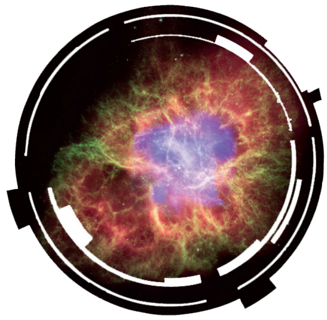
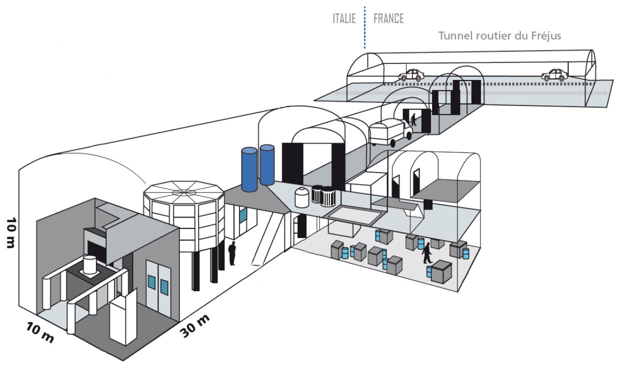
Laboratoire Souterrain de Modane

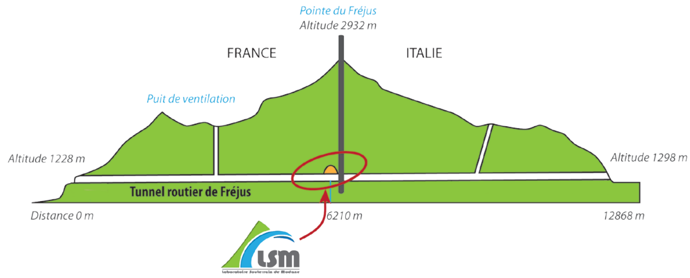
The Laboratoire souterrain de Modane is a joint research unit IN2P3 / CNRS (National Institute of Nuclear and Particle Physics of the National Center for Scientific Research) and UGA (Université Grenoble Alpes).





The LSM hosts fundamental research experiments in particle physics, astroparticle and nuclear physics, and detectors for ultra-low radioactivity measurements concerning environmental applications in the field of dating, determination of the geographical origin of products, and test benches in microelectronics. It also has an activity in biology studies for low radioactivity impact on living cells.

Created in 1982, the laboratory is located in the middle of the Fréjus road tunnel, 1700 meters below the Fréjus peak (4800 meters water equivalent depth).



This is the deepest lab in Europe with an internal volume of 3500 m^3.

A dozen permanent staff (physicists, engineers, technicians) ensures the operation and safety of the laboratory and hosts over one hundred researchers and engineers from around the world (France, Russia, Czech Republic, Germany, United Kingdom , Spain, Japan, USA, ...) who contribute to experiments located in the site.

The LSM has a research agreement with the Joint Institute for Nuclear Research in Dubna (Russia) and the Czech Technical University in Prague (Czech Republic) as part of the International Associated Laboratory JOULE.

It is also part of a European network of underground laboratories comprising LSM, LNGS (Gran Sasso, Italy), LSC (Canfranc, Spain) and BUL (Boulby, UK).

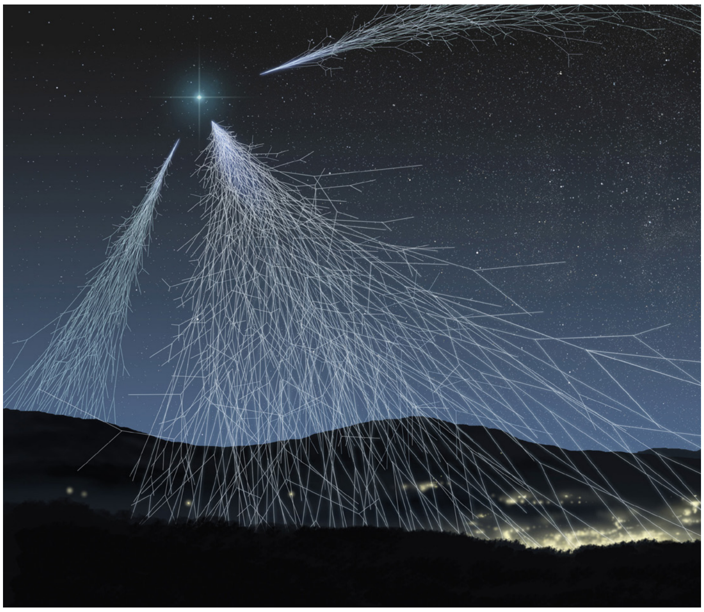
Laboratoire Souterrain de Modane

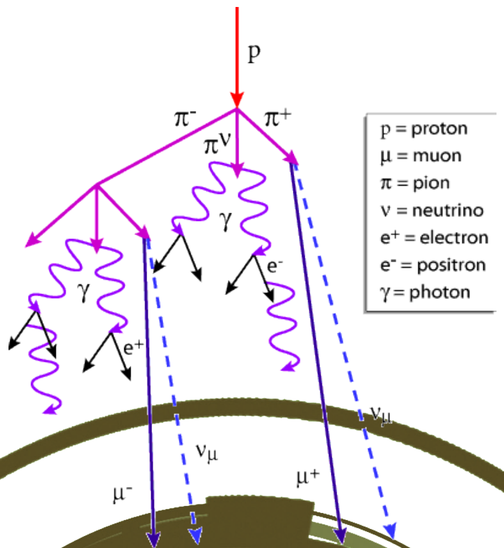
Cosmic radiation

Cosmic rays are high-energy radiation, mainly originating outside the Solar System.

The high-energy «primary» cosmic ray flux consists of:

- Protons (85 to 90%)
- helium nuclei (9 to 14%),
- Heavier atomic nuclei
- Trace amounts of antimatter (and positrons)
- gamma rays and neutrinos.





Penetrating the atmosphere, cosmic rays interact with atomic nuclei of air (nitrogen, oxygen, ...) producing cascades of other particles (pions, kaons, muons, electrons, neutrinos, ...) making up the «secondary» cosmic radiation.

Low energy cosmic rays are emitted by the sun and intermediate energy ones by other more distant sources such as pulsars and supernovae.

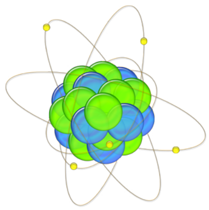
Finally, a recent experiment (Auger, located in Argentina) has shown that the most energetic cosmic rays come from galactic nuclei where there are black holes, final stage of the evolution of super-massive supernovae: here occur the most violent events in our universe.

Above the LSM, the thick layer of rock (1700 m or 4800 meter water equivalent) gives almost total protection against the charged components of cosmic rays that bombard the Earth. While 8 million cosmic rays per square meter per day reach surface of the Earth, only 4 per square meter per day reach the laboratory. The search for rare phenomena thus becomes possible.

Radioactivity

The material is made of atoms, themselves made of:

- An atomic nucleus (protons and neutrons)
- Electrons orbiting around the nucleus.



Particles from nuclei?

Some nuclei are stable. Others, however, are unstable because they have extra energy to release. When they emit radiation and undergo a spontaneous nucleus transformation, the process is called radioactivity. Three types of radiation occur:

- α radiation : The nucleus loses energy by emitting a helium nucleus (2 protons and 2 neutrons) or alpha particle.

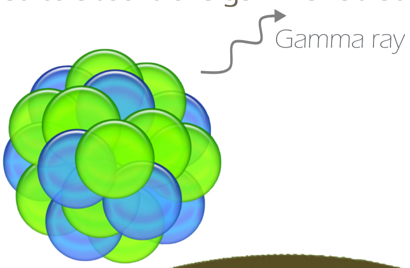
The alpha particle is stopped by a sheet of paper.

- β radiation : The nucleus emits one electron and one antineutrino.

The electron or beta particle (β) is stopped by a few millimeters of aluminum.

- γ radiation : also known as gamma rays, comprises a form of electromagnetic radiation similar to visible light or X-rays but more energetic.

Several centimeters of lead or concrete are needed to absorb the gamma radiation.



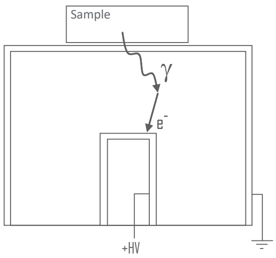
Activity

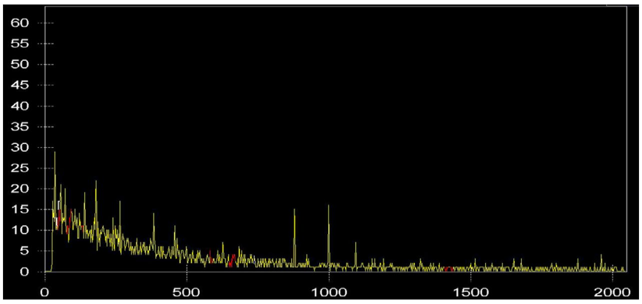
The activity of a radioactive substance is the number of decay of its atoms in one second. It is measured in Becquerels (Bq).

Some examples:
1 liter of sea water: 15 Bq
A 70 kg adult: ~ 7000 Bq
1 gram of radium: 37 billion Bq

Germanium detector

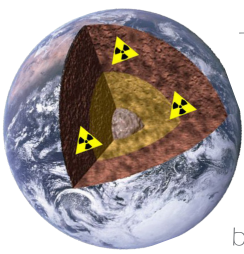
The energy of the gamma radiation (s) emitted is characteristic of the specific nuclear decay. Germanium detectors to measure with great precision the energy of gamma radiation





The different peaks of the spectrum are used to identify the radioactive nuclei in the sample measured.

Did you know?



The natural radioactive elements present in the soil decay by emitting radiation in which energy is dissipated as heat.

Without this heat, our planet would become a cold and lifeless star.

Ultra low radioactivity measurements

In the laboratoire souterrain de Modane, detectors have been developed to measure very low levels of radioactivity. A unique fleet of 14 ultra low background sensors is installed. They are used for the selection of ultra-pure materials, for environmental measurements, for dating and authenticity research.

Some examples :

Measurements of lake sediments

LSM (CNRS-CEA), LSCE (CNRS-CEA), EDYTEM (Université de Savoie-CNRS), CARRTEL (INRA-Université de Savoie)

Identification of radioactive elements in the sediment cores can read the last 150 years of lakes history.

(Earthquakes, pollution, climate change, human activities)

Dating of wines: validate the authenticity of a vintage

CENBG (Université Bordeaux 1 - CNRS), LSM

Atmospheric nuclear testing and the Chernobyl accident produced cesium 137. The wine keeps track of these events, and by measuring the activity of infinitesimal 137Cs contained in each bottle, the vintage of a wine can be verified.

Measurements of radioactivity in the environnement

IRSN (Institut de Radioprotection et de Sureté Nucléaire)

Radioactivity in the environment is monitored through measurements of samples from sediment, rivers, lakes, clouds and other environmental media.

Laboratoire Souterrain de Modane

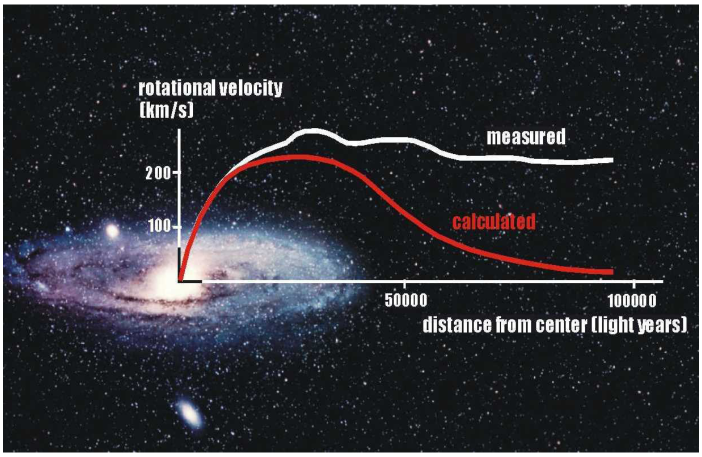
Edelweiss

looking for dark matter

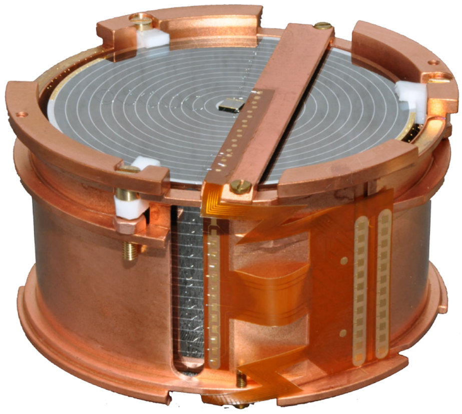
Experiment to detect WIMPs in an underground site

During a clear night everyone can see the stars in our galaxy, the Milky Way. With telescopes, astronomers observe stars invisible to the naked eye, other galaxies and many other celestial objects.

Yet we see only 5% of what is in the universe.



Missing matter, invisible, dark matter, is the subject of numerous investigations around the world. The EDELWEISS experiment, seeks a constituent of dark matter called Weakly Interactive Massive Particles, or WIMPs. these could form as clouds of gas around each galaxy.



EDELWEISS uses germanium detectors called bolometers operating at a temperature close to absolute zero. Ultra sensitive and ultra-pure germanium detectors, simultaneously measure heat (one millionth of °C), and the electrons produced by the recoil of a germanium atom after collision with a WIMP.

All the materials constituting the detector were carefully selected for their low radioactivity.

With 30 kg of germanium bolometers cooled to -273.13 ° C, EDELWEISS is currently one of the most sensitive experiments in the world to search for dark matter.

LSM
Laboratoire Souterrain de Modane

SuperNemo

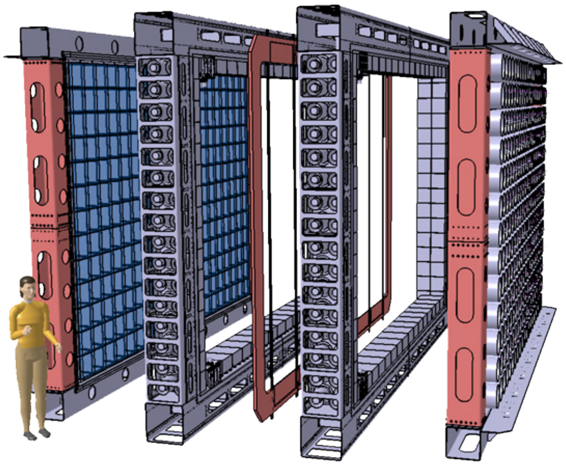
Neutrino Ettore Majorana Observatory

Nature and mass of neutrino

The neutrino is the most abundant elementary particle with mass in the universe and the most mysterious...

This small, electrically neutral particle hardly ever interacts with matter, and so is very difficult to study.

Neutrinos are everywhere :
Hundreds of billions of neutrinos pass through us each second, coming mainly from the sun, but also on earth from nuclear facilities ans from radioactive decay. Occasionally, we receive bursts of neutrinos produced by extreme and distant cosmic events like supernovae , quasars and blazars.



Collaboration involving France, Russia, the United Kingdom, the Czech Republic, the USA, Japan, and Spain

Ettore Majorana, a leading Italian physicist, disappeared mysteriously at the age of 31. He left us a theory still current: some particles, neutrinos, could be their own anti-particles.

The neutrino has an important role in cosmology and astrophysics.

The neutrino could theoretically be its own anti-particle (Majorana neutrino), a property which could explain how matter, that makes up our Universe, was created.

The mass of the neutrino also has a direct impact on the distribution of matter in the universe. It has been proved that the neutrino has mass but no one has been able to measure it exactly.

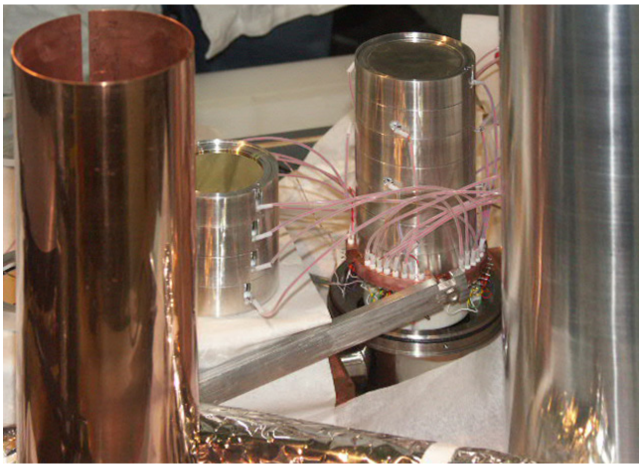
The purpose of the SUPERNEMO experiment is to measure the neutrino's mass and to determine whether the neutrino is its own anti-particle by seeking a hypothetical radioactivity: double beta decay without neutrino emission. This would consist of radioactive emission of two electrons whose total energy is equal to 3.012 MeV.

The principle of the experiment is to use a source of 7 kg of ^{82}Se placed in thin layers between two volumes of gas in a Charpak type wire chamber to identify electrons. The whole is surrounded by a device for measuring the energy of each electron to establish whether the full decay energy is present.

Telescope Germanium Vertical

TGV II

The TGV II facility is a low background spectrometer. It aims at the study of double electron capture of 106Cd. The spectrometer is composed of 32 HPGe planar detectors interleaved with thin-foil samples made of 106Cd enriched to 75%.



The limits on 2vEC/EC decay of Cd-106 to the 2(+),512 keV and 0(1)(+),1334 keV excited states of Pd-106 and on 24 beta(+)beta(+) and 2v beta(+)/EC decay of Cd-106 were improved.

IEAP CTU, JINR Dubna, CSNSM, KU Bratislava, INP

Super Heavy Elements In Nature

SHIN

In nature some nuclei heavier than uranium (98 protons) could be synthesized.

SHIN Experiment (Super Heavy elements in Nature) is looking for potential super-heavy elements (108 or 114 protons). These elements have the same chemical character as osmium or xenon, which are placed in the middle of an array of neutron detectors.

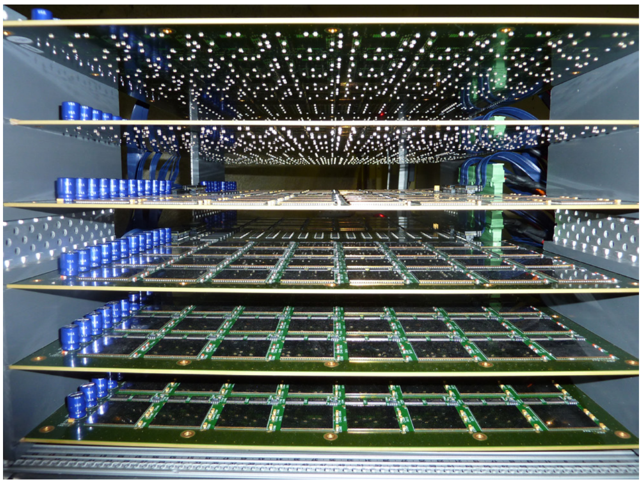
If superheavy elements decay, they would release multiple neutrons, which the SHIN detector should be able to detect.

CSNSM Orsay - JINR Dubna

Real-time neutron and alpha soft-error rate

Are chips of electronic devices sensitive to cosmic radiation?

The width of the tracks of electronic circuits etched in silicon has decreased from 130 nm (or 0.00013 mm) to 65 nm and soon to 45 nm, 32 nm, 22 nm, ...



Electrical charges that carry the information could be disrupted by:

- neutrons created by cosmic rays,
- alpha particles from radioactive decay of impurities of the component.

Knowledge of the radiation sensitivity of the chips is essential to develop stronger nanoelectronic devices.

Real-time testing at LSM allows experiments to more accurately determine the effects of alpha radiation without other sources of disturbance, since the neutrons from cosmic rays are virtually nonexistent in the LSM.

Long-term tests (2 or 3 years) are performed on more than 1500 components.

The method is to write sequences of 0 and 1, corresponding to the absence or presence of an electric charge in a memory, then check whether the alpha particles alter the binary information contained in all memory circuits.

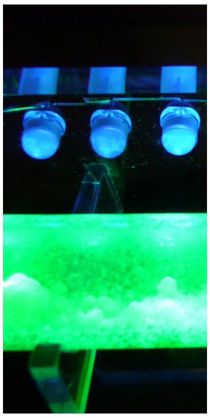
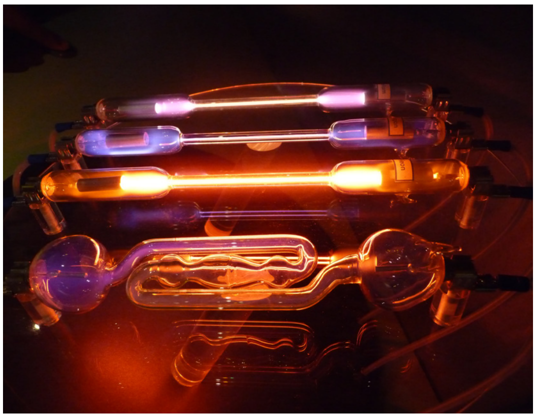
Verification is continuous, the circuitry is scanned several times an hour.

IM2NP Marseille - STI Electronics

LSM Laboratoire Souterrain de Modane

Laboratoire Souterrain de Modane
Carré Sciences

Museum
LITTLE SECRETS of the UNIVERSE

An interactive space dedicated to scientific culture

- Why an underground laboratory?
- "Listen" to cosmic rays with the cosmophone
- Dark Matter search in the EDELWEISS experiment
- NEMO : what is a neutrino?
- The discovery of X-rays & radioactivity
- See natural radioactivity with a cloud chamber
- The little train of natural radioactivity
- Measurements for Environmental Research
- Applications

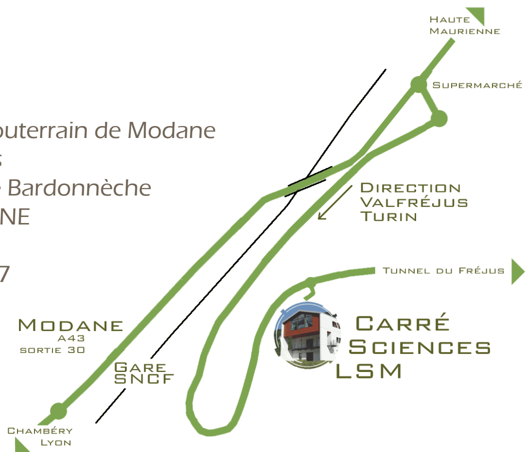
Posters & films, multimedia & virtual tour
Outside: an interactive statue

Free admission
Open to the public:
Monday to Friday from 2pm to 5pm
Groups by reservation (10 & +)
From 10 years
Disabled Access

www.lsm.fr
contact@lsm.fr

Laboratoire Souterrain de Modane
Carré Sciences
1125 route de Bardonnèche
73500 MODANE

04 79 05 22 57



Université Grenoble Alpes
Laboratoire Souterrain de Modane

Archaeological lead

from seabed to the heart of the mountain

Lead shielding

Whether measuring benches equipped with a crystal of germanium or experiments to detect dark matter in the galaxy, the shield close to the detector is the ultimate element that provides protection from radioactive background. As a high atomic number and a very low intrinsic activity are the selection criteria for shielding, lead, and particularly old lead, is very suitable.

The ore of lead (Pb) contains some uranium (period 4.5 billion years) which naturally decays into radioactive ^{210}Pb. Indeed, when the lead is extracted, it is contaminated by natural radioactive elements such as uranium and thorium, whose decays will provide, among other lead 210 with a half-life of 22 years. During the purification of lead by successive skimming, uranium is separated from lead and doesn't contaminate it anymore. The advantage of lead called «archaeological» is that its initial separation occured centuries ago, all the lead 210 has disappeared.

That is why archaeologists found themselves trained in interdisciplinary research of non-radioactive lead!

The quest was successful: a ship from Britain sank, about 400 AD, in the site of the Seven Islands (Ploumanach, Côtes d'Armor). The shell has disappeared, revealing an ancient cargo of lead (270 ingots, 22 tons).

DRASSM (Department of archaeological underwater research)

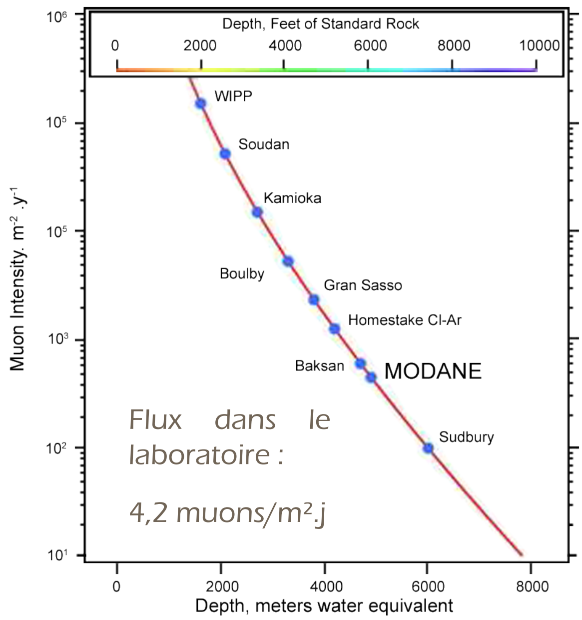
In September 1992, the Heritage Branch of the Ministry of Culture authorised the head of the excavations to make ingots with the least archaeological interest available to physicists. After purification and casting of suitable shielding, the results of measurements made in LSM on this lead indicated a very low level of radioactivity. There is a decrease by a factor 2 of the count rate and no residual radioactivity could be detected.

Given these results, close screens made with archaeological lead are installed on most of the experimental designs of LSM (germanium spectrometers, scintillators, bolometers,...)

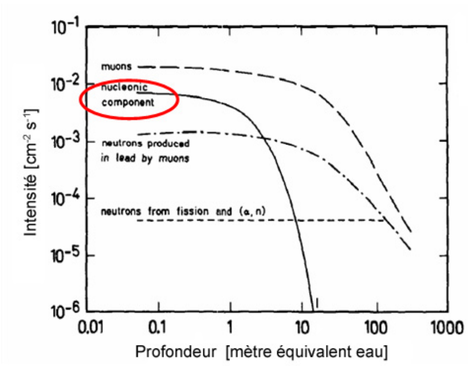
LSM
Laboratoire Souterrain de Modane

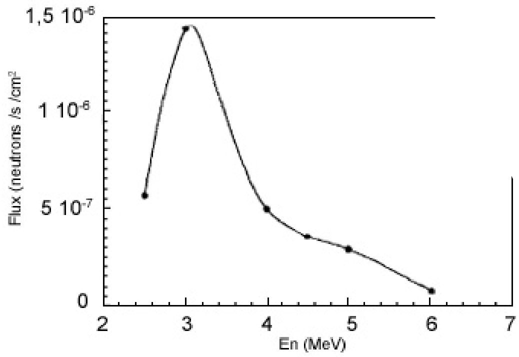
Exceptional Conditions

The LSM is at a depth of 4800meter water equivalent (m.w.e.). This layer of rock reduces by a factor of 2 million the muons of the cosmic rays.



The neutron component of cosmic rays is completely stopped at the laboratory level.





Spectrum of fast neutrons measured at LSM

The neutron rate is reduced by a factor of 1000 relative to the surface. Only neutrons from natural radioactivity and some neutrons created by muons are present in the laboratory.

The neutron flux is 4.10^{-6} neutrons/cm²/s for energies such as 2 MeV < E_n < 6 MeV.

The laboratory is equipped with polyethylene shields that allow the reduction of the thermal neutron rate.

This thermal neutron flux can be monitored in situ during the time of the experiment.

Anti-radon facility

Renewed one and a half times per hour, laboratory air has a radon rate of less than 20 Bq/m³. An air de-dusting system produces 150 m³/h at a rate of 15 mBq/m³, constantly monitored, it is sent around the detectors in overpressure.

Laboratoire Souterrain de Modane

Sedine/News-G_LSM
Spherical Proportional Counter

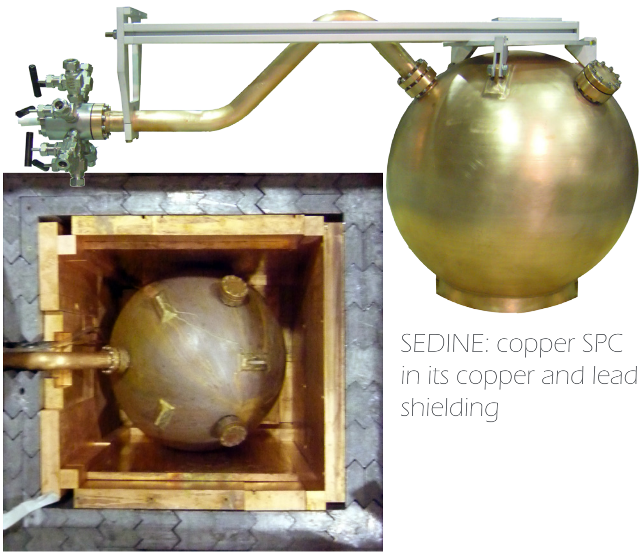
Spherical gaseous detector

SEDINE/NEWS-G_LSM

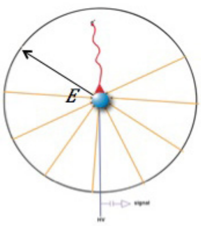
The Spherical gaseous detector (or Spherical Proportional Counter, SPC) is a novel type of particle detector, with a broad range of applications.

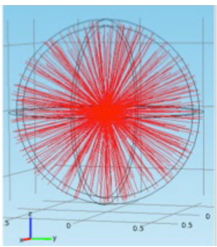
SEDINE, (Ø=60cm) a low background detector installed at LSM, is currently being operated and its aim is dark matter research, in particular Light WIMP's (below 5GeV).

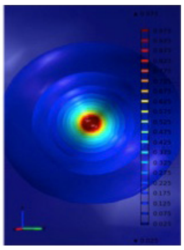
Inner rod and sensor



SEDINE: copper SPC in its copper and lead shielding





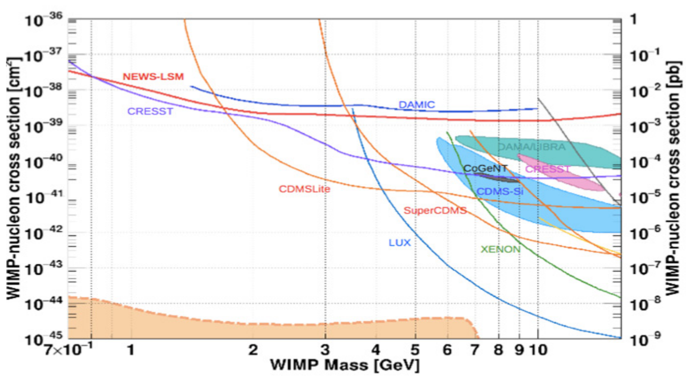


Go to bigger sphere : NEWS_G (New Experiments With Spheres)

and optimised management of radioactive contaminants => NEWS-G_SNOLAB project.

Ø=140 cm detector, blank assembled at LSM and chemical cleaned to remove the deposited Radon daughter from surface before final installation at SNOLAB.

Specific features of these kind of detectors – low capacitance, low threshold, excellent energy resolution, single readout channel in its simplest version, low cost, robustness, flexibility in gas choice and in operating pressure – have led to envisage various applications ranging from Dark Matter detection, Coherent Nuclear Neutrino Scattering study, Double Beta decay search to gamma ray and neutron spectroscopy.



Laboratoire Souterrain de Modane

Low radioactivity measurements with gamma spectrometry

30 years of expertise recognized in ultra low radioactivity.

More than 1500 samples measured per year.

17 hi-purity Germanium detectors,

1 alpha spectrometer,

4 radon detectors,

A radiochemistry laboratory,

A team of researchers and technicians to answewer the needs and develop methods, detectors and dedicated software.

Member of the Becquerel Network (CNRS / IN2P3): Study impact of natural and artificial radioactivity on man and the environment.

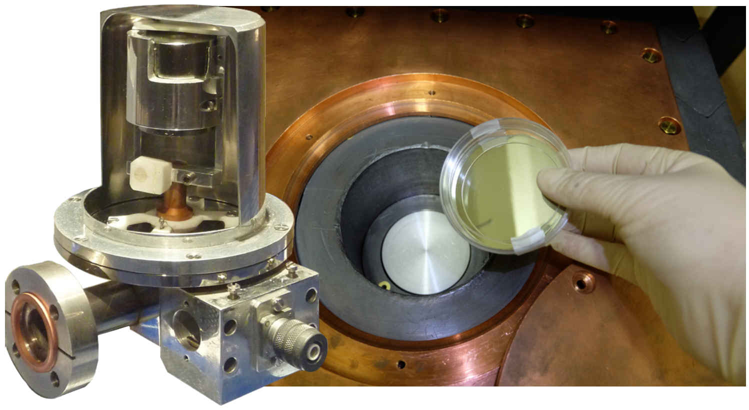
Services, études de faisabilité, méthodologie, conseil, modélisation

Services, feasibility studies, methodology, consultancy, modeling

Quality management system according to NF EN ISO 17025 Approval of the Nuclear Safety Authority.

asn AUTORITÉ DE SÛRETÉ NUCLÉAIRE — ISO 17025

- Improved measurement protocols: reduced measurement time, increased sensitivity.
- Product traceability, non-destructive material control, material characterization.
- Environmental monitoring: sediment cores dating, sedimentation rates, ice cores, anti-fraud measures, Fukushima spill measurements.



Our partners

Most of the operations conducted by the laboratory are covered by a confidentiality undertaking. Industrial partners include STMicroelectronics, IROC Technologies, Canberra Eurysis and Air Liquide.

Liaison with experts from CNRS, CEA and Universities (National and International).

Exchanges with the entrepreneurial network of Rhône-Alpes: Maurienne Expansion, CRITT Savoie, ARDI Rhône-Alpes.

LSM Laboratoire Souterrain de Modane