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Jet Cell Structures for the Eagle Muon Spectrometer

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1. Introduction

This note summarizes the status of the muon system based on the jet cell concept. It is shown that such a system can provide both trigger and momentum information, solely based on the drift cell information. These points are developed in Sections 2 and 3. The mechanical engineering approach is presented in Section 4; the alignment strategy is described in Section 5.

2. The Concept of the 'Tilted Jet Cell' (TJC)

Most recently, we have been considering jet cell structures which are tilted by a certain angle with respect to the polar angle θ of the muon direction. The conceptual configuration is shown in Fig. 1, indicating the layout of such a cell, together with plausible dimensions. In particular, the maximum drift distance d is a compromise between channel count and maximum drift time acceptable in view of a trigger decision. A further constraint on d is imposed by the tilt–condition.

A possible layout of the cells as a function of the polar angle θ is given in Fig. 2. On geometric grounds the tilt–angle δ will be in the range $-20^\circ > \delta > -30^\circ$ relative to θ. In this layout, essentially each track will cross a sensewire plane and will be registered by 6 sensewires.

There are several reasons for considering the tilted geometry. Chambers with a geometry akin to the one considered here have been used previously in several spectrometers [1,2]. Then, the principal goal was to improve the resolution through the improved isochrony of the tilted geometry, as made plausible in Figs. 3 and 4. The drift properties of such a cell are quite good (Fig. 5) and resolutions of $\sigma < 100$ μm have been reported [2], similar to the best reported for high quality drift chambers using standard, fast gases [3]. We propose to operate our drift cells under somewhat less favourable conditions (a larger track segment is projected onto the driftwires than the one used in Ref. 2); nevertheless, we estimate that the resolution should not deteriorate relative to non–tilted geometries. Initial GARFIELD calculations (see Figs. 6 and 7) support this assessment.

Tilting the cell has in our view two advantages which we consider crucial for the reliable operation of a large system:

- tracks crossing the sensewire plane provide an internal t_0–determination
- for the same reason an internal drift velocity monitoring is possible.

An important additional requirement is the identification of the bunch–crossing (BX) in which the muon(s) originated. This information should be available at the time of the Level 1 trigger decision, such that only information belonging precisely to this bunch–crossing need to be transferred to the Level 2 processors. This requirement is particularly relevant for the Inner Detector Information and is in our view a 'non–negotiable' condition. While the precise algorithm to evaluate the BX number is not presented here, we want to make the following observations:

i) since tracks cross the sensewire plane, there is always an 'almost' prompt signal produced. The maximum delay between the first signal and the muon crossing is given by:

$$\tau = \frac{1}{v_D} \cdot \frac{s}{2} \cdot \mathrm{tg}\,\delta \leq 40 \text{ ns}$$

Therefore, the BX number algorithm will only have to interpolate this time interval.

ii) Given the wirelengths of our chambers (at least 4 m) propagation times of the signal along the sensewire will have to be considered for correct BX identification.

It may be possible to provide the second coordinate in a straightforward way, provided the needed accuracy is modest. Charge division would be one possible candidate and an accuracy of ~1% of the total wire length could be expected.

The choice of the drift gas is of course a most important issue. We strongly advocate [1] the use of fast, saturated drift gases. Such gases will not give the potentially excellent resolution achievable with 'cold' gases (e.g. CO_2) but have the overwhelming advantage of better insensitivity of the drift velocity on pressure, temperature, E–field, B–field and impurities. We believe that this is the only safe choice for a system of our magnitude. The gas should be non–flammable and we like therefore a mixture of $Ar/CF_4/CO_2$ [4]. The gas shows good saturation properties already at modest E–fields and is rather fast, see Fig. 8.

3. Triggering

Given the high granularity of the proposed drift chambers, it appears natural to us to use the same strategy as previously considered for a RPC–based system [5]. The work reported in [5] applies directly to the largest part of the detector, typically for $|\eta| < 2.5$. The possible trigger scheme for $|\eta| > 2.5$ needs further evaluation, possibly requiring some improved granularity based on interpolation algorithm between adjacent cells.

4. Mechanical System Engineering

To measure the muon momentum EAGLE is equipped with a toroidal magnet as shown in Fig. 9. This magnet has an octogonal shape, the magnetised iron has a thickness of 2.5 m and a magnetic field of 1.8 T. The muon momentum measurement is accomplished by the determination of both the angles in front and behind the magnetised iron. For this purpose we have considered the following concept:

Inside and outside of both the barrel and the endcap toroids we foresee modules fixed to the iron. These modules, an example of which is shown in Fig. 10, are supposed to be intrinsically stable. They consist of 3 components: 2 sensitive layers kept together at a stable distance by a mechanical structure, which provide an accurate measurement of the angle of a traversing muon. This structure needs to be stable against deformation under its own weight and due to temperature effects. We envisage here the use of composite material based on carbon fibre technology.

Preliminary discussions with industry have shown, that such modules can reasonably be built within dimensions of 4.5m × 4.5m × 1m (height), while guaranteeing a geometrical stability of the order of 100 μm. With such dimensions a total number of 240 modules is needed to cover the whole experiment. For the time being the modules are designed in a pointing shape but obviously a non-pointing geometry would be feasible.

Since each module measures individually the angle of a traversing muon, the momentum measurement requires a relative angular alignment between the two corresponding modules inside and outside the magnet. This can be done by means of thin wires stretched along the magnet through the modules. Each of the modules will be equipped with capacitive proximity sensors providing a relative positioning of the module relative to the wire with a precision of ~ 30 μm. The ends of the wires are attached to a precise frame which is supported by the endplates of the magnet. In this way a geometrical link from corresponding wires inside and outside the magnet is accomplished. A geometrical connection of the wires on the fixed (barrel) part of the magnet to the wires on the moving (endcaps) can be made by optical means such as autocollimation or RASNIK (see also section 5).

The sensitive layers in the module are made of jet cell type drift chambers. Mechanically the cells are created by stacking flat chambers made of sensitive layers and a cathode plane spaced by a frame as shown in Fig. 11. The size of the frames is approximately 2.5 m-4.5 m in length, 150 mm in height and 15 mm thick. Due to the length of the wires, intermediate supporting combs are included in the frame spaced by 700-900 mm. Thus gravitational sagitta of the wires can be limited to 50 μm for a wire tension of approximately 20% of its elastic limit and the total load applied to a frame is of the order of 2 kp. It has to be pointed out that the jet cell is created by the two planes of a given flat chamber and the cathode plane of the adjacent one. Two successive frames are mounted with a small relative angle of max 0.38°, which corresponds to a slight increase of the drift gap of max 0.5 mm. If one operates the cell with a saturated drift velocity, it will not influence the drift performance.

The flat chambers of a module are fixed to a rigid structure precisely connecting the two sensitive layers. The flat chambers are supported by a limited number of combs perpendicular to the frames and next to the wire supports. The supporting structure is designed so that the combs on the top and bottom are linked to each other in a stable way. Preliminary finite element calculations have shown that a carbon fibre structure of that design has a deformation of 50 μm at the places of the combs due to the weight of the module as shown in Fig. 12. Carbon fibre construction has been selected because of its low thermal expansion coefficient of ~ -.3 to 0.5 10^{-6} per degree. Thus we expect a thermal deformation of the modules of less then 50 μm for an operating temperature of 20° C - 30° C. Given the big dimensions of the module, special care has to be taken in the design to take a differential pressure between the drift gas and the atmosphere into account.

5. Alignment

A permanent monitoring of 250 muon supermodules means the implementation of outside 'reference' lines passing in between the modules, in the medium plane of each super module.

Two alternative solutions are presently being considered:

- a pure optical solution consisting of CCD cameras and appropriate targets (special patterns with reference marks or diodes) which will be the outside fiducial marks of each of the modules; informal contacts have been taken (Institüt für Geodasie and Photogrammetrie, ETH Zürich, Prof. A. Grün).
- a pure mechanical - electronic solution consisting of stretched conductive wires and proximity capacitive sensors that will be the outside fiducial marks of each of the modules.

The latter approach is also being considered for the alignment of sensitive CLIC components and recent prototype work has given very encouraging results. This work is being carried out in collaboration with the a French Company (FOGAL), which has delivered many sensor systems for large scale applications. An initial modelling study was carried out indicating that an accuracy of $\sigma \sim 30$ μm would be adequate for the Eagle spectrometer. A conceptual layout showing the possible position of the conductive wire, the capacitive sensors and the additional auxiliary reference marks is shown in Fig. 13. Fig. 14 shows a close-up of the connection of inner fiducial marks and the superlayer.

An important point concerns the connection of the alignment system of the barrel to that of the endcaps for which we imagine optical solutions. We note in passing that the alignment tasks of Eagle are in certain ways not too dissimilar to those needed for the Ascot system for which a laser alignment system has been considered. It is obvious that we should evaluate their solutions to understand possible consequences for Eagle.

References

[1] F. Sauli, High Accuracy Drift Chambers: Tentative Comparison; Note presented to the EAGLE Muon WG, August 5th, 1991.

[2] W. Bertozzi et al., Nucl. Instrum. Methods 141, 457 (1977).

[3] N. Filatova et al., Nucl. Instrum. Methods 143, 17 (1977).

[4] V. Sosnovtsev, private communication.

[5] A. Nisati and M. Torelli, EAGLE note, MUO–NO–002

Figure Captions

Fig. 1 Layout of a tilted jet cell (scale 2:1). Shown is a cell with 6 sensewires, spaced by 8 mm. They are separated by potential wires. Field shaping wires terminate the cells the ensure an identical drift field for the first and last wires.

Fig. 2 Possible tilt of cells as a function of polar angle of the muon. This tilt ensures that every muon traverses a sensewire plane and fires 6 sensewires.

Fig. 3 Simplified geometrical arguments explaining the approximate isochromy for inclined tracks. A displacement of 100 µm corresponds to the average separation of ion clusters in Ar/isobutane.

Fig. 4 Results of a calculation for the drift time using the true field configuration. The line integral is done from points along a 45 line representing a typical track for every 100 µm ion location measured along the signal phase. Plotted is total drift time versus displacement of the ionization for various angles of incidence. Note the apparently equal drift times for ± 100 µm displacements from the minimum in the 45 case. Results for other track angles are also shown.

Fig. 5 Single cell time distribution from a drift cell in the VDC. Plotted is counts per time bin. dN/dt, vs time bin. Drift velocity (ω) and $x = x(t)$ relation can be extracted from such a distribution.

Fig. 6 Garfield simulation of the distribution of the arrival time of the first electron. The rms fluctuation is approximately 1 ns (~ 50 µm).

Fig. 7a Drift time in the drift cell vs drift distance. The solid line gives the relation for the 1st electron, the dashed line for centre of gravity of the first 10 electrons.

Fig. 7b As in 7a, showing the relation close to the sensewire.

Fig. 8 Driftvelocity of Ar / CF_4 / CO_2 as a function of electric field for various compositions.

Fig. 9 Layout of muon supermodules in the Eagle Toroid.

Fig. 10 Layout of a supermodule supporting two super layers.

Fig. 11 Frame of a supercell supporting the sense and potential wires, as well as the Cathode planes.

Fig. 12 Finite element analysis of the deflection of a supermodule, supported kinematically at three points.

Fig. 13 Location of capacitive sensors relative to the alignment wires.

Fig. 14 Location of alignment marks connecting a superlayer to the capacitive sensors in e support structures.

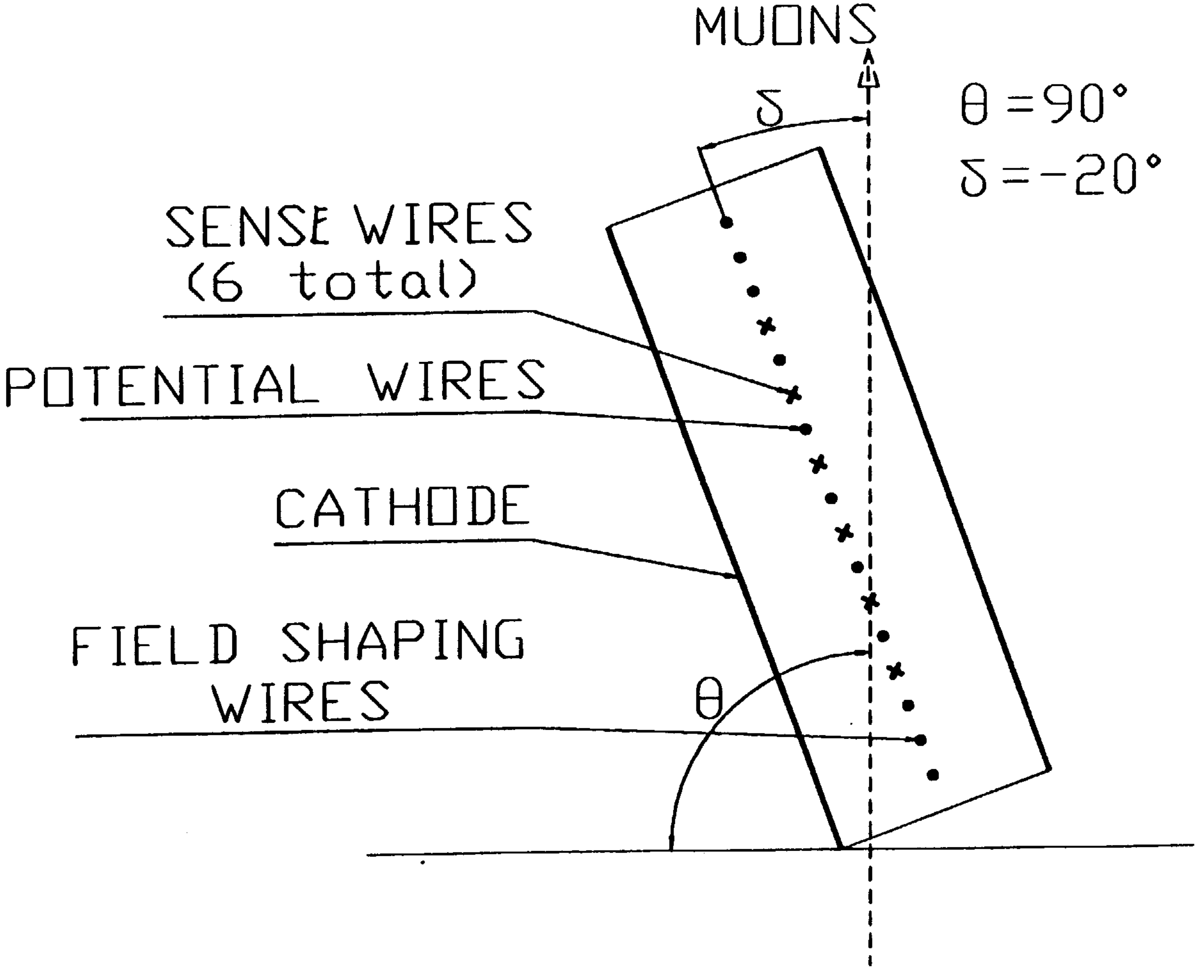

MUONS
δ
θ =90°
δ =−20°
SENSE WIRES
(6 total)
POTENTIAL WIRES
CATHODE
FIELD SHAPING
WIRES
θ

Fig. 1

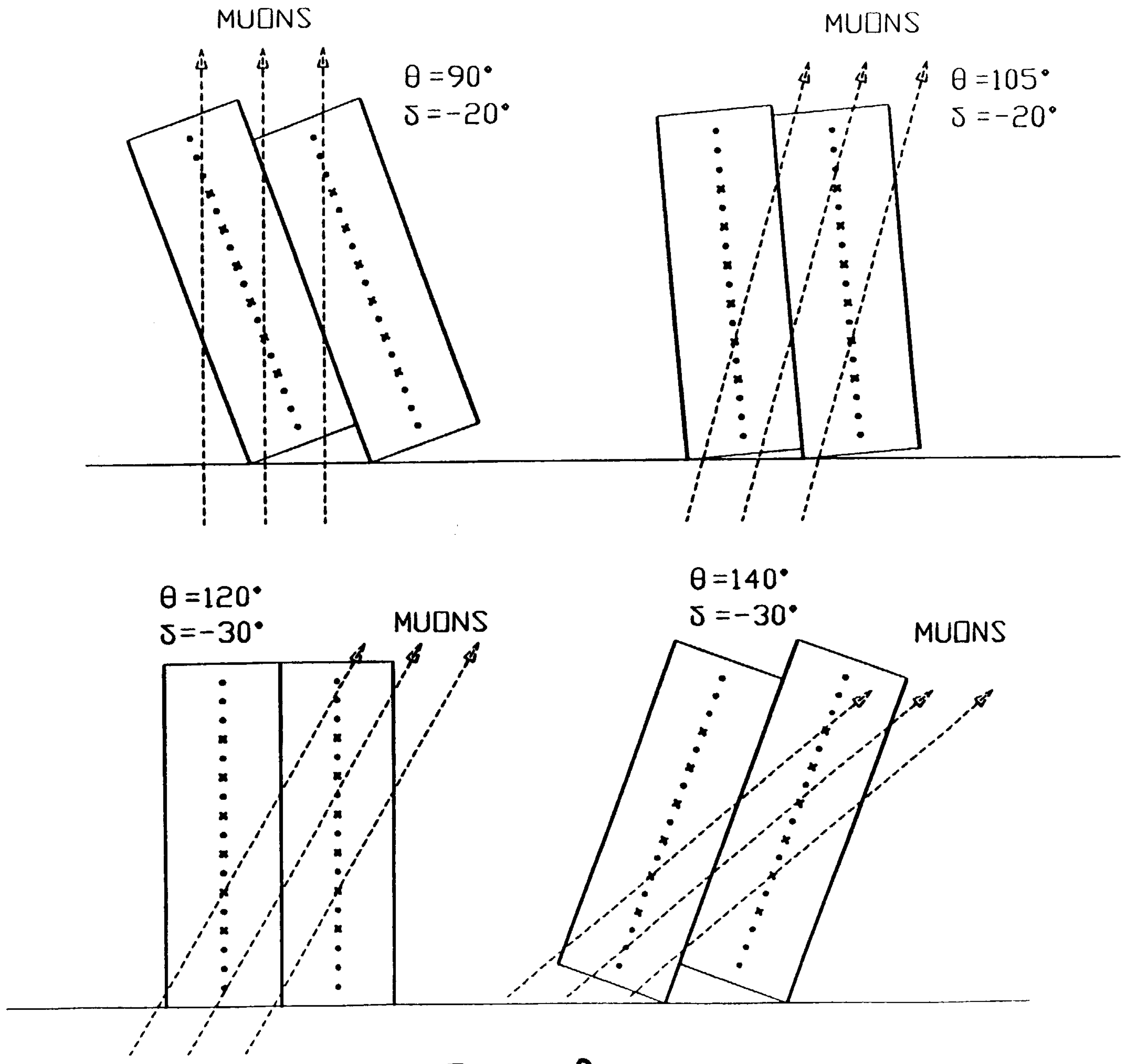


FiG. 2

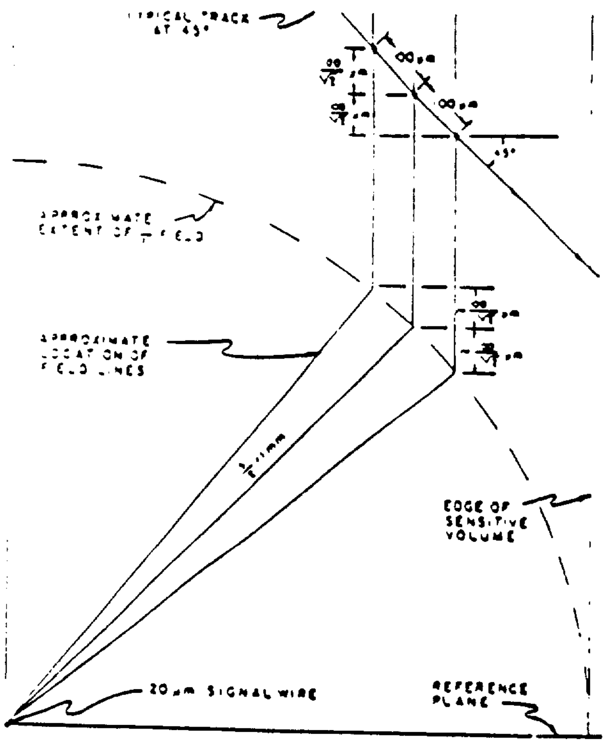


Fig. 3

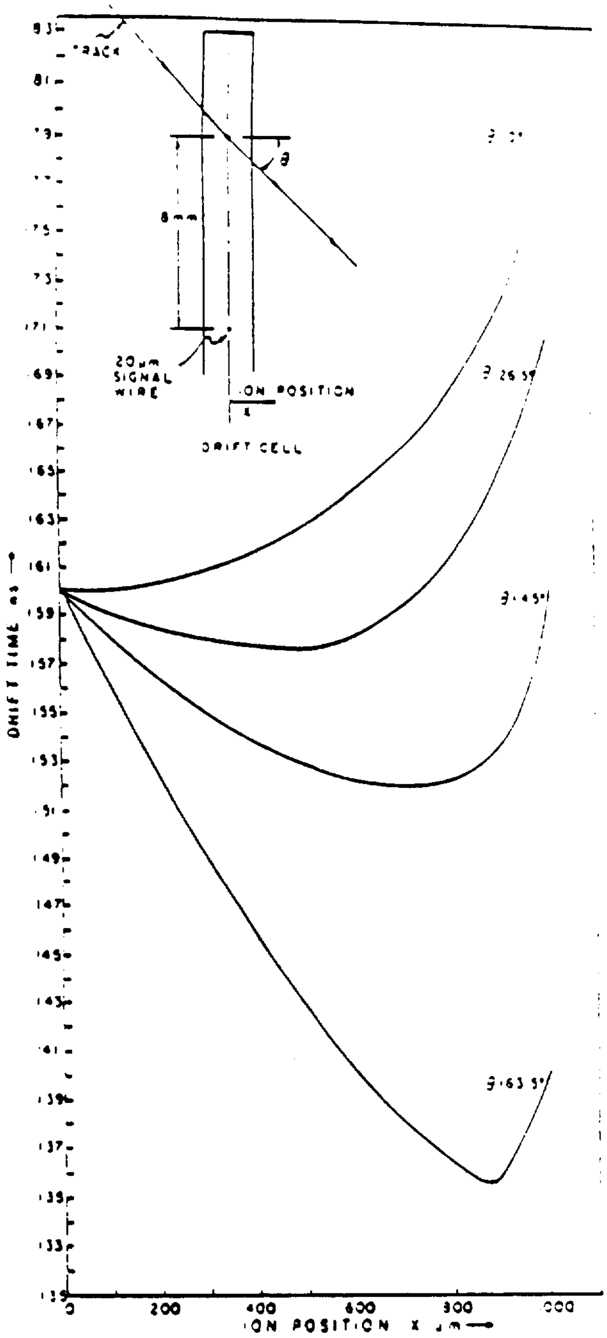


Fig. 4

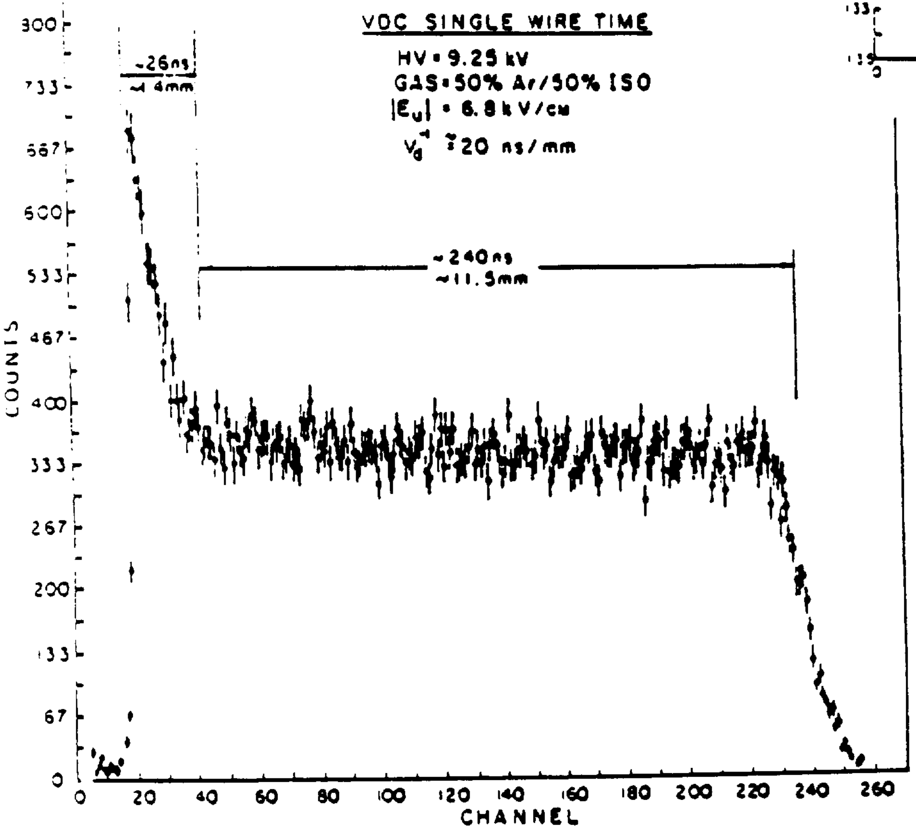


Fig. 5

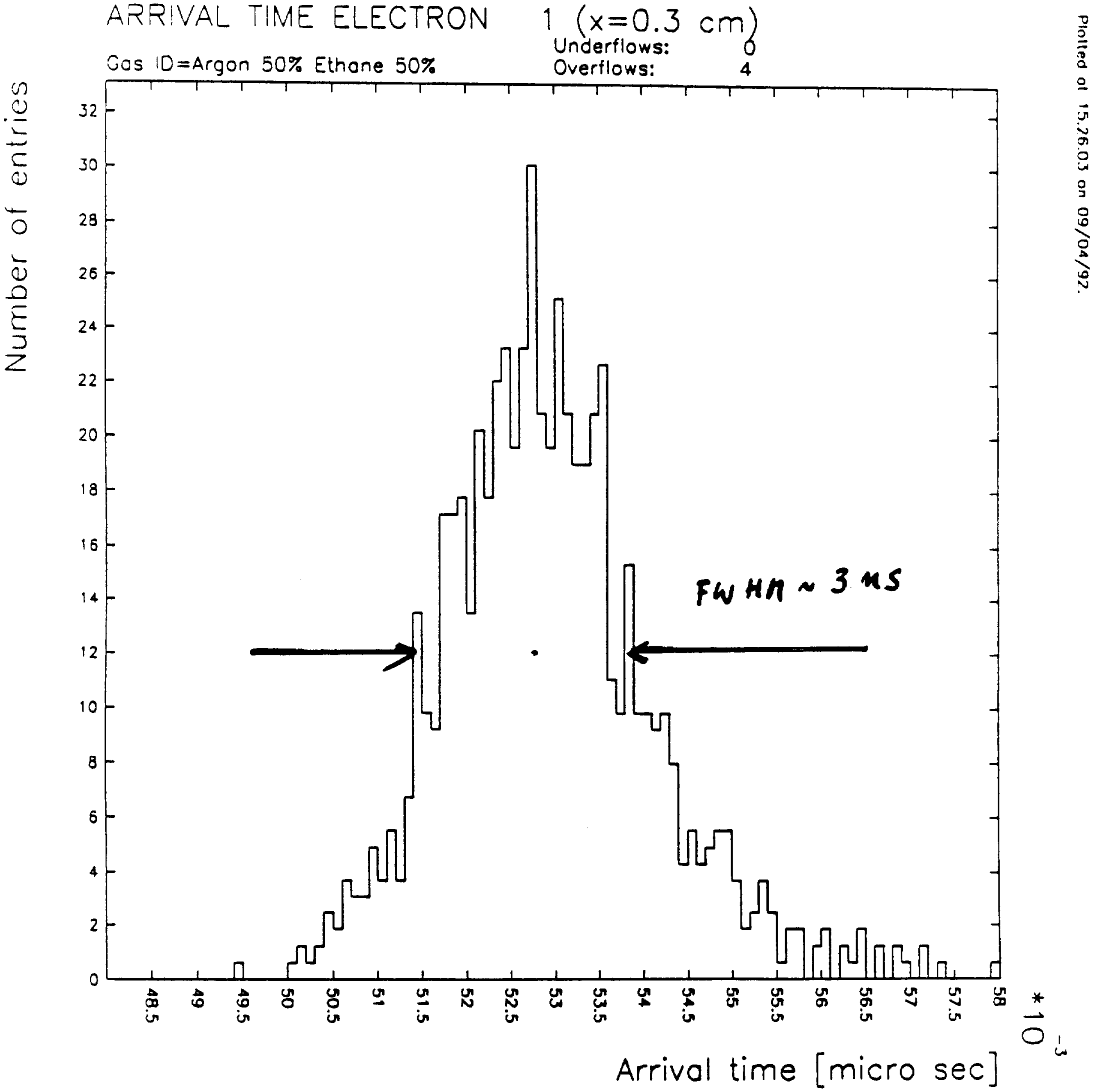
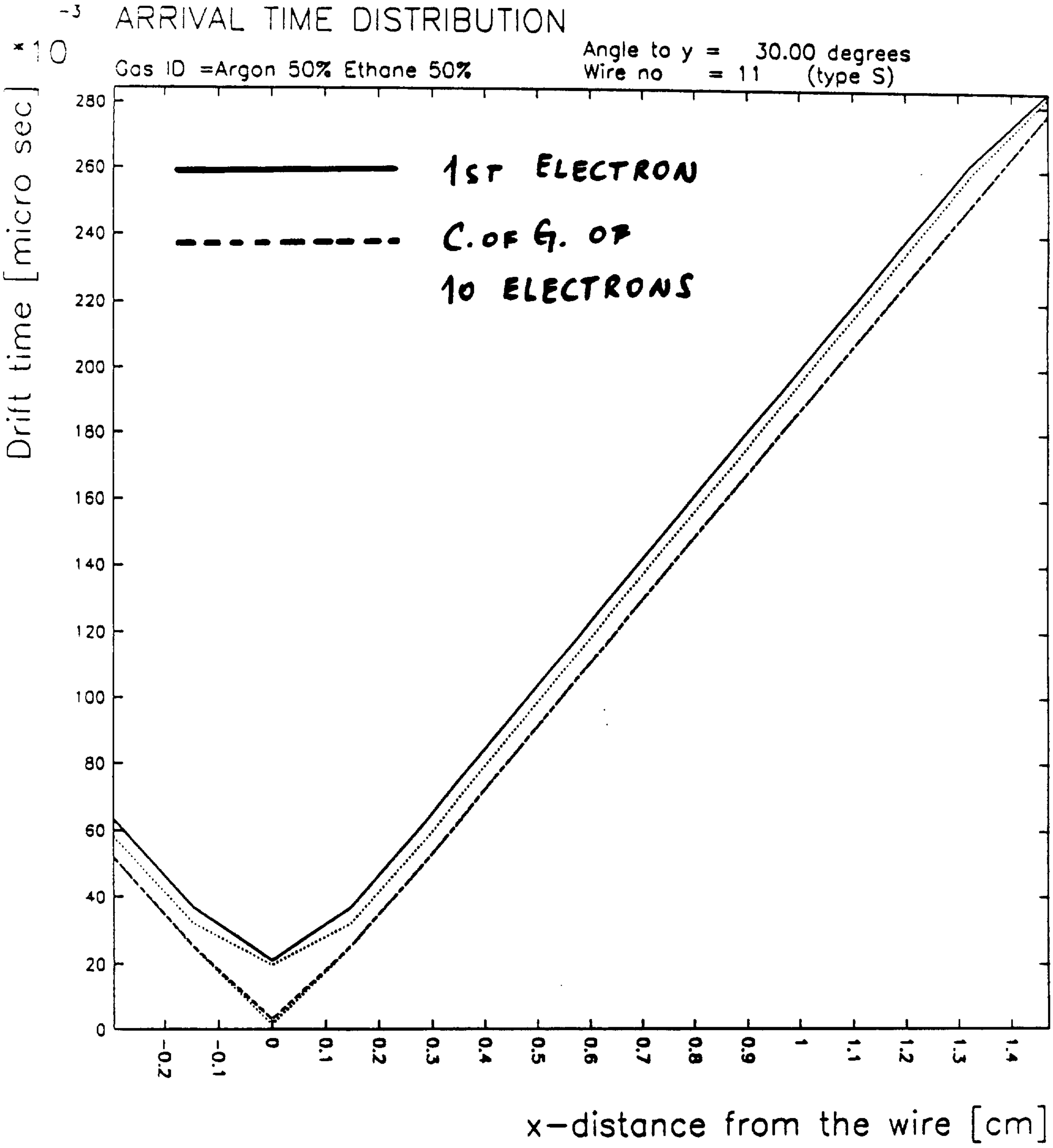

ARRIVAL TIME ELECTRON 1 (x=0.3 cm)
Gas ID=Argon 50% Ethane 50%
Underflows: 0
Overflows: 4
Number of entries
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
48.5
49
49.5
50
50.5
51
51.5
52
52.5
53
53.5
54
54.5
55
55.5
56
56.5
57
57.5
58
*10 -3
Arrival time [micro sec]
FWHM ~ 3 ns
Plotted at 15.26.03 on 09/04/92.

Fig. 6



Plotted at 15.20.47 on 09/04/92.

FIG. 7A

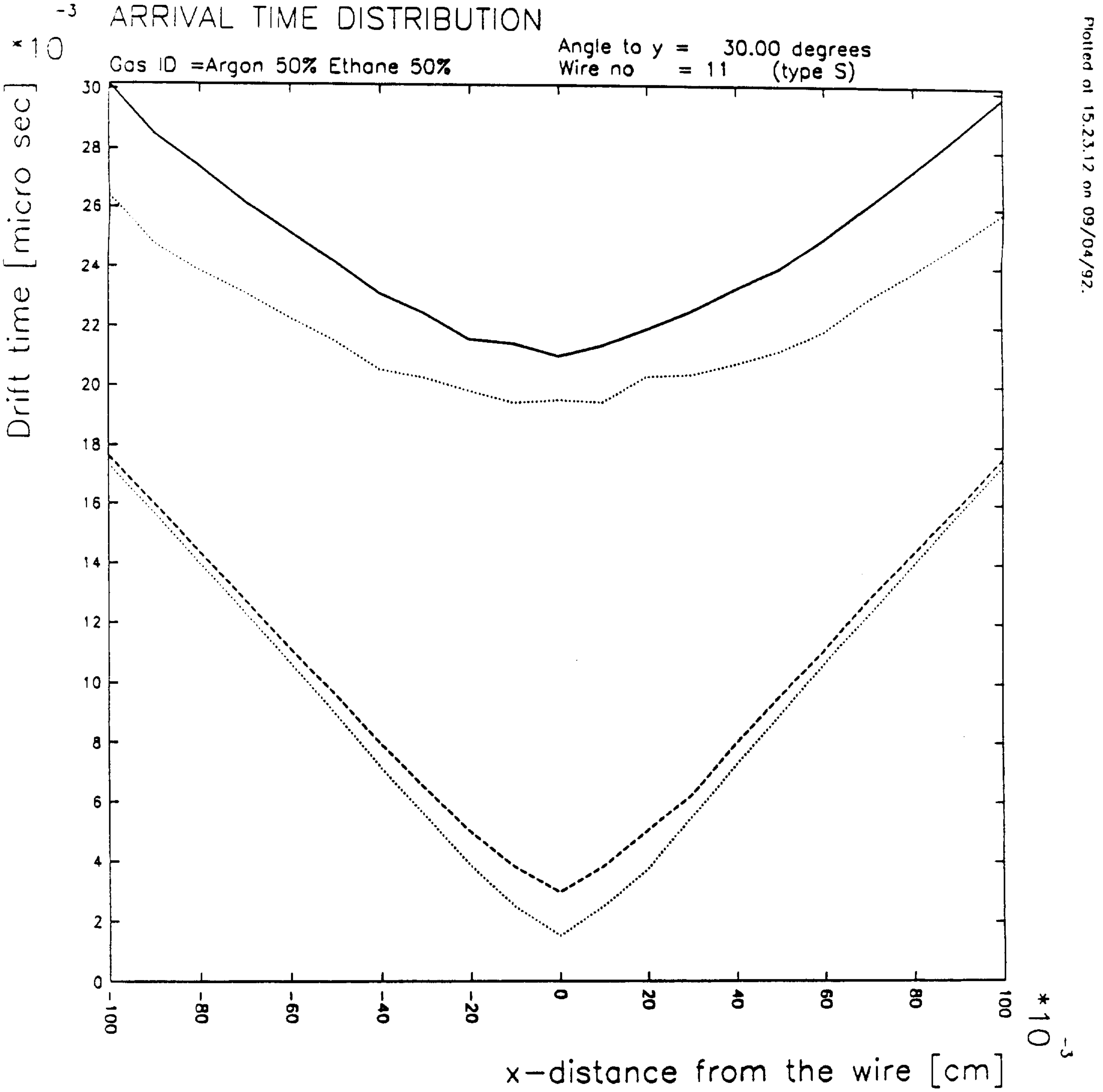
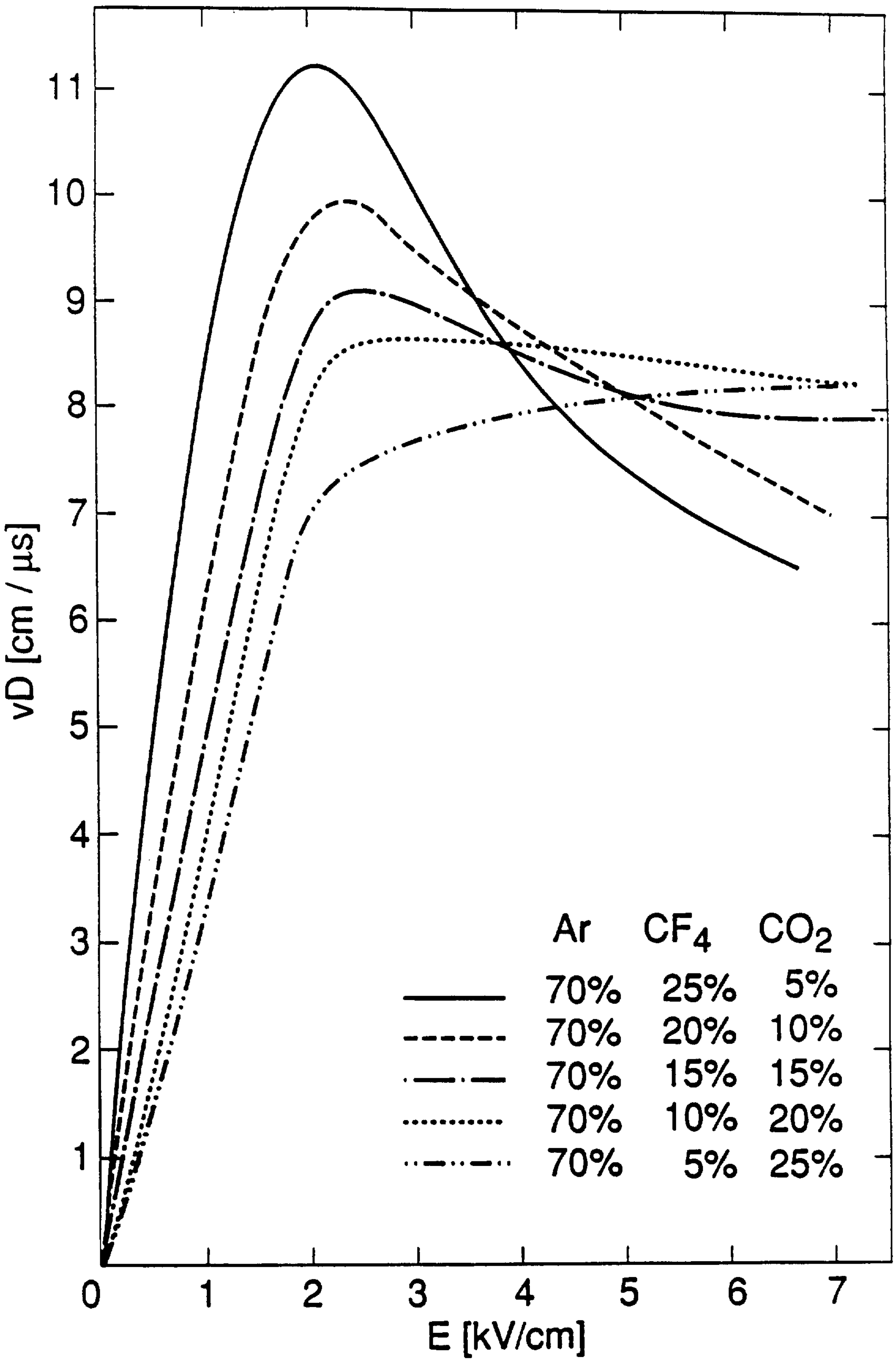

ARRIVAL TIME DISTRIBUTION
Gas ID =Argon 50% Ethane 50%
Angle to y = 30.00 degrees
Wire no = 11 (type S)
Drift time [micro sec]
*10^-3
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
-100
-80
-60
-40
-20
0
20
40
60
80
100
*10^-3
x-distance from the wire [cm]
Plotted at 15.23.12 on 09/04/92.

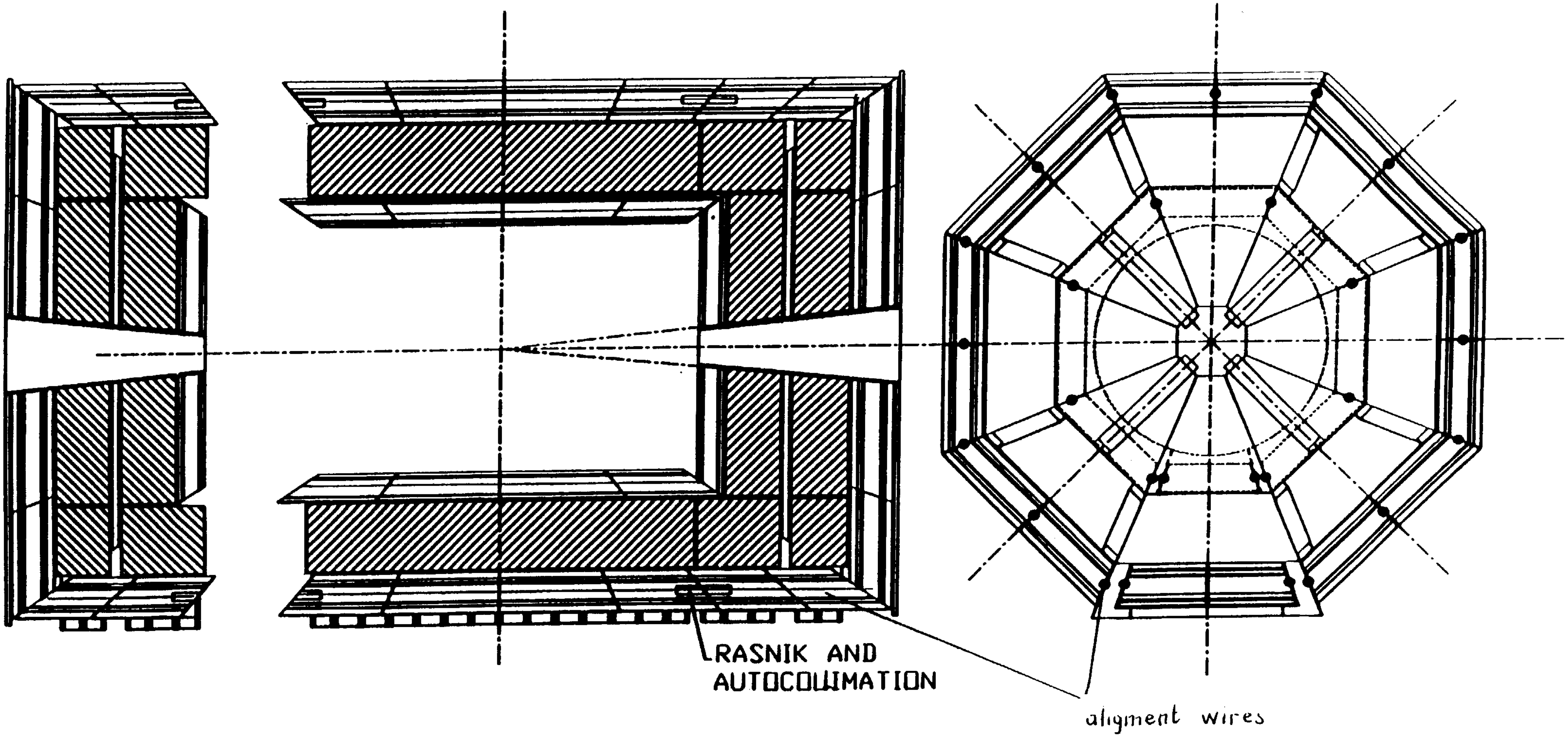
FIG. 7B



vD [cm / µs]
11
10
9
8
7
6
5
4
3
2
1
0
1
2
3
4
5
6
7
E [kV/cm]
Ar CF$_4$ CO$_2$
70% 25% 5%
70% 20% 10%
70% 15% 15%
70% 10% 20%
70% 5% 25%

Fig 8

MUON SYSTEM: OVERVIEW AND ALIGNMENT



EAGLE-MUONS-PPE.TA2
7100008-JR
20.2.92

Fig. 9

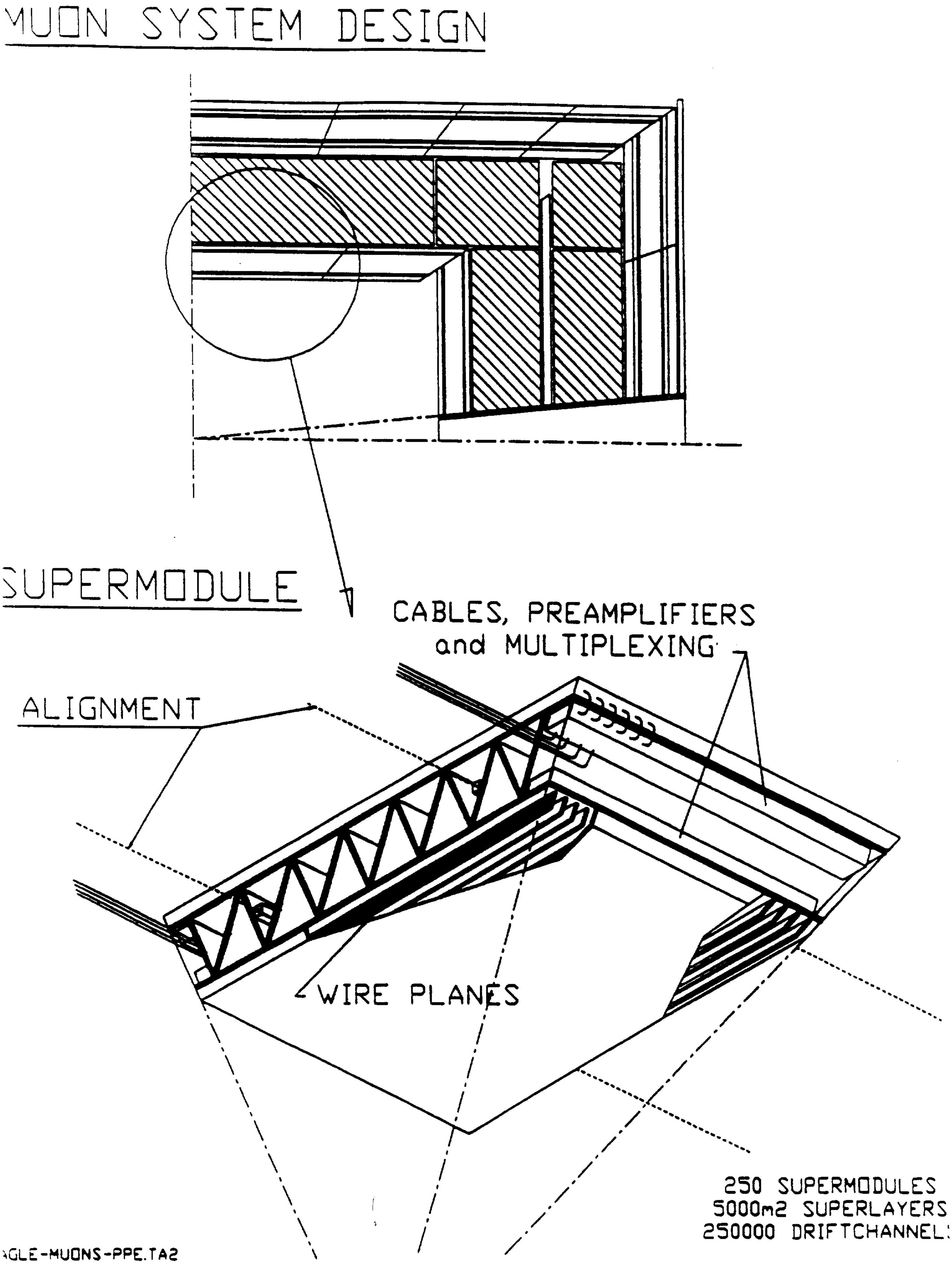
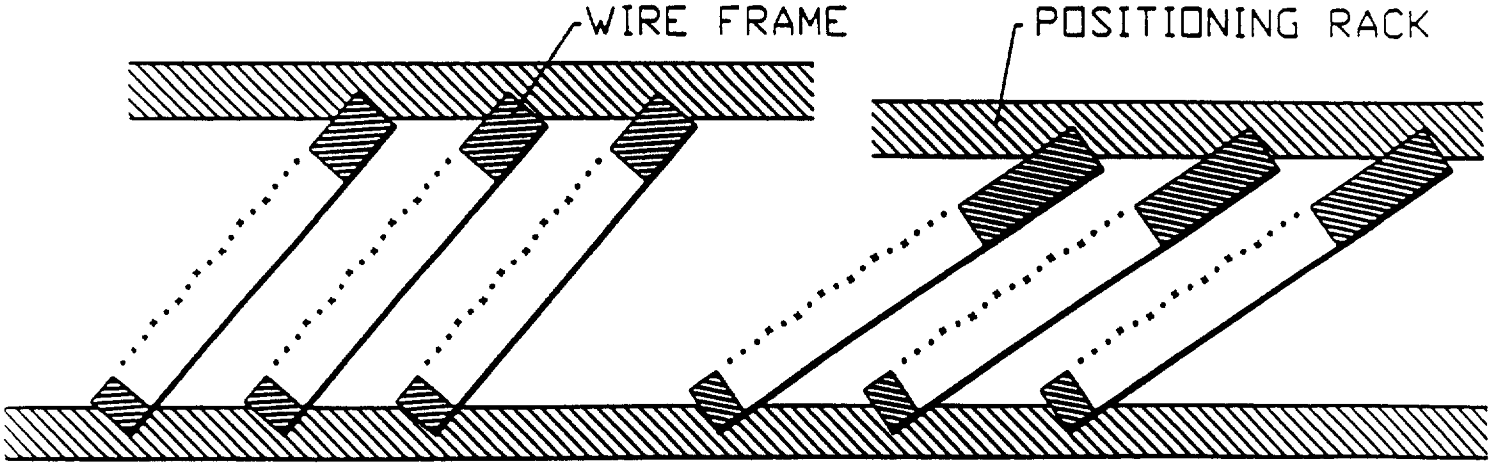

MUON SYSTEM DESIGN
SUPERMODULE
CABLES, PREAMPLIFIERS
and MULTIPLEXING
ALIGNMENT
WIRE PLANES
250 SUPERMODULES
5000m2 SUPERLAYERS
250000 DRIFTCHANNEL
GLE-MUONS-PPE.TA2
7100014-JR
21.2.92

FIG. 10



INCLINATION FOLLOWS ANGLE OF INCIDENCE

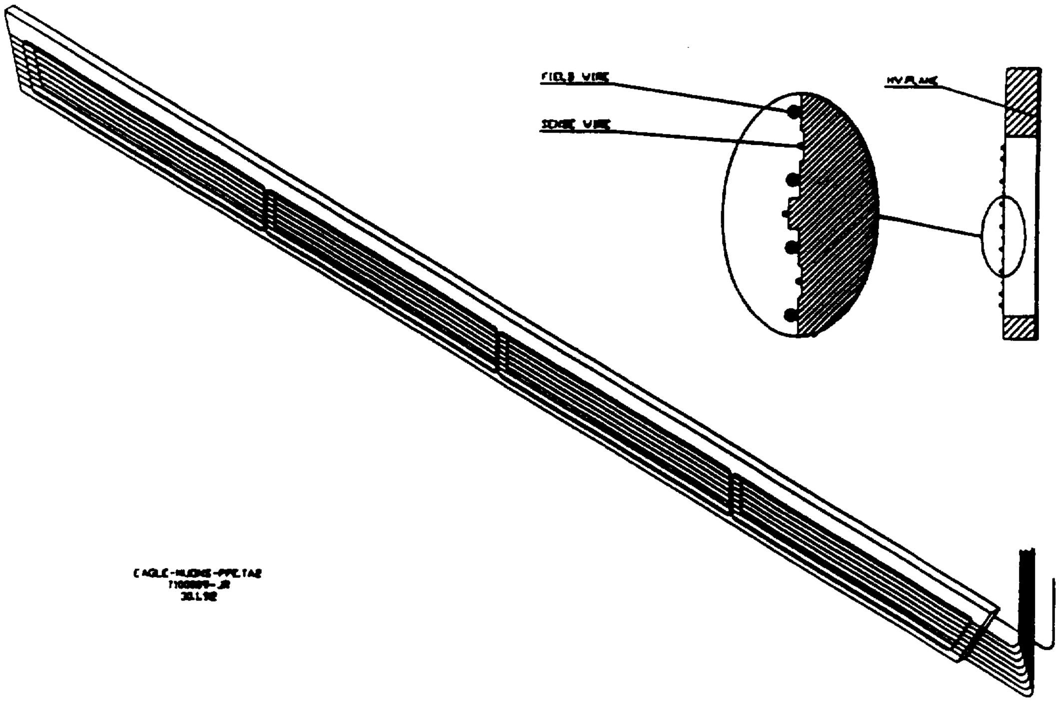


FIG. 11

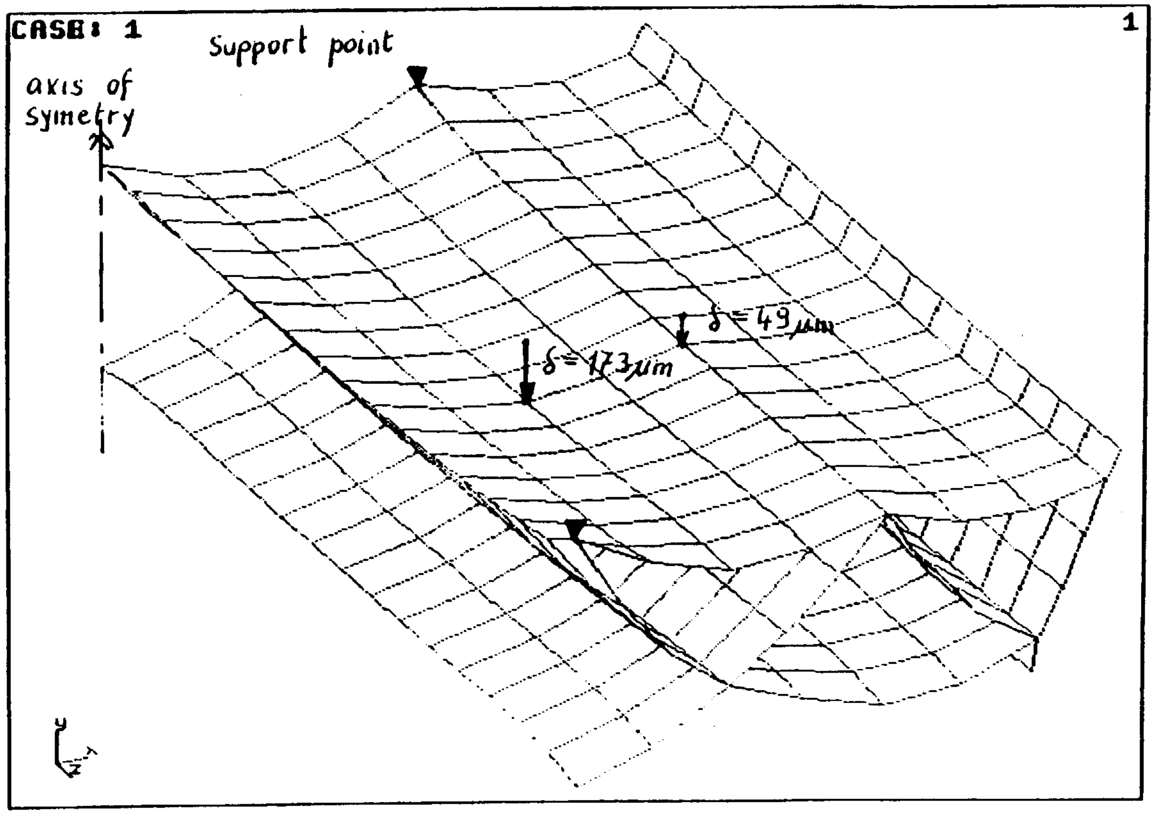

CASE: 1
1
Support point
axis of symetry
$\delta = 49\,\mu m$
$\delta = 173\,\mu m$
y
z
x

FIG. 12

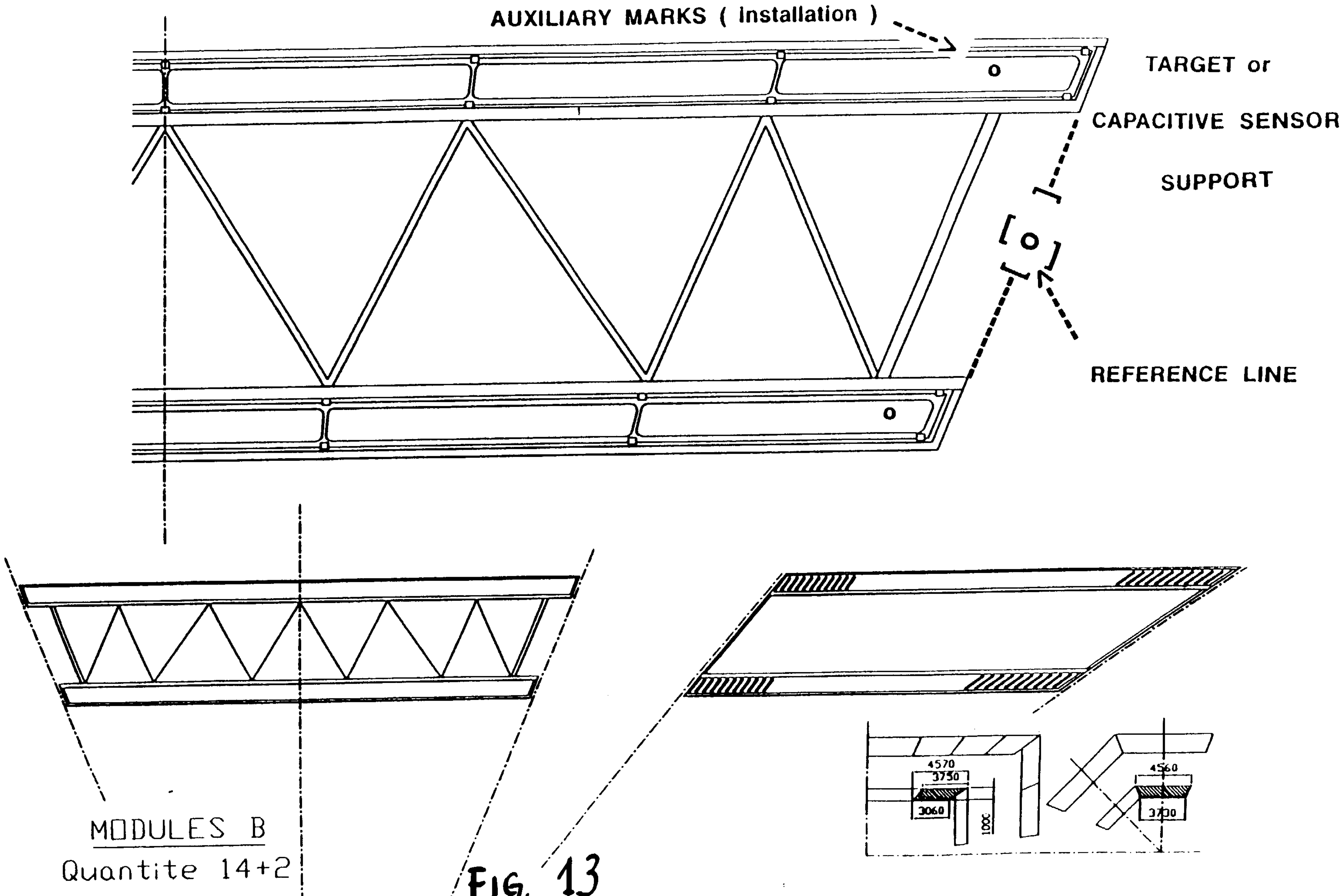

AUXILIARY MARKS (Installation)
TARGET or
CAPACITIVE SENSOR
SUPPORT
REFERENCE LINE
MODULES B
Quantite 14+2
4570
3750
3060
1000
4560
3730

FIG. 13

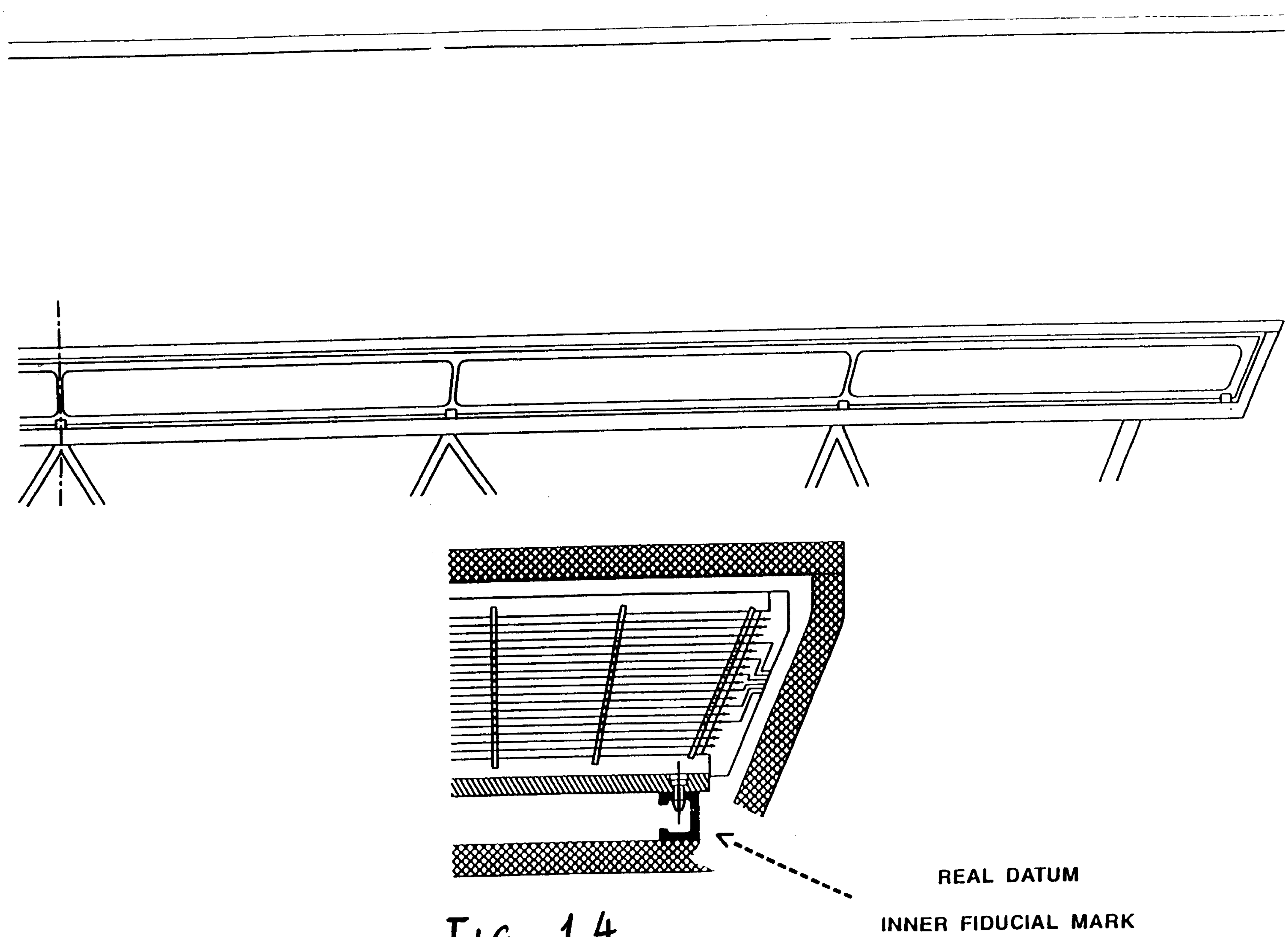


FIG. 14