PERFORMANCE OF PARALLEL PLATE IONIZATION CHAMBER FOR MEDICAL IRRADIATION

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Abstract

We have developed *Parallel Plate Ionization Chambers (PPIC)* to measure not only the cumulative intensity but also the time structure of slow-extracted heavy-ion beams from a medical synchrotron. The characteristics of the PPIC with 3 mm and 1 mm gap distances for 760, 200, 111, and 55 Torr air were investigated with C^{6+} beam (290 MeV/u) at HIMAC. The applied voltage to start the plateau region strongly depends on the beam intensity, and pressure of counter gas. The PPIC can be also used as a useful beam monitor for the time-structure measurement of heavy-ion beams.

1 INTRODUCTION

As a new method of radiation therapy with ion beams, the spot scanning is started at the PSI[1] and GSI[2]. We have also been planning to use the spot scanning method, at HIMAC (Heavy Ion Medical accelerator in Chiba)[3].

Intensity of beams slowly extracted from a synchrotron, in general, varies in time mainly due to the current ripple in the synchrotron magnets. To realize the accurate dose distribution, the speed controlled spot scanning should be achived. In this system the intensity of the slow-extracted beams should be measured at the upstream of the irradiation room.

As a beam monitor for the intensity measurement, a parallel plate ionization chamber (PPIC) is a good candidate, because of its stable operation and wide dynamic range for the detection of the heavy-ion beams. We have developed PPIC. In this paper, we describe on the preliminary results of performances for C^{6+} beams extracted from the HIMAC.

2 DETECTOR CONSTRUCTION

The structure of the PPIC is shown in Fig. 1. We have used air as a counter gas. In order to keep the heavy ion beam qualities, the total effective thickness of PPIC is very thin. i.e.; about $6.15 mg/cm^2$ for 760 Torr air, and about $0.52 mg/cm^2$ for 50 Torr. The electrodes are square-shaped $3\mu m$-thick aluminized polypropylen ($270\mu g/cm^2$ the polypropylen and $20\mu g/cm^2$ the aluminium). These very thin electrodes are fixed in the glass-epoxy frame and set into the aluminum chamber. The gap dependence of the S/N ratios in the detector signal can investigate by using the spacer as shown in Fig. 2.

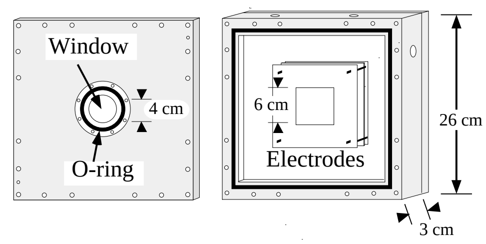

Figure 1: The PPIC. The left figure shows the front lid of the PPIC. The front and rear windows are sealed with O-rings. Three electrodes are mounted in the aluminum chamber.

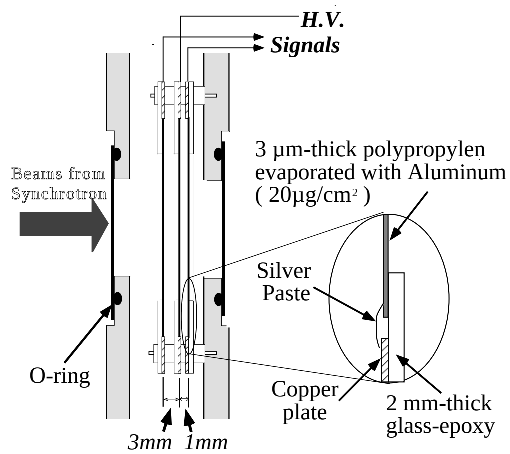

Figure 2: The cross-sectional view of the PPIC. The electrodes are the 3 μm-thick aluminized polypropylen film fixed on the 2 mm-thick glass-epoxy frame. Three electrodes can be arranged with front and rear gap distances of 3 mm and 1mm, respectively.

3 EXPERIMENTAL SETUP

The C^{6+}(290 MeV/u) beams slow-extracted from synchrotron with RF-KO method[4] at around 11/3 resonance are used in the present experiments. The setup of the PPIC experiment is shown in Fig. 3 and Fig. 4.

Before the time structure measurement, we measured the plateau characteristics under different conditions: the gap distances, the beam intensities and gas pressures of air. The picked up signals from the PPIC were integrated during 10 spills in order to reduce the statistical error. To cancel out the fluctuation of C^{6+} beam intensities, we utilized the output signals from the HIMAC ion chamber, which is

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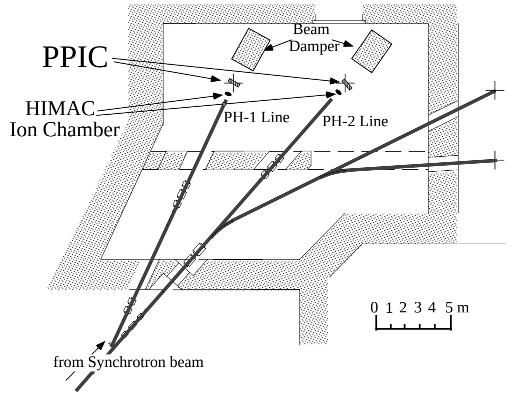

Figure 3: The plane view of the “physics and general” experimental room.

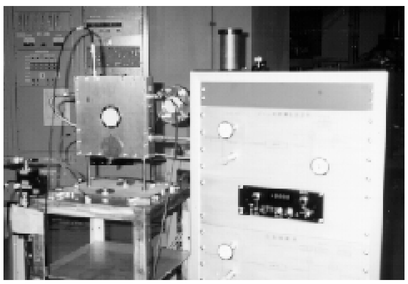

Figure 4: Photograph of the experimental setup of the beam line. From the downstream, the PPIC, the HIMAC ion chamber (the ionization chamber with a the gap distance of 2 mm) set up.

calibrated with Faraday cup.

The charges from the PPIC were converted into voltage signals with current amplifiers and observed by a digital oscilloscope (HEWLETT PACKERD 54540A) triggered by the timing signal of beam extraction. In order to investigate the time response of the PPIC, we compared PPIC signals with those of the 0.2 mm-thick plastic scintillation counter which has been used as a ”Ripple Monitor” at just after the extraction point.

4 RESULTS

4.1 INTENSITY MEASUREMENT

Normalizing the charge signal from the PPIC by that of the HIMAC ion chamber, we have obtained plateau curves for air. We have found that the plateau characteristics depends strongly on the beam intensity. Fig. 5 shows the plateau curves for the 3 mm gap distance PPIC with 759.6 Torr air. The plateau starting voltage is about 24 volts for intensity of 1.7×10^6pps, and about 362 volts for intensity of 1.3×10^9pps.

In the case of beam intensity of 1.3×10^9 pps, the plateau starting voltage is about 17 volts at 50.2 Torr air (see Fig. 6). In the case of with 759.6 Torr air, however, the operation mode can reach the plateau region for around 362 volts.

The dynamic range of the PPIC is illustrated in the top of Fig. 7. It is clear that the signal height of the PPIC

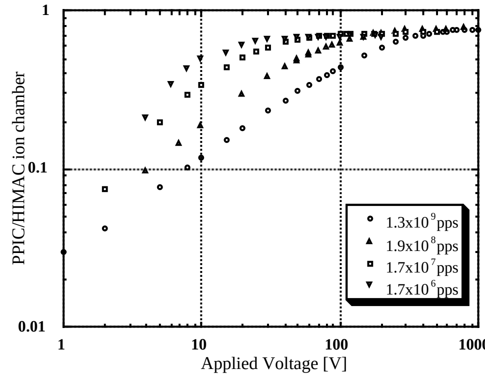

Figure 5: The plateau curve of PPIC(3mm gap distance) with 759.6 Torr air. The beams are C^{6+} (290 Mev/u). The ordinate is the ratio between the output charge from the PPIC and the HIMAC ion chamber.

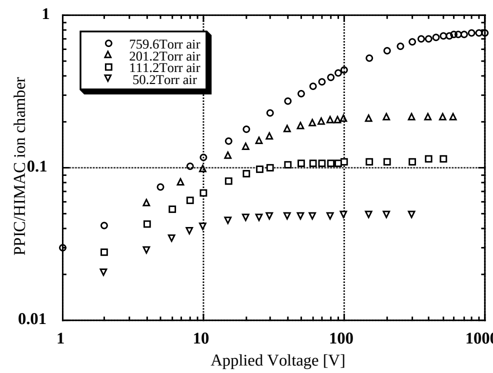

Figure 6: The plateau curve of PPIC(3mm gap distance) with air. The beams are 1.3×10^9pps C^{6+} (290 mev/u). The ordinate is the ratio between the output charge from the PPIC and the HIMAC ion chamber.

are proportional to the pressure of gas density with errors of 10%. The linearity of the signal against the pressure is also confirmed by the bottom of Fig. 7. Consequently, we can deduce that the PPIC signal height is proportional to number of primary ion pairs. It is also due to the density of the primary ion pairs that the plateau characteristics differ in beam intensity and pressure of counter gas.

4.2 TIME STRUCTURE MEASUREMENT

We measure the time structure of the RF-KO extracted beam with PPIC. The time structure of the RF-KO extracted C^{6+} beams measured with PPIC(1mm gap distance) and Ripple Monitor is shown in Fig. 8. Both detectors have the peak of 777, 100 Hz and these linear combination in the frequency spectrum. These frequencies come from the repetition rate of frequency modulation of the RF field as usually used for the therapy at HIMAC and the ripple of AC power line.

When the frequency modulation of RF-KO is changed, the corresponding frequency component come dominant and we can study the time response of the PPIC at that frequency. With the frequency of RF-KO at 3000 Hz, the

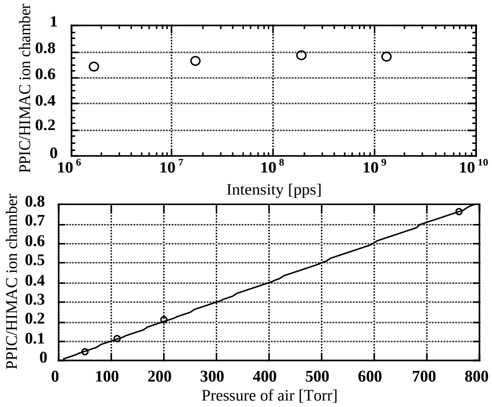

Figure 7: The PPIC signal dependence on the intensity (upper) and the pressure of the counter gas (lower).

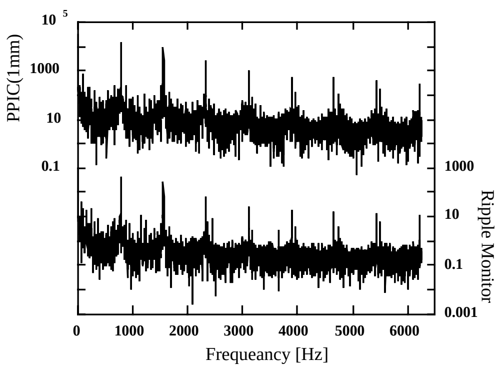

Figure 8: Frequency spectra of the signals from the PPIC(1mm) with the 759.8 Torr air (upper) and the Ripple Monitor (lower). The repetition rate of the frequency modulation of RF-KO field is 777 Hz as usually use for therapy.

frequency response of both detector is as shown in Fig. 9. Because the plastic scintillation counter is fast enough to respond beam change in kHz order, it is concluded that our PPIC system achieve the kHz order time response.

4.3 SUMMARY AND FUTURE PLAN

We can summarize the present results that the PPIC with gap distances of 3mm and 1mm can be used as a useful beam monitor from both viewpoints of beam-intensity and time-structure measurements. Although the 3mm gap distance PPIC needs the higher applied voltage to reach the plateau, we will choose the gap distance of the PPIC 3mm. It is because the electrode films of 1mm gap distance PPIC pull each other by Coulomb force and reduce the effective volume by several percent.

While we continue the further basic study concerning the PPIC characteristics, we are planning to a two-dimensional beam monitor with the PPIC having stripped electrodes so as to observe the two dimensional beam profile at the same time. Because the signal from one strip electrode is smaller than the plane electrode, we choose the pressure of counter gas is 760 Torr.

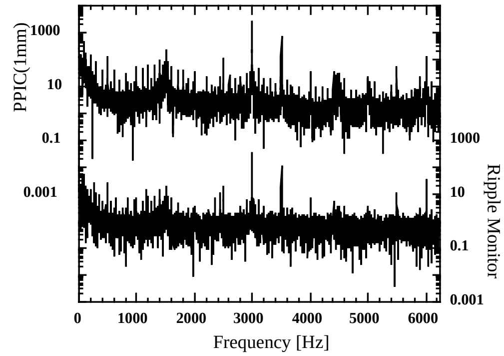

Figure 9: Frequency spectra of the signals from the PPIC(1mm) with the 759.8 Torr air (upper) and the Ripple Monitor (lower). The repetition rate of the frequency modulation of RF-KO field is 3000 Hz.

5 ACKNOWLEDGEMENT

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