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Development of an external beam line for radiobiology experiments at the 18 MeV proton cyclotron facility at CNA

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Cancer is one of the leading causes of mortality world-wide, killing more than one million people per year just in Europe. Nowadays, proton therapy is one of the most promising techniques in the fight against cancer, being two the main bases of its success: (1) the physical advantages of protons with respect to conventional radiotherapy with photons, resulting in a more selective energy deposition in depth; (2) the increased biological effectiveness of protons with respect to photons and their denser pattern of energy deposition in matter, usually determining a more lethal damage to the DNA. The biological effect of protons and other ions with respect to photons is described in terms of the Relative Biological Effectiveness (RBE), i.e., the ratio between the doses of the reference and studied radiation determining the same effect. In clinical proton therapy, a RBE value of 1.1 is currently used [1]. However, there is an increasing awareness that proton RBE is not a constant, but seems to increase linearly with the Linear Energy Transfer (LET) of the proton as it slows down in tissues, especially close to the distal region of the Bragg peak, possibly leading to toxicity in healthy tissue beyond the target.

The rationale behind this work is given by the necessity of performing studies of proton RBE at low energies, close to the Bragg peak region of clinical proton beams (below 40MeV), which would help reaching a consensus on the variation of proton RBE with LET. To do so, a low energy proton beam line was designed and mounted at the 18 MeV proton cyclotron facility installed at the National Centre of Accelerators (CNA, Seville), for the experimental study of RBE in mono-layer cell cultures.

A protocol for the irradiation of biological samples was established, consisting in: (1) an accurate alignment of the target position with the beam axis by means of the steering magnets of the cyclotron external beam line; (2) a verification of the beam profile homogeneity, prior to irradiation, with radiochromic EBT3 films and (3) a control of the environmental parameters, such as temperature and pressure, to avoid extra stress to the cells that could lead to biased results. Finally, a successful irradiation of mono-layer cell cultures was performed, which proved the validity of the beam line for radiobiology experiments.

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