ATRAP - on the way to trapped Antihydrogen

Dieter Grzonka

Forschungszentrum Jülich, Institut für Kernphysik,
52425 Jülich, Germany

The ATRAP experiment at the CERN antiproton decelerator AD aims for a test of the CPT invariance by a high precision comparison of the 1s-2s transition between the hydrogen and the antihydrogen atom.

Antihydrogen production is routinely operated at ATRAP [1] in a nested Penning trap configuration. It is built by a stack of ring electrodes located in a uniform magnetic solenoid field which allows to prepare the required potential structure for the trapping of antiprotons and positrons.

Detailed studies have been performed in order to optimize the production efficiency of useful antihydrogen. The shape parameters of the antiproton and positron clouds, the N-state distribution of the produced Rydberg antihydrogen atoms [2] and the antihydrogen velocity [3] have been studied. Furthermore an alternative method of antihydrogen production via two subsequent charge exchange processes was sucessfully applied [4]. Cs Rydberg atoms prepared by laser excitation pass through a positron cloud were Rydberg Positronium is produced which subsequently interacts with antiprotons resulting in the production of Rydberg antihydrogen in well defined Rydberg states.

For high precision measurements of atomic transitions cold antihydrogen in the ground state is required which has to be trapped due to the low number of available antihydrogen atoms compared to the cold hydrogen beam used for hydrogen spectroscopy. The trapping of neutral antihydrogen atoms works via the force on the magnetic moment in a magnetic field gradient which drives the atoms towards the minimum of the magnetic field for a state with spin orientation parallel to the field direction.

To ensure a high antihydrogen trapping efficiency a magnetic trap has to be superposed the nested Penning trap. A basic question in such a configuration is the possibility to keep the charged particle clouds, the antiprotons and the positrons, in the stabilizing solenoid field which is strongly distorted by the varying field of the magnetic trap.

First trapping tests of charged particles within a combined magnetic/Penning trap have started at ATRAP. The Penning trap was surrounded by a permanent quadrupole magnet. Due to space limitations only a relatively low magnetic field gradient of about 15 T/m was possible. Studies with varying electron densities and different solenoid fields down to 1T were performed where stable trapping of Electron clouds could be achieved.

References:

[1] G. Gabrielse et al., Phys. Rev. Lett. 89, 213401 (2002).

[2] G. Gabrielse et al., Phys. Rev. Lett. 89, 233401 (2002).

[3] G. Gabrielse et al.,Phy. Rev. Lett. 93, 073401 (2004).

[4] C.H. Storry et al., Phy. Rev. Lett. 93, 263401 (2004).