MBHA-001 test program discussion

G. Willering
G. Ninet
F. Mangiarotti
V. Desbiolles
M. Bajko

Magnet test program in report EDMS 2268372

2019 November 13 – 11T technical meeting

Contents

Comparing test program for MBHA to MBHB.

- Cool down and warm up conditions
- HV tests
- Training/holding current tests
- QPS settings
- 4.5 K test
- Magnetic measurements
- Cyclic loading tests
- RRR

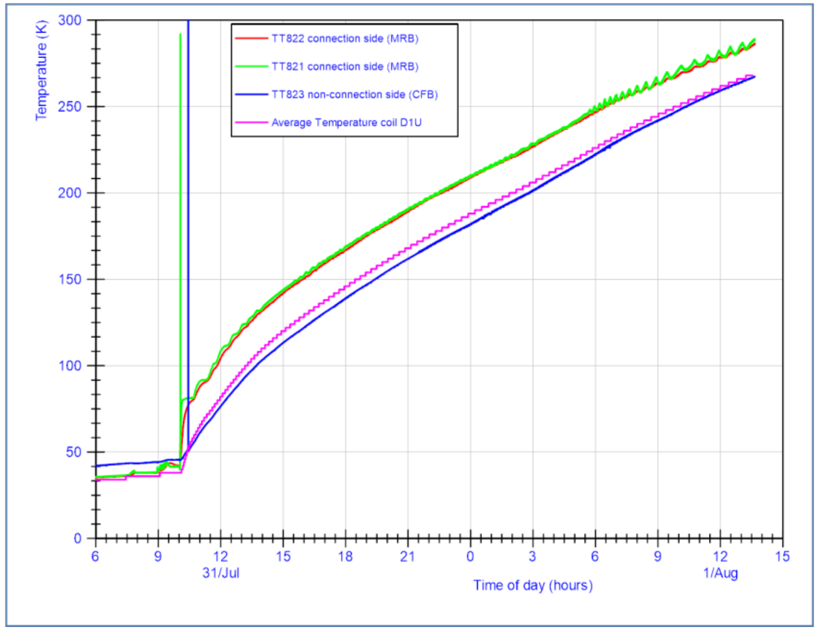
Main difference MBHA compared to MBHB

- Presence of 250 A trim circuit.
- Presence of 550 A MCS circuit and 100 A MCO circuit.

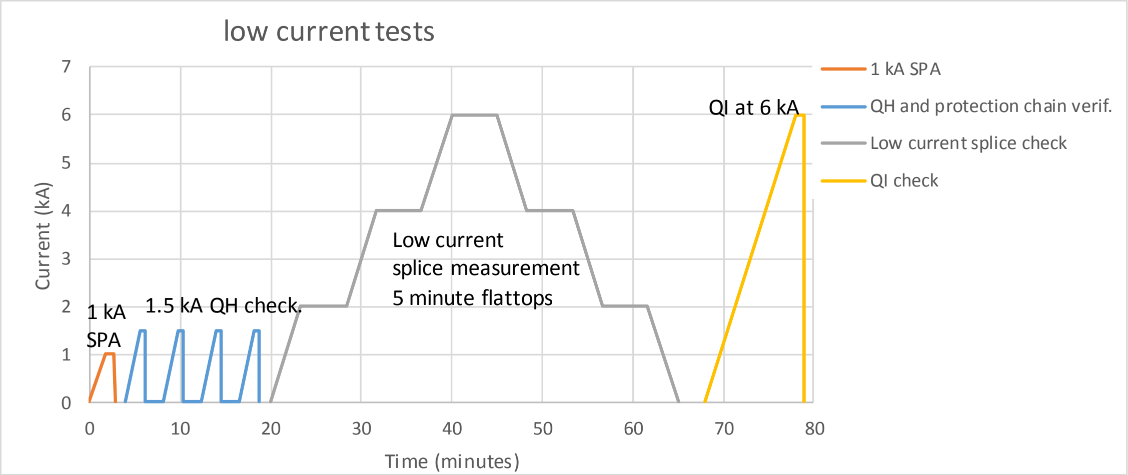
Planning

Cool down and warm up

- MBHB-002: ΔT of 30 K (abort process at >45 K)
- MBHB-002: ΔT of 30 K (abort process at >45 K)



Overview low current powering up to 6 kA



Done in MBHB-002

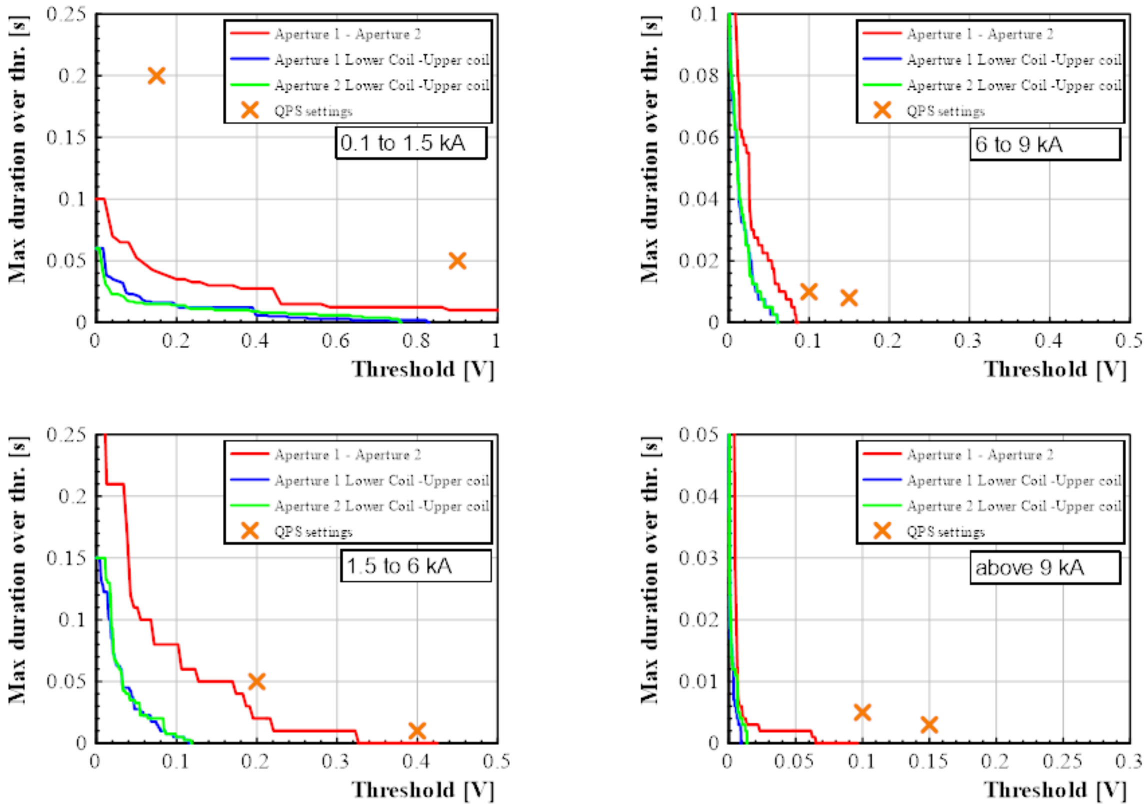
Same proposed for MBHA-001 Cool Down 1

Cool down 2:
Skip low current splice and 6 kA QI.

Flux jumps and Quench Detection settings

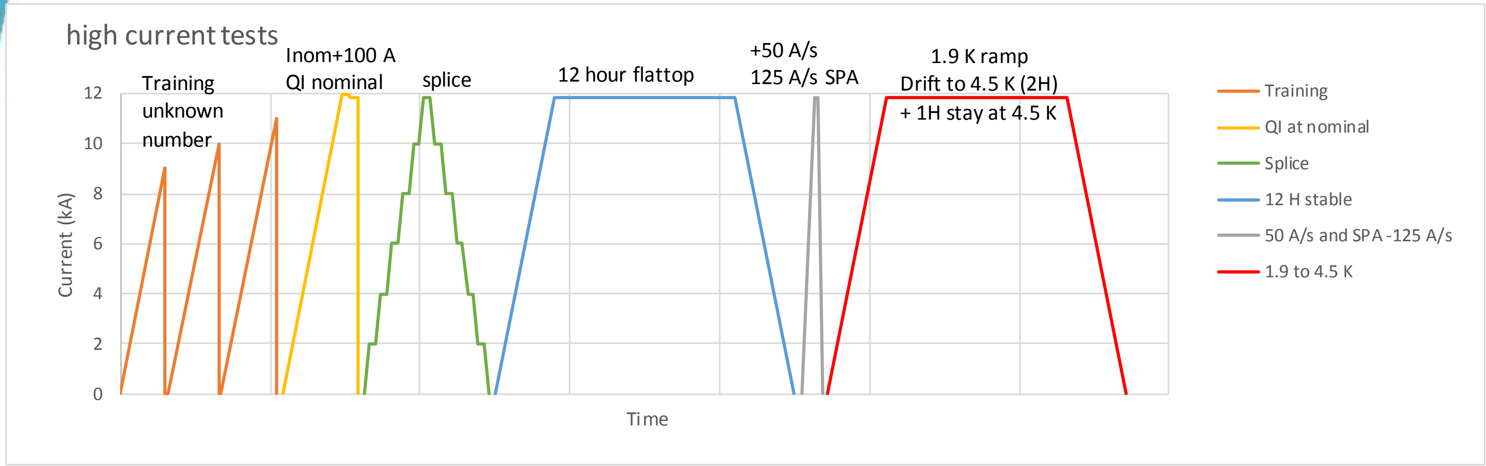
Protection settings optimized for flux jump in MBHB.
Table below shows the settings as used in CD 2.
Proposed for MBHA-001 are the same settings.

	Threshold, validation time	
Current range	**Lowest treshold**	**Shortest validation time**
I < 1.5 kA	150 mV, 300 ms	900 mV, 50 ms (insufficient for protection)
1.5 kA < I < 6 kA	200 mV, 50 ms	400 mV, 10 ms (insufficient for protection)
6 kA < I < 9 kA	100 mV, 10 ms	150 mV, 8 ms
9 kA < I	100 mV, 5 ms	150 mV, 3 ms



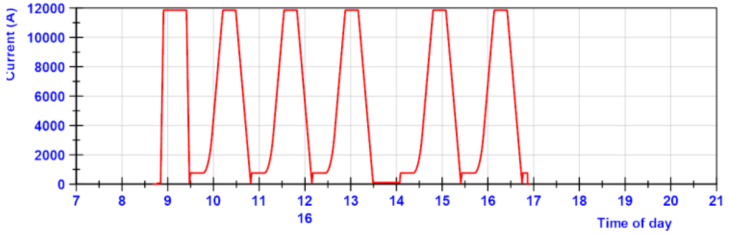
Threshold at 1.5 kA (200 mV, 50 ms) seems to have least margin to flux jump duration. (can we predict flux jump for MBHA?)

Overview high current powering > 6 kA



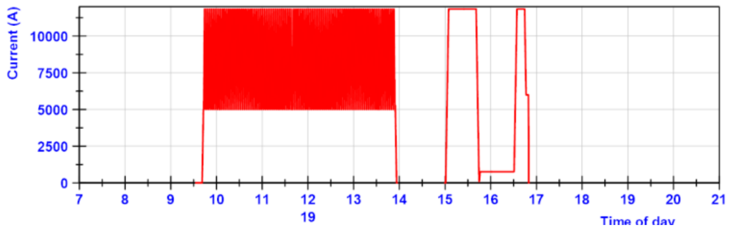
Proposed for MBHA-001

Magnetic measurements (2 days)



Additional done in MBHB-002

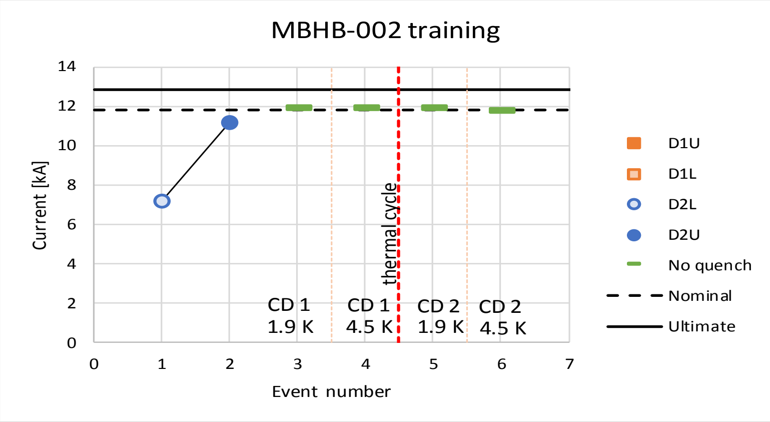
330 cycles from 5 to 11.85 kA in CD 2
(12 hours continous cycling)



Magnet training

Training up to 11.95 kA maximum *(see EDMS 2213035).*
Ramp rate 10 A/s.

MBHB-002 training was very fast with 2 quenches. Hopefully similar for MBHA-001, although more quenches are not excluded.



Stable current

Done for MBHB-002

Cool down 1:
1.9 K, 11.85 kA, 2 hours
4.5 K, 11.85 kA, 1.5 hours

Cool down 2
1.9 K, 11.85 kA, 12 hours
1.9 to 4.5 K, 11.85 kA, 3 hours

Proposed for MBHA-001

Cool down 1:
1.9 K, 11.85 kA, 12 hours
1.9 to 4.5 K, 11.85 kA, 3 hours

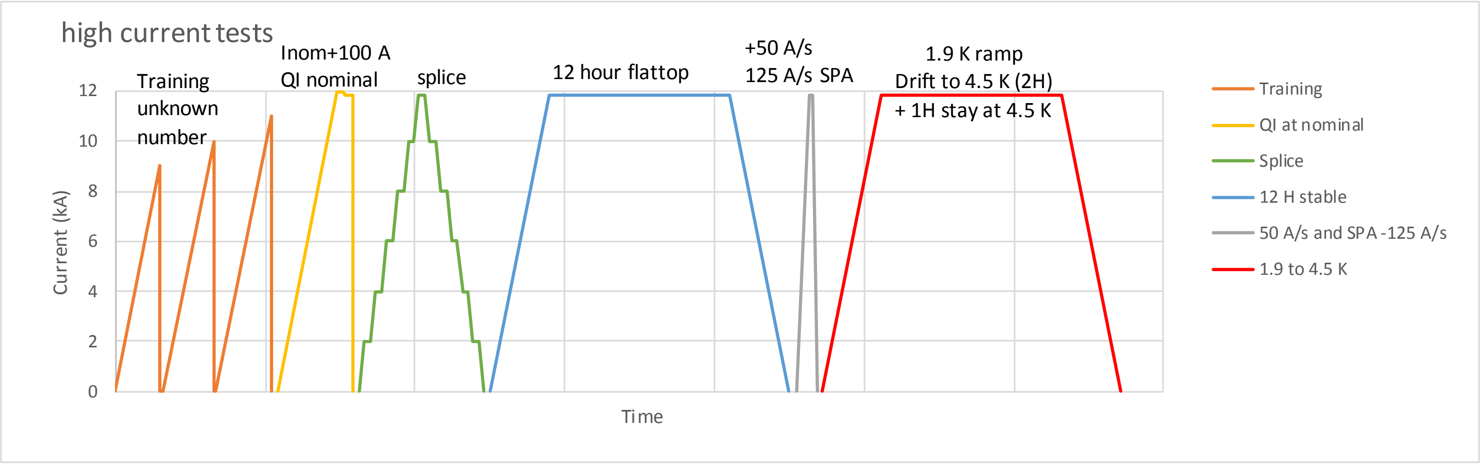
Cool down 2
1.9 K, 11.85 kA, 4 hours
1.9 to 4.5 K, 11.85 kA, 3 hours

Ramp rate studies

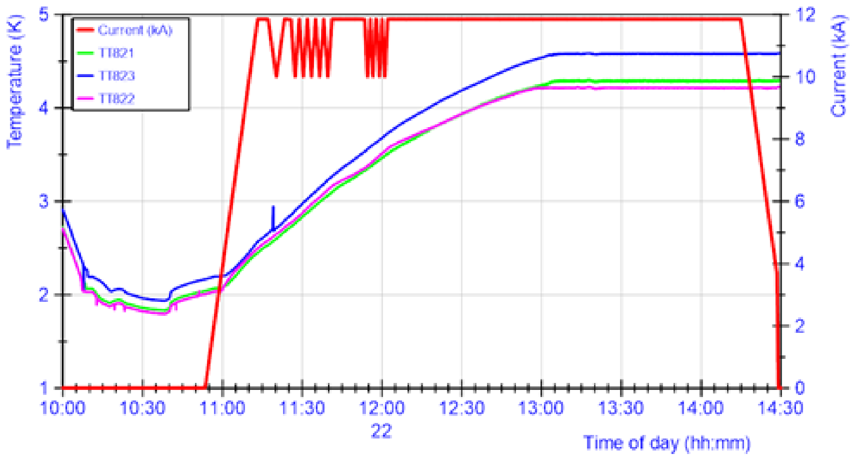
MBHB-002: Ramp up: up to 100 A/s performed.
Ramp down: up to -125 A/s in the SPA test. *(required for the LHC during RB energy extraction).*

MBHA-001: One relatively fast ramp at 50 A/s foreseen at 1.9 K, followed by SPA of - 125 A/s to show this gives no false trips.

Any ramp at 4.5 K will likely not be feasible due to flux jumps in combination with protection levels.



Magnet margin at 4.5 K



Done for MBHB-002: Drifting from 1.9 K to 4.5 K while powering. This avoids flux jump trips at low current.

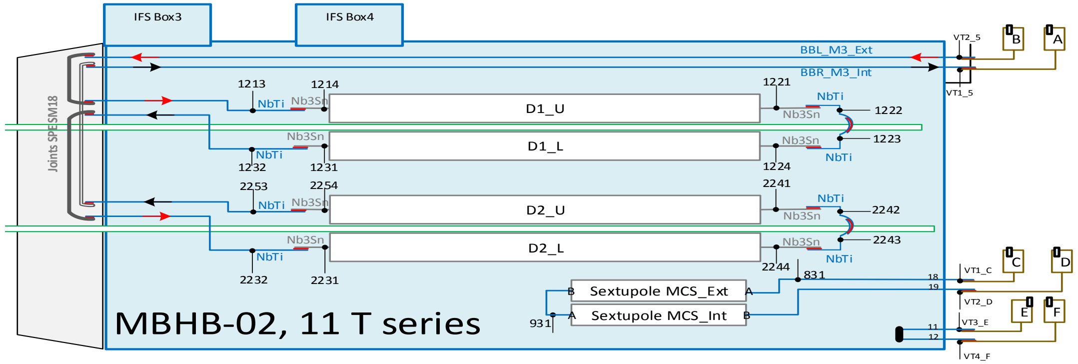
Proposed for MBHA-001: Same method is proposed (excluding high current cycling).

Total time about 5 hours (20 min ramp up, 2 hour T-drift, 1 hour flattop, 1 hour back to 1.9 K).

Splices

MBHB-002

Splice	Resistance [nΩ]	Comment
1213-1214	0.15 (1 splice)	NbTi-Nb3Sn
1221-1224	0.54 (3 splices)	Nb3Sn-NbTi-NbTi-Nb3Sn
1231-2231	0.61 (3 splices)	Nb3Sn-NbTi-NbTi-Nb3Sn
2244-2241	0.50 (3 splices)	Nb3Sn-NbTi-NbTi-Nb3Sn
2254-2253	0.13 (1 splices)	NbTi-Nb3Sn

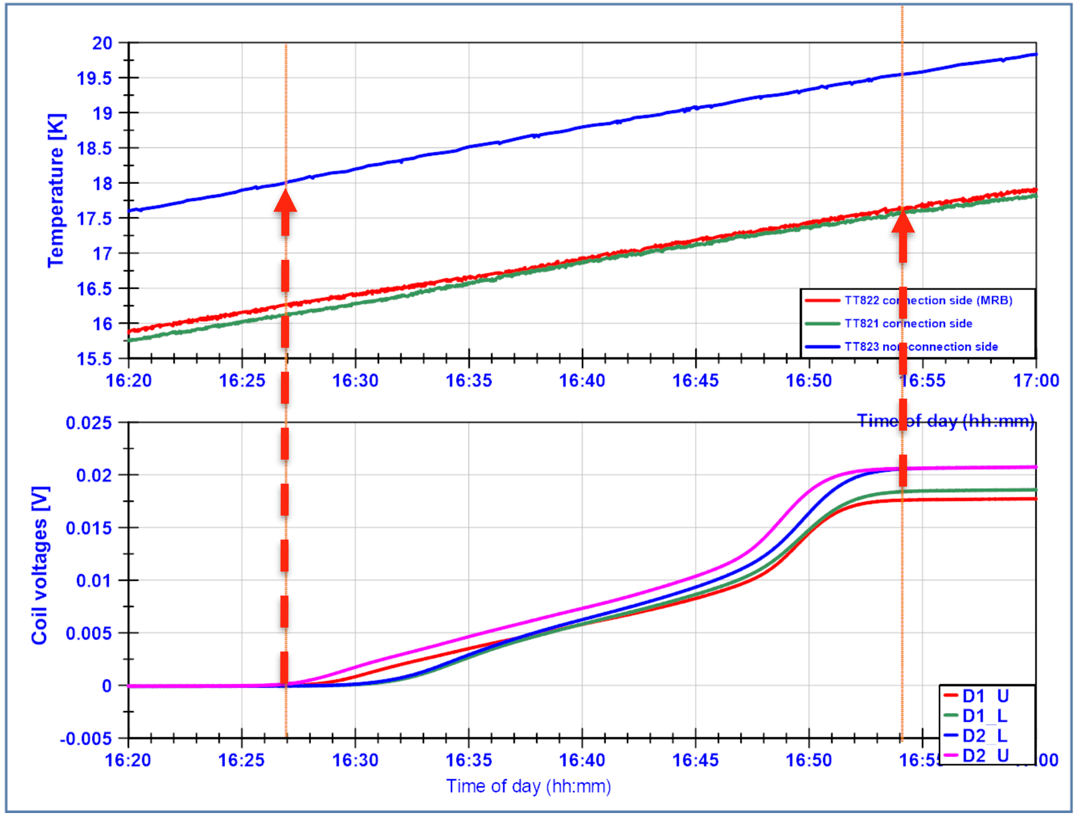


Done in MBHB-002: measure up to 3 splices combined. Only if resistance is high > 1 nOhm per 3 splices, redo measurements for individual splices.

Proposed for MBHA-001: Same method.

RRR

Done in MBHB-002: Accurate transition resistance measurement with slow drift of magnet temperature.



MBHA-001: Two options:

1. Use same method during first warmup (Could waste precious time, half a day minimum, but also impossible if just before a weekend).
2. Find a better moment *(During cooling after a quench, abort cooling once full coil is superconducting, wait until magnet warms up to full transition, then restart cooling down. Other option is after 4.5 K test.)*

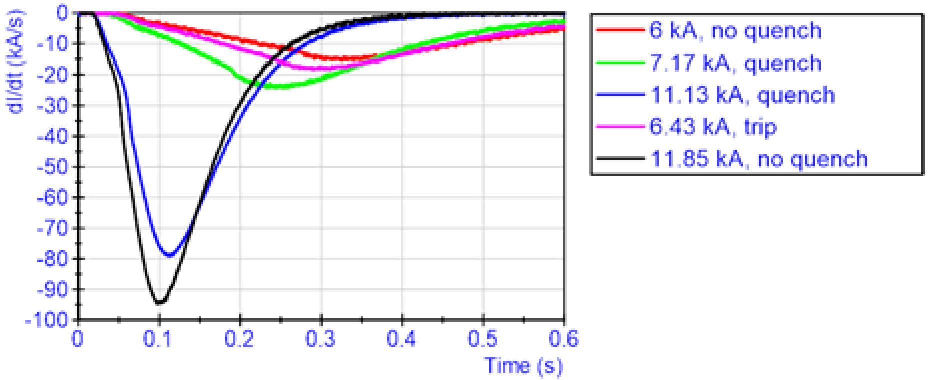
For now option 1 is in the test program. If we manage option 2, option 1 will be discarded.

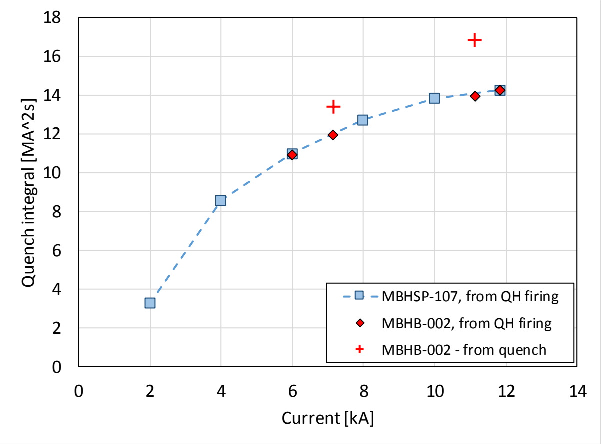
Seen as important parameter.
Most important: avoid time loss.

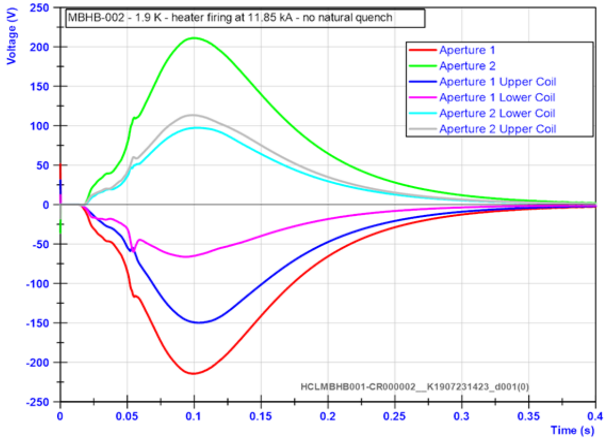
Quench integral study at 6 kA and 11.85 kA

Quench heater firing at nominal current gives multiple important data:

- Voltage imbalance between coils following heater firing (important in HV calculations)
- Quench Integral
- dI/dt characteristics.
- Quench Heater efficiency







MBHB 1.9 K, 11.85 kA

Total resistive voltage = 6500 V.
Voltage Aperture 1: 3040 V
Voltage Aperture 2: 3460 V
Imbalance of 14 %

Heater firing at nominal current, without a natural quench in the magnet.
420 V resitive voltage imbalance between aperture 1 and aperture 2

High Voltage insulation test, instrumentation tests

MBHB-002 and MBHA-001 tests identical.

Note:
MBHB-002 has an MCS magnet circuit.
MBHA-001 has an MCO and MCD magnet circuit.

MBHA-001 has **trim leads**, which are connected to the main circuit. By definition it will see the potential of the main circuit.

Polarity +	Polarity -	Warm initial	cold	Warm final
Dipole-Quench Heaters	Ground	300/660	300/660/1850/**3300**	300/660
Dipole	Quench Heaters - Ground	300/660	300/640/1850/**3200**	300/660
Dipole	Ground	300/660	300/660/1850/**3300**	300/660
Dipole	All Quench Heaters	300/660	300/640/1850/**3200**	300/660
All Quench Heaters	Ground	300/660	300/660/1850/**3300**	300/660
Dipole	MCS-MCD Correctors	250	250/975	250
MCO/MCD Correctors	Ground	250	250/975	250
Ext/Int Passive Busbar	Ground	600	600/1850/**3075**	600
Ext Passive Busbar	Internal Passive Busbar	600	600/1850/**3075**	600
Cryo Heater	Ground		675	
Cold Temp. Sensor	Ground		25	
Dipole	QH1 to QH 8	300/**660**	300/640/1850/**3300**	300/**660**
QH1 to QH 8	Ground	300/**660**	300/660/1850/**3300**	300/**660**
Dipole	Lead EF_BB11&12	250	250/975	250
Lead EF_BB11&12	Ground	250	250/975	250

Test request: 200 K, 3 bar, 750 V during final warm up.
Risk and impact on planning not know yet.
Manual operation, not easy.

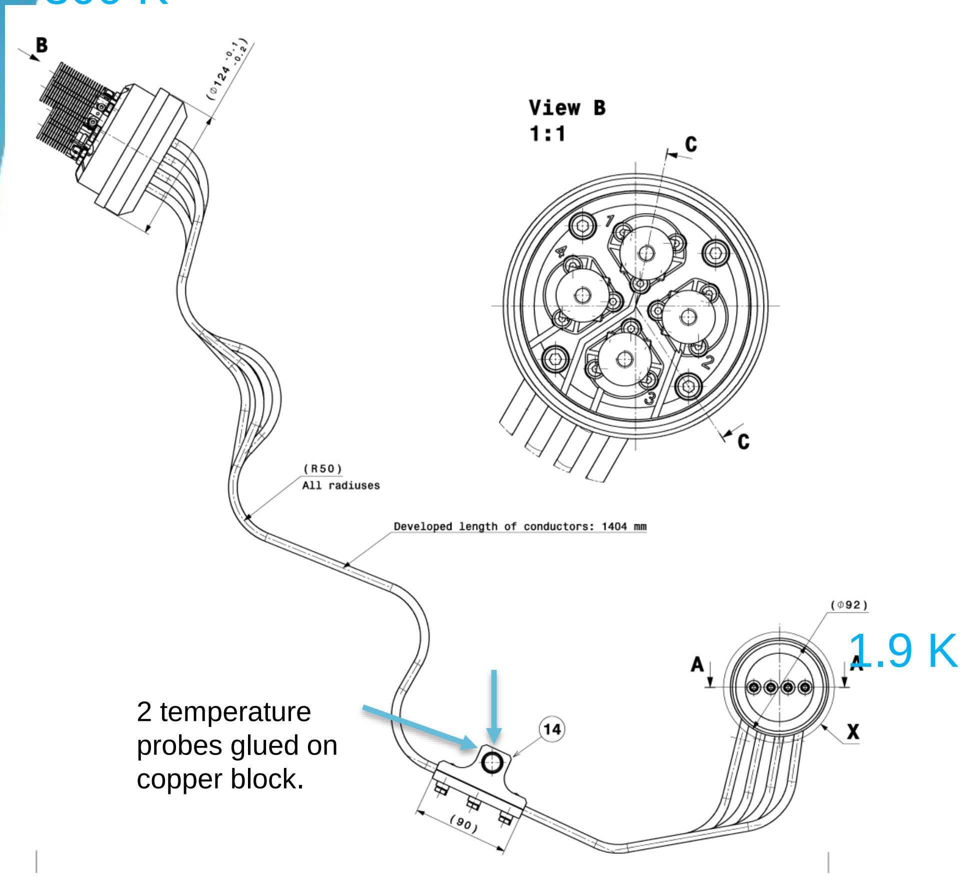
Magnetic Measurements

MBHB: Full measurement set done by Lucio, see EDMS 2219199

MBHA: No time allocated to MM, low priority.
The MM shaft will be used already for quench localisation.
If time permits a machine cycle may be possible.

Trim leads

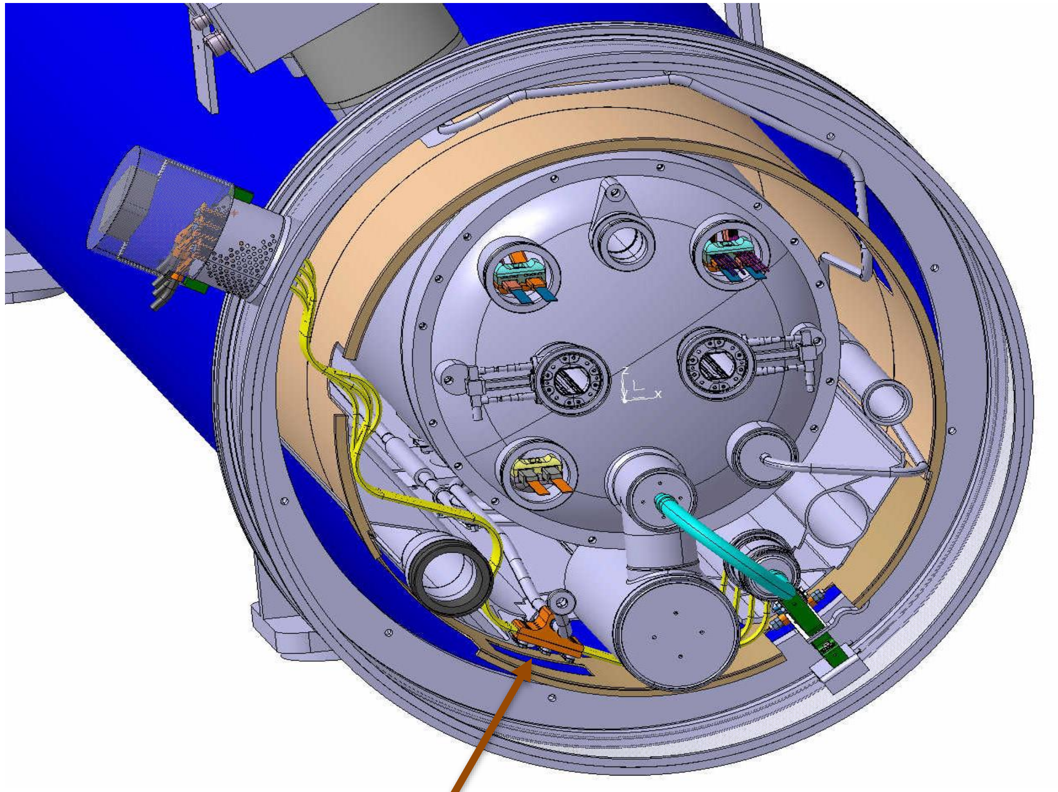
300 K



1.9 K

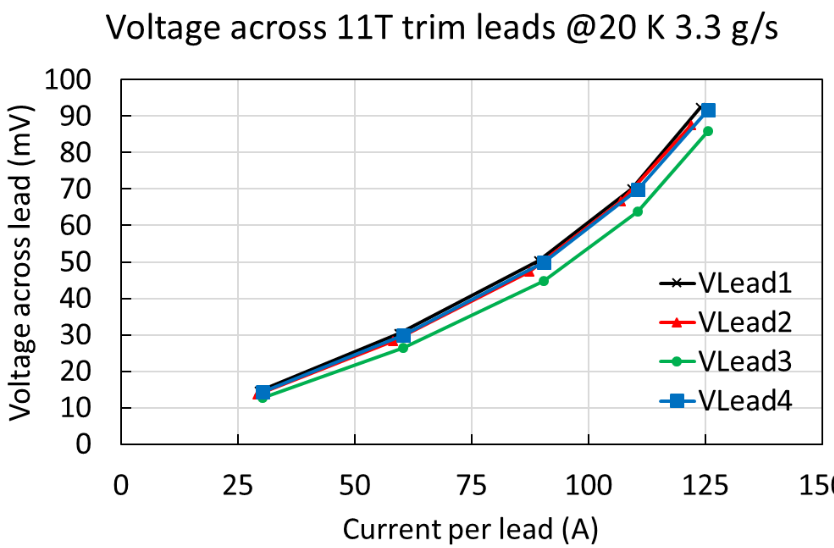
2 temperature probes glued on copper block.

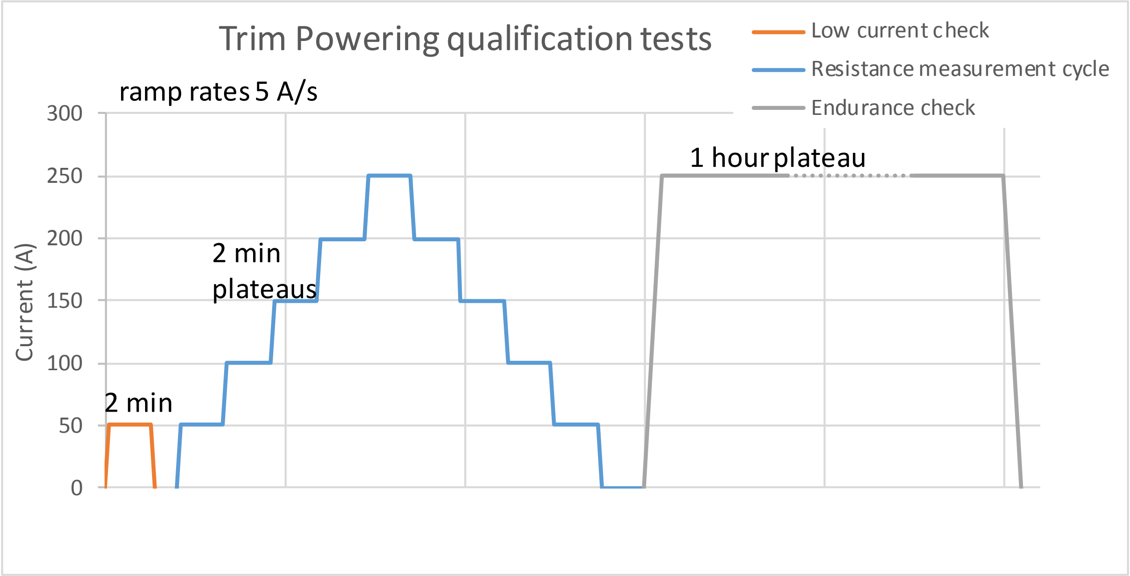
20 K?

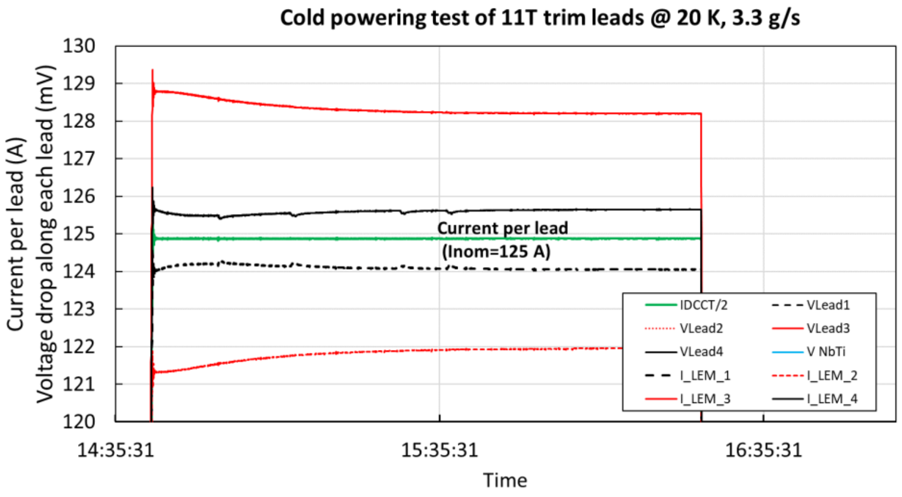


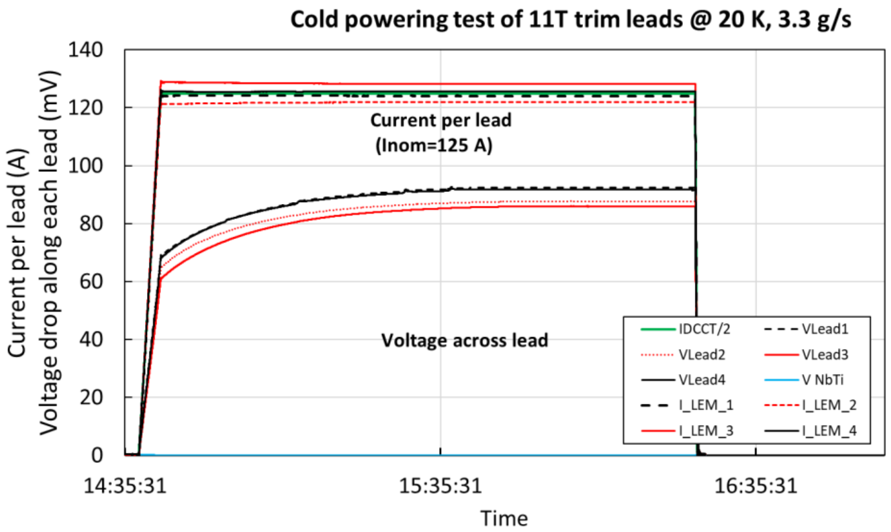
Thermalization

Helium gas flow from CFB boiloff, through magnet feet, then through thermalisation, returning through screen.
Helium T measurement only at exit.
No helium flow measurement.





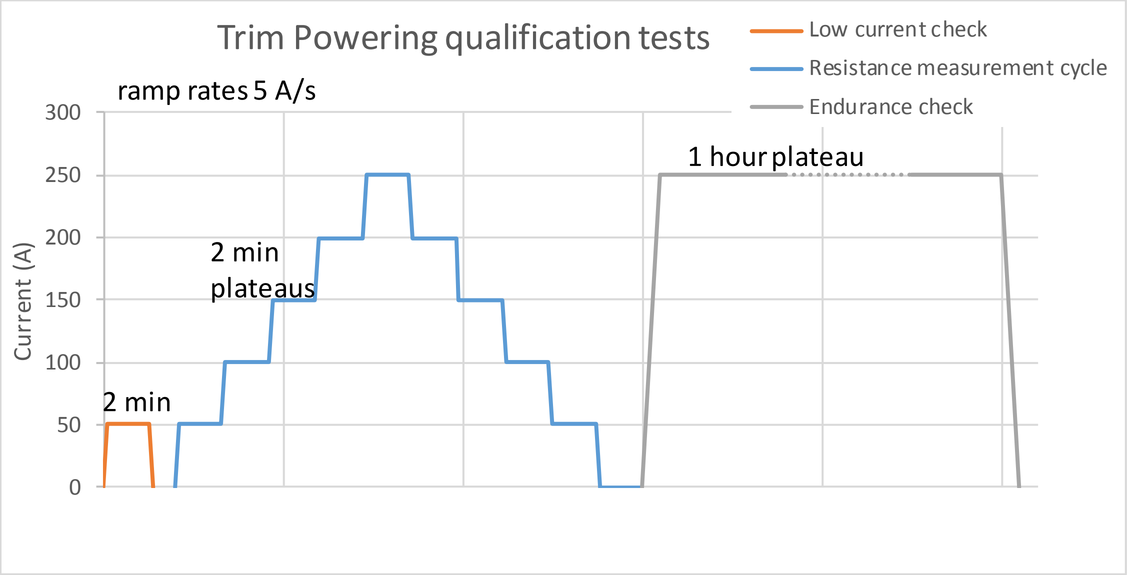




1.5 hour stabilisation time

Trim leads

- Powering with 600 A PC. 13 kA PC always disconnected.
- Quick resistance measurement on 2 minute plateaus, no stabilisation.
- Protection:
  - Normal conducting parts: 150 mV, 10 ms
  - SC parts: 50 mV, 10 ms
- Most important test stable conditions at 250 A.
  - In case of failure, repeat at 220 A.

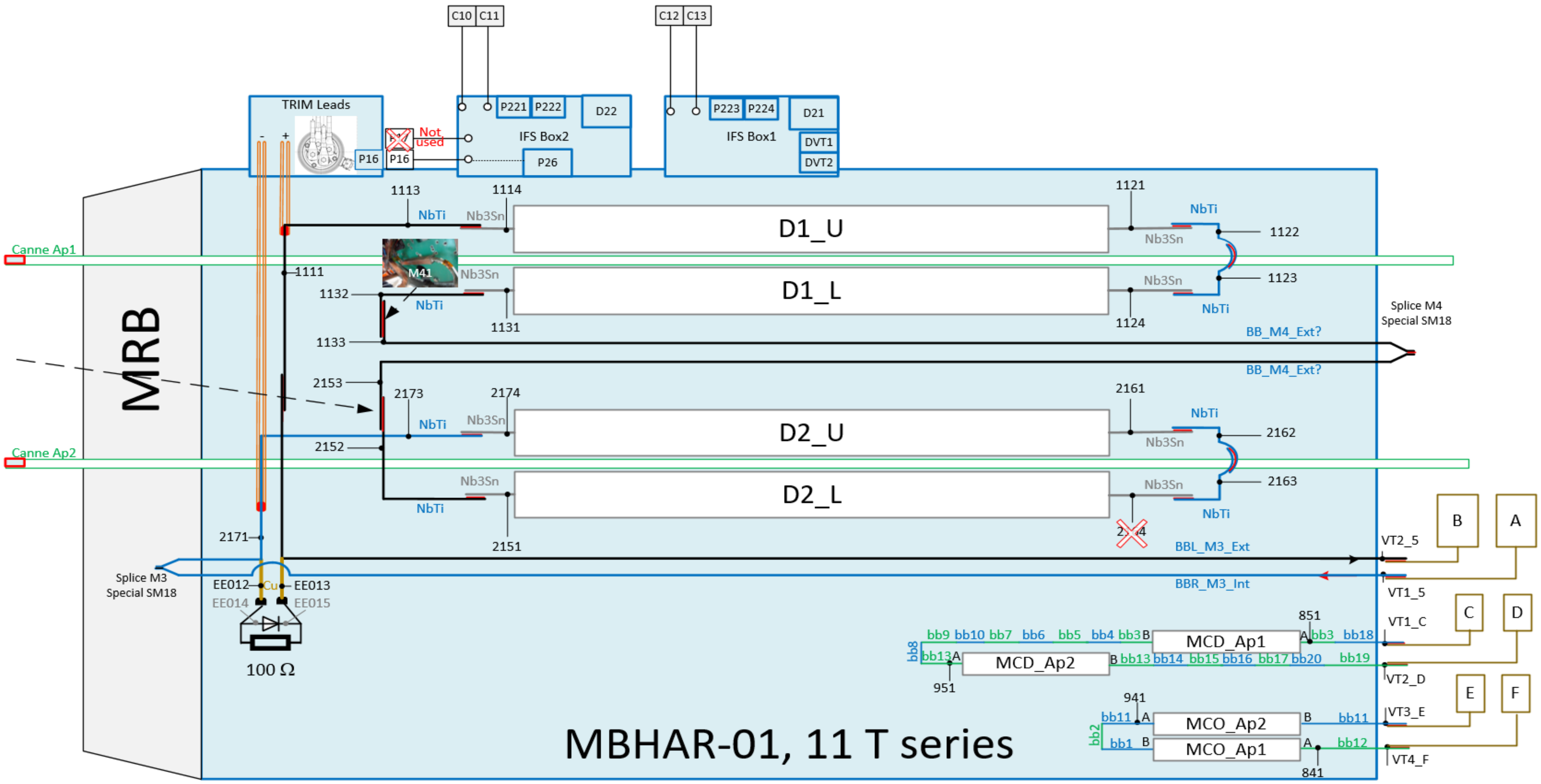


No time or technical possibility for playing with helium flows and temperatures.

Planning

- Zero contingency in planning, including extended working hours for preparation and test.

- Target is start of warm up



C10
C11
C12
C13
TRIM Leads
P16
Not used
P221
P222
D22
IFS Box2
P26
P223
P224
D21
IFS Box1
DVT1
DVT2
MRB
Canne Ap1
Canne Ap2
1113
1114
NbTi
Nb3Sn
D1_U
1121
1122
1123
1124
1111
M41
1132
1131
D1_L
1133
Splice M4
Special SM18
BB_M4_Ext?
2153
2173
2174
2161
D2_U
2152
2162
2163
D2_L
2151
2171
BBL_M3_Ext
BBR_M3_Int
VT2_5
VT1_5
B
A
Splice M3
Special SM18
EE012
EE013
EE014
EE015
Cu
100 Ω
851
MCD_Ap1
MCD_Ap2
bb9 bb10 bb7 bb6 bb5 bb4 bb3
bb3 bb18
bb8
bb13
bb13 bb14 bb15 bb16 bb17 bb20 bb19
951
VT1_C
VT2_D
C
D
941
MCO_Ap2
MCO_Ap1
bb11
bb1
bb2
bb12
841
VT3_E
VT4_F
E
F
MBHAR-01, 11 T series