SHAPIRO 100

Opening UCN – Heroic Period

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DUBNA
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Bio Data

- Spallation Neutron Source, Oak Ridge National Laboratory, USA, Tennessee
- VULCAN, Materials science and engineering diffractometer, instrument scientist
- Dubna: Dec. 1975 – Dec. 1979, UCN – Storage anomaly, A. V. Strelkov

Heroic ?

- lack of prediction
- lack of resources

UCN Storage Anomaly: Heating

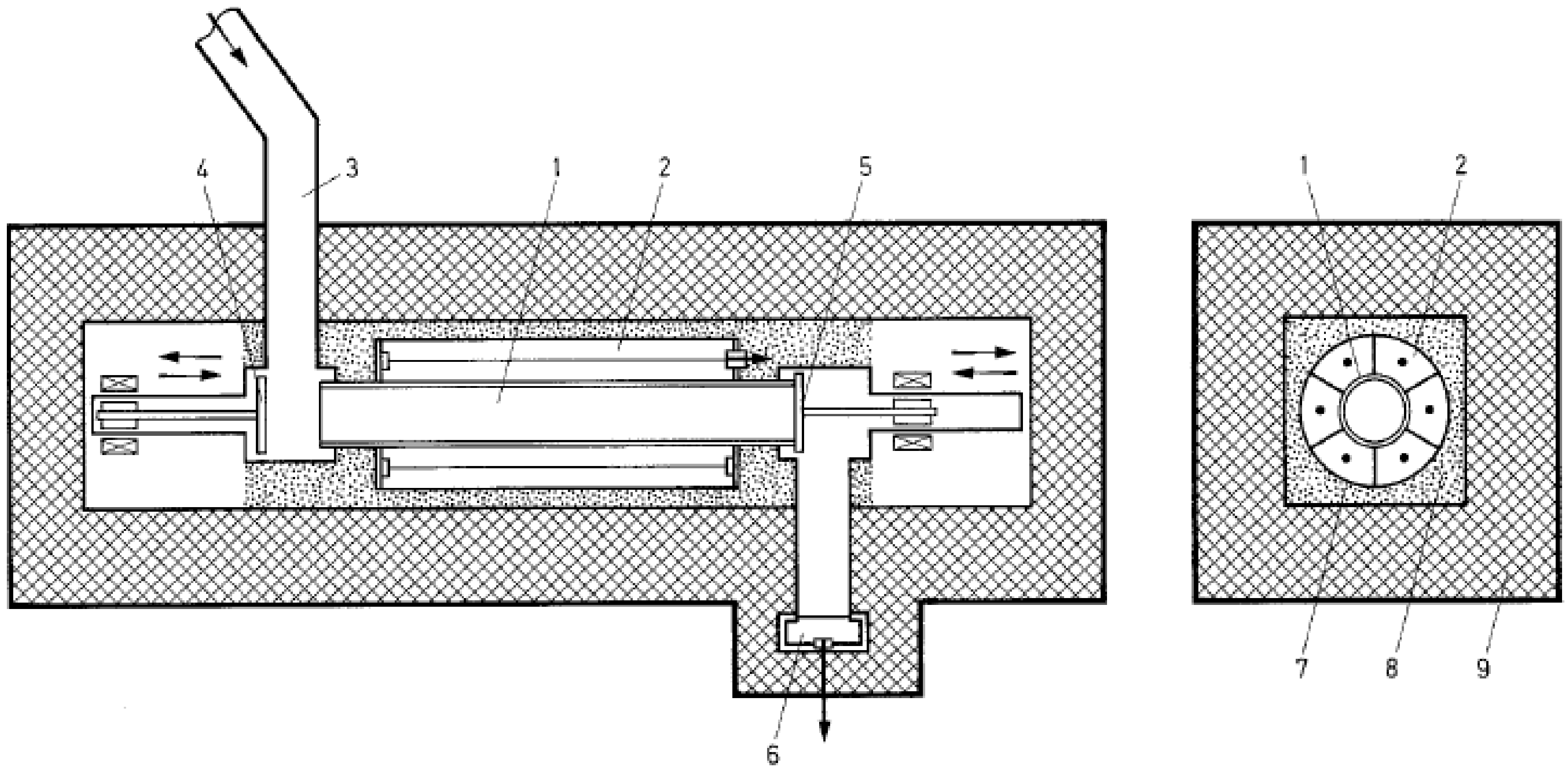
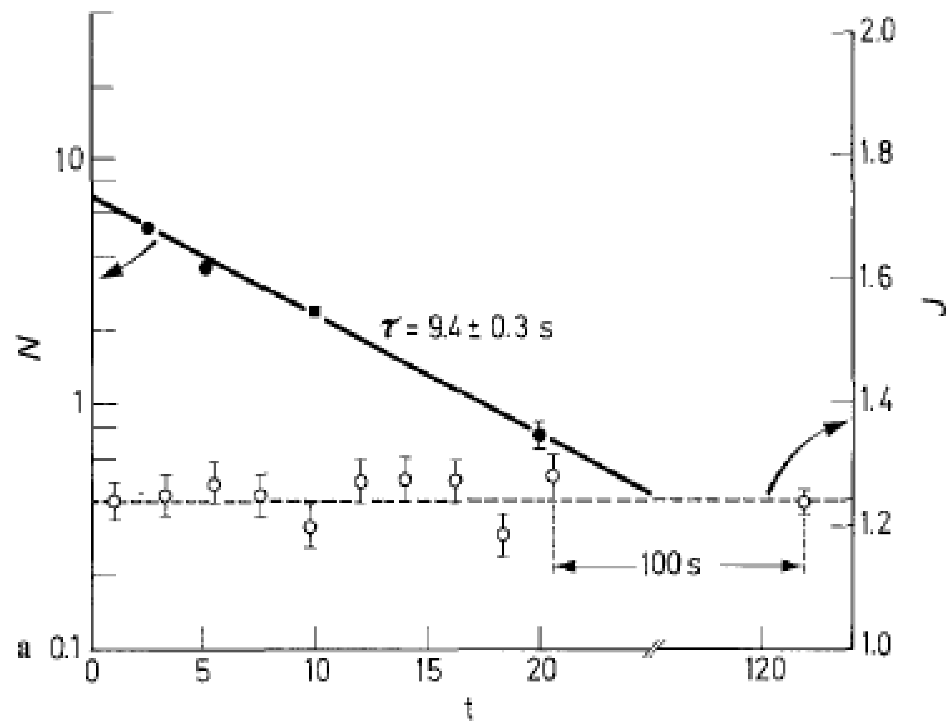
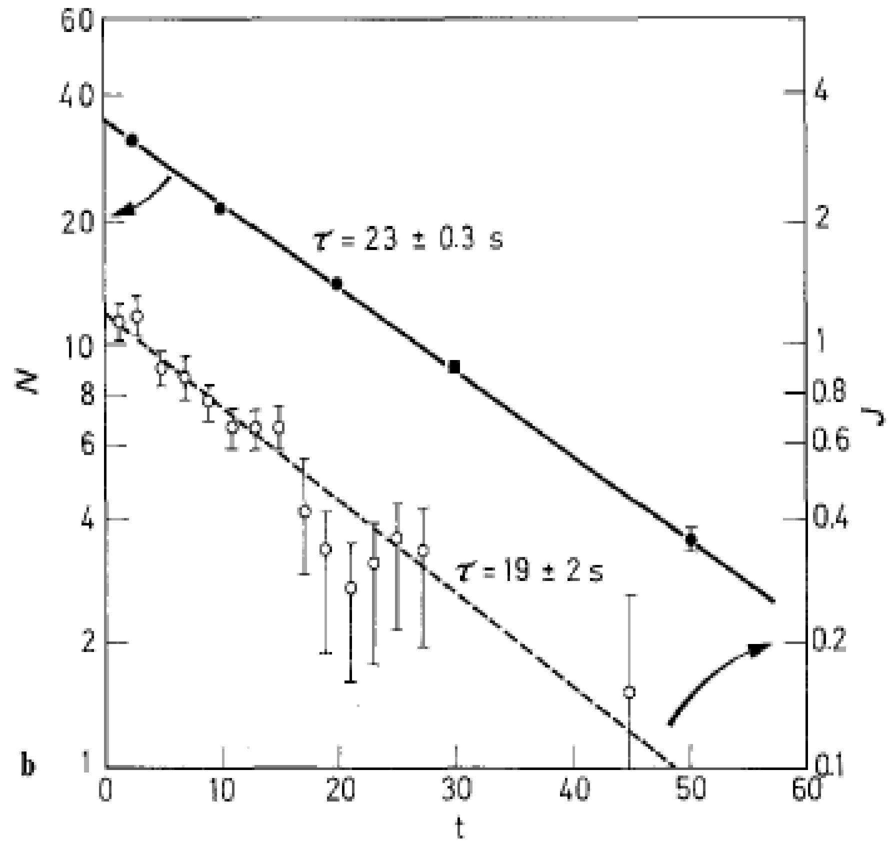


Fig. 1. Experimental set-up. *1* Neutron storage vessel, *2* six-chamber cylindrical He^3 counter, *3* UCN-channel, *4* entrance valve, *5* exit valve, *6* UCN detector, *7* Cd 1.5 mm, *8* B_4C, *9* $(CH_2)_n + B$

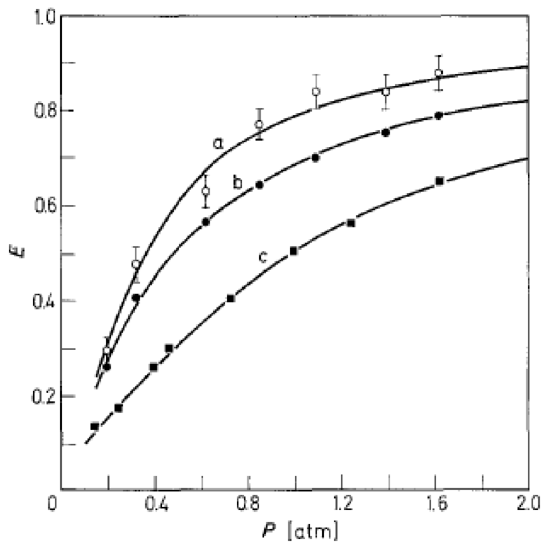
UCN Storage Anomaly: Heating

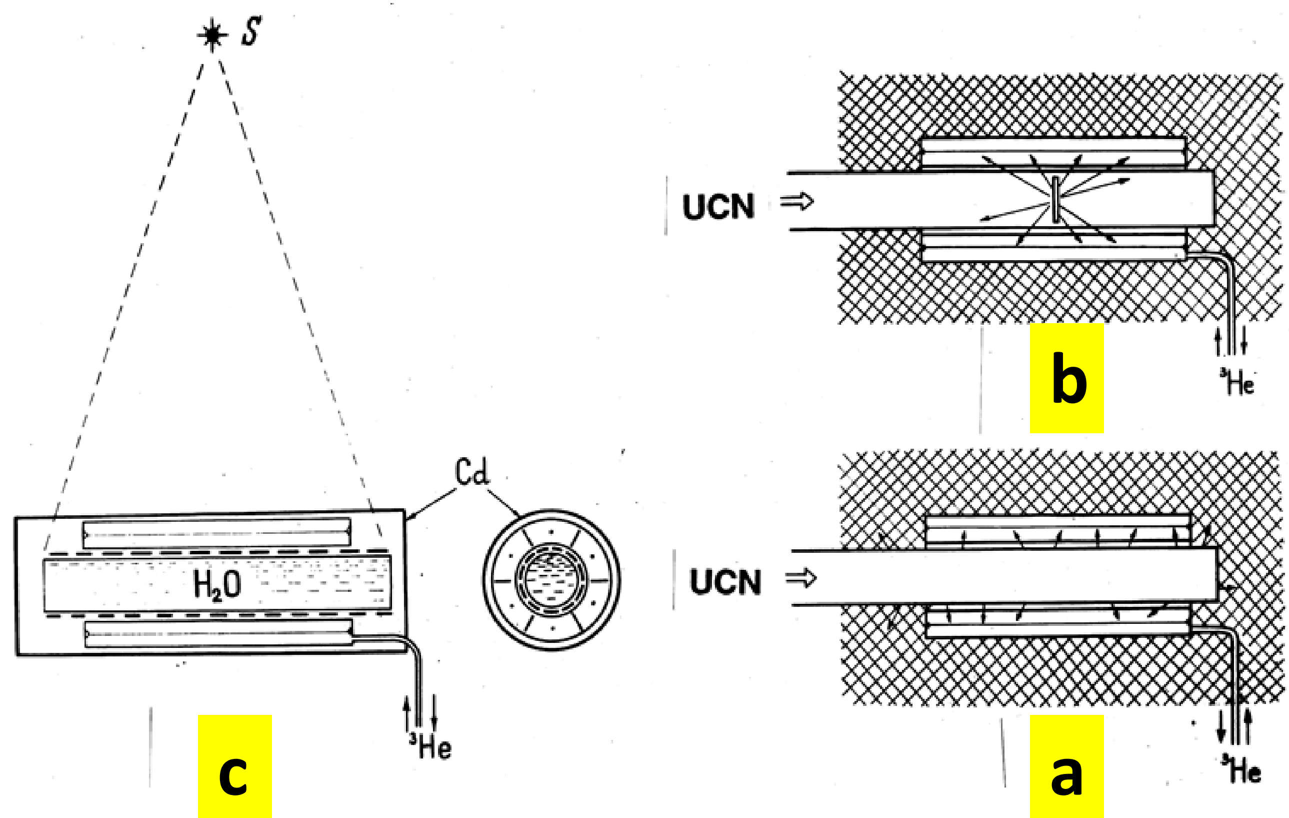




Small He^3 pressure **High He^3 pressure**

UCN Storage Anomaly: Heating





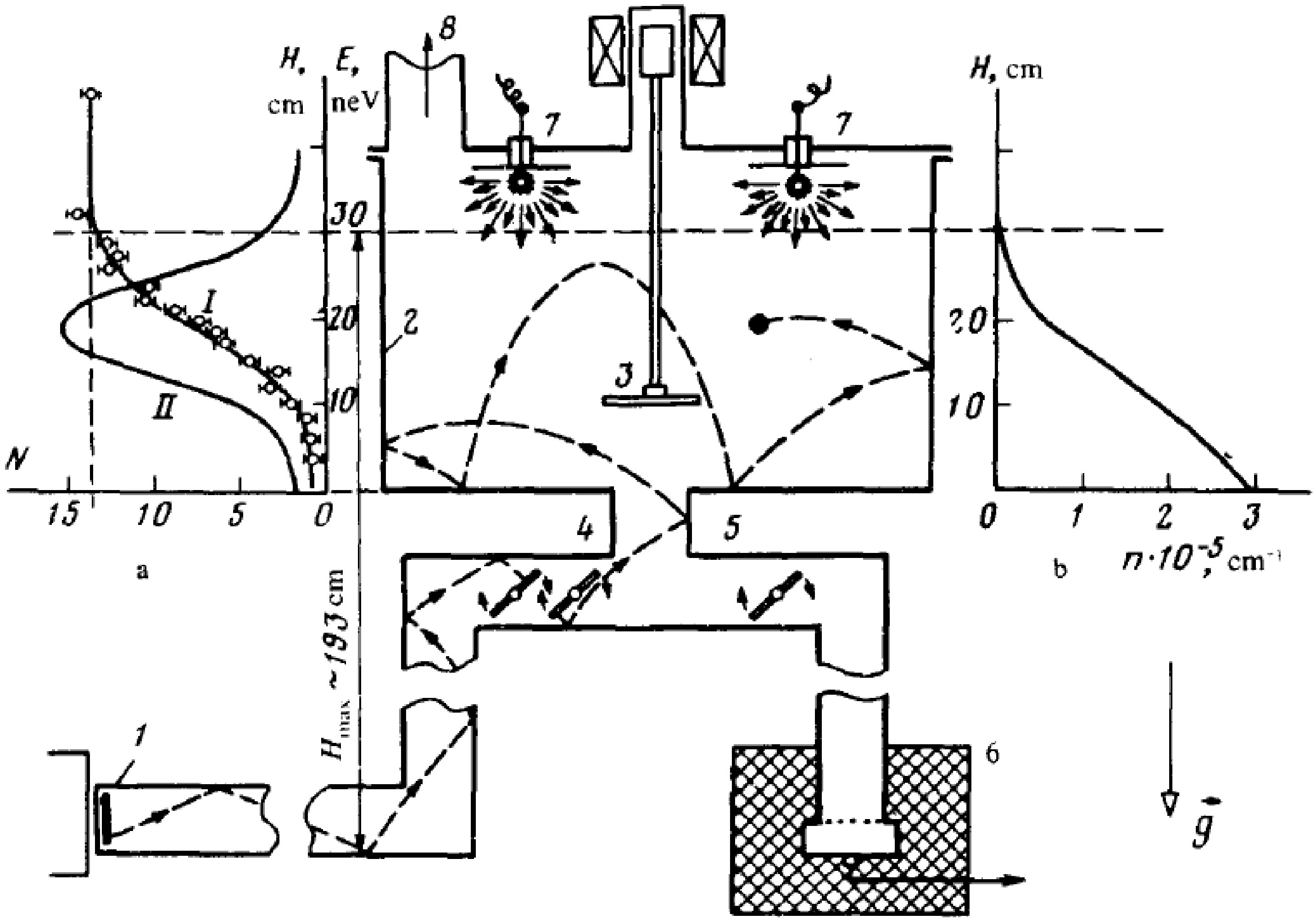
a – UCN heat on walls

b – UCN heat on (CH2)n

c – neutrons moderated by H2O

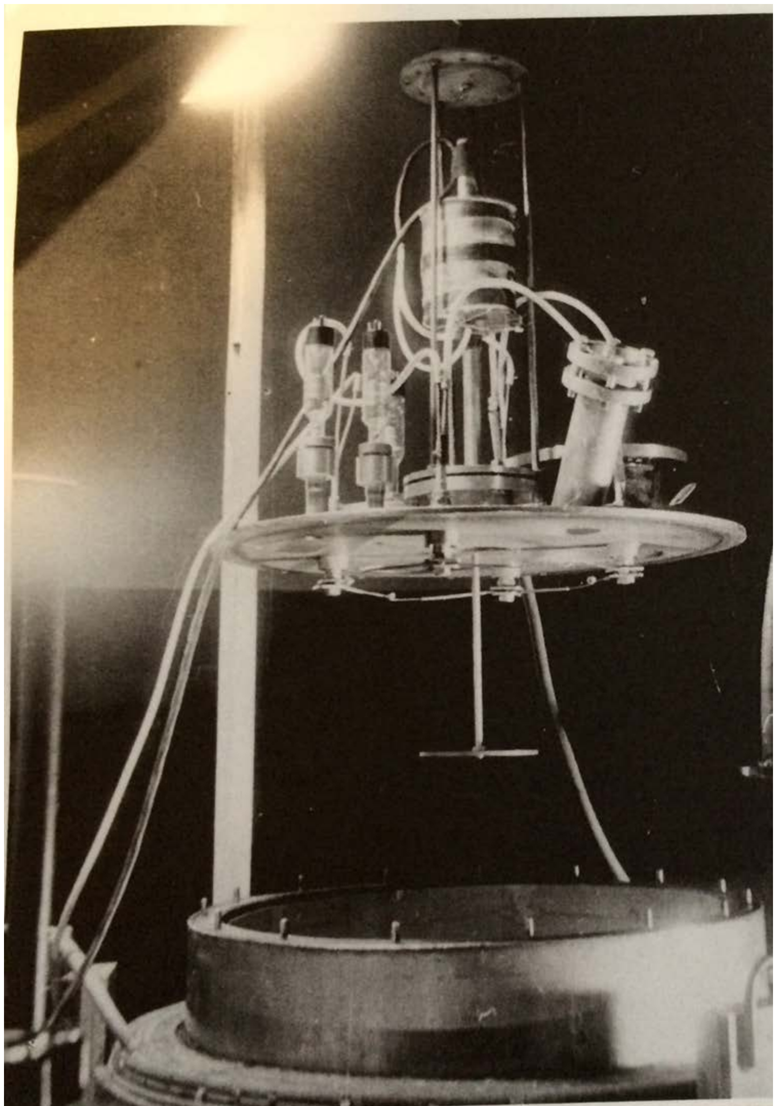
10 meV

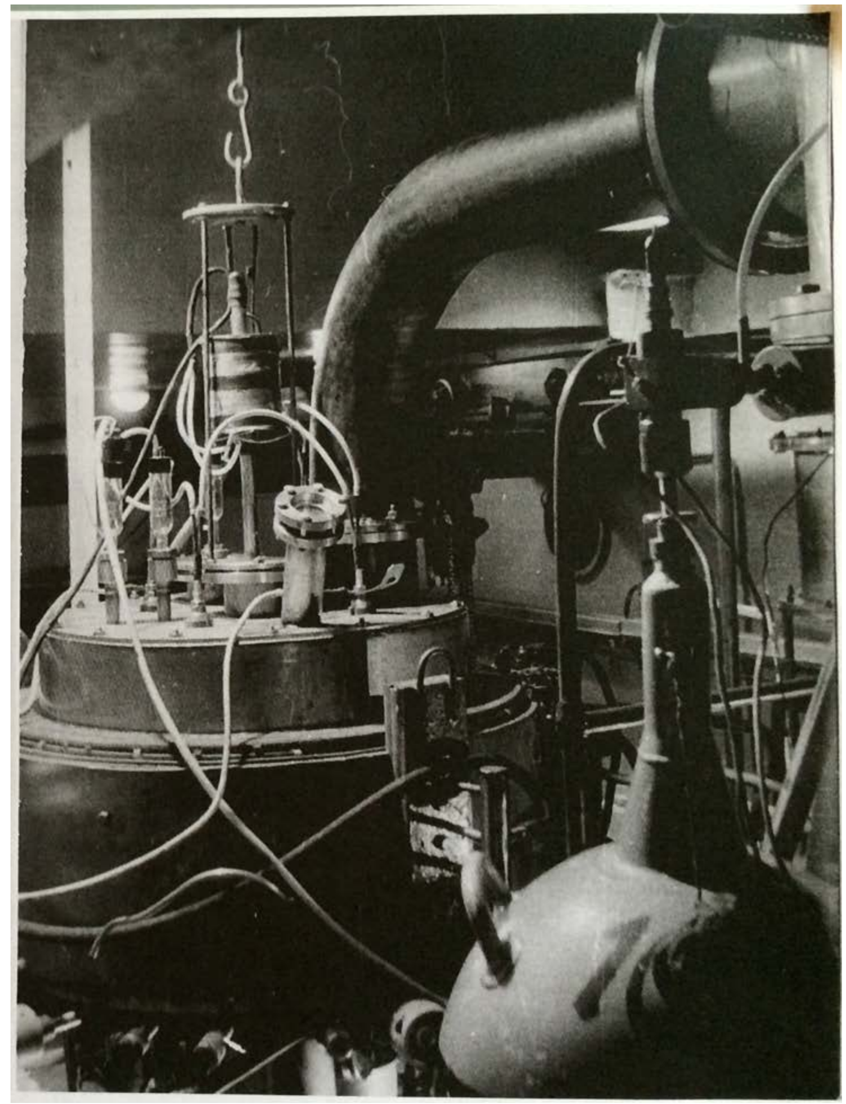
UCN Storage Anomaly: Fresh Walls



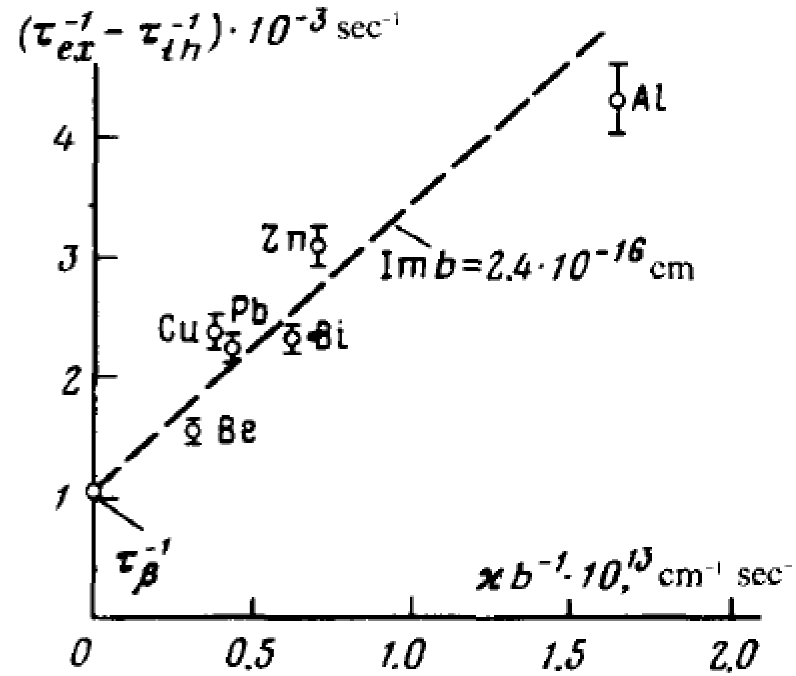
Y.Y.Kosvintsev, Y.A.Kushnir, V.I.Morozov, A.D.Stoica, A.V.Strelkov; JETP Lett. 28, 153, 1978

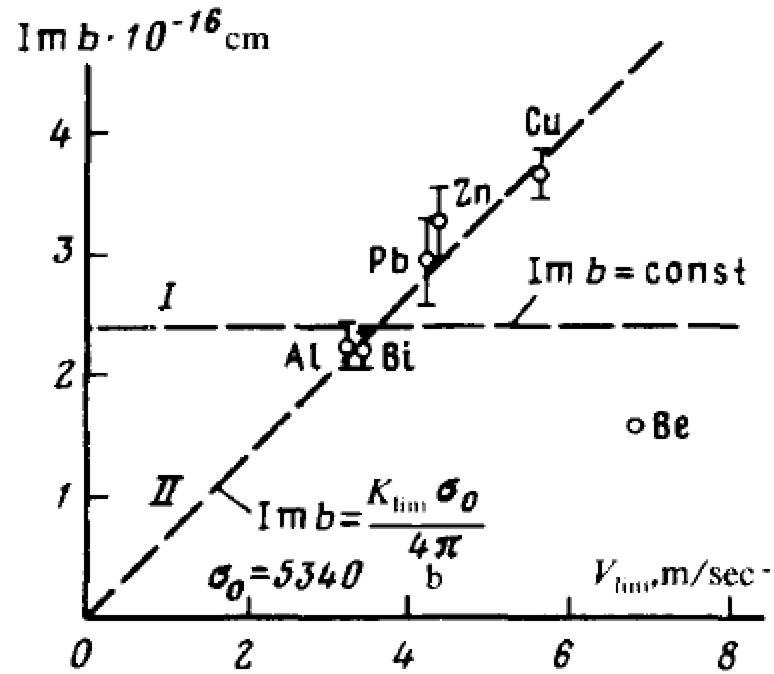
UCN Storage Anomaly: Fresh Walls





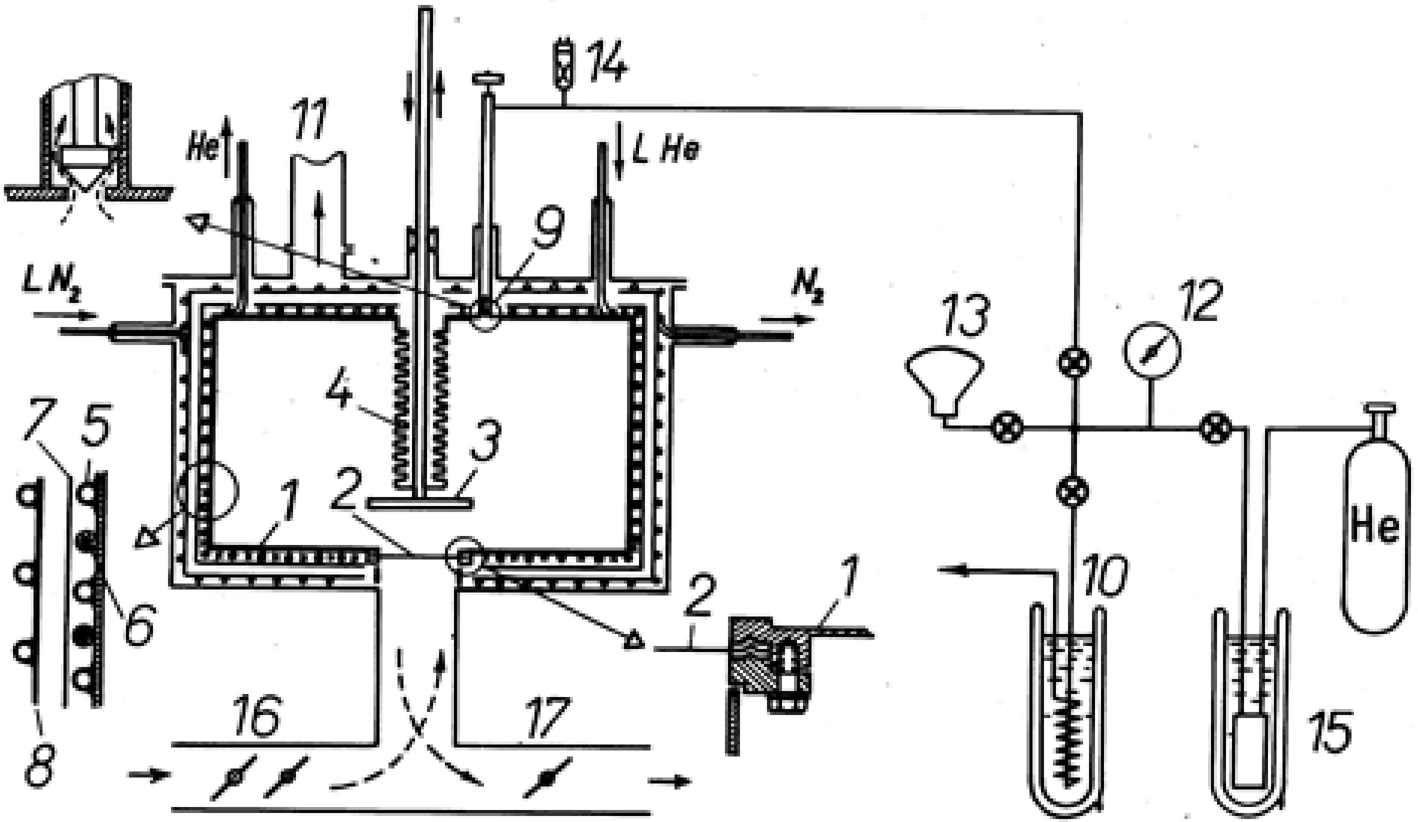
UCN Storage Anomaly: Fresh Walls





$$\frac{1}{\tau_{ie}} = \frac{1}{\tau_{ex}} - \frac{1}{\tau_{th}} = \bar{\mu}\nu = \eta\kappa\,;\;\; \eta = \frac{Imb}{b}$$

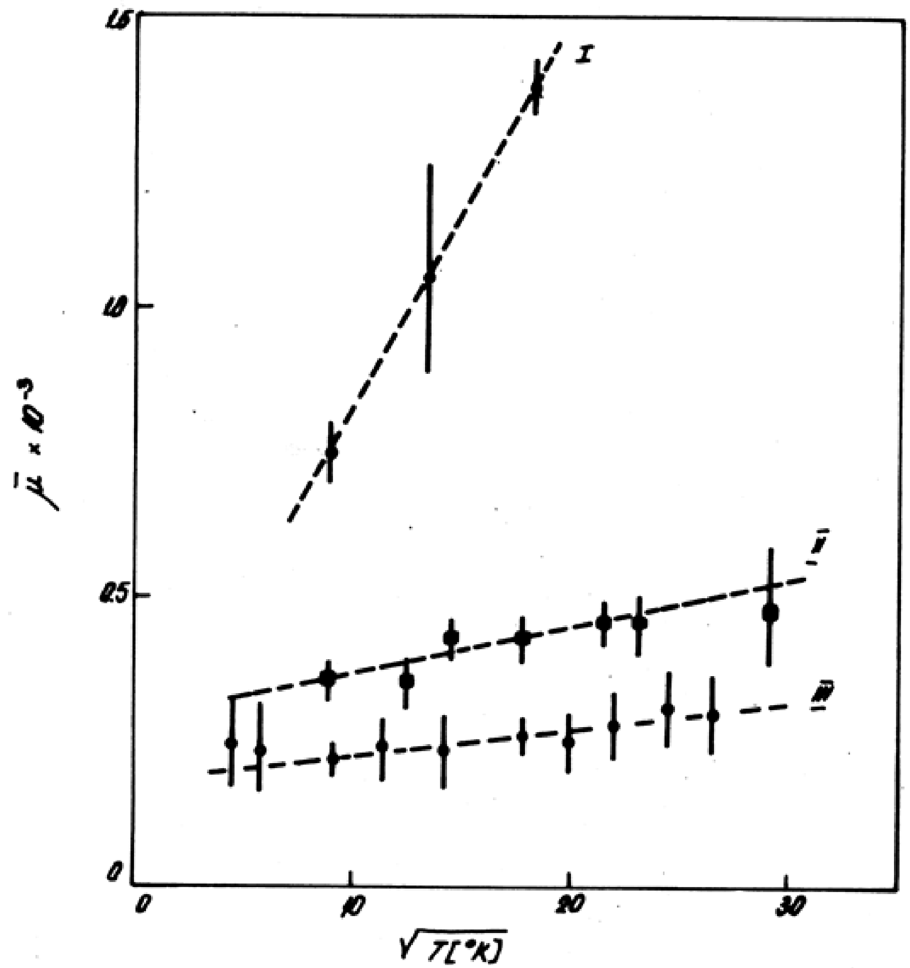
UCN Storage Anomaly: Cold Walls



1 – UCN bottle – 50 cm diameter, 24 cm high; 2 – Al window – 60 mm; 3 – entrance/exit UCN valve; 4 – bellow; 5 – cooling pipe; 6 – heater; 7, 8 – screens; 9, … 15 – vacuum system; 16 – UCN valve for bottle filling ; 17 – valve for UCN outflow to detector

V.P.Alfimenkov, A.D.Stoica, A.V.Strelkov; Comm. JINR P3-80-761, 1980

UCN Storage Anomaly: Cold Walls



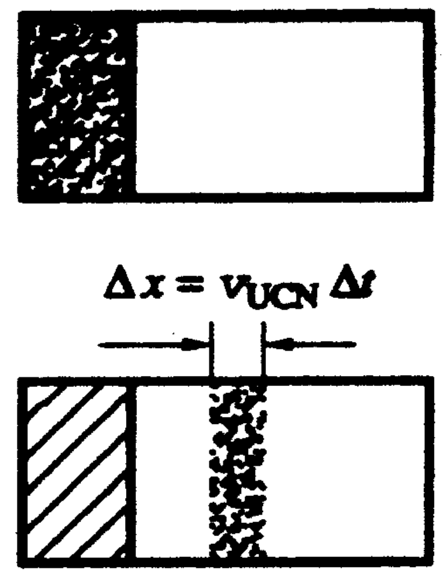
I – Cu before degasing
II – Cu after degasing
III – Be after degasing

Degasing temperature:
700K for 6 hours

$1/\tau_{ie} = \bar{\mu}\nu$; $\nu = 23.3\ s^{-1}$

Dynamic Converter at Pulsed Source

- First step: UCN are generated inside the converter
- Second step: UCN are localized in a guide region with w length determined by the average velocity and the neutron pulse width
- Third step: UCN cloud expand to fill the entire evacuated volume



Dynamic Converter at Pulsed Source

Predictions

$$\Phi_{th}(t) = \Phi_0 \exp\left(-\frac{t}{2\sigma^2}\right)$$

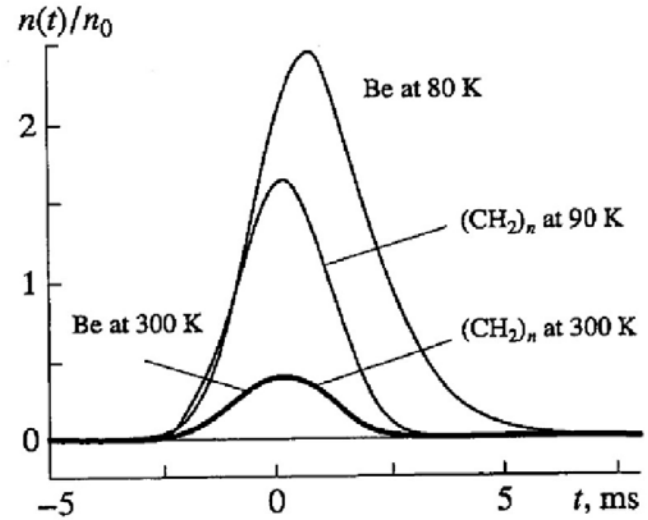
$\mathbf{n_0 = \beta\, \Phi_{th}}$

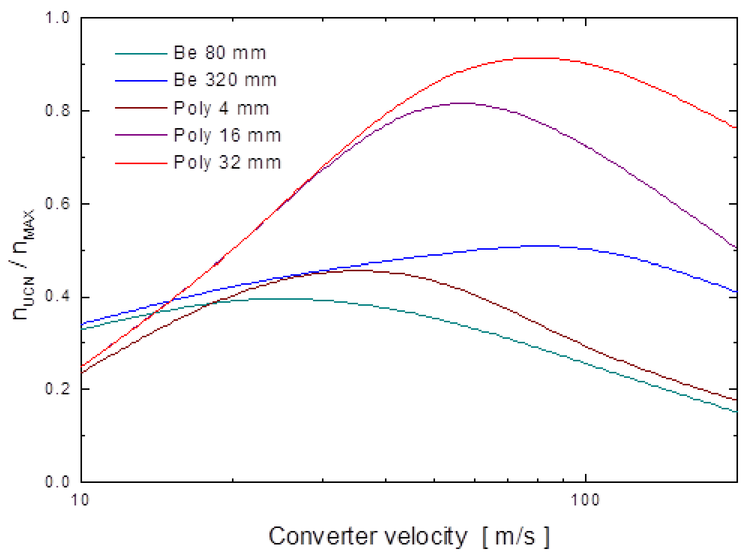
Φ_{th} – thermal neutron flux ;
β – coefficient dependent of wall material (Cu: $5.6 \cdot 10^{-14}$, Be: $9.7 \cdot 10^{-14}$)

$\mathbf{n_{UCN} = G\, n_0}$

G – converter gain factor
(poly: 4.2, Be: 7.8 at 80 K)

Optimal converter:
Polyethylene
32 mm thick
80 m/s velocity





Dynamic Converter at Pulsed Source
Experimental Layout at BIGR

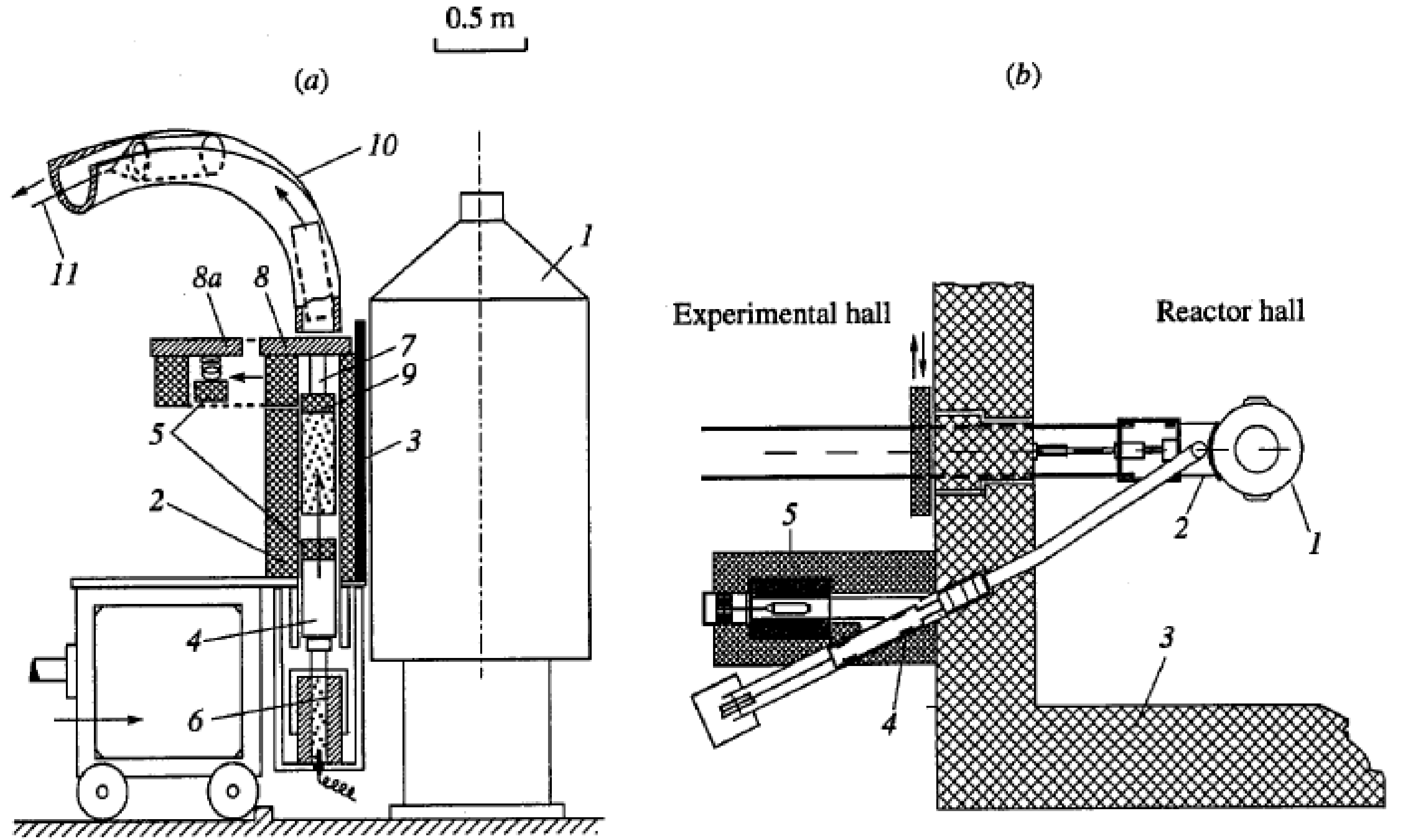
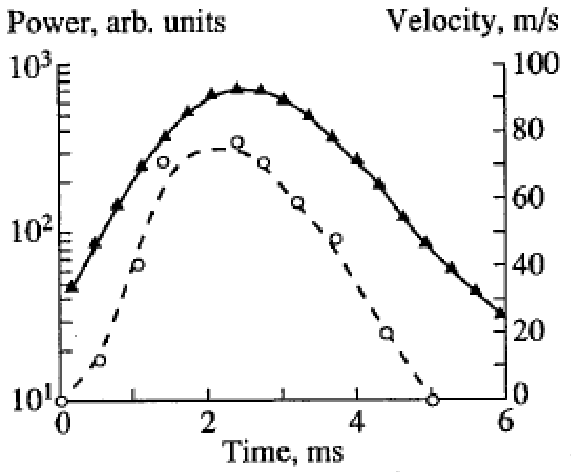
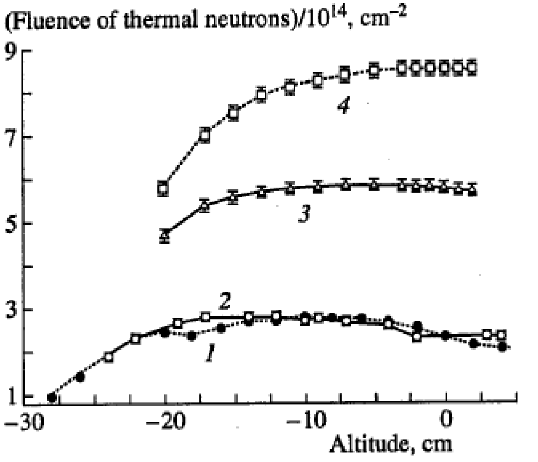


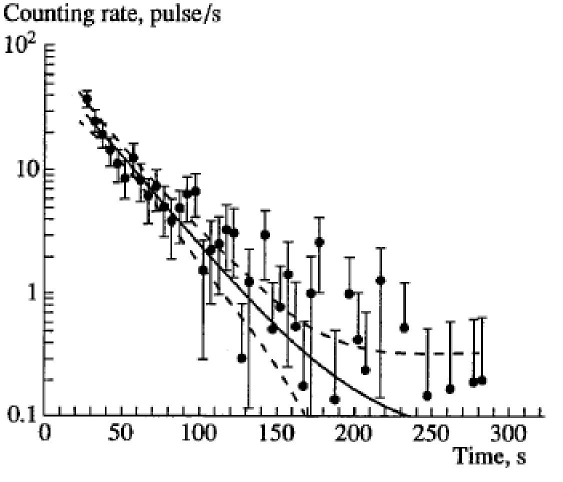
Fig. 1. (*a*) Layout of the movable part of the apparatus: (*1*) reactor core, (*2*) polyethylene-moderator block, (*3*) BC_4 and Cd shield, (*4*) UCN container, (*5*, *9*) converter cooled by liquid nitrogen, (*6*) accelerating system, (*7*) braking system, (*8*, *8a*) massive movable slab, (*10*) transporting chute, and (*11*) rope. (*b*) General view of the apparatus: (*1*) reactor, (*2*) movable platform, (*3*) wall of the hall, (*4*) slide valve, and (*5*) detector.

Dynamic Converter at Pulsed Source
Experimental Details



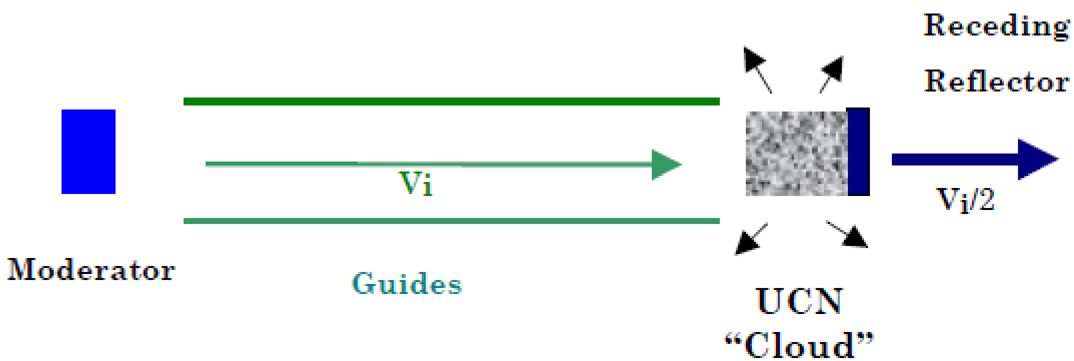


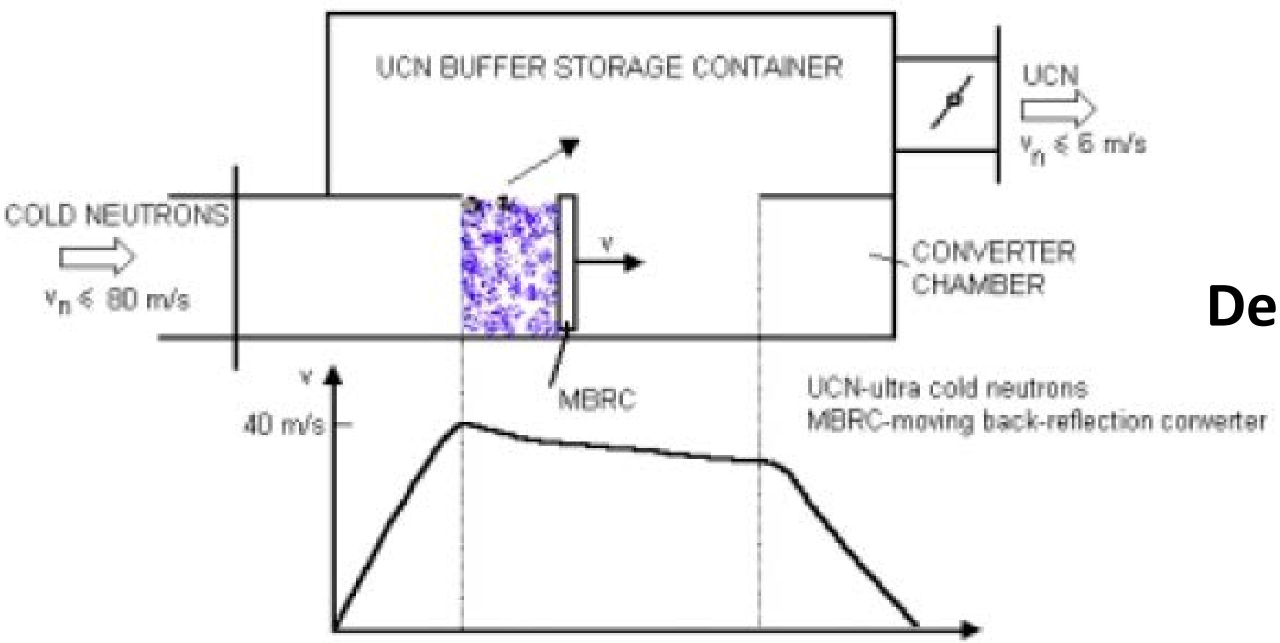
UCN bottle:
100 mm diameter, 300 mm long
Expected initial UCN density:
5000 n/cm^3
Density after transport:
26 n/cm^3



B.V.Bagrjanov, D.G.Kartashov, M.I.Kuvshinov, A.Y.Muzychka, G.V.Nekhaev, A.D.Rogov, I.G.Smirnov, A.D.Stoica, A.V.Strelkov, V.N.Shvetsov; Phys. Atomic Nucl. 65, 787, 1999

Doppler Converter at Pulsed Source





$$v_f = v_i - 2v_0$$

$$\frac{v}{v_{n0}} = \frac{1}{2}\sqrt{\frac{t_0}{t}}\ ;\ v_{n0} = \frac{L_0}{t_0}$$

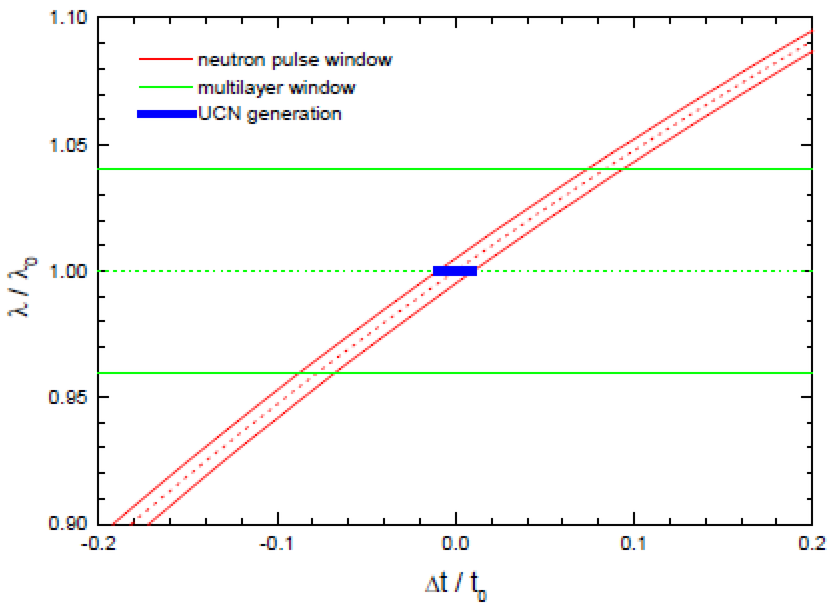
$$\frac{x}{L_0} = \sqrt{\frac{t}{t_0}}$$

Depth-graded multilayer

$$\frac{\Delta d}{d} \approx 10\%$$

Doppler Converter at Pulsed Source

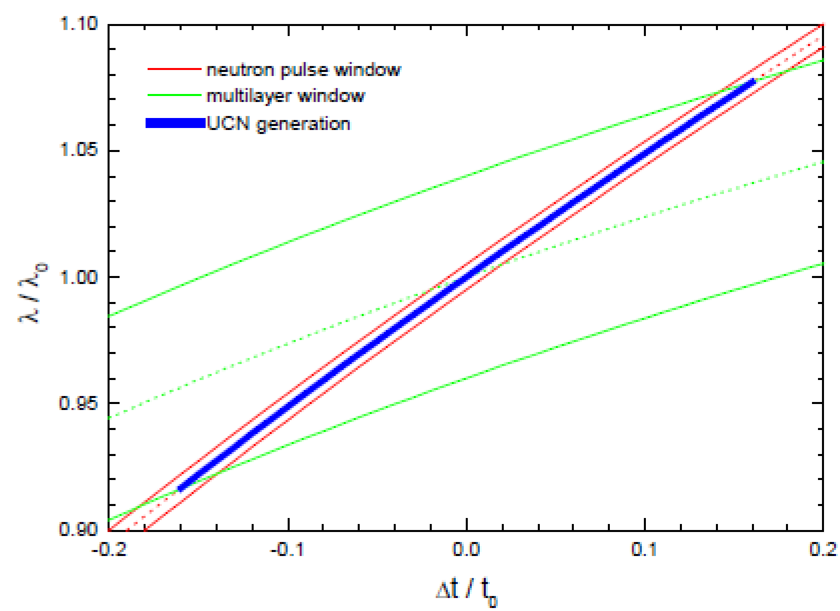
Pulse Synchronized Deceleration



Constant speed

Synchronized deceleration

$$\Delta v_f = v_{n0} \frac{\Delta t}{t_0} \; ; \; \Delta t_f = 2 t_0 \frac{\Delta d}{d}$$



$$n_{UCN} = \pi v_{UCN}^2 \Delta v_f \, \rho_N$$

$$\rho_N \approx 10^7 \, s^3/m^6$$

$\Delta t = 200\ \mu s$; $L_0 = 10$ m ; $n_{UCN} = 10^3\ cm^{-1}$

$\Delta t = 2$ ms ; $L_0 = 12$ m ; $n_{UCN} = 10^4\ cm^{-1}$

…

"If you want to succeed, double your failure rate."