Comparison of MCNP6.1 with PENELOPE2014 for electron dose calculations at very low energies

Seongmoon Jung [a, b], Wonmo Sung [a, b], Sung-Joon Ye [a, b, c*]
[a] *Program in Biomedical Radiation Sciences, Department of Transdisciplinary Studies, Graduate School of Convergence Science and Technology, Seoul National University, Seoul, South Korea*
[b] *Biomedical Research Institute, Seoul National University College of Medicine, Seoul, South Korea*
[c] *Robotics Research Laboratory for Extreme Environment, Advanced Institutes of Convergence Technology, Seoul National University, Suwon, South Korea*
[*] *Corresponding author: sye@snu.ac.kr*

1. Introduction

Recently, MCNP6.1 has been released with an inclusion of extended cross-sections for low energy down to 10 eV for electron and 1 eV for photon [1]. The purpose of this paper is to compare dose calculations in the low energy range between MCNP6.1 and PENELOPE2014 [2].

2. Methods and Results

The PENELOPE code and its physics library have been used and validated for the purpose of microdosimetry calculation [3]. Since PENELOPE2014 offered electron/photon transport down to 50 eV, the cutoff energy for MCNP6.1 was set to 50 eV.

2.1 Dose point kernel for monoenergetic electron sources

Two monoenergetic electron sources (i.e., 100 eV and 1 keV) were assumed to be located at a center of water of which a thickness of shell was 1 nm. 10^6 particle histories were used for each simulation. A single-event method was used to transport the electrons for both codes. Fig. 1 shows dose point kernels (DPK) for the electron sources along distances in water. The range of electrons in MCNP6.1 was shorter than that in PENELOPE2014. In addition, DPK in MCNP6.1 was higher at short distances, while the DPK was lower at relatively long distances than that in PENLEOPE2014.

2.2 Radial dose distribution and dose enhancements by gold nanoparticle

A 50 kVp polychromatic photon spectrum extracted by SpekCalc code [4] was used to stimulate gold nanoparticle (GNP), of which diameter was 50 nm. Photon histories of 10^8 were used for each simulation. Electron phase-space files from the surface of GNP and water nanoparticle (WNP) was saved. By using the phase-space of electron tracks as the source, radial doses were calculated by the same geometrical condition

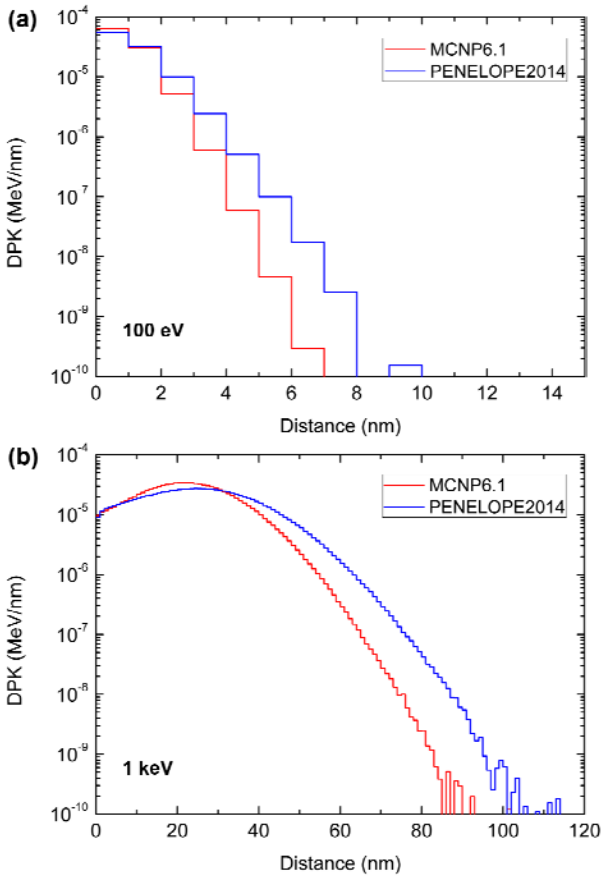

Fig. 1. Dose point kernel for (a) 100 eV electron and (b) 1 keV electron source.

described in *2.1*. The radial doses in MCNP6.1 were slightly higher than those in PENELOPE2014 below the distance of 200 nm from the surface of GNP. The number of electron tracks saved in the phase-space file in MCNP6.1 was slightly higher than that in PENELOPE2014. The radial doses were enhanced by a factor of thousand or even higher.

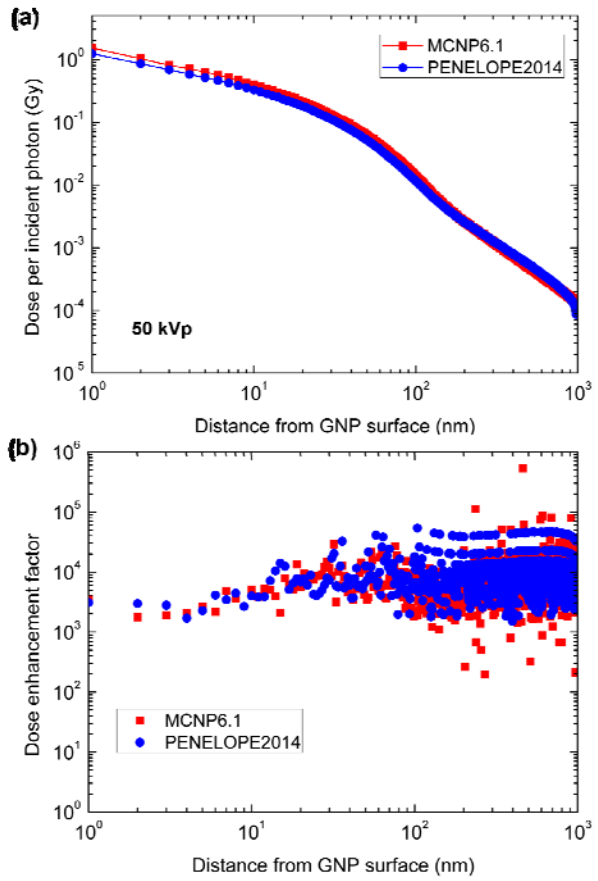

Fig. 2. (a) Radial dose distribution and (b) dose enhancement factor.

3. Conclusions

Transport calculations of MCNP6.1 in the low energy range were benchmarked by PENELOPE2014 in terms of DPK of electron sources. When GNP exists, microscopic dose enhancement factors calculated by the MCNP6.1 and PENELOPE2014 showed some discrepancies, although the factors were in the same order of magnitude. This might be due to use of different electron transport algorithms in MCNP6.1 and PENELOPE.

REFERENCES

[1] T Goorley, M James, T Booth, F Brown, J Bull, L J Cox, J Durkee, J Elson, M Fensin, R A Forster, J Hendricks, H G Hughes, R Johns, B Kiedrowski, R Martz, S Mashnik, G McKinney, D Pelowitz, R Prael, J Sweezy, L Waters, T Wilcox, T Zukaitis, Initial Mcnp6 Release Overview, Nucl Technol. Vol. 180, p. 298-315, 2012.

[2] F Salvat, PENELOPE-2014: A Code System for Monte Carlo Simulation of Electron and Photon Transport, OECD Nuclear Energy Agency, Doc. No. NEA/NSC/DOC(2015)3, 2015.

[3] E Lechtman, S Mashouf, N Chattopadhyay, B M Keller, P Lai, Z Cai, R M Reilly, J P Pignol, A Monte Carlo-based model of gold nanoparticle radiosensitization accounting for increased radiobiological effectiveness, Phys Med Biol. Vol. 58, p. 3075-3087, 2013.

[4] G Poludniowski, G Landry, F DeBlois, P M Evans and F Verhaegen F, SpekCalc: a program to calculate photon spectra from tungsten anode x-ray tubes, Phys Med Biol. Vol 54 N433-N8, 2009.