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CMOS Active Pixel Sensors as Energy-Range Detectors for Proton Computed Tomography

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Proton therapy is gaining importance in the field of radiotherapy because of its potential of conforming the planned dose accurately at different depths defined and controlled by the proton energy, while sparing surrounding healthy tissue. The use of proton therapy for cancer treatment makes the need for developing new and more accurate imaging modalities for treatment planning, based on the direct measurements of tissue stopping power instead of tissue density, as in conventional X-ray Computed Tomography (CT). Since the first proof of concept in the early 70s, a number of technologies have been proposed to perform proton CT (pCT), as means of mapping tissue stopping power for more accurate treatment planning.

The basic requirements for pCT lie in measuring position and direction of individual protons, assess their residual energy in an energy-range detector to infer the most likely path in the patient and the energy deposited. In this way, the stopping power may be calculated along the inferred path. Previous prototypes of energy-range detectors for pCT, are based on the use of scintillator-based calorimeters that measure proton residual energy. However, such approach is limited by the need of a single proton passing through the energy-range detector per read-out cycle. A novel approach to this problem could be the use of pixelated detectors, where the independent read-out of each pixel can simultaneously provide the residual energy of a number of protons in the same read-out cycle, facilitating a faster and more efficient pCT scan. The use of a stack of CMOS Active Pixel Sensors (APSs) as energy-range detector allows to infer residual proton energy by measuring the position where the proton stopped, provided that proton trajectories across the stack of APSs can be accurately tracked.

The feasibility of using a stack of APSs as energy-range detectors for pCT will be presented. Measurements, performed at the MC40 cyclotron at the University of Birmingham (36 MeV protons) and at iThemba LABS in South Africa (190 MeV protons), based on the use of a stack of two large area APSs, will be shown as proof of principle for proton tracking in an energy-range telescope. Monte Carlo simulations using the GEANT4 simulation toolkit, will also be presented to assess the efficiency of the tracking algorithm and the energy-range calibration. The required detector specifications for such a range telescope will also be discussed. The proposed design for a large area and fast read-out CMOS APS for pCT, developed by the Proton Radiotherapy Verification and Dosimetry Application (PRaVDA), consortium will be presented.

Primary author: ESPOSITO, Michela (University of Lincoln and University of Surrey)

Co-authors: Dr PARKER, David (University of Birmingham); POLUDNIOWSKI, Gavin (University of Surrey); NIETO-CAMERO, Jaime (iThemba LABS); ALLINSON, Nigel M (University of Lincoln); EVANS, Philip M (University of Surrey); MANOLOPOULOS, Spyros (University Hospitals Coventry and Warwickshire); GREEN, Stuart (University Hospital Birmingham and University of Birmingham); ANAXAGORAS, Thalis (ISDI Ltd (Image Sensor Design and Innovation)); PRICE, Tony (University of Birmingham and University Hospital Birmingham)

Presenters: ESPOSITO, Michela (University of Lincoln and University of Surrey); ESPOSITO, Michela (University of Surrey)

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