Development and Monte-Carlo-Simulation of the Detector System for the Fast Proton Radiography FROG ◇

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1. Development of the Detector System

The detector system consists of two fiber hodoscopes (for a picture see ref. [1]) and a range telescope (fig. 1). The hodoscopes determine the coordinates of the proton as it passes through the patient, the telescope measures the residual range.

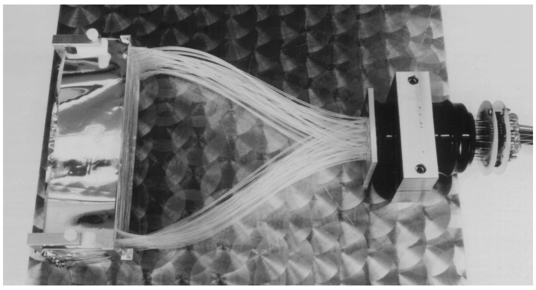

Fig. 1: Top view of the range telescope

We use Bicron BCF-12 scintillating fibers with 2 mm x 2 mm cross section for the fiber hodoscope. The attenuation length of the fibers is important for adjusting the discriminator thresholds of the readout electronics. Therefore a β-source (10 kBq ^{106}Ru, 3.541 MeV maximum energy) was put on a fiber at diffferent distances from the end where the signal was read out by a 16-channel photomultiplier (R4760 by Hamamatsu). The signal was analyzed by an ADC (fig. 2) and the dependence of the peak position of the β-spectrum on the distance is shown in fig. 3.

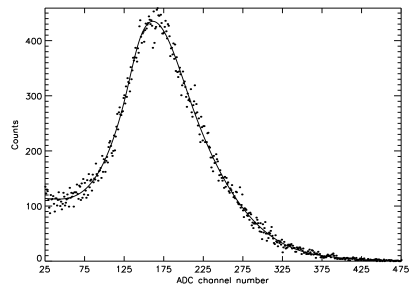

Fig. 2: ADC spectrum of the β-particles detected by a fiber

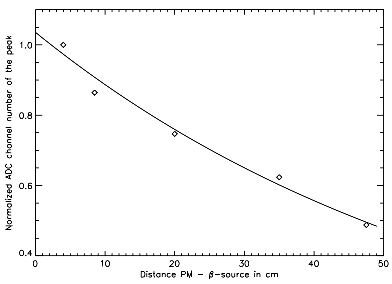

Fig. 3: Attenuation-length measurement

The 1/e length was measured to be 65±1 cm, considerably differing from the manufactorer's data (>300 cm) [2].

The range telescope consists of a stack of 16 scintillator plates (Bicron BC-404 6 cm x 20 cm) separated by a thin aluminized mylar film for optical isolation. Each plate is read out by two wavelength-shifting fibers with 1.5 mm x 1.5 mm cross section (Bicron BCF-91A) which fit into two grooves in the plate. The four ends of the fibers are fixed in front of one photocathode of the above-mentioned photomultiplier. An ADC spectrum of a plate lying in the plateau of the Bragg curve of 177 MeV protons is shown in fig. 4. The signal is clearly separated from the noise.

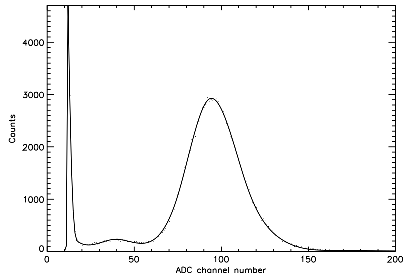

Fig. 4: ADC spectrum of 177 MeV protons detected by a range-telescope plate

2. Monte-Carlo-Simulation of the Detector System

Since the detector-properties are important for the quality of the radiography, a Monte-Carlo-Code was developed. All parameters of the detector (e.g. geometry and numbers of fibers and plates) as well as beam parameters (e.g. homogeneous or pencil beam, momentum band) can be adjusted. Improvements including effects of multiple Coulomb scattering and range-straggling calculations are in progress.

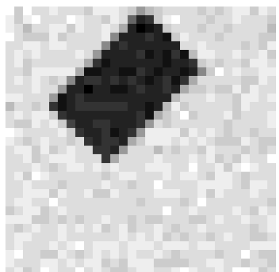

Fig. 5: MC-Simulation of a proton radiography of a rectangular phantom, pixel-size: 1 mm x 1 mm, gray-scale ∼ residual range

References

[1] P. Pemler *et al.*, this report, p. 75
[2] BICRON Corporation, Catalog on Scintillating Optical Fibers (1994)

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