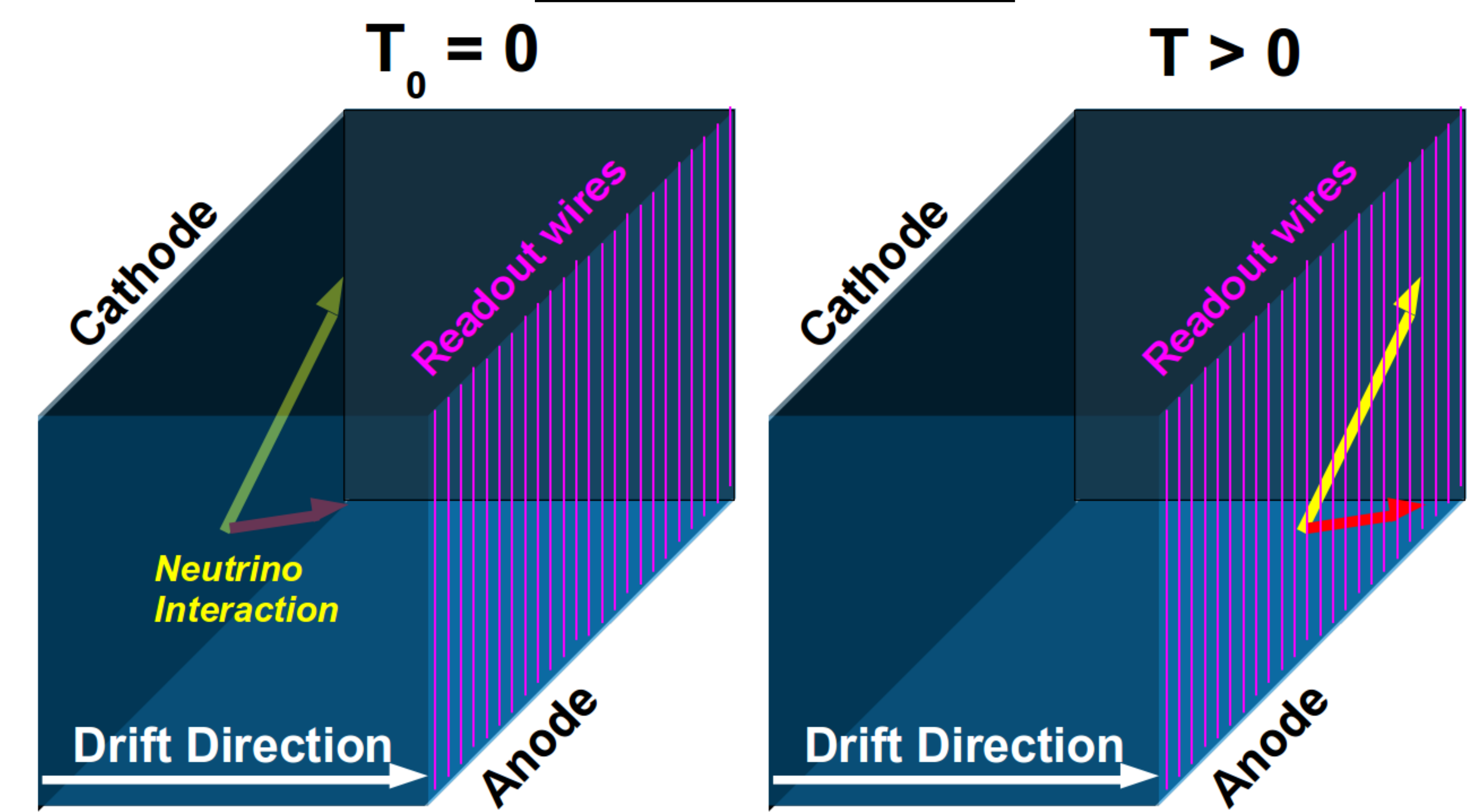# Investigating Surge Protection Devices to Protect Against Transient Over-voltages in Liquid Argon Time Projection Chambers

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High Voltage Breakdowns in LArTPCs

T₀ = 0

Cathode, Readout wires, Neutrino Interaction, Drift Direction, Anode

T > 0

Cathode, Readout wires, Drift Direction, Anode

LArTPC's utilize high voltages to drift electrons created during an neutrino interaction from inside the volume to readout wires

Nominal Condition | *Worst case with cathode spark*


Without Surge Protection
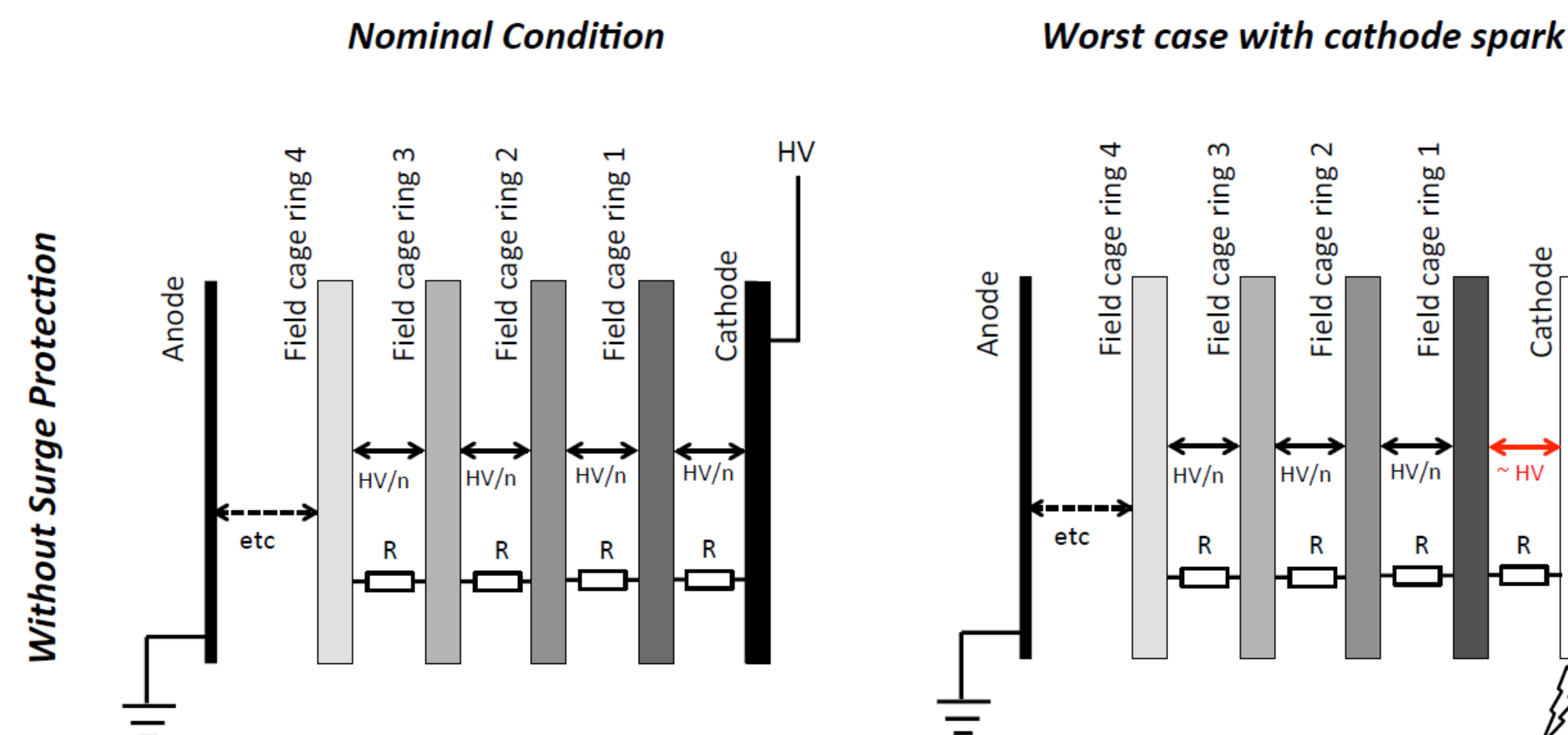
As the volume of argon increases, higher voltages must be applied in order to drift the electrons. This creates a greater likelihood of having a high voltage breakdown
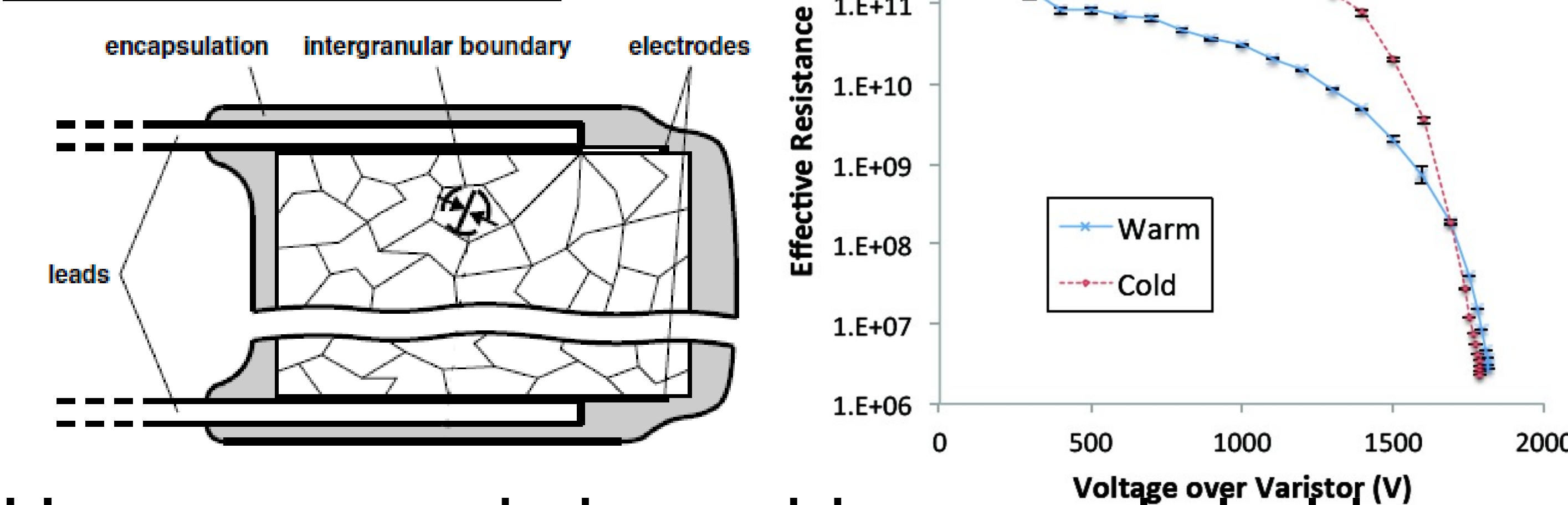
Surge Arrestors Protect Against Over-voltages

With Surge Protection

Without surge protection

With surge protection
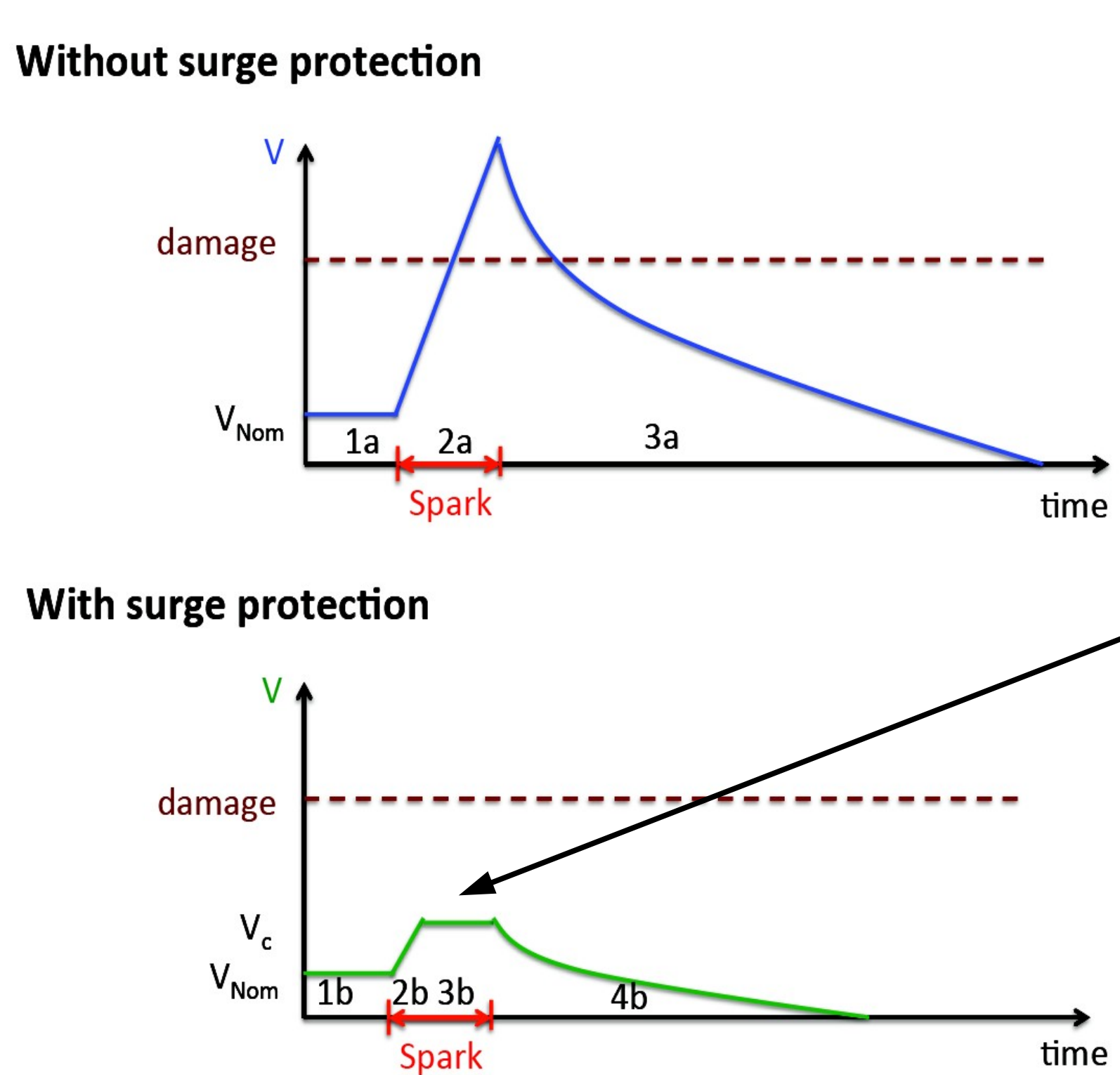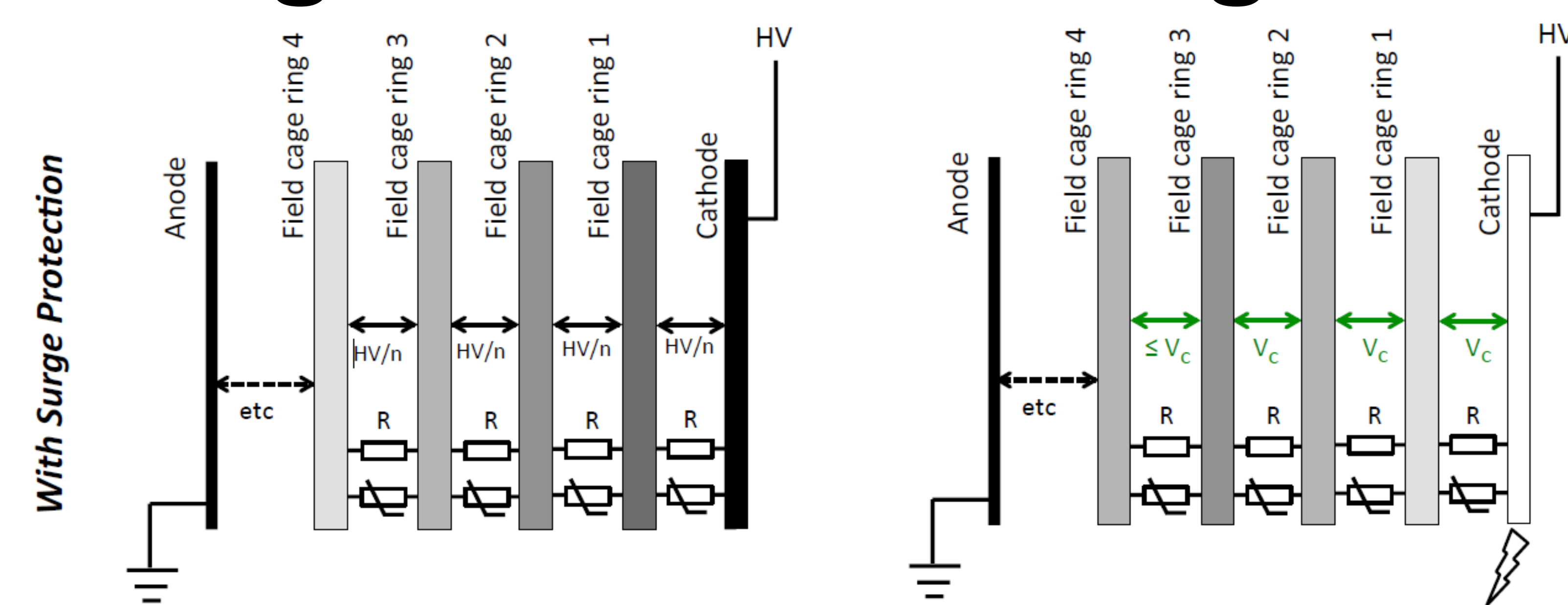
Application of surge protection **"clamps"** the over-voltage and protects components

Varistors and Gas Discharge Tubes (GDTs)

Panasonic Zinc Oxide Non-linear varistor (ERZ-V14D182) & EPCOS GDT (A71-H45X)

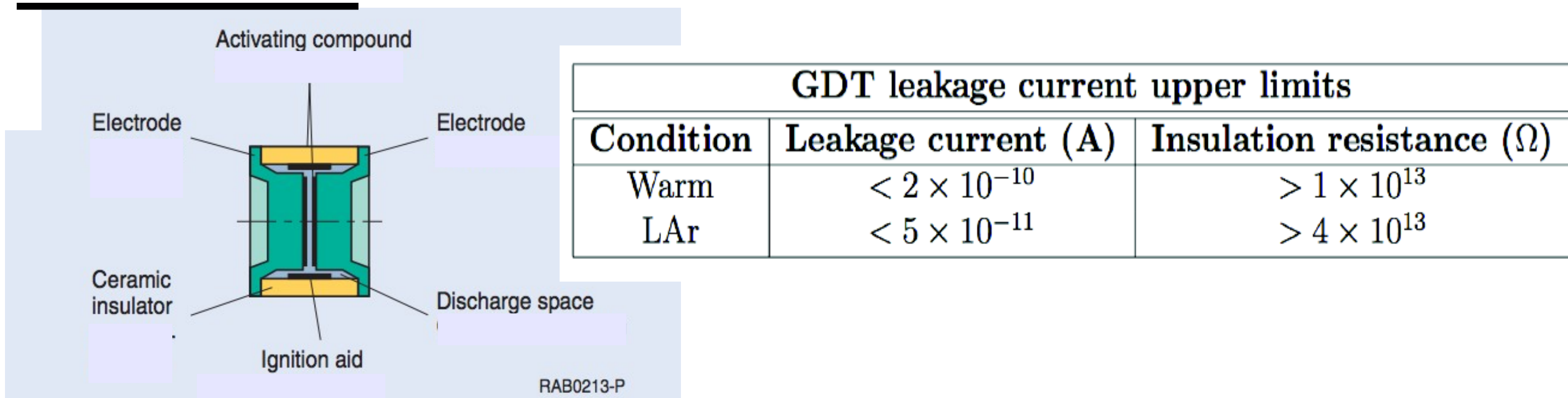### Varistors
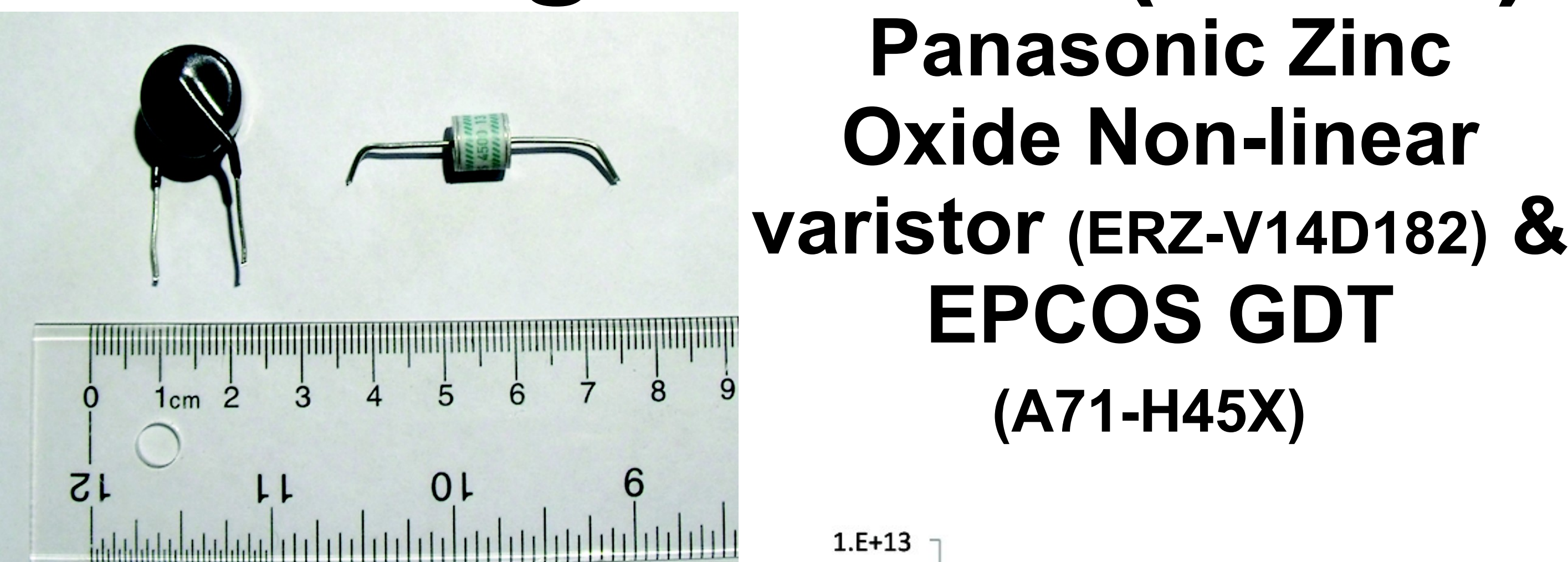
encapsulation, intergranular boundary, electrodes, leads

Use a pressed zinc oxide ceramic held between two electrodes. This matrix behaves like a p-n semiconductor producing a non-linear Voltage/Current curve. At lower voltages varistors have resistances $O \sim 10^{12}\,\Omega$ and quickly transition to conducting near their "clamping" voltage

GDTs

Activating compound, Electrode, Ceramic insulator, Ignition aid, Discharge space

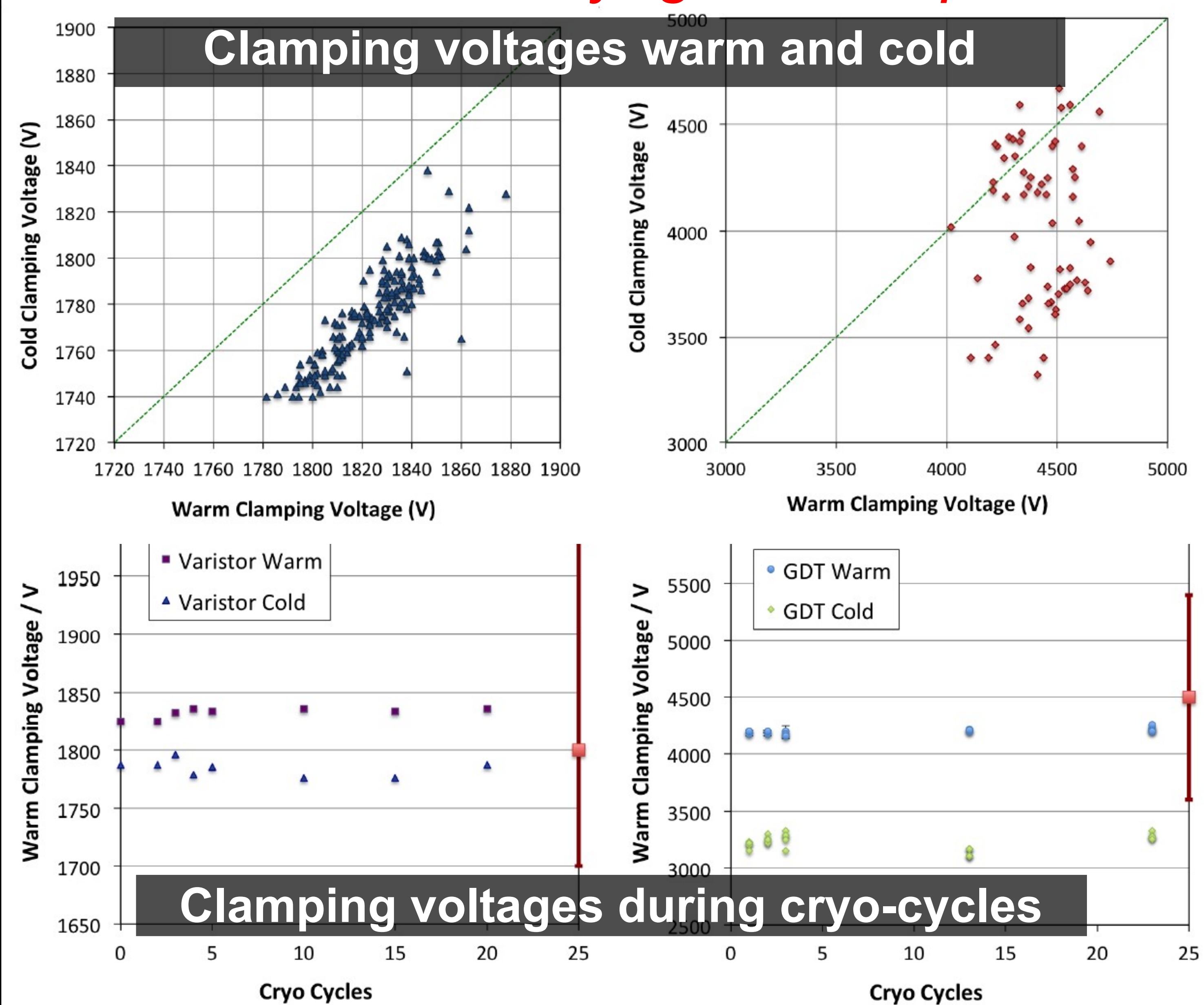| GDT leakage current upper limits		
Condition	Leakage current (A)	Insulation resistance (Ω)
Warm	$< 2 \times 10^{-10}$	$> 1 \times 10^{13}$
LAr	$< 5 \times 10^{-11}$	$> 4 \times 10^{13}$

Consist of a small volume of gas inside a ceramic housing in contact w/ two electrodes. In an over-voltage, a spark forms between the electrodes allowing a current to flow. Current stops flowing when the voltage across the device drops below the extinction voltage.
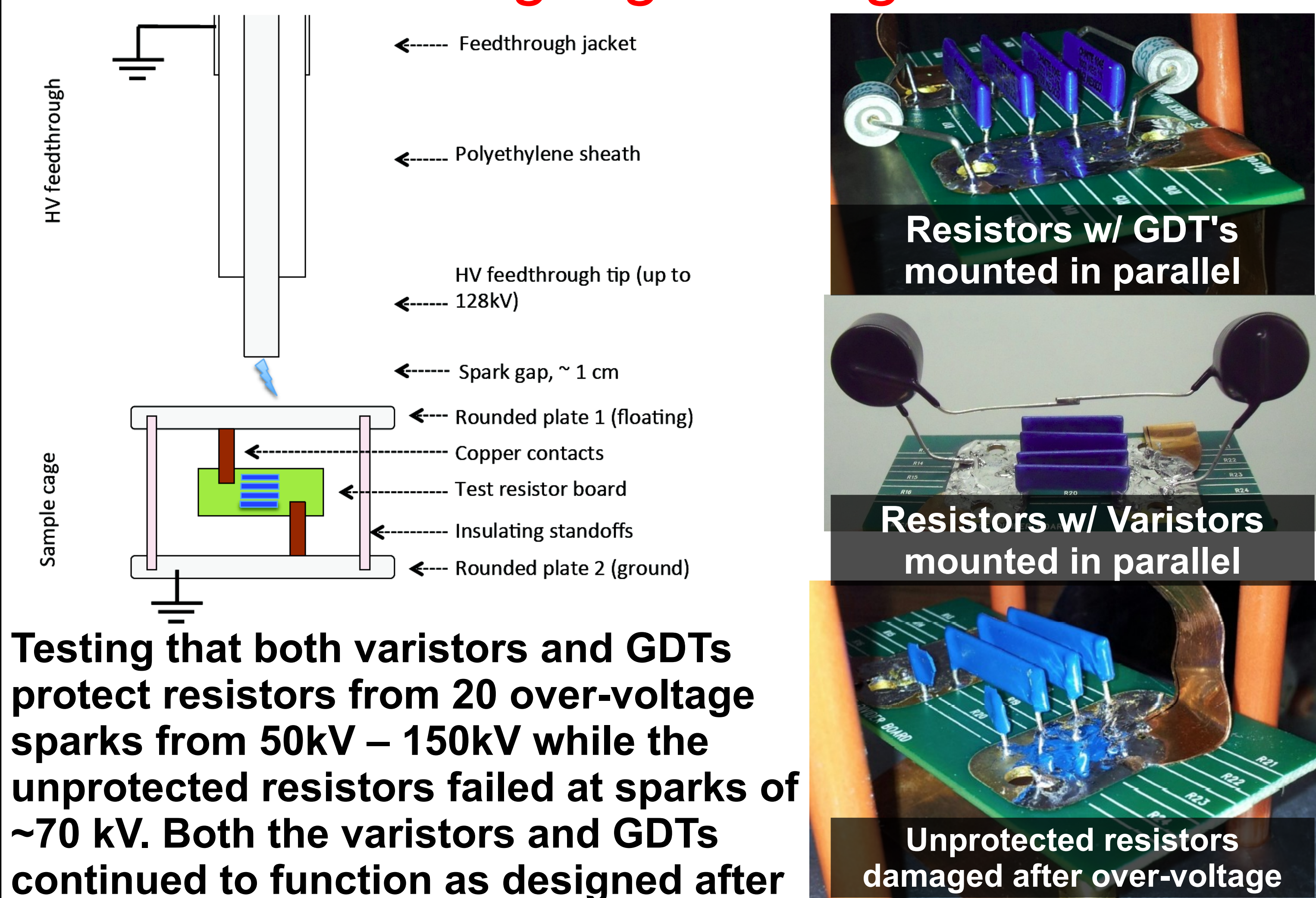
Requirements for Surge Protection in LArTPCs

- Have a significantly higher resistance than the nominal resistance

- "Clamp" an over-voltage to less than a damaging voltage

- Survive repeated discharges at a typical energy of a fault condition

- Function at cryogenic temperatures and in high purity Lar *(high purity tests done, not shown here)*

- No impact on argon purity *(tests done, not shown here)*

- No large flux of photons during nominal running condition *(tests done, not shown here)*

Test Results of Surge Protection in Liquid Argon
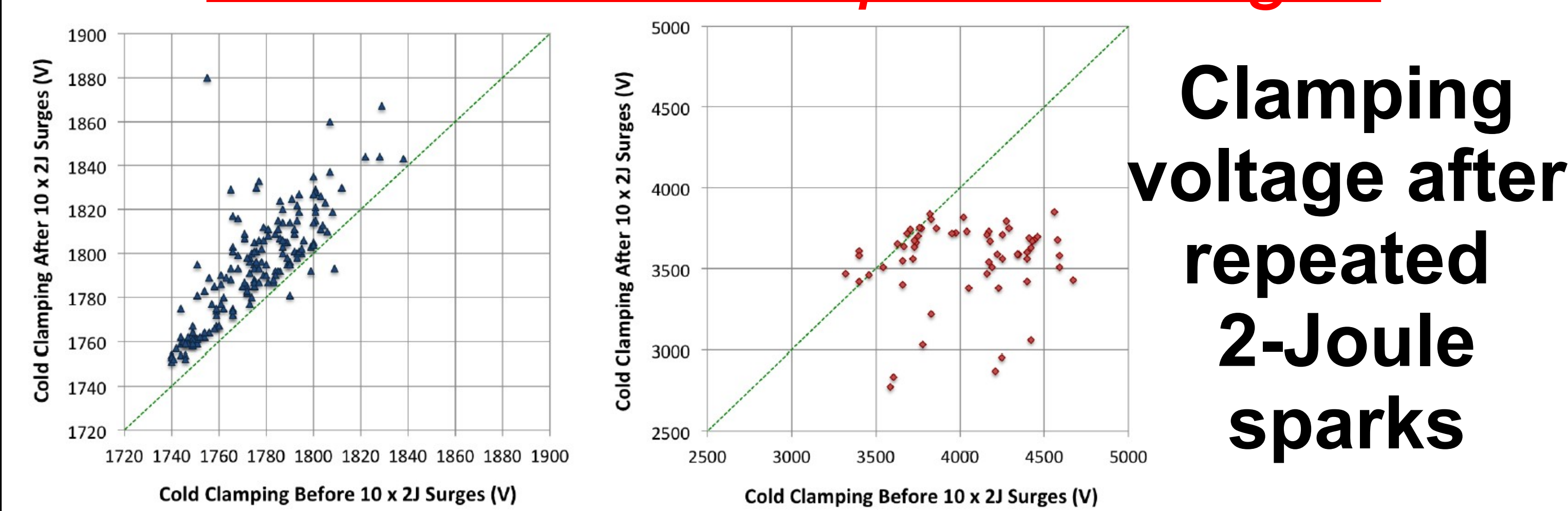
Behavior under cryogenic temperature

Clamping voltages warm and cold

Clamping voltages during cryo-cycles

Protection during high voltage breakdown

Feedthrough jacket, Polyethylene sheath, HV feedthrough tip (up to 128kV), Spark gap, ~ 1 cm, Rounded plate 1 (floating), Copper contacts, Test resistor board, Insulating standoffs, Rounded plate 2 (ground)

Resistors w/ GDT's mounted in parallel

Resistors w/ Varistors mounted in parallel
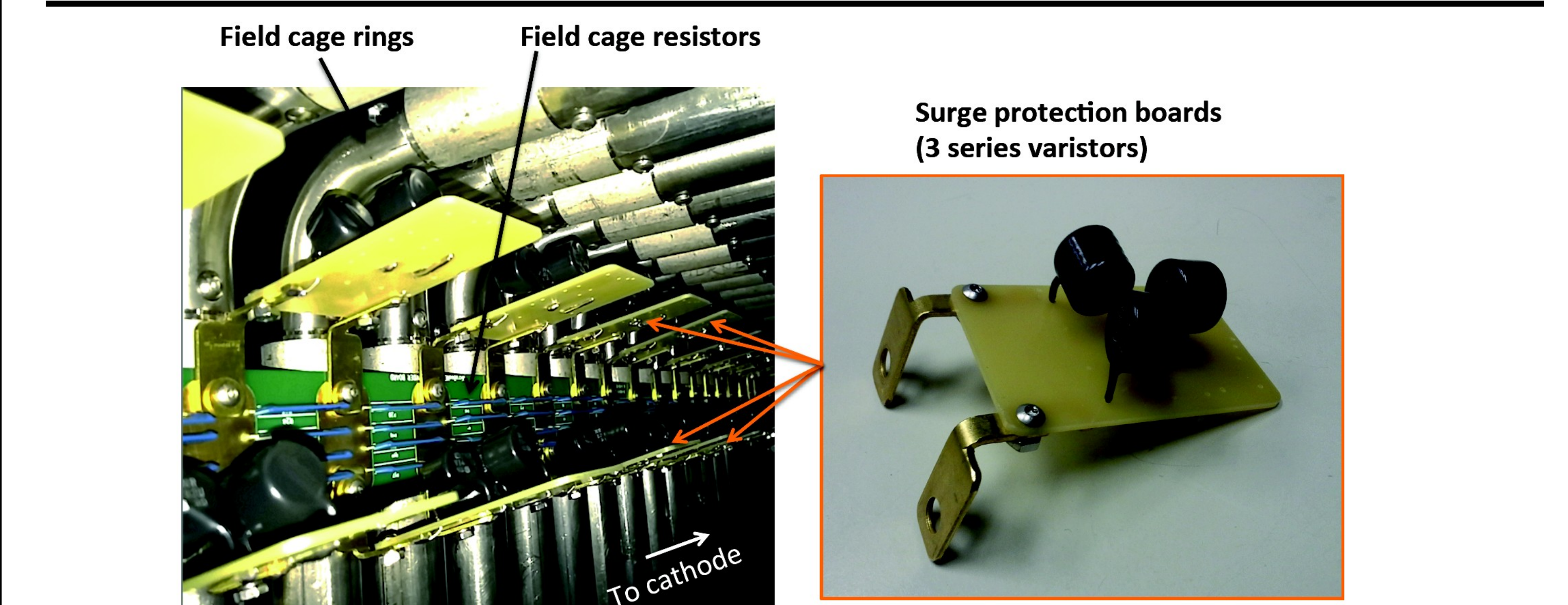
Unprotected resistors damaged after over-voltage

Testing that both varistors and GDTs protect resistors from 20 over-voltage sparks from 50kV – 150kV while the unprotected resistors failed at sparks of ~70 kV. Both the varistors and GDTs continued to function as designed after undergoing the high voltage test

Behavior under repeated surges

Clamping voltage after repeated 2-Joule sparks

Installation into MicroBooNE

Field cage rings, Field cage resistors

Surge protection boards (3 series varistors)

To cathode

Varistors were installed in the MicroBooNE TPC and this will be the first time they have been used in a LArTPC experiment