LHC accelerates its first 'atoms'

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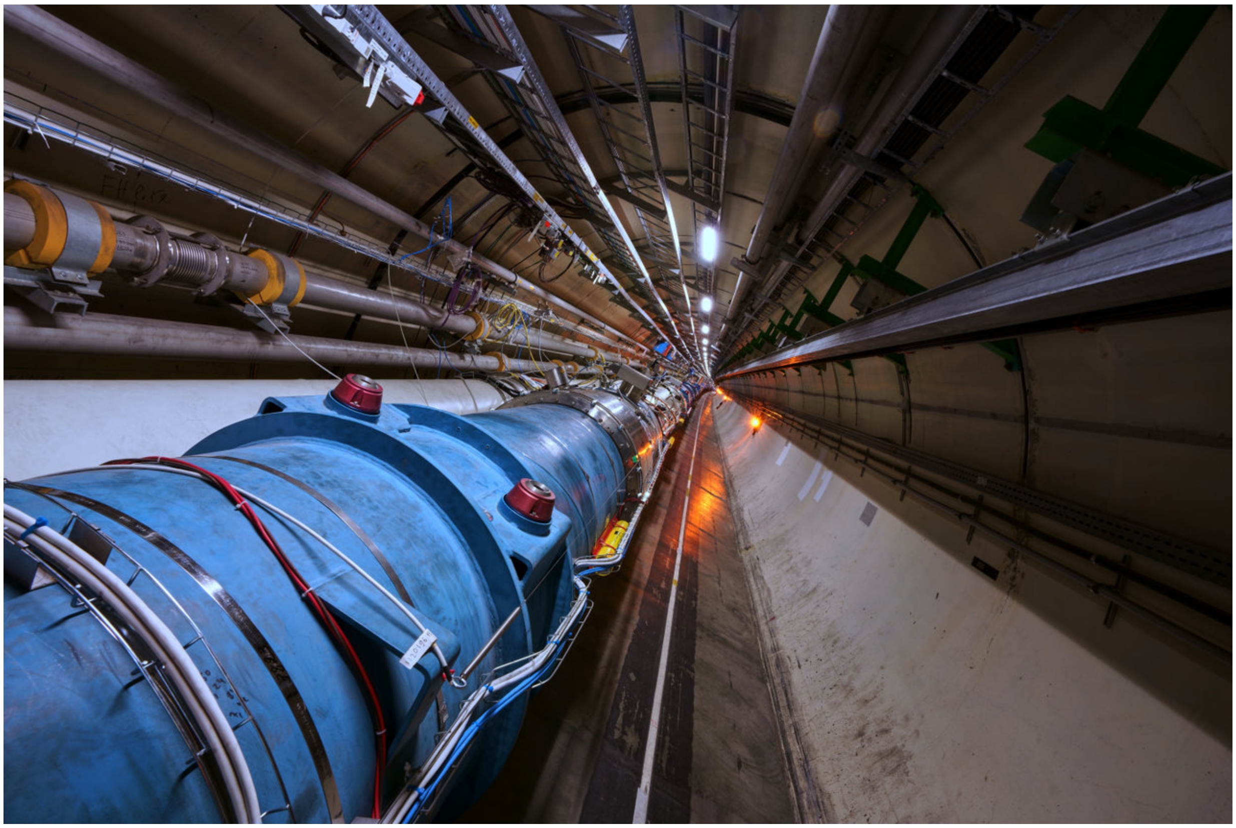

During a special one-day run, LHC operators injected lead "atoms" containing a single electron into the machine. Credit: Maximilien Brice/Julien Ordan/CERN

Protons might be the Large Hadron Collider's bread and butter, but that doesn't mean it can't crave more exotic tastes from time to time. On Wednesday, 25 July, for the very first time, operators injected not just atomic nuclei but lead "atoms" containing a single electron into the LHC.

This was one of the first proof-of-principle tests for a new idea called the Gamma Factory, part of CERN's Physics Beyond Colliders project.

"We're investigating new ideas of how we could broaden the present CERN research programme and infrastructure," says Michaela Schaumann, an LHC Engineer in Charge. "Finding out what's possible is the first step."

During normal operation, the LHC produces a steady stream of proton–proton collisions, then smashes together atomic nuclei for about four weeks just before the annual winter shutdown. But for a handful of days a year, accelerator physicists get to try something completely new during periods of machine development. Previously, they accelerated xenon nuclei in the LHC and tested other kinds of partially stripped lead ions in the SPS accelerator.

"This special LHC run was really the last step in a series of tests," says physicist Witold Krasny, who is coordinating a study group of about 50 scientists to develop new ways to produce high-energy gamma rays.

Accelerating lead nuclei with one remaining electron can be challenging because of how delicate these atoms are. "It's really easy to accidentally strip off the electron," explains Schaumann. "When that happens, the nucleus crashes into the wall of the beam pipe because its charge is no longer synchronised with the LHC's magnetic field."

During the first run, operators injected 24 bunches of "atoms" and achieved a low-energy stable beam inside the LHC for about an hour. They then ramped the LHC up to its full power and maintained the beam for about two minutes before it was ejected into the beam dump. "If too many particles go off course, the LHC automatically dumps the beam," states Schaumann. "Our main priority is to protect the LHC and its magnets."

After running the magnets through the restart cycle, Schaumann and her colleagues tried again, this time with only six bunches. They kept the beam circulating for two hours before intentionally dumping it.

"We predicted that the lifetime of this special kind of beam inside the LHC would be at least 15 hours," says Krasny. "We were surprised to learn the lifetime could be as much as about 40 hours. Now the question is whether we can preserve the same beam lifetime at a higher intensity by optimising the collimator settings, which were still set-up for protons during this special run."

Physicists are doing these tests to see if the LHC could one day operate as a gamma-ray factory. In this scenario, scientists would shoot the circulating "atoms" with a laser, causing the electron to jump into a higher energy level. As the electron falls back down, it spits out a particle of light. In normal circumstances, this particle of light would not be very energetic, but because the "atom" is already moving at close to the speed of light, the energy of the emitted photon is boosted and its wavelength is squeezed (due to the Doppler effect).

These gamma rays would have sufficient energy to produce normal "matter" particles, such as quarks, electrons and even muons. Because matter and energy are two sides of the same coin, these high-energy gamma rays would transform into massive particles and could even morph into new kinds of matter, such as dark matter. They could also be the source for new types of particle beams, such as a muon beam.

Even though this is still a long way off, the tests this week were an important first step in seeing what is possible.

Provided by CERN