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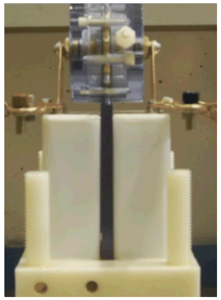

Evaluation of the impact of drive impedance on the performance of spark gap switches

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Outline

- Background / Motivation
- Circuit model development for Linear Transformer Driver (LTD) circuits and switches
- Experimental setup for characterizing LTD switches in a simplified geometry to isolate switch arc behavior
- Circuit modeling results
- Future work

Background

- Many models have been developed to describe the resistance profile of an arc in a spark gap switch
- At Sandia we often use a circuit model developed by Tom Martin
  - Resistance is determined from the arc channel radius - based on work by Braginski
- This model works well, but in practice we often tweak inputs such as number of parallel arcs to improve agreement with experimental data.
- Here we evaluate a test platform that could lead to better switch models

In LTD bricks we've used short circuit tests to evaluate circuit parameters

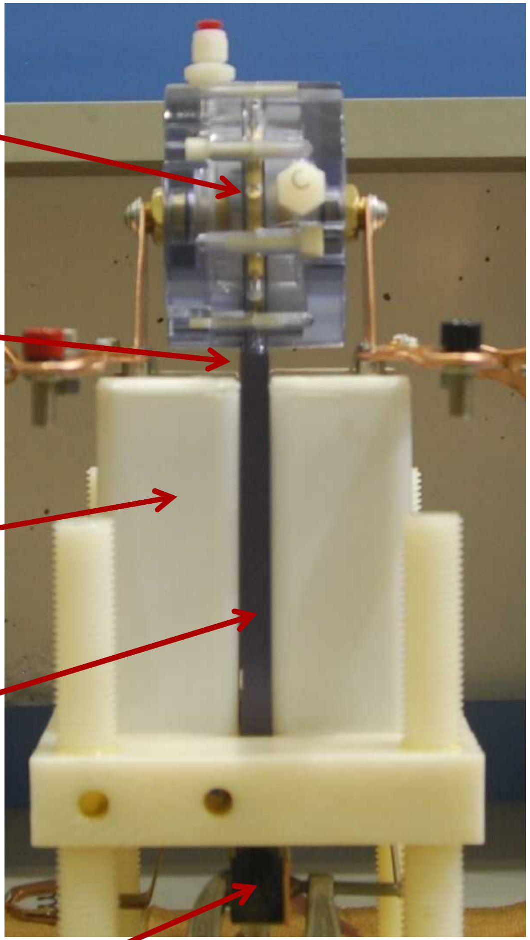
- Shown here is a single brick from a Linear Transformer Driver (LTD) circuit.
- This test circuit uses a near short circuit load to evaluate circuit parameters

LTD Spark Gap

0.5" gap between capacitors and switch housing

2 each 20 nF capacitors

0.5" thick spacer

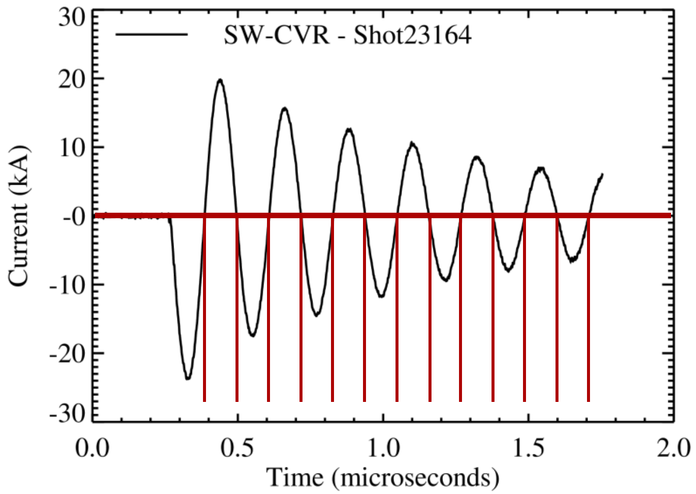


Load = 0.968 mΩ
Current Viewing Resistor (CVR)

Short circuit tests are used to determine inductance and series resistance

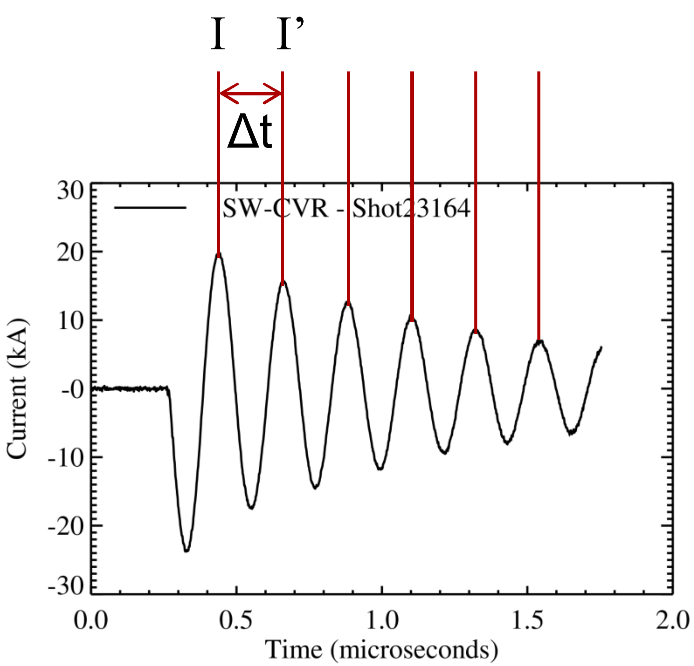
- Circuit inductance is calculated from the ringing period:

$$L = \left(\frac{T}{2\pi}\right)^2 \Big/ C$$



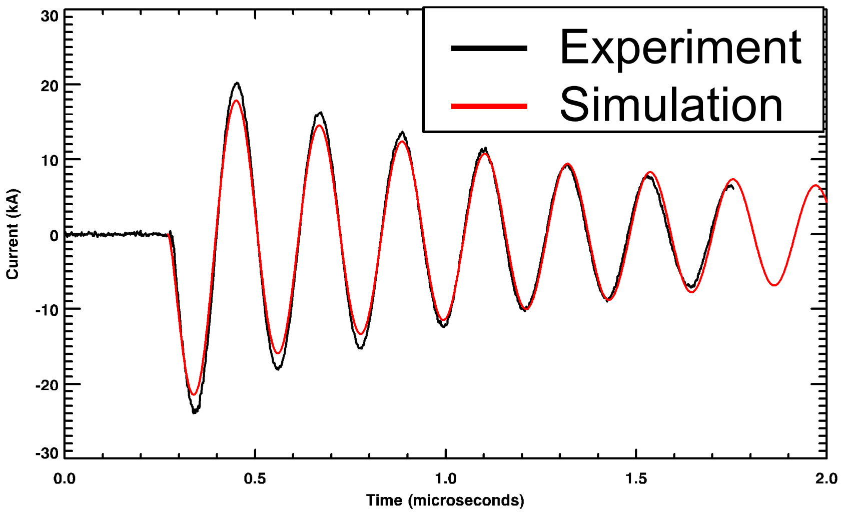
- Late time resistance is calculated from the decay rate of the oscillation:

$$R = 2L\frac{\ln\left(I/I'\right)}{\Delta t}$$

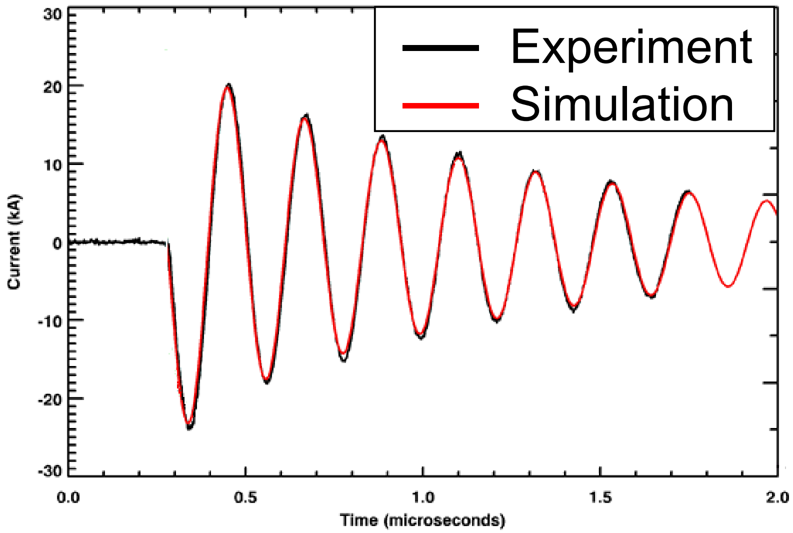


Circuit models of the LTD circuit require small adjustment to match experiment

- Using the measured circuit values we can simulate the experiment.
- Switch model uses experimental gap length, air pressure, and assumes 1 arc channel.

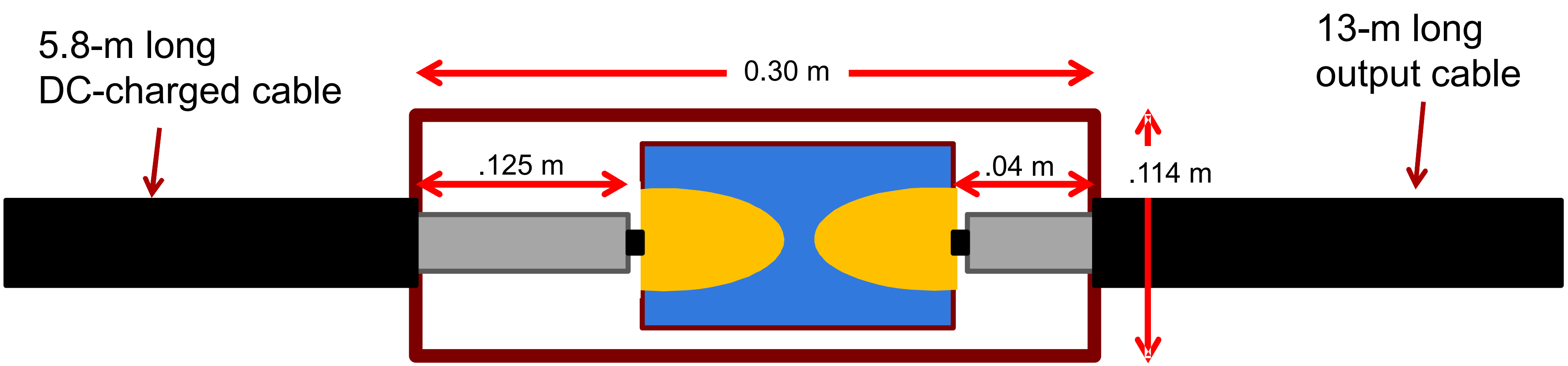


- Improve matching during the first cycle by adjusting switch model inputs:
  - Switch pressure cut in half
  - Number parallel arcs increased to 2.

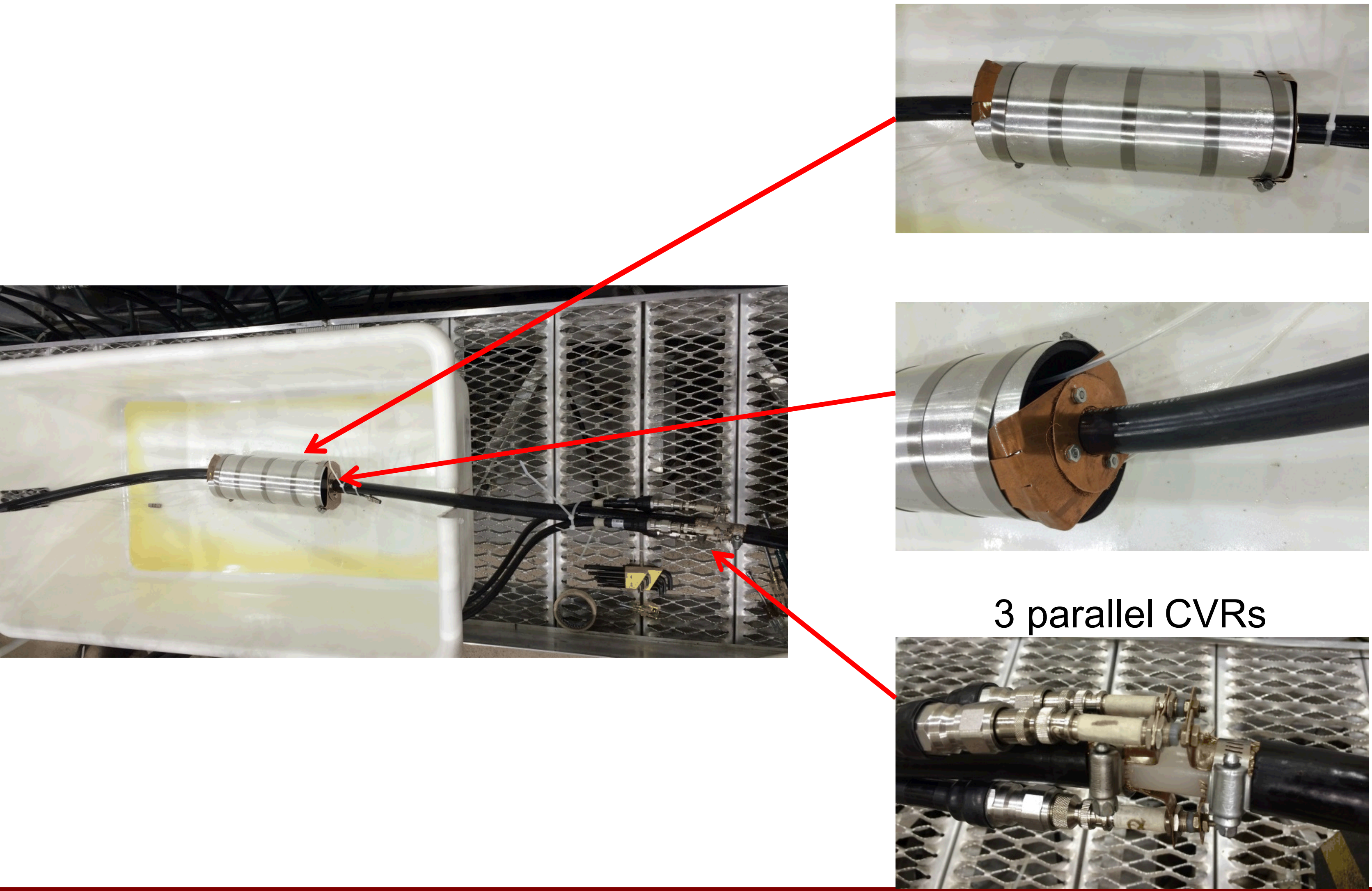


We put together a simple circuit to evaluate switch arcs

- Single gap self-break switch with no trigger plane or pin. Installed in a 0.11 m OD plastic tube surrounded in metal.
- The simple geometry simplifies circuit modeling
- Self-break testing with static air pressure. Charge voltage slowly increased until the switch arced.
- CVR installed in the ground braid of the output cable ~1 m from the switch.



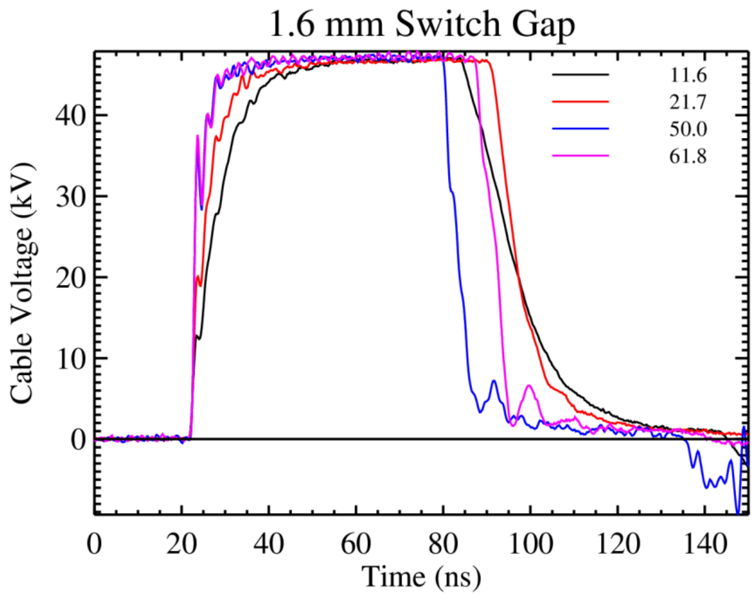
Simplified Switch Test Experimental Setup



Switch was tested with four cable impedances and four switch gap lengths

Pulse Risetime (5-95%)

	1.6 mm Gap	2.5 mm Gap	5.0 mm Gap	10.0 mm Gap
11.6-ohm	19.4 ns	----	26.1 ns	30.4 ns
21.7-ohm	11.8 ns	13.9 ns	18.2 ns	23.4 ns
50.0-ohm	9.1 ns	11.0	11.9 ns	----
61.8-ohm	8.0 ns	10.2 ns	11.1 ns	17.8 ns



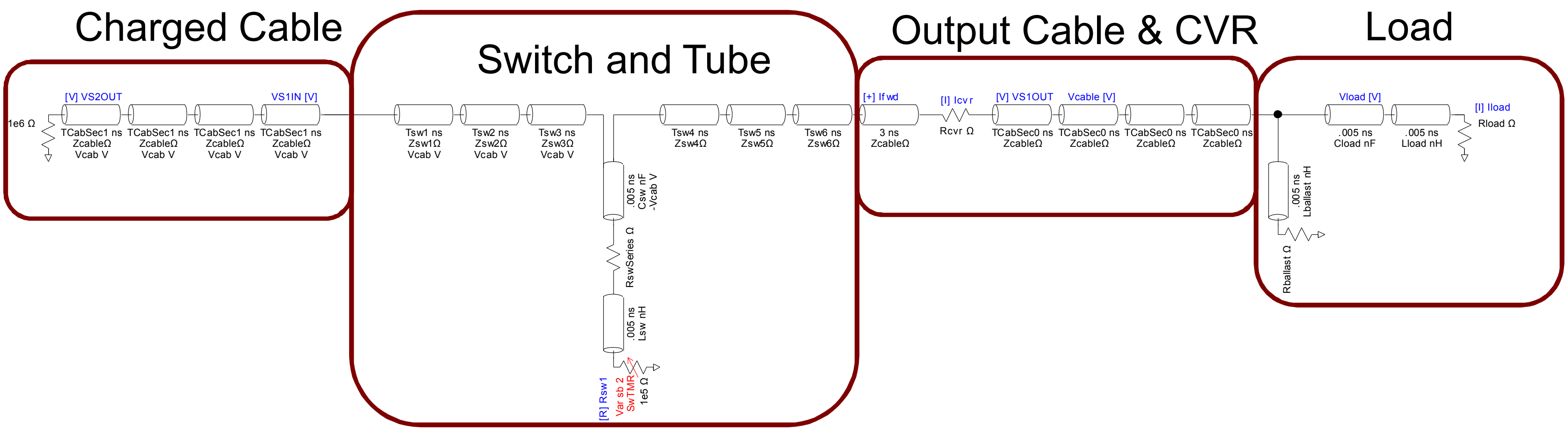
Observed Risetime Trend:

- Proportional to switch arc length
- Inversely proportional to cable impedance

Setup Notes:

- Vcharge = 100 kVDC
- Each waveform is average of 5 shots

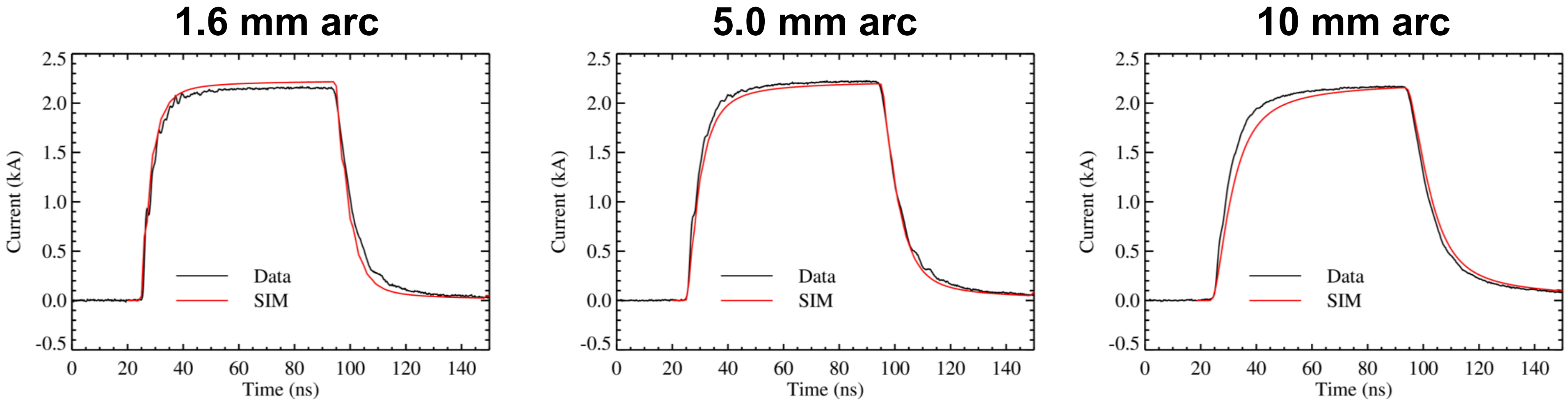
Circuit model of the system is very simple



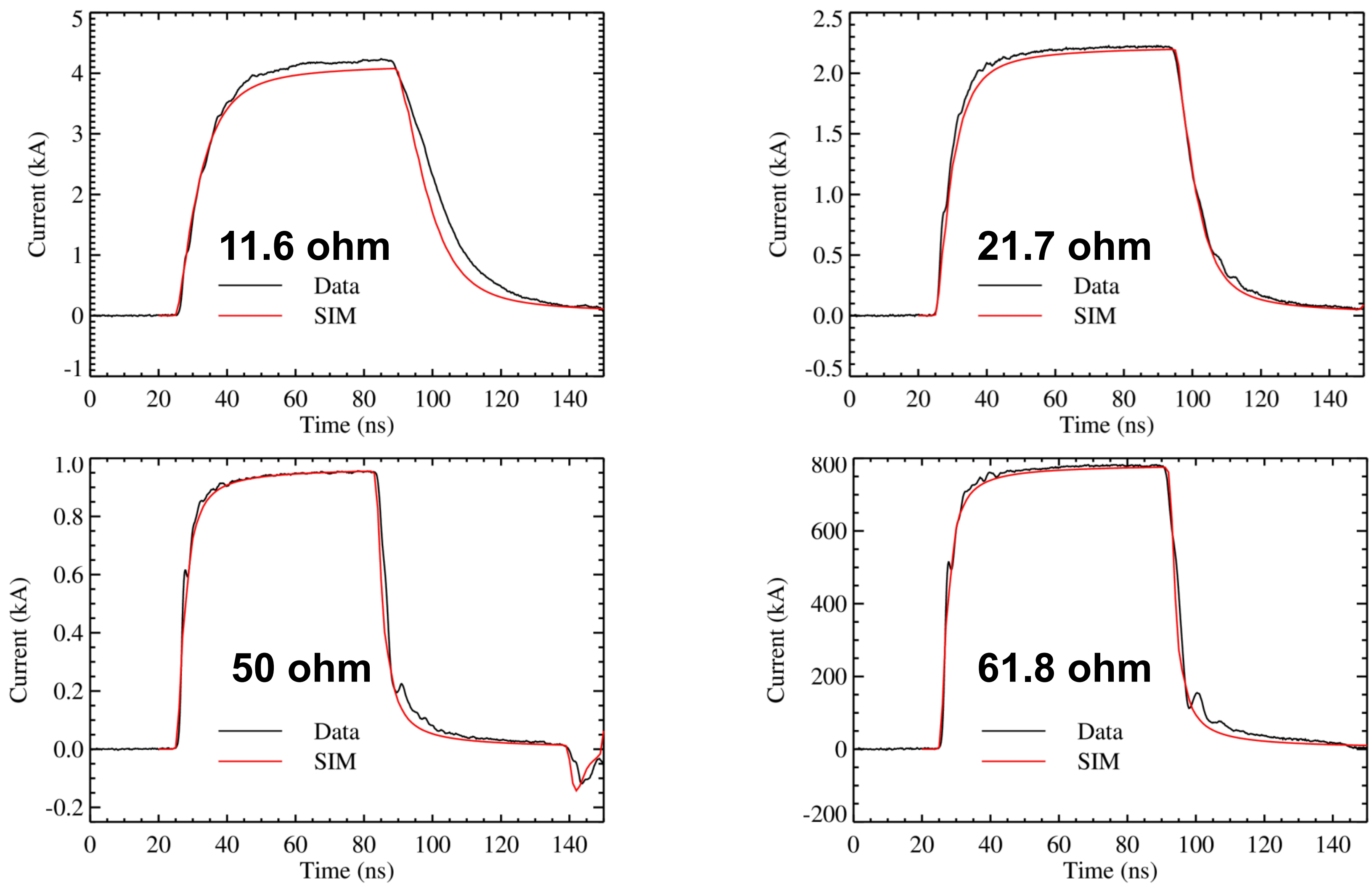
- Switch modeled with Tom Martin switch model which calculates resistance based on gas pressure, arc length, number of parallel arcs, and the current thru the arc.
- Switch also includes series arc inductance, switch capacitance, and constant series resistance.
- Switch connections are simple coaxial geometry
- Cables are broken into four series elements of equal length to reduce length of the longest segment – this helps Bertha (transmission line based circuit code).

The circuit model does not accurately predict all pulse features

- The three cases below use the same circuit geometry (21.7-ohm cable), only changing the switch arc length.
- The Tom Martin arc resistance model does not accurately capture the resistance profile thru the entire pulse
- No one parameter adjustment (such as number of parallel switch arcs) would correct all three cases.



Circuit model doesn't match all 5.0 mm switch gap experiments equally well



Conclusion

- The Tom Martin switch model works very well, but does not accurately predict all configurations.
- Our experiments were not diagnosed well enough to help guide development of an improved model.

- Possible Future Work
  - Repeat experiment with improved voltage and current measurements
  - Develop a model for time varying inductance based on Braginski arc radius (similar to Tom Martin switch resistance model)