Update on impact of field quality

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Outline

- Main results about FQ steering using V1.0
- Implementation of tools for V1.4
- First results of studies using V1.4
- Outlook

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Main results of FQ studies using V1.0

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Dynamic aperture studies for HL-LHC V1.0

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Abstract
Intense efforts have been devoted to the detailed study of the dynamic aperture of the HL-LHC V1.0 optics and layout version, without beam-beam effects, for several configurations, differing by optical properties or properties of the field quality of the new magnets for HL-LHC. In this report, the outcome of these studies is summarised and discussed.

Keywords
HL–LHC, dynamic aperture, field quality

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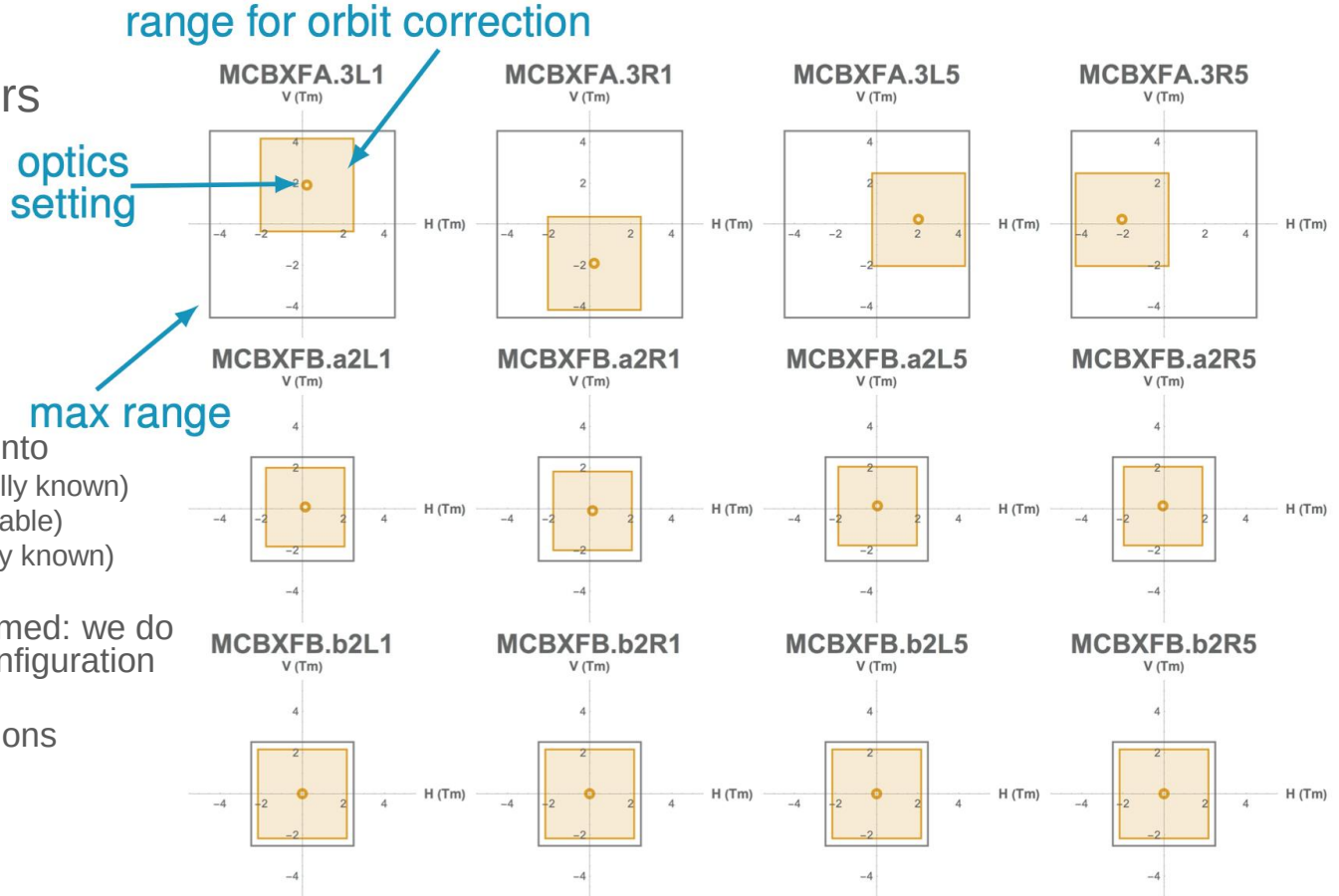
MQXF, MCBRD, and MCBXF FQ and V1.0

- Analysis of the impact of some large multipoles (a3, b3, a4, b5, b6), resulting in the decision to increase the strength of the non-linear correctors in the corrector package.
- Involved situation for the analysis of the impact of the FQ of orbit correctors.
- Stronger impact of FQ of MCBXFs with respect to that of MCBRDs.
- Very strong impact of the assumed signs for the field errors of the MCBXF. This indicates that there are strong compensation effects between the FQ of the various magnets in the IR.

MQXF, MCBRD, and MCBXF FQ and V1.0

Example for the MCBXF orbit correctors



- The strength budget is divided into
  - Separation/crossing bumps (fully known)
  - Orbit correction (estimate available)
  - Triplets misalignments (not fully known)
- A Monte Carlo over all possible configurations should be performed: we do not know a priori what is the configuration producing the worst DA.
- All this is outside of our simulations capabilities!

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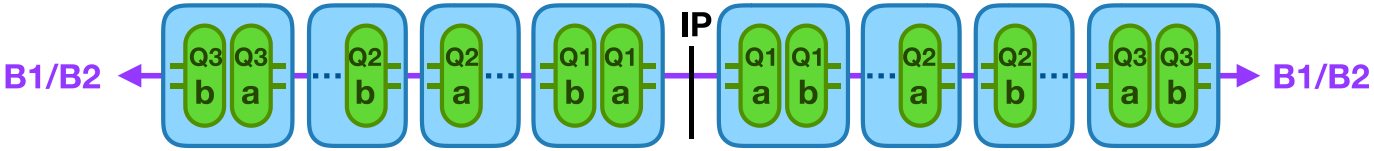
Implementation of tools for V1.4

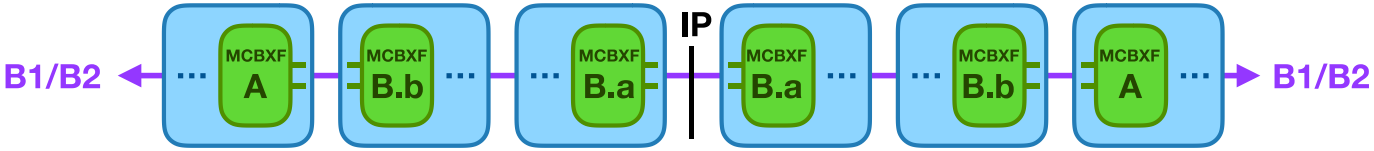
- Strong efforts to review the error routines used in our simulations.
- The conventions for the signs of the multipoles depend on the connection side of the magnet.
- The connection side might have changed with the layout version.
- New routines have been written for the layout V1.4
- Some features of the old routines have been fixed…

MQXF magnets



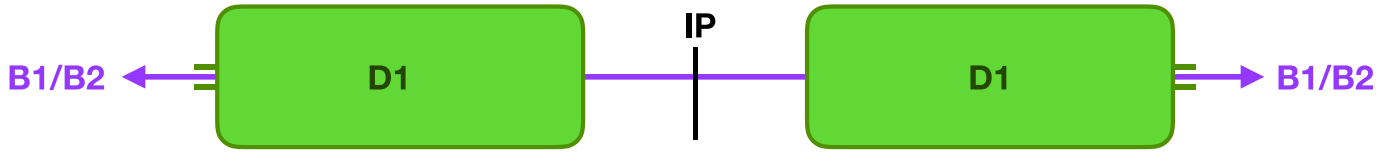
- Single-aperture magnets
- Fringe fields implemented (as multipolar kicks)
- Inverted magnets are
  - Q1b.R, Q2a.R, Q3b.R
  - Q1a.L, Q2b.L, Q3a.L
- Previous routine implemented layout as
  - IP (=Q1=) (=Q2=) (=Q3=)

MCBXF magnets



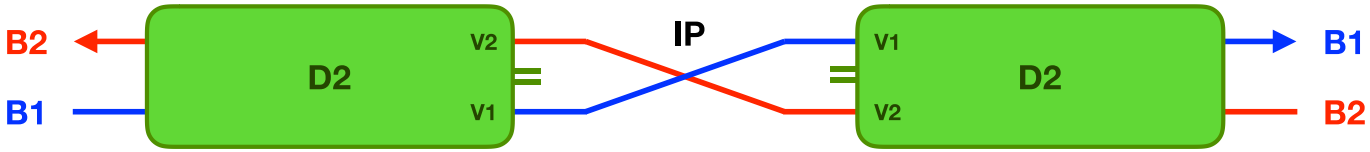
- Single-aperture magnets
- Inverted magnets are
  - MCBXFA.L, MCBXFBa.L, and MCBXFBb.R

MBXF magnets



- Single-aperture magnets
- No fringe fields implemented (it should be done in the future)
- Inverted magnets are
  - D1.R
- Previous routine implemented layout as
  - IP … (D1=)

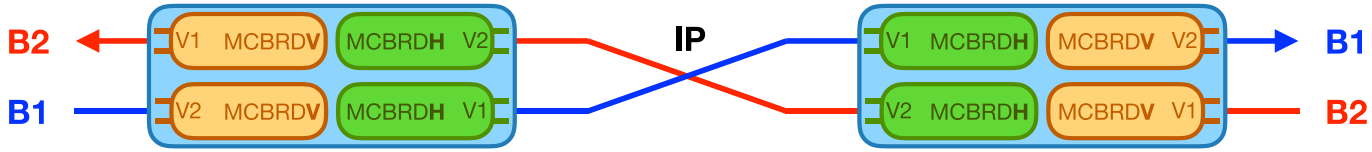
MBRD magnets



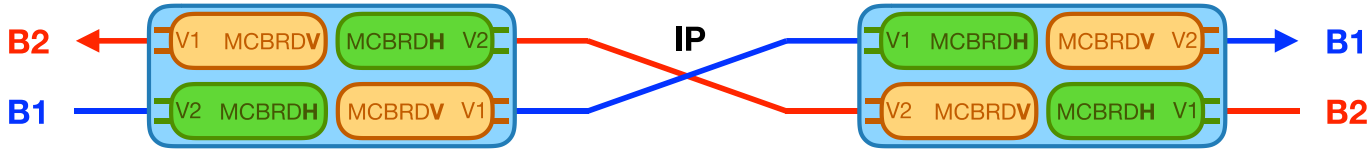
- Double-aperture magnets
- No fringe fields implemented (it should be done in the future)
- Inverted magnets are
  - D2.L
- Apertures are
  - V1 → Beam 1
- Previous routine implemented layout as
  - IP … (D2=)

MCBRD magnets

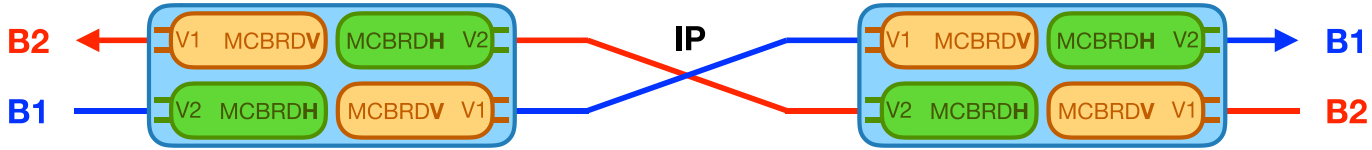
- Layout V1.0



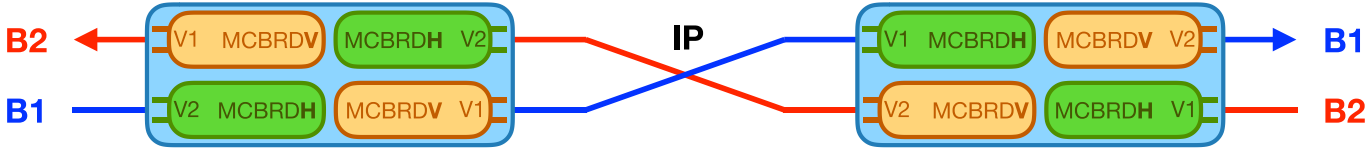
- Layout V1.4



- Layout V1.5

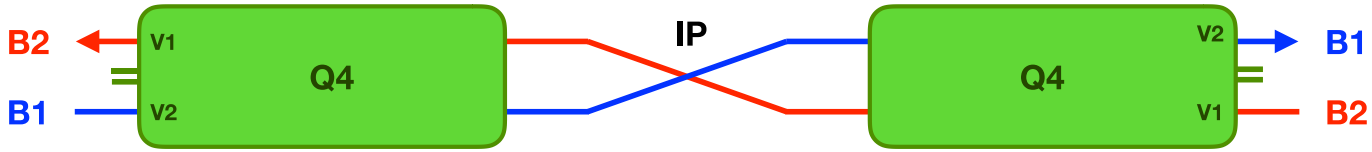


MCBRD magnets



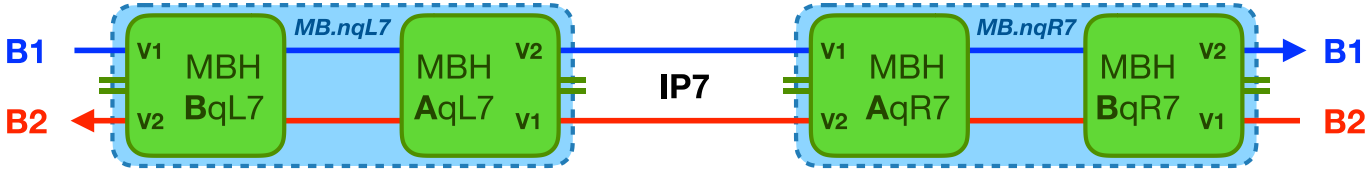
- Double-aperture magnets
- Inverted magnets are
  - MCBRDV.L.B1 and MCBRDV.R.B1
  - MCBRDH.L.B2 and MCBRDH.R.B2
- Apertures are
  - MCBRDH.L.V2, MCBRDV.L.V1, MCBRDH.R.V1, MCBRDV.R.V2 → Beam 1
  - MCBRDV.L.V1, MCBRDH.L.V2, MCBRDV.R.V2, MCBRDH.R.V1 → Beam 2

MQY magnets



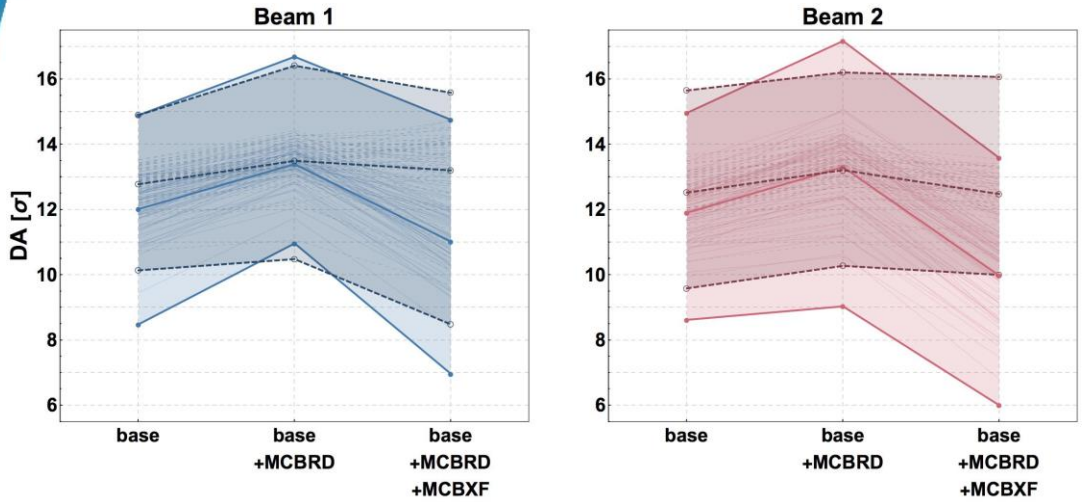
- Double-aperture magnets
- Inverted magnets are
  - Q4.R
- Apertures are
  - V2 → Beam 1
  - V1 → Beam 2
- As of v1.4 no new Q4 installed, but LHC MQY reused. However, they switch places
  - Q4.L1 ↔ Q4.R5
  - Q4.L5 ↔ Q4.R1

MBH magnets



- Double-aperture magnets to replace main dipoles
- Some fixes in the error routines implemented

Comparison of old and new routines



Collision, round optics

octupoles = 0 A

Q'= 3

Qx = 62.31 Qy = 60.32

xing = 250 μrad

. new routines

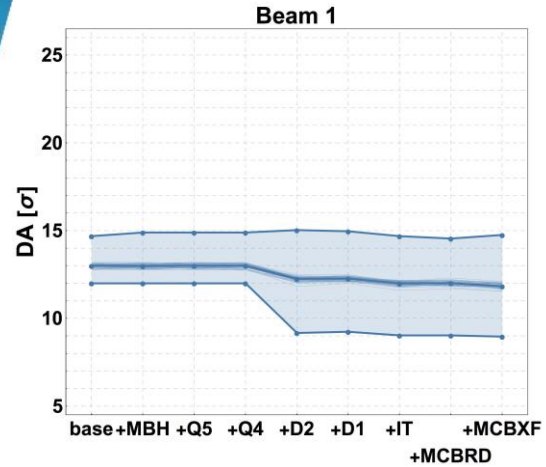
○ old routines

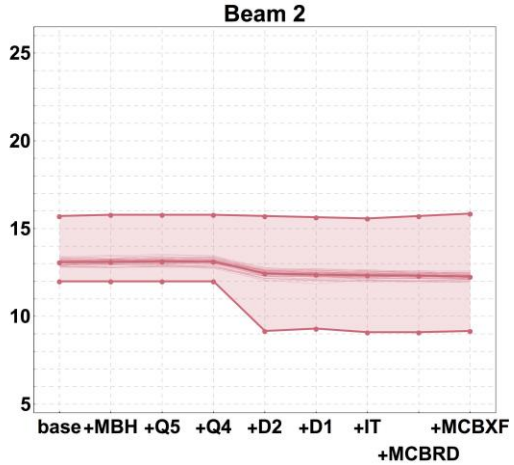
Observations

- New routines introduce a DA reduction with respect to old ones.
- New routines reduce DA difference between Beam 1 and 2.
- Increased sensitivity to MCBXF FQ

All this should be carefully scrutinised!

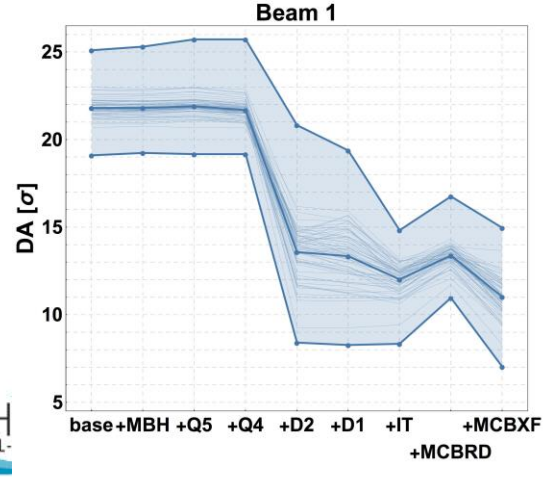
Impact of various magnets families

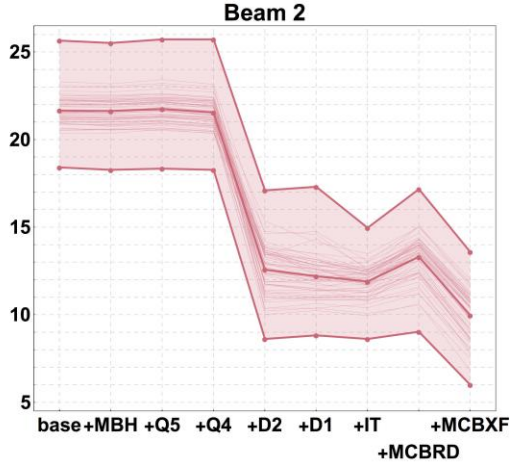




Injection
octupoles = 0 A
Q'= 3
Qx = 62.27 Qy = 60.295
xing = 250 μrad

FQ is not an issue. It is possible to increase the xing up to 295 μrad

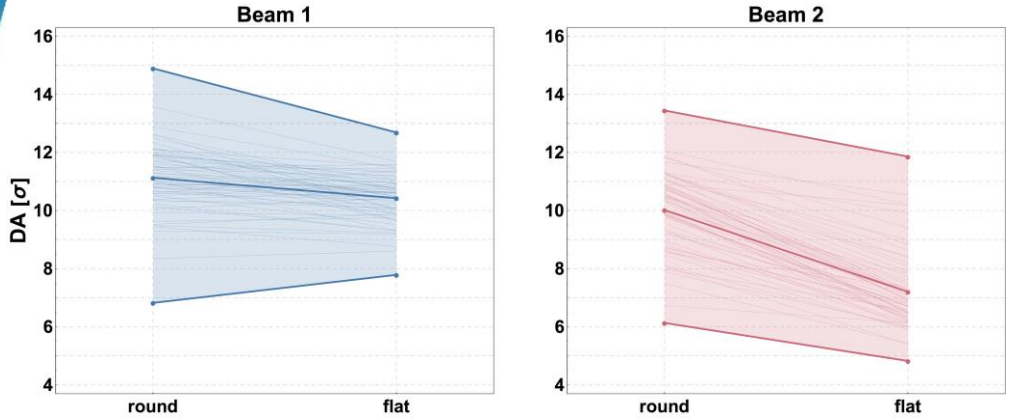




Collision, round optics
octupoles = 0 A
Q'= 3
Qx = 62.31 Qy = 60.32
xing = 250 μrad

IR magnets are dominating the DA. Strong impact of MCBXF

Comparison of round and flat optics



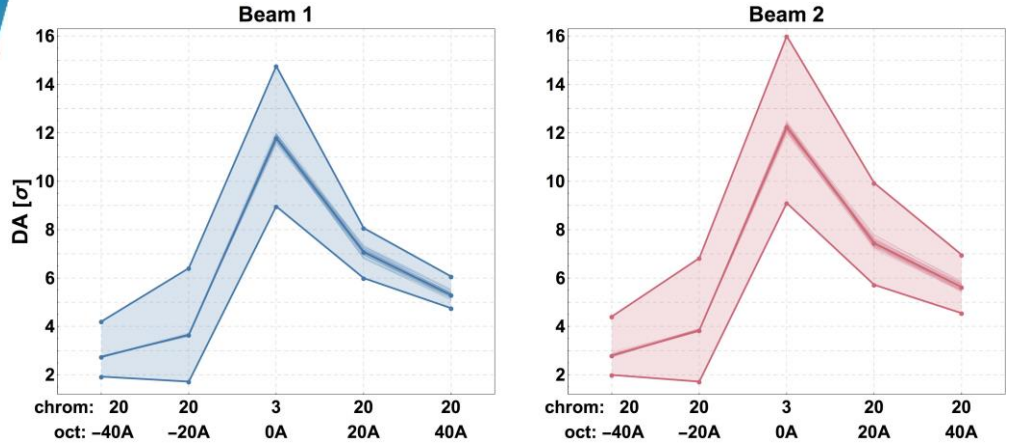
Collision, round and flat optics
octupoles = 0 A
Q'= 3
Qx = 62.31 Qy = 60.32
xing = 250 μrad

Observations

- DA improves for flat optics for Beam 1
- DA worsen for flat optics for Beam 2

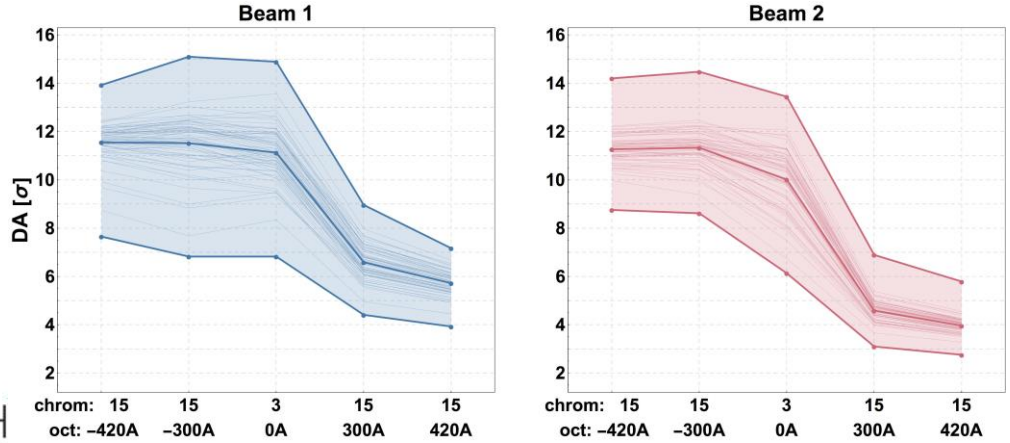
All this should be carefully scrutinised!

Impact of octupoles



Injection
octupoles = 0 A
Q'= 3 or 20
Qx = 62.27 Qy = 60.295
xing = 295 μrad

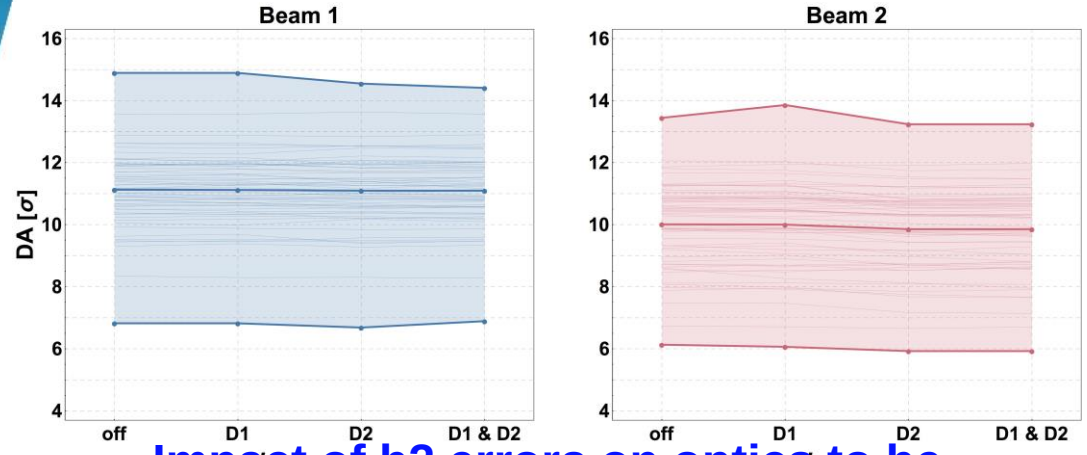
Octupoles strongly dominate DA



Collision, round optics
octupoles = 0 A
Q'= 3 or 15
Qx = 62.31 Qy = 60.32
xing = 250 μrad

Octupoles strongly dominate DA

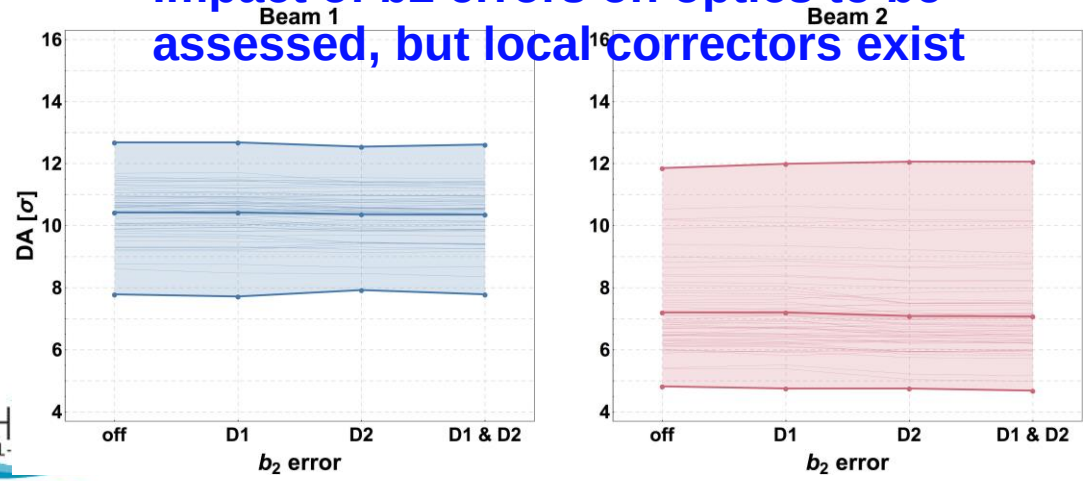
Impact of b2 errors



Collision, round optics
octupoles = 0 A
Q'= 3
Qx = 62.31 Qy = 60.32
xing = 250 μrad

No impact of b2 on DA

Impact of b2 errors on optics to be assessed, but local correctors exist



Collision, flat optics
octupoles = 0 A
Q'= 3
Qx = 62.31 Qy = 60.32
xing = 250 μrad

No impact of b2 on DA

Outlook

- Tracking activities for V1.4 are in fully swing
- Some hot topics under study
  - **Study whether phase advance can be used to increase DA (already successfully done for V1.0)**
  - **Provide FQ acceptance criteria for MCBXFs**
  - **Disentangle direct effects of b3 and of its feed down to b2, e.g. for MCBXF**
- **Establish a firm link between DA and beam lifetime (already in good shape for individual studies, but not used at the design level, yet).**

Thank you for your attention!