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Physicists Detect Last of the 12 Basic Particles

· Science: International team will announce discovery of the elusive tau neutrino--a subatomic loner in the world of matter.

By USHA LEE MCFARLING, Times Science Writer

An international team of physicists will announce today that they have finally snared the tau neutrino--the last and most elusive of the 12 fundamental particles that make up all matter.

All the other particles, from the top quark to the muon neutrino, have fallen into the hands, or at least the detectors, of physicists. But tau neutrinos have eluded detection for decades because they almost never interact with anything else.

Known as the loners of the particle world, trillions of the particles slip through space, earth and our bodies every instant without doing harm, or leaving a trace.

Finding traces of the unimaginably small neutrinos amid the blizzard of subatomic particles that leave more legible fingerprints is a landmark in modern physics. In the past, major steps toward detecting primary particles often have been rewarded with Nobel Prizes.

The finding, in which four neutrinos were detected among 6 million particle collisions, could help scientists improve their understanding of the universe by explaining how the particles and forces within it interact.

According to what is known as the Standard Model of particle physics, everything in the universe is ultimately made up of an assemblage of 12 basic particles, which physicists label either quarks or leptons, including the relatively familiar electron.

Of the assemblage, the neutrino--a variety of lepton--is the hardest to track because it has no electrical charge and little if any mass. Scientists had long thought that neutrinos, which come in three "flavors," had no mass at all, but more recent research has indicated that they may have a minuscule amount.

All that makes neutrinos--particularly the elusive tau variety--very hard to track. The existence of neutrinos was first theorized by Wolfgang Pauli in the early 1930s, but none was detected until 1962. Some physicists had predicted that the tau variety could never be found.

"They're easy to produce but hard to capture," said Regina Rameika, one of the physicists who led the experiment based at the Department of Energy's Fermi National Accelerator Laboratory in Batavia, Ill. "It's a hard game."

Until the tau neutrino was detected, physicists could not say exactly how it would act--or whether it would obey the rules of their current theories.

"What we never know about these newest particles is whether they're straightforward or whether they're strange," said Martin Perl, a physicist at the Stanford Linear

Accelerator Center who won the Nobel Prize for the 1975 discovery of a related particle, the tau lepton. Although he found strong evidence for the existence of tau neutrinos and is the person who named them, his team did not have the technology to find the particles.

"We've been waiting a long time for this," he said. Early indications are that the particles "seem to be sort of normal," he added.

The search, which took seven years, started as kitchen table conversation between two Fermilab physicists, Rameika and her husband, Byron Lundberg. The team eventually swelled to include 54 physicists, which is still small by today's particle physics standards. "It was a family affair," said Rameika.

The experiment took advantage of Fermilab's high-energy particle accelerator. By smashing a beam of protons moving at nearly the speed of light into a block of tungsten, they created a shower of millions and millions of particles of all types.

The main technical challenge was finding a way to screen out most of the particles so that only the three types of neutrinos could get to the detectors. If too many particles got through, their traces would have swamped the detectors and made it impossible to find the subtle traces of the tau neutrinos.

The scientists then had to take another step. They passed the neutrinos through a thin strip of iron. Within the iron, one out of every trillion tau neutrinos interacted with the nucleus of an iron atom. That collision produced a tau lepton. The leptons, in turn, quickly decayed, leaving a telltale 3-D track in layers of a special emulsion, similar to photographic film.

Most neutrinos do not interact with anything and leave no trace in the emulsion. The tau lepton, however, leaves a "track with a kink," said Vittorio Paolone, a physicist at the University of Pittsburg who was a researcher at the University of California at Davis when he helped devise the experiment.

The eventual discovery required three years of sifting through the data from millions of collisions. Lundberg called the search "the proverbial needle in the haystack."

The scientists are most proud of their relatively small budget for a major physics experiment: less than $3 million for hardware. "We scavenged, used old equipment, recycled," said Rameika. Using the emulsion technology devised by Koyu Niwa of Japan's Nagoya University also kept the cost down by limiting the size and number of detectors that were needed, she said.

The findings are to be announced today in a low-key setting--the regular Friday afternoon seminar series at Fermilab, which was also the site of discoveries of two other particles: the bottom quark and the top quark. The results are not expected to be controversial because the signals are quite clear and because the results match what has long been predicted.

There is still much work ahead to understand the details of the newly detected particle and how all known particles interact.

One question involves whether yet another, still hypothetical particle, called the Higgs boson, actually exists. The Standard Model does not fully explain why particles have the mass they do, and some physicists have theorized the boson as the explanation.

Another chief mystery, scientists said, is the mass of the neutrino. If it is conclusively found to have mass, the Standard Model would require serious surgery, said Roger Rusak, a physicist at the University of Minnesota who was part of the team.

There are also intriguing findings suggesting that neutrinos might oscillate from one form to another as they travel through the earth--making understanding them even more of a challenge.

"It's like being in an unfamiliar harbor on a really foggy day in a canoe," said Phil Yager, a physicist at the UC Davis. "The picture is just starting to emerge."

The formal name of the collaboration that found the neutrino is DONUT--Direct

Observation of the Nu Tau. Thursday, Yager was one of many physicists serving up doughnuts in his lab in celebration of the finding--and of the uncertain scientific terrain that lies ahead.

"The thing is so elusive and so hard to deal with," he said, "you're almost always getting surprises."

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Tracking the Tau Neutrino

Scientists have found the first direct evidence for a subatomic particle called the tau neutrino, one of the 12 types of elementary particles thought to make up all matter. Scientists can detect a tau neutrino only by identifying its interaction with an atomic nucleus. Below is their method.

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A beam of high-energy protons moving at nearly the speed of light is sent by a particle accelerator into a block of tungsten. Upon impact, the protons breakup into many different kinds of particles, including a small percentage of tau neutrinos.*

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A filter removes all particles but neutrinos.

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A beam of neutrinos, containing electron, muon and tau neutrinos is sent through a target of iron plates sandwiched with layers of emulsion, which can record traces of the particles.

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When a tau neutrino hits an iron nucleus, the collision produces a tau lepton. This lepton can be detected because it decays quickly and leaves a track ending in a kink or bend. Neutrinos that do not interact pass through the detector without leaving a track.

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Source: Fermi Lab

The Particle Menagerie

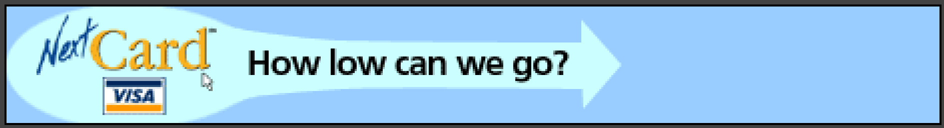
Elementary, or subatomic, particles are the smallest building blocks of matter. Physicists divide them into two categories, leptons and quarks.

There are three lepton particles. All have a charge of negative one. They are the familiar electron, the muon, which is 200 times more massive than the electron, and the tau, which is 3,500 times more massive than the electron.

Each of those three particles has a corresponding neutrino, a ghostly particle with no charge and little if any mass.

Quarks combine to form the protons and neutrons within an atom. Some, which may have existed in the universe when it was younger and higher in energy, can now be created only in particle accelerators. They include a suite of beguilingly named characters like charm, strange, top, bottom, up and down.

Four other particles known as bosons are thought to carry fundamental forces like electromagnetism. These include photons, gluons and W and Z bosons.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