

Trapping Low Energy Antiprotons in an Ion Trap

A thesis presented

by

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to

The Department of Physics

in partial fulfillment of the requirements

for the degree of

Doctor of Philosophy

in the subject of

Physics

Harvard University

Cambridge, Massachusetts

September, 1990

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Abstract

A fraction of antiprotons from the Low Energy Antiproton Ring (LEAR) of CERN are slowed from 5.9 MeV to below 3 keV as they pass through thin foils. Transmitted particle energy distribution and low energy antiproton yield are measured by a time-of-flight technique. The difference in the range of protons and antiprotons (known as the Barkas effect) is observed. While still in flight, up to 1.3×10^5 antiprotons with energies between 0 eV to 3 keV are stored in an ion trap from a single pulse of 5.9 MeV antiprotons leaving LEAR, thus a trapping efficiency exceeding of 4×10^{-4} is established. Trapped antiprotons maintain their initial energy distribution unless allowed to collide with a cloud of trapped electrons, whereupon they slow and cool below 1 meV in 10 s, and fall into a harmonic potential well suited for precision mass measurements. The slowing, trapping and cooling of antiprotons are the main focus of this thesis. The stored antiprotons are in thermal equilibrium at 4.2 K. In this ion trap, the antiproton cyclotron frequency is measured and compared with the proton (or electron) cyclotron frequency. Our new measured ratio of the antiproton and proton inertial masses, with its 4×10^{-8} uncertainty, is more than three orders of magnitude more accurate than previous measurements using exotic atoms. This is the most precise test of CPT invariance with baryons. The antiproton lifetime in an ion trap was measured to be more than 103 days by trapping a cloud of antiprotons for 59 days. This indicates the number density of atoms is less than $100/cm^3$ which corresponds to the pressure in the vacuum chamber being less than 5×10^{-17} Torr at 4.2 K if we apply the ideal gas law.

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Acknowledgements

During my years of Ph.D. study, I have had help from many people. First I would like to thank my thesis advisor, Prof. Gerald Gabrielse, who led the TRAP (TRapped AntiProton) Collaboration and made this work possible. His ideas and insights can be found throughout this thesis. I benefitted a great deal from the other members of the TRAP Collaboration: Johannes Haas, Kris Helmersen, Dr. Hartmut Kalinowsky, Dr. William Kells, Dr. Luis A. Orozco, Dr. Steven L. Rolston, Robert L. Tjoelker, and Prof. Thomas A. Trainor. It is my great pleasure to acknowledge assistance from many people in the Department of Physics at Harvard University, the European Organization for Nuclear Research (CERN) and LEAR, and the Department of Physics at University of Washington during my stay there. While working with Prof. Trainor, we carried out the initial tests of slowing protons and of PPAC detectors at the Nuclear Physics Laboratory of University of Washington. I also appreciate help from my fellow graduate students Ching-Hua Tseng, Loren Haarsma, and Joseph Tan, and from Dr. Benjamin Brown, and Dr. Won Ho Jhe at various stages of this work. This work is supported by the National Science Foundation, the National Bureau of Standards (Precision Measurement Grant), and the Air Force Office of Scientific Research.

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