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Double Chooz: second neutrino detector completed

The CNRS and CEA have completed the construction of a second neutrino detector near the Chooz nuclear power plant (Ardennes, northeastern France). Its measurements will supplement those of the first detector, which was installed five years ago as part of the Double Chooz project to study the characteristics of neutrinos — nearly undetectable elementary particles that are produced in abundant quantities by the Sun and in nuclear reactors. Located 400 meters from the plant's reactor cores, this second detector is inaugurated on September 25, 2014, in a ceremony attended by CNRS and CEA representatives, as well as local government officials, who have given the project their active support.

Scheduled for launch later this autumn, the detector will be used to capture neutrinos produced in the cores of the plant's two reactors, 400 meters away. Its data will be compared with that of the first detector, located one kilometer from the reactors. The researchers expect to see a difference in composition due to the fact that neutrinos change characteristics as they move along their paths. The Double Chooz project was conceived to improve understanding of this phenomenon, and thus contribute to the Standard Model of particle physics.[1]

Studying the "flavors" of neutrinos at nuclear power plants

Tiny nuclear particles one millionth the weight of electrons, neutrinos are a known by-product of "beta" nuclear reactions. They are produced in active nuclear reactors, but also in the Earth's crust and mantle, the human body and stars — the Sun is the most abundant source of neutrinos in our environment. These particles come in three forms, or what physicists call "flavors," but they have a surprising capacity, known as "oscillation," to change flavor while in flight, depending on their energy and the length of their path. These "oscillations" are determined by three parameters, called "mixing angles". Two of these are known with good precision, but the third — which is much smaller and thus difficult to measure accurately — is the subject of the Double Chooz experiment.

The Double Chooz project

The Double Chooz project was launched in 2003 as an international collaboration[2] initiated by researchers from the CNRS and CEA. In 2009, a first detector was installed in an underground laboratory built by EDF in the 1990s, one kilometer from the plant's reactor cores. In 2011, the system was able to detect the transformation of neutrinos in flight, and this discovery was confirmed the following year by other international experiments. Since then, researchers around the world have been competing to measure the third mixing angle with ever-greater precision. Its second detector will give the Chooz site a distinct advantage, and should make it possible to measure the missing parameter with a 10% margin of error within three years.

Like the first detector, this second installation consists of a cylindrical 10,000-liter tank filled with a blend of mineral oils. This massive volume is necessary because neutrinos have very little interaction with matter: they pass through walls, mountains and living beings virtually unaffected. The only way to detect them is to place an enormous quantity of matter in their path. The new detector will only capture about 300 neutrinos out of the hundreds of billions of billions that will pass through it every day. In addition, the installation is buried under 50 meters of rock and surrounded by several concentric barriers to shield it from cosmic radiation and ambient natural radioactivity.

A comparison of the results of Double Chooz with those from similar neutrino detectors in China (Daya-Bay) and South Korea (RENO), as well as particle accelerators (T2K in Japan), will facilitate future projects to investigate the origins of the matter-antimatter asymmetry observed in the Universe. According to the Standard Model theory, which characterizes the behavior of matter since the birth of the Universe 13.7 billion years ago, the Big Bang should have created as much matter as antimatter. But today there seems to be an overabundance of matter, and neutrinos could well hold the key to this mystery.

The laboratory housing this second detector was funded by the ERDF (European Regional Development Fund), the Champagne-Ardenne region, the Ardennes *département*, the Rives de Meuse municipal federation, EDF, the CNRS and CEA.

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[1]*The Standard Model of particle physics is the scientific theory that describes the structure of matter on the scale of its most elementary components, and the way these elementary particles interact with each other.*

[2] *Comprising 30 institutes in Germany, Brazil, Spain, the US, France, Japan and Russia.*

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Illustrations

Overview of the second detector with, in the foreground, the mouth of the detector tank before the installation of its cover.

Photomultipliers on the inside of the tank.
The small number of neutrinos that interact with the liquid in the detector cause very faint vibrations in the matter, which produces light. These light signals are detected and multiplied by the "eyes" lining the walls of the tank.

These images are part of a photo series available from the CNRS Photothèque (photo library), phototheque@cnrs.fr