Self-healing effect from thermal runaway for No-Insulation (NI) REBCO coils

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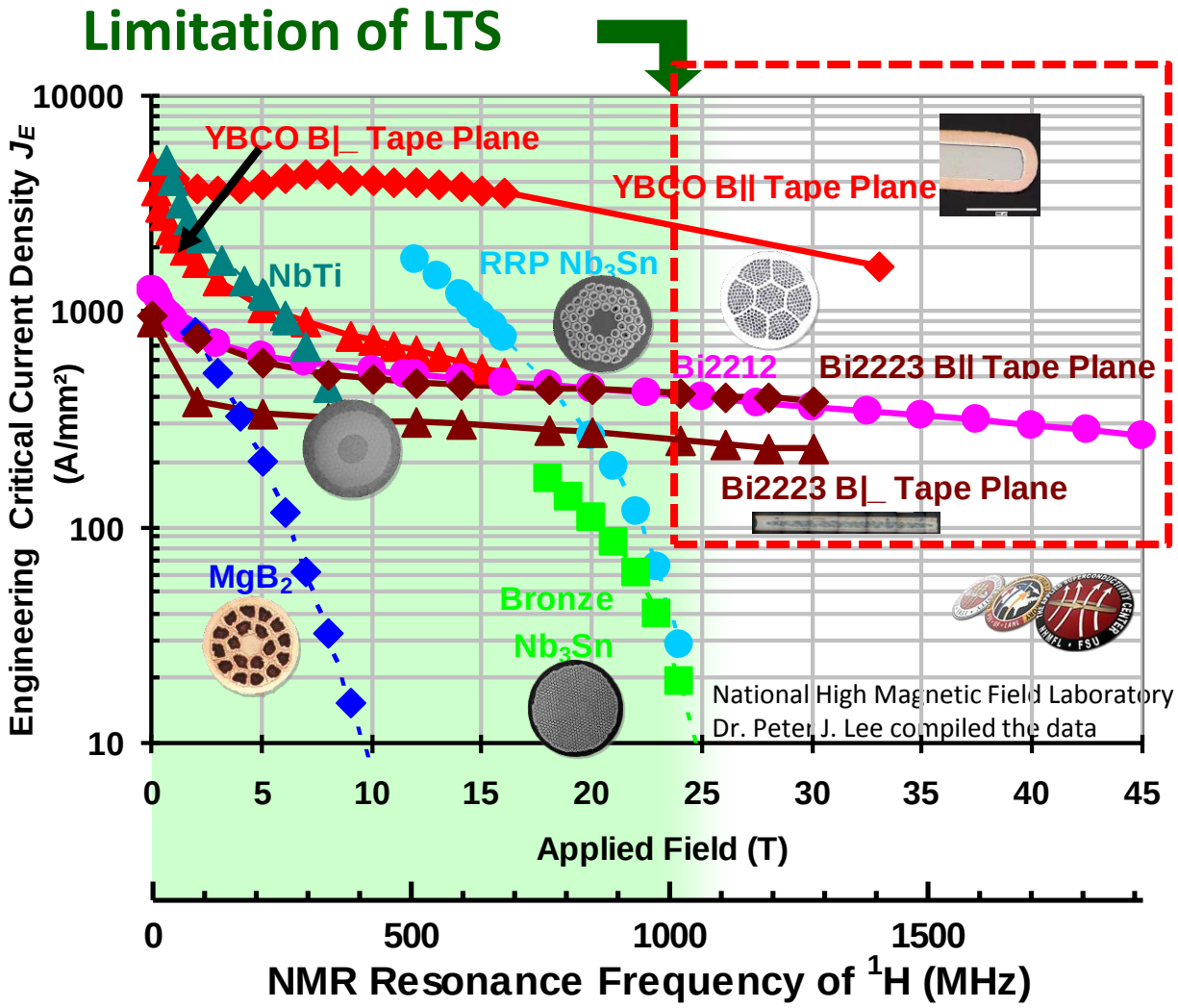
High current density characteristics of REBCO



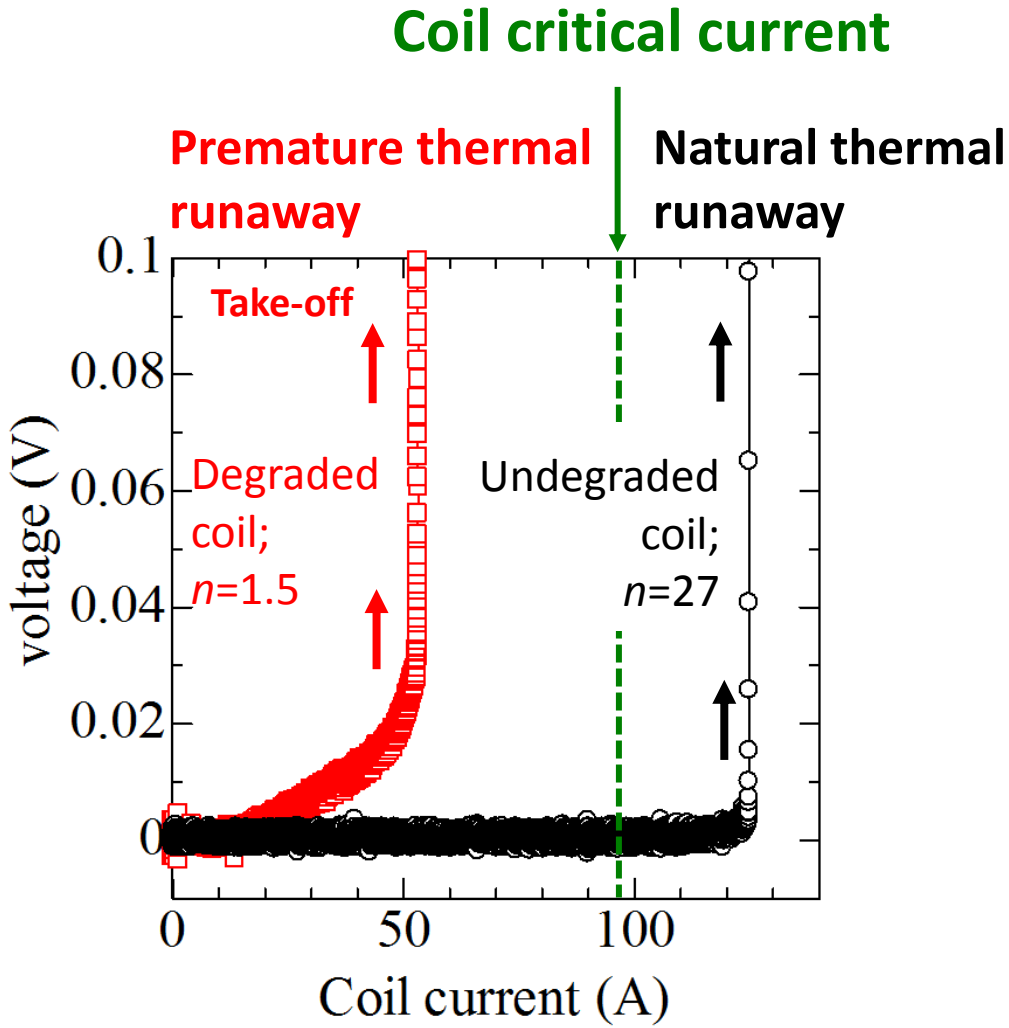
http://www.magnet.fsu.edu/magnettechnology/research/asc/plots.html

HTS

High current density, >200A/mm², in a super-high field over 23.5 T

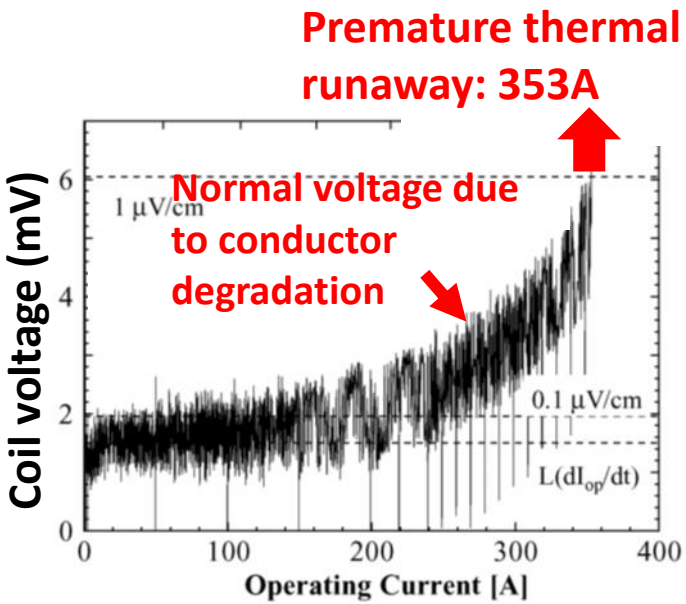
Thermal runaway for REBCO coils

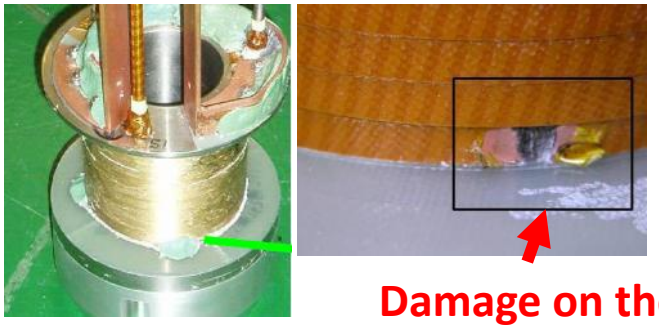
Paraffin impregnated coil at 77K



Yanagisawa et al, *SuST* 2012

REBCO layer-wound coil (17.2T at 4.2K)



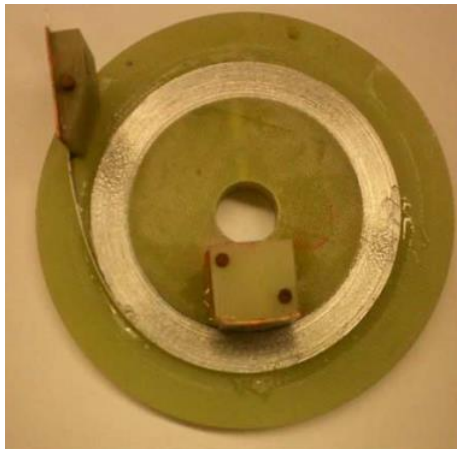


Damage on the coil

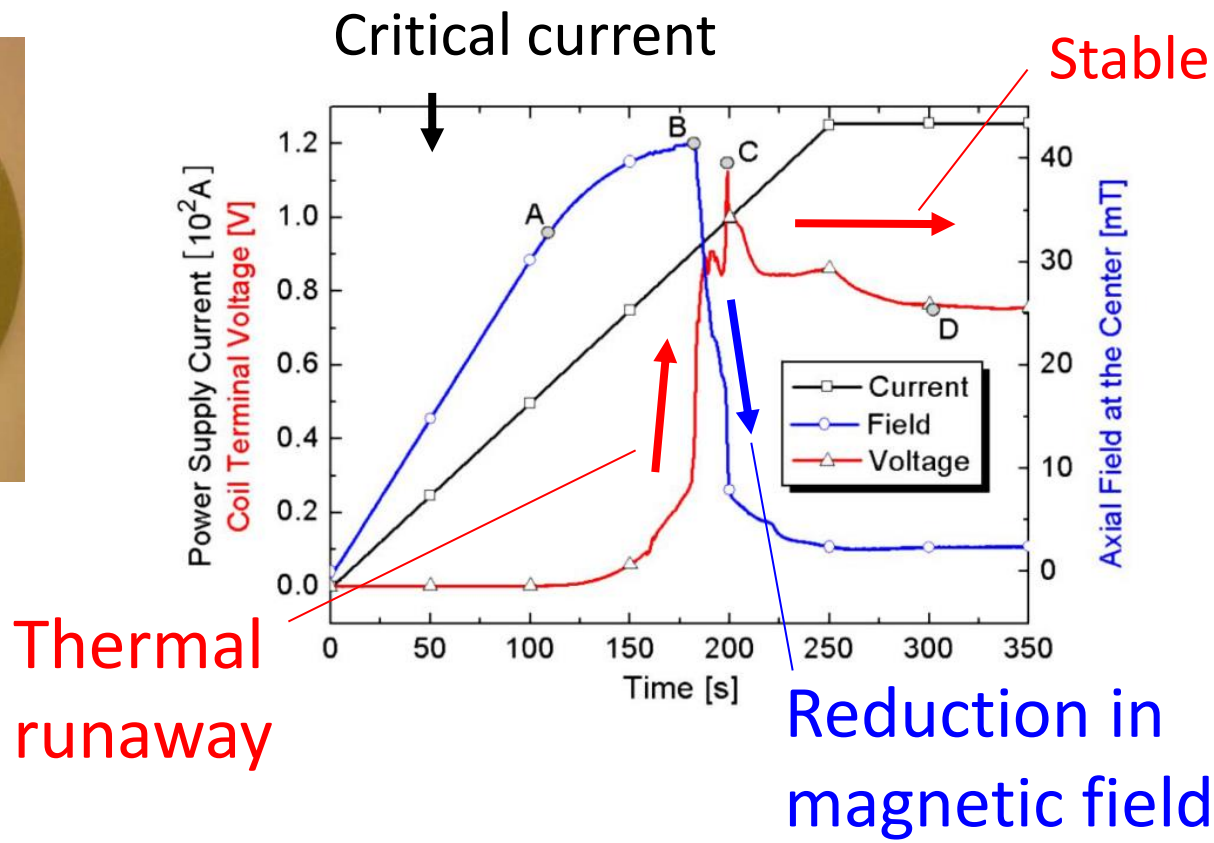
Matsumoto et. al. *IEEE* 9501604 (2012)

No-insulation (NI) method

Hahn et al, *IEEE Trans. Appl. Supercond.*, 21, 1592-1595, 2011.



NI REBCO pancake coil



Self-healing from thermal runaway
=> Mystery of NI coils

Motivation:

Why is thermal runaway for a NI coil self-healed ?

Goal:

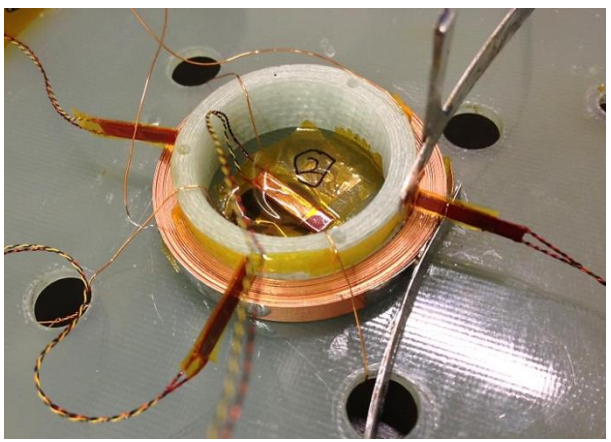
Reveal the mechanism of the self-healing effect by experiments and using simulation

Mechanism of self-healing effect from thermal runaway for NI REBCO coils

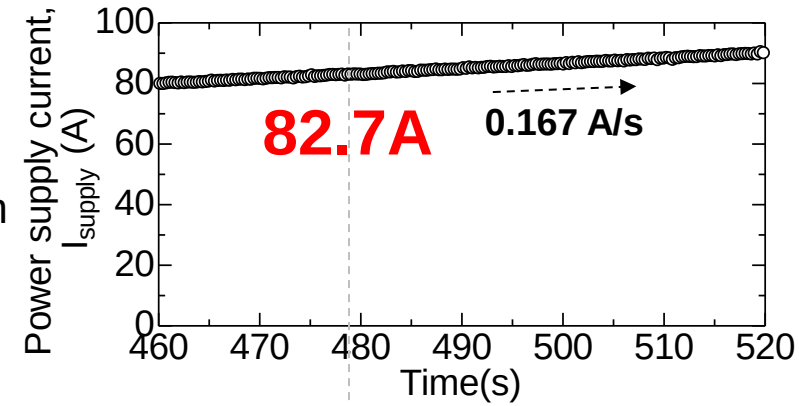
Self-healing from thermal runaway

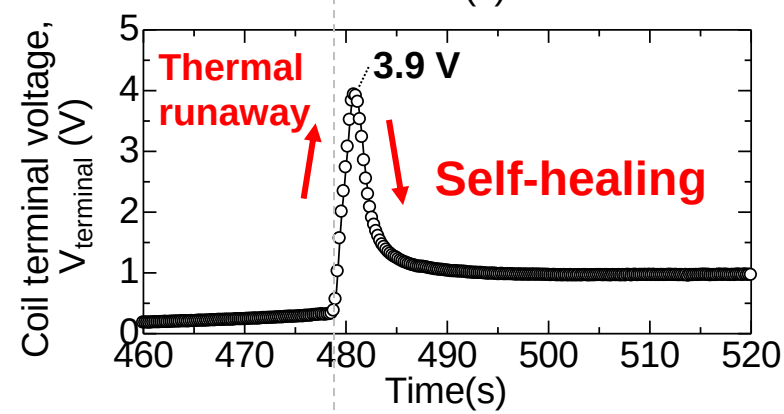
Coil parameters

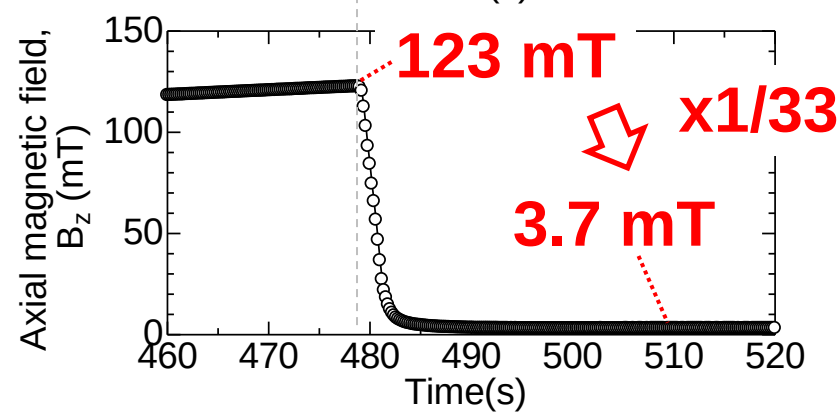
>Conductor: SCS4050
>Winding: single pancake
>ID: 30, OD: 37.1mm, Length: 4.1mm
>Number of turns: 37
>Coil critical current: 55A
(77K, 1μV/cm)



77 K

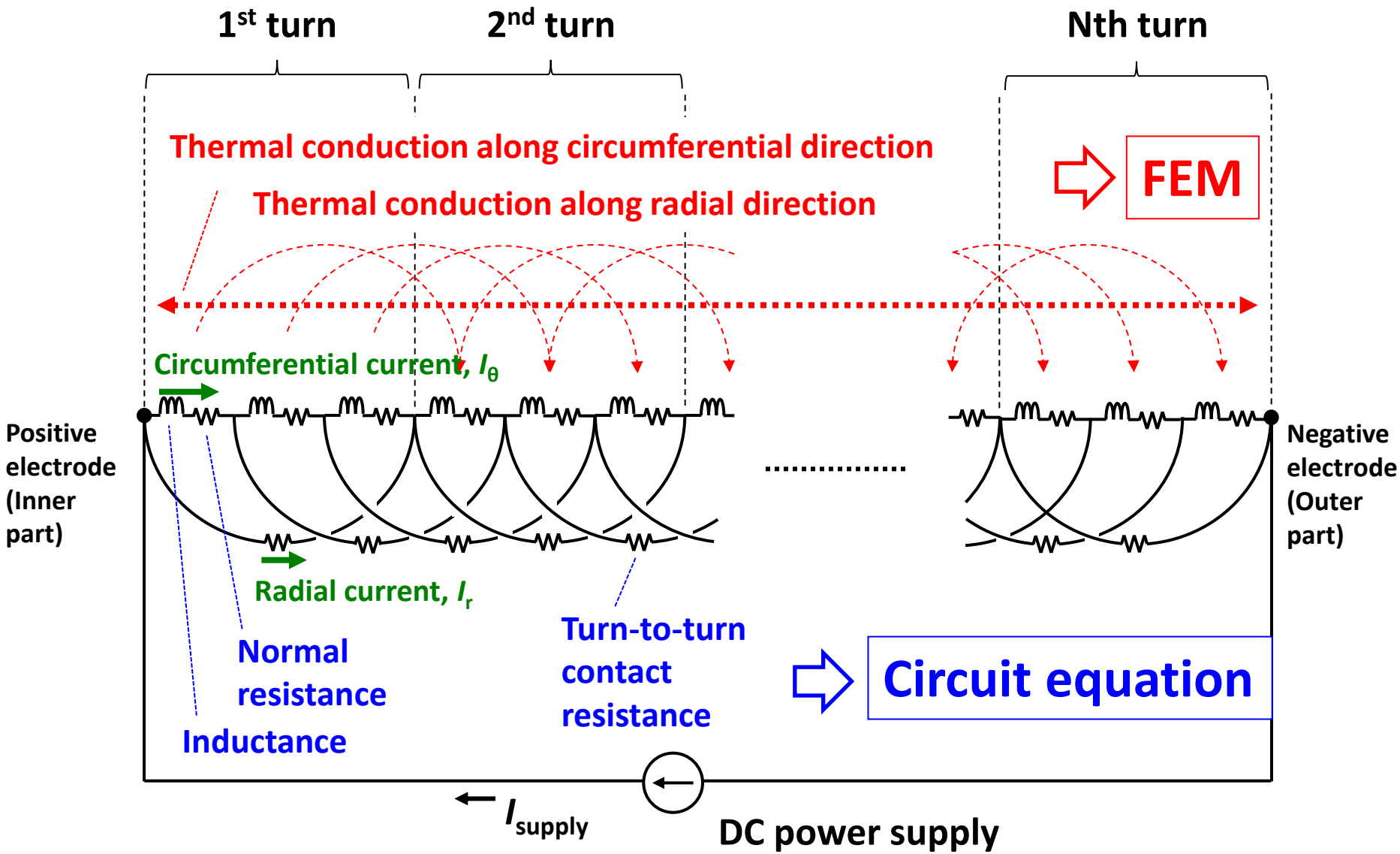






Why?

Simulation model of NI pancake coil

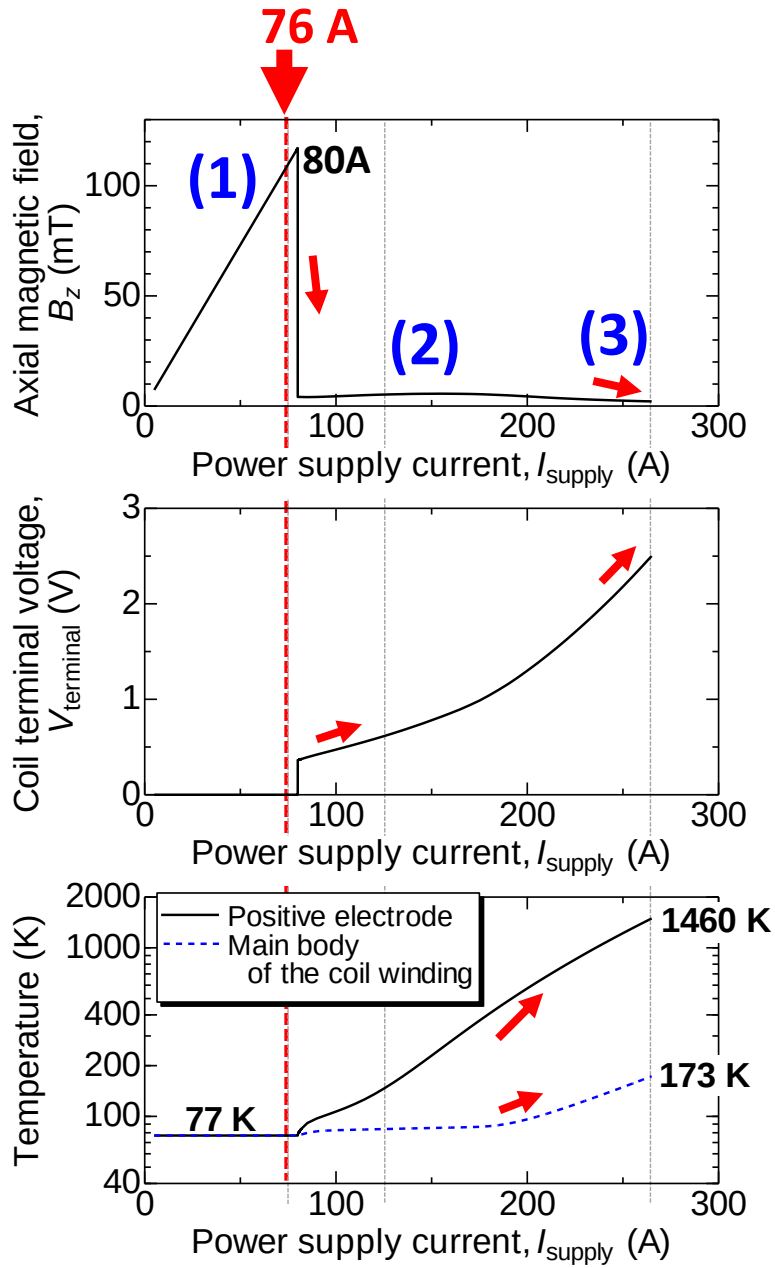


Process of current mode transition (simulation)

Magnetic field

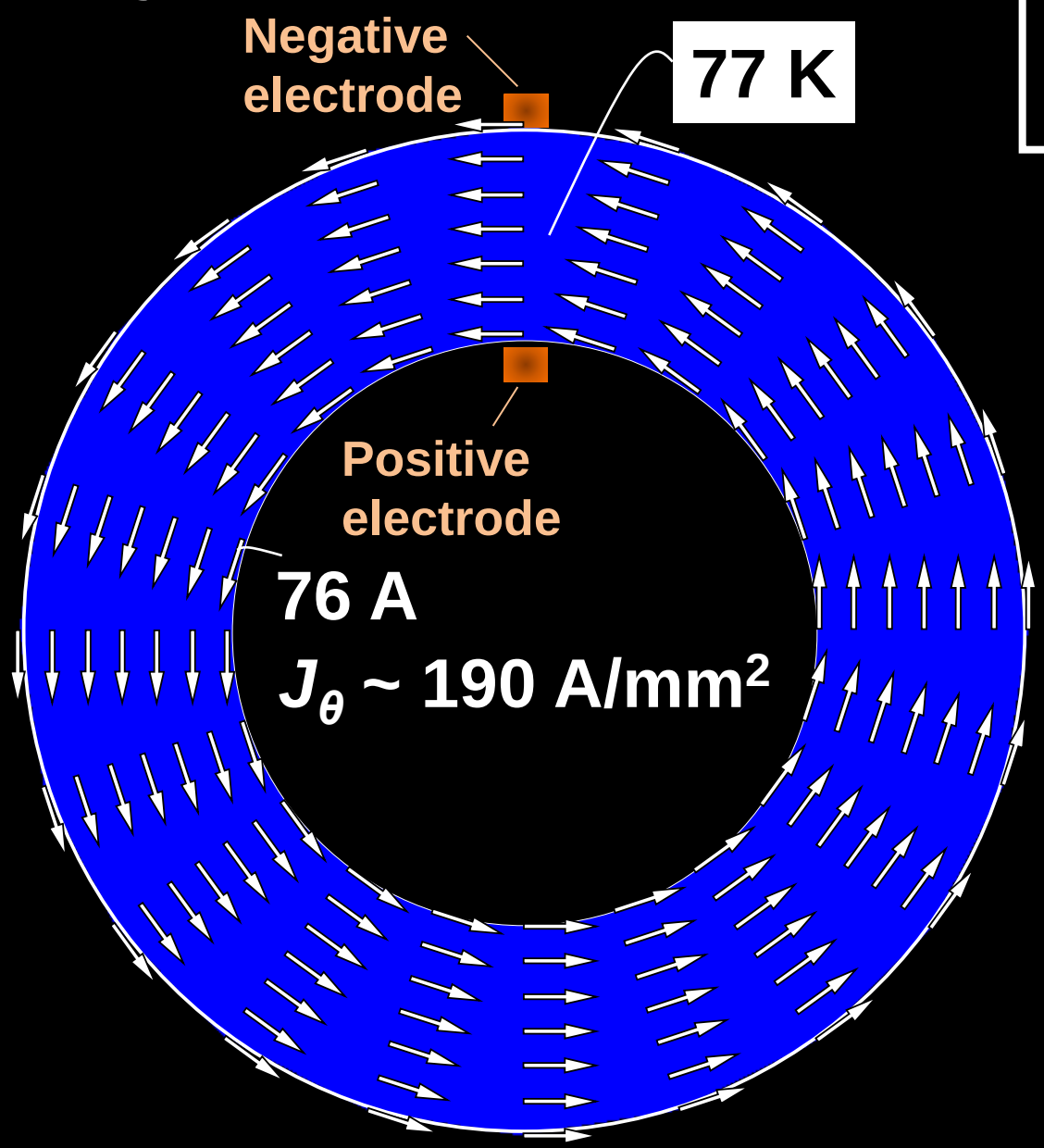
Coil voltage

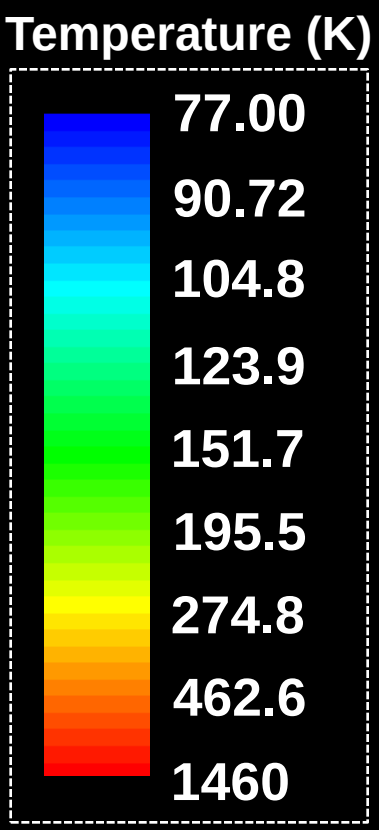
Coil temperature

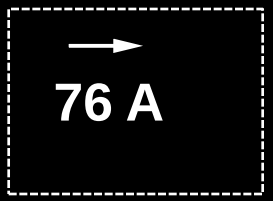


I_{supply}: 76A

"Multi-turn" mode





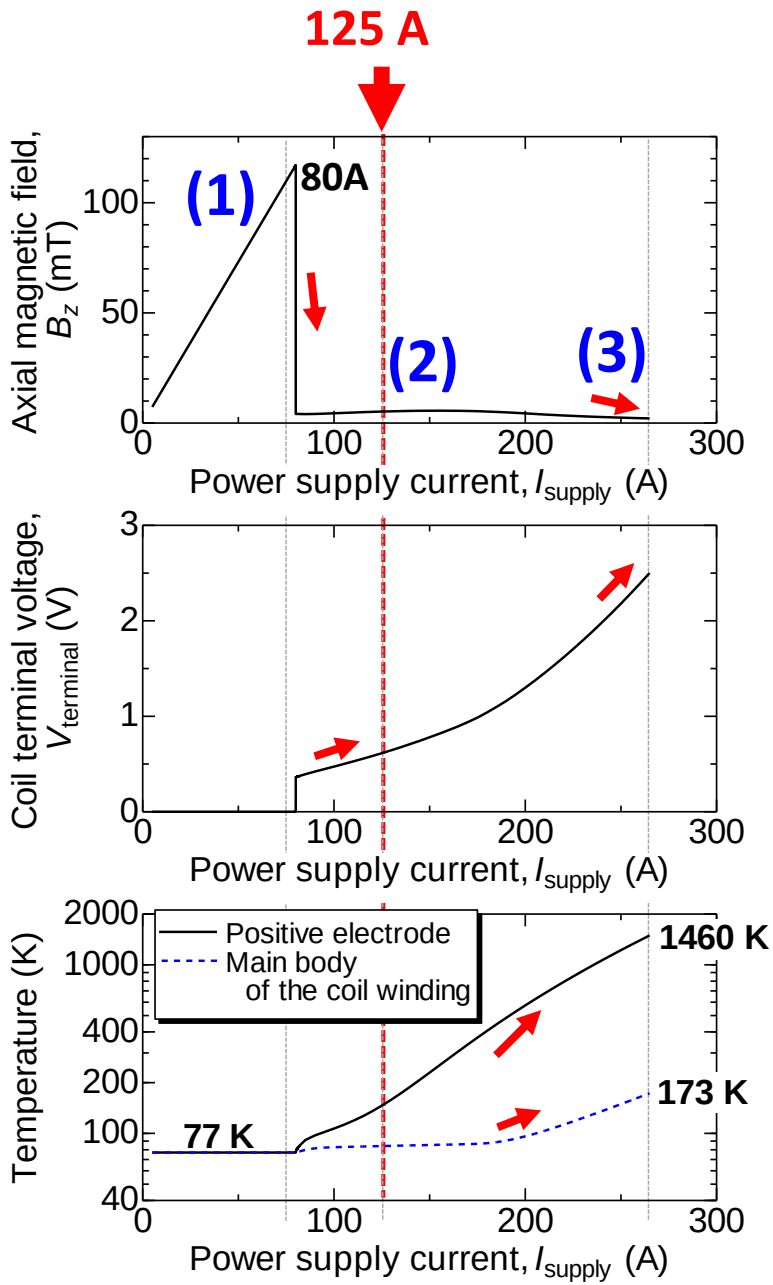


Process of current mode transition (simulation)

Magnetic field

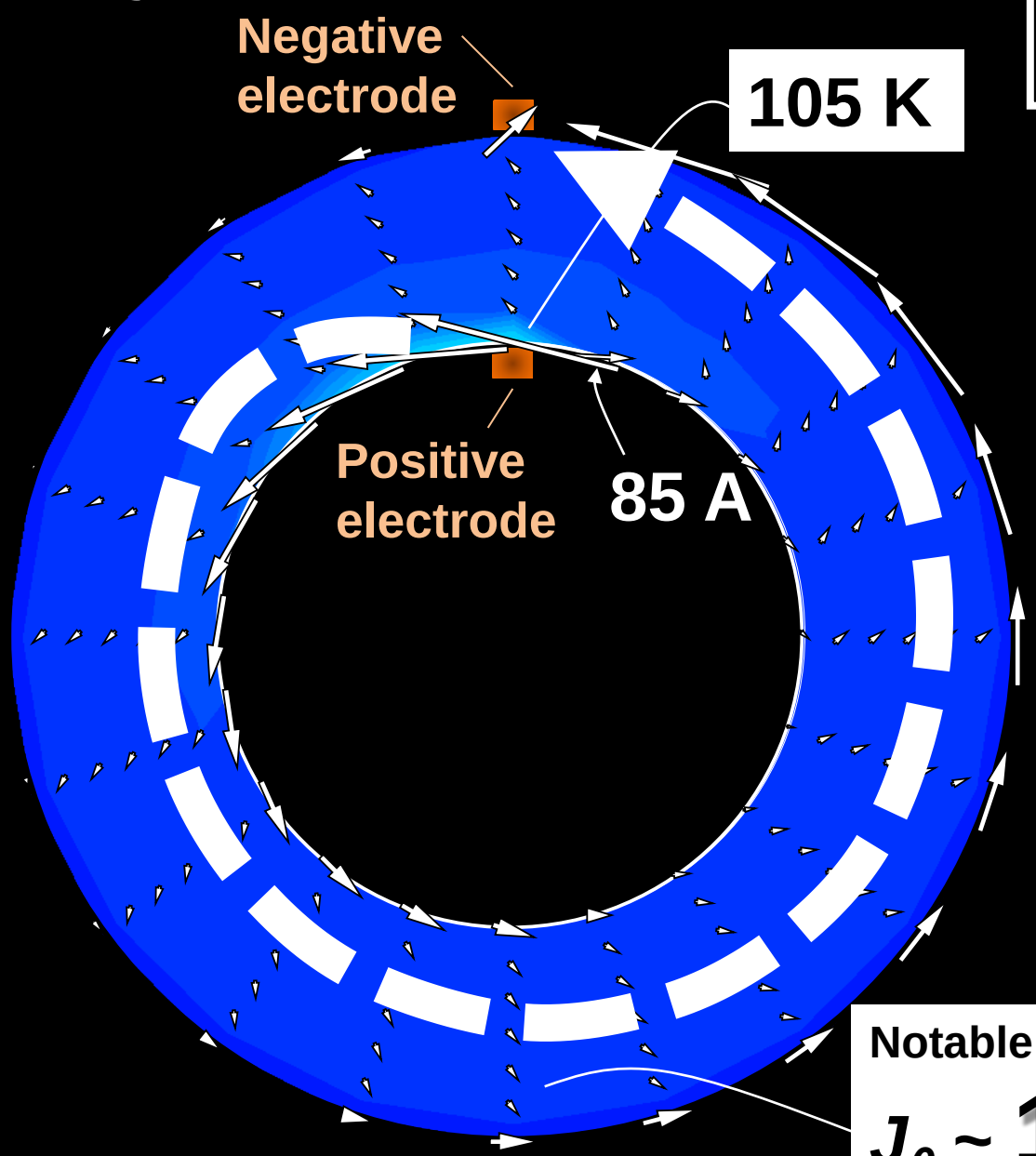
Coil voltage

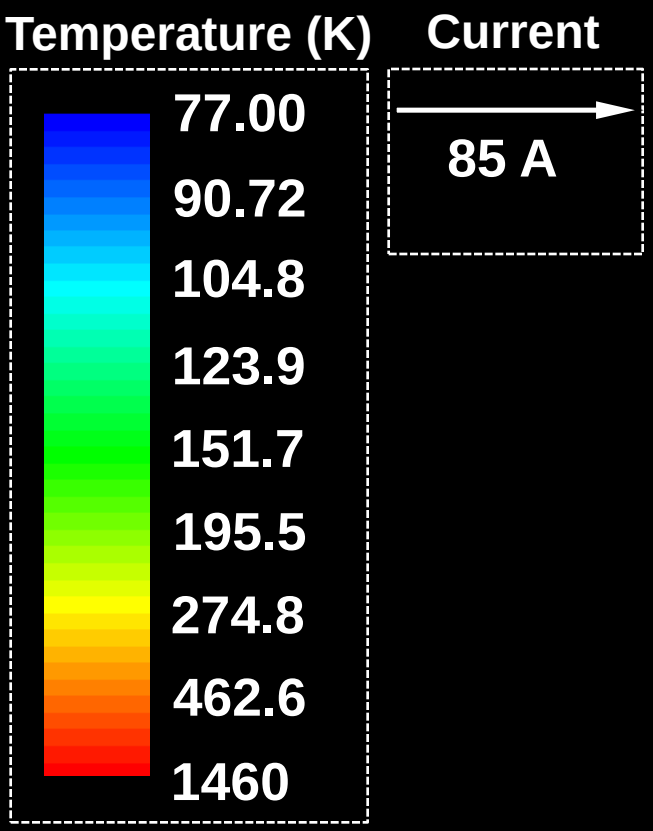
Coil temperature



“Single-turn” mode

I_{supply}: 125A





Notable reduction in current density

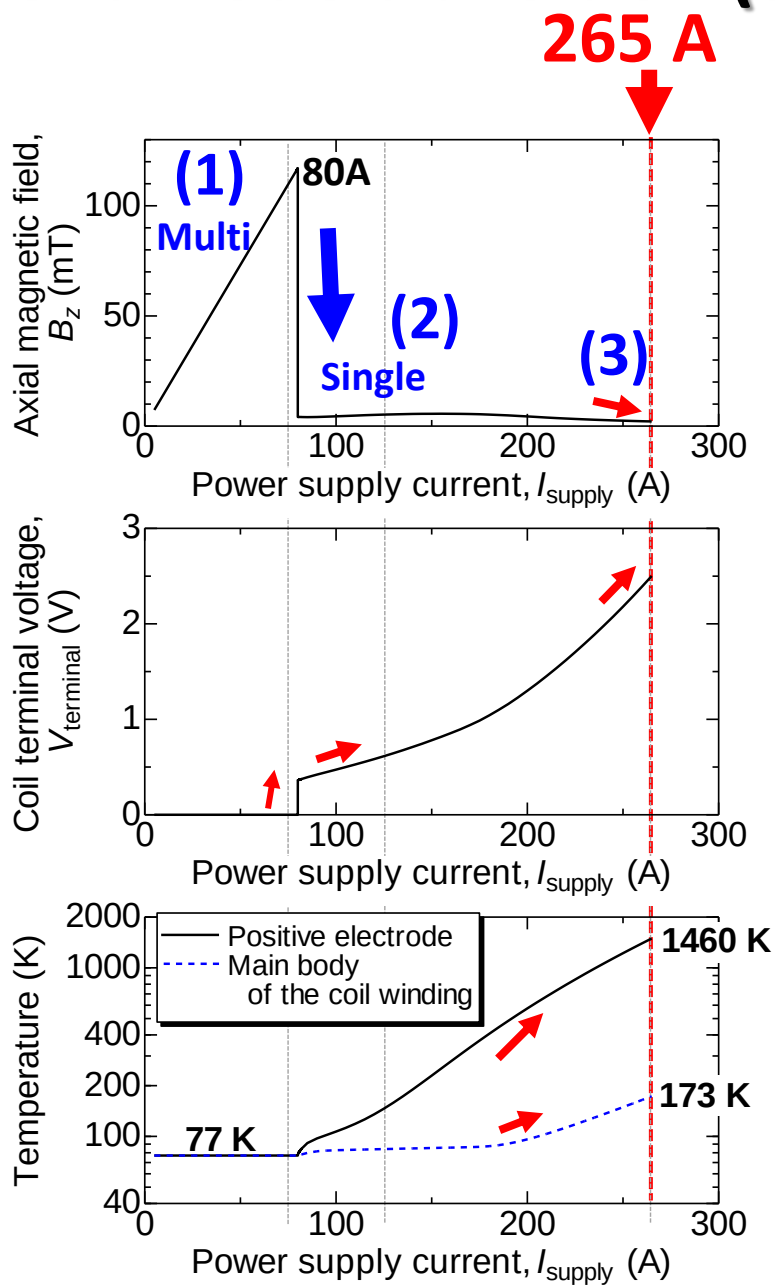
$J_\theta \sim 10.2$ A/mm^2

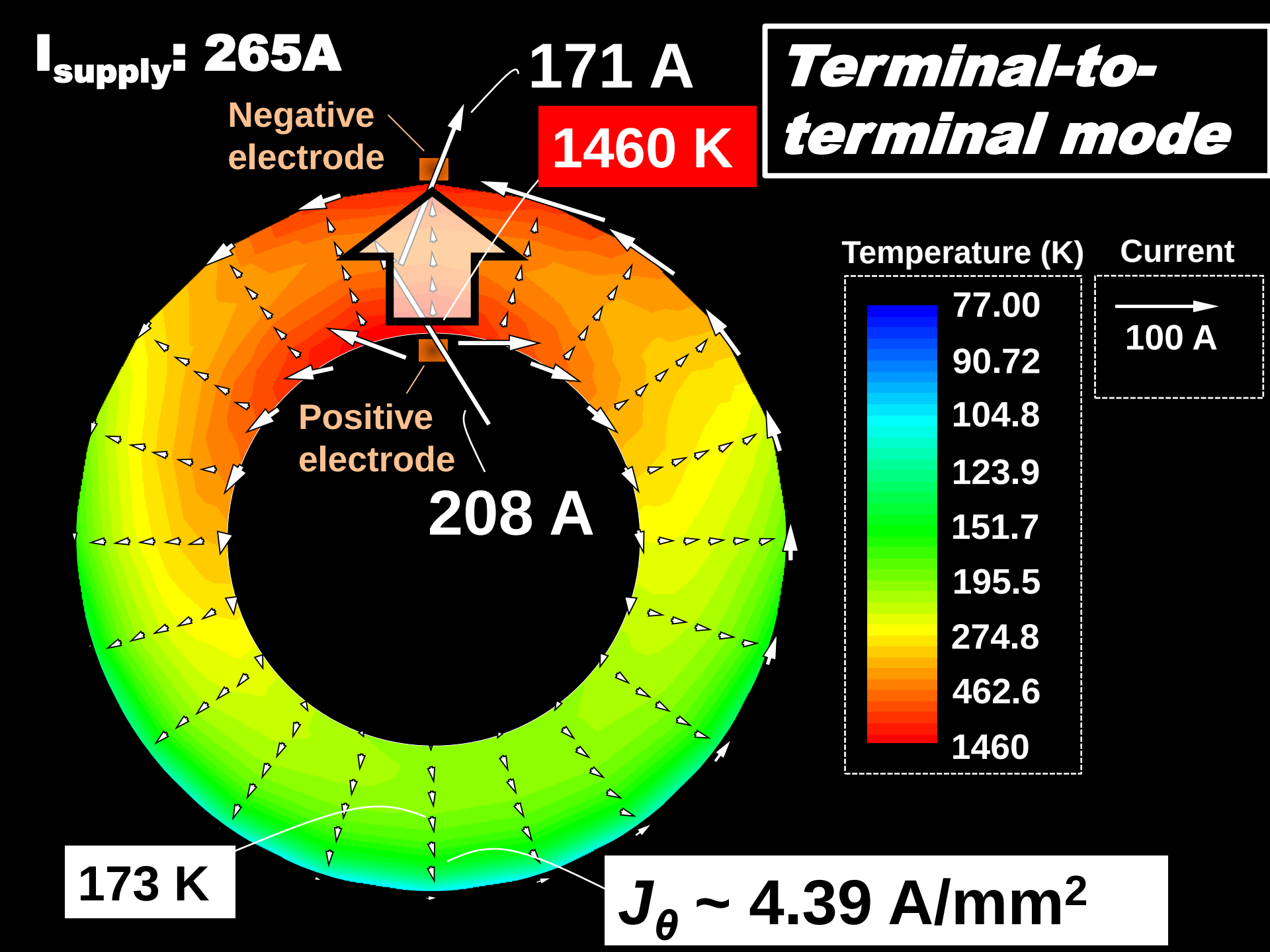
Process of current mode transition (simulation)

Magnetic field

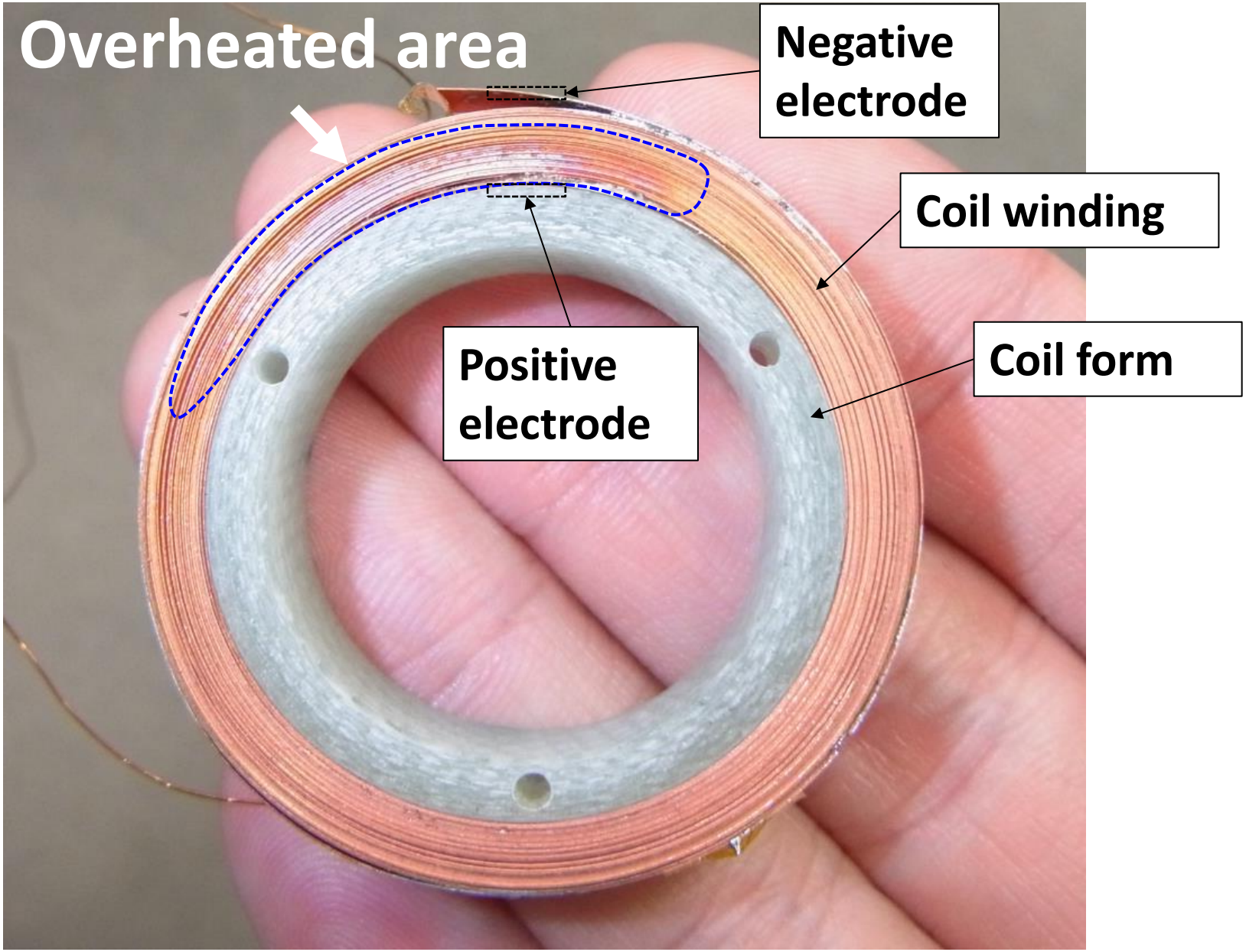
Coil voltage

Coil temperature




I_{supply}: 265A
171 A
Terminal-to-terminal mode
Negative electrode
1460 K
Temperature (K)
Current
77.00
90.72
104.8
123.9
151.7
195.5
274.8
462.6
1460
100 A
Positive electrode
208 A
173 K
J_θ ~ 4.39 A/mm^2

Over heating due to terminal-to-terminal mode (190A)



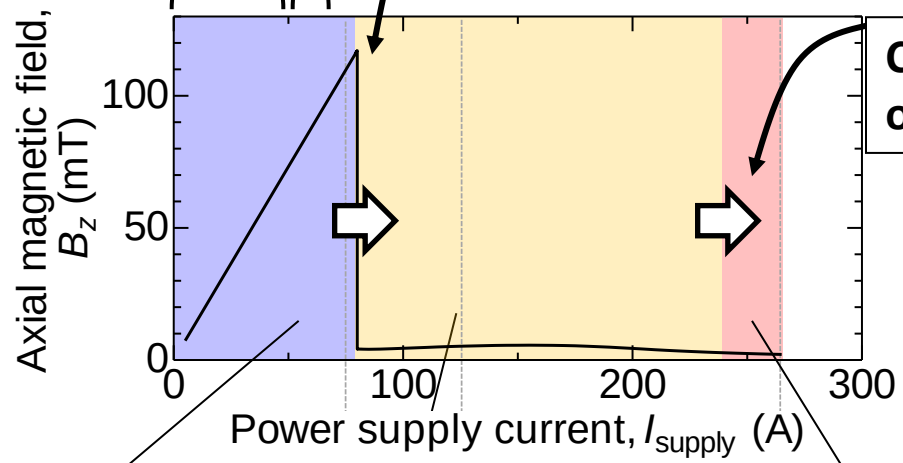
Operation of NI coil

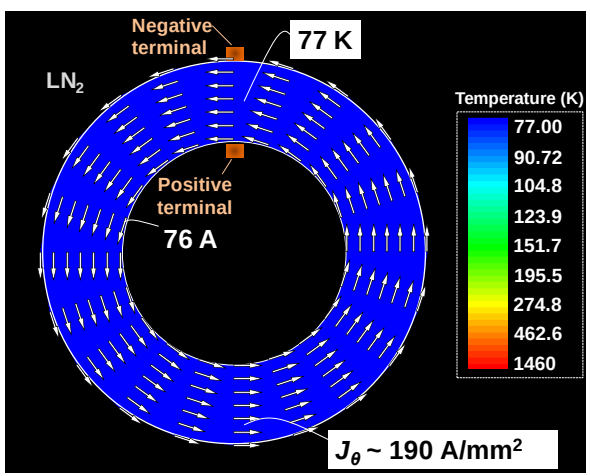
Margin

Normal operation below the critical current

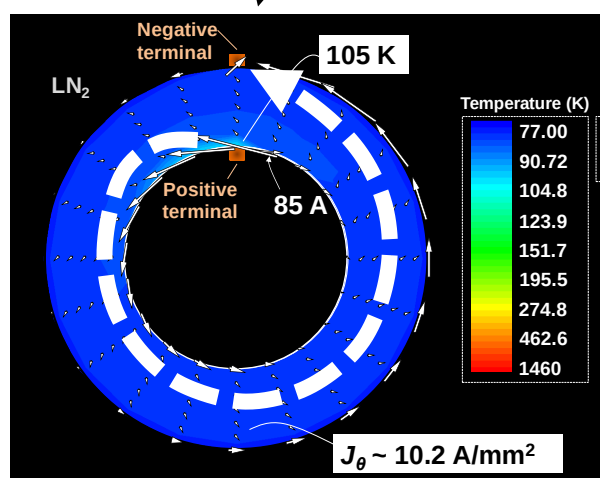
Self-healing from thermal runaway. Helium will be evaporated.

Catastrophic overheating

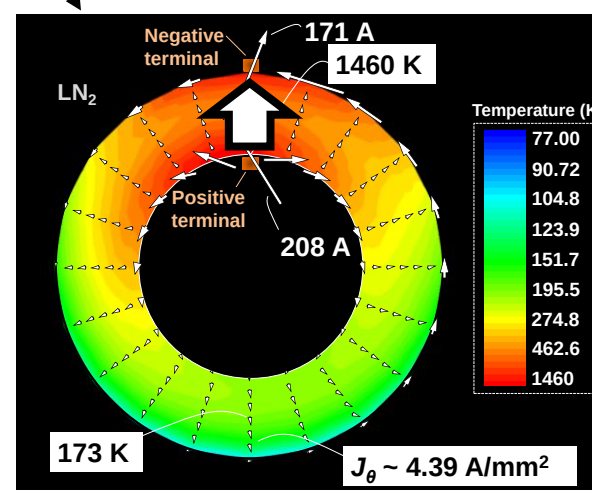




(I) Multi-turn

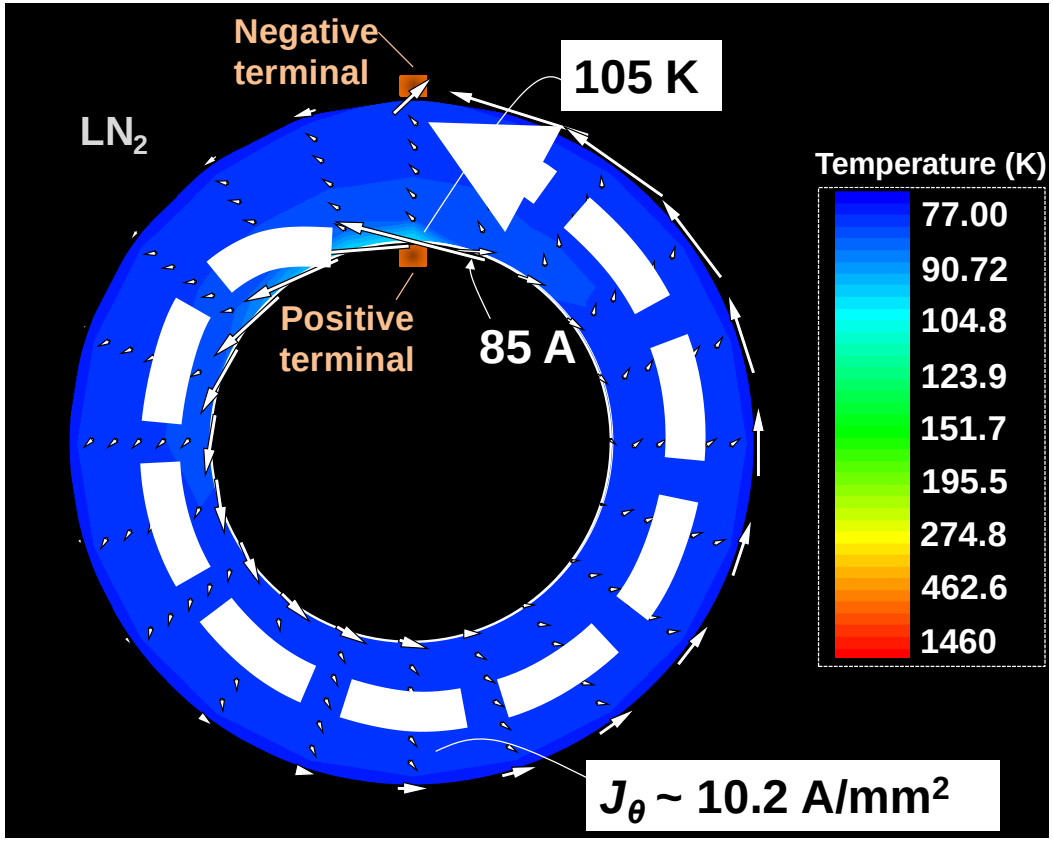


(II) Single-turn (Safe)



(III) Terminal-to-terminal (Hazardous)

“Single-turn ”mode lower current density



Reduction of current density

↓

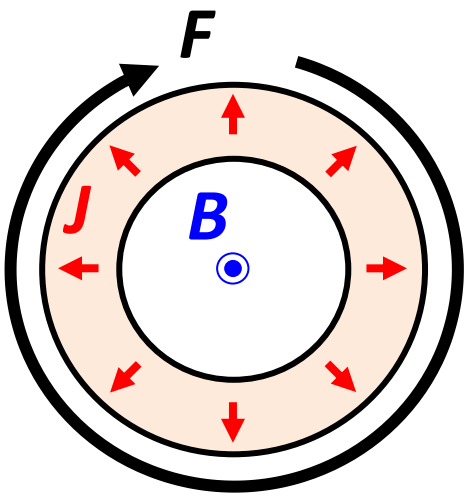
Reduction of heat

↓

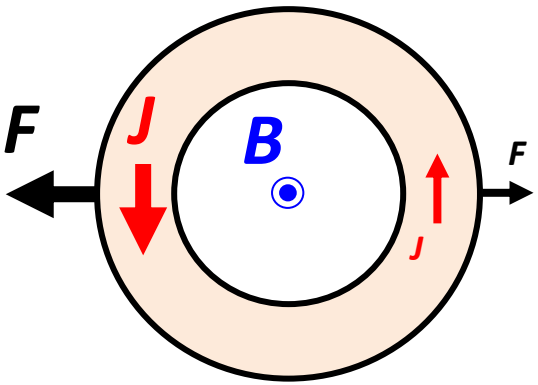
Thermal runaway is self-healed

Problem: Unbalanced electromagnetic force

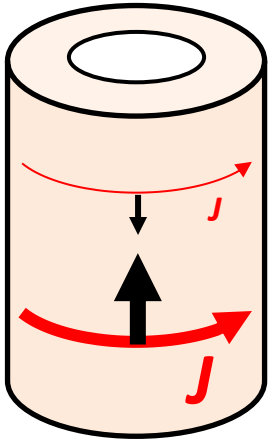
Radial current can cause unbalanced electromagnetic force.



Rotating force



Transverse unbalanced force



Axial unbalanced force

Unbalanced electromagnetic force can damage coils.

Summary

1.NI coils have 3 current mode phase.

(I) Multi-turn (II) Single-turn (III) Terminal-to-terminal

2.”Single-turn” mode transition lower the current density, thermal runaway is self-healed.

→This is the mechanism of NI coils.

3.There is a problem of unbalanced electromagnetic force, which can damage coils.

Thank you for your attention.