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Towards a Rydberg Interferometer to test the Weak Equivalence Principle with Positronium

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The current theory of General Relativity is based on the Weak Equivalence Principle (WEP), which states that the inertial and gravitational mass are equivalent. Tests of the WEP with matter have resulted in its confirmation to a relative precision of 10-15 [1], but there have been hardly any results from experiments involving antimatter. A difference in the gravitational behaviour of matter and antimatter might help to explain the observed abundance of matter in the universe.
We propose an interferometry experiment using Positronium (Ps), the bound state of an electron and its antiparticle - the positron. The short lifetime of the ground-state Ps of 142 ns complicates an interferometry experiment, but this can be circumvented by the excitation to a high Rydberg state, which results in the suppression of annihilation and an increase in the lifetime to tens of μs [2]. The proposed interferometer is an electrical analogue of a Stern-Gerlach experiment; a superposition of Rydberg states with differing static electric dipole moments is allowed to evolve in electric field regions and acquire a measurable phase difference, depending on the interaction of the atomic states with the fields under gravity.
Unlike antihydrogen, Ps is a purely leptonic system, hence it is not influenced by possible effects of the binding energy of quarks on the gravitational behaviour [3]. This makes it a complementary measurement to the ongoing work with antihydrogen at CERN [4].
In the initial stage we will build a proof-of-principle setup with Helium which will afterwards be adapted to Ps. In this poster we will present the measurement technique along considerations on the experimental realisation and possible limitations.

References:

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