PENeLOPE - Preparations for a Precision Neutron Lifetime Experiment

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The neutron lifetime provides important information for particle physics and cosmological models. On the one hand it helps to determine the first element of the CKM quark mixing-matrix and hence allows a test of the standard model of particle physics. Additionally, it is a crucial input parameter for nucleosynthesis models to calculate the primordial helium abundances. However, the latest material storage measurement of τ_n differs from the world average by more than $6\,\sigma$ [1] and demands for a new accurate determination of τ_n.

The most precise measurements so far were performed by storing ultra-cold neutrons (UCN) in material bottles. However, there are significant losses during wall collisions, whose nature is not fully understood. Therefore, systematic errors cannot be decreased much below their present values and a different concept is necessary to improve our knowledge of τ_n. Magnetic storage has been shown to be a viable alternative [2].

In our experimental setup, PENeLOPE (Fig. 1), the volume between two nested cylinders with 50 cm and 12 cm radius respectively, will be used to store UCN. Superconducting coils at the walls and at the bottom of the trap produce a magnetic field of around 2 T. The top at a height of 110 cm may stay open as gravity prevents UCN from leaving there. This results in a storage volume of over 700 l. Furthermore, in PENeLOPE we combine magnetic storage with a second major key for high-precision needs: on-line detection of neutron decay products. The decay protons will be extracted to the top by an electrical potential of 10 kV, post-accelerated by additional 30 kV and focused onto a scintillation detector [3].

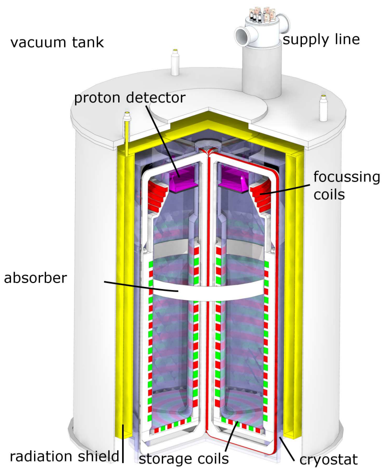

Fig. 1: CAD drawing of the PENeLOPE design

Besides high statistics, which is easily achieved with PENeLOPE by more than 10^5 stored neutrons per cycle, the crucial point for a precise neutron lifetime measurement is to avoid or understand all systematic effects. These are mainly spin flip with subsequent neutron loss and the storage of marginally trapped neutrons. Spin flip is avoided by a thorough design of the magnetic field configuration, whereas high-energetic, marginally trapped UCNs will be removed with an absorber installed at appropriate height. With the AbEx setup, which has been built with big support by the MLL, the efficiency of the ring-shaped absorber was proven to be sufficient down to operating temperatures of 4K. [4]

Right now, at hall 3 of the MLL, a test setup for two superconducting coils is in the commissioning phase. In PENeLOPE filling of the neutrons has to be done while the magnetic field is switched off, making a material storage phase necessary. To minimize this time, the current in the superconducting coils has then to be ramped up as fast as possible. With the coil test setup (CotEx) operational limits like ramping speed and the maximum coil current shall be explored. The two solenoids, about 86 cm in diameter with 1872 windings of NbTi wire, are embedded in a liquid-helium cryostat of about 223 l. They will generate a magnetic field of up to 6.8 Tesla when energized with a maximum current of 250 A. As the coils are connected in series but with opposite current direction, the stray field drops below 1 mT at a radius of 1.6 m. Liquid helium is supplied by the liquefier installed in hall 3. The aluminium cryostat is surrounded by a copper radiation shield cooled down to liquid nitrogen temperature and put in a stainless steel vacuum tank to reduce heat input. An isolation vacuum of $1.5 \cdot 10^{-5}$ mbar at liquid-nitrogen temperature has been reached so far.

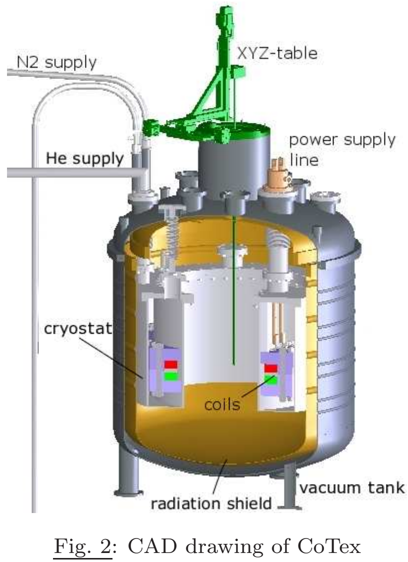

Fig. 2: CAD drawing of CoTex

Furthermore, on top of the setup a linear XYZ-table will be installed. With a vacuum-tight wobble stick it guides a Hall sensor to measure the magnetic field map accurately. First energizing of the coils is expected in the first half of this year.

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References

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