UCN storage in the magnetic trap from permanent magnets

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I. Reflection of UCN by magnetic barrier

Magnetic potential $U = -\vec{\mu} \cdot \vec{B}$,

For magnetic moment of neutron

$$U = 0.6 \cdot 10^{-7} eV \cdot T^{-1}$$

Nuclear potential of Be

$$2.5 \cdot 10^{-7} eV$$

Magnetic field 1 T reflects neutrons up to 3.4 m/s.

$$F = -\nabla U = \nabla(\vec{\mu} \cdot \vec{B}) = \pm\mu\nabla\left|\vec{B}\right|,$$

+ for $\vec{\mu} \uparrow\uparrow \vec{B}$ **and**

– for $\vec{\mu} \uparrow\downarrow \vec{B}$.

II. Probability of depolarization

Case of strong field:

Precession of magnetic moment $\frac{d\vec{\mu}}{dt} = \gamma_n \vec{\mu} \times \vec{B}$ **;**

$$\gamma_n = 1.83 \cdot 10^8 s^{-1} T^{-1}$$

Adiabatic condition

$$\gamma_n B >> (dB/dt)/B = v \cdot \nabla|B|/B$$

(v **-- is the velocity of neutron)**

For case of strong field

(B = 1T), ∇B = 1T/mm and velocity v = 3.4 m/s one can receive next relation for adiabatic condition:

$1.83 \cdot 10^8 >> 3.4 \cdot 10^3$.

Case of weak field: **(V.V.Vladimirski, 1961, JETP 12, 740)**

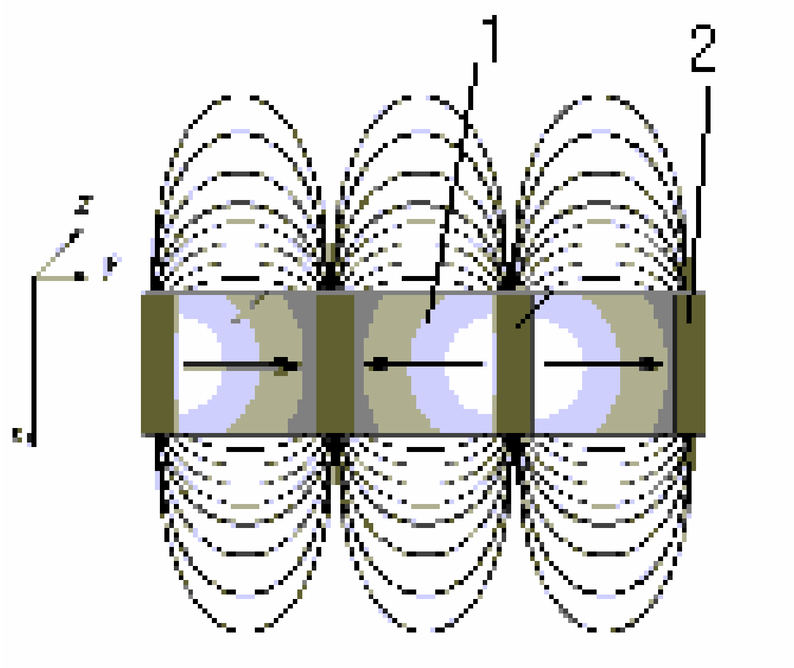
Probability of nonadiabatic spin flip is $w = e^{-\pi\omega\tau}$

$\omega = \mu H_z / \hbar$ **- precession frequency of magnetic moment relative of H_z ,**

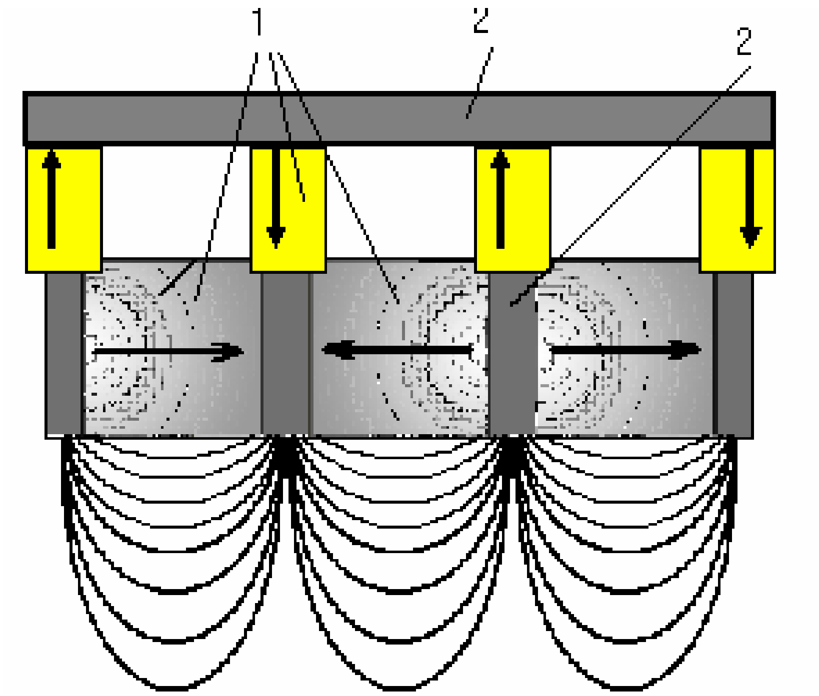
$\tau = H_z / \dot{H}$ **effective time of magnetic field rotation.**

For N passes of neutron near the points of very weak field it's necessary to have $N\, w \ll 1$**. So we receive the relation for minimum value of magnetic field:**

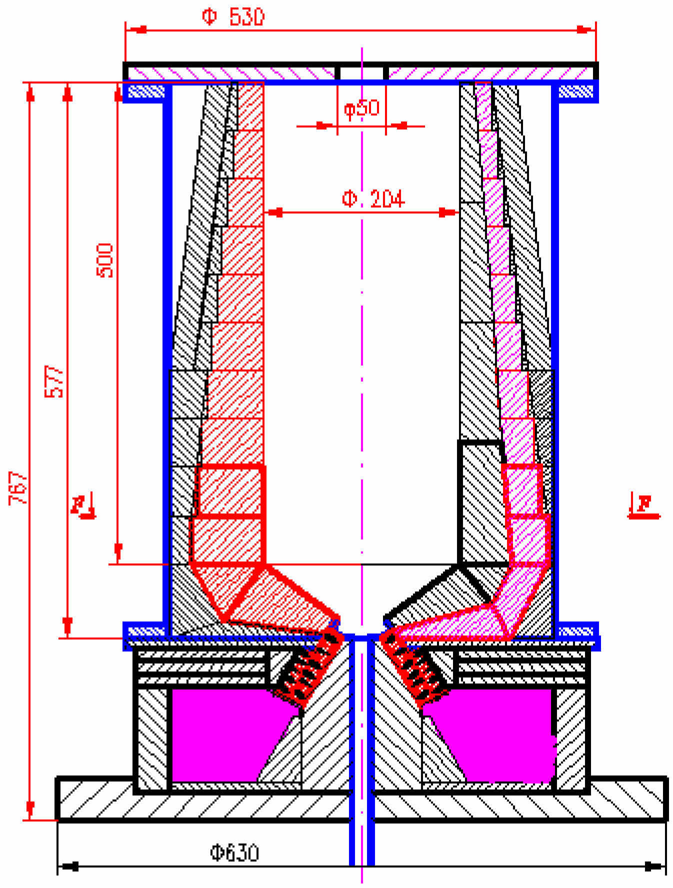
$$\pi\mu H_{z\min}^{2} / \hbar \left|\dot{H}\right| >> ln\ N$$



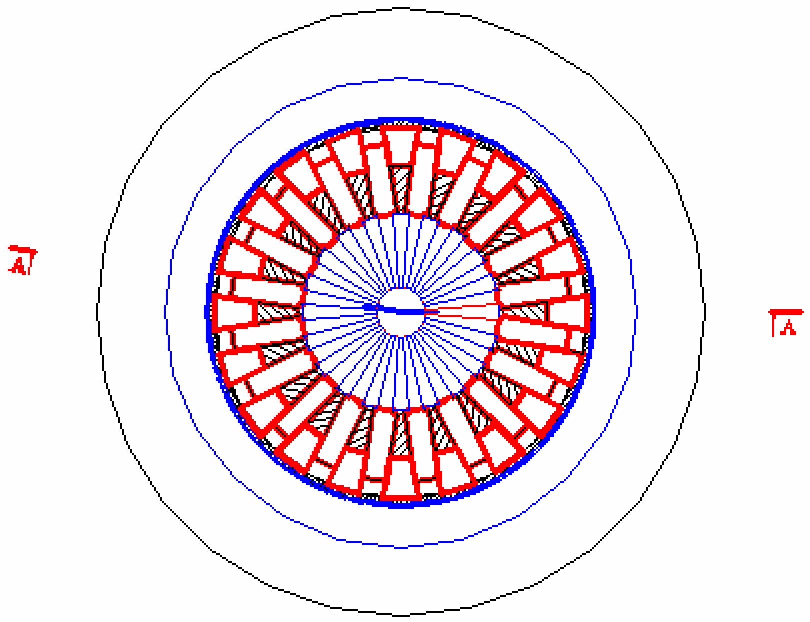
1 – permanent magnet
2 – magnetic field guide

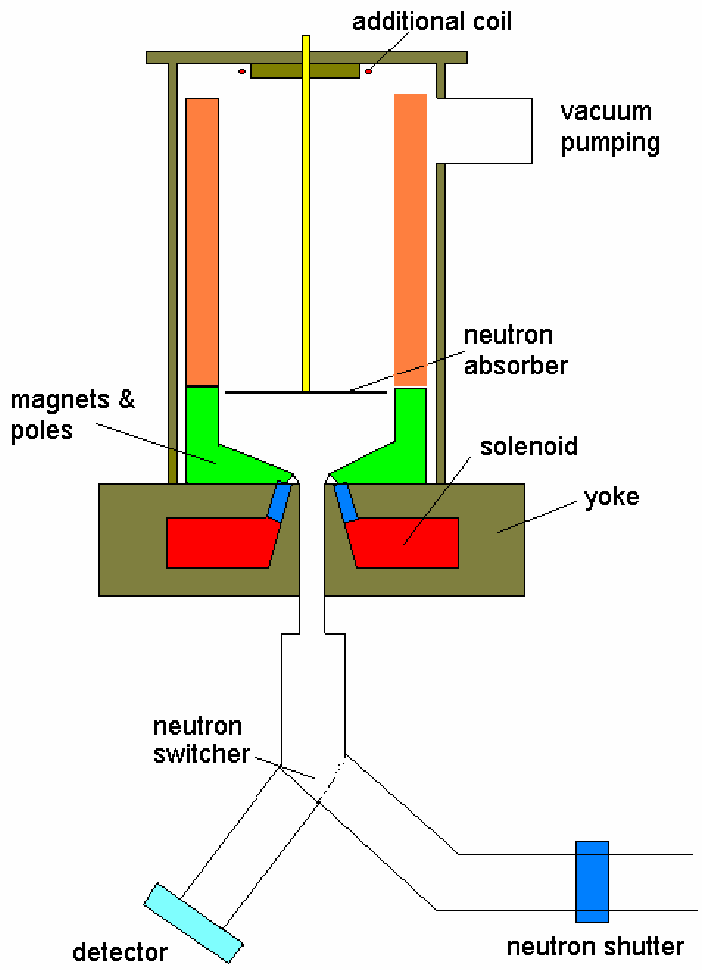


A-A



F-F





MAGNETIC TRAP FROM PERMANENT MAGNETS

1. The trap walls consist of a periodic structure with a characteristic period of ~1cm. The magnetic field decreases quite fast (gradient ~ 2 T/cm).
2. The UCN are transferred to the trap through a neutron guide inside the solenoid at the bottom. After loading the trap this entrance is closed by switching on the current in the solenoid. To facilitate fast operation we use a normal-conducting solenoid with iron core and permanent magnets.

3. **UCN with energies exceeding the solenoid magnetic barrier will penetrate the barrier and disappear. Thus changing the current in the solenoid easily modifies the spectrum of trapped UCN.**
4. **Moreover, by applying a magnetic barrier at the entrance during trap loading, the spectrum may also be cut from the low-energy side. This flexibility in the choice of the UCN spectrum is very useful for eliminating systematic errors in the neutron lifetime measurement.**
5. To avoid UCN depolarization at the points of zero magnetic fields we use the field generated by the lower solenoid, which is orthogonal to the magnetic field from the permanent magnets. For this purpose an iron yoke guides the magnetic field from the solenoid to the top of the trap.
6. **To control the depolarization of UCN we can cover the inner trap walls with thin nickel foil that reflects depolarized UCN. In this case the depolarized UCN penetrate the magnetic barrier inside the solenoid and are measured by the UCN detector installed below the solenoid. Hence this detector may be used as monitor for depolarization losses during neutron storage.**

Storage time for lower part (height is 15 cm): 882 ± 16 s

	Existing lower part of trap	Upper part of trap	Trap of larger diameter
Volume (l)	3.6	15.6 l	62.4 l
Neutrons after 50 sec of cleaning time	62.6±2.0	1770±11	7000
Neutron density after 50 sec of cleaning time	0.017 n/cm^3	0.11 n/cm^3	0.11 n/cm^3
Accuracy of lifetime measuring	16 sec in 6 days	3.1 sec in 6 days	1.6 sec in 6 days
Price	25 000 $	30 000 $	60 000 $

Fit Gaussian