KERNFORSCHUNGSZENTRUM

KARLSRUHE

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Properties of a Hadron Calorimeter Used as a Neutron Spectrometer in an ISR-Experiment

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ABSTRACT

The energy dependence of the pulse height, the resolution and the efficiency of a total absorption neutron calorimeter has been measured for particle energies 3 GeV < T_{kin} < 21 GeV. There are indications that the response and the resolution of the detector are influenced by the number of particles produced in the first nucleon-nucleus interaction of the shower process.

ZUSAMMENFASSUNG

Die Energieabhängigkeit der Pulshöhe, des Auflösungsvermögens und der Nachweiswahrscheinlichkeit eines Neutronenkalorimeters wurde im Energiebereich 3 GeV < T_{kin} < 21 GeV untersucht. Die Impulshöhe und das Auflösungsvermögen scheinen von der Multiplizität des primären Nukleonkernstoßes abzuhängen.

1. INTRODUCTION

For the detection and energy measurement of high energy hadrons, detectors of the calorimeter type become of increasing importance [1-5] since the energy resolution properties increase with the particle energy. Calorimeter type detectors seem to offer the only possibility to detect and measure the energy of neutral hadrons. Calorimeters have already been used by different groups at proton accelerators and at the storage rings [5,6,7]. In this report we describe the properties of a hadron calorimeter of the sandwich type which is used at the split-field-magnet detector facility (SFM) of the proton intersecting storage rings (ISR) at CERN. This calorimeter has some special features which allow to fit it into the detector facility. During the test and calibration runs of the detector at the CERN PS some properties of the shower process have been observed which give additional information concerning the hadron shower which may be important for future applications of this detector type.

2. DESCRIPTION OF THE DETECTOR

Fig. 1 shows the layout of the calorimeter. It consists of three modules of scintillator-copper sandwiches. The scintillators of each module are separately mounted to a photomultiplier tube (Valvo 58 AVP), which is shielded from the fringe field of the SFM by iron pipes [8]. The thickness of the copper converter-plates is 2.2cm and 3cm, the thickness of the scintillator is 0.7cm. The total copper thickness amounts to 73cm, while the total material of the calorimeter corresponds to 7.0 collision lengths. In order to start the hadronic cascade within the front part of the calorimeter four 2.2cm thick copper plates of 10cm × 10cm surface are assembled between the first scintillator plates of the front module followed by the probe counter PC (fig. 1). The conversion within the small copper plates was detected by a pulse height analysis of the probe counter PC, i.e. a pulse height exceeding that of minimum ionising particles. In front of the calorimeter an anticounter is assembled to suppress the detection of charged particles traversing the calorimeter. Its efficiency was measured to be higher than 99.8%.

In order to minimize the loss of parts of the shower by its lateral development the surface area of the counter increases from 200cm^2 at the front side continiously to 250cm^2 at the back. This choice of the set up is based on a Monte Carlo simulation of the shower process [2].

The pulse height spectrum of the three scintillator modules of the calorimeter and the pulse height spectrum of the probe counter were recorded. The energy of the absorbed hadron is determined from the summed pulse heights of the three scintillator modules. In order to monitor the stability of the set up a light diode is attached to each module. It has been calibrated by detecting protons of well defined energy with the calorimeter. The measurements at different days were reproducible within ±1%.

3. OPERATIONAL CHARACTERISTICS

The calibration of the calorimeter was performed at the CERN PS with protons in the energy interval 3 GeV < T_{kin} < 21 GeV.

As fig. 2 shows, the pulse height of minimum ionising particles varies by ±6% over the total area of the calorimeter. The pulse height of the shower for monoenergetic protons hitting the four small front converters at different places varies by less than ±3% (fig. 3). For the three scintillator modules no change of the relative width of the pulse height distribution was observed for different high voltages applied to the dynode system (fig. 4, 5). Therefore in the calibration measurements a high voltage was applied to the photomultiplier tubes which allowed for a maximum dynamic range of the response signal.

For different energies of the primary proton the pulse height spectra of the scintillator modules were summed up and recorded by a multichannel analyser which was gated by the signal of the beam defining counters in order to suppress the background contributions. Fig. 6 shows that the response function is linear in the energy region investigated. The extrapolated line crosses T_{kin} = 0 at a pulse height different from zero. We carefully checked that this effect is not due to shifts of the zero level of the electronics. The observation can be explained qualitatively by the threshold effect of the shower process.

In addition to the response function the absolute and the relative width of the pulse height distribution are plotted in fig. 6. At low energy the absolute width decreases. The present understanding of the shower process and the importance of nuclear phenomena do not allow a simple explanation of the observed trend. However the result is in agreement with the observations of other experiments [2]. For completeness we present in fig. 7 the pulse height distributions of the shower for different energies of the primary particle. Its detailed form is of importance for the unfolding procedure of the measured spectra. The pulse height distributions are approximately of gaussian shape.

4. PROPERTIES OF THE PROBE COUNTER

The probe counter PC has been introduced into the calorimeter assembly (fig. 1) in order to detect the conversion of the incoming hadron within the four copper converters in the front part of the calorimeter. In fig. 8 the pulse height spectrum of this counter is shown. The maximum at small pulse heights is due to minimum ionising particles which have not been converted by the four copper plates. It is followed by two small maxima due to 1 respectively 2 produced particles. In the trigger condition a threshold is set in the pulse height spectrum in order to separate through-going particles from those which are converted. In fig. 9 the efficiency of the calorimeter is plotted which is defined by

η = (number of converted particles with a pulse height in PC greater than a threshold value)/ (number of hadrons hitting the converter)

In the actual experiment a threshold at 500mV will be chosen in order to separate clearly between converted and through-going particles, the efficiency of the calorimeter will than be of the order of 45%, depending on the particle energy (fig.9).

Fig. 10 shows the pulse height spectra of the three modules of the calorimeter for different threshold values of the probe counter PC. The separation of minimum ionising particles is clearly visible. One observes that with increasing threshold values an increasing amount of energy is deposited in the first module.

In fig. 11 for a kinetic energy of T_{kin} = 21 GeV the pulse height of the calorimeter and the width of the response function are plotted for different thresholds in the pulse height spectrum of the probe counter PC. The pulse height increases with increasing threshold values while the absolute width decreases. These measurements have been performed for thickness of the small converter of 8.8cm, 44.cm, and 2.2cm in front of the probe counter PC. The results of these measurements agree within the error limits. At an energy of T_{kin} = 10 GeV of the primary particle the increase of the pulse height as well as the decrease of the absolute width of the pulse height distribution were weaker. These results give support to the assumption that the absolute width and the pulse height of a calorimeter depend on the number of particles produced in the <u>first</u> hit of the primary hadron with the nucleons of the converter. This result may be of importance for the application of calorimeters of the sandwich type to the investigation of neutrino interactions, since the mean multiplicity for these reactions should vary with invariant mass of the hadronic system [9].

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REFERENCES

[1] P. Schludecker
thesis, Karlsruhe 1969

[2] J. Engler, W. Flauger, B. Gibbard, F. Mönnig, K. Runge, H. Schopper
Nucl. Instr. Meth. 106, 189 (1973)

[3] E.B. Hughes, R. Hofstadter, W.L. Lakin and I. Sick
Nucl. Instr. Meth. 75, 130 (1969)

[4] W.J. Willis
BNL Report CRISR 72-15 (1972)

[5] J. Engler, K. Horn, J. König, F. Mönnig, P. Schludecker, H. Schopper, P. Sievers, H. Ullrich, K. Runge
Phys. Lett. 28B, 641 (1968)

[6] J. Engler, W. Flauger, B. Gibbard, F. Mönnig, K. Pack, K. Runge, H. Schopper
Nucl. Phys. (in press)

[7] J. Engler, B. Gibbard, W. Isenbeck, F. Mönnig, J. Moritz, K. Pack, K.H. Schmidt, D. Wegener, W. Bartel, W. Flauger, H. Schopper
Measurements of Inclusive Neutron Spectra at the ISR
Paper, presentend to the IInd Aix-en-Provence Conference, Sept. 1973

[8] P. Hanke, W. Isenbeck, J. Moritz, K.H. Schmidt, D. Wegener
Kernforschungszentrum Karlsruhe, Report KFK 1923
(June 1973)

[9] H. Meyer
Rapporteur talk: International Symposium on Electron and Proton Interactions at High Energies,
Bonn, August 27-31, 1973

FIGURE CAPTIONS

Fig. 1: Lay out of the calorimeter

PC	probe counter
Z1,Z2,Z3	modules of the calorimeter
A	Anticounter
Sc	scintillation material
C	Converter
Cu	copper

Fig. 2: Variation of the pulse height of the calorimeter for minimum ionising particles as a function of the place of incidence.

Fig. 3: Pulse height and resolution of the calorimeter for monoenergetic protons hitting the converter at different places.

Fig. 4,5: Influence of the high voltage applied to the counters on the energy response and the resolution for minimum ionising particles and converted protons respectively.

Fig. 6: Energy dependence of the pulse height and the width of the pulse height distribution.

Fig. 7: Pulse height distribution functions at different energies of the primary particle.

Fig. 8: Pulse height spectrum of the probe counter PC.

Fig. 9: Efficiency of the calorimeter as a function of the pulse height threshold in the probe counter PC.

Fig. 10: Pulse heights of the three calorimeter modules for different thresholds of the probe counter PC.

Fig. 11: Influence of the threshold of the probe counter on the response and the resolution of the calorimeter.

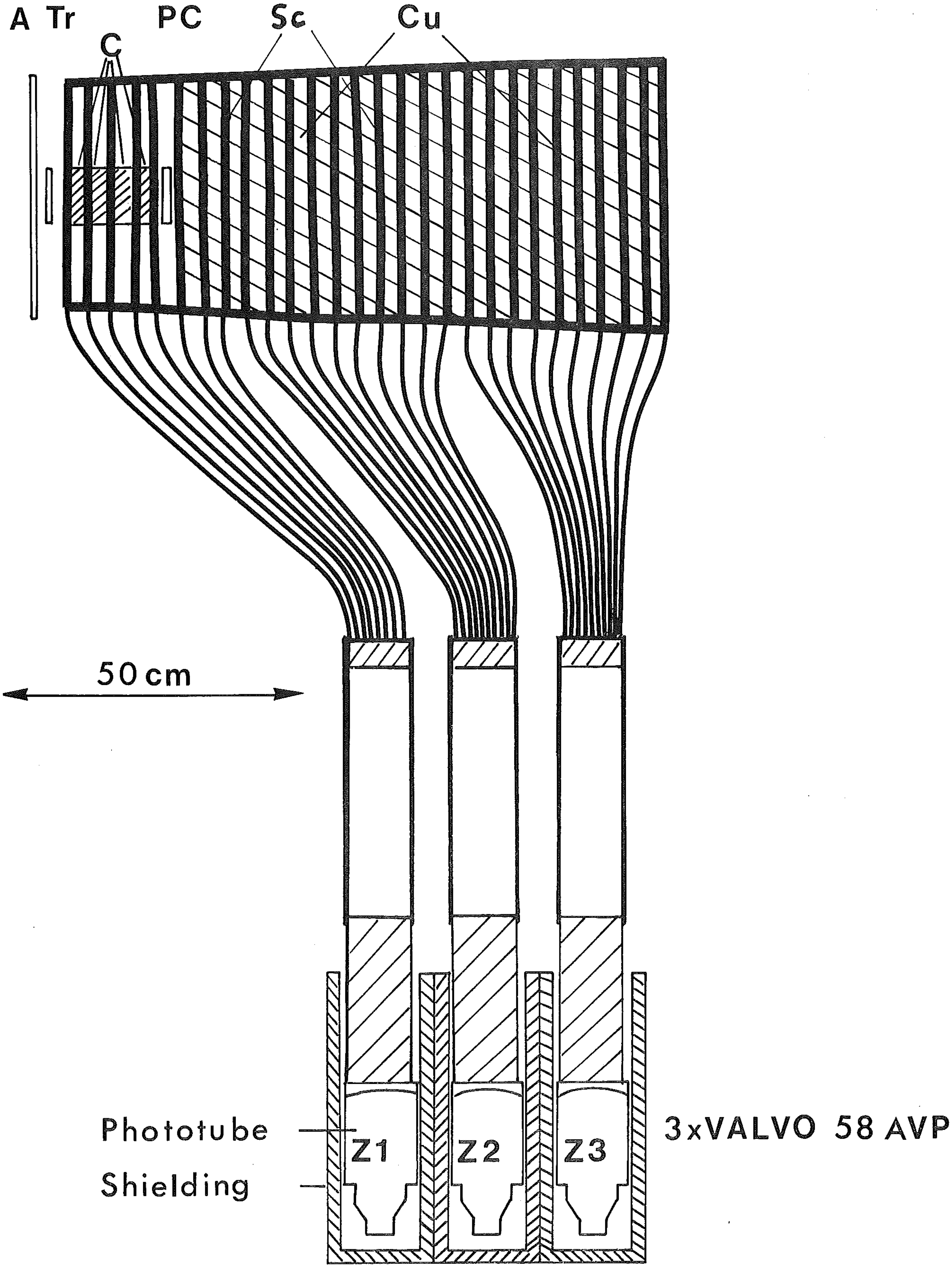
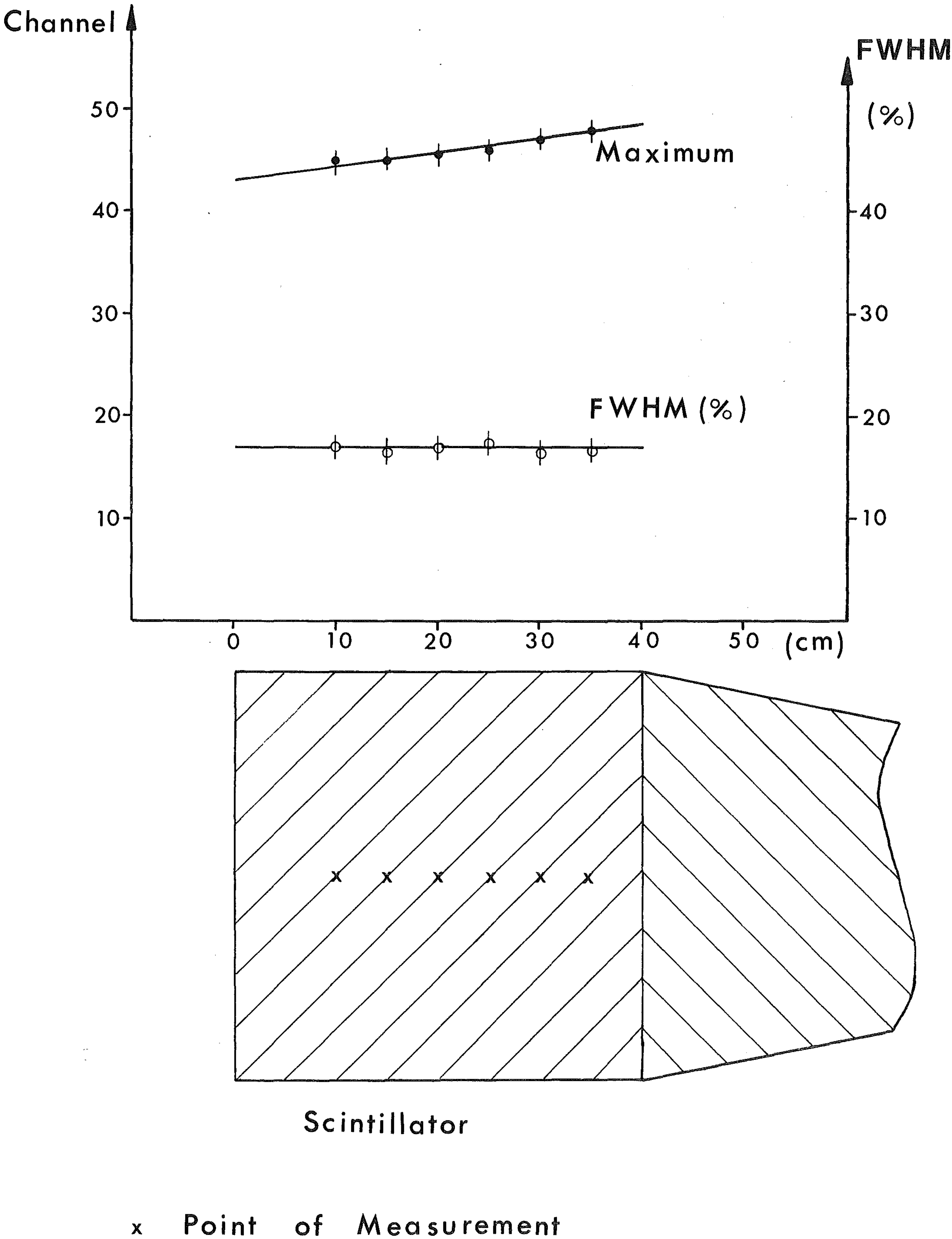

A
Tr
C
PC
Sc
Cu
50 cm
Phototube
Shielding
Z1
Z2
Z3
3xVALVO 58 AVP

Fig.1



Channel
FWHM
(%)
50
40
30
20
10
Maximum
FWHM (%)
0
10
20
30
40
50
(cm)
Scintillator
x Point of Measurement

Fig. 2

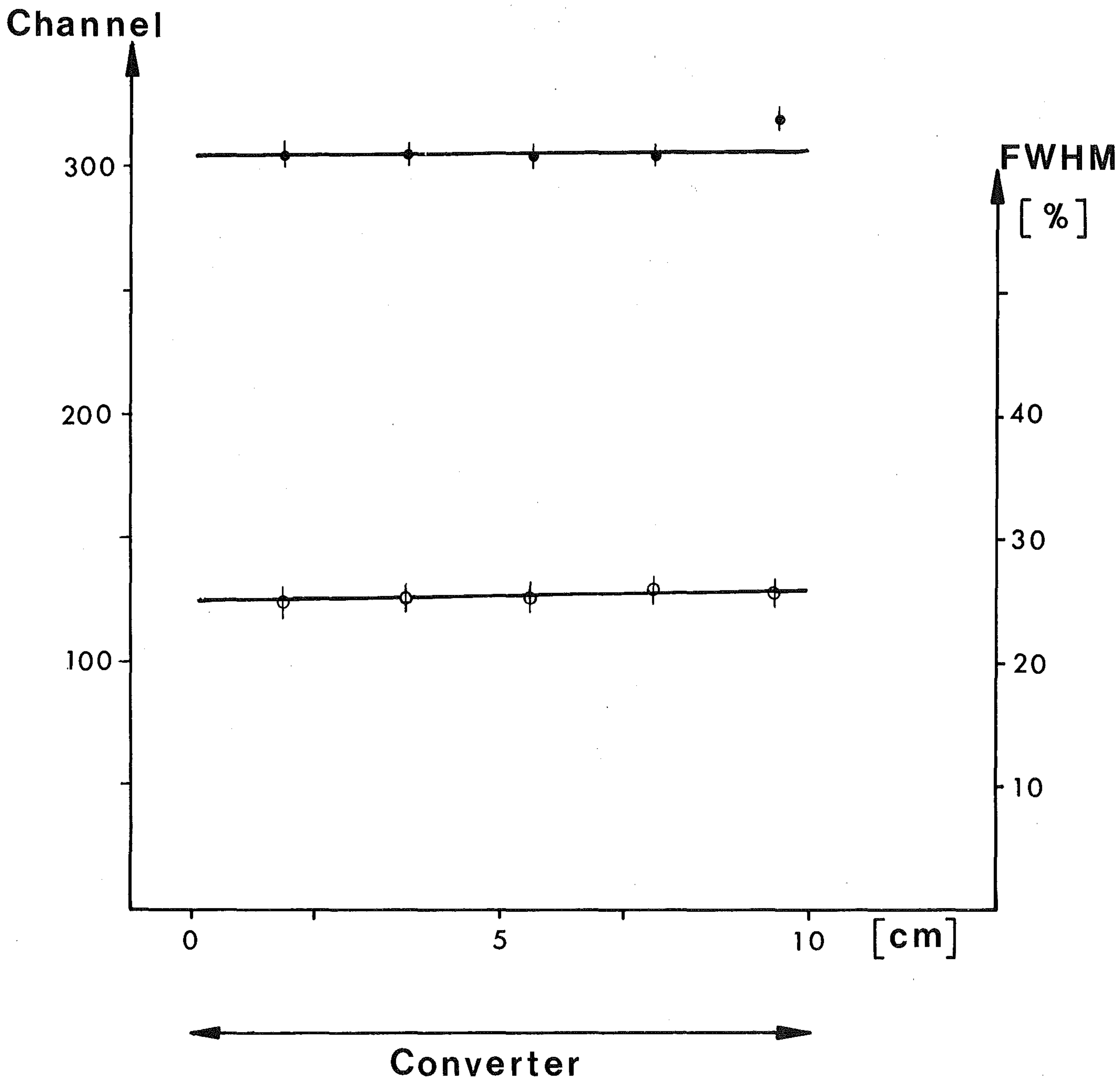


Fig.3

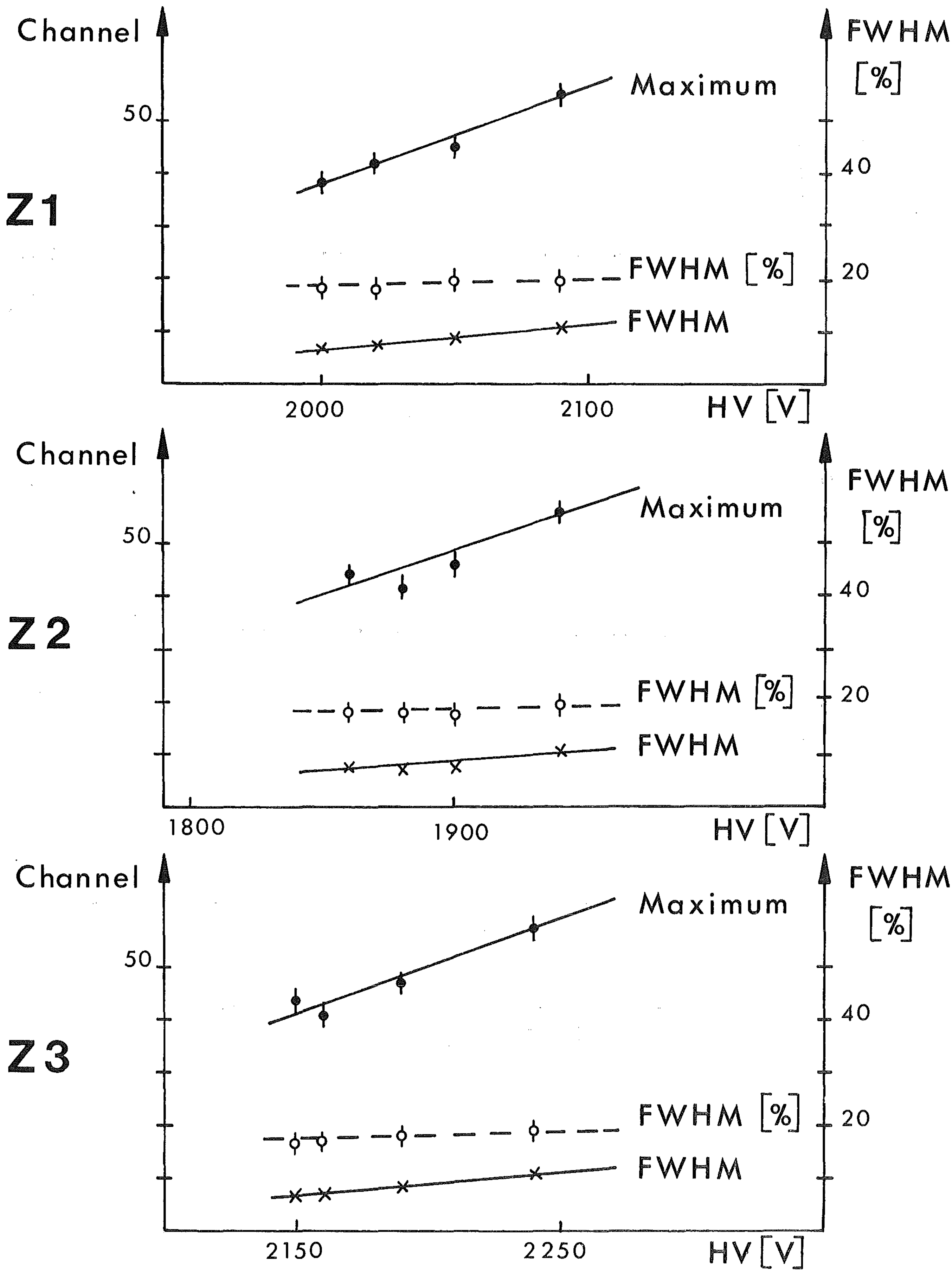

Channel
FWHM [%]
Maximum
50
40
Z1
FWHM [%]
20
FWHM
2000
2100
HV [V]
Channel
FWHM [%]
Maximum
50
40
Z2
FWHM [%]
20
FWHM
1800
1900
HV [V]
Channel
FWHM [%]
Maximum
50
40
Z3
FWHM [%]
20
FWHM
2150
2250
HV [V]

Fig. 4

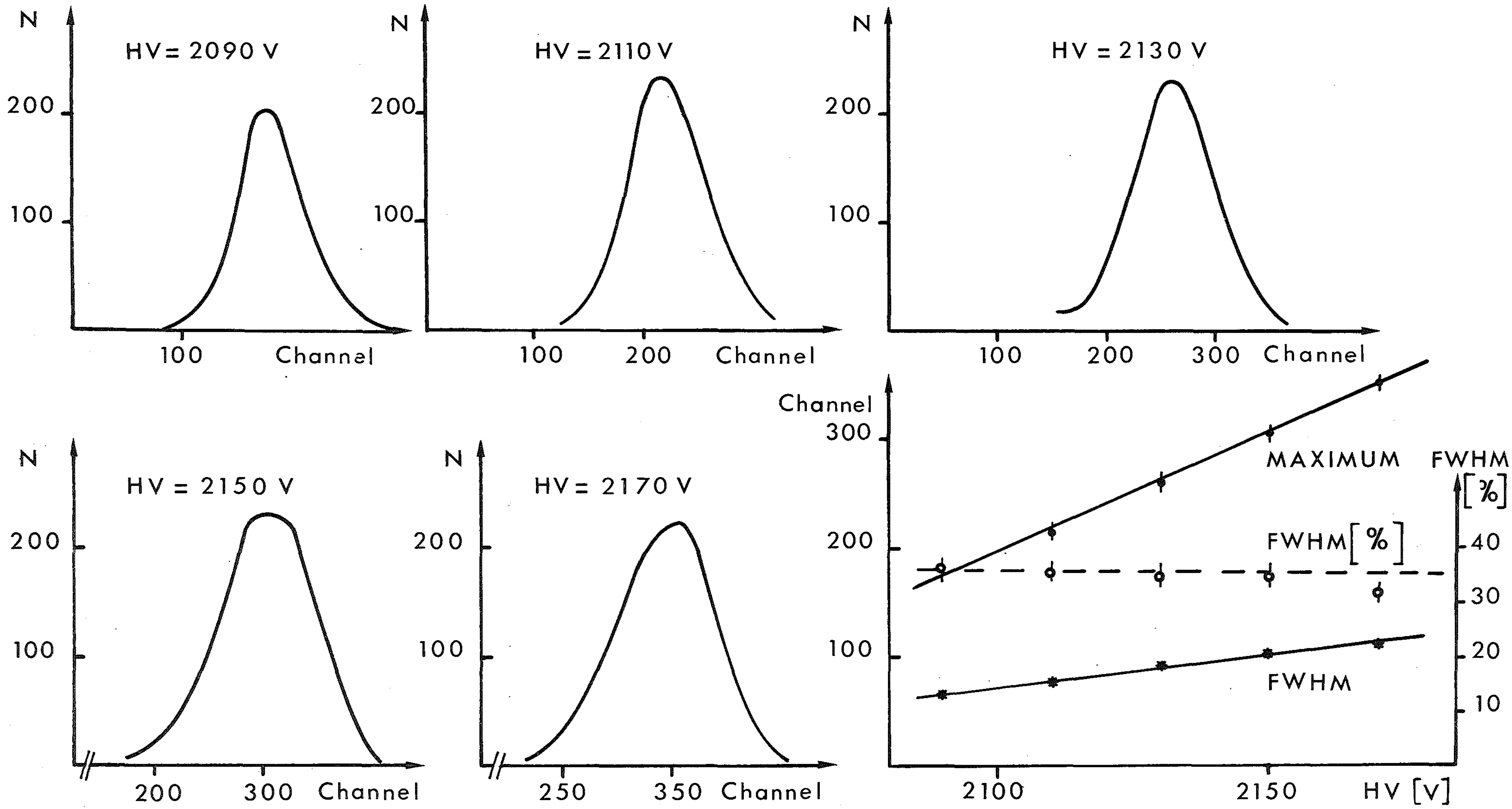

N
HV= 2090 V
200
100
100
Channel
N
HV = 2110 V
200
100
100
200
Channel
N
HV = 2130 V
200
100
100
200
300
Channel
N
HV = 2150 V
200
100
200
300
Channel
N
HV = 2170 V
200
100
250
350
Channel
Channel
300
200
100
MAXIMUM
FWHM [%]
FWHM
FWHM [%]
40
30
20
10
2100
2150
HV [V]

Fig. 5

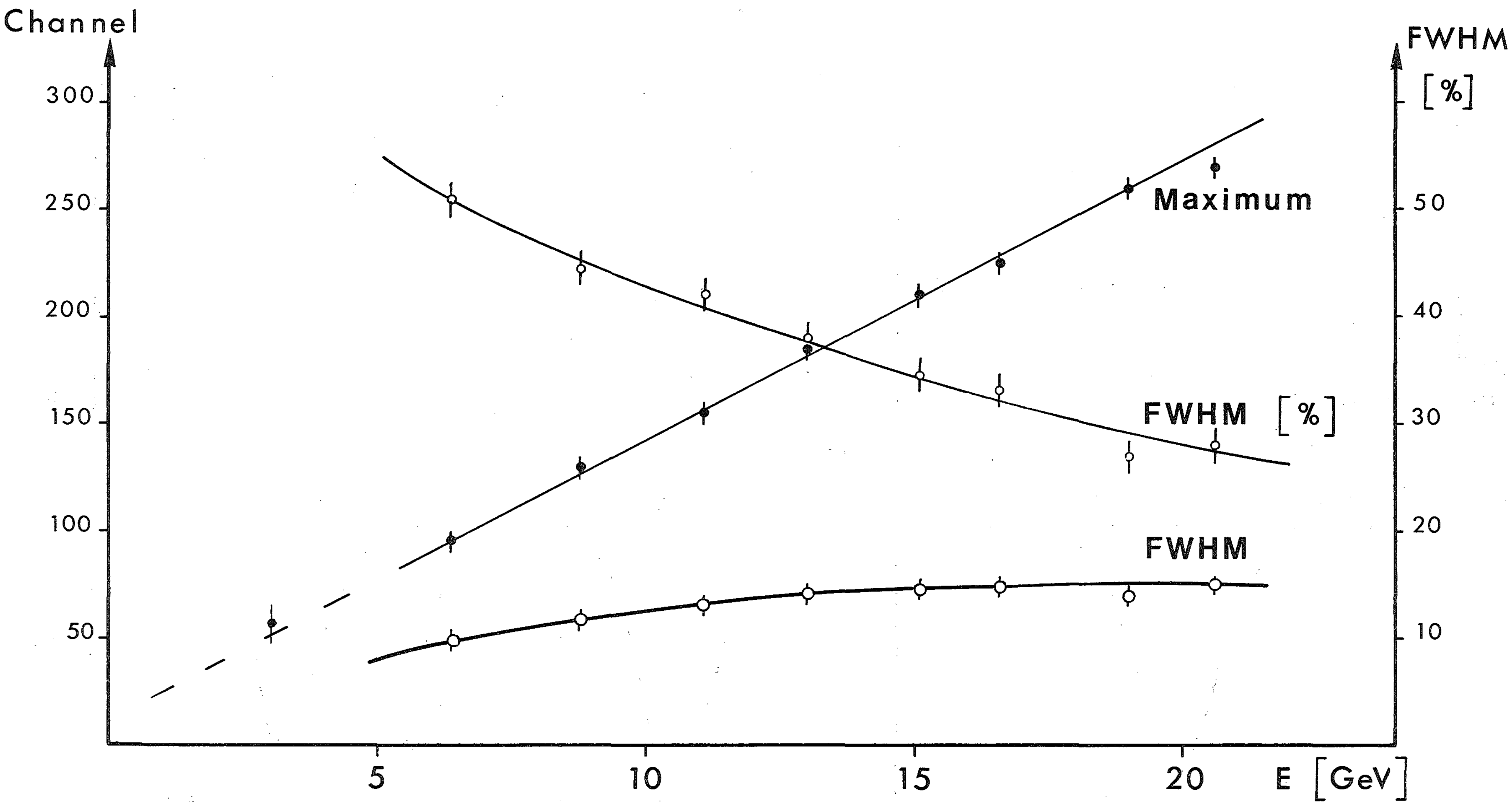

Channel
300
250
200
150
100
50
FWHM
[%]
50
40
30
20
10
Maximum
FWHM [%]
FWHM
5
10
15
20
E [GeV]

Fig. 6

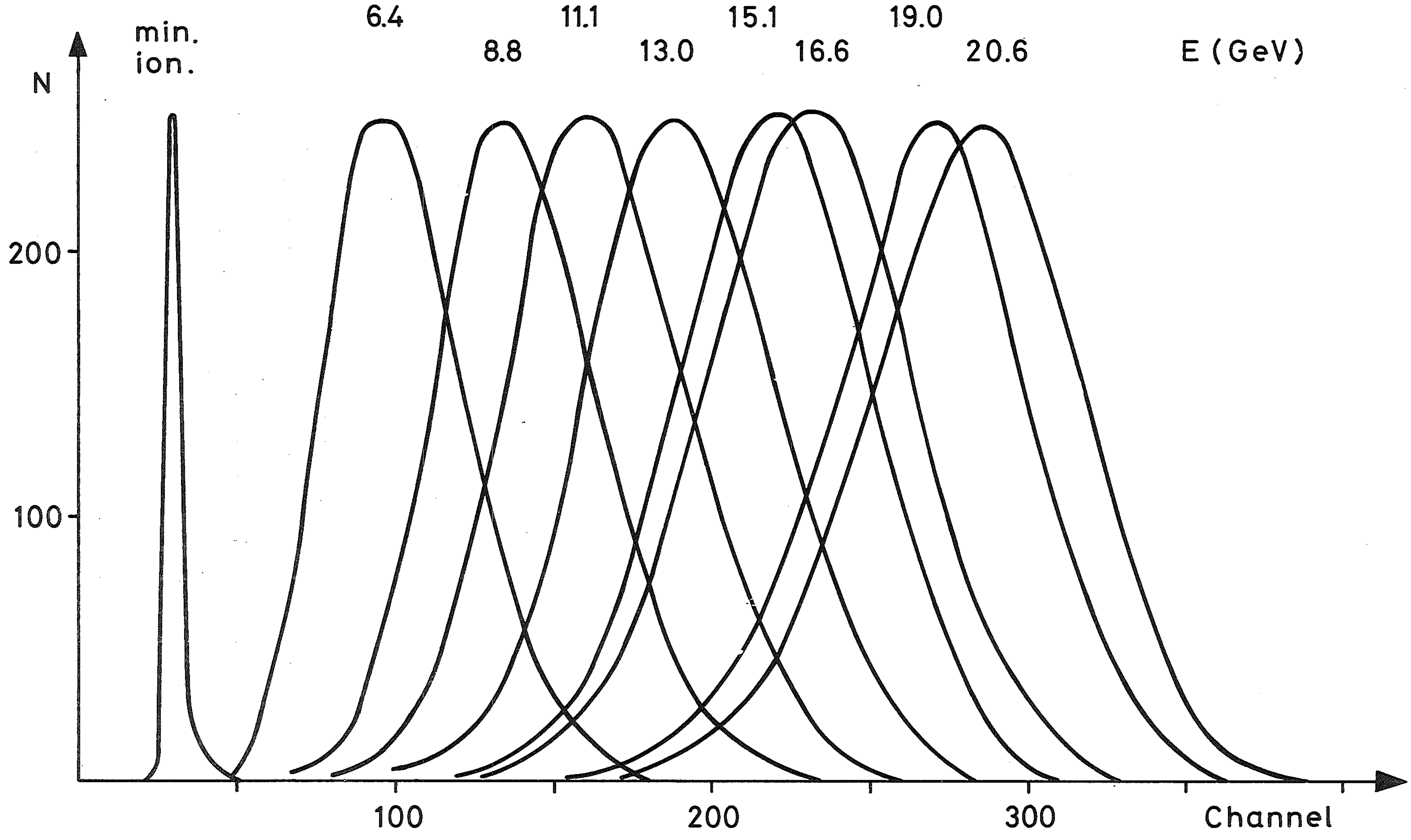

N
200
100
min.
ion.
6.4
8.8
11.1
13.0
15.1
16.6
19.0
20.6
E (GeV)
100
200
300
Channel

Fig.7

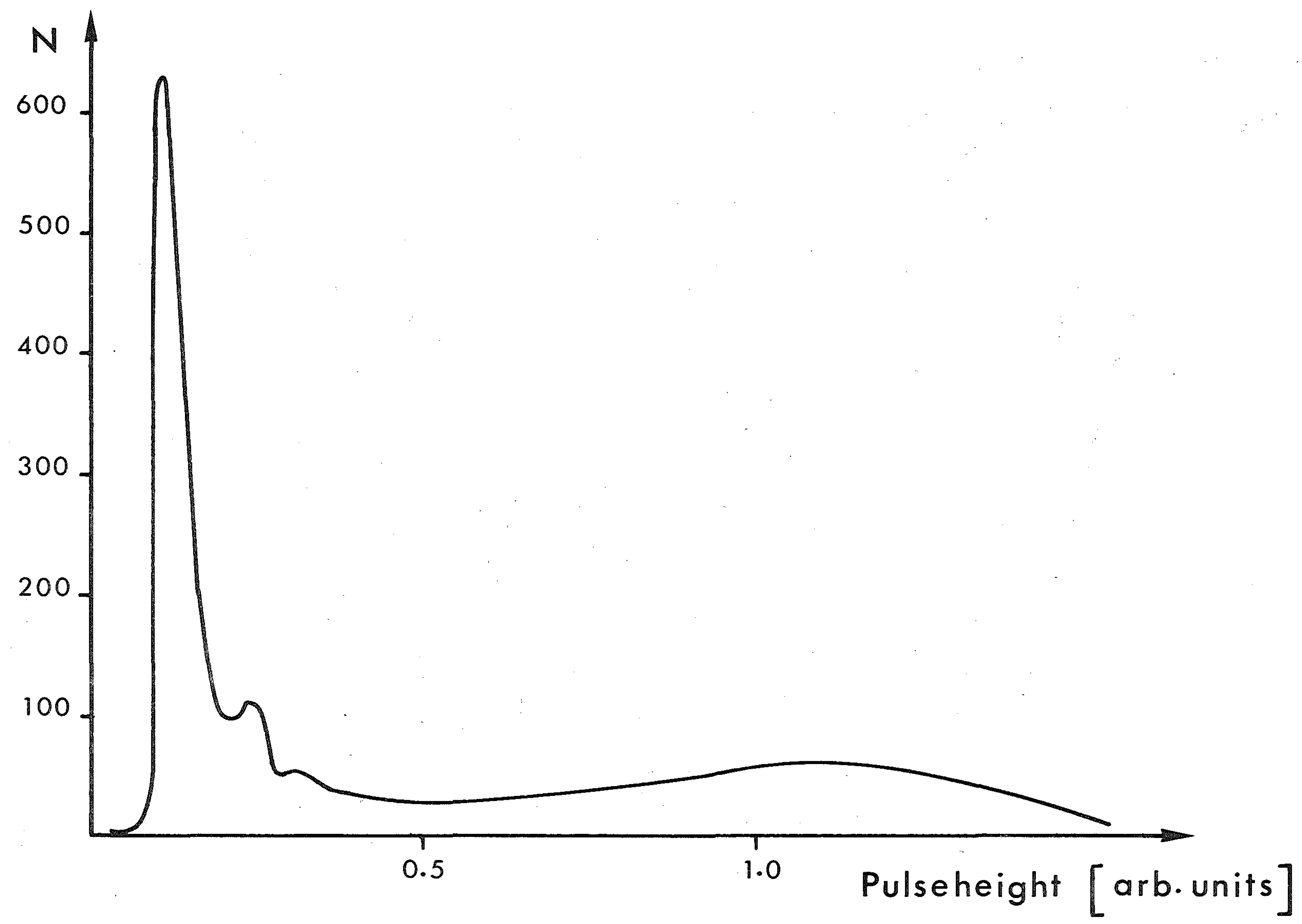


Fig. 8

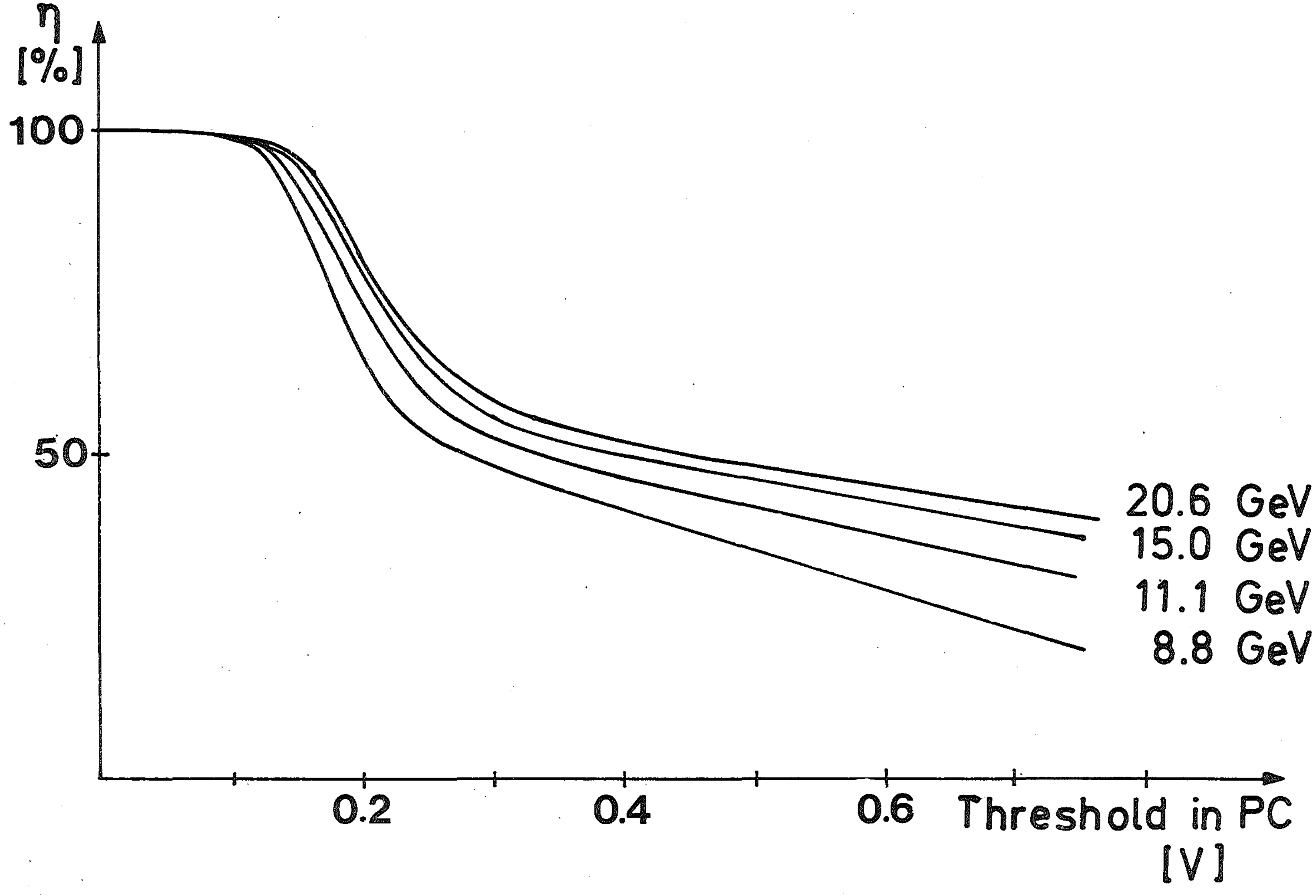


Fig. 9

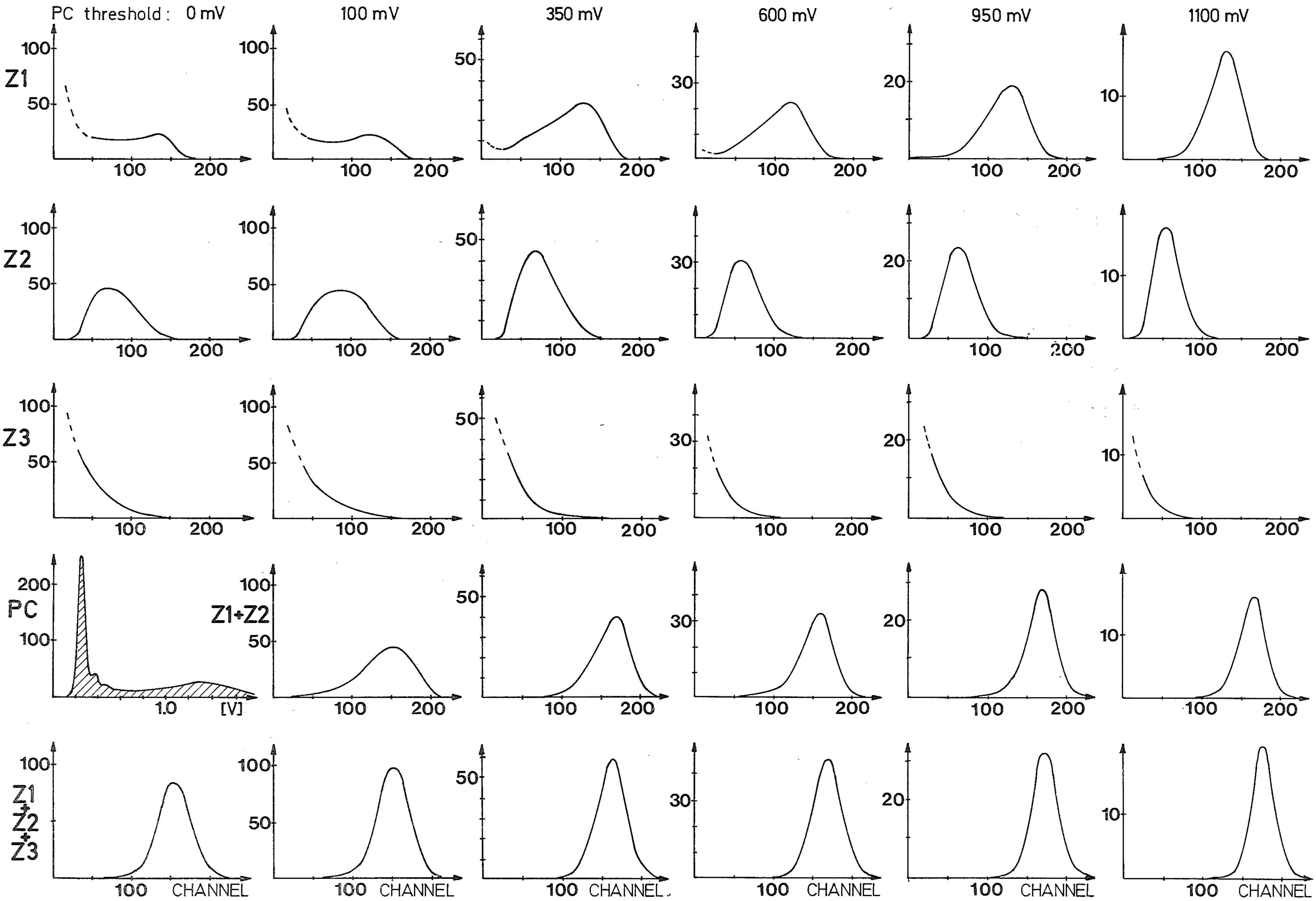

PC threshold: 0 mV
100 mV
350 mV
600 mV
950 mV
1100 mV
Z1
Z2
Z3
PC
Z1+Z2
Z1 + Z2 + Z3
100
50
200
30
20
10
1.0
[V]
CHANNEL

Fig. 10

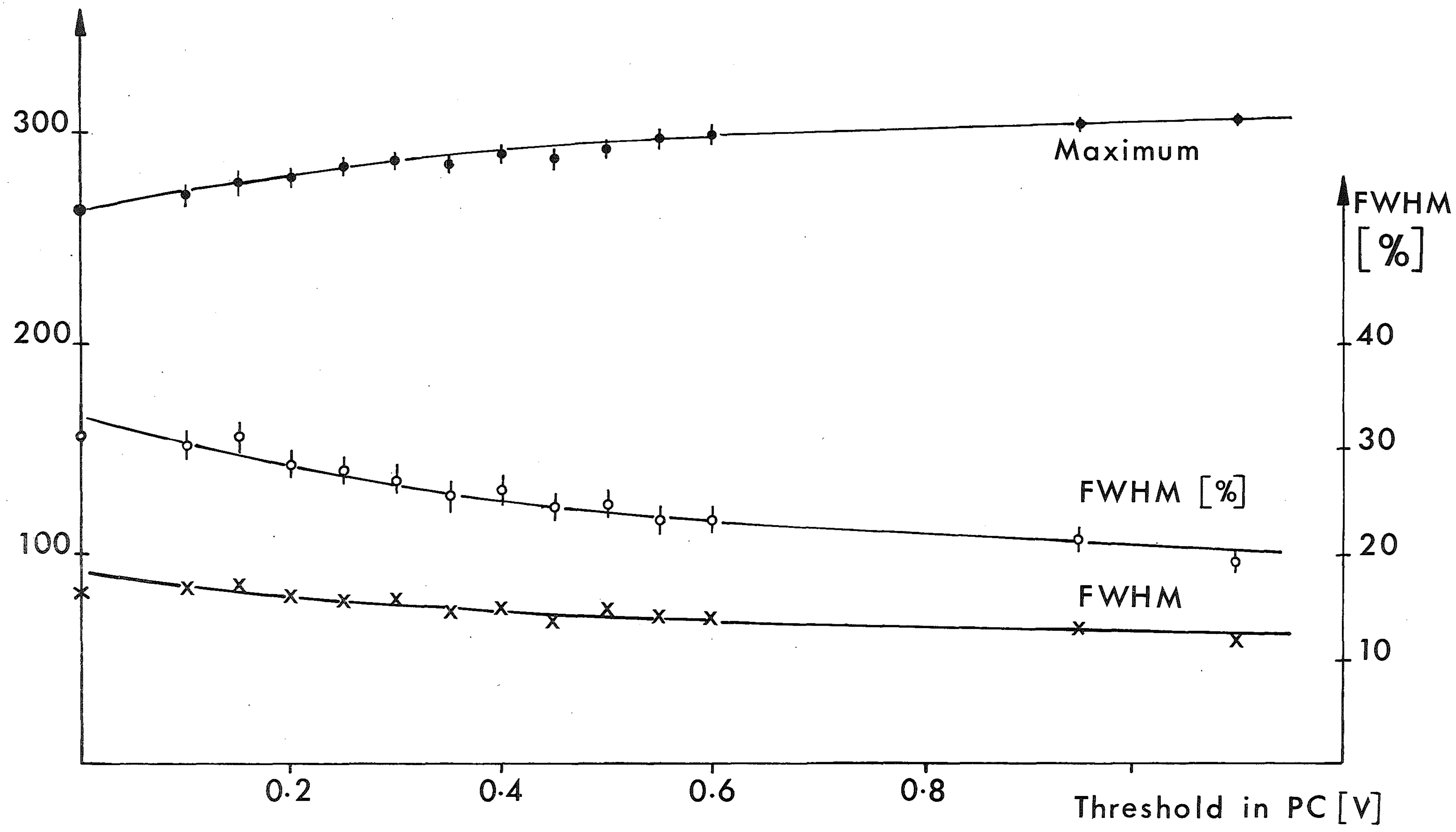

300
200
100
Maximum
FWHM
[%]
40
30
20
10
FWHM [%]
FWHM
0·2
0·4
0·6
0·8
Threshold in PC [V]

Fig. 11