R & D experiments for the PSI UCN source

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Ultra Cold Neutron Source

Manfred Daum,
on behalf of the PSI UCN collaboration

1) **What is the optical potential of solid deuterium (sD_2)?**
2) **What is the neutron velocity distribution out of sD_2?**
3) **Material choice of sD_2 vessel?**
4) **Material choice of storage volume coating?**

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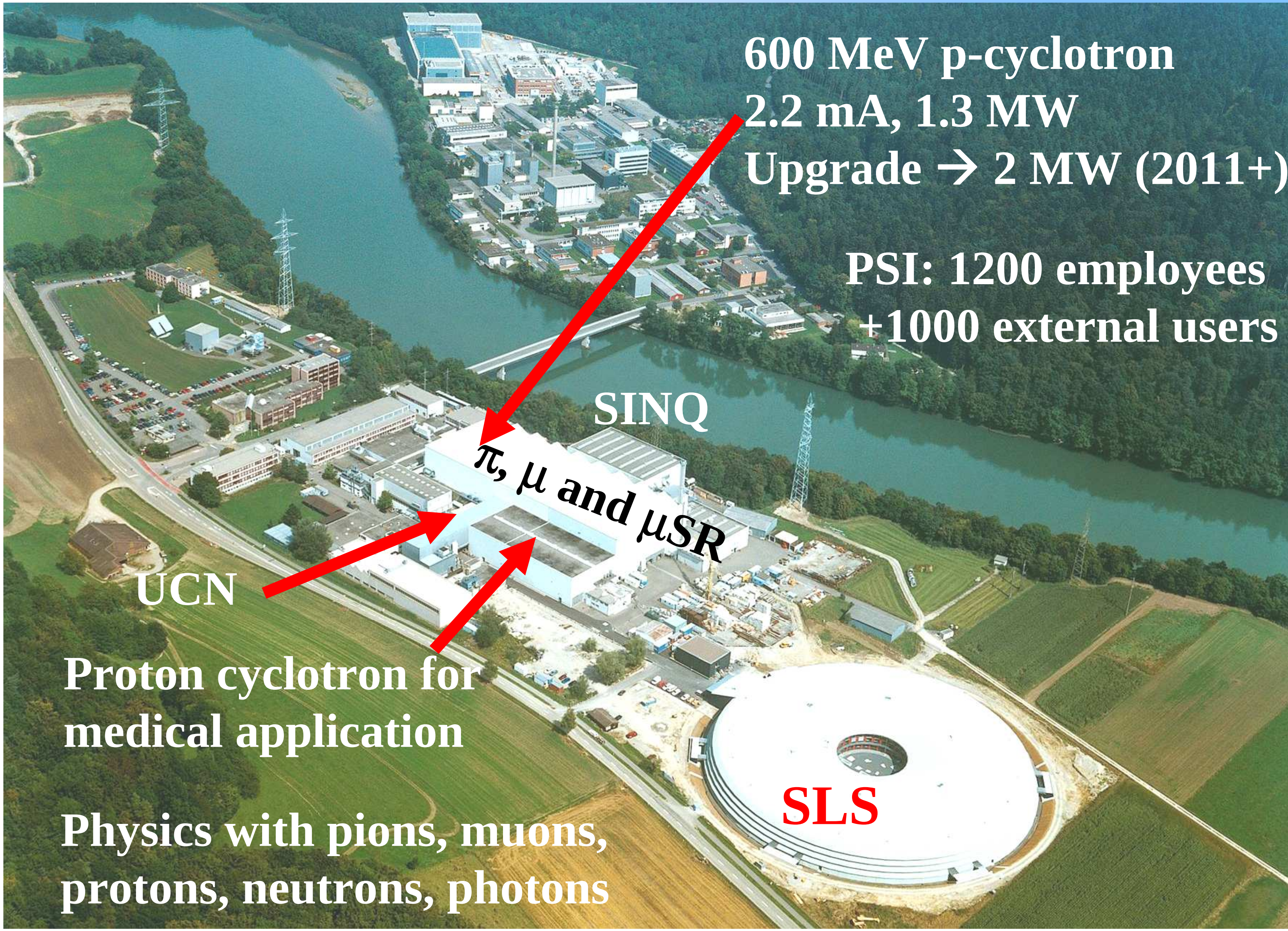
PSI

Zürich - Osaka

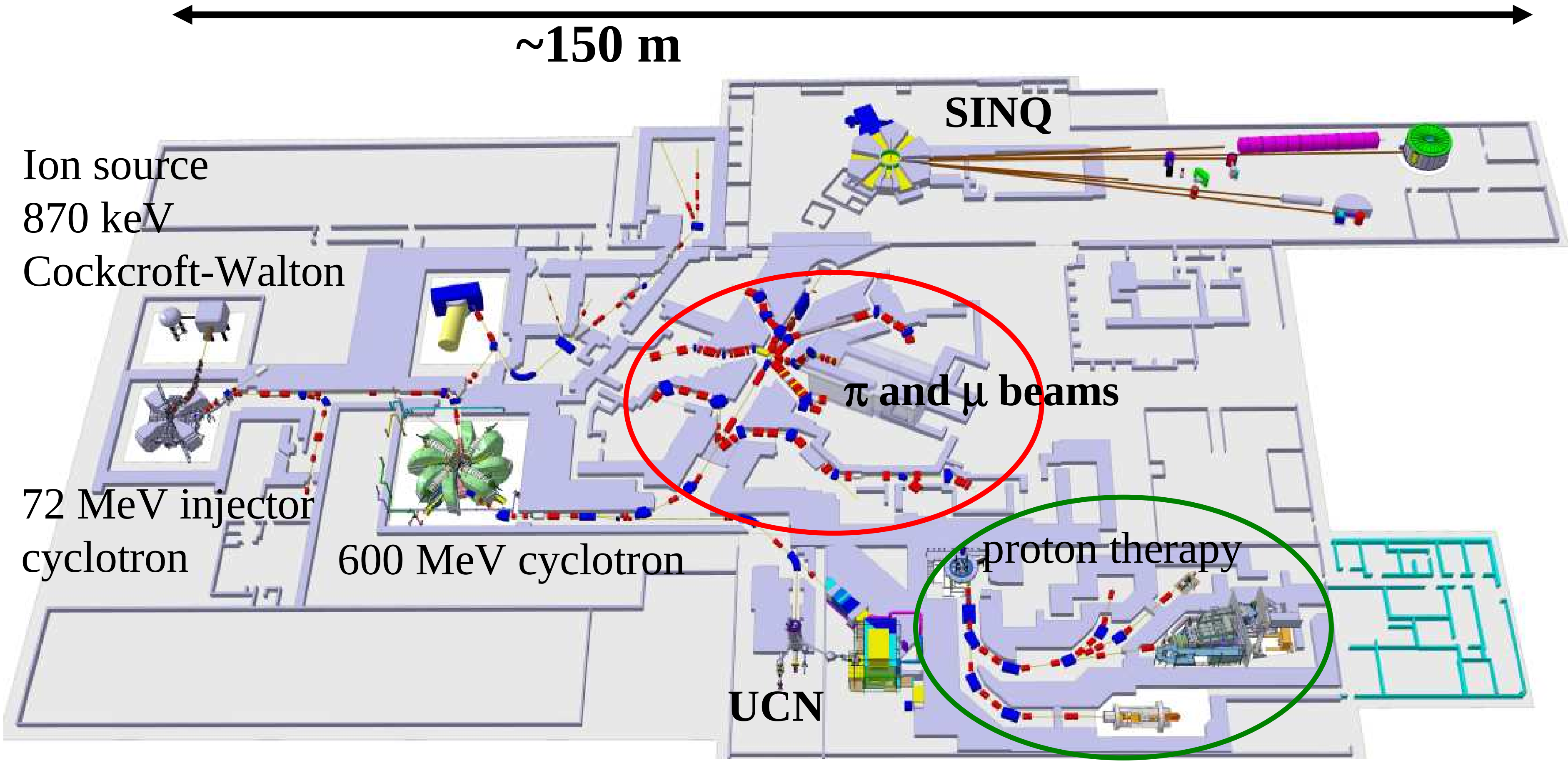
UCN

Ultra Cold Neutron Source

Paul-Scherrer-Institut, PSI

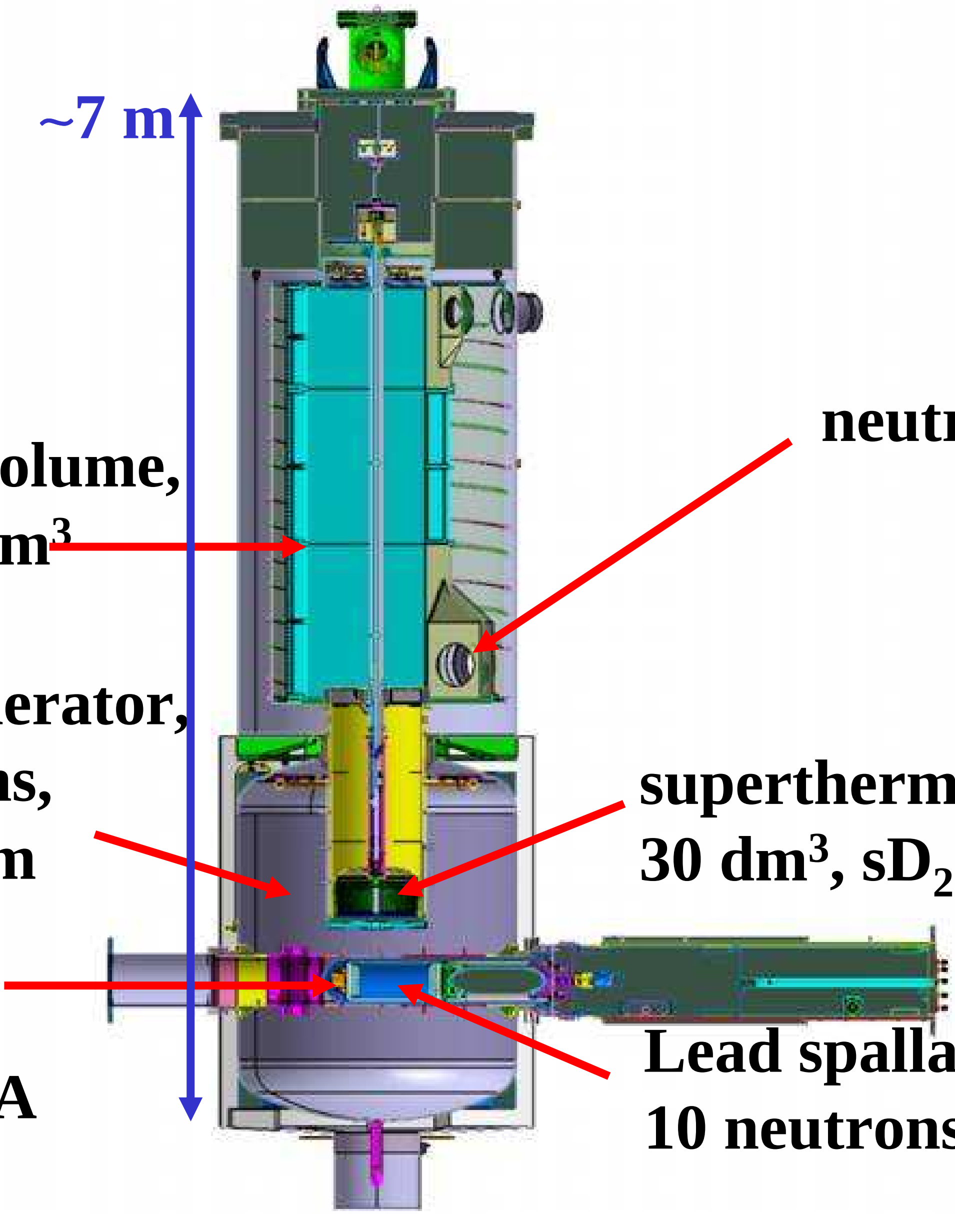


Proton accelerator facility @ PSI



Ring cyclotron: 600 MeV, 2.2 mA
→1.3 MW →worldwide unique!

PSI UCN source



R & D experiments for the PSI UCN source

1) What is the optical potential of solid deuterium (sD_2)?
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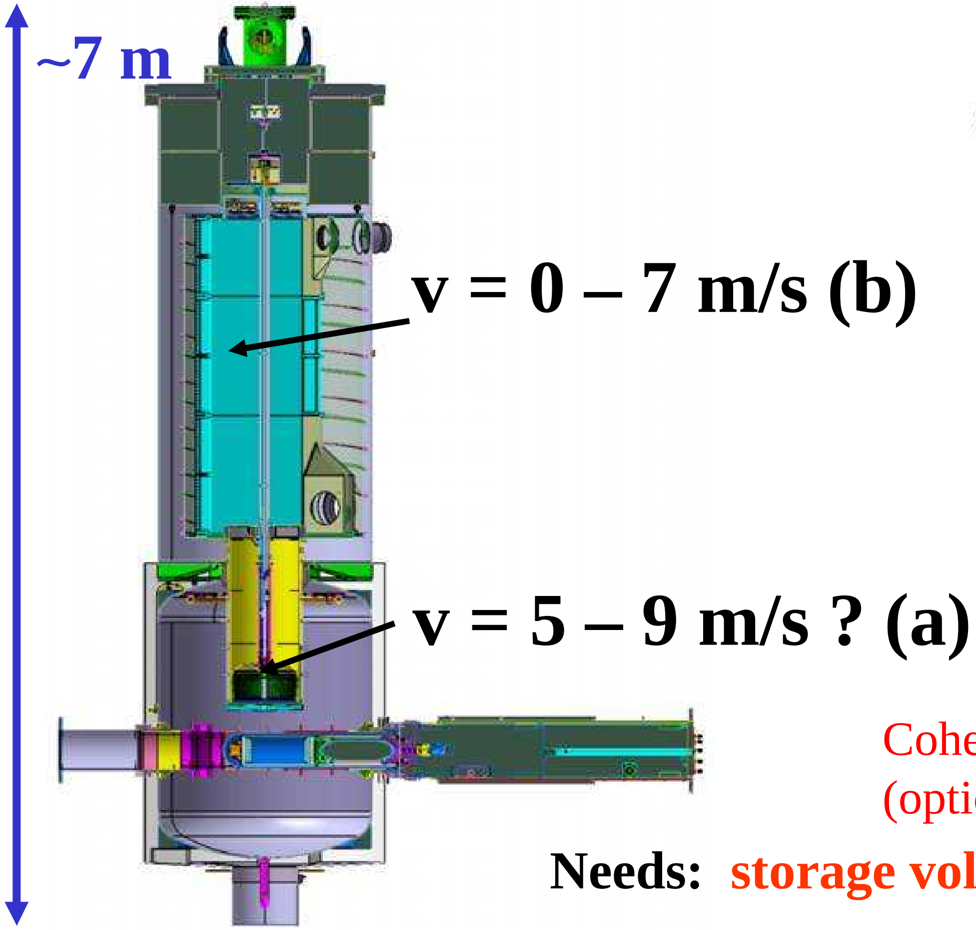
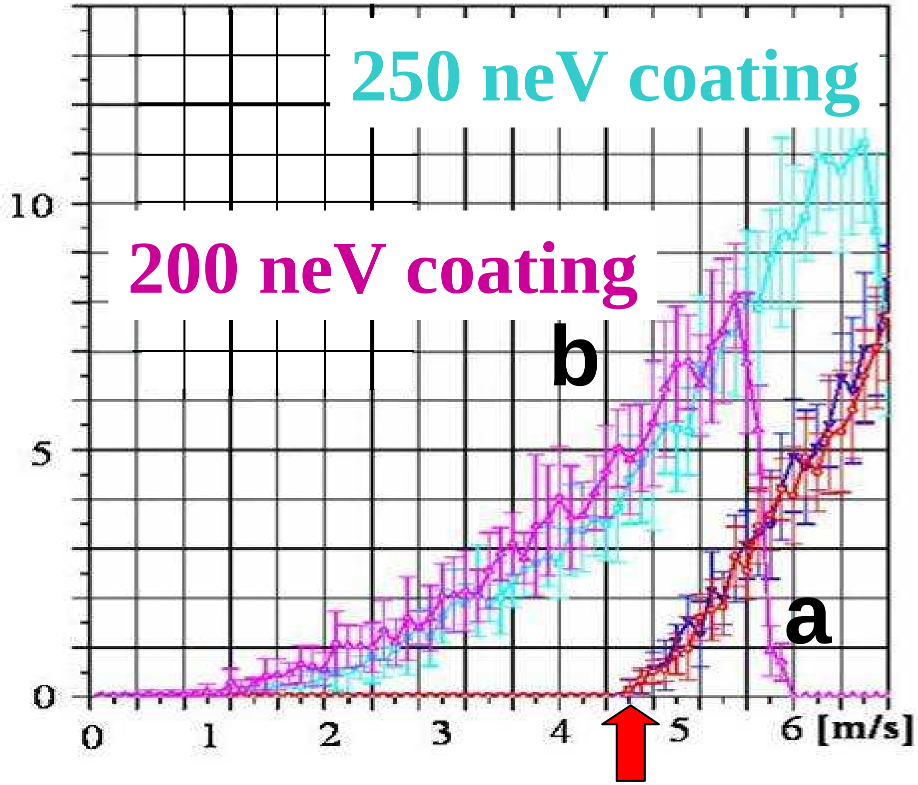
3) Material choice of sD_2 vessel?
4) Material choice of storage volume coating?



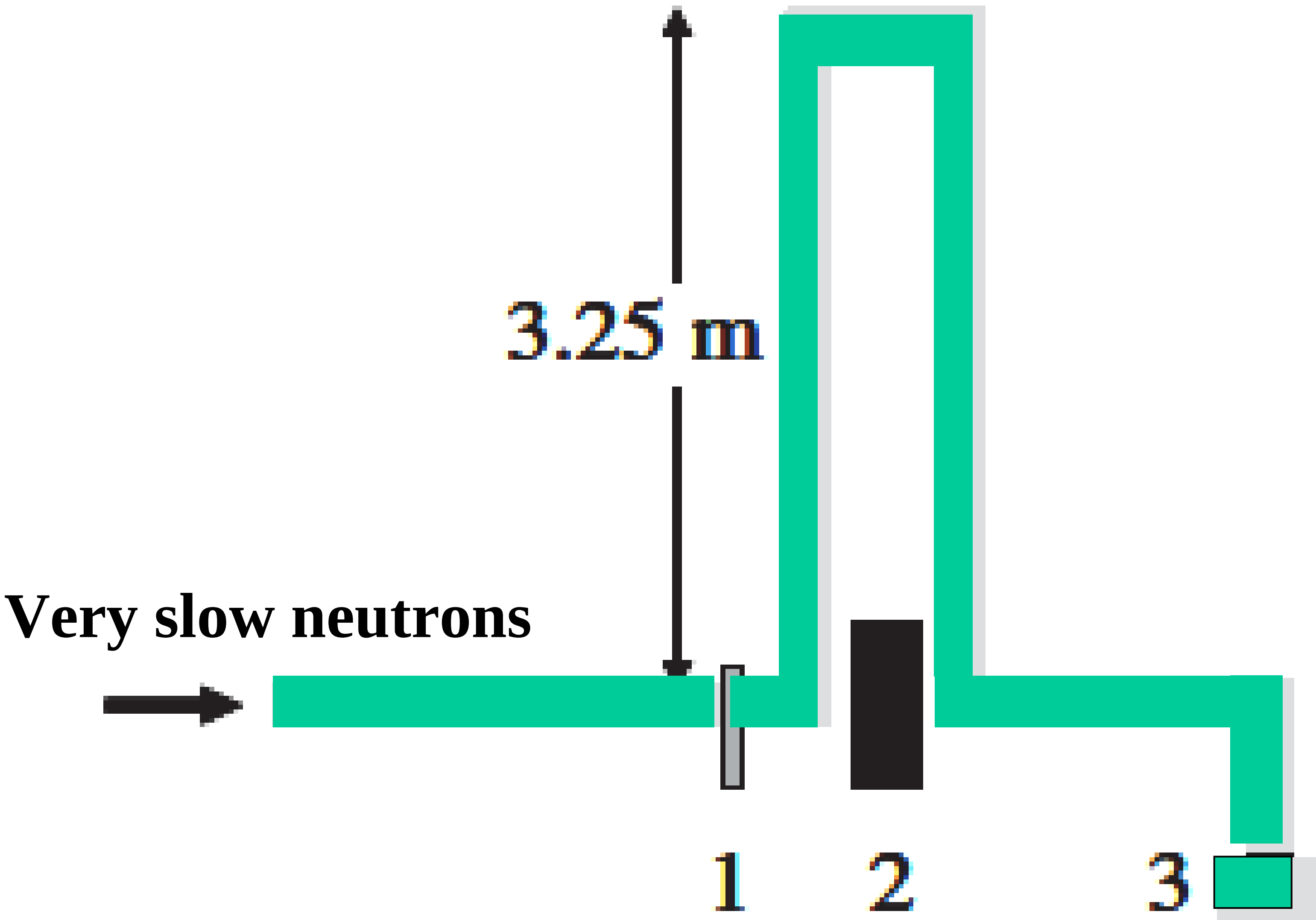
Courtesy A. Fomin, PNPI



Coherent strong interaction surface potential (optical) of solid deuterium (~100 neV ↔ 4.75 m/s)

Needs: storage volume coating (storable neutrons ~v_c^3!)

Measurement of optical potential



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Optical potential of sD_2

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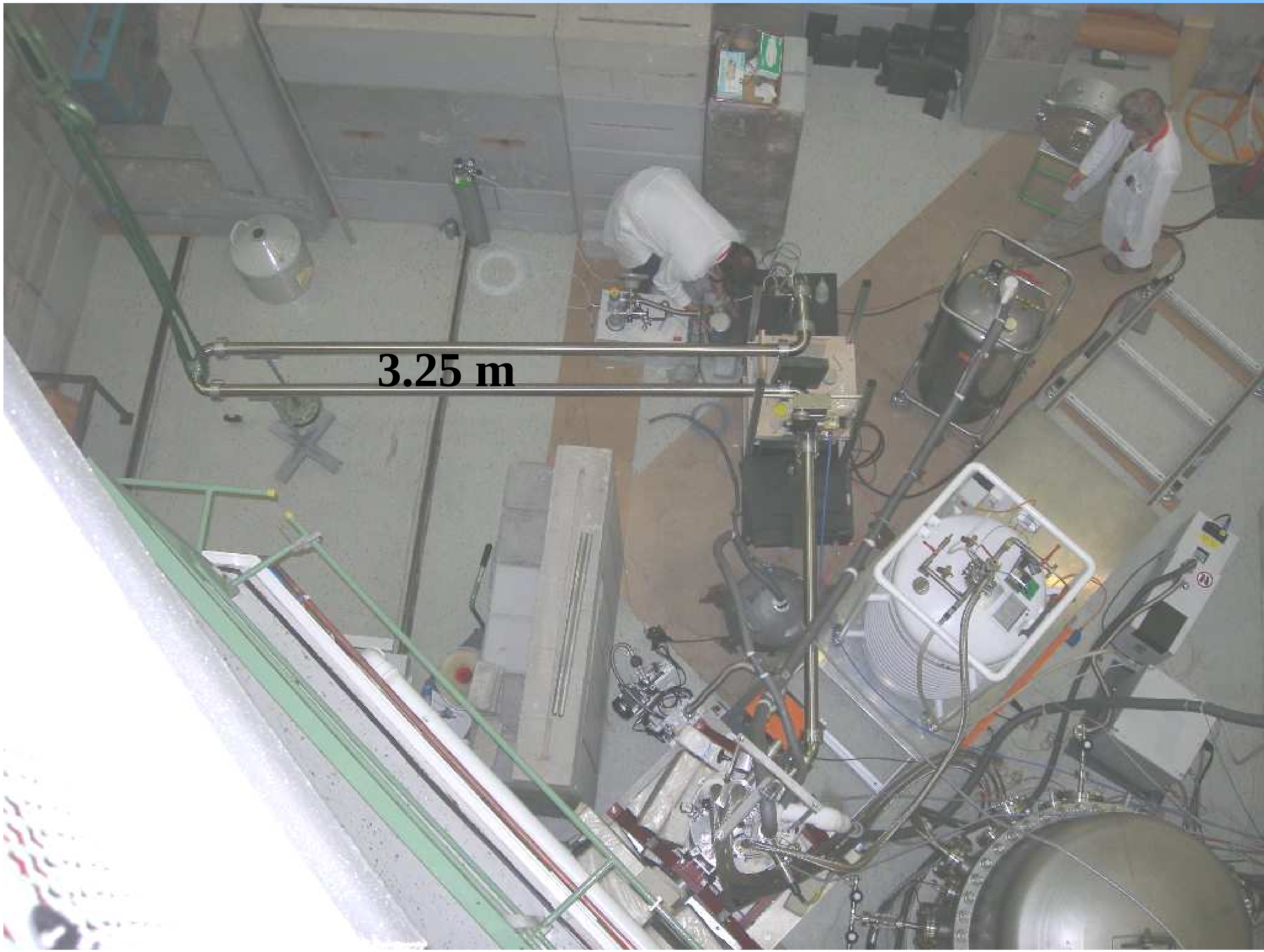
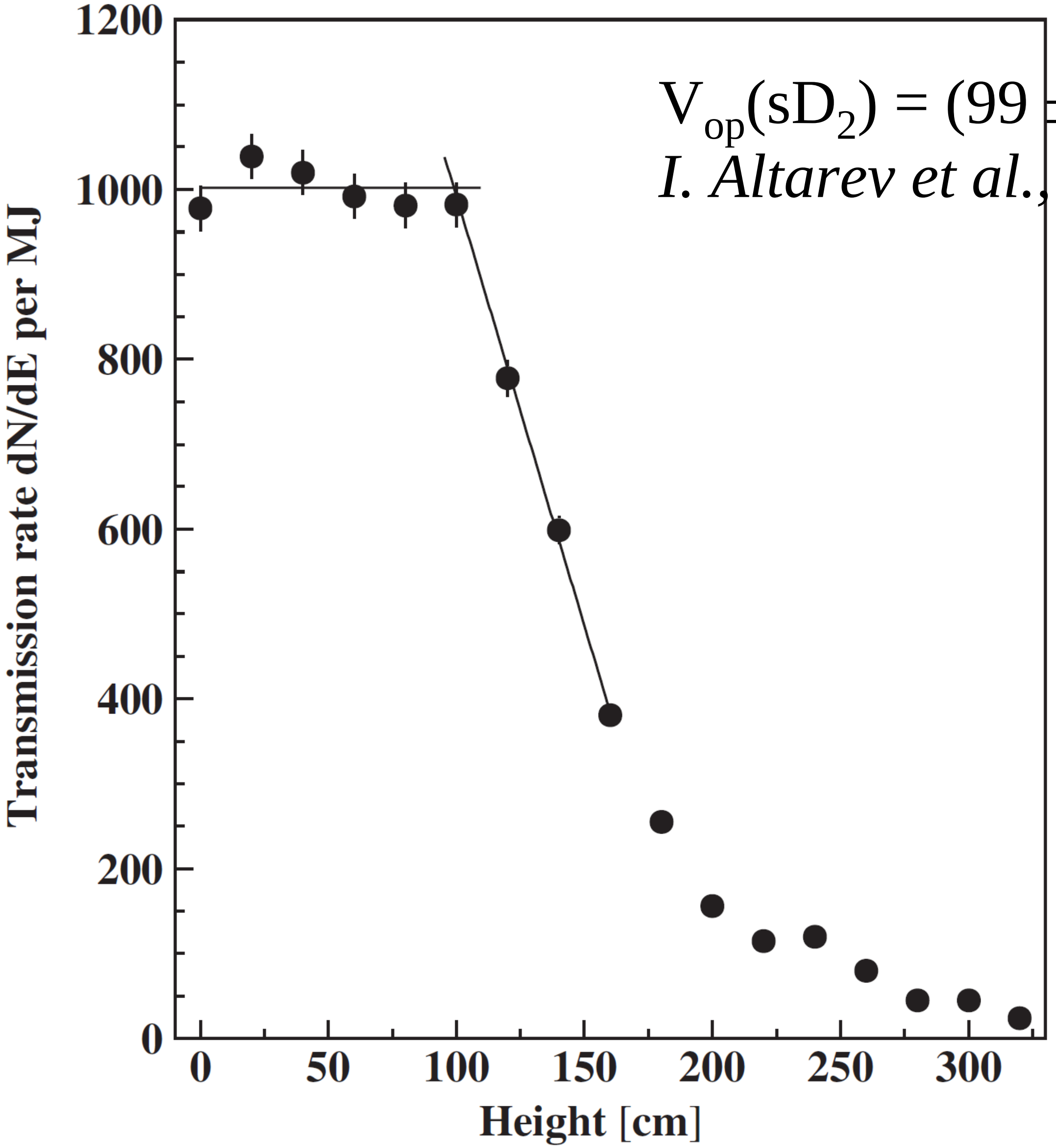


Optical potential of sD_2

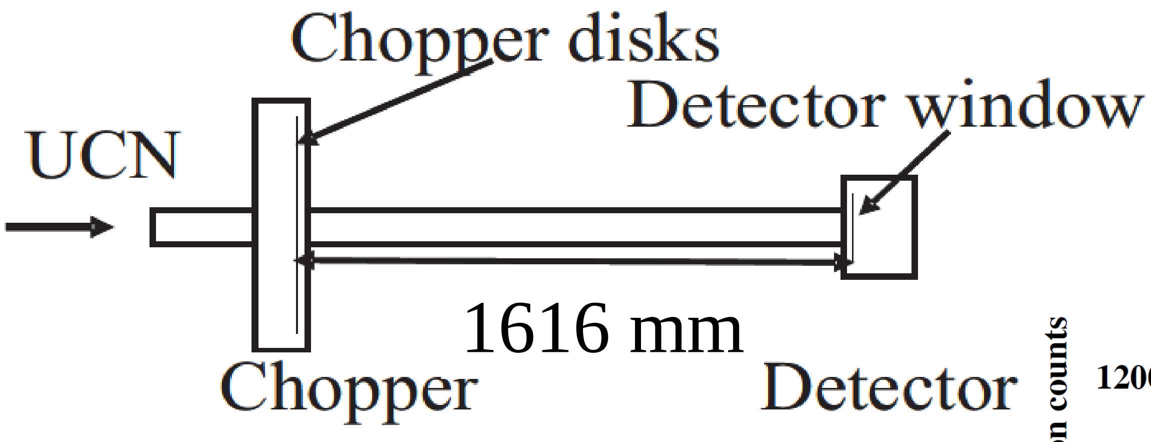
Optical potential of sD_2



$V_{op}(sD_2) = (99 \pm 7)$ neV $\rightarrow$ ~5 m/s

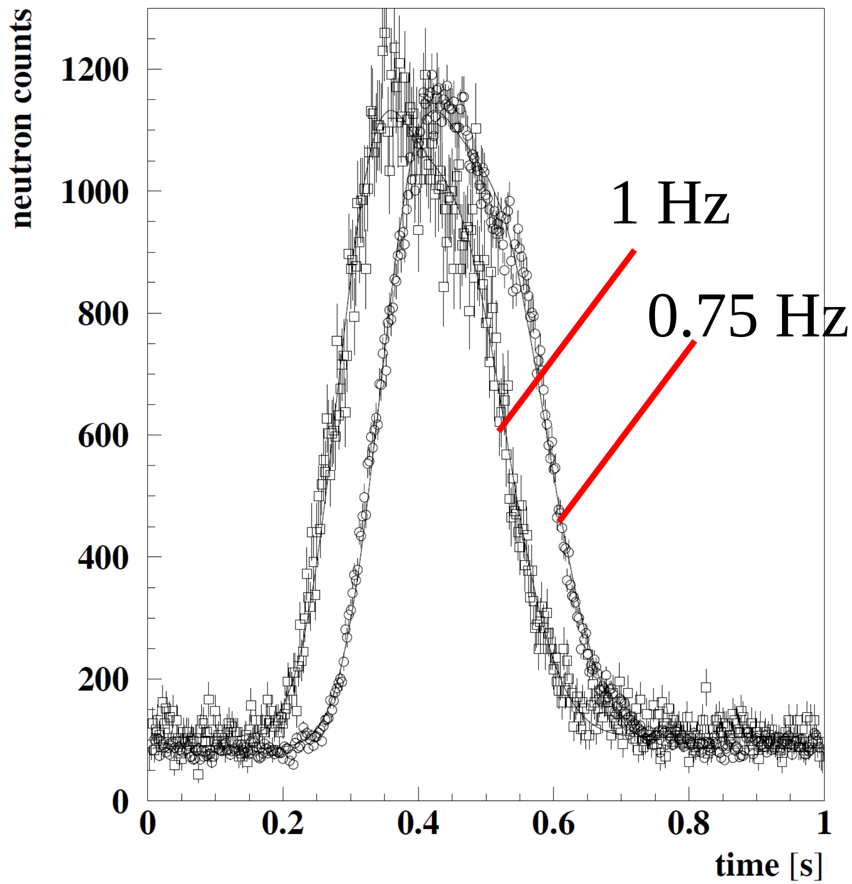
I. Altarev et al., PRL 100, 014801 (2008).

Neutron time-of-flight distribution



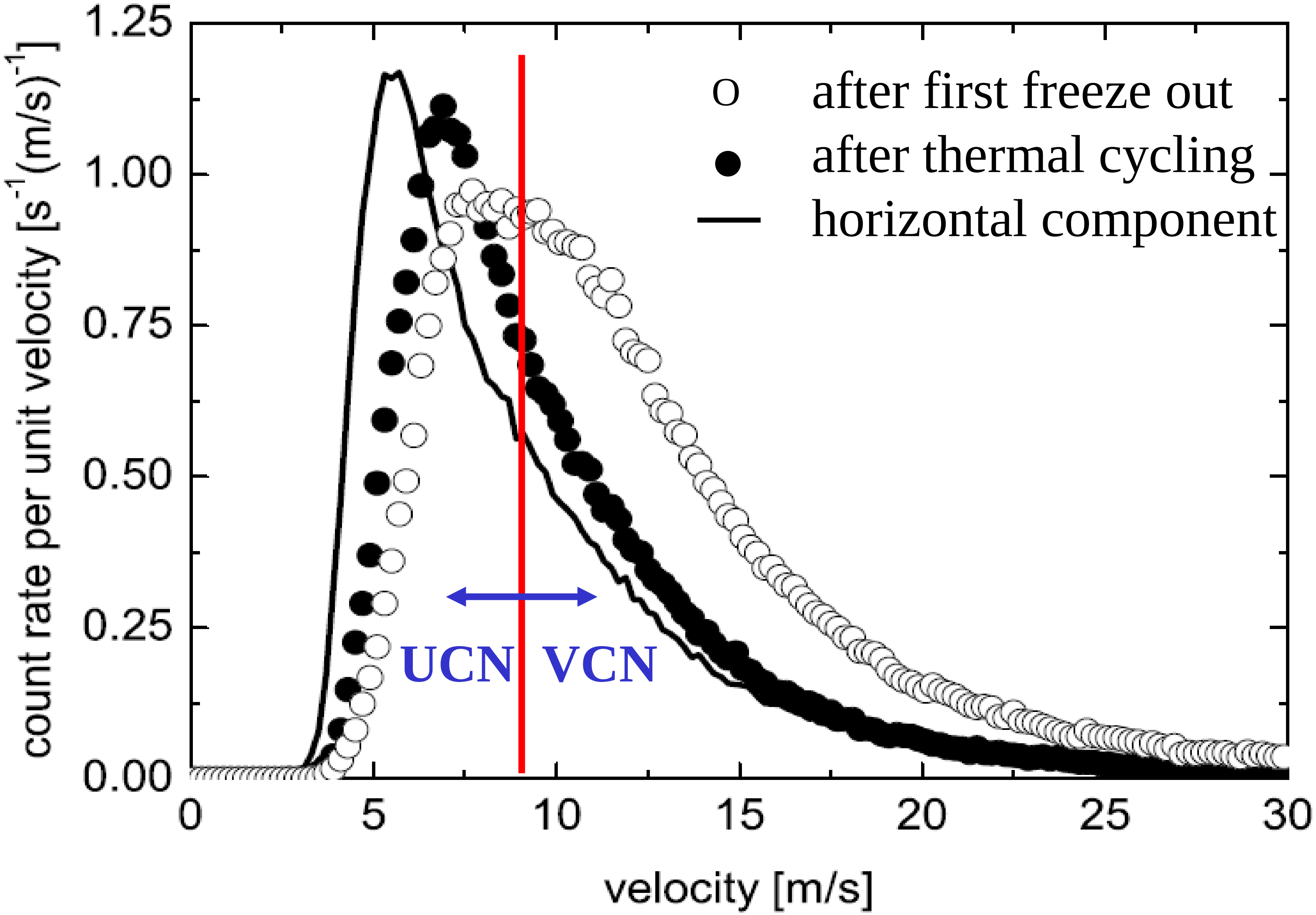
Chopper: 5 % open

Transfer from TOF distribution to velocity distribution needs some Monte Carlo methods.



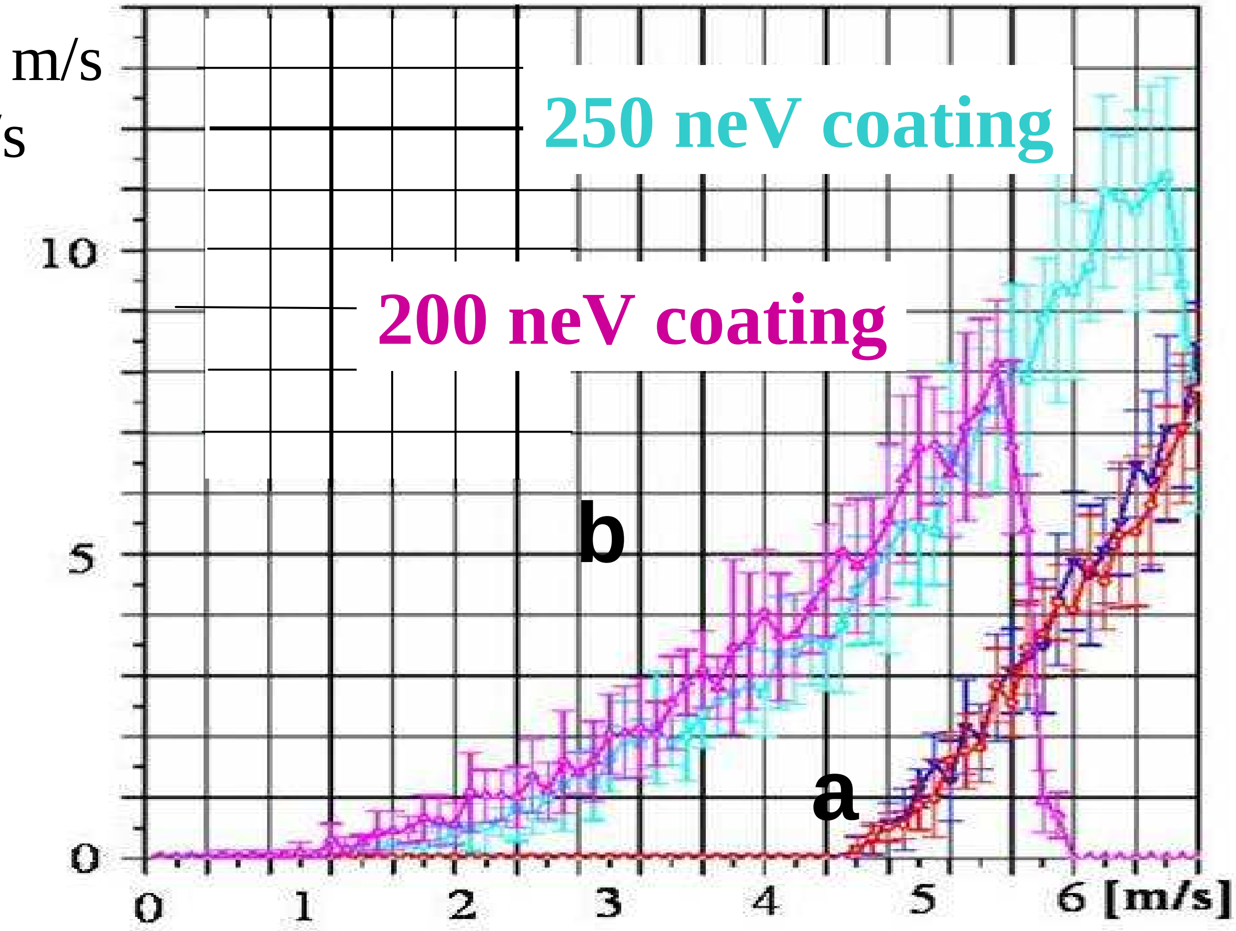
Neutron velocity distribution

I. Altarev et al., EPJA 37, 9 (2008).



Status April 2009

a: v(n) > 4.75 m/s
b: v(n) > 0 m/s

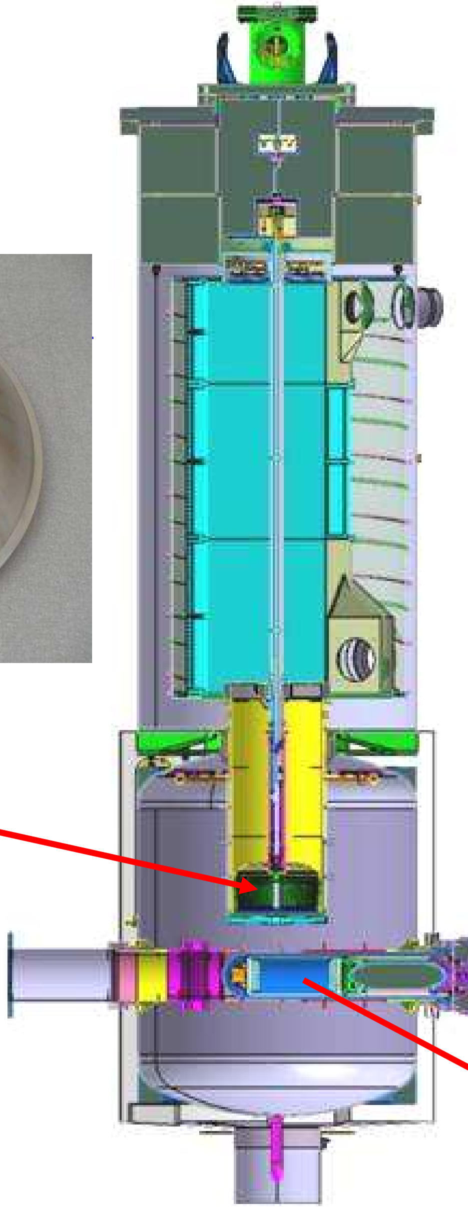


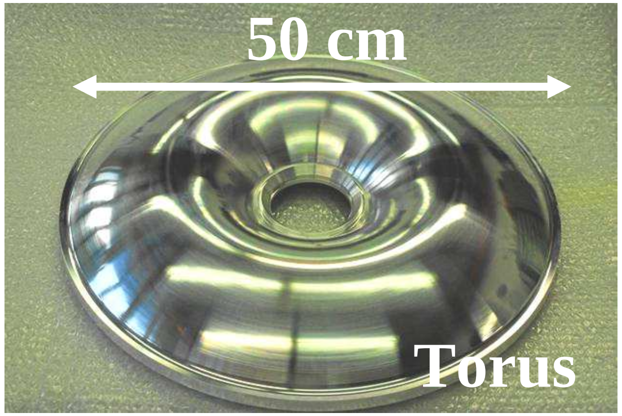
Courtesy A. Fomin, PNPI

PSI UCN source

Relative Masses:

Flat foil	100 %
Torus	110 %
Dome	131 %



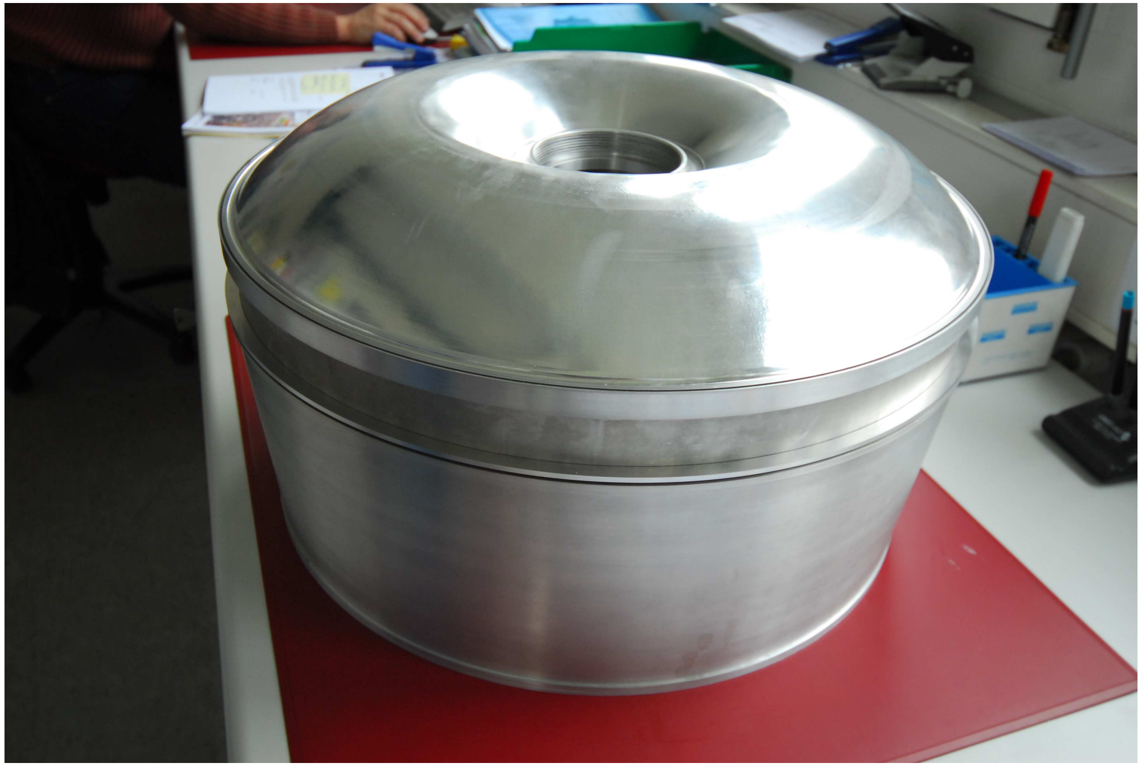


Material choice sD_2 vessel

Possible materials (tensile strength, machining etc):

aluminium alloys

zirconium alloys



From NIST tables:

σ_a(Al) = 0.23 b

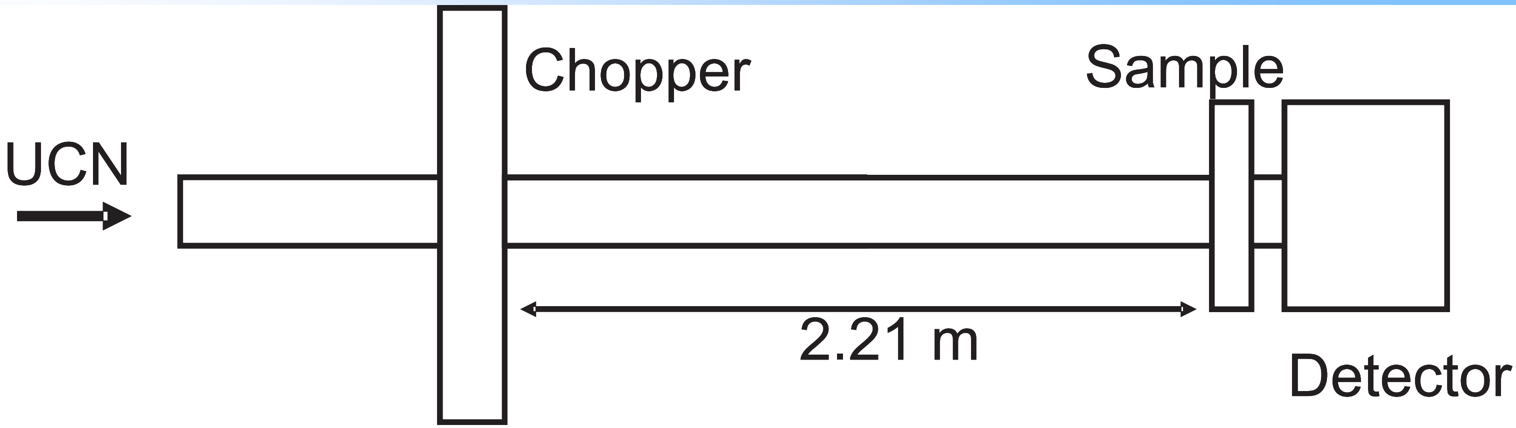
σ_a(Zr) = 0.19 b

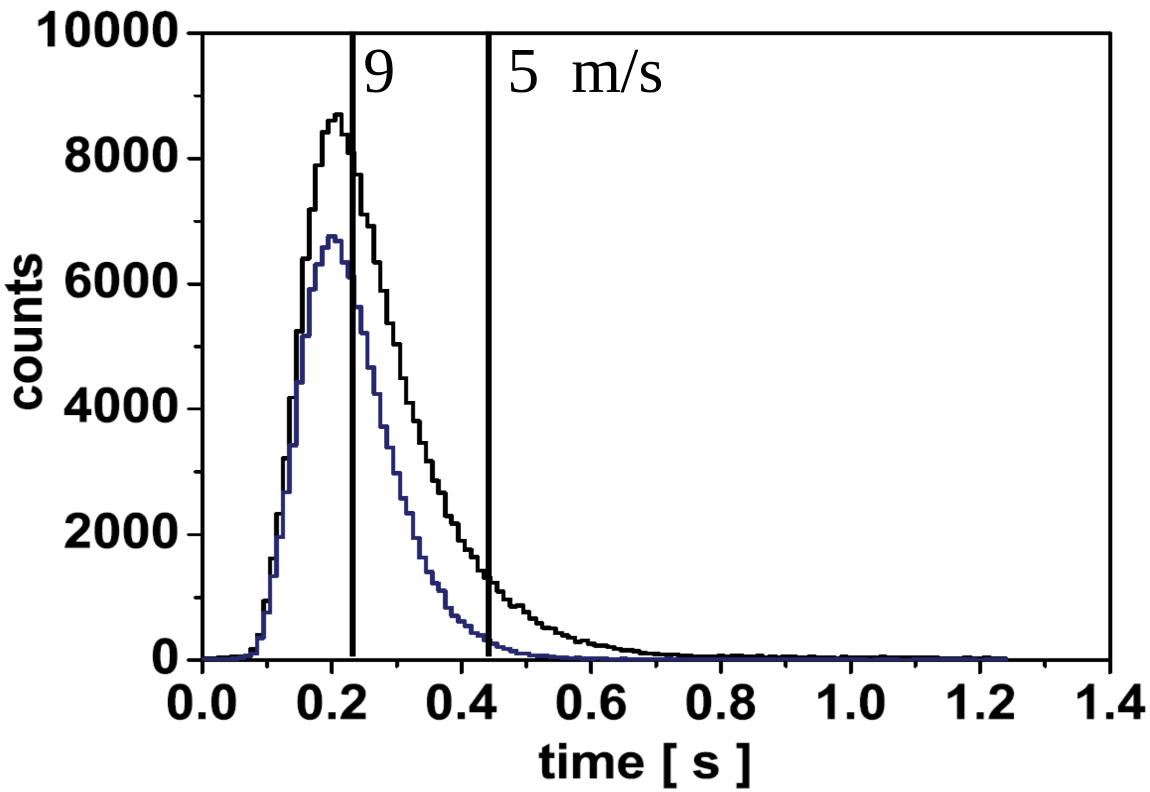
σ_a(steel) = 2.6 b

$$N = N_0 \cdot e^{\left(-\frac{L\cdot\rho}{A}\cdot\sigma_a\cdot x\right)}$$

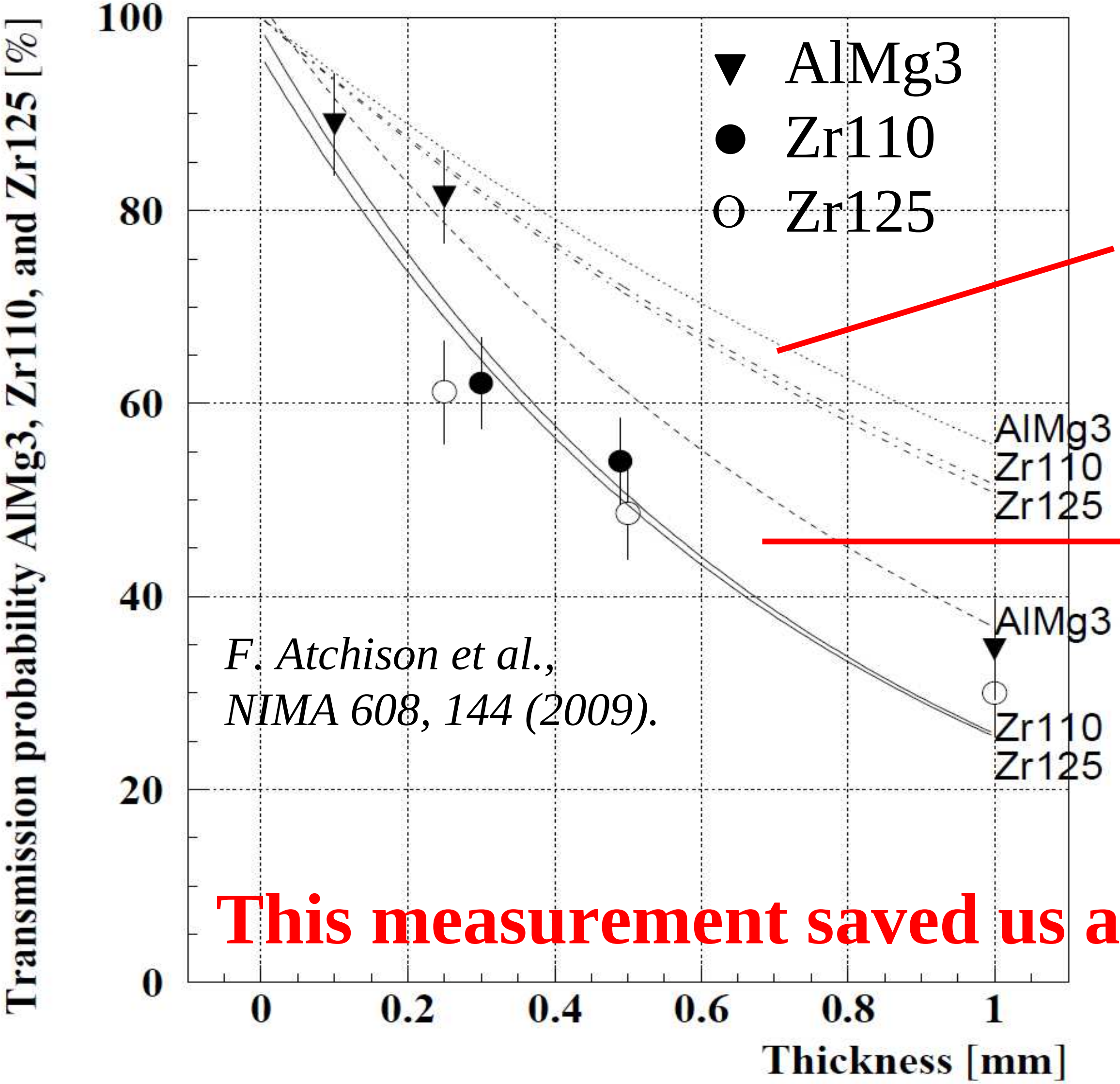
Expectation:
Absorption in Al is 1.75 higher than in Zr (ρ/A!)

Transmission of slow neutrons





Transmission of neutrons of 5-9 m/s through thin foils



From NIST tables:

σ_a(Al) = 0.23 b

σ_a(Zr) = 0.19 b

Expected after material analysis (traces of boron!) :

σ_a(AlMg3) = 0.27 b

σ_a(Zircaloy) = 0.39 b

Measured:

σ_a(AlMg3) = 0.53 b

σ_a(Zircaloy) = 0.98 b

Explanation of discrepancy: surface roughness

A. Steyerl et al. Z. Phys. 250, 1972.

This measurement saved us at least 1 M$

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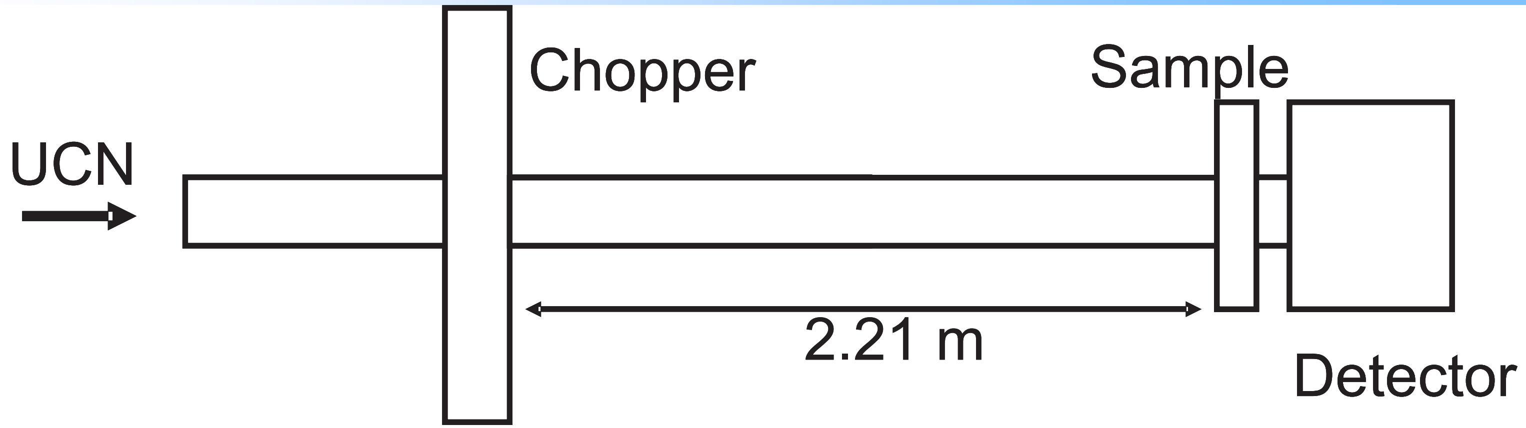
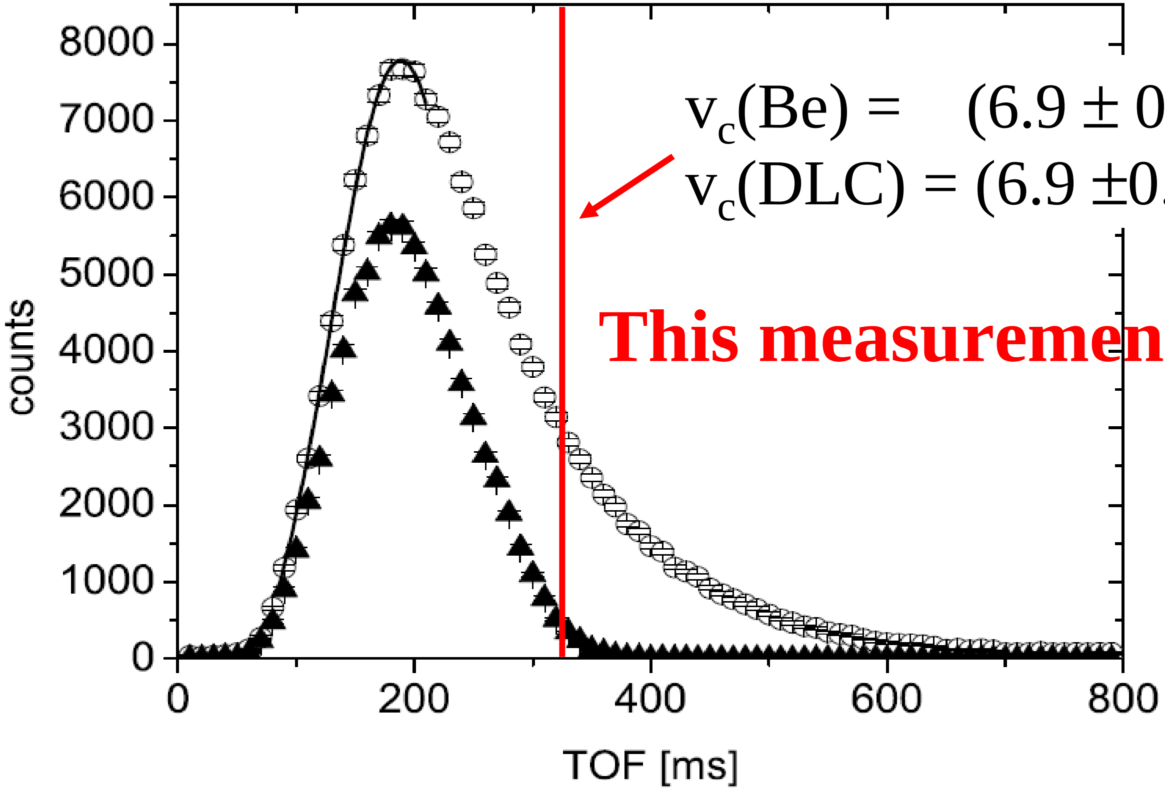
Optical potential of DLC and Be





$v_c(\text{Be}) = (6.9 \pm 0.1)$ m/s
$v_c(\text{DLC}) = (6.9 \pm 0.1)$ m/s

This measurement saved us at least 1 M$

F. Atchison et al.,
Phys. Lett. B 642, 24 (2006),
NIMB 260, 647 (2007).

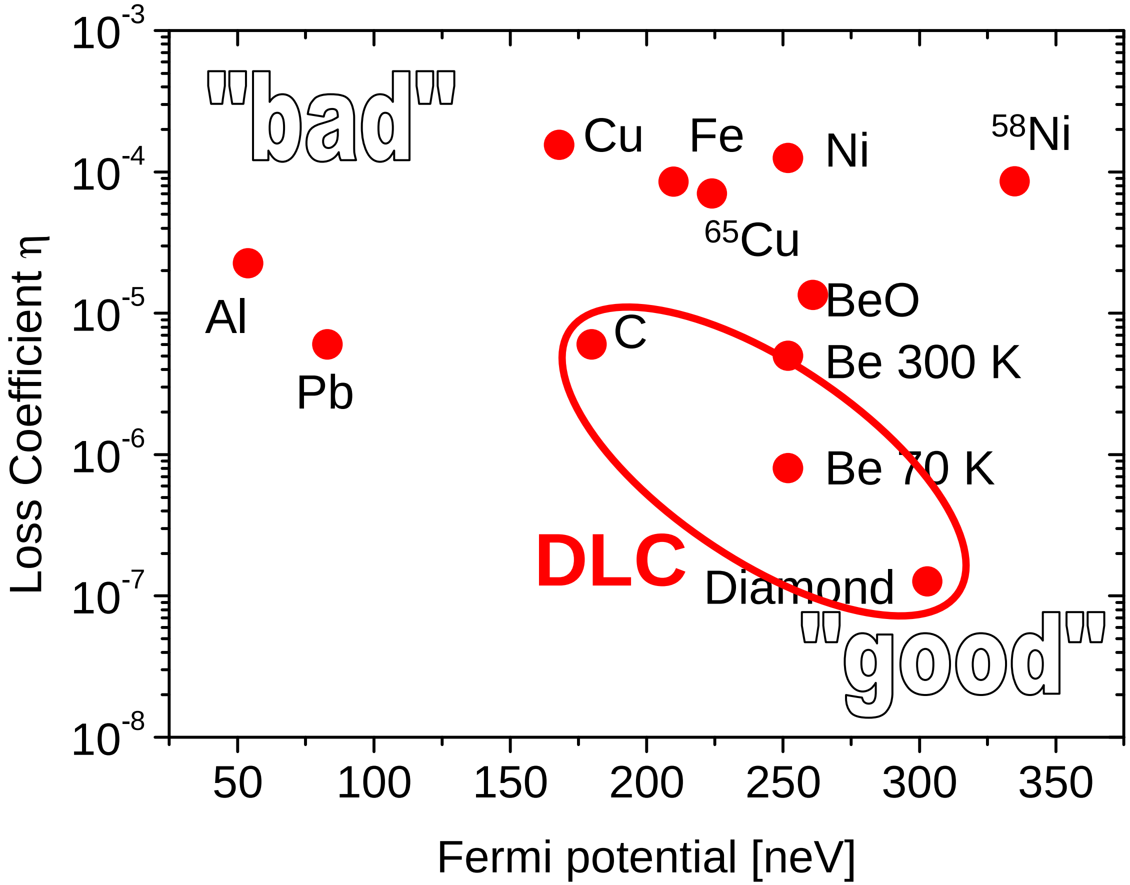
Storage materials

low wall loss probability μ (~η)

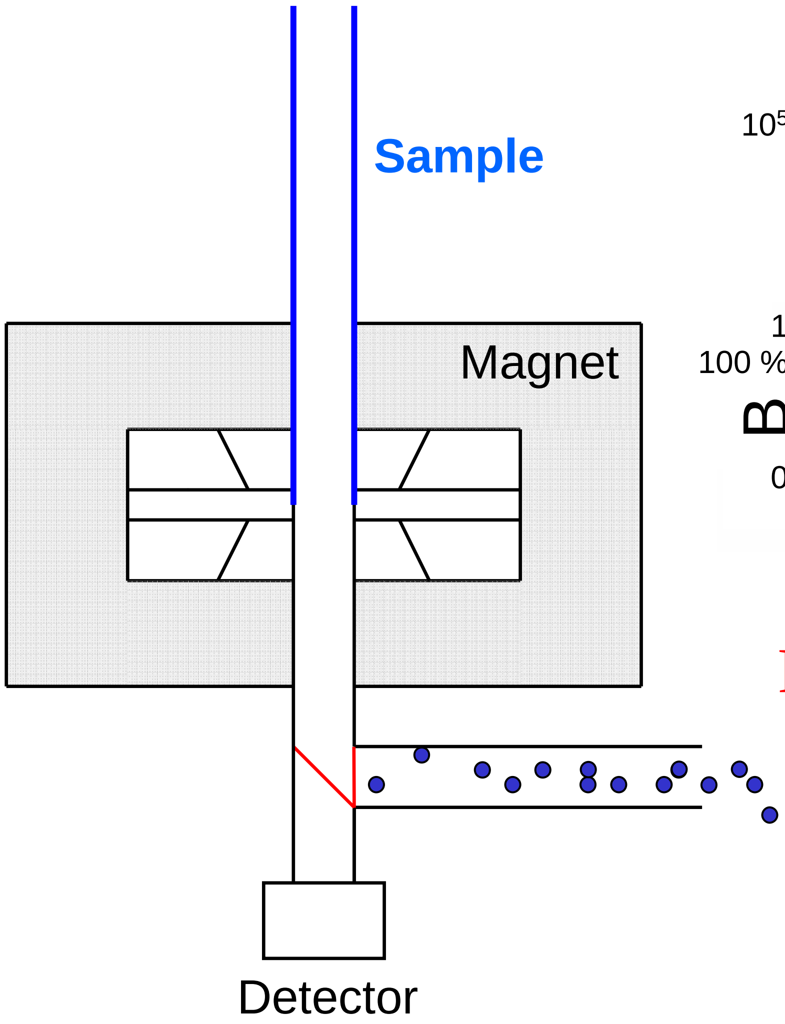
→ long storage time

high optical potential

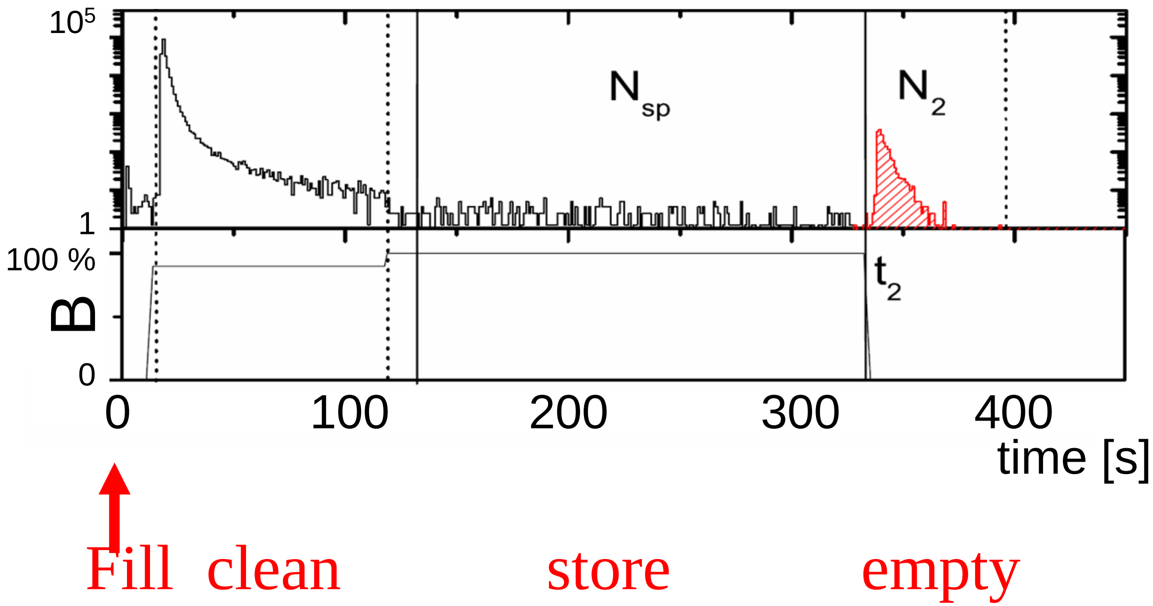
→ more UCN (v^3)



wall material: loss and depolarization



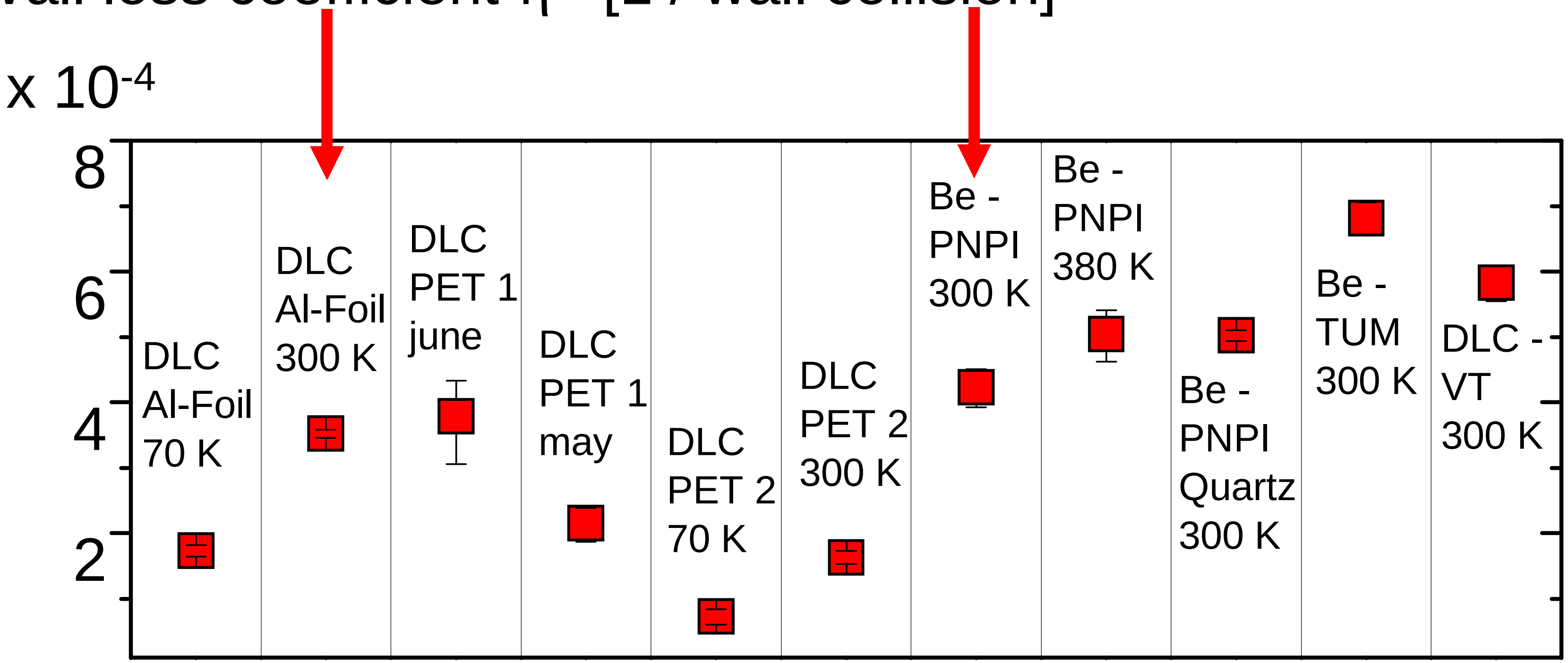
Detector count rate:



UCN from ILL-turbine

Diamondlike carbon

Wall loss coefficient η [1 / wall collision]



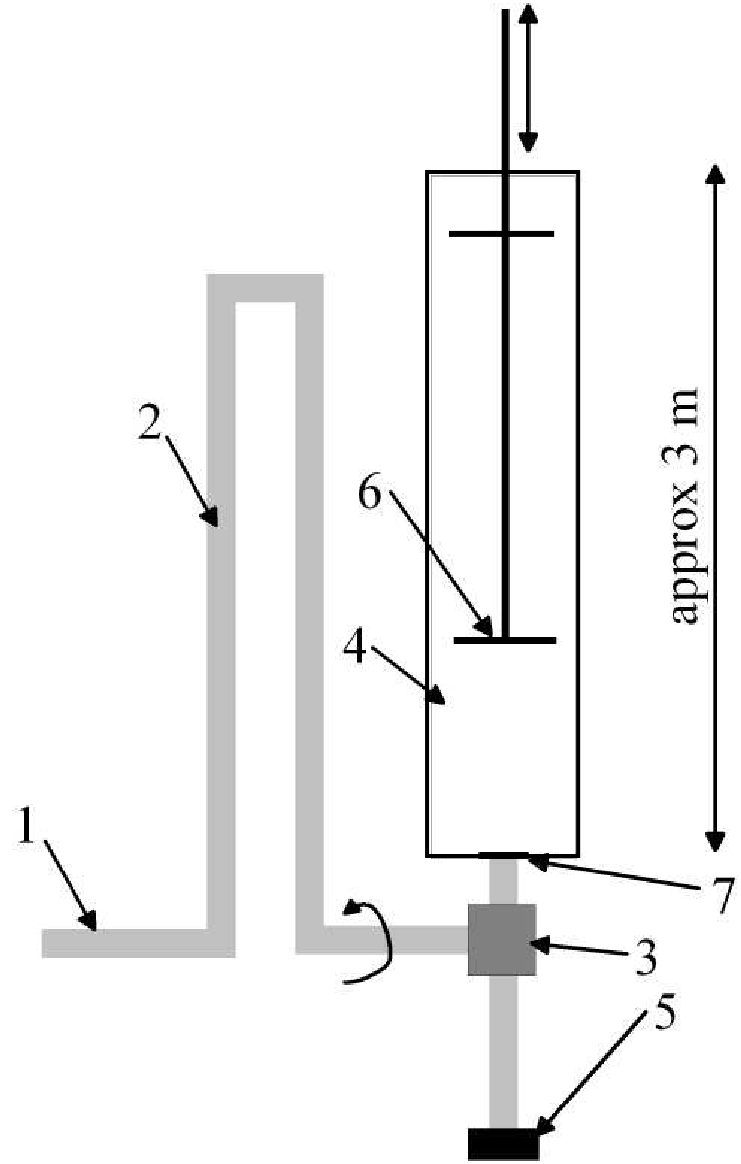
DLC is a good choice ☺ also for β (DLC)=$1 \cdot 10^{-6}$, β (Be)=$10 \cdot 10^{-6}$

PET = polyethylene terephthalate

F. Atchison et al., Phys. Lett. B 625, 19 (2005).

T. Brys et al., Nucl. Instr. and Meth. in Phys. Res. A 550, 637 (2005).

Test Storage Volume @ ILL



Final Results

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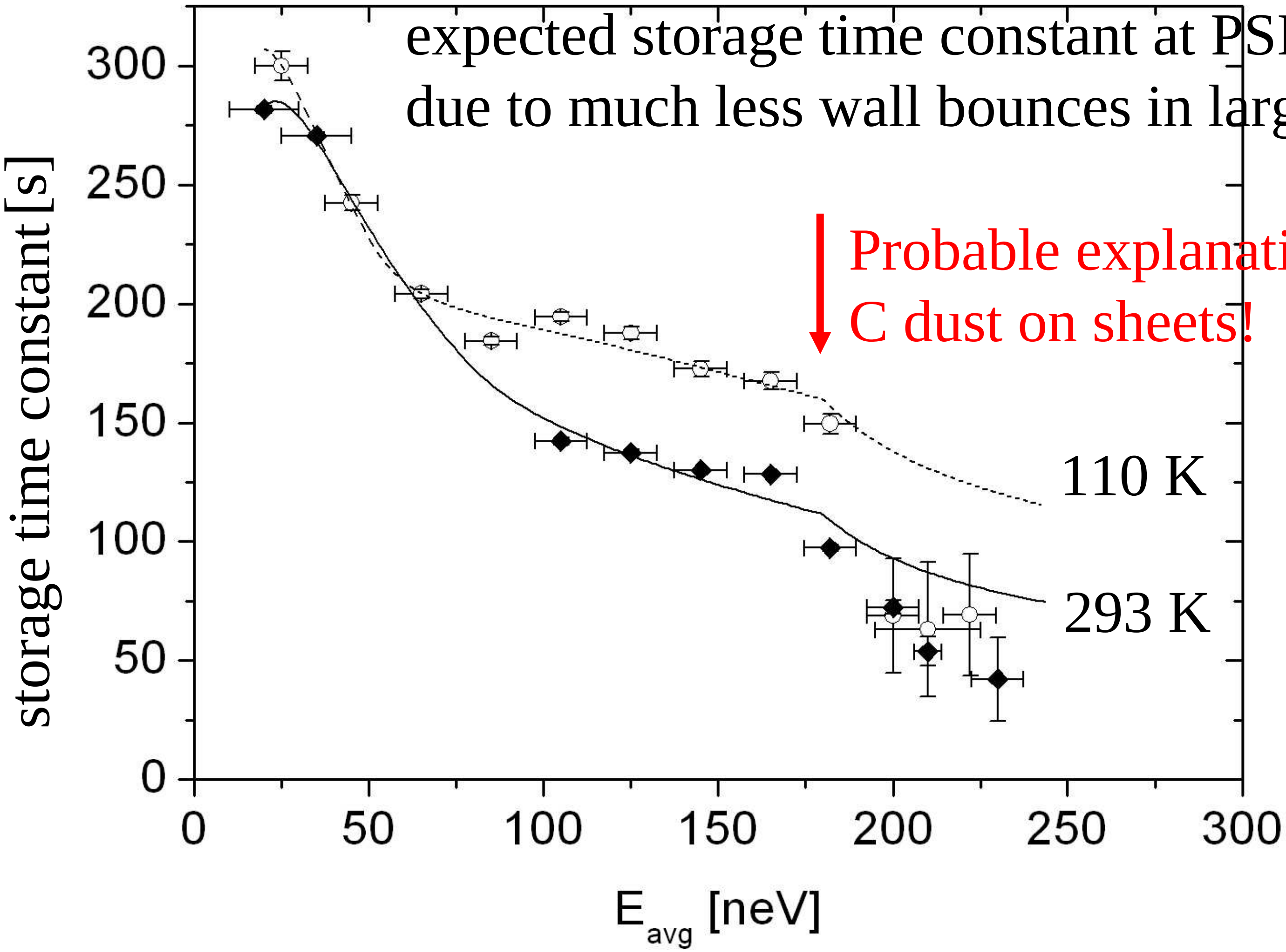
$$N = N_0 \cdot e^{-\frac{t}{\tau}}$$



expected storage time constant at PSI: $\tau \sim 500$ s
due to much less wall bounces in larger volume

Probable explanation:
C dust on sheets!

F. Atchison et al., Phys. Rev. C 74, 055501 (2006).

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On the way to the top!

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Physics of fundamental Symmetries & Interactions

PSI 2010

Swiss Institute of Particle Physics

October 11 – 14, 2010
Paul Scherrer Institut, Switzerland

2nd International Workshop on the Physics of fundamental Symmetries and Interactions at low energies and the precision frontier.

Topics:

- Low energy precision tests of the Standard Model
- Searches for symmetry violations – e.g. T, CP, CPT, Lorentz, Lepton flavor, Baryon number
- Searches for new forces – e.g. spin dependent interactions, modifications of gravity or weak interaction
- Precision measurements of fundamental constants
- Fundamental physics with cold and ultracold neutrons
- Advanced ultracold neutron sources
- Searches for permanent electric dipole moments
- Precision experiments with pions and muons
- Advanced muon sources
- Exotic atoms and molecules
- Precision magnetometry
- Advanced detector technologies

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your feelings: never
argue with an aggressive questioner