TR
KASTAMONU UNIVERSITY
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THE STANDERD MODLE OF PARTICLE PHYSICS

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SYMBOLS AND ABBREVIATION

SM	Standard Model of particle physics
QCD	Quantum Chromo Dynamic
LHC	Large Hadron Collider
ATLAS	A Toroidal LHC Apparatus
CMS	Compact Moun Solenoid
ALICE	A Large Ion Collider Expropriation
LHC-B	Large Hadron Collider Beauty
TPC	Time Projection Chamber
PS	Proton Synchrotron
SPS	Super Proton Synchrotron

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1 Introduction

The standard model of particle physics (SM) was developed after a large number of theoretical research and practical research to describe all that exists in the universe and interactions between particles. This model contributed to the advance of the basic theory of molecules and it tells us to where particle physics arrived and what was predicted of new phenomena later?

In addition, the standard model gives us a brief idea of all the information we need to know about strong interactions and weak interactions in addition to electromagnetic force except gravity. Electromagnetic and weak interaction were combined and they called an electroweak interaction, and this interaction is one of the most important interactions in particle physics.

Electromagnetic force has prolonged been discovered and this was after Hertz discovered electromagnetic wave radiation in 1985 in the beginnings of quantum mechanics.

The electron was the first primary particle to be discovered, weighing about 1/2 MEV, then discovered an unstable particle called the muon, and was weighing 100 MEV in cosmic rays.

The past 50 years have yielded results and information that contributed to the standard model, which will lead to a wide range of discussion and questions.

This theory was developed in the early seventies, as one of the theories of quantum field compatible with the theory of special relativity and quantum mechanics, where all experiments confirm the validity of the predictions of this theory. But the main drawback of this theory lies in its non-characterization of the fourth fundamental force, the force of gravity and all the efforts of theoretical physics now focus on the formation of a complete theory, that is, it describes the four basic forces, including the force of gravity, the process of collecting general relativity that deals with gravity with quantum mechanics is one of the most important dilemmas facing modern physics.

2 What constitutes our universe?

The question that always comes to our mind is what are the components of the world around us and what is its basic structure? It was common that the material consisted of four elements (water, fire, air and dust). But with time and constant experiments to answer precisely this question, which was its atomic theory, which confirmed that the material is only a group of small particles cannot be divided according to their belief at the time.

John Dalton announced this theory in the 19th century. And the experiments of Redford and Schidwick have been credited with discovering the nucleus and its particles of protons and neutrons, and we do not forget the physicists Schrodinger and Heisenberg, who later developed the atomic theory in its final form and now known as the Yukawa theory. This theory is the cornerstone of physics Particles 1930, where this theory explained the force that makes protons and neutrons interconnected within the nucleus.

Between 1970 and 1960, there was a great evolution in particle physics. Scientists built particle accelerators, through which new particles with a very short lifespan were observed. No one knew what these particles were, or whether they were elementary particles or anything else.

Scientists became puzzled after discovering that the idea that protons and neutrons were not elementary particles as they thought and these other particles were smaller than neutrons and protons were the primary particles that helped shape a new mathematical model.

After all the above, scientists recognized that the atomic particles are divided into three elementary particles, which they gave the name of the quarks.

3 The elementary particle

For centuries, scientists knew only the periodic table. It was believed at the time that hydrogen was the least mass of all periodic cyclic elements until particles were discovered a thousand times less than the hydrogen atom. This made scientists look into a scientific explanation of this result, which resulted in the discovery of the electron Was considered the gateway to further research and experiments that resulted in the discovery of protons and neutrons within the nucleus of the atom revolving electrons in closed orbits. But at the beginning of the 1930s, scientists tried to explain several phenomena that a model's inability to form essentially consists of protons, neutrons and electrons. They reached a particle accelerator to find an explanation for what was happening around us. At the end of the 1960s, the scientists came up with a striking conclusion that protons and neutrons are primary particles linked by a powerful force called quarks, which are difficult to divide into smaller ones.

3.1 Elementary fermions:

Quarks and leptons are called Fermions, as lepton enters electroweak interactions, while quarks enter the strong interactions and electroweak interactions. It is important to note that the leptons without quarks have no standard model at all. The pheromones are divided into:

3.1.1 Quarks:

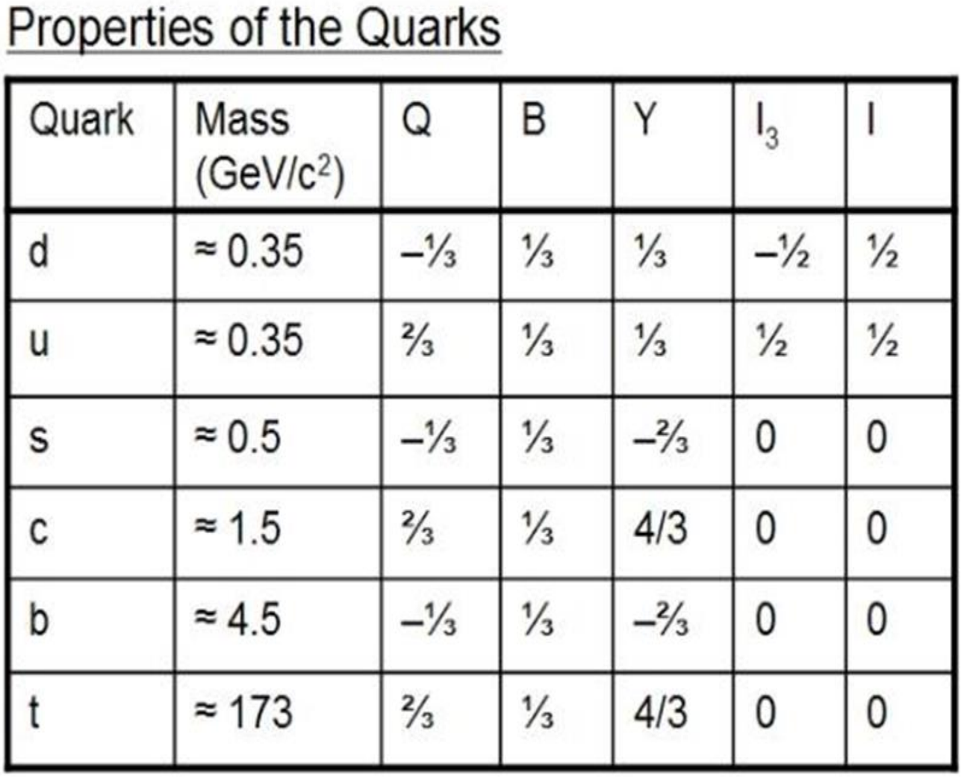
The quark is one of the primary particles, and the inability of the scientists to make the quarks alone to be studied made them take the dispersion experiments in the accelerators of the particles and that led to the knowledge of the existence of three types of quarks, and as a result they discovered that the proton consists of two up quark and one down quark. And the Nitron consists of two down quarks and one up quark quarks.

Quark 10^{-19} cm, and scientists found that the quark is indistinguishable, that is, the smallest thing in the material and that it is small may not have a size and this conclusion has a negative impact on the mathematical equations used.

There are quarks, there are anti-quarks, and when there are a quark and a quark in a vacuum must carry a charge opposite to each other and turn in the opposite way because if that happens, they will clash and then they will disappear.

It is the strong force that makes the quarks coherent together in the neutron or the proton. The following table shows the types of quarks with some of their properties:

Table 3.1 *Properties of the QUARKS*



Properties of the Quarks

Quark	Mass (GeV/c^2)	Q	B	Y	I_3	I
d	≈ 0.35	−⅓	⅓	⅓	−½	½
u	≈ 0.35	⅔	⅓	⅓	½	½
s	≈ 0.5	−⅓	⅓	−⅔	0	0
c	≈ 1.5	⅔	⅓	4/3	0	0
b	≈ 4.5	−⅓	⅓	−⅔	0	0
t	≈ 173	⅔	⅓	4/3	0	0

3.1.2 Leptons:

Lepton is one of the primary particles. The first to be called leptons is in 1948. Strong interactions do not affect this particle, and Lepton does spin (1/2). There are two types of leptons, one of which is lepton with a charge such as an electron Which is the most famous leptons and the most interactive and the formation of composite particles, while the second type is neutrino and is less interactive and therefore do not see much. Leptons also have six flavours, as shown in the table (3.2): Electron, electron neutrino (the lightest and most common), muon, muon neutrino, Tau and Tau neutrinos.

Leptons have properties such as electric charge, mass and spin. In contrast to quarks, leptons do not affect strong force, while gravity, weak force, and electromagnetic force influence them. As in quarks, each type of lepton has antileptons and has the same properties as the lepton except the charge signal.

***Table** 3.2*. *Leptons.*

Name	Symbol	Antiparticle	Charge e	Mass Me v/c^2)
Electron	e^-	e^+	-1	0.511
Electron neutrino	νe	$\bar{\nu}e$	0	Small, but non- zero
Muon	μ^-	μ^+	-1	105.7
Muon neutrino	ν_μ	$\bar{\nu}_\mu$	0	<0.170
Tau	π^-	π^+	-1	1.777
Tau neutrino	ν_π	$\bar{\nu}\pi$	0	<15.5

3.2 Bosons

The bosons are only primary particles carrying the basic forces, (Photon, Gluon, Graviton and Higgs boson). In any case.

3.2.1 Photon

3.2.2 Guoln

3.2.3 Graviton

3.2.4 Boson W-,W+

we will talk about all these bosons and forces later.

3.2.5 Higgs Bosons

Since 1964, Peter Higgs has predicted that there is an initial particle larger than the proton 200 times, which is the boson, later called the Higgs boson. Peter believed that this boson was responsible for the mass acquisition of particles. However, the Higgs boson proved to be practically in Cern by the Large Hadron Collider (we will explain the installation and subsequent use of this device). This was detected on Wednesday, July 4, 2012, and the required boson was 99.999%. After this great discovery, the standard model that predicted the existence of this boson has long been validated.

4 Composite particle (Hadrons)

The Hadrons are complex particles where they arise from quarks union with each other. When two quarks merge, they become mesons while three quarks form baryons. The following figure can give us a simple idea of what the Hadrons are:-

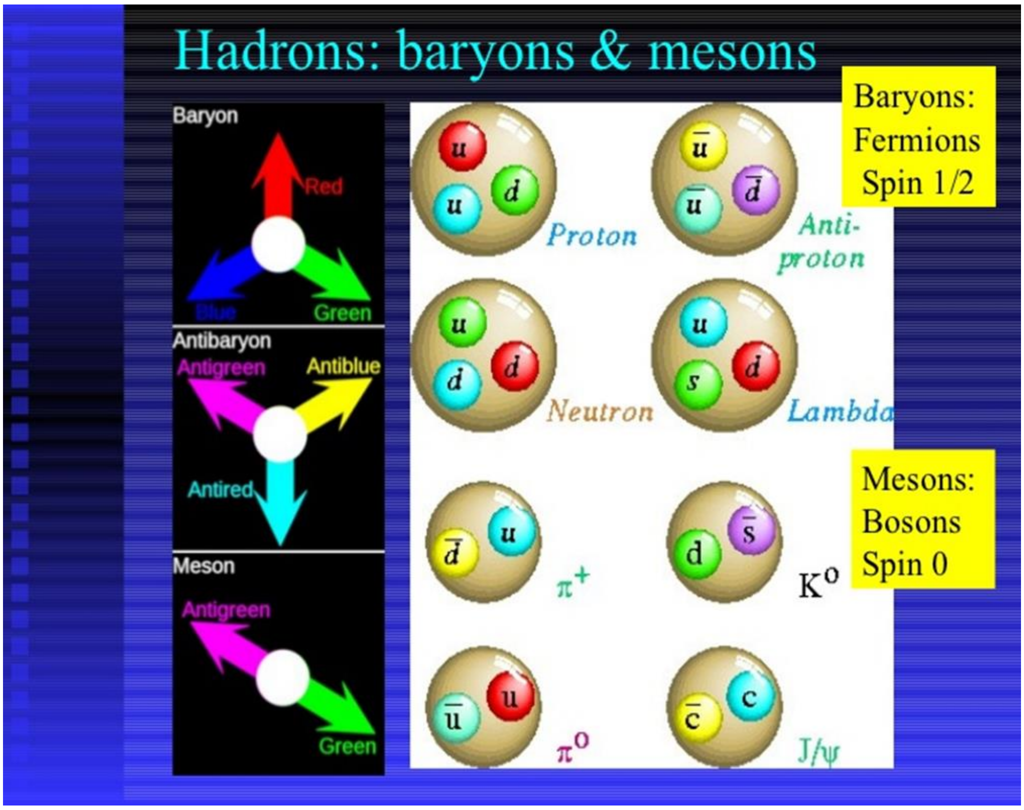


Figure 4.1. *The Hadrons*

4.1 Baryons

Baryons are larger particles than protons. In addition, the baryons possess a half-spinning (1/2, 3/2, 5/2, ...). Baryons are composed of 3 quarks. Protons and neutrons are the best examples of baryons. The following table shows some baryons with some characteristics:-

***Table 4.1** The baryons with some characteristics.*

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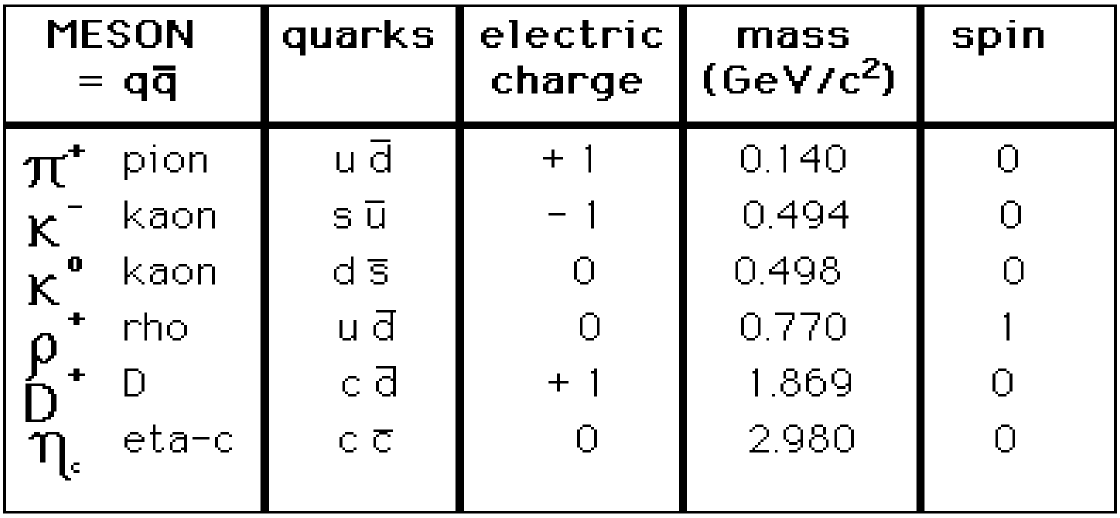
Particle and symbol	Charge/ proton charge	Antiparticle and symbol	Charge/ proton charge	Rest energy/ Mev	Interaction
Proton p	+1	Antiproton p	-1	938	Strong, weak, electromagnetic
Neutron n	0	Antineutron n	0	939	Strong, weak
Electron e^-	-1	Positron e^+	+1	0.511	Weak, electromagnetic
Neutrino v	0	Antineutrino $\overline{\nu}$	0	0	weak
Muon μ^-	-1	Antimuon μ^+	+1	106	Weak, electromagnetic
Pions π^+ ,π^0 ,π^-	+1,0,-1	π^+ for a π^- π^- for a π^+ π^0 for a π^0	-1,0,+1	140,135,140	Strong, electromagnetic π^+ , π^-)

4.2 Mesons

Mesons are complex and unstable particles because they consist of quarks and anti-quarks. In addition, the median age of the median is 2.6 * 10^{-8} s and the mass of the meson is less than the mass of the proton and greater than the mass of the electron. The mesons were discovered by Karl Anderson in 1937. The meson yarn is either zero or one true. When the mesons break apart, an electron, positron, neutrino or photon is produced and the charge of the mesons is either positive, negative or neutral. The best example of mesons is the bion, which consists of quarks and anti-quarks.

Table 4.2. *The mesons.*



MESON $= q\bar{q}$		quarks	electric charge	mass (GeV/c^2)	spin
π^+	pion	$u\bar{d}$	+ 1	0.140	0
K^-	kaon	$s\bar{u}$	− 1	0.494	0
K^0	kaon	$d\bar{s}$	0	0.498	0
ρ^+	rho	$u\bar{d}$	0	0.770	1
D^+	D	$c\bar{d}$	+ 1	1.869	0
η_c	eta-c	$c\bar{c}$	0	2.980	0

5 The Four Forces in Nature

The forces in the world we live in today are the electromagnetic force, the force of gravity, the strong force and the weak force. Gravity is the weakest force in that force, while weak and strong force operates in very short distances between primary particles, particles less than atoms, and strong force is called the strongest force among the four fundamental forces.

The method of the origin of this force by the particles of the carrier of the force exchange between the particles and called the boson, as the exchange of the boson particles between them lead to the emergence of this energy and the bosons divided into four types, the force of gravity carried by Grafton and the electromagnetic force is carried by photon, The weak force carried by Z.W, while the strong force is matched by gluons.

Since the gravitational effect is weak and can be ignored as the standard model is centred around very small particles, gravity can be neglected, so there is no gravitational force in the standard model.

5.1 The electromagnetic force

The photon is the basic component of electromagnetic and the photon is only a boson in the standard model. It is responsible for carrying the electromagnetic force. The photon is also called the two-wave particle because it combines the properties of both particles and waves. Later it was discovered that the photon is only neutrino and interento and then modified the idea that the photon has no mass, in the early sixties has been proven evidence and experience that neutrons have a very small mass.

5.2 The strong force

It was common that the material consisted of protons and neutrons only, and scientists were looking at what the force that carries protons linked inside the nucleus and do not contradict because of the strength of dissonance resulting from the similarity of their charges. But in the early 1970s, scientists realized that protons and neutrons were made up of elementary particles called quarks. All of this explained the quantum chromo-dynamic theory.

Of all this, we find that strong nuclear force is the combination of quarks and anti-quarks in the Hadrons (which we talk about later).

5.3 The gravity force

Gravity is one of the observed forces that we see every day in our lives because it operates under distant distances and gravity does not resemble nuclear power which is a very short range. Gravity is responsible for our stability on the ground, the stability of buildings and everything. The earth around the sun and also the rotation of the moon around the earth.

We will not talk about the force of gravity at length because this research speaks of the standard model theory, which describes three forces out of four (electromagnetic, strong and weak), and gravity was not one of these forces.

5.4 The weak force

Although the force charged by the boson is more powerful than the gravitational force, it is considered weaker than other forces and is effective at very short distances 1 Beta dissolution is the best example of weak force as shown in the following figure:-

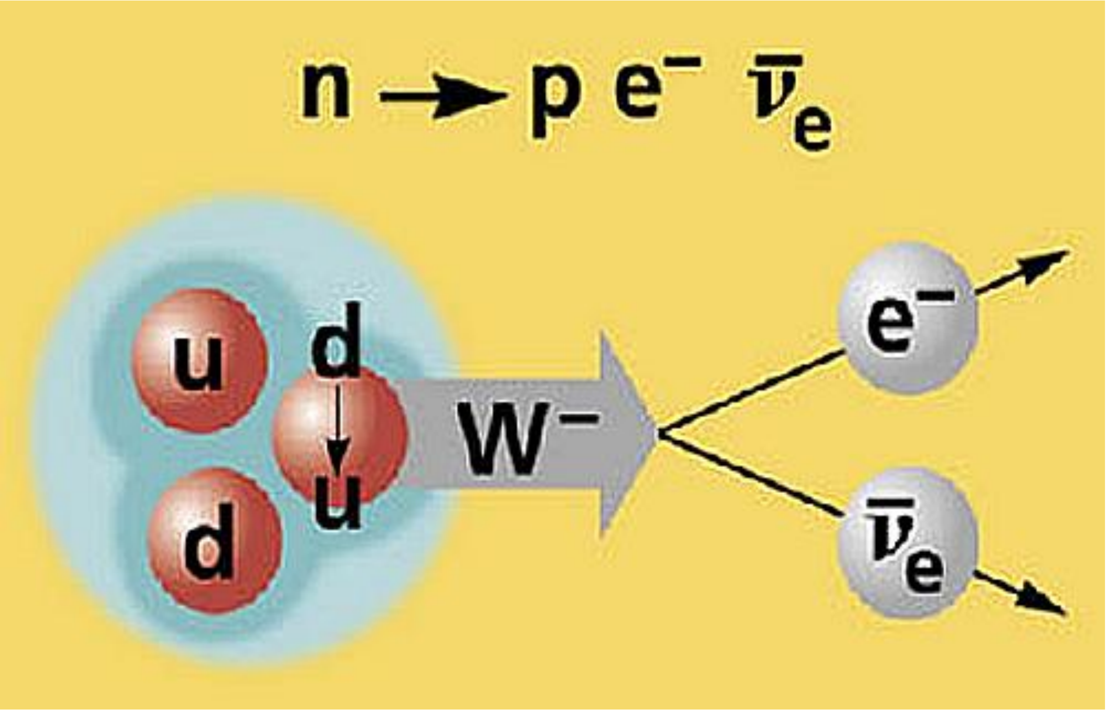


Figure 5.1*Beta dissolution*

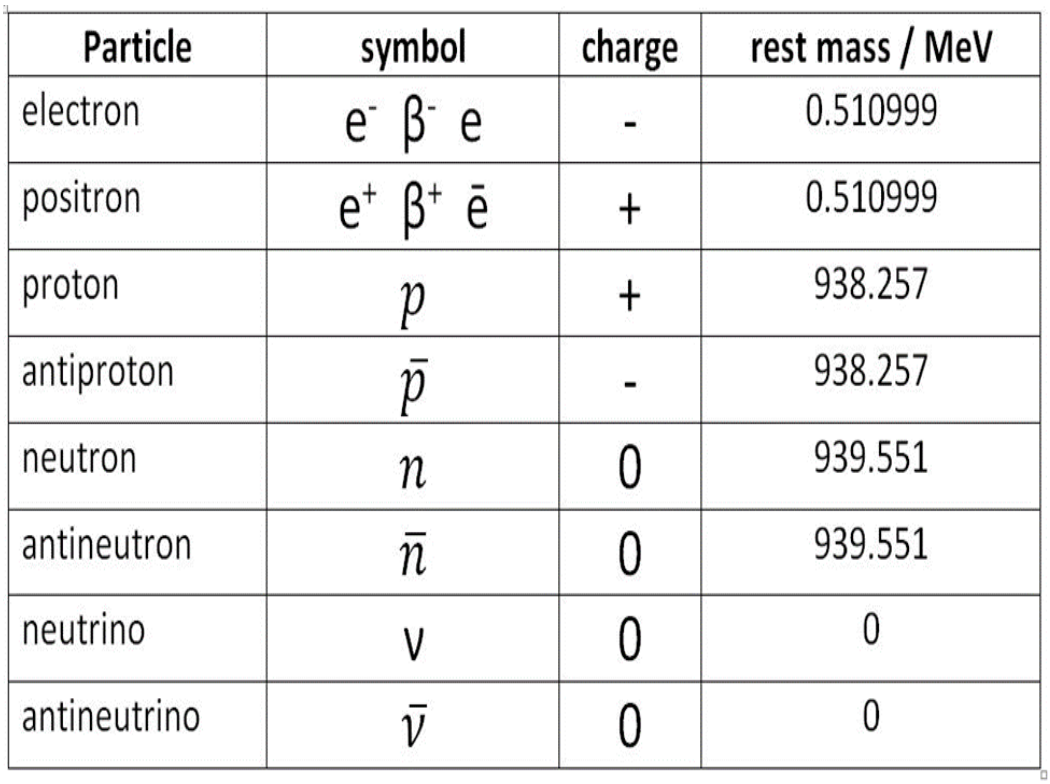
6 Antiparticle

After describing the behaviour of the electron in the electromagnetic field before and after he proposed his theory of relativity, which resulted in two cases, the first description of electrons negative while the other described the electron positive charge and this idea seemed a strange idea some.

But the 1932 discovery is like an electron in its properties, but its charge is positive. It was called Dirac in his theory, which was later called antibodies. Particles and no particles can be the atoms and hence the material because the material cannot be composed of particles and their antiparticles. If a particle encounters a counterpart of the opposite particle, the two will disappear and disappear.

The first evidence of the presence of antiparticles was discovered in 1955 by physicists when they used particle accelerators, which also revealed the presence of more than 200 elementary particles.

Table 6.1. *Particle and antiparticle.*



Particle	symbol	charge	rest mass / MeV
electron	e^- β^- e	-	0.510999
positron	e^+ β^+ $\bar{e}$	+	0.510999
proton	p	+	938.257
antiproton	$\bar{p}$	-	938.257
neutron	n	0	939.551
antineutron	$\bar{n}$	0	939.551
neutrino	ν	0	0
antineutrino	$\bar{\nu}$	0	0

7 Interactions

The basic forces can be called basic interactions, and these interactions are weak and strong interactions and are in a small space and electromagnetic interactions and are visible to us and can be observed.

Physicists described the basic interactions as a separate quantum field and were among the particles given to us by the standard model of particle physics.

The gluon particle is responsible for the strong interaction. This means that the gluon contributes to the binding of the quarks from which the hadrons are formed. As a result, the radon is connected with each other with the same force as the nucleus of the atom.

They are only bosons that make weak interactions. It is the photon that carries the electromagnetic forces that are stronger than the force of gravity, and this is true only in the short distances while in the vast and massive distances, the force of gravity is dominant.

At the end of the seventies, both the unification of electromagnetic interactions and the strong interactions with electroweak theory, physicists attempted to calculate the magnitude of gravity as the first step in the way of unification of electromagnetic force, weak force, strong force with gravity, in a theoretical proposal combining four interactions with Each other.

7.1 Electroweak interactions

The quark can change from one flavour to another through a weak interaction, for instance, in radiation and beta decay, neutrons are divided into electrons and protons, where the down quark is decomposed into an up quark. Thus, the neutrons are converted into protons and the boson is then decomposed into an electron.

Strong interaction is the result of the force of attraction and the contrast between the quarks where the gluon carries this force and called the theory that describes this chromo dynamic QCD.

The Gluon transfer force between matter particles, which are either mesons, quarks or composite particles of quarks, such as neutrons and protons.

8 The Standard Model

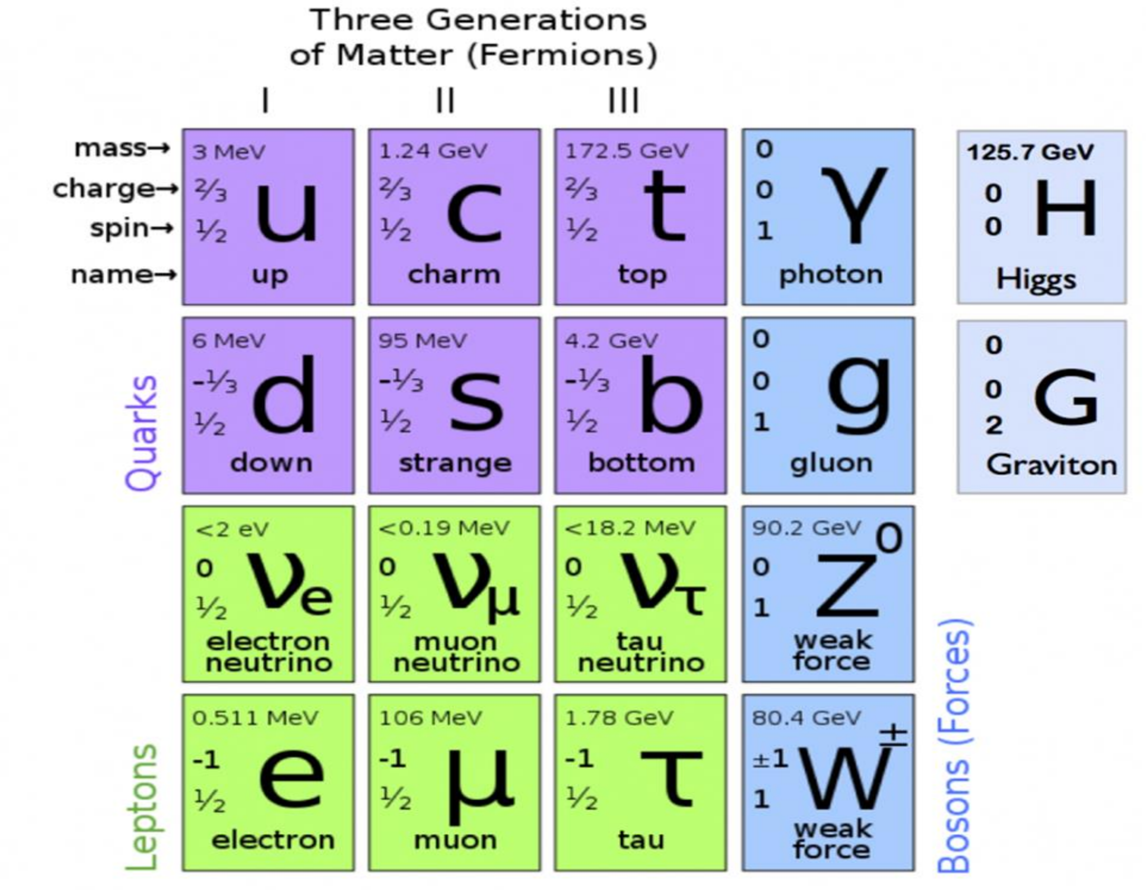
The standard model theory is incomplete, although it describes several new unexplained phenomena. For example, scientists have discovered quarks several years ago and yet they cannot accurately identify the upper quark kernels without experimenting because the standard model does not explain the probability of a mass of particles that are uncertain by commercialization.

So the theory of the standard model of particle physics describes all three interactions (strong, weak and electromagnetic interactions) as this theory passed several stages to develop from 1970 to 2012. After all, this success of the theory of the standard model can be considered the theory of everything. Contains the force of gravity and absolute energy, but it has achieved success theoretically and mathematically.

However, physicists in experimental and theoretical particles have shown great interest in trying to change several strange phenomena, such as the existence of dark matter and also in simulation, where they help in new physics and beyond the standard model.

In the last few years, the standard model has been used in several applications along with particle physics such as astrophysics, nuclear physics and cosmology.

***Table 8.1**. The standard model of particle physics.*



Three Generations of Matter (Fermions)

	I	II	III		
mass→ charge→ spin→ name→	3 MeV ⅔ ½ u up	1.24 GeV ⅔ ½ c charm	172.5 GeV ⅔ ½ t top	0 0 1 γ photon	125.7 GeV 0 0 H Higgs
Quarks	6 MeV -⅓ ½ d down	95 MeV -⅓ ½ s strange	4.2 GeV -⅓ ½ b bottom	0 0 1 g gluon	0 0 2 G Graviton
	<2 eV 0 ½ ν_e electron neutrino	<0.19 MeV 0 ½ ν_μ muon neutrino	<18.2 MeV 0 ½ ν_τ tau neutrino	90.2 GeV 0 1 Z^0 weak force	
Leptons	0.511 MeV -1 ½ e electron	106 MeV -1 ½ μ muon	1.78 GeV -1 ½ τ tau	80.4 GeV ±1 1 $W^\pm$ weak force	Bosons (Forces)

9 Beyond the Standard Model

Although the standard model and its success in describing the interactions of the material, they form only 4% of the universe and the largest proportion in the unexplained part of the standard model, which is dark energy and dark matter.

10 The Large Hadron Collider

The Large Hadron Collider (LHC) is a 328-foot underground machine located between the borders of France and Switzerland. The Large Hadron Collider is one of the projects undertaken by CERN. The Large Hadron Collider is considered to be one of the largest devices manufactured by man and employs a large number of scientists from different countries of the world. As this Collider propels proton beams close to the speed of light and then collides with these beams. The changes occurring on these beams are recorded by six detectors located on the perimeter of the Large Hadron Collider. In addition, the heart of the Large Hadron Collider the coldest place on earth and also the coldest in the world outside the atmosphere.

The reason behind the manufacture of such a device that has cost millions of dollars is knowing what is going on around us in every detail, no matter how small.

10.1 Main detectors in LHC

The Large Hadron Collider contains several main detectors:

10.1.1 Atlas Detector

(A Toroidal LHC Apparatus) the Atlas detector is one of the largest reagents in the LHC but in the world, with a height of 25 meters, a length of 46 meters and a width of 25 meters and a volume of 28750 cubic meters. Inside the detector is a device called Inner Tracker, which is responsible for the monitoring and analysis of what happens to protons during the collision and what is produced after the collision. It also has a Calorimeter that can measure particle energy by monitoring particle movement and information by this detector

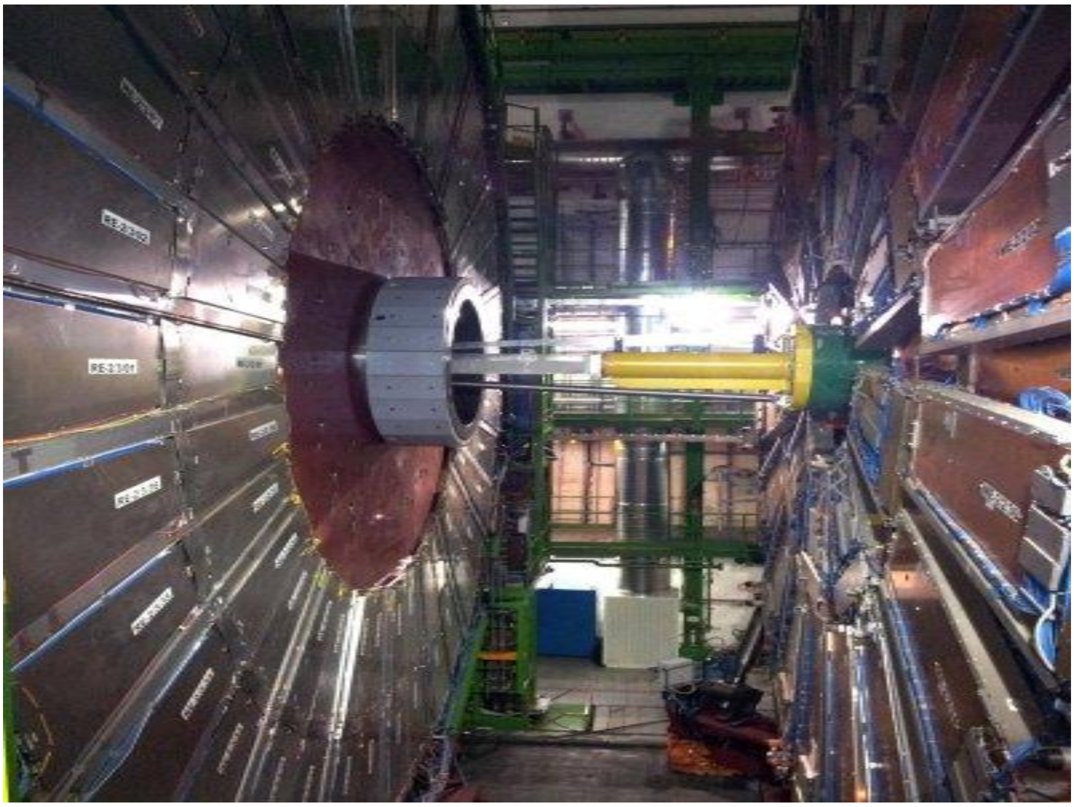


Figure 10.1. *A Toroidal LHC Apparatus (Atlas).*

10.1.2 Detector (CMS)

The name is short for (Compact Moun Solenoid) and this device to measure and monitor the initial particles produced after the collision as in the Atlas detector. There is also a very large magnet surrounds the CMS and has a magnetic field greater than the magnetic field of the Earth by 100 thousand times.

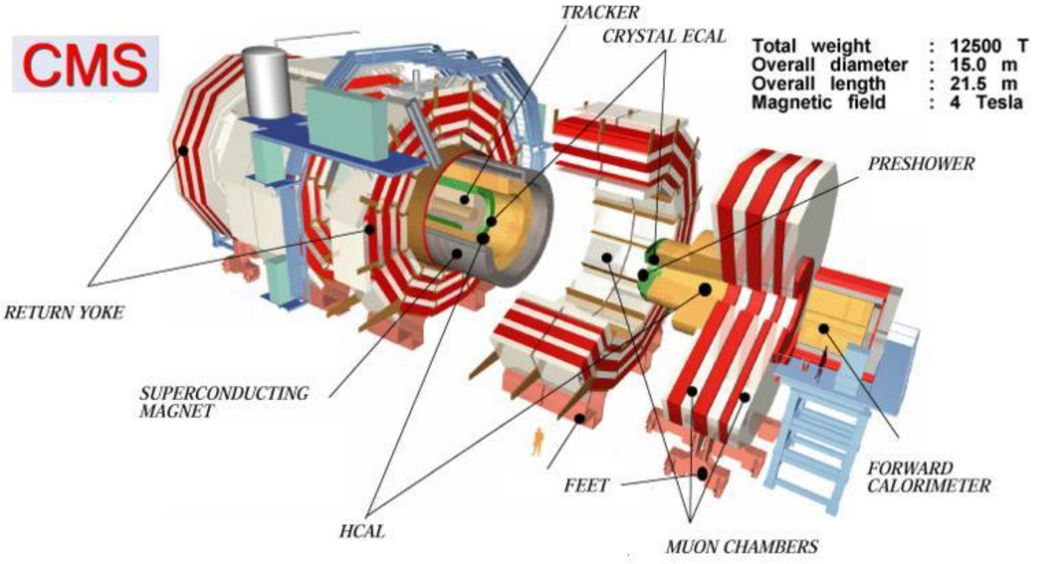


Figure 10.2. *Compact Muon Solenoid (CMS).*

10.1.3 Alice Detector (A Large Ion Collider Expropriation)

It studies the collisions between heavy ions. The Alice detector contains the time projection chamber TPC.

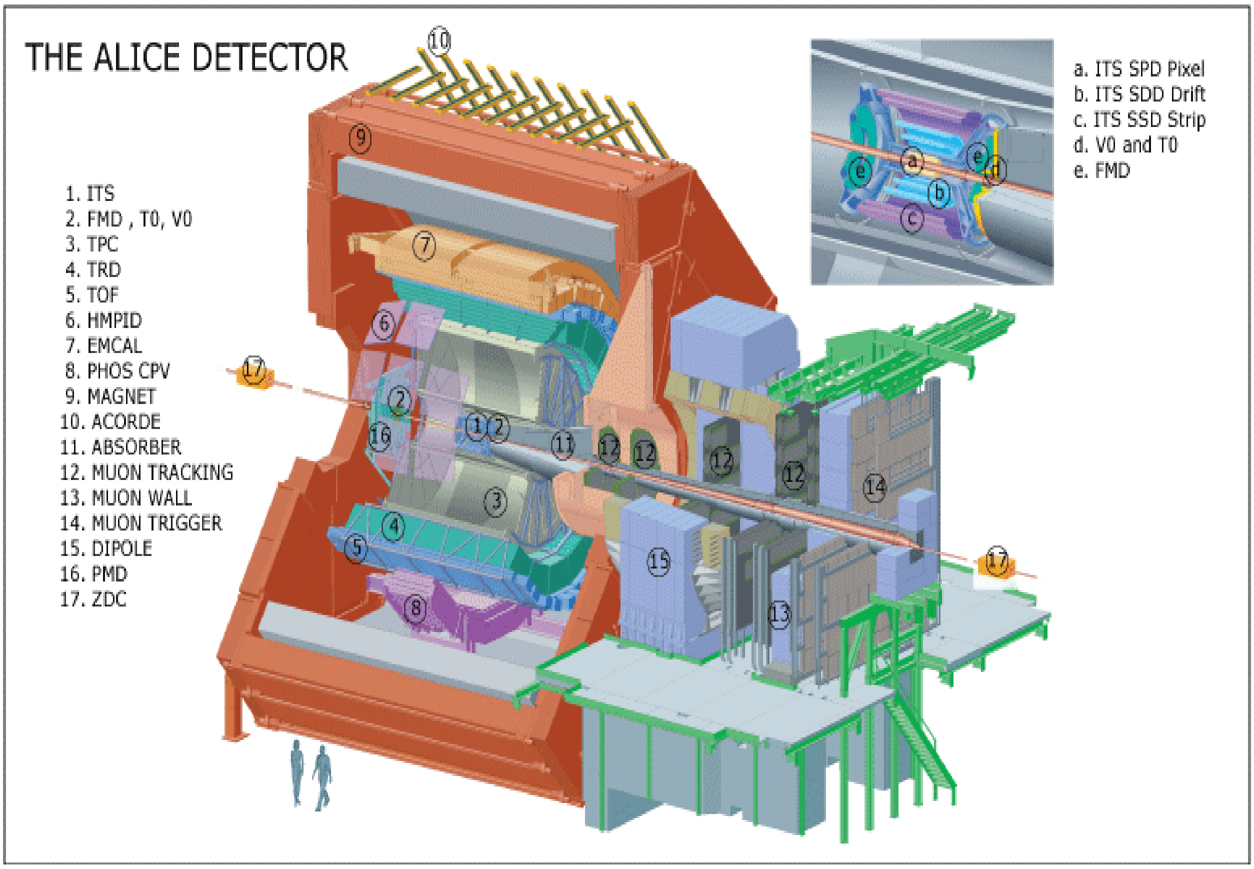


Figure 10.3. *A Large Ion Collider Expriment (Alice).*

10.1.4 Beauty Detector: Large Hadron Collider

Beauty This detector is designed to know the difference between the material we know and the dark matter, by searching for the quarks of beauty.

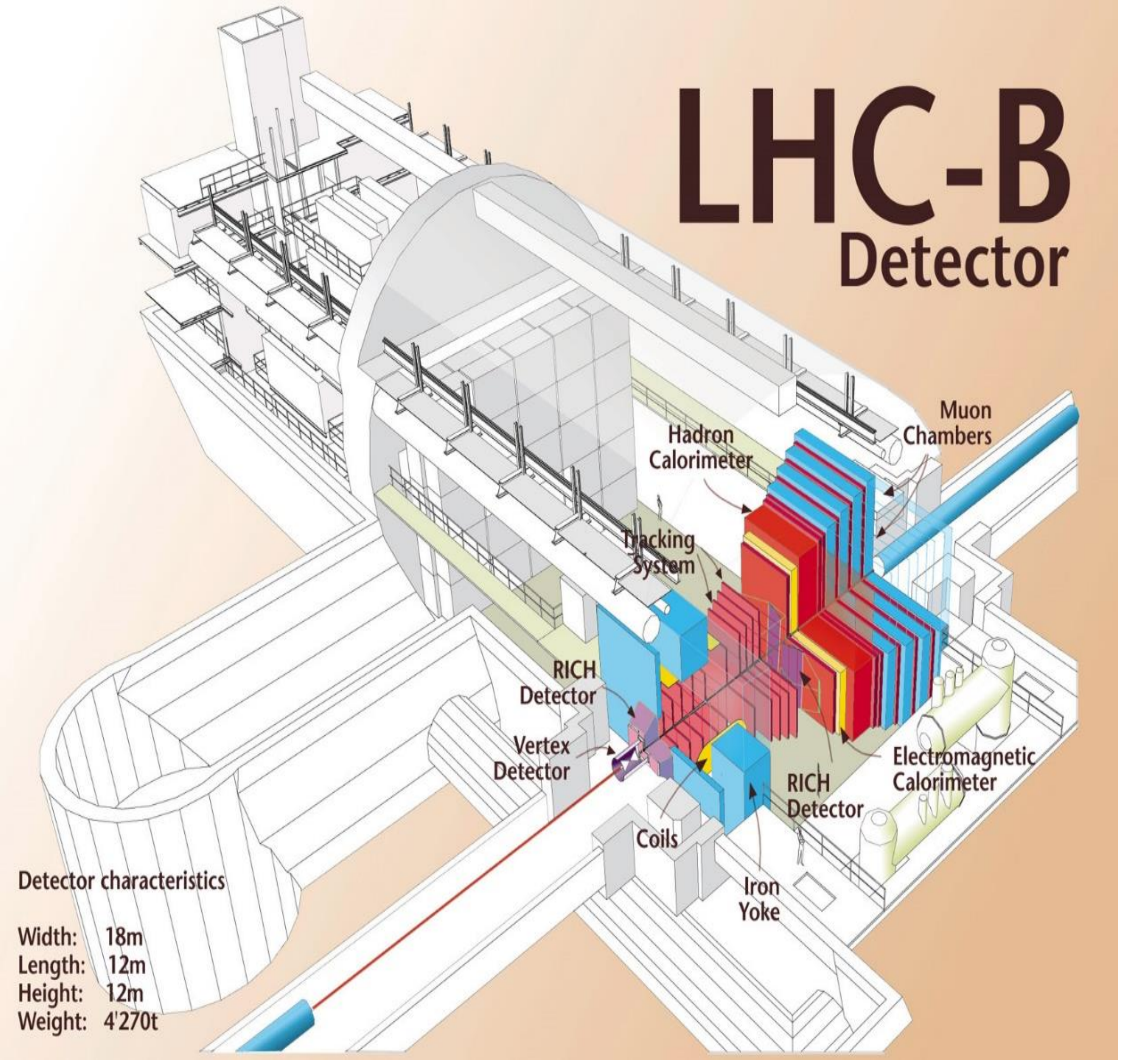


Figure 10.4. Large Hadron Collider Beauty (LHC-B).

There are also two small detectors within the Large Hadron Collider (LHCF), which is an abbreviation for the Great Hadron Collider. The other is Totem (the total measure of a flexible and zoological (cross-section).

There are also thousands of scientists working on each of these detectors

10.2 How the Large Hadron Collider Works:

10.2.1 Acceleration:

At first, protons must be present separately to be accelerated by the device. Proteons can be obtained separately by separating the electrons from the hydrogen atoms. The protons then enter the accelerator called the PS Baster, where the protons are accelerated within it to reach the appropriate speed and energy and then driven by the accelerator PS activator to the accelerator SPS is the accelerator of the super-protons, and then split all the packages so that each proton on its own, At this moment the speed of each Proton is approximately the same speed of light and then the accelerator SPS push these beams to the large Hadron Collider and this is through two tubes, one moving clockwise and the other counterclockwise and at that moment the speed of each proton the same speed of light is almost Each proton is flipped in the tube surrounding the large Hadron Collider Wali 11245 A roll in the second.

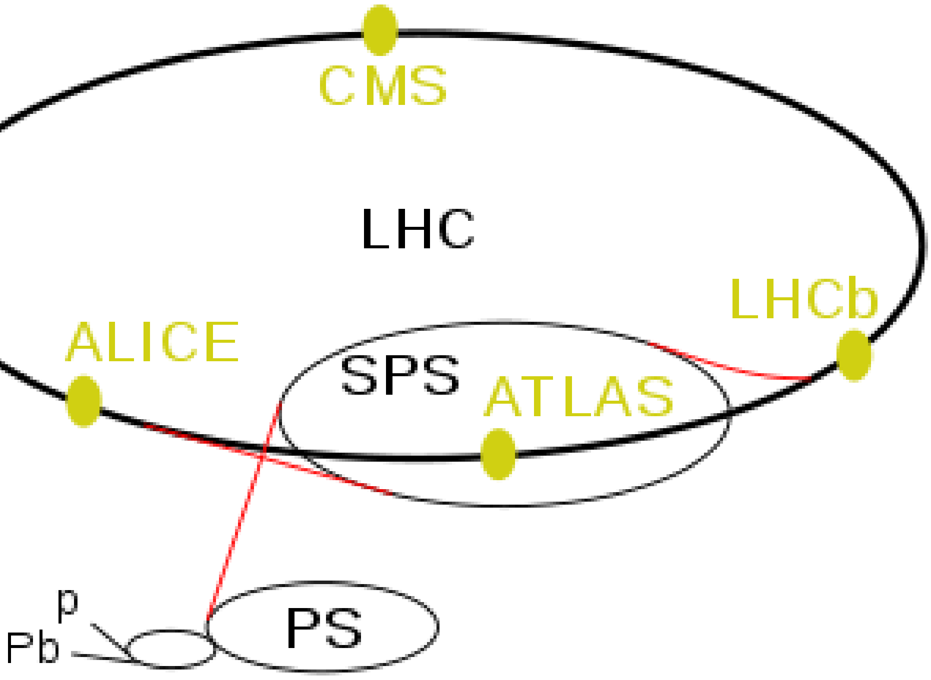


***Figure 10.5**. The accelerators in The Large Hadron Collider (LHC).*

10.2.2 Collision

After the passage of protons within the two tubes coming from the accelerator they go out and since the movement of each other inverse pack and each containing a large number of protons and moving at the speed of light, it occurs about 600 million collisions per second where every proton coming from a tube Collides with the proton coming from the opposite tube and then divided into smaller particles, quarks, and a force known as mullet begins. As we have said before, the quarks are not stable and therefore they have even faded and decompose into new particles. Here we would like to point out that The work of Large Hadron Collider, but it cannot force all righteousness So that there are a number of protons continue to move without resistance or collision with any proton in the opposite direction and at the end of the path there is a part of the device is made of graphite where it absorbs the remaining package of protons and then add this part of the device to protect Large Hadron Collider If there is an error in the package path or the collision has lost control of the package.

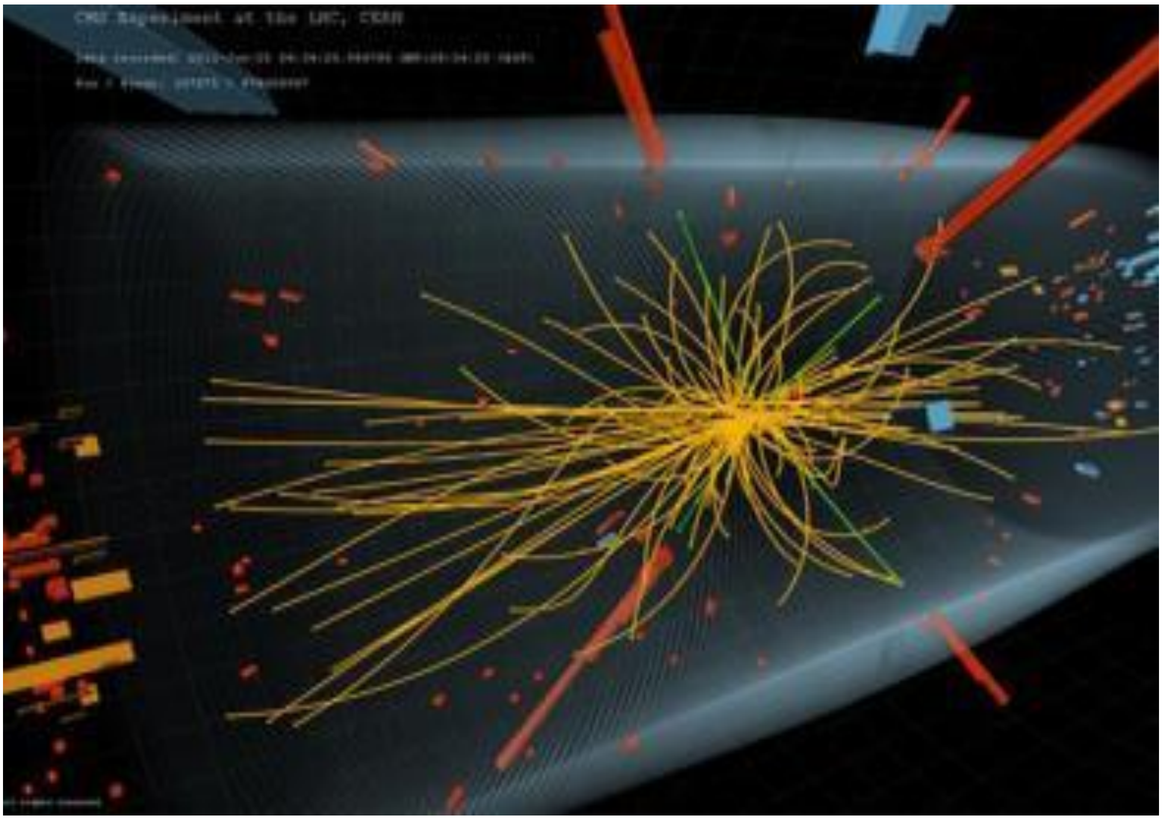


Figure 10.6. *The form of collisions within the large Hadron Collider.*

10.2.3 Data and results of the Large Hadron Collider

After collecting the data from the reagents in the Large Hadron Collider, which is estimated at about 15 million gigabytes, then these data are divided and each part is sent to a computer. After the computers process this data, they are all sent to a central computer, which is called Grid Computing. , Where scientists analyze this information and the results to be used in the understanding of the universe and Maidur around us has been revealed such information on the standard model of physical particles and Higgs boson also discovered that the neutrons do not have a mass.

Scientists also try to answer several questions that the standard model could not answer such as dark matter and other questions that puzzled humans.

Figure 10.7. *Computers in the large Hadron Collider.*

Figure 10.8. *Computing Center* **-** *CERN.*

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