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ON-LINE TESTS ON A SMALL MULTIWIRE PROPORTIONAL CHAMBER IN A SPARK CHAMBER ENVIRONMENT, WITH A REMOTE CAMAC READ-OUT (PRELIMINARY RESULTS AT ≈ 10^5 PARTICLES/BURST)

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1. INTRODUCTION

A 100 × 100 mm^2 MWPC has been set in the incident beam of the CERN-Orsay-Polytechnique-Stockholm experiment at the PS (d_{30} beam in the South Hall) during a parasitic run at reduced intensity (i.e. about 3×10^5 p/sec). The chamber, filled with "magic" mixture was irradiated from 11 to 17 October. The data were read by a prototype CAMAC module, connected with the spark chamber read-out system. Very encouraging results were obtained which should lead to replacing the scintillation-counter beam hodoscopes by multiwire proportional chambers (MWPC) in future running periods.

2. GENERAL WORKING CONDITIONS

2.1 Beam

The d_{30} beam (in the South Hall of the CERN PS) was used at 8 GeV/c, in a parasitic process, with 10% of the usual intensity (i.e. $\approx 1 \times 10^5$ p/burst) with a rather short pulse giving an intensity of about 4×10^5 p/sec. The logic search for events of the type $\pi^- p \rightarrow \bar{p} d$ yielded an average of 11 triggers per burst.

2.2 Set-up (Fig. 1)

The MWPC, set in the incident beam, was separated from the target by two scintillation-counter hodoscopes H_4 and H_5. Close by there was a telescope made of four spark chambers: the edge of the nearest spark chamber was only 140 mm away from the MWPC.

The MWPC has been used as a 6^{th} hodoscope H_6 and its data compared with those of H_5 for checking their consistency.

2.3 Chamber

The chamber was of a standard construction, 100 × 100 mm^2, containing 50 twenty μ Mb wires at a distance of 2 mm from each other. The distance between HV planes and the median plane is 8 mm. HV planes are made of stainless steel wires.

The gas mixture had the following "magic" proportions:

argon: 75%; freon: 0.44%; isobutane: 24%.

(It was obtained by bubbling an argon-freon mixture in isopropyl alcohol at 20°C.)

2.4 Irradiation

As some phenomenon is expected to occur when the magic mixture is used leading to MWPC deterioration after a certain irradiation time, it is important to record here the irradiation suffered by the chamber. The test run amounted to 10^9 p/cm^2; the same chamber had already been working at a full intensity beam (i.e: 10^6 p/burst) for a few days, which yielded a total irradiation of about 5×10^9 p/cm^2.

2.5 Parameters

The MWPC efficiency and resolution have been measured for the different values of two sets of parameters, i.e. the HV and the adjustments of the read-out module (mainly input threshold and timing).

3. READ-OUT SYSTEM

3.1 REFIL

The basic circuit of the MWPC read-out, the REFIL, is a two-unit wide CAMAC module containing amplifiers, one-shots, memories, and the associated read-out circuits for a group of 32 wires (see Appendix I). REFIL can be used in either of two ways:

i) When there are a few wires to be read, the appropriate number of REFIL modules are plugged in any CAMAC crate of the experiment. Each group of 32 wires is thus read as two 16-bit words at subaddresses A_0 and A_1 of each REFIL.

ii) When there are many wires to be read, the first solution becomes too expensive. It is then better to wire special crates, using a reduced dataway, reduced power supplies, and a simple special purpose controller to connect it with any existing chamber read-out system.

The second solution has been implemented in this test: the special controller, COFIL (see Appendix II) links up to 11 REFIL's to the NP core read-out system[1], which is itself, in turn, connected to SCRO[2], a CAMAC spark chamber read-out module (with the added advantage of hardware clustering).

3.2 Organization

The complete system consisted of an SFM type preamplifier[3]) on the chamber itself, driving 24 m of a 32 twisted-pair cable. The gain of this differential output preamplifier is ten, and the saturation level at the output of the order of 700 mV.

The other end of the 32 pair cable was connected to REFIL. The input threshold was adjustable from 4 mV to 40 mV; the over-all delay from input to memory was 370 nsec, which meant that the memory strobe was needed 450 nsec after the event took place in the target. The strobe was derived from the spark chamber trigger signal, widened and delayed: this width (ℓ) and the delay (Δt) were the timing parameters of REFIL.

4. RESULTS

These events were recorded on tape via a Varian 622-i computer, which was also used for intensive on-line tests. Some of the existing routines were modified to analyse the MWPC data, as well as counter or spark chamber data. Some more routines were written for this occasion (for more detail on software see Appendix III).

In this section are presented the main results of the tests, i.e. the efficiency as a function of the various parameters. The total efficiency ε is defined as the total number of events recorded in the MWPC per 1000 triggers.

ε is separated into two terms:

ε' = number of events with 1 or 2 wires hit/1000 triggers;
ε'' = number of events with more than two wires hit/1000 triggers.

4.1 Input threshold

This is a very sensitive parameter: it had to be set at its minimum value to ensure maximum efficiency. Figure 2 shows that 100% efficiency is reached only for thresholds (on 3 kΩ at the wire) between 4 mV and 5.5 mV. These values are defined with a ±1 mV uncertainty. For more than 5.5 mV, efficiency decreases rather quickly when the threshold is increased by means of a bias. This result means that, with the "magic" mixture, to go above 99% efficiency one must detect signals as low as 5 mV. For the final version of REFIL, it is foreseen to lower the minimum threshold to half a millivolt in order to try different gases and to reduce the resistors loading the wires to obtain shorter pulses.

4.2 Strobe delay

The use of standard TTL integrated circuits 7474 as registers led to setting the strobe width to 30 nsec; as the data are strobed into the registers on the leading edge of this pulse, its width has no other effect than to ensure a proper latching of the registers.

Figure 3 shows a plateau of about 30 nsec in the efficiency versus strobe delay curve. Most of this effect is due to REFIL: in order to compensate for a 20 nsec uncertainty in the 32 internal delays, and for the unknown jitter of the chamber pulses, the signals fed to the data inputs and the registers have been enlarged, from the necessary minimum of 30 nsec, to 80 nsec. Thus any jitter smaller than 30 nsec is masked by the read-out. This is mainly due to the fact that REFIL was not initially intended for use with beam chambers. A modification is currently under way, whereby the time resolution will be reduced to less than 10 nsec for studying the jitter of the chamber itself.

4.3 High voltage

This was the only parameter pertaining to the chamber itself, the gas mixture being fixed. Figure 4 shows the current in the chamber during a burst, versus the HV. A process of current accumulation starts at 5.6 kV: the intensity builds up burst after burst and never comes back to zero.

In Figs. 5 and 6 the efficiency curves are plotted for two close values of strobe delay Δt: a variation of 7 nsec in Δt leads to a difference of 200 V in the width of the plateau. This is an indication that the HV has a strong influence on the timing of the pulses on the wires: higher voltages cause the pulses to rise above threshold earlier. A study was then made by varying both Δt and HV parameters. Table 1, which refers to results plotted in Figs. 7 and 8, shows how efficiency can be recovered at relatively low HV and lost at relatively high HV when Δt is increased and inversely when Δt is reduced.

It can also be seen in Fig. 5 that ε'' increases with HV. This would induce a loss of efficiency in the analysis of events and set an upper limit on the useful part of the plateau.

4.4 Concluding remarks

To conclude this section, the main MWPC working results are quoted in comparison with those obtained by H_5.

i) The beam profiles given by H_5 and H_6 are plotted in Fig. 9 showing that in the region where H_5 and H_6 were set, the beam was focused so that beam sizes at the H_5 and H_6 levels differed by $^1/_3$.

ii) In good working conditions

	ε (%)	ε' (%)	ε'' (%)
MWPC	99.5	97.0	1.6
H_5	92.0	90.7	1.0

iii) The total double counting rate in the chamber was of the order of 8.5%, this effect is not concentrated on some particular wire as can be seen from the REHO program output in Appendix III.

5. CONCLUSION

The prototype version of the CAMAC read-out circuit, which has been inserted in the NP wire spark chamber core read-out system, has been working correctly during this run, as well as the MWPC supplied with "magic" mixture, without any perturbation due to the nearby spark chambers.

More tests at higher intensity beam are currently under way with an improved version of REFIL in order to replace scintillator hodoscopes by MWPC. Two 700 × 1200 mm^2 MWPC will also be set up for on-line momentum measurements.

Acknowledgements

We are indebted to the group of G. Charpak for their support and to all the members of CERN-Orsay-Polytechnique-Stockholm Collaboration for helping us take these data and especially B. D'Allmagne, R. Kiessler and G. De Rosny.

REFERENCES

1) J. Lindsay and J. Pizer, Experience with core read-out of large wire chamber arrays, Proc. Int. Symposium on Nuclear Electronics, Versailles, Sept. 1968, p. 22.1-22.7.

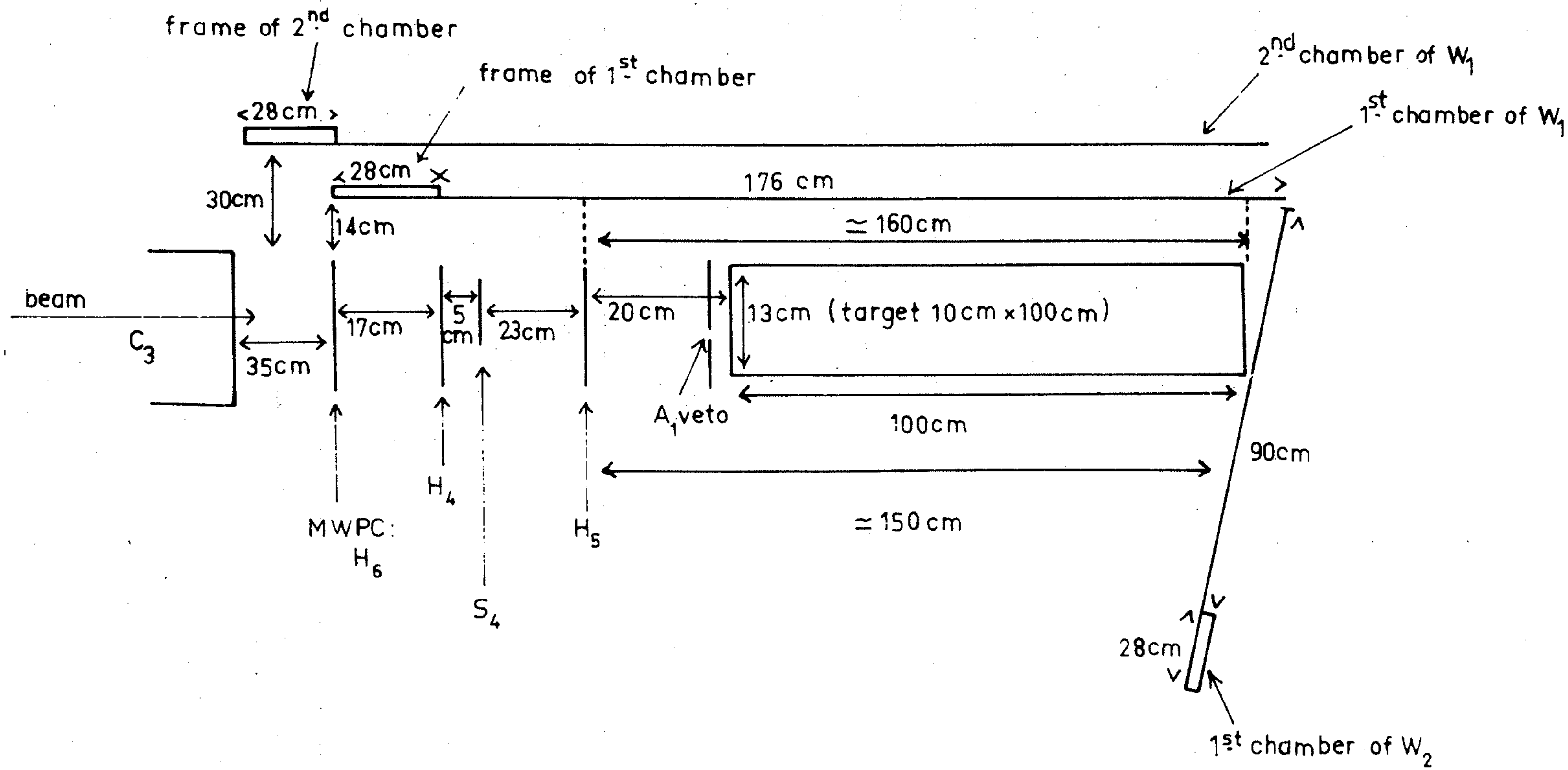
2) R. Block, P. Briandet and A. Simon, SCRO type 041; CERN-NP-CAMAC note 19-00, Nov. 1970.

3) G. Charpak et al., Some features of large MWPC, to be published in Nuclear Instrum. Methods.

Table 1

Δt (nsec)	Limits on proportional plateau P (kV)	Width (V)	Comments
134.5		< 300	We are in the Δt_{min} [a] region: low efficiency at low HV; high efficiency at high HV.
139.5	$5.25 \leq P \leq 5.55$	300	Very narrow plateau and weak loss of efficiency at relatively low HV.
144.5	$5.20 \leq P \leq 5.55$	350	We are still in the Δt_{min} region, but conditions are becoming more convenient, although the plateau is narrow enough.
151.5	$5.15 \leq P \leq 5.55$	400	Reasonable conditions
159.0	$4.95 \leq P \leq 5.55$	600	Best conditions corresponding to best value in Δt: - quite wide plateau - good efficiency unit - recovery of efficiency at relatively low HV (i.e. ≤ 5.0 kV).
164.0	$5.0 \leq P \leq 5.55$	550	Still suitable conditions. But efficiency is weakly decreasing at the highest value of HV (i.e. 5.55 kV).
169.0	$4.95 \leq P \leq 5.25$	300	We approach the Δt_{max} [b] region: - clearly shrunk plateau - loss in total efficiency (i.e. ε remains $\leq 95\%$ along the plateau) - clear loss of efficiency at higher HV (i.e. ≤ 5.3 kV). These effects are clearly seen in the plot: "one count" = f (HV) ε" = f (HV)

a) Δt_{min} = region outside the plateau on the side of lower values of Δt.
b) Δt_{max} = region outside the plateau on the side of higher values of Δt.



(N.B: each telescope W_1 and W_2 has four spark chambers)

Fig. 1 : Set-up.

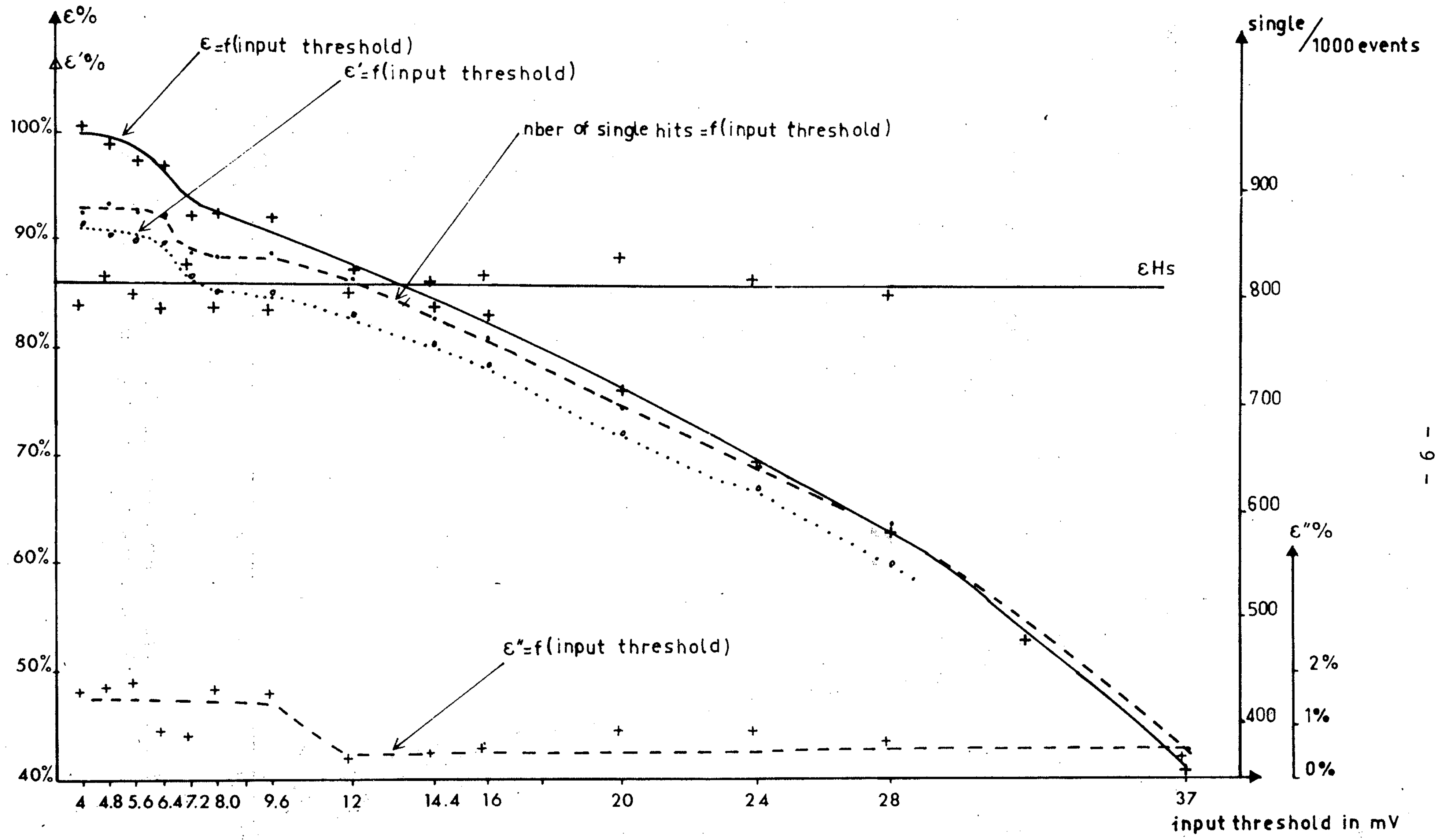


Fig. 2 : Efficiency versus input threshold: HV = 5.3 kV; ℓ = 30 nsec; Δt = 154.5 nsec.

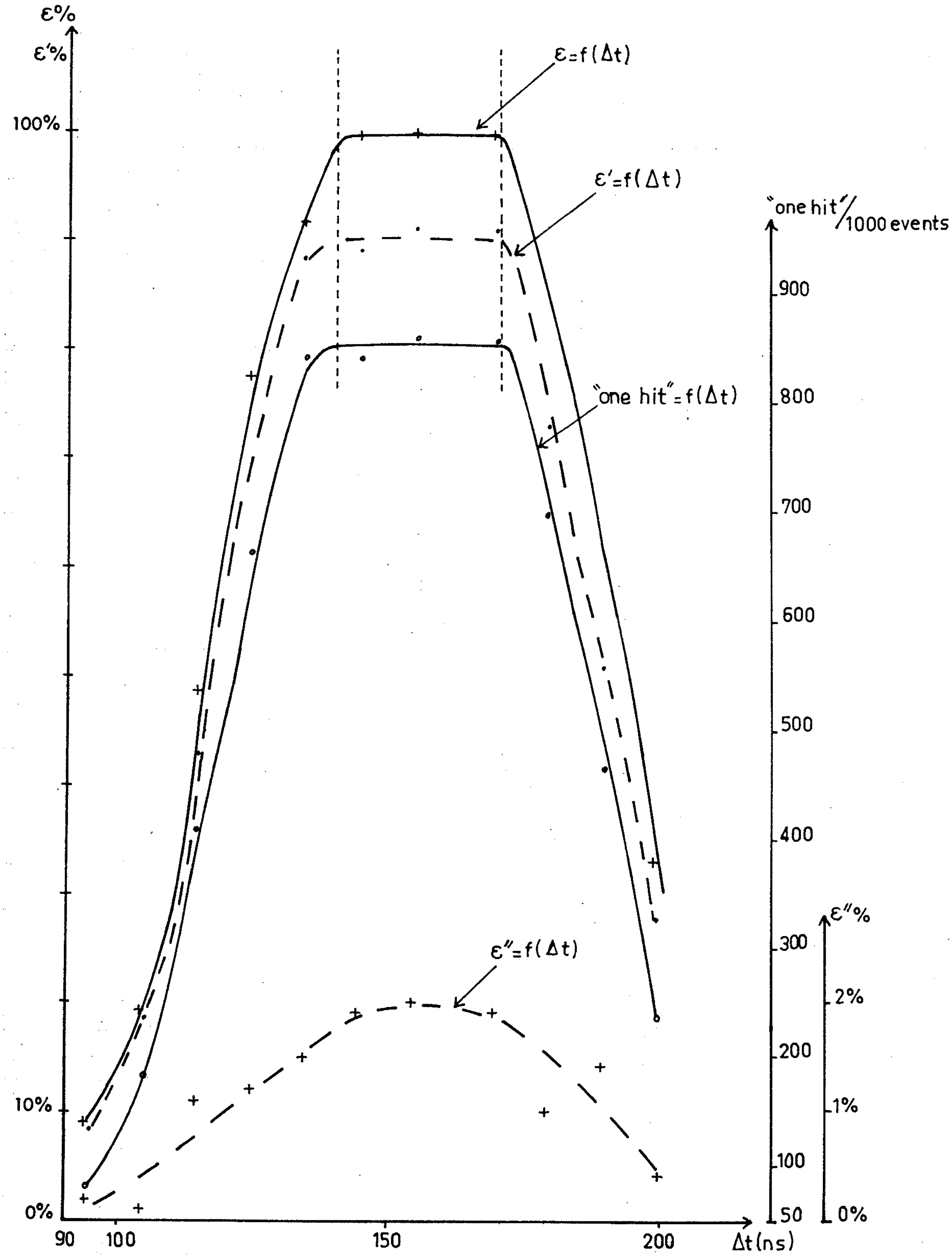


Fig. 3 : Efficiency versus strobe delay: HV = 5.4 kV; Input threshold = 4 mV (±1 mV); ℓ = 30 nsec.

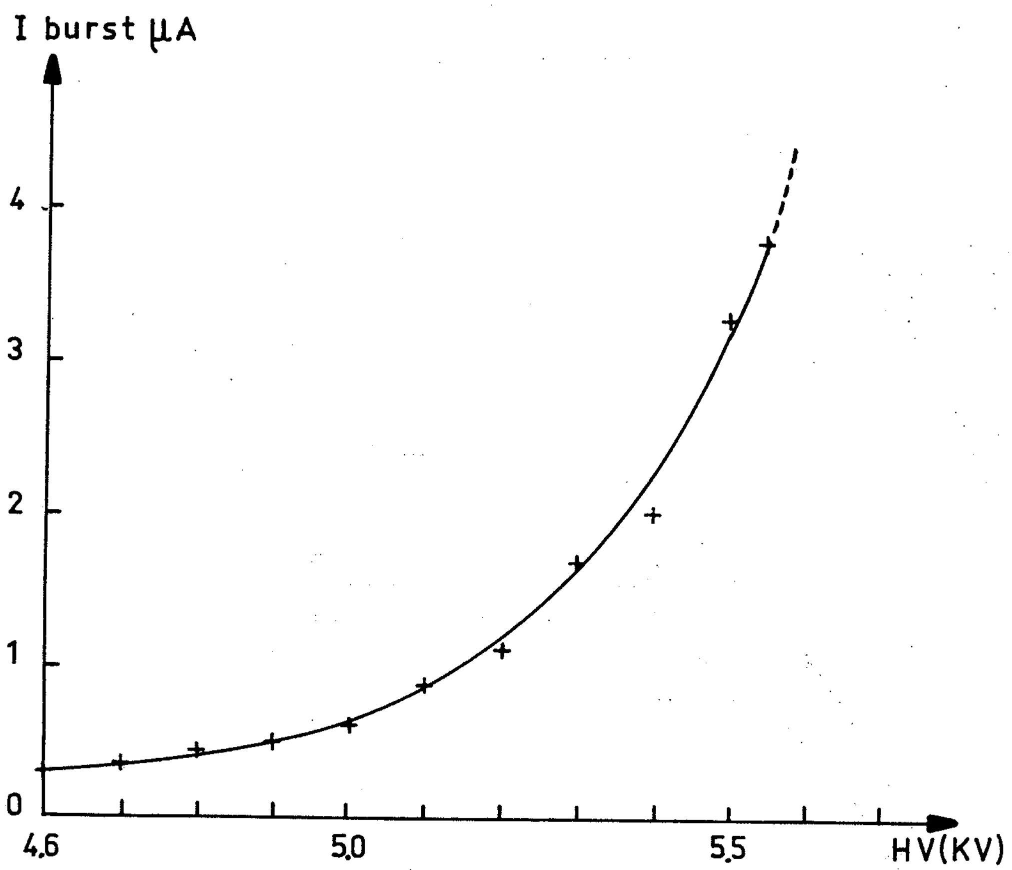


Fig. 4 : Intensity by burst versus HV.

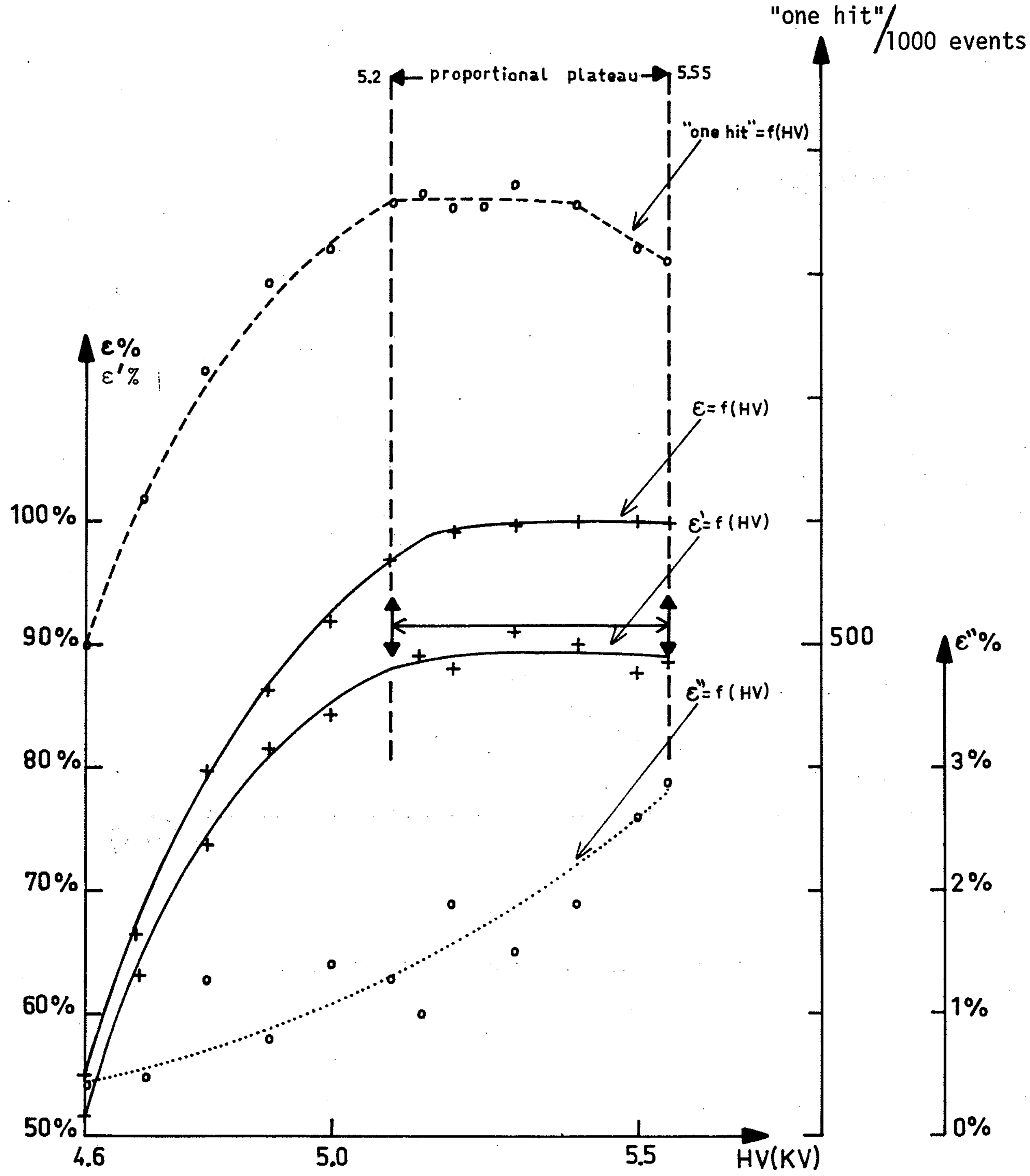


Fig. 5 : Efficiency versus HV: Δt = 151.5 nsec;
Input threshold = 4 mV (±1 mV); ℓ = 30 nsec.

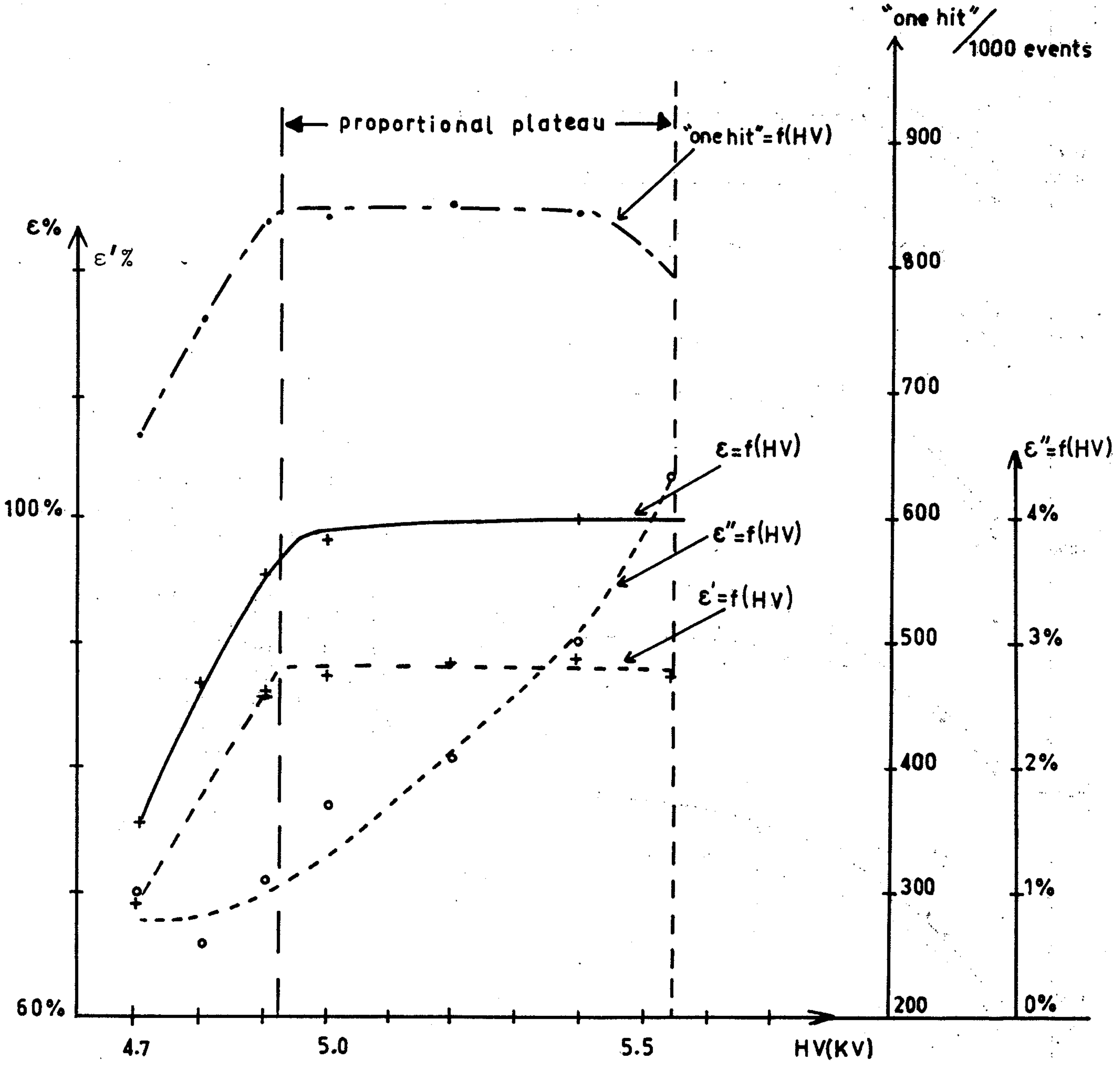


Fig. 6 : Efficiency versus HV: Δt = 159 nsec;
Input threshold = 4 mV (±1 mV); ℓ = 30 nsec.

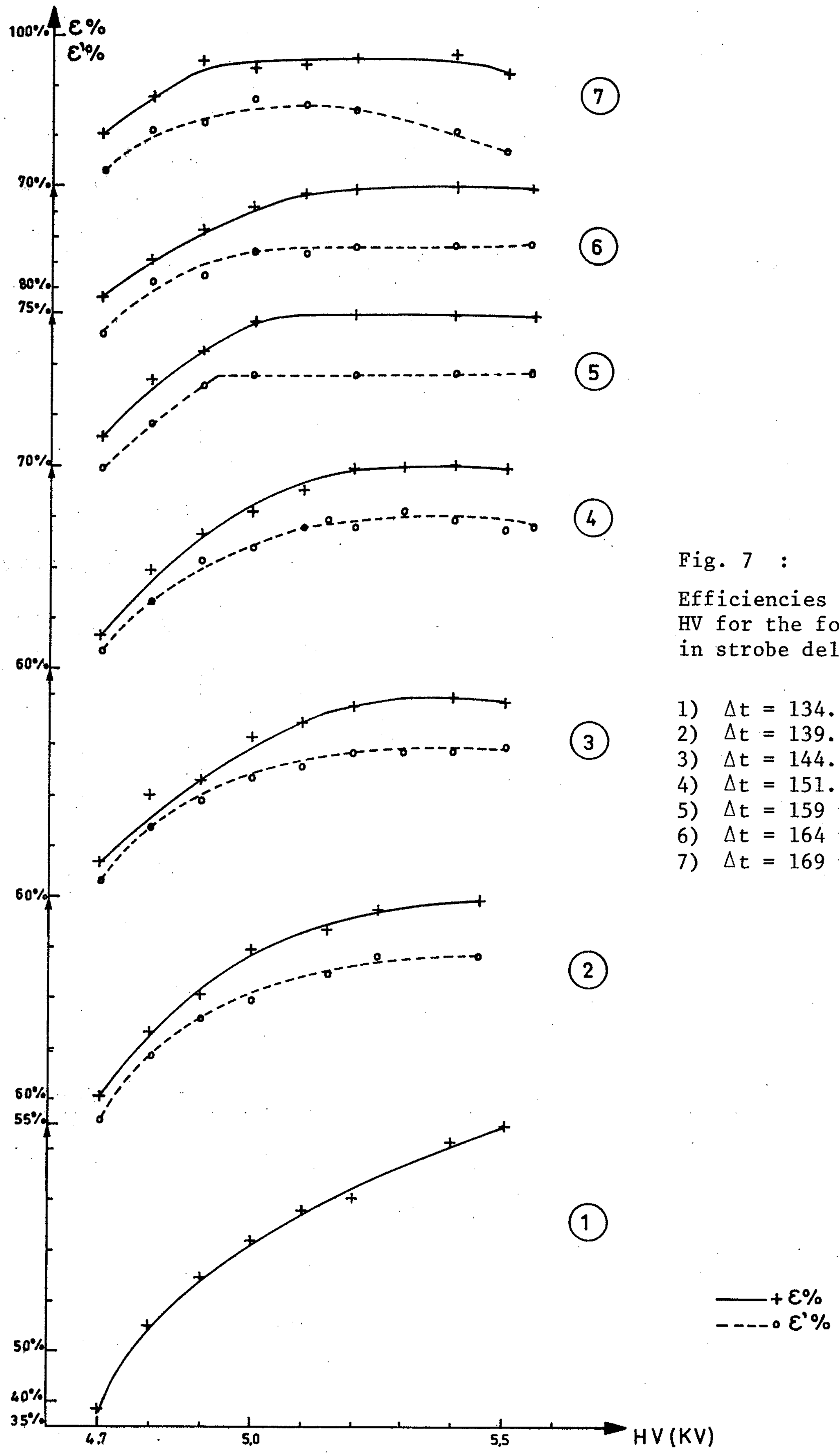


Fig. 7 :

Efficiencies ε and ε′ versus HV for the following values in strobe delay Δt:

1) Δt = 134.5 nsec
2) Δt = 139.5 nsec
3) Δt = 144.5 nsec
4) Δt = 151.5 nsec
5) Δt = 159 nsec
6) Δt = 164 nsec
7) Δt = 169 nsec.

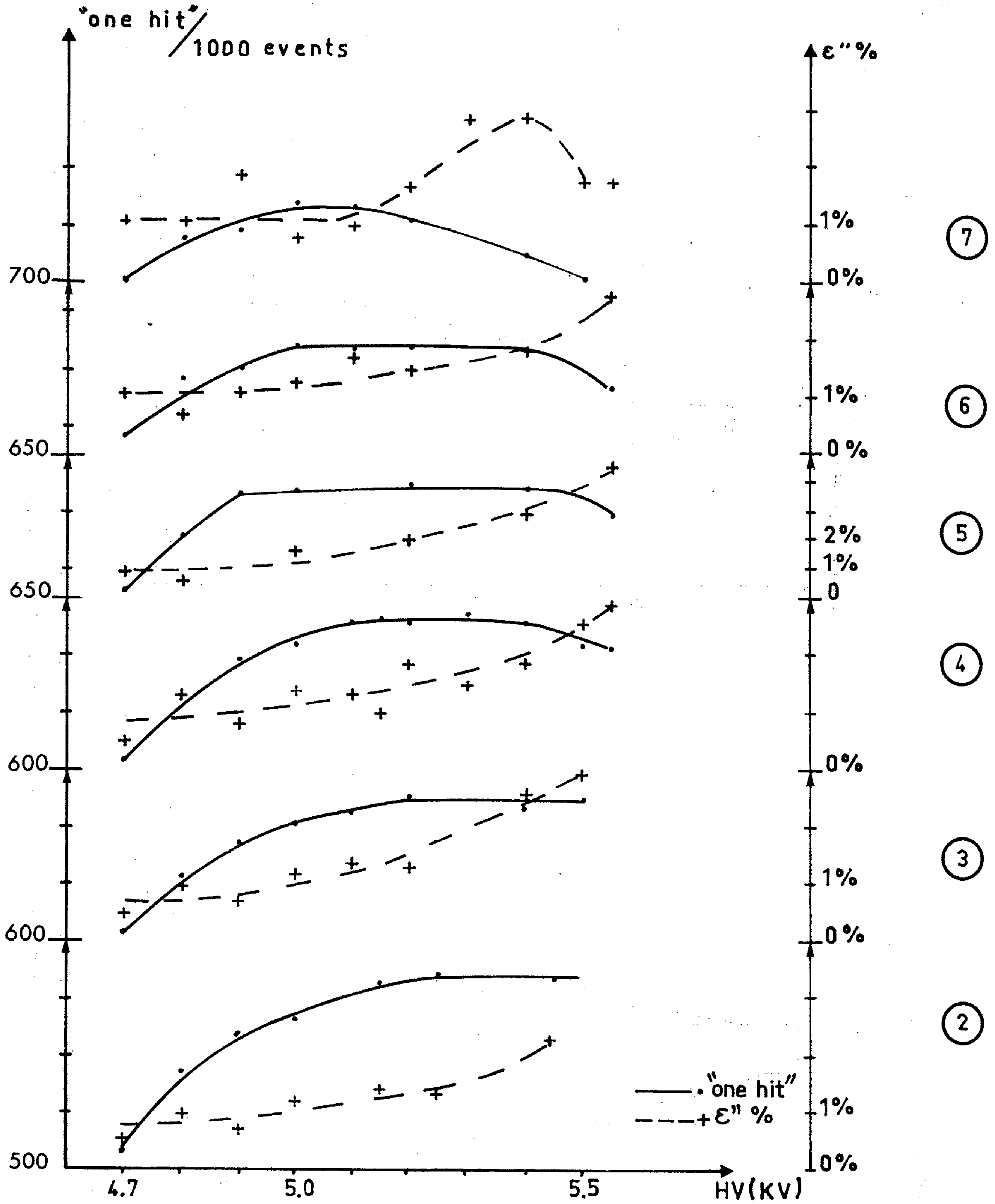


Fig. 8 : Efficiencies and "one-hit" versus HV for the previous values of Δt.

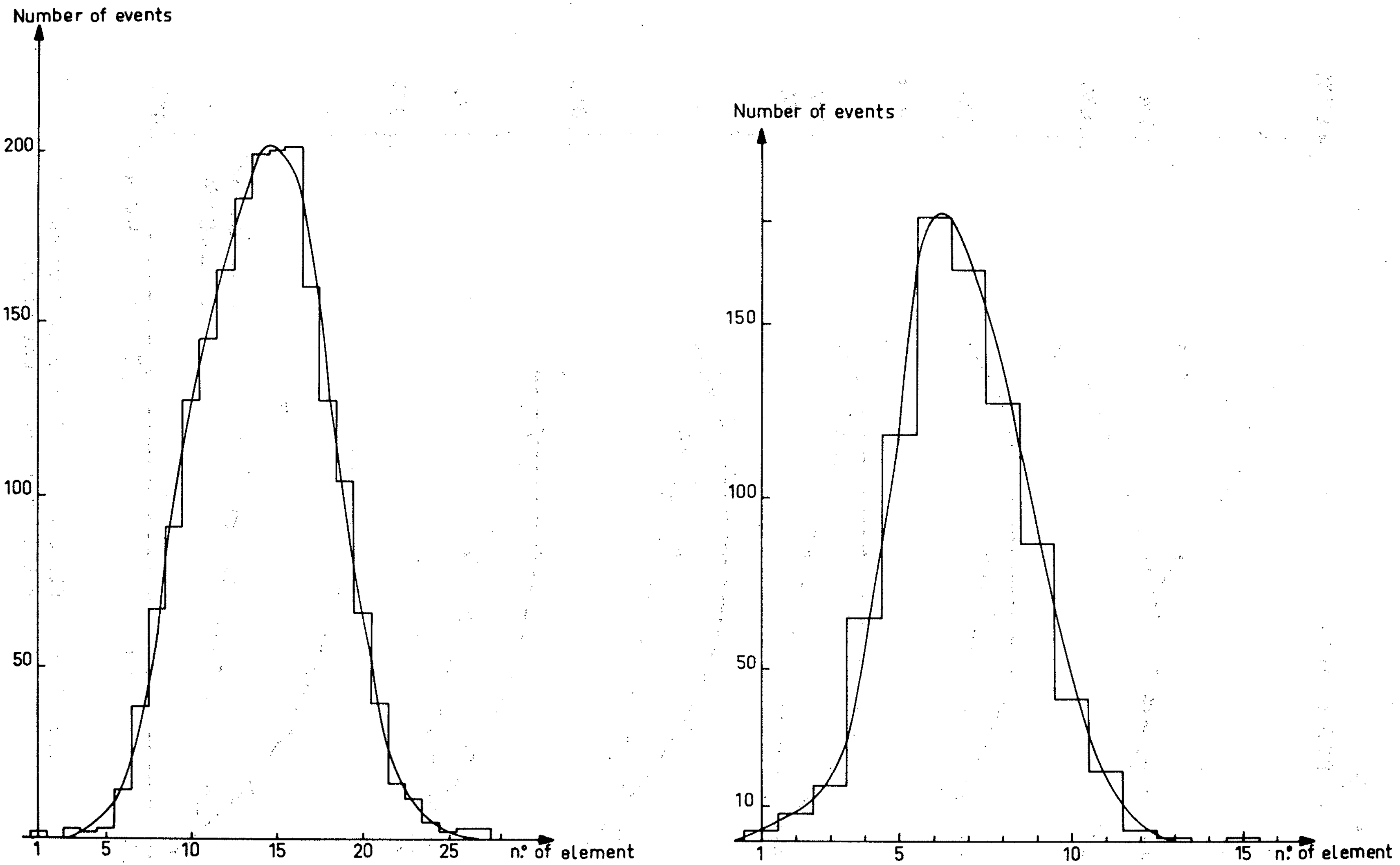


Fig. 9 : Beam profile of MWPC: H_6 (space between wires 2 mm), and beam profile of hodoscope: H_5 (each element is 3 mm wide).

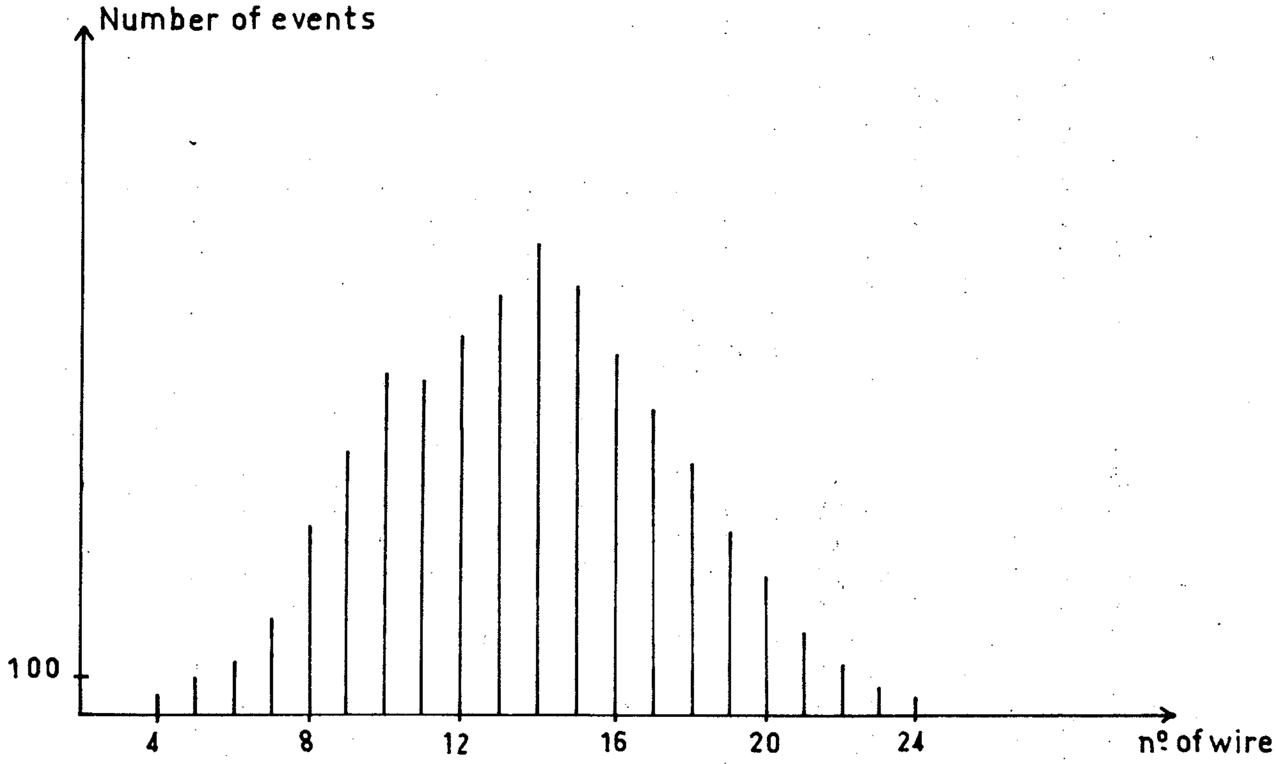


Fig. 10 : Output of CRMP program for statistics of 2,500 events (2358 events in chamber).

Total number of events: 1582 Number of plotted events: 1006

H_6																			
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	5	5	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0	18	2	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	20	9	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	8	34	3	0	0	0	0	0	0	0	0
10	0	0	0	0	0	1	0	2	46	16	1	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	1	34	50	3	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	6	73	10	0	0	0	0	0	0	0	0	0	0
13	1	0	0	0	0	2	51	60	1	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	9	88	16	2	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	2	46	59	0	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	1	8	55	17	1	0	0	0	0	0	0	0	0	0	0	0
17	0	0	0	2	19	17	1	0	0	0	0	0	0	0	0	0	0	0	0
18	0	0	1	5	57	17	0	2	0	0	0	0	0	0	0	0	0	0	0
19	0	0	1	27	23	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20	0	0	3	23	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21	1	3	14	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22	0	3	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
H_5	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19

Fig. 11 : Output of H_1*H_3 program.

REHØ   Number of events: 1012   Number of plotted events: 44

1	1																															
2	0	0																														
3	0	0	0																													
4	0	0	0	2																												
5	0	0	0	0	0																											
6	0	0	0	0	0	2																										
7	0	0	0	0	0	0	0																									
8	0	0	0	0	0	0	0	1																								
9	0	0	0	0	0	0	0	0	4																							
10	0	0	0	0	0	0	0	0	2	6																						
11	0	0	0	0	0	0	0	0	0	1	3																					
12	1	0	0	0	0	0	0	0	1	0	0	7																				
13	0	0	0	0	0	1	0	1	0	1	0	1	8																			
14	0	0	0	0	0	0	0	0	0	0	1	0	0	3																		
15	0	0	0	1	0	0	0	0	0	0	0	2	0	0	8																	
16	0	0	0	1	0	1	0	0	0	0	0	0	3	0	2	12																
17	0	0	0	0	0	0	0	0	0	2	0	1	1	1	0	3	9															
18	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	2														
19	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	1	0	0	4													
20	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	1	1	0	1	8												
21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	3											
22	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	3										
23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2									
24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0								
25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0							
26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0						
27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0					
28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32

Fig. 12 : Output of REHØ program.

APPENDIX I

REFIL: A proportional chamber read-out (scheme I)

This two-unit wide CAMAC module receives signals from 32 wires of a proportional chamber, to amplify, delay, and store them in a two-word (16 bit) register.

This read-out is intended for applications where dead-time and resolution are not essential: the use of straight forward TTL circuits reduces size and cost and yields a recovery time of 500 nsec for wire and a resolution of the order of 50 nsec. A fast version is currently being developed to bring these figures down to 50 nsec and 15 nsec, respectively.

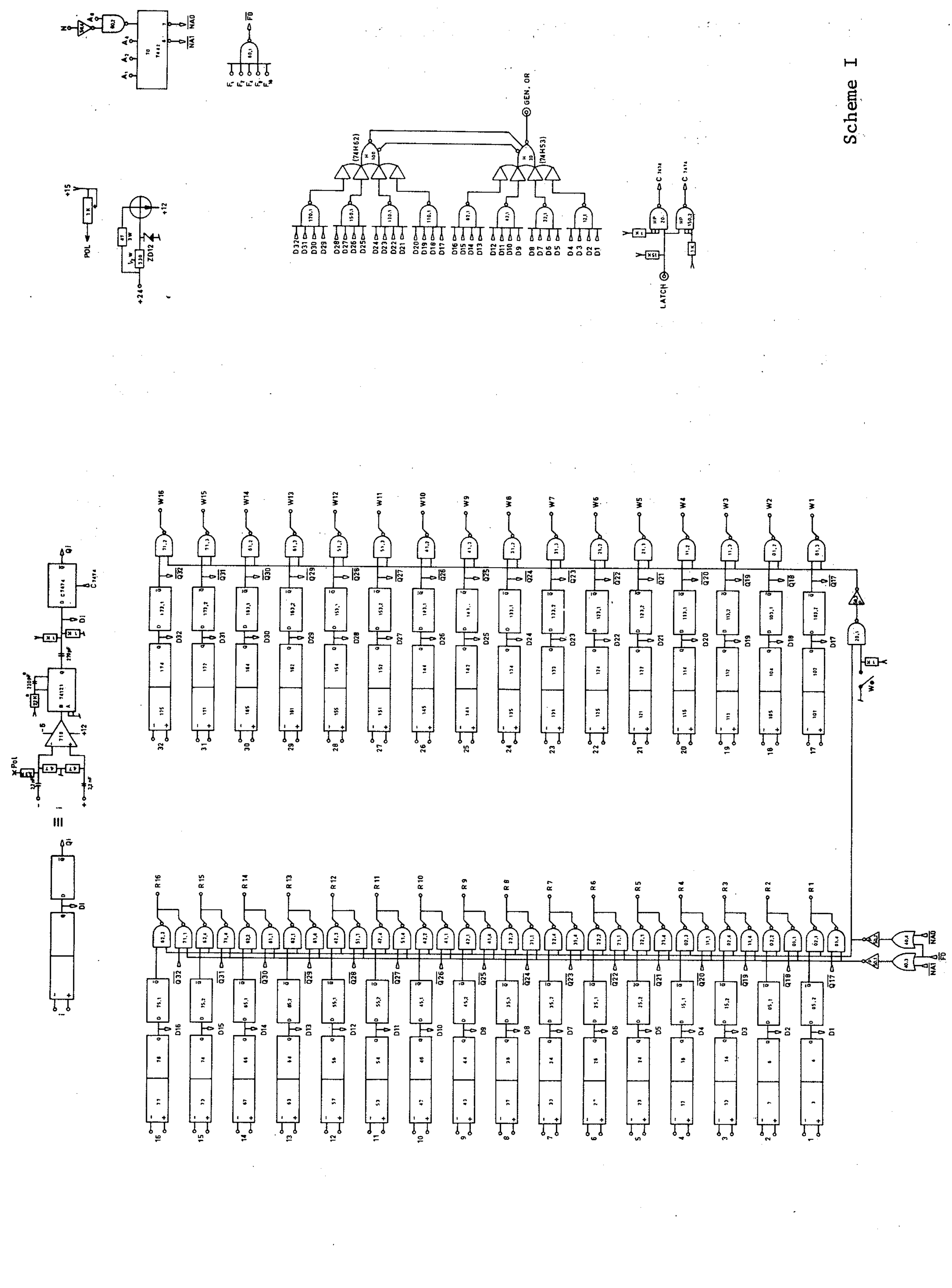
The signals come through the front panel in a 32 twisted pair cable plugged into a 64 way ITT connector. These signals are amplified to saturated TTL levels; the threshold of the input stage is adjustable, from 10 to 75 mV by means of a potentiometer on the front panel. These 32 signals are then delayed for 350 nsec (this value can be modified by replacing 32 capacitors) and differentiated. A general OR of all these differentiated outputs is accessible on the front panel via a Lemo connector (TTL pulse $\sim$ 1 V when terminated on 50 Ω). These outputs are also connected to the registers, and stored upon receipt of a latch command ($\overline{\text{TTL}}$ pulse) through a Lemo on the front panel. These data are read with the CAMAC functions:

N.A(0).F(0): read first 16 bits Q response
N.A(1).F(0): read last 16 bits Q response

An option enabled by a switch on the front panel, connects the last 16 bits to lines W1 through W16 with N.A(0).F(0): the purpose of this standard feature is to use CAMAC crates, containing only REFIL's, not in a normal branch, but in a special link to a SCRO (spark chamber read-out) module.

In this mode, the crates used to read out proportional chambers contain only REFIL modules (up to 11 in one crate, reading 352 wires) and a special three-unit wide controller, COFIL, receiving the 32 bits of each REFIL in one cycle via R1 to R16 and W1 to W16, and sending this information to SCRO.

SCRO then reconstructs clusters and encodes the coordinate of the centre of each cluster.



Scheme I

APPENDIX II

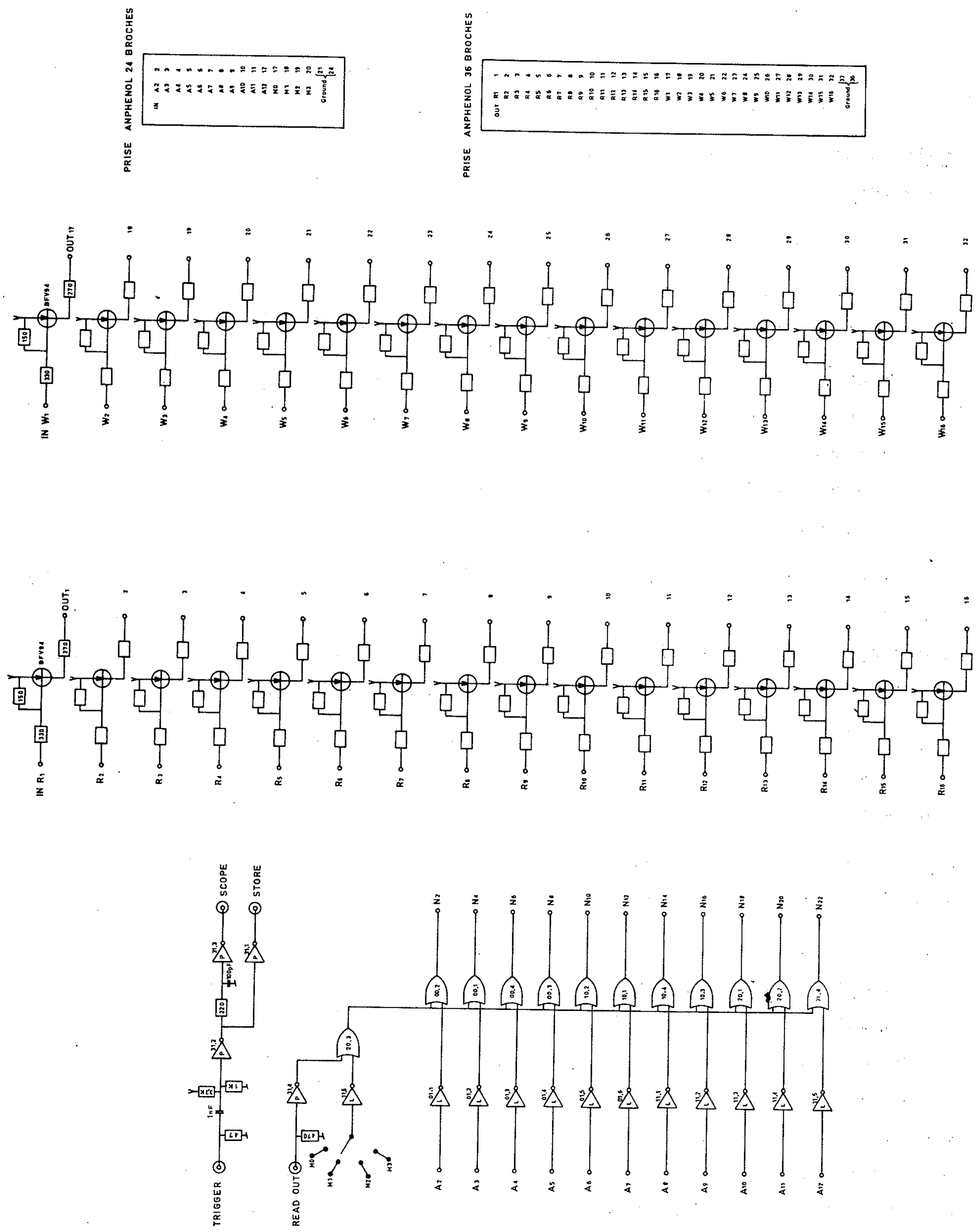
COFIL: A special purpose crate controller for use with REFIL (scheme II)

This three-unit wide CAMAC controller is a very trivial adapter to link 11 REFIL's in a simplified CAMAC crate to the CERN-NP spark chamber core read-out system.

In this organization, there are 32 wires in a "group", 16 "groups" in a "module" and 4 "modules" in a "chamber". Group address and module number are sent as pulses on two wires in a 20-way cable; the "chamber" signal comes through a coaxial cable.

COFIL makes use of group addresses 2 to 12 to select stations 2, 4, ... , 22. The "module" number is selected by a four-way rotary switch on the front panel; it enables, along with the chamber signal, the station selection.

F and A lines are pulled up, generating AOFO. A switch on the front panel of REFIL allows the transmission of 32 bits in one cycle by presenting data bits 17 to 32 on W lines 1 to 16. Thirty-two receivers in COFIL convert this response to +15 mA pulses for logic ones. COFIL also provides the necessary circuitry to convert the NIM trigger pulse to a TTL strobe for the REFIL's and to a delayed TTL pulse for control purposes.


PRISE ANPHENOL 24 BROCHES
PRISE ANPHENOL 36 BROCHES
Ground
BFY94
OUT
IN
TRIGGER
SCOPE
STORE
READ OUT

Scheme II

APPENDIX III

Software

The MWPC was used as a hodoscope but read as a chamber, giving rise to a variety of possible programs.

BEAM: used in d_{30} experiment to check the behaviour of incident beam hodoscopes.

It gives:

- beam profile
- efficiency $= \dfrac{\text{total number of events in the hodoscope}}{\text{required statistics}}$.
- number of "one hit" events in each hodoscope
- number of "two hit" events in each hodoscope
- number of "three hit" events in each hodoscope
- number of "four hit" events in each hodoscope
- number of "five hit" events in each hodoscope.

The physics of the experiment requires just one incident particle, so that off-line analysis is only concerned with "one hit" events in each hodoscope or with "two hit" events on two adjacent elements in each hodoscope, i.e. with the ε' efficiency. Rejected events are represented by ε''.

CRMP = COREMAP: specifically used to check the chamber behaviour in the d_{30} experiment; it displays the histograms of hits on the curves of all the spark chambers (Fig. 10).

H_1*H_3: correlating two hodoscopes with elements in the same direction: here H_5 and H_6, each have vertical elements (Fig. 11).

REHO: specific to hodoscopes; it gives the distribution of correlations when there are two simultaneous hits in one hodoscope. It is visualized on the display as a triangular matrix: at the intersection between a row and a column, the number of hits upon the couple of corresponding counters is quoted. The total double counting rate for each counter is plotted on the diagonal. Figure 12 shows results obtained by REHO for MWPC, for the following conditions: HV = 5.4 kV; Δt = 160 nsec; ℓ = 30 nsec; output threshold = 10 mV. The total double counting rate in the chamber (32 wires) is about 8.5% and under 1.2% for any one wire.

OROR: specific to MWPC; it is similar to LOOK and used for spark chambers in the d_{30} experiment to visualize sparks in the chambers.