The new ultracold neutron source at the Paul Scherrer Institute

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on behalf of the PSI UCN Project Team

5th International Symposium on Symmetries in Subatomic Physics
June 18-22, 2012 KVI, Groningen, the Netherlands

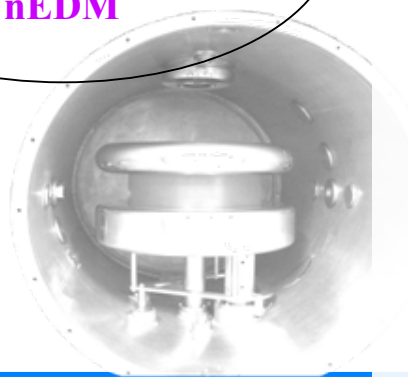
Paul Scherrer Institute
Villigen, Switzerland

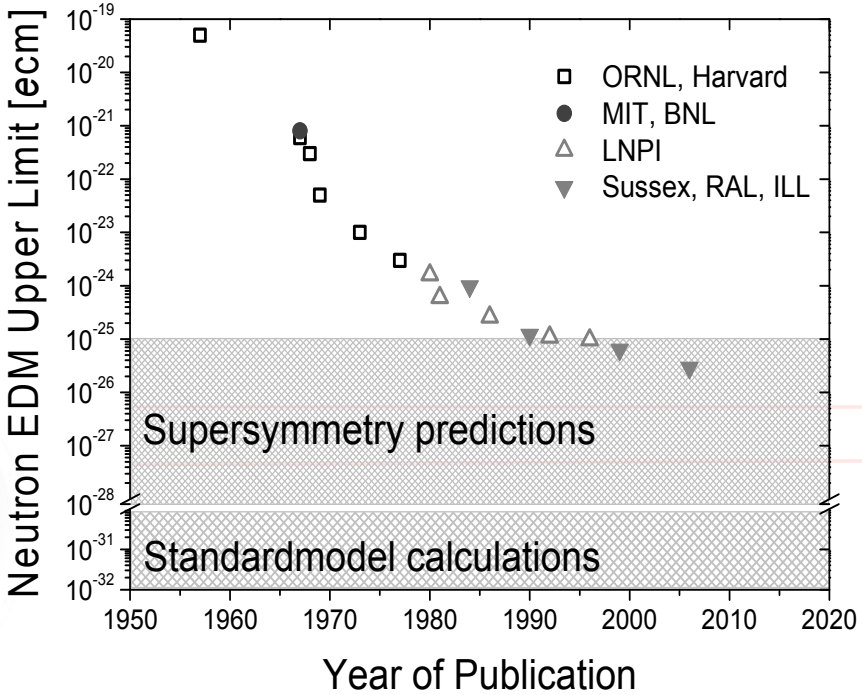
UCN serve as a probe for studying fundamental properties of the neutron

The search for a Neutron Electric Dipole Moment - nEDM - is the driving motivation for the construction of high intensity ultracold neutron (UCN) sources.

nEDM would indicate a new CP violating process
-> could help to explain Baryon Asymmetry of the Universe
-> most SUSY approaches predict a large nEDM.

see talks in the EDM session on Friday, Jacek Zejma will present the PSI nEDM





Current best limit:

$d_n < 2.9 \times 10^{-26}$ ecm

PRL **97**, 131801 (2006)

statistically limited !

UCN serve as a probe for studying fundamental properties of the neutron

Neutron Life Time -> Big Bang Nucleosynthesis, Weak Interaction

Gravitational States of the Neutron -> extra Dimensions, Gravitation

Neutron Decay Parameters -> extra Couplings, V_{ud}

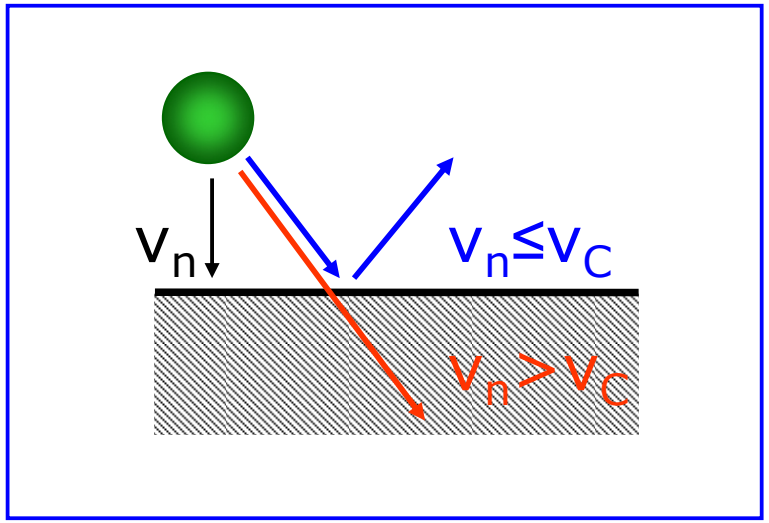
Charge of the Neutron -> Charge Conservation

Neutron-Antineutron Oscillations ->
Baryon Number Violation

Ultracold neutrons can be stored

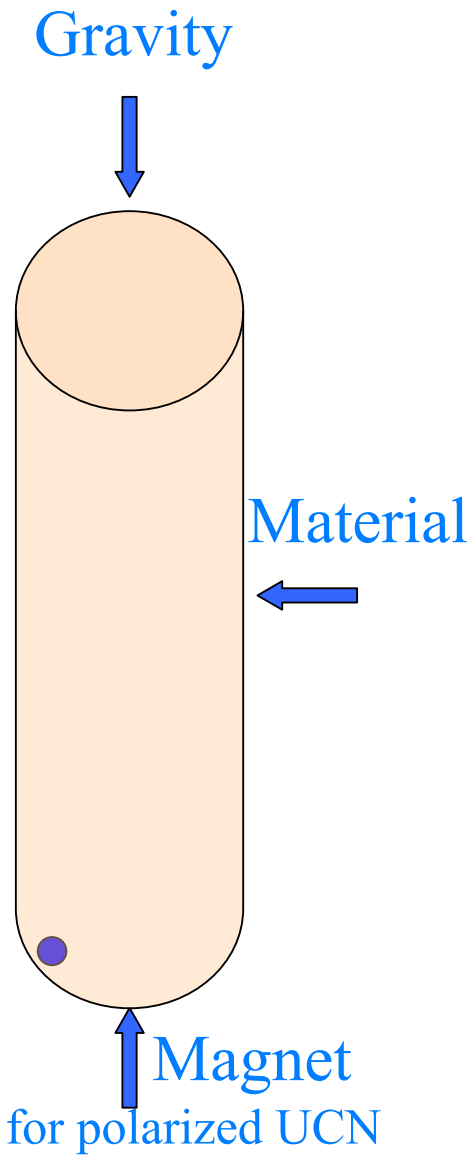
UCN < 300neV ~ 8m/s ~ 3 mK !

Neutrons with Ekin < 300 neV can be stored



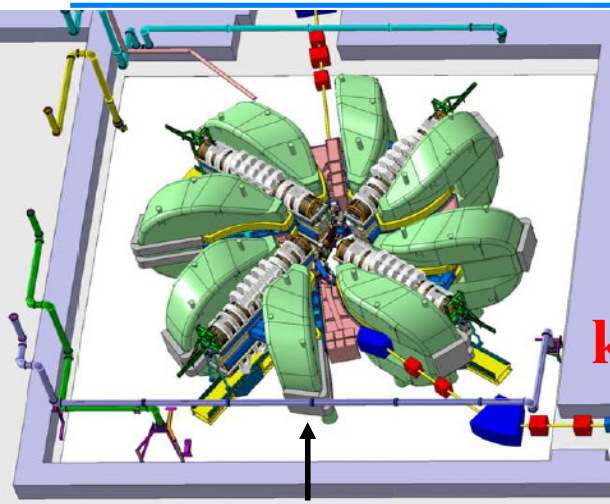
- storage properties are material dependent -
Ni, Ni^{58}, Be, DLC

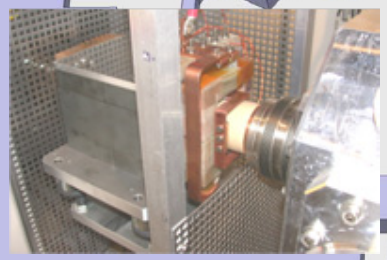
100 neV ~ 1 m
60 neV ~ 1 T



E. Fermi, 1946 , Ya. B. Zeldovich
Sov. Phys. JETP 9, 1389 (1959)

PSI's high intensity proton beam is used for neutron production via spallation





kicker to UCN

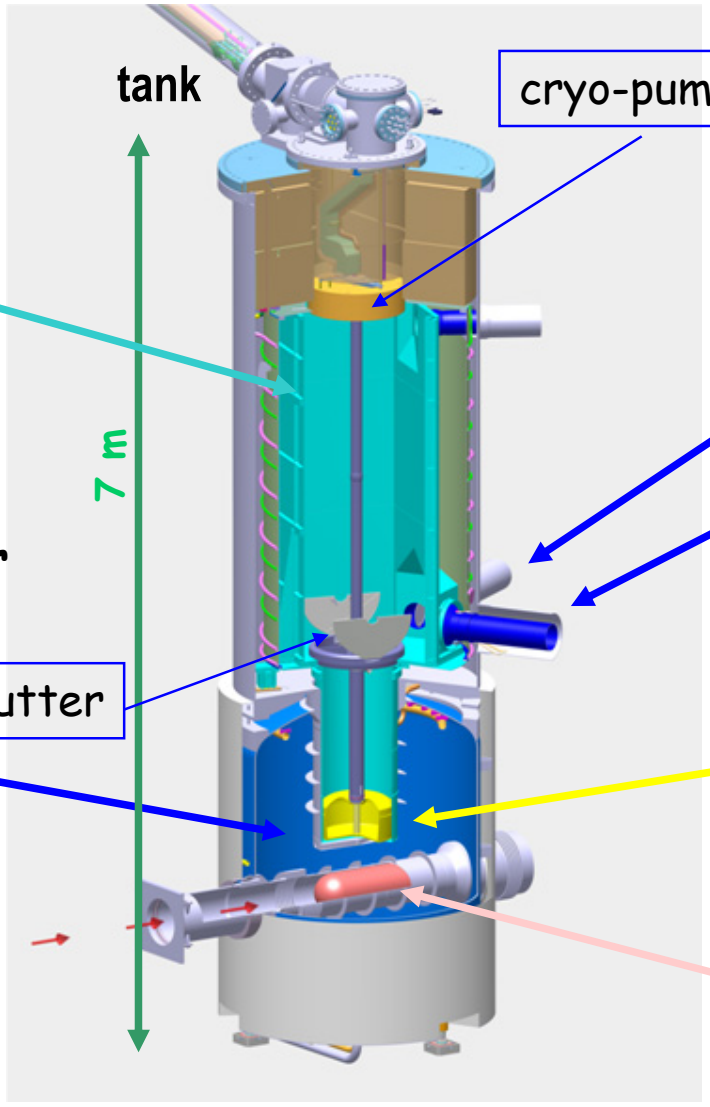
Proton Accelerator
590 MeV Cyclotron
2.2 mA beam current regularly

UCN Source

2 experimental areas / 3 beamlines

nEDM installed

Sketch of the PSI UCN source operation



DLC coated
UCN storage vessel
height 2.5 m, ~ 2 m^3

heavy water moderator
→ thermal neutrons
3.6m^3 D_2O

pulsed
1.3 MW p-beam
600 MeV, 2.4 mA,
1% duty cycle

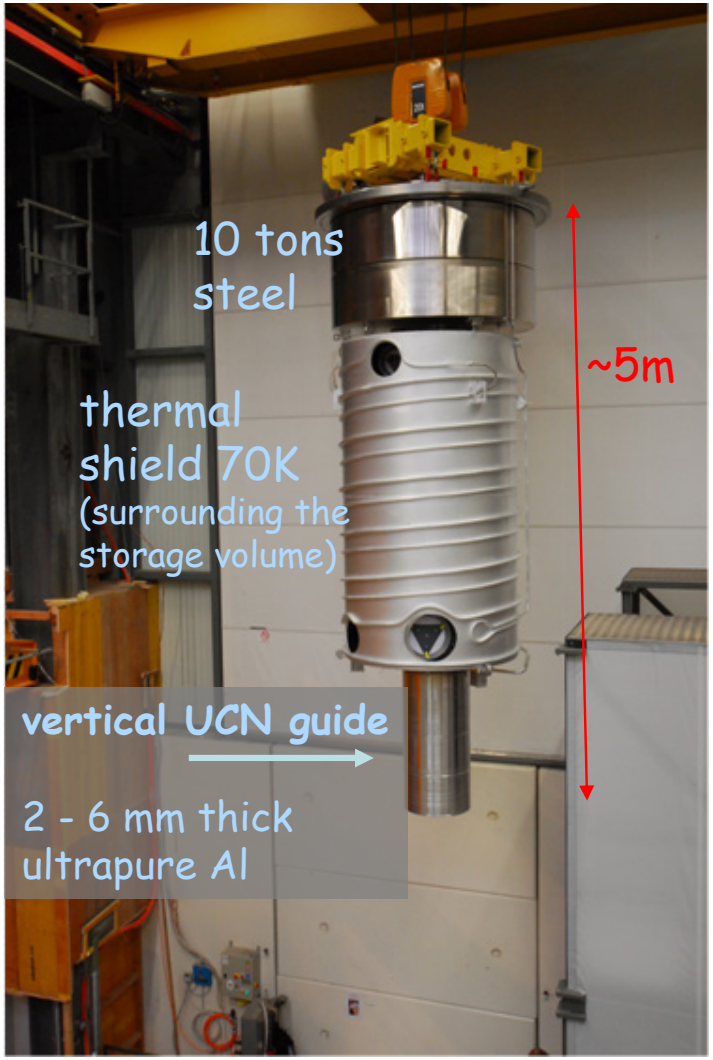
UCN guides towards
experimental areas
8.6m(S) / 6.9m(W)

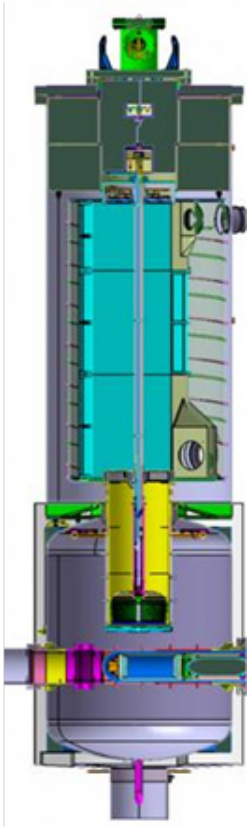
cold UCN-converter
~30 dm^3 solid D_2 at 5 K

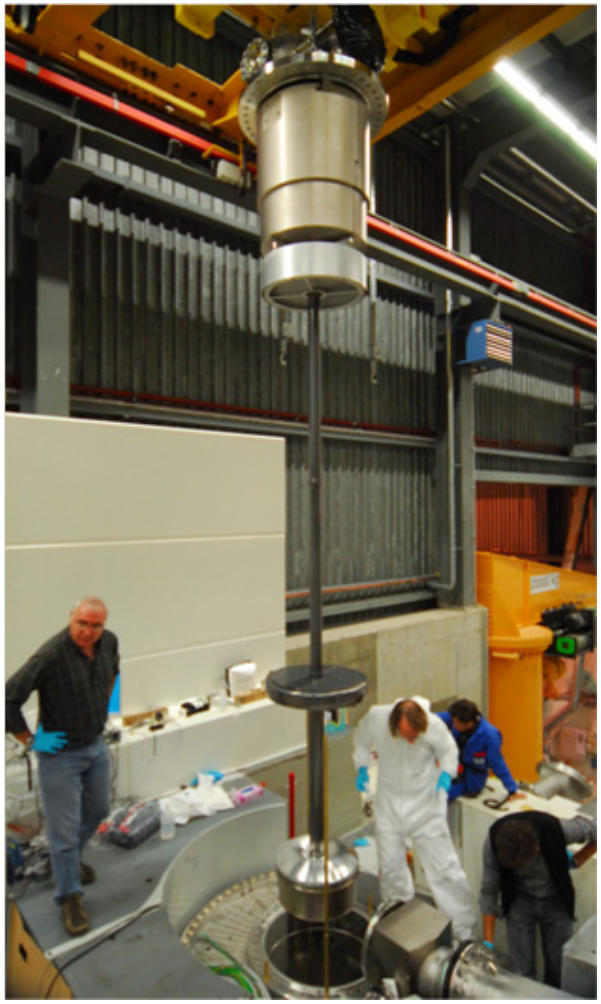
spallation target (Pb/Zr)
(~ 8 neutrons/proton)

Installation of: - the storage volume unit - the deuterium unit, the last part before closing the big vacuum tank

November 5, 2010





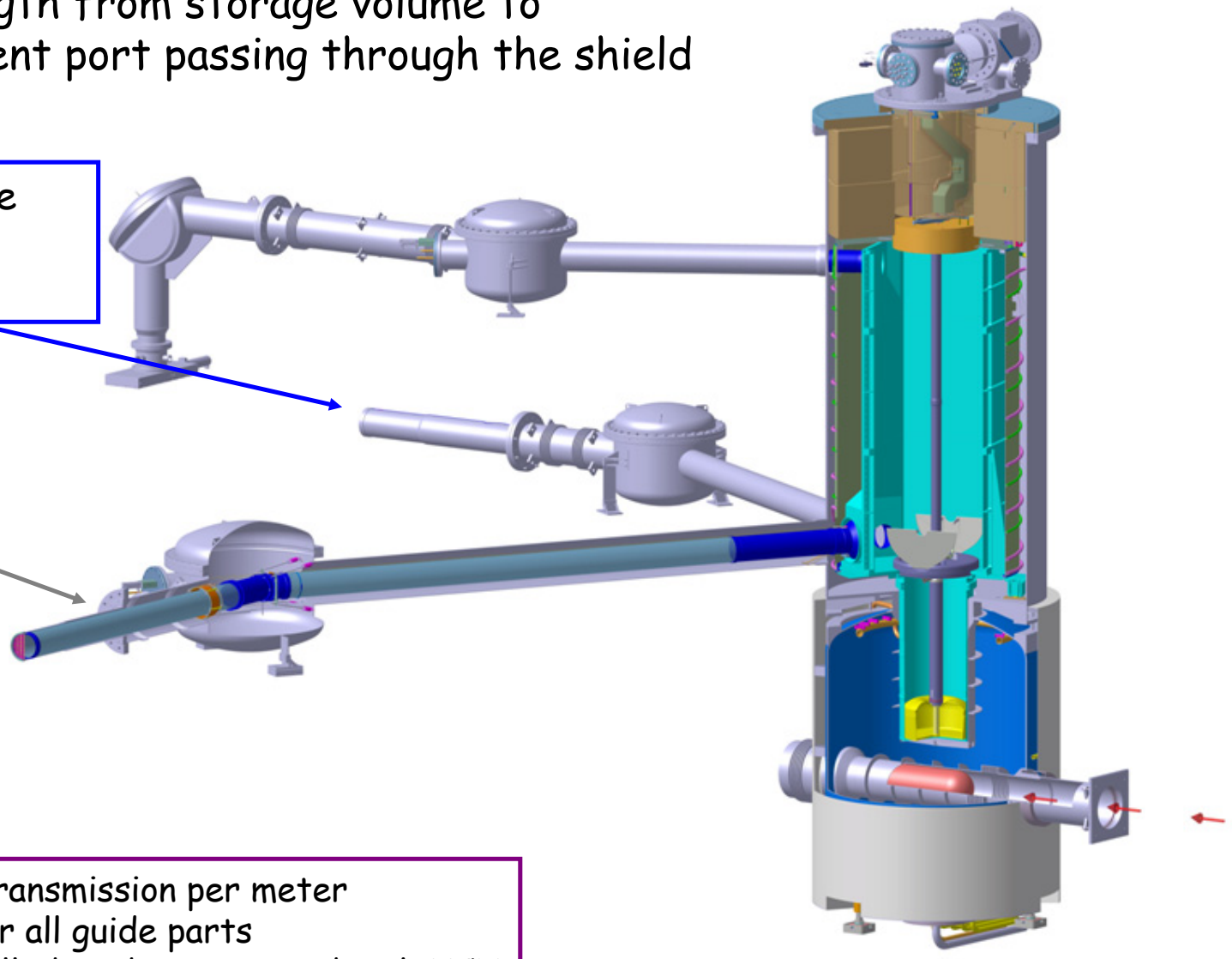


Neutron guides pass the biological shield and guide the UCN to the experimental areas

~8 m length from storage volume to experiment port passing through the shield

detector located at the beamport / end of the guide

glass parts
-surface roughness better than 1nm
-coated with NiMo



nEDM

>98% UCN transmission per meter measured for all guide parts
- every installed guide was tested with UCN

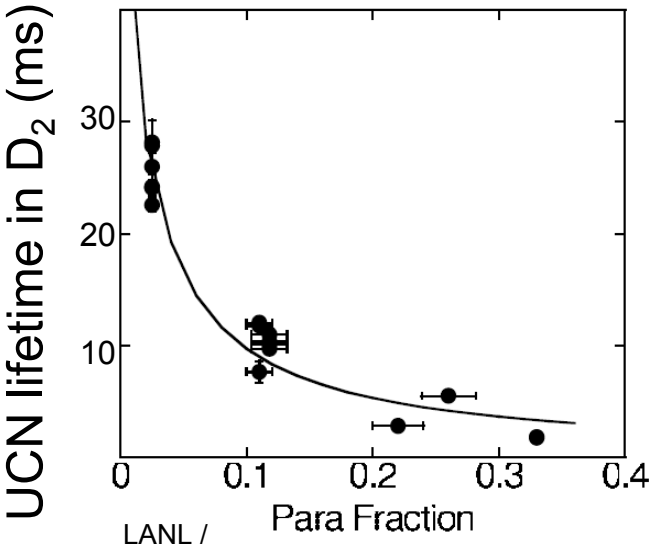
Superthermal UCN production occurs via phonon scattering on the crystal lattice of solid deuterium (or helium)

UCN density:

$$\rho_{UCN} = \Phi_0 \cdot \tau_{UCN} \cdot R$$

2.2mA p-beam

ortho/para fraction



LANL /
C.Morris et al, Phys.Rev.Lett.89(2002)272501

F. Atchison et al., PHYSICAL REVIEW C **71**, 054601 (2005)

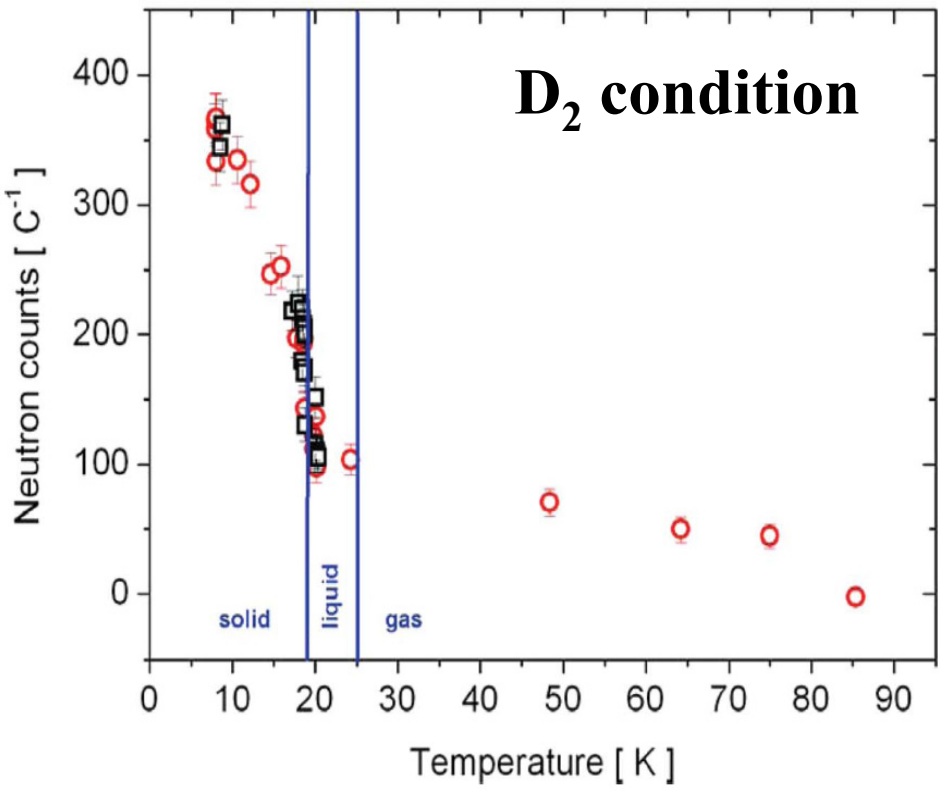
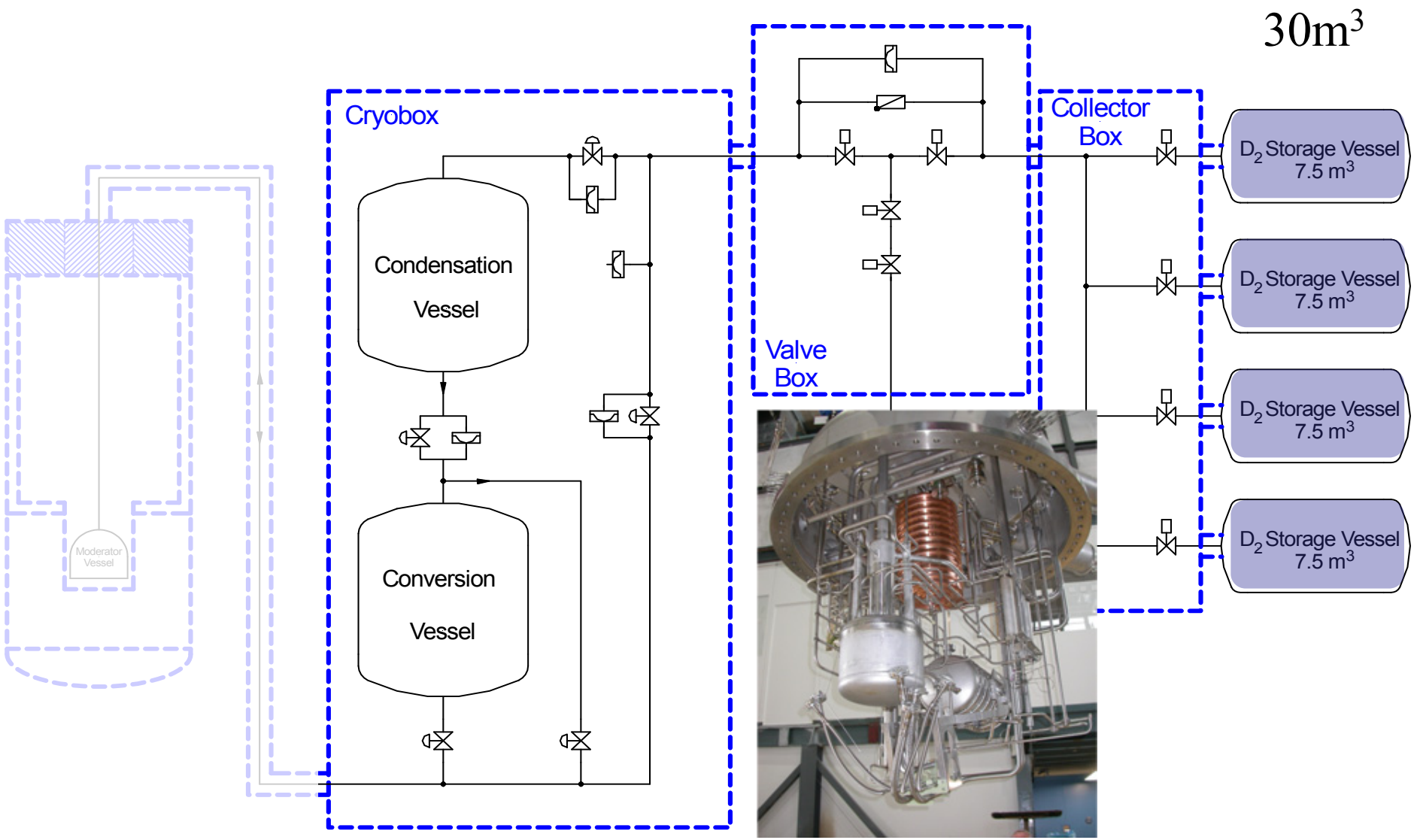


Figure 2. *Experimentally determined temperature dependence of UCN production in deuterium [22]. The sharp increase with solidification is obvious.*

Preparation of the deuterium crystal



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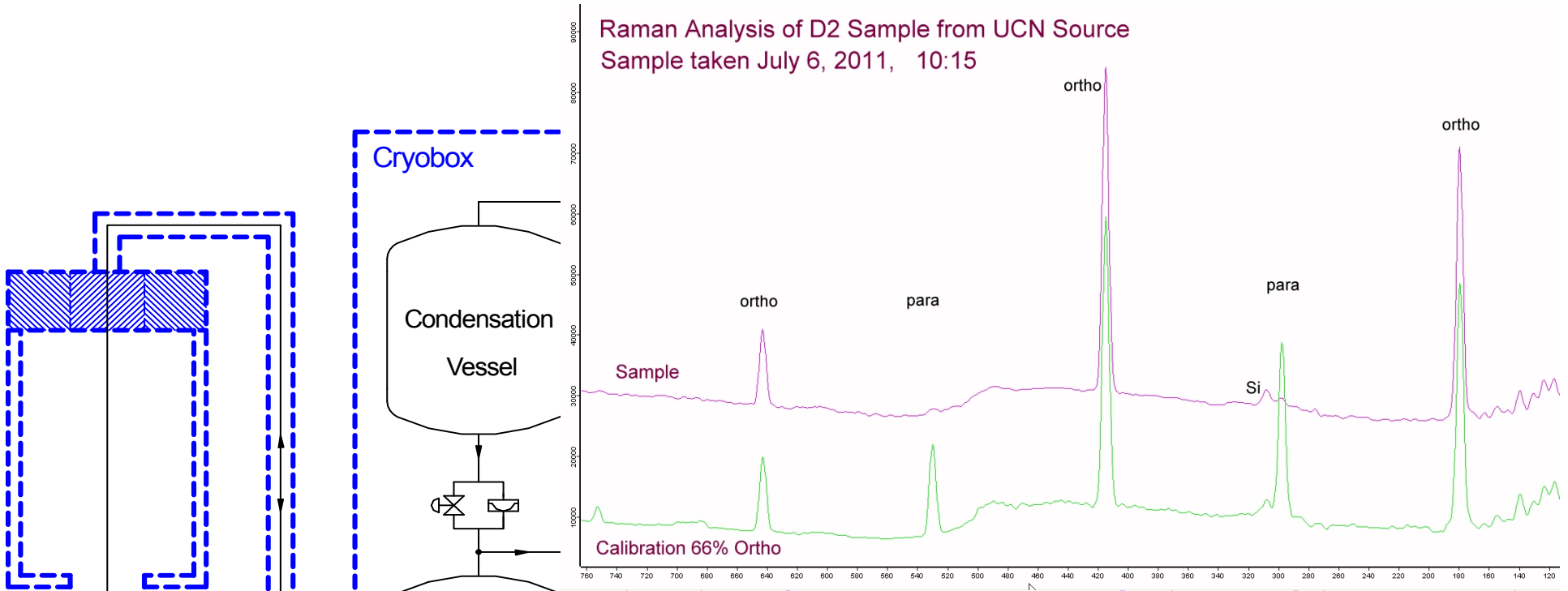
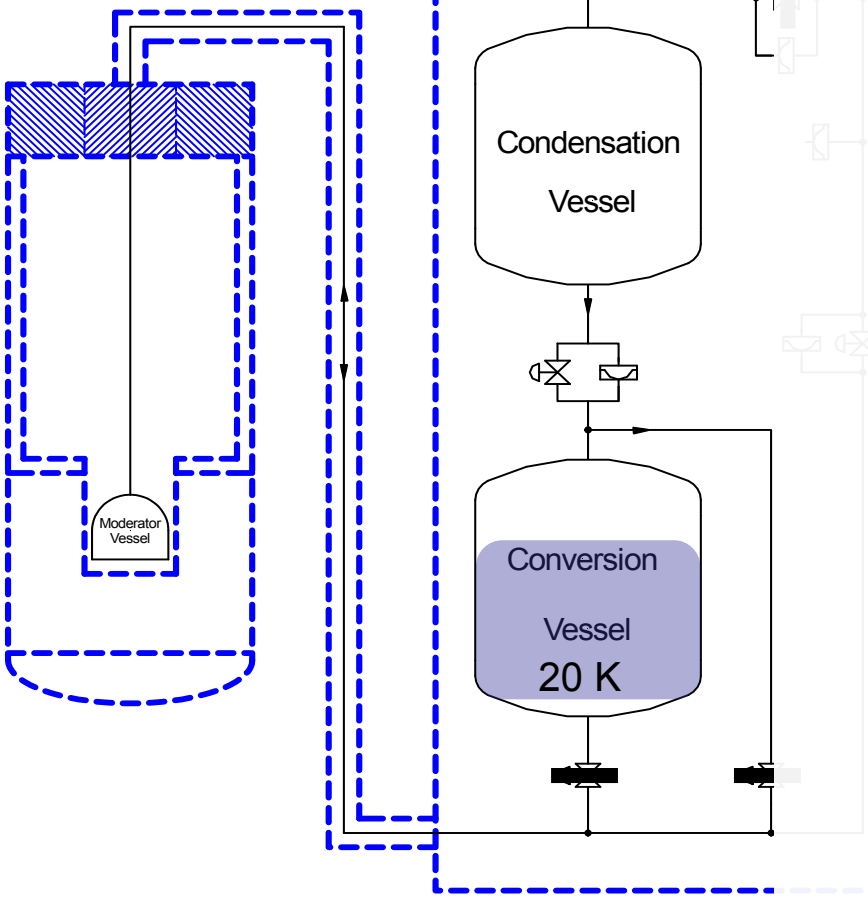


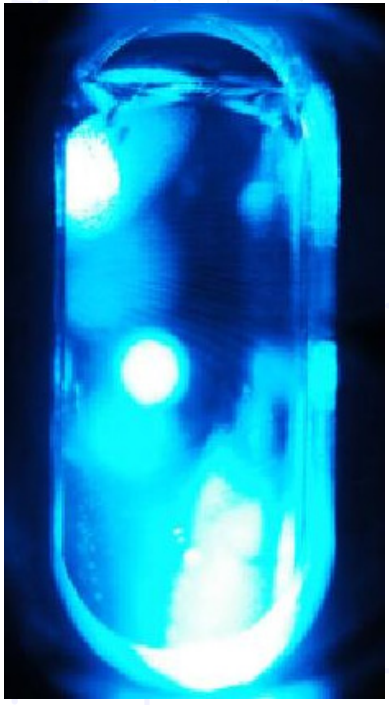
cool-down:

para-ortho conversion
(using Oxisorb)

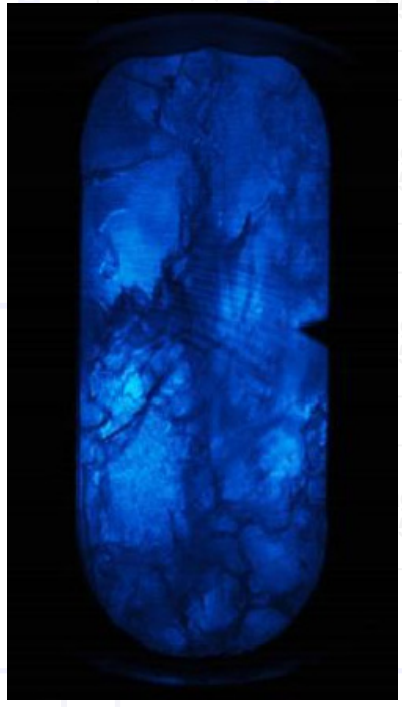
Preparation of the deuterium crystal



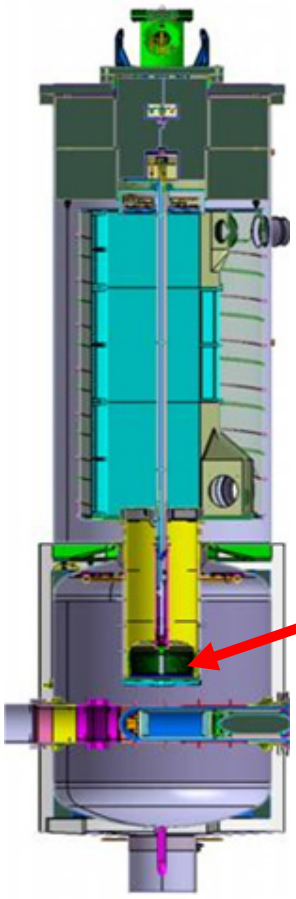
slow crystal

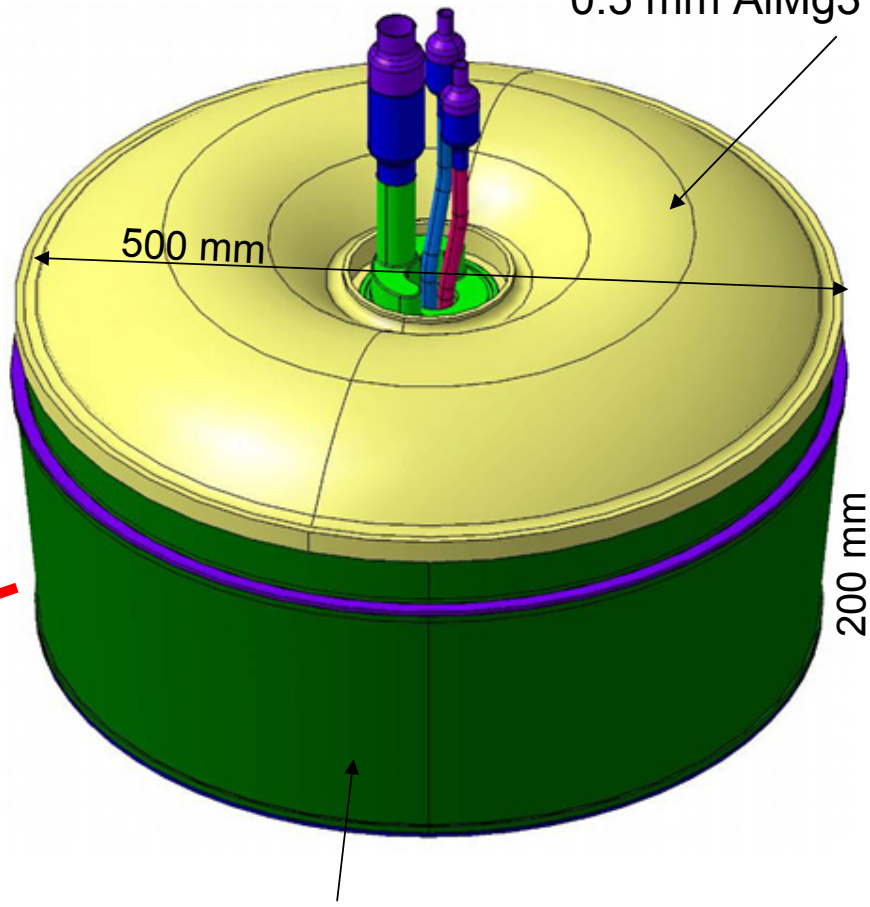


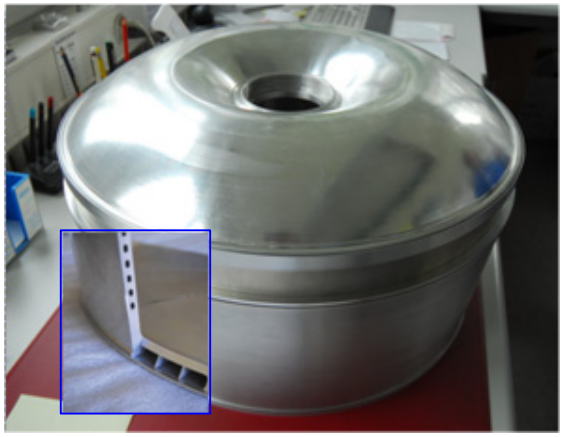
fast growing

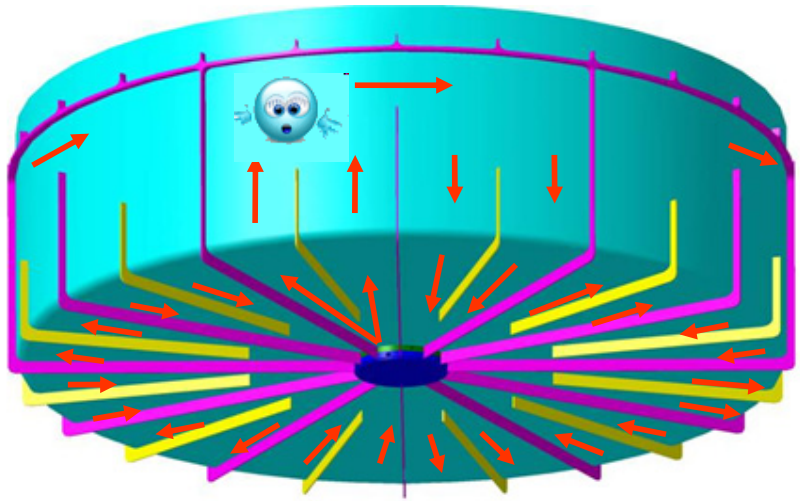


The solid deuterium crystal container is at 5K temperature









Cooling Agent: Supercritical Helium

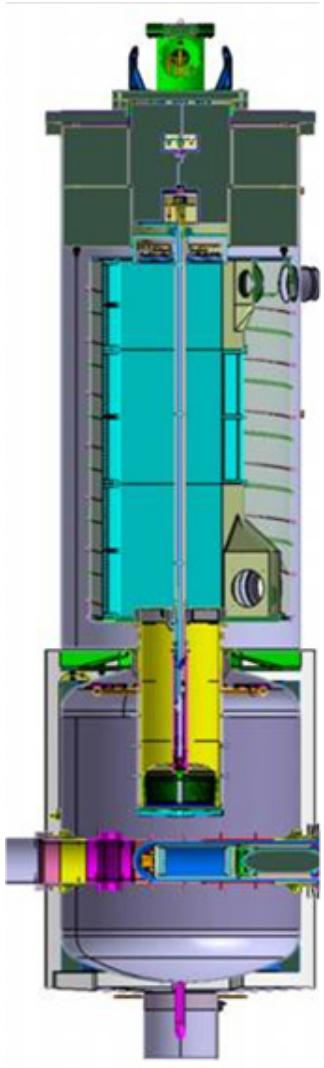
Timeline

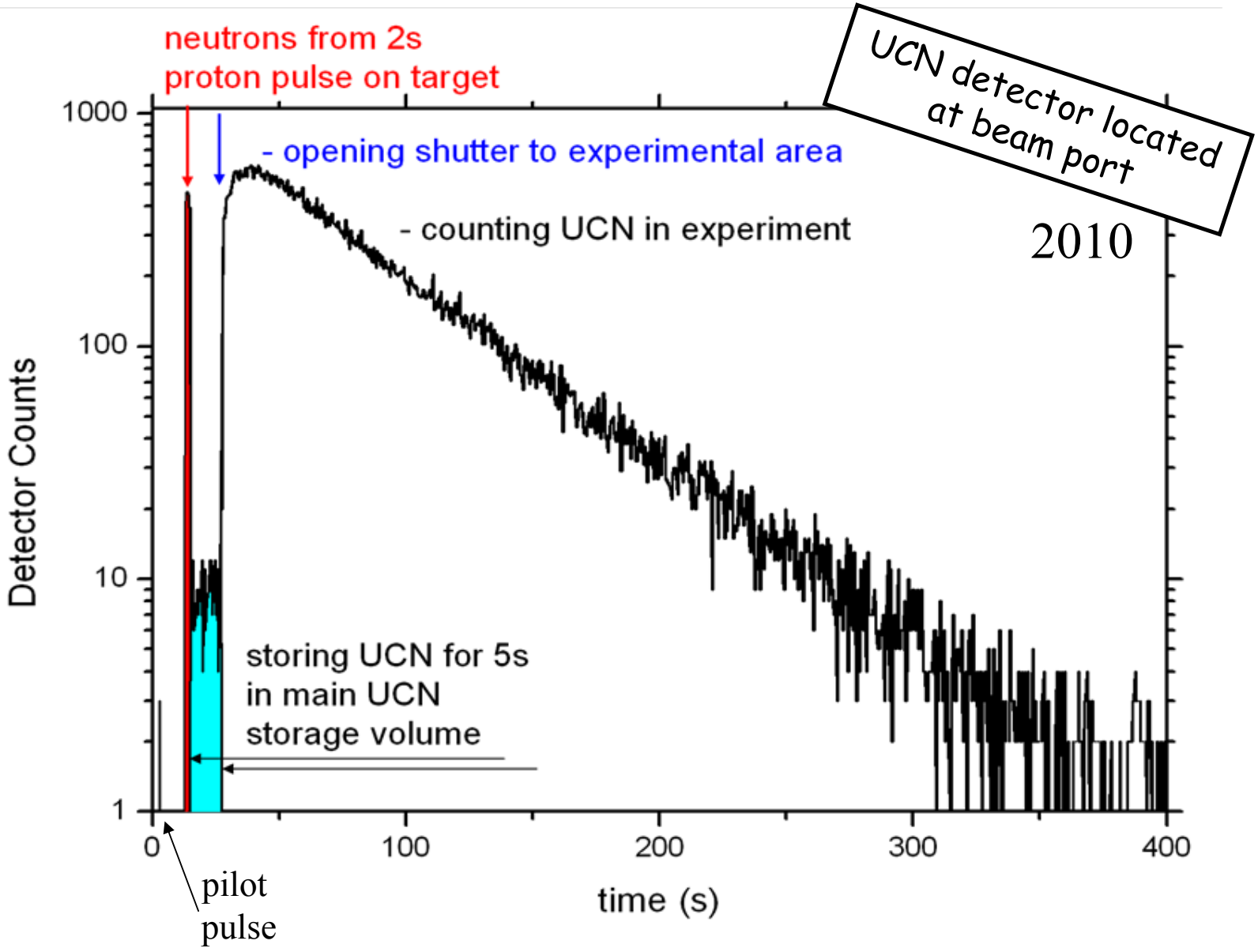
- Construction and commissioning of the source was completed in 2010

- Federal authorities` operation approval obtained in June 2011

- Start-up with first beam August 3, 2011

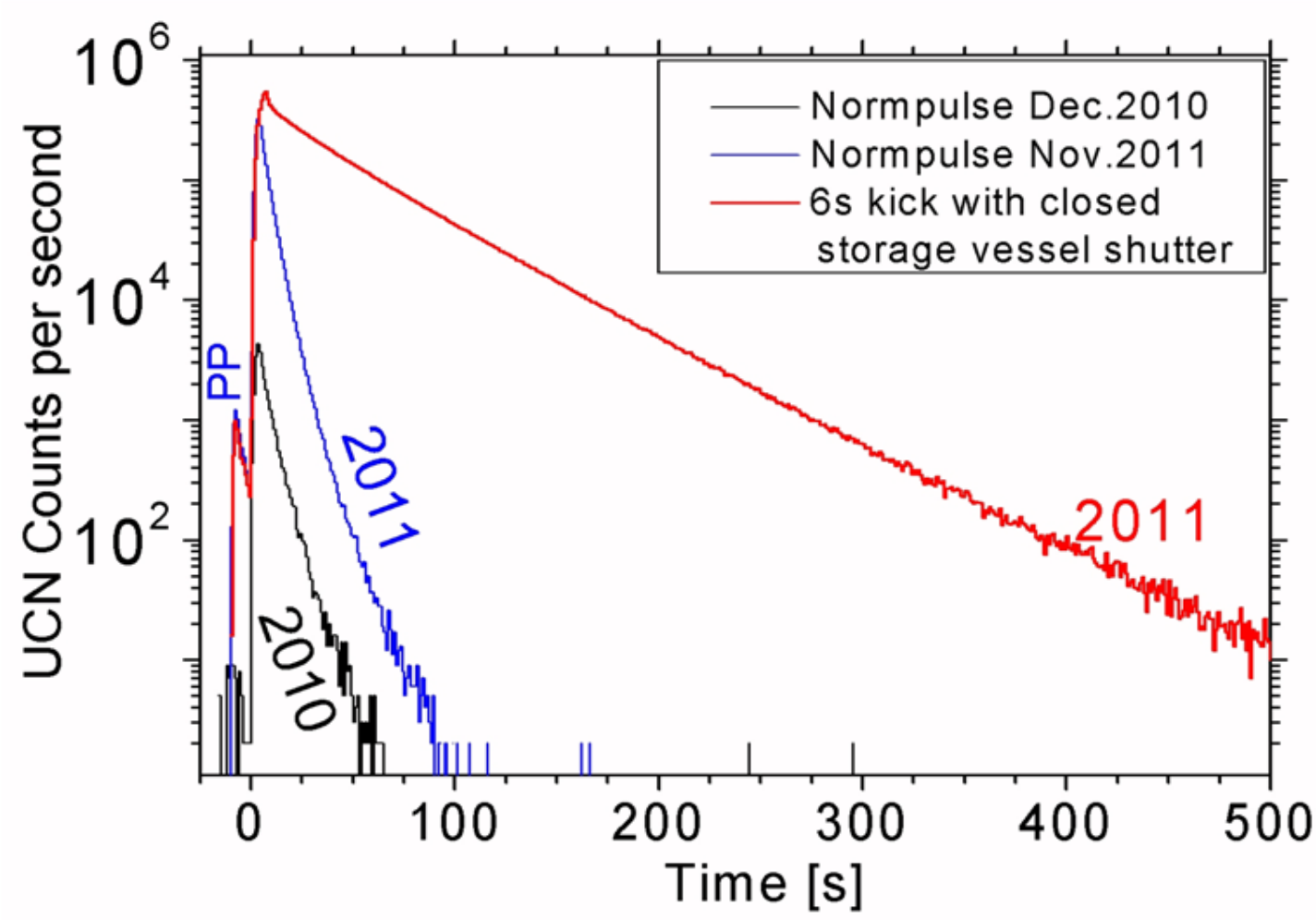
Characteristics of UCN measurement





Continuous performance improvements

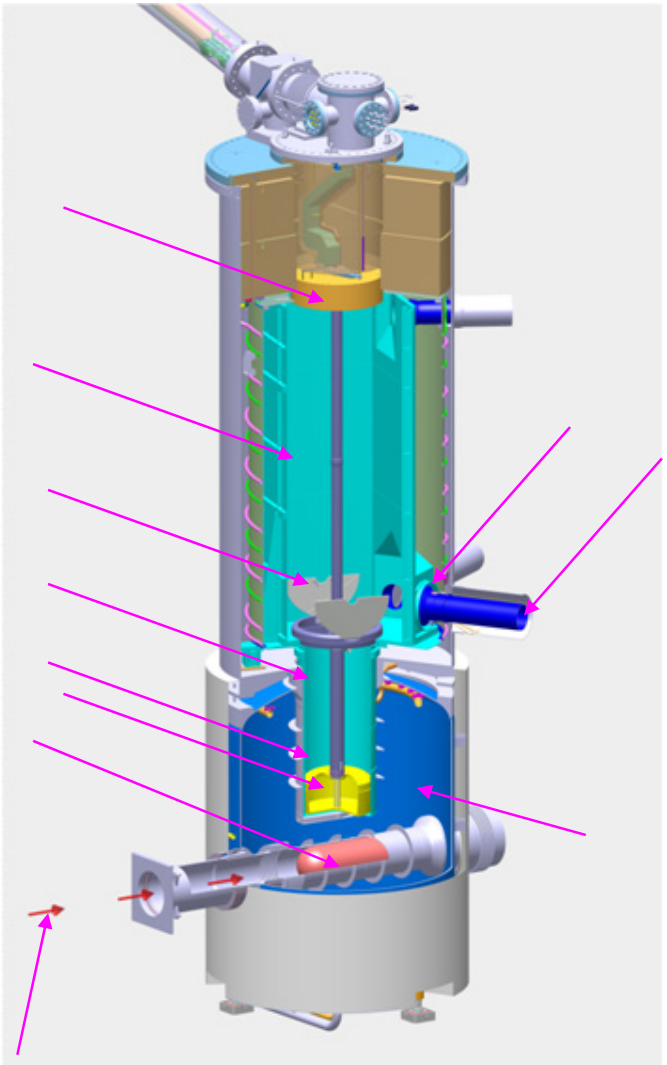
factor 67 (2010 → 2011)



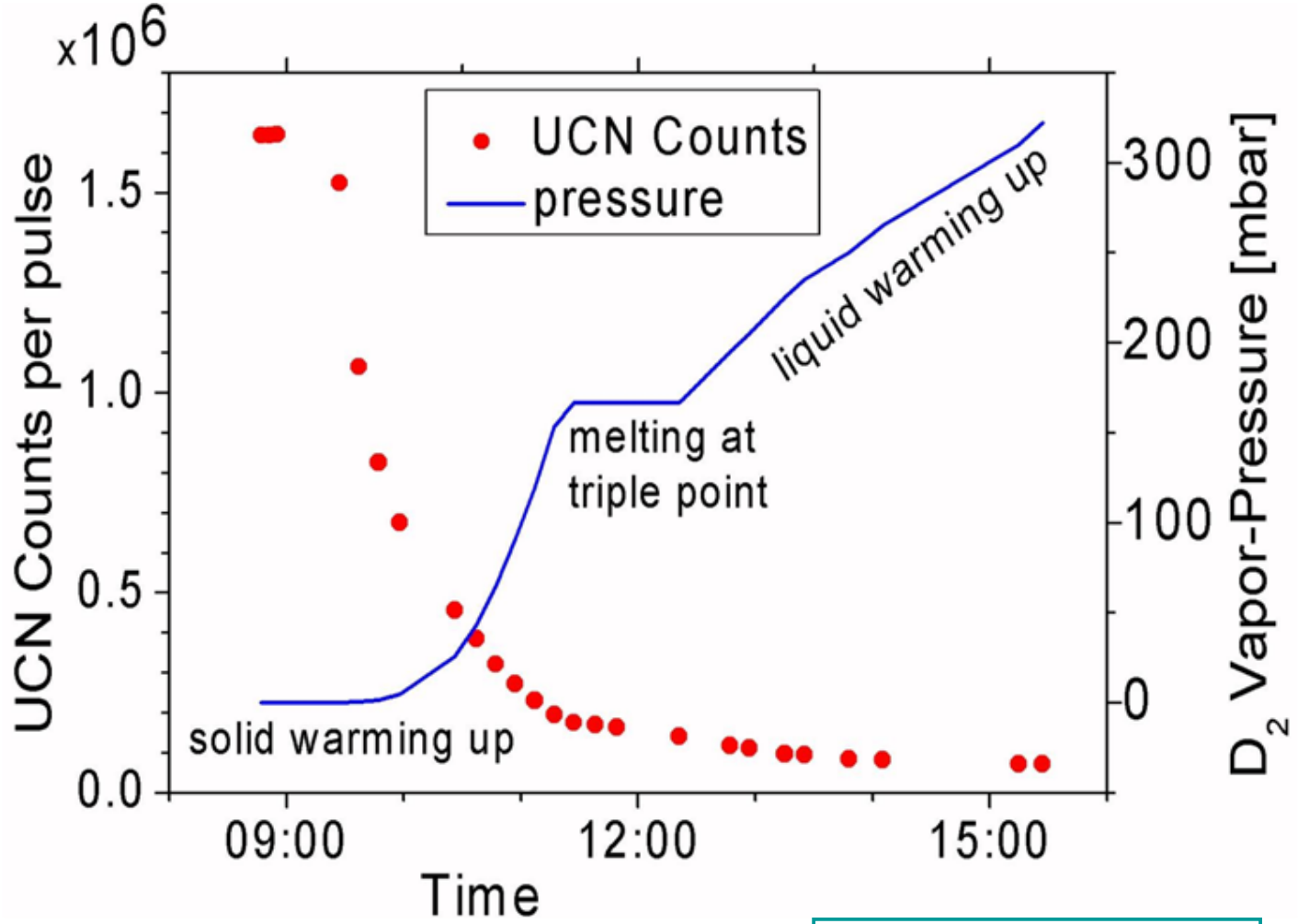
At the end of 2011 only a factor 30 left to reach the design intensity.

Many specific tests were done in order to check the performance of various components of the UCN source.

We now believe the crystal conditions were bad and resulted in the observed UCN yield of 2011.
We are working now on improving this.

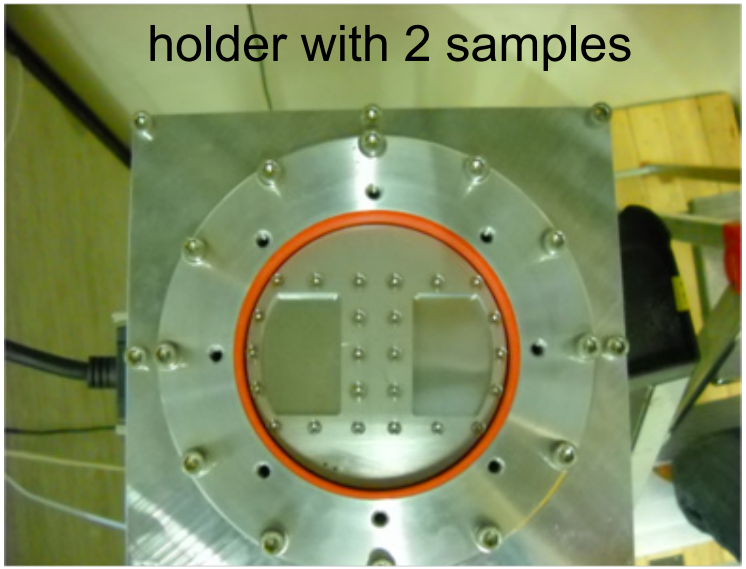


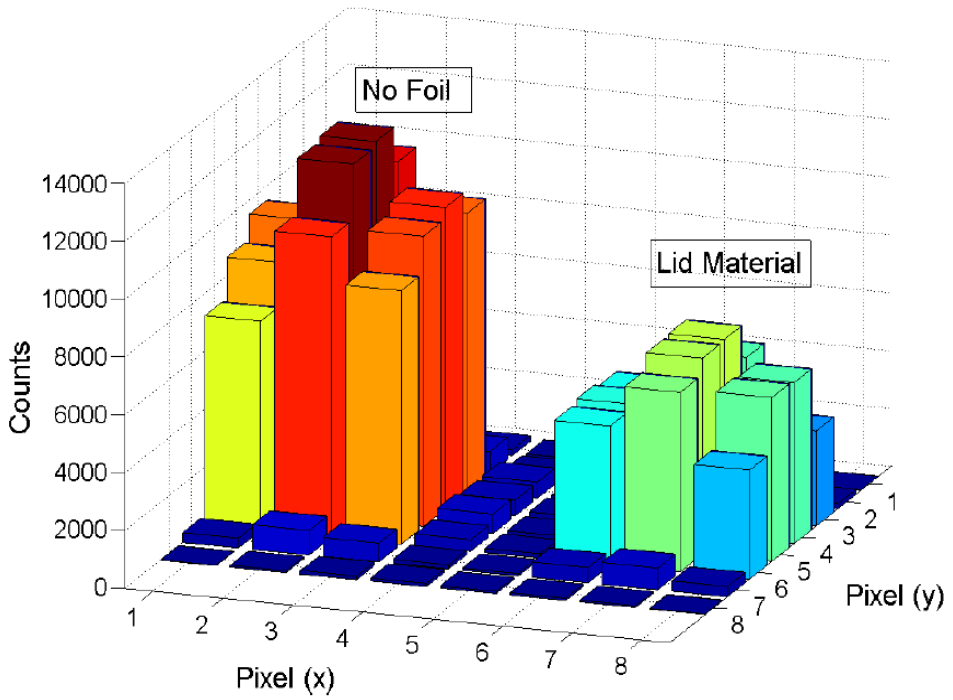
Deuterium Crystal Conditioning



too fast in 2011 !

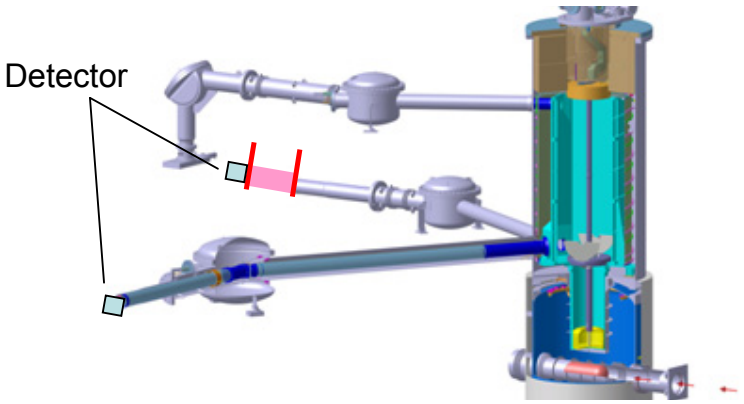
Check moderator lid UCN transmission with similar manufactured and treated lid available from burst pressure test



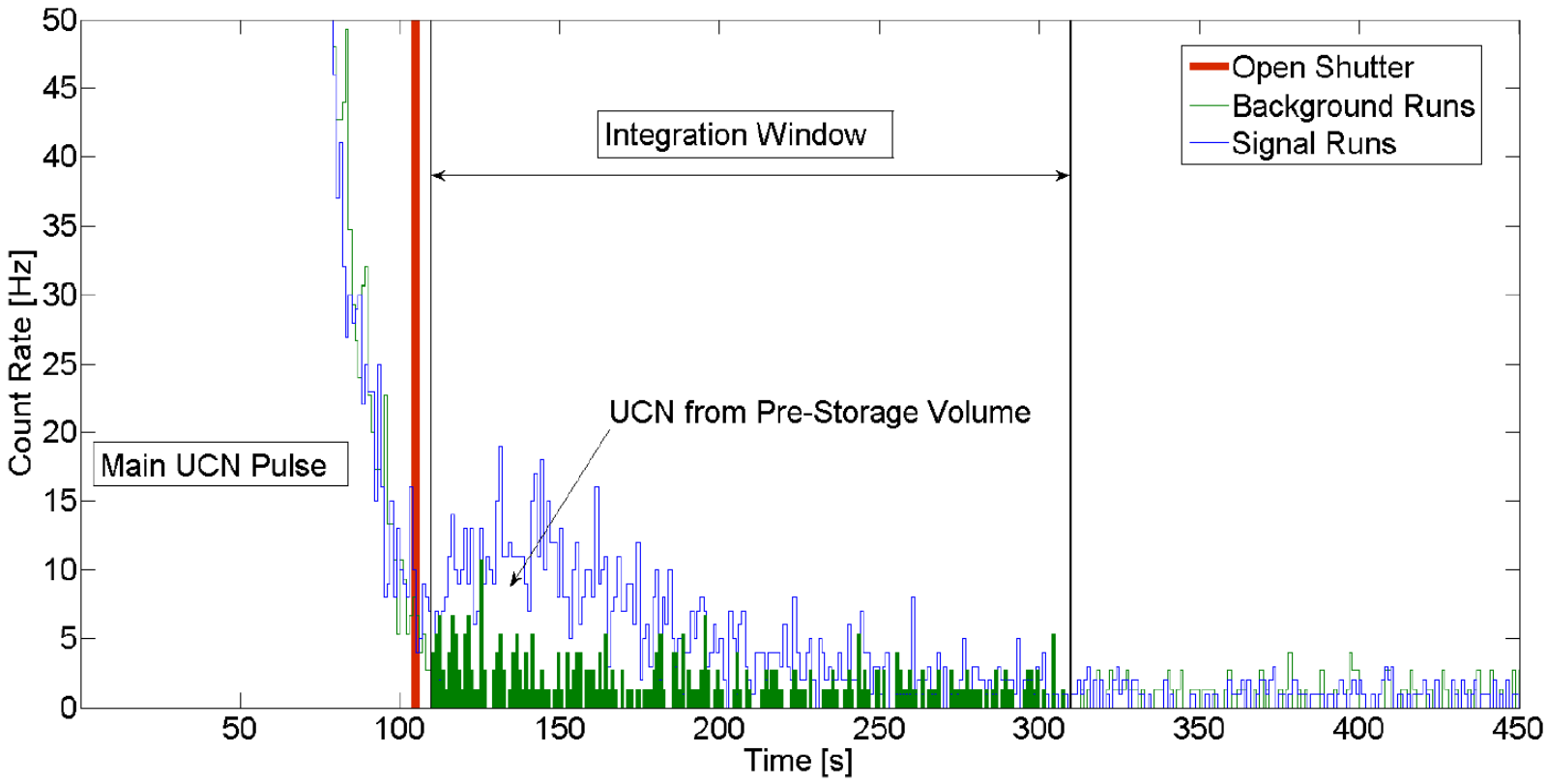


- use lid material from pressure test vessel
- 54% Transmission of 0.5mm thick AlMg3 as expected from previous measurements

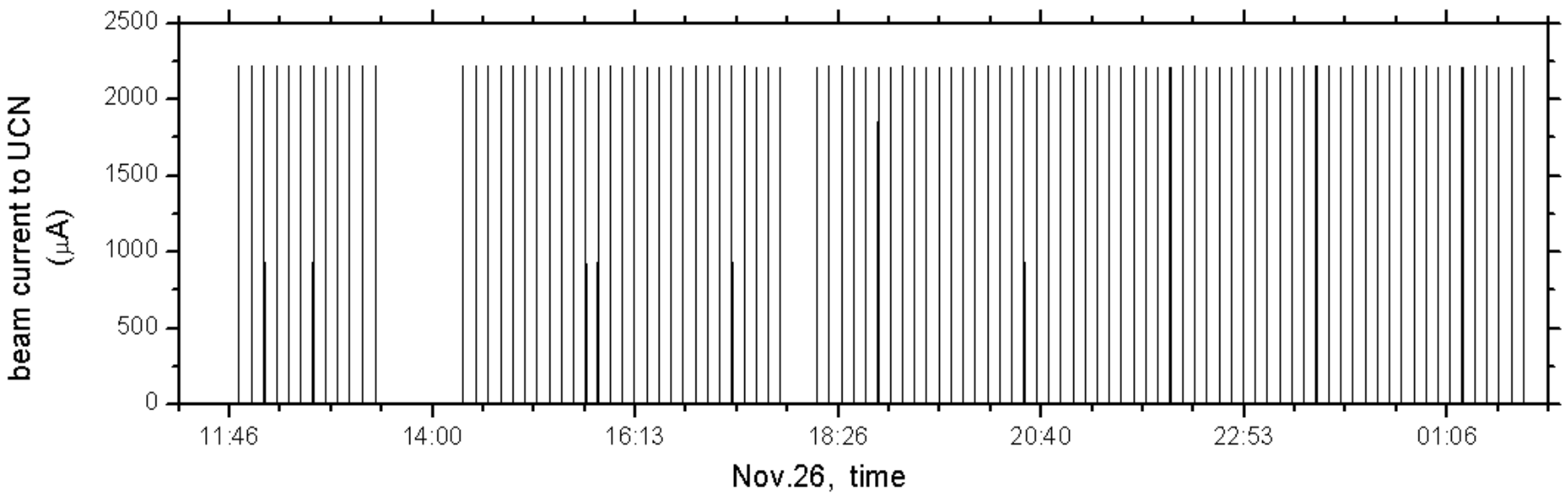
With UCN we can play Ping Pong to understand the properties of guides and storage vessel



example of a test experiment one can only do with UCN



Regular fully automated beam delivery to nEDM over many days without problems



Summary

- All components of the UCN source are commissioned and operating.

- We are presently learning to operate the entire cryo-system for precise temperature control of the D2-crystal growing process. Achieved already results in stabilization on the sub-Kelvin level at various growing stages
- as of today the D2 is liquid and slowly freezing

- Optimization of all source parameters is under way.

- PSI UCN source will have regular beam operation.

- nEDM will start data taking with neutrons soon.

- UCN facility is open for experiment proposals.

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at low energies and the precision frontier

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- 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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