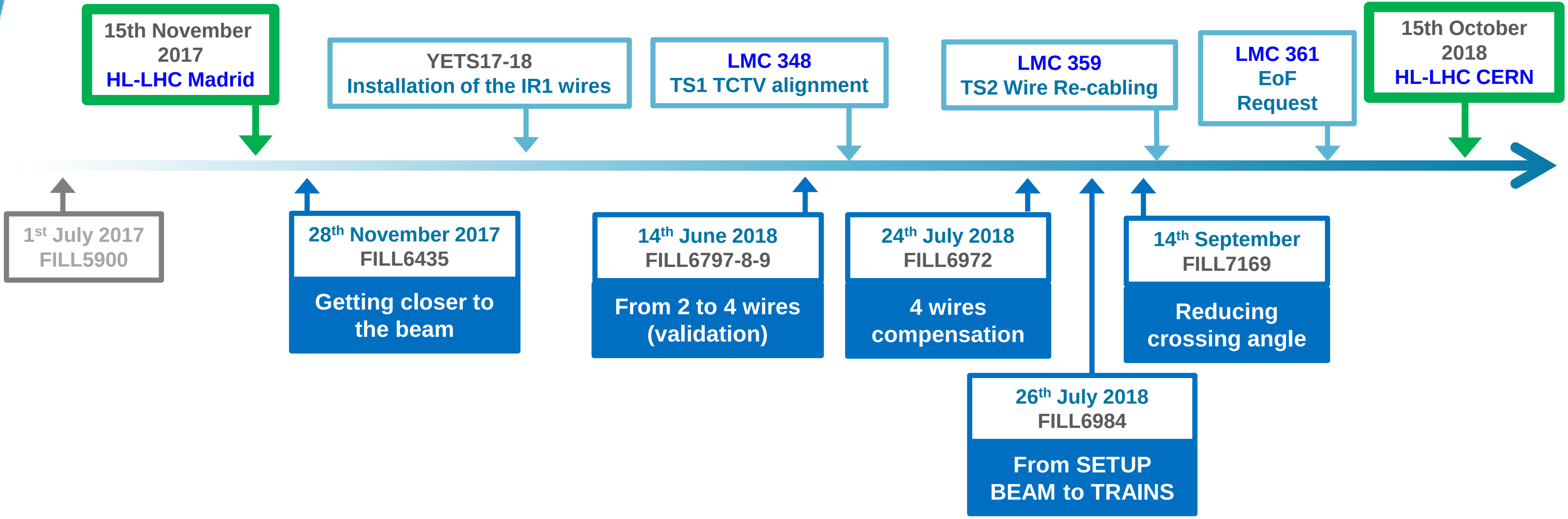
Experimental tests for BBLR compensation with wires in the LHC

S. Fartoukh, Y. Papaphilippou, A. Poyet, A. Rossi and **G. Sterbini**
on behalf of the BBLR wire compensation team.

Special thanks to HL-LHC WP2, WP5, WP13 and LHC MD coordinators.

8th HL-LHC Collaboration Meeting, 17th October 2018, CERN

Outlook



1st July 2017
FILL5900

15th November 2017
HL-LHC Madrid

28th November 2017
FILL6435
Getting closer to the beam

YETS17-18
Installation of the IR1 wires

14th June 2018
FILL6797-8-9
From 2 to 4 wires (validation)

LMC 348
TS1 TCTV alignment

24th July 2018
FILL6972
4 wires compensation

26th July 2018
FILL6984
From SETUP BEAM to TRAINS

14th September
FILL7169
Reducing crossing angle

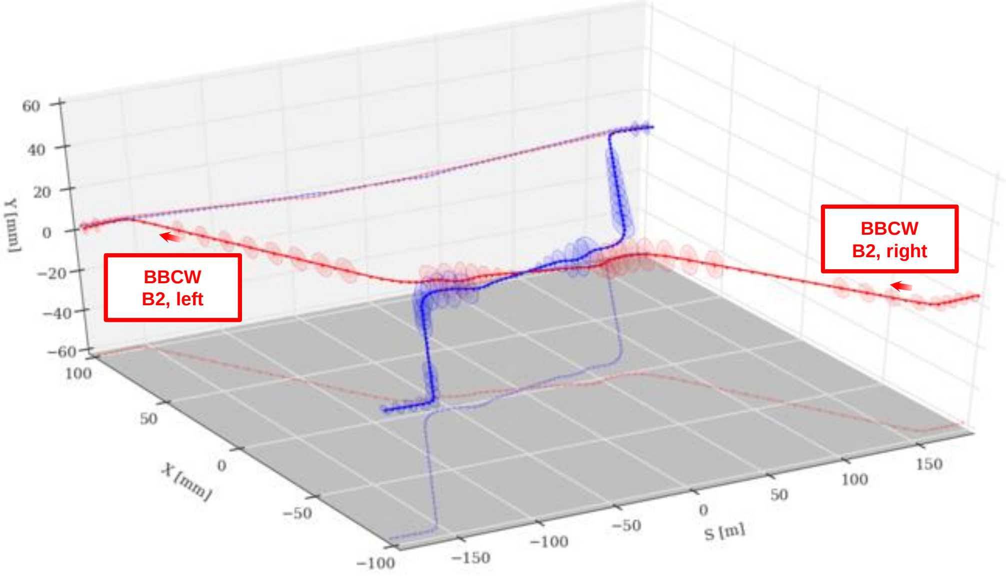
LMC 359
TS2 Wire Re-cabling

LMC 361
EoF Request

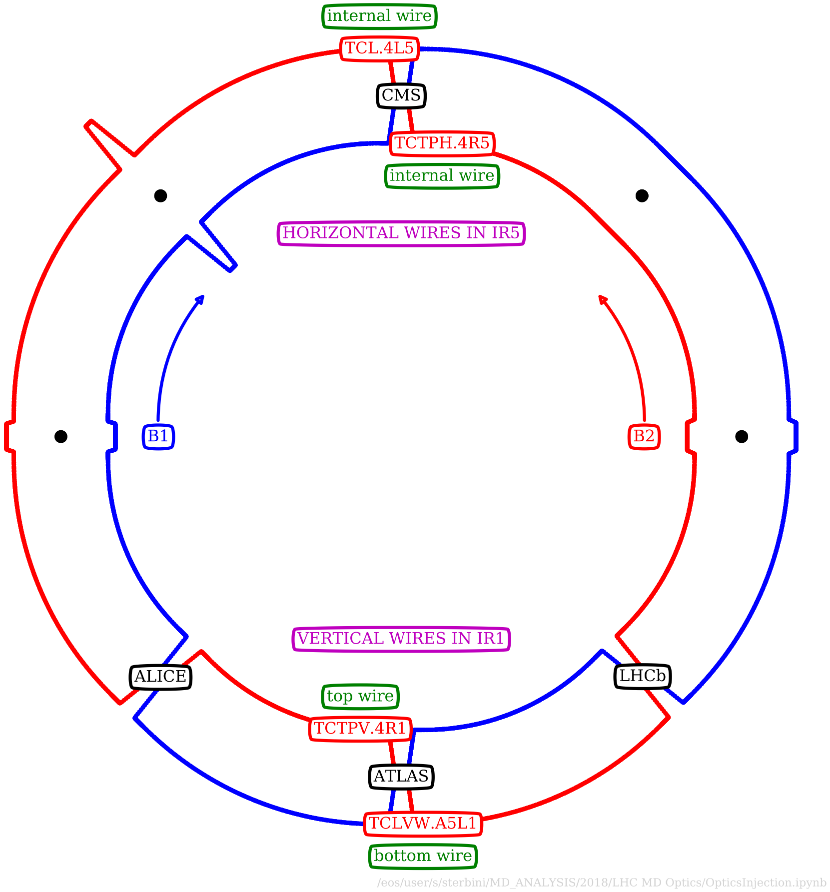
15th October 2018
HL-LHC CERN

- Introduction of the wire compensation.
- Optimization of the wires settings and experimental constraints.
- Experimental results.
- Plans and summary.

The wire compensation principle



The DC wire compensation

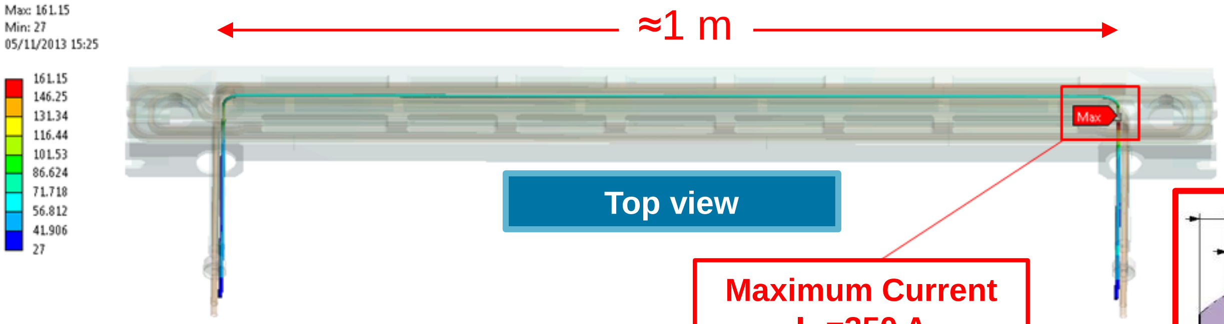


- **Since 2018 four wires prototypes (BBCW) are installed in LHC (B2, IR1+IR5)** with the aim to explore a scenario beyond the Baseline: local compensation of the beam-beam long-range (BBLR) with DC wires.

Integration of the prototype in the collimator

- The **wire-beam distance has to be of the order of few mm** (function of θ_c, s-position and machine optics): LHC wires prototypes are embedded in the jaw of three operational tertiary collimators.

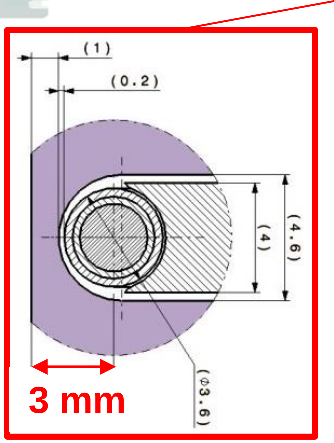
≈1 m



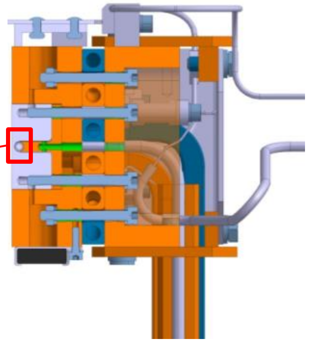
Top view

Courtesy of F. Carra

Maximum Current I_W=350 A



3 mm

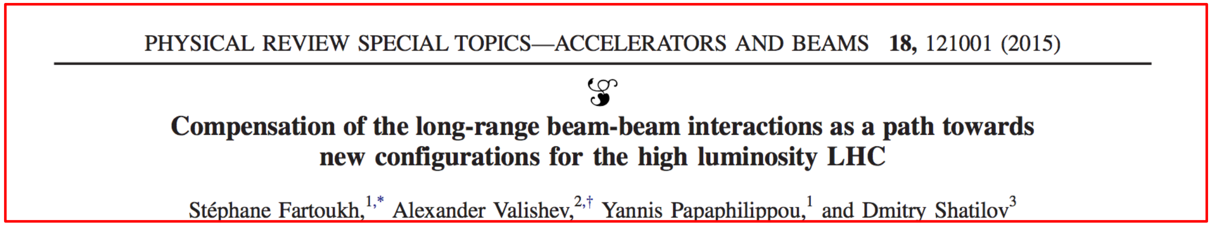


Side view

- During the 2018, it was performed a complete test campaign to ensure the correct functioning of the wire interlocks, the collimator motors and PUs when the wire is powered therefore to preserve the full functionality of this device as collimator.

Wire settings for RDT compensation

We used the RDT criterion presented and described in details in



PHYSICAL REVIEW SPECIAL TOPICS—ACCELERATORS AND BEAMS **18,** 121001 (2015)

Compensation of the long-range beam-beam interactions as a path towards new configurations for the high luminosity LHC

Stéphane Fartoukh,[1,*] Alexander Valishev,[2,†] Yannis Papaphilippou,[1] and Dmitry Shatilov[3]

Long-range driven RDTs

$$c_{pq}^{\mathrm{LR}} \equiv \sum_{k\in\mathrm{LR}} \frac{\beta_x^{p/2}(s_k)\beta_y^{q/2}(s_k)}{d_{bb}^{p+q}(s_k)}$$

$$\Leftrightarrow$$

Wire driven RDTs

wire s-position

$$c_{pq}^{w} = \boxed{N_w}\,\frac{\boxed{{\beta_x^w}^{\frac{p}{2}}\,{\beta_y^w}^{\frac{q}{2}}}}{\boxed{{d_w}^{p+q}}}$$

Wire current

beam-wire distance

- **It is shown as a numerical evidence that by compensating 4 RDTs with 2 wires one can minimize ALL RDTs provided that the wires s-position of BBCW is conveniently chosen.**
- **In case of sub-optimal s-position, beam-wire distance only a subset of RDT can be compensated.**

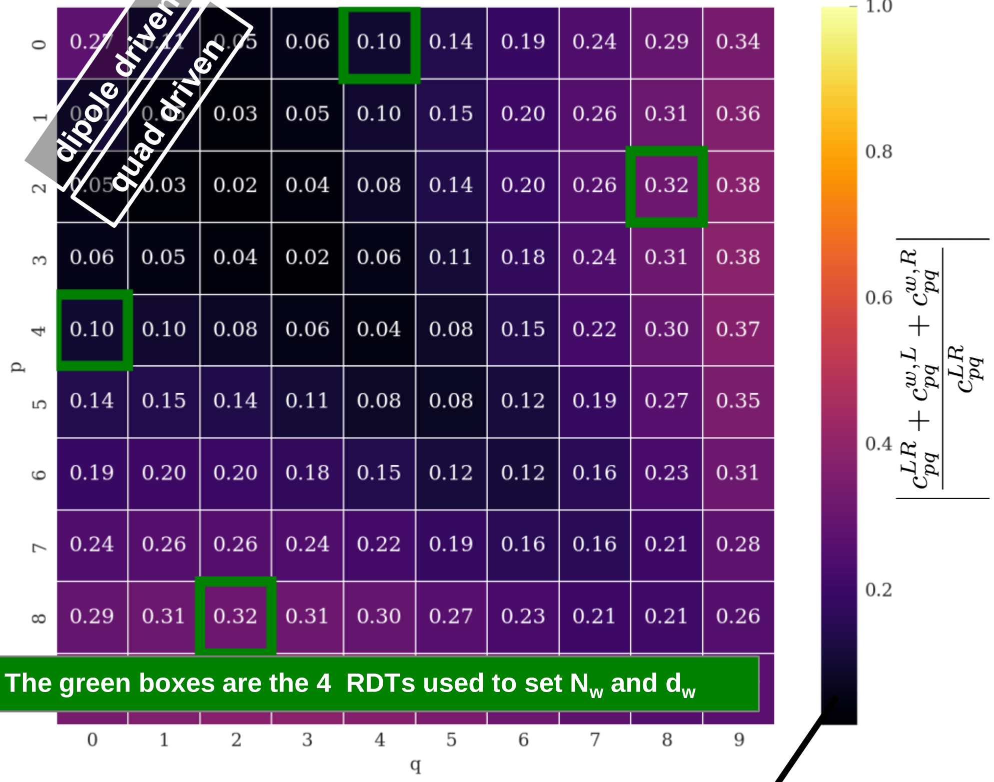
IDEAL settings (β^*= 30 cm, $\theta_c/2$=150 μrad)

Optimal I_W=103 A for 1.15e11 pbb

Optimal s-position= ± 158.3 m

Optimal beam-wire distance= 5.7 mm

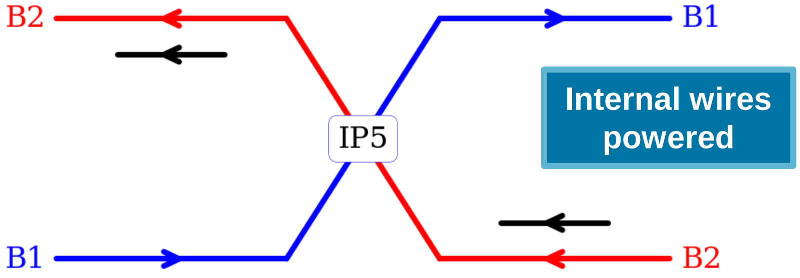
RDT compensation map, + real phase advance



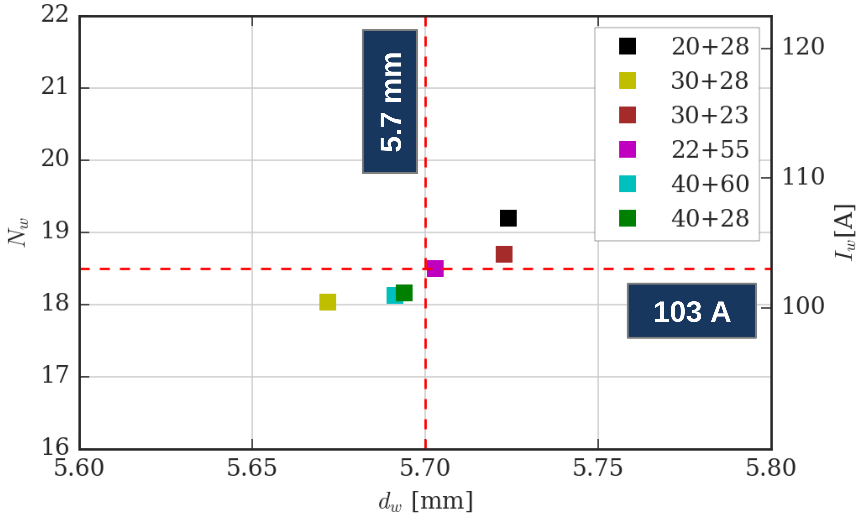
	0	1	2	3	4	5	6	7	8	9
0	0.27	0.11	0.05	0.06	0.10	0.14	0.19	0.24	0.29	0.34
1	0.01	0.05	0.03	0.05	0.10	0.15	0.20	0.26	0.31	0.36
2	0.05	0.03	0.02	0.04	0.08	0.14	0.20	0.26	0.32	0.38
3	0.06	0.05	0.04	0.02	0.06	0.11	0.18	0.24	0.31	0.38
4	0.10	0.10	0.08	0.06	0.04	0.08	0.15	0.22	0.30	0.37
5	0.14	0.15	0.14	0.11	0.08	0.08	0.12	0.19	0.27	0.35
6	0.19	0.20	0.20	0.18	0.15	0.12	0.12	0.16	0.23	0.31
7	0.24	0.26	0.26	0.24	0.22	0.19	0.16	0.16	0.21	0.28
8	0.29	0.31	0.32	0.31	0.30	0.27	0.23	0.21	0.21	0.26

The green boxes are the 4 RDTs used to set N_w and d_w

'0' means FULL compensation



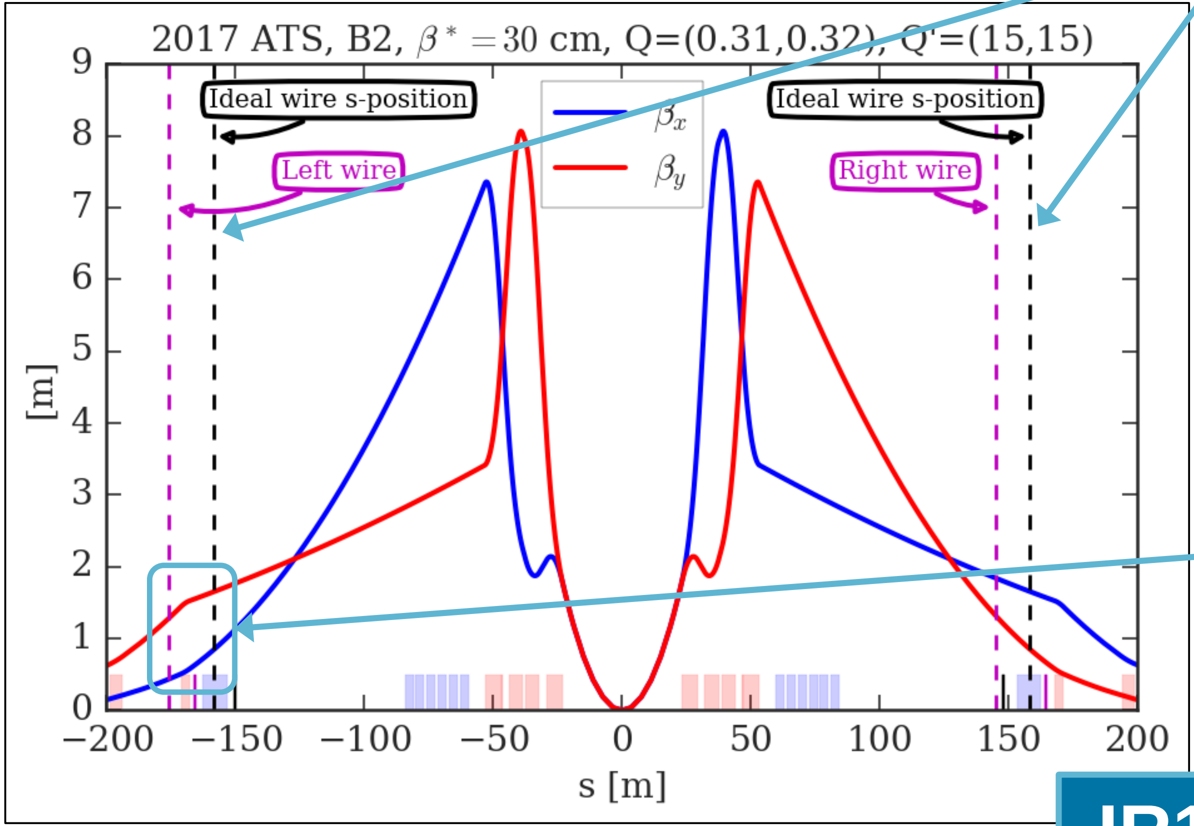
Internal wires powered



REAL s-position (II)

Optimal s-position= ± 158.3 m
⇒ It was not possible to install the wires a the optimal s-positions.

The ideal s-position of the BBCW is ±158.3 m from the IP5. The actual s-position are -150.03 and +147.94 m



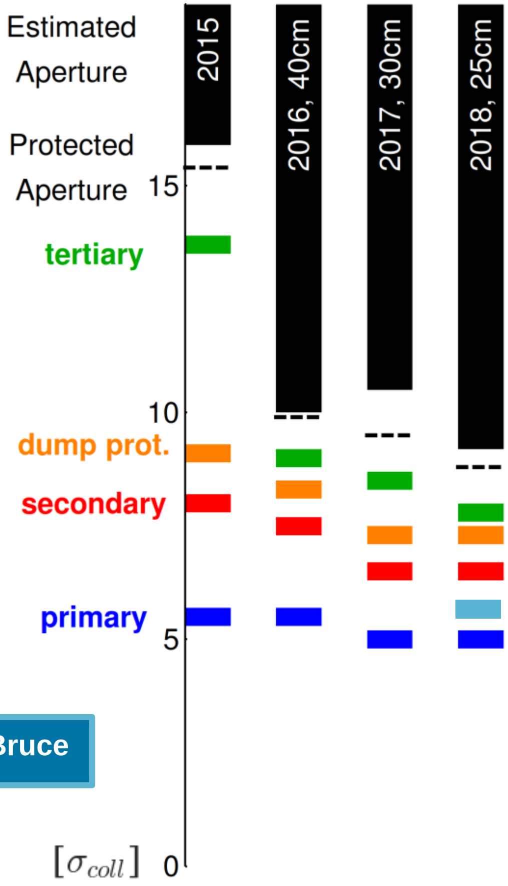
Even a small modification of the s-coordinate has an impact on the symmetry and the optimal beta ratio.

IR1

REAL beam-wire distance

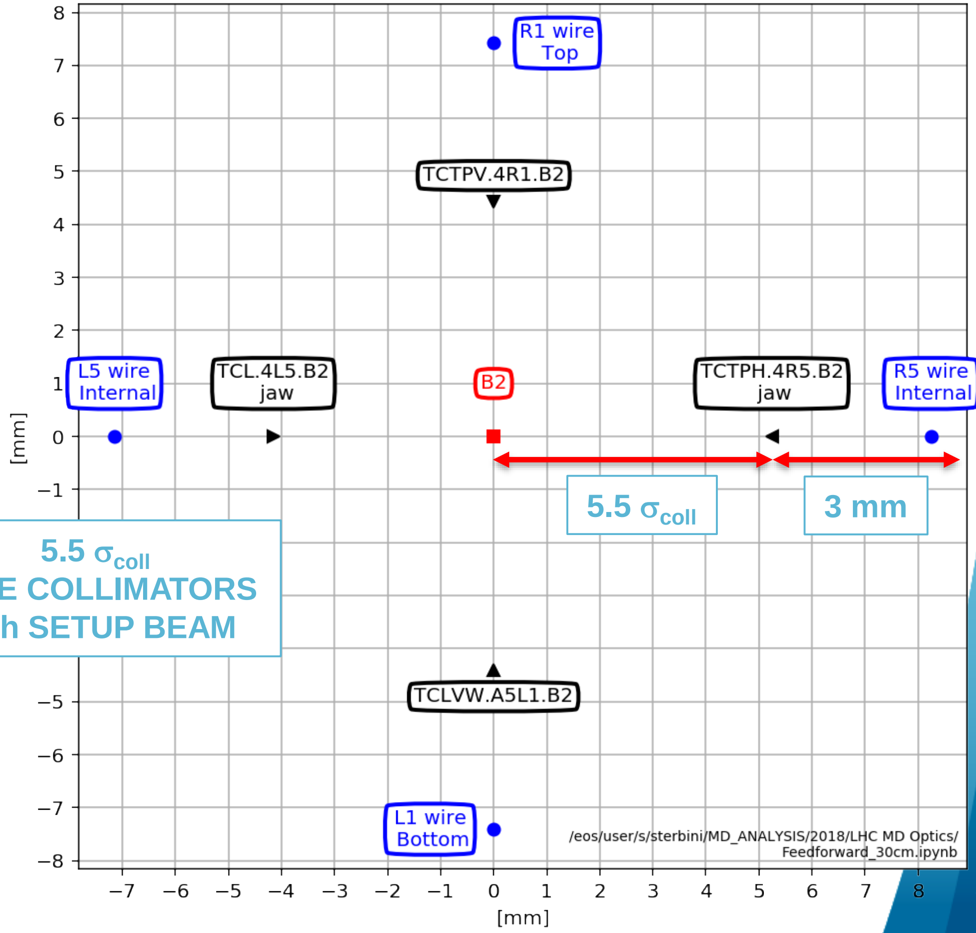
Optimal beam-wire distance= 5.7 mm
⇒ It is not possible to operate the wires at the optimal distance wrt the beam.

Wire	Plane	Wire-beam distance [mm]	σ_{coll} [mm]
R1	V	+7.42	0.80
L1	V	-7.41	0.80
R5	H	+8.24	0.95
L5	H	-7.15	0.75



Courtesy of R. Bruce

5.5 σ_{coll} WIRE COLLIMATORS with SETUP BEAM



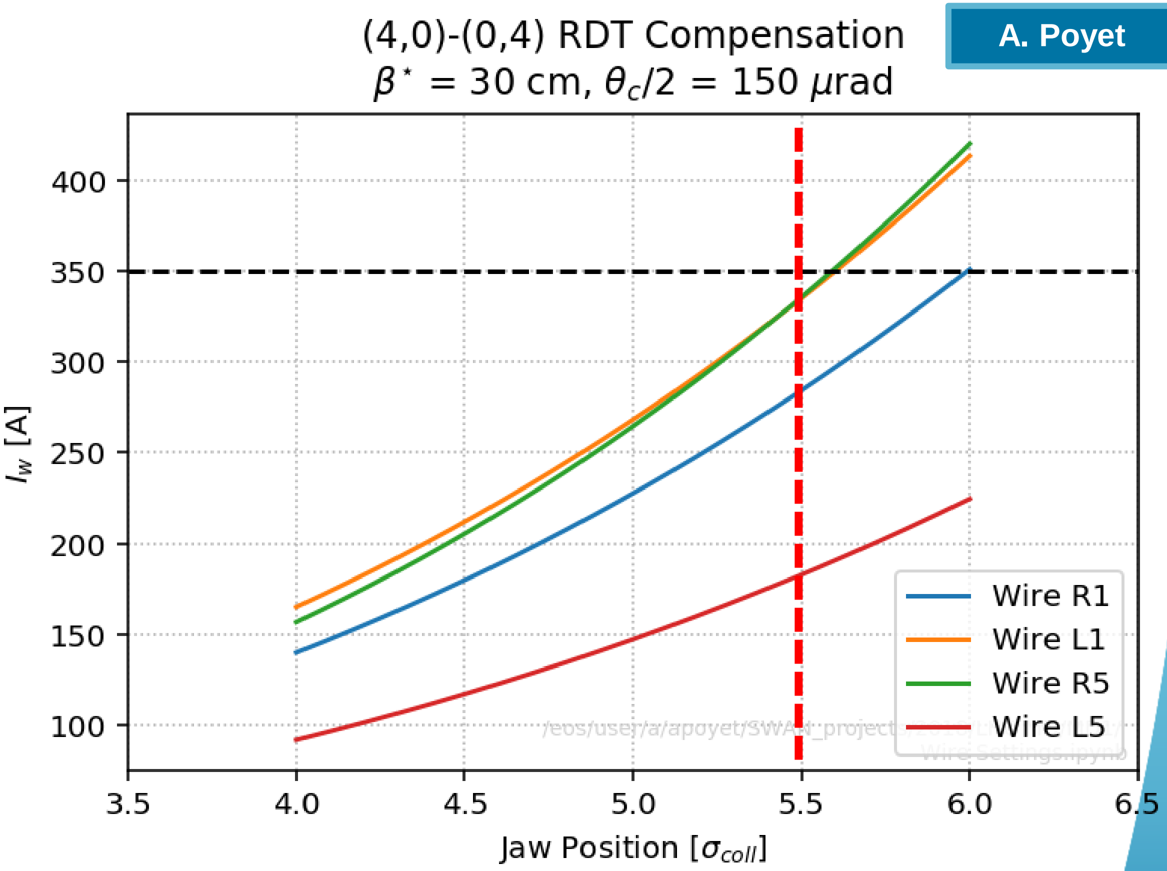
/eos/user/s/sterbini/MD_ANALYSIS/2018/LHC MD Optics/Feedforward_30cm.ipynb

IDEAL ⇒ REAL: back to 2 RDTs compensation

Technical constraints: **only two RDTs** with the 2 wires **at the same jaw position in σ_{coll}**.

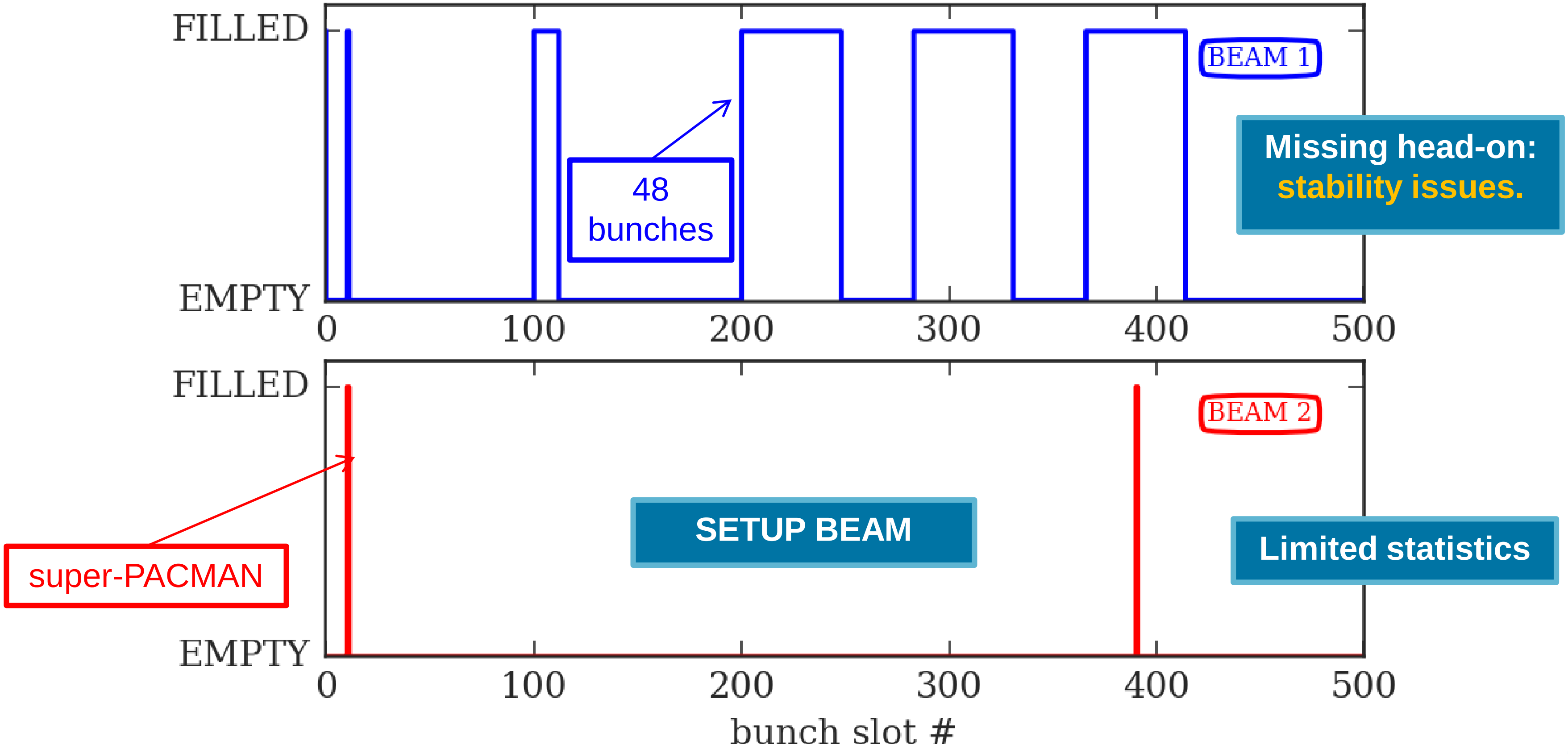
- We choose to compensate **(4,0) and (0,4)**: first order amplitude detuning.
- Tracking studies needed for tuning the optimal position and current [See Kyriakos's presentation].

A. Poyet



IDEAL ⇒ REAL: asymmetric filling scheme

- To approach the wire to the beam the B2 has to be <3e11 p (SETUP BEAM).
- We will mainly concentrate on the two bunches of B2 (Only HO and HO+BBLR).



Missing head-on: stability issues.

SETUP BEAM

Limited statistics

Objectives of the experiments

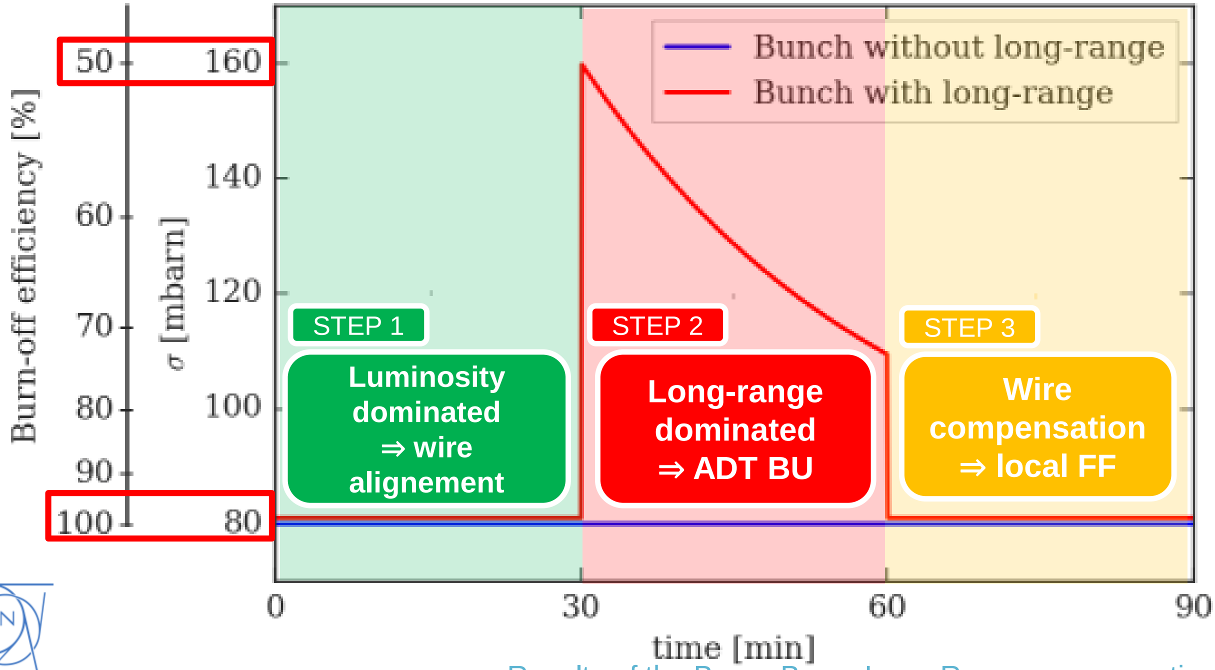
- **Prove the beneficial effect of the WIRES** in a regime dominated by long-range beam-beam effect, ensuring in the mean time that the linear effects of the wire (orbit and tunes) are compensated with feedforwards. Our privileged observable is the bunch “**effective cross-section**”:

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

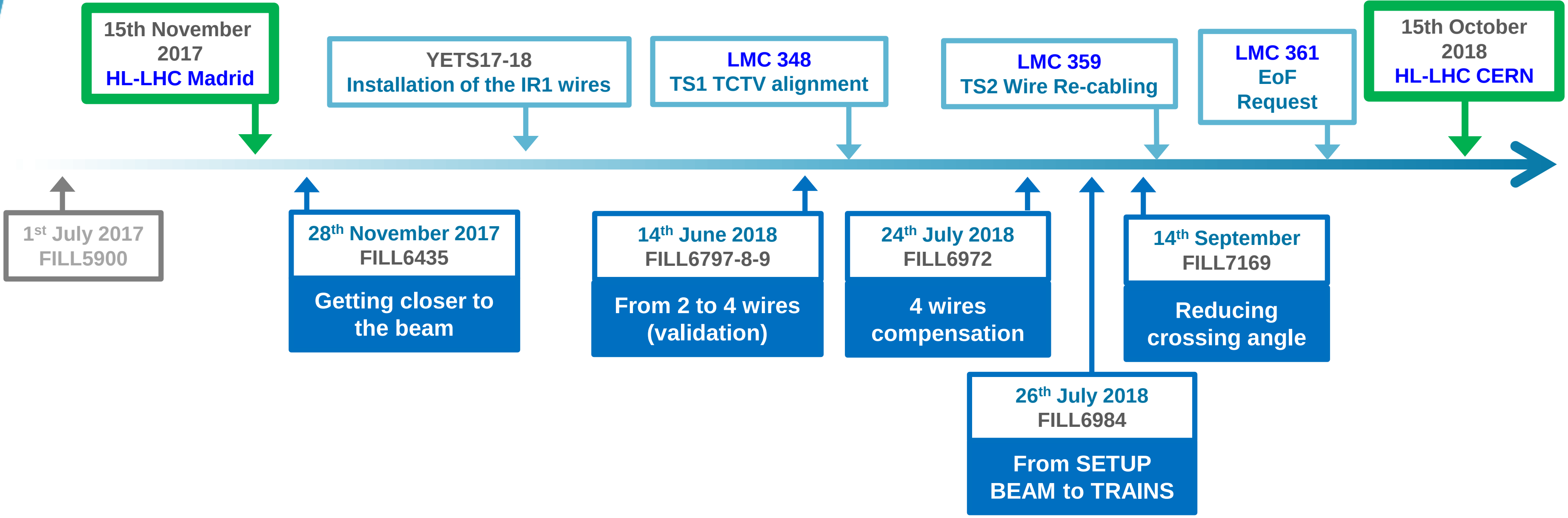
Intensity loss-rate

Instantaneous luminosity

The IDEAL compensation, 2 bunches in B2



Outlook



15th November 2017
HL-LHC Madrid

YETS17-18
Installation of the IR1 wires

LMC 348
TS1 TCTV alignment

LMC 359
TS2 Wire Re-cabling

LMC 361
EoF
Request

15th October 2018
HL-LHC CERN

1st July 2017
FILL5900

28th November 2017
FILL6435
Getting closer to the beam

14th June 2018
FILL6797-8-9
From 2 to 4 wires (validation)

24th July 2018
FILL6972
4 wires compensation

26th July 2018
FILL6984
From SETUP BEAM to TRAINS

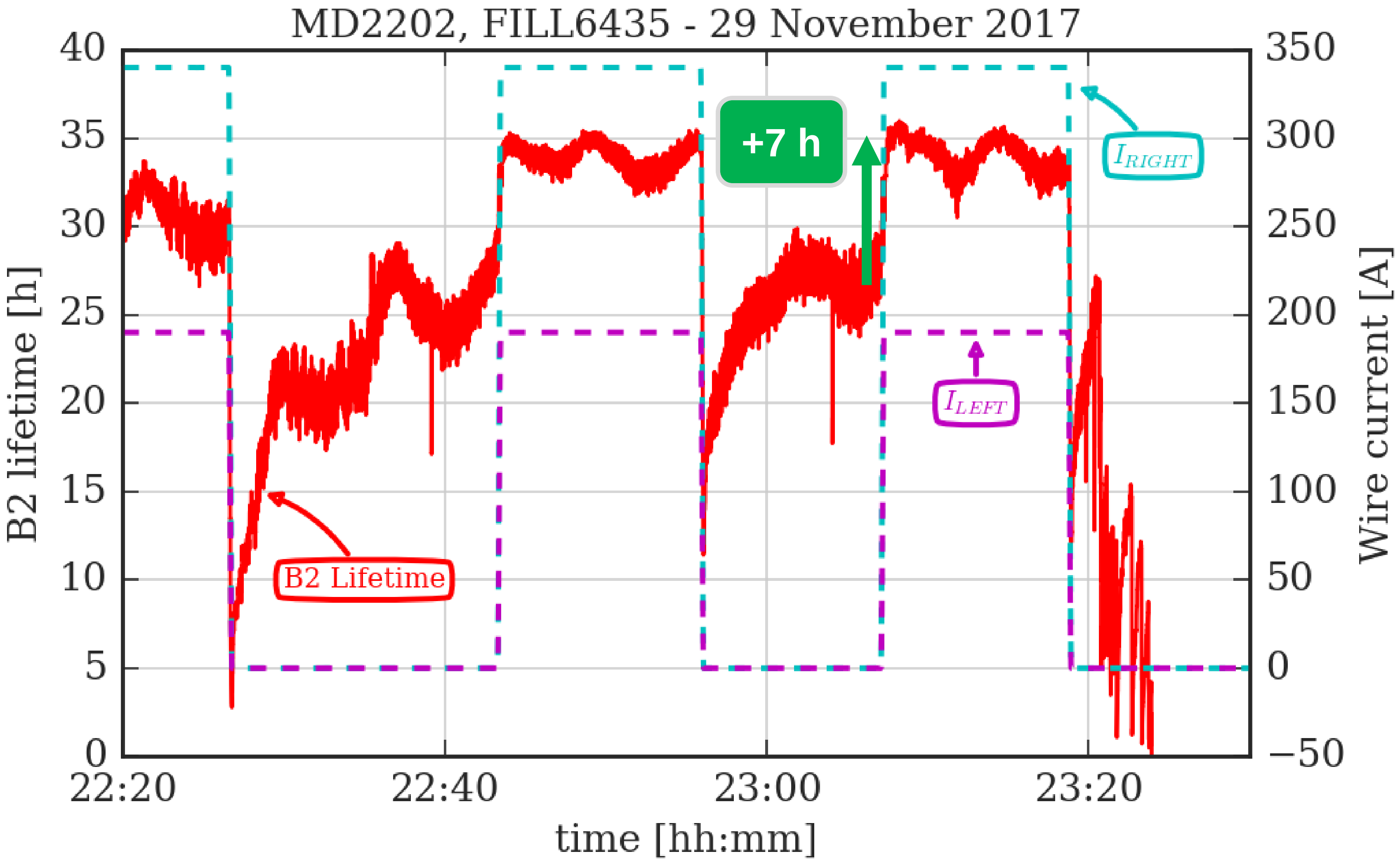
14th September
FILL7169
Reducing crossing angle

- Introduction of the wire compensation.
- Optimization of the wires settings and experimental constraints.
- Experimental results.
- Plans and summary.

Getting from 6 to 5.5 σ_{coll} (only 2 wires)

28th November 2017
FILL6435

Getting closer to the beam

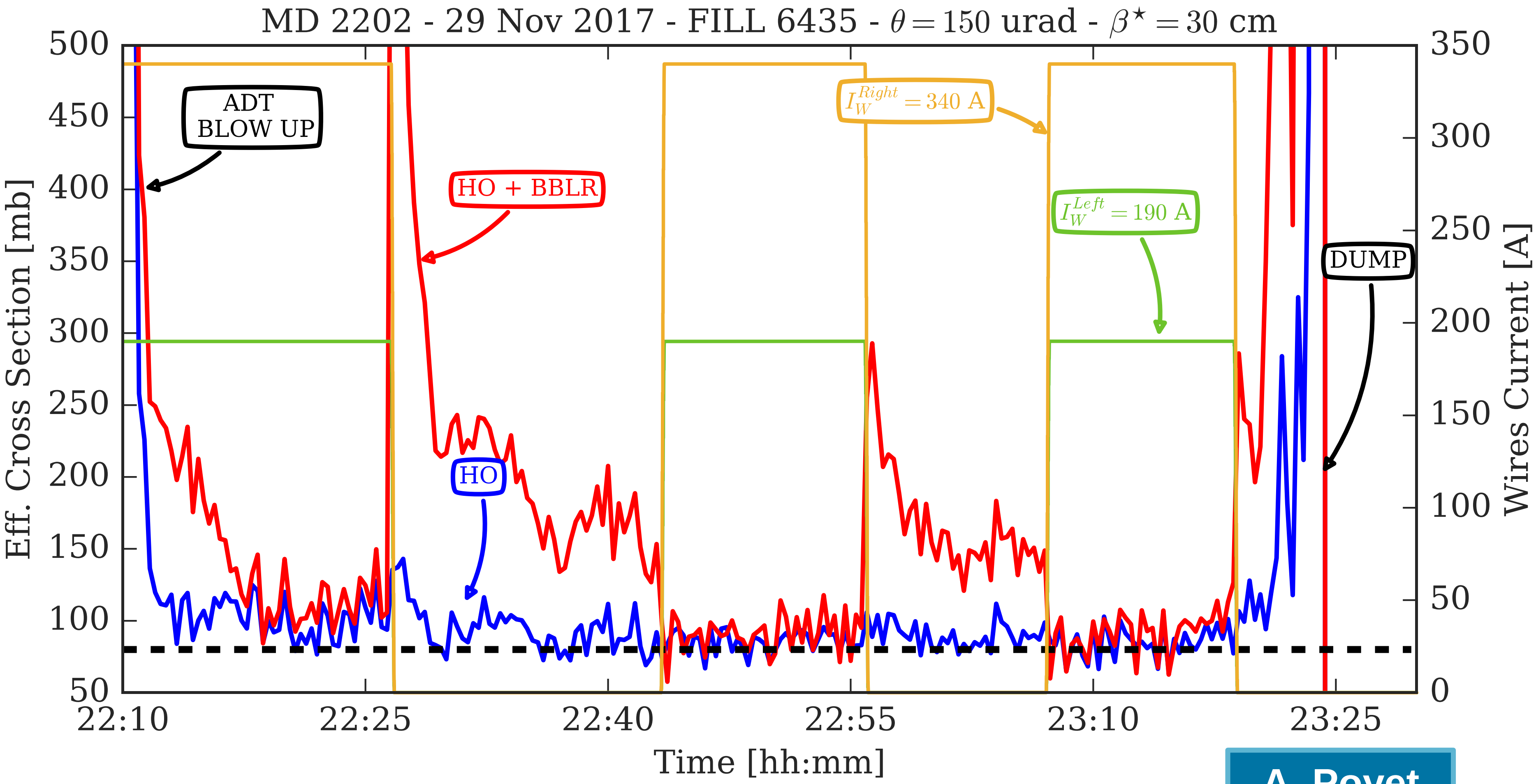


Positive effect of the wires visible on beam lifetime.

Getting from 6 to 5.5 σ_{coll} (only 2 wires)

28th November 2017
FILL6435

Getting closer to the beam



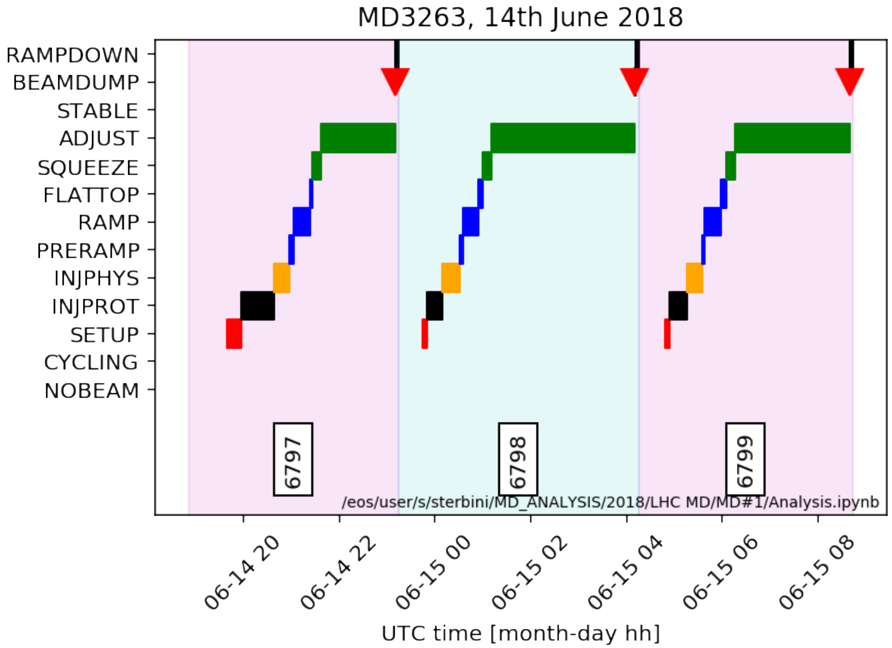
A. Poyet

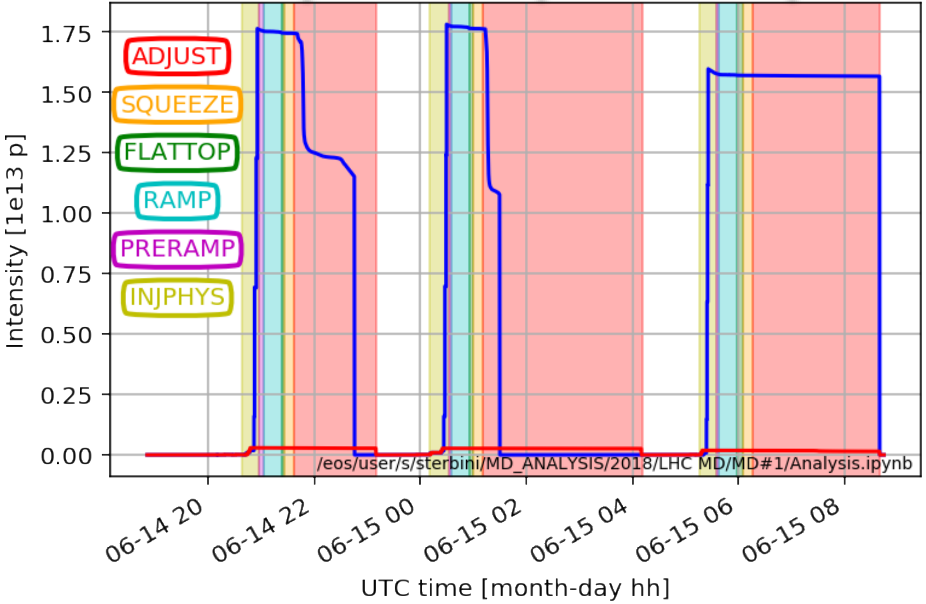
- **Positive effect of the wires visible on the bunch affected by the beam-beam long-range. Super-PACMAN unaffected.**

First tests with the 4 wires

14th June 2018
FILL6797-8-9

From 2 to 4 wires (validation)





TCTPV 5-th axis

Alignment + FF test

Compensation test (50 min)

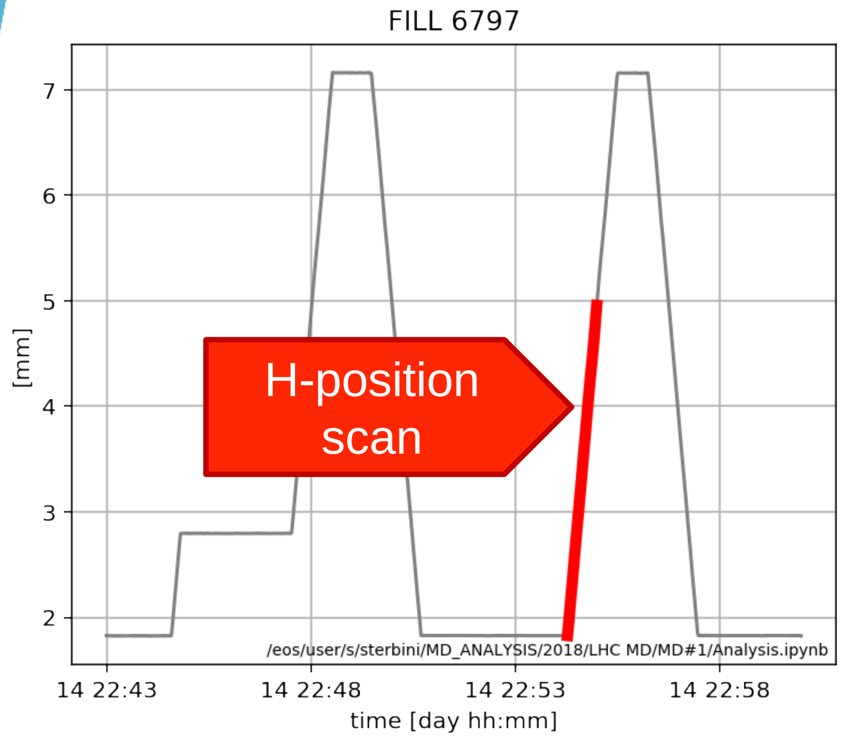
- **Results of the MD jeopardized by the strong beam instability after SQUEEZE. Mainly used for checking the alignment and the feedforwards.**

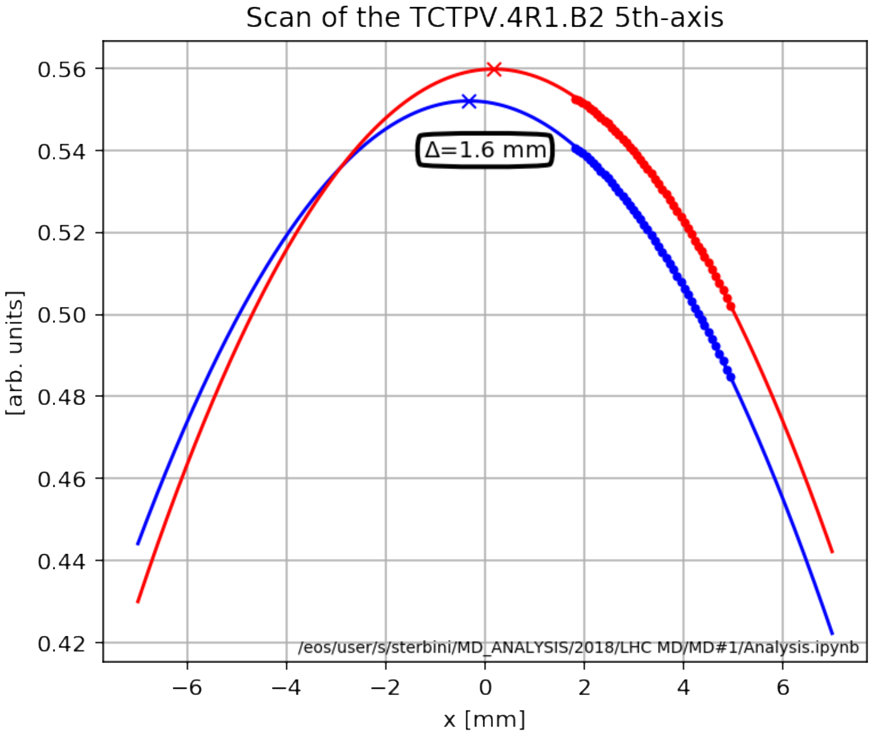
Alignment of the TCTPV

14th June 2018
FILL6797-8-9

From 2 to 4 wires (validation)

LMC 348
TS1 TCTV alignment


FILL 6797


Scan of the TCTPV.4R1.B2 5th-axis

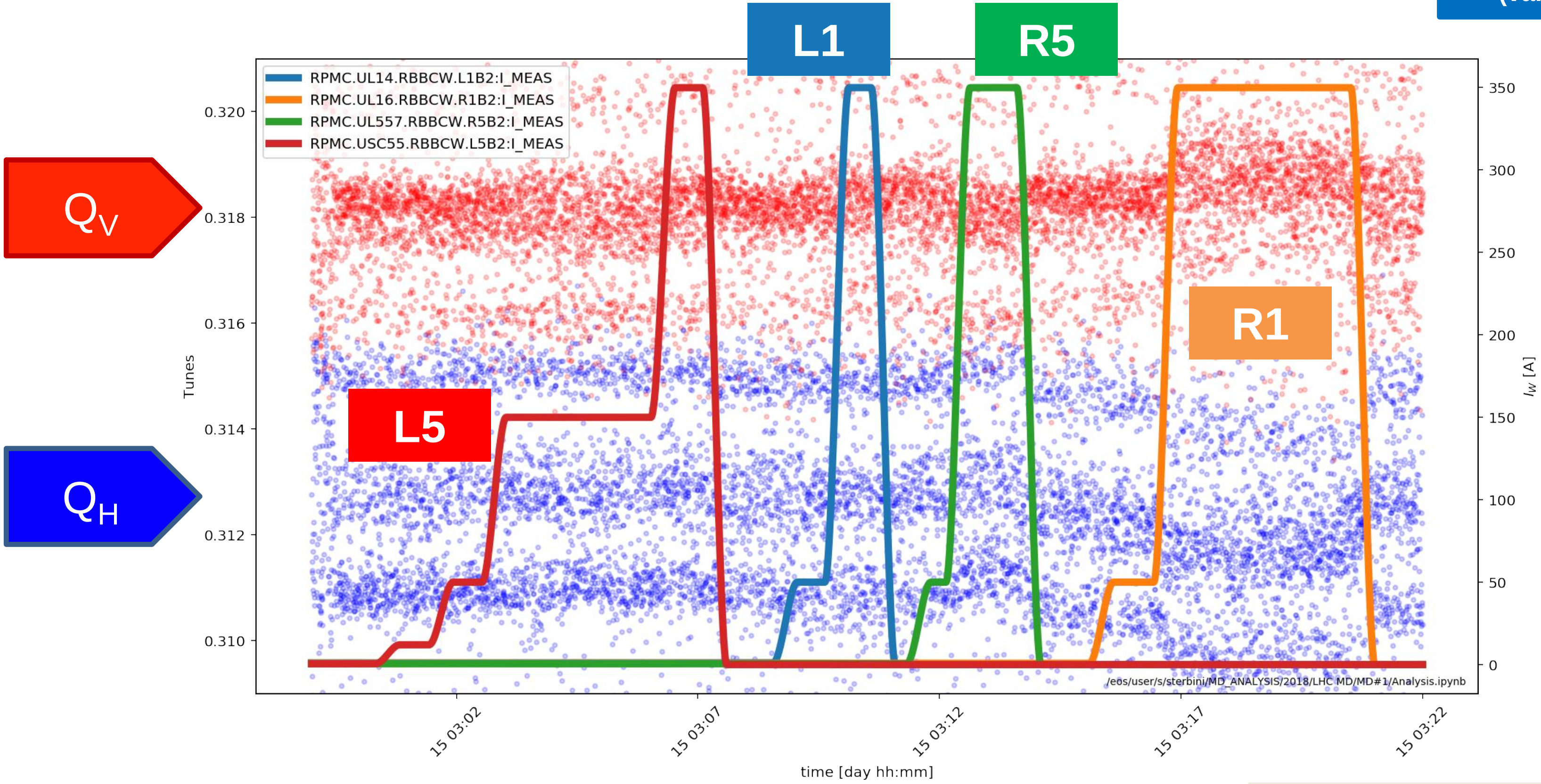
Credit to N. Fuster, S. Redaelli, A. Poyet, A. Rossi, I. Lamas Garcia

- **The 5th axis “manual” alignment performed during TS1.**

First tests with the 4 wires

14th June 2018
FILL6797-8-9

From 2 to 4 wires (validation)



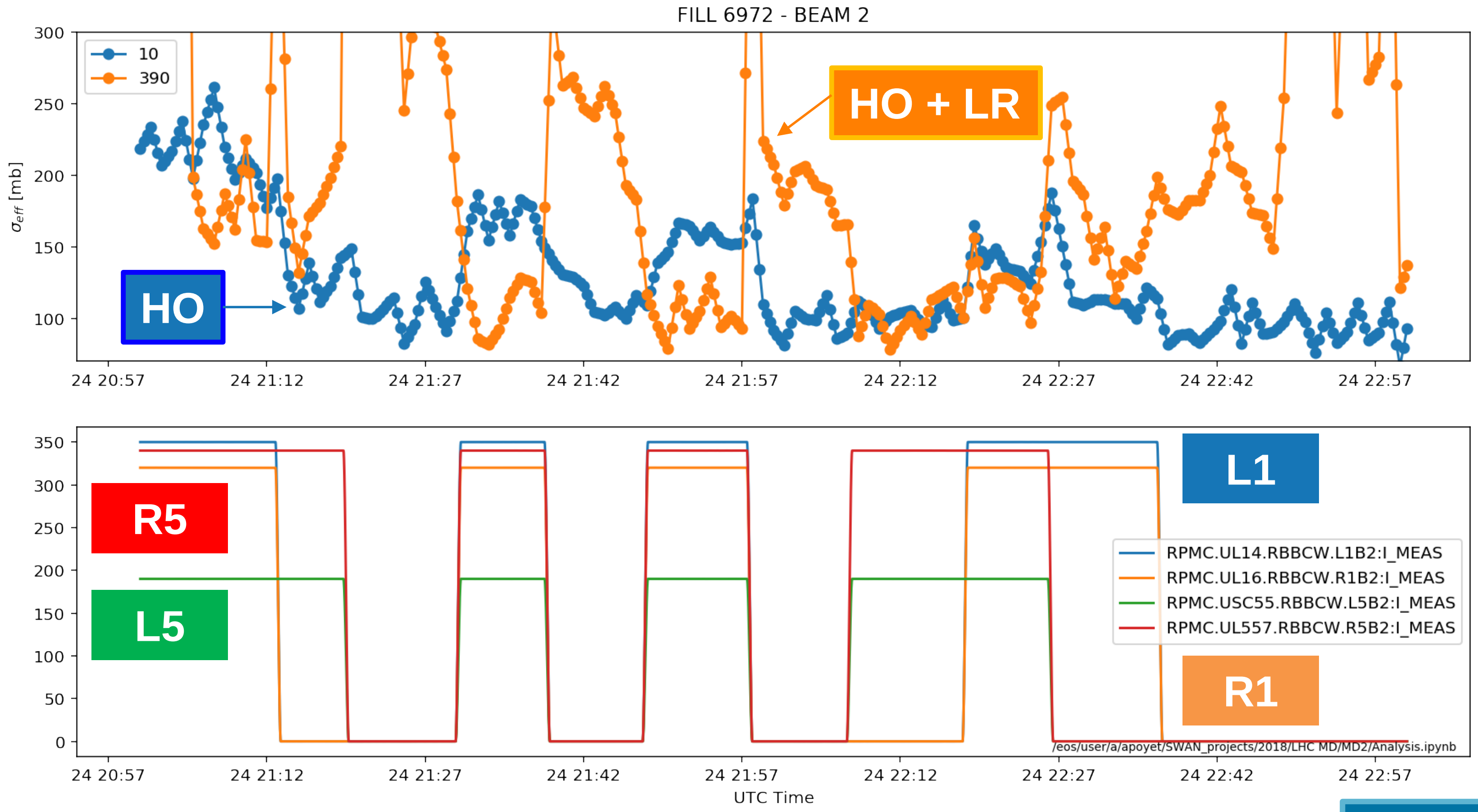
Credit to M. Solfaroli and G.-H. Hemelsoet

- **The 4 wires where powered to check the Q-feedforwards. As expected the R1 feedforward was less efficient (solved with the 5th axis manual alignment in TS1).**

4 wires compensation

24th July 2018
FILL6972

4 wires compensation

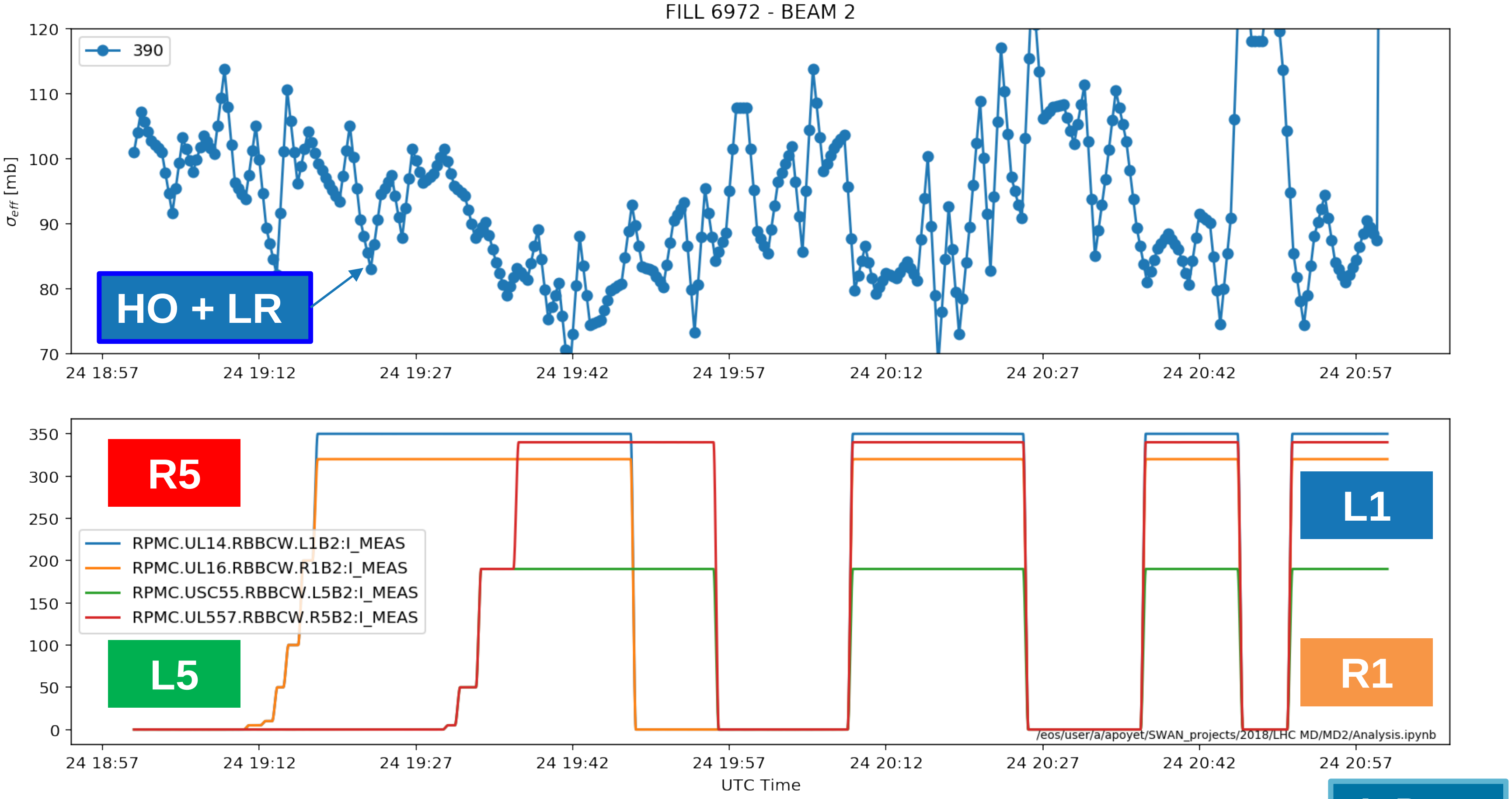


/eos/user/a/apoyet/SWAN_projects/2018/LHC MD/MD2/Analysis.ipynb

A. Poyet

- Compensation with 4 wires. The effect of the IR1 wires is less evident if compared with the effect of the IR5 wires.

4 wires compensation



A. Poyet

- **Test with standard B2 emittance (no BU). A marginal effect of the wires is still visible.**

Crossing angle and compensation

14th September
FILL7169

Reducing crossing angle

A. Poyet

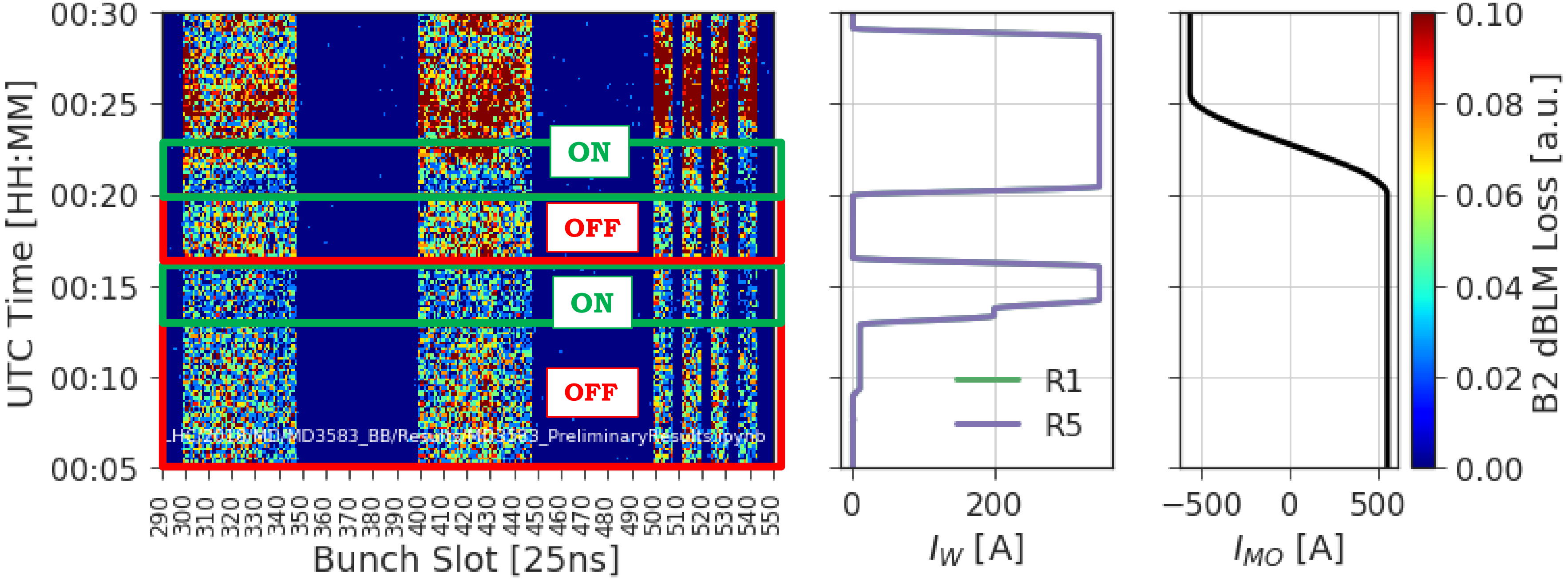
- **Very clear effect of the compensation even at reduced crossing (130 μrad).**

Compensation with trains

26th July 2018
FILL6984

From SETUP BEAM to TRAINS

N. Karastathis



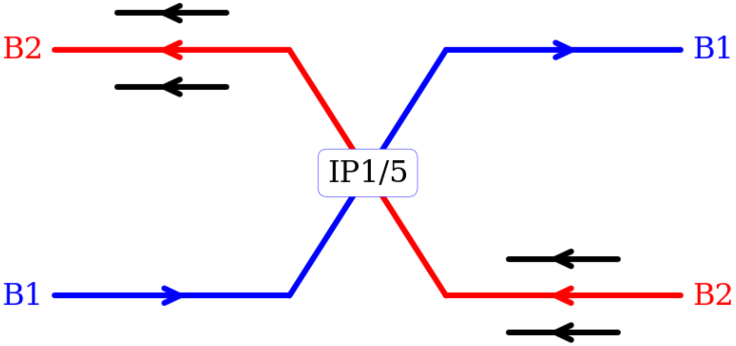
- **As an end-of-MD test the right wires were switched ON (β^*=30 cm and $\theta_c/2$=150 mrad). Signals from dBLM are compatible with reduction of losses on the bunches suffering beam-beam long-range.**

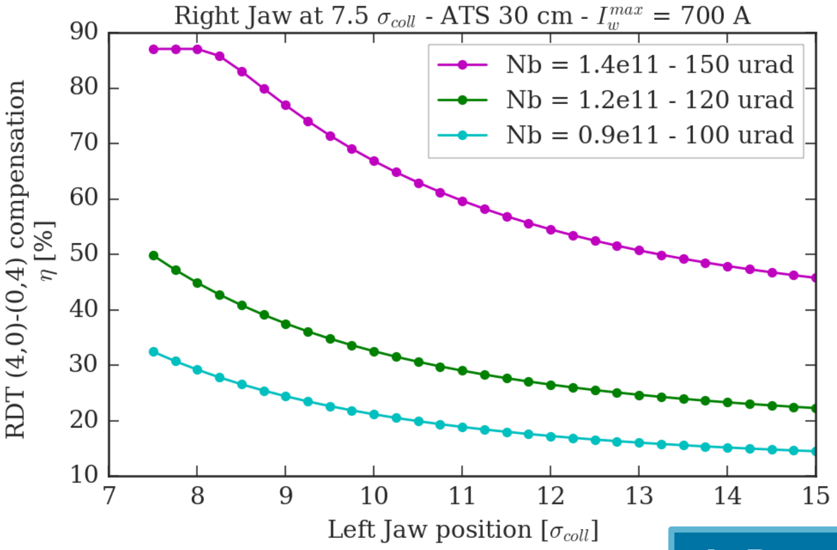
Can we use trains of bunches?

LMC 359
TS2 Wire Re-cabling

LMC 361
EoF Request

- During TS2 the wires were re-cabled in series.
- In this way (only for the "even" multipoles) one double the available I_w and could see an effect also at nominal position.
- ⇒ End-of-Fill MDs requested and dedicated MD allocated for that purpose.
- The goals is to explore the potential of this setup in operational conditions.





A. Poyet

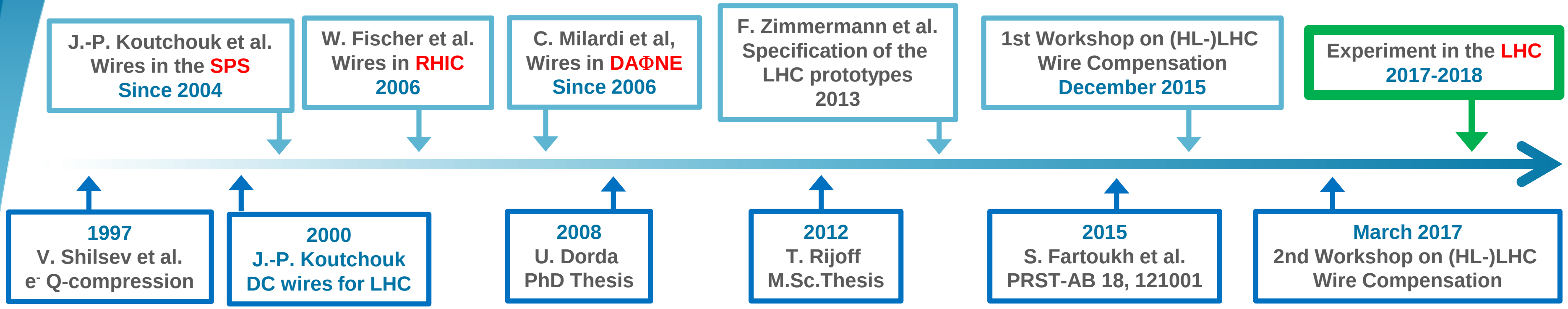
Summary and next steps

- During the last year a rich measurements program to explore the potential of the wire compensation in HL-LHC was performed. A positive effect of the compensation was systematically observed even within the constraints of a sub-optimal setup.

- All the measurement were conducted with round optics and almost the totality with SETUP beam.

- A new cabling of the wires was realized during the TS2: this open the way to test the wires in nominal condition (EoF requested and MD4 slot probably available).

- Next step is the study optimal technical implementation of wires in the HL-LHC layout (⇒next 2 talks).



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 prototypes
2013

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

Experiment in the LHC
2017-2018

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

2000
J.-P. Koutchouk
DC wires for LHC

2008
U. Dorda
PhD Thesis

2012
T. Rijoff
M.Sc.Thesis

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

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

Thank you for the attention!

On behalf of the BBLR wire compensation team

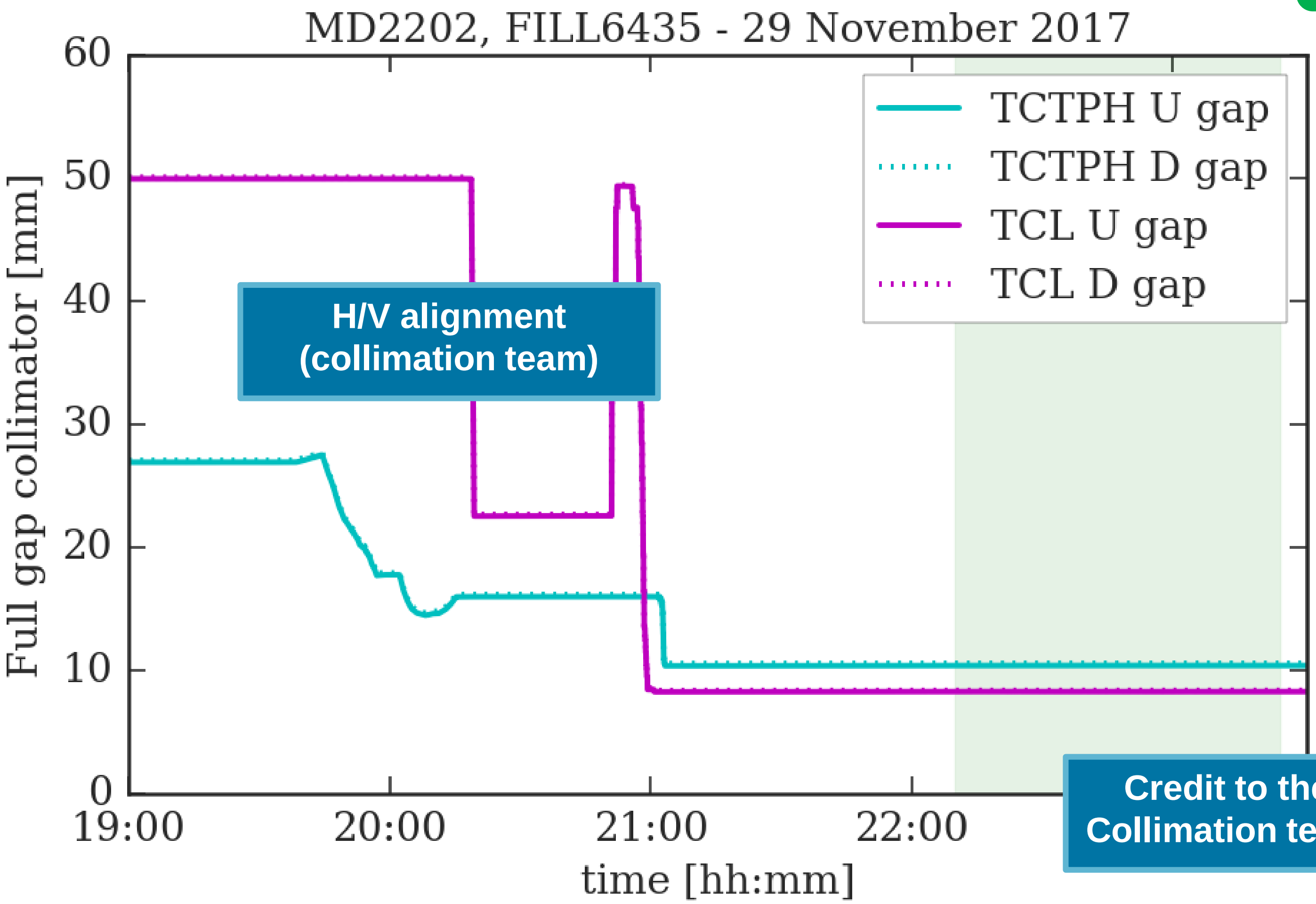
D. Amorim, G. Arduini, H. Bartosik, A. Bertarelli, R. Bruce, X. Buffat, L. Carver, C. Castro, G. Cattenoz, E. Effinger, S. Fartoukh, M. Fitterer, N. Fuster, M. Gasior, M. Gonzales, A. Gorzawski, G.-H. Hemelsoet, M. Hostettler, G. Iadarola, R. Jones, D. Kaltchev, K. Karastatis, S. Kostoglou, I. Lamas 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 prototypes an ***HL-LHC WP2, WP5, WP13 and LHC MD coordinators****.*

BACK-UP SLIDES

Vertical alignment of beam-wires

STEP 1

Luminosity dominated



H/V alignment (collimation team)

Credit to the Collimation team

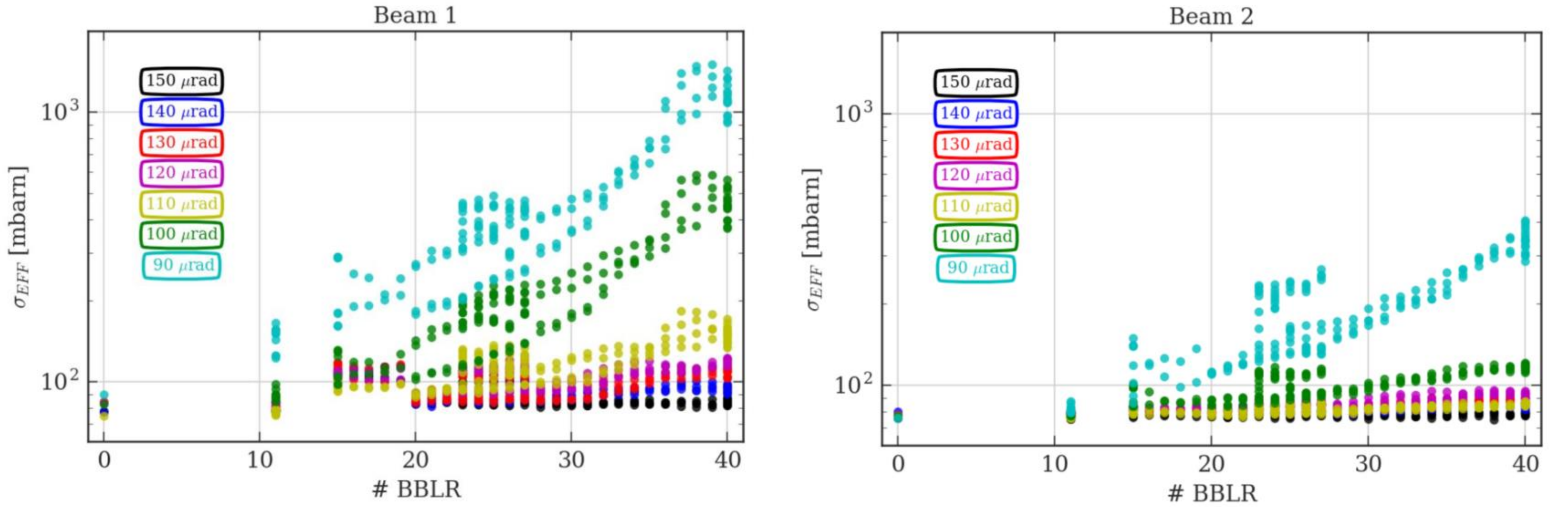
- Important vertical offset (up to 5 mm) to be corrected with the vertical alignment procedure. Not trivial due to lack of V PUs.

Pushing B2 to the BBLR regime

STEP 2

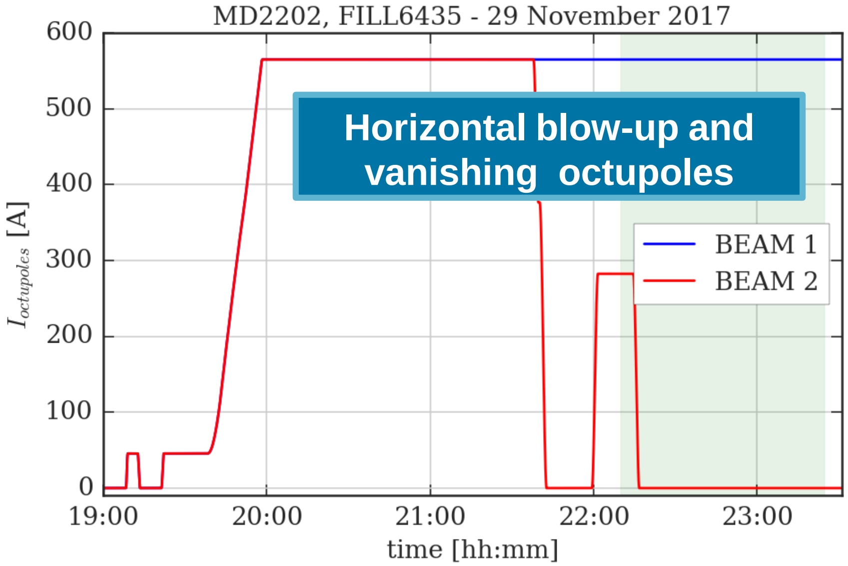
Long-range dominated

Interlude of B1 and B2 difference



To increase the BBLR effect:

1. B2 **H-emittance blown-up** to 5-6 mm mrad [credit to D. Valuch, S. Papadopoulou and M. Fitterer].
2. The tunes were set to a **sub-optimal working point** (0.31, 0.32).



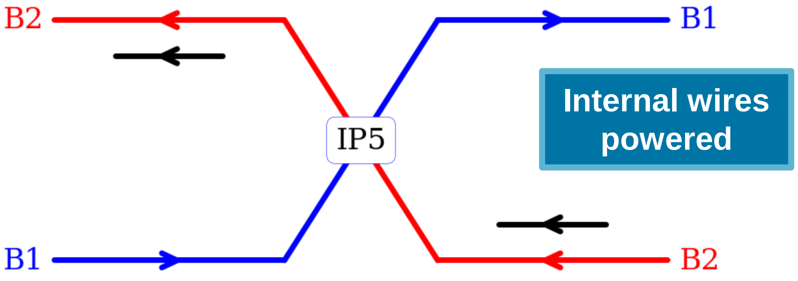
Horizontal blow-up and vanishing octupoles

IDEAL BBCW settings (β^{*}= 30 cm, $\theta_c/2$=150 μrad

Optimal I_W=103 A for 1.15e11 pbb

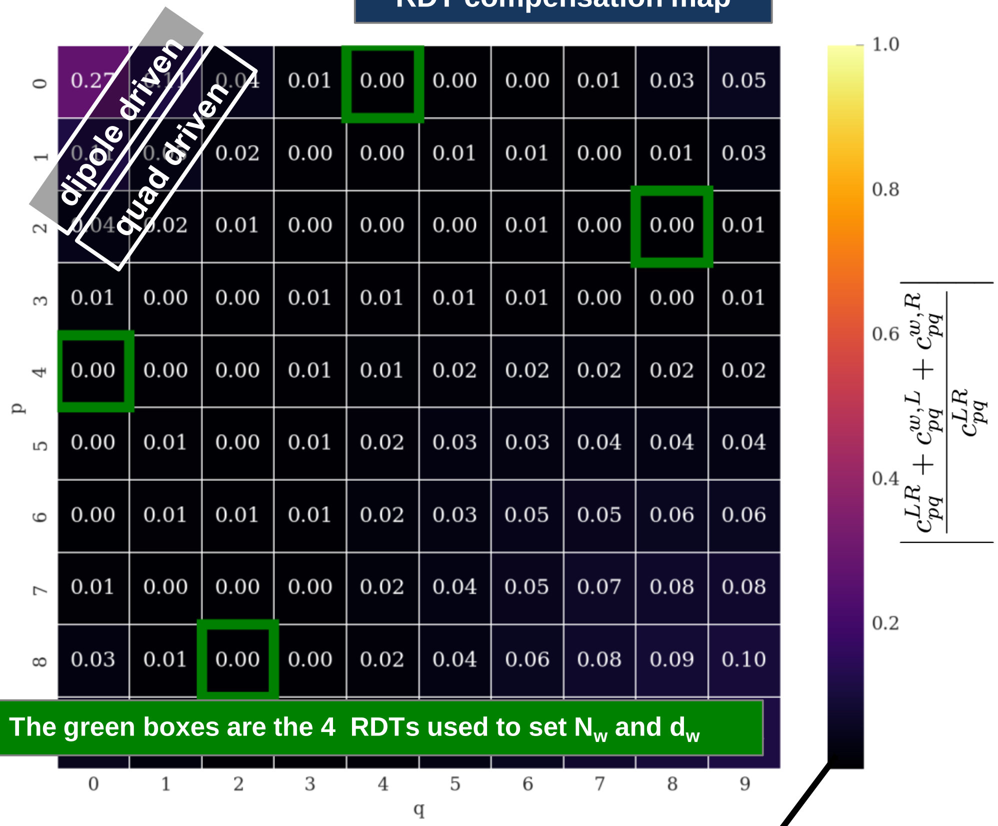
Optimal s position= ± 158.3 m

Optimal beam-wire distance= 5.7 mm



Internal wires powered

RDT compensation map

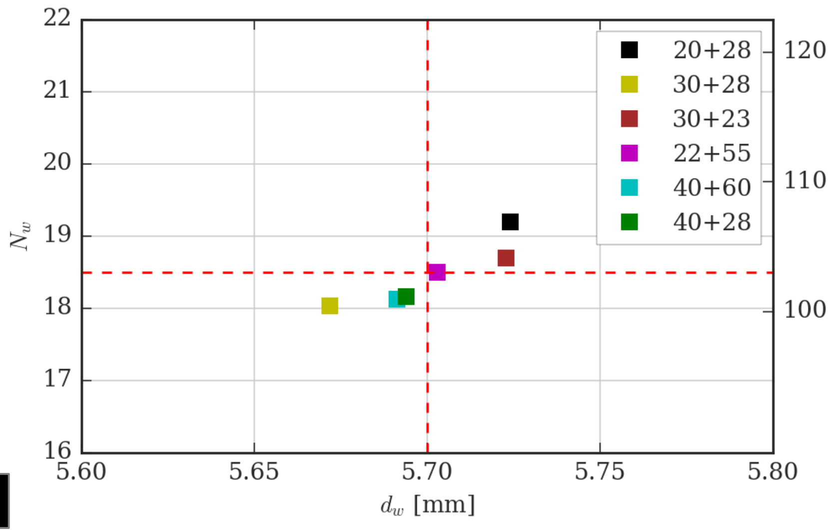


	0	1	2	3	4	5	6	7	8	9
0	0.27	0.11	0.04	0.01	0.00	0.00	0.00	0.01	0.03	0.05
1	0.11	0.05	0.02	0.00	0.00	0.01	0.01	0.00	0.01	0.03
2	0.04	0.02	0.01	0.00	0.00	0.00	0.01	0.00	0.00	0.01
3	0.01	0.00	0.00	0.01	0.01	0.01	0.01	0.00	0.00	0.01
4	0.00	0.00	0.00	0.01	0.01	0.02	0.02	0.02	0.02	0.02
5	0.00	0.01	0.00	0.01	0.02	0.03	0.03	0.04	0.04	0.04
6	0.00	0.01	0.01	0.01	0.02	0.03	0.05	0.05	0.06	0.06
7	0.01	0.00	0.00	0.00	0.02	0.04	0.05	0.07	0.08	0.08
8	0.03	0.01	0.00	0.00	0.02	0.04	0.06	0.08	0.09	0.10

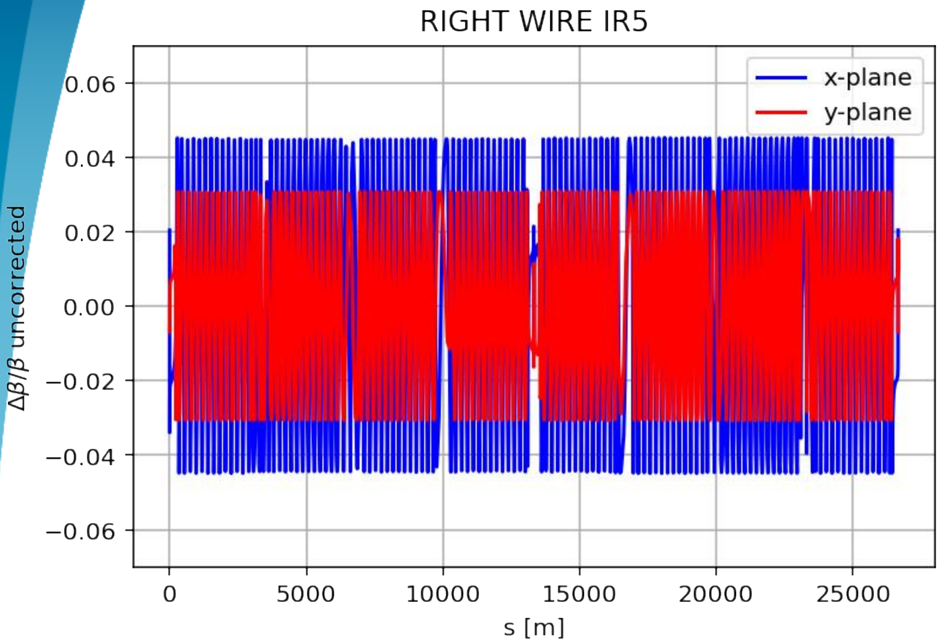
The green boxes are the 4 RDTs used to set N_w and d_w

‘0’ means FULL compensation

2017 ATS, $\beta^* = 30$ cm, Q=(0.31,0.32), Q'=(15,15)

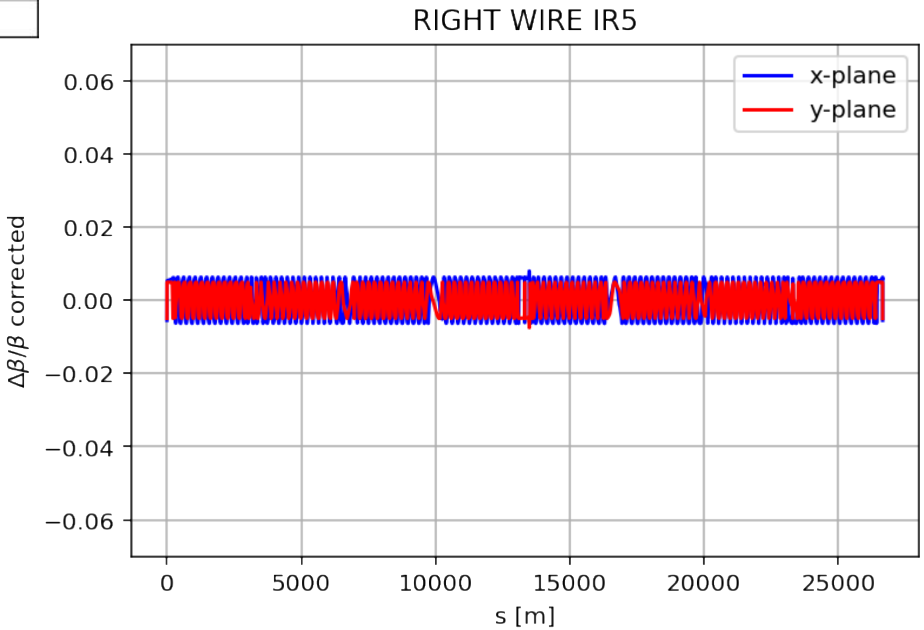


Local correction in Q4/5. Motivation and implication.



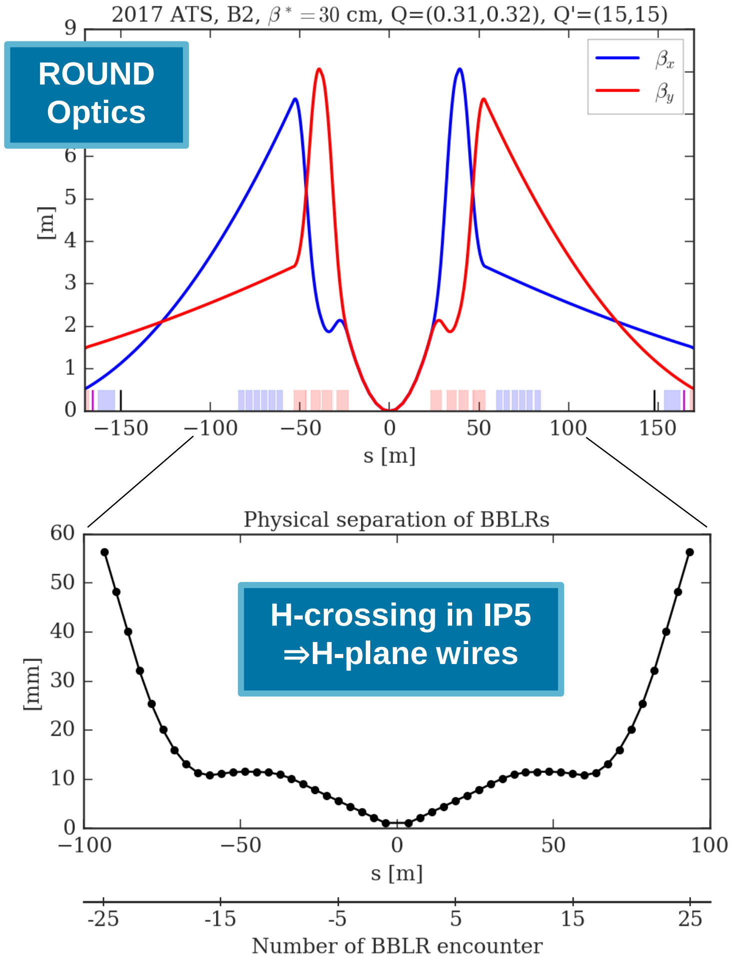
An example of β-beating induced by a wire (R5, 350 A at 5.5 σ_{coll})

β-beating corrected using the Q4 and Q5 (350 A at 5.5 σ_{coll}). Provided that **PC interlock settings** on these 8 quads is relaxed during the MD.



From the formalism to the experiment

We will consider the LHC optics used in the second part of 2017 (**ATS with β*= 30 cm, $\theta_c/2$=150 μrad**). **It corresponds to the condition of the second experiment** (we will consider only IP5).



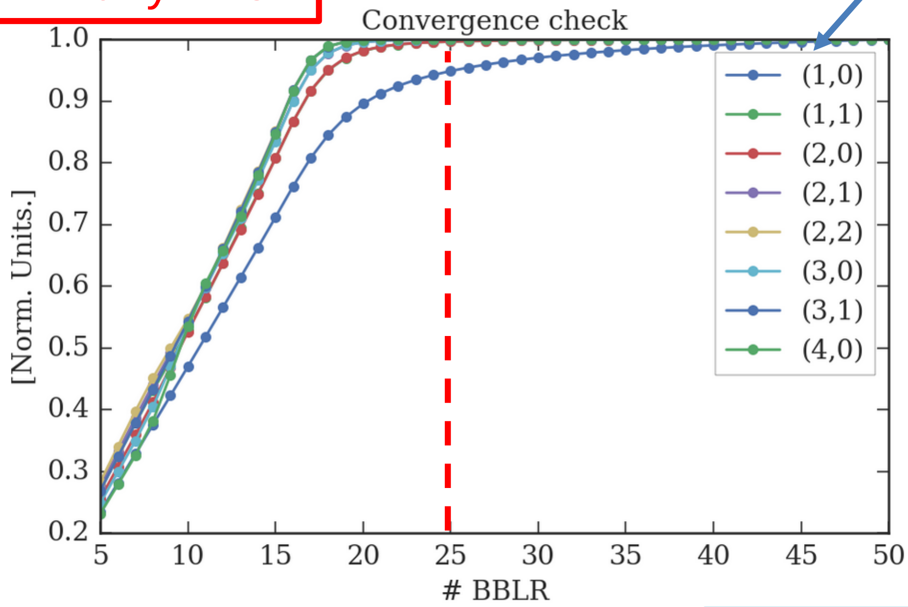
ROUND Optics

H-crossing in IP5 ⇒H-plane wires

$$c^{\mathrm{LR}}_{pq} \equiv \sum_{k\in \mathrm{LR}} \frac{\beta_x^{p/2}(s_k)\,\beta_y^{q/2}(s_k)}{d_{bb}^{p+q}(s_k)}$$

How many LRs?

(p,q)



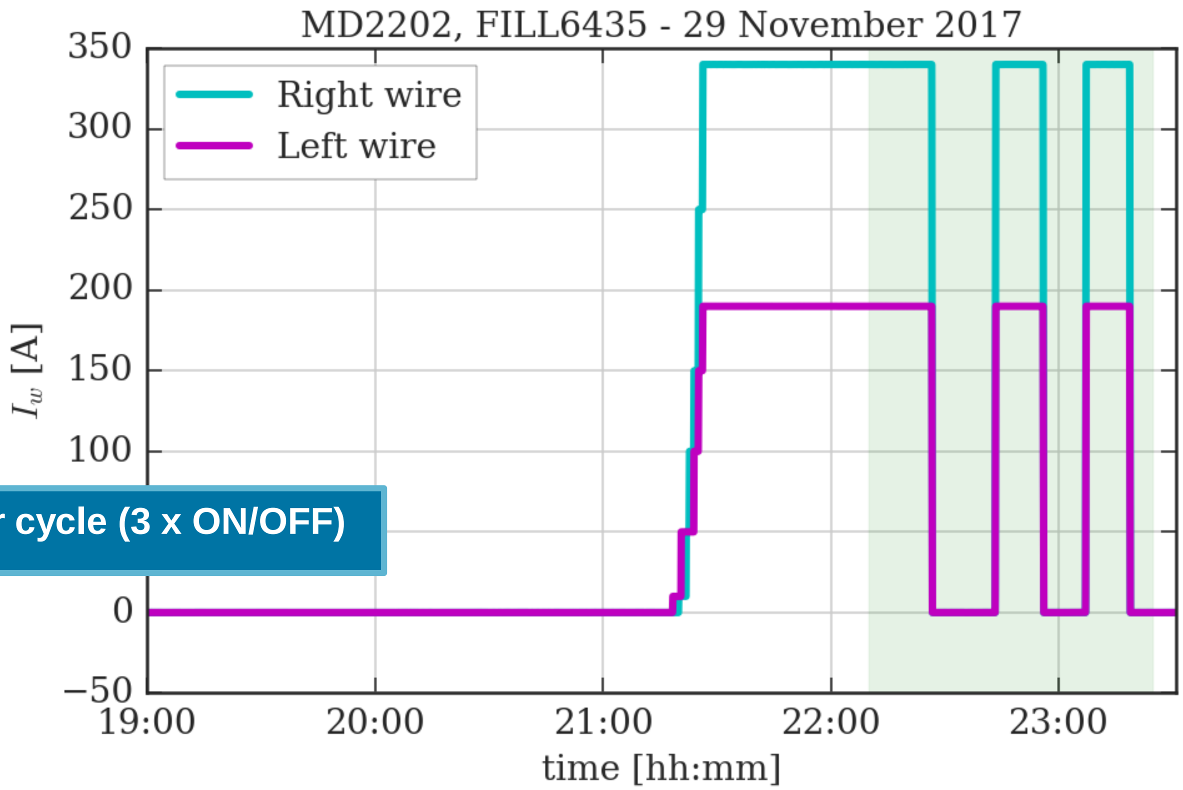
A. Poyet

We consider 25 encounter per side of the IP.

Switching ON/OFF the compensation

STEP 3

Wire compensation



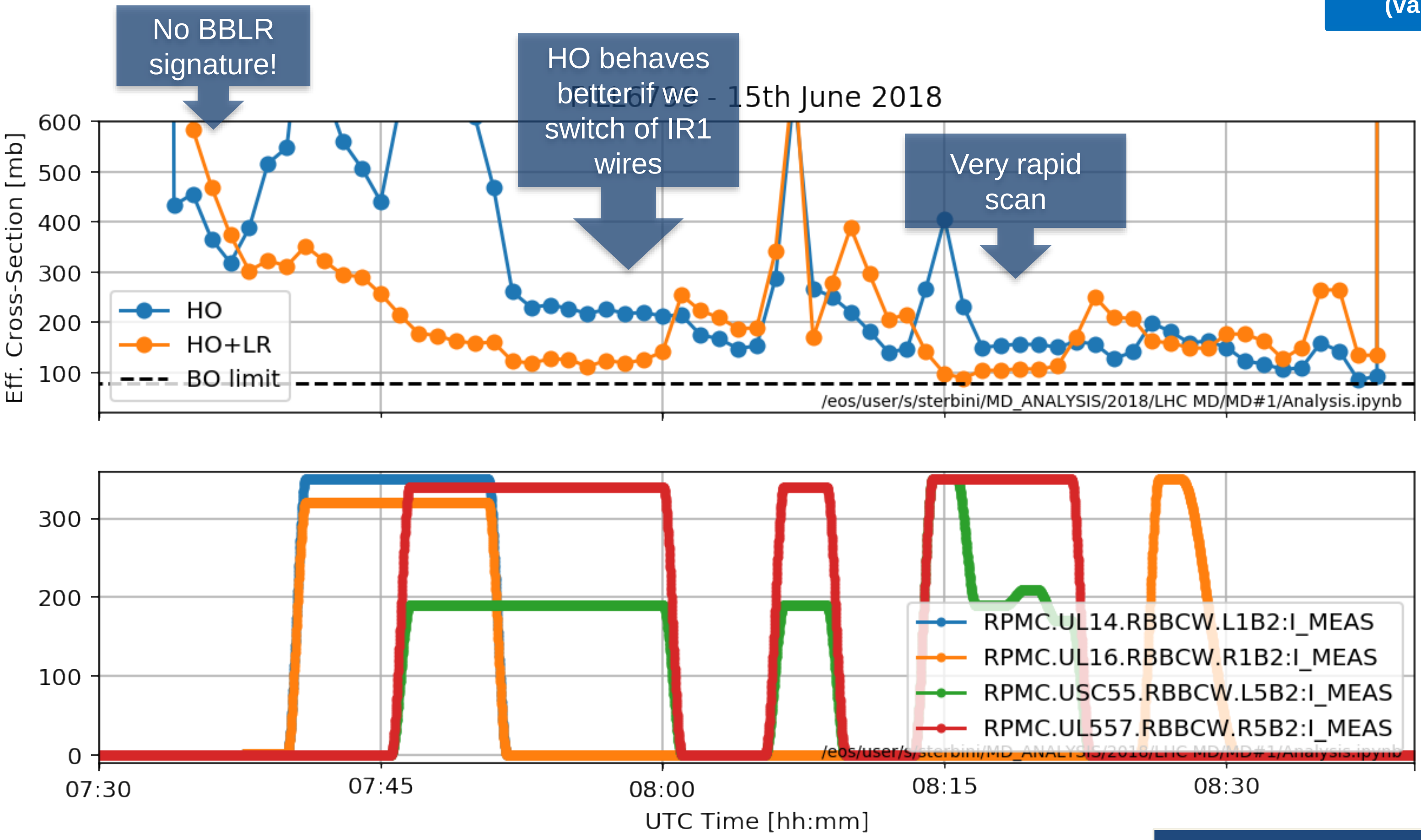
I_W^{MAX}=350 A

Power cycle (3 x ON/OFF)

- The wires were switched ON-OFF for several powering cycles.
- During the powering of the wires, the tunes of the beam (and its position) has to be controlled with high precision: dipolar and quadrupolar contributions of the wires were compensated with feed-forward trims [credit to M. Solfaroli and G.-H. Hemelsoet].

14th June 2018
FILL6797-8-9

From 2 to 4 wires (validation)



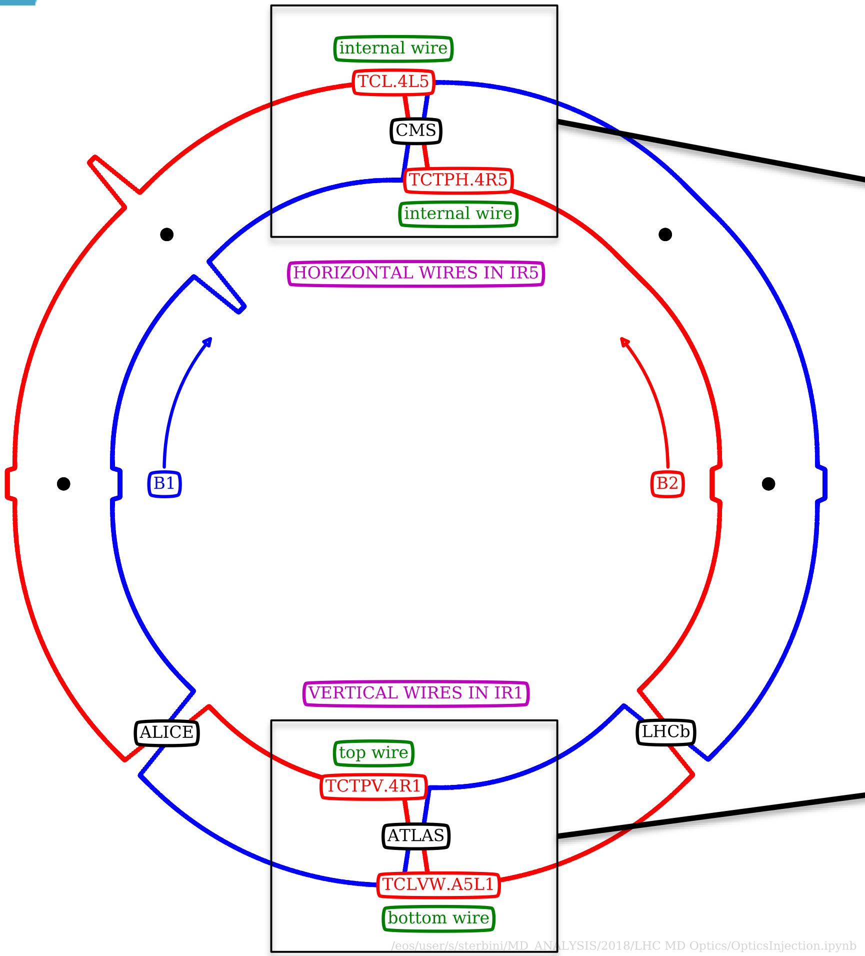
No BBLR signature!

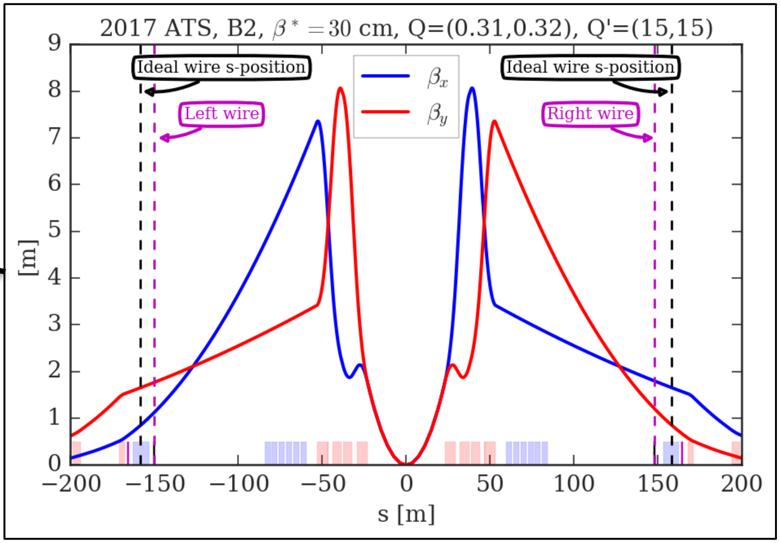
HO behaves better if we switch of IR1 wires

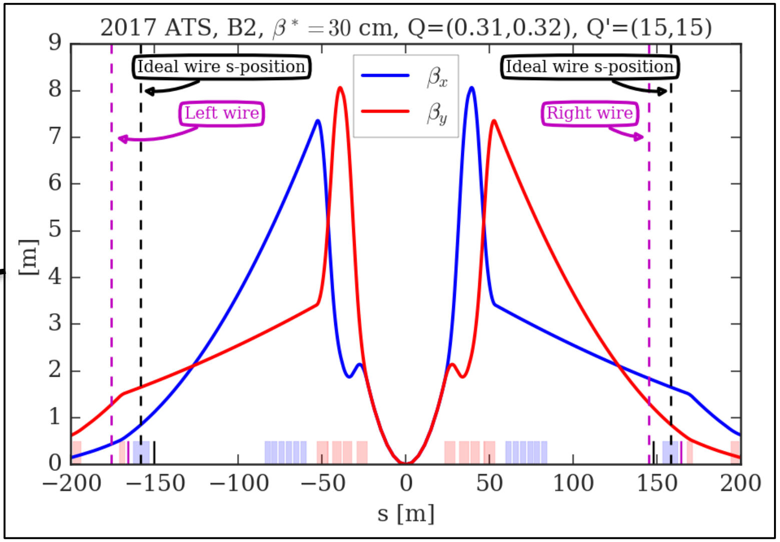
Very rapid scan

Credit to A. Poyet

REAL s-position (I)





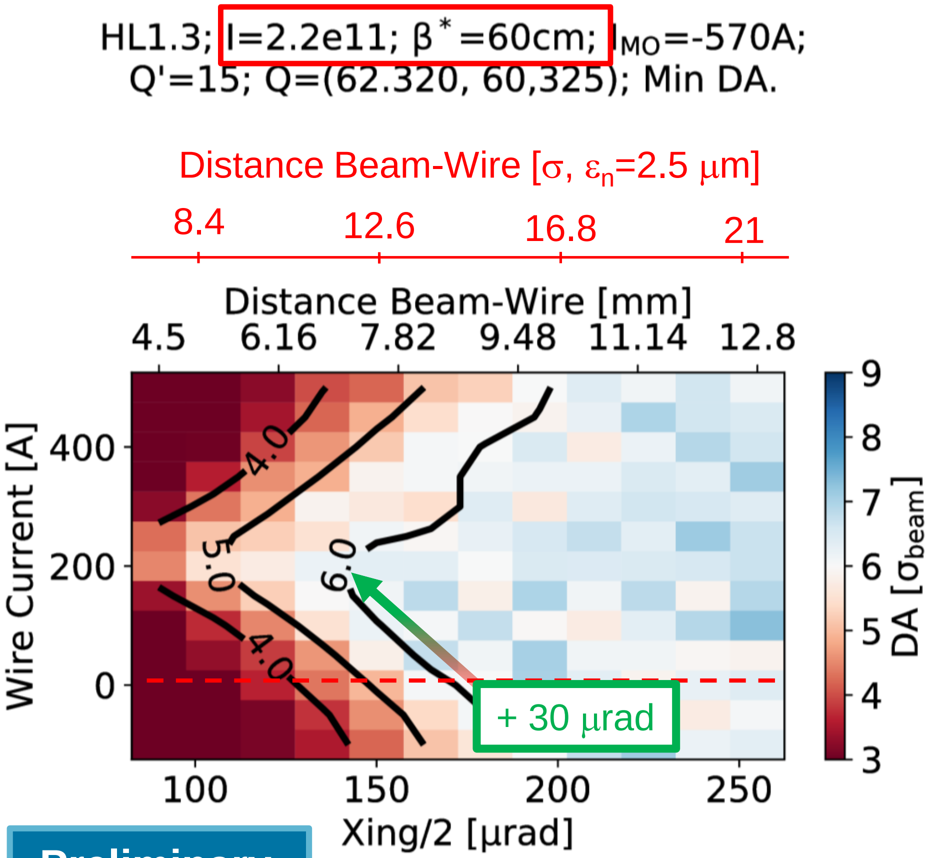


The **TCLVW.A5L1.B2** is NOT an operational collimator.

Compensation studies: from LHC to HL-LHC

- In the beam-beam team significant **efforts are put on the wire compensation tracking studies** with the two-fold aim to benchmark the LHC results and optimize the HL-LHC scenario with the wires.

- For HL-LHC, **preliminary results without a full optimization** of the longitudinal and transverse wire position, are showing an additional gain of the order of 30 μrad for the half-crossing angle.



Preliminary.
HL-LHC start of the levelling

Courtesy of D. Pellegrini

Analysis of the BBCW compensation

- Given the constraint on the minimal beam-wire distance, it was not possible to compensate all the resonances excited by the B1.
- We used the maximum current of the wires (350 A) to attack as much as possible the BBLR octupolar term.
- The octupolar terms induced by the BBLR in IR5 was reduced by **75%**.

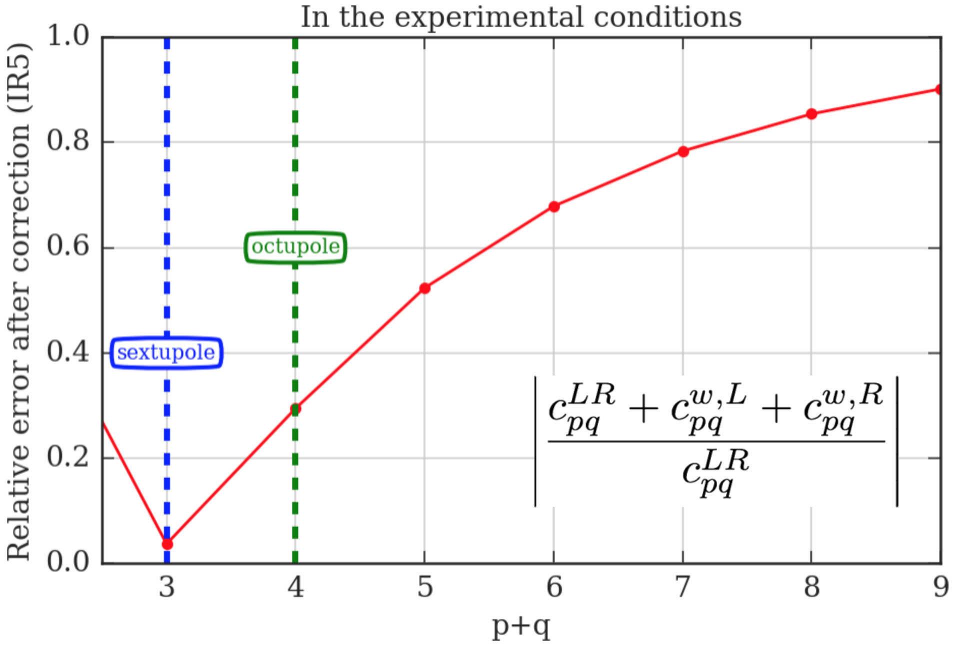
S. Fartoukh et al.
PRST-AB 18, 121001

Strong-beam driven resonance

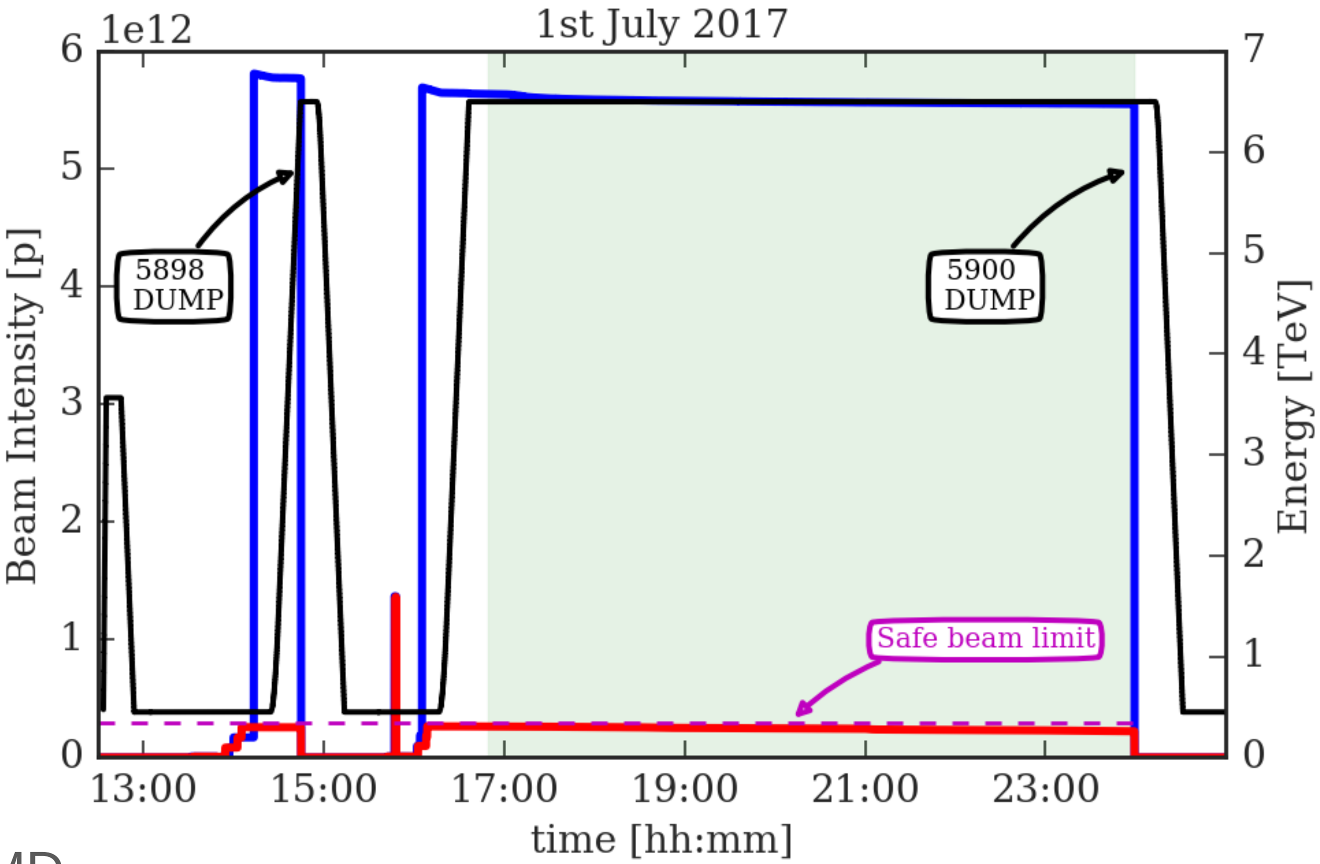
$$c_{pq}^{\mathrm{LR}} \equiv \sum_{k\in\mathrm{LR}} \frac{\beta_x^{p/2}(s_k)\beta_y^{q/2}(s_k)}{d_{bb}^{p+q}(s_k)}$$

BBCW driven resonance

$$\begin{cases} c_{pq}^{w.\mathrm{L}} \equiv N_{w.\mathrm{L}} \times \dfrac{(\beta_x^{w.\mathrm{L}})^{p/2}(\beta_y^{w.\mathrm{L}})^{q/2}}{(d_{w.\mathrm{L}})^{p+q}} \\ c_{pq}^{w.\mathrm{R}} \equiv N_{w.\mathrm{R}} \times \dfrac{(\beta_x^{w.\mathrm{R}})^{p/2}(\beta_y^{w.\mathrm{R}})^{q/2}}{(d_{w.\mathrm{R}})^{p+q}} \end{cases}$$



MD2202



- 10 h MD.
- The FILL5898 was dumped (RF on B1, not clear the reason, RF experts suggest a glitch on the interlock). Half-RF detuning.
- The observations we report concern the FILL5900. Full-RF detuning.

IDEAL CASE: 2 BBCW for IP at s_{opt}=+-159 m

RDT compensation map

	0	1	2	3	4	5	6	7	8	9
0	0.27	0.11	0.04	0.01	0.00	0.00	0.00	0.02	0.04	0.06
1	0.11	0.04	0.01	0.00	0.01	0.01	0.01	0.00	0.01	0.03
2	0.04	0.01	0.00	0.00	0.01	0.01	0.01	0.01	0.00	0.01
3	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
4	0.00	0.01	0.01	0.00	0.00	0.01	0.01	0.01	0.01	0.01
5	0.00	0.01	0.01	0.00	0.01	0.02	0.02	0.03	0.03	0.03
6	0.00	0.01	0.01	0.00	0.01	0.02	0.03	0.04	0.04	0.04
7	0.02	0.00	0.01	0.00	0.01	0.03	0.04	0.05	0.06	0.06
8	0.04	0.01	0.00	0.00	0.01	0.03	0.04	0.06	0.07	0.08
9	0.06	0.03	0.01	0.01	0.01	0.03	0.04	0.06	0.08	0.10

The green boxes are the 4 RDTs used to set N_w and d_w

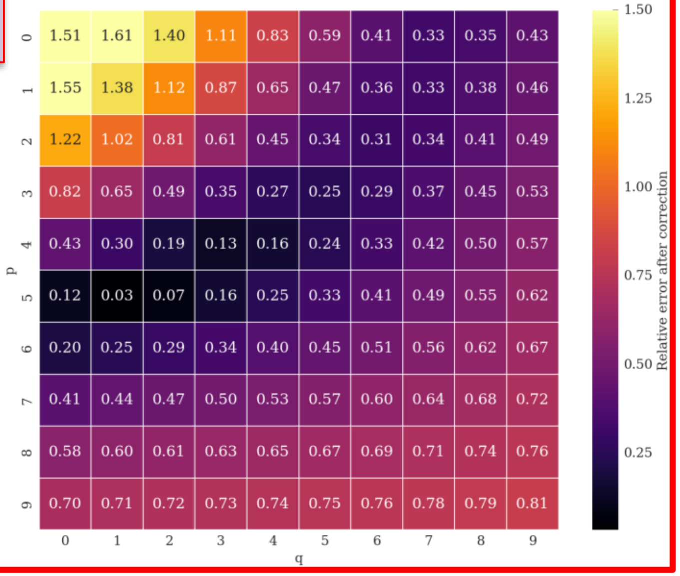
in color code

$$\left|\frac{c_{pq}^{LR}+c_{pq}^{w,L}+c_{pq}^{w,R}}{c_{pq}^{LR}}\right|$$

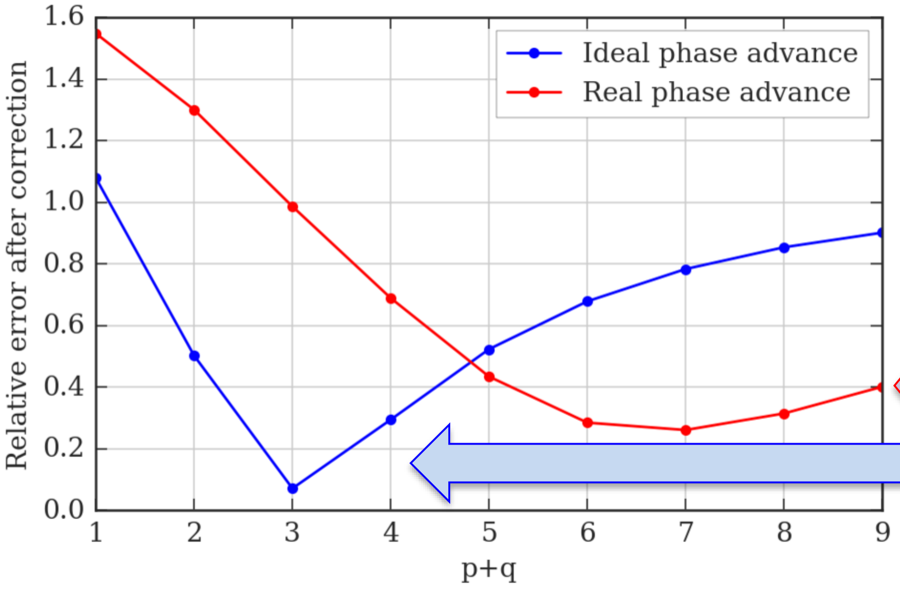
As expected (under the mentioned assumptions) the compensation is covering many more RDTs than the 4 used to set the BBCWs (green boxes). The p+q=1 and p+q=2 could be addressed by using “local” linear magnets (Q4s and the Q4 correctors).

The MD results and the RDT

Real phase advance considered

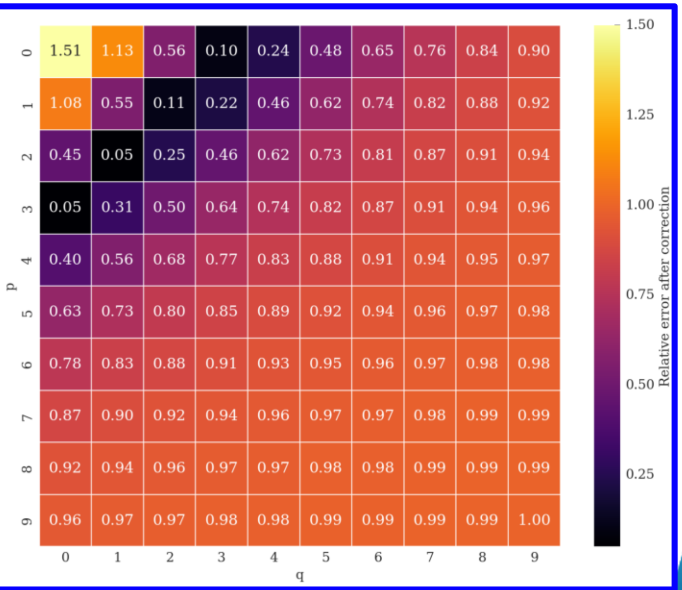


	0	1	2	3	4	5	6	7	8	9
0	1.51	1.61	1.40	1.11	0.83	0.59	0.41	0.33	0.35	0.43
1	1.55	1.38	1.12	0.87	0.65	0.47	0.36	0.33	0.38	0.46
2	1.22	1.02	0.81	0.61	0.45	0.34	0.31	0.34	0.41	0.49
3	0.82	0.65	0.49	0.35	0.27	0.25	0.29	0.37	0.45	0.53
4	0.43	0.30	0.19	0.13	0.16	0.24	0.33	0.42	0.50	0.57
5	0.12	0.03	0.07	0.16	0.25	0.33	0.41	0.49	0.55	0.62
6	0.20	0.25	0.29	0.34	0.40	0.45	0.51	0.56	0.62	0.67
7	0.41	0.44	0.47	0.50	0.53	0.57	0.60	0.64	0.68	0.72
8	0.58	0.60	0.61	0.63	0.65	0.67	0.69	0.71	0.74	0.76
9	0.70	0.71	0.72	0.73	0.74	0.75	0.76	0.78	0.79	0.81



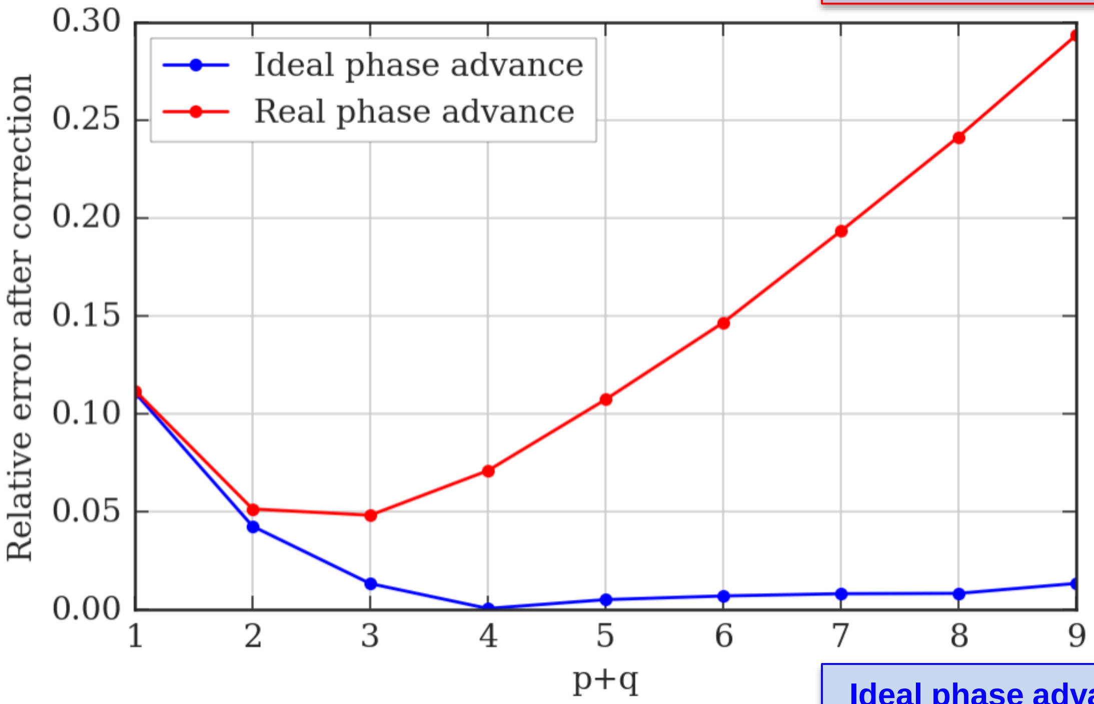
The observed effect of the BBCW can be related to a partial compensation of the detuning terms.

Ideal phase advance considered ($\beta^* \to 0$)

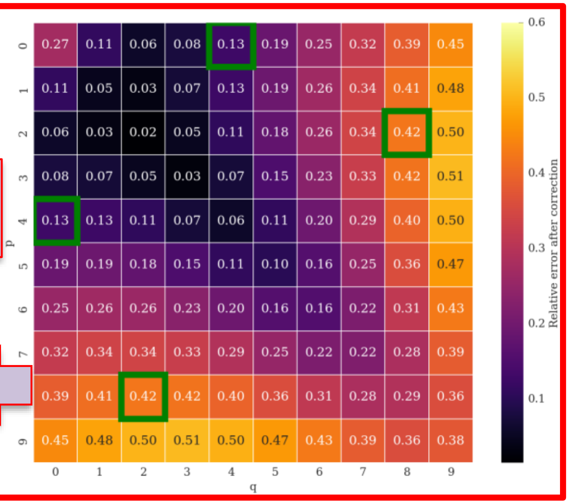


	0	1	2	3	4	5	6	7	8	9
0	1.51	1.13	0.56	0.10	0.24	0.48	0.65	0.76	0.84	0.90
1	1.08	0.55	0.11	0.22	0.46	0.62	0.74	0.82	0.88	0.92
2	0.45	0.05	0.25	0.46	0.62	0.73	0.81	0.87	0.91	0.94
3	0.05	0.31	0.50	0.64	0.74	0.82	0.87	0.91	0.94	0.96
4	0.40	0.56	0.68	0.77	0.83	0.88	0.91	0.94	0.95	0.97
5	0.63	0.73	0.80	0.85	0.89	0.92	0.94	0.96	0.97	0.98
6	0.78	0.83	0.88	0.91	0.93	0.95	0.96	0.97	0.98	0.98
7	0.87	0.90	0.92	0.94	0.96	0.97	0.97	0.98	0.99	0.99
8	0.92	0.94	0.96	0.97	0.97	0.98	0.98	0.99	0.99	0.99
9	0.96	0.97	0.97	0.98	0.98	0.99	0.99	0.99	0.99	1.00

IDEAL CASE: considering the phase advance.

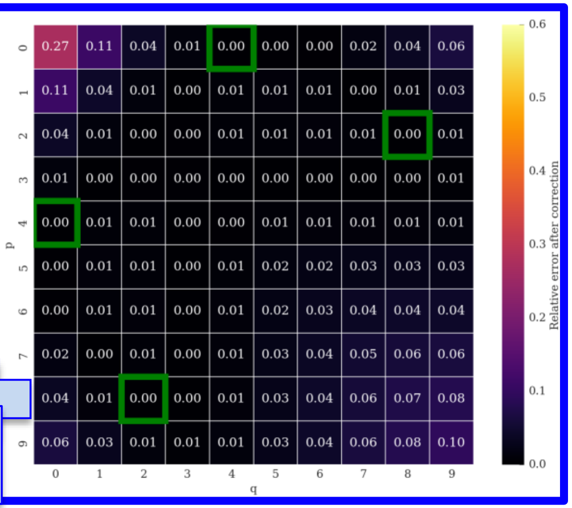


Real phase advance considered



	0	1	2	3	4	5	6	7	8	9
0	0.27	0.11	0.06	0.08	0.13	0.19	0.25	0.32	0.39	0.45
1	0.11	0.05	0.03	0.07	0.13	0.19	0.26	0.34	0.41	0.48
2	0.06	0.03	0.02	0.05	0.11	0.18	0.26	0.34	0.42	0.50
3	0.08	0.07	0.05	0.03	0.07	0.15	0.23	0.33	0.42	0.51
4	0.13	0.13	0.11	0.07	0.06	0.11	0.20	0.29	0.40	0.50
5	0.19	0.19	0.18	0.15	0.11	0.10	0.16	0.25	0.36	0.47
6	0.25	0.26	0.26	0.23	0.20	0.16	0.16	0.22	0.31	0.43
7	0.32	0.34	0.34	0.33	0.29	0.25	0.22	0.22	0.28	0.39
	0.39	0.41	0.42	0.42	0.40	0.36	0.31	0.28	0.29	0.36
9	0.45	0.48	0.50	0.51	0.50	0.47	0.43	0.39	0.36	0.38

Ideal phase advance considered (β*→0)

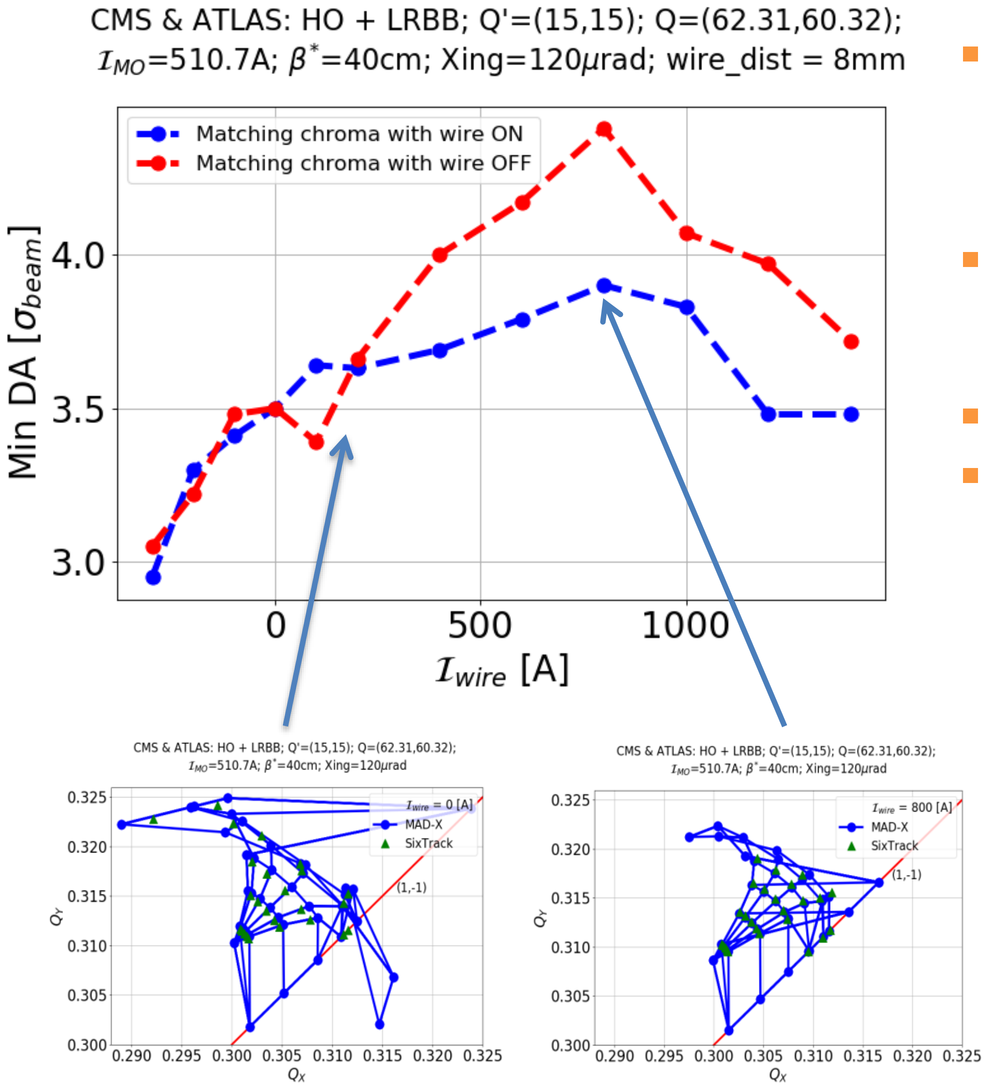


	0	1	2	3	4	5	6	7	8	9
0	0.27	0.11	0.04	0.01	0.00	0.00	0.00	0.02	0.04	0.06
1	0.11	0.04	0.01	0.00	0.01	0.01	0.01	0.00	0.01	0.03
2	0.04	0.01	0.00	0.00	0.01	0.01	0.01	0.01	0.00	0.01
3	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
4	0.00	0.01	0.01	0.00	0.00	0.01	0.01	0.01	0.01	0.01
5	0.00	0.01	0.01	0.00	0.01	0.02	0.02	0.03	0.03	0.03
6	0.00	0.01	0.01	0.00	0.01	0.02	0.03	0.04	0.04	0.04
7	0.02	0.00	0.01	0.00	0.01	0.03	0.04	0.05	0.06	0.06
	0.04	0.01	0.00	0.00	0.01	0.03	0.04	0.06	0.07	0.08
9	0.06	0.03	0.01	0.01	0.01	0.03	0.04	0.06	0.08	0.10

One can quantify a posteriori the effect of the phase advance.

The compensation of the RDT does degrade. The compensation of detuning terms (Q-footprint compression) is not affected.

DA simulations with Wire in MD-like conditions I



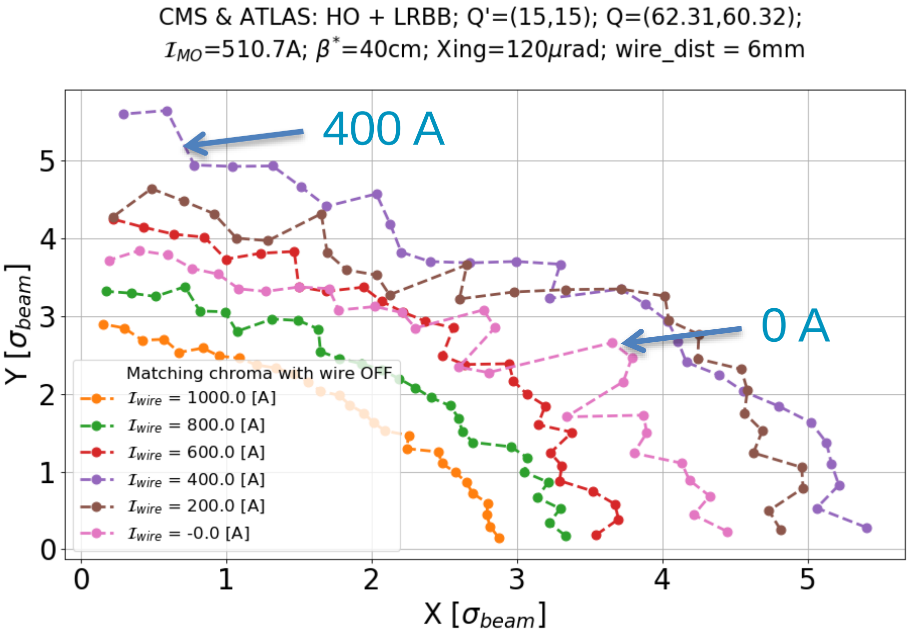
- MD-like conditions: d_w=8 mm. LR in IR1/5 but wire only in IR1, real aspect ratio at wire position, phase advances.
- A modest gain of DA is observed for 8 mm wire-beam distance.
- Optimal DA for 800 A.
- With no rematch of the chromaticity (as in the MD), the gain of DA is improved.

- Good agreement between footprints from MADX and Sixtrack.
- Improvement observed but no clear identification of the optimum.

K. Skoufaris

DA simulations with Wire in MD-like conditions II

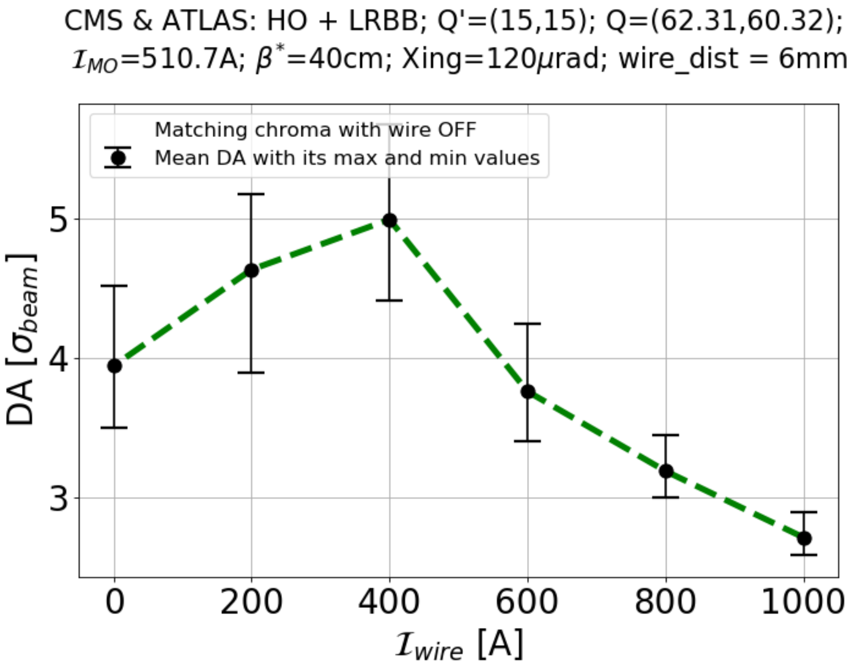
- Push d_w to 6 mm
- Still not ideal conditions: LR in IR1/5 but wire only in IR1, aspect ratio at wire position, phase advances.
- **1σ** (@2.5 μm) DA gained for an optimal wire current of ~400 A.
- Clear improvement over all the angles.



CMS & ATLAS: HO + LRBB; Q'=(15,15); Q=(62.31,60.32); $\mathcal{I}_{MO}$=510.7A; β^*=40cm; Xing=120μrad; wire_dist = 6mm

400 A

0 A



CMS & ATLAS: HO + LRBB; Q'=(15,15); Q=(62.31,60.32); $\mathcal{I}_{MO}$=510.7A; β^*=40cm; Xing=120μrad; wire_dist = 6mm

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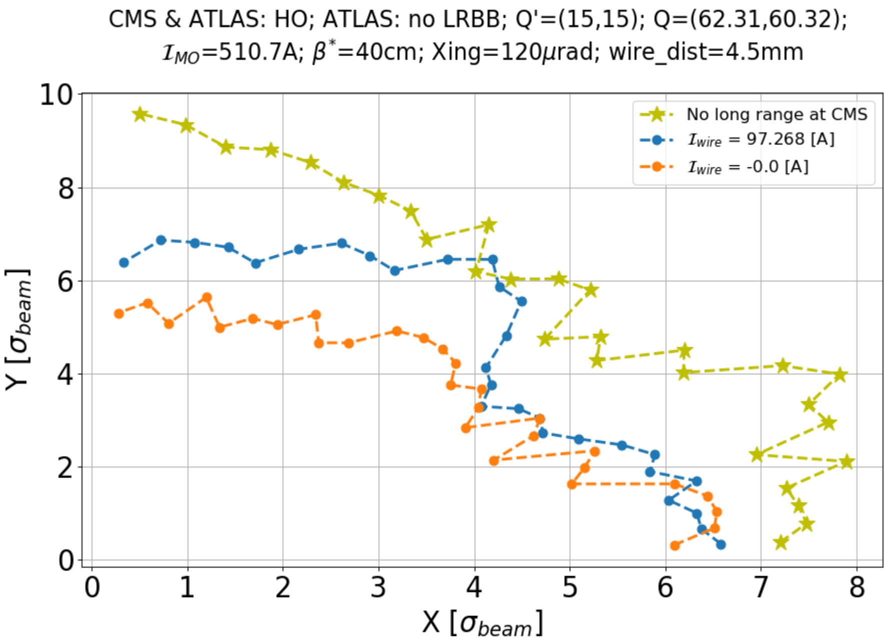
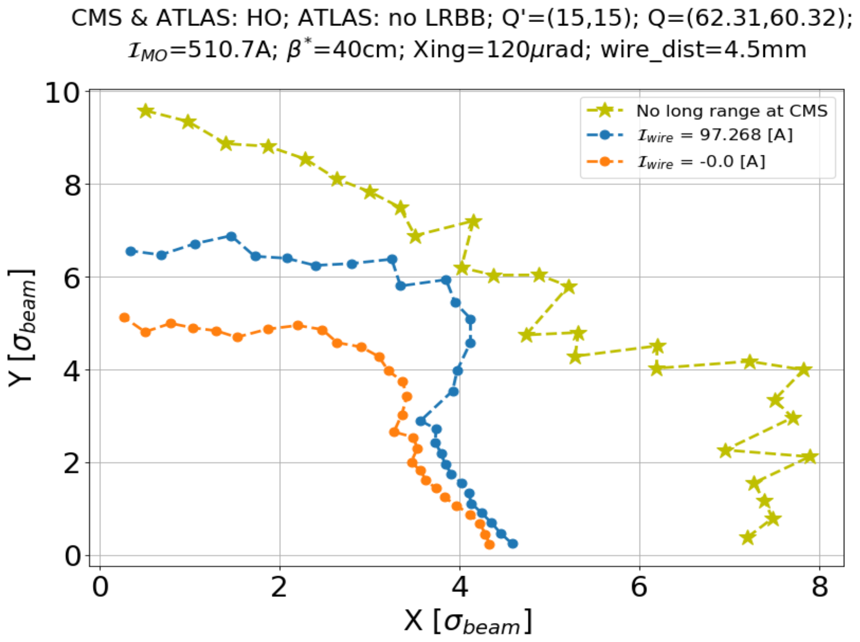
“Strong beam”-wire equivalence: tracking

Standard Strong Beam



Zero-emittance-long-range Strong Beam

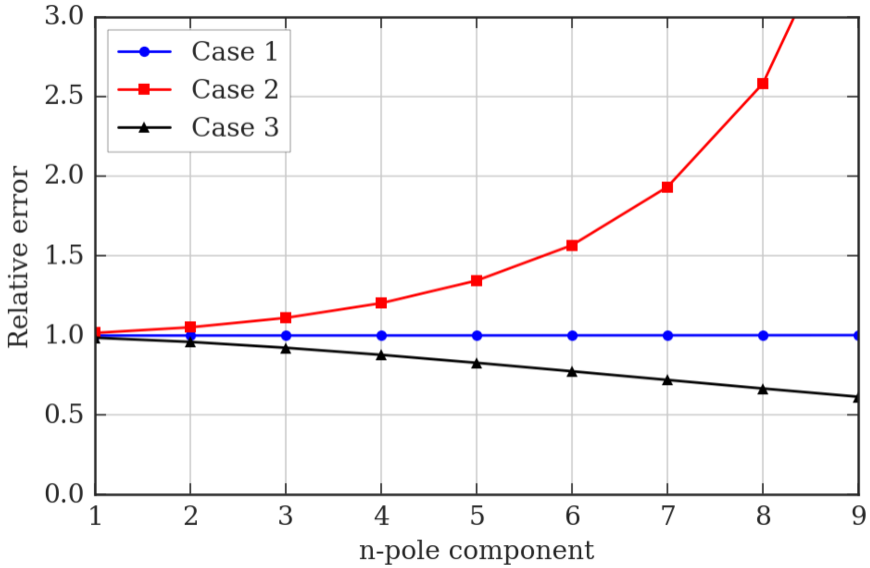


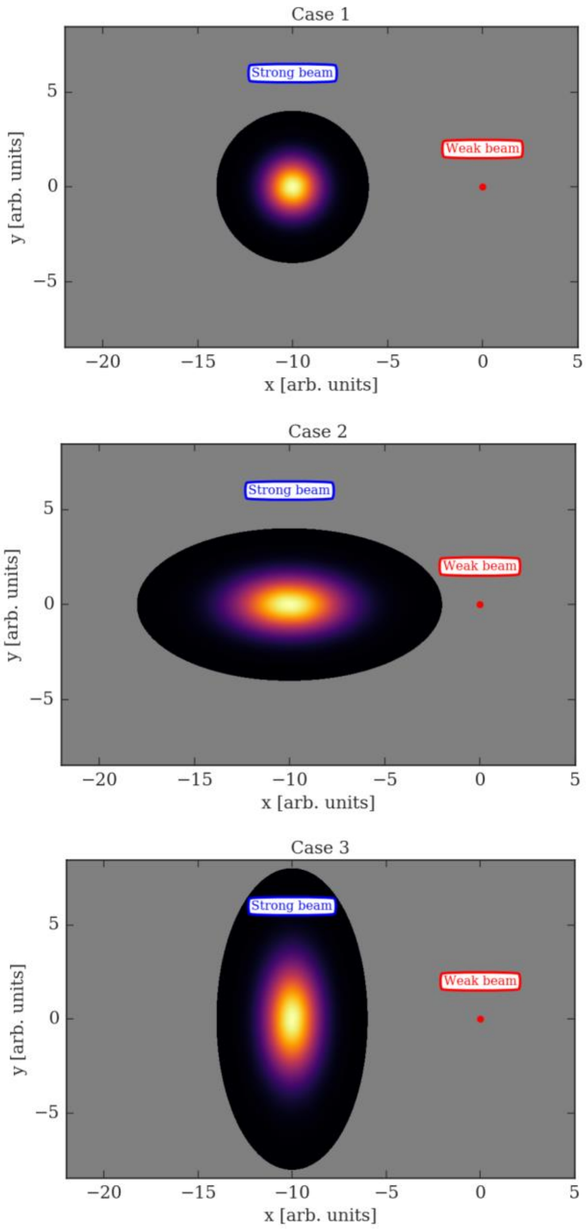
K. Skoufaris

- The zero-emittance-LR strong beam does not show a better DA.
- Effect of phase advance? Plans to test with the wire at ~70 m for better phases.

“Strong beam”-wire equivalence

- For $\beta_x \neq \beta_y$ the “strong beam”-wire equivalence is not valid anymore
- We compare the strong beam field and the wire field in terms of multipoles
- Case 1: $\beta_x=\beta_y$, perfect equivalence
- Case 2: $\beta_x=4*\beta_y$, see plot below
- Case 2: $\beta_y=4*\beta_x$, plot below
- We assume bi-Gaussian density (4 σ cut)





First attempts of BBCW in HLLHC1.3

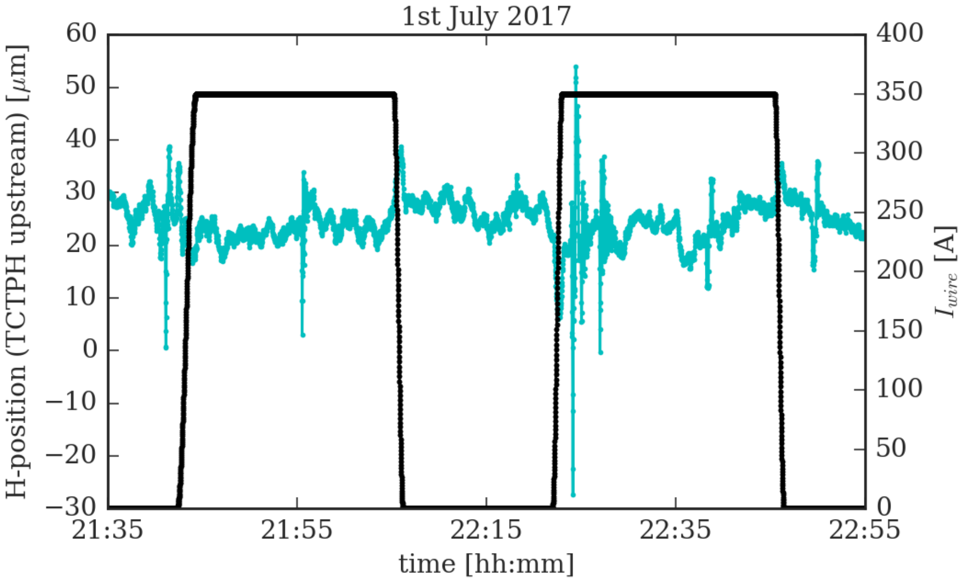
- B1 tracking with **operational settings** for emittance, tunes, chroma, octupoles.
- **4 wires** (L/R IP1/5) installed in the crossing plane.
- The wires are arbitrarily placed at **+/-150m** from the IPs.
- The **distance** is tuned so that the beam-wire normalised separation is the same as the normalised crossing.
- Likely a **suboptimal** configuration to be further refined.

β* = 60 cm	H Beta [m]	V Beta [m]
wire_l1.b1	1052	1181
wire_r1.b1	1178	1054
wire_l5.b1	1054	1182
wire_r5.b1	1181	1055

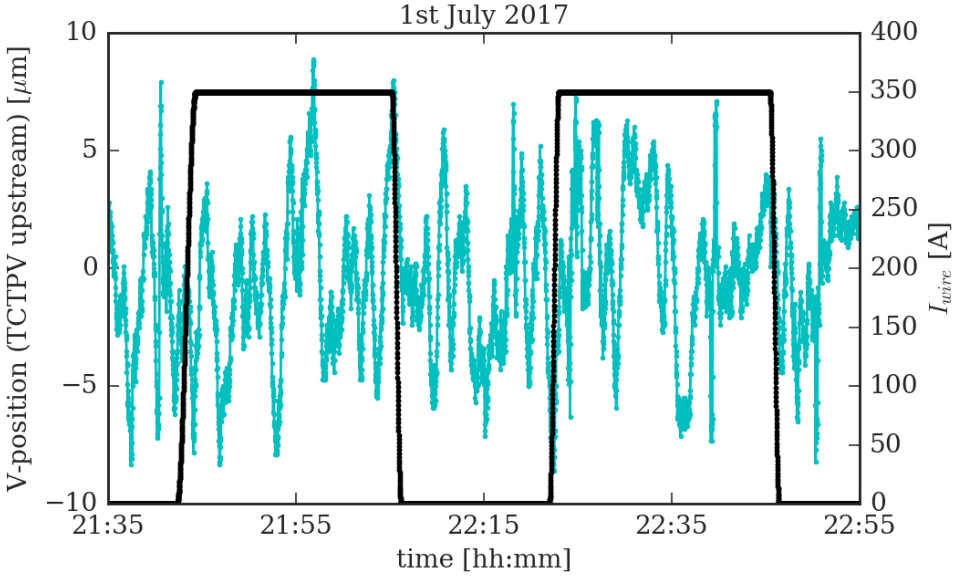
β* = 20 cm	H Beta [m]	V Beta [m]
wire_l1.b1	3006	3641
wire_r1.b1	3649	2999
wire_l5.b1	2995	3645
wire_r5.b1	3636	3003

BBCW MD: sanity checks on H/V-position

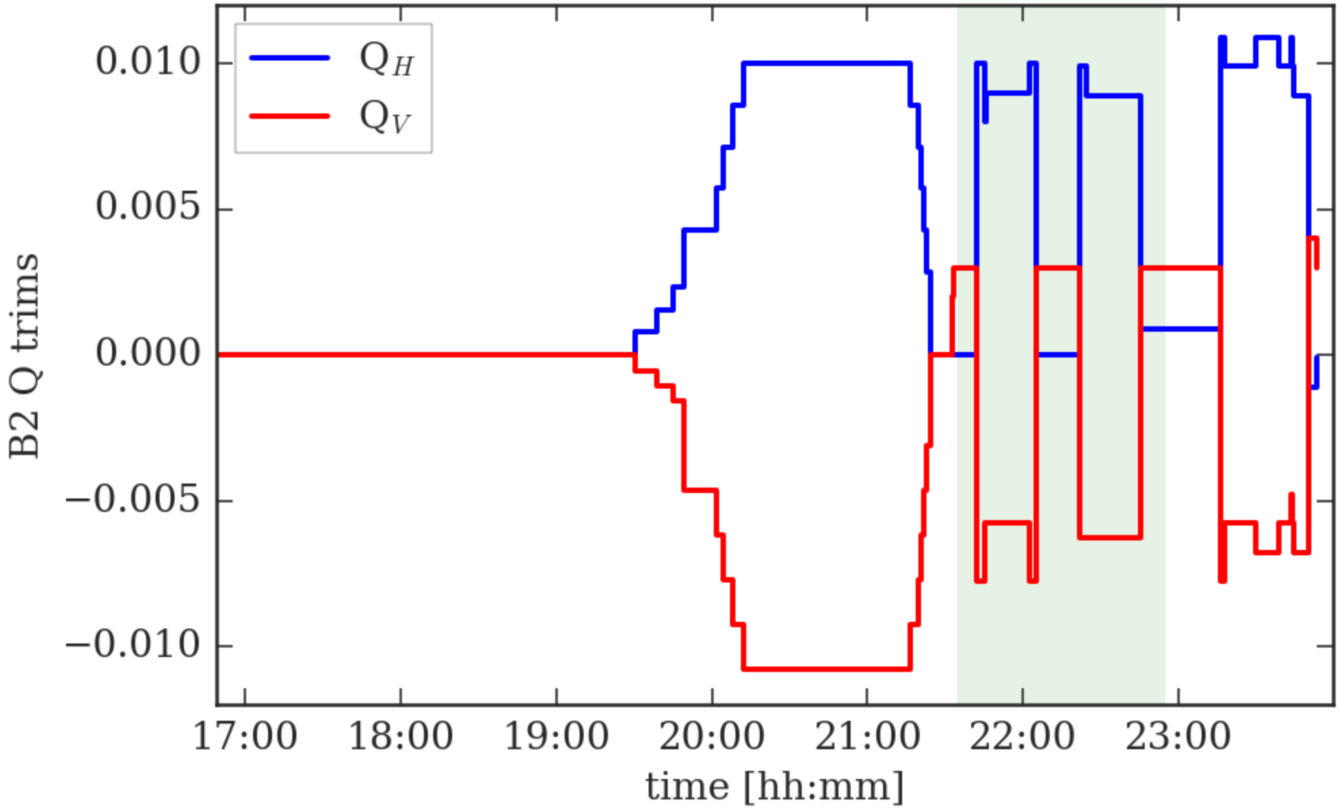
- The H-position of the beam is well under control.



- The V-position and correctors behaviour confirm a very good V-alignment of the BBCW.

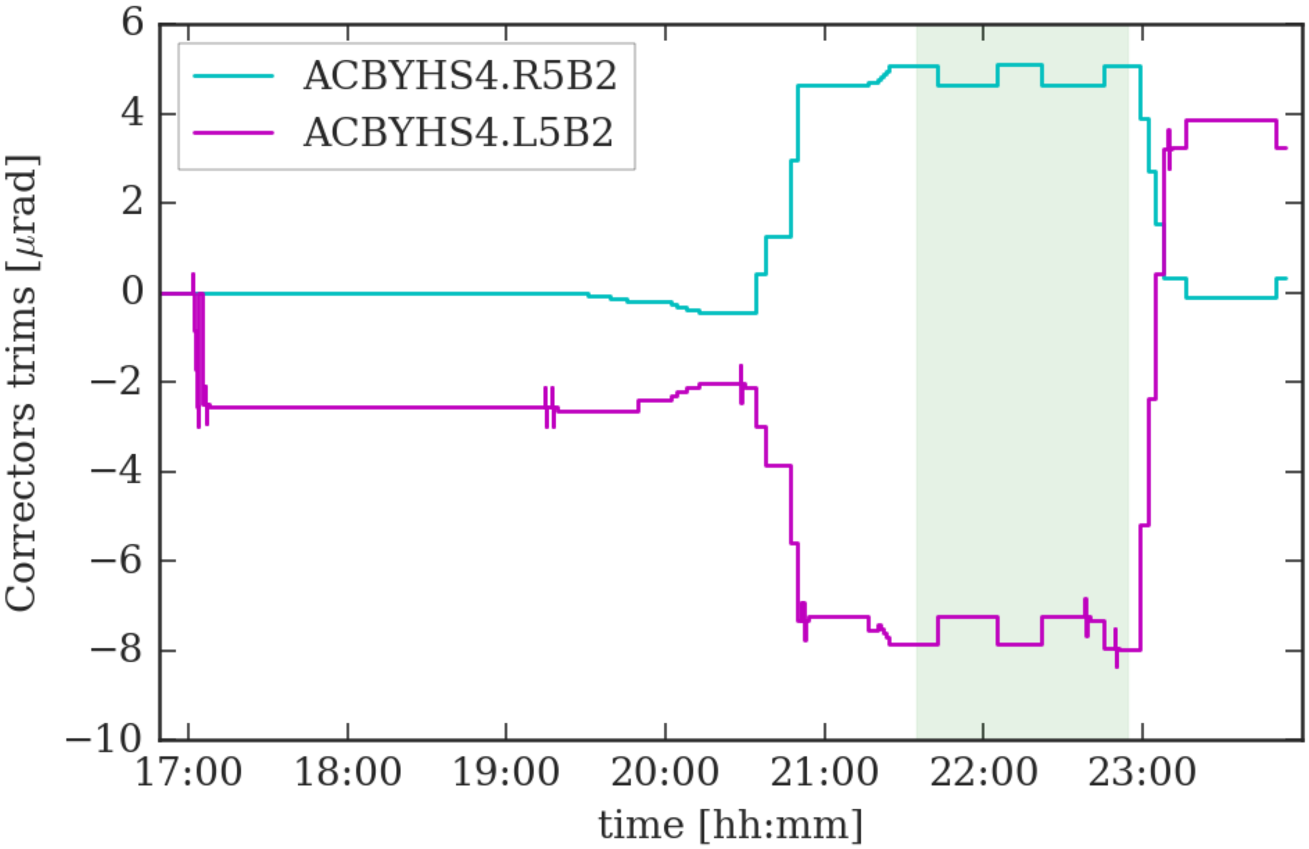


BBCW MD: Q trims



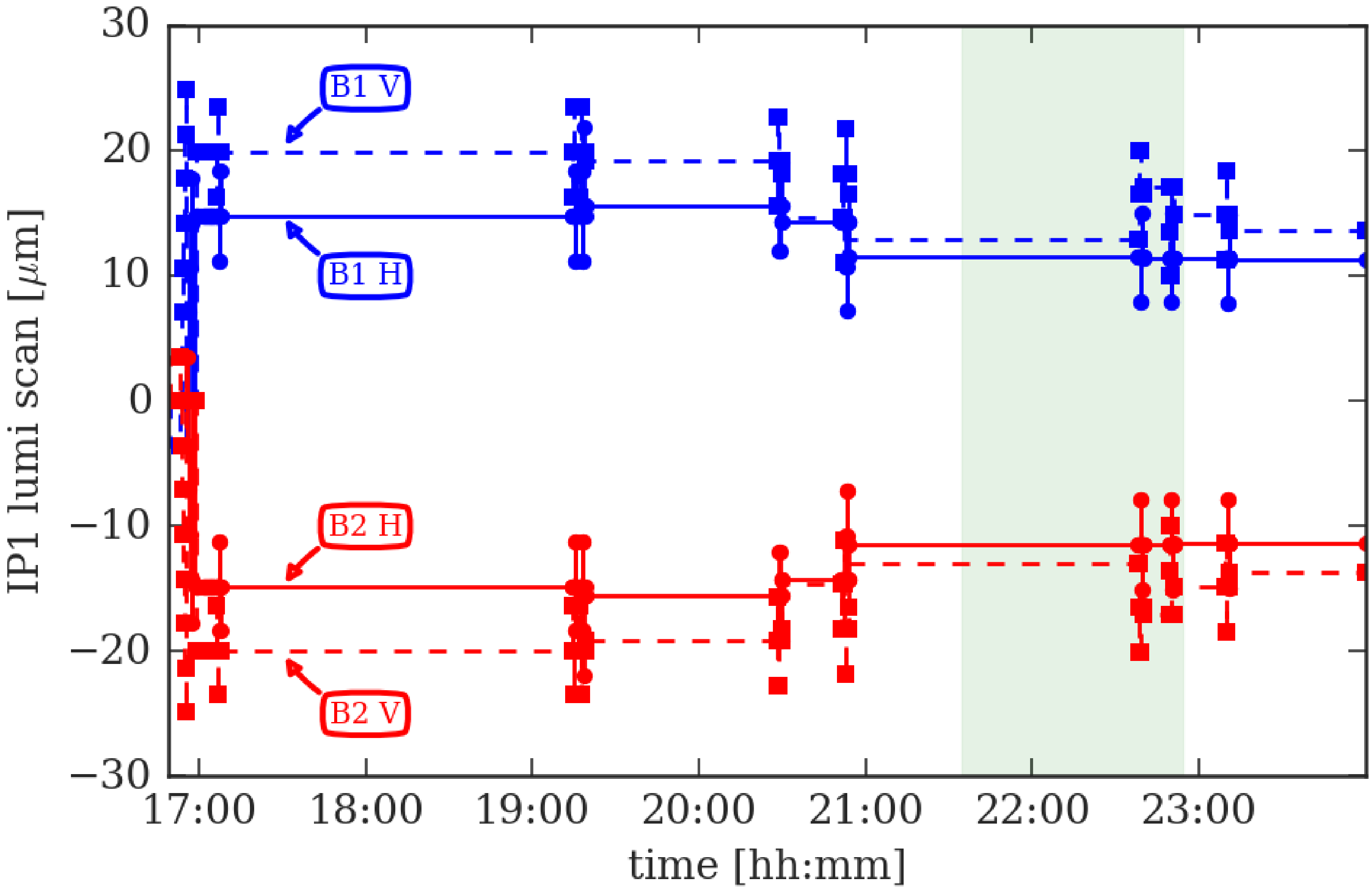
The Q-trims are mostly due to the feedforward.

BBCW MD: dipolar trims

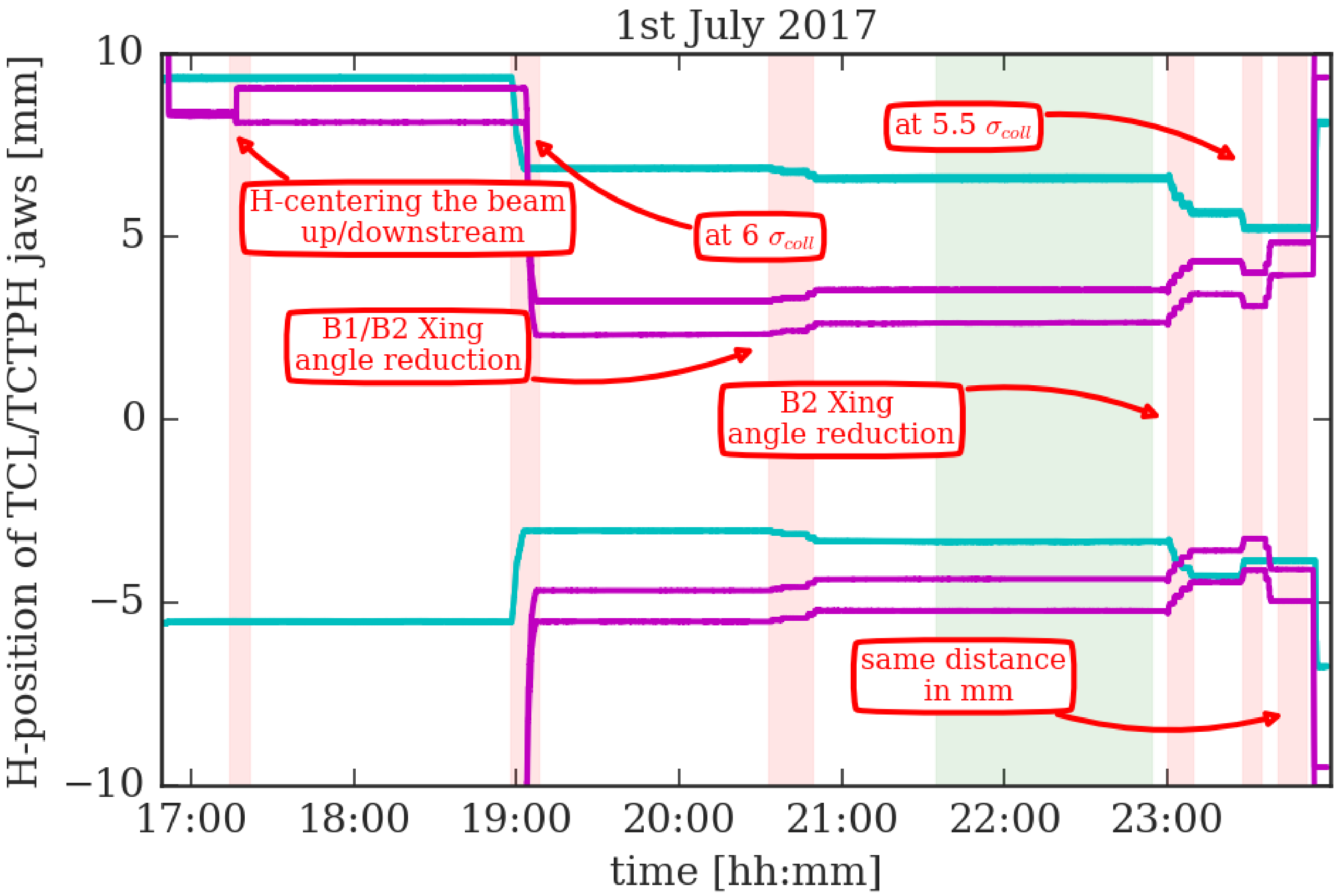


The correctors trims are mostly due to the crossing angle settings.

BBCW MD: optimizing HO collision

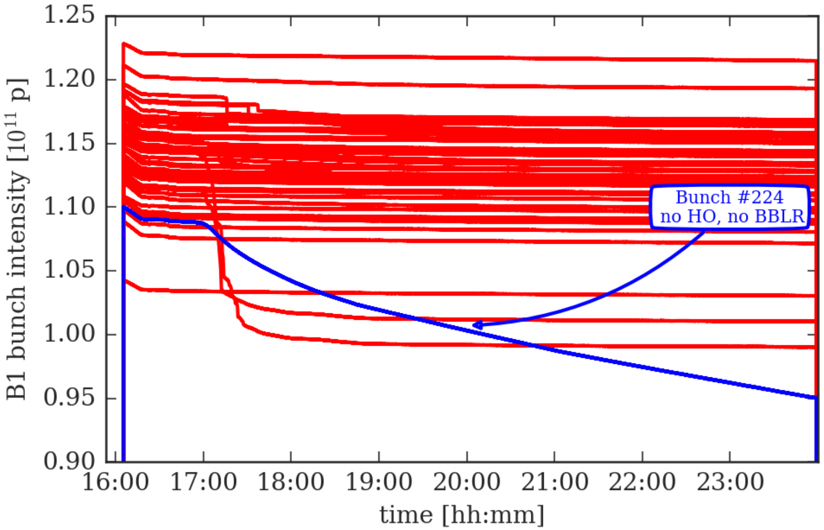


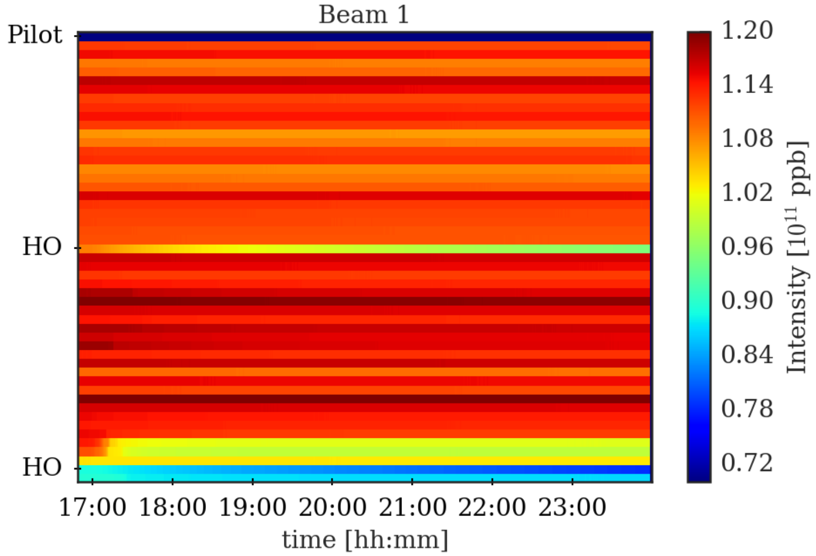
BBCW MD: wires H-positioning



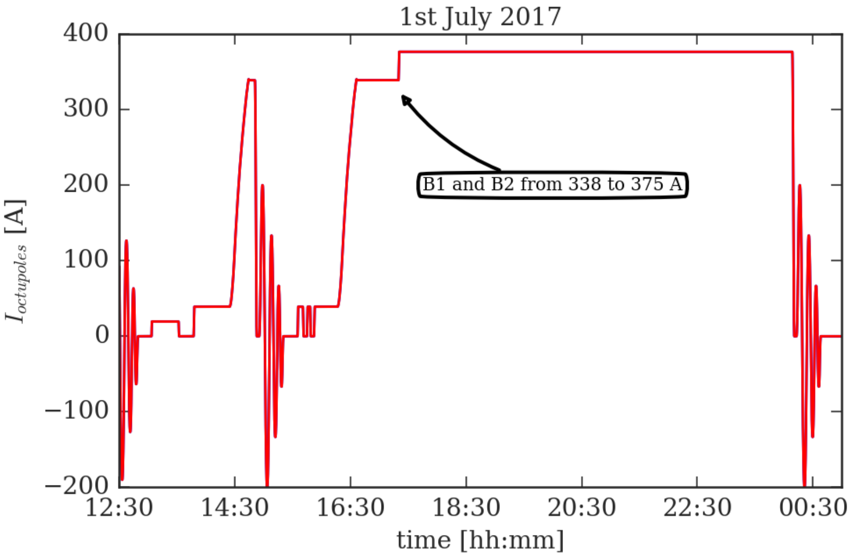
The hectic activity on the BBCW positioning.

BBCW MD: instability of B1



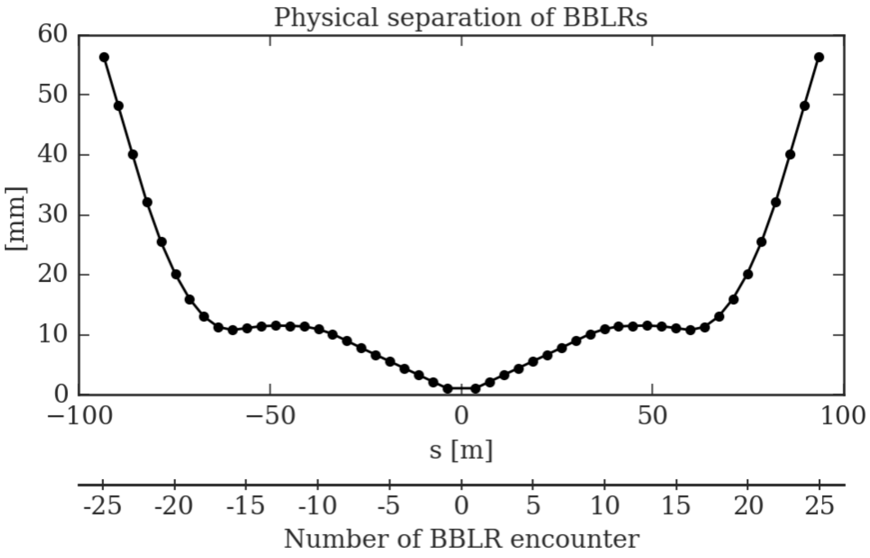


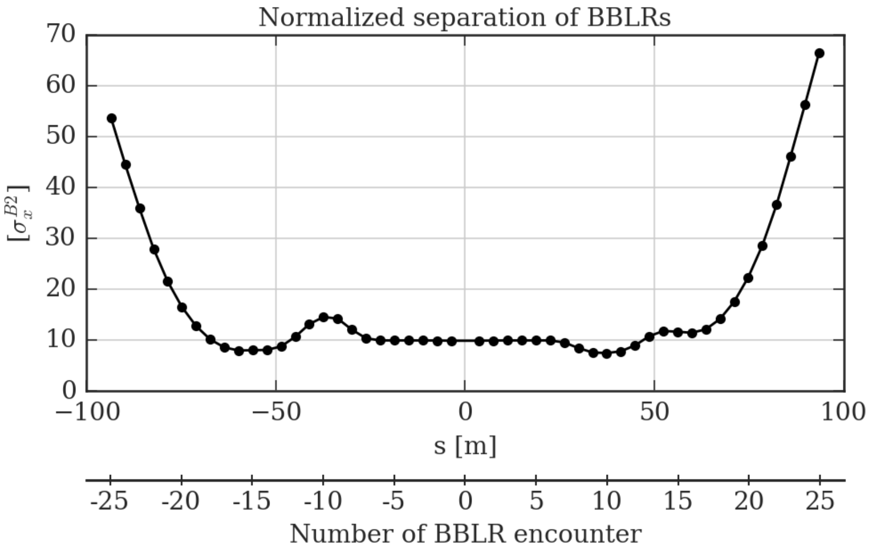
- During next MD we will use stronger octupole settings to avoid the instability of the non-colliding bunches in B1.



ATS 2017 optics

	NAME	X	PX	Y	PY	BETX	BETY	sigma_x at 3.5 um at 6.5 TeV [mm]
7062.030793	TCL.4L5.B2	1.527841e-03	0.000054	0.003836	-4.970527e-05	845.954861	1327.127536	0.653755
7212.060793	IP5	1.936385e-15	-0.000150	-0.001500	-9.267840e-15	0.400000	0.400000	0.014216
7360.005793	TCTPH.4R5.B2	-1.422381e-03	0.000034	0.002863	3.456410e-05	1349.329513	903.299673	0.825659

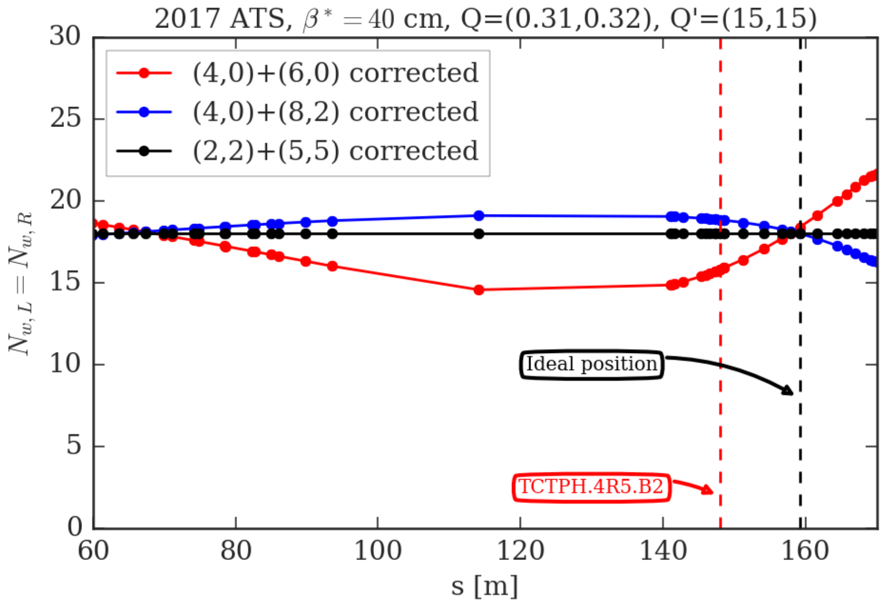


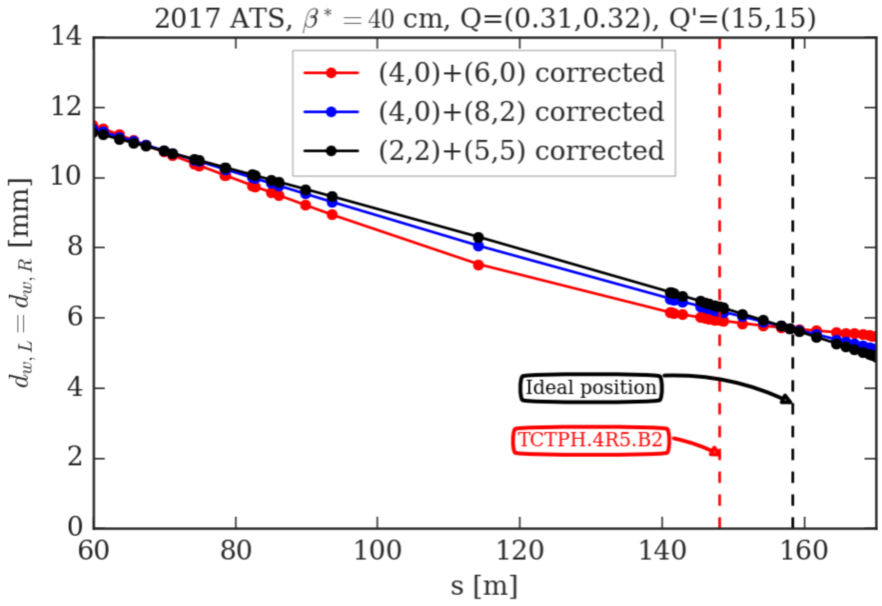


RDT criterion for ATS 2017 and θ_c=150 μm

By plotting the N_w(s) and d_w(s) for different RDT minimization strategy, one sees there are specific s-positions, s_{opt}, that minimizes more than the usual 4 RDTs.

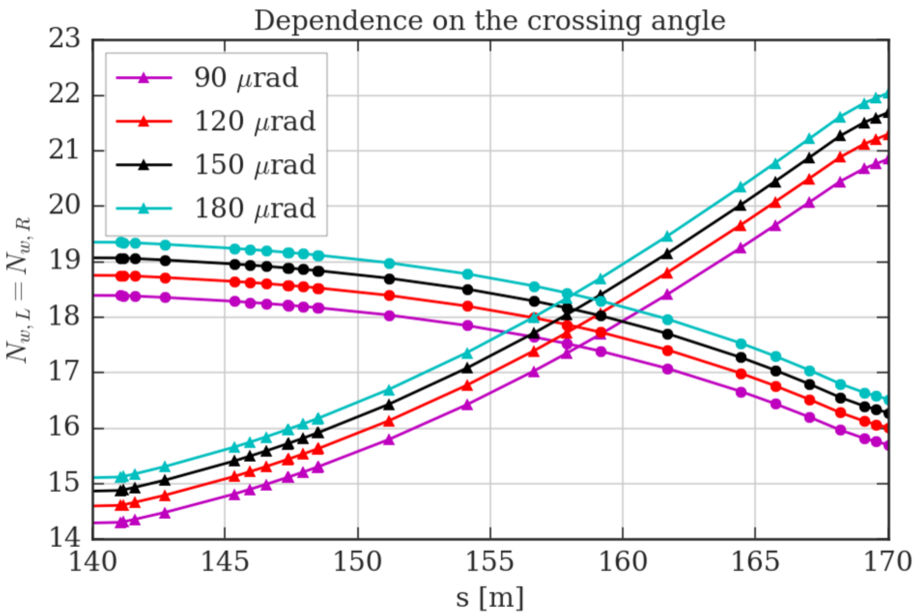
The BBCW is positioned ~10 m apart with respect to the optimal position.

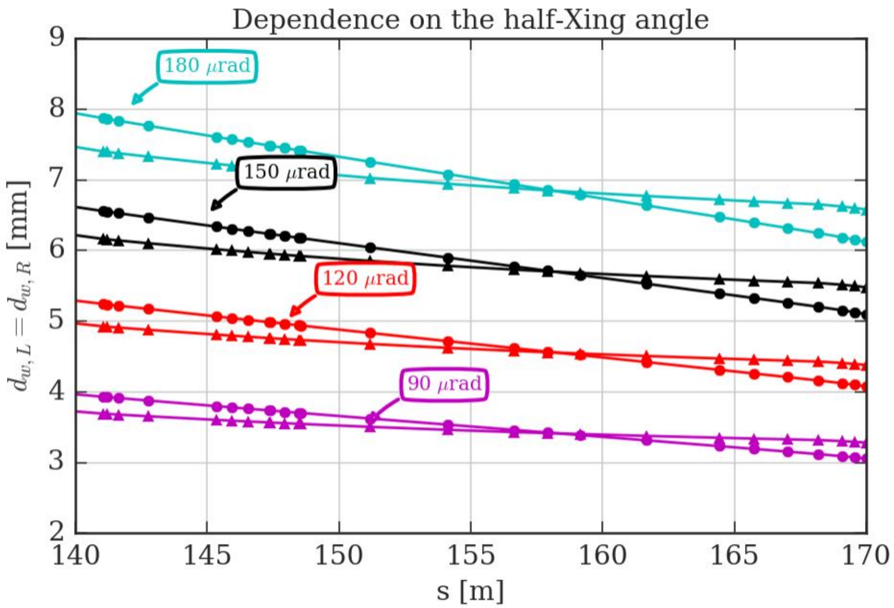

2017 ATS, $\beta^* = 40$ cm, Q=(0.31,0.32), Q'=(15,15)


2017 ATS, $\beta^* = 40$ cm, Q=(0.31,0.32), Q'=(15,15)

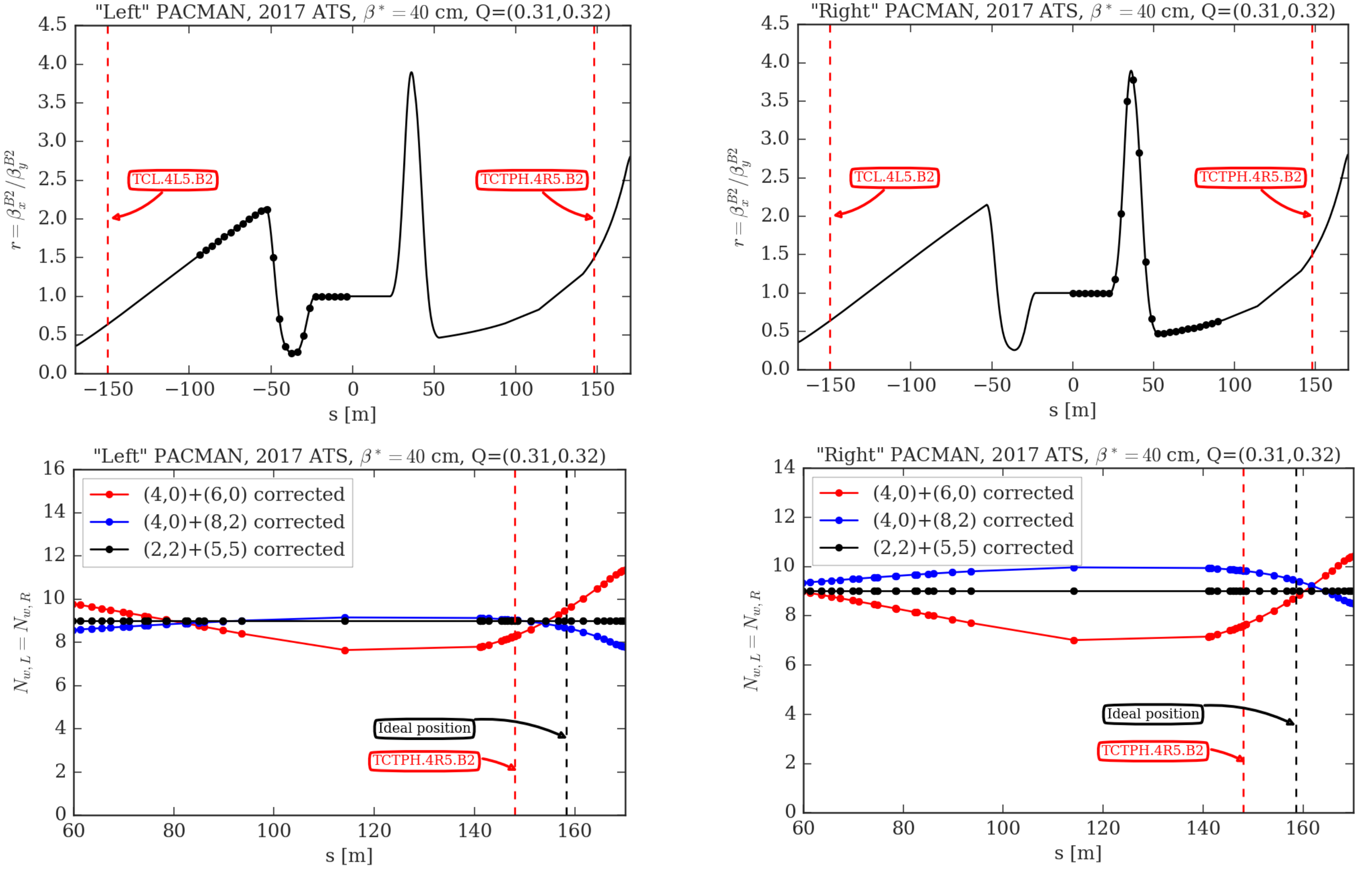
s_{opt}, N_w and d_w on crossing angle

- There is no dependence of s_{opt} on the crossing angle.
- N_w dependence on the crossing angle is marginal (smaller crossing angle, smaller N_w).
- d_w is linearly dependent on the crossing angle.





PACMAN bunches and s_{opt}

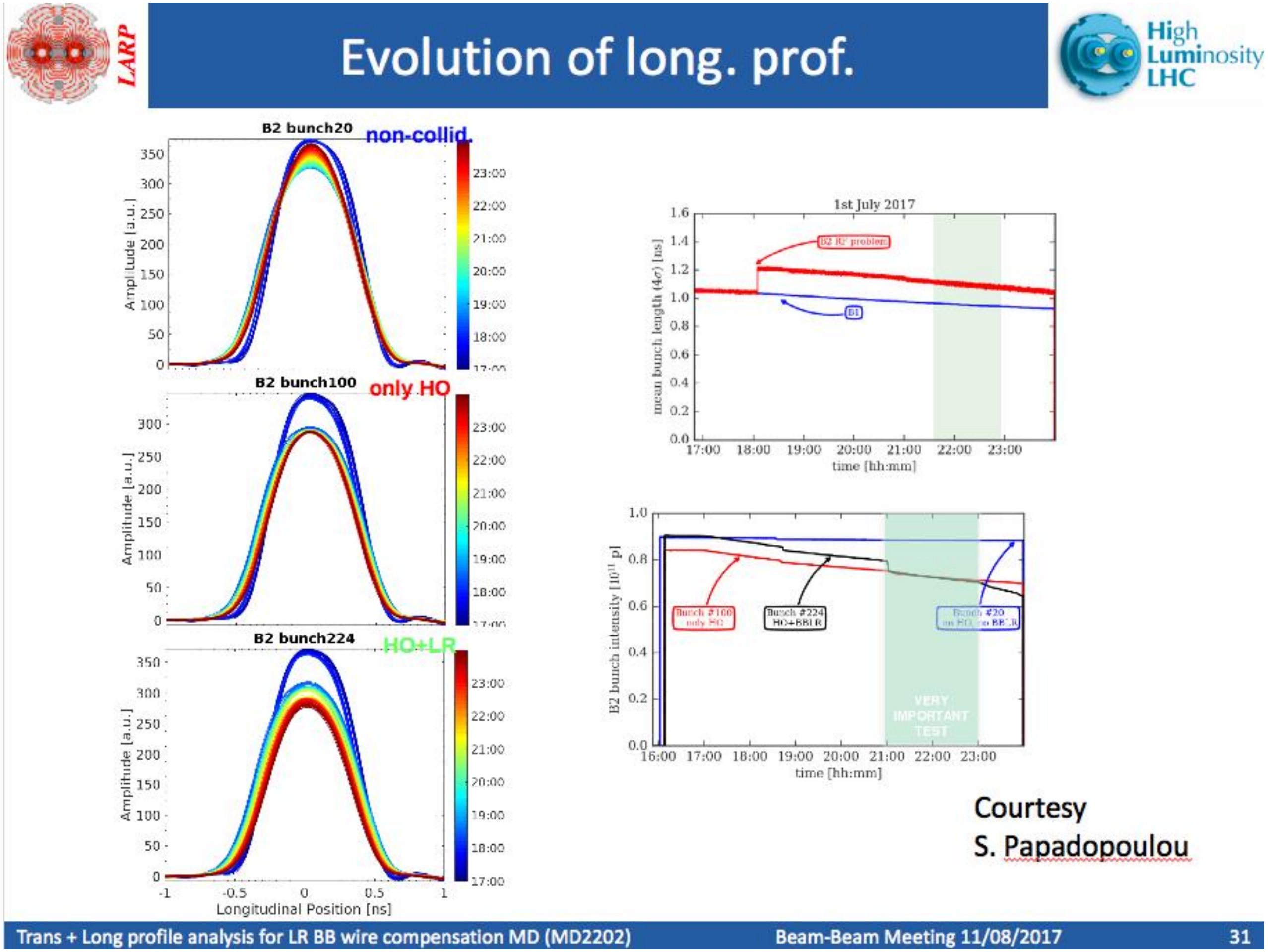


The s_{opt} depends on the PACMAN pattern.

BBCW impact of the beam profiles (I)

- A very detailed presentation by Miriam and Stefania at https://indico.cern.ch/event/658908/

Longitudinal profiles



Evolution of long. prof.

Courtesy
S. Papadopoulou

Trans + Long profile analysis for LR BB wire compensation MD (MD2202)

Beam-Beam Meeting 11/08/2017

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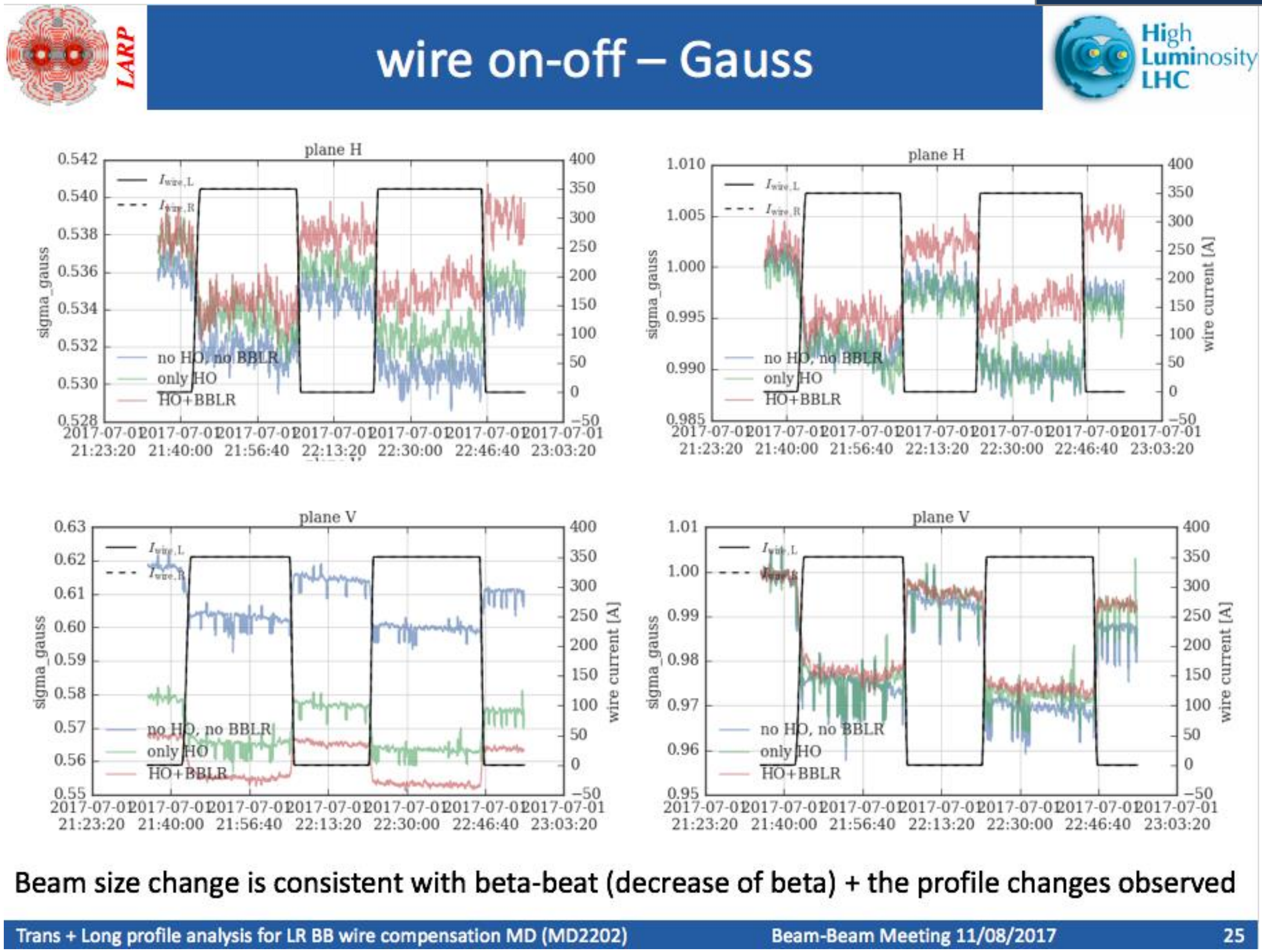
BBCW impact of the beam profiles (II)

- A very detailed presentation by Miriam and Stefania at https://indico.cern.ch/event/658908/

Transverse profiles

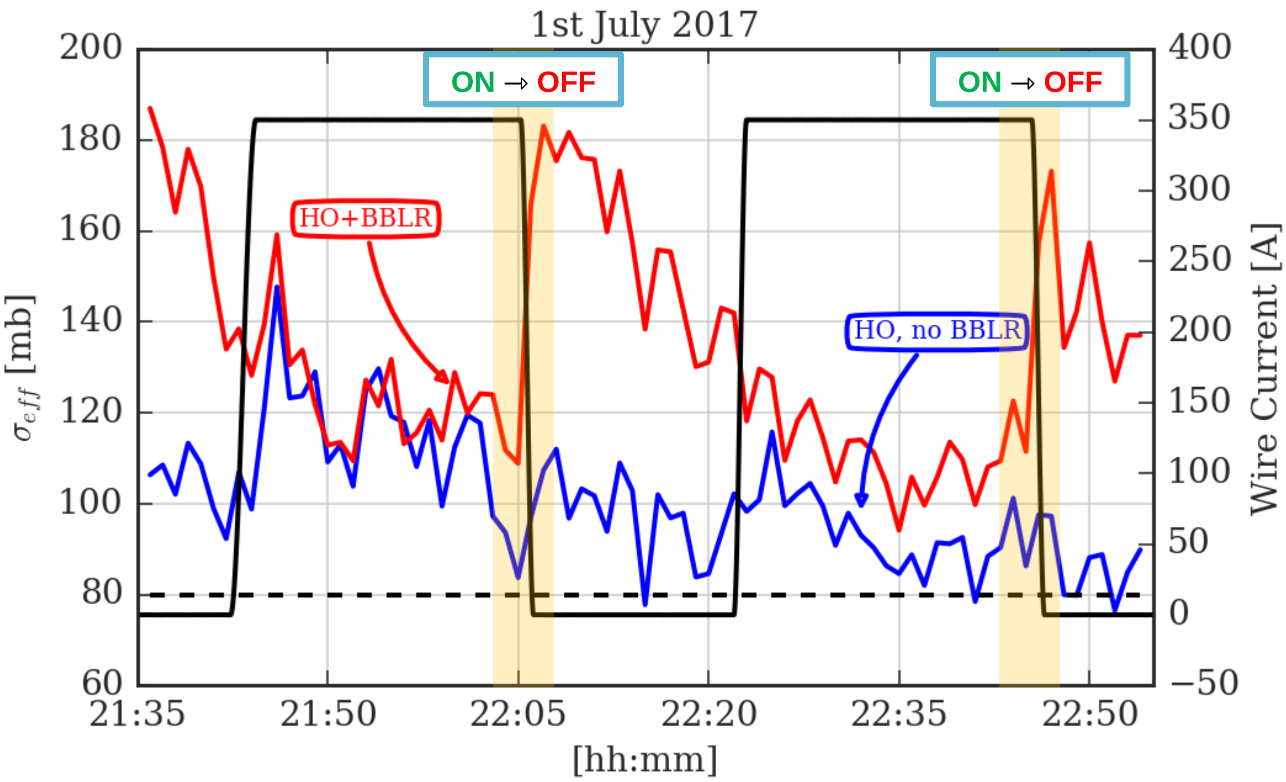


wire on-off – Gauss

Beam size change is consistent with beta-beat (decrease of beta) + the profile changes observed

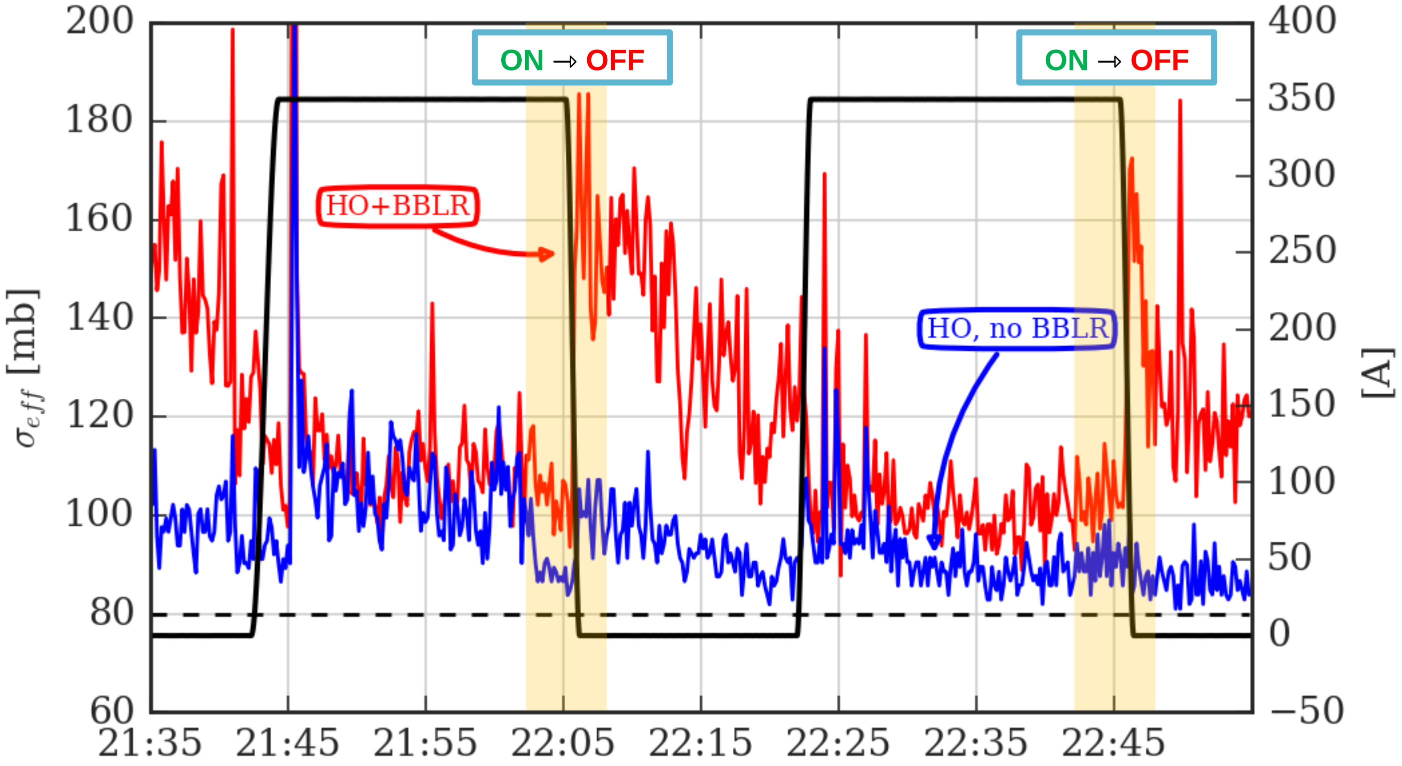
Trans + Long profile analysis for LR BB wire compensation MD (MD2202) Beam-Beam Meeting 11/08/2017 25

Results on the compensation (I)



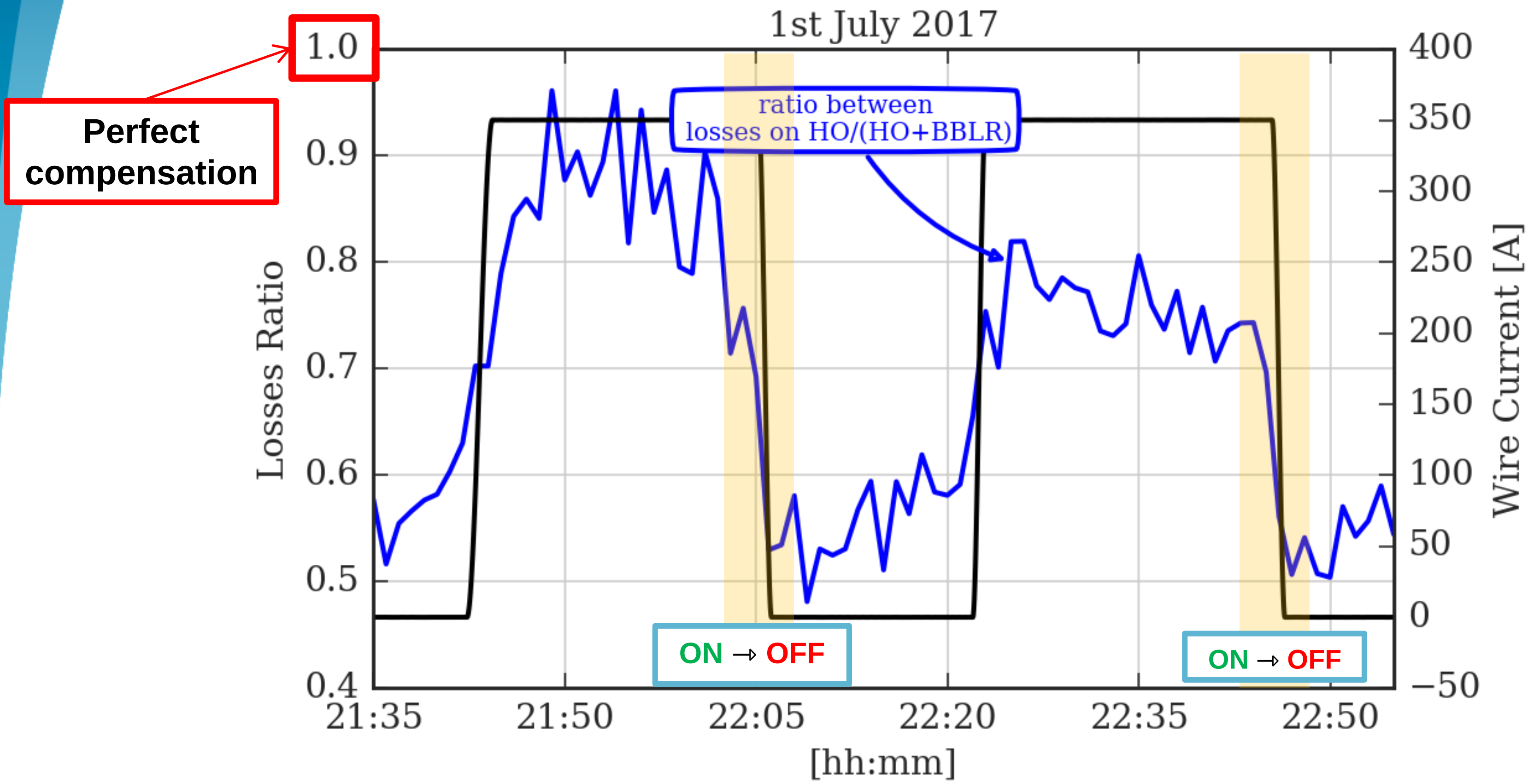
- Compensation seen from the σ_{eff} [credit to N. Karastathis].
- **Clear effect on the BBCW when switching-off: signal compatible with a contraction of the dynamic aperture of the machine.**

Result on the compensation (II)



- Using dBLM signals to compute the cross-section [credit to A. Poyet, A. Gorzawski]: **improved time resolution.**
- A constant calibration factor was adopted to rescale the BLM reading to the FBCT losses.

Result on the compensation (III)



- From the bunch-by-bunch intensity signals we can measure the effectiveness of the compensation on the losses [credit to M. Hostettler].
- **Clear effect of the BBCW.**