BBWC scenarios in Run 3 in view of HL-LHC

G. Sterbini on behalf of the wire team

A. Poyet, K. Skoufaris, A. Rossi, S. Kostoglou, S. Fartoukh, Y. Papaphilippou, H. Bartosik, P. Belanger, O. Kester, D. Kaltchev, M. Marchetto, A. Bertarelli, L. Gentini, J. Wenninger, M. Solfaroli, D. Jaquet, COLL team

7 June 2022, EVENT 1167566

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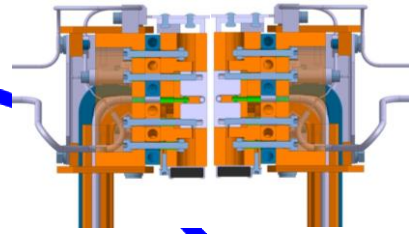
Present status in LHC: B1 got wires!

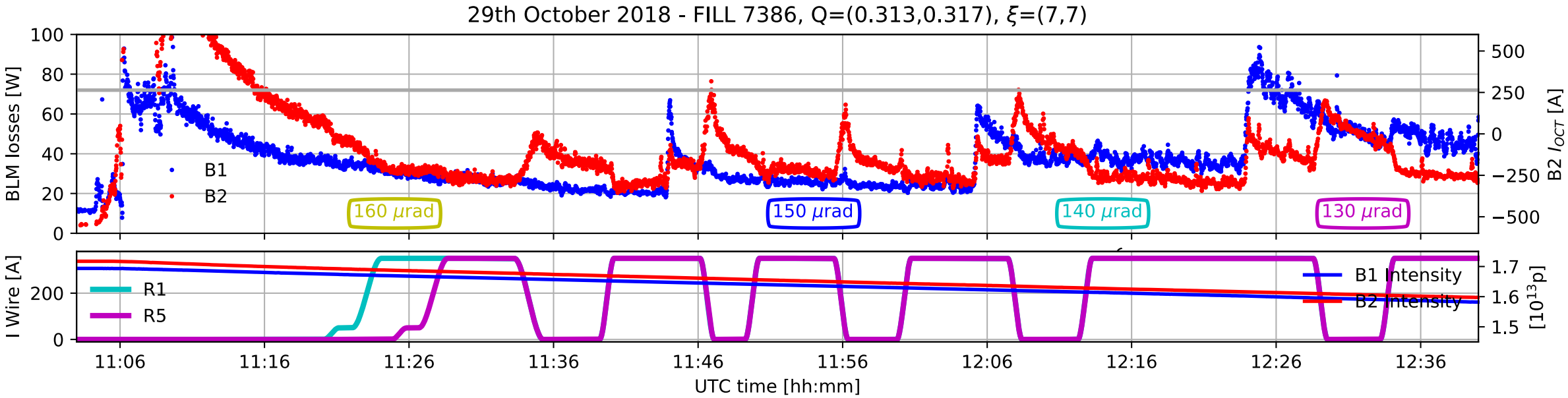
After Run 2, it was proposed

- **to use the wires (2-jaws powered) routinely** during the Run 3 operation
- 2 out of 4 wire demonstrators (L1 and L5) were moved from Beam 2 to Beam 1.
- AIM: **best use of the demonstrators hardware** to acquire *operational experience* (integration of the wire in the cycle) and (moderate) *reduction of beam losses*.
- 2-jaws powered configuration



What we expect with BBCW during R3?

- To reproduce Run 2 MD reduction of losses and of crossing-angle at constant loss rate.
  - **Run 2: B2 → Run 3: B1+B2**
  - **Run 2: MD → Run 3: operational configuration: beam-wire distance defined by TCT settings!**

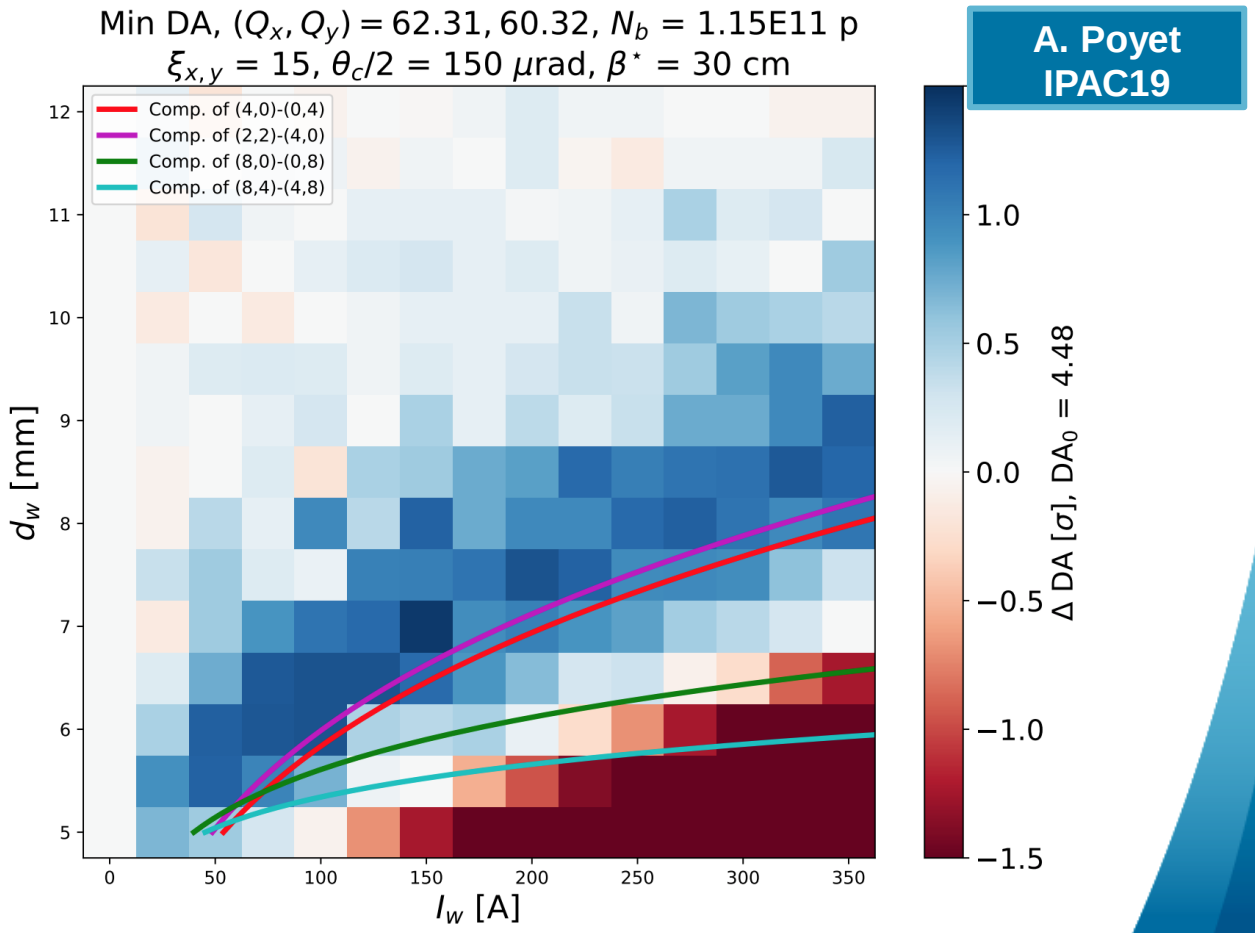


Optimal wire distance/current settings

References to define the wires settings (s-position, wire current and wire distance):

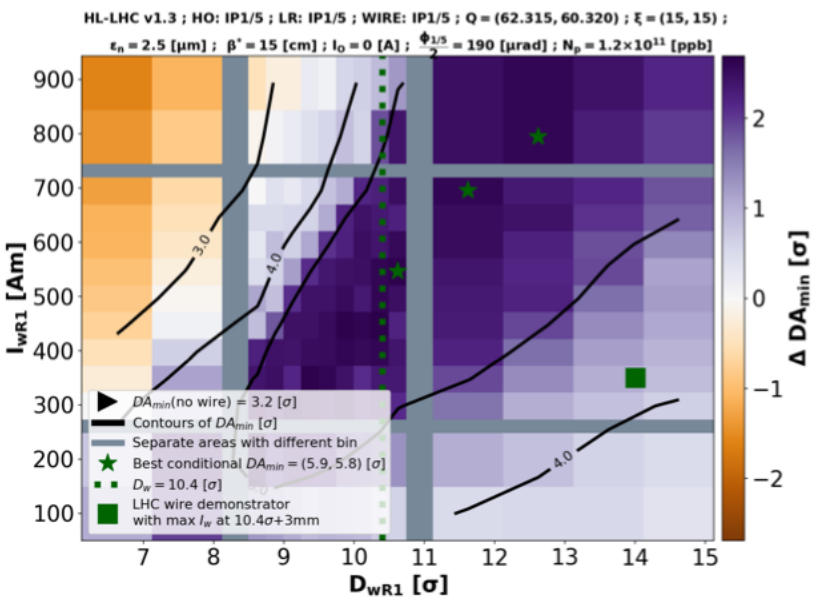
- [1] J.-P. Koutchouk, 2000
- [2] S. Fartoukh, 2015 → approach followed for the LHC MDs and for space reservation in HL-LHC
- [3] D. Kaltchev, 2019

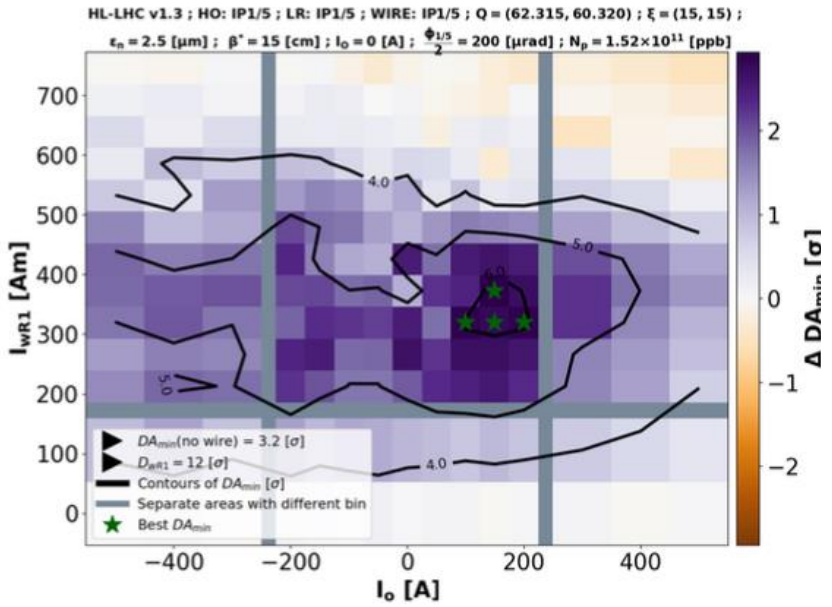
- Numerical simulations and experimental results for **round optics in RUN 2** show that there not single sweet points but a "sweet regions" for compensation (octupolar contribution).

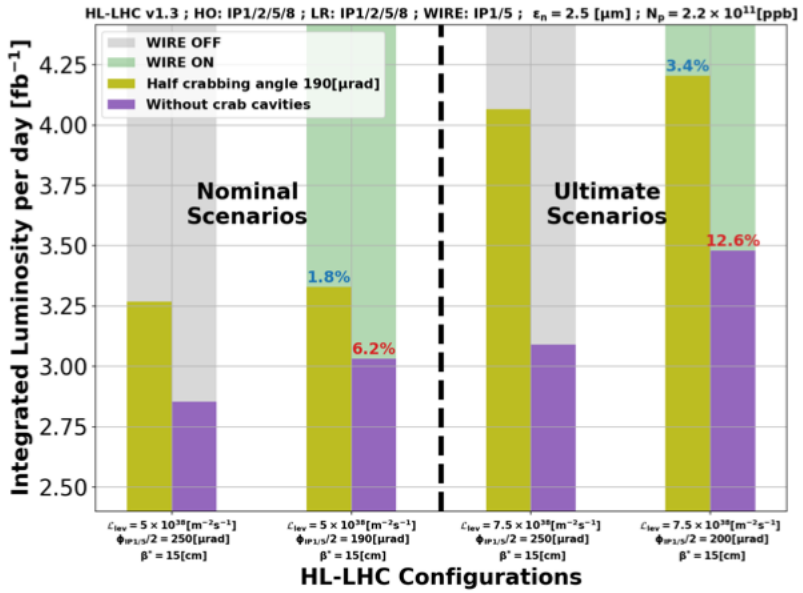


HL-LHC wire compensation

K. Skoufaris, 2021







- This was confirmed by Kyriacos's studies for **HL-LHC round optics**, opening the way to a technical implementation of the wire in the HL
- In the meantime:
  - TRIUMF is exploring an in-kind contribution to the HL wire
  - Satellite workshop at HL CM as preparation for a technical review if confirmed with the management.

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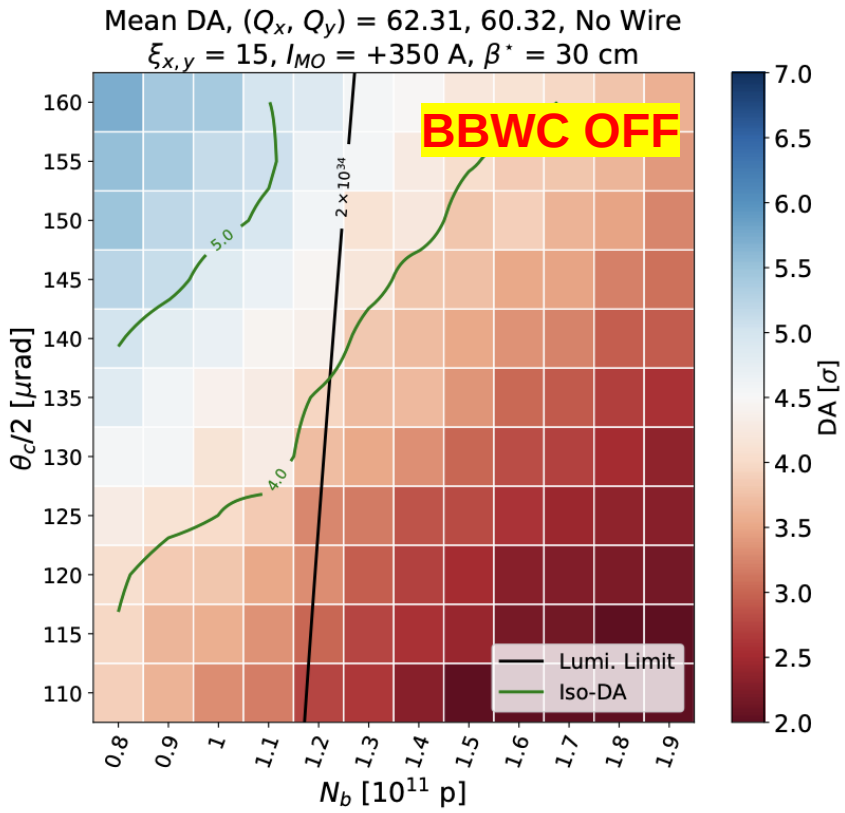
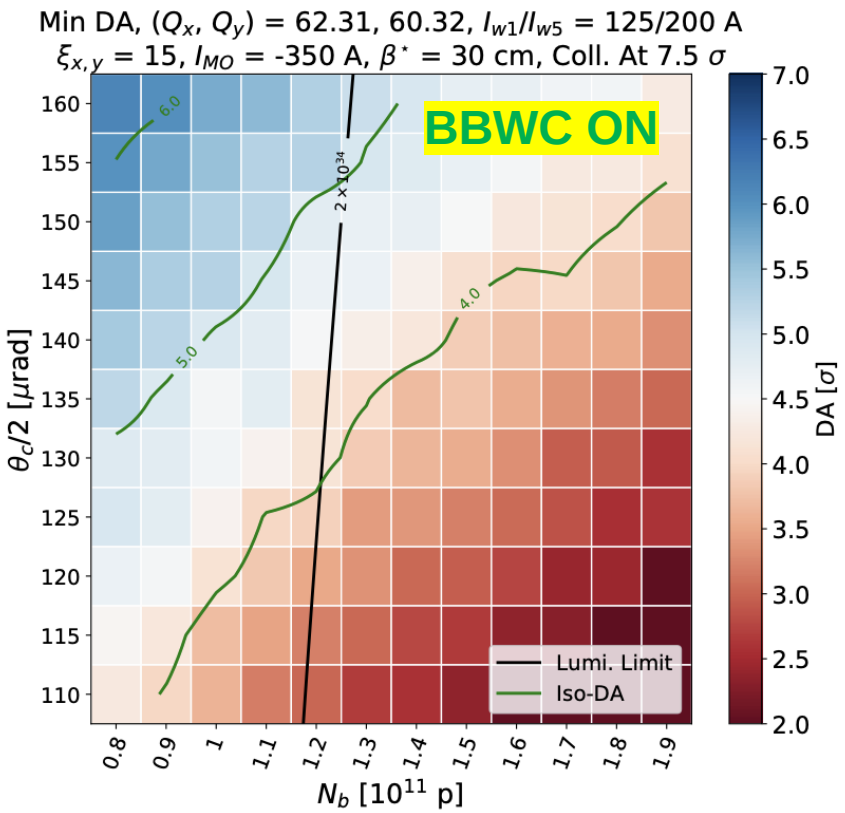
Run 3 numerical simulation

A. Poyet
IPAC21





- Simulations (and B2 observations in the 2018 MD) show that it will be difficult to gain more than ~10 μrad in the crossing angle at the EoL in Run3 (we focused on the 2022 Run).

Main targets in our view

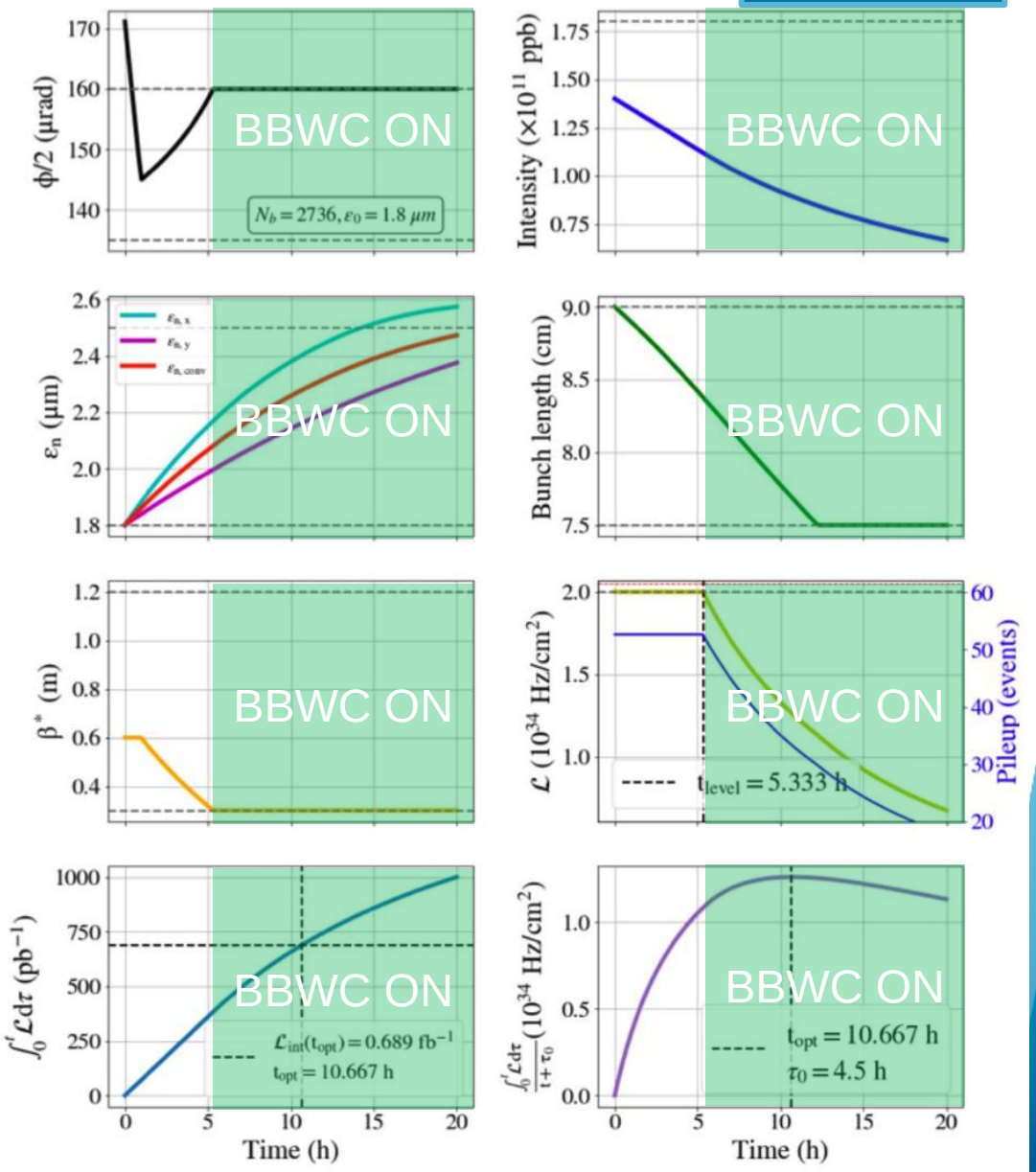
- Show that the 4 wires presently installed in the LHC can be smoothly integrated (**MP**) and used in operation (**BE-OP**) and confirm the Run 2 experimental results in Run 3 (for B1 and B2).

  → Wires ON at the EoL (Iw = 350 A).

RUN 3 2022: BBCW ON at the EoL

S. Kostoglou, Evian 21

- EoL ~5 h from the start of stable beams→ Nb ~ 1.15e11 ppb
- E = 6.8 TeV, β* = 30 cm (tele-index 2)
- $\phi_c/2$ = 160 μrad (IP1 vertical, IP5 horizontal)
- TCT at 8.5 σ@3.5 μm (for β∗= 30 cm)
- Wires (V in IR1 and H in IR5) at
  - 9.2 mm in IR1 for B1 (tctpv.4l1.b1) and B2 (tctpv.4r1.b2)
  - 12.4 mm in IR5 for B1 (tctph.4l1.b1) and B2 (tctph.4r1.b2)



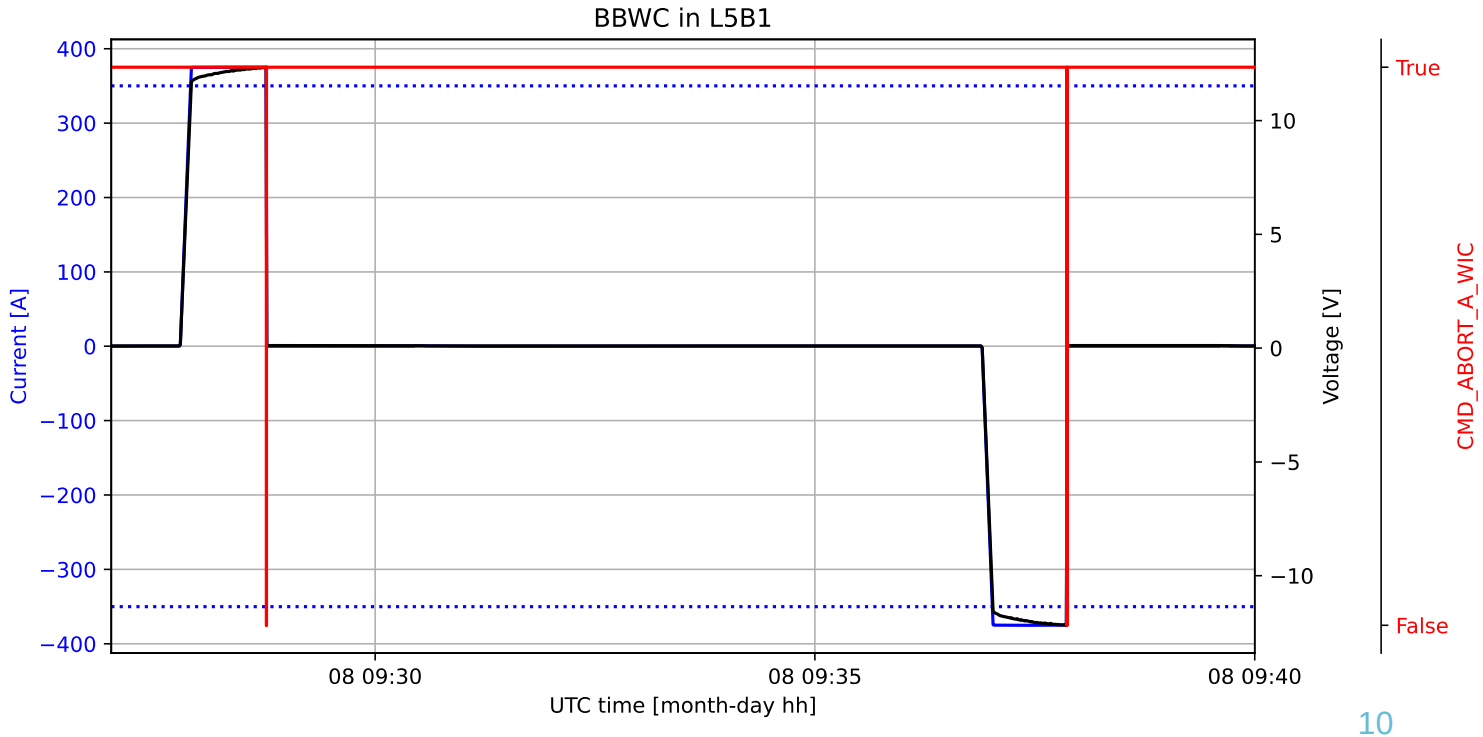
Present status for Run 3

RUN 3: BBWC interlocks (EDMS 2384198)

MPP April 29th, 2022

- WIC to protect the wire overheating (one WIC per TCT wire)
  - Trigger **BIS** (B1/2) and PC OFF in external fault (~1.2 s delay).
- Internal faults of the 4 wires PCs to protect the machine
  - Trigger **BIS** (B1/2) (~1 ms delay).
- **(FGC** settings: allows only -350 A < I < 350 A on the wires)

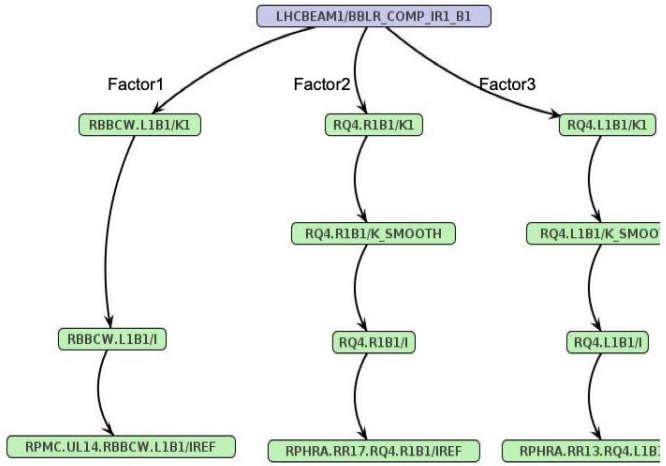
All wires WICs successfully tested during HW commissioning (April 8th, 2022)



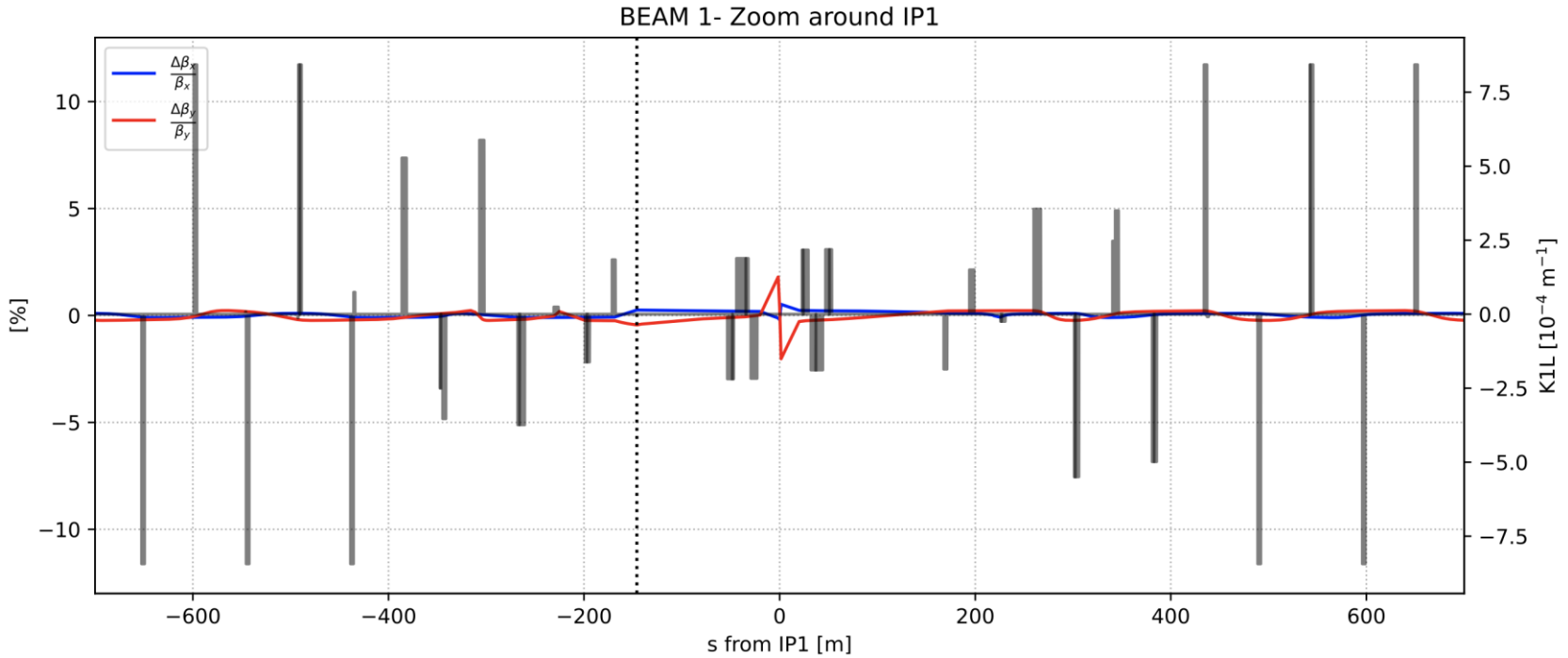
RUN 3: SIS and BBLR

LBOC March 1st, 2022

- **SIS**: window of 0-350 A for the wire current when the wire is used
- **SIS**: PCInterlock system to be open on quads ref to allow the Q-feedforward trim



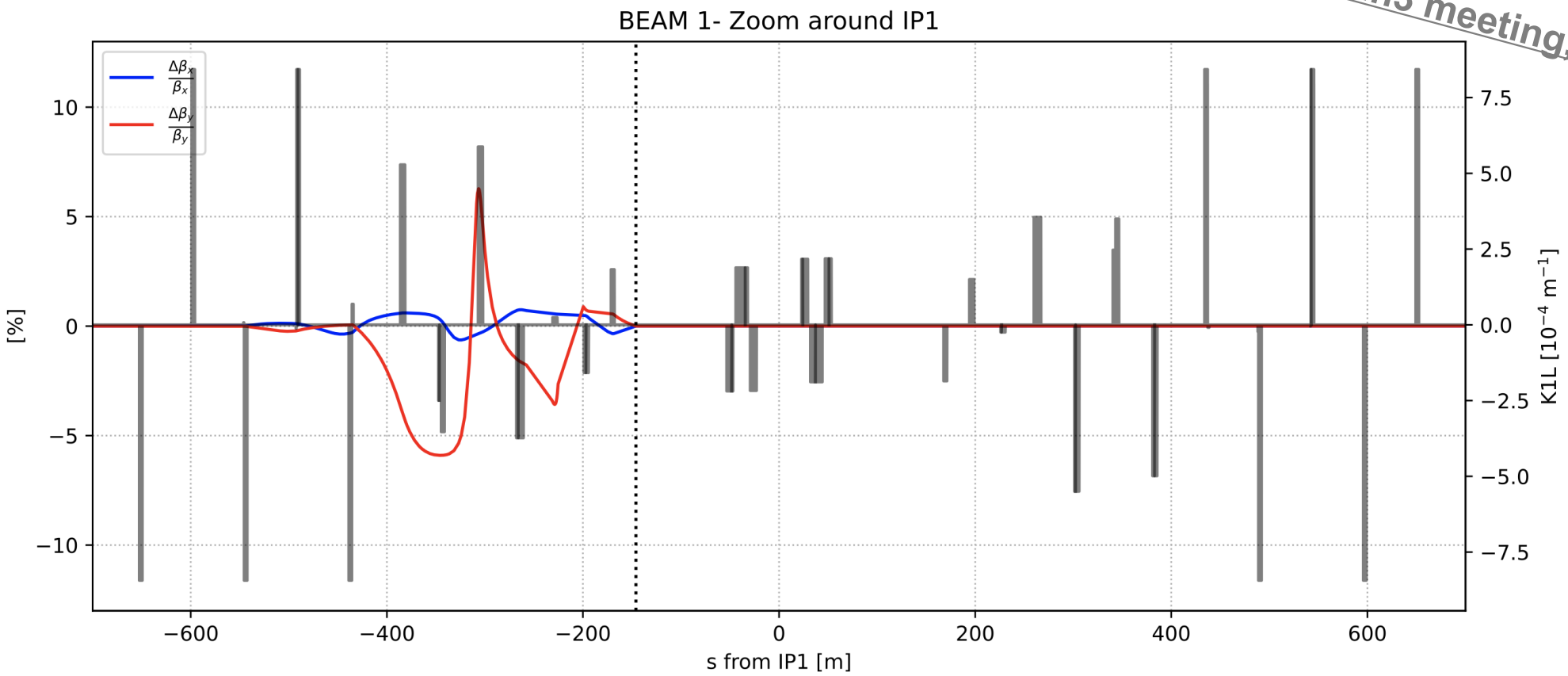
D. Jacquet, LBOC #135



Using the Q4L/R correct the tune but not (fully) the induced beta-beating:
→ minor effect on luminosity (<0.1%)
→ Impact on Forward Physics (<2% effect on the transfer matrices elements)

RUN 3: SIS and BBLR

LHC Run3 meeting, 8 April 2022

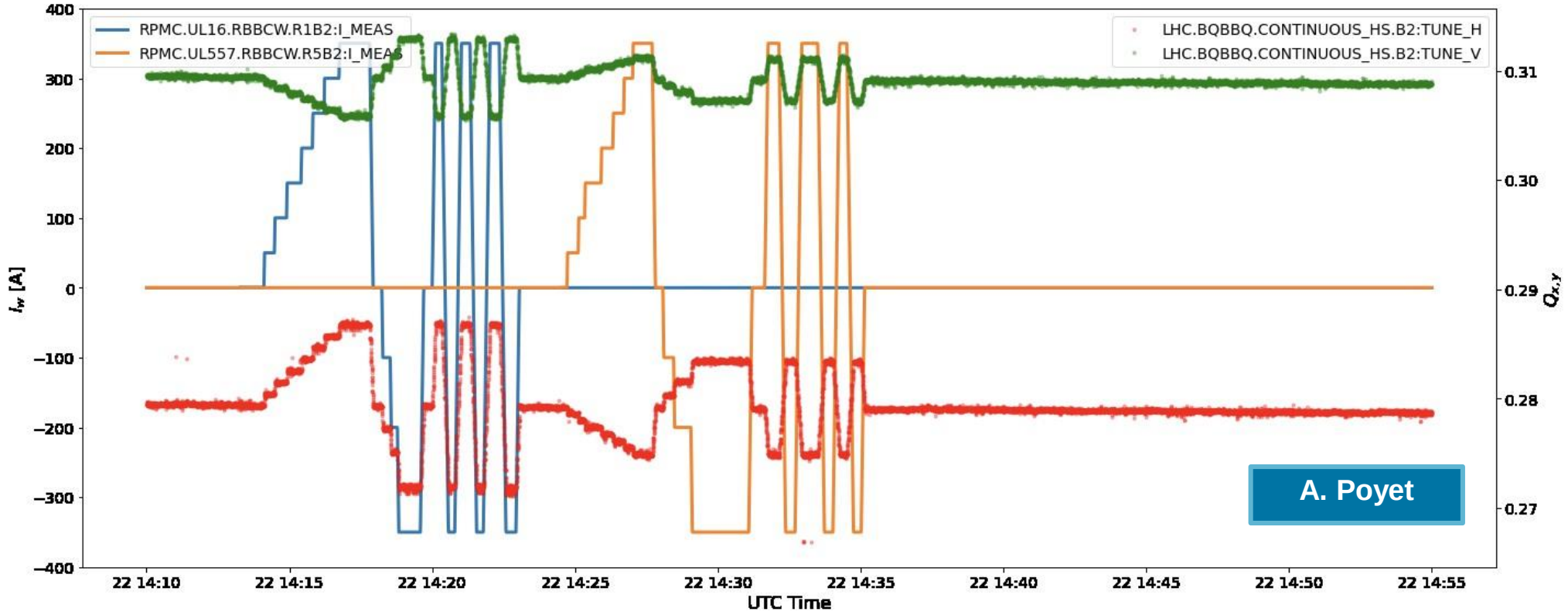


A Q13-Q4 correction was studied (Q6-7 not included) to rematch properly the IP optics.

→ Solution is available and can be tested during MD in 2022 and deployed later stage

RUN 3: commissioning with the beam

Beam Commissioning BBWC@450 GeV
May 22nd 2022

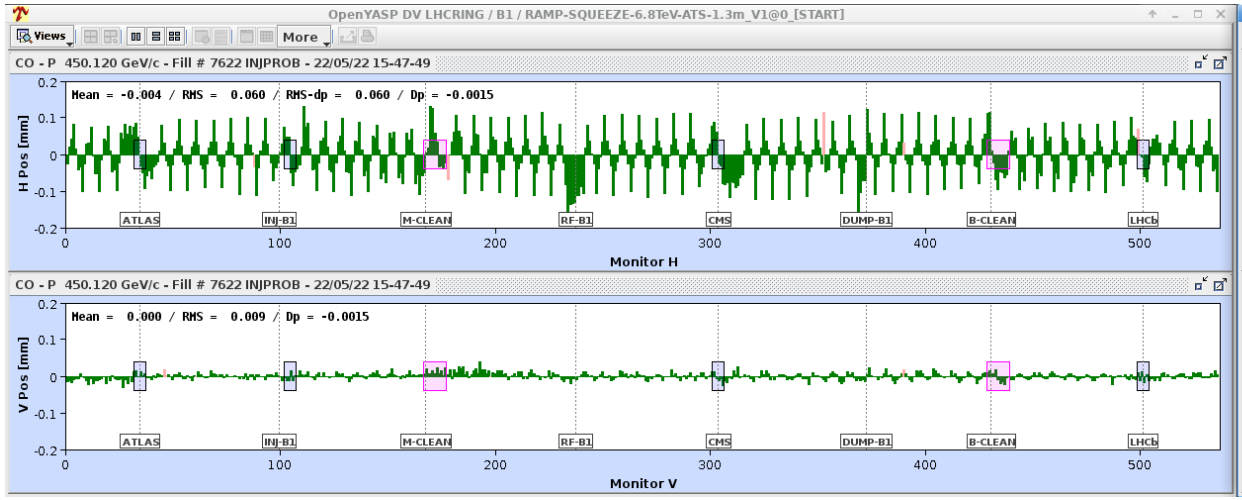


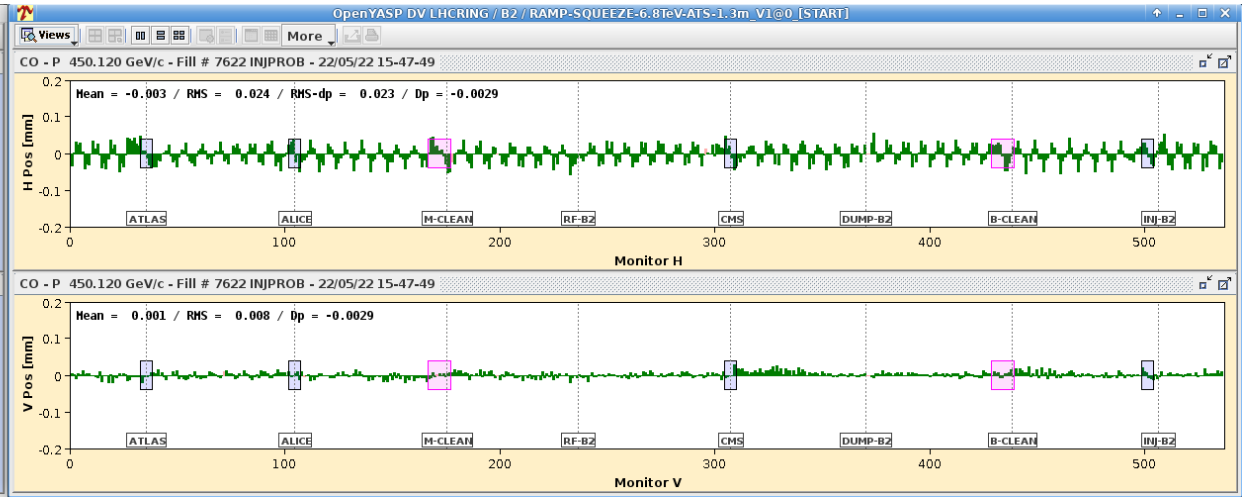
All 4-wire polarities were checked successful with beam at injection (B2 shown in the picture).

RUN 3: commissioning with the beam

Beam Commissioning BBWC@450 GeV
May 22nd 2022

CO effects with IR1 BBWC in B1 ON





When switching ON the BBCW wires in B1 we observed a CO effect on B2 (and vice versa). It needs further investigation (Philippe will help on this front). If the CO feedback is on the effect is fully compensated.

HL-related outstanding aspects

We would like still to address the following points by the September workshop:

- Quantify the impact of wire compensation on the **core-diffusion** and **update the evolution of the Run 4/5 configurations**
- Check the **impedance** of the device and also the **beam induced heating of the wire (→ IWG)**
- Verify if the design (see WP2 Feb 22nd, 2022) is **vacuum compliant** (outgassing and SEY/ecloud of AlO ceramic, UFO, radiation?) and define a strategy for the vacuum **sectorization**
- Verify beam-impact limit and background noise contribution for the experiment (→ **FLUKA, dose on the device/handling, forward physics FP/RP**)
- Check forward physics requirments/conflicts (→ **TREX**).

The configuration of Run 4 with relaxed collimator configuration (TCT @ 13.2 σ) imposes **severe limitations** on the beam-wire distance.

Conclusions

- In Run 3 we will see for the first time BBWC in B1 and deployment of the BB compensation in operation
- Despite the marginal improvement of the performance, this will give additional feedback on the operational aspect of the BBWC
- The compesation will be at the end-of-leveling in 2022. With the TCT moving during the leveling (>2022) we can explore compensation scenarios during the leveling.
- Next steps for Run3: after the collision orbits at $\beta^*=30$ are established → 5th axis alignment of the TCT and Q-knobs checks.
- A word of caution: the Run 4 relaxed TCT settings are challenging for possible new BBWC design and applicatiion in HL-LHC…

Thank you for your attention.

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BACK-UP SLIDES

Can we reuse the PCs?

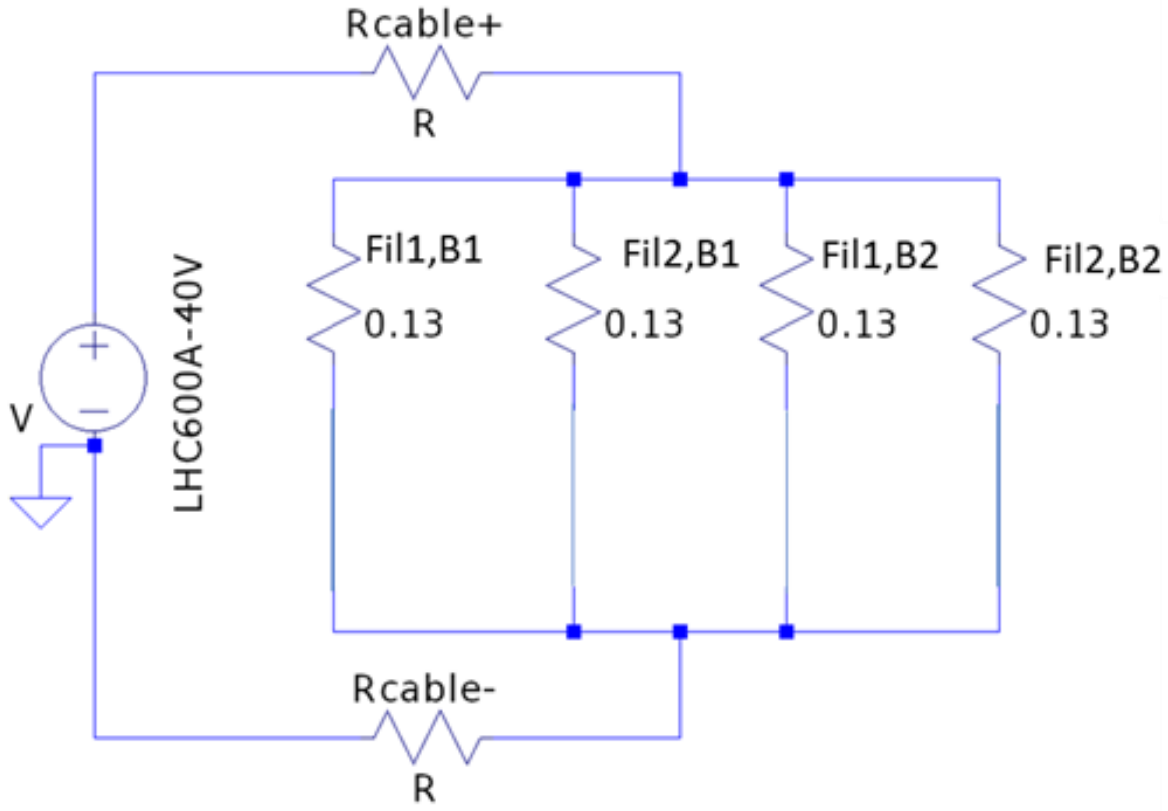
- **LHC600A-40V can operate (for one year, 2024) at 600A in DC operation**, without issue to fear, in theory. They were designed for, even if not operating at that level in the LHC (max 550A).

A quick calculation gives

Assuming the 45 meters to be added are in 2x400 mm2

250 meters (500 meters in total, go and return) of 2x 400 mm2 represents (25°C) 10.6 mOhms, which would, at 600A represents 6.4 Volts.

- **It is better (reliability) to limit the voltage across the total load** (cables + wires) in order to limit the overall power the converter needs to provide. Current calculation gives (20 V - 0.13 Ohms x 150 A - across a wire at 150A + 7 V for DC cables, 2x 400 mm^2), then 27V, which is correct at first glance (40V max).



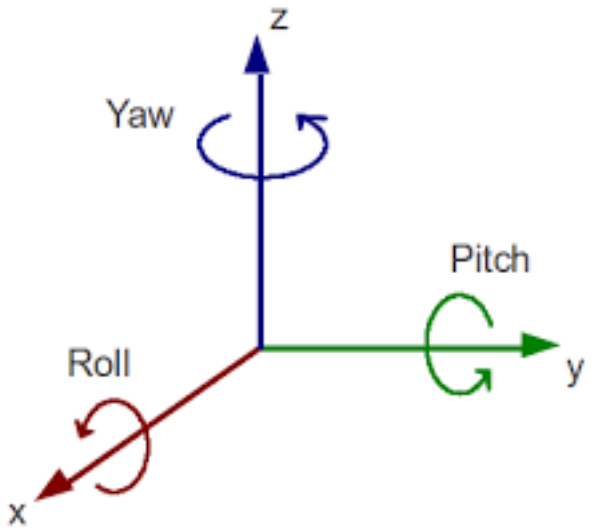
https://indico.cern.ch/event/1099813/

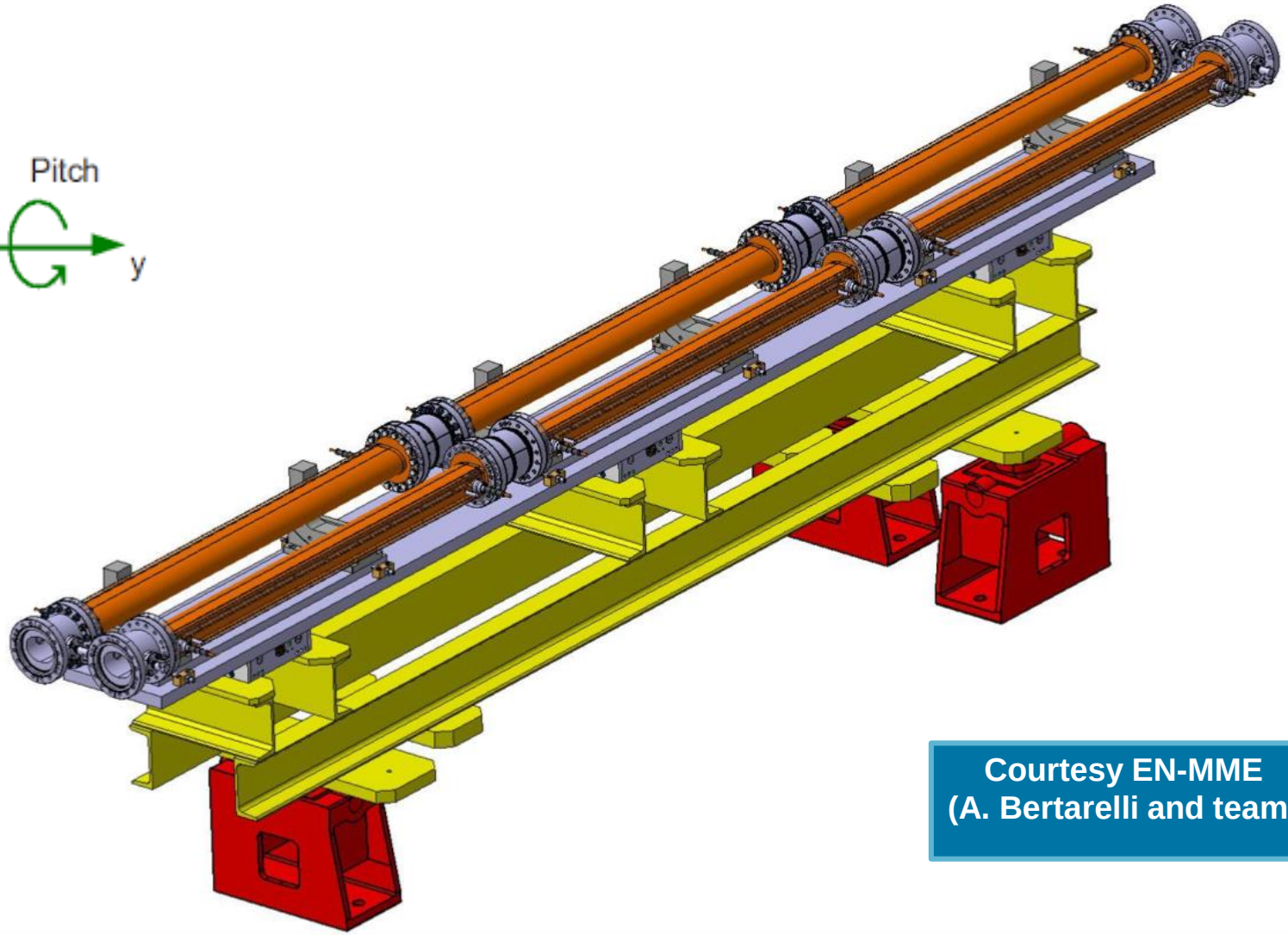
HL-type functional specification

Present HL proposal (iterations are on-going):

- **8 assemblies** (2x beams x2 IPs x2 sides) containing DC wires at room temperature (demineralized water cooling needed).
- The slots are **between HL Q4 and Q5**, starting at 186 m ending at 195 m from IP (9 m).
- **450 Am** per beam/side/IP
- Each tanks contains **3 modules of 1 m pre-aligned on a common girder**.
- **1 mm wire diameter carrying max 150 A**
- Motion of the 1 (or 2) principal axis (parallel to crossing): from 0 to 15 mm (garage position, TODO: verify aperture).
- Motion of the 3rd axis (perpendicular to the crossing): -10 to +10 mm
- Possibility to rotate the V wires tanks when the V-crossing polarity is switched
- (2xH and 2xV BPMs per wire assembly, ~ 1 BLM per wire assembly)

2 wire tanks (each with 3x 1m modules)

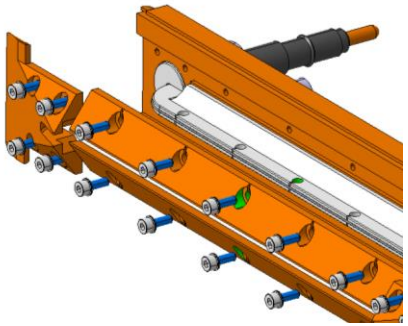


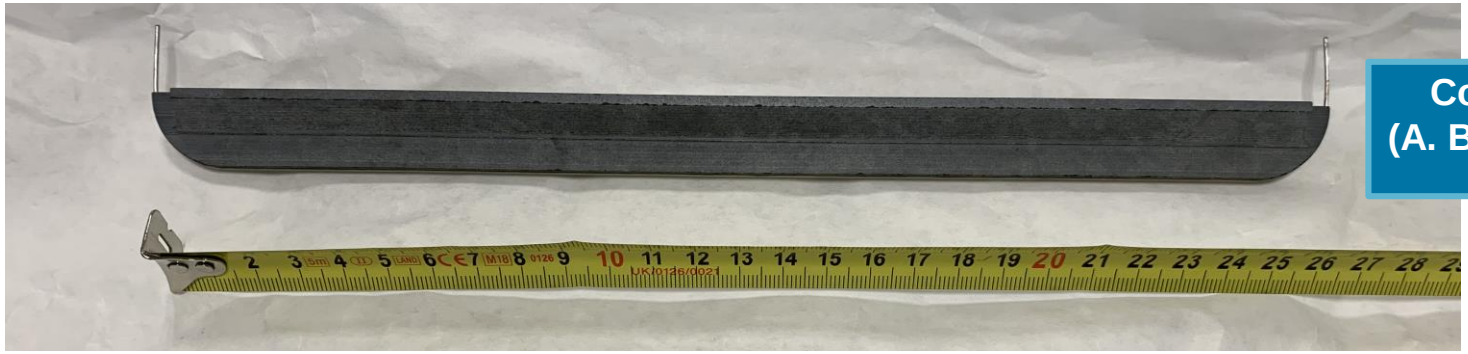


Courtesy EN-MME
(A. Bertarelli and team)

HL-type wire test

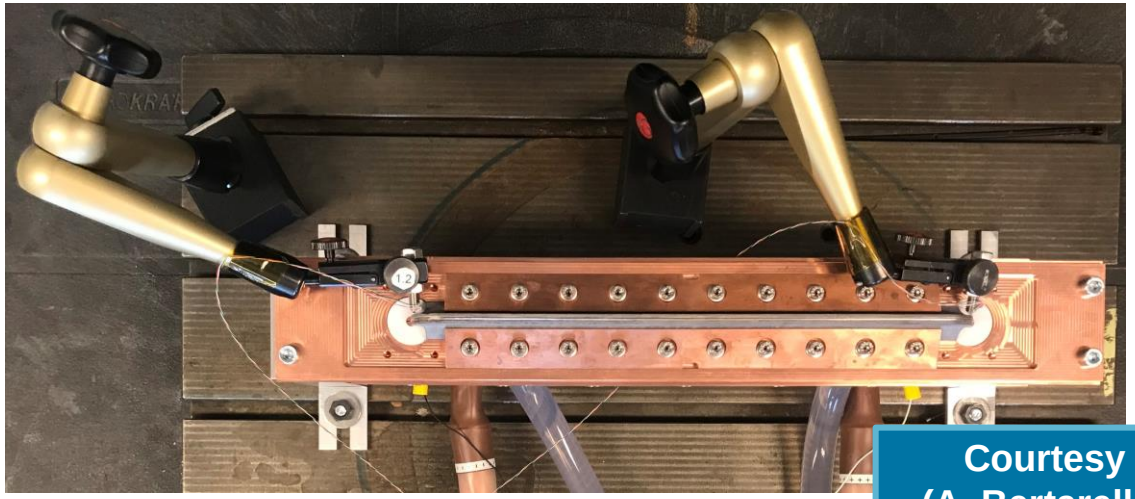
There was an extensive testing campaign by EN-MME on a short HL-type wire.





Courtesy EN-MME
(A. Bertarelli and team)

Results (out/in vacuum) are not yet circulated (EDMS 2432228): the tests were done with 1 mm and 0.8 mm radius molybdenum wires.



Courtesy EN-MME
(A. Bertarelli and team)