Real-time beam-profile monitor for a medical cyclotron

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Introduction

Measuring the beam profile on a medical cyclotron in real time can aid in improved tuning of the cyclotron and give important information for a smooth operation. Typically the beam profile is measured by an autoradiography technique or even by a scintillator that can be viewed in real time [1, 2]. Another method is to use collimators in front of the target to assess the beam centering [3]. All these methods have potential drawbacks including; an inability to monitor the beam in real time for the radiograph, exhibiting a non-linear correlation in signal response to the power deposited for a scintillator, and not providing a 2-dimensional profile of the complete beam for collimators. Our goal was to design a real-time, linear, 2-dimensional beam-profile monitor that is able to withstand the high power of a PET cyclotron.

Material and Methods

The beam-profile monitor (PM) is designed for the TR13, a 13MeV negative hydrogen-ion cyclotron at TRIUMF. The design follows the concept of a 'harp' monitor, widely used at TRIUMF for tuning proton and radioactive ion beams, and is installed on the extraction port without separation from the tank vacuum. The TR13 monitor is designed to withstand a 13 MeV proton beam with a beam current of up to 25 µA, has an active area of 10 by 10 mm and does not affect the 10^{-7} torr tank vacuum. The device consists of a water-cooled Faraday cup made out of aluminium for low activation and two orthogonal rows of eight tungsten electrodes each mounted on a water-cooled support frame. Electrodes are spaced 1 mm apart from each other, see FIG. 1. The electrodes are electrically isolated from each other and each has a current pick-up soldered to it. The material and the shape of the electrodes are optimized to withstand the deposited power of the proton beam. A voltage of -90 V is applied to the electrodes to repel secondary electrons and prevent cross-talk between neighbouring electrodes. The electrode current is amplified using a custom current amplifier, and read by an ADC. From there, the current data is displayed on a PC. This allows one to observe changes of the beam profile in real time. The electronics are designed to read out all sixteen channels in parallel, or, if only a limited number of ADC channels are available, to cycle through the different channels. In our current setup all sixteen channels are read out simultaneously.

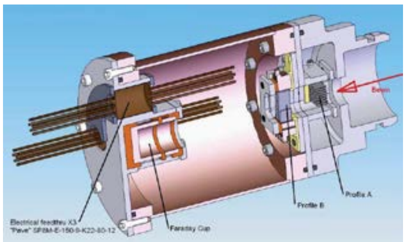

FIGURE 1: Cross-sectional view of the PM design. The proton beam intercepts the monitor blades as it enters the PM from the right.

Results and Conclusion

The beam-profile monitor provides a real-time representation of the proton beam, see FIG. 2. The data can also be recorded and analyzed at a later time. The linearity of the monitor has been measured up to 30 µA of proton beam current [4]. With the use of the monitor, it was possible to increase the output of the ion source into the target by 50% in comparison to the standard tune.

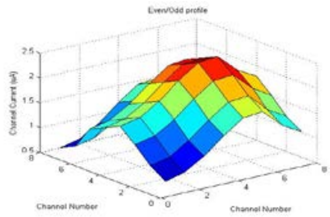

FIGURE 2: Typical output of the beam-profile monitor.

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