Dose and LET Measurements in Ultra High Dose Beams – the Development of the QUADRIL Detector

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The dosimetry for high energy radiotherapy has been since long subjected to very strict metrological requirements and all measurements have to be performed according to well established standards, be it IAEA [1, 2], DIN 6800-2 (2008) [3] or AAPM codes of practice for radiotherapy accelerators issued by AAPM.-TG51. All of these codes and standards rely on the use of ion chambers, still considered as the golden standard in ionizing radiation metrology.

For high dose beams (like for the gamma beams generated at ELI-NP or the high / ultra high dose rate techniques of treatment, like the FFF, and FLASH techniques) there are several corrections to be applied in order to calculate a correct dose from the measured charge. Given the fact that the usual quality of the calibration beam is still Co-60 for consistency reasons, the number of correction factors is rather large, as one can see from the formula used to calculate the absorbed dose in water [2]:

$$D=M_{uncorr}\, k_{elec}\, k_Q\, k_{TP}\, k_S\, k_{pol}\, k_r \quad (1)$$

where M_{uncorr} is the uncorrected indication of the dosemeter, and the rest are correction factors taking into account the calibration (Gy/C) at reference energy (usually Co-60), the energy correction, the air density correction, the ion recombination correction, the bias polarity correction, and all other possible perturbations. k_{elec} is usually supplied by the SSDL, all the other factors must be determined by the field laboratory according to a standardized method. Our presentation will insist on the k_Q - the recombination correction which has standardized methods of measurement, but it is not clear how accurate those methods are for FLASH methods. The paper presents a method which allows simultaneous measurements of dose and recombination corrections [4] and which is now being further developed to allow also LET measurements in FLASH proton therapy.

References

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BEGAM, a new apparatus for the identification of β^- contaminants in radiopharmaceuticals*

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Nuclear medicine relies on the use of radiation from isotopes contained within radiopharmaceuticals both for diagnostic and therapeutic purposes. Diagnostic procedures, like the Positron Emission Tomography (PET) or the Single Photon Emission Computed Tomography (SPECT), detect radiation to create detailed images of the body internal structures. Typically, isotopes used for diagnostic are either pure gamma emitters or undergo β^+ decay and are produced in proton-induced reactions on specific targets, or by using radionuclide generators. However, in both production methods, other radioisotopes can be generated alongside the desired ones resulting in a contamination of the final product, which may expose the patients to unnecessary doses.

In cyclotrons the problem arises from the impossibility of selectively activate only the desired production channel. On the other hand, radionuclide generators cannot completely separate the daughter nuclide from the parent: for instance, radiopharmaceutical ^{99m}Tc may be contaminated by ^{99}Mo.

This study focuses on developing a detection system, Begam, capable of identifying β emitter contaminants in radiopharmaceuticals via coincidence (or anti-coincidence) measurements of β particles and γ rays.

The Begam detector consists of plastic and inorganic scintillators coupled to commercial photodiodes and/or SiPM. The plastic scintillator is chosen for its ability to effectively detect β particles, while the inorganic scintillator are selected based on high light output and good energy resolution, making them suitable for γ ray detection.

We are implementing GEANT4 simulations to tests the realistic configuration of the foreseen device, consisting of a hollow cylindrical plastic scintillator to host the radioactive sample , mounted on top of a solid CsI cylinder. The two layers are surrounded by CsI(Tl) sectors (from 4 to 8) arranged to form a cylinder. The dimensions and number of the scintillators will be decided on the basis of the simulations.

The first test will be performed on an eluate of ^{99m}Tc, to quantitative measure the contamination amount of 99Mo.

In a further future BEGAM will be used to analyze the purity of the radionuclides produced at medical cyclotron to obtain the desired radiopharmaceutical (e.g. 68Ga).

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Investigation of a Composite Mo/Y HTM of clinical size for Proton Therapy Range Verification

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The use of proton beams in cancer treatment offers significant advantages compared to photon therapy due to their depth-dose distribution which is characterized by a small entrance dose and a sharp maximum at the Bragg peak. To ensure the prescribed dose is properly delivered, precise knowledge of beam range in the patient is required.

The Hadron Tumor Marker (HTM) is a new technique for in vivo proton therapy range verification (RV), proposed by Kasanda et al. [1, 2]. HTM-RV is based on the implantation of a small fiducial marker (the HTM) which emits characteristic γ-rays when activated by the treatment beam, with intensities which are maximized for energies near the Bragg peak. The γ-signal intensities are strongly dependent on the beam energy impinging on the HTM (see Fig.1), and thus offer an absolute, model independent measurement of the energy at the marker position and, consequently, the remaining range of the beam. Previous investigations, which used a composite Mo/Y HTM, have demonstrated a sub-millimeter precision in RV.

A composite, homogenous Mo/Y HTM of clinical size has been investigated for the first time in an experiment which was set up at the Cologne 10 MV FN Tandem accelerator. Because of the high control and accuracy, the accelerator provides in beam energy settings, a precise calibration function $R_{Mo/Y}(E_{proton})$, relating a measured γ-ratio $R_{Mo/Y}$ to an energy at marker position, has been established and used for the reconstruction of the energies at marker position for the thicker composite HTM.

The results of the energy and range reconstruction will be presented and discussed. Furthermore, a general overview of HTM-RV for proton therapy will be given.

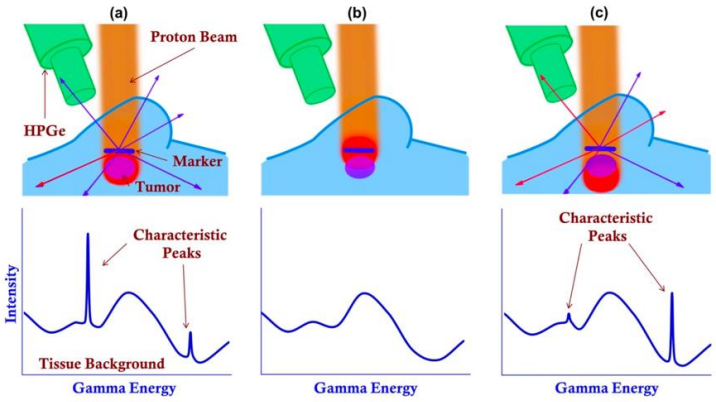

Figure 1: Schematic illustration of the proton dose profile and the resulting γ-ray response of a composite HTM. (a) Ideal treatment scenario; (b) a scenario, where the beam falls short in range, such that no γ-ray is observed; (c) a scenario, where the Bragg-Peak is placed too deep in the tissue, resulting in a changed ratio of the peak intensities because of the higher beam energy at marker position. Figure and description adapted from [2].

References

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