

$\nu - ?$

$m(\nu) - ?$

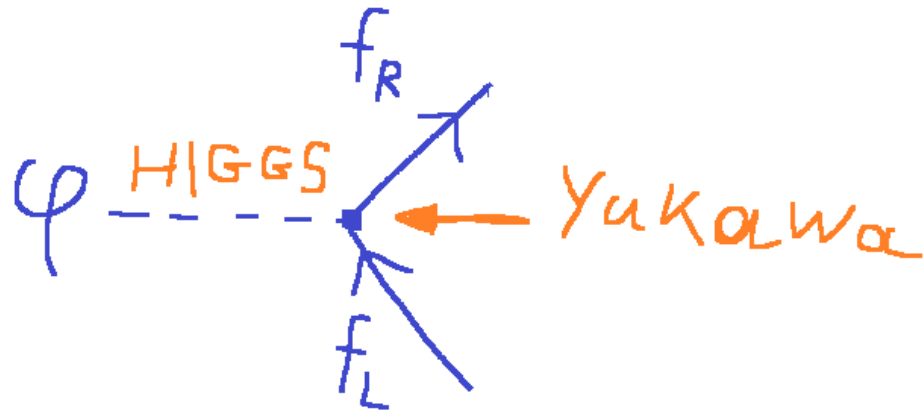


Б. огулов

$$SU(2) \times U(1)$$

$$\begin{pmatrix} u \\ d \end{pmatrix}_L \quad \begin{pmatrix} c \\ s \end{pmatrix}_L \quad \begin{pmatrix} t \\ b \end{pmatrix}_L \quad \left\{ \begin{array}{l} L\text{-Dub} \end{array} \right.$$

$$\begin{pmatrix} \nu \\ e \end{pmatrix}_L \quad \begin{pmatrix} \nu \\ \mu \end{pmatrix}_L \quad \begin{pmatrix} \nu \\ \tau \end{pmatrix}_L \quad \left\{ \begin{array}{l} R\text{-Sing} \end{array} \right.$$



note
 $f_L \bar{f}_R$: Dub
 $f_R \bar{f}_L$: Sing
 ϕ : Dub

$$\lambda \phi \bar{f}_L f_L$$

$$\downarrow \langle \phi \rangle \leftarrow \text{V.E.V}$$

$$\lambda \langle \phi \rangle \bar{f}_L f_L$$

$$m_f$$

Dirac mass

HIGGSTRIIP?

$$\otimes \frac{M_W}{M_Z} = \sin \theta_W$$

HIGGS Sing?

No mass contribution

რას ნიშნავს 2-2 თავს ?

უშასწომო თუ დასრულებულია

უშასწომო - რატომ ?

რად გვუბნის პირდაპირი მითითება

შესანიშნავია ?

რად ვაძიებთ რაღაცას

რად გვინდა მოგვეჩვენოს მათ: "SEE - SAW"

DIRAC MASS

$$g_e \overset{(2)}{\varphi} \overset{(2)}{\nu_L} \overset{(1)}{\bar{\nu}_L}$$

$$m_D(\nu_e) = g_e \langle \varphi \rangle$$

$$\frac{m_D(\nu_e)}{m_D(e^-)} \approx \frac{1}{(10 \leftrightarrow 100)}$$

m

MAJORANA MASS

$$g' \overset{(3)}{\Delta_L} \overset{(2)}{\nu_L} \overset{(2)}{\nu_L}$$

$$m_L(\nu) = g' \langle \Delta_L \rangle$$

$$\langle \overset{(3)}{\Delta_L} \rangle \ll \langle \overset{(2)}{\varphi} \rangle$$

(m_W/m_Z)

"0" 

$$\langle \Delta_L \rangle = 0 \text{ - no v.b. symmetry}$$

$$\begin{array}{c}
 (1) \quad (1) \quad (1) \\
 g' \Delta_R \nu_R \nu_R \quad \text{vs} \quad g' \Delta_R \overline{\nu}_L \overline{\nu}_L
 \end{array}$$

$$m_R(\nu) = g' \langle \Delta_R \rangle \leftarrow \text{propagator} *$$

MAJORANA mass (R)

{ note * } Beyond
 { HIGGS(1) } S.M

"M" 

$$g' \overset{3}{\Delta_L} \overset{2}{\nu_L} \overset{2}{\nu_L}$$

$$g_\ell \overset{2}{\varphi} \overset{2}{\nu_L} \overset{1}{\bar{\nu}_L}$$

$$\left(\begin{array}{c} "O" \\ m \end{array} \right)$$

$$\left(\begin{array}{c} m \\ M \end{array} \right)$$

$$g_\ell \overset{2}{\varphi} \overset{1}{\bar{\nu}_L} \overset{2}{\nu_L}$$

$$g' \overset{1}{\Delta_R} \overset{1}{\nu_R} \overset{1}{\nu_R}$$

"SEE - SAW" mechanism



$$\begin{pmatrix} \sim 0 & m \\ m & M \sim 1 \end{pmatrix}$$

Mixing

$$\nu_1 \sim \nu_L + \epsilon \bar{\nu}_L$$

$$\nu_2 \sim \bar{\nu}_L + \epsilon \nu_L$$

$$\left\{ \begin{array}{l} m(\nu_1) \sim \frac{m^2}{M} \ll m(e^-) \\ m(\nu_2) \sim M \sim O(1) \end{array} \right\}$$

$$m \sim \text{MeV} \quad M \sim \text{TeV} \quad m(\nu_1) \sim \text{eV}$$

N -თა m ბილით

$N \times N$ მატრიცა (3)

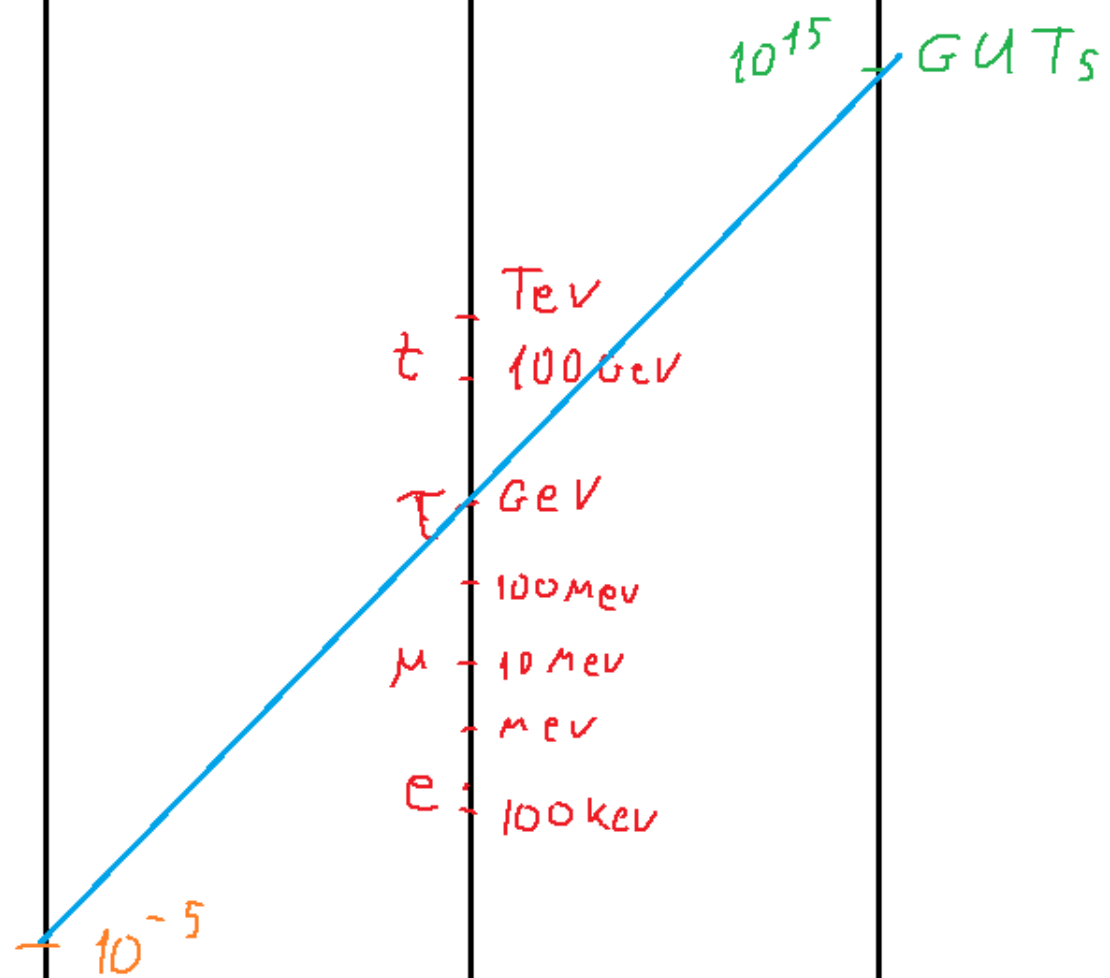
Block diag

$$\begin{pmatrix} m M^{-1} m & 0 \\ 0 & M \end{pmatrix}$$

6×6 - Unitary

3×3 - ~~Unitary~~

$$\begin{cases} N - \text{ბილით } \mathcal{U} \\ N - \text{ბილით } \mathcal{U} \end{cases}$$



3-mass dimensional "SEE-SAW"

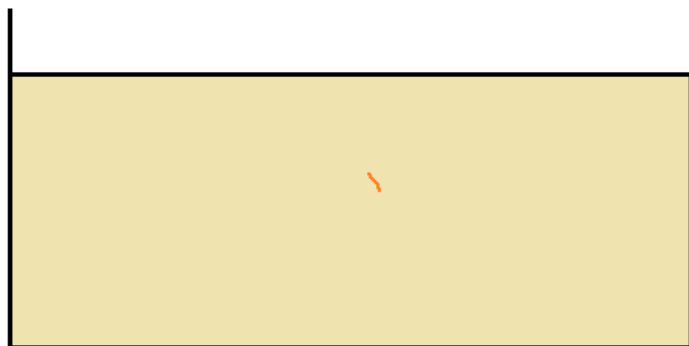
$$\begin{pmatrix} 0 & m \\ m & M \end{pmatrix} \sim \begin{pmatrix} m_u & x \\ x & m_c m_t \end{pmatrix} \sim \begin{pmatrix} m_e & x \\ x & m_\mu m_\tau \end{pmatrix}$$

$$\begin{pmatrix} \wedge & x \\ x & \wedge \end{pmatrix} \sim \begin{pmatrix} f_1 \wedge & x \\ x & f_2 \wedge f_3 \wedge \end{pmatrix}$$

m_ν -ratio

$$m(\nu_e) : m(\nu_\mu) : m(\nu_\tau)$$

$$\left\{ \begin{array}{l} m_e^2 : m_\mu^2 : m_\tau^2 \\ m_\mu^2 : m_e^2 : m_\tau^2 \\ m_e : m_\mu : m_\tau \end{array} \right\}$$



$$\frac{V_z}{V_m} = \begin{cases} z^2/c^2 \\ z/m \end{cases}$$

— $m(V_m)$



$$\frac{V_e}{V_m} = \begin{cases} e/m \\ u^2/c^2 \end{cases}$$

P.M

- $m(\nu_\tau) < 31 \text{ MeV}$
- $m(\nu_\mu) < 270 \text{ keV}?$
- $m(\nu_e) < 7-8 \text{ eV}$

SN 87 $m \lesssim 10 \text{ eV}$ $\text{elim } \tau(\nu_\tau)$

LEP $m(\nu_\tau) > 45 \text{ GeV}$

N.S in COS $\text{Light-}\nu < \sim 3,4$

V -Mix Δ - σ $\sqrt{m_{\mu} m_{\tau}}$ $\sqrt{m_e m_{\mu}}$

$$(\bar{u} \quad \bar{c} \quad \bar{t}) \begin{pmatrix} V_{ud} & V_{us} & \cdot \\ V_{cd} & \cdot & \cdot \\ V_{td} & \cdot & V_{tb} \end{pmatrix} \begin{pmatrix} d \\ s \\ b \end{pmatrix}$$

$$(0.22) \quad V_{us} \sim \sin \theta_{12} \sim 13^\circ$$

$$(0.05) \quad V_{cb} \sim \sin \theta_{23} \sim 2.5^\circ$$

$$V_{cb} \sim 0.2^\circ$$

$$\sin \theta_{12} \sim \sqrt{\frac{m_d}{m_s}} \quad ?!$$

$$(\bar{\nu}_1 \quad \bar{\nu}_2 \quad \bar{\nu}_3) \begin{pmatrix} \nu_e & \nu_\mu \\ \nu_\tau & \nu_{\text{int}} \end{pmatrix} \begin{pmatrix} e \\ \mu \\ \tau \end{pmatrix}$$

$$\theta_{12}^l \sim \sqrt{\frac{m_e}{m_\mu}} \quad ? ? !$$

ν - OSCILLATION

3rd generation 2 - generation long

$$\nu_e(t) = \cos \theta \nu_1 e^{-iE_1 t} + \sin \theta \nu_2 e^{-iE_2 t}$$

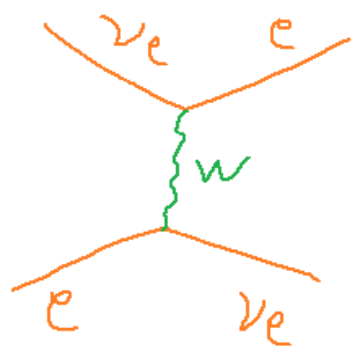
$$\nu_\mu(t) = -\sin \theta \nu_1 e^{-iE_1 t} + \cos \theta \nu_2 e^{-iE_2 t}$$

$$-i \frac{d}{dt} \begin{pmatrix} \nu_e(t) \\ \nu_\mu(t) \end{pmatrix} = \begin{pmatrix} -\Delta E \cos 2\theta & \Delta E \sin 2\theta \\ \Delta E \sin 2\theta & \Delta E \cos 2\theta \end{pmatrix} \begin{pmatrix} \nu_e(t) \\ \nu_\mu(t) \end{pmatrix}$$

$$\Delta E = \frac{\Delta m^2}{2p}$$

$$P(\nu_e \rightarrow \nu_\mu) = \sin^2 2\theta \sin^2 \left(1.27 \frac{L}{E} \cdot \Delta m^2 \right)$$

OSC - ΔE $\cos 2\theta$ $\sin 2\theta$



$$\begin{pmatrix} A - \Delta E \cos 2\theta & \Delta E \sin 2\theta \\ \Delta E \sin 2\theta & \Delta E \cos 2\theta \end{pmatrix}$$










\downarrow
 $\propto G_F n_e$

or $A = 2 \Delta E \cos 2\theta$

Neutrino oscillation

$$-i \frac{d}{dt} \begin{pmatrix} \nu_e(t) \\ \nu_\mu(t) \end{pmatrix} = \begin{pmatrix} 0 & 1 \\ 1 & 0 \end{pmatrix} \Delta E \sin 2\theta \begin{pmatrix} \nu_e(t) \\ \nu_\mu(t) \end{pmatrix}$$

Neutrino oscillation

ν_3								
	+		+		=	ν_e		
	+		+		=	ν_μ		
	+		+		=	ν_τ		