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DESIGN, CONSTRUCTION, AND OPERATIONAL CHARACTERISTICS OF A PROPORTIONAL BEAM HODOSCOPE SYSTEM*

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Introduction

In this paper we describe a high-resolution beam hodoscope system consisting of 4 proportional wire chamber planes of 1 mm wire spacing (Fig. 1). This system is currently in use in a secondary beam at SLAC in conjunction with a wire spark-chamber spectrometer; its main purpose is to measure the position of beam particles before they strike a liquid hydrogen target. In order to match the resolution of the spectrometer and allow the accurate finding of a vertex between incident and scattered tracks, the spatial resolution of the hodoscope had to be 0.5 mm or better. Therefore the wire spacing was chosen to be 1 mm, a rather unconventionally small value. Another important consideration lies in the fact that the beam operates at a high rate of up to 10 MHz and consequently very good time resolution must be achieved in order to limit accidental counts. The described system has been operated successfully for a period of about 10 weeks of running and is currently being modified to improve its performance.

Description of the System

The hodoscope consists of two chambers of active area about 3"×3", each chamber having two gaps. The central ground electrode of each high-voltage gap consists of a sense plane made of 1 mm-spaced parallel wires. The wire angles of the 4 sense planes are respectively 0^o, 90^o, 45^o, and 135^o.

Each sense plane (Fig. 2) comprises 72 active wires: the 0.8-mil gold-plated tungsten wires are individually stretched with a tension of 60 g, rather close to the yield point of 70-75 g and soldered on the printed traces of a motherboard glued to the G-10 frame. Field tapering is achieved by 5 additional wires on each edge of the sense plane. These wires have diameters of 1.2, 1.7, 5, 10, and 25 mils and are soldered to grounded traces on the motherboard. The active wires are read out alternately on both sides permitting the use of side-by-side 44-pin connectors for the readout detector cards without having to fan out the connections from the wires. The readout electronics is mounted on 4"×4" cards which plug directly into the motherboard connectors, each card handling the readout for 4 wires.

The high-voltage electrodes are also made of parallel wires spaced by 1 mm: we have used 3-mil diameter gold-plated tungsten wires. Further development work has shown us that more reliable results can be obtained using aluminum foil instead of HV wires. With the HV wires we have sometimes observed corona breakdown effects forcing us to run the chambers at a lower than optimum high voltage. We are therefore currently replacing the HV planes with a mylar-aluminum foil. Each HV plane is fed through a 22 MΩ, 1/8 W resistor acting as fuse in the event of sparking, thus limiting the risk of breaking sense wires.

The half-gap between the HV plane and the sense wires is 4 mm as guaranteed by the modular construction of the chamber.

We have tried several gas mixtures, always premixed in a single cylinder. Since we are currently using a mix of argon + 20% isobutane + 4% methylal + 0.1% Freon 13 B1, a limitation occurs in the total cylinder pressure of about 50 psi. We feel that this limitation is justified by the convenience of using a gas of reliable composition.

Readout Electronics

The proportional chamber electronics consists of high speed detector cards and buffer circuit cards mounted directly on the motherboard. In addition there is a subcontroller (Fig. 3) mounted near the chamber which is directed by a main controller located approximately 200' away in the data acquisition room providing computer readin.

Each readout detector card[1] reads out 4 wires and comprises (for each wire) a high-gain amplifier, discriminator, monostable delay, coincidence circuit and latch, utilizing emitter coupled (MECL II) circuits. The voltage is then shifted to TTL voltages and readout is accomplished by strobing a SN7401 open collector gate. The threshold is set to 0.3 mV allowing a good efficiency with standard gas mixtures. The delay can be adjusted using a miniature potentiometer on each card to 390 ns, a value fixed by the trigger requirements of the experiment. Under operating conditions delays on all channels are typically set to within ±8 ns of each other.

The subcontroller incorporates a standard sequential shift register technique for computer readin, each shift causing 16 wires to be read in. Each plane has a readout connector and termination buffer card on both sides of the motherboard. Since a high speed detector card is connected to every other wire the strobes from the subcontroller read out 2 detector cards at a time from each side of the motherboard to form the 16 bit data bus. Therefore there are two 8 bit data busses connecting each side of the motherboards to the master card where these 8 bit data busses are interlaced and buffered with SN7407's. In this manner the data is read into the computer such that adjacent wires are represented by adjacent bits. At the end of computer readin a reset pulse resets all of the fast latches. By selecting a particular strobe with the switches on the front panel, the subcontroller will display the associated 16 bits. In addition a test card may be plugged into any detector card slot for checkout.

Since these chambers operate in very close proximity to spark chambers, we utilized some special precautions with respect to electrical noise. The fast coincidence signal is latched just prior to firing the spark chamber thyratrons and all computer readout circuits are connected with terminated RG 174 coaxial cables and receiver circuits incorporate a Signetics Utilogic SU 380A which has a 1.5 volt threshold. The chambers are completely enclosed in an aluminum can, with holes for the beam, as protection from rf noise from the spark chambers, however, no pickup problem was experienced even with the cover off.

To protect the proportional chambers in case a high voltage breakdown should occur, an alarm and automatic high voltage shut down circuit has been included as part of the electronics system. This alarm circuit is designed to monitor up to eight signal planes and works on the principle that as a breakdown begins to occur the background noise on the signal plane increases dramatically. To monitor this rate a special card plugging into the signal plane readout motherboard has been constructed and continually monitors a single signal wire on the edge of the plane. This card consists of a high-speed differential comparator with a variable threshold input which is usually set to about 10 mV. This comparator has a TTL output and is followed by a one-shot which lengthens the pulse and drives a cable to a pulse rate detector.

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Performances of the System

We have tried different gas mixtures. Starting with argon + 20% isobutane we have found the chambers fully efficient at 4.0 kV, provided that the gate is longer than 60 ns. A narrower gate width would have required a higher voltage, leading to breakdown in the chambers. Using the same mixture, but adding 0.1% of Freon 13-B1 with 4% of methylal allowed us to work with a gate width down to 30 ns at a HV of 4.3 kV with full efficiency. All the following results are obtained using this gas mixture in tests done at SLAC in a 14 GeV π beam.

Figure 4 shows a HV plateau curve obtained with a 50 ns-wide fast gate, indicating 100% efficiency above 3.9 kV. For comparison we note that the breakdown voltage was approximately 4.35 kV. For a narrower gate width the HV plateau is attained at higher voltage, as indicated in Fig. 5. It shows that chambers of this type can operate with gates as narrow as 30 ns, an important point when accidental counts are a problem. A coincidence delay curve is presented in Fig. 6 indicating the good uniformity of the delay among a large number of wires.

Finally we point out a limitation of our readout electronics due to the deadtime imposed by the monostable delay (Fig. 7). This test was done with the beam focussed with a Gaussian shape with $\sigma \simeq 4$ wires: a loss of nearly 20% is seen for about 7 particles crossing the chamber inside the 1.5-μs-long SLAC pulse. This difficulty has been overcome by the use of 4 planes at different angles. In the offline analysis we require at least 2 out of 4 possible coordinate points on a beam track with an efficiency in excess of 93% for a beam flux of about 10 particles/pulse.

We are currently improving the present chambers in an effort to achieve greater reliability at high voltages close to the corona breakdown point. Aside for minor details, HV wire planes are being replaced by aluminum foil and a gas mixture with 0.2% Freon 13-B1 is used.

Acknowledgements

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References

1. J. L. Pellegrin, "Threshold and delay circuit for proportional wire chamber electronics," Report No. SLAC-TN-70-22 (September 1970).

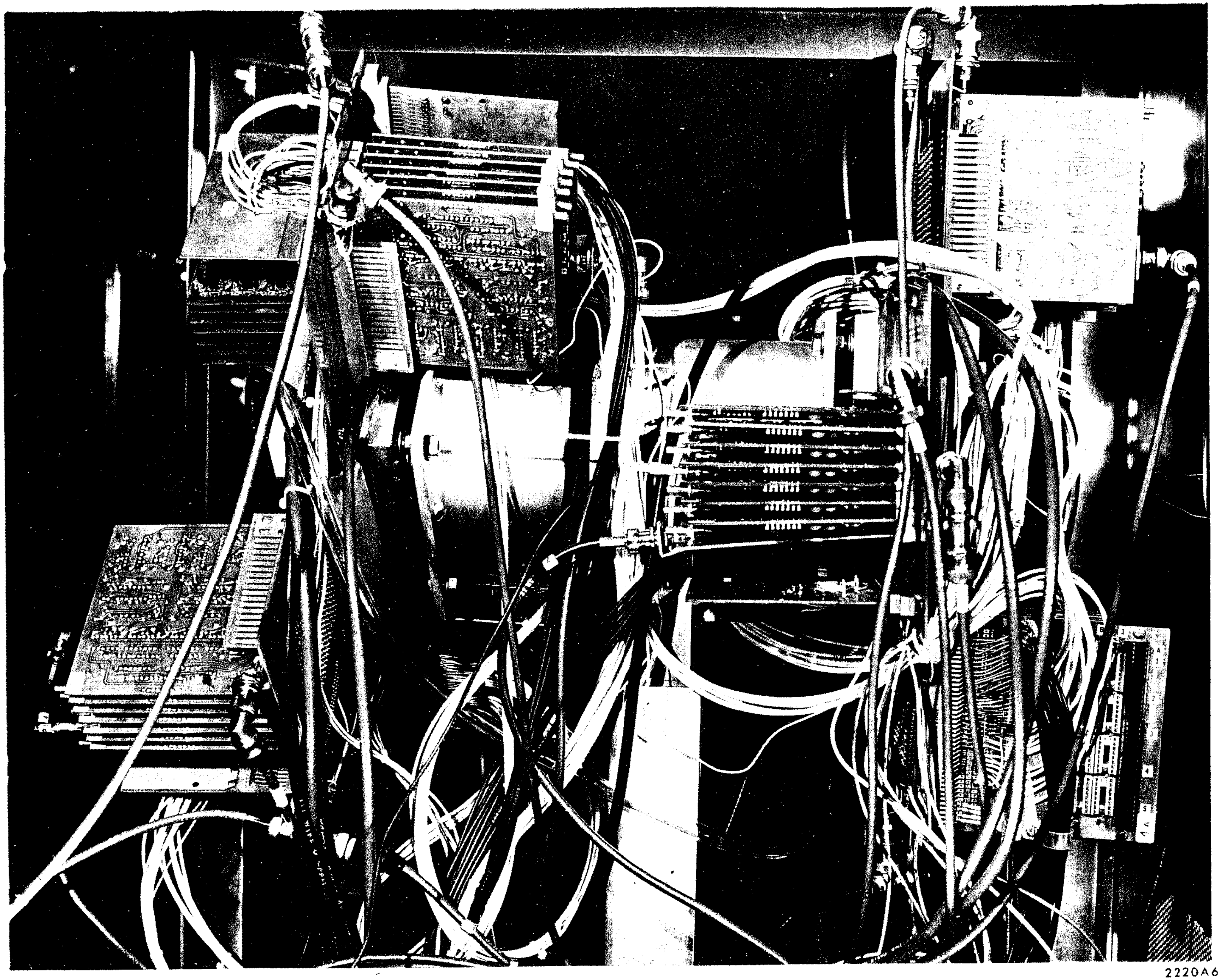

FIG. 1--Proportional beam hodoscope.

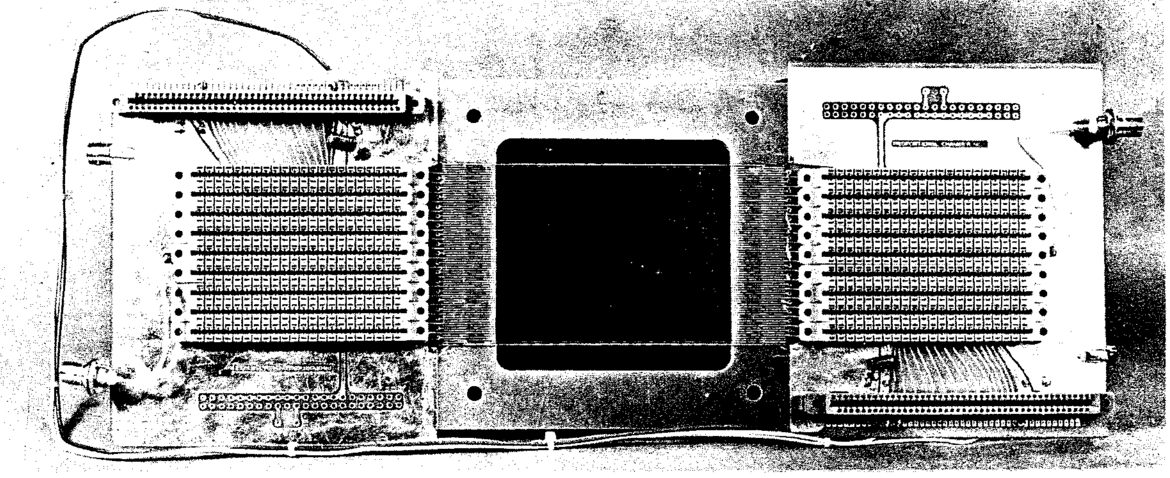

FIG. 2--Proportional chamber sense plane.

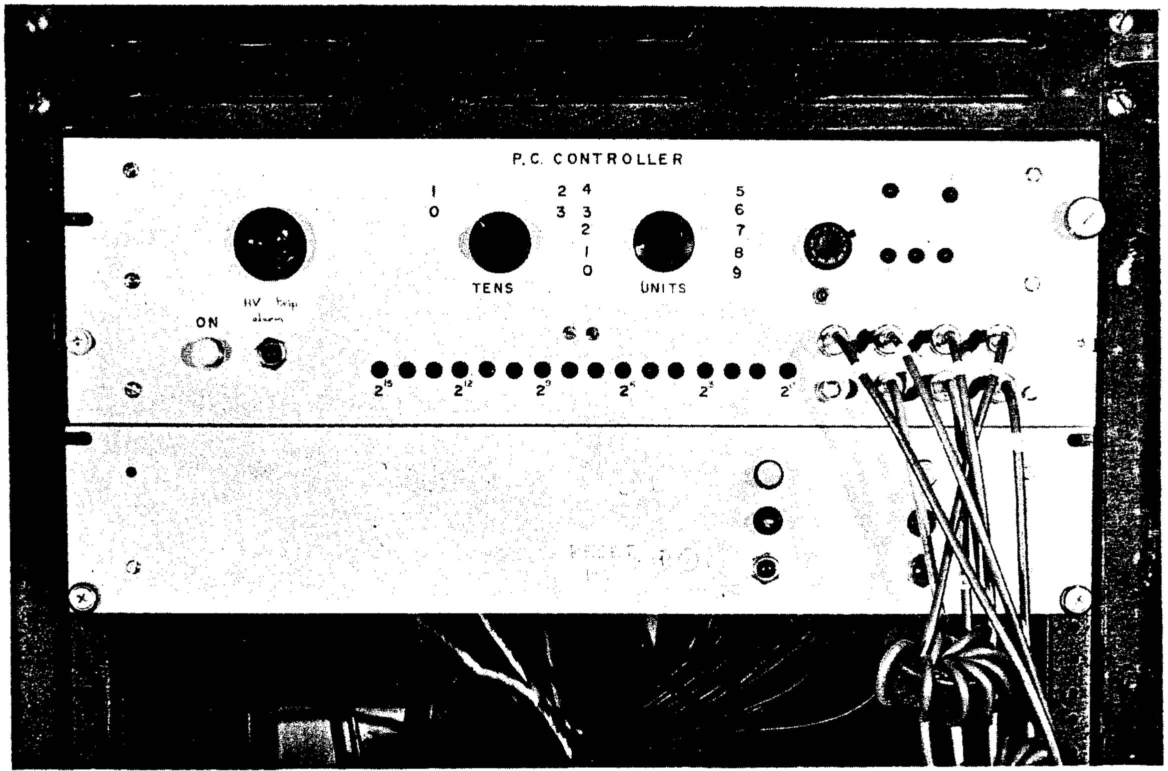

FIG. 3--Proportional chamber controller.

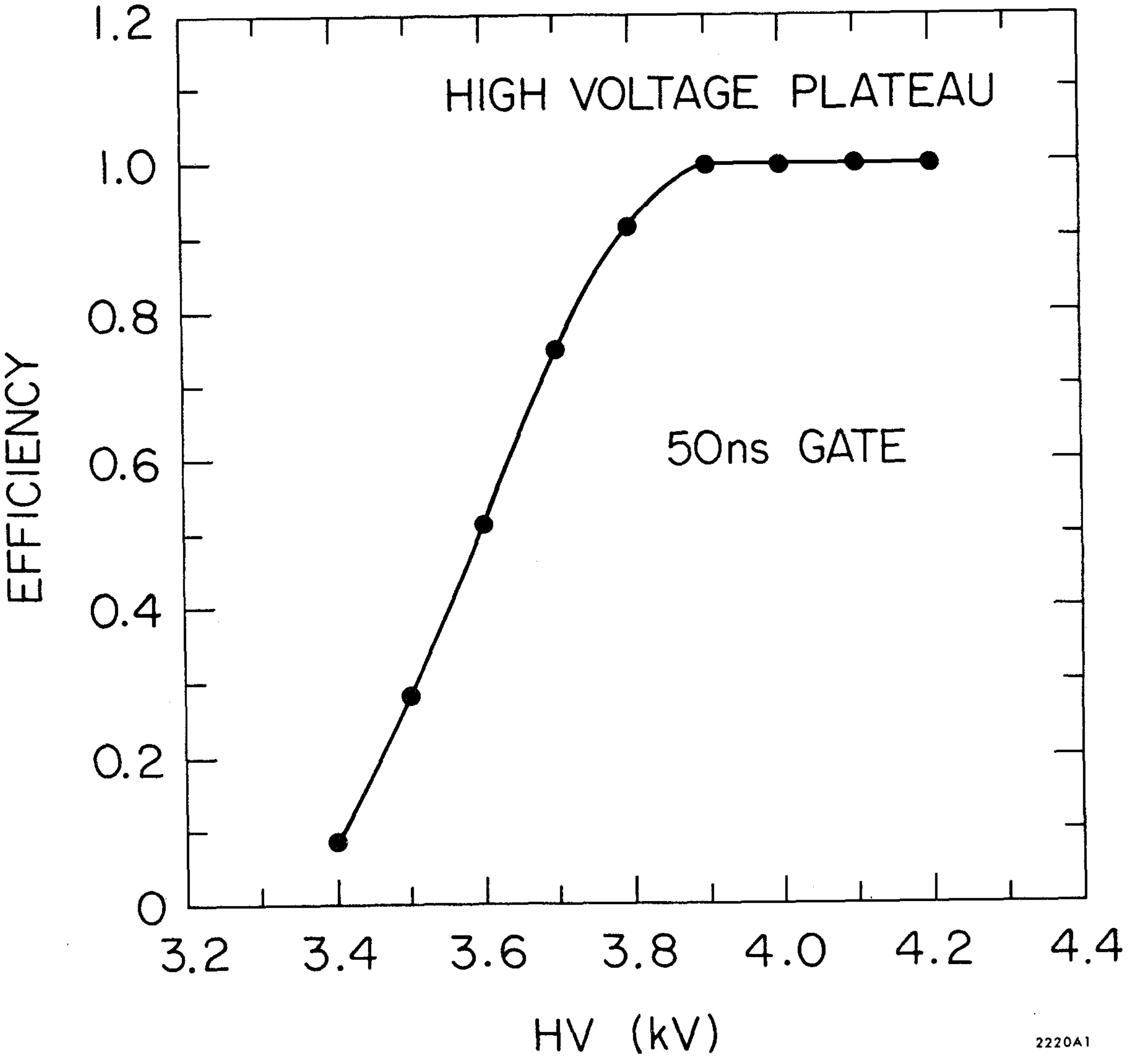

FIG. 4--High voltage plateau curve with a 50 ns wide fast gate.

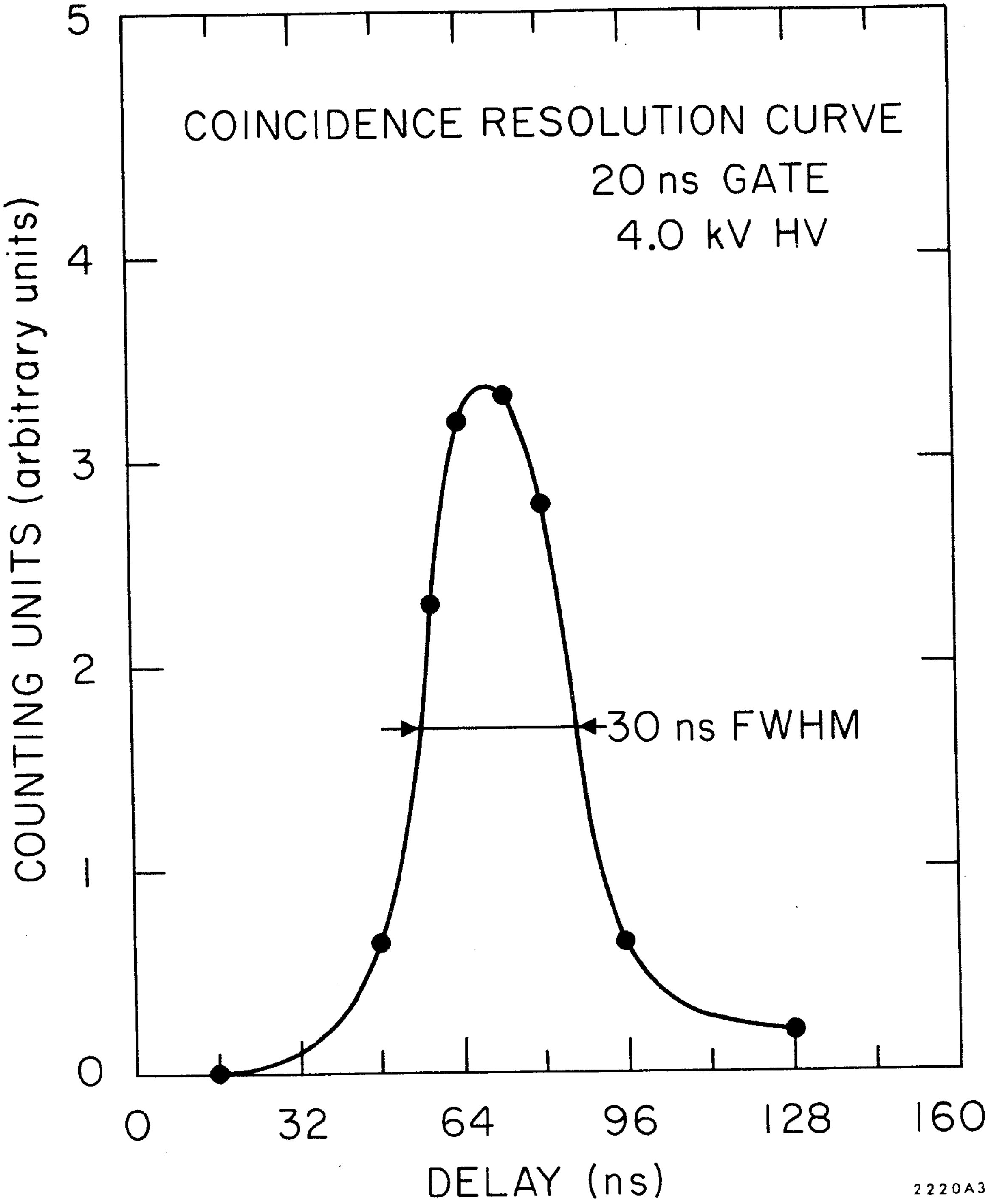

FIG. 5--Coincidence resolution curve with 20 ns wide gate.

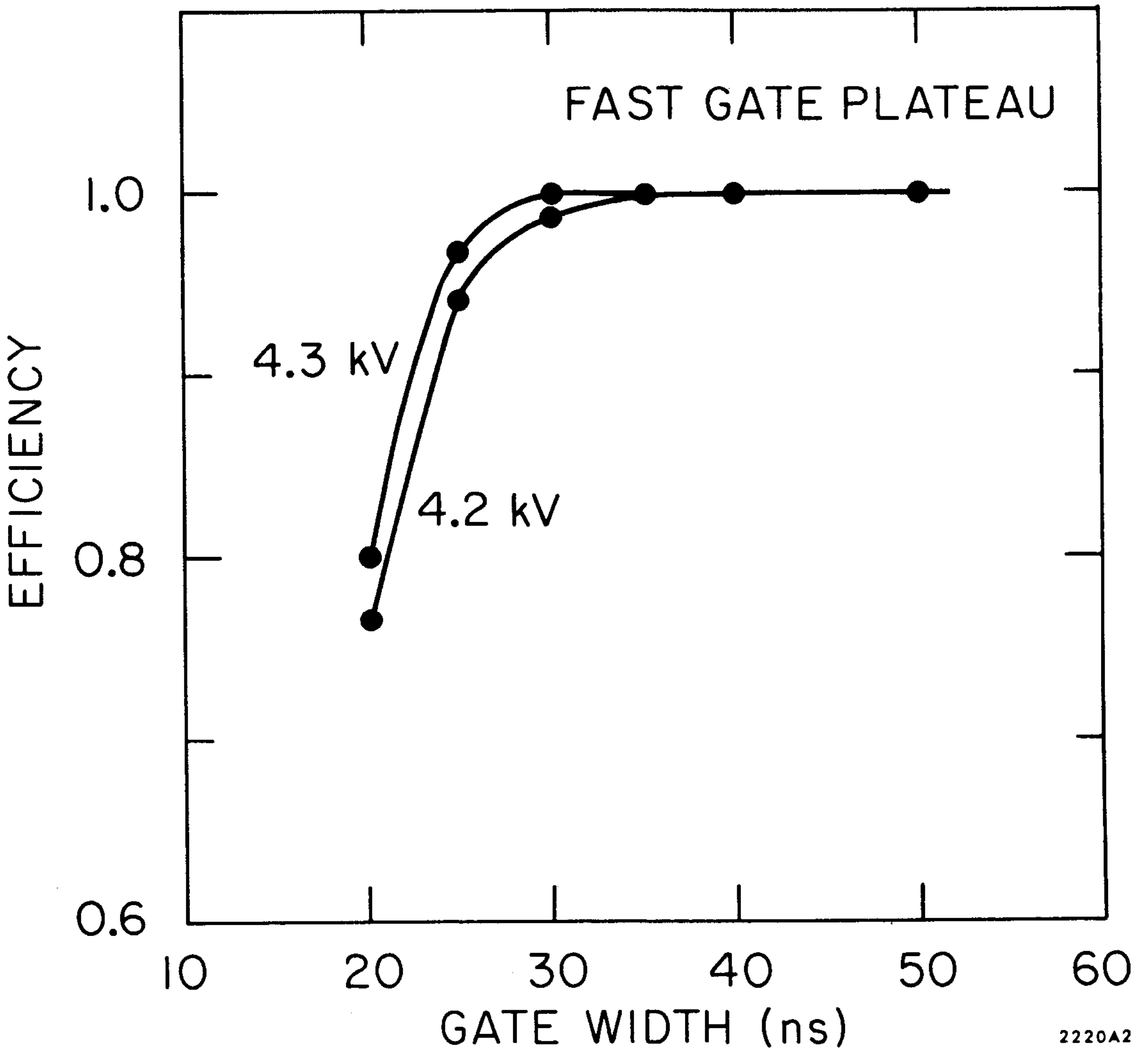

FIG. 6--Efficiency curve as a function of the fast gate width.

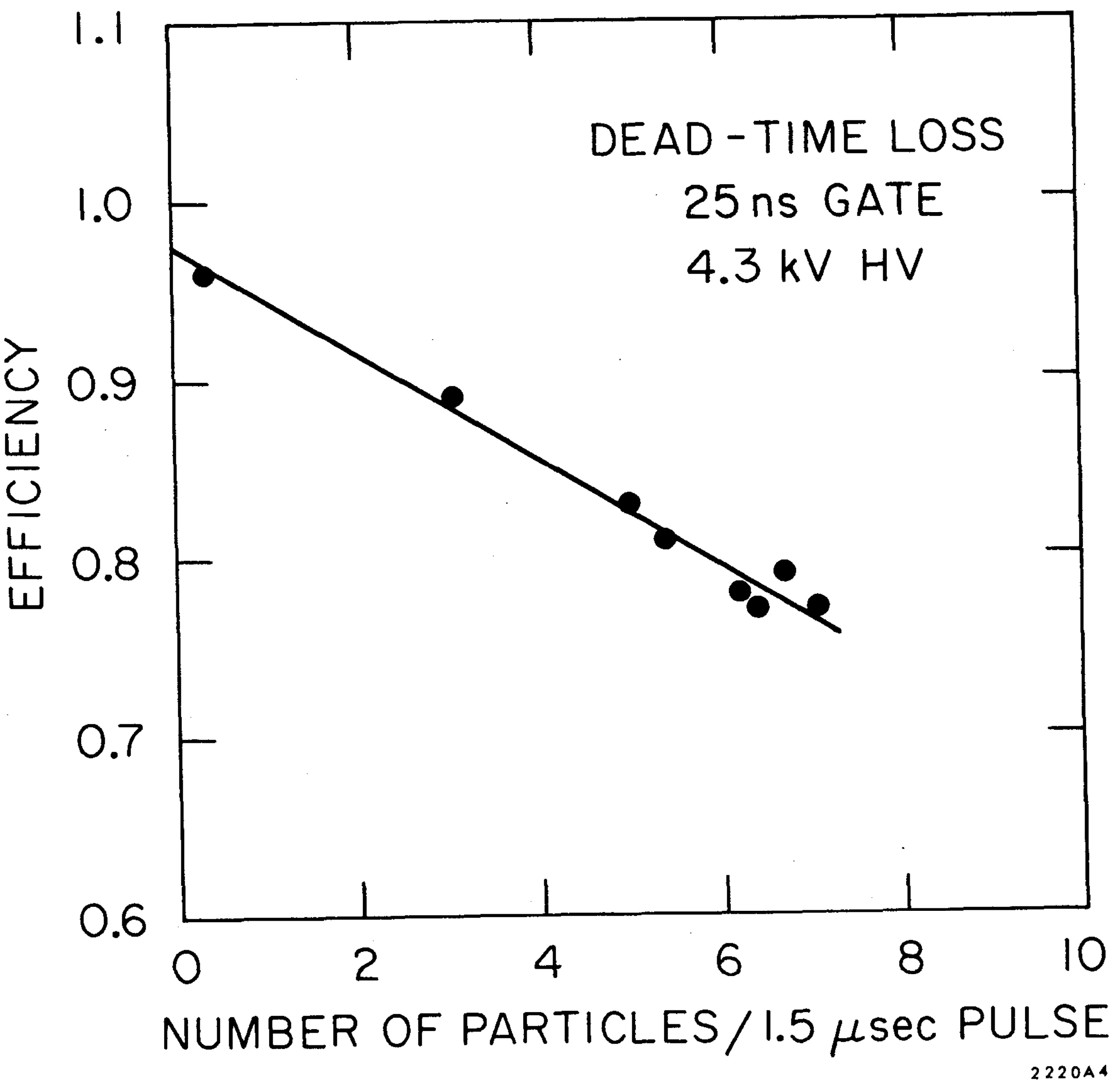

FIG. 7--Deadtime loss as a function of beam flux.