SELF-SHIELDING EFFECTS IN DECAY HEAT CALCULATIONS FOR TUNGSTEN

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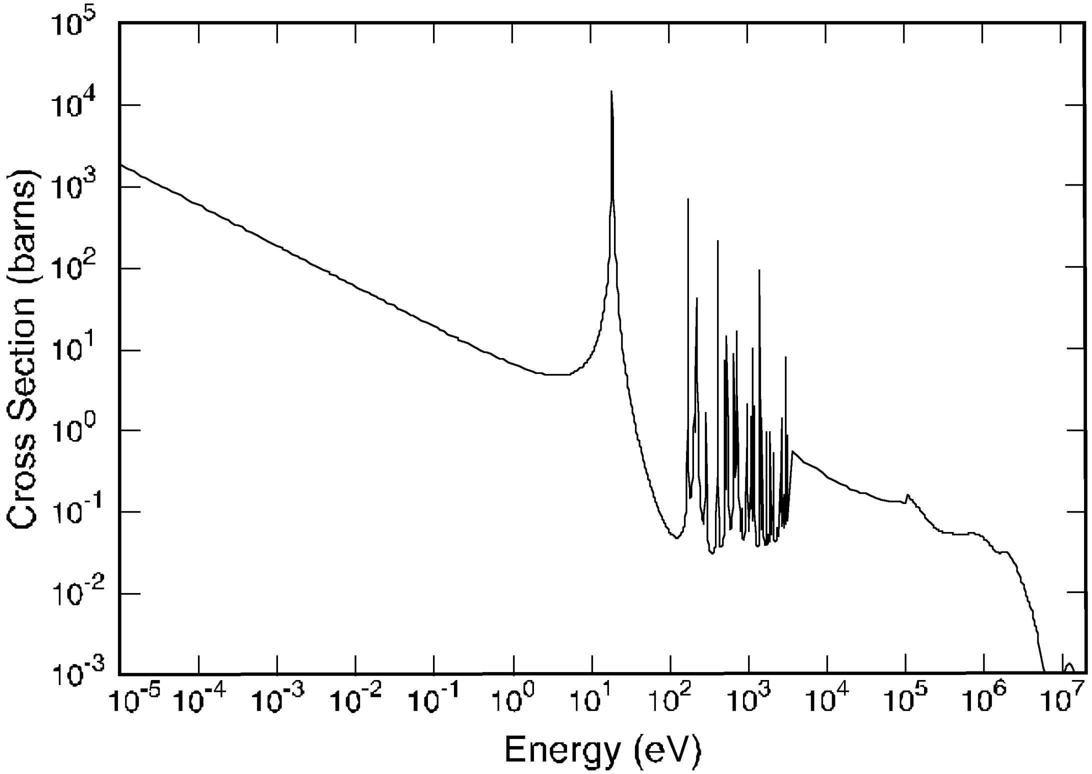
Background

- Tungsten is an attractive candidate for the plasma facing components
- PFC exposed to high energy neutron flux resulting in significant activation
- Decay heat generated in tungsten PFC has important safety consequences
- ^{187}W ($T_{1/2}$= 23.85 h) dominant contributor for several days after shutdown
- It is produced from $^{186}W(n,\gamma)$ reaction with a giant resonance at 20 eV
- Precise representation of geometry and energy variable essential to properly account for self-shielding effects

$^{186}W(n,\gamma)$ cross section



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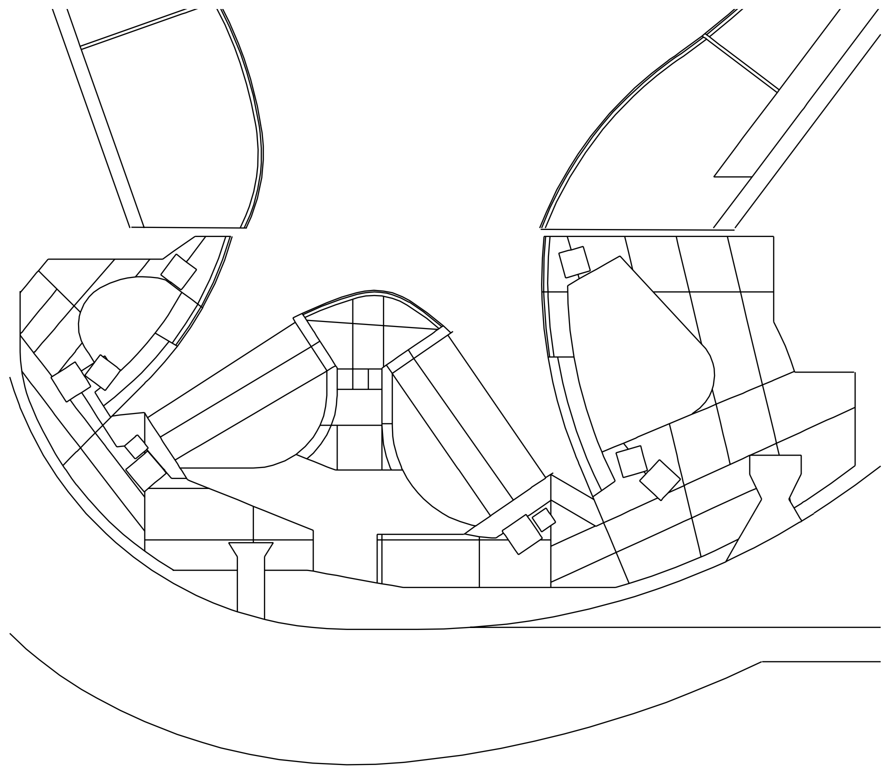
ITER Divertor Model

- Detailed 3-D geometrical configuration of ITER divertor cassette modeled
- Monte Carlo code MCNP-4A used with FENDL data
- Each divertor cassette divided into 103 regions to provide detailed spatial distribution of neutron flux
- Layered configurations of dome PFC and vertical targets modeled accurately with front W PFC modeled separately
- 1 cm W PFC in dome followed by 2 cm thick Cu/water heat sink

Vertical cross section of ITER cassette model



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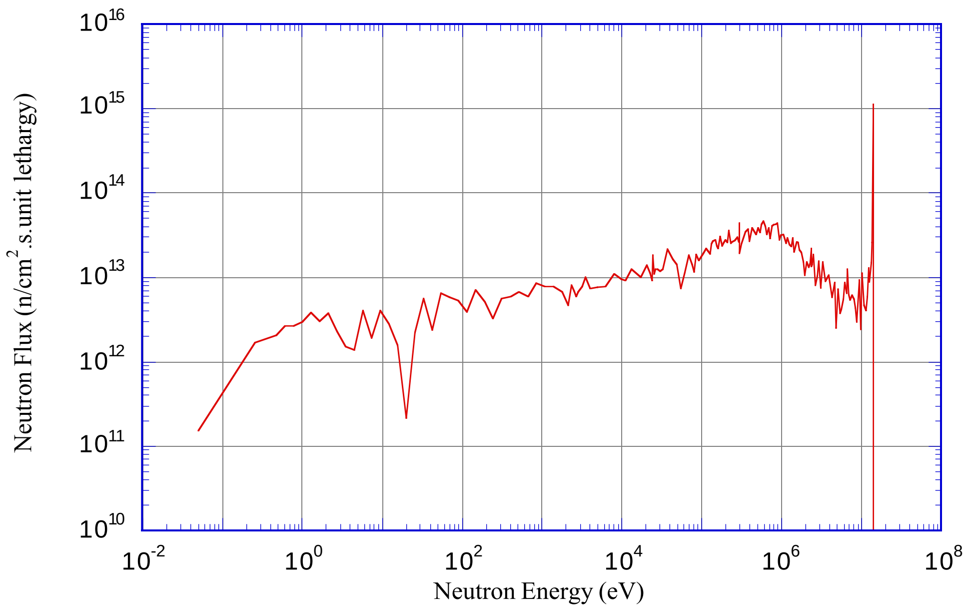
Neutron Energy Spectrum in W PFC

	PeakEnergyIntegrated NeutronFlux(n/cm^{2}s)
Dome PFC	2.16×10^{14}
OuterVerticalTarget	1.81×10^{14}
InnerVerticalTarget	1.16×10^{14}



Large dip in spectrum around 20 eV due to giant ^{186}W (n,γ) resonance

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Geometrical Modeling Effects

- Homogenization of W PFC with Cu/water heat sink significantly overestimates ^{187}W production rate

- Hydrogen in homogenized zone helps slow down neutrons to the ^{186}W(n,γ) giant resonance

- ^{187}W production rate can be overestimated by up to a factor of two depending on thickness of homogenized zone and water content

- Layered configuration must be modeled correctly to properly account for self-shielding

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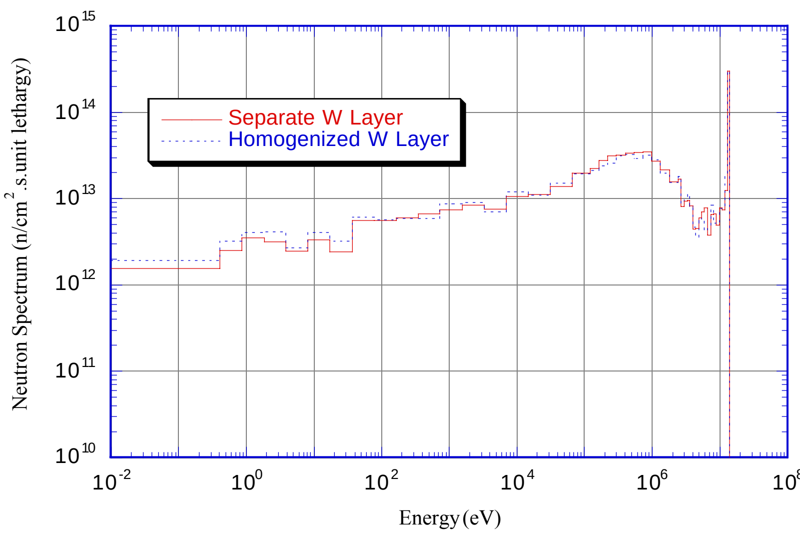
Homogenization Effect

Two calculations performed using 3-D model:

1) 1 cm thick W PFC modeled separately followed by 2 cm thick heat sink layer
2) Homogeneous composition of W, Cu and H_2O used in front 3 cm of dome

^{187}W Production Rate per cm^3 of W (nuclides/cm^{3}s)

Separate 1 cm W Layer	3.8×10^{12}
Homogeneous 3 cm Zone	
Front 1 cm	6.2×10^{12}
Back 2 cm	4.4×10^{12}
Whole 3 cm	5.0×10^{12}



- Value in front 1 cm overestimated by factor of 1.63 with W homogenization
- Homogenization results in spectrum softening

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Effects of Energy Representation

- Resonance self-shielding effects treated correctly in continuous energy (pointwise cross section data) Monte Carlo calculations

- Multi-group activation libraries do not include self-shielded cross sections with smooth 1/E weighting spectrum in resonance region

- Multi-group activation data overestimate $^{186}W(n,\gamma)$ cross section at giant 20 eV resonance

	Relative ^{187}W Production Rate
Directly from MCNP	1
MCNP flux with 46-group activation data	6.9
MCNP flux with 175-group activation data	1.9

Accounting for Self-Shielding in Multi-Group Activation

To properly account for self-shielding in multi-group activation calculation

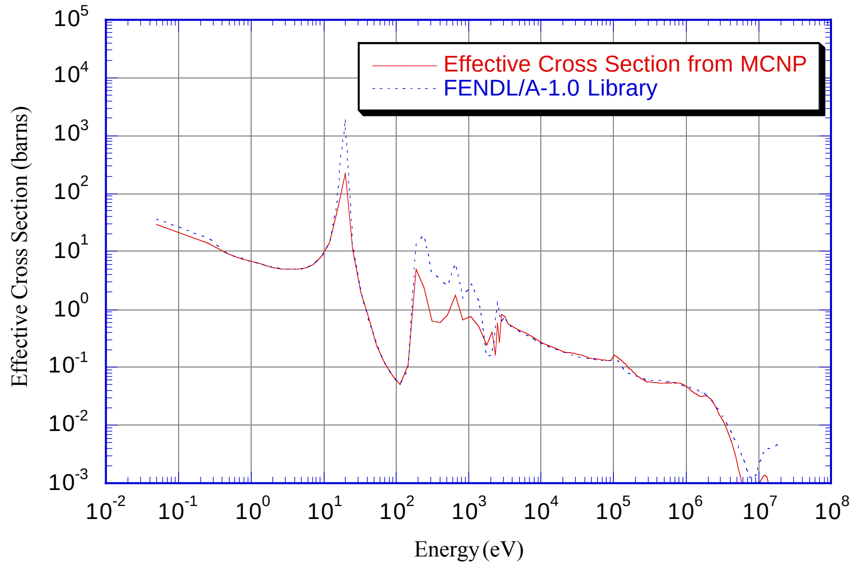
- Bypass reaction rate calculation in activation code and use correct reaction rate calculated from MCNP for reactions with big resonances and which produce dominant radionuclides

or

- Calculate from MCNP the effective multi-group cross sections for the reactions of interest and modify the activation library to include these self-shielded cross sections

Effective Multi-Group Self-Shielded Cross Sections

- The reaction rates and neutron spectra calculated from MCNP were used to determine the effective reaction cross sections in each energy group



- About an order of magnitudeself-shielding observed at the 20 eV resonance

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Conclusions

- Decay heat generated in W PFC dominated by ^{187}W produced from the $^{186}W(n,\gamma)$ reaction characterized by a giant resonance at 20 eV

- Precise representation of the geometry and energy variable is essential to properly account for self-shielding effects

- Large discrepancies in calculated W decay heat result from homogenization with the heat sink that includes water and using non-self-shielded multi-group cross sections in the activation calculation

- For correct analysis one should rely on the continuous energy 3-D Monte Carlo results with proper layered heterogeneous modeling to calculate the spectra and reaction rates or effective self-shielded cross sections to be used in the activation calculation

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