ID de la contribución : **399** Tipo : **Oral parallel contribution**

Dose average linear energy transfer calculation from microdosimetric quantities with the Geant4 toolkit: Application for proton therapy beams

martes, 18 de julio de 2017 17:50 (15)

Introduction

In the last decade, hadrontherapy has gained a great interest in the medical community for its excellent clinical results, leading to the construction and installation of dedicated accelerators in hospital-based clinical centres around the world. Therapy with protons is, by far, the most largely charged particle technique used, having reached a good degree of perfection in clinical practice. However, there is still large space for improvements in what concerns quality assurance and treatment planning verifications. Indeed, protons and heavier ions offer a higher cell-killing effectiveness if compared to photons for a same level of absorbed dose, property that is usually referred to as Relative Biological Effectiveness (RBE). The RBE depends both on radiation quality and on different biological parameters, such as tissue type or endpoint considered, whose knowledge is still limited. Nowadays, a constant RBE value of 1.1 is currently used in radiotherapy treatments with protons, although it is well known that this quantity varies with linear energy transfer (LET), increasing at the distal Bragg peak region [1]. Thus, to take fully advantage of the increasing biological effectiveness of protons, recent studies aim at using dose and dose average LET (Ld) objective functions in treatment planning optimization, working both on LET and dose distributions when optimizing the amount of radiation delivered to the tumour volume [2].

The approach for the calculation of Ld distributions in clinical proton beams may be both based on analytical models or on Monte Carlo simulations. Since most of the Monte Carlo simulations used a very similar method to calculate Ld, whose robustness was not tested for the variation of some critical parameters, in a previous work we decided to address this critical analysis comparing different methods of scoring Ld distributions produced by proton therapy beams in water in a voxelized geometry [3]. Furthermore, in that work we took as reference values for Ld those obtained from microdosimetry calculations according to a formula proposed in [4]. The aim of this work is to further extend the calculations performed in [3], making use of an improved and more efficient code for the calculation of microdosimetric quantities, such as lineal energy and energy imparted per proton electronic collision.

Methods and Results

In our previous work, in order to determine which Ld scoring method provided more reliable results, we resorted to numerical stability against changes of geometry and production cuts, carrying out the calculations with the Geant4 (GEometry And Tracking) toolkit [5-7]. The resulting simulations, with which we could come up with a robust Ld computation method in good agreement with microdosimetry calculations, were done at central beam axis and for primary protons only.

In this work, our goal is to extend to off-axis voxels the calculation of Ld distributions for proton beams in water, including the contribution of secondary protons. To this end, we compared Ld distributions (2D) calculated for clinical proton beams with those computed from microdosimetry spectra obtained for sites of various sizes, whose typical dimension ranged from 0.25 to 10 microns. With respect to our previous work, we implemented a new and more efficient Geant4 application to score microdosimetric quantities, which includes an algorithm capable of randomly place our scoring site in the region occupied by the proton track, including its secondary electrons, as shown in Fig. 1 (left). In doing this, we accounted for electronic equilibrium along the proton track by choosing a world size at least equal to the maximum range of secondary electrons (RMax). In addition, the approach of our new code is suitable to perform calculations with the Geant4-DNA physics package, that simulates step by step interactions of particles in liquid water down to the eV scale [8,9].

Our preliminary results have confirmed the overall validity of our new code. We have also found a slight

dependence, with respect to the site size, of the deviations reported between our "macroscopic" calculation of Ld distributions and those obtained from microdosimetry calculations, as emerges in Fig. 1 (right).

Acknowledgments
This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Sklodowska-Curie grant agreement No 675265, OMA - Optimization of Medical Accelerators, and from the Spanish Ministry of Economy and Competitiveness under grand No FPA2016-77689-C2-1-R. The Monte Carlo simulations were carried out at the FIS-ATOM cluster hosted at CICA (Seville, Spain).

References
[1] T. Matsuura et al., Med. Phys. 37 (2010) 5376-81
[2] N. Bassler et al. Acta Oncol.49 (2010) 1170-76
[3] M. A. Cortés-Giraldo and A. Carabe, Phys. Med. Biol. 60 (2015) 2645-69.
[4] A. M. Kellerer, "Fundamentals of microdosimetry", in: K. R. Kase et al (Eds.), The Dosimetry of Ionizing Radiation, Academic Press INC, 1985, Vol.1, Chap 2.
[5] S. Agostinelli et al., Nucl Instrum. Meth. A 506 (2006) 250-303.
[6] J. Allison et al., IEEE Trans. Nucl. Sci. 53 (2006) 270-8.
[7] J. Allison et al., Nucl. Instrum. Meth. A 835 (2016) 186-225.
[8] S. Incerti et al., Med. Phys. 37 (2010) 4692-4708.
[9] M. A. Bernal et Al., Phys. Med. 31 (2015) 861-874.

Primary author(s) : Sra. BARATTO-ROLDÁN, Anna (Centro Nacional de Aceleradores - Universidad de Sevilla)

Co-author(s) : Dr. CARABE, Alejandro (University of Pennsylvania); Dr. CORTES-GIRALDO, Miguel Antonio (Universidad de Sevilla); Dr. KIMSTRAND, Peter (University of Pennsylvania); Sr. PERALES, Álvaro (Universidad de Sevilla)

Presenter(s) : Sra. BARATTO-ROLDÁN, Anna (Centro Nacional de Aceleradores - Universidad de Sevilla)

Clasificación de la sesión : Nuclear Physics II

Clasificación de temáticas : Nuclear Physics