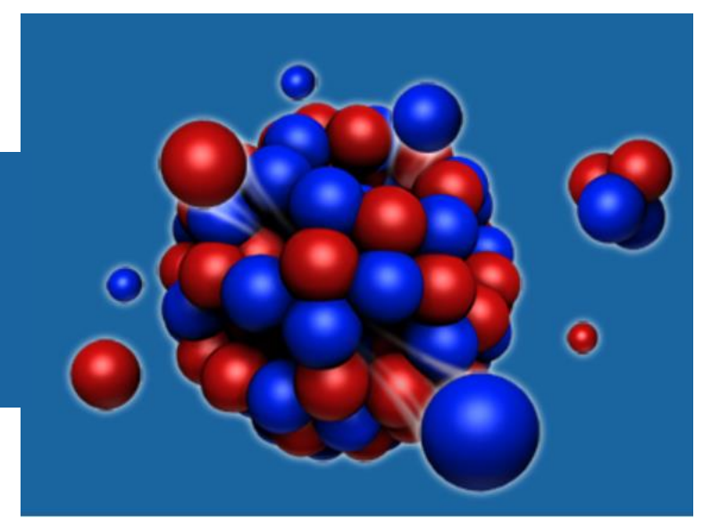
Neutronics Analyses for the ORNL's Spallation Neutron Source Second Target Station

13th International Workshop on Spallation Materials Technology



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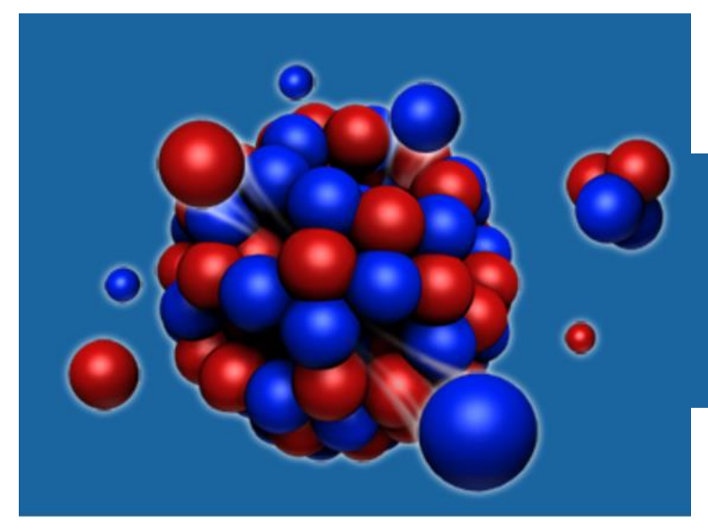

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STS/FTS parameters

FTS (upgraded)

- Short (<1 μs) proton pulses
- 1.3 GeV protons
- 50 Hz repetition rate
- 2 MW beam power
- 40 kJ per proton pulse
- Large beam footprint
- ~ 140 cm^2
- Hg target

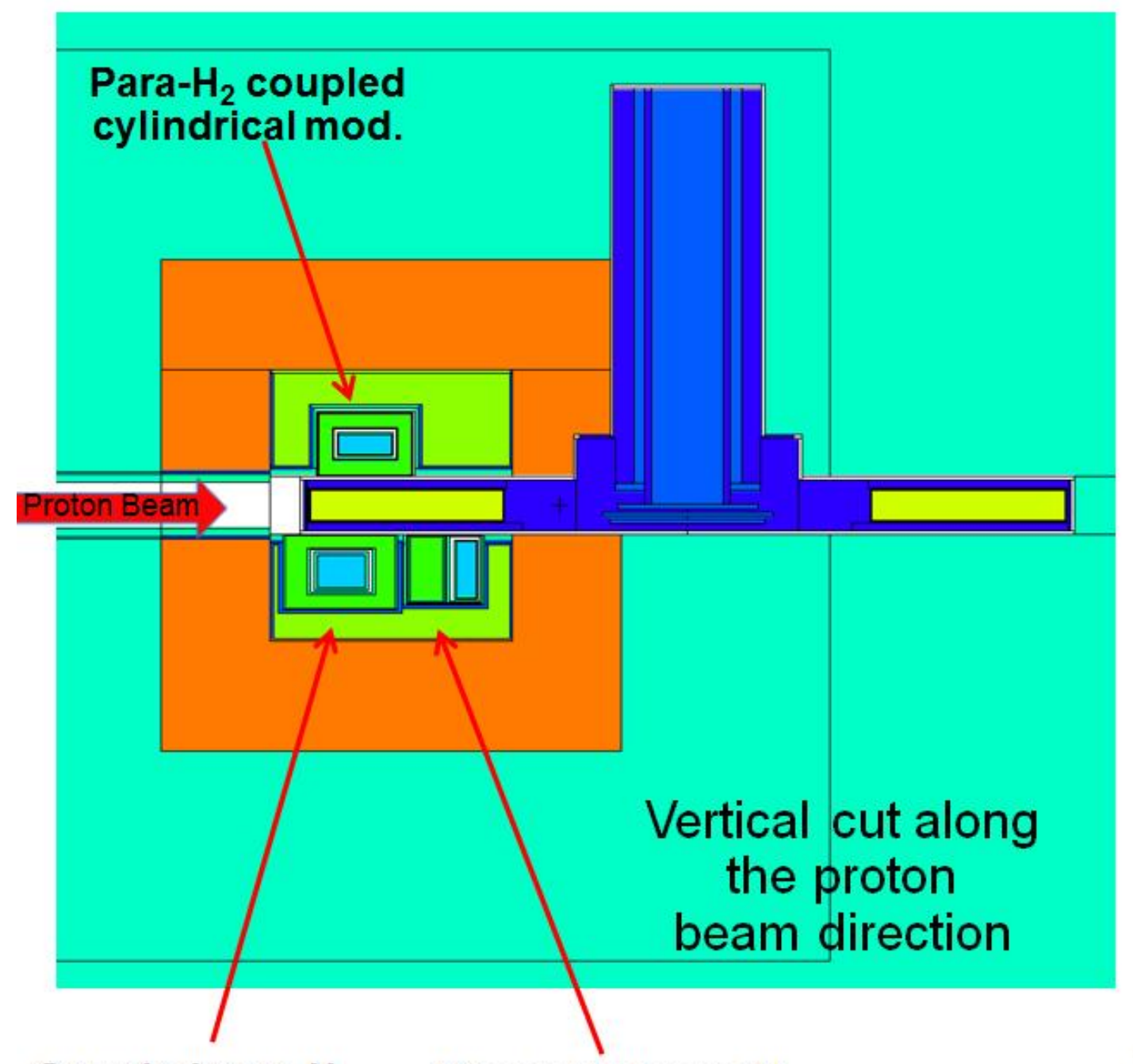
STS

- Short (<1 μs) proton pulses
- 1.3 GeV protons
- 10 Hz repetition rate
- 467 kW beam power
- 47 kJ per proton pulse
- Small beam footprint
- ~ 30 cm^2 (90% of the beam)
- W target (Ta clad, D_2O cooled)

STS requirements

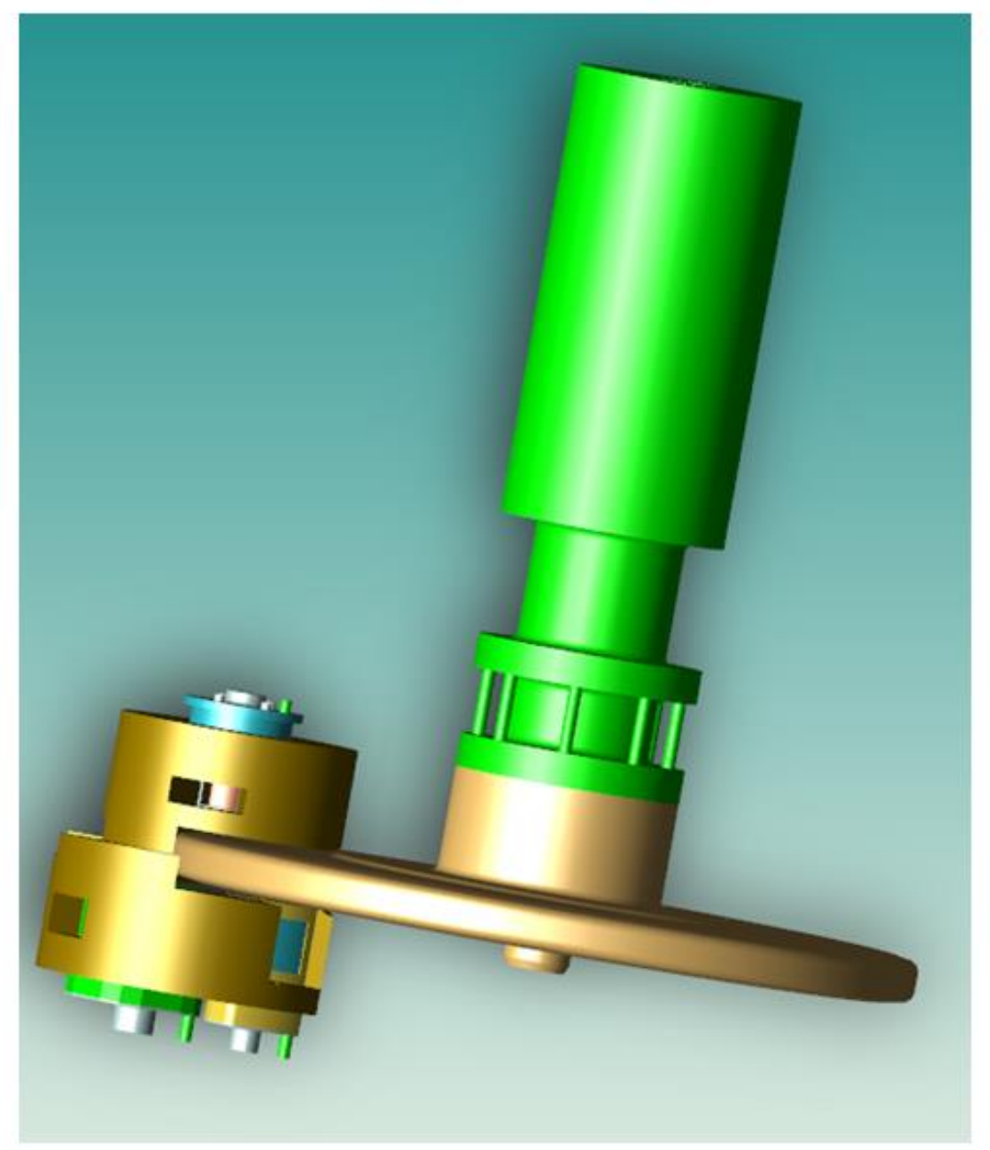
- Provide high peak brightness at long neutron wavelengths
- Priority on coupled moderators
- Accommodate 22 instruments

MCNPX model of the rotating target



Coupled para-H_2 box moderator

Decoupled para-H_2 and H_2O moderator



Model under development using the automatic CAD-to-MCNP conversion code SuperMC

Sources of performance gains in STS v FTS

The STS coupled moderators have 10-13 times higher brightness relative to FTS (at 2 MW) because:

- Positioned at the prime neutron production zone of the target,
- Optimized for para-hydrogen moderator depth,
- Improved the target-moderator coupling and reduced dimensions
- Reduced viewed moderator areas (STS: 3 cm x 3 cm to 5 cm x 5 cm; FTS: 10 cm x 12 cm)

The FTS coupled moderators were not optimized for peak brightness, are located away from the prime neutron production zone, downstream of the decoupled moderators, and were dimensioned to 5.5 cm depth to make them fairly insensitive to ortho-para fluctuations of the uncatalized hydrogen loop.

The STS decoupled moderator has 3 – 4 times higher brightness relative to the FTS decoupled moderators (FTS at 2 MW).

- para-H_2 moderator ~ 3 times
- H_2O moderator ~ 4 times
- STS decoupled moderator is not in optimal location.

Additional performance increases from neutron optics, detectors, ….

- Improvements up to 10-100 in instrument performance possibilities
- STS will be a "4th generation" neutron source

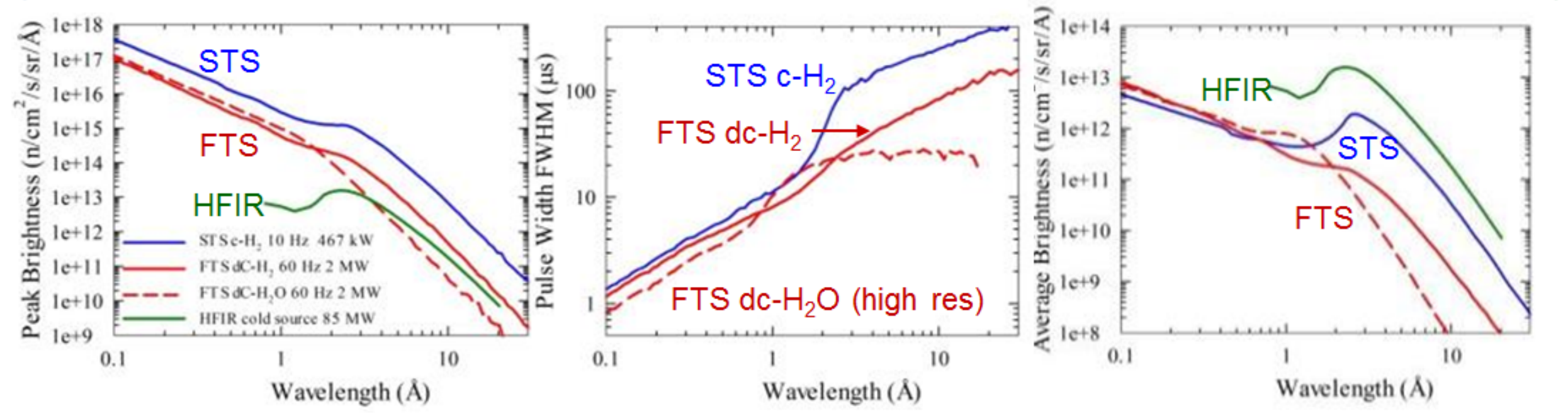
Conclusion

The STS will complement existing FTS and HFIR capabilities and further advance US and ORNL's capabilities in neutron scattering science

STS: Optimized for cold neutrons with high peak brightness
(Coupled moderators, 10 Hz)

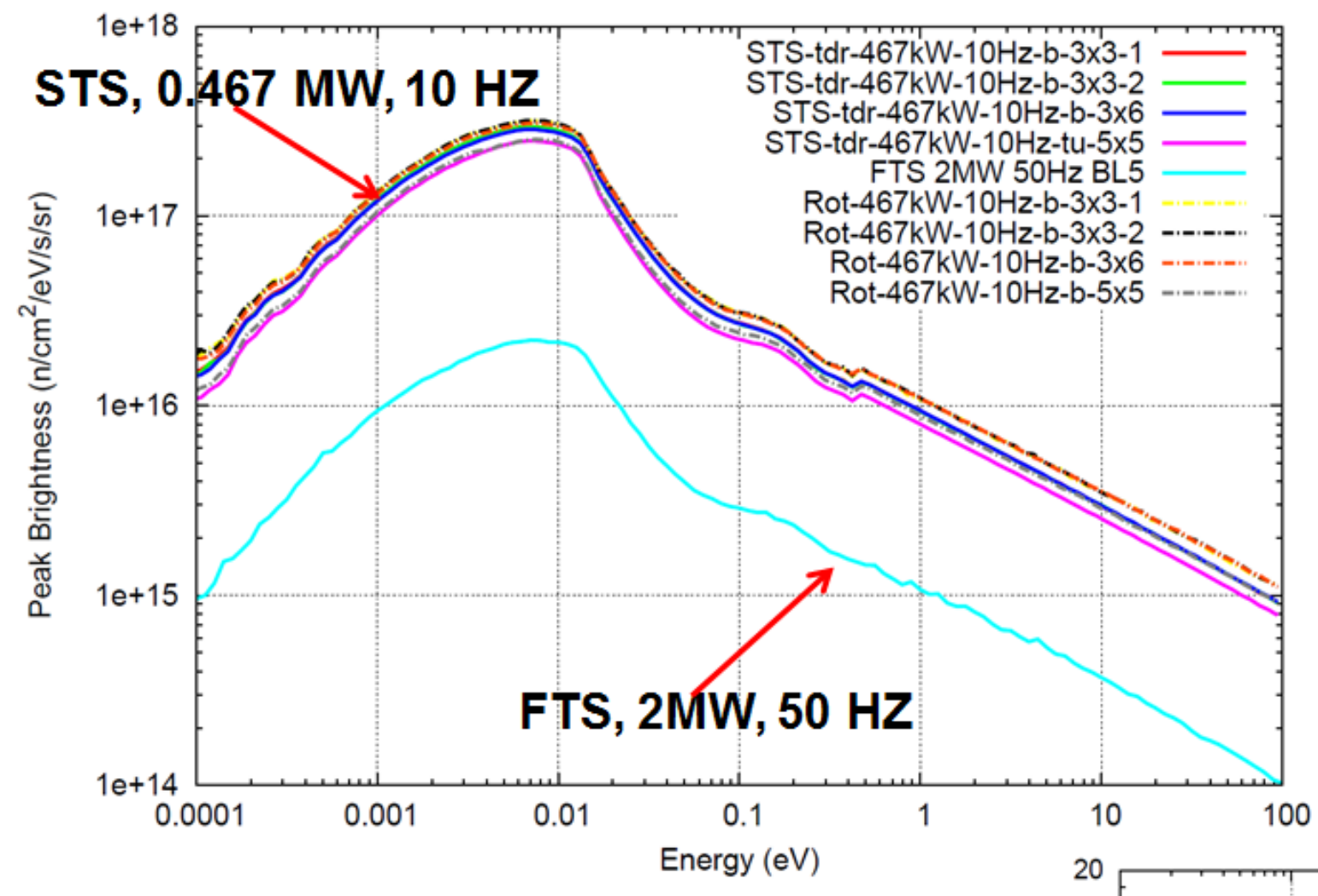
FTS: Optimized for high-wavelength resolution across neutron spectrum
(Decoupled moderators, 60 Hz)

HFIR: Optimized for cold and thermal neutrons with high time-averaged brightness



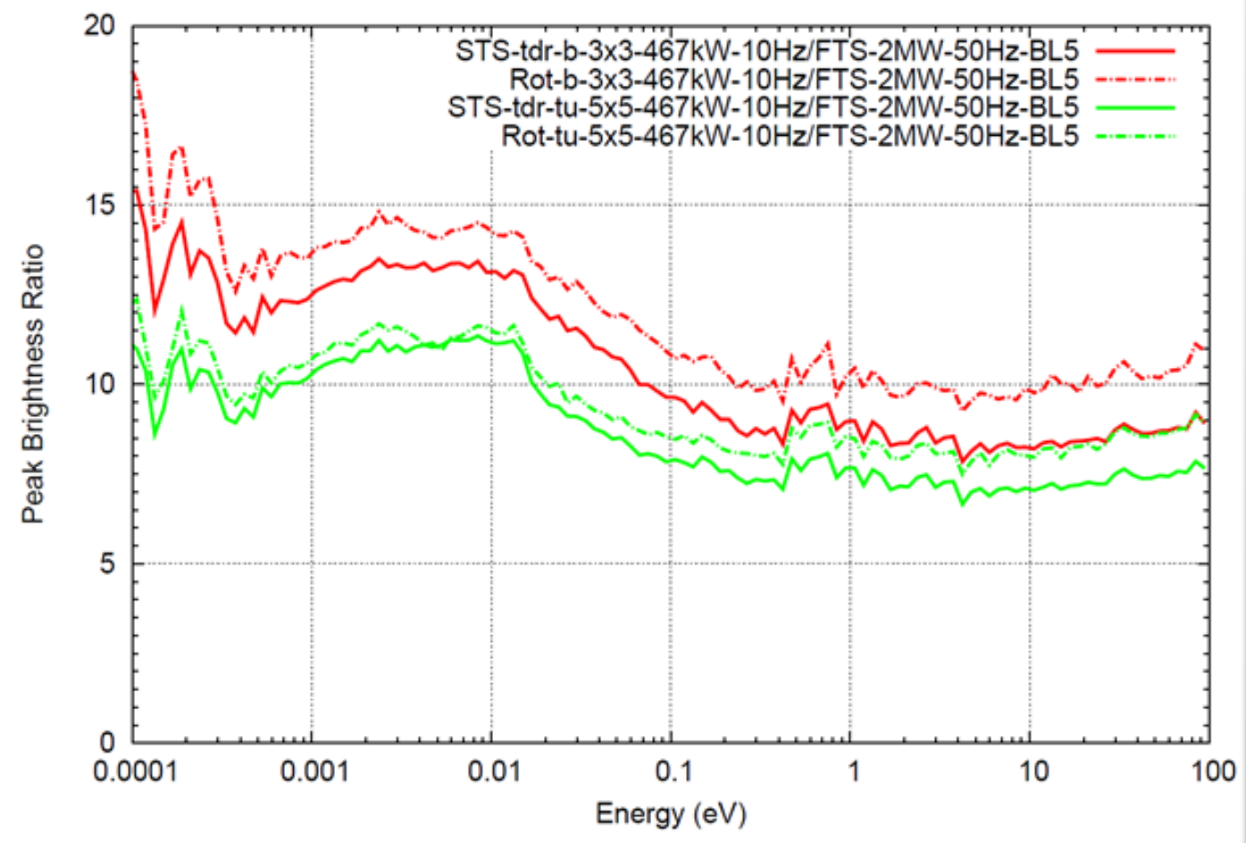
STS a "4th generation" neutron source

Moderator Optimization



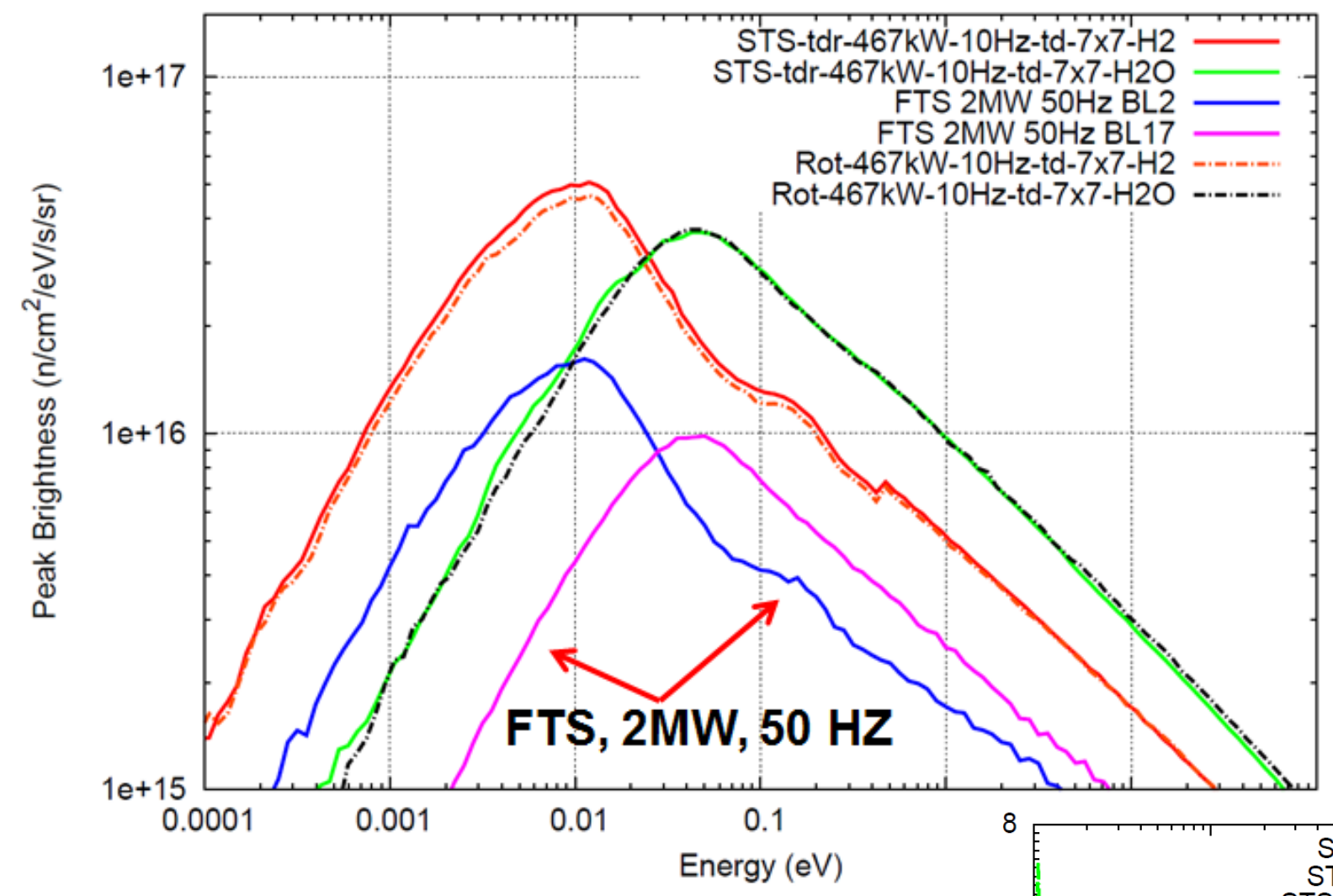
Peak brightness versus neutron energy

Coupled para-H_2 moderators



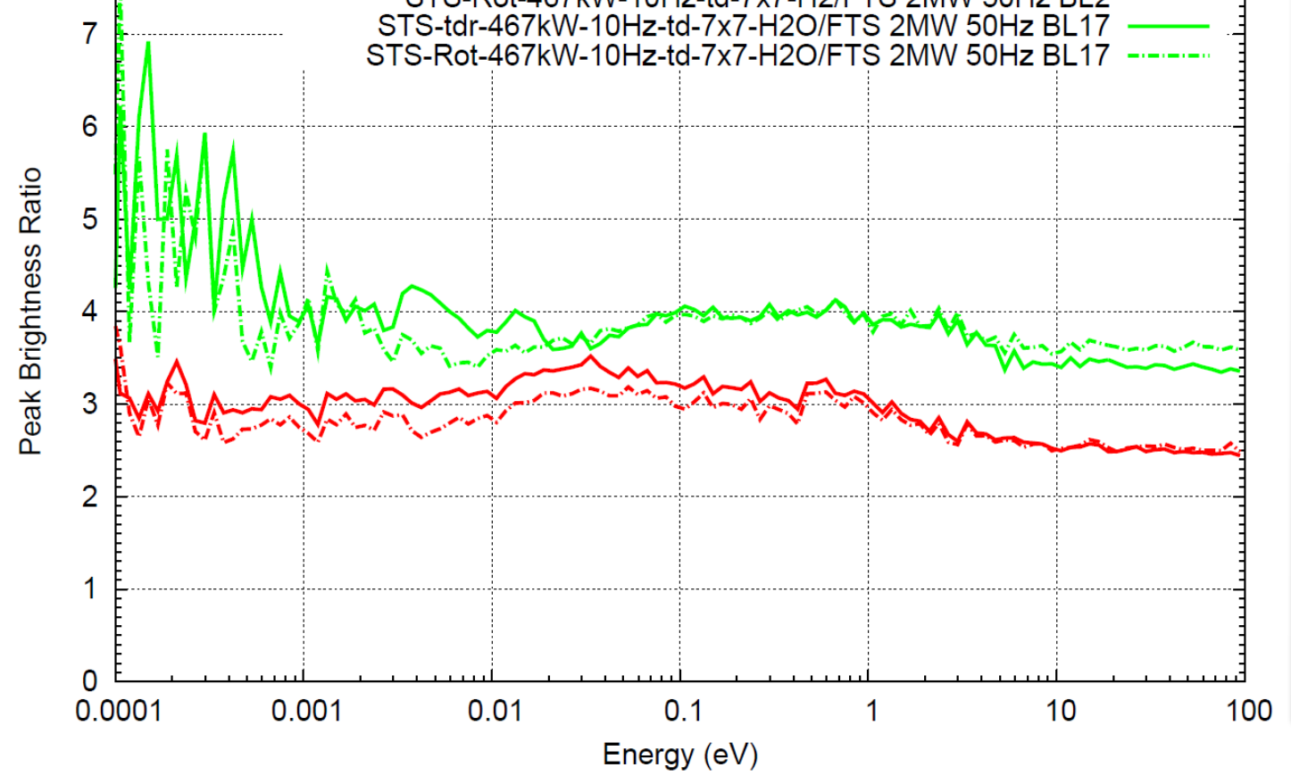
STS coupled para-H_2 moderators exhibit ~ 13 to 10 times higher brightness relative to the FTS coupled moderators (FTS at 2 MW).

FTS BL5 – top downstream



Peak brightness versus neutron energy

Decoupled para-H_2 and ambient temperature H_2O moderators



STS decoupled moderator:

- **para-H_2 moderator ~ 3 times**
- **H_2O moderator ~ 4 times**

higher brightness relative to the FTS decoupled moderators (FTS at 2 MW).

FTS BL 2 – top upstream H_2
FTS BL17 – bottom upstream H_2O

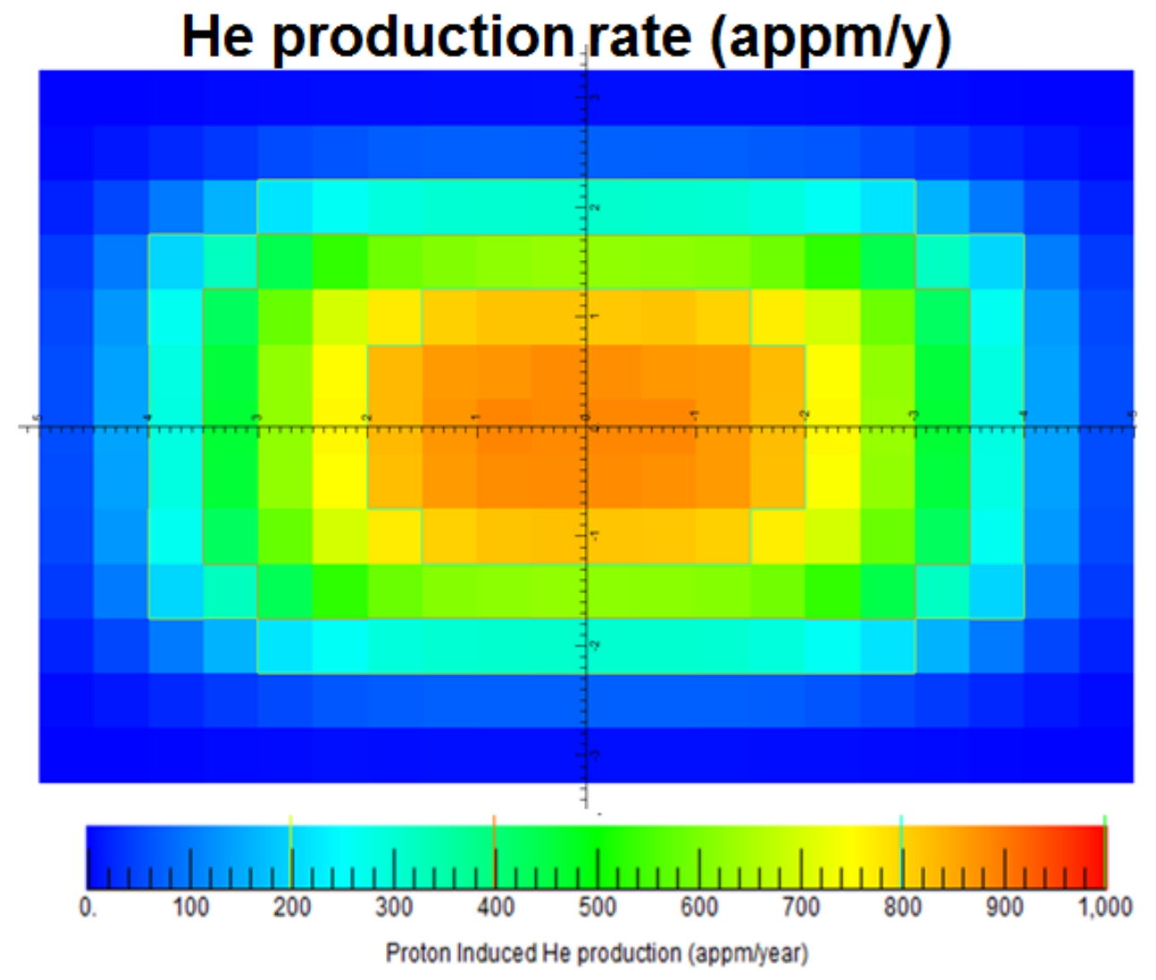
STS decoupled moderator is not in optimal location.

Radiation Damage and Burnout

Aluminum proton beam window: He production rate and dpa rate

Window is 5.1mm thick aluminum, water cooled

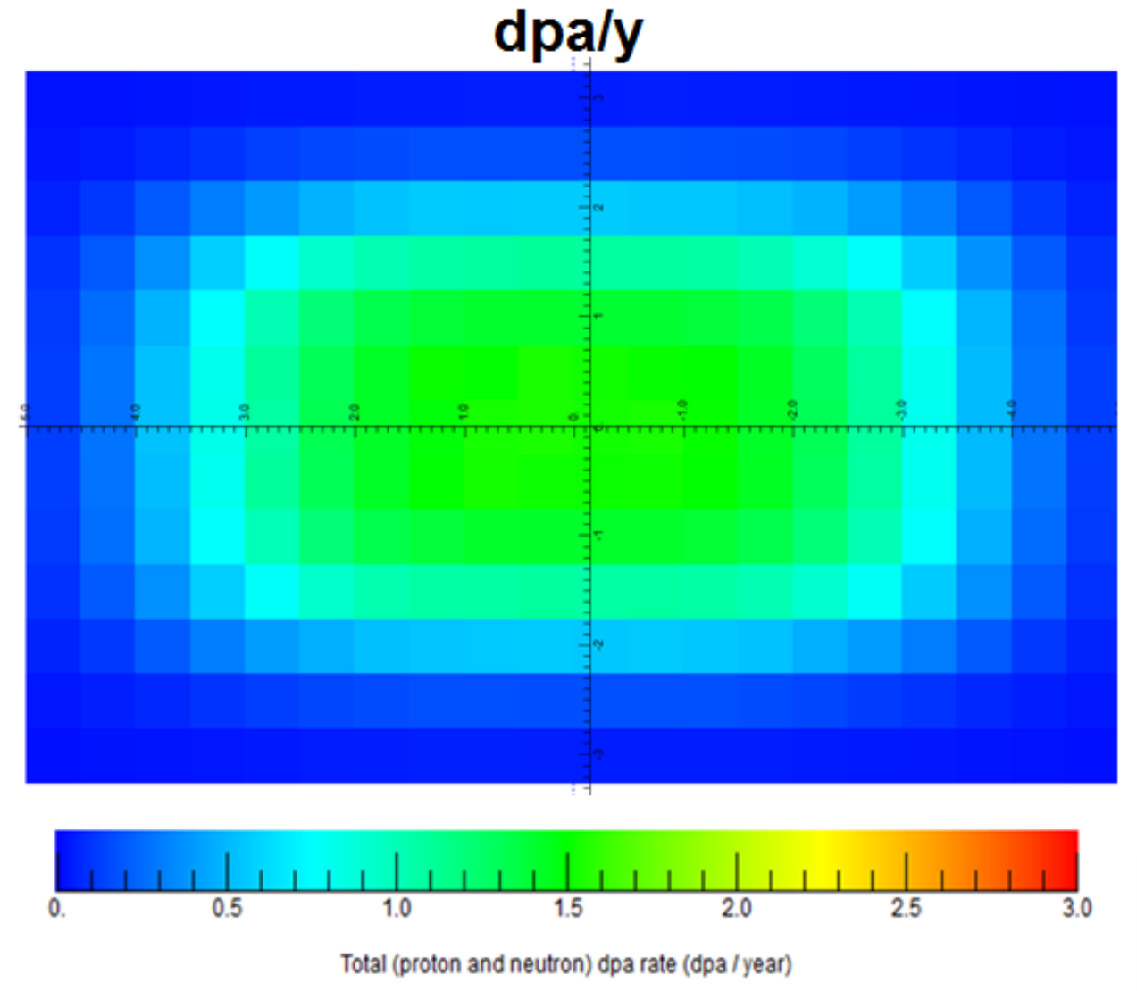
He production rate (appm/y)



Max. He production rate: ~890 appm/y;
Estimated lifetime: 2.2 years;
Neutron contribution is negligible.

Lifetime limit: 2000 appm

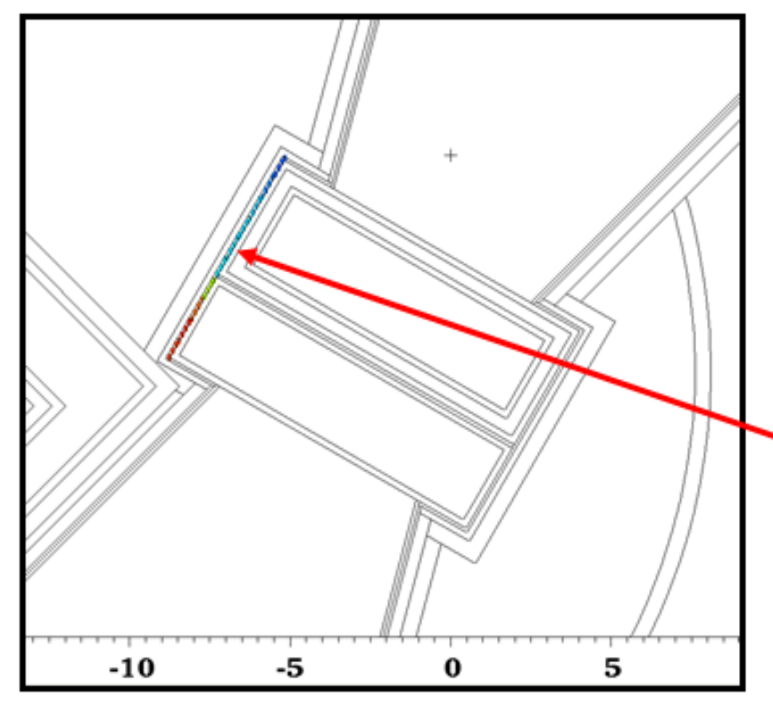
dpa/y



Max dpa rate: 1.54 dpa/y;
Estimated lifetime: 26 years;
Neutron contribution ~12%.

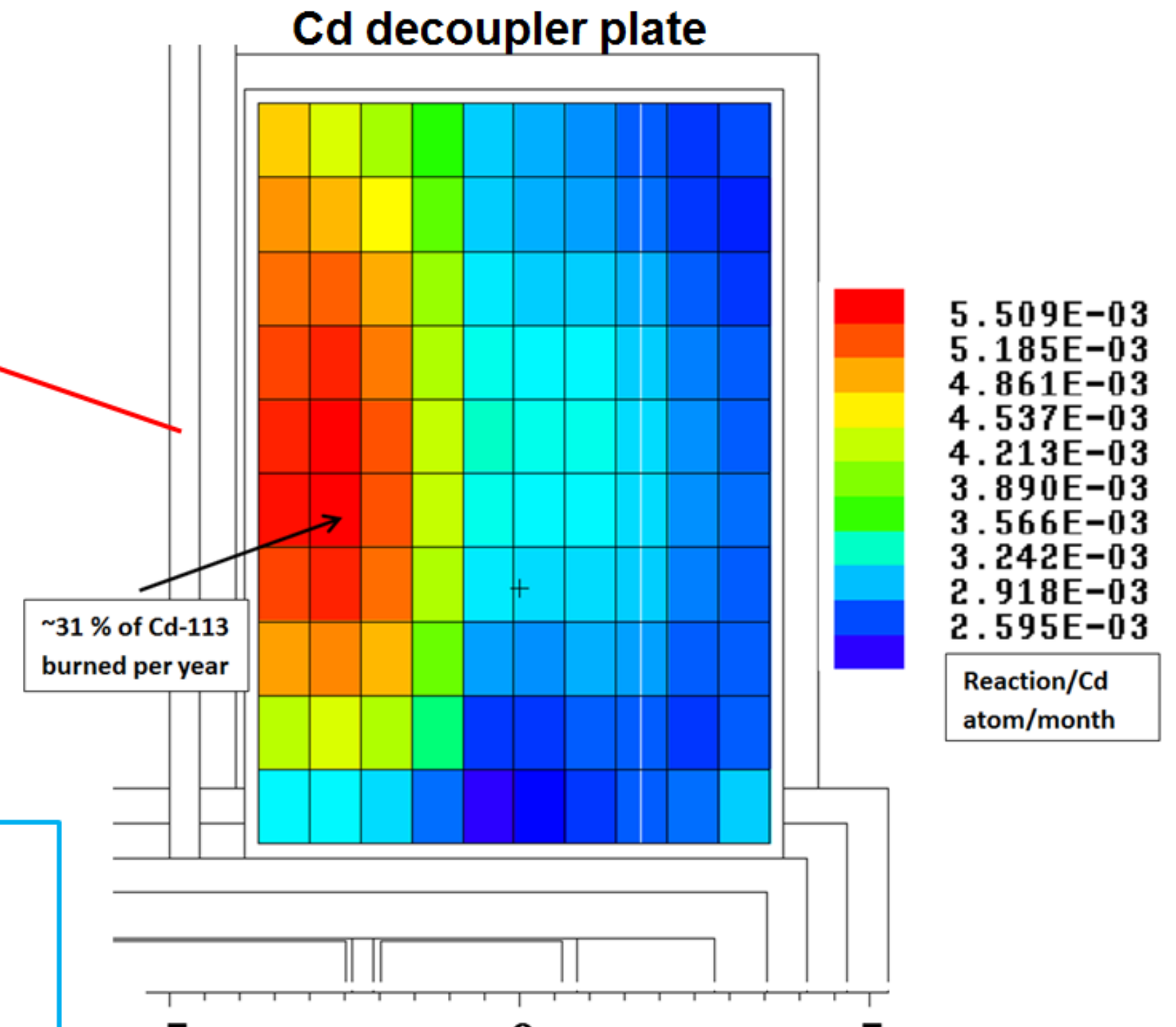
Lifetime limit: 40 dpa

Burnup of Cd decoupler and poison plates



Horizontal cut through the top downstream decoupled moderator

Cd decoupler plate

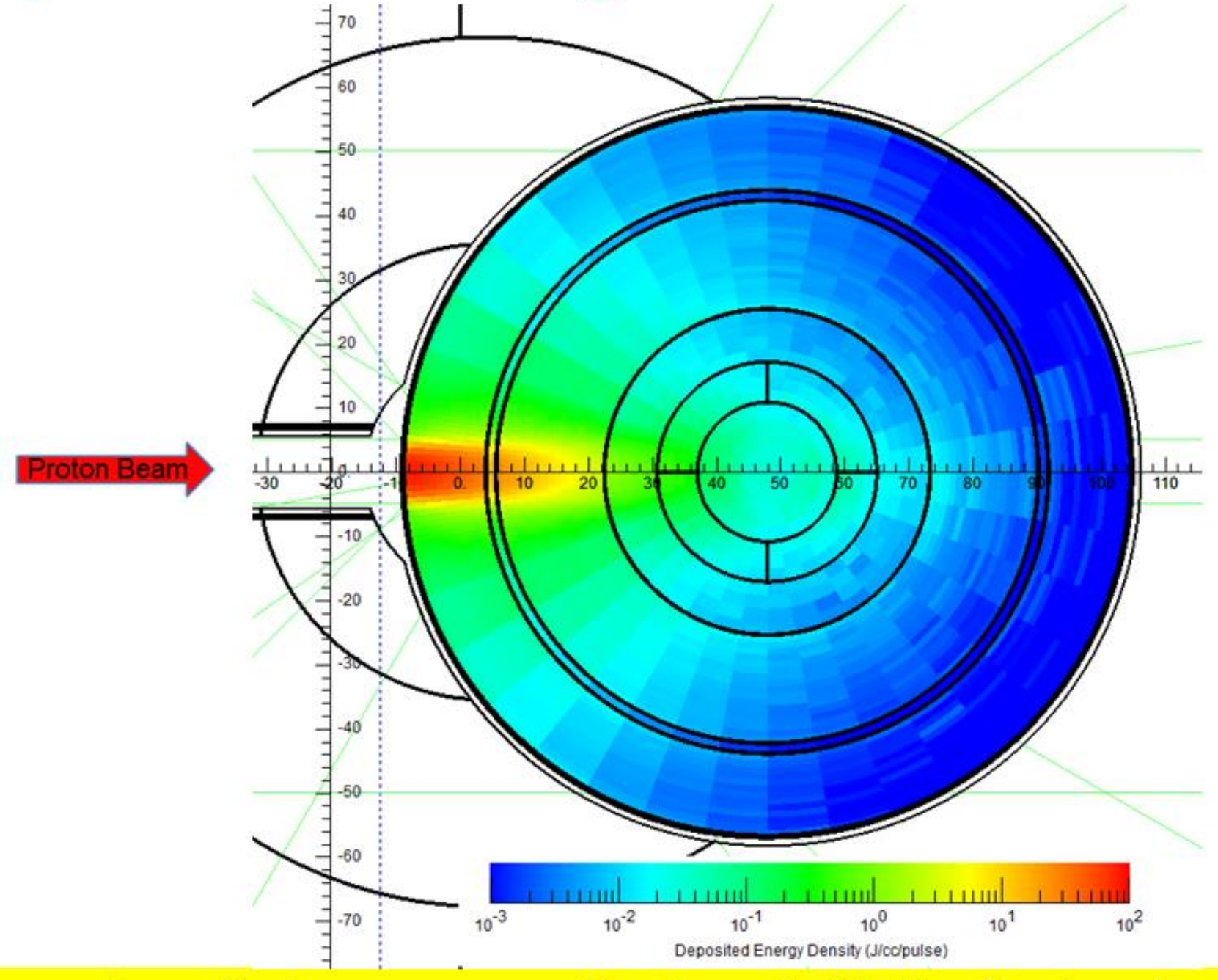


Estimated lifetime:
side decoupler ~3.2 years;
poison plate ~4.6 years;
1 mm Cd assumed

Simple estimates based on initial burnout rate only.

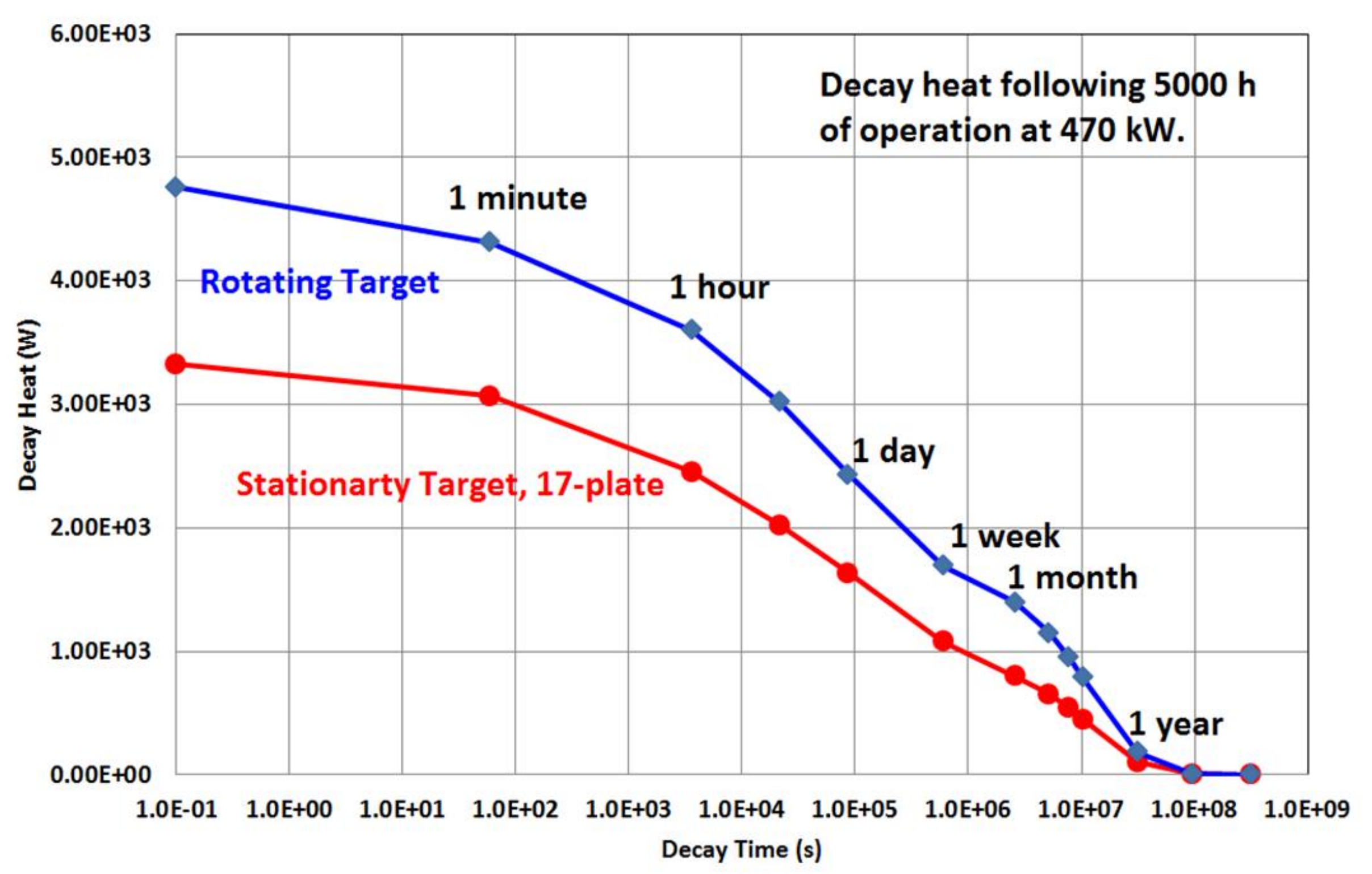
Heating and Activation

Rotating target: consecutive pulses hit different target volume, deposited energy is spread over large volume



Maximum deposited energy per unit volume is 80 J/cm^3/pulse at 0.47 MW proton beam power; which is the same as for the stationary target. However, target rotates and energy is deposited over much larger total volume. Heating rate is not a problem.

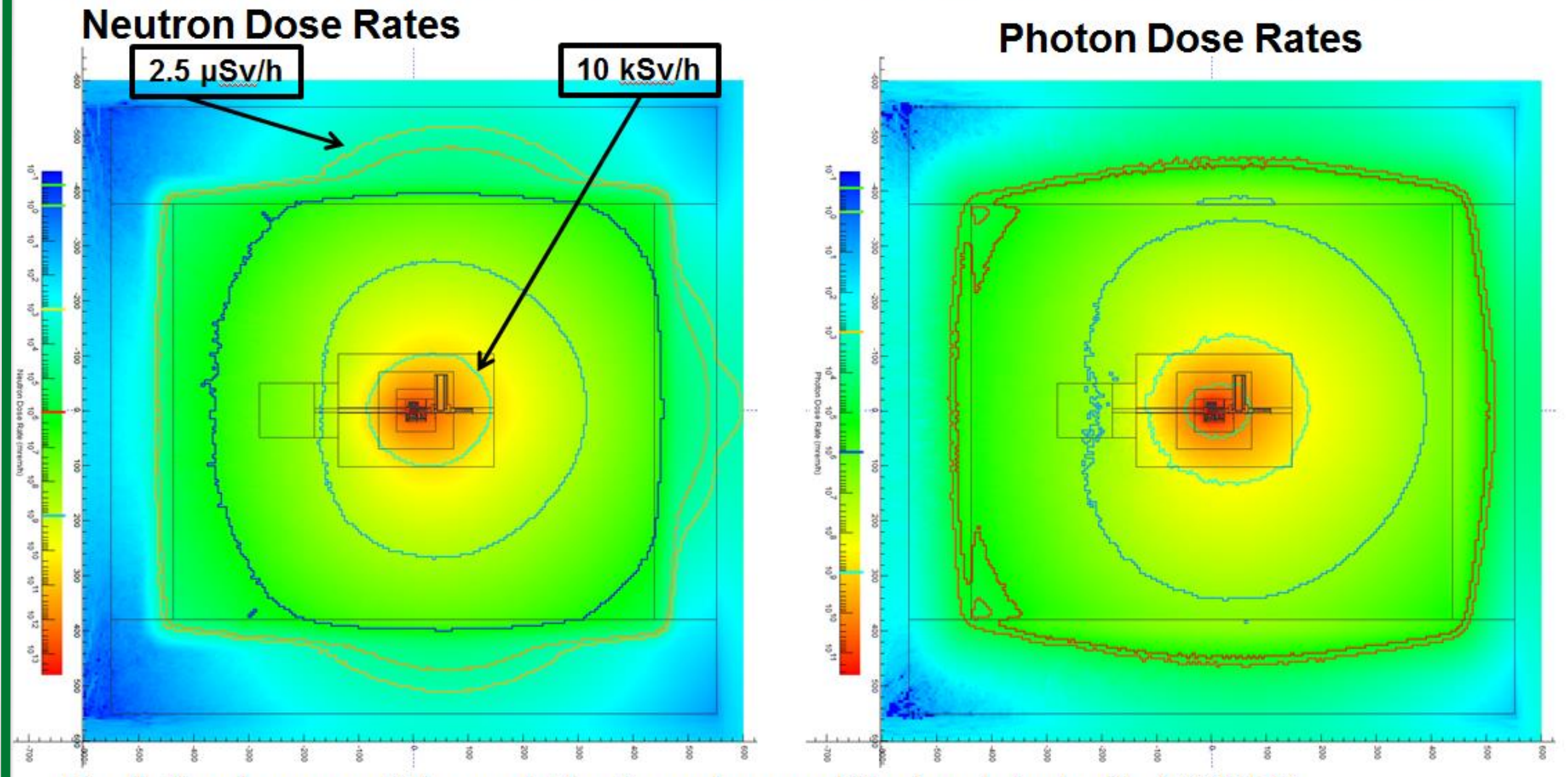
Target decay heat



For the stationary target, high decay heat, confined to small volume, and with relatively small area for cooling, leads to difficulties in extreme accident scenarios such as complete loss of cooling.

Shielding

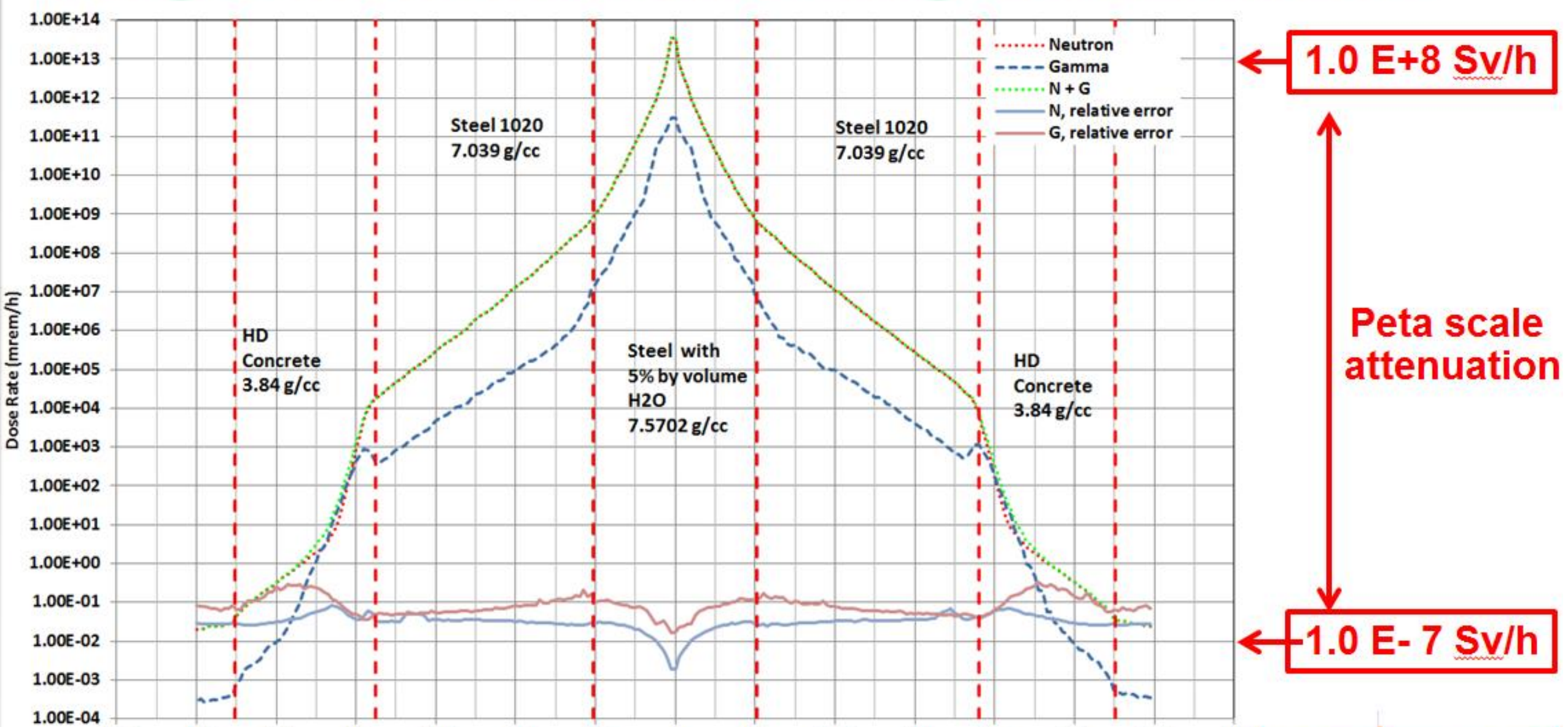
Target monolith shielding calculations

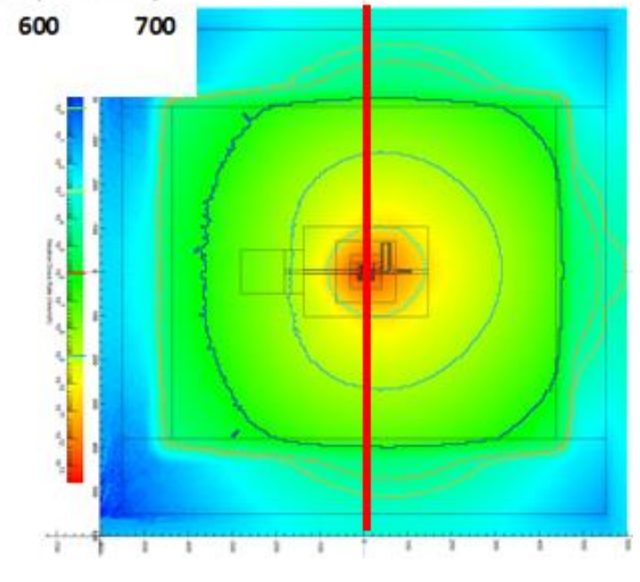


Radiation transport through the target monolith simulated with MCNPX calculations, starting with the proton beam.

ADVANTG methodology used to create weight windows for the subsequent MCNPX analysis.

Target monolith shielding calculations





Successful Monte Carlo simulation of shield with peta-scale (10^{+15}) attenuation.

NPS: 83 million,
1 CPU: 322 days