Experiment on neutrino storage in a magnetic trap

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Preliminary results are reported of an experiment on the containment of ultracold neutrons (UCN) (0–9 neV) in a magnetic trap with field intensity 25 kOe. The number of neutrons accumulated in the trap is 1.05 ± 0.15, and the storage time is 35 ± 10 sec.

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The possibility of containing neutrons with the aid of magnetic fields was first pointed out in[1]. If the neutron is introduced into the interior of a closed magnetic cavity in which the field increases from the center towards the periphery, then it will be stored in the cavity as long as its spin is directed along the field and the energy is $E < \mu H_{max}$, where μ is the magnetic moment of the neutron and H_{max} is the maximum field intensity at the boundary of the cavity. Spin flip (depolarization) reverses the sign of the interaction of the magnetic moment with the field and causes the neutron to leave the containment region.

Papers devoted both to the theoretical analysis of the containment of neutrons by magnetic fields[2–5] and to a description of magnetic traps presently designed or under construction[6–8] have by now been published. The main stimulus to work in this

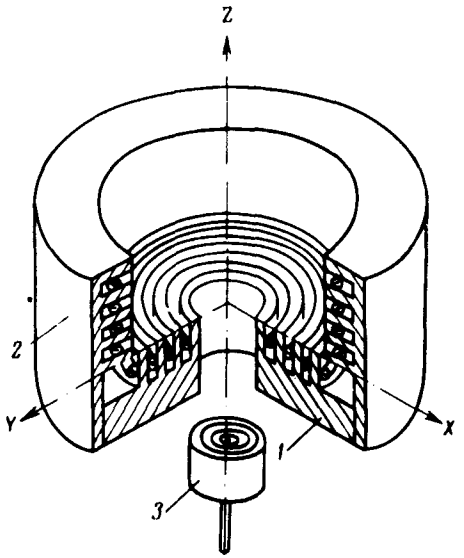

FIG. 1. Schematic diagram of the magnetic trap: 1—flat horizontal mirror; 2—cylindrical vertical mirror; 3—stopper.

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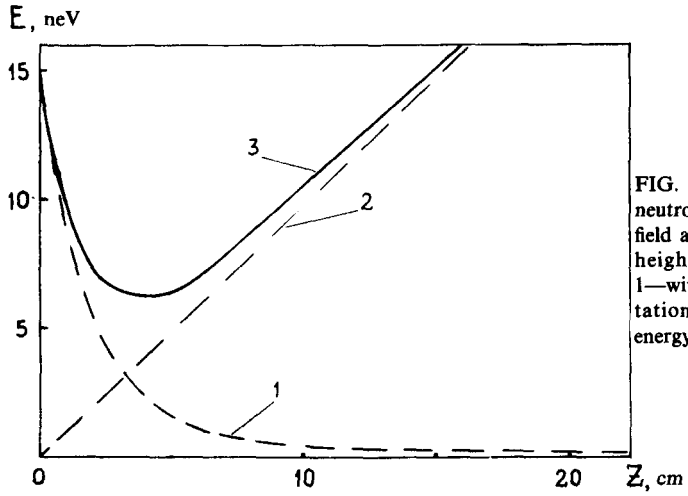

FIG. 2. Dependence of the energy of neutron interaction with the magnetic field and the gravitational field on the height over the horizontal mirror: 1—with magnetic field; 2—with gravitational field; 3—total interaction energy.

direction is the possibility of directly measuring the lifetime of the free neutron with the aid of such systems.[9] The results of experiments on the interaction of UCN with magnetic fields, carried out with the SM-2 reactor,[10–12] served as the basis for the development and construction of the trap illustrated in Fig. 1.

The magnetic system of the trap consists of a flat horizontal mirror and a cylindrical vertical mirror 2. The upward motion of the UCN is limited by the gravitational field.

The horizontal mirror of 80 cm diameter has seven concentric poles, whose gaps contain the supply windings. The vertical magnetic mirror consists of cylindrical armor of 80 cm diameter and four poles in the form of rings with inside diameter 64 cm. In the gaps between the poles are placed three windings in which the number of turns decreases linearly in the upward direction.

The central part of the lower mirror, including two poles and two windings, is an autonomous unit that plays the role of the "stopper" 3. Through the opening closed by the "stopper," the UCN enter the trap and leave it to be recorded. The windings of the mirrors are connected in series. The total power released in the windings in 20 kW, the current is 110 A, and the amplitude of the fundamental harmonic of the current pulsations at a frequency 25 Hz do not exceed 0.2%. The current in the windings of the "stopper" was 120 A, the amplitude of the fundamental harmonic of the pulsations at 30 Hz did not exceed 1.5%, and the power consumption was 1.5 kW.

The windings of the horizontal mirror were cooled with oil, while the vertical mirror and "stopper" were cooled with compressed air.

The field intensity at a height 2 mm from the plane of the poles was 2.5 kOe. The produced field ensured containment in the volume of the trap of neutrons having a kinetic energy in the range 0–9 neV (Fig. 2). At the central pole, at the same height, in the region starting with 6 cm diameter, the field intensity gradually decreases to zero.

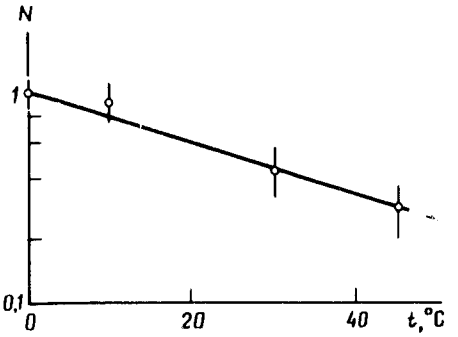

FIG. 3. Dependence of the number of UCN remaining in the trap on the storage time.

The inner surface of the vacuum chamber of the trap, with the exception of the end surface of the magnetic "stopper" and of an angular strip 3 cm wide around the entrance opening, is coated with a UCN absorber (polyethylene).

In the experiments with the trap we investigated the dependence of the number of neutrons that remained in the trap volume on the containment time. The neutron-accumulation time was 60 sec, and the registration time was 20 sec. With the magnetic field turned off, the neutrons entering the trap struck the wall of the vacuum chamber and were absorbed in the polyethylene. The number of neutrons accumulated per cycle in this case was 0.00 ± 0.06, i.e., there was no accumulation.

The results of the experiment with the field turned on are shown in Fig. 3. During one cycle in the trap there are accumulated 1.05 ± 0.15 neutrons and the containment time is 35 ± 10 sec. The results indicate that neutron storage in a magnetic trap has been accomplished.

We are planning in the future to study the influence of the degree of stability of the magnetic field and of the presence of regions with zero intensity in the field on the time of neutron containment in the trap.

It is also of interest to investigate the possibility of depolarization of the UCN that impinge against the central part of the stopper, where the field is weakened.

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