PENeLOPE - On the Way Towards a New Precise Neutron Lifetime Measurement

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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.

In our experimental setup, PENeLOPE (for a figure, see [3]), 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 are guided to the detector at the top by the specially designed magnetic field. The ones emitted downwards are reversed upwards by the large magnetic field at the bottom through the magnetic mirror effect. To efficiently detect the protons, they are post-accelerated via putting the detector on a negative potential of around −30 keV [4].

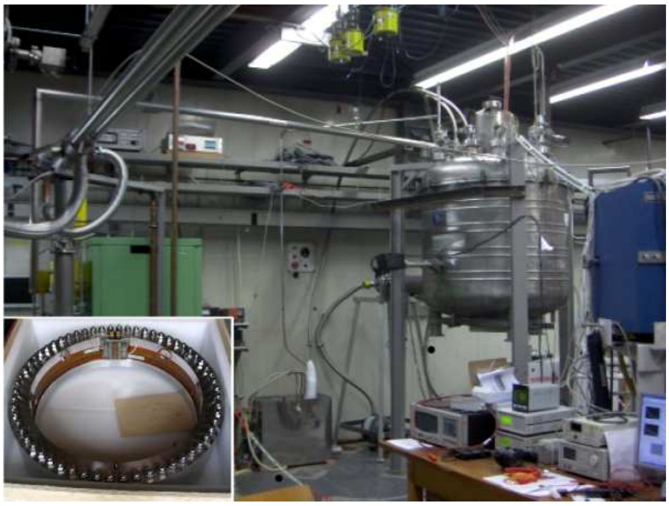

Fig. 1: CoTex setup at MLL. Left lower inlay: superconducting test coil package, which is installed in the cryostat on the right.

In the last year, the test setup CoTEx at hall 3 of the MLL was commissioned (Fig. 1); it incorporates prototypes of two of the main superconducting coils of PENeLOPE [3]. The coils were trained and ramping tests were carried out. Along the way, the benefit of building a prototype before finalising the technical design of such a complicated magnet was proven: Only a current of 175 A instead of the 250 A nominal current could be reached by training (compare Fig. 2), indicating problems in the design of the coil package.

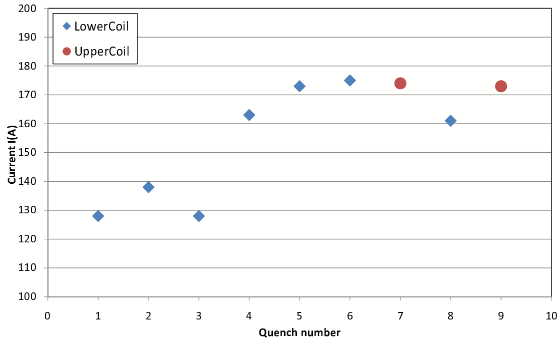

Fig. 2: History of quenches of the CoTEx magnet.

The data was analyzed by the manufacturer of the coils and a possible weak spot indentified: due to the topology of two short solenoids carrying large currents in opposite direction, huge forces are exerted on the coils pushing them apart. Therefore they have to be held together by a large support structure (see inlay of Fig. 1). The horizontal interface of the aluminium support structure with the impregnated coil package was glued together creating strong forces during cool down of the magnet. Energization then resulted in further stress leading to cracks in the epoxy resin of the coil and subsequently a quench.

The next iteration of the prototype will incorporate a low friction layer at the interface to allow smooth movement of the two adjacent materials and therefore reduce stress.

A second development emphasis in the PENeLOPE project lies in the proton detection. Three different detector schemes are investigated: a scintillator-lightguide-photodetector (APD) array with either plastic scintillators or CsI as active layer as well as multi-channel plates.

Additionally, coatings of the neutron storage volume of PENeLOPE are tested, which improve the storage times of the UCN during filling and emptying of the trap, when the main magnets are switched off and PENeLOPE acts as a material bottle: A neutron storage experiment to be conducted at the Institut Laue-Langevin (ILL), Grenoble, is prepared at hall 2 of the MLL, incorporating the AbEx cryostat, which was already used during two UCN beam times [5].

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References

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