Abstract ID: 15459 Title: On the Monte Carlo simulation of electron transport in the sub-1 keV energy range

Purpose: The validity of 'classic' Monte Carlo simulations of electron and positron transport at sub-1 keV energies is investigated in the context of quantum theory.

Methods: Quantum theory dictates that uncertainties on the position and energy-momentum four vectors of radiation quanta obey Heisenberg's uncertainty relation; however, these uncertainties are neglected in 'classical' MC simulations of radiation transport in which position and momentum are known precisely. Using the quantum uncertainty relation and electron mean free path, the magnitude of uncertainties on electron position and momentum are calculated for different kinetic energies; a validity bound on the classical simulation of electron transport is derived.

Results: In order to satisfy the Heisenberg uncertainty principle, uncertainties of 4% or greater must be assigned to position and momentum for 1 keV electrons in water; at 100 eV, these uncertainties are 15% to 22% and are even larger at lower energies. In gaseous media such as air, these uncertainties are much smaller (less than 1% for electrons with energy 20 eV or greater).

Conclusions: The classical Monte Carlo transport treatment is incorrect for sub-1 keV electrons in water as uncertainties on position and momentum must be large (relative to electron momentum and the mean free path) to satisfy the quantum uncertainty principle. Simulations in condensed media (e.g., water) which do not reflect the quantum nature of electrons and positrons are not faithful representations of the physical reality at these low energies, calling into question the results of MC track structure codes simulating sub-1 keV electron transport. Further, the large differences in the scale at which quantum effects are important in gaseous and condensed media suggest that track structure measurements in gases are not necessarily representative of track structure in condensed materials on a micrometer or nanometer scale.