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：
Antiproton Magnetic Moment, Proton Magnetic Moment, Antihydrogen, Fundamental Symmetries, Tests of CPT Invariance, Antimatter Research, High Precision Experiments, Antihydrogen GSHFS

Purpose of Research：
The research of the Ulmer Initiative Research Unit is dedicated to the investigation of the properties of matter and antimatter with ultra-high precision. All relativistic quantum field theories involved in the standard model of particle physics predict a perfect symmetry between matter and antimatter. This property is known as CPT invariance. However, on cosmological scales a striking matter-excess is observed, being one of the hottest topics in modern fundamental physics. Comparisons of matter and antimatter systems at lowest energies and with greatest precision are intriguing in part to discover the fundamental cause of the observed imbalance. In our experiments we investigate systems with low intrinsic energy scales, such as the magnetic moments of the proton and the antiproton, the proton to antiproton charge to mass ratio as well as the ground state hyperfine splitting of antihydrogen. These systems are predicted to be highly sensitive to CPT violation.

1. The effort to perform high precision measurements of the properties of protons and antiprotons is recognized at CERN, Geneva, under the acronym BASE (Baryon Antobaryon Symmetry Experiment). Our main goal is to compare the proton and the antiproton magnetic moments with a precision of at least one part in a billion (ppb). 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. With our recently demonstrated double Penning trap technique a measurement of both, the proton and the antiproton magnetic moment with a precision at the ppb is possible. This will improve the magnetic moment of the proton by 1 order of magnitude and the magnetic moment of the antiproton by about a factor of 1000. Currently we are setting up the BASE apparatus at the CERN Antiproton Decelerator to conduct these measurements. After submission of a Letter of Intent and detailed implementation studies in the framework of a technical design report the Research Board of CERN approved the project in June 2013. The apparatus is currently being implemented into the antiproton decelerator facility. A team of 6 researches (two Ulmer IRU / one University of Mainz / one Max Planck Institute Heideberg / two Tokyo University), led by myself, is working on this effort. At the BASE companion experiment at Mainz which is led by myself and future FPR postdoc Andreas Mooser, recently single spin flip resolution was achieved and the double Penning trap technique has been demonstrated. These are the major steps towards 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. provides constraints of the substructure of the antiproton. We participate in these efforts by

contributing to particle detection low-noise techniques, radio frequency techniques and Penning traps. Our collaboration reported recently the first production of a beam of antihydrogen atoms, which is a major step towards performing the aimed spectroscopy.

Principal Investigator

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Students

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