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Suitcase-Sized Neutrino Detector Hits Pay Dirt At Large Hadron Collider

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Science

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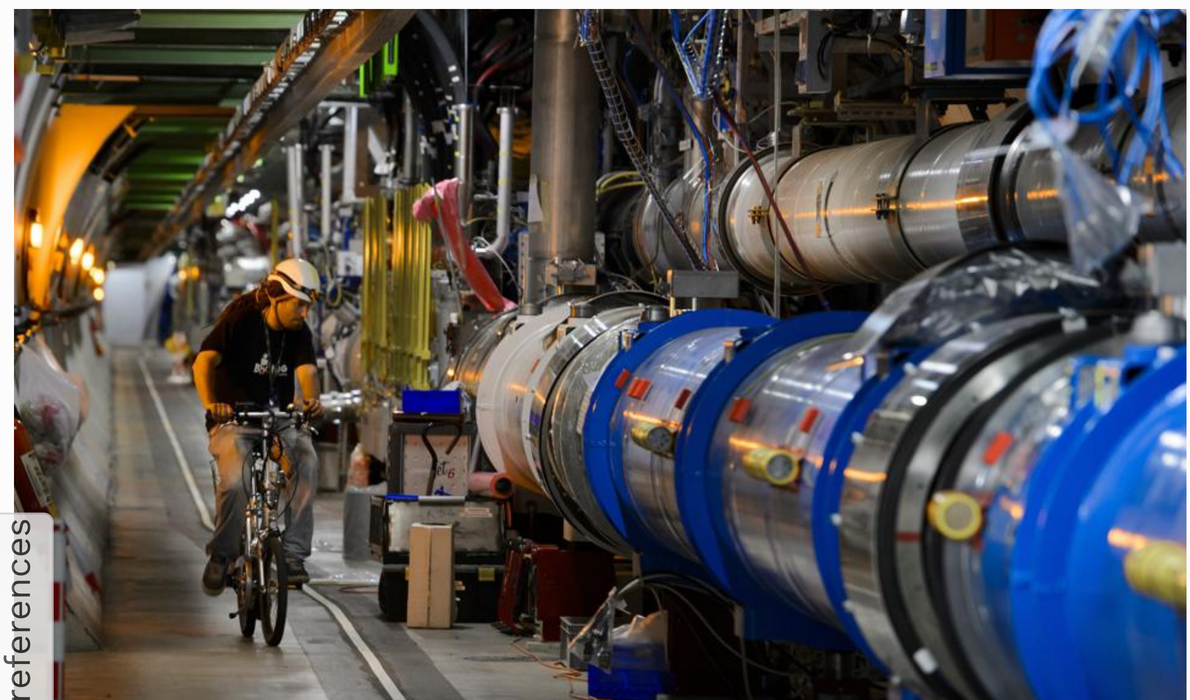

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The first-ever neutrino candidates produced by CERN's Large Hadron Collider (LHC) in Switzerland have been detected by an international team led by physicists at the University of California, Irvine (UCI). The neutrinos —- the lightest and most weakly-interacting particles known —- were detected by a small trial instrument situated along a line tangential to the LHC's main proton collider beam.

In a paper just published in the journal *Physical Review D*, the team detail how they observed six neutrino interactions during a pilot run of the Forward Search Experiment (FASER), a compact emulsion detector installed at the LHC in 2018.

Particle physics is hardly the stuff of cocktail party chit-chat. And unless you're attending an international physics colloquium; discussion of neutrinos, their masses, their types, and their origins remain as convoluted to the general public as pre-big bang cosmology. But neutrinos are likely crucial to tracking down the elusive hidden reality of exotic dark matter. And this new detection is a step in that direction.

"[This] opens a new window," Jonathan Feng, a UCI theoretical physicist and one of the paper's co-authors, told me. "The LHC is famous for detecting the Higgs boson, but it was never thought to be a place where one could detect neutrinos. With this result, we have opened up a brand-new field, namely, neutrino physics at colliders."

By detecting neutrinos produced in the lab, we have complete control of what is going on —- how the particles are produced, and how they are detected, Feng explains. This means that we can be sensitive to small deviations coming from new effects that may signal new laws of nature, he says.

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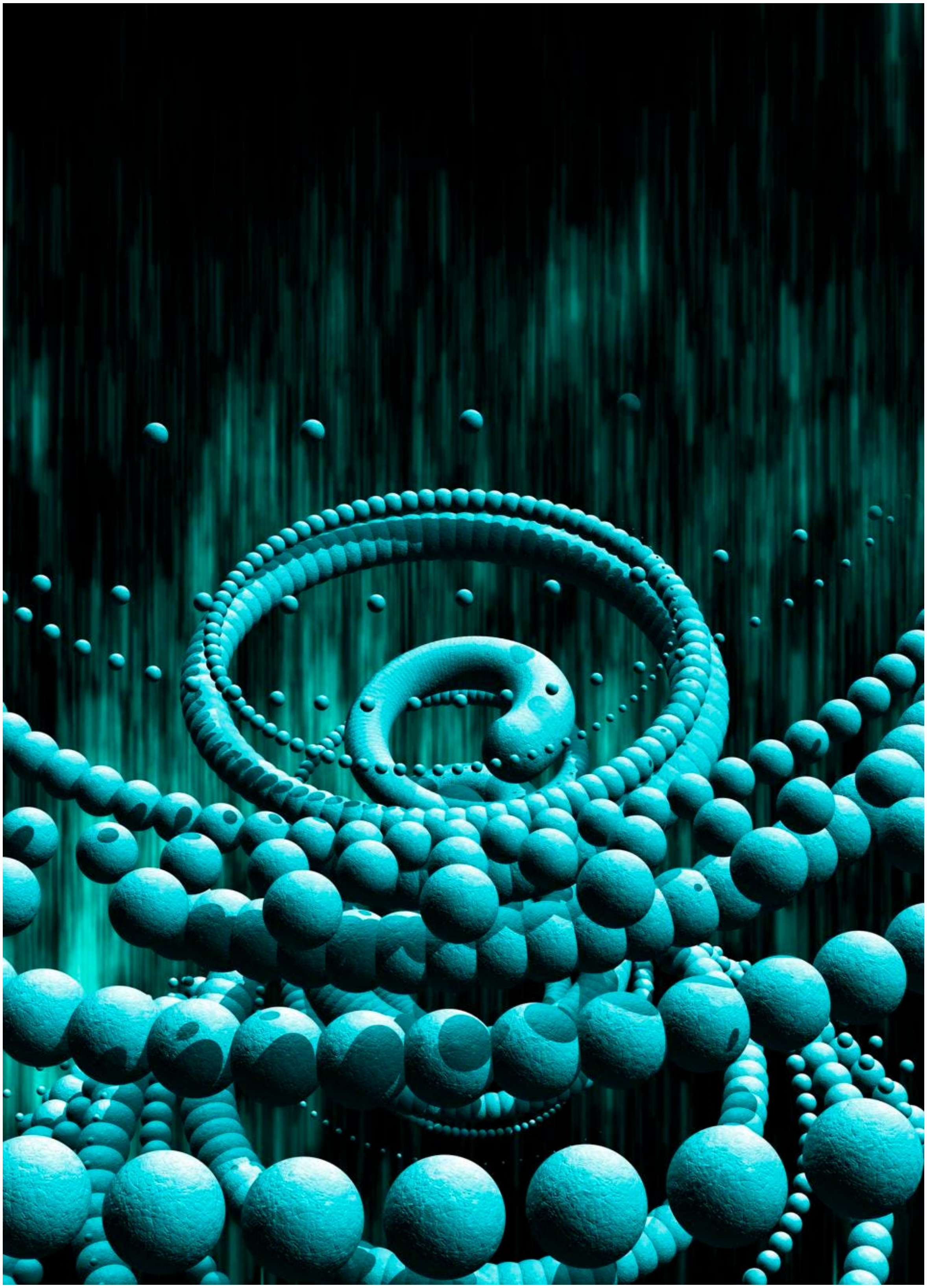
In contrast, when neutrinos are produced naturally elsewhere in the cosmos, if one sees something strange, it's hard to tell whether it's due to a new law of nature or simply a misunderstanding of the neutrinos' ultimate source, says Feng.



Neutrinos, conceptual computer artwork. GETTY

Particle colliders have been in operation for over 70 years, but none have been able to detect neutrinos, says Feng. But Feng says that within one month, he and colleagues were able to detect six neutrino interactions; all using a detector about the size of a suitcase built with recycled parts.

The team's instrument FASERnu catches particle produced along blind spots in the collider's proton beamline.   And it turns out this is where most of the high energy neutrinos go, and these are the easiest to detect,

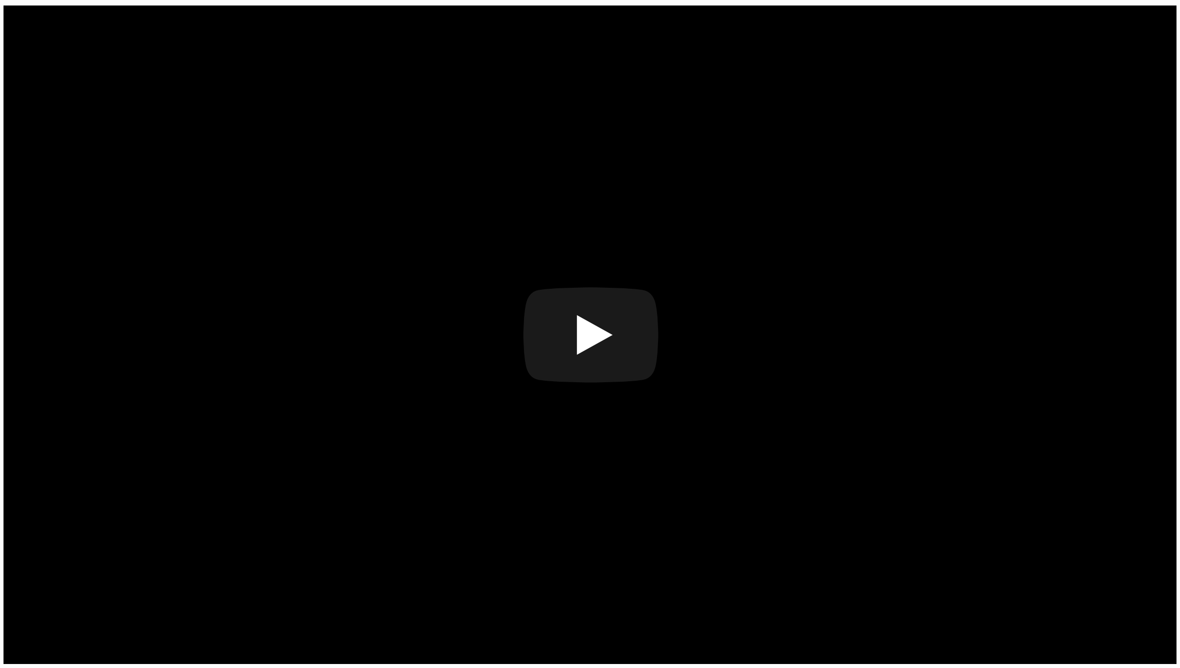
says Feng. This is one reason why he and colleagues were able to detect the neutrinos with such a small instrument, he says.

Neutrinos were first predicted in the 1930's to account for apparent violation of conservation laws in nuclear radioactive beta decay, Dave Casper, a UCI experimental physicist and one of the paper's co-authors, told me.

But they were not discovered until the 1950's.

The reason it took so long is because neutrinos interact so weakly, says Casper. It took a nuclear reactor, in which neutrinos are produced as products of nuclear fission, to have enough neutrinos to detect a handful of them, he says.

Eventually it was established that there are three distinct types, or “flavors” of neutrinos. Initially, all were thought to be without mass. Yet in the 1980s, neutrinos were determined to have some mass, but not enough to account for the missing exotic dark matter.



Neutrinos have masses that are a million times smaller than the next heaviest particle (the electron), says Casper. The vast disparity in mass between neutrinos and the other elementary particles is thought to be a clue to new physics, he says.

What’s the relation between neutrinos and dark matter?

Neutrinos cannot be most of the dark matter — they don't have the right properties, says Feng. But neutrinos and dark matter particles are related in the sense that they are both extremely weakly-interacting particles, he says. For this reason, experiments that are good at finding neutrinos are also good at looking for some kinds of dark matter, Feng notes.

Despite progress in understanding neutrinos, puzzles remain.

We still don't know the basic properties of neutrinos, how to explain the neutrino’s small, but non-zero mass, or even how many kinds of neutrinos there are, says Feng.

But the hope is that this new FASER instrument will usher in a sea-change in our understanding of neutrino physics.

We are starting to exploit the huge number of high-energy neutrinos produced in LHC collisions that have, until now, been “wasted,” says Casper. He notes that the FASER experiment will use provide incredibly high resolution (micron scale) 3-D images of the neutrino interactions that the LHC produces.

What’s next?

Starting in 2022, we will be operating a much larger one-ton detector that

will run for three years, says Feng. We expect to detect 10,000 of the highest energy neutrinos ever produced by human experiments, and this will allow us to study their properties precisely, he says.

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