Ufficio Comunicazione

PRESS RELEASE

August 20, 2007

Gran Sasso performs a cat scan of the Sun

The international experiment Borexino, which is being conducted at the underground laboratories of the Istituto Nazionale di Fisica (*INFN, Italy's National Institute of Nuclear Physics) in the Gran Sasso massif, has observed extremely low-energy neutrinos emanating from the Sun, at a rate of dozens events a day. This is the first time that solar neutrinos have been observed that have an energy equal to or lower than 1 MeV (mega electronvolt) and which are believed to be produced by nuclear reactions that occur within the Sun. It's as if the physicists in the underground laboratories in Gran Sasso were performing a sort of CAT scan of the Sun to analyse its behaviour, using neutrinos, which are "probes" of extremely deep penetration and which provide us with information on what occurs within the Sun.*

Visual materials for journalist available at http://www.infn.it/comunicazione/media/

The international experiment "Borexino", which is being conducted at the laboratories of the *Istituto Nazionale di Fisica Nucleare* (INFN, Italy's National Institute of Nuclear Physics) in the Gran Sasso massif, has already produced results that contribute to the knowledge of how the Sun functions.

For the first time, low-energy neutrinos (energy lower than 1 MeV, that is, one million electronvolts) coming from large nuclear chain reactions thought to originate in the Sun's core have been observed in real time. Until now, only high-energy neutrinos (greater than 5 MeV) caused by a different and relatively rare nuclear chain reaction had been observed in experiments performed in Canada and in Japan.

The results of Borexino will be fundamental for the study of the nature of neutrinos and for confirming the Standard Solar Model, developed a number of years ago to describe how the Sun shine.

These preliminary observations in themselves constitute a success in the field of Physics worldwide.

The experiment is also important because, to leave the Sun's core, neutrinos must pass through solar material, and the study of the intensity and properties of the neutrinos that reach the Earth provides information on the characteristics of the solar material itself.

It's as if physicists working at the underground laboratories in Gran Sasso were performing a sort of CAT scan of the Sun, analysing its behaviour using neutrinos, which act as deep-penetration "probes" which directly bring us information on what occurs in the innermost part of the Sun. In fact, neutrinos, which are produced by a small region around the Sun's core, leave the core unhindered, which requires approximately 2 seconds immediately after being produced, compared to, for example, the 100,000 years required for the same process by photons, which undergo many interactions that completely alter the information they initially carry.

Borexino will also allow "geoneutrinos" to be observed, that is, neutrinos coming from the centre of the Earth, where nuclear reactions are the main cause of the high temperature in the planet's inner strata. These reactions can only be studied by observing the neutrinos that they emit. Because there are no nuclear plants in the vicinity of Gran Sasso, this area is particularly suited to this type of observation: in fact, geoneutrinos cannot be distinguished from those neutrinos (also innocuous) coming from the nuclear reactions produced by a nuclear plant..

The "Borexino" experiment is the result of years of technological research which has allowed materials to be selected and gas and liquid to be purified of radioactive substances, at a level never before reached. These technological developments will have a great impact on the electronic-components and pharmaceutical industries.

How Borexino works

Borexino is being conducted by approximately 100 professionals, including physicists, engineers, and technicians, with the INFN acting as the main financial sponsor, with important contributions from United States , Germany , France, Russia.

The experiment involves the INFN sections and the Universities of Milan, Genoa, and Perugia; the Laboratories of Gran Sasso; the *Technische Universität* of Munich; the Max Planck Institute of Heidelberg; the french APC; the Jagellonian University of Cracow; JINR of Dubna (Russia); the Kurchatov Institute of Moscow; Princeton University and Virginia Polytechnic Institute in the United States.

Borexino will continue to collect data for at least 10 years, the duration of one solar cycle.

Seen from the outside, the detector consists of a dome, 16 metres in diameter, whose interior structure is similar to that of a Russian *matrioska* doll, with one doll fitting within another. In fact, situated within the dome is a mass of 2,400 tons of highly purified water which acts as the first shield against the radioactive emissions of the rocks and the environment that surround the facility and as a detector of the scarce residues of cosmic rays that cross the more than one thousand meters of rock under which the laboratory is located.

Within the volume of water is a steel sphere which contains 2,200 photomultipliers, that is, apparatuses that can detect the flashes of light produced by neutrino collisions. The sphere contains one thousand tons of pseudocumene, a hydrocarbon used to shield the sensitive part of the facility.

Finally, the innermost core of the facility contains 300 tons of scintillating liquid within a nylon sphere. The water and hydrocarbon shields, as well as the scintillator, have a never-before-attained level of radiopurity.

The way in which this apparatus functions can be likened to a pinball machine: when the neutrinos "collide" with the electrons of the scintillator, they transfer their part of the incident energy, causing a flash of light in the liquid. These flashes are seen by the photomultipliers, which is possible because the nylon spheres within the facility are transparent. The apparatus allows the energy of the collisions of the incident neutrinos to be measured and the position of the collisions to be determined.

The CTF apparatus

To prevent disturbances in the observations of such evasive particles as low-energy neutrinos, Borexino researchers had to ensure that the natural radioactivity of the materials used to construct the detector was reduced to “unnatural” levels, in other words, a level of radioactivity much lower than the levels detected in nature.

To this end, after more than 8 years of research, a new technology was developed. The researchers first selected those materials that most responded to these characteristics and then, using this technology, purified the liquids and gases of radioactive residues. The results attained are extraordinary: for each gram of substance used, they arrived at a level of radioactivity of 0.0000000000000001. The nitrogen used in the experiment has a radioactive emission that is approximately one billion times lower than that of nitrogen found in nature.

To measure such low counts, a detector called Counting Test Facility (CTF) was constructed, which contains one thousand tons of extremely pure water and five tons of liquid detector. Having reached this degree of purity and being able to measure it constitute a technological success that could adopted by industries that require particularly pure substances, such as the pharmaceutical or electronic components industries.

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