

# Antimatter

*At CERN, antimatter is of primordial importance. It has been used both as a tool and as a subject of research.*

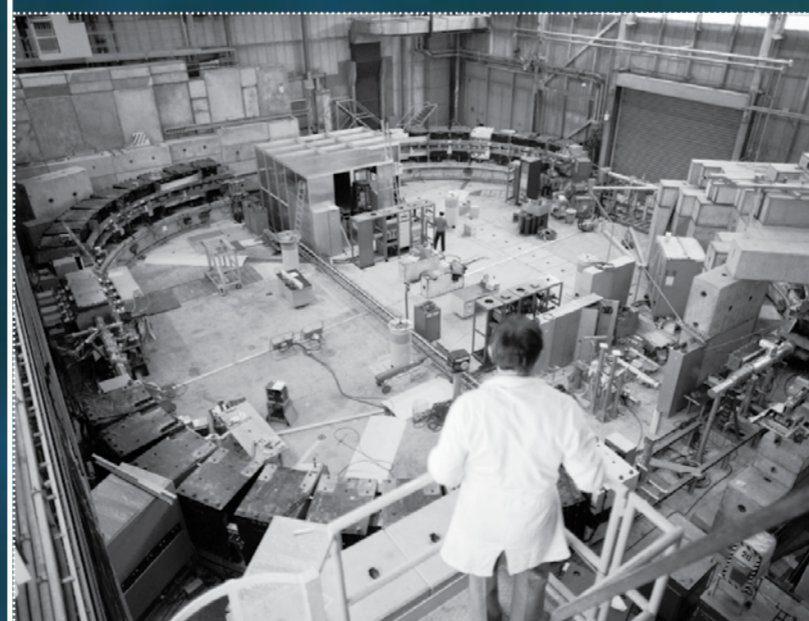
First indications of its existence came in 1928, when Paul Dirac published a theory combining quantum mechanics and Einstein's special relativity to provide a more complete description of electron interactions. The equation he derived predicted electron states of negative energy and, in 1932, his theory was vindicated when the positron was discovered by Carl Anderson, produced by cosmic-ray interactions in the upper atmosphere.

Thus started the exploration of antimatter. For the past 50 years and more, laboratories like CERN have routinely produced antiparticles, and in 1995 CERN became the first laboratory to create anti-atoms artificially. Today, CERN is still at the forefront of antimatter research with the experiments at the Antiproton Decelerator and at the LHC.

One of the first tracks showing the annihilation of an antiproton coming from the PS in the Saclay 81 cm liquid hydrogen bubble chamber (1961).



In 1977, the Initial Cooling Experiment (ICE) demonstrated that Simon van der Meer's stochastic cooling could control beams of charged particles. This paved the way for CERN's proton-antiproton collider at the Super Proton Synchrotron.

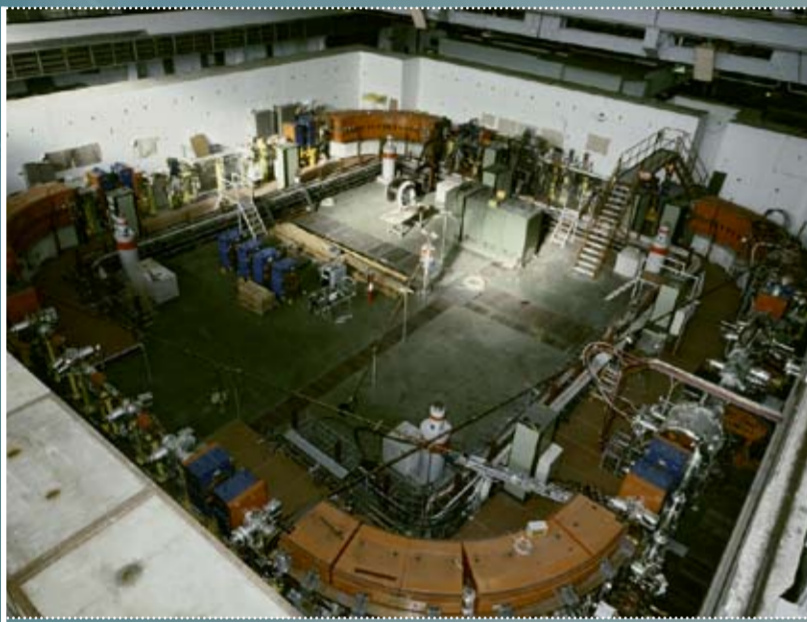


By June 1980, the Antiproton Accumulator (AA) was fully installed and commissioning began. This was the beginning of antimatter production, manipulation and study at CERN.





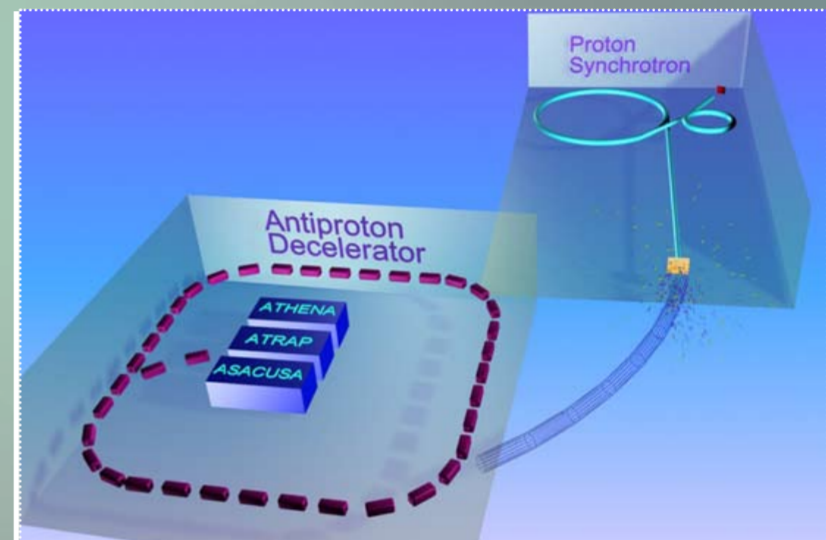
# at CERN



The Low Energy Antiproton Ring (LEAR) was installed in the South Hall in 1982. LEAR was the first machine in the world designed to decelerate antiparticles. Low energy antiprotons from LEAR were used in the 1990s by many experiments. In CPLEAR, neutral kaons and antikaons were produced and their evolution was compared in order to probe some of the processes behind the matter- antimatter imbalance in the universe today. In 1995, the PS210 experiment made the first nine antiatoms.

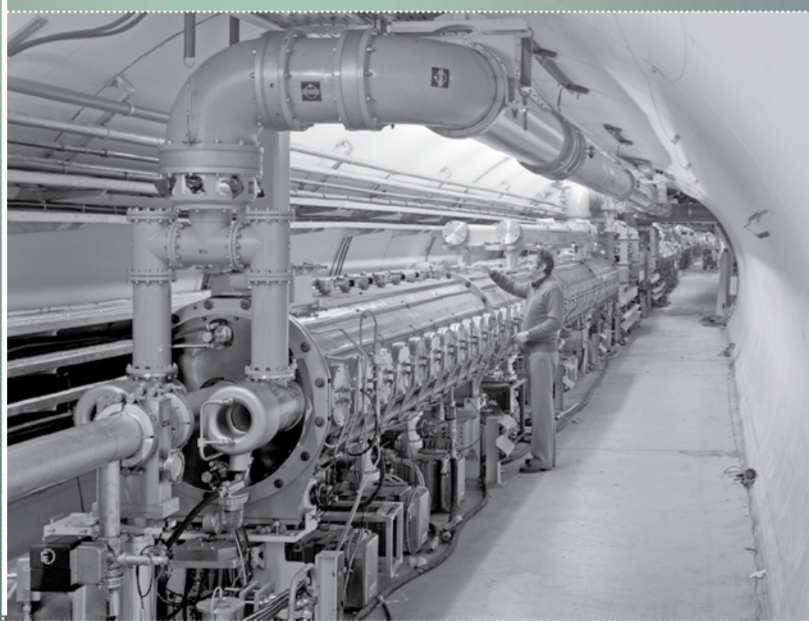


The Antiproton Collector was built around the AA in 1987 to give a tenfold increase in antiproton accumulation rate. The AA was dismantled in 1997 and the AC was then converted to become the Antiproton Decelerator (AD).



From 1998-2001, three experiments were installed at the AD: ASACUSA "Atomic Spectroscopy and Collisions using Slow Antiprotons"; ATHENA "Antihydrogen Production and Precision Experiments" and ATRAP "Cold Antihydrogen for Precise Laser Spectroscopy". ATHENA and ATRAP produced slow antihydrogen atoms and stored them in "traps", allowing extremely accurate comparisons of the properties of hydrogen and antihydrogen. ASACUSA performed precise laser spectroscopy of exotic atoms - atoms where an electron is replaced by an antiproton - to precisely measure the properties of antiprotons.

In 1981 the SPS became a 270 GeV proton - antiproton collider.



The Antiproton Decelerator (AD) started operation in 2000. Thanks to its two cooling systems, the AD slows antiprotons down to a trillionth of their initial energy, so they can combine with positrons and produce antihydrogen.



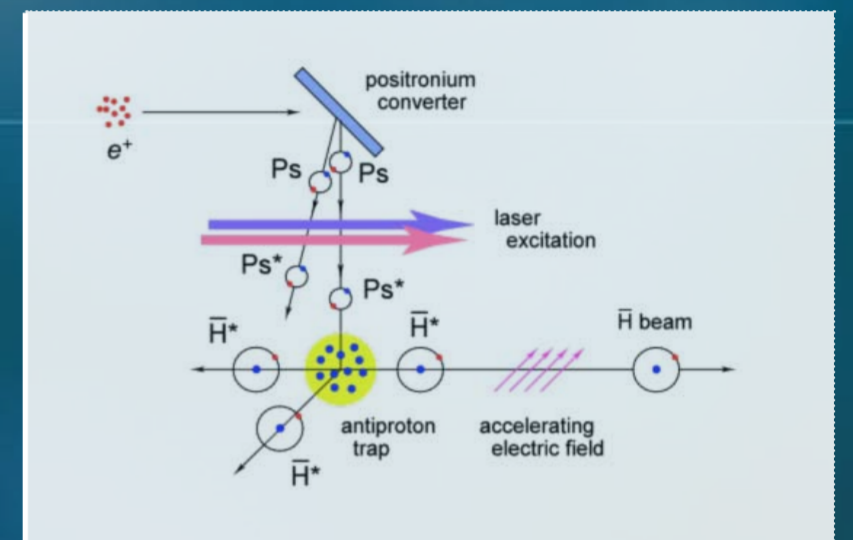




In 2002 the ATHENA and ATRAP collaborations announced the first controlled production of large numbers of antihydrogen atoms at low energies.



Antimatter experiments help us to understand why we live in a Universe that appears to be composed almost entirely of matter, but no antimatter. Today, CERN research on antimatter takes place at both the LHC and the AD. The LHCb experiment at the LHC specialises in investigating the slight differences between matter and antimatter by studying beauty quarks. At the same time, experiments at the AD (ATRAP, ALPHA and ASACUSA) are taking the next step towards precision spectroscopy measurements of antimatter properties: attempting to trap and cool, or to form a beam of, antihydrogen atoms.



AEGIS is the most recent experiment at the AD. As the name suggests (Antihydrogen Experiment: Gravity, Interferometry, Spectroscopy), the experiment is being set up to measure the gravitational interaction between matter and antimatter. Hopes are high that AEGIS techniques and results will add yet another facet to antimatter research at CERN.

Started in 2003, the Antiproton Cell Experiment (ACE) is the first investigation of the biological effects of antiprotons. The results show that antiprotons are four times more effective than protons in damaging the cells of the targeted area. This is a promising result, which shows that antimatter could be used to treat cancerous tumours.

