The new Ultracold Neutron Source at PSI: status and first results from commissioning

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presentation at the

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Overview

- Design concept of the UCN source
- Status of essential components
  - Proton beam
  - Spallation target
  - UCN tank system
  - Heavy water system
  - Deuterium moderation system
  - UCN storage volume
  - Neutron guides
- Summary and Outlook

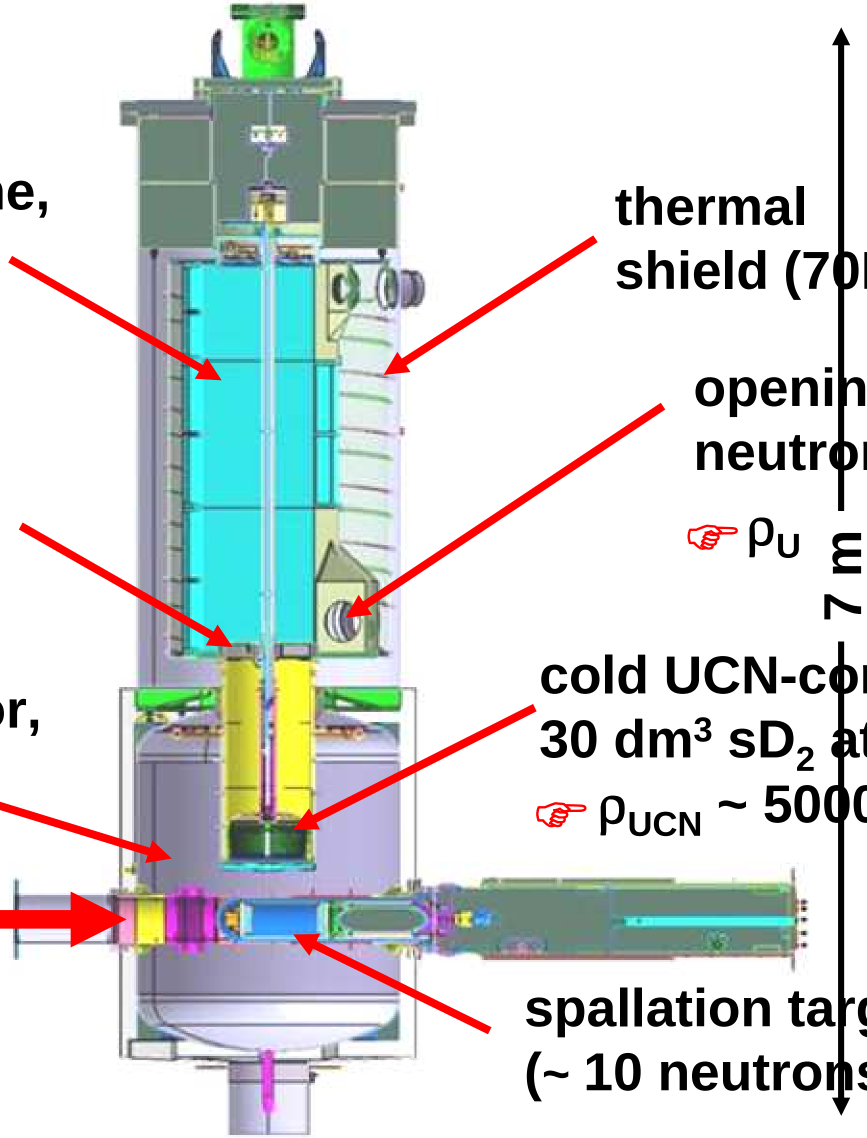
UCN-Source

UCN storage volume,
height 2.5 m, 2 m^3
☞ ρ_{UCN} ~ 2000 cm^{-3}

UCN shutter

heavy water moderator,
thermal neutrons

pulsed
1.3 MW p-beam
600 MeV, 2.2 mA,
1% duty cycle



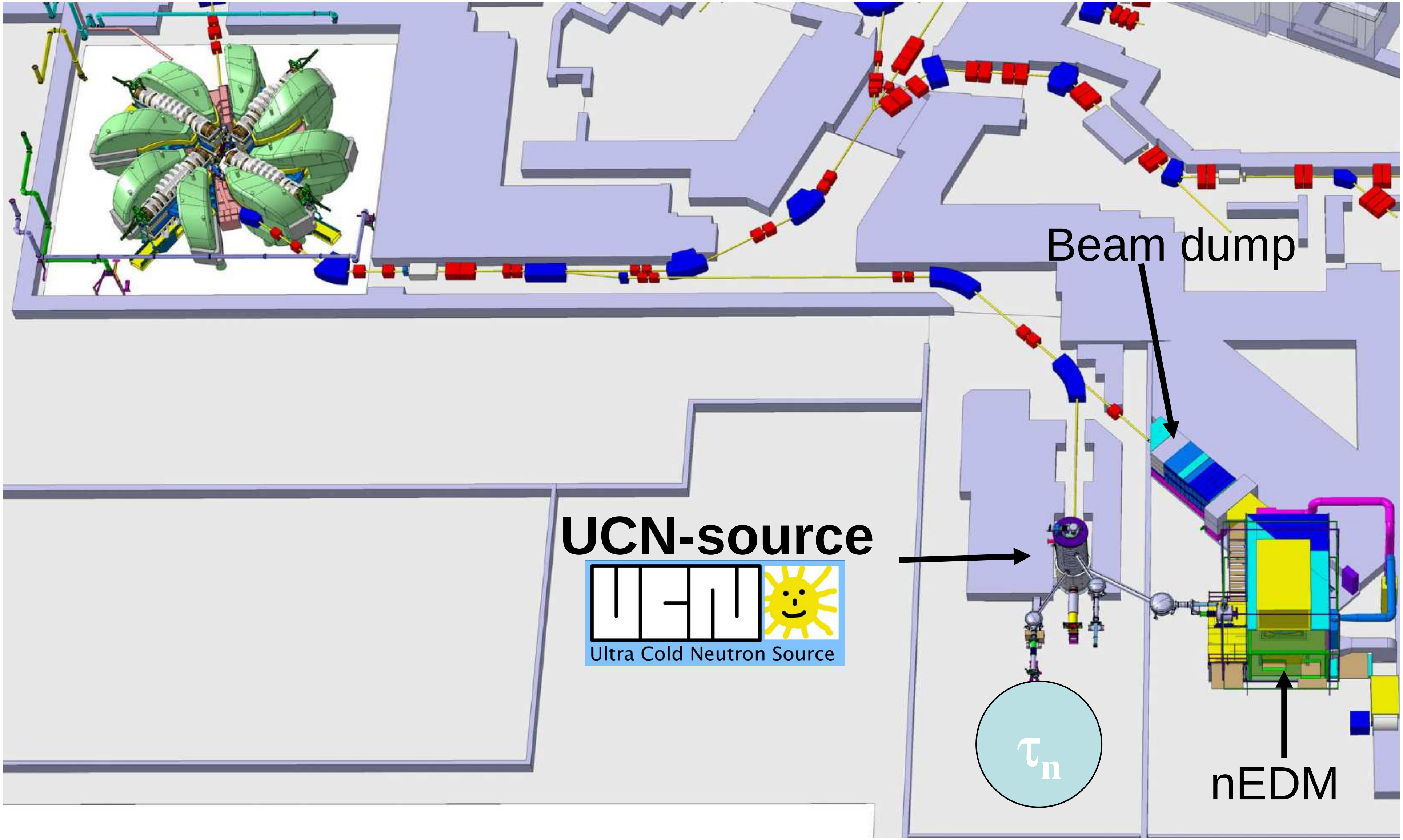
thermal
shield (70K)

opening for
neutron guide
☞ ρ_{UCN} ~ 1000 cm^{-3}

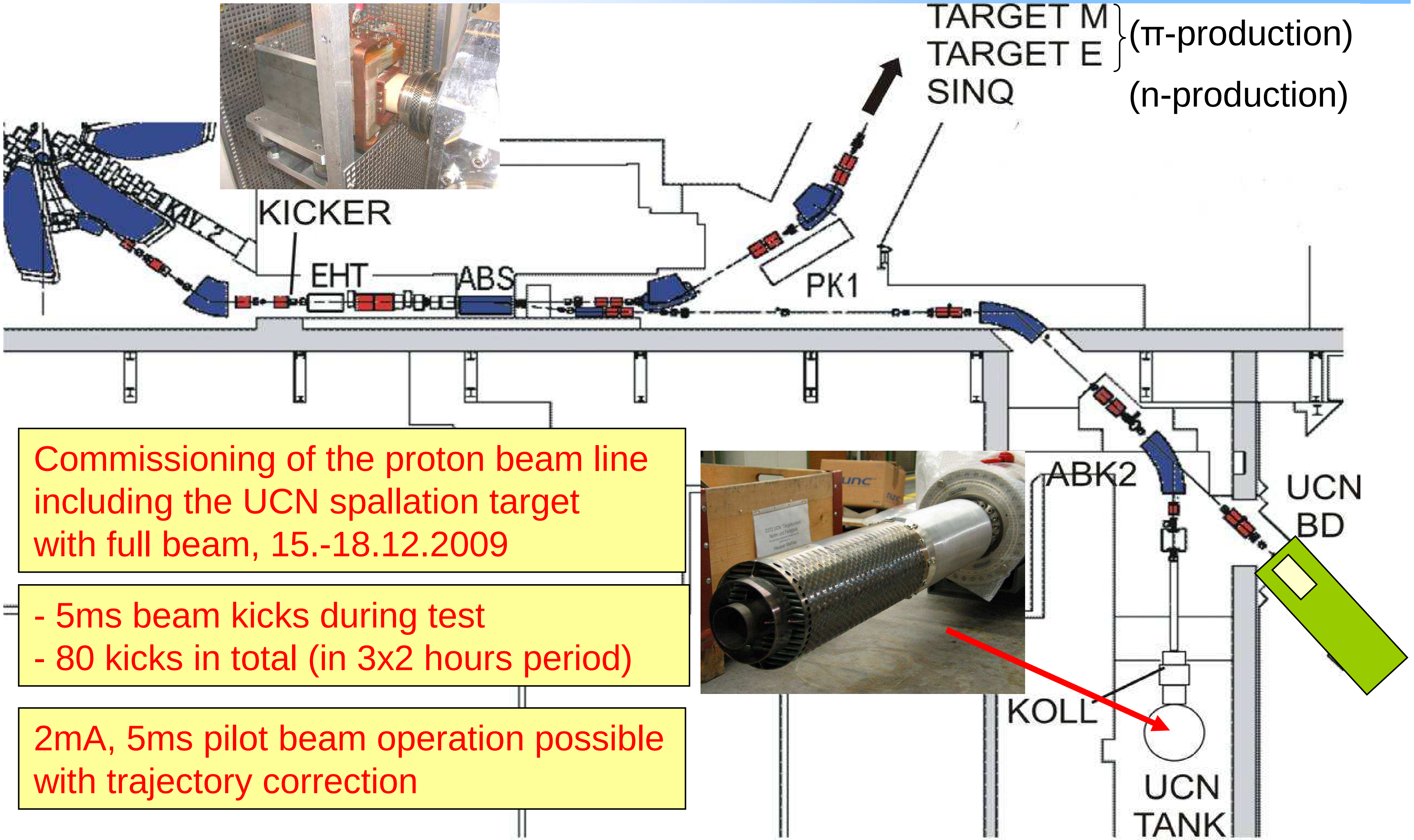
cold UCN-converter
30 dm^3 sD_2 at 5 K
☞ ρ_{UCN} ~ 5000 cm^{-3}

spallation target (Pb/Zr)
(~ 10 neutrons per proton)

Proton accelerator & UCN Source



Proton Beam Line Commissioned

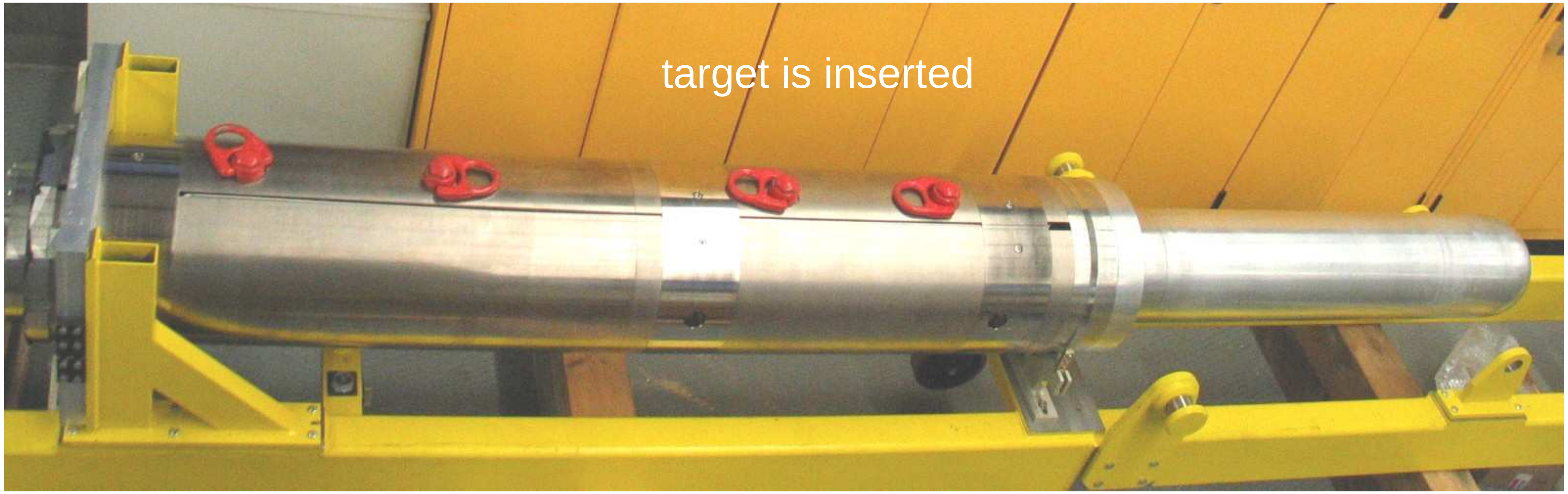


Commissioning of the proton beam line including the UCN spallation target with full beam, 15.-18.12.2009

- 5ms beam kicks during test
- 80 kicks in total (in 3x2 hours period)

2mA, 5ms pilot beam operation possible with trajectory correction

Pb/Zr Spallation Target



UCN Tank

delivery of tank:
Sept. 04, 2008

February
2009

UCN Tank Installations

June 2009

December 2009

Heavy Water System

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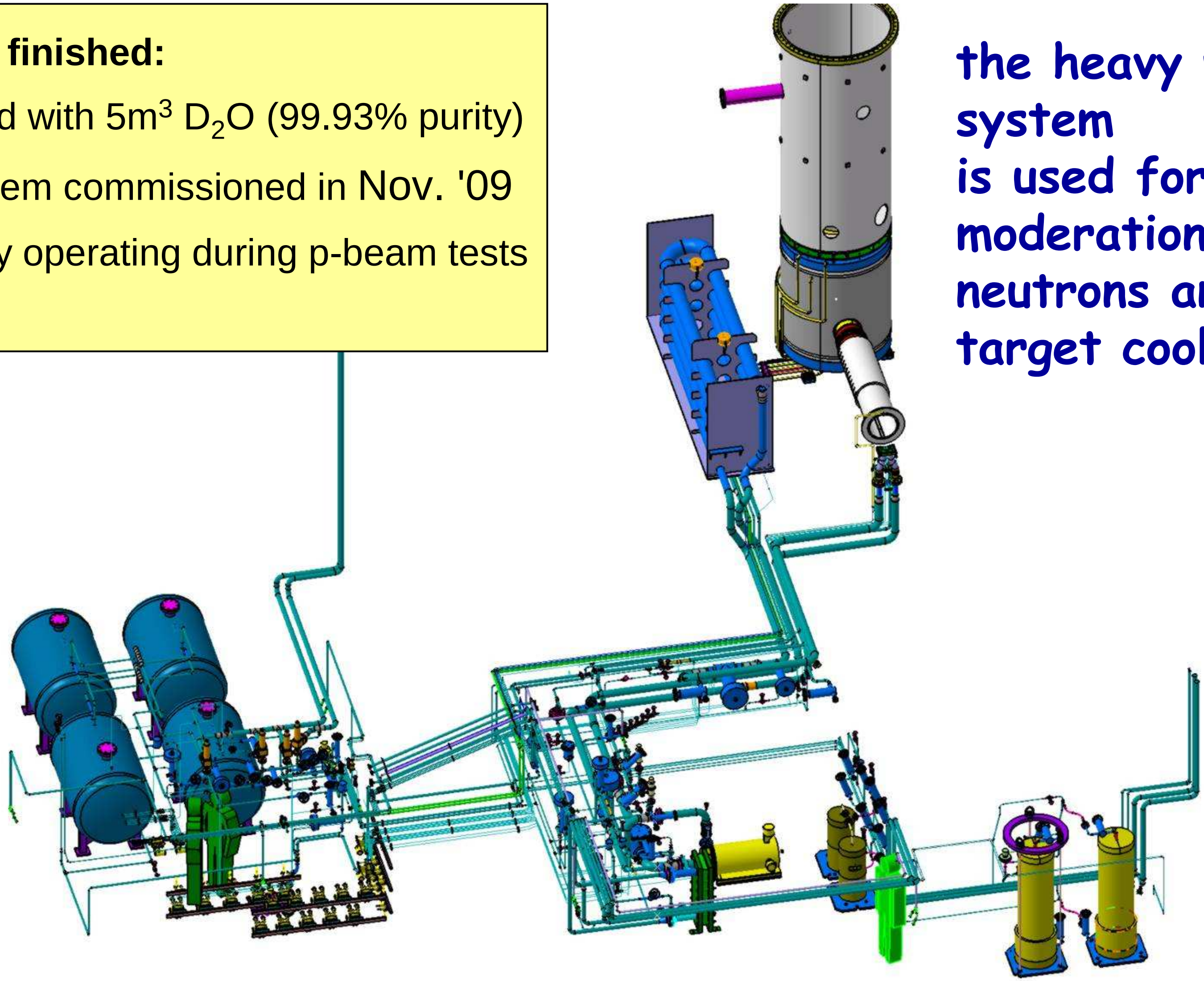
D_2O system finished:

- system filled with $5m^3$ D_2O (99.93% purity)
- control system commissioned in Nov. '09
- successfully operating during p-beam tests in Dec. '09



the heavy water system is used for moderation of fast neutrons and target cooling

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D_2O Cooling Plant

Ultra Cold Neutron Source

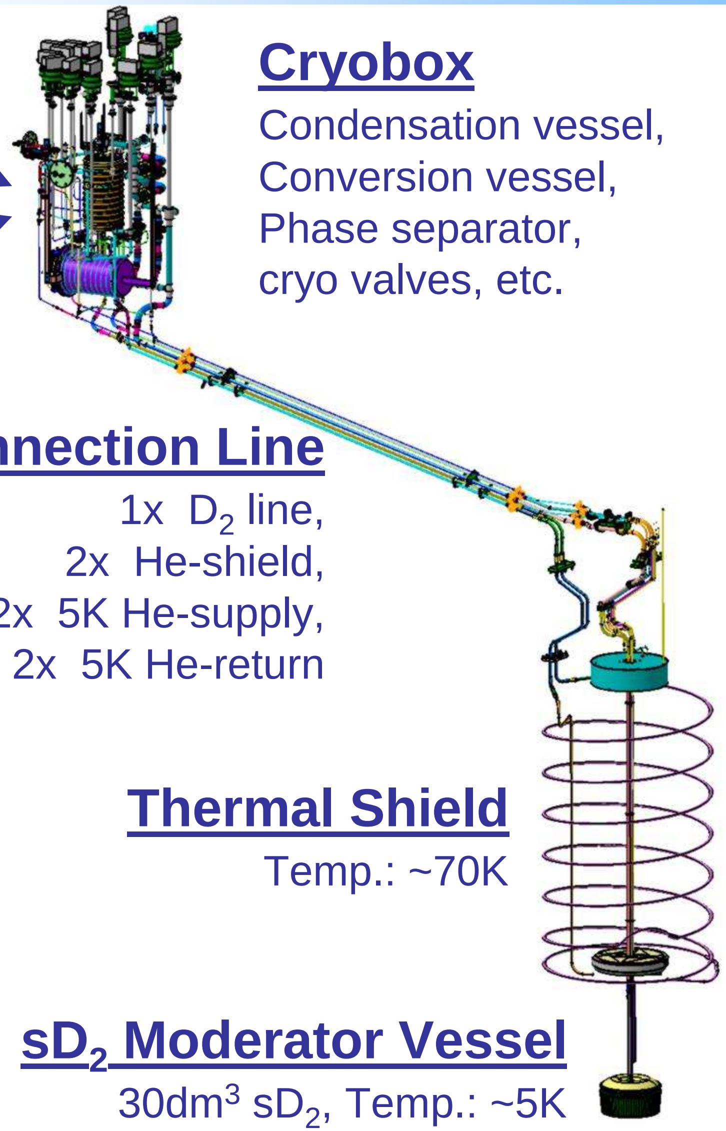
heavy water pump (25 *l*/s)

heat exchanger

He and D_2 Cryogenic System

Helium-Refrigerator

D_2 buffer tanks
$30m^3$, 1bar



Cryobox

Condensation vessel,
Conversion vessel,
Phase separator,
cryo valves, etc.

Cryogenic Connection Line

1x D_2 line,
2x He-shield,
2x 5K He-supply,
2x 5K He-return

Cryopump

Temp.: ~5K

Thermal Shield

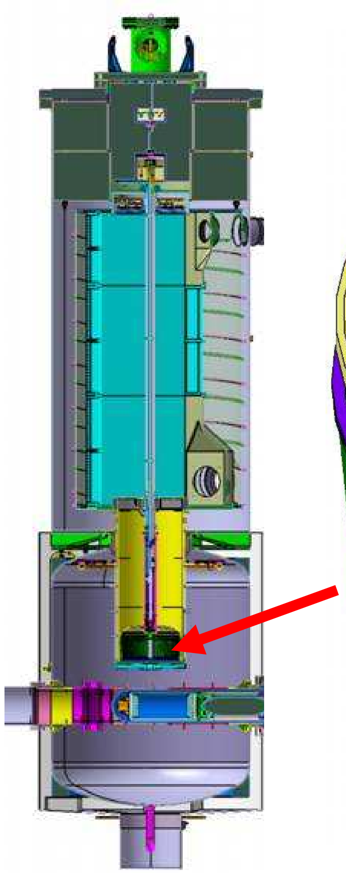
Temp.: ~70K

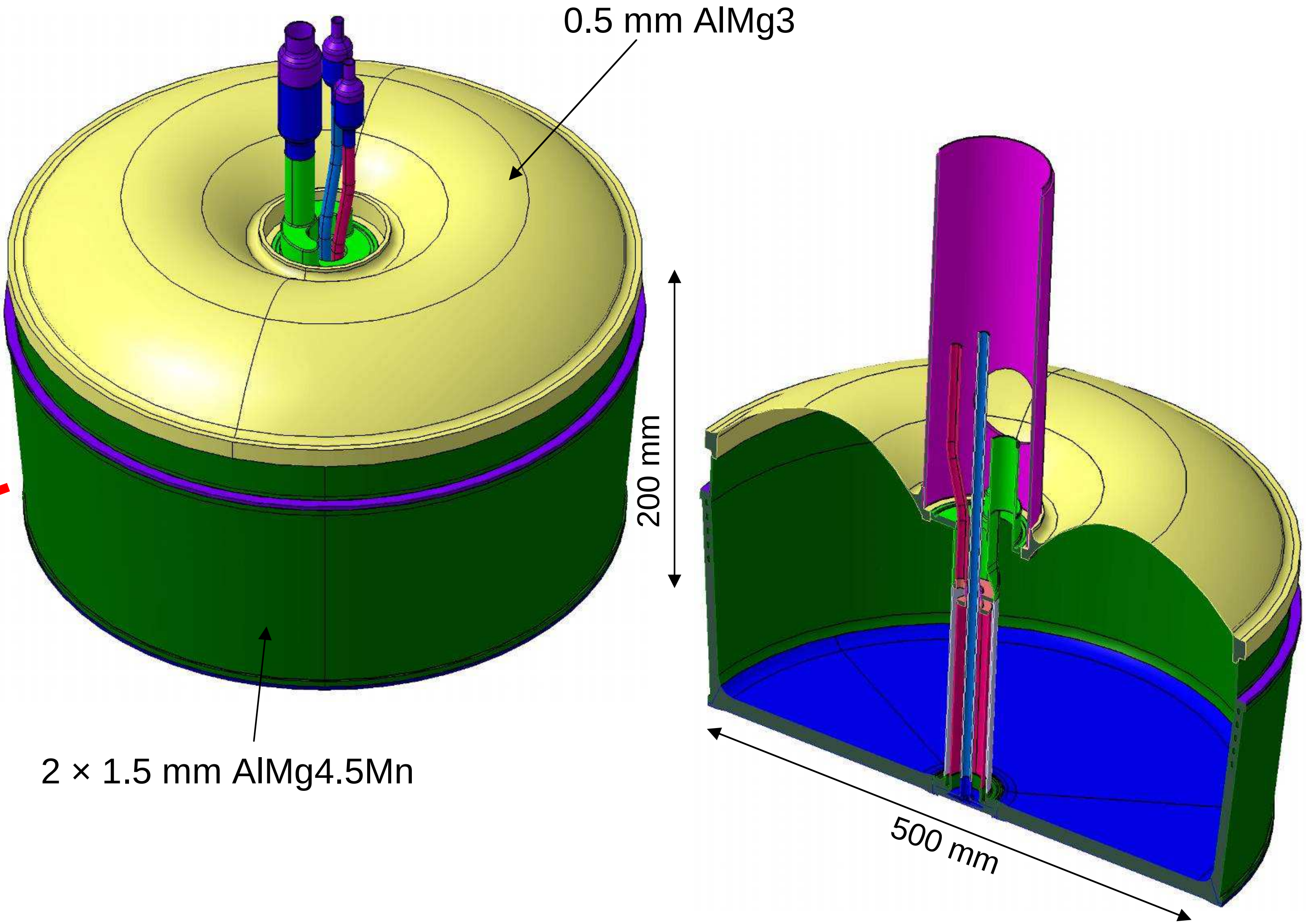
sD_2 Moderator Vessel

$30dm^3$ sD_2, Temp.: ~5K

He-refrigerator cooling power:
370W @4.2K and
2500W @ 80K

sD_2-Moderator Vessel





Production of Moderator Vessel

calotte: 0.5 ± 0.05 mm wall thickness

milled from <u>one</u> AlMg3 piece

bottom part (NiMo coated) with central channels for Helium and D_2

<u>no</u> plastic deformation for inside pressures between -1 ... +3 bar !!

Details of sD2-Moderator Vessel

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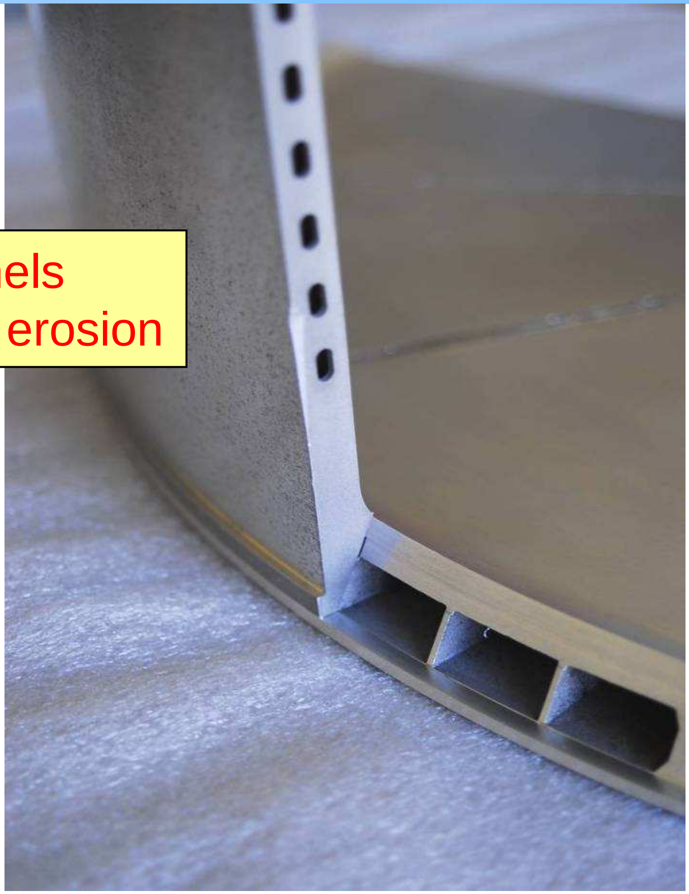
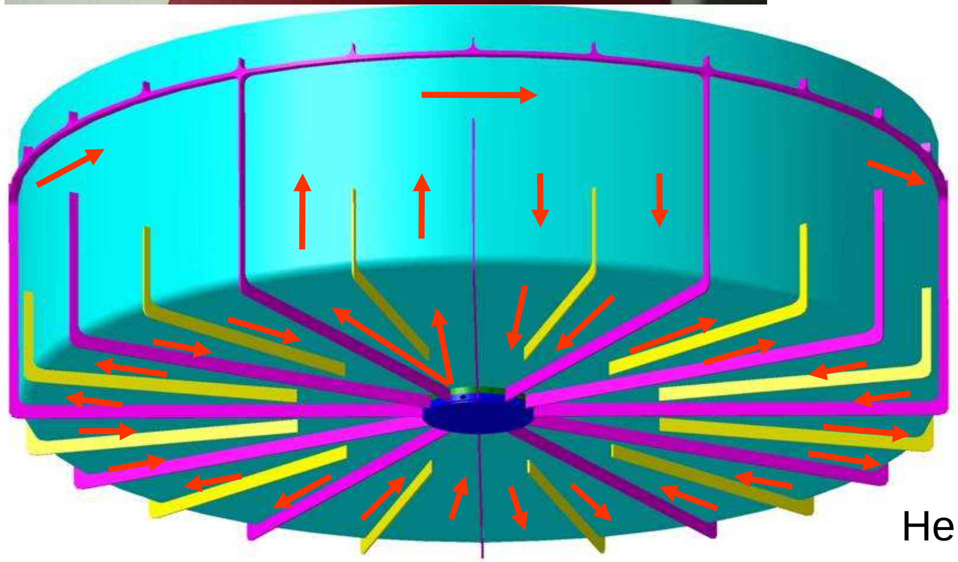
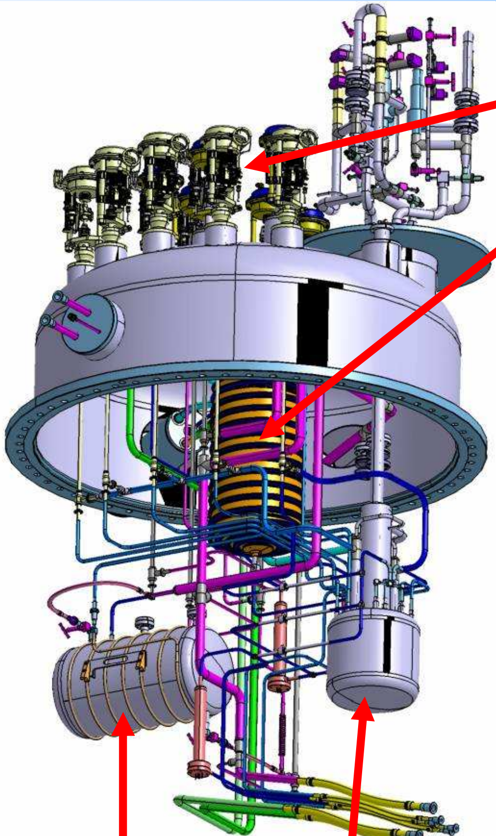
all parts
EB welded

cooling channels
made by wire erosion



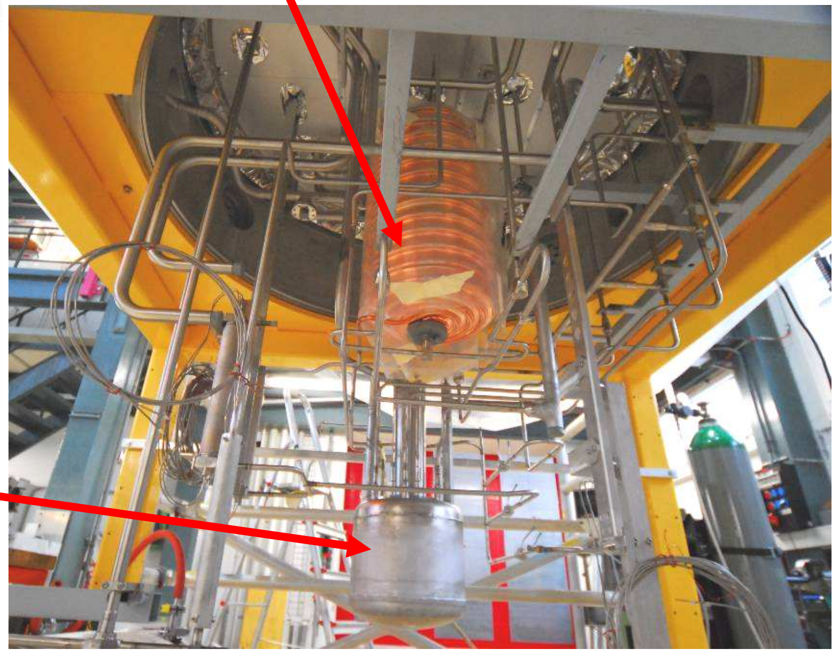


Helium-flow direction



cryovalves

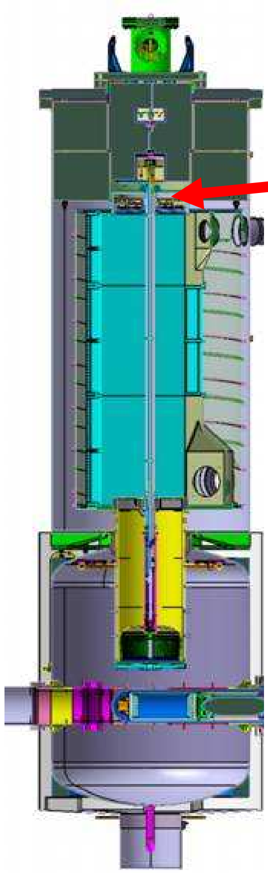
condensation vessel

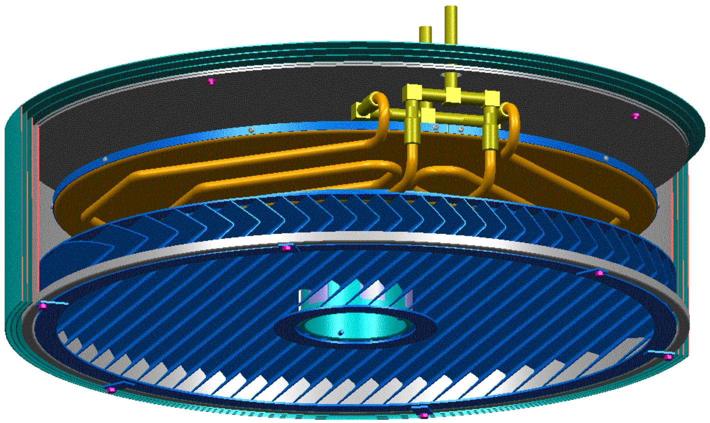


Helium phase separator

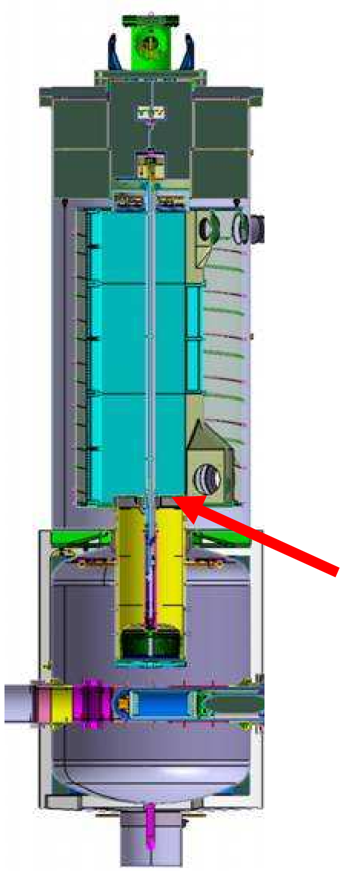
para-ortho conversion vessel

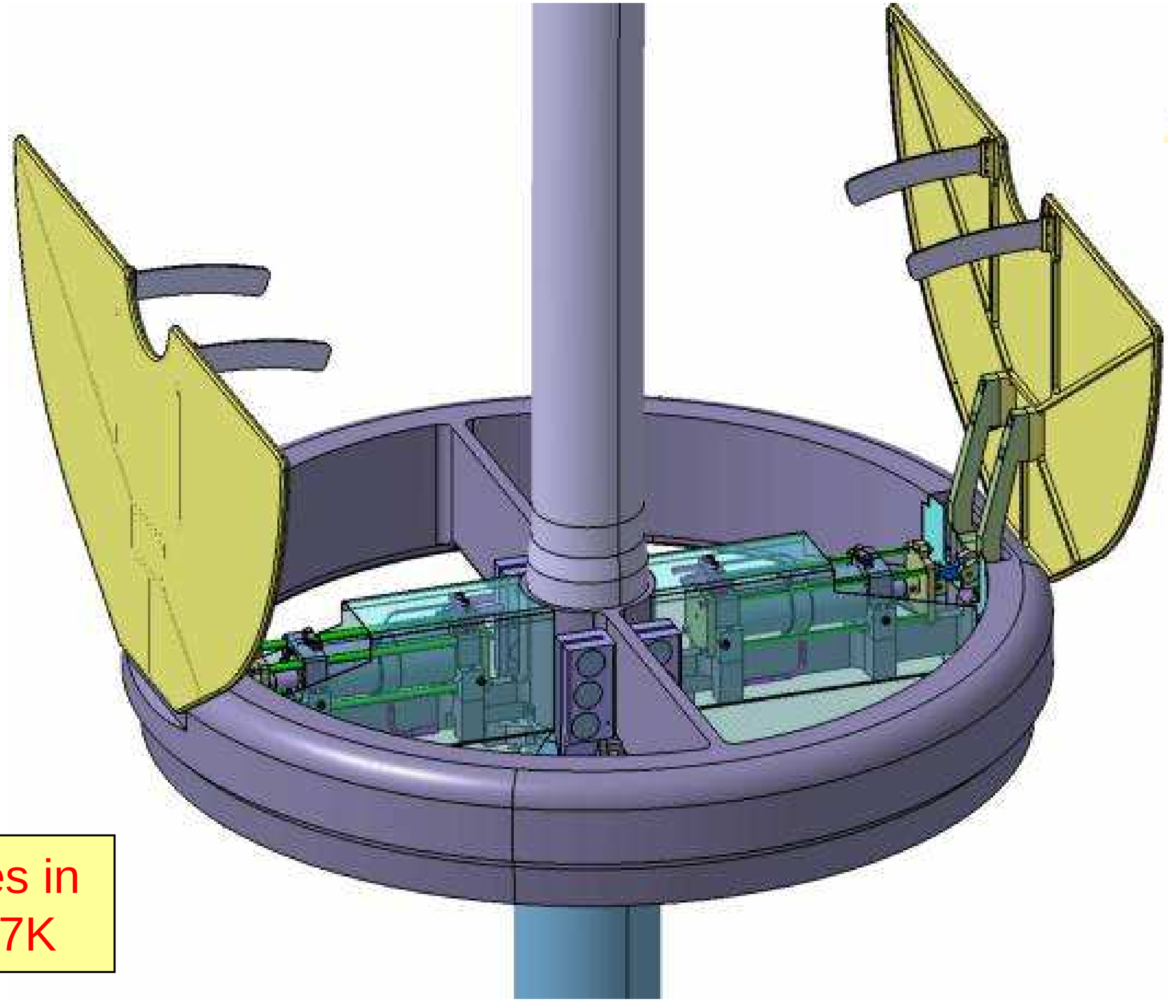
Cryopump





UCN Shutter





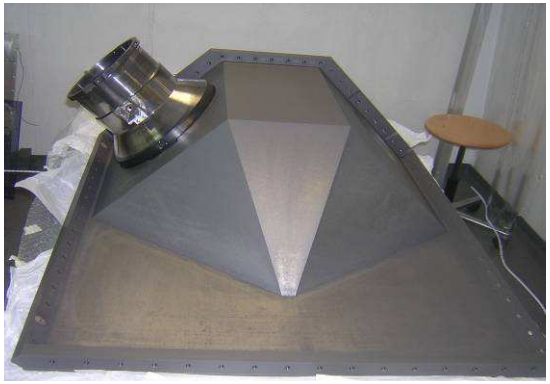
500'000 cycles in vacuum at 77K

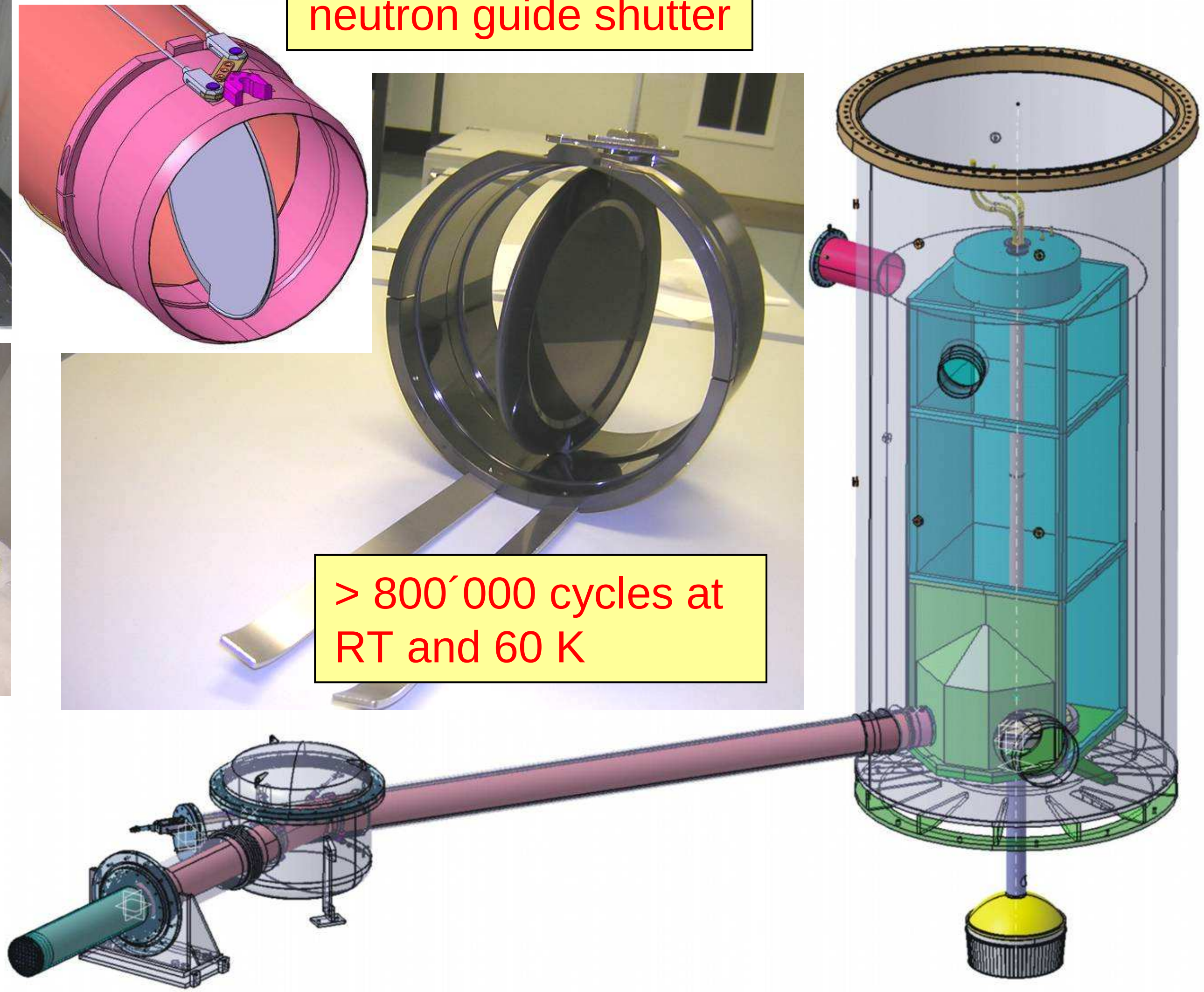
D_2 Gas management System

30 m^3
D_2 gas buffer

valve boxes and D_2 gas management system

Storage Volume and Shutters



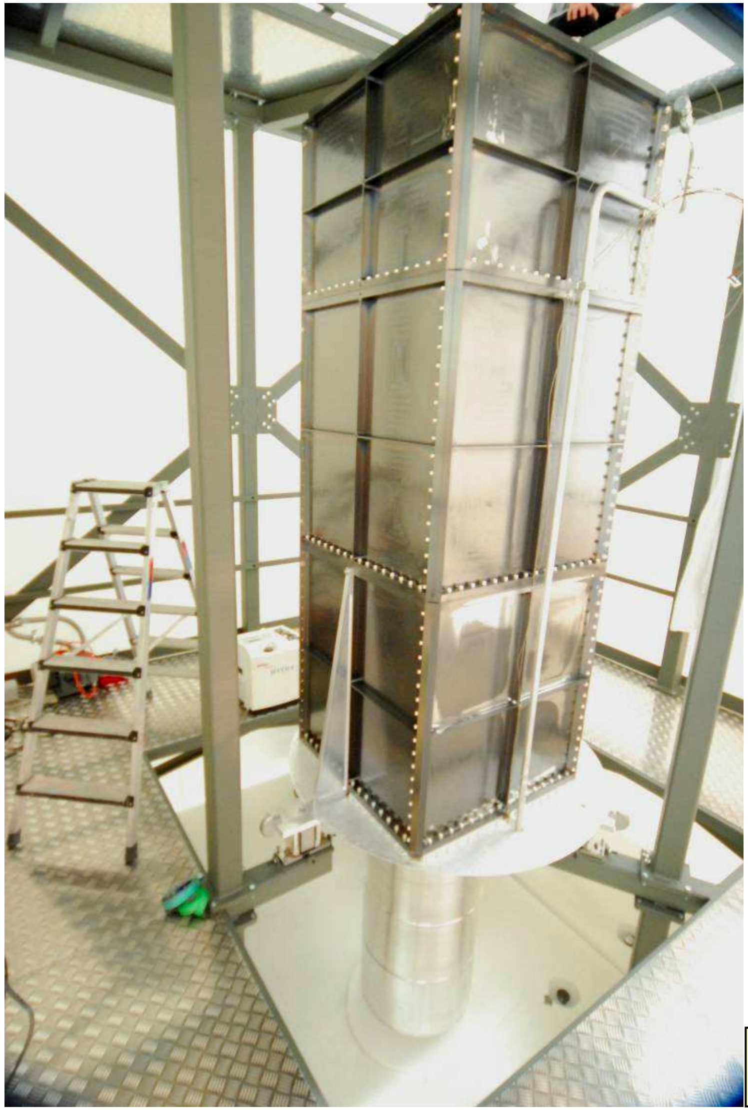


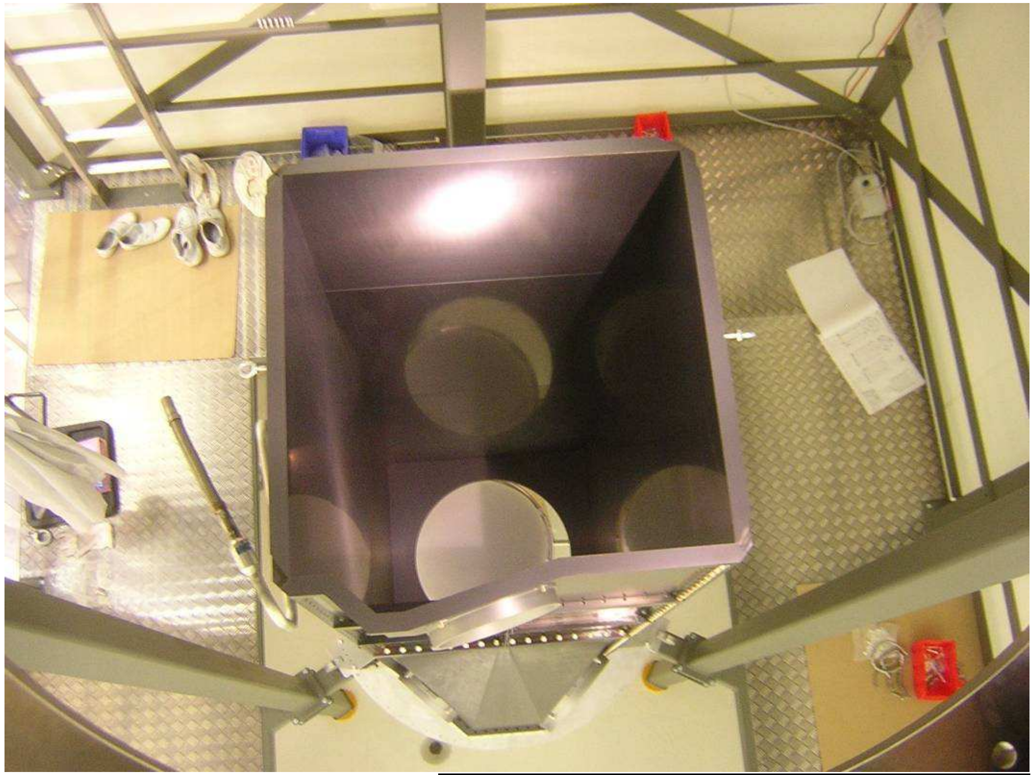
neutron guide shutter

> 800´000 cycles at
RT and 60 K

storage volume:
500nm DLC coated

Mounting of Storage Volume



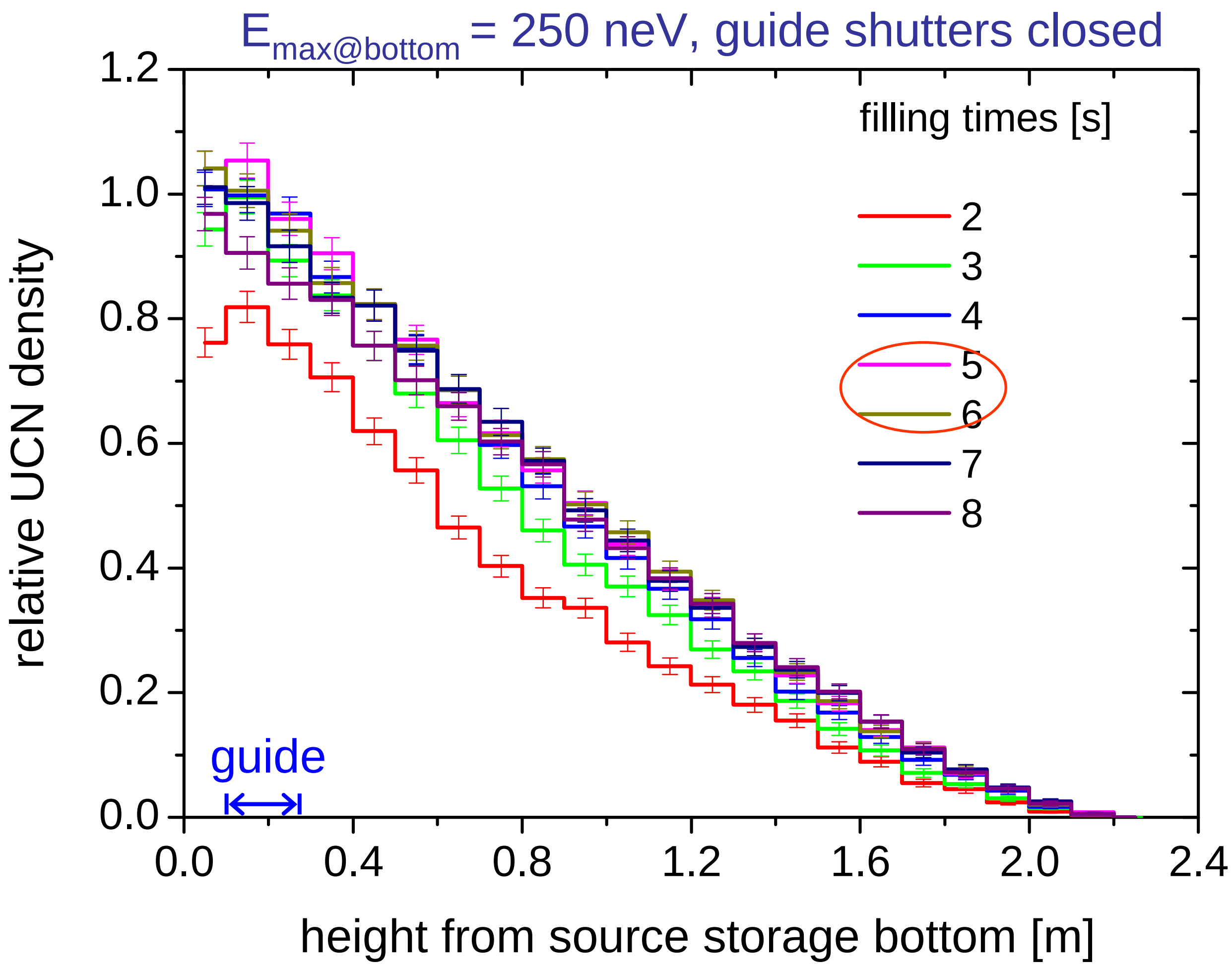


view into storage volume

storage volume in mounting rack (7m)

Source storage volume: Filling

- UCN density profile as function of **source filling time** – snapshots



(by G. Zsigmond)

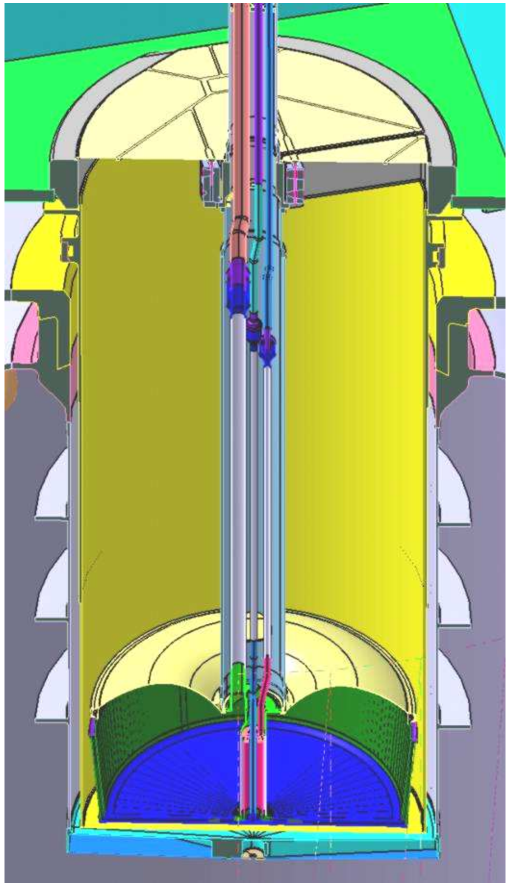
Vertical Neutron Guide

made from ultrapure aluminum

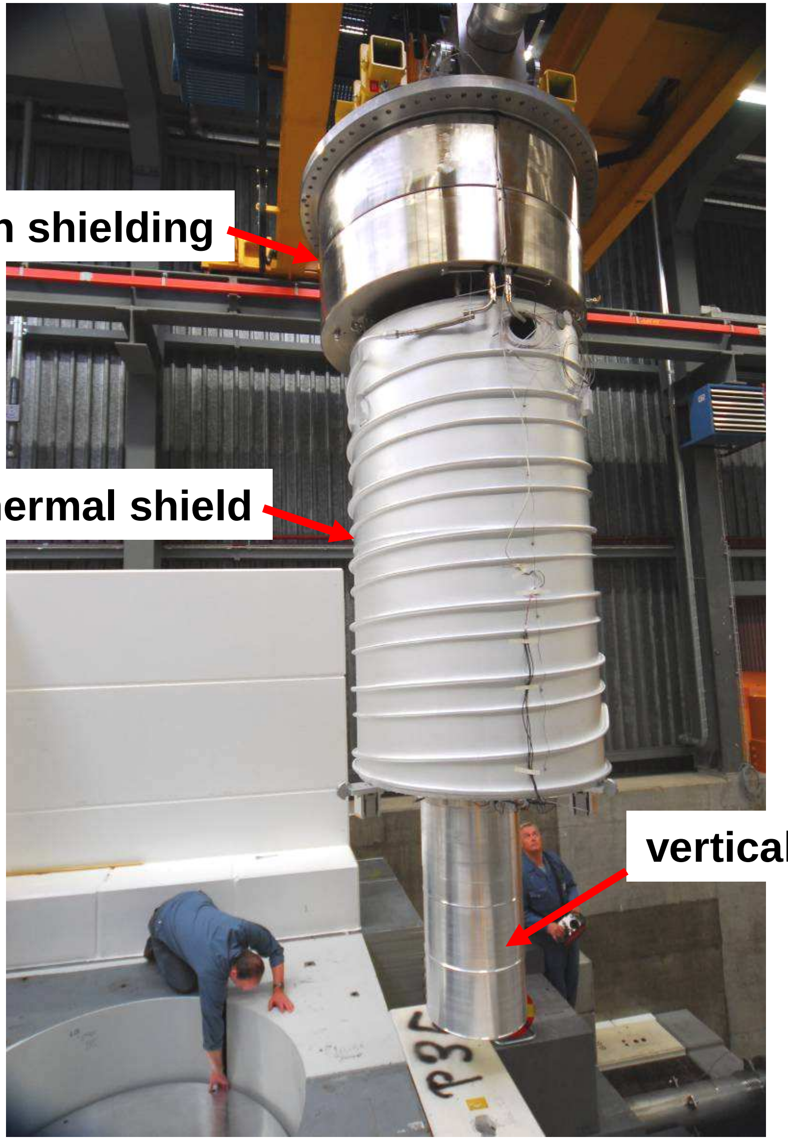
inner surface milled on a vibration-damped diamond mill
roughness: < 50nm

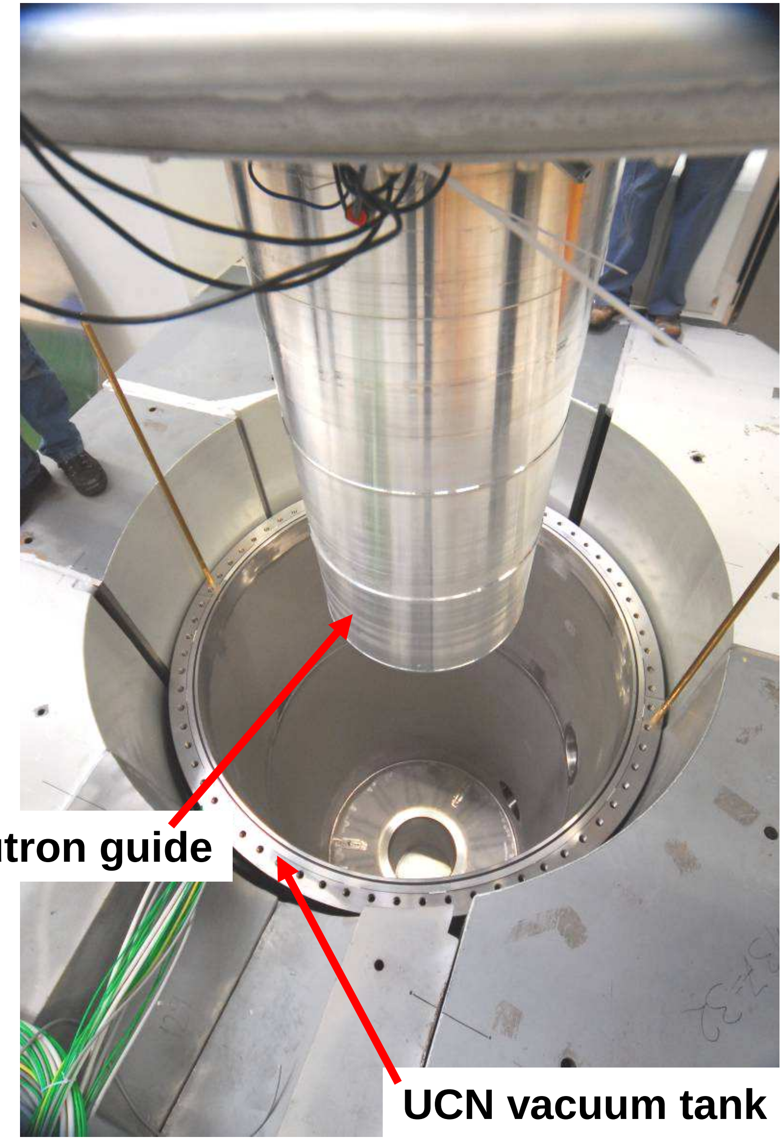
inner surface coated with 500 nm NiMo (85/15)

reflectometry measurement of inner surface:
$V_{Fermi} = 223 \pm 10$ neV



Test Installation of Storage Volume





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UCN Guides

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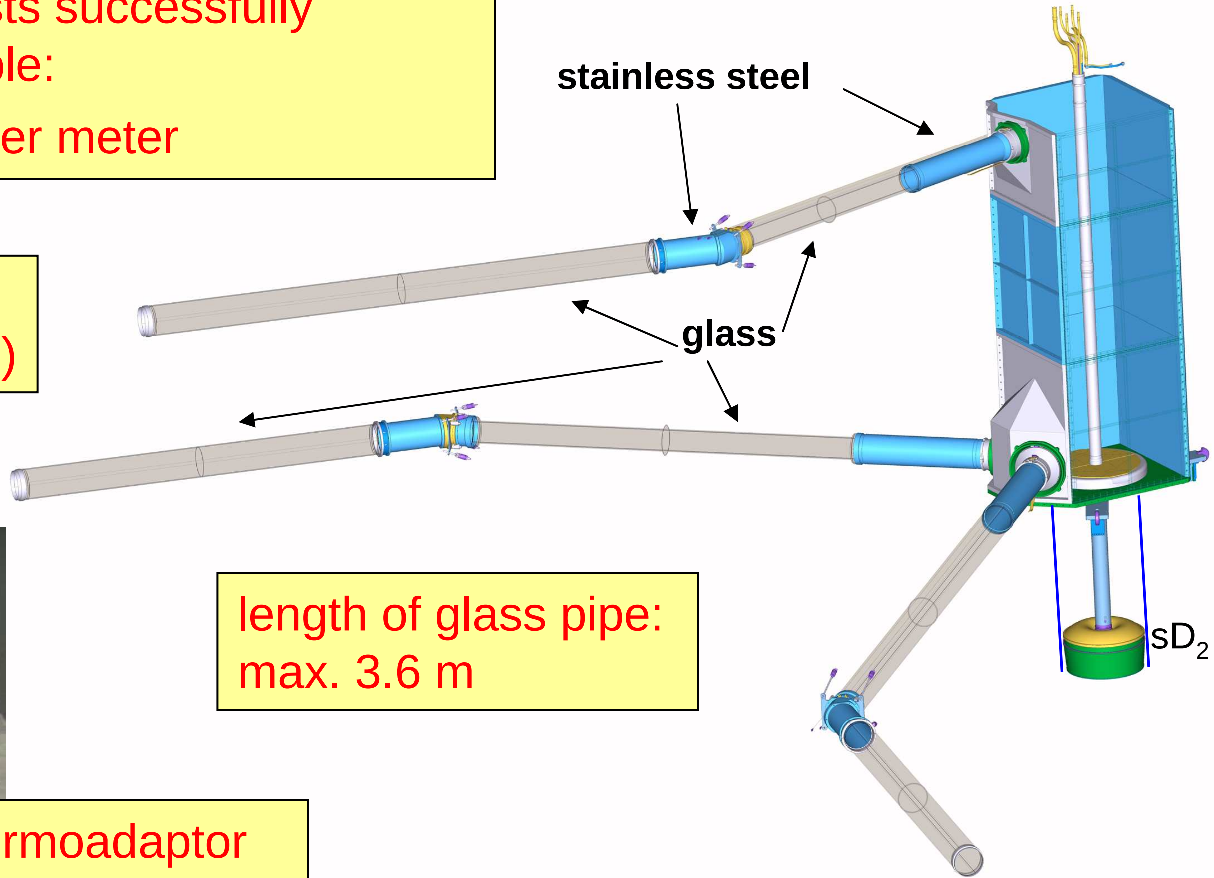
most UCN guides are made of borosilicate glass, Ø = 18cm, transmission tests successfully carried out at ILL in Grenoble:

98% transmission per meter

NiMo coating: ~ 500 nm
roughness: < 1 nm (glass)

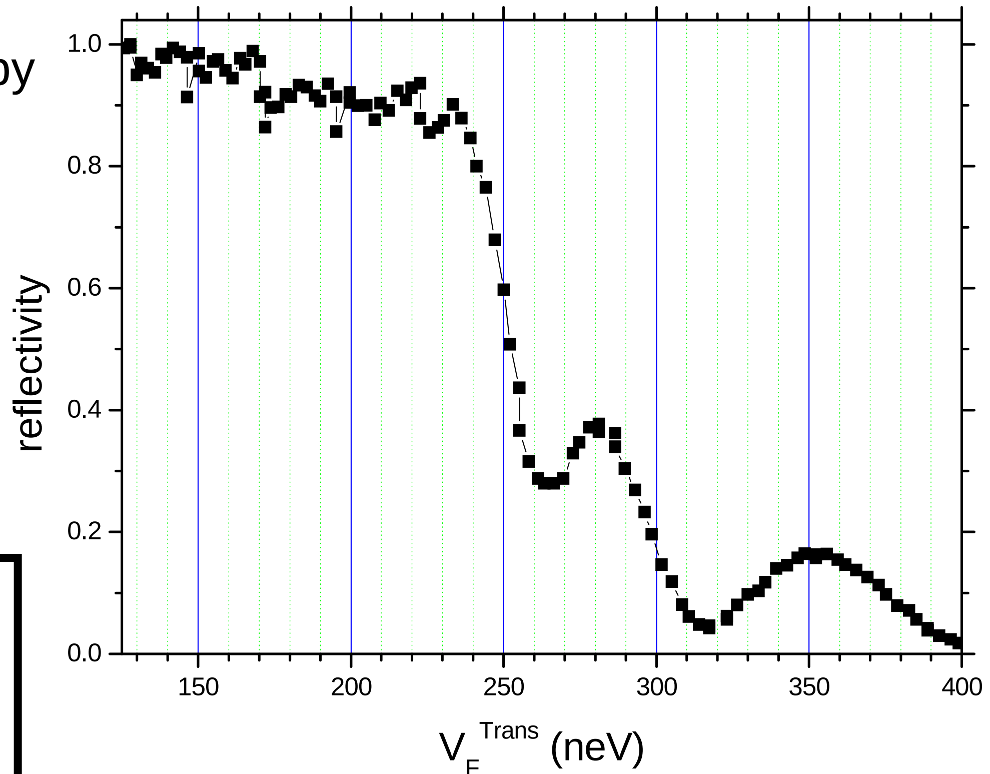


length of glass pipe: max. 3.6 m

thermoadaptor made of stainless steel

Material potential of NiMo surface coating

Measurement of critical reflection angle by means of cold neutrons reflectometry
(at the NARZISS instrument at PSI)



critical reflection angle ⇒ V_F

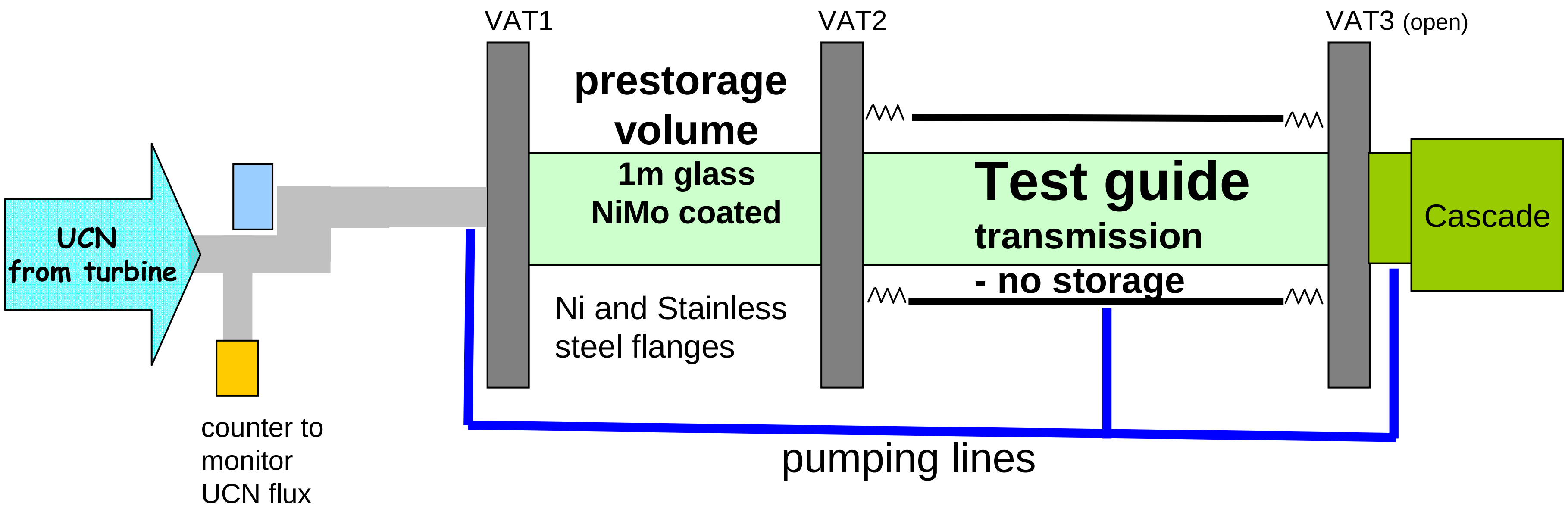
samples for almost all coated guide pieces

glass guide	length (mm)	measured V_{Fermi} (neV)
1W-1	**3499**	**220 ± 10** (all six samples)
1W-2	**2320**	
1S-1	**3668**	
1S-2	**2497**	
2W-1	**1530**	
2W-2	**2650**	

(preliminary)

(B. Lauss / PSI)

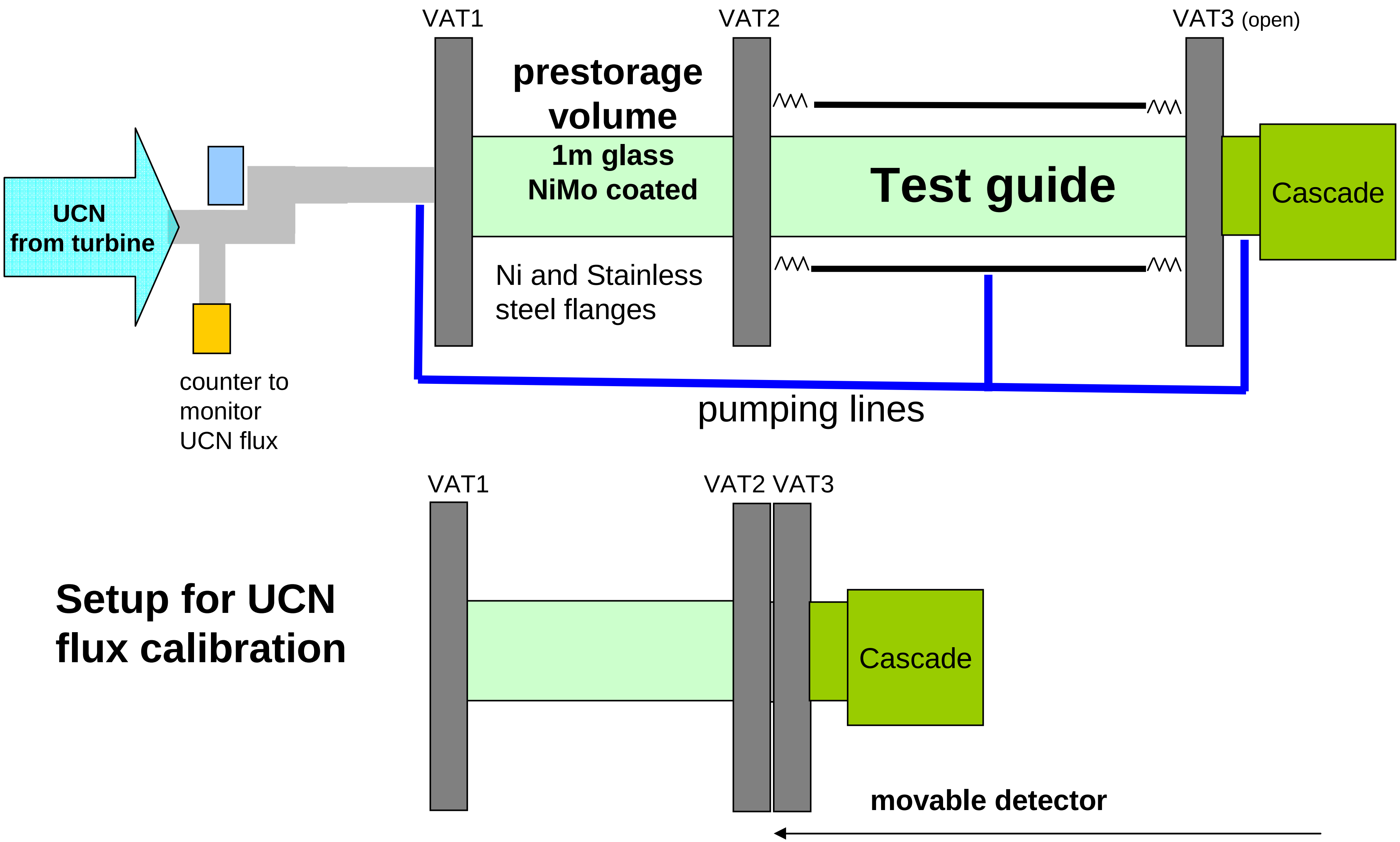
Prestorage method for UCN transmission measurement



storage volume and guide have same diameter

Measurement sequence starts with prestorage to shape UCN energy spectrum then the UCN are sent through the test guide and counted.

Prestorage method for UCN transmission measurement



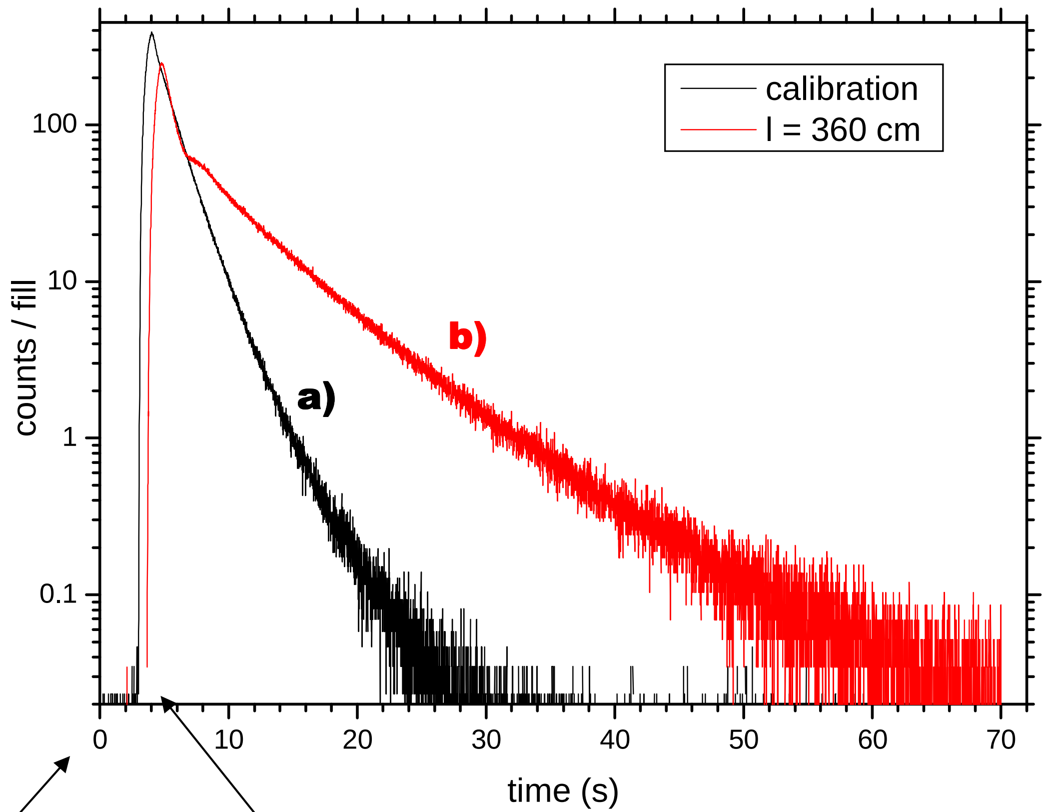
UCN time-of-flight spectrum

Interpretation:

a)
emptying of prestorage volume
-> 1 exp. slope

b)
emptying of prestorage volume +
emptying of 360 cm guide volume
-> 2 exp. slopes

The goal is to separate
direct (specular) transmission
and
scattered (diffuse) transmission



open shutter of prestorage volume

different length -> different T_0

(B. Lauss, L.Göltl / PSI)

UCN transmission results

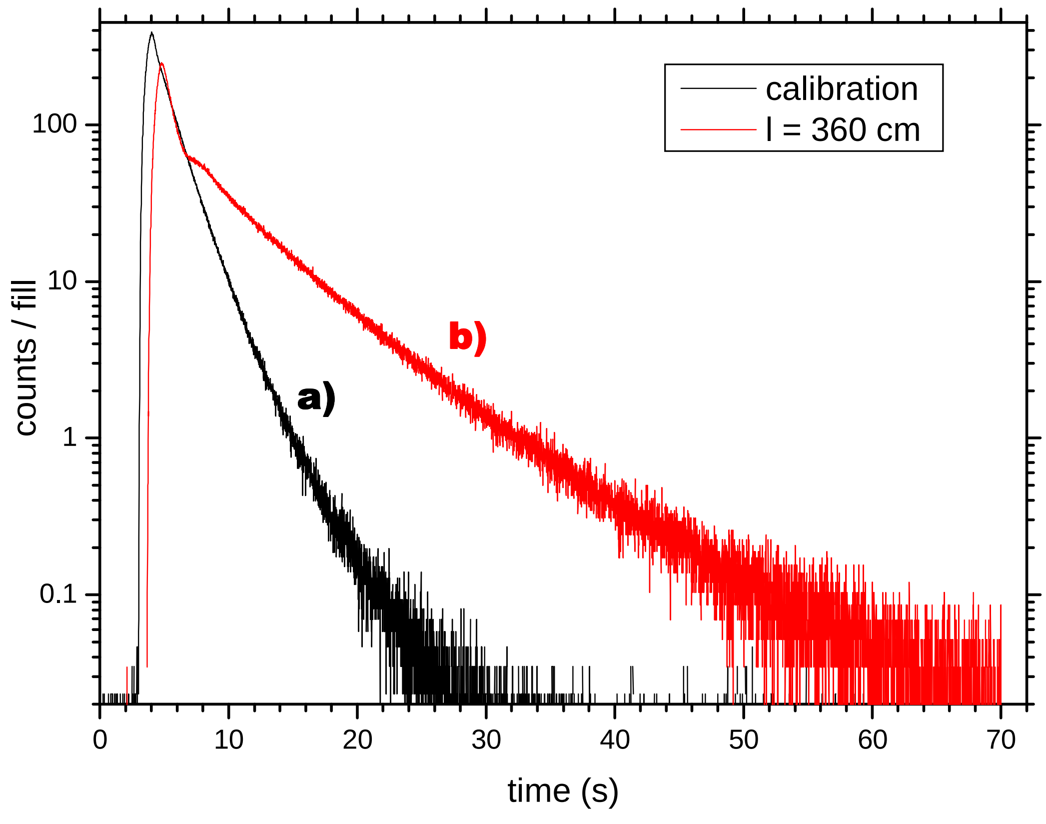
Preliminary results:

Transmission of guides including flanges and slits at connection valves per meter:

T/m = 0.98 ± 0.02

Comparing different lengths of guides allows to remove the flange and slit contributions:

T/m of NiMo coating on glass substrate = 0.99 ± 0.02

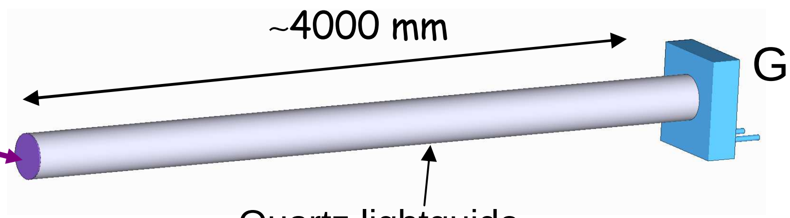


(B. Lauss, L.Göltl / PSI)

Micro UCN detector

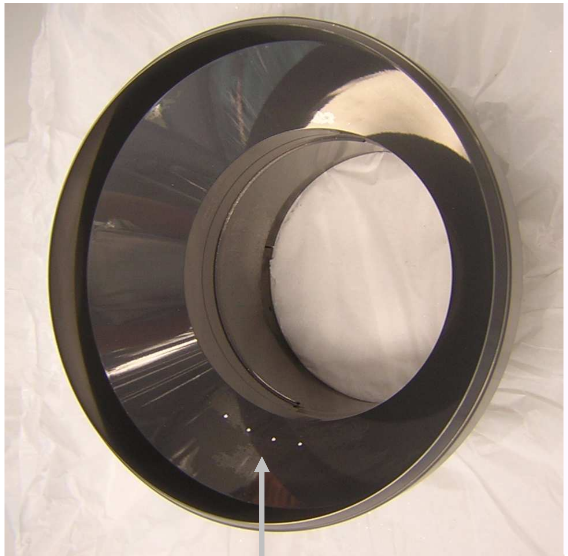
for direct UCN monitoring in storage volume

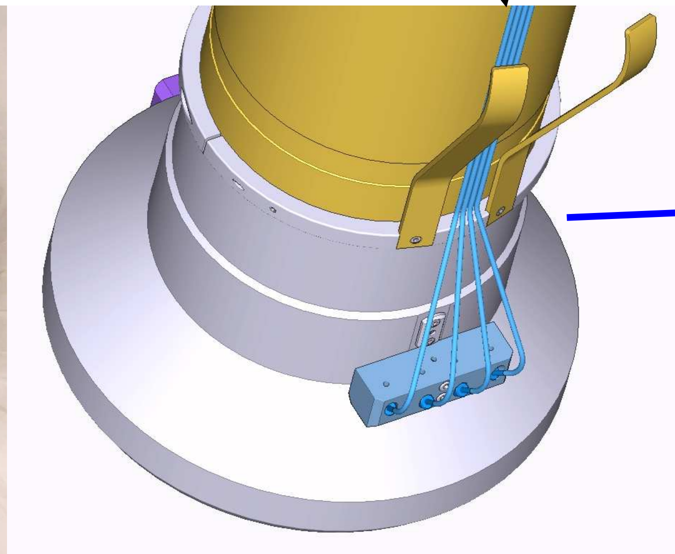
GS10 (^{6}Li based)
glass scintillator
ϕ=3 mm
thickness = 0.1mm

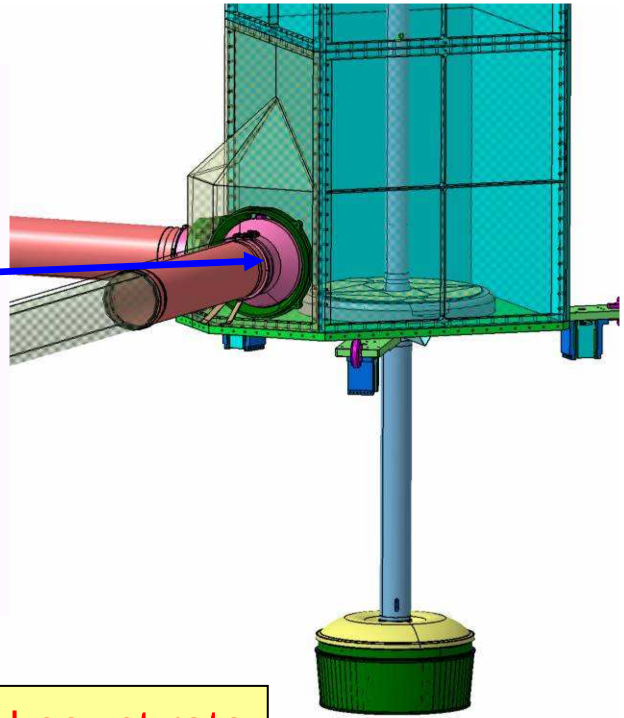


G-APD

Quartz lightguide







ϕ=2mm holes
for 4 counters

by direct measurement of UCN count rate
storage time constants can be evaluated

(L.Göltl / PSI)

Summary and Outlook

- The final assembly of PSI's UCN source is well underway
  - D_2O system: commissioning completed
  - Proton Beam Line: commissioning completed
  - Target: commissioning completed
  - Storage Volume & Neutron Guides: ready for installation
  - Cold Moderator System: assembly close to completion
- We expect first UCN in summer 2010
- The first experiment (nEDM) will start taking data in late 2010 with a strong international collaboration

Thank you !

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Ultra Cold Neutron Source

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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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