CATHODE DISCHARGE SIMULATION

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SIMULATION OPERATION

A Python Based FTCS Method

The Forward Time, Central Space Method

- Movement of Voltage (i.e. charge) through cathode is governed by a diffusion equation.

$$R_s C_s \frac{\partial \varphi}{\partial t} = \nabla^2 \varphi$$

- Uses central difference approx. for laplacian (2nd spacial derivative in 2d)

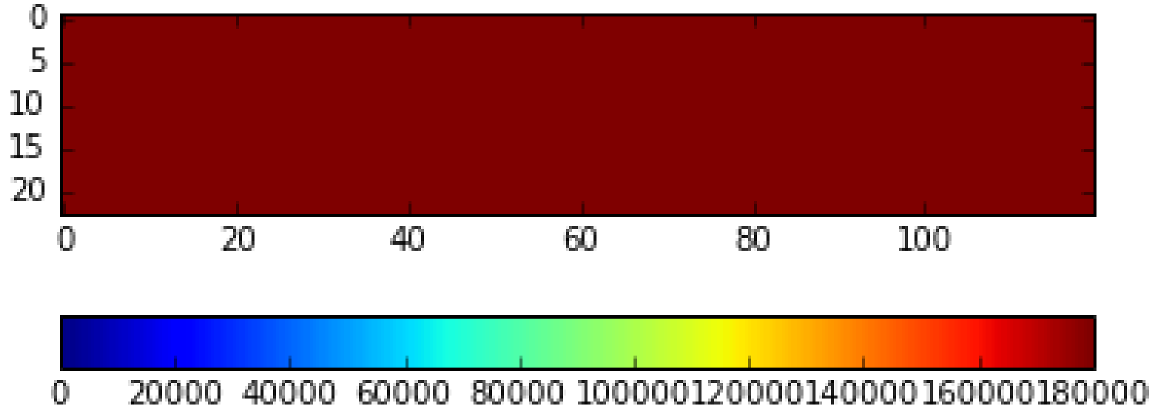
$$\nabla^2 \varphi_{i,j} = \frac{1}{\Delta x^2} \left[\varphi_{i-1,j} + \varphi_{i+1,j} + \varphi_{i,j-1} + \varphi_{i,j+1} - 4\varphi_{i,j} \right]$$

- Combining this with the explicit Euler integration method

$$\Delta \varphi_{i,j} = \frac{\Delta t}{R_s C_s \Delta x^2} \left[\varphi_{i-1,j} + \varphi_{i+1,j} + \varphi_{i,j-1} + \varphi_{i,j+1} - 4\varphi_{i,j} \right]$$

- We want to model the cathode as not just a single plate of dimension Height x Width, but also as a series of n cathodes with dim. (height/n) x width
- Found the simplest method was to use separate numpy arrays for each cathode rather than to combine them into a single array
- To account for the loss of dimension by two in our finite difference calculation of the Laplacian, we can pad each array by 1 on all sides
    - Assumed that no current flows out of cathode except at connections to HV. i.e. no current through the frame. Therefore our padding is set equal to next inward array elements to have no effect on derivatives
- Then, we can connect the cathodes by changing the padding values at specified connection points to the value of the array element of the other cathode to which it is connected.
- Same approach allows connection to HV by instead setting at 0V

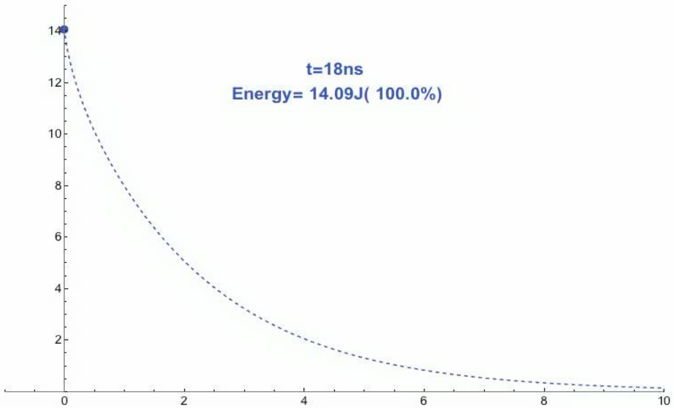
- This multiple array method allows allows us to simulate a single cathode plate by simply connecting the arrays at all points across the edge
- Shown below is a 12m x 2.3m cathode initialized to 180000V, using square 10cm elements

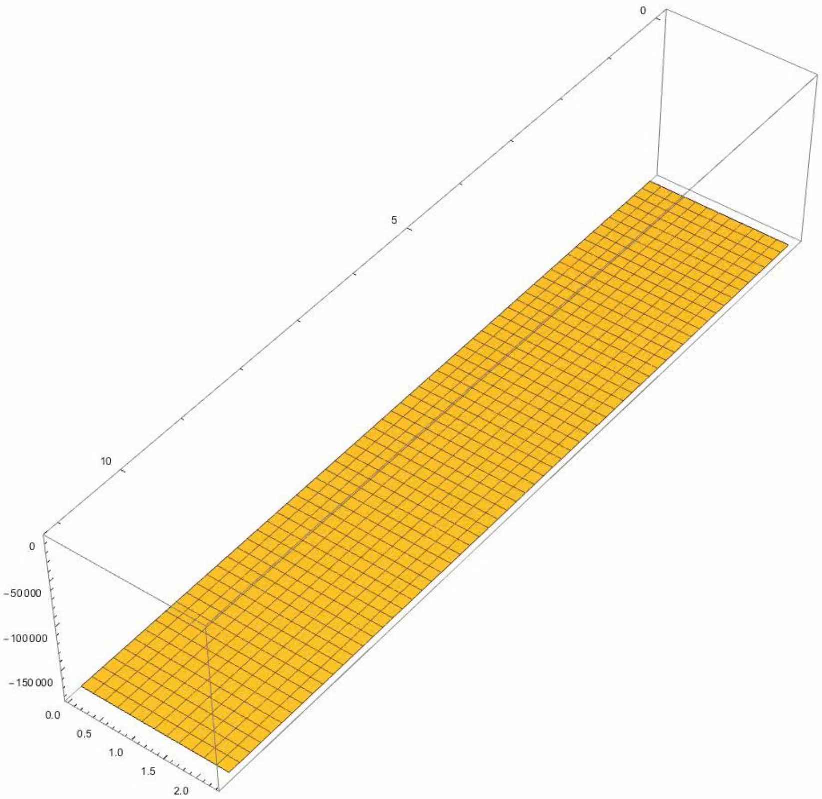


APPLES TO APPLES

Past Simulation Results

- Past results from Bo Yu and Sergio Rescia showed a single cathode plate dropped to ~56% of its initial energy after 1s of discharge
- So, we set up the same cathode parameters, but with our code not accounting for effects from the cathode frame

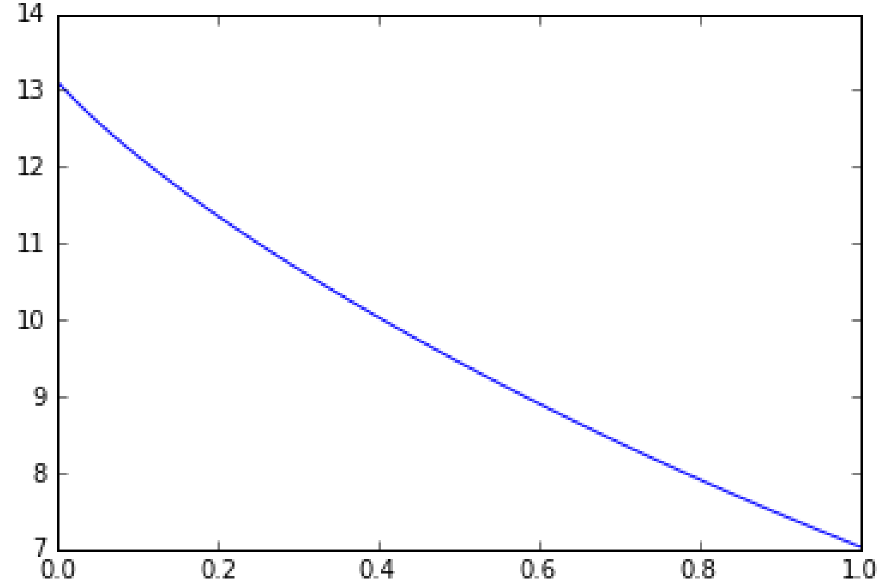




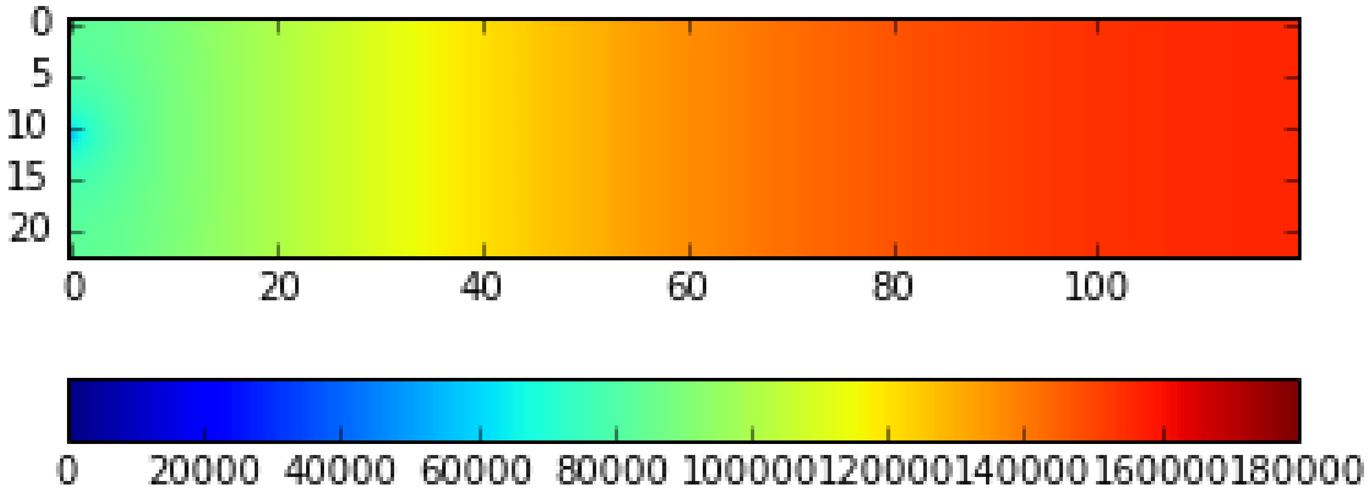
Our Results

- After 1 s of discharge, our simulation found that the energy of the cathode had decreased to 53.7% of its original energy.

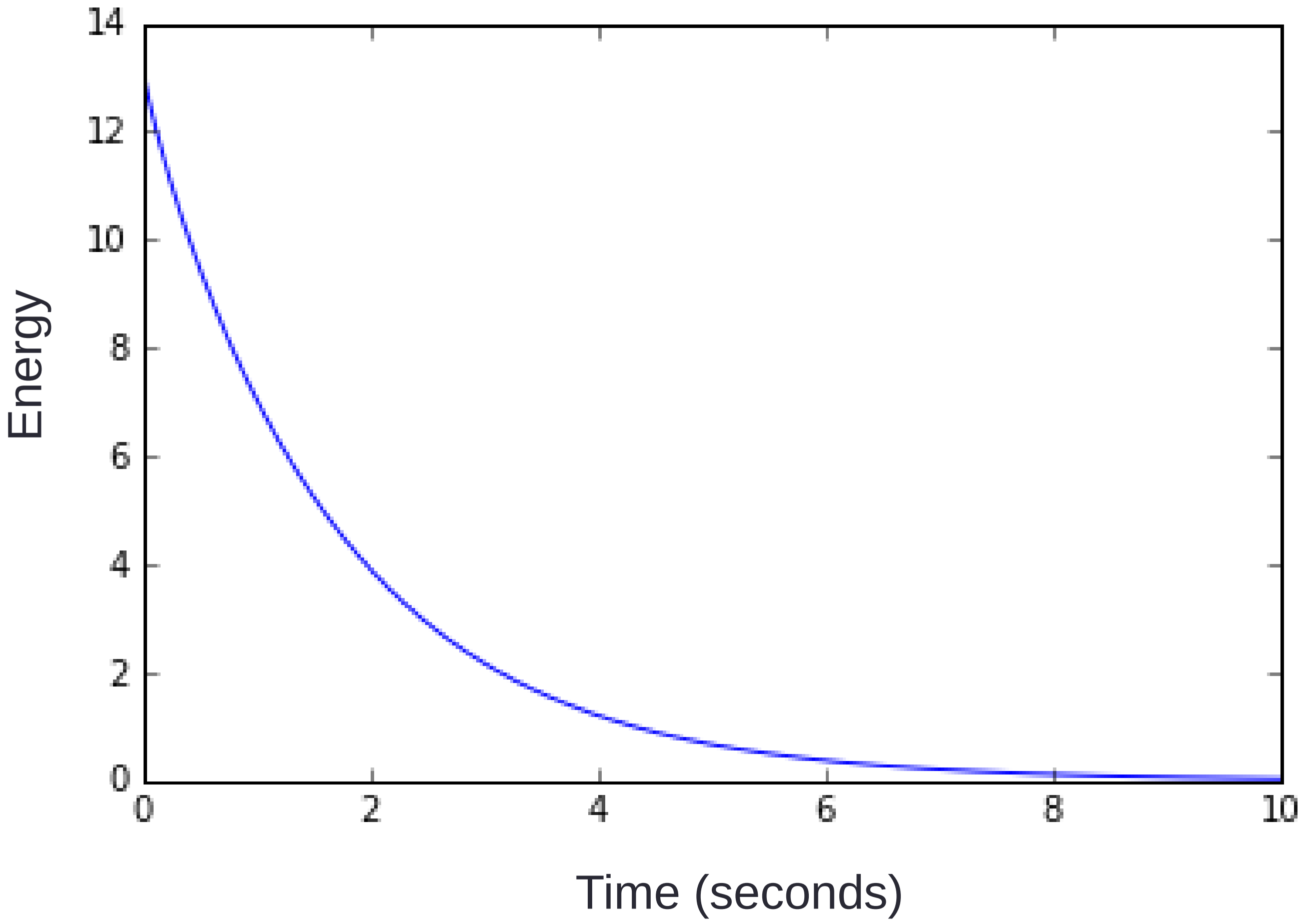
Plot of Energy v. Time



Cathode Voltage at t=1s



- Additionally, over the course of the full 10s data range of the previous results, we saw the following behavior.

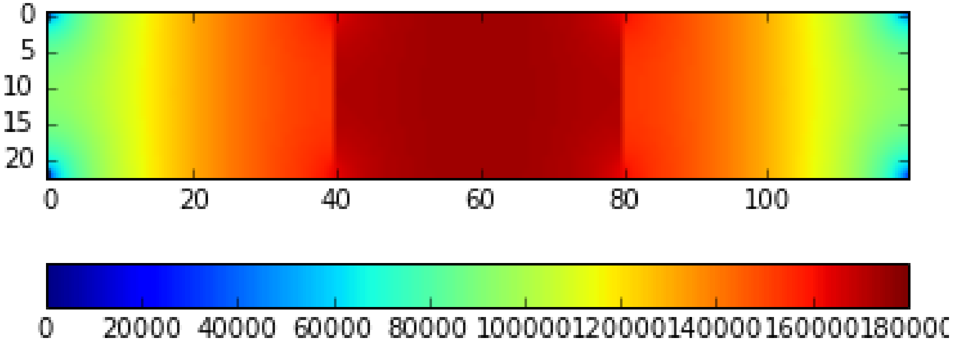


NEW FINDINGS

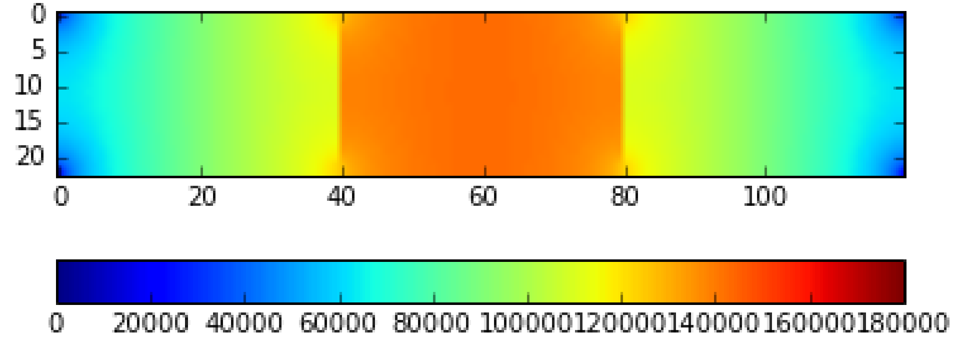
Initial Results for Multi Segment Cathodes

- Now:
  - split same cathode into 3 segments
  - Connected to 0V at topmost and bottommost corners
  - Segments have 2 connections on either side
- Still using a 12m by 2.3m cumulative size for cathode
- Still have dx = .1m
- New R and C
  - R = 1e6 Ohms/sq.
  - C = 7.398e-12 F/m^2

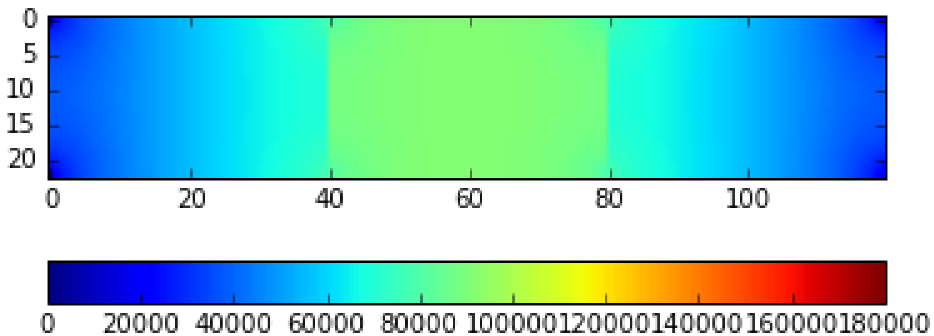
T = 40 us



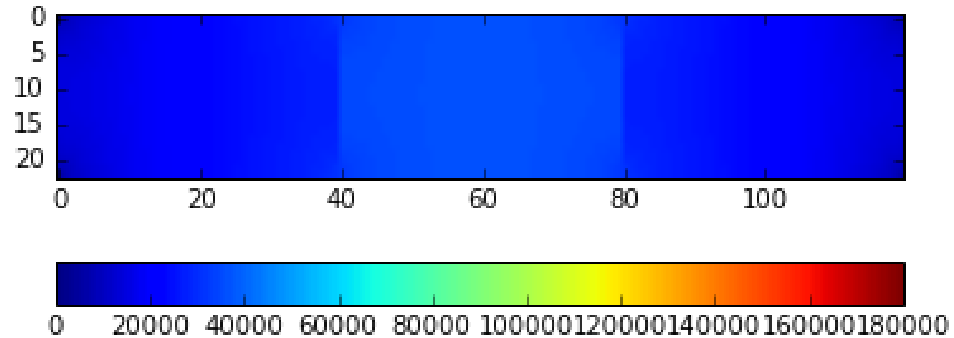
T = 100 us



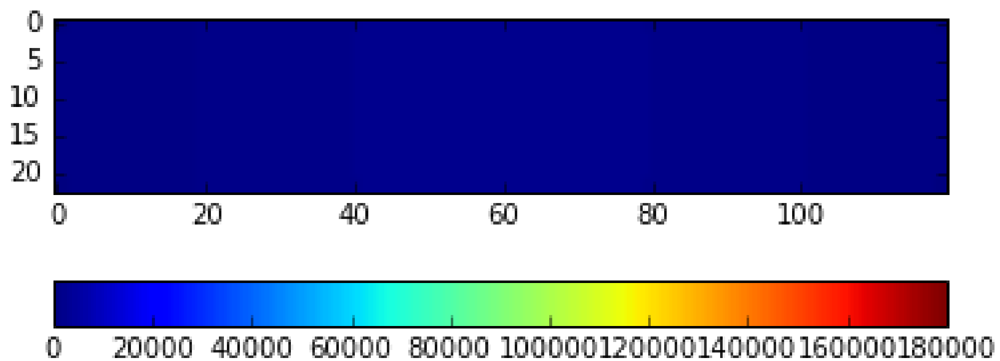
T = 200 us



T = 400 us

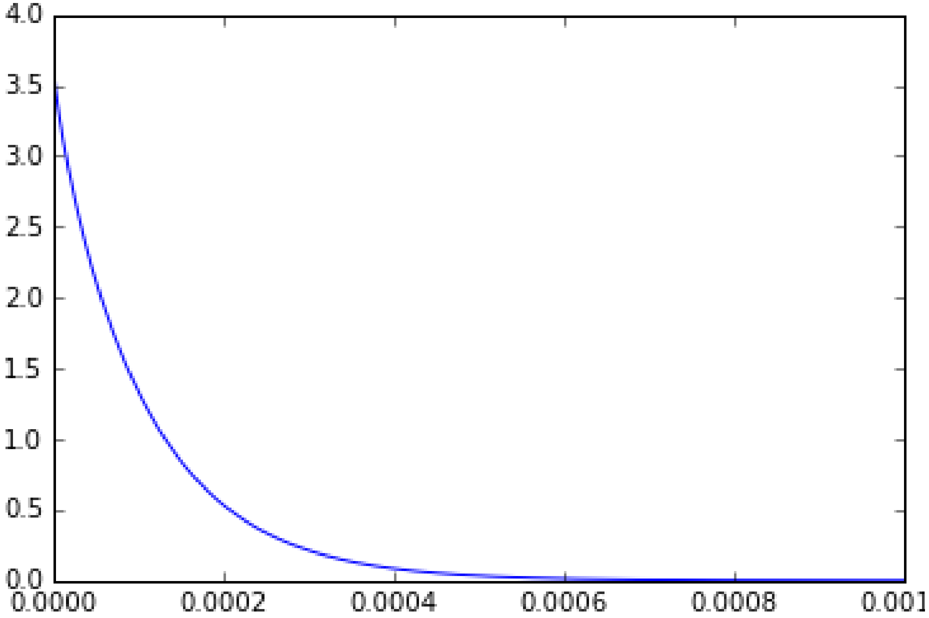


T = 1 ms

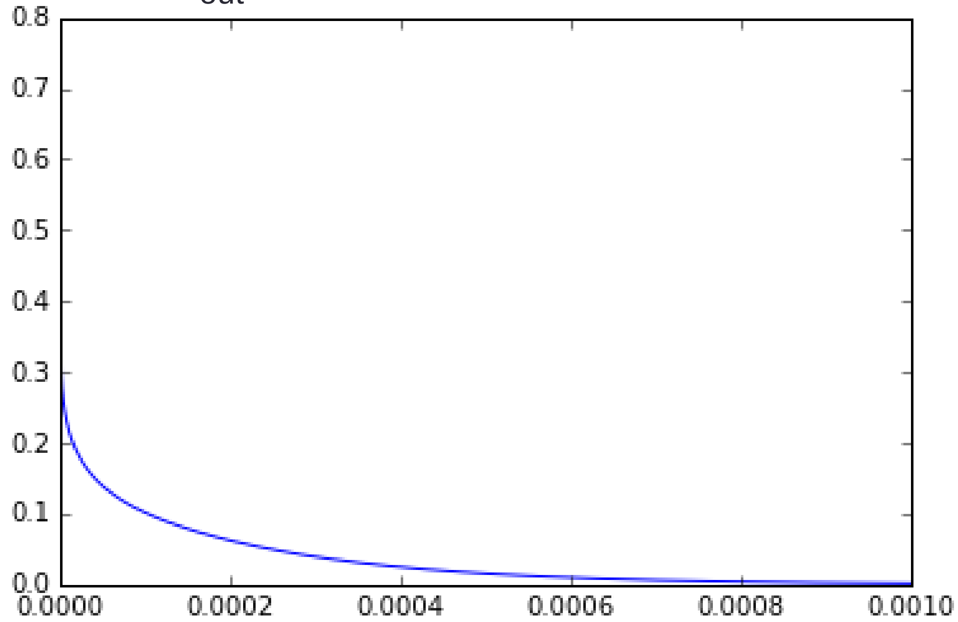


Plotting Energy and Current Out

Energy v. Time

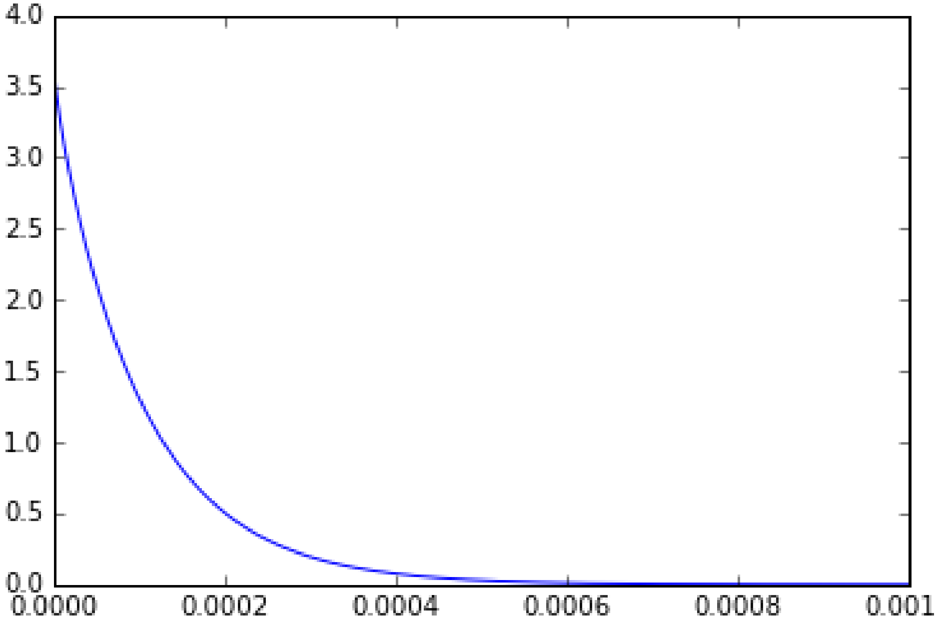


I_{out} v. Time

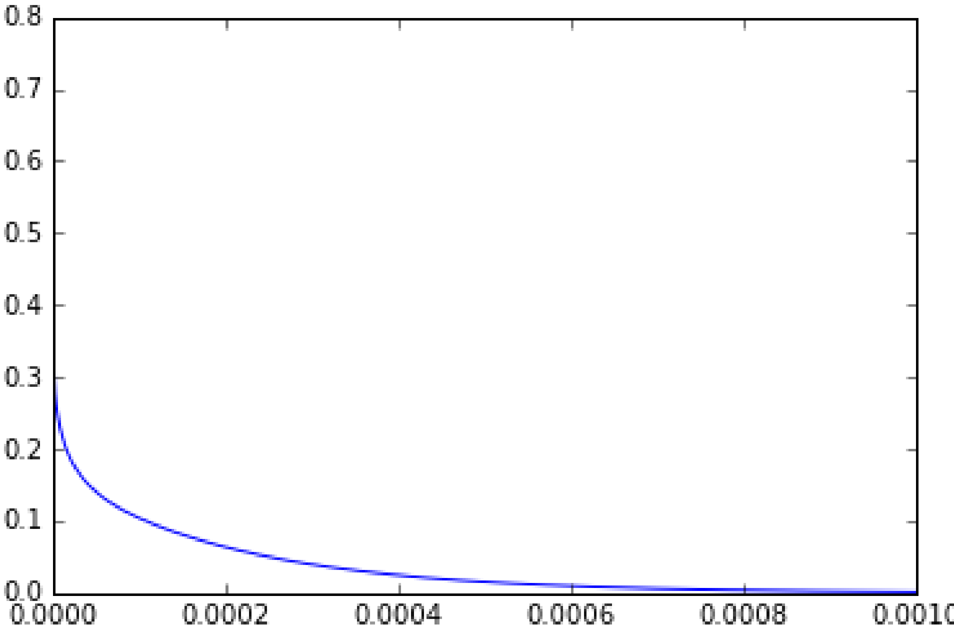


Doubling The Number of Connections on Each Side

Energy v. Time

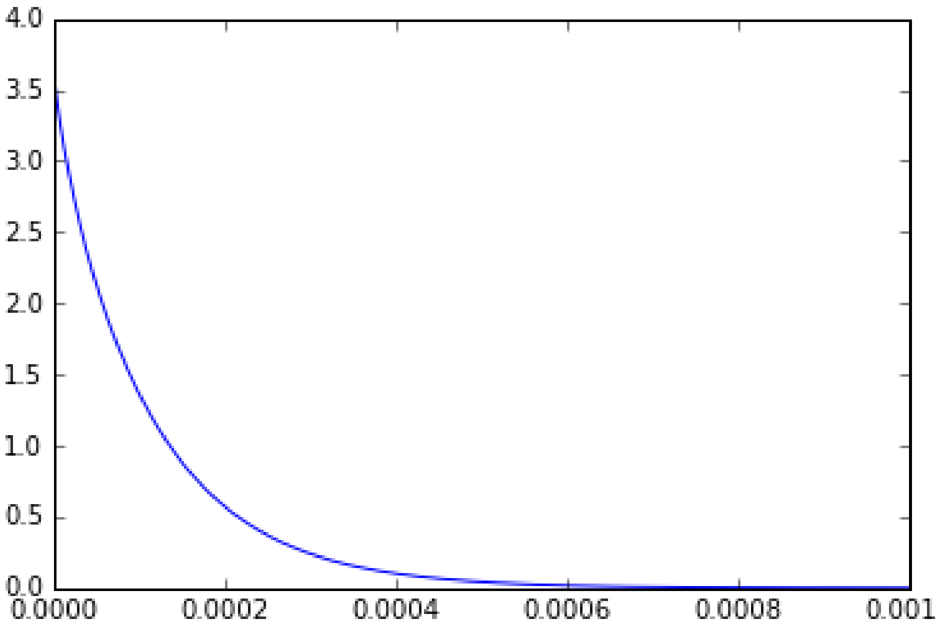


I_{out} v. Time

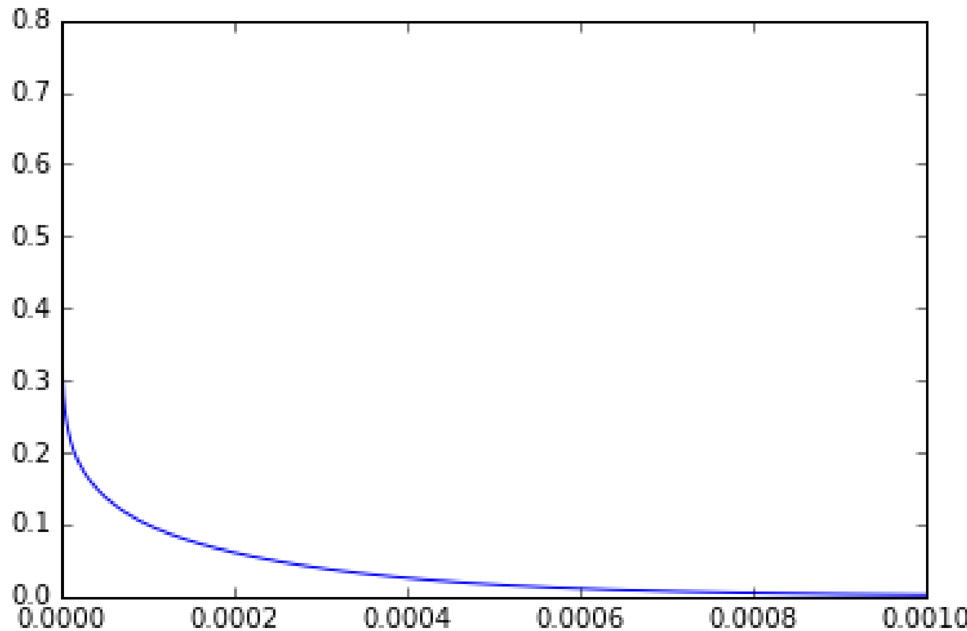


One Connection

Energy v. Time

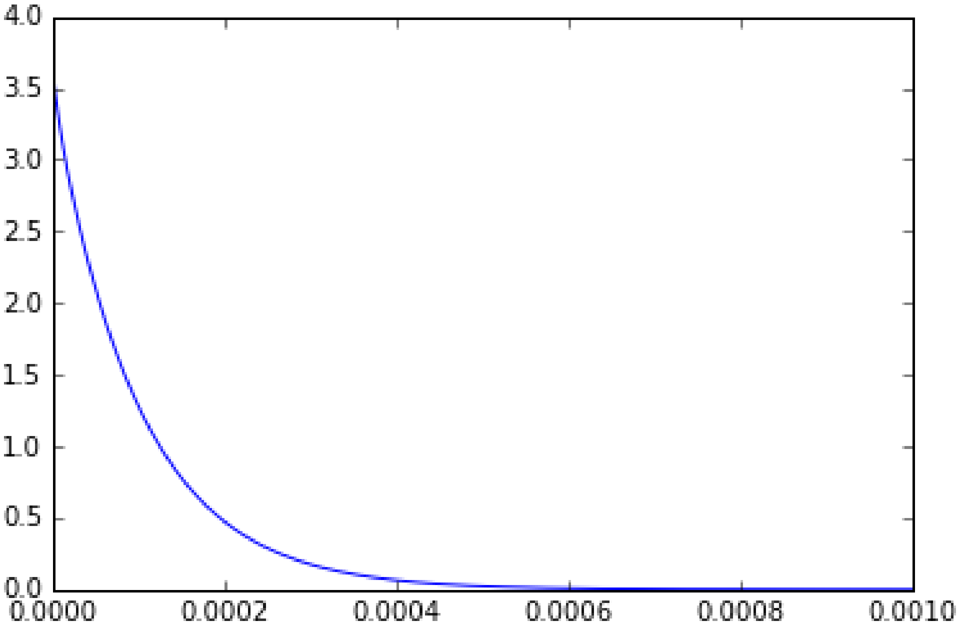


I_{out} v. Time

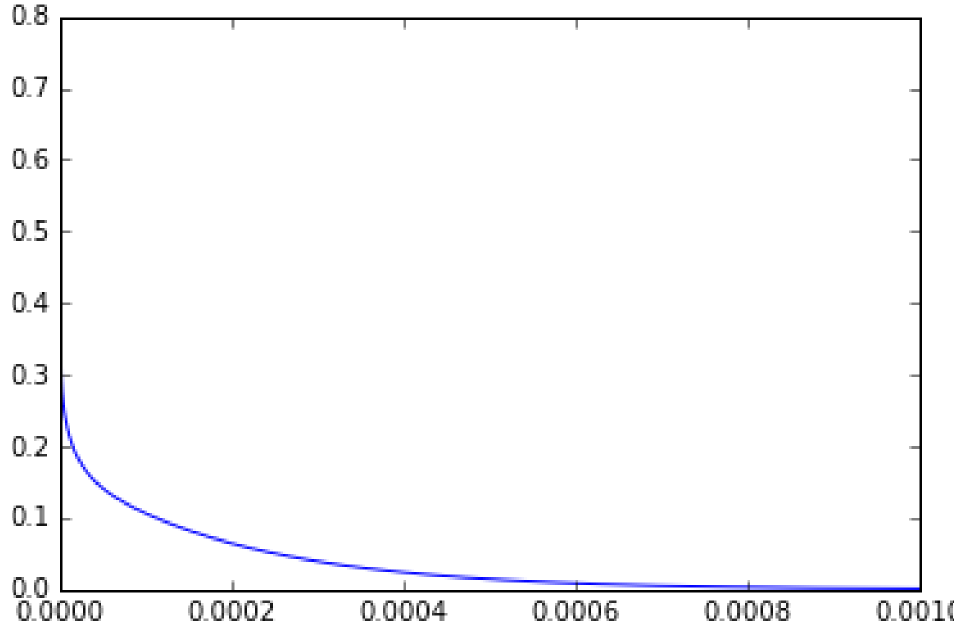


Comparison to all connections

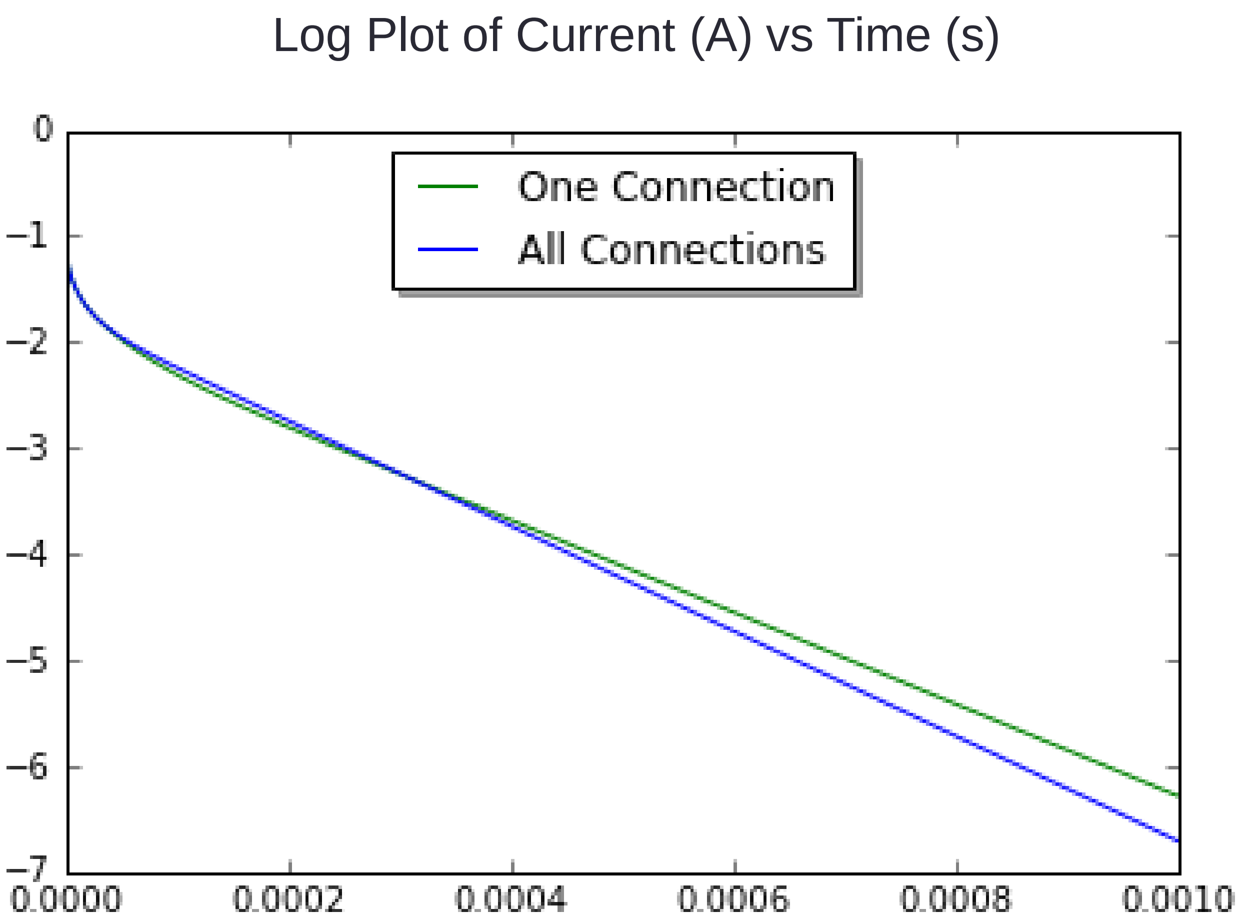
Energy v. Time



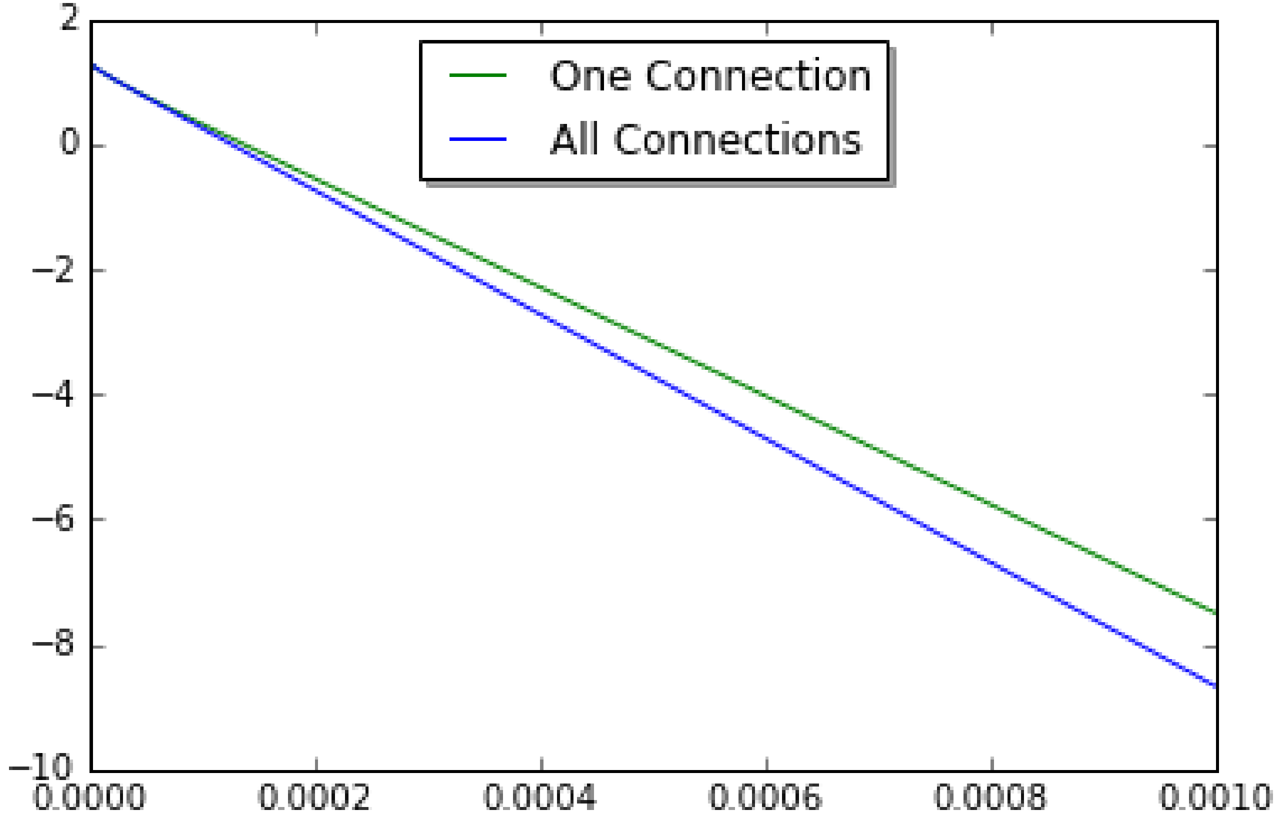
I_{out} v. Time



What's the Difference



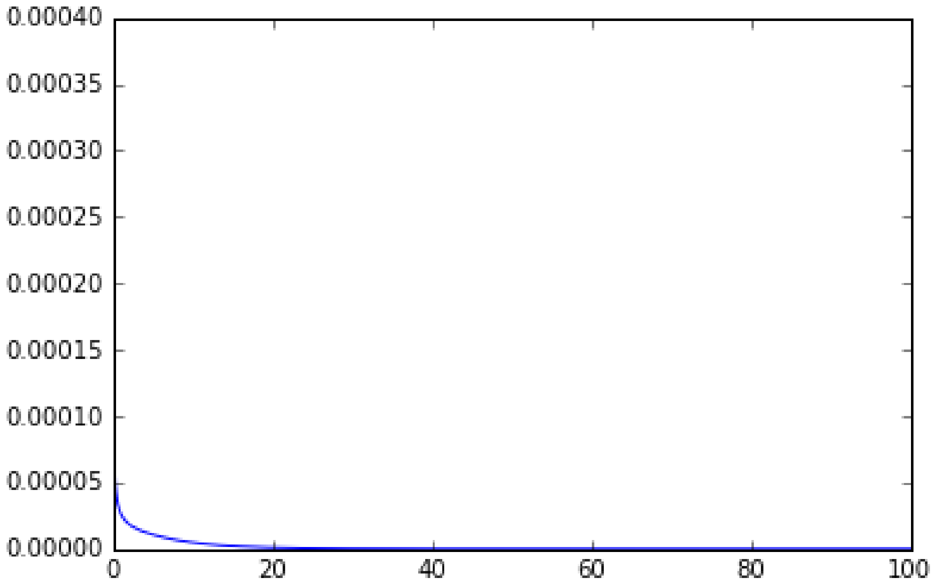
Log Plot of Energy (J) vs Time (s)



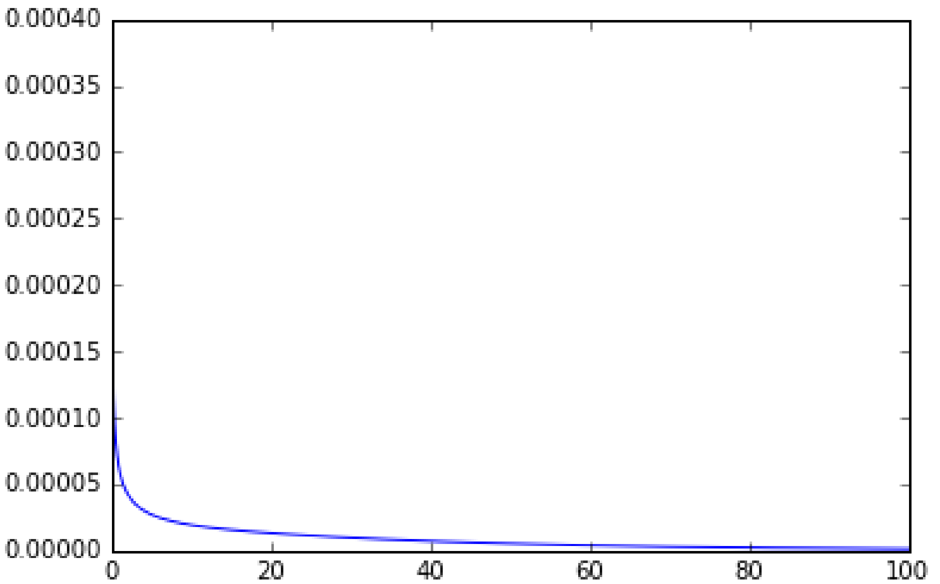
Adding the Field Cage

- After presenting this to the DUNE HV group, I was then asked if I could adding in a simulation of the field cage discharging as they are fed by the same HV cable. So I did that for both of the side lengths of the field cage.

Short Side I

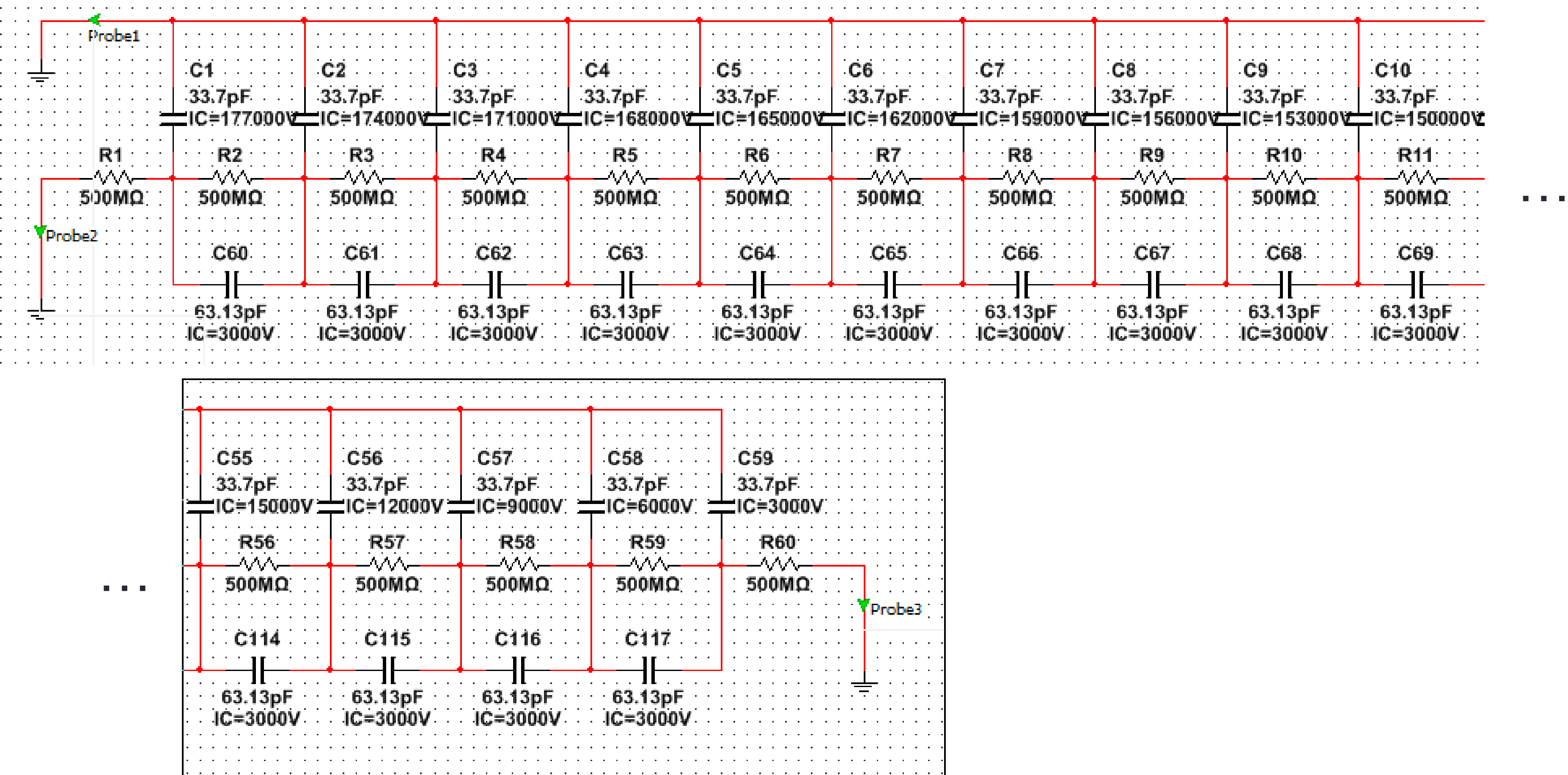


Long Side I



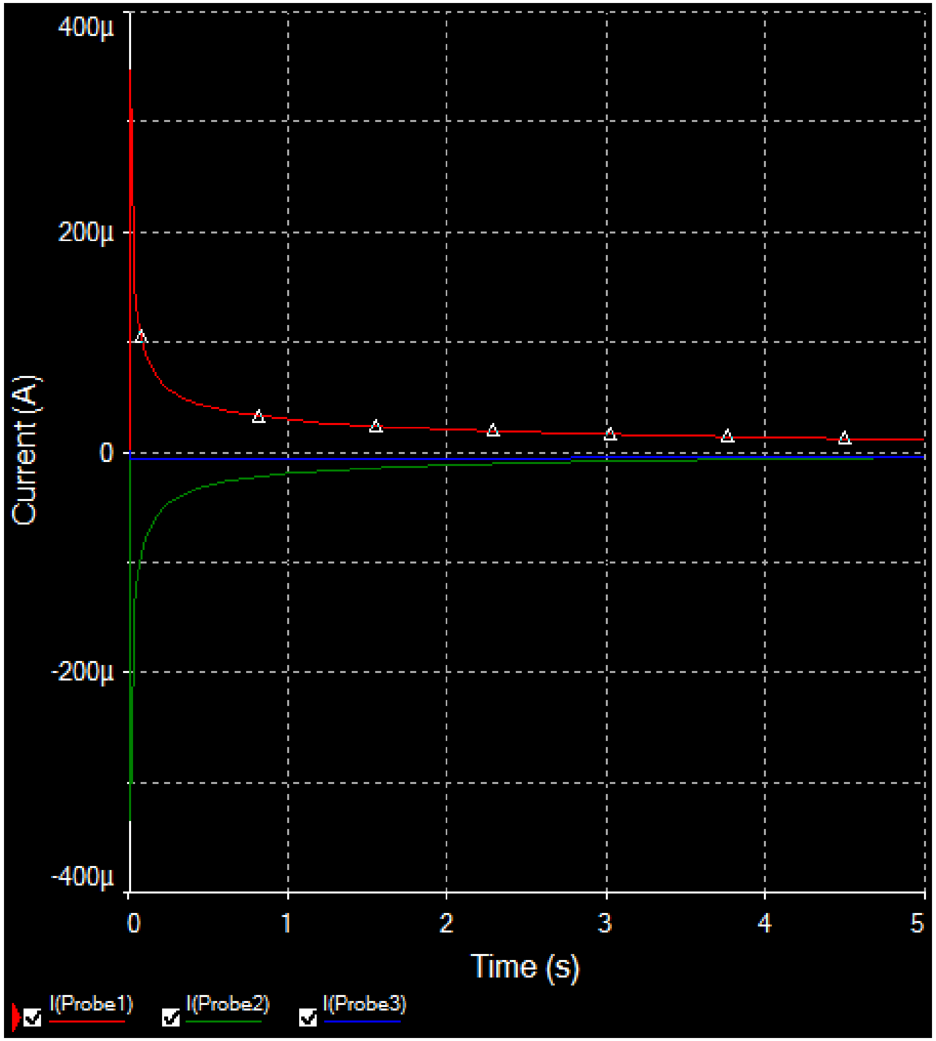
Comparison

- Then, I made a SPICE circuit simulation of the field cage discharge to compare with my results

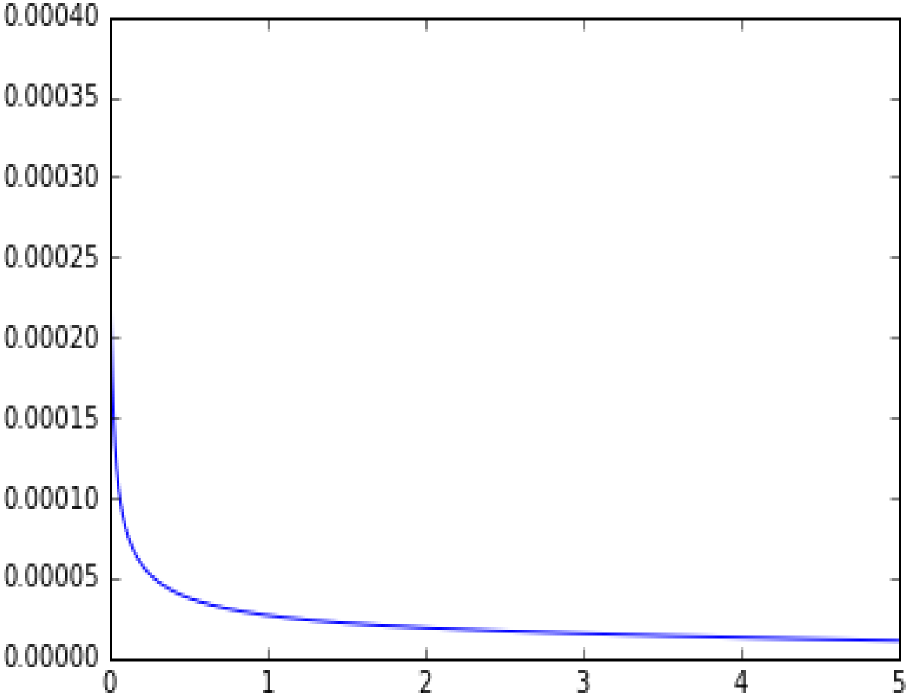


Comparing Results

SPICE



PYTHON



What's Next?

- Now, I'm working on using these simulations of the changing voltage in the cathode to look at what this does to the electric field at the anode plane, to see if the induced currents are large enough to be a problem for the sensitive detection apparati to which it is connected.