Introduction/Motivation and current wire HW

Adriana Rossi on behalf of the BBLR team

with material from O. Aberle, A. Bertarelli, C. Boccard, F. Carra, L. Gentini, Y. Papaphilippou, A. Poyet, K.Skoufaris, G. Sterbini

HL-LHC WP2/WP13 meeting on Wire Compensation, Fermilab, 17 October 2019

This meeting

- Scope of this meeting is to present the latest experimental and simulation results at LHC with the present demonstrator of wire for Beam-Beam Long Range Compensation.
- Present the predictions for the HL-LHC, together with first ideas for the wire hard-ware design and possible implementation.
- Building upon the existing collaboration between TRIUMF and CERN, look for a framework for future contributions from TRIUM to HL-LHC for BBLR wire compensation.

This meeting

LHC

- Adriana Rossi : Motivations and present wire demonstrator
- Guido Sterbini : MD results during LHC Run II and plans for Run III
- Axel Poyet : Modelling of MD results and effect of crossing angles

HL-LHC

- Kyriacos Skoufaris : Simulations for HL-LHC configuration
- Dobrin Kaltchev : Correction of resonant driving terms with wires
- Yannis Papaphilippou : Scenarios and timeline for wire compensation at the HL-LHC
- Alessandro Bertarelli : Wire HW design for HL-LHC

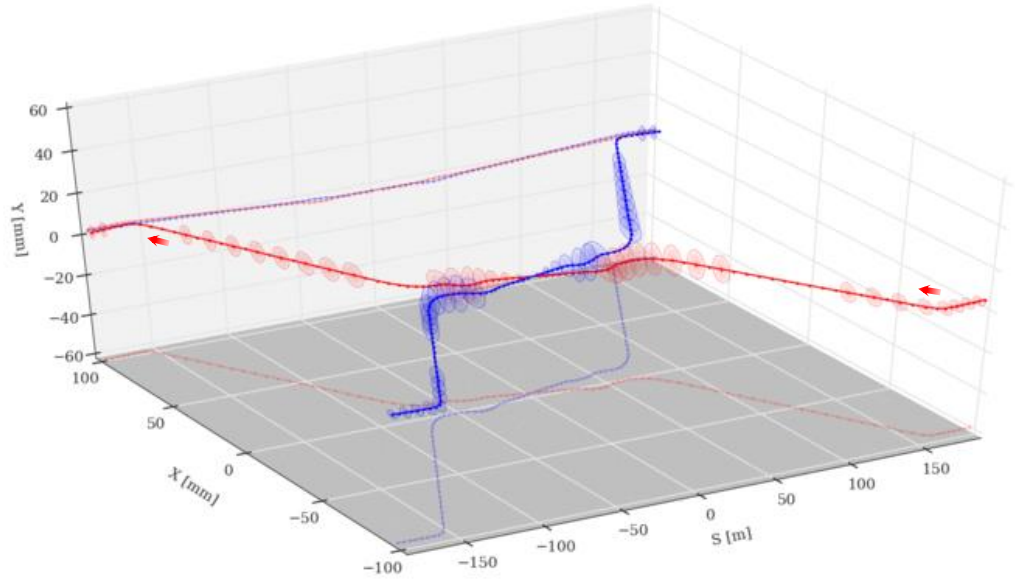
- Oliver Kester: TRIUMF contribution to the BBLR Compensation Project for HL-LHC

Outline

- Brief introduction to BBLR compensation with wire
- Recall the demonstrator HW: wire in-jaw collimator
- Installation phases of the demonstrators in LHC
- Integration in the HL-LHC
- Summary and conclusions

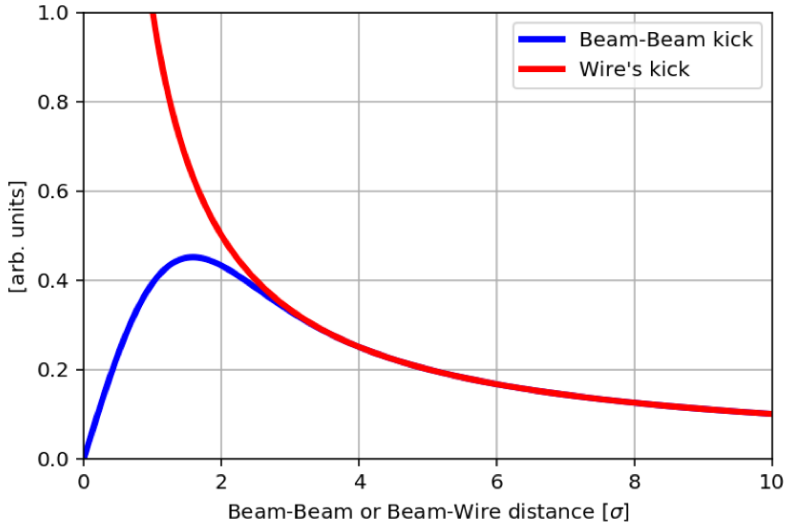
Long-Range Beam-Beam

- LRBB interactions limit accelerator performance
  - Perturb motion at large betatron amplitudes, where particles come close to opposing beam
  - Produce beam blow-up and deterioration of beam lifetime
  - Causes amplitude dependent detuning
  - Limit closing crossing angle and therefore luminosity



Courtesy of G.Sterbini

LRBB Wire compensation



$$D\{x',y'\} = -\frac{2N_p r_p}{g}\frac{\{X,Y\}}{X^2+Y^2}\left(1-e^{\frac{X^2+Y^2}{2s^2}}\right)$$

≈1 for large separation

$$X = x + x_c \quad , \quad Y = y + y_c$$

Courtesy of Y.Papaphilippou

- Can be approximated by an “infinite” wire

$$D\{x',y'\}_w = -\frac{m_0}{2p}\frac{I_w L_w}{Br}\frac{\{X_w,Y_w\}}{X_w^2+Y_w^2}$$

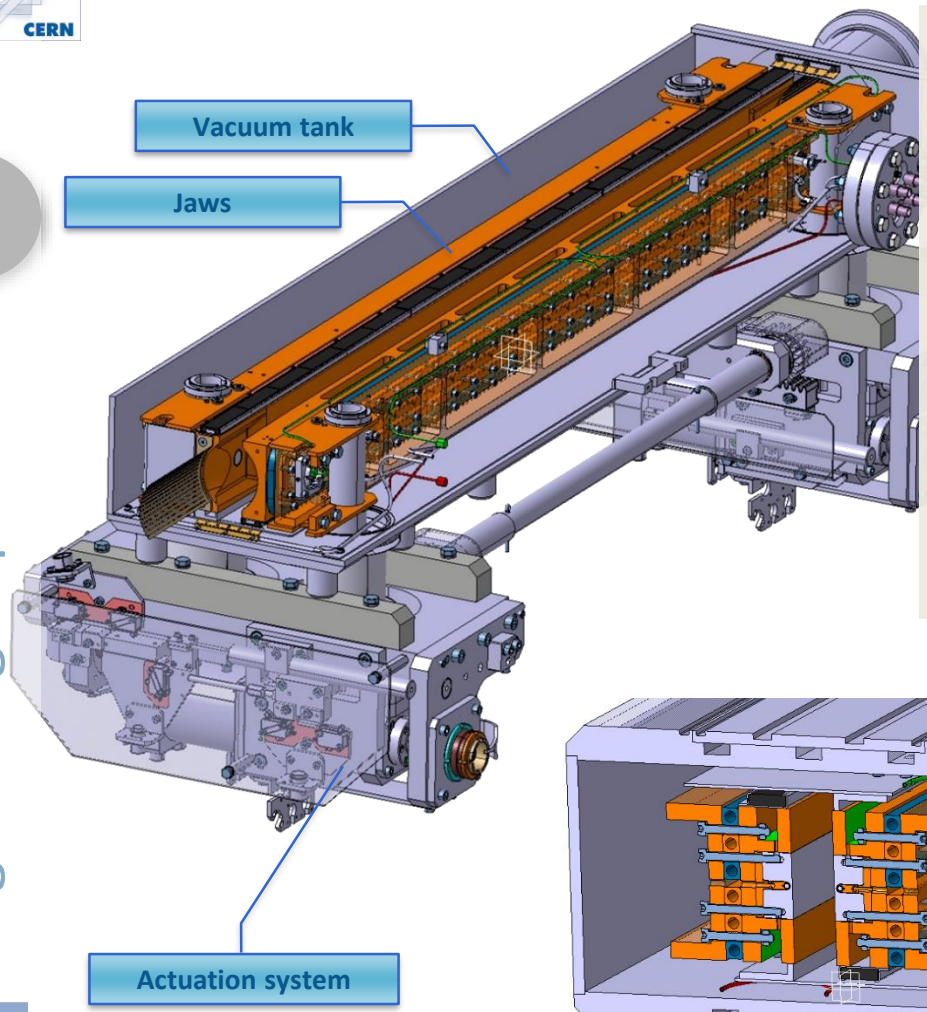
with X/Y (wire separation)

$$X_w = x + x_w \quad , \quad Y_w = y + y_w$$

Recall of design of the demonstrator: wire in-jaw collimator

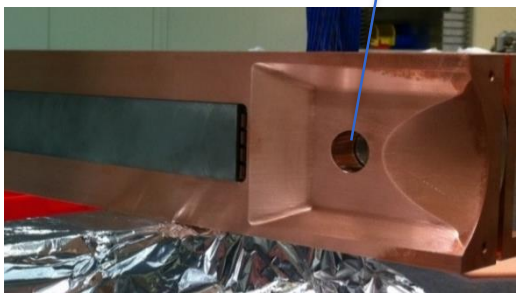
- Requirements for BBLR compensation coming from scaling lows [S.Fartoukh et al., Phys. Rev. ST Accel. Beams 18, 121001 (2015)]
  - Simulations and experiments explored wider range of parameters and configurations: see talks of **G.Sterbini, A.Poyet, K.Skoufaris**
- Design: Wires embedded into operational TCTP type collimators :
  - Joule heating can be cooled by the collimator jaw cooling system
  - The wire can approach the beam while being protected
  - TCT at almost the right beta ratio
  - ➢ **Maintain TCTP collimator complete functionality!**

Wire-Embedded TCTW



Jaw/wire movement

- In the plane of beam crossing the jaw position can be moved with a measured reproducible accuracy of 5 µm and with < 200µrad tilt
- Possibility to move the wire in the transverse plane (collimator 5th axis) to align on orbit ~ 500µm from BPM dedicated measurements

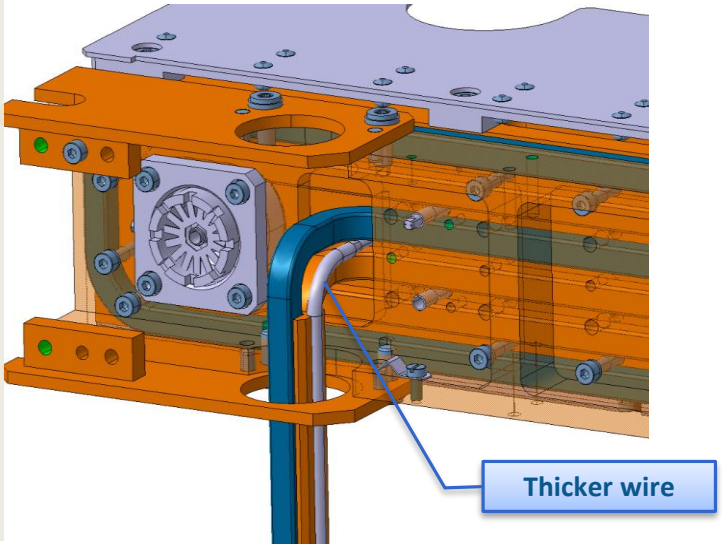


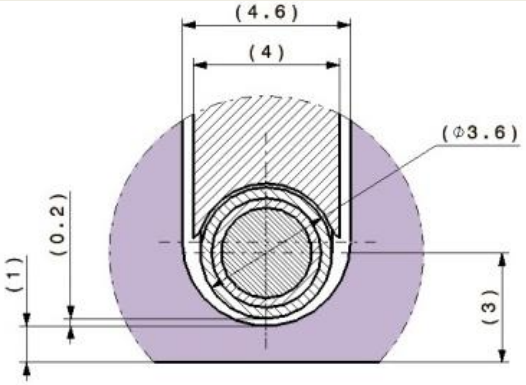
Wire-Embedded TCTW

Wire-in-jaw

- 3 mm wire/jaw surface distance ~ 3 beam sigmas
- Wire-beam distance should be minimized to achieve best compensation performance

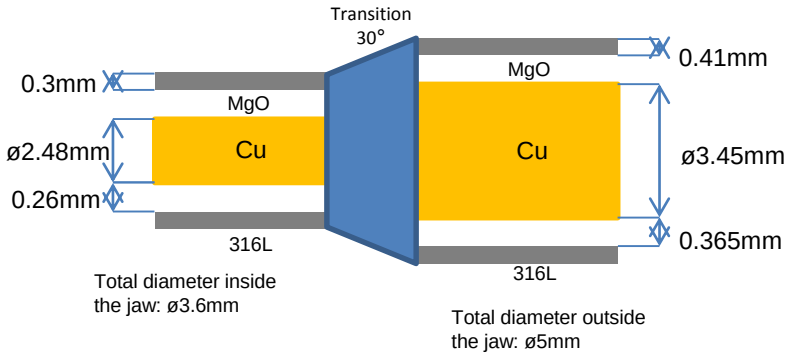
❑ New solution for HL-LHC (see talk of A. Bertarelli)



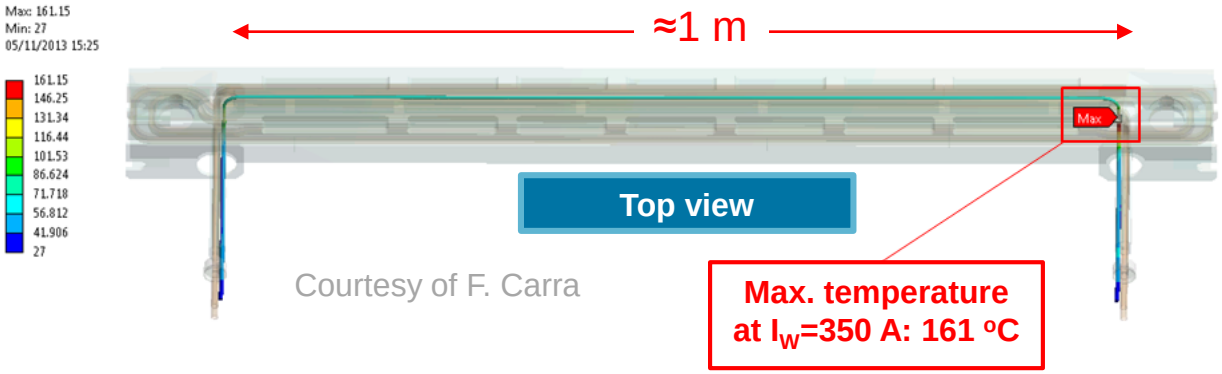


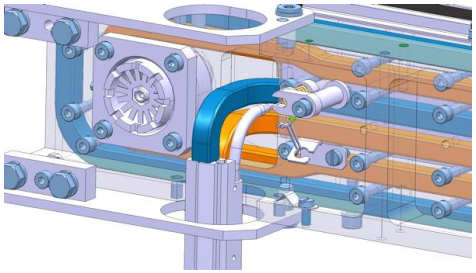
Note gap between wire and tungsten (0.1÷0.2 mm)

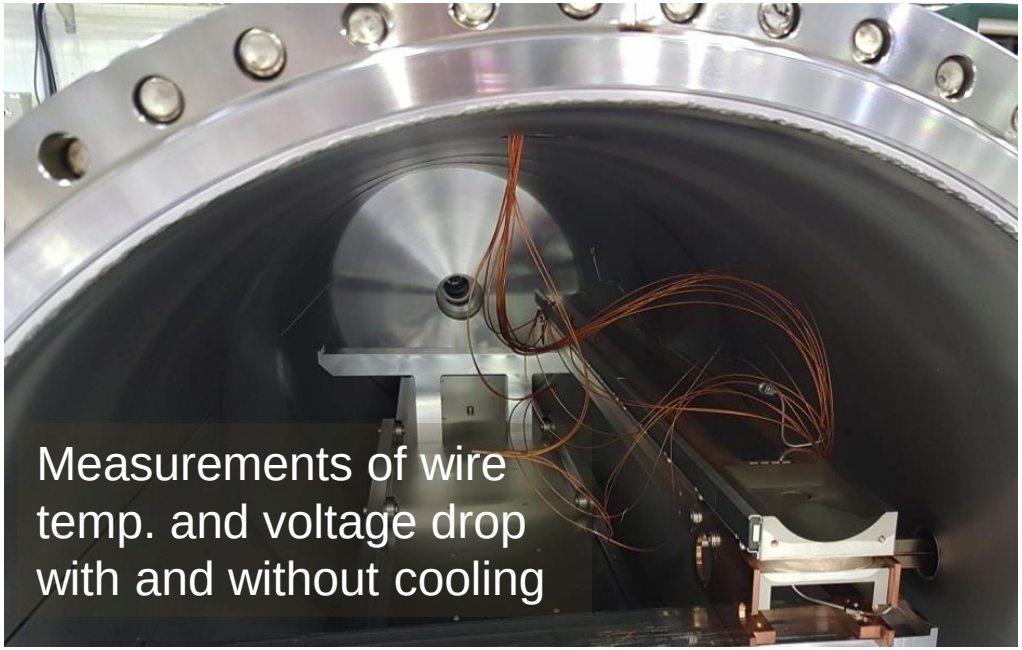
Cable dimensions (for 350A nominal current):

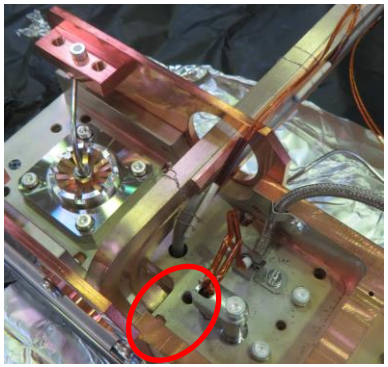


Tests with spare collimator jaw

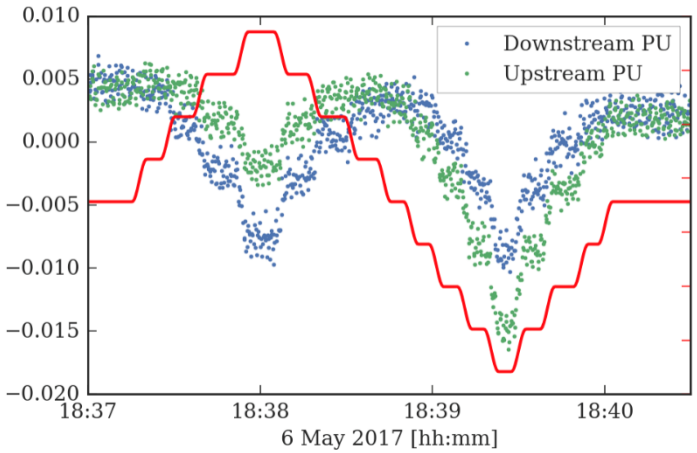








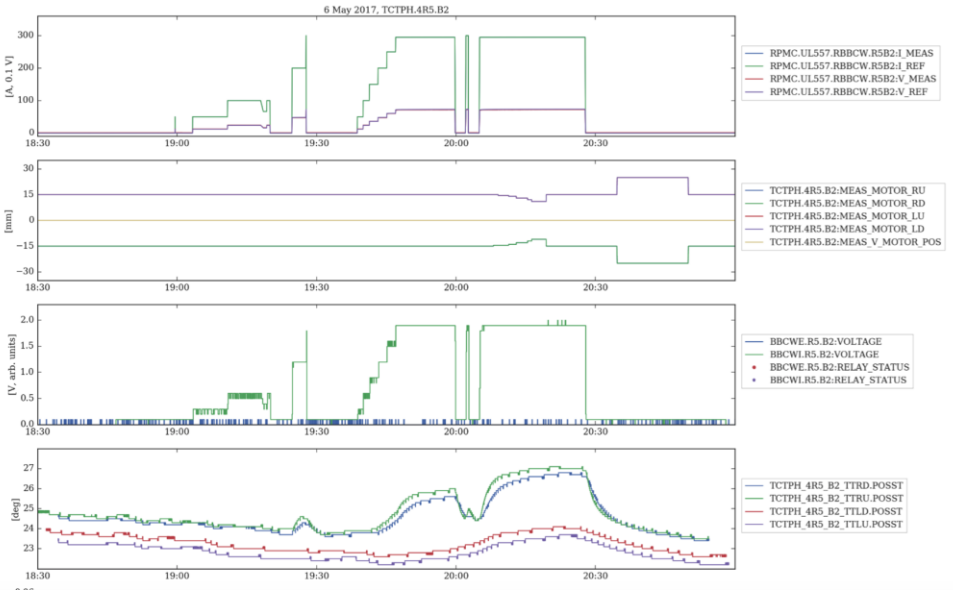
Tests at the LHC (G. Sterbini et al.)



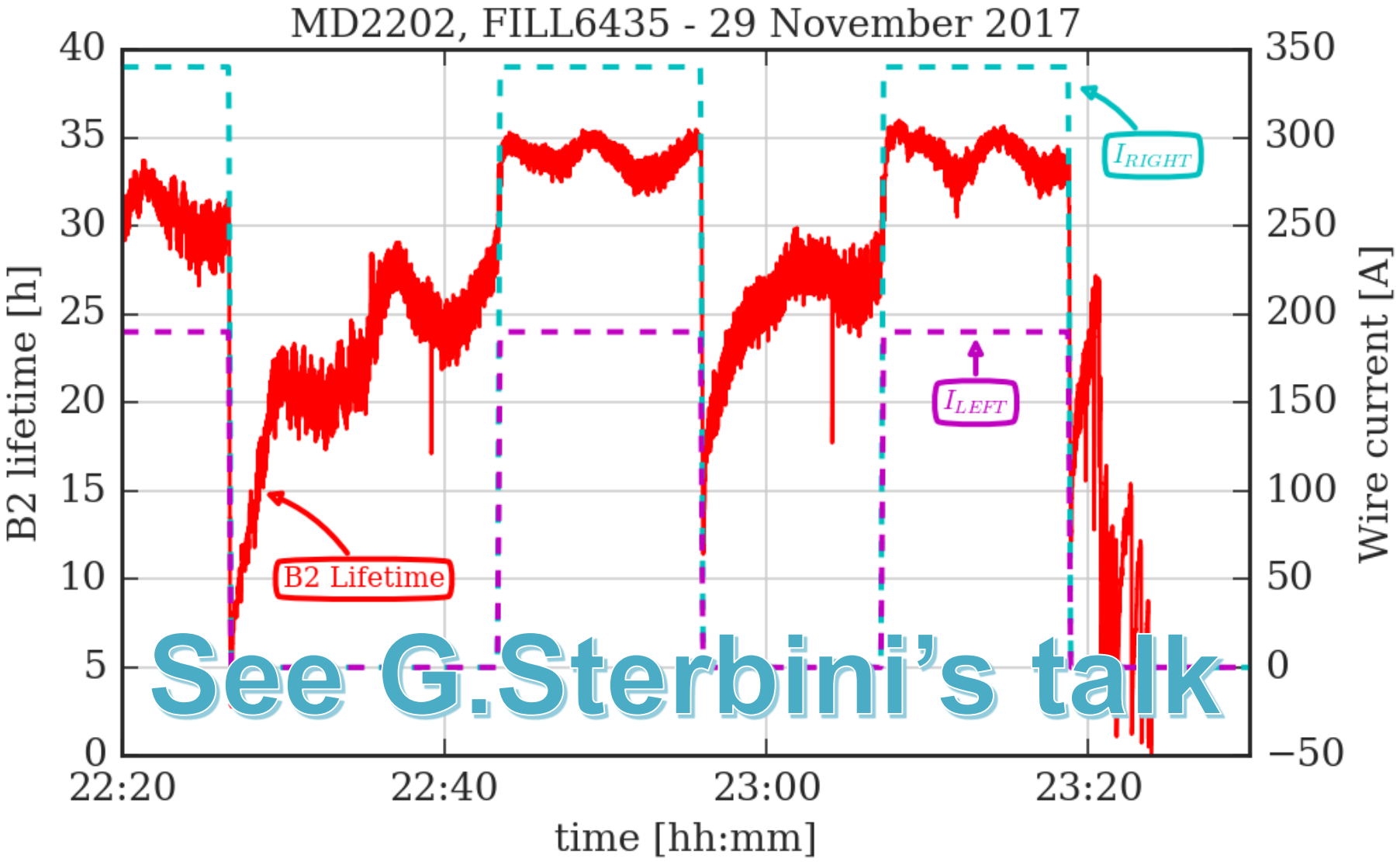
Vertical centering with 3 pilot LHC bunches and orbit vertical bump (steps of 0.5mm)

Pressure (VPG.935.B4.R5) below threshold

Checking jaw temperature and movement with wire current ON

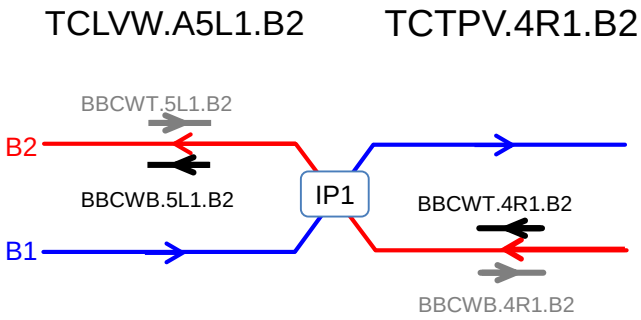


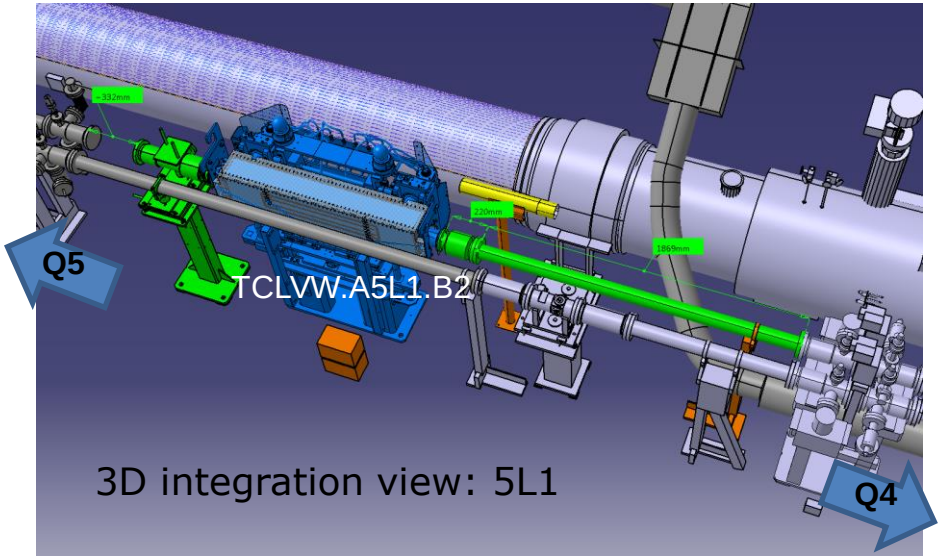
EYETS 2016-17 – replacement of TCTPH.4R5.B2 and TCL.4L5.B2

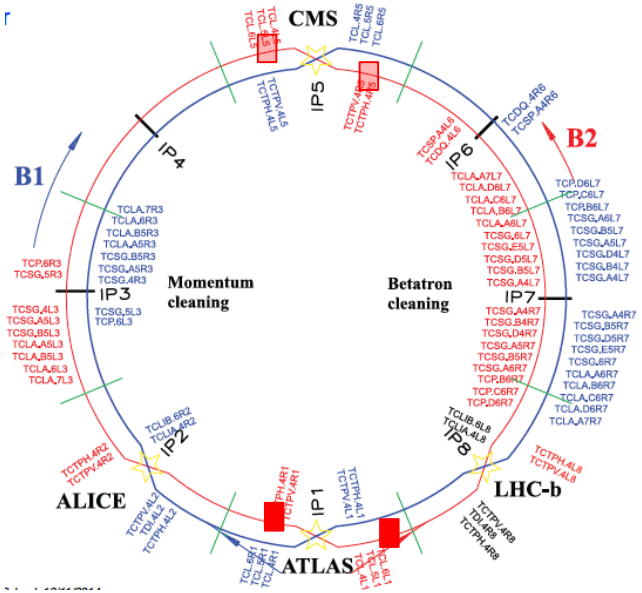


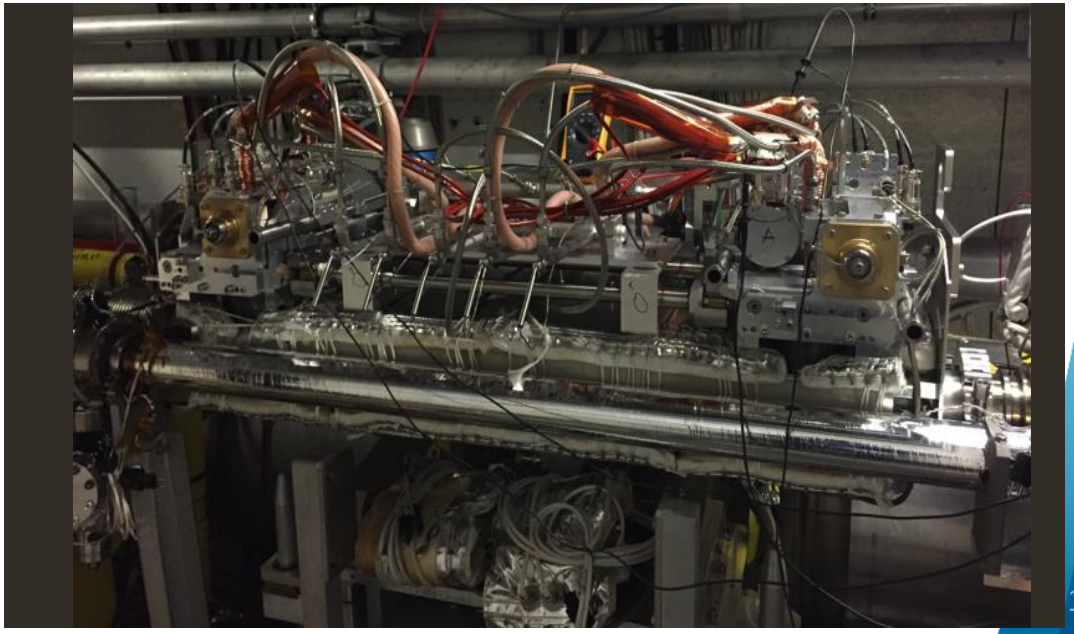
See G.Sterbini's talk

YETS 2017-18 – replacement of TCTPV.4R1.B2 and installation of new TCLVW.A5L1.B2

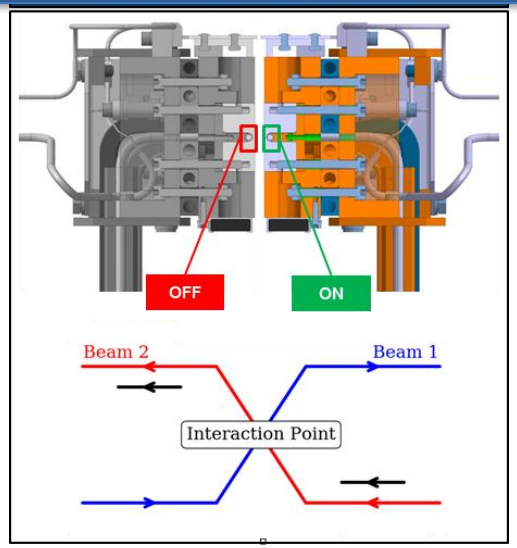




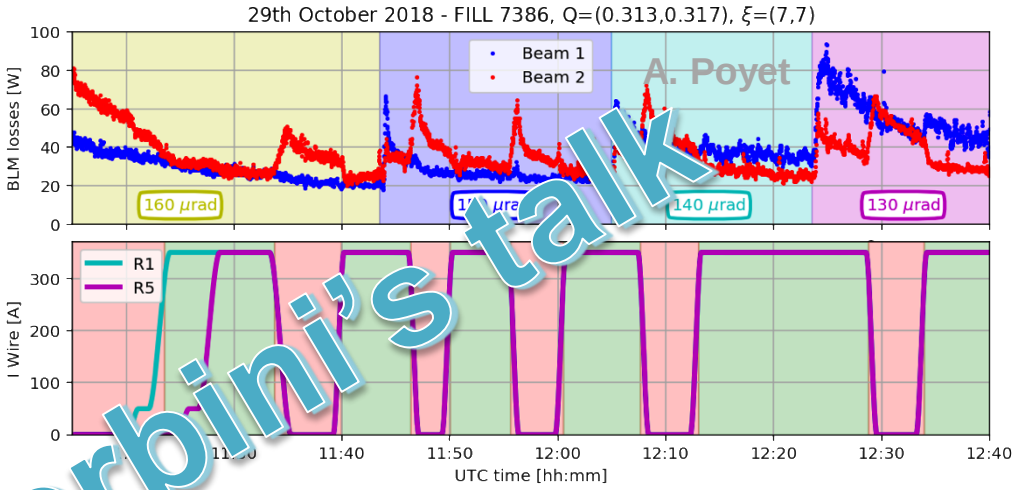


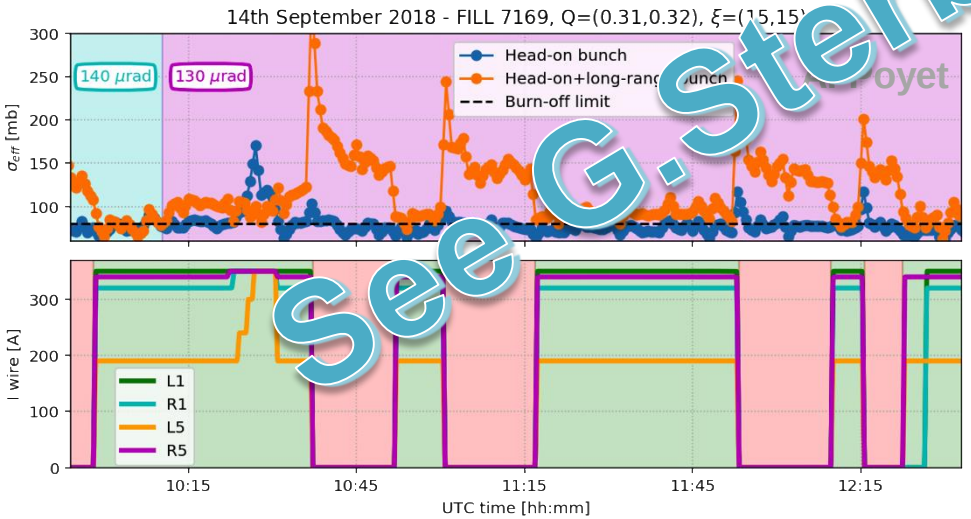


3 bunches, 5-6sigma distance



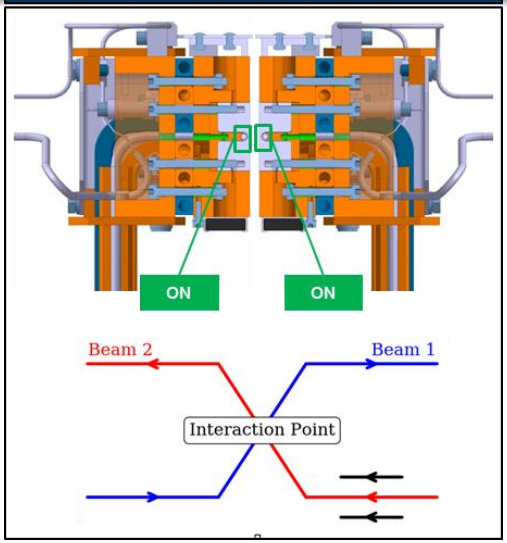
Compensation (TCT ops opening) provides a reduction of B2 (3 trains) losses by ~20%.





Almost full compensation, even at reduced crossing angle, for 1 regular bunch whereas head-on bunch not degraded.

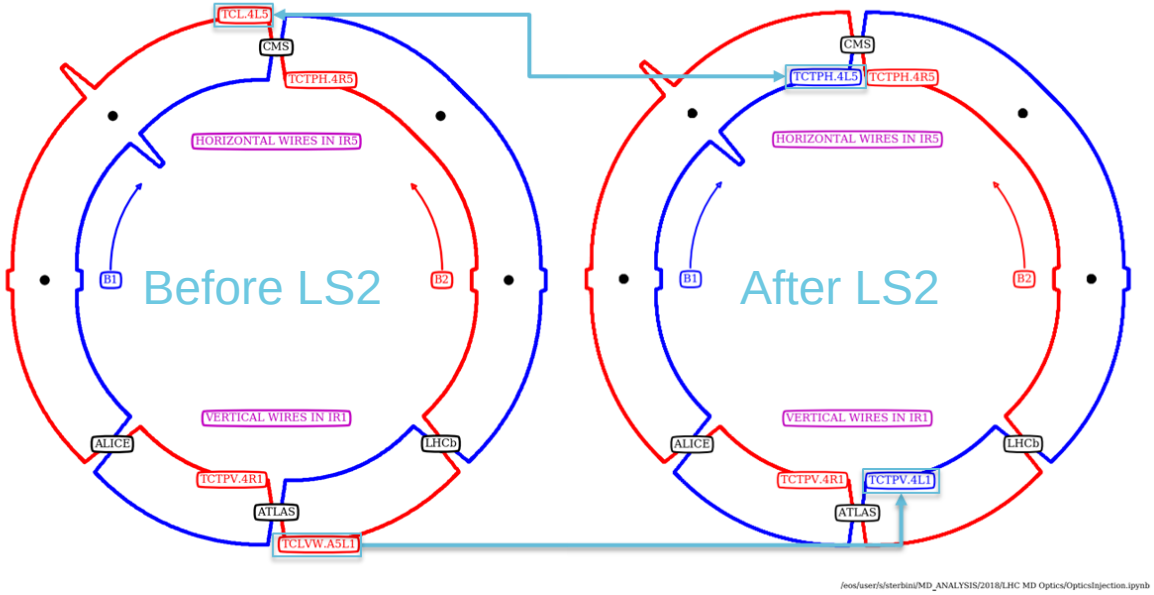
3 trains, TCT operational settings



IPAC19, G. Sterbini, contributed talk WEYYPLM3

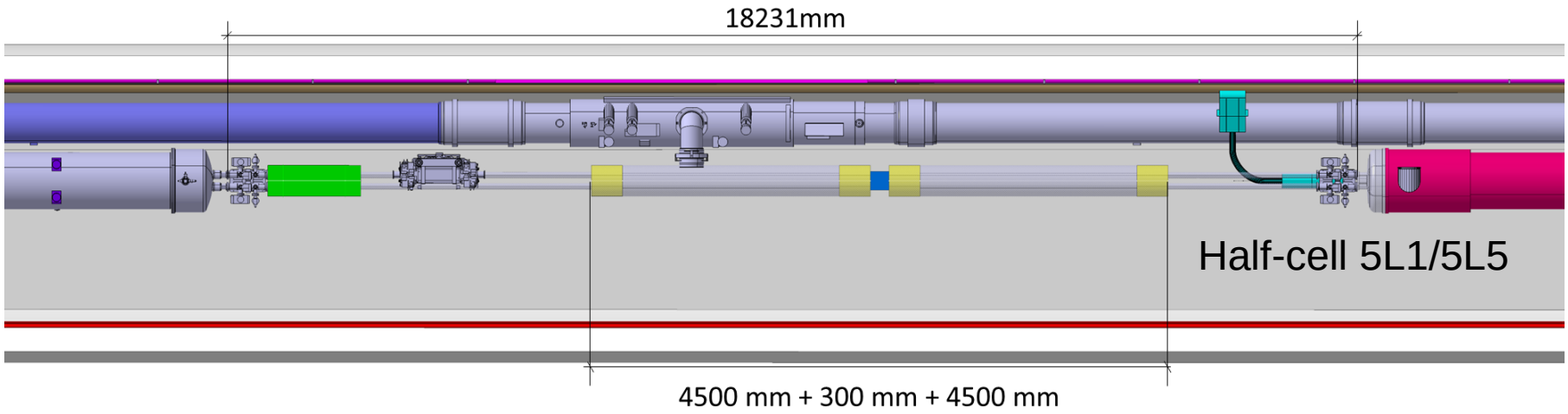
LS2 intervention before Run III

Moving of two wire collimators for BBLR compensation from B2 to B1 on IR1 and IR5

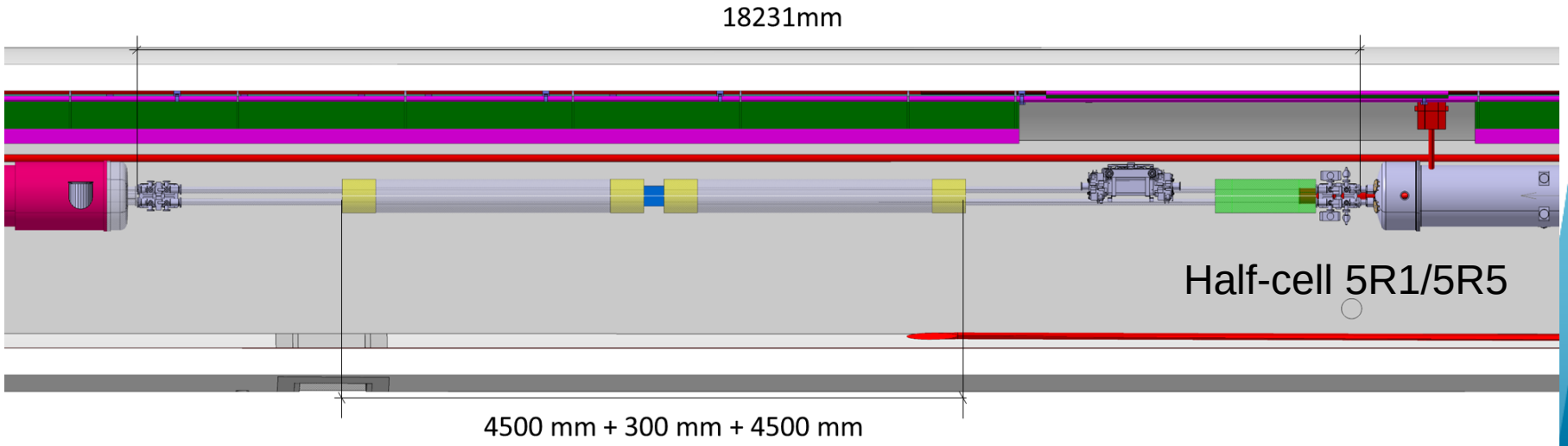


- Clear **potential to improve also B1** as shown for B2 during MDs
- Gain in operational experience with wires during operation in Run III and prove potential for HL-LHC (**wires used operationally**)

INTEGRATION of the BBLRW AT HL-LHC IP1/5

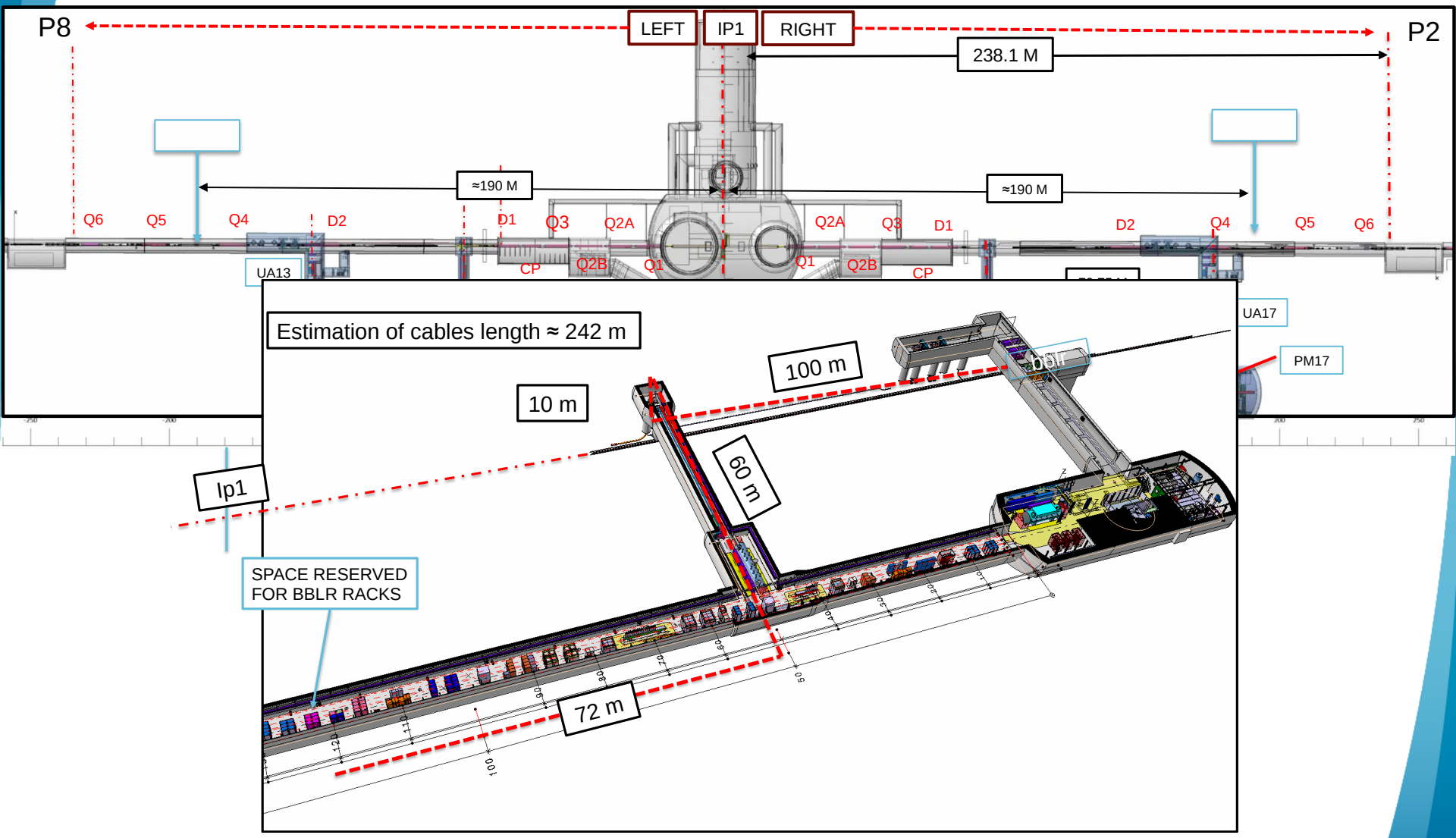


extraction from 3-D Model: ST0990131_01



RACKS IN IP1(=IP5) ZONE (*S.Maridor*)

HL_LHC machine



Future for HL-LHC

See the rest of the meeting!

Summary and conclusions

- Wires have been identified as possible BBLR compensation as early as in the late 1990s
- The first proof of concept was actually implemented in the SPS
- Wire-in-jaw collimators are being successfully used to test compensation at LHC and simulation work have been able to reproduce experimental results (see future talks)
- Results extrapolated to HL-LHC show the possibility of improving standard operations with larger dynamic aperture, more comfortable working point in the tune space, and enhanced performance. Without Carb Cavities, part of the luminosity lost could be recovered.
- **We hope to rise TRIUMF interest in the project and obtain support to introduce this option at the HL-LHC**

TRIUMF

Thank you for your attention

Acknowledgments also to (not exhaustive)

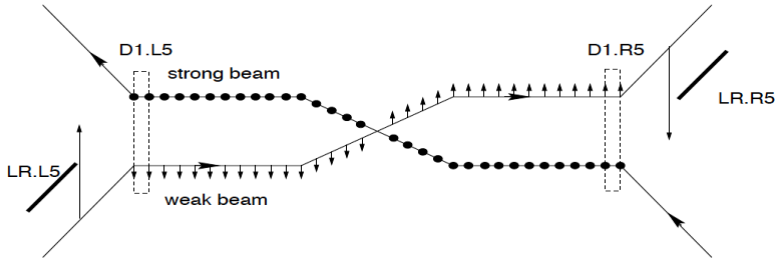
*D. Amorim, G. Arduini, H. Bartosik, R. Bruce, X. Buffat, L. Carver, G. Cattenoz, L. Ceccone, S. Deschamps, W. Devauchelle, E. Effinger, S. Fartoukh, M. Fitterer, N. Fuster, M. Gasior, M. Gonzales, A. Gorzawski, G.-H. Hemelsoet, M. Hostettler, G. Iadarola, R. Jones, D. Kaltchev, K. Karastatis, S. Kostoglou, I. Lamas Garcia, T. Levens, A. Levichev, L. E. Medina, A. Mereghetti, E. Métral, D. Mirarchi, R. Mompo, J. Olexa, Y. Papaphilippou, D. Pellegrini, M. Pojer, L. Poncet, S. Redaelli, B. Salvachua, H. Schmickler, F. Schmidt, M. Solfaroli, R. Tomas, G. Trad, A. Valishev, D. Valuch, D. Wollmann, C. Xu, C. Zamantzas, P. Zisopoulos and all participants to the design, production and commissioning of the wire compensator prototypes (**WP2, WP5, WP13 and LHC MD coordinators**).*

Some literature

① Y. Papaphilippou and F. Zimmermann, “Weak-strong beam-beam simulations for the Large Hadron Collider”, in Phys. Rev. ST Accel. Beams 2, 104001 (1999).

② Y. Papaphilippou and F. Zimmermann, “Estimates of diffusion due to long-range beam-beam collisions”, in Phys. Rev. ST Accel. Beams 5, 074001 (2002).

③ J.-P. Koutchouk, CERN-LHC-Project-Note 223 (2000); Proc. PAC2001, Chicago, p. 1681 (2001).



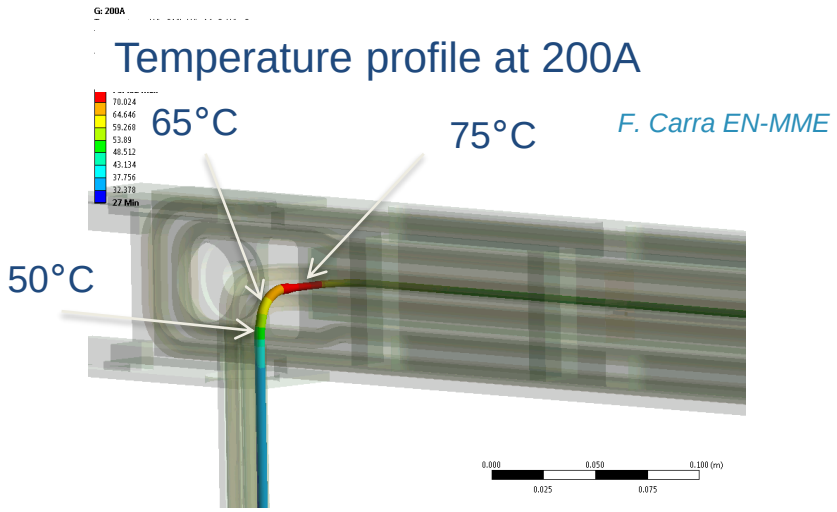
④ F. Zimmermann, “10 years of wire excitation experiments in the CERN SPS“, in Contribution to the ICFA Mini-Workshop on Beam-Beam Effects in Hadron Colliders, CERN, Geneva, Switzerland, 18-22 Mar 2013, CERN Yel-low Report CERN-2014-004, pp.153-166.

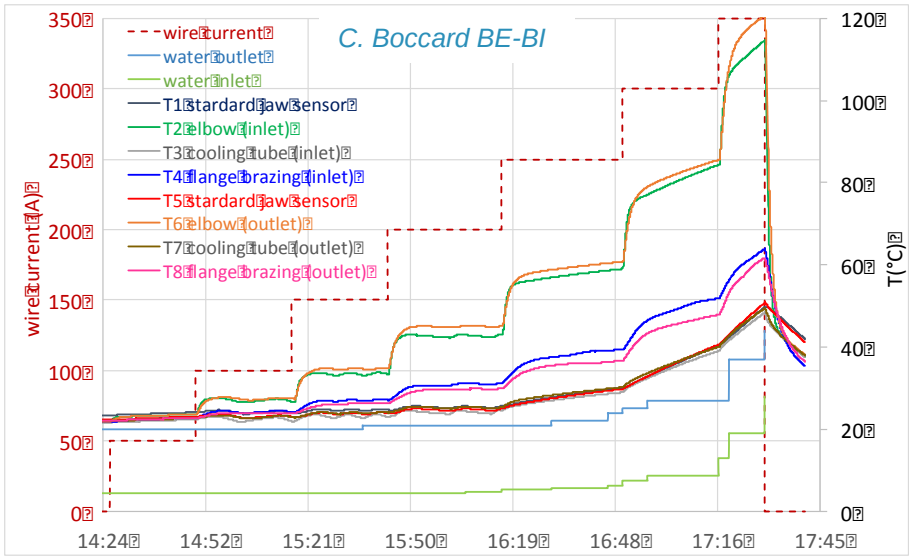
⑤ S. Fartoukh et al, “Compensation of the long-range beam-beam interactions as a path towards new configurations for the high luminosity LHC” in Phys. Rev. ST Accel. Beams 18, 121001 (2015).

⑥ M.Garlasche, A.Bertarelli, F.Carra, “Energy deposition (E.Skordis) and Structural Analysis of Wire-in-Jaw TCTP collimators”, presented at LHC Collimation Working Group #181, 6 Oct 2014.

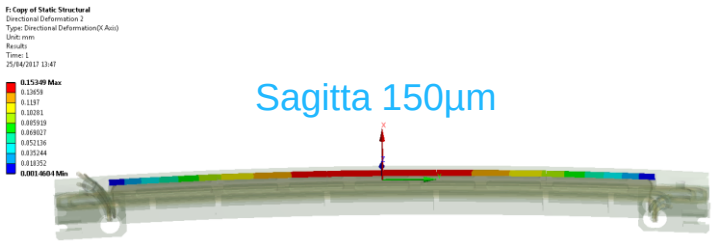
⑦ L.Gentini, “Wire-in-Jaw TCTP collimators recap on design” and O.Aberle “Tests and Assembly”, presented at LHC Collimation Working Group #203, 11 Apr 2016.

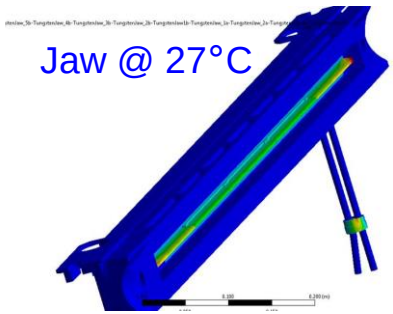
Wire current and temperature with cooling

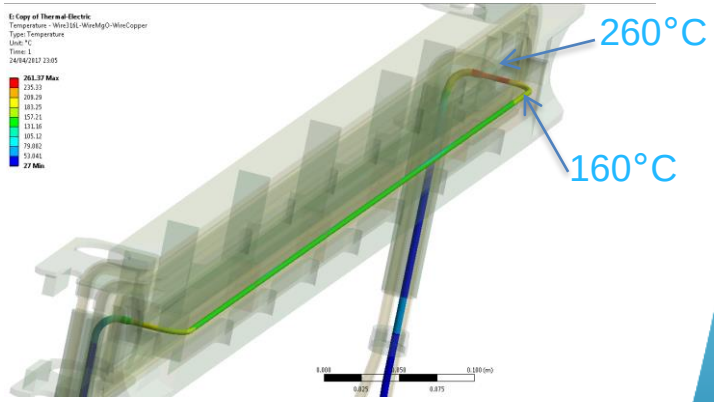




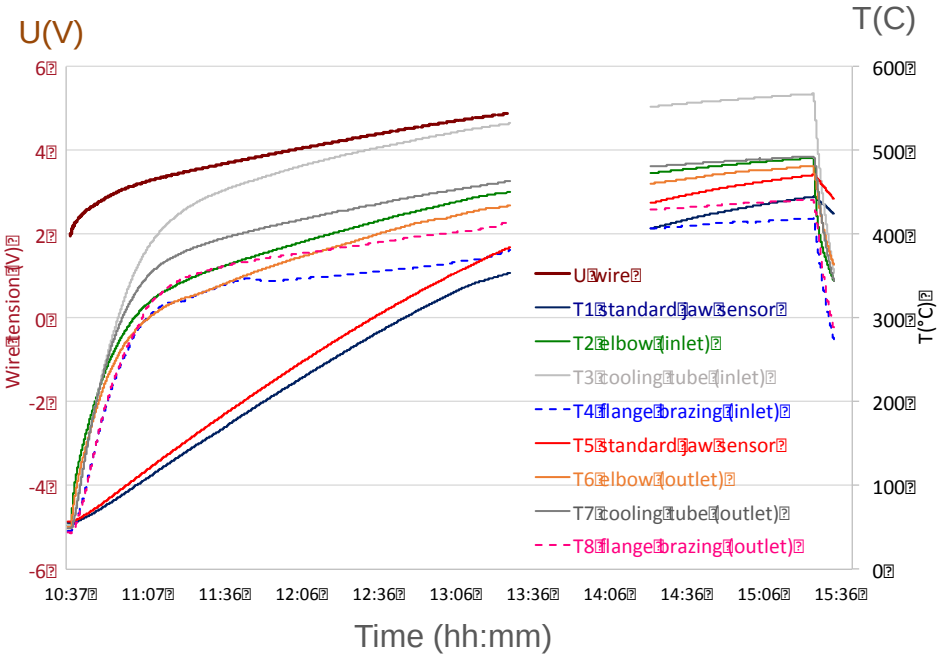
@ 350A

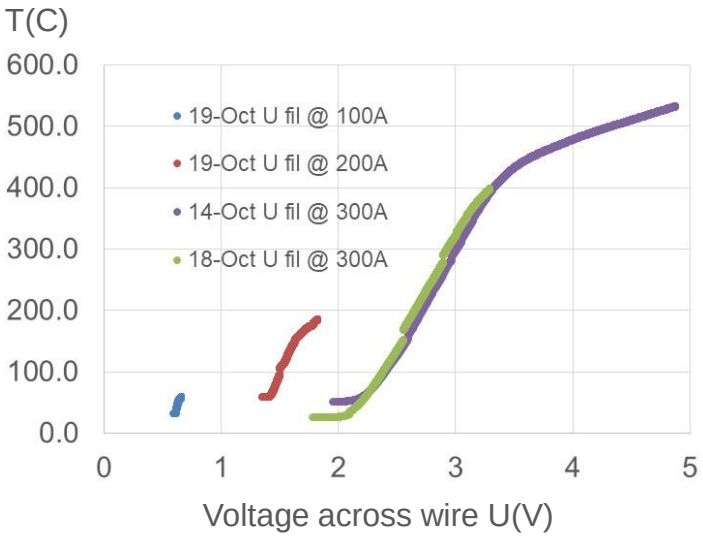






Wire current and temperature without cooling





- With cooling, the wire temperature as simulations: stable a few minutes after the current jump. Hottest spot at 120°C @ 350A
- Without cooling, tests at 100/200/300A: Tw <200-300°C for U_w < 2-3V
- Interlock set at 2.7V (note that U(350A)=2.5V)