What have we Learned From Feather-M0.4 Cold Test

Disclaimer: This presentation focusses on what we have learned from an academic point of view. Practical matters such as failing instrumentation, are not included in this presentation.

Jeroen van Nugteren, Glyn Kirby, Jaakko Murtomaki, Janne Ruuskanen

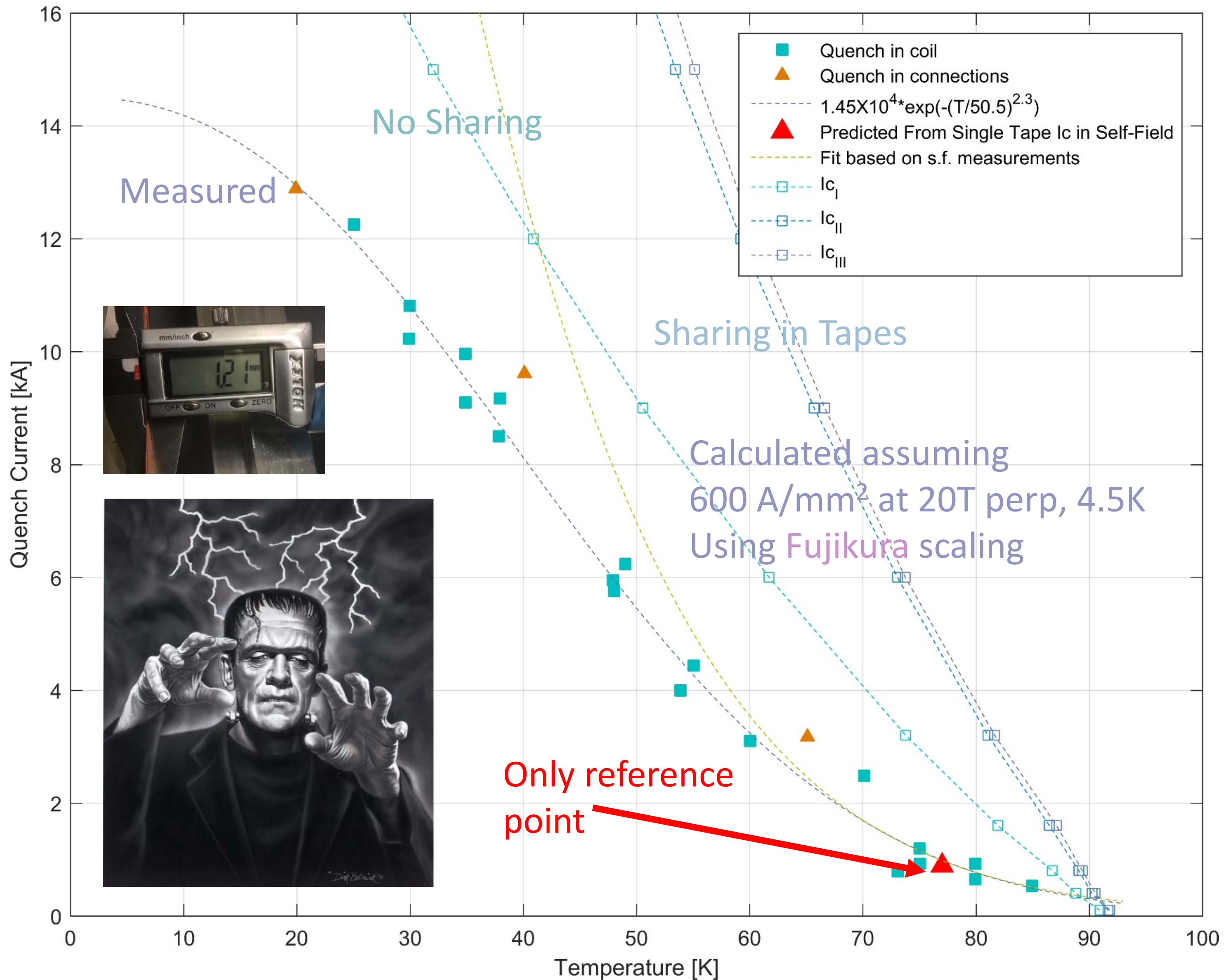
CERN // 7 February 2017

Cable, Insulation, Impregnation 1

- Frankenstein Cable
  - Thicker than the expected 1.2 mm due to dog-boning effects in the copper plating, resulting in only 3 turns on the coil and thus lower overall current density.
  - Next (KIT, Bruker) cable looks already much better.
  - Actually no problem to wind, impregnate, cool down, use, power …
  - Plenty of monsters left (=

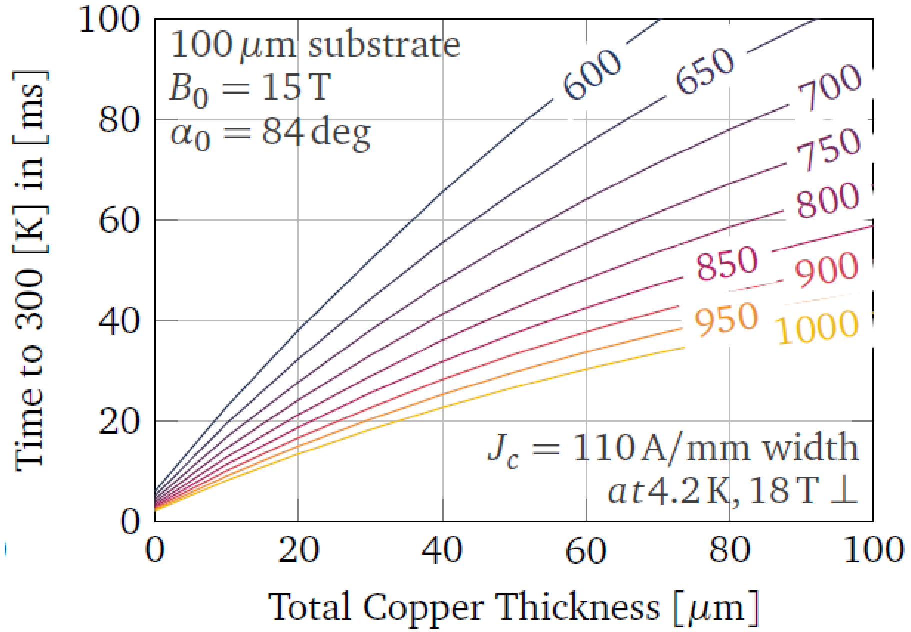
- Impregnation/Insulation System Seems to be Okay! (=
  - No degradation with respect to single tape measurement at 77 K
  - Lack of Critical Current Data on Single Tapes caused bad prediction of critical current of coil
  - Desperately need Jc as function of B, T and theta because predictions of Ic were far off.
  - However able to reach 12kA same current as for Feather-M2 to reach a magnetic field of 5T

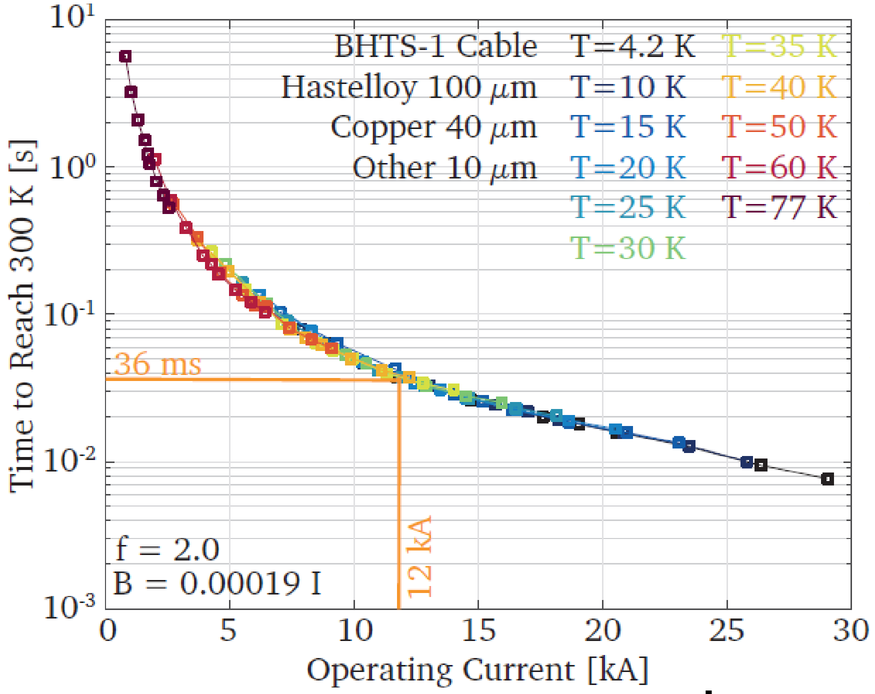
- Need final dissection of the coil to see what it looks like inside.



Thermal Behaviour and Quench 1

- We have not burned our coil thus far in contrast to reports from other groups: why? (cable/gas)
- Variable Temperature Test in Helium gas flow proved to be VERY Useful [1]
  - Go in steps to reduce risk to coil, keep critical current predictable.
  - System at CERN validated and can stabilize within 10K window
  - Gas operation results in less cooling than liquid helium and may prevent non-propagating quench.
- Voltage and Temperature Drift Slow and Soft
  - Coil drifts around when internal heating occurs, additional cooling could be supplied by hand to stop and reverse the drifting
  - Should monitor the temperature of the coil itself
- When real quench does occur (only at critical current) able to Protect the coil using simple voltage taps up to 13kA
  - Using threshold of 8mV with a filter time of 10ms (100 Hz cut-off frequency) is acceptable.
  - No degradation occurred (=
  - The coil did not exhibit any training behaviour, as expected



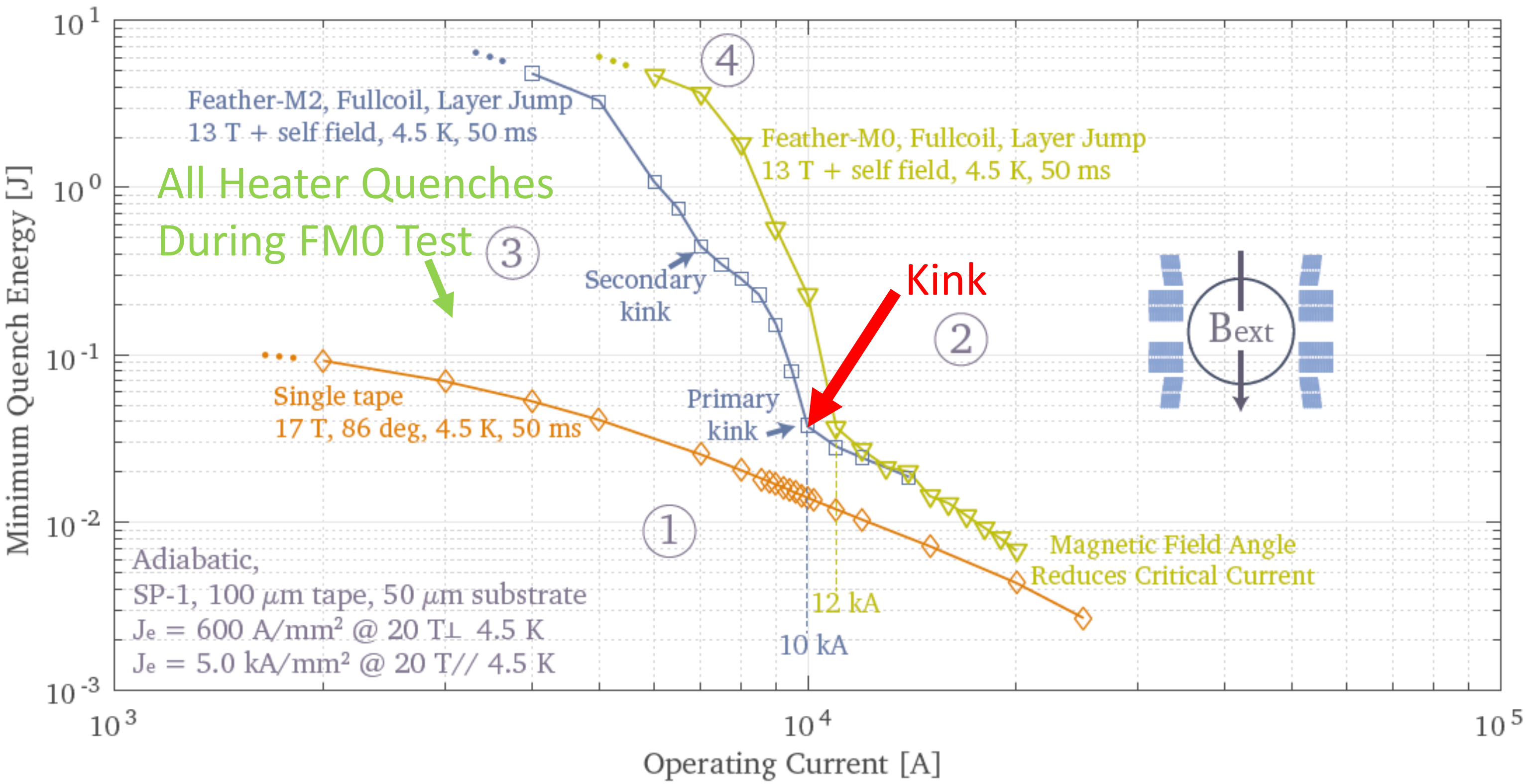


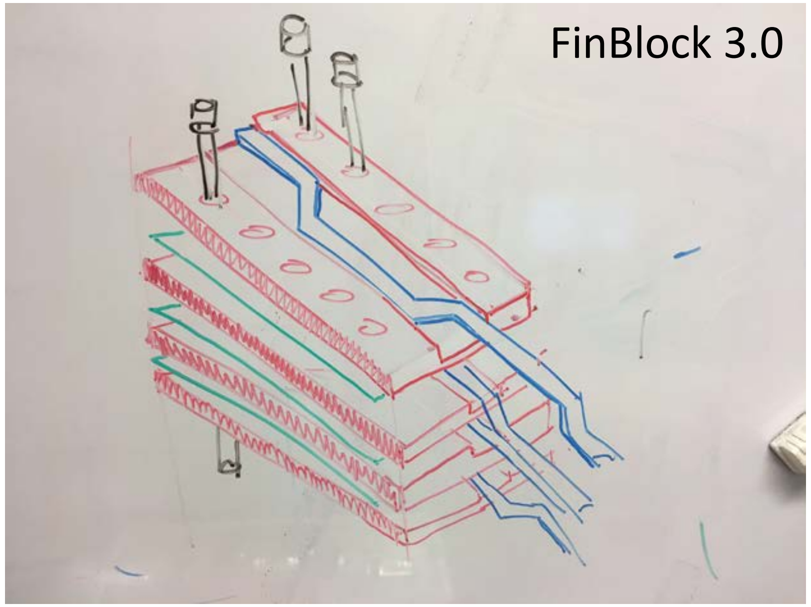
[1] J. van Nugteren, "Normal Zone Propagation in a YBCO Superconducting Tape", MSC thesis, 2012

Thermal Behaviour and Quench 2

- Away from critical current coil is super stable (=
  - Heaters almost can't quench it, hard to do MQE experiment
  - However heater quenches were all performed at around 6kA which is far left of the kink
  - Assumed MQE = 50J, then QE for hitting 3 tapes, were half is dissipated to environment, is around 300J (same order of magnitude as measured)

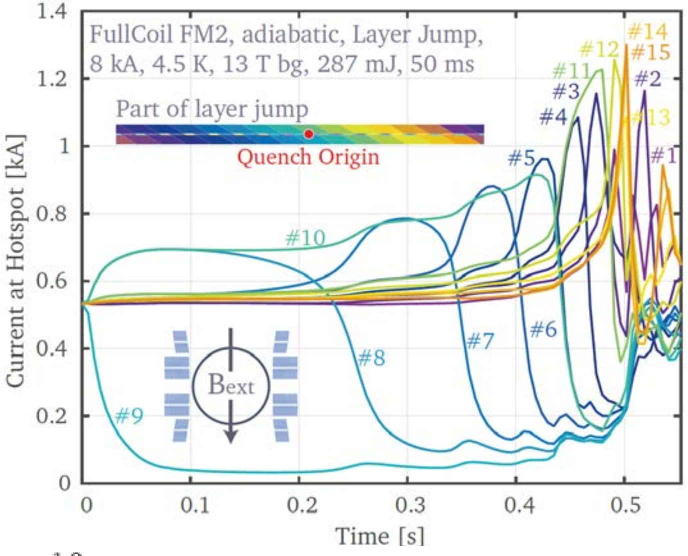
- Joints are the weakest point in the coil
  - Measured joint resistance was relatively low approximately 5 nOhm (low current). Nevertheless all quenches occurred here.
  - Sub-cooling was necessary to move the weak spot into the coil
  - Logical because coil almost no self-field, thus near critical current joint heating limiting factor.
  - Development to improve is ongoing

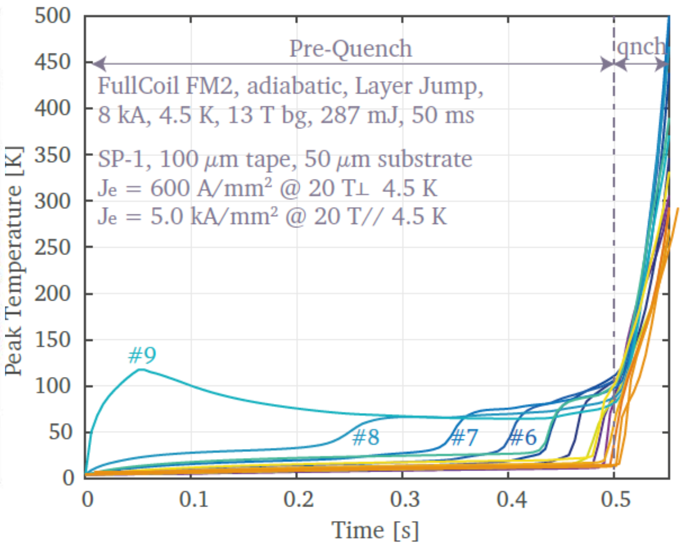


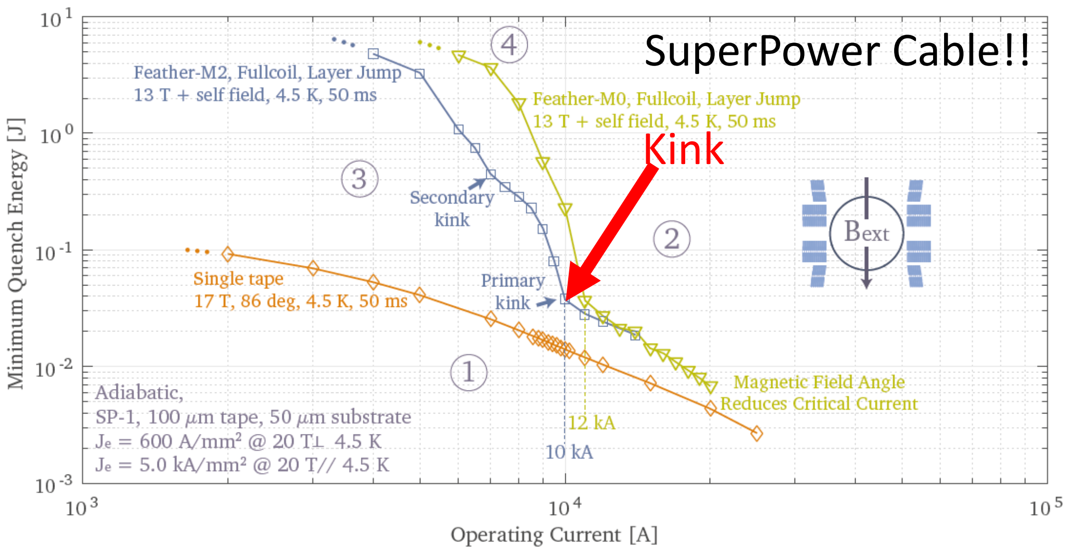


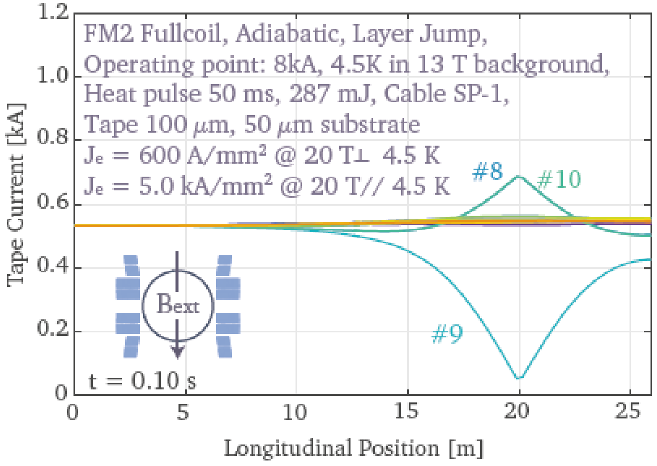
Existence Multi-Strand Behaviour 1

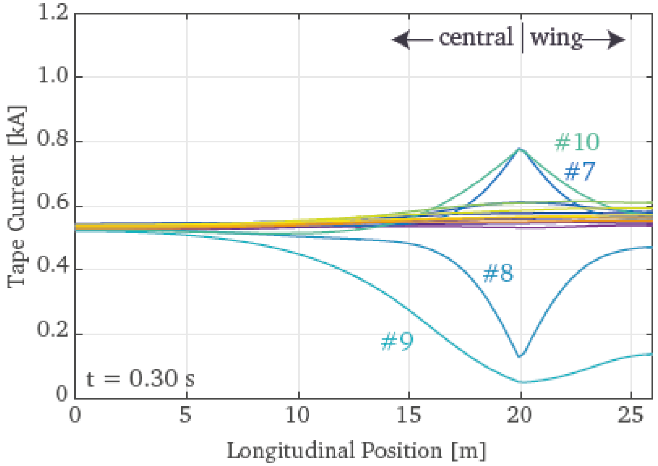
- We wanted to see multi-strand behaviour, to check numerical predictions
  - Current redistribution between strands result in characteristic kink in MQE
  - Pick-Up coils should be able to see redistribution directly
- However measurement with heaters at too low current and pick-up coils too far away from cable

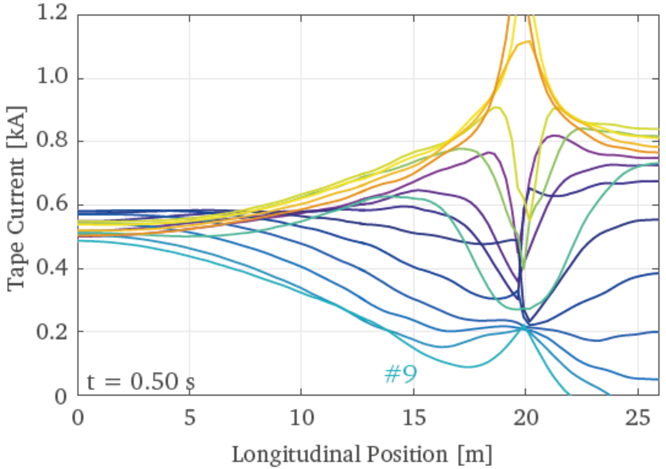






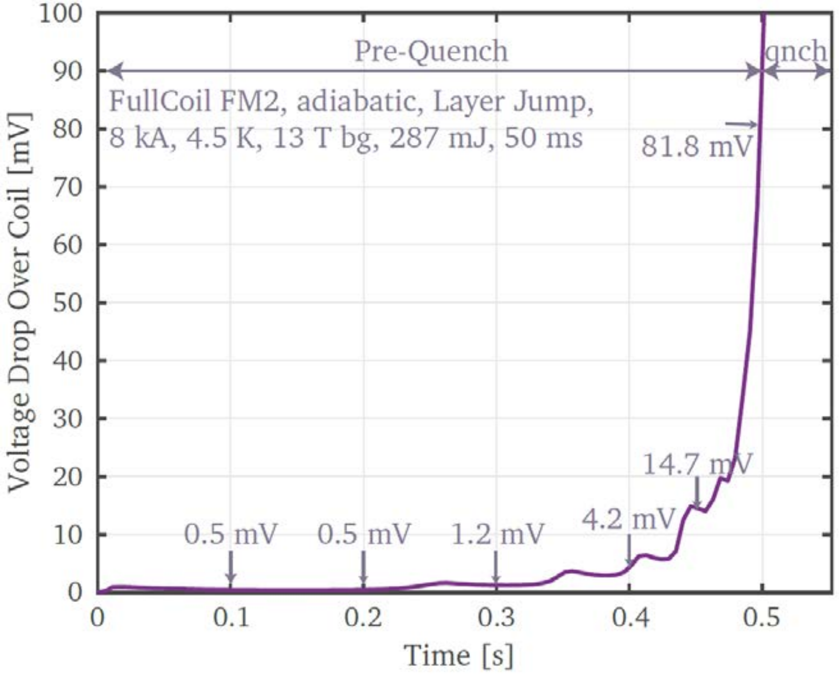


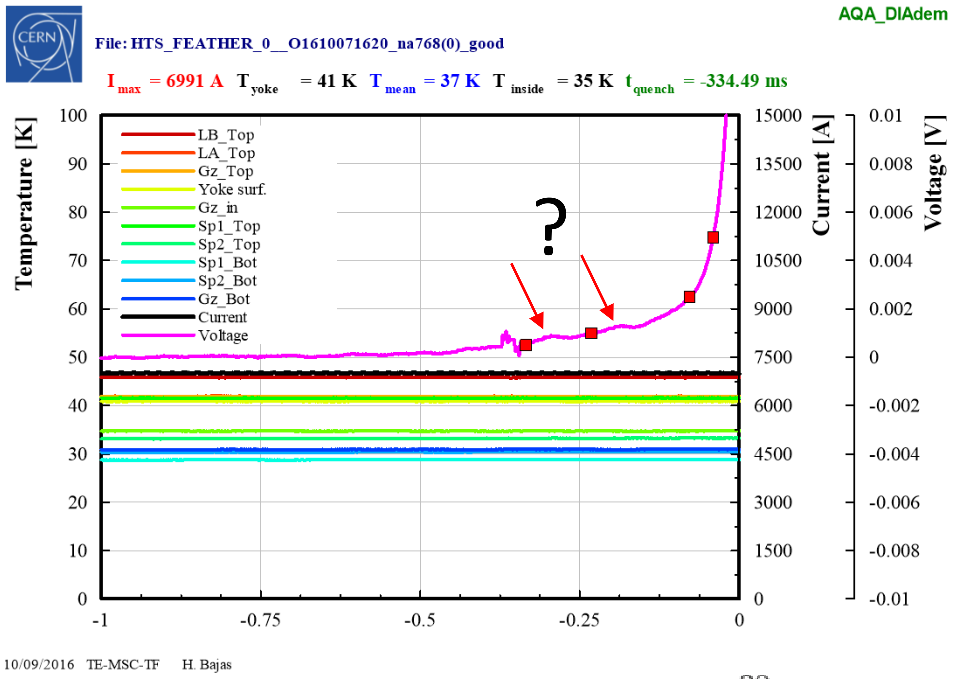




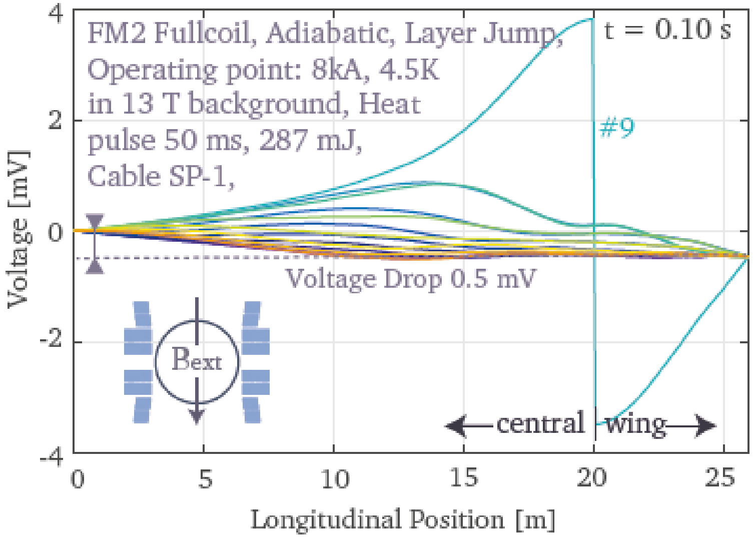
Multi-Strand Behaviour 2

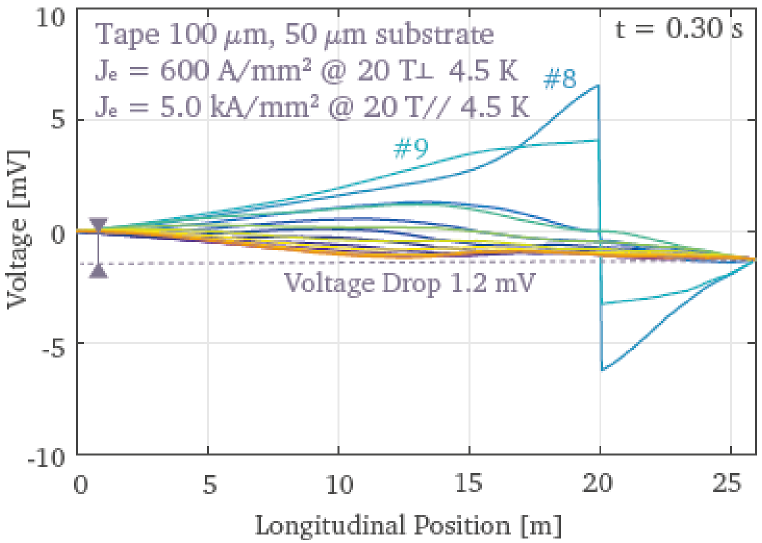
- However voltage taps may see signs of this phenomenon

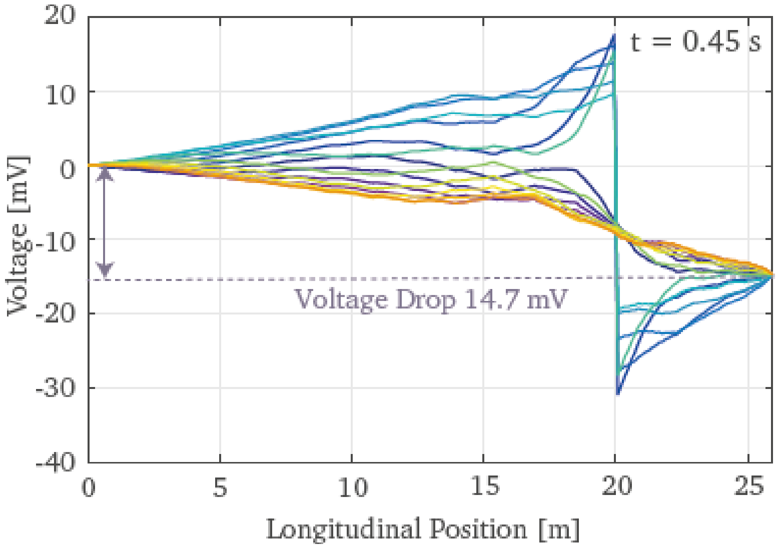




Much longer heat pulse so heat more spread out







Conclusion

- Onward to Feather-M2

Cable, Insulation, Impregnation 2