Rice-born detector finds heaviest antimatter

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Physicists at Rice University and their collaborators have detected the antimatter partner of the helium nucleus, antihelium-4. This newly observed particle is the heaviest antimatter particle ever detected.

Scientists at Rice's Bonner Lab designed and built the new time-of-flight detector that identified antihelium-4. The $7.5 million detector was built by a U.S.-China collaboration led by Rice, with Chinese scientists contributing $2.5 million to the project. The new detector was installed as part of the STAR experiment at the Relativistic Heavy Ion Collider (RHIC) at Brookhaven National Laboratory in New York. STAR scientists announced their find today in the journal *Nature*.

Antimatter is the yang to matter's yin. Both were created in ostensibly equal amounts at the time of the Big Bang, but because matter and antimatter annihilate each other upon contact, most of it disappeared almost instantly. But there was an apparent imbalance that favored matter, which makes up nearly all that we see (and are) today.

Why this is so remains one of the great mysteries in physics. Scientists hope the study of antimatter created in particle accelerators, which attempt to mimic conditions at the beginning of the universe, will offer clues to why nature allows humans to exist.

Last year at Brookhaven, shortly after the long-planned time-of-flight detector was fully installed, evidence of 15 antihelium-4 nuclei (aka anti-alphas) was found among the trillions of particles released when heavy gold ions were collided at nearly the speed of light. These nuclei contain two antiprotons and two antineutrons and do not undergo radioactive decay.

The collisions produce a quark gluon plasma which, when cooled, transitions into a hadron gas that contains protons, neutrons and their antimatter equivalents among many other fundamental particles. This rapidly expanding cloud of particles is where the team found antihelium-4.

"These are massive clumps of antimatter," said Frank Geurts, a Rice assistant professor of physics and astronomy and a lead author of the paper. "The fact that two antineutrons and two antiprotons find each other, produce an anti-alpha, travel two to three meters of air and give us a measurable signal when they pass through the time-of-flight detector is astounding."

Just as astounding was the ability of the STAR detector to capture and identify these heavy antimatter particles among the trillions of particles created in collisions at Brookhaven each year. It would be far easier, Geurts said, to find the proverbial needle in a haystack, but the new time-of-flight detector, which Rice scientists designed and built over the course of a decade, was up to the task. Jabus Roberts, a Rice professor of physics and astronomy, and research scientist Geary Eppley, both co-authors on the new paper, started the research that led to the detector more than 10 years ago. Eppley and William Llope, senior faculty fellow in physics and astronomy and also a co-author, managed the construction and installation of the apparatus.

The detector is a set of 23,000 sensors that surround STAR, short for Solenoidal Tracker at RHIC. These sensors identify the types of subatomic particles released when heavy nuclei collide. The detector tells researchers how long it takes a particle to travel from its creation to the point it passes through one of the sensors and is accurate to a 10th of a billionth of a second.

Rice played a role in the discovery even beyond its creation of the critical detector. A Rice graduate student found the first evidence that antihelium-4 was being created in collisions at RHIC. Jianhang Zhou, now working in private industry in Houston, "dedicated a chapter in his thesis to the fact that he had found two candidates (for antihelium-4)," Geurts said. "At that time, we needed more statistics and a time-of-flight detector to confirm his findings." In fact, the *Nature* paper counts Zhou's two particles among the total of 18 reported, though they were identified at STAR before the time-of-flight detector was installed.

"You could argue that it was not an unexpected particle, but the implications for its discovery and the amount we found agrees with what we were expecting," Geurts said. "We can now see an extension of the periodic system of elements into regions of antimatter and strange matter."

The new observation tops the previous find of an antihydrogen nucleus containing three particles, including an anti-strange quark, by the same team a year ago. The new record will probably stand for a long time, Geurts said.

He suggested even heavier antimatter particles might be found -- but probably not on this planet. A statement from Brookhaven noted that antilithium-6, a heavier antimatter nucleus that does not undergo radioactive decay, is predicted to be a million times more rare, and its discovery is well outside the reach of current technology.

More basic discoveries could be made in distant galaxies where antimatter from the Big Bang may still be detected. The Alpha Magnetic Spectrometer (AMS) that will be mounted on the International Space Station will measure cosmic rays for evidence of dark matter and antimatter. The space shuttle Endeavor will carry the instrument to the ISS if it launches April 29 as planned.

AMS will also look for antihelium-4 that, if found, could be evidence of the existence of larger regions of the universe made entirely of antimatter. The STAR measurement will help scientists understand the conditions in the very early universe that would allow such antimatter galaxies to form.

The discovery of the anti-alpha comes on the centennial of Ernest Rutherford's first modeling of the atom using alpha particles.

Provided by Rice University

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