ALTERNATIVE REFLECTORS FOR THE NIST NEUTRON SOURCE

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NIST Center for Neutron Research

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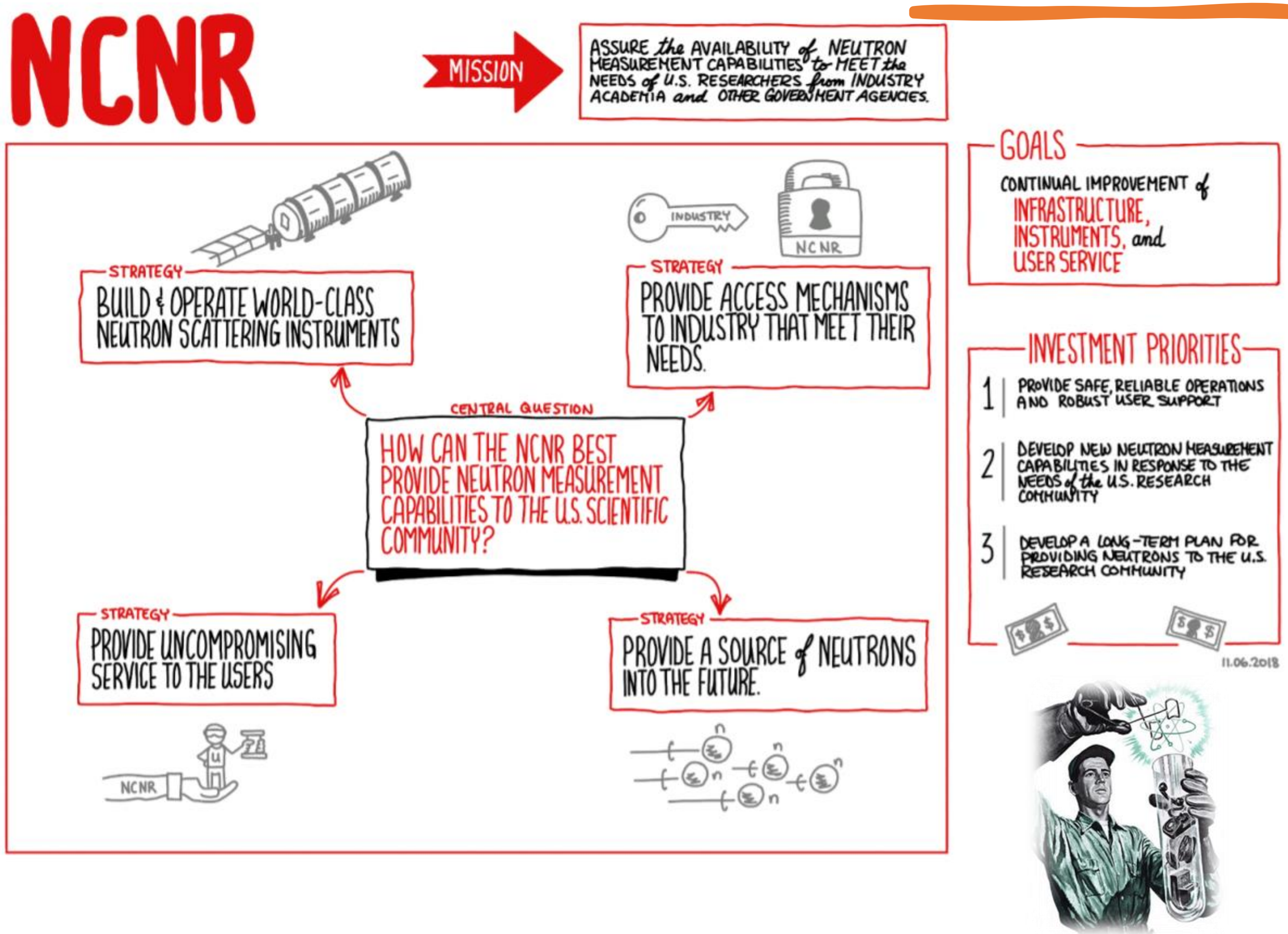
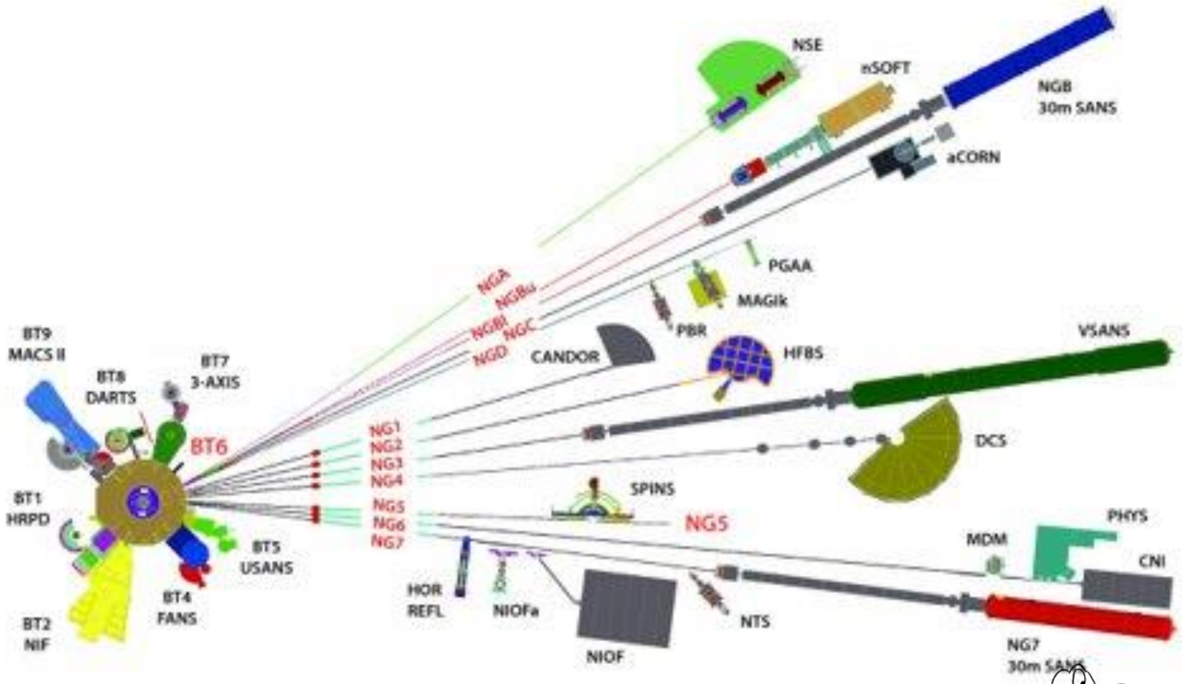
The NIST Center for Neutron Research - NCNR



The National Bureau of Standards Reactor – NBSR

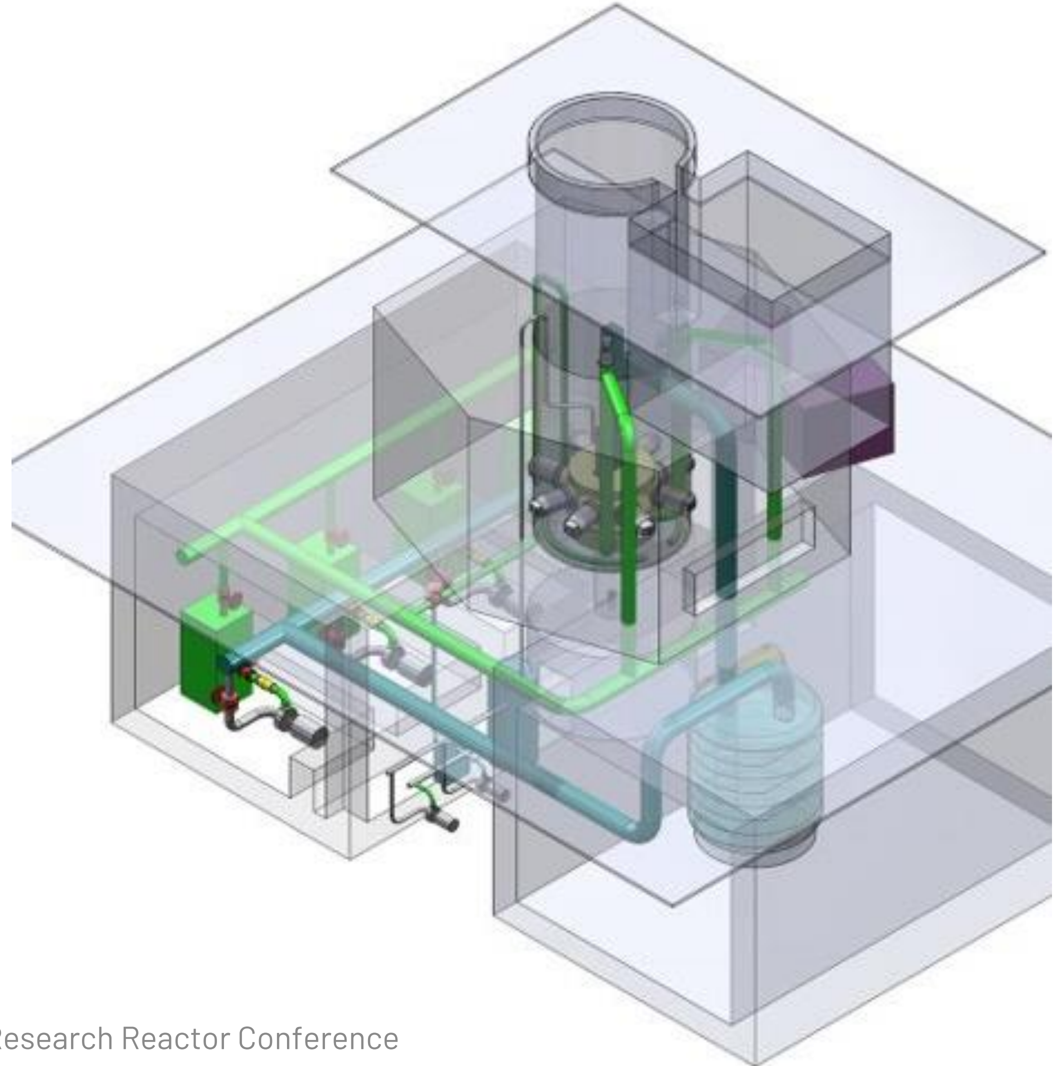
Fulfill those goals since 1967



Introduction to NNS

NNS – NIST Neutron Source Preliminary Design

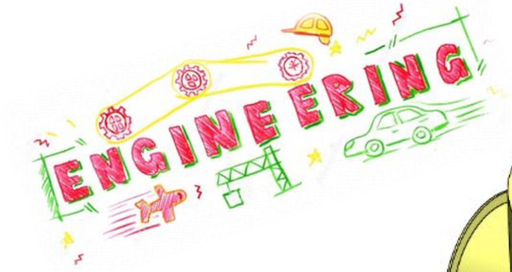
- Light-water-cooled compact reactor core
- Nominal power of 20 MW
- U-Mo LEU (base design)
- Heavy-water reflector tank
- 2 Cold Neutron Sources
- 8 Thermal Neutron Beams
- 40 days operating cycle

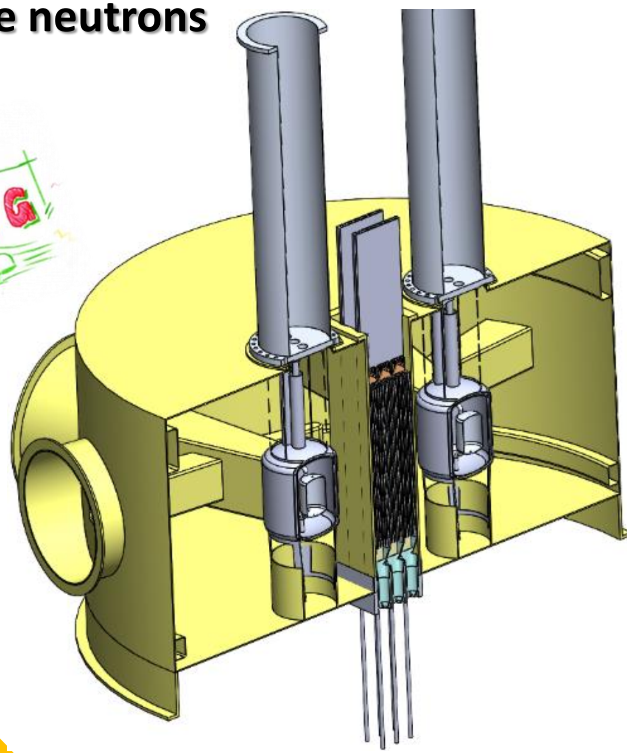


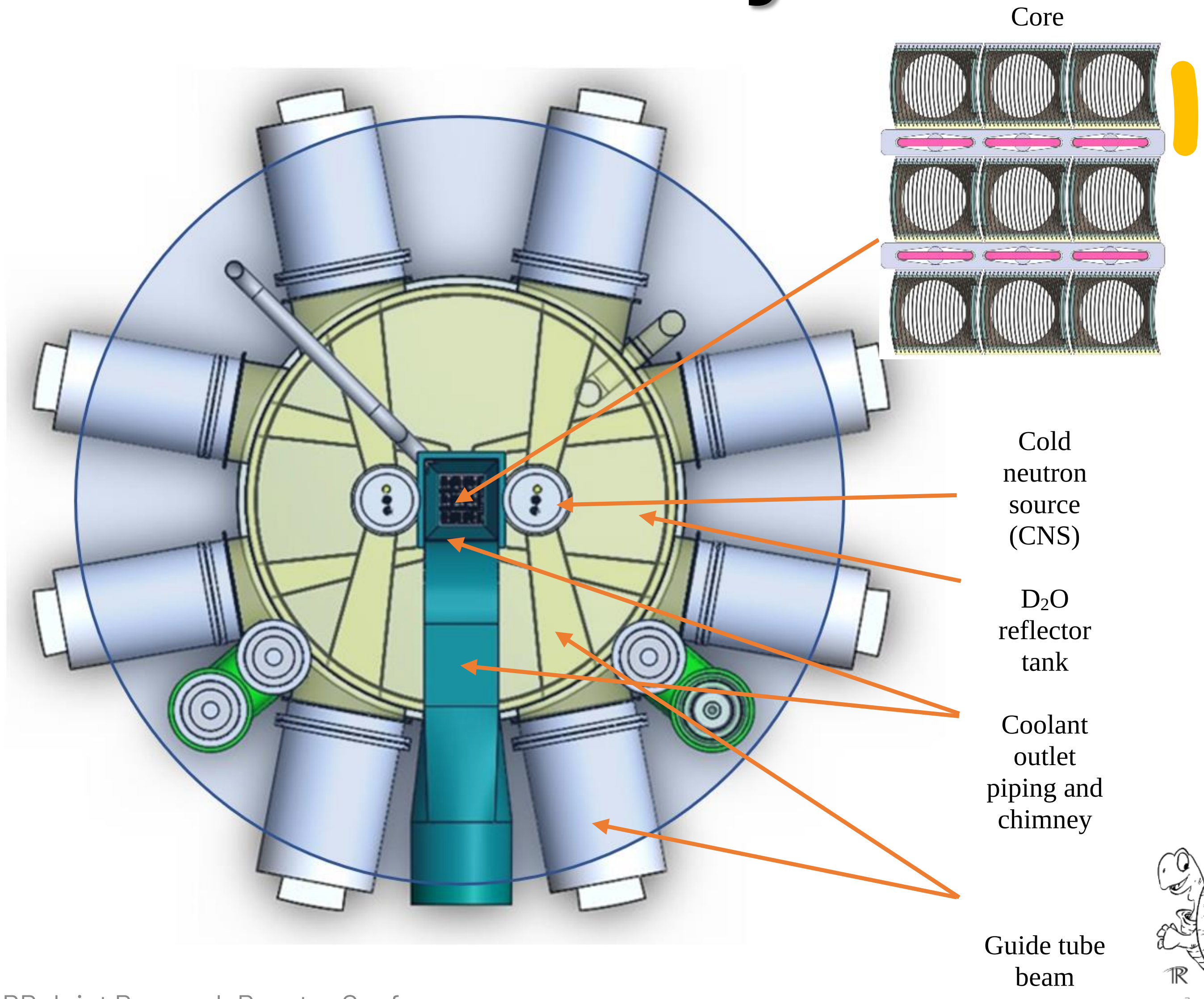
NNS layout

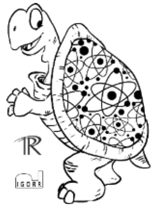
NNS core preliminary design is surrounded by heavy water

- The **heavy water** tank:
  - Holds the Cold Neutron Sources
  - Holds Thermal Neutron Beams
  - **Reflects the core neutrons**



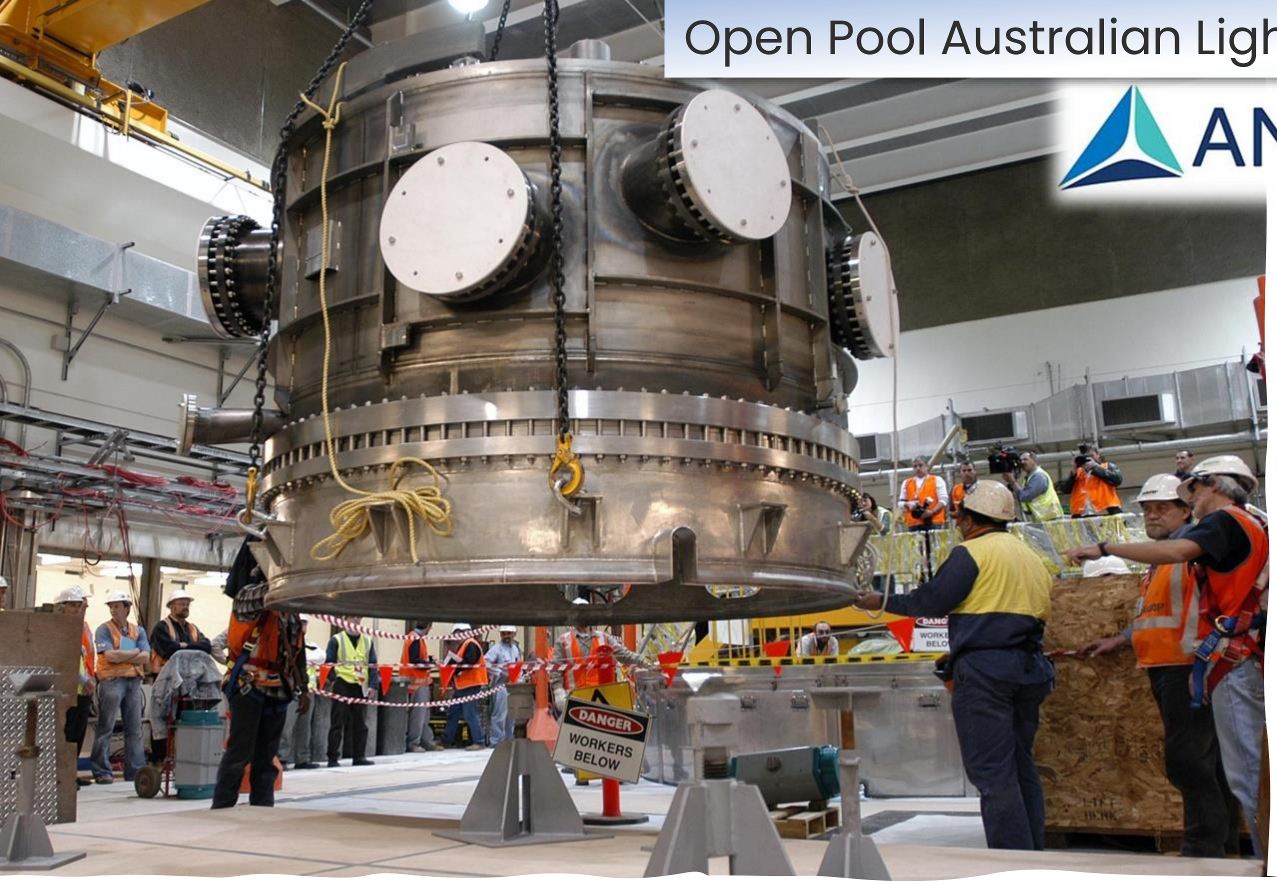


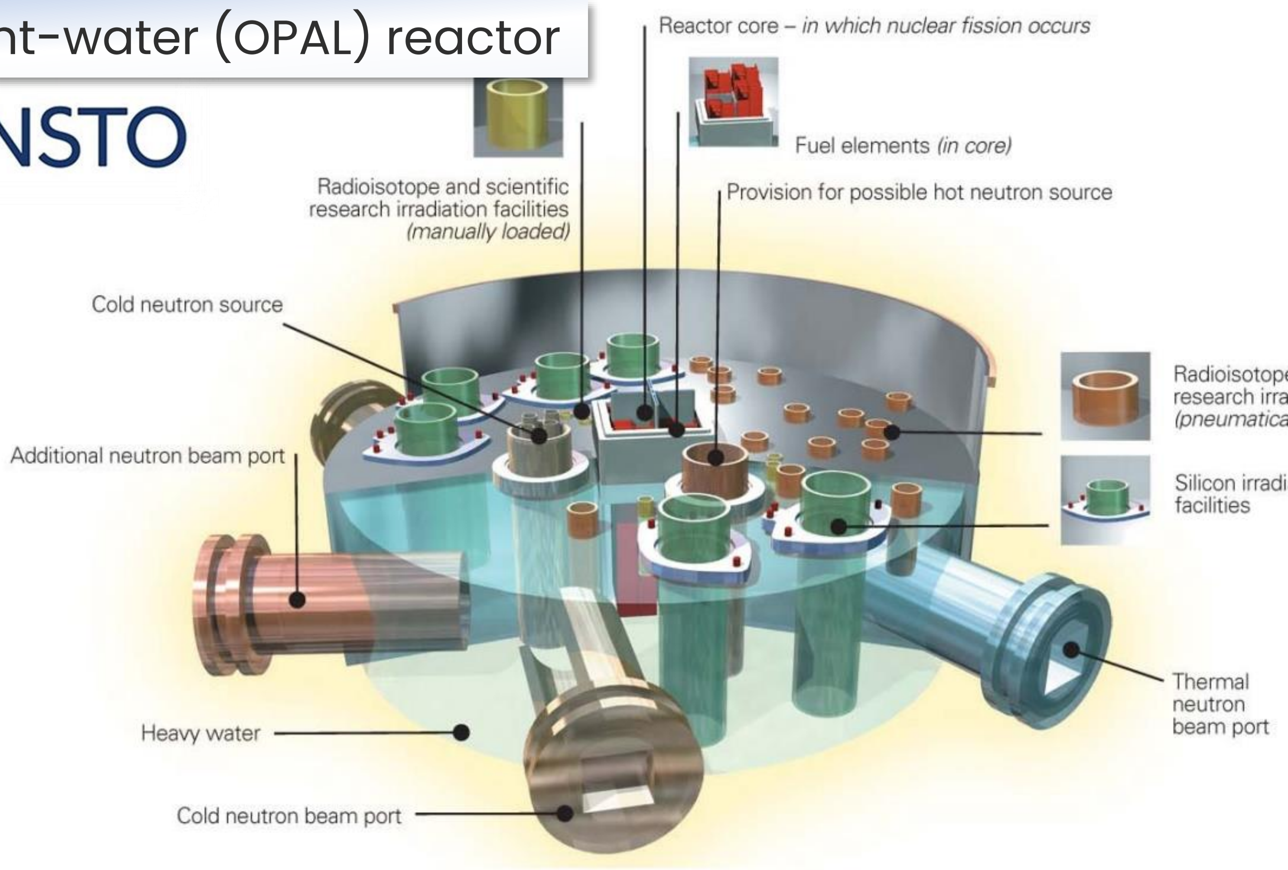




Open Pool Australian Light-water (OPAL) reactor

ANSTO



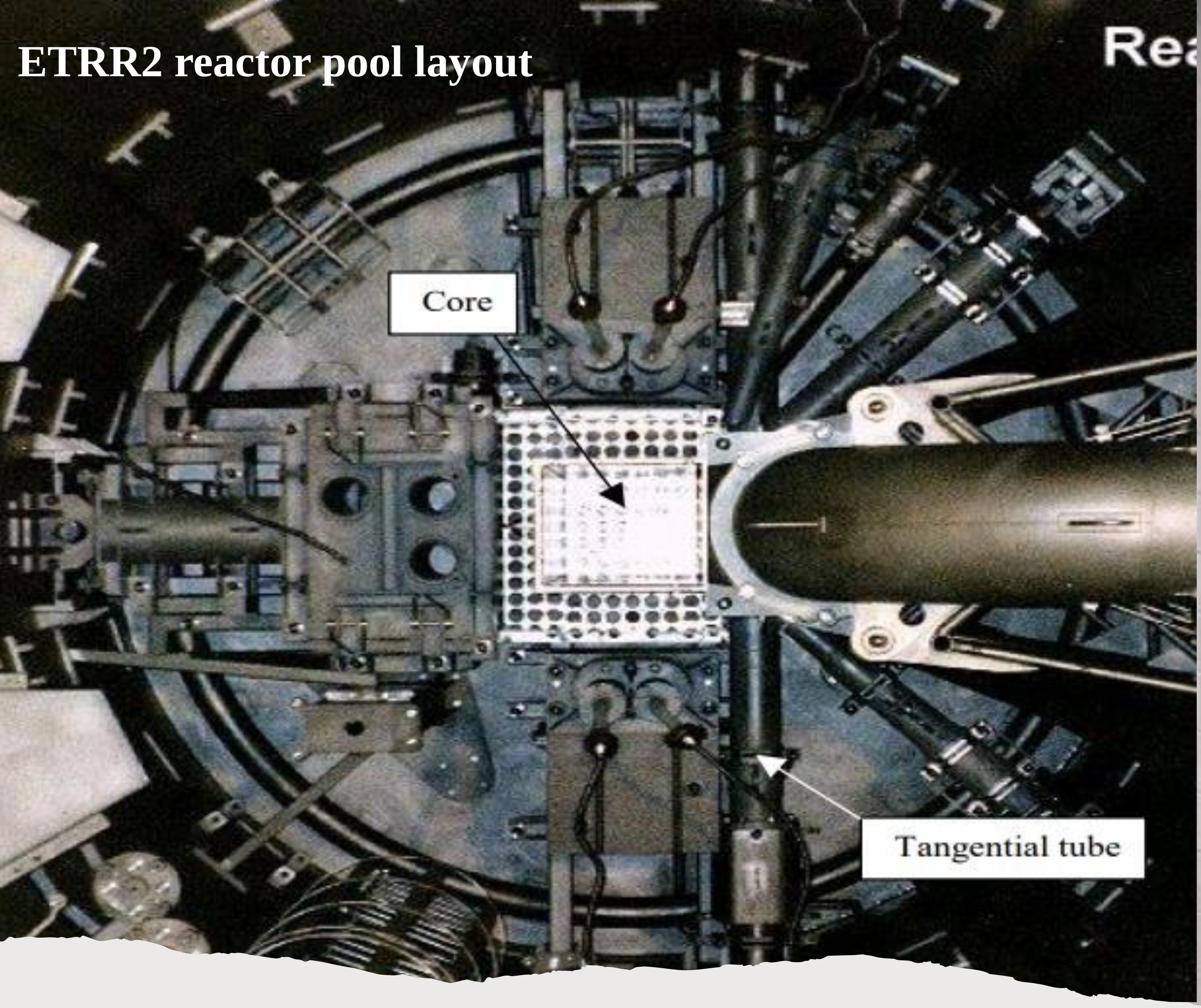


The Heavy Water Reflector

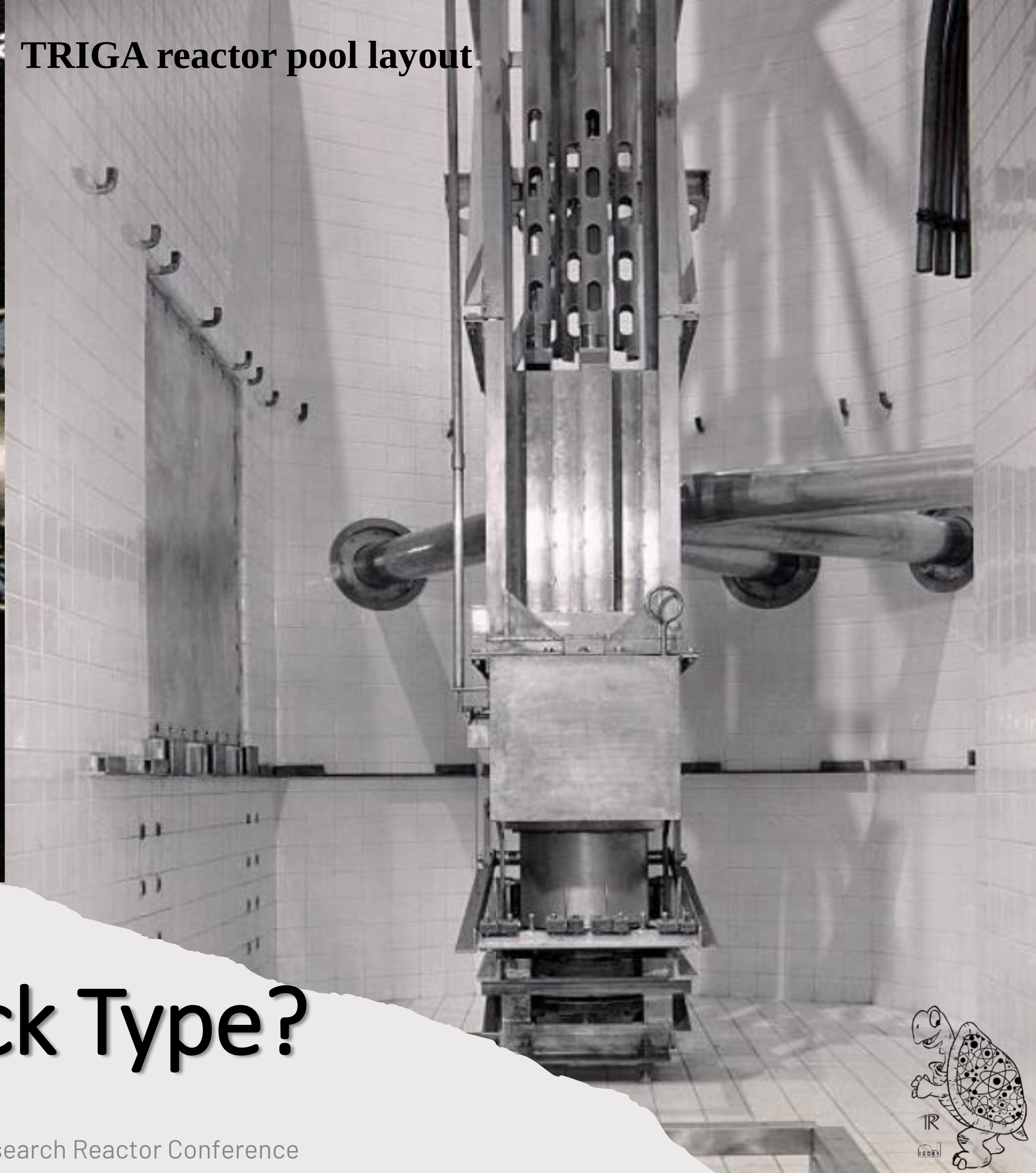
NNS preliminary reflector design is based on similar pool type reactors like OPAL

Since the NNS reactor primary goal is to supply cold and thermal neutrons and the preliminary design does not have any “in-core” (in-pool) radiation facilities an alternative reflector design may be considered

ETRR2 reactor pool layout



TRIGA reactor pool layout



Alternative Reflector - Block Type?

Alternative Reflector Methodology

Assess the possibility to replace the heavy water reflector tank with “block” type elements reflectors

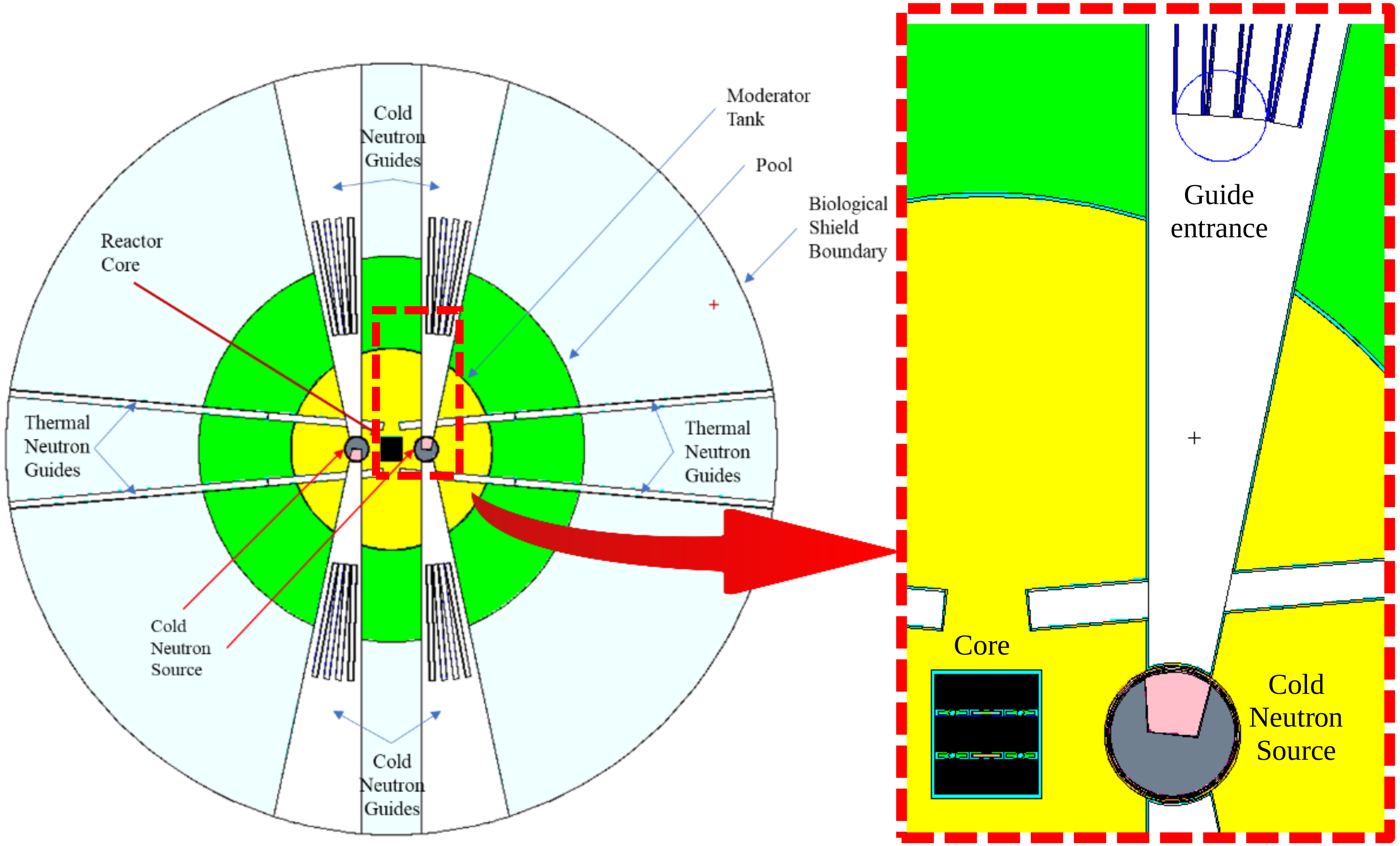
The main output parameters of interest are:

- **Core eigenvalue** (k_{eff}) – the goal is to adjust alternative block type reflector to meet the original (D_2O reflector) eigenvalue within ±250pcm
- **Thermal spectral brightness at thermal guide entrance** - this quantity can be used for a first-round optimization. The primary goal is to keep the shifted thermal Maxwellian neutron flux distribution towards lower energies as in the original (D_2O reflector) design while preserving the designed performance
- **Power density distribution in the fuel elements** – this quantity can directly affect the thermal power limit of the core as well as the fuel cycle (depletion), the goal is to keep the power density destitution as in the original design (D_2O reflector) within ±5%

The Model & Computational Tools

- A Full 3D core was simulated
- MCNP 6.2 Monte Carlo code package with ENDF/B-VII.1 XS
- To improve the statistics of the thermal spectral brightness of the neutrons at the thermal guide entrance the DXTRAN card was used
- For the power density distribution, a mesh tally (FMESH card) with a tally multiplier (FM card) was implemented to account for fission energy deposition.

Uncertainty requirements
- Eigenvalue - less than 60 pcm
- Tally bin - less than 10 %

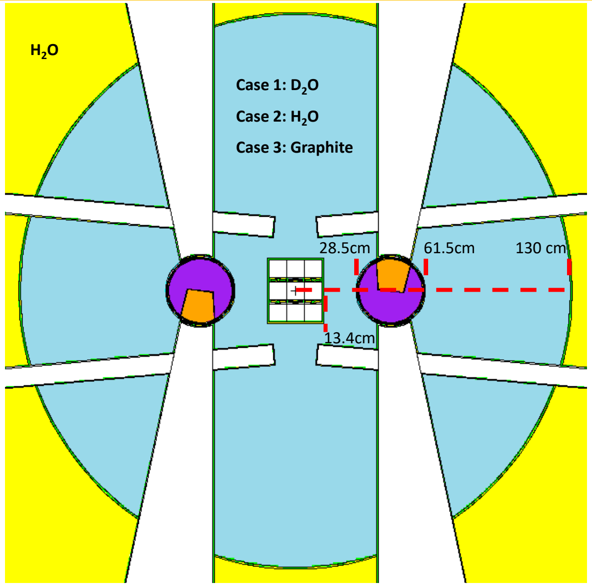


MCNP model planar view, the blue circle on the right side depicting DXTRAN region

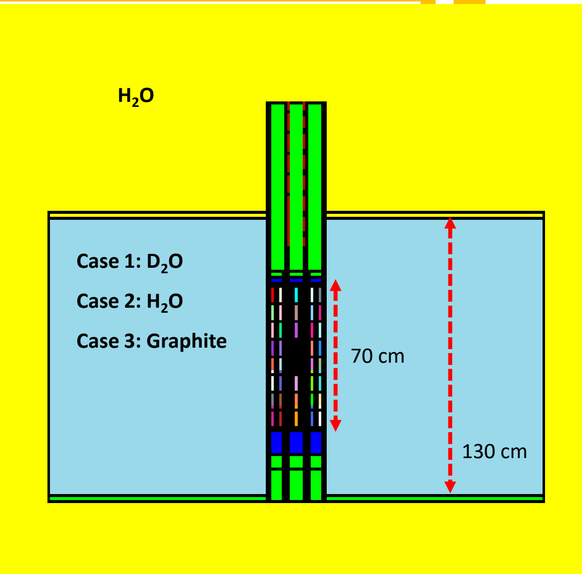
Core Eigenvalue (k_{eff}) Convergence

The evolution of alternative reflector design:

- The original heavy water reflector tank (Case 1)
- Heavy water in the reflector tank was replaced with demineralized light water used in the reactor pool (Case 2)
- Heavy water reflector was converted to a Graphite (Case 3)



Radial



Axial

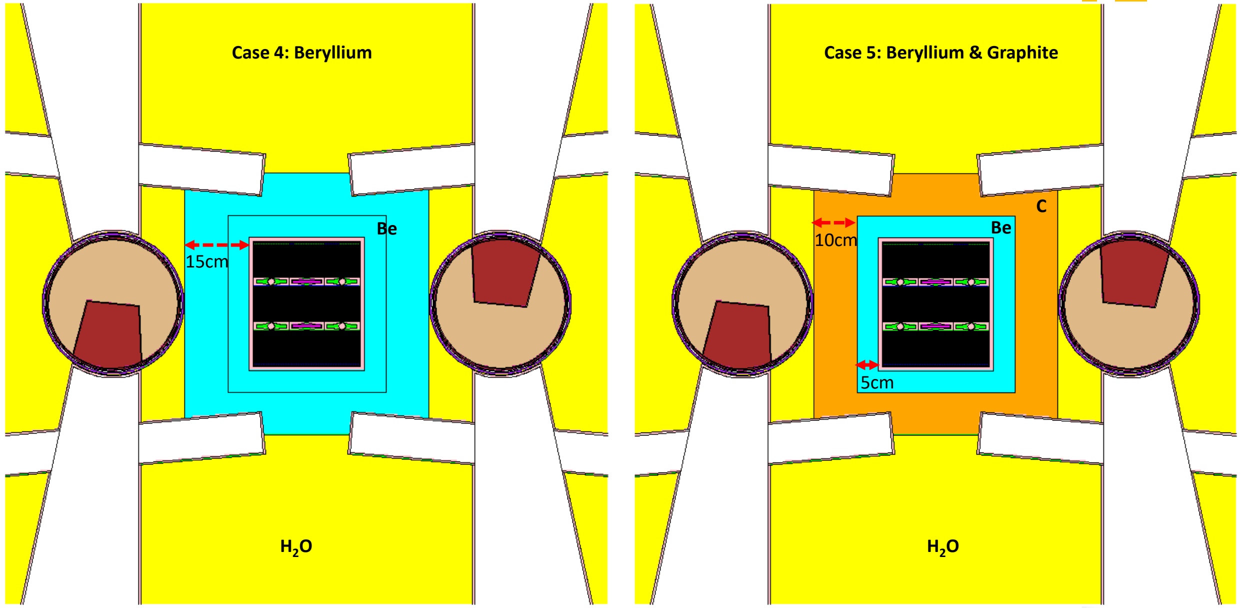
It is cleared that in order to shrink the reflector up to the cold source a neutron multiplication material should be introduced

Case	k_{eff}
1	**0.99996**
2	0.85944
3	0.99479

Core Eigenvalue (k_{eff}) Convergence

The evolution of alternative reflector design:

- Beryllium reflector box (Case 4)
- Beryllium & Graphite reflector box (Case 5)

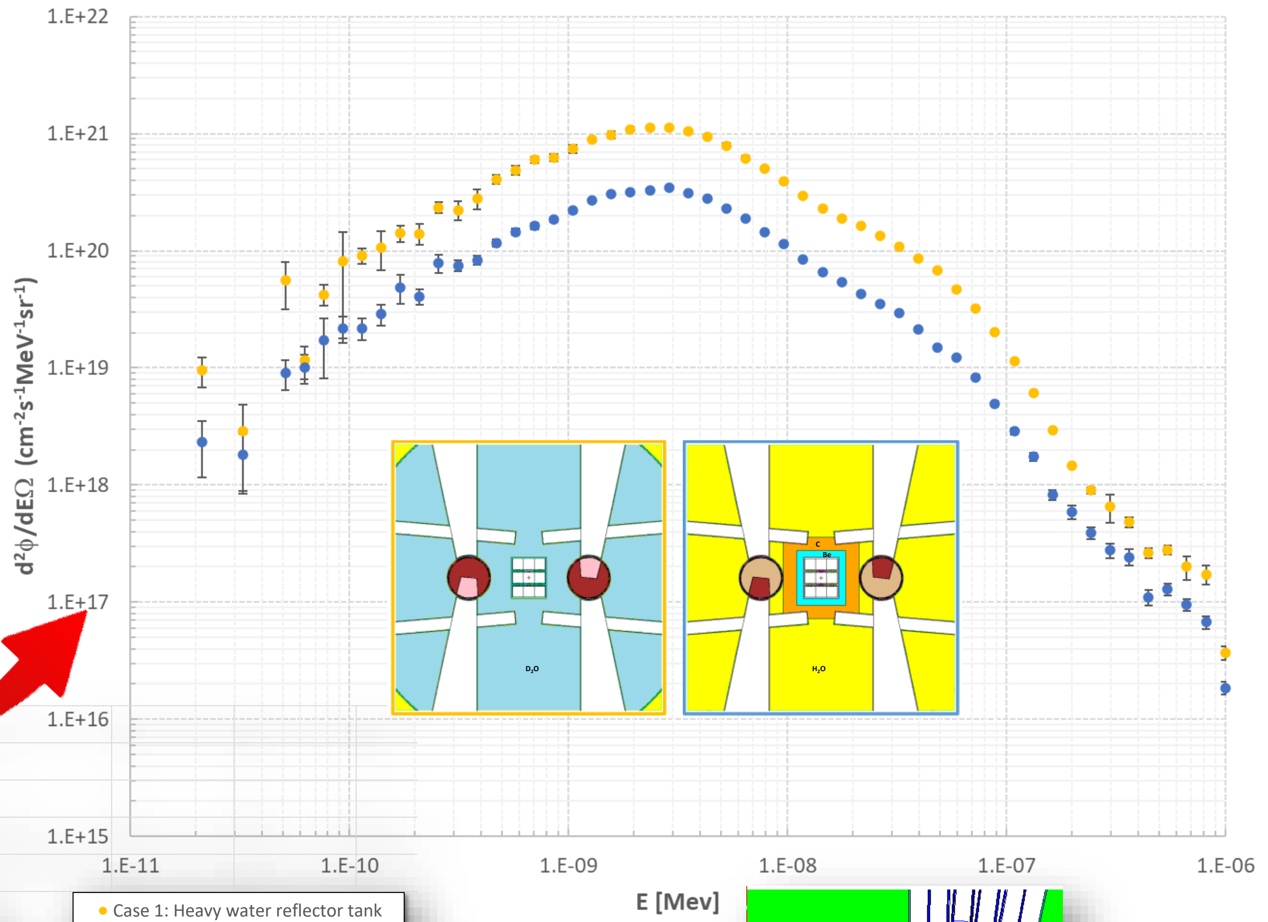


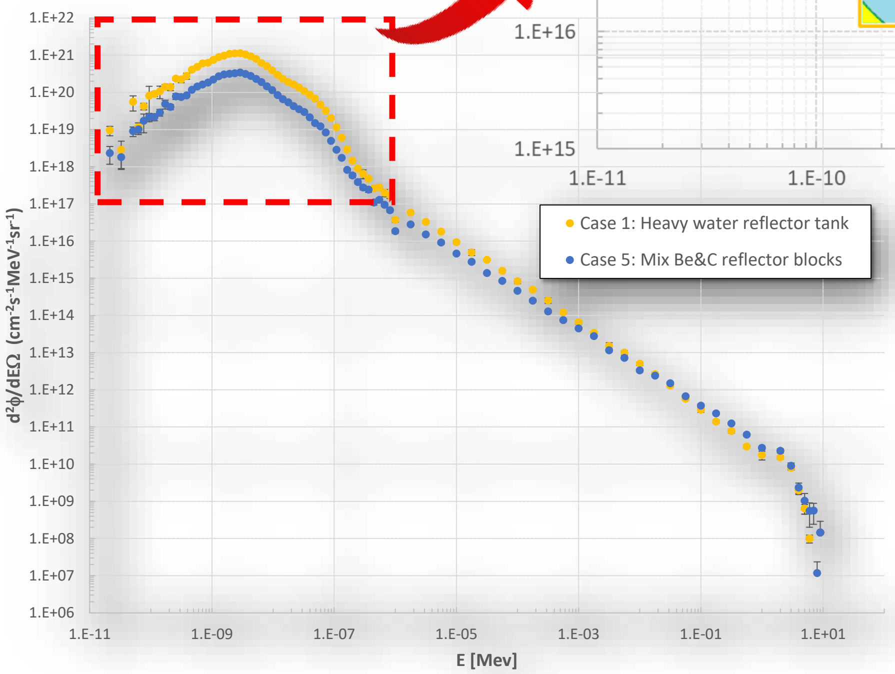
The dimensions of beryllium and graphite were adjusted so that the total thickness of the reflector will be 15 cm.
While the outer reflector zone was made as thick as possible to thermalize the neutrons before reaching the cold source, the inner reflector zone (Beryllium) was adjusted correspondingly to assure core reactivity (match core eigenvalue).

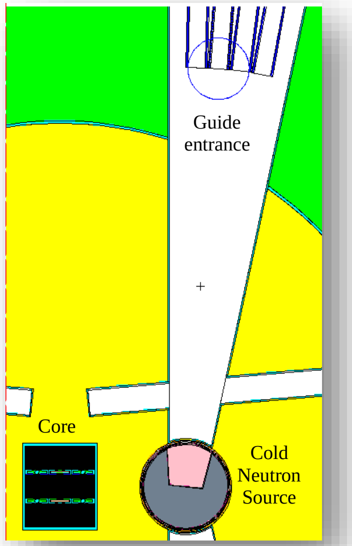
Case	k_{eff}
4	1.03685
5	**1.00223**

Thermal Spectral Brightness at Thermal Guide Entrance

- Thermal neutron spectral brightness distribution shape is preserved
- However, the magnitude of the cold neutron is almost one order of magnitude lower



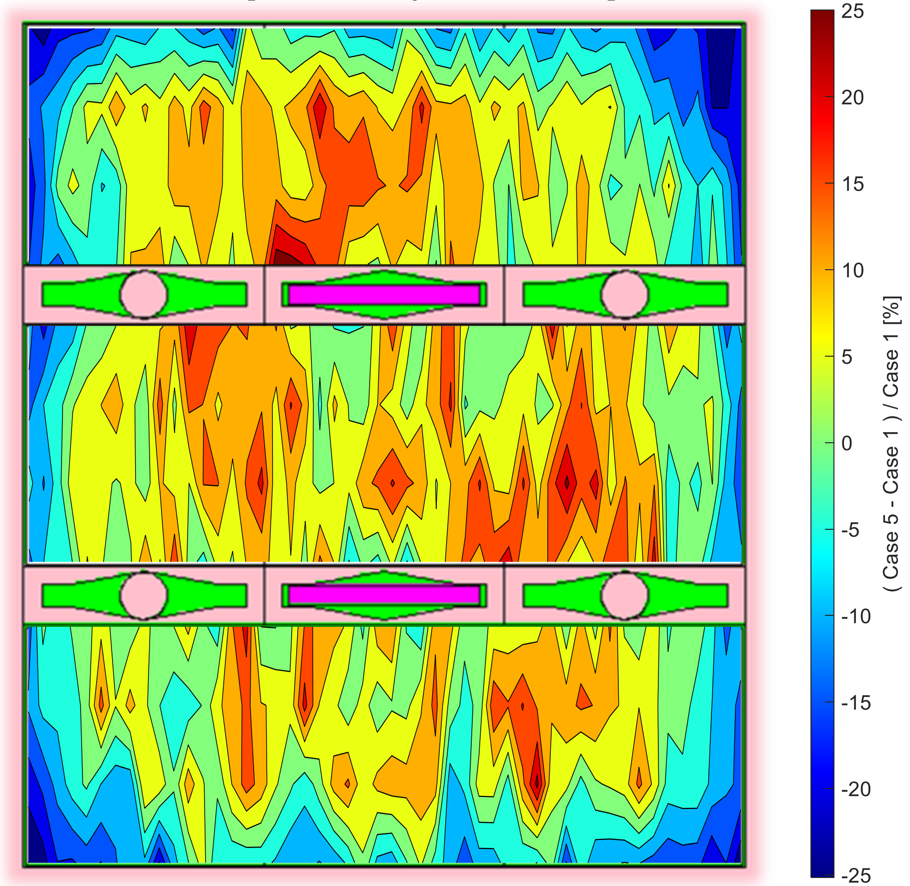




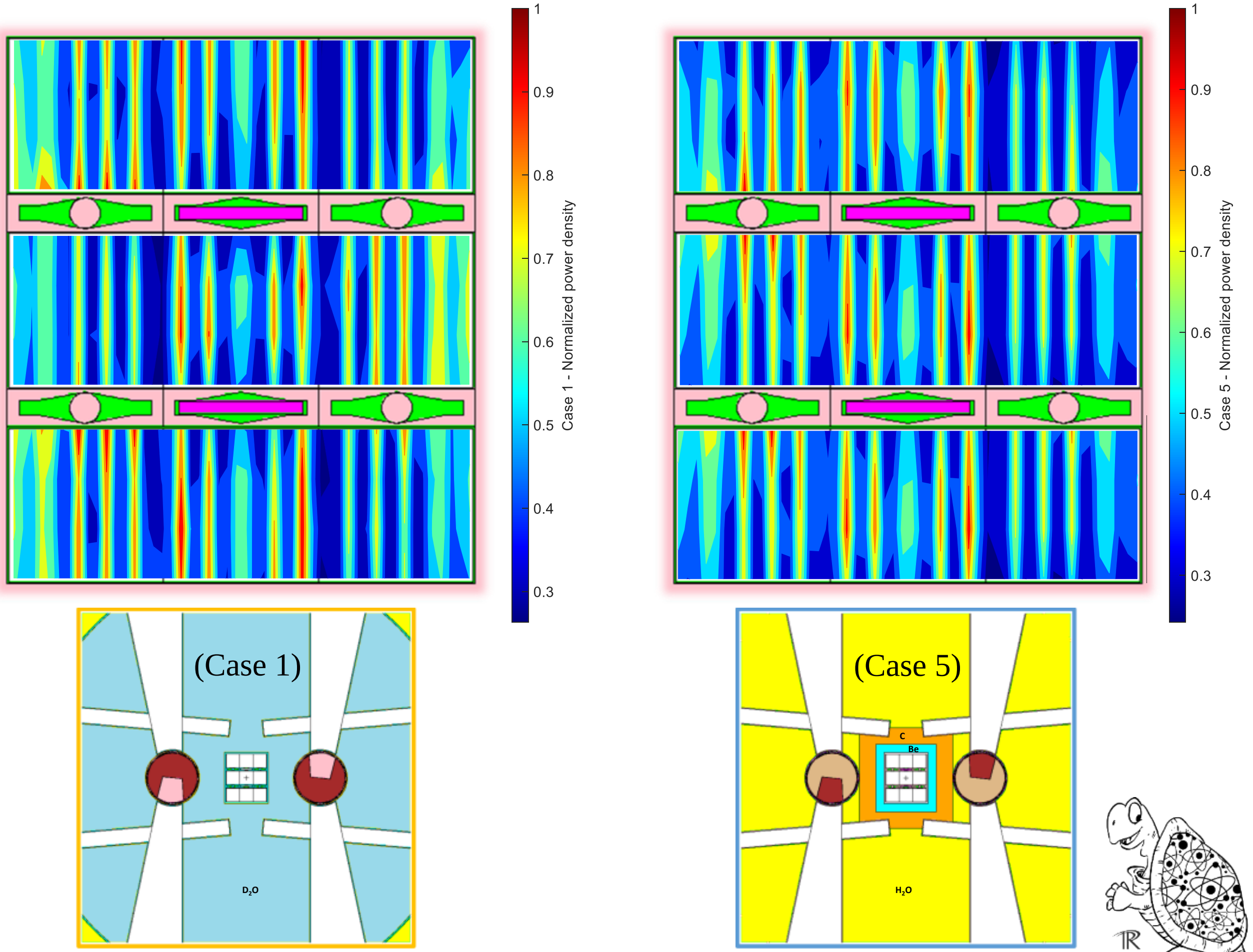
Power Density Distribution in the Fuel Elements

- Radial normalized power in fuel elements for D_2O vs. mixed “block” type reflector
- The mixed “block” type reflector, the fission density shifter towered the core center and it is about 25% higher compared to the D_2O reflector tank

Relative power density difference in percent

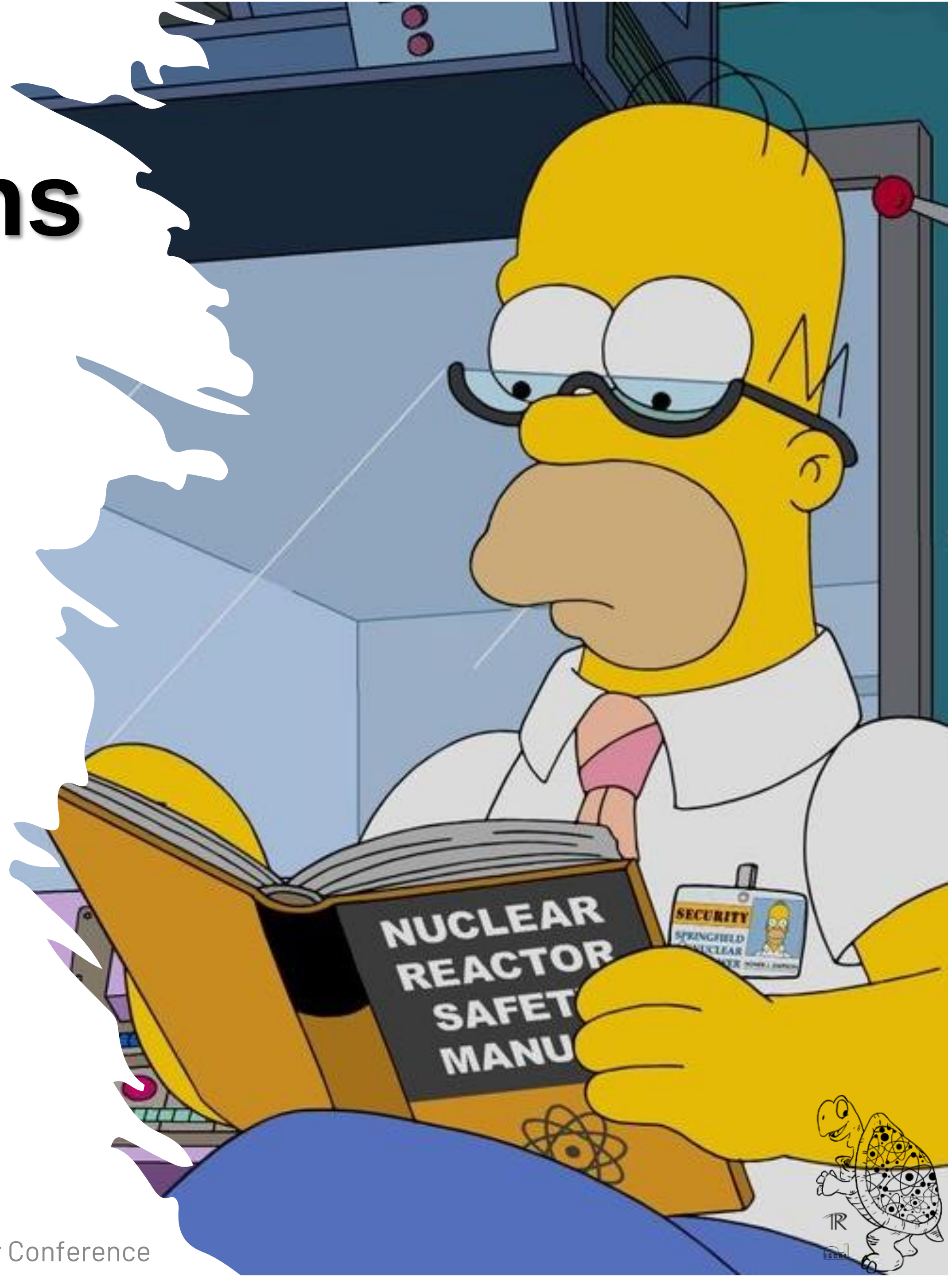


D_2O (Case 1) and mixed “block” type (Case 5) normalized power density distribution



Summary and Conclusions

- The current NNS design feature of a heavy water reflector tank which is comparable to a “block” type reflector is intricate in means of design and manufacture.
- Therefore, in this study, a compact block-type reflector was proposed.
- The primary goal was to introduce an alternative reflector design to the NNS core without impairing neutronic performance.
- Since the NNS core is designed as a very compact core with high leakage a compact block-type reflector required the implementation of neutron multiplication material in the reflector region.
- As the primary objective of the NNS is to supply cryogenically-cooled neutrons at high flux intensity the thermal neutron spectral brightness at the thermal guide entrance was examined.



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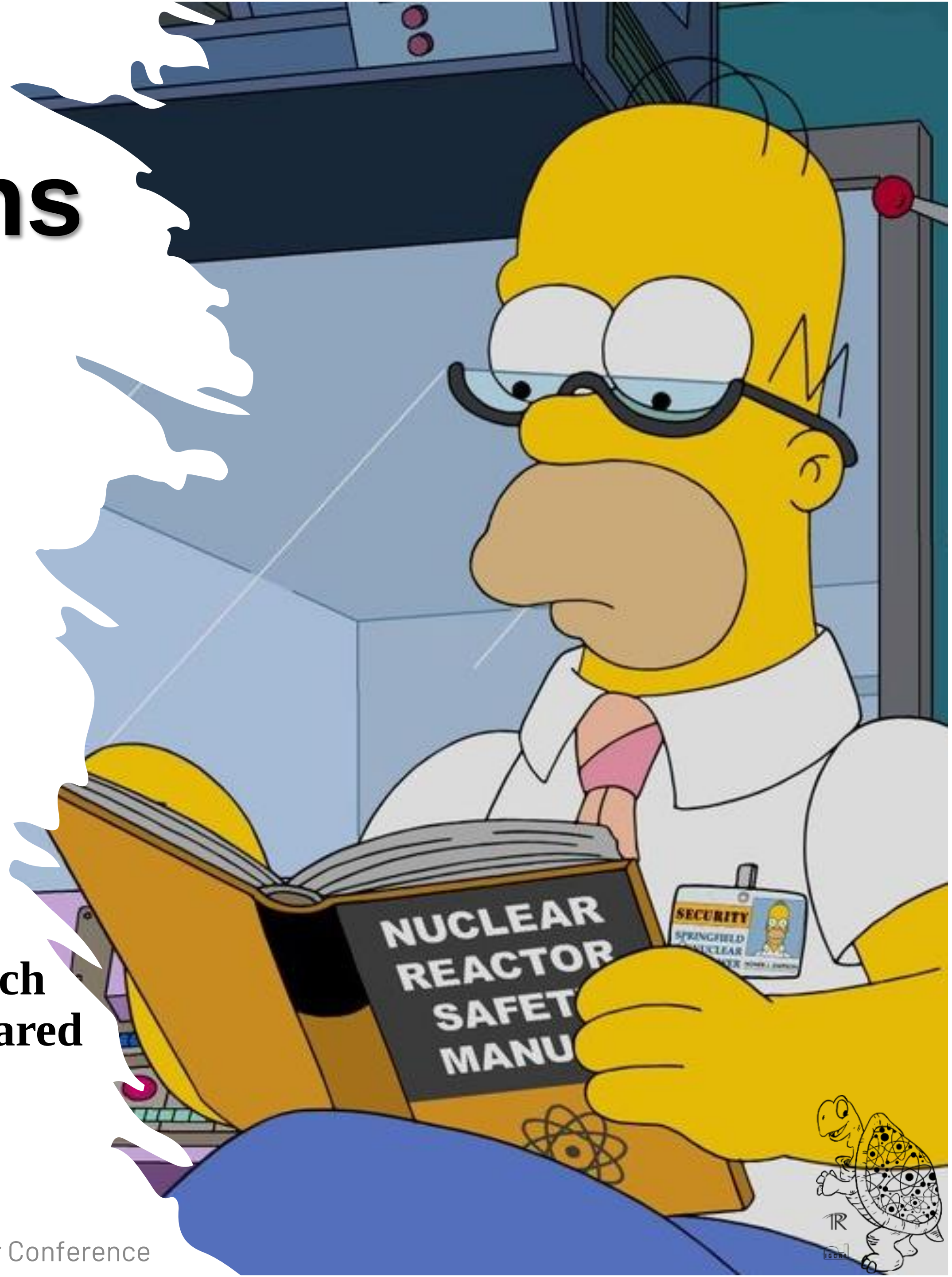
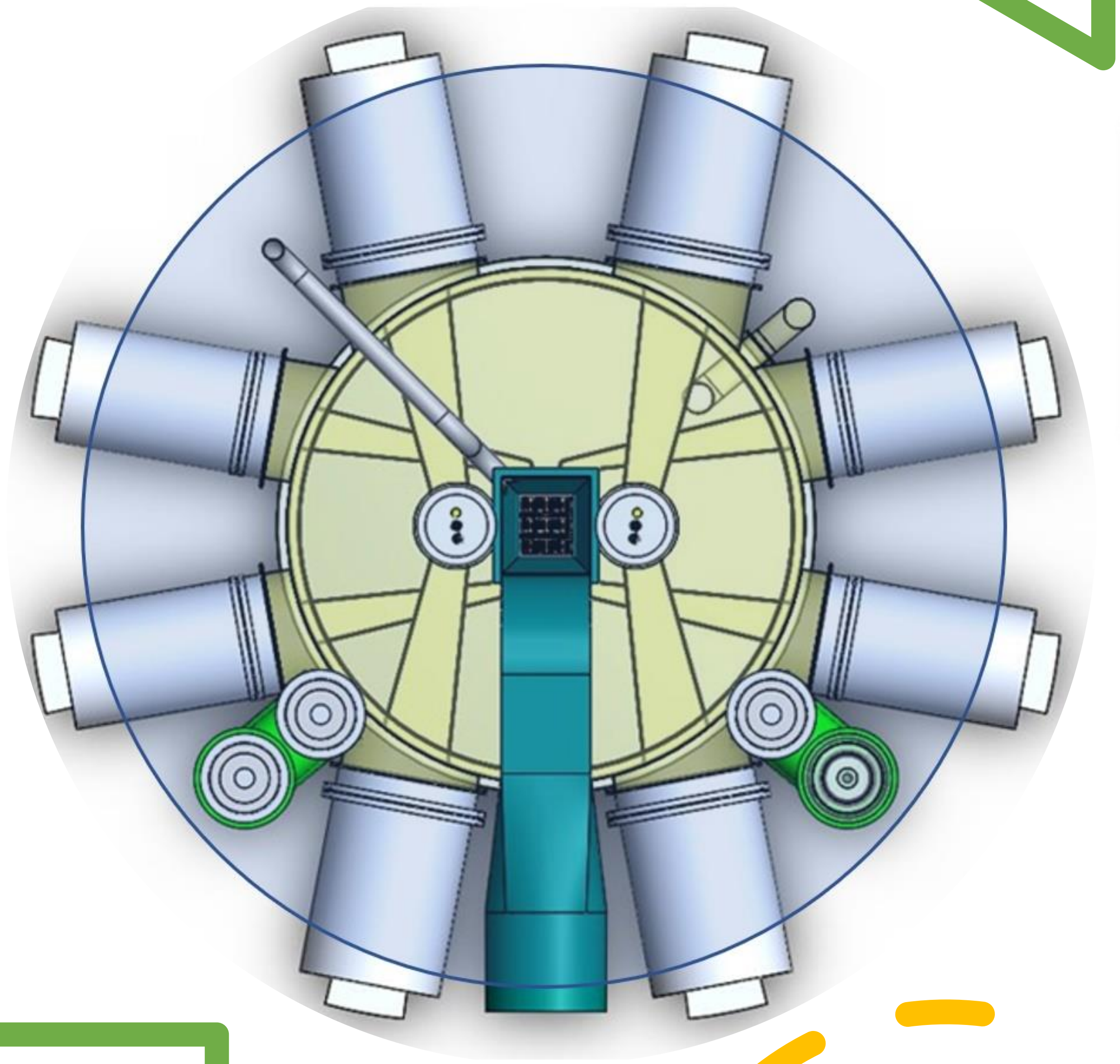
Summary and Conclusions

- While the shape (spectra) of the cold neutrons was preserved the magnitude was decreased by almost one order of magnitude.
- Such degradation may be of significant impact on NNS performance.
- An additional parameter of interest was the core power density distribution had to be unperturbed, which in turn dictates the core power limit (hot spot) as well as the cycle length (burnup).
- For the proposed "block" type reflector the power density distribution had shifted by about 25% which may significantly affect both the core power limit as well as the core shuffling scheme.
- **In summary, it was observed that the current NNS design which embraces a heavy water reflector tank is a superior one compared to the proposed compact "block" type reflector options.**





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