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HIGH SPATIAL RESOLUTION PROPORTIONAL CHAMBERS

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For reactions occurring at high energies in which the secondaries are produced in a very tight forward cone, the importance of high spatial resolution detectors becomes increasingly important. The pioneering work of Charpak[1] indicated that wire chambers operating in the proportional mode of gas multiplication might not only have the possibility of high spatial resolution but be capable of high repetition rates, provide good timing information, be capable of operation in magnetic fields, and also have high multiparticle efficiencies. Subsequent to this early work others[2,3,4,5,6] using similar chamber construction have demonstrated successful operation with wire spacing of a few millimeters. We wish to investigate the operation of chambers with wire spacing of one millimeter as a function of various operating parameters.

Figure 1 shows a cross sectional view of the chamber. Wires of 20 micron gold plated molybdenum were wound on an epoxy-glass frame with a spacing of one millimeter. The wires were then glued to the frame. The chamber was constructed of aluminum and the thin windows served as cathode planes. It was designed to operate at pressures of up to five atmospheres. The spacing of the cathode planes was increased at the epoxy-glass insulator frames to prevent corona discharge. Aluminum guard sheets were sandwiched between the wire plane and cathodes to eliminate the field gradient at the wires between the epoxy-glass frames and provide shielding and a good transmission path for the proportional pulses. With these features the chamber could be operated up to 4000 V at pressures of a few atmospheres.

We find that good shielding of the proportional chambers and proper AC decoupling of the amplifier power supplies is essential. In our design the chamber is enclosed in a copper foil lined wooden box to provide shielding. The ground side of all input and output connectors are soldered to this foil. The DC potentials for the amplifiers are supplied through shielded cables and enter the box through feed through capacitors. With these precautions we have had no difficulty operating our detector within 10 meters of spark chambers and 3 meters of beam transport power supplies.

A section of the amplifier schematic is shown in Figure 2. The amplifier was designed by W. Sippach of Nevis Laboratories and incorporates the use of MECL II integrated circuits. The circuitry for eight wires consisting of a three stage amplifier, a discriminator, and a line receiver for each wire was contained on a single board of about 3 x 6 inches in size. This board also contained an eightfold 'OR' circuit to sum the number of pulses from the eight wires. Care was taken in this design to provide high gain as well as good stability. The discriminator thresholds were adjusted to accept pulses above about 800 microvolts with a minimum width of 50 nanoseconds at the input of the amplifier. Our test chamber consisted of 40 wires of which the center eight were connected to amplifiers and the rest on each side of these were kept at ground potential to insure uniform fields across the center eight.

Tests of this chamber were conducted at Argonne National Laboratory in a spatially separated beam of 2.1 GeV/c π^+. With the geometry shown in Figure 3 about 10^5 pions per pulse traversed the sensitive area of the chamber. The beam was identified geometrically by three small plastic scintillators shown in Figure 3. Relevant parameters of the chamber were determined relative to triple coincidences obtained from this beam telescope. The entire box containing the chamber was mounted on a micrometer stage which could be adjusted relative to the beam telescope with a precision of .001 inch.

To observe the proportional pulses before the amplifier individual wires were connected to ground through 6.8 kΩ resistors. An oscilloscope connected across these resistors displayed the pulse shapes produced by the minimum ionizing particles. The rise time of these pulses was about 50 nanoseconds and varies in amplitude from 0.5 - 20 mV. The majority of the pulses were between 1 and 10 mV. Measurements were made with the following gas mixtures: 8% CO_2 + 92 Ar, 20% i-C_4H_{10} + 80% Ar, 50% i-C_4H_{10} + 50 Ar and 10% CH_4 + 90% Ar. The

10% CH_4 + 90% Ar mixture appeared to be the more suitable for these narrow gap chambers since it produced large pulses with good quenching and was used for all subsequent tests. The probability of having simultaneous pulses on two adjacent wires was about 2%, of having simultaneous pulses on three adjacent wires less than 0.1%. This indicates the chamber spatial resolution is comparable to the wire spacing. For these tests the circuit board was coupled to the wires by multipin connector and the positive output pulses were inverted and fed into fast logic modules and recorded on 100 MHz scalers. We measured the minimum time between the passage of the charged particle and the appearance of the proportional pulse after the discriminator to be about 35 nanoseconds.

Figure 4 shows the variation of chamber efficiency as it was moved across the pion beam defined by the scintillators. The observed width is that expected from the eight sampled wires. The peak efficiency approaches a hundred percent. The steep sides of the distribution are that expected from the sizes of the plastic scintillators. This efficiency was obtained with HV1 = 1500 V and HV2 = 2600 V at atmospheric pressure. To produce higher field gradients near the wires and provide sufficient number of primary electrons we have selected this asymmetric[3] positioning of the cathode planes as shown in Figure 1. An attempt was made to investigate the efficiency as a function of HV1 and HV2. The results are shown in Figures 5 and 6.

The above tests were made at atmospheric pressure, however, we investigated the pressure dependence of the time distribution of the proportional pulses. To accomplish this we have used a time to amplitude converter whose output was fed into a multichannel analyzer. The results are shown in Figures 7a and 7b. At each pressure an attempt was made to adjust the voltages (HV1 and HV2) to obtain maximum efficiency. These voltages are listed in Table I. At a pressure of 0.83 atmosphere the minimum width, 30 nanoseconds, was obtained. Because of the fixed threshold leading edge triggering of the discriminator, systematic delays are expected due to the various pulse amplitudes. Our measurements reveal that FWHM of the time distribution of the systematic delays is about 22 nsec. From these results we conclude that electron drift time is less than 10 nanoseconds.

We are encouraged by these results and feel that chambers even with higher spatial resolutions may result from further development.

We would like to thank S. Dhawan of Yale University for the construction of the circuit boards, C. Kerns for many contributions to the electronics, A. A. Wehmann and G. Chartrand for assistance in the tests and A. Roberts and J. Sculli for many useful discussions. We also appreciate the hospitality of the Argonne National Laboratory, in particular D. D. Jovanovic, for making the beam available to us. Without the support and encouragement of A. L. Read and J. R. Sanford this work would not be possible.

TABLE I

Pressure (atmospheres)	HV1 (volts)	HV2 (volts)	% Efficiency
0.50	1100	1500	49
0.65	1160	2040	98
0.83	1310	2300	100
1.00	1500	2600	100
1.68	1900	3300	86
2.36	2000	3700	75
3.04	3000	4000	70

FIGURE CAPTIONS

Figure 1. Proportional Chamber Construction

Figure 2. Amplifier Schematic

Figure 3. Chamber Test Geometry

Figure 4. Chamber Efficiency versus Position

Figure 5. Chamber Efficiency versus HV1

Figure 6. Chamber Efficiency versus HV2

Figure 7a. and Figure 7b. Relative Time Delay as a Function of Gas Pressure

REFERENCES

[1]G. Charpak, R. Bouclier, T. Bressani, J. Favier, and C. Zupancic, Nucl. Instr. and Meth. 62 (1968) 262.

[2]C. Bemporad, W. Beusch, A. C. Milissinos, E. Schuller, P. Astbury, and J. G. Lee, CERN Report, May 3, 1969.

[3]T. Nunamaker and M. Neumann presented at the Twelfth Scintillation and Semiconductor Counter Symposium.

[4]G. Charpak, D. Rahm, and H. Steiner, CERN Preprint, September 27, 1969 (submitted to Nucl. Instr. and Meth.).

[5]L. J. Koester, R. M. Brown, U. Koetz, and S. Segler, and R. Taylor, Proceedings of the Ispra Nuclear Electronics Symposium, Ispra, Italy (1969).

[6]L. J. Koester, Jr., U. Koetz and S. Segler, University of Illinois Report COO-1195-176, December 1969.

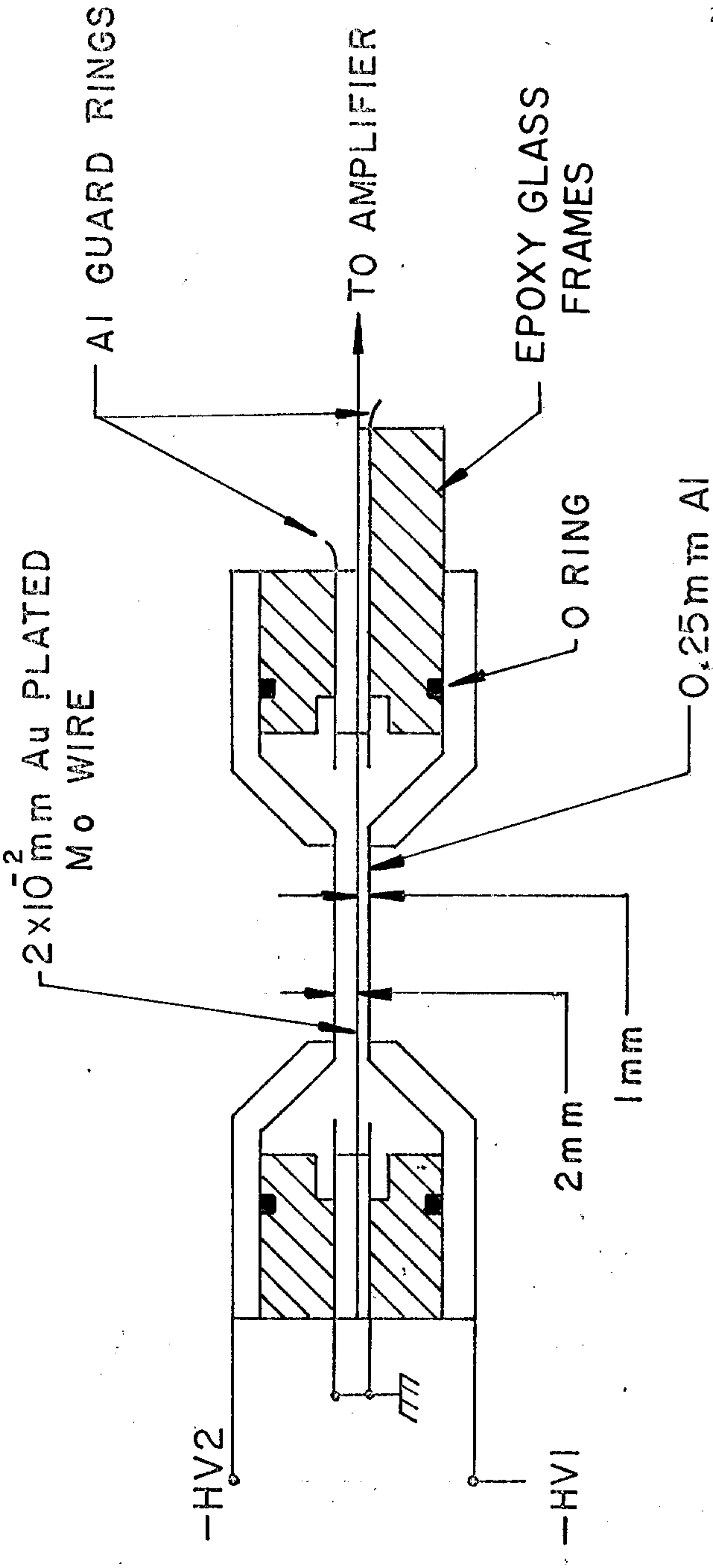
Al GUARD RINGS
TO AMPLIFIER
EPOXY GLASS FRAMES
2×10^{-2} mm Au PLATED Mo WIRE
O RING
0.25 mm Al
2 mm
1 mm
-HV2
-HV1

Figure 1

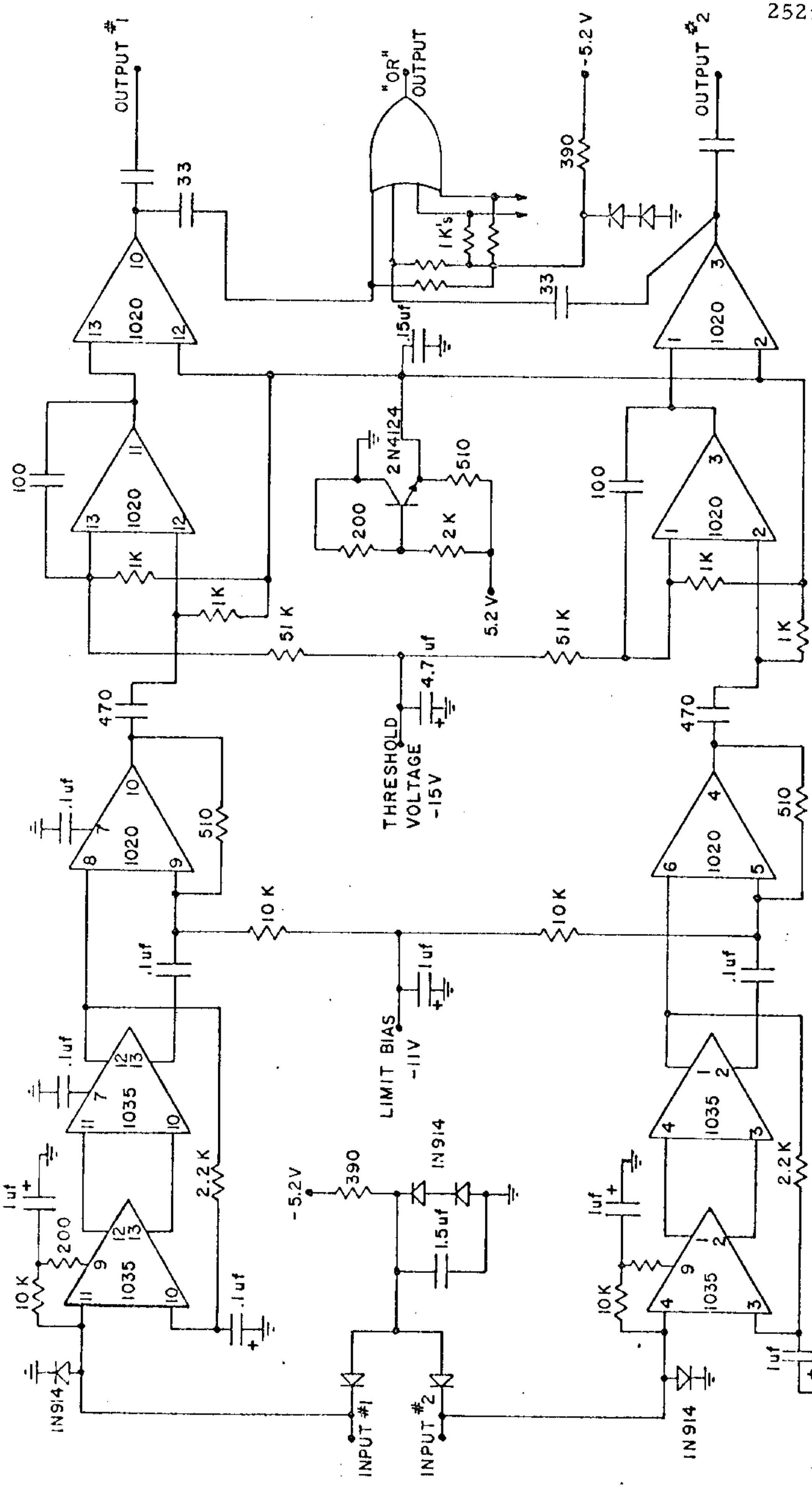
OUTPUT #1
OUTPUT #2
"OR" OUTPUT
-5.2 V
390
1K's
33
33
.15uf
2N4124
510
200
2 K
5.2 V
100
100
1020
1K
1K
1K
51 K
51 K
4.7 uf
470
470
THRESHOLD
VOLTAGE
-15V
510
510
.1uf
10 K
10 K
1uf
LIMIT BIAS
-11V
1035
2.2 K
2.2 K
-5.2V
390
1N914
1.5uf
200
10K
10K
1uf
INPUT #1
INPUT #2
1N914
1N914

Figure 2

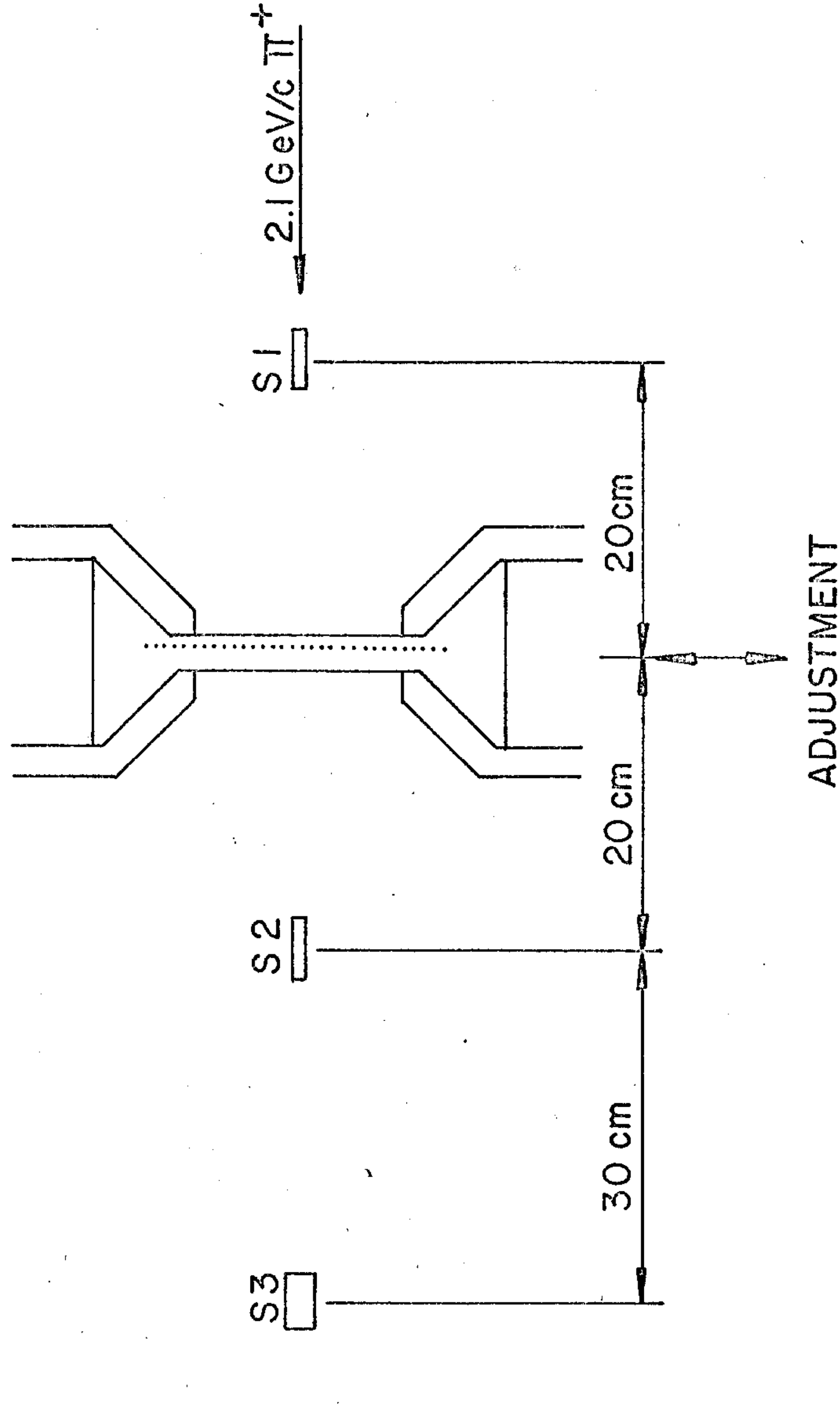

Figure 3

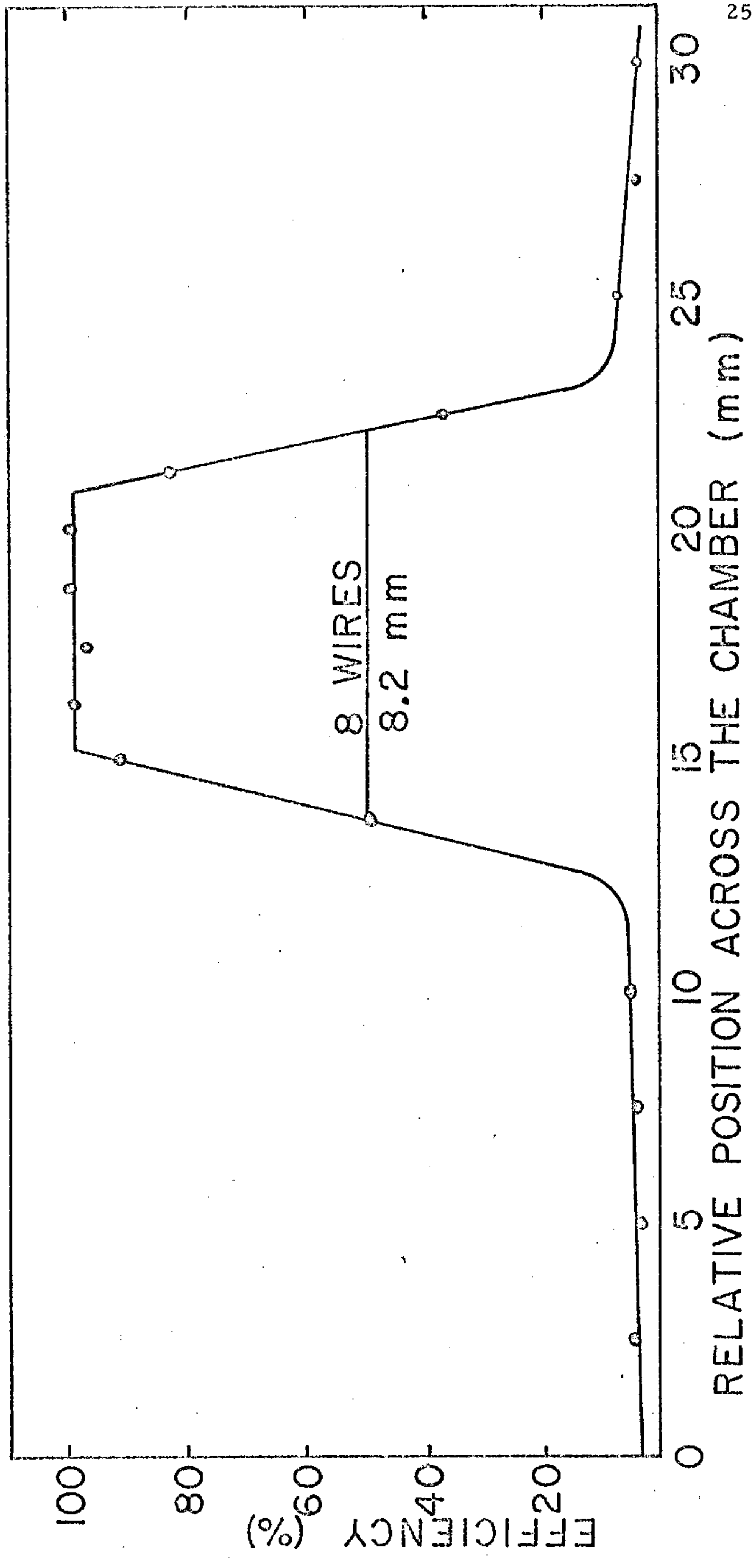
EFFICIENCY (%)
100
80
60
40
20
0
5
10
15
20
25
30
RELATIVE POSITION ACROSS THE CHAMBER (mm)
8 WIRES
8.2 mm

Figure 4

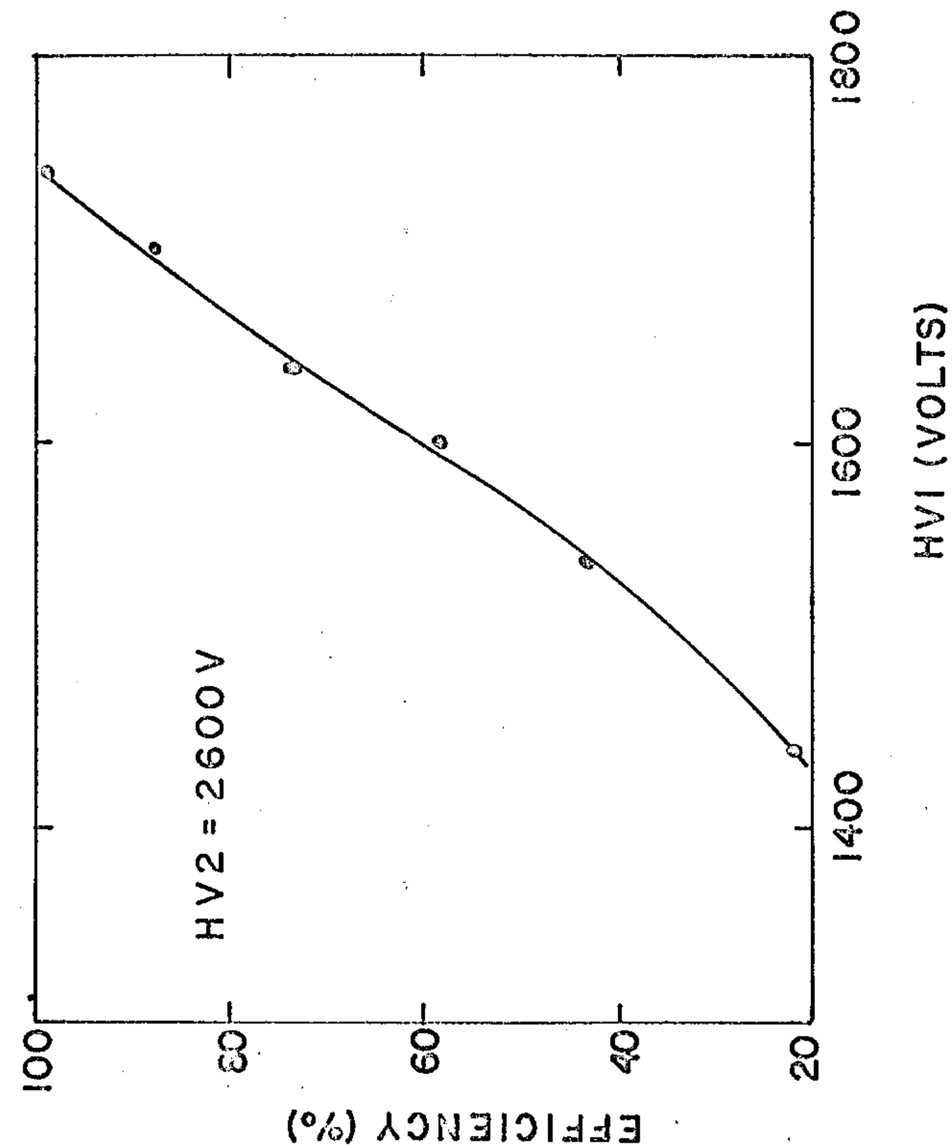

Figure 5

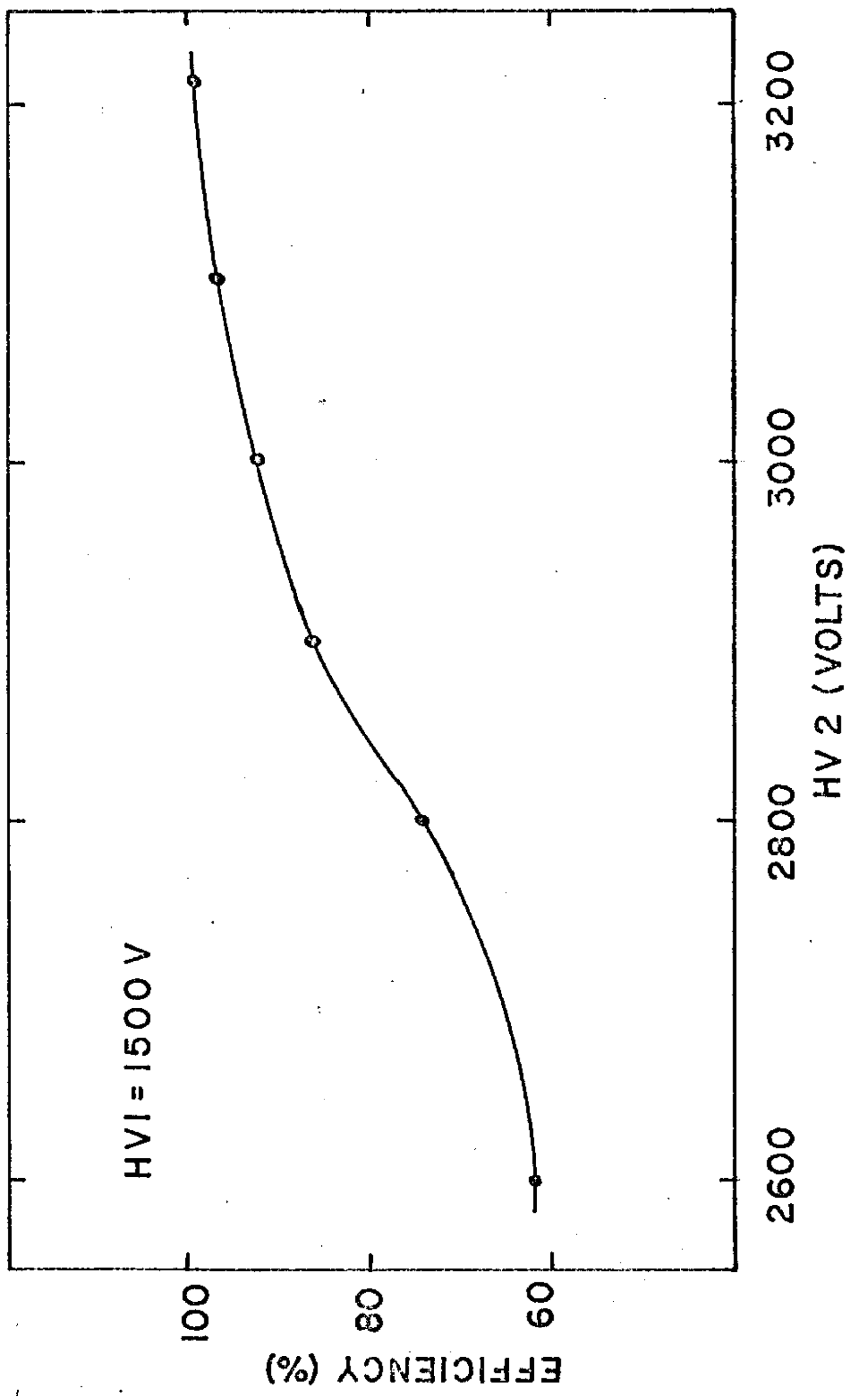

Figure 6

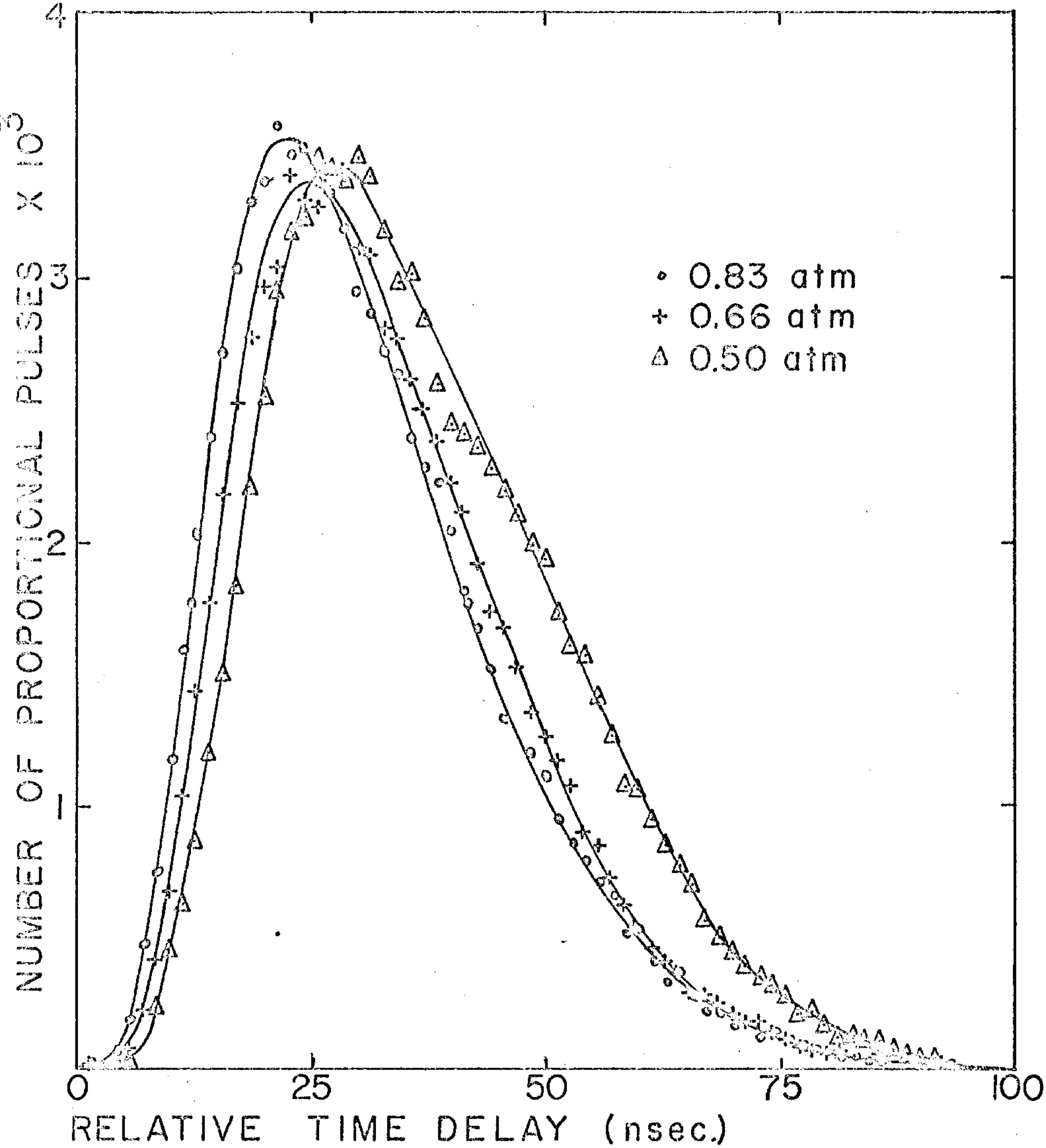
NUMBER OF PROPORTIONAL PULSES X 10^3
4
3
2
1
0
25
50
75
100
RELATIVE TIME DELAY (nsec.)
○ 0.83 atm
+ 0.66 atm
△ 0.50 atm

Figure 7a

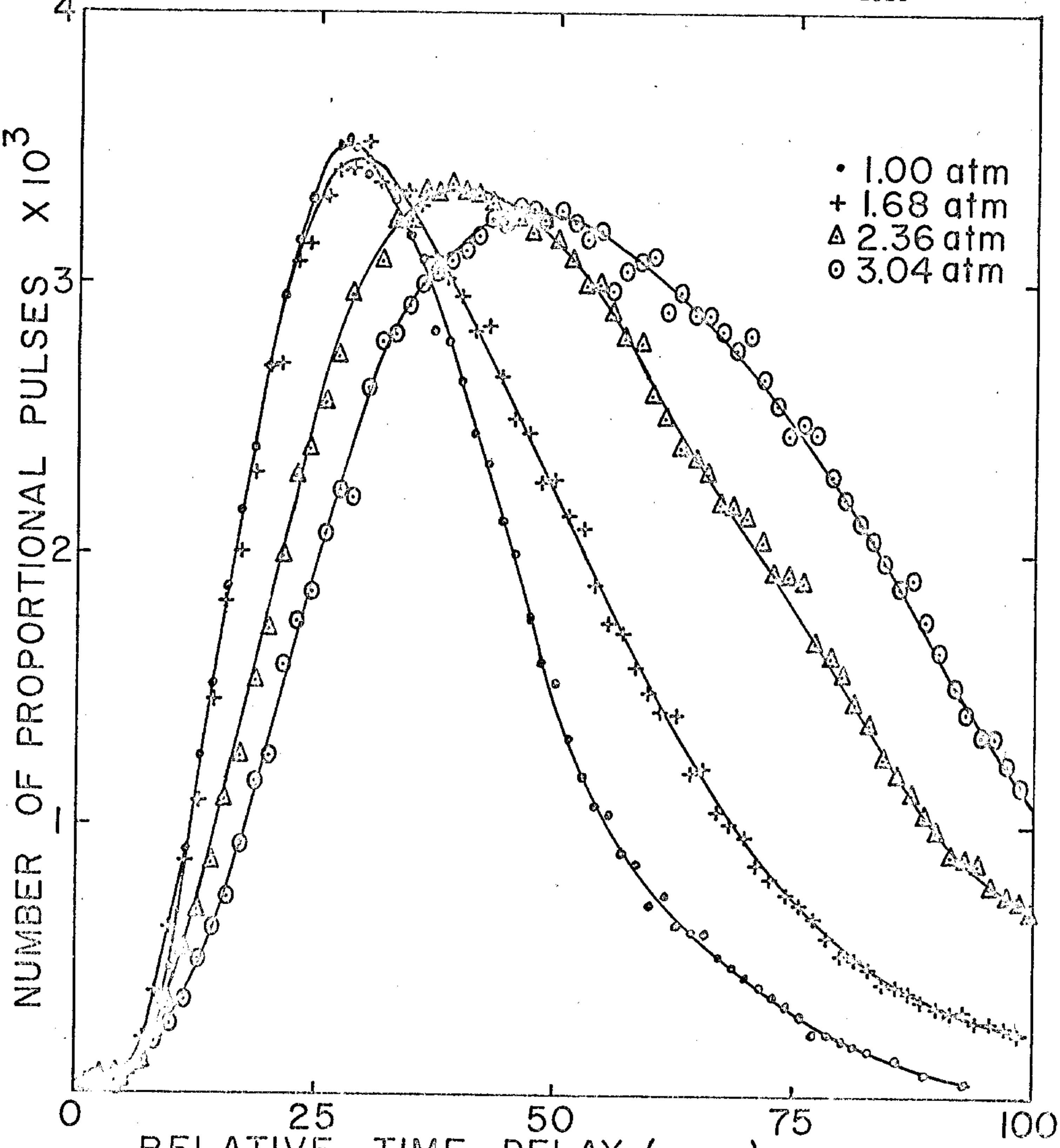
NUMBER OF PROPORTIONAL PULSES X10^3
RELATIVE TIME DELAY (nsec)
0
1
2
3
4
25
50
75
100
• 1.00 atm
+ 1.68 atm
Δ 2.36 atm
⊙ 3.04 atm

Figure 7b