Storage of ultracold neutrons in vessels with wall made out of graphite, fluorine polymer oil and heavy water ice.

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YaF, 2003, in press

1. *UCN storage data as a base for hydrogen hypothesis to explain a main part of "anomaly" for graphite.*

Models:

- *solved hydrogen as two oscillators*
- *two-dimension surface gas & one oscillator of solved hydrogen*

2. *Liquid fluorine polymer with an additional inelastic scattering that falls down at low temperature.*

- *UCN storage data for the polymer thin layer*
  - *on graphite*
  - *on stainless steel*
- *VCN transmission data*

3. *Storage data for heavy water ice free of hydrogen contamination.*

- *Practical coincidence with neutron transmission data*

UCN storage data allow define the total UCN loss probability

$\lambda_{tot} = \lambda_\beta + \lambda_l$ with probabilities of

- λ_β - neutron β-decay and
- λ_l - loss at wall reflection (due to capture and inelastic scattering)

Theory gives $\lambda_l = \eta \cdot \gamma(v)$ where

$$\eta = \eta_c + \eta_{ie} = \frac{mv[\sigma_c(v) + \sigma_{ie}(v,T)]}{4\pi b\hbar}$$

and $\gamma(v)$ - evaluated geometry factor (neutron velocity, gravity, vessel's form and dimensions encountered).

Theoretical value for some materials (Be, graphite, Oxygen etc.)

$\eta \sim (10^{-6} \div 10^{-7})$

Practically achieved $\eta_{exp} \gg \eta$

Why?

Hypothesis *based on a whole rank of experiments*:

- *Unknown UCN*
  - *scattering with a weak T-dependence*
  - *capture*
- *hydrogen as universal contaminant*
- *nanoparticles on a solid surface*

To investigate this phenomenon the following experiments were done

The following studies were done:

The total cross section for cold neutrons were measured for fluorine polymer oils and heavy water, ***ISINN-10, p.376, 2003***.

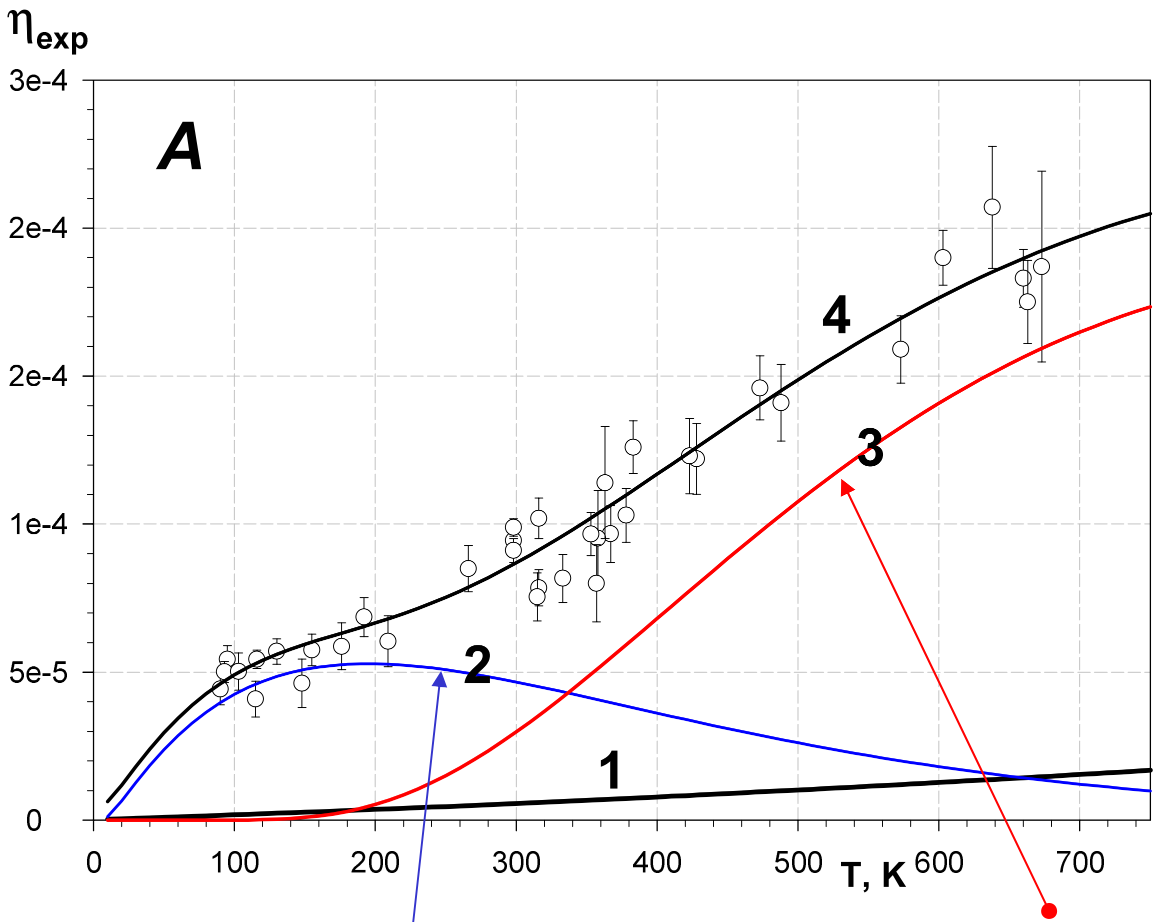
The UCN capture and inelastic scattering at UCN reflection on graphite surface was investigated by (n,γ)-analysis, ***NIM, A.440, p 690, 2000***

The parameter η_{exp} was measured at UCN storage experiments for graphite, graphite and stainless steel both coated by fluorine polymer oil and heavy water ice,

this contribution, details in YaF, 2003, in press.

Graphite vessel

Graphite (1) & **H**ydrogen contamination (2), (3) as **two oscillators**

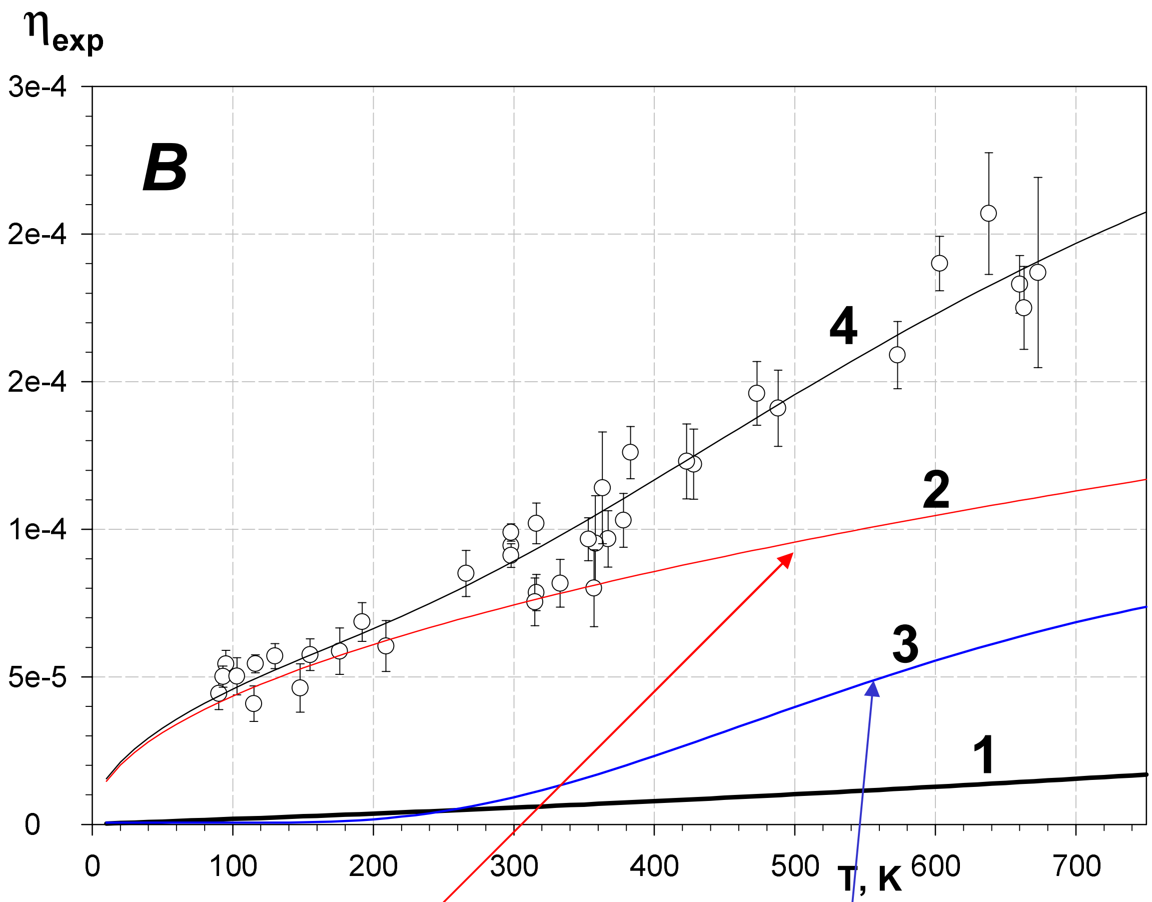


$$\eta^{H}=\eta_{c}^{H}\left(1+\frac{16}{A}\left(\frac{p\sqrt{T_1}}{12}\frac{\exp\left(-cth\left(\frac{T_1}{2T}\right)\right)}{\exp\left(\frac{T_1}{T}\right)-1}+(1-p)\sqrt{T_2}\frac{\exp\left(-cth\left(\frac{T_2}{2T}\right)\right)}{\exp\left(\frac{T_2}{T}\right)-1}\right)\right)$$

(4) - **total fit (**two oscillators): η_c^H **=4.8×10^{-6}**, **T_1= 35K**, **p =0.4**, **T_2= 1050K.**

Graphite vessel

Graphite (1) & **H**ydrogen contamination as **Surface gas** (2) + **Oscillator** (3)



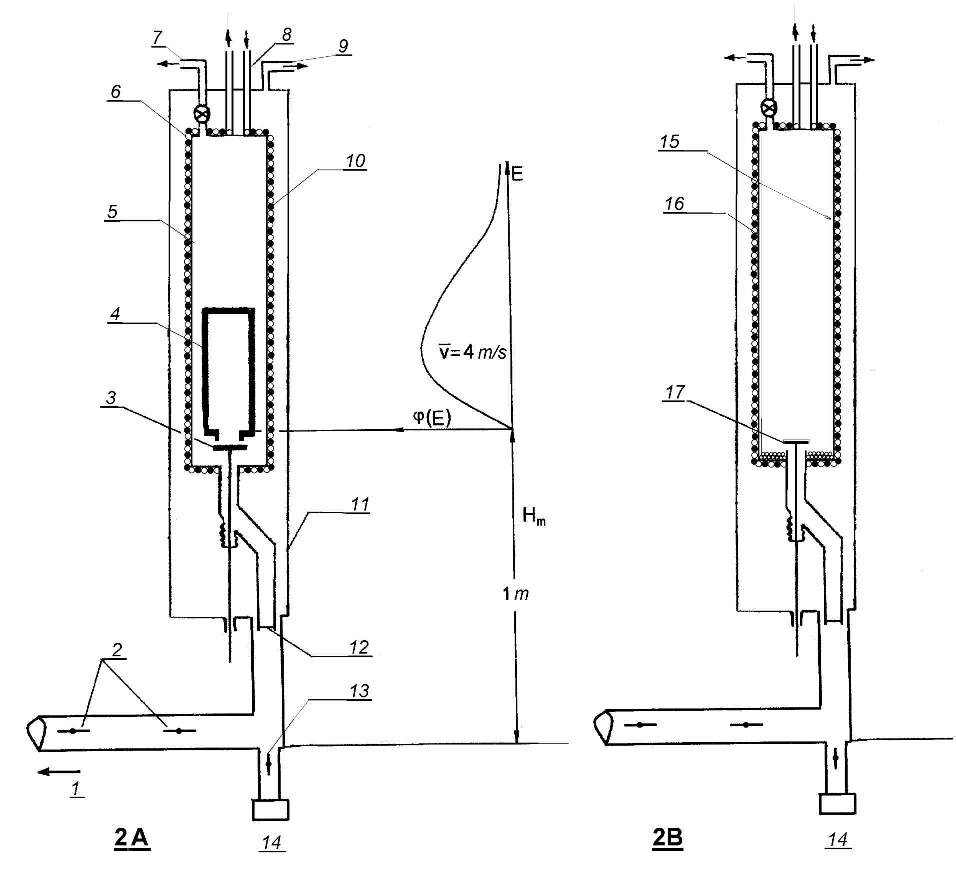
$$\eta^{H(g)} = \eta_c^{H(g)}\left(1 + 60\sqrt{\frac{T}{300}}\right)$$

$$\eta^{H} = \eta_c^{H(s)}\left[1 + 16\frac{\left(\exp\left(\frac{T_2}{300}\right) - 1\right)\exp\left(-cth\left(\frac{T_2}{2T}\right)\right)}{\exp\left(-cth\left(\frac{T_2}{600}\right)\right)\left(\exp\left(\frac{T_2}{T}\right) - 1\right)}\right]$$

(4) - **total fit:** $\eta_c^{H(g)}$**=1.22×10^{-6} (10^{16} *cm*$^{-2}$)**, $\eta_c^{H(s)}$ **= 5.4×10^{-7}** (~3 *at.%)*,
T_2= 1200K.

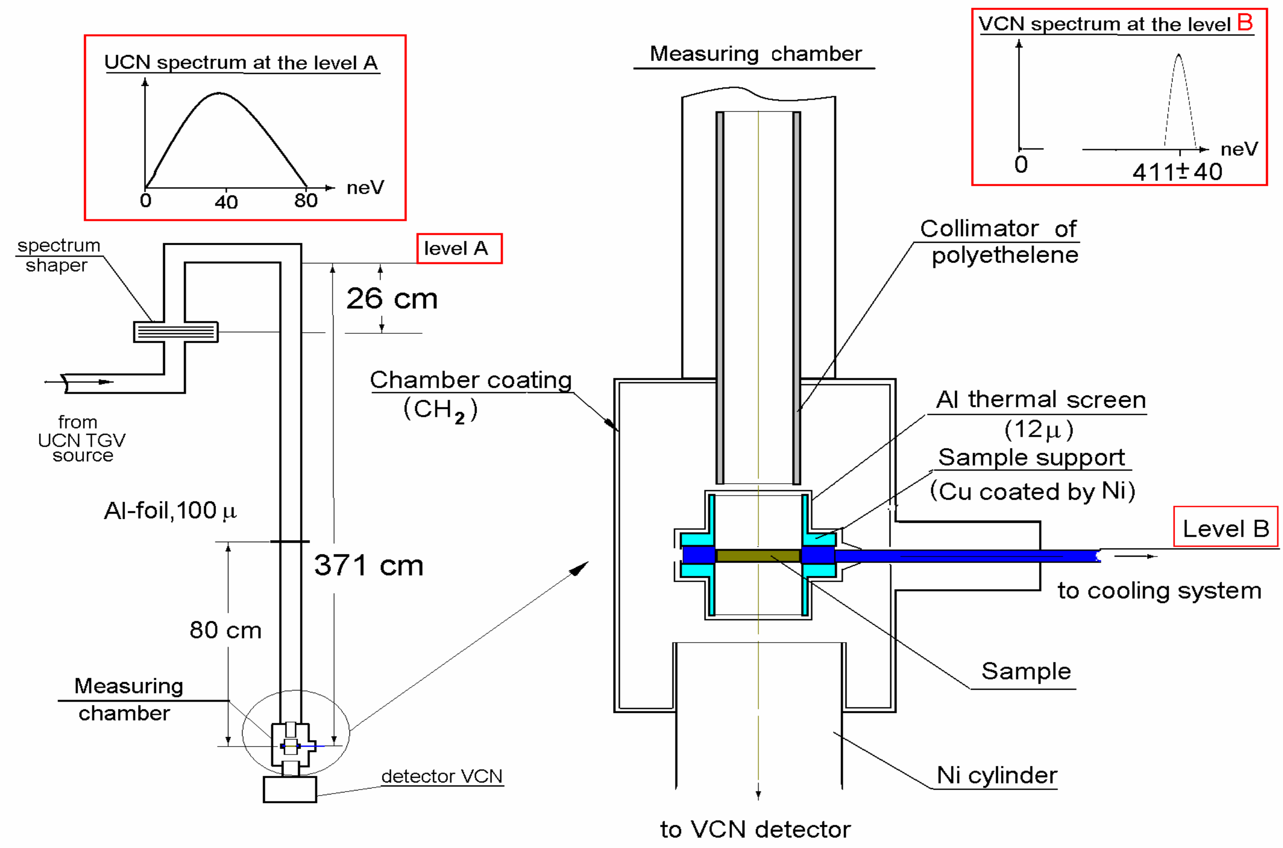
Set-up for UCN storage

A – in graphite vessel, **B** – in stainless steel chamber



1–to the UCN source, *2*–UCN shutters, *3*–graphite UCN shutter, *4*–graphite vessel, *5*–stainless steel chamber, *6*–cooling system tubes, *7*–high vacuum pumping of the vessel, *8*–inlet pipes for LN, *9*– high vacuum pumping of the intermediate chamber, *10*–heater wires, *11*–vacuum housing, *12*–Al-foil, *13*–detector UCN shutter, *14*– detector UCN, *15*–layer of fluorine polymer oil, *16*–UCN storage vessel, *17*– UCN shutter for vessel.

Set-up for measurement of the temperature dependence of cross section



Result for parameter η for vessels coated by fluorine polymer oil YL VAC 18/8.

1. □ ***oil on graphite vessel surface***,

2. ● ***same on stainless steel vessel***,

3. ◇ ***calculated curve from transmission data***

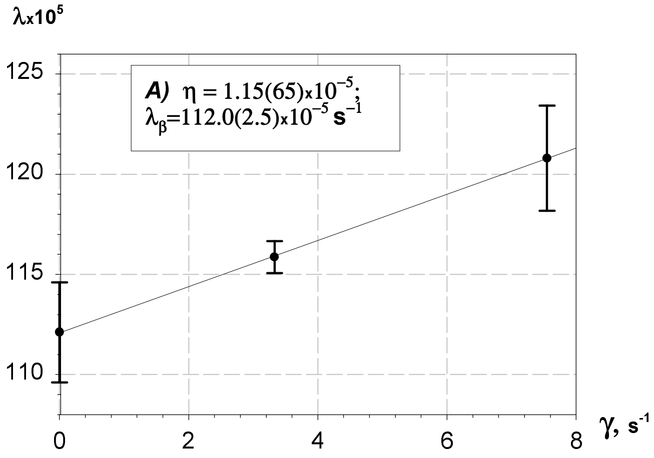
(UCN,γ)-analysis result

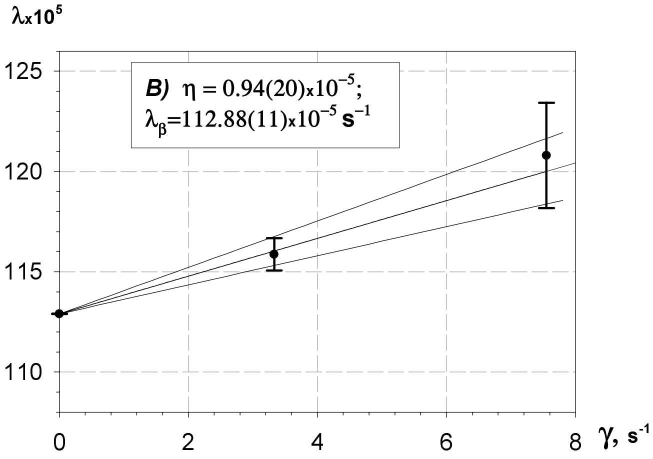
Parameters η_{ie} for ***inelastic scattering*** *via* η_{cap}^{H} for ***hydrogen capture*** of **UCN** at **pyrolytic graphite**.

NIM, A.440, p 690, 2000

UCN storage in vessel with heavy water ice wall

V.I.Morozov. NIM, A.284, p 108, 1989





A) D_2O layer 3000A° thick was made by condensation at 80K inside hermetic vessel free of H_2

B) - recalculated η-value using World mean λ_β is equal to **η= (0.94±0.20)** compared with **η= (0.65±0.05)** (both in **10^{-5}** units) deduced from neutron transmission data for $\mathbf{v_n}$=7.3(5) *m/s*

Conclusion

- **the inelastic reflection of UCN that was not predicted by theory was observed for graphite and it could be explained by a hydrogen surface contamination**
- **additional UCN inelastic scattering was also observed in the case of fluorine polymer oil which was however effectively suppressed by temperature decrease**
- **for heavy water the practical coincidence of the experimental and calculated values of the UCN loss probabilities was observed**