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Relative biological effectiveness in the spatial fractionation of hadron therapy beams.

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Abstract

RELATIVE BIOLOGICAL EFFECTIVENESS IN THE SPATIAL FRACTIONATION OF HADRON THERAPY BEAMS.

González Wilfredo (+) (1), Puerta Daniel (++) (2), Anguiano Marta (2) and Lallena Antonio M. (2)

(1) University of Málaga, Department of Applied Physics I, 29010, Málaga, Spain.
(2) University of Granada, Department of Atomic, Molecular and Nuclear Physics, E-18071 Granada, Spain

-INTRODUCTION-

Radiotherapy is the treatment of cancer using ionizing radiation for curative or palliative purposes. From the Physics perspective, these treatments are prepared through the study of the interactions between the radiation with the tumour and its surrounding healthy tissue. Due to the complexity of the situation, the precise design of these treatments with analytical tools is an impossible endeavour. Hence, we need to use numerical tools such as Monte Carlo simulations in order to examine these processes.

The most widespread sources used in these therapies are electrons and photons. The use of hadrons may improve the effectiveness of the treatment for certain types of cancer and patient profiles. Furthermore, they can spare a larger proportion of the healthy tissue surrounding the tumour. This effect is rooted in the most basic physical properties of hadrons.

At present, more than 10,000 patients have been treated with 12C in the HIMAC and, in the HIT, patients are being treated with 4He and the treatments with 16O are being developed. This technique combined with the spatial fractionation of the beams increases their efficacy and reduces the secondary effects considerably. Theoretical and preclinical studies have been carried out in which the great effectiveness of 20Ne ions is demonstrated [1, 2]. The aim of this work is to compare the biological doses obtained through the use of the spatial fractionation of 4He, 12C and 20Ne ions using the Monte Carlo simulation.

-MATERIALS & METHODS-

Based on the optimization carried out by González et al. [1] we implemented a program in Geant4 and FLUKA Monte Carlo (MC) codes, to calculate dose and the dose-average linear energy transfer (LETd), quantities that help us assess the biological effectiveness of a particle source.

Three different rectangular minibeams were used as sources. The 4He with dimension of 900 um x 2 cm, the 12C with dimension of 600 um x 2 cm and the 20Ne with dimension of 500 um x 2 cm, the others simulation parameters used were similar to values reported in the reference [1].

From the dose and the LETd values obtained by MC, the Relative Biological Effectiveness (RBE) was estimated for the Human Salivary Gland (HSG) cell lines. The RBE calculation was performed adjusting the values presented by Furusawa et al. [3] for the ions studied.

-RESULTS-

The values obtained for the physical dose and the LETd of the 12C and 20Ne ions are very similar to those published by González et al. 2017 and 2018 [1] [4], as we use very similar conditions for the simulations.

We found that the ratio between the dose at the tumour site and normal tissue is much higher in the 20Ne level compared to 12C. However, for the conditions of our study, it is observed, that the biological dose of the 20Ne beam decrease inside the tumor region. This is due to the fact that the dependence between alpha and LETd for HSG cells becomes maximum for values of 150 keV/um. At a depth of 70 mm, that LETd value is already exceeded (>150 keV/um), the alpha values begin to decrease as a result of the overkill effect and so does the biological dose.

-CONCLUSIONS-

• For high energies (> 200 MeV per nucleon) significant differences are found in the dose and LETd values between the two simulation codes used.

• Depending on the response of the tumour cell lines to LETd, the most suitable ion will depend on the depth of the lesion to be treated.

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(+) Corresponding Author: wgonzalez@uma.es

(++) Speaker. If the correspondence concerns the XII CPAN DAYS talk proposal, please email: danipuerta@ugr.es

Primary author(s) : Dr. GONZÁLEZ, Wilfredo; PUERTA MEGÍAS, Daniel (Universidad de Granada); ANGUIANO, Marta (Universidad de Granada); LALLENA ROJO, Antonio M. (Universidad de Granada)

Presenter(s) : PUERTA MEGÍAS, Daniel (Universidad de Granada)

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