New emittance measurement using two PPACs

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Abstract

A new emittance monitor has been developed with two sets of position-sensitive gas counters. It was designed for the precise measurement of the beam emittance about a high-energy beam from the RIKEN Ring Cyclotron. A preliminary test was done.

1. Introduction

At RIKEN Ring Cyclotron[1], the beam emittance has been measured with a combination of movable slits and multi-wire profile monitors[2]. By this monitor, precise data are obtained about the emittance for the low energy beam, for example, a beam from an ion source and from injectors. In the case of high energy, for example 135 MeV/u C beam, this method is not applied, because a thick slit is necessary for this, therefore a signal from wires becomes small. A rough estimation of the beam emittance has been only done using a normal profile monitor for this beam. In the future, the RRC will be used as an injector to the next stage accelerator[3]. For the design of new accelerator, we need the precise emittance measurement for the beam extracted from the RRC.

2. Principle of measurement

We employ two sets of position-sensitive-type PPACs (parallel plate avalanche counter), which is widely used as a counter for nuclear physics experiments in RARF (RIKEN Accelerator Research Facility). Such a PPAC itself can work as a beam profile monitor for the low intensity beam.

Suppose that two position-sensitive detectors are installed in a straight beam line with a distance of L in the interval, and that the sensitive areas are large enough to ensure all particles in the beam through the both detectors. When one particle passes though the detectors, two sets of data; (Xa, Ya) and (Xb,Yb) are obtained as the two-dimensional position data, where the suffix 'a' and 'b' are for the first (upstream) detector and the second (downstream) one, respectively.

From the obtained data, a trajectory of the particle is calculated easily as (Xa,X') and (Ya,Y'), where X'=(Xb-Xa)/L and Y'=(Yb-Ya)/L. If the thickness of the detector is thin, the trajectory is not affected by the existence of the detector. After accumulating these data (Xa,X') and (Ya,Y') for a number of particles in the beam, we can get the beam emittance.

3. Details of PPAC

A PPAC system consists of electrodes, housing, a linear actuator and electronics.

3.1 Electrode and Hardware

Fig. 1 shows the electrode assembly and its housing with two windows.

To use the PPAC as a two-dimensional-position-sensitive detector, its electrode assembly consists of an anode and two cathodes on both sides of the anode. These electrodes are put parallel to each other with separations of 4 mm. The electrode is a thin gold layer (60 μg/cm^2 in thickness) which is deposited on a 2.5 μm Mylar film. The anode is covered with the gold layer all surface on its both sides. On the other hands, the cathode has 51 gold strips whose pitches are 1 mm. The sensitive area is 50 x 50 mm^2.

The charge division method is employed for the signal readout. On one side of the cathode strip, every strip electrodes is connected to the next one through a 200 ohm resistor. Two signals leaded from both ends are introduced to the outside, and used to get the position information.

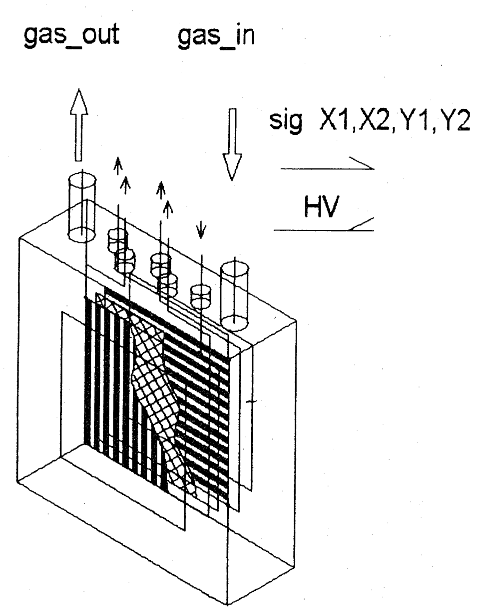

Fig.1 An electrode assembly of PPAC and its aluminum housing with two windows.

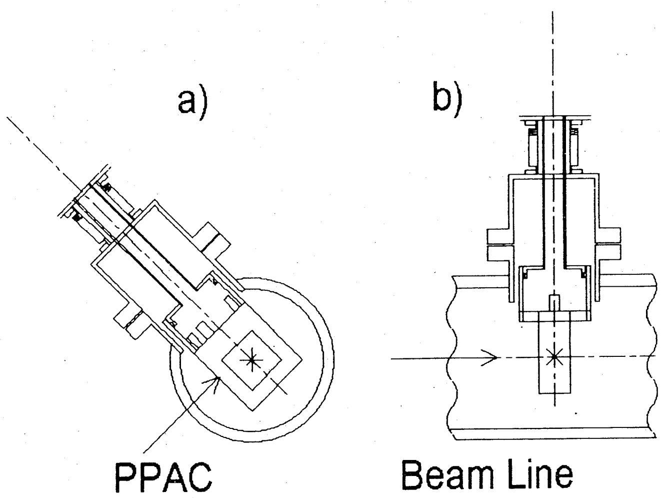

Fig.2 PPAC set on the beam line. (a) cross sectional front view from the upstream of the beam line; (b) cross sectional side view.

The two cathodes are set so that the orientations of strip will be in different way. One is used for the measurement of the X-position and the other is used for the Y-position.

These electrodes are set inside the aluminum box which has two windows (for the beam entrance and exit) of 50 x 50 mm^2 in size and the distance of the two windows is 32 mm. The window film is 2μm Mylar on the surface of which aluminum (8 $\mu g/cm^2$) is deposited. This counter box has a gas inlet and outlet and four feedthroughs for the position signals from two cathodes and one feedthough for the bias voltage to the anode.

As shown in Fig. 2, the counter box is fixed on one end of a support pipe which is driven linearly by a pneumatic actuator. The counter is set exactly on the beam axis remotely when in use, and removed out of the beam area when no use. Two PPACs have been installed inside the beam diagnostic chambers separately, a distance between them is 2.9 m along the beam line just after the extraction of the RRC. There is no forcussing element between the two chambers.

Actually the probe is installed in the beam line with an angle of 45 deg relative to horizontal axis as shown in Fig.2, because the space just above the chamber is reserved for the alignment. Therefore the position data has to be converted into the normal horizontal-vertical coordinate.

Two gas lines and five signal cables are introduced to atmosphere through a counter support pipe. A gas of isobuthane is being supplied as a stable gas flow, keeping a pressure inside the counter around 8 torr. A gas supply system consists of a mass flow controller, a leak valve and a rotary-pump.

3.2 Electronics and Software

In Fig. 3, a block diagram of electronics is shown. A preamplifier is located nearby the counter to keep the precise imformation of the positions.

First, a PC takes eight signals, two signals for the X-position and two signals for the Y-position from each PPACs. If only the eight signals are all above the threshold, 10% of the maximum data range, the PC accumulates these data and calculates the X-position and the Y-position, which are Xa, Xb, Ya and Yb. The reason to set the threshold is to

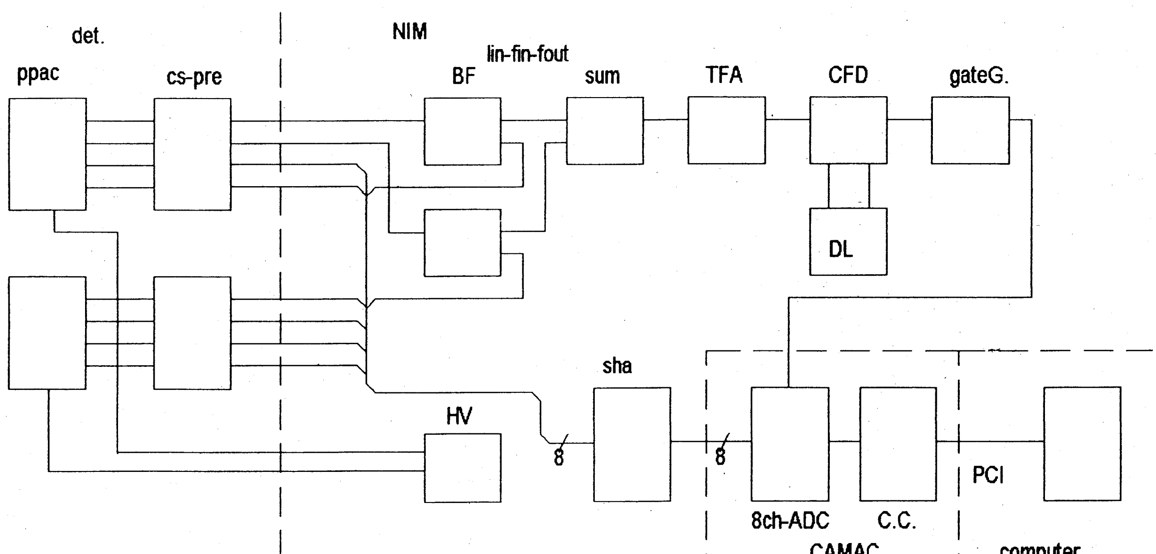

Fig.3 Block diagram of electronics

get a position information accurately. The signals smaller than the threshold have a possibility to make the accuracy worth of the position data. The beam profile is taken by such way, the beam emittance is also calculated by using these data.

4. Error estimation

A scattering of the beam by a material of the upstream counter has the effect on the emittance measurements. A total thickness of one PPAC corresponds to 1.9 mg/cm^2 Mylar. A scattering angle was estimated using by the Ziegler formula. As a result, the scattering angle of the 135 MeV/u Ne beam after passing PPAC is less than 0.1 mrad. This value means the effect of the angler scattering is negligible.

During the measurements with PPAC, the beam has to be attenuated down to order of 10^4 pps. Much attention should be paid in order to attenuate beam without changing the full-beam emittance. A set of the thin copper plate with many small holes on it is used for beam attenuation. We need always check that the beam profile is not changed after the beam attenuation is done.

The position error of PPAC is estimated to be 0.3 mm. The error due to it on beam angle is 0.1 mrad, being negligible.

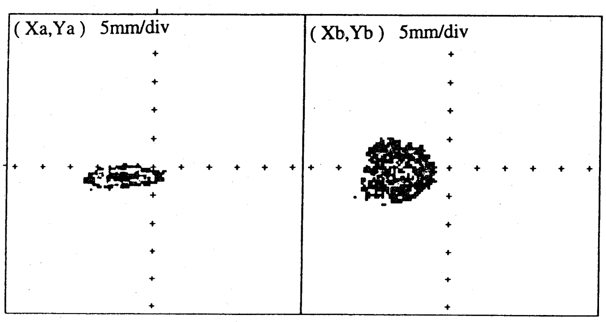

Fig. 4 A beam profile measured by the PPAC

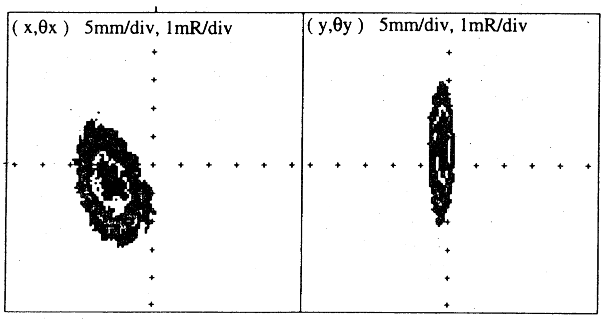

Fig.5 A beam emittance measured by the PPAC

5. Preliminary Test

A test for the emittance measurement was done with a beam of 110 MeV/u ^{22}Ne. The obtained data of the profile and the emittance of the beam are shown in Fig.4 and Fig.5. The obtained emmitances are 20 πmm·mrad for horizontal plane and 7.5 πmm·mrad for vertical. The horizontal data is larger than the expected value. The calibration of position and angle are under way.

6. Conclusion

From the result of beam test, the PPAC can work as a beam emittance monitor instead of the orthodox measurement way with using slits and multi-wire profile monitors. By this method, an accurate measurement may become available.

References

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