HFM

High Field Magnets Programme

Training at 1.9 K and 4.5 K: a conditioning phenomenon?

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With data from many other colleagues
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https://indico.cern.ch/event/1395888/

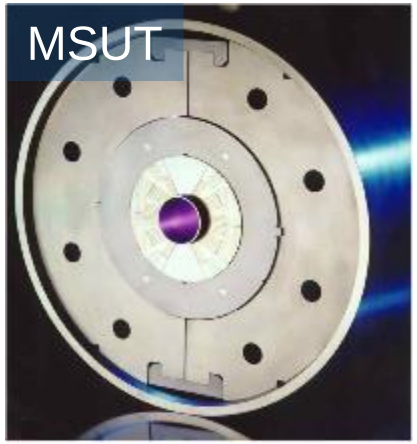
Foreword

- Often a (LTS, accelerator) magnet training is done at 1.9 or 4.5 K. In a few cases, training was done at both temperatures.
- My goal is to analyze these few cases and try to conclude regarding a possible "faster training" at 1.9 K, even for magnets meant to be operated at 4.5 K

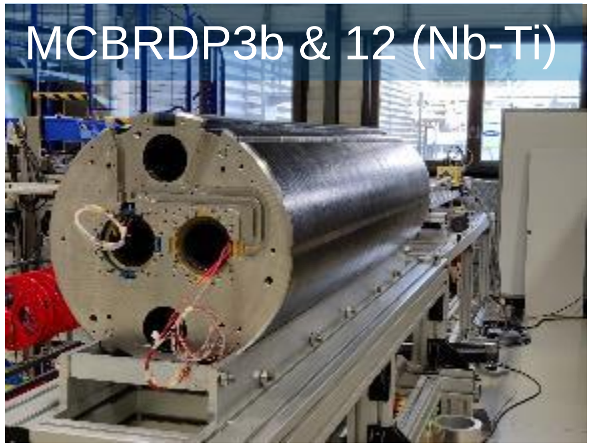
- Please note that I did not test most of these magnets, and where possible I put references to presentations, reports or publications.

Magnets in this presentation

Nb_3Sn quadrupole
cos-θ
bladders and keys

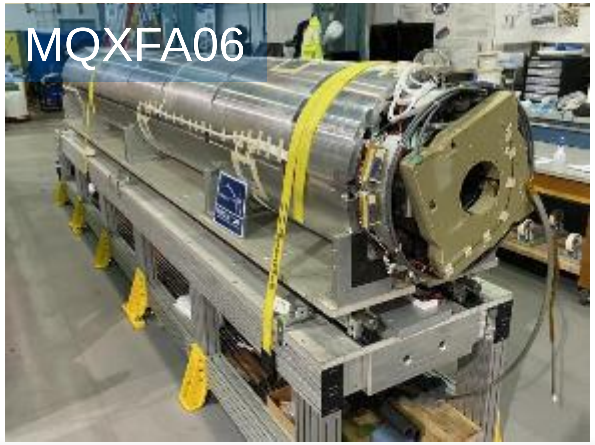


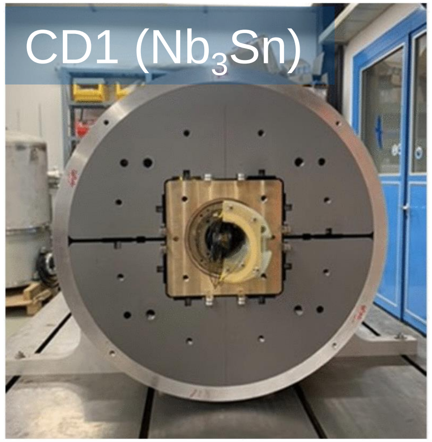
Nb_3Sn dipole
cos-θ
collared coils



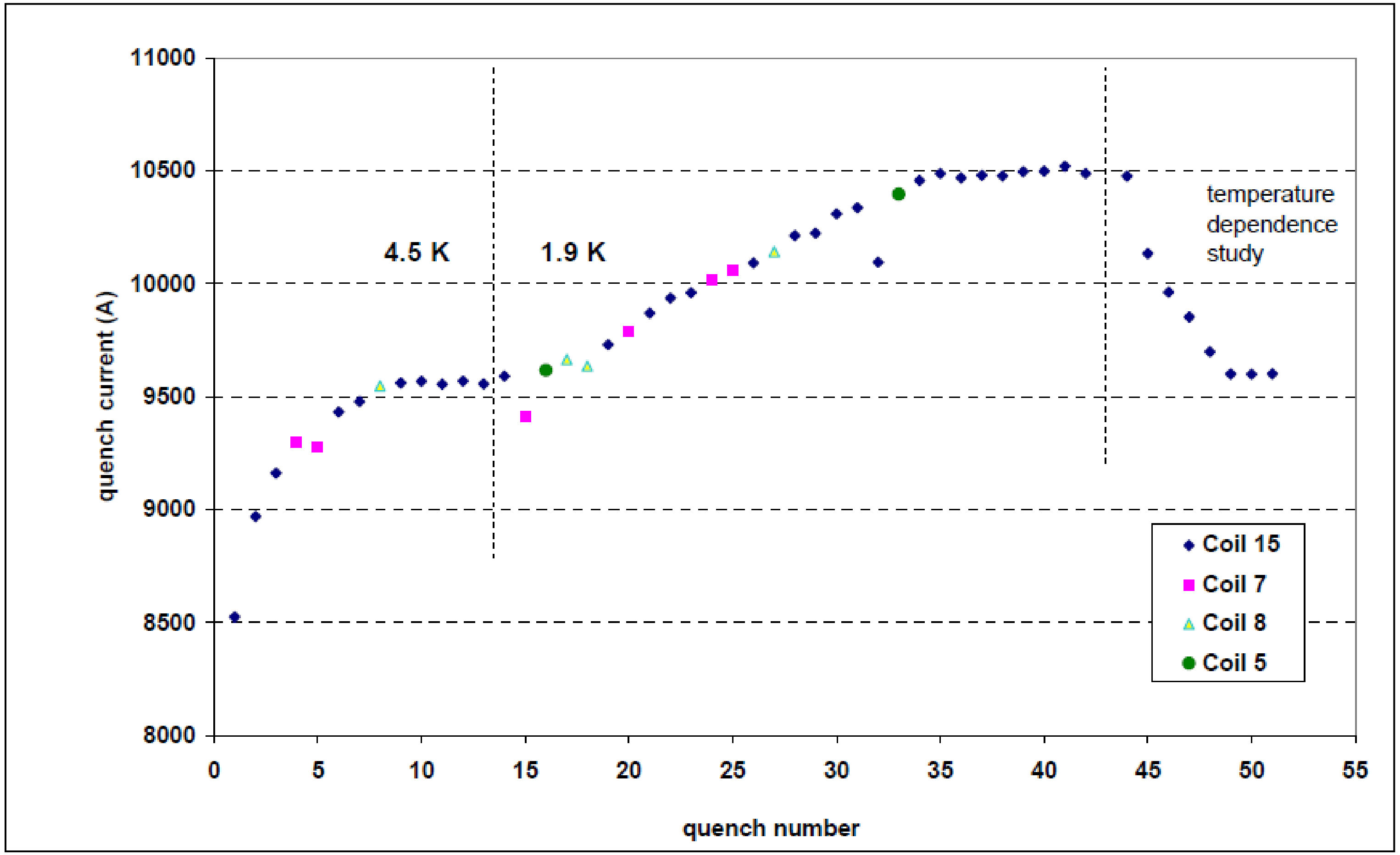
dipole
canted cos-θ

Nb_3Sn dipole
block coils
bladders and keys



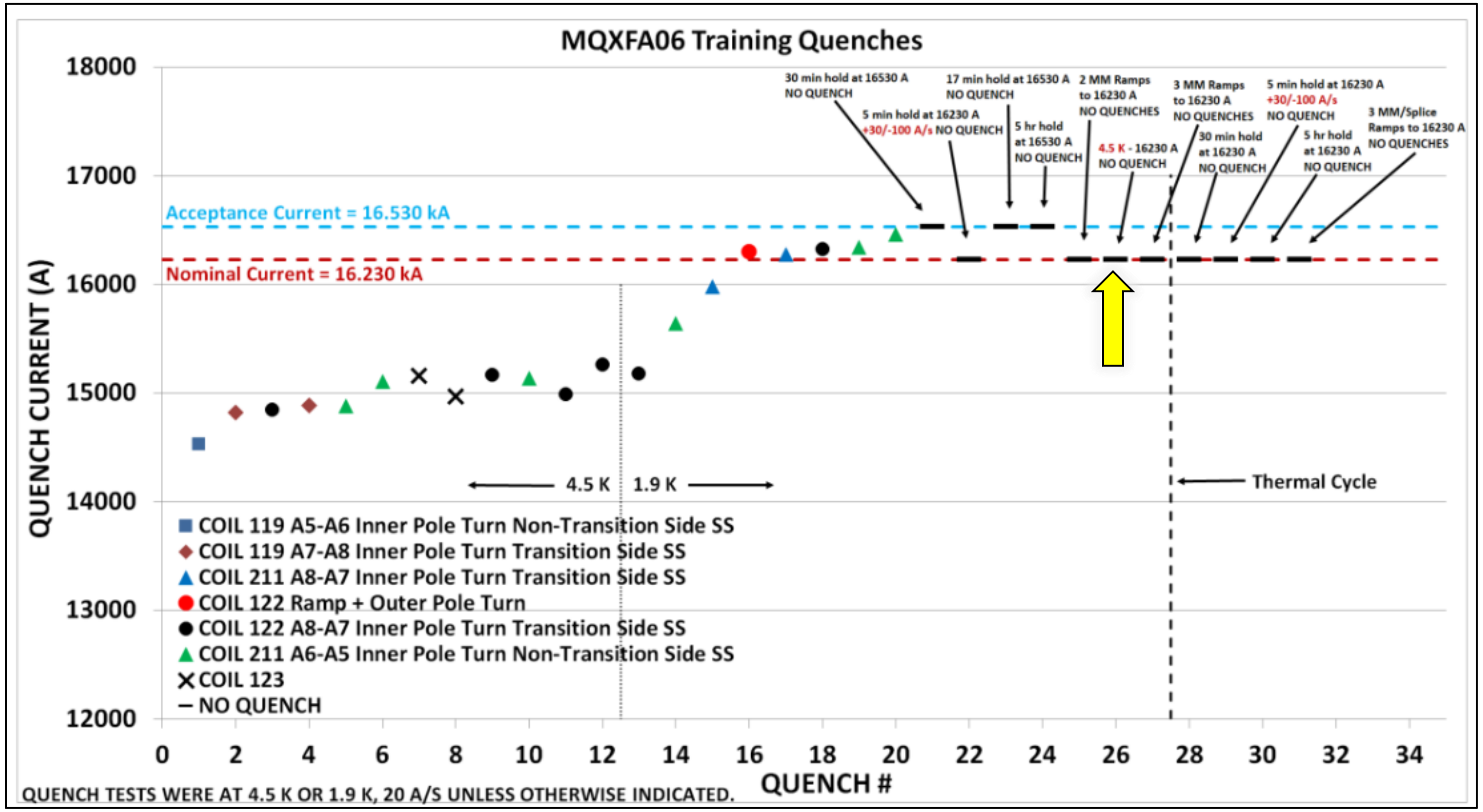


TQS01c



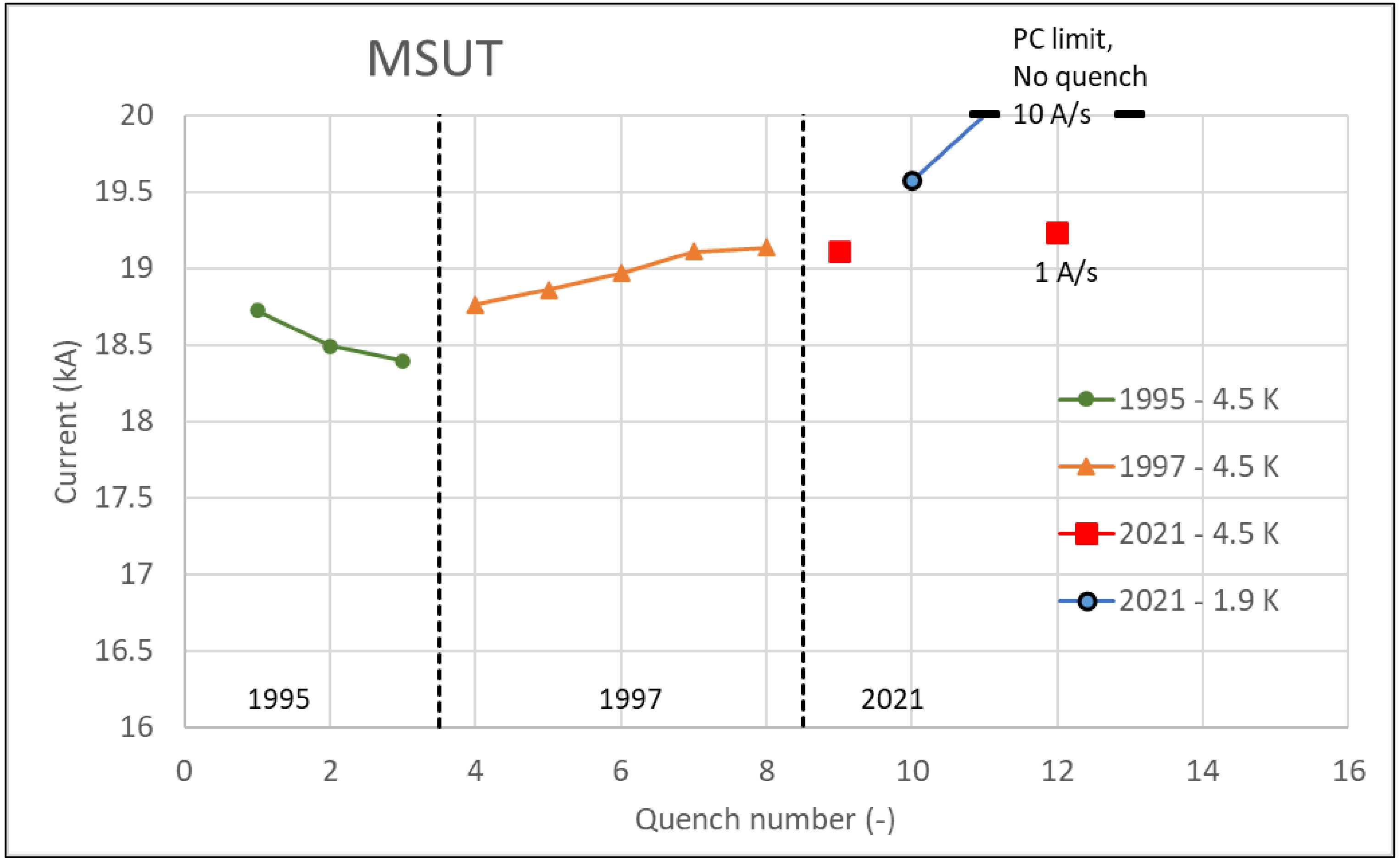
Training at 4.5 and 1.9 K have a similar slope.
Higher current reached at 1.9 K does not influence the quench current at 4.5 K (last three points).

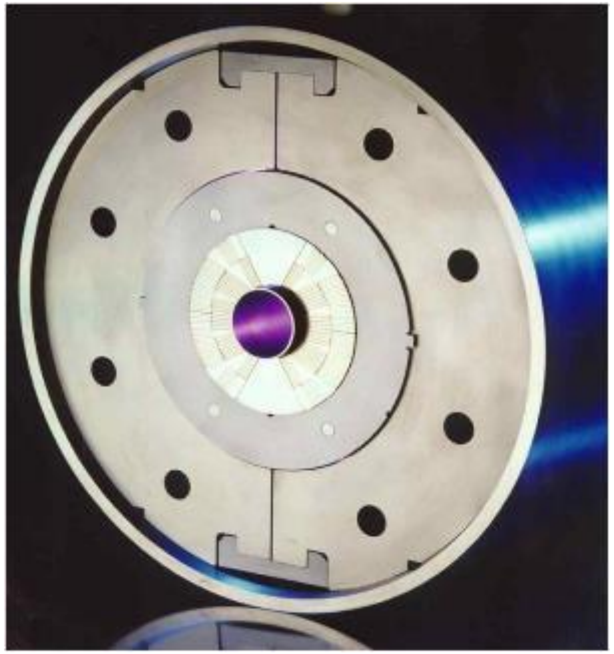
MQXFA06



Training at 4.5 K very slow, compared to 1.9 K.
After training at 1.9 K, 16.23 kA reached at 4.5 K (yellow arrow).

MSUT

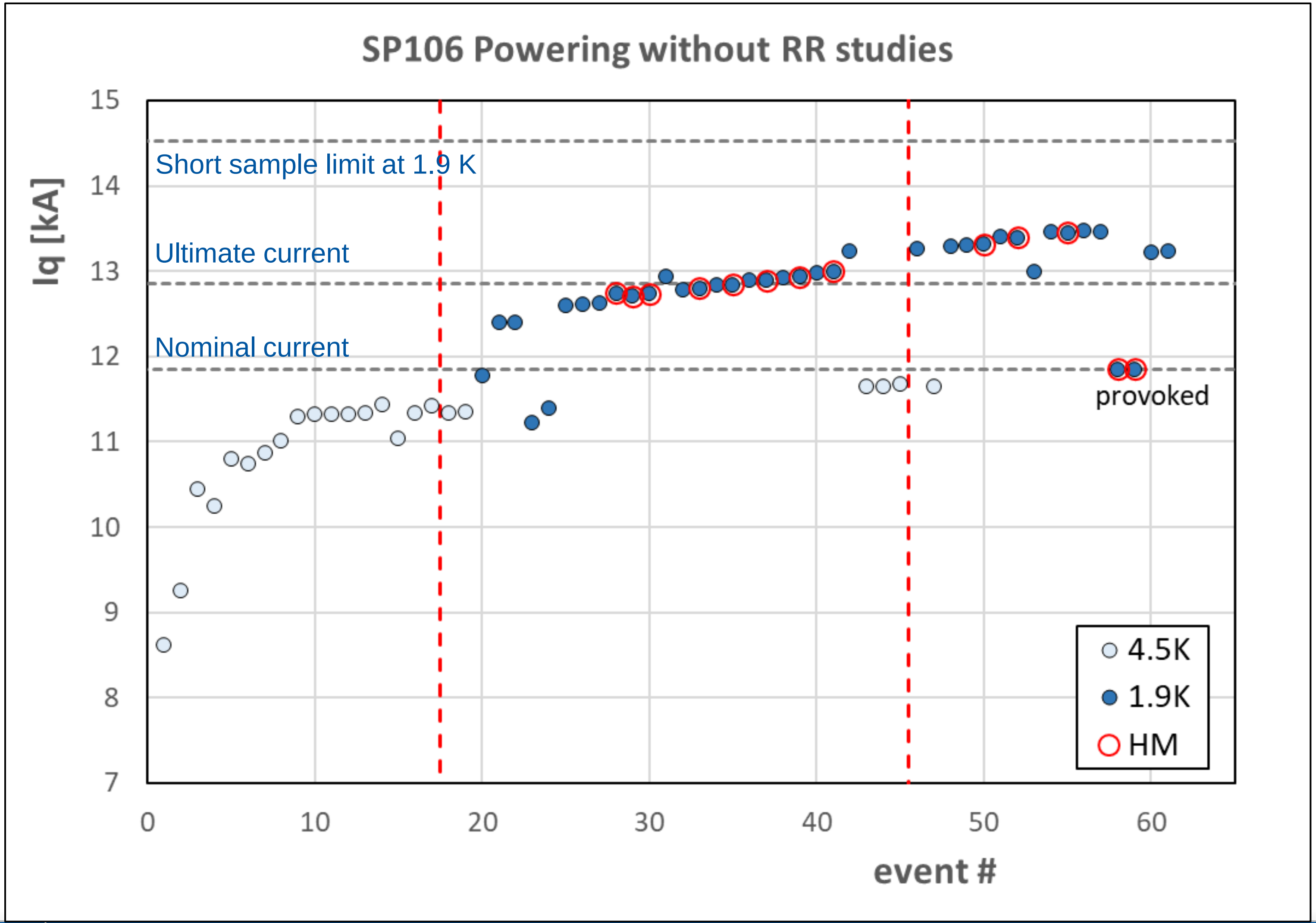




Training at 4.5 K perhaps slower than at 1.9 K. However, reaching higher current at 1.9 K does not change the 4.5 K behavior.

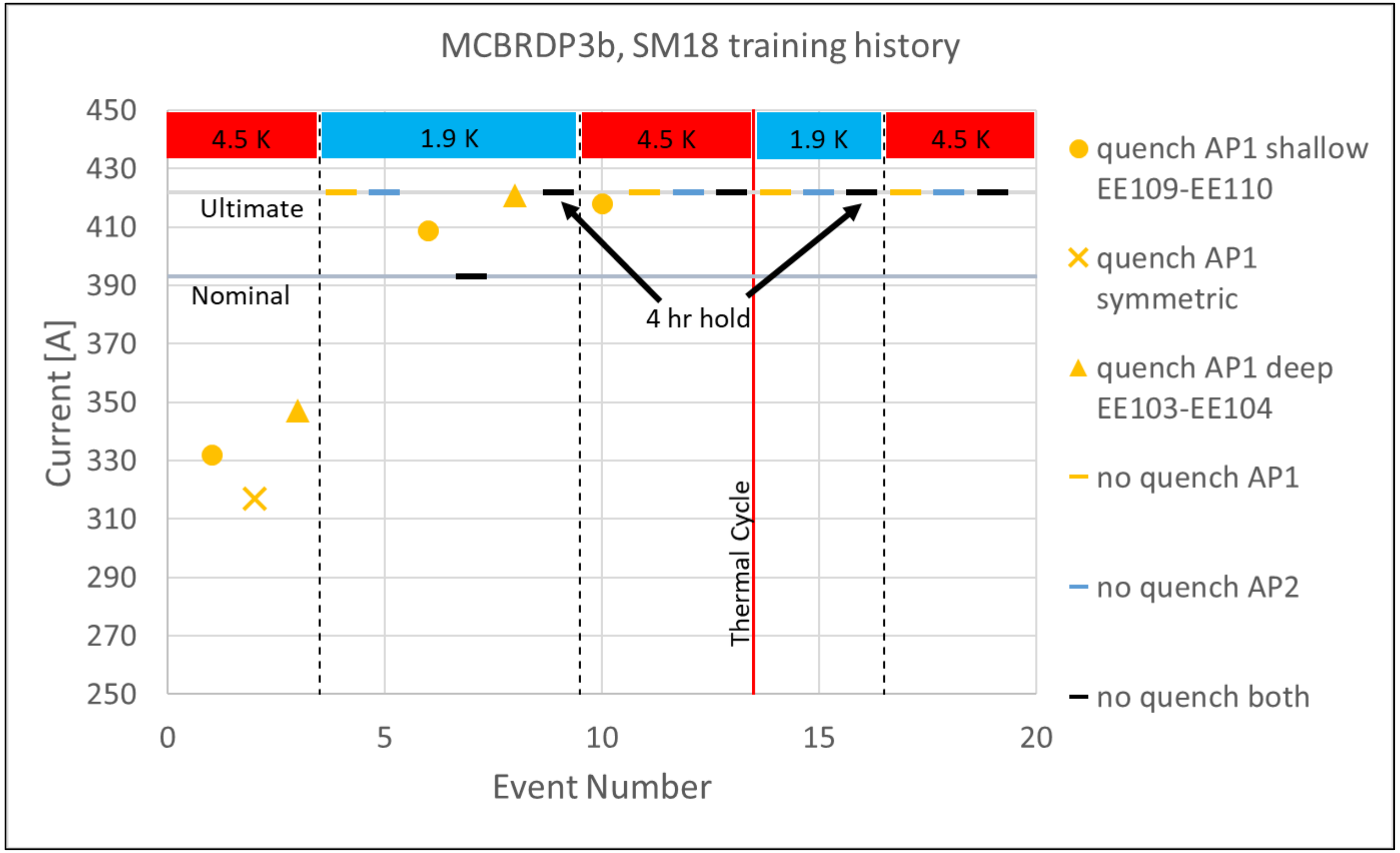
Side note: perfect training memory after 24 years of storage (!).

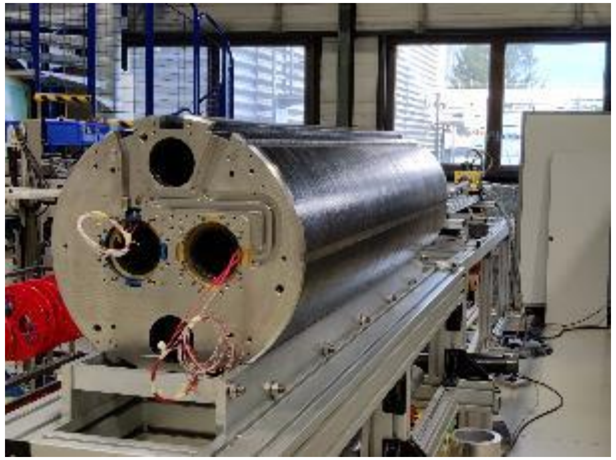
MBHSP106



After quench 9, training rate at 4.5 K much slower than at 1.9 K.
Training to higher current improves a little bit the 4.5 K performance.

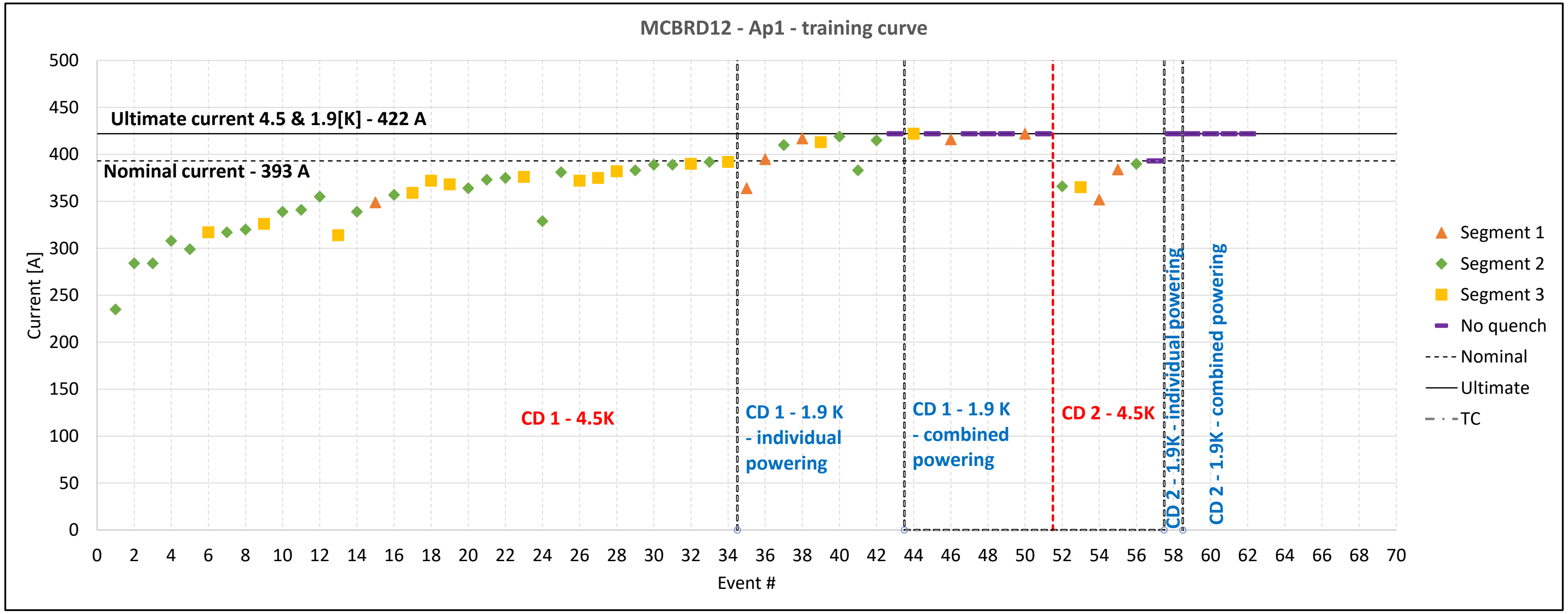
MCBRDP3b

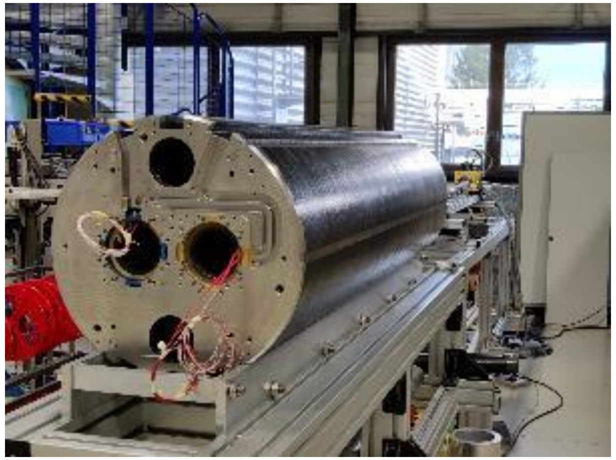




In AP1, training at 1.9 K accelerated the training at 4.5 K.
AP2 was trained in another assembly before at 1.9 K.

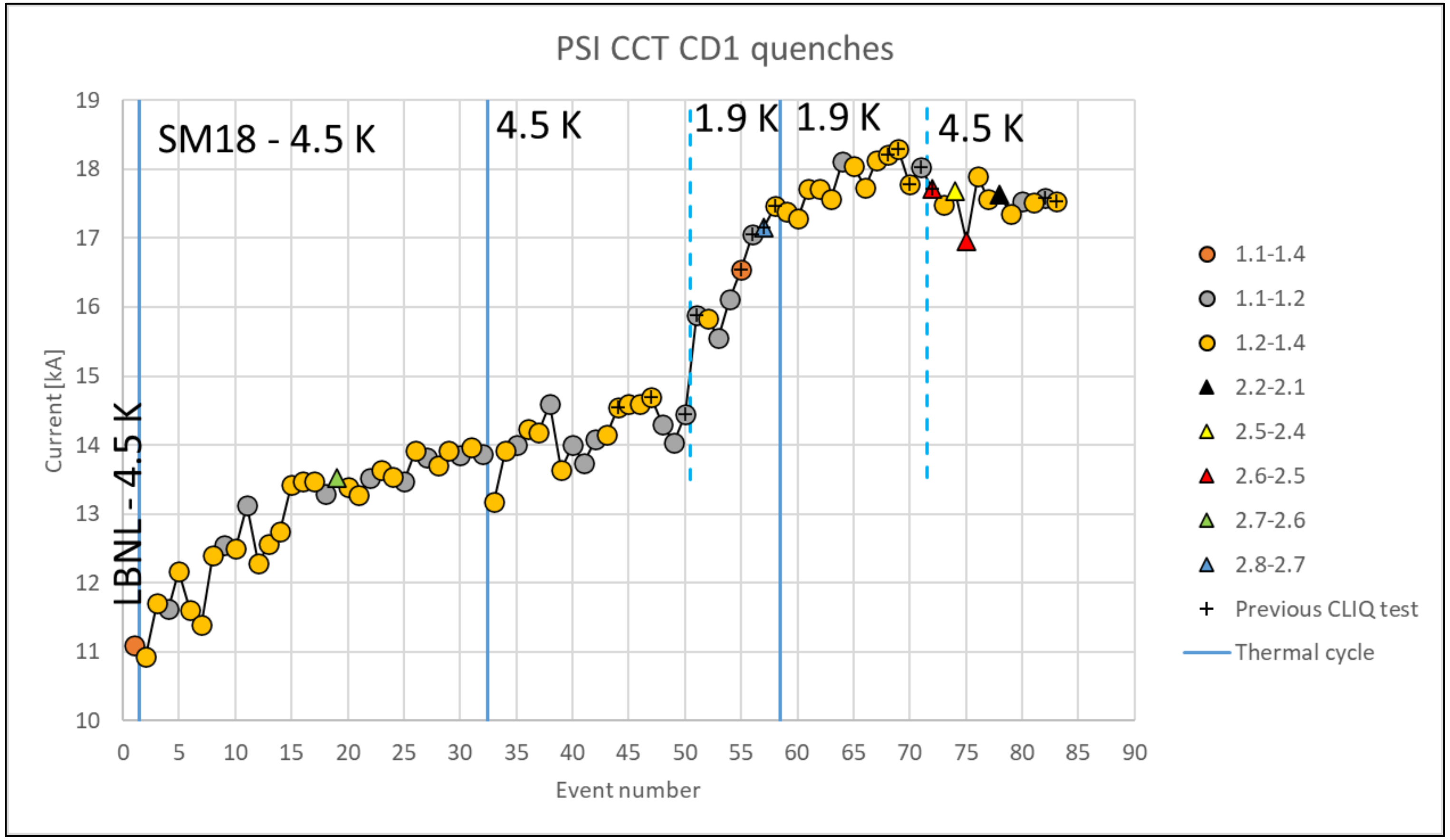
MCBRD12





Training at 4.5 K rather slow, at 1.9 K a bit faster, however the training at 1.9 K to higher current seems to be partially lost after the thermal cycle and back at 4.5 K.

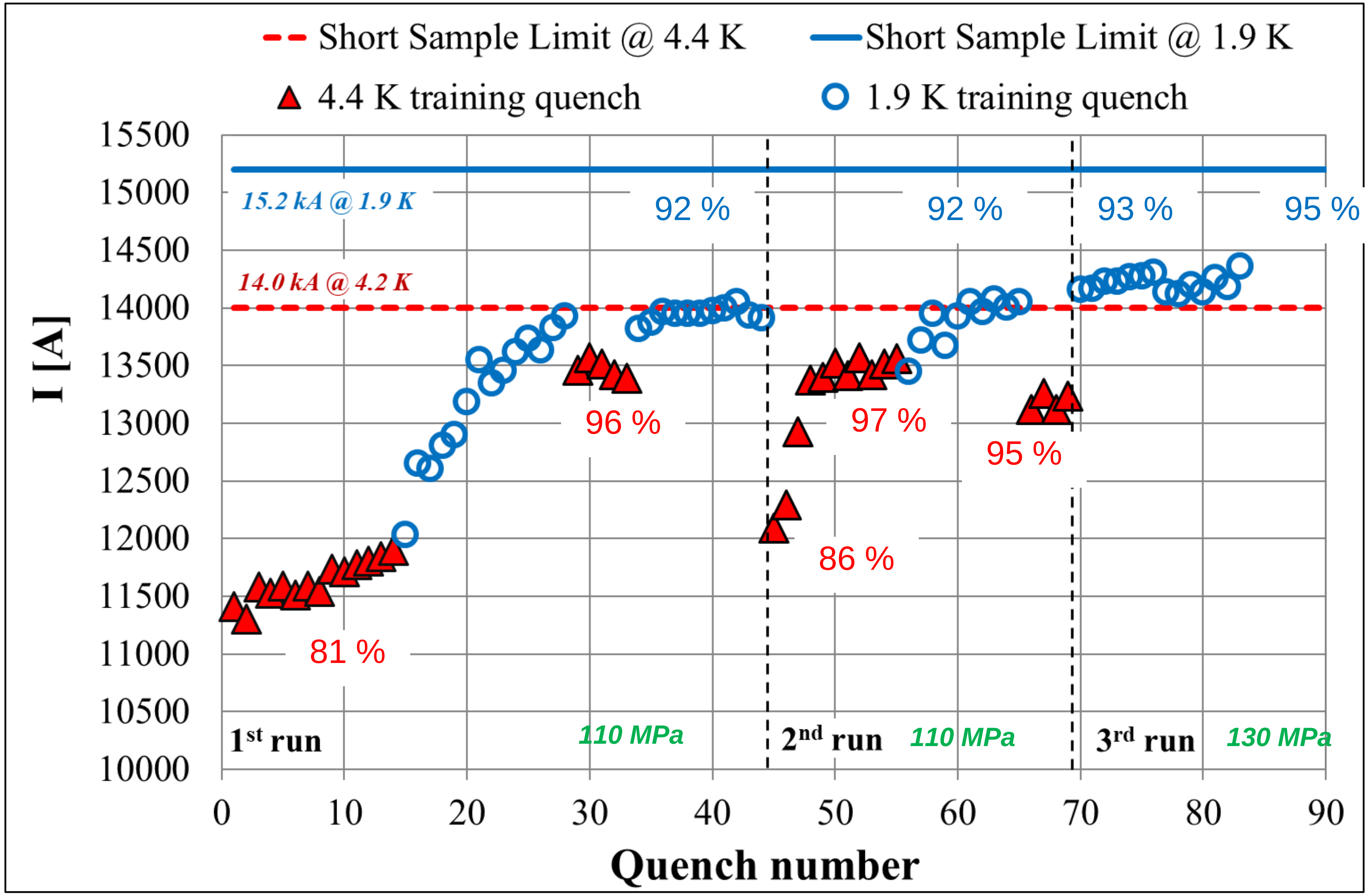
CD1



Training at 1.9 K “pushed” the magnet to a significantly higher current quench level, also at 4.5 K.

Side note: “CLIQ training” of extra ~2.5 kA did not seem to help training in this magnet.

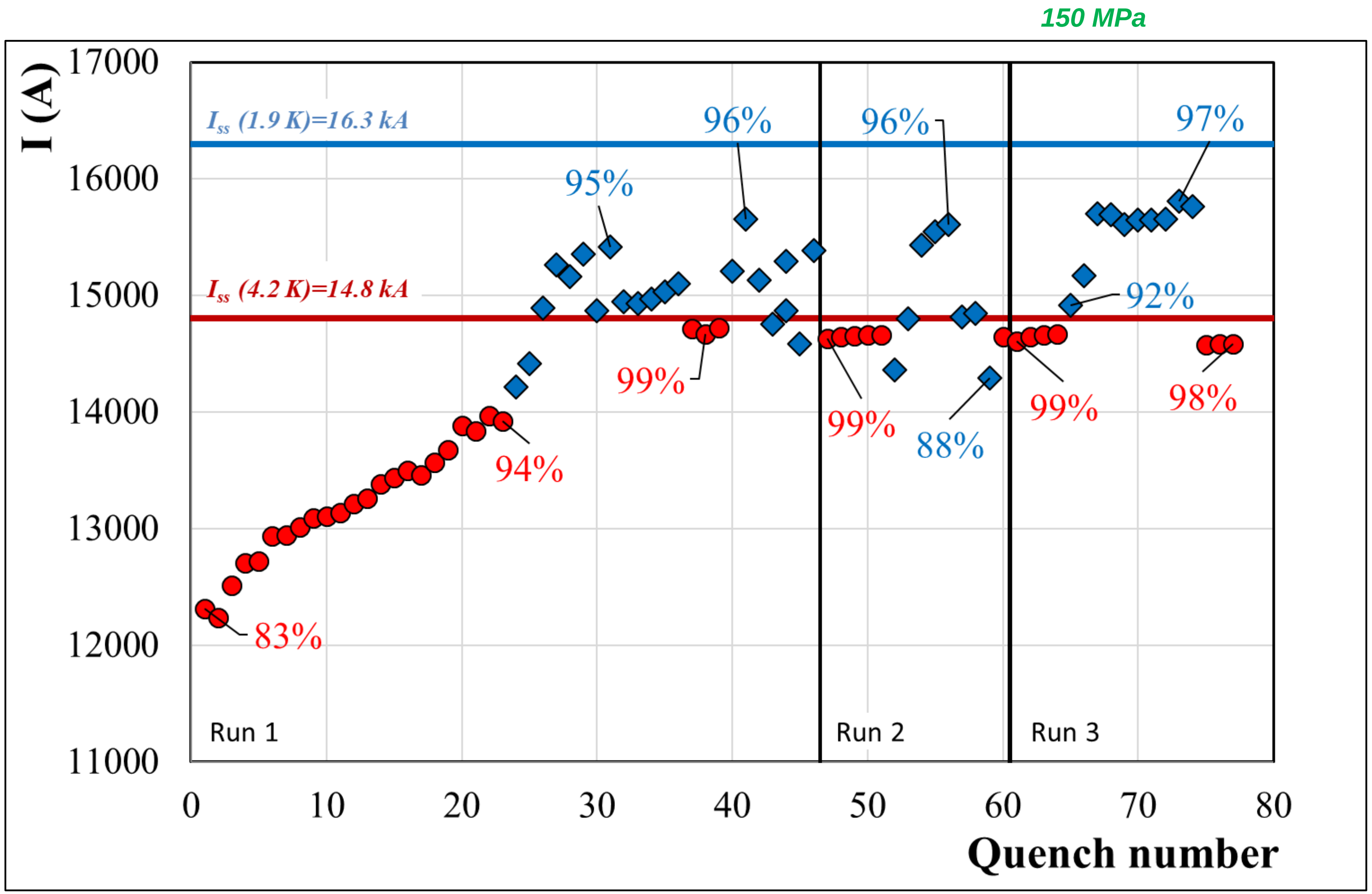
SMC 3a



In the first run, training at 1.9 K is faster than at 4.5 K and pushes the performance at 4.5 K higher.

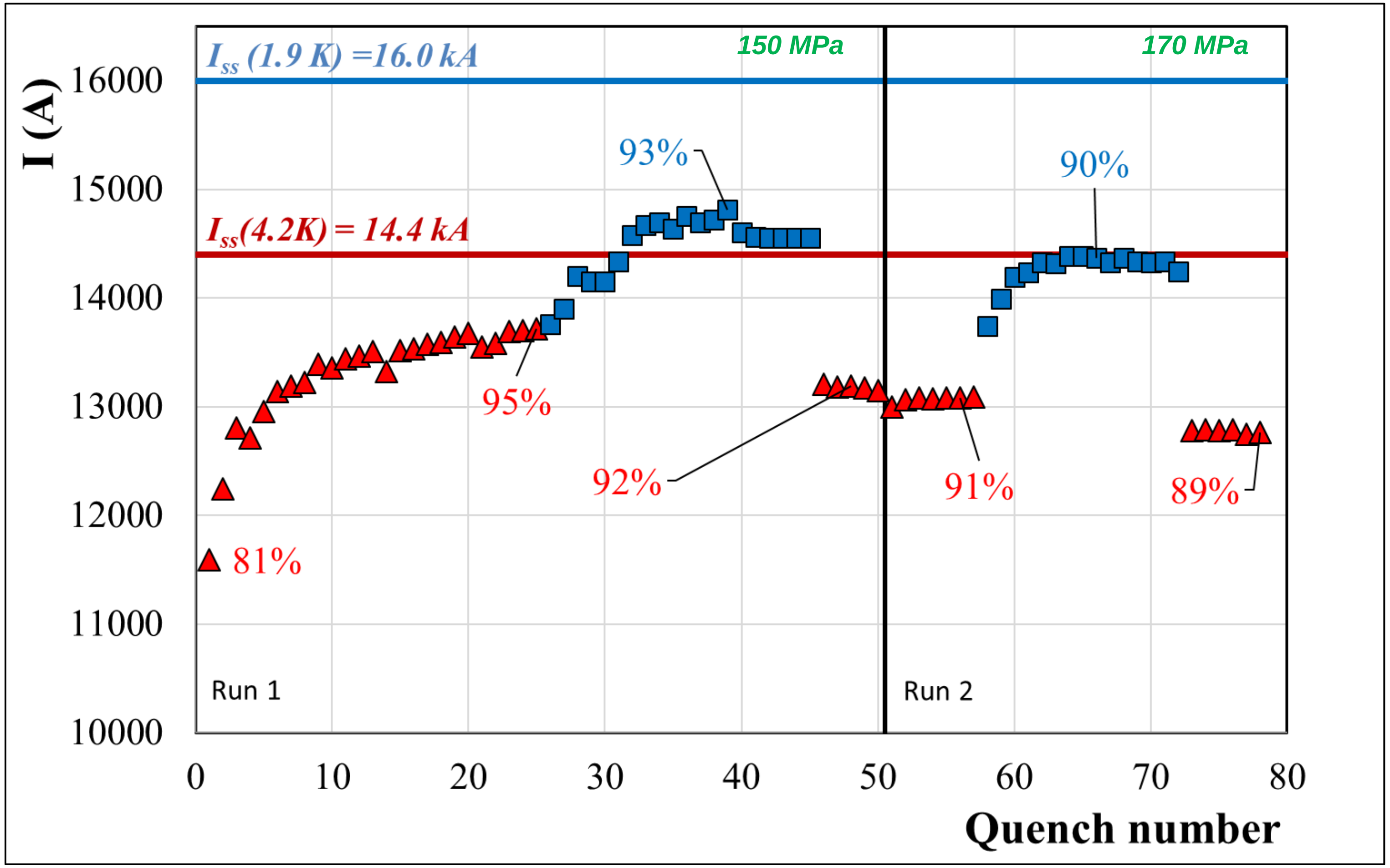
In the second run, training at 1.9 K degrades the performance at 4.5 K.

SMC 11T 03



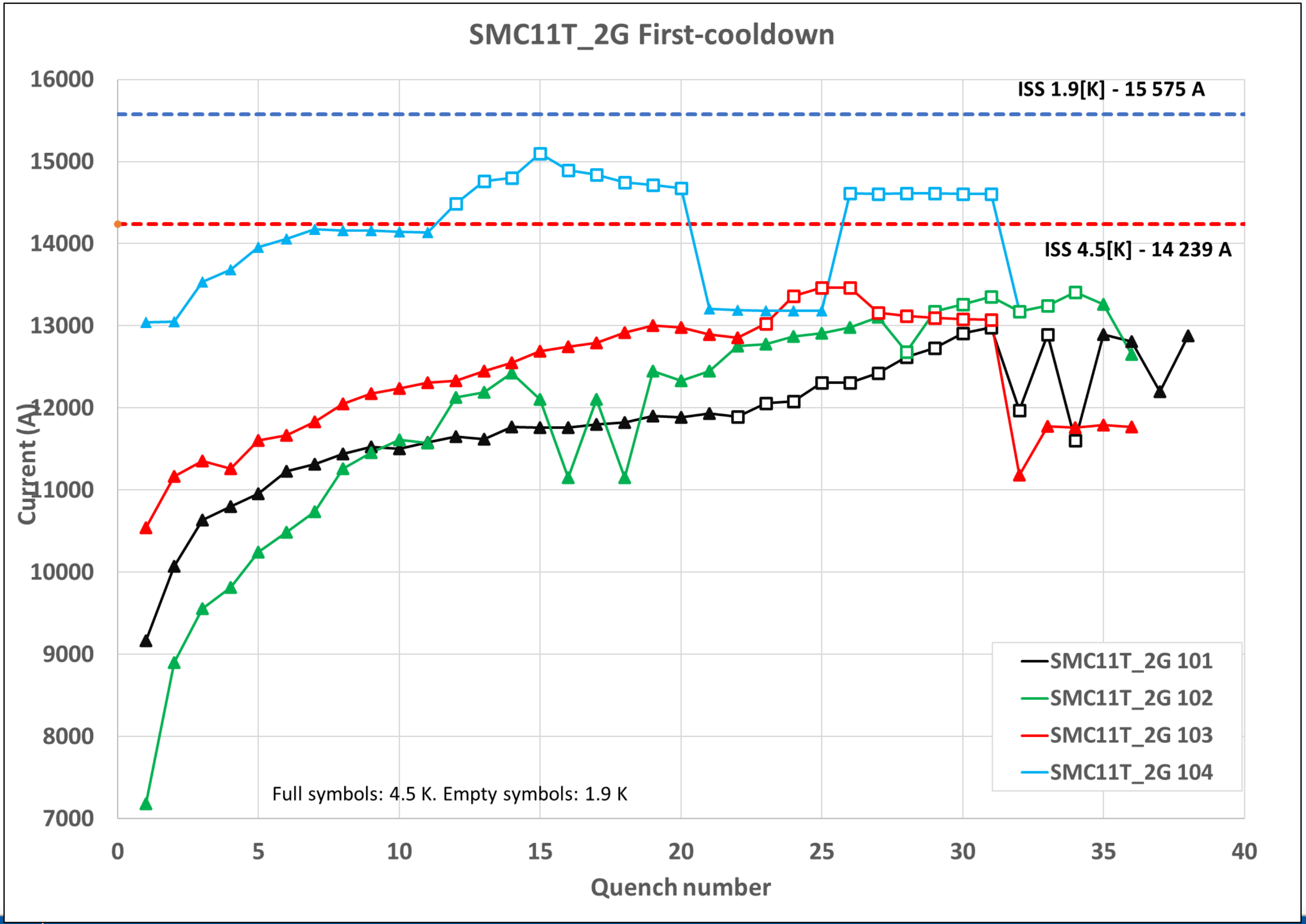
Training at 1.9 K improves the performance at 4.5 K, with no significant side-effects (at 4.5 K).

SMC 11T 04



Training at 1.9 K is faster than at 4.5 K, but the performance at 4.5 K is degraded.

SMC11T_2G

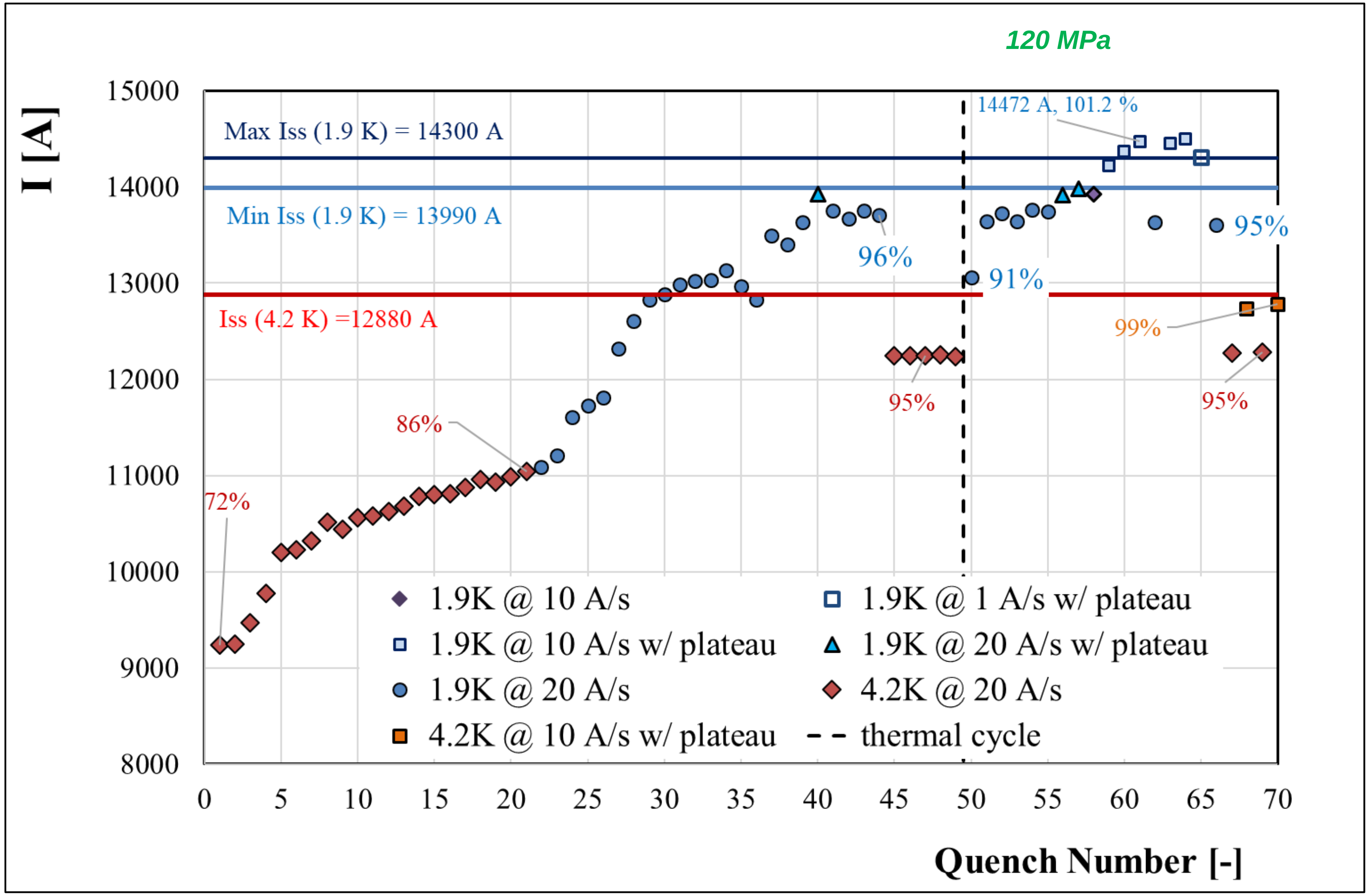


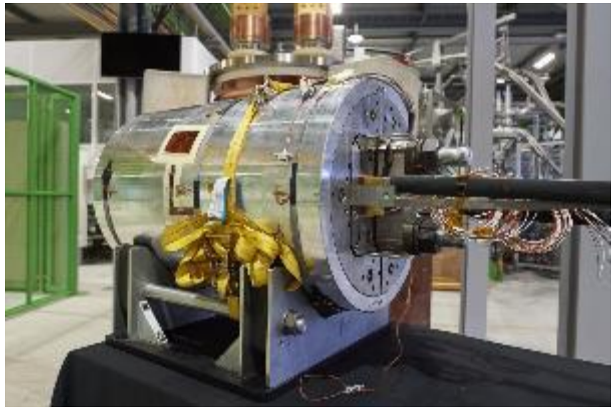
In SMC11T_2G 101: training at 1.9 K improves the performance at 4.5 K.

In 102: training at 1.9 K does not have a significant influence at 4.5 K.

In 103 and 104: the performance at 4.5 K is reduced after 1.9 K training.

RMC QXF





During the first run, training at 1.9 K is faster than at 4.5 K (even after the "knee"). The performance (as fraction of the short sample) after training at 1.9 K is maintained.

Side note: the "with plateau" ramps reach higher current likely due to better extraction of the ramp losses.

Conclusions

- Training at 1.9 K seems to:
  - Accelerate the magnet training (probably due to larger temperature margin). See MCBRDP3, CD1, SMC 3a, SMC 11T 03, SMC 2g 101, RMC QXF.
  - Allow a magnet to go beyond a “blocking point” at 4.5 K (probably for the same reason). See MQFA06, MBHSP106.
- If the magnet is fully trained at 4.5 K, further training at 1.9 K typically does not improve the performance. See MSUT, TQS01c.
- In some cases, training at 1.9 K degrades the magnet. See SMC 11T 03, 04 and SMC 2g 103, 104.