Potential Catastrophic Failure Modes
- Cathode discharge effect on FE electronics

Veljko Radeka, Sergio Rescia, Bo Yu

BNL

CE Review, Oct 14-16, 2016

Cathode Discharge Input to the Anode → drift field disappears

- … a charge is left on the anode: $q = D = \varepsilon^{'}\varepsilon_0 E$
- E= 500 V/cm is planned for LAr TPCs in all our projects
- Charge per unit area:

$$q = 1.5 \times 0.08854 \times 10^{-12} \times 500 = 66\, pC/cm^2$$

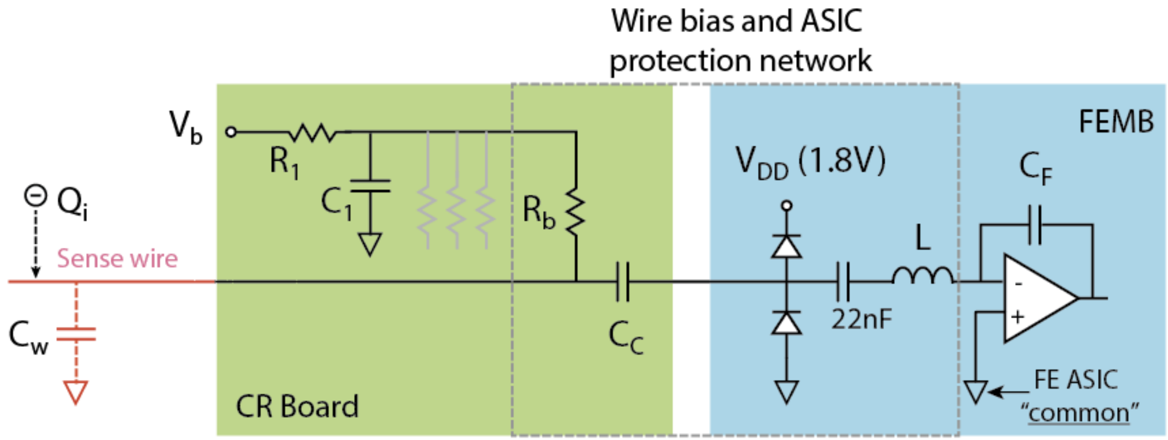
- 5 meter long sense wire, 3 mm wire spacing, occupies ~150 cm^2, resulting in **Q(0)~10 nC**
- Assume: the drift field decays with a time constant ***τ*** **→** the peak current into the readout will be:

$$i_p = {Q(0)}/{\tau} = 10\,A \quad 1\,A \quad 0.1\,A$$

$$for \quad \tau = 1ns \quad 10ns \quad 100\ ns$$

Questions:

1. What current can the readout take without damage?
2. How much do we know about the tau?
3. Can we control tau?



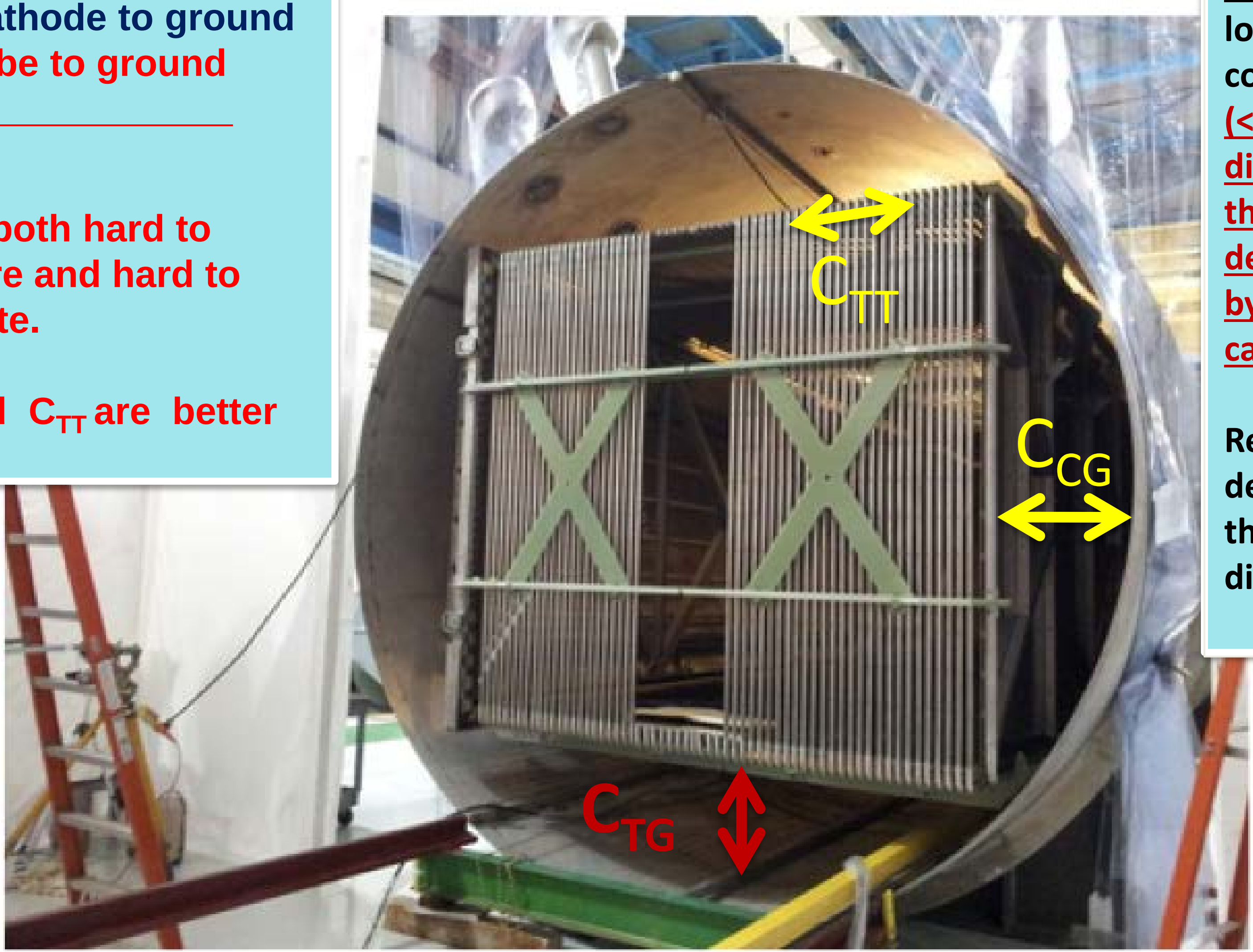
The protection diode in MB, BAV99 is rated at 8 A for 300 µs; with a series resistance of ~ 1ohm the voltage will exceed the CMOS max gate voltage. A peak current of ~ ! A will be in the safe range.

Field Cage-Cryostat is a HV-resistive-capacitive system

C_{TT} = tube to tube
C_{CG} = cathode to ground
C_{TG} = tube to ground

C_{TG} is both hard to measure and hard to calculate.

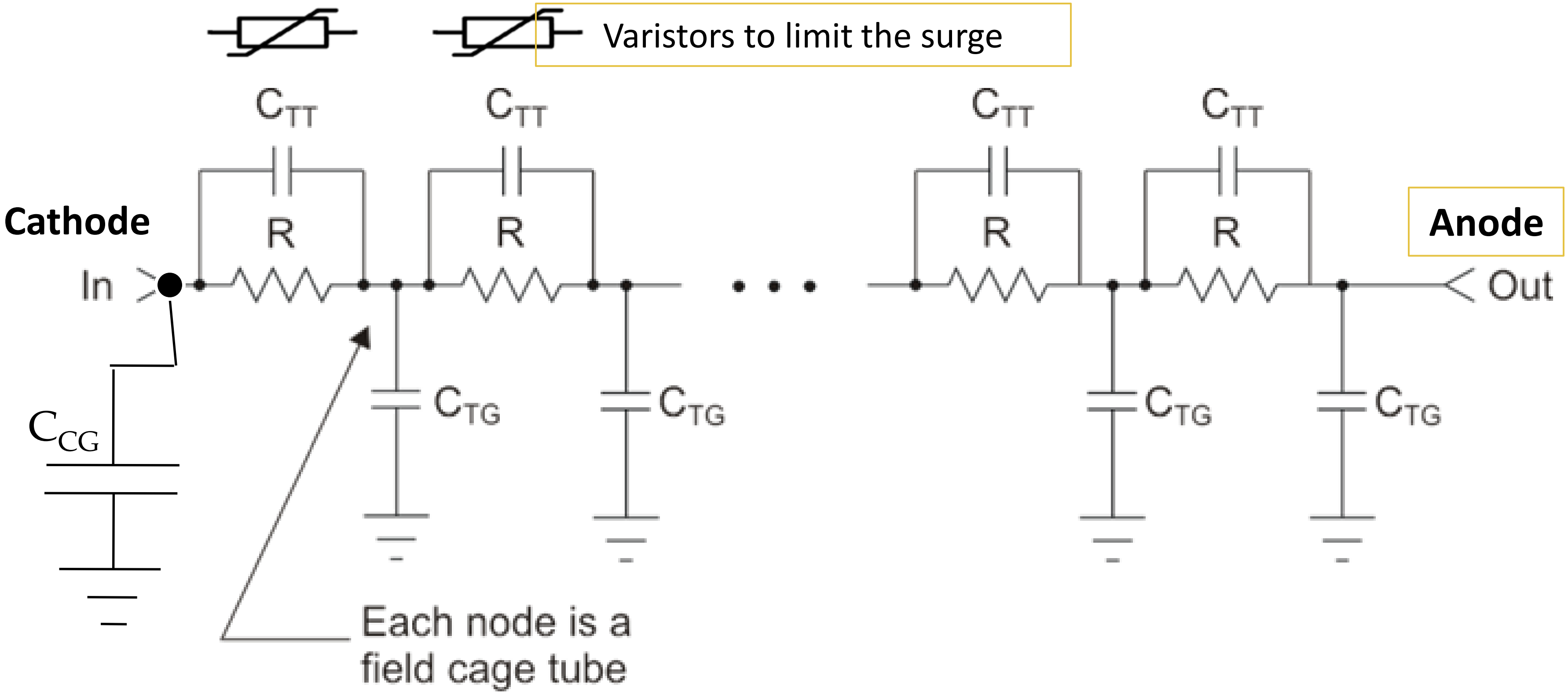
C_{CG} and C_{TT} are better known



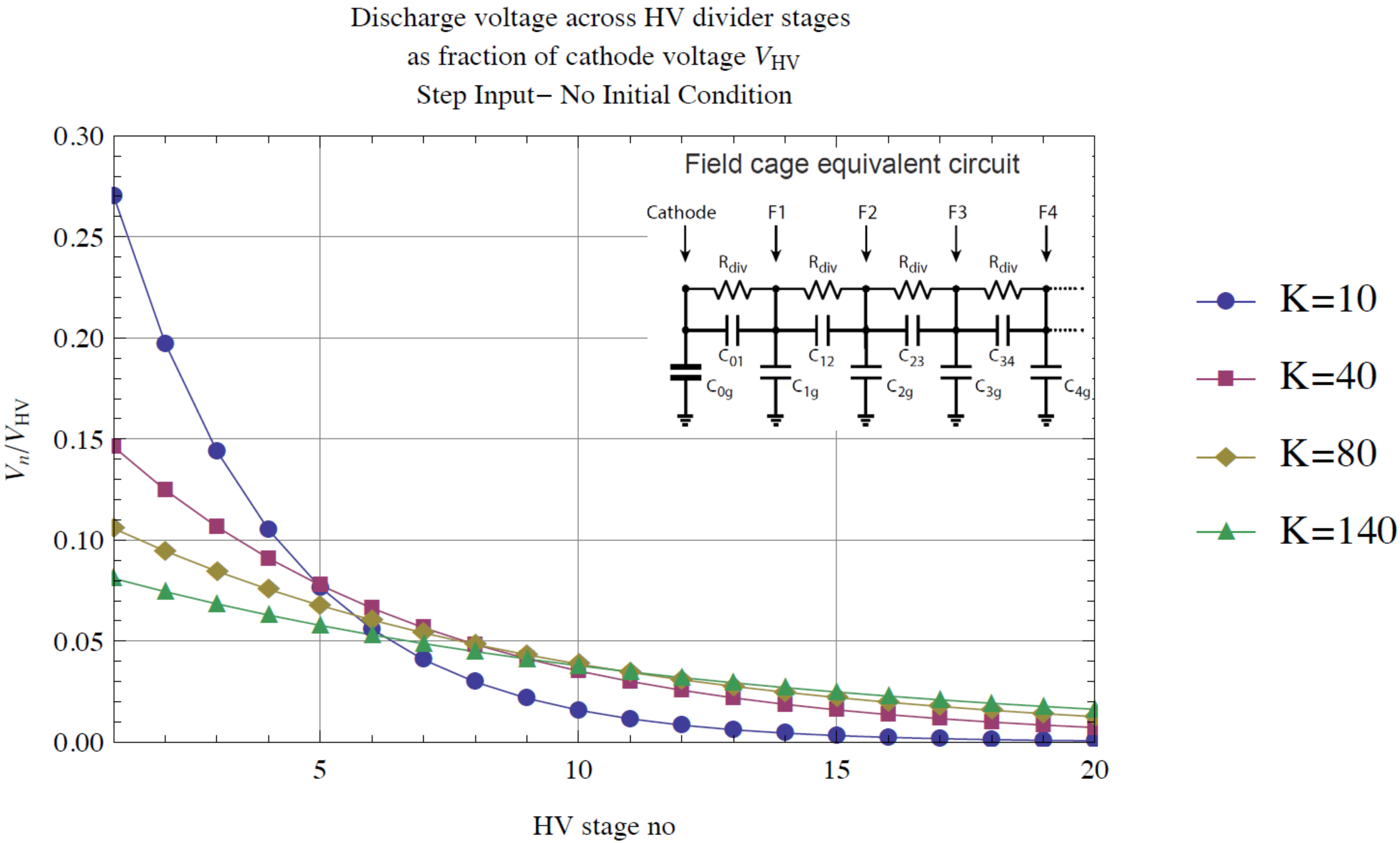
Note: Due to a long RC time constant, dynamic (<1ms) voltage distribution on the field cage is determined solely by the capacitances.

Resistors determine only the static voltage distribution.

TPC Field Cage is a resistive-capacitive network (divider chain)

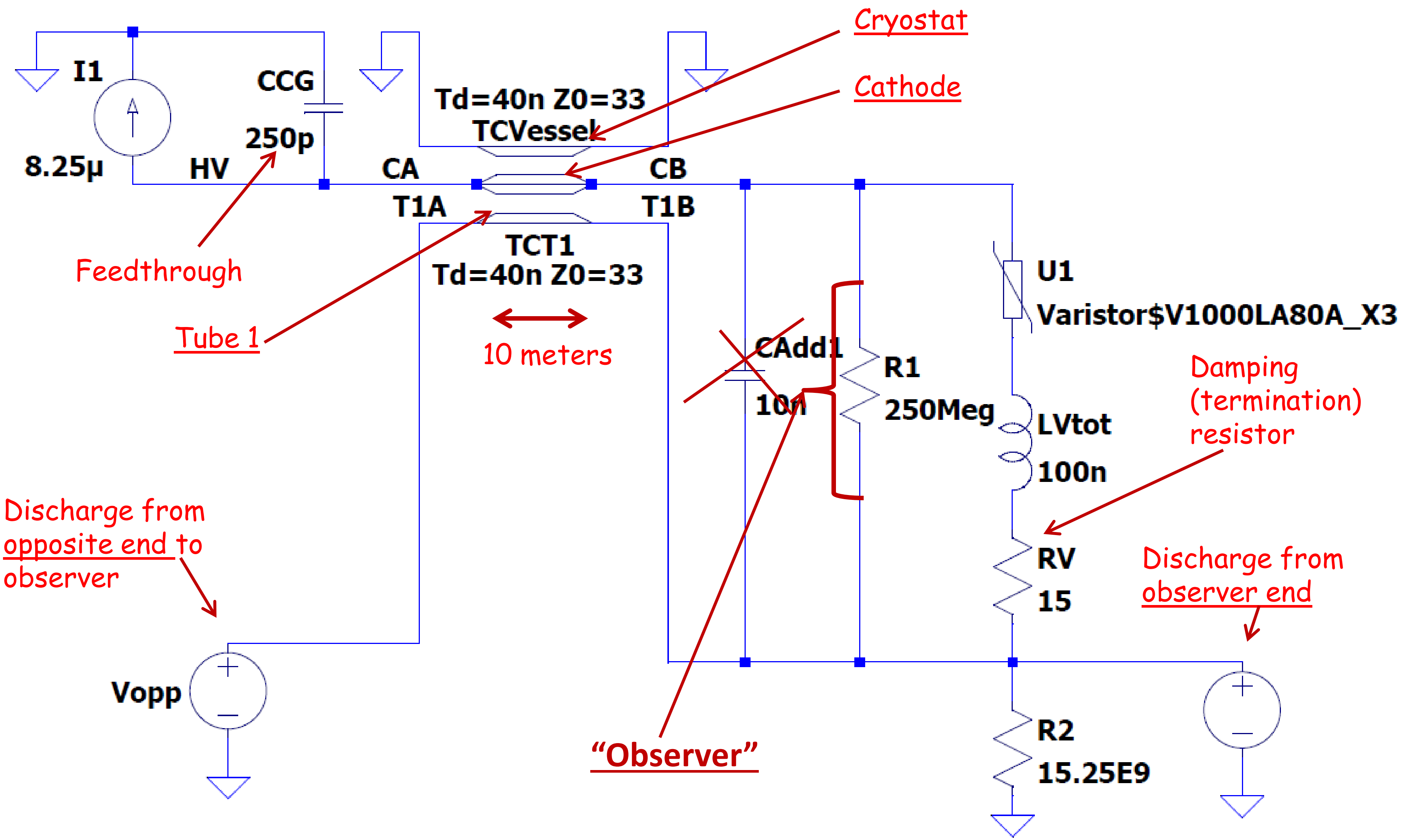


The key parameter in transient voltage distribution after discharge: $K = C_{tt} / C_{tg}$

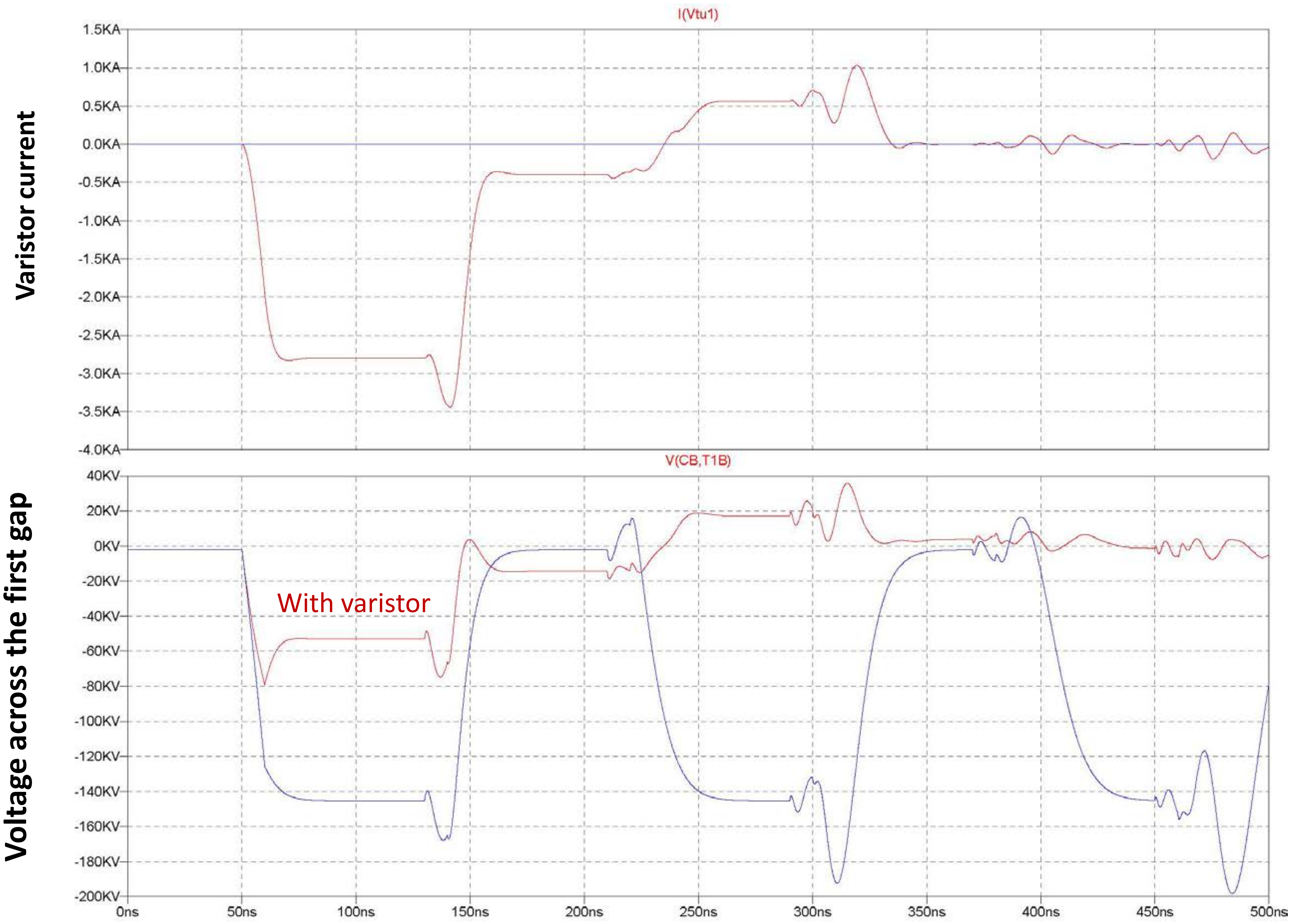


The transient from the cathode spark (short) propagates fast by capacitive division only over ***n/6*** to ***n/3*** field cage tubes; the field cage is then discharged slowly via the large field chain divider resistors.

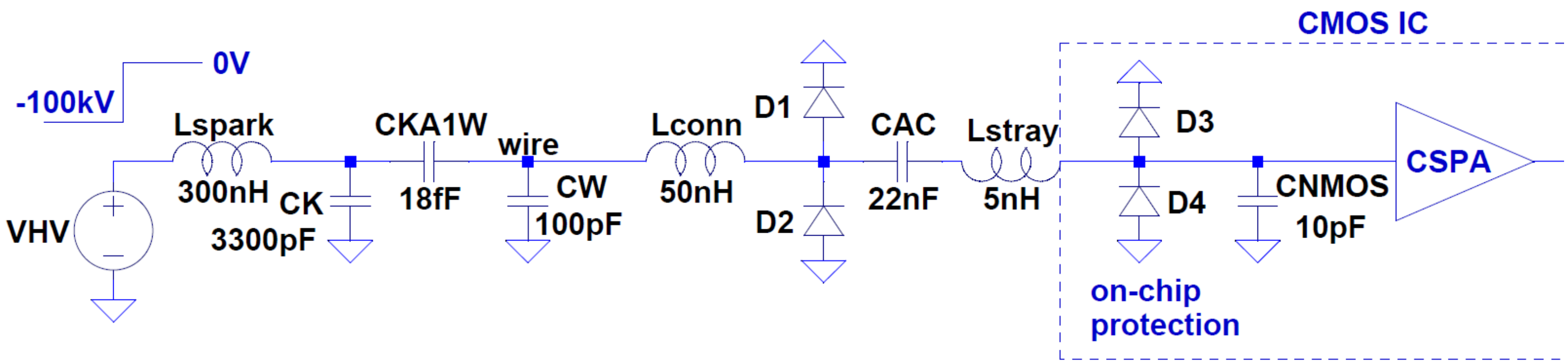
Two-Transmission-Lines Model of the MB Cathode and Tube 1 for Discharge from either end of Tube 1

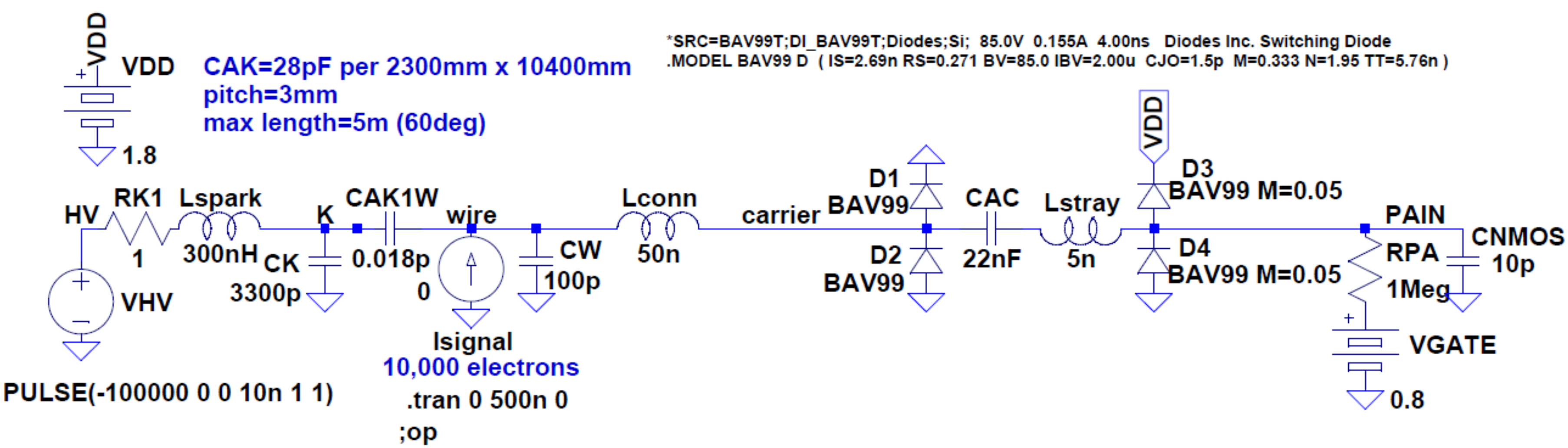


Voltage across the first gap without varistors (blue) ; Varistor current and voltage across the first gap with 3 varistors in series (red); discharge at opposite end

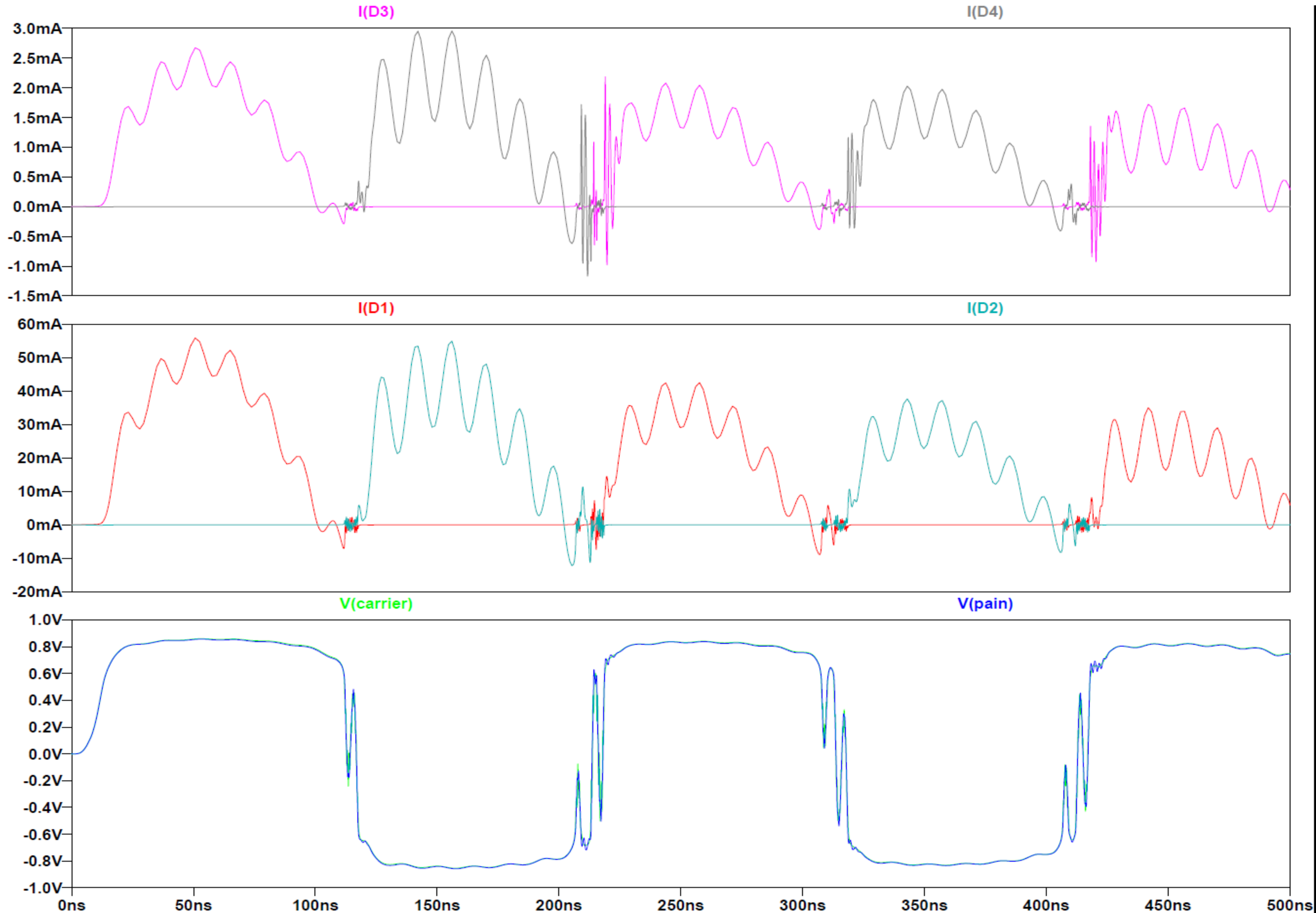


MB input circuit eq. diagrams



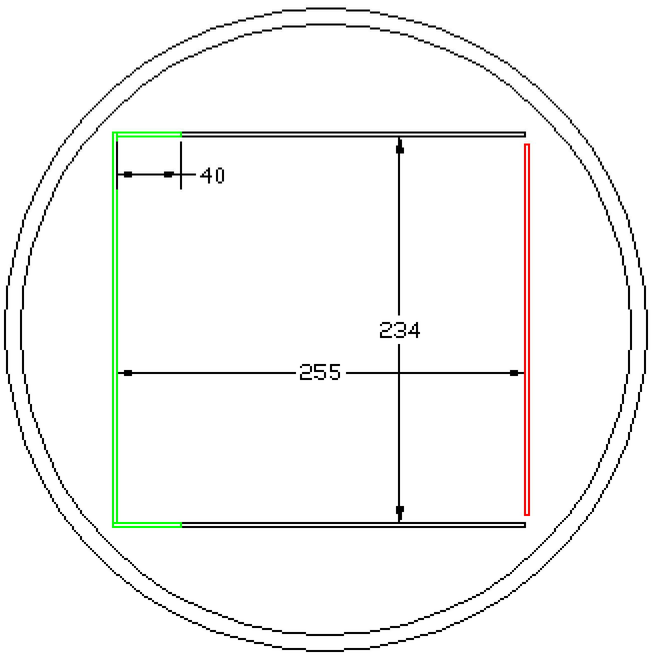


MB discharge simulation

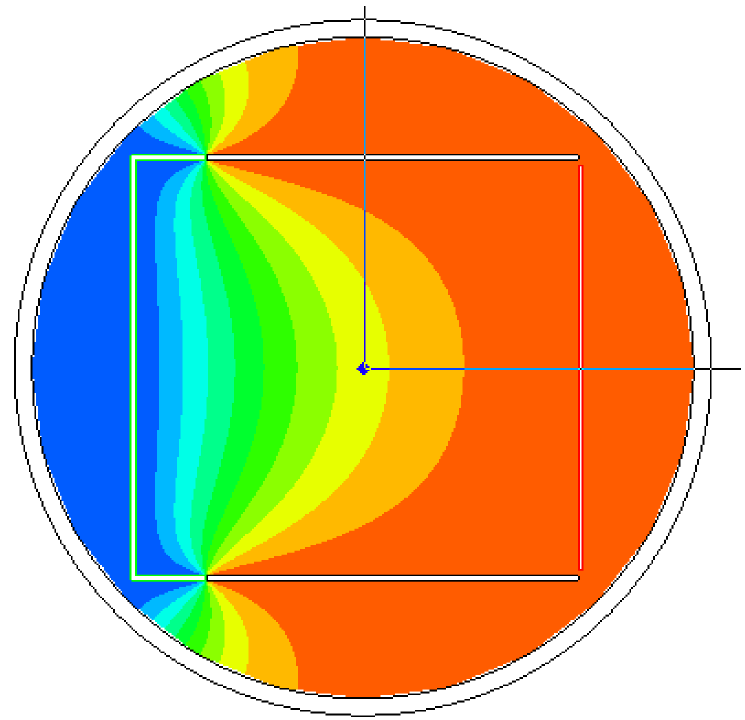


2D MicroBooNE Model

Field cage shielding factor ~ 4.5



-120kV on cathode, rest at ground



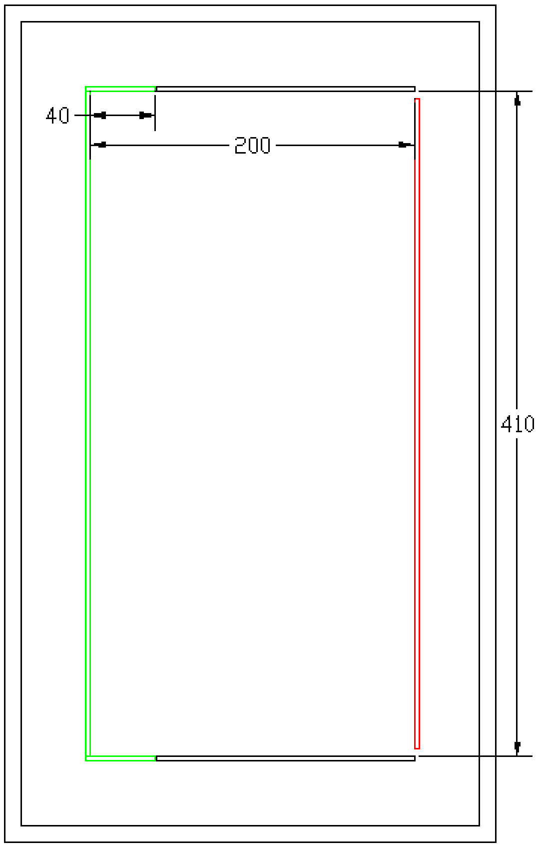
Capacitance matrix:

	anode	cathode
anode	2.07E-10	-2.74E-12
cathode	-2.74E-12	3.30E-10

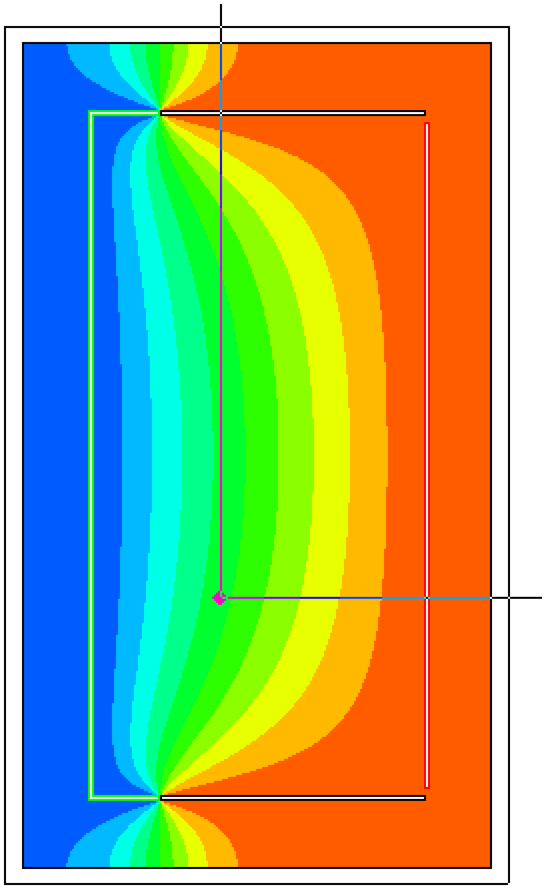
Coupling between cathode and anode planes is 2.74pF /m x 10.4m = 28pF

2D SBND Model (one drift)

Field cage shielding factor ~ 2.5



-100kV on cathode, rest at ground

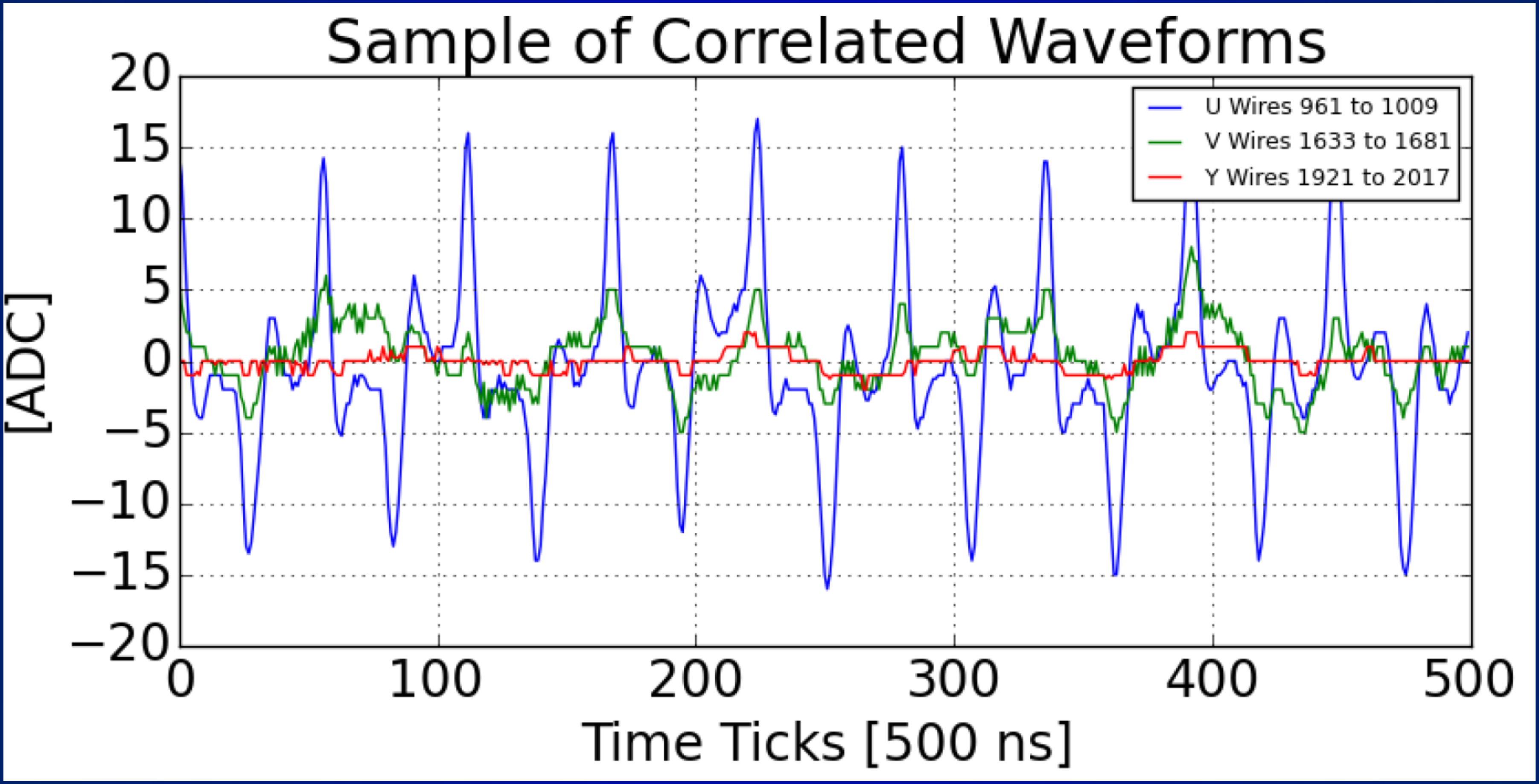


Capacitance matrix:

	anode	cathode
anode	2.80E-10	-1.64E-11
cathode	-1.64E-11	3.54E-10

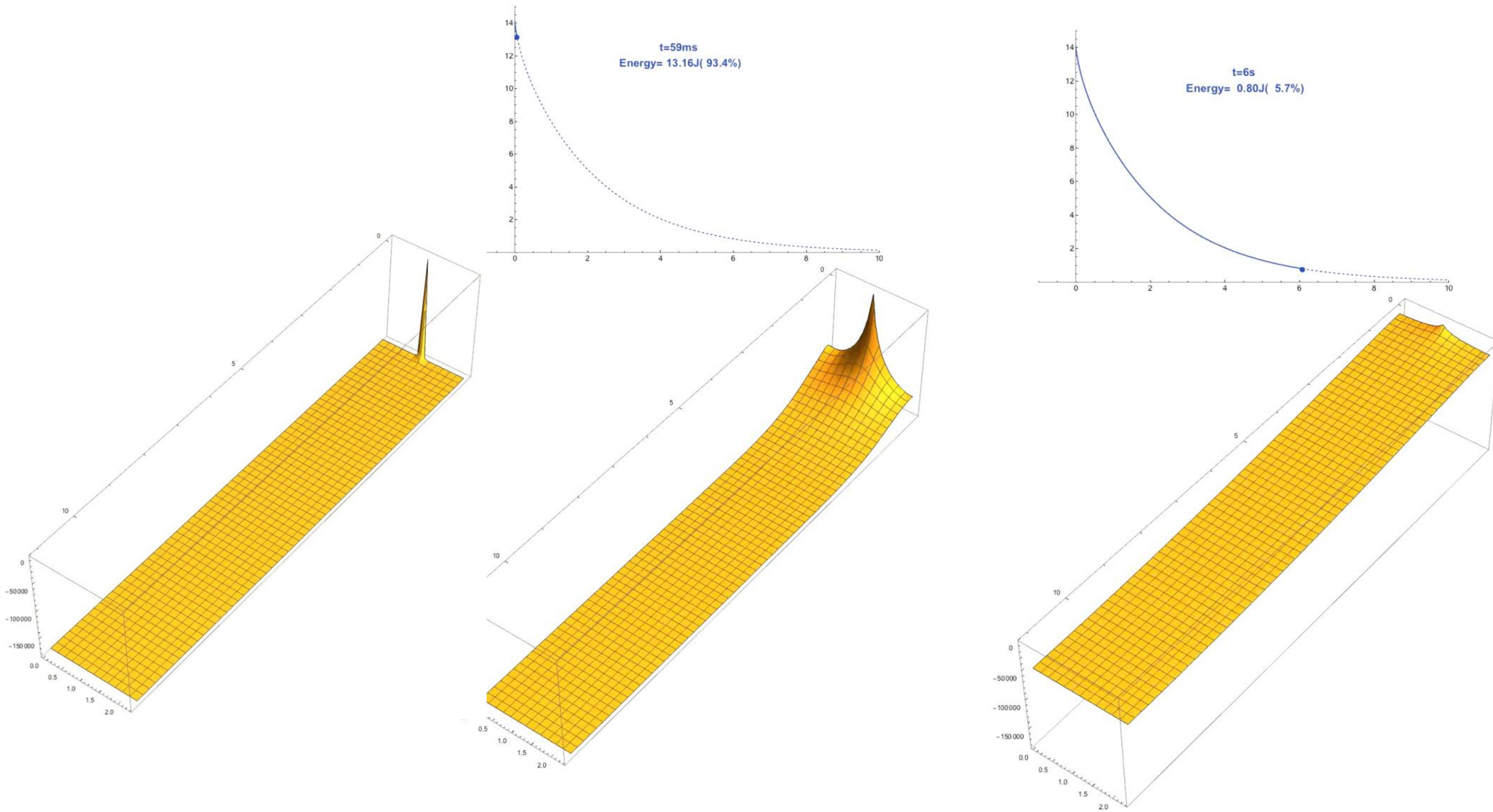
Coupling between cathode and anode planes is 16.4pF /m x 5m = 82pF

HV ripple (36 kHz fundamental) induced on sense wires



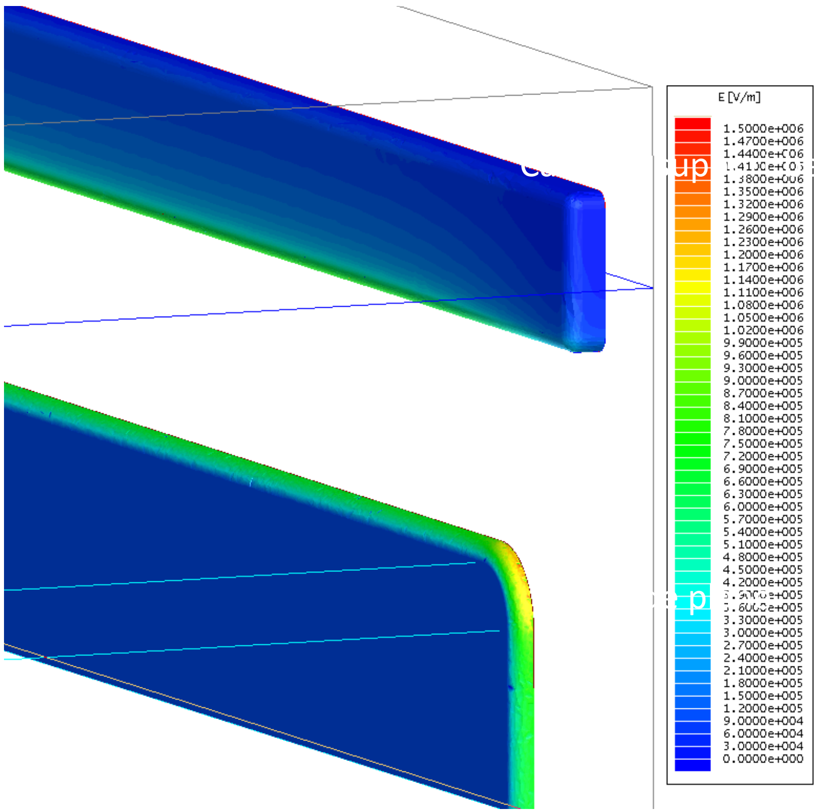
Noise induced by the cathode is progressively attenuated by the shielding effect of the wire planes

Resistive cathode potential vs time



High E field region in SBND

- In SBND, the closest distance between a HV surface and ground is about 30cm, between the top edge of the CPA and the CPA support beam directly above it. The E field along the straight section of the CPA is about 7.4kV/cm, but increases to 15kV/cm at the corner of the CPA.



Summary

1. **MicroBooNE, at highest risk, any increase in HV should be approached with great caution.**

2. **protoDUNE and DUNE designs well protected by resistive cathode-field cage design.**

3. **SBND, low resistance cathode, conservative design to limit the electric field.**