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A MEMORY LEVEL DECISION FOR A 50.000-WIRE PROPORTIONAL CHAMBER DETECTOR*

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ABSTRACT

A memory level decision logic used at the CERN-ISR Split Field Magnet Detector is described. 50.000 wires of the multi-wire proportional chamber detector are grouped into 32 wire memory OR levels, corresponding to 64 mm space resolution. From their pattern, the topology of specific events is defined. The rejection power for wrong events is of the order of 10^2 to 10^3. The decision time is about 1 μsec.

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1. INTRODUCTION

At the CERN intersecting storage rings (ISR) a multi-wire proportional chamber detector has been built for the Split Field Magnet (SFM) Spectrometer1). The "forward" part of the detector, to which we refer, is equipped with 28 proportional chambers of 2 mm wire spacing, most of them 1 m high and 2 m wide (figure 1). Each chamber consists of a vertical and of a horizontal wire plane. The trigger system which is described here makes essential use of the proportional chambers themselves (self-triggering mode).

The event rates at the ISR at full luminosity are of the order of some 10^5 events/sec. The background under reasonable working conditions is about the same. On the other hand, the data acquisition rate is limited to ~ 10^2 events/sec. A two level decision was built, to match the detector to the data acquisition system:

i. A fast decision derived from fast chamber plane signals provides the strobe for the chamber electronics. It accounts for good event timing and rough logical decisions2).

ii. Once strobed into the memory of the chamber electronics, the event can be handled by the memory level decision, to decide whether the event is to be read into the on-line computer.

The separation of fast and memory decision avoids handling many signals in defined time relations. A block diagram of the whole system is given in figure 2.

The logic (figure 1) was built to select low multiplicity events of simple topology such as3):

$$pp \rightarrow pp$$

$$pp \rightarrow p(n\pi^+)$$

$$pp \rightarrow p(p\pi^+\pi^-)$$

from high multiplicity beam-beam interactions and from non beam-beam background.

The basic units of the logic are memory OR levels of groups of 32 wires (MOR's) corresponding to a geometrical resolution of 64 mm. The detector is subdivided into logical "superchambers" with "superplanes", 8 vertical and 8 horizontal in each telescope (T1 and T2). Each "superplane" consists of up to 64 MOR's vertical and up to 32 MOR's horizontal (see figure 3). In total, 1400 signals are handled. For simplicity, we will always use the term plane and chamber instead of "superplane" and "superchamber".

The logic consists of four parts, which are entirely built with TTL integrated circuits.

i. Multiplicity definition.
ii. Cone-gap logic.
iii. Trackfinding logic.
iv. Collinearity and scattering angle matrices.

They are combined in a central decision and computer controlled via CAMAC.

2. MULTIPLICITY DEFINITION

This part of the logic defines particle multiplicities in both detector telescopes. Care has been taken to build it flexible, computer controlled, and with many parallel decision channels (figure 3).

a. Plane adders

The number of MOR's hit in one plane are summed up in modular 32 input adders. The circuit diagram is given in figure 4. The adder results in a 5-bit output with an exact count up to 15 and an overflow ≥ 16. A carry-save-adder technique was used to get short propagation time (typ. 100 ns). There are 44 modules used in the system, with a total of ~ 1400 MOR inputs.

b. Chamber combinative logic

A normal chamber consists of 64 vertical and 32 horizontal groups, handled by 3 plane adders. A combinative logic merges the adder information to either

- total counts in each vertical and horizontal plane (HOR/VER)

or

- minimum and maximum number of counts in both planes of one chamber (MIN/MAX)*).

The options can be chosen by jumper leads.

The second option MIN/MAX gives a lower limit for the number of space points and an upper limit for the number of MOR's hit.

c. Chamber comparator

Comparator circuits check, whether the number of MOR's from the combinative logic is ≤ N, = N, or ≥ N for both HOR and VER (or other combinations) of all chambers. 4 comparator channels are available from each combinative output. They can be set independently, with N between 1 and 15.

The comparators N are set via CAMAC from the computer. The functions ≤, =, or ≥ are chosen by jumper leads.

d. Telescope adders

The corresponding comparator outputs of all chambers in one telescope are summed in 8-input adders working on the same principle as the plane adders. Thus, the frequency of occurrence of all 4 comparator channels of both combinative outputs are obtained simultaneously in both telescopes (altogether 16 channels).

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*) Also combinations HOR/MAX and VER/MIN are possible.

e. Telescope comparator

In a second comparator logic, a threshold M is set to get the minimum number of chambers required. Four thresholds can be chosen simultaneously and independently for all 16 channels.

There is an option to choose which chambers participate in the decision. Usually, all 8 or the first 5 were taken.

The 64 final decisions of the multiplicity chain are converted to NIM standard signal levels.

The standard setting in the experiment[3)] was:

- Combinative logic: MIN/MAX.
- Chamber comparator: ⩾ 1, ⩾ 2, ⩾ 3, ⩾ 4.
- Telescope comparator: ⩾ 3.

This results in the following multiplicity conditions:

i. ⩾ 1 (2, 3, 4) MOR in at least one plane of ⩾ 3 different chambers (MAX).
ii. ⩾ 1 (2, 3, 4) MOR in both planes of ⩾ 3 chambers (MIN).

Condition ii. is a typical acceptance condition for 1 (2, 3, 4) particles, whereas i. was used as a rejection condition against higher multiplicities.

3. CONE-GAP LOGIC

Since the events under consideration occur predominantly at small scattering angles, one can define acceptance cones in the forward direction. For technical reasons, this logic is restricted to the horizontal projection so far.

Two cones with an upper acceptance limit of 100 mrad and 200 mrad were defined in each quadrant. The appropriate MOR's per plane were linked by an OR function. The planes were connected in a gap logic giving a true output only if at least 3 planes were hit and not more than one plane missing in between.

4. TRACKFINDING LOGIC

The trackfinding logic is based on the fact, that tracks are essentially straight in the horizontal projection, where the magnetic field component is small. Thus, only horizontal MOR's are regarded in this decision.

In each quadrant, 16 angular regions are defined optimizing the following requirements:

- the whole intersection is covered (typ. ± 25 cm).
- the whole momentum range is accepted (.5 GeV/c < p < 31 GeV/c).
- good angular resolution (small angular regions and minimum overlap between different regions).

Accordingly, each angular region is defined taking one or two MOR's out of each plane to form a straight road pointing to the intersect.

The logic is illustrated in figure 5: The MOR's per plane, belonging to the same road, are linked together in an OR function, and sent to an 8-input adder, one input per plane, one adder per angular region. These 4 x 16 adders provide a frequency distribution of hits per angular region over the whole quadrant, as e.g. indicated in figure 5.

From this distribution the number of tracks and their position can be extracted with a maximum search algorithm. The algorithm has been realized for all 16 angular regions in parallel using a chain of comparators and gates.

The number of maxima with at least 3 hits sets a lower limit on the number of tracks. The maxima[*)] are used to define the track positions for the collinearity and the scattering angle determination.

The following outputs are available:

- 16 outputs per quadrant for track position (TTL).
- 4 outputs per quadrant for ⩾ 1, ⩾ 2, ⩾ 3, ⩾ 4 tracks (NIM).

5. COLLINEARITY AND SCATTERING ANGLE MATRICES

The horizontal projections of the two outgoing particles in elastic scattering are diametrically opposed lines. To check this collinearity and to determine the scattering angle Θ, full X-Y matrices have been developped. Each module takes 16 X-inputs and 16 Y-inputs. All 256 X-Y coincidences are available and can be added in any combination to 16 final outputs.

The collinearity is checked by two matrices. 16 angular regions from the upper half of telescope 1 (T1 up) are fed into the X-inputs, 16 regions of the lower half of telescope 2 (T2 down) into the Y-inputs of one matrix, (T1 down) and (T2 up) into the other matrix. All events on the main diagonal and the two side diagonals are accepted.

Two other matrices are used to define Θ. In each telescope, 16 horizontal angular regions (X-inputs) are combined with 16 vertical MOR's (Y-inputs). Thus, the inner parts of the matrix correspond to small angles, the outer to large angles. The X-Y coincidences are linked such to form (approximately) concentric circles, each circle corresponding to a certain range in scattering angle Θ.

[*)] For a plateau of > 2 the centre is taken.

This Θ determination was used to scale down the abundant events in the low Θ regions with a Θ dependent scaling factor.

6. CENTRAL DECISION LOGIC

The logic described so far is built with TTL integrated circuits. The final decision from each part is converted to NIM standard levels.

These levels are combined to a final decision in a central logic which is entirely built using commercial NIM modules. Additional signals such as neutron signatures are inserted at this point.

An important feature of the logic is that many reactions can be handled in parallel. In the actual set-up, 16 channels were foreseen to be accepted simultaneously.

7. PERFORMANCE

a. Technical check

A logic of the described complexity has to be checked extensively. A special computer program was run every few hours to compare the result of the hardware with a software logic simulating all hardware decisions. On-line, the program keeps each event in the chamber memory until the hardware decision was found to be correct. Thus, in case of an error, the traceback can be done on DC levels. This turned out to be a substantial advantage of this type of memory logic, compared to serial or fast decisions.

b. Losses and bias

Possible losses of real events in the logic were studied on simulated events and real data. For real data, the logic was tightened gradually, studying the losses in each step. A total loss of ≤ 5% of all events was accepted, provided it is correctable.

c. Rejection power and decision time

The decision time taken by the logic itself was 500 nsec. Including all cables and safety margins, the system deadtime was 2 μsec per fast trigger. For typical trigger rates of ~ 10^4/sec this means a negligible loss of ~ 2%.

A summary of typical cross sections as seen by fast decision (1) and memory decision (2) is given in table 1. The rejection power (3) of the logic can be seen from the table to be of the order of 10^2 to 10^3. The selectivity, i.e. the fraction of real events on magnetic tape after the memory decision is given in (4).

To demonstrate the effect of the logic, figure 6 shows a comparison of an elastic event trigger without and with memory level decision, as it appears on the on-line display of the experiment$^{3)}$.

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FIGURE CAPTIONS

Figure 1 - Block diagram of memory level decision.

Figure 2 - Block diagram of fast and memory decision.

Figure 3 - Block diagram of the multiplicity definition.

a) Multiplicity definition for one chamber with options $\geqslant$ and N = 1, 2, 3, 4.

b) Telescope multiplicity definition for one comparator channel with options $\geqslant$, N = 1, MIN, M = 3.

Figure 4 - Circuit diagram of the 32-input adder.

Figure 5 - Trackfinding logic.

Figure 6 - Display pictures of elastic triggers.

a) Selected by fast trigger only.

b) Also memory level decision required.

TABLE CAPTION

Table 1 - Rejection power and selectivity of the memory decision. Reaction a) includes scaling factors for small Θ. For comparison, elastic scattering for large Θ is given in reaction b).

reaction	(1) fast decision σ_F[mb]	(2) memory decision σ_M[μb]	(3) rejection power σ_M/σ_F	(4) selectivity σ_{real}/σ_M
a) pp elastic	15-25	15-100	$1\ \ -5\mathrm{x}10^{-3}$	0.3
b) pp (big)	10	3- 50	$0.3-5\mathrm{x}10^{-3}$	0.01
c) p $(n\pi^+)$	2-3	40- 60	$2\mathrm{x}10^{-2}$	0.02-0.03
d) p $\pi^+\pi^-$	15-25	400-800	$2\ \ -4\mathrm{x}10^{-2}$	0 0.03

<u>TABLE 1</u>

Rejection power and selectivity

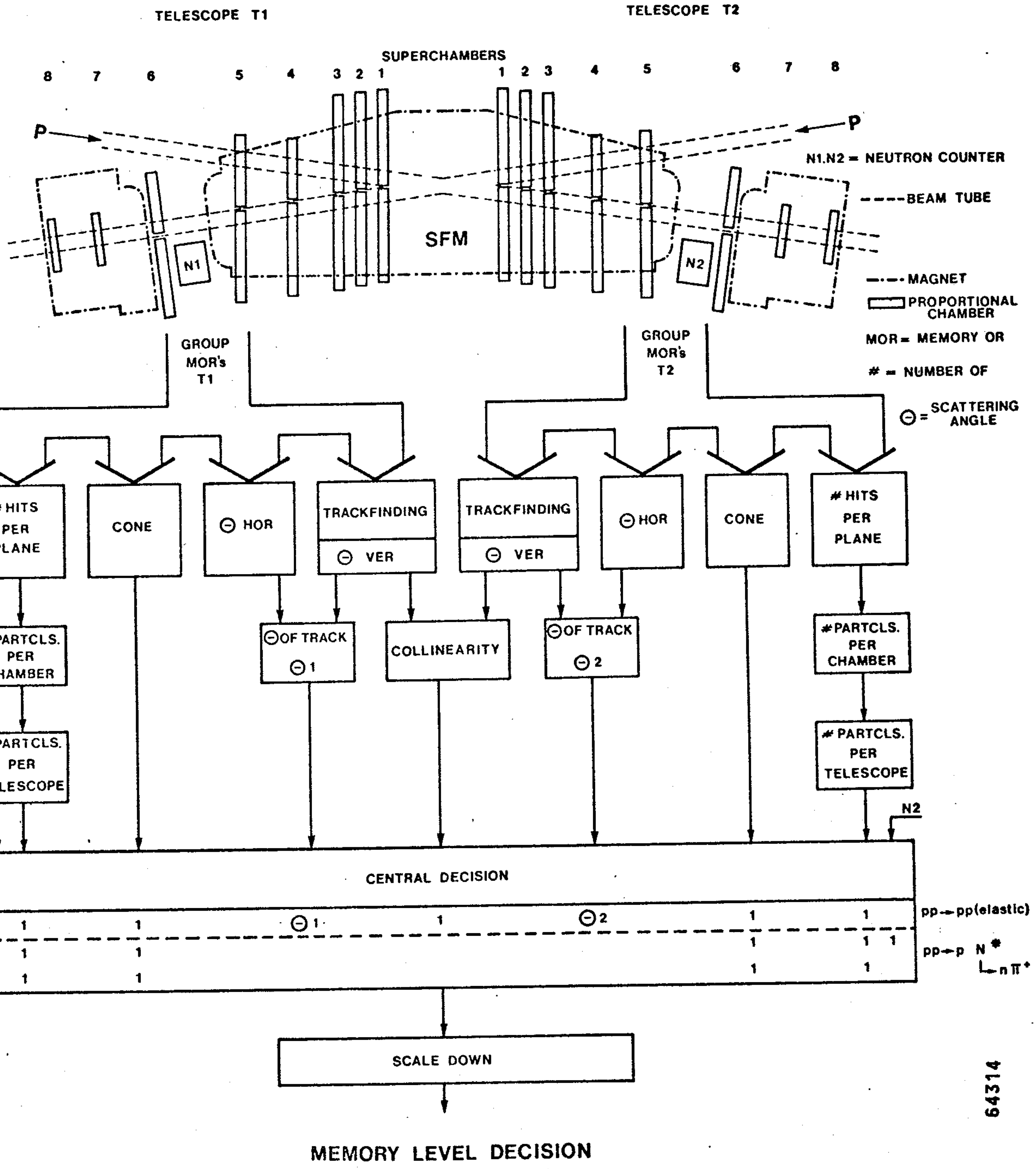
TELESCOPE T1
TELESCOPE T2
SUPERCHAMBERS
8 7 6 5 4 3 2 1
1 2 3 4 5 6 7 8
P
P
SFM
N1
N2
N1,N2 = NEUTRON COUNTER
----BEAM TUBE
—·—·MAGNET
PROPORTIONAL CHAMBER
MOR = MEMORY OR
# = NUMBER OF
Θ = SCATTERING ANGLE
GROUP MOR's T1
GROUP MOR's T2
HITS PER PLANE
CONE
Θ HOR
TRACKFINDING
Θ VER
TRACKFINDING
Θ VER
Θ HOR
CONE
HITS PER PLANE
PARTCLS. PER CHAMBER
Θ OF TRACK Θ1
COLLINEARITY
Θ OF TRACK Θ2
PARTCLS. PER CHAMBER
PARTCLS. PER TELESCOPE
PARTCLS. PER TELESCOPE
N1
N2
CENTRAL DECISION
1 1 Θ1 1 Θ2 1 1
pp→pp(elastic)
1 1 1 1 1
pp→p N*
1 1 1 1 1
└→nπ+
SCALE DOWN
MEMORY LEVEL DECISION
64314

Figure 1

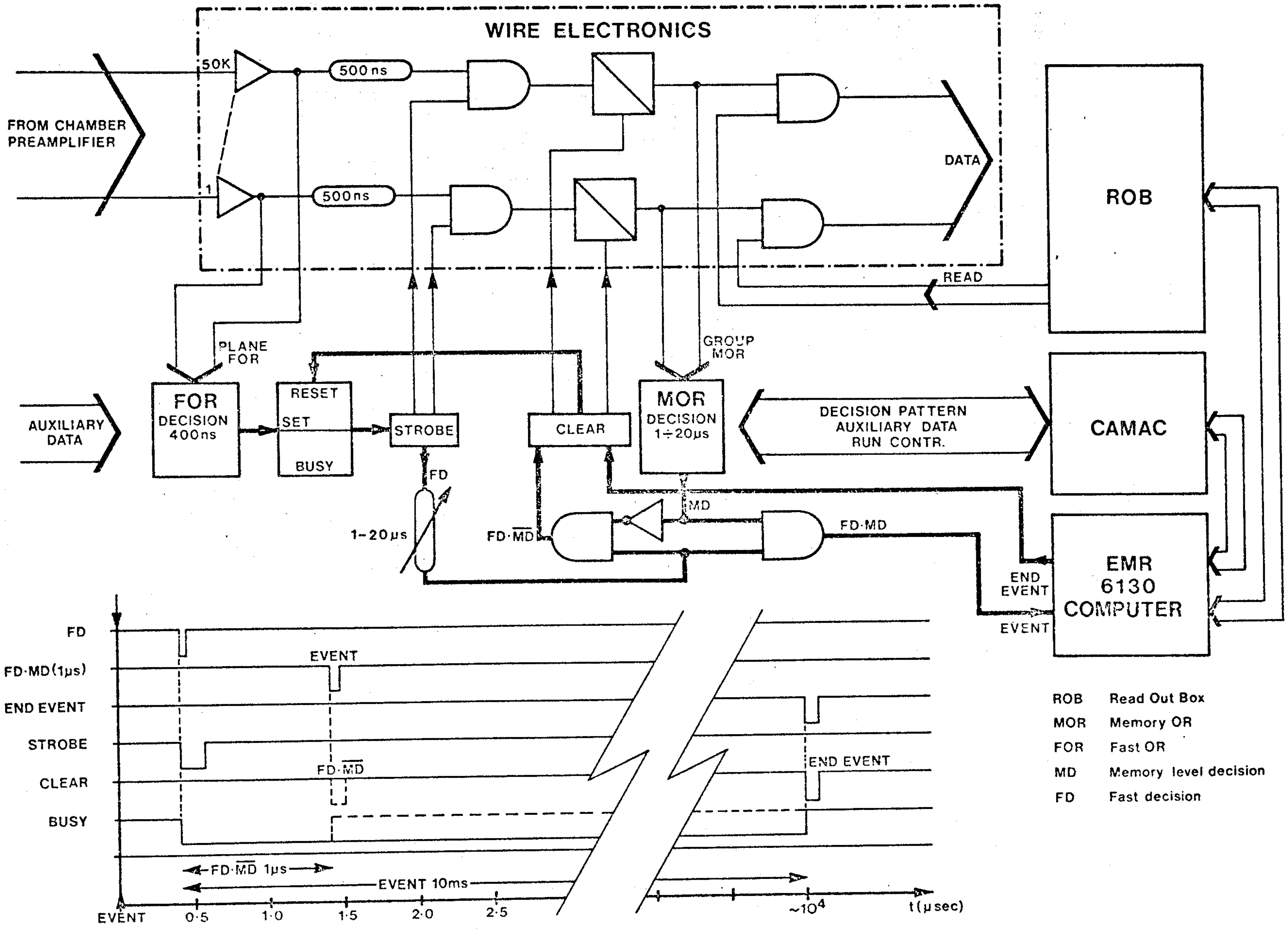

Figure 2

64312

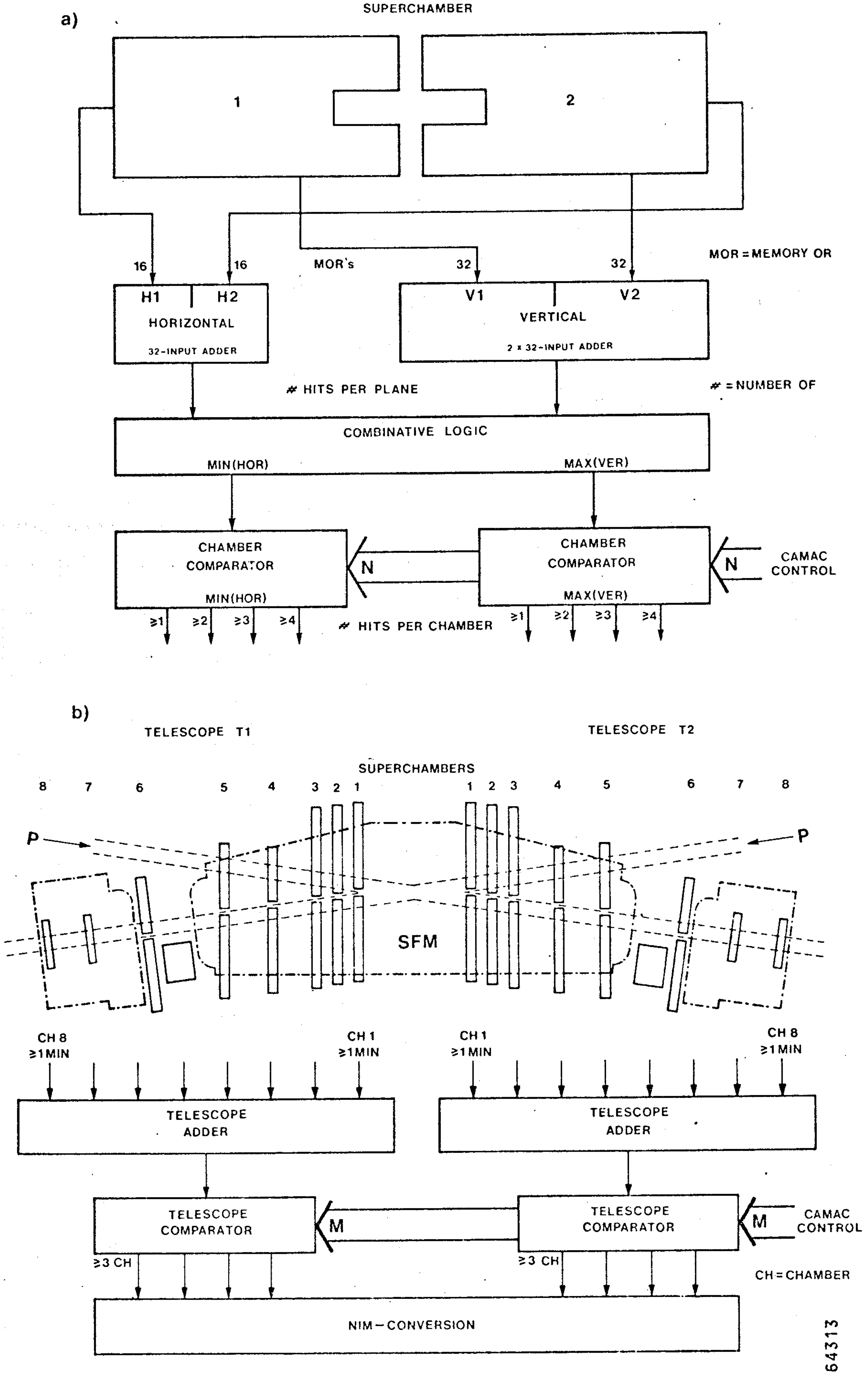
a)
SUPERCHAMBER
1
2
16
16
MOR's
32
32
MOR = MEMORY OR
H1
H2
HORIZONTAL
32-INPUT ADDER
V1
V2
VERTICAL
2 x 32-INPUT ADDER
HITS PER PLANE
= NUMBER OF
COMBINATIVE LOGIC
MIN(HOR)
MAX(VER)
CHAMBER COMPARATOR
MIN(HOR)
N
CHAMBER COMPARATOR
MAX(VER)
N
CAMAC CONTROL
≥1
≥2
≥3
≥4
HITS PER CHAMBER
≥1
≥2
≥3
≥4
b)
TELESCOPE T1
TELESCOPE T2
SUPERCHAMBERS
8
7
6
5
4
3
2
1
1
2
3
4
5
6
7
8
P
P
SFM
CH 8 ≥1 MIN
CH 1 ≥1 MIN
CH 1 ≥1 MIN
CH 8 ≥1 MIN
TELESCOPE ADDER
TELESCOPE ADDER
TELESCOPE COMPARATOR
M
TELESCOPE COMPARATOR
M
CAMAC CONTROL
≥3 CH
≥3 CH
CH = CHAMBER
NIM – CONVERSION
64313

Figure 3

32 Input Adder

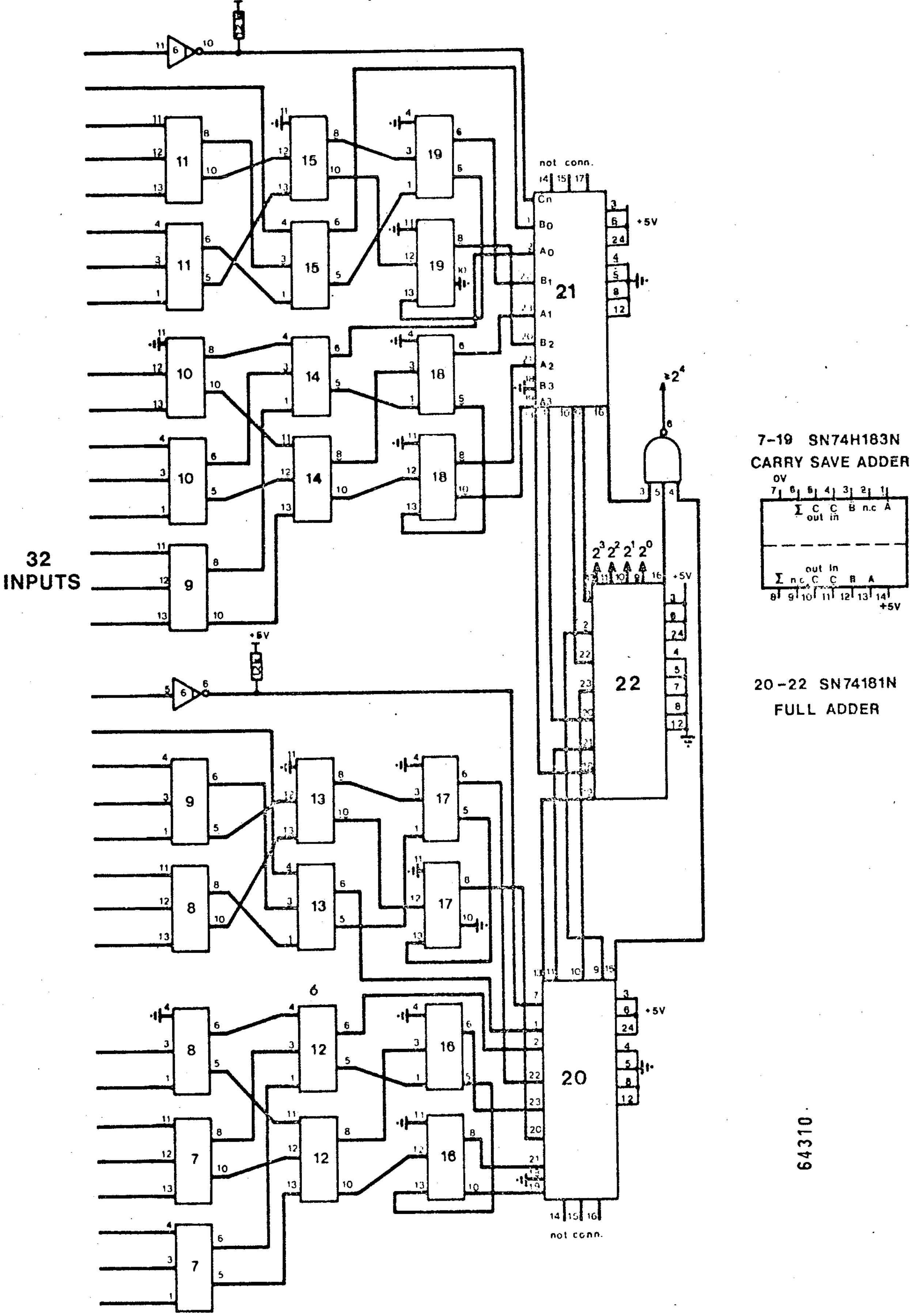

Figure 4

64310

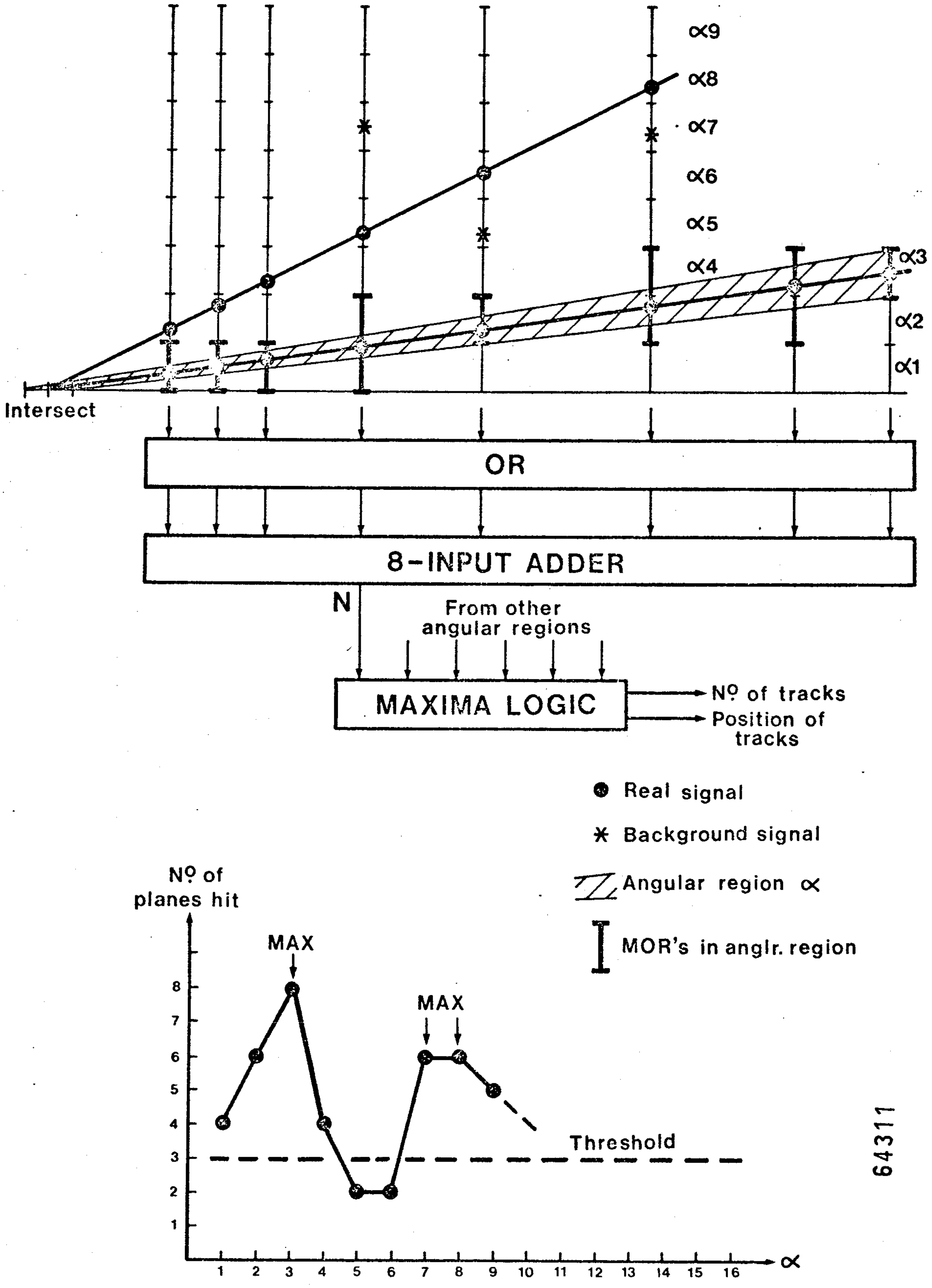
α9
α8
α7
α6
α5
α4
α3
α2
α1
Intersect
OR
8-INPUT ADDER
N
From other angular regions
MAXIMA LOGIC
Nº of tracks
Position of tracks
● Real signal
✱ Background signal
Angular region α
MOR's in anglr. region
Nº of planes hit
MAX
MAX
Threshold
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
α
64311

Figure 5

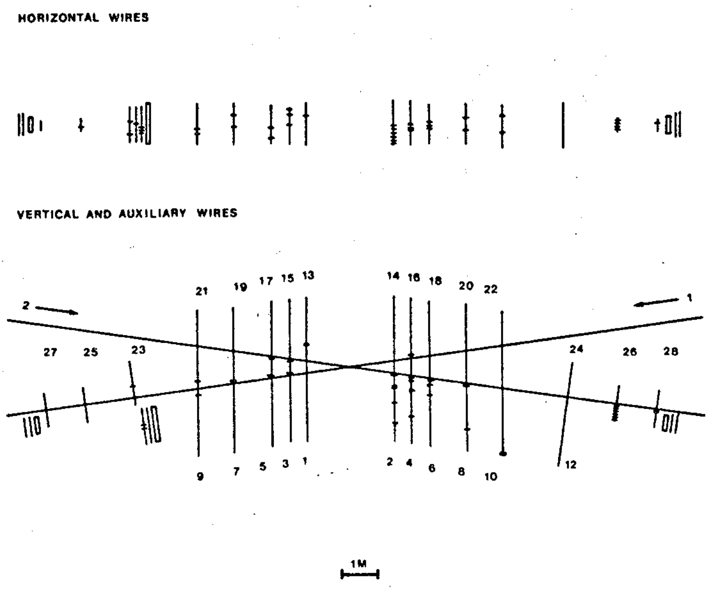

Figure 6a

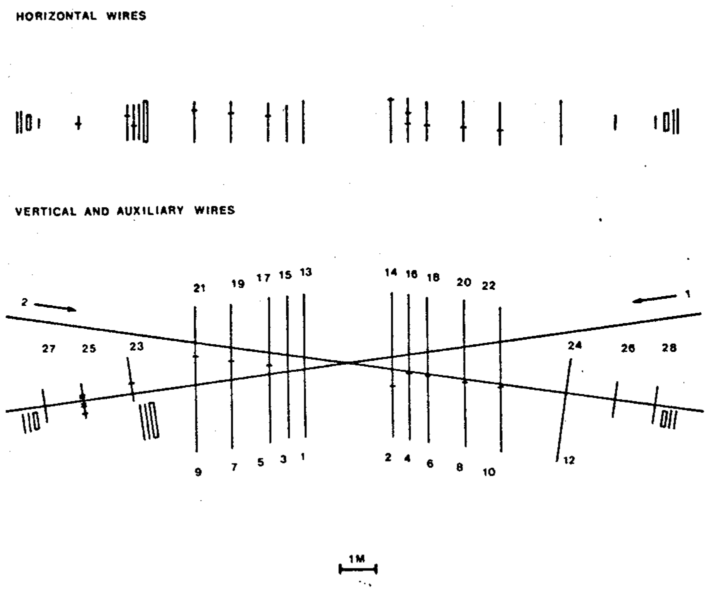

Figure 6b