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In a muon's lifetime: From Fermi's constant to "calibrating" the sun

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This presentation will cover three experiments at the Paul Scherrer Institute, Switzerland, all measuring the muon lifetime with high precision. The MuLan experiment [2] uses a simple soccer-ball like scintillator array to detect the positrons from the decay of positive muons. We collected twice 10^{12} muon decays in two different target materials to obtain the final precision of 1 ppm for the lifetime. This determines the Fermi constant G_F to 0.5 ppm precision [1]. The muon capture experiment MuCap uses a negative muon beam stopped in a time projection chamber as an active target filled with ultra-pure hydrogen gas. The elementary capture process μ^-+p $\rightarrow$ n+ν offers a rare (0.15%) additional disappearance channel. The measured difference of the positive and negative muon's lifetime determines the rate of the capture process to a final precision of 1%. This can be used to derive an improved value of the proton's pseudoscalar form factor g_P to 7% precision. A first result g_P = 7.3 $\pm$ 1.1 has been published [3]. This is a first precise, unambigous determination of g_P and an important test of QCD symmetries. Recently, we started a new experiment, MuSun [4] to measure the μ^-+d $\rightarrow$ n+n+ν doublet capture rate. This measurement will provide a benchmark of the understanding of weak processes in the two nucleon-system. It was shown, that other weak reactions involving the two nucleon system (pp $\rightarrow$ de$^+\nu$ or ν+d reactions) are related to the same low-energy constant, characterizing the two nucleon system at short distances. This constant is not well constrained and therefore the MuSun experiment comes closest to calibrating these basic astrophysical reactions under terrestrial conditions.

[1] In preparation for publication
[2] Phys. Rev. Lett. 99, 032001 (2007)
[3] Phys. Rev. Lett. 99, 032002 (2007)
[4] http://www.npl.uiuc.edu/exp/musun/documents/prop07.pdf