HighNess

ESS progress: the HighNESS project

Luca Zanini
on behalf of the HighNESS Consortium

2024 LENS/ELENA neutron moderator workshop, Paris, 18 April 2024

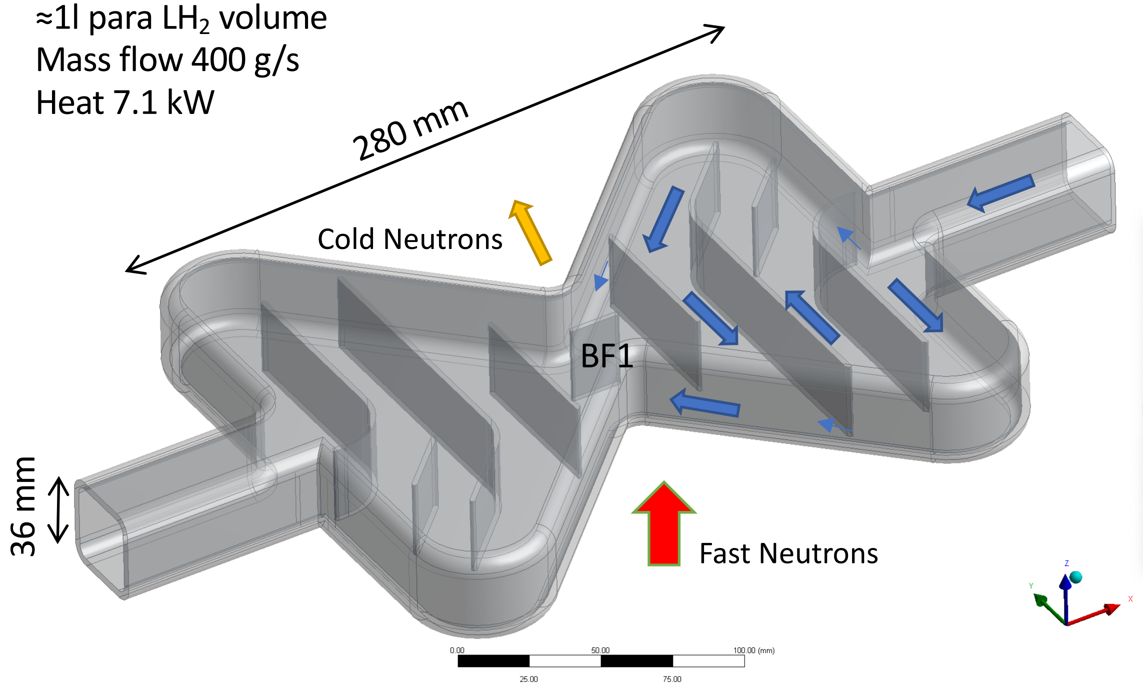
HighNESS is funded by the European Union Framework Programme for Research and Innovation Horizon 2020, under grant agreement 951782

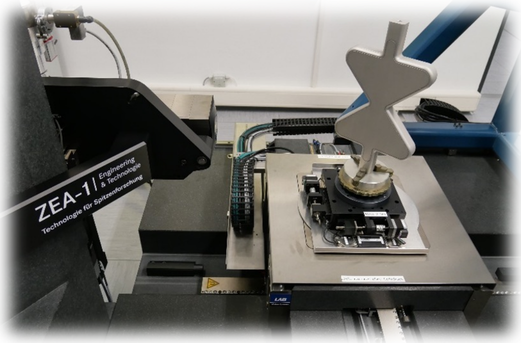
First generation of parahydrogen moderators (BF2) –Twister
Now installed in ESS target monolith

(in-kind FZJ Jülich)

Second generation of parahydrogen moderator (BF1) has been ordered

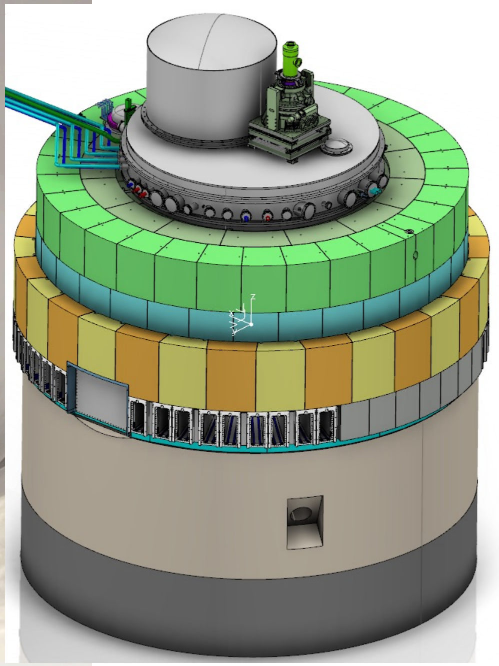
≈1l para LH_2 volume
Mass flow 400 g/s
Heat 7.1 kW



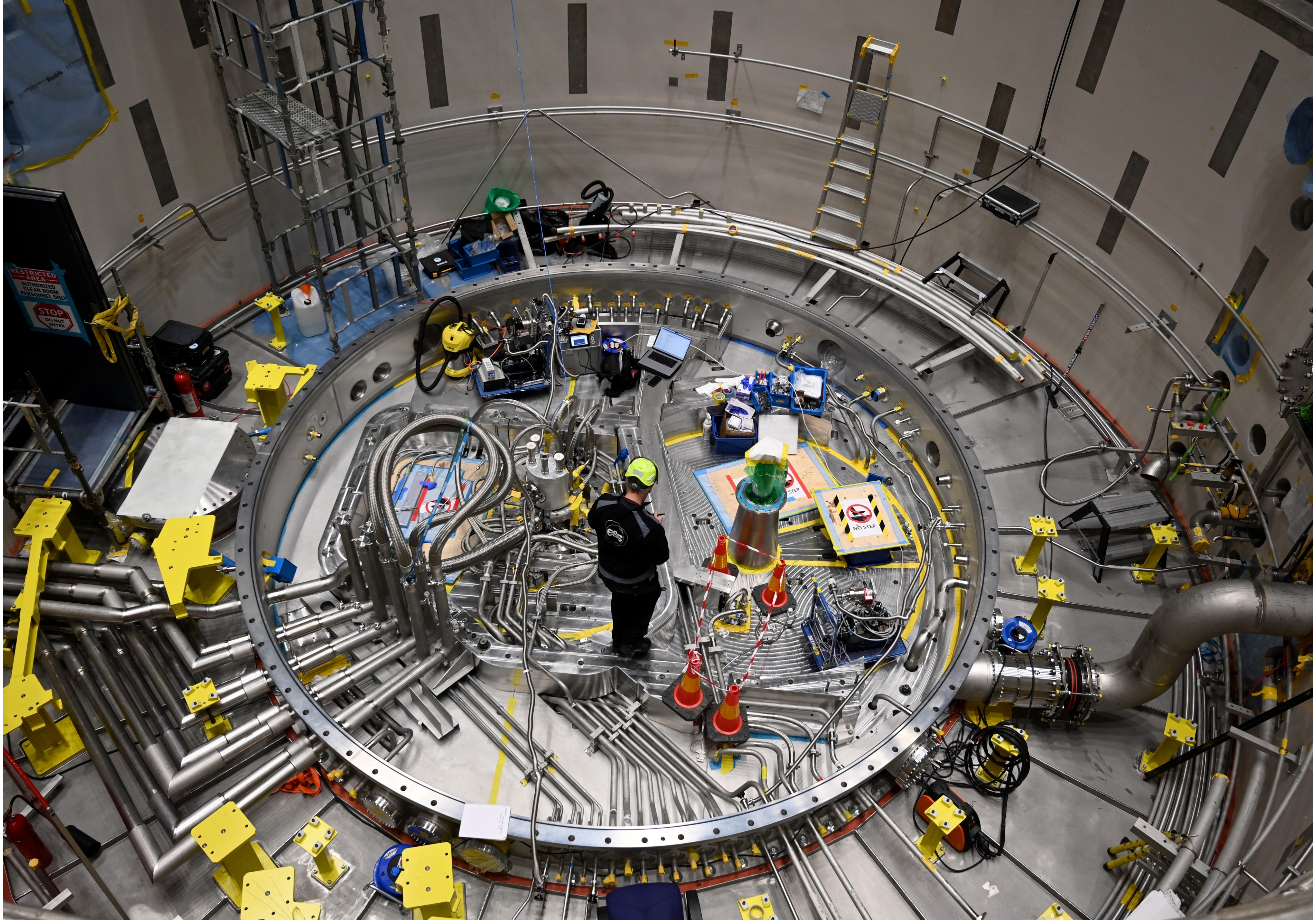


NDT of first prototype

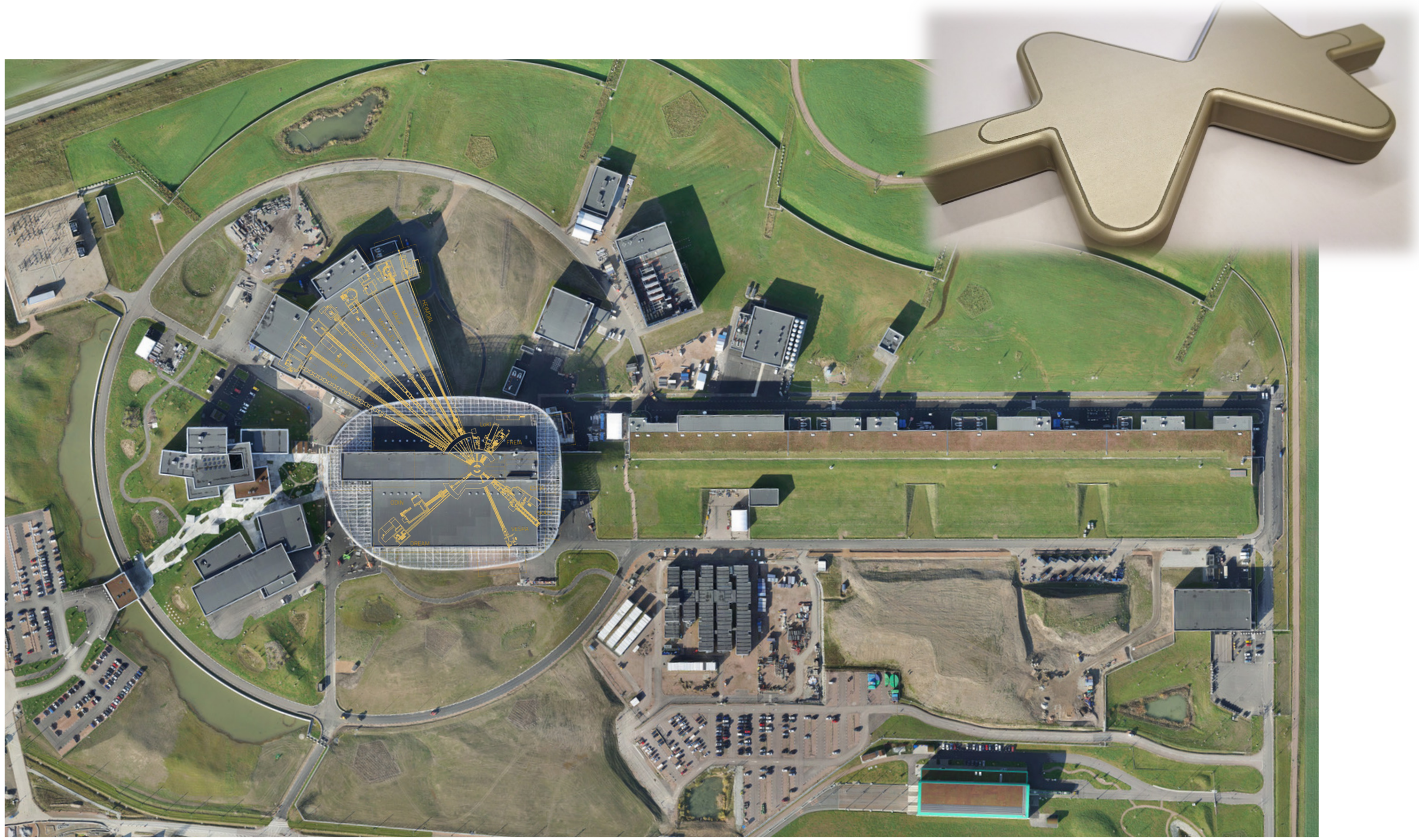
First prototype



(Picture from 2021)


RESTRICTED AREA
AUTHORIZED CLEAN ROOM PERSONNEL ONLY
STOP
DO NOT ENTER
NO STEP

Upgradeability of ESS



ESS schedule

- End 2024: beam on dump
- Mid 2025: beam on target and start commissioning
- 2027: end of construction with 15 instruments looking at upper moderator

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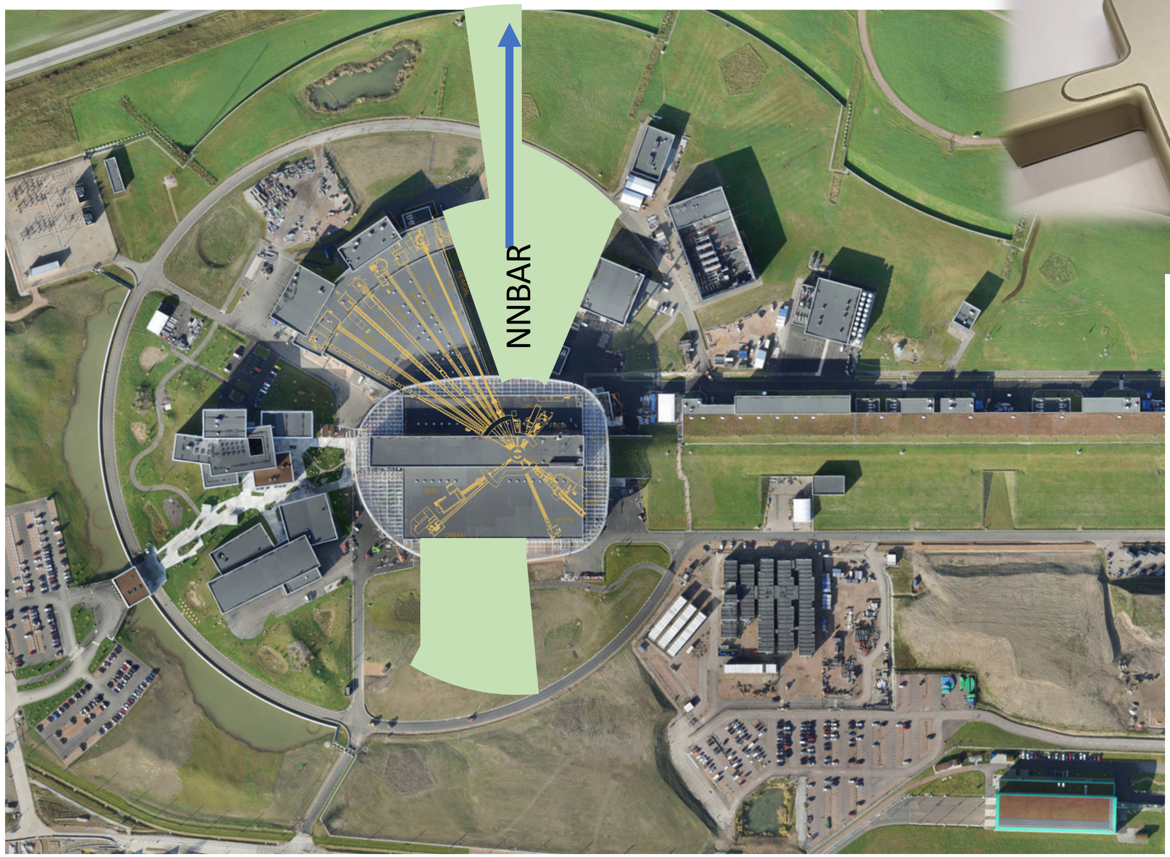
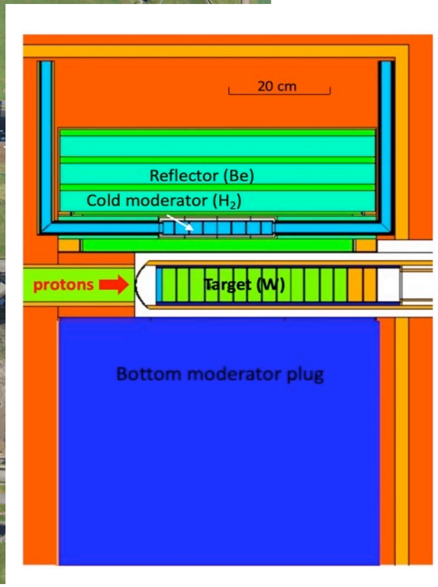
Upgradeability of ESS





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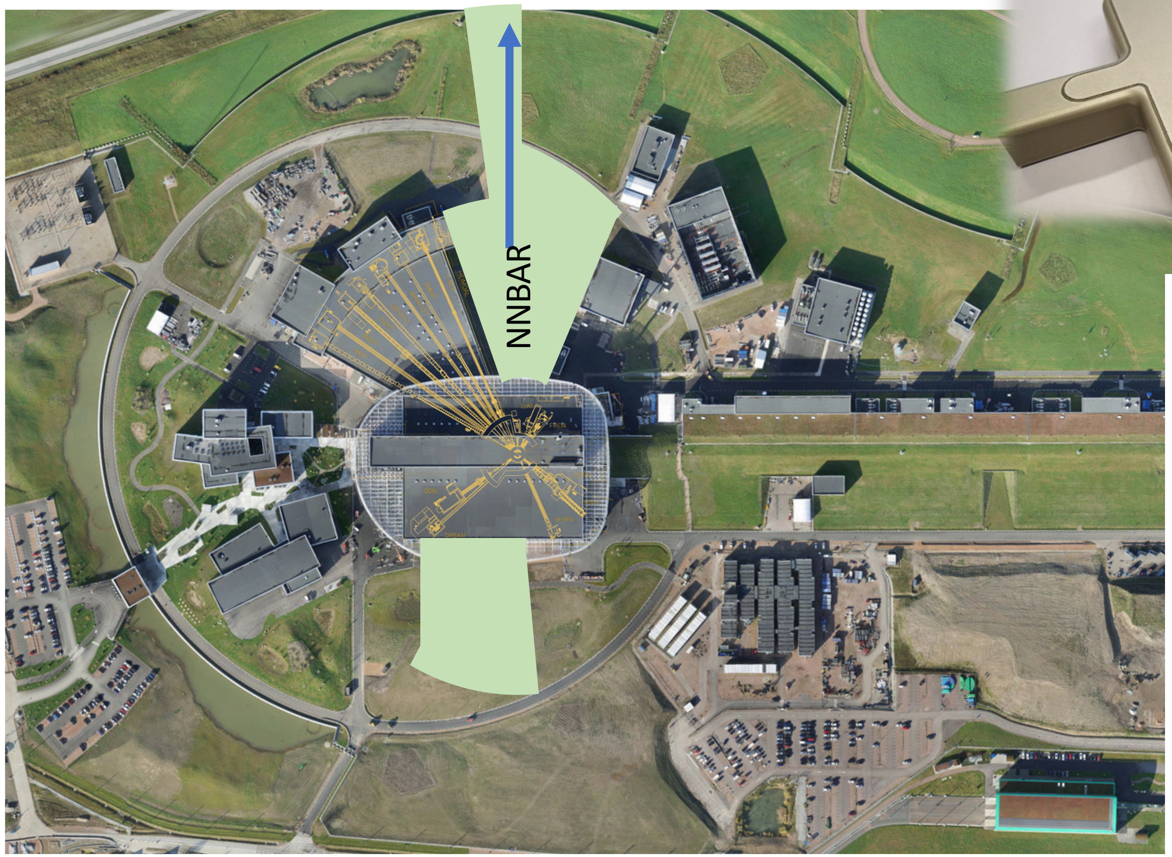
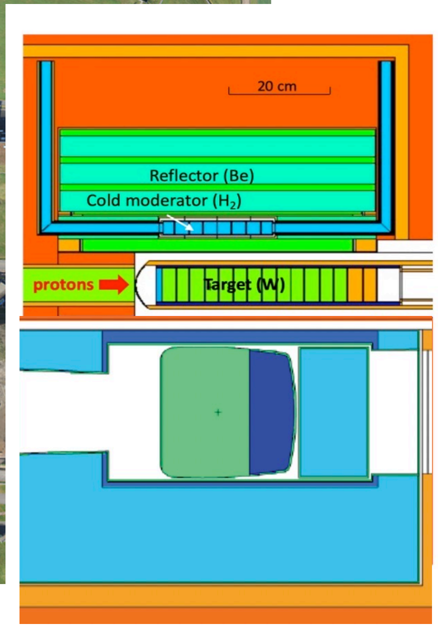
Upgradeability of ESS





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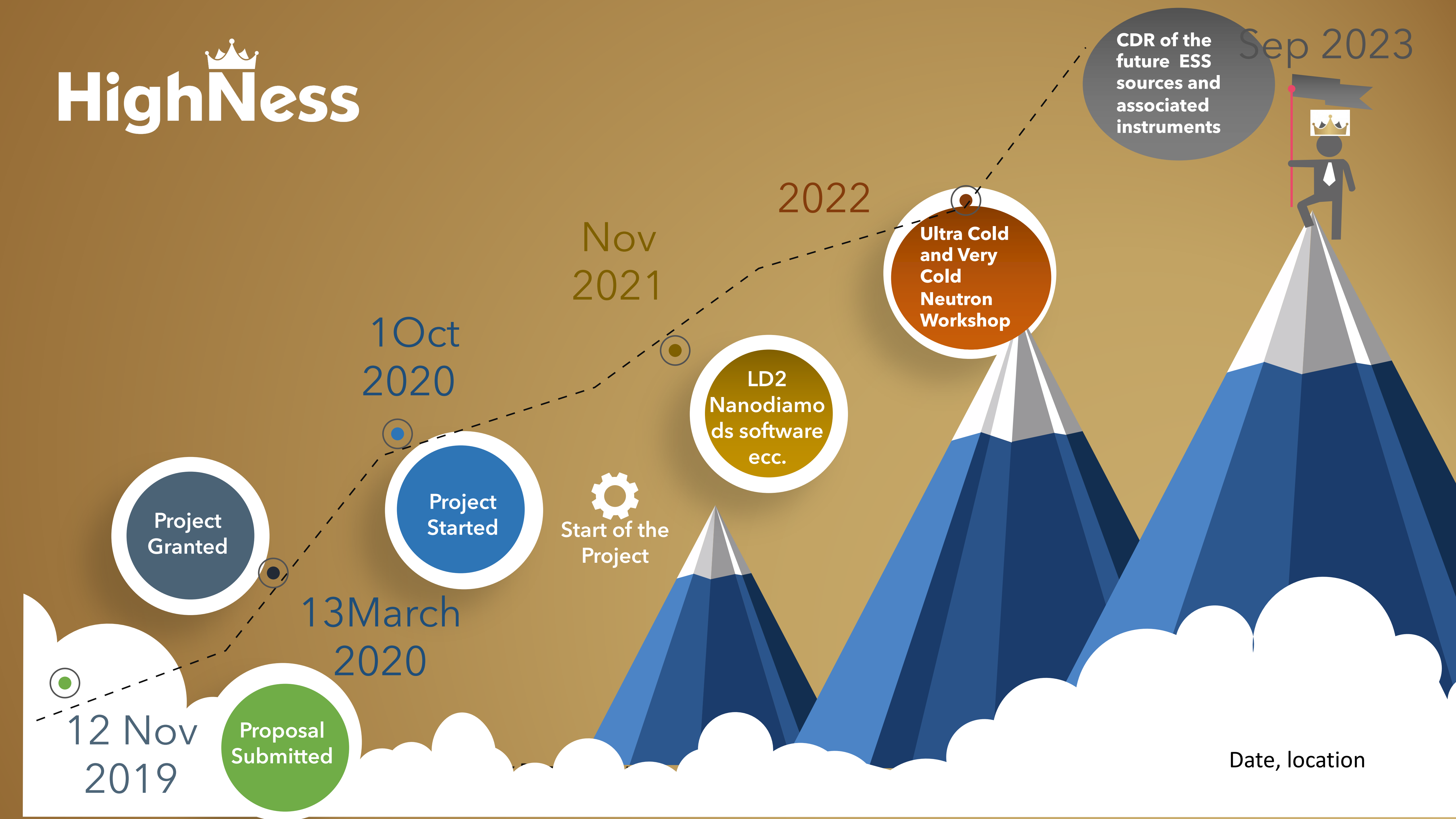
HighNess
12 Nov 2019
Proposal Submitted
Project Granted
13March 2020
Project Started
1Oct 2020
Start of the Project
Nov 2021
LD2 Nanodiamods software ecc.
2022
Ultra Cold and Very Cold Neutron Workshop
Sep 2023
CDR of the future ESS sources and associated instruments
Date, location

HighNESS aims at complementing the ESS current moderator in **two** different aspects

High Intensity

larger emission surface and bigger moderator

Longer wavelengths

Cold, Very Cold and Ultra Cold neutrons

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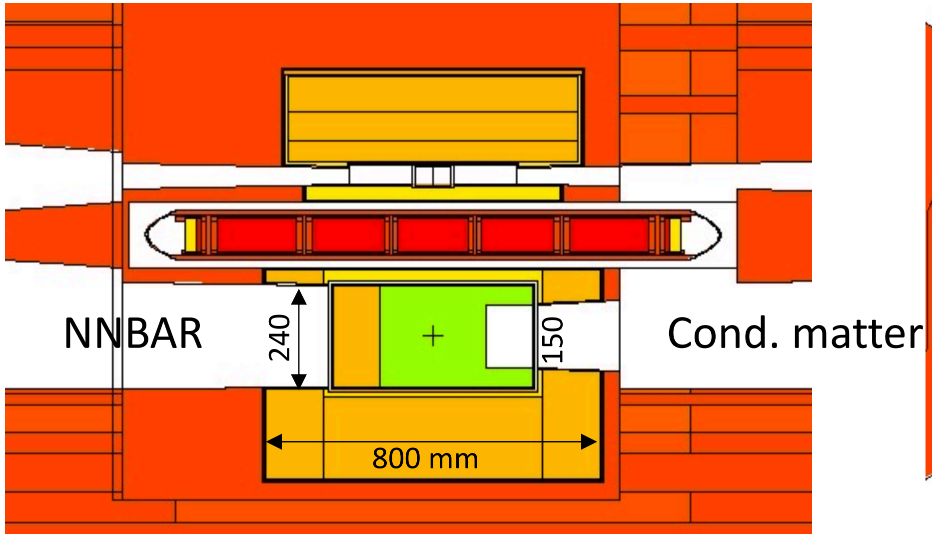
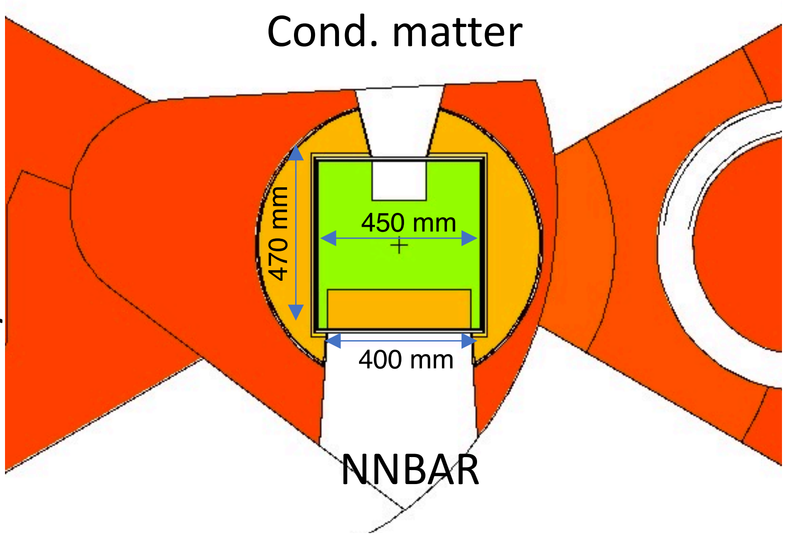
Design of the Cold Source

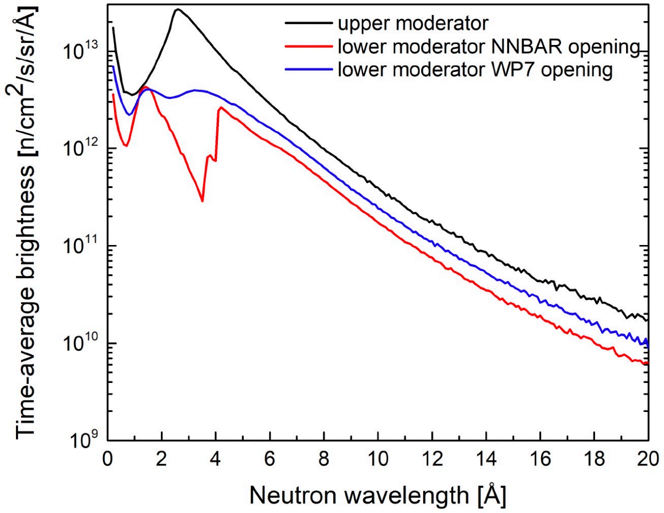
cold	2-20 Å
very cold	10–120 Å
ultracold	> 500 Å



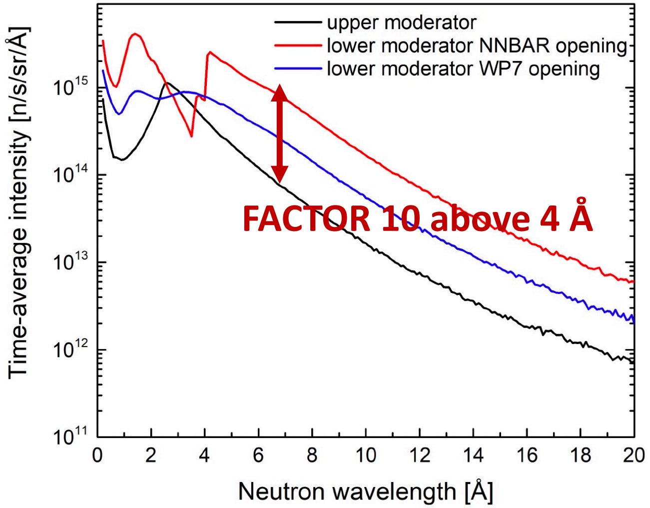


The high-intensity liquid deuterium moderator has been designed with two openings, for NNBAR and neutron scattering instruments

Brightness



Intensity



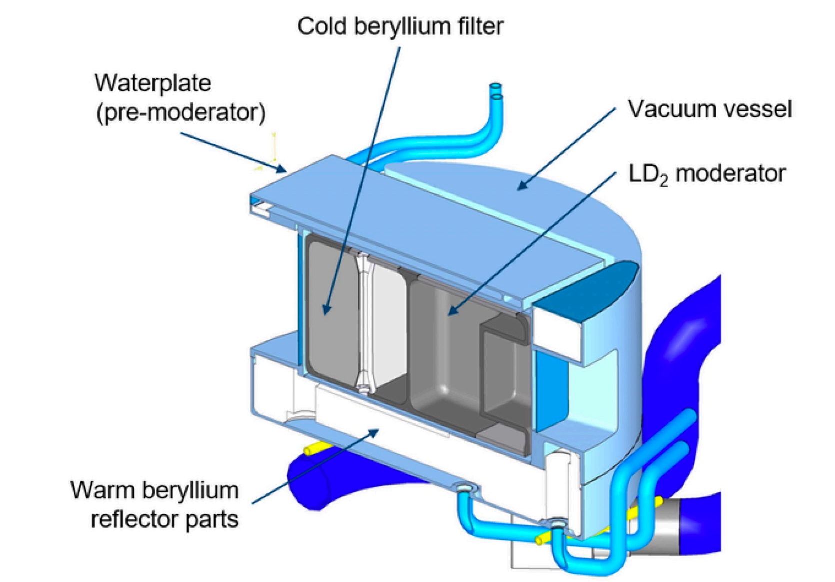
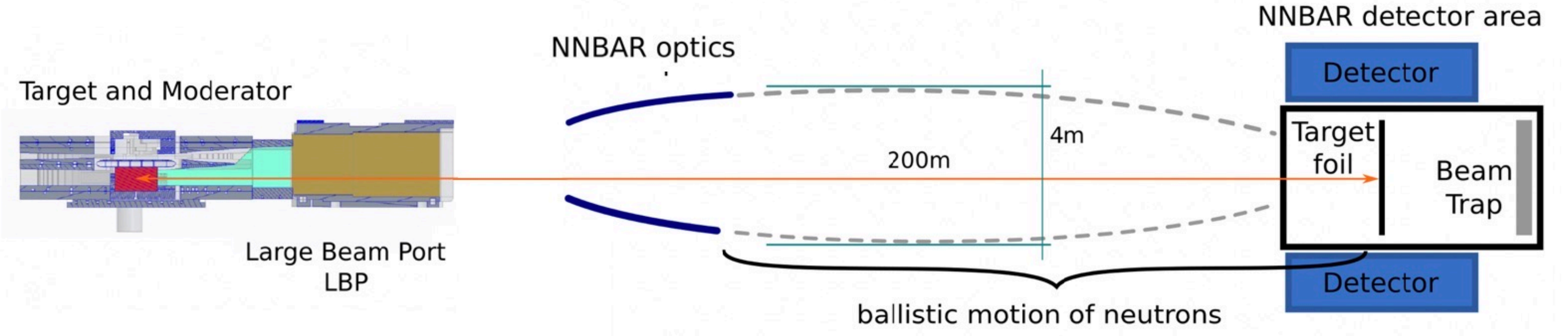


Figure 50: 3D cross section illustration of the lower moderator plug.

Research and innovation Horizon 2020, under grant ag

Sensitivity increase of factor 1000 in search for neutron-antineutron oscillation compared to previous experiment (M. Baldo-Ceolin et al, 1994).



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The HighNESS/LENS workshops on VCN and UCN sources at ESS

First workshop https://indico.esss.lu.se/event/2810/

- On February 2-4 2022, more than 100 scientists and experts from 23 nationalities took part in the workshop

- Workshop proceedings published in a special issue of the Journal of Neutron Research in 2022
https://content.iospress.com/journals/journal-of-neutron-research/24/2

- Follow up workshop 8-9 May 2023

2nd workshop https://indico.esss.lu.se/event/3195/

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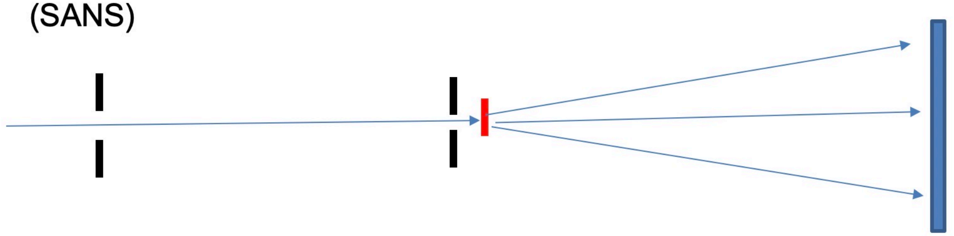
SANS (Mezei) https://indico.esss.lu.se/event/2810/

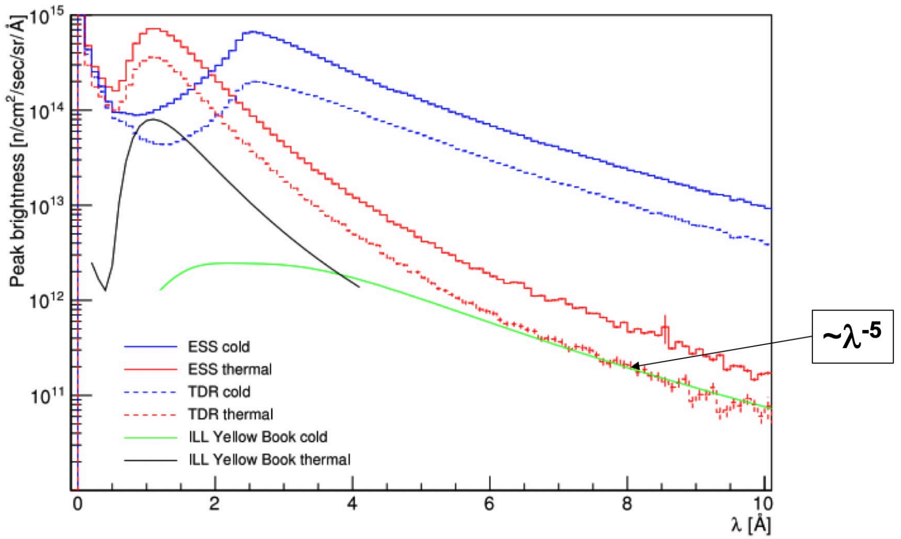
Small angle neutron scattering: small **q** → large scale structures
(SANS)



Through put of incoming beam shaping @ equal resolution: $\propto \lambda^5$

Long wavelength tail of Maxwellian particle spectrum: $\propto \lambda^{-5}$

→ all wavelengths about equivalent for a Maxwellian spectrum



L. Zanini et. al. 2019

Cold moderators are less Maxwellian and a VCN source could offer unprecedented intensity in SANS studies

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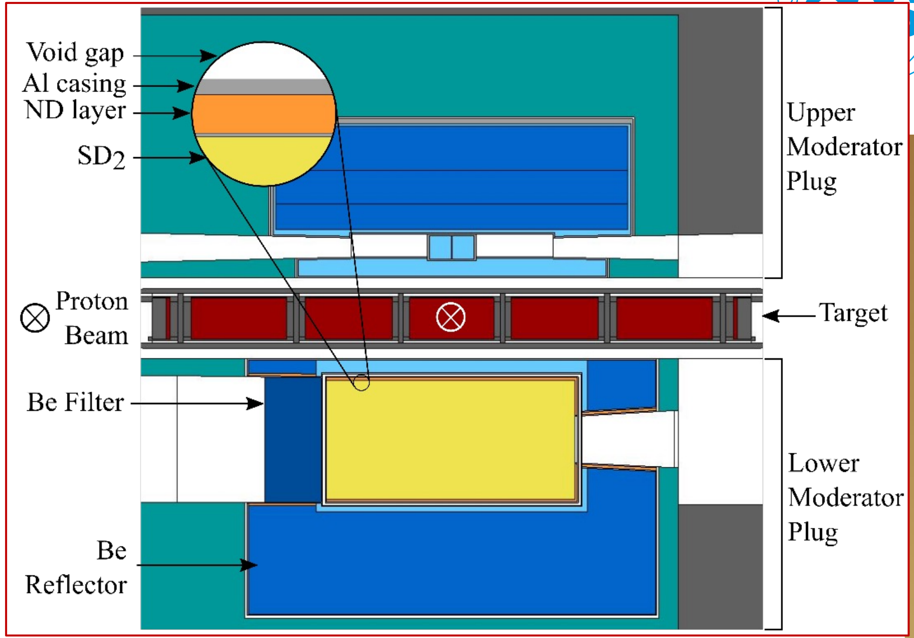
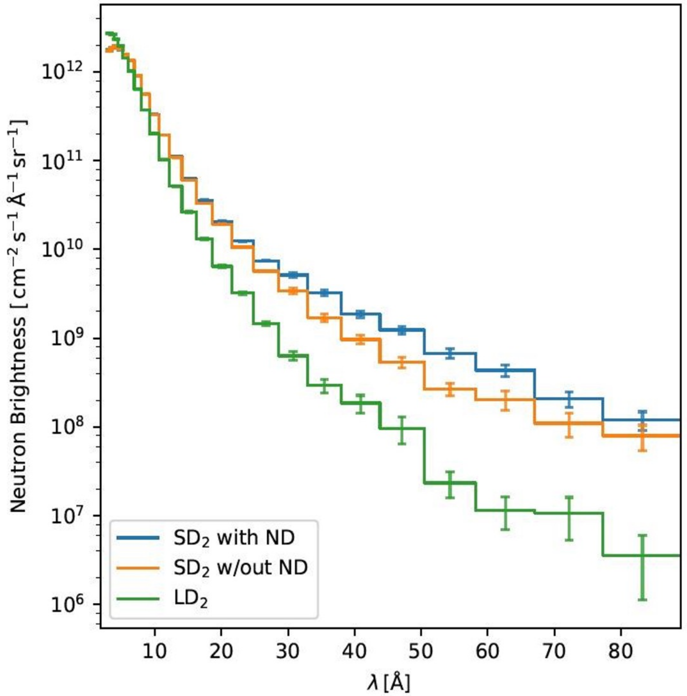
Dedicated VCN moderator

Ferenc Mezei Journal of Neutron Research 24 (2022) 205–210

in order to be advantageous in SANS type of experiments, must therefore provide high intensity at wavelengths $\lambda > 10$ Å, that is above the presumed λ^{-5} dependence of the spectra of current cold moderators (which happens to be only well established in practice for neutron wavelengths below 10–20 Å).

Different, innovative, more sophisticated moderator designs might eventually even offer larger favorable deviation from the λ^{-5} dependence.





~ $\lambda^{-3.5}$

λ^{-5}

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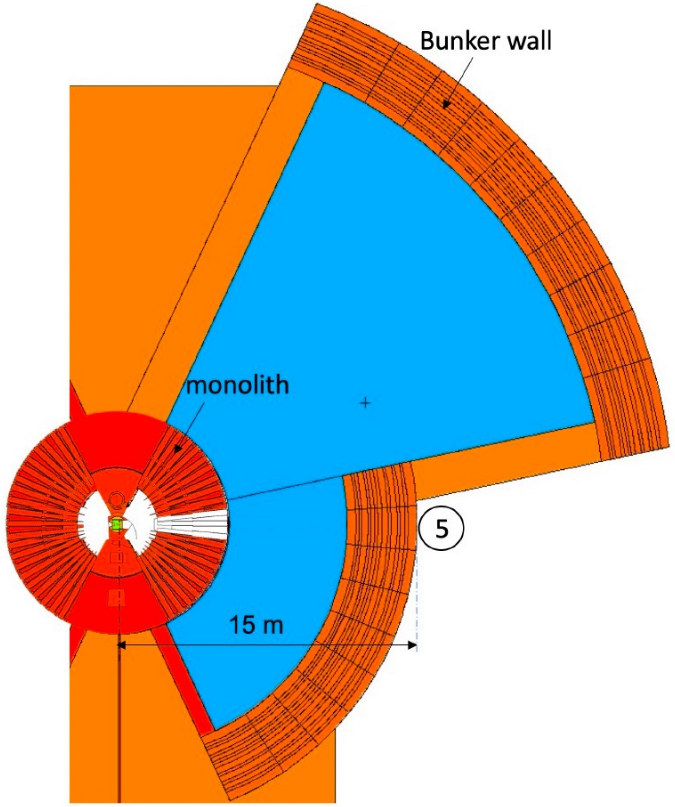
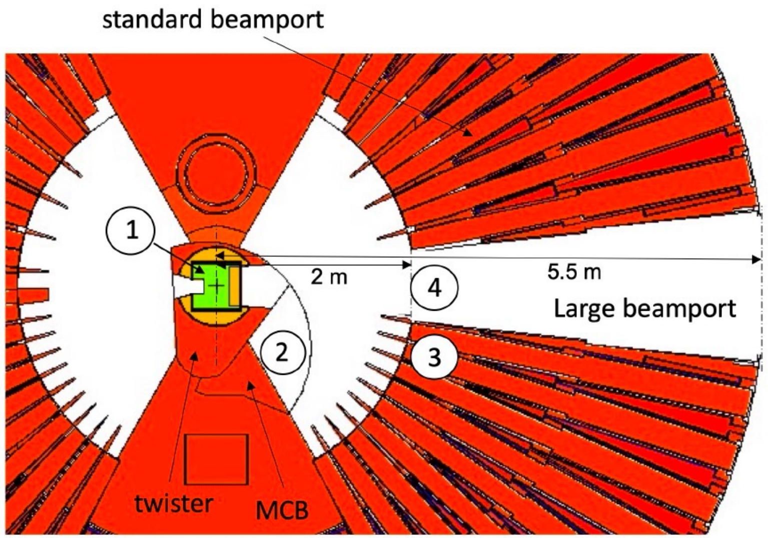
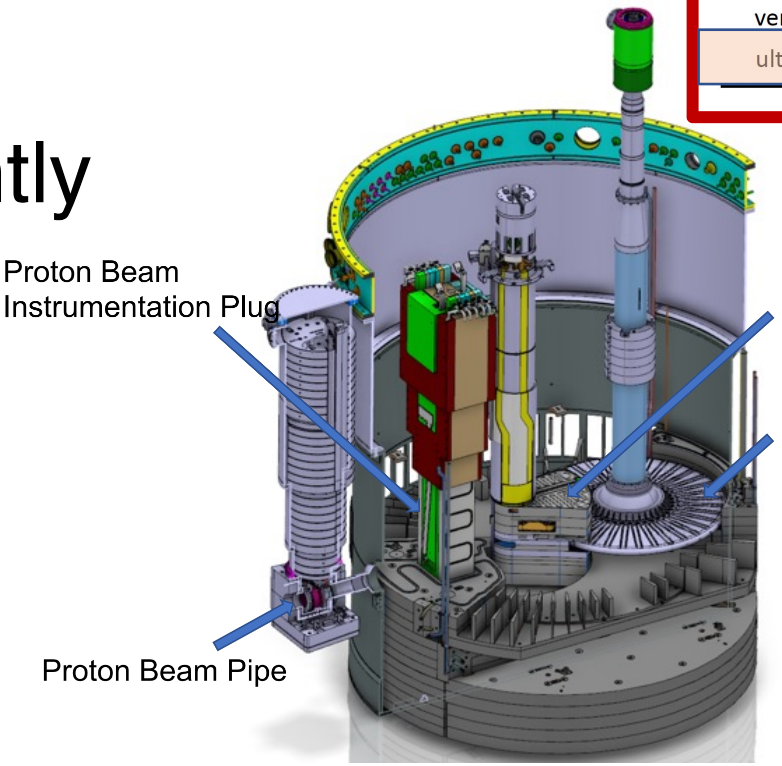
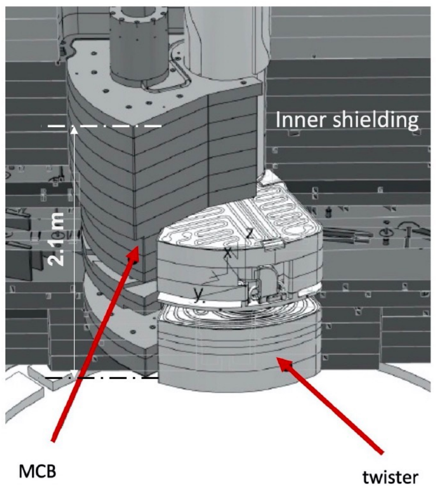
UCN sources: possible locations identified at the workshop are currently under study

cold	2-20 Å
very cold	10–120 Å
ultracold	> 500 Å









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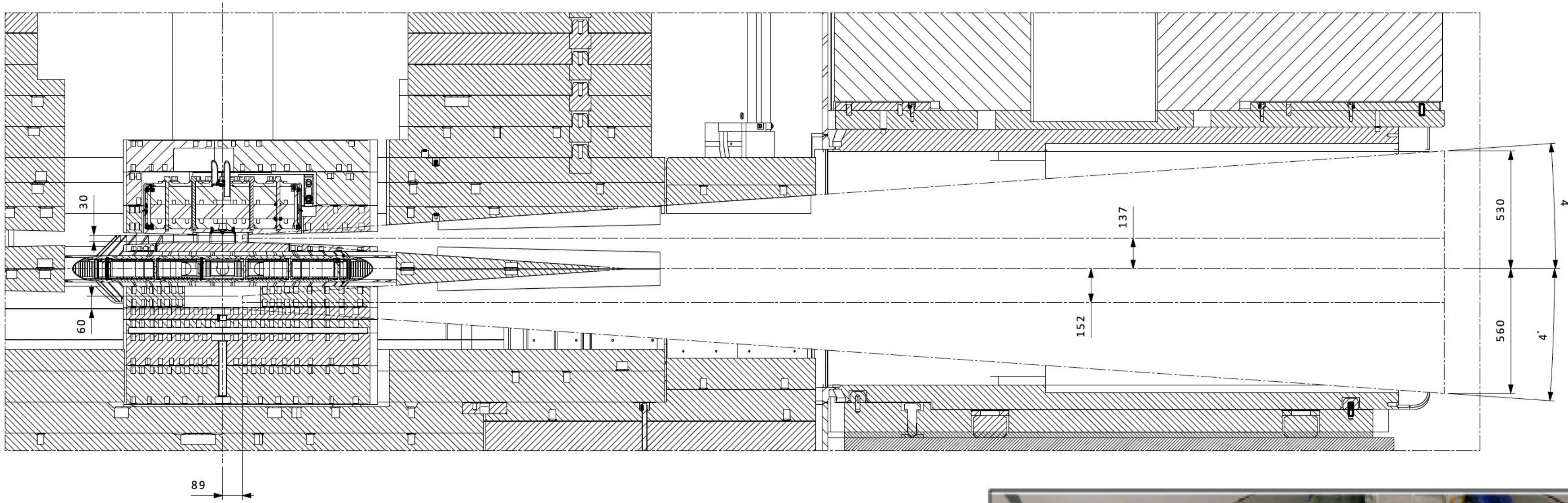
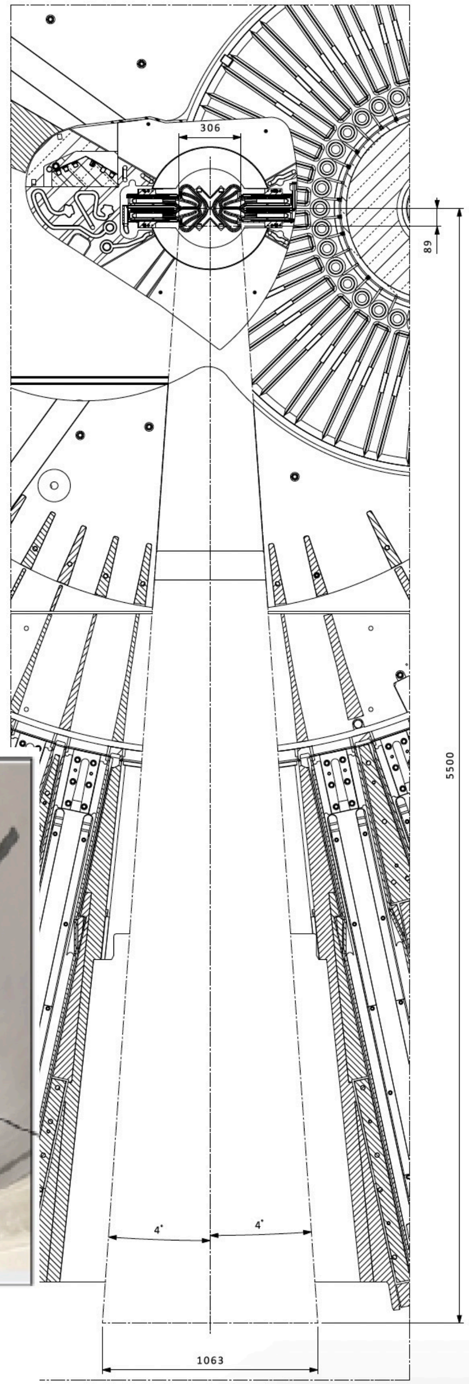
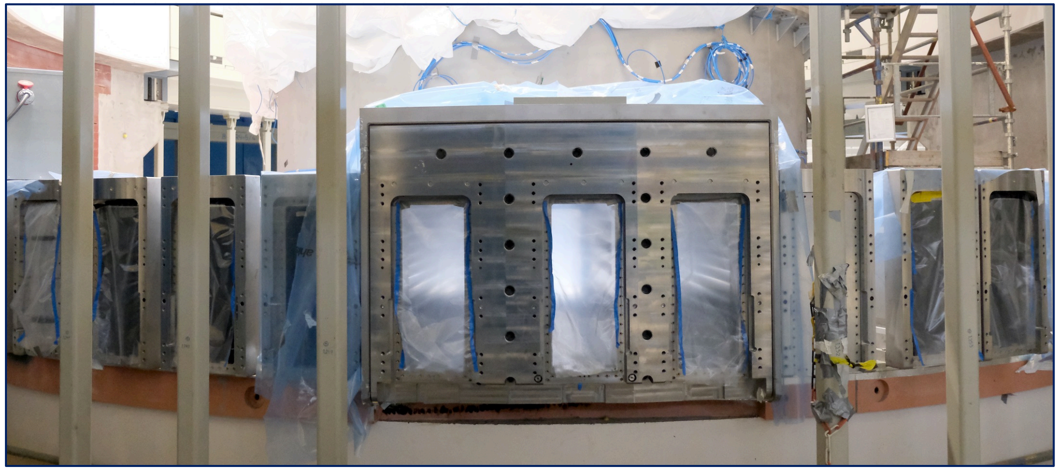
The Large Beam Port for NNBAR could accommodate a UCN source (location 4,5)







regular beamport

monolith vessel

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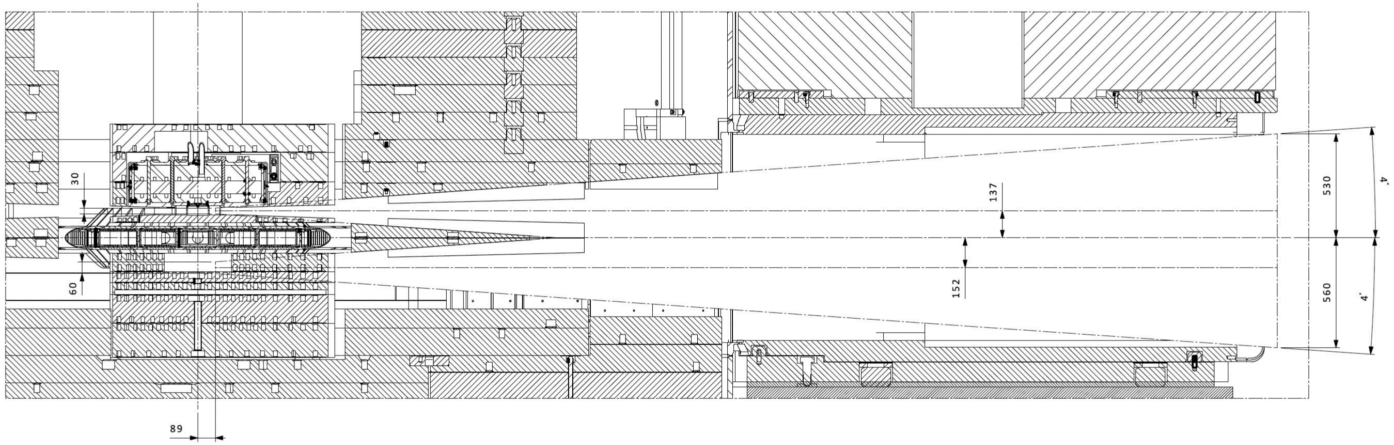
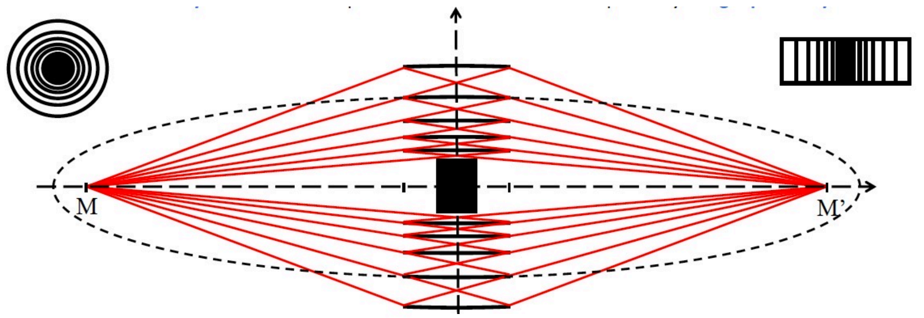
UCN source in large beamport (location 5)

cold	2-20 Å
very cold	10–120 Å
ultracold	> 500 Å

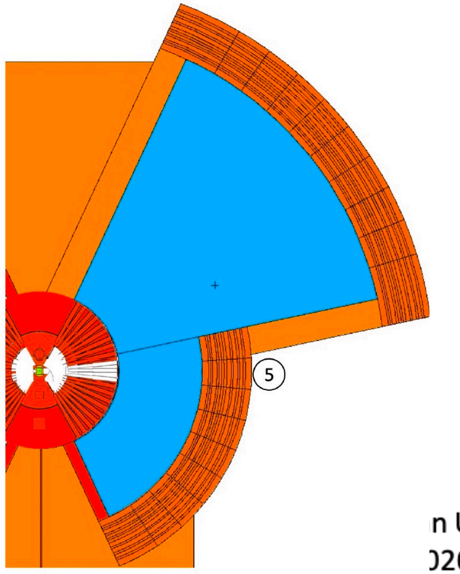
The large beamport for NNBAR could be used for a world-class UCN source



In-beam solution with superfluid He converter and advanced optics system outside the large beamport (concept O. Zimmer)



Neutronic study in progress



- Need a neutron delivery system with high brilliance transfer from moderator to UCN source, with largest technically possible solid angle
- Neutron imaging from the moderator to the UCN source via the arrangement of nested mirrors has been identified as possible solution

Potential production rate in 120 liter source volume of superfluid He: 2.5 x 10^7 n/s

n Union Framework Programme for
)20, under grant agreement 951782

Potential world-leading UCN densities compared to other facilities under design or construction

Results from position 5 (in beam with use of nested mirror optics) are very promising.
Higher production in closer locations, however with bigger challenges

	ρ [cm^{-3} s^{-1}]	ρ V[s^{-1}]	ρ [cm^{-3}]
Gatchina, Russia	$3\ 10^3$	$1\ 10^8$	$6.\ 10^4$
SUPERSUN (ILL)	14	$1.6\ 10^5$	$1.7\ 10^3$
SHIN (compact source)[a]	80	$5\ 10^6$	$4\ 10^3$
LEUNG[b] (inverted geometry)	$5\ 10^4$	$5\ 10^8$	$1\ 10^4$
ESS (NMO) Position 5	**209**	**$2.5\ 10^7$**	**$6.3\ 10^4$**

Source: O. Zimmer, UCN/VCN workshop 2022

[a]arXiv:1810.08722v3 (October 2018)
[b]arXiv:1905.09459 (October 2019)

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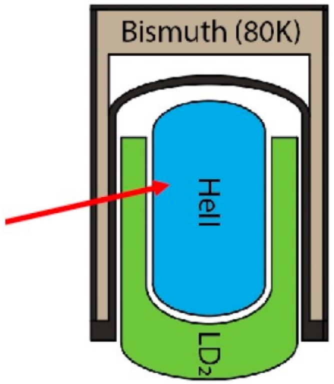
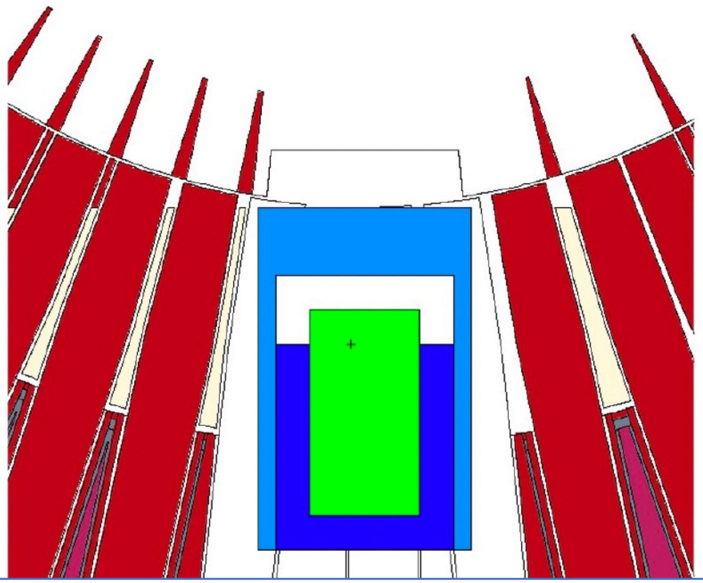
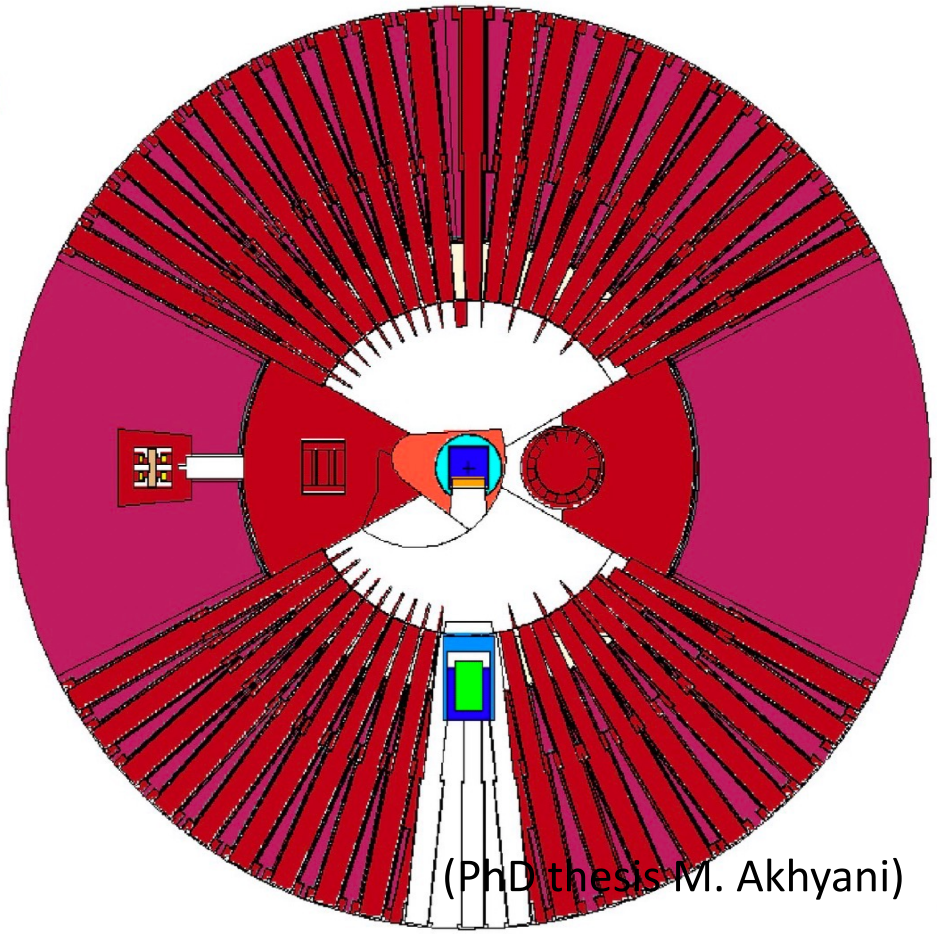
UCN source in large beamport (location 4)

concept by Serebrov-Lyamkin

He4 Box: 60 cm x 30 cm x 32 cm







(PhD thesis M. Akhyani)

Table 5.7: Performance of optimized geometry of He-II UCN source in the LBP.

	He – II Volume [Liters]	P_{UCN} [n/s/cm^3]	$\dot{N}_{\mathrm{UCN}}$ [n/s]	Heat-load [W]
He-II in LBP (Final design)	57.6	590	3.4×10^7	32.2

Conclusions

- The HighNESS project started in October 2020 and ended in September 2023
- The scope is the development of the ESS upgrade
- For the cold source, neutronic and engineering design has been completed, with expected intensity 10 times higher than upper moderator.
- For the VCN source, we have an outstanding design with SD2 + nanodiamonds
- For the UCN source simulations several options have been investigated. We think a world-leading UCN source can be built.
- The HighNESS CDR is under publication as a special issue of JNR, divided in 2 parts: General Results, and NNBAR.
- A follow-up grant proposal, called DICE, has been submitted to EC

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DICE: Development of an Infrastructure for colder neutrons without Carbon Emissions

HORIZON-INFRA-2024-DEV-01 proposal

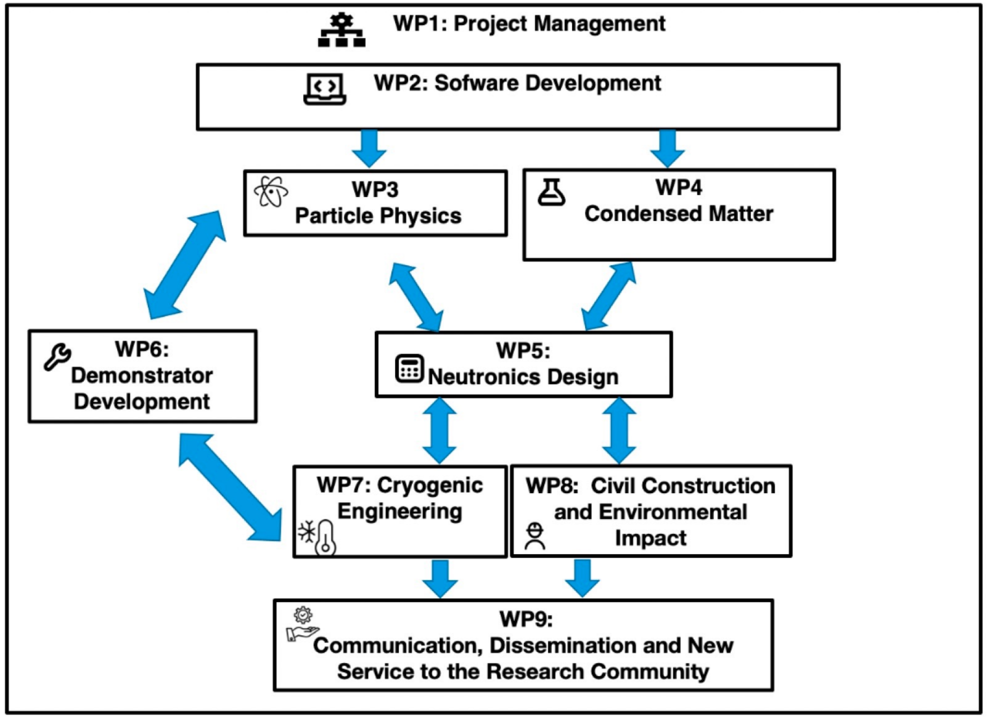
SO4. New services offered to communities

SO3. Source Design and engineering, including sustainability

SO2. Design of the future experiments and instruments

SO1. Software and model development

Cold Neutron source	Very Cold Neutron source	Ultra Cold Neutron source



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Thanks to everybody