Abstract impression of a particle collider. (akinshin/iStock/Getty Images Plus)

SPACE

Physicists Detect Elusive 'Ghost Particles' in The LHC For The Very First Time

MICHELLE STARR 29 NOVEMBER 2021

A major milestone in particle physics has just been made at the Large Hadron Collider (LHC).

For the first time, candidate neutrinos have been detected, not just at the LHC, but in *any* particle collider.

The six neutrino interactions, detected using the neutrino subdetector FASERnu, not only demonstrate the feasibility of the technology, they open up a new avenue for studying these mysterious particles, particularly at high energies.

"Prior to this project, no sign of neutrinos has ever been seen at a particle collider," said physicist Jonathan Feng of the University of California Irvine, co-leader of the FASER Collaboration.

"This significant breakthrough is a step toward developing a deeper understanding of these elusive particles and the role they play in the Universe."

Neutrinos are actually everywhere. They're one of the most abundant subatomic particles in the Universe; but they carry no charge and have almost zero mass so, although they stream through the Universe at almost the speed of light, they barely interact with it at all. Billions of the things are streaming through you right now. To a neutrino, the rest of the Universe is basically incorporeal; that's why they're also known as ghost particles.

Although they interact rarely, that's not the same as never. Detectors such as IceCube in Antarctica, Super-Kamiokande in Japan, and MiniBooNE at Fermilab in Illinois use sensitive photodetector arrays designed to pick up the showers of light that emerge when a neutrino interacts with other particles in a completely dark environment, for example.

But for a long time, scientists have wanted to also study neutrinos produced at particle colliders. That's because collider neutrinos, which emerge primarily from the decay of hadrons, are produced at very high energies, which are not very well studied. Detecting collider neutrinos provides access to neutrino energies and types that are rarely seen elsewhere.

FASERnu is what is known as an emulsion detector. Lead and tungsten plates are alternated with layers of emulsion: During particle experiments at the LHC, neutrinos can collide with nuclei in the lead and tungsten plates, producing particles that leave tracks in the emulsion layers, a bit like the way ionizing radiation makes tracks in a cloud chamber.

The plates need to be developed like photographic film. Then, physicists can analyze the particle trails to find out what produced them; whether it was a neutrino, and then what the neutrino's 'flavor', or type, was. There are three neutrino flavors – electron, muon and tau – as well as their antineutrino counterparts.

In the FASERnu pilot run conducted in 2018, six candidate neutrino interactions were recorded in the emulsion layers. That may not seem like many, considering how many particles are produced in a run at the LHC, but it gave the collaboration two vital pieces of information.

"First, it verified that the position forward of the ATLAS interaction point at the LHC is the right location for detecting collider neutrinos," Feng said. "Second, our efforts demonstrated the effectiveness of using an emulsion detector to observe these kinds of neutrino interactions."

The pilot detector was a relatively small apparatus, at around 29 kilograms (64 pounds). The team is currently working on the full version, around 1,100 kilograms (over 2,400 pounds). This instrument will be significantly more sensitive, and will allow the researchers to differentiate between neutrino flavors and their antineutrino counterparts.

They're expecting that the third observing run of the Large Hadron Collider will produce 200 billion electron neutrinos, 6 trillion muon neutrinos, and 9 billion tau neutrinos, and their antineutrinos. Since we've only detected around 10 tau neutrinos, total, to date, this will be a pretty big deal.

The collaboration is also eyeing even more elusive prey. They have their hopes pinned on a detection of dark photons, which are at the moment hypothetical, but which could help reveal the nature of dark matter, the mysterious directly-undetectable mass that makes up most of the Universe's matter.

But the neutrino detections alone are a tremendously exciting step forward for our understanding of the fundamental components of the Universe.

"Given the power of our new detector and its prime location at CERN, we expect to be able to record more than 10,000 neutrino interactions in the next run of the LHC, beginning in 2022," said physicist and astronomer David Casper of the University of California, Irvine, FASER project co-leader.

"We will detect the highest-energy neutrinos that have ever been produced from a human-made source."

The team's research has been published in *Physical Review D*.