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LET Estimation for Heavy Ion Particles based on a Timepix-based Si Detector

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In the quest to develop a Space Radiation Dosimeter based on the Timepix chip from Medipix2 Collaboration, the fundamental issue is how Dose and Dose-equivalent can be extracted from the raw Timepix outputs. To calculate the Dose-equivalent, each type of potentially incident radiation is given a Quality Factor, also referred to as Relative Biological Effectiveness (RBE). As proposed in the National Council on Radiation Protection 153 (2008), the Quality Factor is the function of Linear Energy Transfer (LET) of the traversing particle. With the Timepix chip device, LET can be measured by the total energy deposited –which could be calibrated from the Timepix chip– divided by the path length of traversing when the particle passes through the Si layer. The Si layer is in this case 300 μm thick, which can be used to calculate the traversing length if there is an algorithm to estimate for angular resolution of incidence.

The raw Timepix-outputs are generated from the Medipix2 Timepix-based Si detector, which is a hybrid semiconductor pixel detector made of 256x256 pixels with 55 μm each readout CMOS-based integrated circuit. This device, developed through a collaboration based at CERN, is able to survive and perform for extended periods in strong radiation fields. When an incident heavy ion penetrates the Si layer, it diffuses and produces a core of charge carriers with track structures embedded within the pixel footprint. The structures are complicated due to the diffusion and the existence of δ-rays, which are recoil particles caused by secondary ionization. A carefully analysis of these track structures is needed to understand the characteristic of particles.

In this paper, we propose an algorithm for estimating angular resolution of incident heavy ion particles, which is an essential step toward calculating LET, Dose and Dose-equivalent based on a Timepix-based Si detector. Given the raw Timepix outputs, we use a segmentation operator to identify clusters –groups of contiguous pixels forming track structures. We then apply a morphology operator to get the primary and stable shape of a cluster. By doing this, noise and δ-rays are effectively removed. It also helps to recognize and separate simple overlapping particles that occur when the exposure time is not shortened enough. A linear regression has been found to determine the direction of incidence. We extract a skeleton of the track based on an analysis of pixels projected onto this line. The angular resolution of incidence is dependent on the length of this skeleton. Having the angle and energies calibrated, LET is estimated before getting Dose and Dose-equivalent.

We use data from HIMAC (Heavy Ion Medical ACcelerator) in Chiba, Japan, and NASA Space Radiation Laboratory at Brookhaven in USA for our experiments. The data frames were taken at different angles and particle charges. In particular, we show experimental results with H-100MeV (0, 30, 60, 75 degree), He-100MeV (0, 30, 60, 75 degree), C-400MeV (0, 30, 60, 85 degree), Fe-400MeV (0, 30, 60, 75, 85 degree). Results show the advantage of our algorithm for angular calculation and LET estimation.

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yes

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