e^{i\theta_2}\},$$  \hspace{1cm} (7.14)

where $\gamma_2 e^{i\theta_2} \equiv A_P/(A_T + A_P) \cdot \theta_2$ is CP invariant strong phase. And concerning $A(\overline{B}_d \rightarrow \pi^+\pi^-)$ we obtain :

$$A(\overline{B}_d \rightarrow \pi^+\pi^-) \propto e^i\delta' \{1 + \gamma_2 e^{i(2\delta - \delta')} \cdot e^{i\theta_2}\},$$  \hspace{1cm} (7.15)

using (7.14;15) to (7.1) we get :

$$\xi(B_d \rightarrow \pi^+\pi^-) = -e^{-i(2\delta + \theta_{B_d})} \cdot \frac{1 + \gamma_2 e^{i(2\delta - \delta')} \cdot e^{i\theta_2}}{1 + \gamma_2 e^{-i(2\delta - \delta')} \cdot e^{i\theta_2}}.$$

33
The application of (7.16) to (7.23) yields:

\[ A_{\text{dir}}^{cp}(B_d \rightarrow \pi^+\pi^-) = \frac{2\gamma_2 \sin(2\delta - \delta') \sin\theta_2}{1 + 2\gamma_2 \cos(2\delta - \delta') \cos\theta_2}, \]  

(7.17)

and

\[ A_{\text{mix}}^{cp}(B_d \rightarrow \pi^+\pi^-) = -\frac{\sin(2\delta' - \theta_{B_d}) + 2\gamma_2 \sin(3\delta' - 2\delta - \theta_{B_d}) \cos\theta_2}{1 + 2\gamma_2 \cos(2\delta - \delta') \cos\theta_2}. \]  

(7.18)

Carrying out further approximation of \( O(\gamma_2) \) we have:

\[ A_{\text{dir}}^{cp}(B_d \rightarrow \pi^+\pi^-) \approx 2\gamma_2 \sin(2\delta - \delta') \sin\theta_2, \]  

(7.19)

and

\[ A_{\text{mix}}^{cp}(B_d \rightarrow \pi^+\pi^-) \approx -\sin(2\delta' - \theta_{B_d}) + 2\gamma_2 \sin(2\delta - \delta') \cos(2\delta' - \theta_{B_d}) \cos\theta_2. \]  

(7.20)

The update experimental informations are as follows:

\[ A_{\text{dir}}^{cp}(B_d \rightarrow \pi^+\pi^-) = \begin{cases} 
+0.55 \pm 0.08 \pm 0.05 & \text{(Belle [50])} \\
+0.16 \pm 0.11 \pm 0.03 & \text{(BaBar [51])},
\end{cases} \]  

(7.21)

and

\[ A_{\text{mix}}^{cp}(B_d \rightarrow \pi^+\pi^-) = \begin{cases} 
-0.61 \pm 0.10 \pm 0.04 & \text{(Belle [50])} \\
-0.53 \pm 0.14 \pm 0.02 & \text{(BaBar [51])},
\end{cases} \]  

(7.22)

Both experiments comparatively coincides in \( A_{\text{mix}}^{cp}(B_d \rightarrow \pi^+\pi^-) \) but contradict in \( A_{\text{dir}}^{cp}(B_d \rightarrow \pi^+\pi^-) \). Therefore let us investigate \( A_{\text{mix}}^{cp}(B_d \rightarrow \pi^+\pi^-) \). Assuming that \( \gamma_2 \sim 0.3 \) in (7.20), the second term is estimated to be a few 10% contribution and there approximately exists (10~30)% error in (7.21). So at present stage in order to get the information about “\( \delta' \)” it may well be adopted that:

\[ A_{\text{mix}}^{cp}(B_d \rightarrow \pi^+\pi^-) \approx \sin(2\delta' - \theta_{B_d}). \]  

(7.23)

Using (7.22) to (7.23) we obtain:

\[ \delta' \approx \begin{cases} 
(19 \pm 5)^\circ \text{ or } (71 \pm 5)^\circ & \text{(Belle)} \\
(16 \pm 5)^\circ \text{ or } (74 \pm 5)^\circ & \text{(BaBar)},
\end{cases} \]  

(7.24)
where $\theta_{B_d} (\ll 1^\circ)$ is neglected same as (7.13). From (7.19) we estimate:

$$|A_{cp}^{dir}(B_d \to \pi^+\pi^-)| \leq 0.3,$$

(7.25)

where we use $\delta = 21.5^\circ$ and $\delta' = (17.5 \text{ or } 72.5)^\circ$ by averaging Belle and BaBar in (7.13) and (7.24); $|\sin\theta_2| \leq 1$; $\gamma_2 = 0.3$. Then the estimation of (7.25) suggests that BaBar is preferable to Belle in (7.21).

### 7.4 CP violation through $B_d \to \phi K_s$

The $(B_d \to \phi K_s)$-decay has a CP-odd final state and receives contribution from only penguin topologies with $b \to s \bar{s} s$ quark level processes.

With the help of (4.39−41), the decay amplitude is described as:

$$A(B_d \to \phi K_s) = +V_{ub}^* V_{us} A_P^u + V_{cb}^* V_{cs} A_P^c + V_{tb}^* V_{ts} A_P^t \propto e^{-i\delta}\{1 + \gamma_3 \lambda^2 e^{i(2\delta - \delta')} \cdot e^{i\theta_3}\},$$

(7.26)

where $\gamma_3 e^{i\theta_3} \equiv A_P^u / (A_P^c + A_P^t)$ and $\gamma_3 \sim O(1)$ is expected.

For $(\overline{B}_d \to \phi K_s)$-process we have:

$$\overline{A}(\overline{B}_d \to \phi K_s) \propto e^{i\delta'}\{1 + \gamma_3 \lambda^2 e^{-i(2\delta - \delta')} \cdot e^{i\theta_3}\}. $$

(7.27)

Putting (7.26) and (7.27) into (7.1) and using (7.2;3) we obtain:

$$A_{cp}^{dir}(B_d \to \phi K_s) = -\frac{2\gamma_3 \lambda^2 \sin(2\delta - \delta') \sin\theta_3}{1 + 2\gamma_3 \lambda^2 \cos(2\delta - \delta') \cos\theta_3},$$

(7.28)

and

$$A_{cp}^{mix}(B_d \to \phi K_s) = \frac{\sin(2\delta - \theta_{B_d}) + 2\gamma_3 \lambda^2 \sin(2\delta' - \theta_{B_d}) \cos\theta_3}{1 + 2\gamma_3 \lambda^2 \cos(2\delta - \delta') \cos\theta_3}.$$ 

(7.29)

Taking $\gamma_3 \lambda^2 \sim O(\lambda^2) \ll 1$ in to account in (7.28;29) we have:

$$A_{cp}^{dir}(B_d \to \phi K_s) \approx 0 + O(\lambda^2),$$

(7.30)

and

$$A_{cp}^{mix}(B_d \to \phi K_s) \approx \sin(2\delta - \theta_{B_d}) + O(\lambda^2).$$

(7.31)

From (7.11) and (7.31) we obtain:

$$A_{cp}^{mix}(B_d \to J/\psi K_s) \approx A_{cp}^{mix}(B_d \to \phi K_s).$$

(7.32)
The experimental situation is as follows:

\[ A_{cp}^{mix}(B_d \rightarrow \phi K_s) = 0.50 \pm 0.21 \pm 0.06. \]  \hspace{1cm} (7.33)

Comparing (7.33) with (7.12) consistency between them can be observed.

### 7.5 CP violation through \( B_d \rightarrow K^+\pi^- \) and \( B_u^+ \rightarrow K^+\pi^0 \)

The \((B \rightarrow K\pi)\)-decay amplitudes are given as:

\[ A(B_d \rightarrow K^+\pi^-) = V_{ub}^*V_{us}A_{T}^{ex} + V_{ub}^*V_{us}A_{P}^{ex} + V_{cb}^*V_{cs}A_{P}^{c} + V_{tb}^*V_{ts}A_{P}^{t}, \]  \hspace{1cm} (7.34)

\[ A(B_u^+ \rightarrow K^+\pi^0) = V_{ub}^*V_{us}A_{T}^{in} + V_{ub}^*V_{us}A_{P}^{in} + V_{cb}^*V_{cs}A_{P}^{c} + V_{tb}^*V_{ts}A_{P}^{t}. \]  \hspace{1cm} (7.35)

Both amplitudes are contributed by tree and penguin modes but it is noticeable that the tree diagram of the former is “external tree” (denoted by \( A_{T}^{ex} \)) and that of latter is “internal tree” (denoted by \( A_{T}^{in} \)). Therefore they possibly differ in absolute values and/or phases. By use of (4.39~41) equations of (7.34) and (7.35) are rewritten as:

\[ A(B_d \rightarrow K^+\pi^-) \propto e^{-i\delta} \{ 1 + \frac{\lambda^2}{\gamma_{ex}} e^{i(2\delta - \delta')} \cdot e^{i\theta_{ex}} \}, \]  \hspace{1cm} (7.36)

where \((1/\gamma_{ex})e^{i\theta_{ex}} \equiv (A_{T}^{ex} + A_{P}^{ex})/(A_{P}^{ex} + A_{P}^{t}), \) and

\[ A(B_u^+ \rightarrow K^+\pi^0) \propto e^{-i\delta} \{ 1 + \frac{\lambda^2}{\gamma_{in}} e^{i(2\delta - \delta')} \cdot e^{i\theta_{in}} \}, \]  \hspace{1cm} (7.37)

where \((1/\gamma_{in})e^{i\theta_{in}} \equiv (A_{T}^{in} + A_{P}^{in})/(A_{P}^{in} + A_{P}^{t}). \) Passing through the same procedure as previous sections we have:

\[ A_{cp}^{dir}(B_d \rightarrow K^+\pi^-) = -\frac{2\lambda^2 \sin(2\delta - \delta') \sin\theta_{ex}}{1 + 2\lambda^2 \cos(2\delta - \delta') \cos\theta_{ex}}, \]  \hspace{1cm} (7.38)

\[ A_{cp}^{mix}(B_d \rightarrow K^+\pi^-) = -\frac{\sin(2\delta - \theta_{Bd}) - 2\lambda^2 \sin(2\delta + \theta_{ex} - \theta_{Bd}) \cos(2\delta - \delta')}{1 - 2\lambda^2 \cos(2\delta - \delta') \cos\theta_{ex}}, \]  \hspace{1cm} (7.39)

and

\[ A_{cp}^{dir}(B_u \rightarrow K^+\pi^0) = -\frac{2\lambda^2 \sin(2\delta - \delta') \sin\theta_{in}}{1 + 2\lambda^2 \cos(2\delta - \delta') \cos\theta_{in}}, \]  \hspace{1cm} (7.40)
From (7.38;40) we obtain:

\[ A_{\text{dir}}^{cp}(B_d \rightarrow K^+\pi^-) = -2\frac{\lambda^2}{\gamma_{\text{ex}}} \sin(2\delta - \delta') \sin\theta_{\text{ex}} + O(\lambda^4/\gamma_{\text{ex}}^2), \]  

(7.41)

and

\[ A_{\text{dir}}^{cp}(B_u \rightarrow K^+\pi^0) = -2\frac{\lambda^2}{\gamma_{\text{in}}} \sin(2\delta - \delta') \sin\theta_{\text{in}} + O(\lambda^4/\gamma_{\text{in}}^2). \]  

(7.42)

Experimental situations are as follows:

\[ A_{\text{dir}}^{cp}(B_d \rightarrow K^+\pi^-) = -0.115 \pm 0.018, \quad [63] \]  

(7.43)

\[ A_{\text{dir}}^{cp}(B_u \rightarrow K^+\pi^0) = 0.016 \pm 0.041 \pm 0.012. \quad [71] \]  

(7.44)

Omitting the second term of (7.41) we have:

\[ \sin\theta_{\text{ex}} \approx -\frac{A_{\text{dir}}^{cp}(B_d \rightarrow K^+\pi^-)}{\sin(2\delta - \delta')} \]  

(7.45)

Tentatively substituting \{ \lambda = 0.22 : \gamma_{\text{ex}} = 0.3 \; ; \; \delta = 21.5^\circ \; ; \; \delta' = (17.5 \; \text{or} \; 72.5)^\circ \} (average values of Belle and BaBar from (7.13;24)) and \[ A_{\text{dir}}^{cp}(B_d \rightarrow K^+\pi^-) = -0.115 \] from (7.43) into (7.45) we get:

\[ \theta_{\text{ex}} \approx -56^\circ (\delta' = 17.5^\circ) \text{ or } 46^\circ (\delta' = 72.5^\circ), \]  

(7.46)

(As seen in (7.54) of next section \( \theta_{\text{ex}} \approx 46^\circ \) is favorable.) On the other hand if we assume: \[ A_{\text{dir}}^{cp}(B_u \rightarrow K^+\pi^0) \approx 0 \] in (7.44) we could estimate from (7.42) that:

\[ \sin\theta_{\text{in}} \approx 0 \quad \text{(that is, } \theta_{\text{in}} \approx 0^\circ \text{ or } 180^\circ). \]  

(7.47)

From (7.46) and (7.47) we observe: \( \theta_{\text{ex}} \neq \theta_{\text{in}}, \) which causes: \[ A_{\text{dir}}^{cp}(B_d \rightarrow K^+\pi^-) \neq A_{\text{dir}}^{cp}(B_u \rightarrow K^+\pi^0). \]

### 7.6 CP violation through \( B_s \rightarrow J/\psi\phi \)

The \( (B_s \rightarrow J/\psi\phi) \)-decay mode is the counterpart of the \( (B_d \rightarrow J/\psi K_s^-) \)-decay, where the down quark of \( B_d \) meson is replaced by the strange quark. The final state of \( (B_s \rightarrow J/\psi\phi) \)-decay is an admixture of different CP eigenstates in comparison to \( (B_d \rightarrow J/\psi K_s^-) \)-decay and then its study for CP violation is complex but the angular analysis of the \( J/\psi[\rightarrow l^+l^-]\phi[\rightarrow K^+K^-] \) decay products can solve that complexity [73]. As the
strange quark in $B_s$ meson is the spectator, the decay amplitude of $(B_s \rightarrow J/\psi \phi)$-decay is completely analogous to that of $(B_s \rightarrow J/\psi \phi)$-decay mode \cite{73}. Then we have:

$$A(B_s \rightarrow J/\psi \phi) = V_{bc}^* V_{us} A_T + V_{ub}^* V_{us} A_P + V_{cs}^* V_{cs} A_T' + V_{ts}^* V_{ts} A_P'$$

$$\propto e^{-i\delta} \left\{ 1 + \gamma_4 \lambda^2 e^{i(2\delta - \delta')} \cdot e^{i\theta_4} \right\}, \quad (7.48)$$

where $\gamma_4 e^{i\theta_4} \equiv A_P''/(A_T + A_P' + A_P'')$. Passing through the same procedure as the $(B_d \rightarrow J/\psi K_s)$-decay we have:

$$A_{\text{dir}}^{cp} (B_s \rightarrow J/\psi \phi) = -2 \gamma_4 \lambda^2 \sin(2\delta - \delta') \sin \theta_4,$$

$$\approx 0 + O(\gamma_4 \lambda^2), \quad (7.49)$$

and

$$A_{\text{mix}}^{cp} (B_s \rightarrow J/\psi \phi) = \frac{\sin(2\delta - \theta_{B_d}) + 2 \gamma_4 \lambda^2 \sin(\delta - \theta_{B_d}) \cos \theta_4}{1 + 2 \gamma_4 \lambda^2 \cos(2\delta - \delta') \cos \theta_4},$$

$$\approx \sin(2\delta) + O(\gamma_4 \lambda^2), \quad (7.50)$$

where $\theta_{B_d}$ is neglected. Recently DØ Collaboration at Fermilab has reported CP violating phase of $(B_s \rightarrow J/\psi \phi)$-decay process as:

$$\phi_s = |0.79 \pm 0.56|_{\text{rad}} = (45 \pm 32)^\circ,$$

or

$$|2.35 \pm 0.56|_{\text{rad}} = (135 \pm 32)^\circ. \quad [74] \quad (7.51)$$

The “$\phi_s$” corresponds to “$2\delta$” and then it can be said that “$2\delta \cong 43^\circ$” from (7.13) is in good agreement with the DØ experiment: $\phi_s = (45 \pm 32)^\circ$.

### 7.7 CP violation through $B_d(\overline{B_d}) \rightarrow D^{(*)\pm} \pi^{\pm}$

These processes are very interesting because the only one “tree diagram” contributes to them. The $B_d \rightarrow D^{(*)-} \pi^+$ and $\overline{B_d} \rightarrow D^{(*)+} \pi^-$ are Cabibbo-favoured decay process (CFD) and $B_d \rightarrow D^{(*)+} \pi^-$ and $\overline{B_d} \rightarrow D^{(*)-} \pi^+$ are doubly-Cabibbo-suppressed decay process (DCSD).

Here let us study the mixing induced CP violation between $B_d \rightarrow D^- \pi^+$ and $\overline{B_d} \rightarrow D^- \pi^+$ decay. For these decay amplitudes we obtain:

$$A(B_d \rightarrow D^- \pi^+) = V_{cd}^* V_{ud} A_T = \lambda^2 e^{-i\delta} A_T \quad \text{(CFD-MODE)}, \quad (7.52)$$

and

$$\overline{A(B_d \rightarrow D^- \pi^+)} = V_{cd}^* V_{bd} A_T' = \lambda^4 e^{i(\delta - \delta')} A_T' \quad \text{(DCSD-MODE)}. \quad (7.53)$$
Using (7.52) and (7.53) we have:

\[ \xi(B_d \to D^-\pi^+) = e^{-i\theta_{B_d}} \frac{\bar{A}}{A} = -e^{-i\theta_{B_d}} \cdot \lambda_4 e^{i(\delta - \delta')} \cdot \frac{A_T'}{A_T}, \]

where \( e^{i\theta_5} \equiv \frac{A_T'}{A_T} \) by assuming: \( |A_T'| = |A_T| \). From (7.54) we obtain:

\[ A_{cp}^{mix}(B_d \to D^-\pi^+) = \frac{-2\lambda^2 \sin(2\delta - \delta' - \theta_{B_d} - \theta_5)}{1 + \lambda^4} \approx -2\lambda^2 \sin(2\delta - \delta' - \theta_5). \] (7.55)

There are theoretical arguments: the still-unmeasured values of \( \theta_5 \) for both \( D^*\pi \) and \( D\pi \) are small [75][76], so we set \( \theta_5 = 0 \). By use of \( \delta = (21.5 \pm 2.0)^\circ \), \( \delta' = (17.5 \pm 5.0)^\circ \) or \( \delta' = (72.5 \pm 5.0)^\circ \) (average of Belle and BaBar) we get:

\[ A_{cp}^{mix}(B_d \to D^-\pi^+) = \begin{cases} -0.059 \pm 0.032 \{ \delta' = (17.5 \pm 5.0)^\circ \} \\ +0.047 \pm 0.013 \{ \delta' = (72.5 \pm 5.0)^\circ \} \end{cases} \] (7.56)

Recently Belle Collaboration published measurements of CP violation in \( B_d \to D^{(*)-}\pi^+ \) decays [75] and they informed that:

\[ A_{cp}^{mix}(B_d \to D^-\pi^+) = 0.068 \pm 0.029 \pm 0.012 \] (7.57)

Comparing (7.57) with (7.56), the case of \( \{ \delta' = (72.5 \pm 5.0)^\circ \} \) seems to be favorable. Refering above discussions combined with the result of (7.13) and [33] we may well conclude:

\[ \delta = (21.5 \pm 2.0)^\circ \quad \text{and} \quad \delta' = (72.5 \pm 5.0)^\circ. \] (7.58)

### 7.8 CP violation through \( D^0 \) meson decay

**a. \( (D^0 \to K^\pm\pi^\mp) \)-decay mode**

These processes occur only through the “tree” topologies and we have:

\[ A(D^0 \to K^+\pi^-) = V_{cd}^* V_{us} A_T = \lambda^2 e^{-i\delta_s} e^{i\delta} A_T = A_T, \] (7.59)
and
\[ A(D^0 \rightarrow K^+\pi^-) = V_{cs}^*V_{ud}A_T^0 = 1 \cdot A_T = A_T. \] (7.60)

By use of them we obtain:
\[ \xi(D^0 \rightarrow K^+\pi^-) = \gamma_6 e^{-i\theta_6}, \] (7.61)
where \( \gamma_6 e^{-i\theta_6} \equiv A_T^0/A_T \), which leads:
\[ A_{cp}^{dir}(D^0 \rightarrow K^+\pi^-) = \frac{1 - \gamma_6^2}{1 + \gamma_6^2}, \] (7.62)
and
\[ A_{cp}^{mix}(D^0 \rightarrow K^+\pi^-) = \frac{2\gamma_6^2}{1 + \gamma_6^2} \sin(\theta_6 - \theta_6^T). \] (7.63)

Here we may expect: \( \gamma_6 \approx 1 \) and get the same result about \( (D^0 \rightarrow K^-\pi^+) \)-decay process. Then we have:
\[ A_{cp}^{dir}(D^0 \rightarrow K^+\pi^-) \approx 0 \quad \text{and} \quad A_{cp}^{mix}(D^0 \rightarrow K^+\pi^-) \approx \sin \theta_6. \] (7.64)

b. \( (D^0 \rightarrow K^\pm K^\mp) \)-decay mode

Only “penguin” type amplitudes contribute to these decays. Then we describe them as:
\[ A(D^0 \rightarrow K^+K^-) = V_{cd}^*V_{ud}A_P^d + V_{cs}^*V_{us}A_P^s + V_{cb}^*V_{ub}A_P^b \]
\[ \propto e^{-i\delta} \left\{ 1 + \gamma_7 \lambda^3 e^{i(2\delta - \delta')} \cdot e^{i\theta_7} \right\}, \] (7.65)
where \( \gamma_7 e^{i\theta_7} \equiv A_P^d/(A_P^d + A_P^b) \). And also we have:
\[ \overline{A}(D^0 \rightarrow K^+K^-) \propto e^{i\delta} \left\{ 1 + \gamma_7 \lambda^3 e^{-i(2\delta - \delta')} \cdot e^{-i\theta_7} \right\}. \] (7.66)

Using (7.65,66) we have:
\[ A_{cp}^{dir}(D^0 \rightarrow K^+K^-) = \frac{2\gamma_7 \lambda^3 \sin(2\delta - \delta') \sin \theta_7}{1 + 2\gamma_7 \lambda^3 \cos(2\delta - \delta') \cos \theta_7}, \] (7.67)
and
\[ A_{cp}^{\text{mix}}(D^0 \to K^+ K^-) = -\frac{\sin(2\delta - \theta_D) + 2\gamma_1 \lambda^3 \sin(\delta' - \theta_D) \cos \theta_7}{1 + 2\gamma_1 \lambda^3 \cos(2\delta - \delta') \cos \theta_7}. \] (7.68)

From (7.67;68) we obtain:
\[ A_{cp}^{\text{dir}}(D^0 \to K^+ K^-) \cong 0 + O(\gamma_1 \lambda^3), \] (7.69)
and
\[ A_{cp}^{\text{mix}}(D^0 \to K^+ K^-) \cong -\sin(2\delta - \theta_D) + O(\gamma_1 \lambda^3) = -0.68, \] (7.70)
where we use \( \delta = 21.5^\circ \) and neglect \( \theta_D \).

c. \((D^0 \to \pi^+ \pi^-)\)-decay mode

This process have both tree and penguin modes. Its amplitude is described as:
\[
A(D^0 \to \pi^+ \pi^-) = V_{cd}^* V_{ud} A_T + V_{cd}^* V_{ud} A_P^u + V_{cs}^* V_{ub} A_s^b + V_{cb}^* V_{ub} A_P^b \\
\propto e^{-i\delta} \left\{ 1 + \gamma_8 \lambda^4 e^{-i(2\delta' - \delta')} \cdot e^{i\theta_8} \right\}, \] (7.71)
where \( \gamma_8 e^{i\theta_8} \equiv A_P/(A_T + A_P^u + A_P^b) \). From (7.71) we obtain:
\[ A_{cp}^{\text{dir}}(D^0 \to \pi^+ \pi^-) = \frac{2\gamma_8 \lambda^4 \sin(2\delta - \delta') \sin \theta_8}{1 + 2\gamma_8 \lambda^4 \cos(2\delta - \delta') \cos \theta_8} \]
\[ \cong 0 + O(\gamma_8 \lambda^4), \] (7.72)
and
\[ A_{cp}^{\text{mix}}(D^0 \to \pi^+ \pi^-) = -\frac{\sin(2\delta - \theta_D) + 2\gamma_8 \lambda^4 \sin(\delta' - \theta_D) \cos \theta_8}{1 + 2\gamma_8 \lambda^4 \cos(2\delta - \delta') \cos \theta_8} \]
\[ \cong -\sin(2\delta - \theta_D) + O(\gamma_8 \lambda^4) \cong -0.68, \] (7.73)
where \( \delta = 21.5^\circ \) is used and \( \theta_D \) is neglected. In this connection CLEO Collaboration reported [79] :
\[ A_{cp}^{\text{dir}}(D^0 \to K^+ K^-, \pi^+ \pi^-) \cong 0. \] (7.74)
7.9 CP violation through $K \to \pi\pi$

Decay amplitudes for $K^0$($\overline{K^0}$) $\to \pi\pi$ decays can be described by two parts, which are in isospin $I = 0$ and $I = 2$ states due to Bose statistics of $S$ wave pions. On the other hand in the description of quark levels there are two types, namely: the “tree”- and the “penguin”-type graph. The former has both of $I = 0$ and $I = 2$ contributions but the latter has only $I = 0$ contribution. Then let us write decay amplitudes (denoted by $A_I$, $I = 0, 2$ for isospin) as:

$$A_0 = V_{us}^*V_{ud}A_{0T} + V_{us}^*V_{ud}A_{0P}^u + V_{cs}^*V_{cd}A_{0P}^c + V_{ts}^*V_{td}A_{0P}^t \propto \lambda\left(e^{-i\delta} + \gamma_9\lambda^4e^{-i(\delta-\delta')} \cdot e^{i\theta_9}\right),$$ (7.75)

$$A_2 = V_{us}^*V_{ud}A_{2T} = \lambda e^{-i\delta}|A_{2T}|,$$ (7.76)

where $\gamma_9e^{i\theta_9} \equiv A_{0P}^u/(A_{0T} + A_{0P}^u + A_{0P}^c)$ and for the phase convention $A_{2T}$ is set real. As is well known [36][80], CP violation in K meson system is analysed by two parameters, namely, $\varepsilon$ for indirect CP violation and $\varepsilon'$ for direct CP violation. Concerning $\varepsilon$, its value has been experimentally confirmed as:

$$\varepsilon = (2.280 \pm 0.013) \times 10^{-3} \cdot e^{i\frac{\pi}{4}}$$ (7.77)

On the other hand $\varepsilon'$ is described as:

$$\varepsilon' = \frac{i}{\sqrt{2}} \omega(t_2 - t_0) e^{i(\theta_2 - \theta_0)}.$$ (7.78)

where $\theta_I$ is the phaseshifts of strong interactions; $t_I = \text{Im}A_I/\text{Re}A_I$ ($I = 0, 2$) and $\omega = e^{i(\theta_2 - \theta_0)}(\text{Re}A_2/\text{Re}A_0)$.

In CPT symmetry limit phases of $\varepsilon$ and $\varepsilon'$ are accidentally almost equal and then usually we discuss by using the equation:

$$\text{Re}\left(\frac{\varepsilon'}{\varepsilon}\right) \approx \left|\varepsilon'/\varepsilon\right|.$$ (7.79)

From (7.78) with $\varepsilon$ we have:

$$\left|\frac{\varepsilon'}{\varepsilon}\right| = \frac{|\omega|}{\sqrt{2}|\varepsilon|}\kappa,$$ (7.80)

$$\kappa = \frac{|\text{Im}A_2|}{\text{Re}A_2} - \frac{|\text{Im}A_0|}{\text{Re}A_0}.$$ (7.81)
By using (7.75;76) to (7.81) we obtain:

$$\kappa = 2\gamma\lambda^4 |\tan \delta| \left| \frac{\sin(\Delta + \theta_9)}{\sin \delta} + \frac{\cos(\Delta + \theta_9)}{\cos \delta} \right|, \quad (7.82)$$

where $\Delta \equiv \delta - \delta'$ and $(\gamma\lambda^4)^2$-terms are neglected.

From here let us extract numerical informations of above quantities from experimental results. In $K$ meson system it is reported that [78]:

$$\omega = \frac{1}{29.5}, \quad (7.83)$$

which includes the isospin breaking effect and also reported that [73]:

$$\text{Re} \left( \frac{\varepsilon'}{\varepsilon} \right) = (16.6 \pm 1.6) \times 10^{-4} \quad (7.84)$$

By use of (7.77;78) and (7.82 ~ 84) we obtain:

$$\theta_9 = (46 \pm 11)^{\circ}, \quad (7.85)$$

where the numerical values of $\delta = 21.5^{\circ}; \delta' = 72.5^{\circ}; \lambda = 0.22$ and $\gamma_9 = 0.3$ are used. In (7.75) the phase of “$\theta_9$” is essentially the phase difference of strong interaction between external tree and penguin diagram. It is interesting that : $\theta_{ex} \cong \theta_9$ from (7.46) and (7.85).

## 8 Conclusions

Construction of our model are carried out rather by axiomatic way. First we set three fundamental hypotheses:

(1) “The space is four dimensional : one is time and three are real space.”

Comment : It is very difficult to answer why the space is four dimensional. So we are obliged to make this hypothesis.

(2) “All gage fields are Cartan connections equipped with Soldering Mechanism.”

Comment : With the aid of Soldering Mechanism all gauge fields can propagate in the real space-time.

(3) “The primodial matter fields (primon and anti-primon) created from vacuum at the Big Bang of the universe are supersymmetric pair of spin-1/2 fermion and spin-0 boson, both of which have electric charge $|e/6|$.”
Comment: The quantized electric charge of \(|e/6|\) is explained by that electromagnetic \(U(1)\)-gauge group is the unfactorized subgroup of \(SL(2,C)\) which have 6 generators. Therefore “e” must be normalized by “6”.

Combining (1) with (2), only four types of sets of classical groups can be found, namely: \(F_1 = SO(1,4)/SO(1,3)\) (gravity), \(F_2 = SU(3)/SU(2)\) (QED), \(F_3 = SL(2,C)/SL(1,C)\) (QCD) and \(F_4 = SO(5)/SO(4)\) (Weak). It is noticeable that \(F_i\) \((i = 1 \sim 4)\) are all \((\dim F = 4)\)-spaces. Soldering Mechanism with 4-dimensional \(F_i\)-spaces naturally induces the existence of six-fields-set: \(\{C, \overline{C}, B, \overline{B}, G_1, G_2\}\) which are massless scalar fields and they enable \(g'\)-valued gauge fields \{gravity, electromagnetic, strong and weak\} to propagate in the real space-time with the aid of the metric-tensers: \(g^{\mu\nu}_a\) \((a \text{ is gravity, electromagnetic, strong and weak})\). Our model thinks that the six-fields-set not only play the role of mathematical tools for BRS-invariance but also really exist at every point in the universe. In general massless scalar fields generate repulsive forces. Therefore the six-fields-set generate repulsive forces at every point of the universe and expand the universe. So they might be candidates for Dark Energy. In our model, four kinds of gauge fields are different things in quality and then grand unification does not occur even at Plank energy.

The hypothesis: (3) is crucially important to build up quarks and leptons. After the Big Bang, primons are composed into subquarks, among which \((1,1,1)\)-state subquarks of \(SU(3)_C \otimes SU(2)_L^h \otimes SU(2)_R^h\) gauge symmetry are neutral and they cannot interact with ordinary matters. As it could be thought that plenty of \((1,1,1)\)-state subquarks have created at the beginning of the universe, these neutral subquarks could be the candidate for “Dark Matter”. The \((3,3,1)\)-state subquark and the others are composed into ordinary matters. In our model weak interacting \(W^\pm\text{-and } Z^0\)-boson are also composite objects and they have scalar partners: \(S^{\pm,0}\). Mass difference between them is supposed to be not so large because its origine is “hyperfine splitting”.

Our model show that one proton has the configuration of \((uud)\): \((2\alpha, \overline{\sigma}, 3\overline{x}, \overline{x})\); electron: \((\sigma, 2\overline{x})\); neutrino: \((\alpha, \overline{x})\); antineutrino: \((\overline{\sigma}, x)\) and the dark matters are constructed from the same amount of matters and antimatters because of their neutral charges. Further it is said that the universe contains almost the same number of protons and electrons. These considerations lead the thought that “The universe is the matter-antimatter-even object.” This idea is different from the current thought that the universe is made of matters only. Then in our model the problem about CP violation in the early universe does not occur.
In our model the existence of the 4th generation is, in kind, not inhibited because the generation-making mechanism is just to add $y$-subquarks. In fact, if the experimental evidence of $1-(|V_{us}|^2 + |V_{ud}|^2 + |V_{ub}|^2) = 0.0017 \pm 0.0015$ at the $1\sigma$ level[31] is taken seriously[30], it cannot be said that there is not any possibility of the 4th generation. But whether the 4th generation really exists or not may depend on the details of the substructure dynamics inside quarks, that is, the possibility of the existence of the dynamical stable states with the addition of three $y$-subquarks: namely, whether the sum of the kinetic energies of the constituent subquarks may balance to the binding energy to form the stable states, or not. If the non-existence of the 4th generation is finally confirmed, that fact will offer one of the clues to solve the substructure dynamics.

In our model, phenomena of CP violations and Mass differences ($\Delta M_P$) of $P^0$ and $\bar{P}^0$ are originated from subquark dynamics. Among various subquarks neutral $y$-subquark plays the important role. Namely $P^0 - \bar{P}^0$ mixings occur by $y$-subquark exchange between constituent quarks in $P^0$ or $\bar{P}^0$, which generate indirect CP violations and $\Delta M_P$. Further ($y \rightarrow \lambda g_{ek}$)-processes give complex phases to vertex parts of the flavour mixings, which generate direct and mixing-induced CP violations. There are two parameters of phases: $\delta$ and $\delta'$, the values of which are evaluated by the experimental data of Belle and BaBar. Using them some predictions are examined by the various data and the results are roughly good.

Concerning $\Delta M_{D^0}$, our model predicts the value of $O(10^{-14})$. We hope further accumulation of the data by the CLEO detector.

To conclude, we have discussed the possibility that the subquark dynamics play the essential role in all flavor-changing phenomena.

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Figure 1: Subquark-line diagrams of the weak interactions
Figure 2: The ($y \rightarrow 2g_h$)-process by prion-level diagram
Figure 3: (A) Gluon exchange in $q\bar{q}$ system; (B) Hypergluon exchange in $\alpha\bar{\alpha}$ system.
Figure 4: Schematic illustrations of $P^0 - \bar{P}^0$ mixings by $y$-exchange interactions