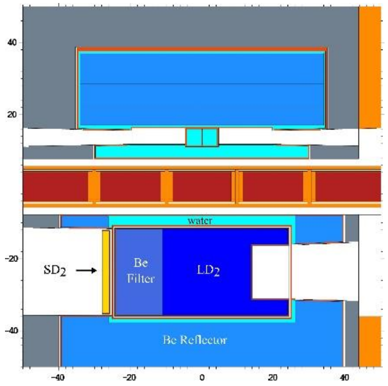
DTU

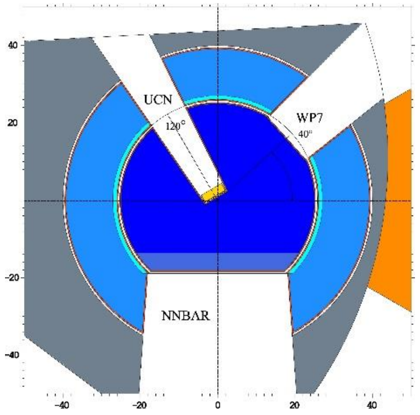
Second Workshop on UCN and VCN Sources at ESS

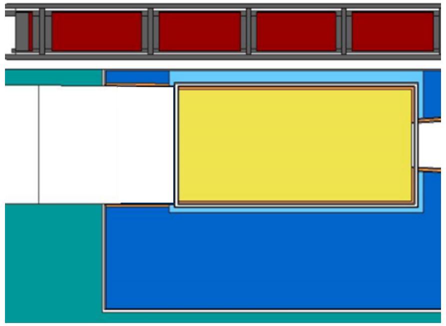
SD_2 UCN Source in the twister

Outline of this presentation

1. SD_2 in the Twister
2. Thin-slab external converter
3. Cylindrical 3-opening design
4. Full SD_2 as primary moderator
5. Scenarios and conclusions

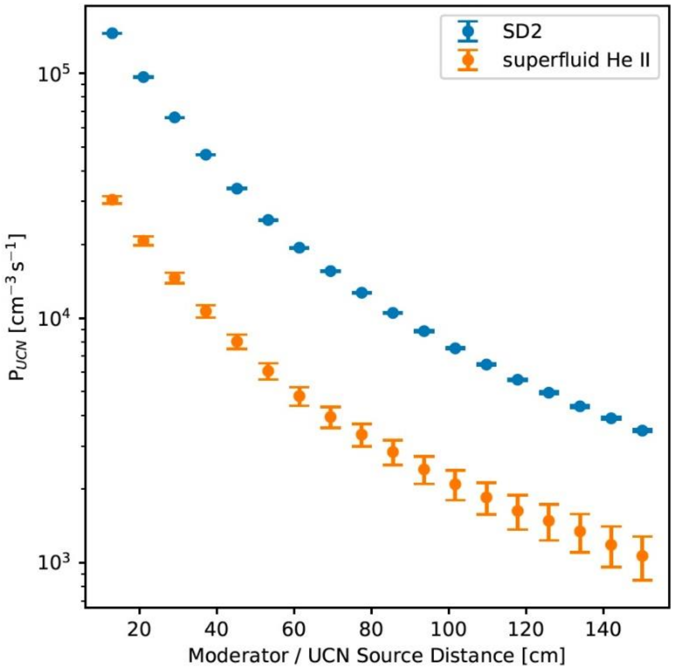


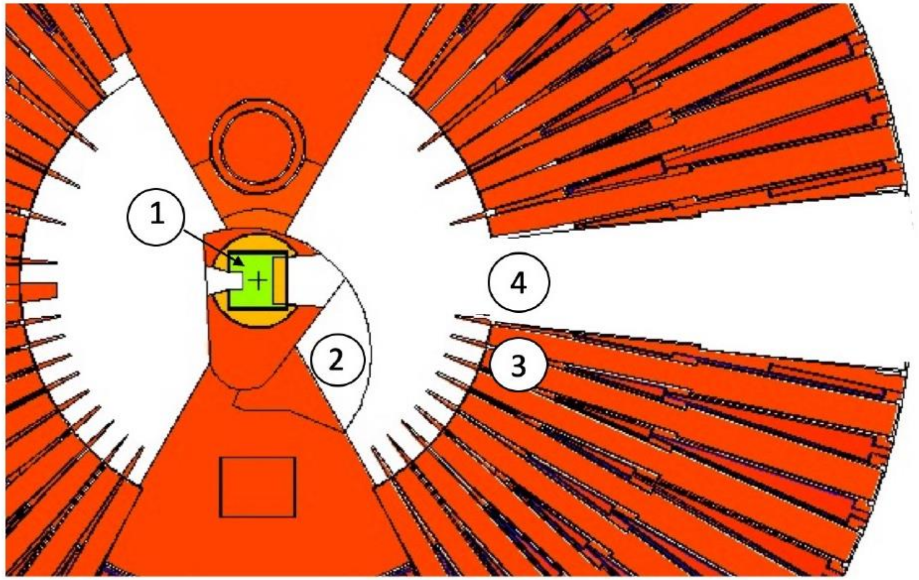




SD_2 in the Twister

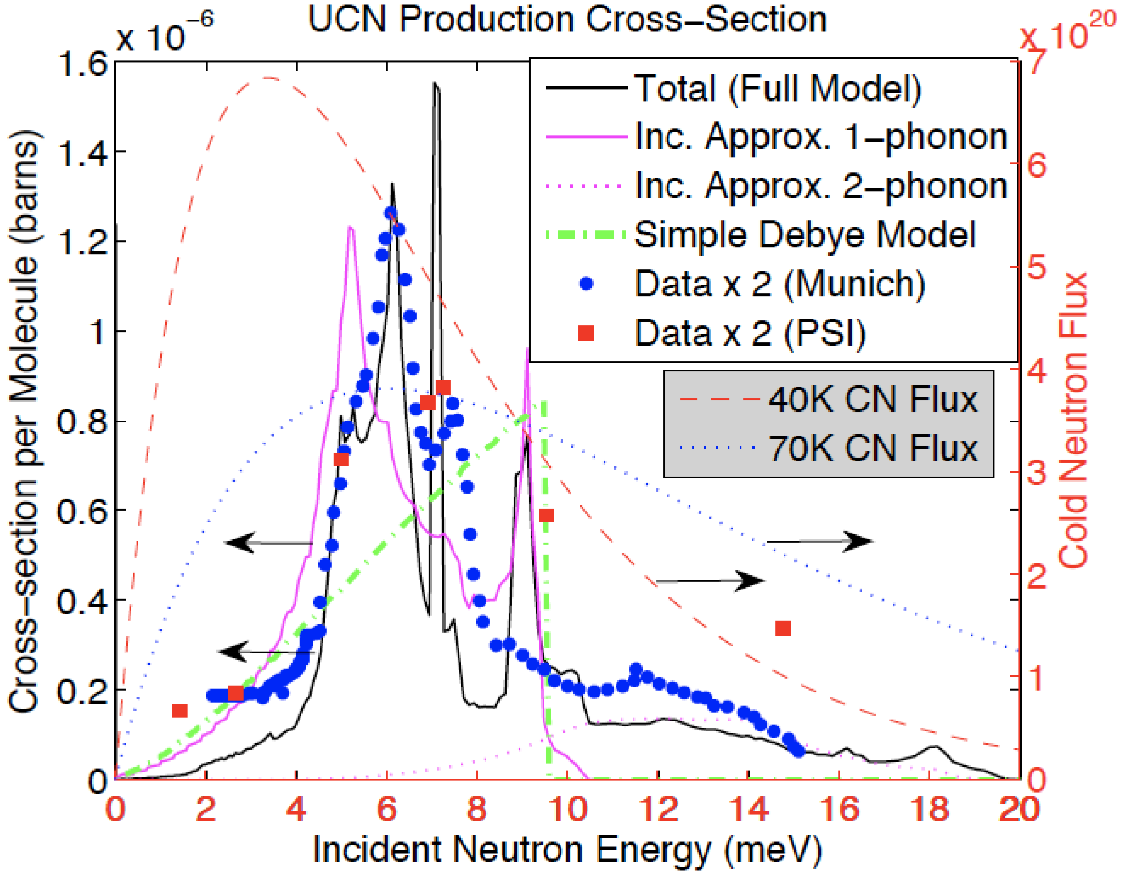
- The rationale behind this concept is to maximize the cold flux delivered to the UCN converter





Calculating the UCN production

- MCNP does not transport UCNs
- We calculated the cold flux and multiplied it by the UCN production cross-section
- The cross-section was calculated from a dynamical scattering function extracted from the IN4 experiment
- More on this in the next talk



Thin-slab UCN converter

- 24 x 40 x 2 cm^3 SD_2 converter @ 5K (1.8 L)
- Al vessel with 2 mm walls

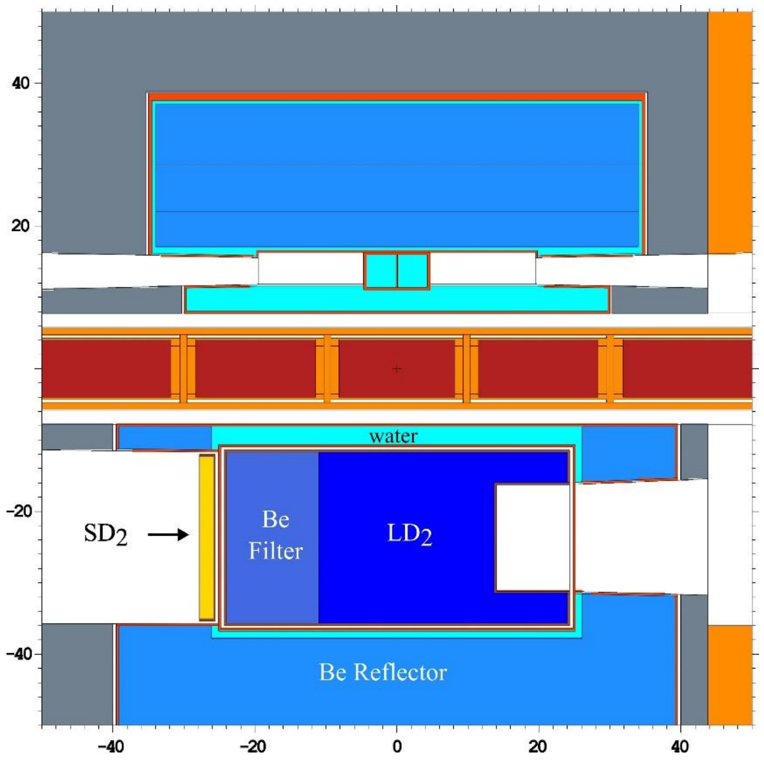
P_{UCN} = 3.07E+5 UCN/cm^3/s

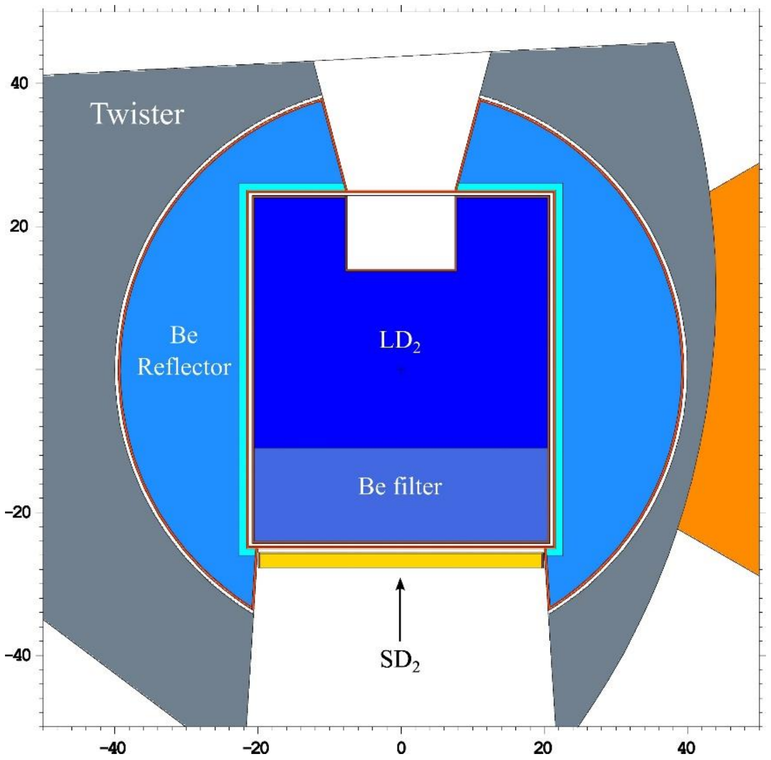
Heat-load = 760 W

No cold Be Filter

P_{UCN} = 4.70E+5 UCN/cm^3/s

Heat-load = 1 kW





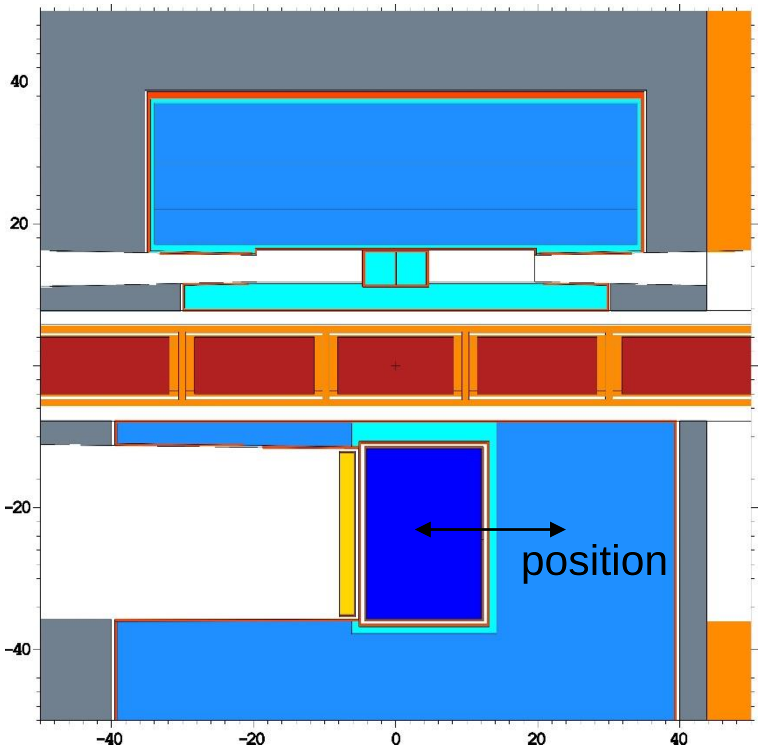
Dedicated cold moderator

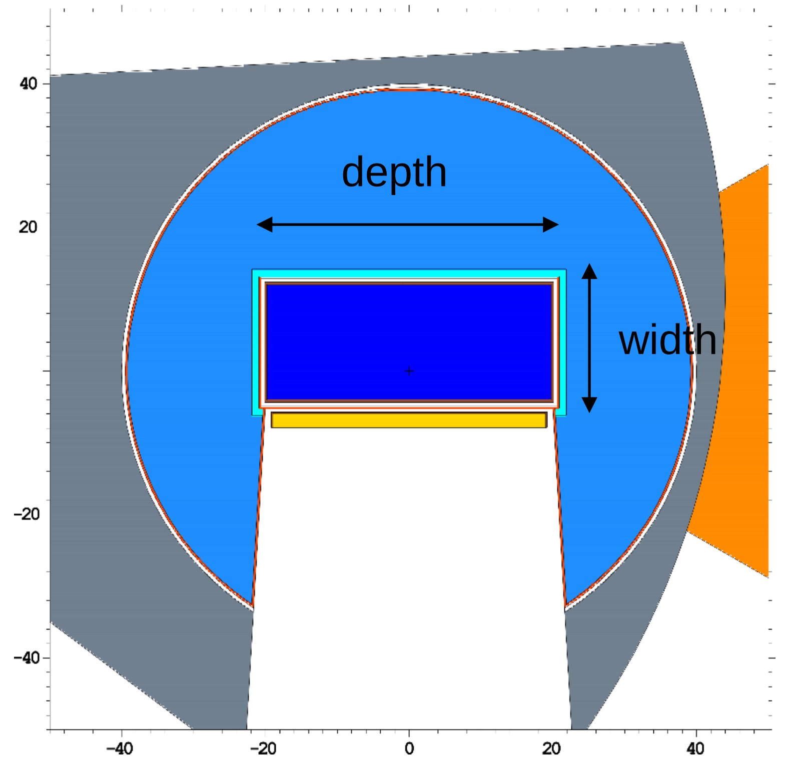
- Optimization of the LD_2 moderator with Dakota
- Paramters: width, depth and position of the moderator
- SD_2 converter is fixed
- Best case: 40 x 16 x 24 cm^3 and a 4 cm center shift

P_{UCN} = 7.72E+5 UCN/cm^3/s

Heat-load = 2.9 kW

No need of large volumes if close to the hot spot of cold neutron production

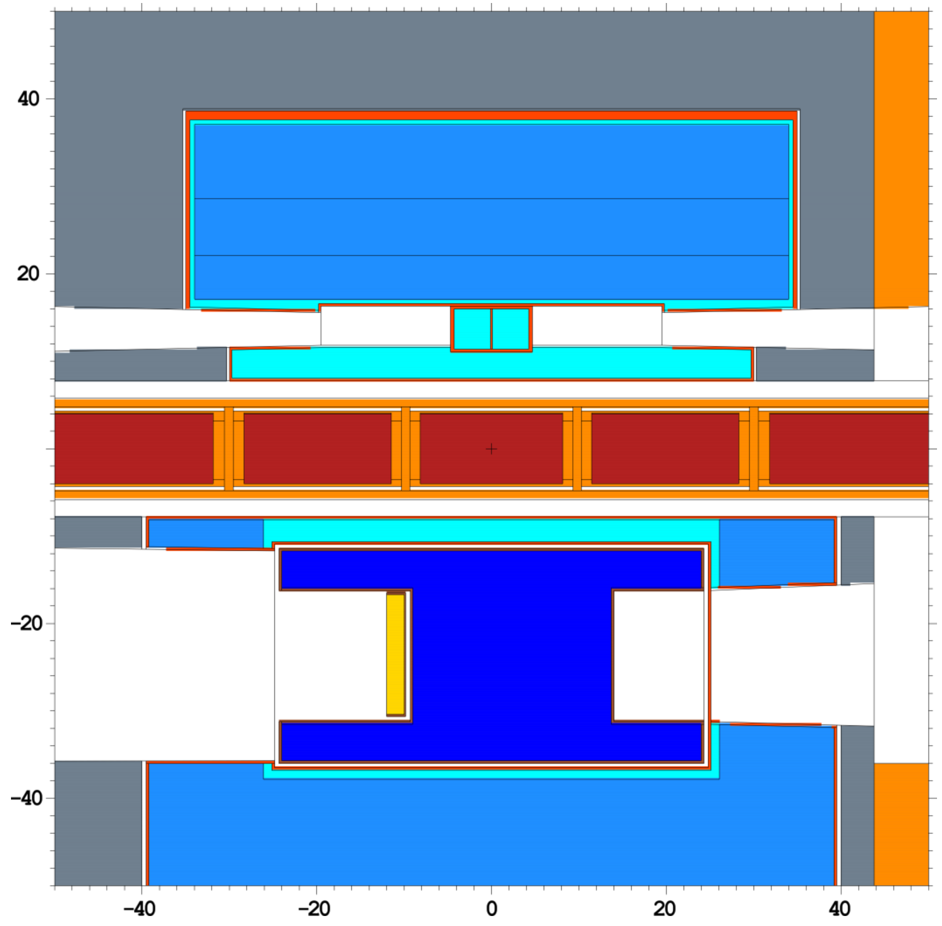




Reentrant hole design

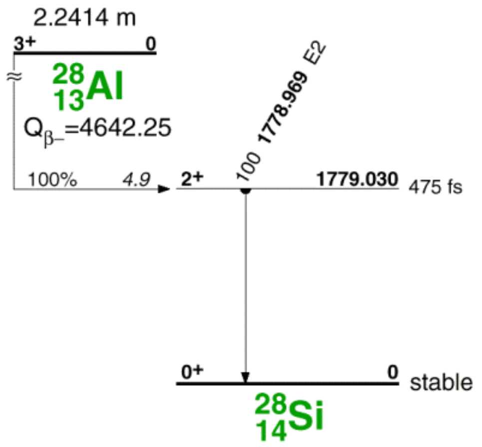
- 2-cm thick SD_2 converter @ 5K at the bottom of a 15 x 15 x 15 cm^3 reentrant hole
- This 0.38 L converter produces a P_{UCN} = 1.31E+6 UCN/cm^3/s
- The production rate though is lower than the previous case, due the smaller volume
- The total prompt heat-load is 560 W, also lower

Essential to optimize the reentrant hole depth to account for both openings



Activation of ^{27}Al

- Neutron activation of ^{27}Al, and subsequent decay of ^{28}Al, contributes to the delayed heat-load on the converter



Estimation of the saturation activity of ^{28}Al (FM card)

β source

γ source

Electron heat deposition

Photon heat deposition

- Decay products add a contribution up to almost **30% of the heat in the Al vessel**, which in turn represents 30% of the total heat-load. So, it is not negligible
- The contribution in the SD_2 cell is approximately 4%, mainly from the surrounding Al vessel

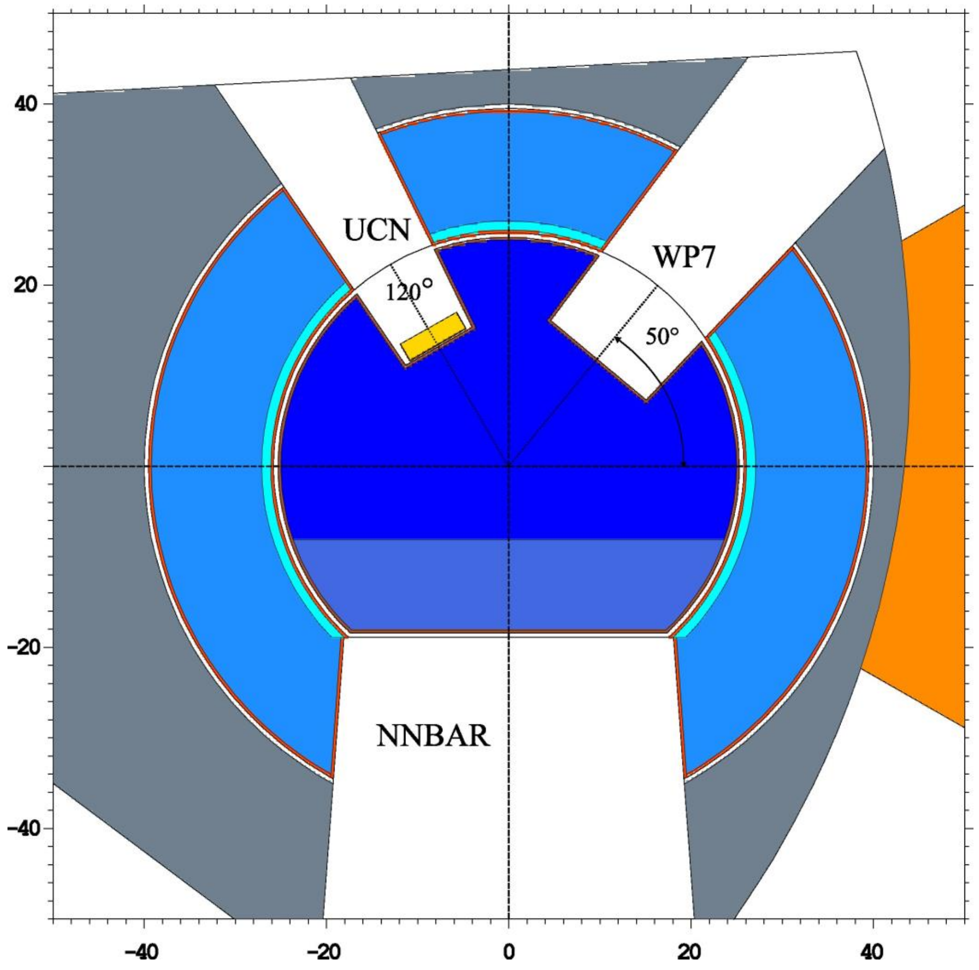
3-in-1 moderator

- Cylindrical moderator 45 cm diameter
- 3 openings
  1. 24x40 NNBAR opening with flat surface and Be filter
  2. 10x10 UCN opening with a deep reentrant hole and a thin-film SD_2 moderator at the bottom
  3. 15x15 neutron scattering opening

Volume = 0.13 L

P_{UCN} = 1.74E+6 UCN/cm^3/s

Heat-load = 520 W



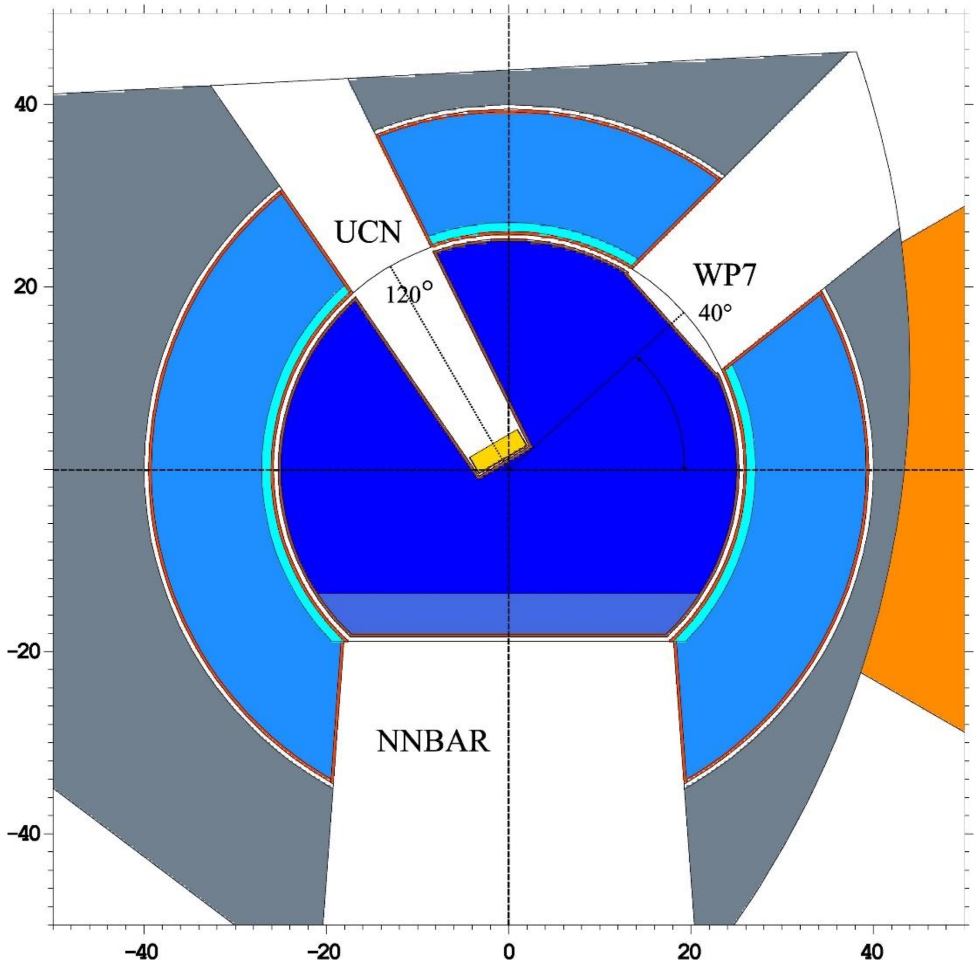
Optimization 3-in-1 moderator

- Competition for the cold neutron hotspot once again
- Optimizing the reentrant hole depths and the Be thickness for the P_{UCN}
- Huge loss on the neutron scattering opening
- need of a wider optimization effort, that considers more parameters and both NNBAR and WP7 FOMs

Volume = 0.07 L

P_{UCN} = 2.34E+6 UCN/cm^3/s

Heat-load = 550 W



SD_2 as primary moderator

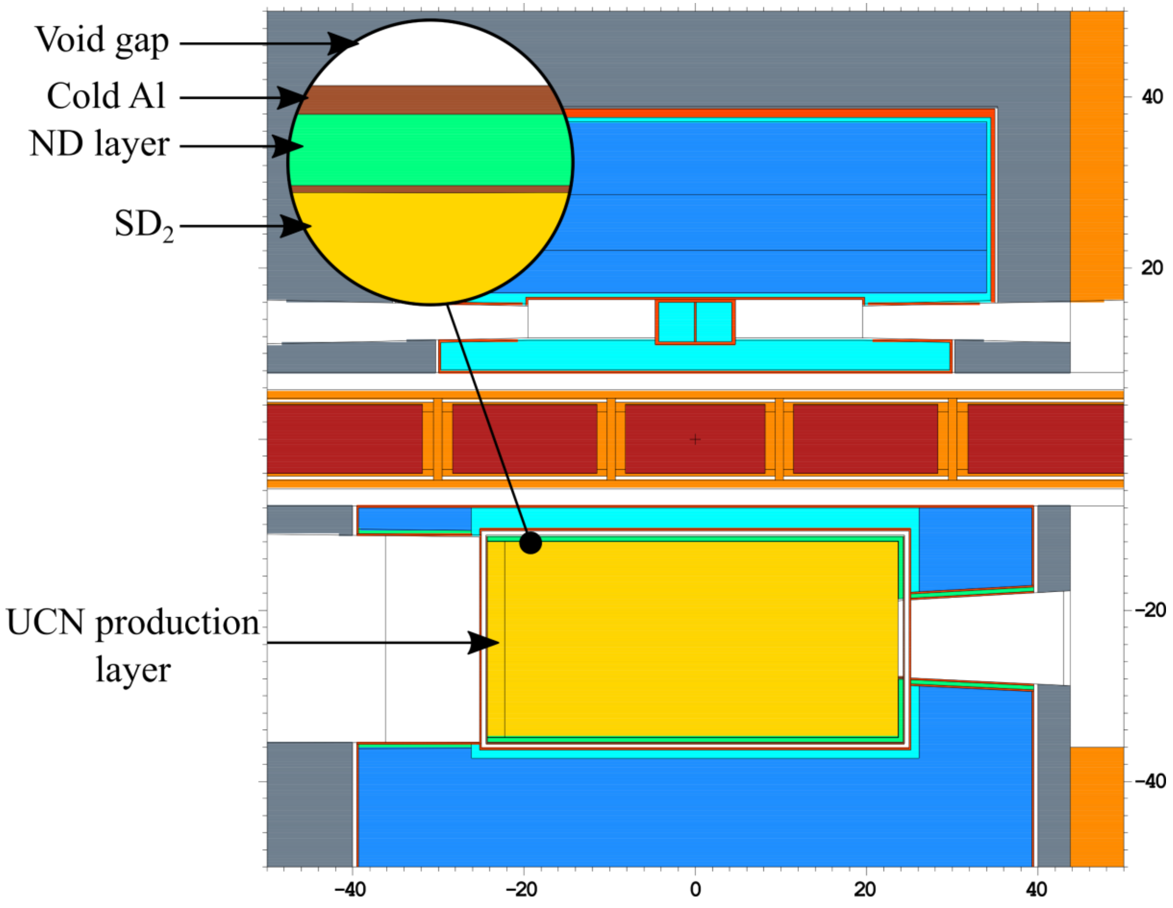
- SD_2 can be used for UCN production
- 48.2 L of SD_2 @ 5 K
- UCN could be extracted from the last 2 cm on the NNBAR side
- No cooling structure should be put here

Volume= 48.2 L

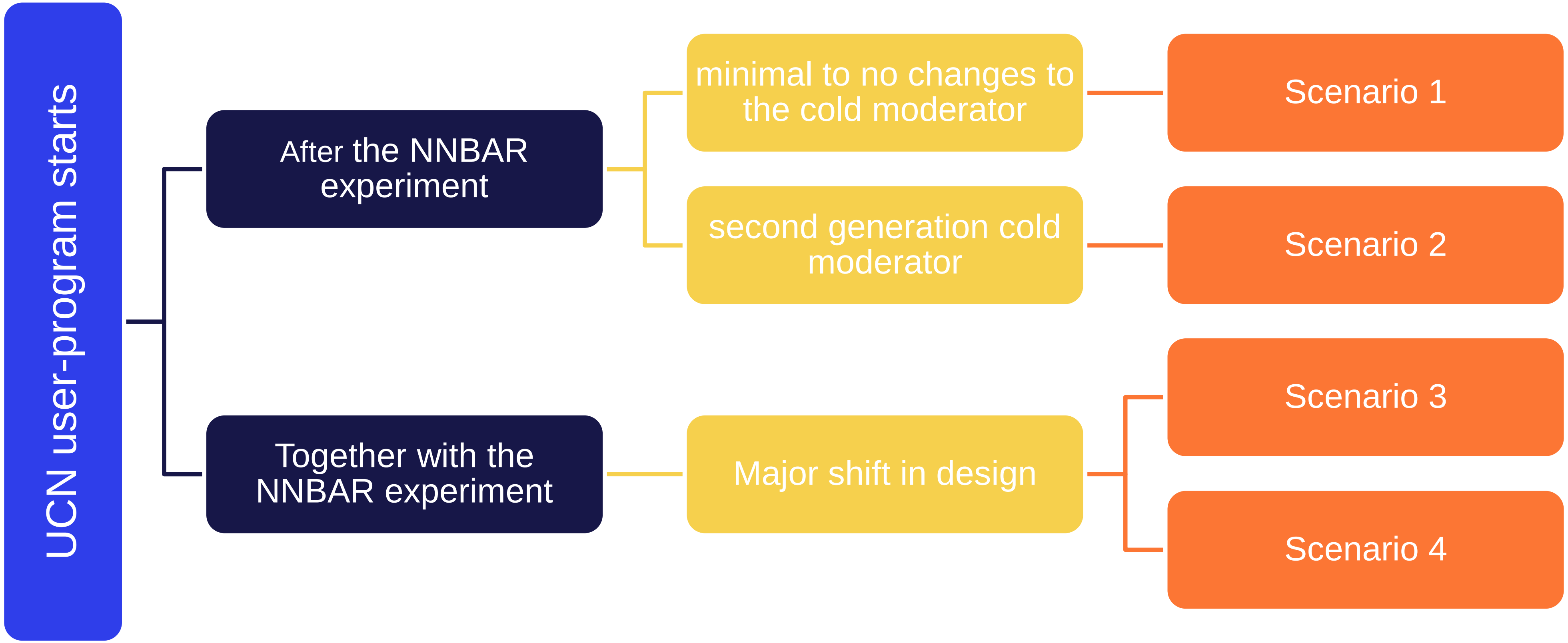
P_{UCN} in the last 2 cm = 9.13E5 UCN/cm³/s

Heat-load = 40 kW

Production of unprecedented VCN intensity for the future of ESS



UCN scenarios

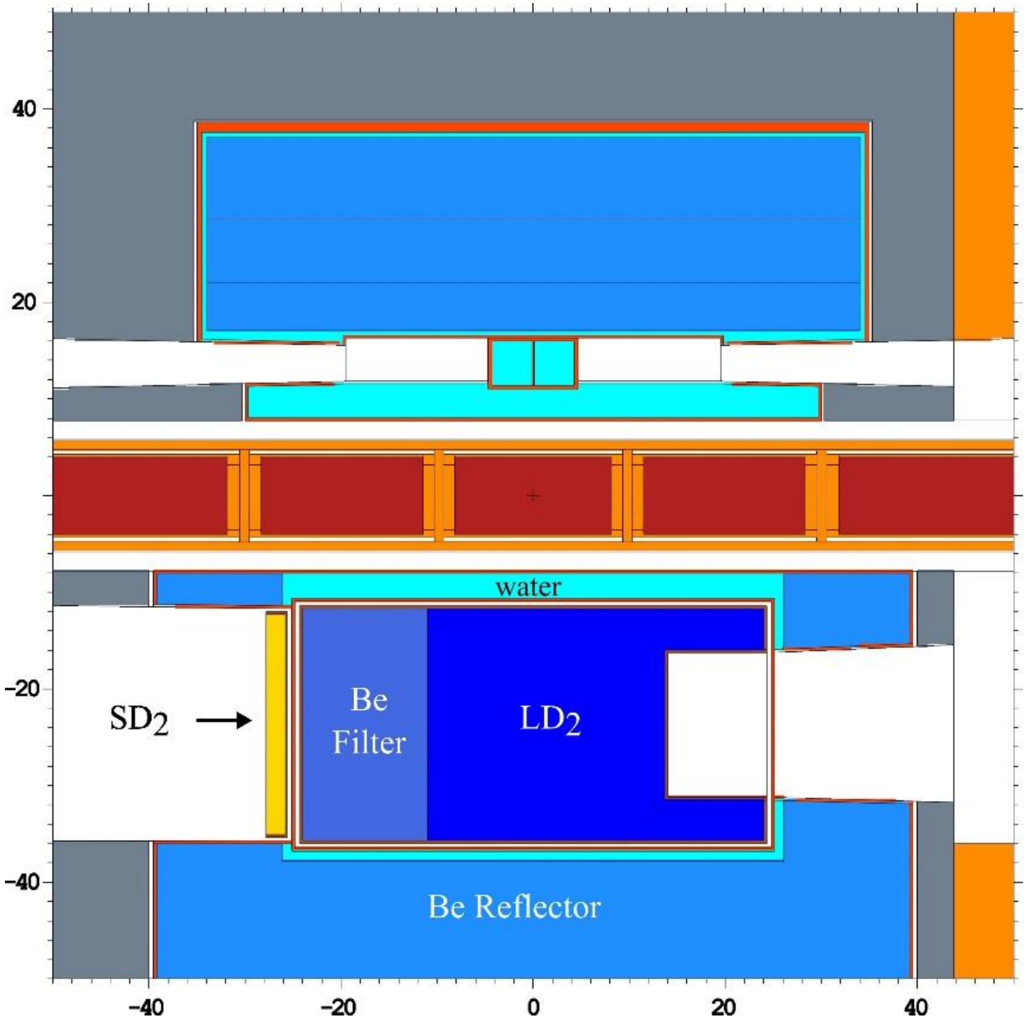


Scenario 1

- The UCN program starts after the NNBAR experiment, and minimal to no changes in the LD_2 moderator are foreseen

- Independent from the LD_2 source
- Be filter could be removed for higher performances

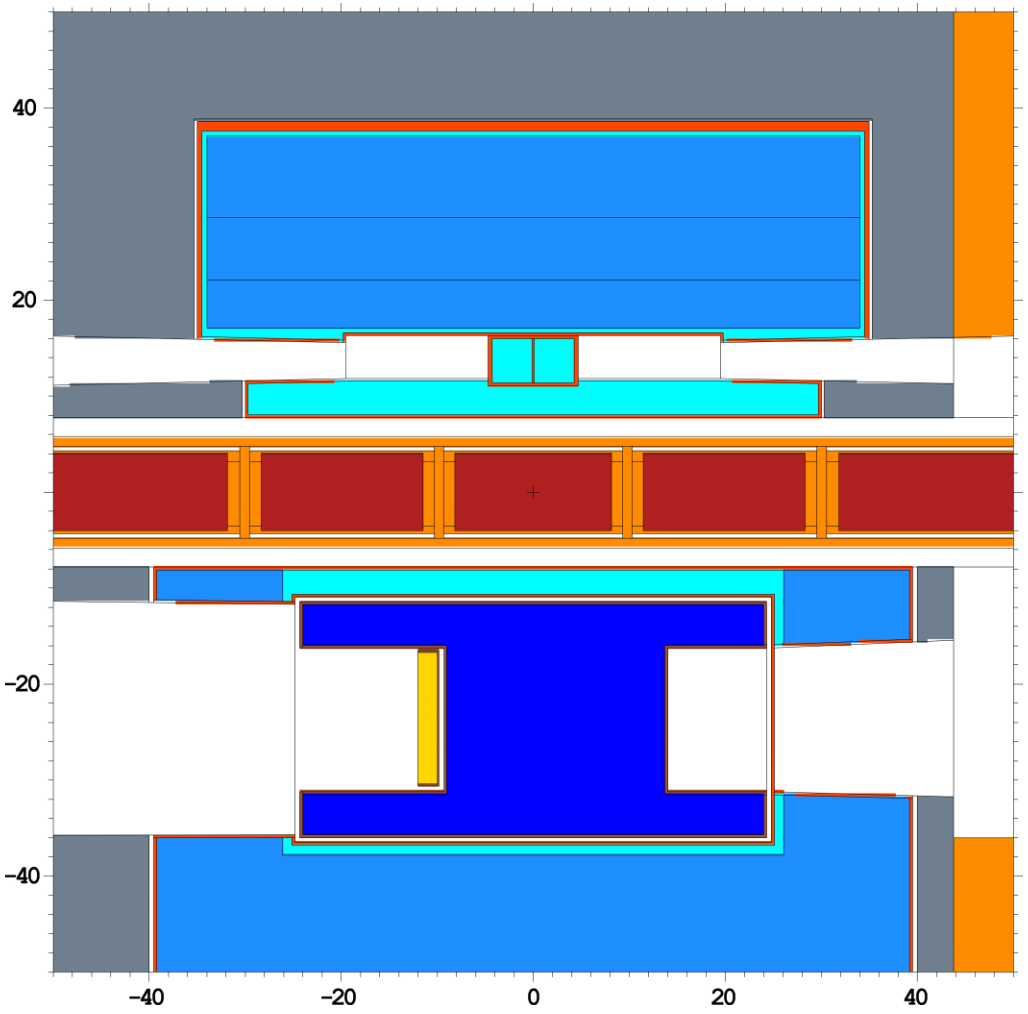
- Possible lack of space to accommodate the cooling infrastructure within the pre-designed cold moderator frame



Scenario 2

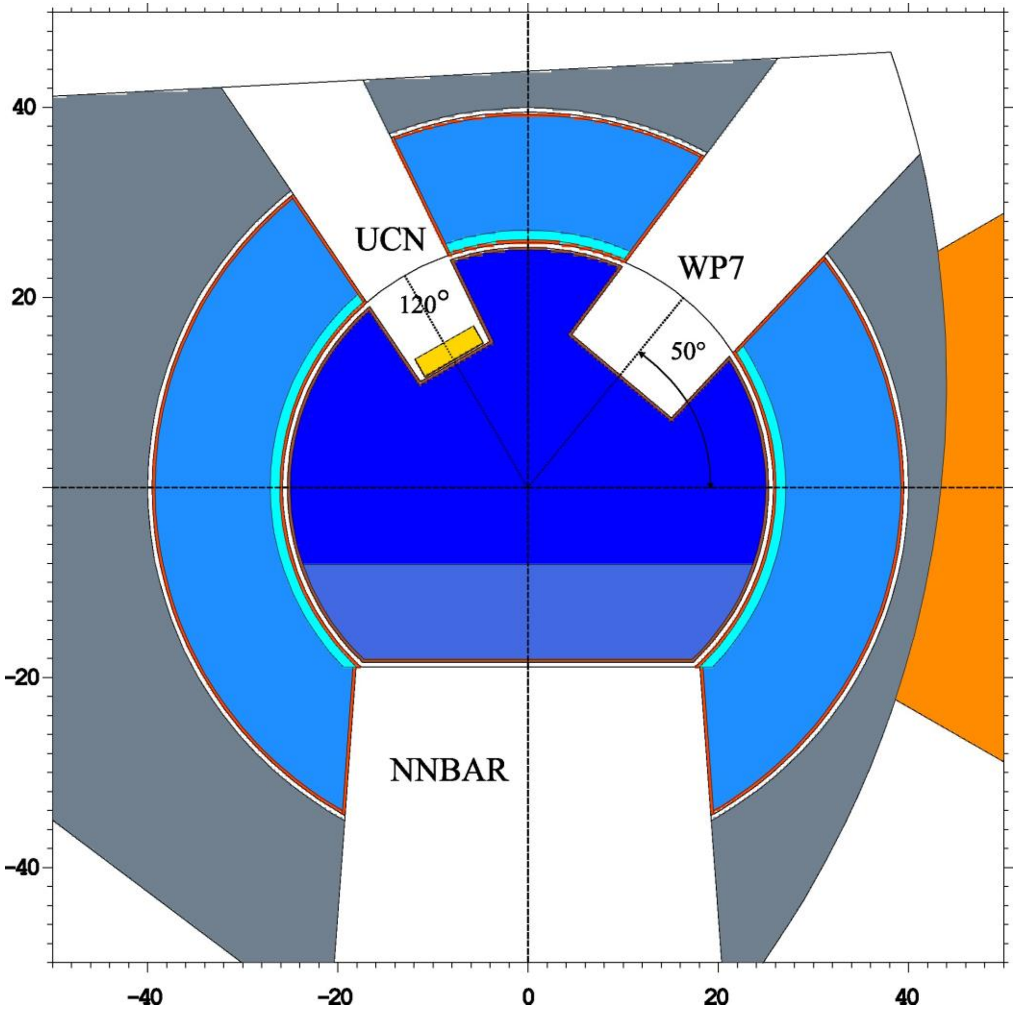
- The UCN program starts after the NNBAR experiment, and a second-generation cold moderator is foreseen

- Design not too far from the first generation
- optimization process of the box moderator will now include one of the FOM for UCN production
- The lack of space for the cooling infrastructure is still an issue, even with a slightly lower heat-load, but the redesign process could take these constraints into account to find new solutions



Scenario 3

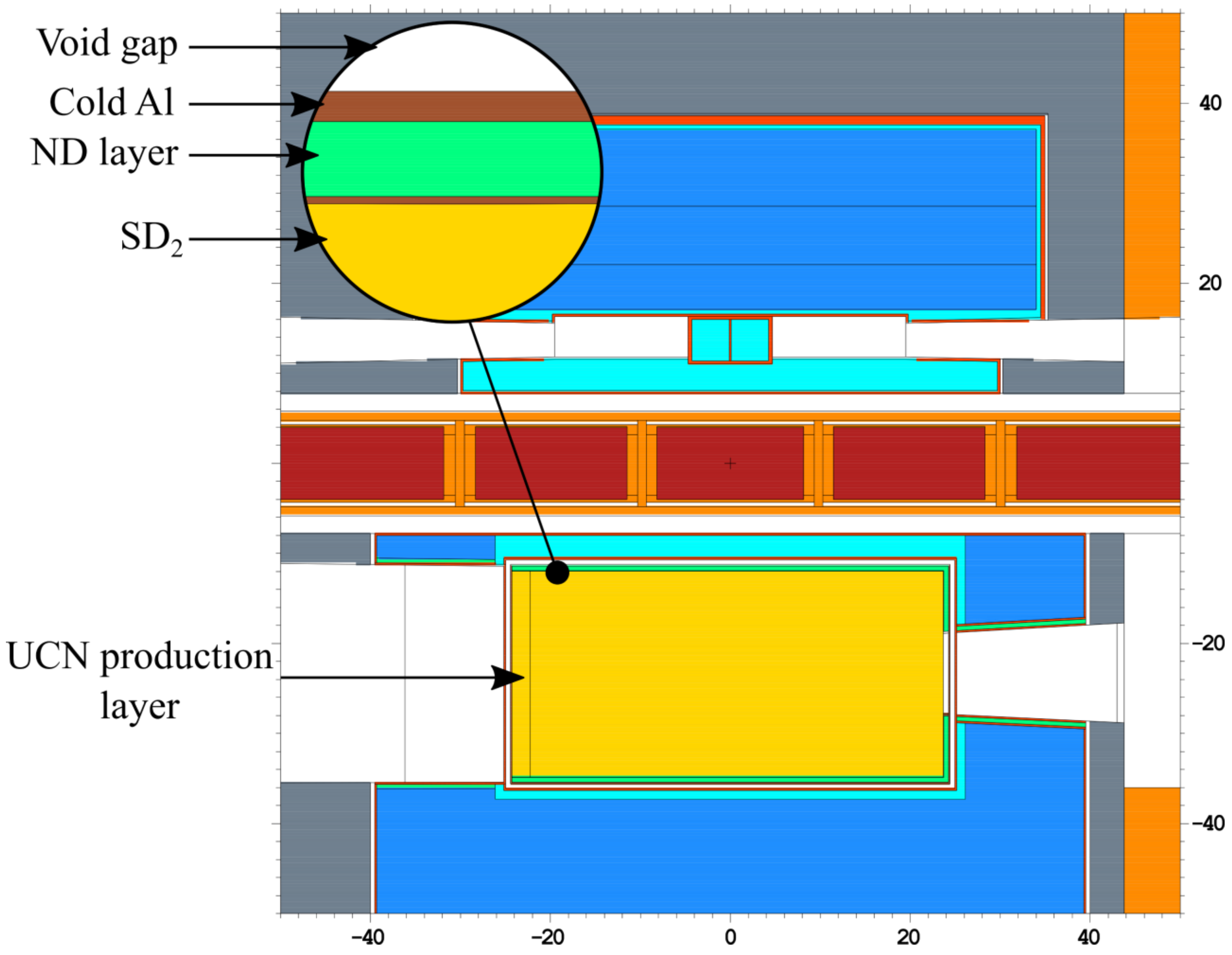
- The UCN program runs together with the NNBAR experiment, which means that a major shift in the design is needed.



- Cylindrical shape allows for a third opening
- Preliminary simulations have shown that the losses for NNBAR and WP7 are far from being crippling
- This design has many parameters and three figure of merits, so one should expect a long and complex optimization process

Scenario 4

- Large SD_2 crystal that could serve the NNBAR experiment, but most likely after



- High VCN intensity
- UCN “for free” produced in the last centimeters
- This design is the most challenging of all both in terms of design and engineering

Conclusion

- All the designs presented have their strengths and their limitations
- Some of the ideas are challenging

	SD_2 Volume [L]	P_{UCN} $[n/s/cm^3]$	$\dot{N}_{UCN}$ $[n/s]$	Heat-load [W]	WP7 FOM [n/s/sr]	NNBAR FOM $[nÅ^2/s/sr]$
Baseline + UCN	1.81	3.07×10^5	5.56×10^8	760	3.23×10^{15}	-
No Be filter + UCN	1.81	4.70×10^5	8.51×10^8	1000	3.06×10^{15}	-
Optimized UCN-only	1.75	7.72×10^5	1.35×10^9	2910	-	-
Reentrant Hole	0.38	1.31×10^6	5.03×10^8	560	2.81×10^{15}	-
Optimized depth	0.38	1.63×10^6	6.26×10^8	730	2.28×10^{15}	-
Optimized size	0.007	2.41×10^6	1.64×10^7	28	2.96×10^{15}	-
3-openings cylinder	0.13	1.74×10^6	2.22×10^8	520	2.84×10^{15}	2.33×10^{17}
Optimized cylinder	0.07	2.34×10^6	1.66×10^8	550	2.33×10^{15}	2.30×10^{17}
Full SD_2 moderator	48.2	6.56×10^5	1.32×10^9	39886	-	-

The future of the ESS user-program CAN be UCN, and, despite the challenges, the in-twister option WILL provide unprecedented intensity

Thank you
for the attention