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MULTIDIMENSIONAL COUPLED PHOTON-ELECTRON TRANSPORT SIMULATIONS USING NEUTRAL PARTICLE S_N CODES

Dan Ilas[1], Mark L. Williams, Douglas E. Peplow, and Bernadette L. Kirk
Oak Ridge National Laboratory

ABSTRACT

During the past two years a study was underway at ORNL to assess the suitability of the popular S_N neutral particle codes ANISN, DORT and TORT for coupled photon-electron calculations specific to external beam therapy of medical physics applications. The study was funded by the National Cancer Institute (NCI) of the National Institutes of Health (NIH) under Grant Number R21 CA114614.

All the coupled photon-electron computations performed in this study were based on cross sections prepared with the CEPXS-BFP code, a Russian-modified version of the CEPXS code produced by Sandia National Lab. The restricted stopping powers produced by CEPXS-BFP were turned into cross sections appropriate for usage in the Boltzmann equation solvers. This task was performed by an auxiliary code that used a weighted 2-step differencing scheme in energy. The computational tests were performed on phantoms typical of those used in medical physics for external beam therapy, with materials simulated by water at different densities.

The comparisons were made against Monte Carlo simulations that served as benchmarks. These reference calculations were performed with either MCNP or EGSnrc.

One-dimensional deterministic calculations led to reasonably good agreement for both photon and electron transport. The agreement for the fluxes was in general better than 5% for both photons and electrons.

Although the results for one-dimensional calculations were encouraging, it appeared that the higher dimensional transport codes had fundamental difficulties in handling the electron transport. The results of two-dimensional simulations using the code DORT with an S_{16} fully symmetric quadrature set agree fairly with the reference Monte Carlo results but not well enough for clinical applications. While the photon fluxes are in better agreement (generally, within less than 5% from the reference), the discrepancy increases, sometimes very significantly, for the electron fluxes. Similar problems arise for three-dimensional simulations, where the three-dimensional code TORT had convergence difficulties for the electron groups. Numerical instabilities appeared in the electron groups. These instabilities were more pronounced with the degree of anisotropy of the problem.

It appeared that at least some of the difficulties originated from the electron cross-section preparation. For example, it is known that the CEPXS code generates consistent electron cross-section sets for one-dimensional neutral particle S_N codes only in conjunction with the use of Gaussian directional sets. The use of other quadrature sets does not guarantee the correctness of

[1] Email address: ilasd@ornl.gov

the procedure. Specialized quadrature sets such as Galerkin quadratures for 3D transport should be examined to ascertain the best approach for medical physics applications.

Computational times for the discrete ordinates calculations compared well with Monte Carlo times for the problems considered. The codes used were general purpose codes, not specialized for voxelized geometries. The specialization of the codes for this type of geometry could lead to significant gains in computational speeds.