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Published: Friday, July 21, 2000

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SCIENCE

Scientists discover missing piece of nature's building blocks

Tau neutrino detection brings physicists closer to solving puzzle

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JAMES GLANZ NEW YORK TIMES

What many physicists consider to be one of the last pieces of the theoretical puzzle that explains the structure of matter has been detected at the Fermi National Accelerator Laboratory near Chicago.

A international team of scientists, including researchers from the University of Minnesota, will announce today that they have detected the tau neutrino, considered to be the most elusive member of nature's most ghostly family of particles, the neutrinos.

The team of 54 physicists from institutions in the United States, Japan, South Korea and Greece used the world's most powerful particle accelerator, Fermilab's Tevatron, to fire an estimated 100 trillion tau neutrinos into an advanced emulsion similar to photographic film.

Four of those neutrinos produced minute but clearly recognizable streaks in the emulsion.

Although their existence had been suspected for 25 years, tau neutrinos had escaped detection because it takes a large amount of energy to create them and because neutrinos pass through most matter almost without a trace.

''It's just been accepted that this guy exists,'' said Regina Rameika, a physicist at Fermilab and a member of the team.

Neutrinos are particles -- with no electrical charge and probably little mass -- that rarely interact with other matter. They are created by some of the most basic physical processes of the universe, such as the decay of radioactive elements and fusion reactions that power the sun.

Until now, the tau neutrino remained one of two major undetected particles in the vast theoretical structure called the standard model of particle physics. The theory describes the properties of all the known building blocks of matter, from quarks, protons, neutrons and electrons to the neutrinos.

The remaining unseen particle, called the Higgs boson, is considered a linchpin of the entire structure. The new finding clears the way for a race between Fermilab and a European laboratory, CERN, to detect the Higgs.

Paul Langacker, a physicist at the University of Pennsylvania who was not part of the group, called the neutrino experiment ‘‘very subtle and difficult’’ and said that as recently as five years ago, many physicists believed that such a detection of the tau neutrino would be all but impossible.

‘‘The remaining piece of the standard model itself is the Higgs particle,’’ Langacker said. ‘‘There are strong indirect indications that it is right around the corner.’’

The experiment is also a step toward clearing up some of the remaining mysteries concerning neutrinos themselves.

According to the standard model, neutrinos have no mass. But two years ago, a Japanese experiment called Super-Kamiokande found evidence that neutrinos do have at least a small mass, without determining what that mass is.

So the detection of the tau neutrino was a crucial prerequisite for planned experiments at Fermilab and CERN to help determine the mass of the neutrino.

The experiments involve shooting beams of neutrinos hundreds of miles underground to distant detectors to see if one type of neutrino changes into another en route. According to advanced theories, any such transmutation would be an indication of the mass.

Knowing the value of the mass could help settle several cosmic mysteries, including how much swarms of neutrinos in space might contribute to the weight of the universe.

‘‘To be able to make tau neutrinos and detect them directly is going to be very important in this whole new world of neutrino physics,’’ said Martin Perl, a Nobel Prize-winning physicist at the Stanford Linear Accelerator Center.

The physicist Wolfgang Pauli first postulated the existence of neutrinos in the 1930s to account for energy and momentum that seemed to vanish during the radioactive decay of various elements. So weakly do the particles interact with matter that physicists had to wait nearly 30 years for the first detection of any neutrinos.

The first two types of neutrinos to be seen are closely associated with electrons and muons, much less bizarre particles that are grouped in a classification called leptons within the standard model. Leptons are a class of particles that do not interact strongly with matter.

So when Perl and colleagues discovered a new lepton, called the tau particle, in 1975, they assumed that the electron neutrino and muon neutrino would soon have company.

But making a tau neutrino requires first making a tau particle -- and because it is much more massive than the other leptons, that requires an accelerator with much greater energies.

''Neutrino experiments are very difficult to begin with,'' said Roger Rusack, a physicist at the University of Minnesota who is a member of the team, ''and we're looking at a neutrino that's very hard to make.''

The team did produce them in bulk by smashing protons accelerated to nearly the speed of light at the Tevatron into tungsten. Tau particles created in the maelstrom decayed into tau neutrinos, which streamed through thick layers of shielding that blocked most other particles and reached the emulsions.

There, very rarely, a tau neutrino collided with an atomic nucleus and produced other particles, including a tau particle, that left a characteristic, kinked trail in the emulsion. The crucial part of that trail was only about a millimeter long, and the technique for finding such subtle features was developed at Nagoya University in Japan, one of the partners in the experiment.