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?

- [x] SU(3)xSU(2)xU(1) gauge theory
- [x] 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?

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

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~a few MeV ≪ m_c~1 GeV ≪ m_t~170 GeV

m_d~a few MeV ≪ m_s~100 MeV ≪ m_b~4 GeV

similar

hierarchical.

And in this basis, the CKM matrix is

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

lepton sector

m_e~0.5 MeV ≪ m_μ~100 MeV ≪ m_τ~1.8 GeV

similar?

m_d~a few MeV ≪ m_s~100 MeV ≪ m_b~4 GeV

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

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.