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PRELIMINARY RESULTS FROM STUDIES OF LIMITED STREAMER TUBES WITH EXTERNAL ELECTRODE READOUT*‡

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ABSTRACT

We report initial results from a new multichannel test facility built to study the properties of chambers constructed for the Warm Iron Calorimeter of the SLD detector as they are made. The correlation between the signal on the external electrodes and the wire is observed. A systematic study of the transition between the proportional and streamer modes of operation is given as a function of argon-isobutane mixture and high voltage. The pulse height spectrum is correlated with the operational plateau of the chambers and may be used to determine optimum operating points under a variety of conditions.

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I. INTRODUCTION

A new detector, the SLD detector,[1] is to be built at SLAC for the colliding beam facility in the Z^0 energy range. One of its features is good electromagnetic and hadronic calorimetry over 98% of the solid angle (Fig. 1). The hadronic energy will be measured by a combination of the 2.87 interaction length (λ) thick Liquid Argon Calorimeter (LAC) inside the solenoid magnetic field and the 4λ thick Warm Iron Calorimeter (WIC). The WIC is made of 14 iron plates, each 5 cm thick, and serves as the return yoke for the magnetic field. The laminated form of the iron allows the insertion of active elements made from plastic streamer tubes similar to those used for the Mont–Blanc proton decay experiment.[2]

The basic element of the chambers is an 8 cm wide, 1 cm thick and 7 m long extruded PVC profile (Fig. 2) which contains eight cells, each 0.9 cm square. The cell walls are coated with a graphite paint to obtain surface resistivity of 100 kΩ to a few MΩ per square. This coating provides a stable electric field and at the same time is transparent to fast transients such as those due to a streamer on the wire. The wire used is 100 μm silver-coated, beryllium-copper supported every 0.35 m by plastic spacers.

The profiles are inserted in extruded PVC envelopes which provide gas tightness when sealed with two end pieces that also contain connections for gas, HV and ground. One side of the cell is not coated with graphite and therefore is not conductive. This configuration has been shown to work well and gives the advantage of simple construction.[2,3] The chambers are operated in the limited streamer mode using a gas mixture of 25% argon and 75% isobutane. The streamer pulses are not read directly from the wire but instead are picked up from external electrodes facing the wires. The pulse can be sensed on both sides of a tube. The calorimetry of the WIC is done via pad electrodes connected in towers of 66 mrad $\times$ 66 mrad. The WIC is also intended to track and to identify muons via the use of strip electrodes which are 1 cm wide aligned parallel to the wires (Fig. 3).

II. THE TEST FACILITY

The test facility is designed to record the response from the individual pad and strip electrodes in each chamber after it is laminated. Signals are brought out via twisted pair cable to low noise preamps[4] which have been modified to extend the integration time to roughly 600 ns. The outputs are sent to and digitized by the SHAM II/BADC system developed at SLAC.[5]

The facility is configured out of the calorimetric data acquisition system built for the MAC detector at PEP.[6] A block diagram of the system is given in Fig. 4.

The essential features of the facility consist of an independent cosmic ray trigger provided by scintillators, simultaneous multiple channel ($\sim$ 1200) readout, and event-by-event recording of the data on disk. These aspects of the system are especially valuable, as they allow one easily to vary cuts on the same set of data and to investigate the response of the system to different possible detection schemes in the final detector.

The data recorded include the temperature and barometric pressure of the chambers under test. In addition, the system includes the response of a monitor chamber as a redundant control of external parameters affecting chamber response.

The gas mixture is controlled by a digital multichannel automated mass flow controller.[7] Crosschecks show the system to repeat its settings to a precision better than 1%. Our calibrations of the system to date are only good to roughly 3%, and show the mass flow controller to be accurate at least to that level. Overall, the system has been quite reliable; the relative mixtures of argon and isobutane quoted will be those of the mass flow control system.

The response of the system to a known charge has been calibrated in two ways. The first is to use a square wave of known voltage and width and the input impedance of the preamplifier, the second is to discharge a known capacitor charged to a known voltage with an RC time constant consistent with the observed chamber pulses into the signal cables. Both methods agree to within 25%, and give a calibration of 3 picocoulombs for 100 SHAM counts.

The data presented in this paper are from the initial studies done with 32 channels to verify that the test system performed properly. In all cases the response shown is the response of a chamber and its electrodes to cosmic rays which intersect the scintillator trigger.

III. PAD AND STRIP RESPONSE

Figure 5 shows a printout of distributions for a set of 16 X–strip signals and the eight associated pad signals. The scintillator trigger included a 10 $\times$ 75 cm^2 scintillator parallel to the strips which isolated cosmic rays to those hitting the central eight strips and four pads. The operating voltage at which the data for Fig. 5 was taken, 4450 V, was chosen to obtain a roughly equal amount of proportional and streamer responses.

Of interest is the fact that, on average, the pad and summed strip responses are approximately equal. Differences can be attributed to the different sampling times of the signals in addition to the detailed geometry of the cathodes. Figure 5a shows the pad-strip correlation, which can be seen to be centered about equal responses, but with a scatter that increases with larger pulse heights. Furthermore, Figs. 5b and 5c show the pulse height spectra for the strips individually and the pads individually to be practically indistinguishable. The increase in scatter as a function of pulse height leads one to suspect the spatial extent of the streamer from the wire towards the cathode to be the source of the deteriorating pad-strip correlation.

As an illustration, Fig. 6 shows pulse height spectra and the pad-strip correlation for two different operating conditions. The selection of operating points is made to keep the streamer response equal while enhancing the amount of proportional signal. What is seen is that the proportional signal possesses a better pad-strip correlation.

To investigate this further, we compared the summed strip and pad signals with the signal obtained through a capacitor from the wires associated with the eight strips. These are shown in Figs. 6c and 6d. When the strip and pad signals are summed and compared with the wire signal, the correlation is much better than that for the strip versus pad signals alone. This is evidence that a significant fraction of charge in the streamer is produced away from the wire as suggested by other authors.[8]

IV. PROPORTIONAL AND STREAMER RESPONSE AS A FUNCTION OF GAS MIXTURE AND HV

A fundamental concern is the choice of the operating point for the chambers with respect to the gas mixture and high voltage, and the stability to variations in these parameters. Figure 7 gives a set of pulse height spectra for a broad range of HV and argon-isobutane mixtures. In general, looking at Fig. 7, one can conclude that higher concentrations of argon lead to a larger separation in the average pulse height for the proportional and streamer modes for a given high voltage. In addition, the transition between proportional and streamer modes occurs more rapidly at higher concentrations of argon as the high voltage is increased. In fact, at the lowest concentrations of argon, the proportional and streamer modes are practically indistinguishable—one sees a smooth transition from one mode to the next.

Figure 8 shows the peaks of the pulse height distribution for the proportional and streamer modes and the percentage of streamers as a function of high voltage and gas mixture. The points for Fig. 8 were determined by eye and are meant only to indicate the general trends of the data.

High voltage plateau curves, commonly obtained from singles counting rates as a function of high voltage, are usually attributed to the gradual transition from proportional to streamer operation.[2] Figure 9 shows pulse height spectra in conjunction with threshold curves taken by our collaborators to study the operation of electronics proposed for the WIC strip electrodes.[9] The pulse height spectra can be used to define an integral efficiency, defined to be the number of events with pulse height greater than a given value over the total number of events. The integral efficiency thus obtained for one high voltage can be scaled to match the threshold curve obtained at the same high voltage. The scale obtained effectively converts SHAM counts to millivolts. The result is shown in Fig. 10 which compares the integral efficiency curves with the threshold curves at different high voltage settings. The good agreement leads us to conclude that the set of pulse height spectra in Fig. 7 have a general applicability to questions of optimum operating points for the chambers with a variety of readout electronics. The data presented in Fig. 7 contain the information needed to produce a three-dimensional description of the chamber performance as a function of high voltage, gas mixture and electronic threshold.

ACKNOWLEDGEMENTS

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FIGURE CAPTIONS

Fig. 1. The SLD Detector (one quadrant shown only).

Fig. 2. Front view of a plastic streamer tube.

Fig. 3. Layout of the pickup electrodes of a chamber.

Fig. 4. The route of all chamber signals from preamplifier to online computer.

Fig. 5. Pulse height distributions for pad and strip sums: (a) Pad and strip pulse height correlation; (b) strip sum pulse height distribution; and (c) pad sum pulse height distribution.

Fig. 6. Pad pulse height distributions, pad-strip correlation, strip vs. wire correlation, and (pad + strip)/2 vs. wire correlation: (a) Pad pulse height distribution and pad vs. strip correlation for chamber operating at 4650 V, 75% isobutane; (b) pad pulse height distribution and pad vs. strip correlation for chamber operating at 4100 V, 65% isobutane; (c) strip vs. wire correlation; and (d) (pad + strip)/2 vs. wire correlation for same conditions as (a).

Fig. 7. Pulse height distribution as a function of both high voltage and isobutane concentration. High-voltage settings increase from bottom to top and are constant horizontally. Isobutane concentration increases from left to right and is constant vertically.

Fig. 8. (a) Peak of streamer pulse height distribution vs. high voltage for varying concentrations of isobutane; (b) peak of proportional pulse height distribution vs. high voltage for varying concentrations of isobutane; and (c) relative percentage of streamer mode vs. high voltage for varying concentrations of isobutane.

Fig. 9. Pulse height spectra and threshold curves obtained for three different high-voltage settings. All use 75% isobutane.

Fig. 10. Comparison of threshold curves (dashed lines) for different high-voltage settings with integral efficiencies obtained from pulse height spectra and converted to millivolts. All use 75% isobutane.

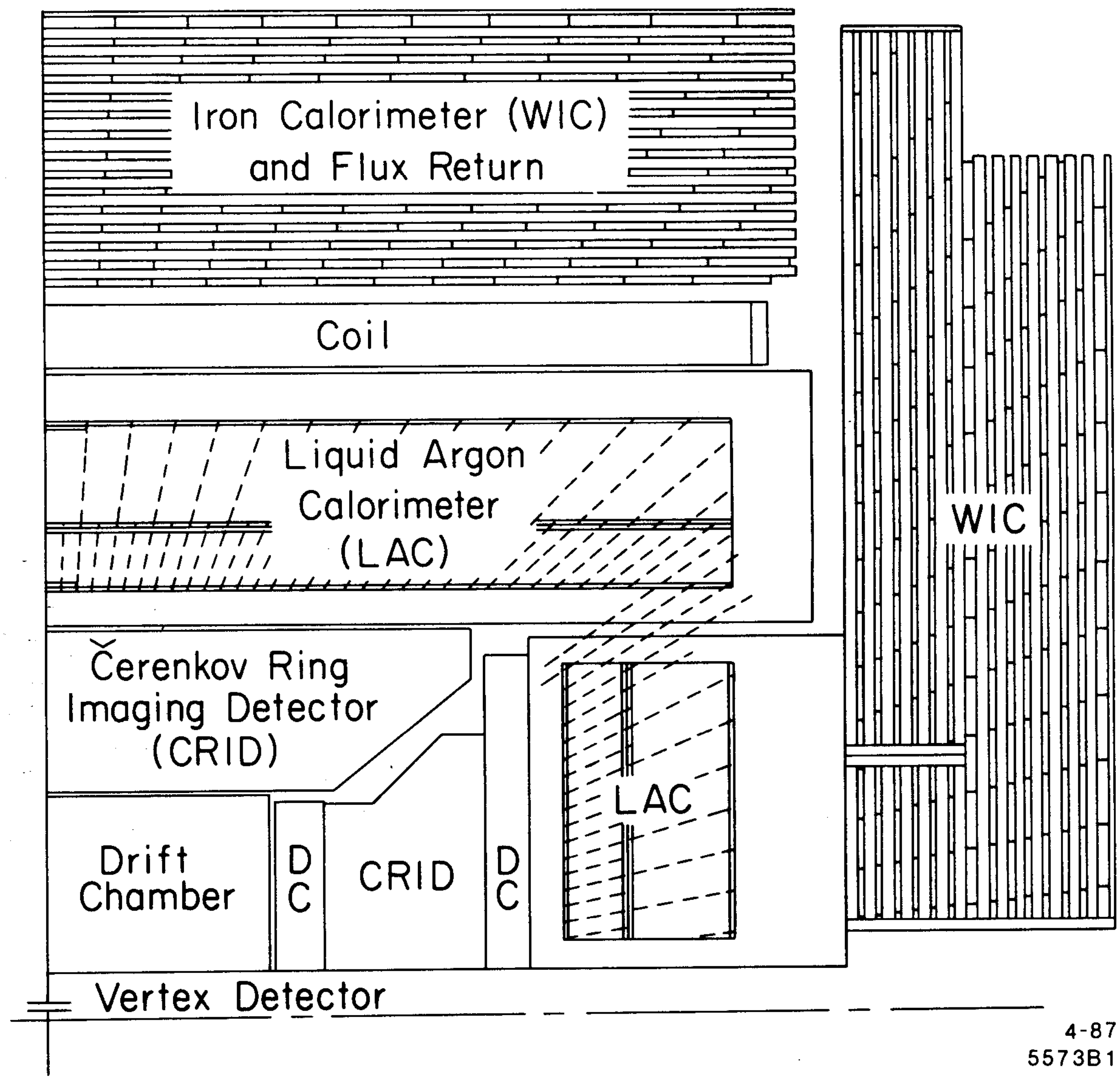

Iron Calorimeter (WIC)
and Flux Return
Coil
Liquid Argon
Calorimeter
(LAC)
WIC
Čerenkov Ring
Imaging Detector
(CRID)
LAC
Drift
Chamber
DC
CRID
DC
Vertex Detector
4-87
5573B1

Fig. 1

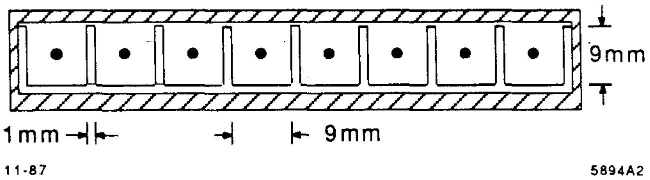


Fig. 2

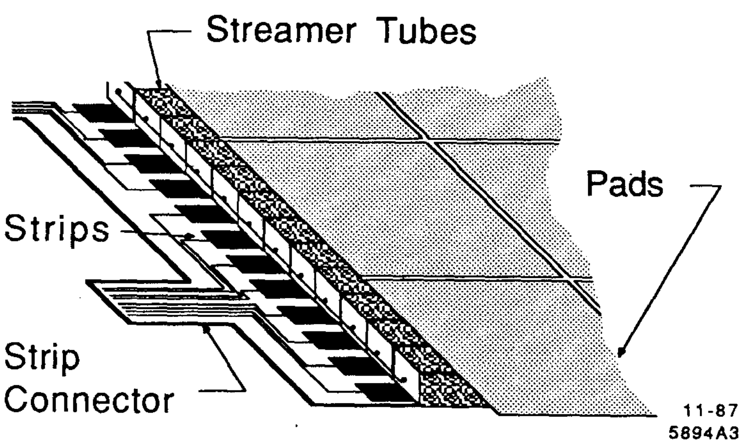
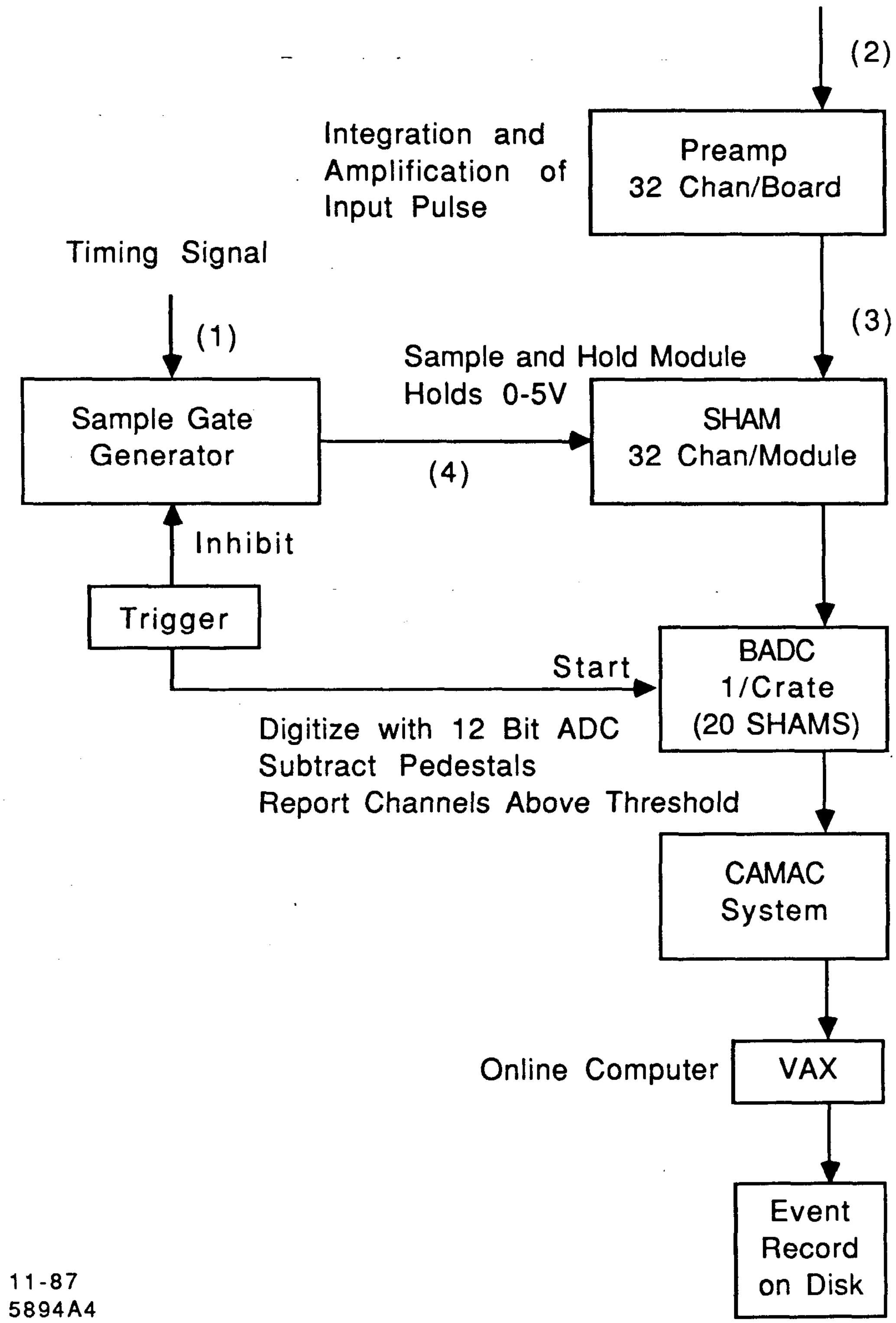


Fig. 3



(2)
Integration and
Amplification of
Input Pulse
Preamp
32 Chan/Board
Timing Signal
(1)
(3)
Sample and Hold Module
Holds 0-5V
Sample Gate
Generator
SHAM
32 Chan/Module
(4)
Inhibit
Trigger
Start
BADC
1/Crate
(20 SHAMS)
Digitize with 12 Bit ADC
Subtract Pedestals
Report Channels Above Threshold
CAMAC
System
Online Computer
VAX
Event
Record
on Disk
11-87
5894A4

Fig. 4

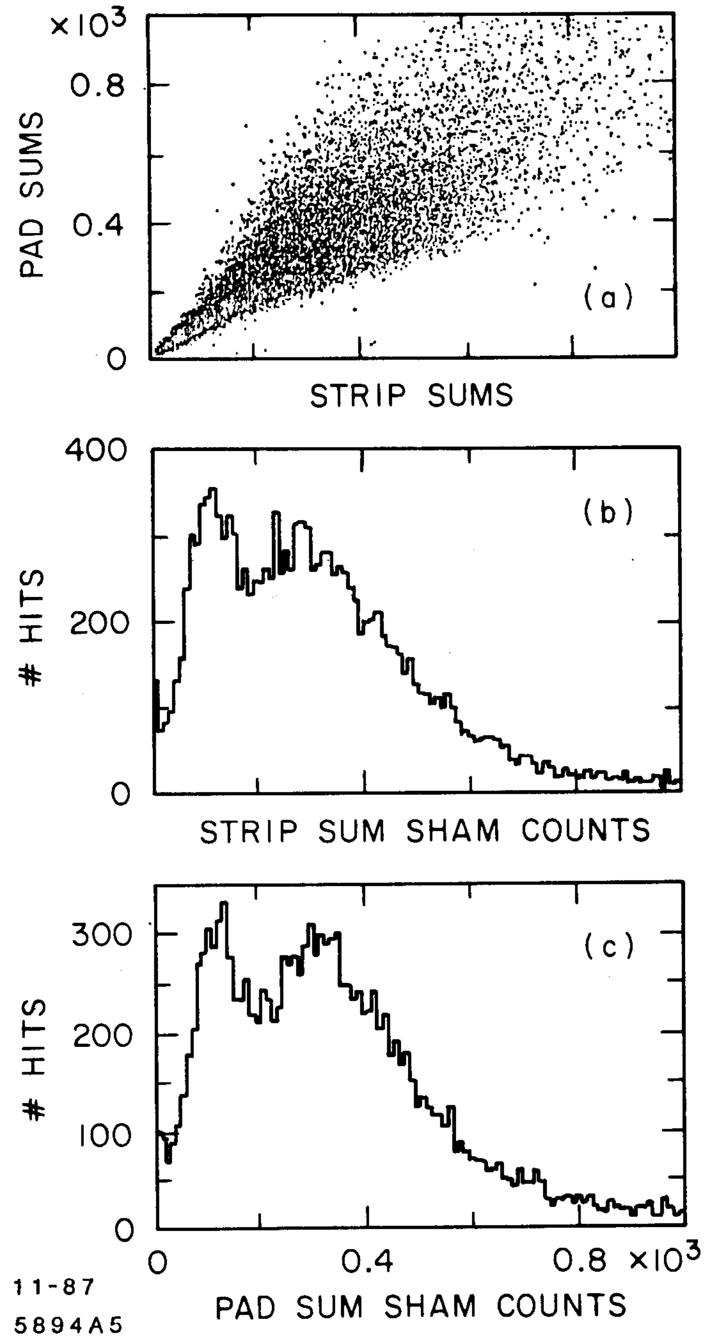

×10³
0.8
PAD SUMS
0.4
0
(a)
STRIP SUMS
400
(b)
HITS
200
0
STRIP SUM SHAM COUNTS
300
(c)
HITS
200
100
0
0
0.4
0.8 ×10³
PAD SUM SHAM COUNTS
11-87
5894A5

Fig. 5

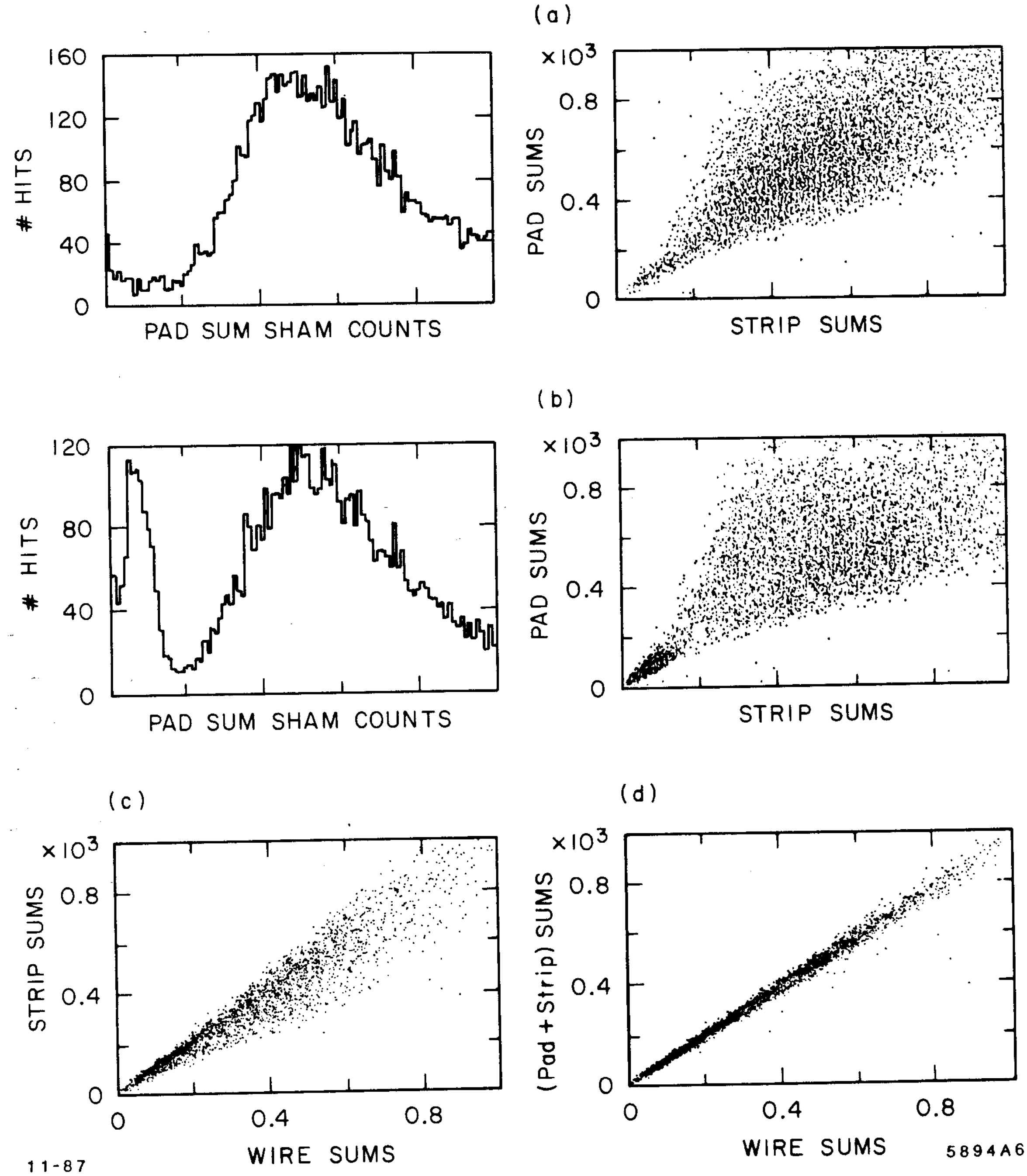

(a)
160
120
80
40
0
HITS
PAD SUM SHAM COUNTS
×10^3
0.8
0.4
0
PAD SUMS
STRIP SUMS
(b)
120
80
40
0
HITS
PAD SUM SHAM COUNTS
×10^3
0.8
0.4
0
PAD SUMS
STRIP SUMS
(c)
×10^3
0.8
0.4
0
STRIP SUMS
0
0.4
0.8
WIRE SUMS
(d)
×10^3
0.8
0.4
0
(Pad + Strip) SUMS
0
0.4
0.8
WIRE SUMS
11-87
5894A6

Fig. 6

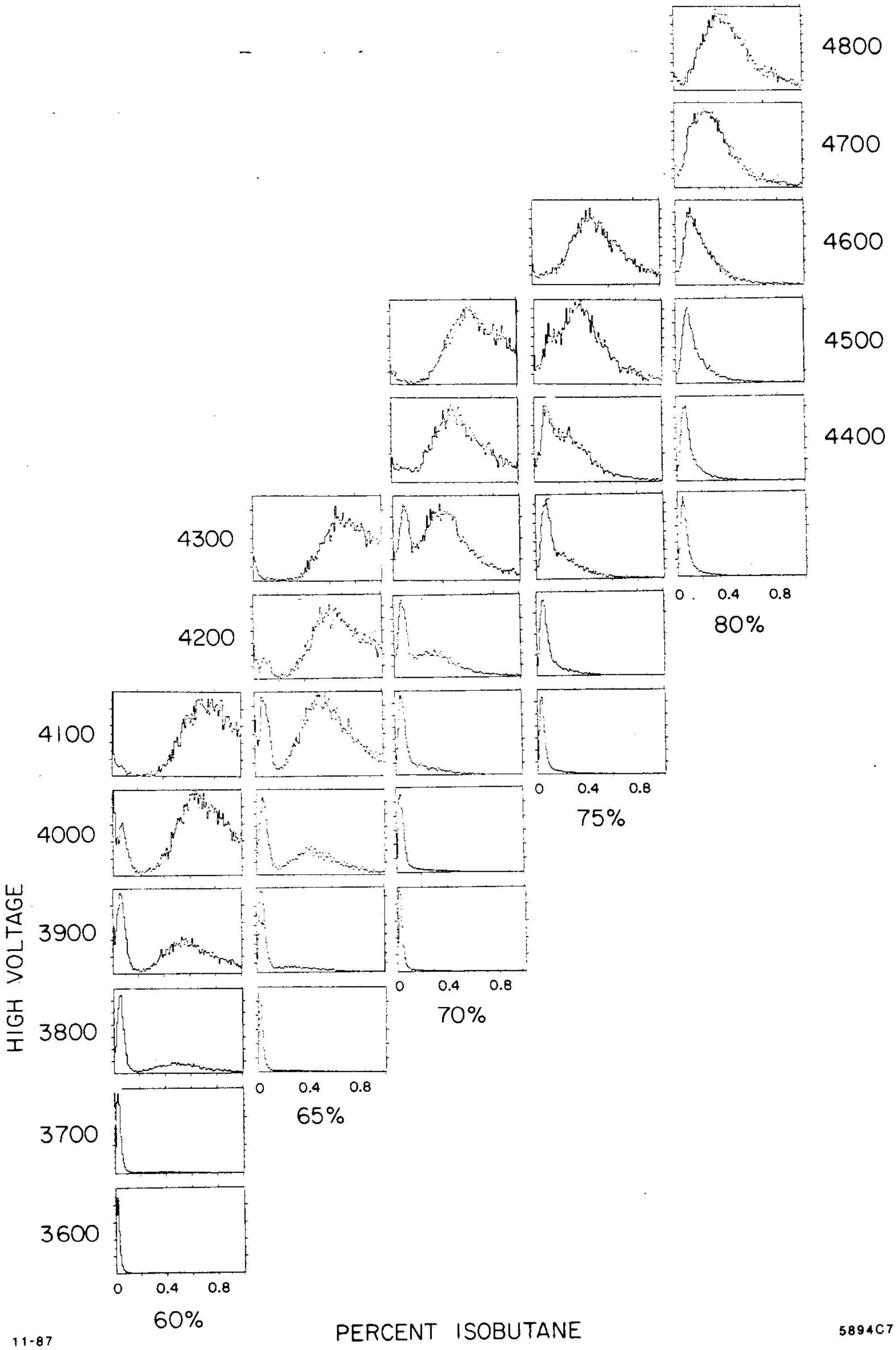
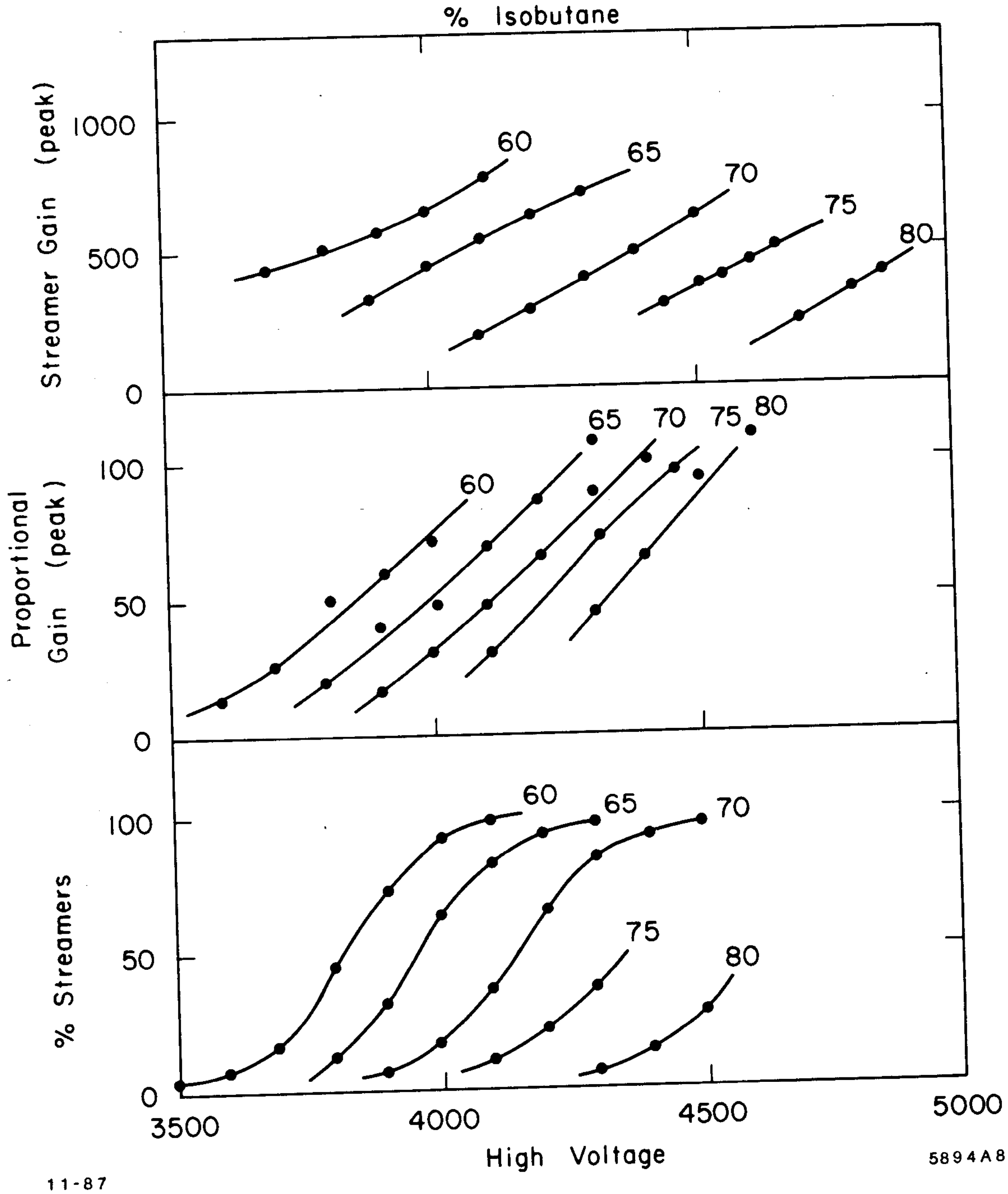
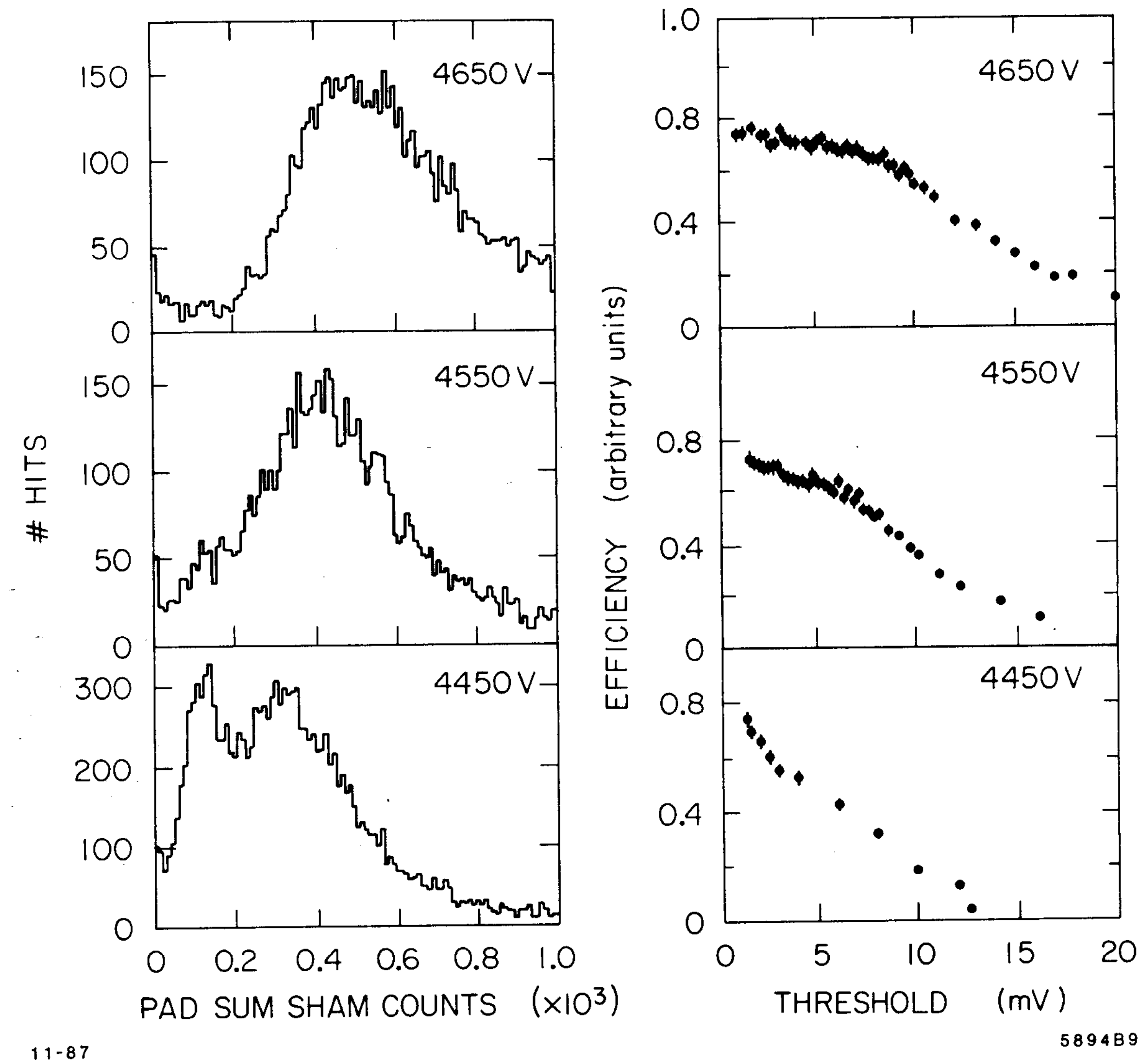

4800
4700
4600
4500
4400
4300
4200
4100
4000
3900
3800
3700
3600
HIGH VOLTAGE
0 0.4 0.8
60%
65%
70%
75%
80%
PERCENT ISOBUTANE
11-87
5894C7

Fig. 7



% Isobutane
Streamer Gain (peak)
1000
500
0
60
65
70
75
80
Proportional Gain (peak)
100
50
0
% Streamers
3500
4000
4500
5000
High Voltage
5894A8
11-87

Fig. 8



4650 V
4550 V
4450 V
HITS
PAD SUM SHAM COUNTS (×10³)
EFFICIENCY (arbitrary units)
THRESHOLD (mV)
11-87
5894B9

Fig. 9

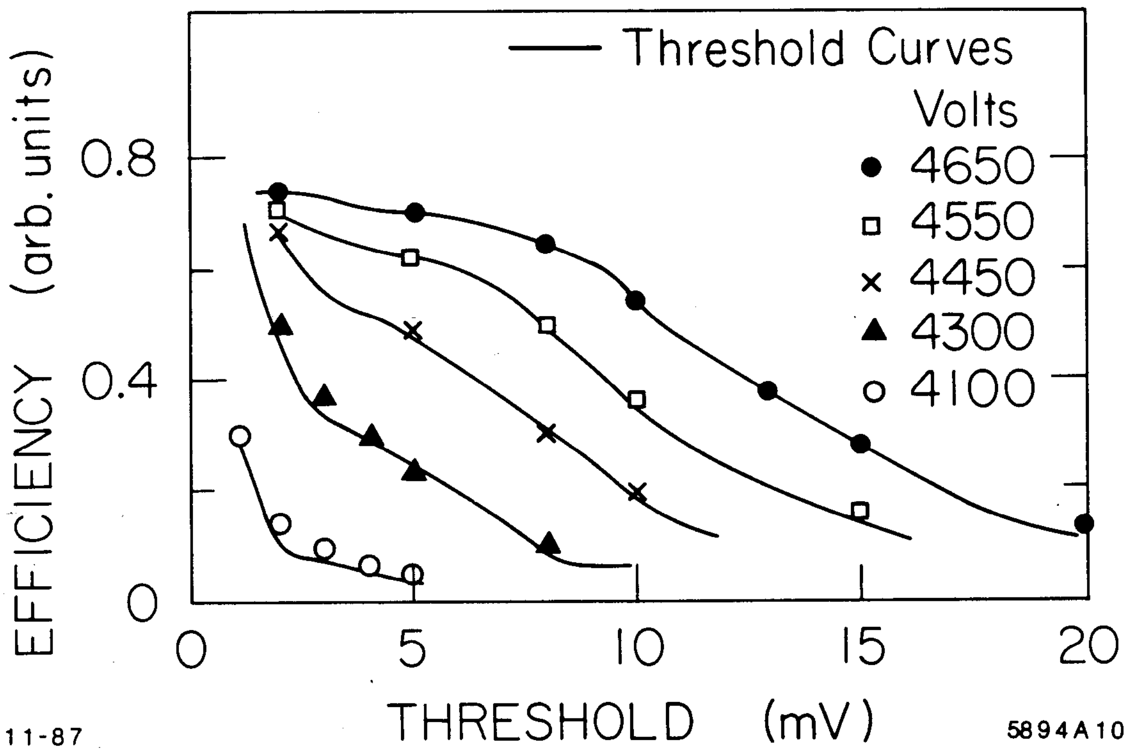

Threshold Curves
Volts
4650
4550
4450
4300
4100
EFFICIENCY (arb. units)
0.8
0.4
0
0
5
10
15
20
THRESHOLD (mV)
11-87
5894A10

Fig. 10