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Mechanical Integration of a Digital Tracking Calorimeter for the Purposes of Proton Computed Tomography

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ABSTRACT

Proton therapy is a novel radiation therapy modality for the treatment of malignant tissues. The high dose gradients that can be achieved using energetic proton beams allow for more conformal treatment plans. However, it has not yet been possible to exploit the full potential of proton therapy due to range uncertainties. An important source of these is the fact that tissue proton stopping powers are calculated using conventional CT-scans of the patient. Conversion from Hounsfield units to proton stopping power introduces additional uncertainties in the range estimates. To tackle this issue, our group is currently developing a Digital Tracking Calorimeter (DTC) that will be used for proton CT purposes in proton therapy. The DTC will allow measurements of proton stopping power in tissue using high energy proton beams that penetrate the patient. The DTC will enable measurements of the residual range (or energy) and tracks of individual protons crossing the patient with a high accuracy and at higher intensities. This work focuses on the mechanical issues related to the realization of a DTC for the purposes of proton CT. An optimal detector prototype should have maximum integrity, reliability, accessibility, safety and maintenance capabilities. All these features depend on precise mechanical design and analysis of entire calorimeter, stack layers, staves and its constituent elements with regards to mechanical and thermal characteristics. Numerical simulations based on Finite Element Method (FEM) have been performed to model the geometry and mechanical properties of the DTC layers.
Thermo-mechanical analysis of DTC layers consisting of monolithic active pixel sensors interleaved with absorber plates has been accomplished. Sensitivity analyses of mechanical strength and DTC layer deformation have been performed taking into account relevant materials and bonding methods. Additionally, thermal behaviour and heat transfer studies for two coolant fluids have been carried out to find the appropriate cooling solution. The proper solution would avoid risks of mechanical failure for each DTC stack and between the stacks. Accordingly, various cooling schemes have investigated and analysed based on mechanical fabrication reliability and applicability.

Keywords: Proton CT, Digital Tracking Calorimeter, Heat transfer, Temperature distribution.

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