RAMDENT : THERMAL RUNAWAY INITIATION METHOD

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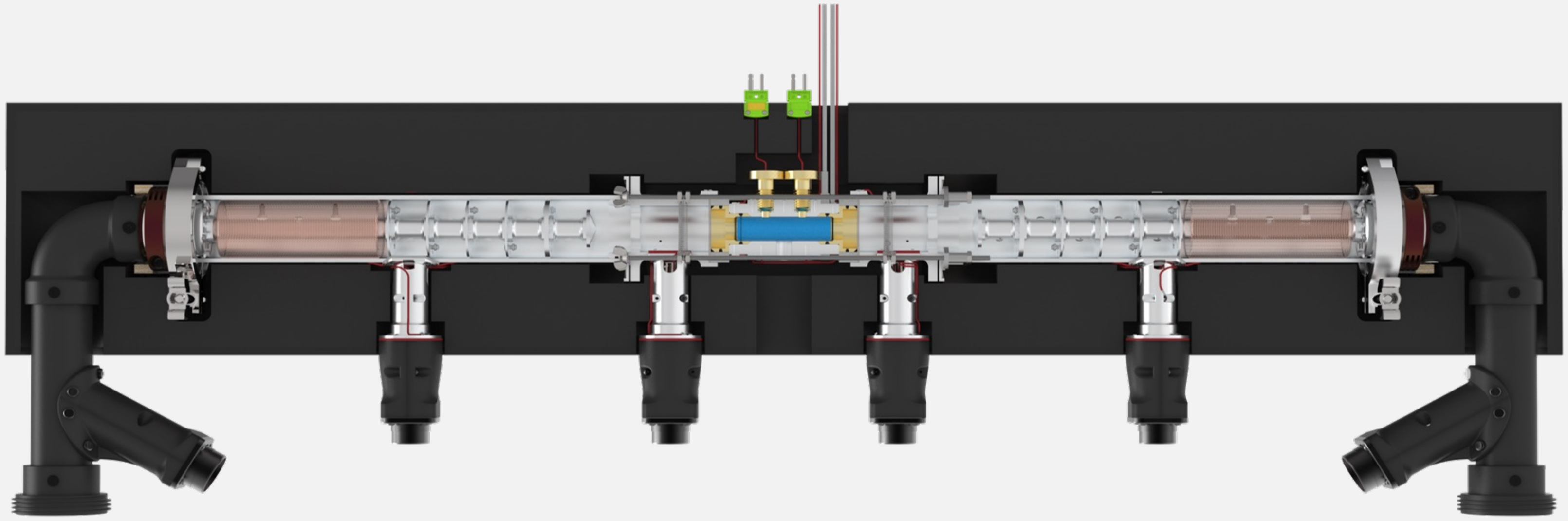
Background

- Developed a calorimeter tailored specifically for measuring thermal runaway-induced energy output

- Able to discern between the fraction of heat conducted through can versus ejected heat



Fractional Thermal Runaway Calorimeter (FTRC)

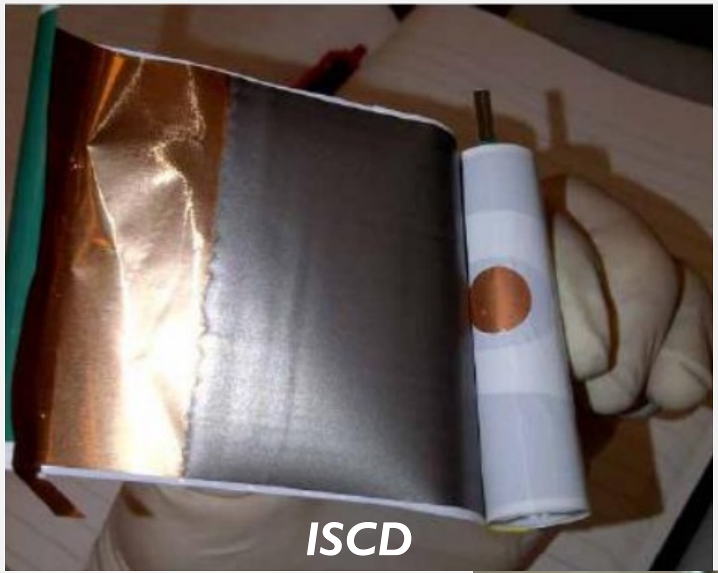
Background

- Type of trigger method employed significantly influences the cell's response during thermal runaway

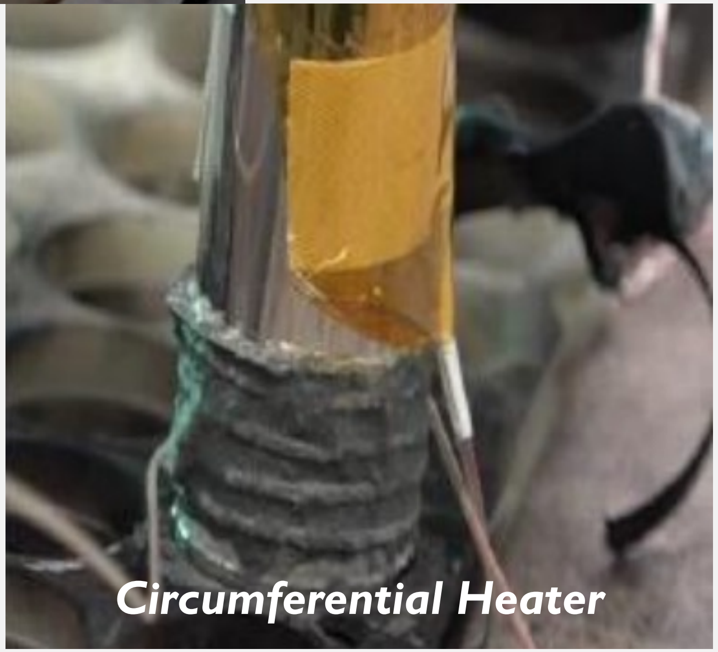
- Influence extends to both thermal and kinetic energy outputs

Background

- Utilizes three primary techniques to initiate thermal runaway in batteries.
  - Nail penetration
  - Heaters
  - Internal Short Circuit Device (ISCD)
- Methods have shown reasonable consistency and success in causing cell failure, but they come with certain drawbacks



ISCD



Circumferential Heater

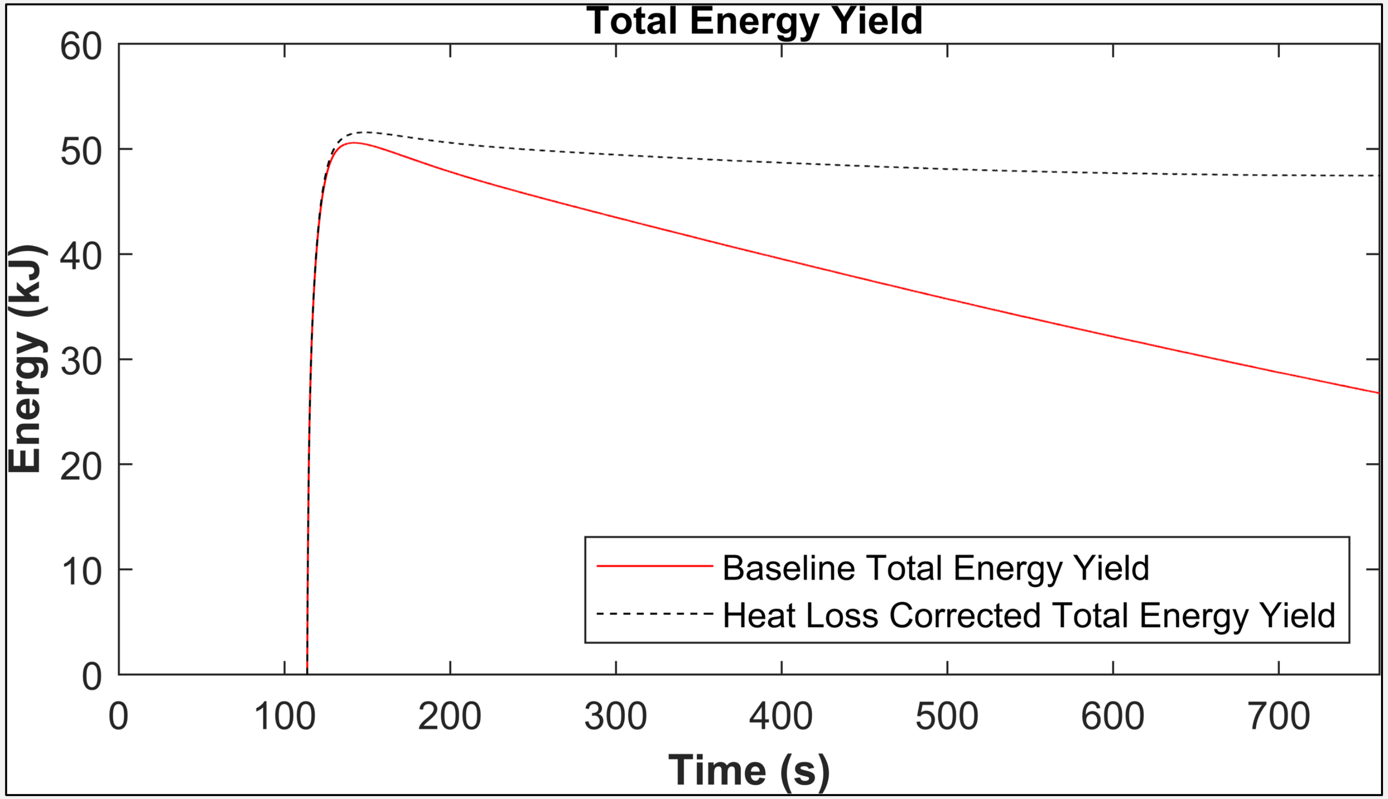
Trigger Mechanism : Heaters

Benefits

- Reliable
- Non-intrusive trigger method

Drawbacks

- Poor Signal-to-Noise Ratio
- Causes Time Delay between Venting and TR



Moli M35A 100% SOC ~ Energy Yield Algorithm (EYAN) Output

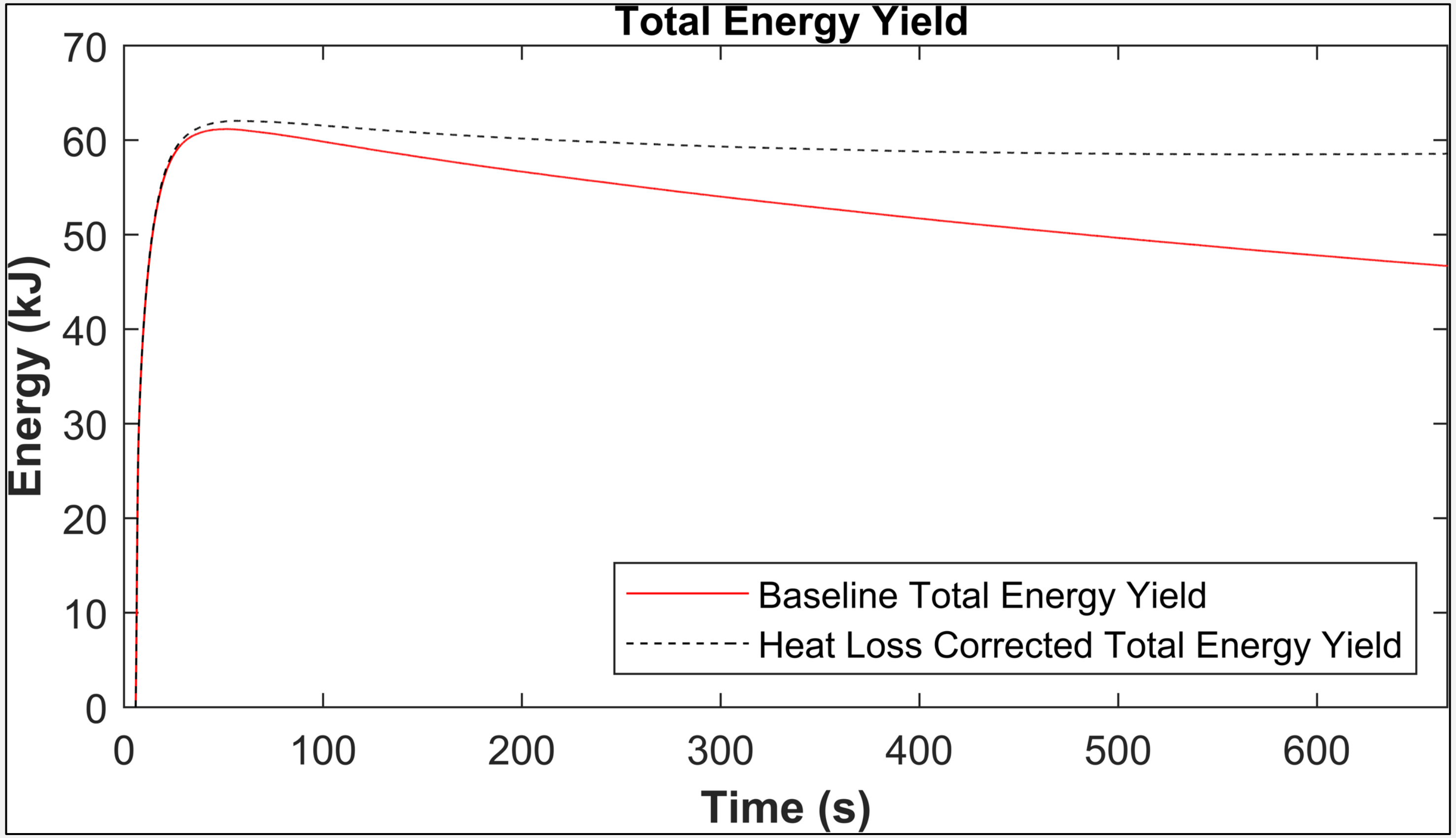
Trigger Mechanism : Nail Penetration

Benefits

- Time effective trigger method
- No Heat Input

Drawbacks

- Additional Thermal Conduction Path
- Can Wall Perforation
- Impedes Jelly Roll Ejection



Moli M35A 100% SOC ~ Energy Yield Algorithm (EYAN) Output

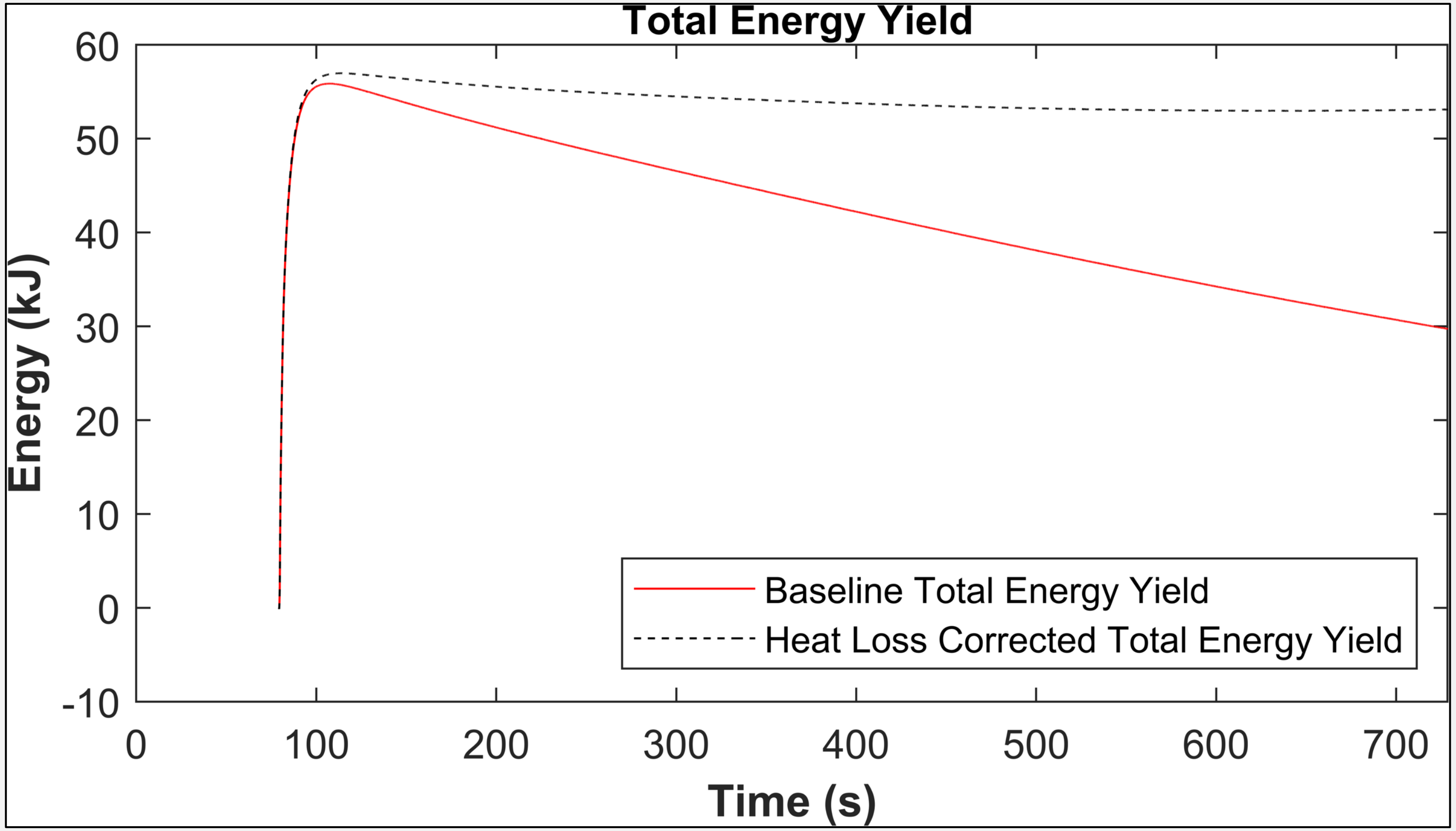
Trigger Mechanism : Internal Short Circuit Device

Benefits

- Control over location of the internal short
- Low energy input

Drawbacks

- Requires willing manufacturer to do implantation
- Expensive to use for testing



Moli M35A 100% SOC ~ Energy Yield Algorithm (EYAN) Output

Trigger Mechanism Comparison

	Heater	Nail Penetration	ISCD
Time Effective		✓	
Non-Intrusive	✓		
Reliable	✓		✓
Cost Effective	✓	✓	
Minimal Energy Input		✓	✓
Signal-Noise Ratio		✓	
Represents a Defect Induced Failure			✓

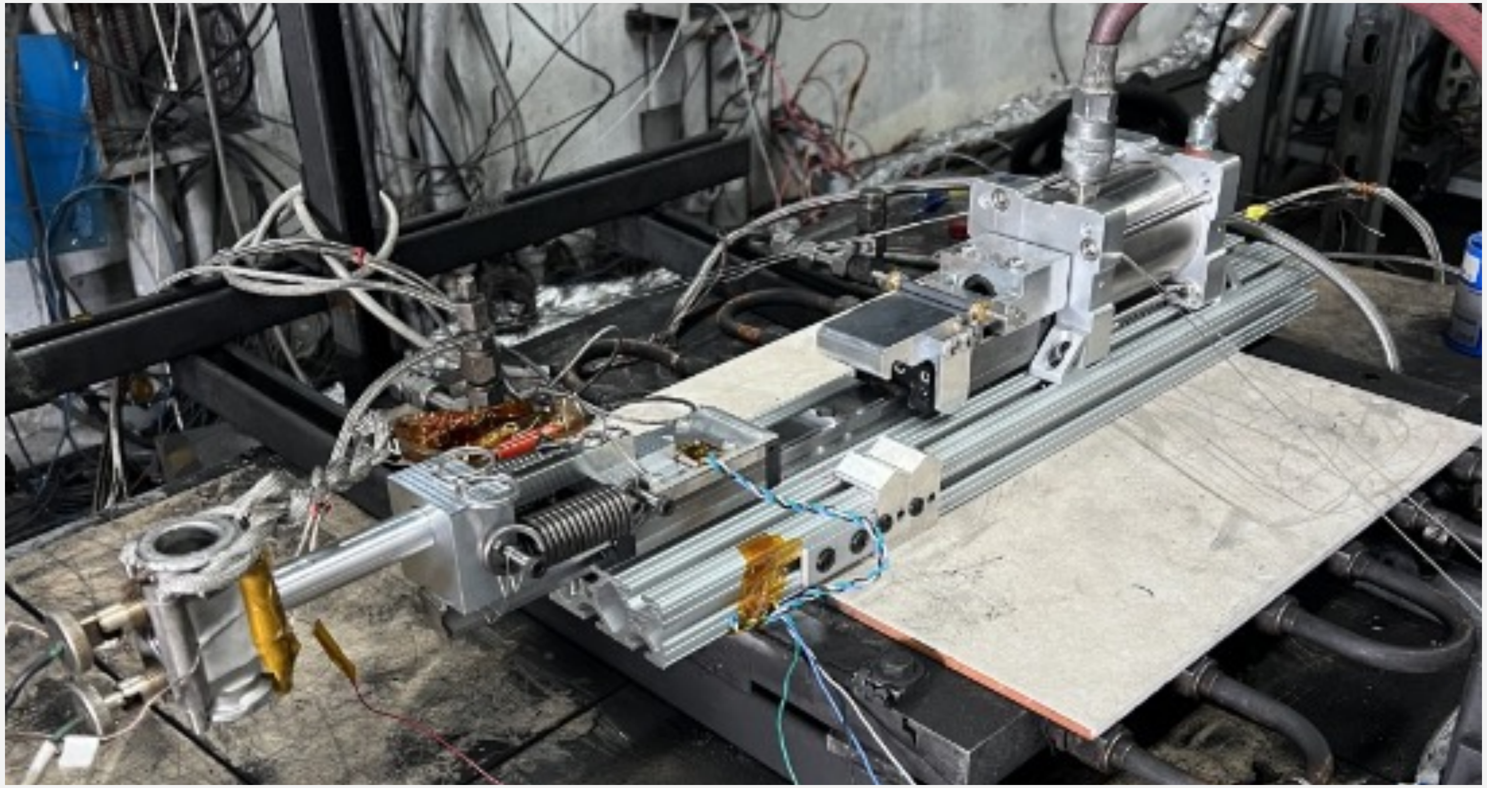
Trigger Method : RamDent

Mechanism Overview

1) Utilizes a ramming component to accelerate a probe

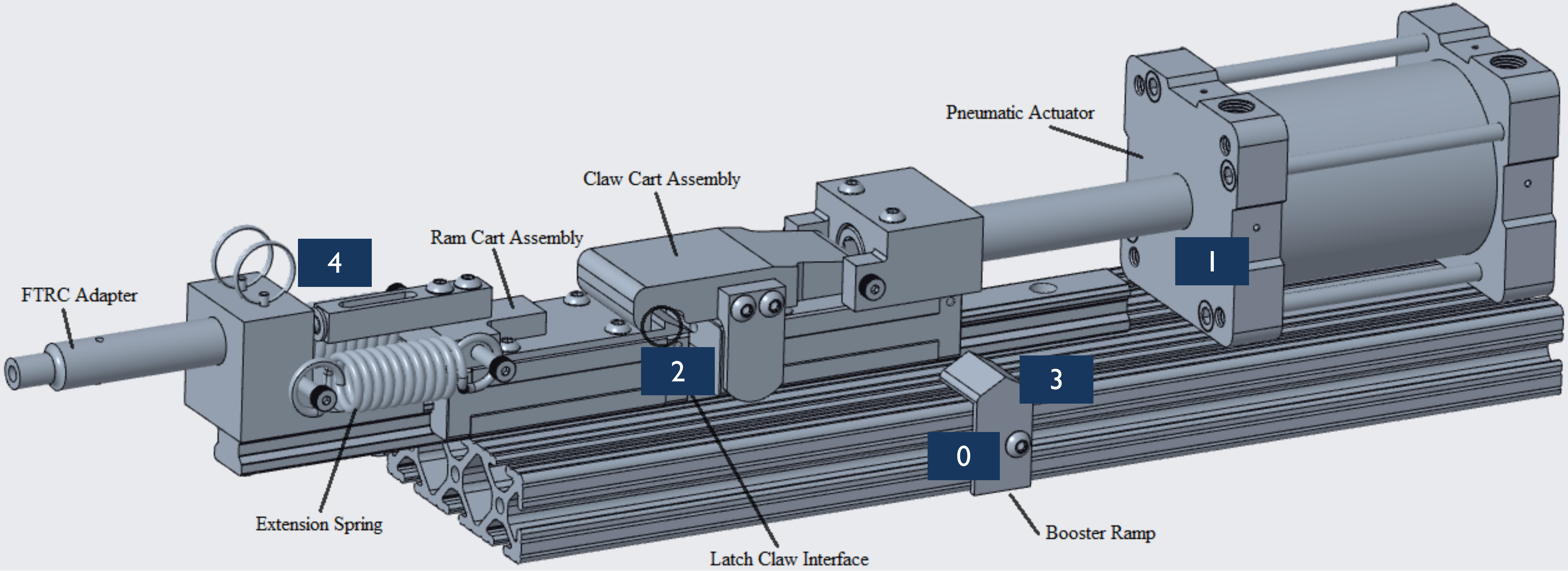
2) Accelerated probe impacts the battery cell

3) Results in subtle deformation of the can wall

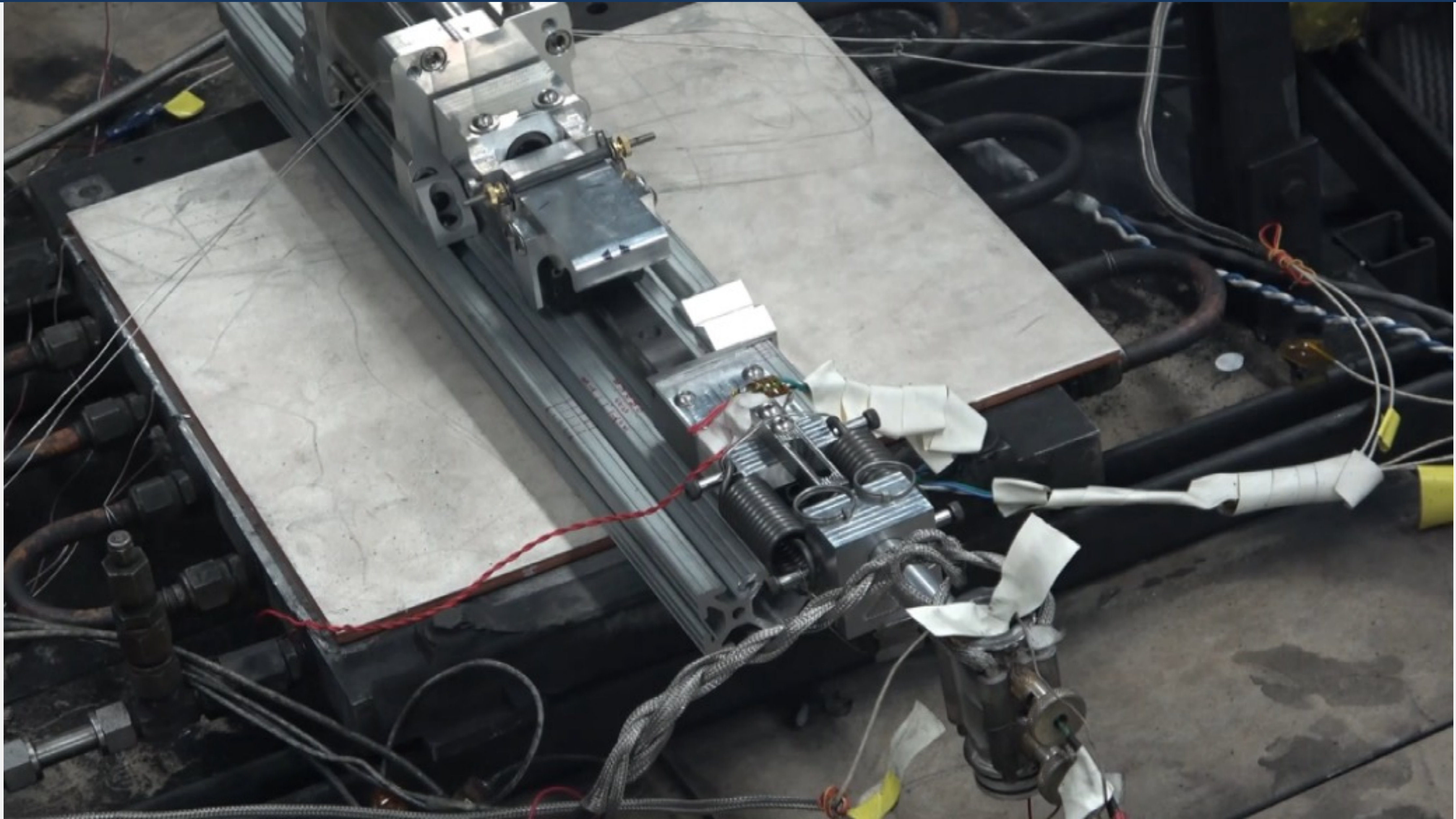


RamDent Device

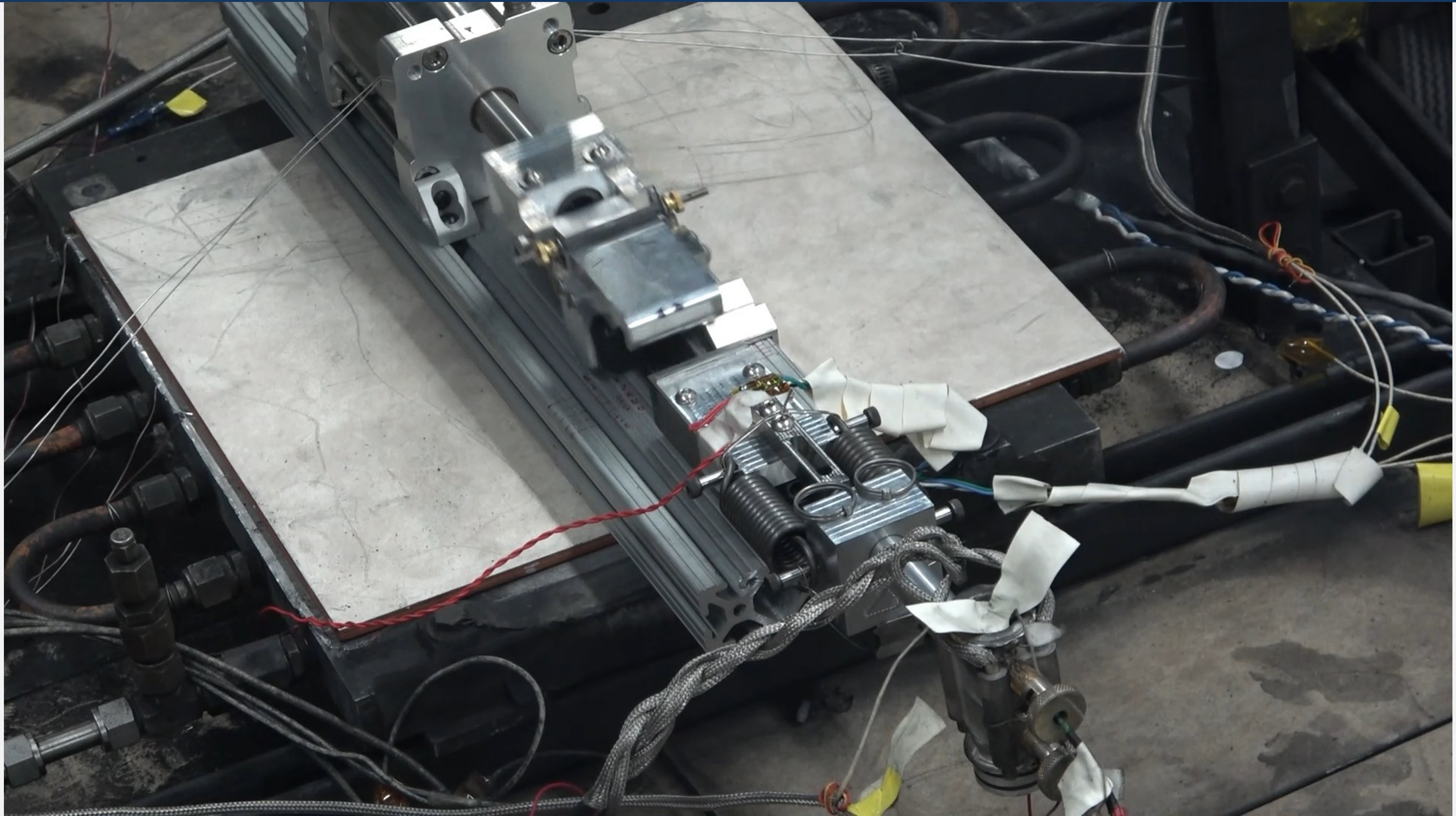
Trigger Method : RamDent



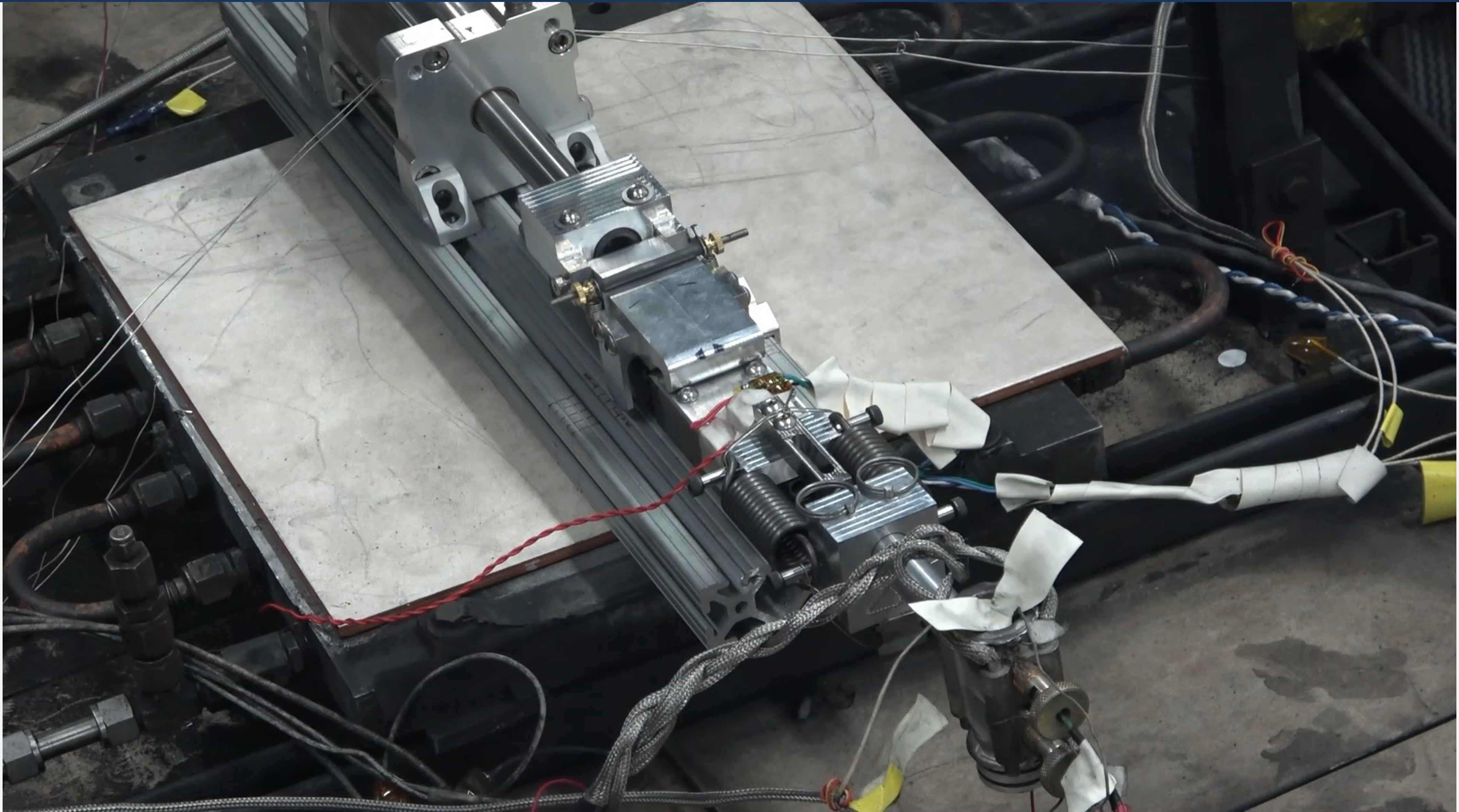
Mechanism Phase 1



Mechanism Phase 2



Mechanism Phase 3



Trigger Method : RamDent

Benefits

- Creates a point defect in the cell
- Allows for fine-tuning of can wall deformation to suit different cell manufacturers and can wall thicknesses
- Able to mechanically and thermally decouple the testing device from the battery cell
- Can quantify minimum can wall deformation to create internal short circuit

Drawbacks

- Requires an additional test series to fine-tune the precise impact needed for specific cell types

Trigger Mechanism Comparison

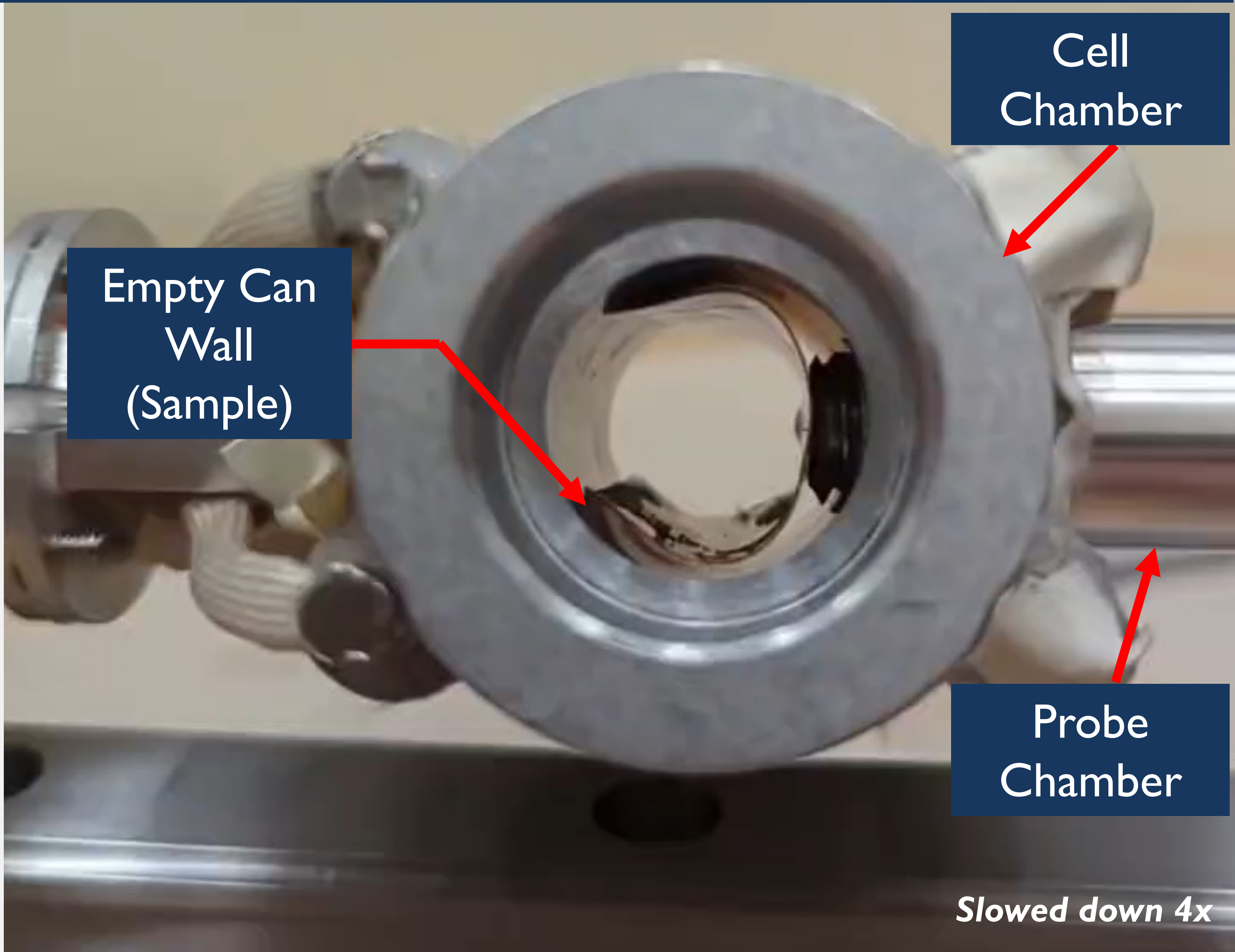
	Heater	*Nail Penetration*	*ISCD*	*RamDent*
Time Effective		✓		?
Non-Intrusive	✓			✓
Reliable	✓		✓	?
Cost Effective	✓	✓		✓
Minimal Energy Input		✓	✓	✓
Signal-Noise Ratio		✓	✓	✓
Represents a Defect Induced Failure			✓	✓

Probe Test

Test Set Up

- Fractional Thermal Runaway Calorimeter (FTRC) cell chamber for 18650 cell formats
- Empty steel can wall
- Probe chamber
- Probe exiting due to ram impact

- Employed a dome-shaped probe to create a precise type of deformation in cell can wall



Experimental Design

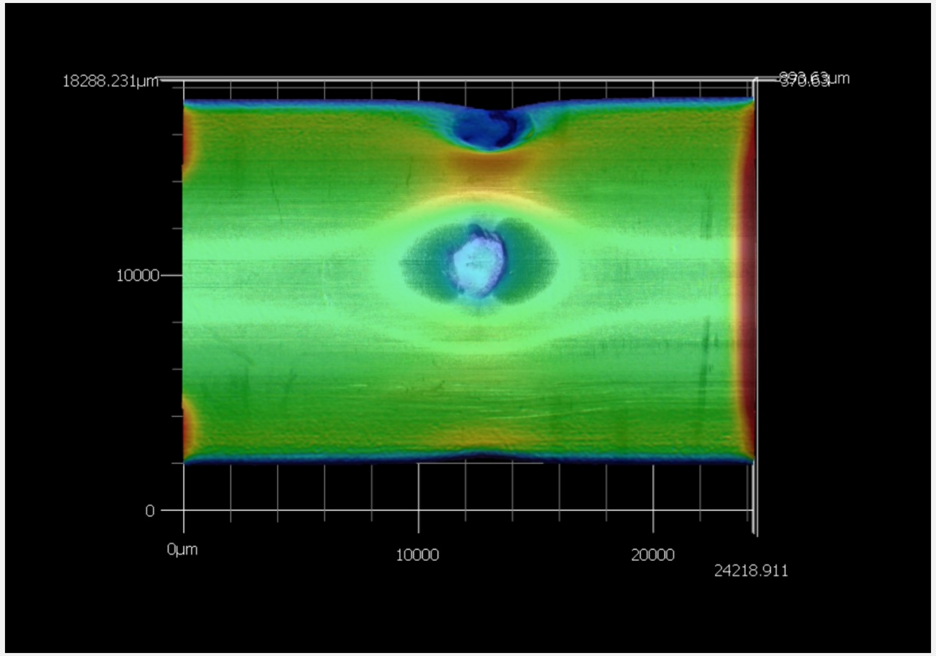
- Selected two distinct 18650 cell types: LG M36 and Panasonic NCR18650A

	LG M36	*Panasonic NCR-A*
Can Wall Thickness	250 μm	125 μm
Capacity	3.4 Ah	3.1 Ah
Anode	Graphite + Si Doping	Graphite
Cathode	Nickel Manganese Cobalt (NMC)	Nickel Cobalt Aluminum (NCA)

Reliability Test: Dent Depth

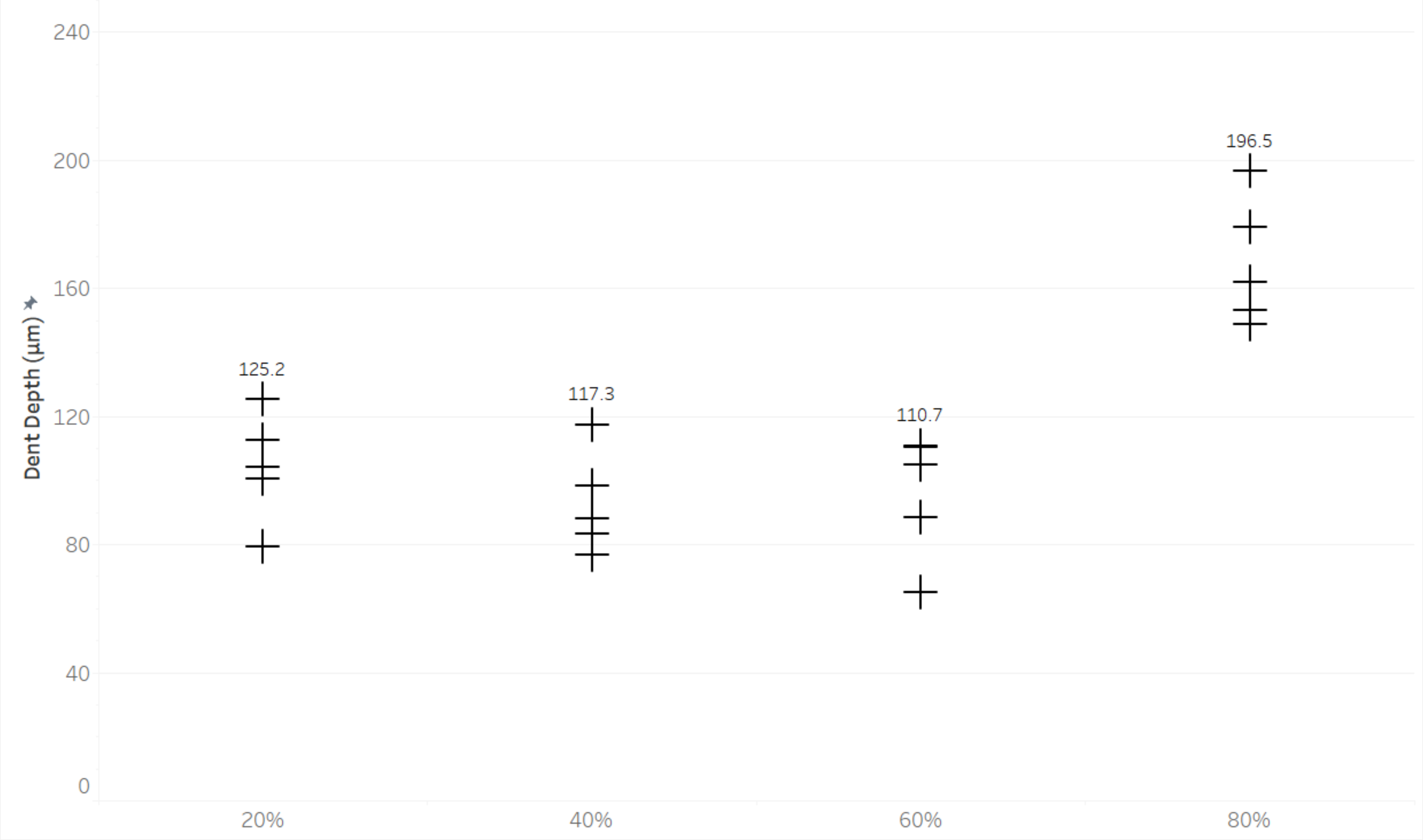
- Extent to which the can wall is indented due to the applied force, measured in micrometers (µm)
- Utilized a 3-D optical profilometer to measure dent depths from discrete force impact intervals (0-100% force output)
- Investigating the dent depths generated to pinpoint the specific range on the force spectrum

LG M36 Initial Dent Test



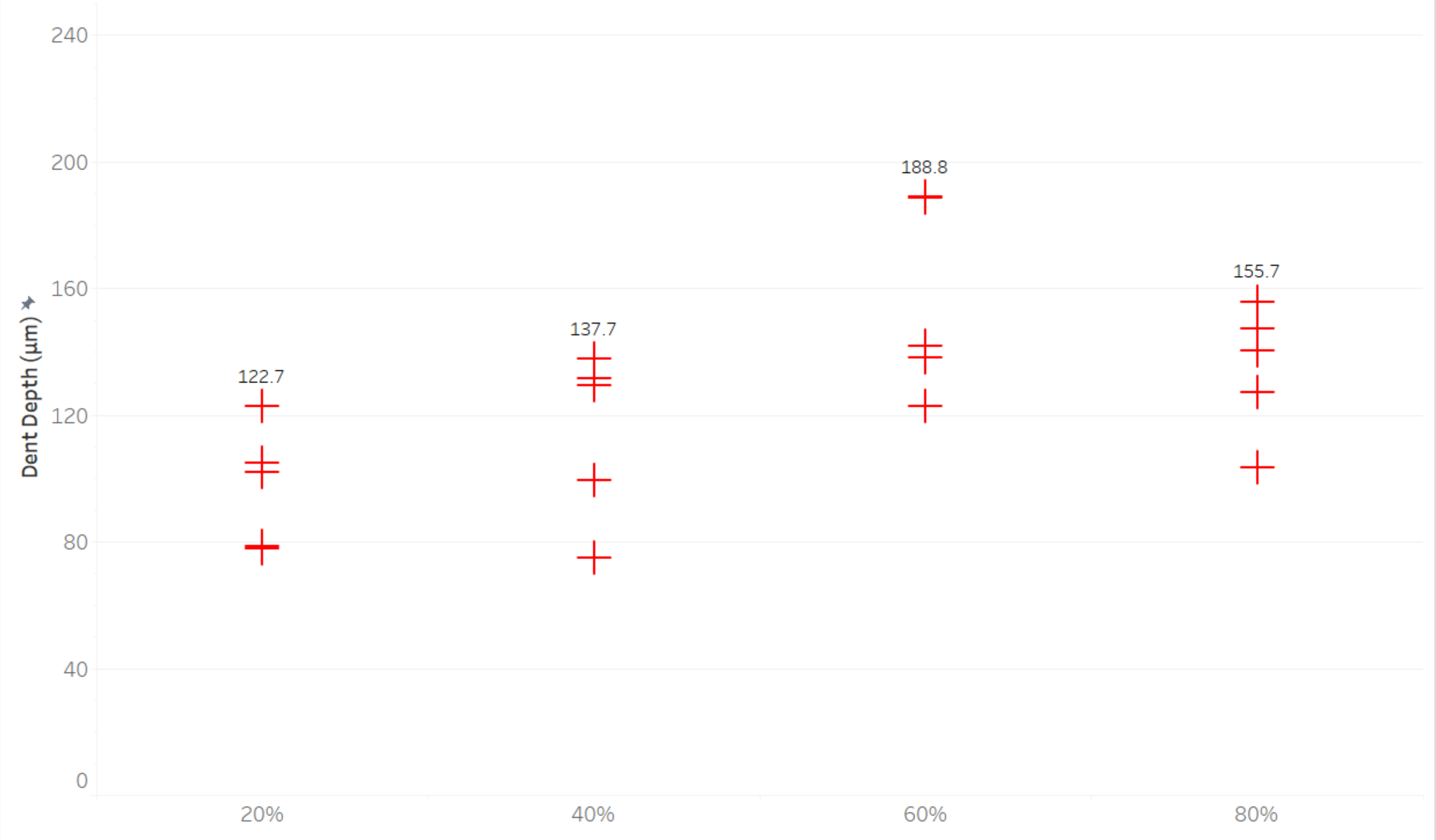
Profilometer Measurement

LG M36 Dent Test



Force Output (± 2.5%)

Panasonic NCR-A Dent Test



Force Output (± 2.5%)

Experimental Design

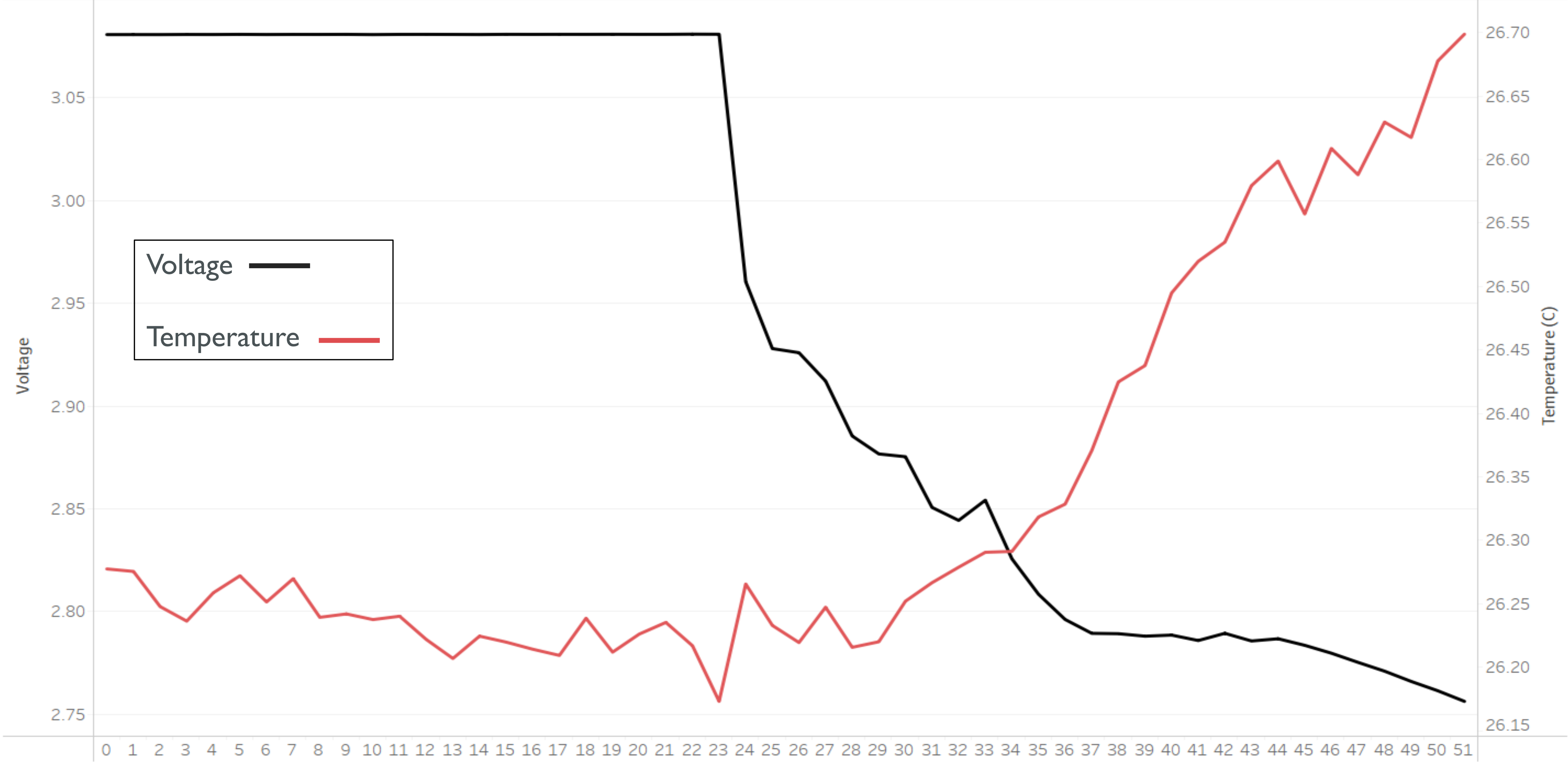
- Split the test series into two categories:
  - Discharged Cell Testing (0% state of charge)
  - Live Cell Testing (100% state of charge)

- Discharged Cell Testing Success - defined by a specified voltage decrease within 5 seconds post-impact

- Live Cell Testing Success - determined by the initiation of an internal short circuit within the cell without can wall perforation

After successfully initiating thermal runaway or an internal short circuit, focus on refining the force output for repeatability

Discharged Cell Test Run - LG M36 (0% SOC)

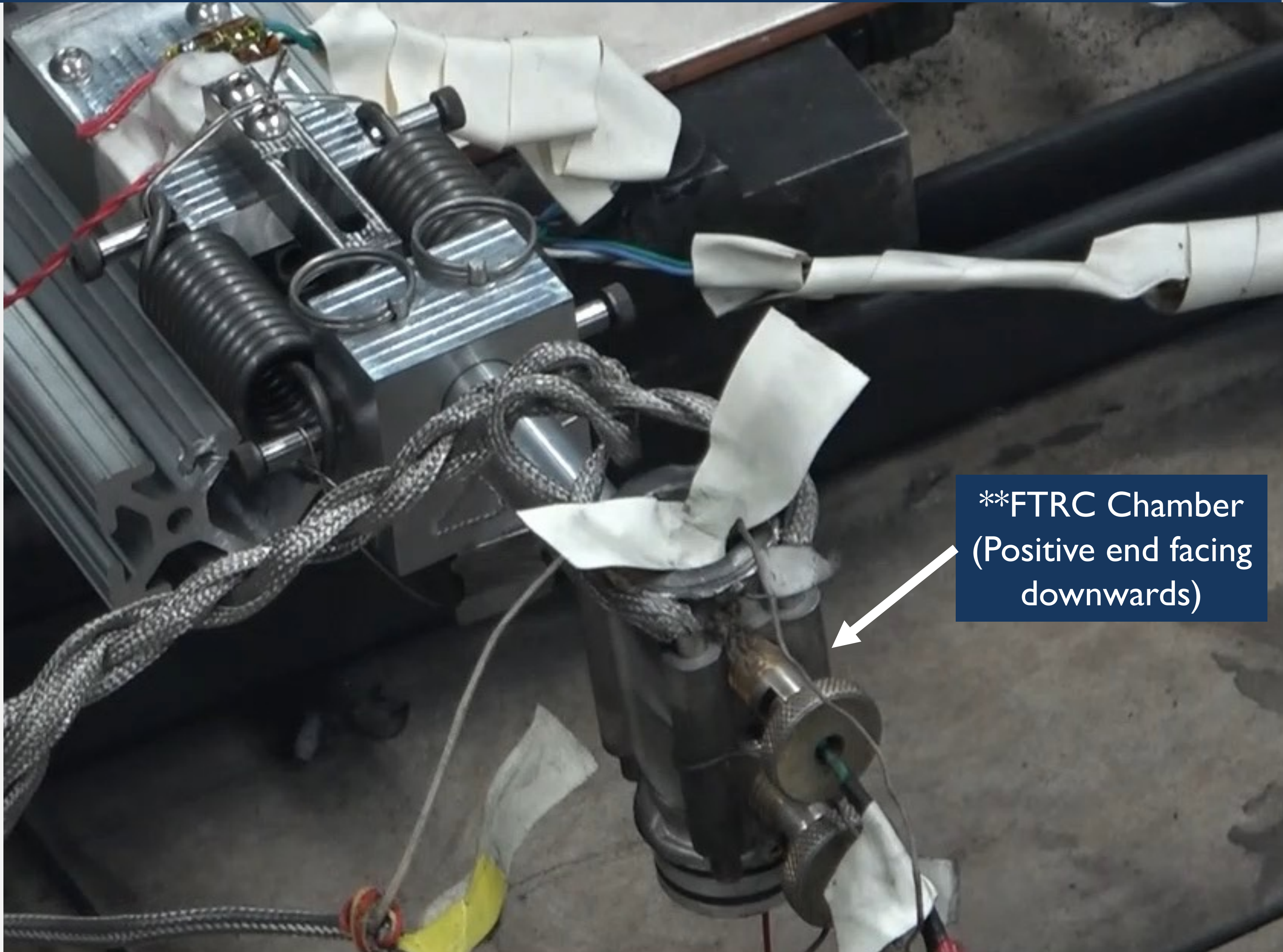


Discharged Cell Test Run – Panasonic NCR-A (0% SOC)

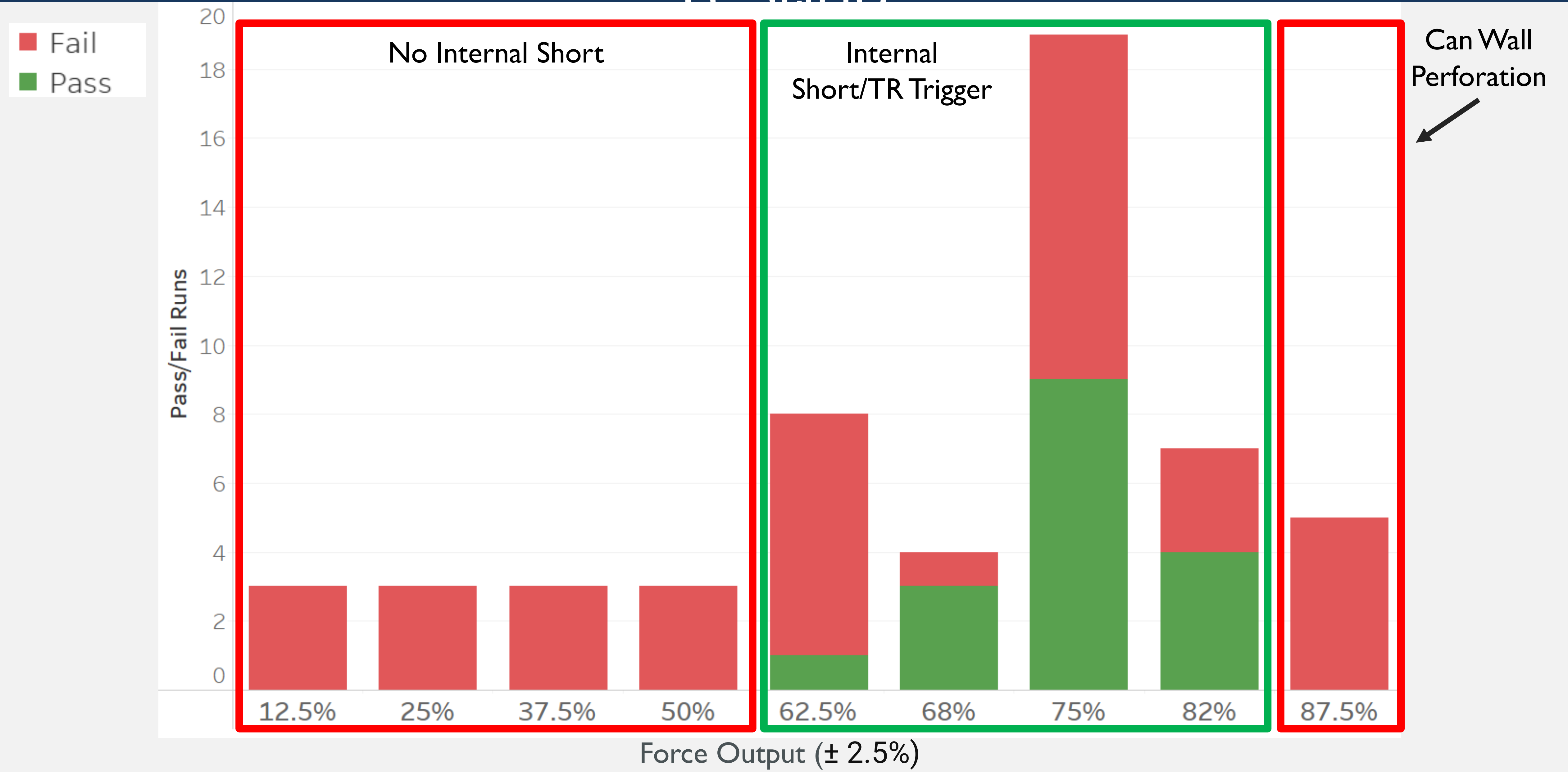
Successful TR Initiation

Run Parameters

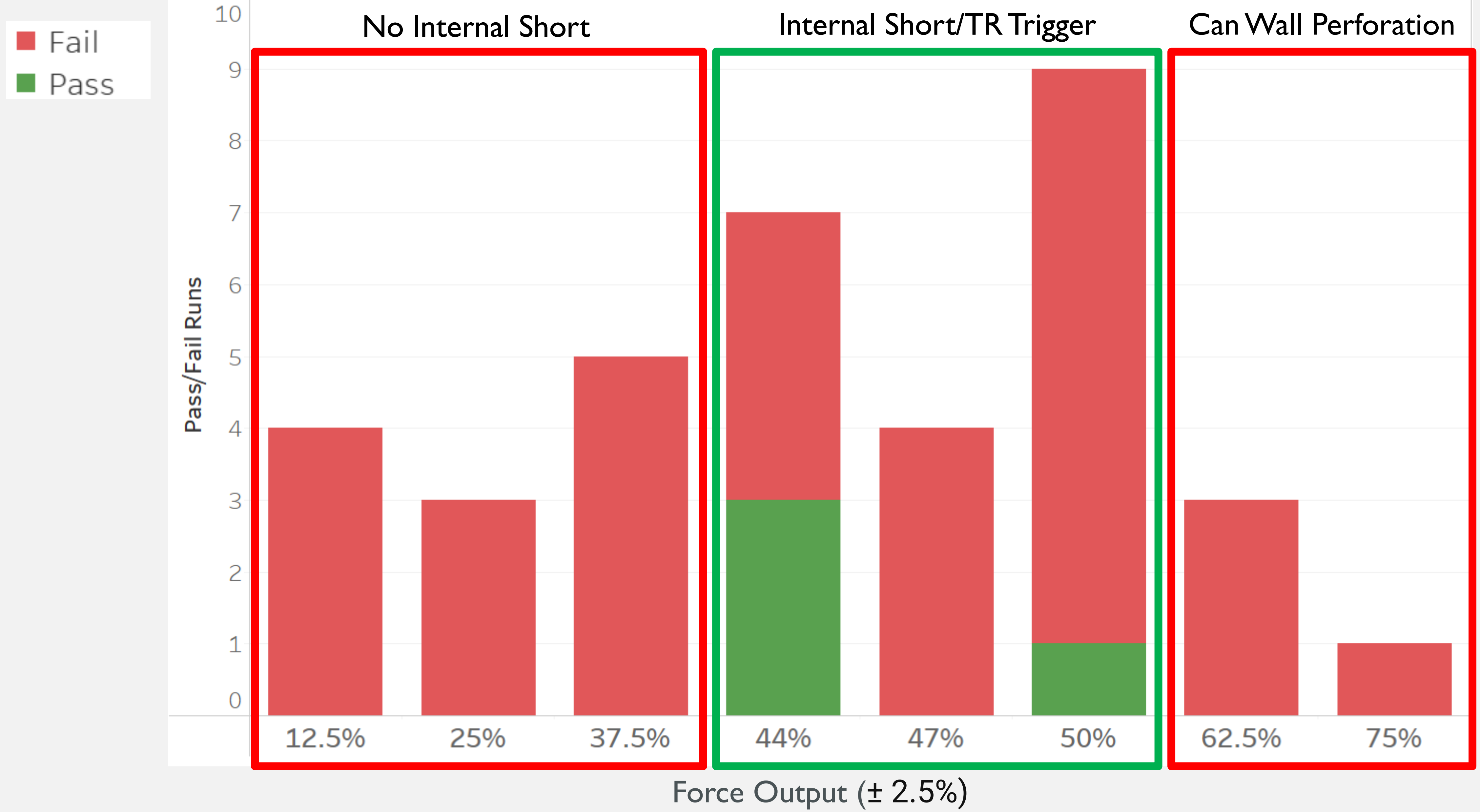
- LG M36 Cell
- 100% State of Charge
- 75% Force Output



Preliminary Findings: LG M36 100% SOC Cell Testing



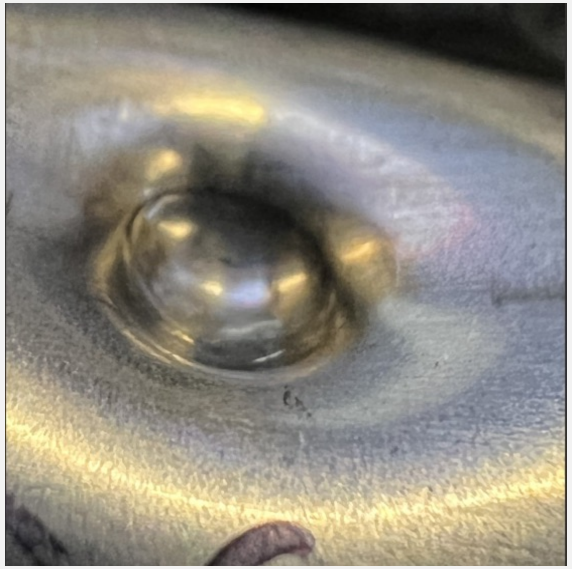
Preliminary Findings: Panasonic NCR-A Live Cell Testing



Limitations of the Method

Due to time required to dial in the following parameters:

- Consistent force output (spring extension)
- Nail tip shape
- Nail tip ductility



LG M36 Test Cell Dent Shape (75% Force Output)

LG M36 Discharged Cells

20 % Force Output *40 % Force Output* *60 % Force Output* *80 % Force Output*

Conclusion

- Preliminary results show it is possible to induce internal shorts without can wall perforation and trigger a thermal runaway response
  - Accomplished with two cell designs with different can wall thicknesses
- Continuing further exploration of this trigger mechanism to improve consistency and worthy of integration into FTRC

Future Work

- Accurately measuring kinetic energy
- Expand Test Series to Additional Cell Types and Sizes
- Integrate into FTRC testing
- Compact Redesign (Beam Time Compatible)
- Incremental SOC Reliability Study

Acknowledgements

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