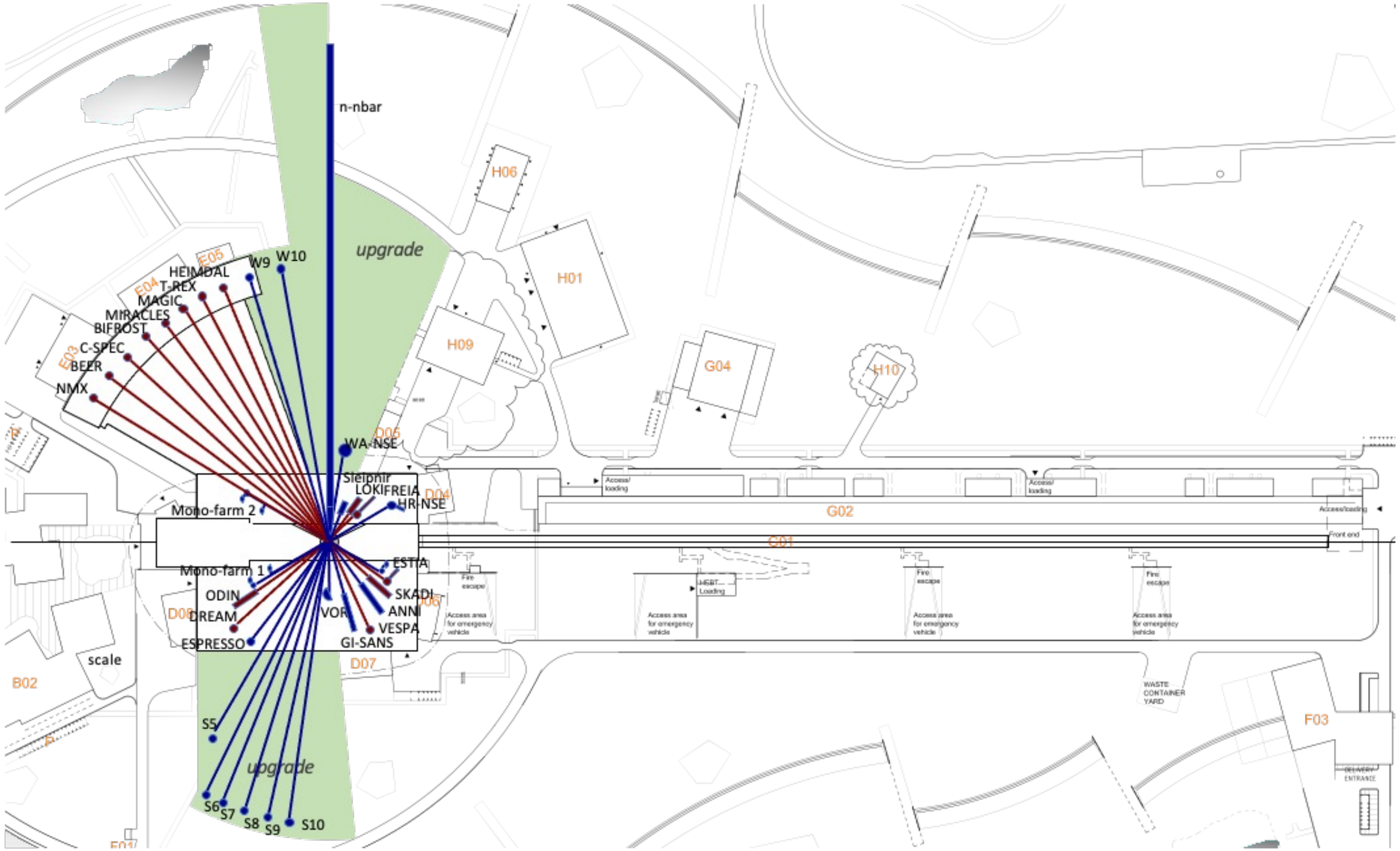
Introduction to the HighNESS UCN/VCN source designs

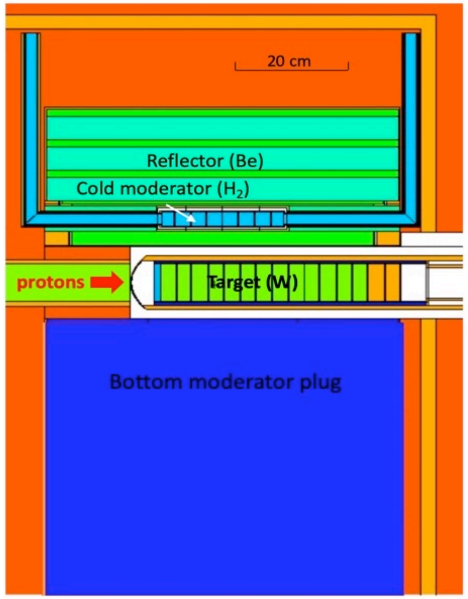
Luca Zanini

for the HighNESS consortium

Second workshop on UCN and VCN sources at ESS, Lund, 9-10 May 2023

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





The green part show the upgrade area

HighNESS source, compared to main source should have:

- Higher intensity
- Colder spectrum

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Ten years ago…

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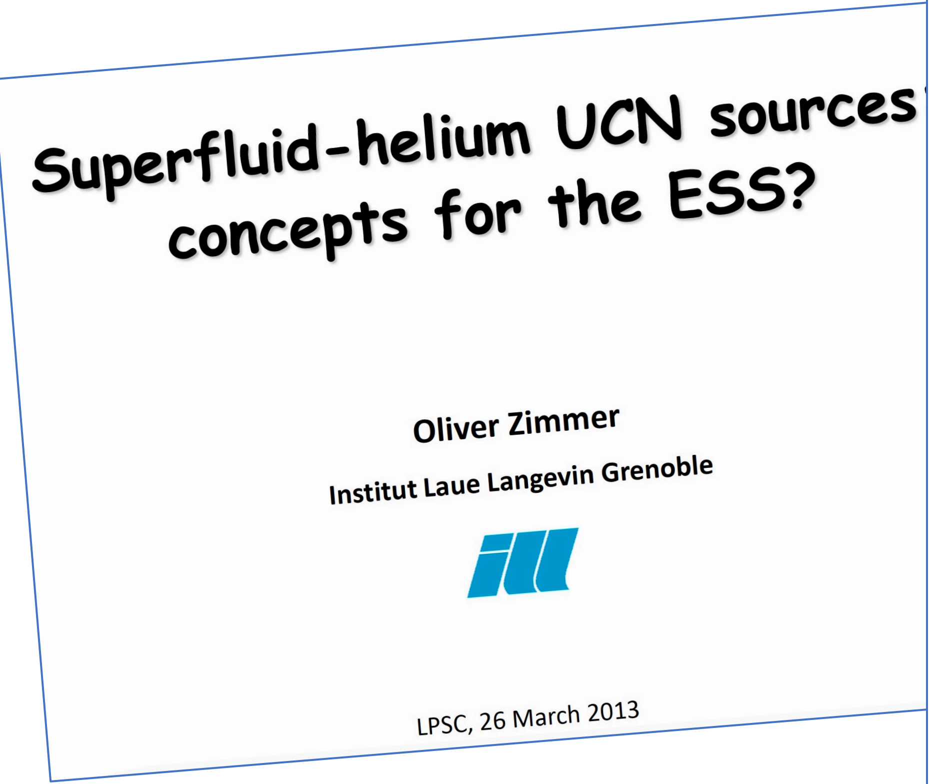
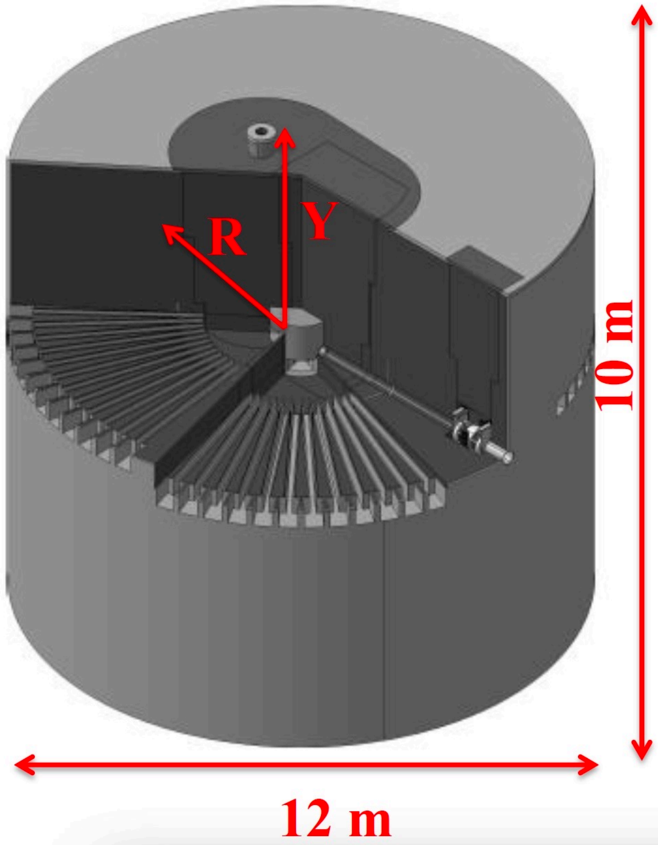


https://lpsc-indico.in2p3.fr/event/866

Potential opportunities for ESS:

- huge feeding guide for ex-pile UCN source
- optimization of cold beam spectrum with colder pre-moderator
- design of optimized in-pile UCN source



Heat deposition in the target monolith

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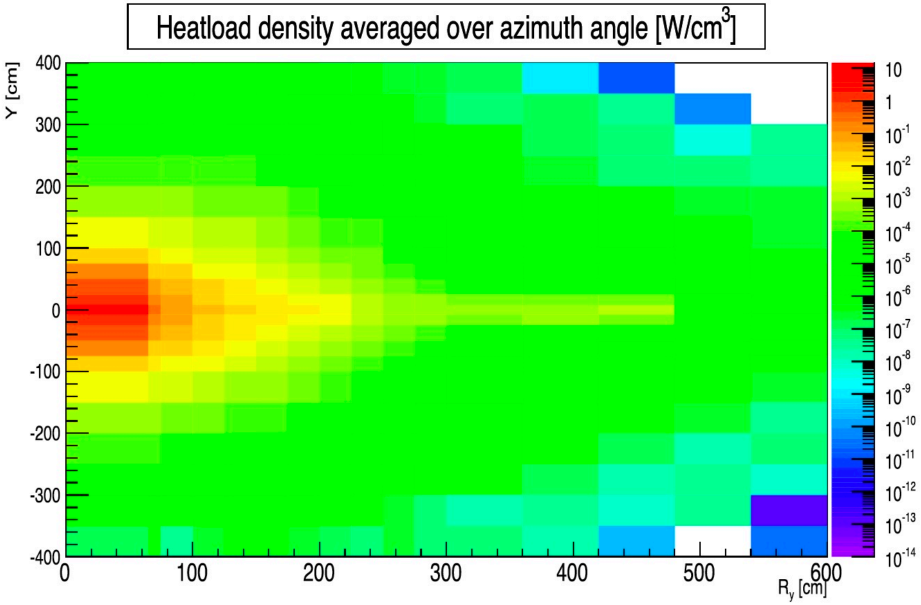

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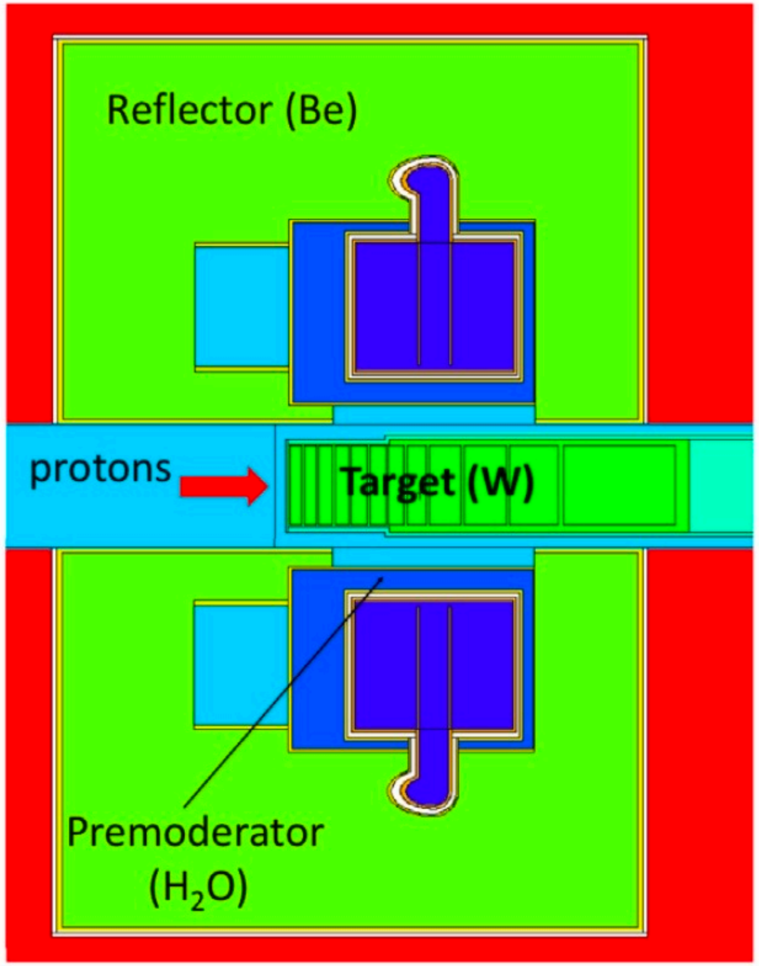
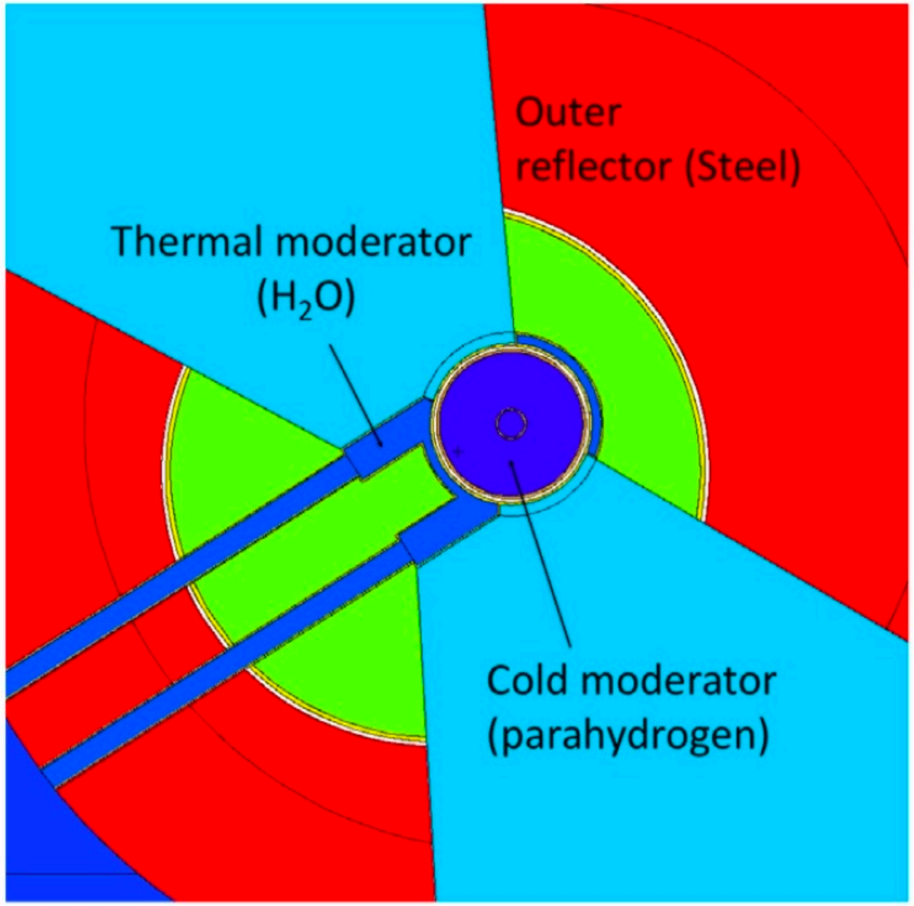
Technical Design Report (TDR) design





M. Magan et al, Nuclear Instruments and Methods in Physics Research A729 (2013) 417–425

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Beam extraction from TDR moderators (2013)

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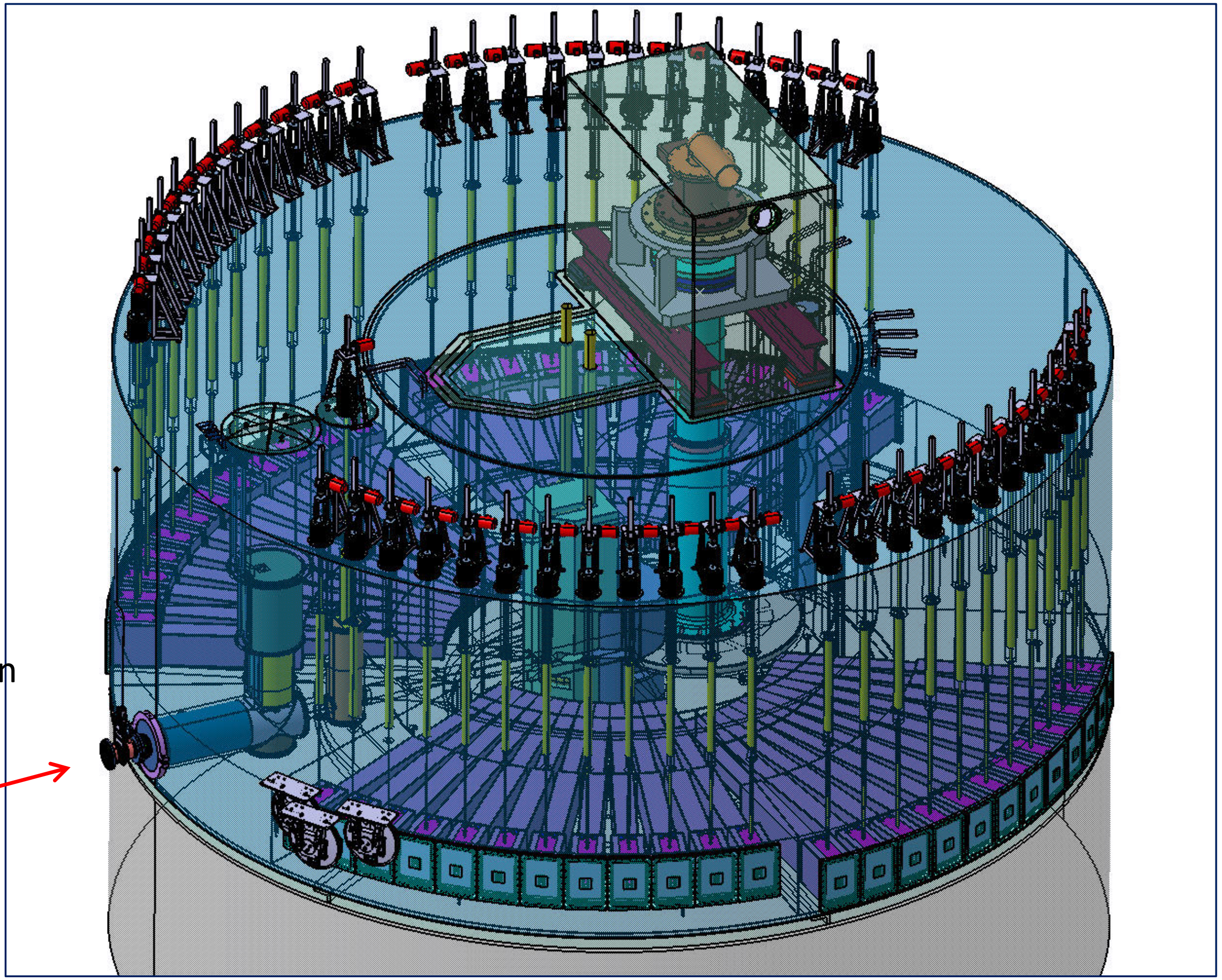
TDR: 2 identical moderators; beamports can look only to one moderator



Proton beam

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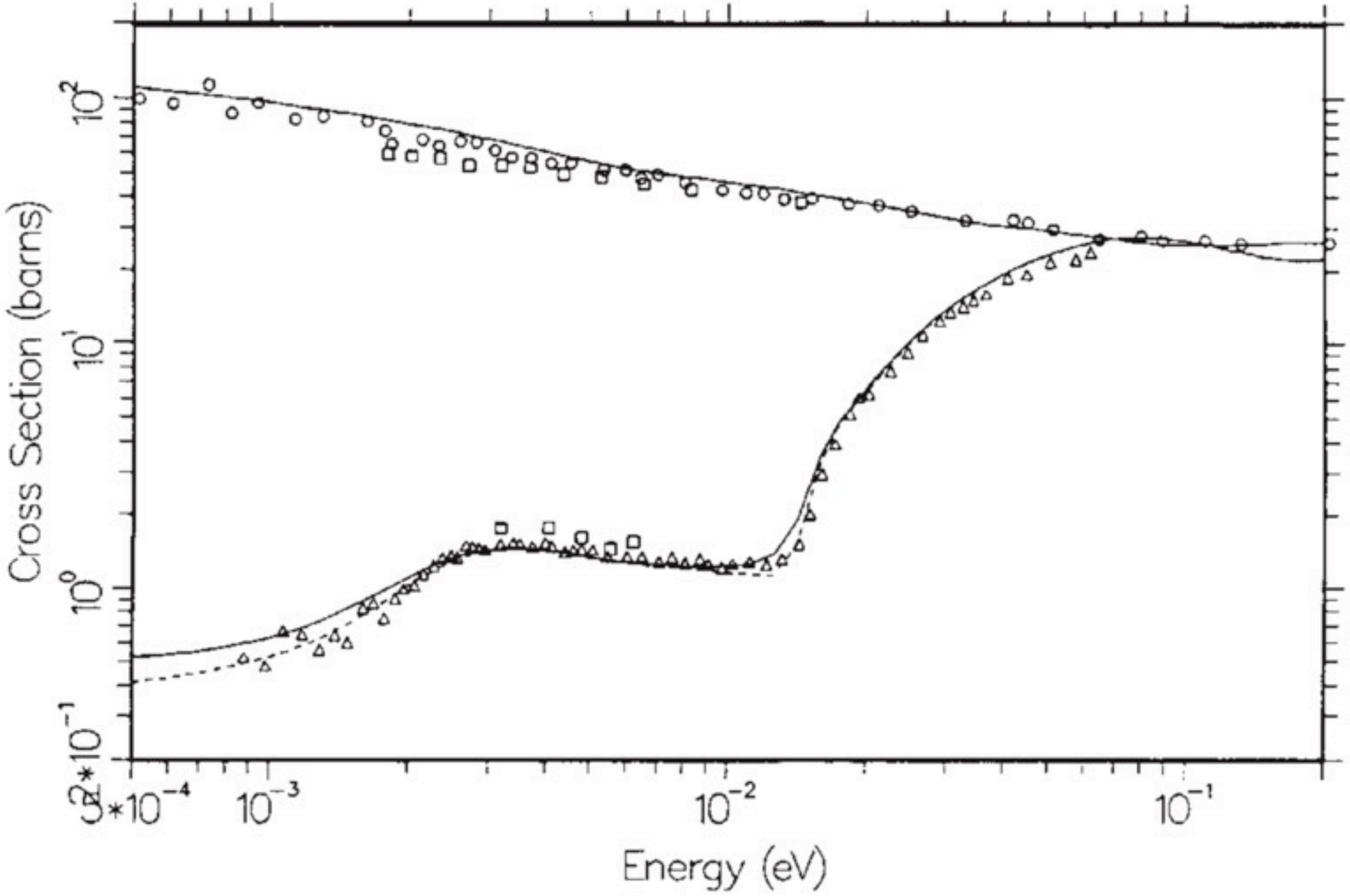
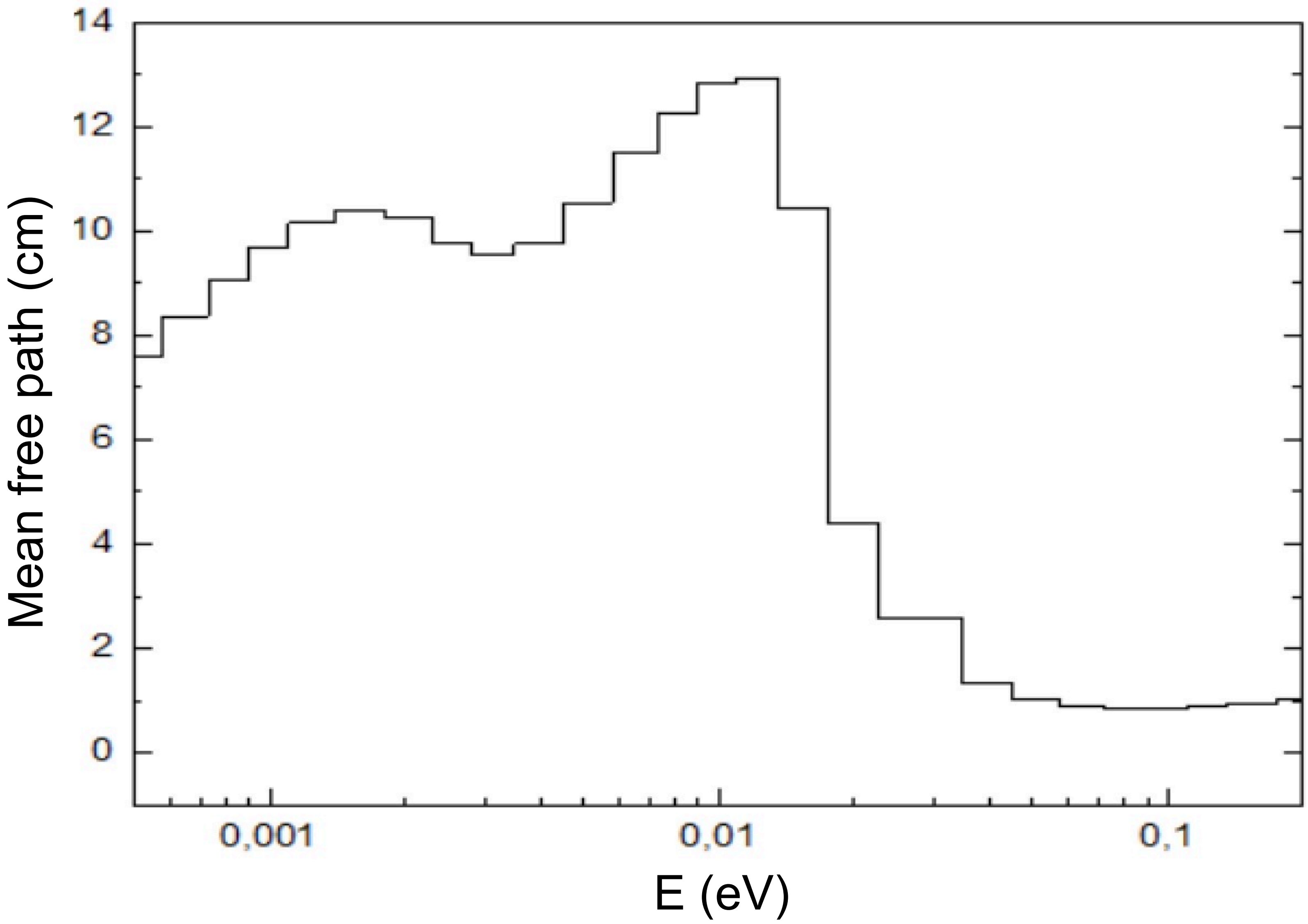


Cross Section (barns)
10^2
10^1
10^0
$2*10^{-1}$
$3*10^{-4}$
10^{-3}
10^{-2}
10^{-1}
Energy (eV)

Higl
Resε



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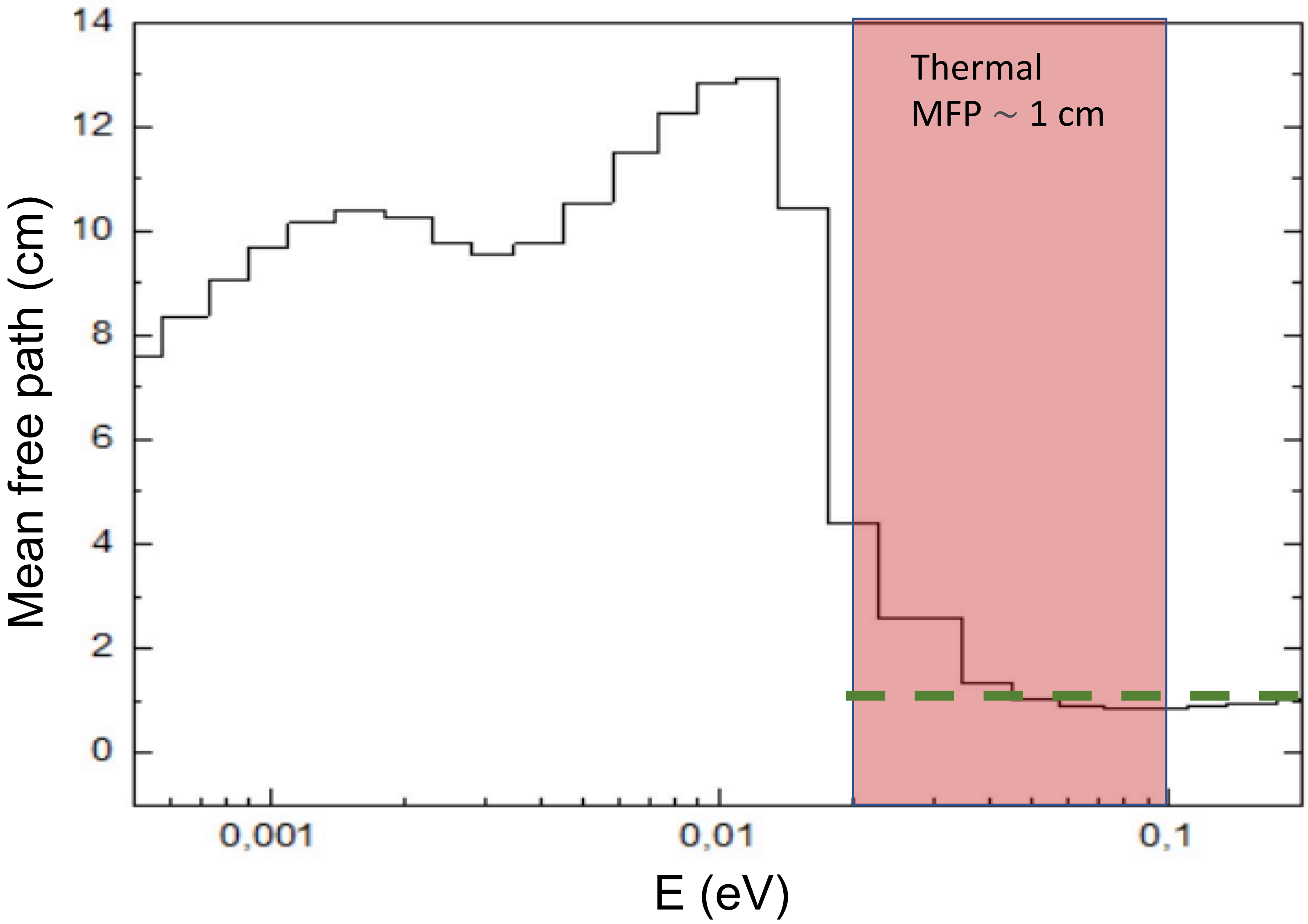

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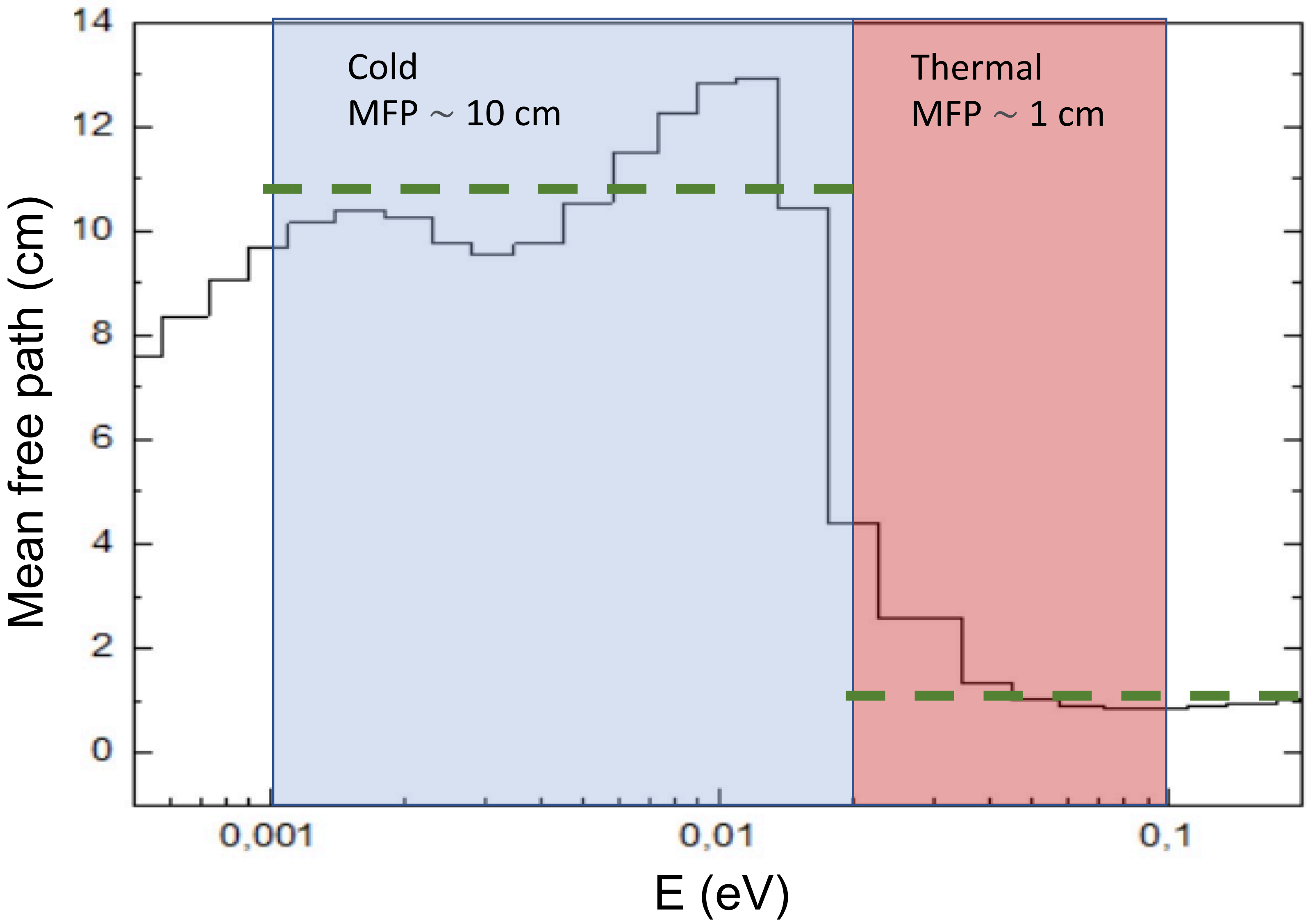

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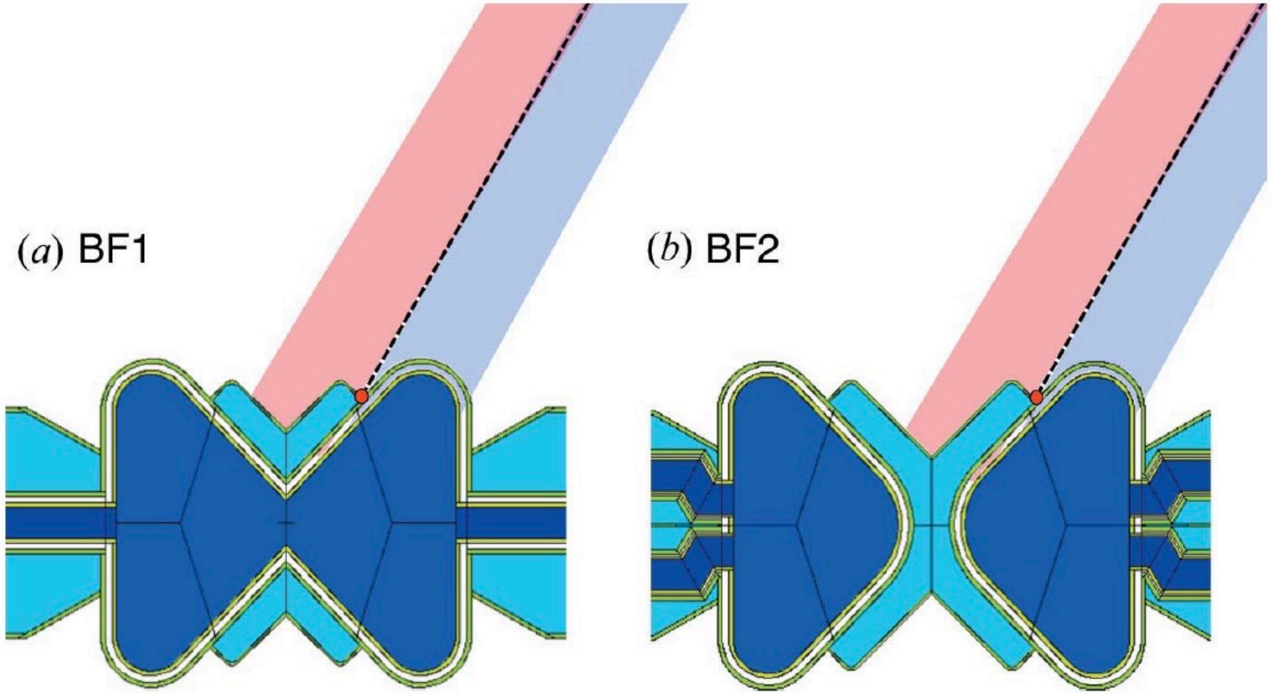

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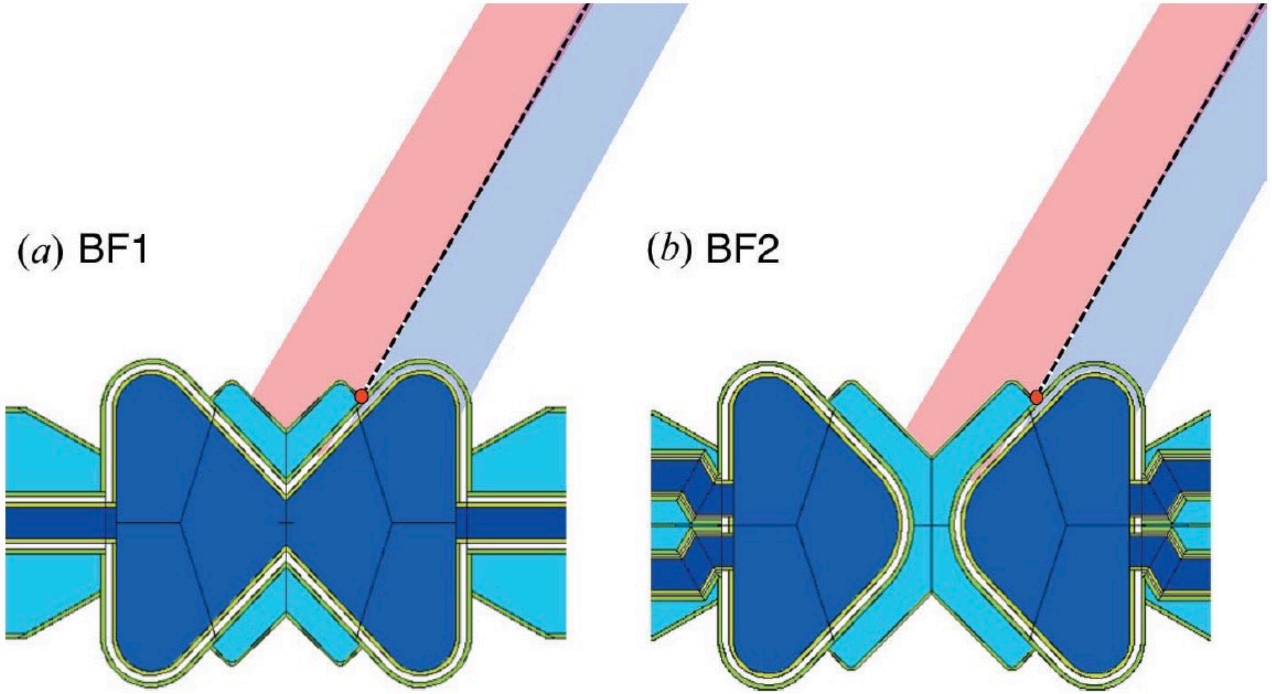
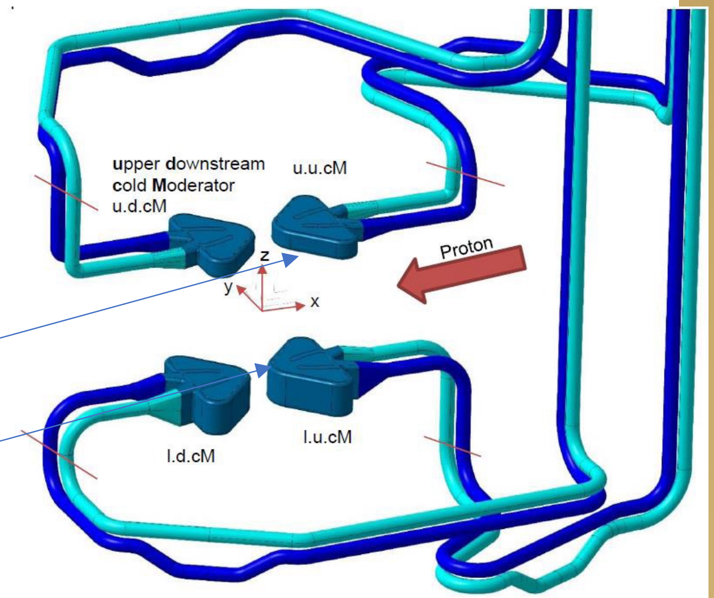


3 cm

6 cm



(Y. Bessler)

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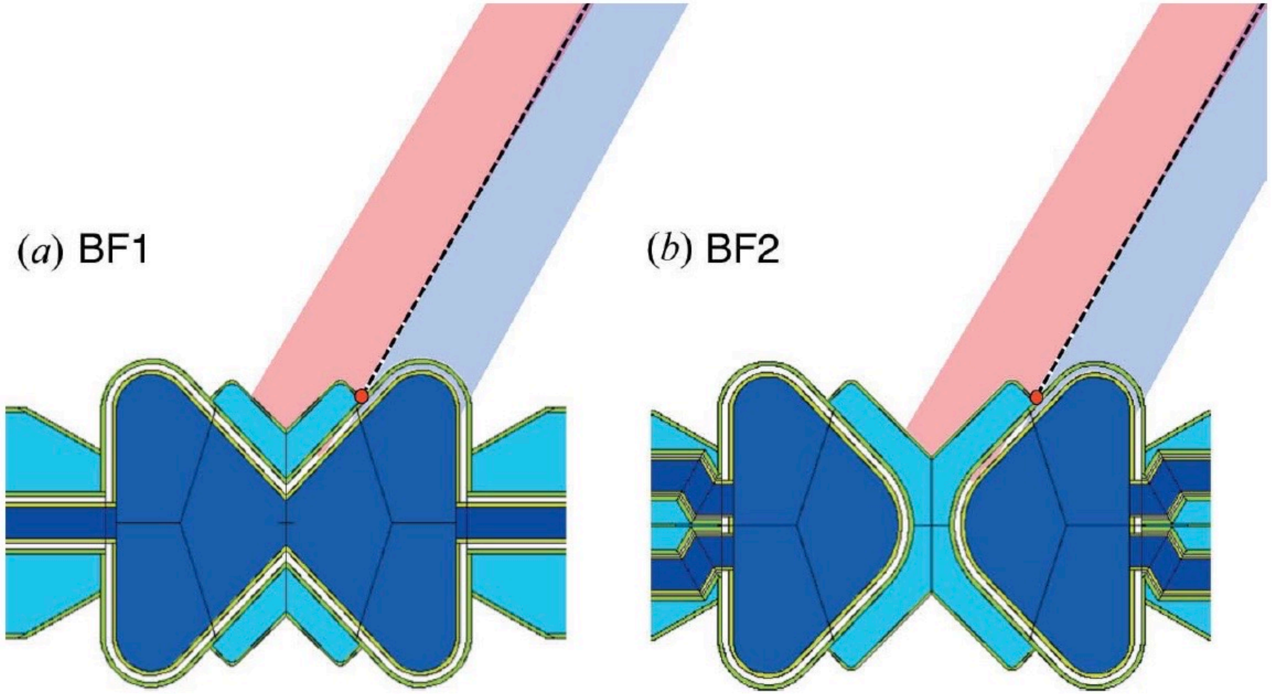

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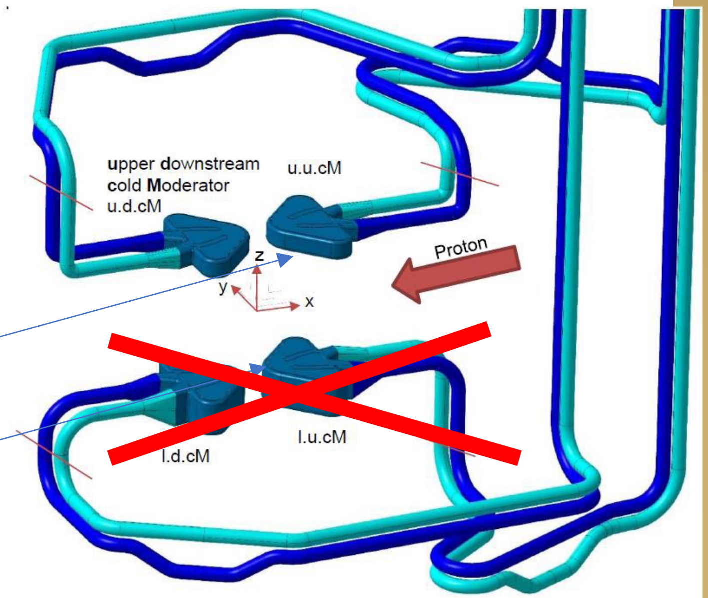

(Y. Bessler)

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The choice to go for low-D moderators had a profound impact on the design of the facility

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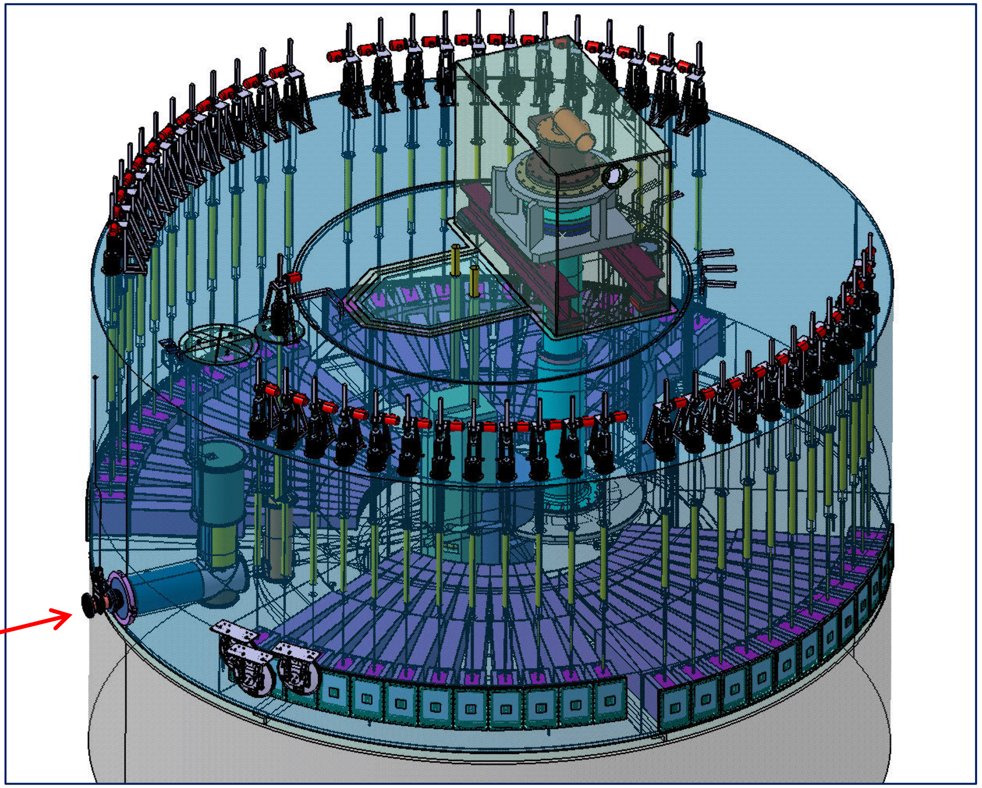
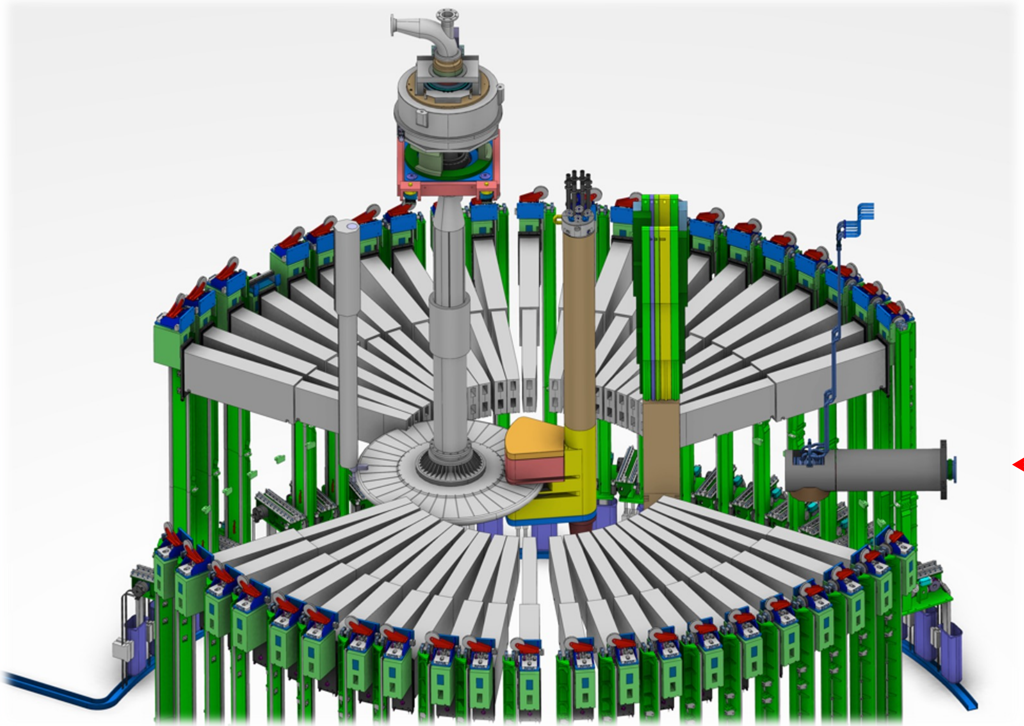
TDR: 2 identical moderators;
beamports can look
only to one moderator

Proton
beam



Present design:
1 upper moderator; lower moderator to be defined
each beamport can look to both moderators



Proton
beam

present

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Research and Innovation H er grant agreement 951782

In summary:

- Efficient neutron economy allowed for a more flexible and with a higher potential upgrade path of ESS, where a new source complementary to the main source can now be built.
- HighNESS is based on that, but relies also on
  - High power from the accelerator (like upper moderator)
  - Large beamport (more than upper moderator)
  - Use of moderator cooling block (novelty in HighNESS).

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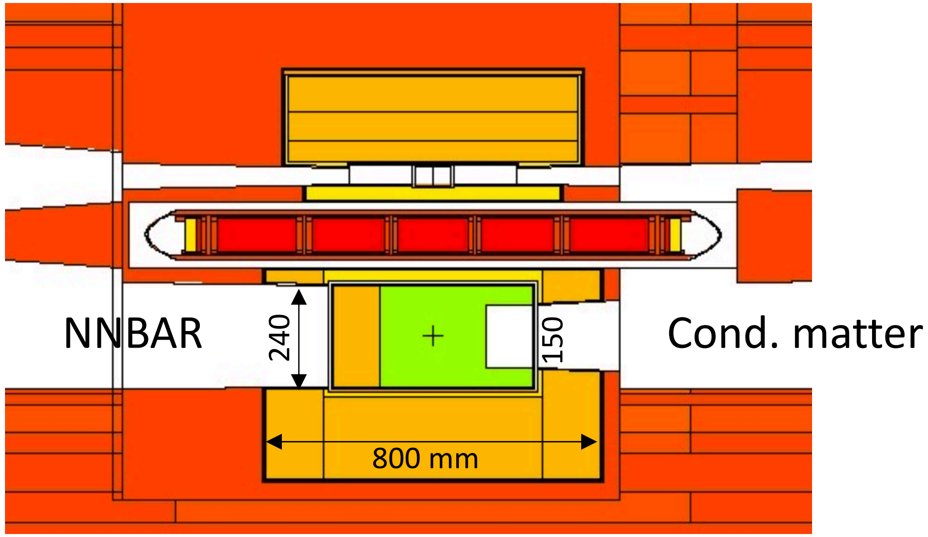
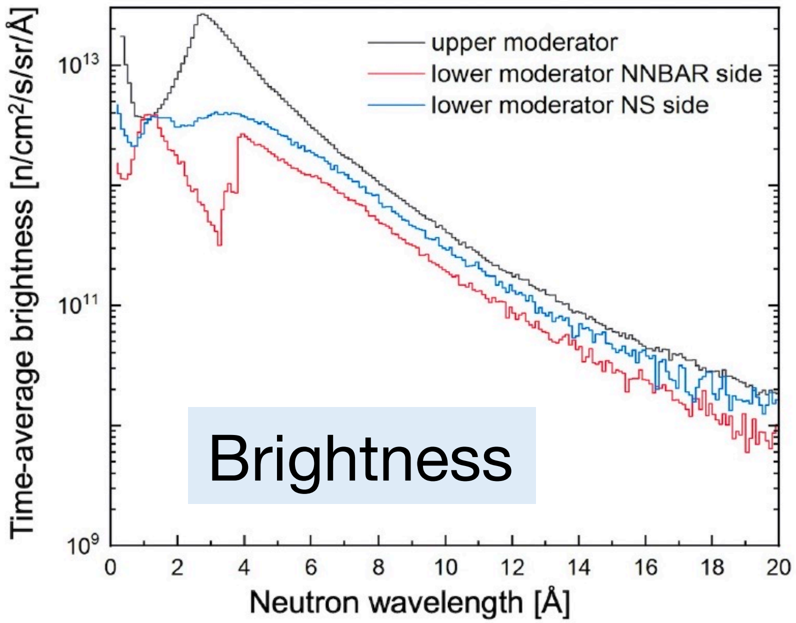
High-Intensity Cold Source

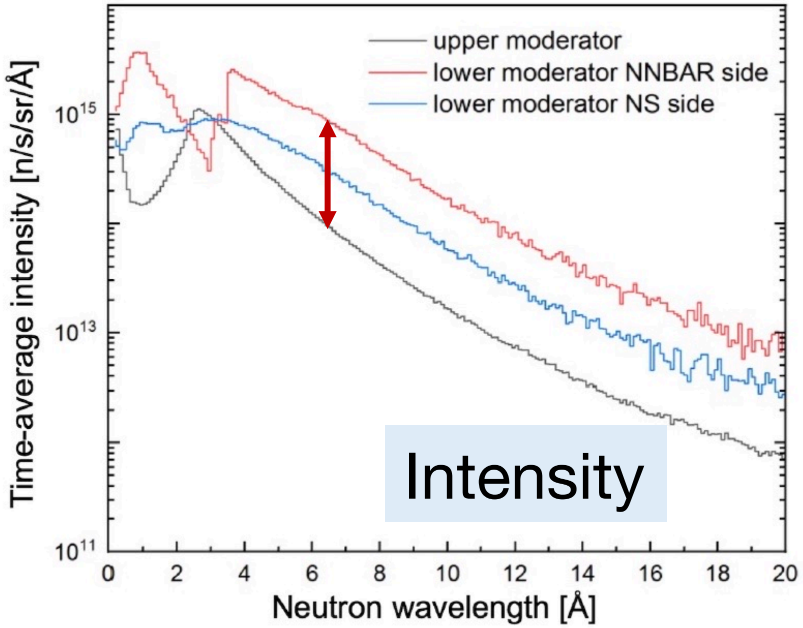


liquid deuterium moderator
two openings,

- NNBAR
- neutron scattering

FACTOR 10 above 4 Å





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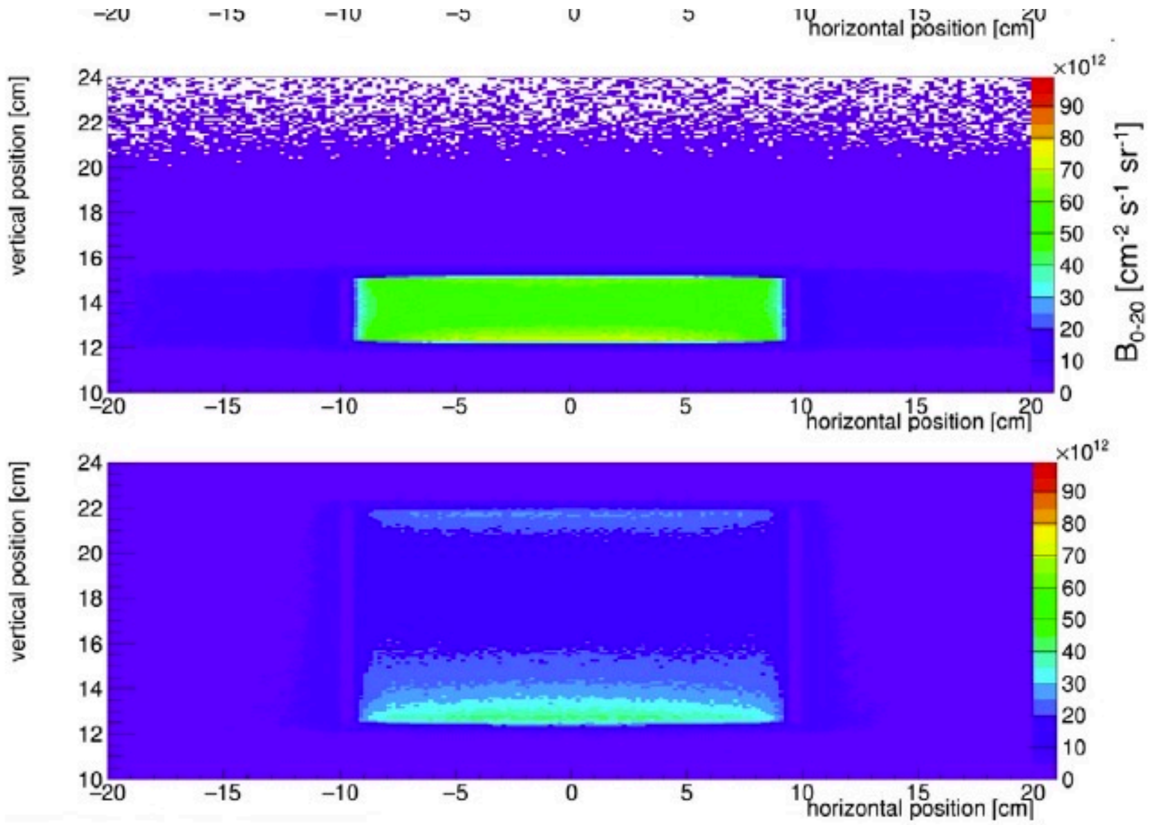
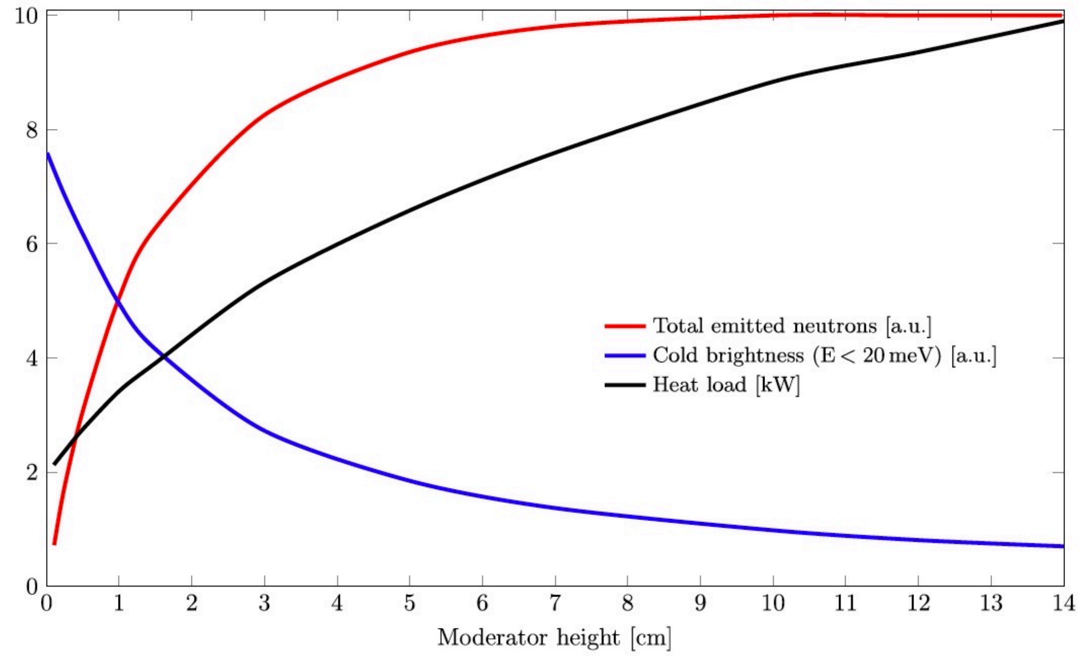
Research and Innovation Horizon 202

We cannot reach high intensity with parahydrogen





L. Zanini et al. Nuclear Inst. and Methods in Physics Research, A 925 (2019) 33–52

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(courtesy U. Odén)

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UCN options

LOCATION

In-pile: inside target monolith $R < 5.5$ m
In-beam: at $R > 5.5$ m

MATERIALS

Superfluid He
Solid deuterium @ 5 K

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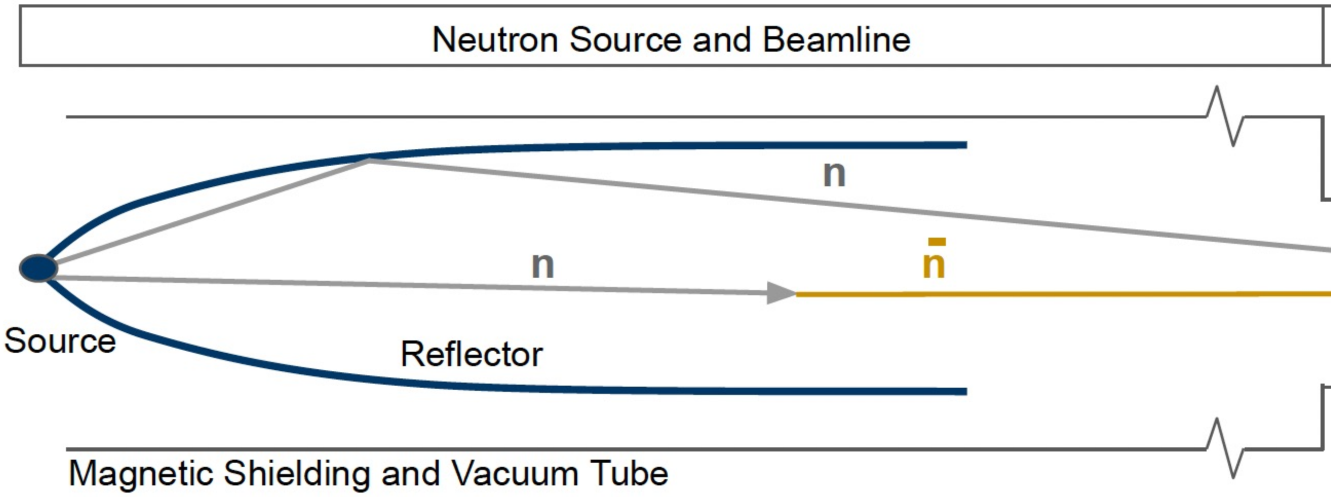
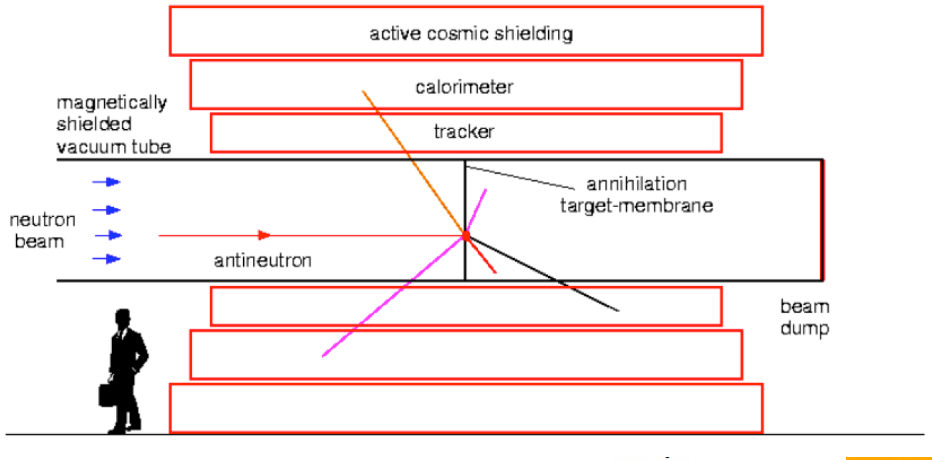
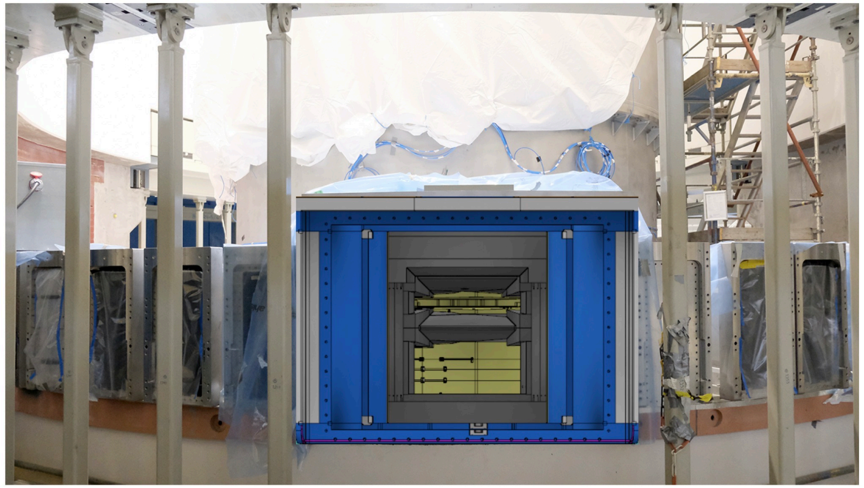
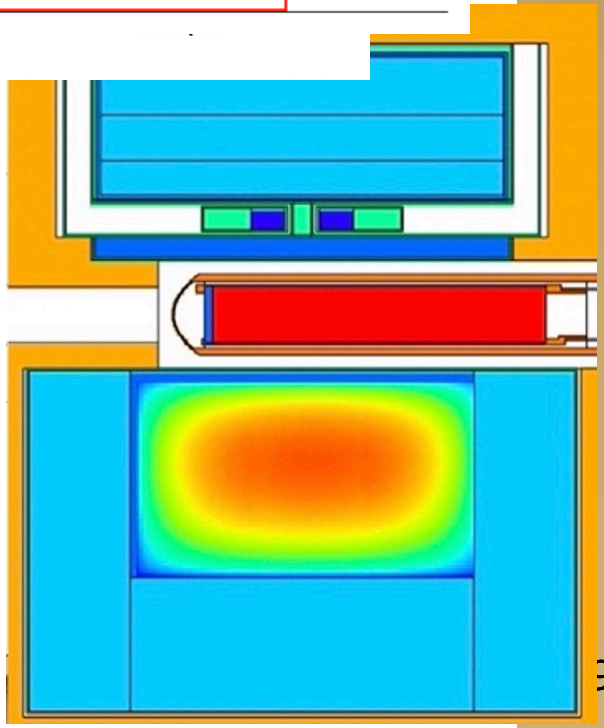
NNBAR at the large beamport
a 1000 gain wrt previous (ILL, 1994) experiment

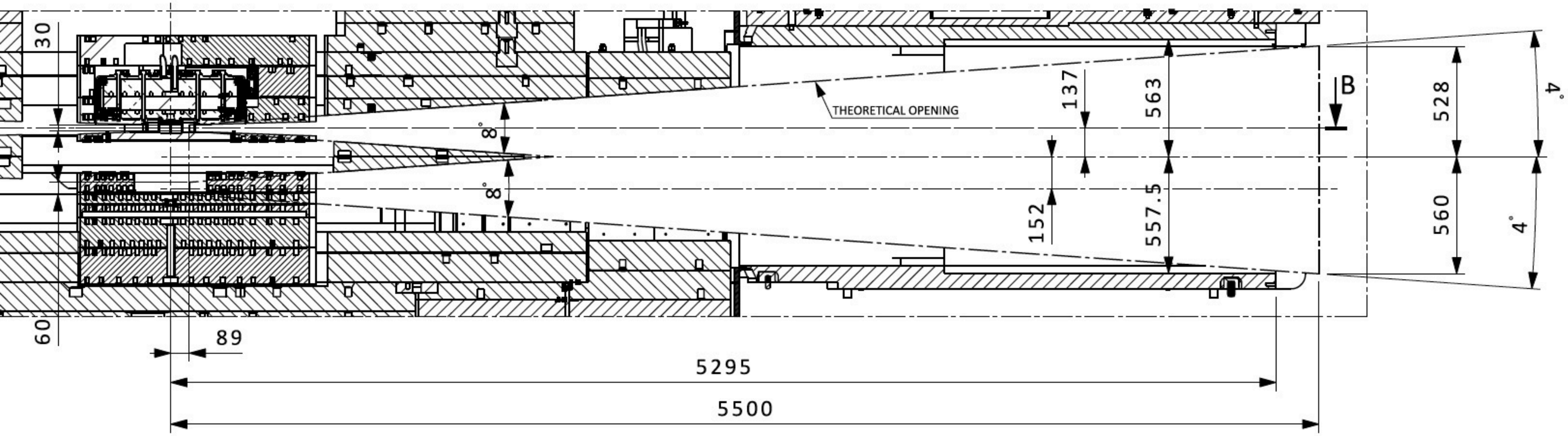




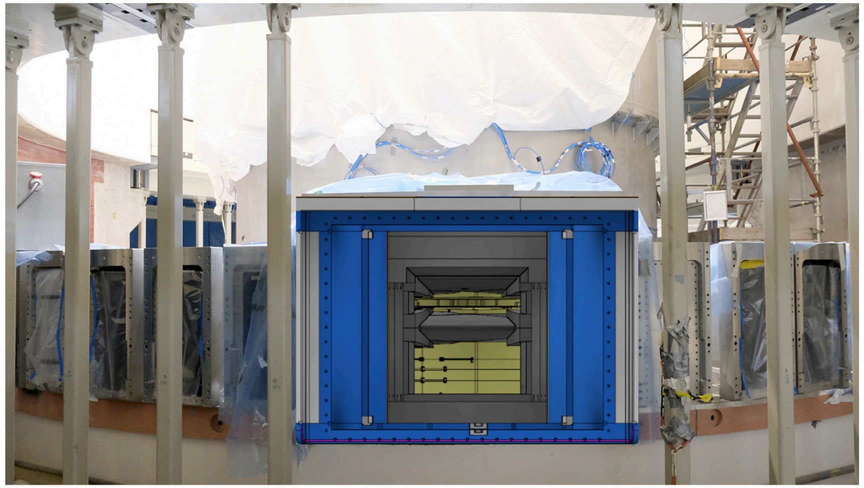


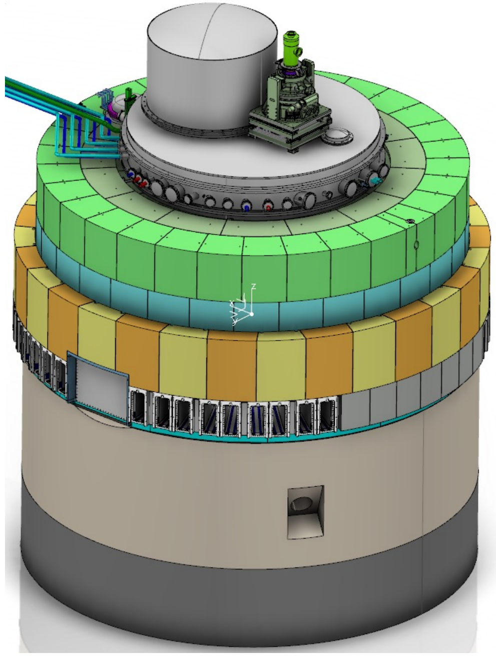


The large beamport offers great opportunities for UCN



NNBAR solid angle:
~ 0.04 sr
Typical neutron scattering solid angle:
~ 0.0006 sr
Advantages for UCN:
(e.g. nested mirrors, insert large source)





The Moderator Cooling Block is a “free”* location for an additional source

HighNess

84 *L. Zanini et al. / Very cold and ultra cold neutron sources for ESS*

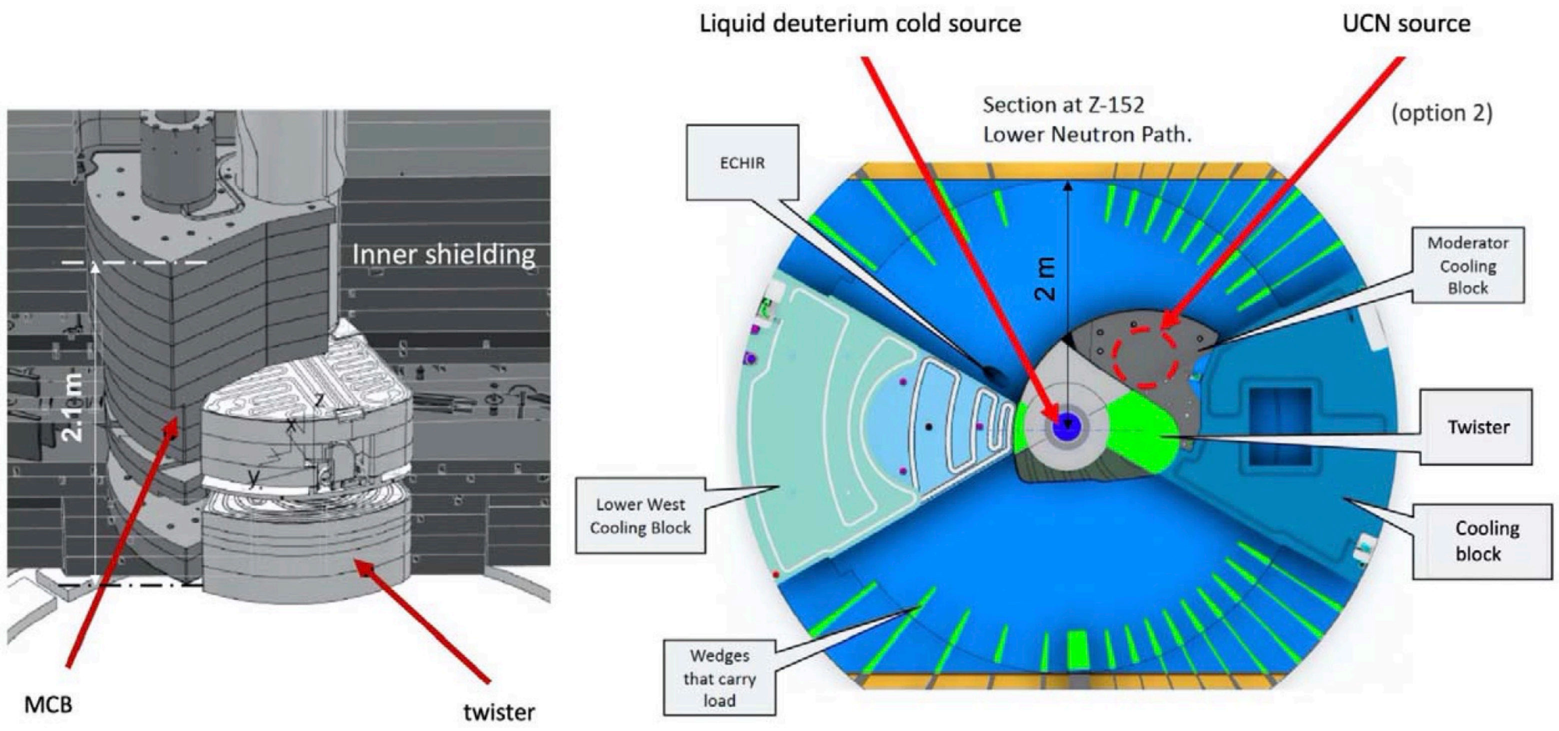


Fig. 6. *Left*: a CAD drawing of the twister and moderator cooling block, with part of the inner shielding for display. *Right*: horizontal view at the height of the lower moderator (courtesy R. Holmberg). The LD_2 moderator is placed inside the twister. A possible location of a secondary source inside the MCB is indicated by the dashed circle.

*Requires handling in the hot cell not required for a standard MCB

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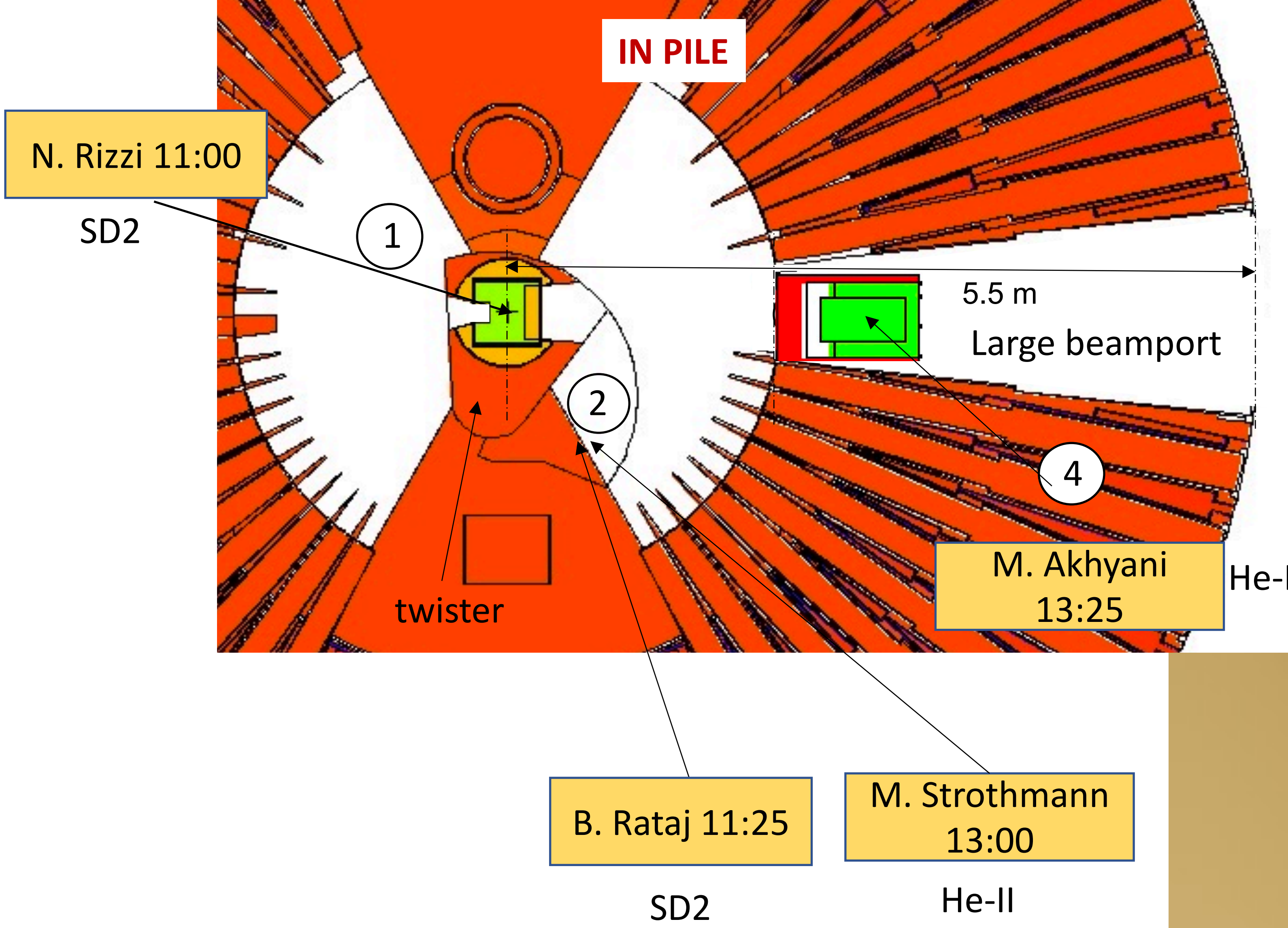

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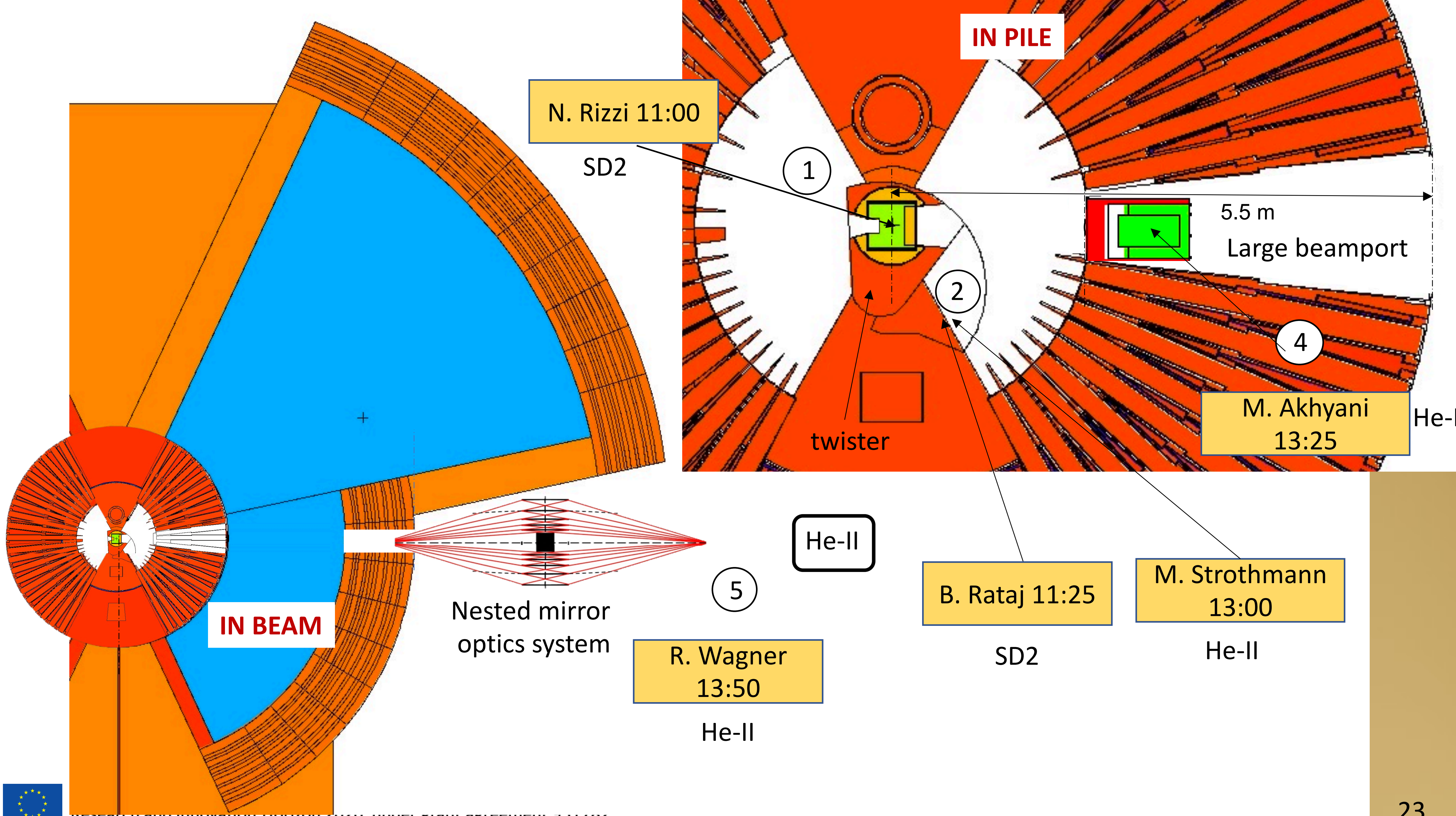
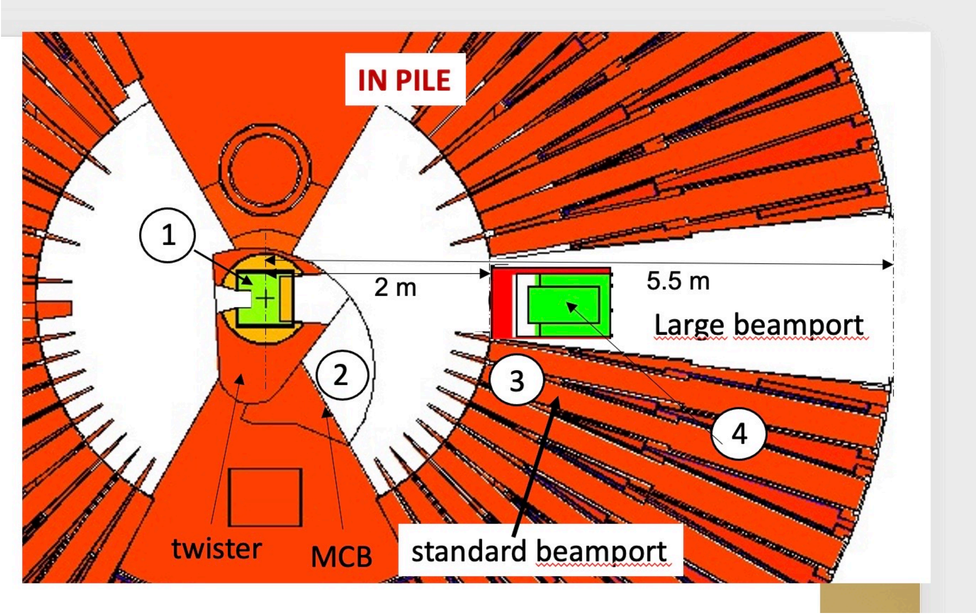
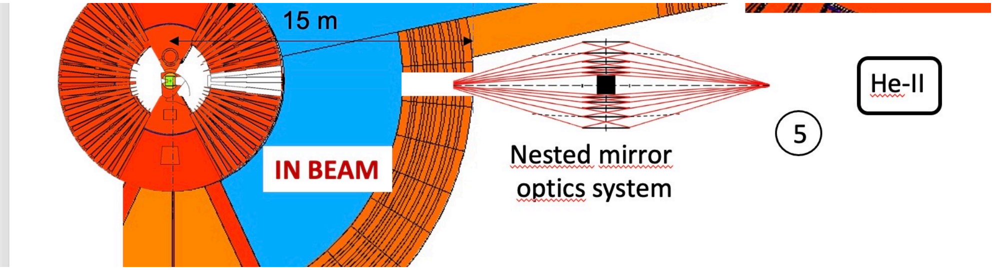

IN PILE
N. Rizzi 11:00
SD2
1
5.5 m
Large beamport
2
4
twister
M. Akhyani
13:25
He-I
Nested mirror
optics system
IN BEAM
He-II
5
R. Wagner
13:50
He-II
B. Rataj 11:25
SD2
M. Strothmann
13:00
He-II

Snapshot from UCN deliverable

some numbers have since improved





Option	Volume [liters]	P_{UCN} [cm^{-3} s^{-1}]	$\dot{N}_{UCN}$ [s^{-1}]	Heat [Watt]
SD_2 thin slab in twister - location 1				
Fig. 5	1.81	3.1×10^5	5.6×10^8	760
Fig. 6	1.75	7.7×10^5	1.4×10^9	2910
Fig. 7	0.38	1.3×10^6	5.0×10^8	560
Fig. 9	0.13	1.7×10^6	2.2×10^8	520
full SD_2 in twister - location 1				
Fig. 10	48.2	6.56×10^5	1.32×10^9	39886
SD_2 thin slab in MCB - location 2				
Fig. 18a	0.91	3.8×10^4	3.4×10^7	159
He-II in MCB - location 2				
Fig. 21	24.3	2160	5.23×10^7	328
He-II in LBP - location 4				
Fig. 24	58	369	2.1×10^7	8
He-II in beam - location 5				
in-beam (D4.3)	114	234	1.53×10^7	

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VCN options

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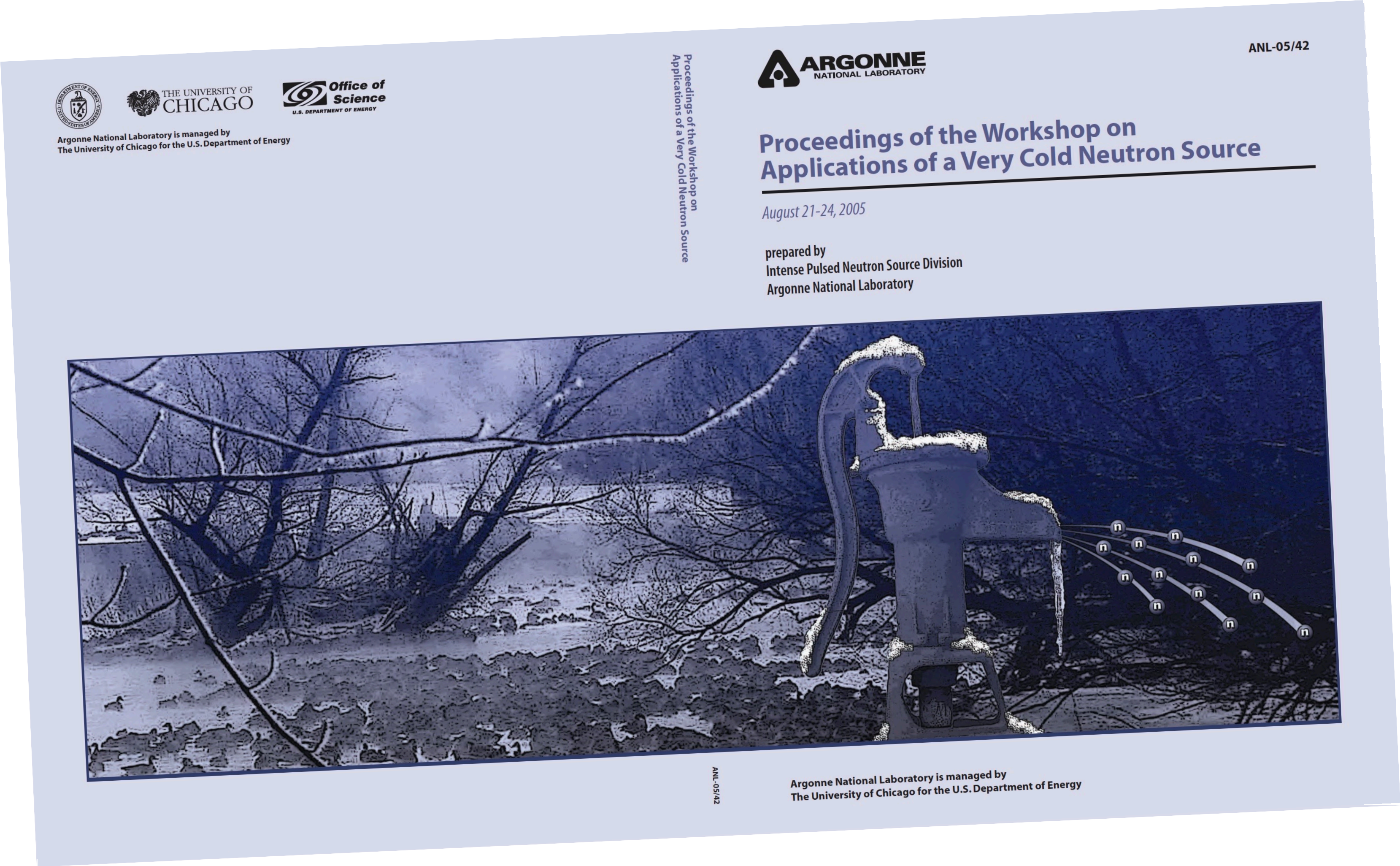
A strong VCN source has been a dream for at least two decades



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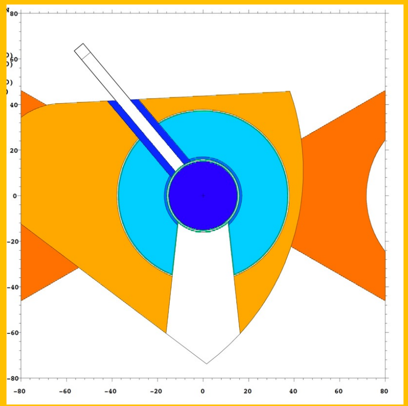
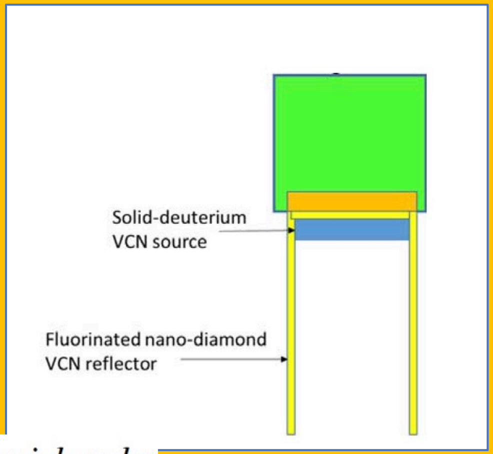
VCN:
1 location (twister);
2 materials: SD2 (+ nanodiamonds), clathrates hydrates

3 concepts:

Extraction from cold source

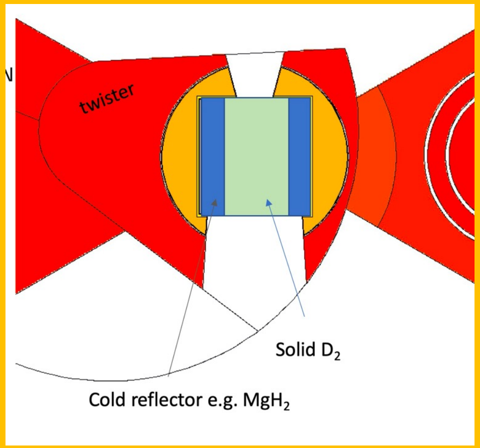


Hybrid LD2-SD2+ nanodiamonds



V. Nesvizhevsky
Journal of Neutron Research 24 (2022) 223–227

Dedicated VCN moderator



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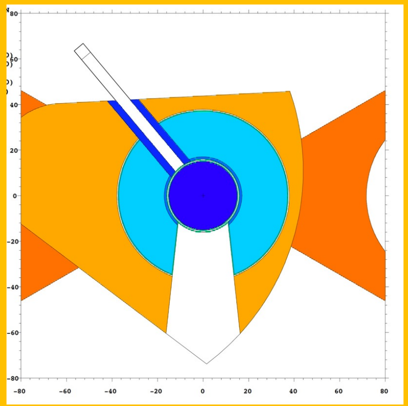
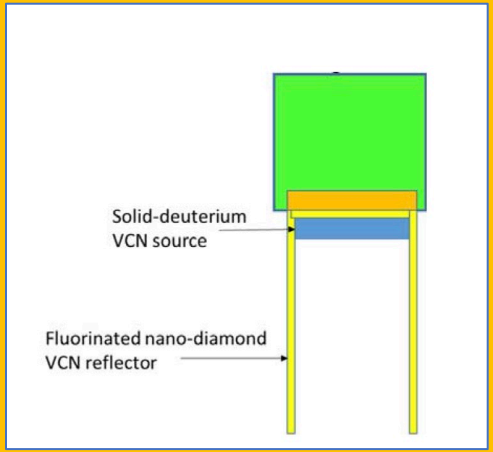
Use of nanodiamonds gives promising gains especially at large divergence angles

Extraction from cold source



Hybrid LD2-SD2+ nanodiamonds



- Use of NDs around cold moderator and at extraction channel will be tested at the Budapest moderator test facility
- Combined use of SD2 and nanodiamonds in the extraction channel give significant gains at the exit of the channel
- **See N. Rizzi talk 14:40**

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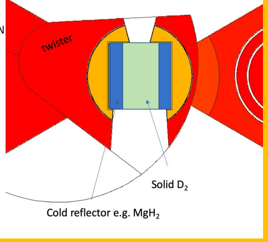
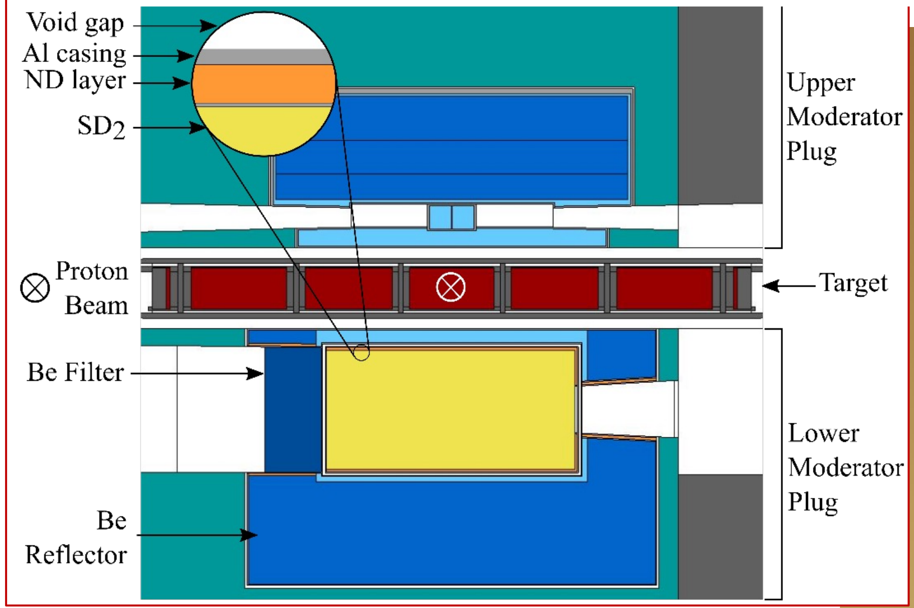


Dedicated VCN moderator

N. Rizzi et al, in preparation
V. Santoro et al, Nucl. Sci. Eng, accepted for publication



- Full SD2 option
  - Seems very promising e.g. for SANS
  - **B. Folsom 15:35**
  - **M. Bertelsen tomorrow 10:55**
- First results on deuterated clathrate hydrates VCN source
  - Shuqi Xu 14*:45*

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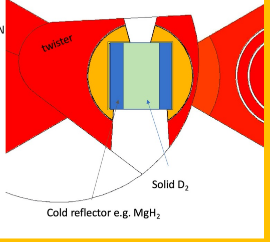

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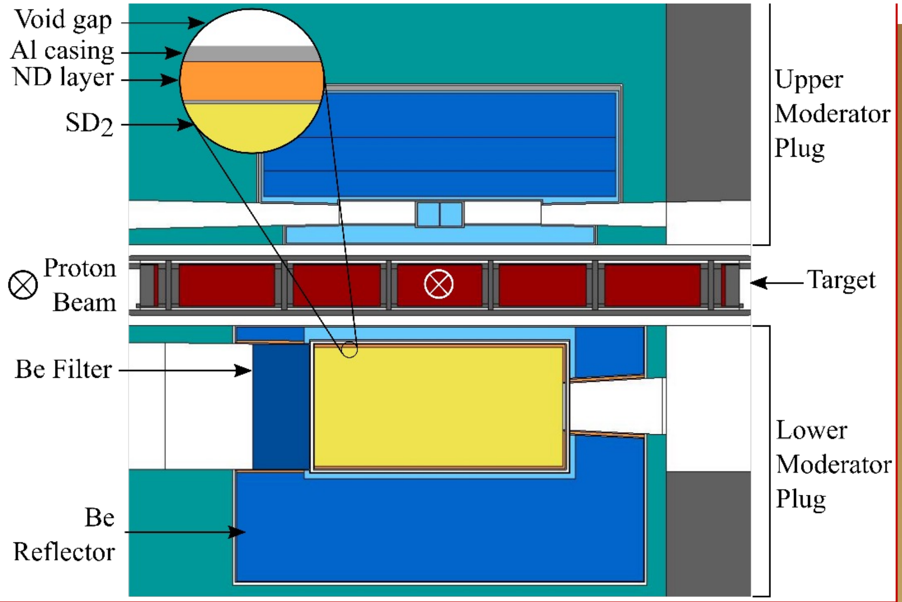

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Ferenc Mezei Journal of Neutron Research 24 (2022) 205–210

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.

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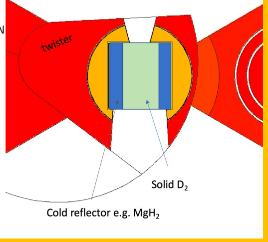

Dedicated VCN moderator

N. Rizzi et al, in preparation

V. Santoro et al, Nucl. Sci. Eng, accepted for publication

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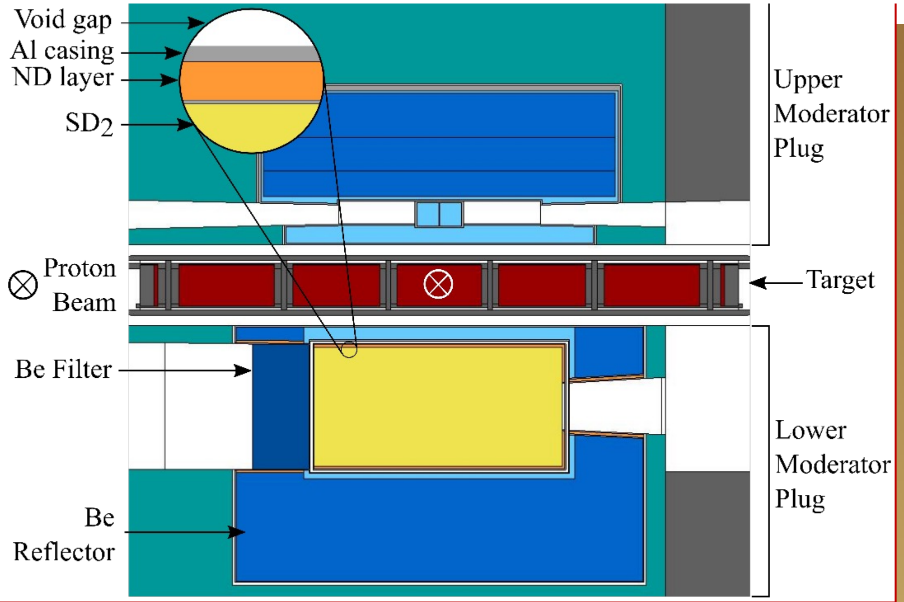

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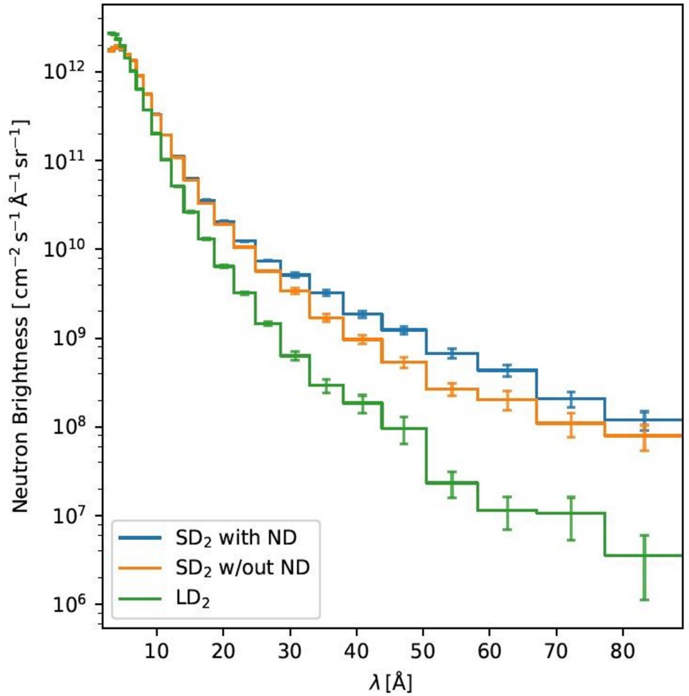

~ $\lambda^{-3.5}$

~ λ^{-5}

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THANK YOU FOR PARTICIPATING TO THIS SECOND WORKSHOP

- Inputs from participants at the first workshop was invaluable
- We welcome more feedback, comments, collaborations from all workshop participants

HighNess

LENS LEAGUE OF ADVANCED EUROPEAN NEUTRON SOURCES

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