



Interlocks and Commissioning of the In-Jaw Wire BBLR Compensator (BBCW) without beam, for Run 3

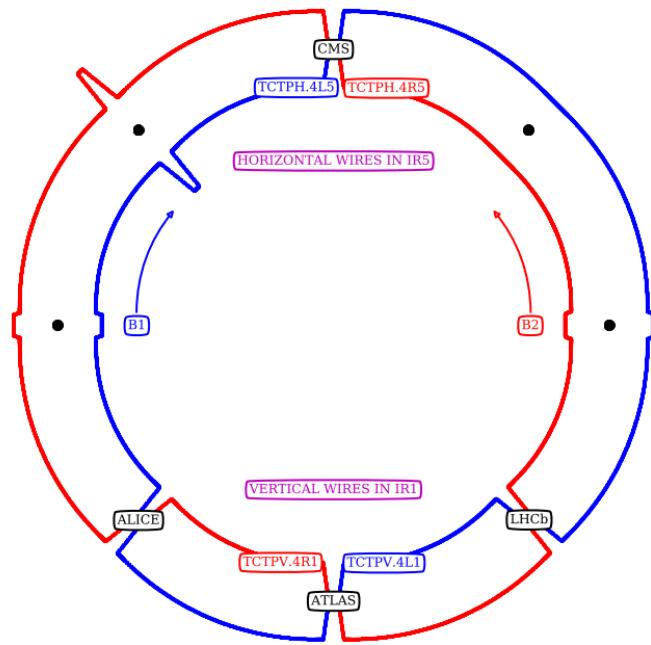
A. Rossi, M. Solfaroli, G. Sterbini,

With contributions from R. Bianchi, A. Frassier, R. Mompo
and data from D. Mirarchi and A. Poyet

#263 Collimation Working Group / #224 Machine Protection Panel
28/04/2022



Current installation layout of TCTW collimators



- ❖ TCTVP.4L1.B1
- ❖ TCTVP.4R1.B2
- ❖ TCTHP.4L5.B1
- ❖ TCTHP.4R5.B2

- 2 wires per collimators in series with current parallel to beam.
- Design current ± 378 A
- Nominal PC current per wire ± 350 A
- Required current during Run 3 0 – 350 A
- Compensation on Q4/Q5 necessary during operation (not discussed)

/eos/user/s/sterbini/MD_ANALYSIS/2018/LHC MD Optics/OpticsInjection.ipynb



LHC

EDMS NO. **2384198** | REV. **0.2** | VALIDITY **DRAFT**

REFERENCE
LHC-TC-EN-0005

Date: 2022-04-13

COMMISSIONING PROCEDURE

LHC Long Range Beam-Beam Compensator Wire (BBCW) Commissioning and Revalidation after Failure Recovery

BRIEF DESCRIPTION:

This document describes commissioning procedure for the Long-Range Beam-Beam compensator Wire during LS2, and following shutdown periods during Run 3, as well as the Revalidation procedure after Failure Recovery.

Latest version under engineering check

DOCUMENT PREPARED BY:

A. Rossi, A. Frassier SY-BI,
Y. Papaphilippou, A. Povet,
G. Sterbini BE-ABP,
M. Solfaroli BE-OP,
R. Mompo TE-MPE

DOCUMENT TO BE CHECKED BY:

G. Arduini,
A.- P. Bernardes,
M. Bernardini, R. Folch,
C. Gaignant, S. Grillot,
V. Montabonnet, C. Mugnier,
F-X. Nuiry, T. Otto, J. Panigoni,
S. Redaelli, M. Taylet,
A. Siemko, R. Steerenberg,
J. Wenninger, D. Wollmann.

DOCUMENT TO BE APPROVED BY:

S. Gilardoni
(SY-STI group leader)

T. Lefevre
(SY-BI group leader)

Outline

- Recall the BBCW related interlocks
- Results on commissioning without beam
- Conclusions

Recap of BBCW interlocks

TCTW protection

- a. **Wire temperature interlock** – beam dumps triggers on
 - Wire overheating
 - Threshold voltage across wire length (which increases with temperature of the wire, due to dependence of resistivity on temperature)
 - If control cards not in place or faulty
 - Non-continuity in the circuit

LHC machine protection

- a. **Power Converter interlock** – beam dumps triggers on
 - Power Converter internal failures
 - BBCW circuit earth fault
- b. **Overcurrent**

Implementation of BBCW interlocks

a. Wire temperature interlock → WIC

If $\Delta V_{BBCW} >$ fixed threshold $\approx 200^\circ\text{C}$ at 350 A, => interlock cards opens a switch to the WIC.

- The WIC will dump the LHC beam and
- Switch off the concerned power converter (external fault).
- The temperature interlock works for both polarities of the wires.
- Tests at ± 375 A and trigger temperature interlock after max. 2 min

b. Power Converter interlock → WIC

If PC_Status = FALSE => LHC beam dump

Implementation of BBCW interlocks

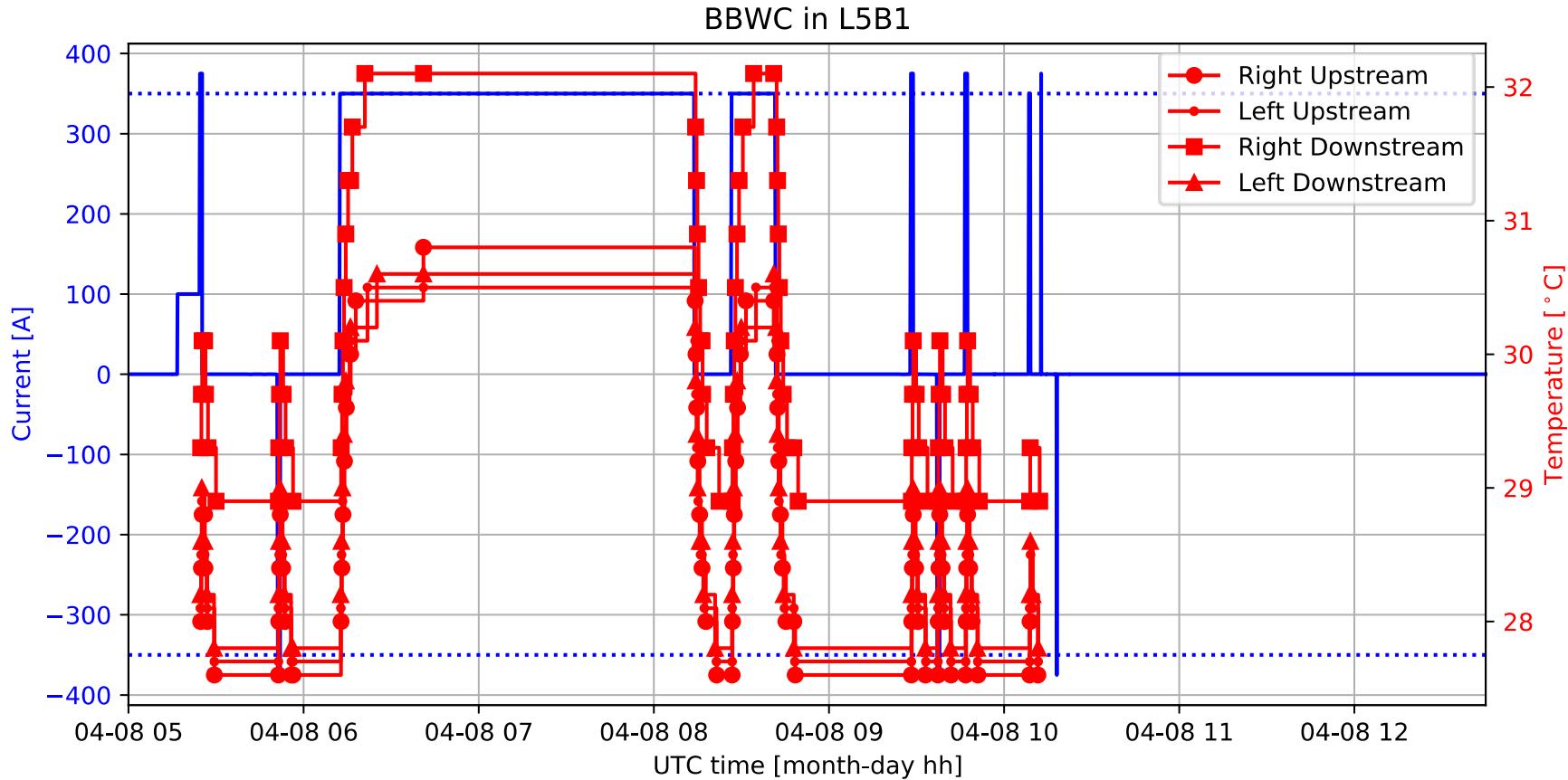
c. Overcurrent

- **FGC (SW) LIMITS.I.NEG and LIMITS.I.POS settings** (=> these thresholds cannot be overpassed, the FGC refuses to execute the command, no beam dump)
 - [-375 A, +375 A] to commission temperature interlock
 - [-350 A, +350 A] during normal operation
- **SIS (SW) interlock** (=> beams dumped, turn off BBCW power converters)
 - [0 A, +350 A] during normal operation
 - To be masked for temperature interlock commissioning or for special MD
- **PCinterlock (SW)** (=> beams dumped, circuit keeps running): only active in operation with NO EFFECT on the circuit.
It triggers if the current goes outside the limits defined for operation.
- **Temperature interlock (HW):**
intrinsically limits the current to ± 375 A

RBAC role
from CCC

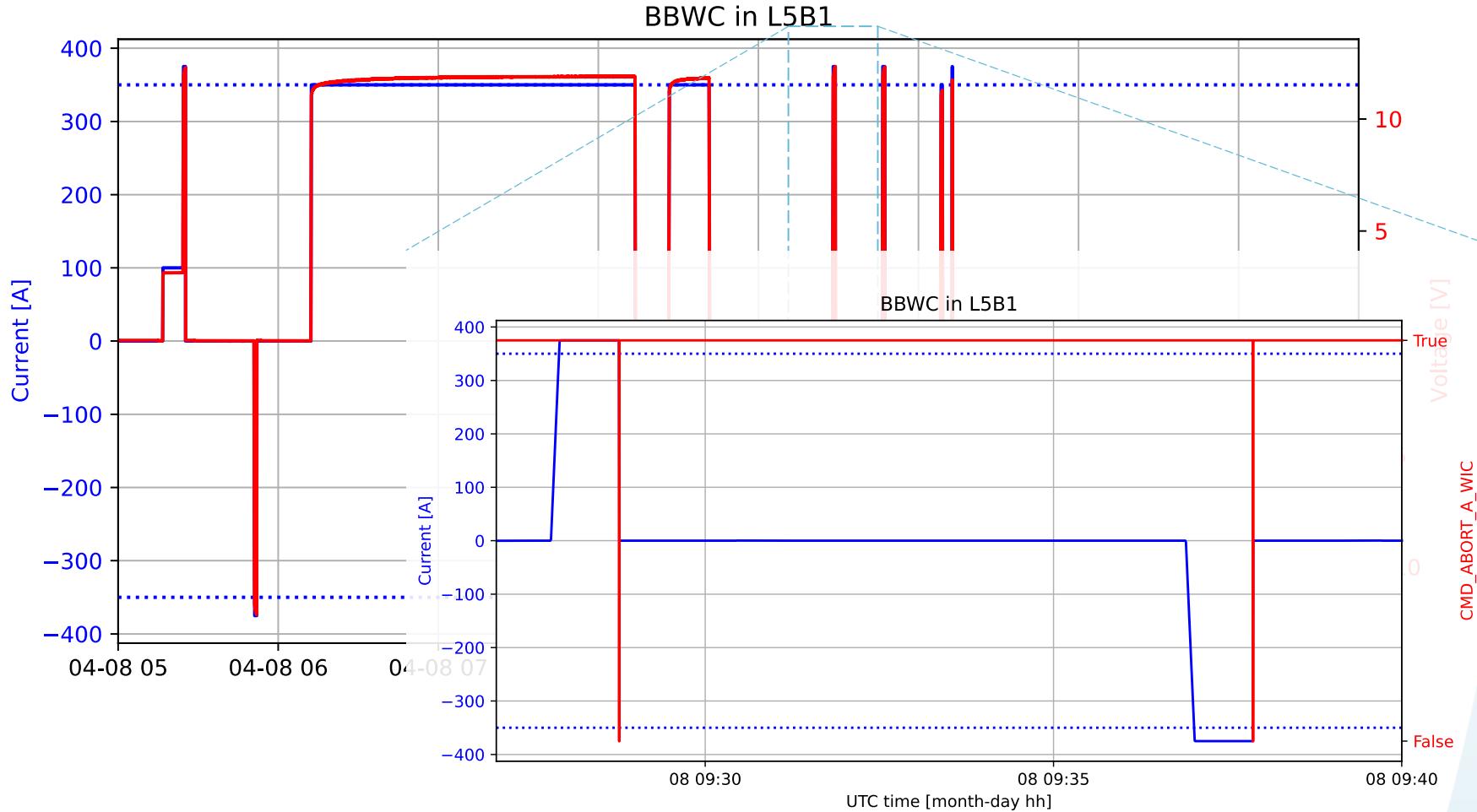
2022 commissioning

Jaw temperature



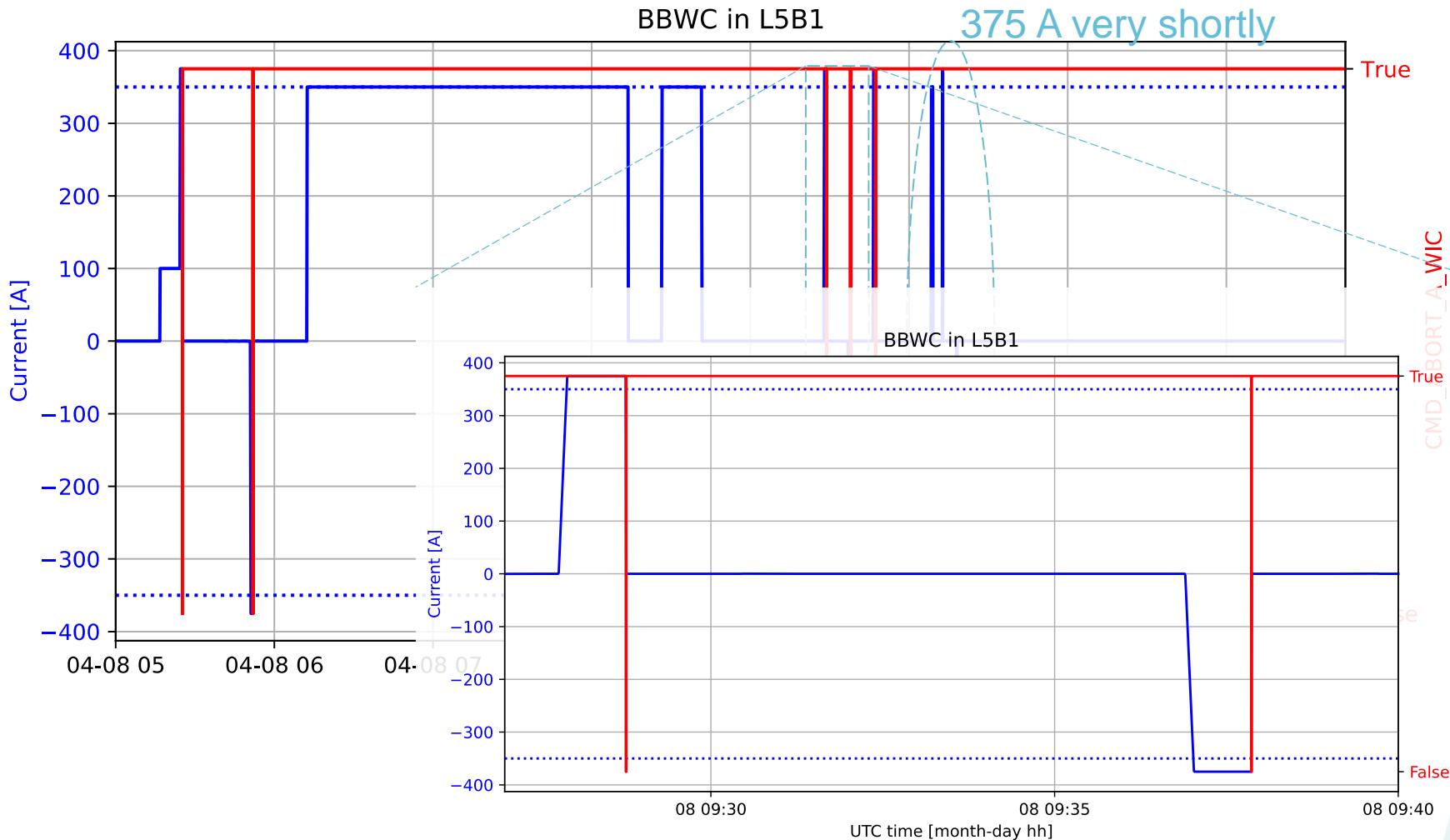
2022 commissioning

Voltage seen at Power Converter

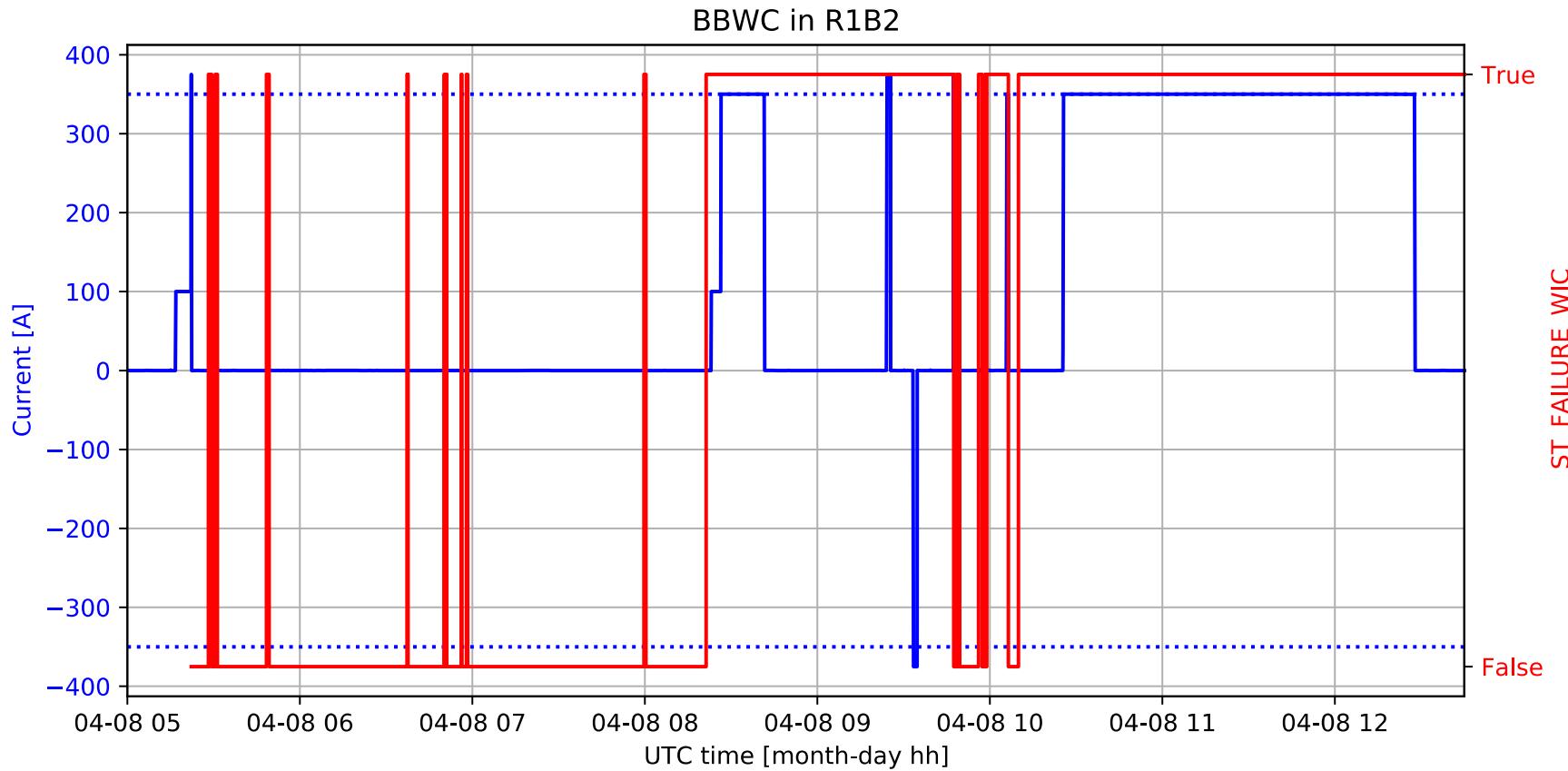


2022 commissioning

WIC – temperature interlock

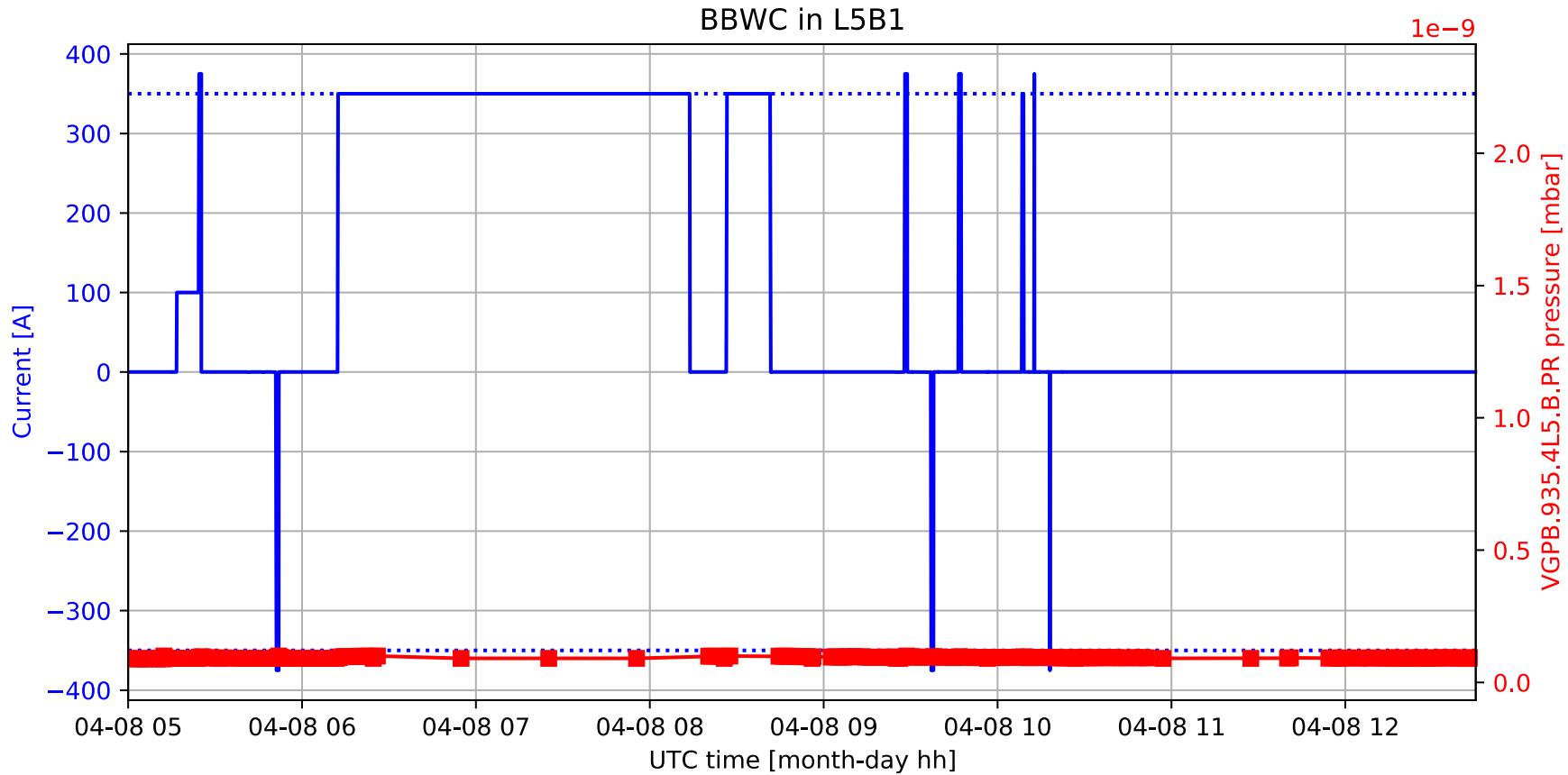


2022 commissioning WIC – power converter interlock



2022 commissioning

Vacuum pressure



Conclusions

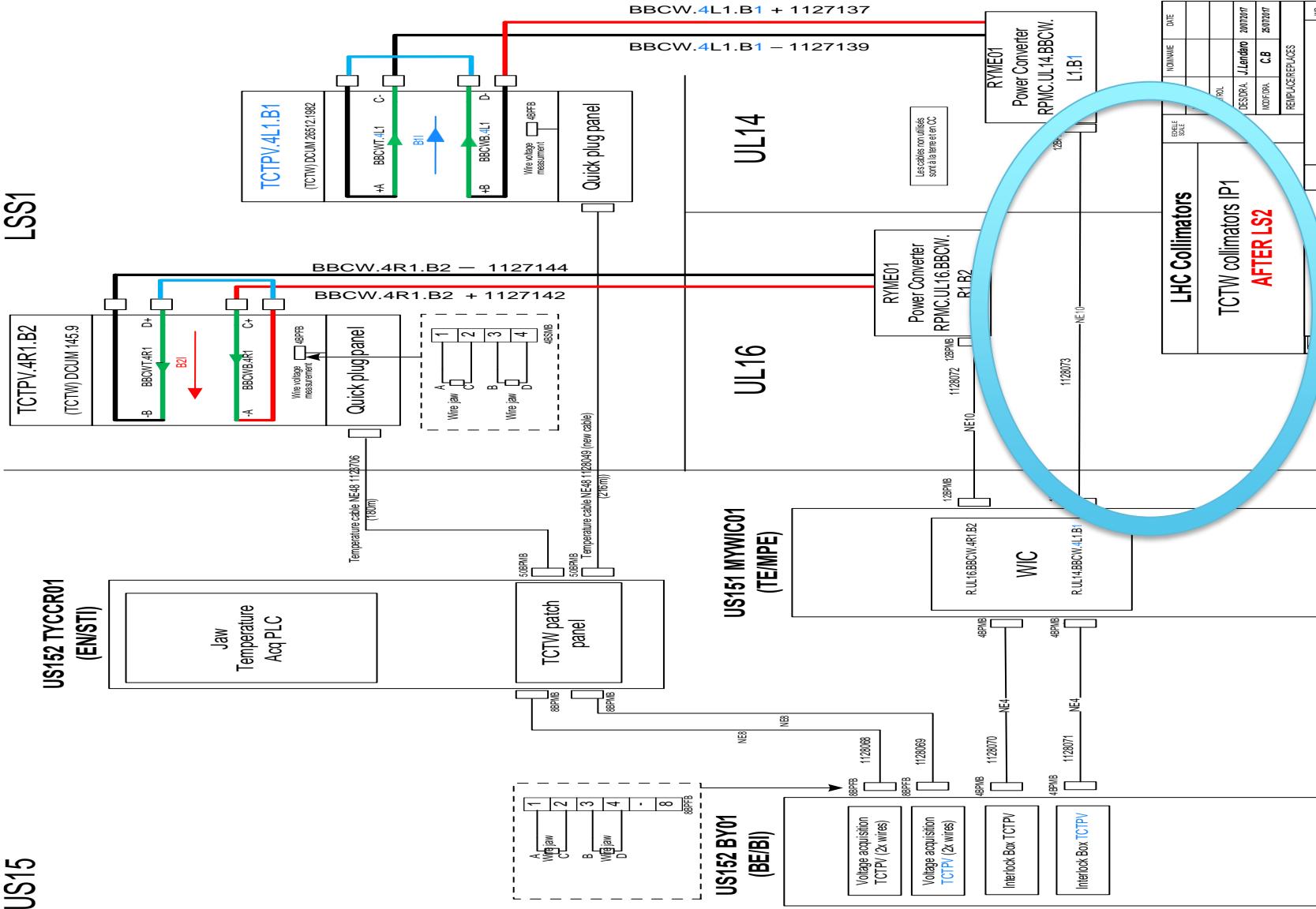
- The BBCW interlocks have been implemented to protect the TCTW hardware overheating, and the machine from BBCW (and circuit associated) failure, as well as from overcurrent.
- The interlocks commissioning without beam was successfully carried out after installation in 2019, and repeated remotely from the CCC in 2022.
- What should be repeated with beam?

Spare slides

US15

US152 TYCCR01
(EN/ST)

LSS1



USC55

**TYCCR01
(ENSTI)**

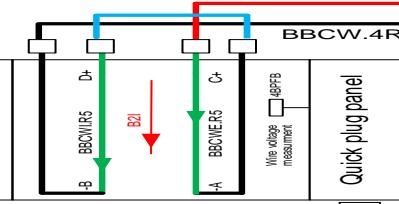


LSS5

Note: The intertent wire (BBCW1) is in the jaw between Beam 1 and Beam 2.

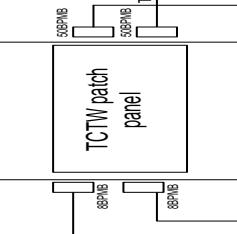
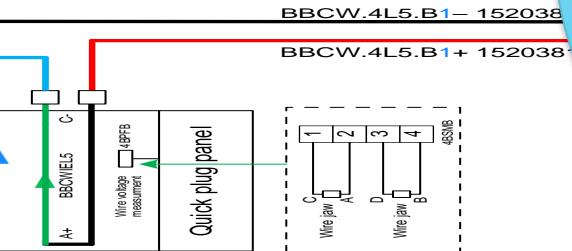
TCTPH.4R5.B2†

(TCTW) DCU 13477



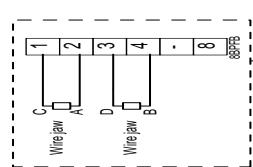
TCTPH.4L5.B1†

(TCTW) DCU 13181



**MYWIC01
(TE/IME)**

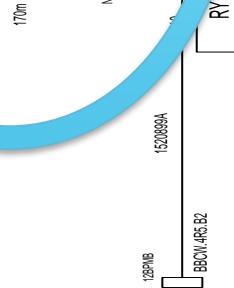
**BY02
(BEBI)**



WIC

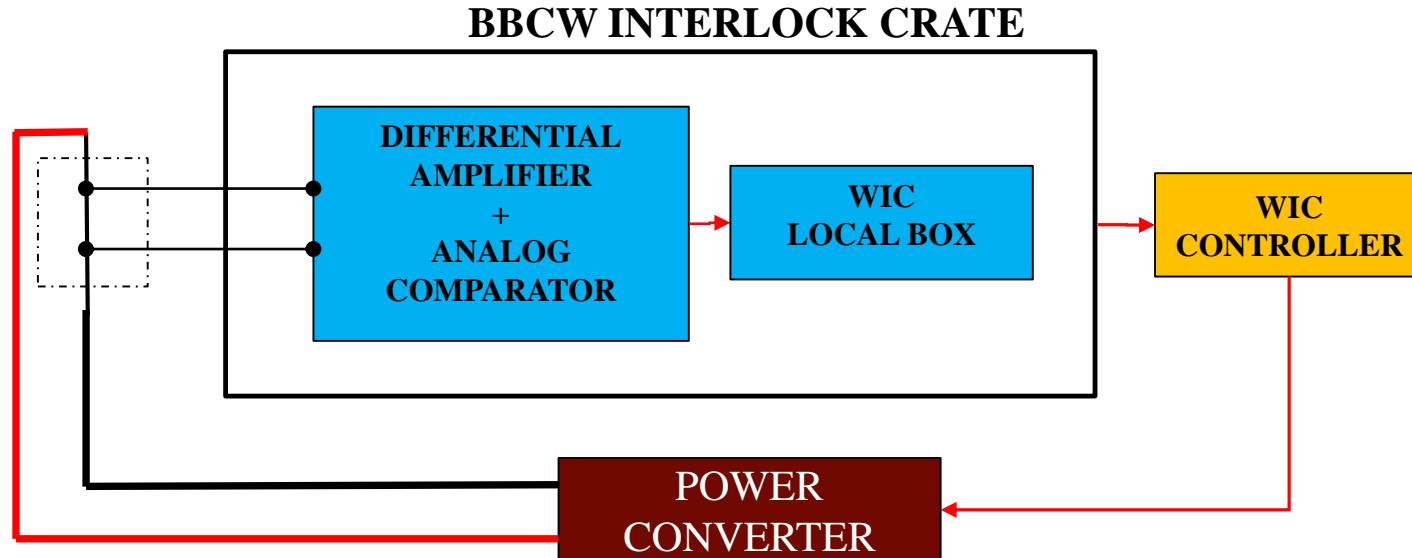
BBLR@CWG 21/09/2020

UL557

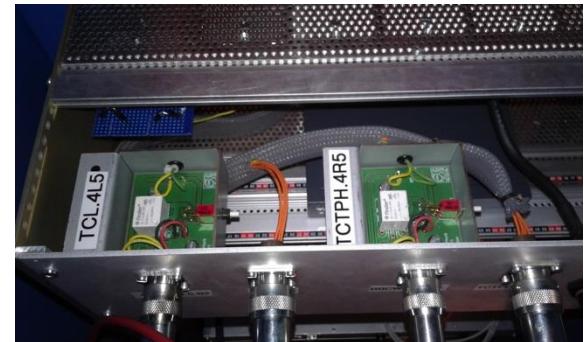


LHC Collimators		REV/E S/N	1 NOMINA	DATE
TCTW collimators IP5	AFTER LS2	APPRO		
		CONTROL	J.Lentato	27/09/2016
		DETERIA	M.DURKA	
		ROSSI	A.ROSSI	
REPLACES				C

BBCW Interlock



- Interlock generated for BIPOLAR current
- THRESHOLD = 2.7V corresponds to
 - +/- 375A cooled (tested)
 - or ~200°C at hottest point on wire when loss of coolant
- FAIL SAFE SYSTEM :
 - Local power supply break
 - Cable removed
 - REDUNDANCY (2 RELAYS) OUTPUT
- Well known basic electronics assembly
- 1 card per wire



Full BBCW commissioning for newly installed

After collimators commissioning and with cooling on

■ **Wire continuity, insulation and polarity**

Before connection

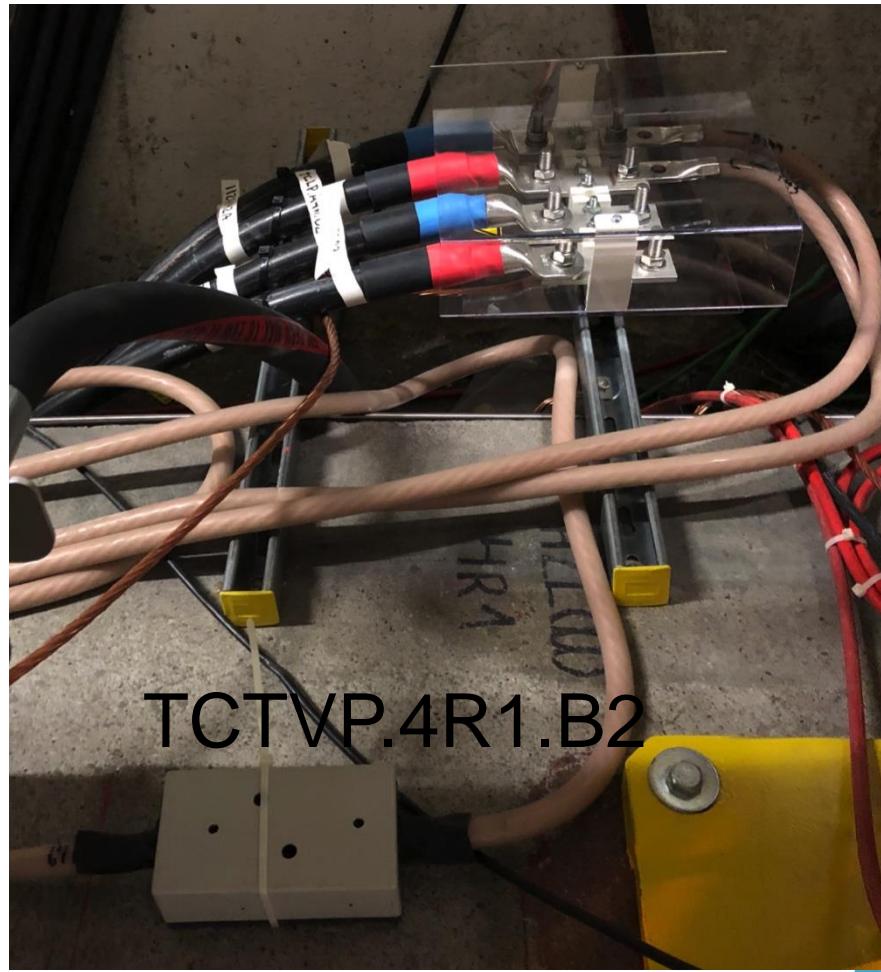
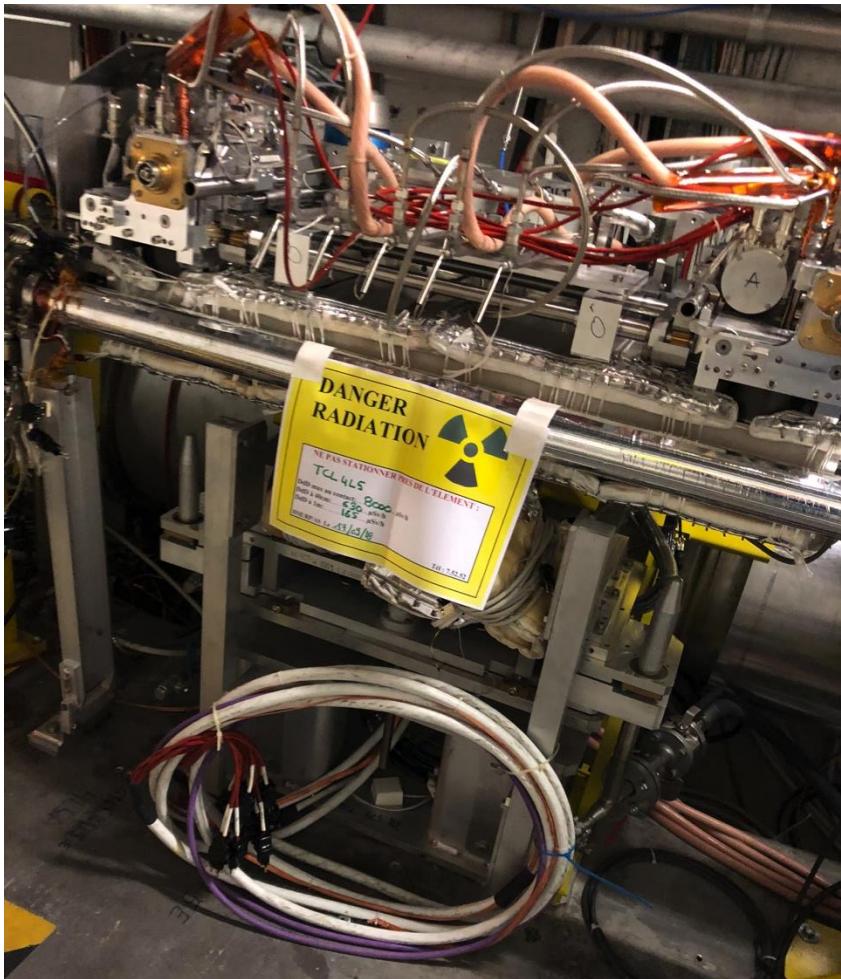
- Set wire interlock threshold to 2.7 V
- Apply 1kV between wire extremities
- Apply 1kV between wire copper core and ground

After connection

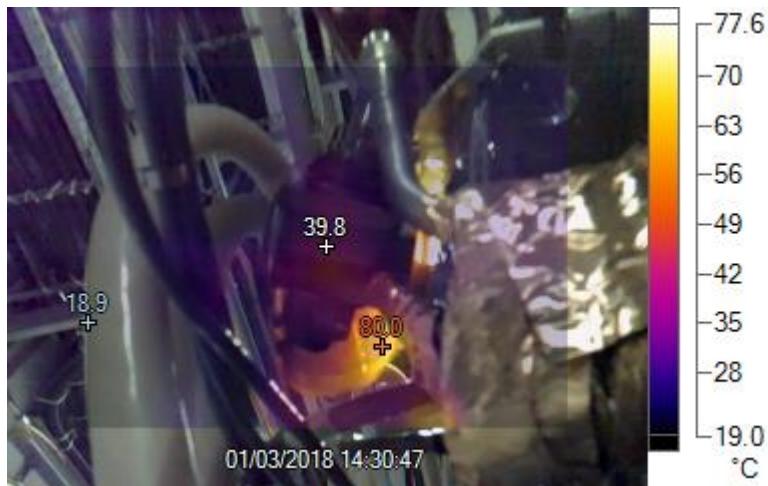
- Unlock power converter and measure/adjust circuit load (TE-EPC)
- Check for wire ground faults at PC
- With low current (+/- 5 A), check wire polarity

■ **Wire collimator sanity (cooling)**

- 350 A on BBCW (=700 A total) for 30-45 min and check
 - Temperature at cable connectors from wire to large power cable should not exceed 60-70 °C after 15 min
 - Collimator jaw temperature should not exceed 35 °C

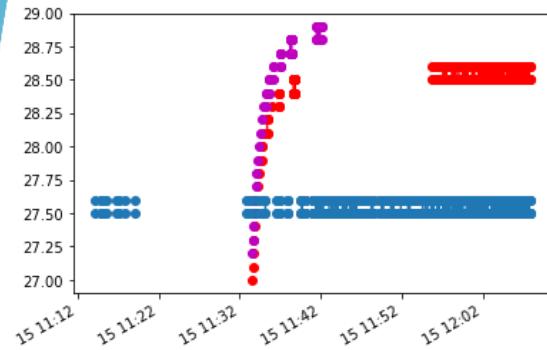


Temperature at cable transitions in IR1

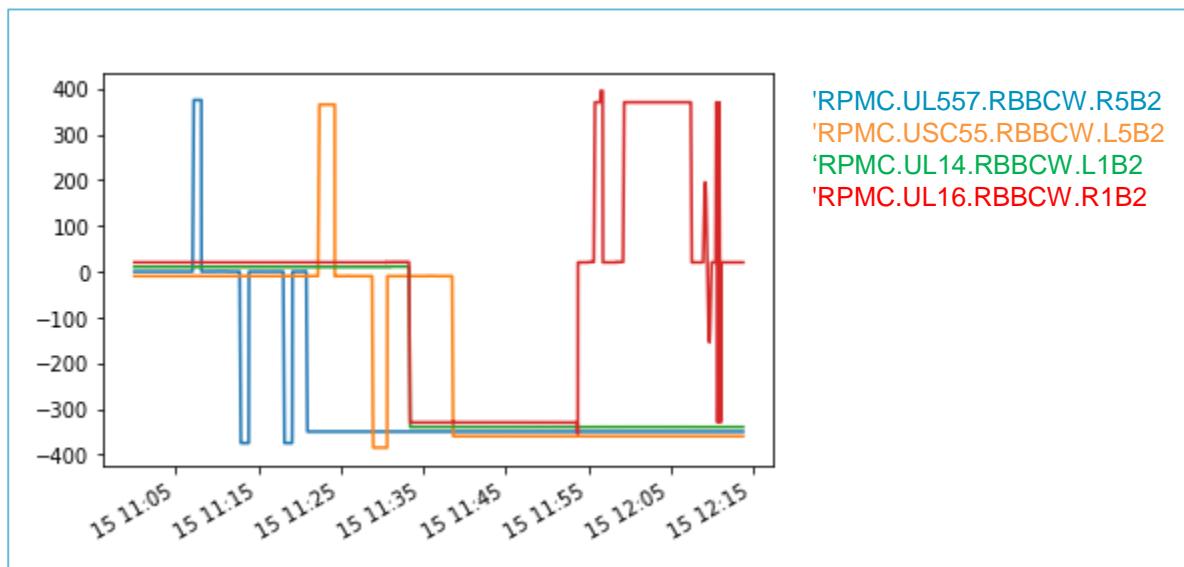
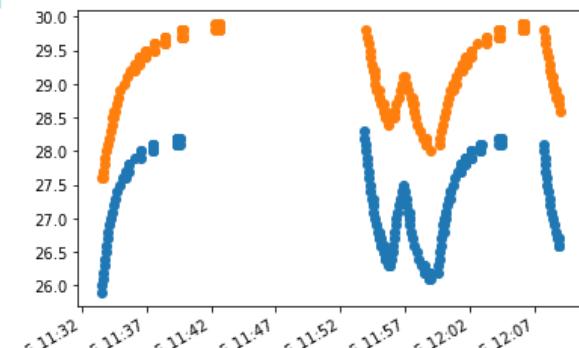


15/03/18 tests: PC current and jaw temperatures

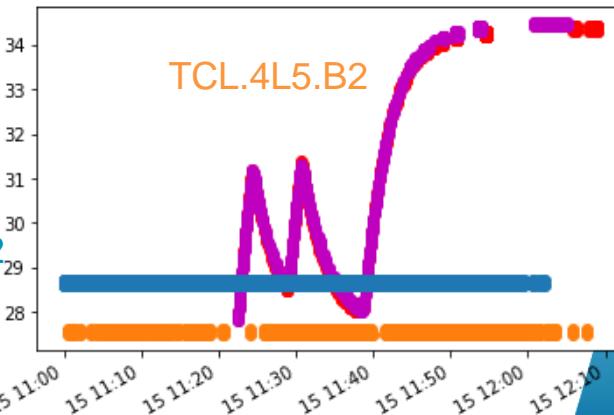
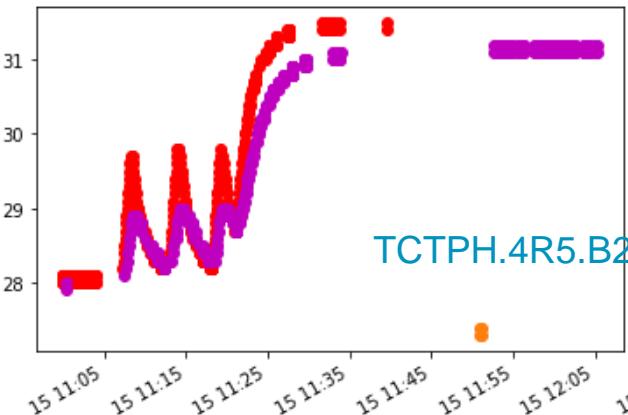
TCLVW.A5L1.B2



TCTPV.4R1.B2



TCTPH.4R5.B2



BBCW commissioning for all collimator

■ Wire interlock

To be performed with Power Converter unlocked and operational

- Wire @ +/- 375 A for ~2 min (max)
 - See Matteo's talk for SW interlocks to mask
 - Wire off, disconnect card (or card chassis) and check that WIC interlock is activated

■ Wire collimator 5th axis

- Move 5th axis to stroke/interlock (EN-STI and EN-SMM)
 - For collimators in IP1, presence in the tunnel required
- Repeat with wire on?

Wire linked failures and interventions required

① Power converters failure → TE-EPC piquet

- Should be easily identifiable from EPC diagnostics

② Wire overheating → EN-STI piquet

- Dedicated card → interlock if wire voltage > preset threshold
- Threshold HW set at the wire control crate
- Interlock immediately (ms) cleared by switching off the wire
- In principle this can only happen in case of loss of collimator coolant

③ Failure of the control card itself → BE-BI

- Interlock will not clear after switching the wire off.
- Needs replacing of the control card

④ Circuit opening → BE-BI + TE-MPE

- Loss of electrical contact at collimator (connector) or damaged cable
- Same as ③ , not cleared after wire switched off, and still present after replacing control card (BE-BI).
- Jumper on WIC interlock to resume operation without wire

TIMBER : voltage at PC, current, WIC for early diagnosis

Tests after intervention and resume of operation

① Power converters failure → TE-EPC piquet

- Will be specified by TE-EPC in commissioning procedure doc
- Resume operation . . .

② Wire overheating → EN-STI piquet

- Will be specified by EN-STI in commissioning procedure doc
- Resume operation . . . case to be analysed

③ Failure of the control card itself → BE-BI

- Card pre-set and pre-tested (probably spare chassis in place)
- After replacement of the card, overheating interlock tested by setting wire current to 375A (as after any shut-down).
- Resume operation **with** wire

④ Circuit opening → BE-BI + TE-MPE

- After replacement of the card **find how to clear WIC interlock and resume operation without wire** + intervention at TS

Power converter failure, FPG and WIC

- There are 4 main reasons to generate POWERING_FAILURE on the FGC2 (which is the one used for the BBCW) and the FGC3 (which is relevant for the RD1s, RD34s and in the future for newer converter installations):
 1. VSFAULT: Voltage source Internal Fault (fast power abort unsafe, over voltage, over current, aux PSU)
 2. VSEXTINTLK: Voltage source External Interlock (water, earth current, equipment stop button)
 3. DCCT faults
 4. FGCFault: which is used for remote testing as asserted from the software as well as the PIC2 tests.
- In the first 3 cases, the signal gets from the voltage source buffers to the FGC FPGA, via a relay to the WIC. Max reaction time = max. 350us (voltage source signal delay) + max. 10us (FPGA processing delay) + max. 3ms (relay reaction time) = **3.36ms**
- In the latter case, it depends on the software and might take from **~8ms** (FGC2, FGC3) to **20/40ms** (FGClite).

M. Zerlauth