Design of a Radial TPC for Antihydrogen Gravity Measurement with ALPHA-g

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The gravitational interaction of antimatter and matter has never been directly probed. ALPHA-g is a novel experiment that aims to perform the first measurement of the antihydrogen gravitational mass. A fundamental requirement for this new apparatus is a position sensitive particle detector around the antihydrogen trap which provides information about antihydrogen annihilation location. The proposed detector is a radial Time Projection Chamber, or *rTPC*, whose concept is being developed at TRIUMF. A simulation of the detector and the development of the reconstruction software, used to determine the antihydrogen annihilation point, is presented alongside with the expected performance of the rTPC.

KEYWORDS: Antihydrogen, Gravity, Gas Detector, TPC

1. Introduction

General Relativity (GR) and the *Standard Model* are incompatible and future experiments will inevitably lead to the modification of one of them, if not both. Testing these theories using antihydrogen ($\overline{\mathrm{H}}$) is the kind of crucial experiment that is needed. For example, GR does not exhaust the possibilities of metric theories of gravity [1], whereas the notion of curved spacetime, that follows from the Einstein's Equivalence Principle (EEP), is a very elegant and general one. Therefore, testing the EEP is not an academic exercise but rather it sets the foundation of the modern conception of gravity. Gravitational tests on antimatter are compelling in order to prove the validity of the EEP in the realm of atomic antimatter [2, 3].

The ALPHA collaboration, based at CERN-AD, has proposed a novel experiment, called *ALPHA-g*, that aims to measure the gravitational acceleration of $\overline{\mathrm{H}}$. The ALPHA-g apparatus is *vertical*, i.e., its axis is parallel to the Earth's gravitational field, with the $\overline{\mathrm{p}}$ and the e^+ injected into the Penning trap from the bottom end. The apparatus is divided into two regions, at different heights, with different functions (see Fig. 1). The lower part, called the trapping or mixing region, is similar to the ALPHA mixing region [4], where an electrode stack, together with a solenoid magnet, are used for $\overline{\mathrm{p}}$ and e^+ manipulation, leading to the formation and trapping of cold $\overline{\mathrm{H}}$. This is achieved by means of a superconducting octupole magnet, that provides the radial confinement, and a set of coils, called *mirror* coils, that provides the axial confinement. The upper part, called the analysis or measurement region, is where the actual determination of the $\overline{\mathrm{H}}$ gravitational acceleration takes place in two stages: first its "sign" (i.e., "up" or "down") and later with 1% accuracy. In order to achieve the