CERN-EP/88-84
15 July 1988

A TEST AND CALIBRATION SET UP FOR MASS-PRODUCED PROPORTIONAL CHAMBERS

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Abstract

The L3 experiment, presently being installed at the European Center for Nuclear Research (CERN) will use a 300 tons Hadron Calorimeter made of depleted uranium plates interleaved with about 8000 proportional chambers. We describe here the procedures and setup developed to test and calibrate these chambers using the depleted uranium plates as radioactive source. An approach to calibration of the calorimeter in situ is also discussed.

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1. INTRODUCTION

The barrel hadron calorimeter of the L3 experiment at LEP consists of 144 modules containing depleted uranium absorber plates interleaved with proportional wire chambers. The total number of chambers in the calorimeter is close to 8'000, the total number of anode wires being around 360'000.

To obtain nominal performance of the calorimeter, one has to ensure the proper operation of each anode wire and to provide a way to calibrate the calorimeter in situ. The radioactivity of uranium turns out to be very useful for chamber test and calorimeter calibration.

In this paper, we review our experience in the use of gamma radioactivity of depleted uranium for the test of the chambers. First, we discuss the depleted uranium radioactivity and the response of a proportional chamber to it. Secondly, a description of the test setup is given and a method to test the uniformity of the chamber response is discussed. Finally, a procedure for the L3 hadron calorimeter calibration in situ using uranium radioactivity is proposed.

2. DEPLETED URANIUM RADIOACTIVITY

The absorber plates of the L3 hadron calorimeter are made of depleted U-238. Uranium is an alpha, beta and gamma radioactivity source. Alpha particles produced by the natural decay of uranium are captured by a protective layer of Cu and Ni (10 to 20 μ thick) covering the absorber plates.

The flux of beta decay electrons emerging from the uranium plate is as high as 400/cm**2*s, the maximum energy of electrons being about 1 MeV. These electrons can be stopped by a metallic sheet of appropriate thickness. The dependence of the counting rate of a proportional chamber facing uranium plate on the Cu sheet thickness is shown in Fig. 1. Above 0.7 mm of Cu, the rate dependence becomes much weaker. As the high counting rate may lead to signal pileup and thus worsens the energy resolution of the calorimeter, the chambers are made with extruded brass tubes with wall thickness of 0.3 mm and additionally protected by 0.7 mm thick brass shielding plates (see Fig. 2 and Ref. [1]).

The gamma rays which penetrate through the shield will cause ionization of the chamber gas. The energy of these gammas is in the MeV range. Therefore, the process contributing dominantly to the production of ionizing electrons is Compton scattering. The electrons are mostly produced in a thin layer of the brass wall adjacent to the inner part of the chamber, their energy being spread over a wide range. The smallest ionization is produced by minimum ionizing relativistic electrons which traverse the chamber and end up in its wall. Less energetic electrons produce more ionization and can even stop in the gas. In Fig. 3, the amplitude spectrum of signals from one of the anode wires of the L3 hadron calorimeter chamber placed between uranium plates is compared with the amplitude spectrum of cosmic muons taken under the same conditions.

The gas gain of a wire sets the amplitude scale whereas the shape of the spectrum which reflects the primary ionization distribution is the same for all the wires. Thus, to check chamber uniformity one can determine the scale parameter from the amplitude spectra collected for each anode wire.

3. CHAMBER AND MODULE TEST

The chamber flushed with the working gas (80/20 A-C02 mixture) is sandwiched between two uranium plates. The negative high voltage is applied to the cathode tubes of the chamber. All anode wires are connected to a multiplexer. A block diagram of the chamber test setup is presented in Fig. 4. The multiplexer driven by an output register connects one by one the normally grounded anode wires to an amplifier. The uranium radioactivity signals are sampled by an ADC (LRS 2249A) which operates in self triggering mode - the gate for the ADC being generated by the leading edge of the signal. The counting rate is 20/cm**2*s.

The data acquisition control and preliminary storage of the data is done using a modified programmable Kinetics System Camac crate controller. The amplitude spectrum is stored in the memory of the controller as a 256 bin histogram. It is then transferred to an IBM personal computer for analysis. The data taking and spectrum storage by the Camac crate controller is performed in parallel with the analysis of the previously collected spectrum by the IBM PC.

In the analysis procedure, the collected spectrum is fitted to a high statistics reference spectrum (Fig. 5). Two parameters : amplitude scale factor (gain G) and histogram content factor are determined in the fit. The dependence of the accuracy of the gain determination using this fit procedure on the histogram statistics (N) is shown in Fig. 6. It can be described as $\sigma_G/G = 1.8/\sqrt{N}$.

The dependence of the gain parameter of the spectrum on the high voltage is shown in Fig. 7. To correct for temperature and pressure variation as well as for gas composition variations, the parameters determined in the chamber response uniformity test are normalized to the periodically updated parameters obtained using the spectrum of signals from two reference proportional tubes with which the test setup is equipped. These tubes are similar to the chamber ones and flushed with the same gas.

In Table 1, the output resulting from the test of a chamber is presented. In the table, for each wire of the chamber the following values are given : the gain, relative to reference spectrum in %, the Chi**2 value per point of fitted spectrum, counting rate with respect to standard one (efficiency , %). The wires 59 and 60 are the reference tube wires. The histograms of the values given in the table are presented in Fig. 8A, 8B, 8C and 8D. The spread of gains of individual wires (Fig. 8A) indicates the choice of spectrum statistics of 4 * 10**3 and hence, the accuracy of 3% (see Fig. 6) to be adequate for the chamber response uniformity test. The uniformity of produced chambers is illustrated by Fig. 9 in which an histogram of average gains of 1900 chambers is shown.

Uranium radioactivity is also used for the test of assembled modules of the L3 hadron calorimeter. In this case, the signals from groups of anode wires (4 - 28 wires per group) are read out. The data are collected and analyzed in the same way as in the chamber uniformity test. The resulting parameters of the spectrum fit reflect the overall status of the tested module. It is worth to mention that given the sufficient statistics one is able to determine the number of working wires in a group through the counting rate of the channel.

4. IN SITU CALIBRATION

The uranium absorber plates of the hadron calorimeter constitute a convenient built-in radioactive source which irradiates all the chambers and can be used for their response calibration in situ.

Calibration using a random trigger is illustrated in the following. The spectrum of amplitudes of signals picked up by randomly gated ADC from a chamber sandwiched between two uranium plates is shown in Fig. 10. Using the above mentioned procedure of the fitting of the measured spectrum to the high statistics reference spectrum, one can determine relative gain and the counting rate of the corresponding channel.

In the test of random trigger calibration, the sampling frequency was 10 kHz, the gate width was 400 ns. The chamber counting rate was 1200/wire/s. The pickup event rate was then 4.8 events/wire/s.

The dependence of the relative accuracy of the fit parameters on the number of collected events is shown in Fig. 11. The variation with high voltage of the gain determined in the fit is shown in Fig. 12. To simulate signals from groups of wires of the calorimeter module, different numbers of anode wires of the tested chamber were ganged together. The result of the fit of data taken with different number of wires is given in Fig. 13.

On the basis of results presented in this section, one can conclude that the spectra obtained with random trigger can be used to monitor the number of wires in operation and the gain variation for the readout channels of the L3 hadron calorimeter.

* * * * *

References

[1] "Proportional Chambers for the Barrel Hadron Calorimeter of the L3 Experiment", L3 Collaboration, A. Arefiev et al., (submitted to Nuclear Instruments and Methods).

Table 1

TEST	UT2	Operator : Tarkovsky
Chamber	I25P3100	
Date	May 22, 1987	
Time	10:20:42	
HV	1840	
Exposition	4 sec	
Temperature	22°C	
Pressure	1022 mbar	

Average Chamber Gain/χ**2/Efficiency = 108.6/1.08/93.8
RMS for Chamber Gain/χ**2/Efficiency = 3.7/0.17/ 5.4

Wire#	Gain(%)	χ**2	Eff.(%)
1	105	.98	71
2	108	.98	85
3	107	1.34	88
4	103	1.16	91
5	107	1.17	92
6	103	1.09	95
7	110	.87	94
8	105	1.03	92
9	113	1.06	94
10	112	1.09	93
11	110	1.28	94
12	103	1.05	93
13	111	1.12	93
14	108	.96	95
15	107	1.09	95
16	101	1.16	93
17	104	1.11	92
18	99	.98	95
19	110	1.16	92
20	113	1.28	93
21	103	1.60	94
22	109	1.23	95
23	108	.95	93
24	109	1.11	93
25	113	.95	93
26	109	1.21	96
27	105	.93	93
28	113	.77	93
29	108	.96	93
30	102	.94	94
31	106	1.17	95
32	104	1.18	96
33	107	1.01	93
34	111	1.26	92
35	111	.83	96
36	104	.86	96
37	105	1.41	92
38	112	1.01	93
39	108	1.33	93
40	105	1.21	94
41	112	.99	96
42	109	1.05	94
43	111	.91	94
44	114	1.38	93
45	112	1.09	92
46	106	1.13	93
47	116	.91	92
48	109	.74	92
49	112	.80	92
50	107	1.05	120
Reference Wires:			
59	102	1.01	87
60	90	1.29	88

FIGURE CAPTIONS

Fig. 1 The dependence of the proportional chamber counting rate on the thickness of the Cu sheet, facing uranium plate. Zero thickness corresponds to unshielded chamber.One U-plate.

Fig. 2 The L3 hadron calorimeter proportional chamber.

Fig. 3 The uranium induced pulse height spectrum (dashed line) in comparison with cosmic muons. The pedestals are subtracted.

Fig. 4 A block diagram of the chamber test setup.

Fig. 5 The reference spectrum of U-induced signals. MIP-most probable amplitude of minimum ionizing particle.

Fig. 6 The dependence of relative accuracy in gain on histogram statistics. Each point represents the RMS of the distribution of multiple gain measurements with given statistics.

Fig. 7 The dependence of the gain parameter on high voltage. The absolute gas gain is about 10**5 at 1.8 KV.

Fig. 8 An example of test data for a chamber :
a) and b) : wire gain distribution.
c) - Chi square values.
d) - The wire rates normalized to reference tube rates.

Fig. 9 The distribution of average wire gains of produced chambers.

Fig. 10 The spectrum of amplitudes of signals picked up by randomly gated ADC. Amplitude scale is the same as in Fig. 5.

Fig. 11 The dependence of relative accuracy of fit parameters on the number of collected events for random trigger calibration.

Fig. 12 The dependence of the gain determined through random trigger calibration on the high voltage.

Fig. 13 Histogram content dependence on the number of ganged wires for the fixed exposures.

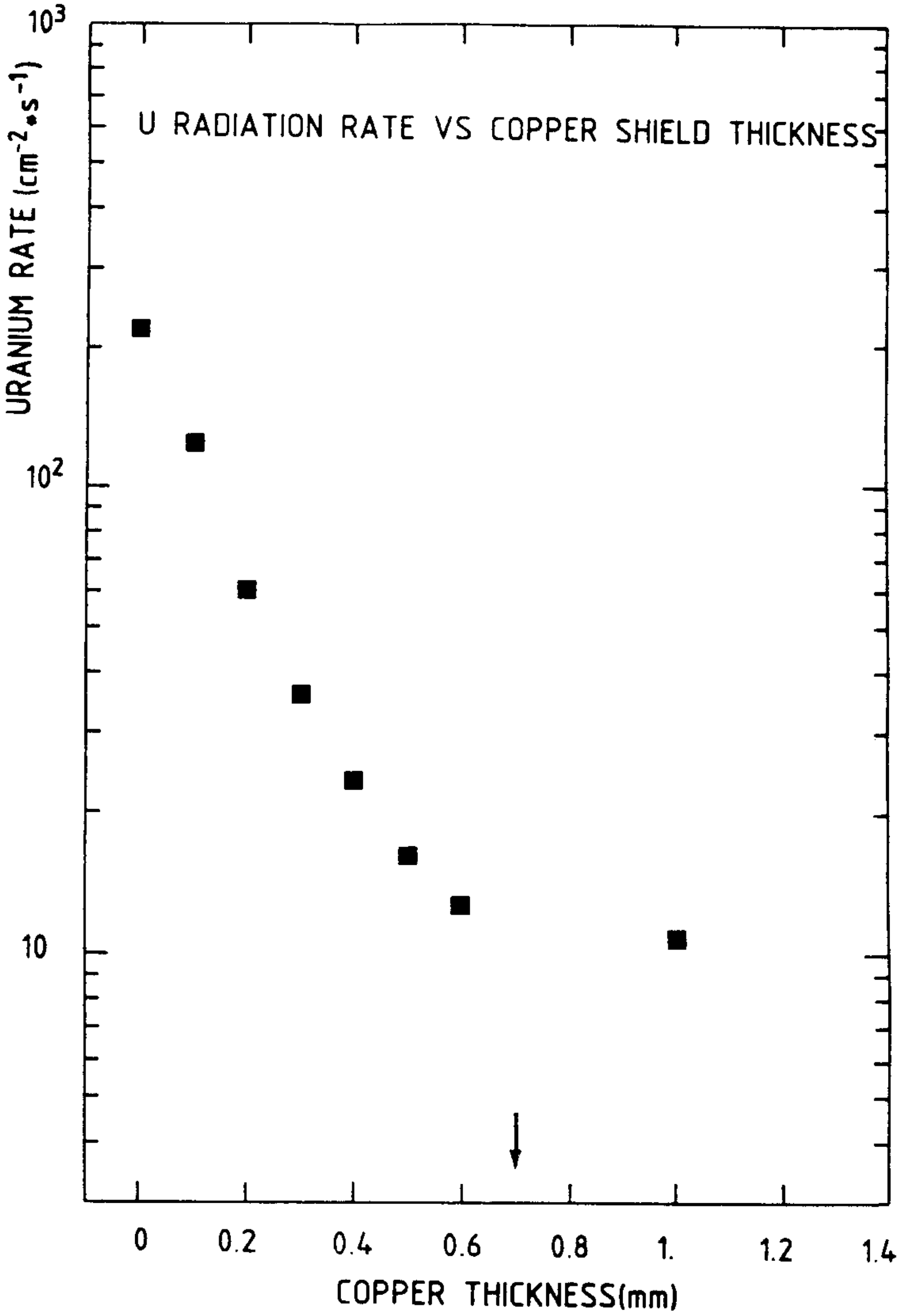

U RADIATION RATE VS COPPER SHIELD THICKNESS
URANIUM RATE (cm^{-2}·s^{-1})
10^3
10^2
10
0
0.2
0.4
0.6
0.8
1.
1.2
1.4
COPPER THICKNESS(mm)

Fig.1

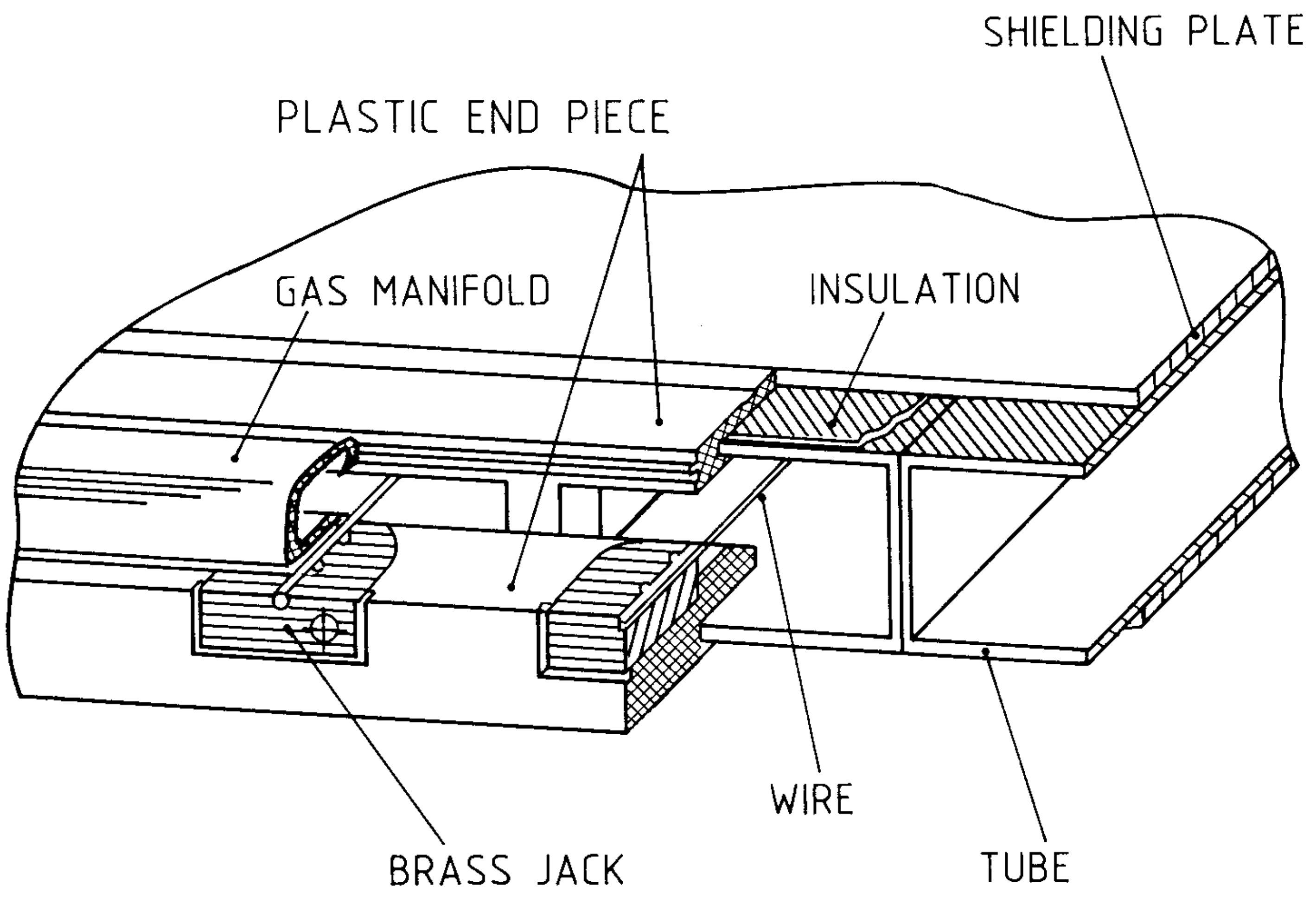

SHIELDING PLATE
PLASTIC END PIECE
GAS MANIFOLD
INSULATION
WIRE
BRASS JACK
TUBE

FIG. 2

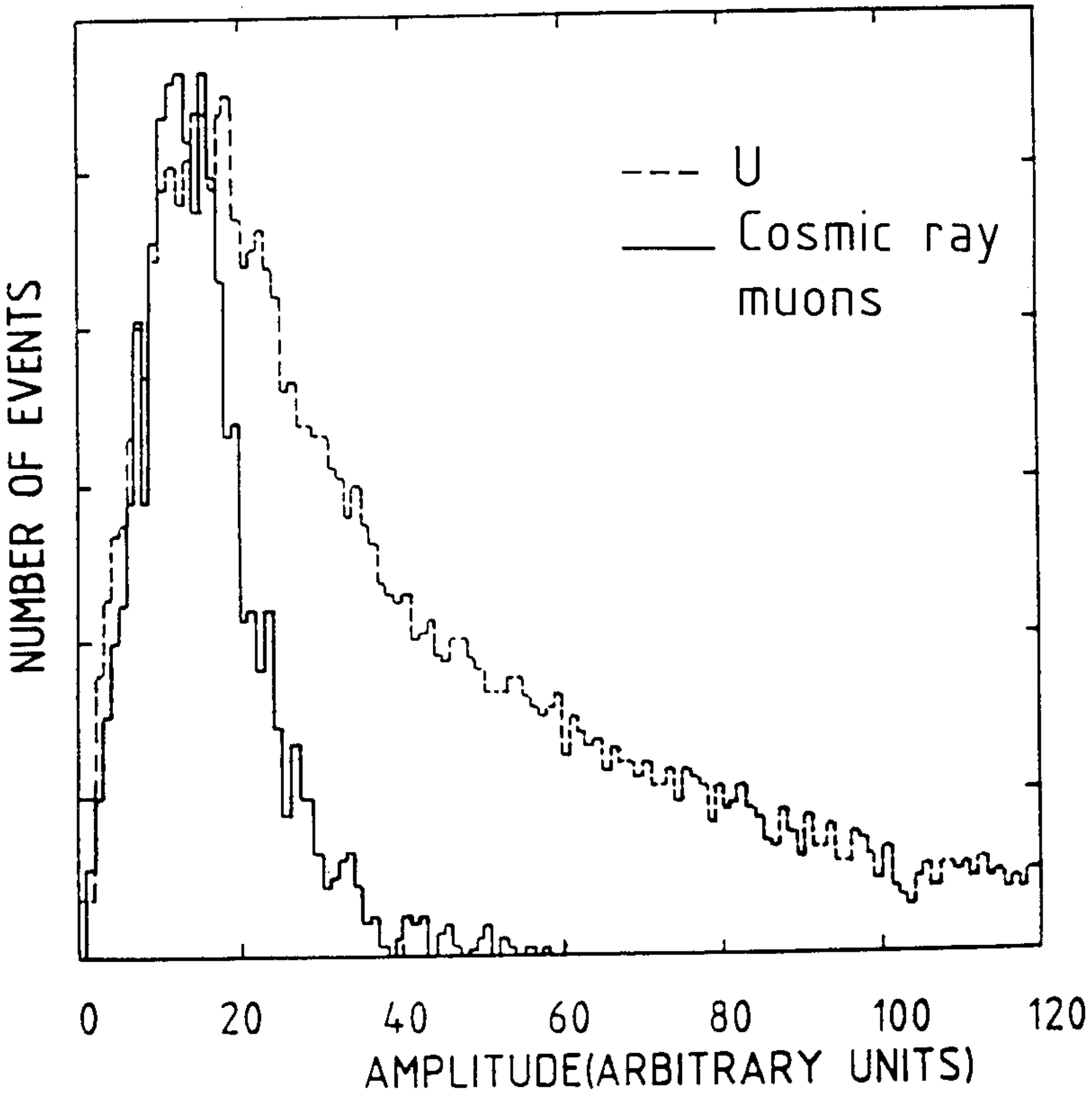

NUMBER OF EVENTS
--- U
—— Cosmic ray muons
0
20
40
60
80
100
120
AMPLITUDE(ARBITRARY UNITS)

FIG. 3

The test setup.

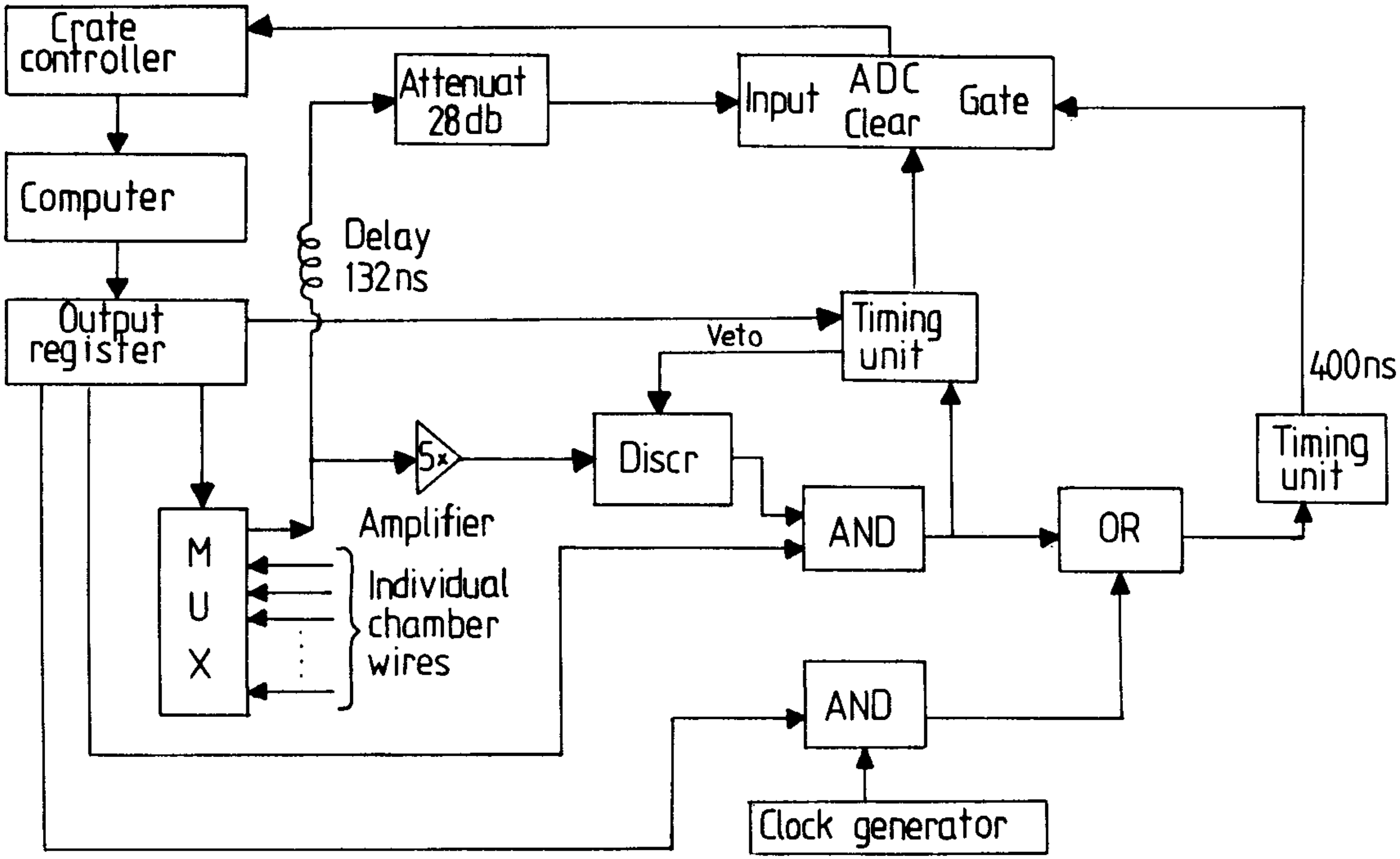
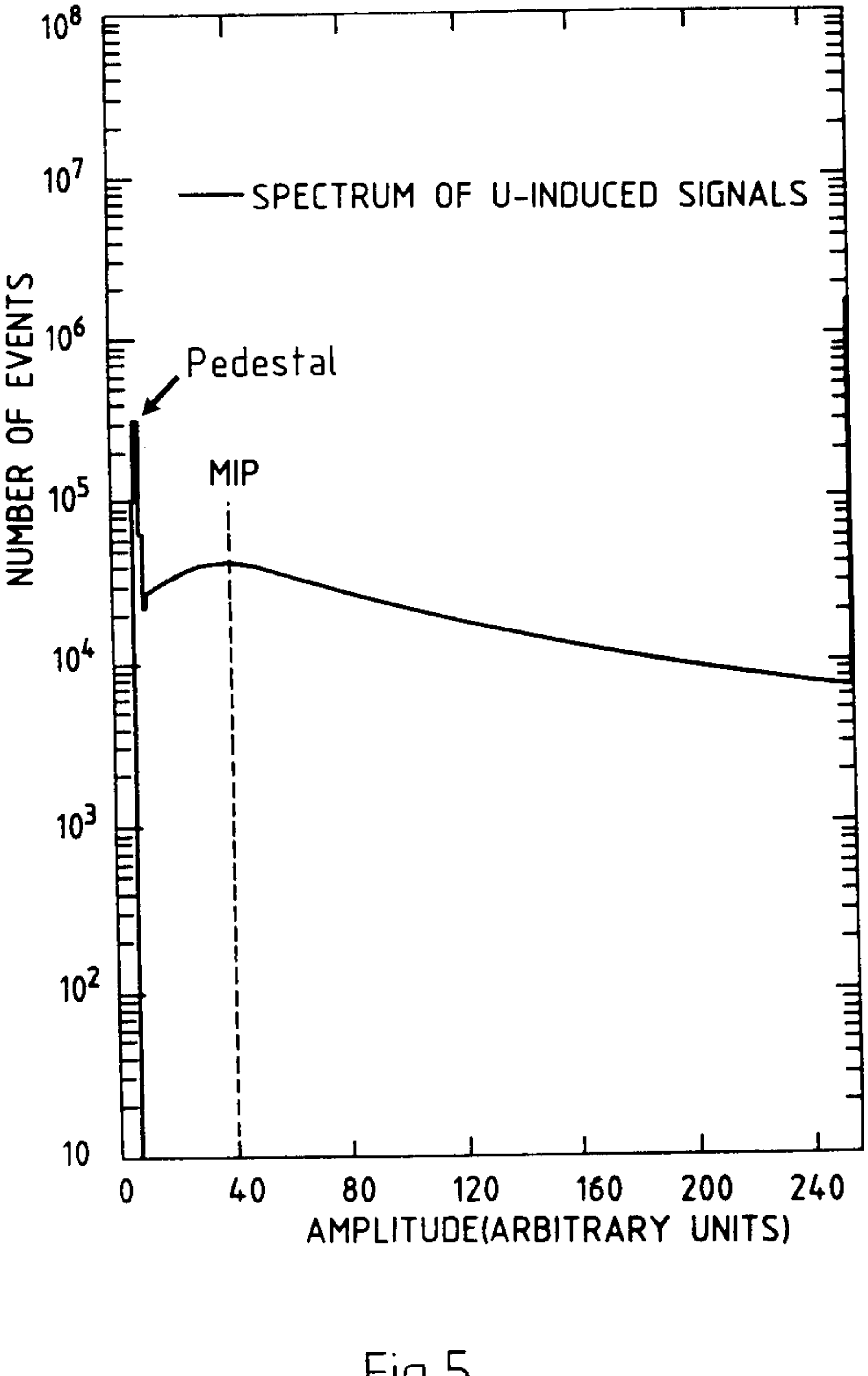
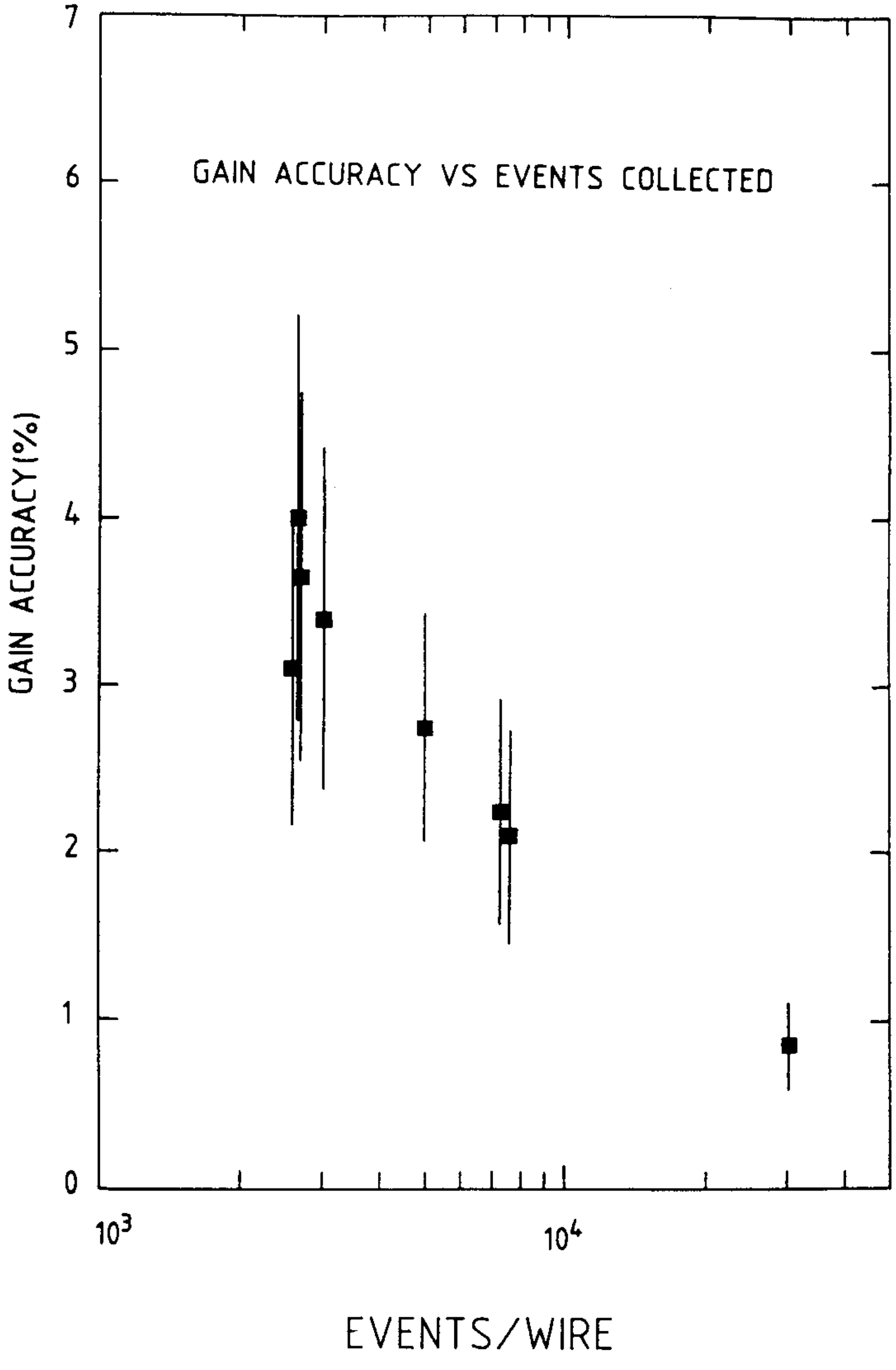


Fig. 4



NUMBER OF EVENTS
10⁸
10⁷
10⁶
10⁵
10⁴
10³
10²
10
SPECTRUM OF U-INDUCED SIGNALS
Pedestal
MIP
0
40
80
120
160
200
240
AMPLITUDE(ARBITRARY UNITS)

Fig. 5


GAIN ACCURACY VS EVENTS COLLECTED
GAIN ACCURACY(%)
0
1
2
3
4
5
6
7
10^3
10^4
EVENTS/WIRE

Fig, 6

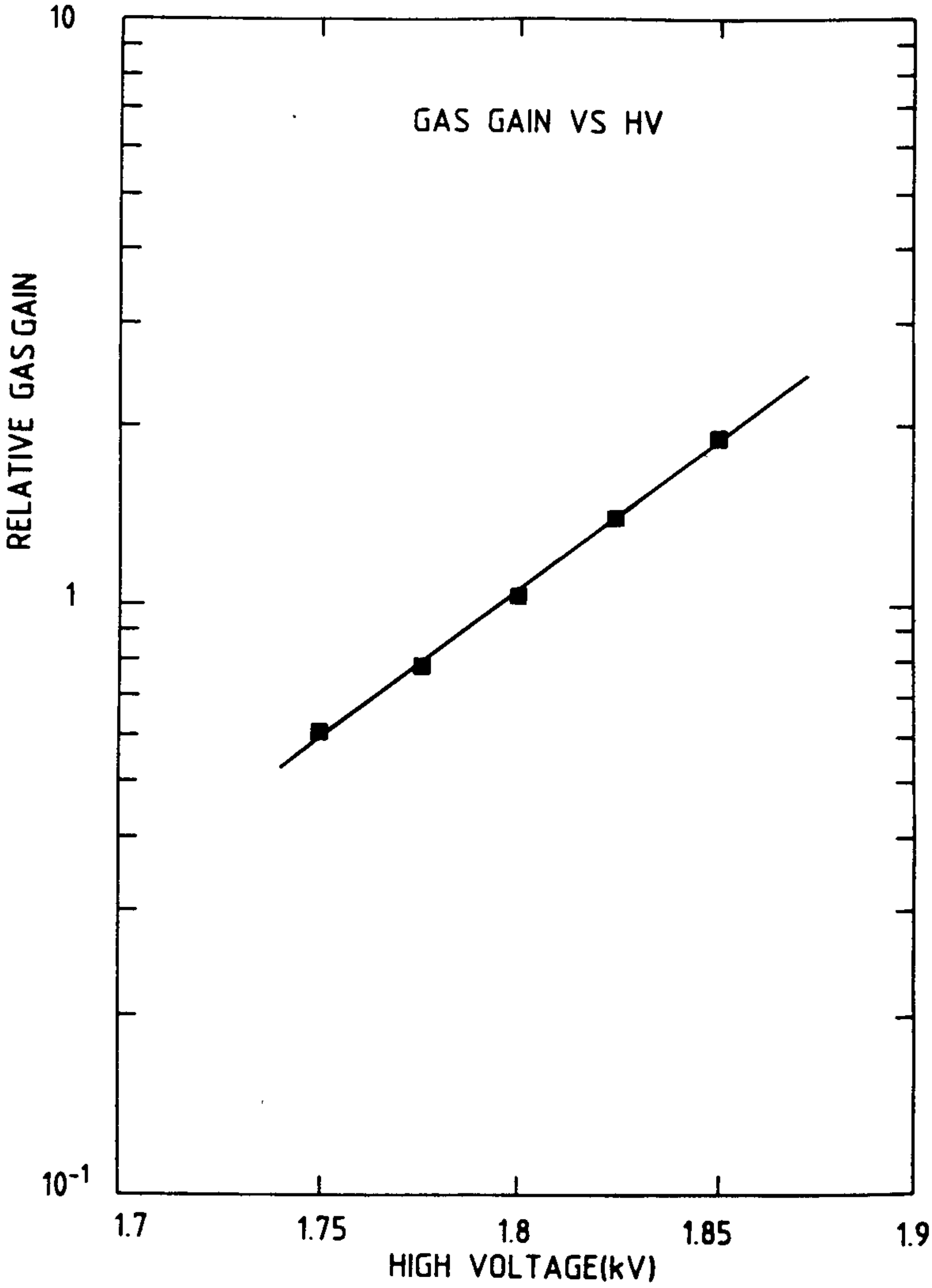

GAS GAIN VS HV
RELATIVE GAS GAIN
10
1
10^{-1}
1.7
1.75
1.8
1.85
1.9
HIGH VOLTAGE(kV)

Fig.7

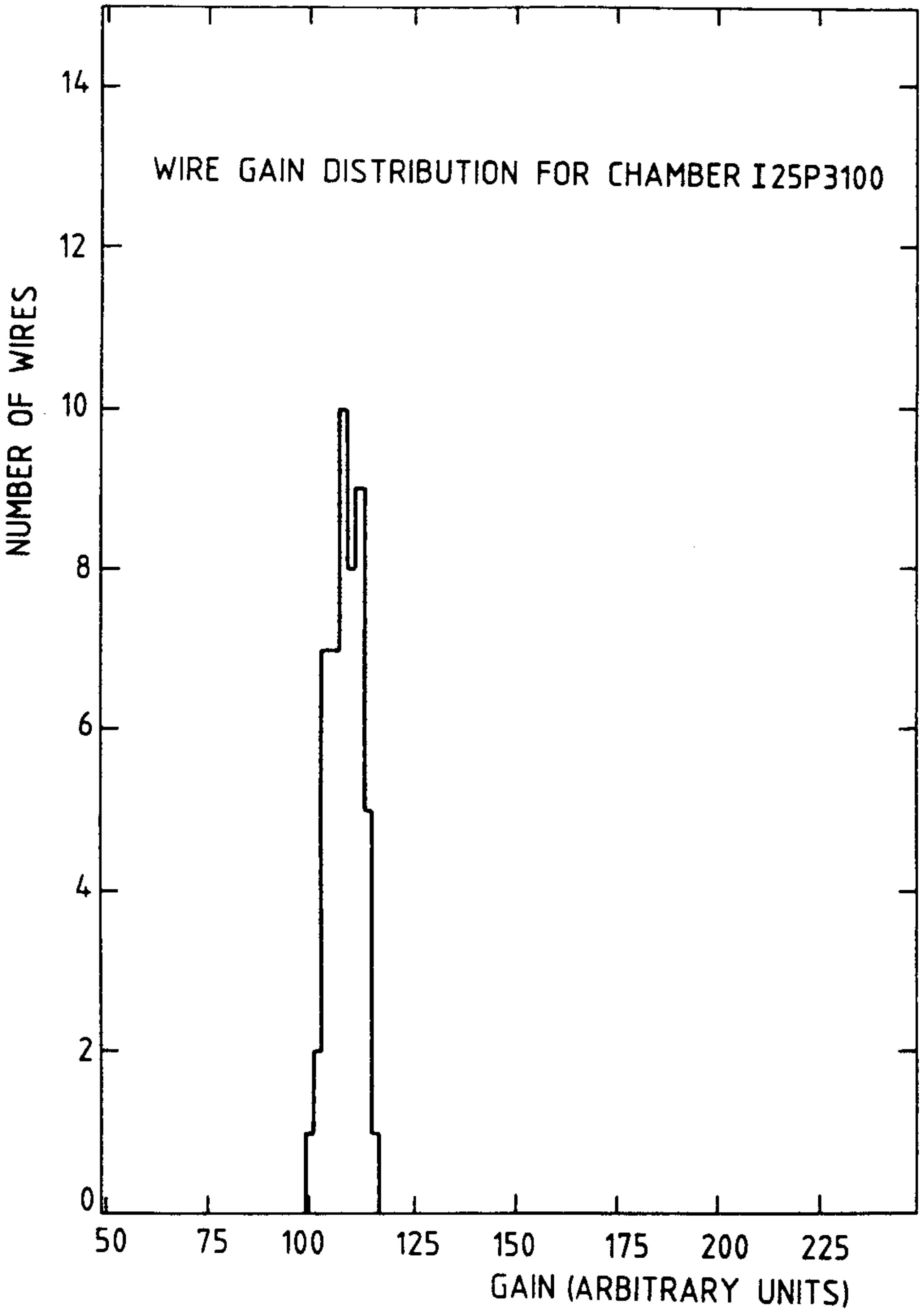
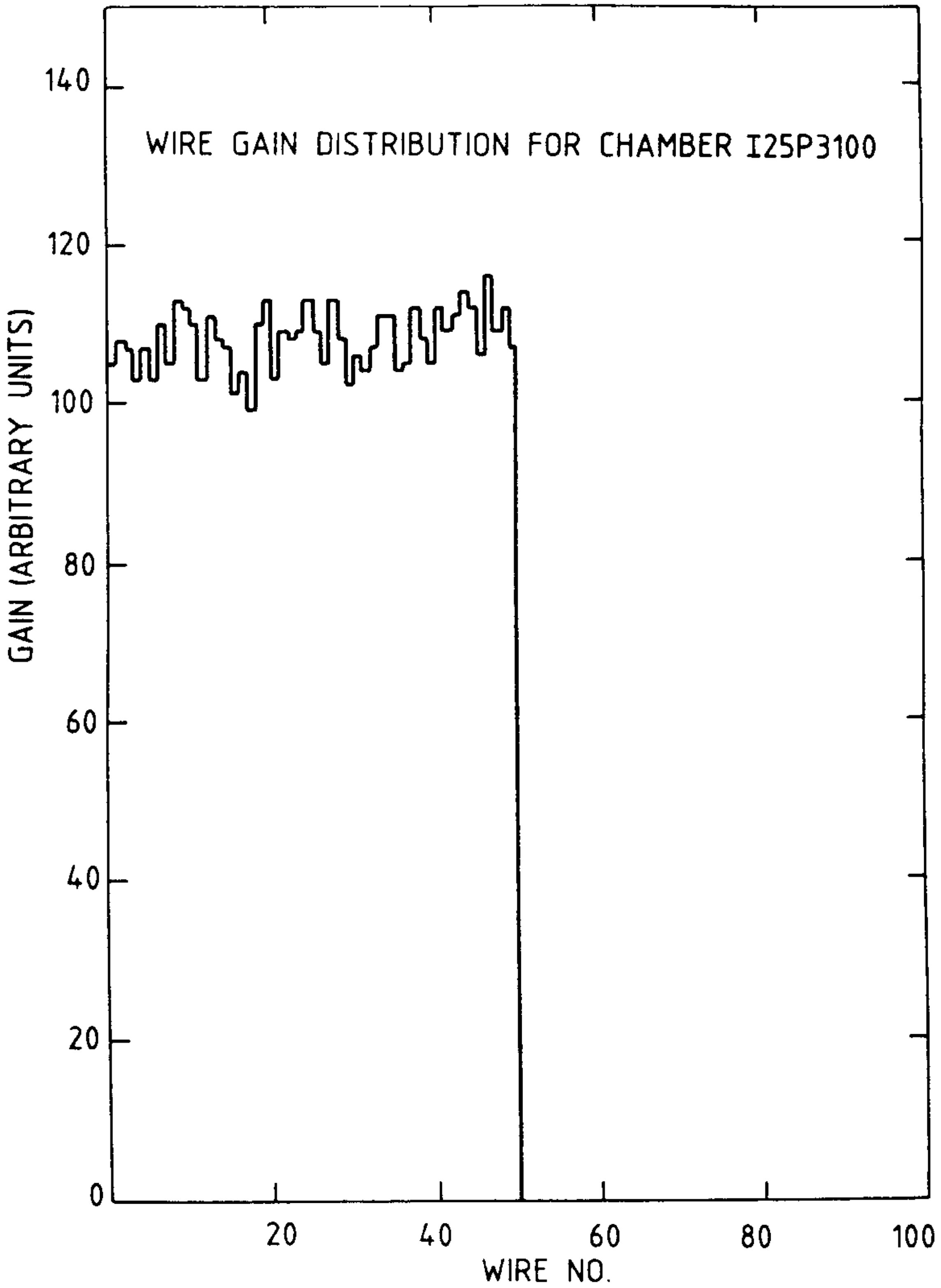

WIRE GAIN DISTRIBUTION FOR CHAMBER I25P3100
NUMBER OF WIRES
14
12
10
8
6
4
2
0
50
75
100
125
150
175
200
225
GAIN (ARBITRARY UNITS)

Fig. 8a



WIRE GAIN DISTRIBUTION FOR CHAMBER I25P3100
GAIN (ARBITRARY UNITS)
140
120
100
80
60
40
20
0
20
40
60
80
100
WIRE NO.

Fig. 8b

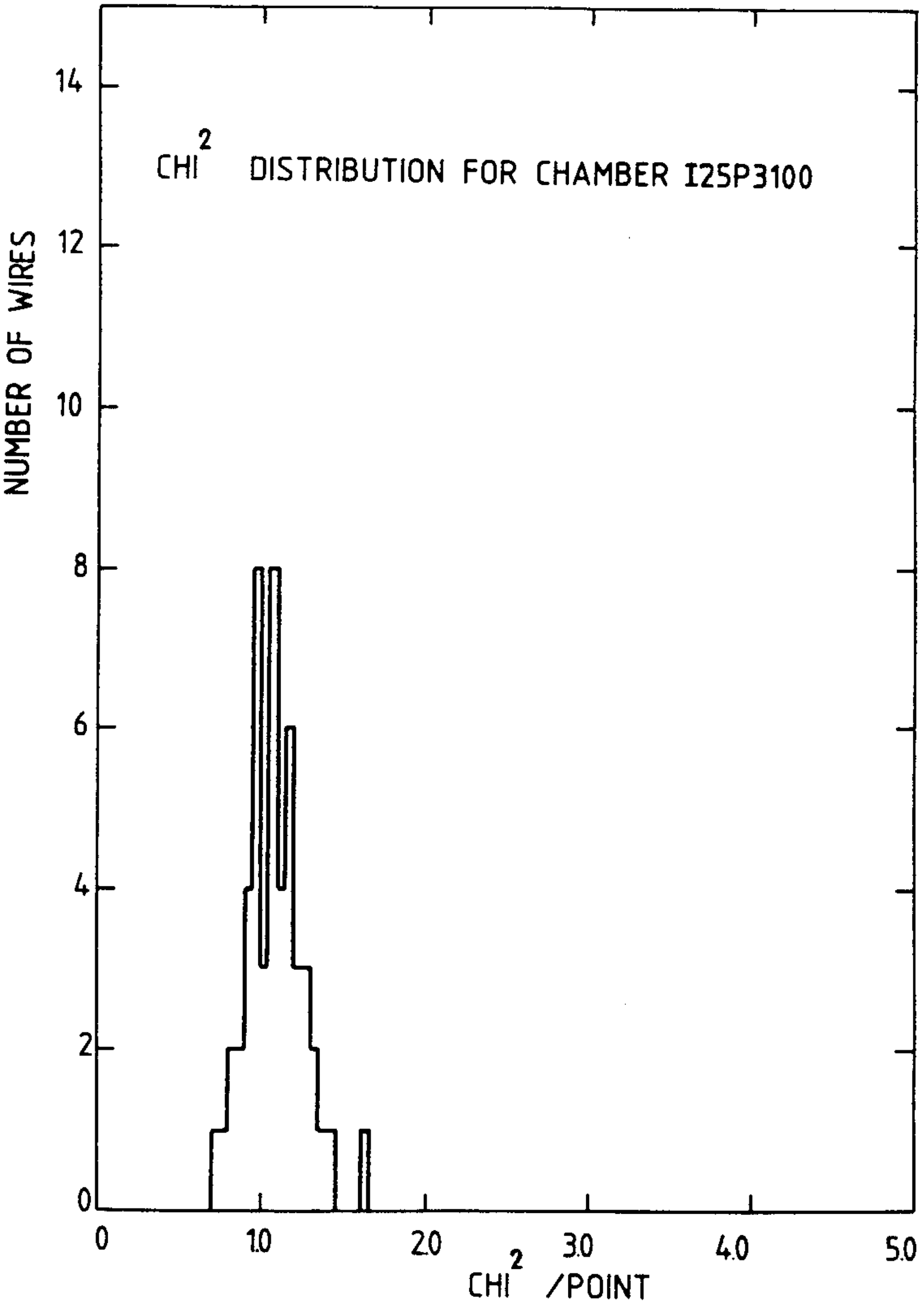

CHI^2 DISTRIBUTION FOR CHAMBER I25P3100
NUMBER OF WIRES
14
12
10
8
6
4
2
0
0
1.0
2.0
3.0
4.0
5.0
CHI^2 /POINT

Fig. 8c

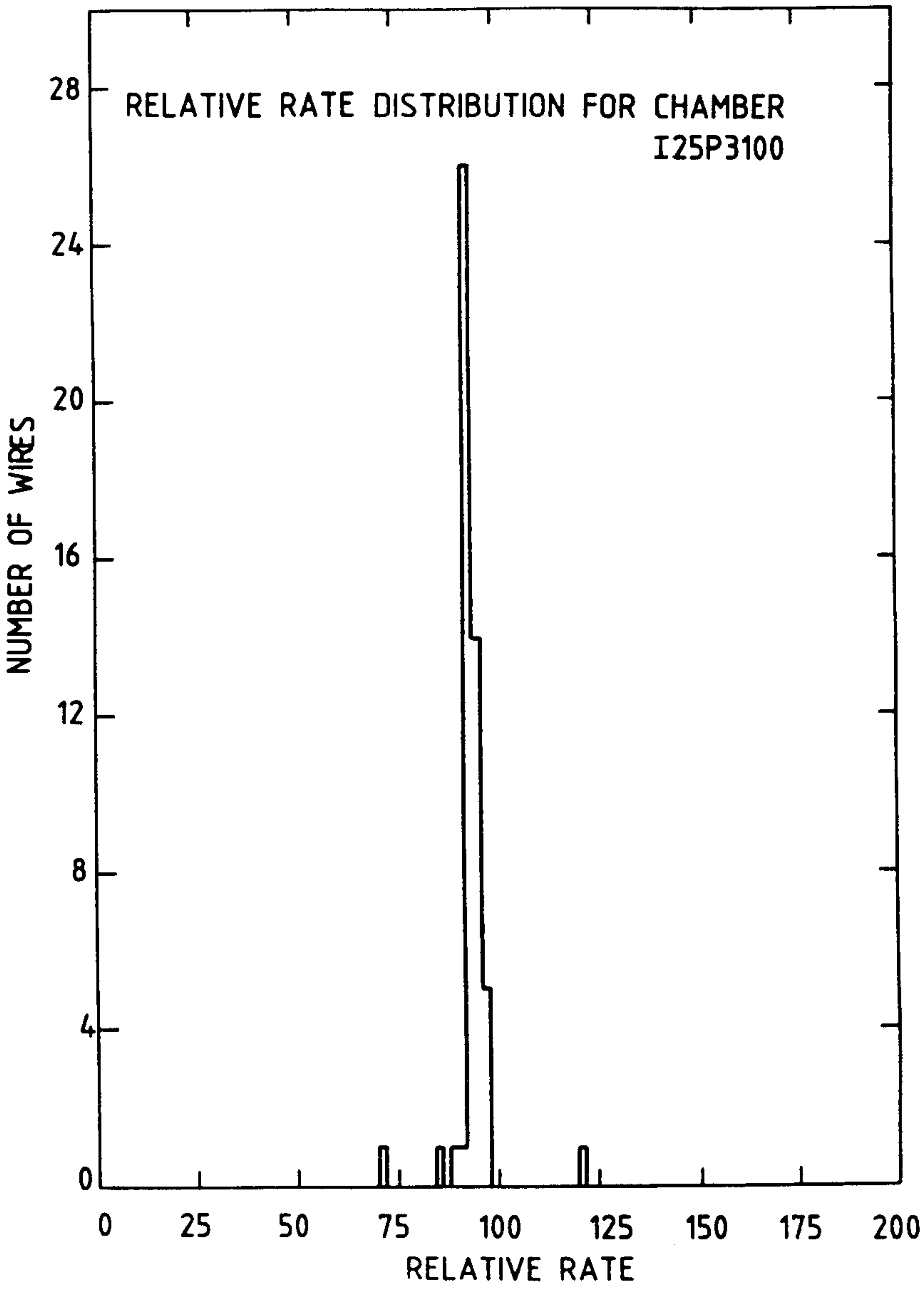

RELATIVE RATE DISTRIBUTION FOR CHAMBER
I25P3100
NUMBER OF WIRES
RELATIVE RATE
0
4
8
12
16
20
24
28
0
25
50
75
100
125
150
175
200

Fig. 8d

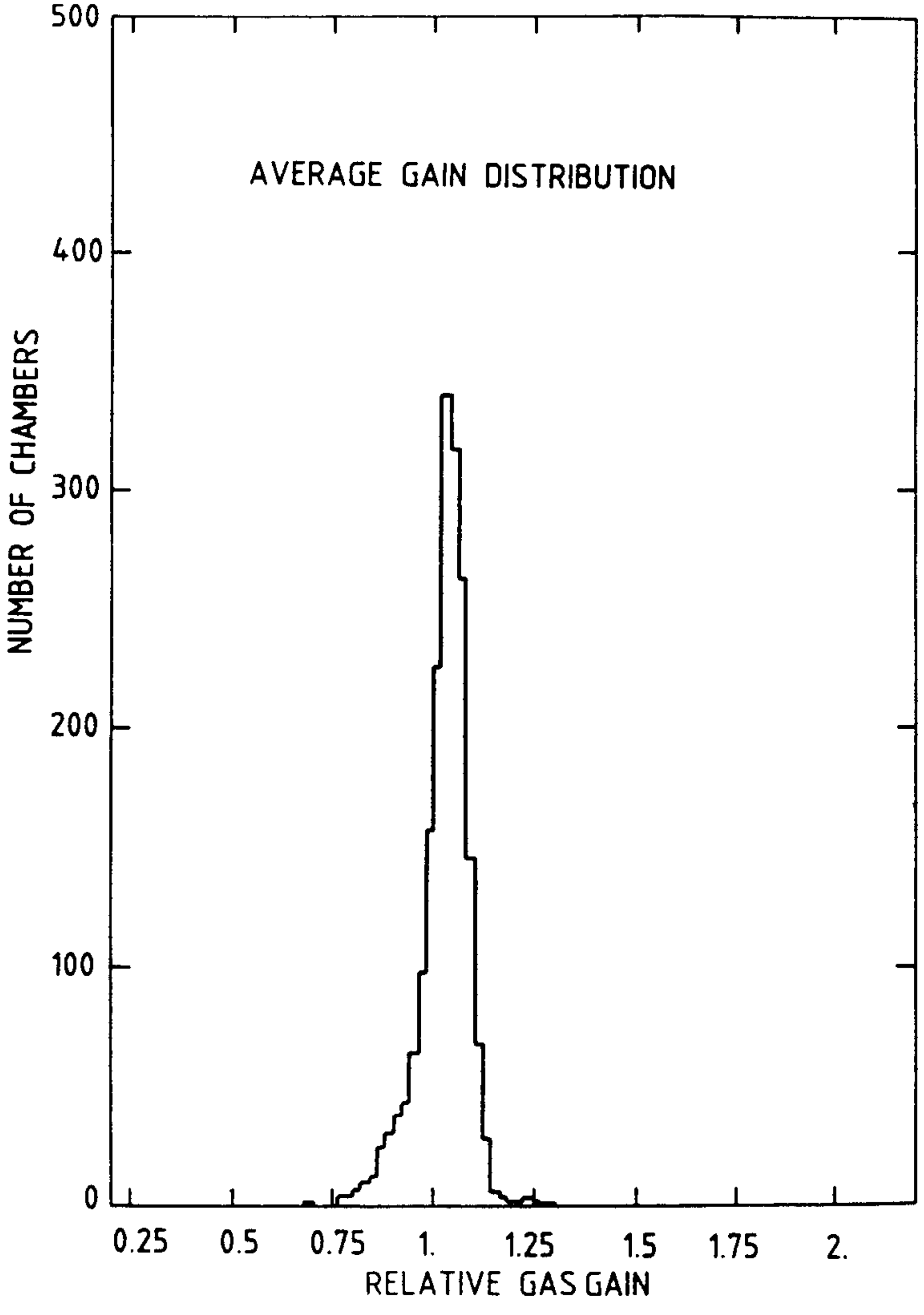

AVERAGE GAIN DISTRIBUTION
NUMBER OF CHAMBERS
500
400
300
200
100
0
0.25
0.5
0.75
1.
1.25
1.5
1.75
2.
RELATIVE GAS GAIN

Fig. 9

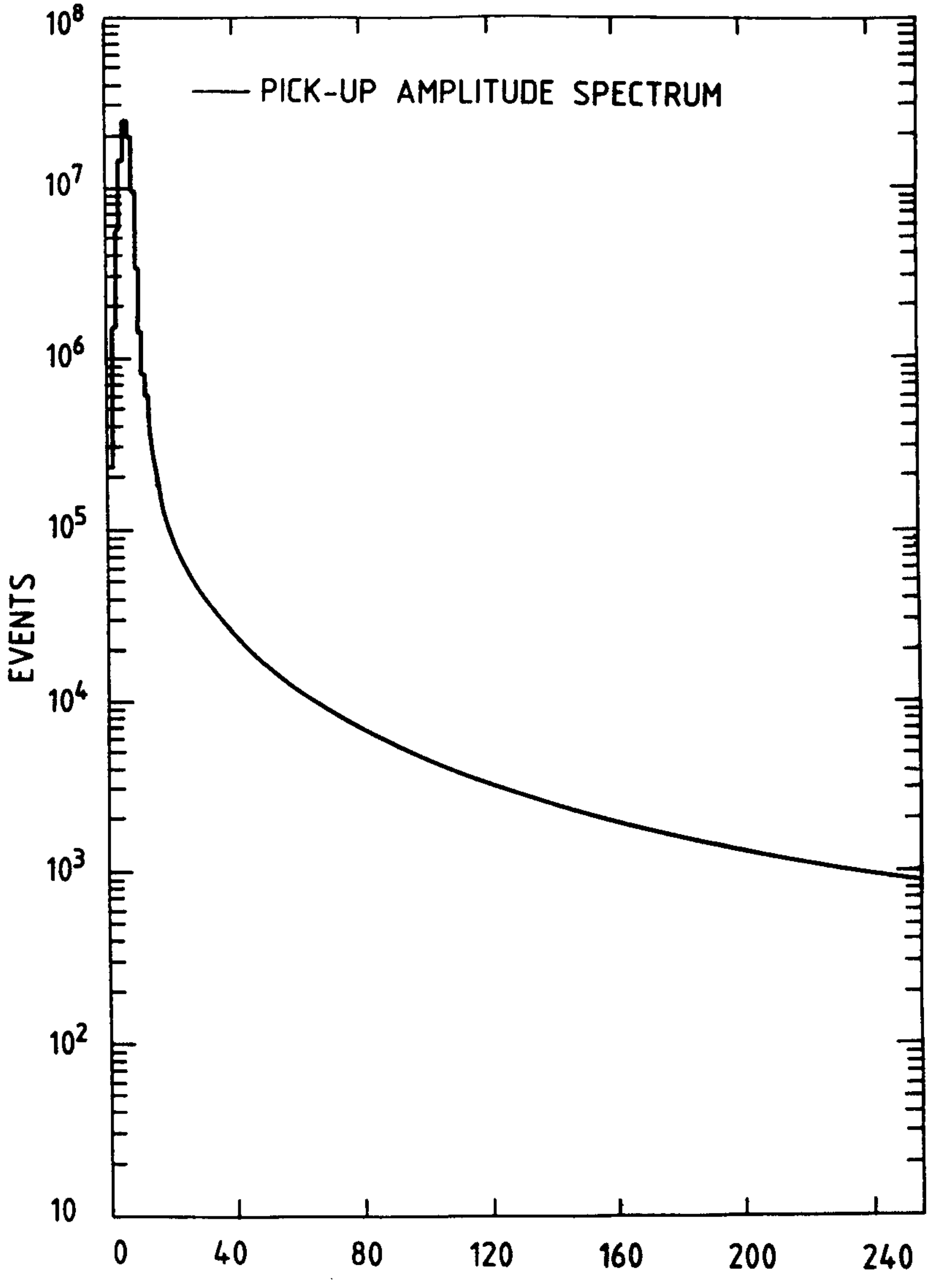

PICK-UP AMPLITUDE SPECTRUM
EVENTS
10^8
10^7
10^6
10^5
10^4
10^3
10^2
10
0
40
80
120
160
200
240
AMPLITUDE(ARBITRARY UNITS)

Fig.10

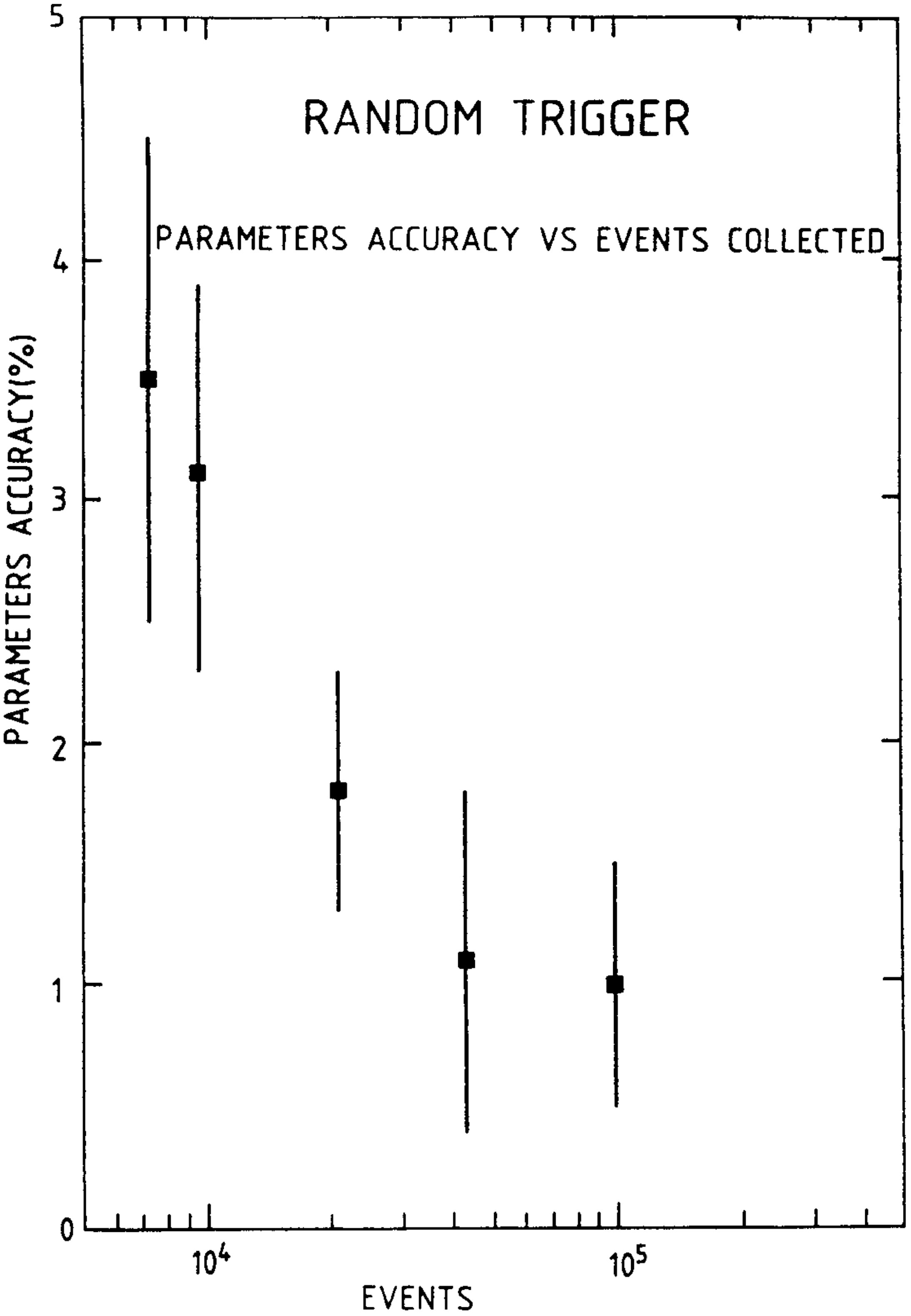
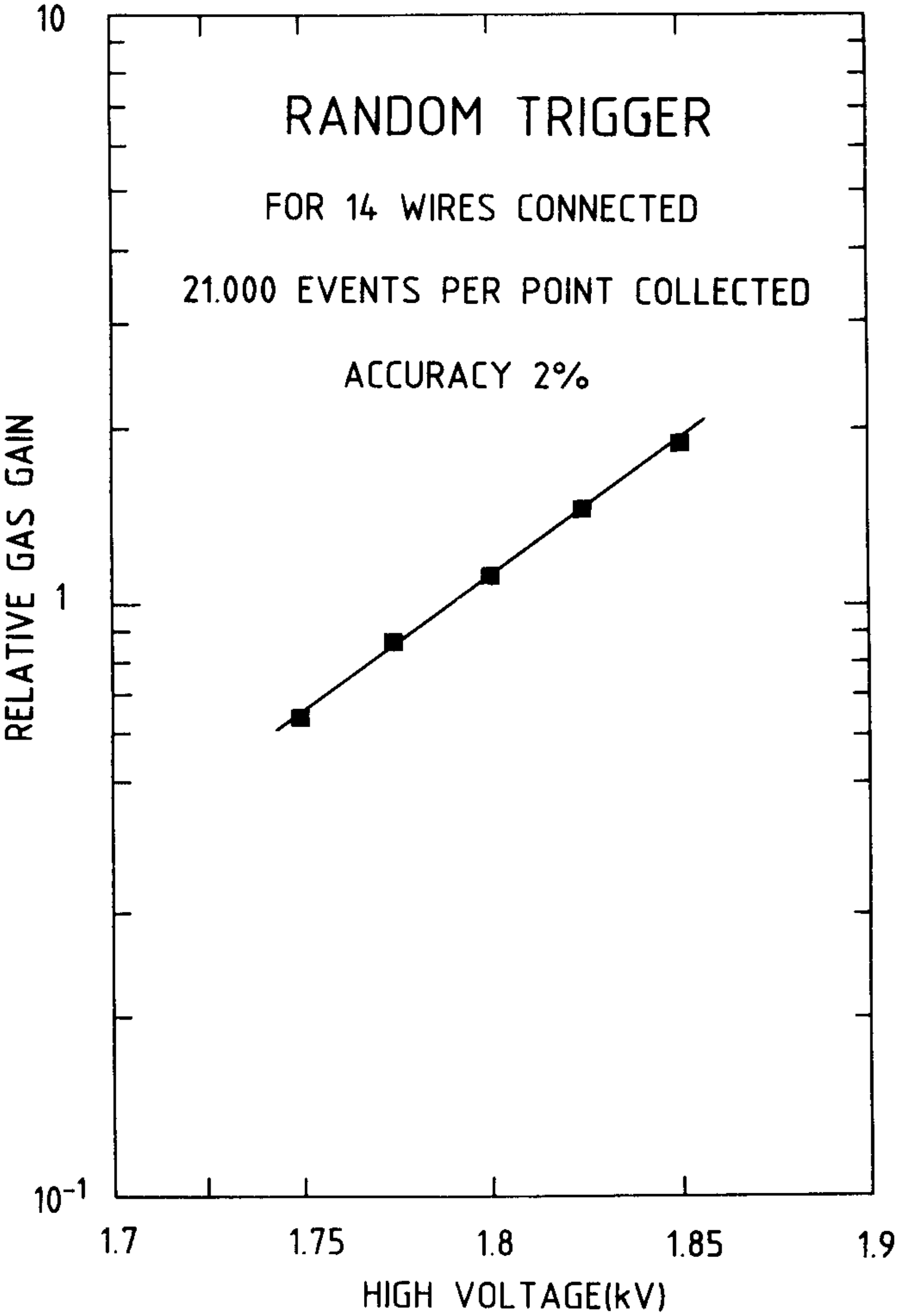

RANDOM TRIGGER
PARAMETERS ACCURACY VS EVENTS COLLECTED
PARAMETERS ACCURACY(%)
5
4
3
2
1
0
10^4
10^5
EVENTS

Fig.11


RANDOM TRIGGER
FOR 14 WIRES CONNECTED
21.000 EVENTS PER POINT COLLECTED
ACCURACY 2%
RELATIVE GAS GAIN
10
1
10^{-1}
1.7
1.75
1.8
1.85
1.9
HIGH VOLTAGE(kV)

Fig, 12

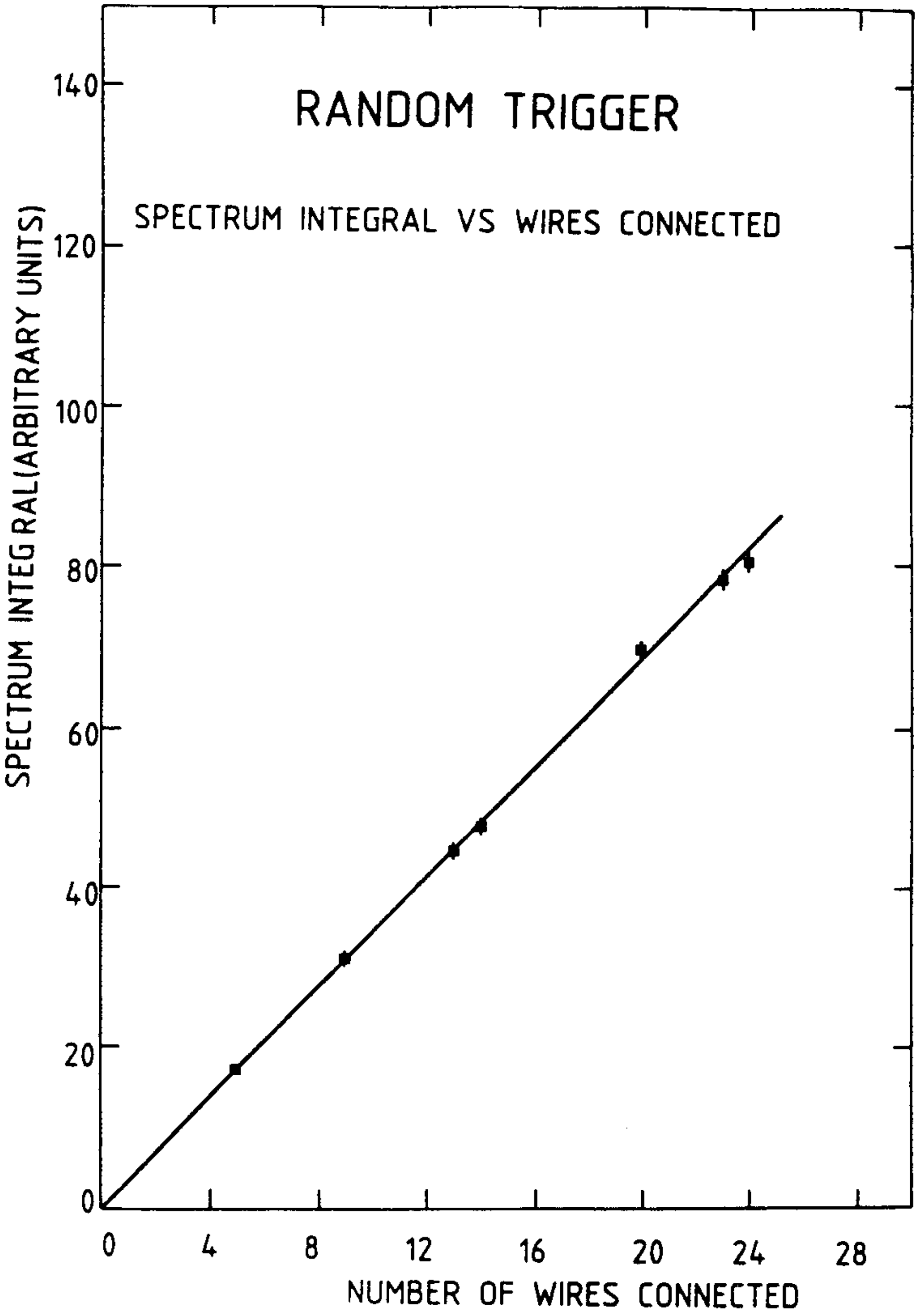

RANDOM TRIGGER
SPECTRUM INTEGRAL VS WIRES CONNECTED
SPECTRUM INTEGRAL(ARBITRARY UNITS)
140
120
100
80
60
40
20
0
0
4
8
12
16
20
24
28
NUMBER OF WIRES CONNECTED

Fig.13