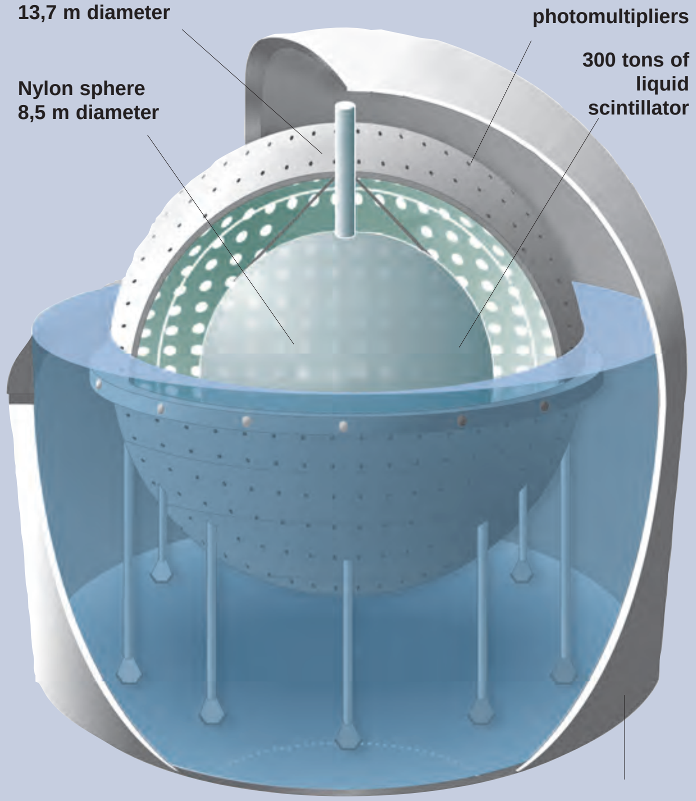
THE DETECTOR

The experiment employs a target mass of 300 tons of pseudocumene, a hydrocarbon produced by oil. This scintillator liquid is contained inside a nylon "balloon" immersed in another 900 tons of the same liquid. All this is contained inside a 13,7 m diameter steel sphere, which in turn is located in a steel tank filled with ultra-pure water, in order to reduce the interference due to particles arising from the natural radioactivity of the mountain rock.

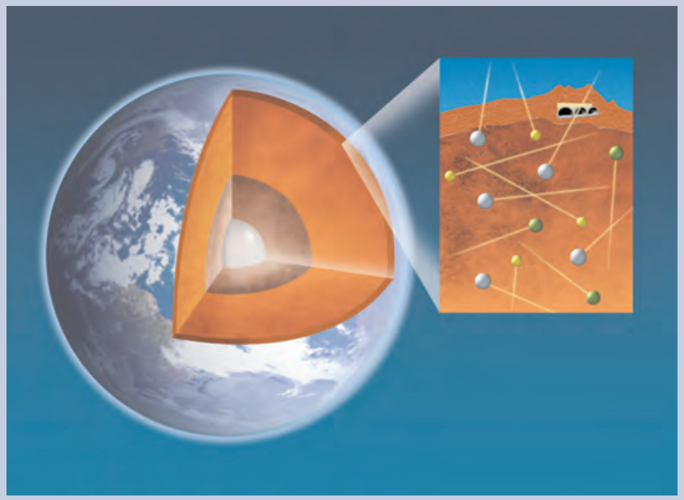
A solar neutrino, while interacting with a pseudocumene molecule inside the target mass, induces the emission of light (scintillation) which is detected by the 2.200 photomultipliers placed on the inner surface of the steel sphere. These sensors produce a current pulse that is registered and analyzed by powerful computers.

Borexino is capable of differentiating between the energies of different events and thus can determine the rate of low energy neutrino interactions.

In order to prevent that the solar neutrino signal (about 40 interactions per day in the target mass) is hidden by the background due to natural radioactive decays, it is extremely important that the scintillator, as well as every other part of the detector, is absolutely pure. With very stringent purification techniques it has been possible to obtain less than one radioactive nucleus in 10.000.000 billion nuclei of the target material (in the rock one can find 1 atom of Uranium and Thorium every million atoms). This high level of purity in a large mass of scintillator was absolutely unthinkable a few years ago.



Though previously impossible, this level of purity enables the study of the lowest energy component of neutrinos emitted by the Sun (up to a few hundred keV), which represents a large fraction of the total number of solar neutrinos. Consider that previously, it was possible to detect only neutrinos with energies above 5.0 MeV - which make up less than 0.01% of all the neutrinos produced by the Sun. Borexino is therefore capable of measuring the flux of all solar neutrinos produced by various reactions. Technical capabilities, as well as continuous and accurate care, have made it possible.



The detector is able to register not only solar neutrinos but also neutrinos produced in the explosion of a Supernova (which is the last phase of life of a massive star) and neutrinos from the Earth.
As a matter of fact, our planet emits a considerable quantity of neutrinos due to radioactivity present in the Earth's crust where nuclear reactions are the main cause of the high temperature of the inner layers of the planet. These reactions can be studied by detecting the neutrinos produced. The area where Gran Sasso lab is located is particularly suitable to this type of observation because of its distance from nuclear power plants. In fact, geo-neutrinos can be confused with the as much innocuous neutrinos produced in the nuclear plants.

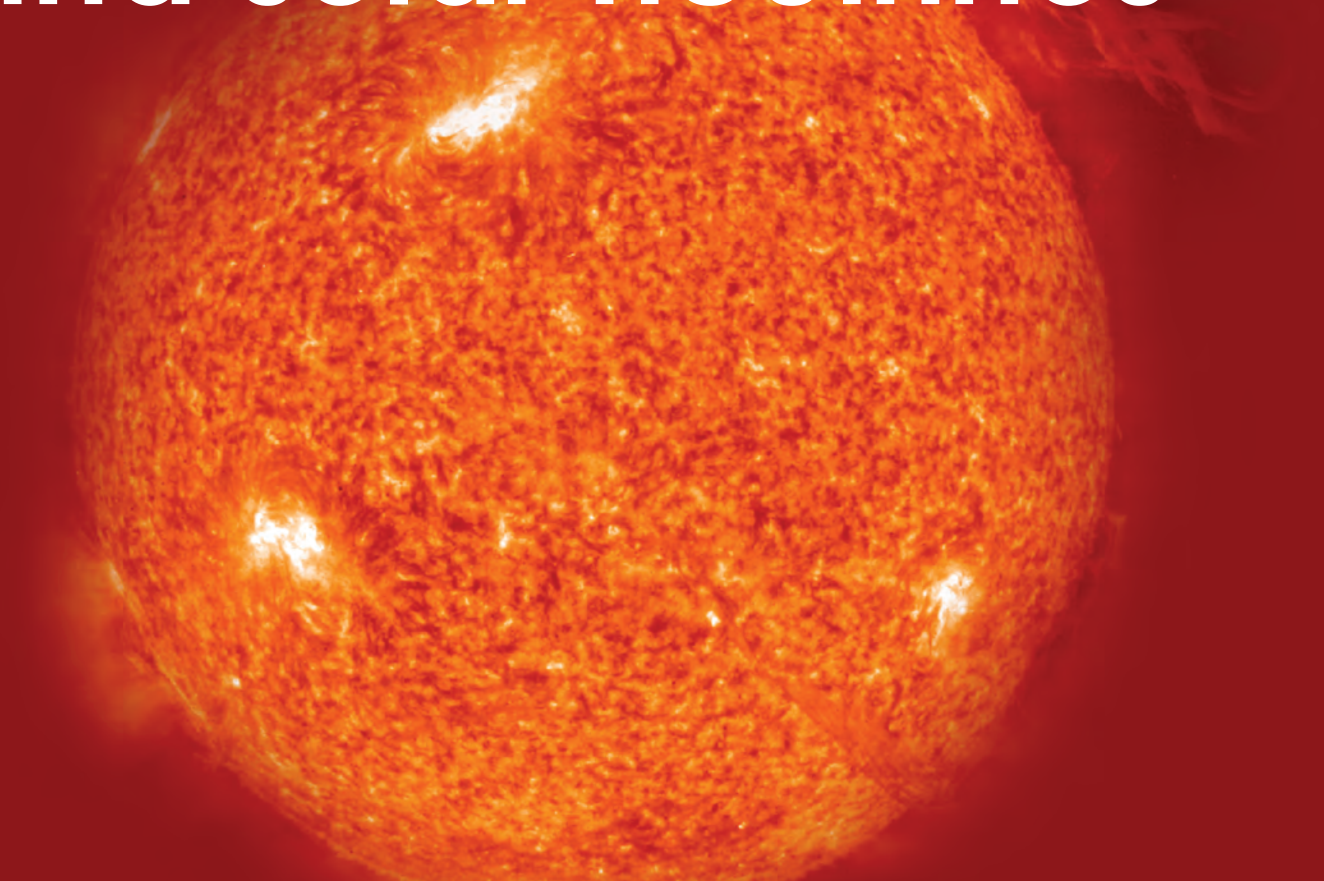
The study of these processes will allow scientists to better comprehend how our Universe works, how it evolves and what its destiny will be.

BOREXINO is realized by an international collaboration mainly among Italy, USA, Germany, France and Russia.

grafica Ciccone Francesca

INFN

BOREXINO
and solar neutrinos



All matter around us is mainly constituted by three particles: protons and neutrons, which make up the atomic nucleus, and electrons, which form the atomic shell.
The Universe, however, reveals a great deal of other particles, present from its very beginning, immediately after the Big Bang.

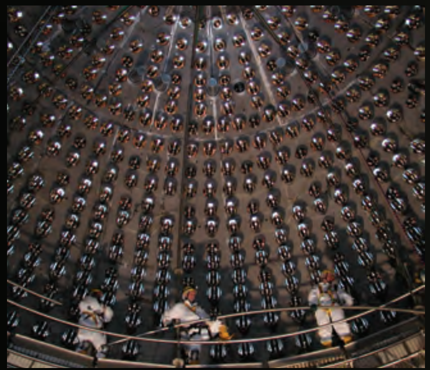
Among the still existing particles, the strangest and most elusive is the neutrino.

Neutrinos, normally indicated with the Greek letter n, are neutral particles with a very low mass, which permeate the Universe and are constantly produced in many processes involving radioactive decays as well as thermonuclear fusion in stars.
The most powerful neutrino source near the Earth is the Sun, 150 million km away, which is able to produce a great amount of them: every second about 60 billion neutrinos reach every cm^2 of the Earth!

Because they interact very weakly, they can easily penetrate huge thicknesses of matter while keeping their original features, thus allowing the study of phenomena directly connected to their origin.

How does the Sun produce neutrinos? In the core of the Sun, where the temperature reaches 15 million °C, a series of nuclear reactions produce neutrinos.
The main process, responsible for 98% of the solar energy production, is the fusion of four protons leading to the formation of a helium nucleus with the emission of a great amount of energy consisting of gamma rays, heat and neutrinos.
While photons produced in the fusion take some hundred thousand years to travel across the 700.000 km solar radius, neutrinos take a bit more than 2 seconds. After an additional 8 minutes they reach the Earth, providing precious information concerning energy production processes in the Sun and stars in general.

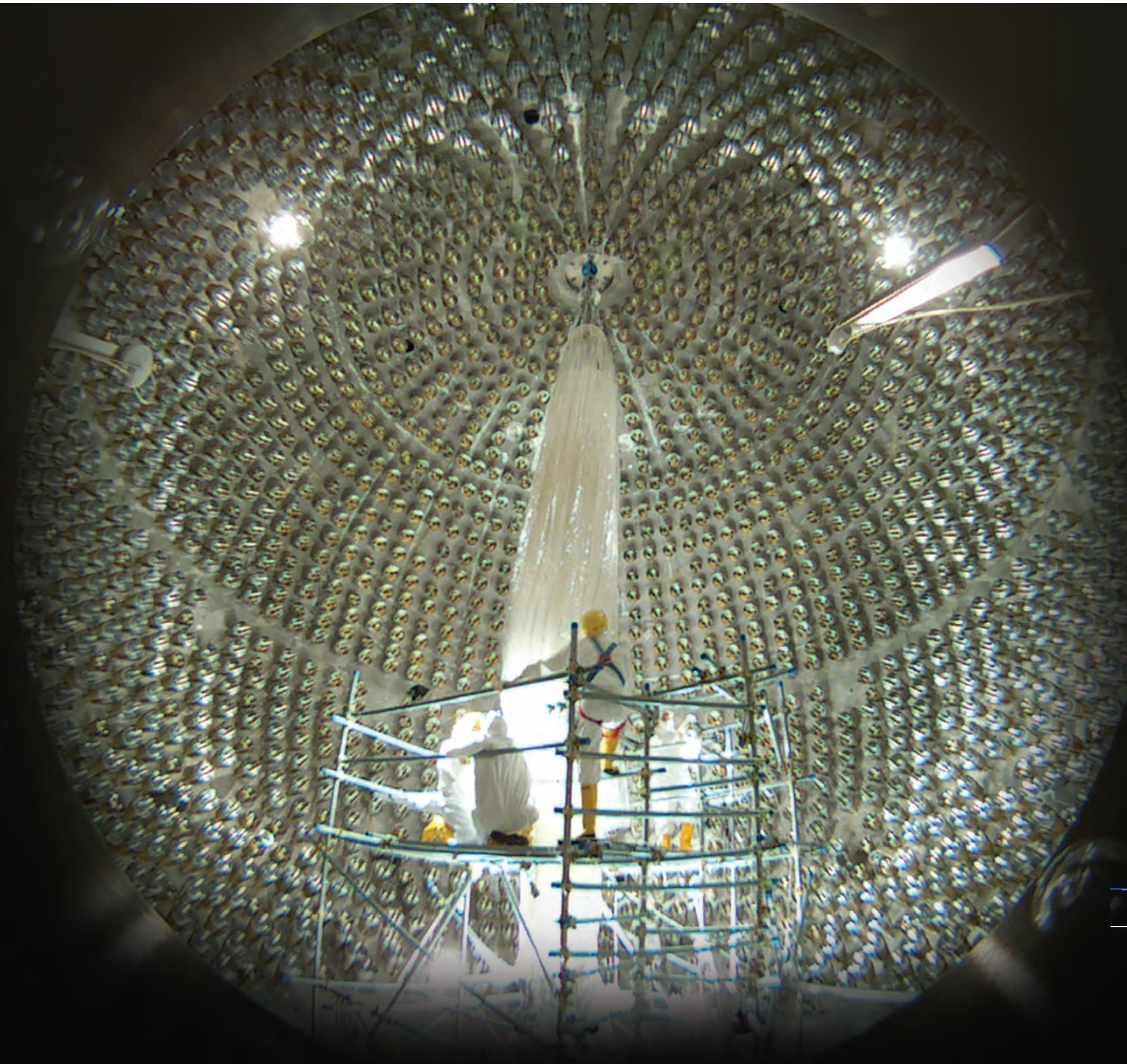
THE SOLAR NEUTRINO PROBLEM

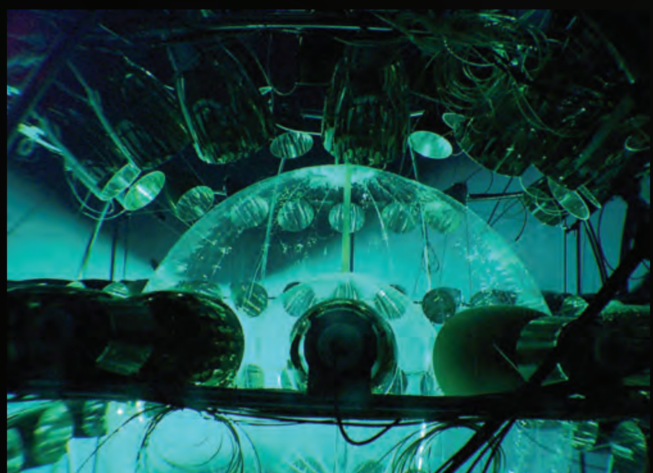


The experimental observation of neutrinos is extremely complex due to the very low interaction rates of neutrinos with matter. In order to face this problem huge experimental apparata have been realized and placed in underground areas in order to avoid the background generated by cosmic rays.

The first proposal to observe solar neutrinos in order to study the Sun, goes back to 1964 with R. Davis and J. Bachall; in 1968 they had the first experimental results.

Amazingly, the number of neutrinos observed in this and other experiments carried out over several years has always been lower than the one assumed by theory. This anomaly, commonly known as “solar neutrino problem”, has inspired new experimental proposals for the study of solar neutrinos such as GALLEX/GNO and BOREXINO, installed at Gran Sasso National Laboratory.





As already mentioned, the Sun produces energy through nuclear fusion reactions. Among these is the Berillium reaction (e- + ^{7}Be --> ^{7}Li + ne), which produces specific neutrinos.

BOREXINO is a detector realized mainly to study these particular solar neutrinos in real time, which, until now, no other detector on Earth has been able to measure. Actually, thanks to Borexino, it will be possible to study hypothetical reactions never before detected; for example the so-called CNO cycle (carbon, nitrogen, oxygen), which, though it does not play a predominate role in our Sun’s reactions, becomes of extreme importance in massive stars. Their detection could contribute towards answering the question: how do stars burn?

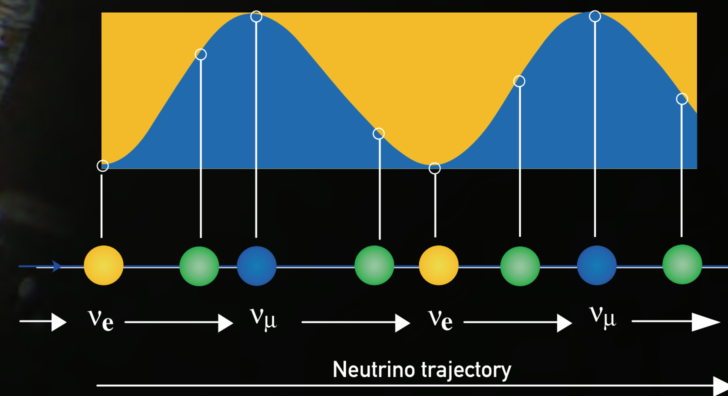
NEUTRINOS OSCILLATION

All the experiments carried out up to now, indicate that the solar neutrinos actually detected are considerably less than those expected. The solution to this mystery is neutrino oscillation. This phenomenon considers the possibility that the three types of existing neutrinos (ne nm nt) can change their “flavor” while traveling.

Neutrinos produced in the Sun are electron neutrinos; while traveling the distance to the Earth part of them will “oscillate” in muon neutrinos (nm).

Since the experimental apparata devoted to study solar neutrinos are designed to detect only electron neutrinos (ne), not other flavors, there will be a relevant decrease in the amount of neutrinos measured on the Earth. Such decrease explains the difference between the expected value of theoretical models and the experimental data.

The neutrino oscillation phenomenon allows us to deduce that these particles, although very small, do indeed have a mass.



GALLEX/GNO

The GALLEX/GNO experiment, carried out from 1991 to 2002, was fundamental in measuring the flux of neutrinos produced in the Sun. The detector consisted of a huge container filled with 100 tons of gallium chloride. Each time a neutrino interacted with the gallium, it produced a germanium atom. The periodic extraction of germanium atoms, through radiochemical techniques, allowed to determine the number of interactions of neutrinos in the apparata.

The number of neutrinos detected by GALLEX/GNO was about 55% the value expected by the Solar Standard Model. This deficiency was explained as due to oscillation, which allows electron neutrinos originating in the Sun to change their type (oscillate) along the way to Earth, becoming no longer detectable by the experiment.