In neutrino-less double-beta decay search, physicists excel

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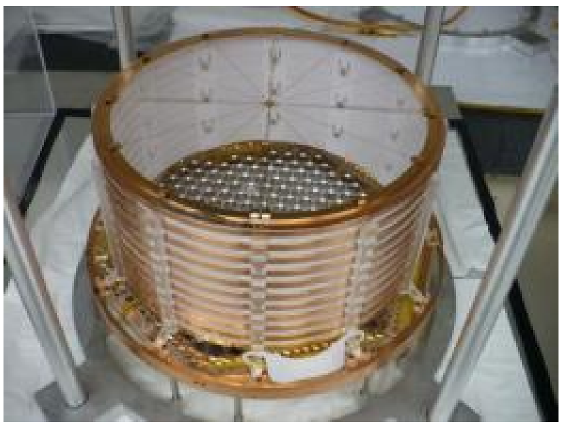

This is half of the innermost detector for EXO-200, a so-called Time Projection Chamber, before it was installed inside the copper cryostat. Credit: UMass Amherst

Physicists Andrea Pocar and Krishna Kumar of the University of Massachusetts Amherst, part of an international research team, recently reported results of an experiment conducted at the Enriched Xenon Observatory (EXO), located in a salt mine one-half mile under Carlsbad, New Mexico, part of a decades-long search for evidence of the elusive neutrino-less double-beta decay of Xenon-136.

Pocar, Kumar and the team of 60 scientists using an instrument called the EXO-200 detector, succeeded in setting a new lower limit for the half-life of this ephemeral nuclear decay. Though no one has yet seen it, important progress was made.

Pocar explains, "This result is particularly interesting because it very nearly excludes a 10-year old claim for observing such a decay in germanium-76. One of the physics community's goals for all this time has been to test that claim. We now have a detector that is able to probe half-lives which are 10^15 times the age of the universe. This alone is a remarkable achievement."

If observed someday, the existence of neutrinoless double-beta decay would require a new theoretical explanation of particle physics, he adds. Many theorists believe that it should exist. "A number of factors make this seem possible. It could tell us something about the asymmetry between matter and anti-matter that we observe in the universe," Pocar notes. Latest findings are reported in the current issue of Physical Review Letters.

Standard double beta decay (where two electrons are emitted by a nucleus, each accompanied by a neutrino), though rare, can be fully explained by current theory and has been observed in a few elements, Pocar says. The EXO-200 experiments made the first observation of this decay in Xenon-136 last summer. In the new experiments, he and colleagues checked the possibility that such decay can occur without any neutrino emissions, which would require new theoretical arguments.

A neutrino is a fundamental particle like an electrons or quark, but with no electric charge. It is the only candidate particle that may prove to be its own anti-particle, with finite mass. Neutrinos interact with other particles only via the weak nuclear force. An electron and a neutrino are emitted simultaneously from an atom's nucleus during nuclear beta decay under the influence of this force. For many decades, scientists thought neutrinos were completely without mass, but they now understand that neutrinos have very tiny masses, at least 500,000 times smaller than that of the electron, Pocar explains. If neutrinos are indeed their own anti-particles, then neutrinoless double-beta decay becomes possible.

"It's a deep question in physics and the answer could shed some light on understanding matter and anti-matter in the universe, one of the fundamental questions of cosmology. Why is the universe we know made of matter and not anti-matter? Finding a particle that is its own anti-particle is a little piece of information that could address this."

At the EXO-200 experiment in New Mexico, a five-foot-diameter copper barrel housed inside a clean room is cooled down by refrigerators to serve as a cryostat. Investigators place a bucket-sized detector inside, seal it and fill it with 200 kg of enriched xenon (containing more of the isotope Xenon136 than usual). They then cool the EXO-200 detector to minus 100 degrees C, which turns Xenon into a liquid three times denser than water. The detector is built with very stringent cleanliness standards to achieve the lowest possible environmental radioactivity, which could be mistaken for double beta decay events.

If neutrinoless double-beta decay of this isotope takes place, the detector will "see" the nucleus emitting two electrons simultaneously during decay, with no neutrinos. The mine's salt and rock shield the detector from most cosmic rays found on the surface, which would make the search for such a rare event impossible, Pocar says.

A smaller lab on the UMass Amherst campus offers Pocar and Kumar, plus postdoctoral researchers Tim Daniels and David Wright, graduate students Sereres Johnston, and undergraduates Josh Bonatt, Monica Harrelson, Devon Ingraham-Adie, Mark Lodato, Cameron Mackeen and Kelly Malone a handy place to test individual detector components and observations made at EXO in a local setup.

All the collaborators, about 60 scientists from institutions in the United

States, Canada, Switzerland, Germany, Russia and South Korea get trained in mine safety in order to take shifts on the experiment.

Provided by University of Massachusetts Amherst