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Studies of Wire Gain and Track Distortion near the Sector Edges of the ALEPH Time Projection Chamber

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Abstract:

The materials used to hold the wires at the sector edges in a large Time Projection Chamber (TPC) introduce distortions of the electric drift field near those edges. These distortions degrade tracking information and cause sometimes large changes in wire gain near the edge. We have studied these two problems for the ALEPH TPC and have found that both can be greatly reduced by the addition of two field correction strips held at appropriate voltages.

Introduction

The ALEPH TPC, [1] (fig. 1) which will operate at LEP at CERN, will be the largest TPC built to date, having a cylindrical volume 4.4 meters in length (the maximum drift distance being 2.2 meters) and 1.8 meters in radius. Up to 21 coordinate points are measured in r-ϕ by cathode pads and in z by drift time, providing three-dimensional tracking. Also, up to 300 dE/dx samples and z measurements are collected by sense wires.

Mechanical constraints such as wire stability limit the size of the proportional chambers used to detect the ionized electrons at the two ends of the detector. A geometry of 18 sectors per endplate has been chosen by ALEPH, as shown in fig. 2. In this design the unavoidable gaps between sectors are staggered to prevent the complete loss of any track.

A cross section of the wire support structure at the sector edges is shown in fig. 3. The plane of anode wires, alternated with field shaping wires at a pitch of 2 mm, lies 4 mm above the cathode plane. A plane of shielding wires of 1 mm pitch and at ground potential lies 8 mm above the cathode plane, and a plane of gating wires of 2 mm pitch lies 14 mm above the cathode plane. The 1 cm wide space where the wire planes are physically supported is insensitive to charged track information. It has been observed [2], [3] that near the sector edge the gas amplification of the anode wires decreases. This drop is due to distortions of the electric field in that region and can lead to significant losses of information up to 1 cm into the chamber. Electrostatic calculations lead us to believe that a further problem may arise, namely that electrons drifting toward the anode wires in the edge region may not drift exactly parallel to the cylinder axis as intended, but could be displaced by the distorted electric field in that region.

To reduce these problems, the ALEPH TPC will feature two "field correction strips" etched onto the support structure (fig. 3). These 1mm wide conducting strips run the entire length of the edge, the upper strip halfway between the sense and shielding grids, and the lower strip halfway between the sense grid and the pad plane. By applying voltages to these two strips the electric field near the edge can be adjusted to compensate for the above effects. Only the upper strip affects the position along the wire to which the electrons drift, while both strips affect the wire gain.

Apparatus

A small TPC test sector has been built in order to investigate the effects of these strips. This test sector is similar to the final ALEPH TPC design. The anode wires are 20 μm gold plated tungsten, while all other wires are 75 μm gold plated copper-beryllium. The wires are held in place by a bead of Versamid 125 epoxy which was milled flat to accomodate the supports for the next wire plane. The pad plane and wire support structure are made of the epoxy fiberglass material G-10. The pads were photochemically etched on copper plated G-10. A gas mixture of $Ar:CH_4$ (91:9) at 1 atmosphere pressure was used. An electric drift field of 150 V/cm was established in the test chamber by a short field cage. As yet no magnetic field has been applied.

Wire Gain Measurements

The wire gain has been measured near the sector edge using an Iron 55 radioactive source. The source is highly collimated, producing a beam less than 2 mm in diameter in the chamber. The activity of the source is 1.4 GBq. The 5.9 keV peak has a resolution of 16 % FWHM (fig. 4). The source is placed on a movable slide inside the gas volume and emits photons perpendicular to the wire direction 2 mm above the sense wires. The wire gain was scanned as a function of distance from the edge by moving this slide. The voltage on the sense wires was held at 1090±1 V during these measurements.

Fig. 5 shows the wire gain vs. distance from the edge for some selected correction strip voltages. The upper and lower correction voltages are the same for these cases. The wire gain is very sensitive to this voltage near the edge, but a voltage of 158 V yields an excellent wire gain curve, which varies by less than 4% up to 0.5 mm from the edge. Thus it appears likely that useful information can be obtained from most of the edge region. This result is in qualitative agreement with [3]. The quantitative differences can be attributed to the various designs of the wire support structure.

Track Distortion Measurements

To investigate the effect of the strips on measured track position, a MOPA N_2 laser has been used to produce tracks. The laser has a wavelength of 337 nm and is collimated through a pinhole with diameter slightly less than 1 mm. The laser is fired across the chamber 2 cm above the sense wire plane so that electrons drift through the electric field of the edge region. The position on the sense wires to which the electrons drift is calculated from the pad signals as a function of the voltages on the correction strips. The beam is then lowered to just above the sense wire plane so that there is no drift, and the measurements repeated. The distortion is defined as the difference between the measurements with and without the drift.

Distortion measurements have been made at several different horizontal positions. As expected, measurements at constant upper strip voltage but at different lower strip voltages show no observable variation in the measured position. Fig. 6 shows the distortion vs. the distance from the edge for various voltages on the upper correction strip. The distortion becomes very sensitive to this voltage at small distances from the edge. It is not possible with only one such strip to completely correct the distortion at all points, but a voltage of approximately -150 V on the upper strip keeps the distortion below 250 µm to within 2 mm of the edge. Additional measurements are planned in the presence of the eventual ALEPH magnetic field of 1.5 T, which is expected to further reduce these distortions.

Combined measurements

Holding a constant voltage of about -150 V on the upper strip, the wire gain scanning procedure is now being repeated with the Iron 55 source for various lower strip voltages. It is expected that voltages will be found which keep the gain variation below 5% and the distortions below 300 μm up to at least 2 mm from the edge, in the absence of any magnetic field.

Conclusions

By the use of only two field correction strips, held at appropriate voltages, the range of tracking information provided by the ALEPH TPC will be greatly improved. Not only can the wire gain be made uniform up to less than 1 mm from the edge, but the tracking performance of the chamber can also be understood in the edge region and can be made uniform over most of this region.

References

[1] ALEPH Collaboration Technical Report, CERN/LEPC/83-2 (1983);
ALEPH Collaboration Status Report, CERN/LEPC/84-15 (1984).

[2] PEP-4 TPC Collaboration private communication.

[3] C. Brand et al., NIM A237 (1985) 501-4;
Itoh, R., Master's thesis, University of Tokyo.

Figure Captions

1. Schematic of the ALEPH TPC.
2. Division of one ALEPH TPC endplate into 18 sectors.
3. Design of the ALEPH TPC sector edge.
4. Fe 55 pulse height spectrum fit to two gaussians plus background.
5. Wire gain vs. distance from the sector edge for various voltages on the field correction strips.
6. Track distortion vs. distance from the sector edge for various voltages on the upper field correction strip.

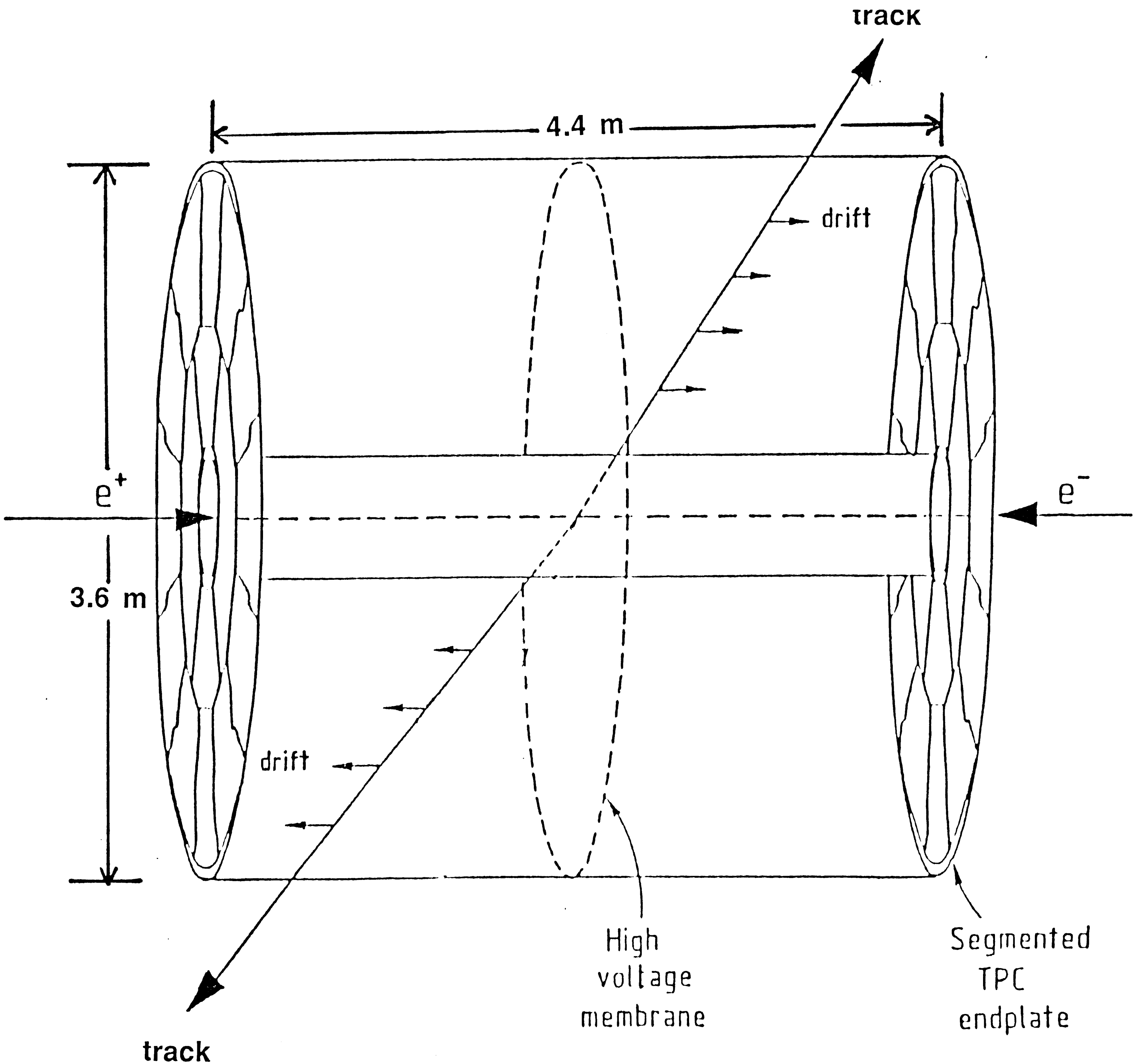
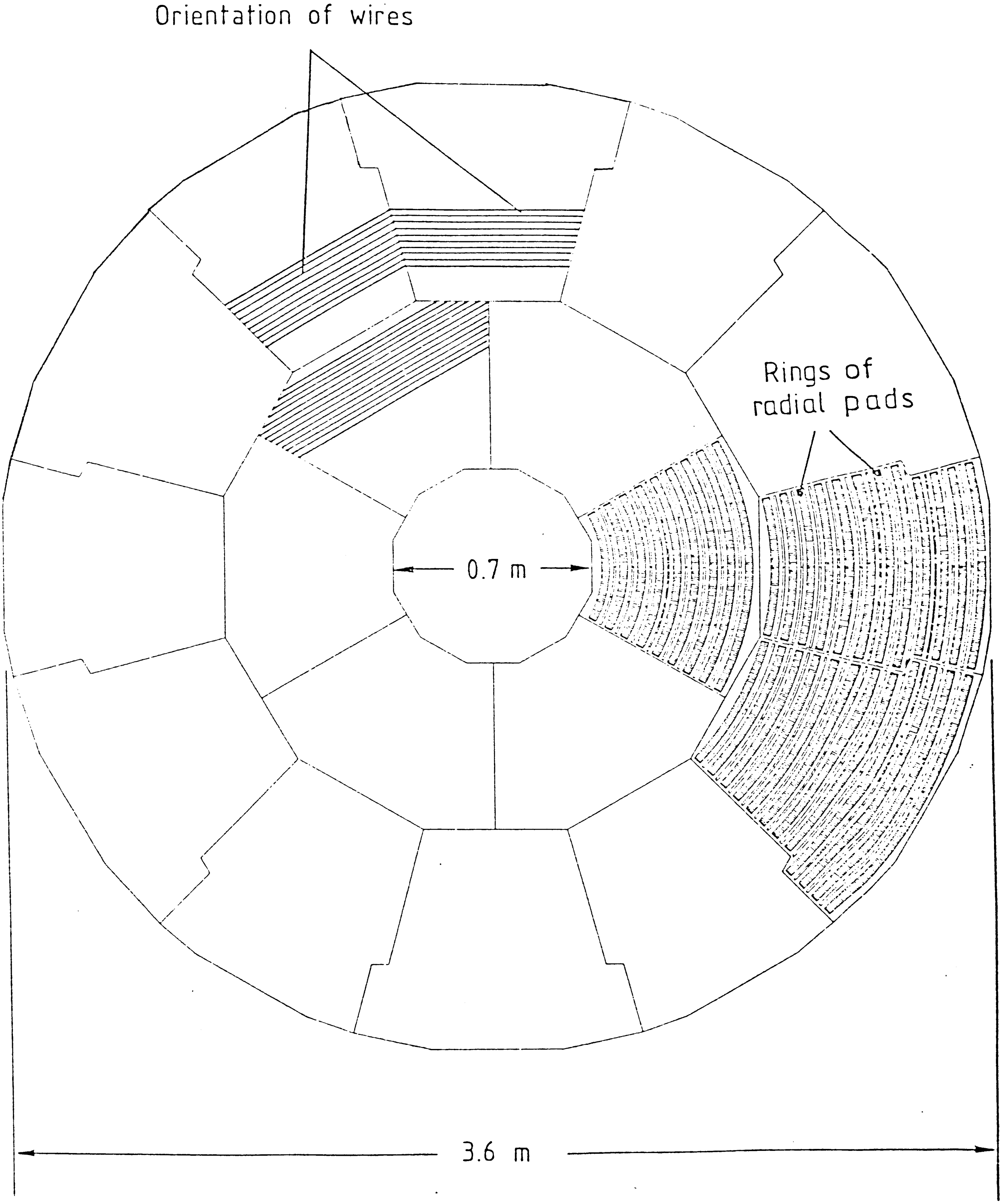

track
4.4 m
drift
e+
e-
3.6 m
drift
track
High voltage membrane
Segmented TPC endplate

Fig. 1

Fig. 2



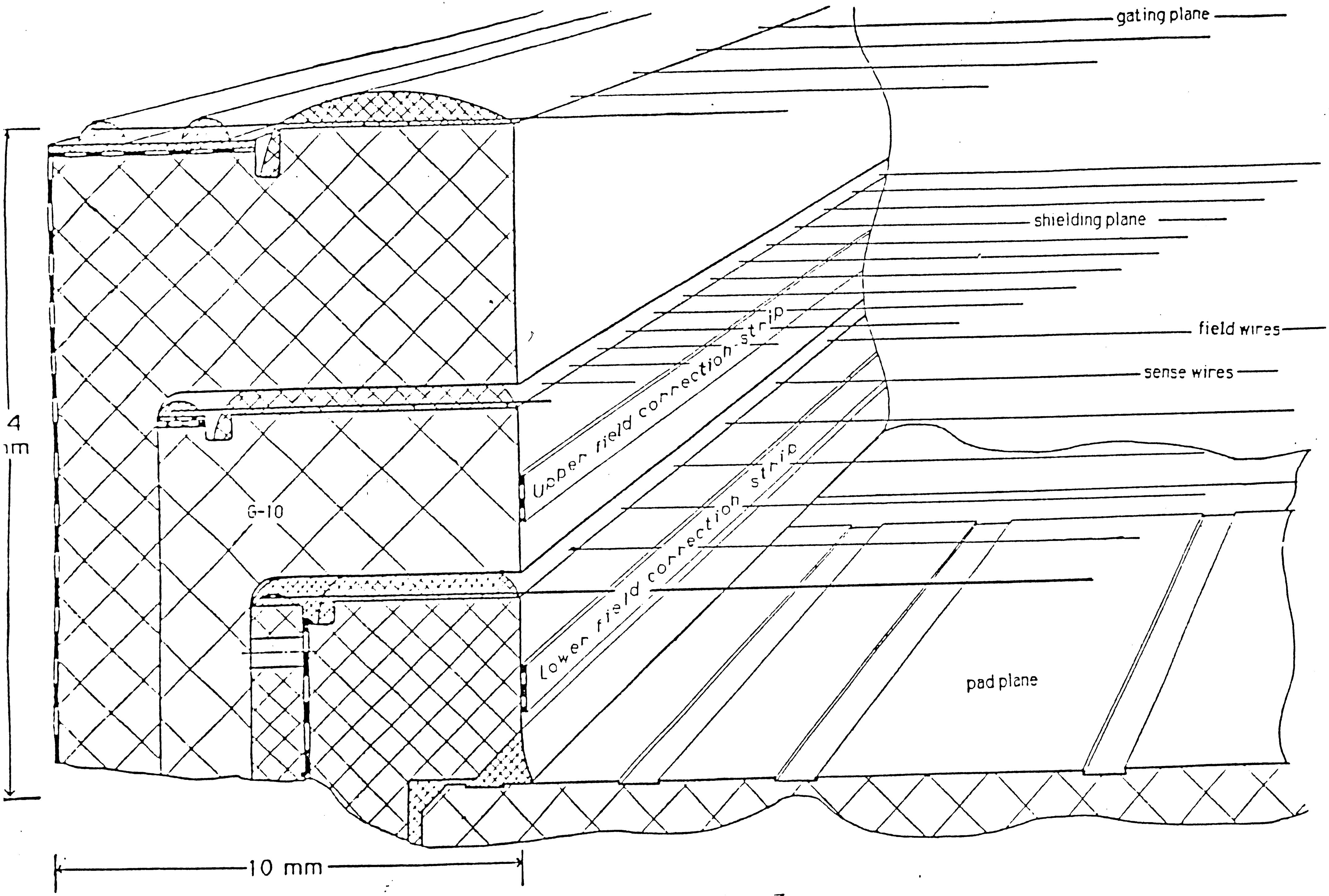

gating plane
shielding plane
field wires
sense wires
upper field connection strip
lower field connection strip
G-10
pad plane
4
mm
10 mm

Fig. 3

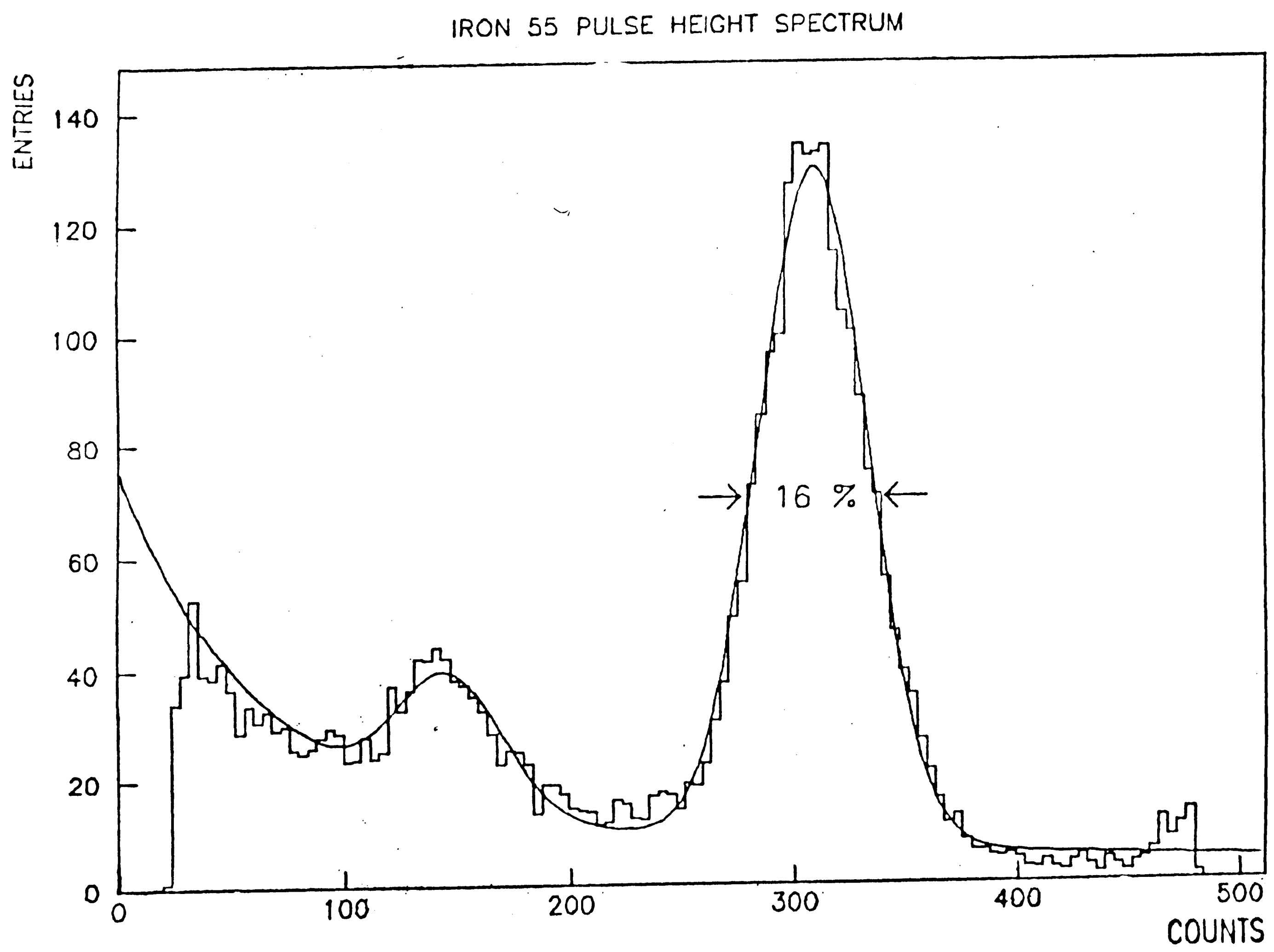

IRON 55 PULSE HEIGHT SPECTRUM
ENTRIES
140
120
100
80
60
40
20
0
0
100
200
300
400
500
COUNTS
16 %

FIG. 4

TRACK DISTORTION VS. DISTANCE FROM THE SECTOR EDGE

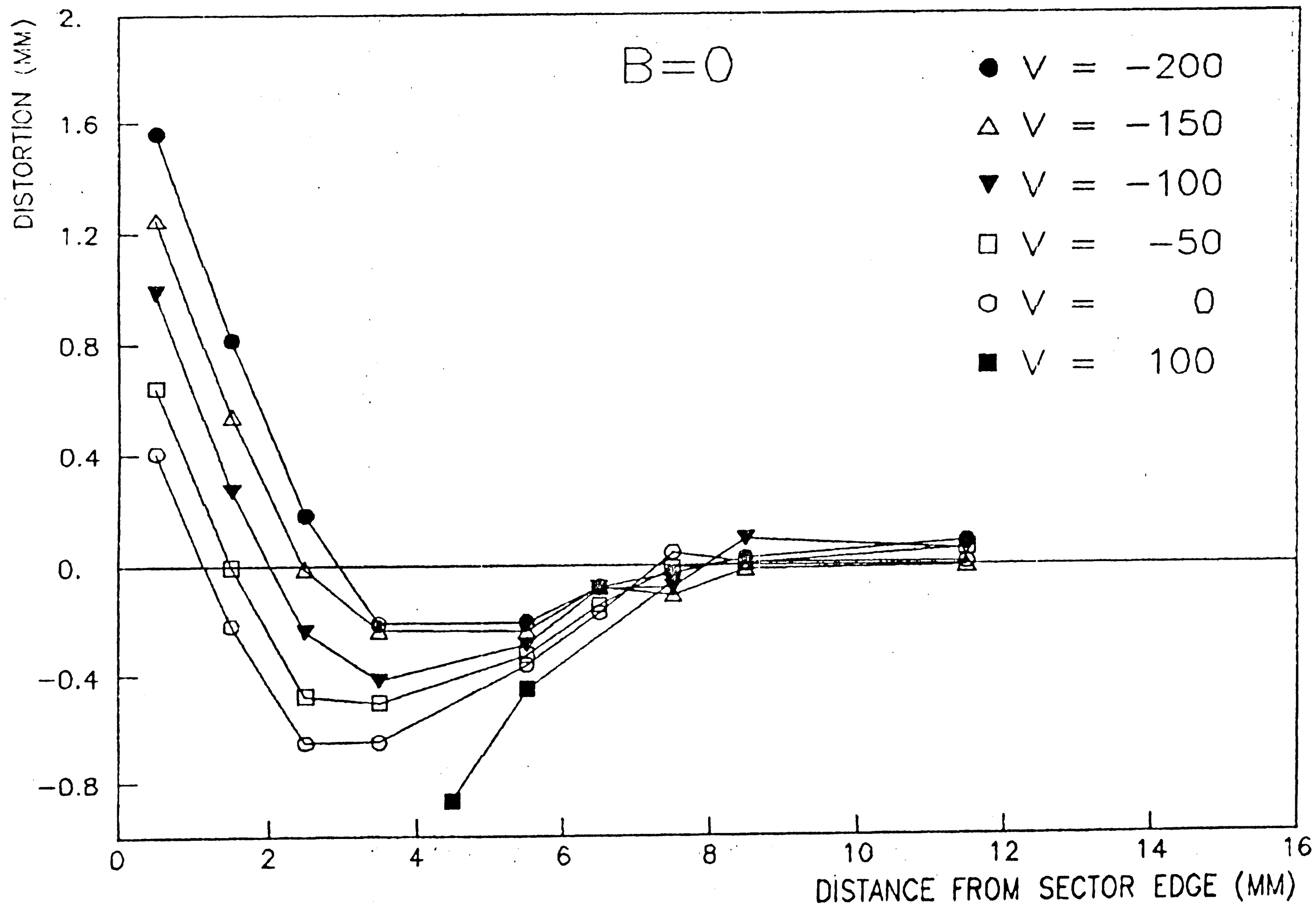
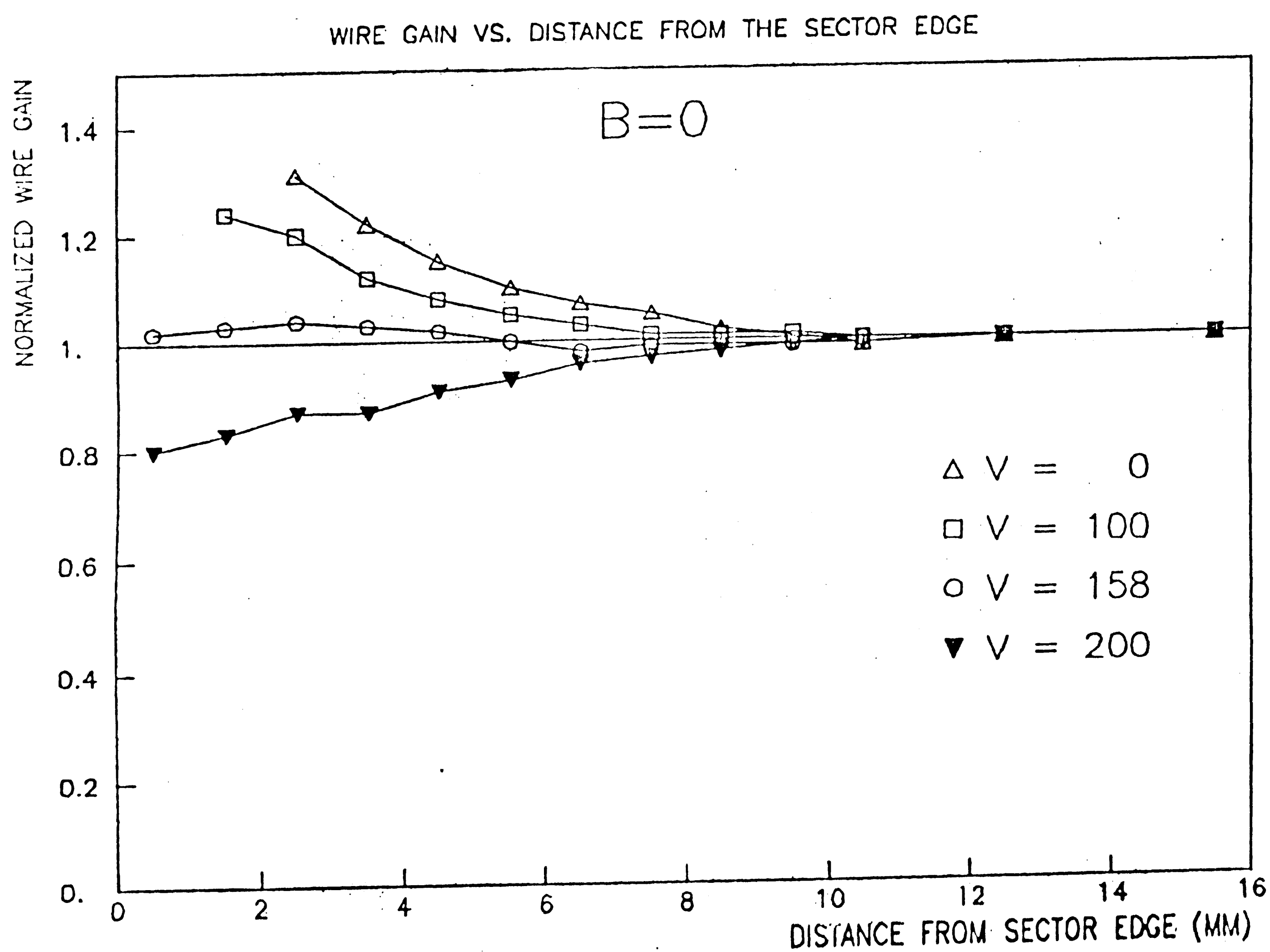


FIG. 6



WIRE GAIN VS. DISTANCE FROM THE SECTOR EDGE
B=0
NORMALIZED WIRE GAIN
1.4
1.2
1.
0.8
0.6
0.4
0.2
0.
0
2
4
6
8
10
12
14
16
DISTANCE FROM SECTOR EDGE (MM)
△ V = 0
□ V = 100
○ V = 158
▼ V = 200

FIG. 5