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ADAPTABLE GEOMETRY, LOW MASS HODOSCOPES USING CATHODE READ-OUT PROPORTIONAL CHAMBERS*

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ABSTRACT

The use of cathode read-out proportional chambers as large area, low mass hodoscopes has been investigated. Measurements of time resolution, space resolution, cathode multiplicity, and chamber capacitance effects are presented here. Comments about future applications are included.

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I. Introduction

The use of positive induced signals on the cathode planes of multiwire proportional chambers (MWPC) to obtain two coordinate read-out from a single gap has been extensively studied.[1-4]

Whereas anode planes are limited to linear coordinate measurements, a much greater flexibility in geometry exists for the cathode planes which can be divided into segments of almost arbitrary shape using printed circuit board fabrication techniques. Therefore, MWPC in which only the induced signal is read out, may provide an alternative to scintillation counter arrays when resolving times of >50 nsec can be tolerated. Further, these chambers are mechanically easy to build since the anode wires are not read out and can be at positive high voltage, while the cathode foils are at ground potential.

Three such hodoscope chambers are currently being constructed as part of the trigger system of the Large Aperture Solenoid Spectrometer (LASS) facility at SLAC.[5] In a solenoidal magnetic field such as LASS, the change in azimuthal angle, ϕ, between two planes perpendicular to the solenoid axis is inversely proportional to the longitudinal momentum (P_L) of a particle. The change in radial distance from the axis of the solenoid between two planes is approximately proportional to P_T/P_L, where P_T is the transverse momentum of a particle. Thus, the cathode foils for the LASS trigger chambers are divided into many ϕ slices and a number of radial regions. Requiring coincidences between radial regions of different planes within a $\Delta\phi$ band, enable an efficient selection of particles in almost any region of the P_T-P_L plane.[6]

In this article we present results of testing a prototype chamber and comment about future possible applications.

II. Prototype Chamber and Experimental Setup

The experimental setup is shown in Fig. 1. The MWPC used 20 μm gold-plated tungsten wire with a 4 mm wire spacing and a 4 mm cathode to anode gap. The anode wires were bussed together to positive high voltage through a 33 MΩ protection resistor. One of the cathode planes was fabricated from stretched continuous aluminum-Mylar laminate (.008 mm aluminum and .075 mm Mylar) whereas the other plane had the desired test pattern etched onto the aluminum by standard printed circuit board techniques. Several planes with different trial test patterns were used during these measurements and are described in the next sections. The gas mixture used was 76% argon, 20% isobutane and 4% methylal. The 4 mm wire spacing in this chamber did not allow the use of Freon in the gas mixture. Indeed, we observed a local loss of efficiency of approximately 3% for the addition of 0.1% Freon 13Bl, in agreement with previously published results.[7]

The measurements were performed using the electrons from a Sr^{90} source collimated to approximately 3 mm in diameter by the aluminum block in front of the counters S_1 and S_2 (see Fig. 1). The chamber was mounted between the source and the trigger counters on a travelling table which allowed precise horizontal movement.

Each of the strips on the test cathode plane were connected to 95 Ω shielded cable leading to a 16 channel amplifier board.[8] Prompt outputs of the amplifiers were put into coincidence with $S_1 \cdot S_2$ to monitor the efficiency of each strip. An overall efficiency was determined by "OR-ing" the individual signals in a coincidence with the trigger counters.

III. Experimental Results

A. Time Resolution and Efficiency

For trigger purposes, we require a time resolution of less than 100 nsec and a uniform efficiency across the entire cathode plane. To measure time resolution, the source was centered on a 1.2 cm wide strip (large compared to the 4 mm chamber gap) which was found to have an efficiency equal to that of the entire plane. The chamber logic output pulse width was fixed at 20 nsec and the counter gate pulse width was varied. Plateau curves for various gate widths are shown in Fig. 2 for a 250 μV amplifier threshold. Delay curves are shown in Fig. 3. It is apparent that for normal incidence 99% efficiency results from a gate width of approximately 40 nsec. This implies, when the finite width of the chamber logic pulse is taken into account, a time resolution of about 50 nsec for the chamber.

The efficiency was found to strongly depend on the separation between strips since the electric field can be appreciably perturbed by polarization charges on the Mylar. Spatial response curves[9] for a cathode plane of 1.2 cm strips separated by varying gaps is shown in Fig. 4. Uniform $\geq$99% efficiency results if the gap between strips is less than 2 mm for our particular chamber geometry. Printed circuit board type artwork can easily meet this requirement.

Because the LASS trigger chamber cathode foils will be divided into different radial regions, the lower region signal traces run alongside of the upper radial region strips. Thus, a false signal could be received, if these traces are not desensitized. A possible solution is to cover the trace with an appropriate dielectric. To investigate this, the cathode foil shown in Fig. 5a was constructed with one strip one-half covered with an insulating material.[10] The spatial response curves in Fig. 5b show the resulting loss of efficiency. (The small bump after the dip in efficiency is a 1 mm wide uncovered trace.) Covering these traces with the appropriate dielectric will eliminate the possibility of receiving spurious radial coordinates and will not disturb the electric field as long as the width is small enough (< 2 mm).

The chamber efficiency was also investigated for foils in which the strips were perpendicular to the anode wires. The results of these tests were to show no difference in the efficiency between strips running parallel to, or perpendicular to the anode wires. This result should have great interest for two coordinate read-out applications that require cylindrical or other non-rectangular geometries.

B. Space Resolution

Space resolution curves were measured for 3 mm wide strips separated by 1 mm (Fig. 6a) and for 1.5 mm strips also separated by 1 mm (Fig. 6b), at a high voltage of 2300 volts and an amplifier threshold of 200 μV. Due to the intrinsic spread of the induced charge, only a slight decrease in the width of a resolution curve for a single strip is observed, although the strip width has been halved.

C. Cathode Multiplicity

The average number of 3 mm strips hit as a function of chamber voltage for normal incidence is plotted in Fig. 7a. The mean cathode multiplicity increases from 2.5 to 2.9, for high voltages of 2.2 kV to 2.45 kV.

In order to obtain better resolution for events in which the cathode multiplicity is high, center finding methods are necessary. For our trigger purposes, we require a fast (< 50 nsec delay) and reliable method of finding the center of a cluster of signals on the cathode plane. Fast analog methods of determining the strip with the maximum induced signal have been investigated.[11] However, due to noise and timing difficulties, the analog method has been rejected in favor of a simple digital center finding circuit. Such a digital method of determining the number of segments hit within a cluster is presently under construction and will find the center of a cluster to an accuracy of approximately one-half strip width.[6]

Since these hodoscopes are to be used in a multiparticle spectrometer measuring particles produced at all angles, it is important to study the multiplicity of hits as a function of the angle of incidence on the chamber. The measurements are shown in Fig. 7b, where the number of 3 mm strips hit is plotted as a function of angle. The chamber was operated at 2250 V and an amplifier threshold of 200 μV. The mean number of strips increases from 2.5 for normal incidence, to 3.5 for 50° from normal.

D. Chamber Capacitance Effects

Capacitance effects relevant in going from the prototype size chamber to the final larger trigger chambers have also been investigated. External capacitors were used to simulate increasing mutual capacitance between strips and larger anode to cathode capacitance. Cathode to anode capacitance of up to 100 pf (corresponding to approximately 450 cm^2 of cathode) caused no loss of efficiency. Increasing this capacitance beyond 100 pf could endanger the safety of the proportional chamber if sparking occurred and, since the capacitance of the proposed chambers is within this range, no further measurements were taken. An increase of greater than 400% ($\sim$ 2 pf for our test geometry) in mutual capacitance between strips, resulted in sharing of the induced signal between strips. Neither of these limits should severely restrict the construction of very large chambers.

IV. Conclusions

The results presented above show that hodoscopes using multiwire proportional chambers in which only the positive induced signals are read out can be versatile particle detectors. Time resolution of approximately 50 nsec and uniform efficiency of greater than 99% can be achieved, while spatial resolution of 1-2 mm appears possible with fast center-finding electronics. A high degree of flexibility in designing the geometry of the cathode planes is inherent in the printed circuit techniques that can be used to fabricate the cathode foils. Construction of very large chambers (2 m $\times$ 2 m) is highly feasible since anode wires can be coarsely spaced. There is, however, a limitation on the maximum area covered by a single hodoscope element due to capacitance effects—a conservative limit is about 450 cm^2.

MWPC with induced read-out provide a lower mass, lower cost, and higher spatial resolution alternative to scintillation counters when time resolution of 50 nsec is acceptable. The main advantage rests on the flexibility and simplicity afforded by the "printed circuit" cathode. For application where a low mass detector is not required, the pattern on the cathode can be even more complicated or more segmented by using a double-sided printed circuit board. These qualities make such chambers a practical alternative when space limitations occur or small granularity is essential, rendering the use of scintillators and light pipes untractable.

We would like to thank A. Kilert, D. McShurley, and B. Walsh for their help in constructing the prototype chamber and test foils, and D. Hutchinson and S. Shapiro for many useful conversations regarding the read-out electronics.

Footnotes and References

1. G. Charpak, D. Rahm and H. Steiner, Nucl. Instr. and Meth. 80 (1970) 13.
2. G. Fischer and J. Plch, Nucl. Instr. and Meth. 100 (1972) 515.
3. G. Charpak and F. Sauli, Nucl. Instr. and Meth. 113 (1973) 381.
4. J. Jeanjean et al., Nucl. Instr. and Meth. 117 (1974) 349.
5. The spectrometer is described in detail in SLAC Proposal E109, R. K. Carnegie, M. Davier, M.G.D. Gilchriese, D. Hutchinson, W. B. Johnson, D.W.G.S. Leith, L. Lyzwanski, P. Schacht, S. Shapiro, S. H. Williams, Stanford Linear Accelerator Center; G. Fox, R. Gomez, H. Jensen, M. Marshall, J. Pine, California Institute of Technology; C. Y. Chien, L. Madansky, A. Pevsner, R. Zdanis, Johns Hopkins University.
6. These chambers are briefly described in SLAC Proposal E109, R. K. Carnegie et al., and are currently under construction. A more detailed description of the chambers and their properties is to be published— B. Bertolucci, M. Davier, M.G.D. Gilchriese, D. Hutchinson, D.W.G.S. Leith, A. Kilert, P. Kunz, P. Schacht, S. Shapiro and C. Woody, Stanford Linear Accelerator Center.
7. B. Dieterle et al., Nucl. Instr. and Meth. 116 (1974) 189.
8. A description of the read-out electronics for the LASS multiwire proportional chamber system to be published—S. Shapiro, M. Davier, B. Friday and M.G.D. Gilchriese, Stanford Linear Accelerator Center.
9. No correction has been made in any of the spatial response or space resolution curves for the 3 mm width of the source.
10. Scotchcast polyurethane resin #225.
11. M.G.D. Gilchriese and D. Hutchinson, LASS Note #3, Stanford Linear Accelerator Center.

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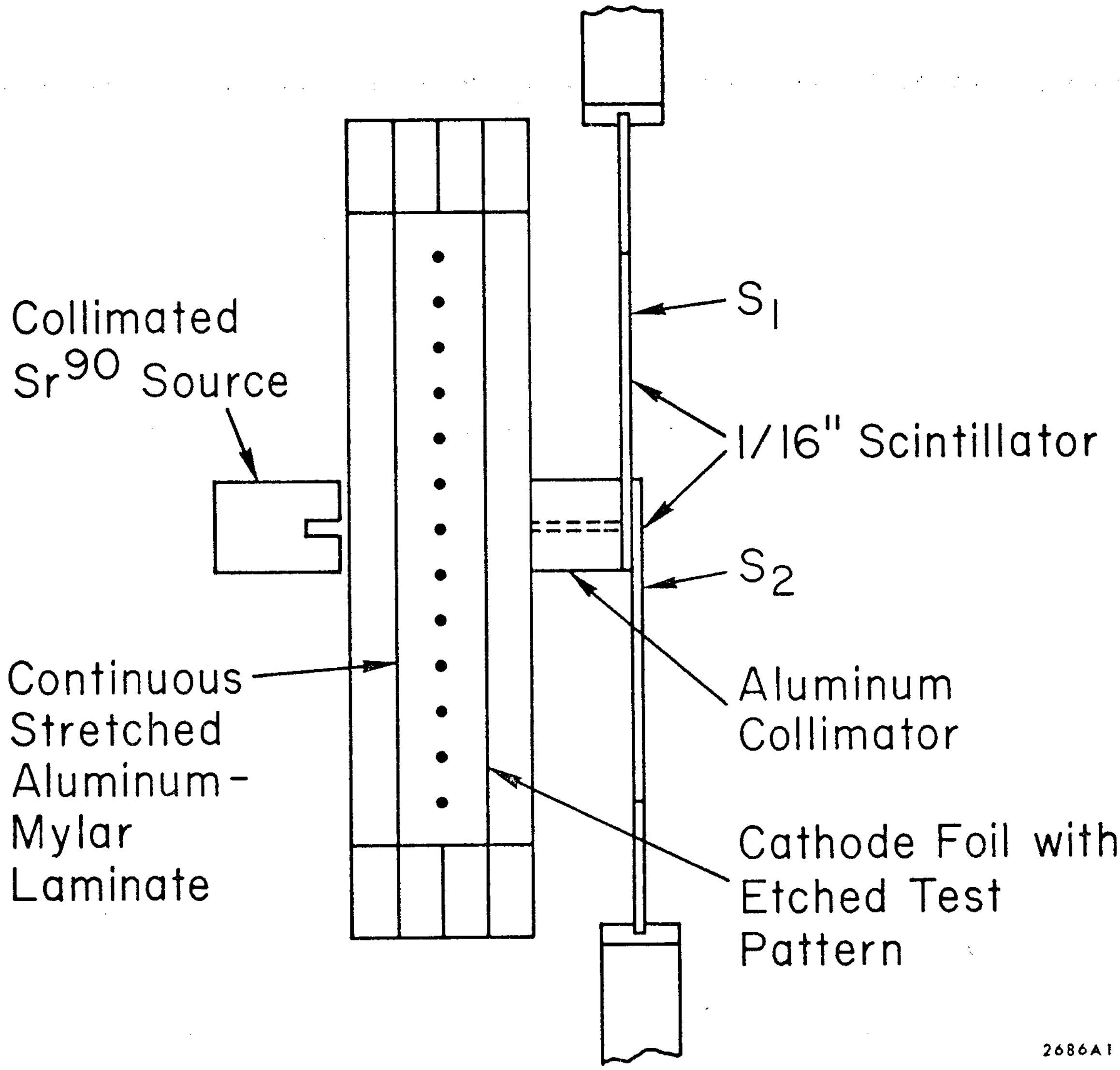
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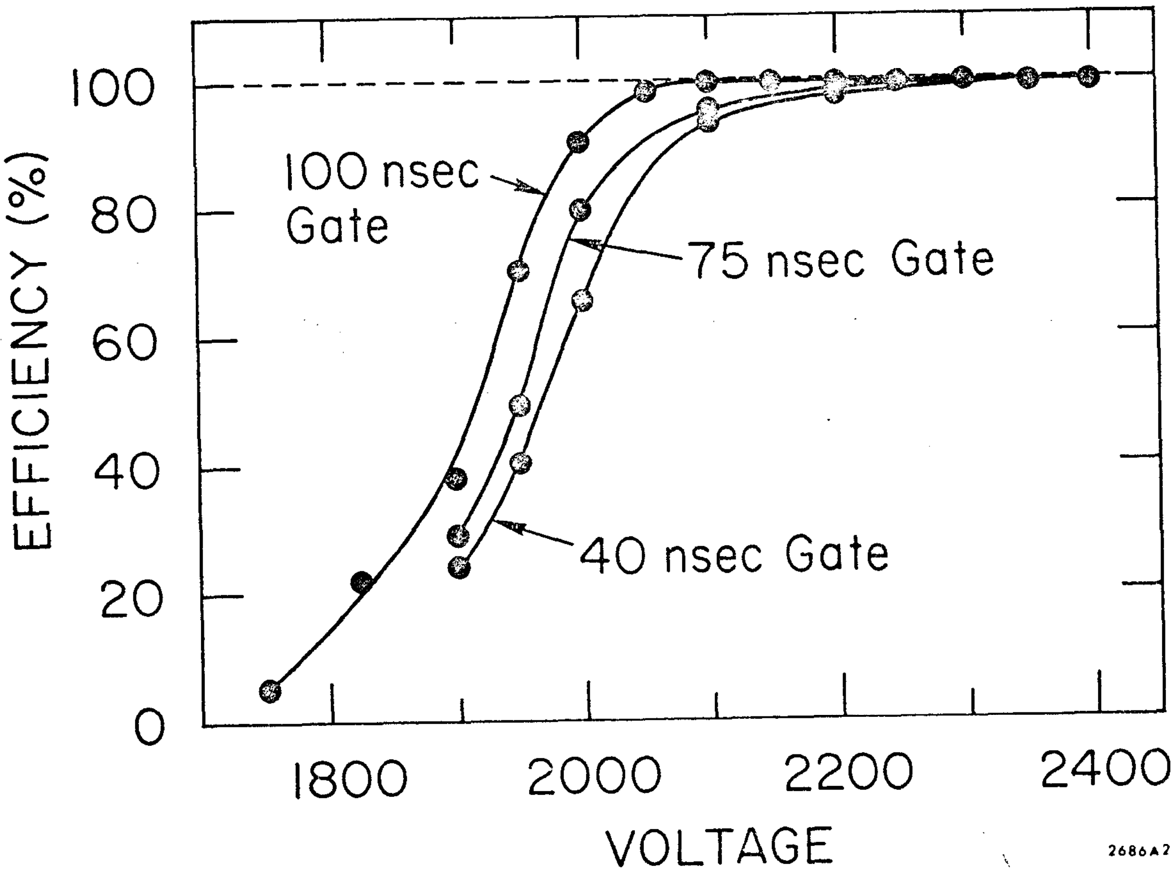
Continuous
Stretched
Aluminum-
Mylar
Laminate
S1
1/16" Scintillator
S2
Aluminum
Collimator
Cathode Foil with
Etched Test
Pattern
2686A1

Fig. 1



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20
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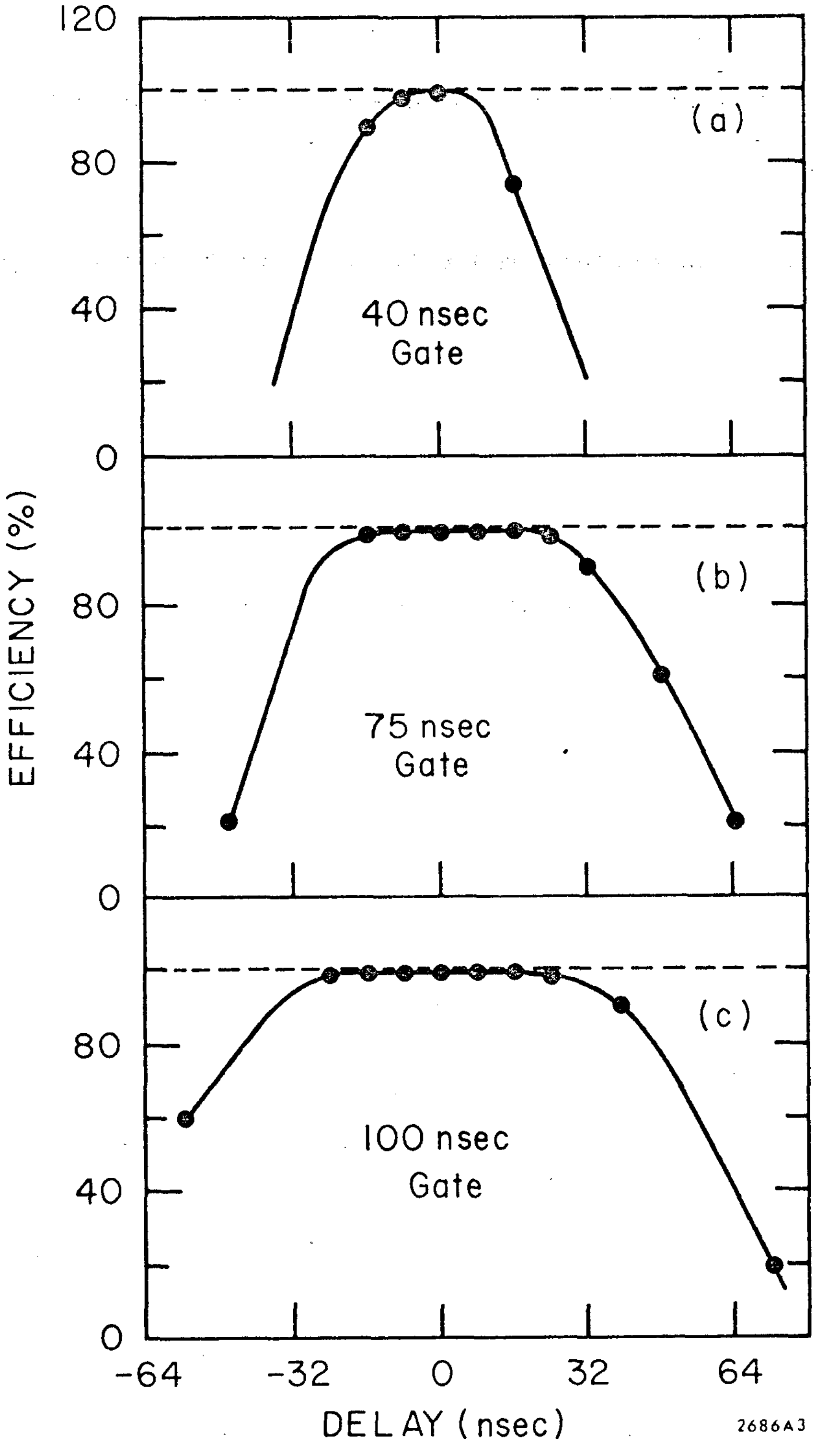
VOLTAGE
2686A2

Fig. 2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80
40
0
(a)
40 nsec
Gate
80
40
0
(b)
75 nsec
Gate
80
40
0
(c)
100 nsec
Gate
EFFICIENCY (%)
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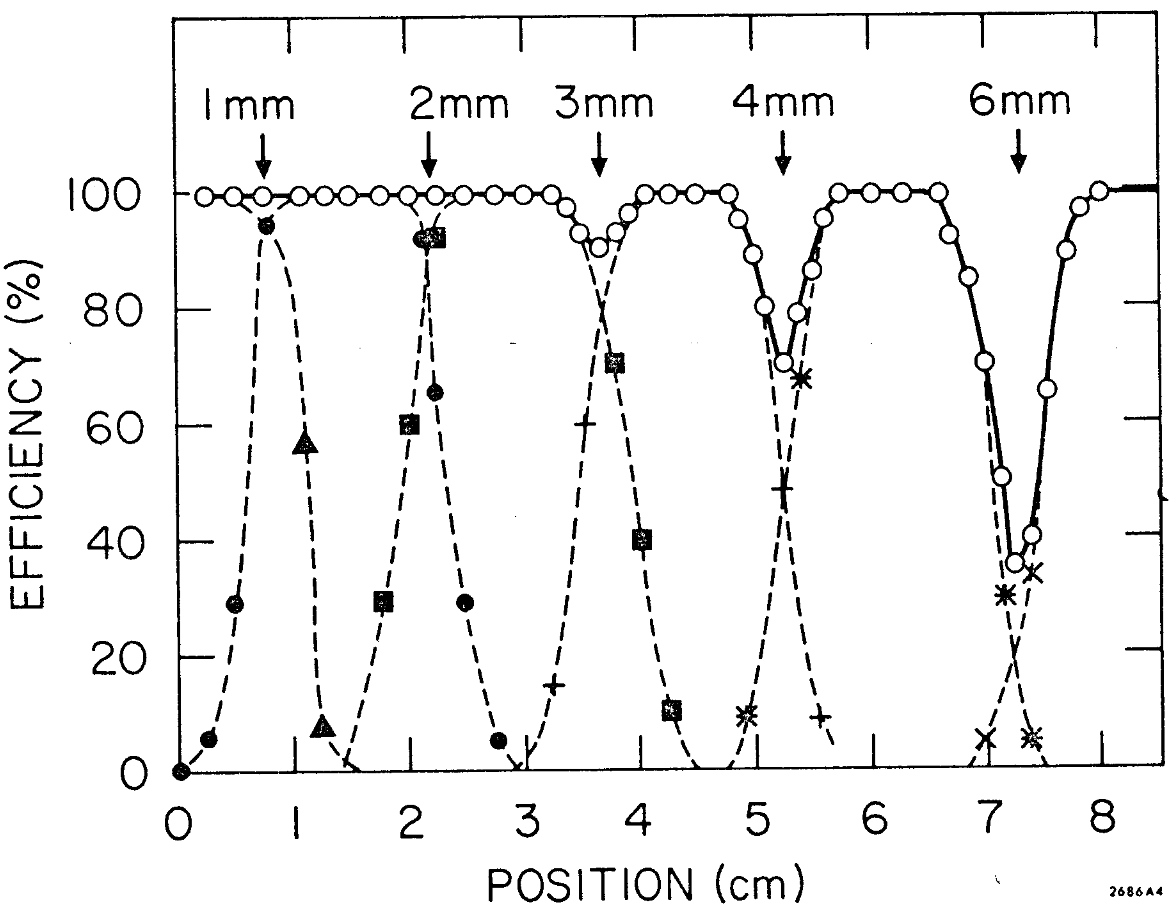
-32
0
32
64
DELAY (nsec)
2686A3

Fig. 3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2mm
3mm
4mm
6mm
100
80
60
40
20
0
EFFICIENCY (%)
0
1
2
3
4
5
6
7
8
POSITION (cm)
2686A4

Fig. 4

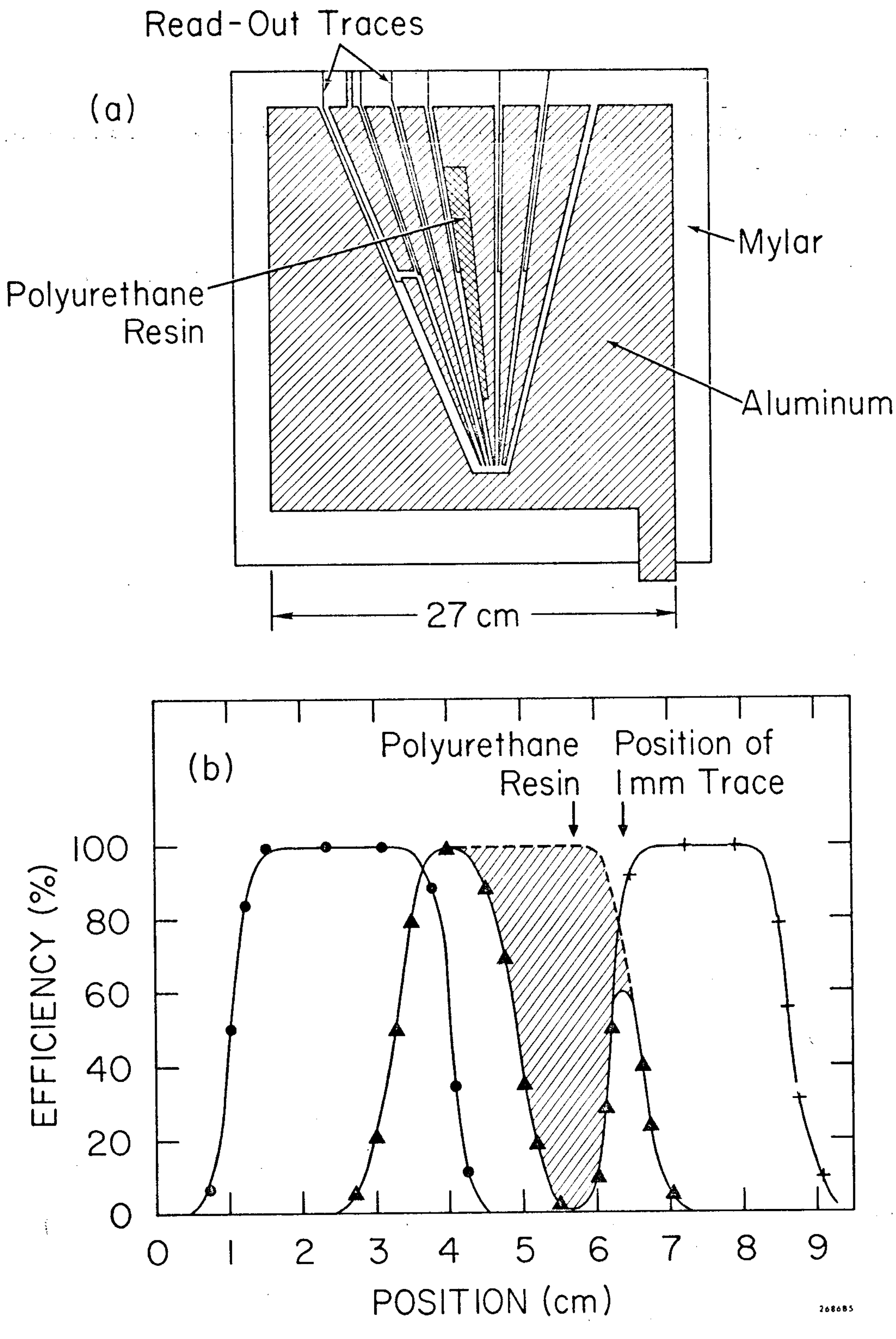

Read-Out Traces
(a)
Mylar
Polyurethane Resin
Aluminum
27 cm
(b)
Polyurethane Resin
Position of 1mm Trace
100
80
60
40
20
0
EFFICIENCY (%)
0
1
2
3
4
5
6
7
8
9
POSITION (cm)
268685

Fig. 5

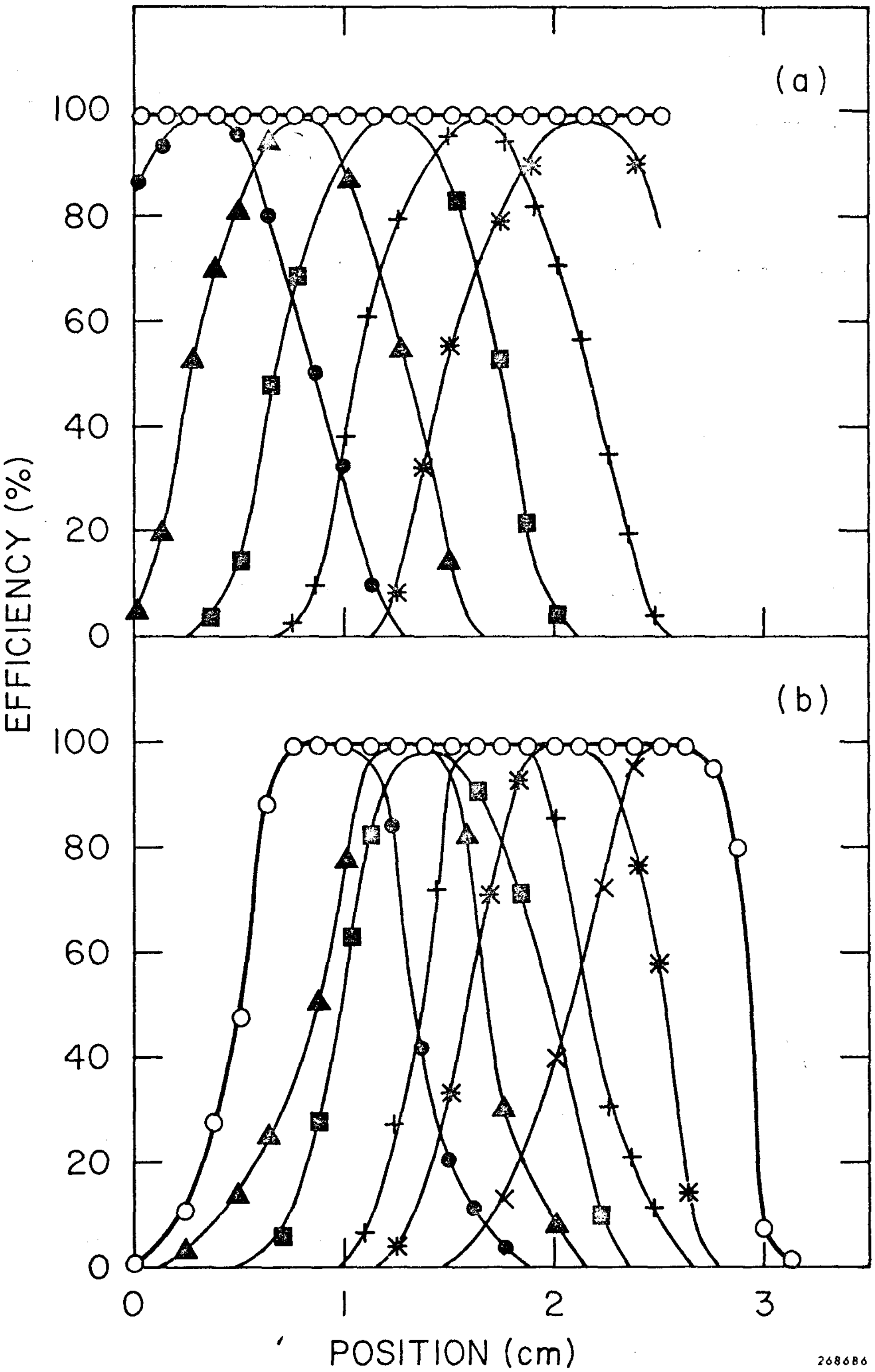
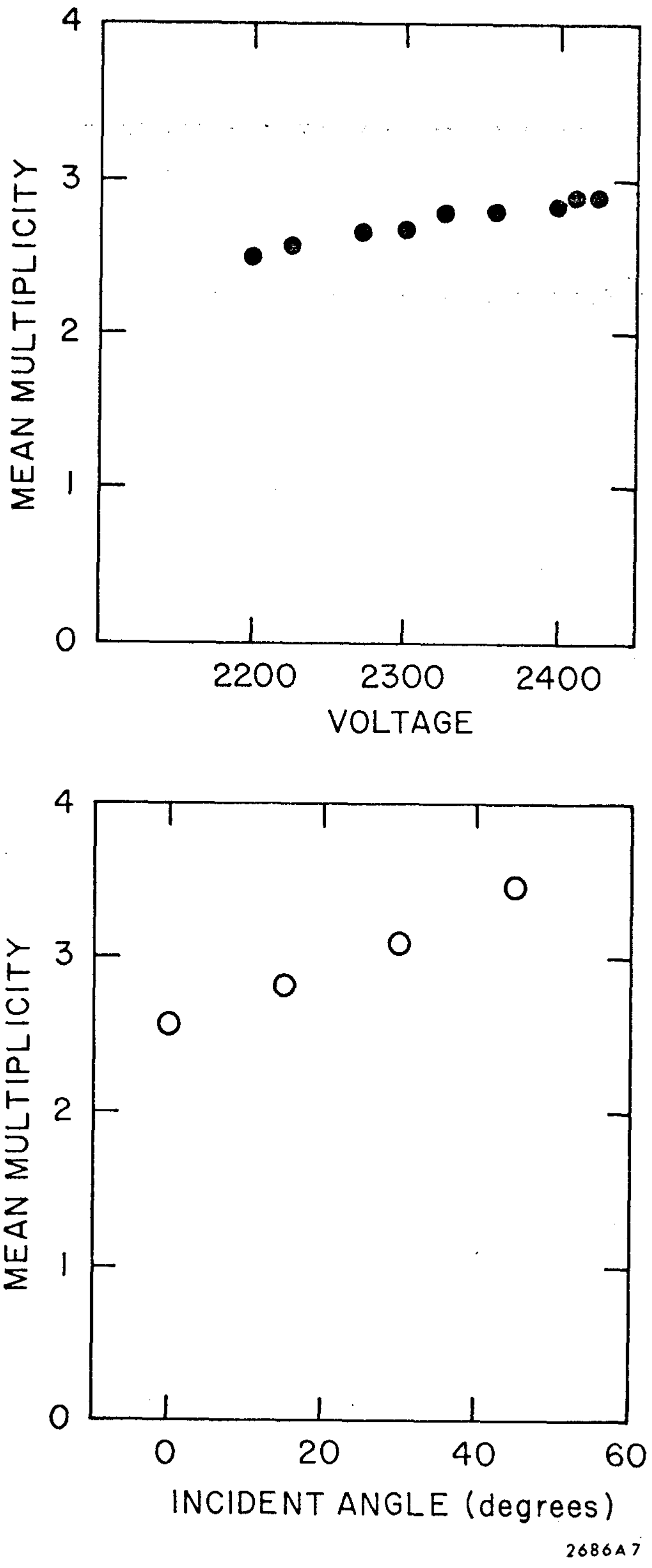


Fig. 6



MEAN MULTIPLICITY
0
1
2
3
4
2200
2300
2400
VOLTAGE
MEAN MULTIPLICITY
0
1
2
3
4
0
20
40
60
INCIDENT ANGLE (degrees)
2686A7

Fig. 7