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# Characterization of a beam-tagging hodoscope for hadrontherapy monitoring

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1 Introduction

In a context where ion beam therapy faces uncertainties concerning ion range verification, solutions for real-time monitoring are investigated. Among them, some exploit the prompt-gammas (PG) emissions [?]. A Compton and a collimated camera coupled to a beam-tagging hodoscope, made of two scintillating fibres planes, are under development within the CLaRyS collaboration. The beam-tagging hodoscope is designed to provide the time-of-arrival of the ions, which is useful to reduce the background, mainly induced by neutrons. The specifications of
the detector are a detection efficiency over 90% for coincidence events in the two planes, with a time resolution below 2 ns FWHM, at counting rates up to 100 MHz. The performance of the beam-tagging hodoscope has been assessed in terms of detection efficiency, time resolution, multiplicity and radiation hardness during experiments at GANIL (Caen) and the Mediterranean Protontherapy Institute (Nice).

2 Material and methods

The final version of the beam-tagging hodoscope is composed of two parallel planes of 1 mm2 square-section polystyrene scintillating fibres, oriented perpendicular one to the other, and transverse to the beam direction. Each plane contains 128 fibres, which gives an active area of 128 x 128 mm2. Fibres are readout on both sides by 8 Hamamatsu multi-anode photomultiplier tubes (PMTs) H8500C. Each PMT is linked to a front-end (FE) card via a 64-channel connector. The main components of this card are two 32-channel readout ASICs, a signal-processing FPGA, a single-channel optical transceiver and an RJ45 connector. The data are then sent from the FPGA to the back-end card (AMC40) of a µTCA acquisition system [2], with a specific protocol [?, 3, 4].
For the performance tests a smaller hodoscope with 32 fibres per plane has also been developed in order to use a single acquisition board to collect all the data of the two planes. Each fibre plane is readout by a single ASIC.
The setup used during the experiments consists in inserting the beam-tagging hodoscope between two plastic scintillators (PSs) located about 5 cm upstream and downstream. The external trigger is provided by the coincidence signal generated from the PSs when a proton impinges the hodoscope. The analog to logic signal conversion is performed in a NIM module. When the PSs counting rate limit is reached, a PS placed out of the beam and calibrated at low beam intensity was used to monitor the beam intensity.

3 Results

This hodoscope successfully provided 2D images of proton beams with a detection efficiency larger than 98% with logical OR condition between the two fibre planes. The detection efficiency with a coincidence between the two planes is close to 75% for beam intensities up to ~ 1 MHz. Moreover, the timing resolution is around 1.5 ns FWHM. Radiation damage was studied with 95 MeV/u carbon ions at GANIL, where fluences up to 1013 ions/cm2 were shown to (temporarily) decrease the detection efficiency by 10%. Overall, the performance show that such a technology is viable for beam monitoring during hadrontherapy. Further improvements of the ASIC developed for the front-end electronics boards are foreseen to reach the counting rate capabilities of the specifications (100 MHz).

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