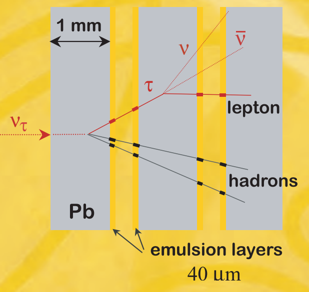
Opera

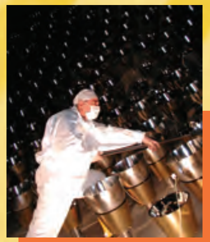


The aim of the experiment is to detect the appearance of the tau neutrinos in a beam that originally was composed almost entirely of muon neutrinos.
The neutrinos, with no electric charge, can be detected only by the particle tracks produced by their interaction in the experimental apparatus. In particular, the tau neutrino produces the tau particle (or tau lepton), along with other particles (hadrons).
The tau particle has an extremely short lifetime and travels typically less than 1 mm before decaying into other particles, for example a muon and two more neutrinos.
The event produced by the neutrno is characterized by a track with a deviation at the point of the decay.
The probability of a neutrino interaction is nevertheless extremely low. To be able to distinguish events of this type, the detector must have a spatial resolution on the order of a micron, as well as large mass.

The OPERA collaboration (Belgium, Bulgaria, Korea, Croatia, France, Germany, Japan, Israel, Italy, Russia, Switzerland, Tunisia, Turkey) has reached this goal by building an experimental apparatus made up of two supermodules.
The detector is made of a sensitive part consisting of 12 million nuclear emulsions assembled with as many thin lead plates to form about 150.000 "bricks" in which the neutrino interacts, and by detectors consisting of scintillating strips which allow the determination, in real time, of the coordinates of the interaction event.
The energy of the muon produced in the neutrino interaction is measured using magnetic fields and tracking devices.
The total mass of the bricks of OPERA is about 1300 tons and this would allow the detection of several tens of tau neutrino events over the next few years.

Icarus

In the upcoming months, Icarus T600 will be completed, a cryogenic detector that uses liquid Argon. The experiment can be defined as an Electronic Bubble Chamber and is designed to provide a wide range of information (spatial resolution, particle identification, 3-D image of the event) and, at the same time, to have the possibility of an electronic readout of the event. The realization of the cryostat represents highly technical undertaking in which are involved a few Italian industries among the most advanced in the cryogenic field. Icarus T600 will detect the neutrino beam and will contribute in providing information on its function and on the values of the oscillation parameters.



Borexino

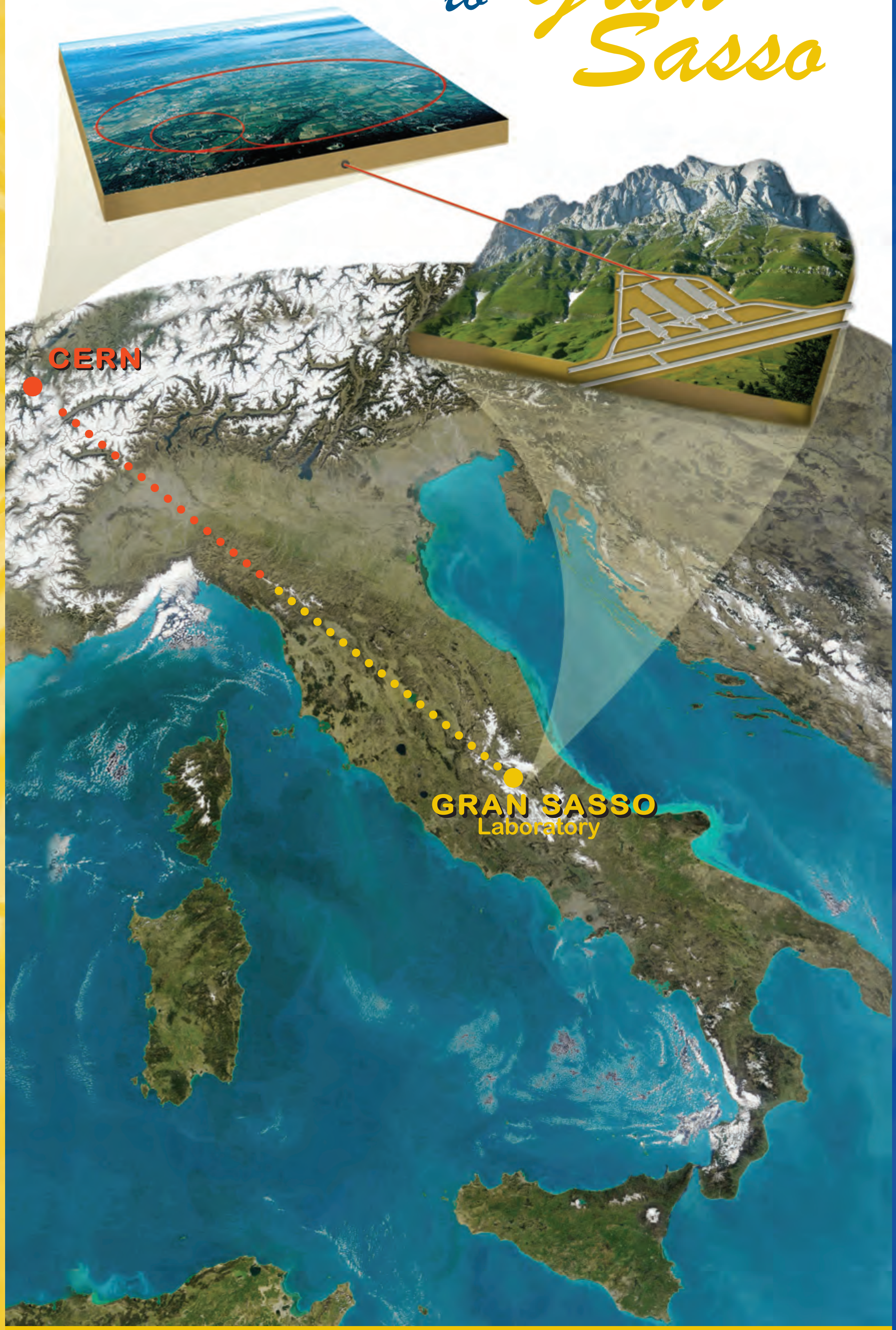
Two other experiments working in the underground laboratory of the Gran Sasso, LVD and BOREXINO, even though realized for other types of research, are able to detect events of the muon neutrino beam from CERN thus giving further informations on the function and the characteristics of the beam.

LVD

grafica Ciccone Francesca

INFN

Cern Neutrinos to Gran Sasso



Every day several billions of muon neutrinos (ν_μ), artificially created at

CERN in Geneva

take about 2 ms to travel the 730 km that separate them from the underground halls of the

Gran Sasso National Laboratory

Within this enormous number of neutrinos scientists seek to detect some which have changed their characteristics along the way from CERN to the Gran Sasso, transforming themselves into tau neutrinos (ν_τ).
Due to the extremely small probability that neutrinos interact with matter, it is necessary to use huge experimental apparata containing material capable of revealing the characteristics of neutrino interactions within it.

Neutrinos

According to the Standard Model of particles, neutrinos are elementary particles without electric charge and with no mass. However, recent experiments have demonstrated that neutrinos do have mass, even if very small. The mass of the electron neutrino would be at least 250,000 times smaller than that of the electron.

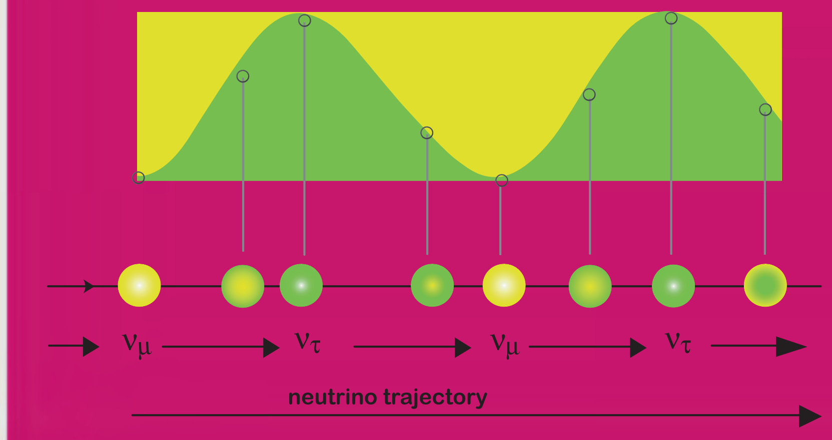
There are three different types of neutrinos in nature: the electron neutrino (ν_e), the muon neutrino (ν_μ) and the tau neutrino (ν_τ) associated respectively to the electron, the muon and the tau particle.

Subject only to the weak and gravitational forces, neutrinos interact rarely with matter, making their detection extremely difficult.

In fact, even though on the Earth's surface 60 billion neutrinos per cm^2 arrive every second from the Sun, it is necessary to construct very large experiments in order to detect at least several of them every day.

Neutrinos are produced in numerous physical processes and are abundant in the Universe, there being around a billion neutrinos for every single proton.
The discovery that they have mass, even if very small, would have strong implications in the understanding of our Universe because it could explain the strong predominance of matter with respect to antimatter, thus shedding light on the origin and evolution of the Universe. Neutrino mass would also have strong implications in the field of elementary particle physics, opening the door on a new era of discoveries…

Neutrino oscillation



According to a theory elaborated by Bruno Pontecorvo at the end of the 50's, neutrinos have the property to transform themselves from one type to another, thus giving way to the oscillation phenomenon.
The demonstration that neutrinos oscillate indicates the presence of a non-zero mass (different for each type) for the neutrinos.
In the hypothesis of the existence of only two types of neutrino, in every instant of its trajectory, the neutrino can be considered a combination of two different states.

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the creation of the *Muon neutrino beam*

The probability of the oscillation depends on the distance travelled by neutrinos and on their energy. Thus the possibility of using a beam of artificially produced neutrinos for which it is possible to define the energy, the type (ν_μ) and the flux, allows the optimization of the transformed neutrinos (ν_τ) detection at Gran Sasso.


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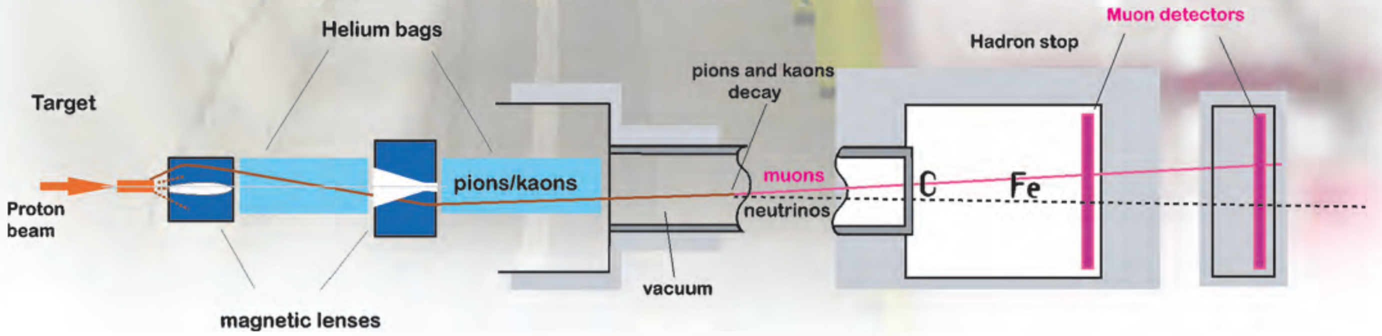
The beam of muon neutrinos is produced at CERN using high energy protons (400 GeV) extracted from the SPS accelerator. About every three seconds 2.4 x 10^{13} protons (24,000 billion) interact with a target made up of 13 cylinders of graphite, each with a diameter of a few millimeters. The product of the interaction is a beam consisting partially of pions (π) and kaons (K), which are focused by means of two magnetic lenses and directed towards the Gran Sasso.



The π and K produced decay along a 1 km long tunnel directed exactly towards the Gran Sasso, giving way to charged particles (muons) and neutrinos (ν), which continue on in the same direction of the particles which generated them.

Thus one obtains an almost pure beam of muon neutrinos (95%) with small traces of anti-muon neutrinos (4%) and electron and anti-electron neutrinos (1%), whose average energy is 17.4 GeV.
The neutrino beam reaches the experimental apparata of the Gran Sasso National Laboratory practically undisturbed, after having travelled 730 km under the Earth's surface.

The neutrino beam, produced at CERN about 100m under the Earth's surface, reaches the Gran Sasso Laboratory after having passed underground with a maximum depth of 11.4 km, due to the curvature of the Earth. At its destination, the neutrino beam will have a diameter of about 2 km.