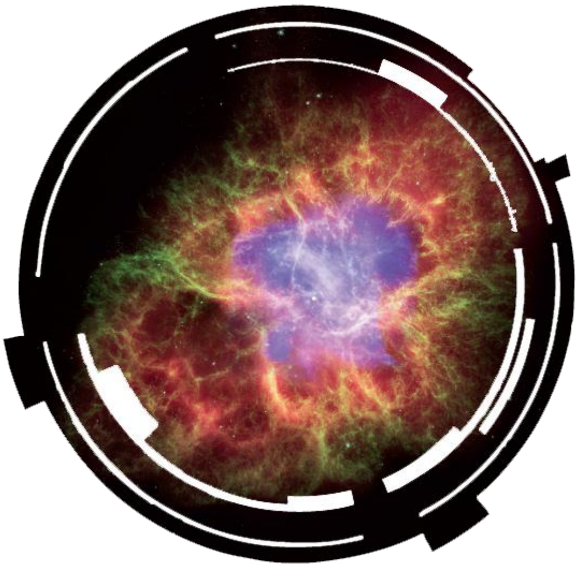
English Guide Book

For onsite consultation, thank you.
A pdf version is available on the website www.lsm.fr

Little Secrets of the Universe



Laboratoire Souterrain de Modane

Little Secrets of the Universe

Welcome to the "Little Secrets of the Universe" exhibition by the Modane underground laboratory.

Through this exhibition you will discover why scientists the world over want to unlock the mysteries of the universe protected by the Alpine mountains.

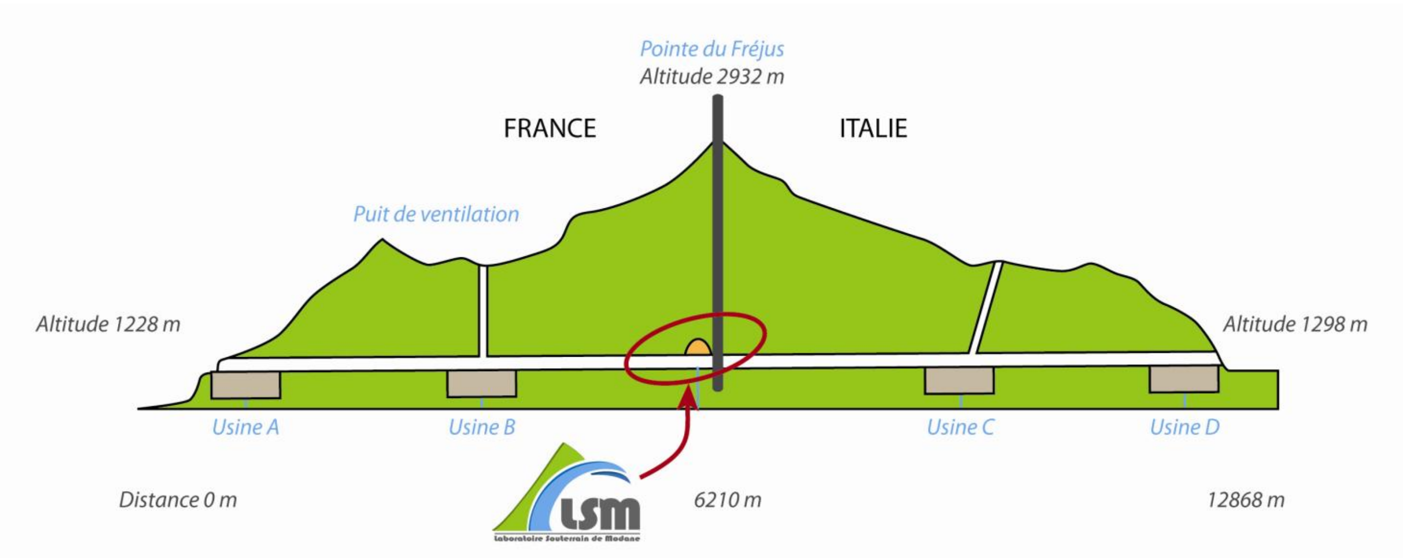
The Modane underground laboratory is a scientific research laboratory which is jointly operated by CNRS and CEA (‘Centre National de la Recherche Scientifique’ and ‘Commissariat à l'Energie Atomique’)

The laboratory was built in 1982, the space having been excavated at the same time as the Fréjus road tunnel, which runs under the Alps and connects France and Italy.

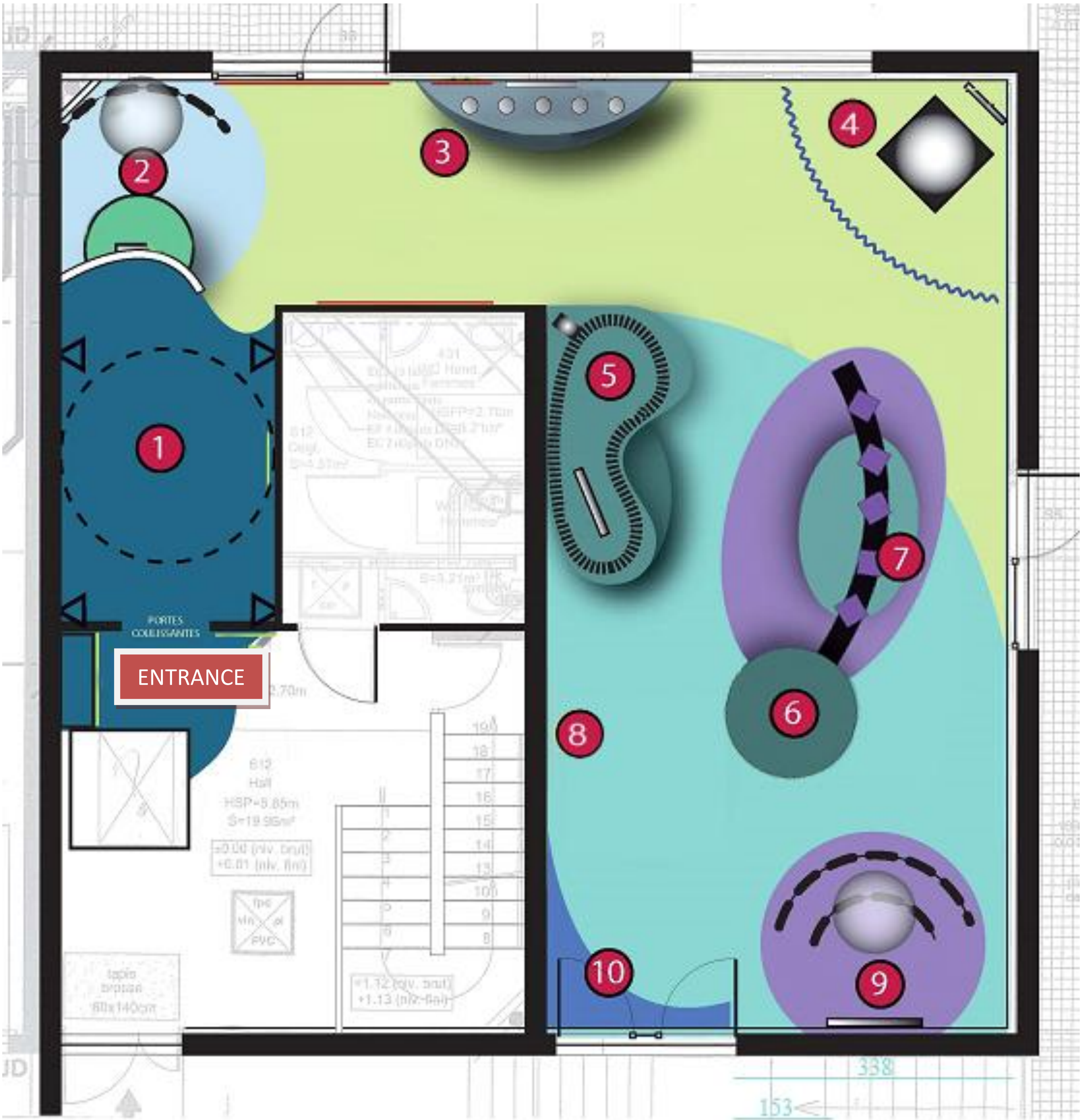
It is located underground, in the middle of the Fréjus tunnel (length 13 km), 1700m below the peak of Fréjus. The thickness and composition of the rock make this laboratory the deepest in Europe and the 2nd deepest in the world, as if the laboratory was 4800m underwater!

The rock cover almost completely removes cosmic rays from the sun (which is like a big nuclear power plant), from supernovae (old stars) or pulsars (neutron stars). Every day, 8 to 10 million cosmic rays (muons) reach each m² of the surface of the Earth. In the laboratory, only 4 cosmic rays per m² per day are able to penetrate the rock cover above!

Measurements done in the laboratory could not be done outside because they would be ‘lost’ in the background noise of cosmic radiation.

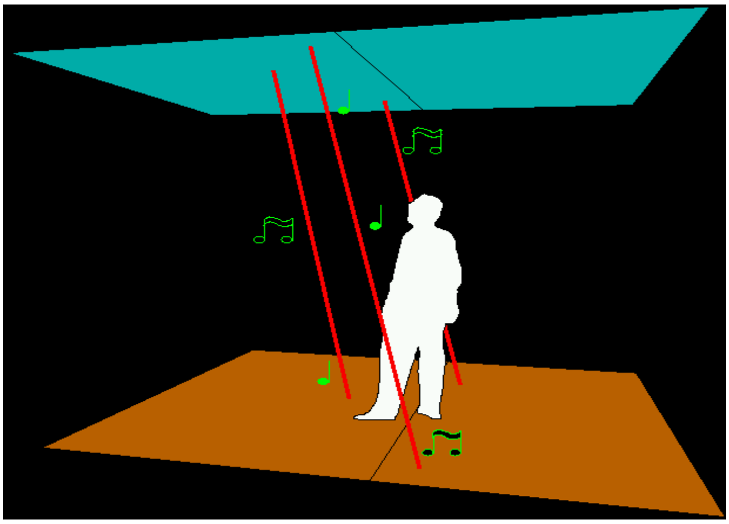


Follow the numbers on this plan:



❶ Cosmophone

Enter into the cosmophone and listen live to the music generated by the cosmic rays. These cosmic rays come from the sun and from strong astrophysical phenomena such as exploding stars, black holes or pulsars that occur in the cosmos. Stand in the centre of the room, look at the screen and you will see and hear some of the cosmic rays that go through us! The flow of primary cosmic rays is made up of protons, helium nuclei and other particles and the cosmophone emits a single sound for this radiation. When it penetrates into the atmosphere, the cosmic ray interacts with the atomic nuclei in the air of Earth's atmosphere or with objects it encounters on its path. It then produces a multitude of other particles (pions, kaons, muons, electrons and neutrinos), which are cosmic ray showers and the cosmophone emits a different sound, like a waterfall.



Particles such as muons (cosmic rays) are the smallest part of matter, we can't see them, we can only detect them.
The cosmophone materializes the cosmic ray by producing a sound.
This is done with 8 detectors coupled to speakers.
Thus, whenever a muon passes through 2 sensors, a sound is emitted and we see it on the screen.

❷ Films about the laboratory

Take a look behind the cosmophone screen and sit down! There are two films for you to watch. By pressing the blue button under the screen, you can watch a 6 minute general presentation of the laboratory and by pressing the green one, you will see a 2 minute film on the planned laboratory extension. We want to make use of the excavation works for the tunnel's emergency gallery to increase the laboratory's volume sevenfold to house future generations of experiments.

- Blue button: General information on the laboratory
- Green button: The extension project

❸ Story of a chain of discoveries

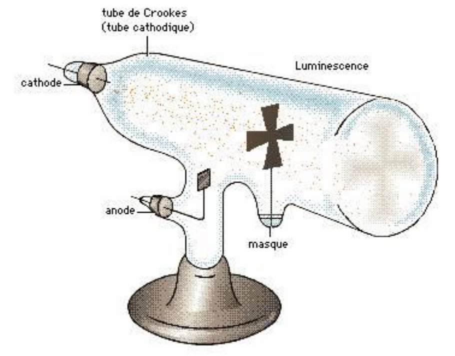
How about a journey into the past?

In this part the experiments that allowed the crucial discoveries about particles, radioactivity and the neutrino, are presented. Objects dating from the nineteenth century have been lent by Maurice Chapellier.

- *Geissler-Plücker tubes*: in 1854, Mr. Geissler, a glassblower specialized in laboratory glassware and Mr. Plücker, professor of mathematics and physics, discovered that after having confined gas under low pressure, when high voltage is applied between two electrodes, a discharge occurs in the tube and the gas becomes luminescent. They observed that the light emitted is characteristic of the nature of the gas.

- *X rays*: Sir William Crookes lowered the pressure inside tubes and in 1879, he discovered the existence of "cathode rays".

  Mr Roentgen managed to illuminate a platinocyanide barium screen as he wrapped the Crookes tube in black paper. He put his hand on a photographic plate and saw that he could see his bones! He had discovered X-rays!!!



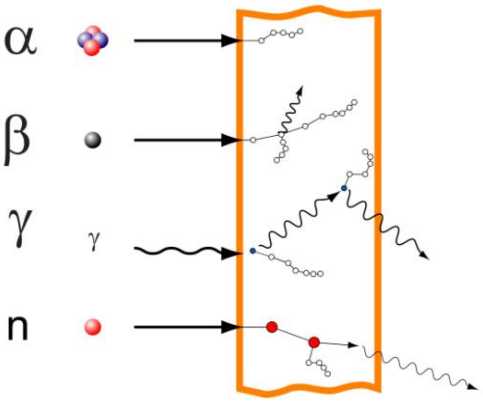
- *Natural radioactivity*: In 1896, Henri Becquerel kept on doing research on the mysterious X-ray. He placed a photographic plate in contact with uranium salt and left it in a drawer. It developed in total darkness. He concluded that uranium salt emits radiation and that there was no link with fluorescence. He called this radiation "uranic rays". This phenomenon has been known thereafter as radioactivity.

- Radium and Polonium (Marie Curie - 1898): Marie Curie performed her thesis on uranium rays and tried to establish whether the emission of Becquerel rays is specific to uranium, and from uranium only, or whether it is a more general property. Marie Curie systematically examined whether other substances have the remarkable property to spontaneously emit radiation. Pitchblende and chalcolite (2 uranium-rich minerals), appeared to be more radioactive than uranium itself! She speculated that other radioactive substances are present in minerals. After chemical purification, Polonium was the first radioactive element discovered by Pierre and Marie Curie in July 1898 in their research on the radioactivity of pitchblende. In December of that year, they discovered radium. The word polonium was chosen in honor of Marie Sklodowska-Curie's Polish origins.

- Neutrino hypothesis (Wolfgang Pauli - 1930) In physics, there is an immutable principle: "nothing is lost, nothing is created, everything is transformed", and this principle is also true for energy. Measurements of energy emitted by beta radioactivity show that the energy carried by the electron is variable. This observation overturned physical science ... but in 1930, Wolfgang Pauli proposed a hypothesis to explain the beta spectra without violating the principle of conservation of energy. This hypothesis was the existence of a new particle: the neutrino. This particle should have a very low mass and interact weakly with matter; it would carry the missing energy but would not be detected.

❹ Cloud chamber

Push aside the black plastic curtain to discover the cloud chamber …



Just a little reminder about radioactivity: in nature, most of the nuclei of the atoms that make up matter are stable. Others have unstable nuclei: they have too many particles (protons or neutrons, or both) which leads them to evolve through disintegration into other nuclei that are stable or not. We call them radioactive since they give off ionizing radiation when they evolve. The radiation is called *ionizing* when its energy is sufficient to eject one or several electrons of the atoms of the matter that it encounters.

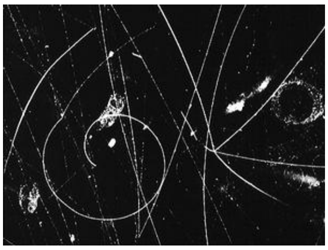
These appear either in the form of particles such as alpha or beta radiation, or in the form of electromagnetic waves like X-rays and gamma rays. Certain elements are extremely radioactive (billions upon billions of Becquerel), whilst others are weak (a few Becquerel). One Becquerel (Bq) is equal to one disintegration per second.

Moreover, the life cycle of these elements (the period during which they give off radiation) varies considerably from one radionuclide to the next. The radioactive period is the duration at the end of which radioactive matter naturally loses half of its radioactivity. Therefore, after 10 radioactive periods, a product's radioactivity is divided by 1000. This period can last a fraction of a second for polonium 214 to 4.5 billion years for uranium 238. Thus we are permanently surrounded by radioactivity, that which comes from the cosmos, that which is in the air like radon, that which comes from rock that still contains uranium or that which comes from the materials around us … or even our own bodies (a human being weighing 70kg produces about 7000 Bq, i.e. 7000 particles that are given off every second).

In the cosmophone the passage of a cosmic ray is shown by a sound. In the cloud chamber, we can see the trace left by a radioactive particle in a fog.

The technique: Alcohol vapour is put in contact with a cold plate (-30°C), which creates fog. If an ionizing particle crosses the chamber, condensation droplets appear along its path. We see different traces: very long straight traces (muons), zigzag traces (electrons) and dense and short traces (the alphas). This chamber is no longer used for experiments, but previously it was one of the first particle detectors.

No radioactivity has been added to the cloud chamber, and what we see is the background radioactivity. It shows that all the materials around us emit radioactivity. In the laboratory, as for cosmic rays, background noise must be removed. To do that we use different types of shields around the experiment.



❺ The small train of radioactivity

Everything is radioactive! The train is loaded with different natural materials

Choose a load:

- Fertiliser (contains potassium)
- Granite (releases of radioactive radon)
- Guarapari Beach Sand (includes radioactive ore)
- Hands of an alarm clock (radium)
- Travellers (radioactive potassium in bones)
- Ambient radioactivity

❻ Radioactivity detectors

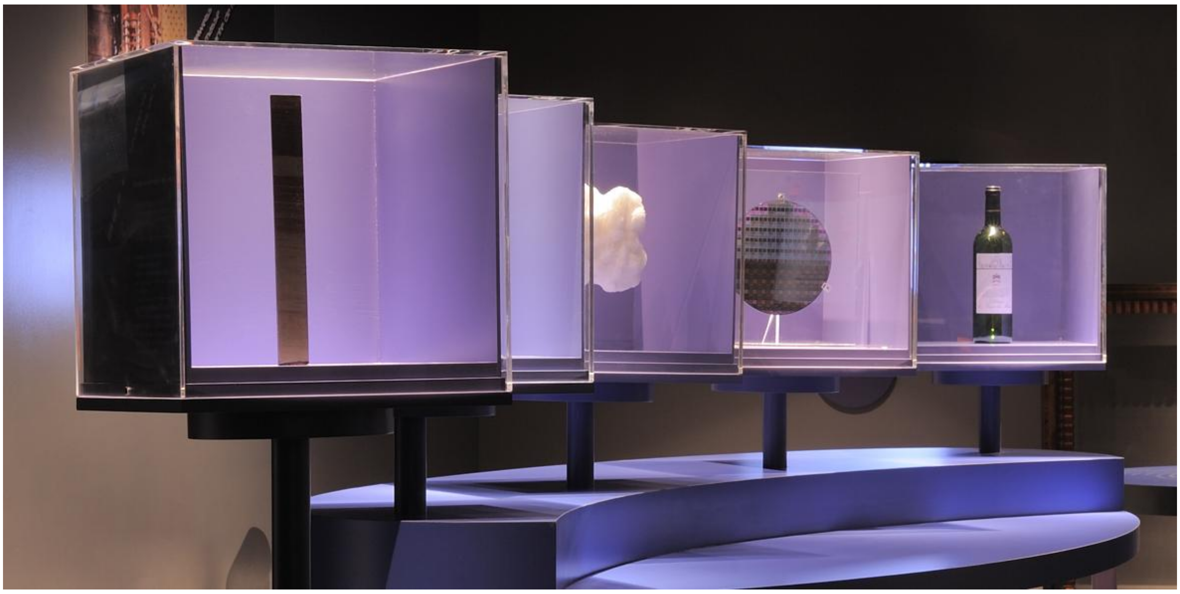
Here you can see the various radioactivity detectors. Rotate the middle section to find the right combination (green light).

- Tracking chamber
- Crystal Germanium
- Plastic scintillator and photomultiplier
- Silicon strips

❼ Applications

In the cubes are presented examples of applied research.

- Accurate dating is crucial. In order to extract climate-related information from lake sediments, it is essential to establish a reliable chronology. Commonly applied methods are based on radio-isotopic dating
- The National Institute of Radioprotection and Nuclear Safety (IRSN) studies the movement of any radioactive pollution transported by clouds.
- Impact of neutron radiation on nanoelectronics.
- Verification of vintage fine wines, by measuring the Cesium 137 (time stamp) to detect possible fraud.



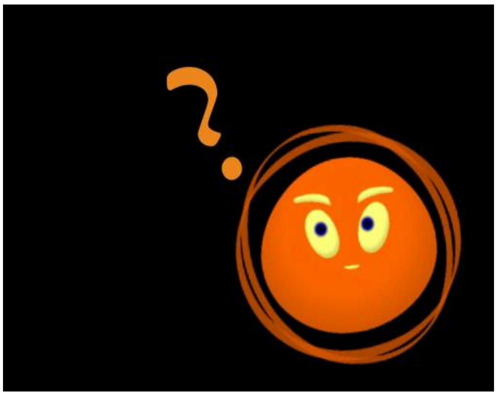
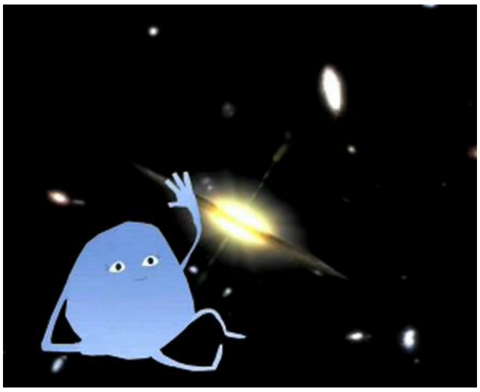
❽ Information boards and Models





❾ Films: Fundamental research experiments

Discover the leading experiments hosted in the lab: Nemo and Edelweiss (5 minutes each)

Let’s take a closer look at one of the experiments carried out in the laboratory: Edelweiss and the universe’s dark matter…

Currently, we only know 5% of the composition of the universe, and these 5% include all of the matter we are made up of (living creatures, Earth, the other planets and all the stars in the universe …). As concerns the rest, 75% is called dark energy and all physicists can say about that is: “We know that we know nothing”.
The remaining 25% is dark matter, something we have known for certain since the 1970’s by observing the movements of the galaxies … but, as yet, we do not know what it is made up of.

The Edelweiss experiment, a joint international project that several French, Russian and German laboratories are taking part in… speculates that it is made up of WIMPs (Weakly Interacting Massive Particles). These particles interact very weakly with matter, which is why we must put the odds on our side to successfully detect them:
Being under the mountain, with the materials used for the experiment having a very low radioactive content and with a thick lead shielding, we can obtain a very low level of background noise. We use germanium crystal detectors, the purest material that can be manufactured. The detector’s core is at a temperature close to absolute zero so even an increase of a millionth of a degree can be detected!

Since the number of possible events is very low (one a year!), the mass of the germanium detector must be increased in order to have a better chance of capturing such a tiny particle … the aim of the experiment is to reach a 1 tonne detector.

❿ Multimedia

A computer allows you to go on a virtual tour of the laboratory. You move from room to room, see every corner of the laboratory, as if you were there.
(This virtual tour is available on the website of the laboratory: www.lsm.fr)

Some selected links to interesting websites are listed on the main page. You can find this page on the internet website www.lsm.fr

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