ATRAP - on the way to trapped Antihydrogen

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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:

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Study of S = -2 baryonic states at FLAIR

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At the future FAIR project of the GSI low energy antiprotons will be available at FLAIR, the Facility for Low energy Antiproton and Ion Research. Within the FLAIR LOI [1] it is proposed to study the production of strangeness S = -2 baryonic states based on ideas proposed for LEAR [2].

The study of the baryon-baryon interaction is a basic tool to investigate the strong interaction. Especially in the strangeness S = -2 sector the available data are strongly limited. Most studies in this field were devoted to the search for the H-particle, a $(B = 2, S = -2)$ system with the quark configuration $(uuddss)$ first proposed by Jaffe [1]. The entrance into the S=-2 baryonic systems is mostly the cascade hyperon Ξ produced via K^- or p induced reactions. Slow Ξ particles can go into interacting ΞN systems which can couple to YY or might also directly connect to the H particle.

With stopped antiprotons a very efficient reaction chain for the production of slow Ξ hyperons can be initiated. In a first step a $\bar{K}^*$ "beam" is produced in the annihilation of a stopped antiproton on a nucleon. The production of $S = -2$ systems proceeds then in a second step via the double strangeness and charge exchange reaction $(\bar{K}^*, K)$. Due to the short decay length of a few fm both, $\bar{K}^*$ production and the double strangeness and charge exchange reaction have to take place in the same nucleus. The special feature of this reaction channel is the low momentum of the produced Ξ hyperon. The 'magic' $\bar{K}^*$ momentum at which the Ξ can be produced at rest is at around 200 MeV/c which is very close to the momentum of the produced $\bar{K}^*$ in the first reaction step.

The studies will start with the pure Ξ production via e.g. $\bar{p}d \to \Xi^- K_s^0 K^{*+}$. To investigate the ΞN , $\Lambda\Lambda$ or H systems a ^3He target has to be used. The slow Ξ hyperons with recoil momenta down to even zero MeV/c have a high probability of producing a (B = 2, S = -2) system. A further extension of the programme may be the production of double hypernuclei. With the technique of recoil-free kinematics the Ξ can also be produced and deposited in more extended nuclei. A highly efficient production of double hypernuclei is expected with this method.

From the experimental point of view the delayed decays of the strange exit particles allows a highly selective trigger on these reaction channels and the event reconstruction is relatively simple. A non magnetic detection system with track reconstruction ability is sufficient for the complete kinematical reconstruction.

References:

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