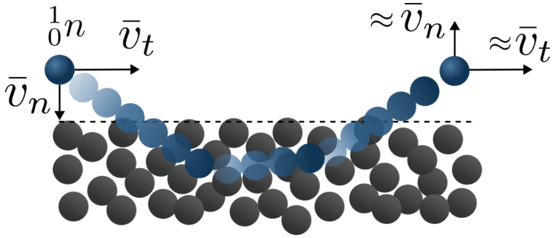
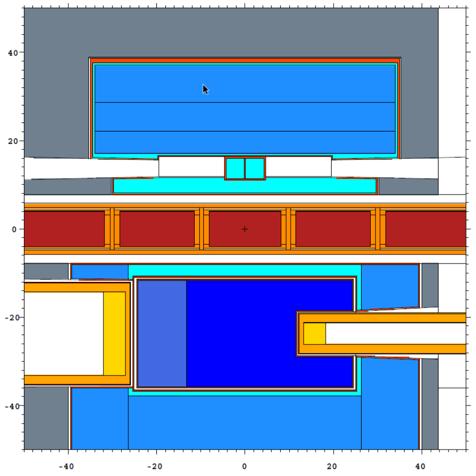
Second Workshop on UCN and VCN Sources at ESS

SD_2-based VCN converter

Outline of this presentation

1. The idea of an SD_2-based VCN converter
2. Nanodiamonds in MCNP
3. Experimental benchmark
4. Converter design at ESS
5. Comparison with other VCN options

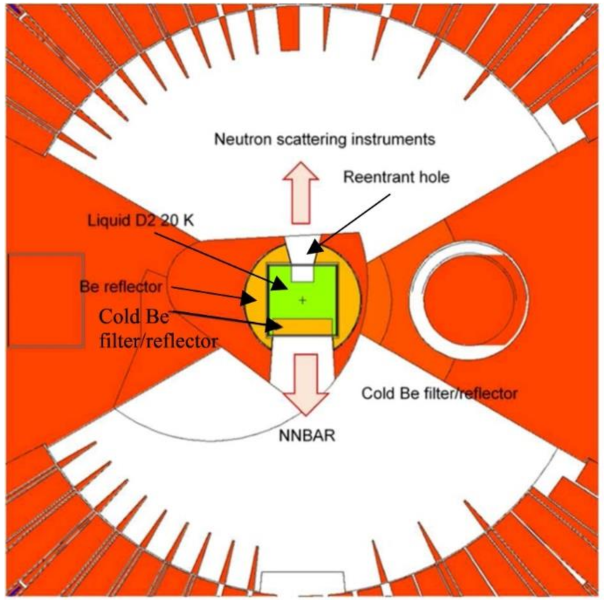


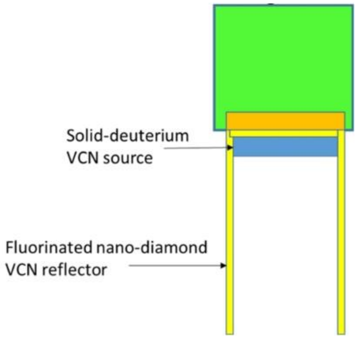


SD_2-based VCN converter

- Idea proposed by Valery Nesvizhevsky at the first workshop [1]

- VCN will improve the sensitivity for $n - \bar{n}$ searches at the ESS
- A dedicated solid-deuterium VCN converter with a reflector was proposed as source
- The material for the reflector would be fluorinated nanodiamonds (F-DND)
- One can accommodate CN, VCN and UCN energy ranges in the same neutron guide





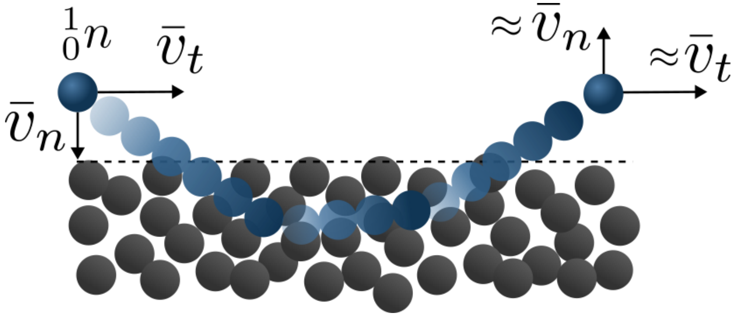
[1] Nesvizhevsky, Valery. 'Why Very Cold Neutrons Could Be Useful for Neutron-antineutron Oscillation Searches'. 1 Jan. 2022 : 223 – 227

Nanodiamonds in MCNP

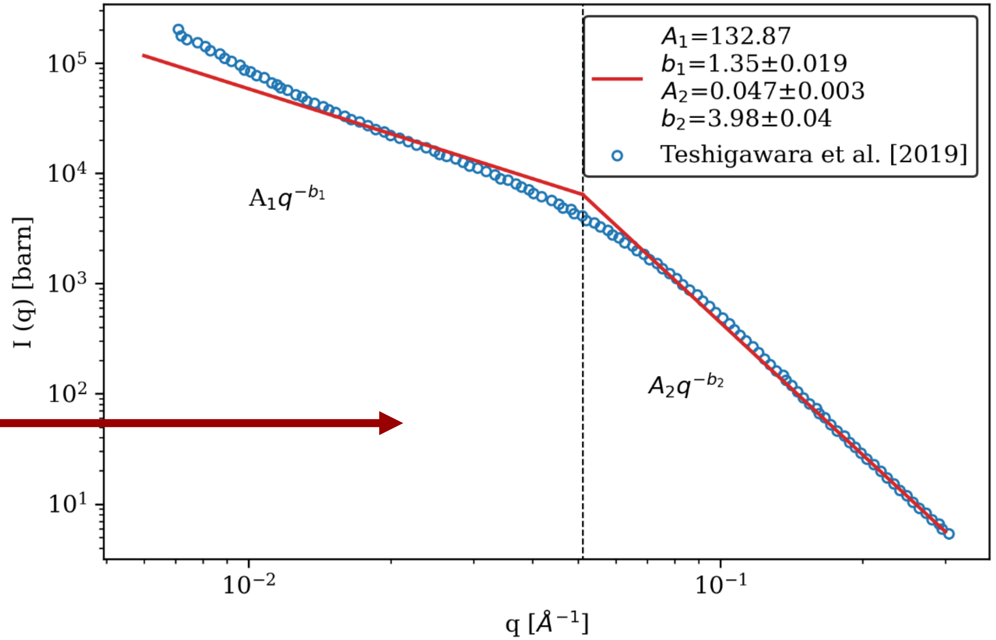
Total microscopic per-atom cross section

$$\sigma_{SANS}(k_0) = \int I(q)d\Omega = \int_0^{2\pi} d\phi \int_0^{\pi} I(q)d\theta$$

$$\sigma_{SANS}(k_0) = \frac{2\pi}{k_0^2}\int_0^{2k_0} I(q)qdq$$



Data from https://doi.org/10.1016/j.nima.2019.03.038

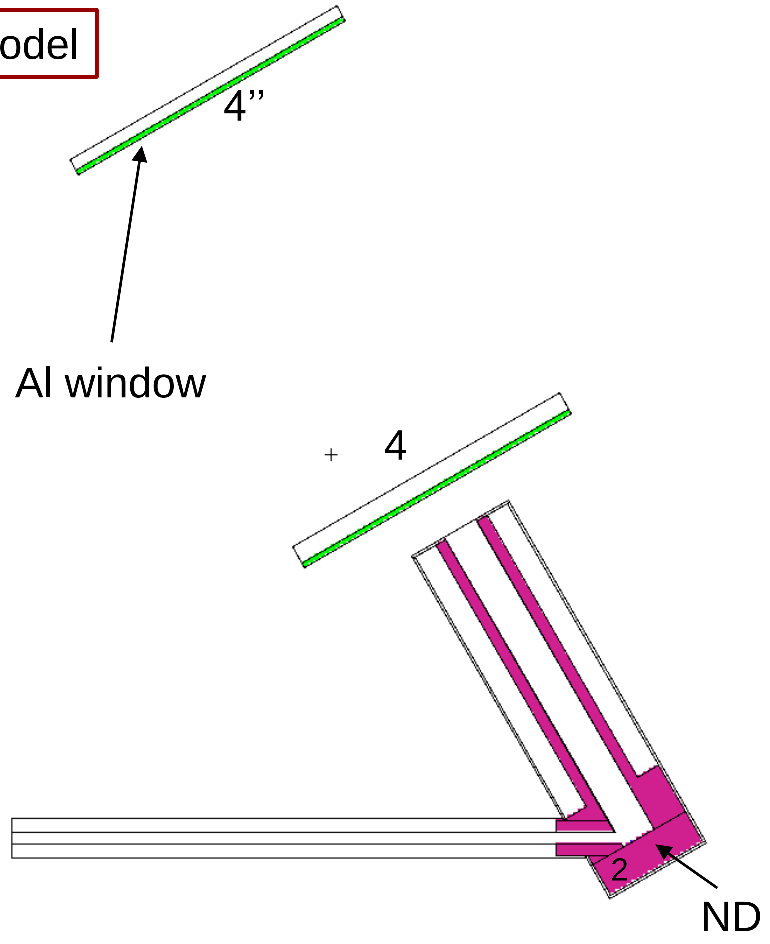


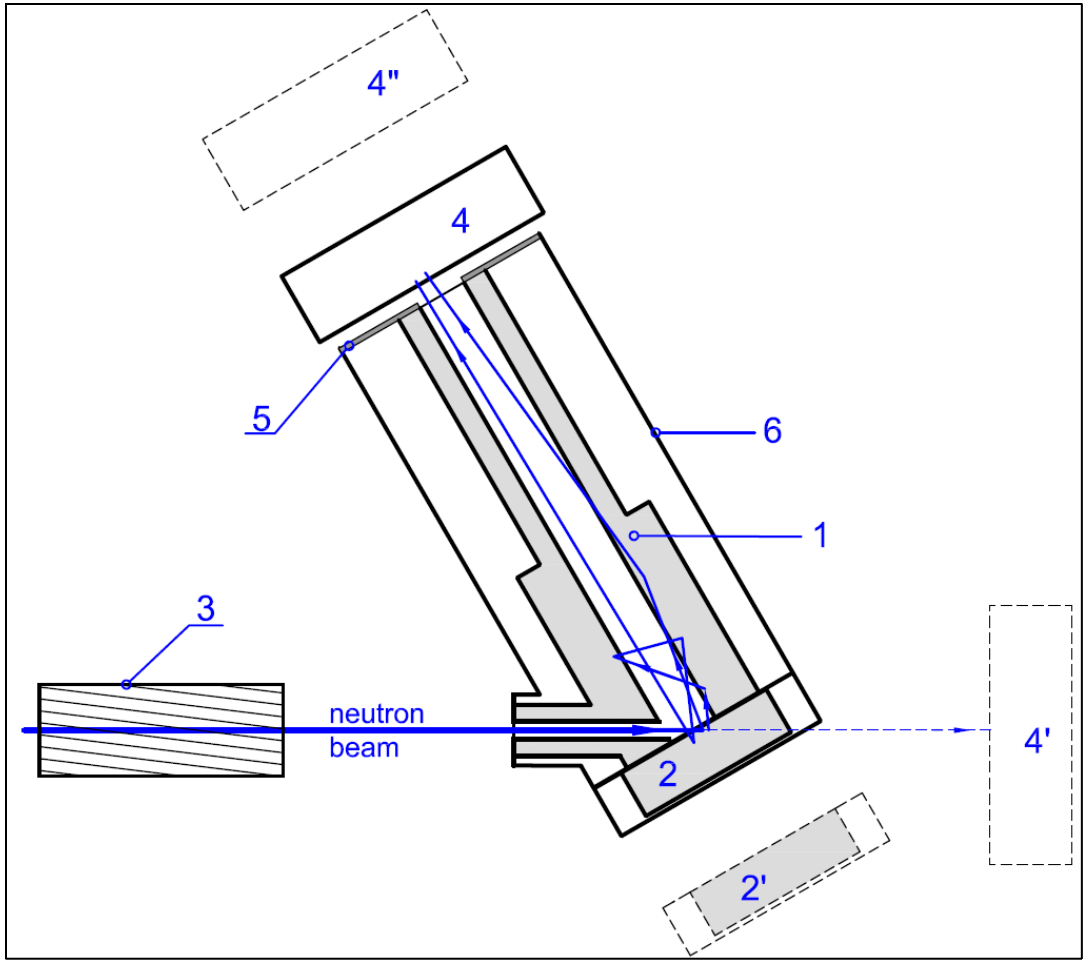
SANS experimental $I(q)$ in absolute units = $\frac{d\sigma}{d\Omega}(q)$ microscopic differential per-atom cross section with units barn sr^{-1}

Benchmark experiment @ PF2

S.M. Chernyavsky et al. https://doi.org/10.1063/5.0124833

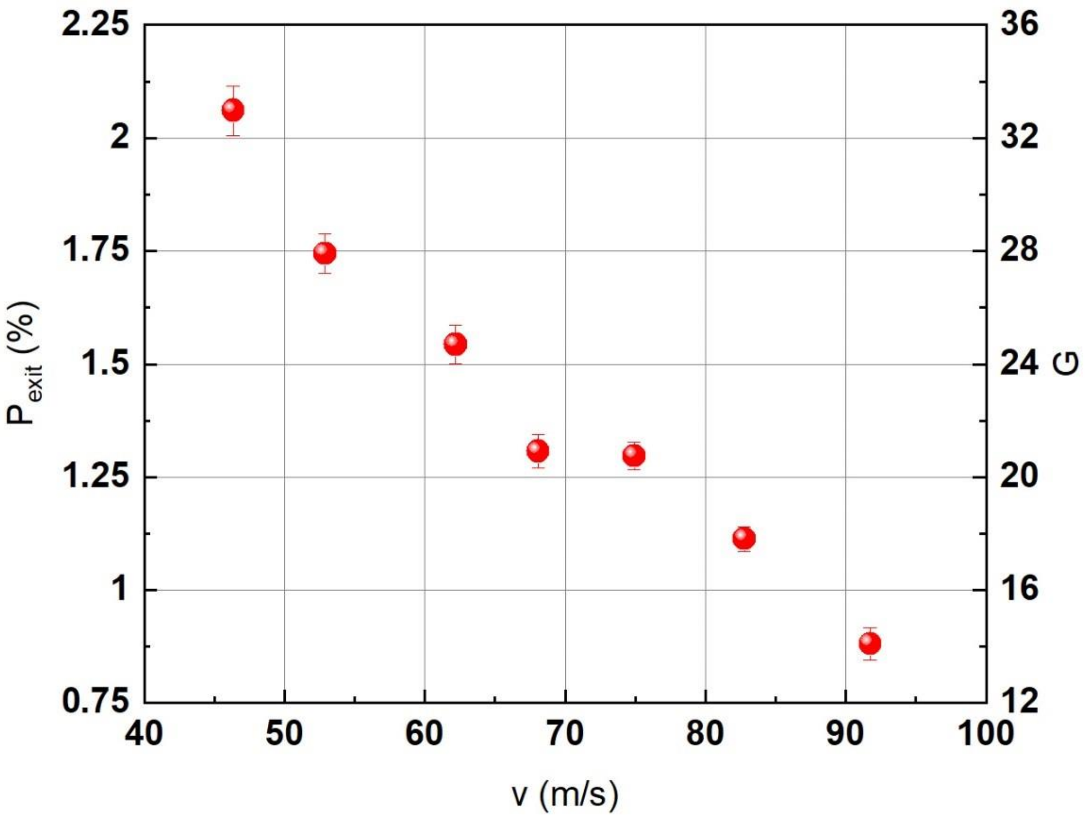
MCNP model

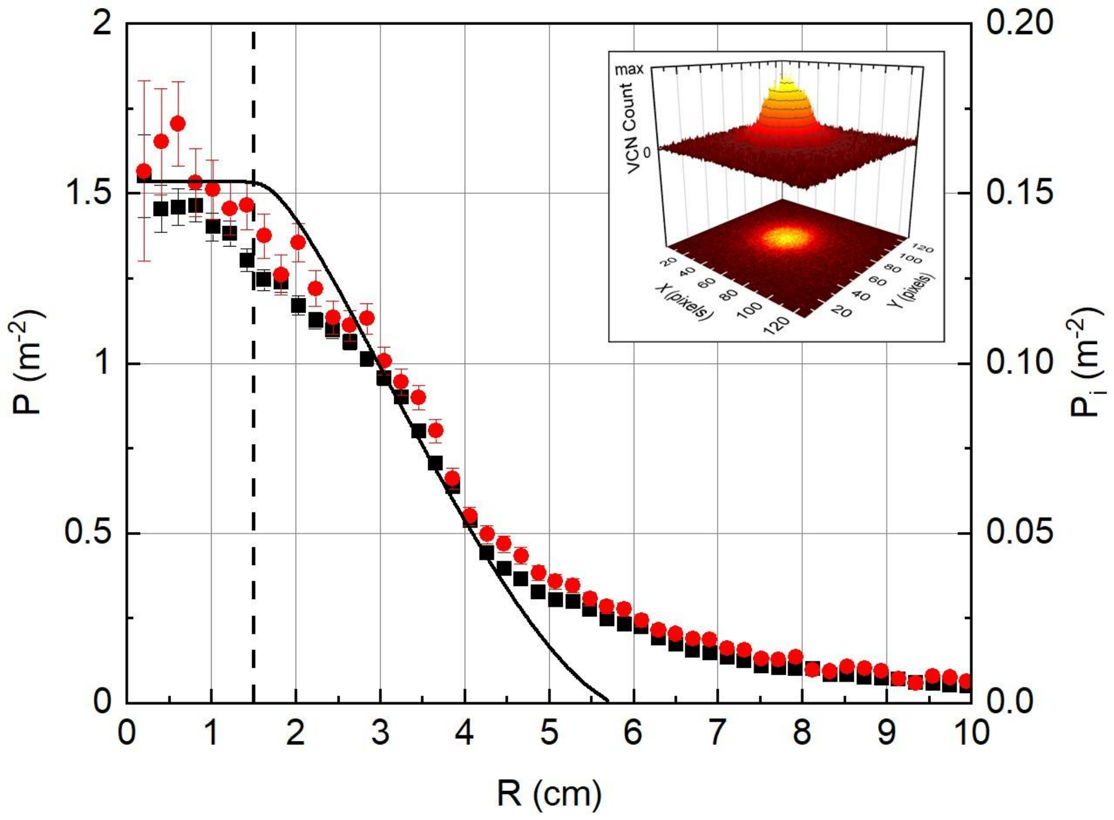




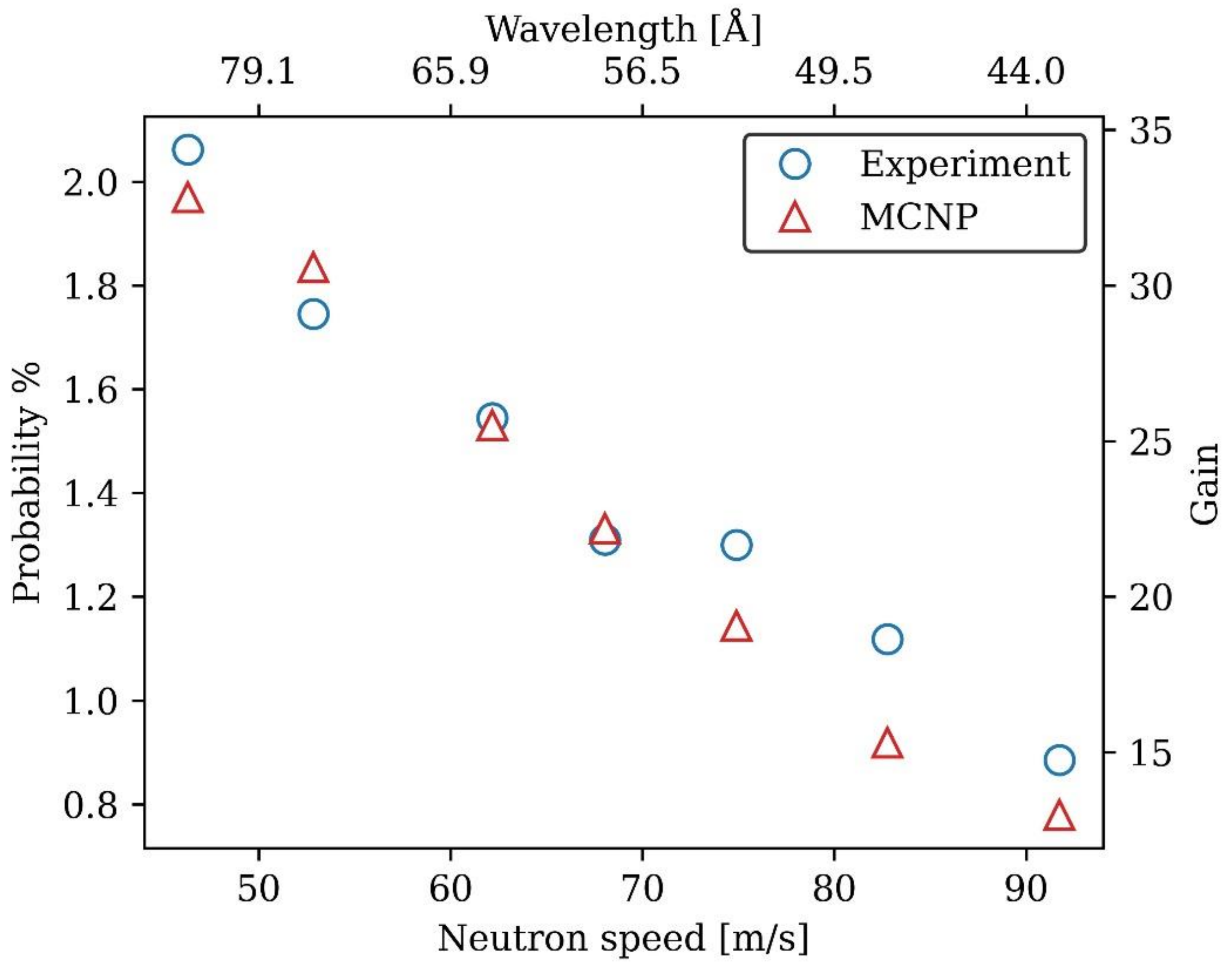
DTU HighNess

Results from the experiment

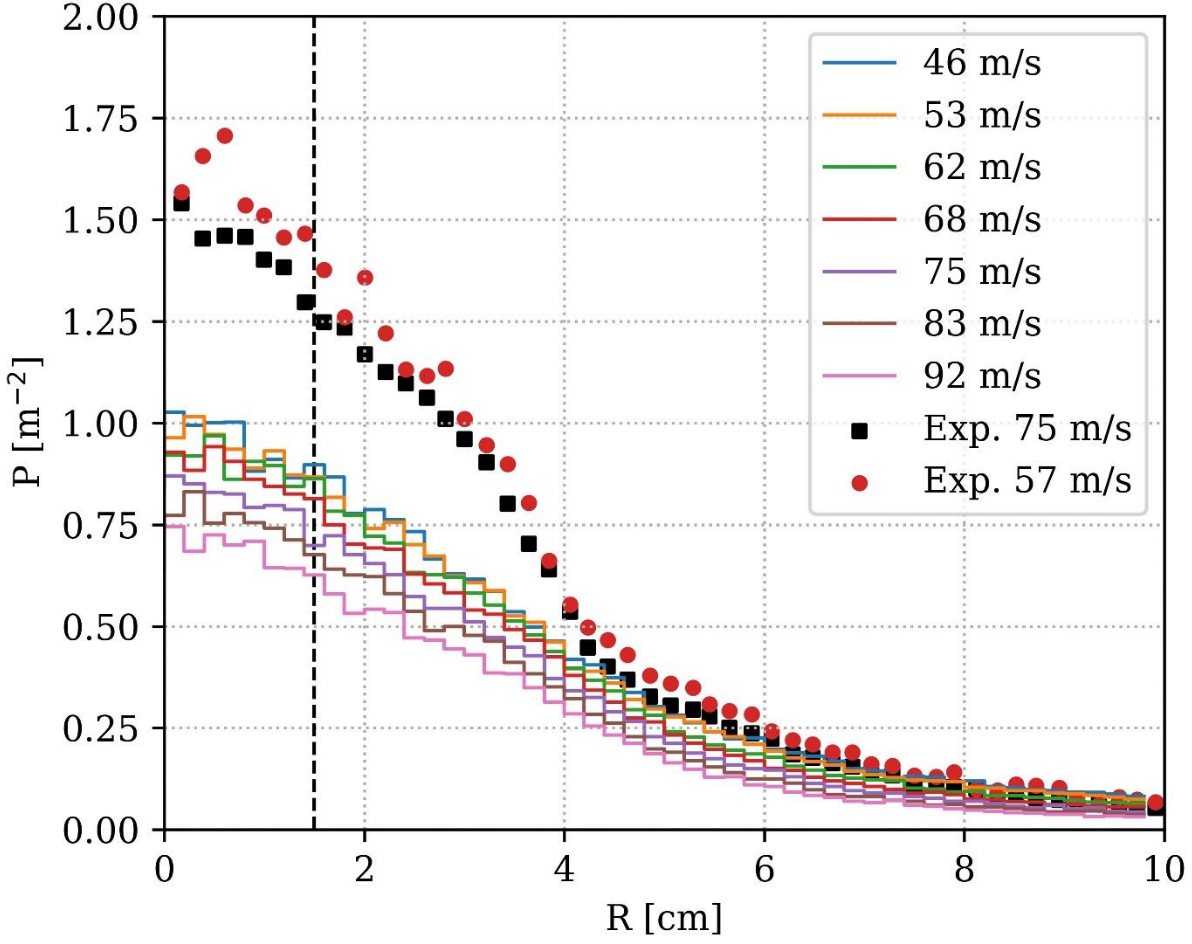




Results from the calculations



Results from calculations



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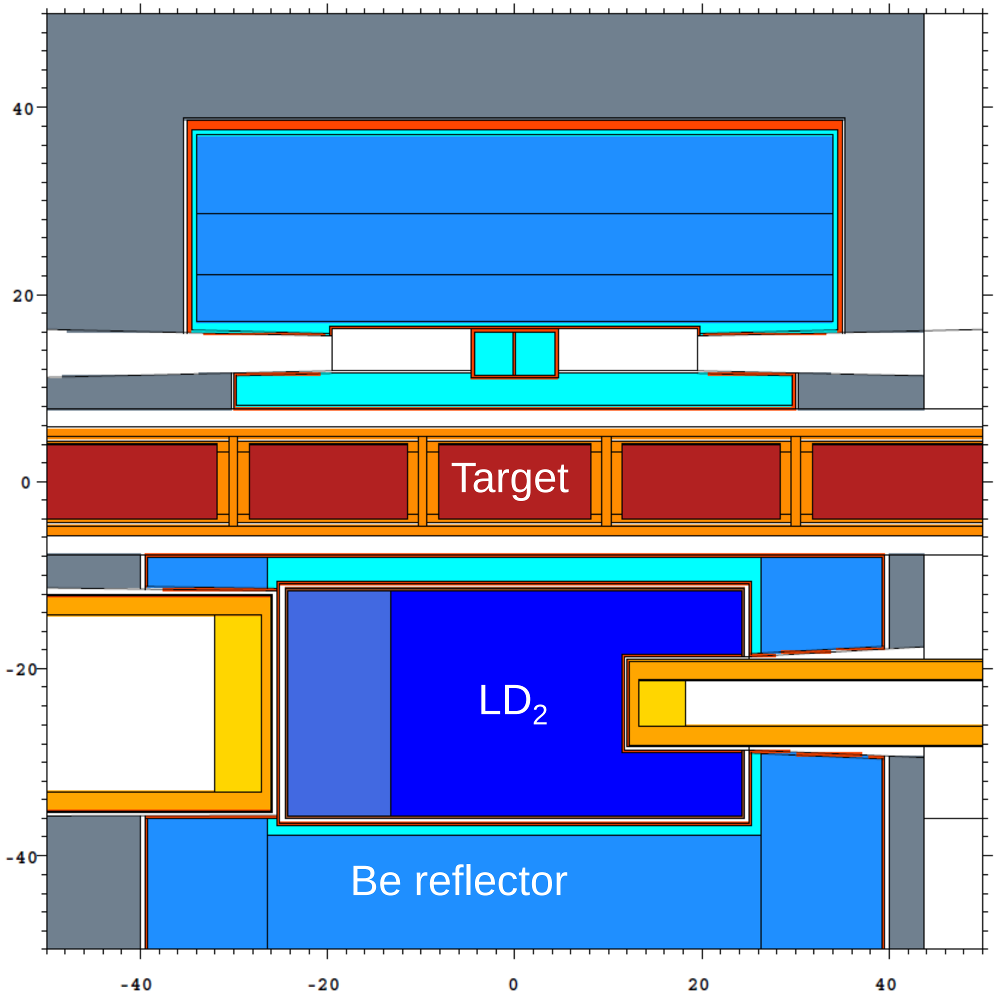
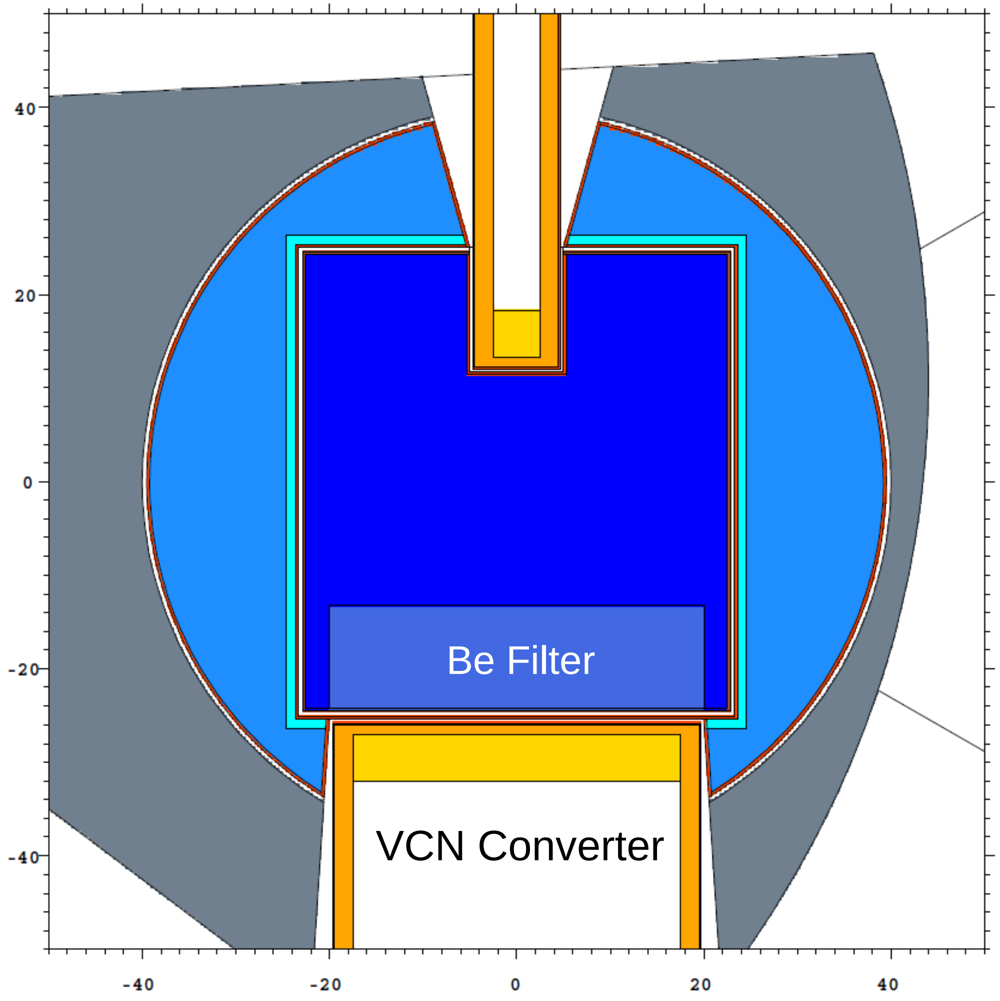
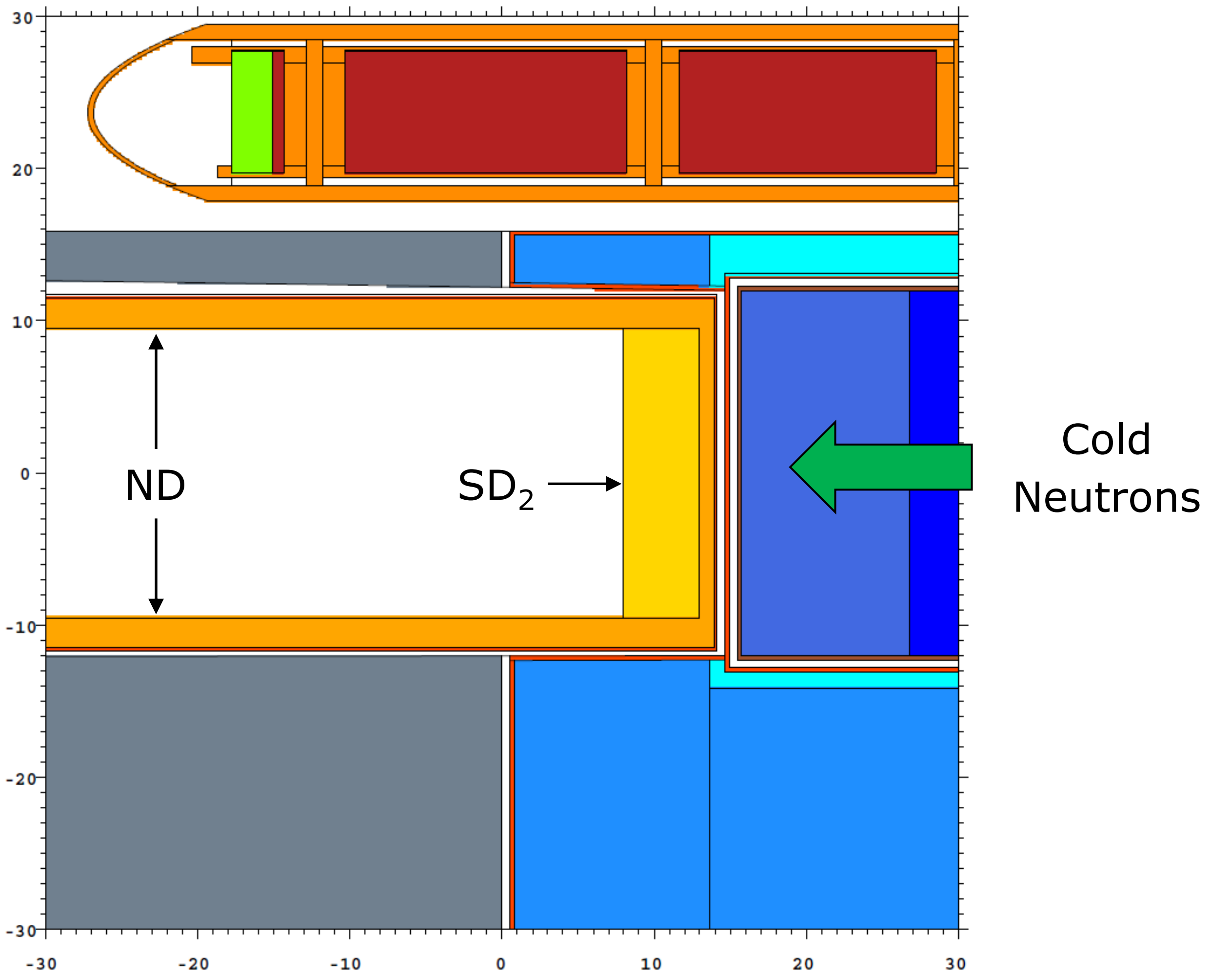
VCN converter at ESS





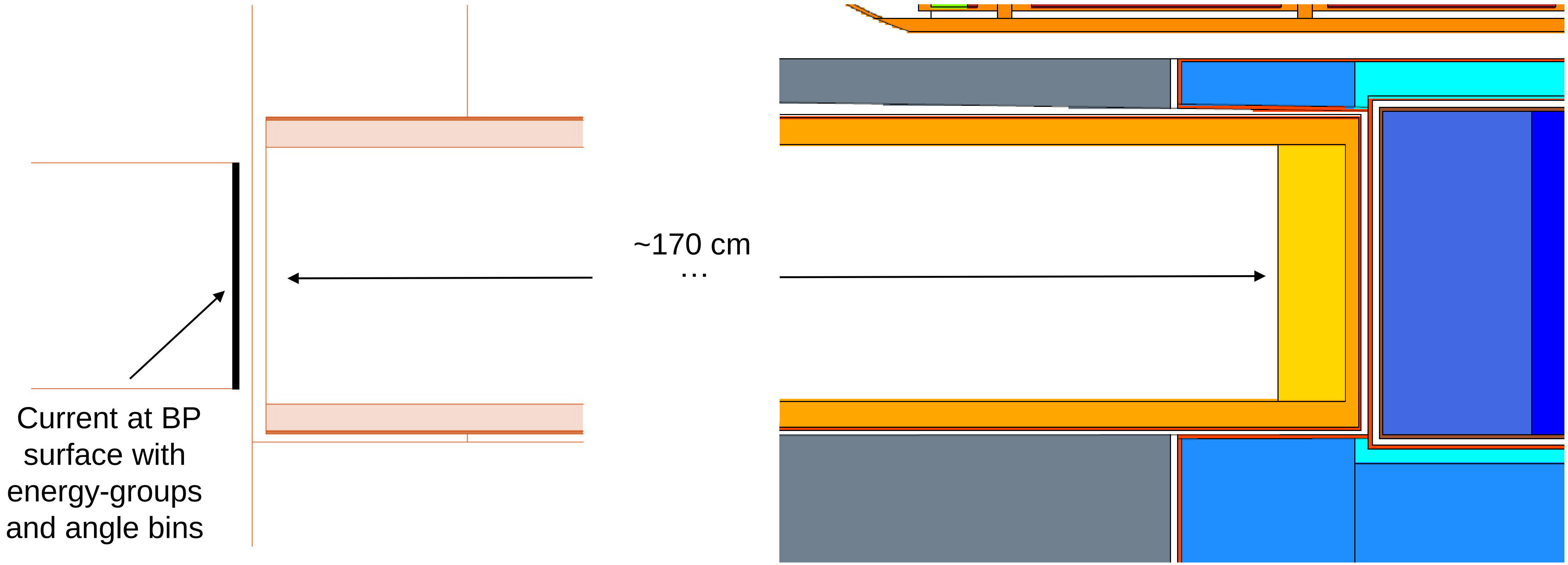
VCN converter at ESS – ideal case



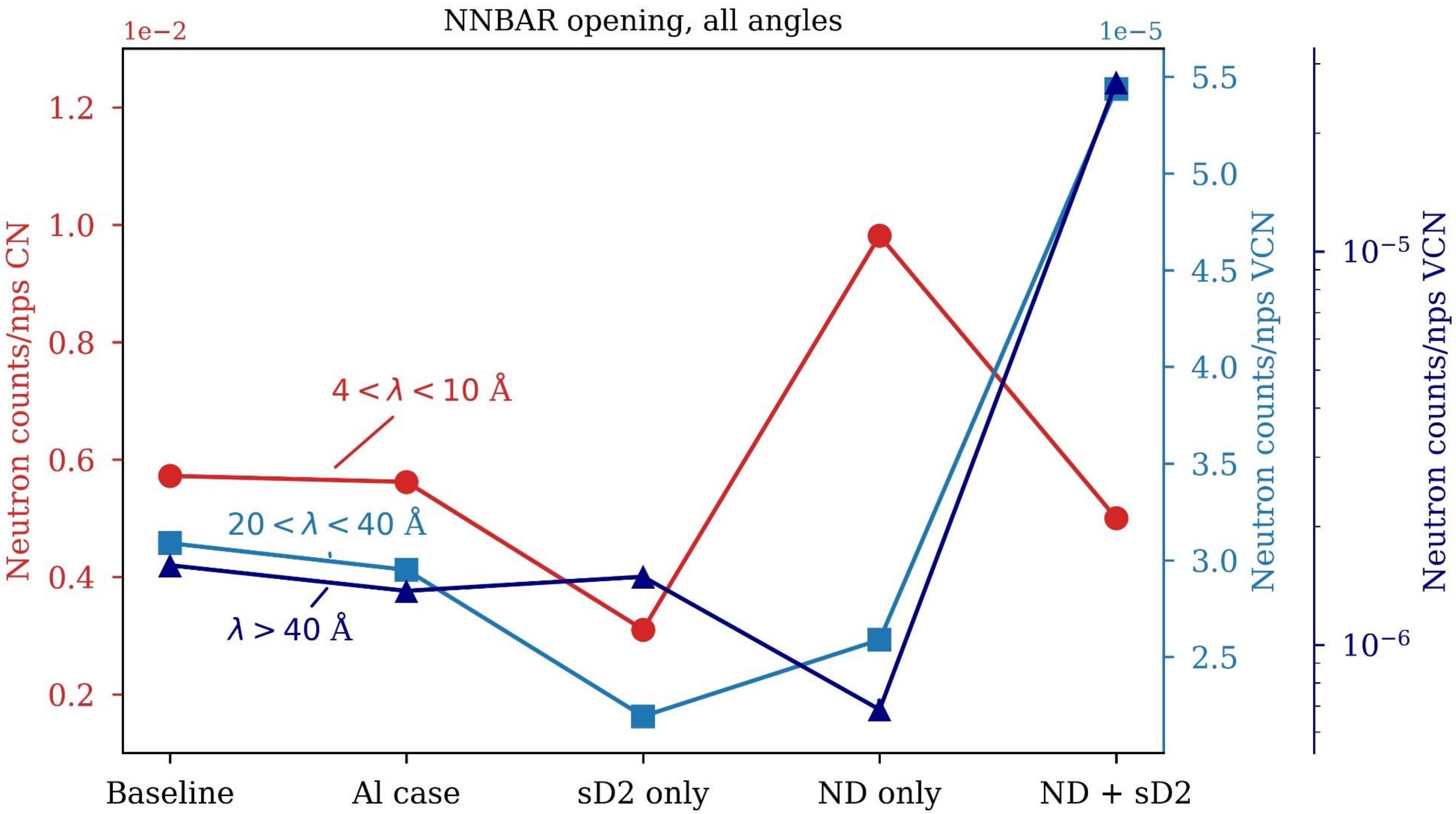
Specifications

- 24 x 40 x 5 cm^3 SD_2 converter @ 5K
- 2 cm ND reflector on the sides
- 1 cm ND facing the cold moderator
- 2 mm Al external case
- No Al interface between SD_2 and ND

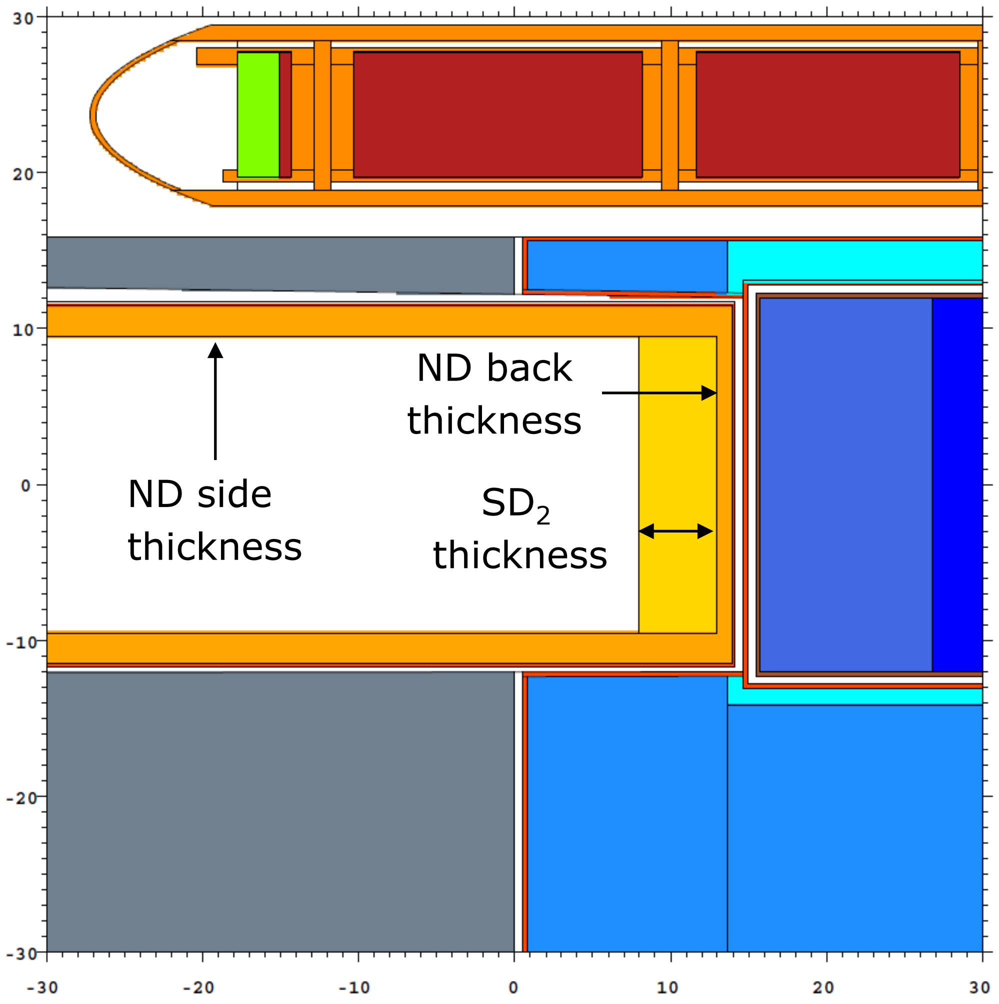
VCN extraction



Preliminary study



VCN extraction optimization



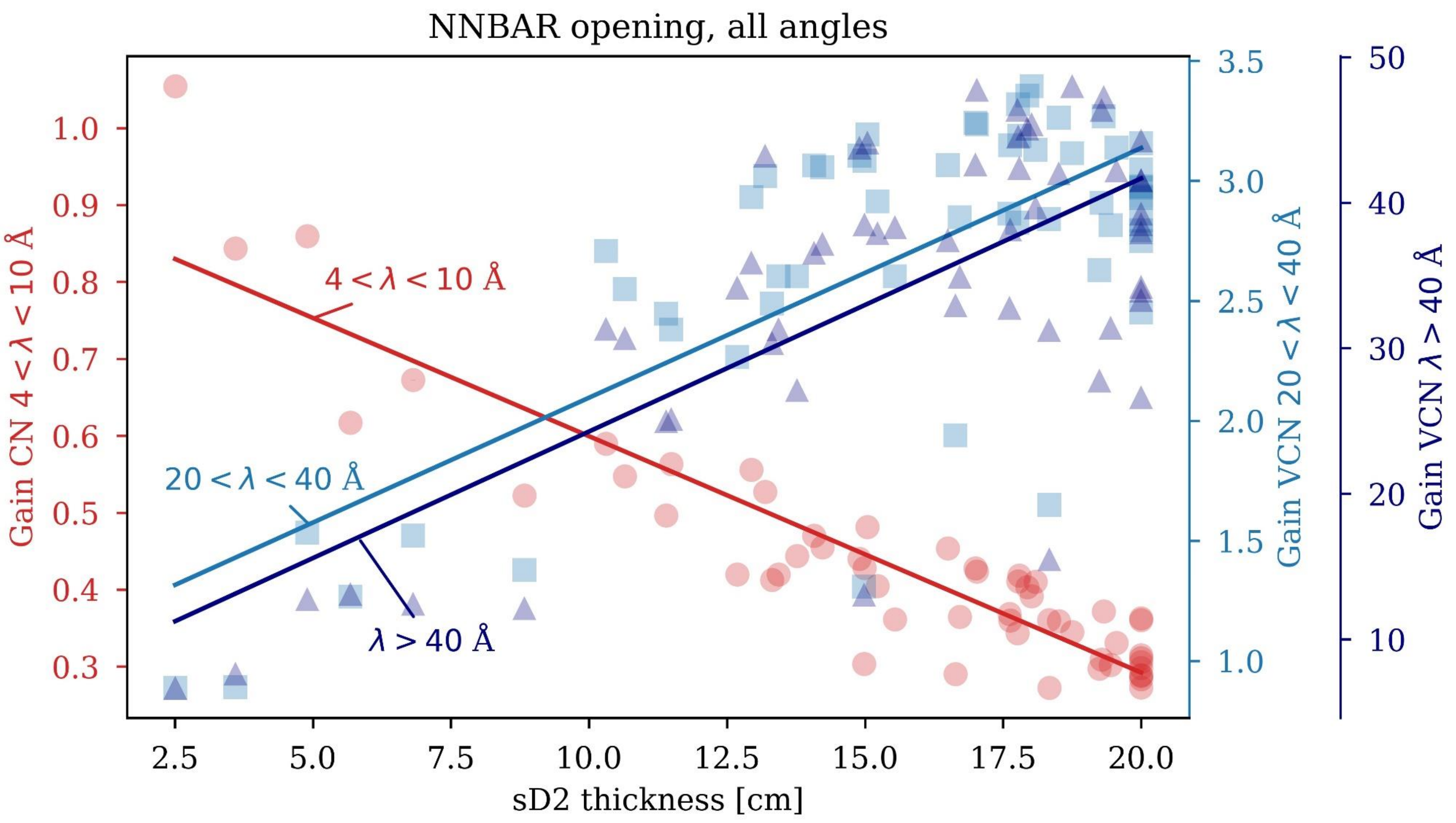
Optimization Parameters

1. SD_2 converter thickness
2. ND thickness on the sides
3. ND thickness facing the cold moderator

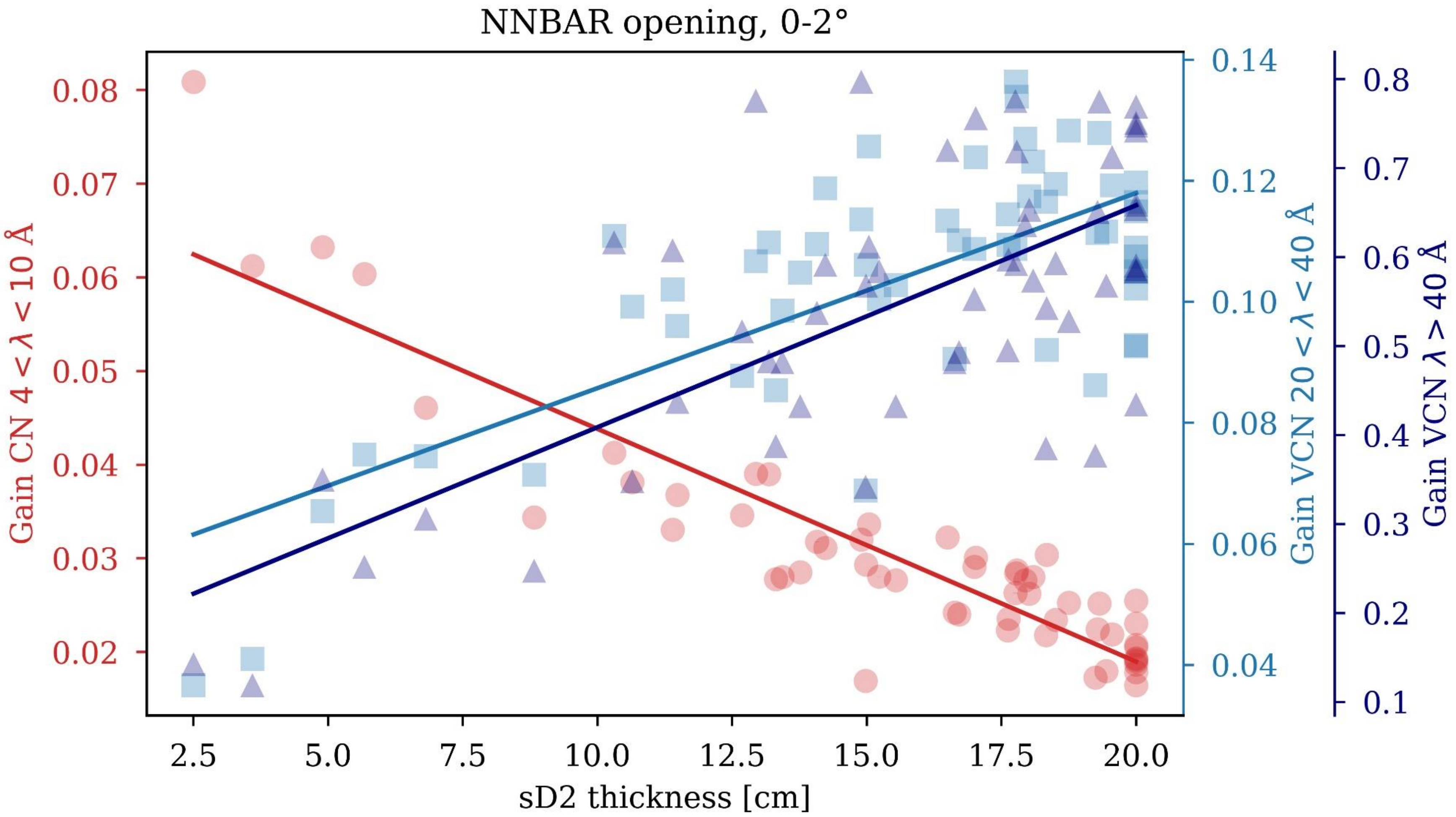
FOM: VCN current 20 Å < λ < 40 Å

	Lower bound [cm]	Starting point [cm]	Upper bound [cm]
1.	1	5	20
2.	0.1	2	5
3.	0.1	1	5

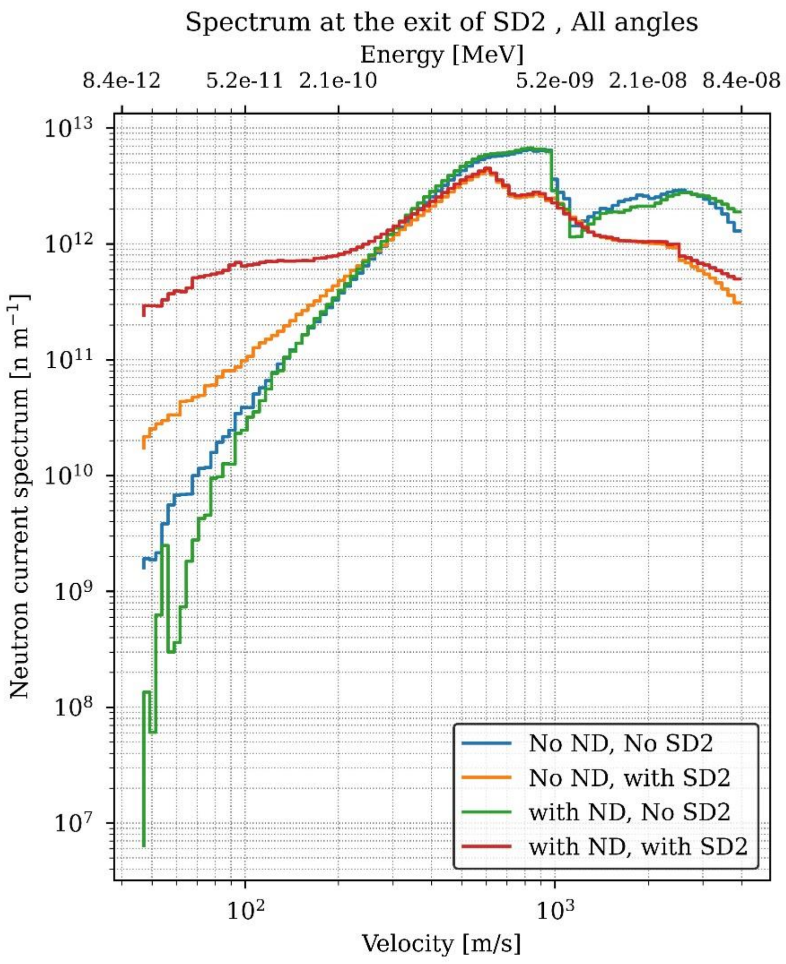
Gains over the baseline (all angles)

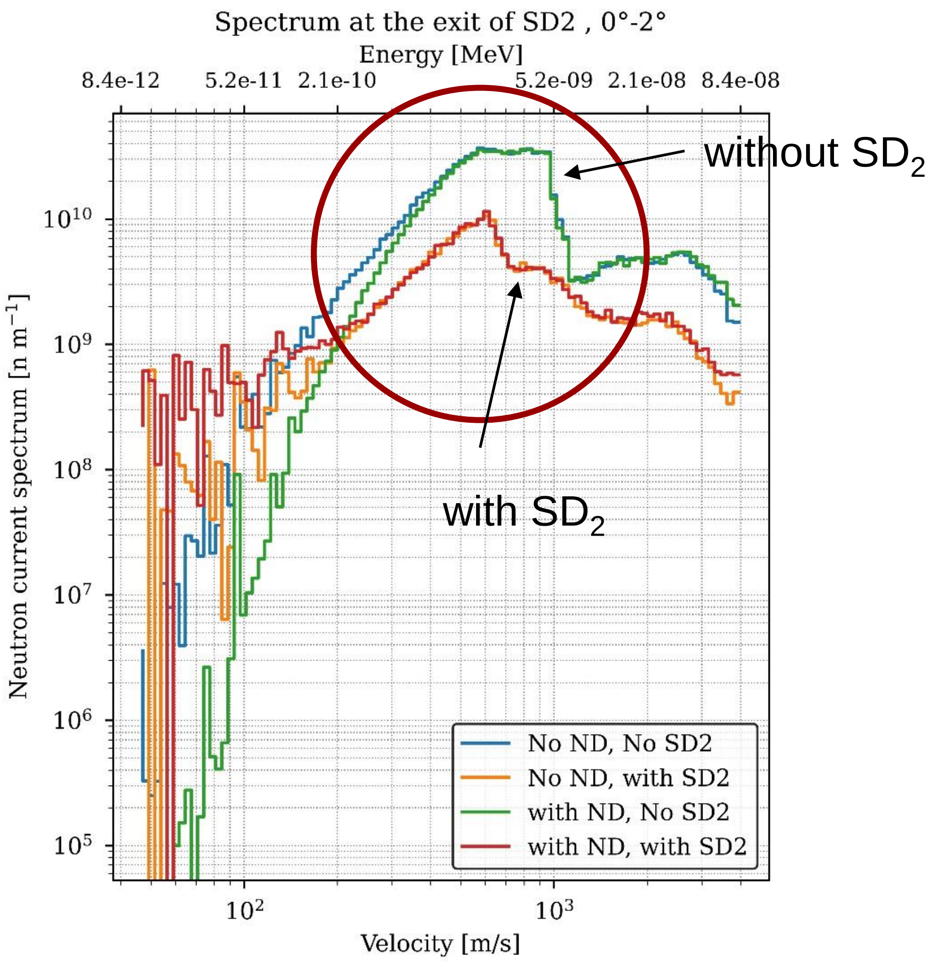


Gains over the baseline (small angles)

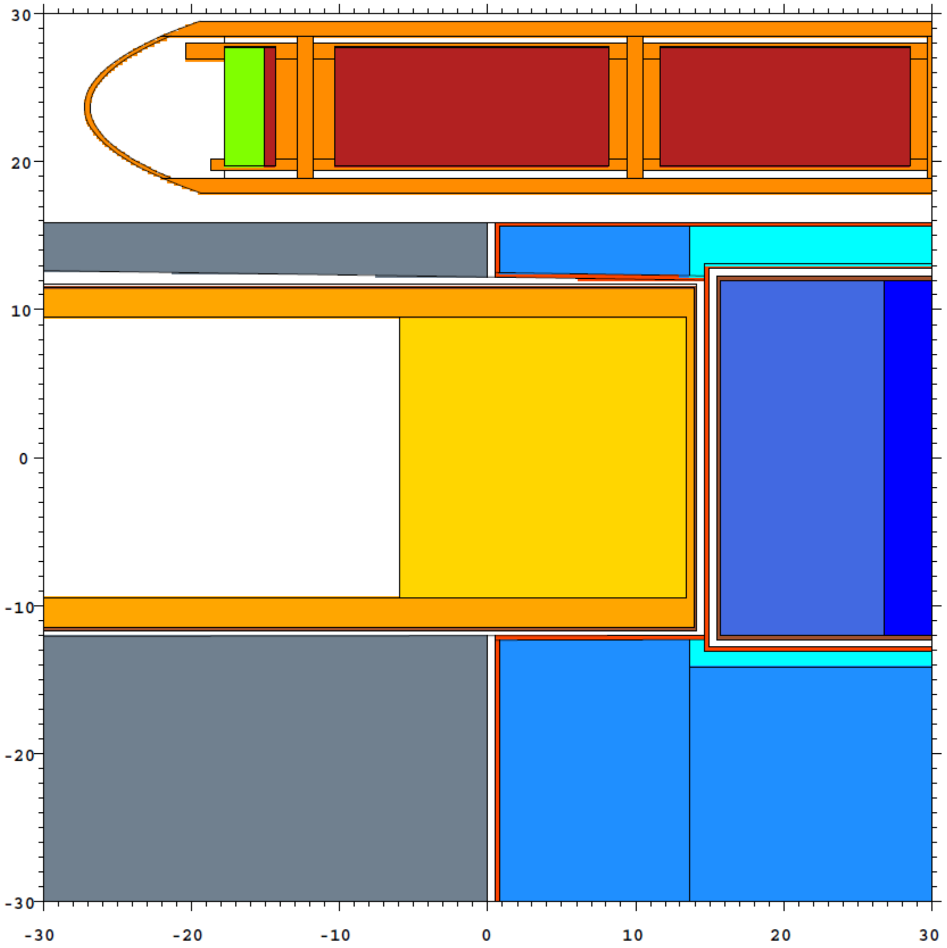


Current spectrum at the exit of SD2





Best case



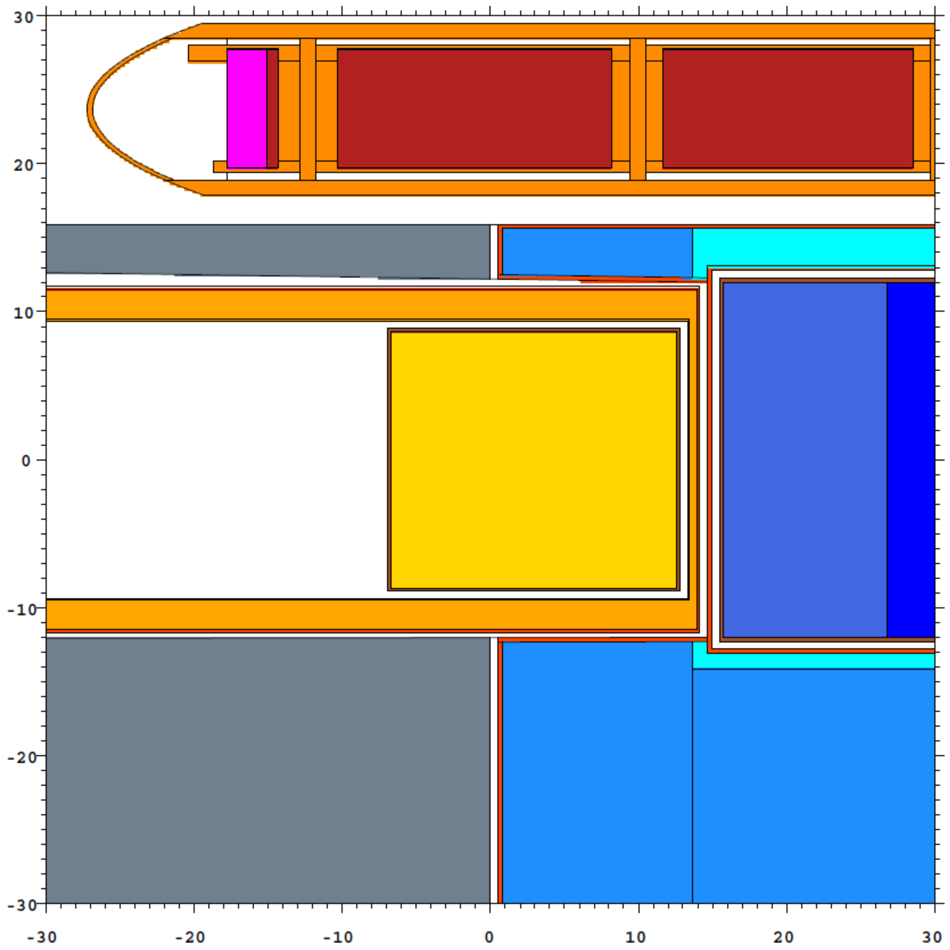
Specifications

- **24 x 40 x 19 cm³ SD_2 converter**
- **2 cm ND reflector on the sides**
- **0.55 cm ND facing the cold moderator**
- 2 mm Al external case
- No Al interface between SD_2 and ND

Energy groups [Å]	λ>40	20<λ<40	4<λ<10
Current @ BP [n/s]	1.17E+12	1.57E+12	3.32E+13
Ratio to Baseline	47	3	0.4

DTU HighNess

VCN converter at ESS – realistic option

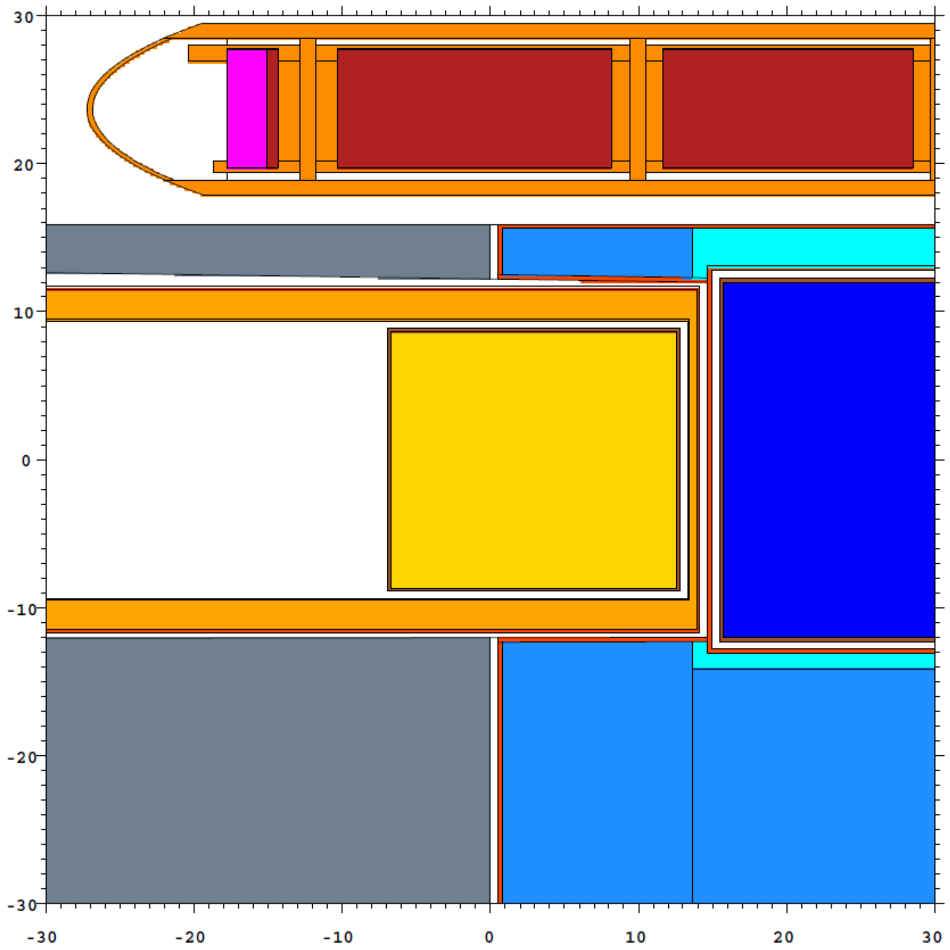


Specifications

- 22 x 38 x 18 cm^3 SD_2 converter @ 5 K
- 2 mm Al vessel @ 5K
- 2 cm ND reflector on the sides
- 0.55 cm ND facing the cold moderator
- 2 m0.55m Al external case @ 293K
- 1 mm Al internal case @ 293K
- 5 mm vacuum gap
- Total heat-load: 2.5 kW

Energy groups [Å]	λ>40	20<λ<40	4<λ<10
Current @ BP [n/s]	6.46E+10	5.36E+11	3.22E+13
Ratio to baseline	↑ 2.6	↑ 1.1	↓ 0.36
Ratio to ideal case	↓ 0.05	↓ 0.34	↓ 0.97

VCN converter at ESS – no Be filter

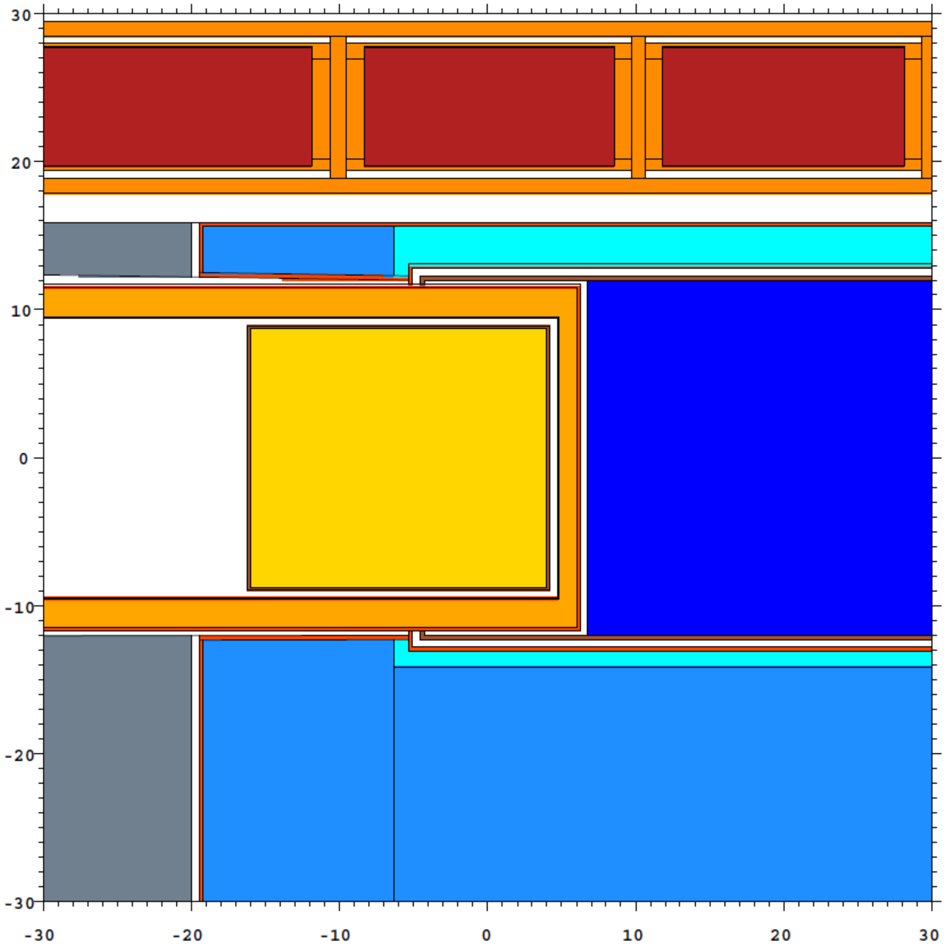


Specifications

- 22 x 38 x 18 cm3 SD2 converter @ 5 K
- 2 mm Al vessel @ 5K
- 2 cm ND reflector on the sides
- 0.55 cm ND facing the cold moderator
- 2 mm Al external case @ 293K
- 1 mm Al internal case @ 293K
- Total heat-load: 3 kW

Energy groups [Å]	λ>40	20<λ<40	4<λ<10
Current @ BP [n/s]	7.79E+10	1.57E+12	3.32E+13
Ratio to baseline	↑ 3.1	↑ 1.4	↓ 0.38
Ratio to Be filter	↑ 1.2	↑ 1.3	↑ 1

VCN converter at ESS – closer to cold source

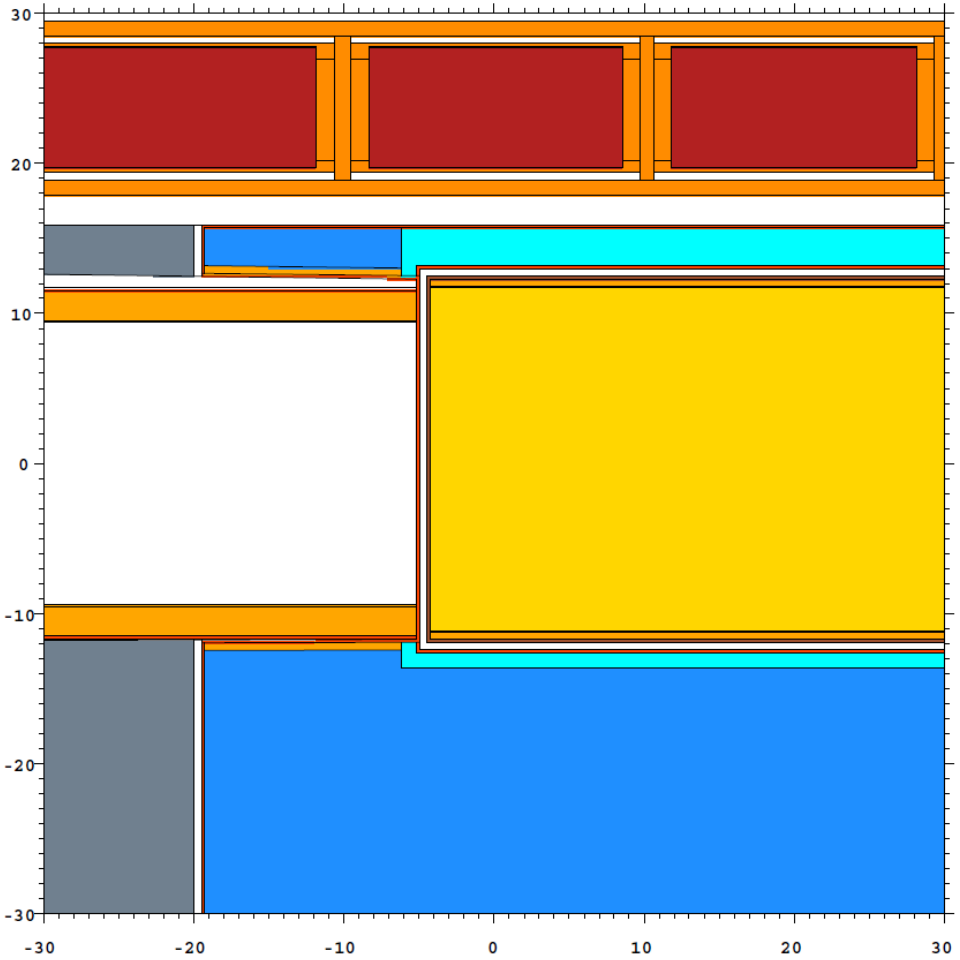


Specifications and **parameters**

- **22 x 38 x 20 cm^3 SD_2 converter @ 5 K**
- 2 mm Al vessel @ 5K
- **2 cm ND reflector on the sides**
- **1.25 cm ND facing the cold moderator**
- 11 cm insertion in LD_2 vessel (fixed)
- Total heat-load: 5.8 kW

Energy groups [Å]	λ>40	20<λ<40	4<λ<10
Current @ BP [n/s]	1.42E+11	1.20E+12	5.69E+13
Ratio to baseline	↑ 5.7	↑ 2.5	↓ 0.6
Ratio to Be filter	↑ 2.2	↑ 2.2	↑ 1.8

Comparisons with Full SD2



- Full SD_2 VCN source studied within HighNESS (see next presentation)
- Our best performing VCN source so far
- ND extraction added for fair comparison

Energy groups [Å]	λ>40	20<λ<40	4<λ<10
Current @ BP [n/s]	6.33E+11	3.46E+12	1.25E+14
Ratio to Best Converter	⬆ 4.5	⬆ 2.9	⬆ 2.2

Conclusions

- The idea presented in the previous workshop is promising
- It potentially needs way less R&D than our best VCN source so far, making it a good option to run together with NNBAR (not with the current design of the optics)
- It is a **flexible design**: many configurations are possible and can be adapted
- Limited computational model for ND may lead to **underestimate** the gains
- Engineering details are crucial to **preserve the ideal gains**

Thank you