Seeing the dark: New experiment could finally shed light on the mysteries of dark matter

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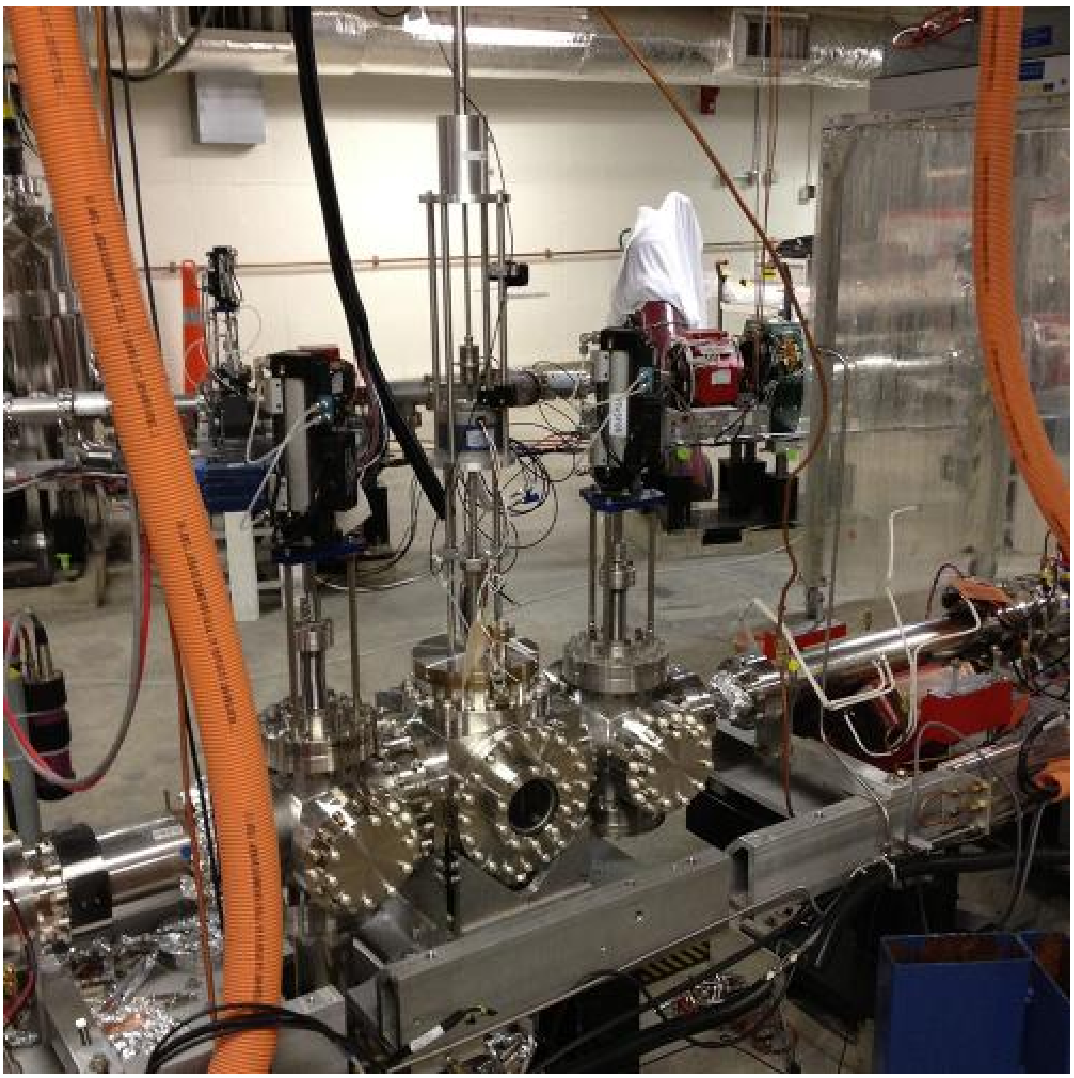

Photo shows a prototype device designed by the MIT team to produce a very narrow, high-powered beam of electrons for an experiment called DarkLight.

The device was tested at the Jefferson National Accelerator Facility to confirm that it could meet the requirements needed to detect a hypothesized particle based on one theory about the nature of dark matter.

Dark matter, believed by physicists to outweigh all the normal matter in the universe by more than five to one, is by definition invisible. But certain features associated with dark matter might be detectable, according to some of the many competing theories describing this elusive matter. Now scientists at MIT and elsewhere have developed a tool that could test some of these predictions and thus prove, or disprove, one of the leading theories.

The work is described in a paper in the journal Physical Review Letters co-authored by MIT physics professors Richard Milner and Peter Fisher and 19 other researchers.

"We're looking for a massive photon," Milner explains. That may seem like a contradiction in terms: Photons, or particles of light, are known to be massless. That's why they travel at the speed of light—something that, according to Einstein's theory of relativity, is impossible for anything that possesses mass.

However, an exotic particle that resembles a photon, but with mass, has been proposed by some theorists to explain dark matter—whose nature is unknown but whose existence can be inferred from the gravitational attraction it exerts on ordinary matter, such as in the way galaxies rotate and clump together. Now, an experiment known as DarkLight, developed by Fisher and Milner in collaboration with researchers at the Jefferson National Accelerator Laboratory in Virginia and others, will look for a massive photon with a specific energy postulated in one particular theory about dark matter, Milner says.

The idea is more than just a theoretical prediction, he adds: There are hints of such a particle from other experiments, making it worthwhile to pursue a definitive answer. But the previous hints, consisting of what Milner calls "anomalous moments of the muon," do not rise to statistical significance. The DarkLight experiment is designed to provide solid confirmation of the massive photon's existence.

If it does exist, that would represent a major discovery, Milner says. "It's totally beyond anything we understand about the physical world," he says. "A massive photon would be totally different" from anything allowed by the Standard Model, the bedrock of modern particle physics, he says.

To prove the existence of the theorized particle, dubbed A' ("A prime"), the new experiment will use a particle accelerator at the Jefferson Lab that has been tuned to produce a very narrow beam of electrons with a megawatt of power. That's a lot of power, Milner says: "You could not put any material in that path," he says, without having it obliterated by the beam. For comparison, he explains that a hot oven represents a kilowatt of power. "This is a thousand times that," he says, concentrated into mere millionths of a meter.

The new paper confirms that the new facility's beam meets the characteristics needed to definitively detect the hypothetical particle—or rather, to detect the two particles that it decays into, in precise proportions that would reveal its existence. Doing so, however, will require up to two years of further preparations and testing of the equipment, followed by another two years to collect data on millions of electron collisions in the search for a tiny statistical anomaly.

"It's a tiny effect," Milner says, but "it can have enormous consequences for our theories and our understanding. It would be absolutely groundbreaking in physics."

While DarkLight's main purpose is to search for the A' particle, it also happens to be well suited to addressing other major puzzles in physics, Milner says. It can probe the nature of a reaction, inside stars, in which carbon and helium fuse to form oxygen—a process that accounts for all of the oxygen that now exists in the universe.

"This is the stuff we're all made of," Milner says, and the rate of this reaction determines how much oxygen exists. While that reaction rate is very hard to measure, Milner says, the DarkLight experiment could illuminate the process in a novel way: "The idea is to do the inverse." Instead of fusing atoms to form oxygen, the experiment would direct the powerful beam at an oxygen target, causing it to split into carbon and helium. That, Milner says, would provide an indirect way of determining the stellar production rate.

Roy Holt, a distinguished fellow in the physics division at Argonne National Laboratory in Illinois, says this work is "a novel and significant technical development that not only opens a new window to search for a new [particle], but also for new studies in nuclear physics." If the planned experiment detects the A' particle, he says, "it would signal that dark matter could actually be studied in a laboratory setting."

More information: "Transmission of Megawatt Relativistic Electron Beams through Millimeter Apertures"
prl.aps.org/abstract/PRL/v111/i16/e164801

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