"PROTON THERAPY PHYSICS - 2ND EDITION" : A BRIEF OVERVIEW

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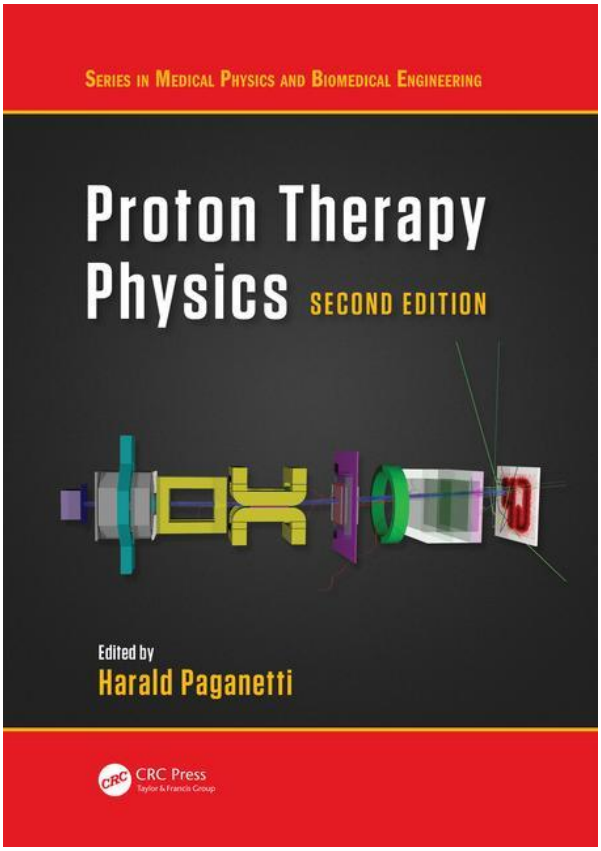
Abstract— **This article is a brief review of the CRC textbook "Proton Therapy Physics – Second Edition" Edited by Harald Paganetti, 2018, CRC Press (Series in Medical Physics and Biomedical Engineering), ISBN-9781138626508**



The first edition of Proton Therapy Physics was published in 2012, at a time when approximately 38 proton and ion beam facilities were operating world-wide (according to the Particle Therapy Co-Operative Group – PTCOG). Today, many of the existing centers have been updated and new ones constructed, with the result that PTCOG estimates there are now 94 centers in operation. Approximately 45 additional centers, or new facilities at existing centers, are under construction with many of them scheduled to begin operation this year or next. PTCOG currently estimates that about 20,000 patients are treated each year with protons. While the numbers of patients treated with protons remains low in comparison to those treated with external beam photons and brachytherapy, this number is increasing steadily.

The treatment capabilities available at proton centers continue to expand as new centers are built and existing centers are updated. The complexity of proton delivery systems similarly is increasing. Several single-room designs have become available with the goal of reducing the cost of the equipment and supporting facility. All modern proton delivery systems now include spot-scanning capabilities, enabling significantly improved conformation of dose distributions to the target volume in comparison to passive-scattered beams.

The rapid changes in technology and availability of proton therapy have warranted a second edition of Proton therapy Physics, and to his credit, the editor delivered a volume with many substantial improvements over the first edition.

The new book retains many of the chapters of the first edition, but all have been updated and expanded. Notably, the 2nd edition has organized the chapters into sections, making it easier to locate a particular topic. The sections of the 2nd edition are as follows:

Section I, Background. The introductory section includes two chapters describing the history and rationale for proton therapy, and the fundamentals of proton interactions in matter. One might expect these chapters to be largely unchanged from the 1st edition, but in fact the focus of both has been revised to better explain the introduction and increased use of spot scanning.

Section II, Beam Delivery. Here, the design of modern cyclotrons and synchrotrons is described in detail, with some time spent describing alternative proton accelerator technologies. It is concluded that the current synchrotrons and isochronous cyclotrons are likely to remain the most common proton delivery systems, and improvements are still being made to both technologies. Subsequent chapters in this section describe the characteristics of clinical proton beams, and the mechanisms for delivering beams to patients. This edition provides separate chapters to explain the technologies behind passive scattering and spot scanning.

Section III, Dosimetry. The first chapter in this section explains shielding design for proton facilities, including the production of secondary radiation. The following chapter describes the development of Monte Carlo codes

for a variety of purposes including MC simulations of particle transport through biological materials and the use of MC techniques for design of the beamline and treatment head. Subsequent chapters deal with dosimetry of proton beams. Another change in the 2nd edition has been to separate the discussion of relative dosimetry from that of absolute and reference dosimetry; this is a valuable change as the equipment and techniques are markedly different and depend somewhat on the type of accelerating system used.

Section IV, Operation. This section also has undergone substantial revision from the 1st edition in that three chapters now are provided to discuss acceptance testing and commissioning, quality assurance, and monitor unit calibration.

Section V, Treatment Planning/Delivery. This large section has a chapter to address the characteristics of dose calculation algorithms and two chapters dealing with treatment planning for single-field uniform dose beams and for scanned beams, including intensity-modulated proton therapy. The sections discussing planning of IMPT are especially helpful, and are careful to include a caution regarding the uncertainties inherent in treatment planning, with a clever reference to a famous work of art. Two chapters in this section deal with precision and uncertainties in beam delivery and in the movement of internal organs; and the section concludes with a chapter on optimization.

Section VI, Imaging. The first chapter on proton image guidance discusses the use of x-ray imaging systems (orthogonal images as well as CT systems) and optical imaging of markers and the patient surface. A second chapter in this section discusses in-vivo treatment verification techniques, such as PET imaging and prompt gamma imaging. The first of these techniques capitalizes on the activation of certain elements in biological materials, giving rise to positron emitters that can demonstrate the range of the proton beam in the patient. At the same time, this chapter is realistic about the difficulties encountered when attempting to guide treatment delivery based on images corresponding to the delivered dose.

Section VII, Biological Effects. The final section comprises two chapters from the 1st edition that describe the physics behind biological effects from proton irradiation, and methods for exploiting the benefits of protons. Only small changes are seen in the 2nd edition, leading to the disappointing conclusion that little progress has been made in this area. However, these chapters are an excellent description of what is known today about the biological effects of proton therapy.

It might be apparent from the descriptions above that there is some overlap among different chapters. This is intentional, according to the editor, to allow chapters to stand alone and improve the usability of the text.

All chapters contain numerous citations to reference material, with ample opportunities for the interested reader to pursue these topics in greater detail. In general, the chapters are well-written and easy to read, although there is some inconsistency in the grammar and a few editorial errors exist in several of the chapters. These do not detract from the readability of the book, nor do they diminish its value. In short, the 2nd edition of Proton Therapy Physics (758 Pages, with 282 B/W illustrations) is a comprehensive, well-written compilation of the key issues in the physics of proton therapy.