Hi, I'm Roberta Manuali, a physics and maths teacher of this school and I'm very happy to present to you the physics clil project I've realised last January-February together with the students of my third class: they were divided into seven groups and each group had to explore a different aspect of the Large Hadron Collider (LHC), the topic of our work.
They worked very hard and I am so proud of them also because they have never studied this part of physics, so if there are some mistakes it's only my fault!
Now, reading this project, I hope you are going to discover a lot of interesting things about the Large Hadron Collider: I wish you all a good travel…at close the speed of light!!

PHYSICS CLIL PROJECT

“To the discovery of the Large Hadron Collider (LHC), the world’s largest and most powerful particle accelerator”

- To probe the matter with particles
- Particle accelerators
- The Large Hadron Collider (LHC)
- Why faster and faster particles?
- The Standard Model
- The Higgs Boson
- Particle detectors. How to build a homemade cloud chamber

[Waveleangth -The experiment]

[Waveleangth – The moral]

To probe the Matter with particles

[Rutherford]

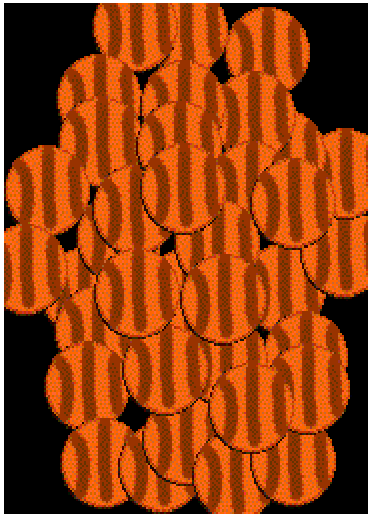
[The accelerators]

Wavelength-The cave

- Pretend that you are unlucky enough to fall into a cave without a flashlight.

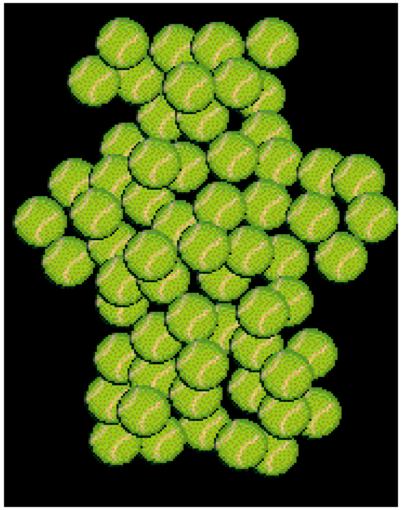
- However, you are lucky enough to have a bucket of glow in the dark basketball. Suddenly, you hear a snuffling sound. Is it a blood-thirsty bear, or your friends playing a practical joke on you?

To find out, you desperately toss in the directions of the snuffling sound, and memorize where the basketballs hit. So you can quickly understand the figure that is in front of you.



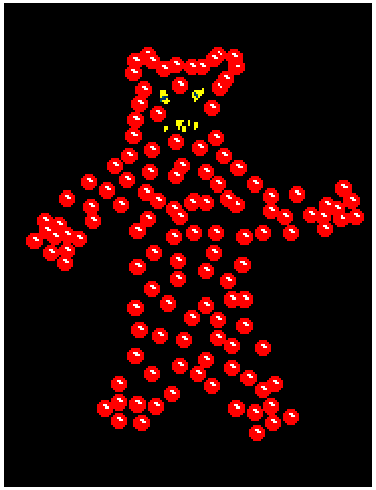
Since basketballs are so big, when they bounce off the thing in front of you, all you can learn about its shape is that it is wide and tall

Fortunately, you ALSO brought a bag of glow-in-the-dark tennis balls. You toss them in the direction of the snuffling.



Tennis balls are still too big to figure out the shape of the object they hit. You only have a rough idea about the thing's outline.

What luck! Your bag of glow-in-the-dark marbles should do the trick! You toss these little balls at the being, and note that you can figure out a pretty clear image of the thing's shape. It seems to be big, hunched over, and have enormous claws. A bear!



Your last thought is that you used the smallest possible probe to get the most information about your fate.

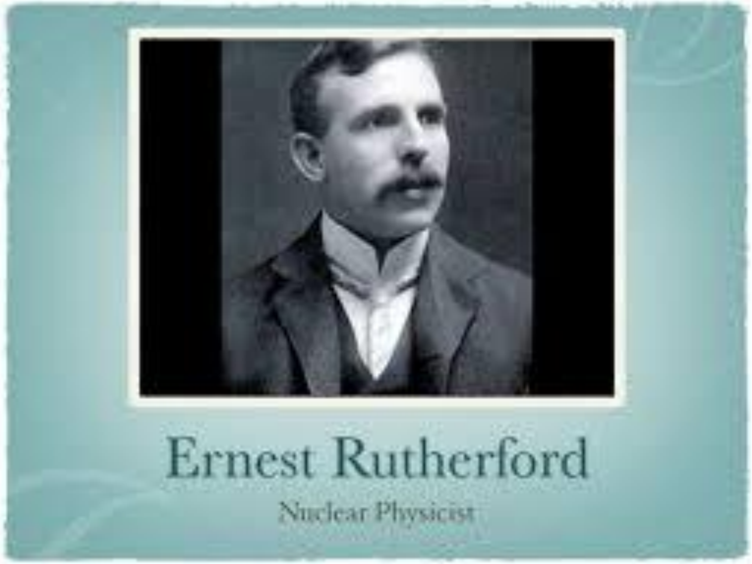
Wavelength-The moral

The morals are:

- don’t throw things to hungry bears
- to gather the most information about an object, you have to use the smallest possibile probe.

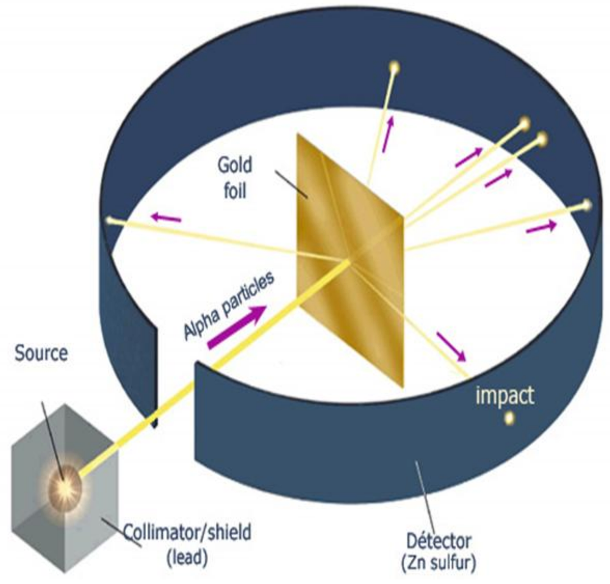
In fact, the marbles are more effective to gather information, because when you reduce the size of the probe, the images become sharper and sharper.

J.J. Thomson was the first scientist who contributed to the birth of a new conception of matter: in fact in 1897 he discovered the existence of subatomic particles. But the greatest contributi on was given by Ernest Rutherford: in fact in 1909 he set up an experiment to test the validity of Thomson's theory about the atom's structure. In this way Rutherford established a way that for the first time physicists could «look into» tiny particles they could not see with microscopes.



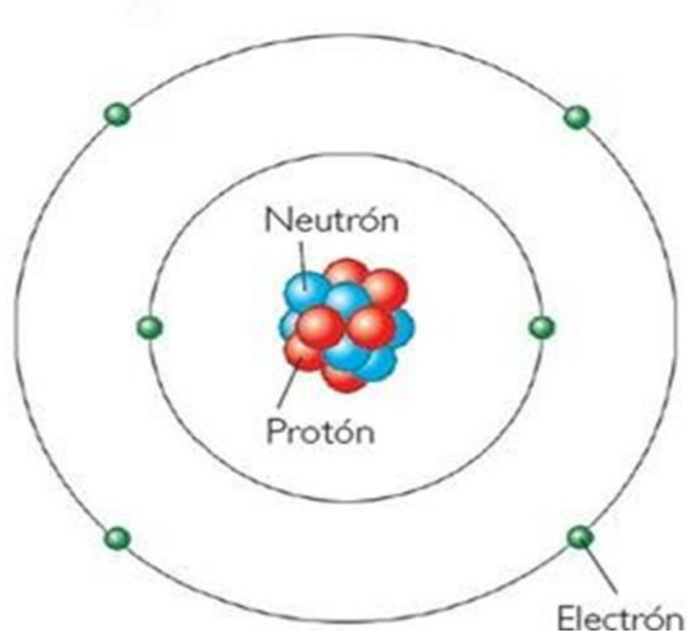
Rutherford's result

In Rutherford's experiment, a radioattive source shot a stream of alpha particles at a sheet of very thin gold foil which stood in front of a screen. The alpha particles would make little flashes of light where they hit the screen. If Thomson's «plum pudding» model was correct all the alpha particles should simply pass through the gold foil and strike the back of the screen. But much to everyone's surprise, some of the particles were deflected at large angles to the foil; some even hit the screen in front of the foil.



Rutherford's analysis

Thanks to his experiment, Rutherford concluded that inside the atom there must be something small, dense and positively charged which rejects only the alpha particles that hit him: the **NUCLEUS** (formed by protons and neutrons)



How physicists experiment

Today almost all particle physicists use, in their experiments, the same basic elements that Rutherford did:

-A beam (the alpha particles)

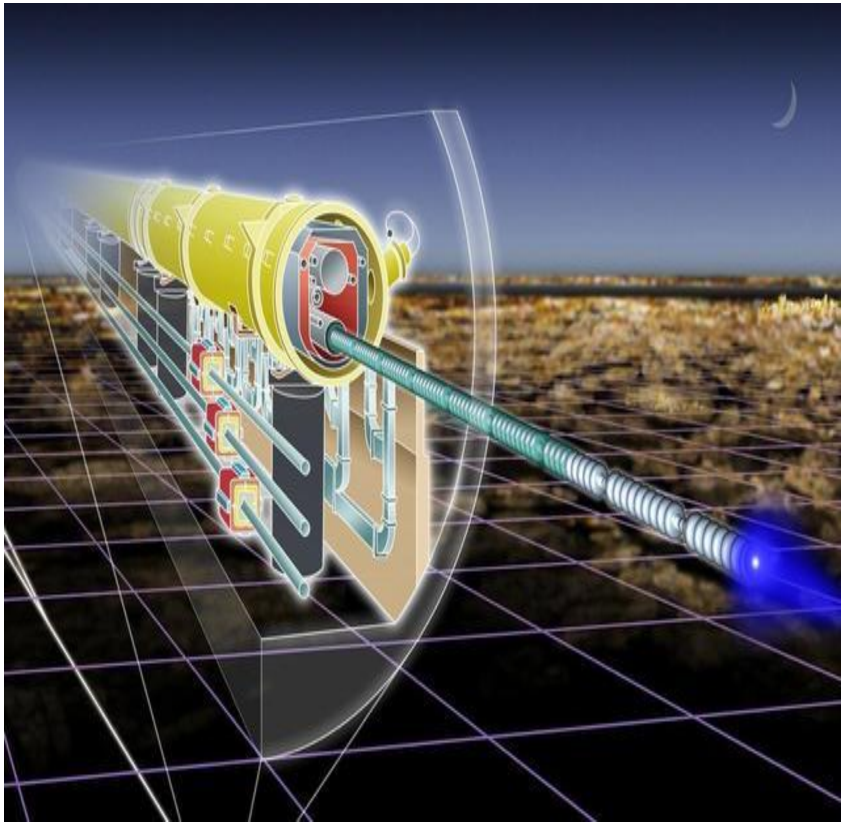
-A target (the gold atoms in the foil)

-A detector (the zinc sulfide screen)

In addition, R. established the practice of «seeing» into the sub–atomic realm by using particle beams.

The physicists tool: THE ACCELERATORS

Physicists can't use light to explore atomic and sub-atomic structures because light's wavelength is too long. However, since ALL particles have wave properties, physicists can use particles as their probes. In order to see the smallest particles, physicists need a particle with the shortest possible wavelength. However, most of the particles around us in the natural world have fairly long wavelengths. How do physicists decrease a particle's wavelength so that it can be used as a probe? A particle's momentum and its wavelength are inversely relatedHigh-energy physicists apply this principle when they use particle accelerators to increase the momentum of a probing particle, thus decreasing its wavelength.



LET’S DO SOME EXERCISE!

RUTHERFORD'S EXPERIMENT

Complete the gaps with suitable words, from the list below:

A beam of 1(.........) particles generated by the radioactive decay of Polonium was directed towards a thin sheet of gold.

The sheet of gold 2(........) surrounded by a circular sheet coated with zinc sulfide (ZnS) used as the detector.

Zinc sulfide emits bright sparks 3(.......) is hit by alpha particles.

According to the model of Thomson, alpha particles would have to cross the gold leaf being deflected in 4(.......)

5(........) it is observed that some particles are also reflected at angles greater than 90 °. This was a completely unexpected event.

6(.......)the experiment Rutherford finally rejected the Thomson's "panettone's model"

In fact, for Thomson's model neither negatively charged particles or the distribution 7(.....) positive charge which was to contain them,would be able to produce deflections so marked.

- 1. a) beta b) alpha c) omega
- 2. a) was b) has been c) were
- 3. a) where b) while c) when
- 4. a) one point b) fifty points c) two points
- 5. a) in fact b) however c) so
- 6. a) after b) during c) before
- 7. a) in b) of c) by

PARTICLE ACCELERATORS

Which are their goals?

How are they made?

How do they work?

What are scientists searching?

How are they made?

A particle accelerator can be

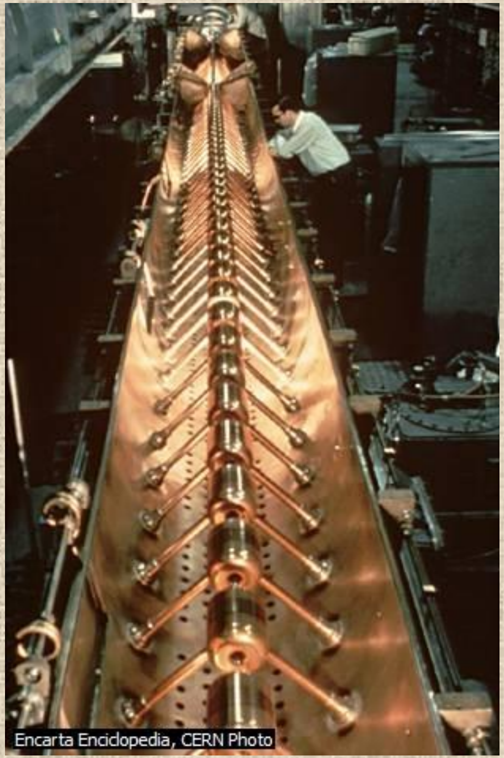
LINEAR

CIRCULAR

Which is better?

LINEAR ACCELERATOR

The linear accelerator also called LINAC is an electric device that makes subatomic particles go faster. Particles are put inside the tube by an electric field that push them into an extremity of the tube; then particles are drown at the opposite extremity.



Alvarez, CERN, Ginevra

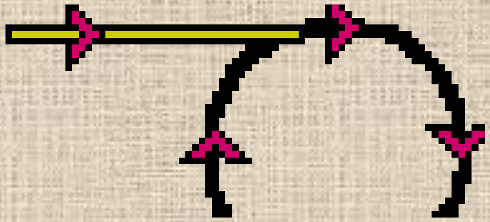
LINEAR ACCELERATOR

Linac can be used

- For fixed target experiments

- As linear colliders

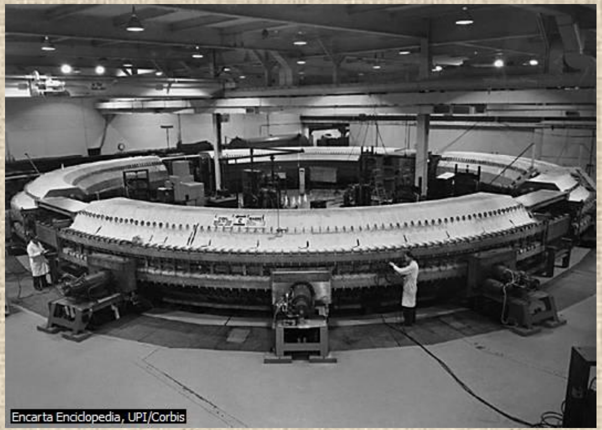
- As injectors to circular accelerators



CIRCULAR ACCELERATOR

The circular accelerator also called SYNCHROTRON is an electric device that makes subatomic particles go faster.

Particles are put inside the tube by an inner generator of the tube with the help of an electric field and then, always thanks to the electric field particles receive a bunch of little kicks.



Brookhaven National Laboratory New York

CIRCULAR ACCELERATOR

To keep any object going in a circle, there needs to be a constant force on that object towards the center of the circle. In a circular accelerator, an electric field makes the charged particle accelerate, while large magnets provide the necessary inward force to bend the particle's path in a circle. The presence of a magnetic field does not add or subtract energy from the particles. The magnetic field only bends the particles' paths along the arc of the accelerator.

ADVANTAGES OF ONE RATHER THAN THE OTHER

Advantages of a linear accelerators are:

- Facility in building it because they have not electromagnetic field;
- That they are much cheaper than others;
- Less radiation of energy rather than circular accelerators.

Advantages of a circular accelerators are:

- Particles obtained have shorter wavelength because in the circular accelerator there is the condition to increase the momentum strongly.
- There is much more possibility of crash between all particles because the motion has never end.

Which are their goals?

The accelerators' goal is to produce ion beams or subatomic particles with high kinetic energy ($k=\frac{1}{2}mv^2$) with the goal to resolve *two physics' problems*

WHICH PROBLEMS?

After catching up the speed of light (c) , the accelerator has the new function to give mass to the accelerated particles to have more kinetic energy ($E=mc^2$) and to study phenomena attributable to the Big Bang.

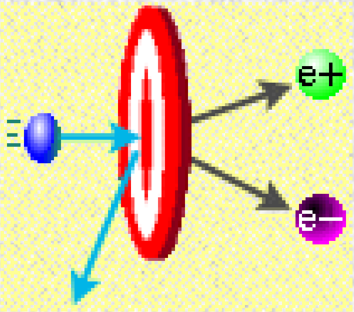
To reduce the wavelengths to hit the atoms

How do they work ?

1. Particles are entered in the accelerator;
2. These are accelerated by electric field (when the accelerator is circular particles are maintained in trajectory through bipolar electromagnetic fields);
3. Particles are used for fixed-target experiments or colliding beams experiments;
4. The scientists study the particles got from the collision

How can we get particles?

Antiparticles: energy particles are thrown to a target which divides them in particles and antiparticles through photons. To create them are useful also electromagnetic fields.



Protons: getting through hydrogens ionizing

Electrons: giving heat a metal

Types of experiments

Two types of experiments exist to create a collision between particles

Fixed-targed experiment

Colliding beams experimen

FIXED-TARGET experiment

Scientists keep particles like electrons or protons and these are accelerated through an electric field to a target which can be solid, liquid or gaseous. A detector records the particles got by the collision. An example could be Rutherford's experiment made to find out the atomic structure.

COLLIDING BEAMS

experiment

In this experiment there isn’t only a beam of particles but two, which are made to collide with high kinetic energy to create collision. This collision creates much more particles than with the other experiment because in this there’s more kinetic energy for the greater presence of initials particles.

What are scientists searching?

Their goal is to search answers on the Standard Model, from the existence of the Higgs boson to the dark matter.

EXERCISE

Connect all quetstions with their own answer

Which is the function of electromagnetic field in the circular accelerators?

Which is the function of electric field in the accelerators?

Which are the benefits of having a circular accelerator over linear accelerator?

Which are the benefits of having a linear accelerator over circular accelerator?

How does a fixed target experiment work?

How does a colliding beams experiment work?

It is used to accelerate particles

Facility in building and cost

A single beam of particles fired at target creating a collision

It is used to conduct the course of particles

Two particles beams clashing create a collision

It gets particles with shorter wavelenght and it has more possibility of collision

EXERCISE

Put missing words into the following text

The particle accelerators are used to accelerate particles giving them ________ energy.

There are two kinds of accelerators: linear and circular.

Linear accelerators are used for ___________ experiments, while circular accelerators are used for ___________ experiments.

They both have an __________ which accelerates particles. Circular accelerators have also an ___________________ that conduces particles within the circle.

The _________ accelerator is easier and cheaper to build up because it hasn't any magnets.

__________ collisions happen when there's a single beam of particles fired at a target, an example is Rutherford's experiment. ___________ collisions happen through the clash of two beams of particles.

Electromagnetic field **Potential** **Colliding beams (x2)**

Kinetic **Fixed-Target (x2)** **Linear** **Electric field** **Circular**

EXERCISE

Put missing words into the following text

The particle accelerators are used to accelerate particles giving them Kinetic energy.

There are two kinds of accelerators: linear and circular.

Linear accelerators are used for Fixed-Target experiments, while circular accelerators are used for Colliding beams experiments.

They both have an Electric field which accelerates particles. Circular accelerators have also an Electromagnetic field that conduces particles within the circle.

The Linear accelerator is easier and cheaper to build up because it hasn't any magnets.

Fixed-Target collisions happen when there's a single beam of particles fired at a target, an example is Rutherford's experiment. Colliding beams collisions happen through the clash of two beams of particles.

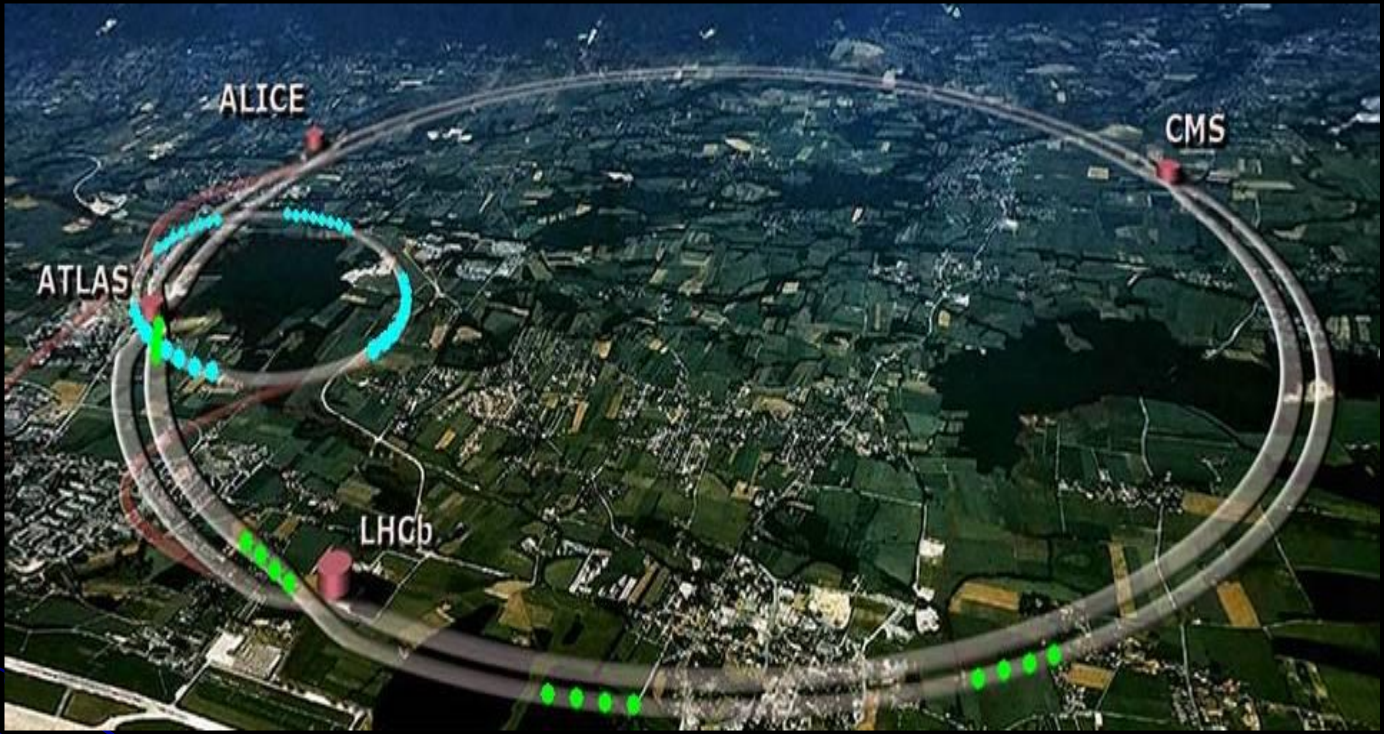
Potential

Circular

LHC

The Large Hadron Collider

What is LHC?



LHC is the acronimic of “Large Hadron Collider”. It is a particle accelerator,situated at CERN of Ginevra.

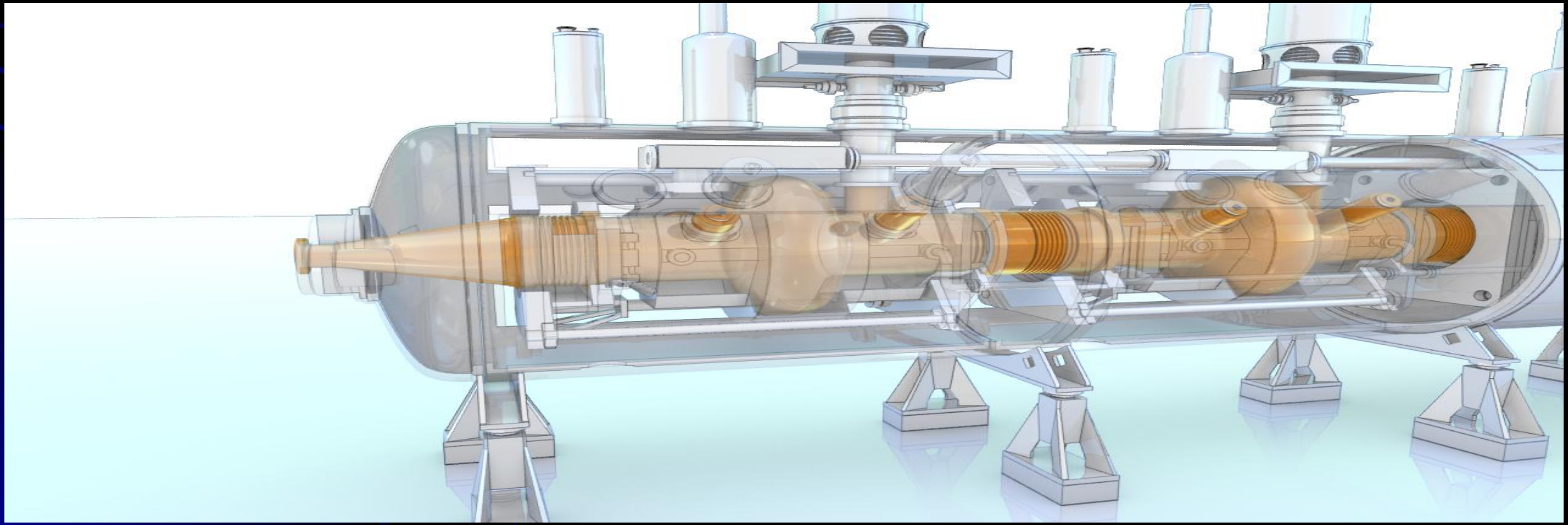
It is the largest and most powerful accelerator in the world; it has a circular shape,and inside it two high-energy beams of protons travel at close the speed of light, before they’re made to collide.

LHC is 27 km long and it stays 100m under Ginevra’s ground…and this fact has created a lot of controversy among skeptics and fatalist.

How are particles accelerated?

Before introducing packages of protons inside it, LHC takes an Hydrogen atom (H) and thanks to a metal cylinder called “DUOPLASMATRON”, in which a strong electric field is applied, it extracts the electron from the atom, by leaving it as a positive ion composed only of one proton.

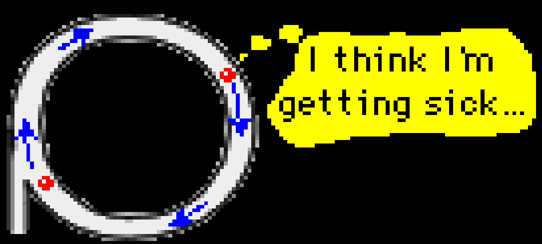
At that point the proton is channeled into the first stage of the acceleration. Proton must be accelerate, but…..HOW?!?!? Proton passes through a system of alternated electric fields. In this way the proton will acquire speed by passing from one electrode to another: once passed the first stage, the electhric charges of the electrodes are inverted in order to let the particles to continue their acceleration.



A linear or circular accelerator?

By only using the tecnology of a liner accelerator, we should need liner accelerator with an unrealistic lenghts, to accelerate protons to 7 TeV.

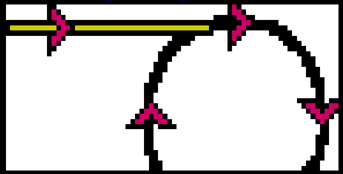
Therefore, we need a circular accelerator to let protons return to the starting position, continuing to be accelerated: a magnetic field is necessary to bend particle path and keep it in an almost circular orbit. But there is a problem: when the liner path of a particle is bent by a magnetic field, the particle misses a bit of energy as radiation. So, to avoid excessive lossof energy, we need circular accelerators with very large rings.



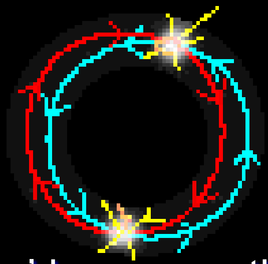
Protons are introduced in the LHC’s ring with an energy of 450 TeV: this energy is provided by all synchrotrons previous to the LHC, which in the past have made the history of accelerators.

How does LHC work?

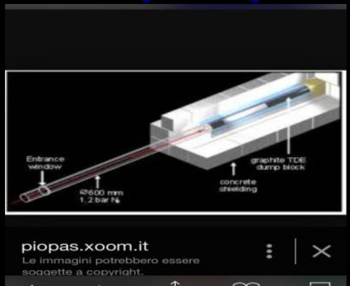
LHC consists of two circular, parallel rings inside which protons are inserted thanks to the accelerator SPS(Super Proton Syncroton).



One group of protons rotates clockwise, the other group rotates counterclockwise. These two tubes are intersected in four points, and it's just in these points that protons can collide.

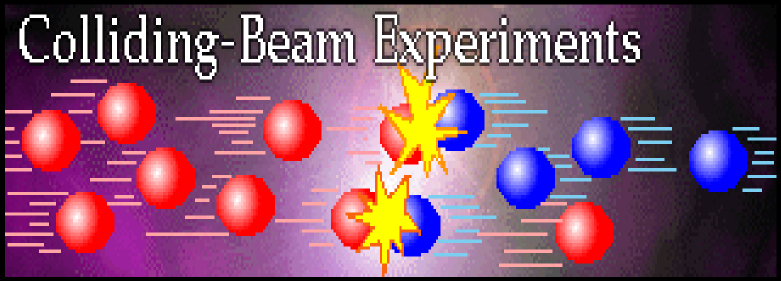


To lead the two protons' beams on their trajectory, we need magnetic fields: they have the task of maintaining the two beams well separated.These magnetic fields allow the particles to maintain their circular trajectory.



How does LHC work?

Protons enter in LHC distributed in packages, called BUNCH, positioned so as to collide in the orbits exactly in the centre of a detector.



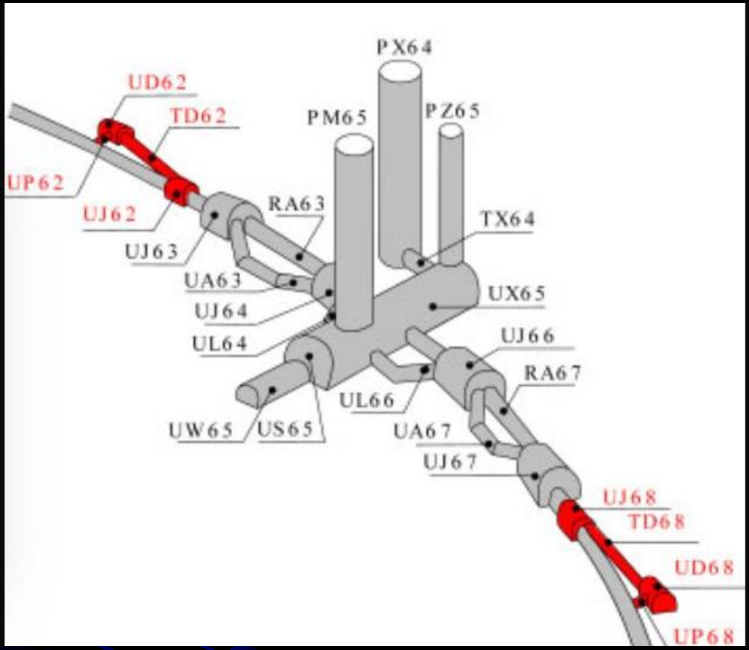
When the bunches bump into each other, some protons collide, but most of them continue undisturbed for another round, because of the repulsive forces between charges of the same sign. Being precisely positioned in the orbit, collisions between Bunches always will take place in the same precise instants.

To increase the probability of the collision, bunches are compacted as much as possible and beams are carefully aligned in order to centre the encounter.

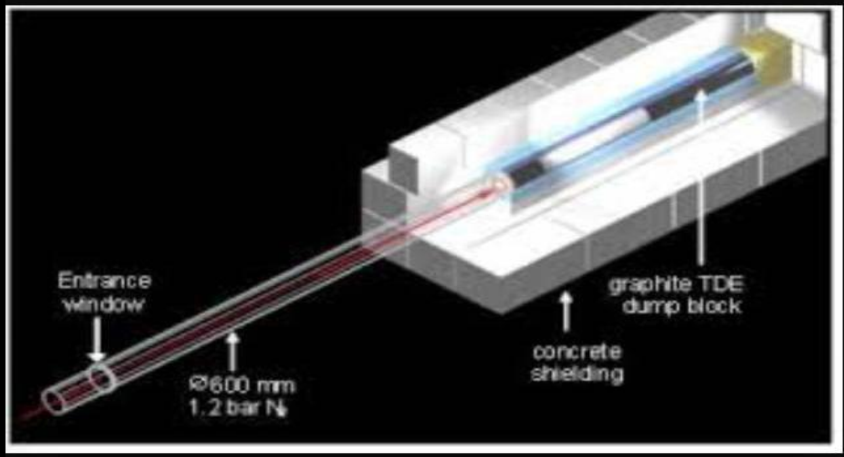
Then the bunches are fattened with the maximum number of protons they contain and also the number of bunches in the machine is increased.

When the packages consume themself, and protons inside the bunches are too few, the accelerator is stopped and new bundles of bunches are introduced in the LHC.

How to stop LHC’s bundles?



“Point 6” of the LHC is equipped with magnetic exchanges which are able to extract the bundles from their circular trajectory, and to divert them along two galleries tangential to the ring, just like on two dead rails



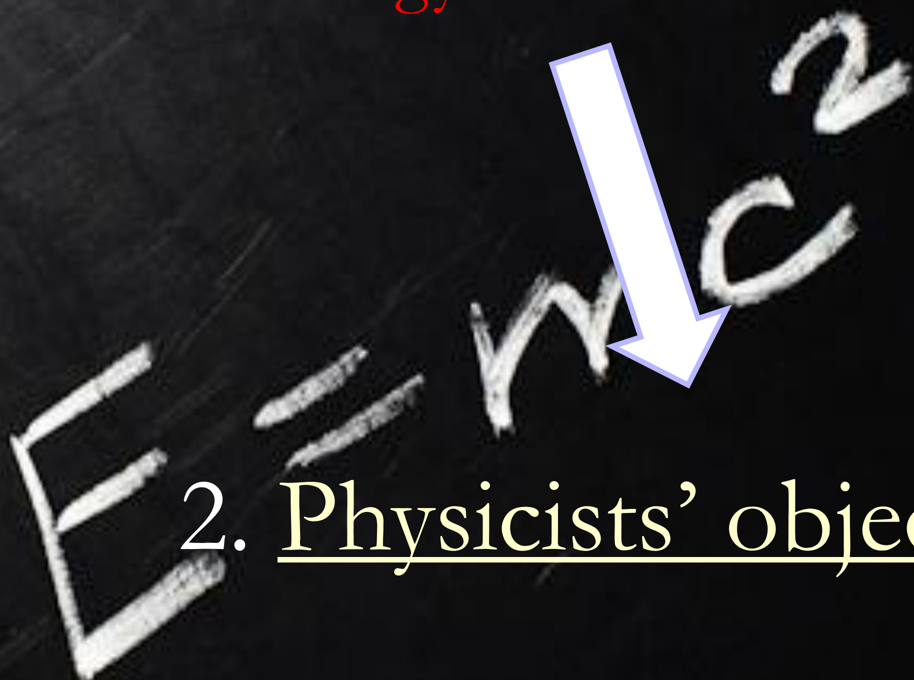
The beams are bumped into a wall.
In effect, at the end of the two rails, a cylindrical block of graphite is provided.
This block is 7 meters long, and its diameter in 70 cm.
This block is inserted in another block of cement, which weighs 750 tonnes, and which in constantly cooled with water.
Moreover to avoid overheating, a system of deflector magnets, scatters the beam at the head of the absorber, so that not all the protons will strike the absorber at the same point.

WHY FASTER AND FASTER PARTICLES?

Why do physicists want to push particles to higher and higher energy?

$E=mc^2$

The first reason is to be found in the equivalence between mass and energy



1. Explanation
2. Physicists' objective

EXPLANATION

The formula $E = mc^2$ says: if a mass m disappears, necessarily there must be an amount of energy E. Conversely, if a quantity of energy E disappears, there must necessarily be a mass m. This means that, in the current demonstration, when a projectile-particle collides with a target-particle, fixed or mobile , the energy contained in the impact centre of gravity before the collision, can be transformed in the mass of new particles: the greater is the energy, the greater is the mass of the particles that can be generated.

PHYSICISTS' OBJECTIVE

Since these collisions can create particles which existed only in the earliest moments after the Big Bang, the objective of physicists is to accelerate as much as possible in order to recreate them.

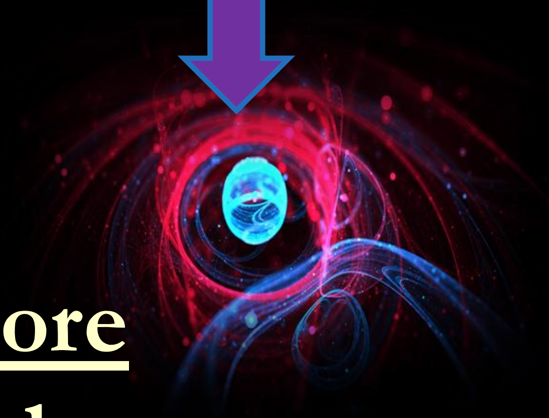
By constantly increasing the energy of accelerators the probability of recreating them will be increasingly greater.

Today these particles don't exist any longer, because even if they are generated in very high-energy natural collisions, they immediately decay into more stable particles.

$E = mc^2$

SUBATOMIC WORLD

The second reason is due to the opportunity of exploring smaller dimensions and observe the subatomic world



More and more closely into the microscope

Why smaller and smaller?

MORE AND MORE CLOSELY INTO THE MICROSCOPE

The second reason to accelerate particles at increasingly great energy, is due to the opportunity of exploring smaller dimensions and observing the greater number of subatomic world's details. At the energies achieved by the big LEP accelerator at Cern, it was possible to explore the 10^-15 m dimensions; with LHC, the successor of LEP, we get to even smaller dimensions.

WHY SMALLER AND SMALLER?

Why do greater energies allow us to explore smaller dimensions in the subatomic world? This is because of the way particles interact when they collide.

TIME TRAVEL

…tion lies in scientists' **desire to go back in time**
…ry first moments of life of the primord…

1.Nowadays

2.Reconstructing History

Nowadays

Thanks to a whole series of studies, researchers have been able to recreate those particles that allowed them to go back to the very first moments of life of the primordial universe. The LHC collisions reproduce what happened a millionth of a millionth of a second after the Big Bang.

UNDERSTANDING THE HISTORY OF THE UNIVERSE

If we imagine to back in time, starting from the moment we live in, we would see the universe getting smaller and temperatures rising, we could observe particles agitating more and more violently and consequently greater energies being exchanged during their collisions.

Greater energy accelerators permit to recreate those conditions which existed in ever more remote times and closer to the Big Bang. So it was that, guided by their observations and experimental results, particle physicists and astrophysicists discovered they were heading in the same direction: understanding the history of the universe immediately after the Big Bang.

EXERCISES

QUESTION LOOP READING, SPEAKING AND LISTENING ACTIVITIES

Each of you is going to receive a strip of paper containing a question and an answer to a separate question: one student begins by reading out their question to the other students; students look at their strips of paper to see if they have the answer; if they do, they read it out, then read out their own question, and so on until questions finish.

QUESTION

1.Where do we find the first reason?
2.What does the Einstein's formula say?
3.How can become the energy during the collision?
4.What's the objective of physicist?
5.Did these particles exist for a long time? Why?
6.What's the second reason?
7.What's the use of LEP accelerator?
8.What's the third reason?
9.What does the LHC collision allow?
10.What could we see going back in time?

ANSWERS

1.We find it in the equivalence between mass and energy.
2.It says that If a mass m disappears, necessarily there must be an amount of energy E. Conversely, if a quantity of energy E disappears, there must necessarily be a mass m.
3.The energy can be turned into particle mass.
4.It is accelerate as much as possible in order to recreate the particles which existed only in the earliest moments after the Big Bang.
5.No, they didn't. They have been generated by a huge quantity of energy and they have decayed into more stable particle.
6.It gives the possibility to explore smaller dimensions and observing the subatomic world.
7. It can explore until 10^-15 m.
8. It gives the possibility to go back in time, up to the very first moments of life of the primordial universe.
9. It allows to reproduce the millionth of a millionth of a second after the Big Bang.
10.We could see the universe getting smaller and temperatures rising, we could observe particles agitating more and more violently and consequently greater energies being exchanged at collision.

CLOZE TEST

COMPLETE THE GAPS WITH SUITABLE WORDS, FROM THE LIST BELOW:

fundamental - mysteries -universe - dark -explosion – different- unknown –protons(X2)- although- ingredients- experiments

This is the link of the exercise’s video
https://www.youtube.com/watch?v=roorfpw5tBA
(2:20/4:47)

Every second two billion .... smash again each other inside the LHC end recreate the conditions that were present less than a billion of a second after the Big Bang. This is when the Universe started in a massive....., pure primordial energy. What's really exciting about this is that some of these new objects, so particles are very different to the particles which originally collided together. In fact, they are particles that we no longer see in the world around us, but ....these new particles only live for short time around the start of the universe, they played a .... role in making the universe look the way it does today.

If we want to understand the origin of the Universe, one of the .... that we need to understand these particles that last so little and that you can't find now in mines because they have disintegrated completely from the origin of the universe.

The more we study it, the deeper we look into things, the more we find there is to find out, because there are some very strange .... in the universe.

We know that mass can turn into energy but we don't know how that happens. We know that back a millions of a second after the Big Bang, matter didn't exist in the form of .... and neutrons, but in a completely ....state and we know that gravity was extremely important back in those earliest times but we don't know exactly how it works. Maybe the reality out there is much closer to science-fiction than the real world. The LHC is like a space craft venturing into the........., looking for answers to these questions and four major ....called ATLAS, ALICE, CMS, and LHCb have built gigantic detectors on the LHC ring to capture the instant of particles collisions. We are going to use them to find out more about the mysteries of the...........

One clear night we can see thousands of stars but all the stuff we can see or detect only accounts for 4% of the whole universe. The rest is made of dark matter and ....energy.


The Standard Model

Why was Standard Model born?

At the birth of the universe, for a few milliseconds, about two hundred particles dispersed in the infinite space, so matter (and antimatter) were born.

The theories and discoveries of thousands of physicists since the 1930s have resulted in a remarkable insight into the fundamental structure of matter:

everything in the universe is found to be made from a few basic building blocks called fundamental particles, governed by four fundamental forces.

The particles of the universe

In the universe there are lots of particles, about two hundred types, but not all of them are fundamental.

The main particles' families are:

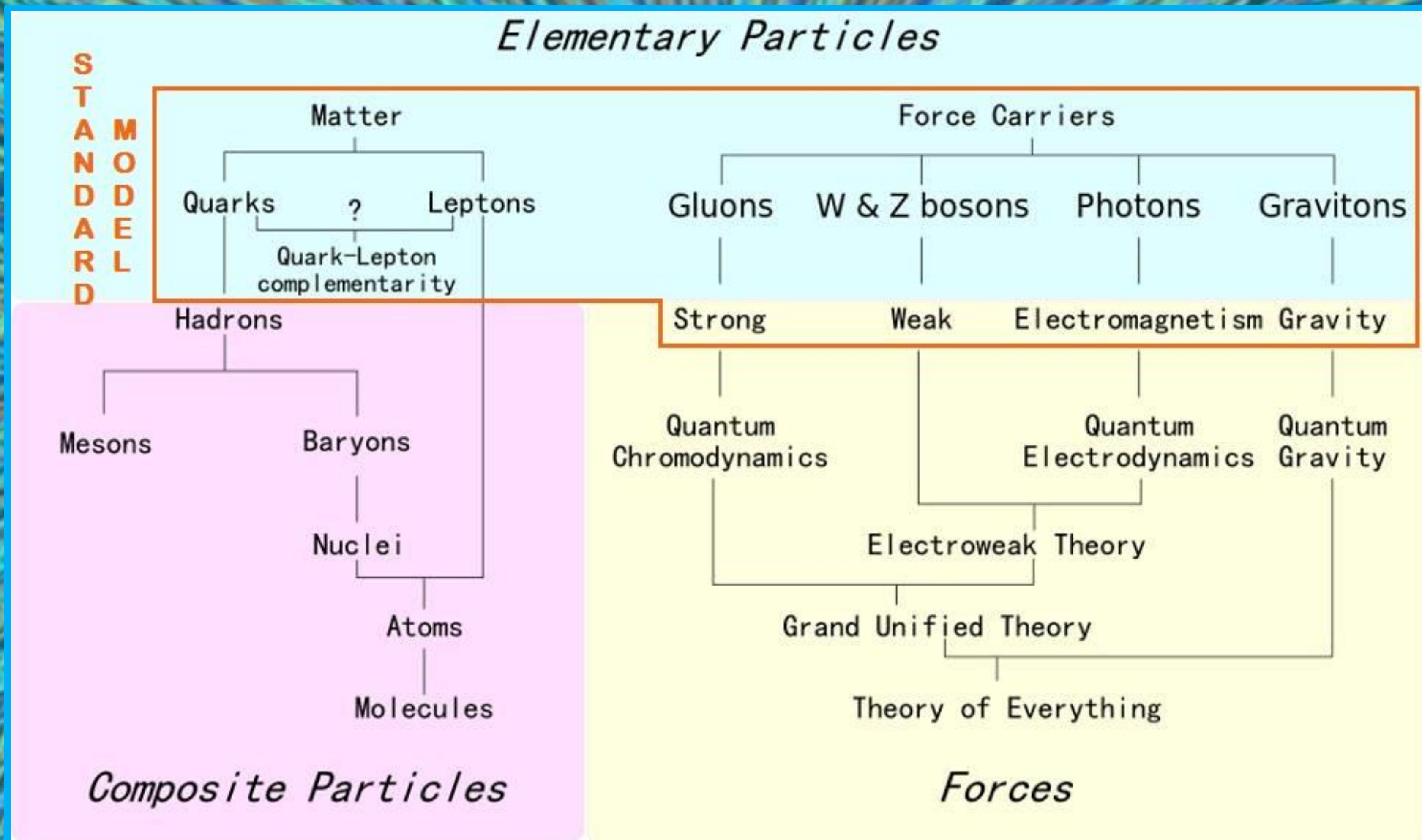
- ***Hadrons:*** divided into Barions and Mesons, divided in turn into other particles.
- ***Bosons***: which include at the time five types.
- ***Fermions***: divided into Quark and *Leptons*.

Only Fermions and Bosons are fundamental particles and when they join they create other particles.

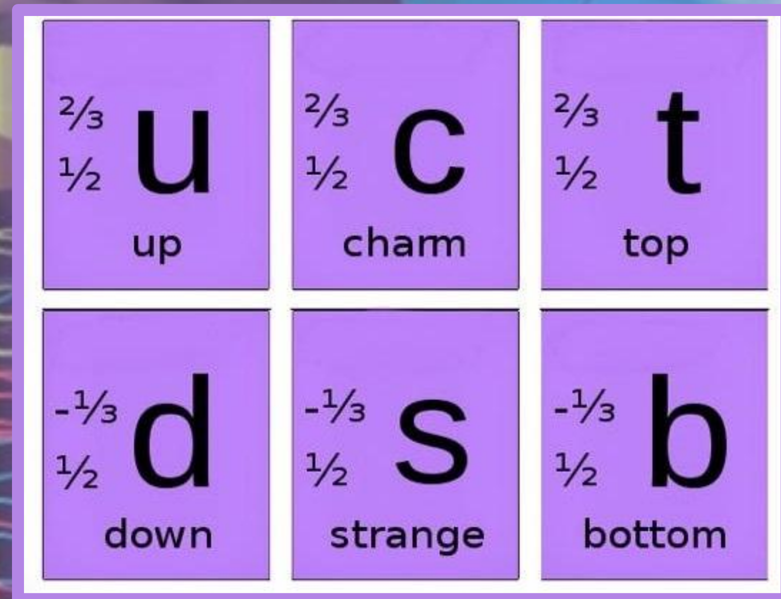
Standard Model studies them.

It has successfully explained almost all experimental results and precisely predicted a wide variety of phenomena, so it has become established as a well-tested physics theory.

The S.M. has an important role to explain the life and the universe



QUARKS



- There are **six quarks**, but physicists usually talk about them in terms of three generations:

  1) **up/down** 2) **charm/strange** 3) **top/bottom**

- All the Quarks have a spin of +1/2, so they satisfy Pauli's principle of exclusion.

UP & DOWN

The Up Quark is a first generation Quark with a positive electrical charge of +2/3.

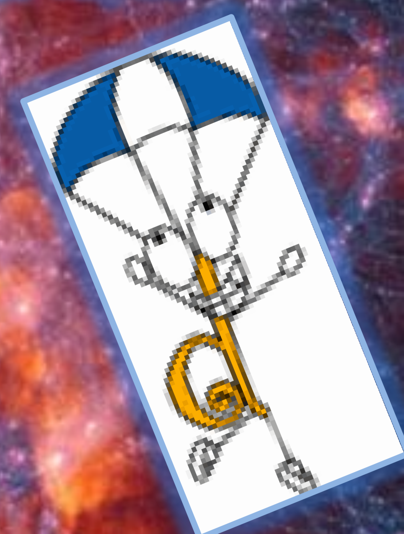
Its antiparticle has got an electrical charge which is equal and opposite, of -2/3.

It is the lightest Quark.

- The Down Quark is a first generation Quark with a negative electrical charge of -1/3.

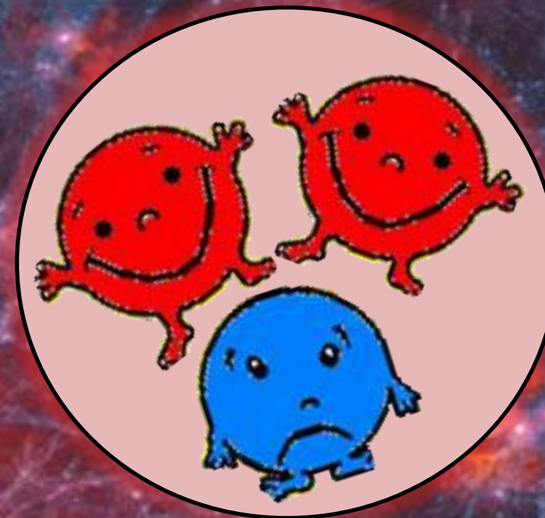
Its antiparticle has an electrical charge of +1/3.

It is the lightest Quark after the Up Quark.



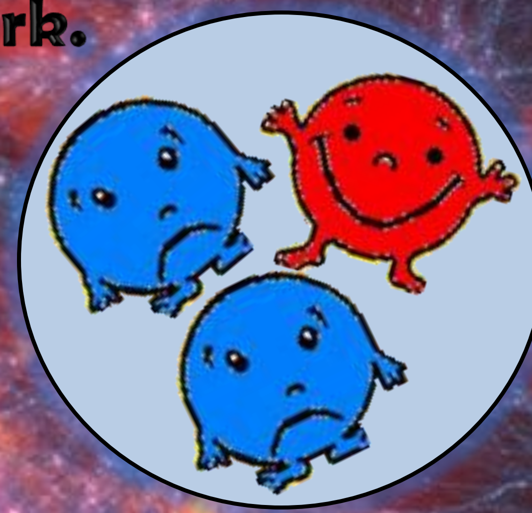
UP + DOWN

According to the Standard Model, the Up Quark and the Down Quark combine and produce....



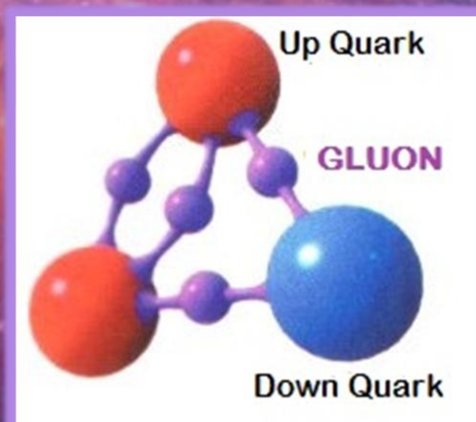
- **Proton: 2 Up Quark + 1 Down Quark.**
- **Neutron: 2 Down Quark + 1 Up Quark.**

PROTON



NEUTRON

This is possible thanks to the Gluon particle.



CHARM & STRANGE

- The Strange Quark is a second generation quark with a charge of -1/3.

Its antiparticle has an electrical charge of +1/3

It is the lightest after the Up and the Down Quarks.

It is so called because it is characterized by a particular quantum number that indicates a very strange feature in the behaviour of that particle.

The Charm Quark is a second generation quark with an electrical charge of +2/3.

Its antiparticle has an electrical charge of -2/3.

It is the fourth quark for heft.

TOP & BOTTOM

The Top Quark is a third generation Quark with a charge . of +2/3.

Its antiparticle has an electrical charge of -2/3.

The Top Quark interacts primarily by the strong interaction but can only decay through the weak force.

It decays almost exclusively to a W Boson and a Bottom Quark, but it can decay also into a Strange or Down Quark.

- The Bottom Quark is a third generation Quark with a charge of -1/3.

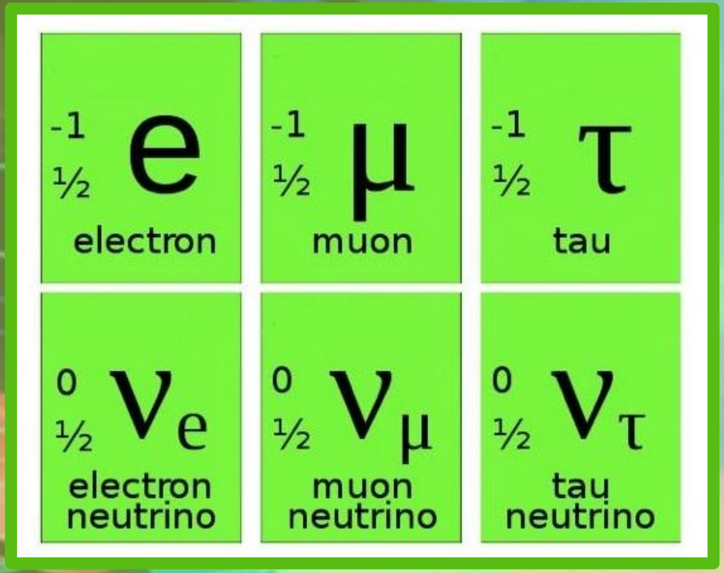
Its antiparticle has an electrical charge of +1/3.

The Bottom Quark can decay into either an Up or a Charm Quark through the weak interaction.

LEPTONS

The other type of matter particles are Leptons which are divided into four types:

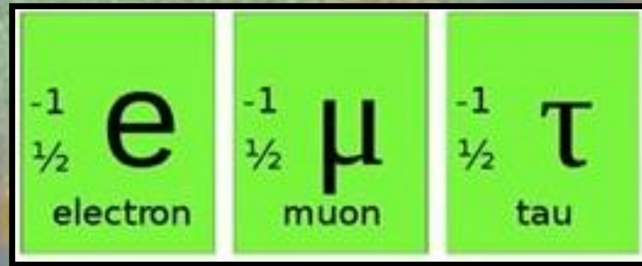
- E particles (or *Electrons*)
- Mu particles (or *Muons*)
- Tau particles (or *Tauons*)
- Three types of *Neutrinos*



- ***LEPTONS DECAY***

  - The Muon and the Tau are not found in ordinary matter at all. This is because when they are produced they decay very quickly, or transform, into lighter Leptons.

  - The Electrons and the three kinds of Neutrinos are stable particles and so they don't decay.



- They belong to three different generations and they interact with:

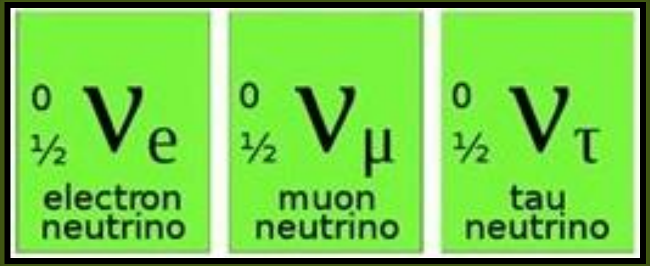
  - Gravitational force
  - Electromagnetic force
  - Weak force

Electron: It's a foundamental constituent of atoms; it significantly characterizes their nature and it determines their Chemical Properties.

Muon: Similar to the Electron, they often join as a group causing the birth of Muonic Atoms.

Tauon: It's very similar to the Electron but it doesn't generate atoms.

NEUTRINOS



They are on their turn divided into three types, each one associated with the other Leptons, according to the outline below

Electron (*e*) ……………. *Electronic Neutrino* (v_e)

Muon (μ) ……………… *Muonic Neutrino* (v_μ)

Tauon (τ) ………………. *Tauonic Neutrino* (v_τ)

- Neutrinos have no electrical charge, very little mass, and they are very hard to find.
- They interact only with Weak and Gravitational force.

BOSONS

All composite particles that contain an even number of fermions are bosons.

- Gauge Bosons are the particles which conduct the four forces.

They are:

Photon

W ± Boson

Z Boson

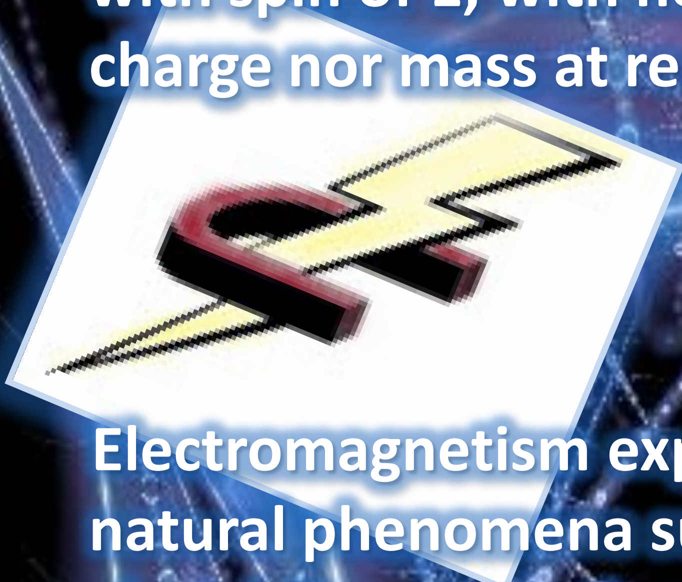
(+ Higgs Boson (recently discovered))

(+ Graviton (only supposed))

We can find Bosons only in groups!

ELECTROMAGNETISM & GRAVITY

The electromagnetism is carried by Photons, Bosons with spin of 1, with neither charge nor mass at rest.



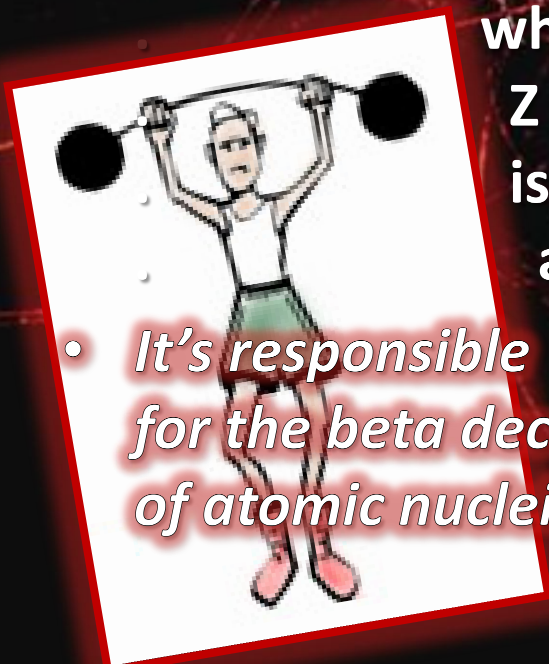
Electromagnetism explains natural phenomena such as electricity, magnetism and light.

It is the unification of two different forces: the electric one and the magnetic one.

The gravity is carried, according to some theories, by Gravitons, Bosons with a spin of 2, with no charge and no mass at rest. However their existence is only a theory.

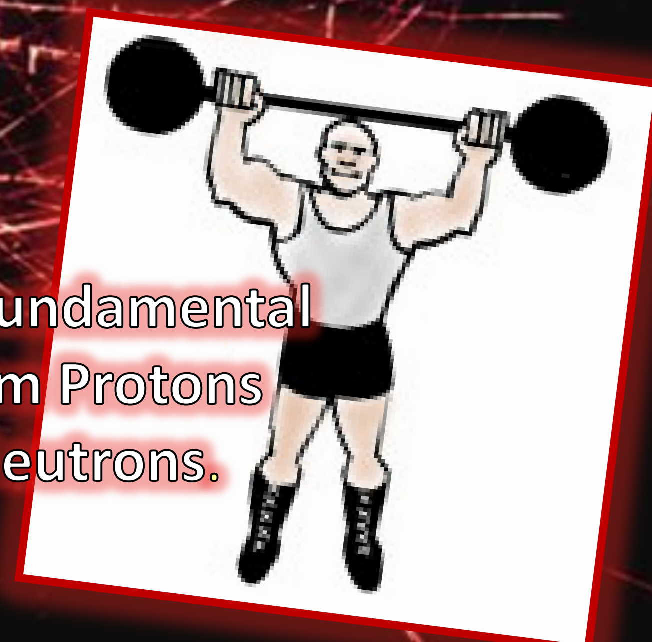
WEAK & STRONG NUCLEAR FORCES

The weak nuclear force is carried by W+, W- and Z Bosons with a spin of 1, the charge of which is +1 or -1 for the W Bosons, while the Z Boson is without any charge.



- *It's responsible for the beta decay of atomic nuclei.*

The strong nuclear force is carried by the Gluons, Bosons with a spin of 1, with neither electric charge nor mass at rest.



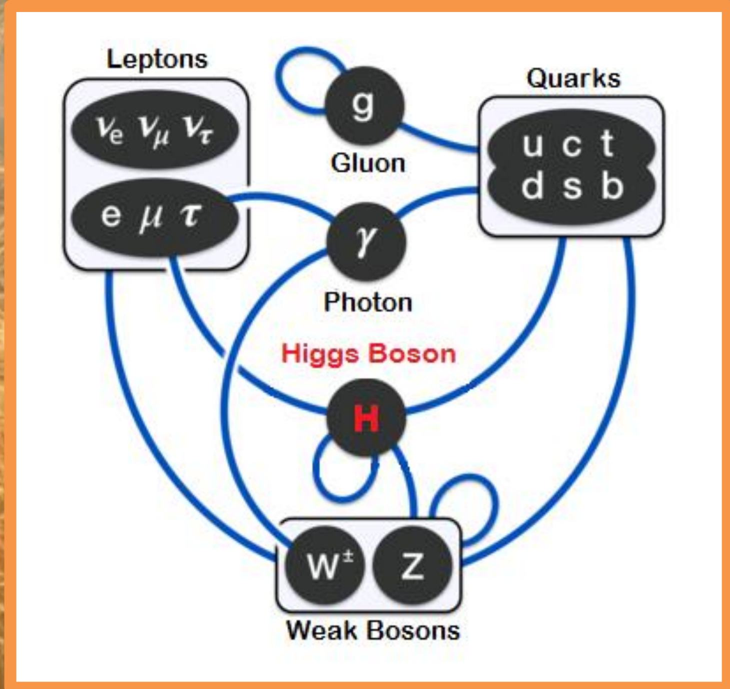
- It's foundamental to form Protons and Neutrons.

THE HIGGS BOSON

Higgs Boson is an elementary, massive and scalar Boson which physicists have recently discovered.

It plays a key role in Standard Model because scientists attribute to it the

. *ability to give the mass to all the particles.*



EXERCISES

1) OPEN QUESTIONS

-What are the fermions and how are the classified in the Standard Model theory?

-How many pairs of quarks can you identify?

-Could you describe the main features of the quark pairs?

-How many fundamental forces does the Standard Model theory identify?

-Which are the fundamental forces?

2) TRUE OR FALSE?

-The quarks do not satisfy the Pauli's principle of exclusion. T F

-The UP and DOWN quarks have got an antiparticle with equal and opposite electrical charge. T F

-Electrons can be combined into more complex particles. T F

-Muons belong to the second generation of particles according to the Standard Model theory. T F

-The existence of a particle associated to gravity force (graviton) has not yet been demonstrated. T F

3) MULTIPLE CHOICE

-The quarks own a spin of:

- 2/3
- 3/4
- 1/2

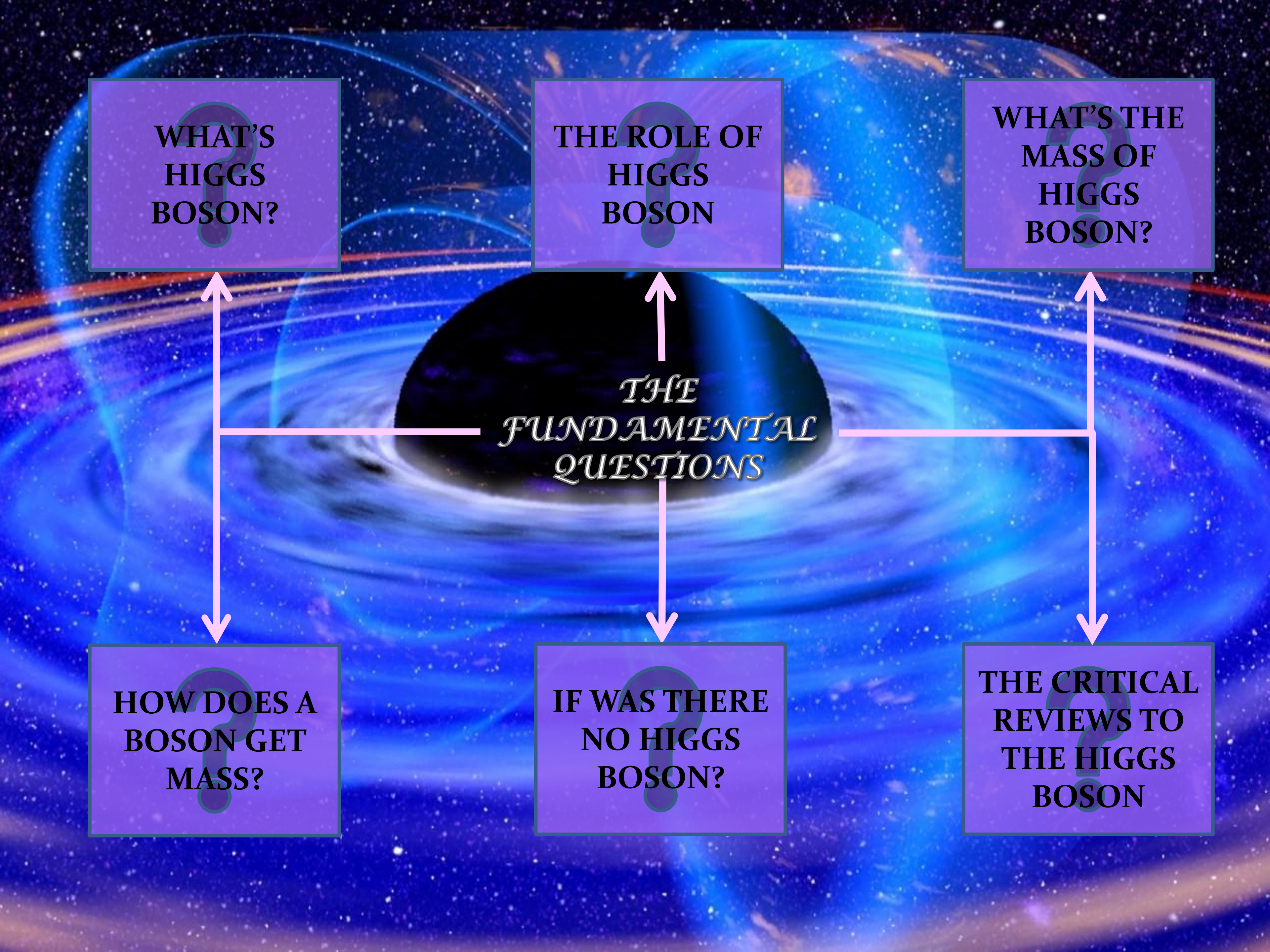
-Which of this particles do not belong to the leptons?:

- Electron
- Photon
- Muon

-Which of these particles has not electrical charge?:

- Muon
- Neutrino
- Tau Particle


HIGGS
BOSON

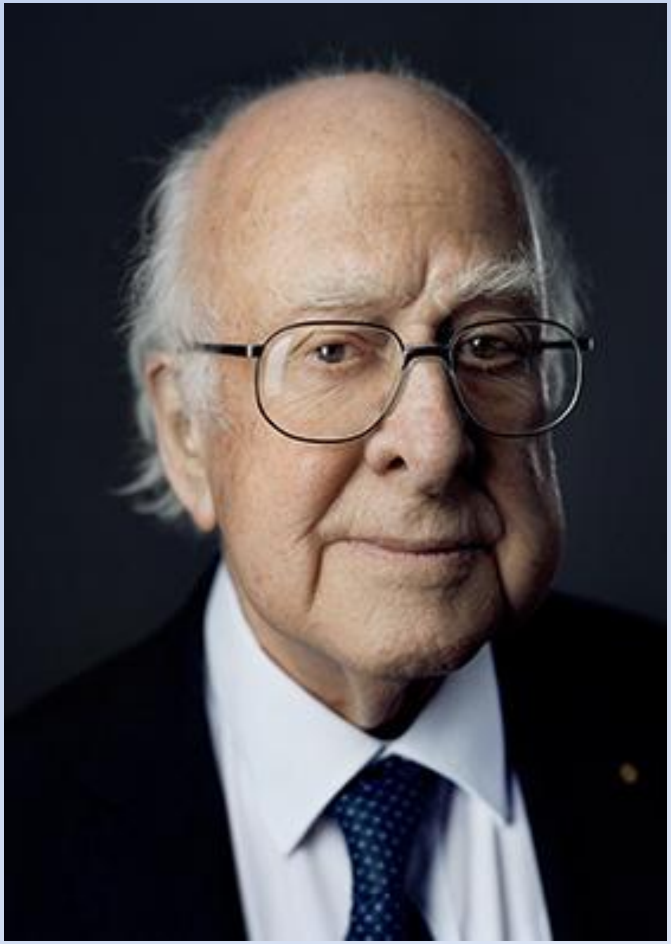

THE FUNDAMENTAL QUESTIONS
WHAT'S HIGGS BOSON?
THE ROLE OF HIGGS BOSON
WHAT'S THE MASS OF HIGGS BOSON?
HOW DOES A BOSON GET MASS?
IF WAS THERE NO HIGGS BOSON?
THE CRITICAL REVIEWS TO THE HIGGS BOSON

WHAT'S HIGGS BOSON?

It was theorized in 1964 by Peter Higgs who realized that, in analogy with other quantum fields, there would be a particle associated with this new field.
It would have intrinsic spin of zero and therefore would be a boson, a particle with integer spin (unlike fermions, which have half-integer spin), and indeed which soon became known as the Higgs boson.
This particle was identified in L.H.C. (Large Hadron Collider) laboratories only in 2012.
It is known as the "God particle".

PETER HIGGS

Peter Ware Higgs was born on the 29th May in 1929 in Newcastle and he is a British theoretical physicist.
He has spent all his life to study and to understand the origin of mass of particles.
While he was walking along the Scottish hills, in 1964, he had the eureka moment and he formulated the theory of the" Higgs Mechanism".
Even if in 1964 scientists were not able to identified this particle in laboratories, this model helped physicists of CERN to discover it in the LHC in 2012.
On the 8th October in 2013, it was announced that Peter Higgs and François Englert would share the 2013 Nobel Prize in Physics.
He is also a member of the Royal Society, or rather the English national academy of sciences.



THE GOD PARTICLE

Higgs boson is known as the “God particle”, this name was coined in a physics book that explains the functions of Higgs boson (written by Leon Lederman).
This name derives by a changing from the name of “Goddamn particle”, due to the difficulty to find this particle.
In Italian we have reinterpreted and translated this statement with “La particella di Dio” (that is “God’s particle”), while in “God particle”, God is simply a quality of the particle (that is “La particella divina”).
Higgs doesn’t share this expression because he believes that it affects the religious creed.

THE ROLE OF HIGGS BOSON

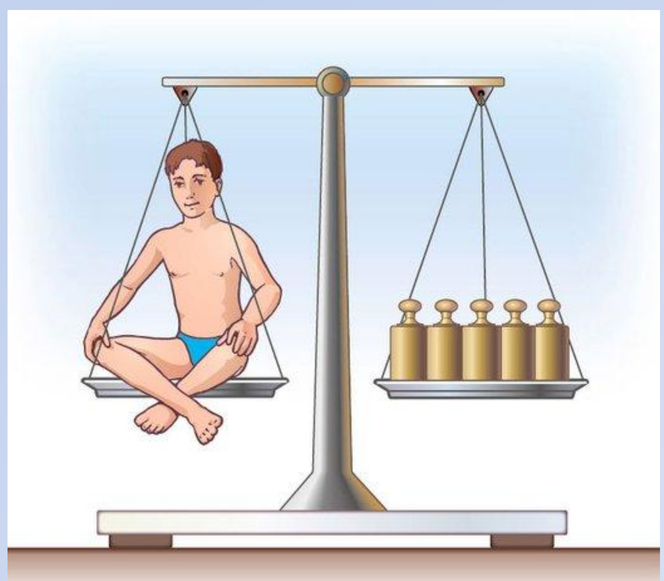
Higgs boson has been the last particle of the Standard Model to be discovered and it is the particle that completes this model.
This particle creates mass: this is the evidence of one of the fundamental rules of physics (all particles have a mass).

As the last tile of a puzzle that completes it.

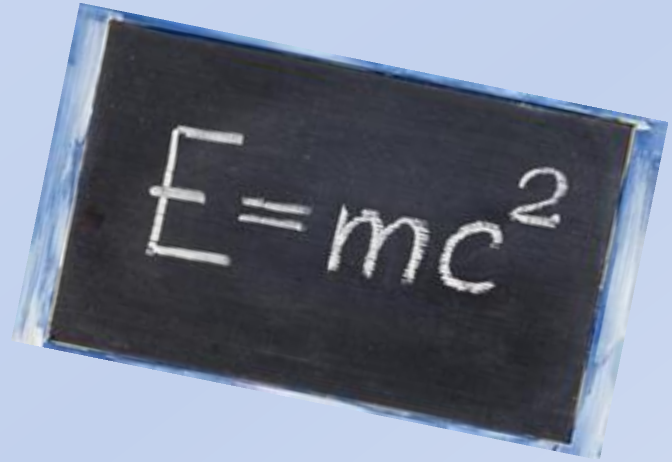
WHAT'S THE MASS OF HIGGS BOSON?

The theory that predicted its existence did not specify the mass of Higgs boson.
But thanks to the L.H.C., we can say that [illegible]on has a mass greater than about 115 GeV/c^2

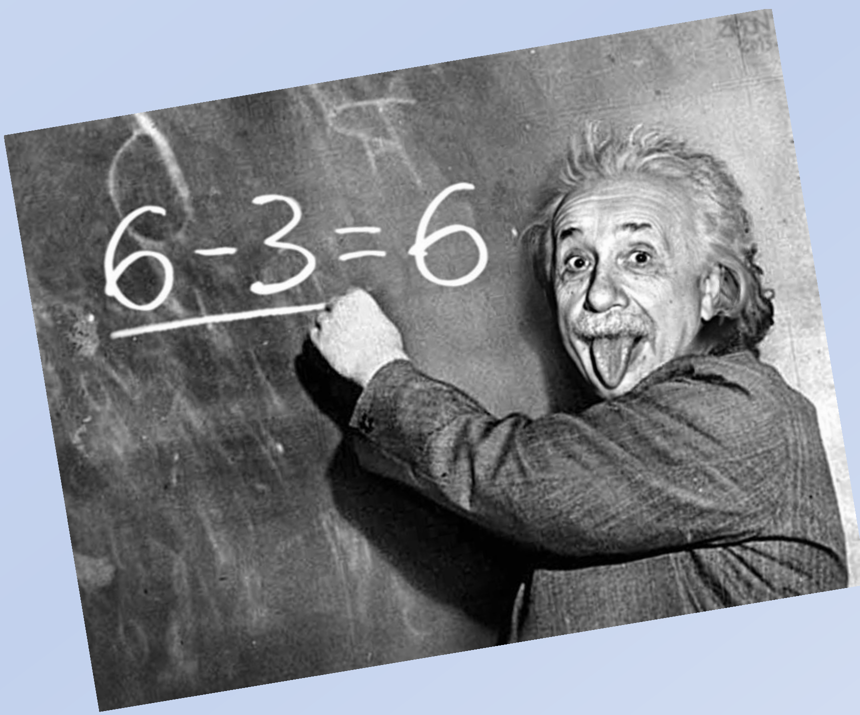
WHAT'S THIS?



$E = mc^2$



IT IMPLIES…



$$1eV / c^2 = 1{,}8 \times 10^{-36}\,kg$$

How does a boson get mass?

Imagine that a cocktail party full of physicists chattering quietly is like a space filled with the Higgs field...

Before walking into the room, Professor Higgs was able to move freely. But after entering the room full of physicists, his speed is reduced.

At some point, Peter Higgs walks in, creating a disturbance as he moves across the room and attracts a cluster of admirers...

The cluster of admirers makes him harder to move around; in other words, he is acquiring mass. This is similar to a massless particle acquiring mass by interacting with the Higgs field.

IF WAS THERE NO HIGGS BOSON?

If there was no Higgs boson, what would the universe be like?
It is not so obvious.
Without it, all the particles would be massless and they would move away at the speed of light, so we couldn’t exist!
The one thing we can be sure of, is that it would be a cold, dark, lifeless universe.
Therefore, the world without the Higgs boson is unbelievable.

THE CRITICAL REVIEWS TO THE HIGGS BOSON

The physicist Vlatko Vedral has advanced the hypothesis that the origin of the mass of the particles does not necessarily have to be caused by the Higgs boson, so he rejects its existence.

The models, which reject the existence of the Higgs mechanism, are known as Higgsless model.

In physics, the Higgsless models are those models that do not require Higgsbosons for the formation of particle mass.

FOUR BIG QUESTIONS

1) Why did it take a long time to discover it?

The Higgs boson ... in nature but you ... artificially in the ... this process ... needed ... long.

2) What does this discovery imply?

"When you reach the top of the hill, there would ... reach." ... Piero Angela, ... This does not mean this ... discovery did not make a breakthrough in the scientific field, however the path is still long.

3) And If we wrong?

"It would be fantastic ... it will be one of the ... situation in science ... we need to ... we haven't understand ...

-Alvaro de Rùjula

4) Why do we have to study these particles?

... really want to understand the origin of the Universe ... big size ... particles, ... that you ... now, because they disintegrated completely, ... the origin of the Universe."

Connect these words with their definition.

A) GeV/c^2

B)A MISTAKE

C)THE GODDAMN PARTICLE

D)HIGGSLESS MODELS

E)HIGGS BOSON

1)A particle which creates mass.

2)Models that reject the existence of the Higgs boson.

3)How we measure the mass of the Higgs boson.

4)A particle very difficult to find.

5)The possible beginning of a scientific revolution.

Choose the correct or best answer.

1) Why did it take a long time to discover it?

a.Because these particles are microscopic.
Because we need a lot of energy.
c.Because it's a long procedure.

2) What does this discovery imply?

Some discovers, but we have to study more.
b.Nothing.
c.We have discovered all, the research is finished.

3) And if we were wrong?

a.It would be a big disaster.
b.We would restart from zero.
.It would be the prelude of a big discovery.

1. Write the missing words in each group (Vlatko Vedral/Higgsless models/Attraction of people/Higgs Mechanism/Mass creation/Dark universe/God particle/How does a boson give mass/Massless particles/Nobel Prize)

Refusal of the existence of the Higgs boson	
Justifications alternative	

Integer spin	
	Higgs boson
Microscopic particle	

Cold universe	No Higgs boson
Lifeless universe	
Unbelievable world	

29th May, 1929	
	Peter Higgs

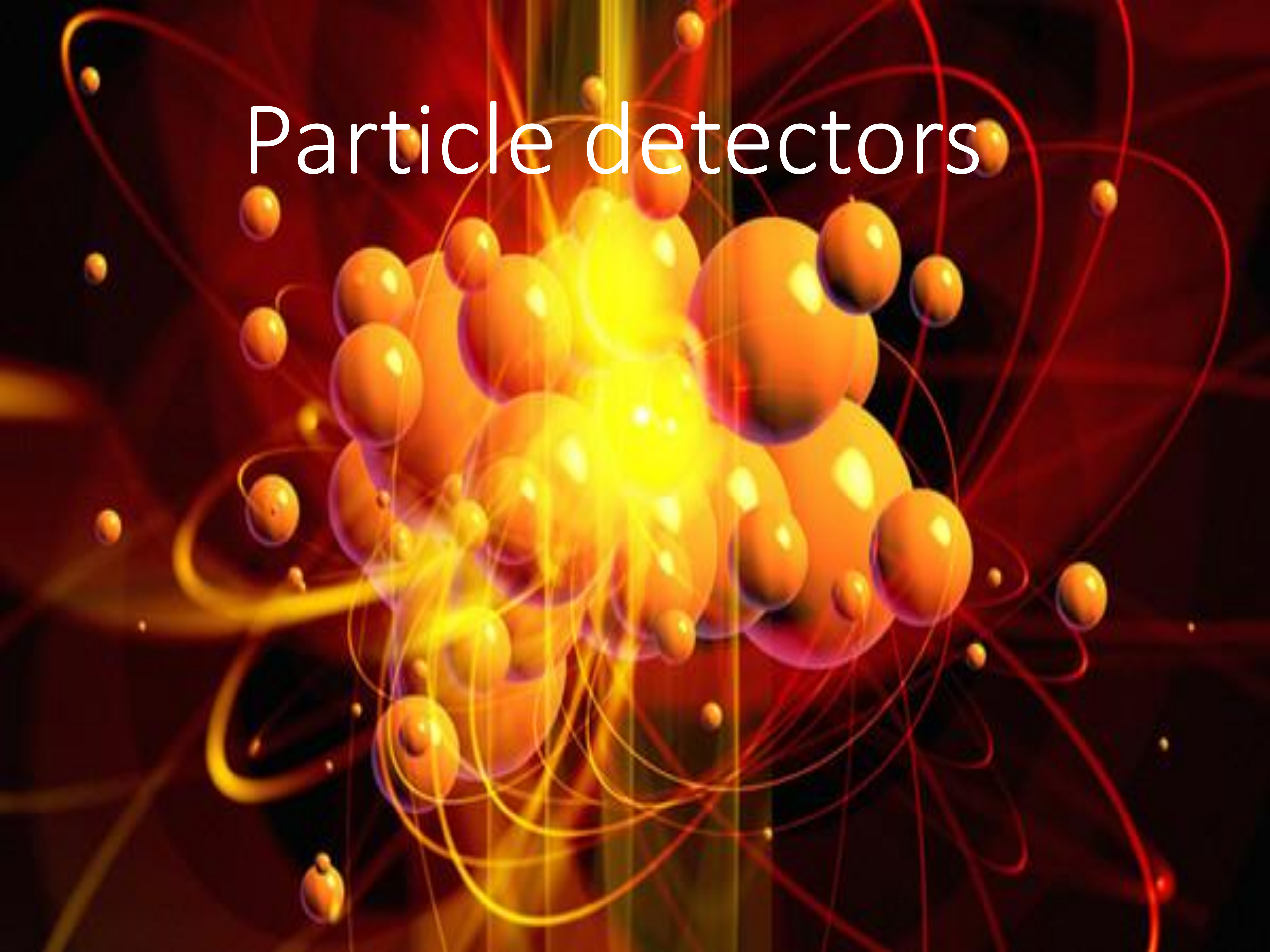
Party full of people	
Entry of Peter Higgs	
Acquisition of mass	

Last particle of S.M.	
	The role

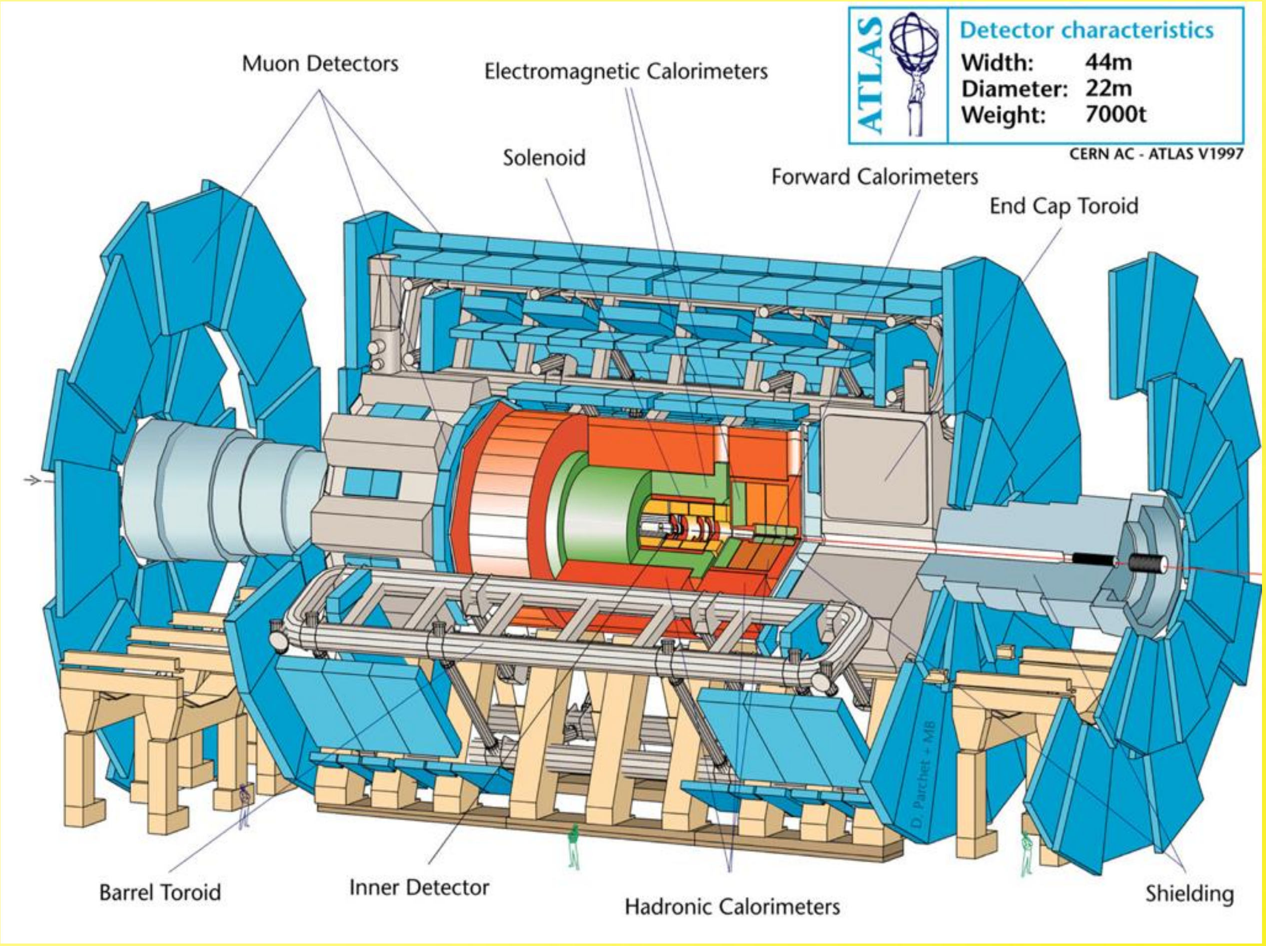
- PARTICLE DETECTORS

- HOW TO BUILD A HOMEMADE CLOUD CHAMBER

Particle detectors



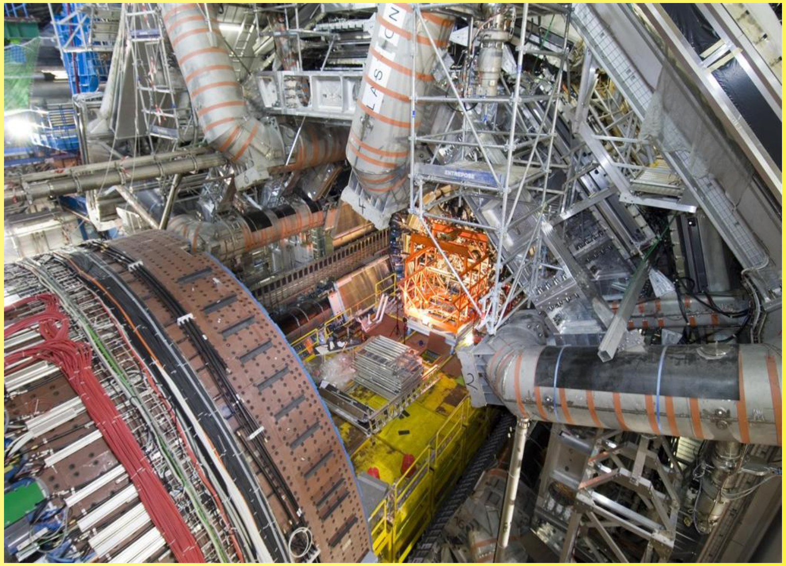
In experimental and applied particle physics, nuclear physics**,** and nuclear engineering, a **particle detector,** also known as a radiation detector, is a device used to **detect**, **track**, and/or **identify high-energy particles**, such as those produced by nuclear decay, **cosmic radiation**, or reactions in a **particle accelerator**. Modern detectors are also used as calorimeters to measure the energy of the detected radiation. They may also be used to measure other attributes such as momentum, spin, charge etc. of the particles.



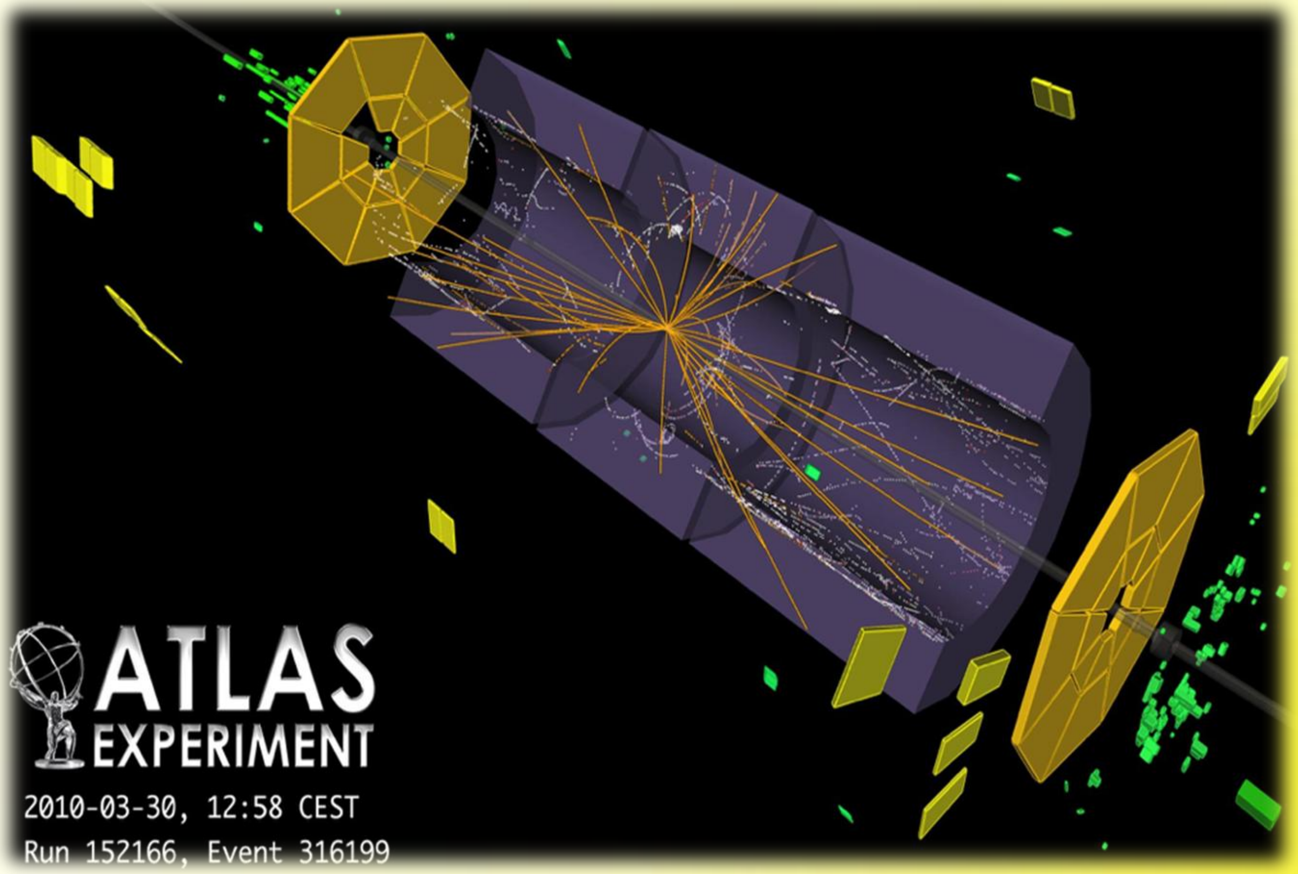
ATLAS (A Toroidal LHC Apparatus) is one of the seven particle detector experiments (ALICE, ATLAS, CMS, TOTEM, LHCb, LHCf and MoEDAL) constructed at the **Large Hadron Collider (LHC),** a particle accelerator at CERN (the European Organization for Nuclear Research) in Switzerland. The experiment is designed to take advantage of the unprecedented energy available at the LHC and observe phenomena that involve **highly massive particles** which were not observable using earlier lower-energy accelerators. It might shed light on new theories of particle physics beyond the **Standard Model**.

ATLAS may also provide the answer for the misterious dark matter and dark energy of the universe and look for extra dimensions of spacetime.

ATLAS is 46 metres long, 25 metres in diameter, and it weighs about 7,000 tonnes; it contains about 3000 km of cable. The experiment is a collaboration involving roughly 3,000 physicists from over 175 institutions in 38 countries. It was one of the two LHC experiments involved in the discovery of the **Higgs boson** in July 2012.



ATLAS detector is designed as a general guideline. When the two beams of protons accelerated by the Large Hadron Collider interact at the center of the detector, **a great variety of different particles** can be produced, in a large energy range. More than focusing on a particular physical process, ATLAS is designed to **measure the widest possible range of signals**. This is to ensure that, whatever **physical characteristics** a new process or a new particle can have, ATLAS is able to reveal and measure their properties. Some experiments at accelerators of past years, such as the Tevatron and the Large Electron-Positron Collider (LEP), were based on a similar philosophy. However, the challenge of the Large Hadron Collider (its unprecedented energy and the high number of events) falls on ATLAS, more than any detector ever built.

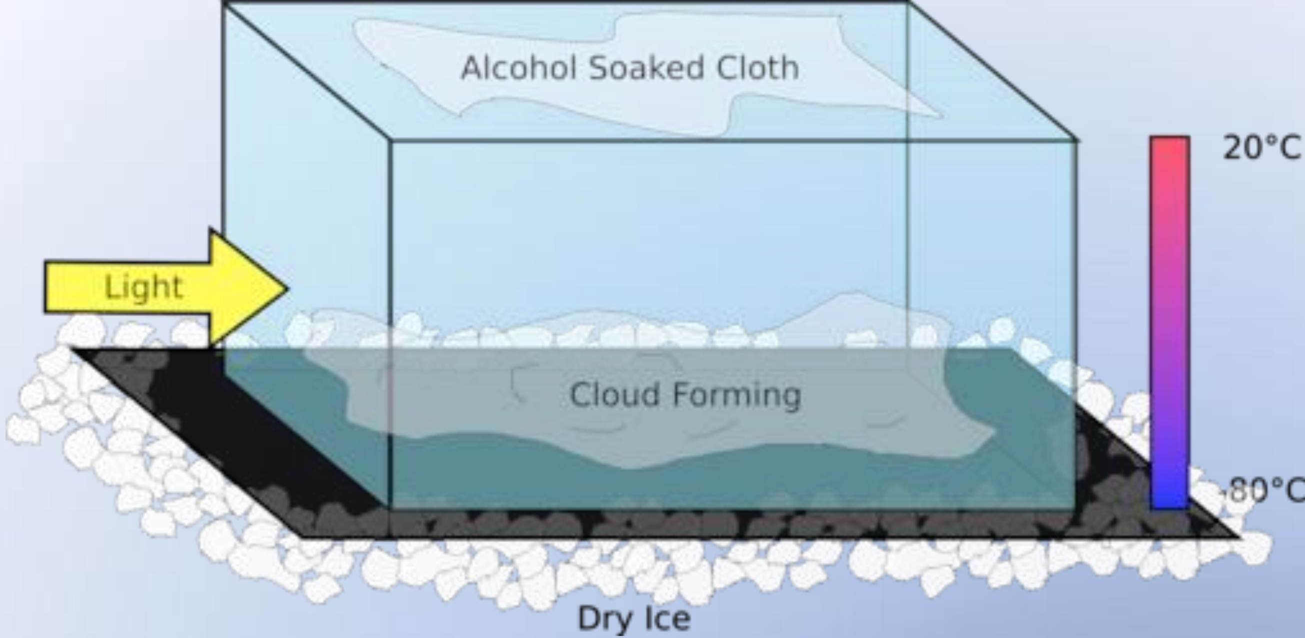


Cloud Chamber

- How does a cloud chamber work?
- How can we build a cloud chamber?
- What can we see?

How does a cloud chamber work?

The cloud chamber, is a particle detector used for **detecting ionizing radiation**. In its most basic form, a cloud chamber is a **sealed environment** containing a **supersaturated** vapor of alcohol. Lightweight isopropyl alcohol vapour saturates the chamber. The result is cloud formation, seen in the cloud chamber by the presence of **droplets falling down** to the condenser. When a **charged particle** (for example, an alpha or beta particle) interacts with the mixture, the fluid is **ionized,** and the particle leave **ionization trail**s because the alcohol vapour is supersaturated. These tracks have distinctive shapes.



Just above the cold condenser plate there is an area of the chamber which **is sensitive to radioactive tracks**. At this height, most of the alcohol has not condensed. This means that the ion trail left by the radioactive particles provides an optimal trigger for condensation and cloud formation. This sensitive area is increased in height by employing a **steep temperature gradient and very stable conditions**. Before tracks can be visible, a **tangential light** source is needed. This illuminates the white droplets against the black background. The black background makes it easier to observe cloud tracks. Drops should be viewed from a horizontal position. If the chamber is working correctly, tiny droplets should be seen condensing. Often this condensation is not apparent until a shallow pool of alcohol is formed at the condenser plate. **The tracks become much more obvious once temperatures and conditions have stabilized in the chamber**. This requires the elimination of any significant drift currents (poor chamber sealing).

How can we build a cloud chamber?

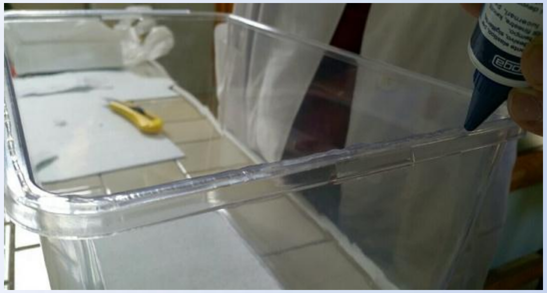
After discovering how a cloud chamber works, we can think of building one by ourselves.

The process is very simple and the necessary objects are easily available.

We need:

- Dry ice (solid carbon dioxide -79.5 ° C)
- Plastic or glass bowl
- Felt
- Black metal plate of the size of the tray
- Polystyrene tray
- Resistant sealant at low temperatures
- Isopropyl alcohol
- Pipettes
- Two lamps of white light

First of all we have to make four holes on the upper surface , to cut the felt and to paste it inside the tray with the **sealant**.

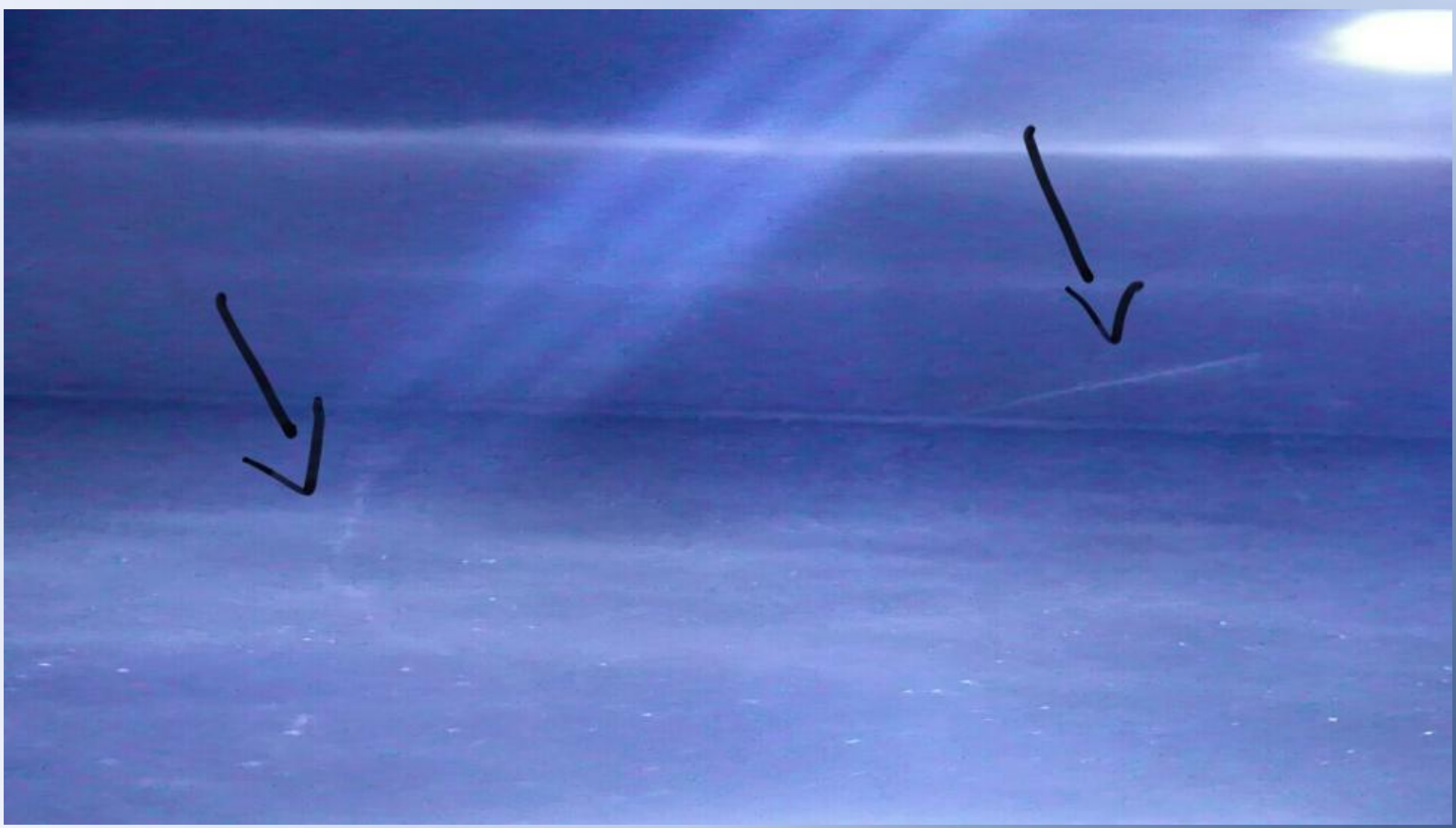


Then we have to paste the **plastic bowl** with the **black metal plate**.

Finally we can put the **chamber** over the **polystyrene tray**, already filled with **dry ice**, and fill the stripe of felt with **alcohol** through the holes made earlier.

What can we see?

We can see two different types of tracks.



Alpha particle's track is broad and shows more evidence of deflection by collisions.

While a muon's one is thinner and straight

Exercises

Title of video: NASA telescopediscovers the origin of cosmicrays
(https://www.youtube.com/watch?v=N1CxA7r-4oc)

Rearrange the sentences byinserting the right number from 1 to 10.
Then complete the gaps with the suitablewords, from the list below.

[ ]Confined by a magneticfield, high-energyparticlesmovearoundrandomly. Sometimesthey cross the ……………….wave.

[ ]Explodingstars and theirremnantshave long beensuspected of producingcosmicrays, some of the…….……….matter in the universe.

[ ]Cosmisrays………………..do so whenthey'redeflected by passingnearnucleus of an atom.

[ ]The interaction of high-energyparticles with light and ……………matter can produce gamma rays, the most……………….form of light.

[ ]Acceleratedprotonsmay collide with an ordinaryproton and produce a …………………….particlecalled a ………………….pion. Thesepionsquicklydacayinto a pair of gamma rays.

[ ]Afterdozens ofhundreds of crossings, the particleismovingnear the speed of light and isfinallyable to …………….. .

[ ]Becausecosmicrayscarry………………….. charge, theirdirectionchangesastheytravelthroughmagneticfieds.

[ ]With each round trip, they gain about 1 percent of their…………… energy.

[ ]If the supernova remnantresidesnear a dense …………………….. cloud,some of thoseescapingcosmicraysmay strike the gas, and produce gamma rays.

[ ]Where and howtheseprotons, electrons and atomic nuclei are ………………..to such high speedshasbeenenduring mystery.

fastest	**boosted**	**ordinary**	**escape**	**short-lived**	**neutral**
shock	**powerful**	**electric**	**molecular**	**original**	**electrons**

Solutions

Correctorder: **5,1,9,4,10,7,3,6,8,2.**

1.Explodingstars and theirremnantshave long beensuspected of producingcosmicrays, some of the **fastest**matter in the universe.

2.Where and howtheseprotons, electrons and atomic nuclei are **boosted** to such high speedshasbeenenduring mystery.

3.Becausecosmicrayscarry**electric**charge, theirdirectionchangesastheytravelthroughmagneticfieds.

4.The interaction of high-energyparticles with light and **ordinary**matter can produce gamma rays, the most**powerful**form of light.

5.Confined by a magneticfield, high-energyparticlesmovearoundrandomly. Sometimesthey cross the **shock**wave.

6.With each round trip, they gain about 1 percent of their**original**energy.

7.Afterdozens ofhundreds of crossings, the particleismovingnear the speed of light and isfinallyable to **escape**.

8.If the supernova remnantresidesnear a dense **molecular**cloud,some of thoseescapingcosmicraysmay strike the gas, and produce gamma rays.

9.Cosmisrays**electrons** do so whenthey’redeflected by passingnearnucleus of an atom.

10.Acceleratedprotonsmay collide with an ordinaryproton and produce a **short-lived**particlecalled a **neutral**pion. Thesepionsquicklydacayinto a pair of gamma rays.

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