7.4 The Standard Model of Particle Physics

We have seen above that leptons and quarks are considered to be fundamental building blocks of nature. In 1960s a theory was proposed which treated electromagnetic and weak interactions in a unified way. Different parts of the unified electroweak theory were proposed by Sheldon Glashow, Abdus Salam, and Steven Weinberg independently. The mathematical soundness of the electroweak theory was proven later by Gerardus 't Hooft in 1971. The electroweak theory predicted the existence of weak force communicating particles, W^+, W^-, and Z^0. The existence of neutral current of Z^0 was seen in 1973 in a track of en electron in a bubble chamber at the European Organization for Nuclear Research (CERN), but the existence of particles W^+, W^-, and Z^0 had to wait another ten years due to the difficulty of creating them since they have enormous masses 80.4 GeV/c^2 and 91.2 GeV/c^2, respectively. These particles were finally discovered in 1983 at the European high energy facility CERN by a team led by Carlo Rubia and Simon van der Meer.

The unified electroweak theory is an important component of the standard model of particle physics. The other component of the standard model is Quantum Chromodynamics (QCD), the theory of the color force between quarks. In 1973 David Gross, H. David Politzer, and Frank Wilczek proved that QCD had an important property called asymptotic freedom, meaning the forces between quarks would be weaker at higher energies or shorter distances, and therefore, perturbation calculations at high energies are reliable. This led to the acceptance of QCD as a fundamental mechanism for the interaction of quarks.

According to the standard model of particle physics there are six flavors each of leptons and quarks as summarized in Fig. 7.13. The leptons and quarks are organized in three families, each having two members. The leptons interact with each other and with quarks by electroweak interactions but they do not "feel" the color interaction since they do not have color property. The quarks interact with leptons by electroweak interaction and with each other through color interaction. The mass of particles are provided by a mechanism called the Higgs mechanism, which predicts the existence of a particle, called the Higgs boson or Higgs particle. The Higgs particle has also been called the God particle in popular literature. The Higgs particle was discovered at CERN in 2012 after 40 years of search. The Higgs particle was found to have a mass between 125 and 127 GeV/c^2.

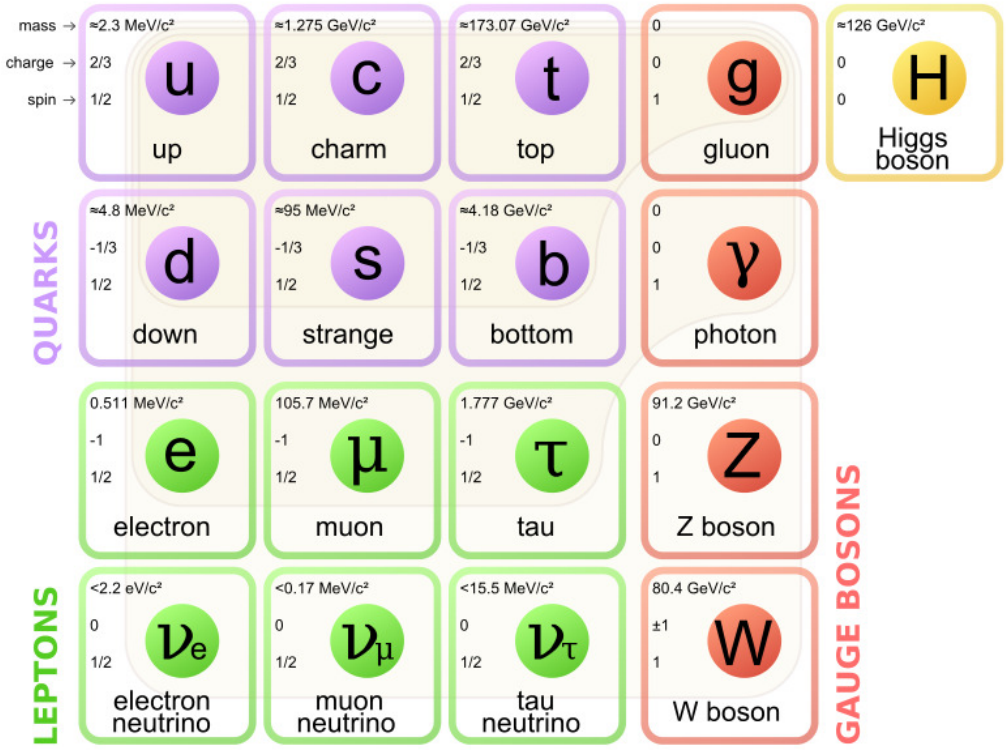

Figure 7.13: Standard model of particle physics. Courtesy: Wikicommons