FRM II
Forschungs-Neutronenquelle
Heinz Maier-Leibnitz

MLZ
Heinz Maier-Leibnitz Zentrum

The Source for Ultra Cold Neutrons at the FRM II

Workshop on Very Cold and Ultra Cold Neutron Sources for ESS

Andreas Frei - 03.02.2022

Photo: Andreas Heddergott

MLZ is a cooperation between:

JÜLICH Forschungszentrum

Helmholtz-Zentrum hereon

Technical University of Munich

Outline

- Layout of the UCN Source at FRM II
- Main Components
- Non-Nuclear Testing Setup
- Current Status
- Next Steps

The UCN-lab at the FRM II

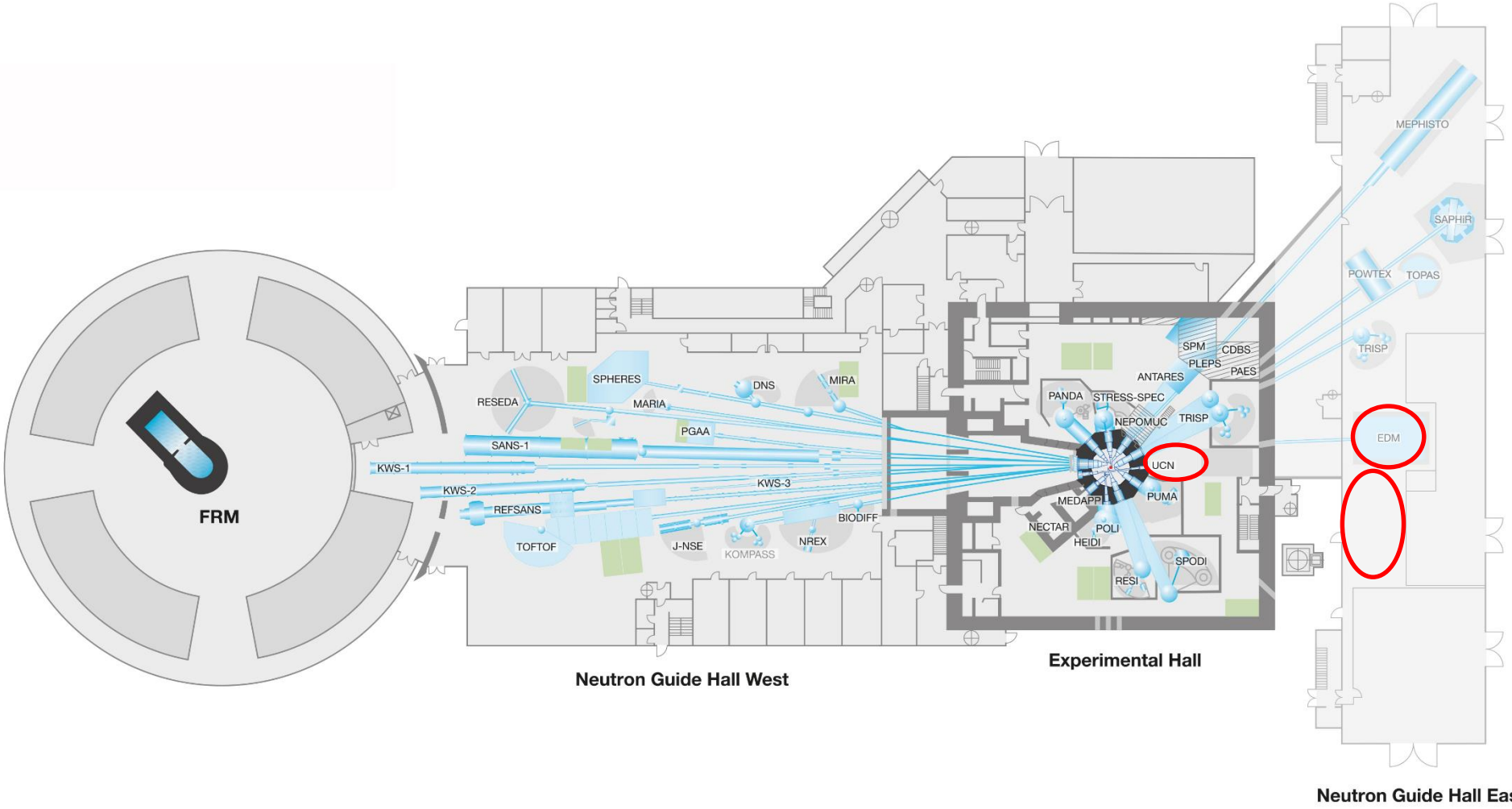
Neutron guide hall east:

- Two UCN beam exits
- PERC

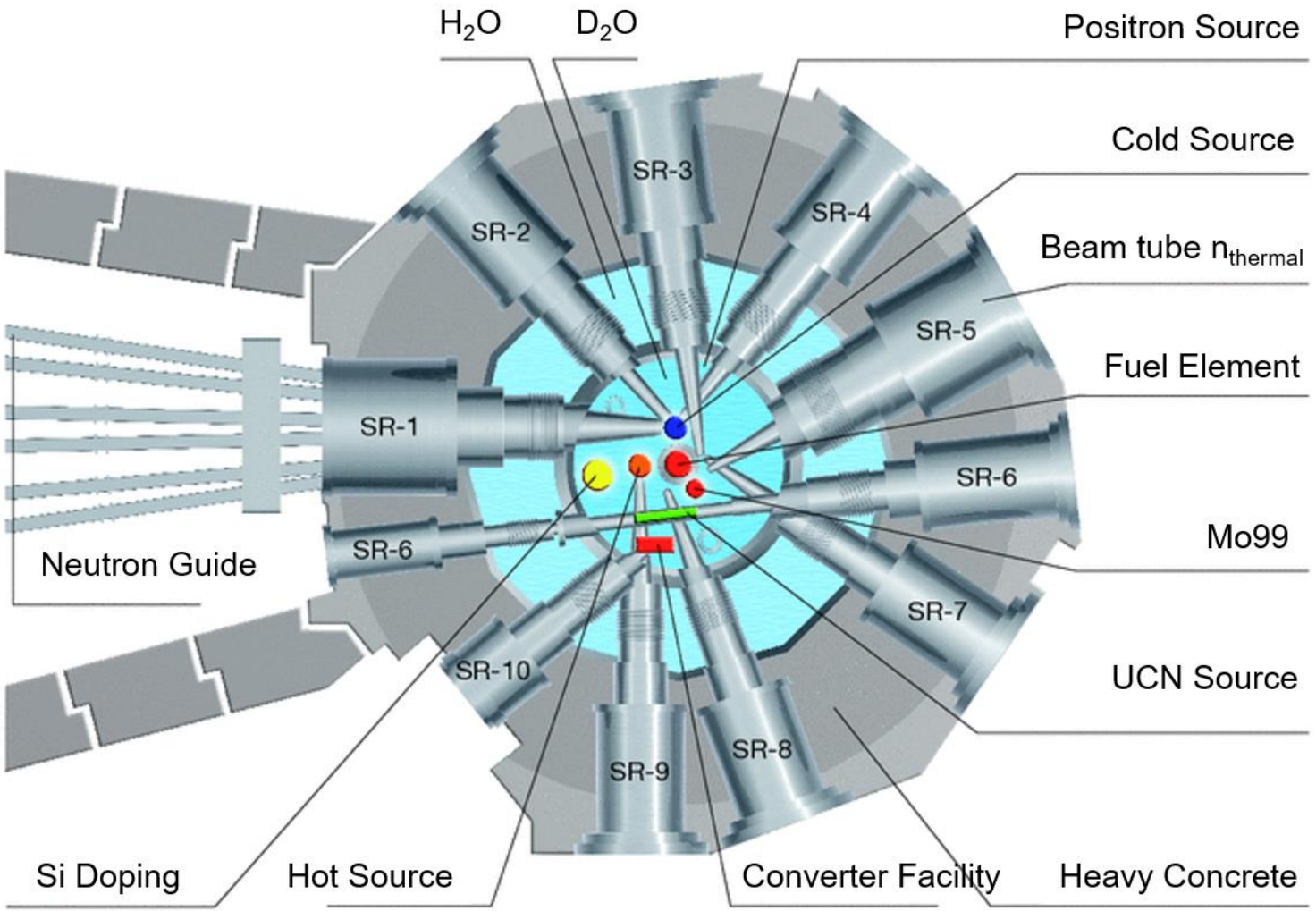
Experiment hall:

- UCN source (inside SR6)
- Two UCN beam exits

The UCN-lab at the FRM II

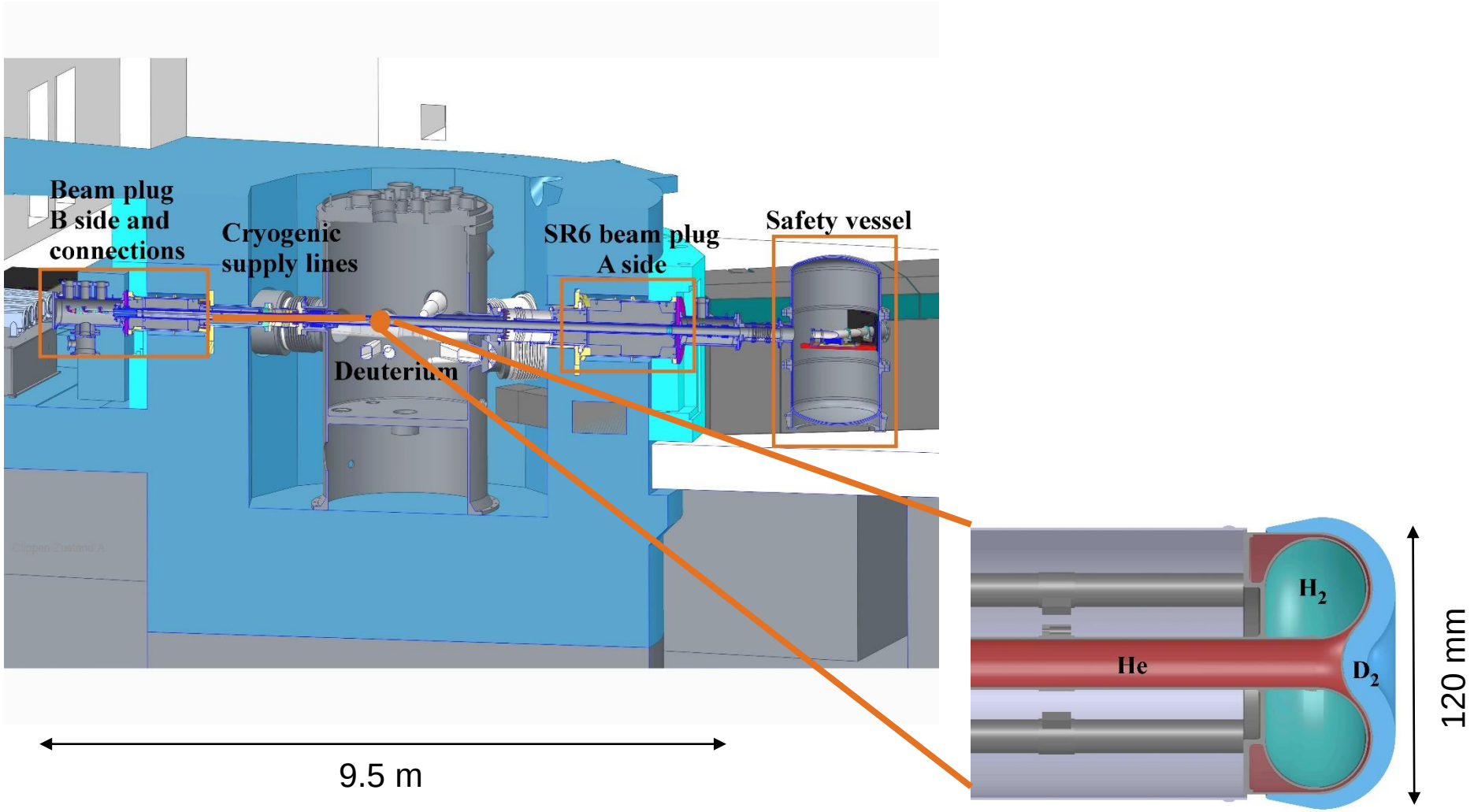


FRM II beam tubes



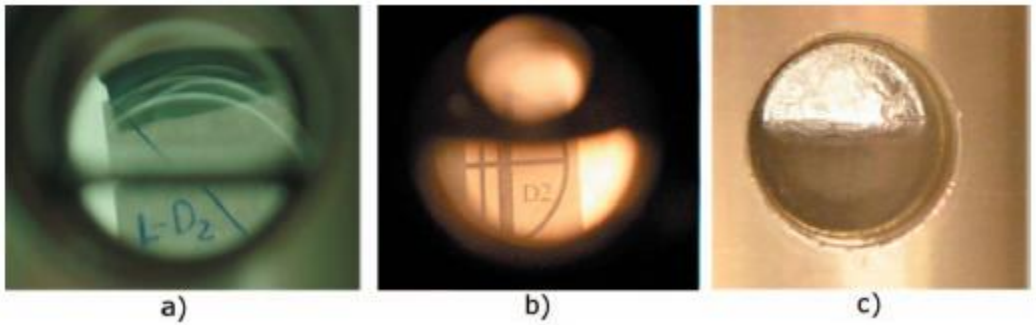
Exchange of beam plug SR6a

UCN Source with sD_2 Converter



Converter Preparation

Deuterium



Deuterium:

a) liquid → solid
b) gaseous → solid
c) “turbofreezing”

Oxygen

Oxygen:

upper left: liquid (90.2K – 54.4K)
upper right: γ-phase (54.4K – 43.8K)
lower left: β-phase (43.8K – 23.9K)
lower right: α-phase (< 23.9K)

Para-Ortho Conversion under irradiation

$$\frac{\partial[\mathrm{D}_2^{\mathrm{o}}]}{\partial t} = -\frac{1}{2}k[\mathrm{D}_2^{\mathrm{o}}] \quad \leftarrow \text{Molecular breakup}$$

$$+\beta(T)\,[\mathrm{D}]c_{\mathrm{o}}^{\mathrm{eq}}(T)\,[\mathrm{D}_2^{\mathrm{p}}]$$
$$-\beta(T)\,[\mathrm{D}]\,(1-c_{\mathrm{o}}^{\mathrm{eq}}(T))\,[\mathrm{D}_2^{\mathrm{o}}] \quad \leftarrow \text{Para} \leftrightarrow \text{Ortho transitions}$$

$$+\frac{2}{3}\alpha(T)\,[\mathrm{D}]^2. \quad \leftarrow \text{Recombination of atoms to molecules}$$

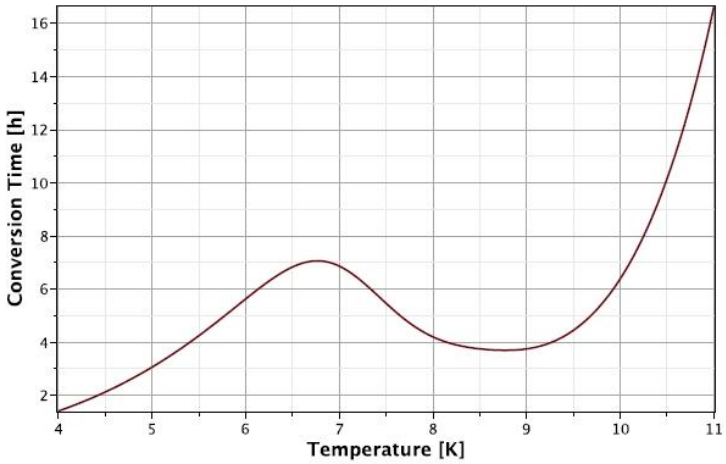


Figure 5.9.: Calculated conversion time for a deuterium crystal under irradiation with a dissociation rate of $k = 2.84 \cdot 10^{-6}\mathrm{s}^{-1}$. The increase in conversion time towards lower temperatures as seen by Collins et al. [Col91] can be partly reproduced.

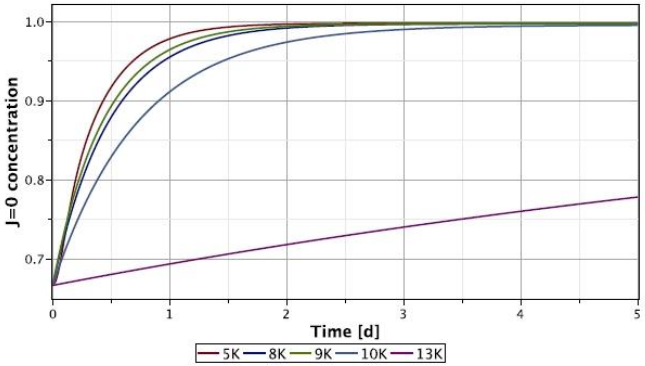


Figure 5.10.: Calculated evolution of the $J=0$ concentration for different temperatures of the ultra-cold neutron source at the FRM II. Within two days of irradiation most of the D_2 will have converted to the ortho state. For temperatures well above 10 K the conversion time increases sharply.

S. Wlokka, PhD Thesis, TUM (2016).

Some numbers…

Technical Data	
Converter temperature min.	5 K
Pre-moderator volume (sH_2) max.	250 cm^3
Converter volume (sD_2) max.	250 cm^3
Cooling power @ 5K max.	1 kW
UCN flux density @ SR6a exit (100 neV – 230 neV)	$6 \cdot 10^5$ $s^{-1}cm^{-2}$
UCN beam aperture (circular guide)	100 cm^2
UCN flux @ SR6a exit (100 neV – 230 neV)	$6 \cdot 10^7$ s^{-1}

The way to UCN at FRM II

Genehmigungsverfahren § 7 AtG

Essential changes of FRM II

Operation of UCN with D_2 and H_2

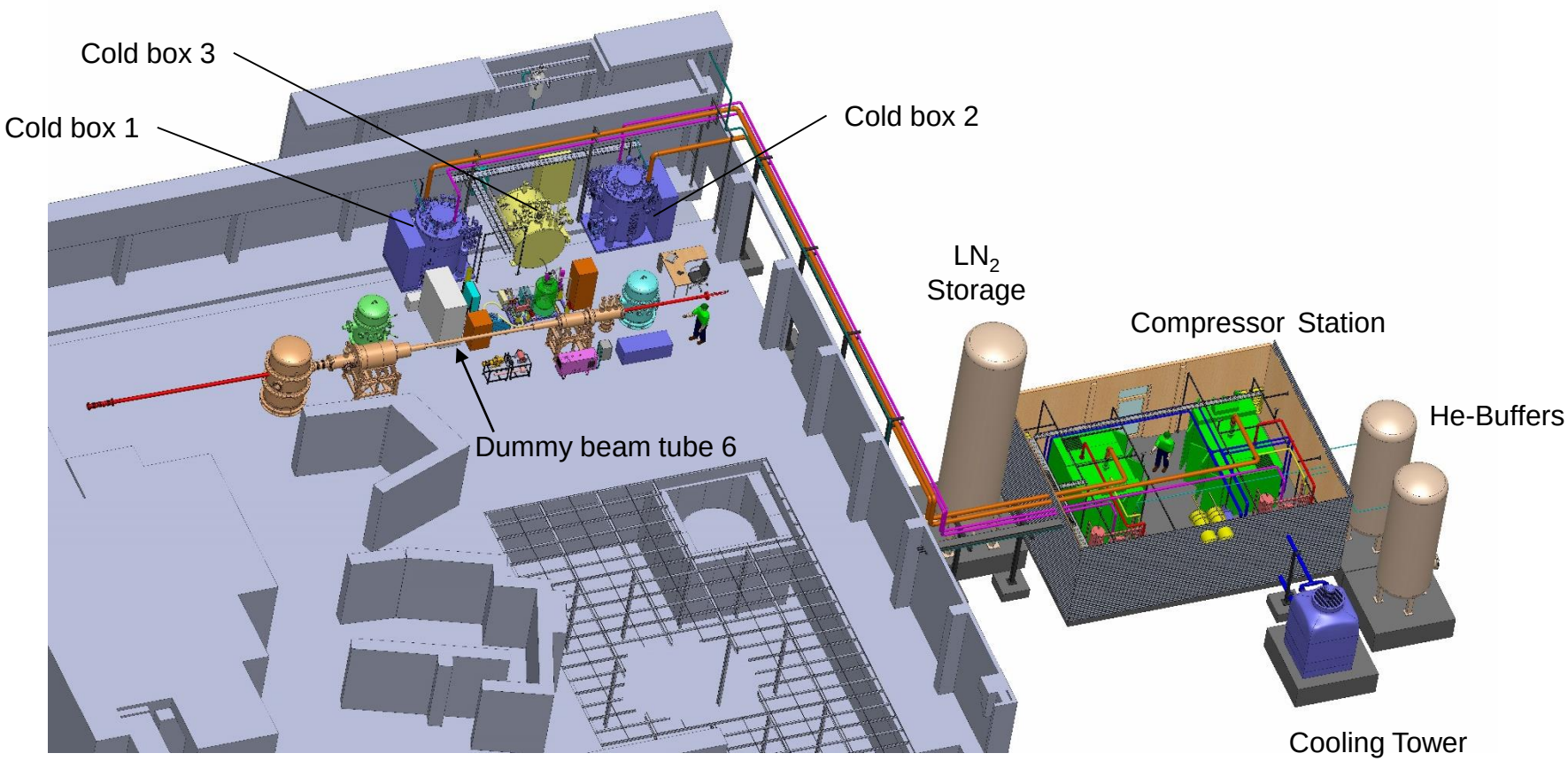
Non-nuclear test mandatory!

Aufsichtsverfahren § 19 AtG

Non-Essential changes of FRM II

All other things,
assembly and installation of
all components

Non-Nuclear Testing



Testing Setup

Compressor Station with He-Buffers and LN_2 Storage

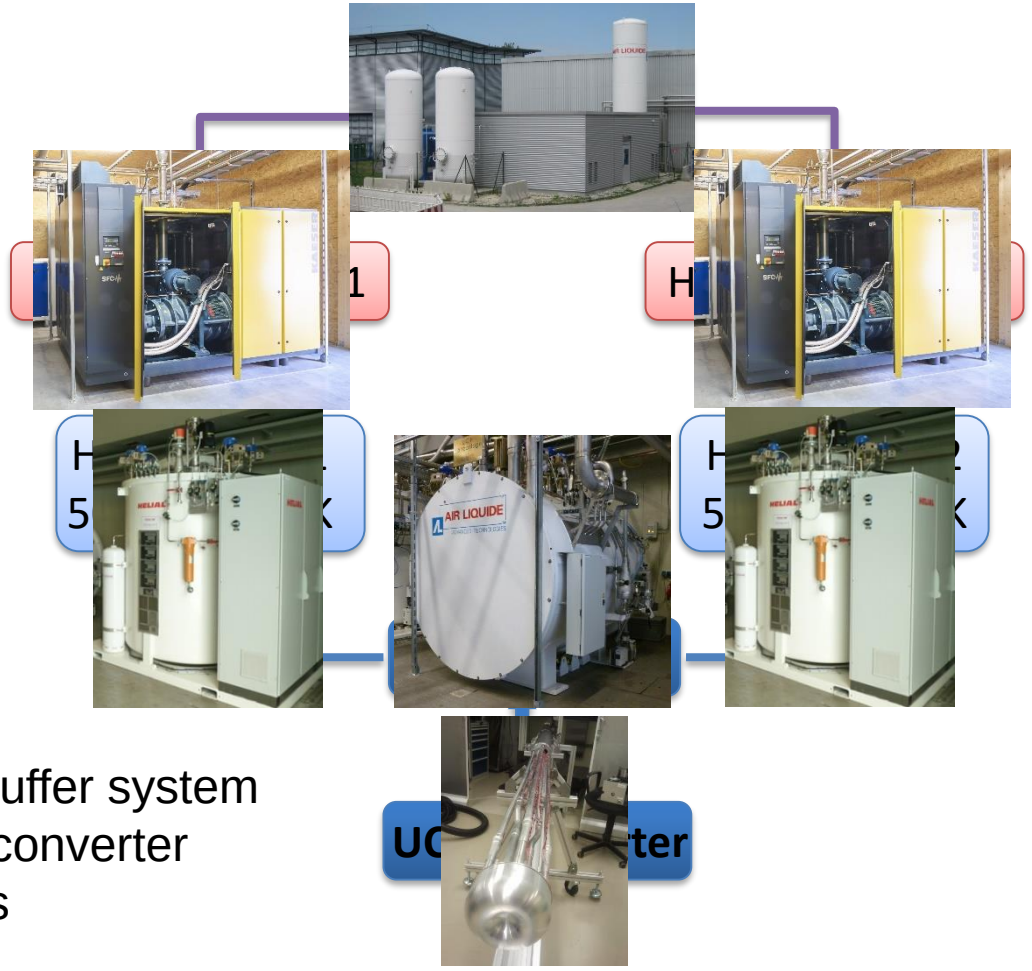
Testing Setup

Cold Boxes with Dummy Beam Tube

Cooling concept

He-Buffers 2x15 m^3, 16 bar / lN_2 12 m^3

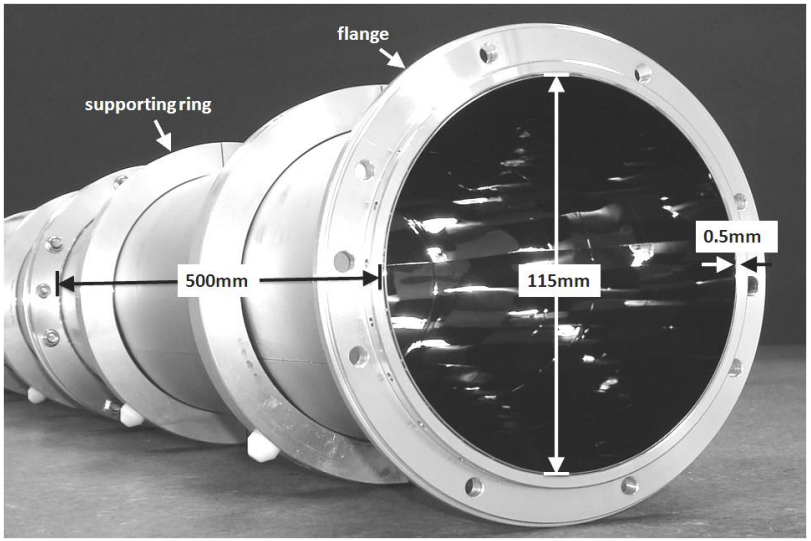
Compressors 2x250 kW,
14.5 bar, 85 g/s



Coldboxes 2x500 W @ 4.5 K
2 Brayton cycles
2 Joule-Thomson-Valves
Liquefaction 70 l/h

Coldbox 3: Heat exchanger with buffer system
Supercritical He cooling circuit to converter
Pressure 3.4 bar, flow rate 120 g/s

UCN Replica Guides



S - D H

NiV (93/7) or NiMo (85/15)
Single section 500 mm
Welded up to 3 – 3.5 m total length

Transmission per guide length:

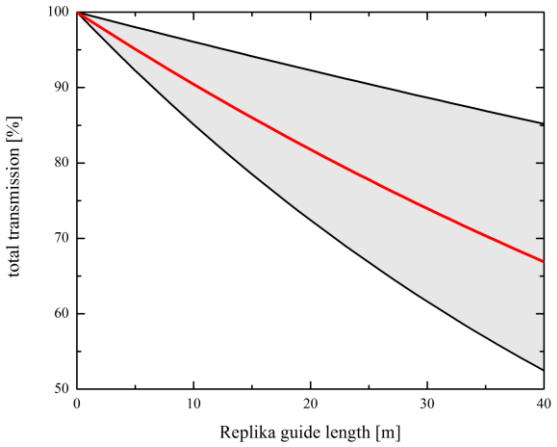
$(0.990 \pm 0.006)\ m^{-1}$

Total transmission on a distance of 40 m

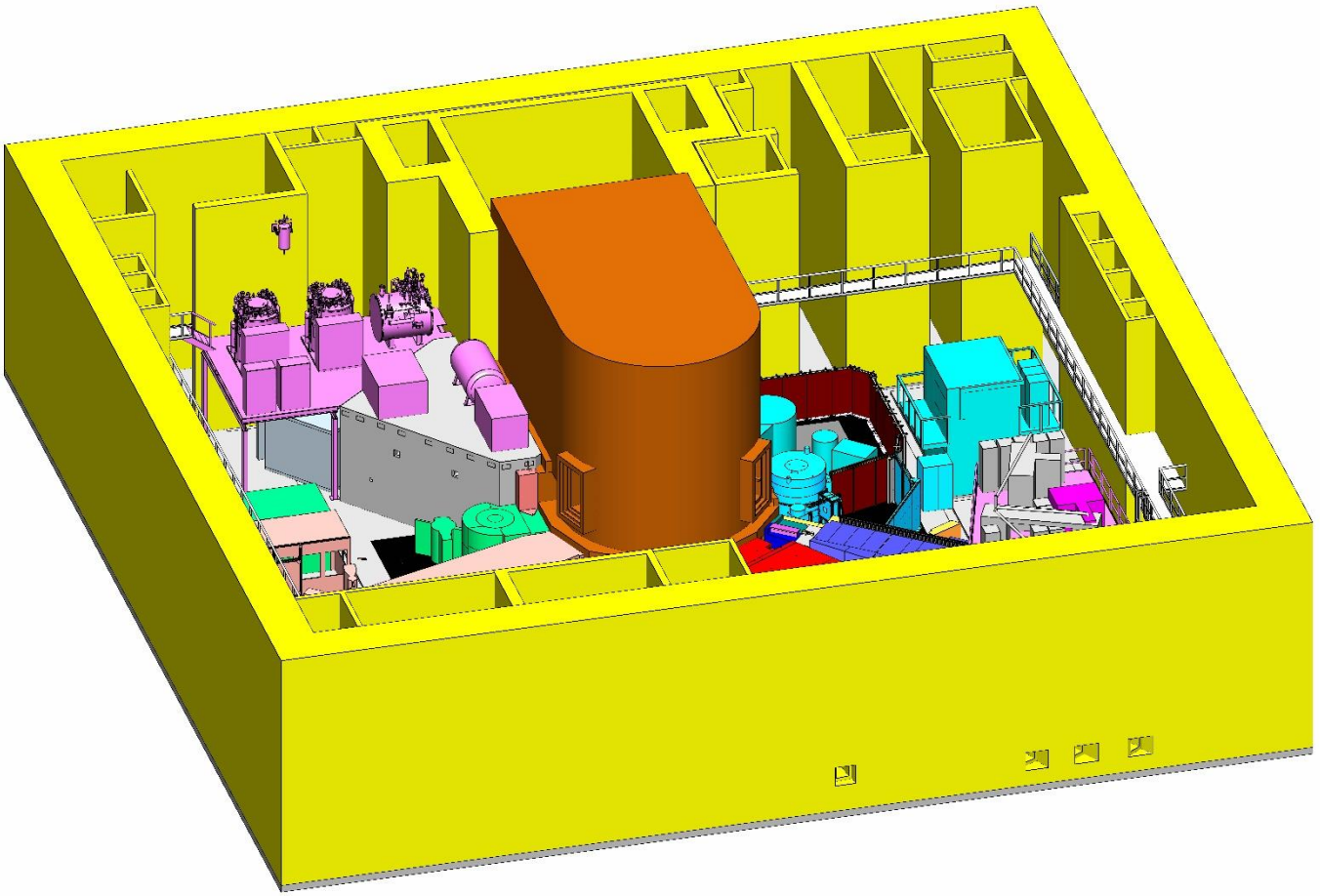
within the error range of:

52.5% - 85.2%

(E_{UCN} < 200 neV)



UCN components in experiment hall



Status

- Security Concept of UCN source approved
- He-cooling machine in operation
- Test phase ongoing
- Installation of auxiliary systems ongoing/pending
- Nuclear licensing procedure ongoing

Status of Licensing Procedure

- Safety report finished
- System description finished
- Concept approved
- Non-nuclear test phase started
- Special nuclear specifications for UCN-source created

Next Steps

- Setup of auxiliary systems at FRM II
- Installation of UCN components in the experiment hall
- Nuclear specifications for special inpile parts
- Fabrication of special inpile parts
- Preparations for second beam plug exchange
- Preparations for installation of inpile parts
- Preparations for commissioning sequences at FRM II
- Ongoing nuclear licensing procedures

The (current) UCN Team

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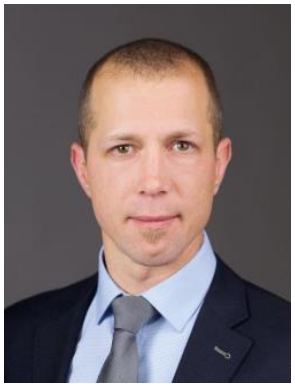
Project Engineer



Christian Wiesner
Project Engineer

… plus more than a dozen students, technicians and engineers, who worked for the UCN project within the last years …

Thank you!


Helmholtz-Zentrum
Geesthacht
JÜLICH
MLZ
Heinz Maier-Leibnitz Zentrum
TUM