ELECTRIC FIELD CALCULATIONS FOR DRIFT CHAMBERS

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INTRODUCTION

Spatial accuracies better than $\sigma = 100\ \mu m$ have been obtained from drift chambers at CERN[1] and FERMILAB[2]. With these chambers the voltage applied to the field shaping wires, drift wires or drift foils is varied in a systematic way to obtain good efficiencies and optimum electric fields across the drift space. Optimizing electric fields includes maximum uniformity in the drift region, elimination of low field regions in the drift area, and producing concentric equipotentials surrounding the signal wire to minimize ambiguities which may be caused by particle trajectories with large angles. Drift chambers with constant potential applied to the cathode planes require excessive potentials between the drift wires (wires between signal wires at the mid-plane) and the signal wires in order to approach saturated electron drift velocities[3]. Saturated velocities become difficult to obtain especially with large drift spaces.

In the following we will briefly describe a method for computing voltages to be applied to the field shaping network around a drift cell, mapping equipotentials across the entire cell and computing field at the midplane. The calculations were made uniquely without the use of the Laplace equations and thus represent an approximation which has born a fair comparison to the results obtained with the standard teledeltos technique for field configurations.

Electric Field Calculations for a Drift Chamber

Electric potentials in the active area of the drift chambers studied were calculated from the known voltages V_i applied to the field-shaping elements of the chamber, i.e., wires and foils. A foil was approximated by a series of wire elements. No boundary condition was assumed with this approximate calculation.

The technique was to solve the set of simultaneous linear equations

$$\left(\ln \quad (d_j/x_{ij})\right)\left(\lambda_j\right) = \left(V_i\right)$$

for the linear charge densities λ_j (arbitrary units). Here the signal wire is assumed to be at ground potential and at a distance d_j from the j^{th} field shaping element in the chamber. x_{ij} is the distance between the i^{th} and j^{th} element under consideration. When $i = j$ then x_{ij} would just be the radius of the element. In addition, by charge conservation, the sum of the charge densities on the field shaping elements equals the charge density on the signal wire. This law is used to check overall calculations. The number of variables λ_j is greatly reduced by symmetry in many cases.

Once the λ_j are determined, the above equation may again be used to compute the electric potential a distance d_j from the signal wire. In that case x_{ij} would be the distance from the point where the potential is calculated to the i^{th} field shaping element which is at potential V_i.

The electric field intensities for the various drift chamber designs were all calculated along the center plane of the chambers where, by symmetry, the resultant of the electric field intensity will be parallel to the plane. Hence, only the x-component need be resolved in order to determine the magnitude.

The expression

$$\vec{E}_i = \sum_j \lambda_j / \; r_{ij} \; \vec{e}_r$$

is the vector equation for the electric field intensity E_i summed over all the contributing elements of the drift chamber whose charge densities are λ_j (including the signal wire). r_{ij} is the distance from the point where E_i is determined to the j^{th} field shaping element.

In actual calculations it is important to tabulate two-dimensional matrix elements which are contributions from the field-shaping wires or foil located on the rectangle, not cylindrically symmetric. Thus it is sometimes necessary to calculate the fields separately for some different configurations.

A collection of program summaries of field calculations for different geometries is given in Appendix I. One of these programs offers CALCOMP plotting option for the equipotentials. Two examples of CALCOMP plots are given in Figures 1 and 2. The tangential electric field lines to the equipotentials are then drawn on the CALCOMP plotted figures. We see from the figures that there are apparent increases in the lengths of the paths through which drifted electrons may follow in the case of Figure 2.

The program PLFL4 calculates electric field intensities in the midplane and potential for the geometry similar to that of FERMILAB parallel foil drift chamber. Figures 3a and 3b show the intensity plots for the configurations shown in the Figures 1 and 2, respectively. The variations in the electric field intensities are even larger away from the midplane for the case of Figure 2.

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1. A. Breskin, G. Charpak, B. Gabiod, F. Sauli, N. Trautner, W. Duinker and G. Schultz, Nucl. Instr. and Meth. 119 (1974) 9-28.

2. M. Atac and W. E. Taylor, Nucl. Instr. and Meth. 120 (1974) 147-151.
   M. Atac and C. Ankenbrandt, Fermilab - Conf-74-108-Exp, (Submitted to the XIV Scintillation and Semiconductor Counter Symposium, Washington, D.C., December 11, 1974).

3. D. C. Cheng, W. A. Kozanecki, R. L. Piccioni, C. Rubbia, L. R. Sulak, H. J. Weedon and J. Whittaker, Nucl. Instr. and Meth., 117 (1974) 157-169.

Figure Captions

Fig. 1 Equipotential and electric field line plots for the parallel foil drift chamber (PFDC) one fourth of the cell is shown. The full scale length is 3mm on X-axis and 10mm on Y-axis. The voltage at foil is 10 unit potential and curves start at a unit of 5.5 with step of 0.15 unit. See Appendix I, PLFL4 for the configuration.

Fig. 2 Equipotential and electric field line plots for the case where the parallel foil is replaced by one wire one fourth of the cell is shown. The full scale length is 3mm on X-axis and 10mm on Y-axis. The voltage at wires which were replaced by foil is 10 unit potential and curves start at 5.5 units with a step of 0.15 unit. See Appendix I, PLFL4 for the configuration.

Figs. 3a&3b Electric field intensity plots for the configurations shown in Figures 1 and 2.

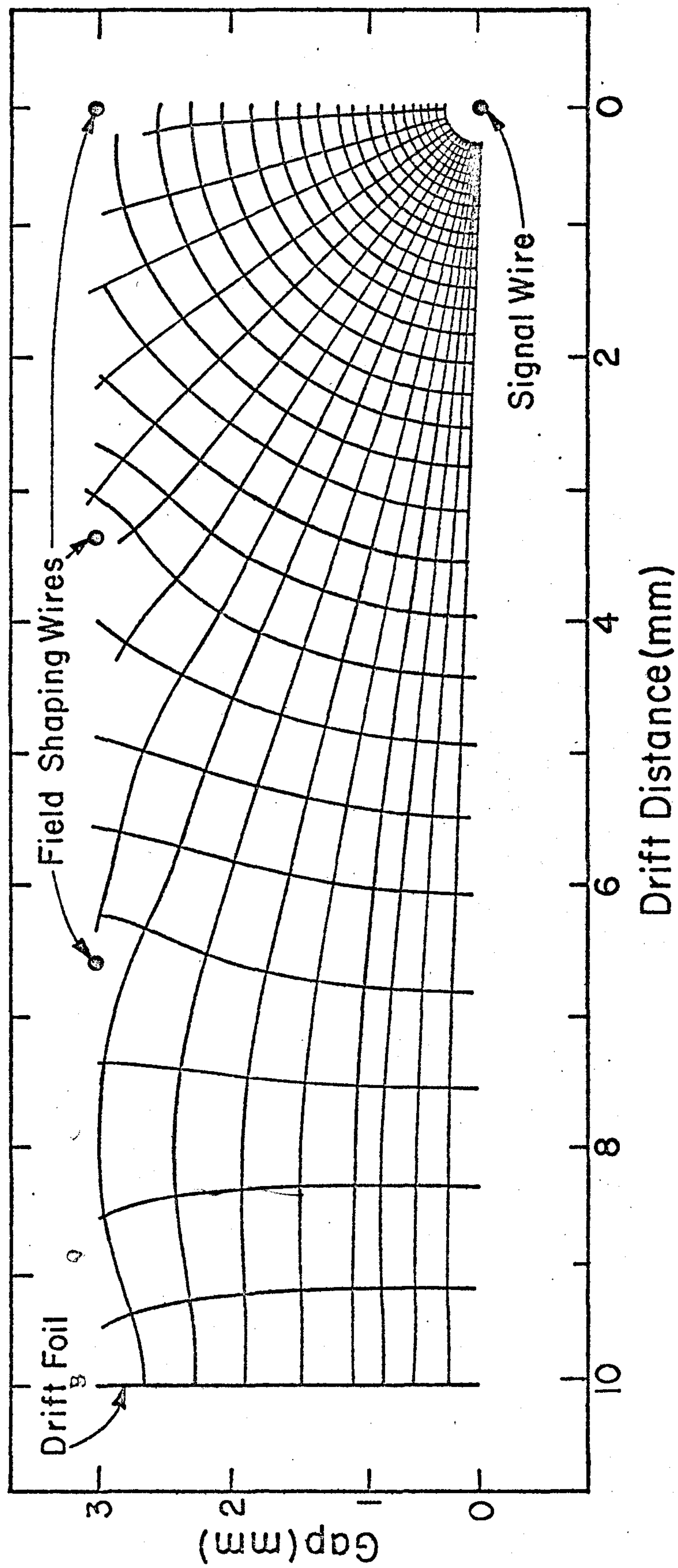

Signal Wire
Field Shaping Wires
Drift Foil
Drift Distance(mm)
Gap(mm)
0
2
4
6
8
10
0
1
2
3

Figure 1

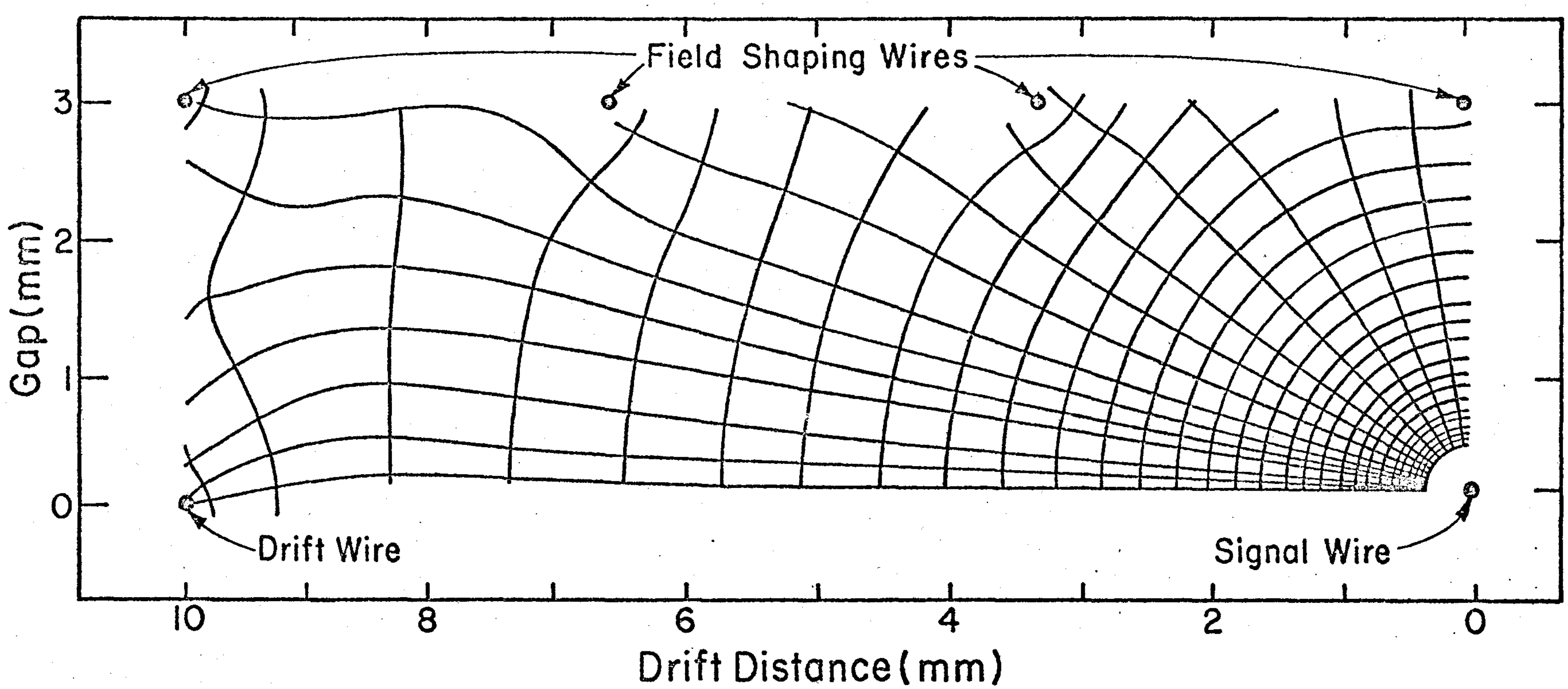
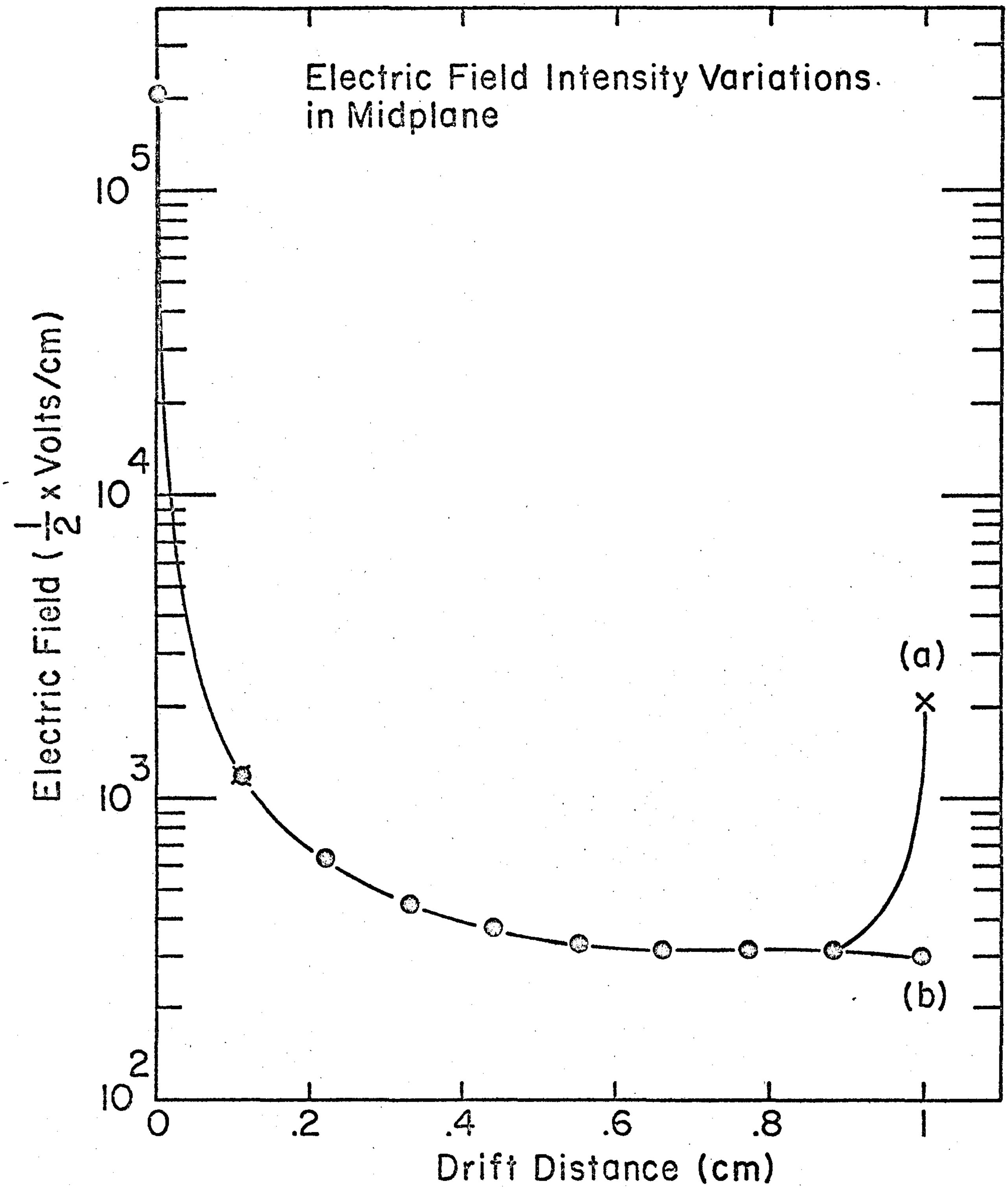

Field Shaping Wires
Drift Wire
Signal Wire
Gap (mm)
3
2
1
0
10
8
6
4
2
0
Drift Distance (mm)

Figure 2

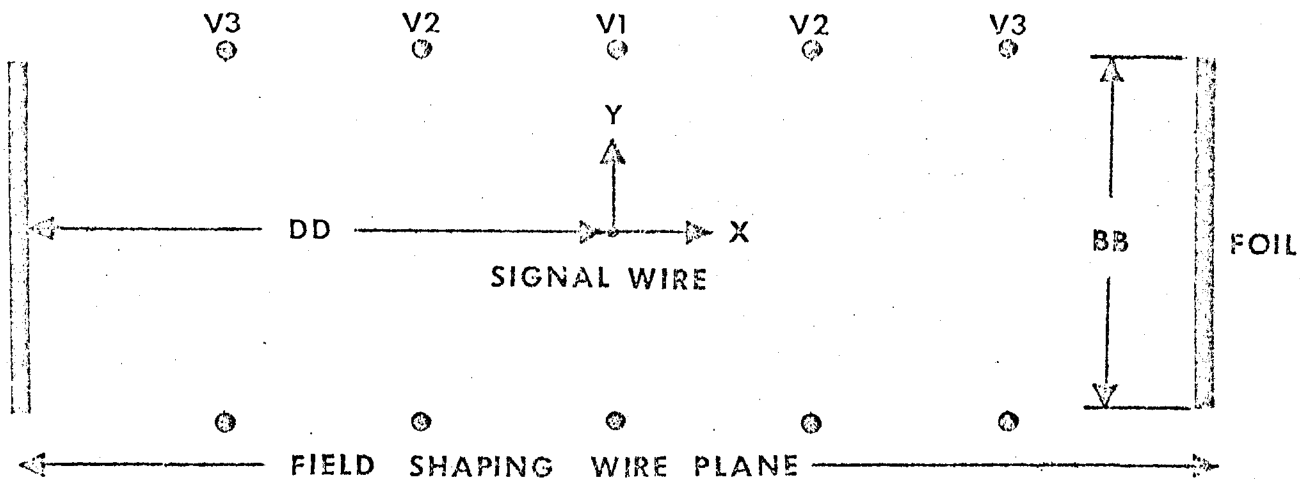


Figures 3a & 3b

Appendix I

PLFL4 Calculation of the electric field intensity and potential in a parallel foil drift chamber with field shaping wires.

GEOMETRY:



VARIABLES:

ROP	Radius of the signal wire.
RG	Radius of the field shaping wires (cm).
BB	Total width of the foils.
DD	Drift distance between foil and signal wire.
VF	Voltage on the foils.
U1(I)	Charge densities of the foil elements.
UA, UB, UC	Charge densities on the field shaping wires.
UP	Charge density on the signal wire.
XP	Distance from signal wire to point where electric field intensity is calculated.
XR	Fractional distance of XP to DD.
EX	x-component of the electric field intensity along the center plane of the drift region.
KFILE	CALCOMP option flag.

INPUT:

ROP, RG, BB, DD, VF

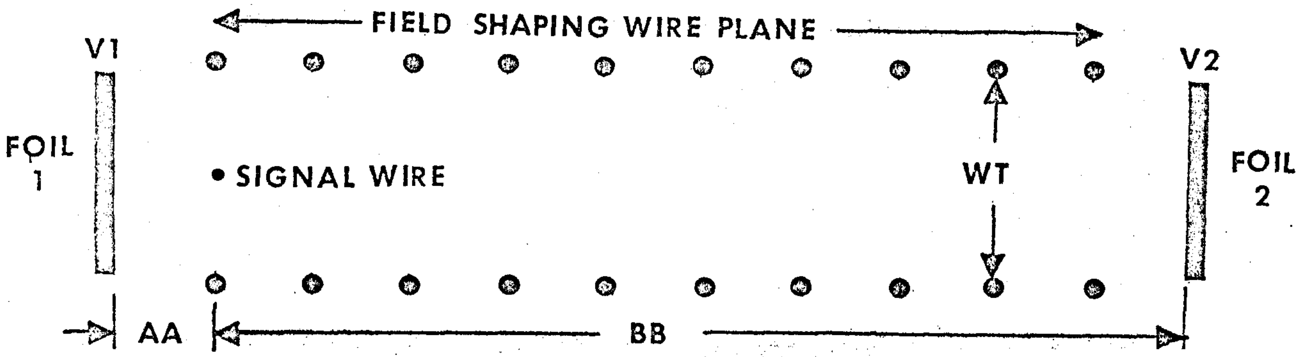
KFILE

OUTPUT:

1. VF Voltage on the foils.
2. U1(1-50) (5/line) Charge densities on the elements of a half foil.
3. UA, UB, UC, UP Charge densities of the field shaping wires and the signal wire.
4. V1, V2, V3 Voltages on the field shaping wires.
5. C1, C2, C3 Distances from the field shaping wires to the signal wire.
6. DELX, DD Increment in the x coordinates of the calculated potentials with the maximum coordinate DD.
7. P, Q, R, S, T x-coordinates of the potential points.
8. T Maximum x-coordinate.
9. DELY, BB Increment in the y coordinates of the calculated potentials with the maximum coordinate BB.
10. P, Q, R, S, T y-coordinates of the potential points.
11. T Maximum y-coordinate.
12. XP, XR, EX Coordinates and electric field intensity along the center plane of the drift region.
13. VR(1-16) Calculated potentials in the drift area.
14. A feature of CALCOMP plotting routines can be added by option. The program creates a DSK file by option besides the standard outputs. Then the CALCOMP program will plot equipotential lines from the above DSK file.

DCFSW   Calculation of the electric field intensity and potential in a parallel foil drift chamber with field shaping wires. (signal wire displaced from the center)

GEOMETRY:



5 mm wire spacing

VARIABLES:

ROP	Radius of the signal wire
RW	Radius of the field shaping wires.
AA	Distance from foil 1 to the signal wire.
V1	Voltage applied to foil 1.
BB	Distance from signal wire to foil 2.
V2	Voltage applied to foil 2.
C1	Distance from the signal wire to the field shaping wire planes.
WT	Total width of the foils.
EX	x-component of the electric field intensity calculated between the signal wire and foil 2.
XP	Distance between the signal wire and the point where EX is determined.
XR	Fractional distance XP/BB
EXQ	x-component of the electric field intensity calculated between foil 1 and the signal wire.
XPP	Distance between foil 1 and calculated EXQ.
XRP	Fractional distance XPP/AA

INPUT: None.

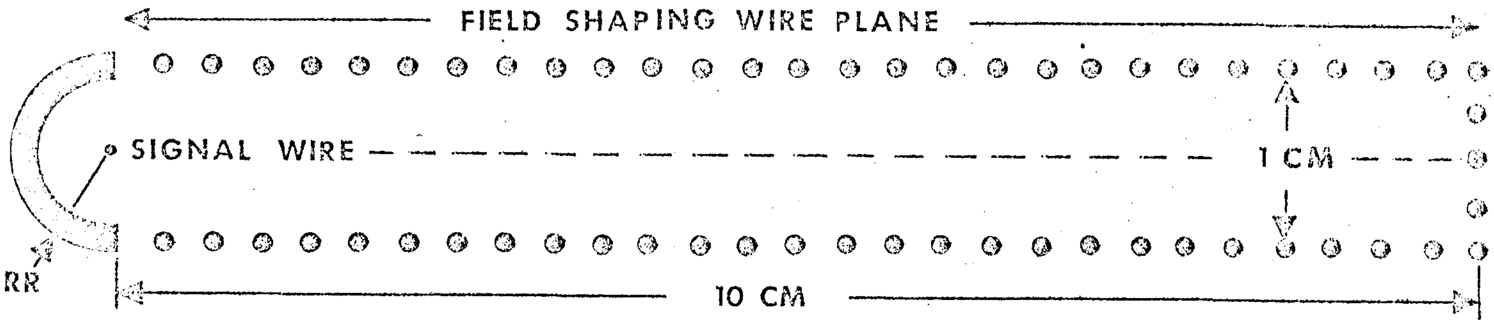
DCFSW (continued)

OUTPUT:

1. V1, ROP
2. U1(1-10) (5 lines) Charge densities on the elements of foil 1.
3. V2
4. U2(1-10) (5 lines) Charge densities on the elements of foil 2.
5. VW(1-10) (1 line) Voltages on the field shaping wire planes.
6. U3(1-10) (1 line) Charge densities on the field shaping wire planes.
7. UP Charge density on the signal wire.
8. DELX Increments in the x-coordinates of the calculated potentials.
9. P, Q, R, S, T (11 lines) x-coordinates of the calculated potential points.
10. DELY Increments in the y-coordinates of the calculated potentials.
11. P, Q, R, S, T, U, V, W (2 lines) y-coordinates of the calculated potential points.
12. AA, BB, WT, V1, V2
13. XP, XR, EX, XPP, XRP, EXQ
14. VR(1-16) (55 lines) potentials in the drift space.

FLPOT Calculation of the electric field intensity and potential in the drift region of a cylindrical foil drift chamber with field shaping wires.

GEOMETRY:



VARIABLES:

Wires in the field shaping wire plane have a 2 mm separation.

RO Radius of the field shaping wires.

ROP Radius of the signal wire.

VZRO Voltage applied to the half cylinder.

VV(I) Voltages on the wires in the field shaping wire plane. VV(51-52) are on the end.

INPUT: None.

OUTPUT:

1. UD(1-50) (printed 5/line) Charge densities on wire plane.

2. UD(51-52) UD(51) is the charge density of the field shaping wire on the center plane of the drift chamber. UD(52) is the charge density on the end field shaping wires which are off the center plane.

3. UD(53-92) (printed 10/line }
4. UD(93-97) } Charge densities on the elements of the half cylinder.

5. UD(98) Charge density on the signal wire.

6. VV(1-50) (printed 10/line) Voltages on the wire plane.

7. VV(51-52) VV(51) is the voltage of the field shaping wire located on the center plane, and VV(52) is the voltage on the end wires off center.

(continued)

FLPOT (continued)

8. AX
9. VX

(8–9) Parameters used in determining the field shaping wire voltages.

10. VZRO, ZVRO ZVRO is the starting voltage applied to the first field shaping wire in the plane.

11. DLVV Additive voltage parameter for the end field shaping wires located off the center plane.

[page by page printout of the field conditions over the entire active region of the drift chamber.]

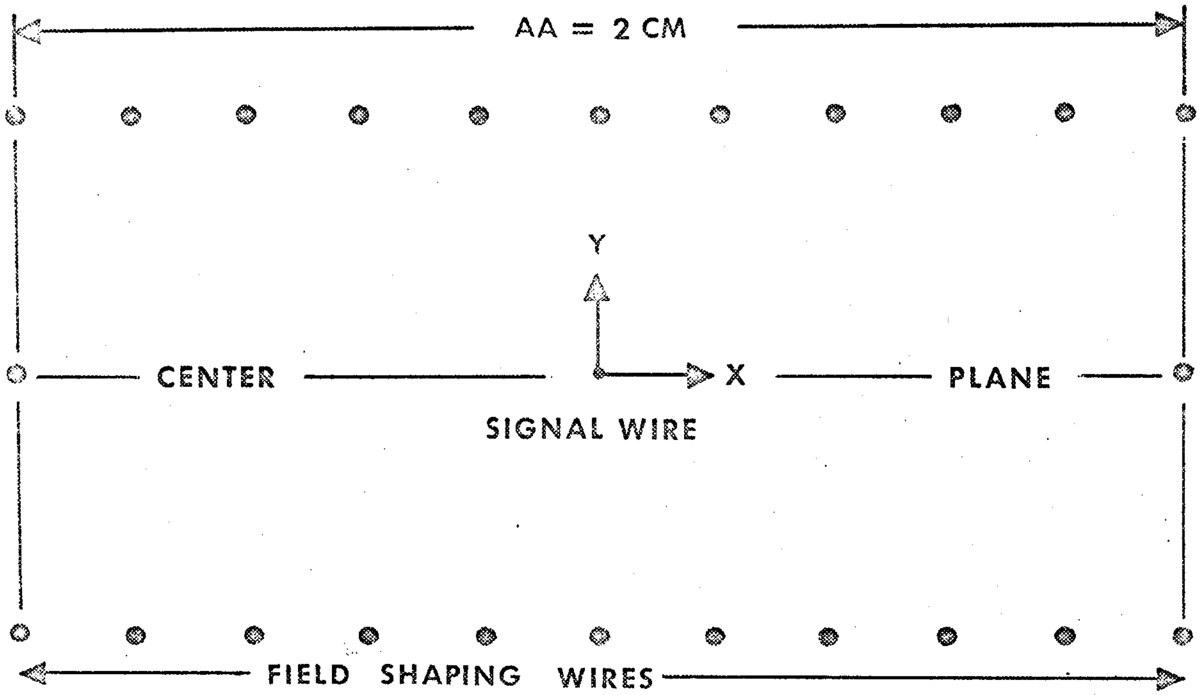
12. VV(1-100) (printed 10/line, one line per page) Voltages on the wire plane, each page contains 1/10 of the drift area.

13. VR(1-20) (printed 20/line) Calculated potentials.

14. EX(1- 10) (printed one line per page) x-component of the electric field intensity along the center plane of the drift region.

<u>FLDVT</u> Calculation of the electric potential in a drift chamber.

GEOMETRY:



VARIABLES:

AA Total width of a cell, (signal wire to signal wire).

RO Radius of field shaping wires.

ROP Radius of the signal wire.

VFS Voltage on the field shaping wires in the center plane of the chamber.

INPUT: None.

OUTPUT:

1. VFS

2. UD(1-11), UD(22-23), UDG
   Charge densities 1-11 are along the field shaping wire planes, 22-23 are in the center plane, and UDG is the charge density on the signal wire.

3. VV(1-6) Voltages applied to the wire planes.

4. VR(1-25) Calculated potentials, 25/line.

FLDFT Calculation of E/p, and drift distance to time in a drift chamber.

GEOMETRY: Same as for FLDVT.

VARIABLES:

PP Pressure inside the drift region (mm Hg).

AA, RO, ROP — Same as in FLDVT.

HVN Negative high voltage applied to the chamber.

VV(1-6), VFS, UD(1-11) — Same as in FLDVT.

UD(22-23) Charge densities on the field shaping wires in the center plane.

UD(25) Charge density on the signal wire.

XL Final distance from the drift electron to signal wire.

XA Distance from signal wire to where E/p is calculated.

XNP Number of incremental steps made by the drift electron.

EOP E/p (volts/cm mm Hg) at distance XA from signal wire.

VAV Average velocity of electron during drift time. (cm/Msec)

DLT total drift time. (Msec)

INPUT: None.

OUTPUT:

1. UD(1-7)
2. UD(8-11), UD(22-23), UD(25)
3. VV(1-6)
4. VFS
5. XL, XA, XNP, EOP, VAV, DLT

<u>DFTVL</u> Calculation of drift distance, time, and velocity from timing spectra.

GEOMETRY: Arbitrary, with a total drift distance of 1 cm.

VARIABLES:

DELT	(nsec/channel) timing calibration.
NST	The # of the beginning channel in the spectrum.
NSP	The # of the last channel in the spectrum.
LT(I)	Counts/channel in the spectrum.
NP	Total number of channels processed.
DLNT	Same as DELT.
TT	Total drift time of the spectrum.
NOP	Channel #.
XX	Drift coordinate (cm).
TU	Drift time (nsec).
DFVL	Drift velocity (cm/μsec)

INPUT:

1. Title card. (skip the first column)
2. HVN High voltage applied to the drift chamber.
3. DELT
4. NST, NSP
5. LT(1- last channel) Ten channels/card.

OUTPUT:

1. Title card.
2. LT(1- last channel) Ten channels/line.
3. NST, NSP
4. Title card. (beginning of a new page)
5. NP, DLNT, TT, HVN
6. NOP, XX, TU, DFVL