CERN

# MD3263

## LR beam-beam compensation using DC wires

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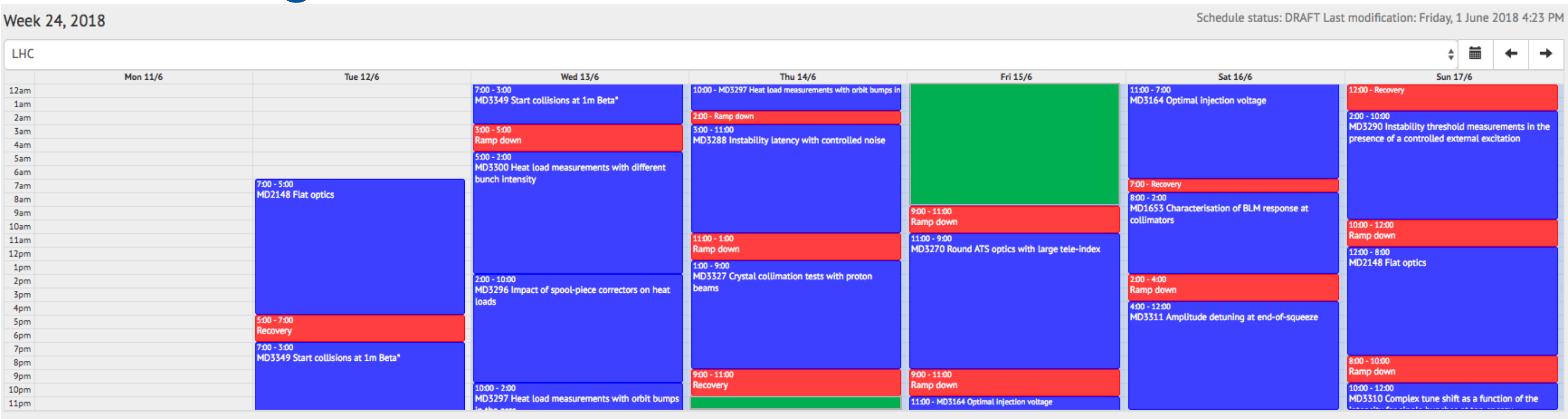
on behalf of the Wire MD team

rMPP, 05 June 2018, https://indico.cern.ch/event/734213/

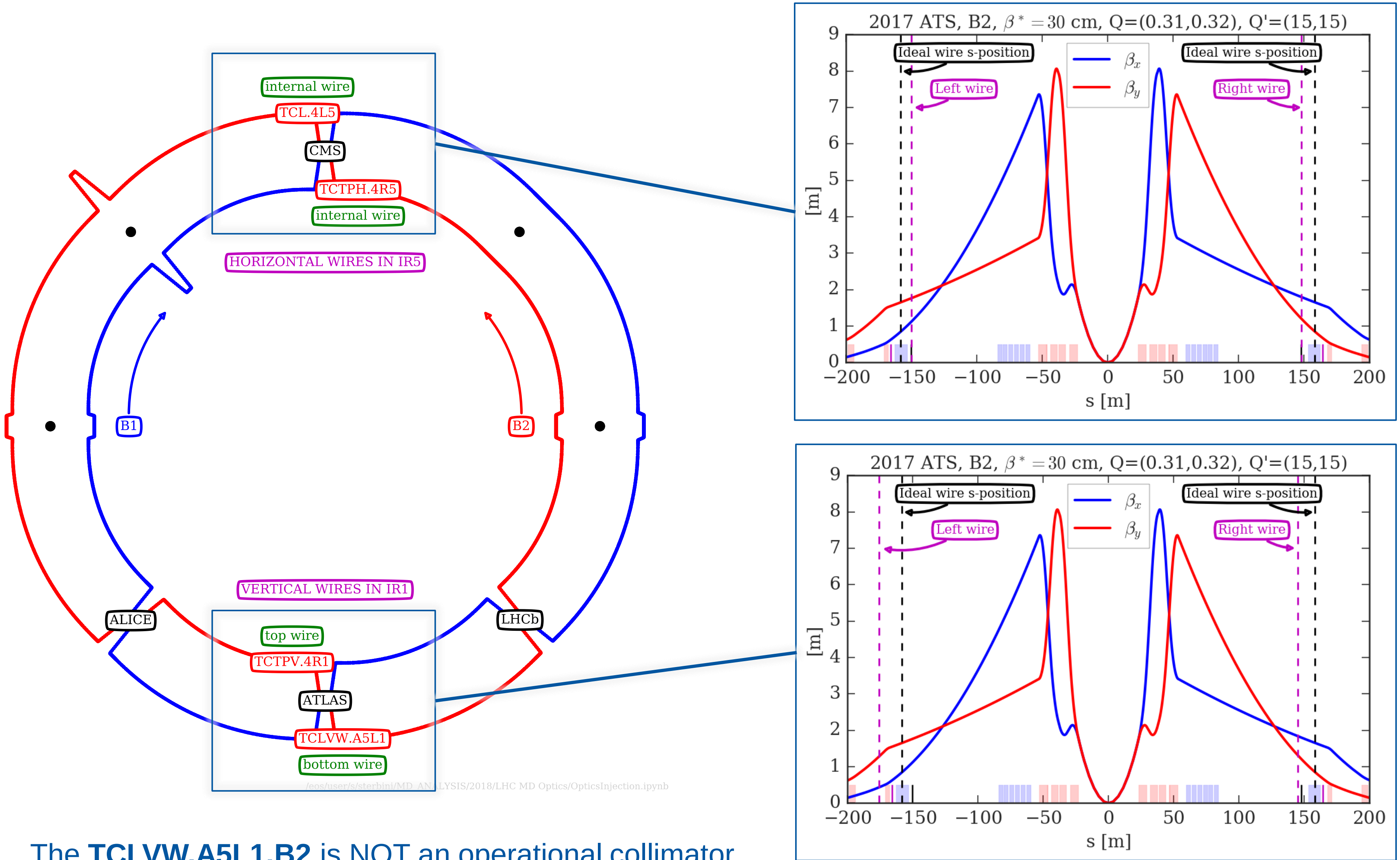
https://asm.cern.ch/md/requests/LHC/3263

# MD3263

- **Assigned time:**
  - MD#1 [10 h]: 4 wires compensation at $\beta^{*}=30$ cm and $\theta_c/2=150$ $\mu$rad (jaws at 5.5 $\sigma_{coll}$)
- **MD Merit:** the goal of the MD is to compensate or mitigate the BBLR effect by using DC wires.



# Hardware overview of wire prototypes




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

# Filling scheme, 25ns_158b_3b_2_0_0_48bpi_MD3263_MD#1

**B1, strong beam**

B2, weak beam

PILOT

SUPER-PACMAN

PACMAN

REGULAR

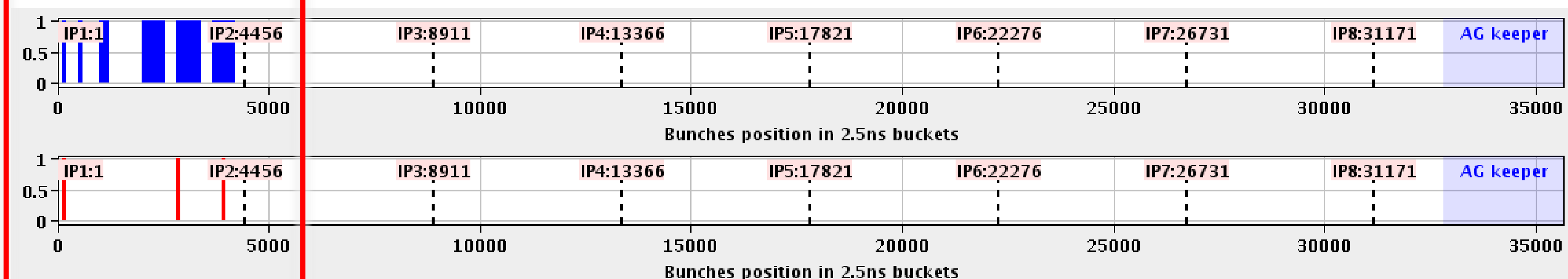
☑ OverInjection ☑ CleaningEnabled

Pilot B1 1001 Pilot B2 701

| RFBucket | Bu Tot | bu/btch | Spc/ns | PSbchs | I level |
|---|---|---|---|---|---|
| 101 | 1 | 1 | 0 | 1 | NOM |
| 501 | 1 | 1 | 0 | 1 | NOM |
| 1001 | 12 | 12 | 25 | 1 | INTR |
| 2001 | 48 | 48 | 25 | 1 | NOM |
| 2831 | 48 | 48 | 25 | 1 | NOM |
| 3661 | 48 | 48 | 25 | 1 | NOM |

| RFBucket | Bu Tot | bu/btch | Spc/ns | PSbchs | I level |
|---|---|---|---|---|---|
| 101 | 1 | 1 | 0 | 1 | NOM |
| 2831 | 1 | 1 | 0 | 1 | NOM |
| 3901 | 1 | 1 | 0 | 1 | NOM |

SETUP FLAG, <3e11 p



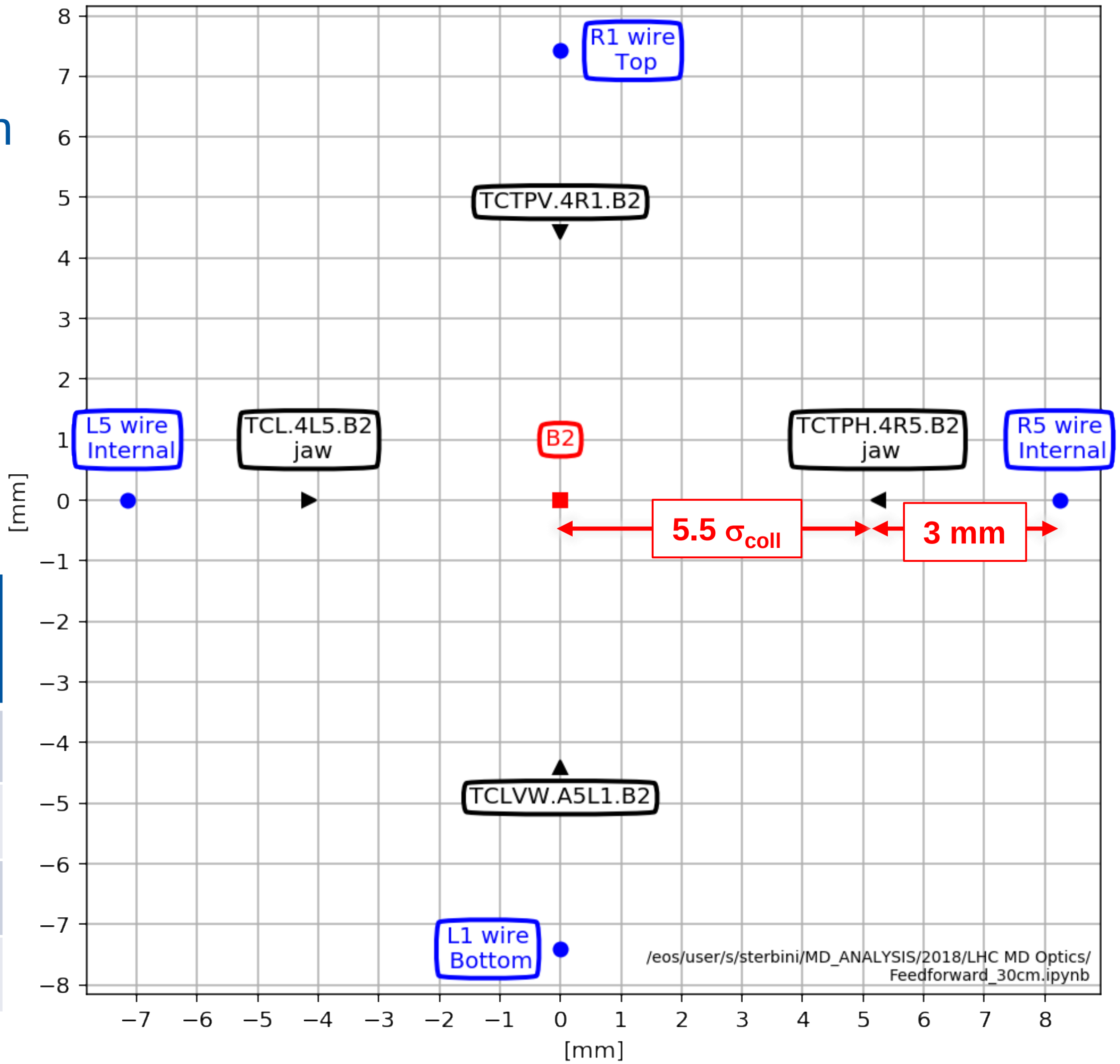

Collision only in IR1/IR5

# Minimum settings of the wire

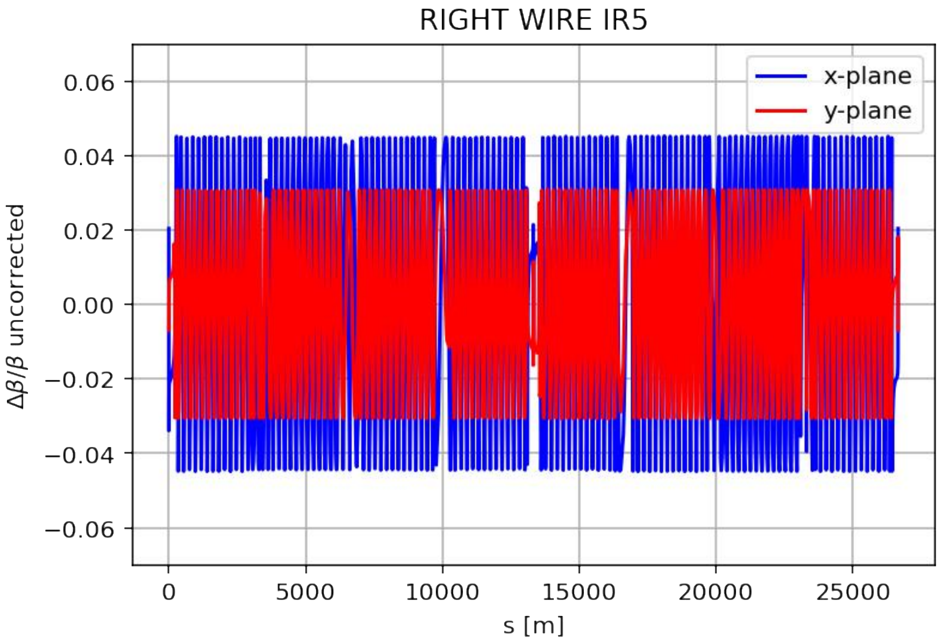
The proposal is to have the wire collimators jaws at **5.5 $\sigma_{coll}$** (as in 2017 MD#4)
with TCSP at 5 $\sigma_{coll}$.
5th-axis alignment is very important (see 348th LMC).

The beam wire distance will be (ideal 5-th axis alignment).

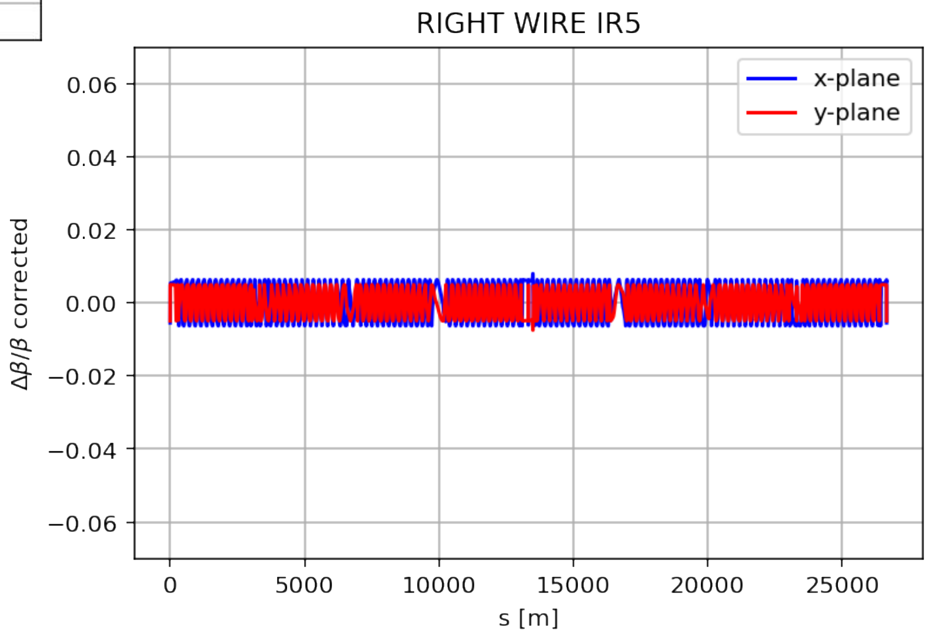
| Wire | Plane | Wire-beam distance [mm] |
|---|---|---|
| R1 | V | +7.42 |
| L1 | V | -7.41 |
| R5 | H | +8.24 |
| L5 | H | -7.15 |



# Local correction in Q4/5. Motivation and implication.




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




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

# Quadrupolar feedforward

We assumed I=350 A and jaw at 5.5 $\sigma_{coll}$ to compute the max variation.

| Wire | Knob | Trim for 350 A, 5.5 $s_{coll}$ [1e-5 $m^{-2}$ ] | Δ [%] |
|---|---|---|---|
| R1 | kq4.r1b2 | -9.11 | -3.98 |
| R1 | kq5.r1b2 | 10.76 | -8.17 |
| L1 | kq4.l1b2 | -1.09 | 0.48 |
| L1 | kq5.l1b2 | -0.52 | -0.54 |
| R5 | kq4.r5b2 | 6.83 | 2.98 |
| R5 | kq5.r5b2 | -7.94 | 6.03 |
| L5 | kq4.l5b2 | 8.19 | -3.58 |
| L5 | kq5.l5b2 | -9.25 | -9.45 |

We propose to apply a 1.2 factor and to have symmetric tolerance windows (the wire PCs are bipolar).

# Dipolar feedforward

We assumed I=350 A and jaw at 5.5 $\sigma_{coll}$ to compute the max variation.

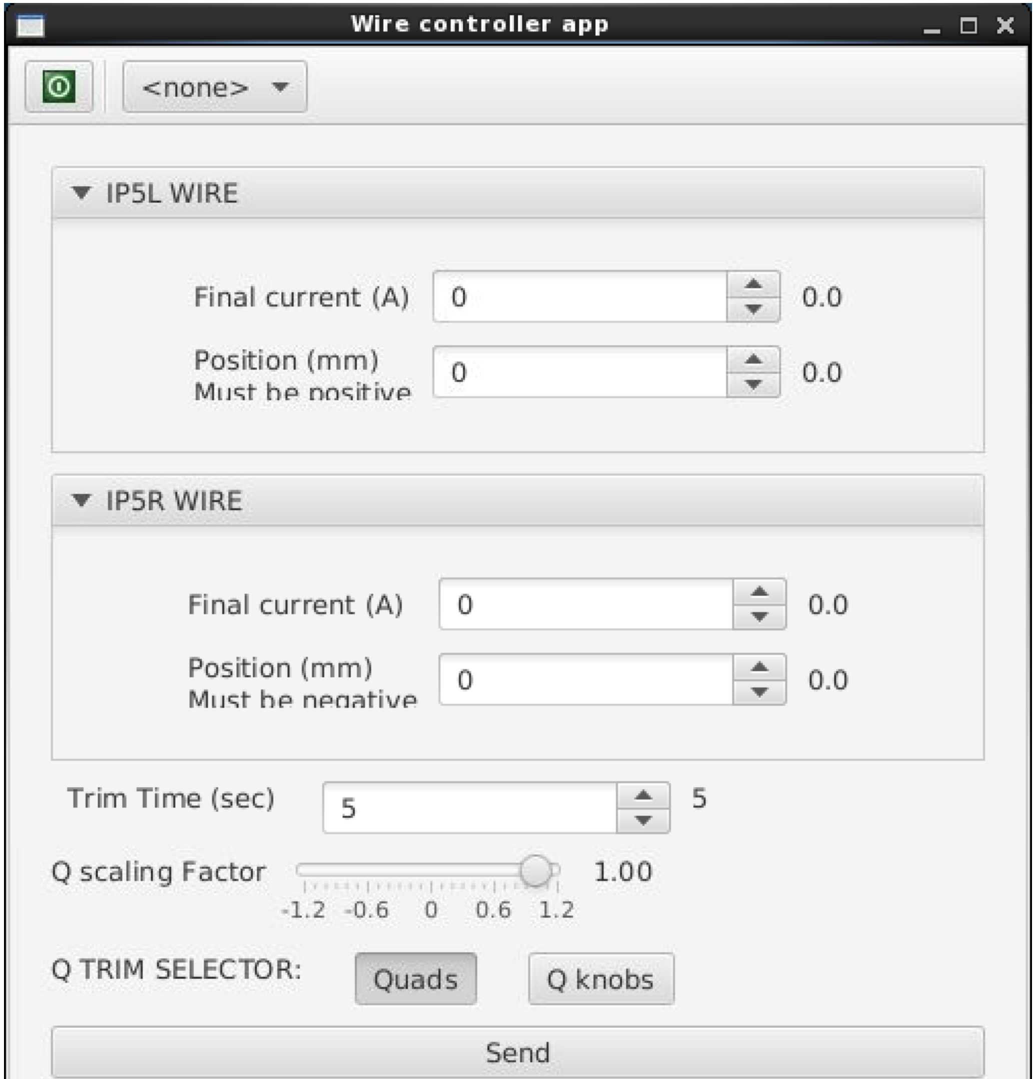
| Wire | Corrector | Trim for 350 A, 5.5 $s_{coll}$ [μrad] |
|---|---|---|
| R1 | MCBYV.4R1.B2 | -0.60 |
| L1 | MCBYV.A4L1.B2 | 0.38 |
| R5 | MCBYH.A4R5.B2 | -0.41 |
| L5 | MCBYH.4L5.B2 | 0.58 |

For this relative small trims, we expect to be in the shadow of the crossing and lumi-scan trim range.

# Feedforward orchestration

**The trim of the wires will be done via GUI (approach already tested in 2017 MD#4).**

The trim of the wires will be synchronized with the dipolar and quadrupolar feedforward.




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

# Xing angle reduction with the wires ON

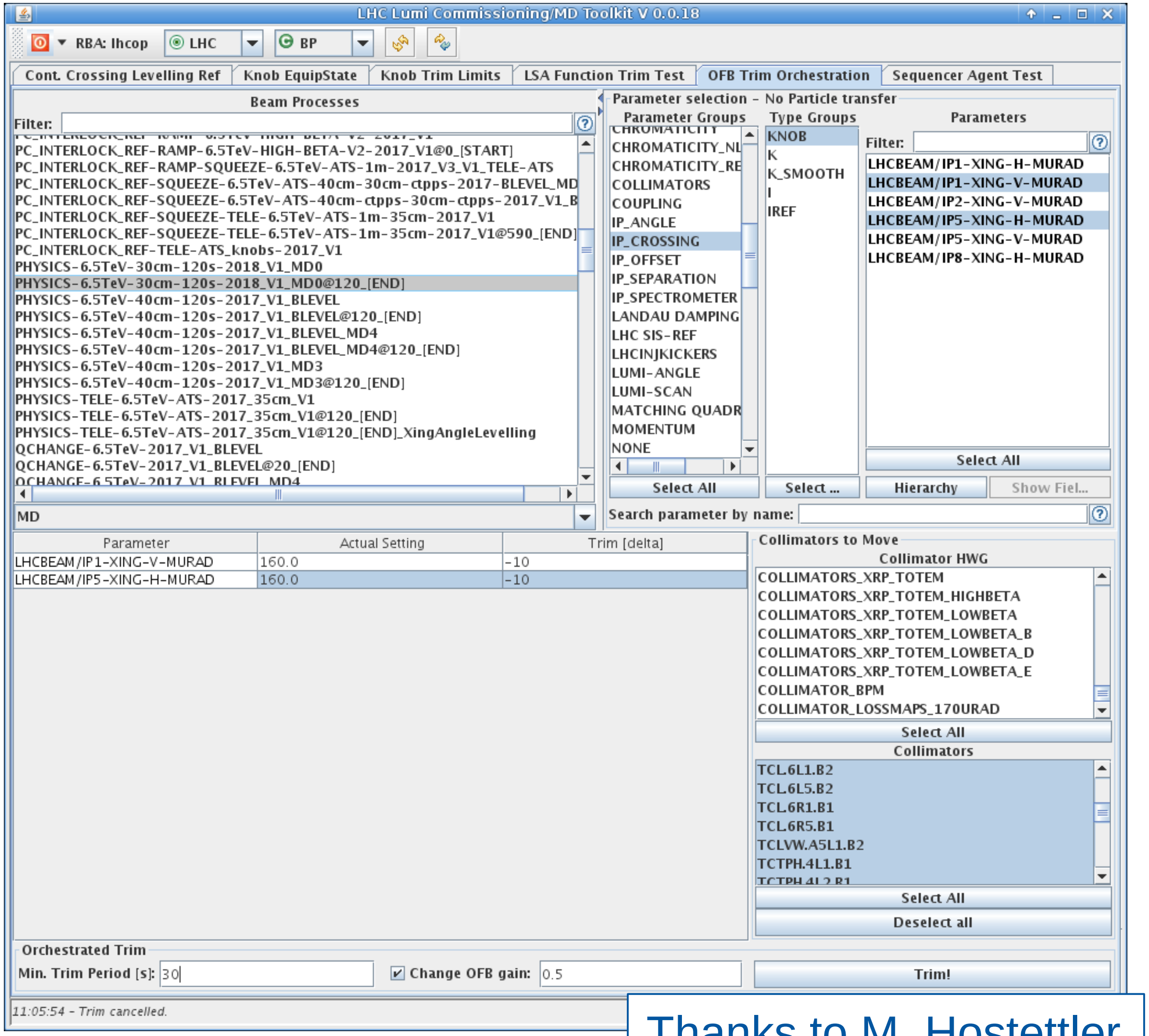
In this case the beam-wire distance should not change ⇒ **feedforward not active**.

During the xing angle reduction (150 ⇒130 $\mu$rad) the wire collimator half gap is constant at 5.5 $\sigma_{coll}$.

The collimators within the xing bumps TCL.4L5.B2

- TCL.4R5.B1
- TCTPH.4L5.B1
- TCTPH.4R5.B2
- TCTPV.4L1.B1
- TCTPV.4R1.B2
- **TCLVW.A5L1.B**

will be moved to follow the beams:




Thanks to M. Hostettler

# Phasing between IP1 and IP5 (I)

The wires are installed on B2. B2 is more resilient than B1 concerning BBLR
⇒ populate B2 tails with H/V blow-up to see and compensate losses.

In the second part of the MD we would like to test the effect of the IP1 ⇒ IP5 phase advance on losses.

The phase advance between IP1 ⇒ IP5 is 38/41 deg larger for B2 than B1 respectively in the H/V planes.

In the past (thanks to S. Fartoukh and M. Solfaroli) two knobs LHCBEAM2/PHASE15_TRIM_H and LHCBEAM2/PHASE15_TRIM_V were prepared for the ATS optics (tele-index independent) and tested in 2016 w/o BBLR.

S. Fartoukh

```
KQTF.A23B2  :=  0.01449247771 * dmux15.b2 + 0.00265943757 * dmuy15.b2;
KQTF.A34B2  :=  0.01449247771 * dmux15.b2 + 0.00265943757 * dmuy15.b2;
KQTF.A78B2  := -0.01449247771 * dmux15.b2 - 0.00265943757 * dmuy15.b2;
KQTF.A67B2  := -0.01449247771 * dmux15.b2 - 0.00265943757 * dmuy15.b2;

KQTD.A23B2  := -0.00269988488 * dmux15.b2 - 0.01446286429 * dmuy15.b2;
KQTD.A34B2  := -0.00269988488 * dmux15.b2 - 0.01446286429 * dmuy15.b2;
KQTD.A67B2  :=  0.00269988488 * dmux15.b2 + 0.01446286429 * dmuy15.b2;
KQTD.A78B2  :=  0.00269988488 * dmux15.b2 + 0.01446286429 * dmuy15.b2;
```

# Phasing between IP1 and IP5 (II)

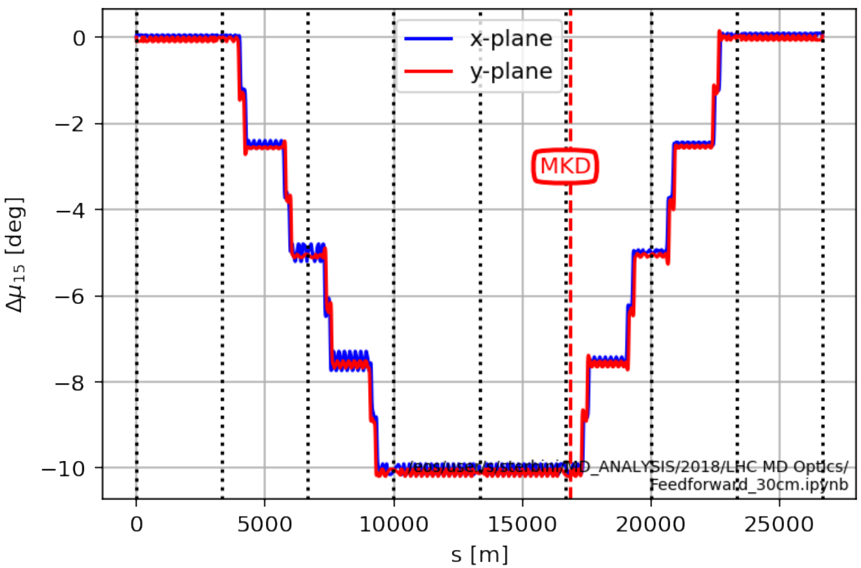
PROPOSAL: use the knob to vary in a range of $-10<\Delta\mu_x<10$ deg (or larger?) and $-15<\Delta\mu_y<15$ deg for B2 (±4.2e-2 and ±2.8e-2 in terms of $Q_{X,Y}$).

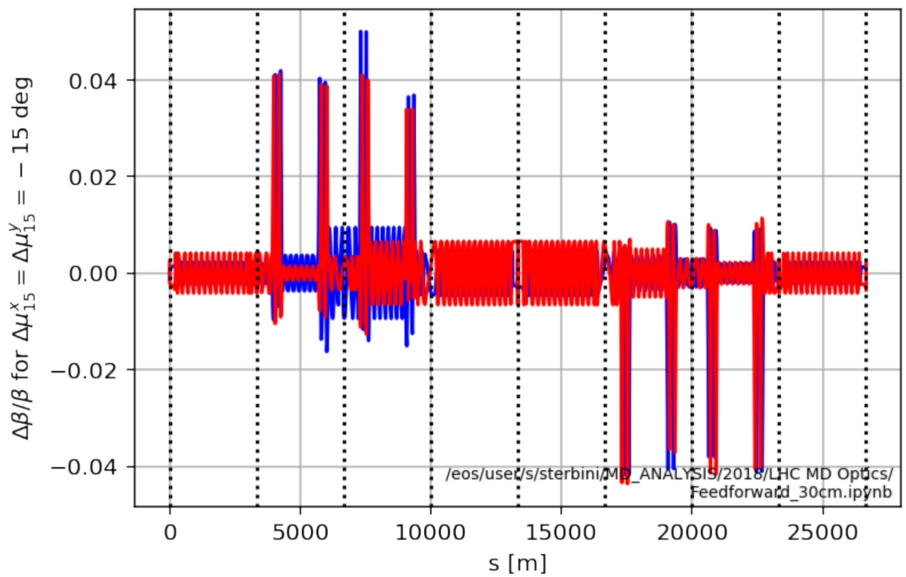
For the NOMINAL case

- $\Delta\mu_x$(MKD.O⇒TCTPH.4R1.B2)=177.4 deg
- $\Delta\mu_x$(MKD.O⇒TCTPH.4R5.B2)=155.1 deg

For the proposed case

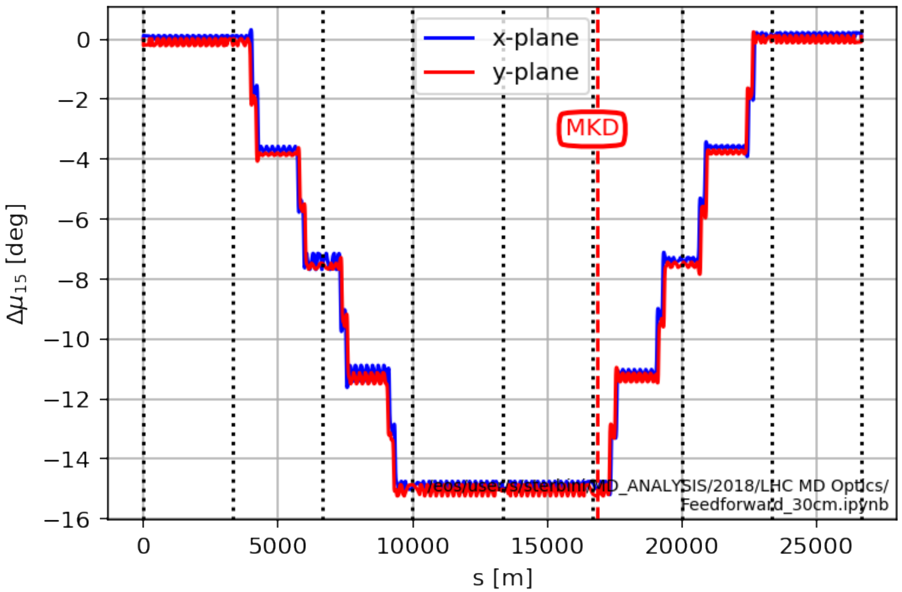
- $\Delta\mu_x$(MKD.O⇒TCTPH.4R1.B2): **varied by $\Delta\mu_x$**
- $\Delta\mu_x$(MKD.O⇒TCTPH.4R5.B2): **not affected.**

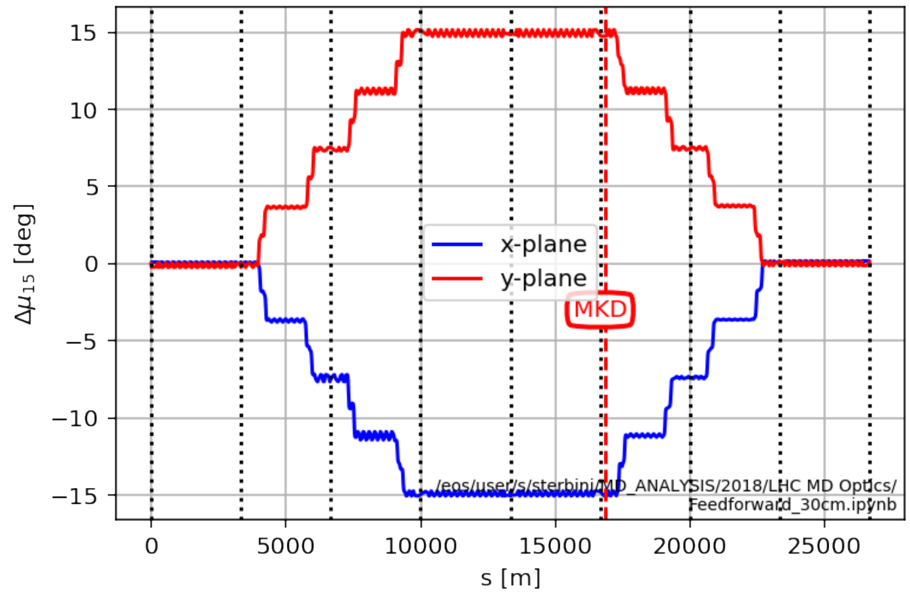


Thank you.

# BACKUP SLIDES


x-plane
y-plane
MKD
Δμ₁₅ [deg]
s [m]
/eos/user/s/sterbini/MD_ANALYSIS/2018/LHC MD Optics/
Feedforward_30cm.ipynb


x-plane
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Δμ₁₅ [deg]
s [m]
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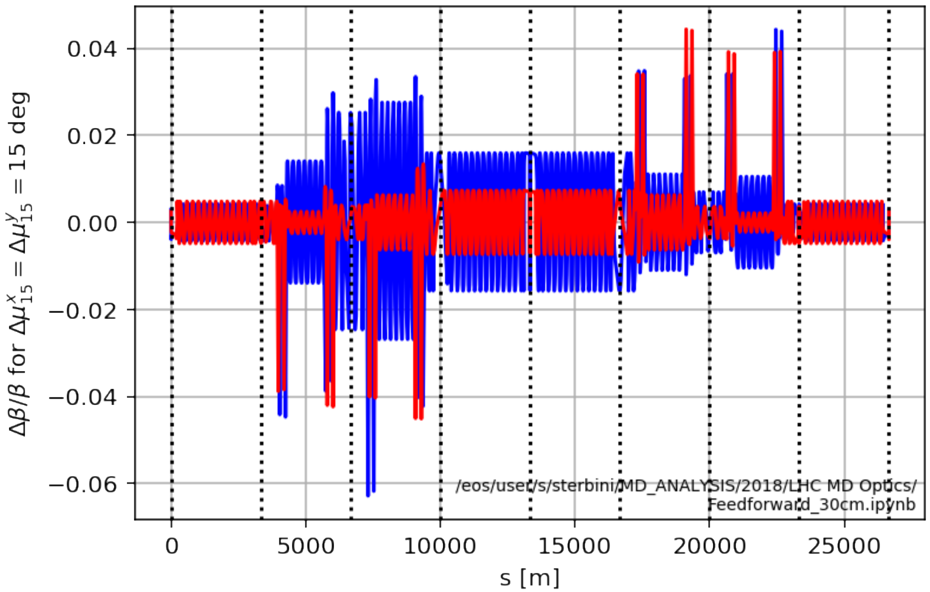
Feedforward_30cm.ipynb


Δβ/β for Δμ^x_15 = Δμ^y_15 = 15 deg
s [m]
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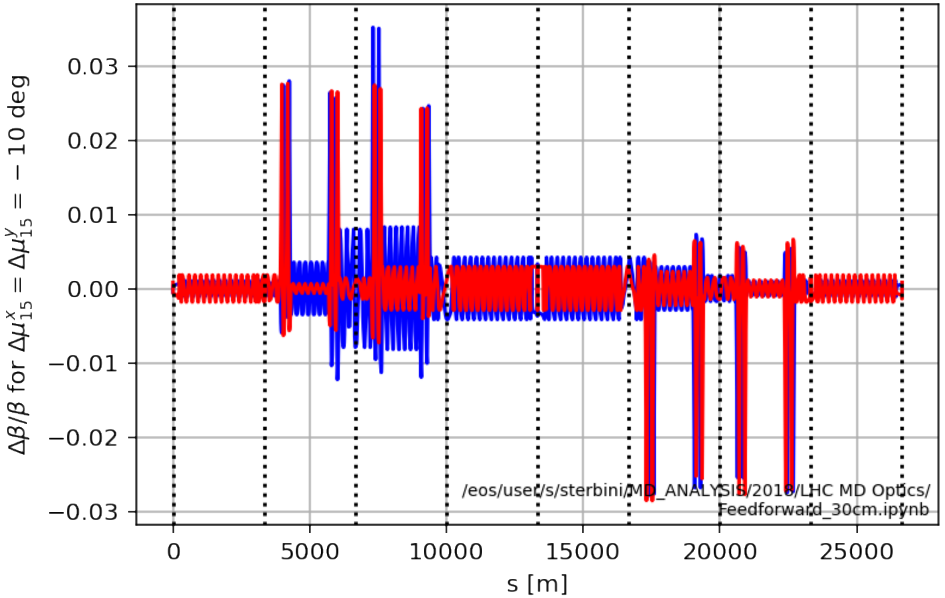
Δβ/β for Δμ^x_15 = Δμ^y_15 = − 10 deg
s [m]
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Feedforward_30cm.ipynb

# **MD3263:** requirements MD#1

**Bunch intensity (1e11 ppb):** Nominal, BCMS trains and pilots

**Number of bunches:** B1: 1 PILOT + 1 NOMINAL+1x12b + 3x48b; B2: <3e11 p in total (3 LHCINDIV + 1 PILOT)

**Transverse emittance (μm):** ~2.2 urad (B2 blown-up, see later)

**Bunch length (4σ, ns):** 1 ns

**Optics:** Flattop ATS optics 30 cm from 160 to 130 urad

**Orbit change:** Yes (crossing angle reduction).

**Collimation change:** Yes (in B2).

**Feedback change:** Yes. B2 bunches need to be blown-up.

**What else should be changed?**

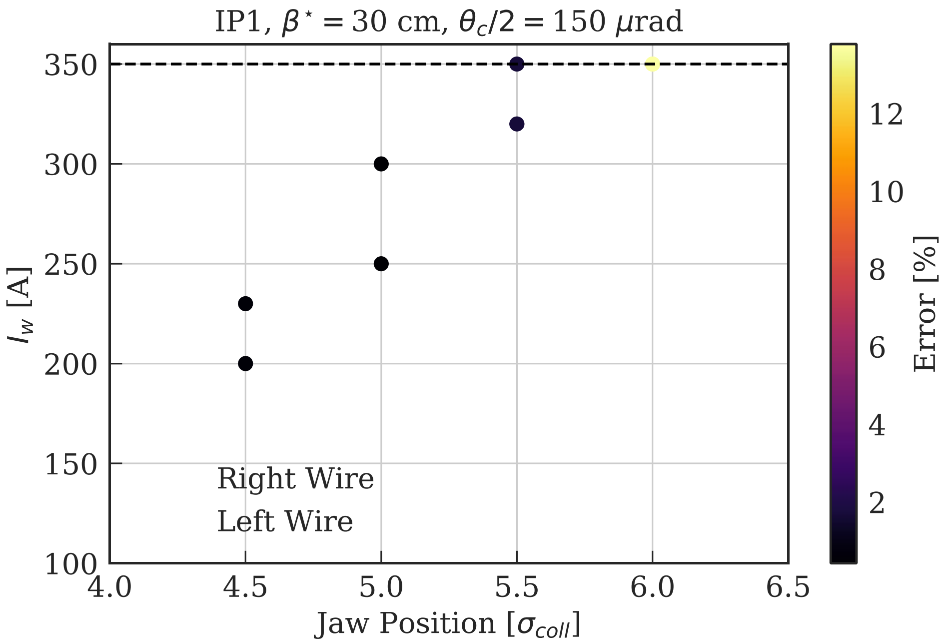
- Mask wire +/-10 A interlocks.
- Mask the “PC interlock” (needed to trim Q4/Q5 of B2).
- Approach the jaws of TCTPV.4R1.B2, TCL.4L5.B2, TCTPH.4R5.B2, TCLVW.A5L1.B2 up to 5.5 $\sigma_{coll}$ (and TCSP/TCP set at 5 $\sigma_{coll}$).
- During collision, octupoles of B1 and B2 at 550 and 0 A.

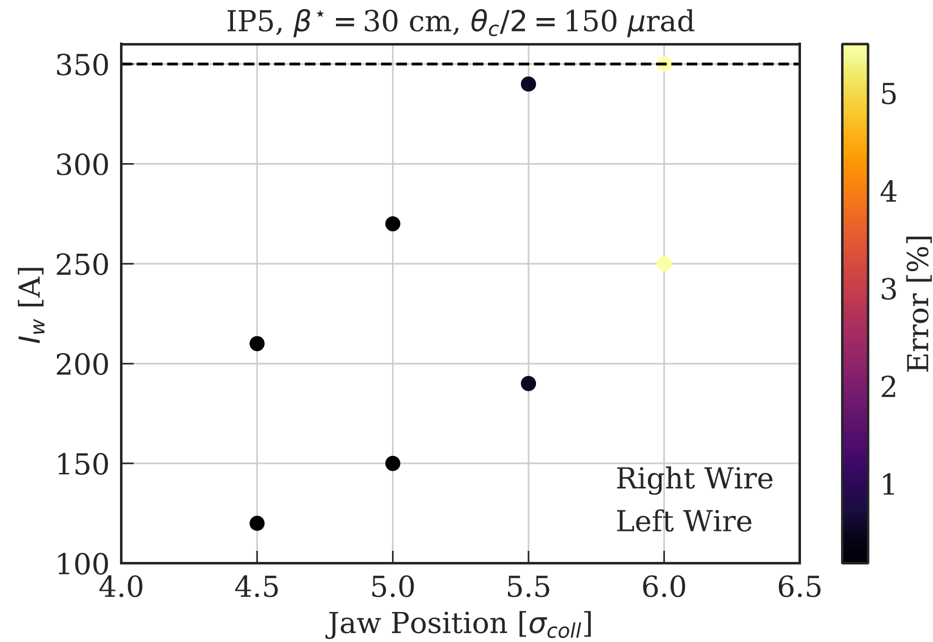
# **MD3263:** main steps in MD#1

1. Put the beam in collision at $\beta*$=30 cm and adjust the octupoles. Go from 160 to 150 urad in IR1 and IR5.
2. Approach all wire-collimators to 5.5 $\sigma_{coll}$ (move the TCSP to 5 $\sigma_{coll}$).
3. Alignment of the 5$^{th}$ axis of all wires
   - ISSUE: limited 5$^{th}$-axis range TCTPV.4R1.B2 => precise alignment not possible.
4. Transverse emittance BU for B2 (separate the beams+increase the octupoles in B2)
5. Compensation ON in IR1.
   - TODO: feedforward for dipole/quadrupole correction.
6. Compensation OFF in IR1.
7. Compensation ON in IR5.
8. Compensation ON with IR1 and IR5.
9. Reduce the crossing angle in step from 150 to 130 urad with the compensation ON
   - TCLVW.A5L1.B2 included in the MD orchestration.

# MD1 and MD2

Constraint of present prototype, optics and setup: we dimension the experiment to correct **only two RDTs** with the 2 wires **at the same jaw position in $\sigma_{coll}$**.



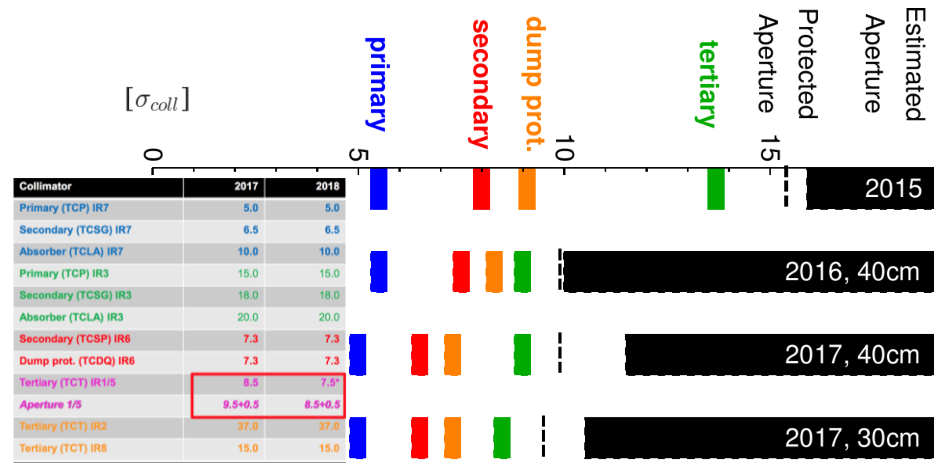




Courtesy of A. Poyet

# The beam-wire distance “problem”

**Optimal beam-wire distance= 5.7 mm**

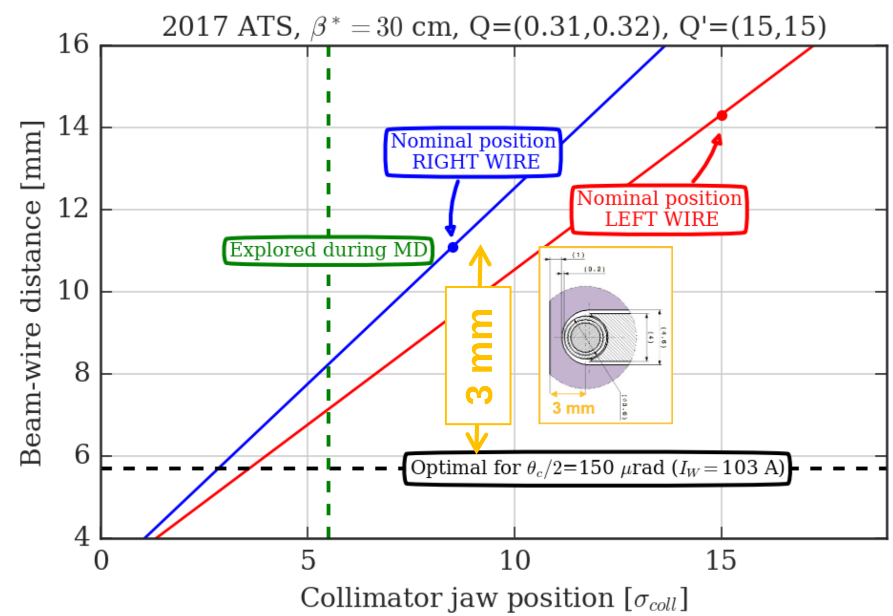
- The optimal beam-wire, $d_W$, is extremely challenging with the present prototype: collimator at **3-4 $\sigma_{coll}$**.
- **In 2017 we tested the 5.5 $\sigma_{coll}$** distance in IR5 (safe beam):results showed that we can have compensation effect (at least for ROUND optics) by addressing only two RDTs.
- **In 2018 to explore the 5 $\sigma_{coll}$.**



| Collimator | 2017 | 2018 |
|---|---|---|
| Primary (TCP) IR7 | 5.0 | 5.0 |
| Secondary (TCSG) IR7 | 6.5 | 6.5 |
| Absorber (TCLA) IR7 | 10.0 | 10.0 |
| Primary (TCP) IR3 | 15.0 | 15.0 |
| Secondary (TCSG) IR3 | 18.0 | 18.0 |
| Absorber (TCLA) IR3 | 20.0 | 20.0 |
| Secondary (TCSP) IR6 | 7.3 | 7.3 |
| Dump prot. (TCDQ) IR6 | 7.3 | 7.3 |
| Tertiary (TCT) IR1/5 | 8.5 | 7.5* |
| *Aperture 1/5* | *9.5+0.5* | *8.5+0.5* |
| Tertiary (TCT) IR2 | 37.0 | 37.0 |
| Tertiary (TCT) IR8 | 15.0 | 15.0 |



**Courtesy of R. Bruce**



# The present roadmap

**MD1**

- Compensation of IR5 and IR1 at 5.5 $\sigma_{coll}$ at 30 cm and 150 urad.

**MD2**

- Compensation of IR5 and IR1 at 5 $\sigma_{coll}$ at 25 cm and 145 urad.

**MD3**

- Repeat MD1/2 using the wire of the opposite jaw. 1 FILL.

SAFE B2

**EoF MD**

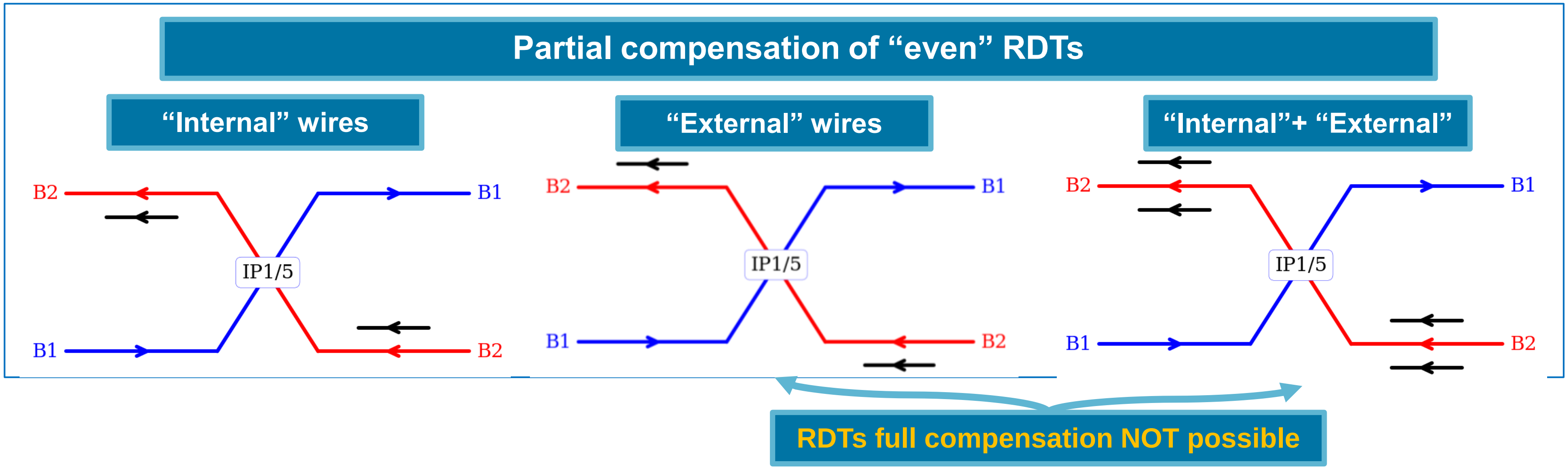
- We would need to change the B2 tune to make it more sensitive to BBLR (or play other tricks) and power all 8 wires.

**MD4**

- OPTION 1 (preferred): repeat with a small train in B2 (>12 bunches) and possibly with tighter collimator settings than the EoF.
- OPTION 2: test the compensation by using different Xing angles in IP1/5 (170/120 urad) (loss of LR compensation of B2, B6,…).

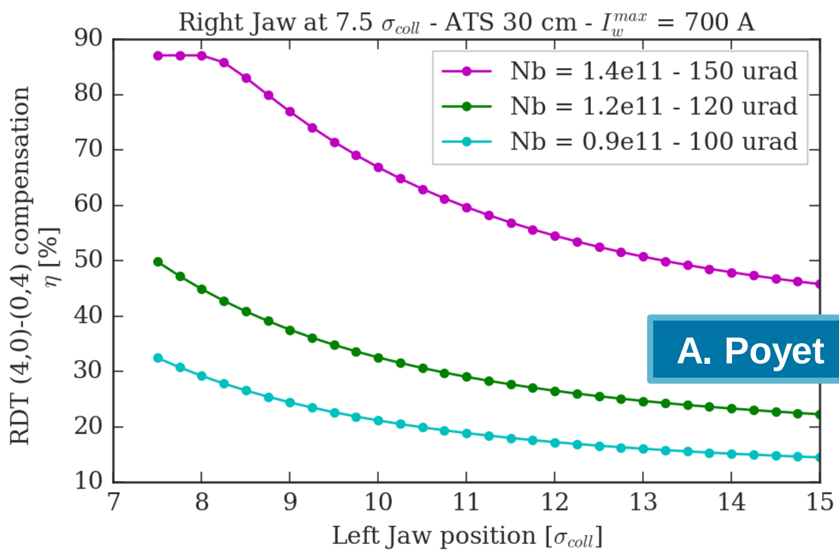
NOT SAFE B2

# MD3, EoF and MD4 : opposite wire




One **could** consider to put the two wires 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.



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