Cold muonium atoms for future atomic physics and gravity experiments

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We are investigating methods to create a novel muonium (Mu) source, based on $\mu^+ \to \text{Mu}$ conversion near to the surface of superfluid helium (SFHe). This source would have the potential of providing high brightness atomic beams for next generation Mu experiments, e.g. to increase precision of present Mu spectroscopy results [1, 2]. We are also investigating the feasibility of using such sources for measuring the gravitational interaction of Mu. The positive muon ($\mu^+$) which is dominating the Mu mass is not only an elementary antiparticle, but a second-generation lepton too. This makes a gravity experiment highly motivated [3], and complementary to gravitational studies of antihydrogen [4, 5, 6] and positronium [7].

State-of-the-art Mu sources (like silica aerogel, mesoporous SiO$_2$) emit Mu atoms with a large (thermal) energy distribution, and wide ($\sim \cos \theta$) angular distribution. Cooling of these porous samples below 100 K results in rapidly declining numbers of vacuum-emitted muonium due to decreased mobility, and atoms sticking to the pore walls [8]. The advantage of using superfluid helium for Mu production at $T < 0.3$ K temperatures is the expected large chemical potential ($E/k_B \sim 270$ K) of the atom. This implies that in the vicinity of the surface, Mu would be ejected with relatively high ($\sim 6$ mm/s) velocities from the bulk to near-vacuum even at the lowest temperatures, while transverse momentum would remain low due to the cold media [9]. In this talk, methods and challenges to create such SFHe Mu sources, the present status, and the feasibility of an antimatter gravity experiment will be discussed.