Contribution ID: **64** Type: **Contributed**

Measuring the gravitational free-fall of antihydrogen

Friday, 14 June 2013 09:55 (25 minutes)

for the AEgIS collaboration.

Antihydrogen holds the promise to test, for the first time, the universality of free-fall with a system composed entirely of antiparticles. The AEgIS experiment at CERN's antiproton decelerator aims to measure the gravitational interaction between matter and antimatter by measuring the deflection of a beam of antihydrogen in the Earth's gravitational field (gbar). The principle of the experiment is as follows: cold antihydrogen atoms are synthesized in a Penning-Malberg trap and are Stark accelerated towards a moiré deflectometer, the classical counterpart of an atom interferometer, and annihilate on a position sensitive detector.

Crucial to the success of the experiment is the spatial precision of the position sensitive detector. We propose a novel free-fall detector based on a hybrid of two technologies: nuclear emulsions, which have an intrinsic spatial resolution of 50 nm but no temporal information, and a silicon strip tracker to provide timing and positional information. In 2012 we tested emulsion films in vacuum with 5 MeV antiprotons from CERN's antiproton decelerator. The annihilation vertices could be observed directly on the emulsion surface using the microscope facility available at the University of Bern. The annihilation vertices were successfully reconstructed with a resolution of 1-2 microns on the impact parameter. If such a precision can be realized in the final detector, Monte Carlo simulations suggest of order 500 antihydrogen annihilations will be sufficient to determine gbar with a 1% accuracy. We will present current research towards the development of this technology for use in the AEgIS apparatus and present prospects for the realization of the final detector.

Summary

The principal of equivalence between gravitational mass and inertial mass is a foundation of general relativity. The universality of free-fall (UFF), the experimental evidence on which the weak equivalence principle is based, has been tested to be valid to a very high precision (1 part in 10 trillion) by many experiments using a variety of techniques [1]. General relativity is a classical theory which makes no distinction between matter and antimatter particles. However, there has never been a direct verification of the weak equivalence with antimatter. Furthermore, it also claimed that an asymmetry in the interaction of gravity with matter and antimatter could be a signature of quantum theories of gravity [2].

The scientific goal of the AEgIS experiment is to measure, in the first instance, the acceleration of antihydrogen in the Earth's gravitational field with a 1% accuracy. In the original proposal for the experiment it was planned to use a silicon strip tracking detector to determine the position of the annihilation vertex with a 10 um position resolution. Monte Carlo simulations suggest that to measure gbar with a 1% accuracy with a detector that has a 10um position resolution, will require the detection of 10,000 antihydrogen atoms. However, only 500 antihydrogen atoms are required for the 1% gbar measurement if the antihydrogen annihilation is reconstructed with a 1 um position resolution. The order of magnitude reduction in the required antihydrogen flux is particularly significant in light of the considerable technical difficulties that must be overcome to produce an antihydrogen beam.

In light of the considerable benefit to AEgIS of a 1 um position sensitive detector, a detector based on nuclear emulsions is currently under development. Nuclear emulsions are photographic films which are optimized for use as particle tracking detectors and are still the most precise particle tracking detector technology currently available. A typical detector consists of a gel with a suspension of silver bromide crystals, in which a track is formed after the passage of an ionizing particle. After chemical development silver grains along the path of the track, with dimensions of 1 μm or less, are visible with an optical microscope. With just a single 50 μm layer it is possible for the full three-dimensional reconstruction of the particle track and a measurement of the energy loss. The intrinsic resolution for tracks in the nuclear emulsion is a mere 50 nm.

In order to evaluate the suitability of a nuclear emulsion based gbar detector for AEgIS, a series of measurements were performed during the 2012 antiproton decelerator (AD) run at CERN. The 5 MeV antiprotons from the AD were directed onto a nuclear emulsion the surface of which was partially covered with a 20 um stainless steel foil. The foil simulates the separation window which will be used in the actual experiment to isolate the emulsion detector from the ultra high vacuum region. The antiproton annihilation vertex was reconstructed with an impact parameter resolution of 1.0 um / 1.4 um in the region uncovered / covered by the stainless steel foil.

A proof of principle of the complete deflectometer was tested by passing antiprotons through a small moiré deflectometer coupled to an emulsion film. Tests were also performed to check that the emulsions could operate in the AD radiation environment. This talk will describe these measurements and detail further progress towards the realization of the final free-fall detector and the gbar measurement in general.

[1] B. Heckel et al., Advances in Space Research, 25(6):1225 – 1230, 2000.
[2] M. Nieto et al., Physics Reports, 205(5):221 – 281, 1991.

Primary author: Dr STOREY, James (University of Bern)

Presenter: Dr STOREY, James (University of Bern)

Session Classification: Gravity

Track Classification: Gravity and Antimatter