Modelling of MD Results and Effects of Crossing Angle

A. Poyet

HL-LHC Satellite Meeting: Wire Compensation – Fermilab – 17th October 2019

Outline

- Introduction and simulations parameters

- BBCW in an ideal setup

- Simulating the MD setup in the LHC
  - 1-jaw powering configuration (MD#3)
  - 2-jaws powering configuration (MD#4)

- BBCW: Towards an implementation in operation during the LHC Run III
  - Tune optimization
  - Octupoles and wires compromise
  - Effect of the crossing angle

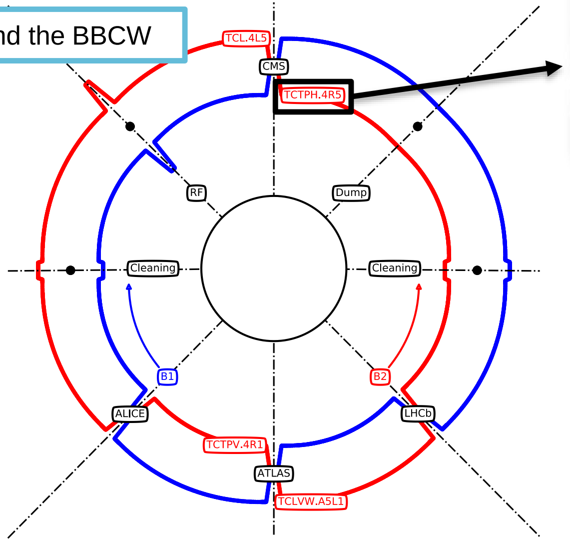
Outline

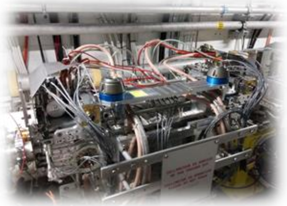
- **Introduction and simulations parameters**
- BBCW in an ideal setup
- Simulating the MD setup in the LHC
  - 1-jaw powering configuration (MD#3)
  - 2-jaws powering configuration (MD#4)
- BBCW: Towards an implementation in operation during the LHC Run III
  - Tune optimization
  - Octupoles and wires compromise
  - Effect of the crossing angle

Simulating the BBCW in the LHC

- BBCW are **currently installed and have been tested in the LHC** [1]
- For further studies, simulations are required
- The observable is **DA**, obtained by running MAD-X and SixTrack
- LHC Machine with novel optics scheme: **ATS Optics** [2]
- **Only B1 is simulated** and the wires are therefore installed on this beam

LHC Ring and the BBCW





Wires in collimator

Parameter	Symbol	Reference value
Bunch Intensity	N_b	1.15E11p
β-function at the IP	β^*	30cm
Half crossing-angle	$\theta_c/2$	150μrad
Tunes	Q_x, Q_y	62.31, 60.32
Chromaticities	$\xi_{x,y}$	15
Octupole Current	I_{MO}	0A
Number of turns		10^6

Simulation reference parameters

Outline

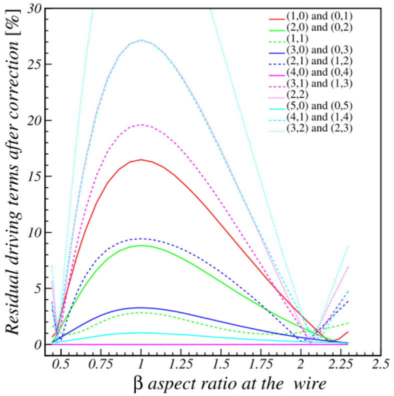
- Introduction and simulations parameters
- **BBCW in an ideal setup**
- Simulating the MD setup in the LHC
  - 1-jaw powering configuration (MD#3)
  - 2-jaws powering configuration (MD#4)
- BBCW: Towards an implementation in operation during the LHC Run III
  - Tune optimization
  - Octupoles and wires compromise
  - Effect of the crossing angle

BBCW in an ideal setup

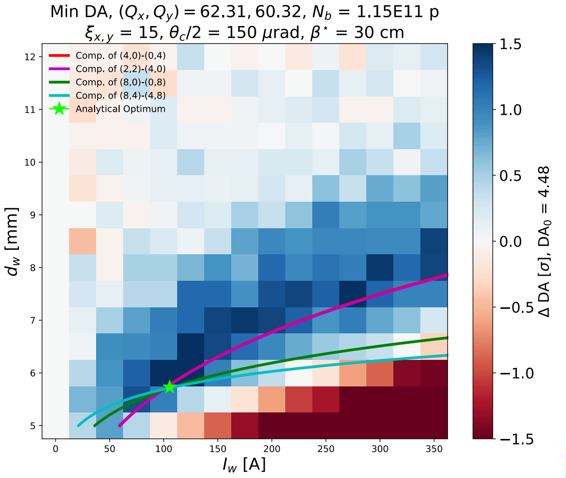
- In 2015, it has been shown that **compensating 2 RDTs lead to the minimization of all** [3]:
  - Proposed for HL-LHC
  - 2 wires per IP per beam
  - Located at a given aspect ratio

- Resonances compensation lines cross at the predicted point

- Large “blue” area → **Do we need a compensation of all RDTs?**



Residual after compensation of the (4,0)-(6,0) RDTs



DA results for the ideal setup

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

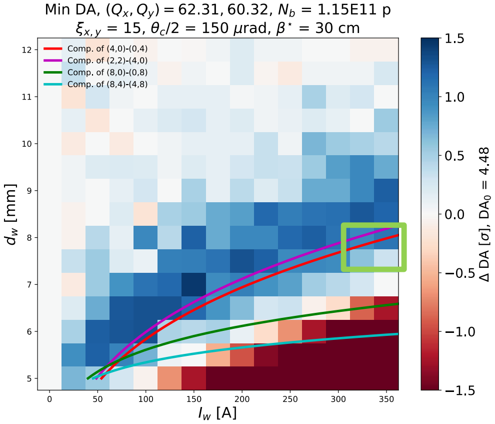
Stéphane Fartoukh,[1,*] Alexander Valishev,[2,†] Yannis Papaphilippou,[1] and Dmitry Shatilov[3]
[1]*CERN, CH 1211 Geneva 23, Switzerland*
[2]*Fermi National Accelerator Laboratory, P.O. Box 500, Batavia, Illinois 60510, USA*
[3]*Budker Institute of Nuclear Physics, SB RAS, Novosibirsk 630090, Russia*
(Received 3 September 2015; published 1 December 2015)

Outline

- Introduction and simulations parameters
- BBCW in an ideal setup
- **Simulating the MD setup in the LHC**
  - 1-jaw powering configuration (MD#3)
  - 2-jaws powering configuration (MD#4)
- BBCW: Towards an implementation in operation during the LHC Run III
  - Tune optimization
  - Octupoles and wires compromise
  - Effect of the crossing angle

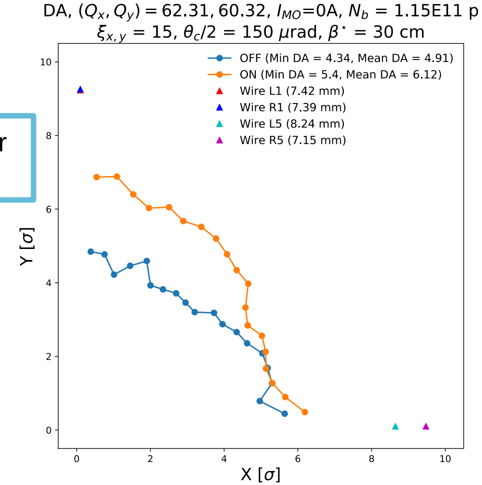
Simulating the MD setup: MD#3

- First experimental setup: **1-jaw powering** configuration
  - Only internal wire powered
  - Safe beam: **collimators closed at 5.5σ**
  - Wires powered to compensate the **(4,0)-(0,4) RDT**
- DA analysis: no more crossing of the RDT lines but still **~1.3 σ DA gain**
- Better gain in the vertical plane due to **asymmetric DA in the bare machine**

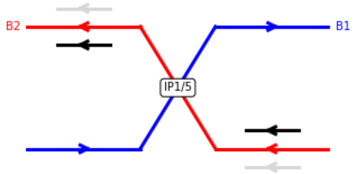


DA dependency on wires current/position (1-jaw powering config.)

DA in configuration space for MD#3



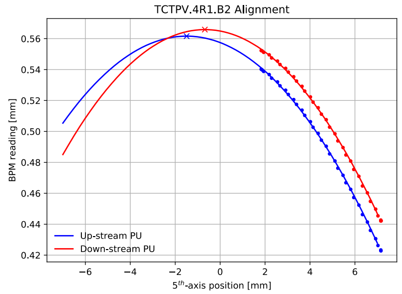
Wire Compensator	s from IP [m]	$I_{w,4004,MD}$ [A]	$d_{w,MD}$ [mm]
Wire R1	176.17	350	-7.39
Wire L1	-145.94	320	7.42
Wire R5	150.03	190	-7.15
Wire L5	-147.94	340	8.24



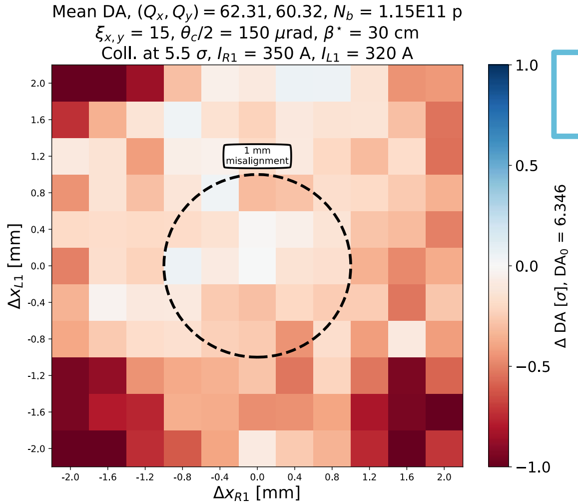
Effect of a 5th-axis misalignment

- After installing the wire prototypes in IR1, **a misalignment of the 5th-axis was observed (~2mm)** [4]
- The first MD was an opportunity to **measure** this misalignment and to **partially realign** the collimator during the following technical stop
- DA study was done to understand **the sensitivity** on this alignment
- **Below ~1mm** misalignment, the effect on DA is negligible
- Results obtained after the re-alignment showed that it had a beneficial effect (misalignment < 1mm)

Alignment procedure during the MD



DA dependency on the misalignment

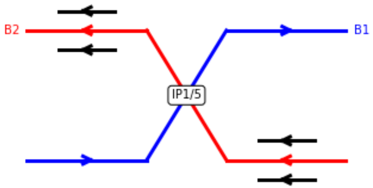


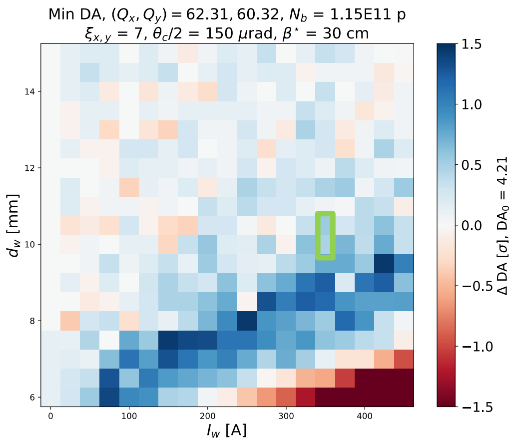
Simulating the MD setup: MD#4

- Second experimental setup: **2-jaws powering** configuration
  - Both internal/external wires powered
  - Only 1 collimator per IP
  - Non-safe beam: **collimators opened at 8.5σ (operational settings)**
  - Wires powered up to their maximal possible currents

- From the scan, similar possible improvements (not reachable experimentally)

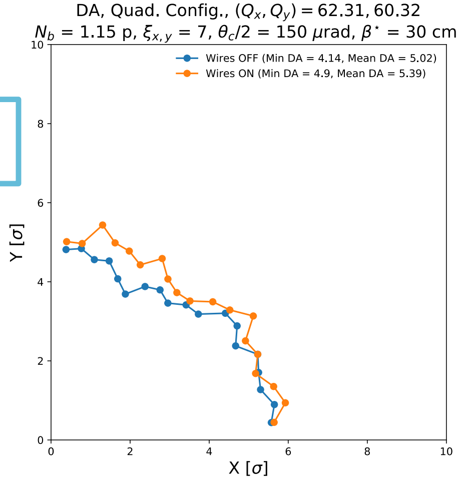
- In configuration space, effect not so visible but still ~0.8σ **gain in minimum DA**





DA dependency on wires current/position (2-jaws powering config.)

DA in configuration space for MD#4



Wire Compensator	s from IP [m]	$d_{w,OP}$ [mm]
Wire R1	176.17	N.A.
Wire L1	-145.94	9.83
Wire R5	150.03	N.A.
Wire L5	-147.94	11.1

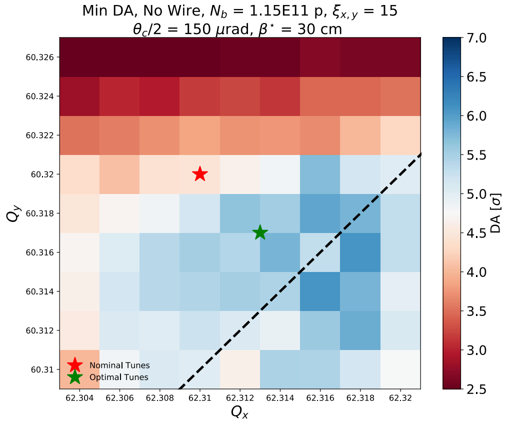
Outline

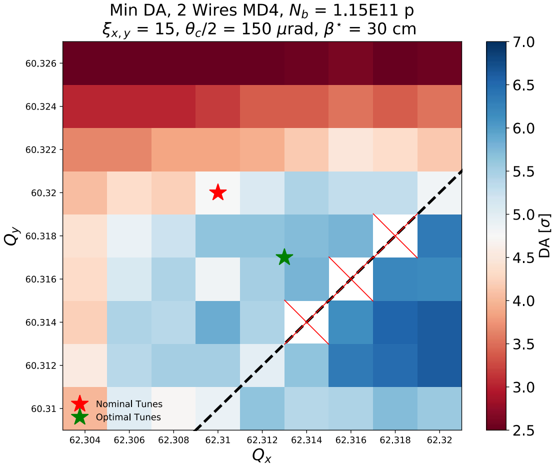
- Introduction and simulations parameters
- BBCW in an ideal setup
- Simulating the MD setup in the LHC
  - 1-jaw powering configuration (MD#3)
  - 2-jaws powering configuration (MD#4)
- **BBCW: Towards an implementation in operation during the LHC Run III**
  - Tune optimization
  - Octupoles and wires compromise
  - Effect of the crossing angle

Towards Run III: Wires and tune optimization

- Wires are now prepared to be used in operation during the LHC Run III
- In those conditions, tertiary collimators are foreseen to be opened at 8.5σ[1]
- It is known that DA can be optimized by adjusting the tunes [5]
- Wires open the tune space
  - Especially around the 3rd integer resonance
  - Interesting to accommodate additional non-linear effects (e-cloud)

DA dependency on tunes
(no wires)





DA dependency on tunes
(2 wires, coll. at 8.5σ)

[1] For comparison, the case with the collimators opened at 7.5σ was also studied

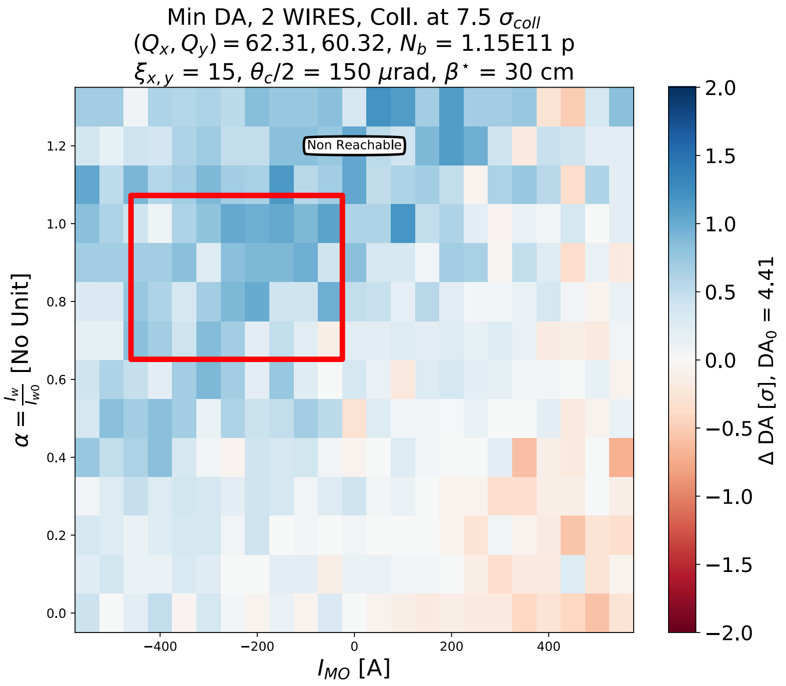
Towards Run III: Compromise wires/octupoles

- Experimentally, it has been shown that **octupoles can be used to mitigate BBLR** interactions (with high tele-index) [6]

- Octupoles are needed for **coherent stability**

- A **compromise** between wires and octupoles can be considered

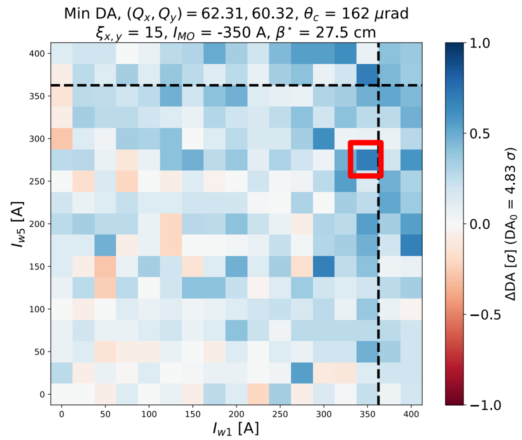
- **Negative octupoles** could help the compensation scheme of the wires

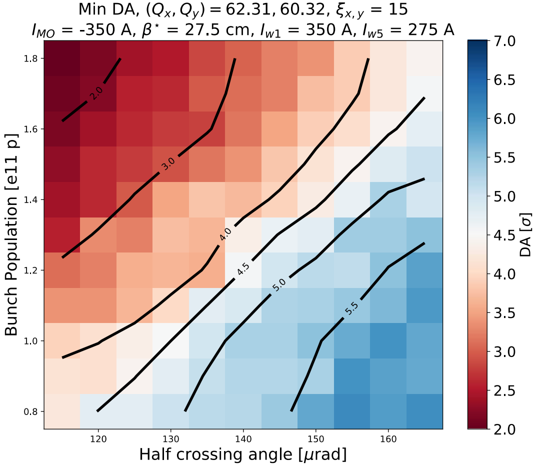


Run III: Effect on the crossing angle

- Experimentally, **we observed that it is possible to reduce the crossing angle**, without increasing the losses [1]
- DA dependency on crossing angle and bunch intensity confirms this result
- Run III scenario: **crossing angle anti-levelling up to 162 μrad [7]**
- Possible use of the wires: power at the **end of the fill to reduce the crossing angle**, keeping the DA ~ 5σ
- **Clear possible gain:**
  - **1.2e11 p → 150 μrad**
  - **0.8e11 p → 135 μrad**

DA as a function of wire currents (coll. at 8.5 σ)





DA with 2 wires (coll at 8.5 σ)

Conclusions

- Simulations are **reproducing the observations** made during the experiments, showing a beneficial effect of the BBCW
- In an ideal setup (i.e., compensation of all RDTs), the wires can bring up a **DA improvement up to 1.5 σ**.
- But the **BBCW are flexible** (i.e., no need to compensate all RDTs) and even further form this ideal setup, improvements **above 1 σ** are observed.
- Going closer to operation, effects on DA are less visible ($< 1\ \sigma$) but simulations show the possibility of **closing the crossing angle**.
- The BBCW are promising and their **implementation in operation during the LHC Run III** should give us more **experience in operating those devices in view of HL-LHC.**
- Next steps: continuing to **explore scenario for Run III** (in terms of intensity, beta star, crossing angle…) and **take into consideration collisions in IP2/8.**

Thank you for your attention

Credits to the wire team, and to the ABP-HSI section for the work on the simulations!

References

[1] G. Sterbini, *MD results during LHC Run II, and plans for Run III*, this meeting

[2] S. Fartoukh, *An Achromatic Telescopic Squeezing (ATS) Scheme for the LHC Upgrade*, IPAC 2011

[3] S. Fartoukh and al., *Compensation of the bean-beam long-range interaction as a path towards new configurations for the high-luminosity LHC*, PRAB, **18**, 121001, 2015

[4] A. Poyet and al., *MD3263: Beam-Beam Long-Range Compensation using DC wires in the LHC*, not published yet

[5] D. Pellegrini and al., *Multi-parametric response of the LHC Dynamic Aperture in presence of beam-beam effects*, IPAC17

[6] S. Fartoukh, *Round Telescopic Optics with Large Telescopic Index*, CERN-ACC-2018-0032

[7] N. Karastathis, *Beam-Beam Bases Optimization of the LHC Performances: A View Towards Run III*, Beam-Beam & Luminosity WG, May 2019, https://indico.cern.ch/event/817173/contributions/3445803/attachments/1858856/3054202/nkarast_BBLS_31052019.pdf