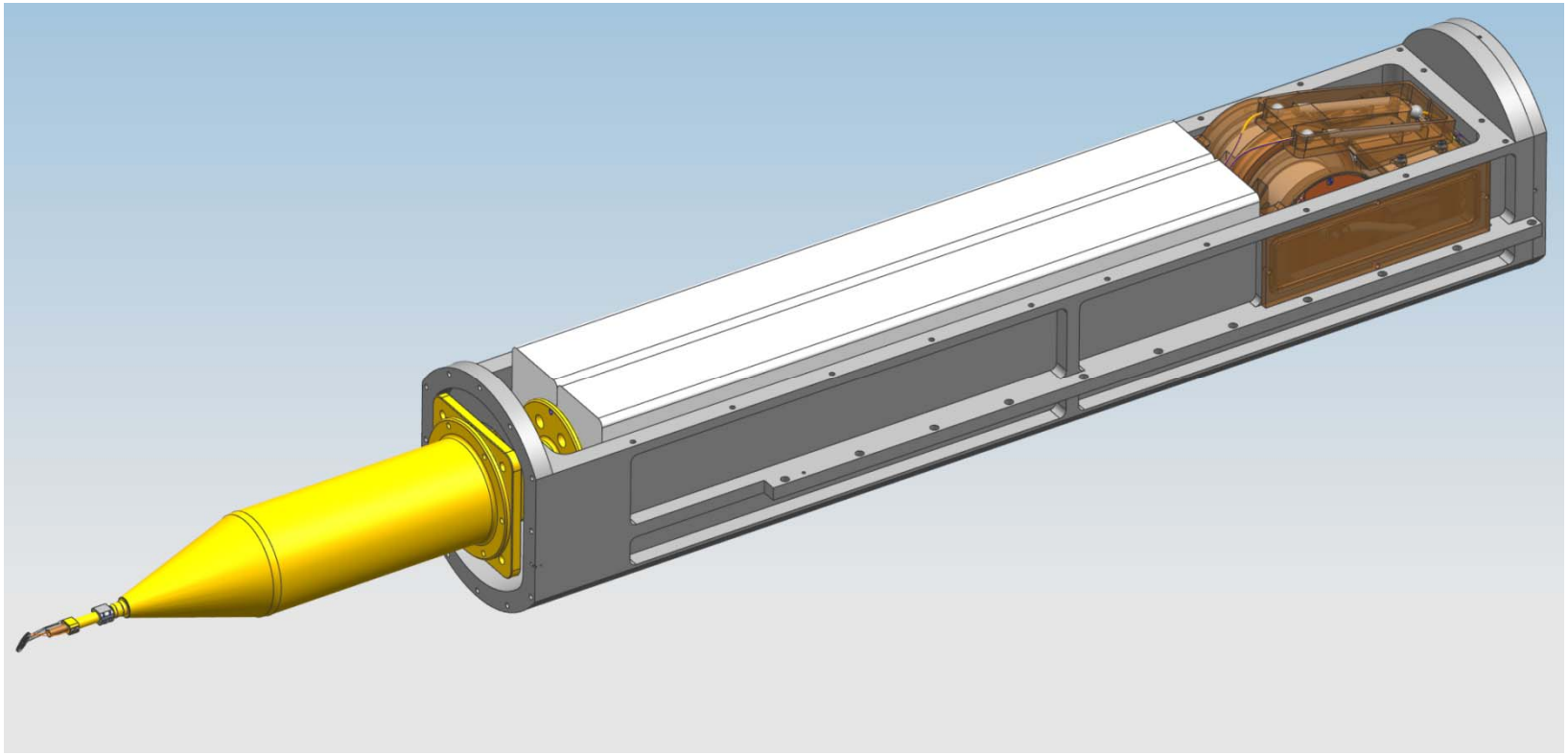
MIFEDS Gen III: A TIM-based 30-T pulser

R. B. Spielman, G. Brent, R. Shapovalov, R. Moshier, and G. Fiksel

Laboratory for Laser Energetics, University of Rochester

Rochester, NY 14623, USA



MIFEDS Gen III Conceptual Design

- **MIFEDS Gen III must fit in a existing TIM**
  - **Complete MIFEDS Gen III hardware in CY 2018**
  - **Minimize Omega systems engineering and approvals**
- **Minimize new pulsed-power components**
  - **Use existing GP-14B vacuum switches & trigger units**
  - **Use existing capacitor-charging power supplies**
  - **Initially use the improved MIFEDS Gen II transmission line**
- **MIFEDS Gen III must be able to provide more B (30 T goal for ICF capsules) than MIFEDS Gen II**

Gen II / Gen III specification comparison

	MIFEDS 2	MIFEDS 2.1 (lab test mods)	MIFEDS 3
Distinguishing characteristics	Qualified design	Higher capacitance, modified T-line, Coil holder, wire, SF_6	New design, Custom caps., External charger
Stored energy (kJ)	0.2	0.45	2.25
Capacitance (μF)	1.0	2.2	5.0
Internal inductance (nH)	150	150	90
Short Ckt. current (kA)	37	48	100
Rise time (μs)	0.5	0.7	1
Max op. voltage (kV)	20	30	30

MIFEDS Gen III Performance Goals

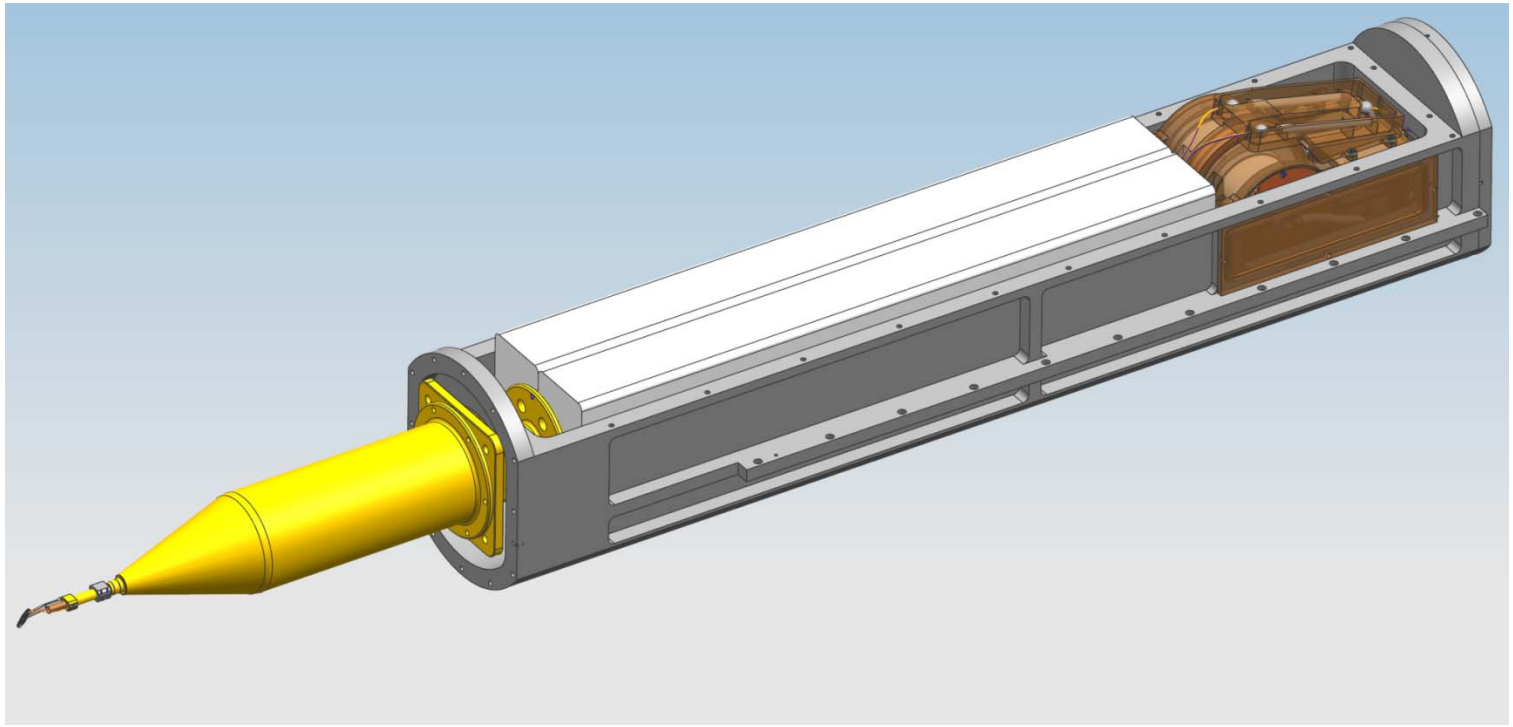
- A pulser capable of ~100-kA maximum current.
  - There will be a 50-kA limit on the capacitors and the switches.
  - Reversal limits assume a matched resistive load
- Current rise time ~ 1 μs
  - Run two capacitors and two switches in parallel to reduce pulser inductance and resistance and increase the output peak current
  - Rise times ~ 1 μs are an optimum tradeoff between coil action (driving to short pulses) and voltage (driving to long pulses).
- Peak charge voltage – 30 kV
  - 35-kV maximum voltage on the capacitor and the vacuum switches
  - Higher voltages increase risk breakdown in the TIM
  - Allow the HV power supplies to be external to the TIM (TIM volume)
- 30-T goal (coil limited)
  - Pulser capable of driving coils with a wide range of inductance

How MIFEDS Gen III increases peak B

- Custom capacitors will increase the total stored energy to 2250 J and peak current to 50 kA per capacitor. Operate up to 30 kV.
- Switches in parallel hold the internal pulser inductance down (~ 90 nH).
- Modified transmission line and coil holders will increase load voltage hold off from 12 kV to 30 kV.
  - Design will eliminate features that cause E-field enhancement and arcing
- At fields above ~25 T, coil motion & heating (coil action) reaches a point where no coil can survive and coils using smaller wire size vaporize.
  - The best way to minimize action is a fast rise time, requiring low-inductance design.
  - Mass produced 1-shot coils
- Above 50 T, multi-turn coils become problematic as inter-winding forces become very large.

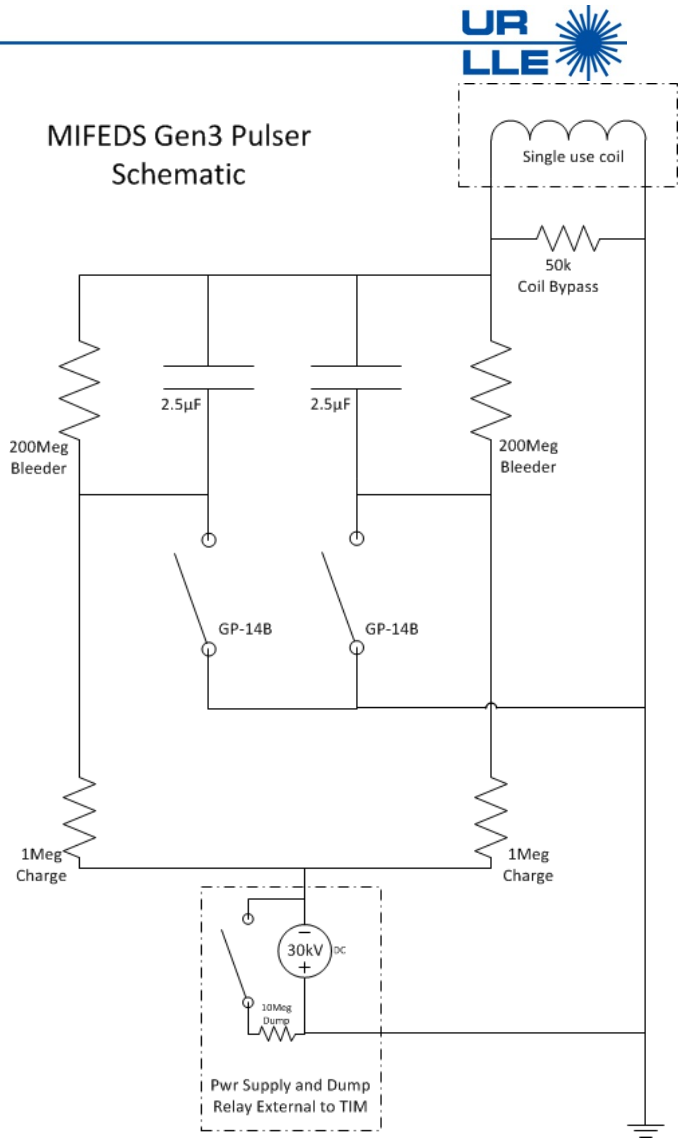
MIFEDS Gen III: Two parallel pulsers

- **We chose to use two, 2.5-μF capacitors (custom) and two, Excelitas Technologies GP-14B vacuum switches as the pulser.**
  - **One capacitor and one switch per sub-pulser with two sub-pulsers in parallel**
  - **Ground-side switching**



MIFEDS Gen III: Circuit Schematic

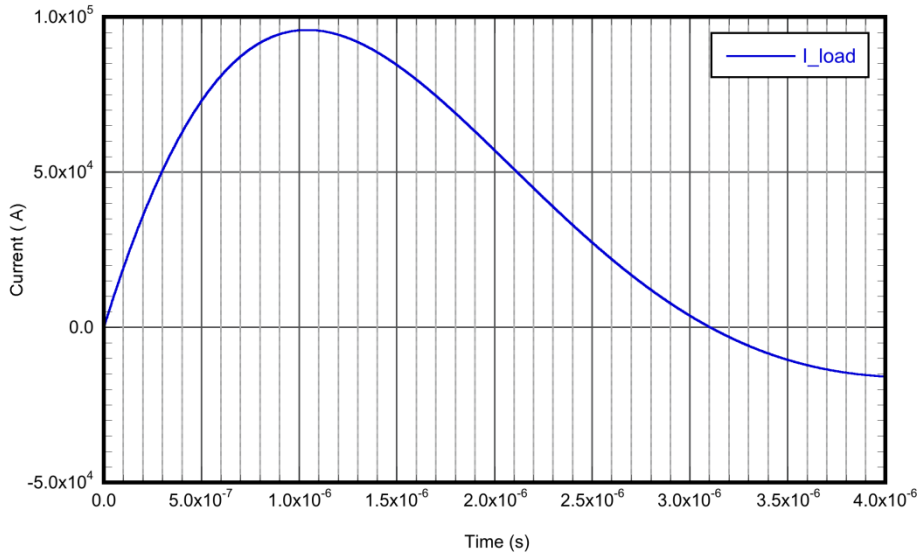
- **Ground-side switching**
- **Bleeder resistors: 30 kV to 50 V in 53 min**
- **Dump circuit: 30 kV to 50 V in 3 min**
- **Charge & Dump profile check post shot verifies dump circuit integrity**
- **Coil bypass resistor ensures capacitors have ground connection when coil is removed or destroyed**
- **Charge resistors limit cable chain coaxial cable fault current to 60 mA**

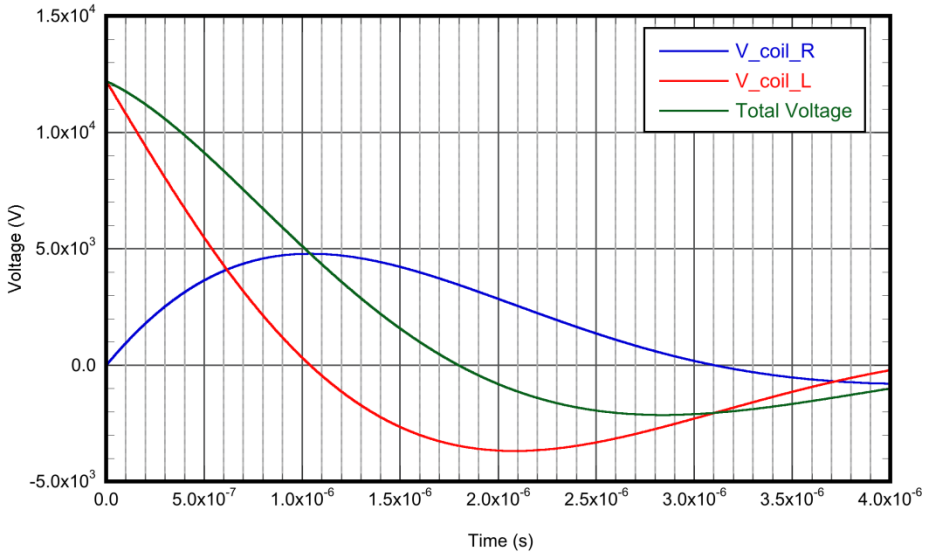


MIFEDS Gen III can deliver a maximum of 100 kA

- **Circuit simulations by Roman Shapovalov showed that the proposed MIFEDS Gen III pulser could deliver ~ 100 kA in 1 μs to a 60-nH load.**
  - **Total C = 5 μF @ 30 kV (2.25 kJ) using dual GP-14B vacuum switches in a grounded configuration, matched load to minimize reversal.**
- **Peak current into a 92 nH load is 85 kA with R_m = 0.189 Ω.**
- **Peak current into a 900 nH load is 54 kA with R_m = 0.44 Ω.**

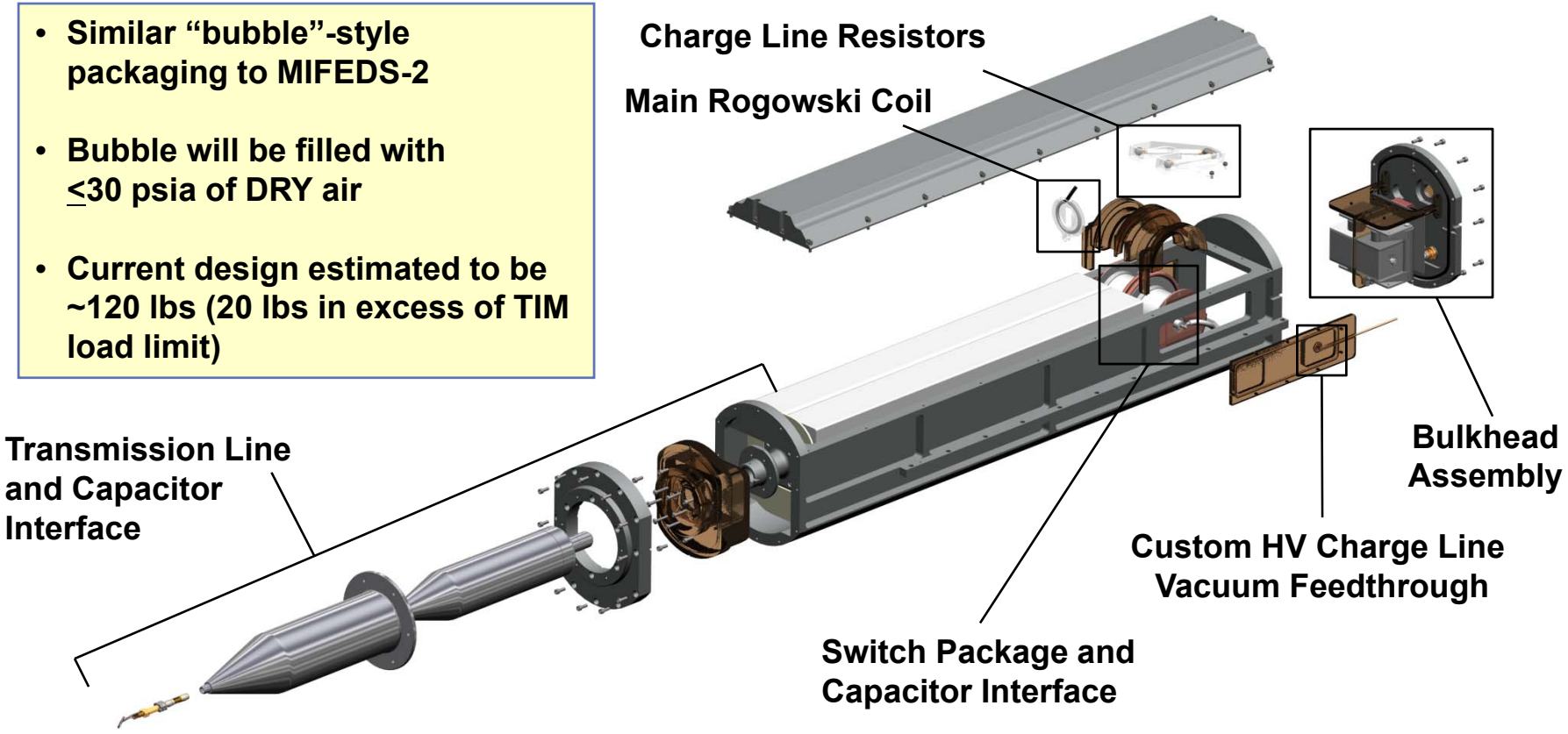
60-nH coil



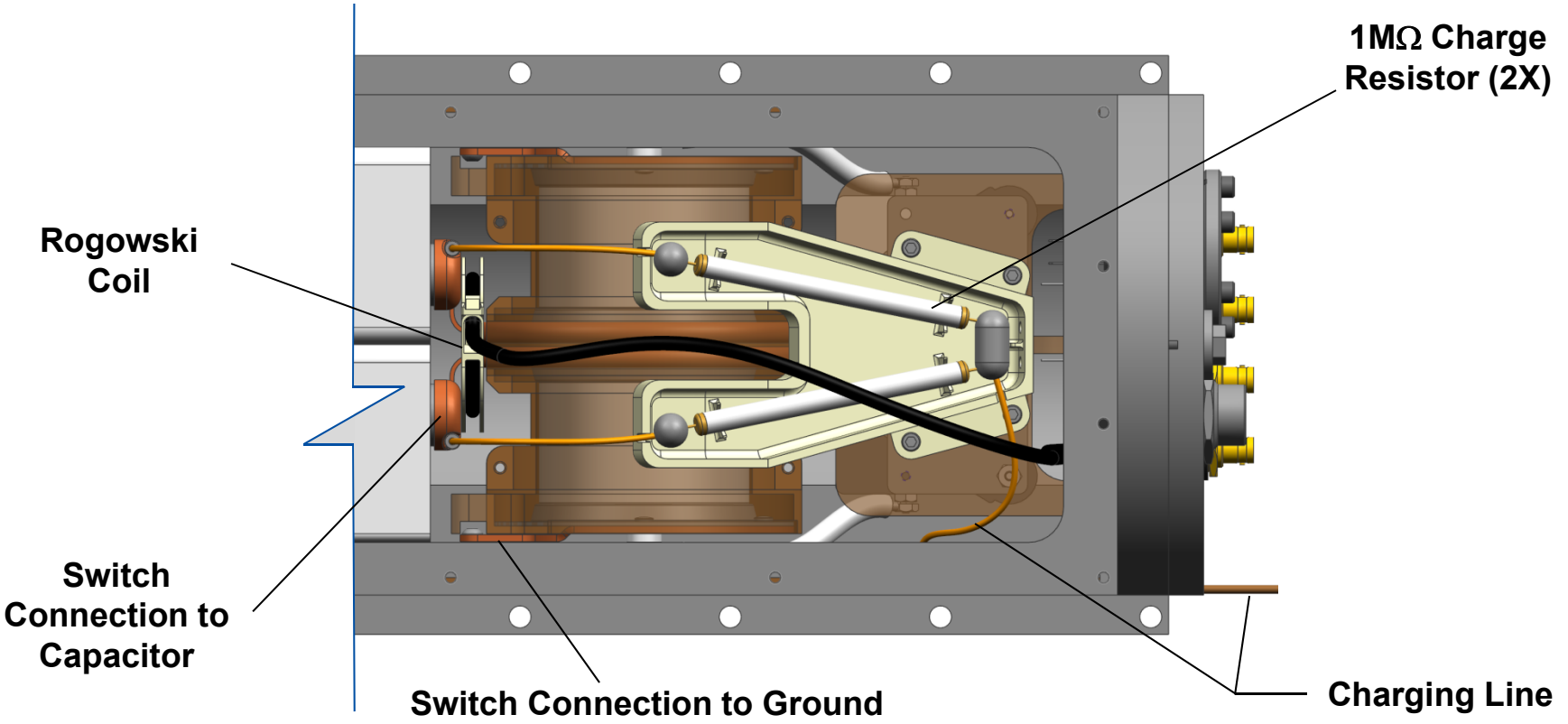


MIFEDS Gen III: Assembly Breakdown

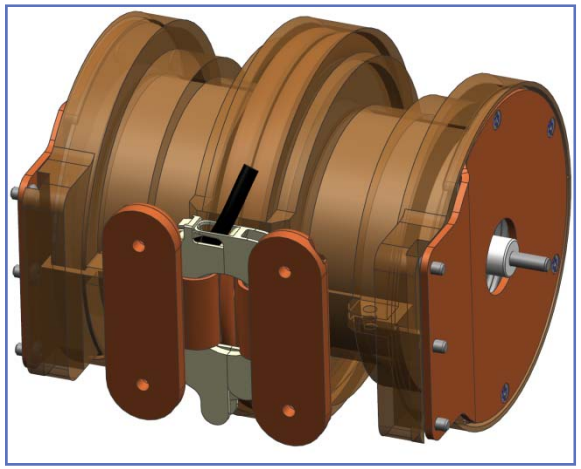
- Similar “bubble”-style packaging to MIFEDS-2
- Bubble will be filled with ≤30 psia of DRY air
- Current design estimated to be ~120 lbs (20 lbs in excess of TIM load limit)



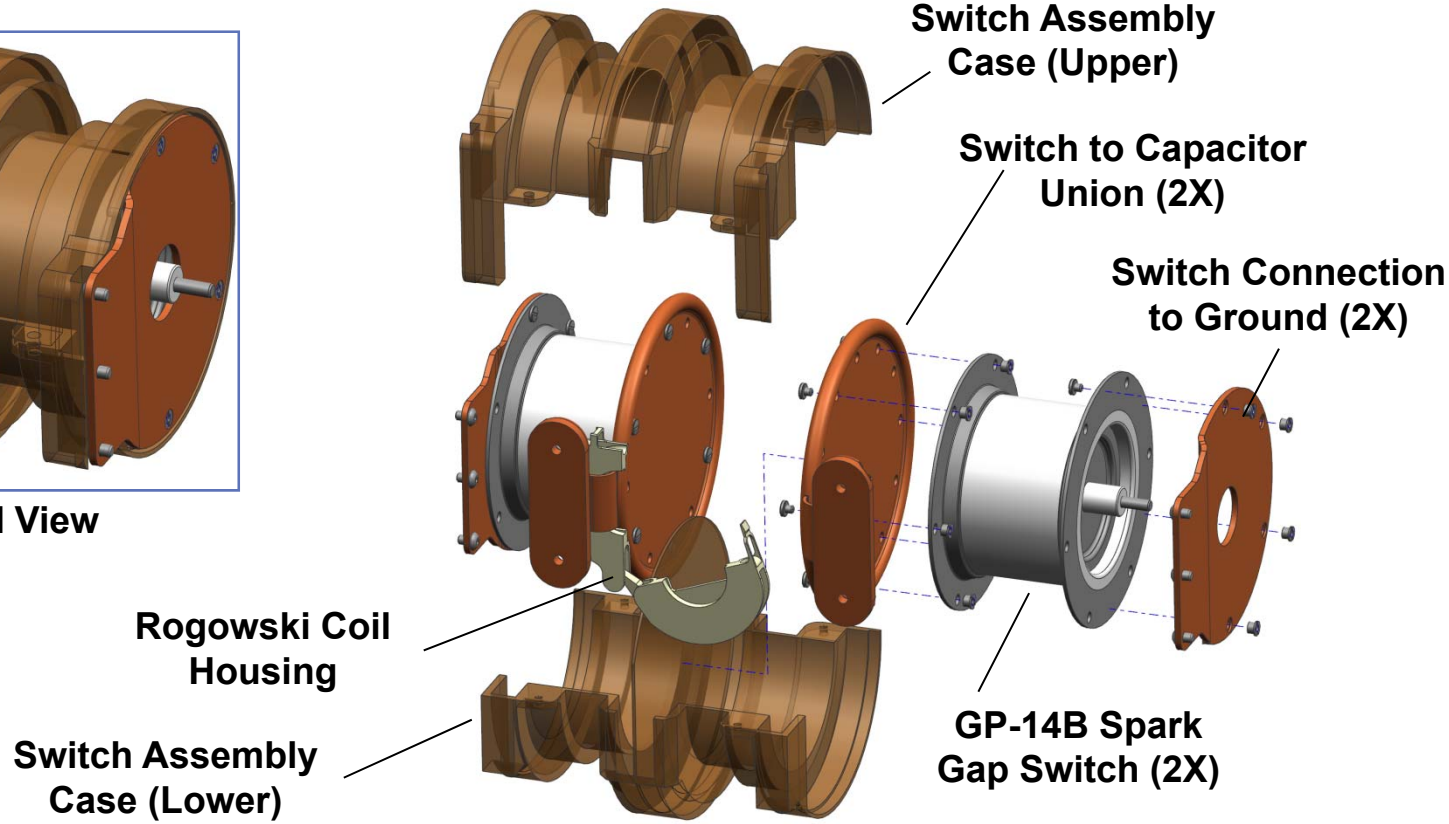
Dual Switches & Charging Resistors (Top View)



Switch Assembly Showing Field Shapers and Insulators

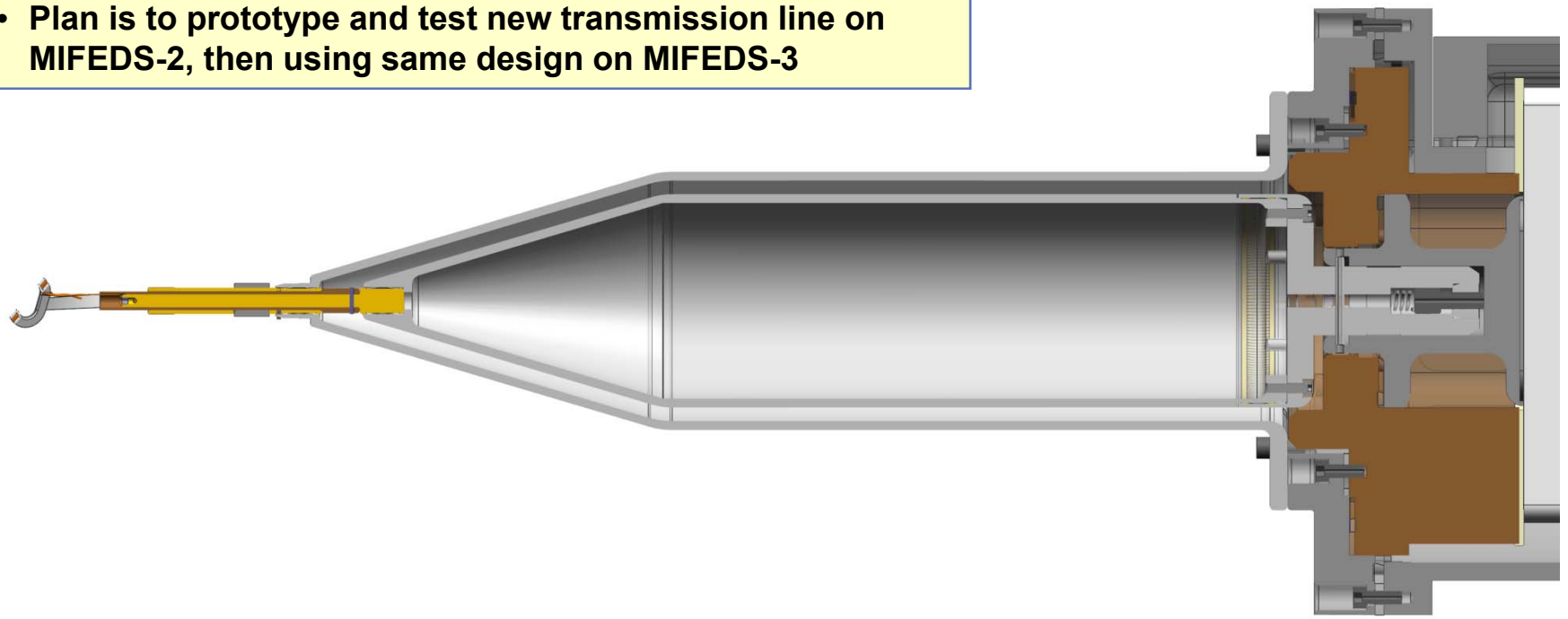


Assembled View

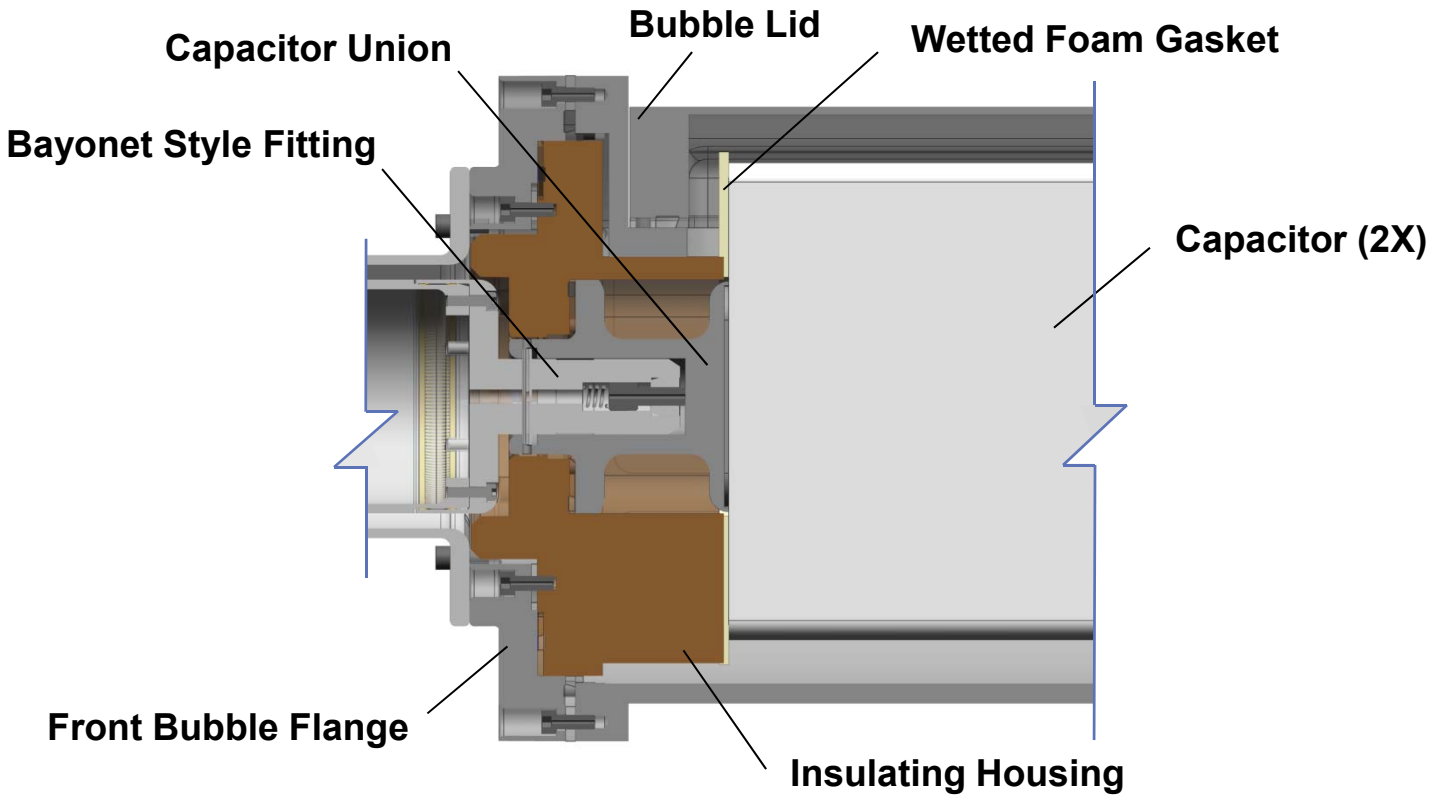


Transmission Line

- **MIFEDS Gen III uses the improved transmission line from MIFEDS-2**
- **Plan is to prototype and test new transmission line on MIFEDS-2, then using same design on MIFEDS-3**



Transmission Line to Capacitor Interface



Gen III Testing

- Hipot testing of new custom capacitors (PulseLab)
- Testing of GP-14B switches with new trigger board design and isolation concept (PulseLab)
- Initial testing of new controller and software (PulseLab)
- Testing of custom HV vacuum feedthrough (DTIM)
- Testing new coaxial transmission line (MIFEDS Lab)
- Testing fully assembled pulser into robust coil (MIFEDS Lab)
- New coil design testing (MIFEDS Lab)

Summary

- **MIFEDS Gen III CDR is complete.**
- **Final mechanical drawings are underway.**
- **Custom capacitor quotes are in with solid proposals from GA and SARA.**
- **MIFEDS Gen III should deliver up to 100 kA to a 60-nH coil.**
- **Peak field of up to 30 T for direct-drive fusion experiments.**