Weak nuclear force is less weak

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Credit: versageek via flickr

The force that governs some of the reactions that keep our sun shining is not quite as weak as scientists had previously thought. As a consequence, our estimation of how energetic the sun actually is just went up by a tiny amount.

The evidence for this weak nuclear force comes from the decay of muons, essentially heavier cousins of the electron, one of the building blocks of atoms.

Just as biologists sometimes study the tiniest and most ephemeral of organisms such as fruit flies, which live for barely a day, to learn things about human disease, so physicists often study the properties of particles that last a fraction of a second to learn about the universe.

The muon lives only about 2 millionths of a second -- 2 microseconds -- far from the realm of human sensation but long enough for scientists to make detailed measurements. The state of digital electronics is so advanced that measurements far shorter than this, even down to trillionths of a second or less, can easily be made.

Watching muons decay is not like propping up a Geiger counter next to a box full of radioactive uranium. That's because muons are so short lived they have to be made anew, as if they were medical isotopes. At the Paul Scherrer Institute in Switzerland a dedicated proton beam was used to create muons amid collisions with a graphite target.

Researchers then gathered a fine spray of muons, directed them and stopped them in their own metal target which was surrounded by a detector that could track the muons' demise. The decay of over 2 trillion muons provided the best yet value for the average muon lifetime. It comes out to 2.1969803 microseconds.

"This is the most precise lifetime determination of any state in the atomic or subatomic world," said David Hertzog, one of the leaders of the experiment and a professor at the University of Washington in Seattle.

This lifetime, known to an uncertainty of one part per million, is so precise that it can be used to make a new determination of the intrinsic strength of the weak nuclear force, which operates over only a very short range inside the nucleus of atoms.

Scientists know of four physical forces. Gravity, a form of mutual attraction, keeps the Earth going around the sun and keeps us from floating into space. The electromagnetic force is responsible for holding atoms together, for bonding atoms into molecules, for impelling the movement of electrons through wires in the form of electricity, and for light waves. The strong nuclear force holds nuclei together and is responsible for some kinds of radioactivity.

The weak nuclear force, the fourth and last force to be discovered by physicists in the twentieth century, helps to turn protons into neutrons inside the sun, a necessary step in converting those protons into heavier elements like helium and releasing the radiant energy that makes its way to Earth. The weak force also acted billions of years ago inside exploding stars known as supernovas to make the elements such as oxygen and carbon found in our own bodies and other natural things on Earth.

The strength of the weak force is encapsulated in a number called the Fermi constant, named for the Italian-American scientist Enrico Fermi. Hertzog said that the new value for the Fermi constant is about 0.00075 percent greater than the previous value. Thus the weak force is just a tiny bit stronger than we thought.

William Marciano, a scientist at the Brookhaven National Laboratory on Long Island, N.Y. was impressed by the muon experiment.

"It was a difficult but beautiful measurement carried out by a very experienced and talented group of researchers," Marciano said.

Marciano also points out that muons, short lived as they might be, are interesting in their own right, and actually practical. Muons were used to study the pyramids in Egypt. Muons can be created in the atmosphere by incoming cosmic rays, mysterious streams of particles from deep space. Because these muons can penetrate great amounts of material without stopping, even during their short lives, they were used as a sort of "medical scanner" for probing for hidden cavities inside the pyramid by setting up detectors above and in the basement.

Marciano said that muons might also be useful for medical imaging and for scanning cargo containers for hidden nuclear materials.

Another expert on the weak force, University of Wisconsin professor Michael Ramsey-Musolf, considers the muon experiment to be a tour-de-force piece of work. The important thing for him is that the uncertainty of the muon lifetime has now dropped by a factor of ten. But he also said that a more precise lifetime and a more precise knowledge of the strength of the weak nuclear force tells us just a bit more about nature.

"This implies that the sun does indeed burn more brightly and that the decay of nuclei is somewhat faster," Ramsey-Musolf said.

The new muon results are scheduled to be published in the journal Physical Review Letters.

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