A transportable antiproton trap to unlock the secrets of antimatter

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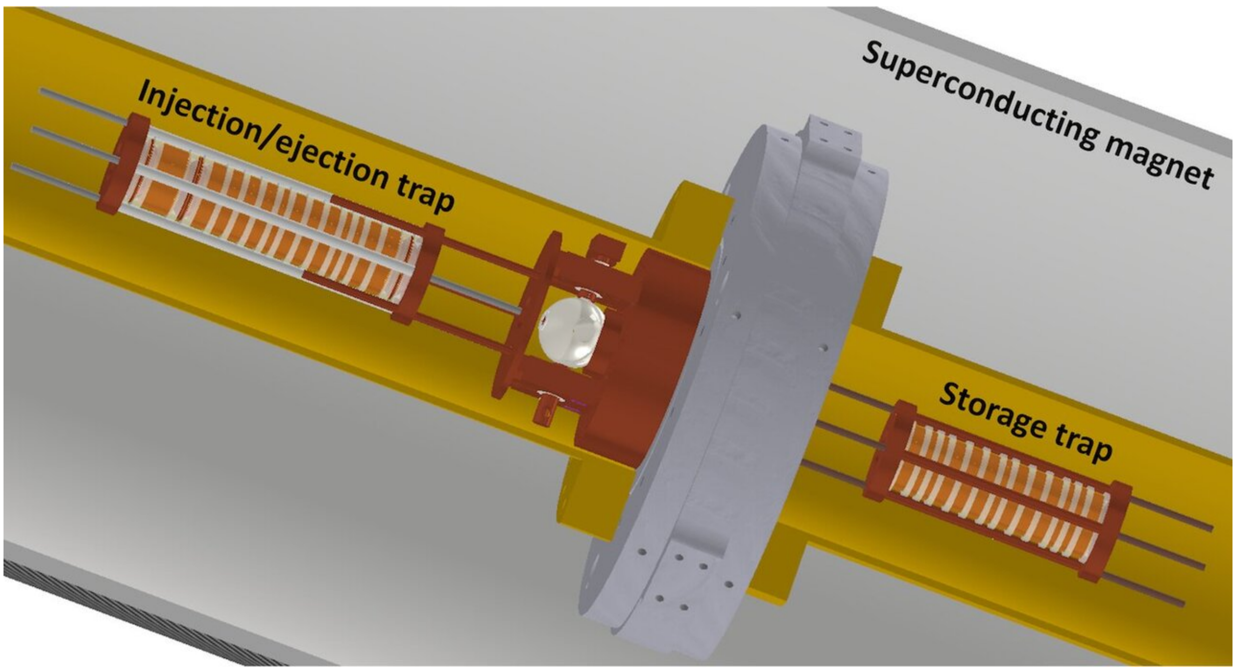

The layout of the transportable antiproton trap that BASE is developing. The device features a first trap for injection and ejection of the antiprotons produced at CERN's Antiproton Decelerator, and a second trap for storing the antiprotons. Credit: Christian Smorra

The BASE collaboration at CERN has bagged more than one first in antimatter research. For example, it made the first ever more precise measurement for antimatter than for matter, it kept antimatter stored for a record time of more than a year, and it conducted the first laboratorybased search for an interaction between antimatter and a candidate particle for dark matter called the axion. Now, the BASE team is developing a device that could take antimatter research to new heights—a transportable antiproton trap to carry antimatter produced at CERN's Antimatter Decelerator (AD) to another facility at CERN or elsewhere, for higher-precision antimatter measurements. These measurements could uncover differences between matter and antimatter.

The Big Bang should have created equal amounts of matter and antimatter, yet the present-day universe is made almost entirely of matter, so something must have happened to create the imbalance. The Standard Model of particle physics predicts a certain difference between matter and antimatter, but this difference is insufficient to explain the imbalance, prompting researchers to look for other, as-yet-unseen differences between the two forms of matter. This is exactly what the teams behind BASE and other experiments located at CERN's AD hall are trying to do.

BASE, in particular, investigates the properties of antiprotons, the antiparticles of protons. It first takes antiprotons produced at the AD—the only place in the world where antiprotons are created daily–and then stores them in a device called a Penning trap, which holds the particles in place with a combination of electric and magnetic fields. Next, BASE feeds the antiprotons one by one into a multi-Penning-trap set-up to measure two frequencies, from which the properties of antiprotons such as their magnetic moment can be deduced and then compared with that of protons. These frequencies are the cyclotron frequency, which describes a charged particle's oscillation in a magnetic field, and the Larmor frequency, which describes the so-called precessional motion in the trap of the intrinsic spin of the particle.

The BASE team has been making ever more precise measurements of these frequencies, but the precision is ultimately limited by external disturbances to the set-up's magnetic field. "The AD hall is not the calmest of the magnetic environments," says BASE spokesperson Stefan Ulmer. "To get an idea, my office at CERN is 200 times calmer than the AD hall," he says, smiling.

Hence the BASE team's proposal of making a transportable antiproton trap to take antiprotons produced at the AD to a measurement laboratory with a calmer magnetic environment. The device, called BASE-STEP and led by BASE deputy spokesperson Christian Smorra, will consist of a Penning-trap system inside the bore of a superconducting magnet that can withstand transport-related forces. In addition, it will have a liquid-helium cooling system, which allows it to be transported for several hours without the need of electrical power to keep it cool. The Penning-trap system will feature a first trap to receive and release the antiprotons produced at the AD, and a second trap to store the antiprotons.

The overall device will be 1.9 meters long, 0.8 meters wide, 1.6 meters high and at most 1000 kg in weight. "These compact dimensions and weight mean that we could in principle load the trap into a small truck or van and transport it from the AD hall to another facility located at CERN or elsewhere, to further our understanding of antimatter," says Smorra, who received a European Research Council Starting Grant to conduct the project.

The BASE team has started to develop the device's first components and expects to complete it in 2022, pending decisions and approvals. Stay tuned for more developments.

Provided by CERN

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