Ion beam monitoring using bremsstrahlung X-rays

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Particle therapy provides a high and localized deposited dose to the target tumor thanks to the Bragg peak. The development of online beam monitoring tools with non-invasive methods represents an important challenge. Some studies deal with the use of prompt gamma radiations to localize the Bragg peak, with a resolution of several millimeters[1]. A novel promising approach using the detection of the bremsstrahlung X-rays is actually investigated, and requires improvements[2,3]. Both methods have performance mainly limited by counting statistics and noise signal. These latter depend on the fundamental parameters such as X-ray production cross sections. The presented work consists firstly to valid a theoretical model of the bremsstrahlung cross sections with experimental measurements. Secondly, the feasibility to use the bremsstrahlung X-rays coming from a PMMA target and a water tank, considered as biological medium surrogate, in order to monitor proton beams is studied.

An experimental set-up was designed to irradiate a PMMA target and a water tank with proton beams delivered by the ARRONAX cyclotron[4] in the energy range from 17 MeV to 50 MeV. A silicon drift detector recorded the bremsstrahlung X-ray energy spectra. A model based on theoretical bremsstrahlung cross sections[5] was developed to compare with experimental data. The differential cross sections were previously measured on carbon target to compare the results to data available in the literature[6].

Cross sections were measured in the range of 10 mbarn.keV^{-1} to 1000 mbarn.keV^{-1}. A significant agreement was found with both model and literature. Moreover, simulations fitted with good agreement the bremsstrahlung spectra emitted by the PMMA target, confirming the sensibility of the method (10^4 X-rays/nC detected) and validating the ion bremsstrahlung model. Moreover, proton beam energy can be monitored using the bremsstrahlung X-rays thanks to the spectrum hardening, due to the variation of the bremsstrahlung cross sections. In fact the evolution of the bremsstrahlung spectra measured at different depth in a water tank follows the energy loss of the proton beam. These results are encouraging in order to localize proton range. However, the experimental set-up has to be improved to localize the Bragg peak with significant accuracy. For that purpose, GATE simulations are under development. Fundamental studies must also be carried out to link the bremsstrahlung signal to the deposited dose, in order to perform dosimetry in radiobiology experiments and hadrontherapy.

Keywords: Bremsstrahlung X-rays, Ion beam monitoring, Radiobiology, Hadrontherapy

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