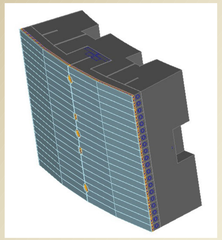
Assessment of the Surface Source Approach in 3-D Fusion Neutronics Analysis

T.D. Bohm, B. Smith, M.E. Sawan, P. Wilson *Fusion Technology Institute, University of Wisconsin-Madison, USA*

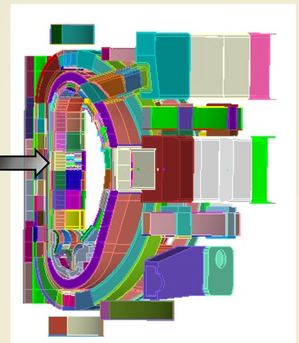
Introduction

- The surface source write/read capability has been implemented in CAD based DAG-MCNP
- Previous work showed a uniform source in a hybrid 1-D/3-D approach overestimated nuclear heating by 30% compared to the surface source approach when used on ITER FWS module 13
- In this work a detailed CAD model of FWS Module 4 is placed within a complete 40° sector CAD model of ITER to calculate a reference result
- The reference results are compared to results from a surface source approach for Module 4
- Calculations on a simplified ITER model are used to understand the artifacts seen in the surface source approach

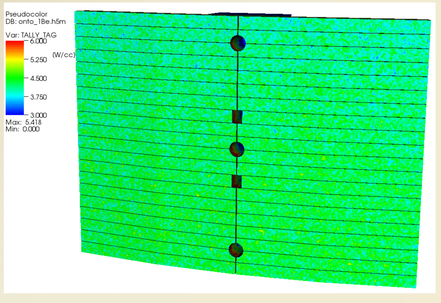
FWS Module 4 in Full ITER Model

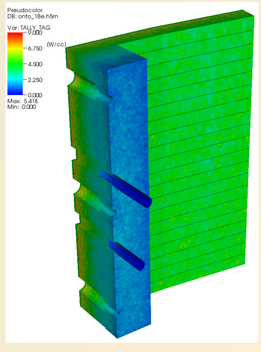


Detailed Module 4 CAD model

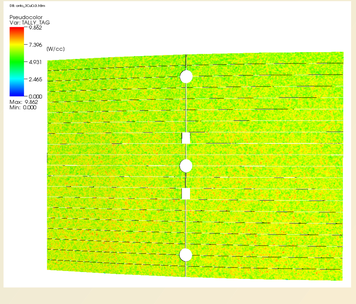


Detailed 40° ITER Model

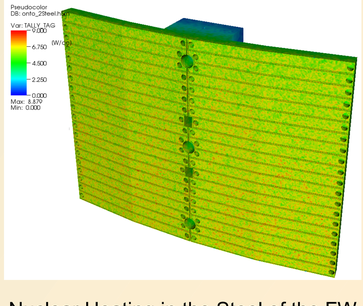




Nuclear Heating in the FW of Module 4

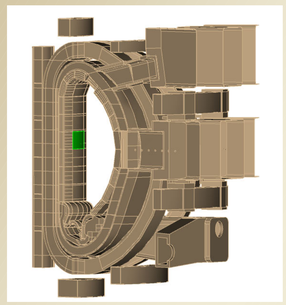


Nuclear Heating in the CuCrZr of the FW

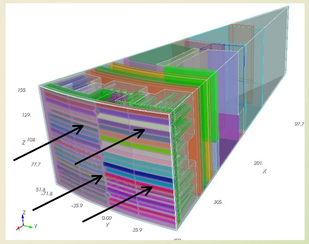


Nuclear Heating in the Steel of the FW

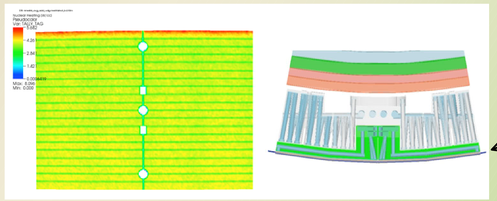
FWS Module 4 with Surface Source



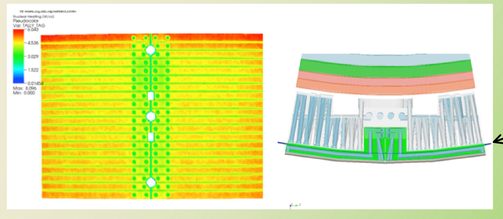
Surface used to record surface source



Module 4 CAD model with surface source



Nuclear heating in the Be in the FW



Nuclear heating in the steel in the FW

- Peaking artifact seen in surface source results at the top of Module 4

Comparison of CAD based Results

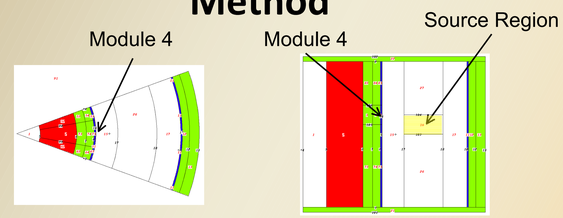
Neutrons crossing into Module 4 per second

Uncollided neutrons	Full model	3.34×10^{17}
	Surface source	3.37×10^{17}
	% Difference	0.9%
Total neutrons	Full model	7.66×10^{17}
	Surface source	7.68×10^{17}
	% Difference	0.3%

Total nuclear heating (MW) in Module 4 by material

Material	Full Model	Surface Source	% Difference
Beryllium	0.0535	0.0543	1.50%
CuCrZr	0.0350	0.0356	1.71%
Steel	0.757	0.790	4.36%
Water	0.150	0.157	4.67%

Assessment of the Surface Source Method

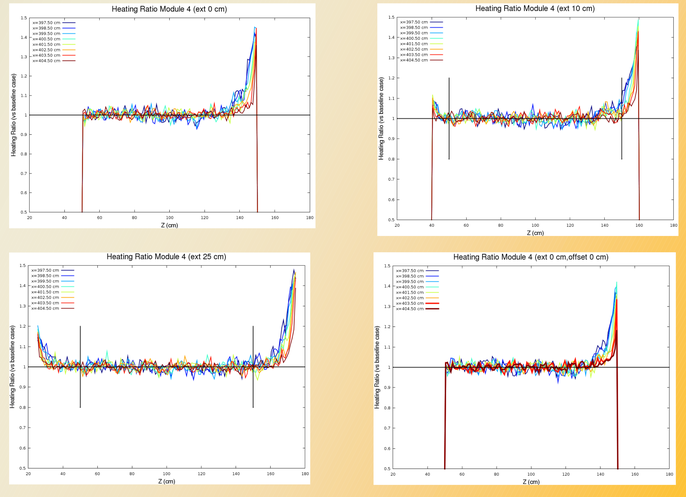


Simplified Full Model of Module 4 (Native MCNP)

Simplified Surface Source Model of Module 4

Cases Examined (all cases have 1 cm offset except case 4):

1) Surface Source same size as Module 4 (z=50-150 cm)
2) Surface Source extended 10 cm above and below Module 4 (z=40-160 cm)
3) Surface Source extended 25 cm above and below Module 4 (z=25-175 cm)
4) Same as Case 1 but with surface source having 0 cm offset



FW heating ratio as a function of height along Module 4 (Cases 1-4)

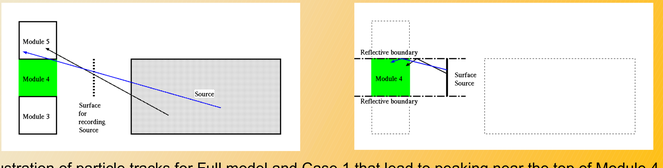


Illustration of particle tracks for Full model and Case 1 that lead to peaking near the top of Module 4

Conclusions

- The surface source method is accurate for toroidal fusion systems provided the surface source and associated reflecting boundaries are extended at least 10-25 cm beyond the module of interest and the surface source is close to the module of interest
- The surface source method requires more human effort but less computation time than the full model method