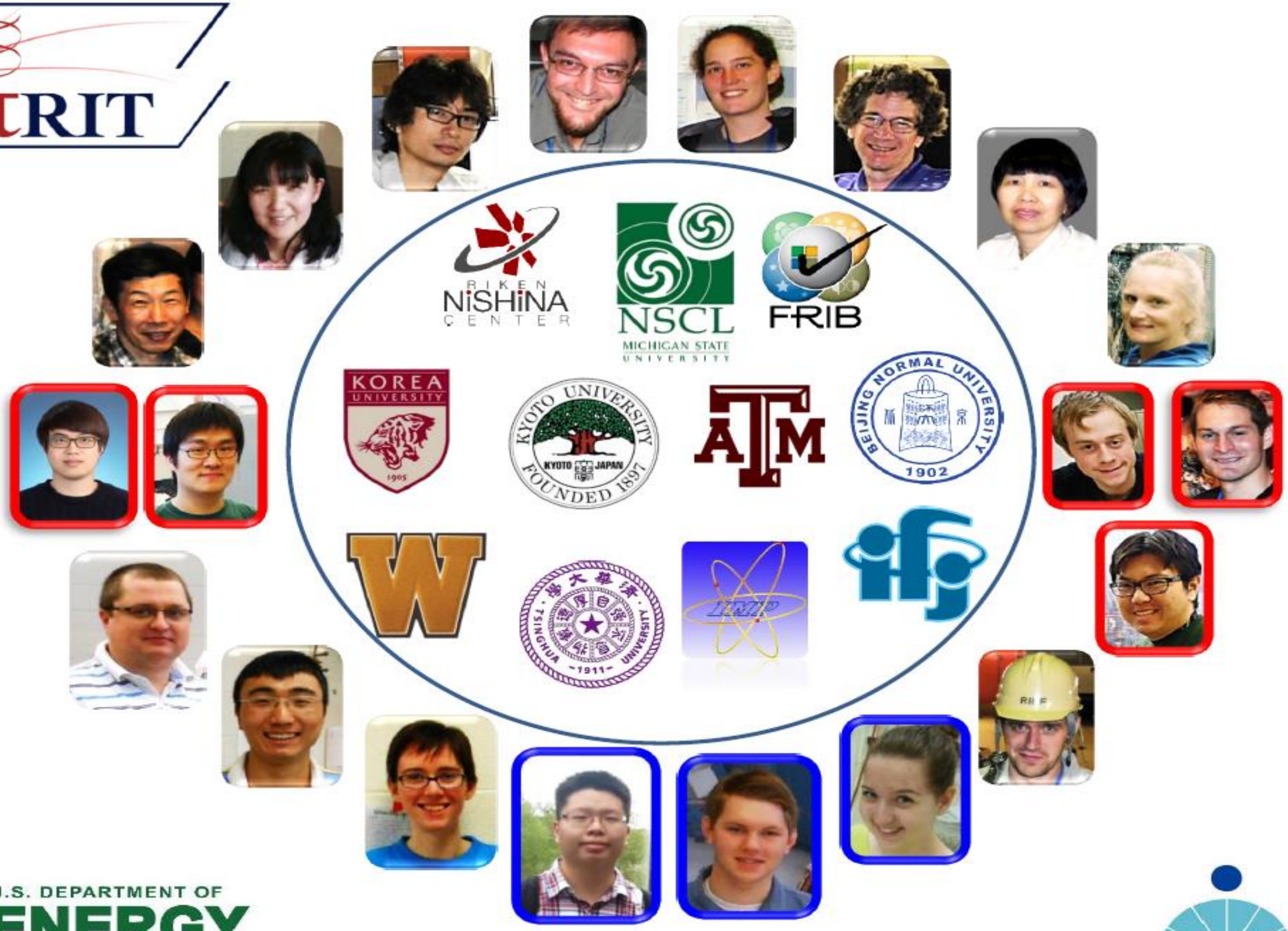
Design of Gating Grid in the SπRIT TPC

SπRIT



U.S. DEPARTMENT OF ENERGY
Office of Science

Suwat Tangwancharoen, for SπRIT-TPC collaboration

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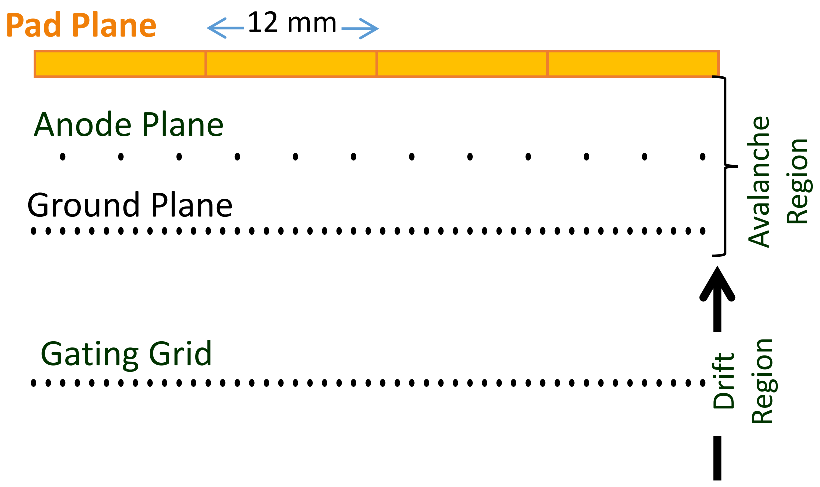
SpiRIT TPC : Principle of operation

- TPC is placed in a magnetic field which align with E-field in the TPC.
- Beam particles ionize detector gas (P-10).
- Ionized electrons drift in the opposite direction of the electric field towards charge sensitive pads.
- 3D paths from the position on the pads and arrival time.
- Momentum from the curvature of the path.
- Particle types from the energy loss and the curvature.



<u>Field cage</u>

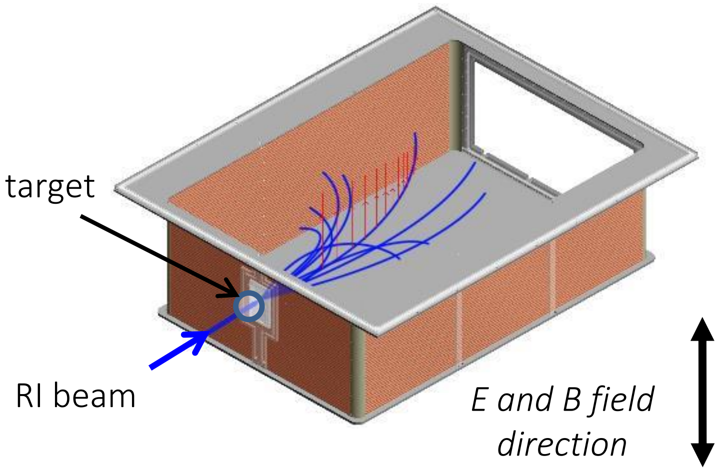


Figure courtesy of J. Estee

<u>Pad plane</u>

Path in horizontal plane from pad positions

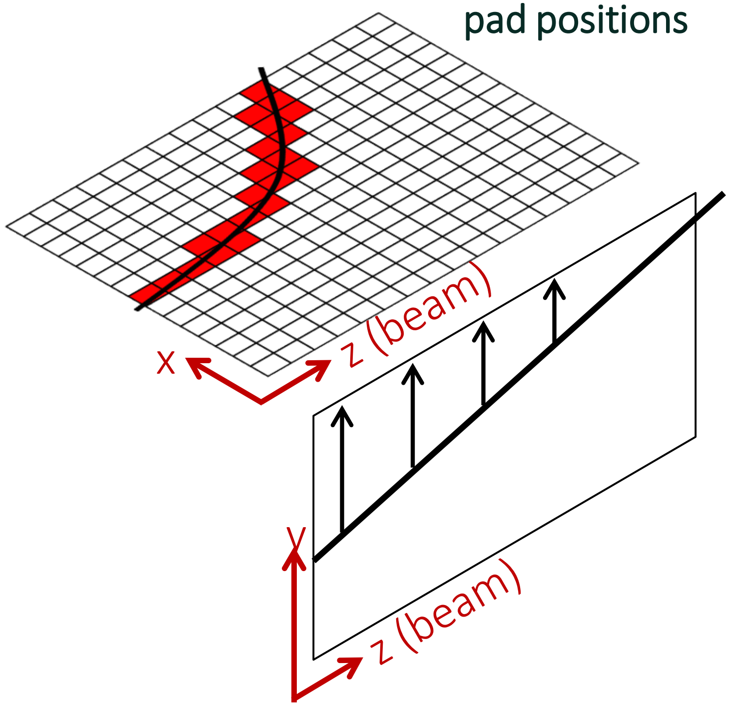
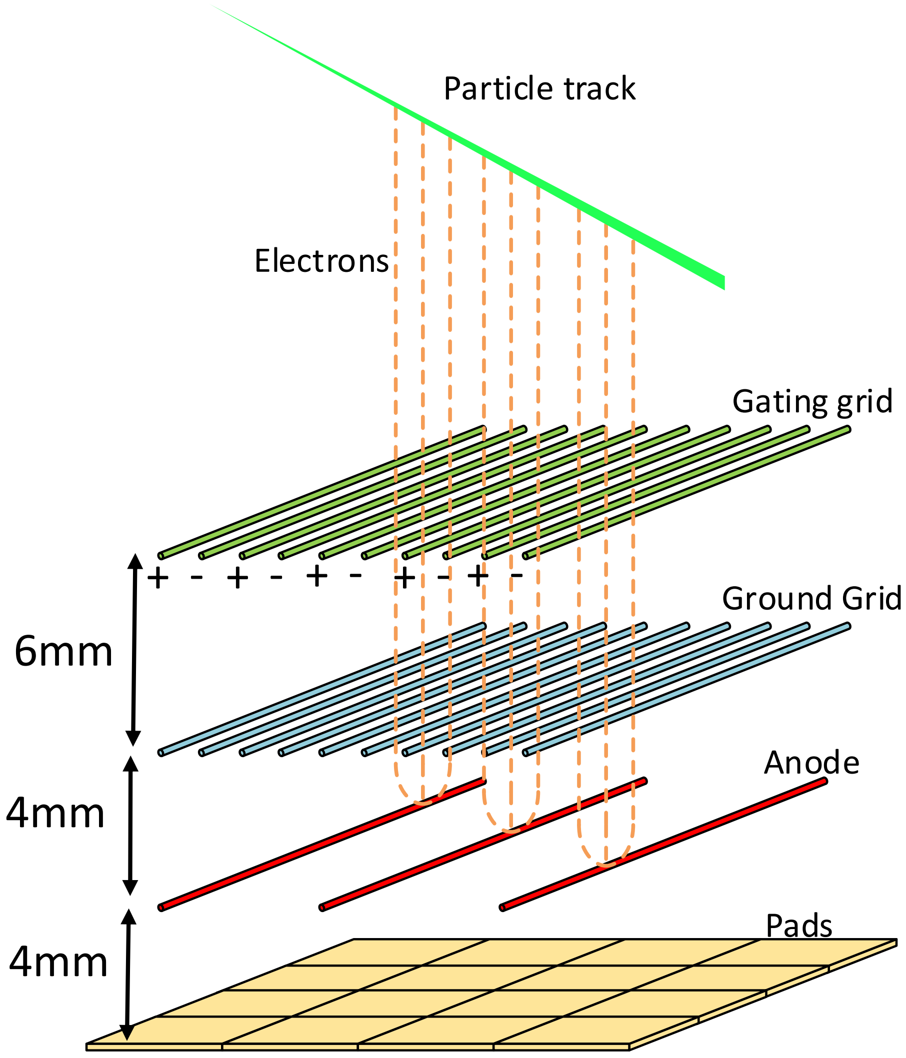


Figure courtesy of J. Barney

Gating grid for SπRIT TPC:

opens for real events in ~200ns. Gating grid driver shorts positive and negative wires, $I_{ave} \approx$ 18 A.

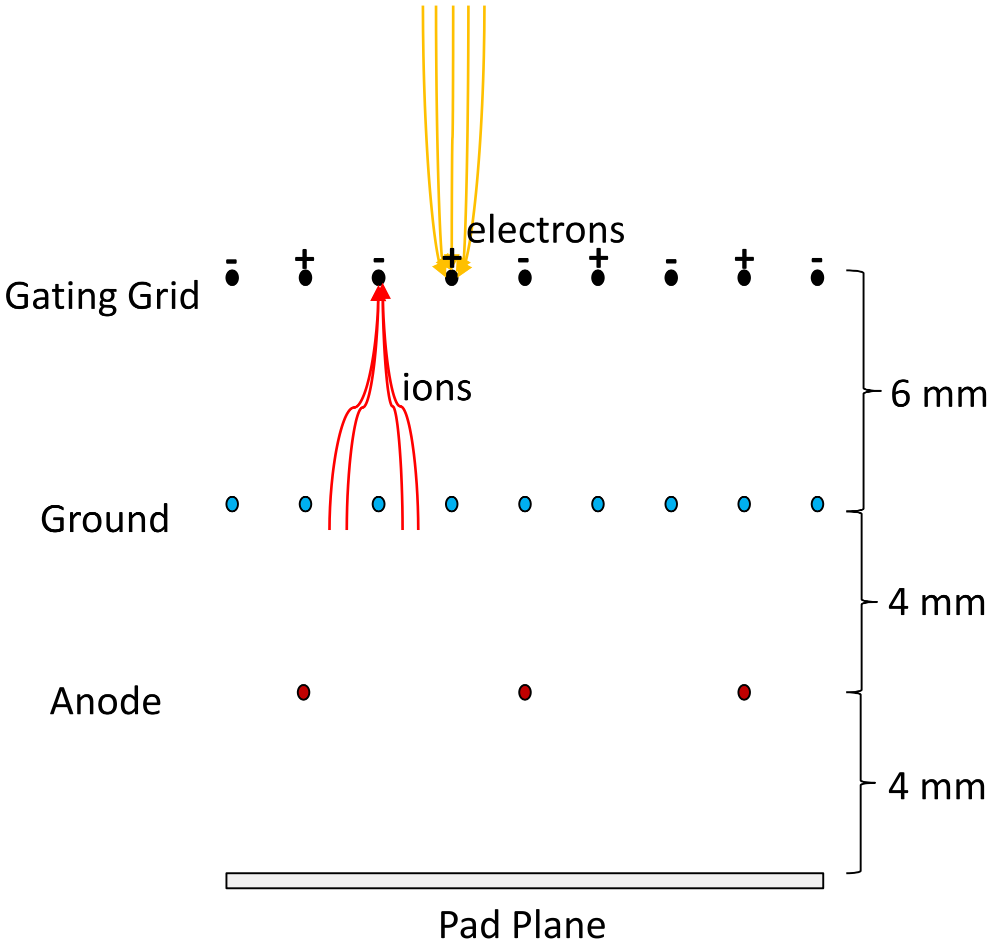


Gating grid is opened

Plane	Material	Diam (μm)	Pitch (mm)	Height (mm)	Tens. (N)	Volt. (V)	# of wires
Anode	Au-W	20	4	4	0.5	~1400	364
Ground	Cu-Be	75	1	8	1.2	0	1456
Gating	Cu-Be	75	1	14	1.2	-110±70	1456

Operation of Gating Grid

- **Open** : All wires have the same potential (-110 V). all electrons can pass through to the multiplication region.
- **Close** : Alternative wires are biased up or down by 70 V (-40 V and -180 V). No electrons and ions pass the gating grid.



Closed configuration

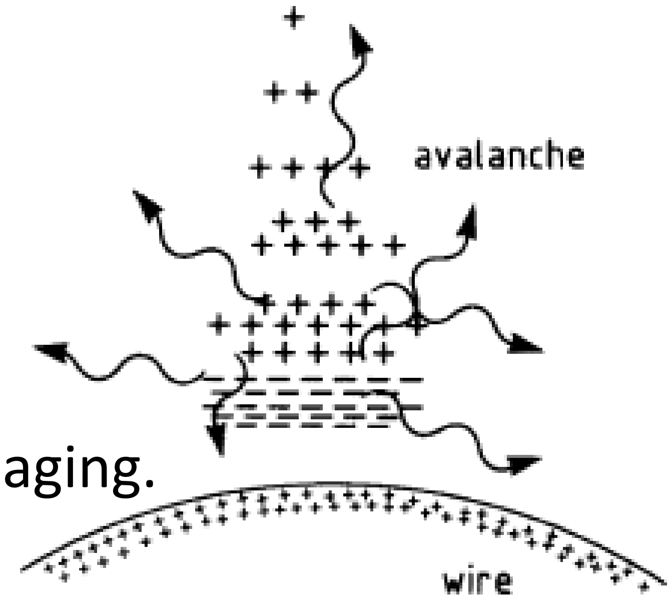
Function of gating grid

- Prevent positive ions from drifting into the drift volume.
- Prevent amplification of unwanted events.
- Reduce aging of wires.

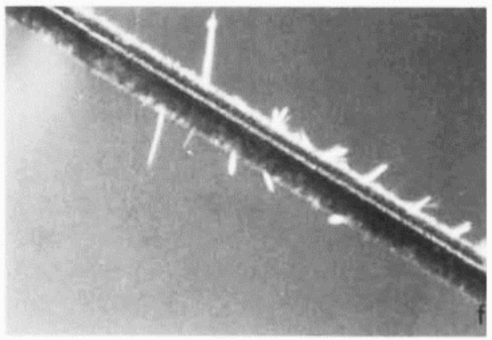
In typical experiment, the gating grid will stay closed most of the time until there is a candidate event.

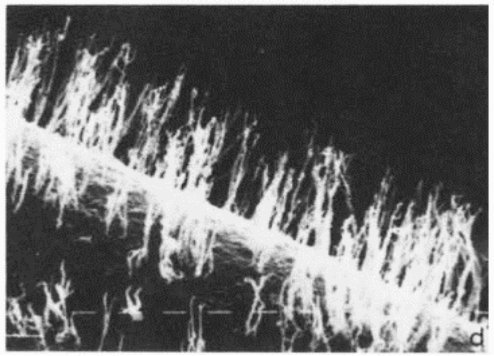
Gating Grid reduces the Effect of free (space) charges

- Majority of ions come from the avalanche near the anode wire.
- Disturb the field in the drift volume.
- Affect the drift velocity and the arrival time of electrons.
- Accumulation of negative polymers will accelerate the detector aging.

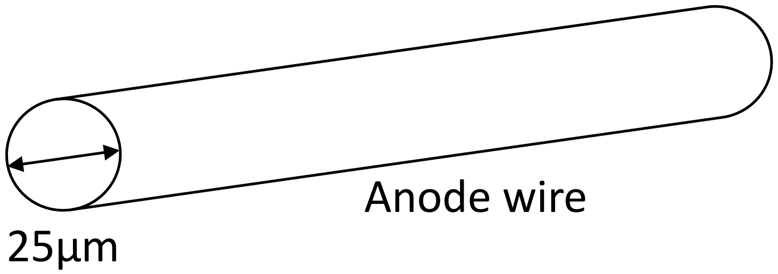


W. Blum, W. Riegler, and L. Rolandi



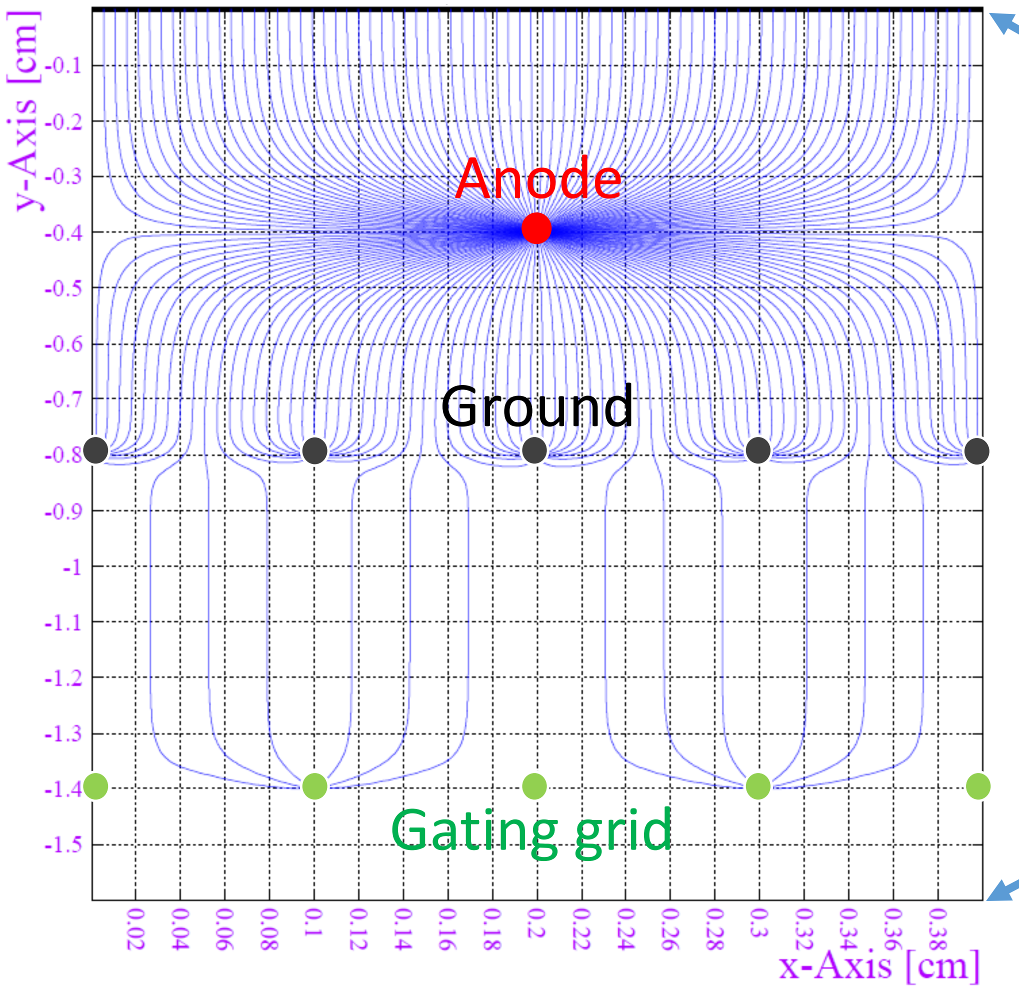


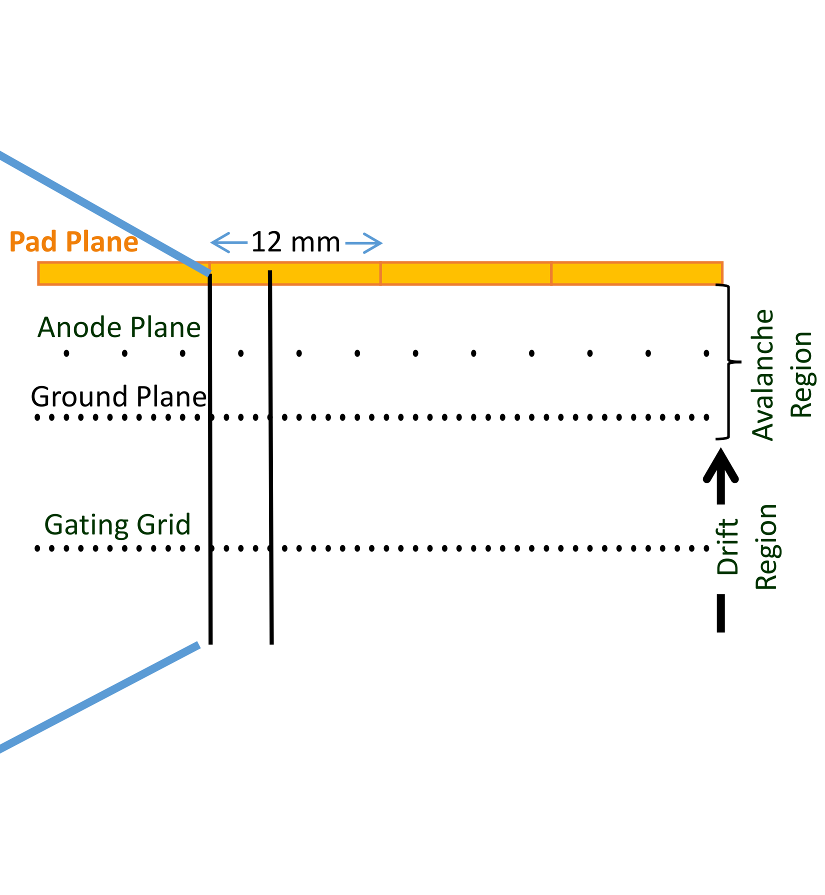
"Whisker" polymer deposits on anode wire.
taken from J. Kadyk, NIM A300 (1991) 436



Garfield Simulation for gating grid: e Drift lines

Positive ion drift lines



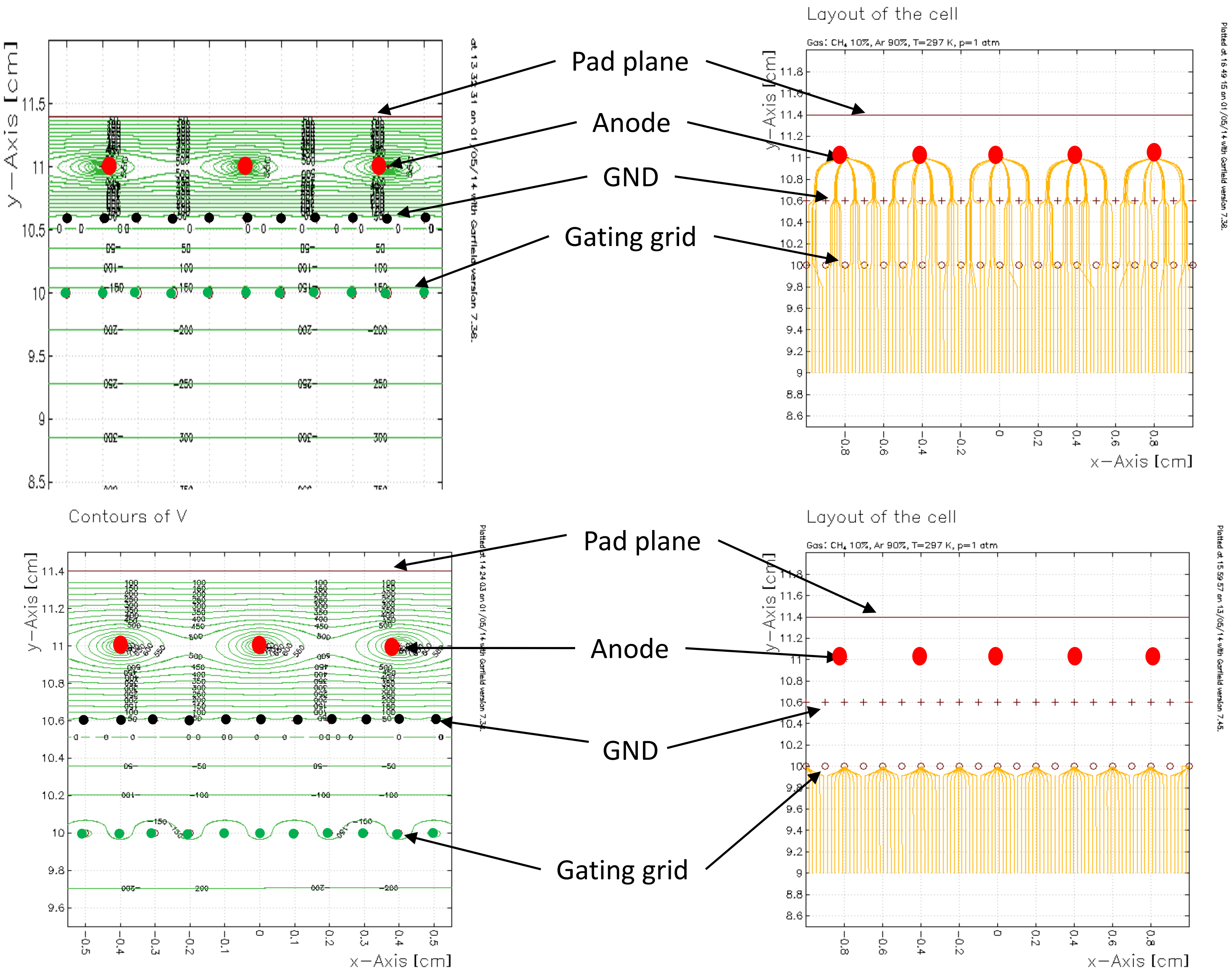


Equipotential lines

Electron drift lines

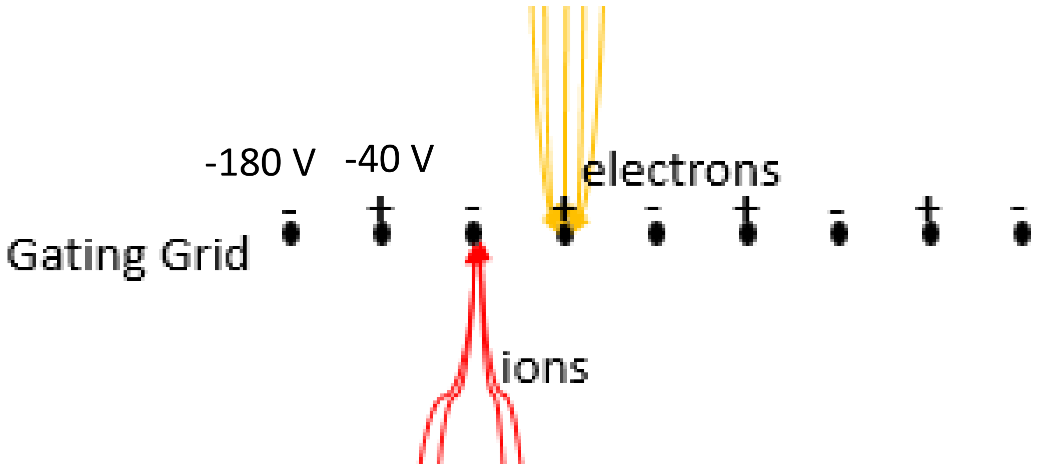
OPEN

CLOSE



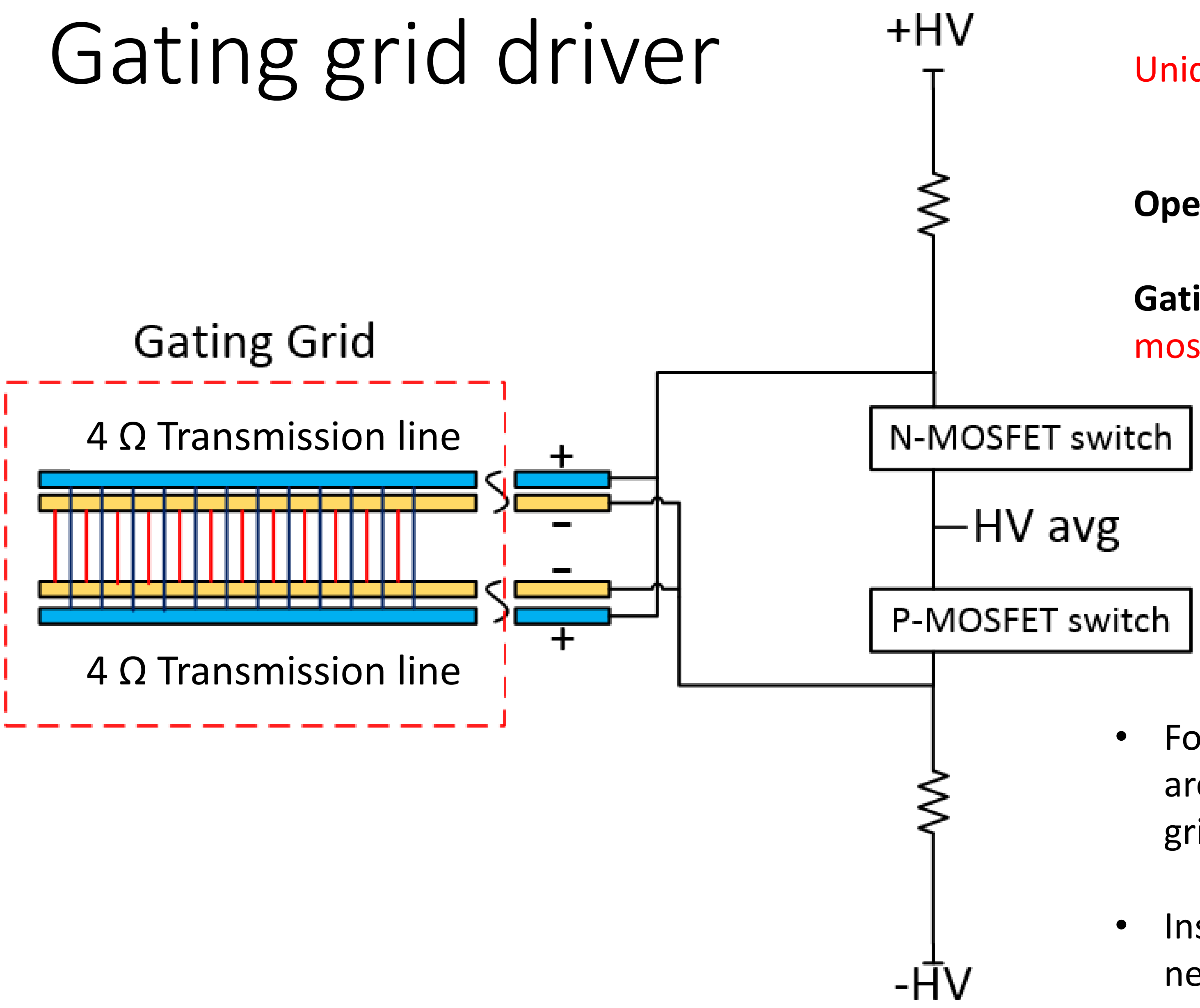
Design criteria of gating grid driver

- Open the gating grid as fast as possible to reduce the “dead region.”
- Discharge both alternative wires of the gating grid at the same rate to reduce the unwanted induced signal on the pads.



Closed configuration from Garfield

Gating grid driver



Unique design to short two power supplies

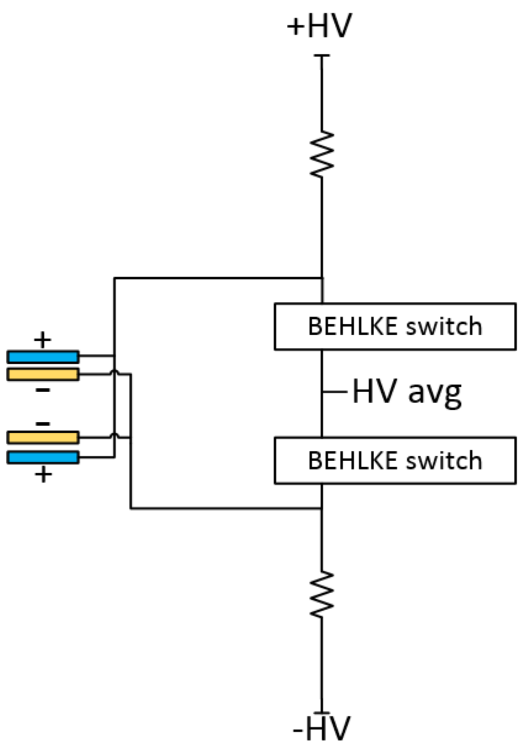
Operation of the driver

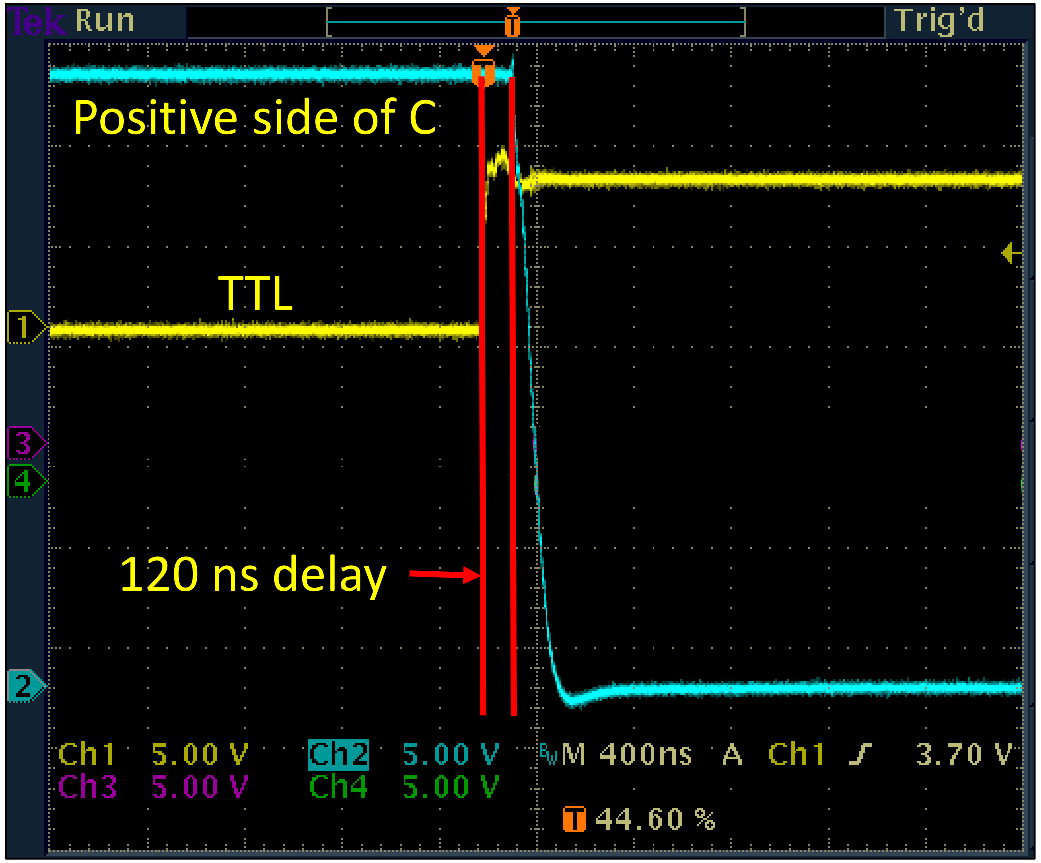
Gating grid open : +HV and –HV shorted through the mosfet switches.

- For SπRIT TPC, low impedance transmission lines are used to transfer the charges from the gating grid.
- Insure that the discharge from positive and negative sides is the same.

Prototype 1

- Use 2 BEHLKE switches (HTS 21-14).
- Test with the standard capacitor (11.6 nF)
- The propagation delay of the switches are 120 ns (too long).
- There is a negative peak after discharging.



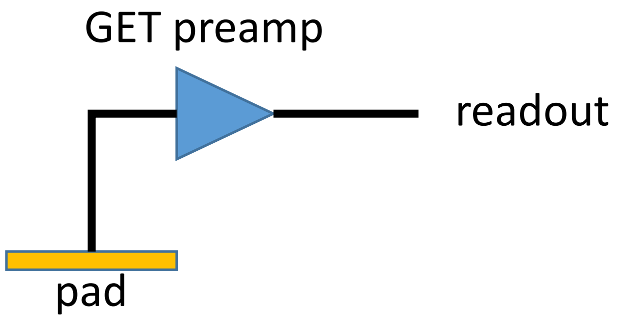


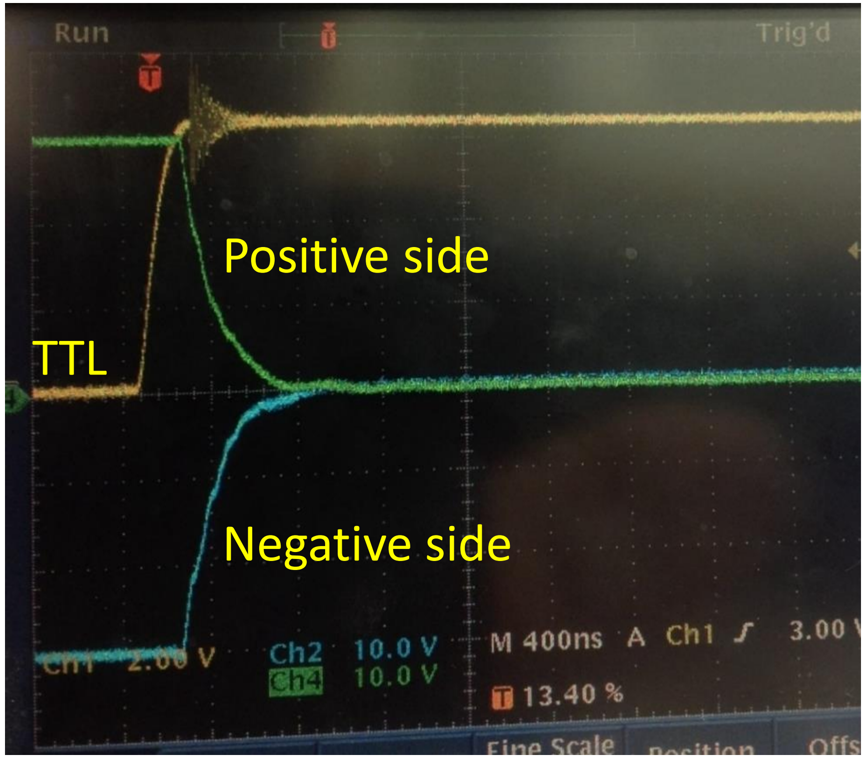
SPICE analysis of the prototype 1

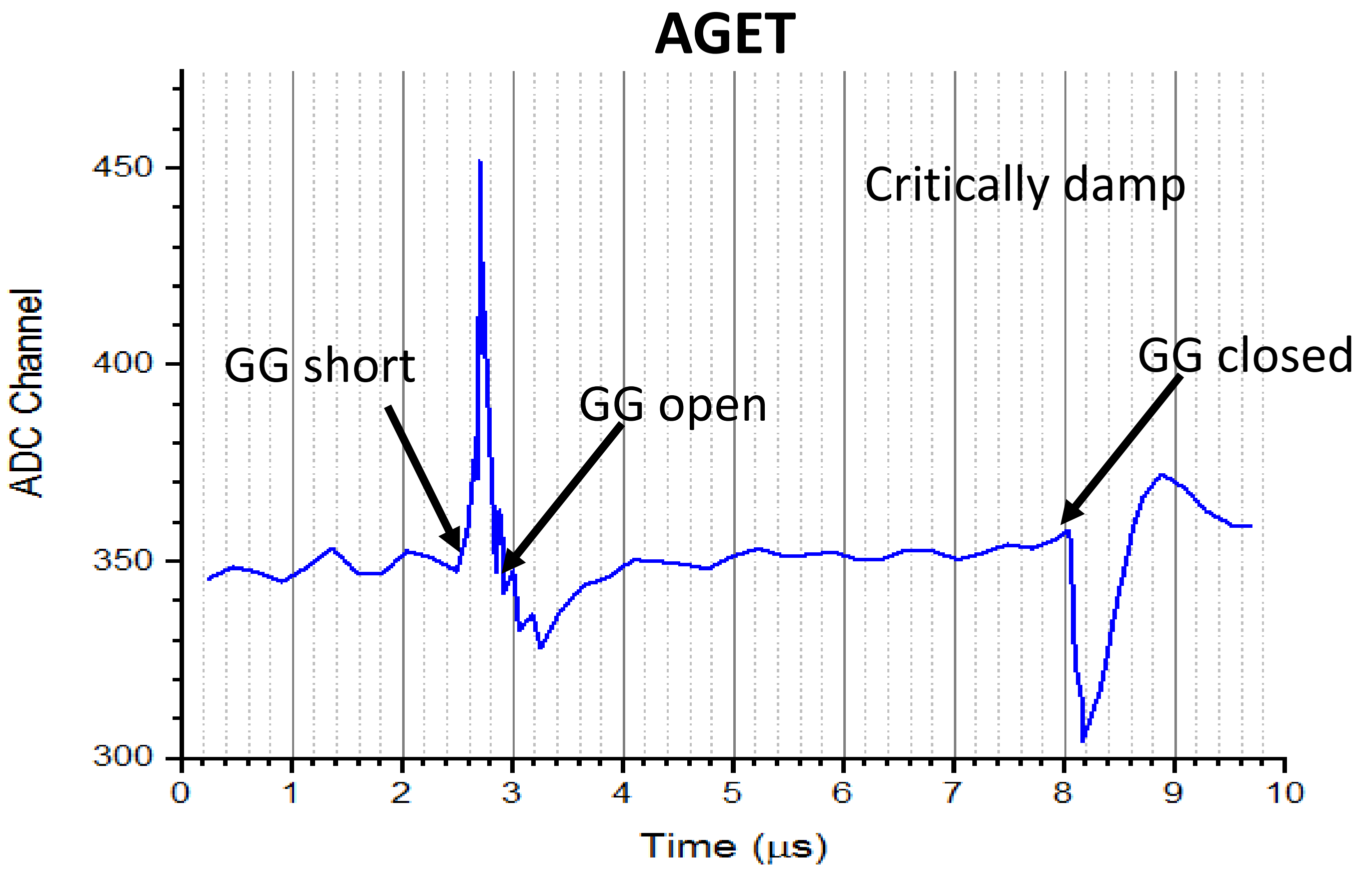
- Inductance L = 160 nH
- For C = 27 nF, circuit is critically damp.
- The capacitance of the gating grid (including 2 transmission lines) is 26.5 nF.

Test of Prototype 1 with TPC

- The capacitance of the gating grid is measured to be 26.5 nF including 2 transmission lines.
- Critically damp as expected.

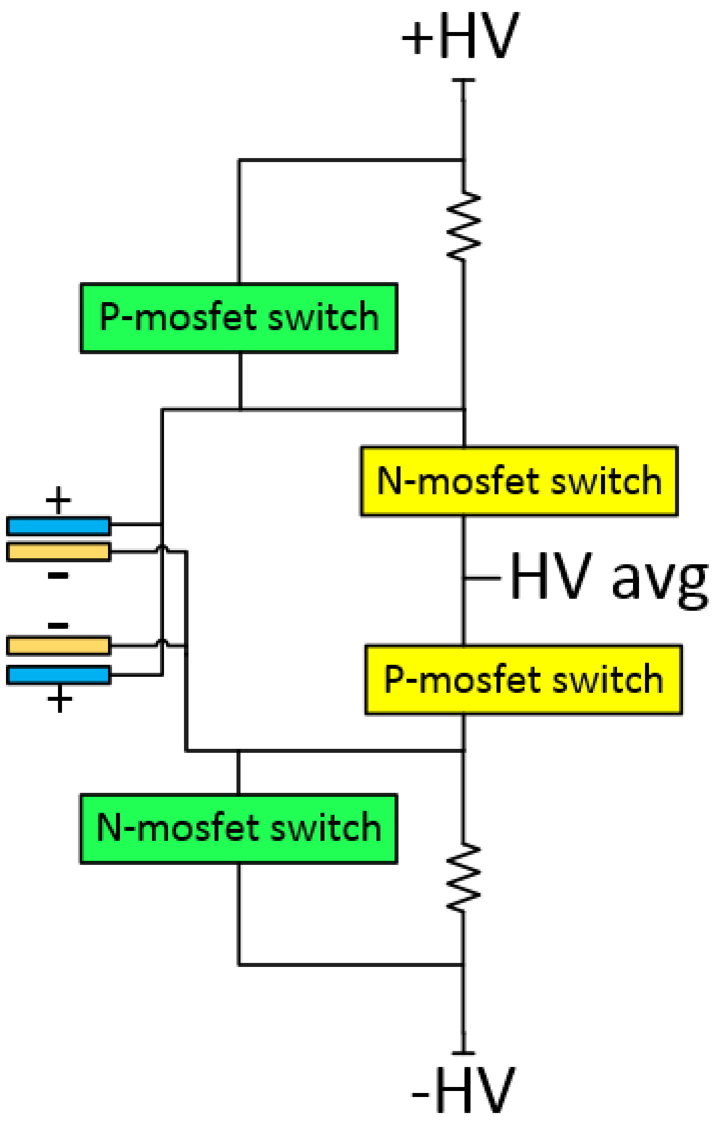






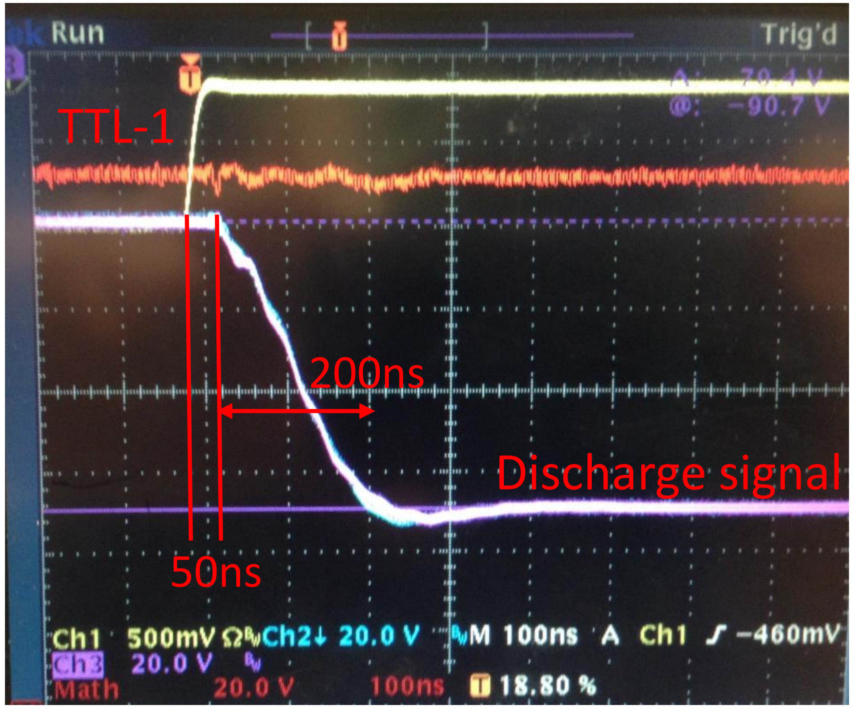
Present Prototype

- Use 2 pair of N-type and P-type mosfets that have the same turn-on delay time.
- Green pair of mosfet switches is for closing the gating grid quickly.



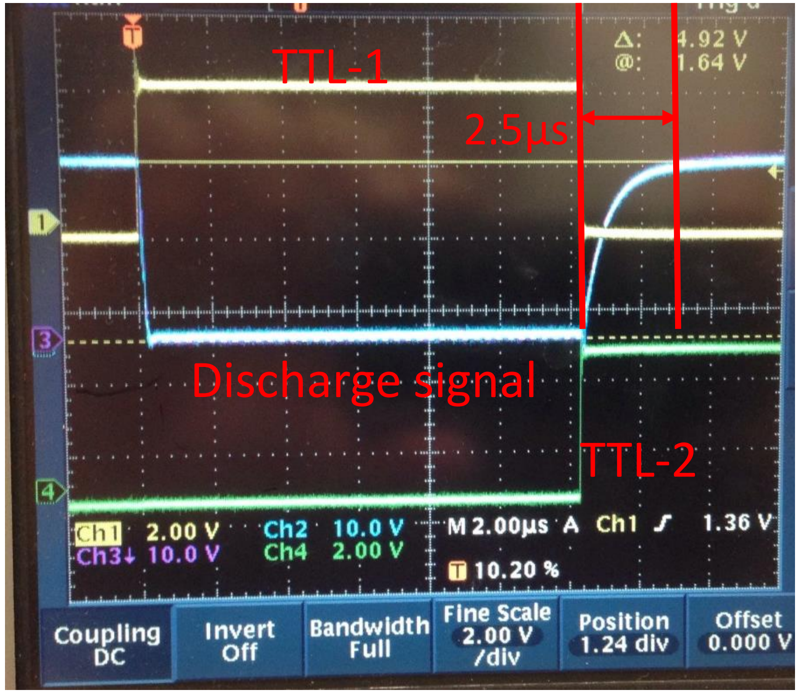
Present Prototype (test with C =27 nF, R = 2 Ω, RC = 54ns)

OPEN

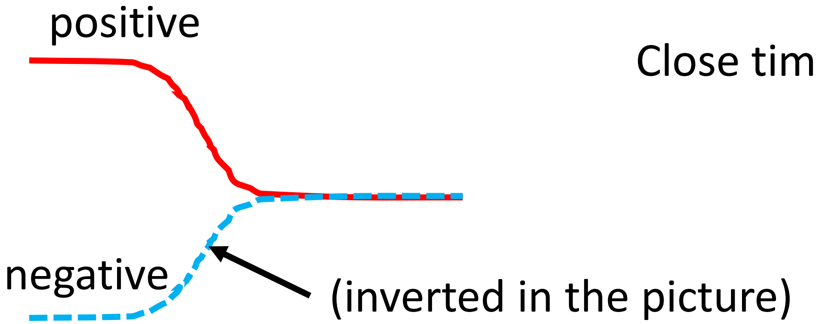


Turn on delay time 50 ns
Open in 250 ns

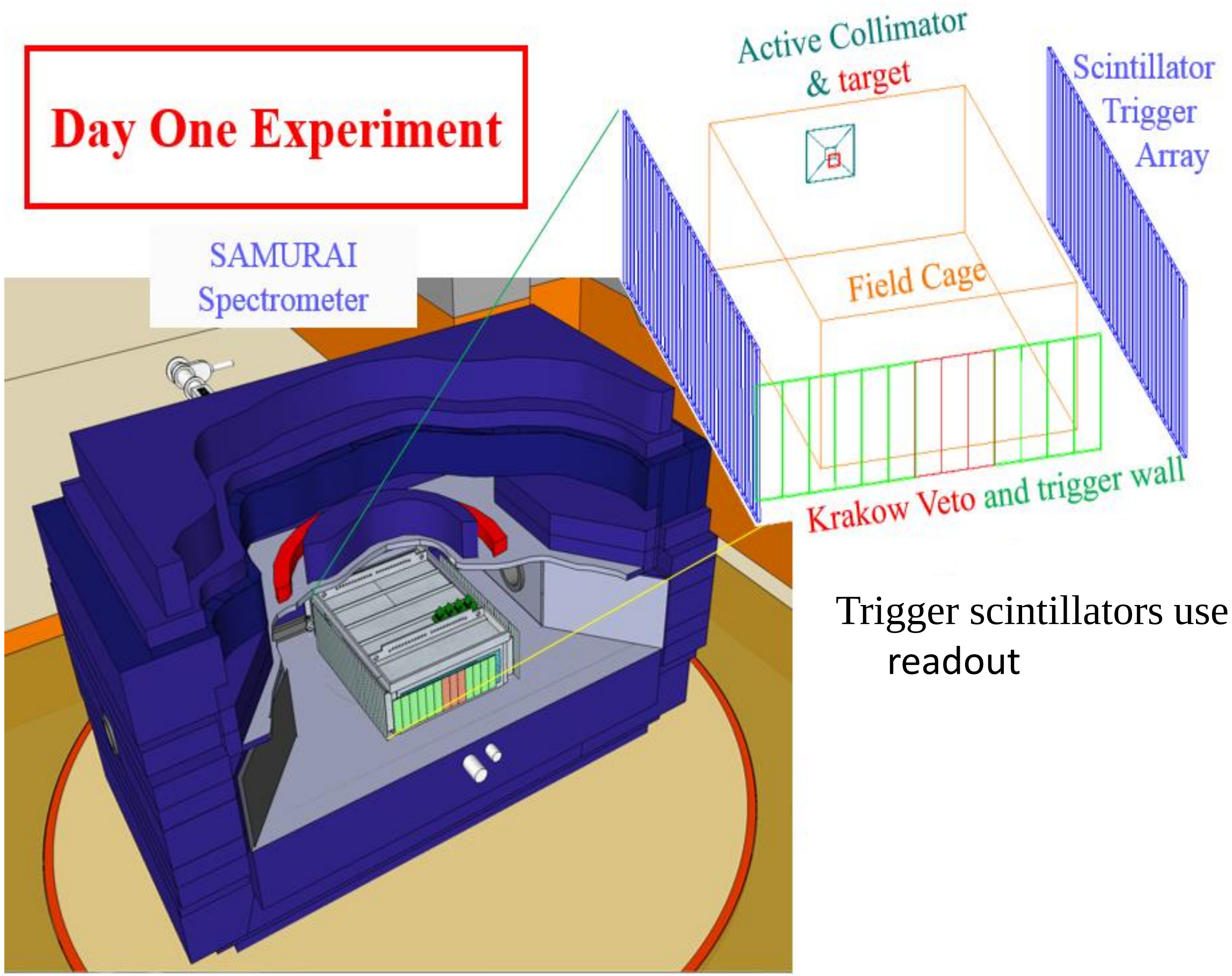
CLOSE



Close time 2.5 µs



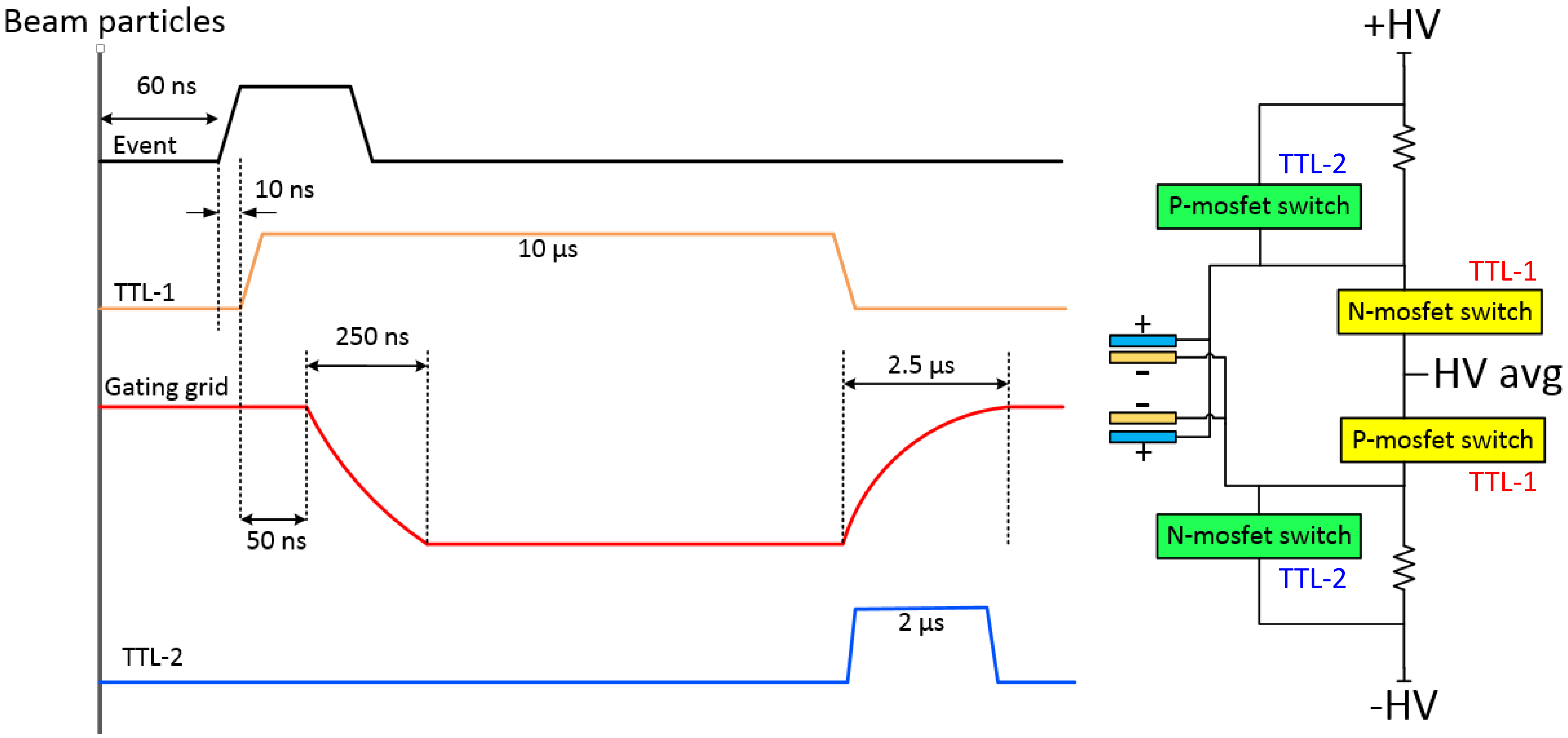
Trigger system



Trigger scintillators use MPPC readout

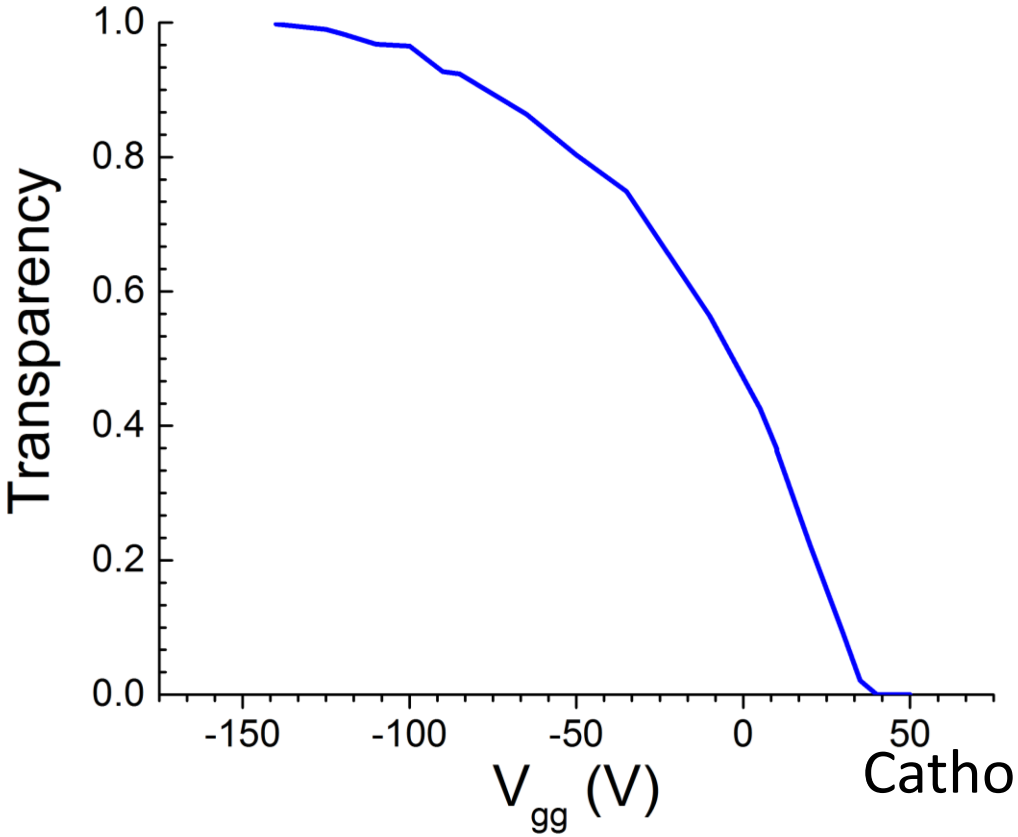
Condition: Central collision

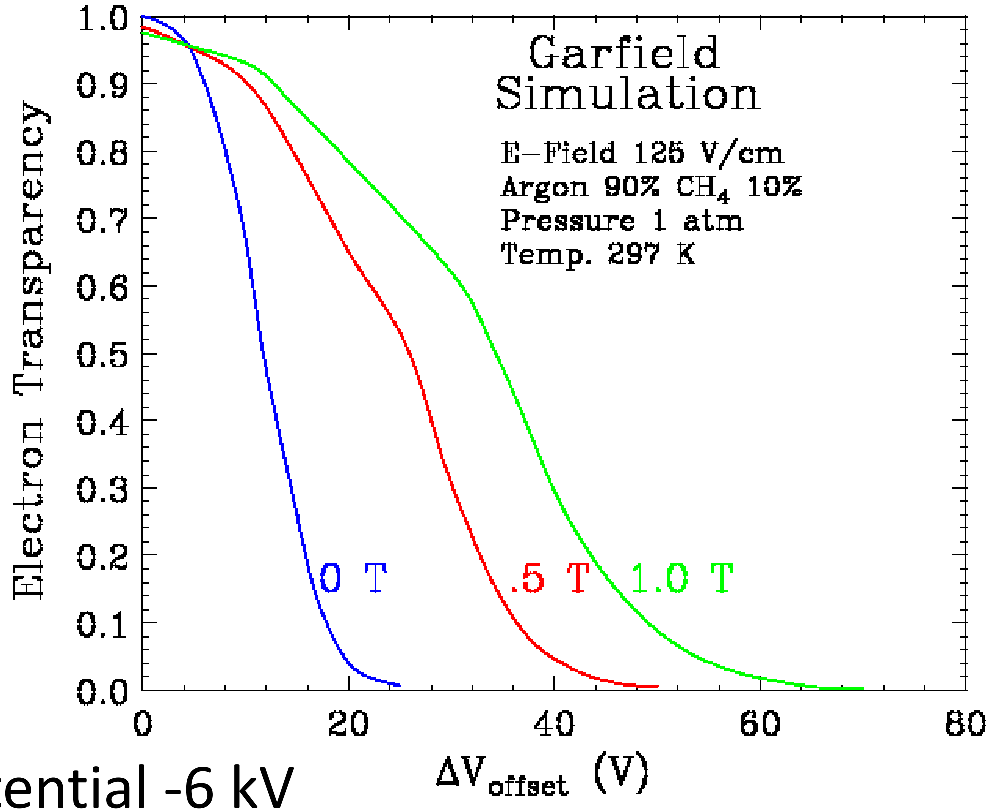
- High multiplicities in the Scintillator trigger array and forward trigger array
- Veto of Heavy residue (Z >20)


Beam particles
60 ns
Event
10 ns
10 µs
TTL-1
250 ns
2.5 µs
Gating grid
50 ns
2 µs
TTL-2
+HV
TTL-2
P-mosfet switch
TTL-1
N-mosfet switch
+
-
HV avg
-
+
P-mosfet switch
TTL-1
N-mosfet switch
TTL-2
-HV

Backup slides

Electron transparency for gating grid





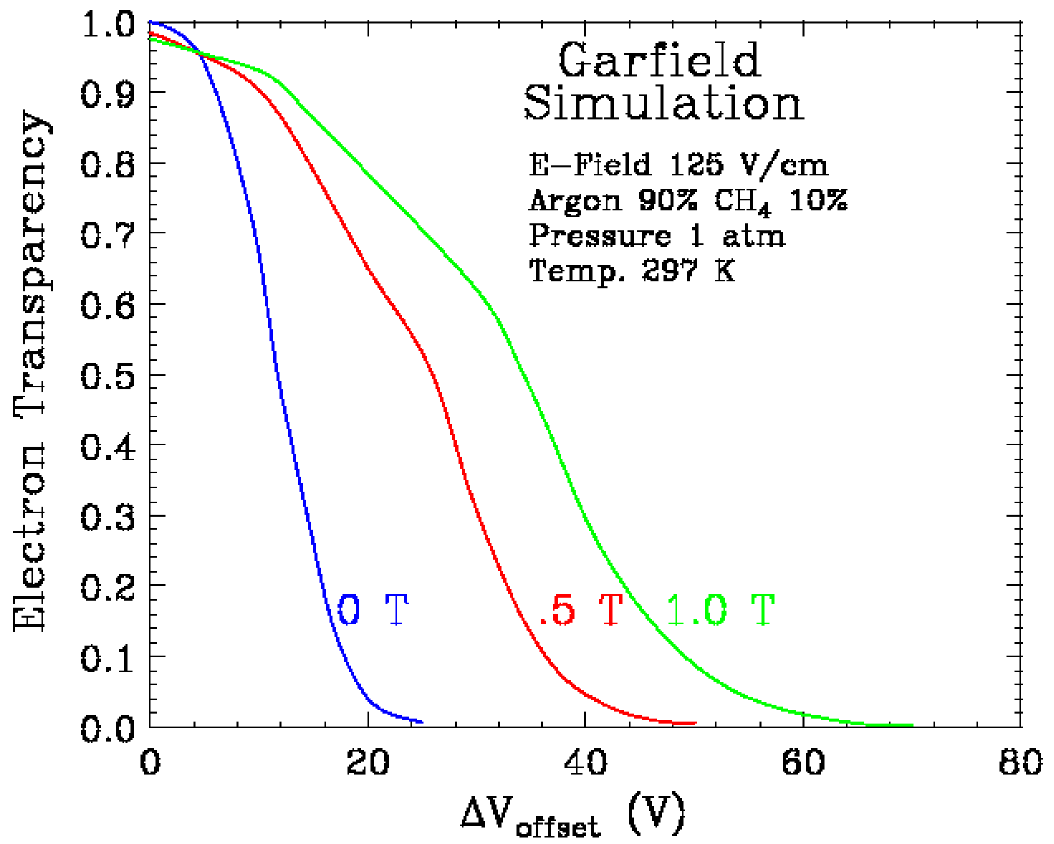
Cathode potential -6 kV

Gating grid Open : V_{gg}

Gating grid Close : $V_{gg} \pm \Delta V_{offset}$

Voffset increase with B-field

Electron transparency for gating grid



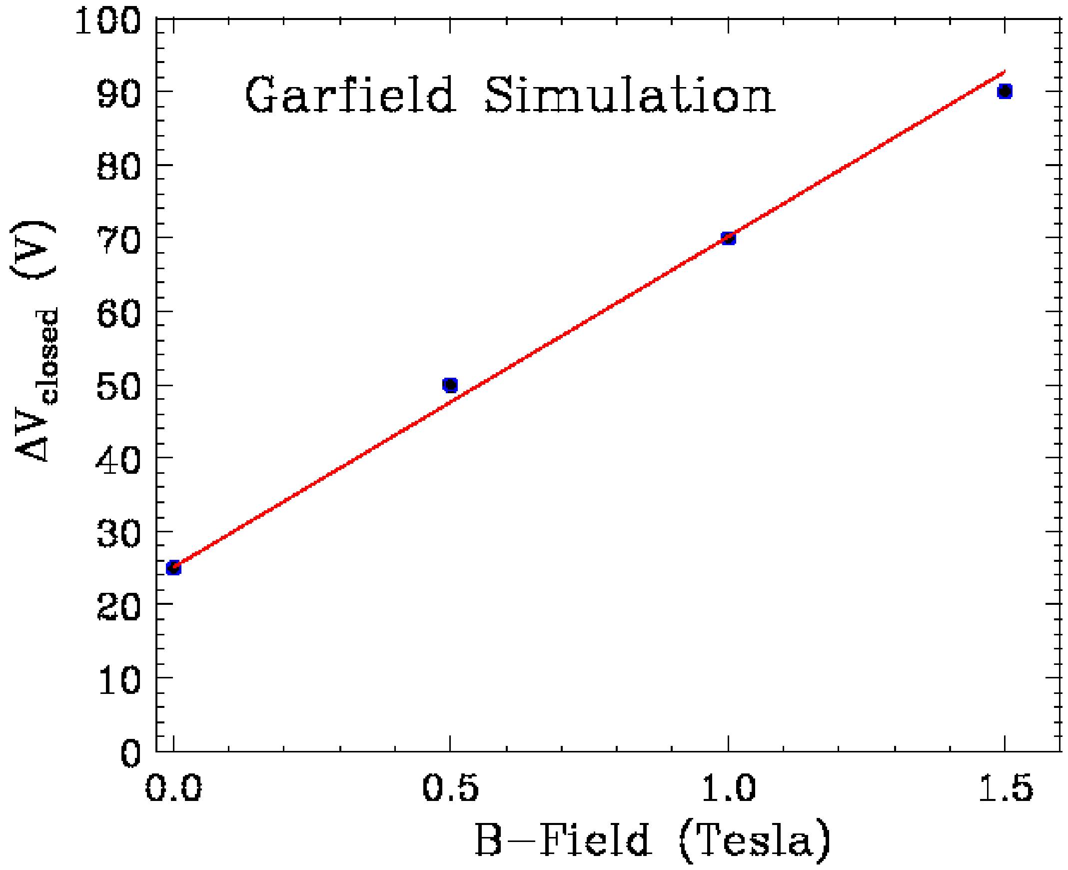
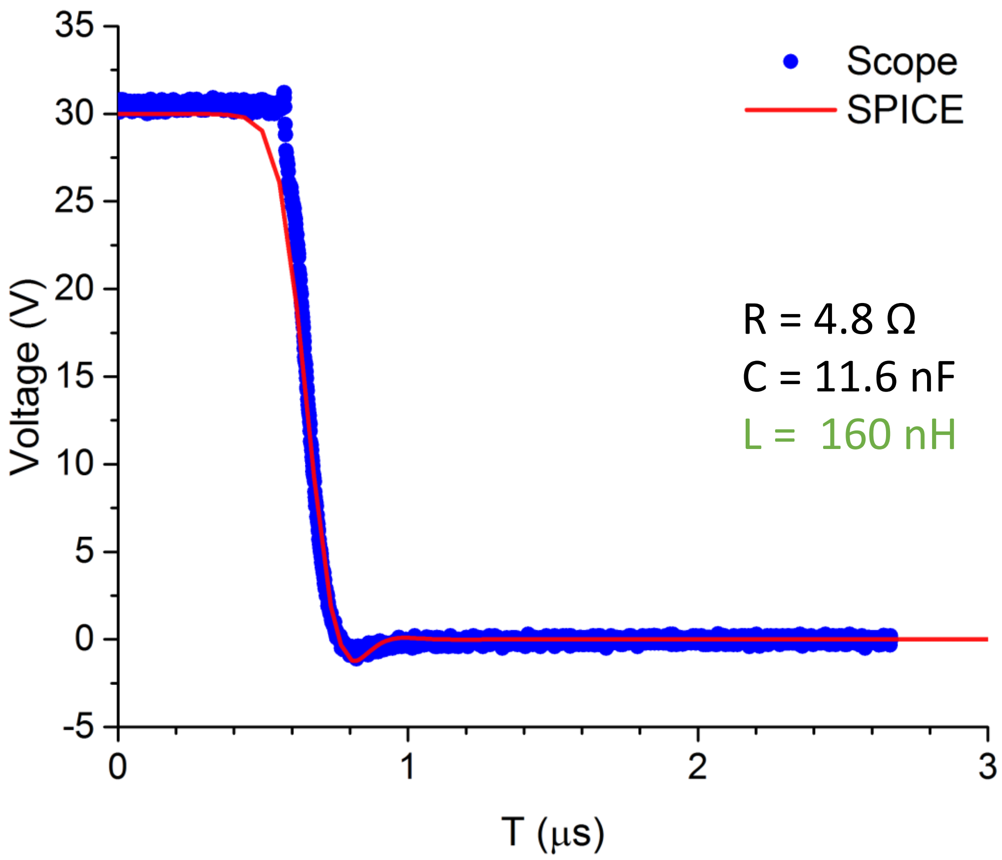


Figure courtesy of J. Estee

SPICE (Simulation Program with Integrated Circuit Emphasis)



Using RLC series circuit to analyze the signal shape.

- The signal suggests that the system is slightly underdamp.
- Need to be at least critically damp to get rid of the negative peak.
- Assume that most inductance comes from the driver circuit.
- Therefore, C needs to be 27 nF to achieve critically damp if R =4.8 Ω and L = 160 nH.
- The capacitance of the gating grid of the SpiRIT TPC is measured to be 26.5 nF including 2 transmission lines.

GG with transmission lines