The diode non-conformity in Sector 2-3

EDMS 2593310

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Special thanks to

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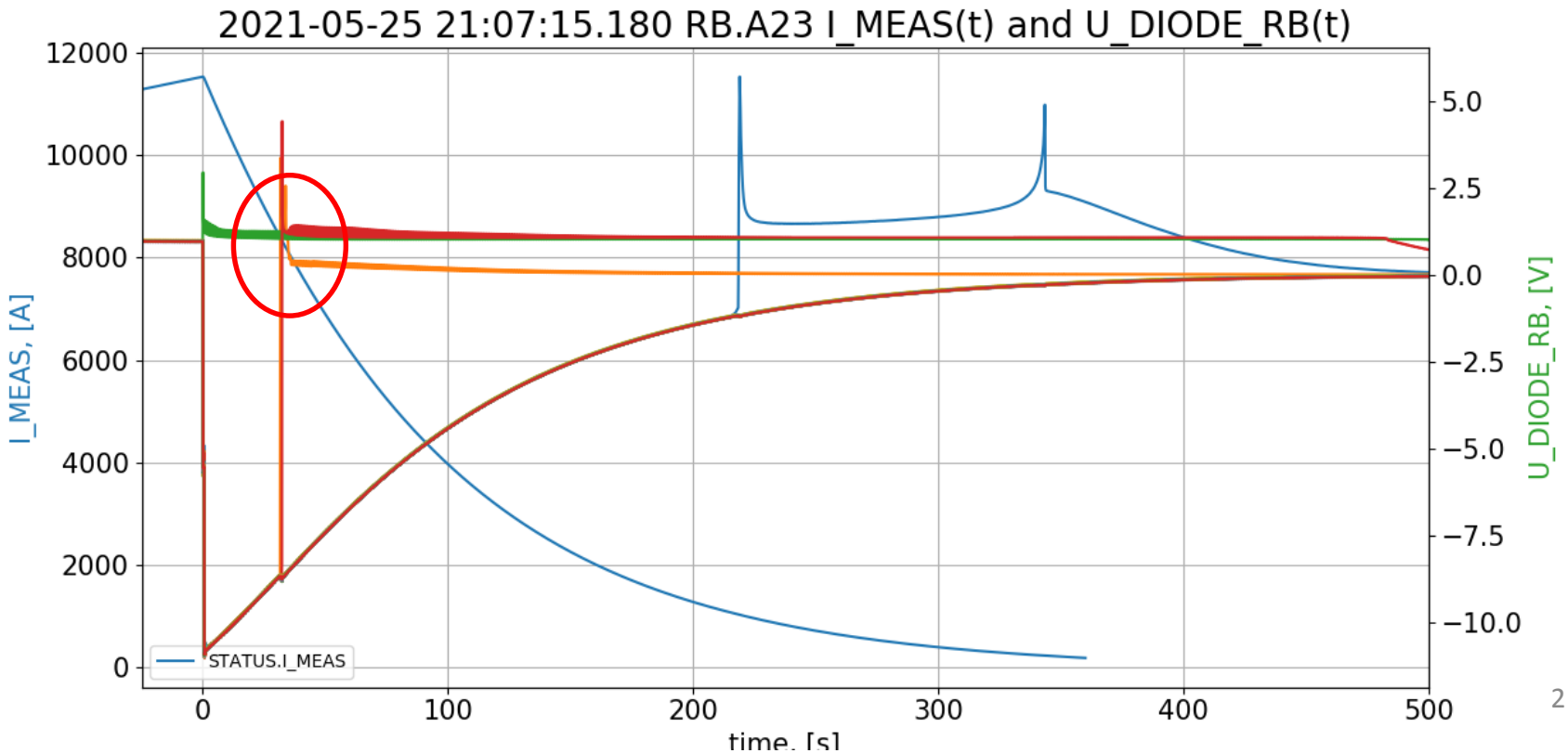
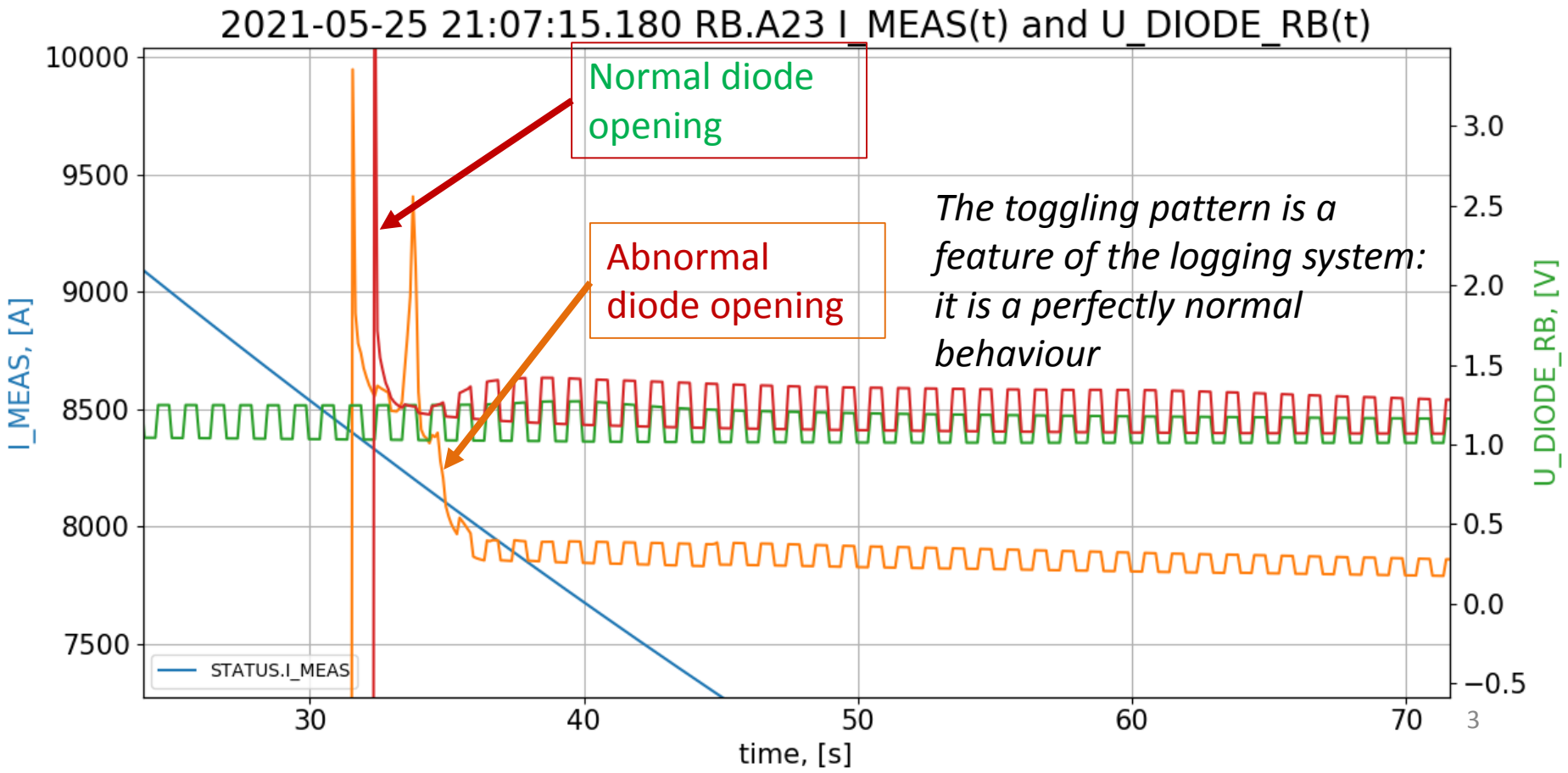
Observations (1/2)

- **25/05/2021 21:07:15 - Training quench on MB.B23R2, 11537 A**
- At ~8 kA magnet A23R2 quenches due to GHe propagation from the training quench
- MP3 analysis of NXCALS data identifies an atypical behaviour at the level of the diode of A23R2



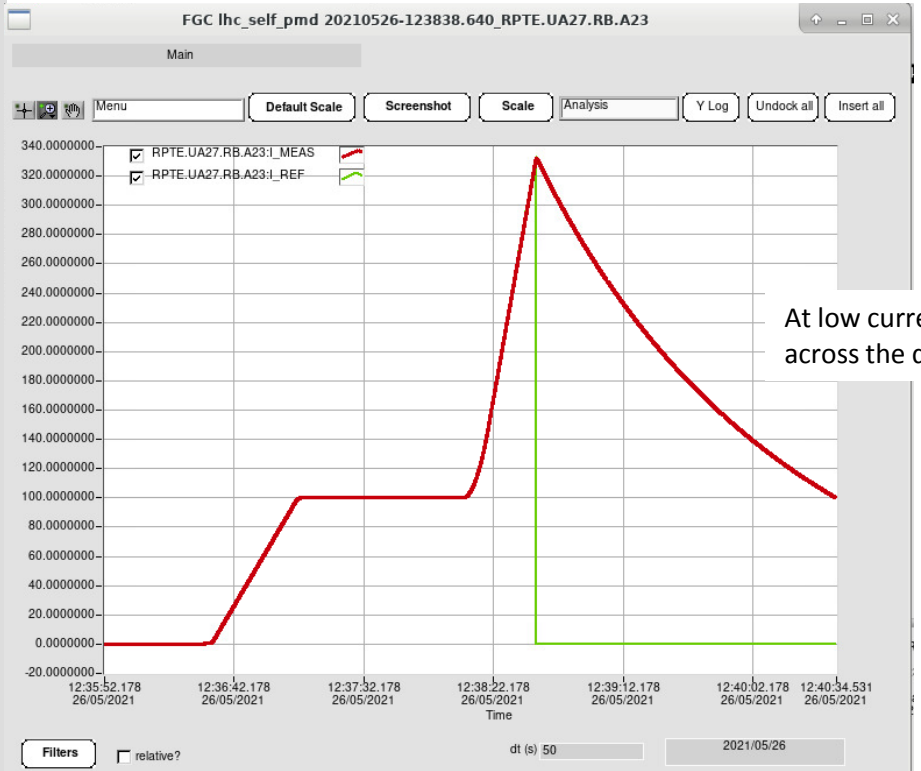
Observations (2/2)

- **25/05/2021 21:07:15 - Training quench on MB.B23R2, 11537 A**
- When looking into the details one can notice that the diode first opens as normal, then the voltage drops from 1 V to 0V *(the voltage should remain at about 1 V during the circuit discharge)*



Attempt to ramp the current up

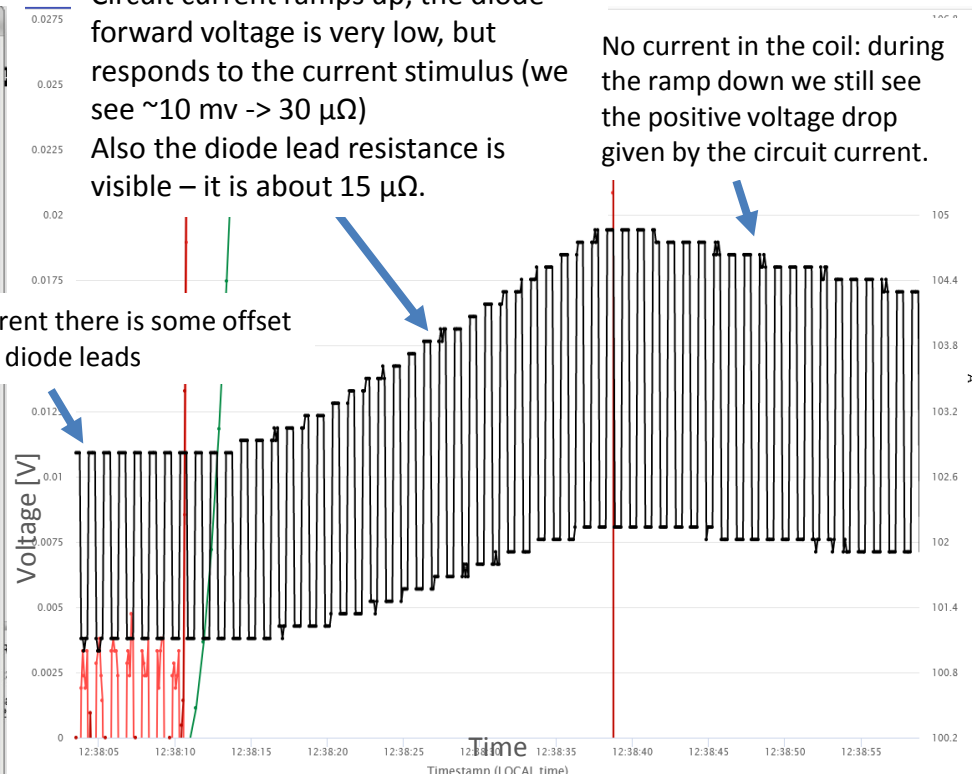
- 26/05/2021 12:38:38 - Trip of RB.A23 at 330 A
- The origin of the trip is nQPS at magnet A23R2
  - *nQPS is the protection system that monitors the bus-bars*
- The current does not flow through the magnet but through the diode
- Visible residual resistance of the diode and the resistance of diode leads



Circuit current ramps up, the diode forward voltage is very low, but responds to the current stimulus (we see ~10 mv -> 30 µΩ)
Also the diode lead resistance is visible – it is about 15 µΩ.

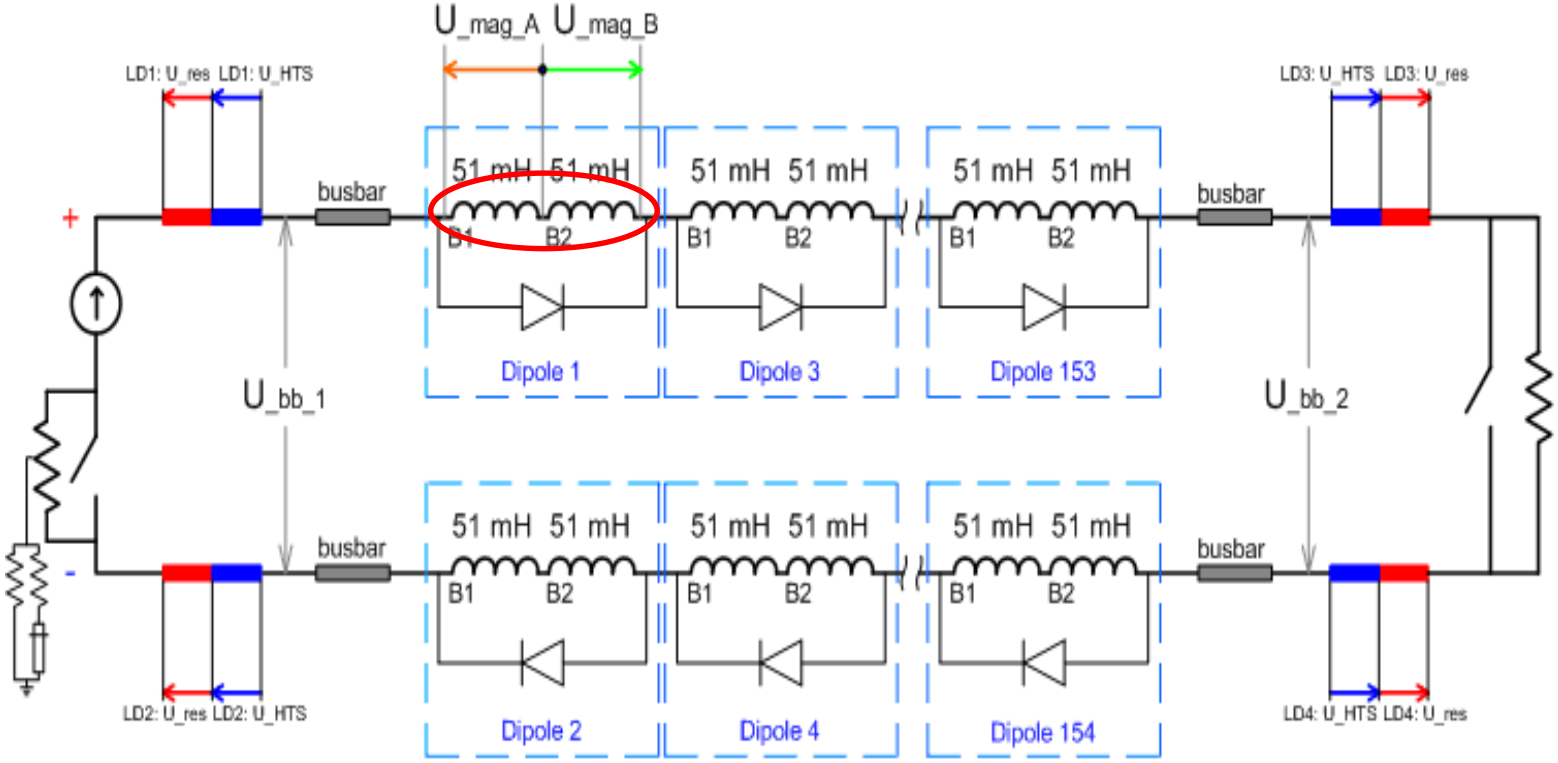
No current in the coil: during the ramp down we still see the positive voltage drop given by the circuit current.

At low current there is some offset across the diode leads



Where are the cold bypass diodes?

The cold diode assembly (at ~1.9K in normal operation of LHC) is a protection component of superconducting magnets. In case of a quench, the diode bypasses the magnet and takes over the circuit current.

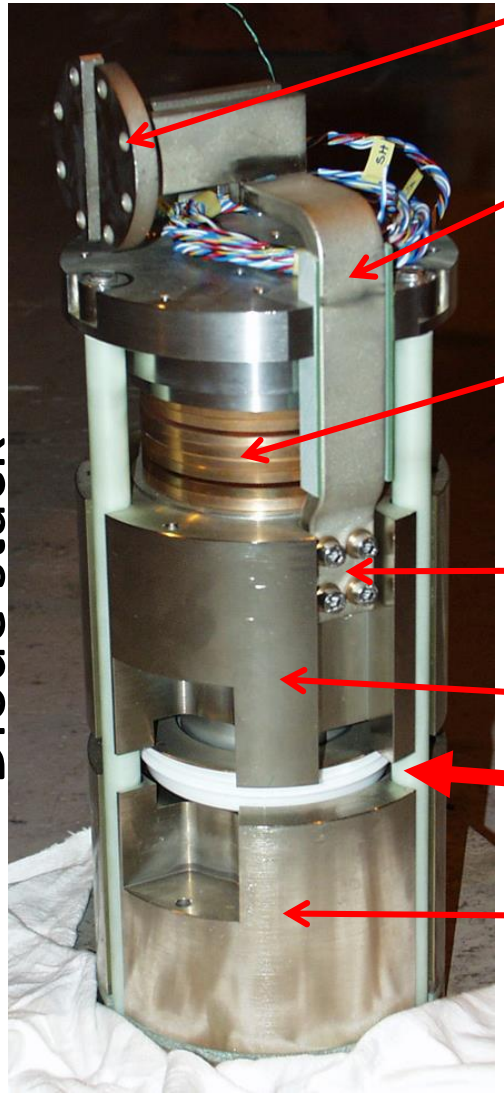


Schematic of the LHC main dipole circuit.

Cold diode has to carry up to 12 kA during the current decay with τ = 100 s for main dipole and τ = 30s for main quadrupoles.

How is the diode circuit built?

Diode stack



Half-Moon bolted connection

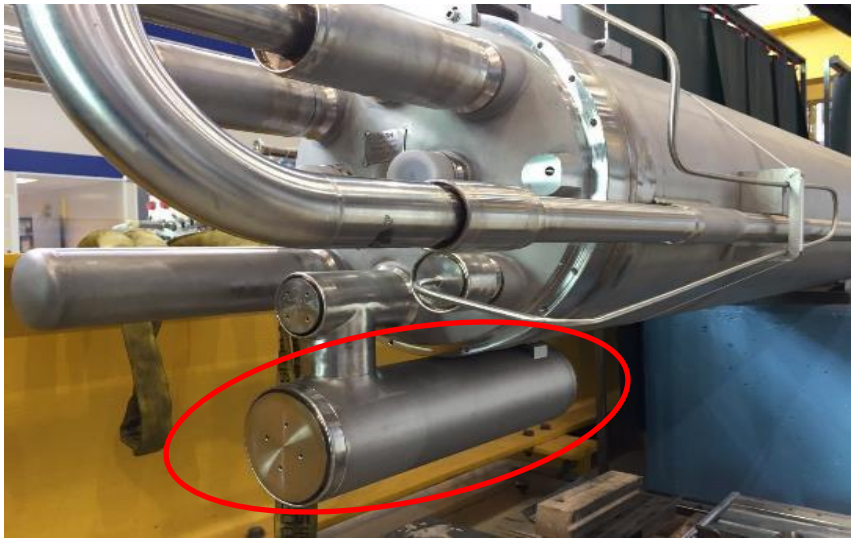
Diode busbar

Washers apply constant 40 kN pressure on diode press-pack

Busbar - heat sink bolted connection

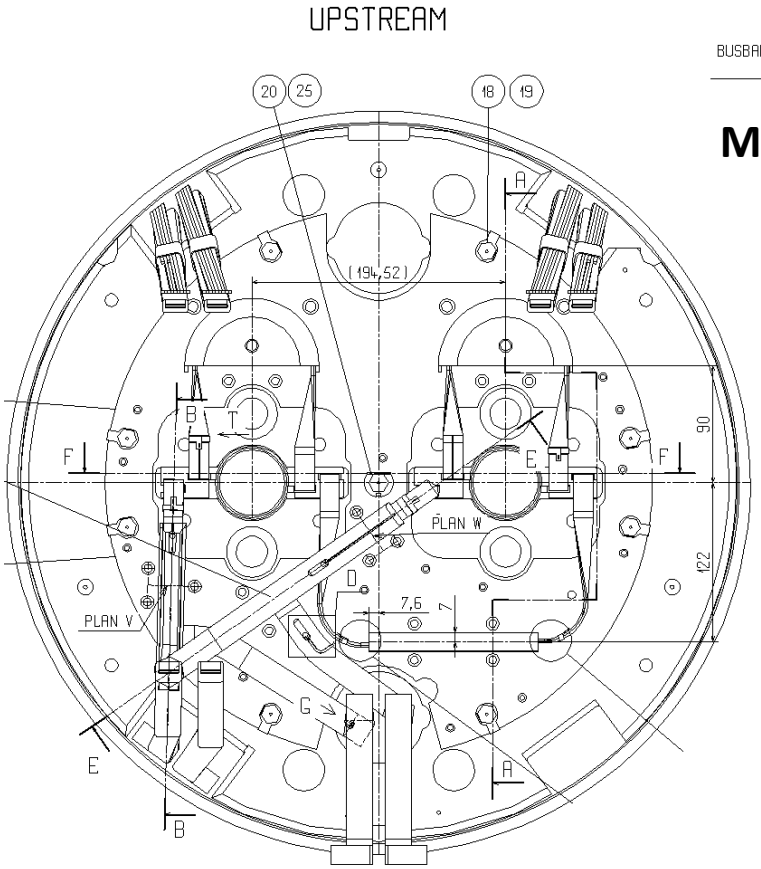
Heat sink

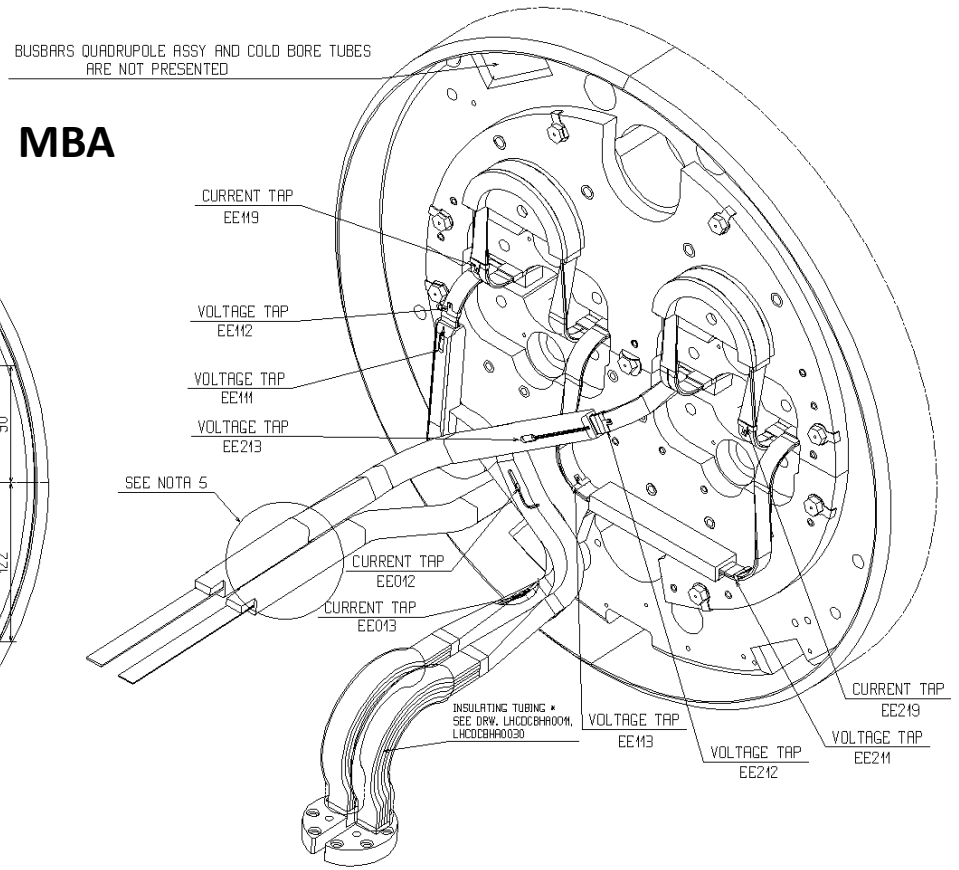
Heat sink

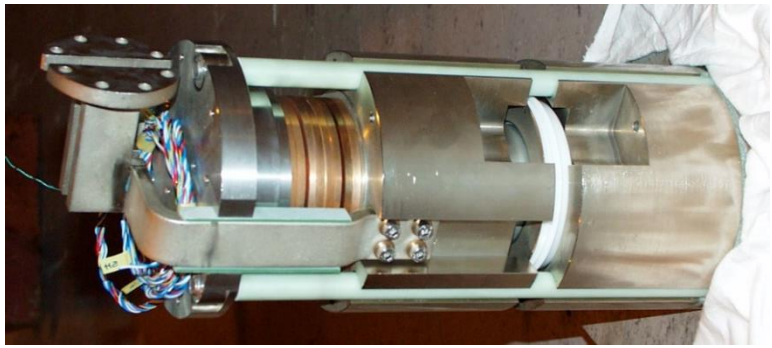


Voltage taps on the diode press-pack

Diode connection to the magnet







Standard ELQA tests

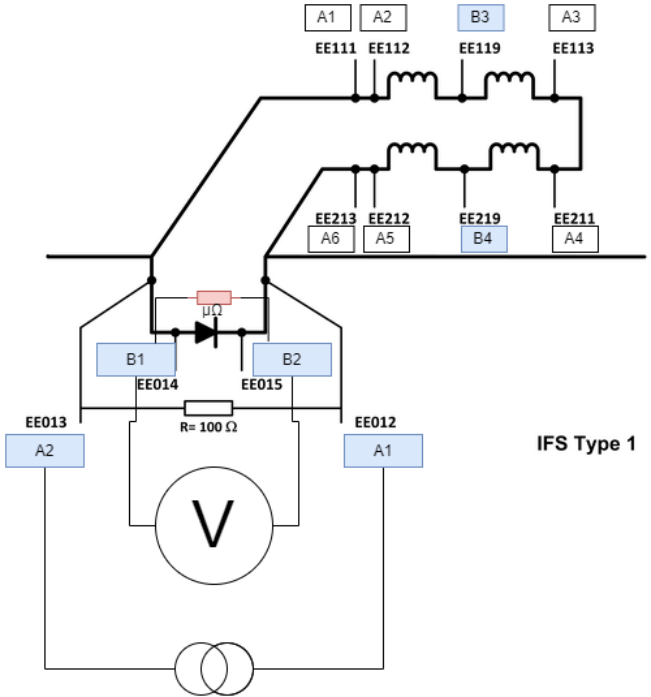
After the diode failure ELQA tests were carried out, leading to the following conclusions:

- The instrumentation of the magnet is OK
- The resistances of quench heaters are OK
- The insulation of quench heaters is OK
- The HV test at 2100 V of the full RB.A23 circuit passed with correct leakage current
- The diode does not behave correctly

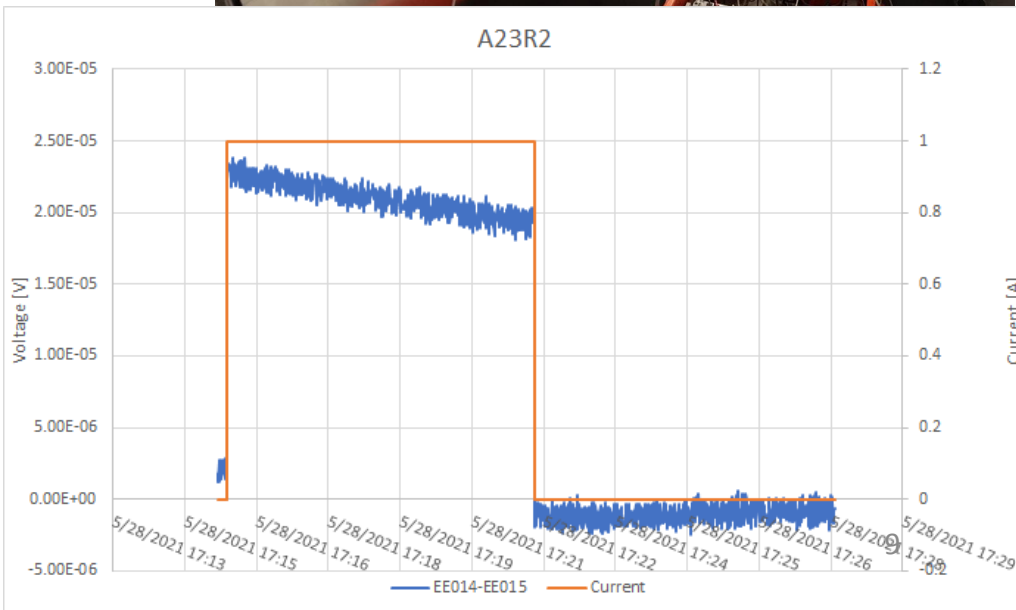
ELQA diagnostics

- Multiple special measurements performed
- The coils and instrumentation are sound
- Diode is in short-circuit:
  - The first such case in the LHC
  - R_{short}=20 μΩ
- No other apparent collateral damage

MB with left polarity: In sectors 2-3, 4-5, 8-1



IFS Type 1



Search for precursors

- MP3 and ELQA launched the analysis of:
  - The magnet and diode history
  - Previous powering events
  - ELQA test results
- No precursor was found
- The diode developed the short circuit during the first second of quench on 25.05.2021 without any precursor

Diode history

- Magnet number HCLBBLA000-CR01**3636**
  - Refurbished magnet
  - Installed during LS1
- Diode press-pack number 81305
  - Originating from the initial batch of diodes (the same as most of the diodes in the LHC)
- Diode stack number MDA1235
  - Refurbished diode stack (reassembled with a new press-pack)
  - All tests were successful
  - Endurance tested in SM18 (according to standard test procedure) – no issues

Conclusions

- Diode of A23R2 is in short-circuit
- The failure occured during a GHe propagation quench at 8 kA
- This is the first such fault in the LHC
- There is no other damaged component in this magnet
- **The diode assembly needs to be replaced**
- Warm-up of the sector has started
- No precursors were identified
- Inspection of the shorted diode, once disassembled, will be performed in order to try to understand the causes of the failure