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Full Solid Deuterium VCN source for ESS

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8 May 2023

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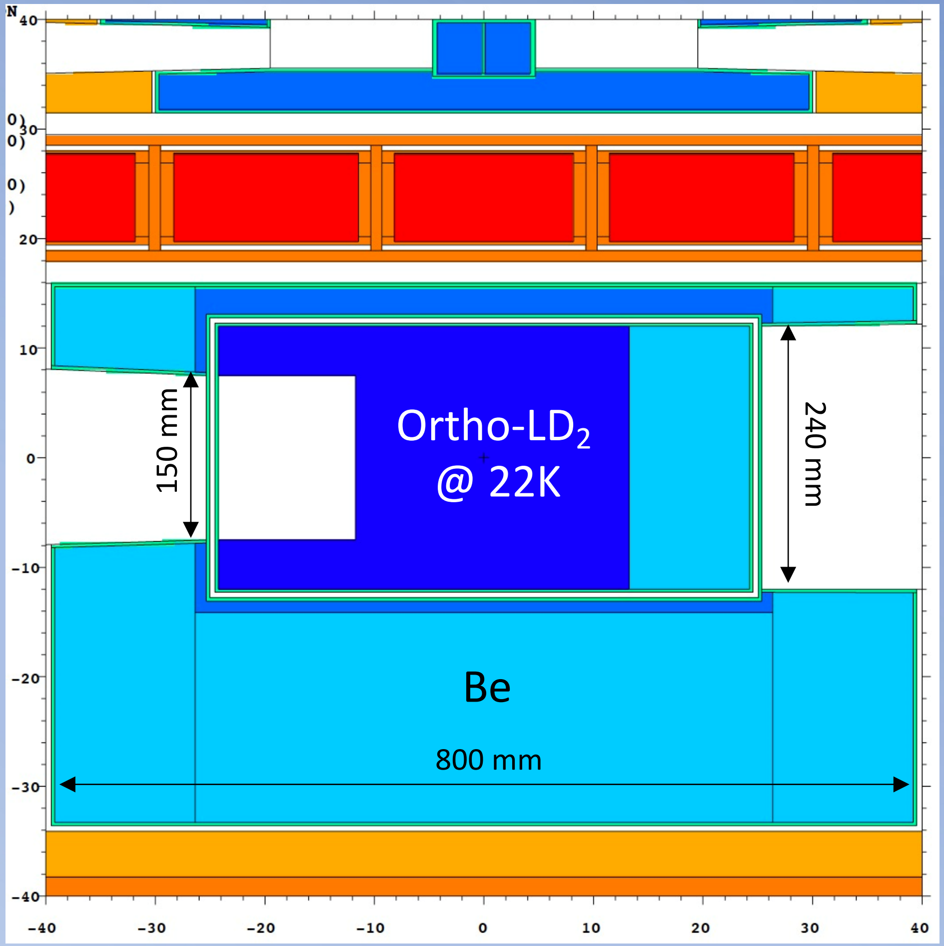
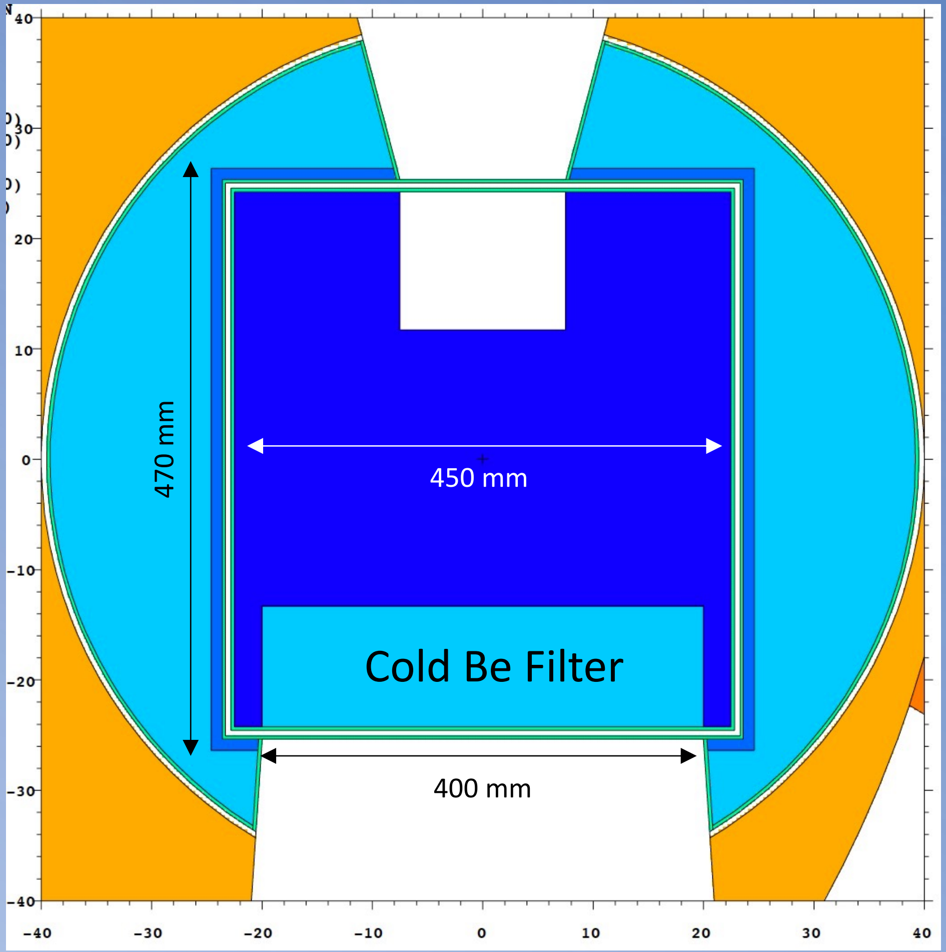
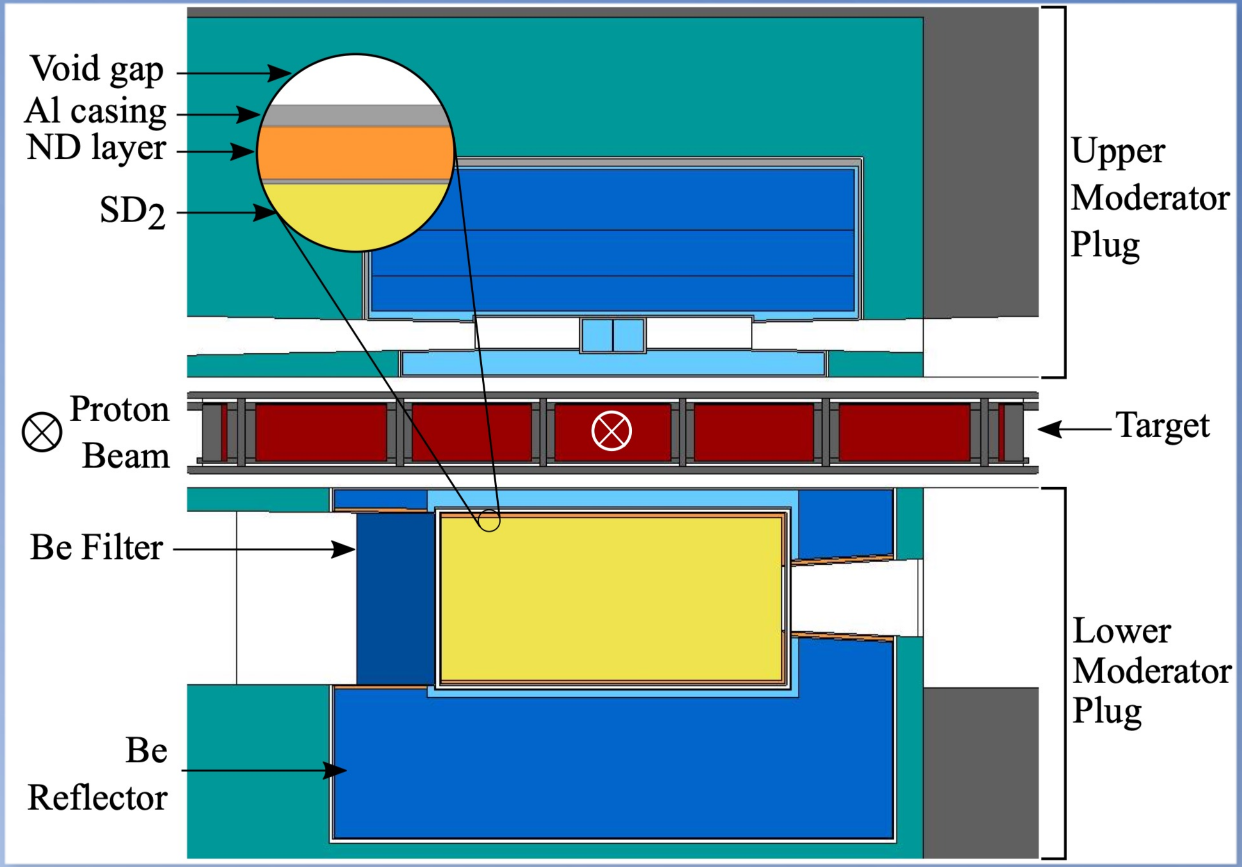
The baseline cold source





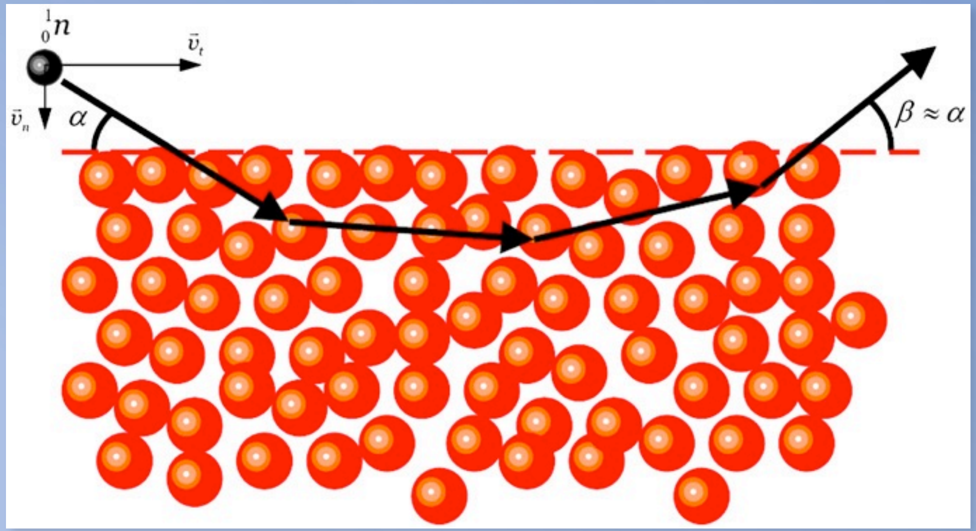
SD_2 VCN moderator

- 45 x 49 x 24 cm^3 box shape
- 50 L of solid-D_2 at 5 K
- Reflector layer made of ND, 5 mm thick
- 10-cm Be filter at 20 K on the NNBAR side



Why nanodiamonds?

- Nanodiamond Powder samples showed efficient reflector properties for very cold neutrons (VCN) up to 10^{-4} eV [1]
- Good quasi-specular reflectivity for cold neutrons [2]
- Nanoparticles provide a sufficiently large cross-section for elastic scattering on a spatial scale comparable to VCN wavelengths
- Carbon has a low absorption cross-section



Ref [3]

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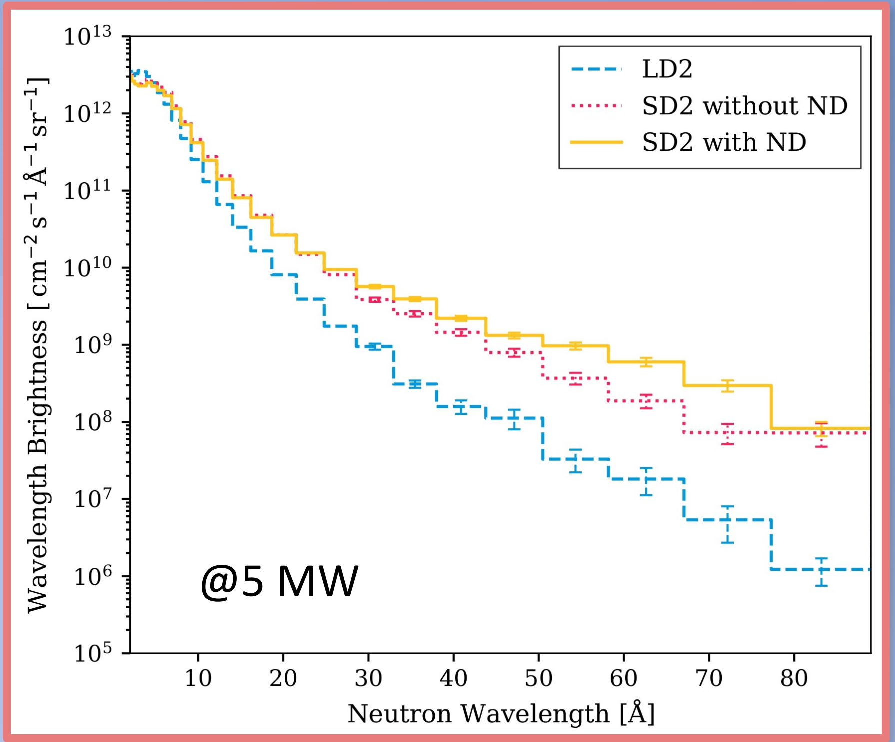
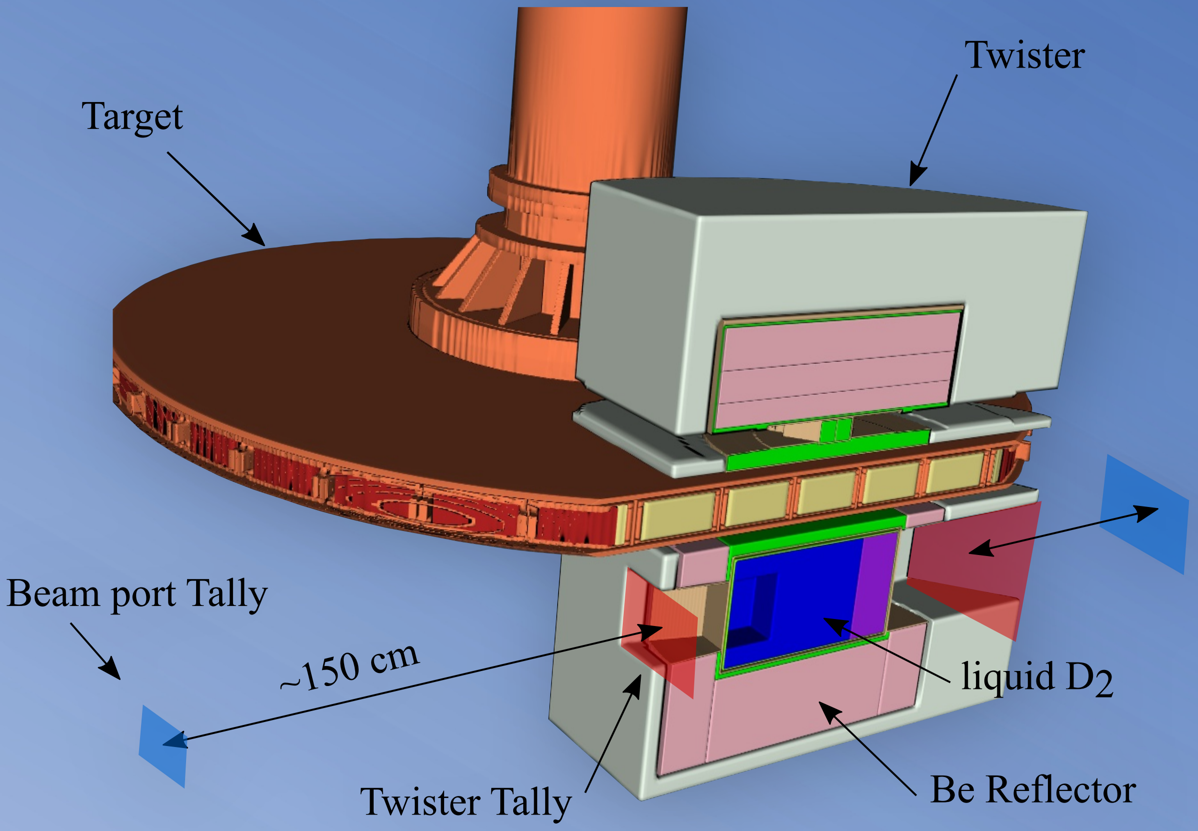
Performance



LD2: VCNs go as a Maxwellian tail with λ^{-5} dependence

SD2 w/ND: Approximately $\lambda^{-3.5}$ dependence



Gains for SD2 over LD2 Baseline

	> 40 Å	10 Å to 40 Å	4 Å to 10 Å	2.5 Å to 4 Å
N.S.	19.0	2.4	1.2	0.7
NNBAR	14.3	2.3	1.3	0.6

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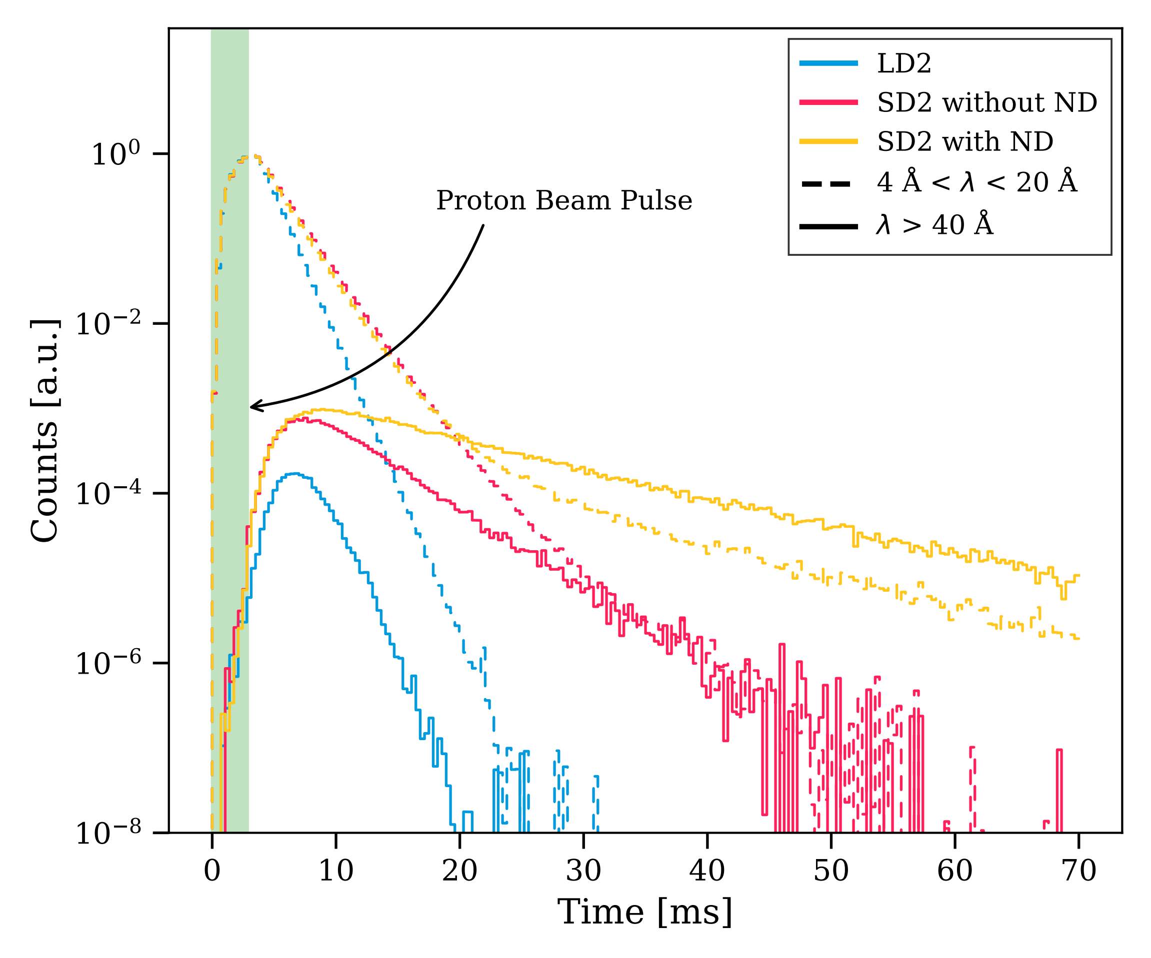
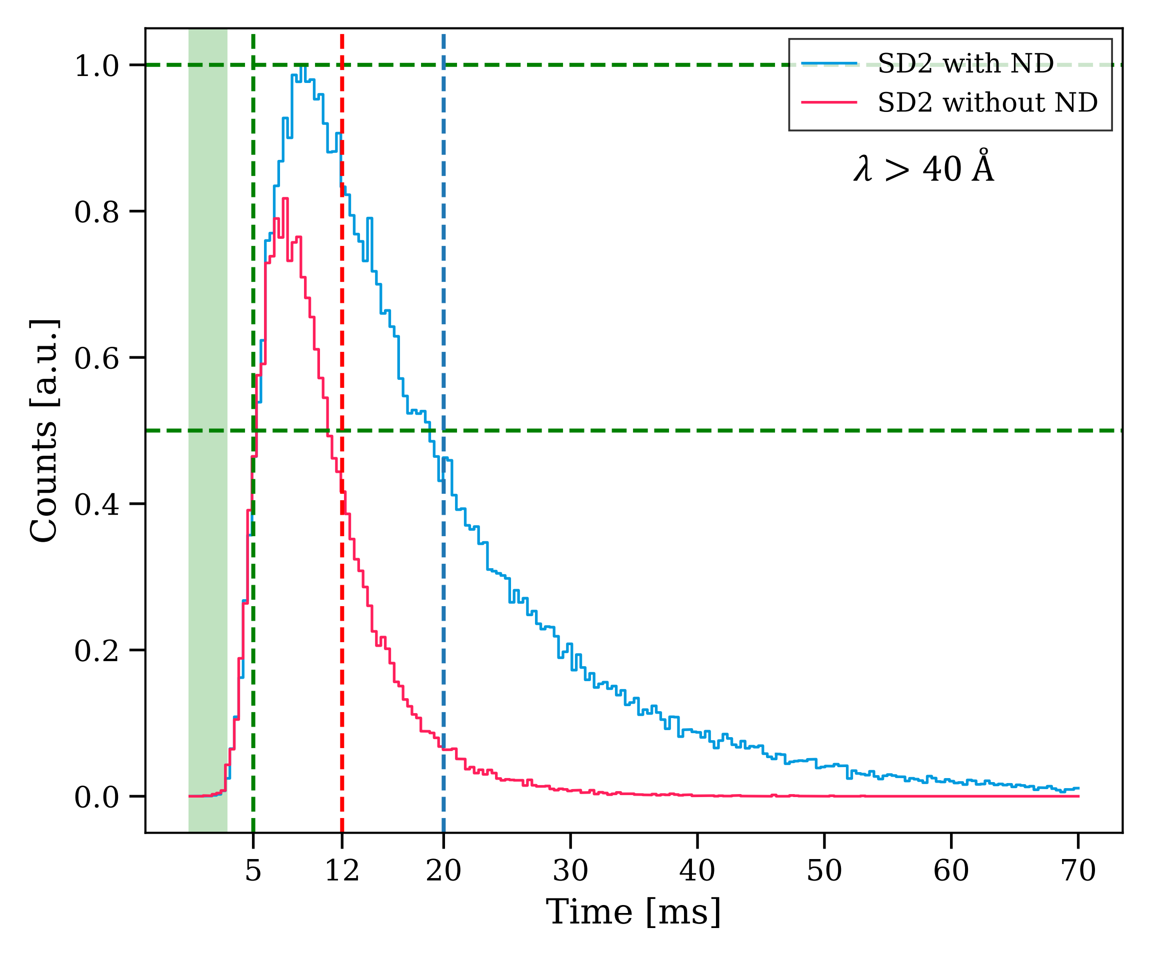
Pulse characteristics





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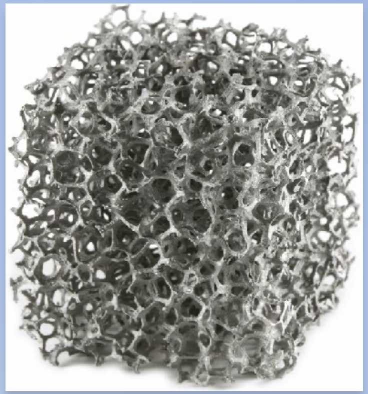
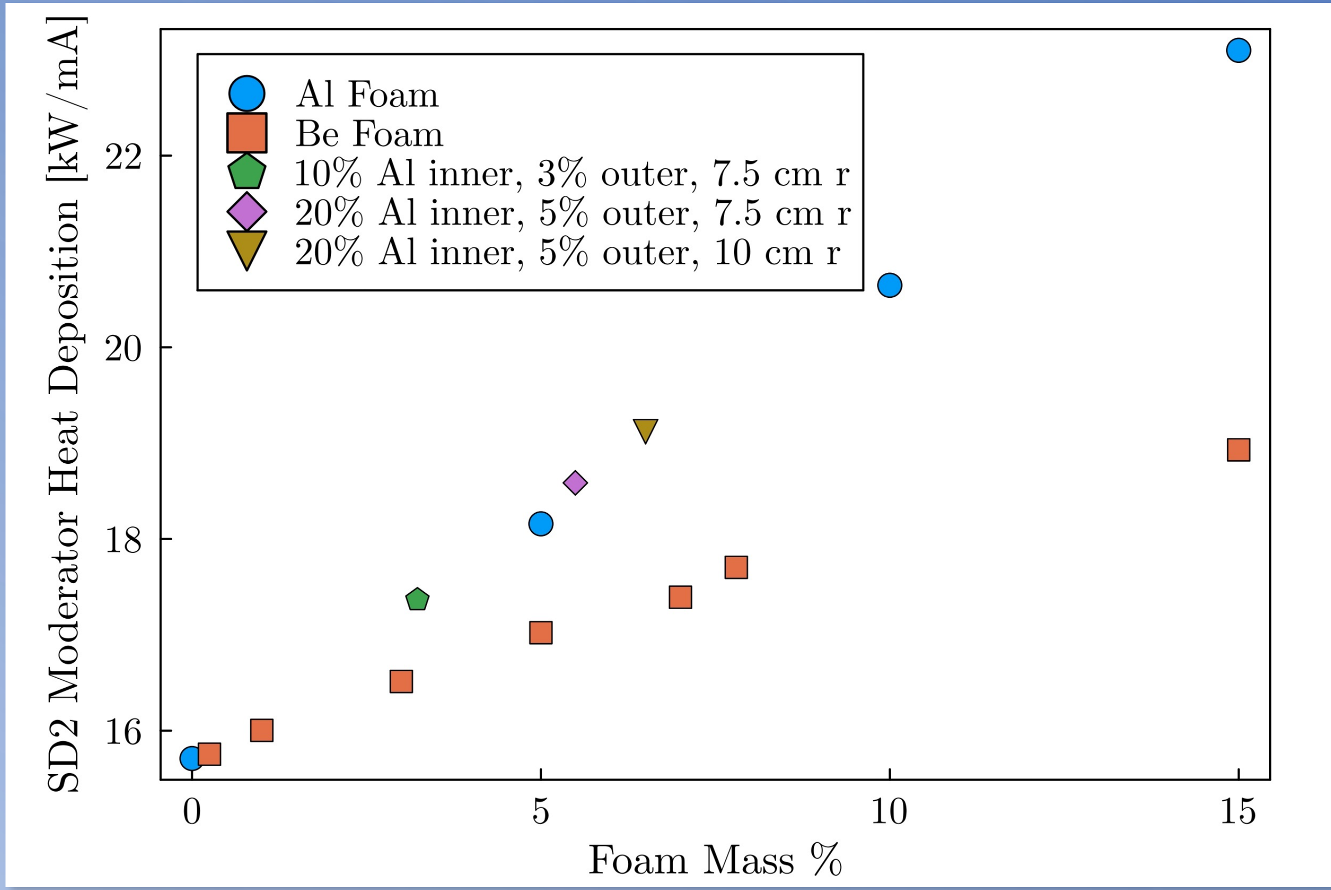
How do we plan to cool it?

- Preliminary calculations show that it is possible to cool the SD2 volume within the ESS environment **at 2 MW** beam power by use of aluminum foam and conventional liquid-He channeling
- Beryllium performs better in terms of both self-heating and neutronics, further testing is needed to determine its viability at 5 MW.

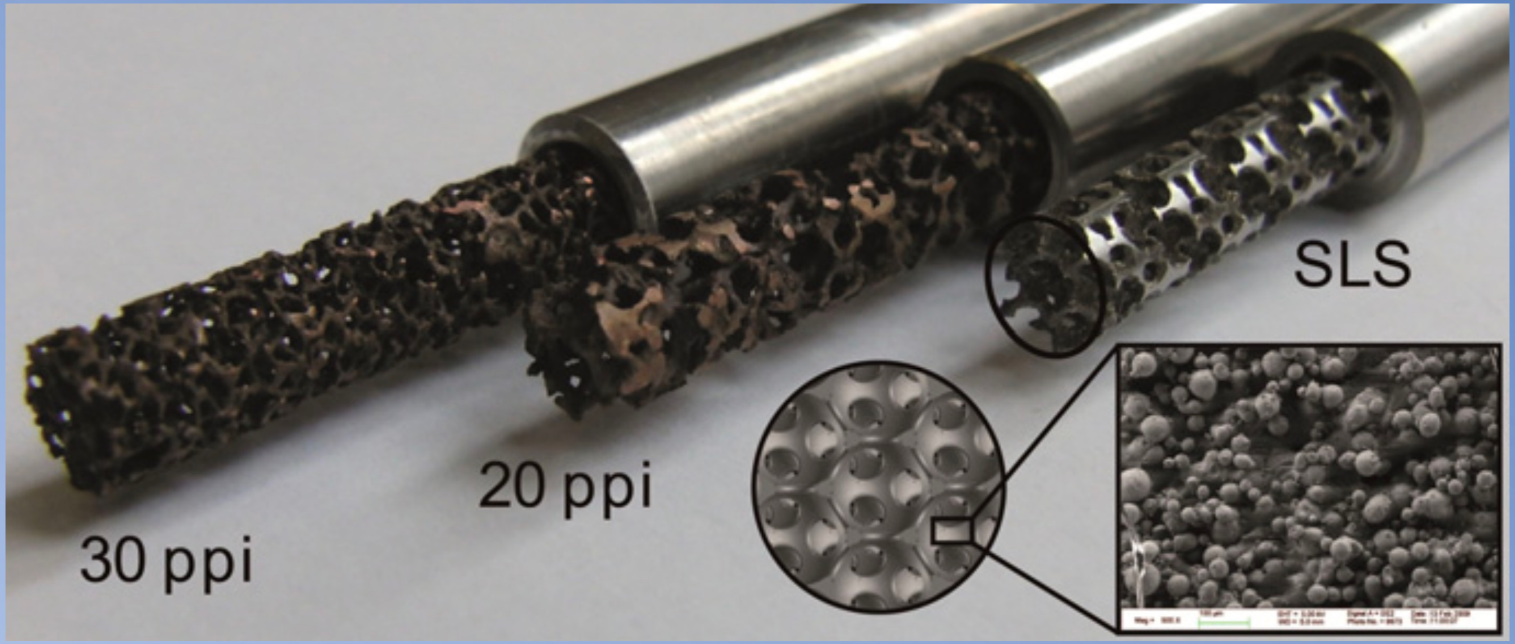




Conventional vs. SLS (3D printed) foams

- SLS has better heat extraction in some applications. May be prohibitively expensive with beryllium due to toxicity measures. Outer surface is left porous.

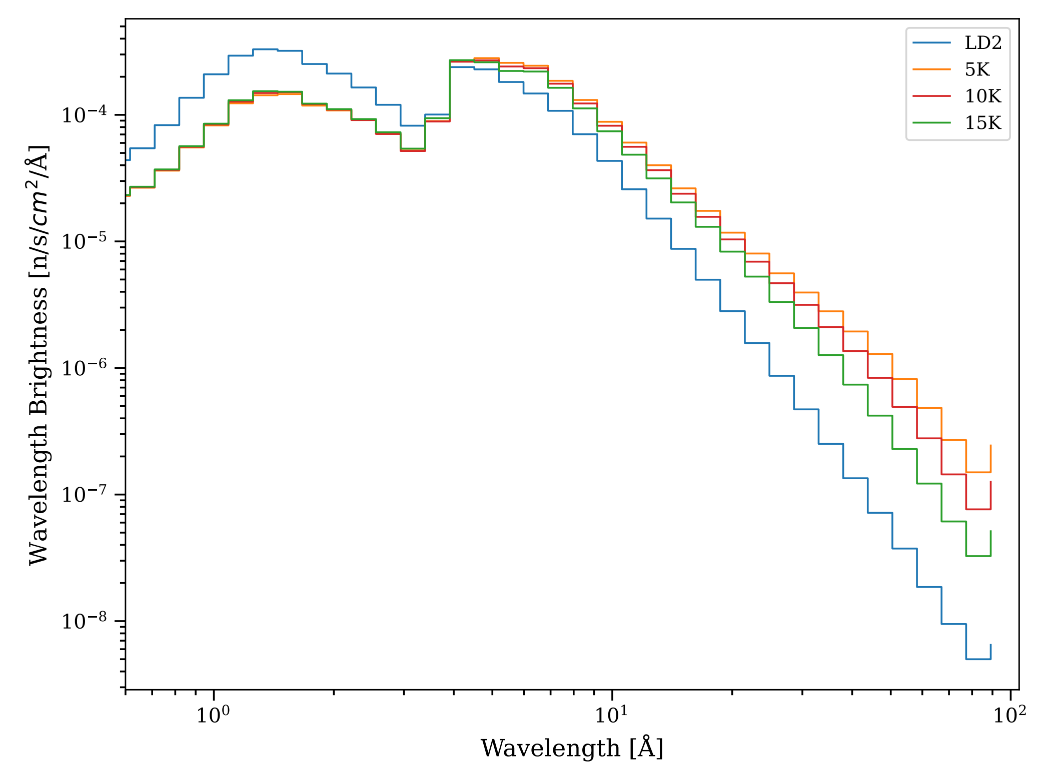
- With conventional foaming-agent production, density and porosity can be tuned homogeneously. This is a more mature technology and may be more feasible for beryllium.



[6]

VCN production with SD_2 temperature

- Early studies show a limit of 10 K is optimal to avoid cracks in the SD2 crystal.
- Thermal conductivity for SD2 drops by a factor of 30 from 5K to 12K [7]. This may present engineering constraints.



(WP7 Side)

Conclusions

- We found that solid-D_2 could be used to build a high-intensity VCN source
- Nanodiamonds are almost transparent in transmission for cold neutrons, but at lower energies they show optimal properties as reflector material
- Nanodiamond fabrication for VCNs has improved in the last few years; nanodiamond reflector performance is thus likely to exceed our current estimates.
- Cooling is going to be challenging, but:

1. A VCN source could operate at higher temperature than 5 K
2. We should not give up on the possibility to innovate

- In any case, solid-D_2 could play a role in the future of the ESS. With the right amount of effort and expertise there is fertile ground for designing the first high-intensity VCN source

Thank you
for your attention

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References

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