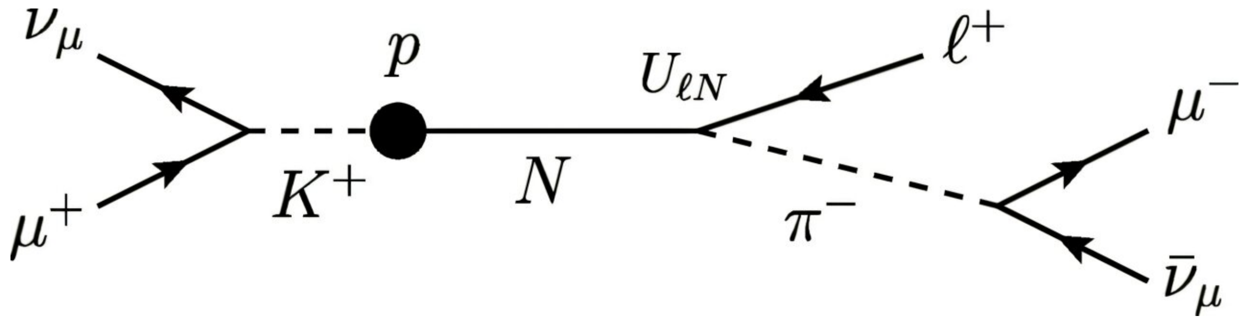
Life's building blocks may not be stable—just really, really long-lived

September 22 2025, by Kelly Izlar



Proton decay chain. Credit: *Physical Review Letters* (2025). DOI: 10.1103/cxvm-p412

Although the building blocks of life such as hydrogen and oxygen appear stable to us, many theories of physics predict that they are actually just tremendously long-lived, with the particles found in their nuclei slowly, but ultimately decaying.

To investigate this idea, researchers have been hunting for evidence of this decay by looking for faint signals of decaying protons in Japan's Super-Kamiokande observatory.

So far, no definitive signals of proton decay have emerged, implying that if the proton does decay, it probably has a lifetime exceeding 10^{33} years—that's 10 with 32 zeros behind it.

But the Japanese observatory can't see every type of proton decay: if the decay fragments are too low in energy, they would be invisible to the detector.

In a recent study published in *Physical Review Letters*, Virginia physicists showed that two other observatories—the Jiangmen Underground Neutrino Observatory (JUNO) and the Deep Underground Neutrino Experiment (DUNE)—should soon be able to see these lower-energy proton decays thanks to their complementary detector designs.

"Lowering the detection threshold will open a much wider window to include decays that might have fallen through the cracks in earlier searches," said Ian Shoemaker, associate professor in the Department of Physics and study co-author.

Working with Julian Heeck from the University of Virginia, Shoemaker found that proton decay experiments can also be sensitive to protons decaying anywhere inside Earth, if they decay into new elementary particles.

Most intriguingly, said Shoemaker, one of these new particles could be the long-sought-after "sterile neutrino," which would finally allow scientists to understand the origin of neutrino mass.

"Our initial exploration of these signatures hints at many novel exciting opportunities for theoretical and experimental work that could lead to the groundbreaking discovery of new physics," Shoemaker said.

More information: Julian Heeck et al, Nucleon Decays into Light New Particles in Neutrino Detectors, *Physical Review Letters* (2025). DOI: 10.1103/cxvm-p412

Provided by Virginia Tech