PENeLOPE - A Precise Experiment to measure the Neutron Lifetime Operating with Proton Extraction ◇

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The neutron lifetime has always been an active area in fundamental research. Various measuring methods have been developed and utilized: Beam methods for thermal and cold neutrons and storage methods for ultra-cold neutrons. The precision ranges from 95 s some 30 years ago to 0.8 s for the latest measurements. The value adopted by the Particle Data Group [1], $\tau_{\mathrm{n}} = 885.7 \pm 0.8\,\mathrm{s}$, is mainly determined by one measurement with ultra-cold neutrons (UCN) stored in a bottle with fomblin coated walls [2]. A new experiment, using the same method, but cooled fomblin [3], determined the lifetime to $\tau_{\mathrm{n}} = 878.5 \pm 0.8\,\mathrm{s}$, a deviation of more than $6\,\sigma$ from [1]. Therefore it is mandatory to scrutinize the results again by conducting a new and complementary measurement.

In order to avoid wall losses, the main uncertainty of the above mentioned experiments, one may use a magnetic field to contain UCN (see also [4]). This complementary method should allow a reduction of systematic errors.

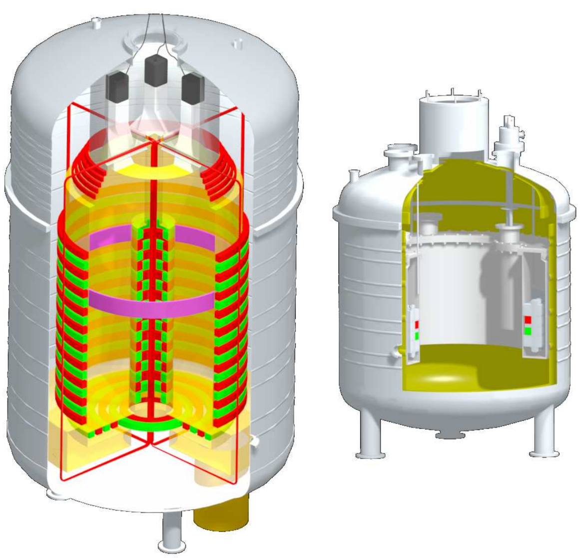

Fig. 1: **(left)** Schematic view of the magnetic storage device for UCN. The superconducting storage solenoids have alternating current direction. Five coils at the top serve to focus the accelerated decay protons onto the detector. **(right)** Schematic view of the test cryostat. Two solenoids are packed inside a support structure and surrounded by He vessel, N_2-shield and vacuum tank.

Fig. 1 (left) shows a schematic view of the planned superconducting-magnet trap PENeLOPE [5]. The four racetrack coils on the axis serve to avoid zero-field regions with their enhanced danger of neutron spin flip and its subsequent loss. Monte Carlo simulations clearly show that this spin-flip suppression current is necessary as may be seen in Fig. 2: the spin-flip probability stays well below 10^{-5} as long as the current is higher than half of the nominal current (8 kA). If the current is lower, the magnetic field in certain parts of the storage volume is too weak to fulfill the condition of adiabatic spin transport.

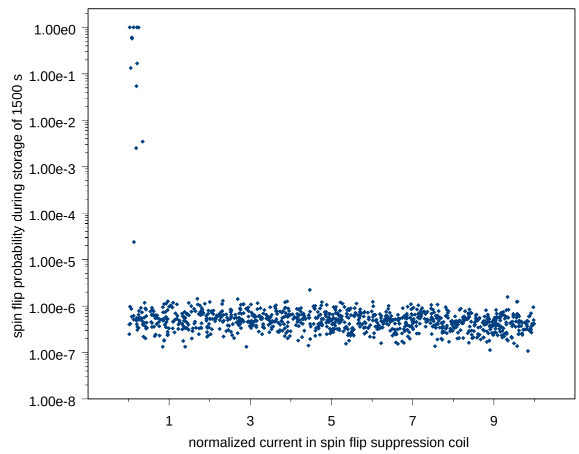

Fig. 2: Spin-flip probability of neutrons after magnetic storage of 1500 s versus spin-flip suppression current

With a trap depth of 110 neV and a volume of about $700\,\mathrm{dm}^3$, we may store between 10^5 and 10^7 UCN per filling, depending on the UCN source, so that the statistical error will not dominate. Together with the possibility to detect spin-flipped UCN and to vary the magnetic flux density by changing the current in the superconducting coils, this allows to investigate possible systematic effects thoroughly. Thus we expect to decrease the total error for τ_{n} to about 0.1 s.

As a key feature, the system allows the collection of decay protons. This is done with an efficiency of around 70% through an intelligent design of the magnetic field and an additional electric extraction field. After acceleration to more than 30 keV, the protons hit a large-area detector, which is currently developed and tested at the institute [6]. Applying this detection method also demonstrates an advantage of magnetic storage, as decay-proton detection with a material trap has not been achieved yet.

Two pre-experiments are one the way: The coil design including cooling, pumping, ramping of the storage coils, magnetic field measurements, high voltage and so on will be tested at the MLL in 2006. A schematic view of the test cryostat is shown in Fig. 1 (right). Another important aspect, cleaning the UCN spectrum from high-energy neutrons ($E_{\mathrm{kin}} >$ trap depth), which still have a storage time comparable to τ_{n}, has to be optimized. These so called marginally trapped neutrons would cause a systematic effect on the measured lifetime. On this account, a proposal for beam time at the ILL, Grenoble, has been submitted.

References

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