A Magnetic Storage Device for Neutron Lifetime Measurements

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Two important weak-interaction parameters may be determined from the β-decay of the free neutron: the absolute value of the matrix element V_{ud} and the ratio $\lambda = g_{\mathrm{A}}/g_{\mathrm{V}}$ of the axial-vector and vector coupling constants. Here the knowledge of the neutron lifetime τ_{n} and a parameter of one of the correlations between neutron direction or spin and direction and/or spin of the decay products is sufficient.

Most experiments on τ_{n} stored ultra-cold neutrons (UCN) in material bottles. The value for τ_{n} adopted by the Particle Data Group [1] is mainly determined by one measurement [2]. The results from different groups scatter appreciably. This may be due to the fact that UCN losses in the traps by wall collisions are not fully understood. Magnetic trapping avoids neutron contact with the trap walls and stays free from the systematic uncertainties connected with this source of losses. Hence experiments with *magnetic* traps are complementary to the common method.

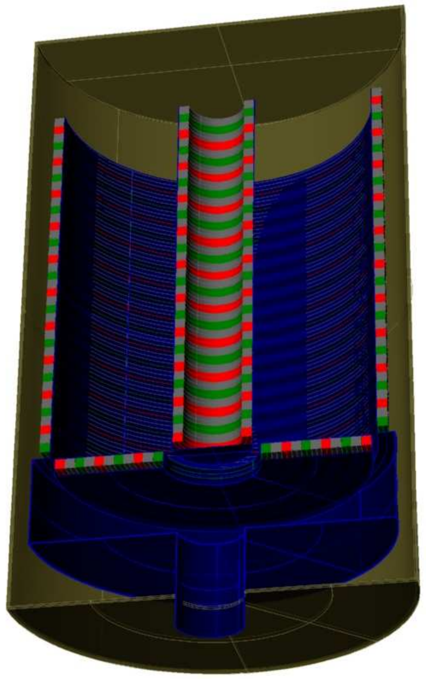

Fig. 1: Schematic view of the magnetic storage device for UCN. The superconducting coils are shown in dark grey and the soft- iron layers in light grey. For more details cf. text.

A schematic view of the planned trap with superconducting magnets is shown in Fig. 1. A torus with 10 cm inner and about 50 cm outer radius and with a height of around 1.2 m is composed of sandwiches of superconducting ring coils with rings of permendur (a NbFeV alloy) or soft iron in between. The bottom of the trap is put together from concentric rings, again from soft ferromagnetic material between superconducting coils. The axis of the torus stands vertical and the top remains open. A field at the walls of about 2 Tesla is sufficient to confine UCN with energies below 120 neV. Gravitation prevents these UCN from leaving through the top. Two ring-shaped slits in the lower edges allow filling the trap and detecting depolarized neutrons.

At a volume of about 900 dm^3 and a UCN density of well above 10^3/cm^3 at FRM II we may expect to store more than 10^8 UCN with the right orientation of the magnetic moment in one filling.

In order to fill the UCN storage unit the trap is operated with a weak magnetic field in the outer slit. To this end the coils at the lower, outer edge (cf. Fig. 1) are switched off. After filling with neutrons of one spin direction the entrance slit may be closed by a shutter covered with Be or ^{58}Ni. Now the current in the coils is increased again, slow enough to leave the current in the other coils nearly unaffected. Afterwards the shutter may be opened again.Under these circumstances the time constant for filling through a 3-5 cm slit is as low as about 10 s.

After trapping the neutrons, we can determine their number as a function of time. The most desirable method is accelerating the protons from neutron decay towards the top of the setup by an electric field generated via field wires at the torus walls. A voltage of about 5 kV between bottom and top seems sufficient. According to calculations more than 90% of the protons reach the top of the torus; this because part of them are reflected in the magnetic field near the walls. After further acceleration to about 30 keV and some focusing these protons hit a thin foil of larger area from a suitable material (e.g. kapton with a very thin Al layer). Ion-induced electron emission frees electrons that are accelerated towards a scintillator that is held at zero potential. The scintillation light is detected with sensitive photomultipliers or hybrid photomultiplier tubes.

Important sources of systematic errors in the experimental value of τ_{n} may be i) the presence of neutrons of wrong polarization (high-field seekers) at measurement start and ii) neutron spin flip during the measuring cycle. In both cases neutrons may escape from the storage volume and are lost. In order to detect them, the walls of the trap will be covered by beryllium or DLC (diamond-like carbon). Thus these neutrons are reflected at the walls and finally leave the trap through the slits at the bottom to be detected by a UCN counter below the set-up.

Covering the trap walls with Be has another advantage. If energetic UCN penetrate through the magnetic wall, they are reflected by Be with very small losses and stay in the storage volume. As such events are expected to be rare, this kind of losses may be kept negligible.

The conceptual layout of the magnetic trap is almost ready and construction work will start in the second half of 2003.

References

[1] K. Hagiwara *et al.*, (Particle Data Group), Phys. Rev **D66** (2002) 110001
[2] S.S. Arzumanov *et al.*, Nucl. Instr. Meth. **A440** (2000) 511