FDC Garfield Studies – v1.0

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There are several rules of thumb regarding proper settings of the high voltage in a horizontal drift chamber. The two main ones regard the electric field on the surface of the sense wire and on the surface of the field wire. The basic parameters are given by:

- E_s should be roughly 300 kV/cm at the surface of the sense wire to obtain an avalanche multiplication factor (or gas gain) $\mathcal{G}$ of a few times 10^4.
- $E_f \leq 20$ kV/cm to stay away from conditions that lead to field wire emission, cathode deposits, and noise.

In the small FDC prototype cathode chamber we can test the chamber configuration with cathode planes surrounding a wire plane that consists of alternating sense and field wires. The sense to field wire separation is 5 mm and the wire plane to cathode plane separation is 5 mm. Simon Taylor has plateaued the chamber in a gas mixture consisting of 90% argon / 10% CO_2 and found that the chamber plateau occurs when the sense to field wire potential difference is about 1950 V. In this configuration the cathode planes are grounded. However for this plateau potential difference of 1950 V, the field configuration within the chamber, along with the resolution of the cathode coordinate and the sense wire timing depend strongly on the specific voltages chosen for V_s and V_f.

This configuration with both sense and field wires represents our present nominal design choice for the FDC system. The main issue here is how the optimization of the performance of the drift chamber affects the performance of the cathode readout. Normally cathode chambers do not include field-shaping wires between the sense wires as only the cathodes are meant to provide a precision coordinate. We would like to achieve precision coordinate reconstruction using both the charge collected on the cathodes and the drift time information from the sense wires. Of course without field-shaping wires, the chamber would have an electric field configuration that would not allow for use as a horizontal drift chamber with any reasonable degree of resolution. A horizontal drift chamber needs to have sufficient field lines in the plane of the wires so that the first electron that drifts in to the sense wire comes from the plane of the wires.

However, the inclusion of field-shaping wires in the wire plane will necessarily reduce the charge collected on the cathode and change its distribution (spread) on the cathode. Both of these effects need to be studied so that guidance can be made regarding the final design choice.

This document is based on a study of the chamber field configuration and charge distribution using the GARFIELD program that is part of the CERNLIB software package. Here

I show the chamber field configurations for a number of different high voltage operating conditions. This leads to a number of points that can be made regarding FDC chamber operation and also leads to a number of studies that can be performed to converge on a choice for operation.

It should be noted that the Hall B chambers are operated in a configuration in which the total charge on the field wires is equal to the total charge on the sense wires. The cell configuration is hexagonal, with each sense wire surrounded by six field wires. The electric field on the surface of the sense wire is about 240 kV/cm and that on the surface of the field wires is about 17 kV/cm.

Configuration: V_s=1750 V, V_c=0 V

• Begin by considering the FDC without any field wires. Here all of the field lines that leave the sense wires terminate on the cathode plane. The charge on the wires is the same as the sum on the two cathode planes. However given that there are no field lines between the sense wires, this configuration cannot work as a horizontal drift chamber.

	Charge	Surface field	Field at $2r$	Surface pot.	Pot. at $2*r$
Sense wire	267.37	267.37	133.78	1750.0	1564.5

Table 1: Charge, surface electric field, electric field at twice the wire radius, surface potential, and potential at twice the wire radius. The electric field is given in units of kV/cm and the potential is given in units of V.

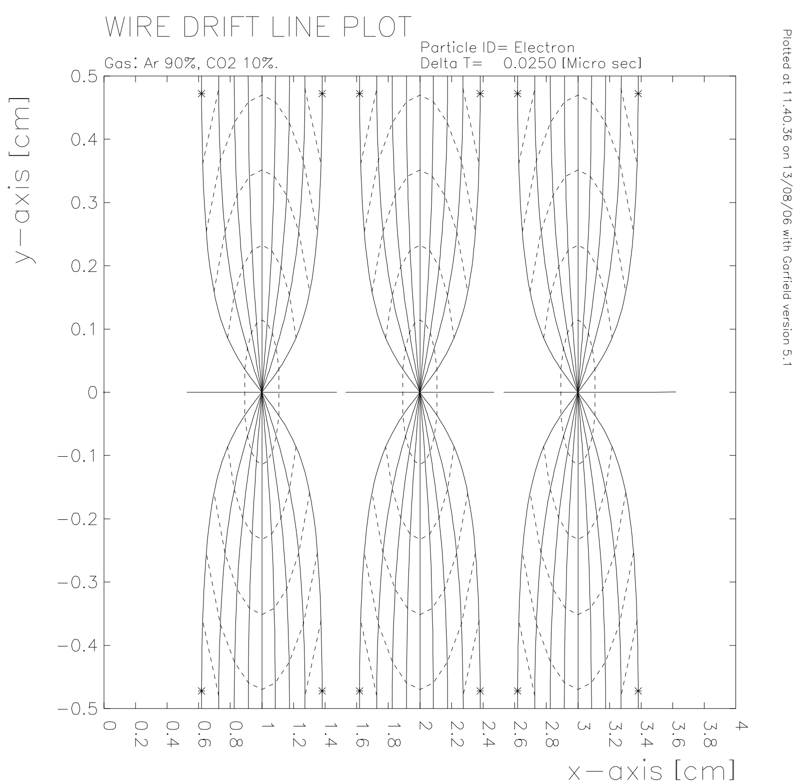

Figure 1: V_s=1750 V, V_c=0 V

Configuration: V_s=1173 V, V_f=-777 V, V_c=0 V

• Now consider selecting a field configuration with $\Delta V_{sf} = 1950$ V but with the charges on the sense and field wires matched as in the Hall B chambers. Here the field configuration would allow operation as a horizontal drift chamber, and there is no electrostatic force on the cathode planes. However as no field lines go to the cathode planes, they can provide no information and this design cannot work for the cathode chamber. This represents one extreme configuration.

	Charge	Surface field	Field at $2r$	Surface pot.	Pot. at $2*r$
Sense wire	203.82	203.82	101.91	1173.0	1031.7
Field wire	-203.93	29.14	14.58	-777.0	-635.6

Table 2: Charge, surface electric field, electric field at twice the wire radius, surface potential, and potential at twice the wire radius. The electric field is given in units of kV/cm and the potential is given in units of V.

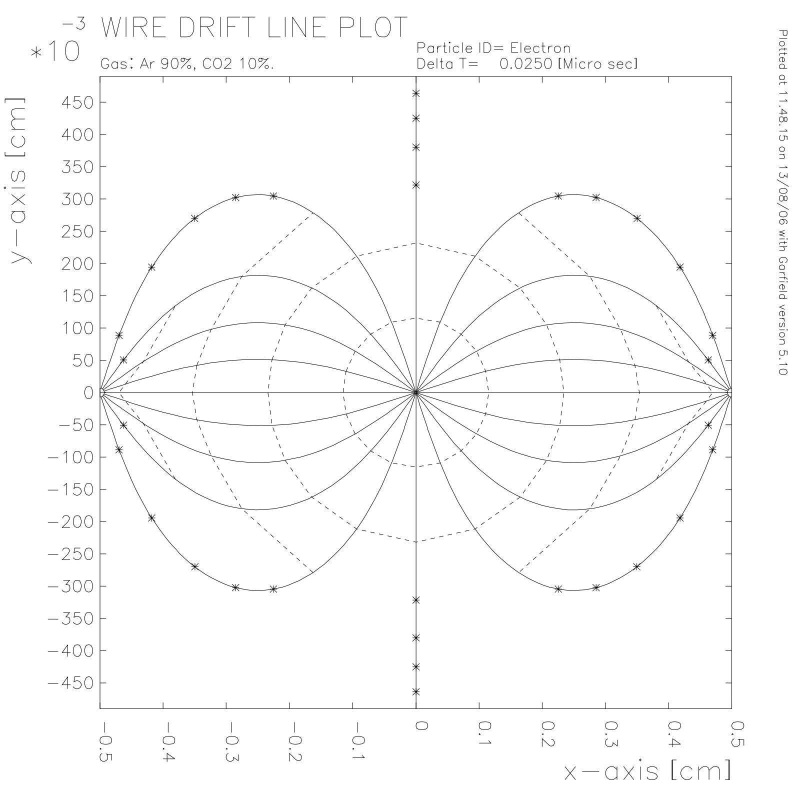

Figure 2: V_s=1173 V, V_f=-777 V, V_c=0 V

Configuration: V_s=1950 V, V_f=0 V, V_c=0 V

• Now consider selecting a field configuration with $\Delta V_{sf} = 1950$ V but with the field wires grounded. This field configuration is very close to that without the field wires altogether with essentially all of the field lines terminating on the cathode planes. This would optimize the resolution of the cathode position measurement but would not work as a horizontal drift chamber. This represents the other extreme configuration.

	Charge	Surface field	Field at $2r$	Surface pot.	Pot. at 2^*r
Sense wire	301.33	301.33	150.66	1950.0	1741.1
Field wire	-56.62	8.09	4.04	0.0	39.2

Table 3: Charge, surface electric field, electric field at twice the wire radius, surface potential, and potential at twice the wire radius. The electric field is given in units of kV/cm and the potential is given in units of V.

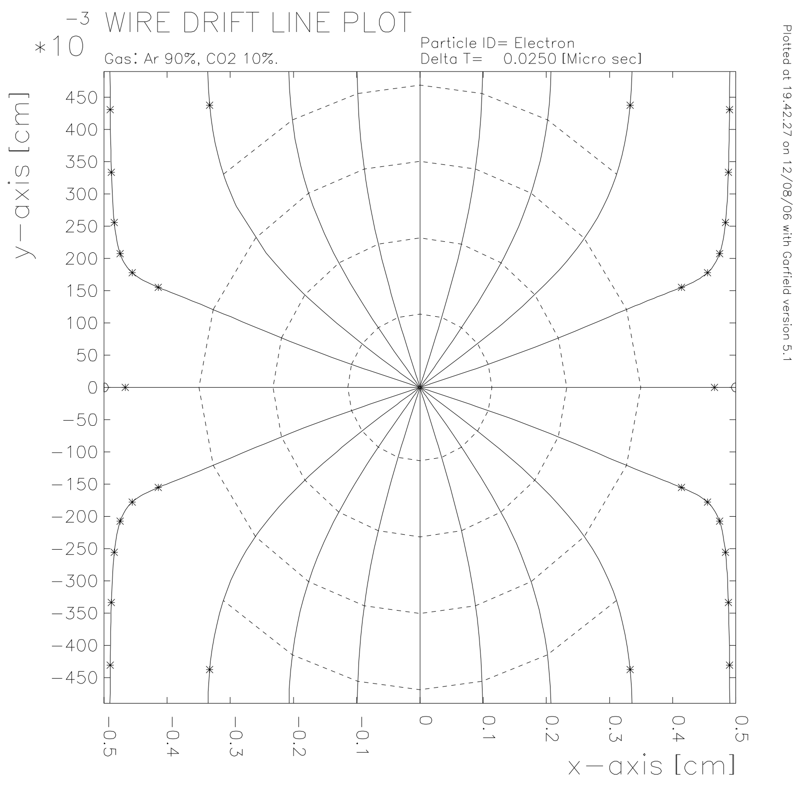

Figure 3: V_s=1950 V, V_f=0 V, V_c=0 V

Note: It is clear that any field configuration that optimizes the resolution of the measurement on the cathode plane will not work for the wire plane and vice versa. A balance must be achieved and detailed studies with the prototype chamber can serve to provide quantitative details.

Configuration: V_s=1650 V, V_f=-300 V, V_c=0 V

• Configuration with $\Delta V_{sf} = 1950$ V. This represents the configuration chosen by Simon that gives the best cathode position resolution. Note that the number of field lines that terminate on the field wires is equal to the number that terminate on the cathode planes. Here the charge on the sense wire is roughly balanced by equal charges on the field wires and cathode planes. This represents what will be called the nominal configuration.

	Charge	Surface field	Field at $2r$	Surface pot.	Pot. at 2^*r
Sense wire	263.68	263.68	131.84	1650.0	1467.2
Field wire	-113.49	16.21	8.11	-300.0	-221.3

Table 4: Charge, surface electric field, electric field at twice the wire radius, surface potential, and potential at twice the wire radius. The electric field is given in units of kV/cm and the potential is given in units of V.

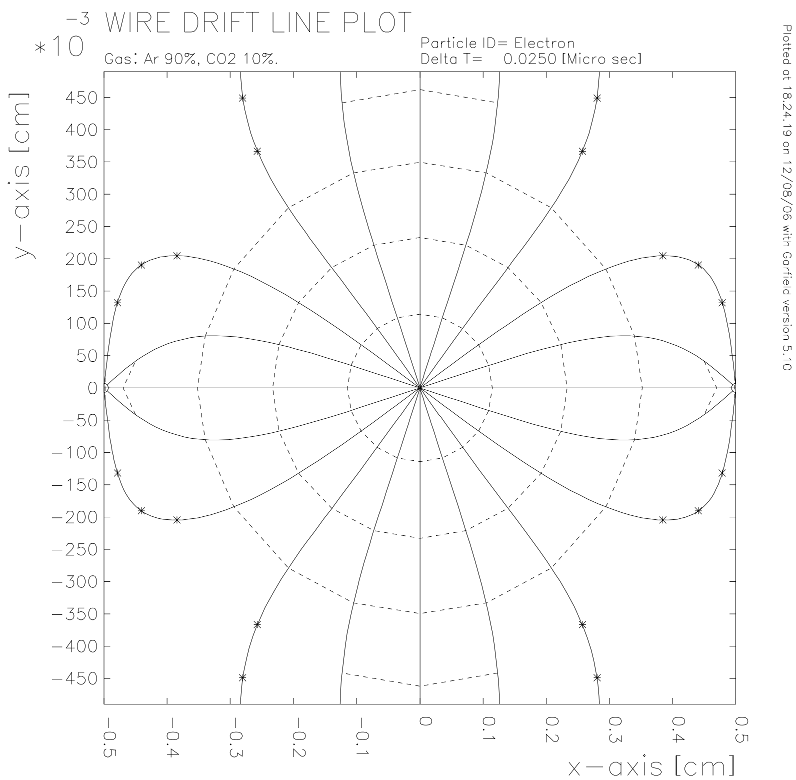

Figure 4: V_s=1650 V, V_f=-300 V, V_c=0 V

Configuration: V_s=1750 V, V_f=-200 V, V_c=0 V

• Configuration with ΔV_{sf} = 1950 V. Now raise the sense wire voltage by 100 V and decrease the field wire voltage by 100 V. In this configuration the cathodes collect the large fraction of the charge. The charge balance between cathodes and field wires is roughly 65% to 35%. Presumably this configuration would improve the position resolution at the cathodes and decrease the timing resolution from the wires.

	Charge	Surface field	Field at $2r$	Surface pot.	Pot. at $2{*}r$
Sense wire	276.23	276.23	138.11	1750.0	1558.5
Field wire	-94.53	13.50	6.75	-200.0	-134.5

Table 5: Charge, surface electric field, electric field at twice the wire radius, surface potential, and potential at twice the wire radius. The electric field is given in units of kV/cm and the potential is given in units of V.

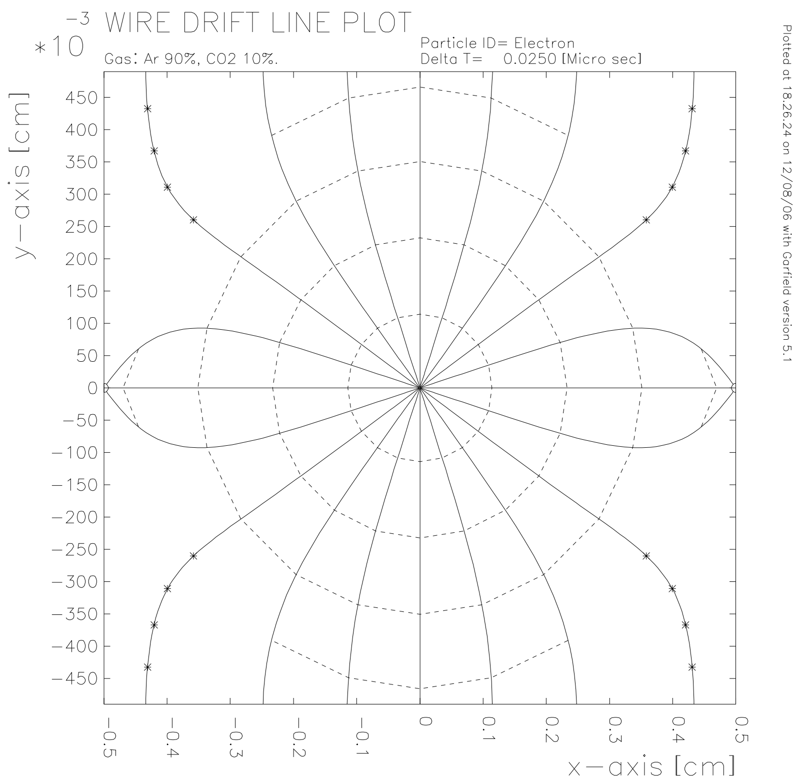

Figure 5: V_s=1750 V, V_f=-200 V, V_c=0 V

Configuration: V_s=1550 V, V_f=-400 V, V_c=0 V

• Configuration with ΔV_{sf} = 1950 V. Now decrease the sense wire voltage by 100 V and increase the field wire voltage by 100 V. Here the number of field lines terminating on the cathodes and field wires does not change, but the width of the charge distribution on the cathode will be narrower/. Just as for the nominal voltage configuration, here the charge on the sense wire is roughly balanced by equal charges on the field wires and cathode planes. The field at the surface of the sense wires is very close to the 20 kV/cm design number. However, it should be noted that Mac Mestayer feels strongly that this value is a *very* conservative one.

	Charge	Surface field	Field at $2r$	Surface pot.	Pot. at $2*r$
Sense wire	251.13	251.13	125.57	1550.0	1375.9
Field wire	-132.45	18.92	9.46	-400.0	-308.2

Table 6: Charge, surface electric field, electric field at twice the wire radius, surface potential, and potential at twice the wire radius. The electric field is given in units of kV/cm and the potential is given in units of V.

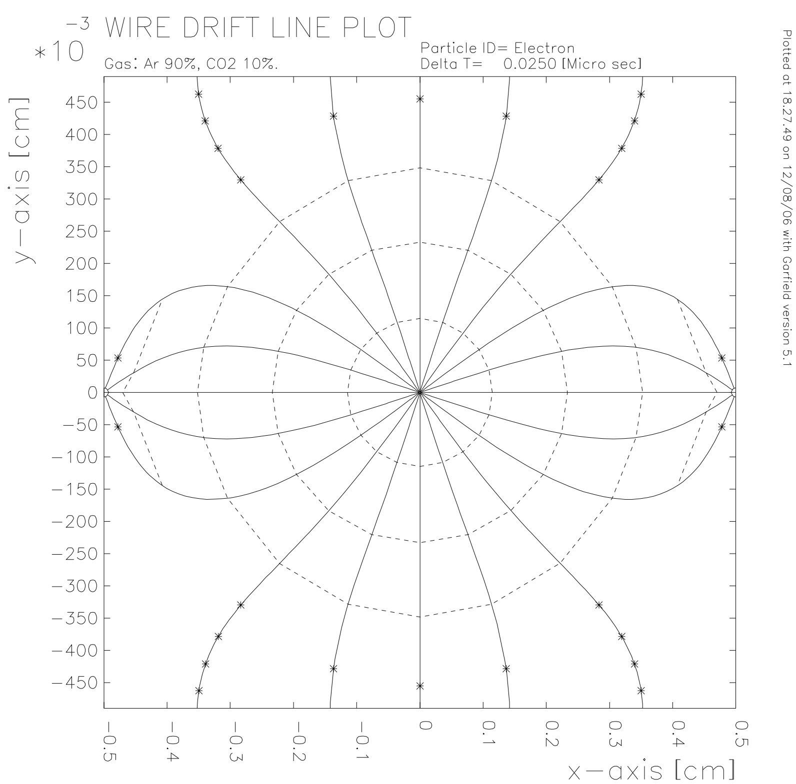

Figure 6: V_s=1550 V, V_f=-400 V, V_c=0 V

Configuration: V_s=1750 V, V_f=-300 V, V_c=0 V

• Configuration with ΔV_{sf} = 2050 V. This configuration increases the gain in the system by increasing the sense wire voltage by 100 V. One way to generally improve the resolution in the system, is to increase the gain. Of course this will also increase the noise and decrease the chamber lifetime. The field line configuration is very similar to the nominal configuration.

	Charge	Surface field	Field at $2r$	Surface pot.	Pot. at $2*r$
Sense wire	279.13	279.13	139.57	1750.0	1556.5
Field wire	-116.40	16.63	8.31	-300.0	-219.3

Table 7: Charge, surface electric field, electric field at twice the wire radius, surface potential, and potential at twice the wire radius. The electric field is given in units of kV/cm and the potential is given in units of V.

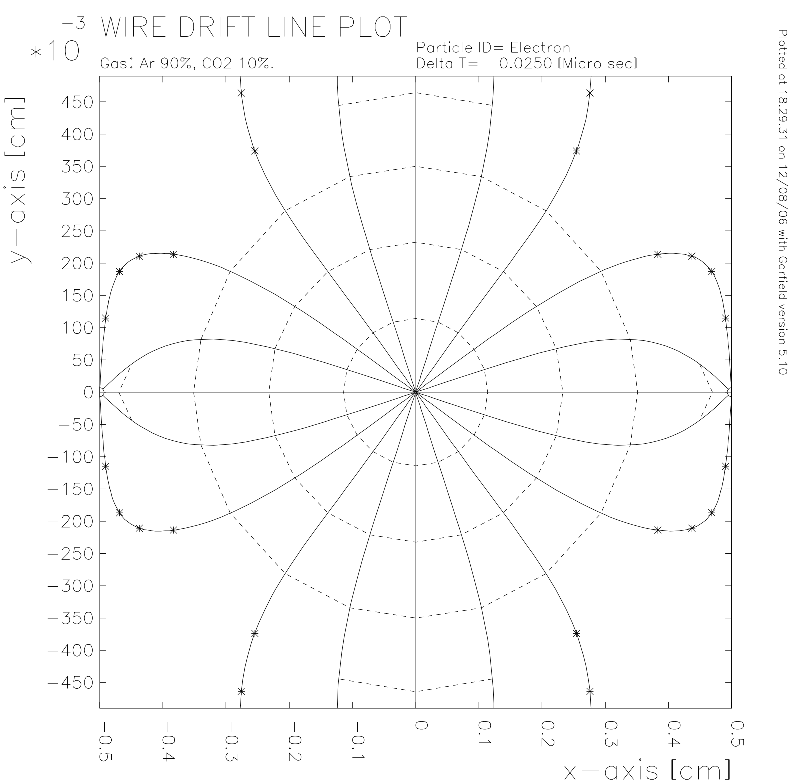

Figure 7: V_s=1750 V, V_f=-300 V, V_c=0 V

Configuration: V_s=1650 V, V_f=-400 V, V_c=0 V

• Configuration with $\Delta V_{sf} = 2050$ V. Another attempt to increase the gain of the system, this time by increasing the field wire voltage compared to the nominal configuration by 100 V. Here the field line configuration is similar to the nominal one, but the field strength on the surface of the field wires is essentially at 20 kV/cm.

	Charge	Surface field	Field at $2r$	Surface pot.	Pot. at $2*r$
Sense wire	266.58	266.58	133.29	1650.0	1465.2
Field wire	-135.36	19.34	9.67	-400.0	-306.2

Table 8: Charge, surface electric field, electric field at twice the wire radius, surface potential, and potential at twice the wire radius. The electric field is given in units of kV/cm and the potential is given in units of V.

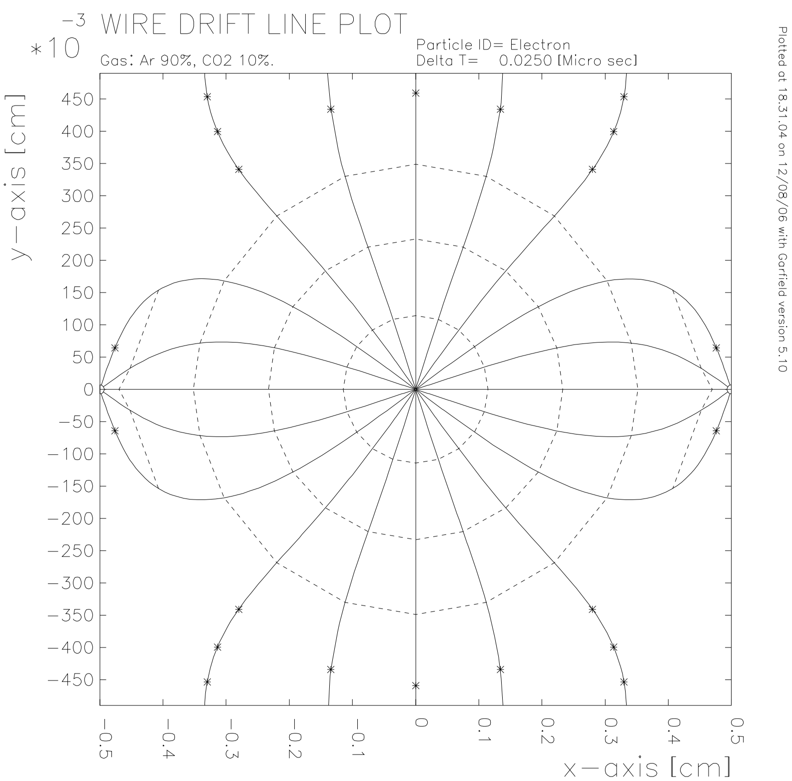

Figure 8: V_s=1650 V, V_f=-400 V, V_c=0 V

GARFIELD Input File: FDC_SF.DAT

```
&cell
rows
s 1 .002 0.000 0.000 1650.
f 1 .014 0.500 0.000 -300.

period x 1.000

PLANE V=0 Y=0.50
PLANE V=0 Y=-0.50

&magn
components 0 0 0. tesla

&gas
mix argon 90 co2 10
TEMPERATURE 300.0 K
PRESSURE 1.0 ATMOSPHERE
*magboltz argon 90 co2 10
&drift
drift wire contour .025
```

GARFIELD Commands:

1). Run `GARFIELD`.
2). At prompt "Ready (Main)", type "< FDC_SF.DAT".
3). Hit enter when prompted.
4). When `GARFIELD` has finished generating field plot, enter "&field".
5). Generate tables of charges and field strengths using:
    "sel p" then "check wire"
    "sel f" then "check wire"