UW IEC Group 2011: Continuing Preparations for 300 kV Operation – Device Switching

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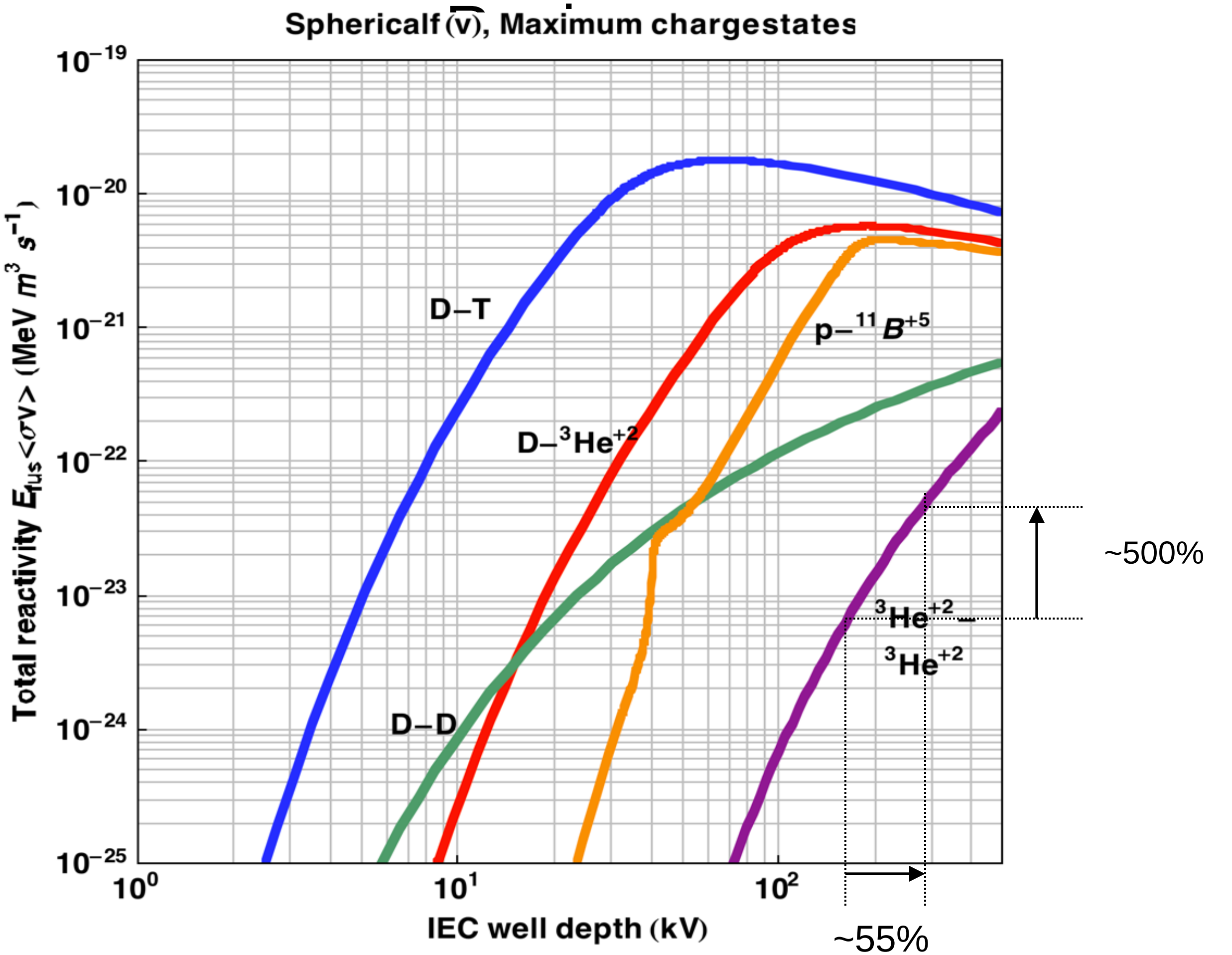
Inertial Electrostatic Confinement Group

Motivation for Using Greater Cathode Voltages

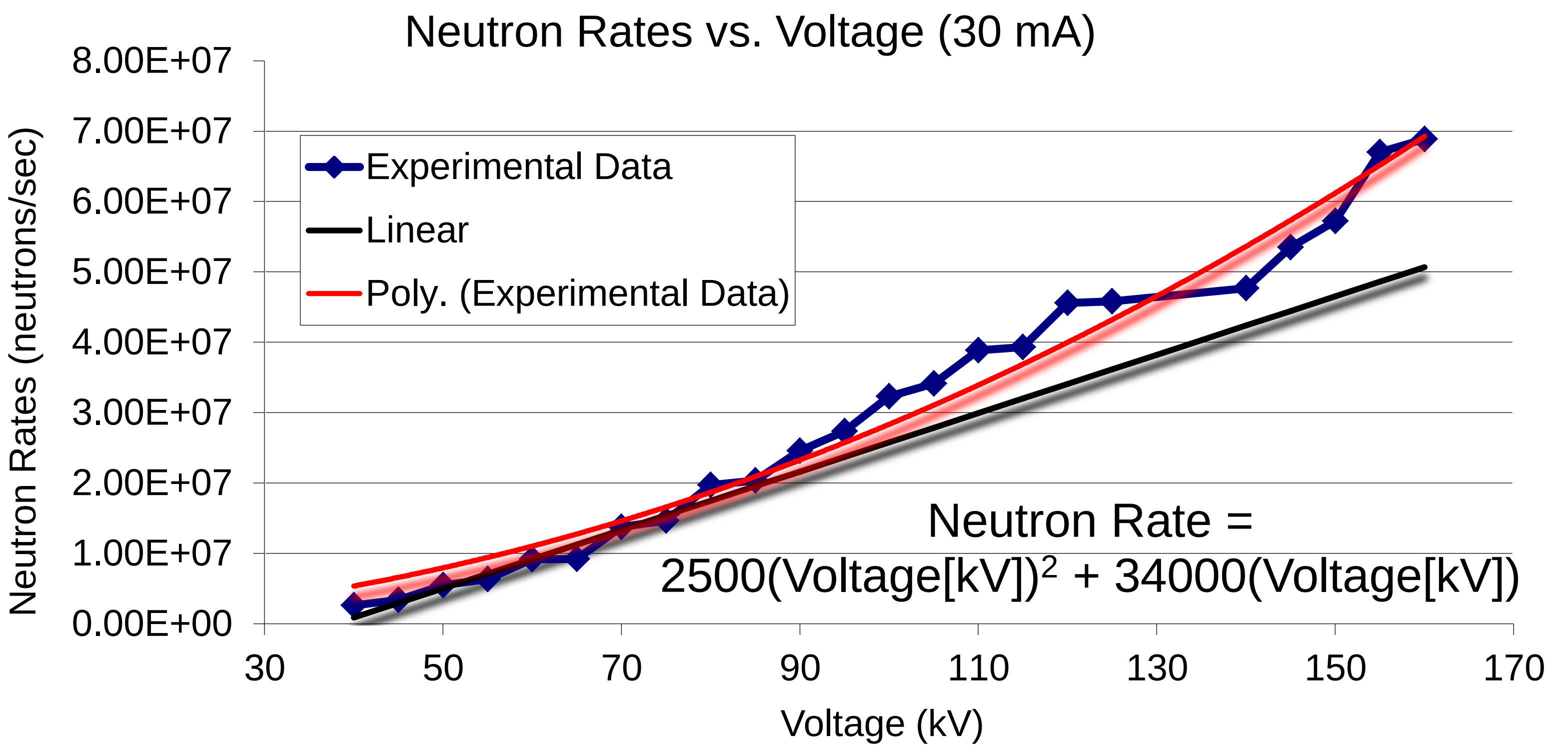
Improved access to ^{3}He-^{3}He Fusion



Source: J. F. Santarius

Motivation for Using Greater Cathode Voltages

- Neutron flux appears to be monotonically increasing with voltage (greater voltage ==> more neutrons)



From 2008 Workshop Donovan presentation (WE-08)

Adaptations for 300 kVDC

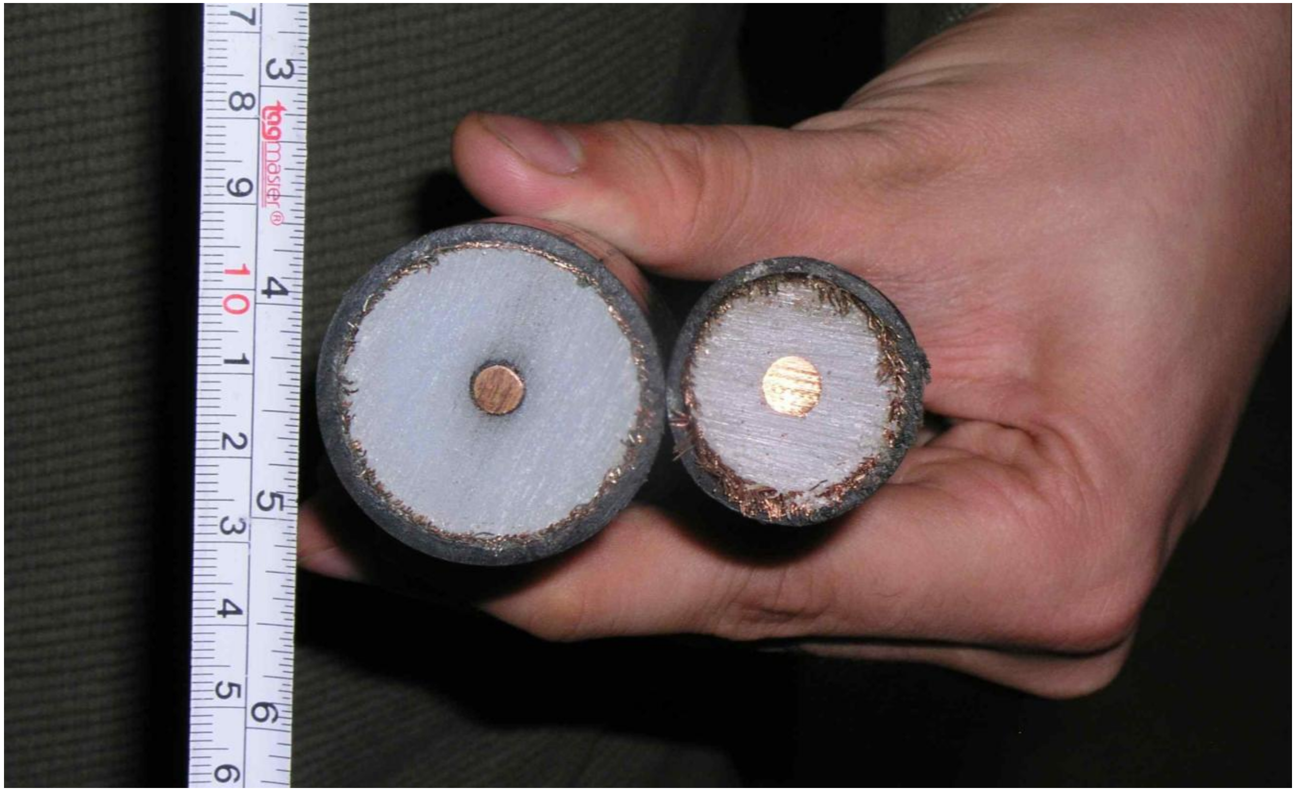
Completed:

- Power Supply upgrade (done)
- Vacuum Feed-through assemblies (covered by Becerra during this workshop)

In Progess:

- Cabling
- Series Resistance assembly ("resistor barrel")
- Switching

Cabling



(New) 300 kVDC cable, left, and (current) 200 kVDC cable, right

The new cable is much less flexible, and more subject to flexure-induced failures.

High Voltage Switch and Series Resistance Assembly

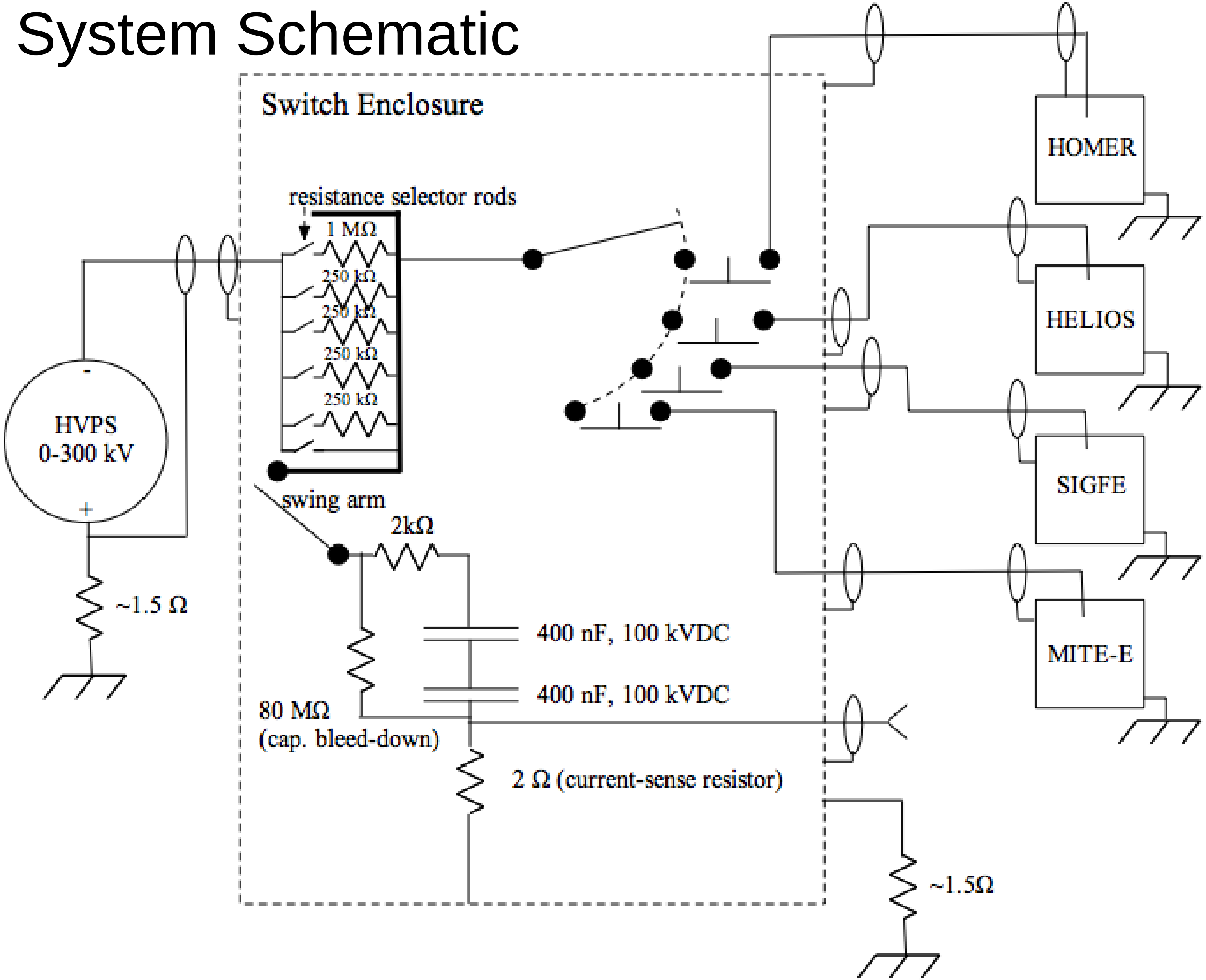
Specifications:

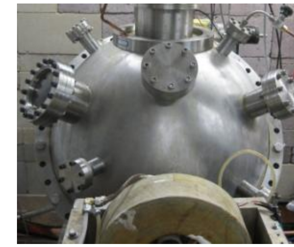
1. Cold-switch the high-voltage power supply between four different devices
2. Removing and replacing cables not to be required
3. Non-inductive series resistor of 50 kΩ able to carry 200 mA current in steady state
4. Resistor to be adjustable to higher resistances (though at a lower current), and completely bypassable
5. Pulsing capacitor and related equipment is to be in the same enclosure as the switch.

Switch Design Drivers

- 35 cm path length between 300 kV surface and ground (to prevent track arcing)
- 15 cm (oil filled) distance between 300 kV surface and ground (to prevent through-oil arcing)
- Electric field below ~5 MV/m
- Resistor System requires electrostatic shielding
- Capacitor system switched in parallel with power supply for pulsing

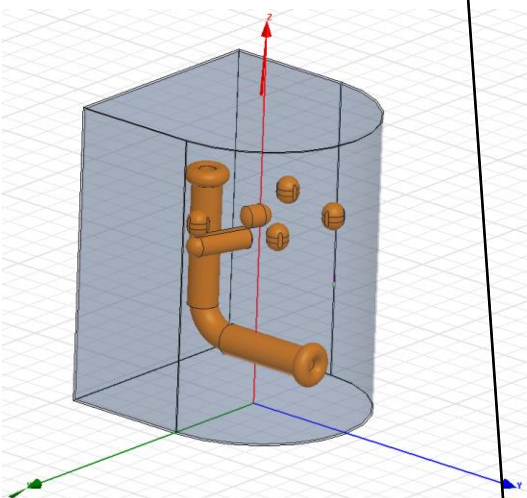
System Schematic

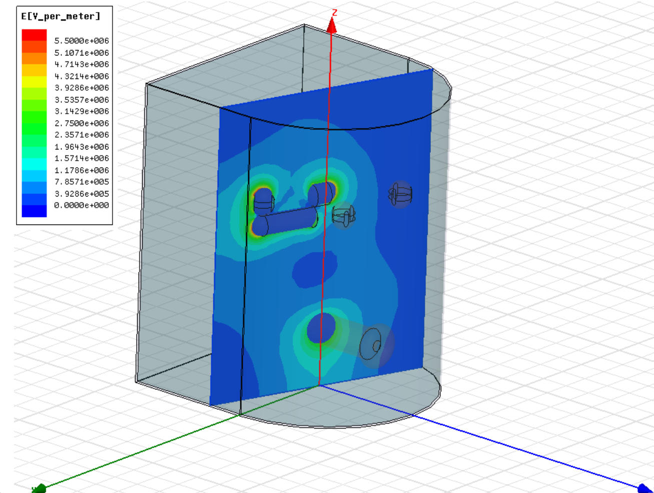




Design & Construction methodology

Design/Redesign
Concept

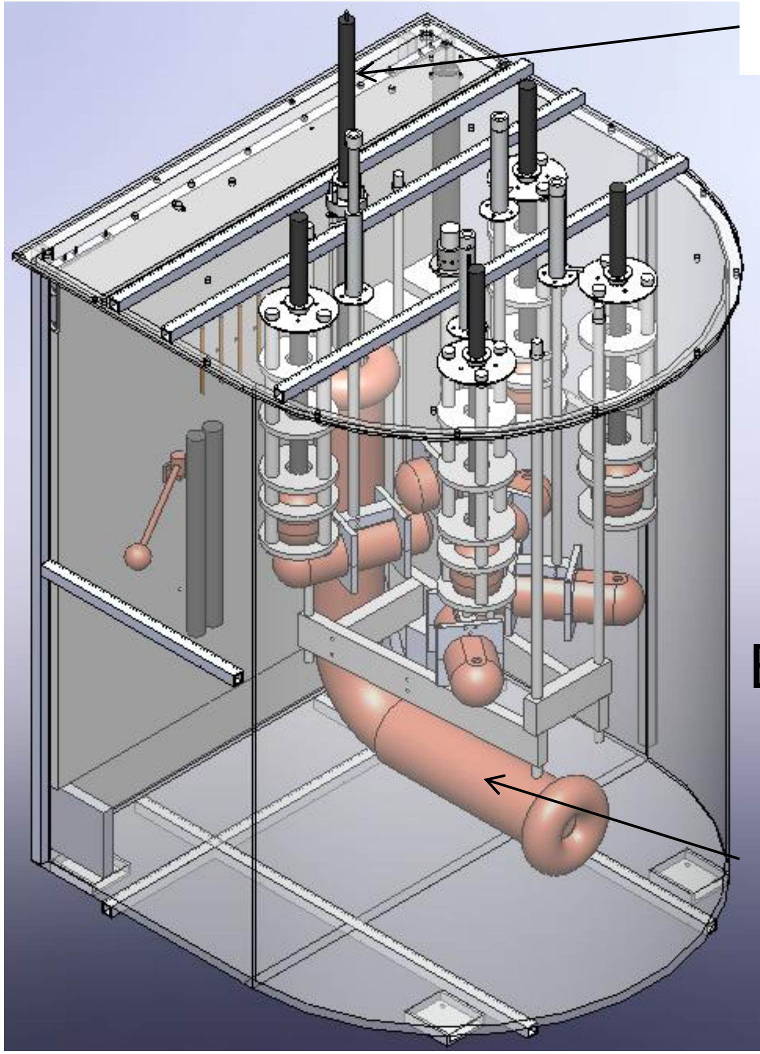




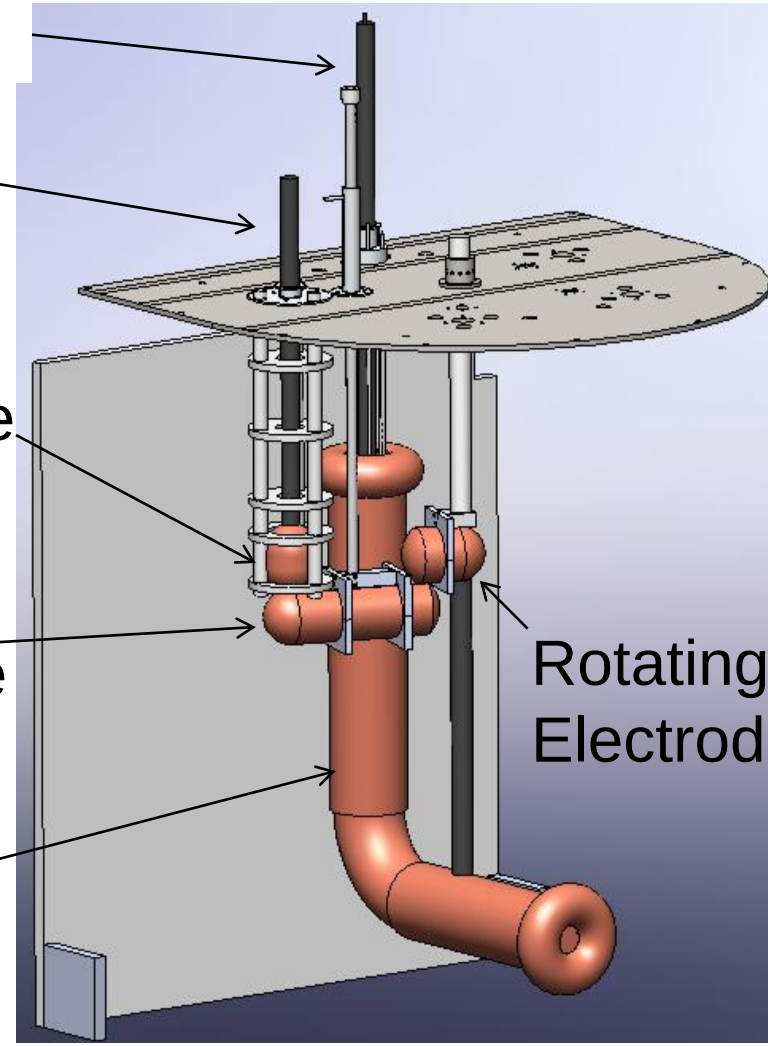
Simulation (MAXWELL -3D)

Construct → Test ↔ Modify

Final System Layout



Switching Electrodes



Power In

Power Out (4)

Output Electrode (4)

Bridge Electrode (4)

Resistor tube

Rotating Electrode

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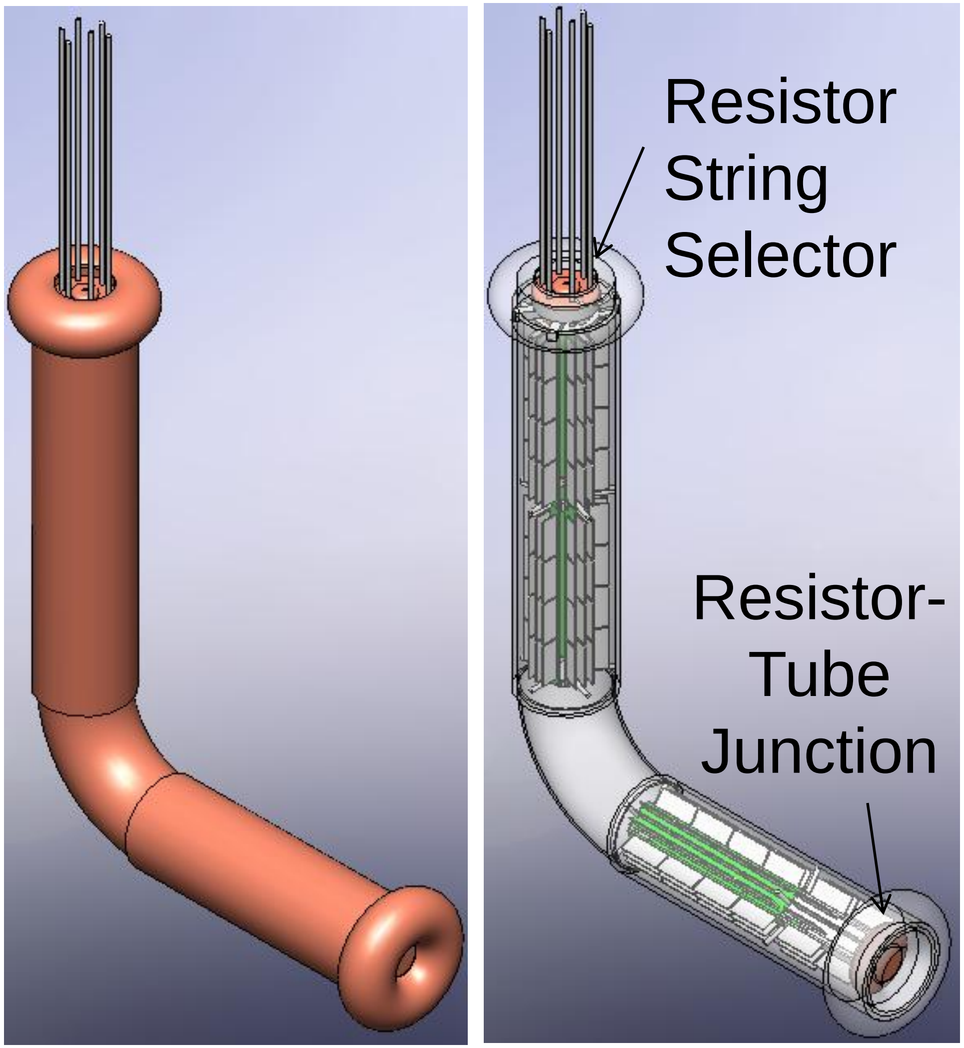
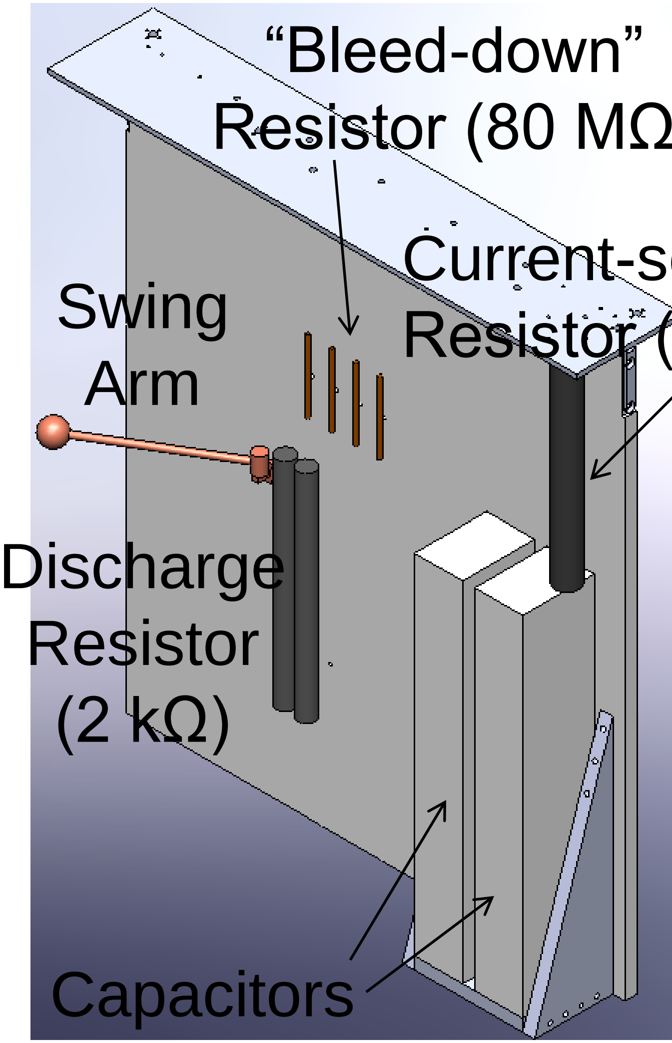
Resistor System

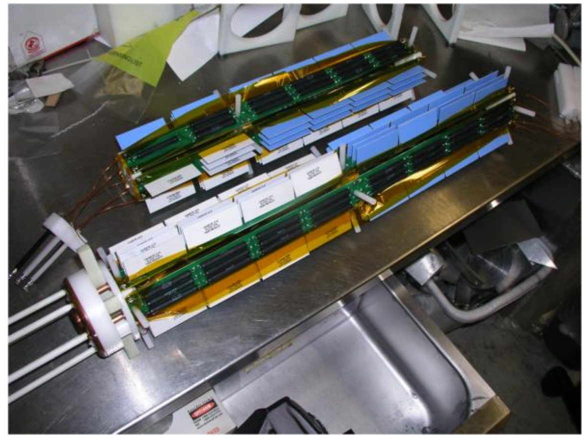


Capacitor System



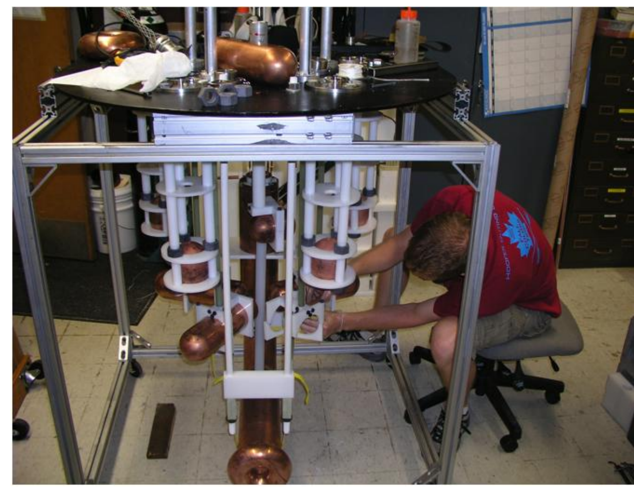
Manufacturing – Internal Components

Electrodes (5 types)



Series Resistor Strings ←

Support components (and electrodes) →

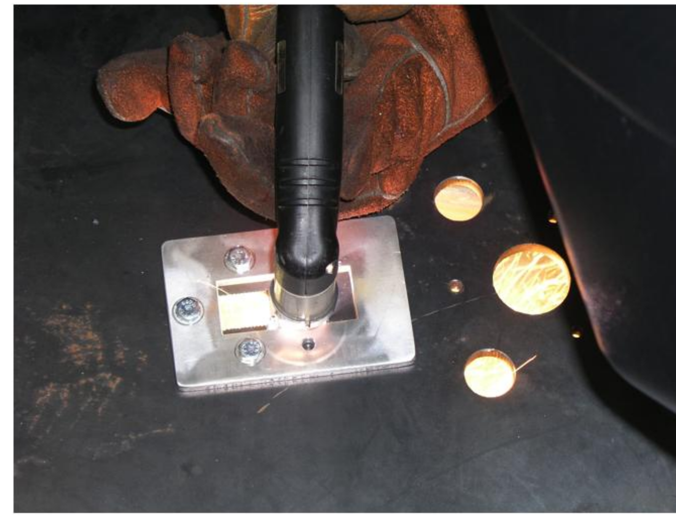


Manufacturing – External Components (Tank)

Tank Body Volume

~ 1200 L

Removing scale ←



Leak Checking
(note red dye) ←

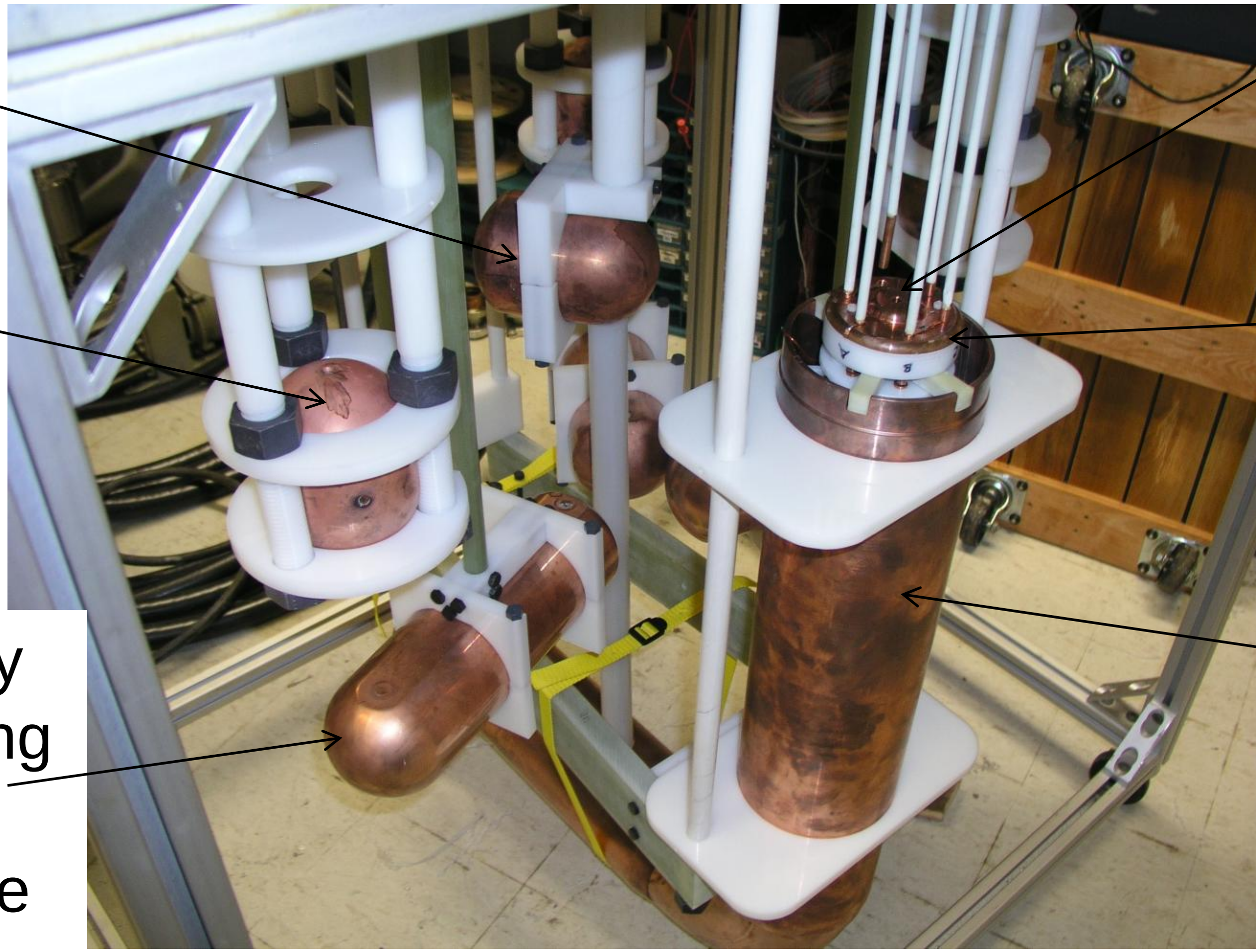
Plasma Cutting
Slot into Lid

Implementation: Electrode Assembly

Rotating Selector Electrode

Output Electrode 1 of 4

Vertically Translating Bridge Electrode 1 of 4



Power Input Contact

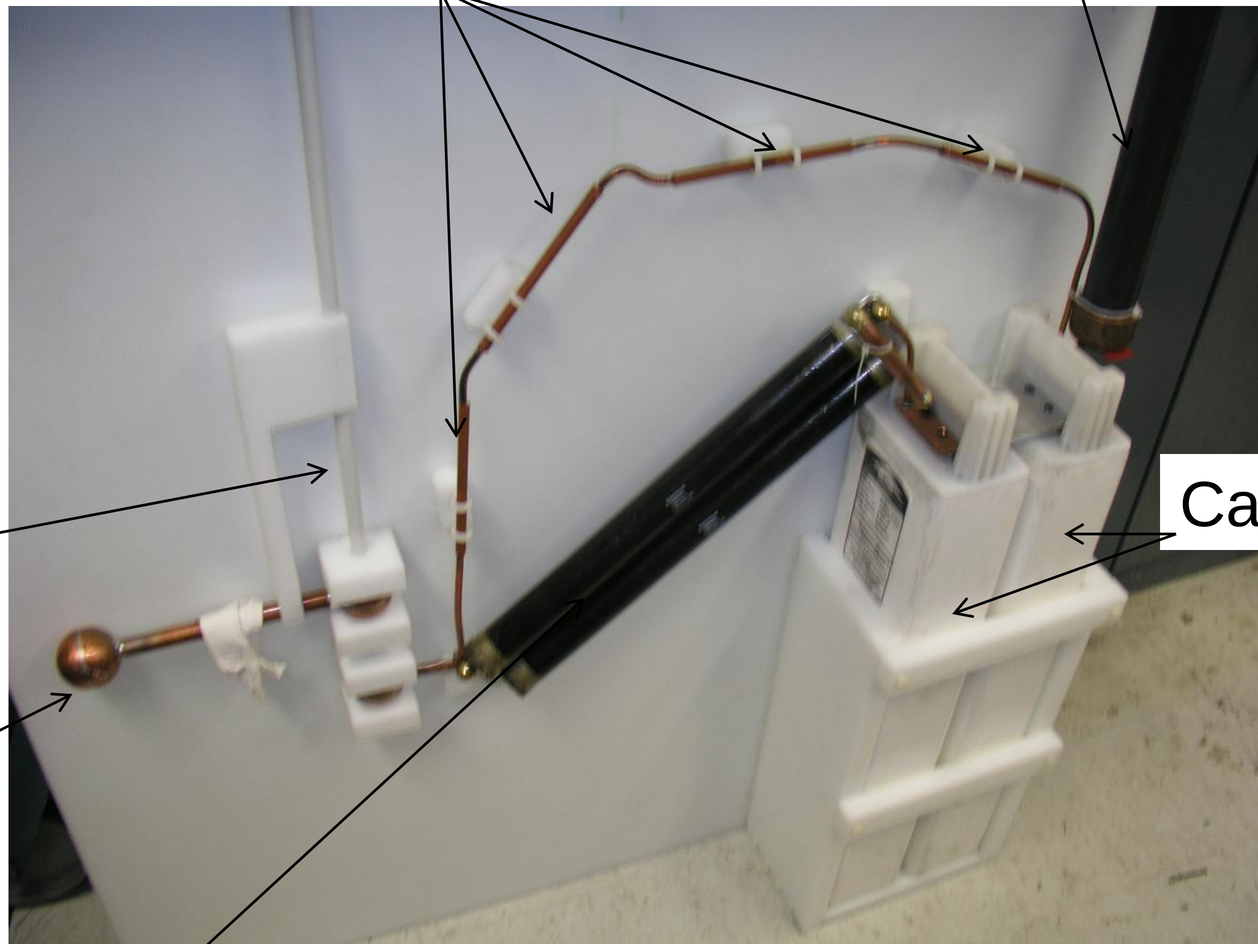
Resistor String Selector

Resistor Tube

Implementation: Pulsing

"Bleed-Down" Resistor (4 X 20 MΩ)

Current Sense Res. (2 Ω)



Swing Arm Control Rod

Capacitors

Swing Arm

Discharge Resistor (2 kΩ)

Testing: Resistor Assembly

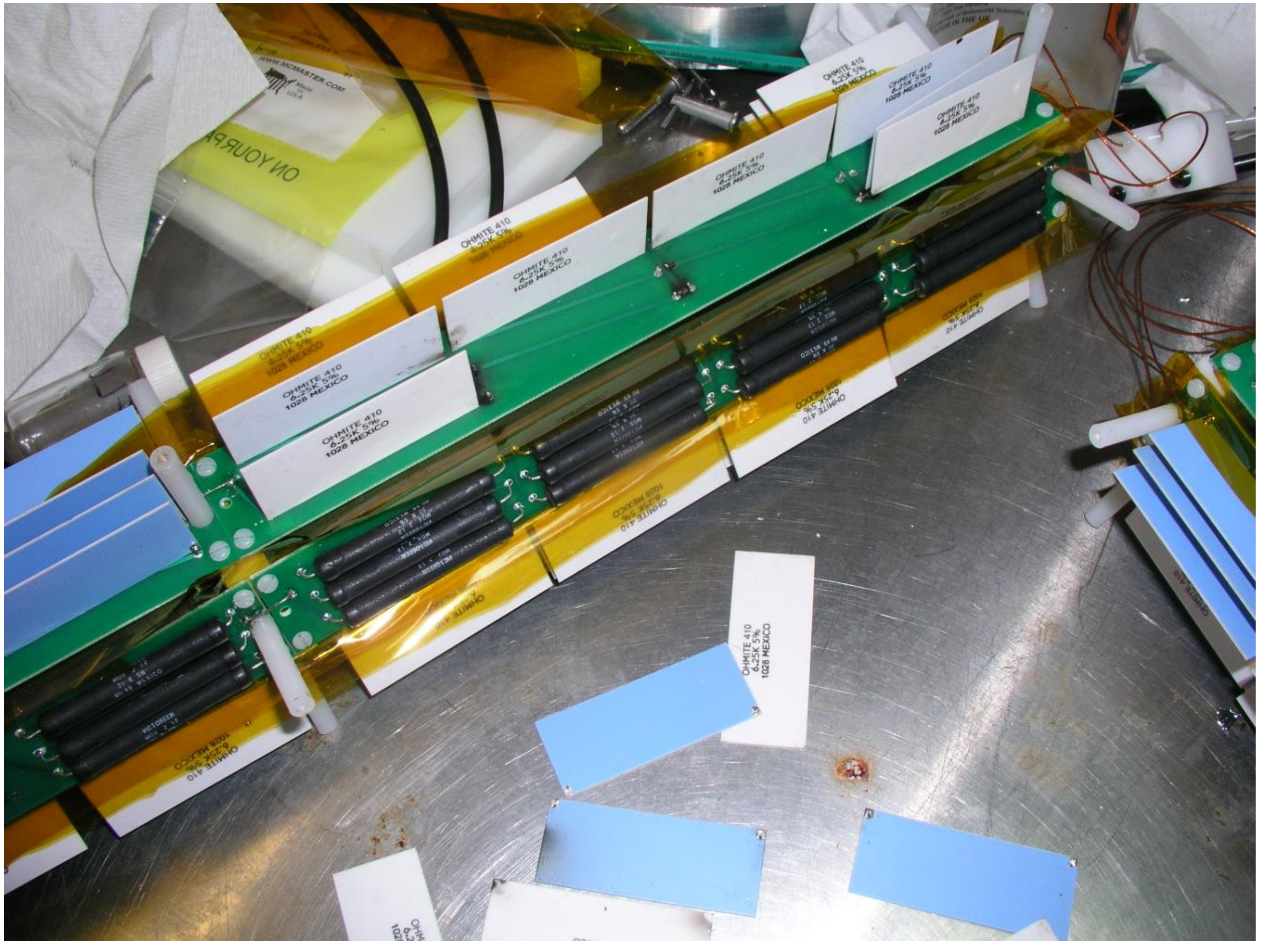
Initial Testing Failure: Internal Arc (corrected later)

Final Assembly

Installation of the pulsed system in the switch tank →

Photo of main switch assembly being lowered into switch tank ←

Testing: Resistor Assembly

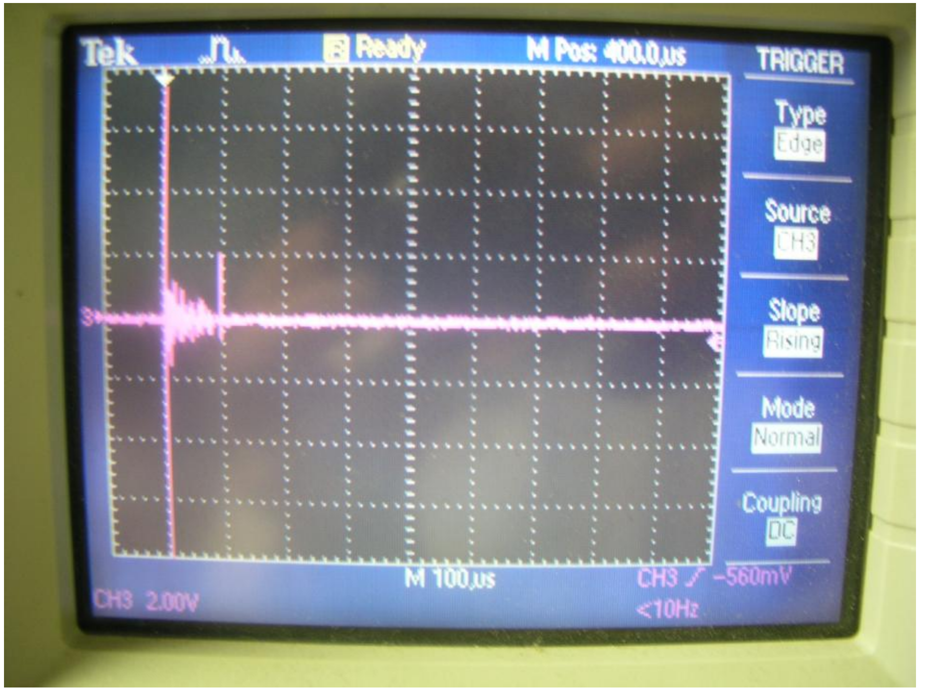


Initial Testing Failure: Insufficient Cooling (later corrected)

System Testing: High-Potential Test to 100 kV Without Dielectric Oil

Result: Unexpected, very short-time-scale arcs occurred in IEC devices when they were connected via the new switch, but not otherwise!

Vertical scale is 1 A / division: arc peak current is off scale!



Arc duration is approx. 100 µsec.

Testing Results Summary:

- OK: The resistor string assemblies, as modified, can withstand the anticipated voltages and currents that are expected in regular operation.
- OK: The resistor string assemblies, when immersed in oil, will not exceed their temperature limits.
- OK: The assembled switch has been tested to 100 kV DC in air, which implies that it will likely be able to work at 300 kV DC when immersed in oil.
- FAIL: When an IEC devices is connected through the new switch, arcing within the device occurs at 60 kV DC. **This does not occur when the device is connected via the present resistor barrel.**

Why are these "micro-arcs" in our IEC devices not seen when we use our present (designed for 200 kV DC) resistor barrel?

Present Resistor Barrel – internal components exposed

It is our “working assumption” that some electrical characteristic of the present resistor barrel prevents these arcs.

We are attempting to determine what this characteristic is in order that we might incorporate it into the new switch

Analytic procedure (in progress):

1. Make measurements of overall impedance characteristics, i.e., |Z| at various frequencies

2. Attempt to fit the observed characteristics with a lumped parameter model

3. If unsuccessful, adjust the model and attempt a fit again.

Summary of Current Status:

- Switch components have been built and successfully tested
- System-level testing of the assembled switch failed with a peculiar “micro-arcing” which occurs in our IEC devices when powered through the new switch, but not through the present resistor barrel.
- Analysis of the current resistor barrel is in progress

Questions?