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SEARCH FOR NEW PARTICLES AT THE ISR - USING THE SPLIT FIELD MAGNET

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INTRODUCTION

Following our previous documents:

1- Quark search at ISR - presented at the ISR users' meeting, 10-11 June 1968;

2- A proposal to search for fractionally charged or massive particles at the ISR - CERN/ISRC/70-31, 8 December 1970;

3- CERN/ISRC/70-31 Add. 1, 14 May 1971;

we present here a version of our proposal adapted to the Split Field Magnet facility, stating the limitations, acceptance and ultimate background levels. Estimates of the budget and time requirements will also be given.

For details not reported in this document we refer the reader to our previous documents 1,2 and 3.

METHOD.

Only a rough outline will be given since it has been described twice before. It is to measure, where possible, the specific ionisation, velocity and momentum of the particle so as to determine both its charge and mass. Extrapolating from previous experiments shows that at least eight good scintillation counters plus some method of reconstructing or seeing the events is required.

In principle, specific ionisation and velocity are sufficient to measure the charge. However, false events in cosmic ray measurements have been seen to be due to γ-ray showers and to interactions. A magnetic field between two sets of counters opens out the interaction products and makes them visible. It also reduces the background from narrow pairs of particles and knock-on electrons. To search for integrally charged massive particles, a measurement of the momentum is also a necessity.

The main differences between the set-up to be described below, and that described previously are the simplification of the trigger system to take advantage of the electronics and selection capabilities associated with the Charpak chambers, and the removal of two safety factors - namely the visual spark chambers interleaved between the scintillators to observe possible complicated background processes and the chambers to observe high multiplicity events in case quarks are produced only in association with $\gtrsim$ 30 other particles. The difficulty of operating the proportional chambers in close proximity to the spark chambers has led us, somewhat unwillingly, to omit them.

SET-UP

Figs 1 and 2 show the plan and vertical views of one half of the apparatus. Telescopes A,B,C,D,E,F,G,I,K,and L are in the trigger, whereas M,N,O,P,Q,R,S,T are 'observer telescopes' to fill up the solid angle. The idea is that quarks should not be produced singly so if a quark is detected in a complete telescope, there is ~ 30% probability of observing its partner either in another telescope or in the 'observer telescopes', though with reduced accuracy in the latter.

Each of the telescopes A,B,C,D,E,F,G,I,K, and L consists of four layers of scintillator 2.5cm thick, interleaved with 0.5cm of Pb to decouple adjacent layers The counters are divided so that the loss of events by the presence of a second track in the counter is less than 30%. The hodoscope counters are to protect against multiple particle events.

FAST COINCIDENCE AND ELECTRONICS

The fast coincidence will be made as simple as possible, relying on the slow logic system and computer to filter the data before storage on magnetic tape. Only the first two counters in each set of four counters will be used in the trigger and a 'Fast coincidence' will be defined as a coincidence between any two aligned telescopes, e.g. (A-B, or E-G) with the conditions on the first two counters of each telescope:

$$\left\{ \frac{dE}{dX} \Big/ \frac{dE}{dX}\bigg|_{MIN} < 0.9 \right\} . \text{ OR. } \left\{ \frac{dE}{dX} \Big/ \frac{dE}{dX}\bigg|_{MIN} > 1.2 \right\} \text{ AND. } \left\{ \begin{array}{l} \text{only one} \\ \text{hodoscope} \\ \text{element hit} \end{array} \right\}$$

The electronic block diagram is shown in Figs 3,4,5,6,7.

RATES AND BACKGROUND

Table 1 shows the more important background processes about which we have thought. It shows the rates at the various stages of data aquisition and, in the right hand columns, the ultimate rejection power attainable All charge states are very satisfactory except for charge + 4/3e, which is now not as good as previously because of the removal of the inter-counter spark chambers

We intend to investigate the effect on the ultimate background of the thickness of absorber between the telescope counters.

This difficulty for the + 4/3e charge state is reflected in the fact that no one at an accelerator has so far measured the possible charge +4/3e content of the nucleon break-up.

The flow diagram of the data aquisition is shown in table II together with some indication of the background processes which are rejected at each stage.

SOLID ANGLE

The total solid angle covered by all counters is about 30% and that covered by the possible coincidences between eight counters is 9%. Fig. 8 shows the azimuthal acceptance for coincidences between eight counters as a function of the polar angle about the downstream beam direction. The solid angle is quoted in this graphical form to avoid misunderstanding. The acceptance for quark production depends on the model. Thus it will range from 18% (two quarks produced) for purely isotropic production to 100% for strongly peripheral production of very massive particles.

SENSITIVITY OF THE EXPERIMENT

Since any estimate is mass, charge and model dependent, we will use the 100% geometric acceptance quoted above, bearing in mind that the result could be five times lower.

Estimates of losses in the trigger selection vary from 0.3 to 0.7 for charge states except Q = 4/3e which is a factor of two lower Hence, for a running time of 100 days, at a luminosity of $10^{30}/cm^2$ sec, one event corresponds to a cross section of

$$\sigma = 3.8 \times 10^{-36} \text{ to } 1.6 \times 10^{-34}$$

In conclusion, the ISR experiment is more sensitive than present machine experiments for masses above

a) 6 GeV for charge $-^1/_3$
b) 5.5 GeV for charge $-^2/_3$
c) 4.2 GeV for charge $-^4/_3$
d) All masses for charge $+^4/_3$
e) All masses for charge 2
f) Masses above 3 GeV for charges $\pm 1, +^1/_3$ and $+^2/_3$.

DATA HANDLING

We have estimated a transfer rate to magnetic tape of ~ 0.2 event/sec, giving a total of $\sim 10^7$ events to be analysed by more refined methods, which would entail the use of about 100 magnetic tapes and 200 hours of 6600 CP time. We wou'd require the full-time help of a small computer programmer for six working months, starting in time for the detailed division of the data sorting between hardware and soft-ware to be made in close collaboration with him.

TIME AND BUDGET REQUEST

a) TIME

1) We request 10 days of parasiting time on a variable energy PS beam (pions from 1 GeV to several GeV) to attempt a reduction in the charge $^4/_3$ background and to test our ideas on the rejection levels attainable.

2) We request 20 days of parasiting time at ISR with four Charpak chambers and a single telescope to check the functioning of the system and to measure the background levels, as soon as possible.

3) We request 100 days of running time with the split-field magnet facility

b) BUDGET.

Table III shows a break-up of the budget for counters, electronics and constructions

c) RELATION BETWEEN TIME AND BUDGET

The solid angle could be partly reduced, with a reduction in construction budget but with an increase in running time. For example a 50% reduction in solid angle would need 25% less counters (and correspondingly less cost). Since cost and running time are not inversely proportional, we consider that the full set-up is to be preferred.

Table 1

Background processes and rates

		Transfer rates/sec			Ultimate level*)	
	Background source	To slow Logic	To Computer	To Tape	Others	Q = 4/3
1.	Superposed randoms simulating dE/dx > 1	36	26	6×10^{-4}	$< 10^{-12}$	$< 10^{-12}$
2.	Low momentum particles simulating dE/dx > 1	150	6	0.1	$< 10^{-12}$ (except for triton triggers)	$< 10^{-12}$
3.	Independent pulse height fluctuations	480	0.3	2×10^{-4}	$< 10^{-12}$	$< 10^{-11}$
4	Scattering chambers giving wrong momentum P	-	-	-	$< 10^{-12}$	$< 10^{-13}$
5.	Spurious sparking giving incorrect P (Probability 10^{-2}/plane needed)	-	-	-	$< 10^{-12}$	$< 10^{-12}$
6	Knock-on electrons simulating dE/dx > 1	3	3	2×10^{-8}	$< 10^{-12}$	$< 2 \times 10^{-8}$
7	Two particles in one telescope	360	13	6×10^{-2}	$< 10^{-12}$	$< 10^{-12}$
8	Low energy γ simulating dE/dx < 1	< 0.2	$< 10^{-12}$	$< 10^{-12}$	$< 10^{-12}$	$< 10^{-12}$
9.	High energy γ simulating dE/dx > 1	16	1.6	10^{-2}	$< 10^{-12}$	$< 10^{-10}$
10.	Pair of particles, one scatters out after 1st telescope, simulating dE/dx > 1	4.5	$< 10^{-1}$	$< 10^{-2}$	$< 10^{-12}$	$< 10^{-7}$ (90° telescope) $< 10^{-11}$ (at small angles)
11.	Tritons etc.	10^{-2}	10^{-2}	10^{-2}	10^{-6} tritons	-
12	Statistical fluctuations on pulse edge simulating Q < 1	< 3	3×10^{-4}	3×10^{-8}	$< 10^{-12}$	$< 10^{-12}$
13	Dead time in the dE/dx > 0.9 veto	< 3	< 3	$< 10^{-12}$	$< 10^{-12}$	$< 10^{-12}$
14.	Particles in light guides	$< 5 \times 10^{-4}$	$< 10^{-12}$	$< 10^{-12}$	$< 10^{-12}$	$< 10^{-12}$

*) Probability of quark simulation in our telescopes.

Table II

Data acquisition

FAST LOGIC

i) Trigger off dE/dx $\neq$ minimum using four counters in each telescope

SLOW LOGIC

i) Correction of pulse height in all counters by the 32-wire groups Rejection of more pulse-height fluctuations.

ii) Identification of double tracks by the 32-wire groups Rejection of knock-on electrons, randoms, multiple tracks

iii) Require momentum > 1.5 GeV/c Rejection of slow protons giving high dE/dx

iv) Rejection of $Q = 4/3e$ angles > 85°, where there is no magnetic analysis

COMPUTER ON LINE

i) Finer corrections of pulse height in all counters for light attenuation

ii) Rejection of double tracks with finer precision

iii) Calculation of time-of-flight Check that timing in adjacent counters is equal. Apply a time cut to exclude $\beta = 1$ particles for charges + 4/3e

iv) Possibly check that momentum in successive sections of the trajectory is the same

Table III

Budget

Construction

Scintillator dE/dx counters	1550 kg at 100 S Fr/Kg	155,000
Scintillator hodoscopes	100 kg	10,000
Mounting plus light guides		50,000
Lead	2500 kg	40,000
Mechanical work		50,000
		305,000

Photomultipliers

XP 1040	120 × 2600 S Fr	(base + tube)	312,000
56 AVP	48 × 1500 S Fr	" "	72,000
XP 110	156 × 500 S.Fr	" "	78,000
Supplies (56 + 1040)	18 × 3900 S Fr		70,200
Supplies (110)	6 × 3900 S Fr		23,400
			555,600
Available XP 1040 ∿ 40			100,000
			∿ 450,000

Electronics

Shapers + discriminators		272 × 800 S.Fr.	217,600
Hodoscopes shapers		156 × 200 S Fr	31,200
Hodoscopes majority coincidences		18 × 600 S.Fr.	10,800
{ $\frac{dE}{dx}$ trigger }	AND	76 × 100 S.Fr	7,600
	OR	51 × 100 S Fr	5,100
{ Time-of-flight }	OR	5 × 700 S Fr.	3,500
	AND	4 × 1550 S Fr	6,200
	5-fold stroded AND	31 × 1500 s Fr	46,500
Linear gate + stretcher amplifiers + encoders (ADC)		304 × 800 S Fr	243,200
NIM crates		56 × 3000 S Fr	168,000
			739,700
Available electronics			∿ -240,000
			500,000
		TOTAL	1,250,000

FIGURE CAPTIONS

Fig. 1 : Top view of the experimental set-up. Only one-half of the set-up is shown; the groups of counters symmetric to E,F and G are named I,K and L respectively, the "observer" counters symmetric to M,N,O and P are named Q,R,S and T respectively. H_1 to H_{18} are hodoscope matrices. Also shown is the proposed layout of the Charpak chambers in order to fit in the trigger counters.

Fig. 2 : Side view of one-half of the experimental set-up. Counters B are not shown.

Fig 3 : The signals which are derived from each counter:
a) from the counters used in the fast trigger
b) from the other counters.

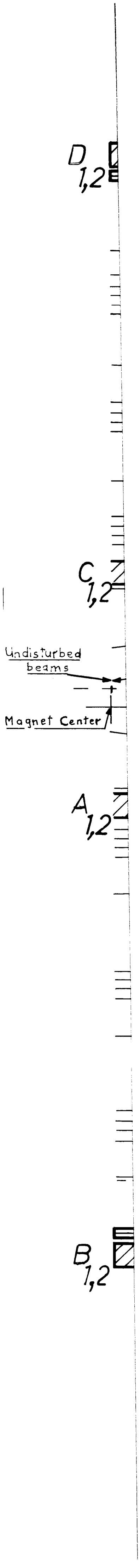
Fig. 4 : The logic to select the "Low" pulses (<0.9 minimum ionization) and the "High" pulses (>1.2 minimum ionization). For the "High" signals the outer counters are vetoed if ≥ 2 particles are detected in the hodoscope matrices.

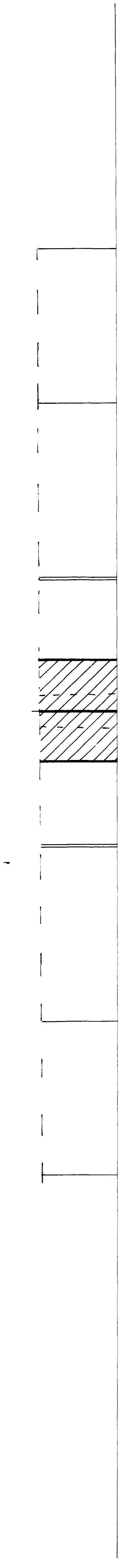
Fig. 5 : The fast $\frac{dE}{dx}$ trigger. All the possible coincidences A_1 (top), A_2 (bottom) [see Fig. 2] and B_1 (right), B_2 (left) [see Fig. 1] are made. Telescopes EFG, etc. are treated in the same way.

Fig. 6 : The time-of-flight circuit. All the times are referred to the first layer of counters in each telescope. Moreover a signal T is used to correlate the timing of the different telescopes.

Fig. 7 : Flow diagram of the data acquisition.

Fig. 8 : Acceptance in ϕ of one-half of the set-up.


D
1,2
C
1,2
Undisturbed
beams
Magnet Center
A
1,2
B
1,2



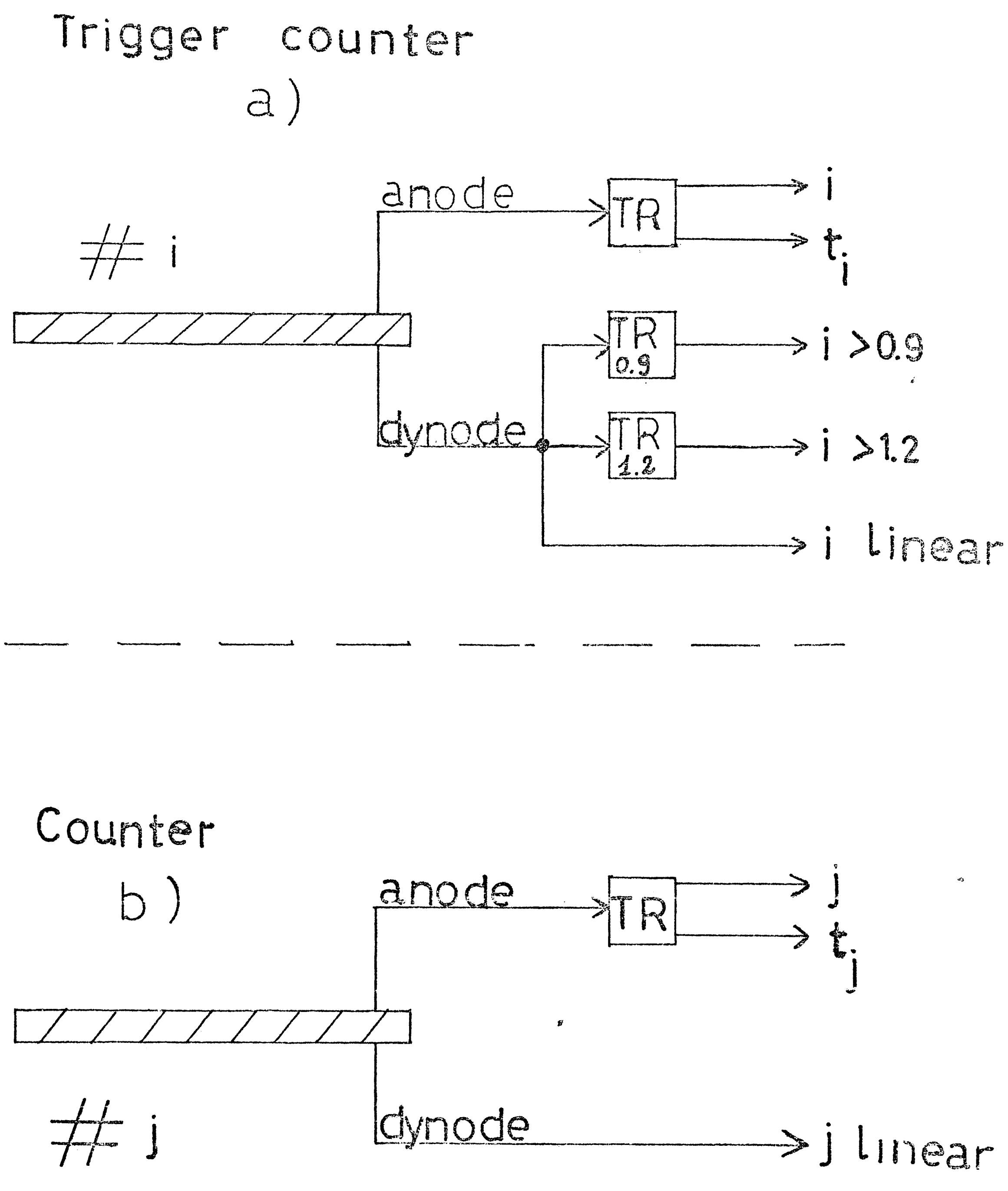

Trigger counter
a)
i
anode
TR
i
t_i
dynode
TR 0.9
TR 1.2
i >0.9
i >1.2
i linear
Counter
b)
j
anode
TR
j
t_j
dynode
j linear

Fig. 3

Basic 4 # logics

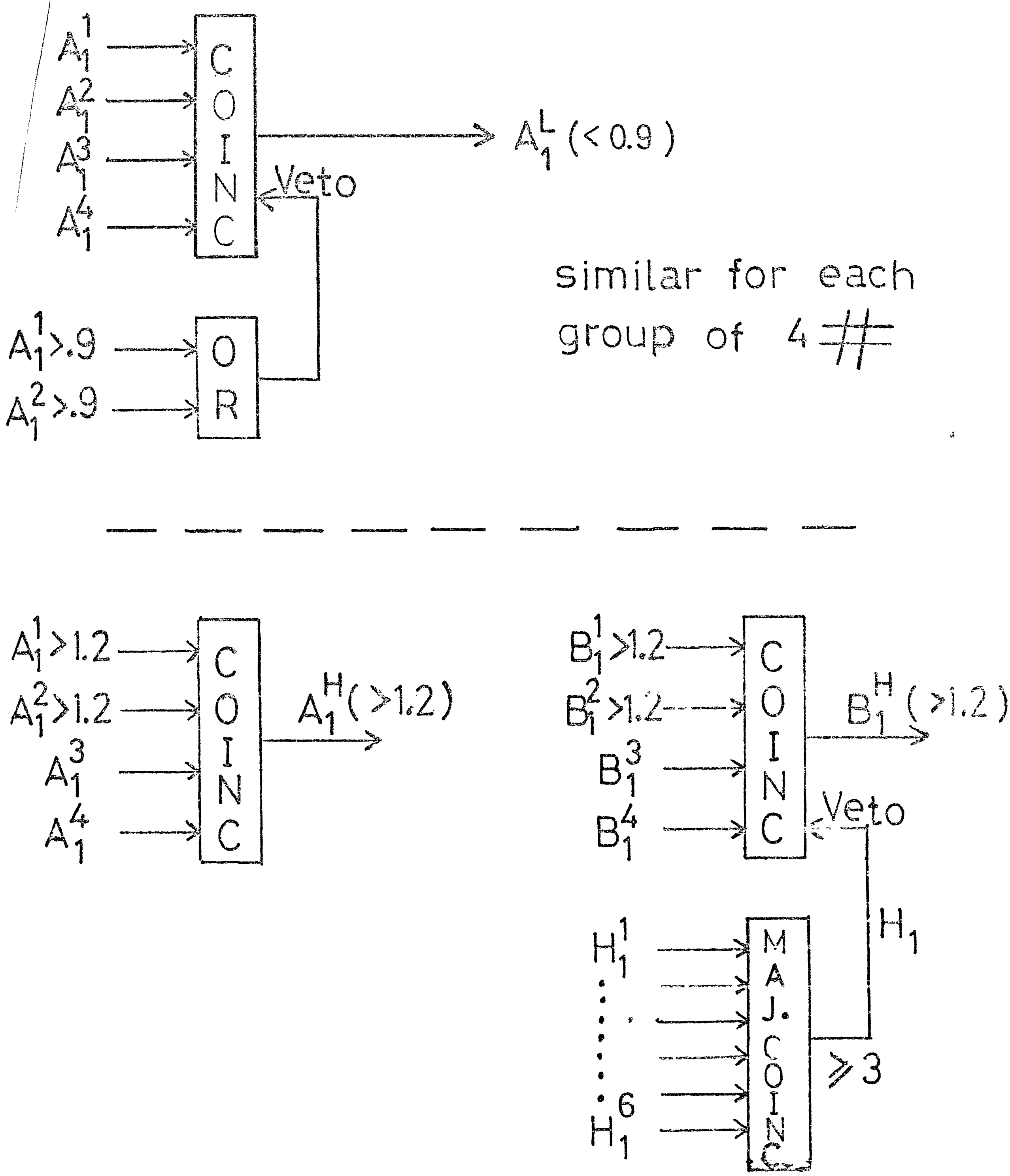


Fig. 4

$\frac{dE}{dX}$ trigger

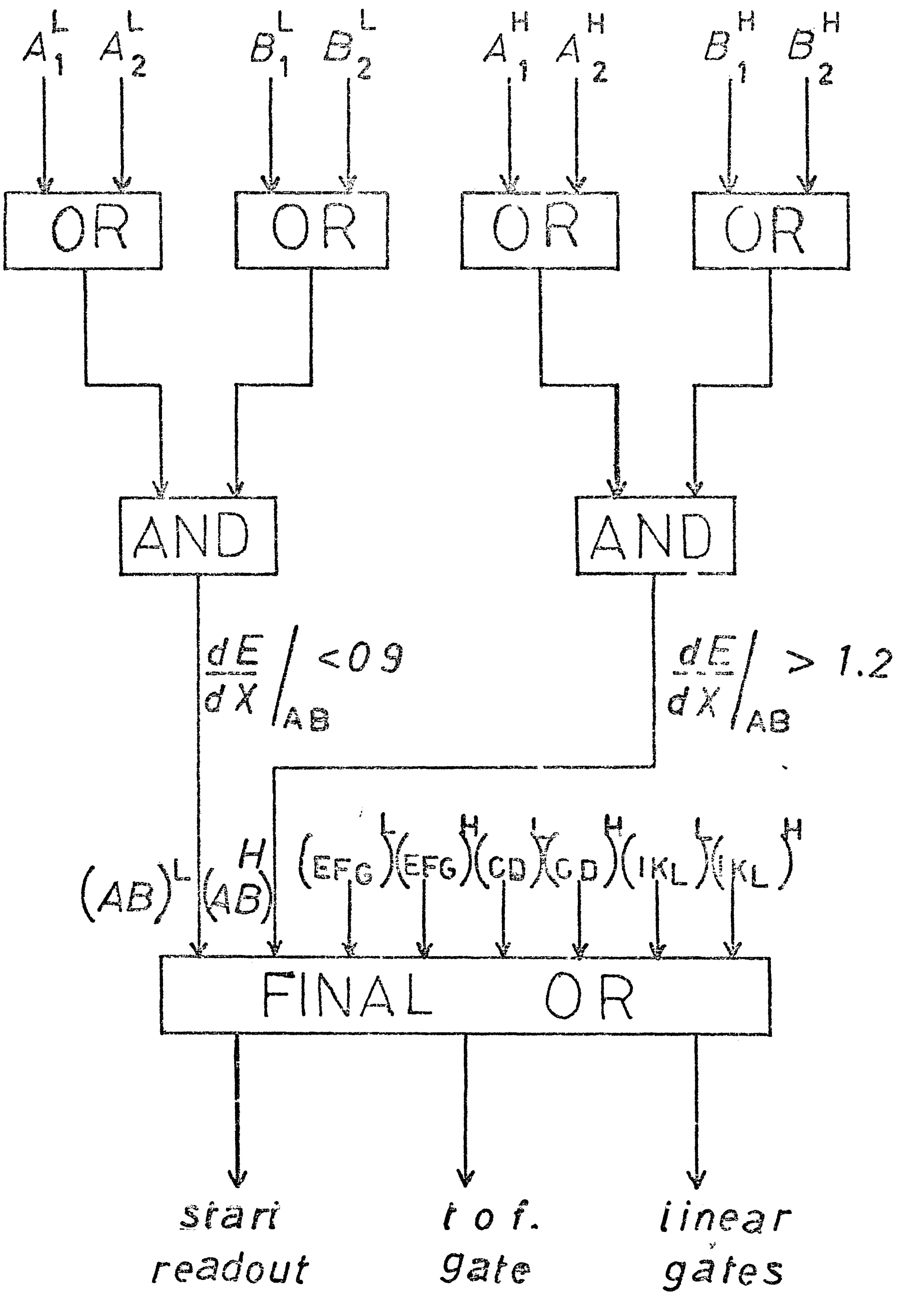


Fig. 5

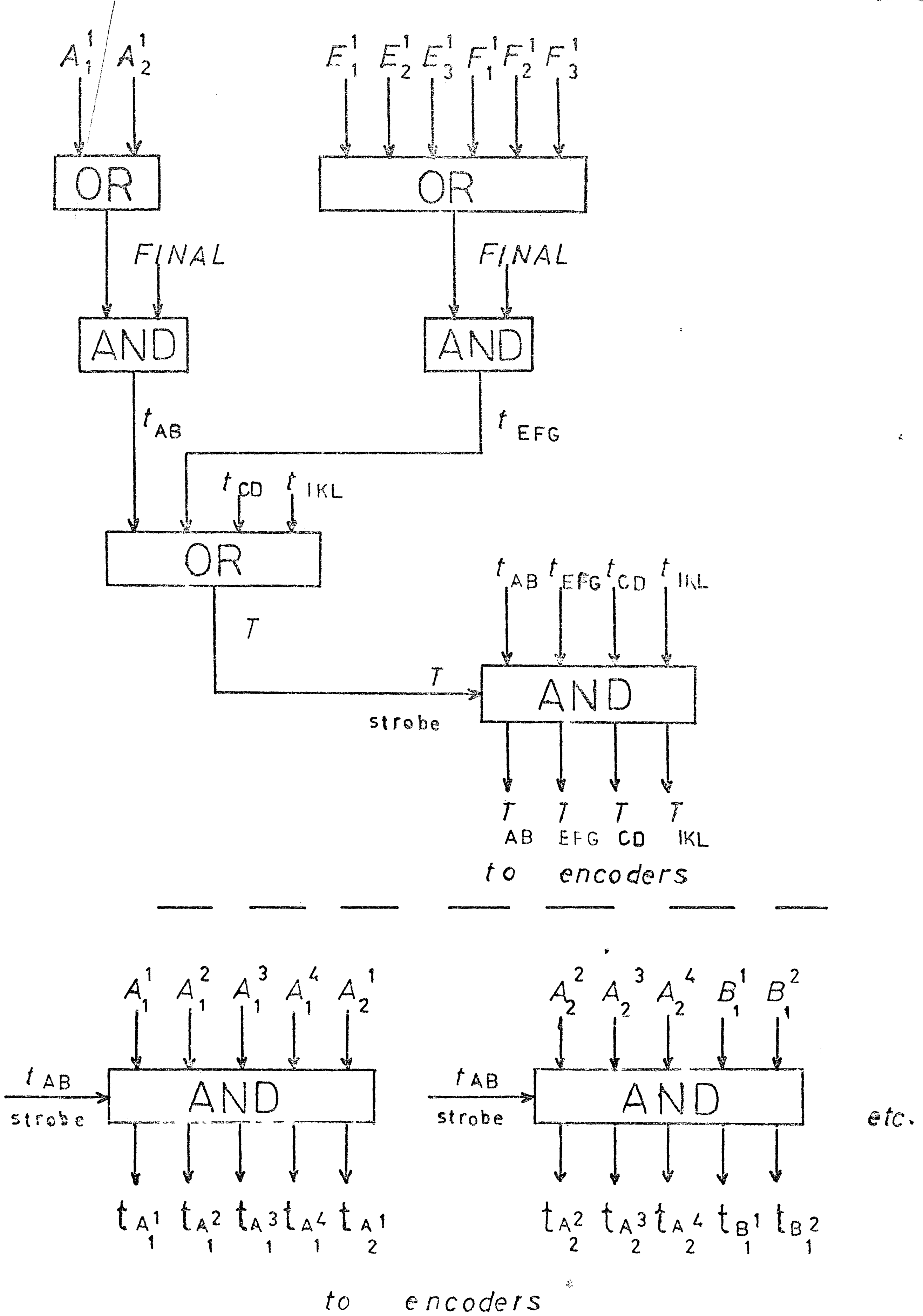

A¹₁ A¹₂
E¹₁ E¹₂ E¹₃ F¹₁ F¹₂ F¹₃
OR
OR
FINAL
FINAL
AND
AND
t AB
t EFG
t CD
t IKL
OR
T
t AB t EFG t CD t IKL
T
strobe
AND
T AB T EFG T CD T IKL
to encoders
A¹₁ A²₁ A³₁ A⁴₁ A¹₂
t AB
strobe
AND
t A¹₁ t A²₁ t A³₁ t A⁴₁ t A¹₂
A²₂ A³₂ A⁴₂ B¹₁ B²₁
t AB
strobe
AND
t A²₂ t A³₂ t A⁴₂ t B¹₁ t B²₁
etc.
to encoders

Fig. 6

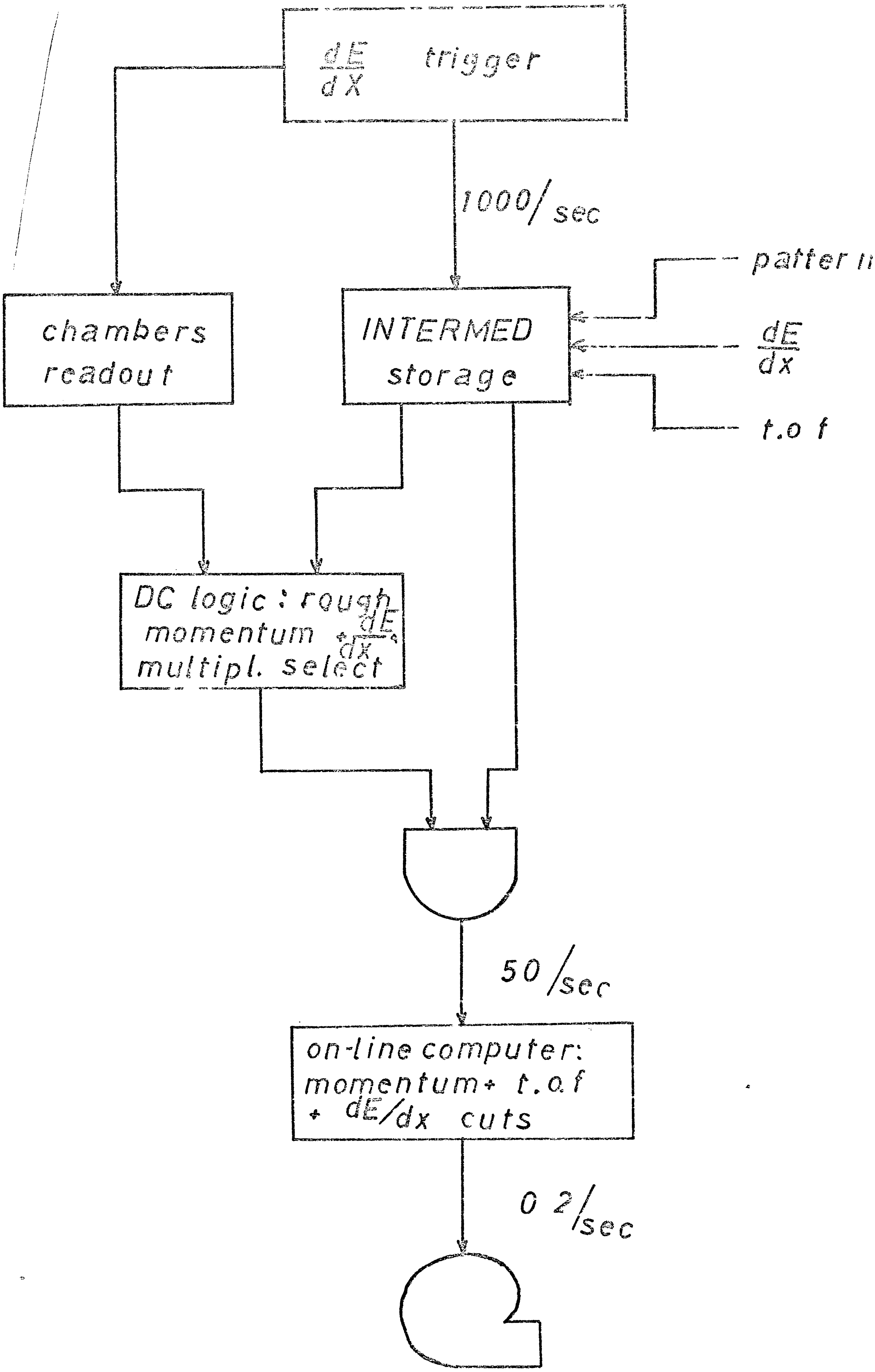

dE/dX trigger
1000/sec
pattern
dE/dx
t.o f
chambers readout
INTERMED storage
DC logic : rough momentum + dE/dx multipl. select
50/sec
on-line computer: momentum + t.o.f + dE/dx cuts
0 2/sec

Fig. 7

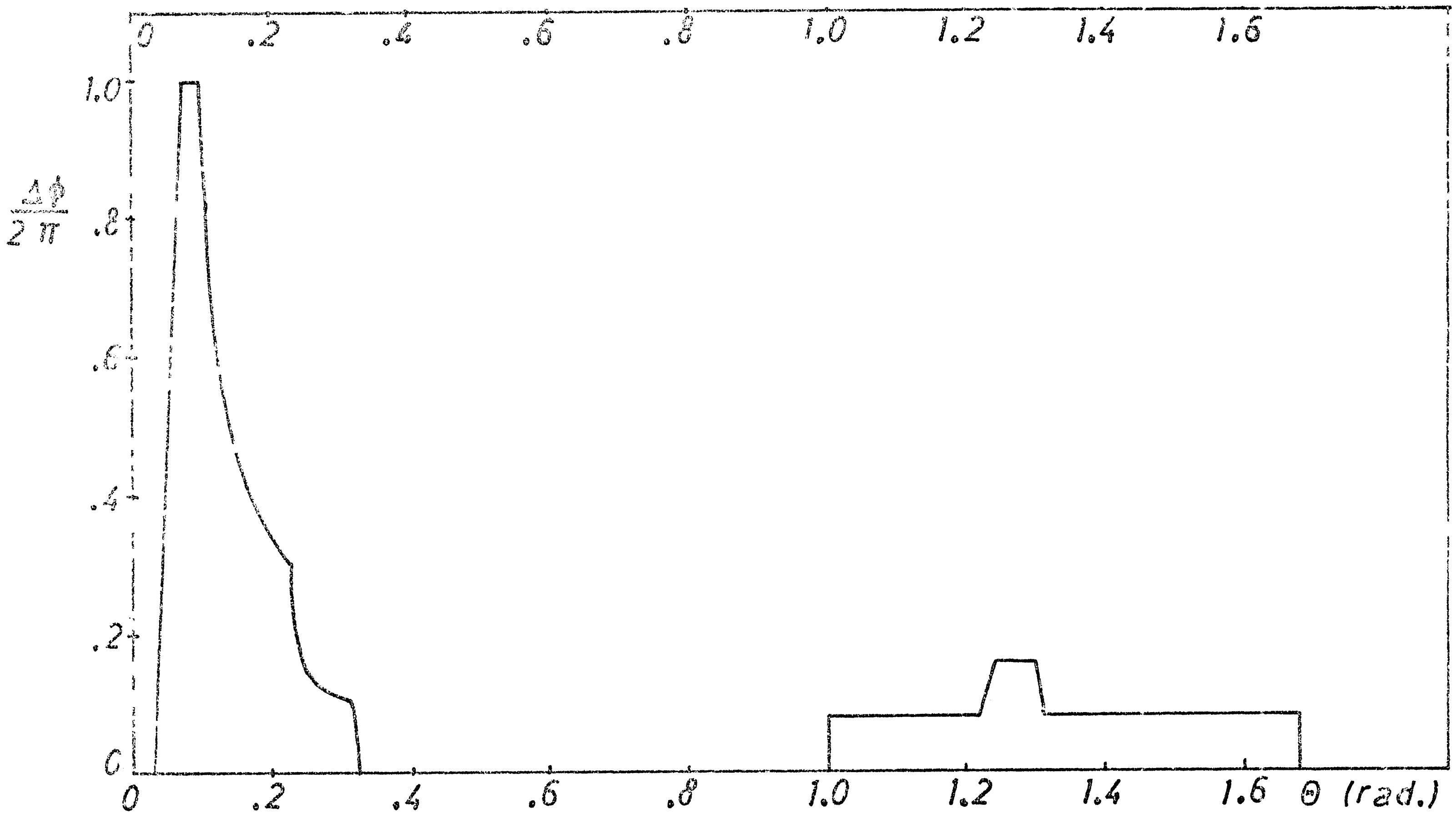


Fig 8