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INSTITUTE FOR NUCLEAR STUDY
UNIVERSITY OF TOKYO
Tanashi, Tokyo 188
Japan

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High-Resolution, Two-Dimensional Focal-Plane Detector for Intermediate-Energy Heavy Ions*

Y. Fuchi, M. H. Tanaka, S. Kubono, H. Kawashima and S. Takaku

Institute for Nuclear Study, University of Tokyo
Midori-cho 3-2-1, Tanashi, Tokyo, 188 Japan

T. Ichihara

Institute of Physical and Chemical Research
Hirosawa 2-1, Wako, Saitama, 350-01 Japan

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ABSTRACT

A large-area, high-resolution two-dimensional position sensitive gas detector has been developed for intermediate energy heavy ions. The x position information is obtained by a multi-cathode method and the y position by measuring the drift time of electrons. This detector has no left-right ambiguity and no dead layer in the sensitive area as like a multi wire drift chamber, resulting in a detector system which is thin and homogeneous in the whole sensitive area. The overoll position resolutions of o.22 mm and o.40 mm (FWHM) were obtained for x and y directions, respectively. This detector system has been shown to be very useful for high-resolution heavy ion experiment at intermediate energies.

I. INTRODUCTION

A two-dimensional position detector has been developed as a focal plane detector of a high resolution, magnetic spectrograph, the SMART (a Swinger and a Magnetic Analyzer with Rotators and twisters)[1] for intermediate-energy heavy ions at the Institute of Physical and Chemical Research (RIKEN).

The requirements for the detector is as follows: The sensitive area is 50 cm in the x direction (the momentum dispersion direction) and 10 cm in the y direction (the angle direction). The position resolutions should be better than 0.5 mm (FWHM) in both x and y directions. The maximum counting rate should be no less than 10^4 cps. The particle identification should be made completely up to Ne, while rejecting the multi-hit events.

To meet these requirements, a gas proportional counter was adopted. A MWDC (Multi Wire Drift Chamber) has been widely used for a large area detector. Such a detector system has been used for the first focal plane of SMART. However, it has a left-light ambiguity, and thus 4 layers of MWDC are used to solve this ambiguity. This fact together with many dead areas prevents a high position resolution measurement for intermediate energy heavy ions. Furthermore, a detector system of MWDC needs a large number of read-out elements.

On the contrary, a SWPC (Single Wire Proportional Counter) does not have a left-light ambiguity. However, the position resolution by a charge division method for SWPCs is ordinary about 1/1000 of the length of the sensitive wire. Therefore, the charge division method is not applicable here.

A new method for read-out which uses multi-cathodes has been reported[2]. This read-out method is known to give a high position resolution irrelevant to the wire length. Therefore, the multi cathode method with a SWPC was adopted for the read-out of the x position information.

On the other hand, a good y position resolution (<0.5 mm)[3] is achieved for a drift space of 35 mm with a focal plane detector for the QDD spectrograph[4] at Institute for Nuclear Study, University of Tokyo (INS). Since the drift space for SMART is 10 cm, about three times higher voltage would be required for the drift plate to get the same electric field. Since this could not cause any problem, a single drift space of 10 cm was adopted here for the y position measurement.

The particle identification using ΔE-E or ΔE-TOF information has been used successfully with the detector for the QDD spectrograph too. This particle identification method is also applied for the present system.

From these considerations discussed above, a hybrid structure was adopt which has a drift space of 10 cm and a proportional counter which has multi-cathodes to realize high position resolutions in both x and y directions.

II. DETECTOR DESIGN

Figure 1 shows a cross sectional view of the cathode-read-out single-wire drift counter (CRDC) designed here. The effective height, the length and the depth are 100 mm, 500, mm and 30 mm, respectively. To realize a uniform electric field in the drift region, field wires with a diameter of 50 μm are used at the interval of 10 mm.

The anode wire is a gold plated tungsten wire of 55 cm-long and a diameter of 12.5 μm. The cathode was divided into 60 strips whose width is 7.5 mm with a 0.5 mm separation between them. The width of the strips was decided by the noise levels of the whole system and the required x position

*Presented at IEEE 1992 Nuclear Science Symposium, Florida, October 25-31, 1992 resolution. A high x position resolution should be obtained by a cathode width of about the distance between the anode wire and the cathodes[2]. Therefore, the distance between the anode wire and the cathodes was set to 7.5 mm.

The strips were followed by charge-sensitive pre-amplifiers independently, which were enclosed in the detector box in order to reduce the noise level.

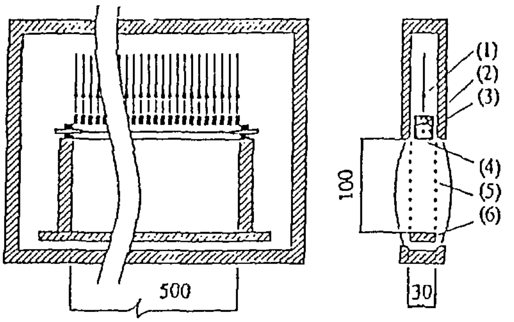

Fig. 1 A schematic view of the CRDC. (1) pre-amplifier, (2) cathode-strip, (3) anode-wire, (4) grid, (5) field-wire, and (6) drift-plate.

The anode signal also provides ΔE information which can be used for the particle identification. On the other hand, the position in the y direction is determined by measuring the drift time of the secondary electrons. Plastic scintillators are placed behind the CRDCs for fast timing to determine y position as well as the TOF information.

The whole detector system consists of two CRDCs and two plastic scintillators. They are all arranged in a series and perpendicularly to the beam direction in the vicinity of the second focal plane of the SMART.

The distance between the two CRDCs is 55 cm. Using two dimensional CRDC signals, ray tracing is performed. The plastic scintillators are placed just behind the second CRDC. Two-scintillator system are effective to reduce background events for intermediate-energy heavy-ions. Figure 2 shows the arrangement of the detector system and the rays reconstructed.

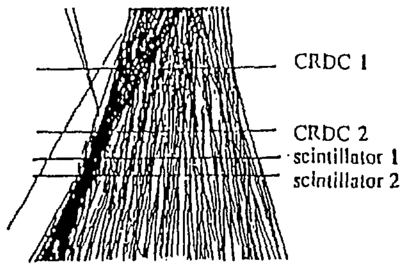

Fig. 2 The arrangement of the detector system and the rays reconstructed.

III. RESULT AND DISCUSSION

A beam test was performed with a faint proton beam of 30 MeV from the SF-cyclotron at INS, since this beam gives roughly the same energy loss as the 120 MeV/u ^{12}C beam. The x and y position resolution were tested individually.

A smaller size CRDC, which fit in the focal plane of the QDD spectrograph, was placed on the focal plane of the QDD spectrograph at 0 degree for a test of the x position resolution. The CRDC was operated while flowing a mixed gas of Ar 70% and CH_4 30% at an atmospheric pressure. The anode voltage was 1980 V. The overall x position resolution obtained was 0.22 mm FWHM, as shown in Fig 3. This resolution includes the beam size.

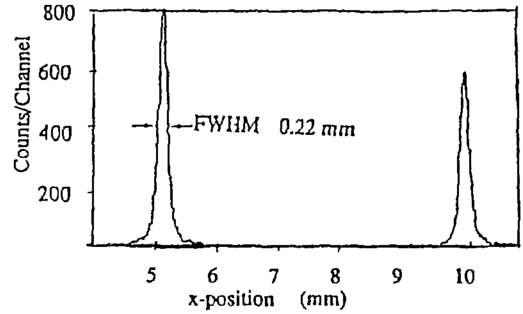

Fig. 3 An x position spectrum for 30-MeV protons obtained by the CRDC. The distance between the two peaks is 5.7 mm.

The position resolution in the y direction was tested by a single wire drift chamber (SWDC), since the CRDC with 10-cm-height drift space dose not fit to the focal plane box of the QDD spectrograph. Two slits (0.2 mm width) was placed just before and behind the SWPC. The applied voltage for the drift space was 3000 V (the electric field strength is 300 V/cm). Under this condition, the drift velocity of the electrons was found to be well saturated.

The position resolution in the y direction was tested at the point of 1.5 cm and 8.5 cm from the grid. The overall y position resolution was 0.4 mm in FWHM at both points.

Simultaneously, the position resolution in the x direction was tested at the same points, and 0.4 mm FWHM was obtained for both points. The dispersion of electrons drifted in the drift chamber was not observed through this resolutions.

From these experimental results, the present CRDC has been proved to satisfy the requirements for the position resolutions.

The CRDCs were used for heavy-ion reaction studies at intermediate energies. Figure 4 shows a two-dimensional spectrum of ΔE and TOF for particle identification of ^{12}N from the $^{12}C(^{12}C,^{12}N)^{12}B$ reaction at E/u = 135MeV.

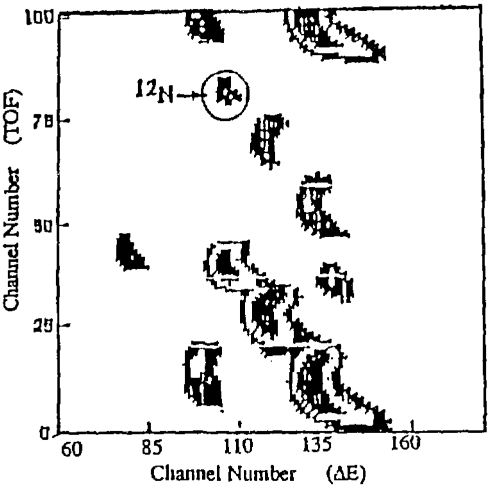

Fig. 4 The particle identification of ^{12}N from the $^{12}C(^{12}C,^{12}N)^{12}B$ reaction at E/u = 135 MeV.

Figure 5 shows momentum spectra of ^{12}N from the $^{12}C(^{12}C,^{12}N)^{12}B$ reaction. The upper one is the spectrum at θ_{lab} = 0 to 0.25 degrees. The peak at around 470 channel is the ground-state transition. The one at around 510 channel is a doublet of $(2^-,4^-)$. The lower spectrum is the one at θ_{lab} = 0.5 to 0.75 degrees.

Although there are some properties to be tested, the CRDCs are in operation successfully for high resolution heavy-ion experiments at intermediate energies at RIKEN.

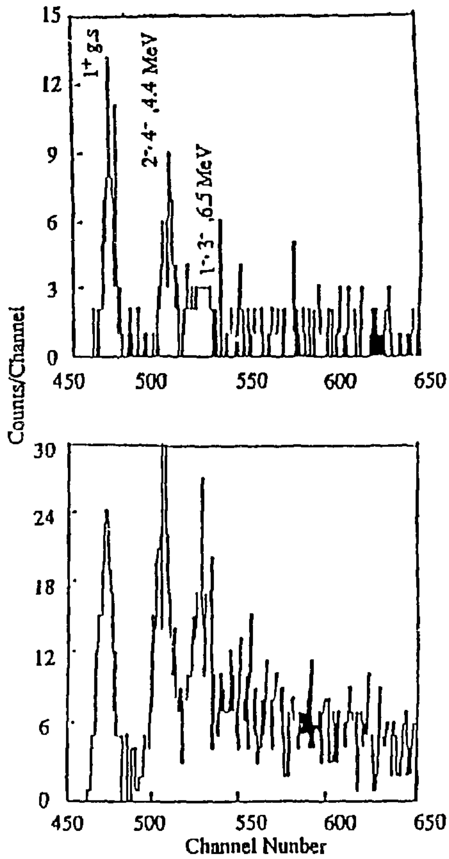

Fig. 5 The momentum spectra of ^{12}N from the $^{12}C(^{12}C,^{12}N)^{12}B$ reaction at E/u = 135MeV.

References

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