DEVELOPMENT OF A BEAM TRAJECTORY MONITORING SYSTEM USING e^+/e^- PAIR PRODUCTION EVENTS

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Particle beams, such as the proton or carbon beams, deposit large energy just before stopping points which are called the Bragg peak. Therefore, cancer cells can be killed by matching the Bragg peak position and the cancer position. Conversely, if the position of the Bragg peak deviates from cancer cells even a little, normal cells will be killed. Thus, in the particle beam therapy, it is important to monitor the Bragg peak position. To monitor the Bragg peak position, positron emission tomography (PET) detectors or Compton cameras have been studied. On the other hand, we develop a new system to monitor the Bragg peak point by measuring pair production events occurred in the system with gamma rays from exposed points. In the pair production event, since the e^+/e^- pair goes in the travelling direction of the gamma ray, determining the travelling direction of the pair makes it possible to determine the gamma ray's travelling direction and its trajectory. The Bragg peak position can be determined by obtaining the intersection of the trajectory of the gamma ray and the trajectory of the particle beam. This system consists of 20 layers of detectors lined up at 10 mm intervals, particle beam monitor, and a block of scintillator on the downstream side for a trigger. Each layer is composed of wavelength shifting fibre (WLSF) sheets and a Ce:YSO sintered scintillation board. The size of the scintillation board is 300 mm*300 mm*1 mm. The sheets are made by arranging 1500 WLSFs with a diameter of 0.2 mm. The board is sandwiched between sheets, where the directions of the sheets are in orthogonally x and y directions. In the Ce: YSO crystals, about a half of the interactions are pair production events at around 7 MeV, and when it becomes 20 MeV or more, pair production events become a majority. When a charged particle passes through the board, a particle deposits mean energy of 0.9 MeV. Therefore, although the energy deposit at the pair produced layer is unstable, particles consume 1.8 MeV of energy on average at following layers, because an e^+ and an e^- pass through the layer. In a case of occurring the Compton scattering, the energy loss in following layers are 0.9 MeV in average; only an e^- pass through the layer. Although an e^+ annihilates and generates gamma rays, such a gamma ray deposits under 0.511 MeV. Therefore, pair production events can be extracted if there are 1.3-2.3 MeV loss of energy at few layers continually. The following contents have been simulated on GEANT4, Monte Carlo simulation code. The distribution of secondarily generated gamma rays on carbon beam therapy was simulated. We counted gamma rays reach to the surface of 300 mm of a sphere centred at the Bragg peak position, then calculated its trajectory, and extracted events which trajectory closer to the 1 mm distance to the carbon beam trajectory. It was calculated that 20% of gamma rays over 40 MeV which are observed on the side of the phantom came from within 1 mm from the carbon beam trajectory, and the distribution of such gamma rays have the peaks at the Bragg peak position and carbon beam's incident point. This becomes more prominent as energy increase. The number of gamma rays with 40-100 MeV come from the Bragg peak position was calculated approximately 1200 per 10^9 carbon beams, which is the number of carbon beams per second on cancer treatment. Next, gamma rays of 10-51 MeV were shot perpendicular to the centre of the system. Whether or not e^+ was observed in each scintillation board was recorded. The data of total energy deposit on scintillation boards and its positions were also taken. If some energy over 0.511 MeV is deposited on a layer, and 1.3-2.3 MeV at next 2 layers, that event was judged as a pair production event. We confirmed that our system can define pair production events over 96% accuracy when gamma-rays' energy are 40 MeV. In addition, the number of charged particles which passed sintered scintillator was counted by using WLSF sheets with a 98% possibility. In an actual system, the number of reacted detectors and the magnitude of energy deposit on the scintillation block will be used for a trigger condition. It is expected that this system makes it possible to monitor the Bragg peak position in real time on particle beam cancer treatment.