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Study of proton slit scattering

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INTRODUCTION

The knowledge of slit scattering is necessary for snout design of proton beam delivery system and for determination of the minimum air gap between exit of patient aperture and body surface of patient. While a pre-collimator is usually placed upstream of the patient aperture collimator to shape the beam coarsely, the patient aperture is placed at the downstream end of the snout. The protons scattered at large angles by the pre-collimator should be shielded by the snout to shut off the uncontrolled dose given at the patient position. In addition, it will be useful if the modification of dose distribution due to the slit scattering can be taken into account for dose calculations for proton treatment planning in the future. Taking these applications into mind, we studied the effect of proton slit scattering by measurements and calculations.

METHOD

We used the horizontal proton beam line of Proton Medical Research Center, University of Tsukuba for the experiment. Experimental arrangement is shown in figure 1. 248 MeV proton beam is incident on the beam delivery system. The beam energy was adjusted by inserting a variable-thickness ABS resins, which resulted in the change of phase space parameters of the incident beam. The Gaussian-shaped beam was shaped by a horizontal slit with 14 cm opening width before entering the final slit. The final slit is a rectangular parallelepipeds brass block (15cm $\times$ 15cm $\times$ 7cm) blocking off the half of the whole beam. The dose distributions in the horizontal direction were measured by a silicon semiconductor detector scanned in water. The wall of the water vessel is lucite of 10 mm in thickness. The air gap between the exit surface of the brass block and the entrance of the water vessel, and the incident beam conditions (energy, energy spread, and phase space parameters) affect the dose distributions. Phase space parameters of the beam were verified by the measured dose distributions of protons passing through the X-collimator with a known opening width at different depths.

RESULTS

Figure 2 shows the measured lateral dose distributions in the horizontal direction at different conditions. The residual range of the proton beam incident on the final slit is about 31 cm in water for the case of fig.2. Prominent peak can be observed in fig.2(a) at the entrance position of water vessel in the case of no air gap. When the air gap is set at 5 cm, the peak becomes broader as seen in fig.2(d). When the peak gets smaller as the measurement depth in water increases as seen in fig.2(b) and fig.(c) and cannot be noticed at the position 10 cm deep in water.

DISCUSSION

The measurements were compared with calculations using a simple Monte Carlo method considering the energy loss and multiple Coulomb scattering. The relative number and distributions of energy, angle, and position of protons scattered at the slit surface determine the dose distribution. Since the dose distribution was sensitive to the relative alignment of beam direction and the edge surface of the slit, we studied the misalignment effects. Characteristics of experimental results can be described by the simple model.

CONCLUSION

We studied the slit scattering effect of proton beam. The results are well described by the simple Monte Carlo calculation. Therefore the calculation model can be used for predication of surface scattering effects by a coarse-collimator and a patient aperture collimator.

Figure 1. Experimental arrangement of proton slit scattering (top view)

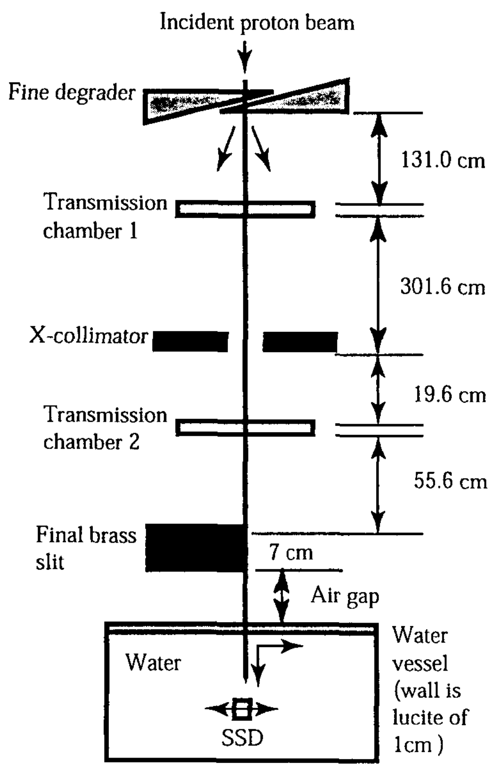

Figure 2. Measured dose distributions in horizontal direction in various conditions