

Ulmer Initiative Research Unit

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Key Sentence :

1. Measure the magnetic moment of the proton and the antiproton with ultra-high precision.
2. Measure the ground state hyperfine splitting of Antihydrogen with high precision.

Key Word :

Particle Physics, Atomic Physics, Fundamental Symmetries, CPT Tests, Antimatter Research, High Precision Experiments, Proton/Antiproton Magnetic Moments, Antihydrogen GSHFS

Purpose of Research :

The research of the Ulmer Initiative Research Unit is dedicated to the precision investigation of the properties of matter and antimatter with ultra-high precision. All relativistic quantum field theories which are involved in the standard model of elementary particle physics predict a perfect symmetry between matter and antimatter. However, on cosmological scales this symmetry seems to be broken. While the visible universe is entirely made out of matter, antimatter can only be observed under highly exotic conditions. This not yet understood asymmetry is one of the hot topics in modern fundamental physics. Our precision experiments compare the properties of matter and antimatter with high precision. A deviation of the measured results for matter and the perfect antimatter mirror image would pave a path towards an explanation of this asymmetry. In our experiments we specifically concentrate on systems with a low intrinsic energy scale. Such systems are predicted to be highly sensitive against CPT violation.

1. The here described effort is recognized at CERN under the acronym BASE (Baryon Antibaryon Symmetry Experiment).

Regarding sensitivity against CPT violation the most sensitive measurable quantities are the magnetic moments of the proton and the antiproton. While the magnetic moment of the proton is known at a relative precision of 10ppb, the magnetic moment of the antiproton is only known at the level of 4.4ppm. We developed an experimental technique to measure the magnetic moment of a single proton stored in a cryogenic double Penning trap. This method has the potential to conduct a measurement with a precision of at least 1 ppb and has the potential to improve the magnetic moment of the proton by 1 order of magnitude and the magnetic moment of the antiproton by more than a factor of 1000. Currently we are setting up an experiment at the CERN Antiproton Decelerator to conduct this high precision comparison. We submitted a Letter of Intent which was welcomed by the CERN super proton synchrotron committee. We were invited to implement the experiment into the antiproton decelerator facility in close collaboration with the AD community. Detailed implementation studies including the simulation of a beamline and the construction of an independent experimental zone were proposed to CERN in a recently submitted technical design report. This report was evaluated positively by CERN and the SPSC will propose approval to the CERN research board. The apparatus is currently being developed. A team of 5 researches (two Ulmer IRU / one University of Mainz / one Max Planck Institute Heideberg / one Tokyo University) which is led by myself permanently working on the development of the apparatus. At the BASE companion experiment at Mainz which is led by future FPR postdoc Andreas Mooser, recently single spin flip resolution was achieved. This is a major step towards the application of the double Penning trap technique and a precision

measurement of the proton magnetic moment at the level of 1ppb.

2. The Ulmer IRU is a collaboration member of the ASACUSA CUSP experiment. The research subject is the precision measurement of the ground state hyperfine splitting of antihydrogen atoms. Combining these data with the results of 1. constraints of the substructure of the antiproton are obtained. We participate in these efforts by contributing our knowledge on particle detection and low-noise techniques, as well as our expertise on radio frequency techniques in general. Compared to earlier results, in the last antiproton run at CERN the antihydrogen yield was improved by a factor of 10 and encouraging results towards a first production of an antihydrogen beam were produced. Very recently charged electron plasmas were detected in the antihydrogen mixing trap with a particle detector developed at the Ulmer IRU laboratory at CERN. Using this technique opens up the perspective to a quantitative investigation of antihydrogen production as production rate as a function of particle number and particle temperature. The techniques will be implemented into the CUSP apparatus in the near future.

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