Study of the current limiting capacity of 2G HTS tapes

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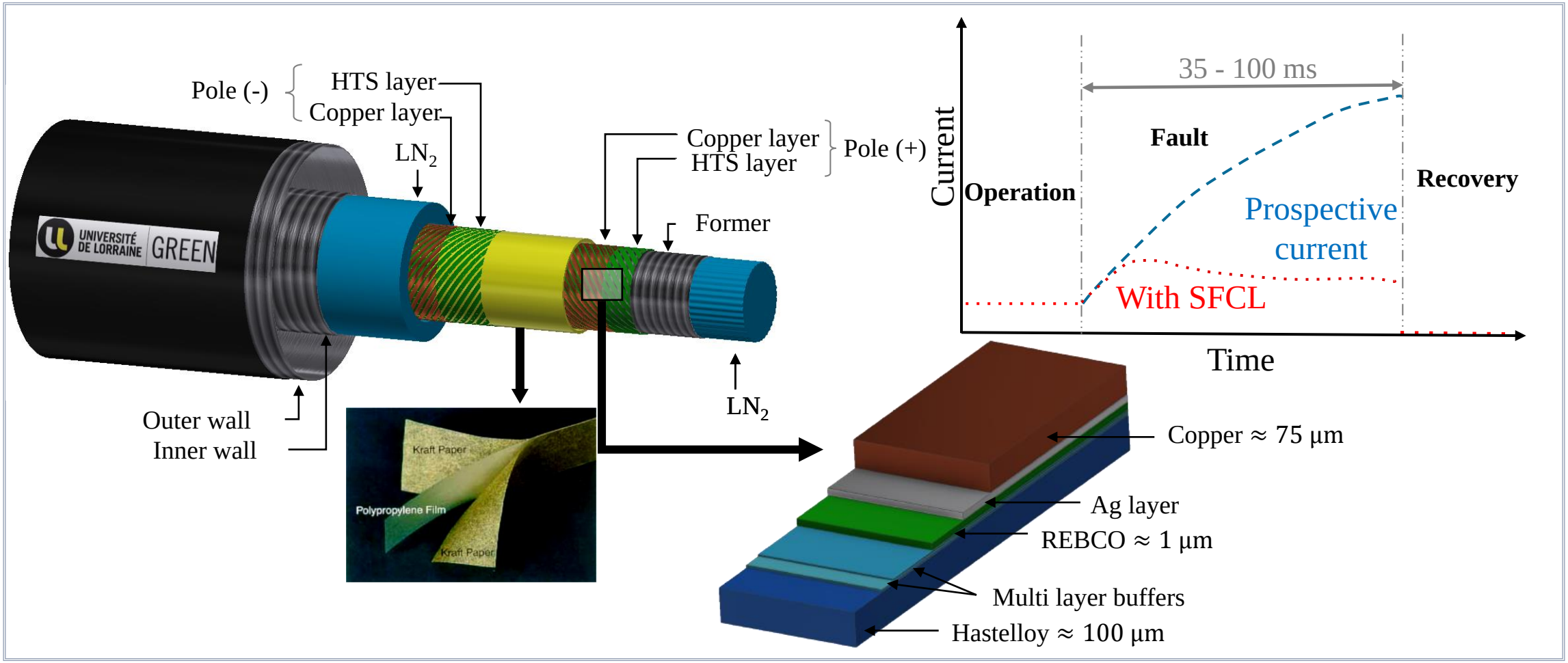
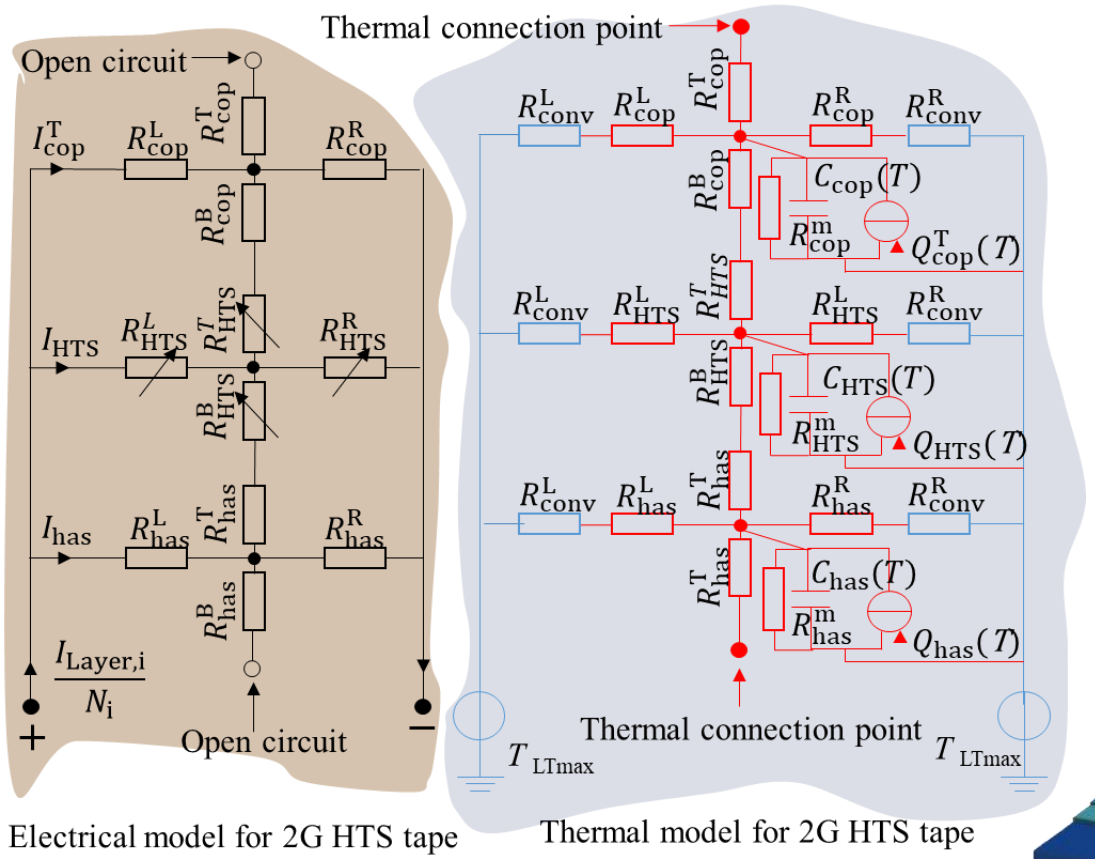
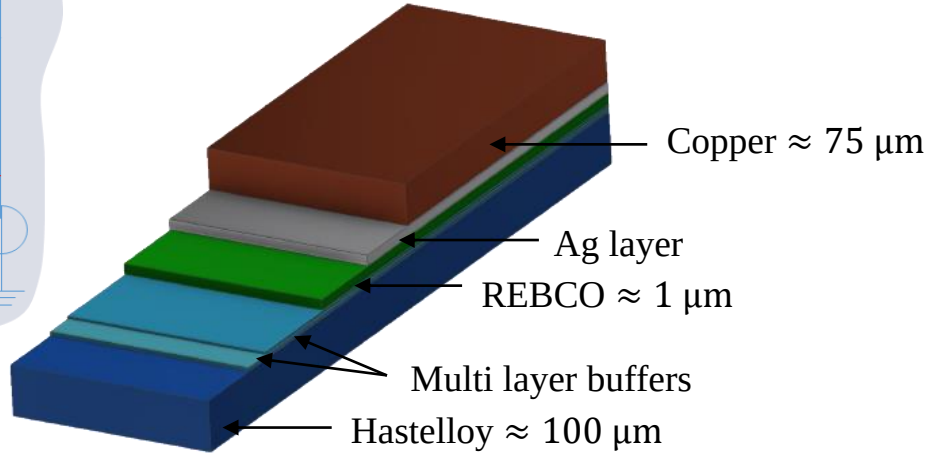
Context


Pole (-)
HTS layer
Copper layer
LN2
Copper layer
HTS layer
Pole (+)
Former
UNIVERSITÉ DE LORRAINE
GREEN
Outer wall
Inner wall
LN2
Kraft Paper
Polypropylene Film
Kraft Paper
Current
35 - 100 ms
Fault
Operation
Recovery
Prospective current
With SFCL
Time
Copper ≈ 75 µm
Ag layer
REBCO ≈ 1 µm
Multi layer buffers
Hastelloy ≈ 100 µm

Electro-thermal model

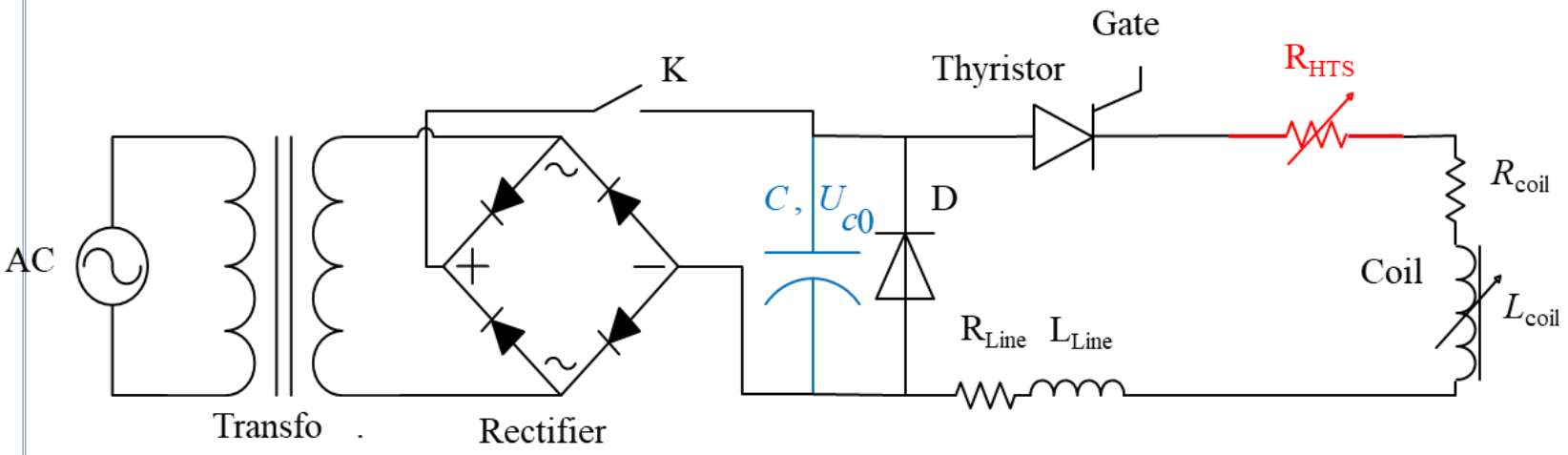


- Coupled electrical and thermal:
  - ❖Electrical and thermal conductivities variation with temperature is accounted
  - ❖HTS is modelled through E-J law



Experiment principle

- Validation of the tape model on a simpler case:
  - ❖ Capacitor bank discharged in a coil throug a single tape
  - ❖ Pulsed current >> Ic



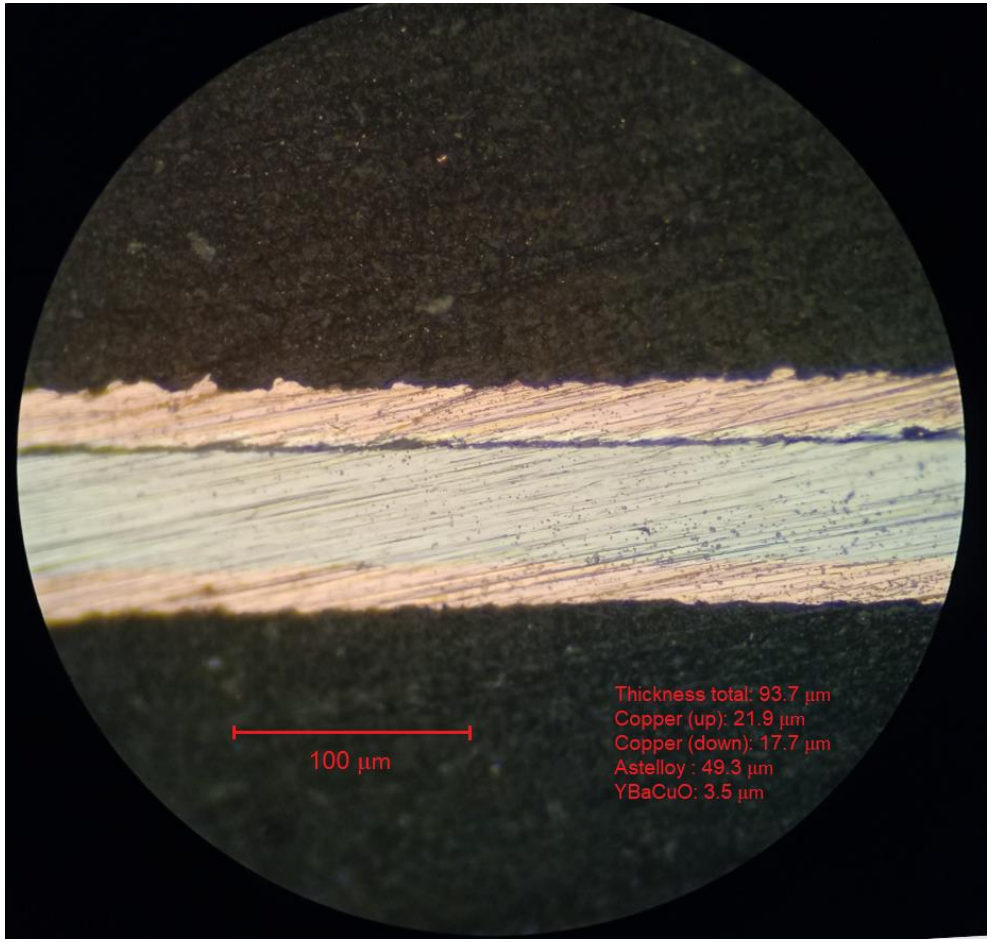
10 kJ – 25 kA
5 mF – 2000 V

Tape characteristics

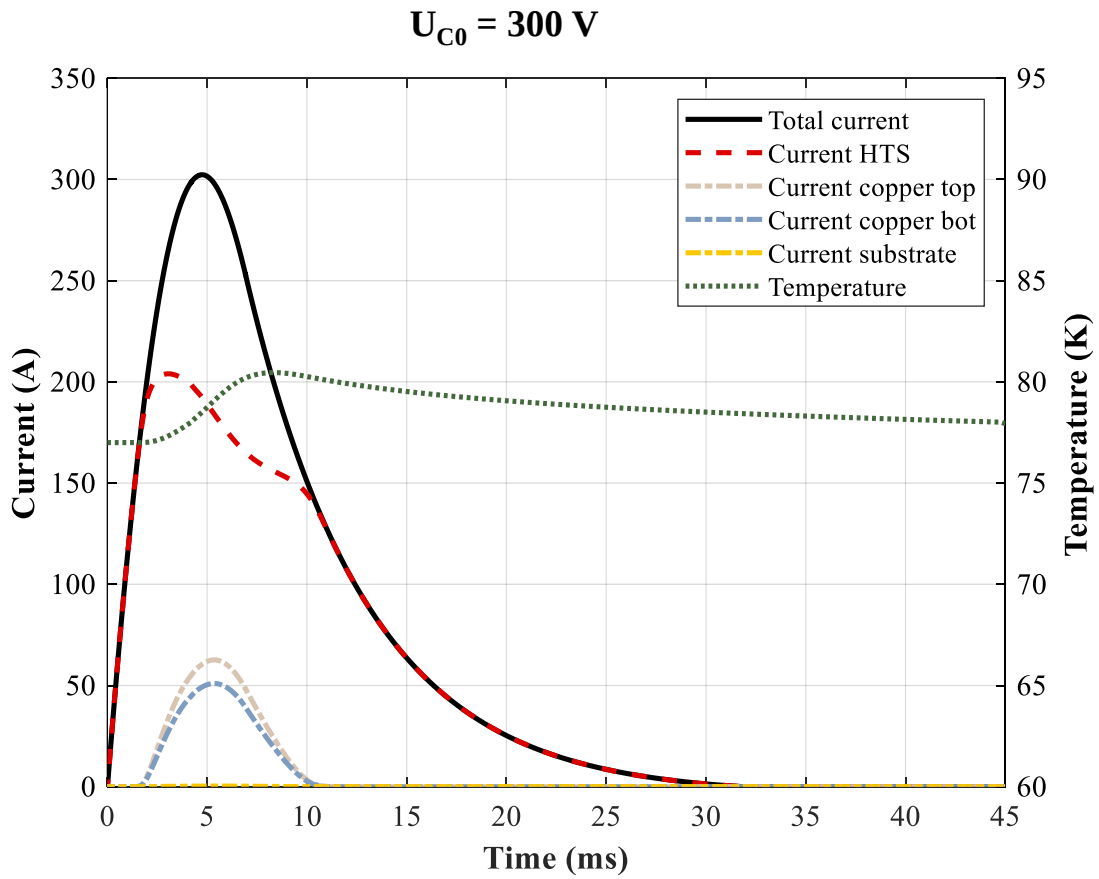
- One tape tested so far
- Goal: Validate the model on tapes with different widths and copper thicknesses

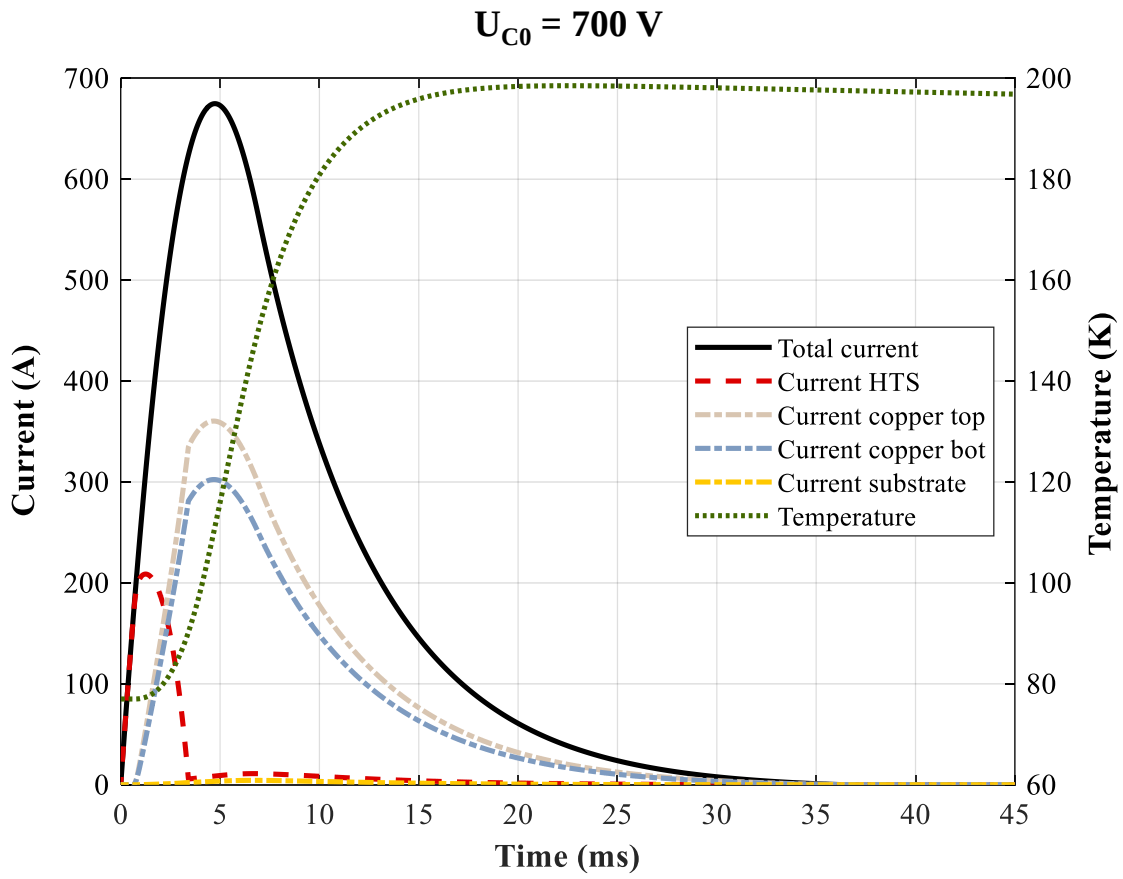
- Tape properties at 77 K:

Manufacturer	Shanghai Superconductors
Ic	138,5 A
n	22
Width	4 mm



Model results

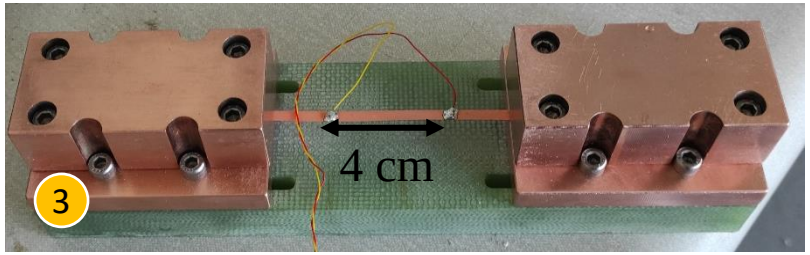


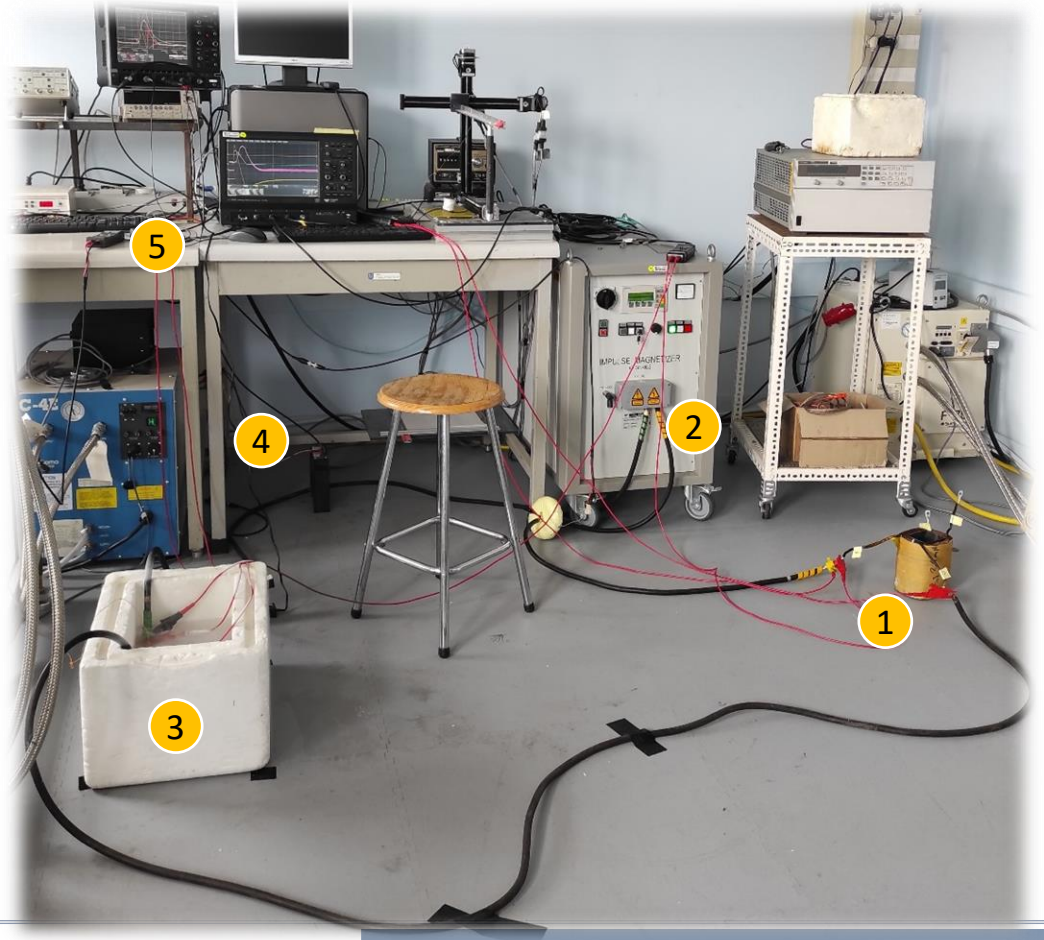


Experimental setup

1. Coil
2. Capacitor bank
3. Sample + Cryostat
4. Current measurement
5. Voltage measurement

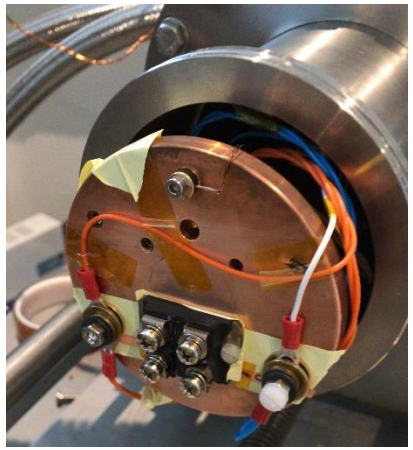
HTS tape

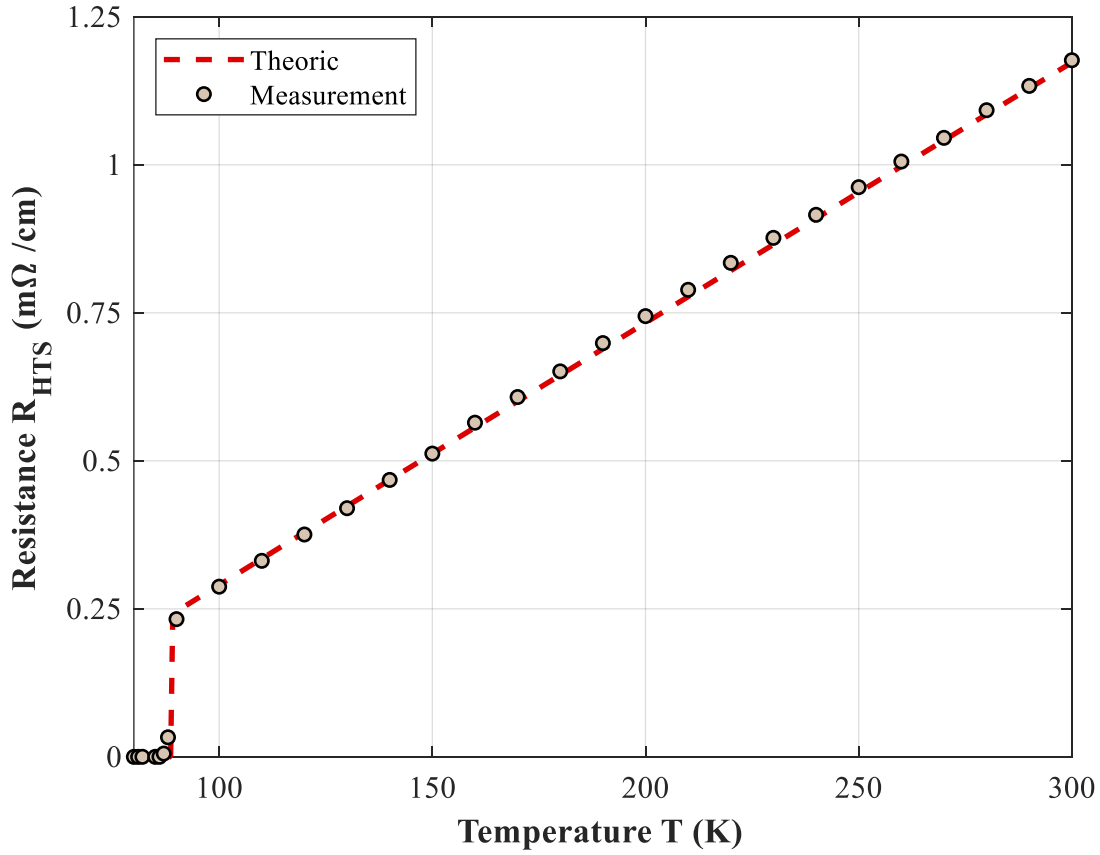




Temperature estimation from resistance

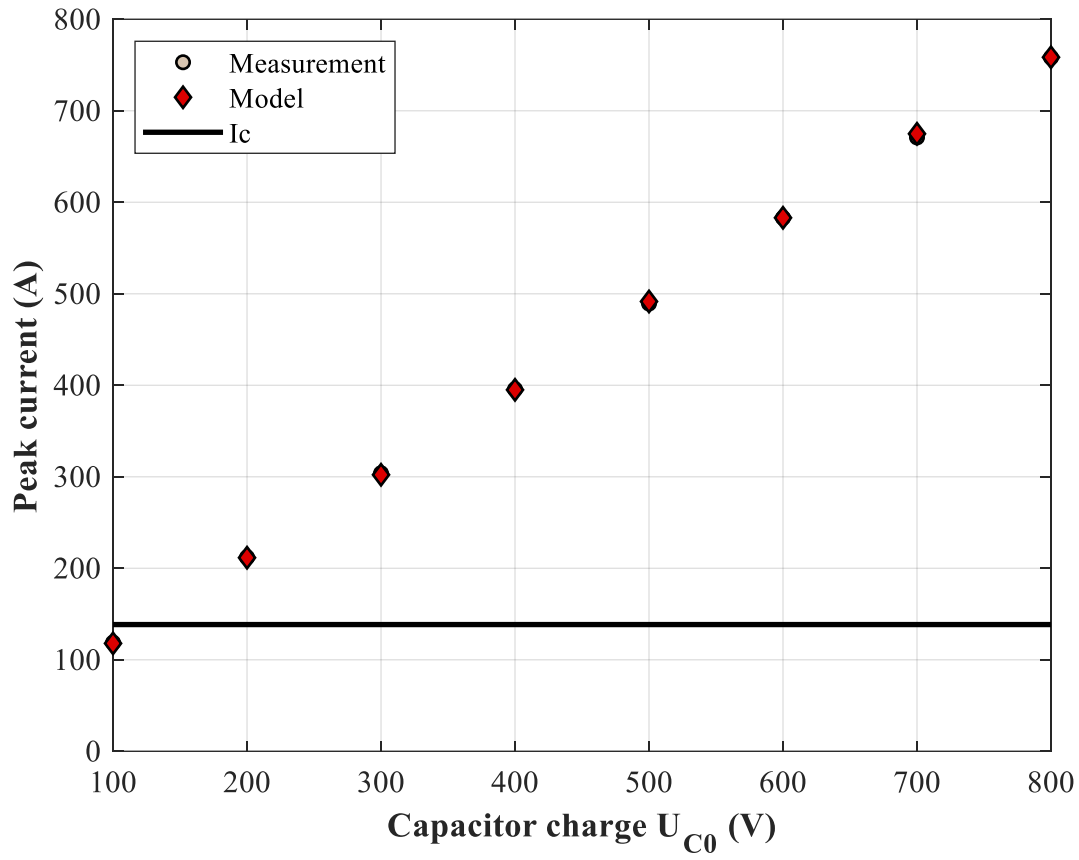
- Direct measurement of temperature is impossible
- Indirect measurement above *T*c
  - ❖ Tape's *R*(*T*) characteristics is measured with a cryocooler
  - ❖ Temperature deducted from voltage measurement above *T*c



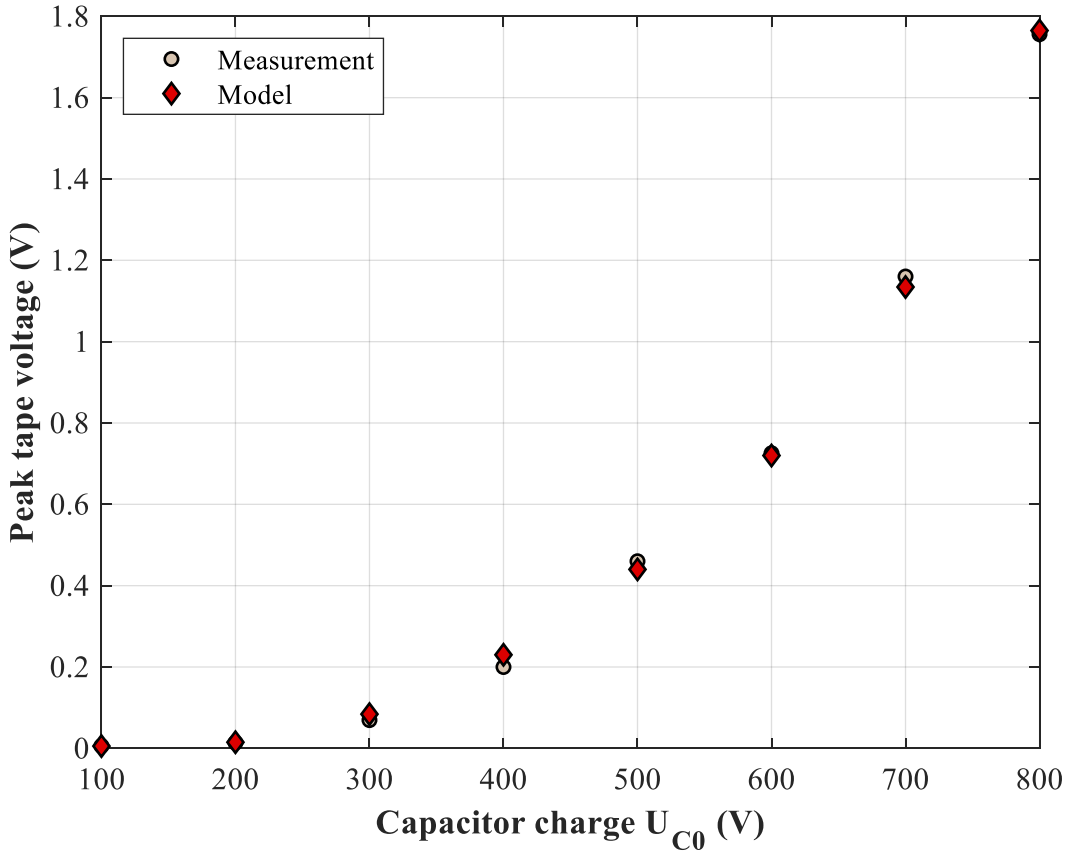


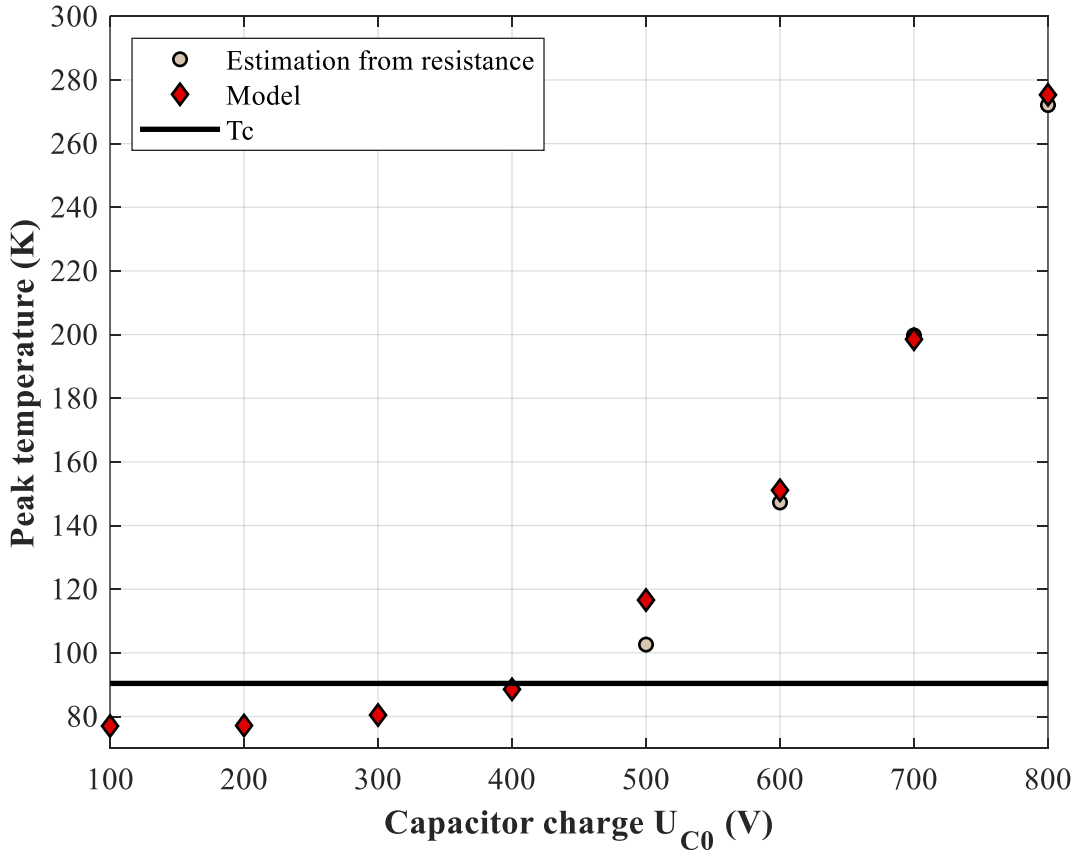
Results: Peak current

- Very good agreement on peak current
  - ❖ Depends mostly on the coil inductance and resistance

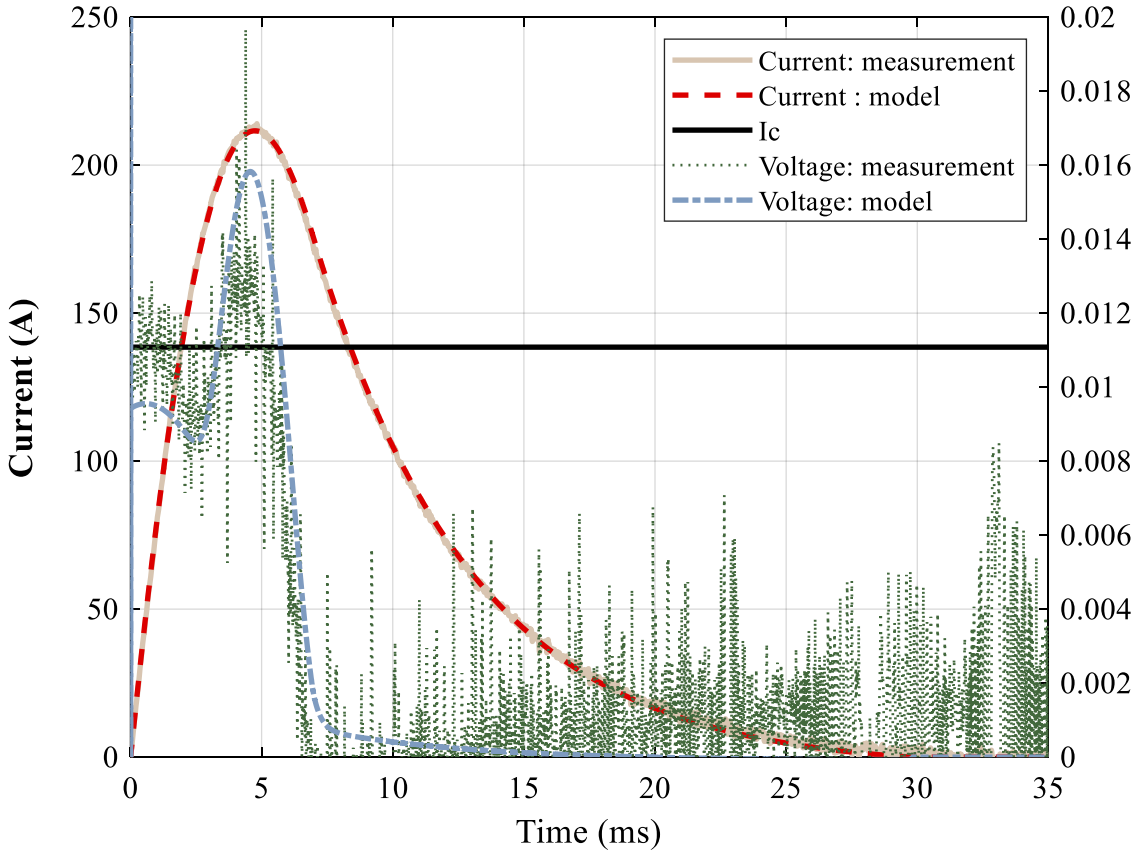


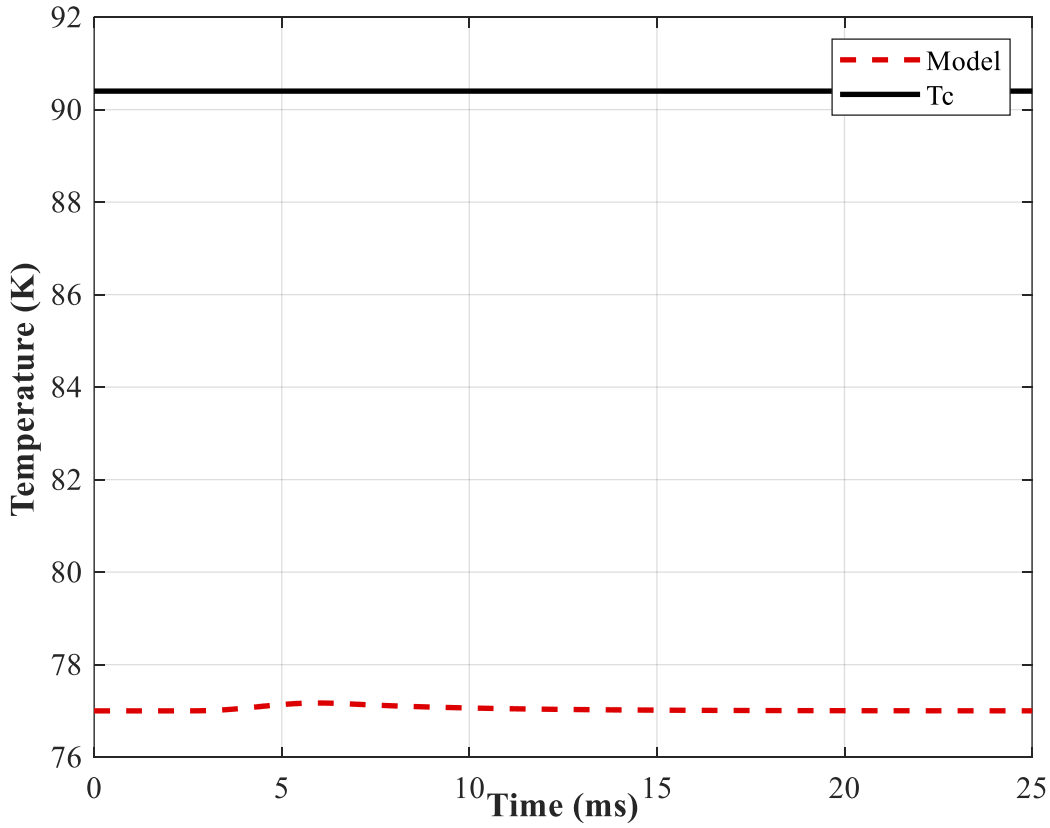
Results: Voltage and temperature



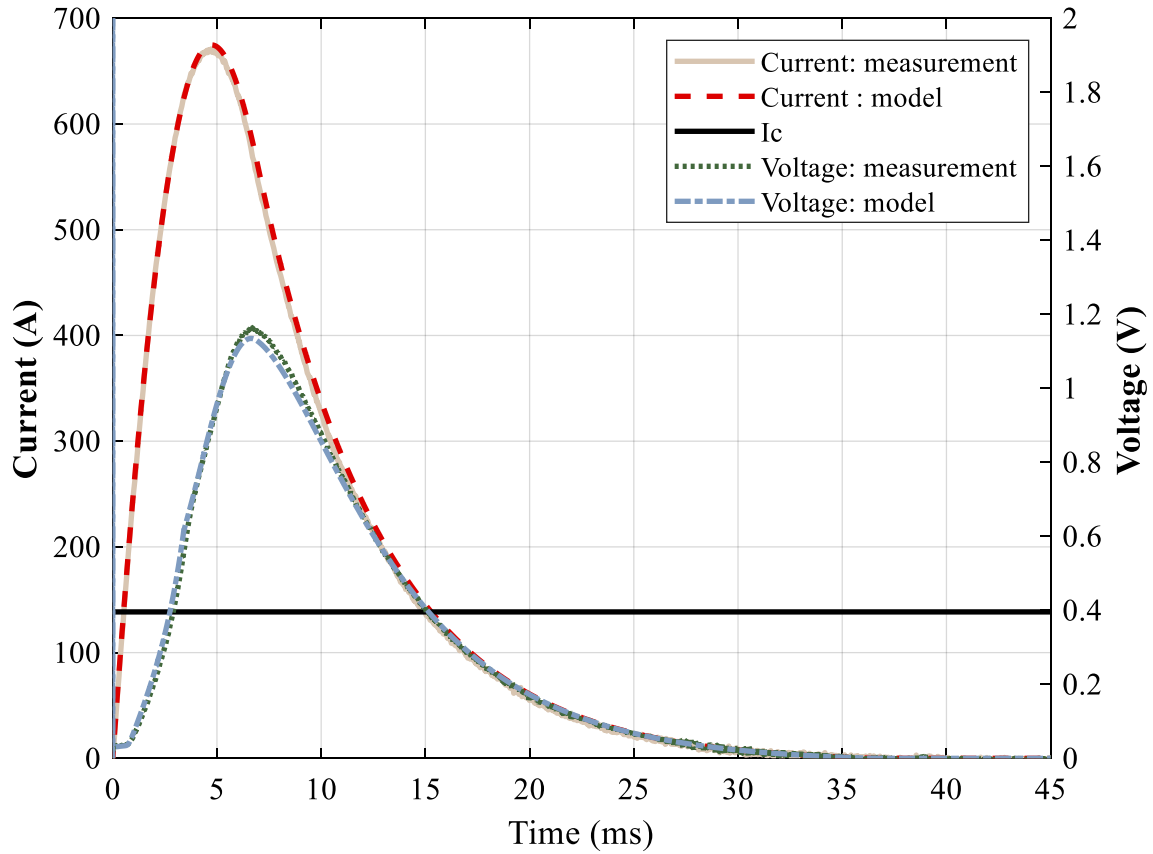


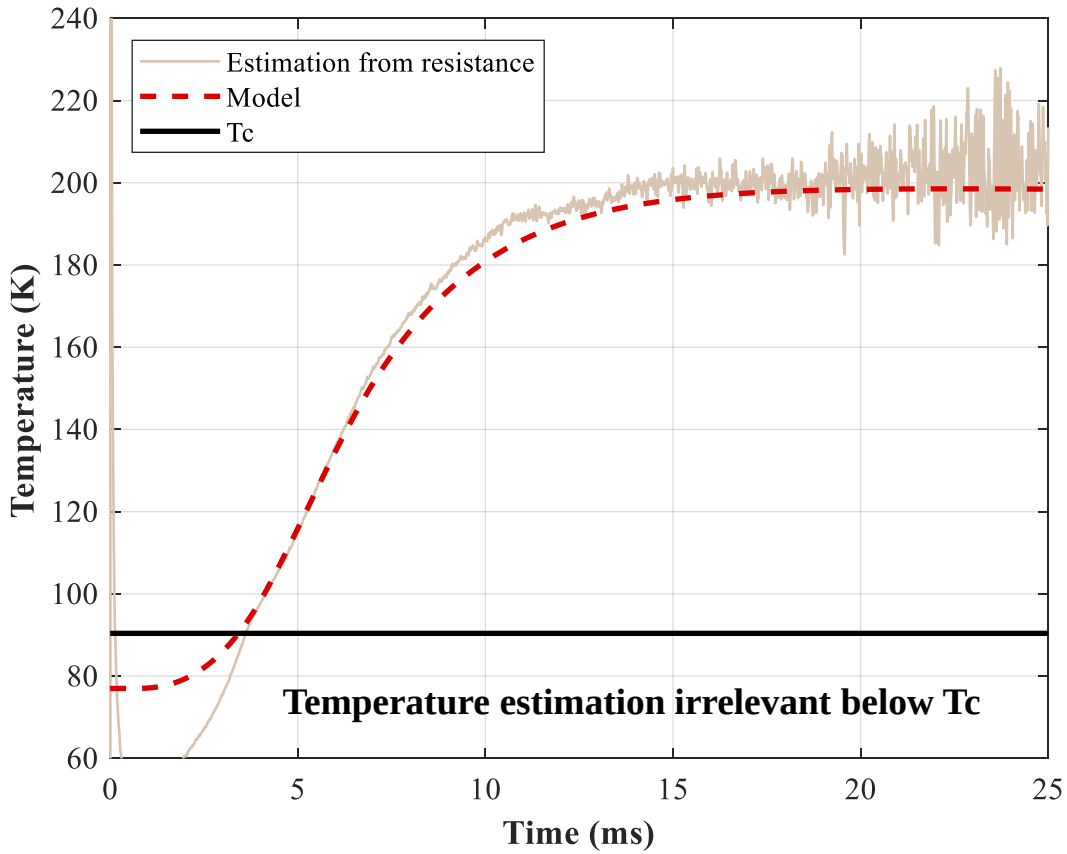
Results: Pulse ~ *Ic* (U_{C0} = 200 V)



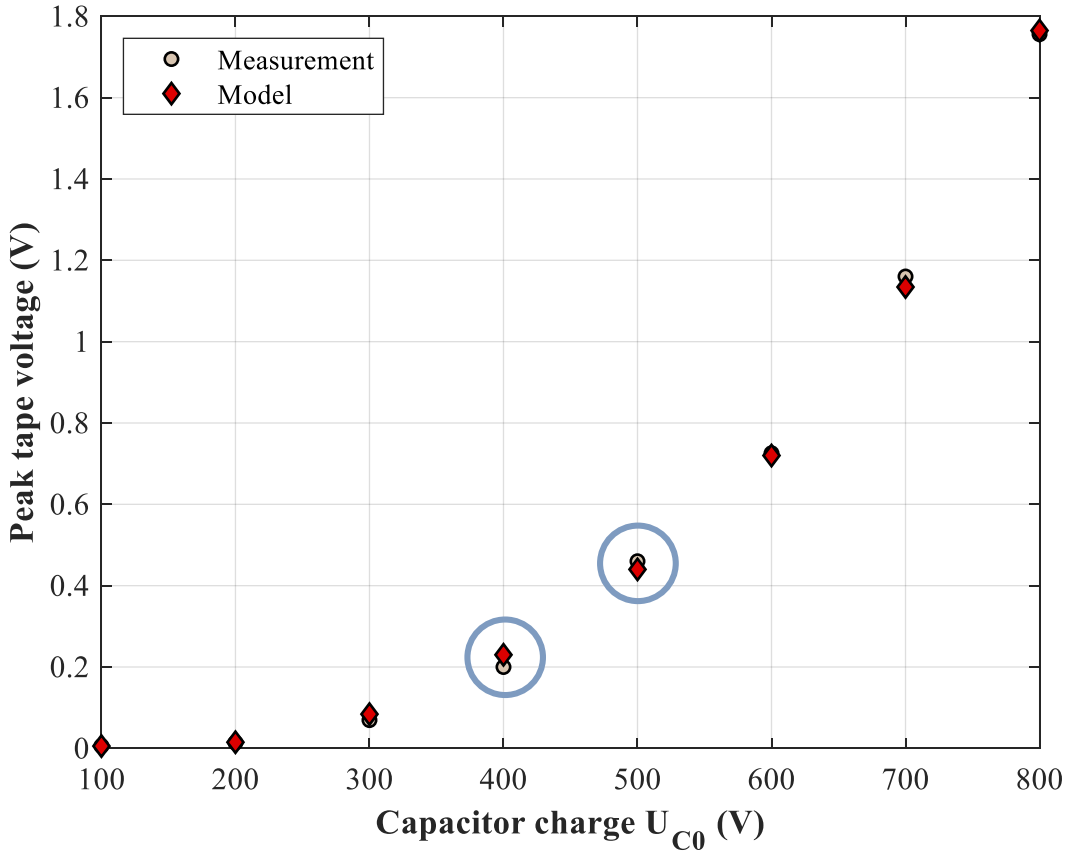


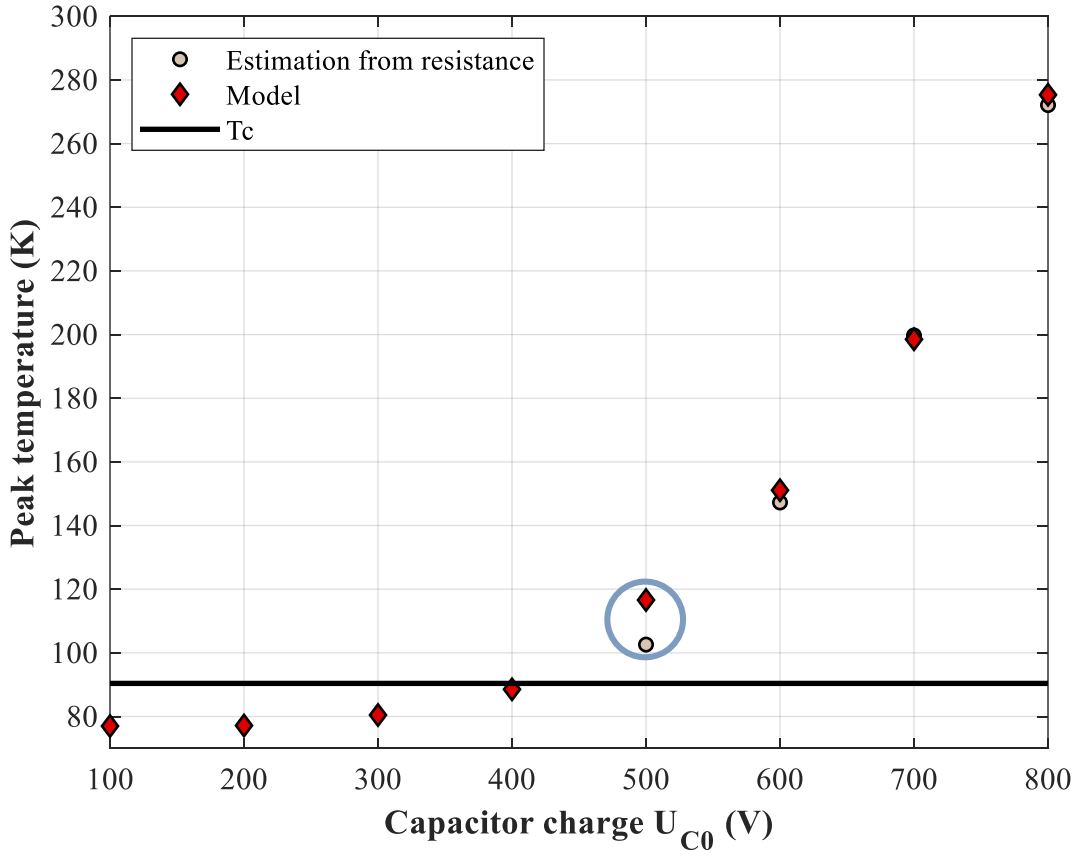
Results: Pulse >> *Ic* (U_{C0} = 700 V)



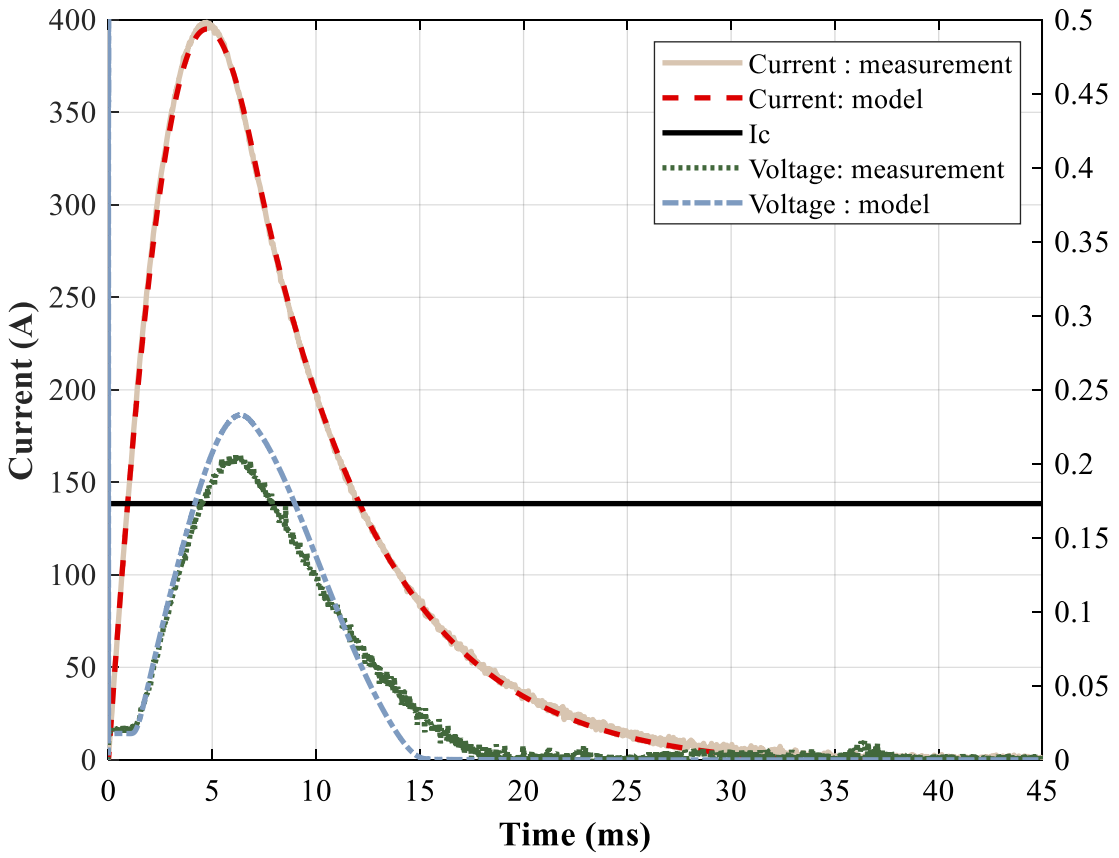


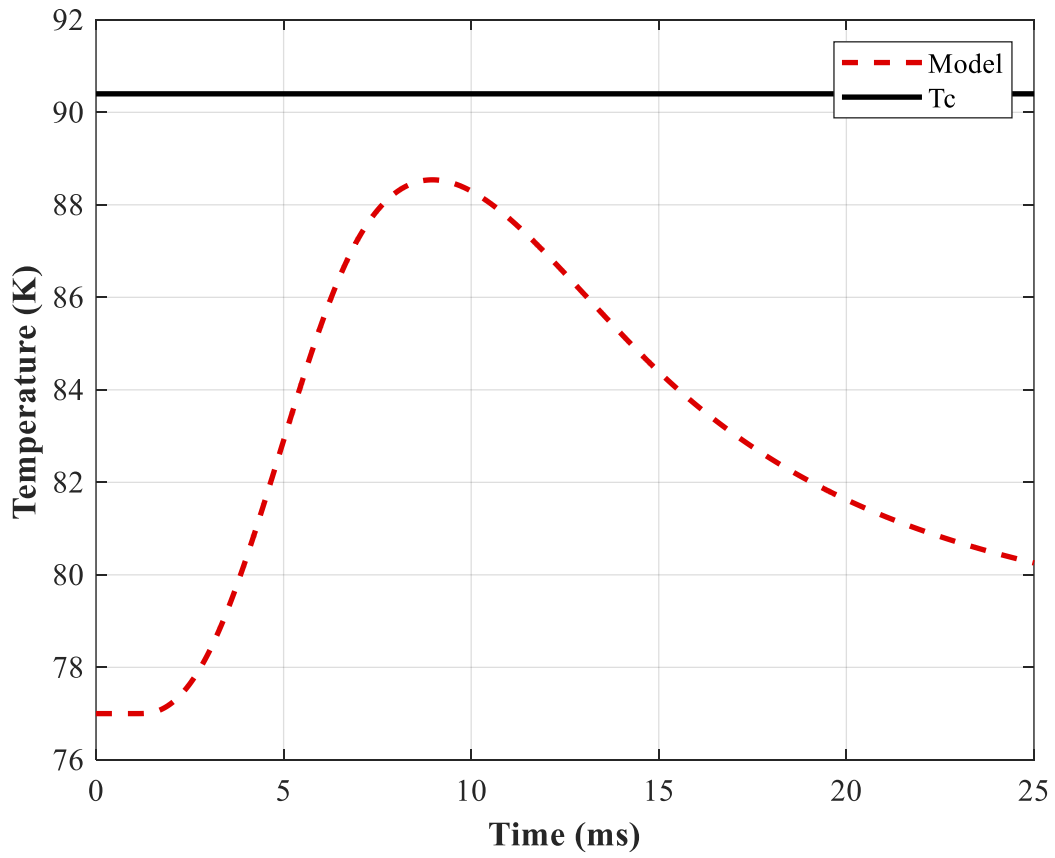
Results: Voltage and temperature



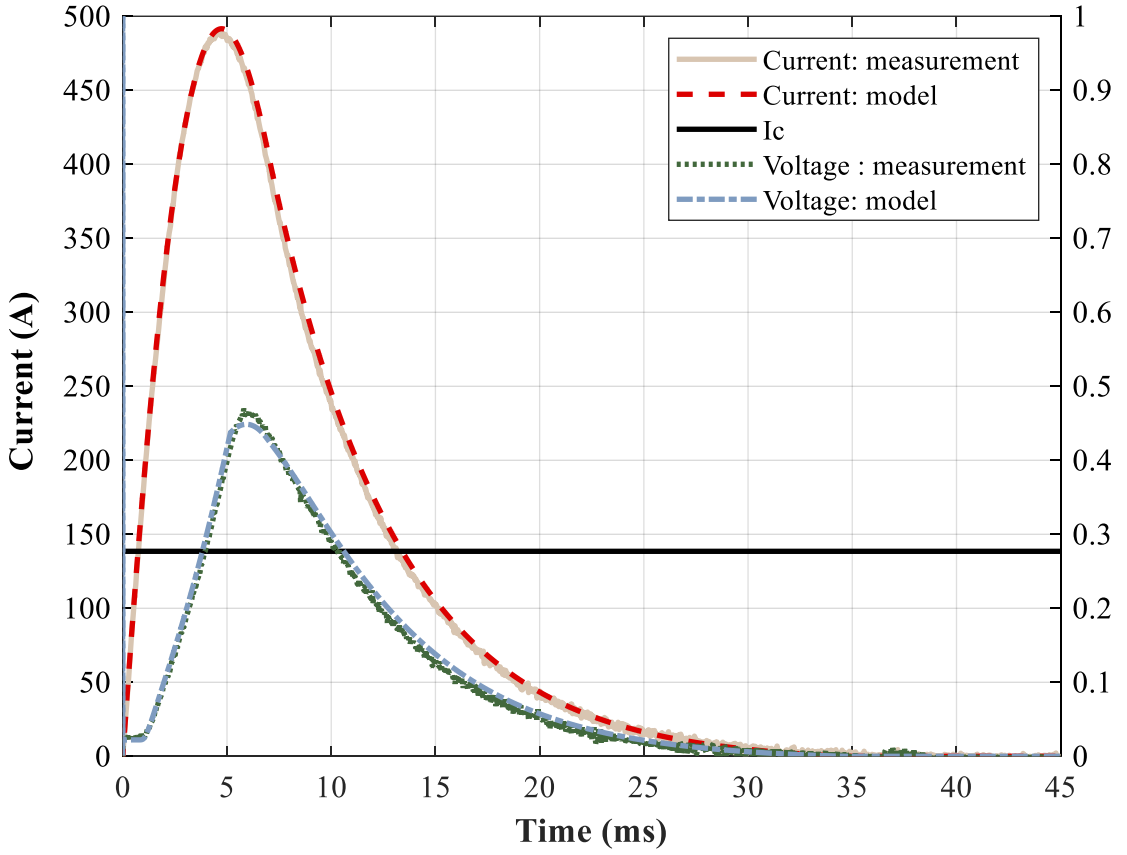


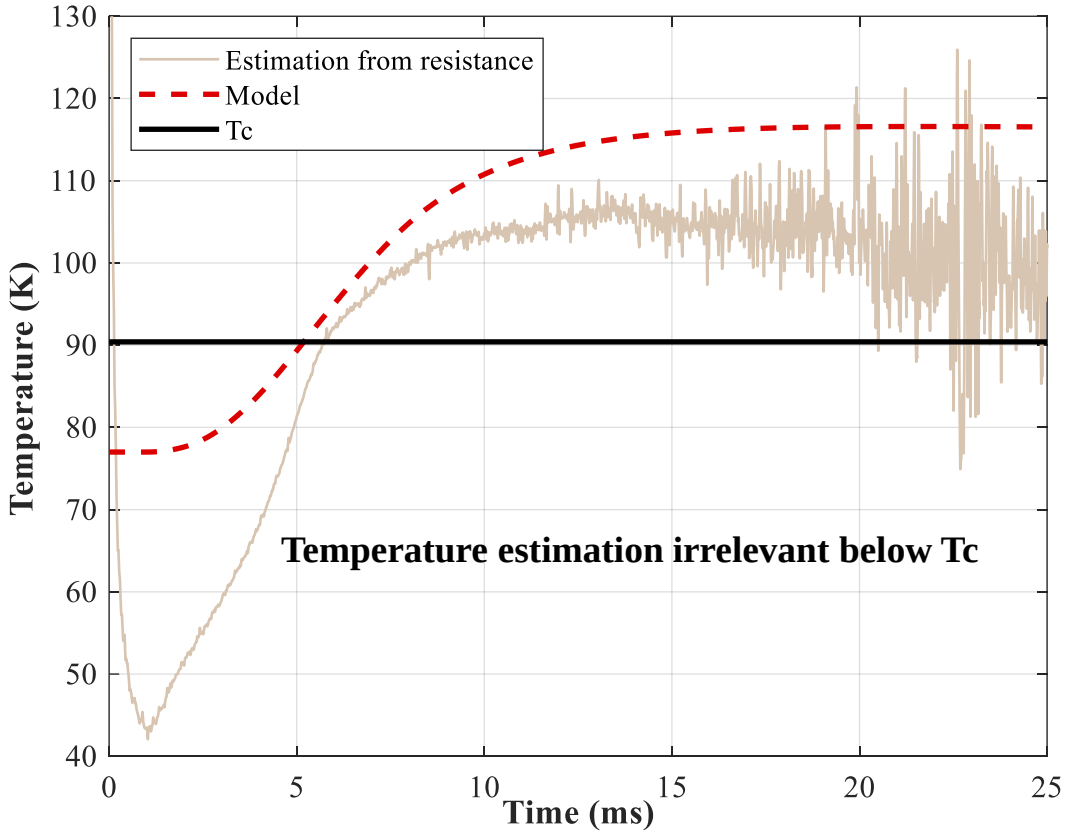
Results: Pulse at 400 V





Results: Pulse at 500 V

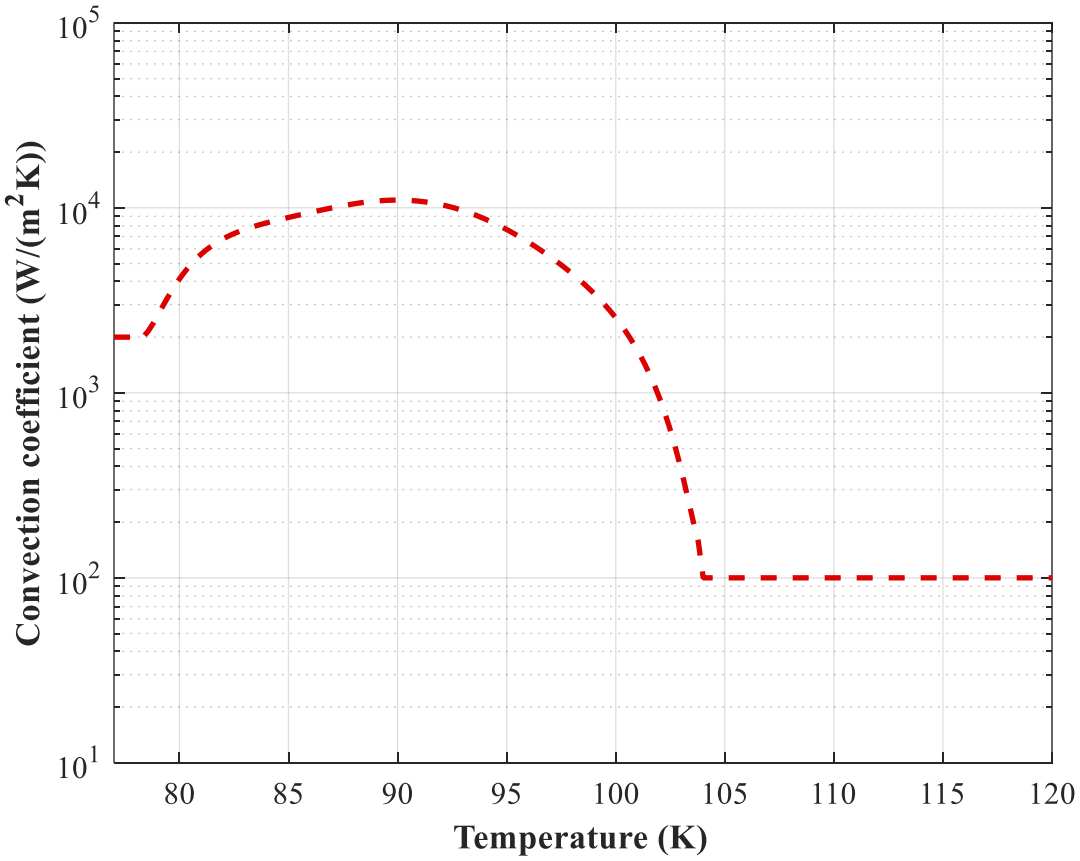




Results: Differences causes

Diverging points appears close to *T*c

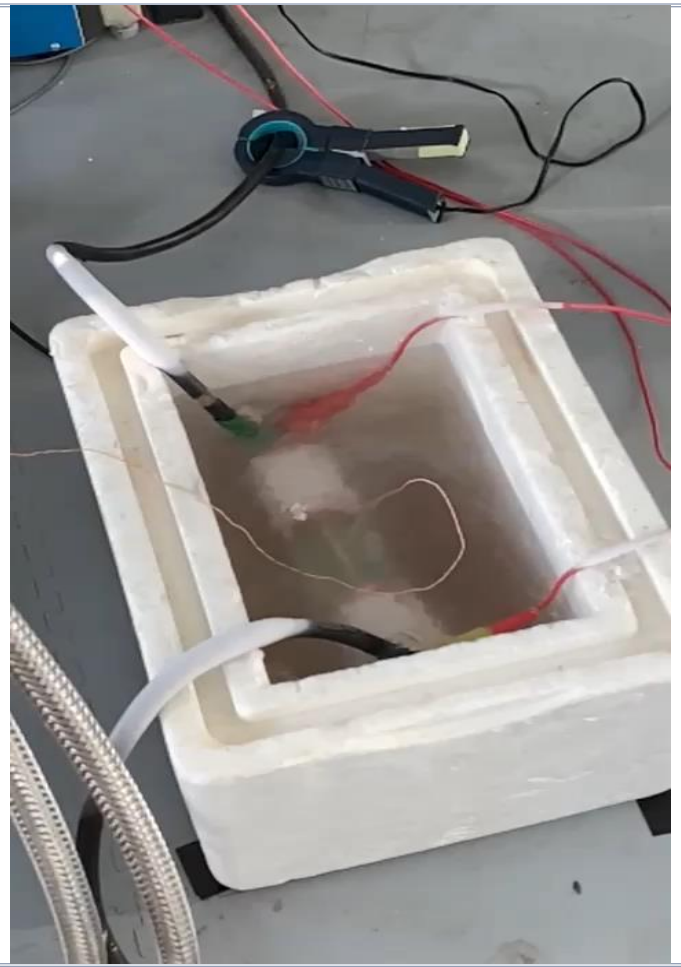
- *I*c and *n* around *T*c
  - ❖ *I*c and *n* characterized at 77 K and extrapolated linearly
- Convection heat exchange coefficient
  - ❖ Coefficient vs temperature comes from literature [1,2]
  - ❖ Important impact on the temperature
  - ❖ Below 105 K → Nucleate boiling

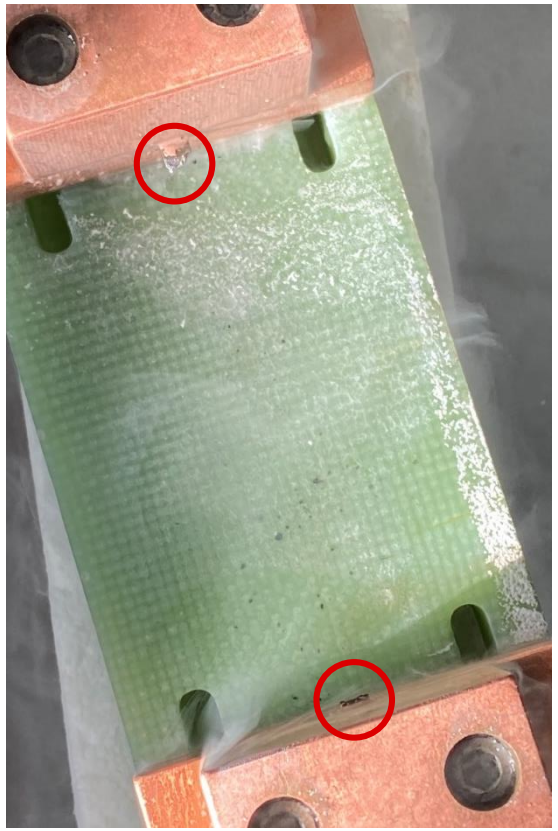


[1] De Sousa, W. T. B., Polasek, A., Dias, R., Matt, C. F. T., & de Andrade Jr, R. (2014). Thermal–electrical analogy for simulations of superconducting fault current limiters. Cryogenics, 62, 97-109.
[2] Baudouy, B., Defresne, G., Duthil, P., & Thermeau, J.-P. (2015). Transfert de chaleur à basse température. Techniques de l'ingénieur Froid industriel, be9812. https://doi.org/10.51257/a-v1-be9812

Destructive pulse

- Pulse value (from model):
  - ❖Peak current: 1 300 A
  - ❖Peak voltage: 33 V
  - ❖Peak temperature: ~5 000 K

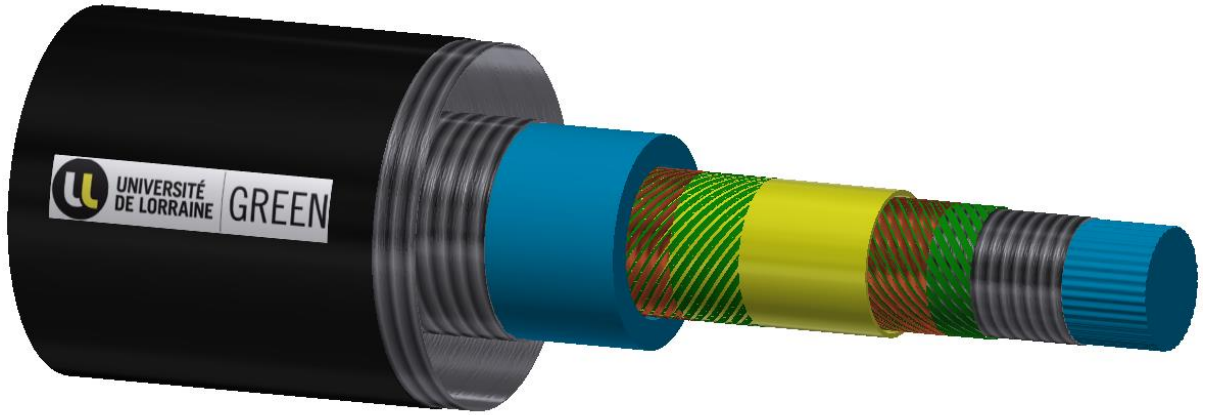




Conclusions

- Electro-thermal model of the tape validated
- Main error cause is convection coefficient:
  - ❖ Present setup → Natural phase change convection
  - ❖ Actual cable → Forced single phase convection

- **Next steps:**
  - ❖ Model of a complete cable
  - ❖ Simulate the fault behavior



Thank you for your attention

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