MD results during LHC Run-II & plans for Run-III

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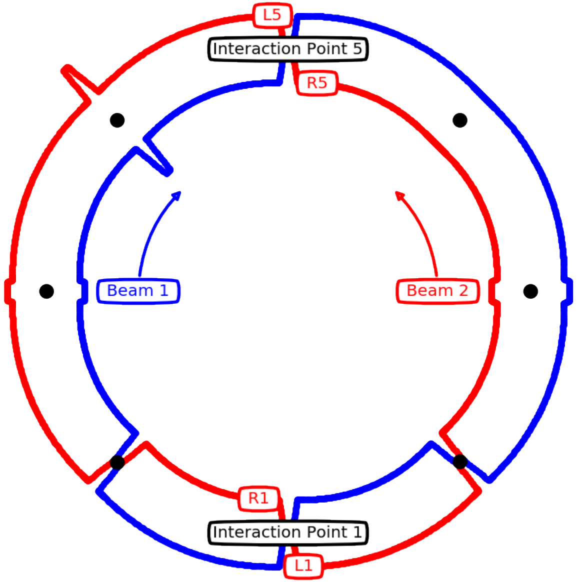
WP2/WP13 HL-LHC Wire Compensation Meeting, Fermilab, 17th October 2019

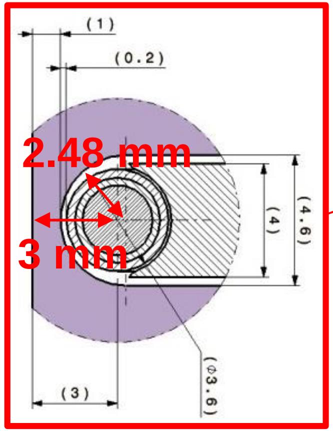
Outlook

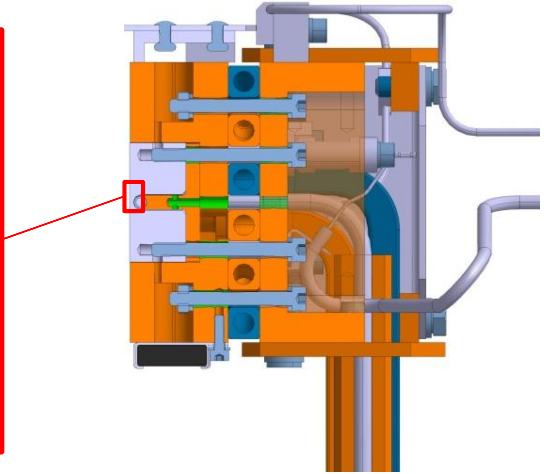
- Experimental constraints and optimization of the wires settings
- Experimental objectives and results (Run-II)
- Next steps (Run-III)
- Summary

The LHC wire demonstrators



Layout of the wire installation, not to scale





Courtesy of L. Gentini

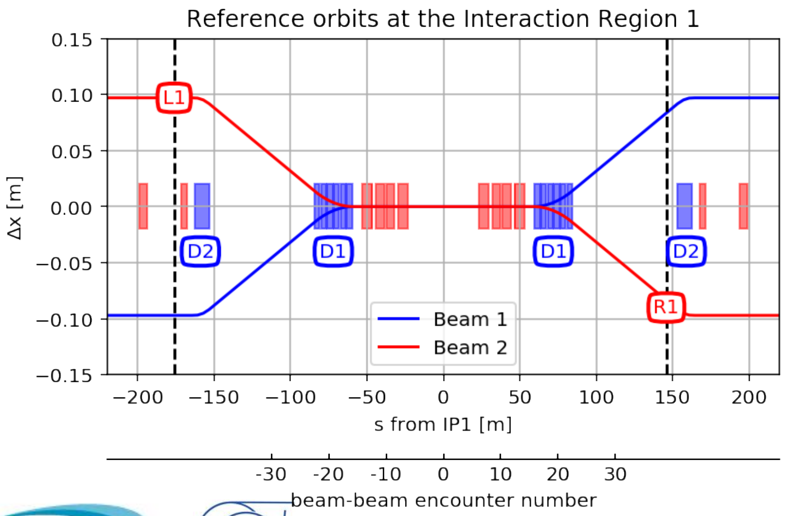
Front view

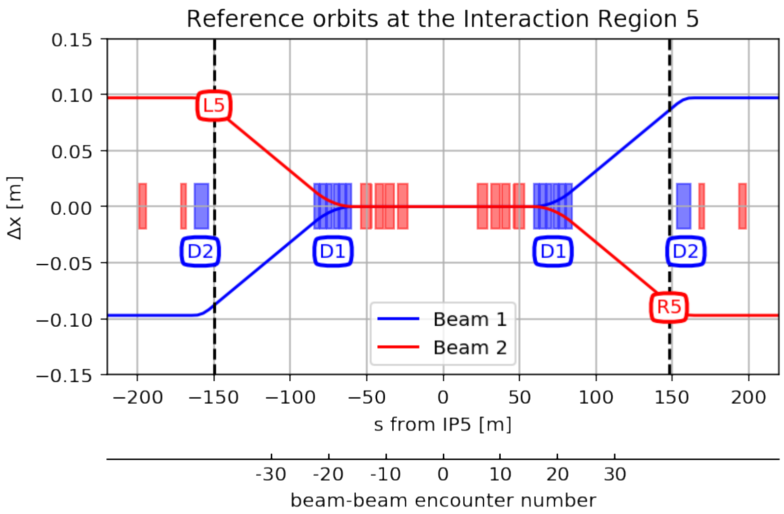
- **Since 2018 four wire demonstrators are installed in LHC (B2, IR1+IR5)** with the aim to explore the potential of the wires in HiLumi HL-LHC PROJECT

Longitudinal position of the wires

- The longitudinal position of the wires was driven by the present position of the collimators and the integration constraints.
- Symmetric position in the IR5.

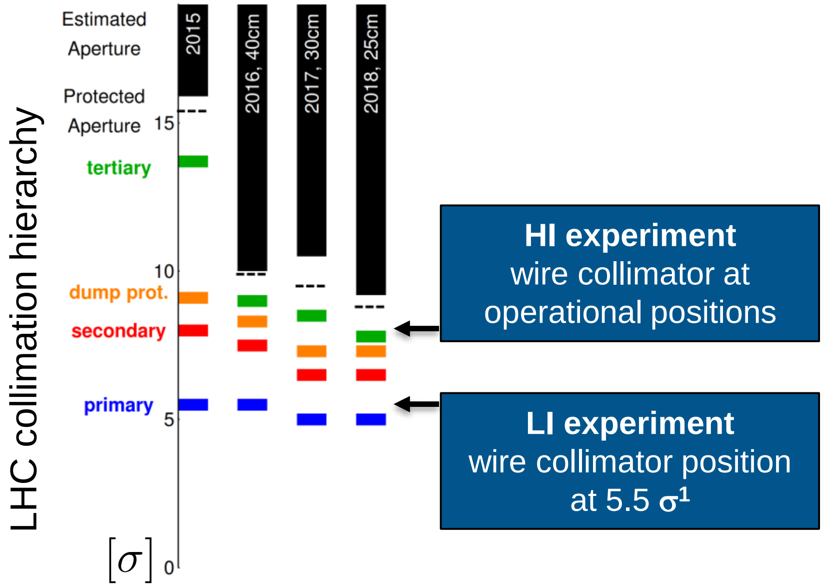
Wire demonstrator	s from the Interaction Point [m]
L1, collimator not-used in operation	**-176.17**
R1, tertiary collimator	**145.94**
L5, IP debris collimator	**-150,03**
R5, tertiary collimator	**147.94**





Transverse positions of the wires

- The wire are installed in the crossing plane of the Interaction Region, i.e.,
  - vertical in IR1,
  - horizontal in IR5.
- Given the constraints of the LHC collimation hierarchy, two classes of experiments were performed
  1. **LI**: **Low Intensity** experiment with wire-collimator just in the shadow of the primary collimators
  2. **HI**: **High-Intensity** experiment with wire-collimator at the operational position.



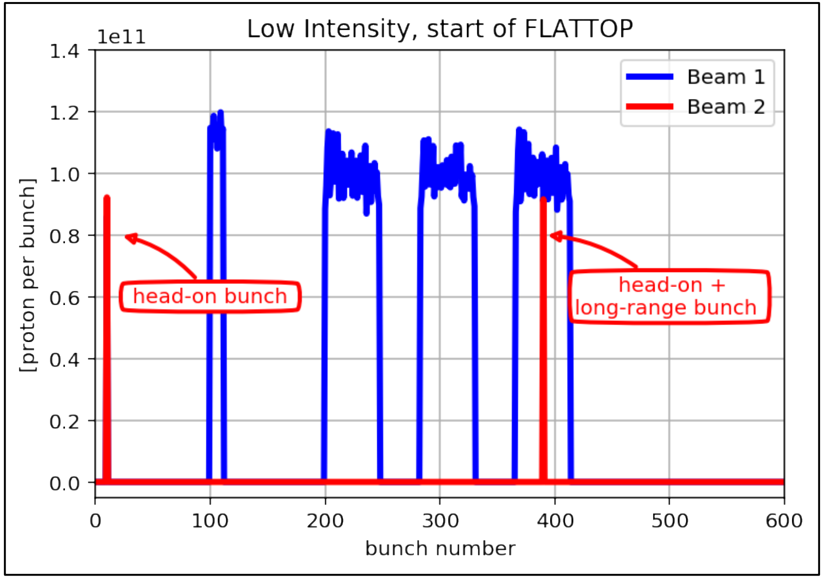
Courtesy of R. Bruce

Wire demonstrator	LI experiment	HI experiment
	beam-wire distance [mm]	
L1	**-7.41**	not powered
R1	**7.42**	**9.83**
L5	**-7.15**	not powered
R5	**8.24**	**11.10**

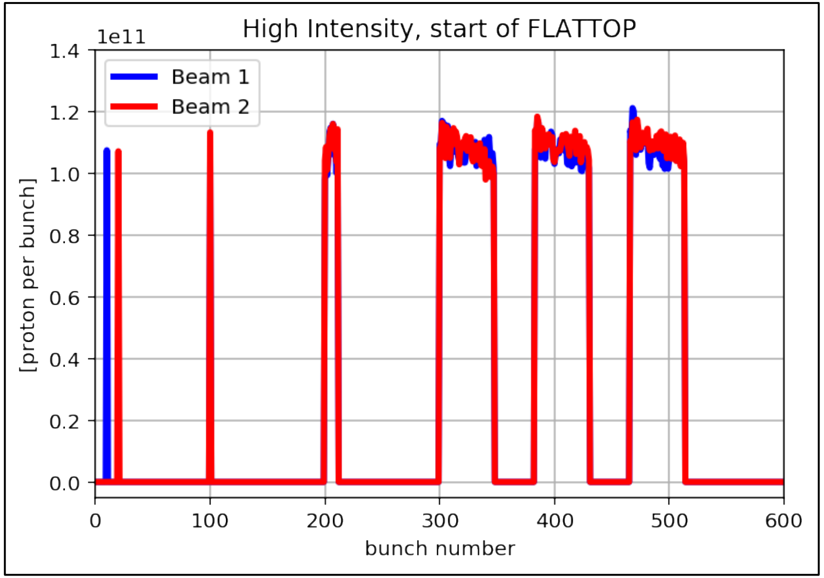
[1] An ε_n=3.5 mm mrad assumed.

Filling schemes and beam-beam encounters

Low Intensity experiment



High Intensity experiment



- In the **LI experiment** the first bunch of B2 see only two head-on's (in IP1 and IP5) and the second bunch experiences head-on and long-range encounters.
- In the **HI experiment** we have a rich distribution of beam-beam interactions in IR1/5.

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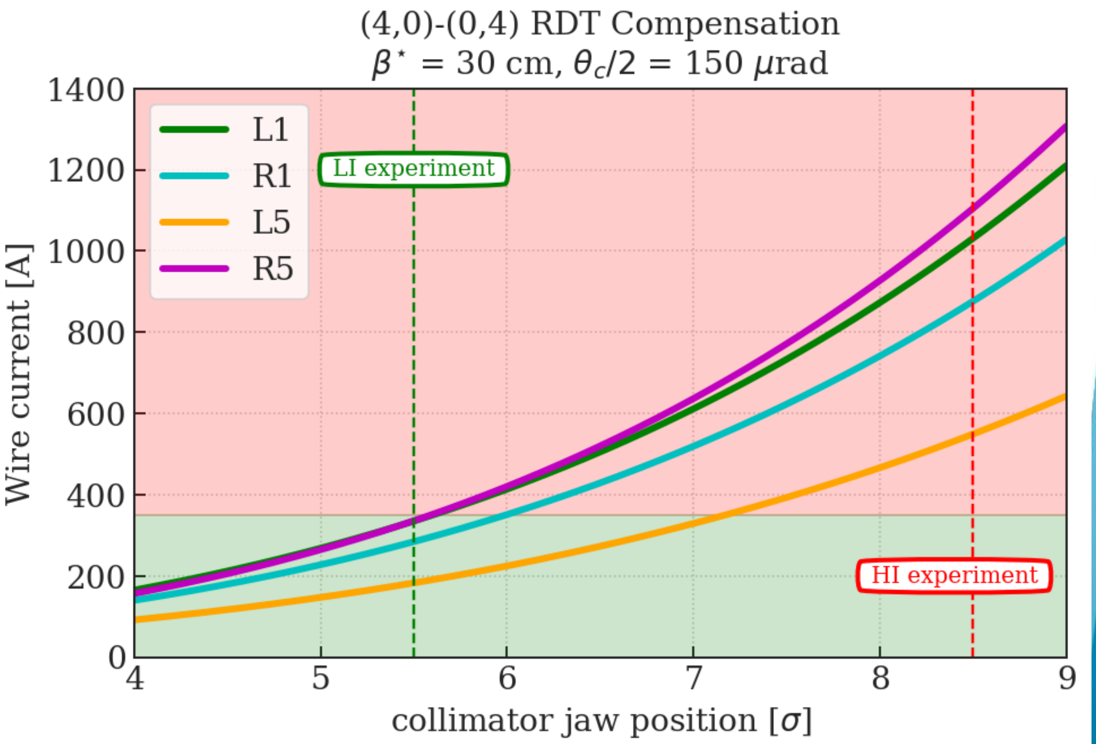
Wire current settings I

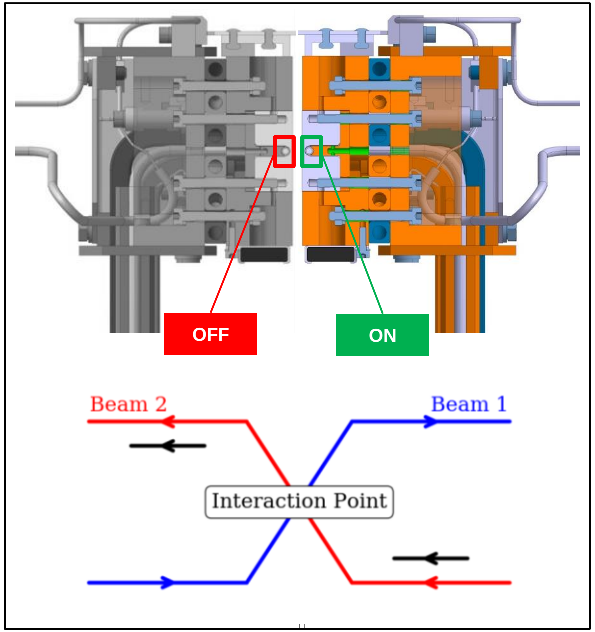
- The experimental setup allowed to minimize only two Resonance Driving Terms.
- We set the wire currents to compensate the **(4,0) and (0,4) RDT**: first order amplitude detuning.
- For the HI experiment, due the larger beam-wire distance, the current for the compensation is not compatible with the standard wire configuration.



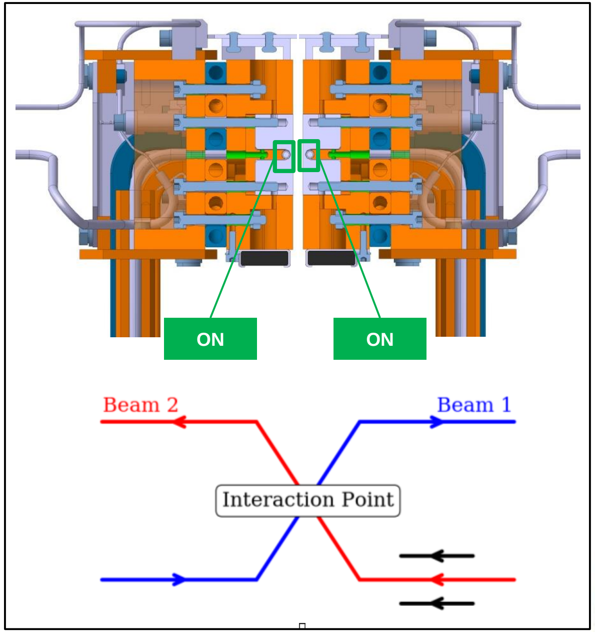
Wire current settings II

- In the wire-collimator, both jaws house a wire.
- In the **LI experiment** only the wire of one single jaw was powered.
- For the **HI experiments** the wires of both jaws where powered: this allowed to double the integrated strength of the quadrupolar, octupolar, etc., components.

LI experiment: 1-jaw powered



HI experiment: 2-jaws powered



Wire demonstrator	LI experiment	HI experiment
	Current [A]	
L1	350 x 1	not powered
R1	320 x 1	350 x 2
L5	190 x 1	not powered
R5	340 x 1	350 x 2

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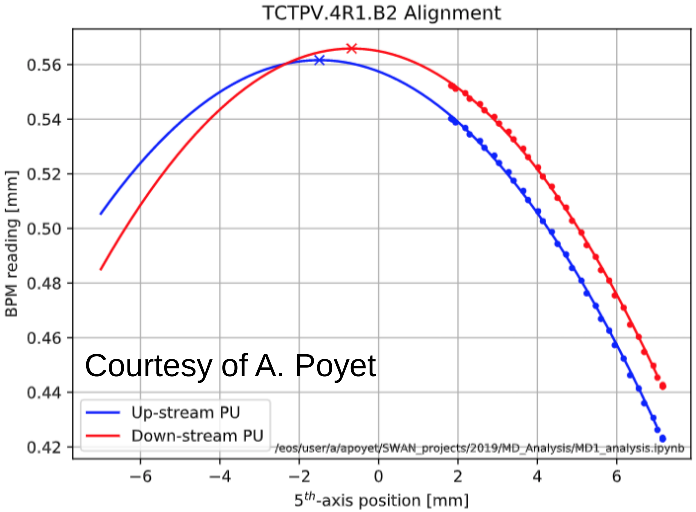
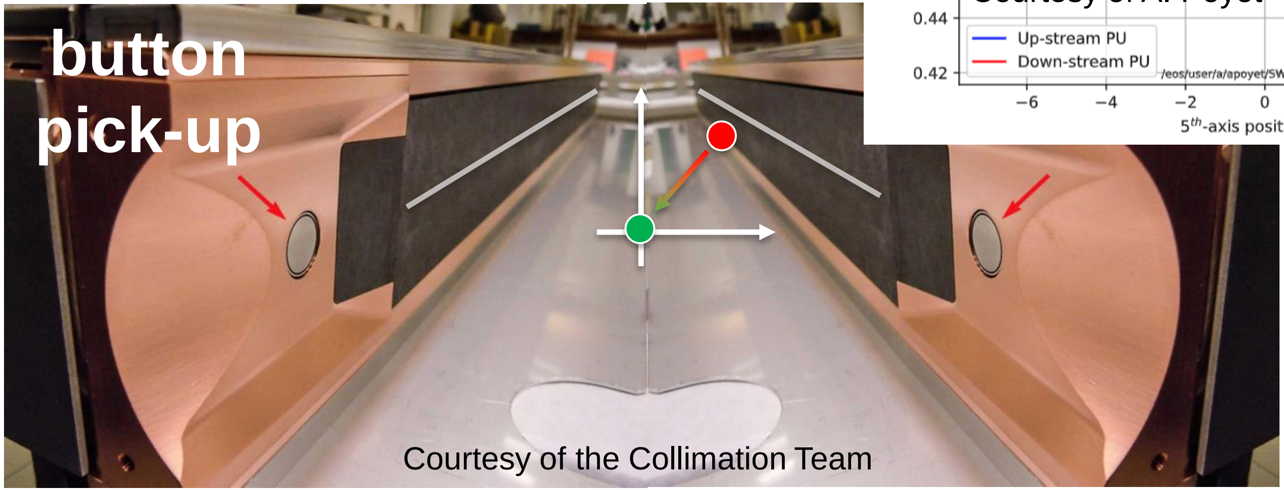
Beam-wire alignment

- Alignment of the wire is critical. The jaw of the collimators has 2 button pick-up that allows

1. to center the beam within jaws,
2. to align the wire and the beam.



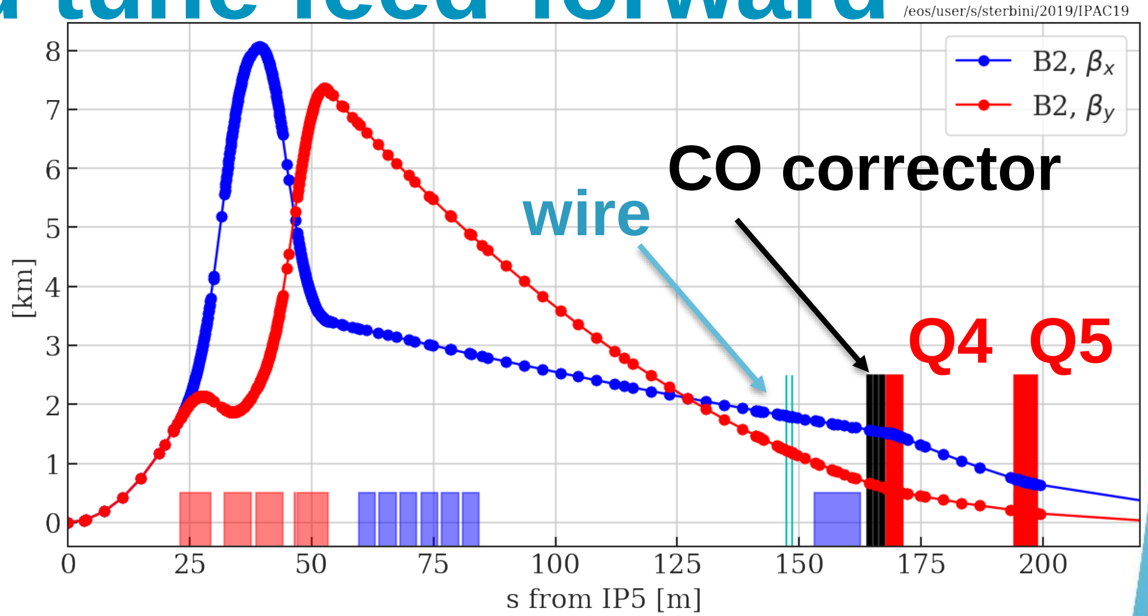
Courtesy of A. Poyet

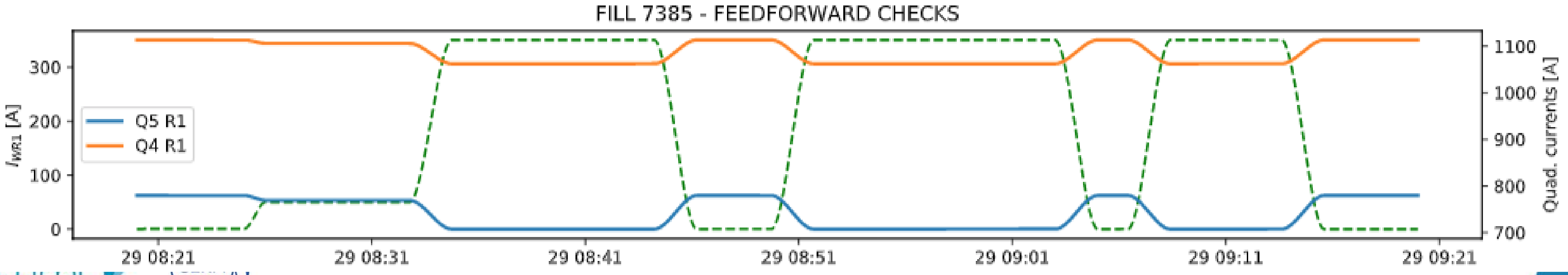


Courtesy of the Collimation Team

Orbit and tune feed-forward

- The effect of the wires on the orbit (dipole) and linear optics (quadrupoles) where locally compensated using
- CO corrector close to Q4 trims (+ orbit feedback)
- Q4 and Q5 trims





Courtesy of A. Poyet

Outlook

- Experimental constraints and optimization of the wires settings
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Objectives of the experiments

- **Prove a beneficial effect of the wires demonstrators** in a regime dominated by long-range beam-beam effect. The compensation should not degrade the lifetime of the head-on bunches.

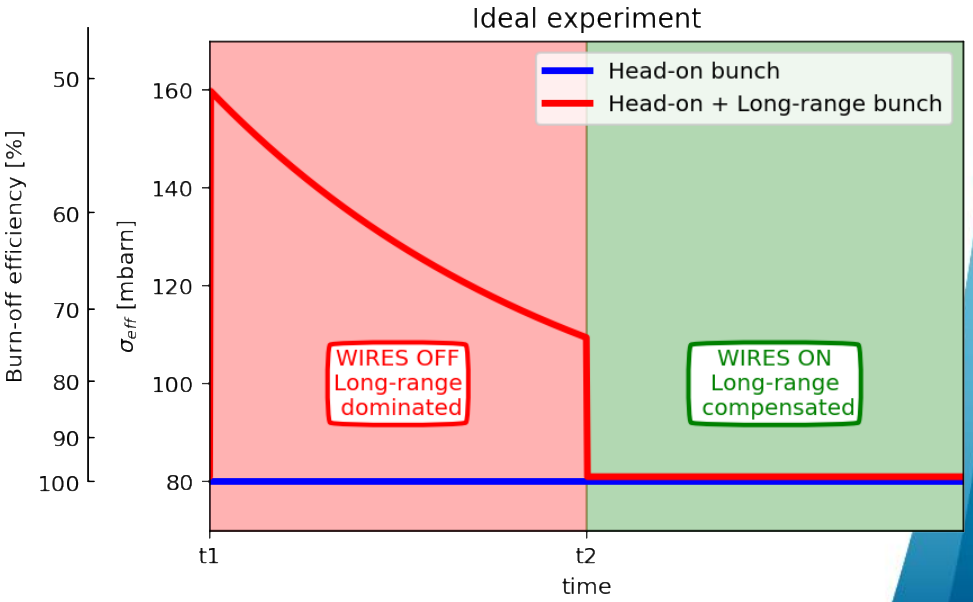
- We need to guarantee the beam-wire alignment and that the linear effects of the wire (orbit and tunes) are compensated with feedforwards.

- The main observables are the beam losses, its lifetime and the **bunch effective cross-section** (σ_{eff})..

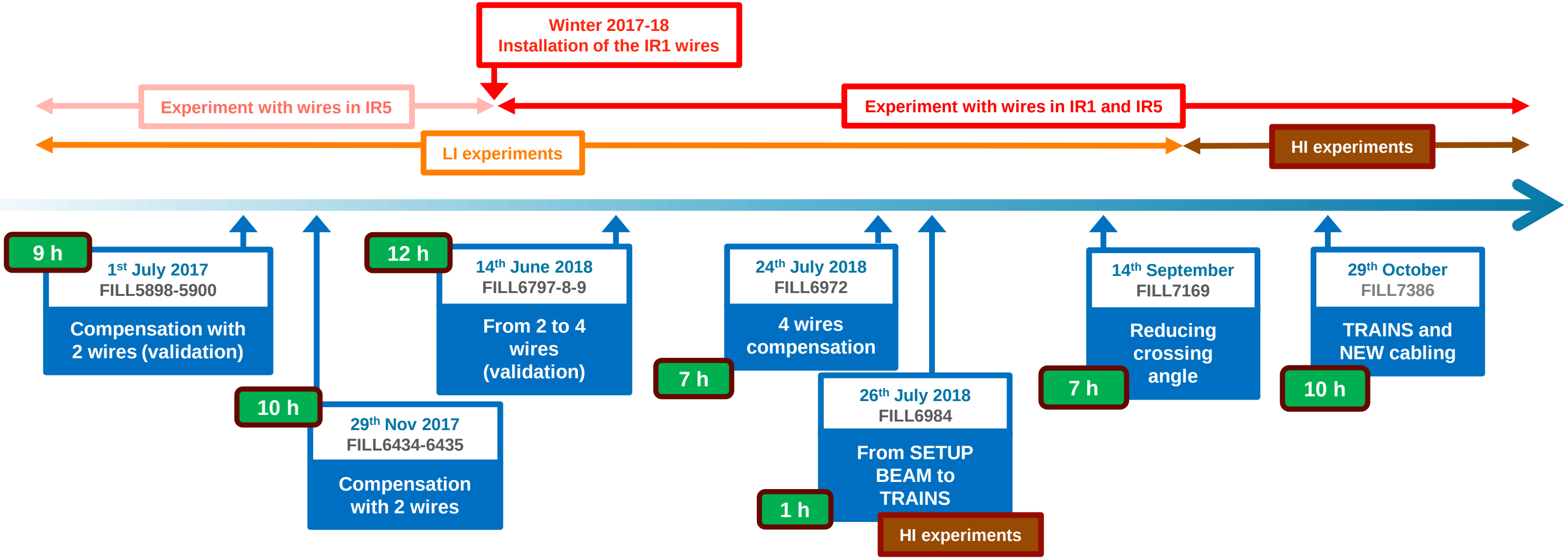
$$\sigma_{EFF} = -\frac{1}{\sum_{IP} L_{IP}} \frac{dN}{dt}$$

Instantaneous luminosity

Intensity loss-rate

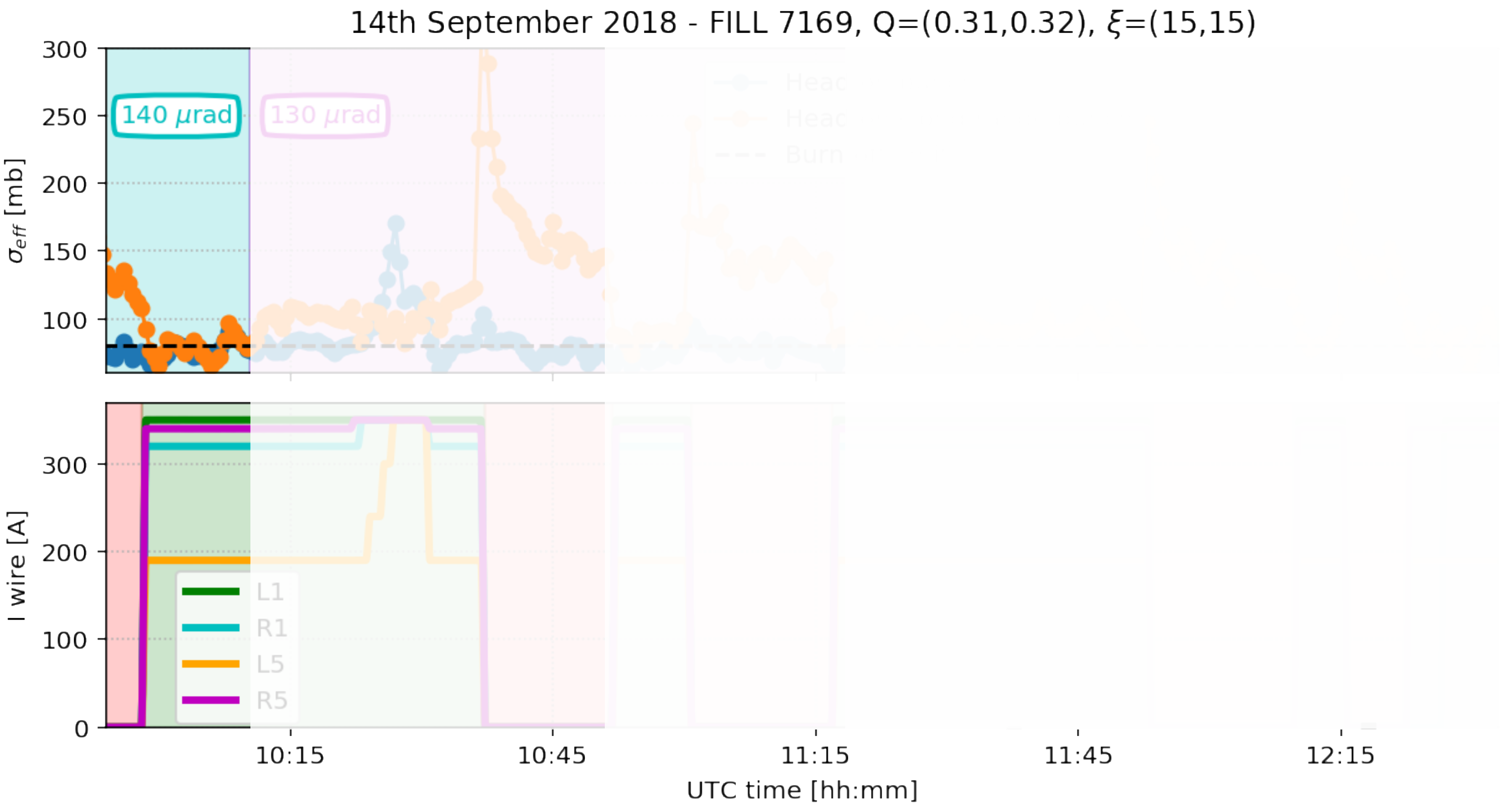


The experimental campaign



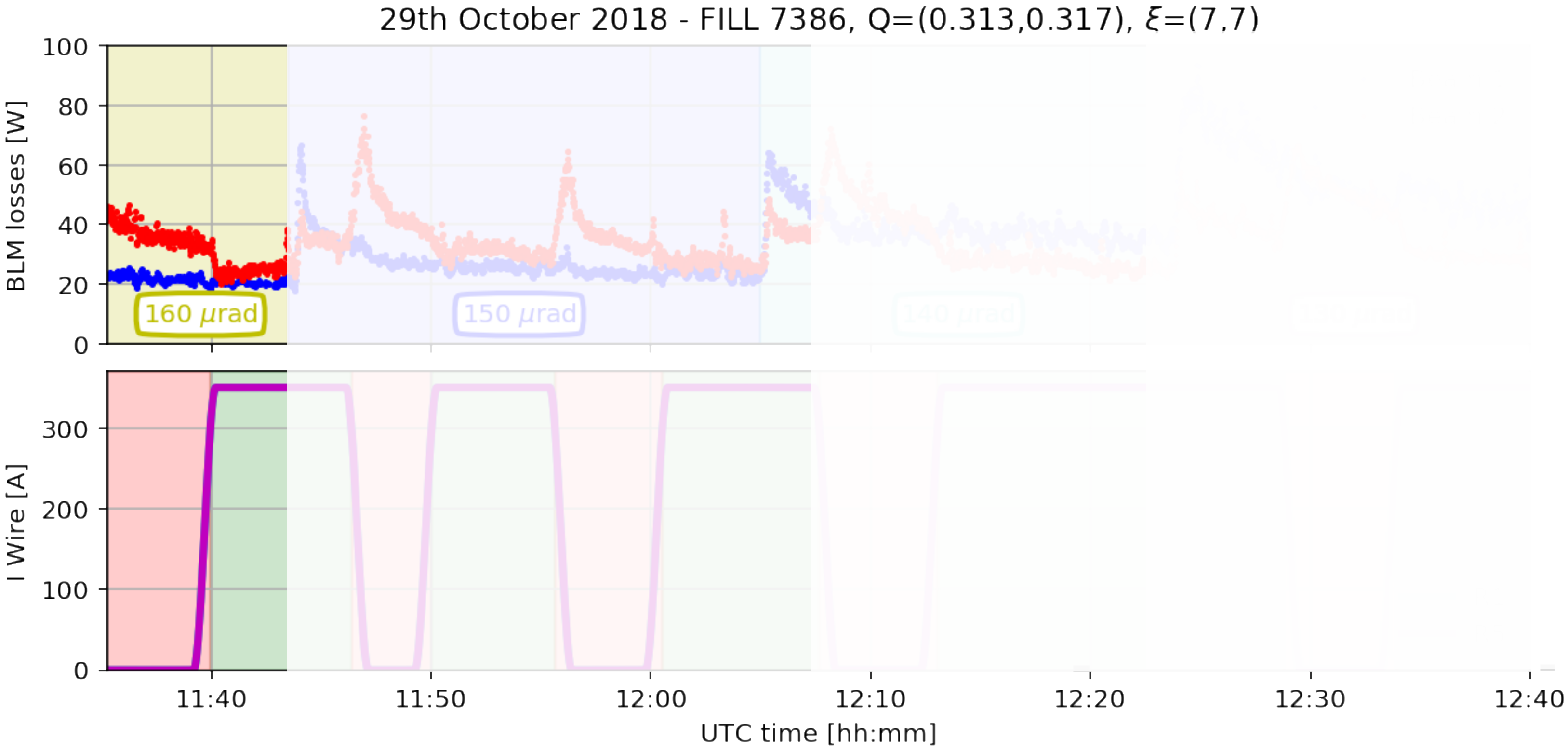
- A rich experimental campaign was performed during the last 2 years: the compensation effect was systematically observed.

Low-Intensity experiment



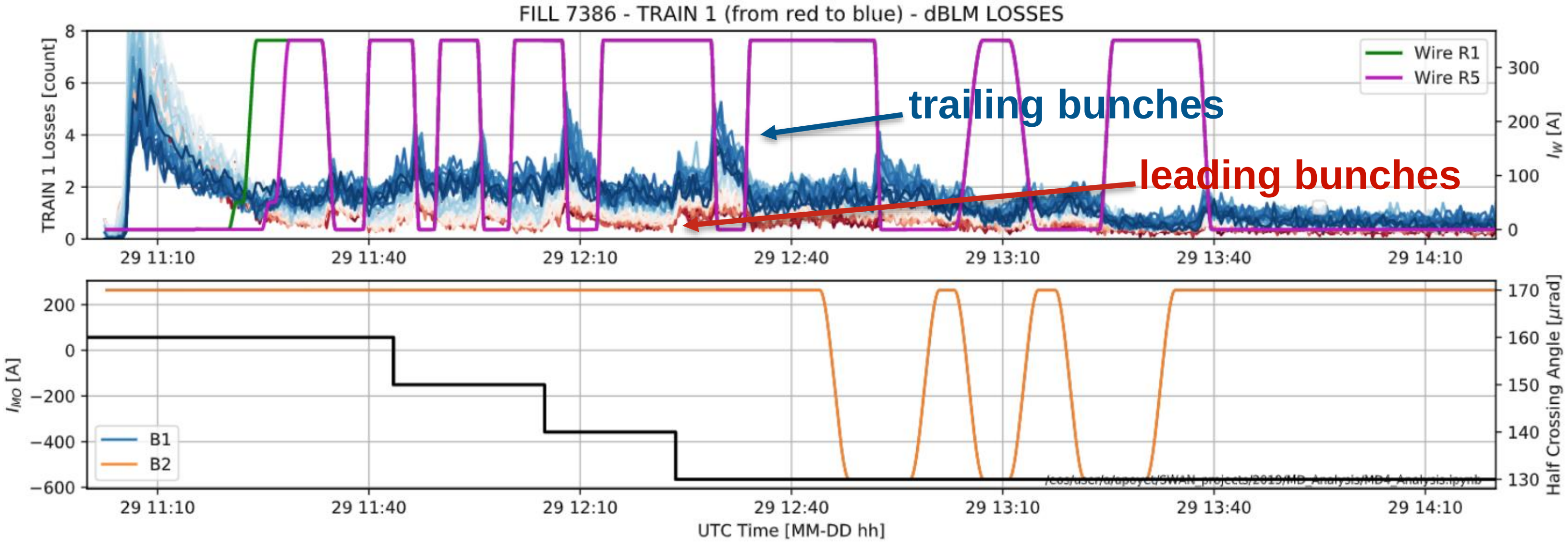
- **Almost full compensation, even at reduced crossing angle, for regular bunch whereas head-on bunch not degraded.**

HI experiment (operational conditions)



- **Compensation provides a reduction of B2 losses of ~20%.**

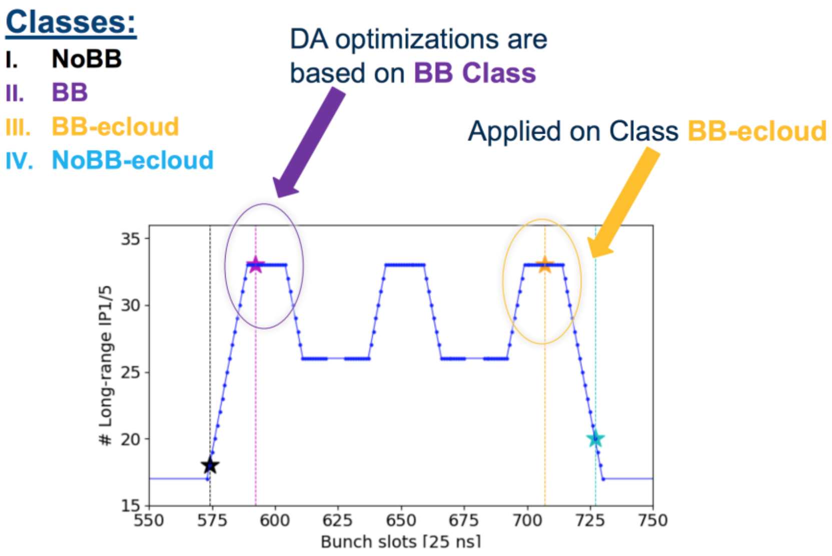
Bunch-by-bunch analysis (I)

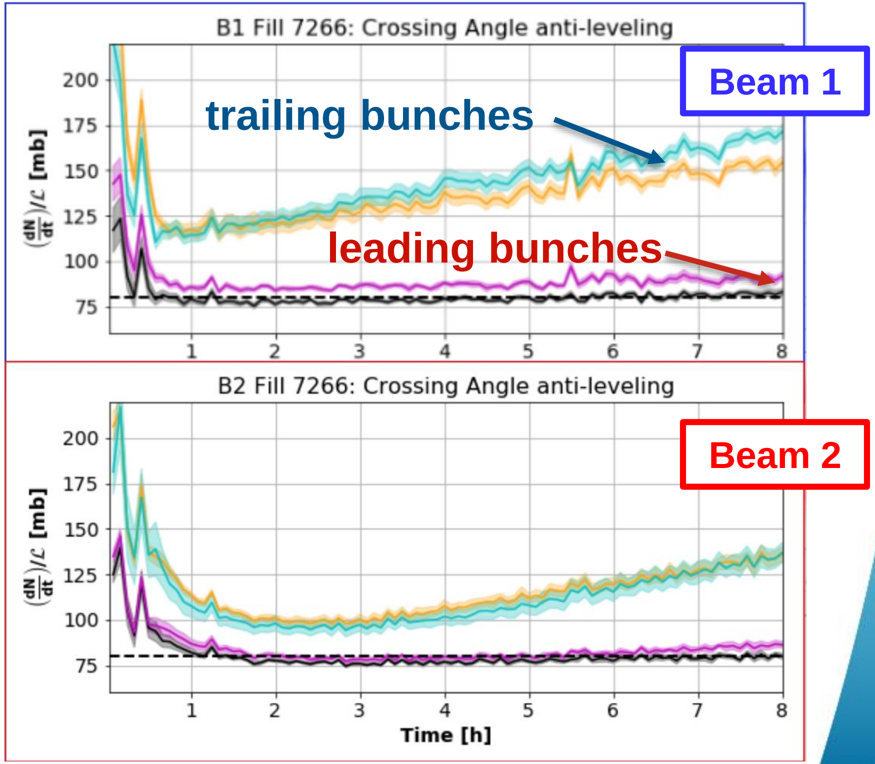


- In the HI experiment the wire is more effective for the trailing bunches.

Bunch-by-bunch analysis (II)

- Several observation during 2018 run showed indeed that the trailing bunches are the most critical in terms of losses.

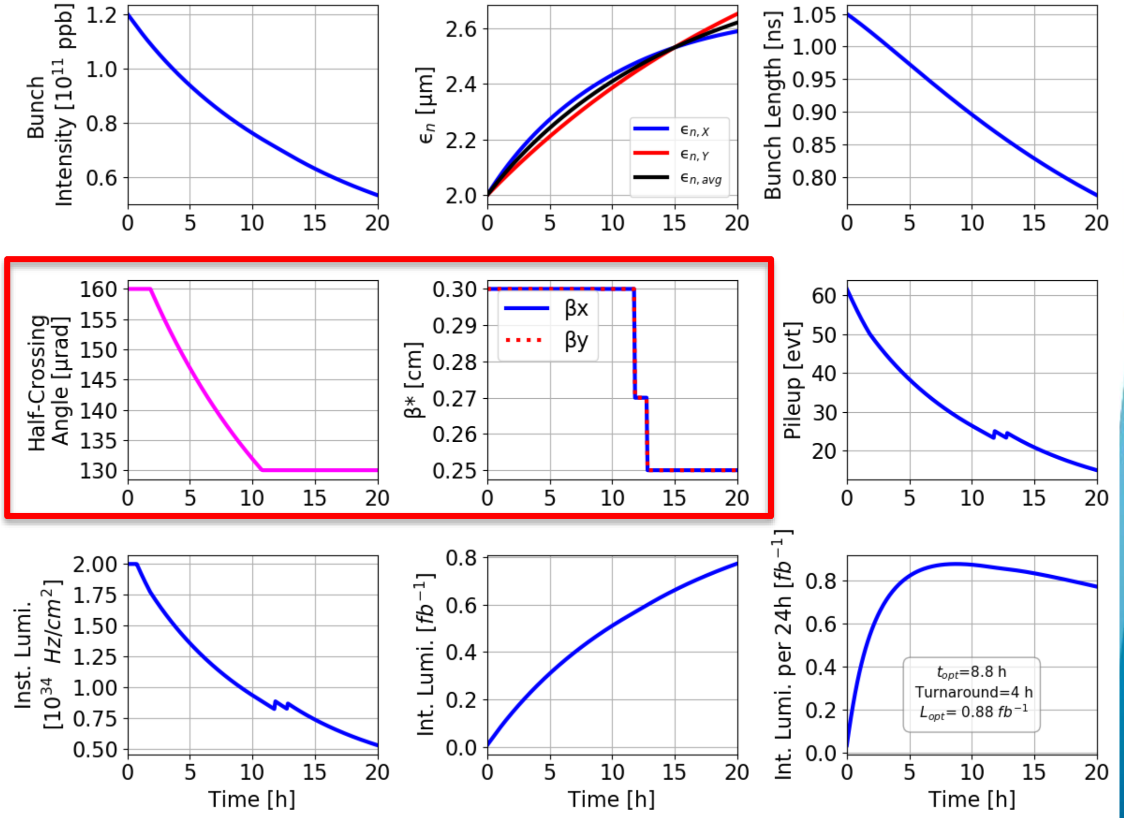




Courtesy of S. Kostoglou and S. Papadopoulous

Run-II (2018) Fill Profile

- The crossing angle reduction and its interplay with e-cloud and BB are considered the responsible of the losses on the trailing bunches.
- In Run3 one can use the wire to alleviate this effect.



Courtesy N. Karastathis

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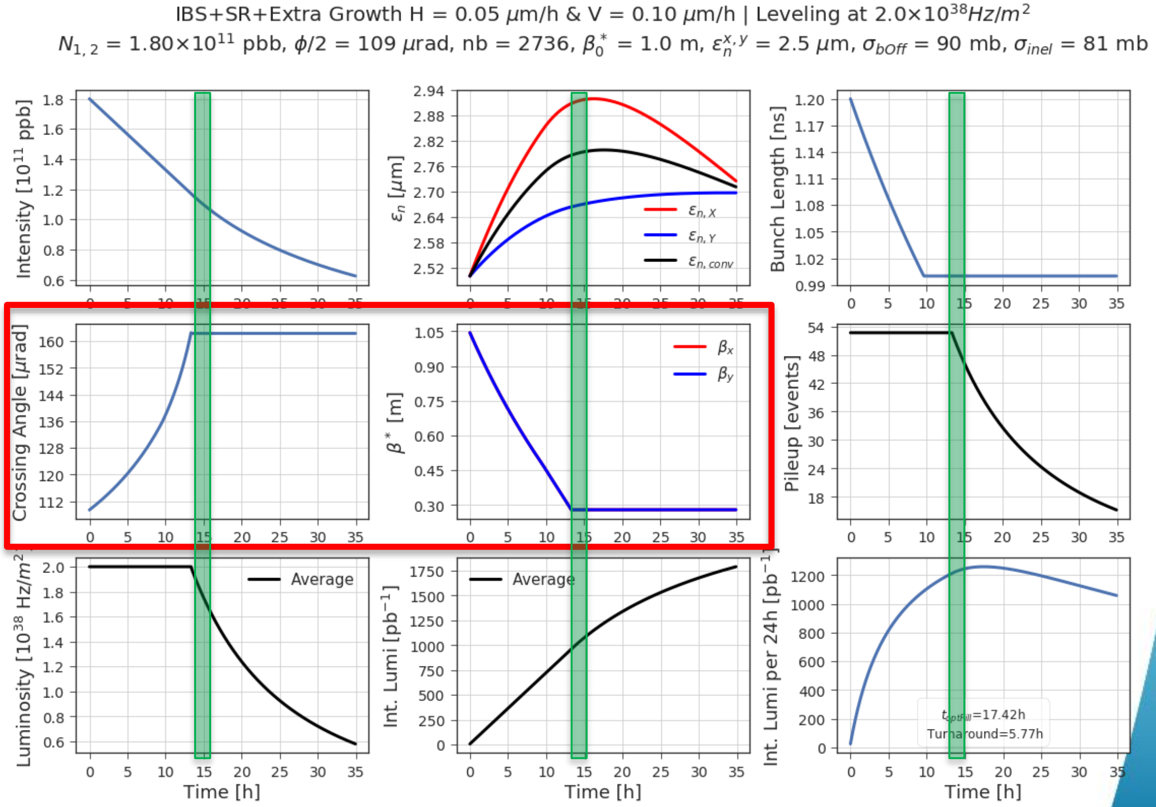
Run-III Fill Profile (2021-23)

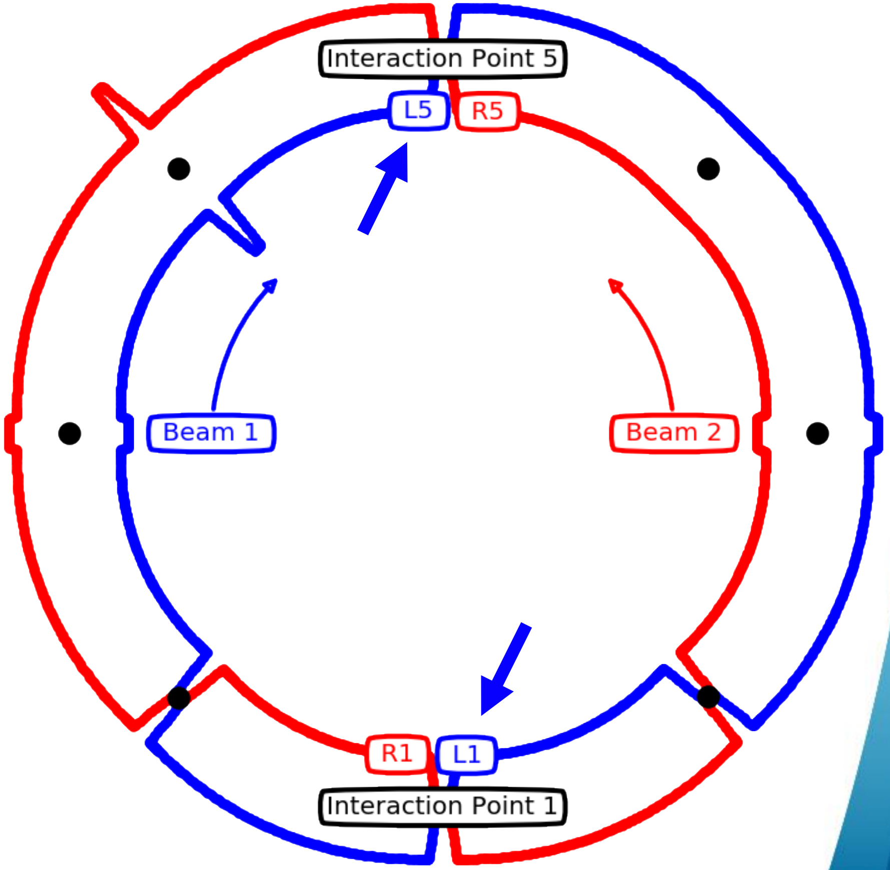
- In 2021: **round optics** with IP1 crossing in V-plane and IP5 crossing in H-plane.
- The wires could be switched on at the end of the leveling.
- We assume Run-III collimation settings similar to Run-II ones.



Courtesy of S. Fartoukh and N. Karastathis

Next steps and proposals

- Following these encouraging results, it was proposed
  - **to use the wires routinely** during the next LHC operation period in the High-Intensity configuration
  - **to equip also the Beam 1** with wires by moving two wire demonstrators (L1 and L5) from Beam 2 to Beam 1.



Summary

- In 2017-18 a rich measurements campaign was performed to explore the potential of the wire compensation for HL-LHC. For the first time in a hadron collider, the positive effect of the compensation was systematically observed in operational-like conditions.

- Following these results we proposed to use the wire demonstrators operationally for the next LHC run. Using the wire in Run-III will maximize what we can learn from the present demonstrators in view of HL-LHC possible applications.

Thank you for the attention.

J.-P. Koutchouk et al.
Wires in the SPS
Since 2004

W. Fischer et al.
Wires in RHIC
2006

C. Milardi et al,
Wires in DAΦNE
Since 2006

F. Zimmermann et al.
Specification of the
LHC wires, 2013

1st Workshop on (HL-)LHC
Wire Compensation
December 2015

Experiment in the LHC
2017-2018

1997
V. Shilsev et al.
e^- Q-compression

1999
Y. Papaphilippou, F. Zimmermann
PRST-AB 2, 104001

2000
J.-P. Koutchouk
DC wires for LHC

2004
B. Erdeley, T. Sen
FERMILAB-TM-2268-AD

2007
H. J. Kim, T. Sen
PAC07-THPAN114

2008
U. Dorda
PhD Thesis

2012
T. Rijoff
M.Sc.Thesis

2015
S. Fartoukh et al.
PRST-AB 18, 121001

2016
A.S. Patapenka et al.
NAPAC2016-TUPOB17

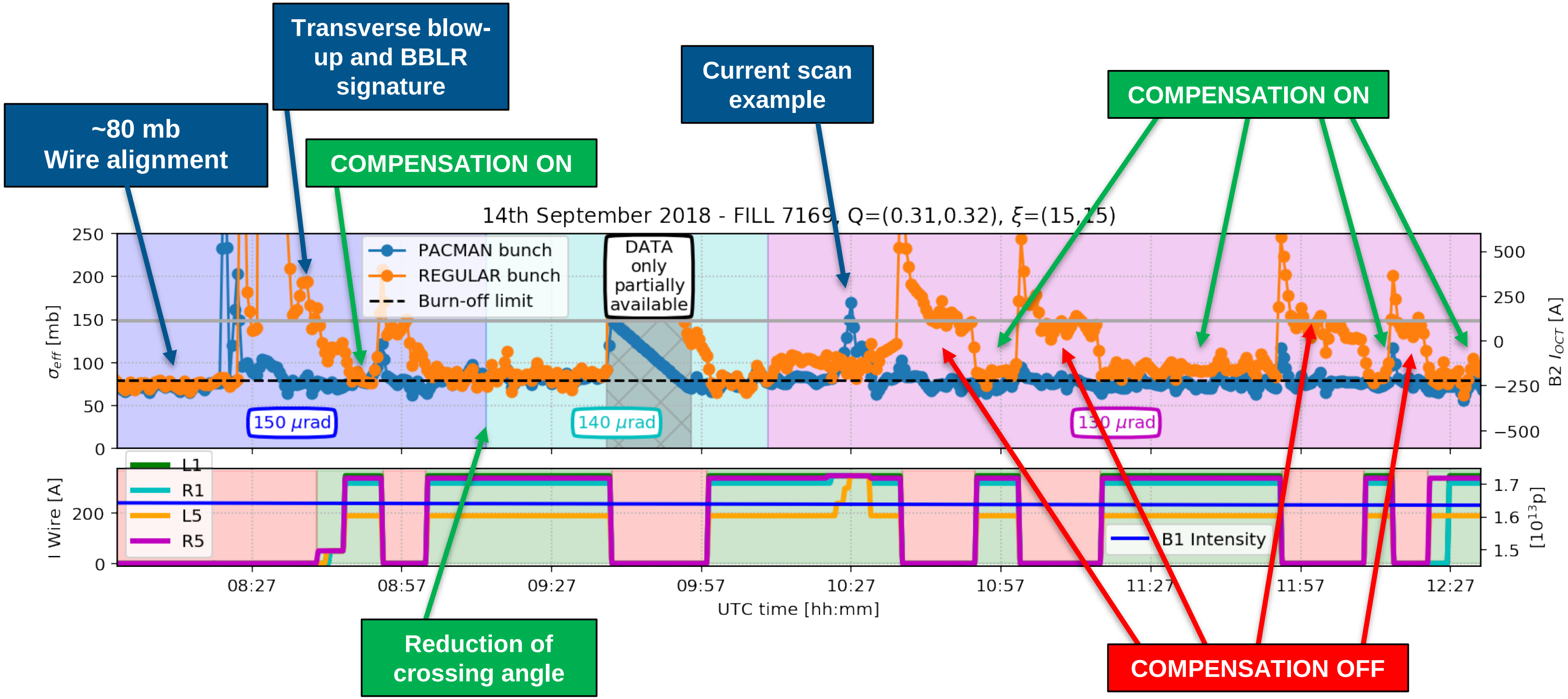
March 2017
2nd Workshop on (HL-)LHC
Wire Compensation

On behalf of the HL-LHC wire compensation team

D. Amorim, G. Arduini, H. Bartosik, A. Bertarelli, R. Bruce, X. Buffat, L. Carver, C. Castro, 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, 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, J. Wenninger, C. Xu, C. Zamantzas, P. Zisopoulos and all participants to the design, production and commissioning of the wire compensator demonstrators.

BACKUP SLIDES

Low-Intensity experiment



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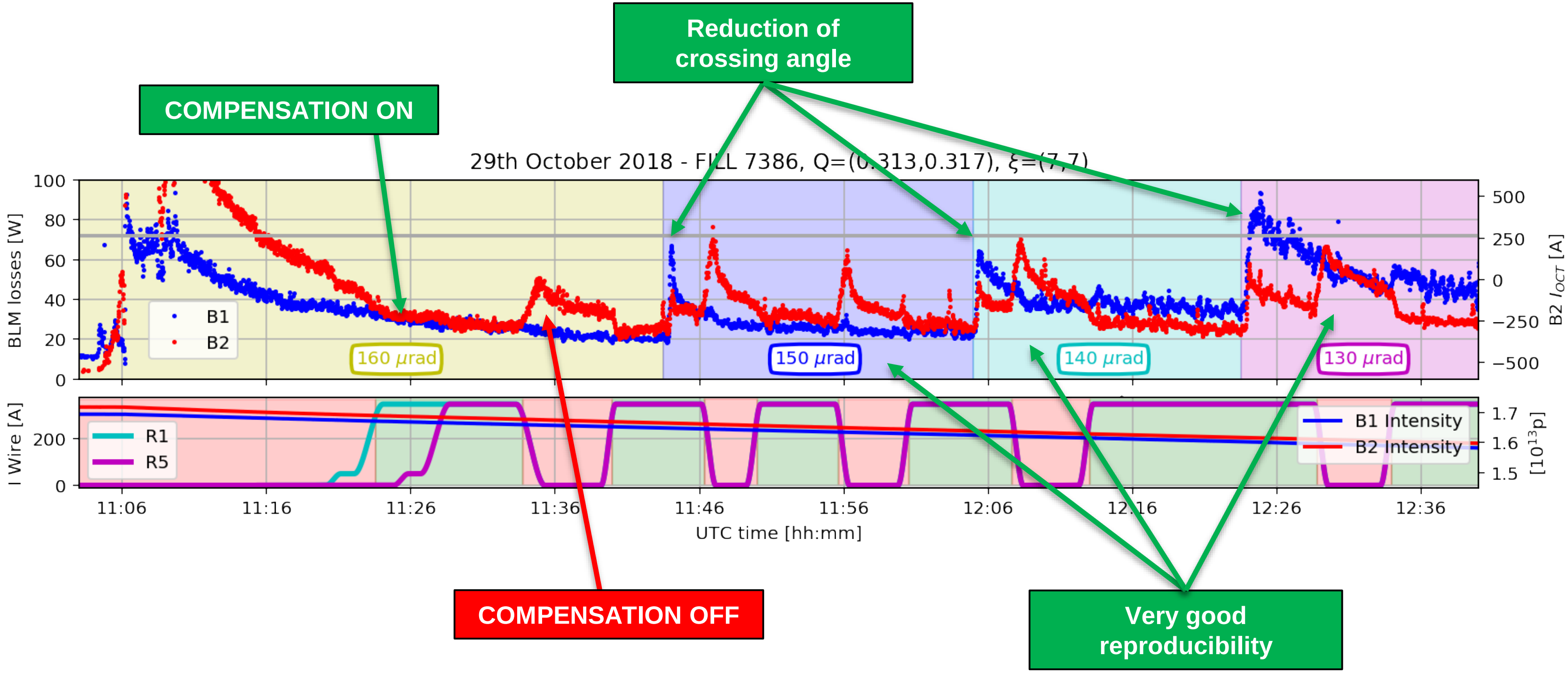

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