First Beam of Antihydrogen Atoms

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ASACUSA at CERN, Antiproton Decelerator (AD), a Japanese-European collaboration working on antihydrogen production for the CPT symmetry test, has unambiguously detected an antihydrogen beam 2.7 meters downstream from the production region, for the first time. This is an important milestone towards high precision tests of the CPT symmetry via antihydrogen spectroscopy.

It is well-known that matter and antimatter are always created in equal amounts in laboratory experiments. It is also believed that the same quantities of matter and antimatter were created at the Big Bang. However, the present universe is just made of matter, and no trace of the "primordial" antimatter has been observed. What then had happened to the antimatter that was once in the Universe?

To answer this question, the ASACUSA collaboration decided first to investigate the properties of antihydrogen atoms, the simplest antimatter made of one antiproton and one positron (anti-electron). To do so, antihydrogen atoms in the form of a beam were prepared, which enabled the study of the properties with high precision so they could be compared with those of hydrogen atoms, one of the best studied atoms on earth.

Figure 1 shows a schematic drawing of the experimental setup employed by the ASACUSA collaboration, which consists of the cusp trap to synthesize antihydrogen atoms and to extract them as a focused beam in low-field-seeking (LFS) states along the beam axis, the microwave cavity to induce hyperfine transitions from LFS states to high-field-seeking (HFS) states, the sextupole magnet to refocus/defocus the LFS/HFS states, and the antihydrogen detector on the right end. By counting how many antihydrogen atoms reached the target when the microwave cavity was tuned to specific frequencies, the frequencies of the hyperfine transitions could be determined precisely.

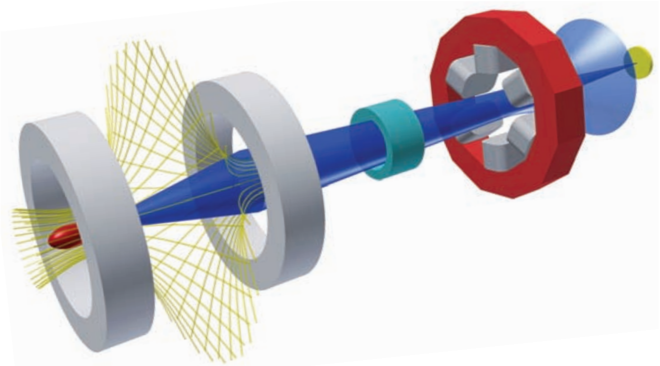

Fig. 1: From left to right: the cusp magnets (grey), the microwave cavity (green), the sextupole magnet (red and grey), and the antihydrogen detector (gold). Credit: Stefan Meyer Institute. Antihydrogen atoms are neutral but tiny magnets, and can be manipulated by magnetic fields. The cusp magnets and the sextupole magnet focus and defocus antihydrogen atoms in LFS and HFS states, respectively.

Till now antihydrogen atoms have been produced and often been trapped in so-called magnetic bottles. In this way, they could be inspected for a macroscopic time, which in principle guaranteed high precision measurements. On the other hand, the magnetic bottle unavoidably required strong and non-uniform magnetic fields, which caused serious Zeeman broadening and made high precision spectroscopy difficult.

The ASACUSA collaboration therefore adopted another scheme, i.e., extract antihydrogen atoms from the antihydrogen formation region so that influences of magnetic fields would be negligibly small.

We now have the proof that 80 cold antihydrogen atoms reached the antihydrogen detector 2.7 meters downstream from the cusp trap. The next step was to see if fewer were observed when the microwave cavity was turned on at the right frequency.

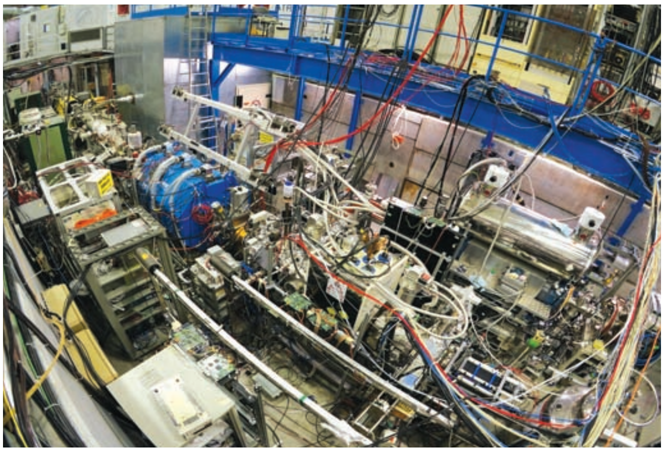

Fig. 2: A photo of the ASACUSA experimental setup for the antihydrogen beam.

Yasunori Yamazaki graduated from Osaka University in 1973, got a doctoral degree in 1978, was employed by Tokyo Institute of Technology as a Research Associate in 1978, moved to the University of Tokyo as an Associate Professor in 1988, became a Professor in 1993, was joint-appointed as the Chief Scientist of RIKEN in 1993. He was appointed as the Distinguished Senior Scientist, RIKEN in 2010. Yamazaki works on cold antihydrogen synthesis for the CPT symmetry test, and at the same time studies radiation effects on living cells with a MeV microbeams as well as the interaction of slow highly charged ions with insulators.