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Problems of Standard Model, Review

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Abstract

It is assumed that standard model is the most successful theory of particle physics but it is not perfect. In this paper, I am interested to flash the published results of various proposals of theoretical physicists in various modes of Standard Model and beyond. There are no specifications theory to declare new model to till date, although some ideas that would modify the standard model in many ways helps to understand the existing results.

Keyword: Graviton, Vacuum energy, Higgs boson, Grand unified theory, Dirac mass

Introduction:

The Standard Model is a set of mathematical formulae and measurements describing elementary particles and their interactions. It is just like the periodic table which describes the atoms and their characteristics. The Standard Model categorizes the elementary particles - fermions and bosons although it is an incomplete theory to give the final answer of nature and composition of matter. The classification of elementary particles in shown in figure 1.

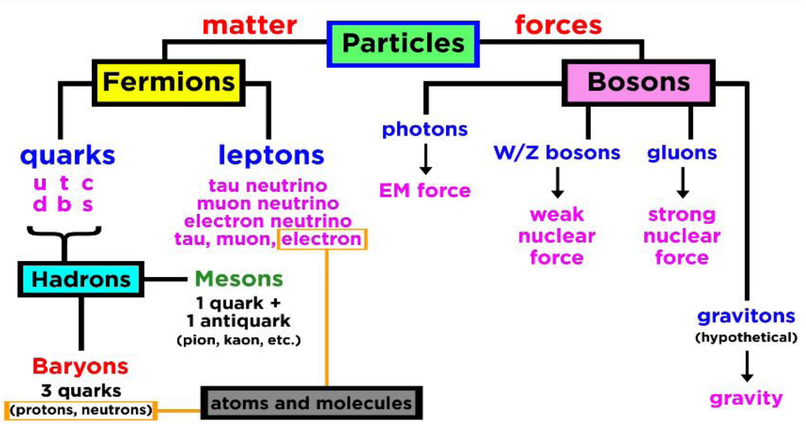

Fig 1: Classification by Standard model

The physics of particles believed that there are two kinds of fundamental particles. They are quarks and leptons. There are six quarks and six leptons. Each quark and lepton has

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antiparticle. Most of the matter in universe is made by combination of quarks named "up" and the "down" quarks. Electrons are lepton which are light particle. Protons and neutrons are heavy particles formed by combination of up and down quarks. The rest of the twelve fundamental particles are more commonly found in high energy environments, just after the Big Bang.

Most of the theories believe that there are four fundamental forces in the universe a) gravity b) electromagnetic c) weak d) strong forces. The electromagnetic force comes in play among all charged fundamental particles including some leptons and quarks while the weak force is responsible for radioactive decay. It actually makes neutrons turn into protons. The strong force is only felt by qurks. Notice that the force is strong in comparison to weak force. Each force except gravity is associated by force carrying particles 'BOSONS' just like a mediator in any interaction. Bosons controls the interaction of physical forces.

The Photon, Gluon, W boson, Z boson are experimentally verified bosons. Other bosons like Higgs boson, graviton, bosonic superpatners bosons are predicted but not experimentally verified or not clearly confirmed bosons. (Zimmerman, 2020)

Hence the standard model is a mathematical model of 12 fundamental particles with three outstanding forces. However, there are many unsolved issues like gravity, origin of mass, cause of variation of mass and possibility of other particles beyond these twelve particles so called fundamental. Our understanding is incomplete until the fate of dark matter and dark energy is resolved.

The figure 2 below shows the basic properties (like mass, charge, spin) of elementary particles form different experimental outcome.

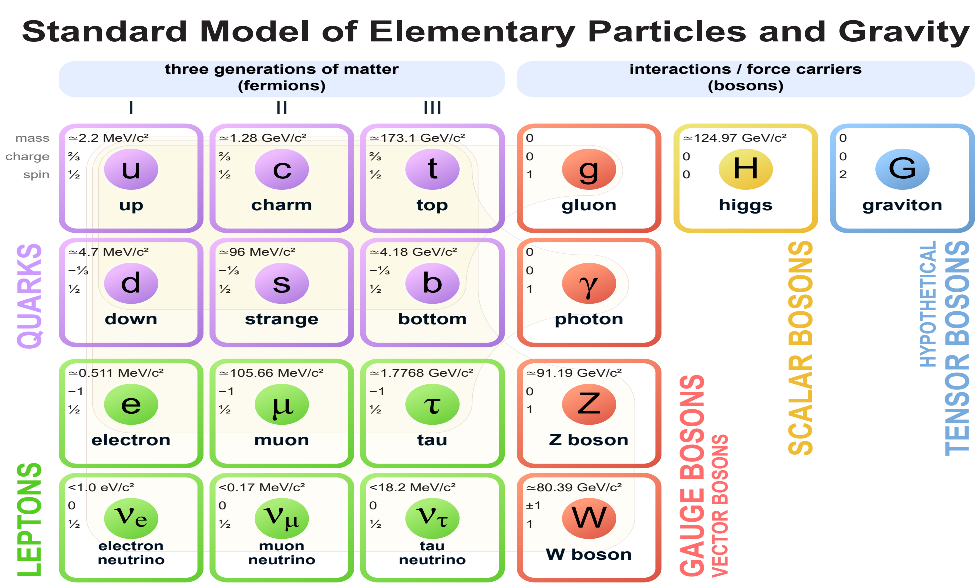

Fig2: Elementary particles in standard model
(source: **Sandford *University Los Alamos National Lab***)

Fundamental physical phenomenon on the basic of standard model

We are going to discuss some fundamental physical phenomenon from the eye of standard model.

1. Neutrino masses

The standard model predicts that neutrino should have no mass just like photon. The physicist has noted that neutrino oscillate and transform one to another as they move. These arguments are accepted from neutrino oscillation experiments. If mass terms for the neutrinos is added in standard model then it leads to new theoretical problems. Since the mass terms should be unexpectedly small and hence they act like other fundamental particles in the Standard model which violates the standard model prediction on neutrino hypothesis.

Experimentally, it is observed that the neutrino oscillations give only information on (dm_i)^2. The absolute value of neutrino mass (m_i) is still unknown. Plank result found that the mass of neutrino is less than 0.136 electron volt (Valantino etal., 2015). Similarly, by titanium beta decay analysis, the upper limit of neutrino mass is confirmed about 2.2 electron volt. (Asseev etal., 2011)

2. Dark matter and dark energy

The standard model explains only 4% of the energy present in the universe. The physics about 96% of energy is so much vague to explain by Cosmological observations. Out of 96% of energy about 27% be dark matter, which would behave just like other matter. This matter only interacts weakly with the standard model fields. Standard Model does not supply any fundamental particles or exchange particles that are good to explain dark matter phenomenon. The rest is a constant energy density for the vacuum called dark energy. It is huge problem , how this kind of mismatch is leading in early stage of universe. (Krauss, 2009)

3. Matter and antimatter ratio

As we know the universe around us is dominated mostly by matter. If the universe is originated by Big -bang, then matter and antimatter should have been produced in equal order just like two sides of a single coin. But some mechanisms kept the matter and antimatter from their usual pattern of total destruction lead imbalances. The standard model fails to explain the causes of imbalances. The clue behind this issue are not resolved properly. Although many experiments are going on to solve this ratio problem

4. Gravity and graviton:

Gravity is an unexplained theory from standard model. Actually, the standard model was not designed to explain the most common physical phenomenon gravity. The weakest force of nature does not seem to have any impact on the subatomic interactions according to standard model. Although the particle physicist assumed that the particle graviton might transmit gravity just like a photon in electromagnetic theory. (Bilson, 2006)

Standard model against experiment

There are no such experiments performed with minimum uncertainties is widely agree by the standard model. The fundamental concept of standard model is considered to be the threshold of a discovery in particle physics although some theoretical ideas will deviate to some extent from standard model. There is no physics beyond the standard model discovered to till date which are fully supported by the experimental result. (Eva, 2014)

There are large number of experiments and results which significantly violates the Standard Model expectation with many statistical or experimental errors. On the other hand, any "beyond the Standard Model" physics not able to find the exact differences between the theoretical outcome and experimental results with newness explanation in standard model prediction.

Actually, physicists seek to determine if a result is a mere statistical fluke or experimental error on one side and a sign of new invention on next side. It is found that more statistically significant results cannot be mere statistical flukes but can still result from experimental error or inaccurate estimates of experimental precision.

Here are some examples in which the experiments are tailored to be more sensitive to experimental results that would distinguish the Standard Model from the eye of theoretical alternatives.

A. Size of Muonic Hydrogen:

The standard model theoretically predicts the size of hydrogen (electron -proton system) and muonic hydrogen (electron-muon system). The result of atomic size of muonic hydrogen deviate significantly when it is measured by using physical constants developed by standard model. That means, doubts arise on the order of accuracy and error analysis procedure in previous technique**.** Due to lack of well-motivated theory that could explain the differences in measurements have caused the physicist to be hesitant to describe these results as contradicting the Standard Model instead the apparent statistical significance of the result as well as a lack of any clearly identified possible source of experimental uncertainties in the results.

B. Ba-Bar Experiment:

According to this experiment when electron and positron are collided, B and $\overline{\text{B}}$ mesons are produced and then decays into a D meson and a tau lepton with anti-neutrino. But this kind of decay is not sufficient to break the claim of standard model assumption on this issue. It is due large level of uncertainty. But the results are a strong enough to search the theory beyond standard model and to deduce the properties of Higgs bosons**.** (Koppenburg etal., 2016)

Theoretical predictions

Standard model is a quantum field theory (QFT). It explains the interactions between the fermions, electromagnetic, strong and weak forces. And the interactions are governed by s symmetry principle. The more symmetric the theory, the more couplings are related. We understand everything in the standard model including the origin of boson W, Z and fundamental fermions.

Symmetry breaking is the beauty of standard model which can be explained by Higgs mechanism. The mechanism is very much useful to know the how fundamental particle obtain mass. The boson is predicted by the Standard Model's called Higg's boson. How the weak gauge symmetry is broken and how particle attain the mass is explained through this mechanism. The scientists using the Large Hadron Collider (LHC) announced the discovery of a particle consistent with the Higgs boson, with a mass of order 126 GeV/c2. A Higgs boson was confirmed to exist. The experiment are still on going to confirm all properties predicted by standard model. (Lee, 2019)

Theoretical problems

a. Mass problem:

As we know the standard model generate the idea of particle mass through a process called spontaneous symmetry breaking. It happens when the vacuum has less symmetry than the interaction of them. To achieve this kind of breaking, one need scaler field that is Higgs field. It is seen that Higgs mass need some quantum correction due to presence of virtual particle (top quarks). The actual mass of Higgs particle much smaller than this correctios which can upset the Higgs field. Hence mass correction is the major problem in the standard model**.** (Barranco, 2016)

b. Strong Charge -parity (CP) problem -

The CP problem is the problem with standard model itself. Theoretically, it can be argued that the standard model should contain a term that breaks CP symmetry- relating matter to antimatter in the strong interaction sector. Experimentally, however, no such violation has been found, implying that the coefficient of this term is very close to zero. This fine tuning is also considered unnatural.

Grand Unified theory (GUT)

It is a theory that combines strong, weak and electromagnetic interactions among particles in a single gauge group with in a symmetry. The three gauge symmetries includes the color, isospin and hypercharge denoted as SU (3), SU (2) and U(1) respectively corresponding to the three basic forces. The coupling constants of each of these symmetries' changes with the energy. At the energy of order 10^16 GeV, the coupling is constant for all kinds of forces. As the energy larger then this order, three-gauge symmetries of the standard model are unified in one single frame of gauge symmetry with a simple group gauge and just one coupling parameter. As the energy lower then this order, the symmetry is spontaneously broken to the standard model symmetries. (Ross, 1984). Figure 3 and 4 gives the information of unification order.

This kind of unification of symmetry according as energy order are called Grand Unified Theories (or GUTs). The energy scale at which the unified symmetry is broken

is called the GUT scale. GUT predicts a) the creation of magnetic monopoles in the early universe
b) instability of the proton.
But neither of which have been observed leads the theory beyond GUT (quantumdiaries.com, 2014)

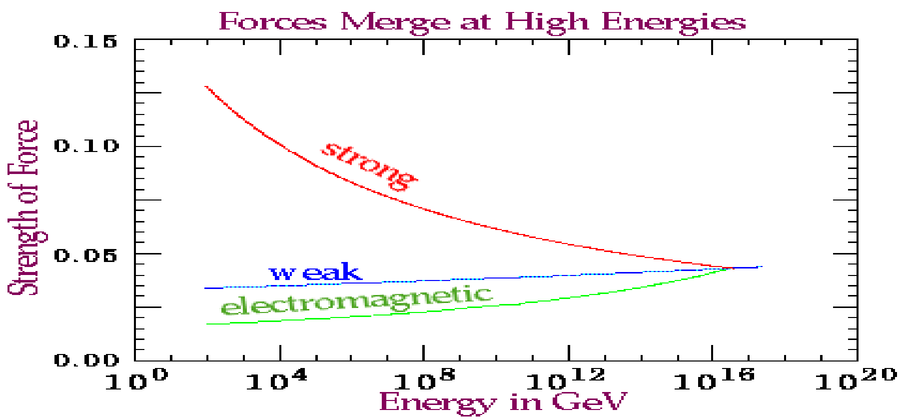

Fig 3: Merging of forces according as grand unification

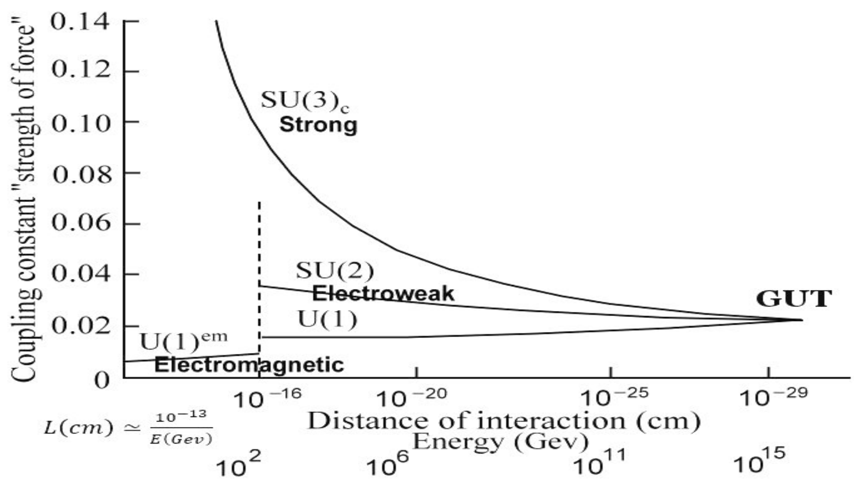

Fig 4 : Early stage unification at small distance (source :Universe-review.ca)

Supersymmetry

By the process of supersymmetry, the exchange between fermionic and bosonic particles take place**.** Such a symmetry predicts the existence of supersymmetric particles, called s *s-particles* also called shadow particle. If supersymmetry breaks, the heavier particles named super particles are existed. They are so heavy as a result existing particle collider may not be strong enough to produce them. It is complex mathematical ideas based on group theory so it is extended form of standard model. Supersymmetry is

a) generalization of space time symmetries of quantum field theory.
b) transforms fermions into bosons or vice versa
c) will ultimately explain the large-scale structure from W, Z masses to plank mass of order 10^19 GeV.
d) also provides a frame work of unification of particles physics and gravity.
e) It solves gauge hierarchy problems with the introduction of super partners (S particles) (CERN, 2019)

Neutrinos

Neutrino is a lepton. It does not participate in strong interaction. It has zero charge so does not undergo electromagnetic interactions. As a result, it is very much difficult to detect. Although neutrino do interact by weak force and are created as a result of certain types of radioactive decay or nuclear reaction. There are three flavors of neutrino a) Electron neutrino b) muon neutrino c) tau neutrino and their antiparticle pair. During beta decay, electron neutrino and its anti-particle are generated when neutrons changes into protons or vice versa. Neutrino have provided the evidence that new physics beyond standard model exists. According to standard model "neutrinos are massless" . This model does not predict the non-zero mass and mix among the neutrino of different families like quarks. Experimentally these two facts are true and hence contradiction arises. Neutrino oscillation experiments suggest that muon neutrinos can transmute in to electron neutrinos and vice versa on their way. It is also observed that electron neutrinos arriving at the Earth from the center of the sun would be too few in number out of expectation. This phenomenon of neutrinos oscillating from one flavor to another is only possible if t neutrinos have different masses and types. So, the oscillation experiments are strong proof indicating neutrinos must have ma**ss**. But neutrino oscillation experiments are unable to measure the absolute mass of the neutrino. (Zuber, 2004 and Barranco, 2019)

Theory of everything (TOE)

It is a theory of assumption that combined all physical phenomenon as a single physics. A theory that fully explains and links together all known physical phenomena and predicts the outcome of any experiment that could be carried out in principle. The theory wants to generate a theory which would unify the Standard Model and general relativity in a frame of quantum gravity. It would be desired to know actual mass of particle with high order of accuracy as a combined physics, that gives the core of origin of mass. (Robert, 2006)

String theory

The theory of relativity and the problems of quantum mechanics is explained by a single physics commonly called the physics of string. It is said that string is the physics of physical reality. This hypothesis assumed that the particles are one-dimensional string like entities whose vibrations determined the overall behavior of particles i.e. properties, massm charge etc. It is sophisticated mathematical model that binds atomic nuclei together by a strong force. The concept of string developed about 1960's. It is one of the proposed models to be road of theory of everything that describe all known particles and forces. This theory would supersede the standard model of physics. Many scientists believe in string theory because of its mathematical beauty. The physical world explained by this theory by the equations are considered extremely satisfying.

The theory of gravity is compared with vibrating string just like the properties of graviton, a quantum of gravitational wave just like a photon. There are 11 dimensions to work so it is beyond the dimension (3 space and one time) we normally experience. The theory simply elaborates "how the extra dimensions are curled up in an extremely minute space of order 10^-33 centimeters". Notice that NASA can't normally detect them. Researcher have used so called string theory to answer fundamental questions about the universe. The physics of string are used as a special tools to study the i) mathematics of black hole ii) big bang theory which will provide the clue of origin. The vector model of string theory is shown in figure 5. Some scientists have even attempted to use string theory to treat the physics of dark energy and the mysterious force accelerating the expansion of space and time. (Brian,1999)

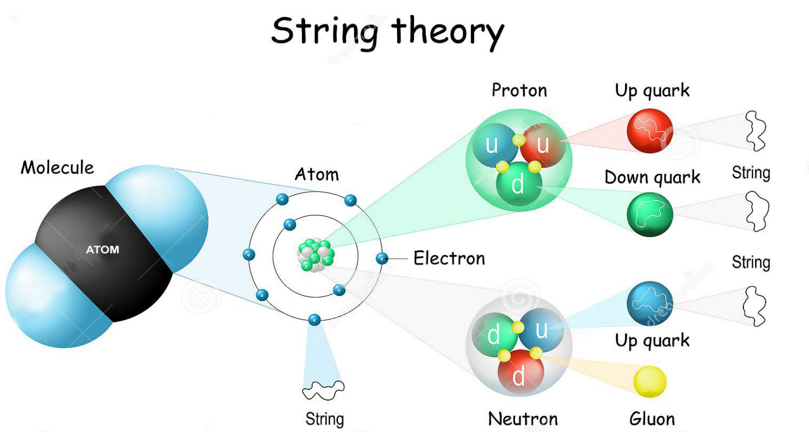

Fig 5: vector diagram of particles

Conclusion

It is concluded that the standard model is a highly successful framework that predicts the nature of interactions among particles with great accuracy order. Although there are so many lacks that leads the scientist to search for more basic structure and interaction which will be the complete theory in particle physics. The model currently we understood is unable to explain the three generations of leptons and quarks and why we need three generations. Similarly, it makes no prediction for estimating the masses of quarks and leptons. The strength of interaction order is not answered clearly.

It is hoped that the new discovery will fulfill all kinds of lacks in standard model with highly accurate measurements**.** We are expecting the theory in a single box frame like Grand unified theory (GUT) to overcome all kinds of problem in standard model with experimental verification.

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