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Comparison of Predictions by MCNP and EGSnrc of Radiation Dose imparted to various Material Targets by Beams and small volumetric Sources.

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Abstract:

While MCNP is well known among nuclear engineers in the US and in recognized countries with similar commercial nuclear interests, the code EGSnrc (which is the preferred within the American Association of Physicists in Medicine) is not as widely known among engineers/physicists engaged in traditional nuclear engineering. Both MCNP and EGSnrc are highly adept at modelling the transport of hard photons (1keV to hundreds of MeV's). EGSnrc is optimized in order to model the transport of electrons in a significantly more time efficient manner than MCNP. However, there is more statistical reliability with MCNP in the modelling of electrons when they are in the last few keV's worth of energy in their journeys than one finds in the results of EGSnrc, which is extensively optimized for time efficient electron transport modelling.

It is instructive to point out that EGSnrc is designed exclusively for the transport of photons and electrons(+-), not for hadrons (i.e. protons, alphas, etc.). This is rather limiting in versatility for EGSnrc compared to MCNPX, which now does include many hadrons in addition to alphas. The predominant modes of radiation therapy are still done with hard photons, semi-hard photons, and less frequently with energetic electrons; either from accelerators or radioisotopic sources (e.g. Ir-192 etc.). Radiographic imaging relies on positrons and photons. Thus, EGSnrc is versatile enough with its choices of radiative particles for para-clinical applications. For geometric configurations and designs in the medical realm, virtually all material samples and targets are arranged within rectangular voxels, whose planar boundaries are aligned with their respective x,y, and z axes. While this might seem very limiting to the traditional nuclear engineering oriented user of MCNP, this is quite sufficient for the medical physicists and medical physics developers, who almost always work with 3 dimensional images of patients which are mapped as voxels with a grid-partitioning of often more than 70 by 70 by 50. These mappings of the densities and the images are recorded as files which are translated from the CT image files of a given patient or specimen.

In this paper, material samples (or specimens) have been setup so as to be subdivided into voxels which often are simplified as cubes at the size of 1 cubic centimeter. These cubic or rectangular voxels are varied in material density and chemical compositions (atomic ratios for the "m-card" parameters of MCNP). These specimens are simulated as being irradiated by local point sources and rectangularly collimated beams of radiative particles chosen to be either photons or electrons. Each example of material sample with irradiation configuration is done both by MCNP as well as EGSnrc.

It is the simulated doses imparted to each voxel via MCNP and also via EGSnrc that are recorded and reviewed for similarities and differences of performances between what the two codes. Dose per voxel is emphasized because medical physicists are mostly interested in doses resulting from radiation, not in the transmissions of particles.

The simulation results between MCNP and EGSnrc are similar but not identical. Among preliminary examples of simulation for a given setup of material filled voxels which are irradiated by rectangular beams of either photons or electrons, it was generally found at most energy levels that EGSnrc predicts slightly higher doses than MCNP does. These are the doses imparted to samples within the target and to the material regions surrounding the target. Another noticeable trend in such geometries of the rectangularly collimated beam of monochromatic photons is that EGSnrc predicts a larger contribution from buildup in local dose "downstream" along the target than MCNP, for energies above 1 MeV. For energies above 5MeV, this discrepancy in dose predictions within the first 3 centimeters of beam penetration leads EGSnrc to predict near-surface doses to be greater than 10 percent larger than the MCNP's predictions. An immediately apparent performance trend is that EGSnrc simulations of photons are over 40 percent faster than those of MCNP, using the same number of particles and the same computer for the simulations. When simulating electrons and given the same CPU and other equivalent computer hardware, EGSnrc is over 300 percent faster than MCNP. However, one needs to be prepared for the appearance of a minuscule (but nonzero) subgroup of electrons during these EGSnrc simulations.

There are many geometries out of voxels with various beams and volumetric sources (volumetric sources simulating 'seeds' or radiative point sources) which will be considered in this paper.