Title: Final Report: Monte Carlo Track-Structure Simulations for Low-LET
Selected-Cell Radiation Studies
Project ID: 0005019
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SUMMARY

The role of cell-cell communication in tissue responses to ionization radiation remains an incompletely understood aspect of radiation biology that may give rise to thresholds in the dose responses for important endpoints such as tumor induction. Many experimental systems are active or proposed to study bystander effects by means of selected-cell irradiation, including electron and photon microbeams and broad-beam irradiators. By variations in beam intensity and energy, these devices modulate the number and stopping power of particles slowing down or stopping in a selected population of cells.

This project provided computational dosimetric assistance to the microbeam irradiators by state-of-the-art Monte Carlo low-LET track-structure simulations.

ACCOMPLISHMENTS

The following major goals were achieved: (1) incorporated condensed phase effects in track-structure calculations based on published theory and experimental results for liquid water, (2) developed methods for simulating focused low energy photon microbeam irradiations, and (3) used the improved capabilities to address dosimetry issues in selected-cell irradiation with electron and photon microbeams.

During the grant-period, 1) thirteen reviewed papers, authored or co-authored by the PI were published in the scientific literature; 2) seven poster-papers were presented at U.S. and International Radiation Research meetings; and 3) poster-papers were presented at five annual DOE Low-dose workshops. Complete references to these publications and presentations are in the Bibliographic Section.

STUDENT SUPPORT

Partial support was provided to six students during the grant-period; they were

Arzu Kurtulus, Master of Science in Computer Science, December 2001, thesis entitled "A Visualization Tool for Ionization Track Structure"

Masaki Kameya, Doctor of Philosophy in Computer Science, August 2002, thesis entitled "A Smooth, Efficient Representation of Reflectance".

Kui Wei, Master of Science in Computer Science, December 2002, thesis entitled "Parallel Processing Implementation of a Monte Carlo Code for Positive Ion Track Simulation".

James E. Mitchell, Master of Science in Computer Science, December 2003, thesis entitled "Electron Track Endpoint Scoring in the Monte Carlo Track Structure Simulation"

Michael T. Batdorf, Master of Science in Computer Science, December 2005, thesis entitled "Computational Representations for Electron Microbeam Microdosimetric Quantities in One Micron Diameter Spherical Targets"

Bojana Ginovska, Bachelor of Science in Computer Science, May 2005; senior student project (poster presented at DOE Low-dose Workshop) entitled "Comparison of Soft X-ray and Ion Irradiation in a Model of V79 Mammalian Cells".

BIBLIOGRAPHY

The following publications appeared and presentations were made during the grant period:

W. E. Wilson and H. Nikjoo, "A Monte-Carlo Code for Positive Ion Track Simulation", *Radiat. Environ. Biophys.*, 38, 97-104, (1999).

W.E. Wilson and D.J. Lynch, "Track-structure Simulations for Selected-cell Irradiation Studies", a poster paper presented at the DOE Low Dose Radiation Research Program, Workshop I, November 10-12, 1999, Washington, D.C.

S. Uehara, L.H. Toburen, W.E. Wilson, D.T. Goodhead, and H. Nikjoo, "Calculation of electronic stopping cross sections for low-energy protons in water", *Radiat.*

Phys. and Chem., 59, 1-11, (2000).

J.H. Miller, M. Sowa Resat, N.F. Metting, K. Wei, D.J. Lynch, and W.E. Wilson, "Monte Carlo Simulation of Single-Cell Irradiation by an Electron Microbeam", Radiat. Envir. Biophysics, 39, 173-177 (2000).

W.E. Wilson, D.J. Lynch, K. Wei, and J.H. Miller, "Microdosimetry for Low-Dose Low-LET Selected Cell Irradiations", In proceedings of ANS topical meeting, Spokane, Sept. 17-21, (2000).

W.E. Wilson, J.H. Miller, D.J. Lynch, and K. Wei, "Low-LET Microbeam Dosimetry" a poster paper presented at the 48th Annual meeting of the Radiation Research Society, San Juan, Puerto Rico, April 21-25, 2001.

W.E. Wilson, D.J. Lynch, K. Wei, and L.A. Braby, "Microdosimetry of a 25 keV Electron Microbeam", Radiat. Res., 155, 89-94, (2001).

Low-LET Microbeam Dosimetry, W.E. Wilson, J.H. Miller, D.J. Lynch, K. Wei and A. Kurtulus, a poster paper presented at the DOE Low Dose Radiation Research Program, Workshop II, June, 2001, Washington, D.C.

H. Nikjoo, S. Uehara, Khvostunov, Cucinotta, W.E. Wilson, and D.T. Goodhead, "Monte Carlo track structure for radiation biology and space applications", Physica Medica vol XVII, Supplement 1, pp 38-44 (2001).

Nikjoo, H., O'Neill, P., Wilson, W. E. and Goodhead, D. T., "Computational Approach for Determining the Spectrum of DNA Damage Induced by Ionizing Radiation", Radiat. Res. 156, 577-583 (2001).

R.D. Stewart, W.E. Wilson, J.C. McDonald, and D.J. Strom, "Microdosimetric Properties of Ionizing Electrons in Water: A Test of the PENELOPE code system". Phys. Med. Biol. 47(1), 77-88 (2002).

W. E. Wilson, J. H. Miller, D. J. Lynch, K. Wei and A. Kurtulus, "Low-LET Microbeam Dosimetry", Radiat. Res., 158, 377-378, (2002).

J. H. Miller, W. E. Wilson, D. J. Lynch, K. Wei, A. Kurtulus and H. E. Trease "Low-LET Microbeam Dosimetry", Radiat. Res., 158, 378-378, (2002).

W. E. Wilson, J. H. Miller, D. J. Lynch, K. Wei and M. Kameya, "Low-LET

Microbeam Dosimetry", a poster paper presented at the DOE Low Dose Radiation Research Program, Workshop III, March 25-27, 2002, Washington, D.C.

W. E. Wilson, J. H. Miller, D. J. Lynch and K. Wei, "Soft X-ray Microbeam Dosimetry", a poster paper presented at the 49th Annual meeting of the Radiation Research Society, Reno, Nevada, April 20-24, 2002.

D. J. Lynch, W. E. Wilson, R. R. Lewis, M. Kameya and J. H. Miller, "Dosimetric Calculations for Electron Microbeams", a poster paper presented at the 49th Annual meeting of the Radiation Research Society, Reno, Nevada, April 20-24, 2002.

W. E. Wilson, J. H. Miller, D. J. Lynch, R. R. Lewis, "Microdosimetry Calculations for Low-LET Microbeam Facilities", a poster paper presented at the 6th International Workshop. 12th L.H. Gray Workshop: Microbeam probes of Cellular Radiation Response, St. Catherine's College, Oxford, United Kingdom, March 29-31, 2003; Extended abstracts in Radiat. Res., 161, 105-106, (2004).

W. E. Wilson, J. H. Miller, D. J. Lynch, R. R. Lewis and M. T. Batdorf, "Microdosimetry calculations for low-LET bystander experiments with microbeams", a poster paper presented at the 12th International Congress of Radiation Research, August 17-22, 2003, Brisbane, Australia.

W.E. Wilson, J.H. Miller, D.J. Lynch, R.R. Lewis and M. Batdorf, "Low-LET Microdosimetry Calculations", a poster paper presented at the DOE Low Dose Radiation Research Program, Workshop IV, October 27-29, 2003, Washington, D.C.

L. H. Toburen, M. Dingfelder, N. Ozturk, W. Friedland, W. E. Wilson, J. L. Shinpaugh and H. G. Paretzke, "Sensitivity of Electron Transport Calculations to Elastic and Inelastic Scattering Cross Sections", Radiat. Res., 161, 106-107, (2004).

W.E. Wilson, J.H. Miller, D.J. Lynch, R.R. Lewis and M. Batdorf "Analysis of Low-Energy Electron Track Structure in Liquid Water", Radiat. Res., 161, 591-596, (2004).

Mainardi, E., Donahue, R.J., Wilson, W.E., and Blakely, E.A. (2004) Comparison of microdosimetric simulations using PENELOPE and PITS for a 25 KeV electron microbeam in water. Radiation Research 162:326-331.

W.E. Wilson, J.H. Miller and M. Batdorf, "Calculation of the Quality of Low Energy

Microbeams", a poster paper presented at the 51st Annual meeting of the Radiation Research Society, St. Louis, Missouri, April 24-27, 2004.

D. J. Lynch, W. E. Wilson, M. T. Batdorf, M. B. Sowa Resat, G. A. Kimmel and J. H. Miller, "Monte Carlo Simulation of the Spatial Distribution of Energy Deposition for an Electron Microbeam" Radiat. Res. 163, 468-472 (2005).

B. Ginovska, J. H. Miller, D. J. Lynch and W. E. Wilson, "Comparison of Soft X-rays and Ion Irradiation in a Model of V79 mammalian Cells", a poster paper presented at the DOE Low Dose Radiation Research Program, Workshop V, April 25-27, 2005, Washington, D.C.