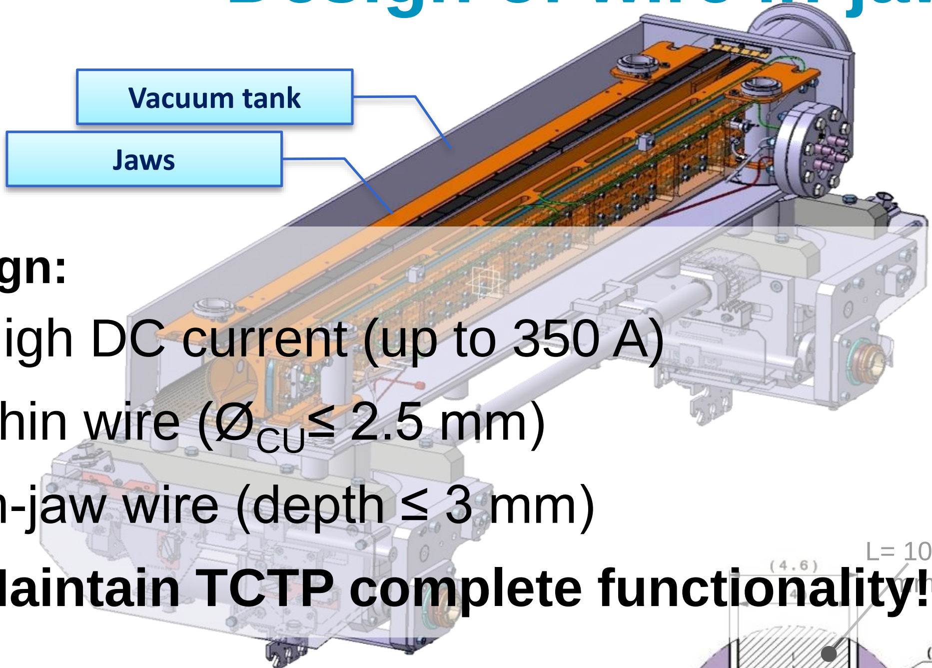
Wire: logic of interlock

A. Rossi on behalf of (alphabetical):

BE-ABP, BE-BI, BE-OP, EN-MME, EN-ACE, EN-STI, TE-EPC, TE-VSC

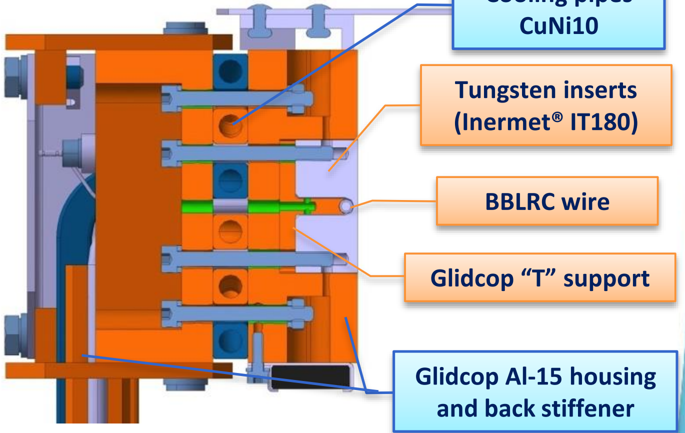
144th MPP meeting, 07 April 2017

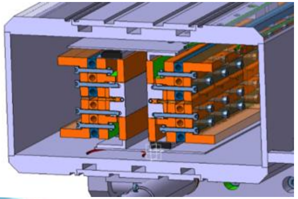
Design of wire in-jaw collimator

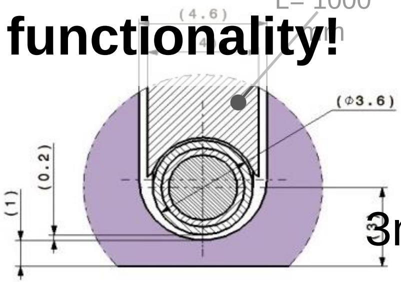


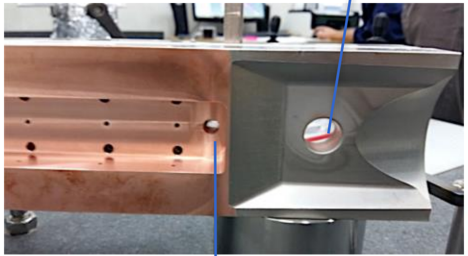
Design:

- High DC current (up to 350 A)
- Thin wire ($\varnothing_{CU} \leq 2.5$ mm)
- In-jaw wire (depth ≤ 3 mm)
- **Maintain TCTP complete functionality!**







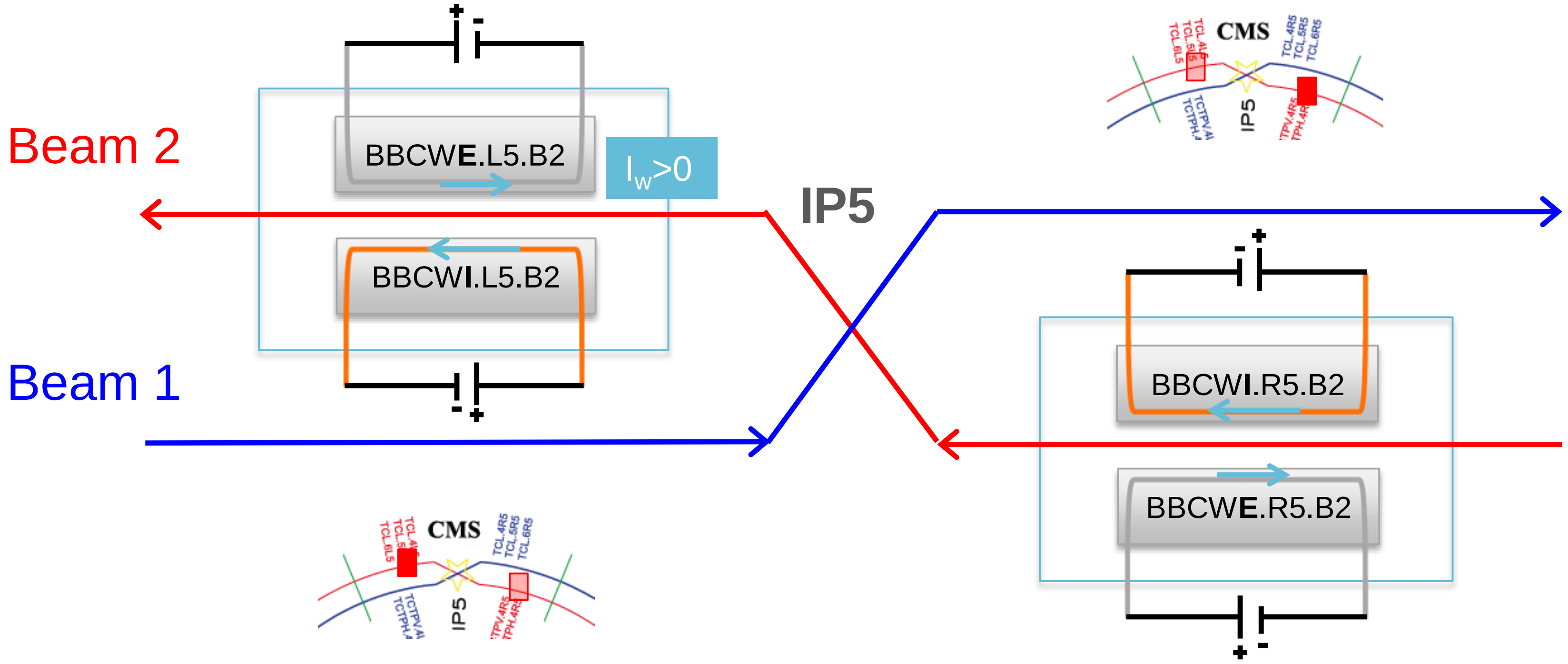


L. Gentini (EN-MME) & O. Aberle (EN-STI)

In-jaw wire collimators installed during EYETS 2016-17

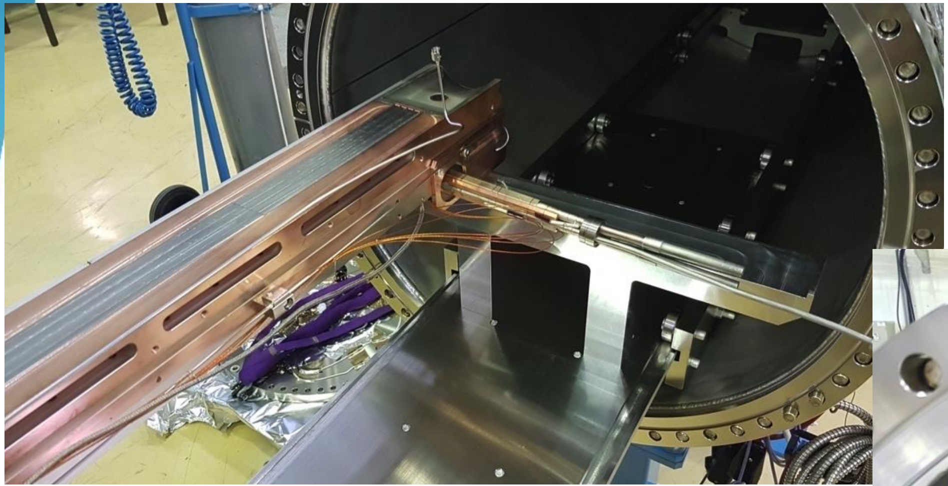
TCL.4L5.B2

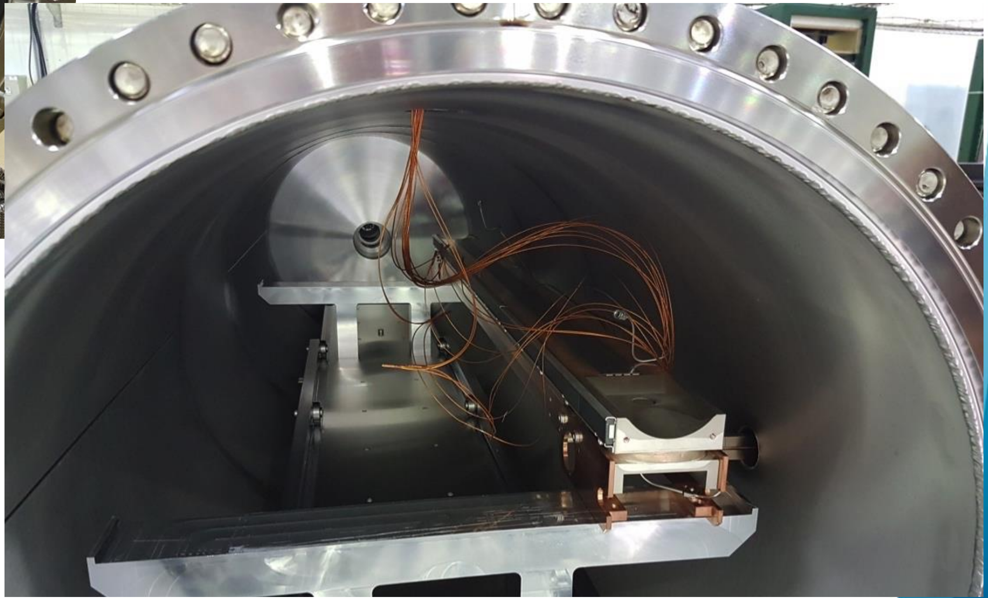
TCTPH.4R5.B2



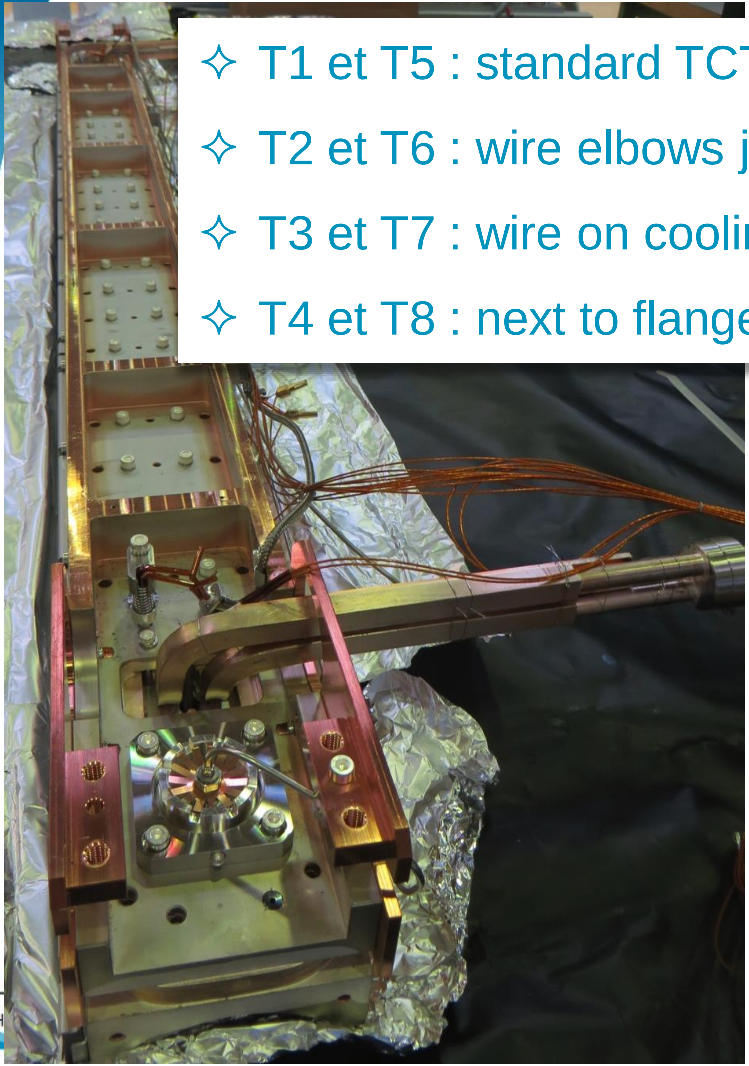
Polarity set for LRBB compensation

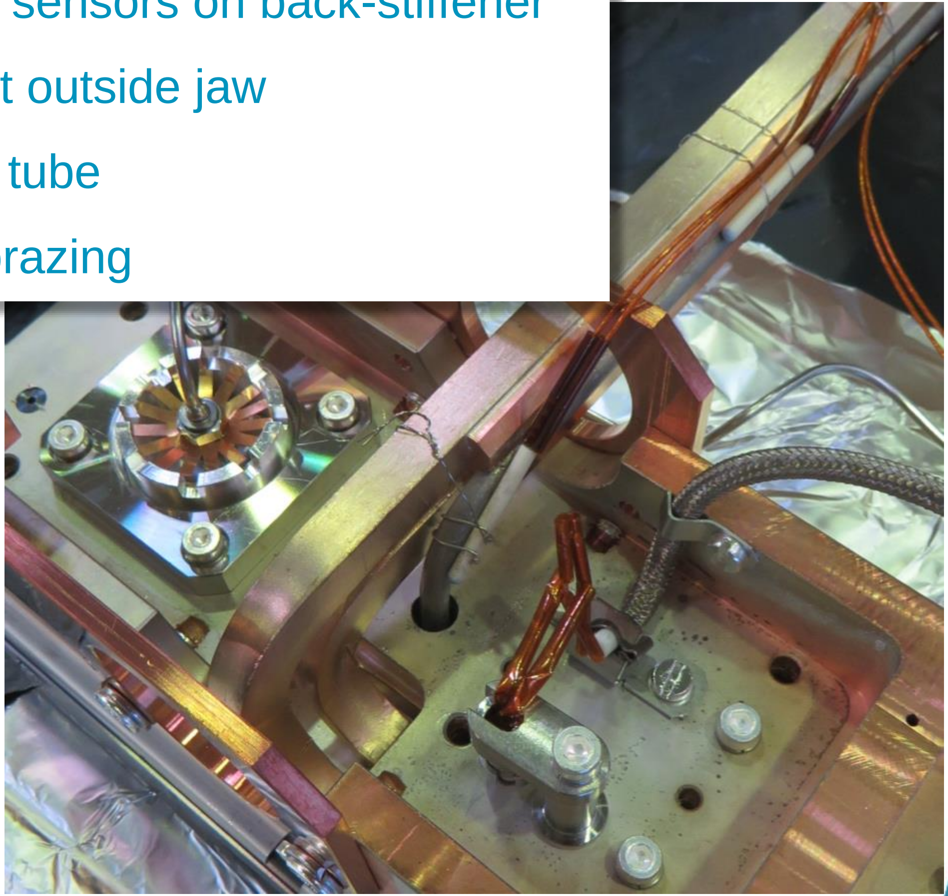
Prototype jaw for lab tests





- $U_w = R_w(T_w) \times I$
- Lab: measure U_w and T_w as f(I)
- Tunnel: Measure U_w to infer T_w

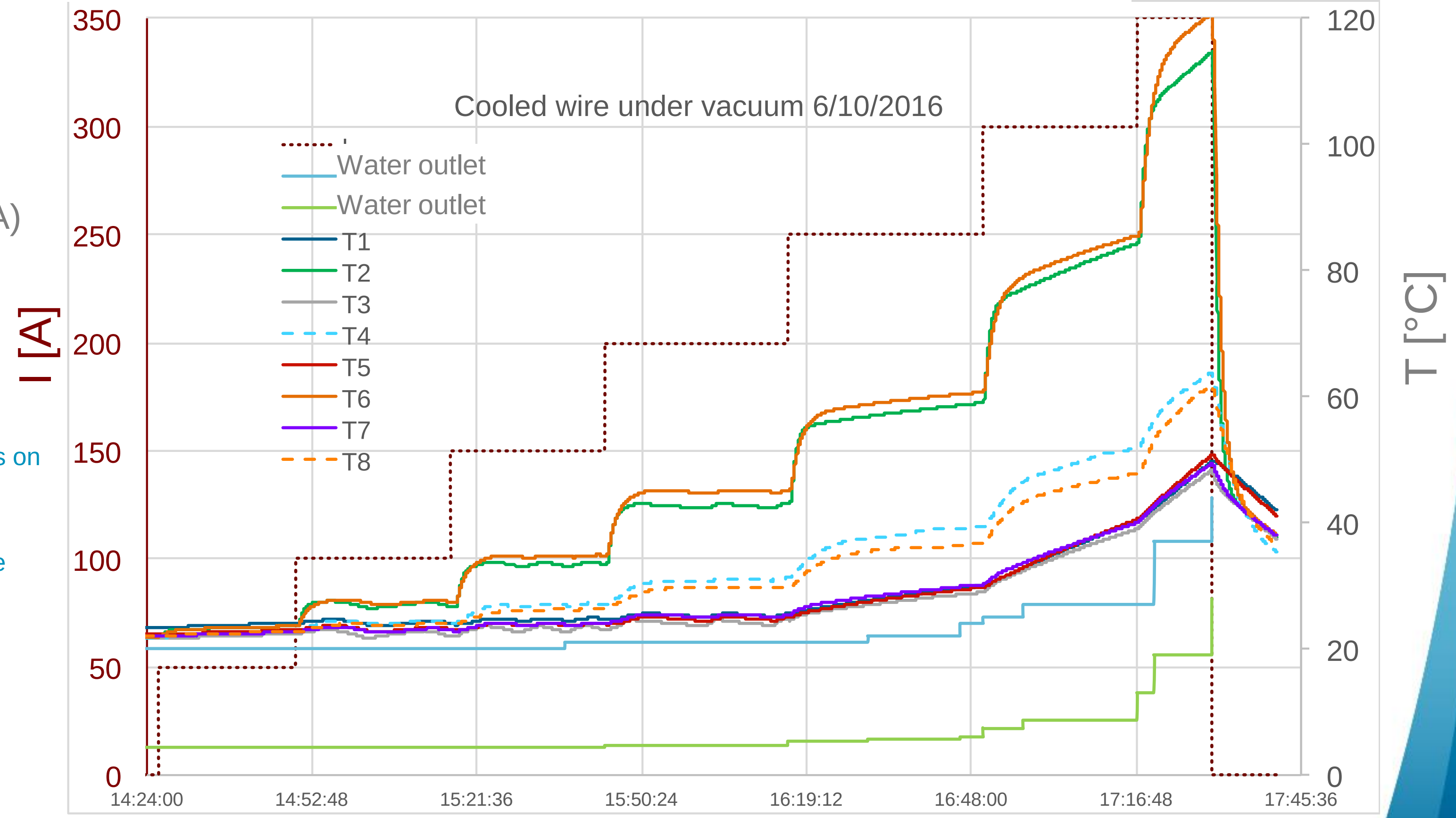




- ✧ T1 et T5 : standard TCTP sensors on back-stiffener
- ✧ T2 et T6 : wire elbows just outside jaw
- ✧ T3 et T7 : wire on cooling tube
- ✧ T4 et T8 : next to flange brazing

Wire current and tension with cooling

Measurements confirmed by simulations (~180°C @ 350A)



−T1 et −T5 :
standard TCTP sensors on back-stiffener

−T2 et −T6 :
wire elbows just outside jaw

−T3 et −T7 :
wire on cooling tube

- -T4 et - -T8 :
next to flange brazing

All temperature at 100A – no cooling

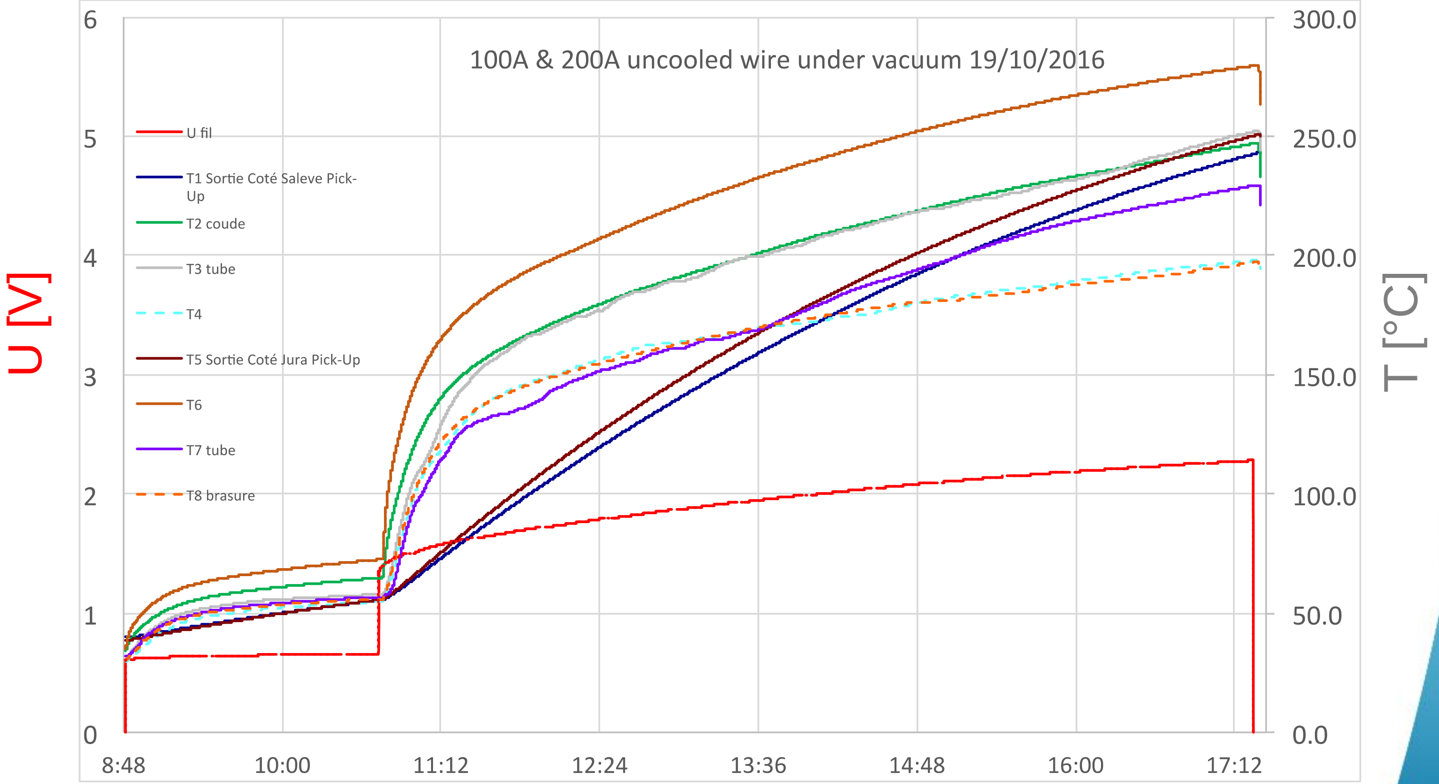
hottest part wire under vacuum, not in contact with jaw

–T1 et –T5 :
standard TCTP sensors on back-stiffener

–T2 et –T6 :
wire elbows just outside jaw

–T3 et –T7 :
wire on cooling tube

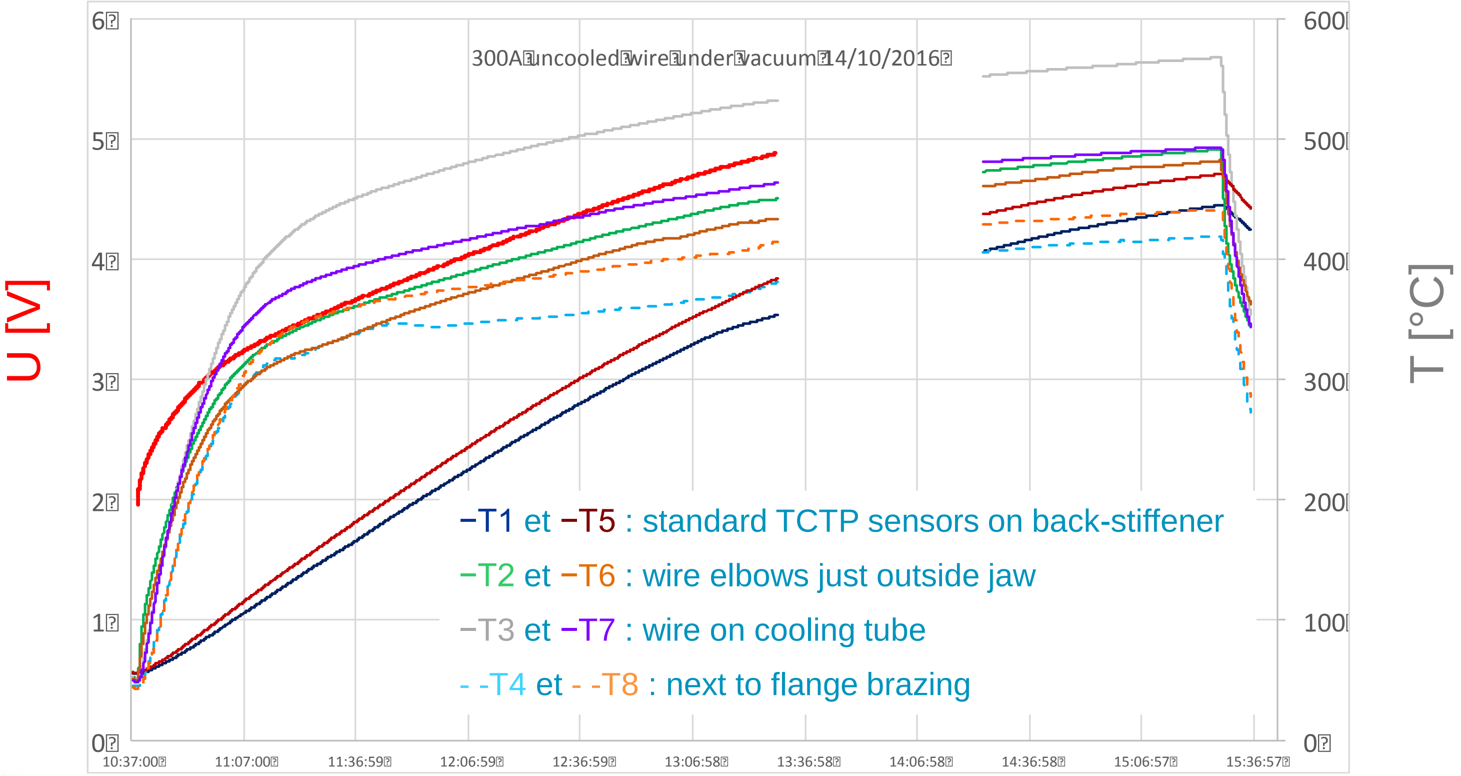
- -T4 et - -T8 :
next to flange brazing



C. Boccard

All temperature at 300A – no cooling

hottest part wire under vacuum, not in contact with jaw



C. Boccard

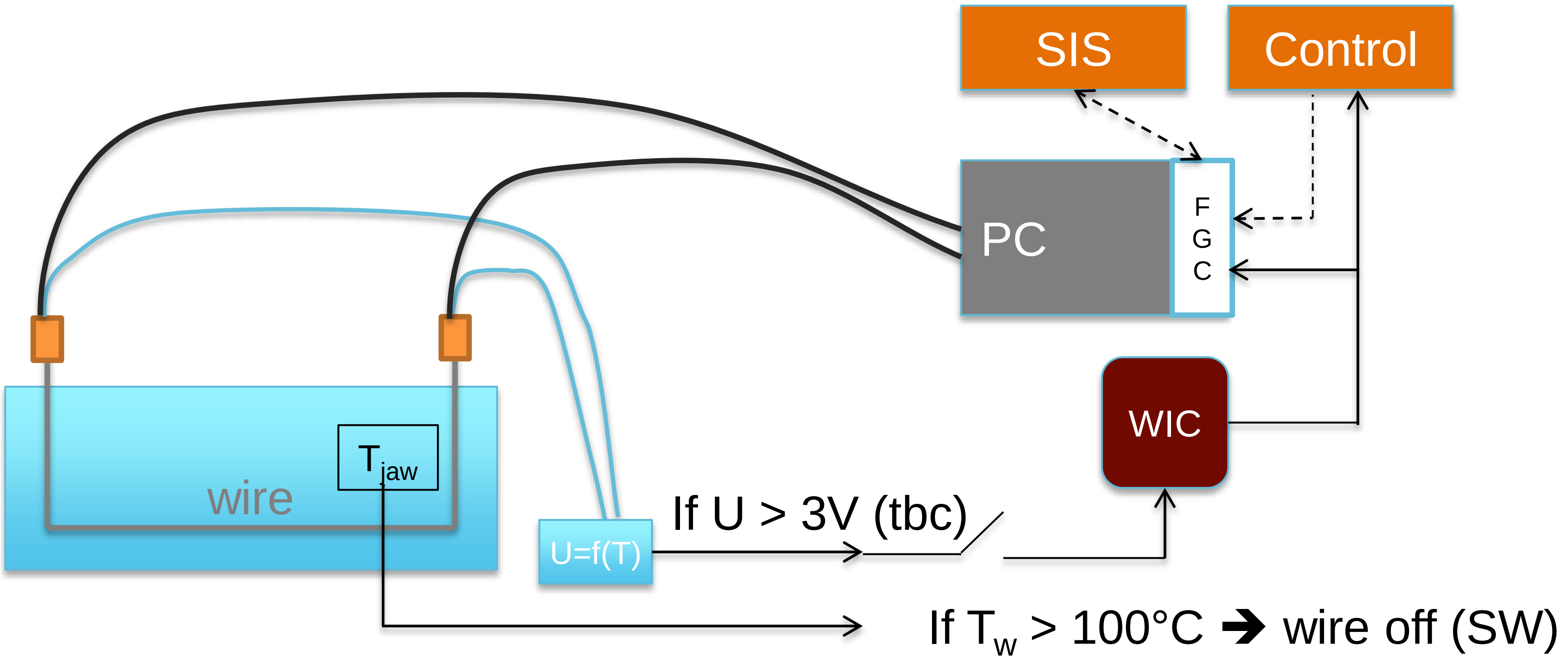
If wire on accidentally during standard LHC operations

- The maximum kick < beam-beam effect, which so far has not caused any machine protection issues
- SIS interlock on the status of the PC

$\Delta r' = -\frac{B_w L_w}{(B\rho)}$	TCT.4R5.B2		TCL.4L5.B2	
$B_w = \frac{\mu_0 I_w}{2\pi r}$	Injection energy	Collision energy	Injection energy	Collision energy
β at collimator (m)	159	2148	79	772
σ (mm)	1.08	1.04	0.76	0.62
collimator setting (σ)	13	9	25	15
r (mm)	17.00	12.38	21.98	12.37
B (T)	3.53E-03	4.85E-03	2.73E-03	4.85E-03
Δr' (μrad) @ 300A	2.61	0.25	2.02	0.25
σ' (μrad)	6.77	0.48	9.61	0.81
ratio Δr'/σ'	0.39	0.51	0.21	0.31

- LHC RunII pp physics – injection, optics 2016
- LHC Run II pp physics – Collision (0.4m), optics 2016

Wire protection and interlocks



Long-range beam-beam wire compensators - Low Level Interlocks

M. Gonzalez

Introduction

- Wires in collimator jaws used to compensate beam effects
- High currents needed
  - Temperature increase
  - Cooling system should compensate up to some point
- Need an interlock for protection
  - V on wire proportional to temperature
  - Set the interlock when V > threshold
  - Failsafe

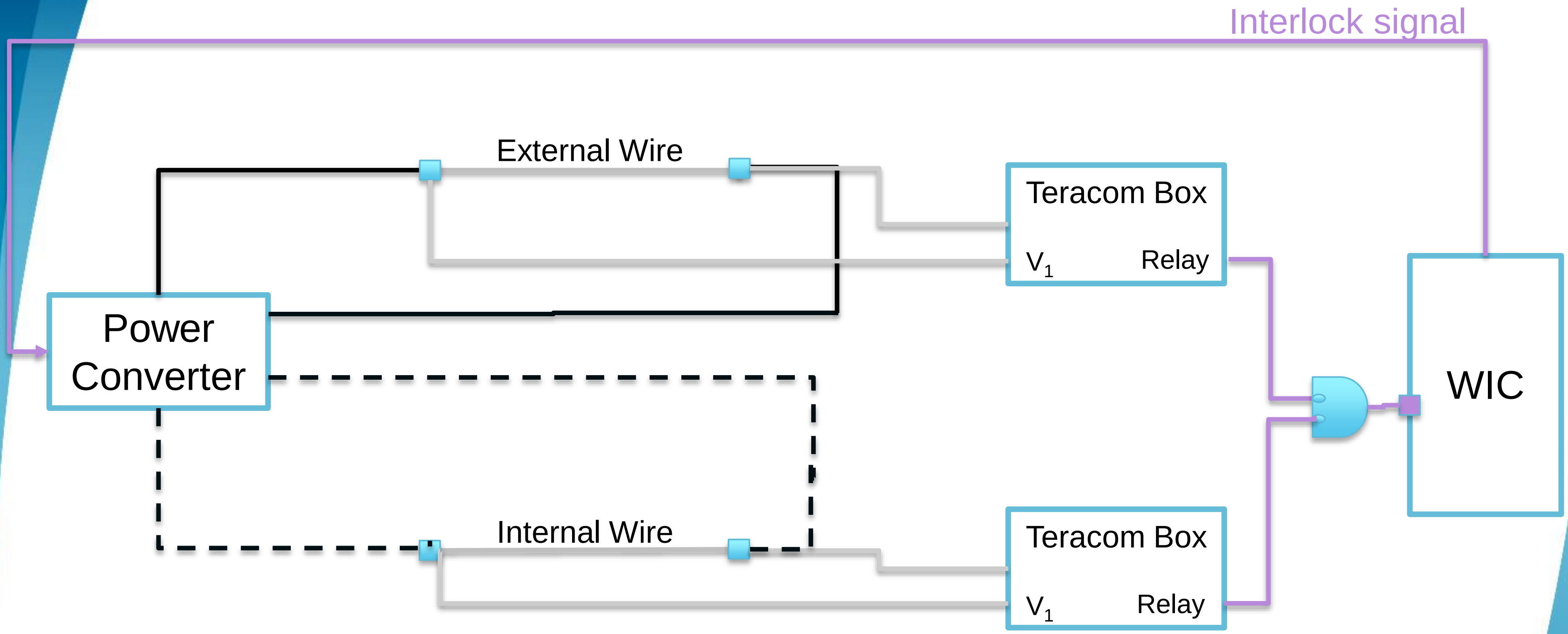
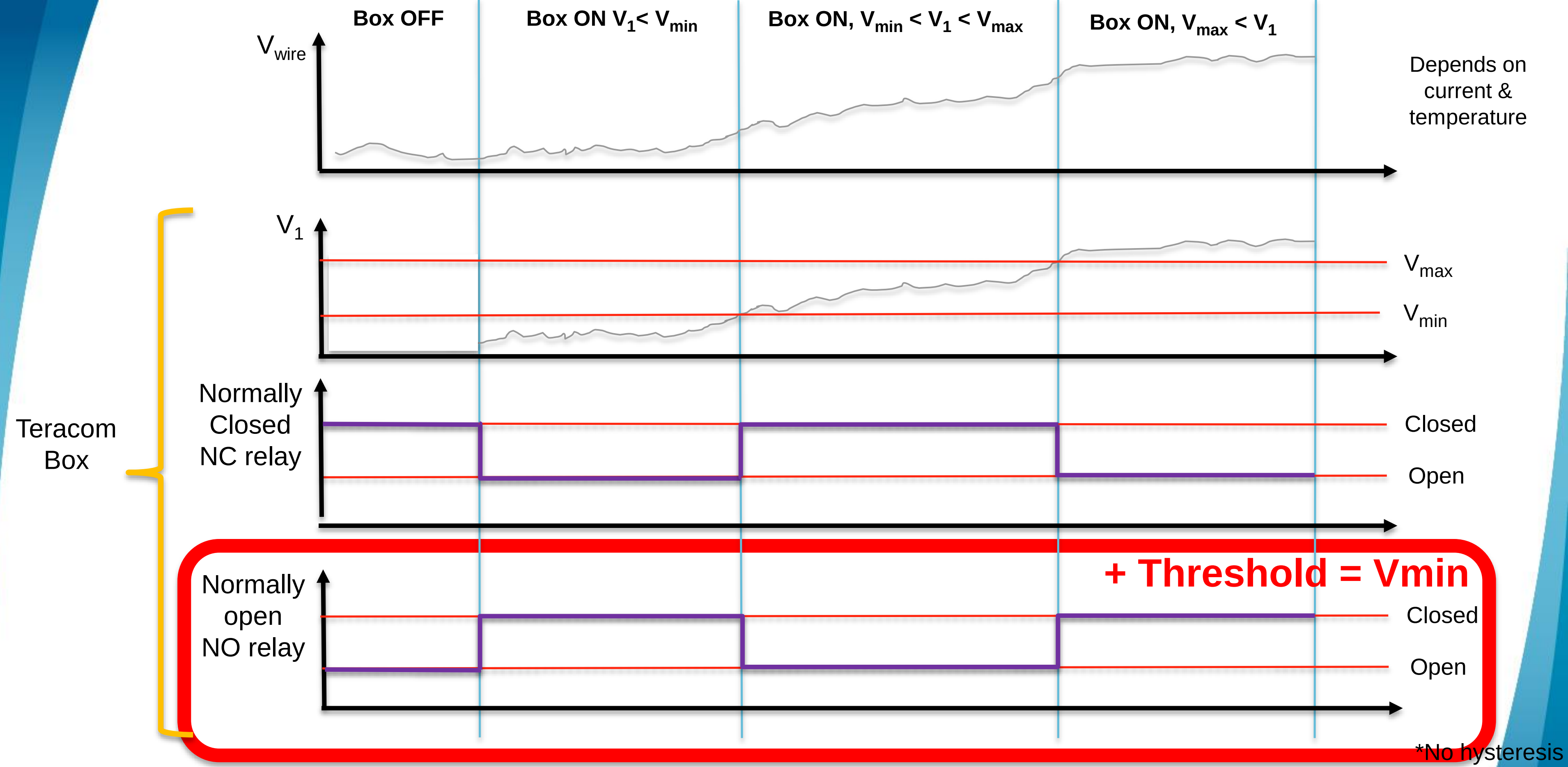


*Diagram represents one of the sides in P5 (L or R)
*The PC can only power one wire at a time (manual switch)



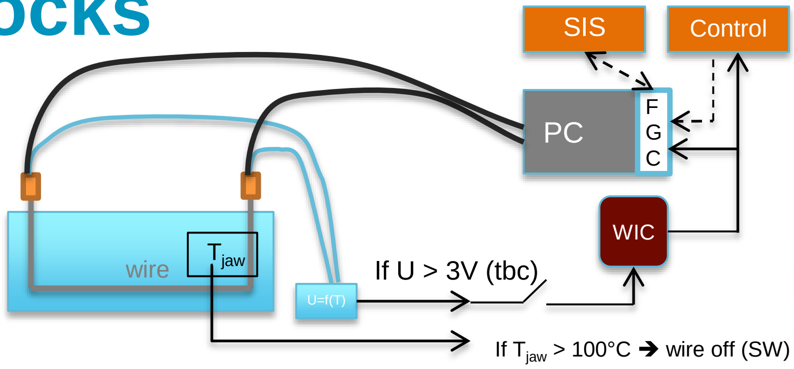
Box OFF
Box ON $V_1 < V_{min}$
Box ON, $V_{min} < V_1 < V_{max}$
Box ON, $V_{max} < V_1$
V_{wire}
Depends on current & temperature
V_1
V_{max}
V_{min}
Teracom Box
Normally Closed NC relay
Closed
Open
Normally open NO relay
+ Threshold = Vmin
Closed
Open
*No hysteresis

Status

- Proposal
  - Use NO contacts
  - Vmin as threshold
  - Vmax to a non-reachable value (max 60V)

  } Failsafe
- Tests @ P5
  - Re-cabled L5 connections to use NO contacts [J. Albertone]
  - Tested successfully on 4th April
    - Wire (BBCWE.L5.B2) + PC (RPMC.USC55.RBBCW.L5B2)
    - PC permit only when U_w < Vmin
    - Box disconnection triggered PC switch off
- Potential Issues?
  - Need to have 2 Teracom boxes active even if only one wire can be used at a time
  - 4 Teracom boxes in the same enclosure (2 left side + 2 right side)
- New requirements
  - Bipolar currents
  - …

Wire protection and interlocks



- U=f(T) unipolar + always ON
- PC polarity set by FGC (SW)
- HW interlocks works for high current
  - SIS interlock to limit $-10 < I_w < 10A$ with beam through REMOVE_PERMIT to PC – to be masked during MD
  - Could add a SIS interlock to restrict to unipolar range throughout the full year (e.g. -10A …. 300A) through REMOVE_PERMIT to PC
  - Optimal: The SIS could read the T_{jaw} and REMOVE_PERMIT to PC if $T_{jaw} > 100°C$
- Wire current with RBAC role to expert only
- MD procedure :
  - Check polarity of PC
  - Check sanity of box (Vmin = 0)
  - Display all relevant signals in the CCC throughout the MD (PC current, temperatures, box reading….)

HiLumi HL-LHC PROJECT

For a mid/long-term solution (from Markus)

- We need a bipolar measuring unit, which is isolated from the measurement on the wire. Introducing a ground through the measurement device not only limits bipolar use, but bears a considerable risk if you have shorts and the power converter ground fuse blows, in which case your device will get the full current from the converter.... Is it too late to add a simple isolation amplifier before the box?

- A PLC based solution or even using a (differently) programmed quench detector (which are built for exactly such purpose) might be something worth looking into?
  Seems to me too much

Hardware readiness

- Wire tests on the surface
  - Collimator under pumping (after bake-out) and with cooling on:
    - LVDTs reading when wire @ 350A : no sensitivity observed
    - Pressure when wire @ 350A : ~ 10^{-8} mbar
    - Jaw temperature < 50°C
    - Wire temperature outside collimator tank ~300°C after thermal bridge adjusted
- Both collimators installed + bake-out + standard commissioning completed
- Wire HW tests + HW interlock completed
    - LVDTs reading when wire @ 350A : no sensitivity observed
    - Pressure when wire @ 350A + cooling < few 10^{-10} mbar
    - Jaws moved with wire @ 350A
    - Temperature increase of the jaw < few degrees
    - Temperature of wire outside jaw ~ 150-170°C
    - WIC ok
    - NO interlock on WIC ok
  - Detailed presentation at CWG on 8th of May.
- Control system to be completed and commissioned

Thank you for your attention

and thank you to all contributors

Possibly not all :

BE-ABP: S.Redaelli, Y.Papaphilippou, S.Fartoukh, G.Sterbini . . .

BE-BI: H.Schmickler, J.Albertone, C.Boccard, M.Gonzalez Berges, R.Jones . . .

BE-OP: M.Pojer . . .

EN-MME: A. Bertarelli, A. Dallocchio, M. Garlasche, L.Gentini, F.Carra . . .

EN-STI: O.Aberle; I.Lamas Garcia; J.Lendaro; M.Di Castro . . .

EN-ACE: D.Tortrat, JF.Fuchs . . .

TE-EPC V.Montabonnet, C.Coupat, L.Ceccone, M.Magrans de Abril, Q.King . . .

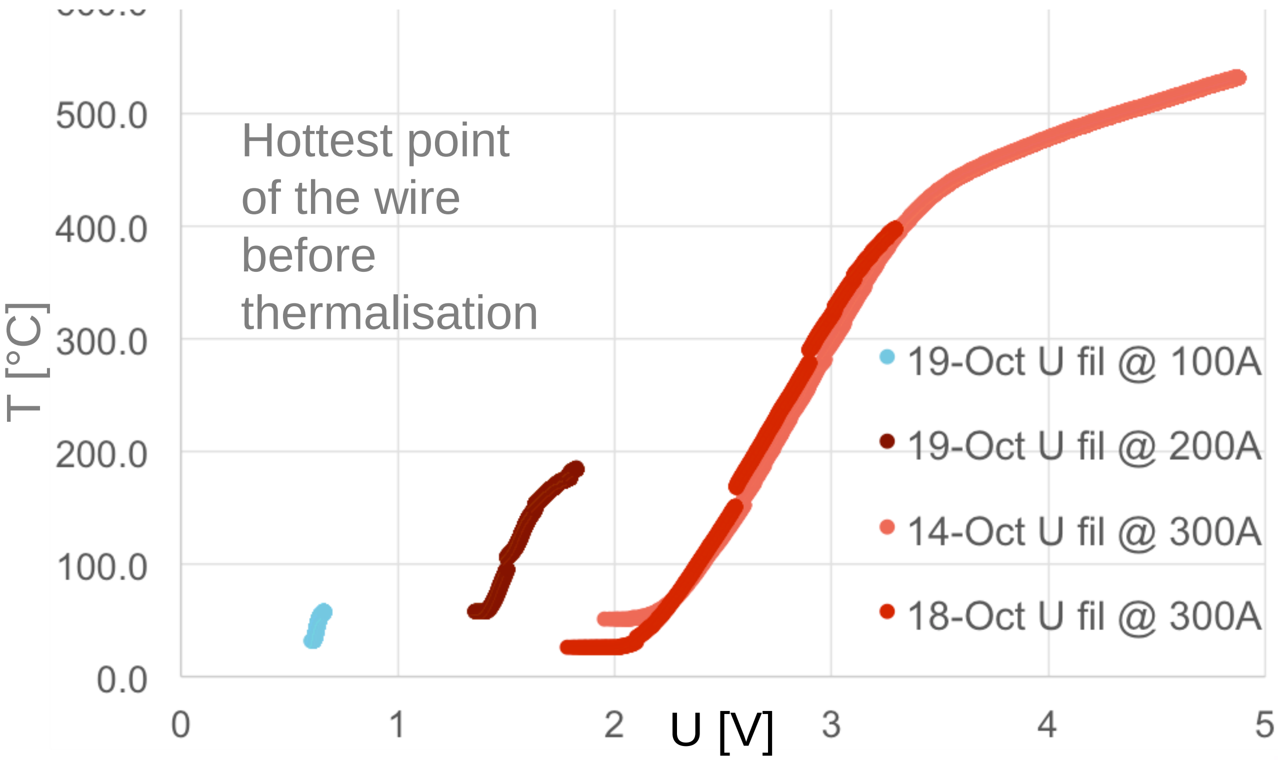
TE-MPE: R.Mompo, D.Wollmann, M.Zerlauth, J.Uythoven

TE-VSC: G.Cattaneoz, G.Bregliozzi . . .

Wire temperature and tension without cooling

U	=	R @ 50°C	x	I
0.63	=	6.30E-03	x	100
1.26	=	6.30E-03	x	200
1.89	=	6.30E-03	x	300

U	=	R @ 200°C	x	I
0.98	=	9.80E-03	x	100
1.96	=	9.80E-03	x	200
2.70	=	9.00E-03	x	300



By limiting the wire tension we avoid overheating in case of loss of cooling