Cold Muonium Beam for Atomic Physics and Gravity Experiments

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We are investigating methods to create a novel muonium (Mu) source, based on $\mu+ \rightarrow$ Mu conversion in superfluid helium (SFHe), which has the potential of providing high brightness Mu beams for next generation laser spectroscopy experiments. 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 [1], and complementary to gravitational studies of antihydrogen [2, 3, 4] and positronium [5].
State-of-the-art Mu sources (like silica aerogel, mesoporous SiO_2) emit Mu atoms with a large (thermal) energy distribution, and wide (~ cos θ) 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 [6].
Our proposed method relies on stopping $\mu+$ in a thin layer of SFHe, and forming Mu by capturing an electron from the ionization trail. A fraction of the Mu diffuses to the SFHe surface within their lifetime, where emission into vacuum occurs. The velocity of the emitted Mu (~ 6 mm/μs) is given by their large chemical potential ($E/kB \sim 270$ K) in SFHe, while the low temperature of the liquid ($T < 0.3$ K) determines their transverse momentum [7].

References

[1] Kirch, K. *et al*., *In International Journal of Modern Physics: Conference Series*, **30**, 1460258, (World Scientific, 2014).
[2] Charman, A. *et al*,. (Collaboration ALPHA), *Nature Communications*, **4**, (2013), 1785.
[3] Scampoli, P. and Storey, *J. Modern Physics Letters A*, **29**, (2014), 1430017.
[4] Perez, P. and Sacquin, *Y. Classical and Quantum Gravity*, **29**, (2012), 184008.
[5] Cassidy, D. and Hogan, *International Journal of Modern Physics: Conference Series*, **30**, 1460259 (World Scientific, 2014).
[6] Antognini, A. *et al.*, *Physical Review Letters*, **108**, (2012), 143401.
[7] Taqqu, D. *Physics Procedia*, **17**, (2011), 216 223.