

新学術領域研究

「ニュートリノフロンティア」

研究会 2014

neutrino frontier workshop 2014

opening address, December 21, 2014, Fuji-Yoshida

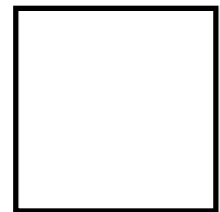
Where are we?



$SU(3) \times SU(2) \times U(1)$ gauge theory



Higgs mechanism for gauge boson masses



mechanism for fermion masses

What's particle physics?

$$Z[g] = \int [d\phi] e^{i \int d^4x \mathcal{L}(\phi)}$$

↑
coupling constants

↑
Lagrangian

new physics?

$$Z[g, g_{\text{new}}] = \int [d\phi][d\phi_{\text{new}}] e^{i \int d^4x \mathcal{L}(\phi, \phi_{\text{new}})}$$

boring..

What we really want to
know is

$$Z[g] = \int [d\phi] e^{i \int d^4x \mathcal{L}(\phi)}$$



this function. this is the physics.

all the physical quantities are encoded in this function.
probably more data is needed to make a real progress
in particle physics.

fermion masses?

there are many **mysteries** in the **fermion masses**.

Why **neutrinos** light?

Why (not) hierarchical?

A large phase $\delta_{KM} \sim O(1)$ and an extremely small phase $\theta \lesssim 10^{-10}$ in the quark mass matrix. Why?

Why three **generations**?

Is there any principle for **Yukawa** interactions?

In the quark sector

there seems to be a nontrivial structure.

$$m_u \sim \text{a few MeV} \ll m_c \sim 1 \text{ GeV} \ll m_t \sim 170 \text{ GeV}$$

$$m_d \sim \text{a few MeV} \ll m_s \sim 100 \text{ MeV} \ll m_b \sim 4 \text{ GeV}$$

similar

hierarchical.

And in this basis, the CKM matrix is

$$V_{\text{CKM}} \sim \begin{pmatrix} 1 & & \\ & 1 & \\ & & 1 \end{pmatrix} \quad \text{not} \quad \begin{pmatrix} 1 & 1 & \\ & 1 & \\ & & 1 \end{pmatrix} \quad \text{or} \quad \begin{pmatrix} 1 & & 1 \\ & 1 & \\ 1 & & 1 \end{pmatrix}$$

lepton sector

$$m_e \sim 0.5 \text{ MeV} \ll m_\mu \sim 100 \text{ MeV} \ll m_\tau \sim 1.8 \text{ GeV}$$

similar?

$$m_d \sim \text{a few MeV} \ll m_s \sim 100 \text{ MeV} \ll m_b \sim 4 \text{ GeV}$$

$$\Delta m_{21}^2 \sim (0.01 \text{ eV})^2 \quad \Delta m_{31}^2 \sim (0.04 \text{ eV})^2$$

doesn't look like hierarchical

big mixing angles

$$U_{\text{PMNS}} \sim \begin{pmatrix} 0.8 & 0.6 & 0.15 \\ & 0.5 & 0.7 \\ & & 0.7 \end{pmatrix}$$

A large Yukawa interaction

implies the elementary Higgs boson.

And it is clear that the fermions are giving potential to the Higgs field at the quantum level.

→ access to nature of the **Higgs** field.

CP violation requires a phase in **fermion masses**.

→ access to nature of baryon asymmetries
in the **Universe**.

Anyway,

to understand **both**

the nature of our **fundamental law**

and

the **history of the Universe,**

Neutrinos are the key.

Let's enjoy this year's progress in the neutrino physics
in this workshop.