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Evaluation of SNS Beamline Shielding Configurations using MCNPX Accelerated by ADVANTG

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Shielding analyses for the Spallation Neutron Source (SNS) at Oak Ridge National Laboratory pose significant computational challenges, including highly anisotropic high-energy sources, a combination of deep penetration shielding and an unshielded beamline, and a desire to obtain well-converged 'nearly global' solutions for mapping of predicted radiation fields. The majority of these analyses have been performed using MCNPX with limited variance reduction (source biasing and cell-based splitting and Russian roulette) that was largely based on the analyst's insight into the problem specifics. Development of the variance reduction parameters required extensive analyst time, and was often tailored to specific portions of the model phase space.

We previously applied a developmental version of the ADVANTG code to an SNS beamline study to perform a hybrid deterministic/Monte Carlo analysis and showed that we could obtain nearly global Monte Carlo solutions with essentially uniform relative errors for large-volume mesh tallies with typical spacing of a few centimeters. The use of weight window maps and consistent biased sources produced using the FW-CADIS methodology in ADVANTG allowed us to obtain these solutions using substantially less computer time than the previous cell-based splitting approach. While those results were promising, the process of using the developmental version of ADVANTG was somewhat laborious, requiring user-developed Python scripts to 'drive' much of the analysis sequence. In addition, limitations imposed by the size of weight-window files in MCNPX necessitated the use of relatively coarse spatial and energy discretization for the deterministic Denovo calculations that we used to generate the variance reduction parameters. We recently applied the production version of ADVANTG to this beamline analysis, which substantially streamlined the analysis process. In addition, we developed and applied spatial- and energy-collapsing capabilities in ADVANTG. These collapsing options allowed us to eliminate the necessity of applying a priori group collapsing to the HILO2K library, and reduced restrictions on the Denovo spatial mesh. These changes, along with the support for parallel Denovo calculations using the current version of ADVANTG, give us the capability to improve the fidelity of the deterministic portion of the hybrid analysis sequence, obtain improved weight-window maps, and reduce the time required for the analysis sequence.

Summary

We applied the ADVANTG code in conjunction with MCNPX to perform hybrid deterministic/Monte Carlo shielding analyses for SNS beamline studies. ADVANTG automates the generation of variance reduction parameters for continuous-energy Monte Carlo calculations using the Forward-Weighted Consistent Adjoint Driven Importance Sampling (FW-CADIS) methodology. Our results demonstrate that the use of ADVANTG to accelerate these challenging MCNPX calculations provides 'nearly global' Monte Carlo solutions with essentially uniform relative errors. This approach results in substantial savings in computer time and in the time required by analysts to develop efficient variance reduction parameters.

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