Precise Measurement of Beam Energy and Range with TOF and Counter Telescope System

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ABSTRACT

In order to improve the accuracy of charged-particle radiation therapy, the beam energy was measured precisely using a TOF-system, and the range using a counter telescope system. A Si detector and a Ge detector were used to estimate the range straggling as a ΔE and an E detector, respectively, because they have good energy resolution and the output pulse heights don't depend on the atomic number of detected particles. The results were compared with the theoretical values by a calculation code.

Keywords: TOF, energy measurement, range measurement, straggling.

1. INTRODUCTION

In charged-particle radiation therapy, the beam energy and the parameters of various equipments were determined to concentrate the dose on a tumor which is confirmed by a CT image. Therefore, it is important to know the relation between the beam energy and the range in order to decrease the influence for normal tissue, and to make the treatment more effective. Although there are some calculations on the energy-range relation, there are differences of about 2% among them[1)]. Thus, in this work the experimental data measured precisely were compared with the calculations.

2. EXPERIMENTAL PROCEDURE

2.1. Energy measurement

The energy of charged particles was measured using a TOF-system installed in the PH1 course of NIRS-HIMAC. The TOF-system can determine beam energy by measuring the flight time and the flight pass length of charged particles precisely. Figure 1 shows the principle of the flight time measurement. At first, two plastic scintillators were set closely each other to measure the flight time T_1 that defines the origin of the flight time. The signals from both scintillators were fed to a time to amplitude converter (TAC) to get a time spectrum. After that, one of two photomultiplier tubes (PMTs) was removed and attached to another plastic scintillator placed about 12 m downstream in the PH1 course to measure the flight time T_2. The beam energy was calculated using Eqs.(1) and (2), where m_0 is the rest mass of a charged particle and c is the velocity of light. The error of the beam energy using this system was estimated to be less than 0.1%.

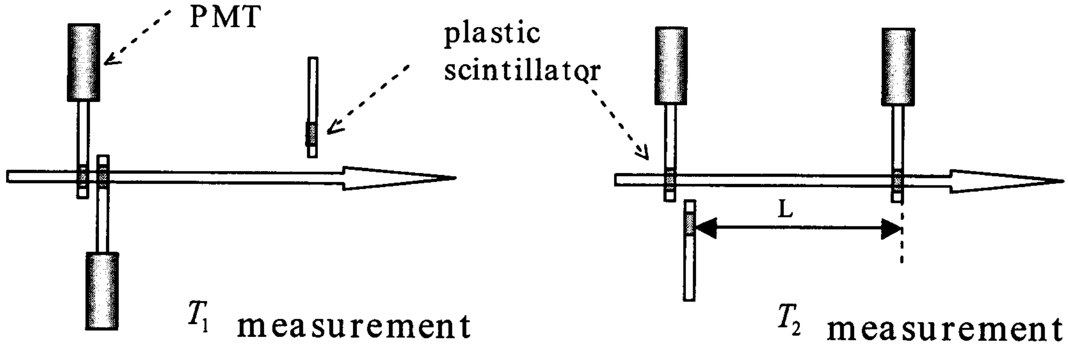

Fig.1 TOF-system

$$T = T_2 - T_1 \quad (1)$$

$$E = \left[\frac{1}{\sqrt{1-(L/cT)^2}} - 1\right] m_0 c^2 \quad (2)$$

2.2. Range measurement

The experimental setup for the range measurement is shown in Fig.2. Charged particles were injected to a "water column" whose thickness can be changed optionally in the order of 5 μm. The number of charged particles was counted by a plastic scintillator of 50 μm in thickness placed just in front of the water column. The particles were identified and counted by a ΔE-E counter telescope which was set just behind the water column. In the particle identification, a plastic scintillator is often used as a ΔE-detector[2]. However, in this work, a Si detector and a Ge detector were used as a ΔE detector and an E detector, respectively. The reason is that their outputs have no Z-dependence and they have good energy resolution, which is of great advantage to the measurement of the range straggling. By changing the thickness of the water column and counting the number of primary particles behind the water column, the range of charged particles was obtained precisely.

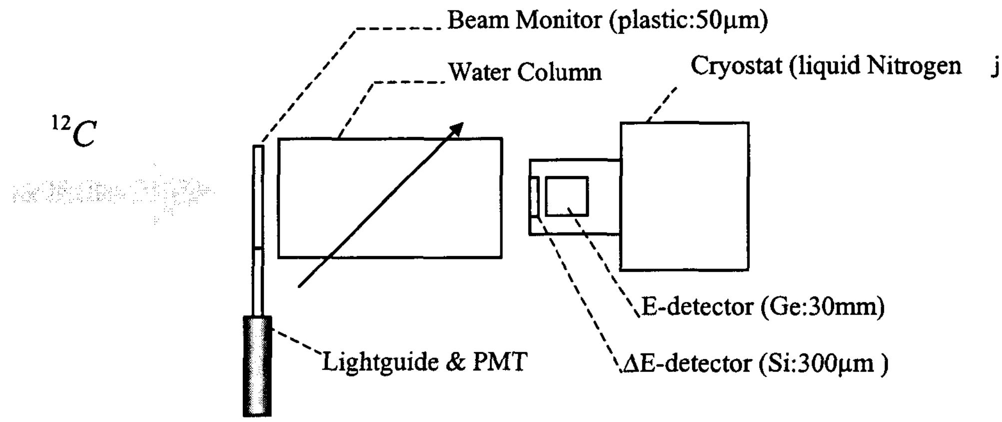

Fig.2 Experimental setup for range measurement

3.RESULTS

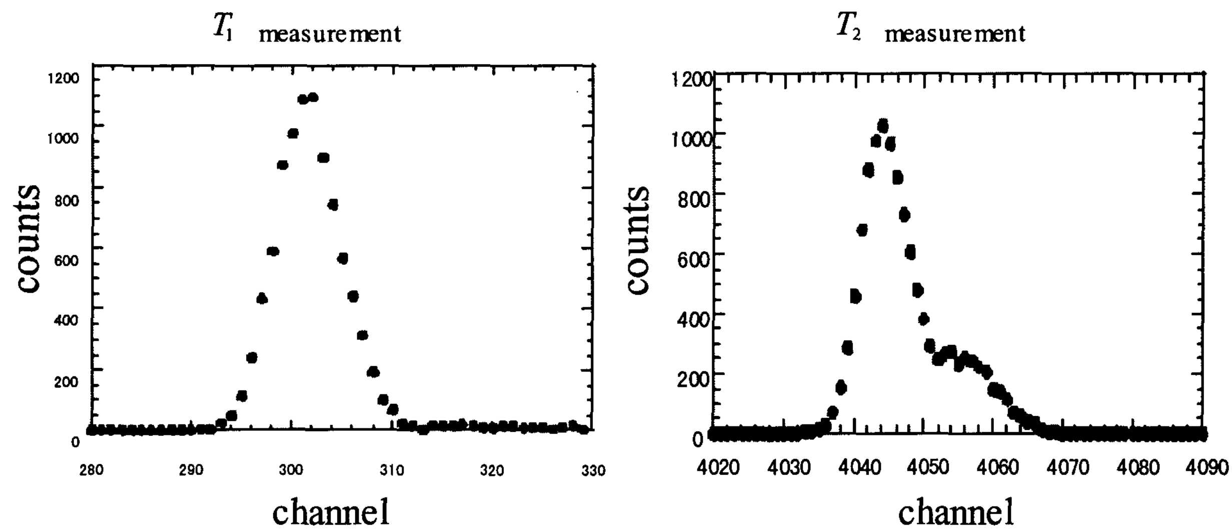

Fig.3 TAC spectra for ^{12}C beam of 135 MeV/u

Figure 3 shows the time spectra for ^{12}C of 135 MeV/u. A time calibrator (ORTEC Model 462) was used for the time calibration. The flight pass length was measured using a laser range finder (Leica Disto pro3). Substituting these results for L and T in Eq.(2), the beam energy was obtained with an error of 0.055% for ^{12}C of 135 MeV/u. Figure 4 shows the fluence of ^{12}C of 135 MeV/u. The range is defined as a target thickness corresponding to the middle point of the straight line with a steeper slope. In order to estimate the range straggling of incident particles, first the total number of particles in each energy spectrum, which obtained in the above-mentioned measurements, was normalized to a given number. Then the number of particles of a given energy is plotted as a function of water thickness, and the range straggling was defined as a spread of the plotted data in this work. However, since there is a large amount of statistical error in this way, it is difficult to derive the straggling from the results.

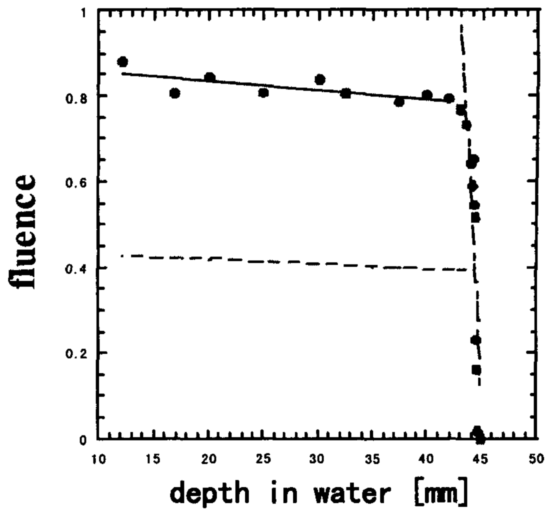

Fig.4 Fluence for ^{12}C beam of 135 MeV/u.

4.CONCLUSION

The beam energy and the range were measured using a TOF and a ΔE-E counter telescope system, respectively. We could measure the bean energy with an error less than 0.1%. However, it is necessary to pursue the cause of two peaks in the TAC spectrum shown in Fig.3. Furthermore, in order to improve the accuracy of the energy measurement, it is effective to enlarge the sensitive area of the plastic scintillators or to align the TOF system with the beam line precisely again. There are differences between the experimental ranges and the results by calculation codes[3]. Taking the data under different conditions and comparing them with the calculation enables us to make the code more general one.

REFERENCES

1. T.Kanai, T.Sakauchi, Y.Ohno, T.Kohno, N.Matsufuji, M.Torikoshi and M.Kanazawa, "Precise Measurement of Heavy-ion Range" NIRS-M-133 HIMAC-023(1999)300
2. N.Matsufuji, T.Kanai, H.Komami, T.Kohno, "The Response of a NE102A scintillator to passing-through relativistic heavy ions" *Nucl. Instr. and Meth.* A437, pp.346-353,1999
3 M.H.Salomon, LBL Report 10446(1980)N.Matsufuji, T.Kanai, H.Komami, T.Kohno, "The Response of a NE102A scintillator to passing-through relativistic heavy ions" *Nucl. Instr. and Meth.* A437, pp.346-353,1999