CHARACTERISTICS OF MULTIWIRE PROPORTIONAL CHAMBERS FOR POSITRON IMAGING

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Abstract

We describe multiwire proportional chambers (MWPC) designed for use in a positron camera for Nuclear Medicine applications. The coordinates of the two annihilation gamma rays are detected in the chamber by their interaction with thin lead converters placed on both faces of each chamber. In order to obtain reasonable efficiencies (10%) the lead converters have been made in a square honeycomb-like structure, which increases the effective surface area and also permits the application of a drift field to extract the electrons into the active area of the MWPC.

Introduction

The principle of imaging by coincidence detection of the annihilation 0.51 MeV gamma rays from positron emitting radioactive isotopes has been previously discussed.[1,2,3]

We describe here our development of a positron camera using MWPC's coupled to lead converters as the position-sensitive gamma detectors.

The basic concept of such a camera is shown schematically in fig. 1. An object with an unknown distribution of a positron-emitting radioisotope is placed approximately midway between the two MWPC detectors which are enclosed in gas-tight aluminum boxes. We are using MWPCs with a sensitive area of 48 x 48 cms placed 50 cms apart subtending a large solid angle relative to the subject. The coordinates of the two 0.51 MeV gamma--one in each detector--will be stored in a PDP-11 Computer. From the stored data, the spatial distribution of the radioisotope in the object can be computed using various numerical techniques.[4] Finally, from the computed distribution, the output can be displayed as a series of two-dimensional projections, or in a three-dimensional isometric format.

Multiwire Proportional Chamber Detector

Chamber Construction

The position sensitive gamma detectors consist of four MWPCs, two inside each detector box as shown in fig. 1. The basic chamber construction is similar to what we have used previously[5] and is shown schematically in fig. 2. The cathode planes consist of stainless steel wires 100-micron diameter with a 2-mm spacing between wires. The anode plane consists of stainless steel wires 25-micron diameter with a 3-mm spacing between wires. The cathode-to-anode spacing is 4 mm. The area of the wire plane sensitive region is 48 x 48 cm. Readout of ionizing events is done by the delay line method.[6] The construction of the chamber and wire planes is shown in the photograph fig. 3.

The gamma rays are detected by the conversion electrons produced from lead converters. Since the detection efficiency for 0.51 MeV gamma rays from a flat lead surface is only ~ 0.3%, we have used a honeycomb structure of lead in order to increase the effective surface area and thus provide a reasonable efficiency. These lead converters are placed parallel to the cathode planes with a 4-mm spacing.

Honeycomb Lead Converter.

The structure of various lead converters is shown in fig. 4. Of these, 4d is the most effective; it is made by soldering together a series of corrugated lead-plated plastic strips. The plastic is 50 microns mylar with a copper plating 25 microns thick on which a subsequent layer of lead 50 microns thick is plated on both sides. The cell shape is square with rounded corners, approximately 3 mm on a side. Since it is necessary to drift the electrons from within the cells into the sensitive area of the chamber between the cathode and anode planes, the copper-lead platings are made in the form of strips each 3 mm wide and insulated from each other so that a potential of the order of 100 volts can be applied between the layers.

The gas filling is 30% CH_4 and 70% Argon at atmospheric pressure. This mixture was chosen since it has a high drift velocity[7] (10 cms/μsec) and thus minimizes the time spread for collecting electrons originating at different depths within the honeycomb structure.

Results

We have made measurements on the following parameters which are important for the operation of a positron camera; (a) spatial resolution, (b) time resolution, (c) detection efficiency.

These measurements were all performed using a test chamber with a sensitive area of 15 x 15 cm. A Na-22 positron source was used and the gamma rays incident on the chamber were collimated and timed by placing the source between the chamber and a small NaI crystal detector and recording coincidence counts between both

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detectors. For the spatial accuracy measurements we used in addition a 1.5 mm wide lead slit, placed over the front surface of the chamber, in order to define more precisely the position of the incident gamma rays.

Figure 4 shows the shape of various converter configurations that were tried in order to increase the detection efficiency. The saw-toothed shape in fig. 4a did not give any appreciable increase compared to a flat surface. The parallel trough of fig. 4b gave an efficiency of 0.7% while the simple box arrangement in fig. 4c gave only an efficiency of 0.8%. This last value was lower than expected and we attribute it to the lack of a drift field inside the trough. We then tried layered converters of the type shown in fig. 4d in which a drift field is created by applying a voltage of ~ 100 volts between each section. We made measurements on two-, three- and four-layer converters of this type: in general, with suitable drift voltages we found that the detection efficiency is proportional to the surface area.

The time resolution of the detector is also a function of the converter size and of the gas mixture. Using the 70% Ar - 30% CH_4 gas we found that the FWHM time spread increases from 100 nsec for a two-layer converter to 200 nsec for a four-layer converter.

The spatial resolution of the chamber was measured for all of these converter configurations and, in general, was the same for all, if the high energy portion of the spectral distribution is eliminated by using an upper level cut-off to eliminate large pulses that appear to be due to conversion electrons from the converter edges closest to the sensitive region of the chamber.

The measured distributions are shown in figs. 5 and 6 for three and four layers. The detection efficiencies for 0.51 MeV gamma incident at 0 ± 20° are 1.6%, 2.2% and 2.6% for the two-, three- and four-layer converters, while the spatial distribution has a FWHM of 4 mm for all types, after correction for the 1.5 mm collimating slit width.

Conclusions

A MWPC coupled to a layered lead converter provides a suitable detector for gamma rays from positron annihilation. A positron camera consisting of two such detectors with each box containing two separate wire chambers and four honeycomb converters can have a mean efficiency of ~ 10% for gamma incident in the angular range 0 ± 20°.

Assuming a positron camera consisting of two detectors with sensitive area 48 x 48 cms placed 50 cms apart with a resolving time of 200 nsec, we estimate that an 80 microcurie source will give 10,000 coincident events per sec with 10% accidentals.

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References

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Figure Captions

Fig. 1. Schematic configuration of the positron camera showing two MWPC detectors placed symmetrically with respect to gamma-emitting object.

Fig. 2. Schematic of wire chamber construction.

a. Sectional side view showing the relative positions of the lead converters and the three wire planes.

b. Top view showing cathode and anode planes as well as the X and Y delay lines coupled to the cathode planes.

Fig. 3. Photograph of detector box with one lid and one wire plane removed. Converters are not mounted.

Fig. 4. Schematics of various lead converter configurations.

a. Saw-toothed shape.

b. Simple trough.

c. Honeycomb box with no internal drift field.

d. Layered honeycomb for providing internal drift field.

e. Photograph of a section of four-layered converter.

Fig. 5. PHA output showing time spread of pulses provided by initial annihilation gamma rays measured in coincidence with NaI crystal.

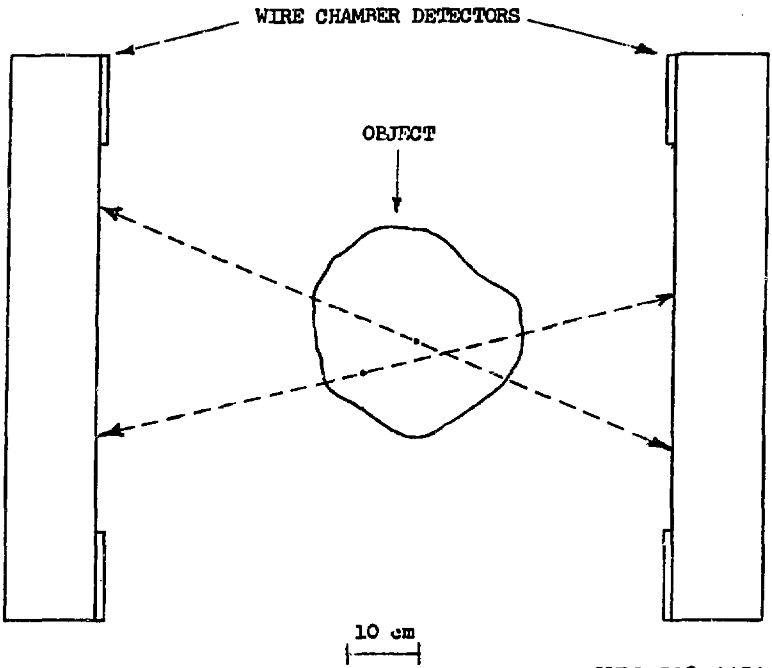
a. Three-layer converter.

b. Four-layer converter.

Fig. 6. PHA output showing spatial resolution along X or Y coordinate. Position of incident 0.51 MeV gamma defined by 1.5 mm lead collimator.

a. Three-layer converter.

b. Four-layer converter.



XBL 739-1171

Fig. 1

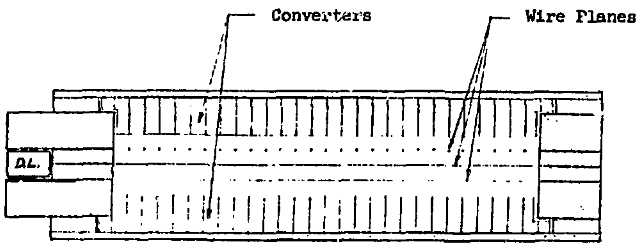
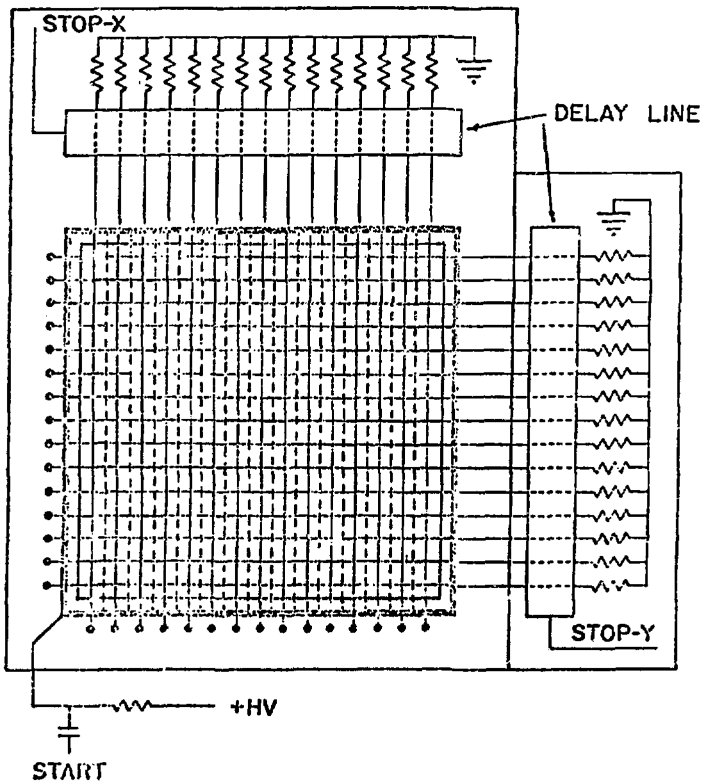


Fig. 2a



XBL 739-1173

Fig. 2b

XBB738-4857

Fig. 3

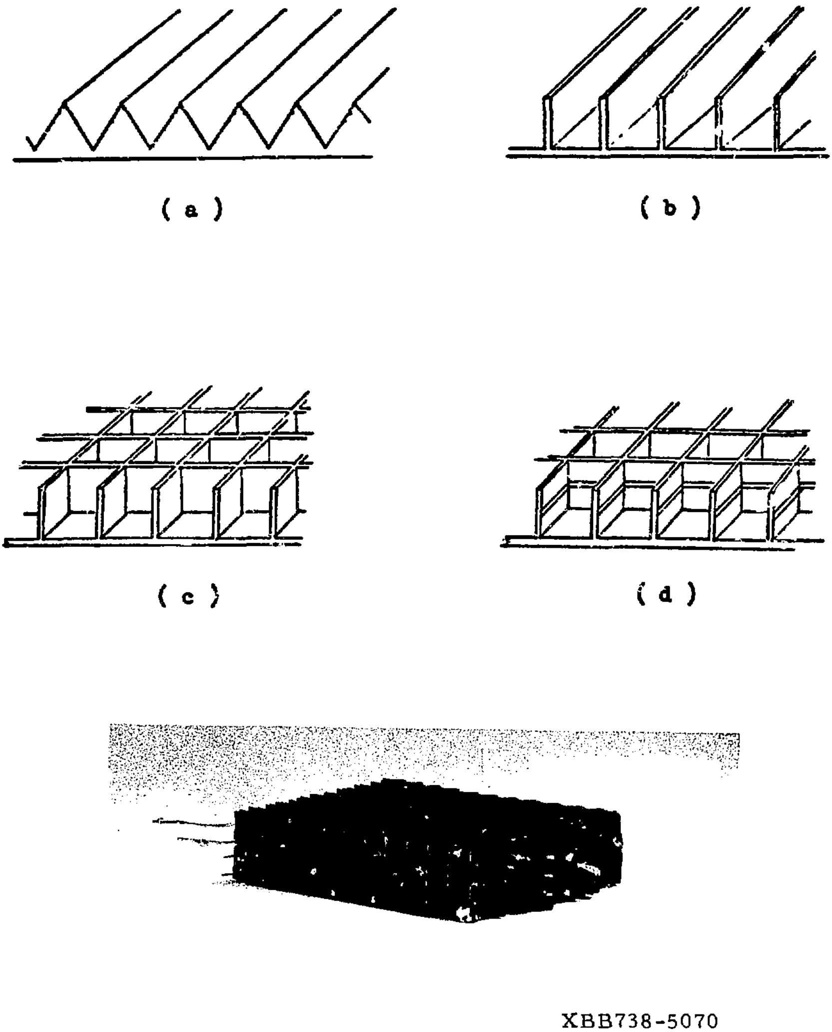
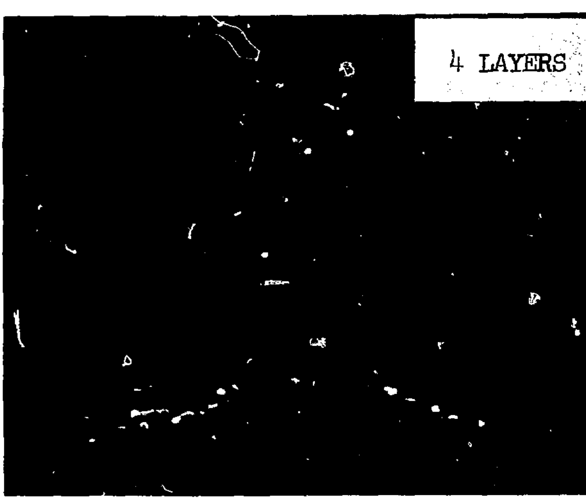


Fig. 4

110 ns/DIV.

(a)

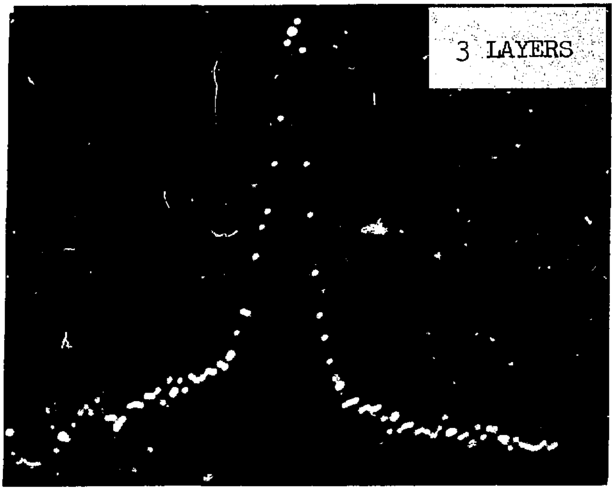


110 ns/DIV.

(b)

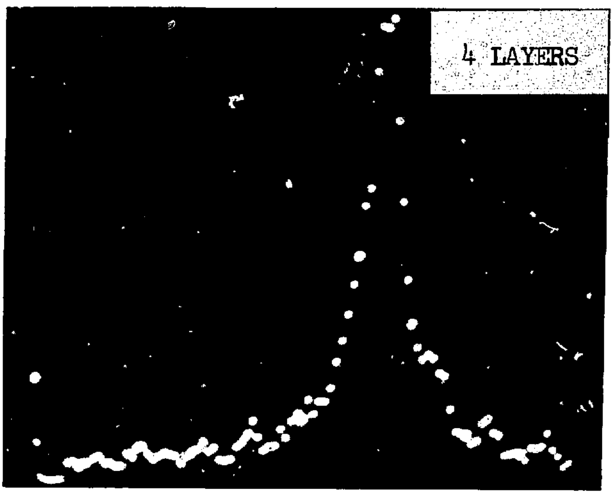
X_B739-5357

Fig. 5



5 MM/DIV.

(a)



5 MM/DIV.

(b)

XBB739-5356

Fig. 6