

Radiation Physics for Nuclear Medicine

Marie Claire Cantone • Christoph Hoeschen
Editors

Radiation Physics for Nuclear Medicine

 Springer

Editors

Prof. Dr. Marie Claire Cantone
Università degli Studi di Milano
Dept. of Physics
Via Celoria
20133 Milano
Italy
marie.cantone@unimi.it

Prof. Dr. Christoph Hoeschen
Helmholtz Zentrum München
Deutsches Forschungszentrum
für Gesundheit und Umwelt (GmbH)
Ingolstädter Landstr. 1
85764 Neuherberg
Germany
Christoph.hoeschen@helmholtz-muenchen.de

ISBN 978-3-642-11326-0 e-ISBN 978-3-642-11327-7
DOI 10.1007/978-3-642-11327-7
Springer Heidelberg Dordrecht London New York

Library of Congress Control Number: 2011921696

© Springer-Verlag Berlin Heidelberg 2011

This work is subject to copyright. All rights are reserved, whether the whole or part of the material is concerned, specifically the rights of translation, reprinting, reuse of illustrations, recitation, broadcasting, reproduction on microfilm or in any other way, and storage in data banks. Duplication of this publication or parts thereof is permitted only under the provisions of the German Copyright Law of September 9, 1965, in its current version, and permission for use must always be obtained from Springer. Violations are liable to prosecution under the German Copyright Law.

The use of general descriptive names, registered names, trademarks, etc. in this publication does not imply, even in the absence of a specific statement, that such names are exempt from the relevant protective laws and regulations and therefore free for general use.

Product liability: The publishers cannot guarantee the accuracy of any information about dosage and application contained in this book. In every individual case the user must check such information by consulting the relevant literature.

Cover design: eStudio Calamar, Figueres/Berlin

Printed on acid-free paper

Springer is part of Springer Science+Business Media (www.springer.com)

In Memory of Niky Molho (1938–1993)

The training course held in Milan on November 2008 on Radiation Physics in Nuclear Medicine, on which basis this book is conceived, was dedicated to memory of Niky Molho, on the occasion of the fifteenth anniversary of his death. Niky Molho was Professor of Medical Physics at the Università degli Studi di Milano (State University of Milan), Faculty of Medicine, and leader of the Research Unit on Medical Physics at the Department of Physics of the same University.

It was February 21, 1993 when a sudden death took Niky away from his dedicated and passionate teaching and research activities at the age of 55.

After receiving the University degree in Physics in 1962, he started to direct his research interests in the field of experimental nuclear physics, with particular attention for studies concerning reaction mechanisms, models of interpretation, gamma spectroscopy and instrumentation. From 1970 when he started to teach physics to the medical students of the Faculty of Medicine in Milan, he started also to focus his research activity toward the medical field, by making full use of his accumulated experiences and knowledge in nuclear physics. He started the development of a new methodology, based on nuclear activation by mean of proton beams for the quantitative analysis of trace elements in biological samples. Such methodology was used with great success for the determination of oligo-elements in human blood. On these premises he started a very close cooperation with the Institute of Biophysical Radiation Research of the GSF in Frankfurt am Main, Germany. This collaboration has been kept alive by his former students and collaborators until these days, although the German counterpart has now changed its name (Helmholtz Zentrum München, German Research Center for Environmental Health, Department of Radiation Sciences) and location (Munich).

Also as a result of this cooperation, he then oriented his efforts to the investigation of the metabolism of oligo-elements by using stable isotopes as tracers, opening a new field of research of fundamental importance for potential applications in various medical fields, including radiation protection. The result of the biokinetic studies that were initiated by Niky more than 25 years ago are actually currently employed for the validation and the revision of the biokinetic models for selected radionuclides presented by the International Commission on Radiological Protection, ICRP.

Beyond his scientific contributions, Niky has to be remembered as a passionate teacher at the Faculty of Medicine in Milan, where he became full professor in 1987. Over the years he also supervised a significant number of diploma theses in physics and master theses in medical physics at the University of Milan with dedication and contagious enthusiasm.

In parallel with his research and teaching activities, he dedicated a great deal of time and efforts to the promotion of the Medical Physics at all levels, since he was really convinced of the importance of this interdisciplinary branch of Physics. He has been actively involved in the most important initiatives in this field in Italy and in Europe. An example of this activity is the organization of the first course of EFOMP Advanced School of Medical Physics in Como, Italy, May 1992, dealing with ‘Metabolism Studies using Magnetic Resonance Spectroscopy and Positron Emission Tomography’, with participants and students from all over Europe.

As colleagues and students of those days, now active in various positions in Italy and in Europe, we all remember very well how Niky was constantly available and attentive to our concerns, questions and needs. In particular, he was able to establish an open mind dialogue with young students in physics, even on difficult and controversial matters, as only, an enthusiastic and passionate teacher can do. Many of us will always look respectfully at his rigor him as a precious “second father”.

Marie Claire Cantone

Contents

Part I Introduction

- 1 The Role of Radiation Physics in Nuclear Medicine** 3
Marie Claire Cantone and Christoph Hoeschen
- 2 The Molecular Imaging Pathway to Biomedical Physics**..... 7
Fridtjof Nüsslin

Part II Fundamental Processes on Radiation Physics

- 3 Mechanisms of the Interactions Between Radiation and Matter**..... 15
Giuseppe Battistoni
- 4 Principles of Monte Carlo Calculations and Codes**..... 35
Alberto Fassò, Alfredo Ferrari, and Paola R. Sala

Part III Radiation Sources and Radiopharmaceutical Productions

- 5 Sealed Radionuclide and X-Ray Sources in Nuclear Medicine** 61
Sören Mattsson and Arne Skretting
- 6 Radiopharmaceutical Production**..... 71
Uwe Holzwarth
- 7 Research and Development of New Radiopharmaceuticals**.....105
Gerhard Holl

Part IV Radiation Detectors for Medical Applications

- 8 Basic Principles of Detection of Ionizing Radiation Used in Medical Imaging**141
Andrej Studen and Marko Mikuž

9	Scintillators and Semiconductor Detectors	161
	Ivan Veronese	
10	New Trends in Detectors for Medical Imaging	175
	Gabriela Llosá and Carlos Lacasta	
Part V New Frontiers in Nuclear Medicine		
11	The PET Magnifier Probe	195
	Carlos Lacasta, Neal H. Clinthorne, and Gabriela Llosá	
12	Algorithms for Image Reconstruction	211
	Christoph Hoeschen, Magdalena Rafecas, and Timo Aspelmeier	
13	Biokinetic Models for Radiopharmaceuticals	233
	Augusto Giussani and Helena Uusijärvi	
14	Voxel Phantoms for Internal Dosimetry	257
	Maria Zankl, Helmut Schlattl, Nina Petoussi-Henss, and Christoph Hoeschen	
	Index	281