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Theory of Heavy Ion Collision Physics in Hadron Therapy

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Theory of Heavy Ion Collision Physics in Hadron Therapy

Edited by

DŽEVAD BELKIĆ
Professor of Mathematical Radiation Physics
Nobel Medical Institute, Karolinska Institute
Stockholm
Sweden

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John R. Sabin
and Erkki Brändas

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Preface

This Special Issue is within a wider realm of physical and biological effects of irradiation of tissue and tissue-like targets by energetic heavy ions of high relevance to hadron therapy. The main goal is to review the leading theories describing fast collisions of ions with atoms and molecules by emphasizing the possibilities for improving the existing data bases for energy losses of heavy charged particles during their passage through matter. Ion-atom collisions are included in this topic by presenting those theoretical formalisms that are universally applicable to general targets, including molecules from tissue. Although the main focus is on energy losses due to electromagnetic interactions, also reviewed are the pertinent cross sections and stopping powers for nuclear reactions. Data bases of electronic and nuclear stopping powers coupled with the associated modeling of biological responses of cells to irradiation are essential to hadron therapy.

When determining a treatment plan for a patient with cancer, the radiation oncologist must make a key assumption on the actual amount of dose needed to eradicate all the tumor cells. It is here that the biophysical input is required, accounting for the precise extent of the deposited physical doses, as well as for their biological counterparts that modify the initial impact of radiation by the cell repair processes. The overall success of radiotherapy is contingent upon the dose planning, dose delivery and dose verification systems. To meet with success, radiotherapy must include the most adequate descriptions of energy losses of particle beams in tissue and the cell recovery. Deep-seated tumors are usually treated with energetic hadrons because of the optimal conformity of heavy ions to the targets by way of a very precise local deposition of doses in the vicinity of the Bragg peak.

Versatile biophysical aspects of the topics of this Special Issue are expounded through 14 chapters with the following specific themes:

Chapter 1 (H. Bichsel) examines the stochastic variations of energy losses and biological effects of protons and carbon nuclei in their high-energy collisions with water.

Chapter 2 (H. Paul) performs a comparative analysis of the accuracy of different methods and simulation codes for stopping powers and ion ranges.

Chapter 3 (J.R. Sabin, J. Oddershede and S.P.A. Saue) reviews the theoretical and experimental aspects of determination of the mean excitation energy of water.

Chapter 4 (F. Ziad) studies the molecular scale Monte Carlo simulations of ion tracks using the GEANT4-DNA code with the inclusion of the effects of secondary electrons.

Chapter 5 (J. Beebe-Wang, P. Vaska, F.A. Dilmanian, S.G. Peggs and D.J. Schlyer) investigates the radiation treatment verifications in proton therapy using positron-emission tomographic imaging and Monte Carlo simulations.

Chapter 6 (I. Abril, R. Garcia-Molina, P. de Vera, I. Kyriakou and D. Emfietzoglou) reports on inelastic collisions of energetic protons in tissue-like media using a combination of molecular dynamics and Monte Carlo simulations.

Chapter 7 (C.C. Montanari and J.E. Miraglia) presents a combination of the dielectric formalism with the shell-wise local plasma approximation for inelastic processes in high-energy ion-matter collisions.

Chapter 8 (M.A. Bernal-Rodriguez and J.A. Liendo) assesses the usefulness of the available empirical cross sections relative to the continuum distorted wave theories and experimental data for single ionization of liquid water by protons, alpha particles and carbon nuclei.

Chapter 9 (R.D. Rivarola, M.E. Galassi, P.D. Fainstein and C. Champion) reviews distorted wave methods for electron capture, ionization and excitation processes in high-energy inelastic collisions of ions with water.

Chapter 10 (C. Champion, J. Hanssen and R.D. Rivarola) presents the results of the first Born approximation for ionization and electron transfer in energetic collisions between multiply-charged ions and water.

Chapter 11 (T. Kirchner, M. Murakami, M. Horbatsch and H.J. Lüdde) reports on cross sections for single- and multiple-electron processes in ion-water collisions using the time-dependent density functional theory in the independent electron model.

Chapter 12 (Dž. Belkić, I. Mančev and N. Milojević) deals with the four-body formalism of distorted wave second-order perturbation methods for double electron transitions through simultaneous electron transfer and ionization processes in ion-atom collisions at high impact energies.

Chapter 13 (V.Yu. Lazur and M.V. Khoma) reviews the theoretical concept of the Dodd-Greider integral equations with Coulomb interactions for one- and two-electron capture processes in fast ion-atom collisions.

Chapter 14 (Dž. Belkić and K. Belkić) contributes to a further improvement of the effectiveness of the current radiation treatments of cancer through the amended dose planning systems based on an adequate description of cell survival valid at all doses as predicted by the new mechanistic repair-based Padé linear-quadratic biophysical model.

Dževad Belkić, Guest Editor
Professor of Mathematical Radiation Physics
Nobel Medical Institute, Karolinska Institute
Stockholm
Sweden

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CONTRIBUTORS

Isabel Abril
Departament de Física Aplicada, Universitat d'Alacant, E-03080 Alacant, Spain

Joanne Beebe-Wang
Brookhaven National Laboratory, P.O. Box 5000, Upton, NY 11973, USA

Dževad Belkić
Nobel Medical Institute, Karolinska Institute, P.O. Box 260, S-171 76 Stockholm, Sweden

Karen Belkić
Nobel Medical Institute, Karolinska Institute, P.O. Box 260, S-171 76 Stockholm, Sweden

Mario A. Bernal-Rodríguez
Instituto de Física Gleb Wataghin, Universidade Estadual de Campinas, Brazil

Hans Bichsel
CENPA, University of Washington, Seattle, WA 98195-4290, USA

Christophe Champion
Université Bordeaux 1, CNRS/IN2P3, Centre d' Etudes Nucléaires de Bordeaux-Gradignan, CENBG, Gradignan, France

Pablo de Vera
Departament de Física Aplicada, Universitat d'Alacant, E-03080 Alacant, Spain

F. Avraham Dilmanian
Brookhaven National Laboratory, P.O. Box 5000, Upton, NY 11973, USA

Dimitris Emfietzoglou
Medical Physics Laboratory, University of Ioannina Medical School, GR-45110 Ioannina, Greece

Pablo D. Fainstein
Centro Atómico Bariloche, Comisión Nacional de Energía Atómica, Avda E. Bustillo 9500, 8400 Bariloche, Argentina

Ziad Francis
Saint Joseph University, Faculty of Sciences, Department of Physics, Mkalles, Beirut, Lebanon

Mariel E. Galassi
Instituto de Física Rosario (CONICET-UNR) and Facultad de Ciencias Exactas, Ingeniería y Agrimensura, Universidad Nacional de Rosario, Avenida Pellegrini 250, 2000 Rosario, Argentina

Rafael Garcia-Molina
Departamento de Física, Centro de Investigación en Óptica y Nanofisica, Universidad de Murcia, E-30100 Murcia, Spain

Jocelyn Hanssen
Laboratoire de Physique Moléculaire et des Collisions, UMR CNRS 7565, Université de Lorraine, Metz, France

Marko Horbatsch
Department of Physics and Astronomy, York University, Toronto, Ontario, Canada M3J 1P3

Mykhaylo V. Khoma
Theoretical Physics, Uzhgorod National University, Uzhgorod, Ukraine

Tom Kirchner
Department of Physics and Astronomy, York University, Toronto, Ontario, Canada M3J 1P3

Ioanna Kyriakou
Medical Physics Laboratory, University of Ioannina Medical School, GR-45110 Ioannina, Greece

Volodymyr Yu. Lazur
Theoretical Physics, Uzhgorod National University, Uzhgorod, Ukraine

Jacinto A. Liendo
Departmento de Física, Universidad Simón Bolívar, Caracas, Venezuela

Hans Jürgen Lüdde
Institut für Theoretische Physik, Goethe-Universität, D-60438 Frankfurt, Germany

Ivan Mančev
Department of Physics, Faculty of Sciences and Mathematics, University of Niš, Niš, Serbia

Nenad Milojević
Department of Physics, Faculty of Sciences and Mathematics, University of Niš, Niš, Serbia

Jorge E. Miraglia
Instituto de Astronomía y Física del Espacio, CONICET and Universidad de Buenos Aires, casilla de correo 67, sucursal 28, C1428EGA, Buenos Aires, Argentina

Claudia C. Montanari
Instituto de Astronomía y Física del Espacio, CONICET and Universidad de Buenos Aires, casilla de correo 67, sucursal 28, C1428EGA, Buenos Aires, Argentina

Mitsuko Murakami
Department of Physics and Astronomy, York University, Toronto, Ontario, Canada M3J 1P3

Jens Oddershede
Institute for Physics, Chemistry, and Pharmacology, University of Southern Denmark, 5230 Odense M, Denmark

Helmut Paul
Atomic Physics and Surface Science, Institute for Experimental Physics, Johannes Kepler University, Altenbergerstrasse 69, A-4040, Linz, Austria

Stephen G. Peggs
Brookhaven National Laboratory, P.O. Box 5000, Upton, NY 11973, USA

Roberto D. Rivarola
Instituto de Física Rosario (CONICET-UNR) and Facultad de Ciencias Exactas, Ingeniería y Agrimensura, Universidad Nacional de Rosario, Avenida Pellegrini 250, 2000 Rosario, Argentina

John R. Sabin
Departments of Physics and Chemistry, University of Florida, Gainesville, Florida 32611, USA

Stephan P.A. Sauer
Department of Chemistry, University of Copenhagen, Copenhagen, Denmark

David J. Schlyer
Brookhaven National Laboratory, P.O. Box 5000, Upton, NY 11973, USA

Paul Vaska
Brookhaven National Laboratory, P.O. Box 5000, Upton, NY 11973, USA

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