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Development of a new space dosimeter based on LET measurements for heavy charged particles

Radiation dose for human body is evaluated using a dose equivalent, H, defined as a product of an absorbed dose and a quality factor given as a function of LET. In space, there exist many kinds of radiations such as galactic cosmic rays, where charged particles and neutrons are main components contributing to radiation dose. LET of these distributes from 0.2 to 600keV/μm. To evaluate H, it is essential to measure LET. A Tissue Equivalent (TE) Proportional Counter, TEPC, has been a standard space dosimeter, which is a proportional counter made of TE materials. In TEPC, since no position information is given, LET can not be measured directly and a lineal energy, y, is used instead. Obviously, y does not represent LET accurately. H obtained with TEPC is reported to be more than twice that with a real LET spectrometer. We have been developing a new dosimeter, Position Sensitive Tissue Equivalent Chamber (PS-TEPC). PS-TEPC is a time projection chamber using a small micro-pixel chamber (μ-PIC, 2.6x2.6cm) as a 2-demetional readout device. In μ-PIC, the anode and the cathode strip electrodes are orthogonally arranged with a pitch of 400μm and pixel-like anode pillars of 50μm diameter are formed at the center of each cathode opening. Due to an electrical field between the anode and the cathode, a gas gain of ˜10ˆ4 is obtained. We have demonstrated successfully the feasibility of PS-TEPC using heavy ion beams. We are trying to complete the prototype. The status of PS-TEPC is given.

Summary (Additional text describing your work. Can be pasted here or give an URL to a PDF document):

In radiation dosimetry, radiation effects on human body are evaluated using the dose equivalent H, defined as a product of the absorbed dose D and the quality factor Q given as a function of a linear energy transfer (LET). In space, there exist many kinds of radiations such as galactic cosmic rays and their secondary particles. Charged particles (protons and heavy ions) and neutrons are considered as main components contributing to radiation doses in space. LET of these radiations distributes from 0.2 to 600 keV/μm. From these, it is essential to measure directly LET of radiation for evaluation of H in space. A Tissue Equivalent Proportional Counter (TEPC) has been used by the NASA group as a standard space dosimeter, which is a simple gas proportional counter made of tissue equivalent plastics and filled with tissue equivalent gas. Since no position information is given in TEPC, the assumption that LET is equal to a lineal energy (the deposited energy divided by the mean chord length of the detector) is normally used to achieve a real time measurement. Obviously the lineal energy does not represent LET accurately. The dose equivalent obtained using TEPC is reported to be more than twice that measured with the real LET spectrometer such as RRMD-III. RRMD-III, however, is not consisted of tissue equivalent materials, and has smaller detection view (<42%) and no sensitivity for neutron. The ideal real-time detector should have the following properties: (1) position sensitivity, (2) made of tissue equivalent materials, and (3) wide detection view (～4π).

We are developing a new dosimeter in space, Position Sensitive Tissue Equivalent Chamber (PS-TEPC), which is designed as a time projection chamber (TPC) using a micro-pixel chamber (μ-PIC) so as to measure the energy deposition and the track length of radiation simultaneously. The μ-PIC consists of a double-sided printed circuit board (PCB). The anode and the cathode strip electrodes are orthogonally arranged with a pitch of 400□m on the both side of 100□m thick polyimide insulator. Pixel-like anode pillars of 50μm diameter are formed at the center of each cathode opening through the insulator. Due to an electrical field between the anode and the cathode, a gas gain of ～104 is obtained without any additional gas multiplication devices. In this study, we aim to demonstrate feasibility of PS-TEPC, to design and to complete the prototype of PS-TEPC usable in space. Our final goal is to establish the dosimetric system in space using PS-TEPC.

The feasibility of PS-TEPC was examined from the results obtained for a large TPC with 100x100 mm2 μ-PIC using heavy-ion beams from Heavy Ion Medical Accelerator in Chiba (HIMAC) in National Institute of Radiological Sciences (NIRS). The TPC was filled with Ar+10%C2H6 or tissue equivalent gases (C3H8 + 39.6%CO2 + 5.4%N2 and CH4 + 32.5%CO2 + 3.2%N2), and irradiated with C6+ (400MeV/n)、Si14+ (800MeV/n)、and Fe26+ (500MeV/n). As a result, The beam profiles obtained from tracking data demonstrated well with the actual shapes of the beams, and data of 3-dimensional tracks for each particle was obtained successfully. The deposited energy of the particle alone the track was also successful measured. The LET obtained from these

data was in good agreement with the calculated value.
To develop a prototype of PS-TEPC used in space, we designed newly the μ-PIC with a size of 26x26 mm2, and manufactured a small-type TPC (effective detection volume; 26x26x50 mm3) constructed with tissue equivalent materials such as A-150 plastic and acrylic acid resin. By connecting two electrodes neighboring each other in this μ-PIC, the readouts of 32x32 channels are maintained. Despite the position resolution becomes worse (about 800μm), this makes it possible to simplify the readout circuits. The TPC was designed so as to be separate from its readout circuit systems. We have tested this prototype by measuring the LET distributions in propane-base tissue equivalent gas for He2+ (230MeV/n), C6+ (400MeV/n), Si14+ (800MeV/n), and Fe26+ (500MeV/n) in HIMAC. The measured LET distributions were in good agreement with the calculated values.
In the final form, a preamplifier system is directly attached to μ-PIC readouts in the detector unit to achieve good signal-to-noise ratios. The other circuits such as signal processing, data analysis and data transmission to the ground are installed together into the control unit. The outer size and the weight of the detector unit are expected to be within 80x80x100 mm3 and 3kg, respectively. The present status of PS-TEPC will be given in detail at the conference.

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