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On the Substructure of Quarks and Leptons

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Abstract

The geometricratio-like quark mass spectrum and quark-flavor mixings in weak interactions are investigated using a preon model proposed by the author. It is found that these phenomena are unifyingly understood by the vew that quarks and leptons are the bound-systems of preons in effective power-law potentials. The spectrum of quark-masses essentially comes out owing to the power-law nature of the potential and quark-flavor mixings come out from the fact that SU(3)-octet neutral scalar particles inside quarks annihilate into two gluons. Some other topics such as meson-antimeson mass-mixing and FCNC are explained by the present model. The lepton-mass spectrum is also discussed.

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1 Introduction

The discovery of the top quark has finally confirmed the quark-lepton-symmetric global SU(2)-doublet structure and the phenomenological generation-structure, which is originated from Weinberg's investigation of leptons and studied by Glasow, Iliopoulous and Maiani concerning quarks[1, 2, 3]. The Glashow-Weinberg-Salam model (what is called Standard Model) have successfully explained various experimental evidences. But it cannot answer the questions about the origins of (1) the mass-spectrum of quarks and leptons, (2) the generations and (3) the quark-flavor mixings, etc. In order to orvercome such difficulties some attempts have done, for example, grandunification, supersymmetry, composite, etc.

In this article we consider a possibility of a composite model. The fundamental conception of our model is that the intermediate vector bosons are all massless, elementary fields and belonging to the adjoint representations of some gauge groups and that there exist two kinds of the elementary matter fields: spin-1/2 fermion field and spin-0 scalar field. Thus quarks, leptons and also weak bosons of W, Z are all composite objects of such elementary matter fields and the usual weak interactions are regarded as the effective residual interactions as the strong ones. In order to answer the beforementioned questions,(1)(2)(3), if quarks and leptons are elementary, it is necessary to introduce some extrenal relationship among quarks and leptons or some kinds of symmetries in an ad hoc way. On the other hand the composite models have abilitiy to expound these problems unifyingly with the internal dynamics of substructure systems of quarks and leptons.

In the present work we investigate these subjects from such a point of view. In section 2, we study some theoritical aspects of the stationary bound state problem and consider a toy model for preparation of further discussions. In section 3, a composite model of quarks and leptons is explained which has been proposed by the author. In section 4, we mention the main part of this work. Namely, we discuss the origin of the quark-mass spectrum, the quark-flavor mixings and the generation from our model. In section 5, we discuss the lepton mass spectrum,the posibility of the forth generation and some remnant issues.

2 Theoretical preliminaries and toy model

In order to investigate the basic equations of the theory of bound states it is necessary to treat partial integro-differential many-time equations in Minkowski's space with integrals over four dimensional regions of space-time, which do not admit the stationary treatment. Concerning this point Królikowski and Rzewuski showed that covariant one-time formulation of the many-body problem in quantum field theory is obtained by transforming the conventional many-time equations of this problem into other equivalent equations which relate only those values of the wavefunction and its derivatives which correspond to one space-like hypersurface σ [4]. By this thoughts they showed the processes to convert the Bethe-Salpeter equation into an equivalent one-time equation posessing the form of a Schrödinger equation and described the example of non-relativistic stationary equations for n- spinless particles interacting by means of two-body multiplicative potentials [5].

$$(E_n - H_n)\psi_n(\mathbf{x_1}, \cdots, \mathbf{x_n}) = 0, \tag{1}$$

with

$$H_n = -\sum_{i=1}^{n}\{\frac{1}{2m_i}\}(\{\frac{\partial}{\partial \mathbf{x_i}}\})^2 + \sum_{i<j} V_{ij}^{(n)}(|\mathbf{x_i} - \mathbf{x_j}|). \tag{2}$$

where m_i and $\mathbf{x_i}$ are mass and coordinate of i-particle and $V_{ij}^{(n)}$ is a potential between i-particle and j-particle. Applying the above treatment to n=2 and we get the Schrödinger equation in three dimensions:

$$-\frac{1}{2\mu}\nabla^2\psi(r) + [V(r) - E]\psi(r) = 0, \tag{3}$$

where μ is the reduced mass of the two-body system, E is the total bound state energy, $r = |\mathbf{x_1} - \mathbf{x_2}|$ and $\nabla^2 = (\partial/\partial r)^2$. In order to study bound states in a central potential we refer the Virial Theorem for eq.(3):

$$< T >= E - < V >=< \frac{r}{2}\frac{dV}{dr} >, \tag{4}$$

where $<>$ denotes an expectation value, $T = \{1/2\mu\}\nabla^2$ and $V = V(r)$ [6].

For the special case of a power-law potential we consider

$$V(r) = \lambda r^{\nu}, \tag{5}$$

where $\lambda > 0$ and $-2 < \nu < \infty$. Applying eq.(4) to eq.(5) we get

$$< T >= \frac{\nu}{2} < V >= \frac{\nu}{2+\nu}E. \tag{6}$$

In case of a smooth varying potential we may well have

$$< V(r) >= V(< r^2 >^{\frac{1}{2}}), \tag{7}$$

where $< r^2 >^{\frac{1}{2}} (\equiv \mathbf{r})$ is the mean square radii and also we get from eq.(5):

$$< V(r) >= \lambda \mathbf{r}^{\nu}. \tag{8}$$

Here let us apply the above treatment to some toy models. Considering the system composed of two particles with masses m_1, m_2 interacting in the central potential, then we get the total mass:

$$M = m_1 + m_2 + E_B, \tag{9}$$

where E_B is a binding energy of two particles and equal to E in eq.(3) and also from eq.(4) we have

$$E_B =< T > + < V > . \tag{10}$$

Besides, the assumption that constituent masses m_1, m_2 are much smaller than kinetic energies ($m_1, m_2 << < T >$) would lead the equation:

$$M \cong E_B = (1 + \frac{\nu}{2}) < V >, \tag{11}$$

where we use eq.(6). Combining eq.(11) with eq.(8) we have

$$M \cong \lambda (1 + \frac{\nu}{2})(\mathbf{r})^{\nu}., \tag{12}$$

This equation provides, a useful guide to estimate the relation between mass and size of the bound system.

Next, let us suppose the interaction radii $\mathbf{r}$ decreases to $\mathbf{r}', (\mathbf{r} > \mathbf{r}')$(See (a)$\rightarrow$ (b) in Fig(1)), then we get

$$M' \cong \lambda (1 + \frac{\nu}{2})(\mathbf{r}')^{\nu}, \tag{13}$$

where M' is the total mass of the new system. From eq.(12) and eq.(13) we find the simple evidence:

$$\frac{M'}{M} \cong (\frac{\mathbf{r}'}{\mathbf{r}})^{\nu}, \tag{14}$$

and we can state that if $\nu < 0$, we have $M' > M$ because $\mathbf{r}'/\mathbf{r} < 1$. Further we study the following case

$$\frac{M'}{M} \cong (\frac{\mathbf{r}'}{\mathbf{r}})^{\nu} \quad \text{and} \quad \frac{M''}{M'} \cong (\frac{\mathbf{r}''}{\mathbf{r}'})^{\nu}., \tag{15}$$

In eq.(15) if $\mathbf{r} > \mathbf{r}' > \mathbf{r}''$ (as (a),(b),(c) in Fig.(1)) and if $\nu < 0$, then we obtain

$$M < M' < M'', \tag{16}$$

and if $\mathbf{r}'/\mathbf{r}=\mathbf{r}''/\mathbf{r}'$,then we find

$$\frac{M'}{M} = \frac{M''}{M'}., \tag{17}$$

In this case the relationship among $\mathbf{r}, \mathbf{r}', \mathbf{r}''$ and M, M', M'' is that of the geometrical progression. Another example is the case of (a)$\rightarrow$ (d) in Fig(1). In this case we may roughly estimate

$$M''' \cong 3(1+\frac{\nu}{2}) < V(r''') > \cong 3\lambda(1+\frac{\nu}{2})(\mathbf{r}''')^{\nu}, \tag{18}$$

where we use eq.(2). Then we have $M''' > M$, if $\nu < 0$ and $\mathbf{r} > \mathbf{r}'''$.

3 A composite model of quarks and leptons

The author has proposed a composite model of quarks and leptons [7]. This model has two kinds of preons such as a spin-1/2 fermionic field (denoted by Λ) and a spin-0 bosonic field (denoted by Θ) which are both carrying the electric charge $''e/6''$. The reason why we choose the bosonic-fermionic (global supersymmetric) preon model is as follows: the construction of neutral composite fermionic matters (neutrinos in practice) needs both kinds of matters, fermionic as well as bosonic, if they carry the same charge for the Abelian gauge or belong to the same fundamental representation for the non-Abelian gauge group[9]. The value of $''e/6''$ has come from following thoughts: all gauge fields must be the connection fields beloging to Cartan-type which has a machinery of "soldering" (for details of soldering mechanism, refer to [15]) Then the electromagnetic field (usually in $U(1)$ gauge group) is also in the same situation and belongs to $SL(2,C)$ gauge group in our model, which is equipped with "soldering mechanism" and has 6 generators. Therefore the minimum unit of electric charge may be $''e/6''$, compared with $''e''$ for usual $U(1)$ gauge group with one generator. Both Λ and Θ (preon) have the same transformation property of $(3,2,2)$ under the unbroken local gauge symmetry of $SU(3)_{QCD} \otimes SU(2)^L_W \otimes SU(2)^R_W$. The final goal is to build quarks and leptons with Λ and Θ. For that purpose we first construct two-body systems of Λ and Θ. They are "intermediate clusters" which contain at least one singlet state of any $SU(3)_{QCD} \otimes SU(2)^L_W \otimes SU(2)^R_W$. The results are as follows:

$$\alpha \;=\; (\Lambda\Theta) \qquad ,\alpha_{\mathbf{L}} = (\bar{3},3,1), \alpha_{\mathbf{R}} = (\bar{3},1,3) \;\; Q = e/3, spin 1/2; \tag{19a}$$

$$\beta = (\Lambda\overline{\Theta}, \overline{\Lambda}\Theta), \beta_{\mathbf{C}} = (8,1,1), \beta_{\mathbf{L}} = (1,3,1), \beta_{\mathbf{R}} = (1,1,3) \quad Q = 0, spin0; \tag{19b}$$

$$\mathbf{x} = (\Lambda\Lambda, \Theta\Theta), \mathbf{x_L} = (\overline{3}, 3.1), \mathbf{x_R} = (\overline{3}, 1, 3) \quad Q = e/3, spin0; \tag{19c}$$

$$\mathbf{y} = (\Lambda\overline{\Lambda}, \Theta\overline{\Theta}), \mathbf{y_c} = (8,1,1), \mathbf{y_L} = (1,3,1), \mathbf{y_R} = (1,1,3) \quad Q = 0, spin0. \tag{19d}$$

Notice that a three-preon system cannot construct the singlet states of $SU(2)$. So we disregard that choice. Here we call $\alpha, \beta, \mathbf{x}, \mathbf{y}$ in eq.(19) "subquark". Using α and $\mathbf{x}$ we can make quarks and leptons of the first generation:

$$\mathbf{u} = (\alpha\mathbf{x}), \quad (3,1,1); \quad Q = \frac{2}{3}e; \tag{20a}$$

$$\mathbf{d} = (\overline{\alpha\mathbf{x}}\mathbf{x}), \quad (3,1,1) \quad Q = -\frac{1}{3}e; \tag{20b}$$

$$\nu = (\alpha\overline{\mathbf{x}}), \quad (1,1,1) \quad Q = 0; \tag{20c}$$

$$\mathbf{e}^- = (\overline{\alpha\mathbf{x}\mathbf{x}}), \quad (1,1,1) \quad Q = -e. \tag{20d}$$

In order to make the members of higher generations, we should consider that orbital and radial exitations seem to have the wrong energy scale and then the most likely type of exitations is the addition of preon-antipreon pair [8]. The results for 2nd and 3rd generations are as follows:

$$\begin{cases} \mathbf{c} : (\alpha\mathbf{x}\mathbf{y_c}) \\ \mathbf{s} : (\overline{\alpha\mathbf{x}}\mathbf{x}\mathbf{y_c}) \end{cases} \quad \begin{cases} \nu_\mu : (\alpha\overline{\mathbf{x}}\mathbf{y_{L,R}}) \\ \mu^- : (\overline{\alpha\mathbf{x}\mathbf{x}}\mathbf{y_{L,R}}) \end{cases} \quad \text{2nd generation} \tag{21a}$$

$$\begin{cases} \mathbf{t} : (\alpha\mathbf{x}\mathbf{y_c}\mathbf{y_c}) \\ \mathbf{b} : (\overline{\alpha\mathbf{x}}\mathbf{x}\mathbf{y_c}\mathbf{y_c}) \end{cases} \quad \begin{cases} \nu_\tau : (\alpha\overline{\mathbf{x}}\mathbf{y_{L,R}}\mathbf{y_{L,R}}) \\ \tau^- : (\overline{\alpha\mathbf{x}\mathbf{x}}\mathbf{y_{L,R}}\mathbf{y_{L,R}}) \end{cases} \quad \text{3rd generation.} \tag{21b}$$

The illustration for quarks is in Fig.(2). We can make vector or scalar particles with (1,1,1),

$$\begin{cases} W^+ \sim (\alpha^\uparrow\alpha^\uparrow\mathbf{x}) \\ W^- \sim (\overline{\alpha}^\uparrow\overline{\alpha}^\uparrow\overline{\mathbf{x}}) \end{cases} \quad \begin{cases} Z_1^0 \sim (\alpha^\uparrow\overline{\alpha}^\uparrow) \\ Z_2^0 \sim (\alpha^\uparrow\overline{\alpha}^\uparrow\mathbf{x}\overline{\mathbf{x}}) \end{cases} \quad \text{Vector-sector} \tag{22a}$$

$$\begin{cases} S^+ \sim (\alpha^\uparrow\alpha^\downarrow\mathbf{x}) \\ S^- \sim (\overline{\alpha}^\uparrow\overline{\alpha}^\downarrow\overline{\mathbf{x}}) \end{cases} \quad \begin{cases} S_1^0 \sim (\alpha^\uparrow\overline{\alpha}^\downarrow) \\ S_2^0 \sim (\alpha^\uparrow\overline{\alpha}^\downarrow\mathbf{x}\overline{\mathbf{x}}) \end{cases} \quad \text{Scalar-sector.} \tag{22b}$$

,where $\alpha^\uparrow$; $\alpha^\downarrow$ mean spin-up; spin-down. In the standard model weak bosons of W and Z are massive gauge fields equipped with the Higgs mechanism. On the other hand there is a alternative concept that every gauge bosons are elementary massless fields and usual weak interactions are the effective residual forces due to the substructure dynamics. Then if we adopt this consideration, W and Z are regarded as composite objects of the substructure matters and play the same role as ρ-mesons in **QCD**. In our model $W^\pm, Z_1^0$ and Z_2^0 in eq.(22) can be assigned to such ones and usual weak interactions occur essentially by the rearrangements of α,$\mathbf{x}$ as seen in Fig.(3).

4 Verification of compositeness of quarks and leptons

If quarks and leptons are really composites of subquarks, what phenomena must be explained ? They would include (1)the mass spectrum of quarks and leptons (2)the quark-flavor-mixing in weak interactions (3)closeness to the Dirac magnetic moments (4)non-existence of low-lying spin-3/2 exitations, etc. With regard to (3) and (4) ,our model, as shown in eq.(20) , eq.(21), has an advantage that all quarks and leptons have only one spin-1/2 fermion (α, or $\overline{\alpha}$). This fact would lead a speculation that low-lying spin-3/2 exitationed states cannot exist conpared with low-iying nucleons possessing three spin-1/2 fermions(quarks) and that only one α (or $\overline{\alpha}$) which causes the magnetic moment may be regarded to wear the clouds of bosonic $\mathbf{x}$ and $\mathbf{y_c}$ and then external electromagnetic fields would feel α (or $\overline{\alpha}$) pointlike by Gauss- Law for electric charges and would, as a result, recognize that quarks and leptons have the Dirac magnetic mommment. Next discussions about (1) and (2) are as follows:

(1) Mass spectrum of quarks and leptons.

The experimental constraints such as the $g-2$ measurements request that quarks and leptons have sizes smaller than $10^{-17}cm$. Combining this fact with the notion of compositeness of quarks and leptons, the most characteristic feature imaginable is that the subquarks have very large kinetic energies and their masses may be estimated essentially zero. From Fig.(4) we notice several points. First of all the mass spectra of both quarks and leptons seem to be "geometricratio-like". Actually we can roughly parametrize them as follows:

$$M_{UQ} = 1.7 \times 10^{-4} \times (10^{2.05})^n \quad \text{Gev} \quad \text{for u,c,t} \tag{23a}$$

$$M_{DQ} = 3.0 \times 10^{-4} \times (10^{1.39})^n \quad \text{Gev} \quad \text{for d,s,b} \tag{23b}$$

$$M_{DL} = 3.6 \times 10^{-4} \times (10^{1.23})^n \quad \text{Gev} \quad \text{for e,}\mu\text{, }\tau\text{,} \tag{23c}$$

where $n = 1, 2, 3$ are for the generation number. These parametrizations are obtained by using 2nd and 3rd generations. So they do not coincide with 1st generation so well. But we need some discussions about this point. In 2nd and 3rd generations the kinetic energies of subquarks must contribute most to the mass of quarks and leptons and on the contrary, the masses of subquarks and other fine structure parts must be negligible. This situation is very different from the hadronic mass spectrum which has the features full of variety because the constituent quarks inside hadrons have comparable values of masses, kinetic energies, potential energies and contributions from fine structure

parts. As for the masses of the 1st generation we could probably speculate that the kinetic energies of subquarks are rather small and comparable to masses of subquarks and other fine structure parts, which might cause that masses of the 1st generation are off from the dashed lines in Fig.(4). We notice that electron mass behaves most pecuriarly among all members and that other members including top-quark behave rather naturally. The peculiarity of electron mass might become a clue to investigate the motions of subquarks in future.

Here we assume that discussions in section 3 can apply to quark masses. In our model of eq.(21) total numbers of constituent subquarks (α,$\mathbf{x}$,$\mathbf{y}$) are as follows: 3 subquarks for c-quark; 4 for t; 4 for s; 5 for b. Then by using eq.(23) and discussions in section, (3) we find

$$\frac{M_{\mathbf{b}}}{M_{\mathbf{s}}} = \frac{5}{4}\left(\frac{\mathbf{r_b}}{\mathbf{r_s}}\right)^{\nu_D} = 10^{1.39}, \tag{24a}$$

$$\frac{M_{\mathbf{t}}}{M_{\mathbf{c}}} = \frac{4}{3}\left(\frac{\mathbf{r_t}}{\mathbf{r_c}}\right)^{\nu_U} = 10^{2.05}, \tag{24b}$$

where M_q,$\mathbf{r}_q$ ($q = \mathbf{b}, \mathbf{s}, \mathbf{t}, \mathbf{c}$) are quarkmass and mean interaction length of constituents (α, $\mathbf{x}$, $\mathbf{y_c}$) inside quarks; $\nu_{D,U}$ are powers of potentials of down- or up-quark sector. And from this we get

$$\frac{\mathbf{r_b}}{\mathbf{r_s}} = 10^{\frac{1.30}{\nu_D}}, \tag{25a}$$

$$\frac{\mathbf{r_t}}{\mathbf{r_c}} = 10^{\frac{1.93}{\nu_U}}, \tag{25b}$$

where we suppose $\nu_{D,U} \neq 0$. If we set $\nu_{D,U} < 0$, then we get $\mathbf{r_b} < \mathbf{r_s}$ and $\mathbf{r_t} < \mathbf{r_c}$.

(2) Quark-flavor-mixing in weak interactions.

Before discussing this issue we rewrite quark sectors of eq.(20) and eq.(21) to

$$\begin{cases} <\mathbf{u}| =< \alpha\mathbf{x}| & ; \ <\mathbf{d}| =< \overline{\alpha}\overline{\mathbf{x}}\mathbf{x}| \\ <\mathbf{c}| =< \alpha\mathbf{x}\mathbf{y_c}| & ; \ <\mathbf{s}| =< \overline{\alpha}\overline{\mathbf{x}}\mathbf{x}\mathbf{y_c}| \\ <\mathbf{t}| =< \alpha\mathbf{x}\mathbf{y_c}\mathbf{y}\mathbf{c}| & ; \ <\mathbf{b}| =< \overline{\alpha}\overline{\mathbf{x}}\mathbf{x}\mathbf{y_c}\mathbf{y_c}|. \end{cases} \tag{26}$$

In our model quark-flavor-mixings occur by creation or annihilation of "$\mathbf{y_c}$" inside quarks. "$\mathbf{y_c}$" is a neutral scalar particle carrying $SU(3)$-octet color charge and, therefore, is coupled to two gluons (See Fig.(5)). Then usual charged weak interactions are shown schematically as in Fig.(6). "α", "$\mathbf{x}$" and "$\mathbf{y_c}$" inside quarks are essentially confined by $SU(2)_W^{L,R}$ and also confined by $SU(3)_{QCD}$ within radius of a few Tev^{-1}[10]. The **QCD** senario demonstrates a running coupling constant as:

$$\begin{cases} \frac{1}{\alpha_s(Q)} = \frac{1}{\alpha_s(\Lambda)} + b\ln(\frac{Q^2}{\Lambda^2}), \\ b = \frac{1}{4\pi}(11 - \frac{2}{3}N_f - \frac{1}{12}N_s), \end{cases} \tag{27}$$

where N_f ;N_s is a number of fermion ; scalar, and Λ is an arbitrary momentum scale. As α is fermionic and $\mathbf{x}$, $\mathbf{y_c}$ are bosonic, we set $N_f = 1, N_s = 2$. Then we calculate $b = 0.8$, using which to eq.(27) we obtain

$$\frac{1}{\alpha_s^q} = 0.8 \ln\left(\frac{Q^2}{\Lambda_q^2}\right), \tag{28}$$

where "q" of α_s^q and Λ_q means that subquarks are confined inside quarks by α_s^q at the momentum scale: $\Lambda_q \sim$ a few Tev. We illustrate it in Fig.(7) where we denote α_s^h for usual quark confinement phenomena at $\Lambda = 0.2$ Gev. Usually the quark-flavor-mixing ratios in weak interactions are indicated by **CKM** matrix element $|V_{ij}|$'s as

$$\begin{cases} |V_{\mathrm{ud}}| = 0.974 \pm 0.0010 & , \quad |V_{\mathrm{us}}| = 0.2205 \pm 0.0018 \\ |V_{\mathrm{cd}}| = 0.204 \pm 0.017 & , \quad |V_{\mathrm{cb}}| = 0.040 \pm 0.005 \\ |V_{\mathrm{cs}}| = 1.01 \pm 0.18 & , \quad |V_{\mathrm{ub}}/V_{\mathrm{cb}}| = 0.08 \pm 0.02, \end{cases} \tag{29}$$

All of them have been determined dy the experiments[11]. Refering Fig.(6) we find $|V_{\mathrm{us}}|$ and $|V_{\mathrm{cd}}|$ correspond to (a) and paying attention to the experimental fact of $|V_{\mathrm{us}}| \cong |V_{\mathrm{cd}}|$ and non-equality of **s**-quark and **c**-quark mass we could conjecture that $(\mathbf{y_c} \to 2g)$-process in Fig.(5) is factorized from net weak interactions which are shown essentially in Fig.(3). Considering this point, we demonstrate charged weak currents of quarks by using the formulations of eq.(26) as:

$$< \mathrm{u}|\mathrm{d} > \;=\; < \alpha\mathbf{x}|\overline{\alpha}\overline{\mathbf{x}}\mathbf{x} >_{\mathrm{ud}} = < U|D >_{\mathrm{ud}} \tag{30a}$$

$$< \mathrm{u}|\mathrm{s} > \;=\; < \alpha\mathbf{x}|\overline{\alpha}\overline{\mathbf{x}}\mathbf{x}\mathbf{y}_c >_{\mathrm{us}} = < U|D >_{\mathrm{us}} < D|(2g) \to \mathbf{y_c} >_{\mathrm{us}} \tag{30b}$$

$$< \mathrm{u}|\mathrm{b} > \;=\; < \alpha\mathbf{x}|\overline{\alpha}\overline{\mathbf{x}}\mathbf{x}\mathbf{y}_c\mathbf{y}_c >_{\mathrm{ub}} = < U|D >_{\mathrm{ub}} < D|(2g)(2g) \to \mathbf{y}_c\mathbf{y}_c >_{\mathrm{ub}} \tag{30c}$$

$$< \mathrm{c}|\mathrm{d} > \;=\; < \alpha\mathbf{x}\mathbf{y}_c|\overline{\alpha}\overline{\mathbf{x}}\mathbf{x} >_{\mathrm{cd}} = < \mathbf{y}_c \to (2g)|U >_{\mathrm{cd}} < U|D >_{\mathrm{cd}} \tag{30d}$$

$$< \mathrm{c}|\mathrm{s} > \;=\; < \alpha\mathbf{x}\mathbf{y}|\overline{\alpha}\overline{\mathbf{x}}\mathbf{x}\mathbf{y}_c\mathbf{y}_c >_{\mathrm{cs}} = < U\mathbf{y}_c|D\mathbf{y}_c >_{\mathrm{cs}} \tag{30e}$$

$$< \mathrm{c}|\mathrm{b} > \;=\; < \alpha\mathbf{x}\mathbf{y}_c|\overline{\alpha}\overline{\mathbf{x}}\mathbf{x}\mathbf{y}_c\mathbf{y}_c >_{\mathrm{cb}} = < U\mathbf{y}_c|D\mathbf{y}_c >_{\mathrm{cb}} < D\mathbf{y}_c|(2g) \to \mathbf{y}_c >_{\mathrm{cb}} \tag{30f}$$

$$< \mathrm{t}|\mathrm{d} > \;=\; < \alpha\mathbf{x}\mathbf{y}_c\mathbf{y}_c|\overline{\alpha}\overline{\mathbf{x}}\mathbf{x} >_{\mathrm{td}} = < \mathbf{y}_c\mathbf{y}_c \to (2g)(2g)|U >_{\mathrm{td}} < U|D >_{\mathrm{td}} \tag{30g}$$

$$< \mathrm{t}|\mathrm{s} > \;=\; < \alpha\mathbf{x}\mathbf{y}_c\mathbf{y}_c|\overline{\alpha}\overline{\mathbf{x}}\mathbf{x}\mathbf{y}_c >_{\mathrm{ts}} = < \mathbf{y}_c \to (2g)|U\mathbf{y}_c >_{\mathrm{ts}} < U\mathbf{y}_c|D\mathbf{y}_c >_{\mathrm{ts}} \tag{30h}$$

$$< \mathrm{t}|\mathrm{b} > \;=\; < \alpha\mathbf{x}\mathbf{y}_c\mathbf{y}_c|\overline{\alpha}\overline{\mathbf{x}}\mathbf{x}\mathbf{y}_c\mathbf{y}_c >_{\mathrm{tb}}, \tag{30i}$$

where we denote $< \alpha\mathbf{x}| \equiv < U|$, $< \overline{\alpha}\overline{\mathbf{x}}\mathbf{x}| \equiv < D|$ for brevity. Considering **QCD** coupling constant $\alpha_s^q(Q)$ in $(\mathbf{y}_c \to (2g))$- processes we write the expectation values of these as:

$$\begin{cases} \alpha_s^q(Q_{qq'})^2 B_{qq'} & = & | < \mathbf{y}_c \to (2g)|U; D; (U or D)\mathbf{y}_c; (U or D)\mathbf{y}_c\mathbf{y}_c >_{qq'} | \\ \alpha_s^q(Q_{qq'})^4 B_{qq'} & = & | < \mathbf{y}_c\mathbf{y}_c \to (2g)(2g)|U; D >_{qq'} |, \end{cases} \tag{31}$$

where $B_{qq'}$ is an unknown factor due to the dynamics of the transition from q'-quark to q-quark and $Q_{qq'}$ is a effective momentum transfer of present interactions. Here let us assume that the net weak interaction is not influenced by the kind of the initial and the final quark. Then we introduce the following notations as:

$$\begin{cases} |<U|D>| & \equiv \ |<U|D>_{qq'}| \\ |<U\mathbf{y}_c|D\mathbf{y}_c>| & \equiv \ |<U\mathbf{y}_c|D\mathbf{y}_c>_{qq'}|. \end{cases} \tag{32}$$

By using eq.(30),(31) and (32) we define the quantities $M_{qq'}$, which may relate to CKM matrix element $V_{qq'}$, as follows :

$$M_{\mathrm{ud}} \equiv \frac{|<\mathbf{u}|\mathbf{d}>|}{|<U|D>|} = 1 \tag{33a}$$

$$M_{\mathrm{us}} \equiv \frac{|<\mathbf{u}|\mathbf{s}>|}{|<U|D>|} = \alpha_s^q(Q_{\mathrm{us}})^2 B_{\mathrm{us}} = \frac{|V_{\mathrm{us}}|}{|V_{\mathrm{ud}}|} \tag{33b}$$

$$M_{\mathrm{ub}} \equiv \frac{|<\mathbf{u}|\mathbf{b}>|}{|<U|D>|} = \alpha_s^q(Q_{\mathrm{ub}})^4 B_{\mathrm{ub}} = \frac{|V_{\mathrm{ub}}|}{|V_{\mathrm{ud}}|} \tag{33c}$$

$$M_{\mathrm{cd}} \equiv \frac{|<\mathbf{c}|\mathbf{d}>|}{|<U|D>|} = \alpha_s^q(Q_{\mathrm{cd}})^2 B_{\mathrm{cd}} = \frac{|V_{\mathrm{cd}}|}{|V_{\mathrm{ud}}|} \tag{33d}$$

$$M_{\mathrm{cs}} \equiv \frac{|<\mathbf{c}|\mathbf{s}>|}{|<U\mathbf{y}_c|D\mathbf{y}_c>|} = 1 \tag{33e}$$

$$M_{\mathrm{cb}} \equiv \frac{|<\mathbf{c}|\mathbf{b}>|}{|<U\mathbf{y}_c|D\mathbf{y}_c>|} = \alpha_s^q(Q_{\mathrm{cb}})^2 B_{\mathrm{cb}} = \frac{|V_{\mathrm{cb}}|}{|V_{\mathrm{cs}}|} \tag{33f}$$

$$M_{\mathrm{td}} \equiv \frac{|<\mathbf{t}|\mathbf{d}>|}{|<U|D>|} = \alpha_s^q(Q_{\mathrm{td}})^4 B_{\mathrm{td}} = \frac{|V_{\mathrm{td}}|}{|V_{\mathrm{ud}}|} \tag{33g}$$

$$M_{\mathrm{ts}} \equiv \frac{|<\mathbf{t}|\mathbf{s}>|}{|<U\mathbf{y}_c|D\mathbf{y}_c>|} = \alpha_s^q(Q_{\mathrm{ts}})^2 B_{\mathrm{ts}} = \frac{|V_{\mathrm{ts}}|}{|V_{\mathrm{cs}}|} \tag{33h}$$

$$M_{\mathrm{tb}} \equiv \frac{|<\mathbf{t}|\mathbf{b}>|}{|<U\mathbf{y}_c\mathbf{y}_c|D\mathbf{y}_c\mathbf{y}_c>|} = 1. \tag{33i}$$

From eq.(29) and eq.(33) we can estimate $M_{qq'}$ numerically as follows :

$$\begin{cases} M_{\mathrm{us}} = 0.226 \pm 0.002 \quad , \quad M_{\mathrm{ub}} = 0.0034 \pm 0.0012 \\ M_{\mathrm{cd}} = 0.207 \pm 0.019 \quad , \quad M_{\mathrm{cb}} = 0.042 \pm 0.013. \end{cases} \tag{34}$$

By using eq.(33. b, f) and eq.(34) we have

$$\frac{M_{\mathrm{us}}}{M_{\mathrm{cb}}} = \frac{\alpha_s^q(Q_{\mathrm{us}})^2 B_{\mathrm{us}}}{\alpha_s^q(Q_{\mathrm{cb}})^2 B_{\mathrm{cb}}} = 6.0 \pm 1.9. \tag{35}$$

If we assume $B_{\mathrm{us}} \simeq B_{\mathrm{cb}}$, we get approximately

$$\frac{\alpha_s^q(Q_{\mathrm{us}})}{\alpha_s^q(Q_{\mathrm{cb}})} \simeq 2.4. \tag{36}$$

From eq.(28) we get the interesting equation :

$$\frac{Q_{\rm us}}{Q_{\rm cb}} = \exp\left\{\frac{1}{1.6\alpha_s^q(Q_{\rm us})}\left(1-\frac{\alpha_s^q(Q_{\rm us})}{\alpha_s^q(Q_{\rm cb})}\right)\right\}. \tag{37}$$

If we use eq.(36), we obtain

$$\frac{Q_{\rm us}}{Q_{\rm cb}} = \exp\left\{\frac{-0.875}{\alpha_s^q(Q_{\rm us})}\right\}. \tag{38}$$

As we have no experimental informations about $\alpha_s^q(Q_{\rm us})$, let us set $\alpha_s^q(Q_{\rm us})$= 0.3; 0.4; 0.5 tentatively. Then we calculate respectively

$$\frac{Q_{\rm us}}{Q_{\rm cb}} = 0.05;\ \ 0.11;\ \ 0.17. \tag{39}$$

So we could imagine that $Q_{\rm us}/Q_{\rm cb} = 1/10 \sim 1/100$. The characteristic feature of our model is that particles of $\alpha, \mathbf{x}, \mathbf{y}_c$ interact each other inside quarks and then we could suppose there exists the relation between mean interaction length $\mathbf{r}_q$ and effective interaction energy $Q_{qq'}$ of $\alpha_s^q(Q_{qq'})$. For the present case we may assume

$$\frac{\mathbf{r}_{\rm b}}{\mathbf{r}_{\rm s}} = \frac{Q_{\rm us}}{Q_{\rm cb}}. \tag{40}$$

From eq.(25), (39) and (40) we obtain

$$-0.65 < \nu_D < -1.3. \tag{41}$$

We find ν_D is "negative" and may be close to the Coulomb-like potential. By using eq.(33, b ; d) and $M_{\rm us}\simeq M_{\rm cd}$ we have

$$\alpha_s^q(Q_{\rm us})^2 B_{\rm us} \simeq \alpha_s^q(Q_{\rm cd})^2 B_{\rm cd}. \tag{42}$$

If we assume $B_{\rm us}\simeq B_{\rm cd}$, we obtain $\alpha_s^q(Q_{\rm us})\simeq\alpha_s^q(Q_{\rm cd})$. From this result we could suppose that the interaction length among α, $\mathbf{x}$, $\mathbf{y}_c$ inside s-quark is roughly eqal to that of c-quark. But this may be accidental because ν_D and ν_U appeared in eq.(24) may well be different in general. Here let us examine the following equation by use of eq.(33, c ; f) :

$$\frac{M_{\rm cb}}{M_{\rm ub}} = \frac{\alpha_s^q(Q_{\rm cb})^4 B_{\rm cb}^2}{\alpha_s^q(Q_{\rm ub})^4 B_{\rm ub}} = \left(\frac{\alpha_s^q(Q_{\rm cb})}{\alpha_s^q(Q_{\rm ub})}\right)^4, \tag{43}$$

where we assume $B_{\rm cb}\simeq B_{\rm ub}$ in the last equation. Putting values of $M_{\rm cb}$ and $M_{\rm ub}$ of eq.(34) into eq.(43) we get

$$\frac{\alpha_s^q(Q_{\rm cb})}{\alpha_s^q(Q_{\rm ub})} = 0.87 \pm 0.21. \tag{44}$$

Then it would be said that

$$\alpha_s^q(Q_{\mathrm{cb}}) \simeq \alpha_s^q(Q_{\mathrm{ub}}). \tag{45}$$

This consistency is to be expectd primarily. Next issus to be investigated is the t-quark phenomena. By using eq.(25) and eq.(28) and the assumption :$\mathrm{r_t}/\mathrm{r_c} = Q_{\mathrm{cd}}/Q_{\mathrm{ts}}$(which is similar to eq.(40)) we obtain

$$\frac{1}{\alpha_s^q(Q_{\mathrm{ts}})} = \frac{1}{\alpha_s^q(Q_{\mathrm{cd}})} - \frac{1}{\nu_U} \times 7.1. \tag{46}$$

From eq.(33, d; h) we obtain

$$|V_{\mathrm{ts}}| \simeq \left(\frac{\alpha_s^q(Q_{\mathrm{ts}})}{\alpha_s^q(Q_{\mathrm{cd}})}\right)^2 |V_{\mathrm{cd}}||V_{\mathrm{cs}}|, \tag{47}$$

where we might assume $B_{\mathrm{cd}} \simeq B_{\mathrm{ts}}$ because they are both the quantities of the same up-quark sector. And from eq.(33, g ; h) we have

$$|V_{\mathrm{td}}| \simeq \alpha_s^q(Q_{\mathrm{ts}})^2 |V_{\mathrm{ts}}|, \tag{48}$$

where we assume $B_{\mathrm{ts}} \simeq B_{\mathrm{td}}$, $\alpha_s^q(Q_{\mathrm{ts}}) \simeq \alpha_s^q(Q_{\mathrm{td}})$ same as eq.(45) and $|V_{\mathrm{ud}}| \simeq |V_{\mathrm{cs}}| \simeq 1$. Using eq.(46), (47), (48) and parameterizing $\alpha_s^q(Q_{\mathrm{cd}})$ and ν_U we can calculate $|V_{\mathrm{ts}}|$ and $|V_{\mathrm{td}}|$. Results are listed in Table (1). It seems that a large negative ν_U is preferable and $|V_{\mathrm{td}}|$ is the order of 10^{-4} which is one order smaller than the values of $|V_{\mathrm{td}}|$ by the usual unitarity assumption.

Next issue to be examined is the flavor changing neutral current (**FCNC**). In the standard model in which quarks are elementary, the suppression of **FCNC** is explained in the context of the external relationship among quarks such as **GIM** mechanism. But the composite models generally have a possibility to explain it with the subquark dynamics inside quarks. In case of our model **FCNC** might occur by the interference of two amplitudes to which Z_1^0 and Z_2^0 contribute. We illustrate the case of (sd)-transition in Fig.(8). We could show this as the following equation as :

$$< (\alpha\overline{\alpha})|H|\mathrm{y}_c \rightarrow (2g) >_{Z_1^0} \simeq - < (\alpha\overline{\alpha})(\mathrm{x}\overline{\mathrm{x}})|H|\mathrm{y}_c \rightarrow (2g) >_{Z_2^0}, \tag{49}$$

where H is a hamiltonian to induce **FCNC** which is not known yet. We notice that this kind of phenomenom would not occur in the leptonic neutral currents because $(\mathrm{y}_c \rightarrow (2g))$ -process des not happen inside leptons.

The last subject to be studied is the mass-mixings of P_s-meson and anti P_s-meson (P_s is neutral pseudoscalar meson)such as $\mathrm{K}^0 - \overline{\mathrm{K}^0}$, $\mathrm{D}^0 - \overline{\mathrm{D}^0}$,$\mathrm{B}_{\mathrm{d}}^0 - \overline{\mathrm{B}_{\mathrm{d}}^0}$ and $\mathrm{B}_{\mathrm{s}}^0 - \overline{\mathrm{B}_{\mathrm{s}}^0}$.

Usually we investigate the mixings of $(P_s \leftrightarrow \overline{P_s})$ by using following formulations with the vacuum insertion approximation :

$$\Delta M_P = \mathrm{k}|M_{12}(P_s \leftrightarrow \overline{P_s})| = \mathrm{k}B_P \mathrm{f}_P^2 M_P \Phi_P, \tag{50}$$

where M_P is P_s-meson mass; $\Delta M_P = |M_P - M_{\overline{P}}|$; $M_{12}(P_s \leftrightarrow \overline{P_s})$ is a transition mass matrix element of the dispersive part; k is a common factor for all mesons from various dynamics; B_P is a "Bag" factor; f_P is a decay constant of P_s-meson; and Φ_P is the contribution from the unknown underlying dynamics to induce $(P_s \leftrightarrow \overline{P_s})$-transition[12]. Here let us extract the informations about Φ_P from the recent experiments(listed in the Particle Data Group[11]). Then, by using eq.(50), we obtain

$$\Phi_{\mathbf{B_d}} \simeq 2.4\Phi_{\mathbf{K}}; \quad \Phi_{\mathbf{B_s}} > 8.3\Phi_{\mathbf{K}}; \quad \Phi_{\mathbf{D}} < 8.0\Phi_{\mathbf{K}}, \tag{51}$$

where we use the assumption that $B_K \mathrm{f}_K^2 = (0.17Gev)^2$; $B_D \mathrm{f}_D^2 = (0.19Gev)^2$ and $B_B \mathrm{f}_B^2 = (0.33Gev)^2$ [12]. From eq.(51) we may well expect

$$\frac{\Phi_P}{\Phi_K} = \quad O(1) \ \sim \ O(10) \qquad P = D, \ B_d, \ B_s. \tag{52}$$

In our model $(P_s \leftrightarrow \overline{P_s})$-mixings could happen due to "$\mathbf{y}_c$-rearrangements" between two quarks inside the present P_s-meson as seen in Fig(9). This is a kind of the super-weak interaction originated by Wolfenstein [13]. This interaction could occur when quarks overlap each other, because $\mathbf{y}_c$-particles are confined essentially inside quarks. Then we can write for $\Phi_{\mathbf{P}}$ as :

$$\Phi_P = \quad A_P \frac{G_{SW}}{\Lambda_q^2}, \tag{53}$$

where $G_{SW}(Gev^{-2})$ stands for the strength of the present interactions, Λ_q has appeared in eq.(28) and A_P is the contribution from the details of the subquark dynamics inside quarks constructing the present P_S-meson. It is noticed that the recent report of $\Lambda_q = a \ few \ Tev$[10] is consistent with $M_N = 1 \sim 10 \ Tev$, which is a mass of a flavor-changing super-weak neutral scalar particle if it may exist[14]. In our model Φ_P has nothing to do with CKM matrix elements and the results of roughly-equal values among $\Phi'_P s$ seen in eq.(52) could be speculated by analogy of the high-energy hadronic interactions owing to "quark-rearrangements".

5 Discussion

What has to be first discussed is that we apply eq.(1) and eq.(2) to the quark- mass spectrum .They describe the non-relativistic picture . On the other hand the subquark

dynamics inside quarks must be surpassingly relativistic. In order to discuss this point let us refer to the electron mass. The eq.(23), also Fig.(4) , shows the lepton-mass spectrum seems to have the same behavior as those of quarks. In our model there exist "three" subquarks ($\overline{\alpha}$, $\overline{\mathbf{x}}$, $\overline{\mathbf{x}}$) inside a elctron. But the meaning of "three" must be the least number of subquarks (characterizing the various quantum numbers of a electron) that are renormalized with the infinite numbers of subquark-antisubquark pairs from a point of view of the usual field theory. However the stability of a electron is so peculiar that the mass eigenstate of a electron could be "effectively" treated by the sationary description of the non-relativistic bound state problem concerning "three" subquarks if we treat "the mean values for time". In our model the characteristic of the generation structure (that is, geometricratio-like spectrum) does not come from any quantum number effects(such as n, l, s) but essentially from the number of subquarks. This situation may be the same that the mass gap between the low-lying nucleon mass and the ρ- meson mass comes essentially from the different numbers of the constituent quarks (namely, 3 to 2). In this connection the latter case mainly depends on the masses of the constituent quarks but the former case may depends on the large kinetic energies and potential energies of the constituent subquarks,

Next, the interesting featue of Fig.(4) is the similarity of the slopes between that of (**d**, **s**, **b**) and (**e**, μ, τ), both of which have the same number of subquarks. We may speculate that the dynamics inside both are similar. In our model the generation number depends on adding the "**y**"-particles. Then it is, in principle, allowed to rase the generation number without restriction just as the Periodicity-Law of the atoms. If we set $n = 4$, in eq.(23), we obtain 19 Tev for the up- quark sector , 109 Gev, for the down-quark sector and 30 Gev for leptonic sectoras seen in Fig.(4). Concerning the neutrino masses , if we believe the solar neutrino experiments with **MSW**-effect ($\Delta m^2 \sim 10^{-5}\ eV$), the mass of ν_μ may be around $10^{-2\sim-3}\ eV$. Here, learning the similarity of the slopes between the down-quark masses and the lepton masses, it is predicted that the mass of ν_τ is around $10^{-1}\ eV$ and 10 eV for the 4th generation with the assumtion that the slope of the neutrino masses is the samme as that of the up-quark sector. But whether our Universe allows the existence of the 4th generation or not is an open question. Eq.(21) says that the generation-scheme of the leptons depends on adding "$\mathbf{y}_{L,R}$"-particles which belong to the adjoint representation of $\mathbf{SU(2)}_W^{L,R}$. If ($\mathbf{e} - \mu - \tau$) mixings exist, they are induced from ($\mathbf{y}_{L,R} \rightarrow (2g_{SU(2)_W})$)-processes (from which $\mu \rightarrow \mathbf{e}\gamma$ cannot occur). The experimental evidences show that the mixings have not been observed yet. As the reason of this, it is speculated that the sizes of the

leptons are so small that the running coupling constant of $SU(2)$-gluons is very small owing to that the intreaction length among subquarks inside leptons is very short.

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Figure Caption

Fig.(1) Schematic pictue of the bound states controled by the power-law potential $V(r) = \lambda r^{\nu}$.

Fig.(2) Schematic picture of the quarks composed of $\alpha(\bullet)$, $\mathbf{x}(\circ)$ and $\mathbf{y}_c(\triangle)$.

Fig.(3) Residual weak interactions by composite $\mathbf{W}$, $\mathbf{Z}$

Fig.(4) Spectrum of quarks and leptons.

Fig.(5) $(\mathbf{y}_c \rightarrow (2g))$-process, g is a $\mathbf{SU(3)}$ octet gluon.

Fig.(6) Charged weak interactions explained by $(\mathbf{y}_c \rightarrow (2g))$-process.

Fig.(7) Runnibg coupling constant :α_s

$\mathbf{SU(3)}_c^h$: $N_f = 4$ confining quarks inside hadrons

$\mathbf{SU(3)}_c^q$: $N_f = 1$, $N_s = 2$ confining subquarks inside quarks.

91 Gev : $\mathbf{Z}$-boson mass.

Fig.(8) Flavor changing neutral currents.

Fig.(9) $\mathbf{P}^0 \leftrightarrow \overline{\mathbf{P}}^0$-mixing by $\mathbf{y}_c$ rearrangements.

Table Caption

Table(1) The values of $|V_{\mathbf{ts}}|$ and $|V_{\mathbf{td}}|$.

$\alpha_s^q(Q_{\mathbf{cd}})$ and ν_U are parameters.

Fig1

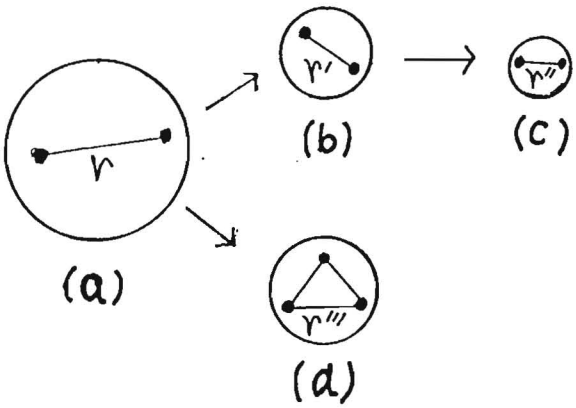

Fig 2

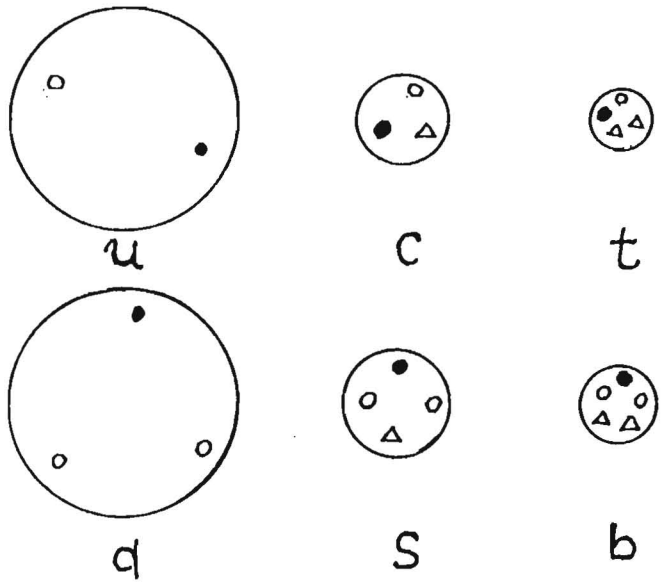

Fig 3

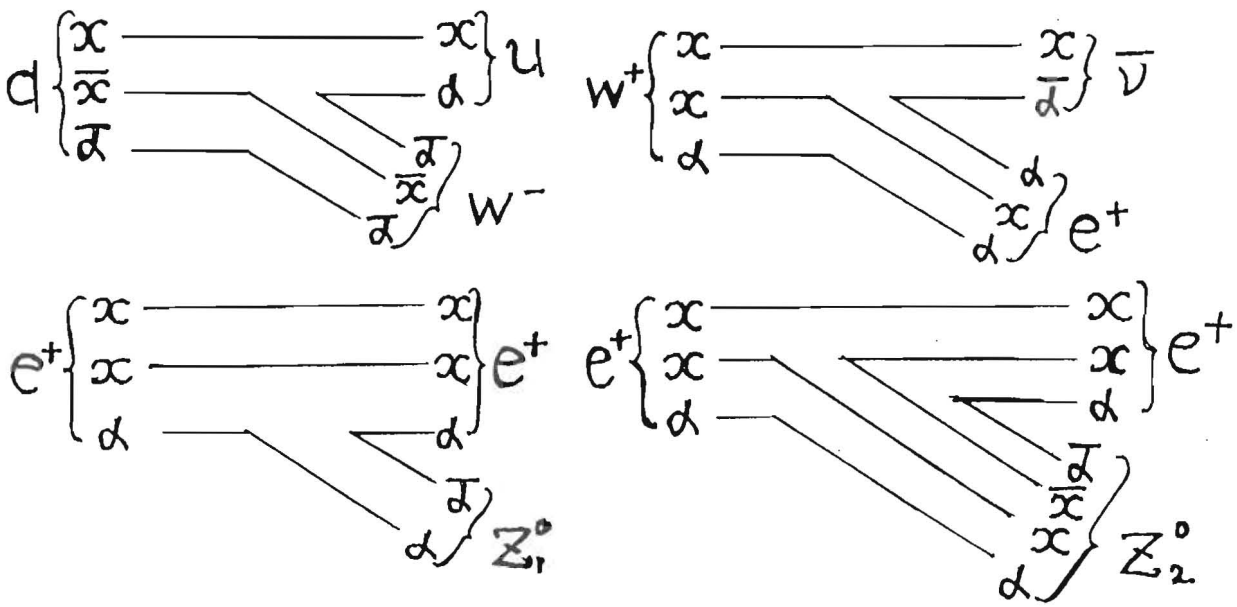

Fig 5

Fig4

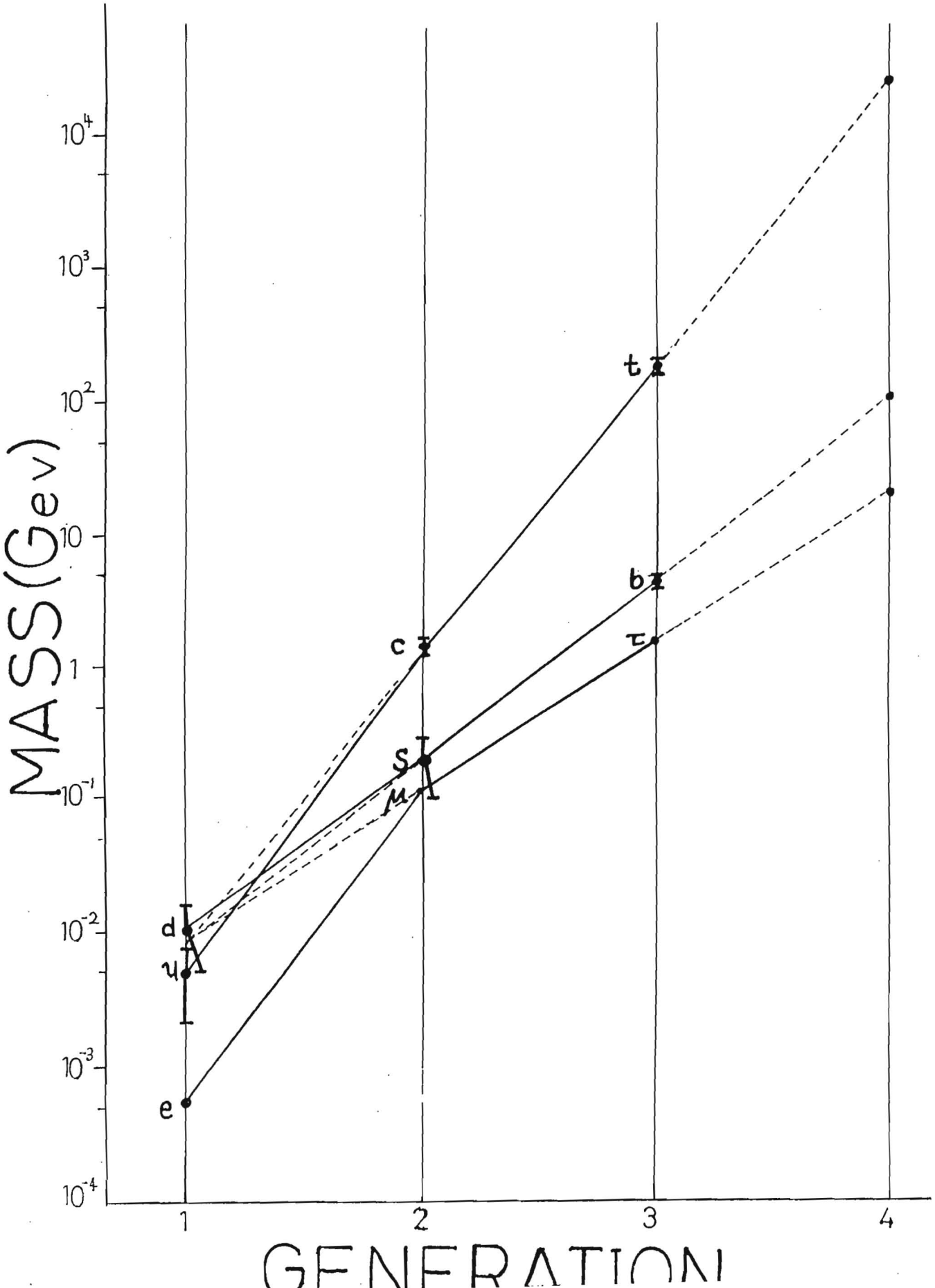
MASS(Gev)
10^4
10^3
10^2
10
1
10^{-1}
10^{-2}
10^{-3}
10^{-4}
t
b
τ
c
s
μ
d
u
e
1
2
3
4
GENERATION

Fig6

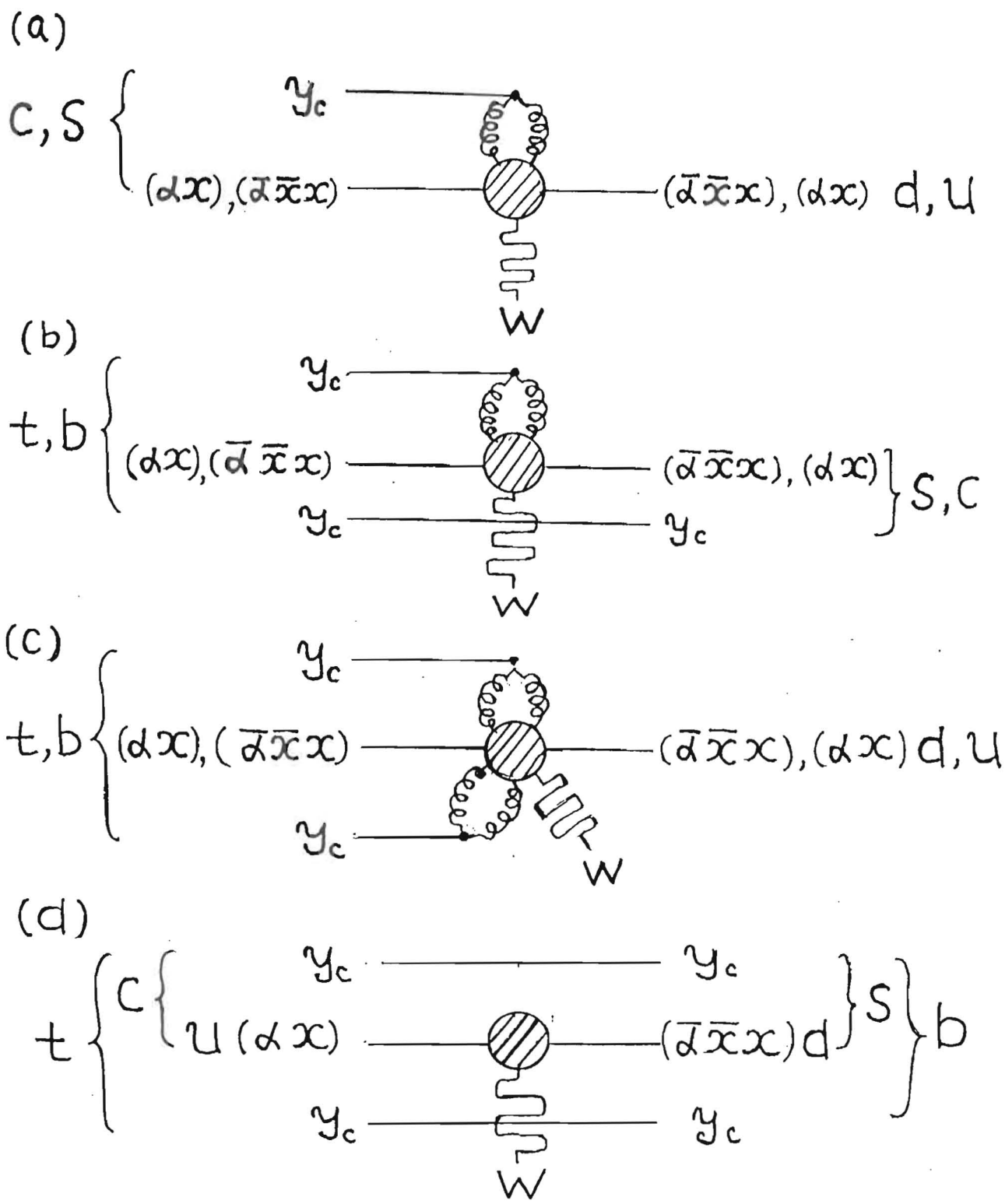
(a)
c, s
y_c
$(\alpha x), (\bar{\alpha}\bar{x}x)$
$(\bar{\alpha}\bar{x}x), (\alpha x)$ d, u
W
(b)
t, b
y_c
$(\alpha x), (\bar{\alpha}\bar{x}x)$
$(\bar{\alpha}\bar{x}x), (\alpha x)$
s, c
y_c
y_c
W
(c)
t, b
y_c
$(\alpha x), (\bar{\alpha}\bar{x}x)$
$(\bar{\alpha}\bar{x}x), (\alpha x)$ d, u
y_c
W
(d)
t
c
y_c
y_c
u (αx)
$(\bar{\alpha}\bar{x}x)$ d
s
b
y_c
y_c
W

Fig 7

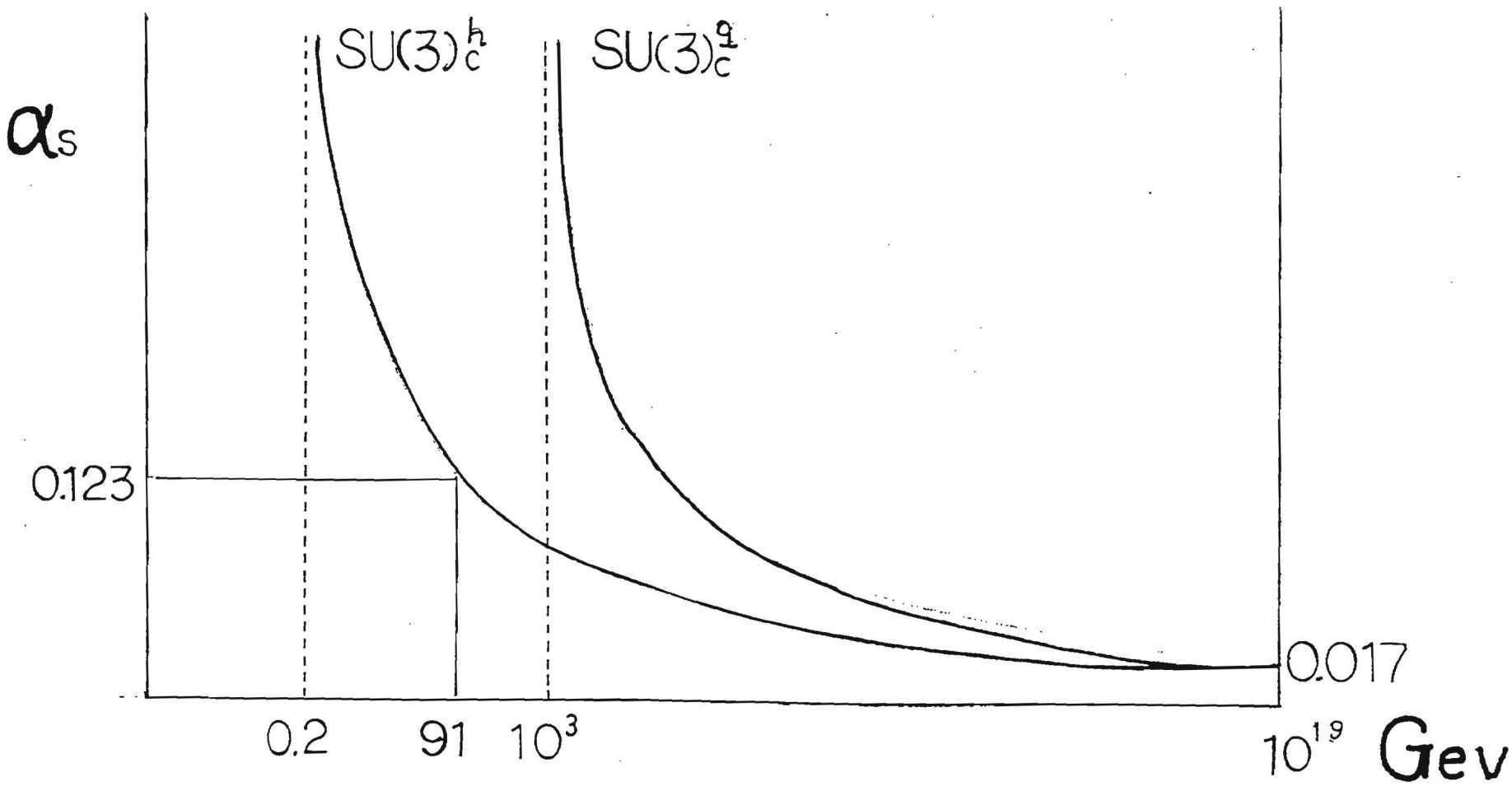

Fig8

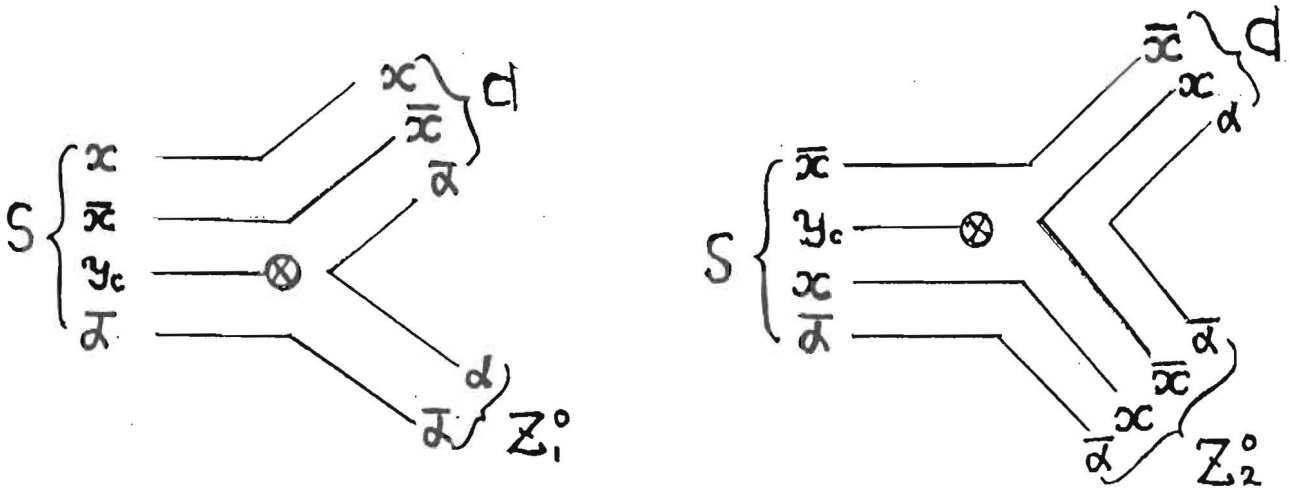

Fig9

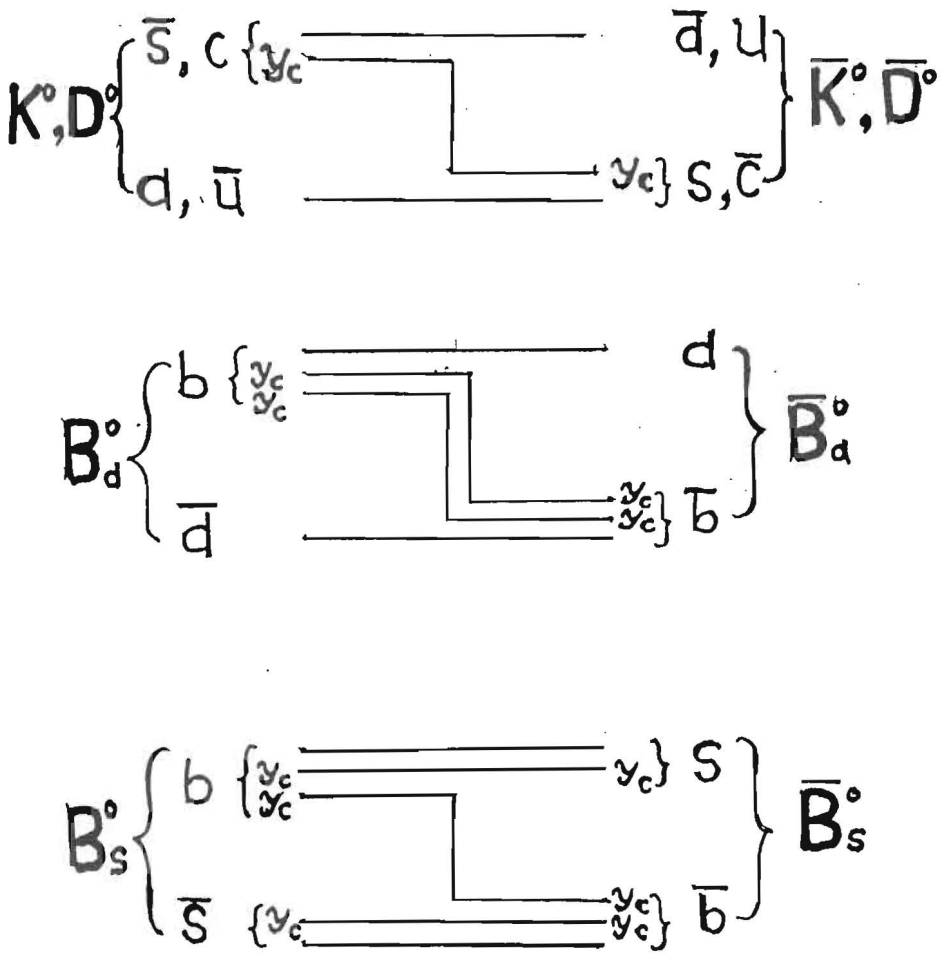

Table1

ν_U \ $\frac{\lvert V_{ts}\rvert \times 10^{-2}}{\lvert V_{td}\rvert \times 10^{-4}}$ \ $d_s^q(Q_{cd})$		0.2	0.3	0.4	0.5
-1.0	$\lvert V_{ts}\rvert$	3.5	2.2	1.4	1.0
	$\lvert V_{td}\rvert$	2.5	2.1	1.6	1.3
-1.3	$\lvert V_{ts}\rvert$	4.8	3.1	2.1	1.5
	$\lvert V_{td}\rvert$	4.5	4.2	3.4	2.8
-1.5	$\lvert V_{ts}\rvert$	5.5	3.6	2.5	1.5
	$\lvert V_{td}\rvert$	5.9	5.7	5.0	3.4
-1.9	$\lvert V_{ts}\rvert$	6.9	4.6	3.4	2.6
	$\lvert V_{td}\rvert$	9.3	9.4	9.0	8.1