Fast Proton Radiography at the PSI Gantry FROG ◇

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1. Introduction

The detector system designed for proton radiography at the PSI is based on two position-sensitive fiber hodoscopes and a energy-sensitive range telescope [1–3].

2. Radiographs

One of the first radiographs taken at the PSI gantry is shown in fig. 1. The phantom consists of a 20 mm thick perspex plate with letters of 5mm width engraved with a depth of 10mm. It was scanned by a proton pencil–beam (15mm FWHM, E=177 MeV, 10^6 protons/sec) delivering a fixed number of protons per detector pixel. The residual range of the protons (ΔR) was measured by the range telescope in coincidence with the hodoscopes. The shading in fig. 1 corresponds to the proton range which is represented by the mean value calculated from the range distribution for each pixel. A big value is represented by a bright shade of grey. The dark spots in fig. 1 result from a misalignment of the fibers leading to a deviation from the fixed number of protons in some of the pixels [2,3].

Fig. 1: Radiograph of a perspex plate (100mm x 100mm x 20mm) with engraved letters (width 5mm, depth 10mm); Residual range represented by shading

3. Residual range and density resolution

In order to gain information on the density resolution of the system a special phantom was scanned. It consists of a perspex plate with cylindric holes. The hole width varies between 5mm and 20mm, the depth between 0.5mm and 8mm. Fig. 2 shows the mean residual range ΔR of the protons having passed the phantom. From fig. 2 we learn that the system is capable of resolving a structure of 0.5 mm depth and 10mm width (indicated by a white circle, left column, second from top) for a 15 mm thick phantom. This corresponds to a density resolution of about 3% (as estimated in [3]).

Fig. 3 shows the correlated range uncertainties, which is the standard deviation σ calculated from the range distribution for each pixel. Again a big value is represented by a bright shade of grey. From fig. 3 and the corresponding range uncertainty distribution (see [2] figs. 3 and 4) we can obtain information on inhomogeneities encountered by the protons on their path through the sample. The zones of large density gradients especially perpendicular to the beam direction give rise to large range uncertainties due to multiple Coulomb scattering of the protons as can be seen in fig. 3.

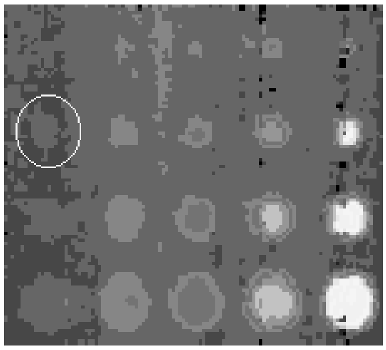

Fig. 2: Residual range of protons; Radiograph of a perspex plate (15mm thick) with engraved holes, hole width in mm (bottom to top): 20, 15, 10, 5; hole depth in mm (left to right): 0.5, 1, 2, 4, 8

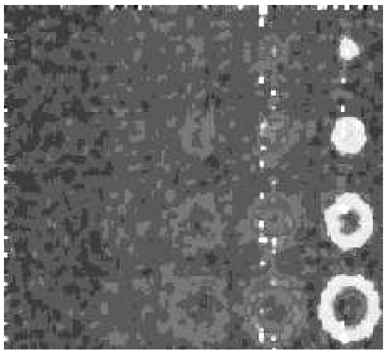

Fig. 3: Range uncertainties of protons, corresponding data to fig. 2

Information of this kind may be used as an input to treatment planning in proton therapy in addition to CT–based planning.

References

[1] P. Pemler *et al.*, Jahresbericht 1995
[2] P. Pemler *et al.*, Jahresbericht 1996, p.75
[3] P. Pemler, Ph.D. thesis, LMU München, 1997

◇ Supported by the Bavarian Minister for Environmental Affairs