Physica Medica 30 (2014) 242–248

Contents lists available at ScienceDirect

Physica Medica

journal homepage: http://www.physicamedica.com

Original paper

Use of IAEA's phase-space files for the implementation of a clinical accelerator virtual source model

Alexis Rucci [a,b,*], Claudia Carletti [a,b], Walter Cravero [a,b], Bojan Strbac [c]

[a] Instituto de Física del Sur, Universidad Nacional del Sur, Consejo Nacional de Investigaciones Científicas y Técnicas, Av. Alem 1253, 8000 Bahía Blanca, Argentina
[b] Departamento de Física, Universidad Nacional del Sur, Av. Alem 1253, 8000 Bahía Blanca, Argentina
[c] International Medical Centres, Centre for Radiotherapy, Dvanaest beba bb, 78000 Banja Luka, Bosnia and Herzegovina

ARTICLE INFO

Article history:
Received 12 February 2013
Received in revised form
5 July 2013
Accepted 19 July 2013
Available online 7 August 2013

Keywords:
Radiotherapy
Monte Carlo
Phase-space
IAEA
Virtual source model

ABSTRACT

In the present work, phase-space data files (phsp) provided by the International Atomic Energy Agency (IAEA) for different accelerators were used in order to develop a Virtual Source Model (VSM) for clinical photon beams. Spectral energy distributions extracted from supplied phsp files were used to define the radiation pattern of a virtual extended source in a hybrid model which is completed with a virtual diaphragm used to simulate both electron contamination and the shape of the penumbra region. This simple virtual model was used as the radiation source for dosimetry calculations in a water phantom. The proposed model proved easy to build and test, and good agreement with clinical accelerators dosimetry measurements were obtained for different field sizes. Our results suggest this simple method could be useful for treatment planning systems (TPS) verification purposes.

Introduction

Monte Carlo (MC) methods have shown to be a reliable, accurate and practical approach for simulation of electron and photon beams used in clinical applications involving complex geometries [1–3].

Dose calculation applying MC methods is typically split into two parts. First, a detailed transport of the complete beam through the accelerator treatment head is carried out. Photon energy and spatial distributions in a clinical accelerator treatment head depend on its detailed structure. In order to achieve an acceptable level of accuracy, it is imperative to have detailed information on the shape and materials of the treatment head components through which radiation transport is simulated [4]. Usually, however, this information is not provided by the accelerators suppliers, or it is provided with insufficient detail to guarantee an accurate MC simulation of radiation transport through complete treatment heads. When detailed treatment head information is available and MC simulation for radiation transport through it can be performed, simulation output is usually stored into a phase space (phsp) file, in which each particle state (type, energy, position and direction) for a predefined plane is stored [5,6].

Radiation transport within the target (patient or water phantom) is then calculated using the previous phsp as the radiation source for a new MC simulation. A given phsp corresponds to a definite state for the accelerator head (primary beam type and energy, jaws aperture, other beam modifiers as included in the first step), and may correspond to different actual treatment fields, if patient position, gantry position, etc, are changed. Thus, dosimetry corresponding to different targets may be calculated using the same phsp file. The precise plane at which the phase space state is scored may vary depending on the treatment requirement. Applicators, multileaf collimators, compensators, and different tray accessories placed between the jaws and the clinical target may be included as part of the target or the treatment head as best suited. In general, voxelized geometry is suitable for the patient simulation, whereas simpler geometry is used in some Monte Carlo codes (e.g., quadric surfaces are used in PENELOPE) for structure delimitation in the treatment head, and those requirements may constrain the phsp scoring plane position [7,8].

* Corresponding author. Instituto de Física del Sur, Universidad Nacional del Sur, Consejo Nacional de Investigaciones Científicas y Técnicas, Av. Alem 1253, 8000 Bahía Blanca, Argentina.
E-mail addresses: alexisrucci@gmail.com, alexis.rucci@uns.edu.ar (A. Rucci).

1120-1797/$ – see front matter © 2013 Associazione Italiana di Fisica Medica. Published by Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.ejmp.2013.07.127

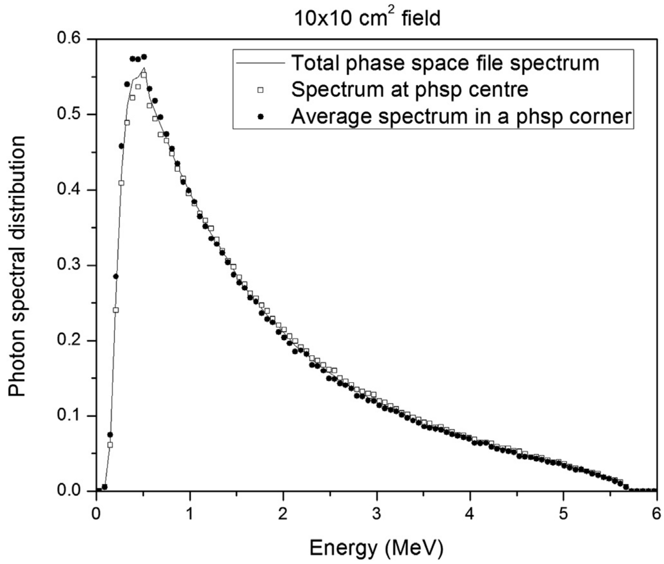

Figure 1. Photon spectra for a 6 MV and 10 × 10 cm^2 field, corresponding to a Varian Clinac iX accelerator at the water phantom surface, obtained from the IAEA's phsp data. Continuous line: photon energy spectrum from the entire scoring square. Filled circle: idem for photons taken from a 1 cm^2 square at each of the phsp scoring square corners. Hollow square: Spectrum from a 1 cm^2 square at the center of the phsp scoring square.

Considering the statistical uncertainties related to the stochastic nature of radiation transport processes, huge phsp files are needed in order to take account of the primary beam physical properties as well as the effect of the structures in the accelerator head [9,10].

The International Atomic Energy Agency (IAEA) started to work on a phase space databank a few years ago (http://www-nds.iaea.org/phsp/phsp.htmlx). The aim of this project is to establish a freely available public database of phsp data for clinical accelerators and ^{60}Co units used for radiotherapy applications, easing the access to several photon and electron beams for each specific machine. Phsp files in the databank contain the detailed description of the scored particles. IAEA's phsp files should provide information about position, direction, kinetic energy, statistical weight, type and storage information of each scored particle. IAEA format also takes into account the possibility that an accelerator source is simulated with a so called *event generator* that mimics the treatment source using either a full Monte-Carlo simulation or a beam model of the radiation therapy source [11]. A review process is carried out on submitted phsp data before acceptance into the database. Consistency checks and experimental validation is required for submitted phsp data, and range of applicability must be documented by submitters [11]. IAEA has committed to the provision of subroutines to read and write IAEA-format binary files. Conversion routines exist for commonly available simulation packages (MCNP, EGS, PENELOPE, etc.) [12,13].

Phsp data are usually tallied at the surface of a water phantom, a useful position for commissioning or verification albeit not practical if we want to simulate a complete treatment that includes other beam modulators, starting from these phsp files.

Absorbed dose will depend on the initial energy spectrum for primary photons as well as secondary particles generated both in the accelerator head and the target. It is possible, however, to build a system able to simulate the same energy deposition without explicitly taking into account the original accelerator head geometry. This technique is known as virtual source model (VSM), and its main advantage is that the process is faster than the classical MC simulations and the number of histories doesn't depend on the size of the phase space data [9,14–17]. VSM development implies the optimization of several parameters in order to obtain a good enough approximation to the dose deposition obtained with the complete MC transport. These include position of each virtual source (also shape and density distribution in case of extended sources), energy distribution, etc. Some models include primary photons, secondary photons and electron contamination sources [17,18]. When the number of VSM variables is too long, optimization becomes cumbersome, and we may end replacing a complicated geometric problem with a complicated optimization one.

An intermediate approach involves replacing the accelerator head by a combination of virtual sources and simplified geometrical structures through which radiation is transported. This kind of method is called *hybrid model* [19]. It could be very useful if applicators or MLC were to be added to the treatment simulation. A realistic VSM needs to take into account the contribution from electron contamination. However, the electron contamination source can be replaced, in a hybrid model, by a simple structure which generates it.

Based on the IAEA phase space data for external radiotherapy beams, we have made dose calculations for different field sizes and

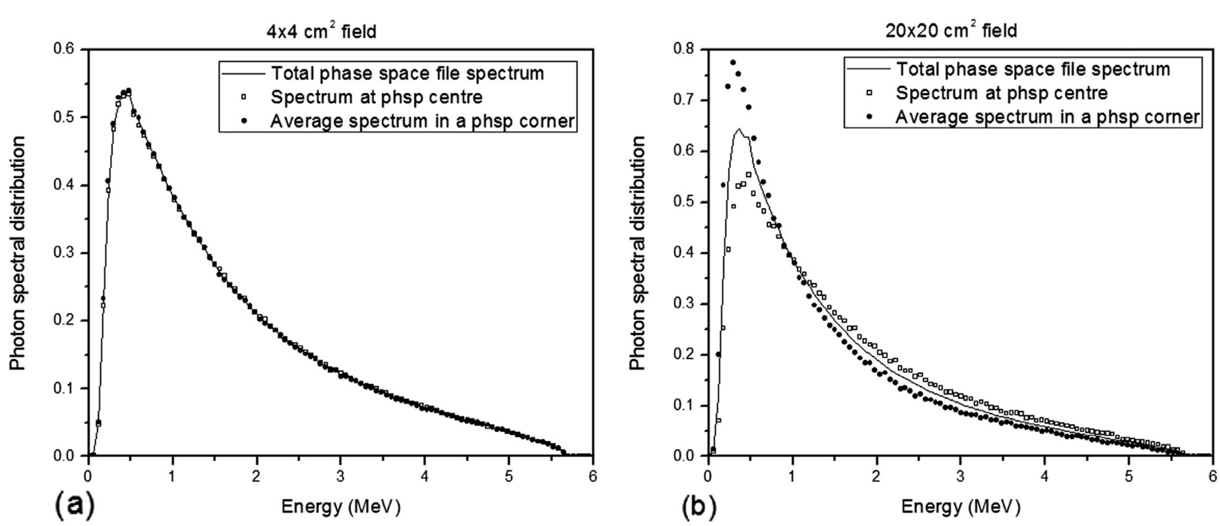

Figure 2. Idem Fig. 1 for (a) 4 × 4 cm^2 field and (b) 20 × 20 cm^2 field.