CLAS Note 92-016

# Minimizing Cathode Emission in Drift Chambers

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## Abstract:

Steve Christo and I have constructed test chambers to study the emission of electrons from negatively charged field wires. We have determined empirically that a drift chamber filled with an argon ethane mixture becomes inundated with noise signals due to the release and immediate amplification of electrons from the surface of cathode wires when the magnitude of the electric field at a distance of 8 $\mu m$ from the wire surface exceeds $50 kV/cm$. This gives an approximate description of the critical field behavior for widely varying diameters of the cathode wires ($12\mu m$ to $150\mu m$ diameter wires were tested). We point out that this new rule of thumb supersedes the old and venerable "20 kV/cm" rule.

## Motivation:

The CLAS drift chambers were designed in compliance with the old "20 kV/cm" rule of thumb;[1] that is, the electric field at the surface of the field wires was designed to be less than 20 kV/cm when the chamber was at its nominal operating point. In practice, this meant that for our 1 cm radius hexagonal cells with $20\mu m$ diameter sense wires, the sense wires have a surface field strength of about 280 kV/cm and the $140\mu m$ aluminum field wires have a surface field strength of about 20 kV/cm. We had certain reservations about the 20 kV/cm rule from quick calculations and from conversations with Sauli,[2] but it seemed a moot and esoteric point until we began having problems obtaining quality gold-plated aluminum wire.

At this point, we looked into the possibility of using another material for the field wire; of necessity a denser material. However, our endplates' rigidity was matched to the anticipated stresses on the aluminum wire. Denser wire would necessitate higher forces on the endplates unless we could make the wire thinner. This would violate the 20 kV/cm rule, so we began our investigation.

Although necessity is the mother of invention, curiosity is the sister. While testing cathode emission, we realized that such tests would also be useful to test the surface quality of the wires, and to look for the sources of the emission with the goal of avoiding gas amplification at cathode surfaces.

## First Approach:

The first approach was to string a wire to be tested down the axis of a tube, and to run it a negative high voltage, recording the current drawn versus the voltage applied. A piece of brass tubing, 3/4 in. dia. by 34 in. long, was fitted with nylon endcaps which had a hole drilled to accept the crimp pins. Gas fittings were silver soldered on the ends of the tube. Data collection runs were taken for 5 different wires: $12\mu m$ stainless steel (SS) from California Fine Wire (CFW), $70\mu m$ SS CFW, $140\mu m$ Al CFW (from large prototype), $140\mu m$ Al Electrometals, and $150\mu m$ SS CFW.

The data are shown in Figure 1. Note the rapid rise in the current as the voltage is increased. This graph quite clearly shows that the critical voltage at which the current rapidly increases past $1\mu A$ is a function of wire diameter; the smaller diameter wires having a lower value of critical voltage. In addition, the critical voltage seems to be a function of the surface quality of the wires. The $140\mu m$ wires were known to have poor surface quality, and their critical voltages were substantially lower than that for the $150\mu m$ stainless steel wire.

This test suffers from low sensitivity; we measure currents at the $100nA$ level and above, which indicates that the wire is in streamer mode. The solution to this problem is to amplify the signals due to emitted electrons and count them.

## Second Approach:

The idea of the next test was to still have the wire to be tested strung down the axis of the device, but in this case to be surrounded by small diameter anode wires which would amplify the emitted electrons which drifted to them. A cross sectional view of the chamber is shown in Figure 2. The "test" wire is in the center, surrounded by six "anode" wires and then six "field" wires in an hexagonal arrangement. The chamber is sealed by a conducting, grounded gas bag.

By adjusting the test, anode and field wire voltages independently, we can keep the electric field constant at the surface of the anode wire while varying the electric field at the surface of the test wire. In this way we change the emission characteristics of the field wire but keep the gas amplification constant. The field is dominantly determined by the voltage, and hence surface charge density, of the field wires. This is because there are six field wires and only one test wire. A beneficial side effect is that the electric field at the surface of the field wires is very low, below about 8 kV/cm.

The electric field values at the wire surfaces were calculated with the GARFIELD[3] program, and the values are shown in Tables 1 - 3, for three different diameter test wires.

| Chamber Voltages and Surface Electric Fields - 140$\mu m$ Test Wire | | | | | |
|---|---|---|---|---|---|
| V(test) | V(anode) | V(field) | E(test) | E(anode) | E(field) |
| 1500 V | 3500 V | 850 V | -14.5 kV/cm | 310. kV/cm | -6.5 kV/cm |
| 1000 | 3400 | 800 | -26. | 310. | -6.5 |
| 500 | 3300 | 750 | -38. | 310. | -6.5 |
| 0 | 3200 | 700 | -51. | 310. | -6.5 |
| -500 | 3100 | 650 | -63. | 310. | -6.5 |
| -1000 | 3000 | 600 | -75. | 310. | -5.5 |
| -1500 | 2900 | 550 | -87. | 310. | -5.5 |
| -2000 | 2800 | 500 | -99. | 310. | -5.5 |
| -2500 | 2700 | 450 | -111. | 310. | -4.5 |
| -3000 | 2600 | 400 | -123. | 310. | -4.5 |
| -3500 | 2500 | 350 | -135. | 310. | -4.5 |

| Chamber Voltages and Surface Electric Fields - 70$\mu m$ Test Wire | | | | | |
|---|---|---|---|---|---|
| V(test) | V(anode) | V(field) | E(test) | E(anode) | E(field) |
| 1500 V | 3500 V | 850 V | -25.6 kV/cm | 308. kV/cm | -6.5 kV/cm |
| 1000 | 3400 | 800 | -47. | 308. | -6.5 |
| 500 | 3300 | 750 | -68.1 | 308. | -6.5 |
| 0 | 3200 | 700 | -89.4 | 308. | -6.5 |
| -500 | 3100 | 650 | -111. | 308. | -6.5 |

| Chamber Voltages and Surface Electric Fields - 12$\mu m$ Test Wire | | | | | |
|---|---|---|---|---|---|
| V(test) | V(anode) | V(field) | E(test) | E(anode) | E(field) |
| 1500 V | 3500 V | 850 V | -114.6 kV/cm | 306. kV/cm | -6.5 kV/cm |
| 1000 | 3400 | 800 | -126. | 304. | -6.5 |

## Data Collection Procedure:

The data was collected in the following way: the voltages on the anode, field and test wires were set according to the accompanying tables. For one such voltage setting, three quantities were recorded: the primary pulse height produced by an $Fe^{55}$ source as measured visually on a scope, the scaled number of counts due to the source for a 10 second interval, and the scaled number of counts with the source removed (called "background") for a 30 second interval. These scaler measurements were done for three different discriminator settings; at 10, 20 and 40 millivolts.

During the course of the data-taking (May 8 - July 1, 1992) a number of problems were encountered and solved. First, we increased the amplifier gain such that the $Fe^{55}$ pulse height was between 500 and 600 mV. Since an $Fe^{55}$ X-ray liberates about 227 electrons in argon ethane, our discriminator thresholds of 10, 20 and 40 mV correspond to about 5, 10 and 20 primary electrons respectively. These are probably over-estimates since a single electron drifting in to the anode wire is not affected by effects such as cluster spreading or charge screening which can lower the maximum pulse height for the 227 electron cluster from an $Fe^{55}$ X-ray.

Second, we observed a hysteresis effect in the cathode emission; that is, high count rates could persist even after the voltages and hence, surface fields, were lowered. For this reason we started with a voltage setting corresponding to low surface electric fields and moved to higher field values; we did counts for all discriminator settings before changing to the next voltage setting. Third, we noticed that the count rates decreased with time as we moved through the first few voltage settings. We attributed this to a "burning-in" effect which we don't understand but which we empirically observed to take about 8 hours. Fourth, we noted that the $Fe^{55}$ count rate depended on discriminator setting. This seemed wrong; closer inspection revealed that the discriminator was occasionally double-pulsing. We eliminated this problem by lengthening the discriminator output pulse.

## Results, Conclusions and Further Questions:

Our results are presented in the form of graphs in which we plot the 30 second background rate as a function of the calculated electric field at the test wire surface. We show separate curves for the three different discriminator settings. The six different figures (3 - 8) display the results for $12, 70, 100 and 150\mu m$ diameter stainless steel wires, and two runs for 140$\mu m$ diameter gold-plated aluminum wire.

What can we conclude from this? First, the critical electric field at which a clean field wire starts generating sizeable dark noise due to avalanche conditions is 50 kV/cm at a radius of $8\mu m$ from the surface. Second, the larger diameter wires show about a factor of 10 greater rate at a 10 mV threshold compared to one at 20 mV. Perhaps the high rate at the low discriminator setting corresponds to single electron emission is which the gas gain fluctuates up? Third, even though the noise doesn't increase significantly until about 50 kV/cm, are there long term aging effects which are more pronounced at field values which are greater than 20 kV/cm but less than 50 kV/cm? We are conducting aging tests to answer the last question.

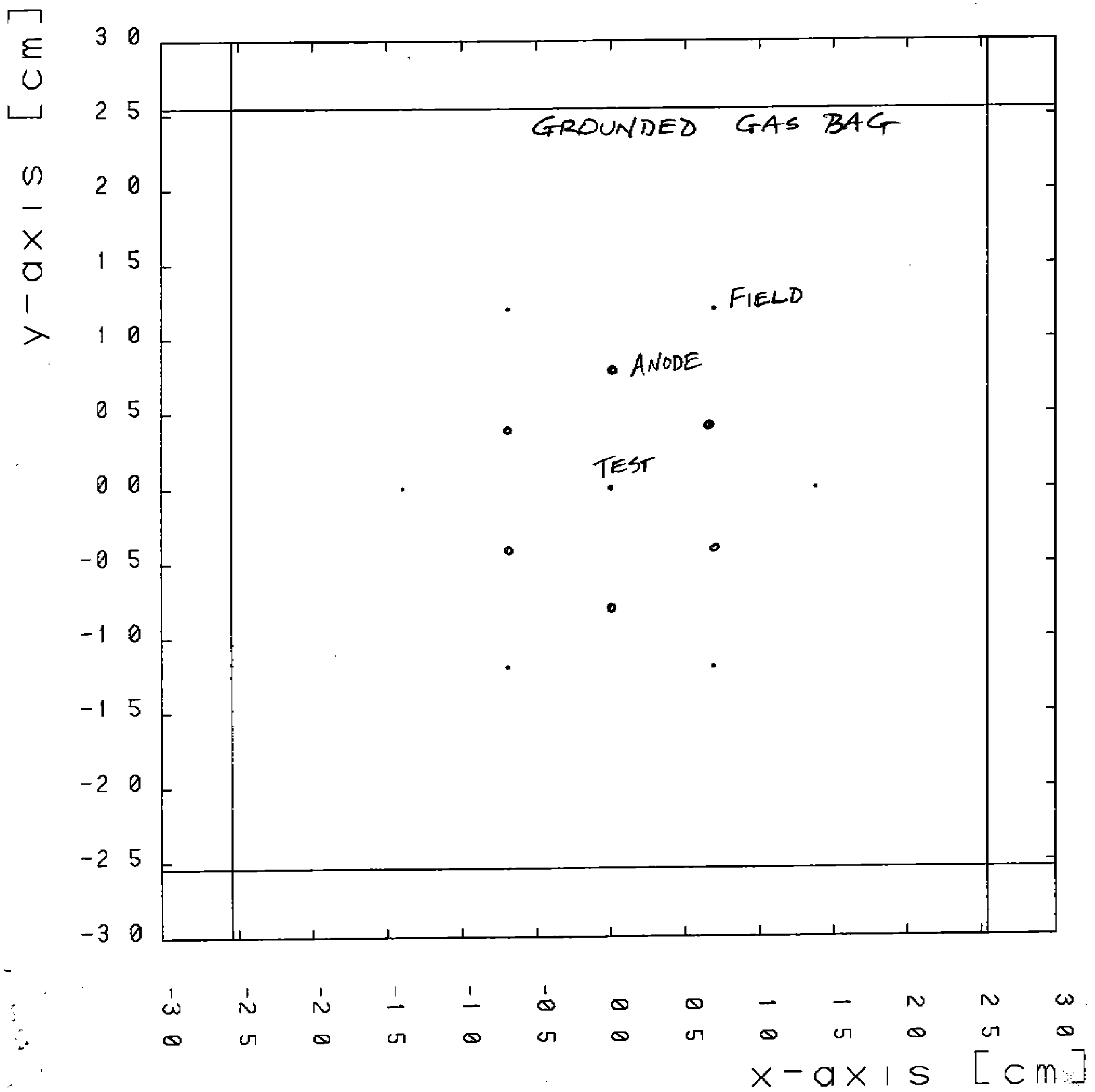
**References:**

[1.] "Wire Chamber Aging", John Kadyk, NIM A300 (1991) p. 436-479.
On page 467 is the following passage: "It is commonly understood that it is essential to design wire chambers such that the field at the cathode wire surfaces does not exceed a certain strength, usually taken to be about 10 - 20 kV/cm. This field is somewhat smaller than values usually calculated for onset of avalanche processes, but not by large factors. Since wire imperfections will increase fields locally, and any incipient Malter layer formation will reduce the work function at the cathode surface, there is a need to keep the ambient field here at least as low as 20 kV/cm."

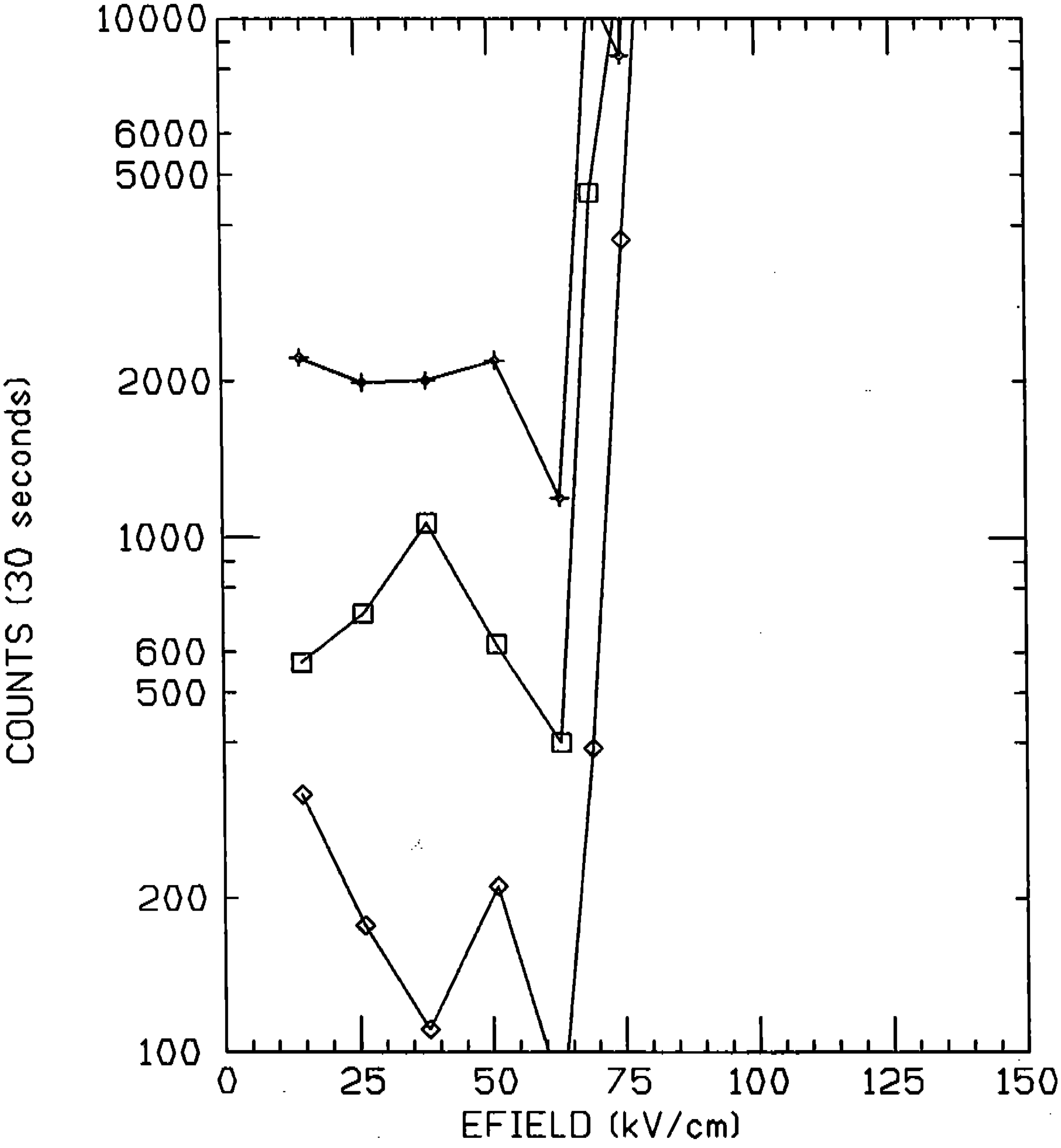
[2.] private communication, F. Sauli.

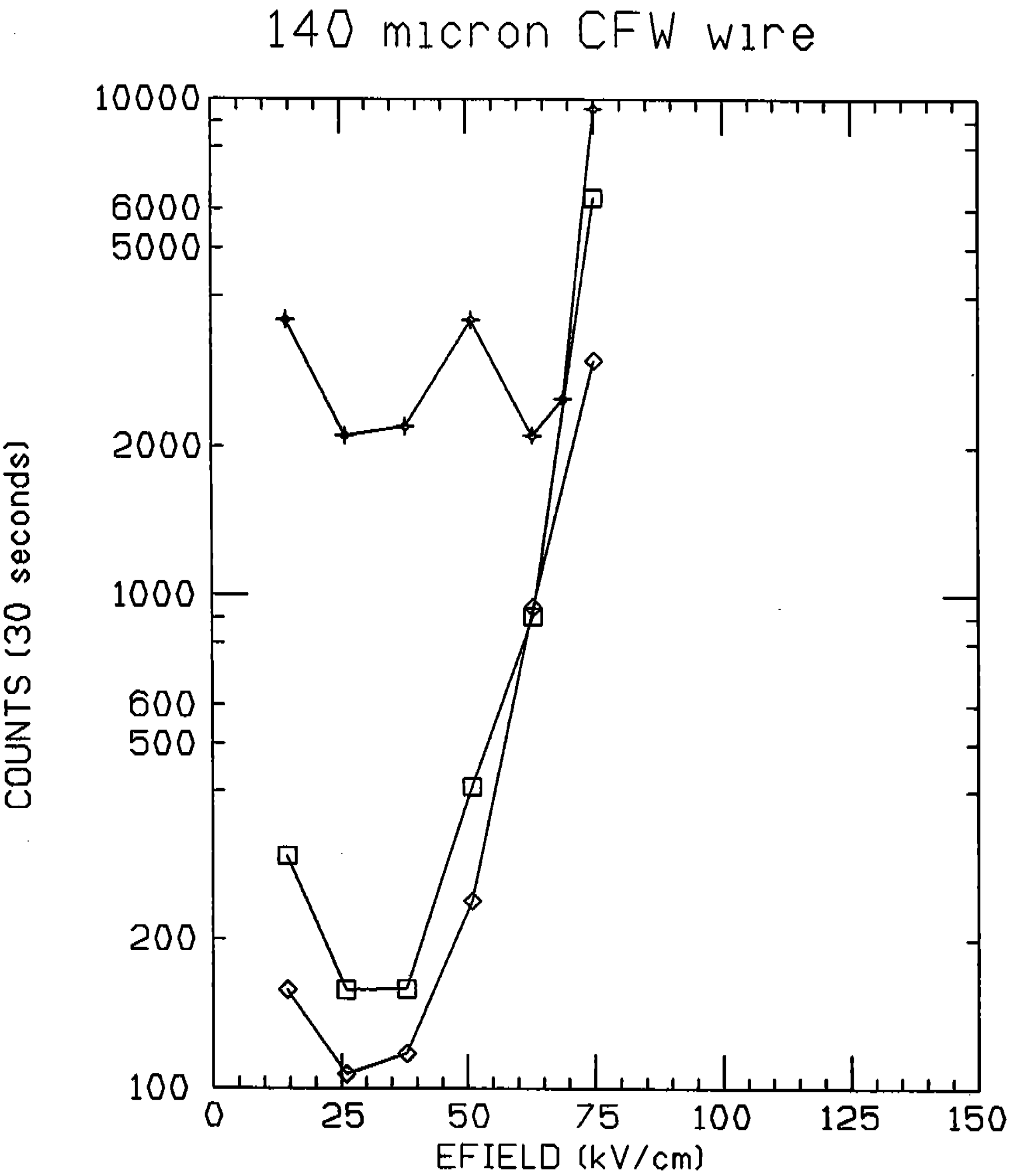
[3.] "GARFIELD, A Drift Chamber Simulation Program", R. Veenhof, M. Guckes, K. Peters, HELIOS Note 154.

# WIRE DRIFT LINE PLOT

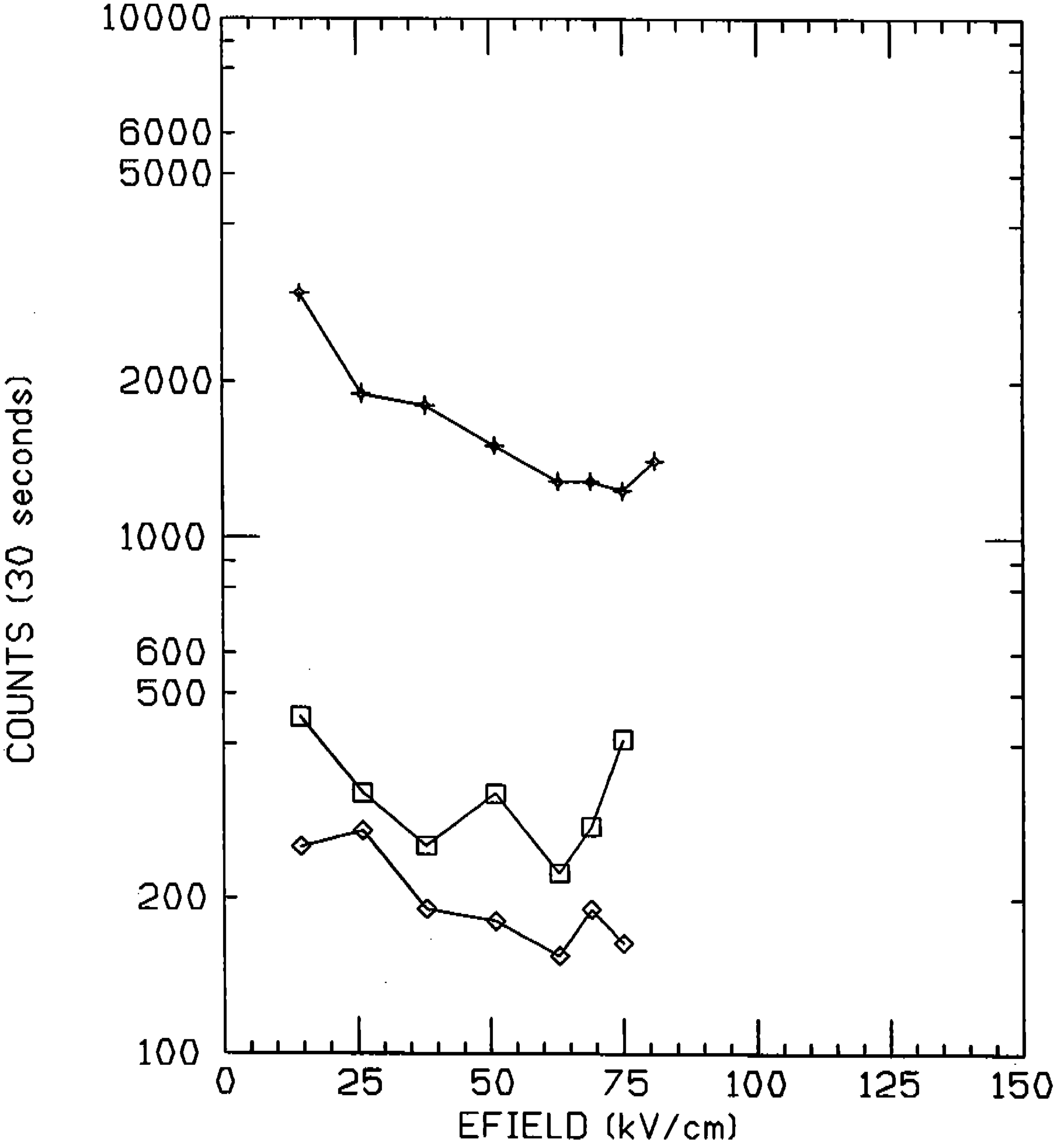


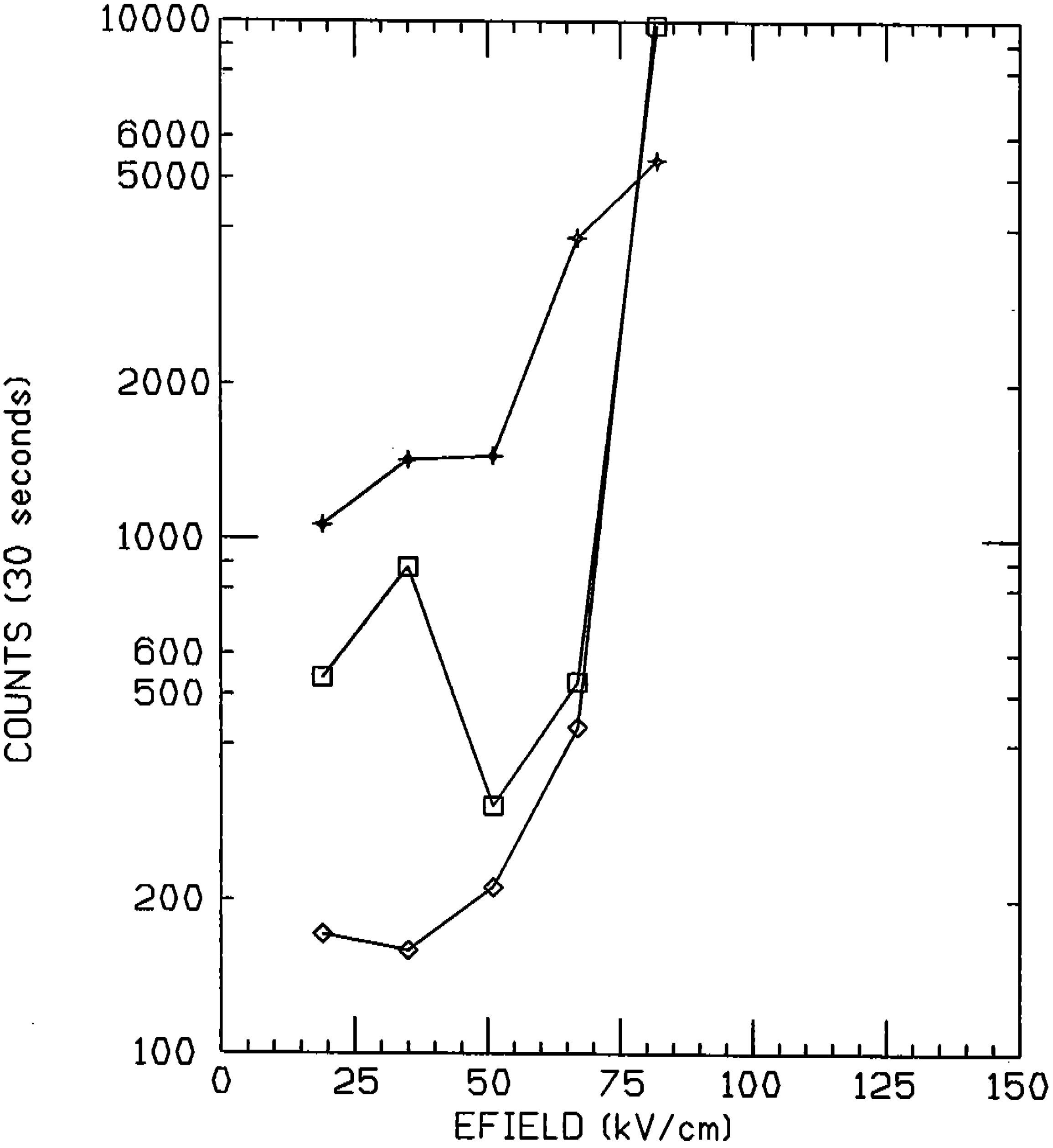
# 140 micron CFW wire




140 micron CFW wire
10000
6000
5000
2000
1000
600
500
200
100
COUNTS (30 seconds)
0
25
50
75
100
125
150
EFIELD (kV/cm)

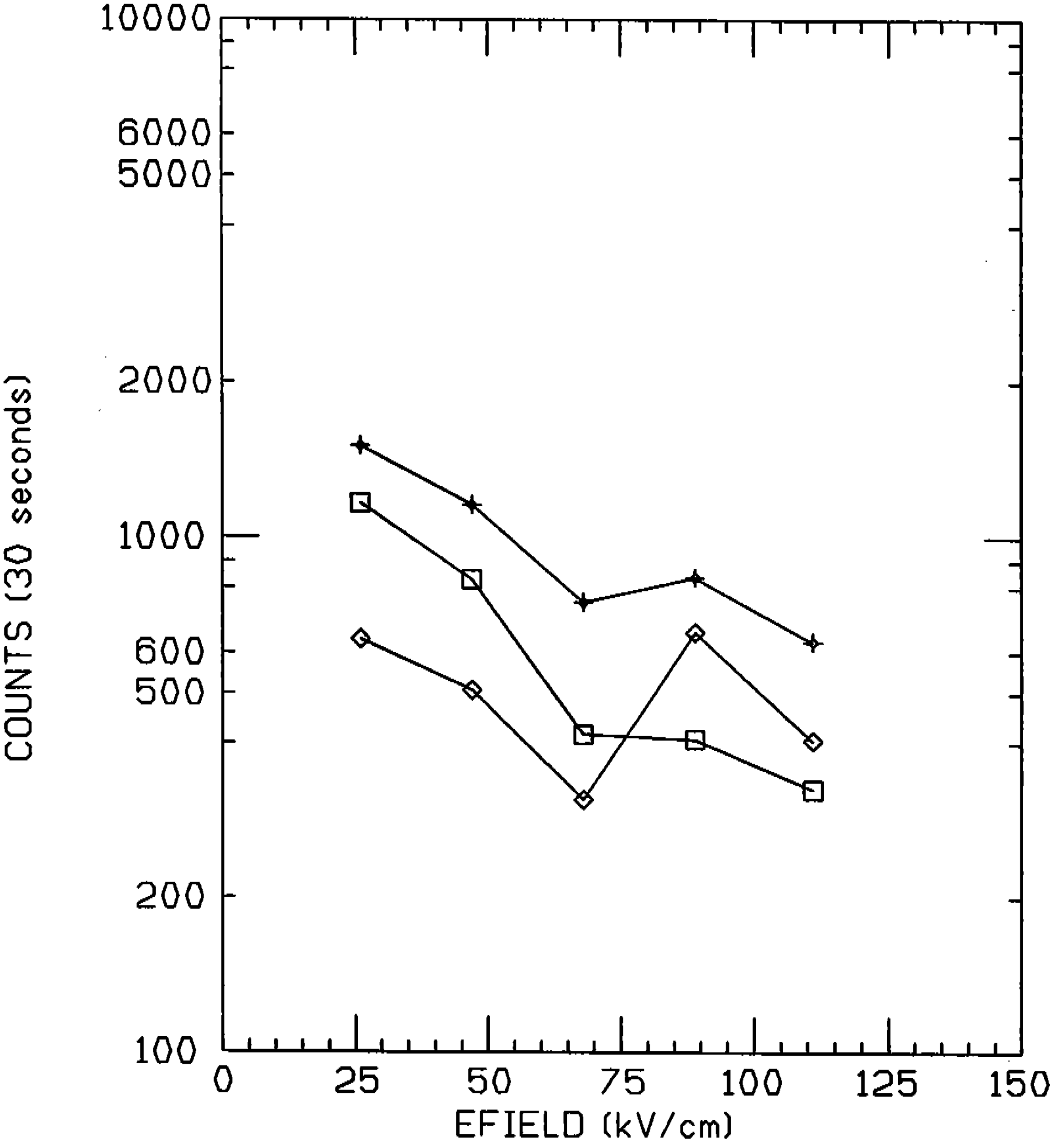
# 150 micron steel wire

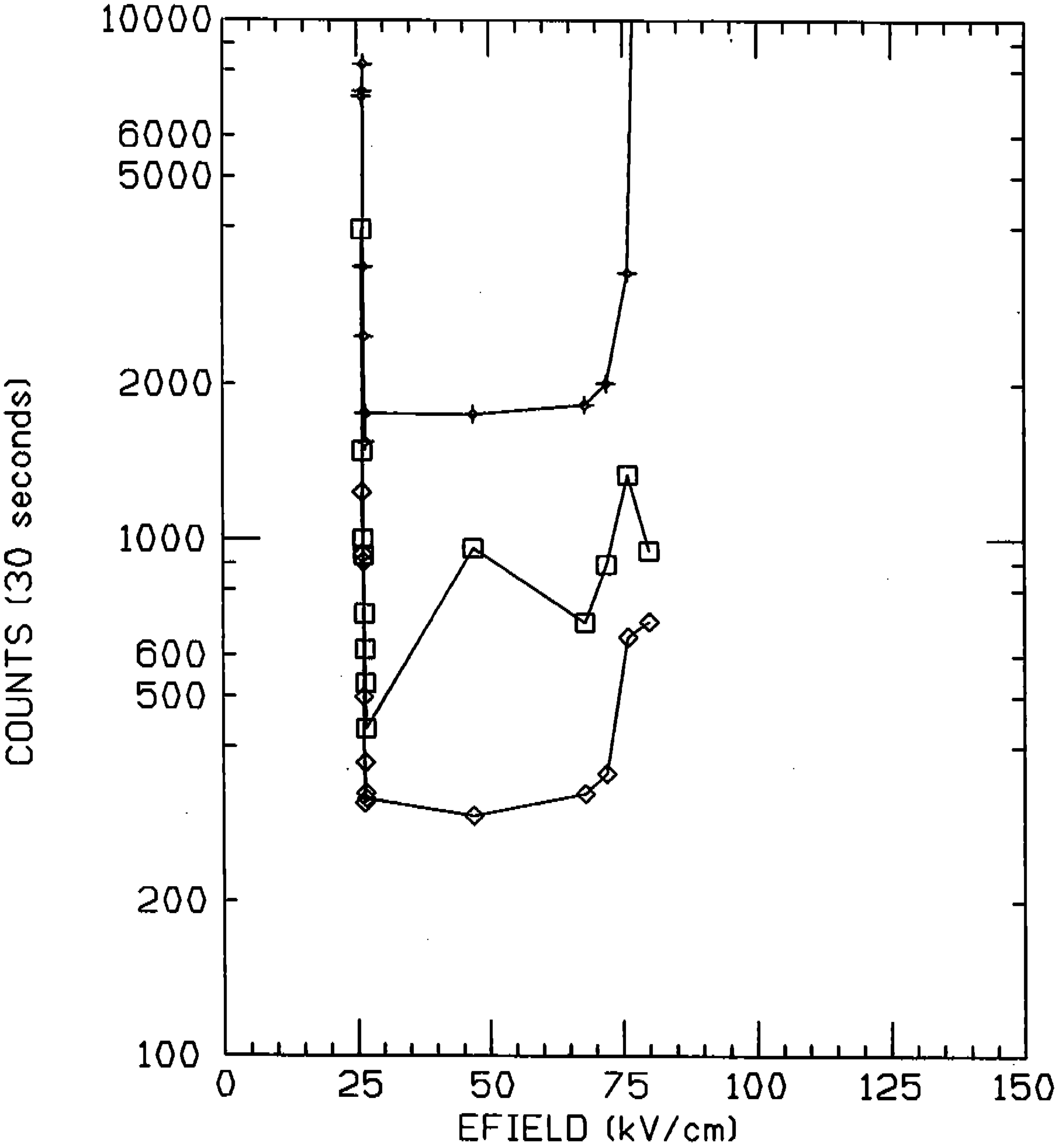




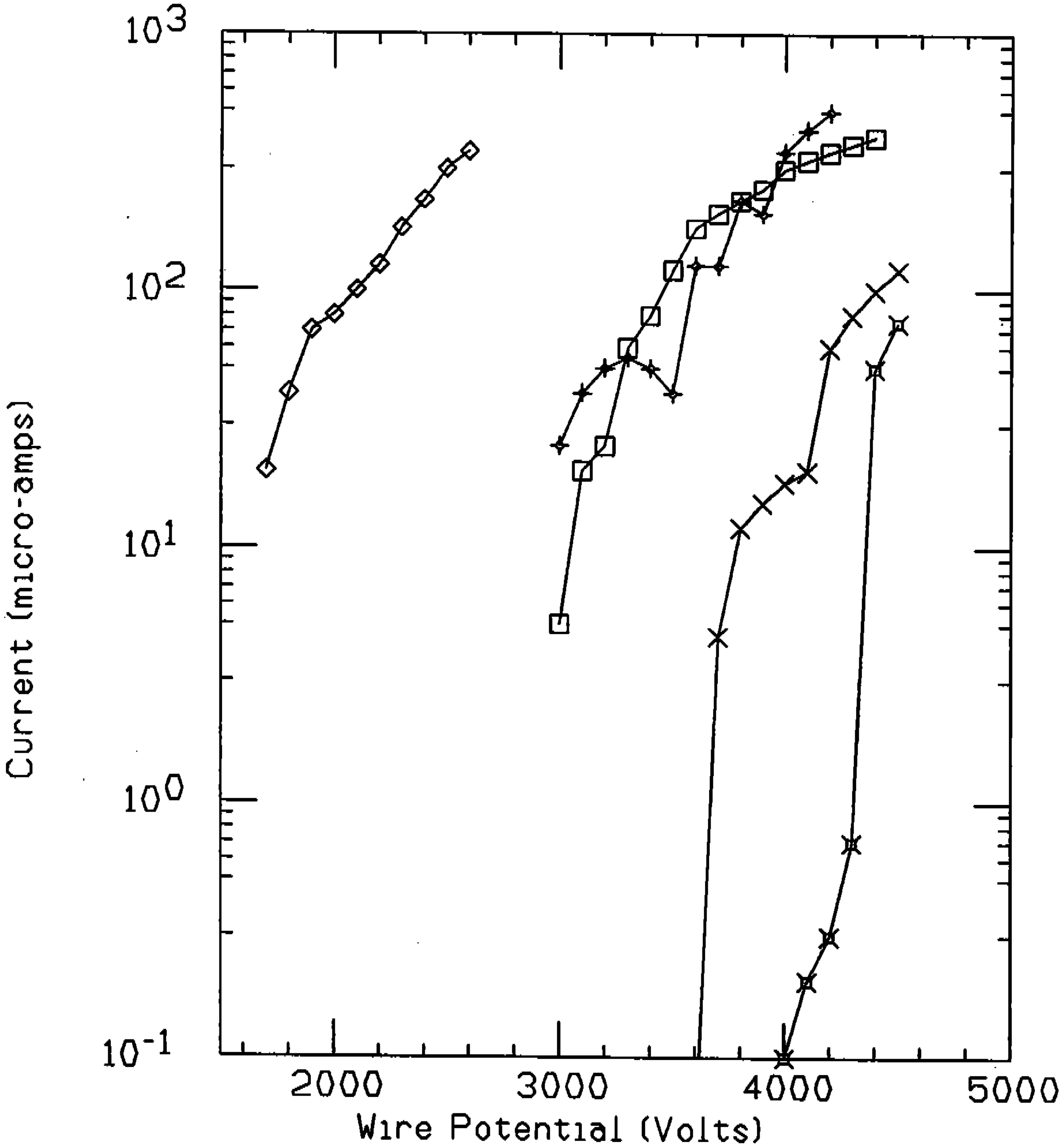
100 micron steel wire

# 70 micron steel wire

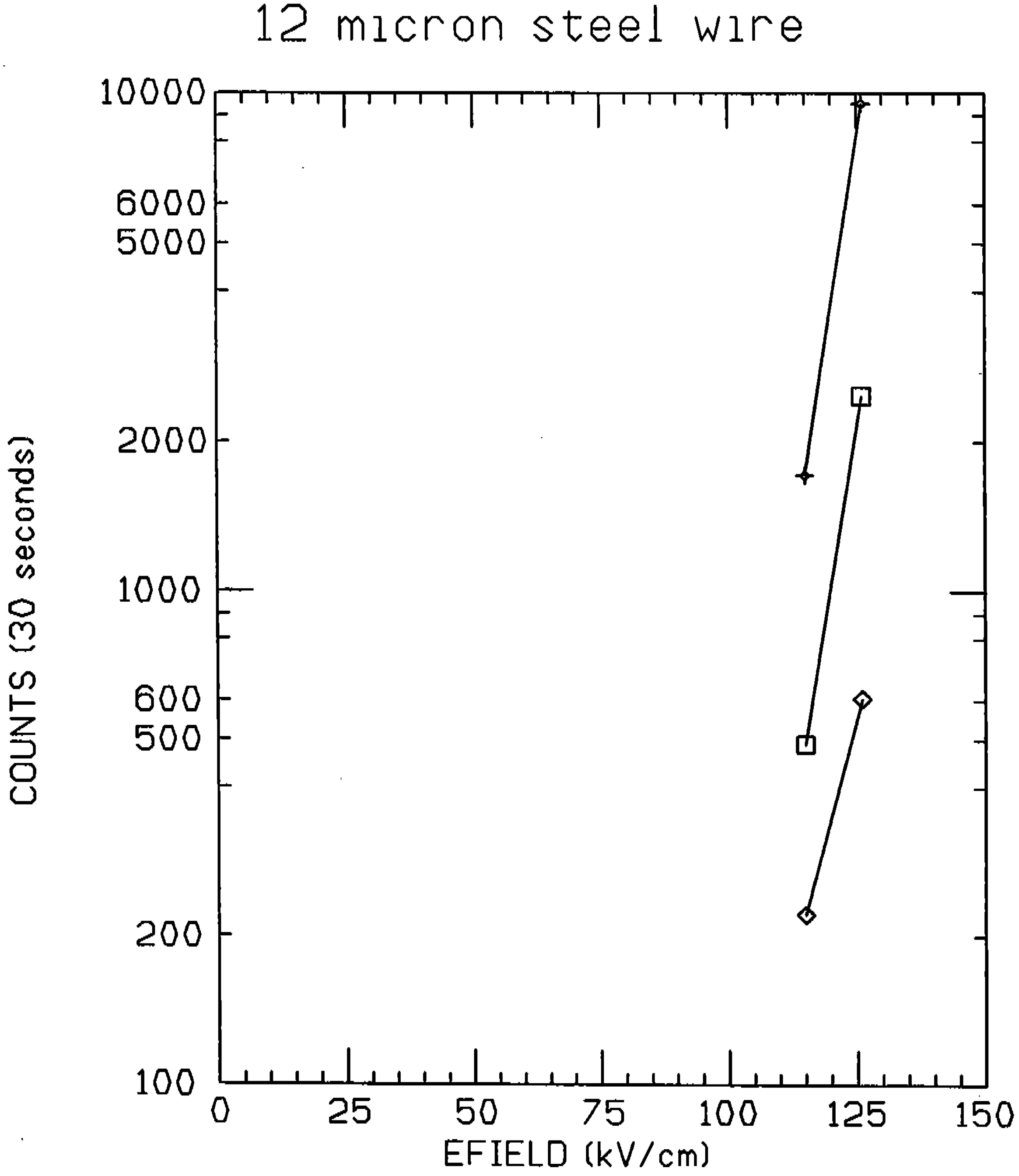




70 micron steel wire



$10^3$
$10^2$
$10^1$
$10^0$
$10^{-1}$
Current (micro-amps)
2000
3000
4000
5000
Wire Potential (Volts)


12 micron steel wire
COUNTS (30 seconds)
10000
6000
5000
2000
1000
600
500
200
100
0
25
50
75
100
125
150
EFIELD (kV/cm)