CNGS: CERN NEUTRINO TO GRAN SASSO

At CERN in Geneva, a beam of protons is sent to interact with a graphite target with the aim to generate a neutrino beam. The neutrinos, produced and directed towards the Gran Sasso Laboratory, reach the experimental halls after traveling underground for 730 km, with a maximum depth of 11.4 km under the surface of the Earth.

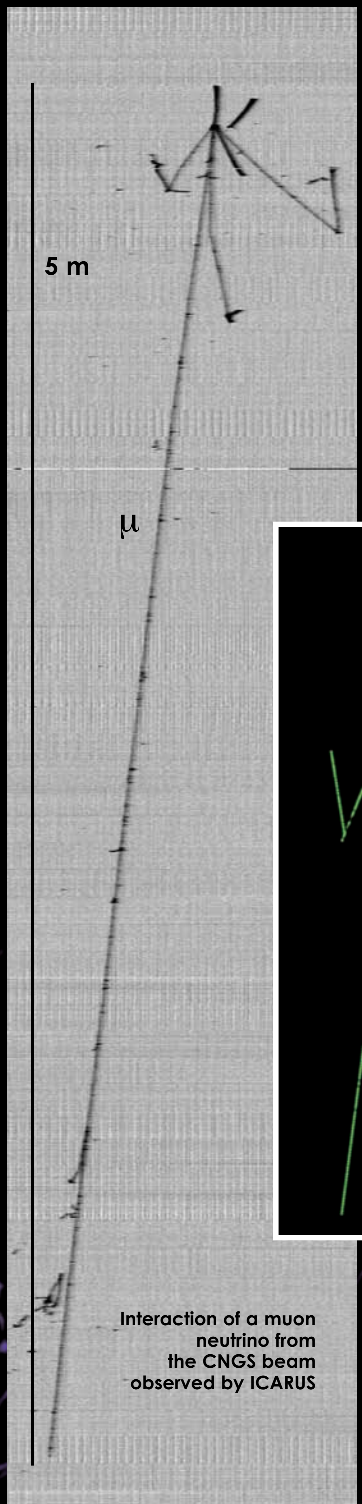
NEUTRINO OSCILLATION

The neutrino is a neutral particle, of extremely small mass, that interacts very weakly with matter. This makes its detection very difficult and it is therefore necessary to construct enormous apparata to increase the probability of an interaction.

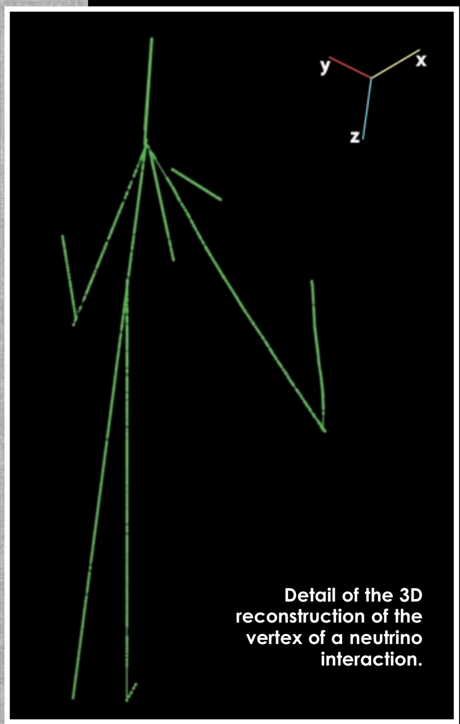
In nature, there are three different types of neutrinos: electron neutrino, muon neutrino and tau neutrino, of different masses, associated respectively to the electron, the muon and the tau particle.

According to the theory of neutrino oscillations, hypothesized for the first time by Bruno Pontecorvo at the end of the 50's, they have the property to change from one type to another while they travel through space or matter.

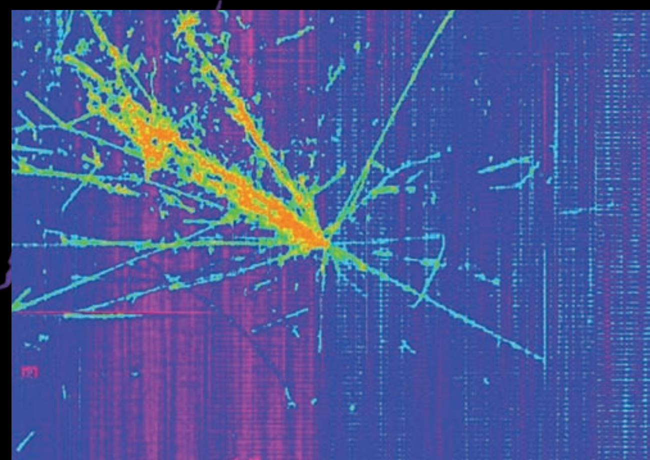
Thanks to the study of these transformations, it is possible to obtain information on the fundamental properties of neutrinos, in particular, on their masses.



Interaction of a muon neutrino from the CNGS beam observed by ICARUS



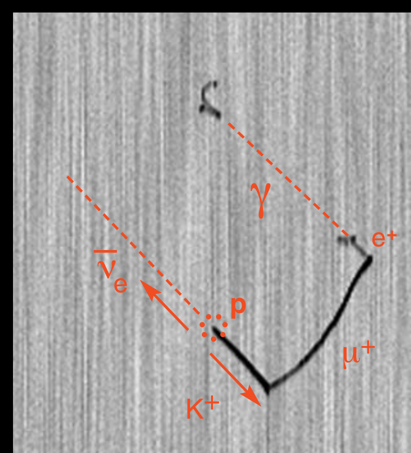
Detail of the 3D reconstruction of the vertex of a neutrino interaction.



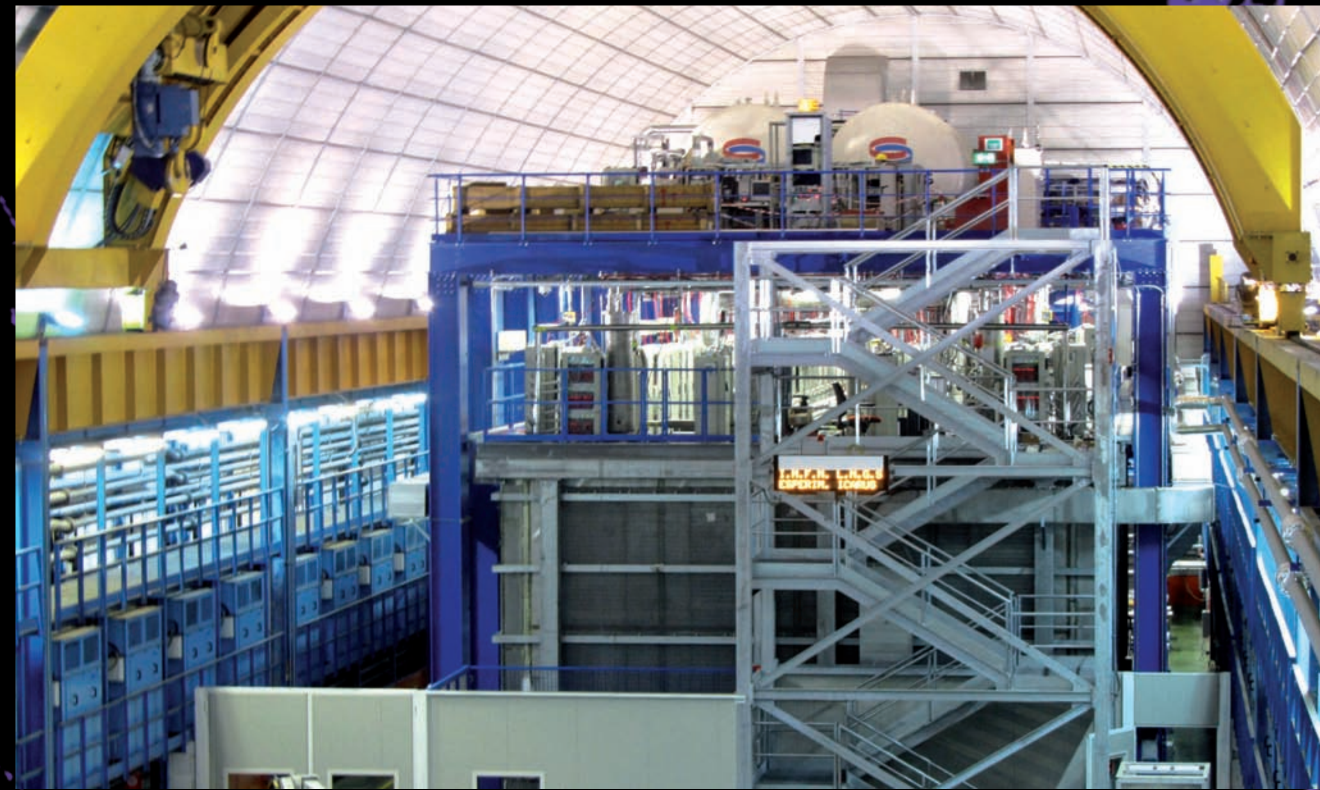
INSTABILITY OF MATTER

A possible decay of a proton or a neutron of the argon into lighter particles could be visualized and identified with extreme precision by the detector.

The quality of the measurements of this kind of apparatus would allow discovering the instability of matter even on the basis of a single observed event.



Computer simulation of a proton decay inside the detector



ICARUS

Imaging Cosmic And Rare Underground Signals

ICARUS (Imaging Cosmic And Rare Underground Signals) is a huge detector containing 600 tons of liquid argon, installed in the Gran Sasso National Laboratory (LNGS) to study "rare events" and, among these, neutrino interactions.

In particular, the experiment is dedicated to the detection of neutrinos from a beam produced at CERN in Geneva and sent to LNGS. Its aim is to study the phenomenon of oscillation, that is, the transformation of a neutrino from one type to another.

Among the tens of billions of neutrinos that reach the Gran Sasso every day, after traveling 730 km underground in about 2 milliseconds, ICARUS expects to detect a few muon neutrino events per day and in all, a couple of tau neutrinos in its foreseen period of data taking.

ICARUS can also study neutrinos from natural sources, in particular solar neutrinos, produced in thermonuclear reactions in the Sun, and atmospheric neutrinos, produced by the interactions of the cosmic rays with the Earth's atmosphere.

Thanks to its high precision in the reconstruction of the interactions and the measurement of their energy, in the future, the ICARUS technology will contribute towards clearing up one of the most important and fundamental questions of physics, linked to the stability of matter: the decay of a proton.

THE DETECTOR

The ICARUS detector is an original idea of Prof. Carlo Rubbia, Nobel prize in physics. In a large volume of liquid argon, 8 x 4 x 20 m^3, maintained at a cryogenic temperature of -186 °C, are located four identical particle detectors (TPC chambers). Each chamber is made up of one metallic wall (cathode) and three planes of wires (anode).

ICARUS uses liquid argon to detect the tracks of the ionizing particles produced by cosmic rays and neutrinos. This technology conceptually represents the evolution of the famous bubble chamber, an instrument consisting of a chamber filled with a liquid (hydrogen or deuterium), in which the passage of particles was detected by photographing the micro-bubbles generated by ionization. The bubbles corresponded, in details, to the paths of the ionizing particles.

ICARUS is able to register events with the same spatial and energy resolution as the bubble chambers, but at extremely higher rate. Due to the characteristics of the wire detector immersed in 600 tons of liquid argon, it is possible to reconstruct three-dimensionally the passage of the particles, reading the electric charges left along the track by the ionization process.

IONIZATION SIGNAL

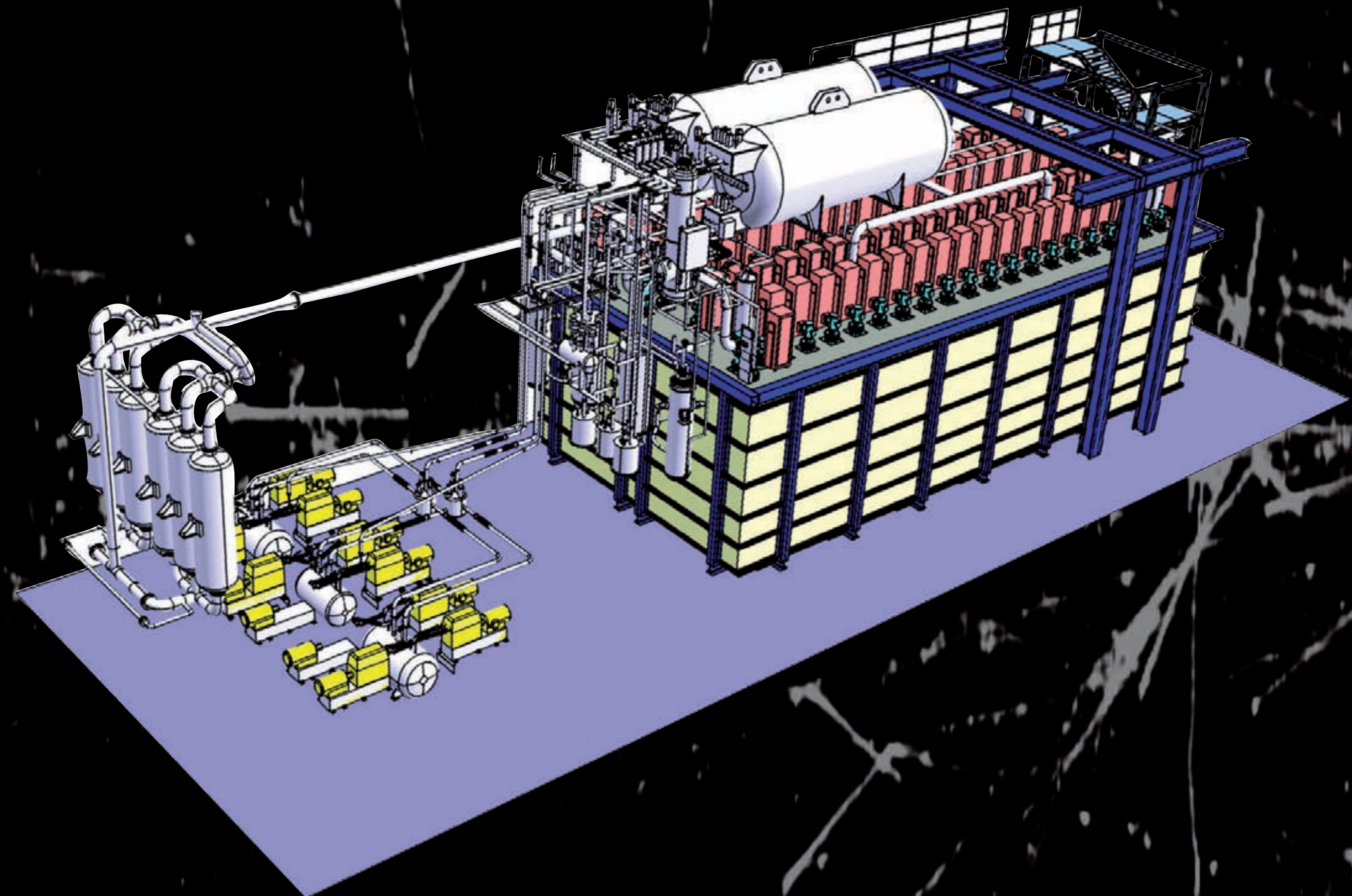
The electrons produced in the ionization move towards the planes of wires under the effect of an electric field, generated by a potential difference of 75 kV applied between the cathode and anode.

Sophisticated electronics registers wire by wire, instant by instant, the electric charges that reach the anode, providing an image of the tracks left by the particles in the argon. The measure of the total charge of the ionization allows to determine the total energy deposited by the interaction.

SCINTILLATION LIGHT

The interaction of the particles, while ionizing the argon, produces scintillation light (photons) that diffuses instantly in all directions.

The scintillation light is detected by photomultipliers immersed in the argon. These devices signal immediately to the electronic acquisition system that an interaction has occurred and that the event must be registered.

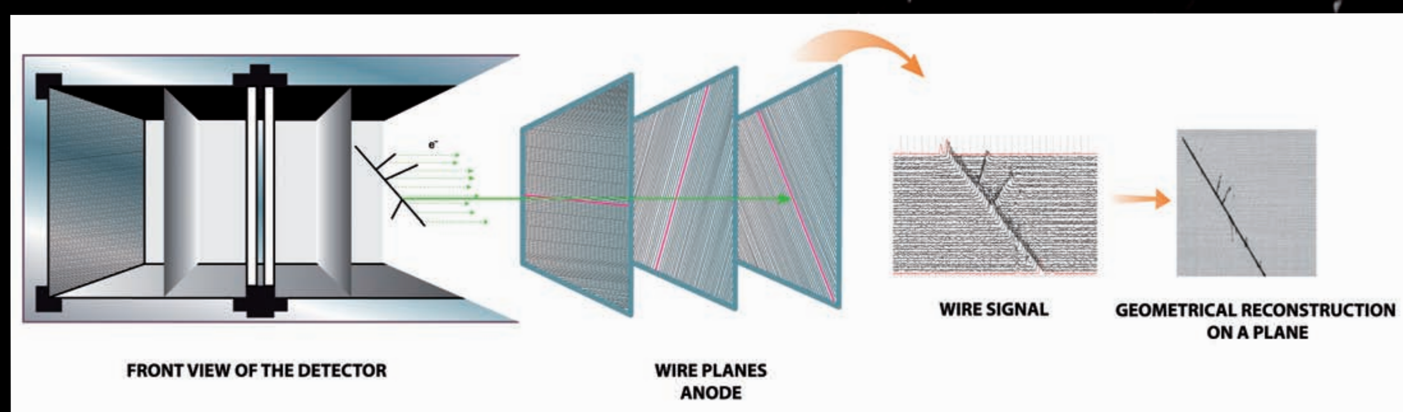


PURITY OF THE ARGON

The purity of the argon and of the materials used in ICARUS is a fundamental requirement for the operation of the detector.

The contaminants in the argon (such as oxygen and water) could capture the ionization electrons, making the measurement impossible. The impurities must therefore be at most a few tens of mg in 600 tons (that is, a few atoms in every 100 billion) to allow the electrons to remain free long enough to reach the wires (a few milliseconds).

To obtain the required purity, recirculation techniques have been developed to filter the argon both in gas phase and in liquid phase.



RECONSTRUCTION OF THE EVENTS

Each anode is made up of three parallel planes of wires of different orientation. Each plane is composed of thousands of steel wires, hair thin (150 μm in diameter), placed at a distance of 3 mm one from the other.

The first two planes measure the current induced by the passage of the ionization electrons near the wires, while the last plane collects the charges, thus allowing the measurement of the energy of the event with high precision.

The three-dimensional reconstruction of the event is possible thanks to two spatial coordinates given by the crossing of the wires and a third obtained by the time required by the electrons to reach the anode.

Each electronic image obtained by the detector is made up of about 60 billion pixels, each one corresponding to an elementary volume of 6 cubic millimeters containing some thousands of electrons of ionization.