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Effect of Collimation Slit and Shield Thickness in a Prompt Gamma-based Proton Beam Range Measurement System

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1. Introduction

The proton beam has a unique advantage over the electron and photon beams in that it can give very high radiation dose to the tumor volume, while effectively sparing the neighboring healthy tissue and organs. For the clinical application of the proton beam, it is very important to confirm the location of the proton beam in the patient, preferentially during the treatment. It has been suggested that the range of the proton beam in the patient can be determined by measuring prompt gammas from the proton beam passage [1]. Recently, a prototype prompt-gamma scanning system has been constructed and tested using experimental and therapeutic proton beams. The measurement results for the proton beams of 70 – 230 MeV showed that a clear correlation exists between the distribution of the prompt gammas and the proton beam range [2-3].

The scanning method, however, is not suitable for the upcoming 'spot scanning' technique. The 'spot scanning' technique provides three-dimensional dose conformation by dynamic scanning of a pencil-type proton beam and it is not possible to scan the moving spot of the proton beam. This problem can be, in principle, avoided by collecting information from multiple points at the same time, by using an array of detectors and an appropriate collimation system (with multiple collimation slits).

The object of this study is to determine an optimal design of the measurement system, in terms of the width of the collimation slit and the shield thickness, for the array type measurement system. The MCNPX Monte Carlo simulation code [4] was used to simulate the response of the measurement system for different conditions of the collimation slit and the shield thickness.

2. Methods and Results

This study used the MCNPX code to simulate the 80 MeV proton beam (pencil beam) delivered to a water phantom (20 cm x 20 cm x 40 cm). The prompt gammas generated from the nuclear interaction of the protons in the water phantom are transported through the water phantom and the measurement system, and finally counted at the CsI(Tl) scintillation detector. The CsI(Tl) detector is shielded by a collimation system with 10 cm of the thickness and 0.2 cm of the collimation slit (Figure 1). The measurement system scans the distribution of the proton beams along the beam line. The simulation was repeated changing the width of the collimation slit and the shield thickness of the measurement system. In this study, the variation of the shield thickness was achieved by changing the density of the shield material.

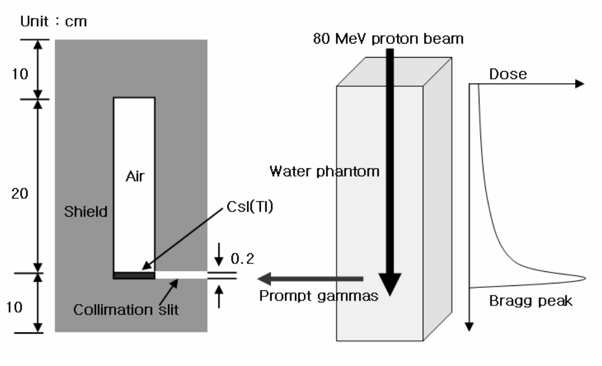

Figure 1. Schematic diagram of experiment in this study.

2.1 Width of collimation slit

The width of the collimation slit affects both the counting efficiency and the measurement accuracy of the system. For example, a very narrow collimation slit can predict the distribution of the prompt gammas (origins) very accurately but, on the other hand, it will result in a significant reduction of the counting efficiency, requiring a longer measurement time for the same counts at CsI(Tl) detector. To see the effect of the collimation slit, this study considered three widths of the collimation slit (2 mm, 5 mm, and 10 mm).

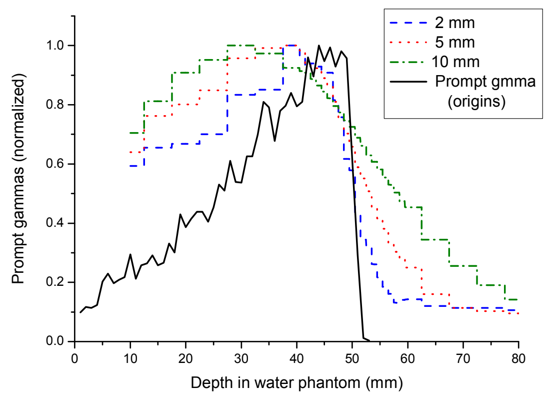

Figure 2. Origins of the prompt gamma and the distribution of the prompt gammas for the different collimation slit width - 2 mm, 5 mm, and 10 mm.

Figure 2 shows narrower collimation slit provide more accurate measurement of the distribution of the prompt gammas (origins). From the result, it is believed that the width of the collimation slit should not be greater than 5 mm. The 10 mm result is obviously unacceptable in most clinical applications where at least a few millimeters accuracy is essential in the prediction of the proton beam range in the patient.

2.2 Shield thickness

The distribution of the prompt gammas is determined with changing the shield thickness of the collimation system. The thickness of the shield thickness is simulated by changing the density of the shield material - that is, the regular density (11.34 g/cm^3) of the shield lead represents 10 cm; 5 cm of the shield thickness was simulated by 5.67 g/cm^3 of the material density and 20 cm of the shield thickness was simulated by 22.68 g/cm^3 of the material density.

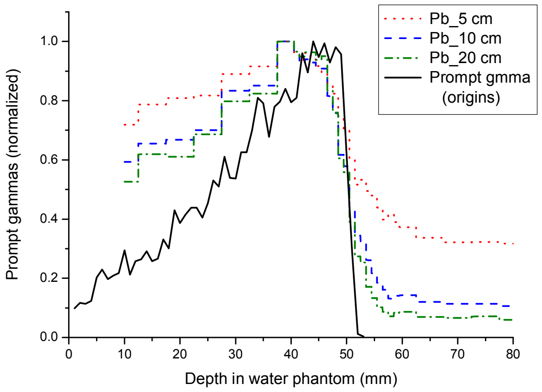

Figure 3. Origins of the prompt gamma and the distribution of the prompt gammas for the different shield thickness - 5 cm, 10 cm, and 20 cm.

Figure 3 shows the distribution of the prompt gammas for the different thickness of the shield thickness. The result shows that the shield thickness of 10 cm is enough for background shielding. The shield thickness of 20 cm is not acceptable, significantly spreading out the distribution of the prompt gammas.

3. Conclusion

This study determined the optimal design of the measurement system in terms of the width of the collimation slit and the shield thickness of the measurement system. Our results shows that the width of the collimation slit should not be greater than 5 mm, and that the 10 cm shield thickness of the collimation system is enough to shield the background radiations. The current work considered only one collimation slit and gives a suitable guideline for the shielding design of a multiple slit collimation system for the use in an array type measurement system.

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REFERENCES

[1] F. Stichelbaut and Y. Jongen, Verification of the Proton Beam Position in the Patient by the Detection of Prompt γ-Rays Emission, PTCOG-39, San Francisco, 29 October, 2003.
[2] C. Min, M. Youn, J. Kim and C. Kim, Prompt gamma measurements for locating the dose falloff region in the proton therapy, Applied physics Letters 89, 183517, 2006.
[3] K. Seo, J. Kim, and C. Kim, Determination of Proton Beam Distal Fall-off Position by Measuring Prompt Gamma Rays from Proton Nuclear Reaction. in Proc. Of the 30th Conf. in spring, Korea Soc. Of Med. Phys., p.100, 2005.
[4] J Hendricks, MCNPX User's Manual Version 2.5.e, LA-UR-04-0569, LANL, 2004.