'Neutrino oscillation': Particle chameleon caught in the act of changing

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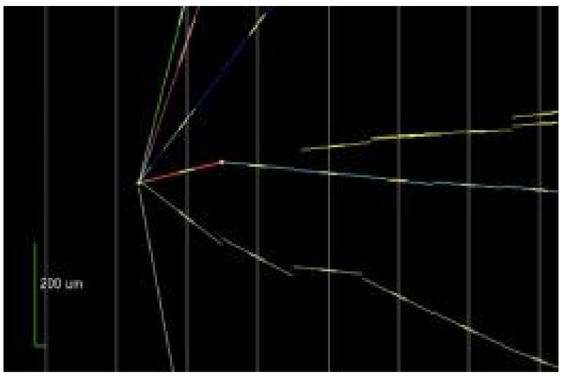

(PhysOrg.com) -- Researchers on the OPERA experiment at the INFN's Gran Sasso laboratory in Italy today announced the first direct observation of a tau particle in a muon neutrino beam sent through the Earth from CERN, 730km away. This is a significant result, providing the final missing piece of a puzzle that has been challenging science since the 1960s, and giving tantalizing hints of new physics to come.

The neutrino puzzle began with a pioneering and ultimately Nobel Prize winning experiment conducted by US scientist Ray Davis beginning in the 1960s. He observed far fewer neutrinos arriving at the Earth from the Sun than solar models predicted: either solar models were wrong, or something was happening to the neutrinos on their way. A possible solution to the puzzle was provided in 1969 by the theorists Bruno

Pontecorvo and Vladimir Gribov, who first suggested that chameleon-like oscillatory changes between different types of neutrinos could be responsible for the apparent neutrino deficit.

Several experiments since have observed the disappearance of muon-neutrinos, confirming the oscillation hypothesis, but until now no observations of the appearance of a tau-neutrino in a pure muon-neutrino beam have been observed: this is the first time that the neutrino chameleon has been caught in the act of changing from muon-type to tau-type.

Antonio Ereditato, Spokesperson of the OPERA collaboration described the development as: "an important result which rewards the entire OPERA collaboration for its years of commitment and which confirms that we have made sound experimental choices. We are confident that this first event will be followed by others that will fully demonstrate the appearance of neutrino oscillation".

"The OPERA experiment has reached its first goal: the detection of a tau neutrino obtained from the transformation of a muon neutrino, which occurred during the journey from Geneva to the Gran Sasso Laboratory," added Lucia Votano, Director Gran Sasso laboratories. "This important result comes after a decade of intense work performed by the Collaboration, with the support of the Laboratory, and it again confirms that LNGS is a leading laboratory in Astroparticle Physics".

The computer display of the first tau-neutrino candidate event is shown above. One can see a detail of the region around the point of interaction of the neutrino (coming from the left of the figure) producing several particles identified by their tracks in the brick. The detection of the track with a "kink" is the likely signature of a tau-neutrino interaction, with a probability of about 98%. The picture describes a volume of only a few cubic millimetres, but rich of valuable information for the

OPERA physicists.

The OPERA result follows seven years of preparation and over three years of beam provided by CERN. During that time, billions of billions of muon-neutrinos have been sent from CERN to Gran Sasso, taking just 2.4 milliseconds to make the trip. The rarity of neutrino oscillation, coupled with the fact that neutrinos interact very weakly with matter makes this kind of experiment extremely subtle to conduct. CERN's neutrino beam was first switched on in 2006, and since then researchers on the OPERA experiment have been carefully sifting their data for evidence of the appearance of tau particles, the telltale sign that a muon-neutrino has oscillated into a tau-neutrino. Patience of this kind is a virtue in particle physics research, as INFN President Roberto Petronzio explained:

"This success is due to the tenacity and inventiveness of the physicists of the international community, who designed a particle beam especially for this experiment," said Petronzio. "In this way, the original design of Gran Sasso has been crowned with success. In fact, when constructed, the laboratories were oriented so that they could receive particle beams from CERN".

At CERN, neutrinos are generated from collisions of an accelerated beam of protons with a target. When protons hit the target, particles called pions and kaons are produced. They quickly decay, giving rise to neutrinos. Unlike charged particles, neutrinos are not sensitive to the electromagnetic fields usually used by physicists to change the trajectories of particle beams. Neutrinos can pass through matter without interacting with it; they keep the same direction of motion they have from their birth. Hence, as soon as they are produced, they maintain a straight path, passing through the Earth's crust. For this reason, it is extremely important that from the very beginning the beam points exactly towards the laboratories at Gran Sasso.

"This is an important step for neutrino physics," said CERN Director General Rolf Heuer. "My congratulations go to the OPERA experiment and the Gran Sasso Laboratories, as well as the accelerator departments at CERN. We're all looking forward to unveiling the new physics this result presages."

While closing a chapter on understanding the nature of neutrinos, the observation of neutrino oscillations is strong evidence for new physics. In the theories that physicists use to explain the behaviour of fundamental particles, which is known as the Standard Model, neutrinos have no mass. For neutrinos to be able to oscillate, however, they must have mass: something must be missing from the Standard Model. Despite its success in describing the particles that make up the visible Universe and their interactions, physicists have long known that there is much the Standard Model does not explain. One possibility is the existence of other, so-far unobserved types of neutrinos that could shed light on Dark Matter, which is believed to make up about a quarter of the Universe's mass.

The OPERA Collaboration presently includes about 170 researchers from 33 institutions and 12 countries.

More information: The OPERA experiment - operaweb.lngs.infn.it/spip.php?rubrique39

Please see a related AFP story below

Physicists solve mystery of missing neutrinos

Scientists in Europe announced Monday they had likely solved the case of the missing neutrinos, one of the enduring mysteries in the subatomic universe of particle physics.

If confirmed in subsequent experiments, the findings challenge core precepts of the so-called Standard Model of physics, and could have major implications for our understanding of matter in the universe, the researchers said.

For decades physicists had observed that fewer neutrinos -- electrically neutral particles that travel close to the speed of light -- arrived at Earth from the Sun than solar models predicted.

That meant one of two things: either the models were wrong, or something was happening to the neutrinos along the way.

At least one variety called a muon-neutrino was actually seen to disappear, lending credence to a Nobel-winning 1969 hypothesis that the miniscule particles were shape-shifting into a new and unseen form.

Now scientists at Italy's National Institute for Nuclear Physics have for the first time observed -- with 98 percent certainty -- what they change into during a process called neutrino oscillation: another type of particle known as tau.

"This will be the long-awaited proof of this process. It was a missing piece of the puzzle," said Antonio Ereditato, a researcher at the Institute and spokesman for the OPERA group that carried out the study.

"If true, it means that new physics will be required to explain this fact," he said by phone.

Under the prevailing Standard Model, neutrinos cannot have mass. But the new experiments prove that they do.

One implication is the existence of other, as yet unobserved types of neutrinos that could help clarify the nature of Dark Matter, which is believed to make up about 25 percent of the universe.

"Whatever exists in the infinitely small always has repercussions in the infinitely big," Ereditato said.

"A model which could explain why the neutrino is so small without vanishing will have profound implications for the understanding of our universe -- how it was, how it evolved, and how it will eventually die."

The transformation of the neutrino occurred during a programmed journey from Geneva to the Gran Sasso Laboratory near L'Aquila in central Italy.

The European Organization for Nuclear Research (CERN) provided a laser-like beam composed of billions upon billions of muon neutrinos that took only 2.4 milliseconds to make the 730-kilometer (453-mile) trip.

The rarity of neutrino oscillation, coupled with the fact that the particles interact only weakly with matter, bedeviled the scientists.

Unlike charged particles, neutrinos are not sensitive to the electromagnetic field normally used by physicists to bend the trajectory of particle beams.

They can also pass through matter, and thus keep the same direction of motion from their inception.

It took nearly four years from the time the beam was switched on to witness the muon-to-tau metamorphosis.

Provided by CERN