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POSITION SENSITIVE COUNTER DEVELOPMENT AT THE LINAC

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POSITION SENSITIVE COUNTER DEVELOPMENT AT THE LINAC

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In a novel application of the multiwire proportional counter we have imaged a collimated neutron beam. Although preliminary, the results are of sufficient import to be described here because of the potential wide application of the multiwire proportional counter to Laboratory problems. The counter was operated with a counting gas pressure of 20 Torr; the counting gas was pure C_4H_{10} . The radiator was a ^{235}U foil. Under these conditions, the counter is (1) relatively insensitive to charged particles (other than fission fragments), (2) insensitive to γ -radiation, and (3) has an efficiency for the detection of fission fragments independent of incident neutron energy over a wide range of neutron energies.

I. INTRODUCTION

The multiwire counter and its traditional applications are described in a cursory fashion, followed by a description of a very simple experimental arrangement used to image a neutron beam. Simple refinements of the experimental arrangement will result in much sharper images.

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Charpak, Bouclier, Bressani, Favier, and Zupančič¹ noticed in 1968 that position information could be deduced from the proportional counter with good accuracy and good time resolution. Multiwire proportional counters (MWPC) rapidly came into common use in both intermediate- and high-energy physics laboratories; information from these counters is used to calculate the trajectory of the individual charged particles which contribute to a nuclear event. With special techniques, rates of 10^4 particles/(sec-mm²) can be dealt with. Spatial accuracies of 200 μ m and time resolutions of 8 nsec are obtained. Figure 1 schematically illustrates the evolution of the multiwire proportional counter. Counters are operated in and beyond the proportional region, and with a variety of gas mixtures. Typically, wire spacings are 2 mm, and the cathode to anode distance is 4 mm. Anode wires are 20 - 40- μ m diameter, while cathode wires are 100- μ m diameter. The wire directions of the two cathode planes are arranged in an orthogonal fashion and (x,y) position information is obtained by measuring the centroid of the charge induced on the cathode wires when proportional counter action occurs at the anode wire. Several methods of readout are used: the arrangement of Fig. 1 uses resistive wire, and determines the location of a pulse by measuring its R-C time constant. Energy and time information are usually obtained from the anode pulse. In medium-and high-energy physics experiments, banks of these counters are used to determine particle trajectories using ray tracing techniques.

A single MWPC can also be used to image point events;² a low-energy x-ray photoelectric interaction is the prototype event. The experimental arrangement is straightforward. An interaction volume is located in front of a MWPC. A charge cloud, produced in the interaction volume by an event,

drifts along an electric field gradient into the MWPC. The spatial resolution is limited by the physics of the interaction and by the diffusion of the charge cloud as it drifts through the interaction volume. Rates $> 10^5 \text{ sec}^{-1}$ can be accommodated and accuracies of $35 \mu\text{m}$ (FWHM) can be obtained with exceptional care. A schematic x-ray pin hole camera is illustrated in Fig. 2.

In order to image a neutron beam, the neutron must be made to undergo a reaction which results in a charged particle; the charged particle is counted in the MWPC. Reactions such as (n,f) , $^3\text{He}(n,p)$, $^1\text{H}(n,p)n$ and $^{10}\text{B}(n,\alpha)$ are suitable reaction candidates. Image resolution is determined by twice the range of the charged particle in the gas. In the usual case the charged particle has a significant range in the gas, steps such as the use of high-pressure gas or the exploitation of reaction kinematics must be considered. These two techniques have been applied to obtain an image of meV neutron beams.^{3,4} The n,γ reaction has also been used; in this case, conversion electrons produced by the decay of the product nucleus were counted.⁵ New developments in the gas-filled counter field include counter operation at low counting gas pressures. This makes possible a counting system which uses the technique of ray tracing to image neutron beams because conditions may be arranged so that the secondary particle has a range in the counting gas sufficient to traverse two counters. One possible experimental arrangement uses a fission foil immersed in the volume of a multiwire proportional counter; the counter is operated with C_4H_{10} as the counting gas at a pressure of 20 Torr. A schematic experimental arrangement is illustrated in Figure 3.

Christianson⁶ extensively used gas counters in this rather different region of gas pressure, the 20-30 Torr region; here the range of a fission fragment in gas at 20 Torr is roughly 660 mm. The operation of flat plate counters at low pressures may be understood from the Paschen curve for gases. For isobutane (C_4H_{10}) at a pressure $P = 20$ Torr, a potential $V = 500$ V, and anode-cathode spacing of 2-3 mm, conditions are rather close to breakdown, and an electron in the gaseous medium gains enough energy between collisions to cause ionization in its next encounter. An initial charge deposition q_0 in the gas a distance x from an anode will be multiplied into $q = q_0 e^{\alpha x}$; for example, a gas gain of about 1000 for a line of charge is readily realized. [Note the application to situations where presently the simple ionization chambers is used as fission fragment detectors. The use of flat plate avalanche counter reduces sensitivity to γ rays, enhances the signal of fission fragments relative to α particles, and produces more signal.] Although the original application was to flat plate counters, there is no reason not to use this technique with multiwire counters. Here, one may operate with a combination of the avalanche mode and the usual proportional action at the anode wires. See references 7 and 8 for detailed reports of the MWPC operated with organic counting gasses at low pressures.

II. EXPERIMENT

The MWPC in this mode of counting operation permits ray tracing with fission fragments since the range of the fission fragment is long compared with reasonable counter dimensions. The full potential of this scheme has not yet been exploited due to the extensive hardware and analysis requirements, but a rather simple test has been made. The experimental arrangement is cruder yet than that schematically illustrated in Fig. 3; a single counter, 25 cm on a side, was located with its front face normal to a collimated neutron beam. The anode to cathode spacing was 3 mm, and both anode and cathode wires were spaced 2.5 mm apart. A filling gas of isobutane (C_4H_{10}) was used; the pressure was set at 25 mm. A potential of 550 V was applied to the anode wire. A 93 percent ^{235}U foil, $10 \times 10 \text{ cm}^2$ and 3-mm thick, was located 5 mm behind the counter; it was normal to the beam. The "delay line" method was used to determine the coordinates of the event. Briefly described, in this method each cathode wire is connected in turn to a tapped delay line, here characterized by $\Delta t = 10 \text{ nsec}$. The centroid of the charge induced in each cathode plane is determined; from the time relationship between this and the anode pulse a spatial coordinate is calculated. In this test, an image was obtained in the following way. The spatial coordinate was related to pulse height, which was applied to the input of an oscilloscope operated in "x-y" mode. An unblank pulse suitably timed was obtained from the anode pulse, and the oscilloscope display was photographed. One such photograph is illustrated in Fig. 4. The scale is such that each grid square represents $\sim 32 \text{ mm}$ on a side. The calculated beam spot at the ^{235}U foil

was $6.6 \times 1.8 \text{ cm}^2$. The representation of the beam cross section with this simple $1/r^2$ image is good. The neutron beam and exposure time are only roughly characterized. The neutron beam was obtained using the LLL E-Division 100 MeV Electron LINAC; the neutron source strength was $10^{13}/\text{sec}$ and it is (roughly) parameterized by a Maxwellian with a characteristic temperature of 1 MeV. The source to counter distance was $\sim 12 \text{ m}$. It took approximately 20 seconds to obtain the result illustrated in Fig. 4. The horizontal and vertical lines near the left hand side and the lower part of the figure represent events in which one of the cathode pulses exceeded a discriminator level, but not the other. These may be eliminated from the display with the imposition of some straightforward logic conditions. Future experiments will use ray tracing techniques. See Fig. 3.

The time resolution of the counters is of some interest. In a discrete line of charge, one obvious parameter of interest is the separation of the anode wires, d . An upper limit to the time distribution is then $t = d/v$, where v is the electron velocity in the gas. This is some 8-10 nsec for the present configuration. In the present experiments, the measured time resolution is $< 6 \text{ nsec}$ but further work remains to be done. For small $4 \times 4\text{-cm}^2$ counters a time resolution of 0.8 nsec has been reported.⁸

Some characteristics of the counter are worth noting.

- (1) These counters are dE/dx counters, because of the low counting gas pressure. Therefore, they offer a good rejection rate for α particles in the presence of fission fragments. [In a separate test using flat plate electrodes, fission fragments at the rate of 10/sec have been counted with 100 percent efficiency and (complete

separation in the pulse height distribution) in a background rate of 10^7 α -particles/sec.]

- (2) These counters are reasonably insensitive to gamma radiation. They use a hydrocarbon counting gas, and they operate at low pressure.
- (3) These counters may be made in a variety of configurations.
- (4) These counters can operate in an electrically noisy environment, at least in the sense of the Linac, with simple electronics.
- (5) The image sharpness is independent of the neutron energy, if the (n,f) reaction is used. Suitable choice of a converter foil will emphasize certain regions of neutron energy; e.g., instead of ^{235}U , a ^{232}Th foil may be used. Hydrogenous foils may be used, and "knock-on" protons counted.
- (6) It is clear that this technique permits one to measure the spatial distribution of reaction products independently of the neutron beam size upon the target.
- (7) It is straightforward to think of counting schemes where the energy and mass distribution of fission fragments can be obtained, along with the geometry of each event.

III. CONCLUSIONS

A simple arrangement exploiting a position sensitive multiwire proportional counter has been used to "image" a neutron beam. Satisfactory qualitative results have been obtained. Immediate work is planned to obtain:

1. The image quality using ray tracing and multiple counters, and a measure of the position resolution.
2. The timing resolution using a ^{252}Cf source and measuring n, γ coincidences.
3. Some information about the pulse-height distributions on the cathode and anode wires.
4. Experience with the counter in n,f measurements (independent of its use on imaging array).
5. Appropriate instrumentation.

This work represents one application of the multiwire proportional counter at the laboratory. The potential for neutron radiography is clear. Multiwire counters also can be used for x-ray and γ -ray imaging, a rapidly developing field.

IV. ACKNOWLEDGMENTS

The success of the MWPC is critically dependent upon the laying down of the wires on the counter frames. For these counters, the winding of the wires was done at LAMPF. Staff cooperation was very much appreciated.

Fig. 1. Evolution of the multiwire proportional counter. From C. J. Borkowski and M. K. Kopp, Rev. Sci. Instr. 46, 951 (1975).

Fig. 2. Schematic of a spherical Drift Chamber. Angular Aperture: 90° . Drift length: 10 cm. Radii of the entrance and exit electrodes: 18 cm and 28 cm, respectively. From G. Charpak, Z. Hajduk, A. Jeavons, R. Stubbs, and R. Khan, Nucl. Instr. Meth. 122, 307 (1974); G. Charpak, C. Demierre, R. Kahn, J. C. Santiard, and F. Sauli, IEEE Trans. Nucl. Sci. NS-24, 200 (1977).

Fig. 3. Schematic experimental arrangement for measurements of fission fragment trajectories.

Fig. 4. Photograph of the oscilloscope display of x-y data from the MWPC.

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