Is nature exclusively left handed? Researchers study chilled atoms to find out

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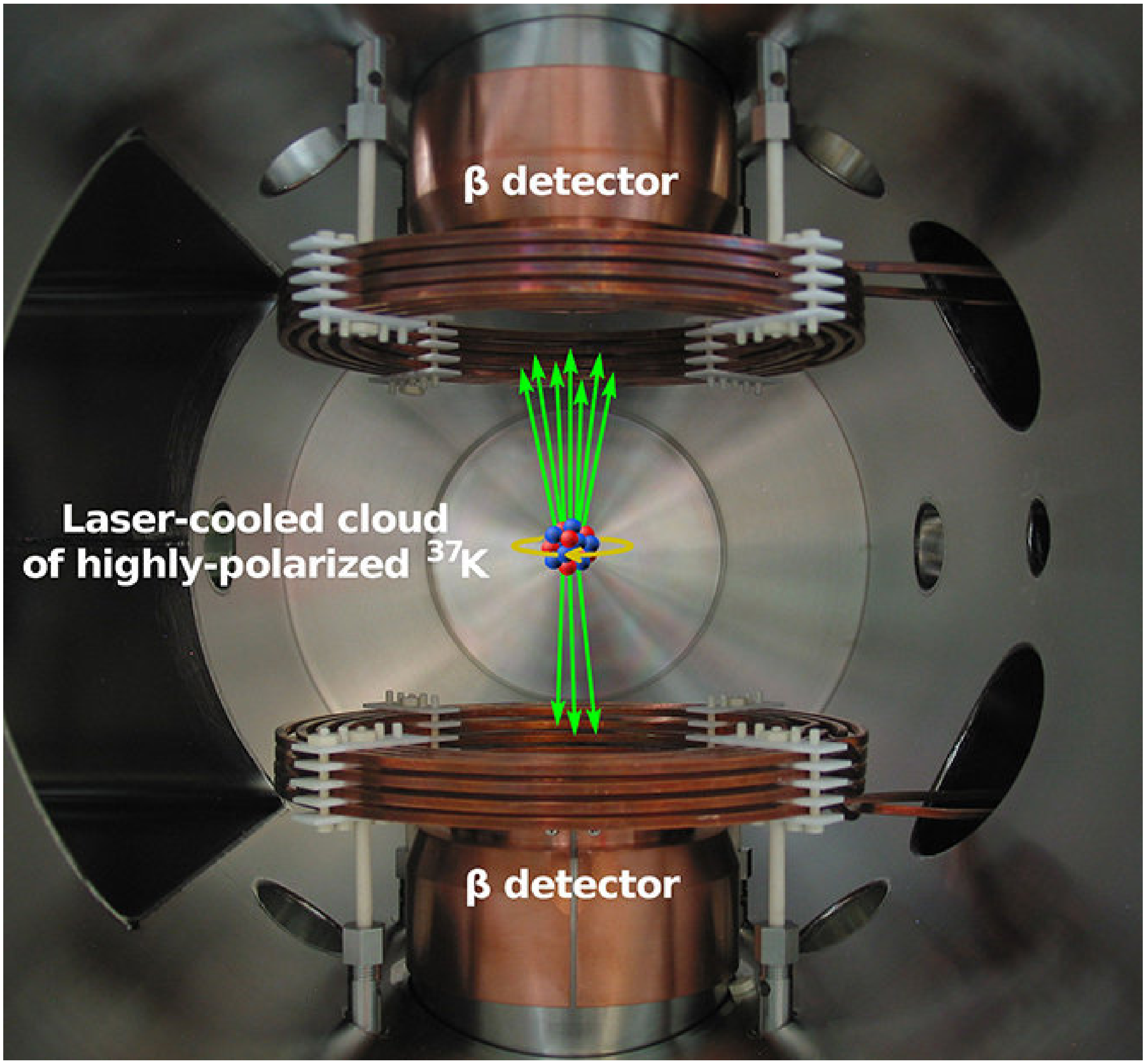

The measurement chamber of the TRIUMF Neutral Atom Trap (TRINAT) experiment where the decays of potassium-37 (37K) atoms are observed. Beta (β) particle detectors placed above and below the trap center, along the polarization axis, measure the momenta of the βs in the direction of, and opposite to, the nuclear polarization, allowing the precise measurement of the asymmetry to ±0.3 percent. Not shown are two micro-channel plate detectors and an electrostatic hoop system to collect and observe the daughter recoiling ions and shake-off electrons. Credit: US Department of Energy

The study of how atoms radioactively decay has played a critical role in developing the standard model, our modern understanding of our universe's evolution since the Big Bang. Experiments investigating one form of decay, where a radioactive nucleus emits a beta particle to become more stable, have led to revolutionary ideas that are part of the standard model. The most surprising result from beta decay is that nature is not ambidextrous, but is "left-handed." Handedness refers to a beta particle's spin; if you curl the fingers of your left hand to follow the spin and your thumb points along the direction of motion, the beta particle is left-handed. No right-handed beta particles have ever been observed.

Scientists produced a pure sample of atoms, which decayed, and then more precisely measured the beta particle spin than was done in the past. They found no right-handed particles, strengthening the claim that nature is left-handed and providing researchers with a technique for improved searches for right-handed particles as well as tests of other aspects of the standard model.

Using lasers and magnetic fields, researchers are now able to suspend clouds of atoms in a small volume in space and polarize them with very high efficiency. These techniques provide an ideal source of short-lived atoms, allowing the beta spin to be measured with great precision. By comparing the observed values to their standard model prediction, such measurements are sensitive to a wide variety of "new physics" predicted by potential successors to the standard model.

The study of how atoms radioactively decay has played a critical role in developing the standard model, our modern understanding of the fundamental forces and particles governing our universe. One of the ways a nucleus decays, known as beta decay, is caused by the weak nuclear force. In one flavor of this process, a proton in the nucleus becomes a neutron resulting in a beta particle (now known to be an anti-electron) and a neutrino being emitted. Experiments investigating beta decay have led to a number of revolutionary ideas that have become cornerstones of the standard model. Perhaps the most surprising and illuminating of these came from a 1957 experiment that looked at the asymmetry of betas emitted with respect to the initial nuclear spin of polarized cobalt-60: it demonstrated the startling fact that nature is not ambidextrous, but rather appears to be "left-handed." Handedness refers to the orientation of the spin of a particle; if you curl the fingers of your left hand to follow the spin and your thumb points along the direction of motion, the particle is left-handed. No right-handed particles (in the limit of zero mass) have ever been observed, but there is no compelling reason why they should not exist. In fact, many proposed extensions to the standard model propose right-handed particles do exist and are just difficult to detect. The improved precision of asymmetry measurements using modern techniques can improve searches for right-handed particles as well as test other fundamental aspects of the standard model.

Using the TRIUMF Neutral Atom Trap (TRINAT) facility, a collaboration from Texas A&M University, TRIUMF (Canada's national particle accelerator center), Tel Aviv University, and the University of Manitoba combined magneto-optical trapping and optical pumping techniques to produce an ideal source of short-lived potassium-37 atoms. The magneto-optical trap is extremely selective, only confining the isotope of interest. It provides a very confined and cold cloud of highly polarized atoms that decay from a very shallow trap within an exceptionally open geometry. This allows the researchers to measure the momenta of both the recoil and emitted beta daughters in a nearly background-free environment with minimal beta scattering effects. Two beta telescopes, placed along the polarization axis, observe the number of betas emitted parallel and anti-parallel to the nuclear polarization. The direction of the polarization is easily reversed by simply changing the sign of the circularly polarized optical-pumping light. This is an ideal situation for determining the correlation of the beta with the initial nuclear spin, that is, the beta asymmetry parameter.

The asymmetry observed in the beta detectors determines the beta asymmetry parameter for potassium-37 to within 0.3 percent of its value. This is the best relative accuracy of any beta-asymmetry measurement in a nucleus or the neutron, and is in agreement with the standard model prediction. This experiment has increased sensitivity to new physics compared to other nuclear searches. It improves the determination of the quark flavor changing strength parameter for this nucleus by a factor of 4. The researchers have identified ways to improve the precision to better than a part-per-thousand, at which point the result will be complementary to searches for new physics at large-scale facilities such as the Large Hadron Collider. In addition to improving the beta asymmetry parameter measurement, researchers will use TRINAT to measure other polarized and unpolarized correlation parameters.

More information: B. Fenker et al. Precision Measurement of the β Asymmetry in Spin-Polarized K37 Decay, *Physical Review Letters* (2018). DOI: 10.1103/physrevlett.120.062502

B Fenker et al. Precision measurement of the nuclear polarization in laser-cooled, optically pumped37K, *New Journal of Physics* (2016). DOI: 10.1088/1367-2630/18/7/073028

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