FRONTIERS

Bringing Nobel Prize Physics in the Classroom

Discover particles with a cloud chamber

DCU ELLINOGERMANIKI AGOGI NUCLIO EGO EUROPEAN GRAVITATIONAL OBSERVATORY IASA Paris Centre for Cosmological Physics Co-funded by the Erasmus+ Programme of the European Union léargas

Astroparticles group B

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Contextualization

4 secondary physics teacher

3 already mount a cloud chamber with advance students

4 teachers interested in modern physics

4 teachers working in Inquiry based learning

In particle physics, very large detectors are used to study elementary particles. Particles such as protons are accelerated in a particle accelerator, and made to collide with each other. The detectors record these collisions, which release a lot of energy to create new particles according to Einstein’s $E=mc^2$. In a way, detectors are microscopes; the smaller the details researchers want to see, the larger the microscope and its lenses need to be. Various detectors have been built, for example at CERN, DESY and Fermilab.

Astroparticle physics combines physics and astronomy. In the cosmos, huge matter bursts, together with very strong magnetic fields create what can be considered a ‘natural’ particle accelerator. To perform astrophysics research, observing particles, scientists ‘just’ need to build the right detectors.

So let´s build cloud chambers.

Plus,

- Test different sources of radiation: natural and artificial,
- Use the cloud chambers in different geographic locals (at different altitudes, latitudes and longitudes).

Background information for teachers

Interesting links / sources

https://scoollab.web.cern.ch/cloud-chamber

http://microcosm.web.cern.ch/en/cloud-chamber-video#overlay-context=en/cloud-chamber

http://inspiringscience.rdea.gr/delivery/view/index.html?id=d9d4548e86fc449699bbd42ada36377f&t=p

http://inspiringscience.rdea.gr/delivery/view/index.html?id=228690c20d7141fc9ecfe69221302584&t=p

https://www.scienceinschool.org/2010/issue14/cloud

https://www.scienceinschool.org/2010/issue14/radon

Overview of this lesson pack:

Name of the activity	Astroparticles detector
Topics introduced	Constitution of the atom, elementary particles, astroparticles, cosmic rays, natural and artificial sources of radiation, radioactive decay.
Curriculum Connection	**PORTUGAL**: 10th grade- Unit 1.1 - Mass and atomic size 12th grade -Unit 3.2 - Introduction to quantum physics; Unit 3.3 - Atomic nucleus and radioactivity **FRANCE**: radioactivity 10th grade: conservation of mass and charges 11th grade: nucleosynthesis, fission, fusion, half-live 12th grade optional: (N,Z) diagram; alpha, beta, gamma radiations ; exponential decay **ITALY:** 10th grade: Astronomy, Kinematics 12th grade: Thermodynamics, conservation of mass and charges. 13th grade (Italy has 5 upper secondary grades): Astronomy, Radioactive decay, Nuclear forces, The Atom, Lorentz Force between charged particles and magnetic fields, Energy.
Reference Demonstrator	*Build your own Cloud Chamber* and *Measuring Particle Properties with a Virtual Cloud Chamber*
Age of students	14-18
Duration	4 hours: 1 hour preparation, 1 hour pre-lab discussion (what do you expect?), 1 hour lab observation, 1 hour post-lab discussion (what you saw matches what you expected?)

Overview of this lesson pack:

Type of activity	This activity is divided into three parts: theory (pre lab), practice (lab) and pos lab. The theory component will be to make an introduction to the subject and, at the end, the discussion of the results; the practical component is build the cloud chamber and the observation. The lab activity consists in the preparation of the needed material, in 2 periods, discussions amongst pupils, in the experiment observation. It allows to see traces of particles coming from the outer space (Galactic Cosmic Rays, GCR), or from the Earth (natural background radioactivity, less likely), or even from artificial sources (thoriated tungsten welding rods are an off-the-shelf technology).
Description of activity	Teacher activities: ● Diagnosis the basic knowledge ● Choose how guided the question for the pupils should be ● Form groups ● Explain the lab activity, ● Build the chamber, ● Help the students to understand what they see ● Apply quizzes to evaluate knowledge Student activities: ● Answer quizzes ● Research about radioactivity, particle detection ● (Build the chamber- for advanced students) ● Observe and register data/observations in spreadsheet created by them ● Classify the tracks ● Create a short report or scientific poster (or article)

Overview of this lesson pack:

Equipment requirements	Normal classroom, computer, video projector, smartphones and students Part1 - Build an Cloud Chamber · Straight-sided, clear plastic or glass container (e.g. a fish tank) with a base about 30 cm x 20 cm, and a height around 20 cm (other sizes can be used, but the effects may vary) · Aluminium sheet (about 1 mm thick, same thickness as the base of the fish tank) · Shallow tray somewhat larger than the base area of the fish tank · Two lamps, one of them strong (not LED lamp) · Strip of felt (about 3 cm wide and long enough to wrap around the inside of the fish tank, e.g. somewhat more than 1 m long) · Glue (not alcohol-soluble) · Black insulating tape or duct tape · Isopropyl alcohol (isopropanol) · Dry ice Part2 - Detect particles 3 smartphone camera plus support Dark room Radioactive sources: Artificial - Tungsten rods with thorium; smoke detector with americium; … Natural - Radon Lab report
Prior knowledge for students	Atom constitution, atomic representation (atomic number and number of mass), the evolution of atomic model. Scales. Type of elementary particles that exist and their origin.

From teacher to teacher:
Working with the Cloud Chamber

What is the activity for? The main objectives

You are about to build a device that will allow you to detect invisible particles. You won't see the particles, you will be able to notice, from time to time, contrails that are traces of their passage inside the box that we're going to assemble, a box named "Cloud Chamber". You will produce kind of a "fog" or "cloud" inside a box, through which the particles will pass and leave traces of their trajectories. The traces will be the only sign witnessing their passage, and they will be visible for a short period of time, but long enough to impress your retina. O be able to spot more traces, you might want to use optical recording device with a suitable frame per second rate (even cameras on board of many smartphones can now offer that frame rate).

From teacher to teacher, experience handed over: what you need (and sometimes you will have to buy or to prepare) in order to assemble the experiment, for any cloud chamber you're going to get (one cloud chamber is suitable for 4 pupils, not more, if you want all of them to work on it and give their active contribution). (1)

- A plastic box, transparent like the ones used in fish tanks, size approximately 50×30 cm the base and 30/40 cm height.
- Adhesive felt, (one side felt, the other sticky material) or normal felt and glue (but this doesn't work as well, the alcohol melts the glue, the felt could fall if the glue quantity is too much or too little); buy possibly a bolt of felt, it will be used to line the plastic transparent box.

Adhesive felt

- Approximately 3kg dry ice (solid CO_2). Please be sure that your school can handle it and keep it cold, otherwise you will have to purchase it maximum a couple of days before.
- 2 metal trays, metal plates or whatever metal flat surface that can host the plastic tank base on top of it; it must be a good heat conductor to exchange heat from the warm and the cold source, and allow to have one low temperature below and one high temperature above the fish-tank.
- A polystyrene box or other thermal insulating material box, where you will put the dry ice.
- A hot water container.

From teacher to teacher, experience handed over: what you need (and sometimes you will have to buy or to prepare) in order to assemble the experiment, for any cloud chamber you're going to get (one cloud chamber is suitable for 4 pupils, not more, if you want all of them to work on it and give their active contribution). (2)

One torch, or one mobile neon, or one led stripe, with white light.

A bottle of alcohol (ethanol, common alcohol, will be good, if you find isopropanol 90% (isopropyl) it would be even better because it evaporates more rapidly. The isopropanol is used to clean electronics component, just in case you should need some hints where to find it. For the volume of the plastic box 30 ml alcohol will be enough, you adjust the quantity to the plastic tank volume.

One piece of black paper could be useful to protect from unwanted light or air currents the tank sides.

Adhesive material (putty, adhesive rubber strips)

One pipette

Only if you want to use artificial particle sources to be able to see more particles, instead only galactic particles:

two thoriated tungsten welding rods, two for each plastic tank.

2% thoriated tungsten rods

For everyone's safety before, during and after the lab (1):

<u>Needed devices:</u>

Thermal gloves for the people who will take care of and handle dry ice

Safety glasses for anyone in the lab

Only if you want to use artificial particle sources to be able to see more particles, instead only galactic particles:

The thoriated tungsten rods emit alpha particles, with low penetration, it's not dangerous, but you need to handle them with precautions.

For everyone's safety before, during and after the lab (2):

Behaviour rules:

Keep isopropanol away from fires, it's highly flammable!

Open the windows right after using dry ice, it's CO_2!

Use always thermal gloves when handling dry ice, you can get burns from object at very low temperatures.

Only if you want to use artificial particle sources to be able to see more particles, instead only galactic particles:

If you buy many of these welding rods, you should keep them in a metal box, labelled "radioactive".

You need to dispose of rods that should show signs of consumption. Please warn your pupils to use particular attention when handling these welding rods.

Building the cloud chamber

Using the thermal insulating gloves, put the dry ice in the polystyrene or any other thermally insulated container you're using. Set the metal tray or the metal plate on top of it so that the metal will start to cool down. The metal plate should completely cover the dry ice box. It will be the low temperature source for this experiment.

Put the plastic tank face up, opened and glue the felt pieces to the bottom of the tank or if felt is back-adhesive stick it to the bottom, (actually the bottom will be the upper part during the experiment). You can also cover a small upper part of the lateral surfaces with felt, if you want.

With the pipette pour the alcohol onto the felt (not too much, especially if you used the glue for the felt, but anyway a fair quantity)

Put dark card or the black paper on top of the metallic tray, to get the dark background you need at the bottom of the chamber, to observe what happens.

Turn around the plastic tank or fish-tank, glue it to the metallic tray or plate, and use the black paper or dark card to protect the lower side of the tank from light or air, gluing it to the plate as well, so that the fish-tank is completely sealed.

Place the other metallic plate on top of the fish tank, place the hot water container on top of it. This will be the high temperature source of our experiment.

Operating the cloud chamber

Turn the light off and be sure that all the lab windows are closed, you don’t want external light coming in. We will use only the torches to get light where we want.

Switch on the torch or the light source you choose (neon, etc.) casting the light directly into the plastic tank, our “cloud chamber”, from one lateral side. You might now need to wait a couple of minutes, so that the desired cloud start forming, thanks to the difference from the upper and the lower tray temperatures. The cloud or the fog should be visible near the bottom of the tank. At this point you must look down from above, to the dark background of the bottom tray. You might want to take short films from time to time, of what happens inside the chamber, to get the chance of examining it in detail later.

White trails of different lengths should appear from time to time…

Another cloud chamber version: adding radioactive sources

You might want to increase the chance of spotting the contrails showing particles' passage in your cloud chambers. One solution is given by thoriated tungsten rods. These small rods, used to weld, contain 2% thorium, and have excellent welding performance. This material contains radioactive elements, even below the tolerance thresholds allowed, and must be used with precaution. The thoriated tungsten rods emit alpha particles, that can be detected in the chamber. You are using a sort of artificial particle producers device (a couple for each cloud chamber)

The preparation for the chamber is the same as described above. In this case you just have to attach the rods to the center of the bottom tray, under the black paper. Should you have a third tray you might want to attach the rods to the center of this plate, put it on top of the cold plate, possibly add dry ice onto the bottom plate, cover the new plate with the rods with black paper (it will be the new background for your observation), and then turn around the plastic box and do the following operations as described in the previous paragraph. You should now be able to spot more contrails than the ones observed in the cloud chamber without rods.

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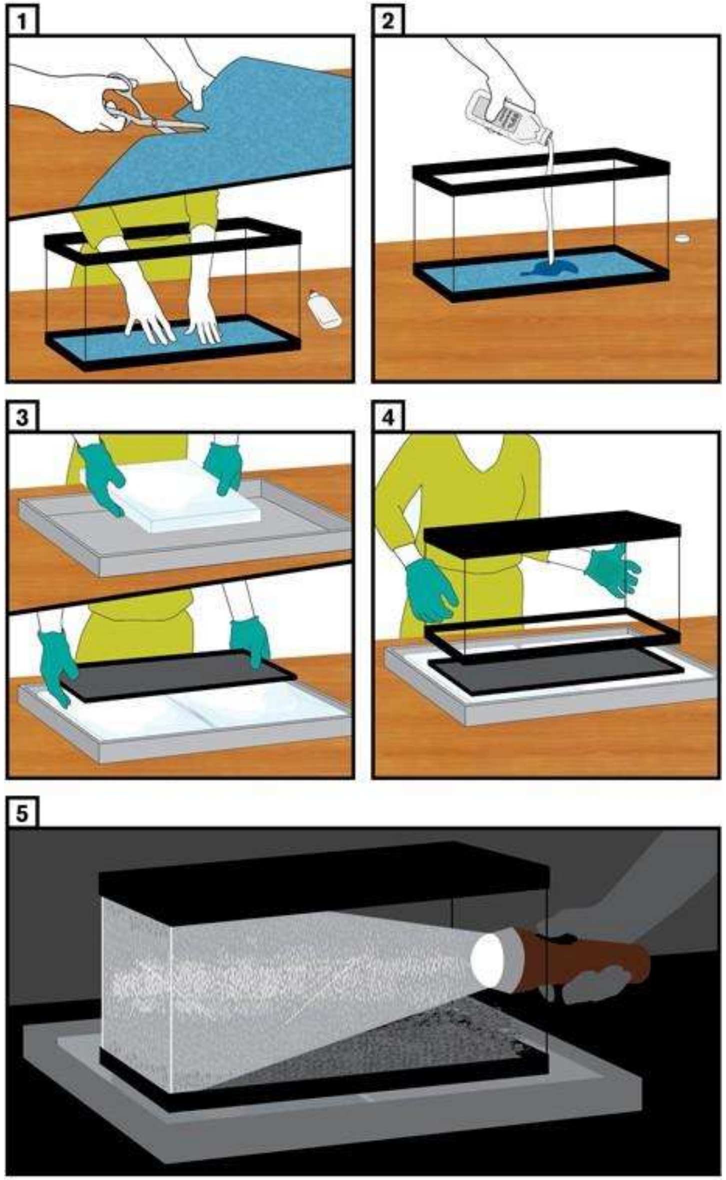
To give you a visual idea



6. Troubleshooting and FAQ

Although cloud chambers are a very reliable research tool, things might not work from the beginning and you might encounter some of the following challenges or questions.

Challenge / Question	Solution
"I don't see any tracks!".	Vary the position of your light source – make sure that the sensitive layer of the detector (approx. 1 cm above the metal plate) is well illuminated. Make sure the dry ice is in good contact with the metal plate. If the dry ice is rather old, scrape off the surface layer of the ice blocks to get rid of water ice which freezes onto the dry ice. Add more isopropanol to make sure the chamber is well saturated. Check that the chamber is airtight; you can use tape or plasticine to seal it.
"I only see mist, and no tracks."	Wait. It takes approx. 5 minutes for the chamber to get to the right temperature. Make sure that you use the right alcohol – other alcohol have different "activation energies" that so that cosmic rays will not be able to start the condensation process.
"I see big clouds at the edges of the chamber."	This probably means you have an air leak. Make sure that the chamber is tightly sealed.
"I can't see tracks because the black metal plate has a cover of snow."	This sometimes happens, if the metal plate is exposed to normal air and dry ice at the same time: The water vapour from the air freezes onto the metal plates procuring a white icing. Start again; make sure to close the chamber as soon as possible e.g. by preparing the felt with isopropanol before you place the metal plate on top of the dry ice.
"I have read that some cloud chambers use high electric fields. Why?"	A strong electric field (approx. 100 V/cm) is often used for professional cloud chambers to pull ion tracks down to the sensitive region of the chamber. As ionising particles pass above the sensitive area of the chamber, they leave an ion trail behind but no condensation start. When pulled down to the supersaturated layer, condensation around the ions starts and droplets can be observed.
"I have learned that magnets deflect electrically charged particles but my fridge magnet has no effect."	To see the curvature of high-energy particles in a magnetic field with your bare eye, you need very strong magnetic field of several Tesla. For example: the bending radius of a high-energy electron ($m_e = 0{,}51 \frac{MeV}{c^2}$) with $E = 1\,GeV$ in a magnetic field of $B = 2\,T$ is $1.7\,m$! $E = \sqrt{m_e^2 \cdot c^4 + p^2 \cdot c^2} \approx p \cdot c$ (*for* $m \ll p$, *highly relativistic particles*) $p \cdot c = e \cdot r \cdot B \cdot c \Leftrightarrow r = \frac{E}{e \cdot B \cdot c} = 1.7\,m$
"What is the squeaking sound when I put the metal plate on top of the dry ice?"	When the metal plate is placed on the dry ice, a strange loud noise is produced. This happens because the dry ice sublimates instantly upon contact with the warm metal plate. The gas bubbles burst because of the pressure by the metal plate – that is causing the noise.

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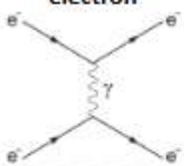
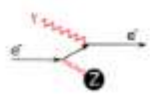
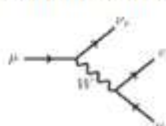
Pictures © Karlsruher Institut für Technologie (KIT)	Particle	Explanation
	**muon or anti-muon**	Thin straight tracks - fast particles with high kinetic energy - they ionise molecules without scattering - high energy muons, electrons or their corresponding anti-particles - source: secondary cosmic particles
	**electron or positron**	
	**α particle system**	Thick straight tracks (approx. 5 cm): - alpha particle systems (2p2n) - massive particle systems with high "ionisation density" (for alpha: 1 MeV/cm) - source: Radon-222 gas, natural radiation
	**electron** 	Curly / curved tracks: - slow electrons scatter with other electrons via electromagnetic interaction - the lower the momentum of a particle, the easier it scatters - Photoelectrons are low energy electrons set free by high energy photons (via Photoelectric effect) - Source: muon transformation, beta emitters, photoelectric effect
	**photoelectron** 	
	**muon transformation** 	Kinks: This could be a muon (or anti-muon) transforming into an electron (or positron), a neutrino and an anti-neutrino.
Y	**electron-muon-**  **scattering**	Y-shape: This could be a muon knocking off an electron (bound to an atom) via electromagnetic scattering.

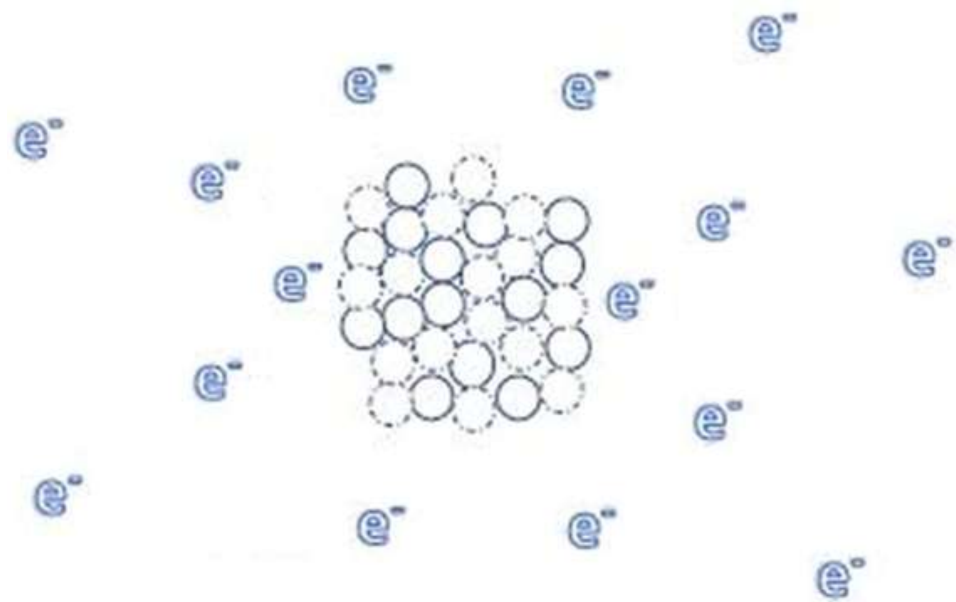
Presentation for students

Teacher guidelines can be found in the notes attached to each slide

Diagnosis-quizz

1. Color the protons RED
2. Color the neutrons BLUE
3. Write a plus (+) in each proton.
4. Color the electrons in the first energy level GREY, the electrons in the second energy level GREEN and in the third energy level BLACK.
5. What atom is featuring above?
6. What is it atomic number?
7. What is it atomic mass?

SCAN ME



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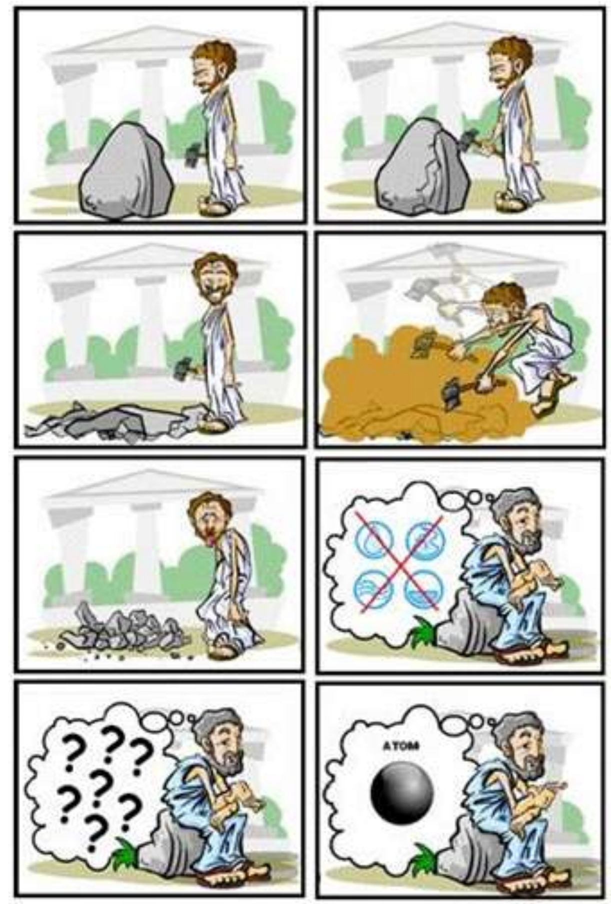
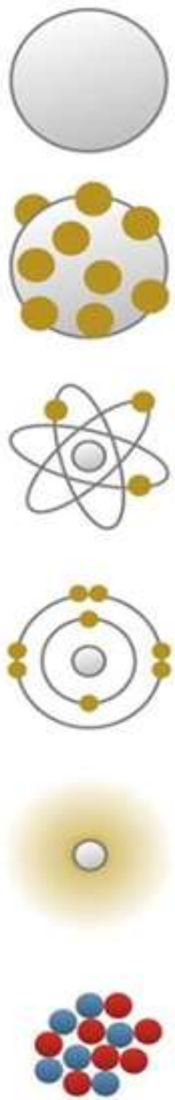
BEYOND SUBATOMIC PARTICLES!

How will consist matter?

The first ones who imagined the existence of atoms were the Greek philosophers Leucippus and Democritus who, around 450 BC, said that everything would be made up of tiny indivisible particles, hence the origin of the name "atom", which comes from Greek.





The evolution of atomic models occurred through technological advances in the 19th century.

Some scientists, such as Thomson, Rutherford and Bohr were able to carry out experimental tests increasingly accurate. With this, not only found that it was actually made up of tiny particles, but it was also possible to understand more and more about the atomic structure.

Scientists were using the information discovered by other scientists, and there as it was making new discoveries, the earlier ideas were replaced by new ones. The concepts that remained were correct, but those who were not proven true passed to be abandoned.

SOLID SPHERE MODEL | **PLUM PUDDING MODEL** | **NUCLEAR MODEL** | **PLANETARY MODEL** | **QUANTUM MODEL**

JOHN DALTON — 1803

Dalton drew upon the Ancient Greek idea of atoms (the word 'atom' comes from the Greek '*atomos*' meaning indivisible). His theory stated that atoms are indivisible, those of a given element are identical, and compounds are combinations of different types of atoms.

J.J. THOMSON — 1904

Thomson discovered electrons (which he called 'corpuscles') in atoms in 1897, for which he won a Nobel Prize. He subsequently produced the 'plum pudding' model of the atom. It shows the atom as composed of electrons scattered throughout a spherical cloud of positive charge.

ERNEST RUTHERFORD — 1911

Rutherford fired positively charged alpha particles at a thin sheet of gold foil. Most passed through with little deflection, but some deflected at large angles. This was only possible if the atom was mostly empty space, with the positive charge concentrated in the centre: the nucleus.

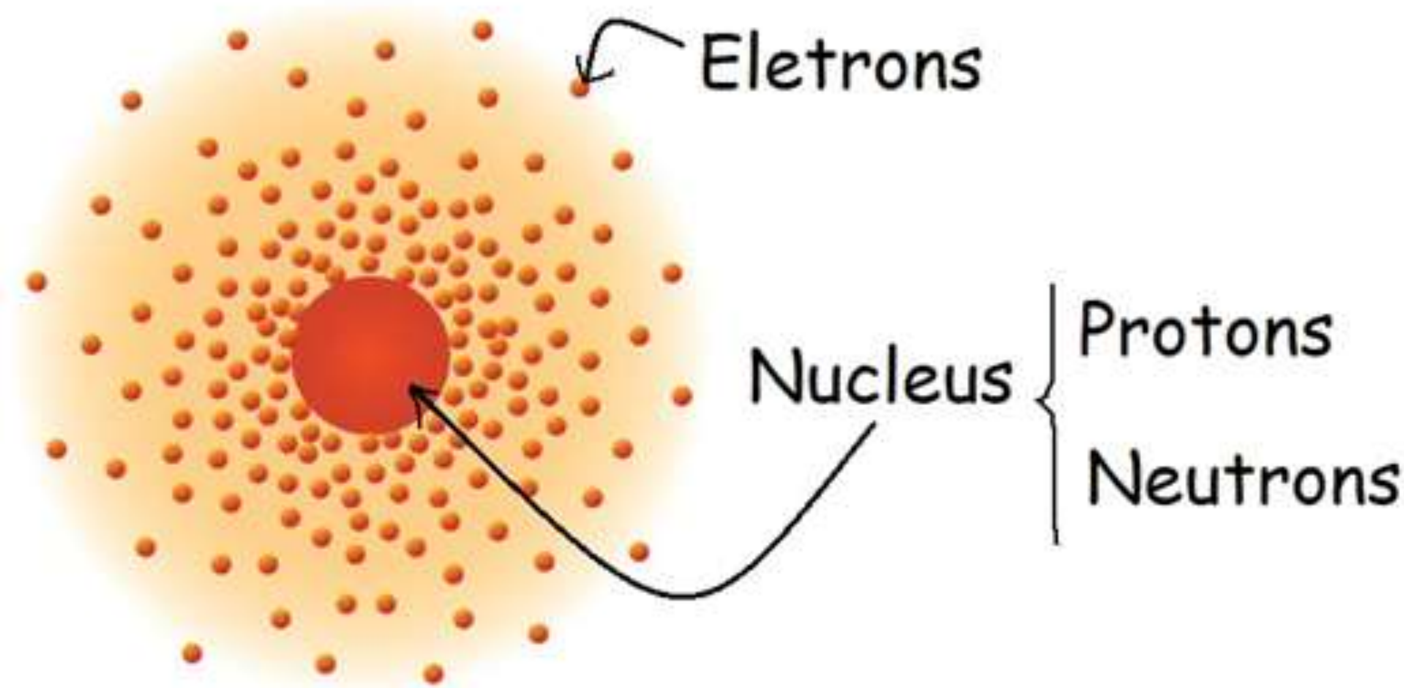
NIELS BOHR — 1913

Bohr modified Rutherford's model of the atom by stating that electrons moved around the nucleus in orbits of fixed sizes and energies. Electron energy in this model was quantised; electrons could not occupy values of energy between the fixed energy levels.

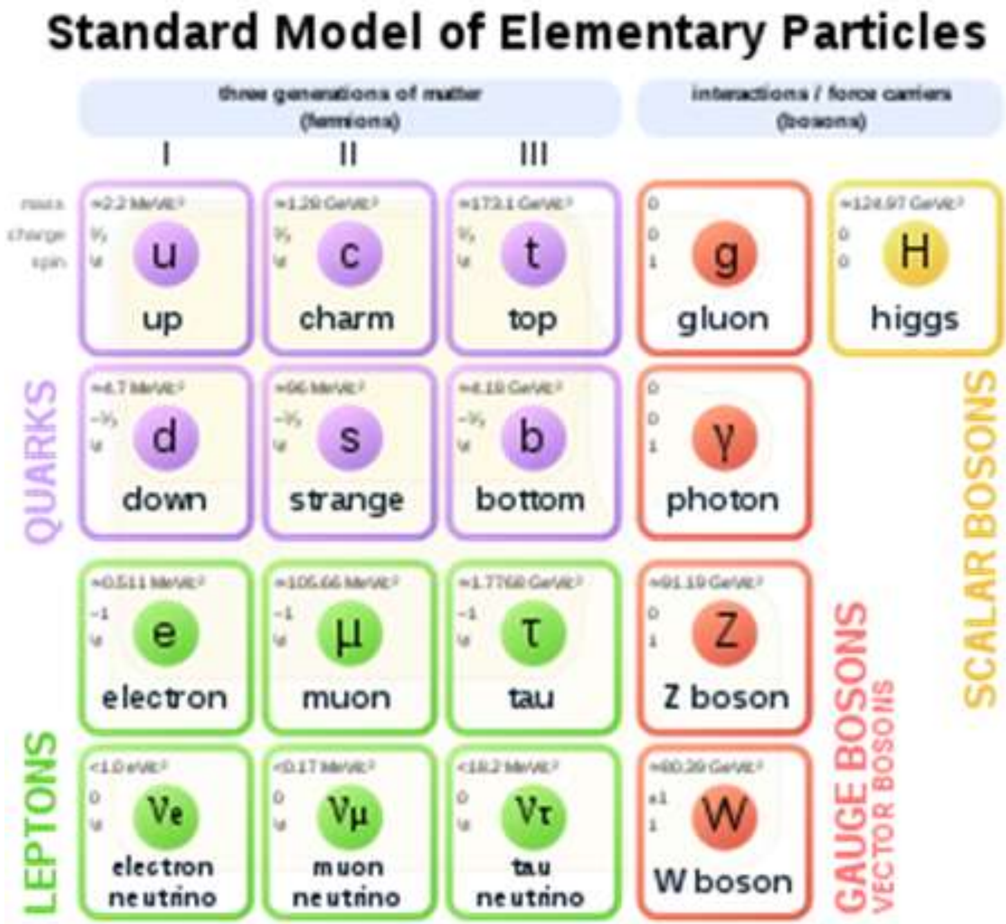
ERWIN SCHRÖDINGER — 1926

Schrödinger stated that electrons do not move in set paths around the nucleus, but in waves. It is impossible to know the exact location of the electrons; instead, we have 'clouds of probability' called orbitals, in which we are more likely to find an electron.

The atom!



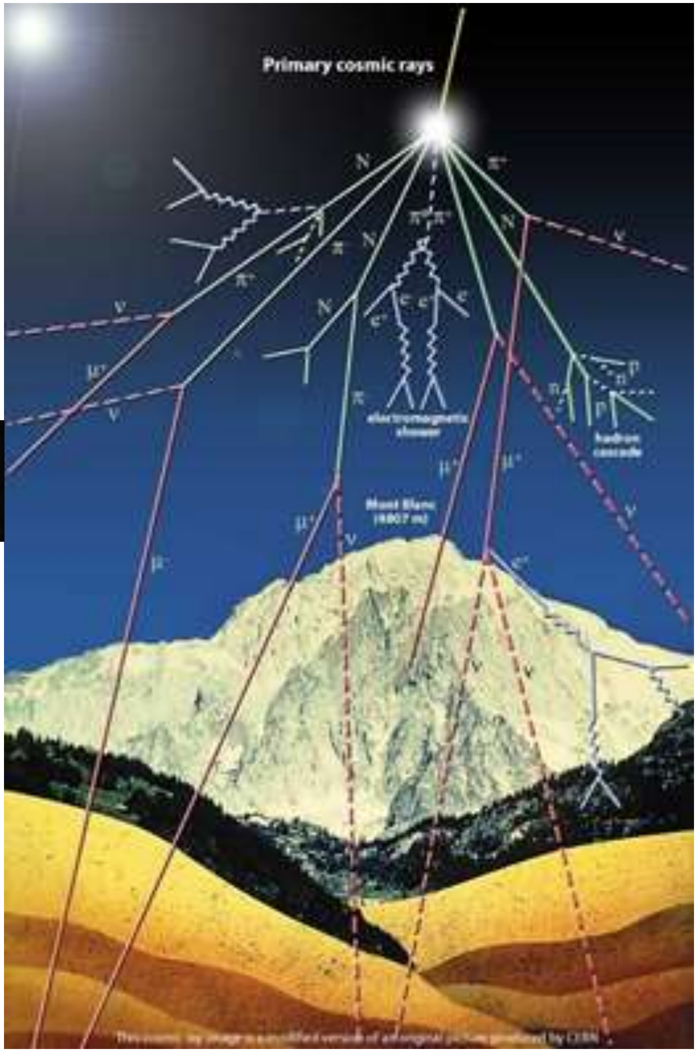
But there is more… much more!

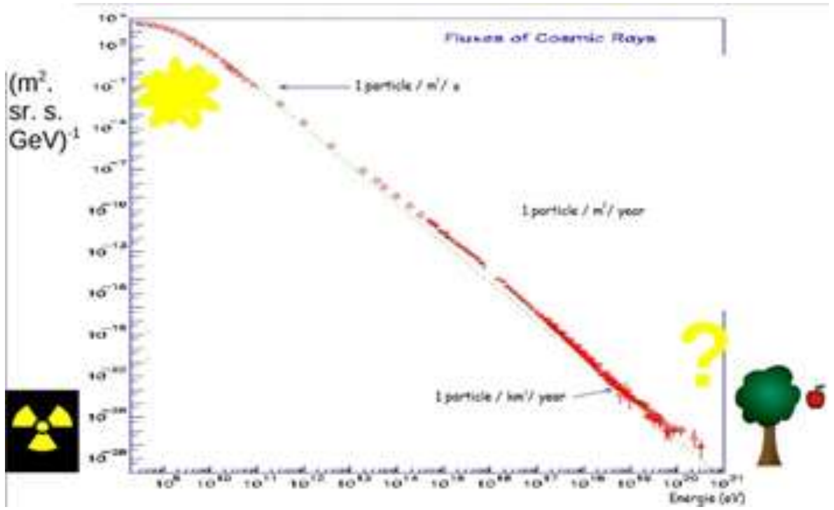


The electrons are elementary particles, but not protons and neutrons, they are composed of quarks.

But ... where can we find these particles?

In cosmic rays!





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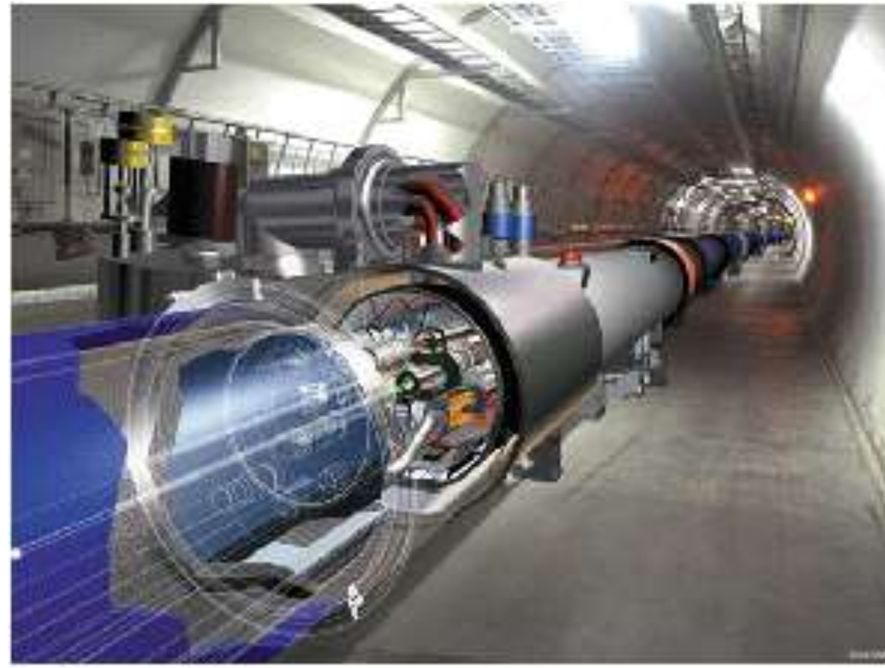


An atom is made up of a nucleus (with protons and neutrons) and the electronic cloud.

The presence of neutrons in the nucleus is very important to guarantee nuclear stability.

Despite the electrostatic forces of repulsion between protons, the protons and neutrons are held together in atomic nuclei due to the strong nuclear force.

It is noted that the mass of an atomic nucleus (with the exception of protium) is always less than the sum of the masses of its nucleons (protons and neutrons).

This difference in mass between the protons and the separate neutrons and the same protons and neutrons together is due to the binding energy of the nucleus.

Being the equivalence relation between Einstein's mass and energy:

$$E = m\,c^2$$

In the process of forming a nucleus from nucleons considered separately corresponds an equivalent mass decrease the energy released:

$$\Delta E = \left(Z\,m_p + N\,m_n - M\right)c^2$$

The binding energy of the nucleus is the energy released when a nucleus is formed from their constituents or energy to break up a nucleus provided in the constituent particles.

The greater the difference in mass between the separate separate nucleons to form the atomic nucleus, the greater the binding energy of the nucleus and the more stable the nucleus.

The binding energy associated with a nucleus is an indicator of the stability of the nucleus.

To compare the stability of two nuclei, it is more significant to use the binding energy per nucleon, ΔE / nucleon:

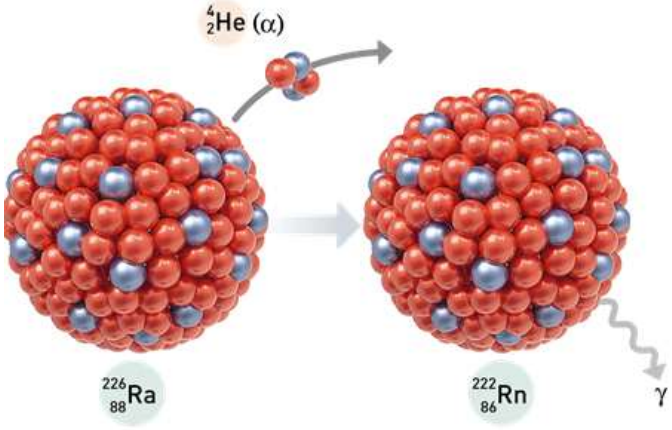
$$\Delta E / \text{nucleon} = \frac{\Delta E}{A}$$

When a nucleus is not stable, it becomes another nucleus that is more stable due to the emission of particles and / or electromagnetic radiation.

This phenomenon is called also by radioactivity or by radioactive decay.

In a radioactive decay, alpha, beta and / or gamma radiation particles can be emitted.

Alpha decay:



$$^{A}_{Z}X \rightarrow {}^{A-4}_{Z-2}Y + {}^{4}_{2}He$$

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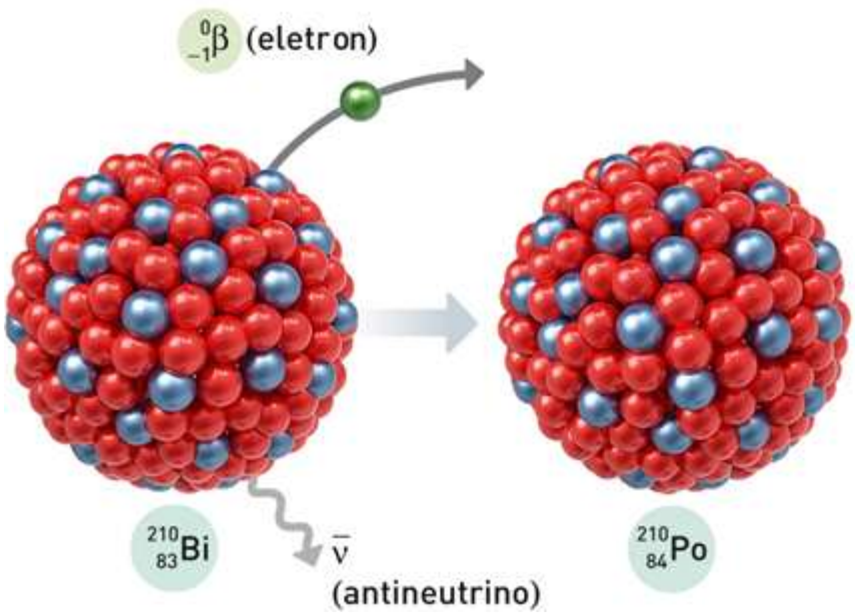
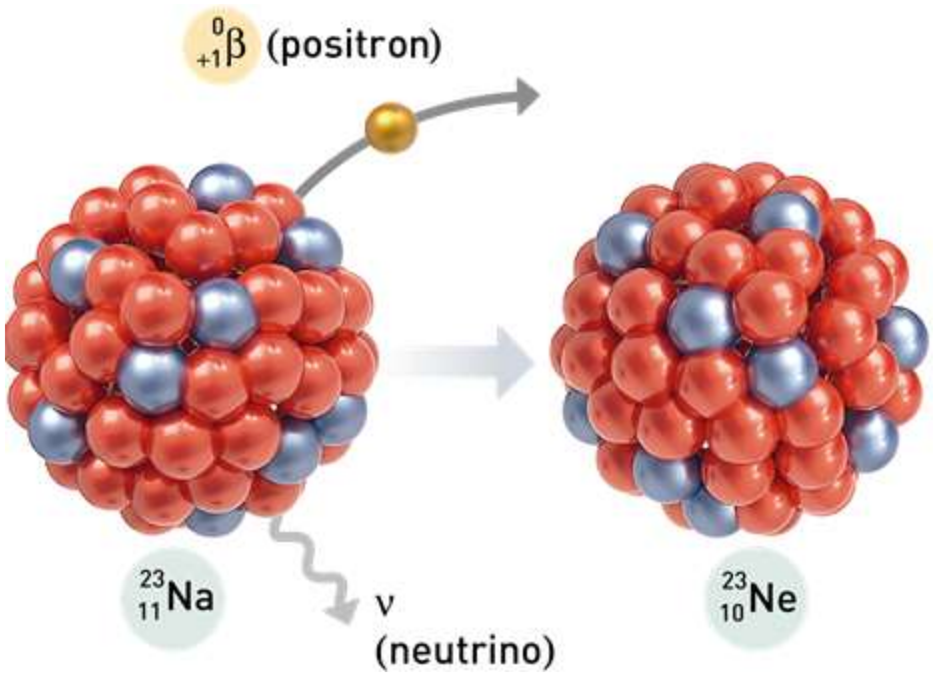
The beta decay can be β+ or β-.

β- decay:



$$^{A}_{Z}X \rightarrow\ ^{A}_{Z+1}Y + ^{0}_{-1}\beta + \bar{\nu} \quad \text{ou} \quad ^{A}_{Z}X \rightarrow\ ^{A}_{Z+1}Y + e^{-} + \bar{\nu}$$

β+ decay:



$$^{A}_{Z}X \rightarrow {}^{A}_{Z-1}Y + {}^{0}_{+1}\beta + \nu \quad \text{ou} \quad {}^{A}_{Z}X \rightarrow {}^{A}_{Z-1}Y + e^{+} + \nu$$

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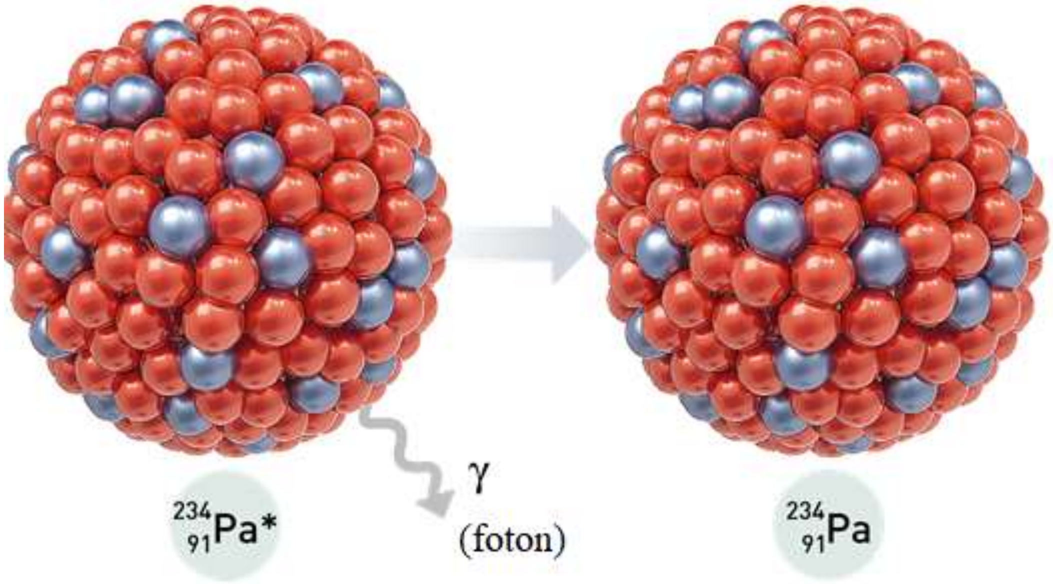
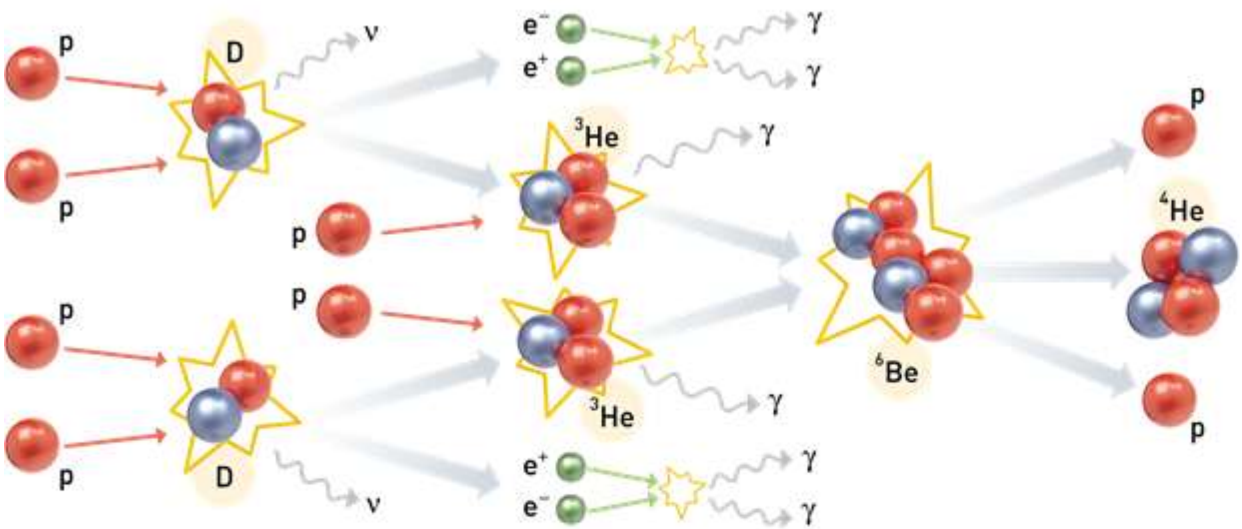
Gama decay:



$$^{A}_{Z}X \rightarrow {}^{A}_{Z}X + \gamma$$

Nuclear fusion:



$$ {}^{2}_{1}H + {}^{3}_{1}H \rightarrow {}^{4}_{2}He + {}^{1}_{0}n $$

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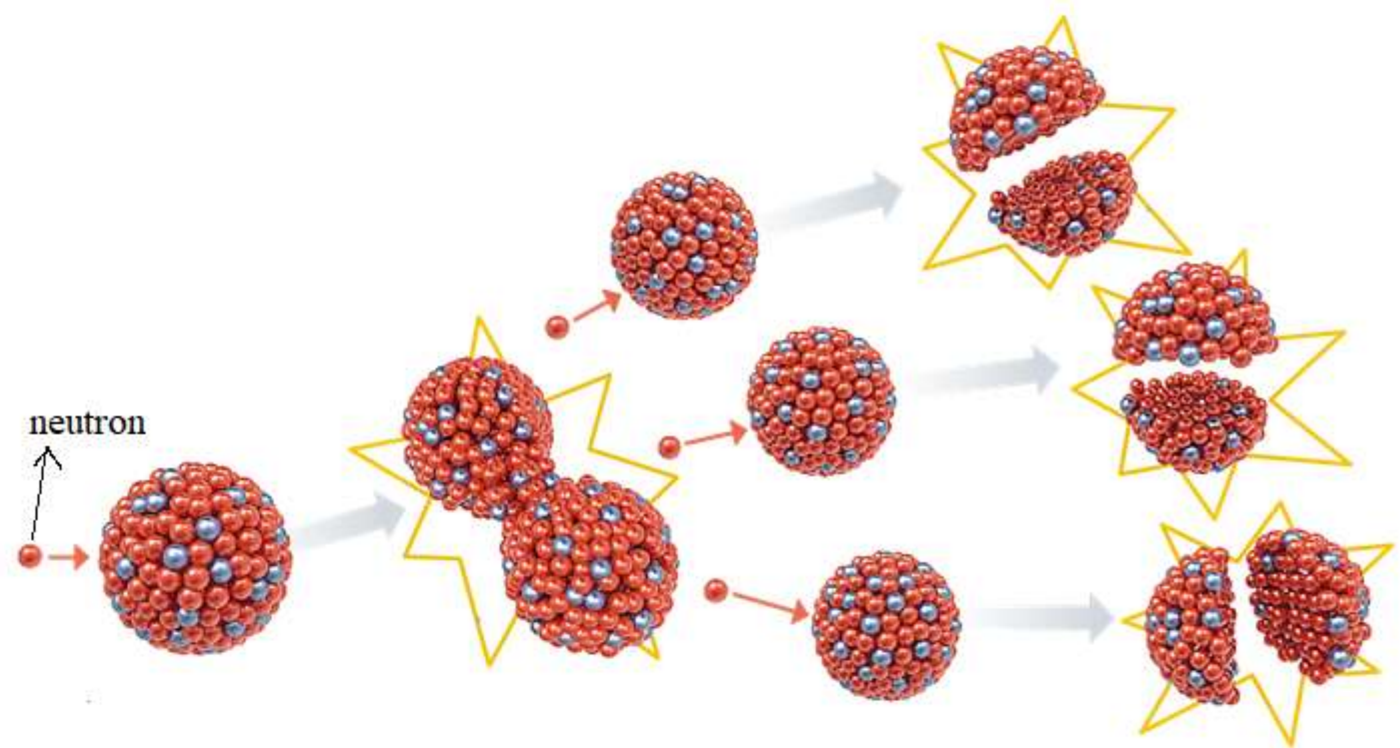
Nuclear fission:



$$^{235}_{92}\mathrm{U} + {}^{1}_{0}\mathrm{n} \rightarrow {}^{90}_{38}\mathrm{Sr} + {}^{143}_{54}\mathrm{Xe} + 3\,{}^{1}_{0}\mathrm{n}$$

Radioactive Decay Law

$$N = N_0 \, e^{-\lambda t}$$

λ - decay constant, characteristic of the substance

N_0 – number of radioactive nuclei in the sample initially

The average lifetime, τ, is equal to the inverse of the decay constant.

$$\tau = \frac{1}{\lambda}$$

The decay period, also known as the half-life, is the time that elapses before the initial number of radioactive nuclei is halved:

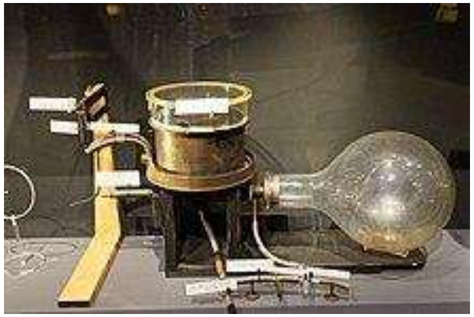
$$t_{1/2} = \tau \ln 2$$

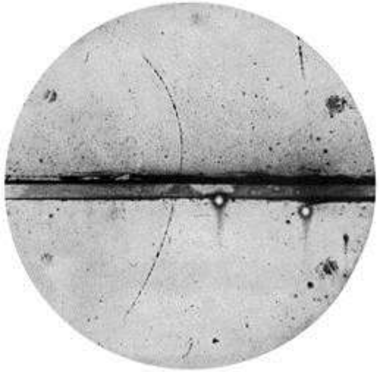
The decay rate, R, of a radioactive sample is a measure of how quickly disintegration occurs at a given moment:

$$R = \lambda N \Rightarrow R = R_0 \, e^{-\lambda t}$$

A short story of the cloud chamber

This is one of the oldest particle detector!
The scottish physicist Charles T.R Wilson discovered it in 1911 (picture left).
He actually wanted to understand cloud formation!
He received a Nobel Prize for it, as well as the american Carl Anderson who discovered two particles with the chamber: the positron (a antielectron, see right) in 1932 and the muon.





Others detectors were invented, like bubble chamber and wire chamber (by Georges Charpak), and there are huge detectors in the European Organisation for Nuclear Research CERN (Swiss).

You know perhaps other particle detectors such as a dosimeter for the people who works with radioactivity.

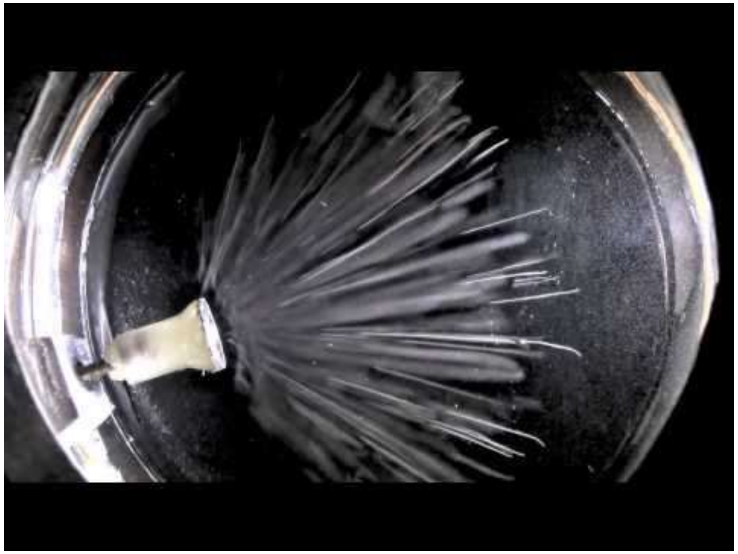
Nevertheless, cloud chamber are still used : in CERN, scientists are using the proton synchrotron to search if cosmic radiations impact climat (picture below).

Can we see radioactivity with a cloud chamber ?

1. watch the video to have a look to the three types of radiation :

https://youtu.be/VTHQYjkCqV0

2. Watch the videos of a alpha source and a beta source and give the differences between the two radiations :



Did you recognize this two types of tracks in your cloud chamber ?

Analyse a video of a cloud chamber with natural sources

If you can’t take a video of your cloud chamber :

http://microcosm.web.cern.ch/en/cloud-chamber-video#overlay-context=en/cloud-chamber

https://scoollab.web.cern.ch/sites/scoollab.web.cern.ch/files/documents/SL_CloudChamber_video_960x540.m4v

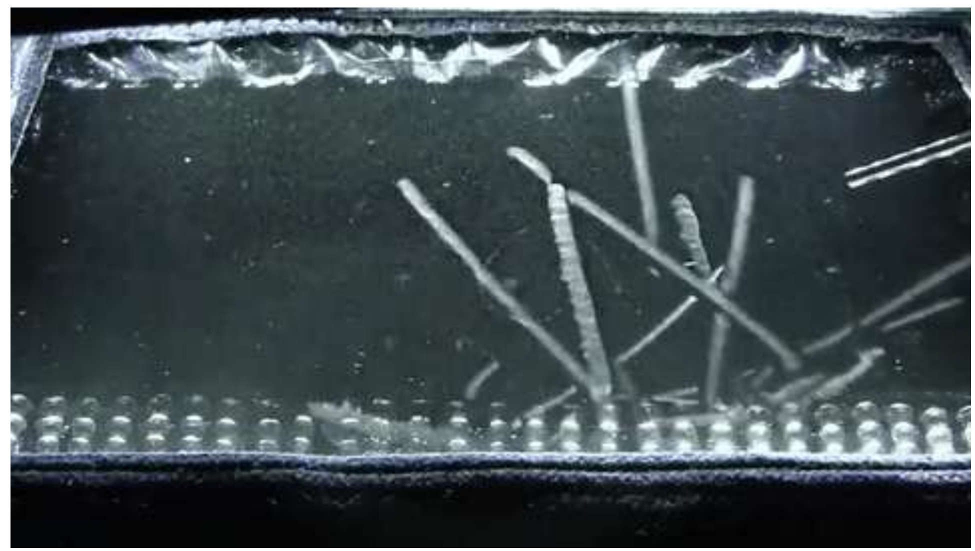
low speed video : https://www.youtube.com/watch?v=LQtGObF_fpI

1. Describe the differences between the tracks you can see.

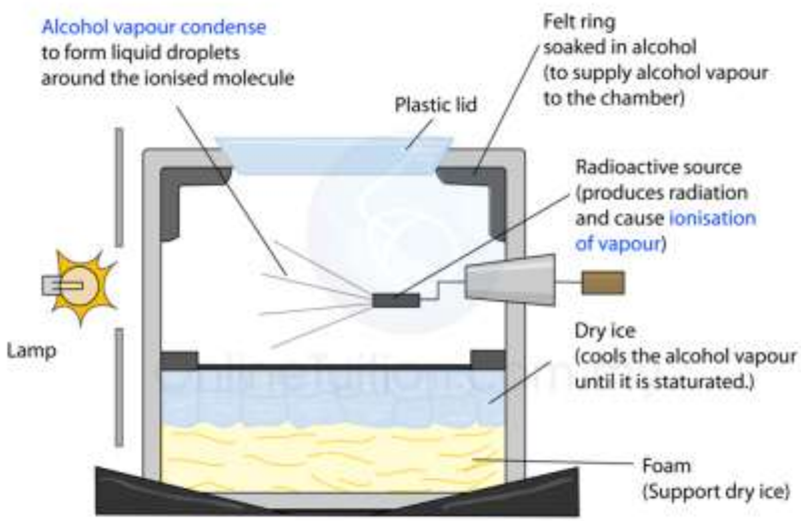
What can be the differents properties of the particles who could explain those differents tracks ?

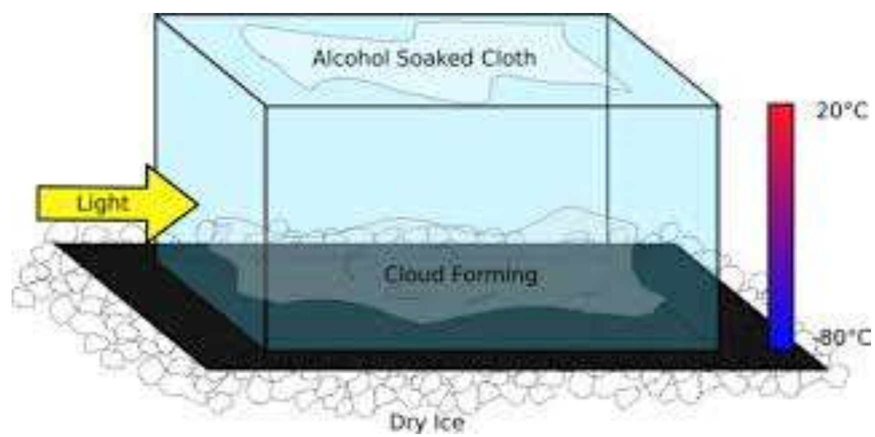
1. Can you count the tracks you see within a minute ?
2. Can we observe natural / artificial radioactivity ?
3. Where can we put our cloud chamber to see more / less tracks ?

Test your capacity



Build the cloud chamber



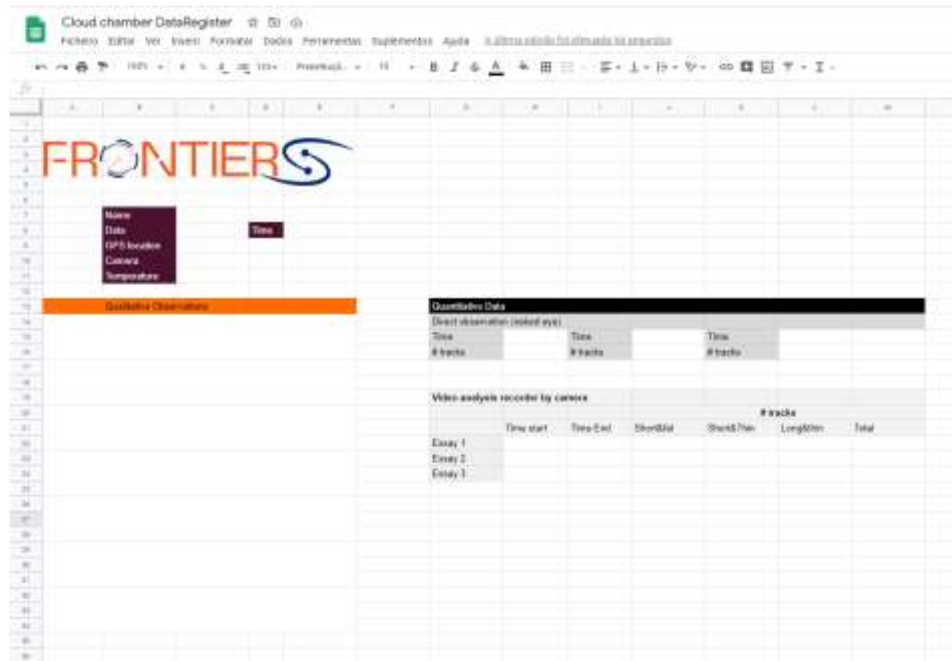


Pos-Lab activity

Analysis and interpretation

Divide the class in 3 groups to analyse the videos recorded so that each group do a statistic analysis.

1. Register GPS location and temperature.
2. How many types of tracks can you observe ?
   Do you have an idea why there is thin/ thick tracks ?
   Could it be due to the charge of the particule ?
1. Can you measure the length of the tracks ?
2. *Do you have an idea of the speed of the particules ?*
   What can be the effect of a quick/slow particle ?
1. How many tracks in a minute. Watch the video and with your smartphone chronometer, count how many tracks you can see in a minute. Repeat 3 times.

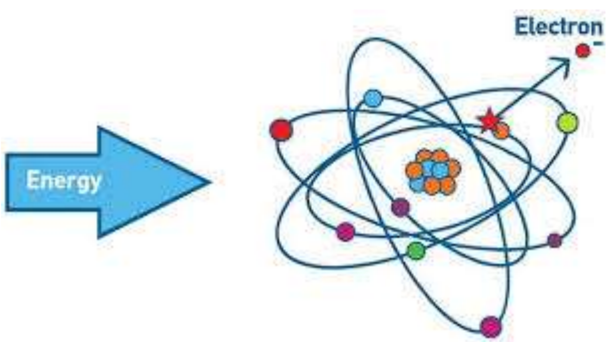


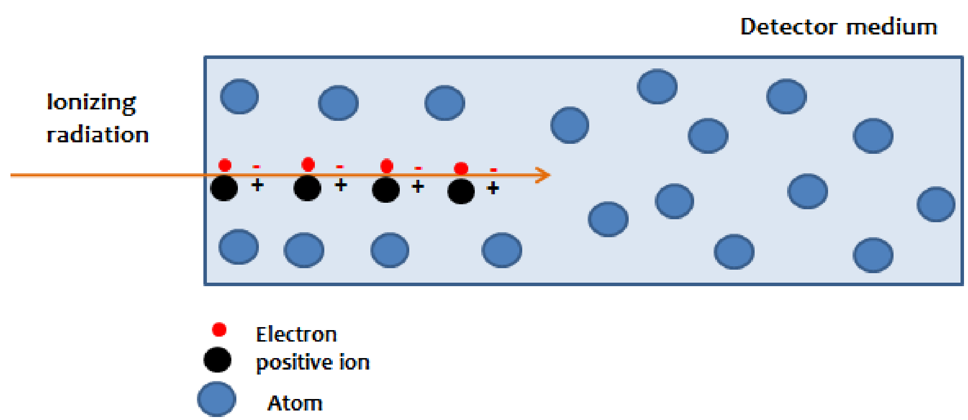
Would you observe more particles when the cloud chamber is on the ground floor of a building or on the top?

Do you think we can observe more tracks at the see level or on a mountain ?

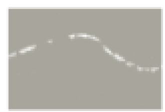
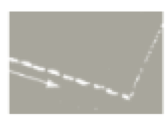
Explanation of the tracks

The particles who come in the cloud chamber have so many energy that they can ionize an atom of the alcohol, that means eject an electron and create a positive ion This occurs along the track and disturbs the unsaturated alcohol vapor wo condenses along the track : a little cloud is born !





Data table (e.g.)

How many/min	picture	particle	explanation
		muon	like a heavier electron, cosmic particle, with high speed
		electron	slowlier particle with a -1 charge
		alpha	helium ion with a 2+ charge
		transformation	a particle decay into new particles

Conclude and communicate result/explanation

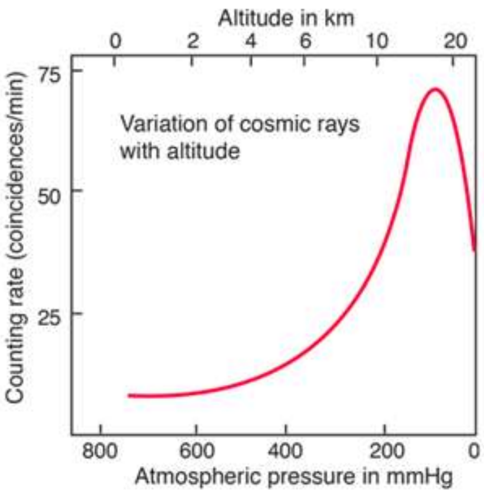
Create a short video showing your experimental procedure and your results.

Present this video to other classmates to explain how a cloud chamber works, observations record and what results you get.

Since they analyse the same interactions, they can compare their statistical results.

Write a short report. E.g. – Google Science Journal app or a Padlet

Conclusions/reflection



- Reflect on other investigations could you do with this detector

Looking to this graph, obtained by Pfotzer, in 1936.

Particles in Cosmic Rays

1. At what altitude you will get more countings?
2. What are the differences with altitude? Why do such differences exist?
3. Can you conclude, taking into account these differences with altitude, if the particles you observe come from the earth or from outer space?
4. Return to the graph, present a reason for the decreasing line above 18km.
   It suggests that the detection method used was mainly detecting secondary particles rather than the primary particles reaching the Earth from space.

1. If we repeat this activity in Portugal, Italy, France, Pakistan... would we get different observations/data?
2. We are searching for particles coming from outer space. How could you do to get more particles or other particle besides the ones you observed? Propose an experience.

Pos-Lab activity

Evaluation/reflection

- Reflect on the experimental procedure:

1. Was it easy or difficult?
2. What would you do different? Where there errors? If so, how to minimize then?

TO GO FURTHER

1. How can we explain that a track divide into two tracks ?

   Can a particle transform (decay) in two new particles ?

1. In a magnetic field, we can observe circle tracks (see image above). So, what is the effect of a magnetic field to a charged particle ? Why will a circle be smaller? Can a particle lose energy in the medium where it is passing through ?

To see more : https://applets.kcvs.ca/cloudChamber/cloudchamber.swf

http://inspiringscience.rdea.gr/delivery/view/index.html?id=4e02bc093ba843a0bcc03c7bb34f9d74&t=p

1. How is it possible to observe muon in our cloud chamber ?

   Actually, muons are created because cosmic protons decay in high atmosphere. And a muon has a short life, in average 2,2 microsecond. Calculate the distance it can go with a speed of 0,98 c (light speed) before it disappears.

   But in fact, muons come to our detector after a 15 km travel across the atmosphere. Einstein explained us this is a relativity effect for particles travelling close d : it seems to us that have a longer life. It can be calculate how much longer : time*

$$\frac{1}{\sqrt{1-\frac{v^2}{c^2}}}$$