TEST OF A MULTI-LAYER FARADAY CUP FOR QUICK BEAM-ENERGY MEASUREMENTS AT PROSCAN

H. Berkhoff, T. Böhringer, A. Coray, R. Dölling, P.A. Duperrex, M. Schippers

Measurements with a test setup of a multi-layer Faraday cup have been performed at the NA3 gantry to establish its accuracy for measurements of the beam energy and momentum-spread.

INTRODUCTION

A quick and easy way to perform measurements of the range of protons can be used to measure the beam energy from the new super-conducting cyclotron COMET. A range measurement in water will be part of the acceptance test, but to make a quick check, and also to allow for easy energy verifications in the PROSCAN facility, a range measurement using a Multi-Layer Faraday cup (MLFC), see e.g. [1], has been studied.

MULTI-LAYER FARADAY CUP

The MLFC essentially consists of a stack of thin sheets of conducting material, see Fig. 1 and Fig. 4. The 0.3 mm thick copper sheets are insulated with respect to each other and each sheet is connected to a current measurement device. In our setup we used the standard electronics for the beam profile monitors in PROSCAN. The beam is stopped in the stack, and by measuring the direct proton current from each sheet, a current distribution is measured, which yields a direct measurement of the range in copper.

When operated in air, it is essential that there is no air between the copper sheets, since this would cause a deterioration of the signal from charge created in the air. Therefore we used 0.075 mm kapton as insulator between the sheets. The kapton also prevents charge created in the remnant air to cross the gap between the copper sheets.

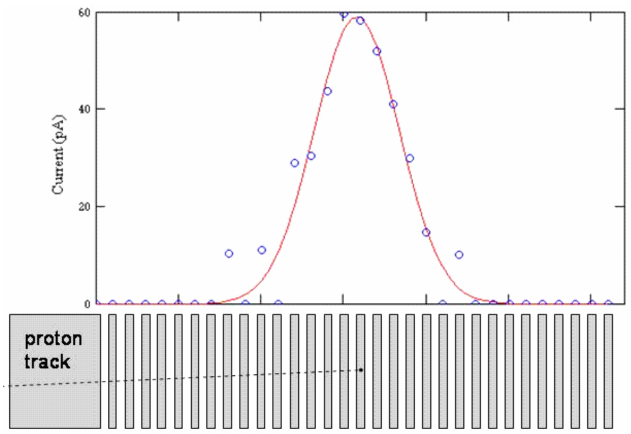

Fig. 1: Principle of a Multi-Layer Faraday cup, optimized for a fixed energy of approx. 200 MeV. The current measured from each copper layer and a Gaussian fit have been plotted above.

RESULTS

A first test was made at the gantry, using 214 MeV protons at a beam current of approx. 0.6 nA. The MLFC was simply set up on the patient table of the gantry. By inserting different plates of the range shifter, the energy of the beam entering the MLFC has been varied between 194 and 214 MeV. The current distributions (see e.g. Fig. 1) have been fitted with a Gaussian function, from which the beam energy (position) and momentum spread (width) has been derived. In Fig. 2 the energy measurement is plotted for different settings of the range shifter plates.

The momentum spread dp/p contributes to the total width of the range profile as:

$$\sigma_{total}^2 = \sigma_{natural}^2 + \sigma_{(dp/p)}^2 \qquad (1)$$

where $\sigma_{natural}$ represents the natural range straggling ($\approx 0.0105 \cdot Range$). A test of a momentum-spread measurement has been done by adjusting the aperture of the momentum defining slit FDS1X in the beam line to the gantry. At the slit location the dispersion is 50 mm/%dp/p. Figure 3 shows the measured momentum spread, as a function of slit aperture. The straight line indicates the momentum spread that could theoretically pass the slits. The measurements reproduce earlier results taken from the distal fall-off of the Bragg peak in water (data have been included for comparison). The deviations from the expected spread at small and large aperture are due to the limited resolution and beam size, respectively.

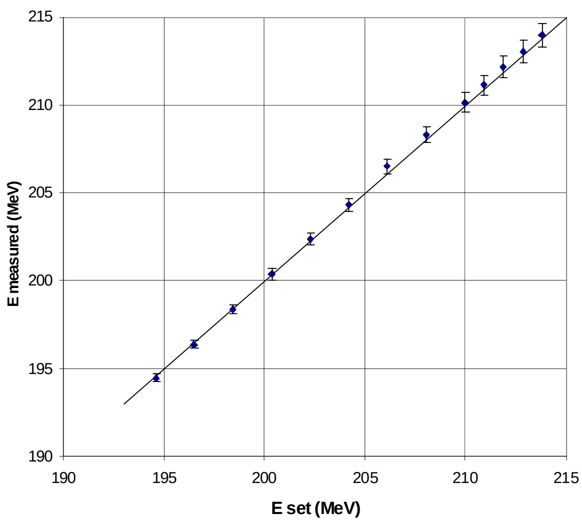

Fig. 2: Energy measured with the MLFC as a function of the beam energy set by the range-shifter plates. The error bars represent +/-3 sigma.

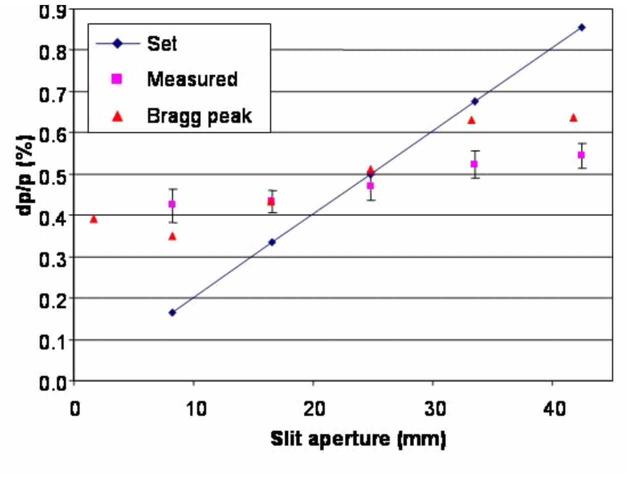

Fig. 3: Momentum-spread measured with the MLFC and from the distal slope of the Bragg peak in water, as a function of the aperture of the momentum-defining slit. The error bars represent +/-1 sigma.

CONCLUSION

These first measurements have shown that it is possible to make a quick and easy measurement of the beam energy (accuracy <0.1 %) and momentum spread (accuracy ~7 %). In a follow-up project different versions of the device will be designed for routine use at several locations in the PROSCAN facility.

REFERENCES

[1] B. Gottschalk et al., Med. Phys. 26 (1999) 2597-2601.

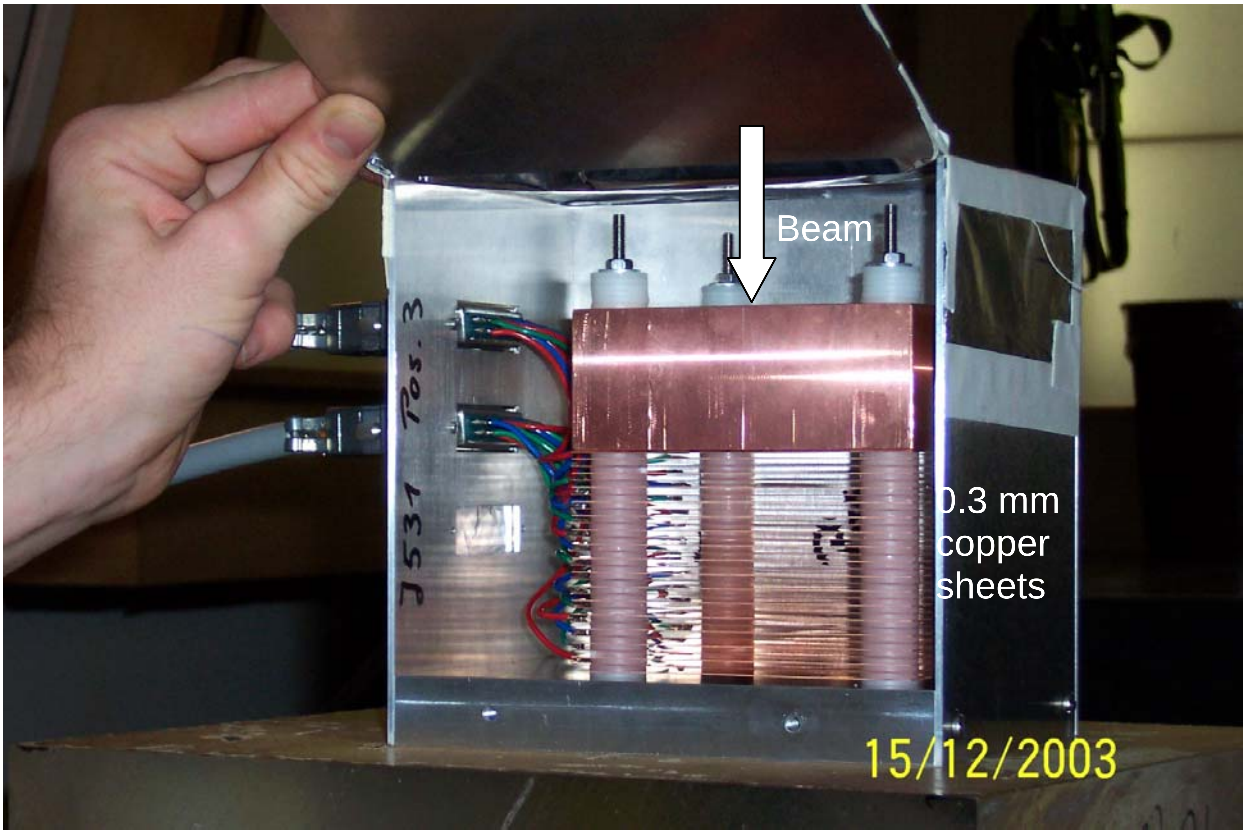

Fig. 4: Picture of the MLFC, before adding the kapton insulation between the sheets. The MLFC has been mounted in a grounded aluminum box, covered with a thin foil at the beam entry side.