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 this particular option.

This meeting

LHC

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

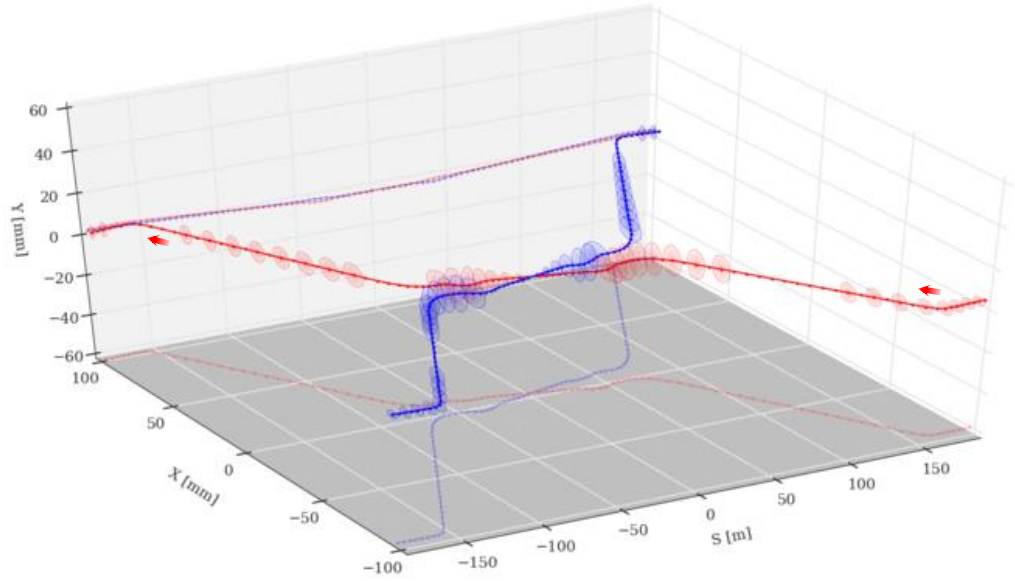
HL-LHC

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

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

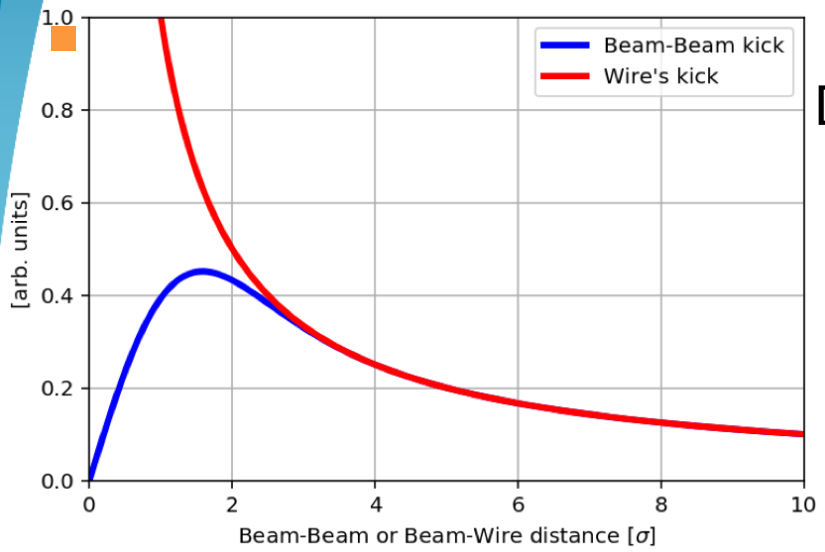
Long-Range Beam-Beam

- 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)

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

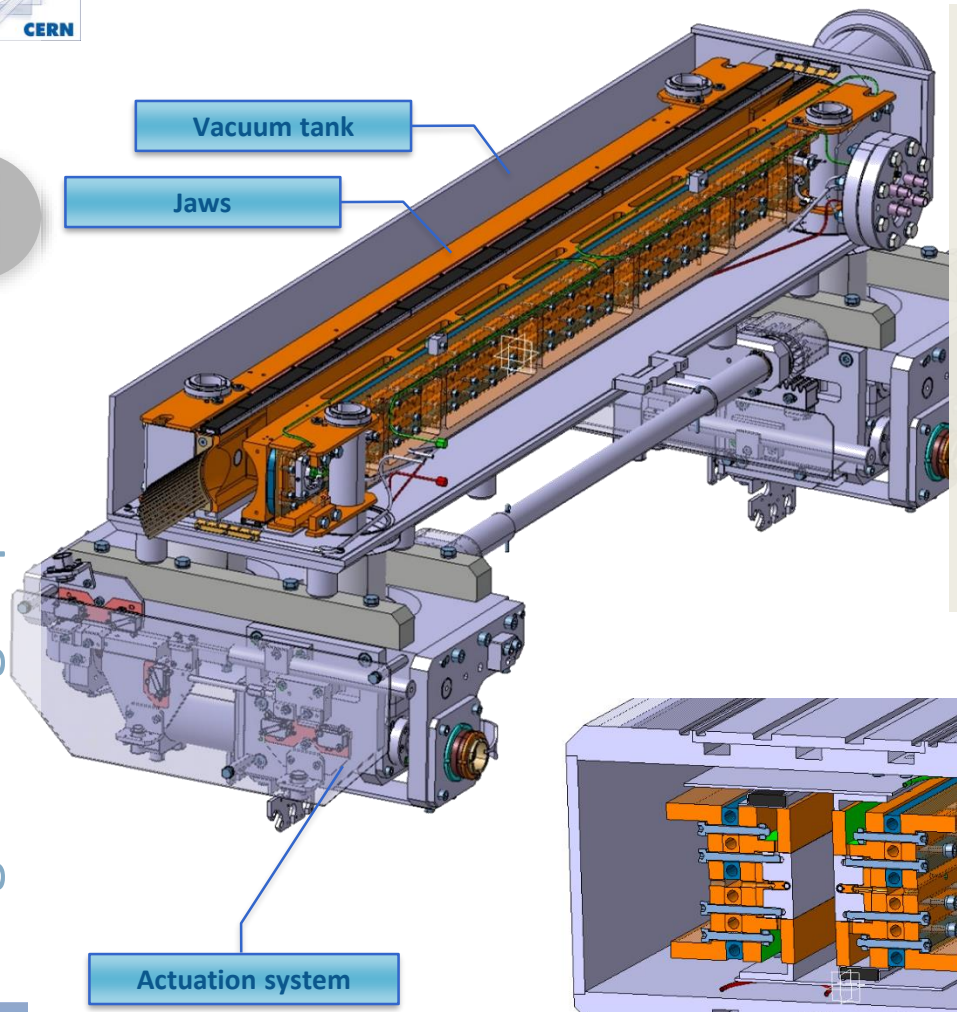
Recall of design of wire in-jaw collimator

- Requirements for BBLR compensation:
  - High current –> cooling
  - Approaching the beam at fo
  - Specific (initially β_x/β_y~0.5 and 2 on both sides of IP)

See next talks for experimental founding's

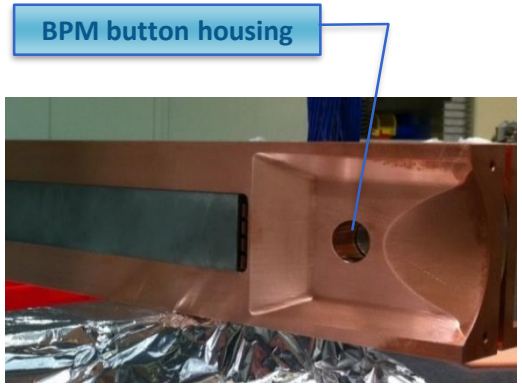
- Design:
  - Wires embedded into operational TCTP type collimators :
    - Joule heating can be cooled by the collimator jaw cooling system
    - The wire can approach the beam while being protected
    - TCT at almost the right beta ratio
  - **Maintain TCTP collimator complete functionality!**

Wire-Embedded TCTW



Jaw - wire movement

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

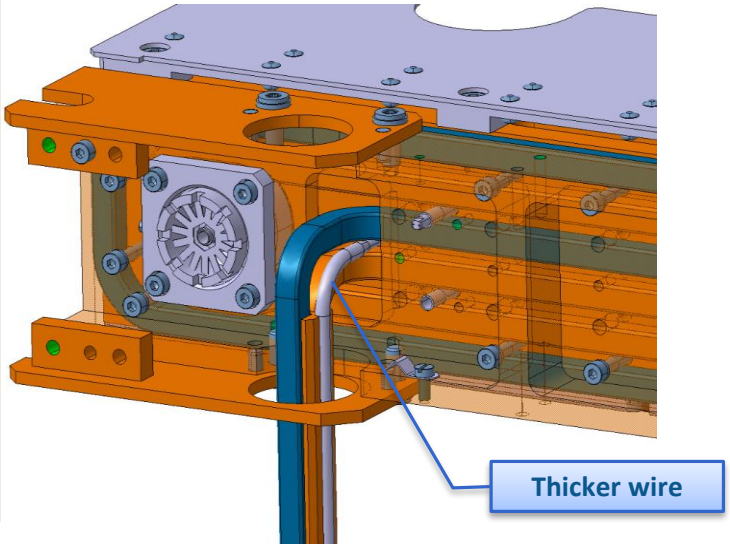


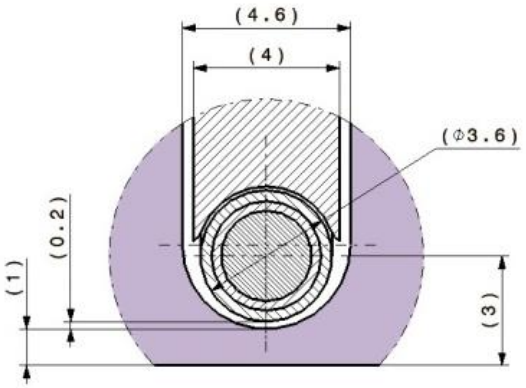
Wire-Embedded TCTW

Wire-in-jaw

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

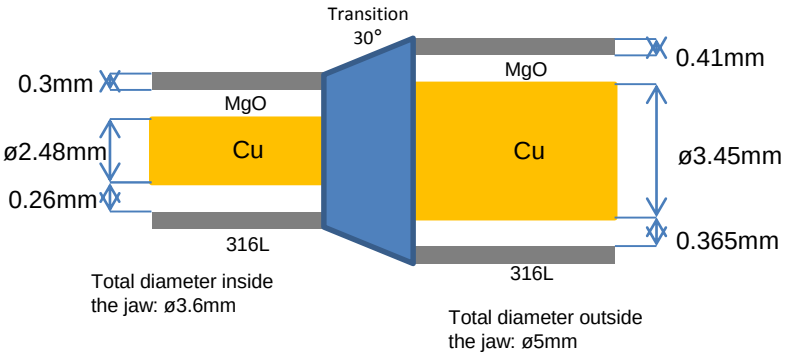
❑ New solution for HL-LHC



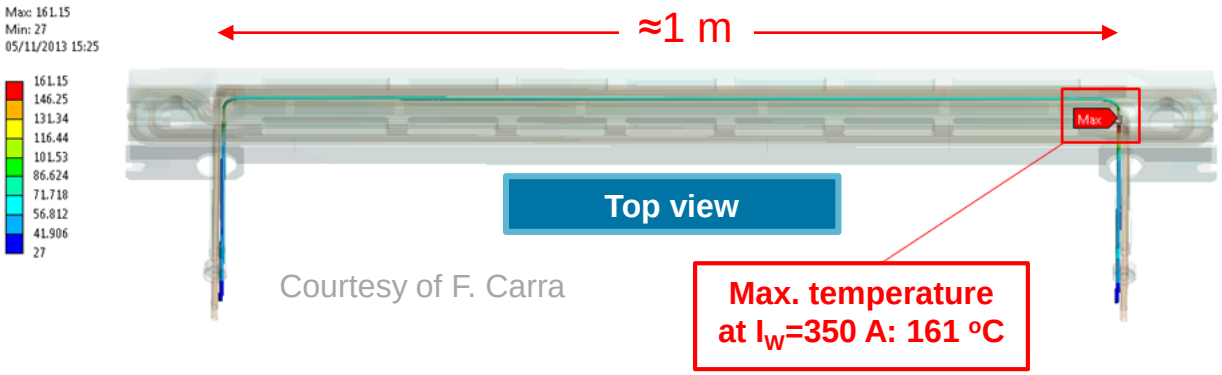


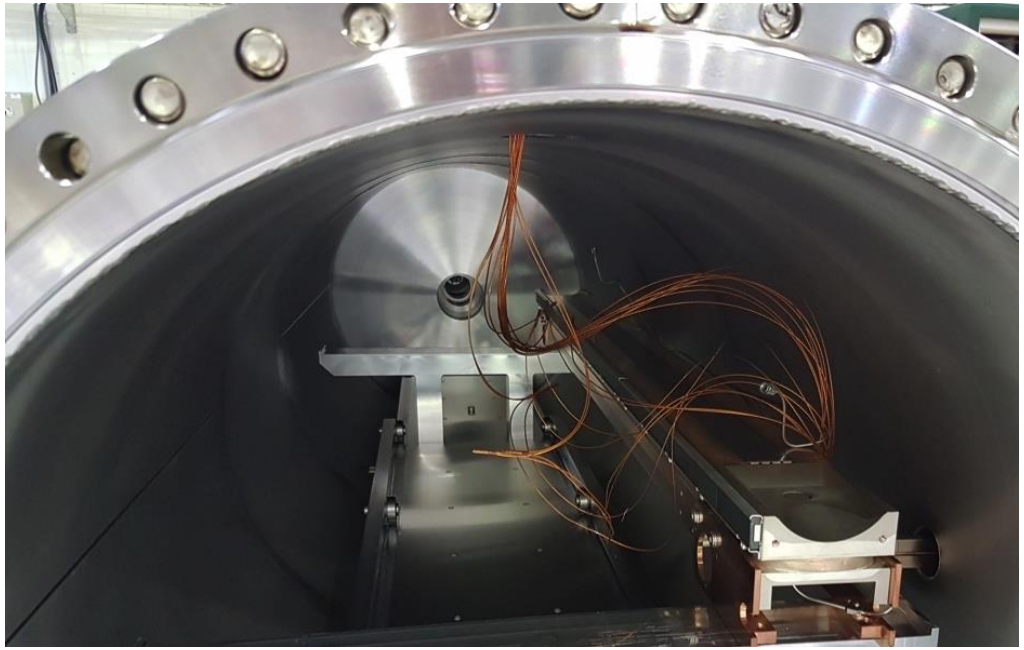
Note gap between wire and tungsten (0.1÷0.2 mm)

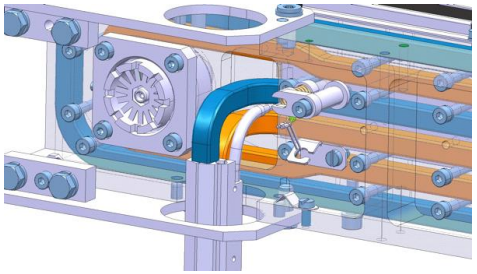
Cable Dimensions:

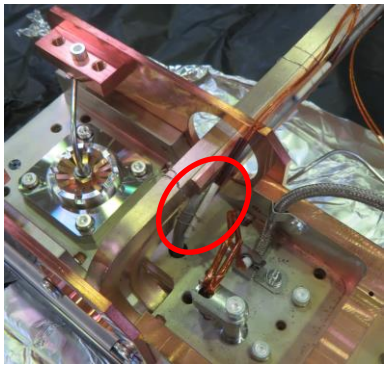


Tests of the wire in the collimator jaws

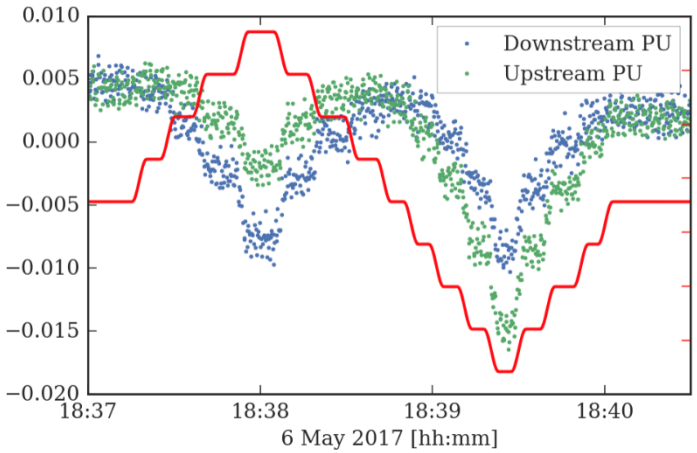






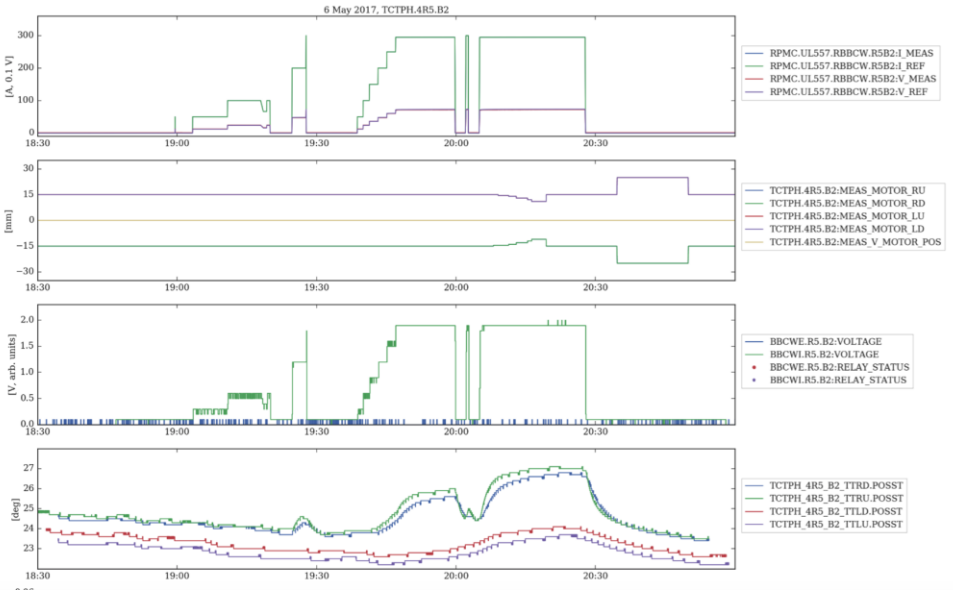


Tests at the LHC (G. Sterbini et al.)



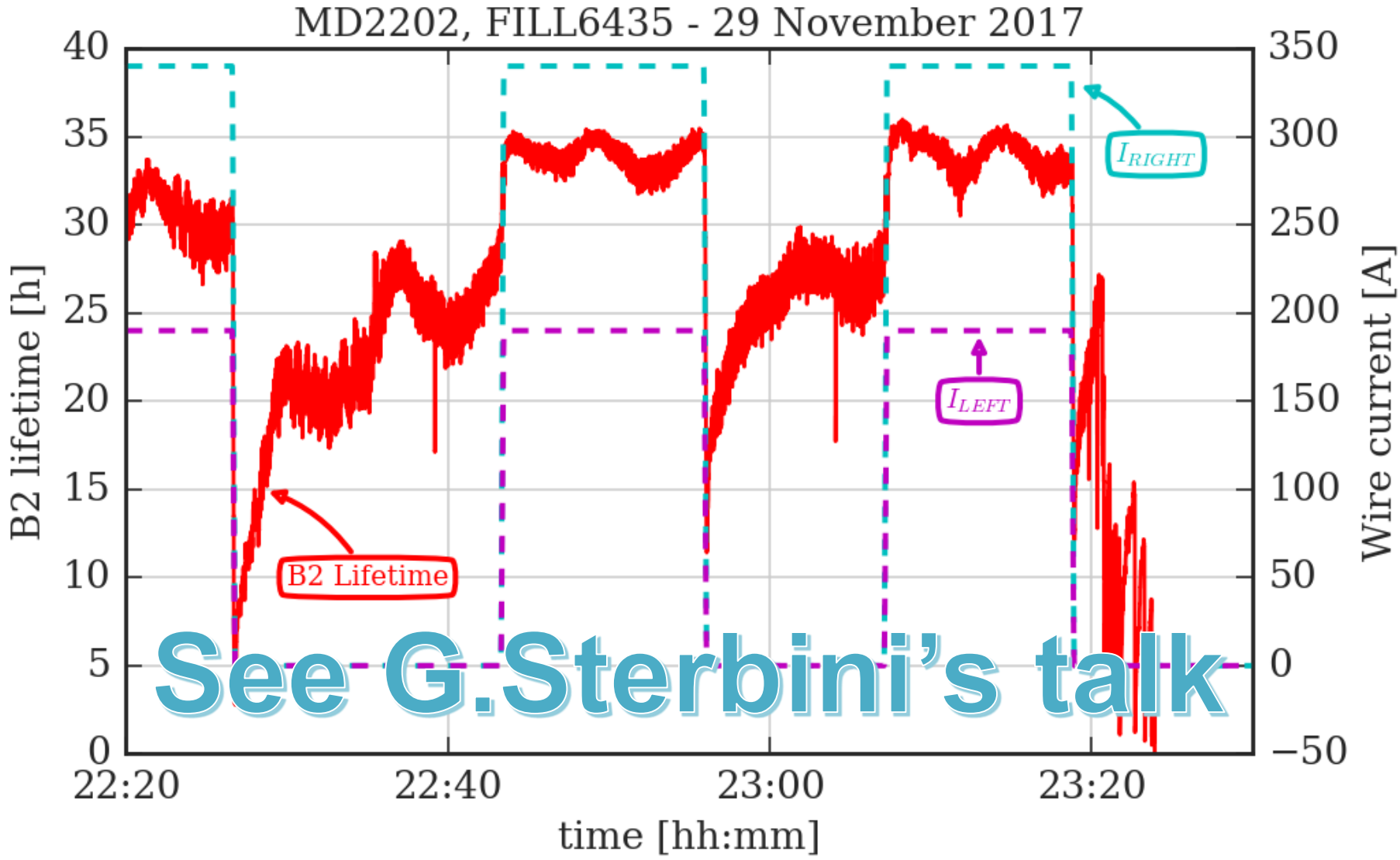
Vertical centering with 3 pilot LHC bunches and orbit vertical bump (steps of 0.5mm)

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



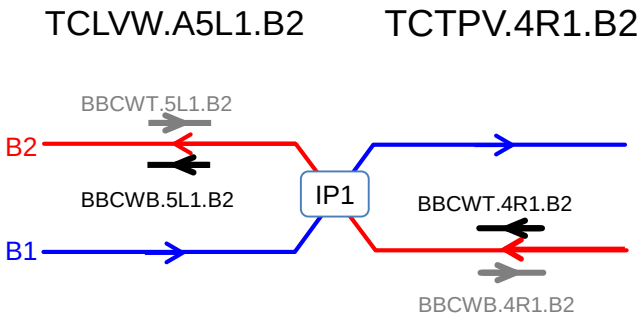
Checking jaw temperature and movement with wire current ON

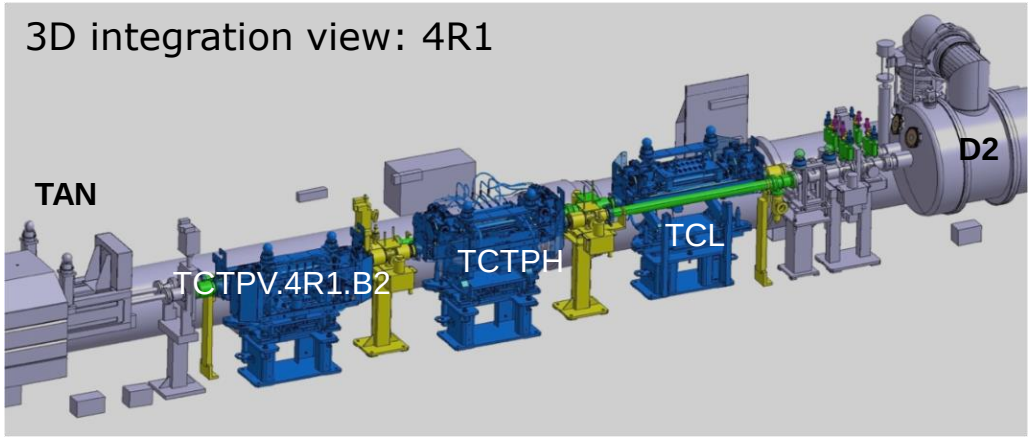
EYETS 2016-17 – replacement of TCTPH.4R5.B2 and TCL.4L5.B2

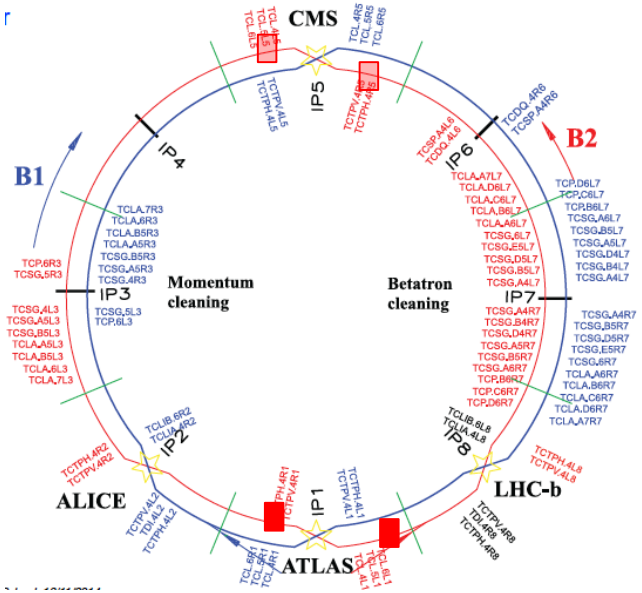


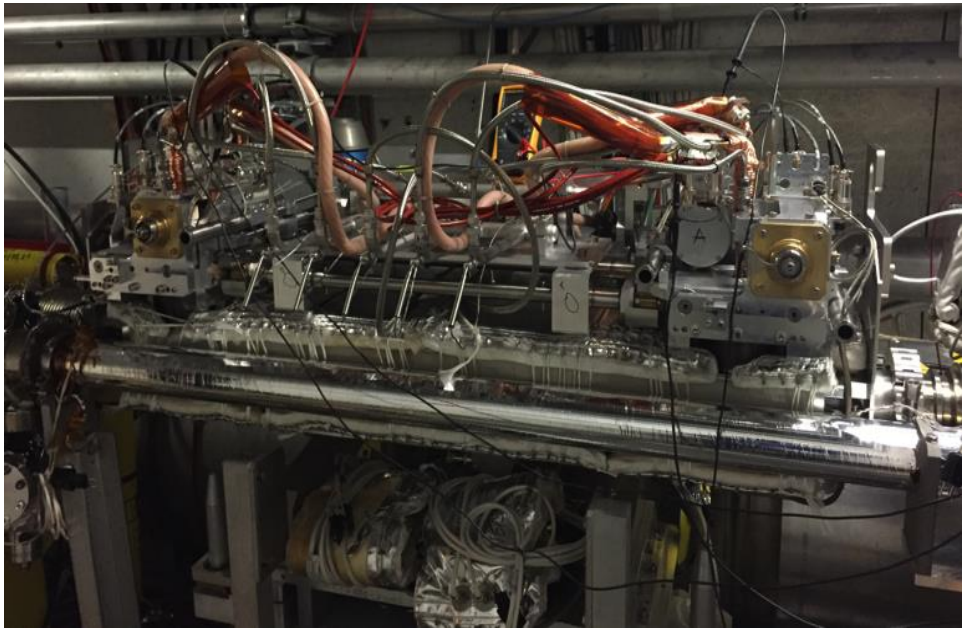
See G.Sterbini's talk

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

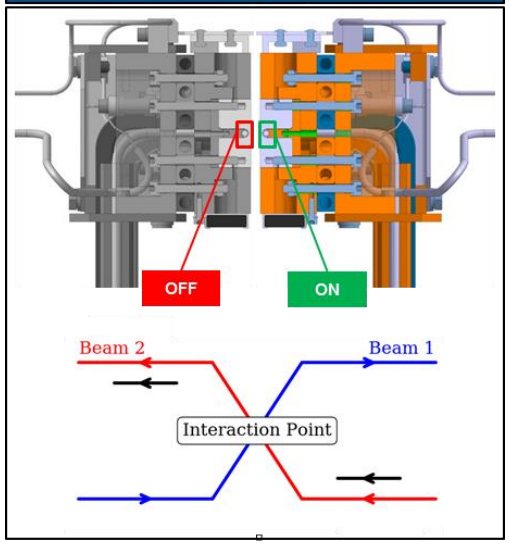




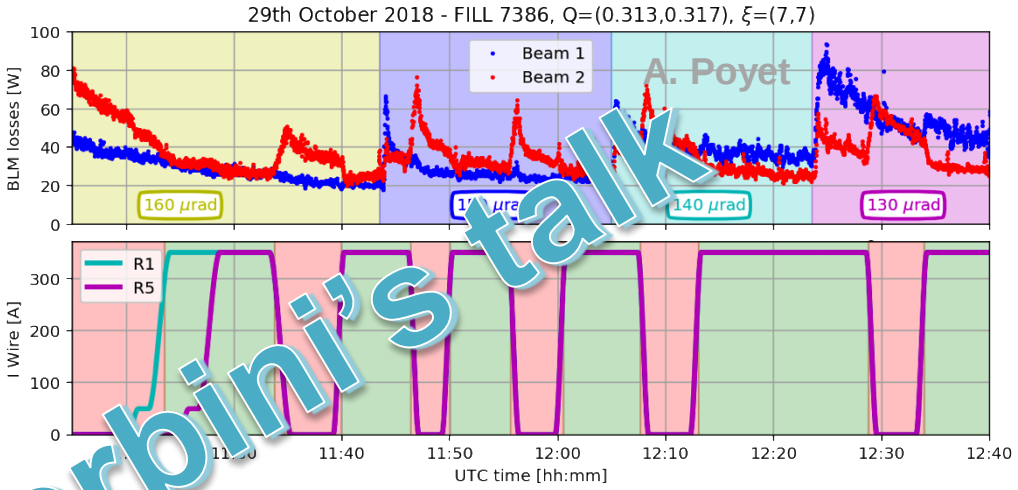


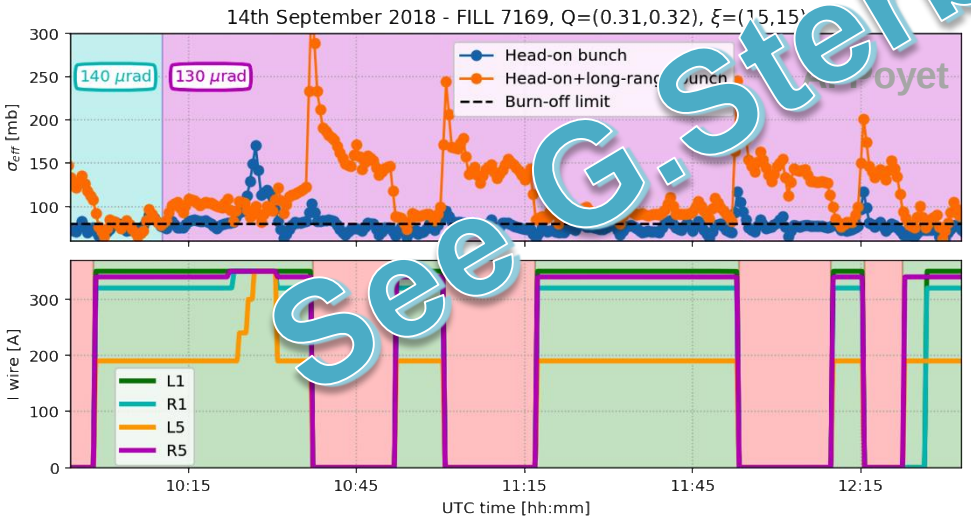


Low intensity experiment

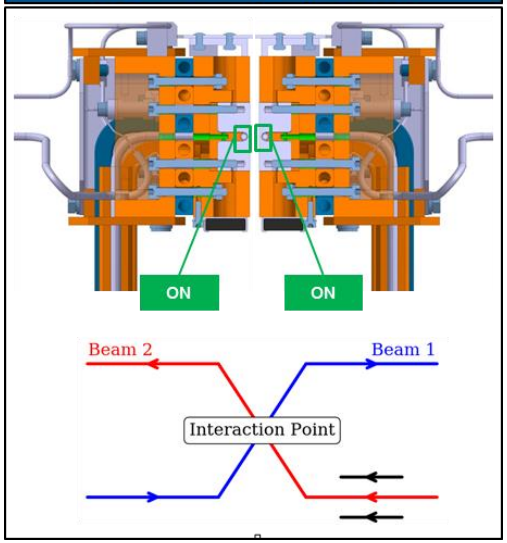


Compensation provides a reduction of B2 losses by ~20%.





High intensity experiment



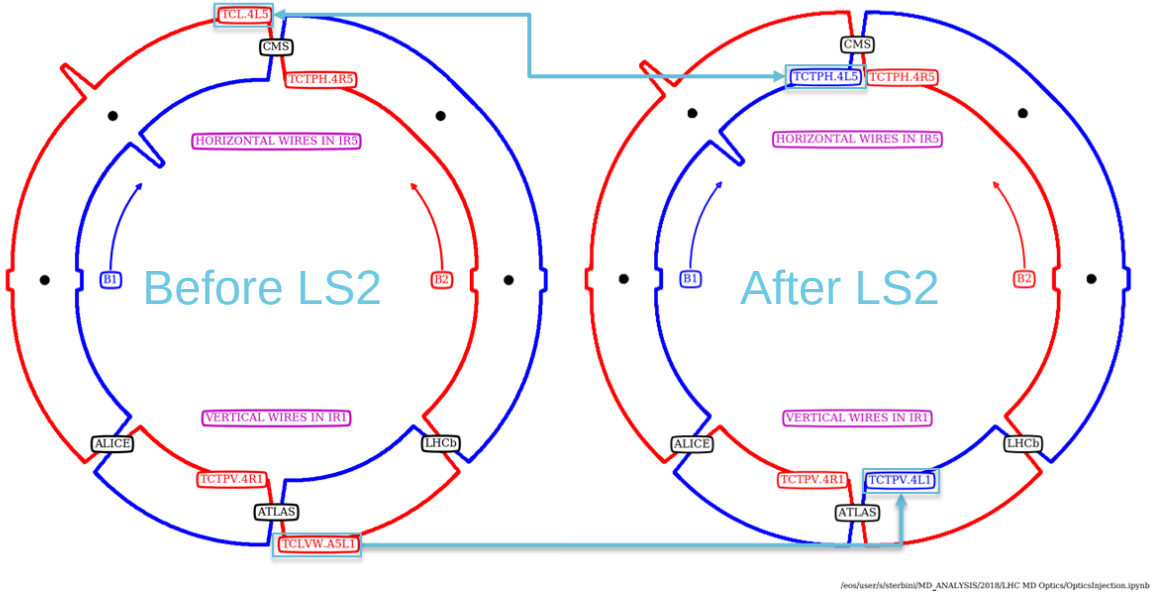
Almost full compensation, even at reduced crossing angle, for regular bunch whereas head-on bunch not degraded.

IPAC19, G. Sterbini, contributed talk WEYYPLM3

See G. Sterbini's talk

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**)

Future for HL-LHC

See the rest of the meeting!

Summary and conclusions

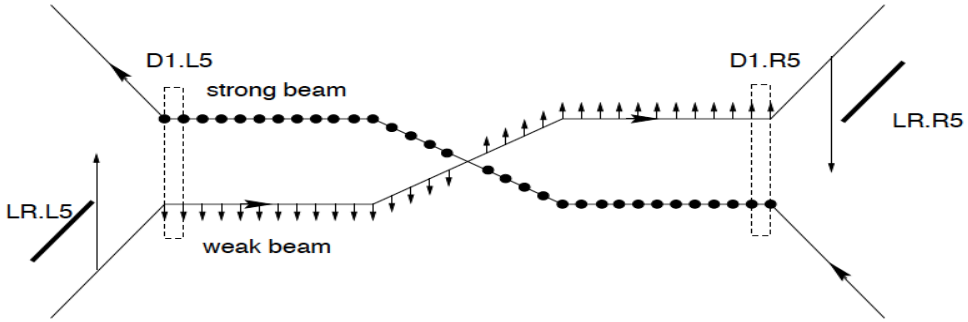
- Wires have been identified as possible BBLR compensation as early as in the late 1990s
- The first proof of concept was actually implemented in the SPS
- Wire-in-jaw collimators are being used to test compensation at LHC and simulation work have been able to reproduce experimental results (see future talks)
- Results extrapolated to HL-LHC show the possibility of achieving up to 10% more luminosity without crabbing, and larger dynamic aperture and more comfortable working points with crabbing
- **We hope to rise TRIUMF interest in the project and obtain support to introduce this option in the baseline**

Thank you

*D. Amorim, G. Arduini, H. Bartosik, R. Bruce, X. Buffat, L. Carver, G. Cattenoz, 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, J. Olexa, S. Papadopoulou, Y. Papaphilippou, D. Pellegrini, M. Pojer, L. Poncet, A. Poyet, S. Redaelli, A. Rossi, B. Salvachua, H. Schmickler, F. Schmidt, K. Skoufaris, M. Solfaroli, G. Sterbini, R. Tomas, G. Trad, A. Valishev, D. Valuch, 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**).*

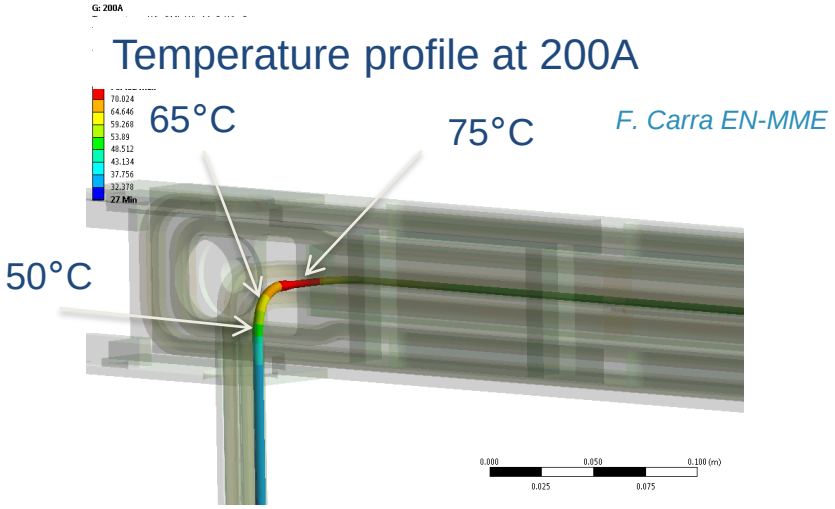
History with literature

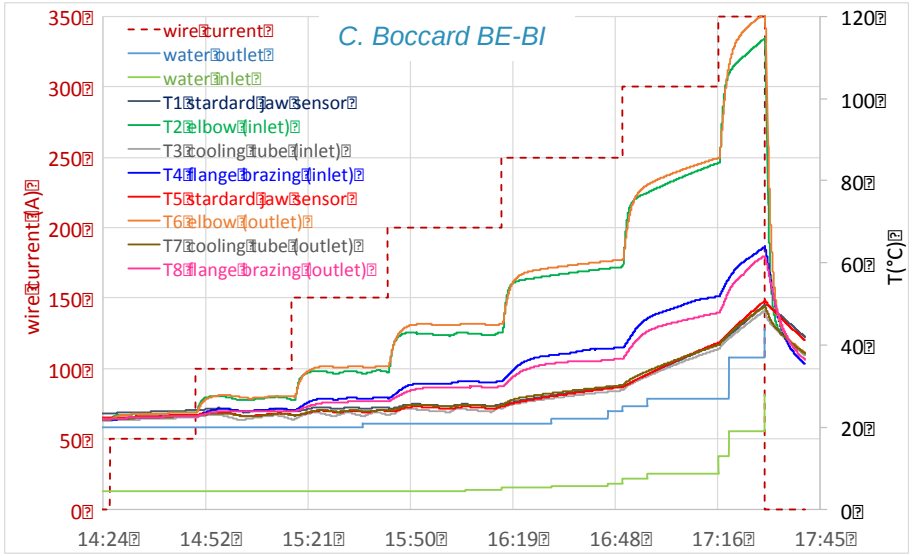
- J.P.Koutchouk, LHC Note 223, CERN 2000



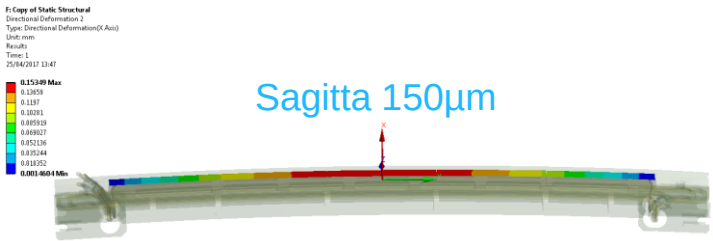
- Mmm
- Mmm
- LHC Collimation Working Group #181, 6 Oct 2014
  - Energy deposition (E.Skordis) and Structural Analysis (M.Garlasche, A.Bertarelli, F.Carra) of Wire-in-Jaw TCTP collimators
- LHC Collimation Working Group #203, 11 Apr 2016
  - Wire-in-Jaw TCTP collimators recap on design (L.Gentini) and Tests and Assembly (O.Aberle)

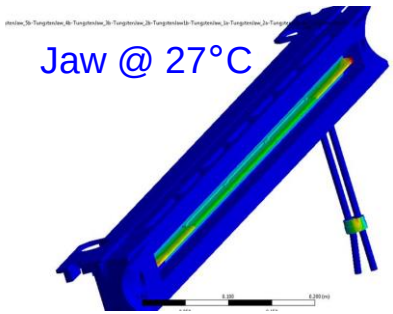
Wire current and temperature with cooling

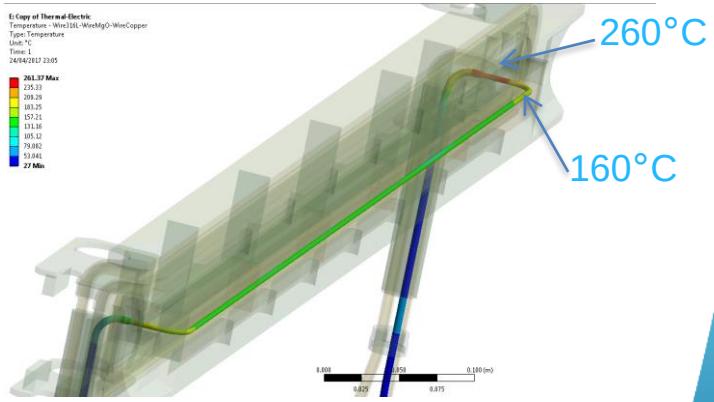




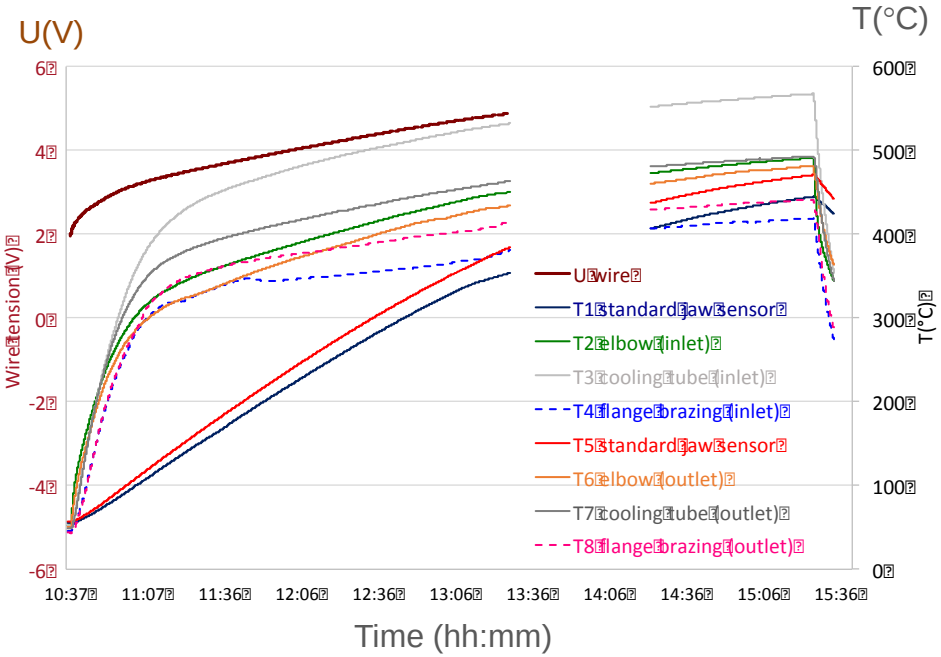
@ 350A

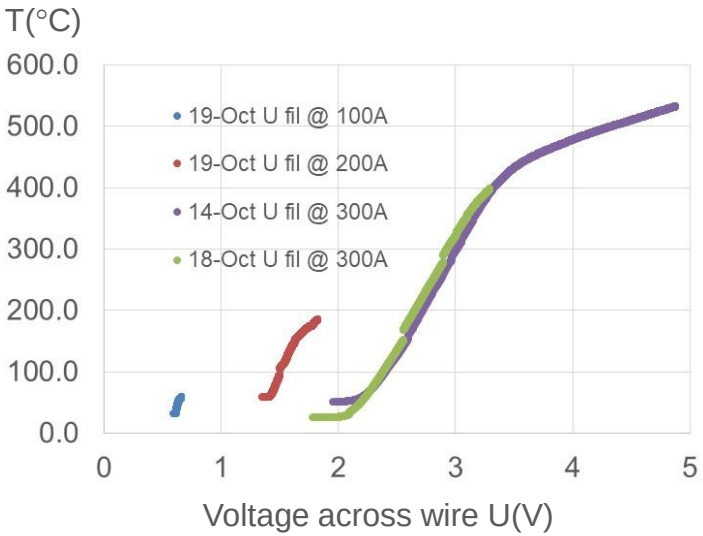






Wire current and temperature without cooling





- 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)