



Research supported by the High Luminosity LHC project

HiLumi LHC: Performance of Non-Linear Correctors

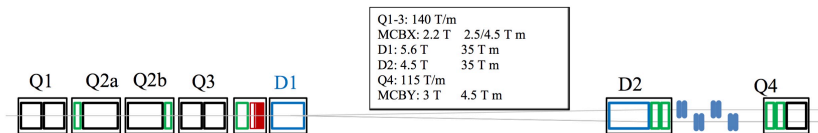
F.F. Van der Veken *in collaboration with M. Giovannozzi and R. De Maria*

Outline

- 1 Introduction
- 2 Mispowering of Non-Linear Correctors
- 3 Misalignment of Non-Linear Correctors

Aim

- We want check the robustness of the non-linear correctors
- How is dynamic aperture influenced under mispowerings and misalignments of the correctors?
- First order by order, then over 64 random mispowering and misalignment realisations
- Two versions: with and without correction of D2



Setup

- HLLHC 1.0 optics
- All errors are assigned at nominal value, except b_3 of D2:
 - mispowering studies: b_3 of D2 is maximal (3.8 units)
 - misalignment studies: b_3 of D2 is nominal (1.0 units)
- Octupole strength set to zero in order to have a clean result
(we want to see trends)

Setup

- In total **1056** studies, with on average **2100** jobs each



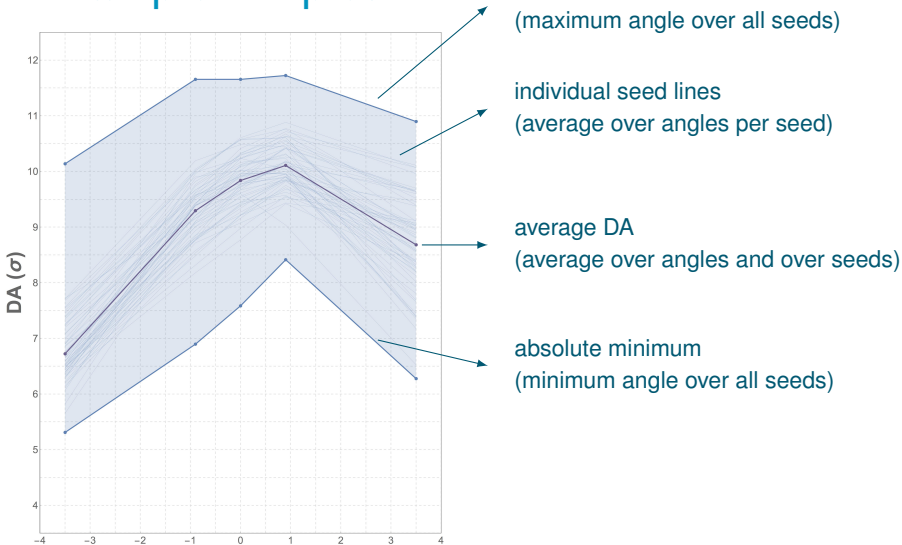
LHC@home
SixTrack

⇒ submission to BOINC!

Many thanks to A. Mereghetti for the new scripts, and to the numerous LHC@Home volunteers

- DA is calculated over:
 - 5 angles (15°, 30°, 45°, 60°, and 75°)
 - 60 random realisations of the machine ('seeds')

Example DA plot



Outline

- 1 Introduction
- 2 Mispowering of Non-Linear Correctors**
- 3 Misalignment of Non-Linear Correctors

Aim

- Check impact of mispowering of non-linear correctors on DA
- Assume mispowering comes from scaling of beta function
 - ⇒ Size of mispowering will depend on order

Maximum mispowering per order

Resonance driving terms are given by

$$h^{m,l} = \int_{IR_L} ds k_{n-1}(s) \sqrt{\beta_x(s)}^m \sqrt{\beta_y(s)}^l + (-)^n \int_{IR_R} ds k_{n-1}(s) \sqrt{\beta_x(s)}^m \sqrt{\beta_y(s)}^l$$

Assign K_n (corrector strength) such that $h^{m,l} \equiv 0$:

$$h^{m,l} = K_{n-1}^L \mathcal{N}_L^{m,l} + (-)^n K_{n-1}^R \mathcal{N}_R^{m,l} + h_{\text{ERR}}^{m,l} \equiv 0$$

$$\mathcal{N}_L^{m,l} = \sqrt{\beta_x(\text{left corrector})}^m \sqrt{\beta_y(\text{left corrector})}^l$$

$$h_{\text{ERR}}^{m,l} = h^{m,l} \text{ without contribution of correctors}$$

Two such criteria depending on m, l (e.g. for b_3 we minimise $h^{1,2}$ and $h^{2,1}$)

Maximum mispowering per order

Solution is

$$K_{n-1}^L \equiv -\frac{\mathcal{N}_R^{l,m} - (-)^n \mathcal{N}_R^{m,l}}{\mathcal{N}_L^{m,l} \mathcal{N}_R^{l,m} - \mathcal{N}_L^{l,m} \mathcal{N}_R^{m,l}} h_{\text{ERR}}^{l,m}$$
$$K_{n-1}^R \equiv -\frac{\mathcal{N}_L^{m,l} - (-)^n \mathcal{N}_L^{l,m}}{\mathcal{N}_L^{m,l} \mathcal{N}_R^{l,m} - \mathcal{N}_L^{l,m} \mathcal{N}_R^{m,l}} h_{\text{ERR}}^{l,m}$$

Introduce scaling of beta function, $\beta_{x,y}^L \rightarrow \alpha^L \beta_{x,y}^L$, then:

$$K^L \rightarrow \frac{1}{(\alpha^L)^{\frac{n}{2}}} K^L$$
$$K^R \rightarrow \frac{1}{(\alpha^R)^{\frac{n}{2}}} K^R$$

Maximum mispowering per order

For a maximum scaling of 10% ($\alpha=1.1$), we get:

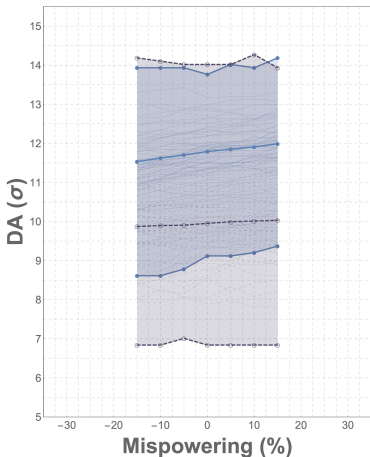
$$\begin{aligned}n = 3 &\Rightarrow \frac{\delta K}{K} = 13.125\% \Rightarrow \text{take 15\%} \\n = 4 &\Rightarrow \frac{\delta K}{K} = 17\% \Rightarrow \text{take 20\%} \\n = 5 &\Rightarrow \frac{\delta K}{K} = 20.625\% \Rightarrow \text{take 25\%} \\n = 6 &\Rightarrow \frac{\delta K}{K} = 24\% \Rightarrow \text{take 30\%}\end{aligned}$$

Order by order

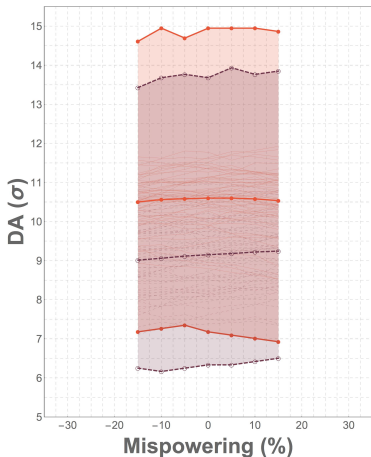
- As a first investigation, we mispower all correctors of the same order with the same factor, step by step

Mispowering of sextupole correctors

Beam 1



Beam 4

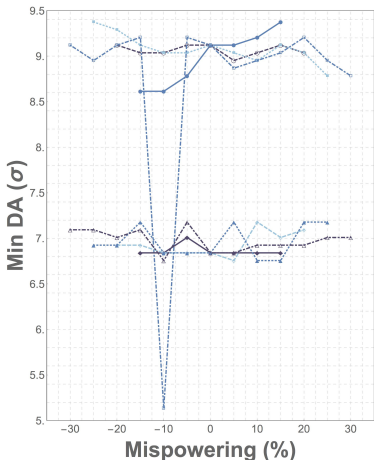


$E = 7000 \text{ GeV}$
 $\varepsilon_n = 2.5 \mu\text{m}$
 $\beta_1^* = 0.15 \text{ m}$
 $\beta_2^* = 10 \text{ m}$
 $\beta_5^* = 0.15 \text{ m}$
 $\beta_8^* = 3 \text{ m}$
 $\theta_c^{1,5} = 590 \text{ mrad}$
 $d_{sep}^{1,5} = 4 \text{ mm}$
 $Q_x = 62.31$
 $Q_y = 60.32$
 $Q' = 3$
 $I_{MO} = 0 \text{ A}$
 $\mu_x^{1 \rightarrow 5} = 31.210$
 $\mu_y^{1 \rightarrow 5} = 30.373$
 $\phi_1 = 90^\circ$
 $\phi_5 = 0^\circ$
 $b_3 \text{ of D2} = 3.8$

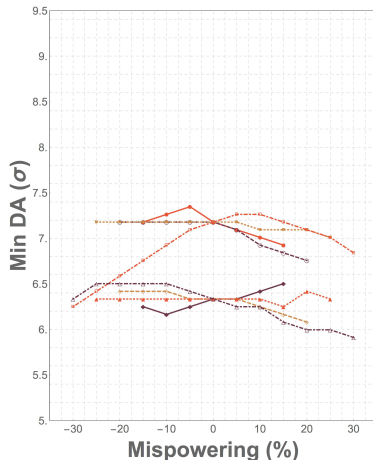
— D2 correction
 - - - no D2 correction

Mispowering of normal correctors

Beam 1



Beam 4



$E = 7000 \text{ GeV}$
 $\epsilon_n = 2.5 \mu\text{m}$
 $\beta_1^* = 0.15 \text{ m}$
 $\beta_2^* = 10 \text{ m}$
 $\beta_5^* = 0.15 \text{ m}$
 $\beta_8^* = 3 \text{ m}$
 $\theta_c^{1,5} = 590 \text{ mrad}$
 $d_{sep}^{1,5} = 4 \text{ mm}$
 $Q_x = 62.31$
 $Q_y = 60.32$
 $Q' = 3$
 $I_{MO} = 0 \text{ A}$

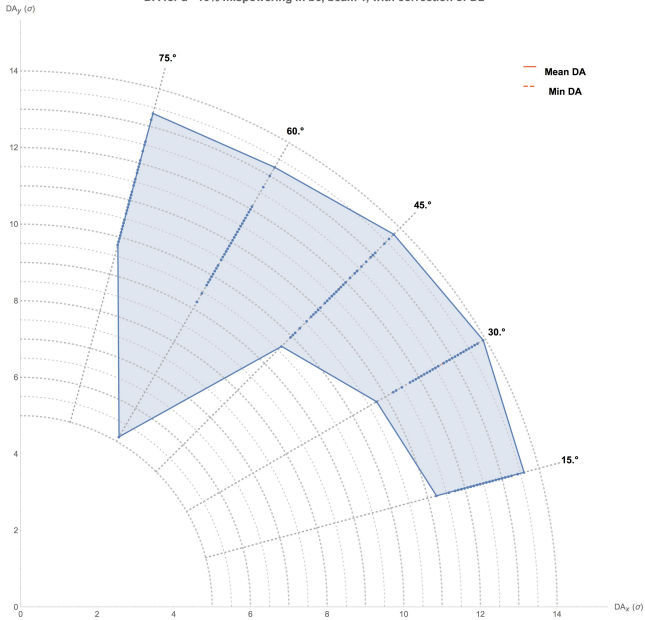
- b3, with D2 corr
- b4, with D2 corr
- b5, with D2 corr
- b6, with D2 corr
- b3, no D2 corr
- b4, no D2 corr
- b5, no D2 corr
- b6, no D2 corr

$\mu_x^{1 \rightarrow 5} = 31.210$
 $\mu_y^{1 \rightarrow 5} = 30.373$
 $\phi_1 = 90^\circ$
 $\phi_5 = 0^\circ$
 $b_3 \text{ of D2} = 3.8$

Dropping seeds

- The extreme drop in beam 1, b6, with D2 correction, is striking, but is it physical?
- Let us investigate this particular study

DA for a -10% mispowering in b6, beam 1, with correction of D2



Averaged over all angles

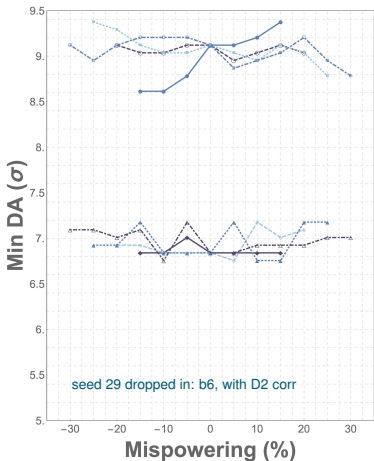


Dropping seeds

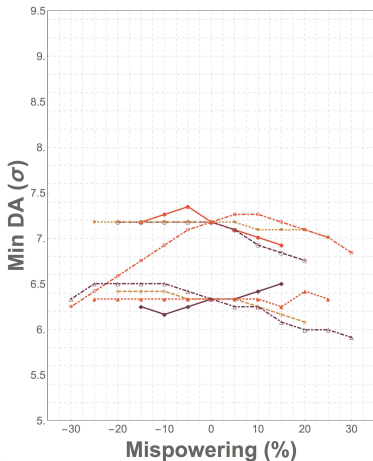
- The minimum is only in one angle and one seed, all other points are 4σ away
- This particular seed (29) can safely be dropped

Mispowering of normal correctors

Beam 1



Beam 4



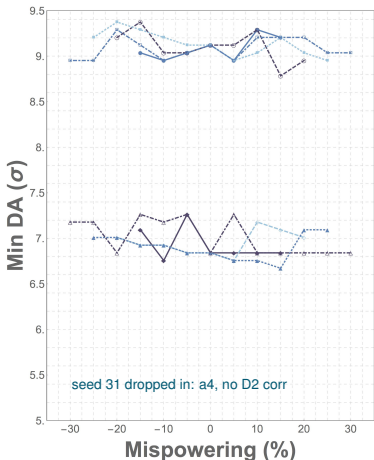
$E = 7000 \text{ GeV}$
 $\varepsilon_n = 2.5 \mu\text{m}$
 $\beta_1^* = 0.15 \text{ m}$
 $\beta_2^* = 10 \text{ m}$
 $\beta_5^* = 0.15 \text{ m}$
 $\beta_8^* = 3 \text{ m}$
 $\theta_c^{1,5} = 590 \text{ mrad}$
 $d_{sep}^{1,5} = 4 \text{ mm}$
 $Q_x = 62.31$
 $Q_y = 60.32$
 $Q' = 3$
 $I_{MO} = 0 \text{ A}$

- b3, with D2 corr
- b4, with D2 corr
- b5, with D2 corr
- b6, with D2 corr
- b3, no D2 corr
- b4, no D2 corr
- b5, no D2 corr
- b6, no D2 corr

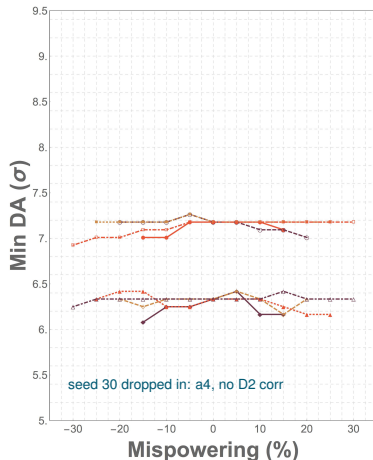
$\mu_x^{1 \rightarrow 5} = 31.210$
 $\mu_y^{1 \rightarrow 5} = 30.373$
 $\phi_1 = 90^\circ$
 $\phi_5 = 0^\circ$
 $b_3 \text{ of D2} = 3.8$

Mispowering of skew correctors

Beam 1



Beam 4



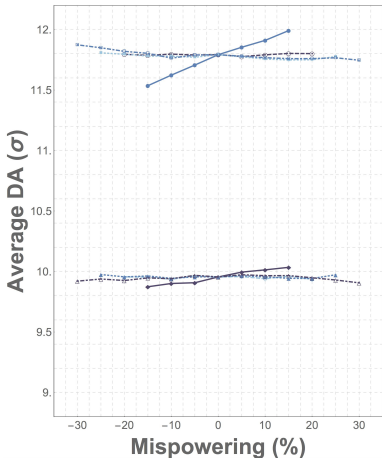
$E = 7000 \text{ GeV}$
 $\epsilon_n = 2.5 \mu\text{m}$
 $\beta_1^* = 0.15 \text{ m}$
 $\beta_2^* = 10 \text{ m}$
 $\beta_5^* = 0.15 \text{ m}$
 $\beta_8^* = 3 \text{ m}$
 $\theta_c^{1,5} = 590 \text{ mrad}$
 $d_{sep}^{1,5} = 4 \text{ mm}$
 $Q_x = 62.31$
 $Q_y = 60.32$
 $Q' = 3$
 $I_{MO} = 0 \text{ A}$

- a3, with D2 corr
- a4, with D2 corr
- a5, with D2 corr
- a6, with D2 corr
- a3, no D2 corr
- a4, no D2 corr
- a5, no D2 corr
- a6, no D2 corr

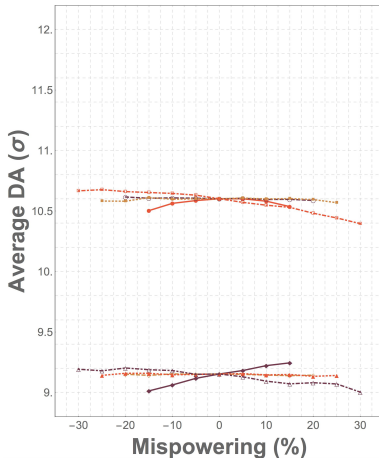
$\mu_x^{1 \rightarrow 5} = 31.210$
 $\mu_y^{1 \rightarrow 5} = 30.373$
 $\phi_1 = 90^\circ$
 $\phi_5 = 0^\circ$
 $b_3 \text{ of D2} = 3.8$

Mispowering of normal correctors

Beam 1



Beam 4



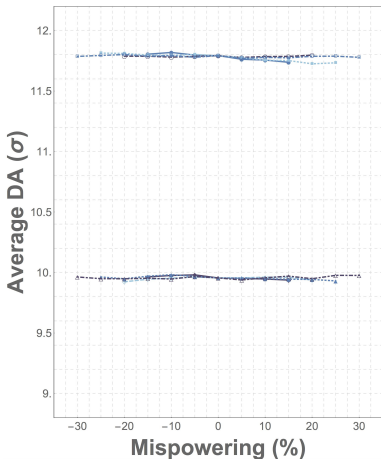
$E = 7000 \text{ GeV}$
 $\epsilon_n = 2.5 \mu\text{m}$
 $\beta_1^* = 0.15 \text{ m}$
 $\beta_2^* = 10 \text{ m}$
 $\beta_5^* = 0.15 \text{ m}$
 $\beta_8^* = 3 \text{ m}$
 $\theta_c^{1.5} = 590 \text{ mrad}$
 $d_{sep}^{1.5} = 4 \text{ mm}$
 $Q_x = 62.31$
 $Q_y = 60.32$
 $Q' = 3$
 $I_{MO} = 0 \text{ A}$

- b3, with D2 corrector
 - - - b4, with D2 corrector
 - · - · b5, with D2 corrector
 - · - · b6, with D2 corrector
 - b3, no D2 corrector
 - - - b4, no D2 corrector
 - · - · b5, no D2 corrector
 - · - · b6, no D2 corrector

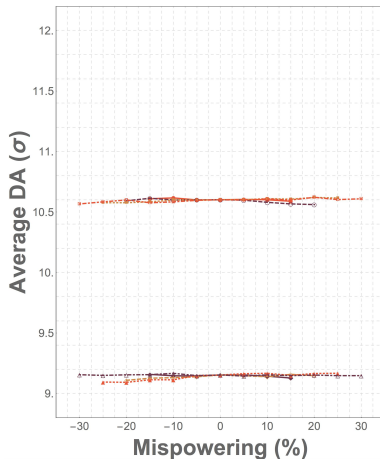
$\mu_x^{1 \rightarrow 5} = 31.210$
 $\mu_y^{1 \rightarrow 5} = 30.373$
 $\phi_1 = 90^\circ$
 $\phi_5 = 0^\circ$
 $b_3 \text{ of D2} = 3.8$

Mispowering of skew correctors

Beam 1



Beam 4



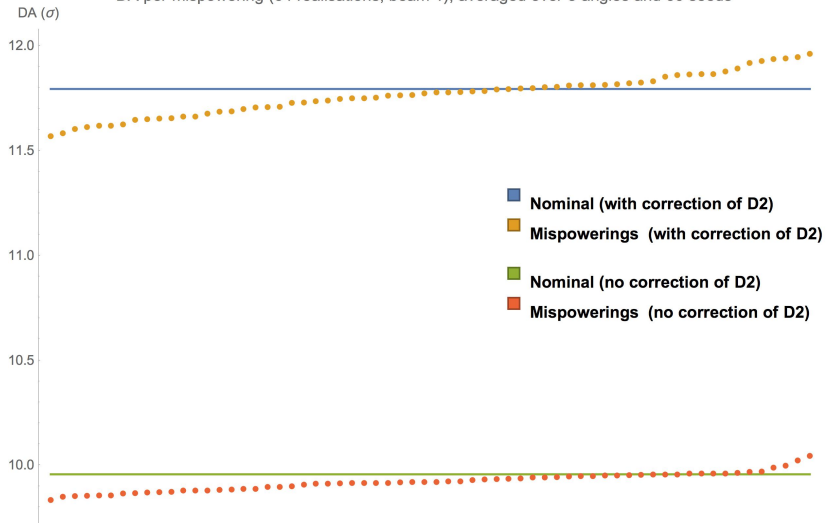
$E = 7000 \text{ GeV}$
 $\varepsilon_n = 2.5 \mu\text{m}$
 $\beta_1^* = 0.15 \text{ m}$
 $\beta_2^* = 10 \text{ m}$
 $\beta_5^* = 0.15 \text{ m}$
 $\beta_8^* = 3 \text{ m}$
 $\theta_c^{1,5} = 590 \text{ mrad}$
 $d_{sep}^{1,5} = 4 \text{ mm}$
 $Q_x = 62.31$
 $Q_y = 60.32$
 $Q' = 3$
 $I_{MO} = 0 \text{ A}$

- a3, with D2 correction
- - - a4, with D2 correction
- · - a5, with D2 correction
- · - a6, with D2 correction
- a3, no D2 correction
- - - a4, no D2 correction
- · - a5, no D2 correction
- · - a6, no D2 correction

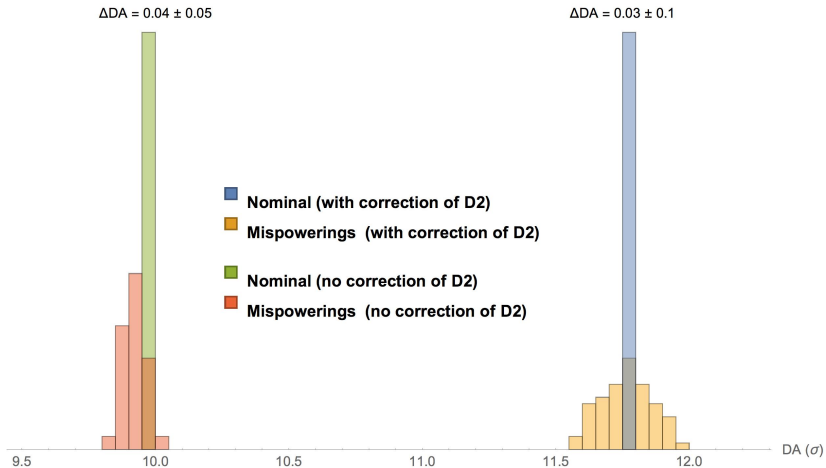
$\mu_x^{1 \rightarrow 5} = 31.210$
 $\mu_y^{1 \rightarrow 5} = 30.373$
 $\phi_1 = 90^\circ$
 $\phi_5 = 0^\circ$
 $b_3 \text{ of D2} = 3.8$

- Effect on DA of stepwise mispowering is negligible
- Next: random mispowering:
 - different mispowering for every corrector
 - uniformly distributed around nominal value
 - maximum mispowering scales with order:
 - 15% for a3 and b3
 - 20% for a4 and b4
 - 25% for a5 and b5
 - 30% for a6 and b6
 - 64 different random realisations

DA per mispowering (64 realisations, beam 1), averaged over 5 angles and 60 seeds

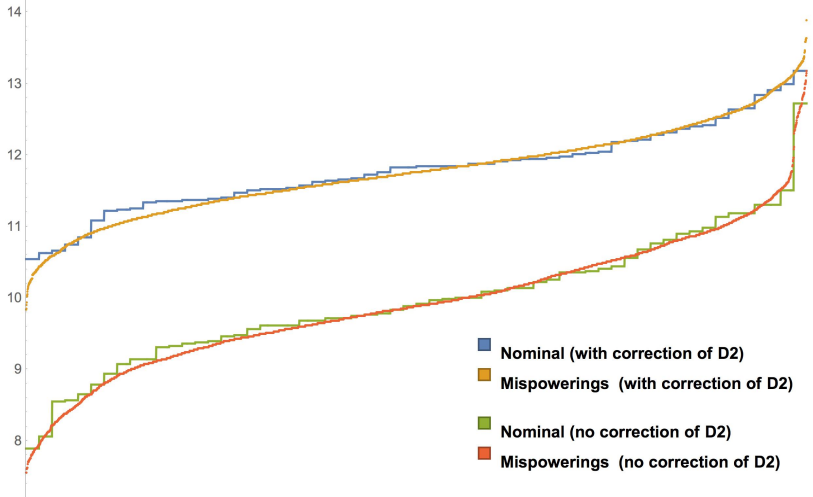


DA per mispowering (64 realisations, beam 1), averaged over 5 angles and 60 seeds

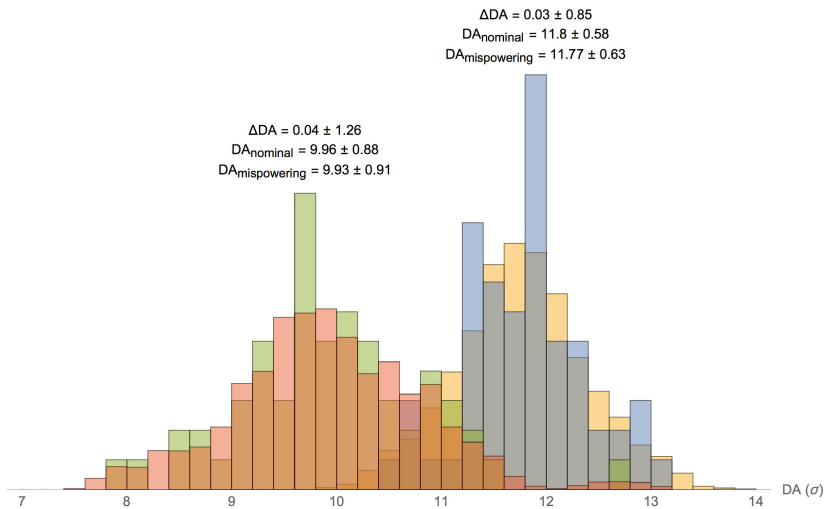


DA per mispowering (64 realisations, beam 1) and per seed (60 seeds), averaged over 5 angles

DA (σ)



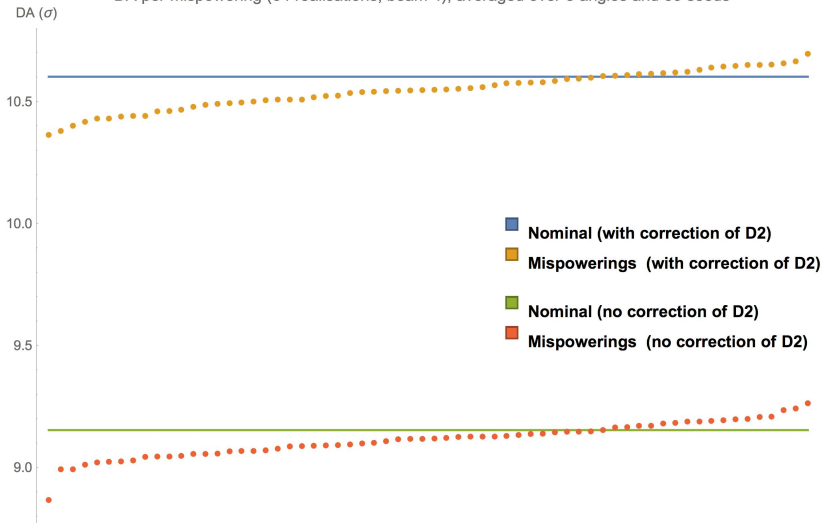
DA per mispowering (64 realisations, beam 1) and per seed (60 seeds), averaged over 5 angles



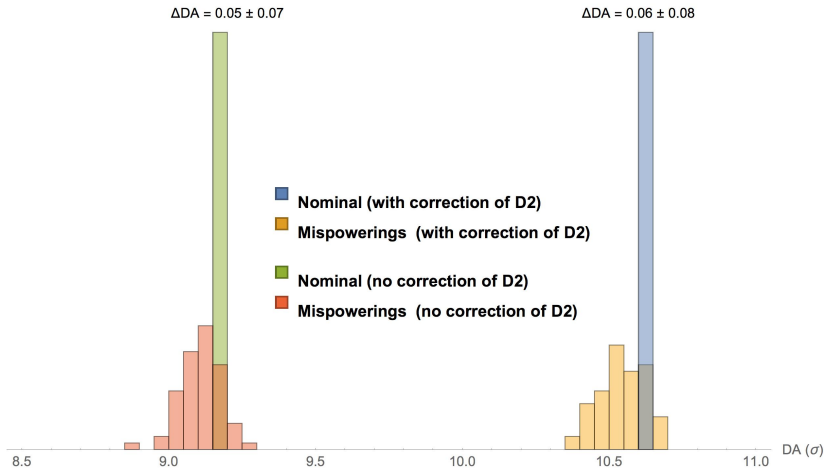
Conclusion

- System is very resistant for mispowerings
- Almost no shift in average DA, spread is under control
- Even on seed-by-seed basis mispowering follows nominal
- Confirmation of usefulness of correcting D2
- Similar result for beam 4 (except for one realisation with one particular bad seed)

DA per mispowering (64 realisations, beam 4), averaged over 5 angles and 60 seeds

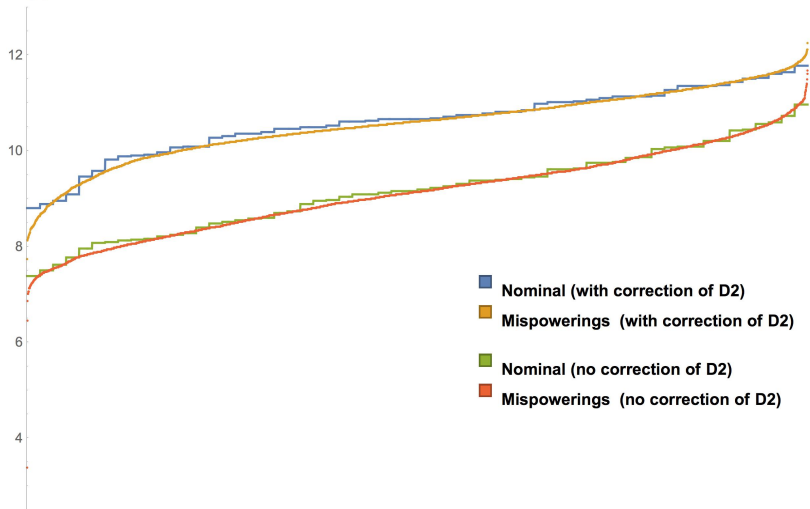


DA per mispowering (64 realisations, beam 4), averaged over 5 angles and 60 seeds



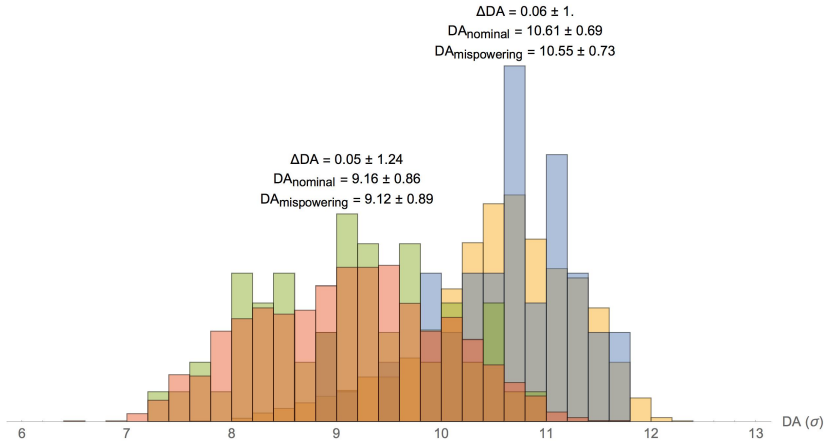
DA per mispowering (64 realisations, beam 4) and per seed (60 seeds), averaged over 5 angles

DA (σ)



- Nominal (with correction of D2)**
- Mispowerings (with correction of D2)**
- Nominal (no correction of D2)**
- Mispowerings (no correction of D2)**

DA per mispowering (64 realisations, beam 4) and per seed (60 seeds), averaged over 5 angles

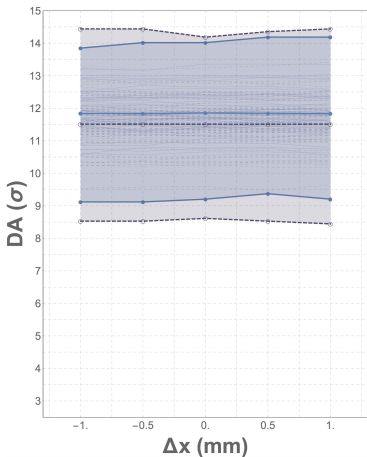


Outline

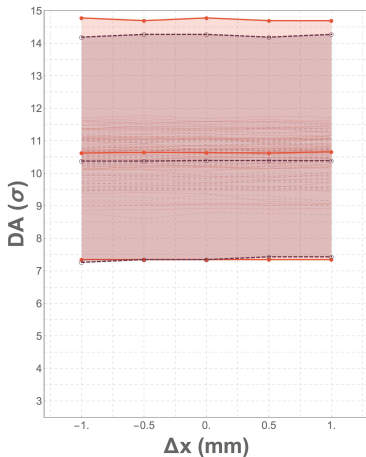
- 1 Introduction
- 2 Mispowering of Non-Linear Correctors
- 3 Misalignment of Non-Linear Correctors**

Misalignment of sextupole correctors

Beam 1



Beam 4

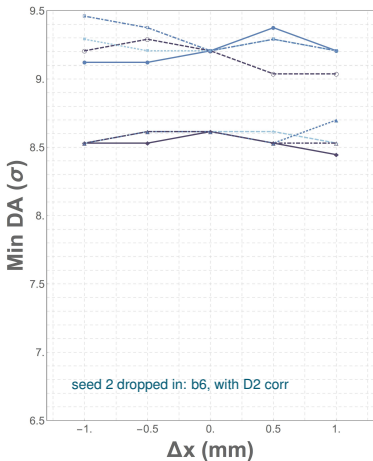


$E = 7000 \text{ GeV}$
 $\epsilon_n = 2.5 \mu\text{m}$
 $\beta_1^* = 0.15 \text{ m}$
 $\beta_2^* = 10 \text{ m}$
 $\beta_5^* = 0.15 \text{ m}$
 $\beta_8^* = 3 \text{ m}$
 $\theta_c^{1,5} = 590 \text{ mrad}$
 $d_{sep}^{1,5} = 4 \text{ mm}$
 $Q_x = 62.31$
 $Q_y = 60.32$
 $Q' = 3$
 $I_{MO} = 0 \text{ A}$
 $\mu_x^{1 \rightarrow 5} = 31.210$
 $\mu_y^{1 \rightarrow 5} = 30.373$
 $\phi_1 = 90^\circ$
 $\phi_5 = 0^\circ$
 $b_3 \text{ of D2} = 1.0$

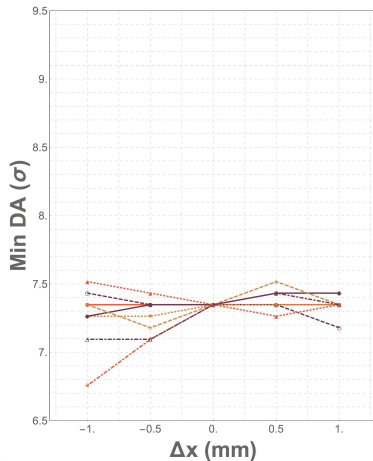
— D2 correction
 - - - no D2 correction

Misalignment of normal correctors

Beam 1



Beam 4



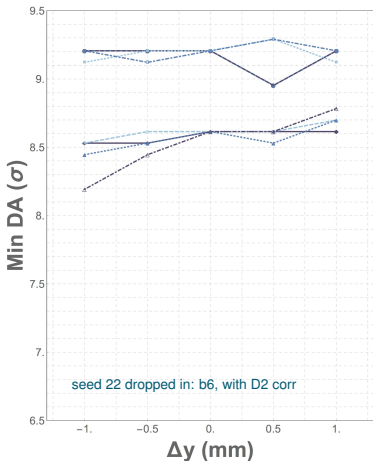
$E = 7000$ GeV
 $\epsilon_n = 2.5$ μm
 $\beta_1^* = 0.15$ m
 $\beta_2^* = 10$ m
 $\beta_5^* = 0.15$ m
 $\beta_8^* = 3$ m
 $\theta_c^{1,5} = 590$ mrad
 $d_{sep}^{1,5} = 4$ mm
 $Q_x = 62.31$
 $Q_y = 60.32$
 $Q' = 3$
 $I_{MO} = 0$ A

- b3, with D2 corr
- b4, with D2 corr
- b5, with D2 corr
- b6, with D2 corr
- b3, no D2 corr
- b4, no D2 corr
- b5, no D2 corr
- b6, no D2 corr

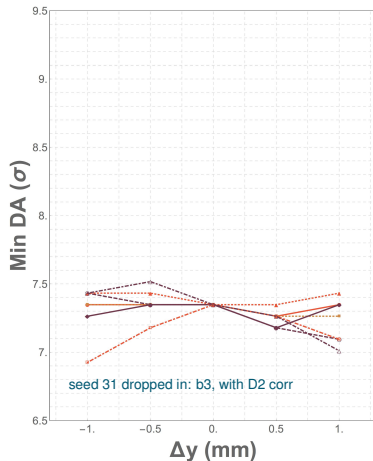
$\mu_x^{1 \rightarrow 5} = 31.210$
 $\mu_y^{1 \rightarrow 5} = 30.373$
 $\phi_1 = 90^\circ$
 $\phi_5 = 0^\circ$
 b_3 of D2 = 1.0

Misalignment of normal correctors

Beam 1



Beam 4



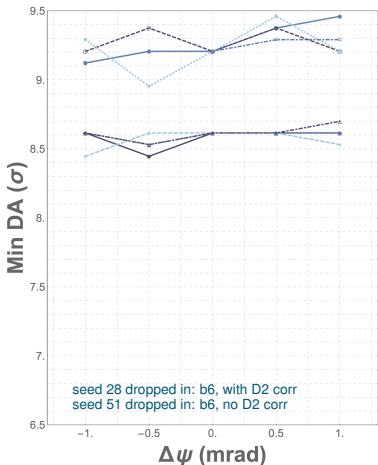
$E = 7000 \text{ GeV}$
 $\epsilon_n = 2.5 \mu\text{m}$
 $\beta_1^* = 0.15 \text{ m}$
 $\beta_2^* = 10 \text{ m}$
 $\beta_5^* = 0.15 \text{ m}$
 $\beta_8^* = 3 \text{ m}$
 $\theta_c^{1,5} = 590 \text{ mrad}$
 $d_{sep}^{1,5} = 4 \text{ mm}$
 $Q_x = 62.31$
 $Q_y = 60.32$
 $Q' = 3$
 $I_{MO} = 0 \text{ A}$

- b3, with D2 corr
- b4, with D2 corr
- b5, with D2 corr
- b6, with D2 corr
- b3, no D2 corr
- b4, no D2 corr
- b5, no D2 corr
- b6, no D2 corr

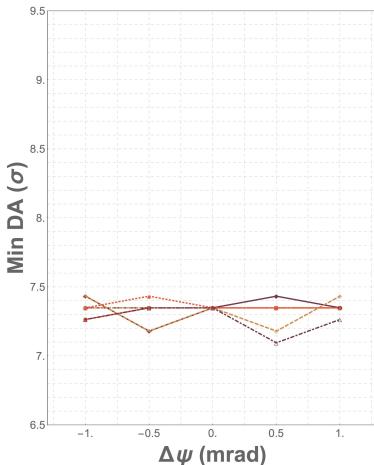
$\mu_x^{1 \rightarrow 5} = 31.210$
 $\mu_y^{1 \rightarrow 5} = 30.373$
 $\phi_1 = 90^\circ$
 $\phi_5 = 0^\circ$
 $b_3 \text{ of D2} = 1.0$

Misrotation of normal correctors

Beam 1



Beam 4



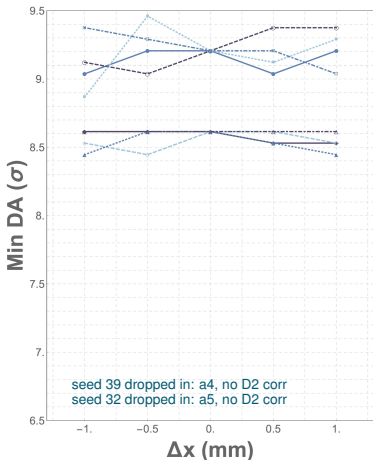
$E = 7000 \text{ GeV}$
 $\epsilon_n = 2.5 \mu\text{m}$
 $\beta_1^* = 0.15 \text{ m}$
 $\beta_2^* = 10 \text{ m}$
 $\beta_5^* = 0.15 \text{ m}$
 $\beta_8^* = 3 \text{ m}$
 $\theta_c^{1.5} = 590 \text{ mrad}$
 $d_{sep}^{1.5} = 4 \text{ mm}$
 $Q_x = 62.31$
 $Q_y = 60.32$
 $Q' = 3$
 $I_{MO} = 0 \text{ A}$

- b3, with D2 corr
- b4, with D2 corr
- b5, with D2 corr
- b6, with D2 corr
- b3, no D2 corr
- b4, no D2 corr
- b5, no D2 corr
- b6, no D2 corr

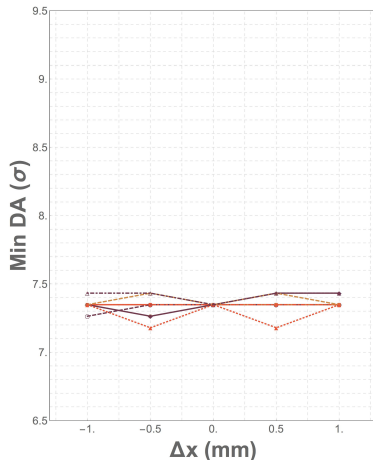
$\mu_x^{1 \rightarrow 5} = 31.210$
 $\mu_y^{1 \rightarrow 5} = 30.373$
 $\phi_1 = 90^\circ$
 $\phi_5 = 0^\circ$
 $b_3 \text{ of D2} = 1.0$

Misalignment of skew correctors

Beam 1



Beam 4



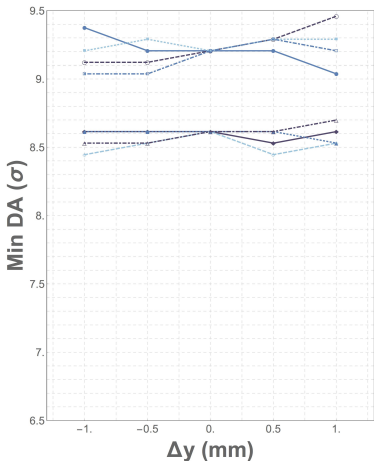
$E = 7000 \text{ GeV}$
 $\epsilon_n = 2.5 \mu\text{m}$
 $\beta_1^* = 0.15 \text{ m}$
 $\beta_2^* = 10 \text{ m}$
 $\beta_5^* = 0.15 \text{ m}$
 $\beta_8^* = 3 \text{ m}$
 $\theta_c^{1,5} = 590 \text{ mrad}$
 $d_{sep}^{1,5} = 4 \text{ mm}$
 $Q_x = 62.31$
 $Q_y = 60.32$
 $Q' = 3$
 $I_{MO} = 0 \text{ A}$

- a3, with D2 corr
- a4, with D2 corr
- a5, with D2 corr
- a6, with D2 corr
- a3, no D2 corr
- a4, no D2 corr
- a5, no D2 corr
- a6, no D2 corr

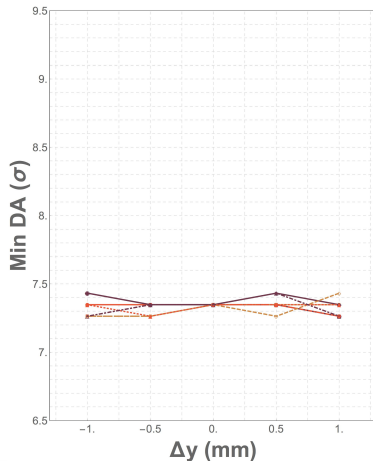
$\mu_x^{1 \rightarrow 5} = 31.210$
 $\mu_y^{1 \rightarrow 5} = 30.373$
 $\phi_1 = 90^\circ$
 $\phi_5 = 0^\circ$
 $b_3 \text{ of D2} = 1.0$

Misalignment of skew correctors

Beam 1



Beam 4



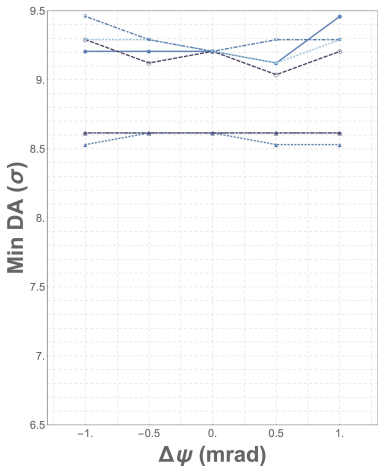
$E = 7000 \text{ GeV}$
 $\epsilon_n = 2.5 \mu\text{m}$
 $\beta_1^* = 0.15 \text{ m}$
 $\beta_2^* = 10 \text{ m}$
 $\beta_5^* = 0.15 \text{ m}$
 $\beta_8^* = 3 \text{ m}$
 $\theta_c^{1,5} = 590 \text{ mrad}$
 $d_{sep}^{1,5} = 4 \text{ mm}$
 $Q_x = 62.31$
 $Q_y = 60.32$
 $Q' = 3$
 $I_{MO} = 0 \text{ A}$

- a3, with D2 corr
- a4, with D2 corr
- a5, with D2 corr
- a6, with D2 corr
- a3, no D2 corr
- a4, no D2 corr
- a5, no D2 corr
- a6, no D2 corr

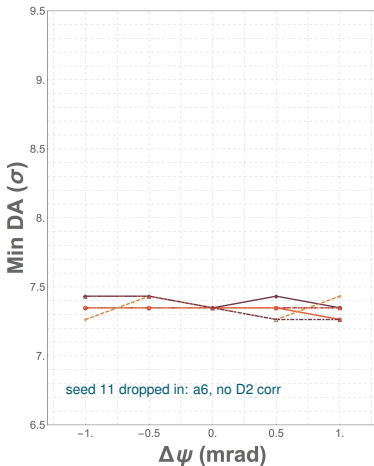
$\mu_x^{1 \rightarrow 5} = 31.210$
 $\mu_y^{1 \rightarrow 5} = 30.373$
 $\phi_1 = 90^\circ$
 $\phi_5 = 0^\circ$
 $b_3 \text{ of D2} = 1.0$

Misrotation of skew correctors

Beam 1



Beam 4



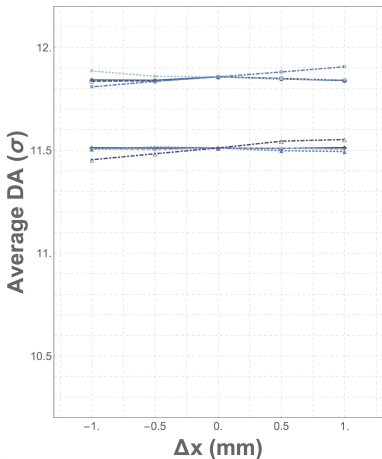
$E = 7000 \text{ GeV}$
 $\epsilon_n = 2.5 \text{ } \mu\text{m}$
 $\beta_1^* = 0.15 \text{ m}$
 $\beta_2^* = 10 \text{ m}$
 $\beta_5^* = 0.15 \text{ m}$
 $\beta_8^* = 3 \text{ m}$
 $\theta_c^{1.5} = 590 \text{ mrad}$
 $d_{sep}^{1.5} = 4 \text{ mm}$
 $Q_x = 62.31$
 $Q_y = 60.32$
 $Q' = 3$
 $I_{MO} = 0 \text{ A}$

- a3, with D2 corr
- a4, with D2 corr
- a5, with D2 corr
- .-.- a6, with D2 corr
- a3, no D2 corr
- a4, no D2 corr
- a5, no D2 corr
- .-.- a6, no D2 corr

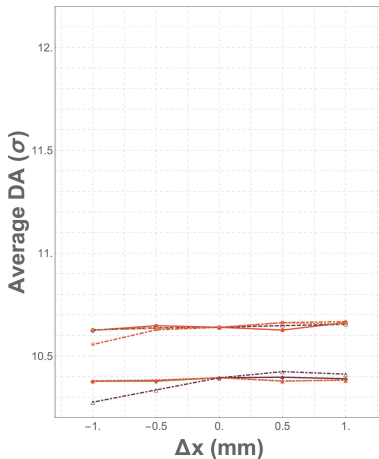
$\mu_x^{1 \rightarrow 5} = 31.210$
 $\mu_y^{1 \rightarrow 5} = 30.373$
 $\phi_1 = 90^\circ$
 $\phi_5 = 0^\circ$
 $b_3 \text{ of D2} = 1.0$

Misalignment of normal correctors

Beam 1



Beam 4



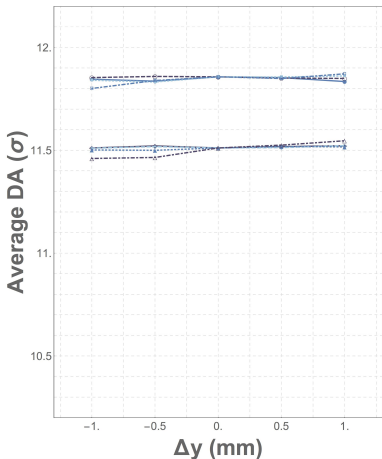
$E = 7000$ GeV
 $\epsilon_n = 2.5 \mu\text{m}$
 $\beta_1^* = 0.15$ m
 $\beta_2^* = 10$ m
 $\beta_5^* = 0.15$ m
 $\beta_8^* = 3$ m
 $\theta_c^{1.5} = 590$ mrad
 $d_{sep}^{1.5} = 4$ mm
 $Q_x = 62.31$
 $Q_y = 60.32$
 $Q' = 3$
 $I_{MO} = 0$ A

- b3, with D2 correction
- - - b4, with D2 correction
- · · b5, with D2 correction
- · - b6, with D2 correction
- b3, no D2 correction
- - - b4, no D2 correction
- · · b5, no D2 correction
- · - b6, no D2 correction

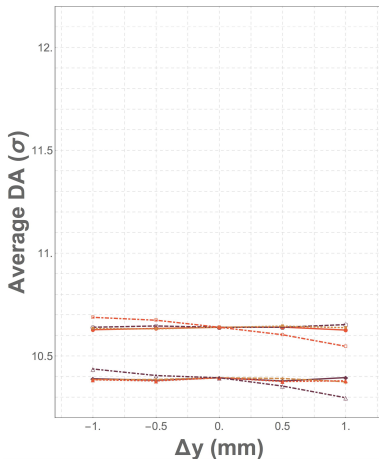
$\mu_x^{1 \rightarrow 5} = 31.210$
 $\mu_y^{1 \rightarrow 5} = 30.373$
 $\phi_1 = 90^\circ$
 $\phi_5 = 0^\circ$
 b_3 of D2 = 1.0

Misalignment of normal correctors

Beam 1



Beam 4



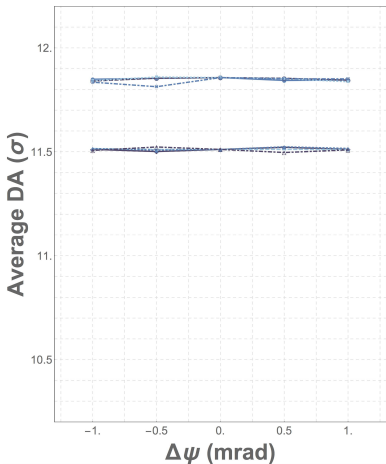
$E = 7000$ GeV
 $\varepsilon_n = 2.5 \mu\text{m}$
 $\beta_1^* = 0.15$ m
 $\beta_2^* = 10$ m
 $\beta_5^* = 0.15$ m
 $\beta_8^* = 3$ m
 $\theta_c^{1.5} = 590$ mrad
 $d_{sep}^{1.5} = 4$ mm
 $Q_x = 62.31$
 $Q_y = 60.32$
 $Q' = 3$
 $I_{MO} = 0$ A

- b3, with D2 correction
- b4, with D2 correction
- b5, with D2 correction
- .-.- b6, with D2 correction
- b3, no D2 correction
- b4, no D2 correction
- b5, no D2 correction
- .-.- b6, no D2 correction

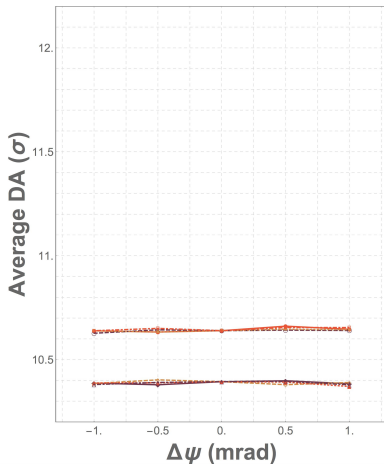
$\mu_x^{1 \rightarrow 5} = 31.210$
 $\mu_y^{1 \rightarrow 5} = 30.373$
 $\phi_1 = 90^\circ$
 $\phi_5 = 0^\circ$
 b_3 of D2 = 1.0

Misrotation of normal correctors

Beam 1



Beam 4



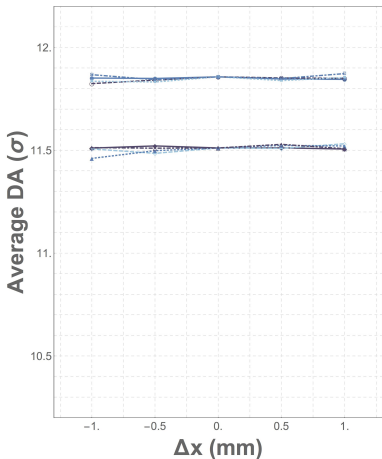
$E = 7000$ GeV
 $\varepsilon_n = 2.5 \mu\text{m}$
 $\beta_1^* = 0.15$ m
 $\beta_2^* = 10$ m
 $\beta_5^* = 0.15$ m
 $\beta_8^* = 3$ m
 $\theta_c^{1,5} = 590$ mrad
 $d_{sep}^{1,5} = 4$ mm
 $Q_x = 62.31$
 $Q_y = 60.32$
 $Q' = 3$
 $I_{MO} = 0$ A

- b3, with D2 c
- b4, with D2 c
- b5, with D2 c
- b6, with D2 c
- b3, no D2 c
- b4, no D2 c
- b5, no D2 c
- b6, no D2 c

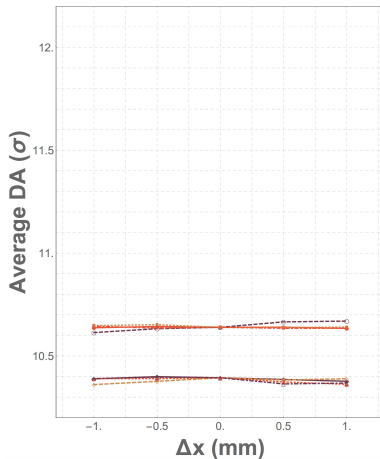
$\mu_x^{1 \rightarrow 5} = 31.210$
 $\mu_y^{1 \rightarrow 5} = 30.373$
 $\phi_1 = 90^\circ$
 $\phi_5 = 0^\circ$
 b_3 of D2 = 1.0

Misalignment of skew correctors

Beam 1



Beam 4



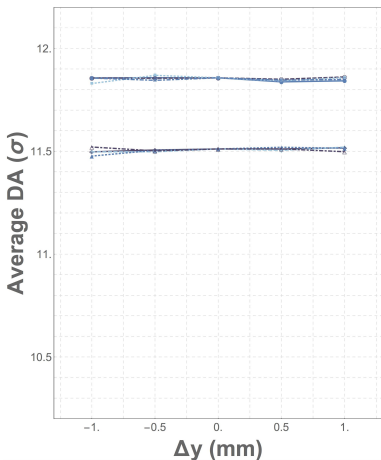
$E = 7000$ GeV
 $\varepsilon_n = 2.5$ μm
 $\beta_1^* = 0.15$ m
 $\beta_2^* = 10$ m
 $\beta_5^* = 0.15$ m
 $\beta_8^* = 3$ m
 $\theta_c^{1,5} = 590$ mrad
 $d_{sep}^{1,5} = 4$ mm
 $Q_x = 62.31$
 $Q_y = 60.32$
 $Q' = 3$
 $I_{MO} = 0$ A

- a3, with D2 correction
- - - a4, with D2 correction
- · · a5, with D2 correction
- · - a6, with D2 correction
- a3, no D2 correction
- - - a4, no D2 correction
- · · a5, no D2 correction
- · - a6, no D2 correction

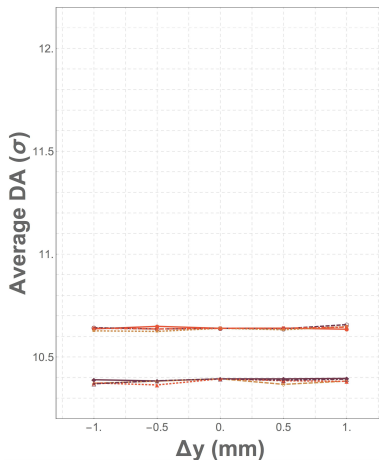
$\mu_x^{1 \rightarrow 5} = 31.210$
 $\mu_y^{1 \rightarrow 5} = 30.373$
 $\phi_1 = 90^\circ$
 $\phi_5 = 0^\circ$
 b_3 of D2 = 1.0

Misalignment of skew correctors

Beam 1



Beam 4



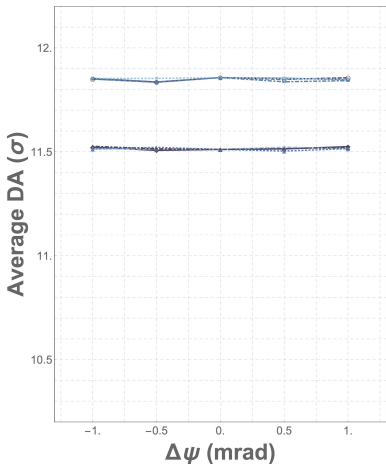
$E = 7000 \text{ GeV}$
 $\varepsilon_n = 2.5 \mu\text{m}$
 $\beta_1^* = 0.15 \text{ m}$
 $\beta_2^* = 10 \text{ m}$
 $\beta_5^* = 0.15 \text{ m}$
 $\beta_8^* = 3 \text{ m}$
 $\theta_c^{1,5} = 590 \text{ mrad}$
 $d_{sep}^{1,5} = 4 \text{ mm}$
 $Q_x = 62.31$
 $Q_y = 60.32$
 $Q' = 3$
 $I_{MO} = 0 \text{ A}$

- a3, with D2 correction
- - - a4, with D2 correction
- · - a5, with D2 correction
- · - a6, with D2 correction
- a3, no D2 correction
- - - a4, no D2 correction
- · - a5, no D2 correction
- · - a6, no D2 correction

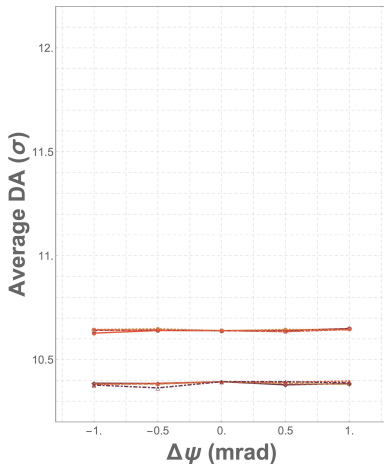
$\mu_x^{1 \rightarrow 5} = 31.210$
 $\mu_y^{1 \rightarrow 5} = 30.373$
 $\phi_1 = 90^\circ$
 $\phi_5 = 0^\circ$
 $b_3 \text{ of D2} = 1.0$

Misrotation of skew correctors

Beam 1



Beam 4

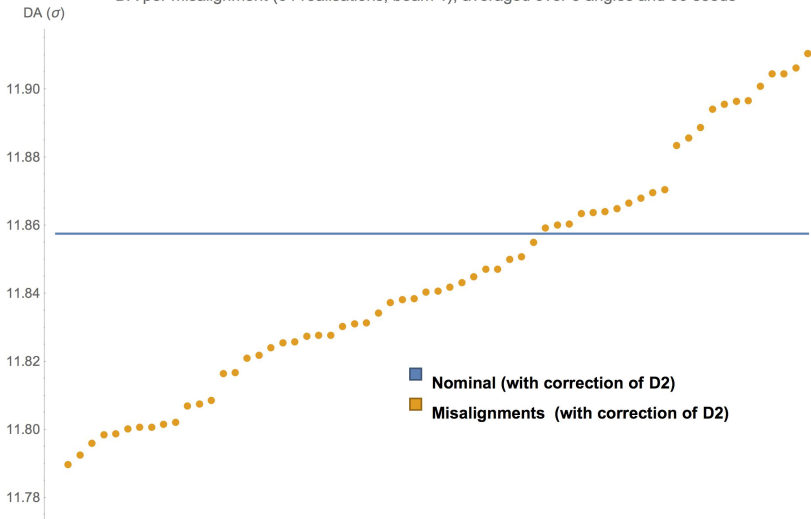


$E = 7000$ GeV
 $\varepsilon_n = 2.5$ μm
 $\beta_1^* = 0.15$ m
 $\beta_2^* = 10$ m
 $\beta_5^* = 0.15$ m
 $\beta_8^* = 3$ m
 $\theta_c^{1,5} = 590$ mrad
 $d_{sep}^{1,5} = 4$ mm
 $Q_x = 62.31$
 $Q_y = 60.32$
 $Q' = 3$
 $I_{MO} = 0$ A

- a3, with D2 c
- a4, with D2 c
- a5, with D2 c
- a6, with D2 c
- a3, no D2 c
- a4, no D2 c
- a5, no D2 c
- a6, no D2 c

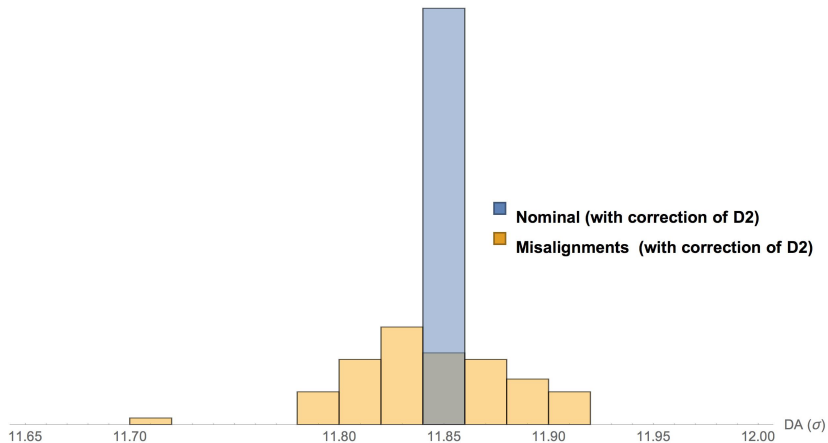
$\mu_x^{1 \rightarrow 5} = 31.210$
 $\mu_y^{1 \rightarrow 5} = 30.373$
 $\phi_1 = 90^\circ$
 $\phi_5 = 0^\circ$
 b_3 of D2 = 1.0

DA per misalignment (64 realisations, beam 1), averaged over 5 angles and 60 seeds



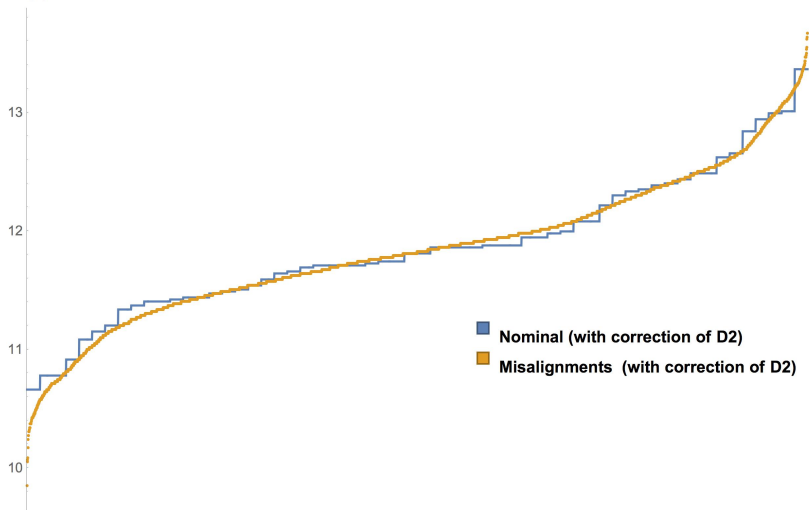
DA per misalignment (64 realisations, beam 1), averaged over 5 angles and 60 seeds

$$\Delta DA = 0.02 \pm 0.04$$



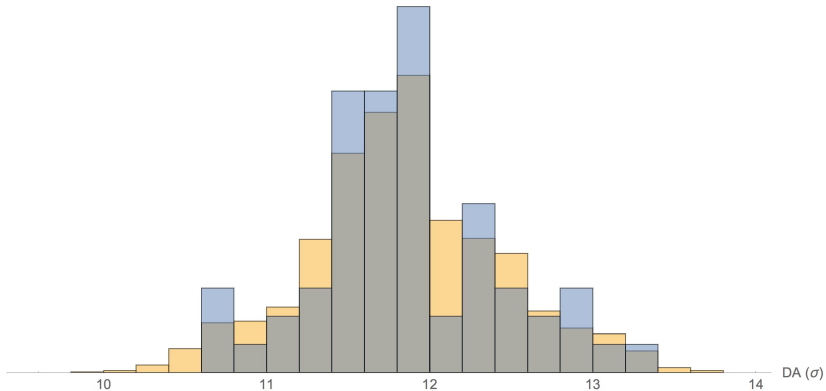
DA per misalignment (64 realisations, beam 1) and per seed (60 seeds), averaged over 5 angles

DA (σ)

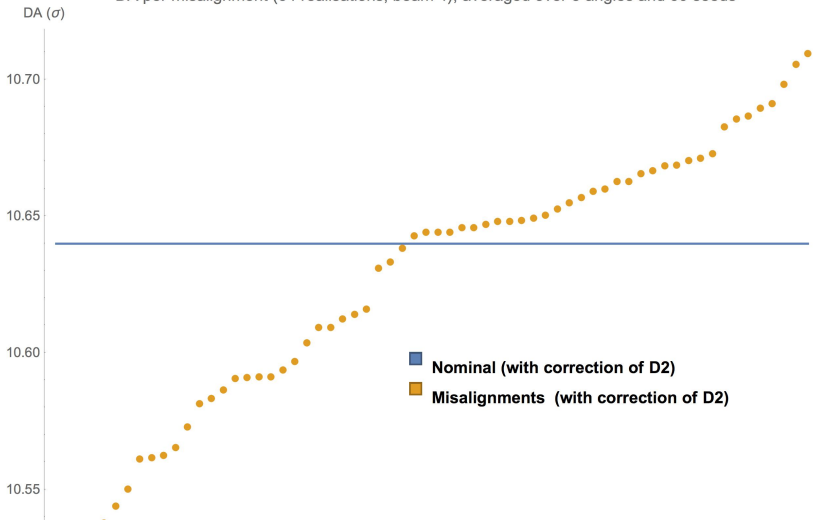


DA per misalignment (64 realisations, beam 1) and per seed (60 seeds), averaged over 5 angles

$\Delta DA = 0.02 \pm 0.83$
 $DA_{\text{nominal}} = 11.86 \pm 0.57$
 $DA_{\text{misalignment}} = 11.85 \pm 0.6$

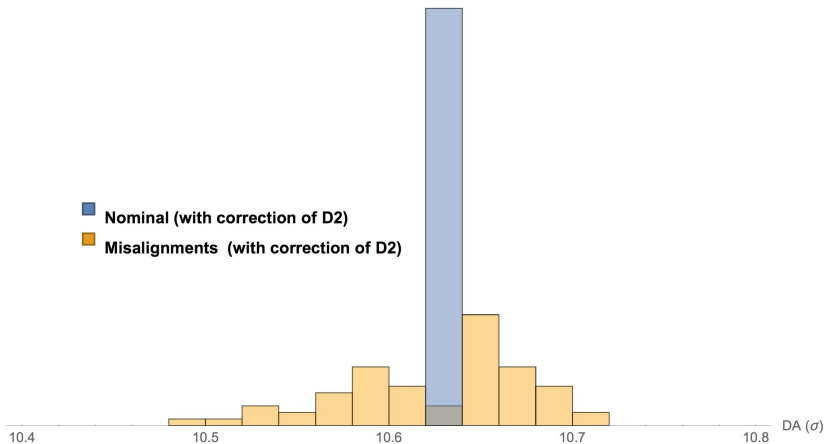


DA per misalignment (64 realisations, beam 4), averaged over 5 angles and 60 seeds



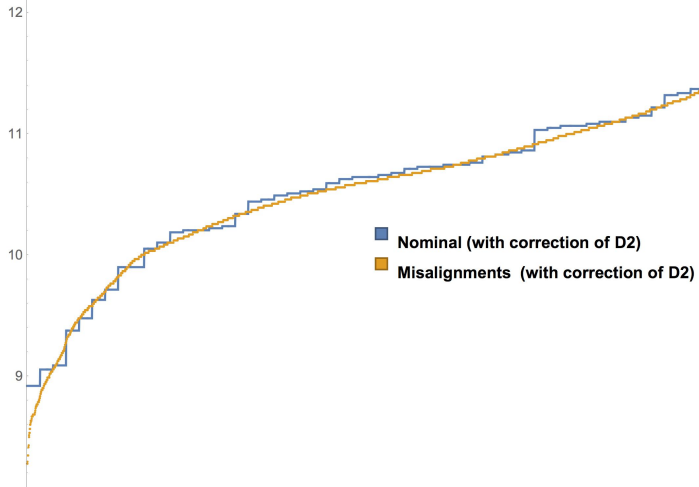
DA per misalignment (64 realisations, beam 4), averaged over 5 angles and 60 seeds

$$\Delta DA = 0.02 \pm 0.06$$



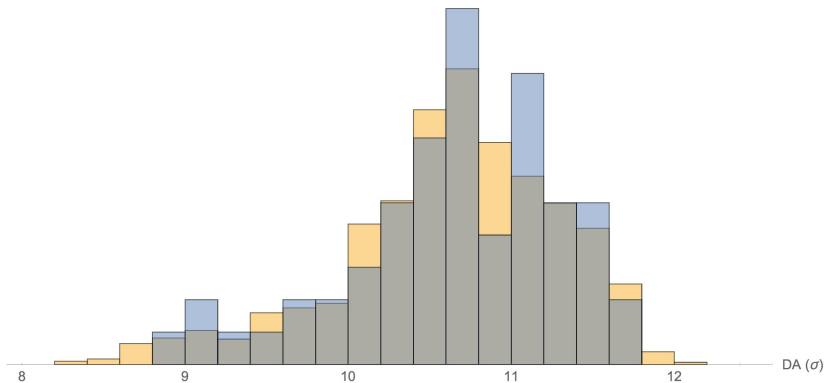
DA per misalignment (64 realisations, beam 4) and per seed (60 seeds), averaged over 5 angles

DA (σ)



DA per misalignment (64 realisations, beam 4) and per seed (60 seeds), averaged over 5 angles

$\Delta DA = 0.02 \pm 0.94$
 $DA_{\text{nominal}} = 10.64 \pm 0.66$
 $DA_{\text{misalignment}} = 10.63 \pm 0.68$

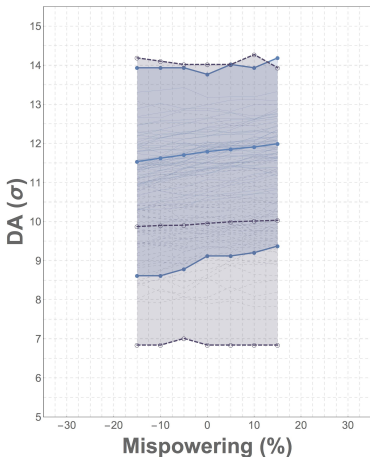


Backup Slides

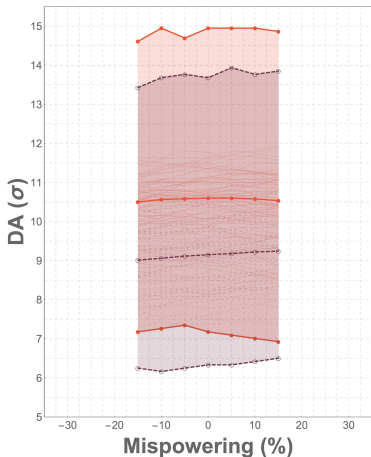
Mispowerings

Mispowering of sextupole correctors

Beam 1



Beam 4

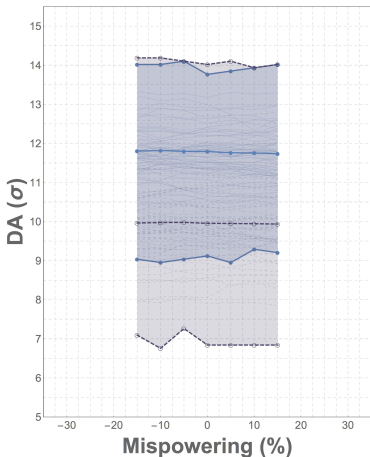


$E = 7000 \text{ GeV}$
 $\varepsilon_n = 2.5 \mu\text{m}$
 $\beta_1^* = 0.15 \text{ m}$
 $\beta_2^* = 10 \text{ m}$
 $\beta_5^* = 0.15 \text{ m}$
 $\beta_8^* = 3 \text{ m}$
 $\theta_c^{1,5} = 590 \text{ mrad}$
 $d_{sep}^{1,5} = 4 \text{ mm}$
 $Q_x = 62.31$
 $Q_y = 60.32$
 $Q' = 3$
 $I_{MO} = 0 \text{ A}$
 $\mu_x^{1 \rightarrow 5} = 31.210$
 $\mu_y^{1 \rightarrow 5} = 30.373$
 $\phi_1 = 90^\circ$
 $\phi_5 = 0^\circ$
 $b_3 \text{ of D2} = 3.8$

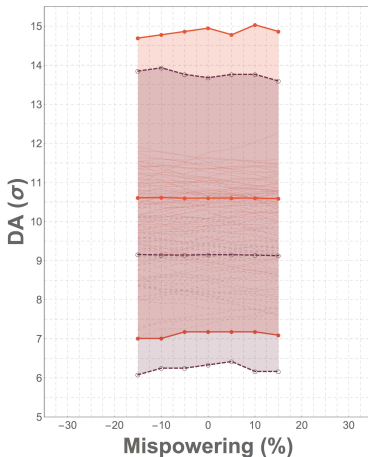
—+— D2 correction
 - - - - no D2 correction

Mispowering of skew sextupole correctors

Beam 1



Beam 4

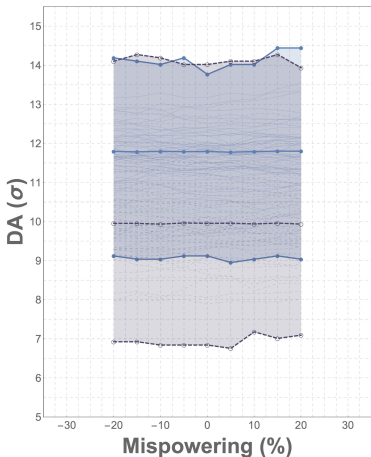


$E = 7000 \text{ GeV}$
 $\varepsilon_n = 2.5 \mu\text{m}$
 $\beta_1^* = 0.15 \text{ m}$
 $\beta_2^* = 10 \text{ m}$
 $\beta_5^* = 0.15 \text{ m}$
 $\beta_8^* = 3 \text{ m}$
 $\theta_c^{1,5} = 590 \text{ mrad}$
 $d_{sep}^{1,5} = 4 \text{ mm}$
 $Q_x = 62.31$
 $Q_y = 60.32$
 $Q' = 3$
 $I_{MO} = 0 \text{ A}$
 $\mu_x^{1 \rightarrow 5} = 31.210$
 $\mu_y^{1 \rightarrow 5} = 30.373$
 $\phi_1 = 90^\circ$
 $\phi_5 = 0^\circ$
 $b_3 \text{ of D2} = 3.8$

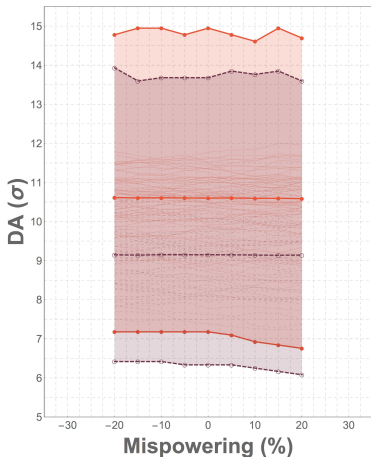
+ D2 correction
 --- no D2 correction

Mispowering of octupole correctors

Beam 1



Beam 4

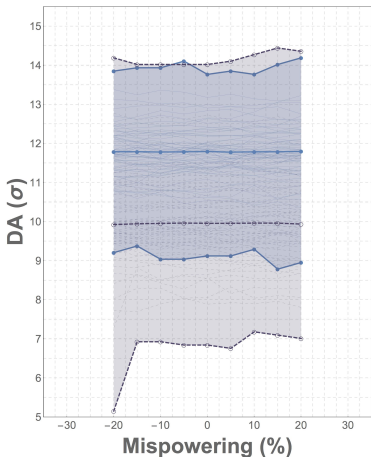


$E = 7000 \text{ GeV}$
 $\varepsilon_n = 2.5 \mu\text{m}$
 $\beta_1^* = 0.15 \text{ m}$
 $\beta_2^* = 10 \text{ m}$
 $\beta_5^* = 0.15 \text{ m}$
 $\beta_8^* = 3 \text{ m}$
 $\theta_c^{1,5} = 590 \text{ mrad}$
 $d_{sep}^{1,5} = 4 \text{ mm}$
 $Q_x = 62.31$
 $Q_y = 60.32$
 $Q' = 3$
 $I_{MO} = 0 \text{ A}$
 $\mu_x^{1 \rightarrow 5} = 31.210$
 $\mu_y^{1 \rightarrow 5} = 30.373$
 $\phi_1 = 90^\circ$
 $\phi_5 = 0^\circ$
 $b_3 \text{ of D2} = 3.8$

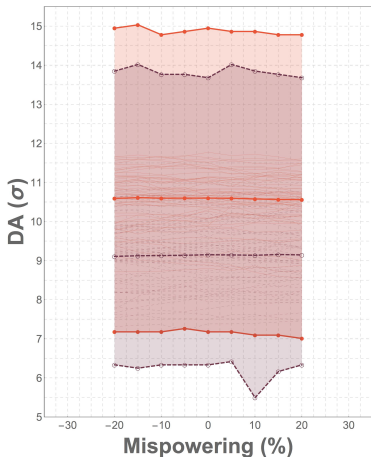
— D2 correction
 - - - no D2 correction

Mispowering of skew octupole correctors

Beam 1



Beam 4

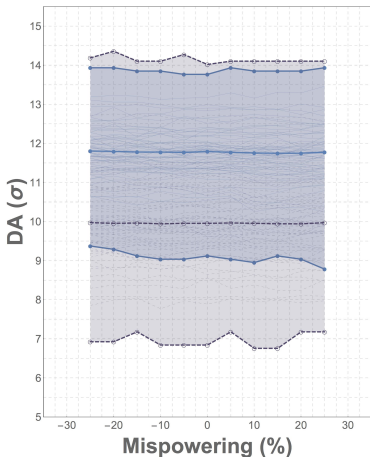


$E = 7000 \text{ GeV}$
 $\varepsilon_n = 2.5 \mu\text{m}$
 $\beta_1^* = 0.15 \text{ m}$
 $\beta_2^* = 10 \text{ m}$
 $\beta_5^* = 0.15 \text{ m}$
 $\beta_8^* = 3 \text{ m}$
 $\theta_c^{1,5} = 590 \text{ mrad}$
 $d_{sep}^{1,5} = 4 \text{ mm}$
 $Q_x = 62.31$
 $Q_y = 60.32$
 $Q' = 3$
 $I_{MO} = 0 \text{ A}$
 $\mu_x^{1 \rightarrow 5} = 31.210$
 $\mu_y^{1 \rightarrow 5} = 30.373$
 $\phi_1 = 90^\circ$
 $\phi_5 = 0^\circ$
 $b_3 \text{ of D2} = 3.8$

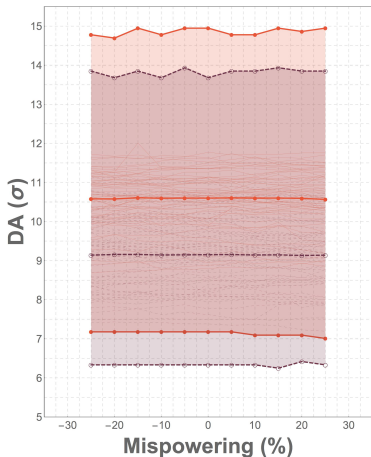
+ D2 correction
 --- no D2 correction

Mispowering of decapole correctors

Beam 1



Beam 4

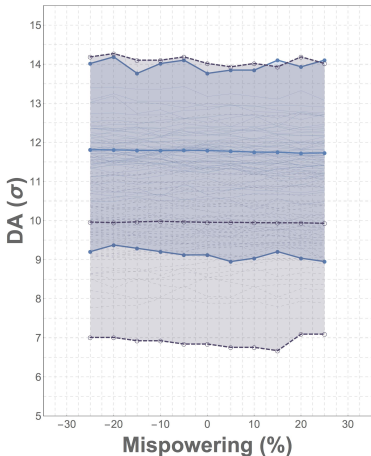


$E = 7000 \text{ GeV}$
 $\varepsilon_n = 2.5 \mu\text{m}$
 $\beta_1^* = 0.15 \text{ m}$
 $\beta_2^* = 10 \text{ m}$
 $\beta_5^* = 0.15 \text{ m}$
 $\beta_8^* = 3 \text{ m}$
 $\theta_c^{1,5} = 590 \text{ mrad}$
 $d_{sep}^{1,5} = 4 \text{ mm}$
 $Q_x = 62.31$
 $Q_y = 60.32$
 $Q' = 3$
 $I_{MO} = 0 \text{ A}$
 $\mu_x^{1 \rightarrow 5} = 31.210$
 $\mu_y^{1 \rightarrow 5} = 30.373$
 $\phi_1 = 90^\circ$
 $\phi_5 = 0^\circ$
 $b_3 \text{ of D2} = 3.8$

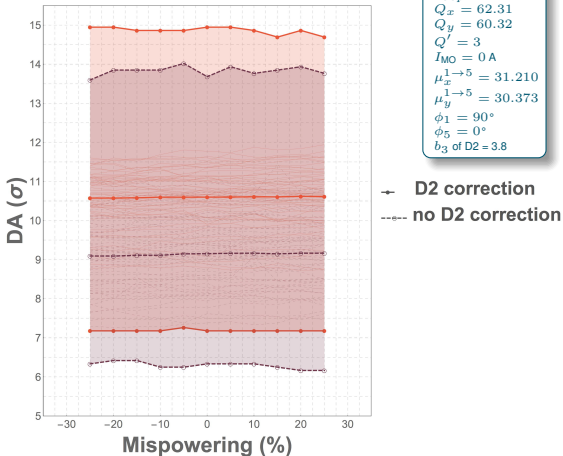
+ D2 correction
 --- no D2 correction

Mispowering of skew decapole correctors

Beam 1



Beam 4

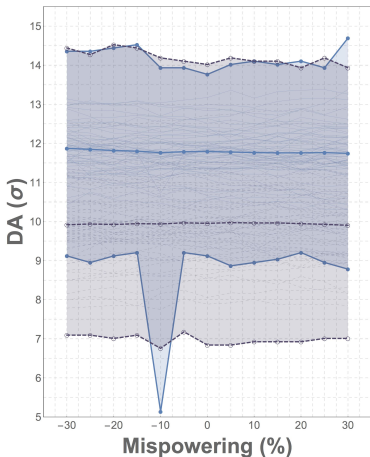


$E = 7000 \text{ GeV}$
 $\varepsilon_n = 2.5 \mu\text{m}$
 $\beta_1^* = 0.15 \text{ m}$
 $\beta_2^* = 10 \text{ m}$
 $\beta_5^* = 0.15 \text{ m}$
 $\beta_8^* = 3 \text{ m}$
 $\theta_c^{1,5} = 590 \text{ mrad}$
 $d_{sep}^{1,5} = 4 \text{ mm}$
 $Q_x = 62.31$
 $Q_y = 60.32$
 $Q' = 3$
 $I_{MO} = 0 \text{ A}$
 $\mu_x^{1 \rightarrow 5} = 31.210$
 $\mu_y^{1 \rightarrow 5} = 30.373$
 $\phi_1 = 90^\circ$
 $\phi_5 = 0^\circ$
 $b_3 \text{ of D2} = 3.8$

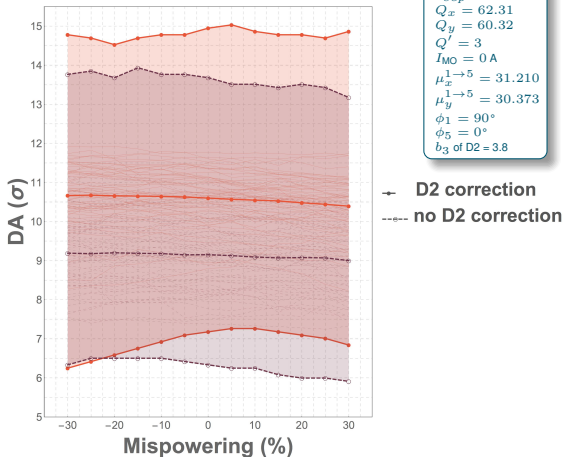
— D2 correction
 - - - no D2 correction

Mispowering of dodecapole correctors

Beam 1



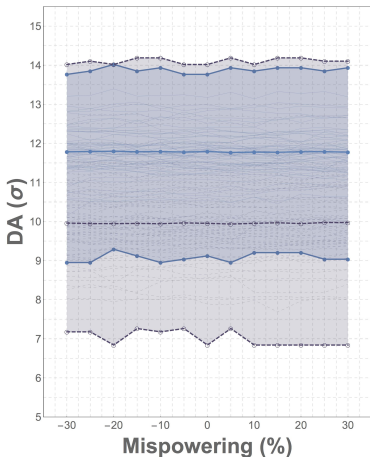
Beam 4



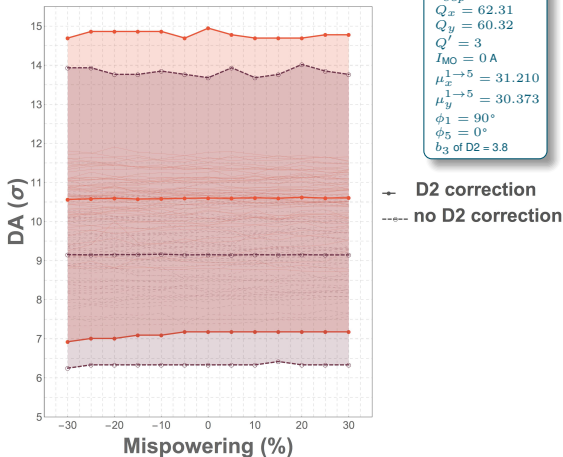
$E = 7000 \text{ GeV}$
 $\varepsilon_n = 2.5 \mu\text{m}$
 $\beta_1^* = 0.15 \text{ m}$
 $\beta_2^* = 10 \text{ m}$
 $\beta_5^* = 0.15 \text{ m}$
 $\beta_8^* = 3 \text{ m}$
 $\theta_c^{1,5} = 590 \text{ mrad}$
 $d_{sep}^{1,5} = 4 \text{ mm}$
 $Q_x = 62.31$
 $Q_y = 60.32$
 $Q' = 3$
 $I_{MO} = 0 \text{ A}$
 $\mu_x^{1 \rightarrow 5} = 31.210$
 $\mu_y^{1 \rightarrow 5} = 30.373$
 $\phi_1 = 90^\circ$
 $\phi_5 = 0^\circ$
 $b_3 \text{ of D2} = 3.8$

Mispowering of skew dodecapole correctors

Beam 1



Beam 4

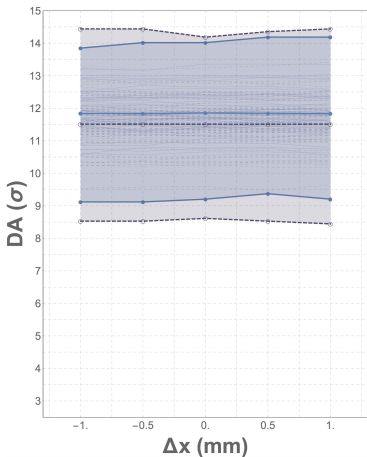


$E = 7000 \text{ GeV}$
 $\varepsilon_n = 2.5 \mu\text{m}$
 $\beta_1^* = 0.15 \text{ m}$
 $\beta_2^* = 10 \text{ m}$
 $\beta_5^* = 0.15 \text{ m}$
 $\beta_8^* = 3 \text{ m}$
 $\theta_c^{1,5} = 590 \text{ mrad}$
 $d_{sep}^{1,5} = 4 \text{ mm}$
 $Q_x = 62.31$
 $Q_y = 60.32$
 $Q' = 3$
 $I_{MO} = 0 \text{ A}$
 $\mu_x^{1 \rightarrow 5} = 31.210$
 $\mu_y^{1 \rightarrow 5} = 30.373$
 $\phi_1 = 90^\circ$
 $\phi_5 = 0^\circ$
 $b_3 \text{ of D2} = 3.8$

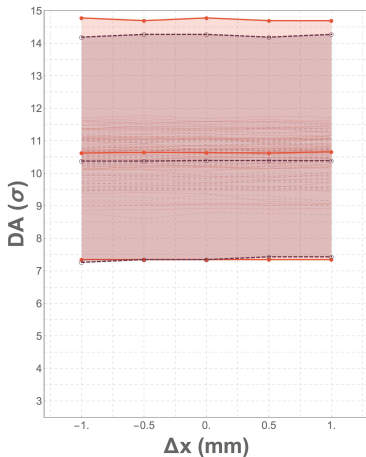
Misalignments

Misalignment of sextupole correctors

Beam 1



Beam 4

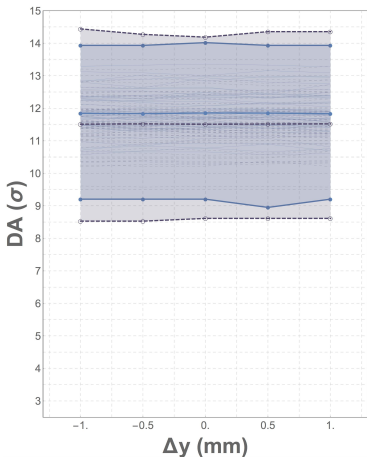


$E = 7000 \text{ GeV}$
 $\epsilon_n = 2.5 \mu\text{m}$
 $\beta_1^* = 0.15 \text{ m}$
 $\beta_2^* = 10 \text{ m}$
 $\beta_5^* = 0.15 \text{ m}$
 $\beta_8^* = 3 \text{ m}$
 $\theta_c^{1,5} = 590 \text{ mrad}$
 $d_{sep}^{1,5} = 4 \text{ mm}$
 $Q_x = 62.31$
 $Q_y = 60.32$
 $Q' = 3$
 $I_{MO} = 0 \text{ A}$
 $\mu_x^{1 \rightarrow 5} = 31.210$
 $\mu_y^{1 \rightarrow 5} = 30.373$
 $\phi_1 = 90^\circ$
 $\phi_5 = 0^\circ$
 $b_3 \text{ of D2} = 1.0$

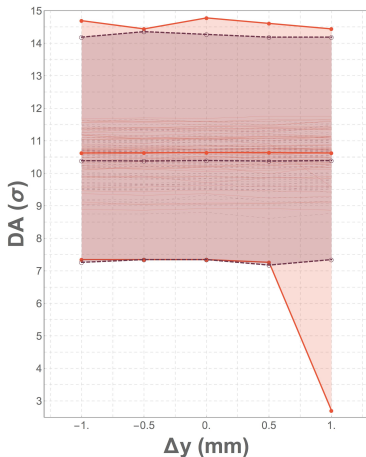
— D2 correction
 - - - no D2 correction

Misalignment of sextupole correctors

Beam 1



Beam 4

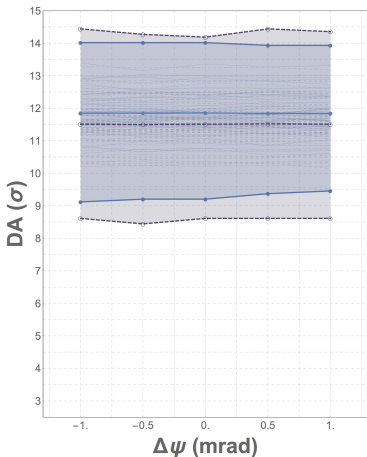


$E = 7000 \text{ GeV}$
 $\epsilon_n = 2.5 \mu\text{m}$
 $\beta_1^* = 0.15 \text{ m}$
 $\beta_2^* = 10 \text{ m}$
 $\beta_5^* = 0.15 \text{ m}$
 $\beta_8^* = 3 \text{ m}$
 $\theta_c^{1,5} = 590 \text{ mrad}$
 $d_{sep}^{1,5} = 4 \text{ mm}$
 $Q_x = 62.31$
 $Q_y = 60.32$
 $Q' = 3$
 $I_{MO} = 0 \text{ A}$
 $\mu_x^{1 \rightarrow 5} = 31.210$
 $\mu_y^{1 \rightarrow 5} = 30.373$
 $\phi_1 = 90^\circ$
 $\phi_5 = 0^\circ$
 $b_3 \text{ of D2} = 1.0$

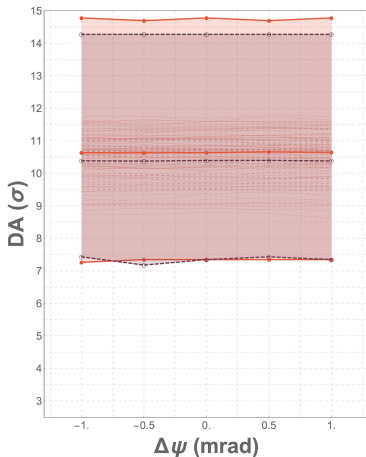
— D2 correction
 - - - no D2 correction

Misrotation of sextupole correctors

Beam 1



Beam 4

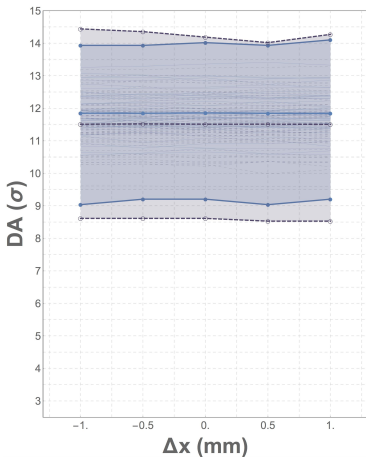


$E = 7000 \text{ GeV}$
 $\epsilon_n = 2.5 \mu\text{m}$
 $\beta_1^* = 0.15 \text{ m}$
 $\beta_2^* = 10 \text{ m}$
 $\beta_5^* = 0.15 \text{ m}$
 $\beta_8^* = 3 \text{ m}$
 $\theta_c^{1,5} = 590 \text{ mrad}$
 $d_{sep}^{1,5} = 4 \text{ mm}$
 $Q_x = 62.31$
 $Q_y = 60.32$
 $Q' = 3$
 $I_{MO} = 0 \text{ A}$
 $\mu_x^{1 \rightarrow 5} = 31.210$
 $\mu_y^{1 \rightarrow 5} = 30.373$
 $\phi_1 = 90^\circ$
 $\phi_5 = 0^\circ$
 $b_3 \text{ of D2} = 1.0$

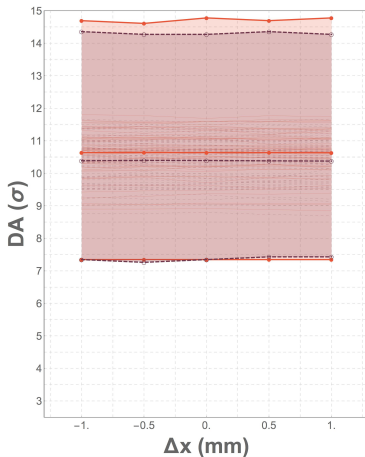
— D2 correction
 - - - no D2 correction

Misalignment of skew sextupole correctors

Beam 1



Beam 4

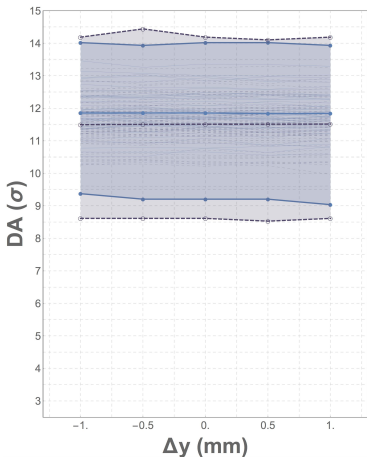


$E = 7000 \text{ GeV}$
 $\epsilon_n = 2.5 \mu\text{m}$
 $\beta_1^* = 0.15 \text{ m}$
 $\beta_2^* = 10 \text{ m}$
 $\beta_5^* = 0.15 \text{ m}$
 $\beta_8^* = 3 \text{ m}$
 $\theta_c^{1,5} = 590 \text{ mrad}$
 $d_{sep}^{1,5} = 4 \text{ mm}$
 $Q_x = 62.31$
 $Q_y = 60.32$
 $Q' = 3$
 $I_{MO} = 0 \text{ A}$
 $\mu_x^{1 \rightarrow 5} = 31.210$
 $\mu_y^{1 \rightarrow 5} = 30.373$
 $\phi_1 = 90^\circ$
 $\phi_5 = 0^\circ$
 $b_3 \text{ of } D2 = 1.0$

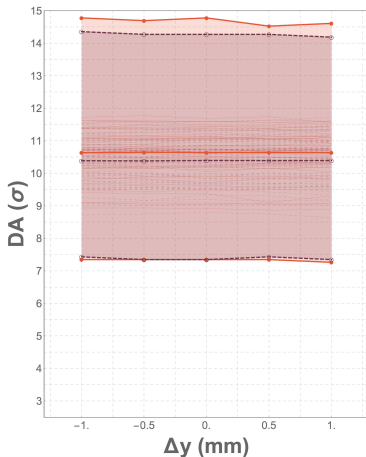
—•— D2 correction
 - - - - no D2 correction

Misalignment of skew sextupole correctors

Beam 1



Beam 4

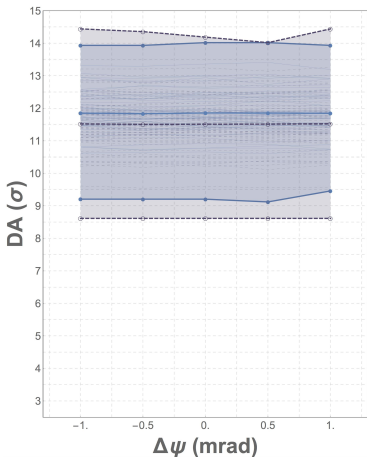


$E = 7000 \text{ GeV}$
 $\epsilon_n = 2.5 \mu\text{m}$
 $\beta_1^* = 0.15 \text{ m}$
 $\beta_2^* = 10 \text{ m}$
 $\beta_5^* = 0.15 \text{ m}$
 $\beta_8^* = 3 \text{ m}$
 $\theta_c^{1,5} = 590 \text{ mrad}$
 $d_{sep}^{1,5} = 4 \text{ mm}$
 $Q_x = 62.31$
 $Q_y = 60.32$
 $Q' = 3$
 $I_{MO} = 0 \text{ A}$
 $\mu_x^{1 \rightarrow 5} = 31.210$
 $\mu_y^{1 \rightarrow 5} = 30.373$
 $\phi_1 = 90^\circ$
 $\phi_5 = 0^\circ$
 $b_3 \text{ of D2} = 1.0$

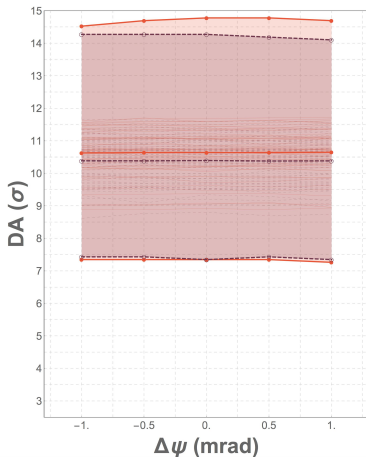
— D2 correction
 - - - no D2 correction

Misrotation of skew sextupole correctors

Beam 1



Beam 4

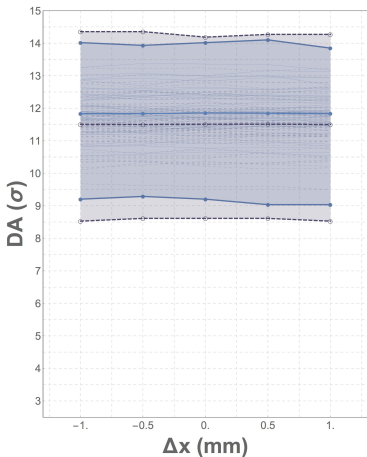


$E = 7000 \text{ GeV}$
 $\epsilon_n = 2.5 \mu\text{m}$
 $\beta_1^* = 0.15 \text{ m}$
 $\beta_2^* = 10 \text{ m}$
 $\beta_5^* = 0.15 \text{ m}$
 $\beta_8^* = 3 \text{ m}$
 $\theta_c^{1,5} = 590 \text{ mrad}$
 $d_{sep}^{1,5} = 4 \text{ mm}$
 $Q_x = 62.31$
 $Q_y = 60.32$
 $Q' = 3$
 $I_{MO} = 0 \text{ A}$
 $\mu_x^{1 \rightarrow 5} = 31.210$
 $\mu_y^{1 \rightarrow 5} = 30.373$
 $\phi_1 = 90^\circ$
 $\phi_5 = 0^\circ$
 $b_3 \text{ of D2} = 1.0$

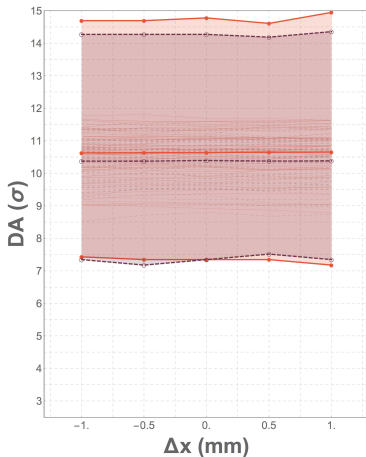
—•— D2 correction
 - - - - no D2 correction

Misalignment of octupole correctors

Beam 1



Beam 4

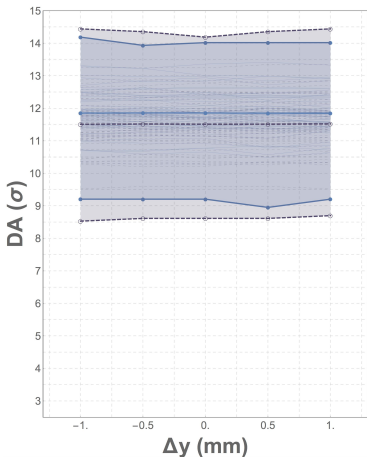


$E = 7000 \text{ GeV}$
 $\epsilon_n = 2.5 \mu\text{m}$
 $\beta_1^* = 0.15 \text{ m}$
 $\beta_2^* = 10 \text{ m}$
 $\beta_5^* = 0.15 \text{ m}$
 $\beta_8^* = 3 \text{ m}$
 $\theta_c^{1,5} = 590 \text{ mrad}$
 $d_{sep}^{1,5} = 4 \text{ mm}$
 $Q_x = 62.31$
 $Q_y = 60.32$
 $Q' = 3$
 $I_{MO} = 0 \text{ A}$
 $\mu_x^{1 \rightarrow 5} = 31.210$
 $\mu_y^{1 \rightarrow 5} = 30.373$
 $\phi_1 = 90^\circ$
 $\phi_5 = 0^\circ$
 $b_3 \text{ of D2} = 1.0$

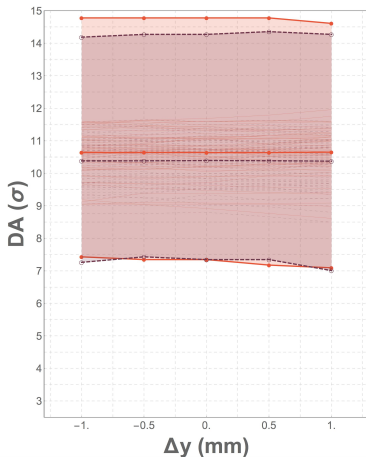
— D2 correction
 - - - no D2 correction

Misalignment of octupole correctors

Beam 1



Beam 4

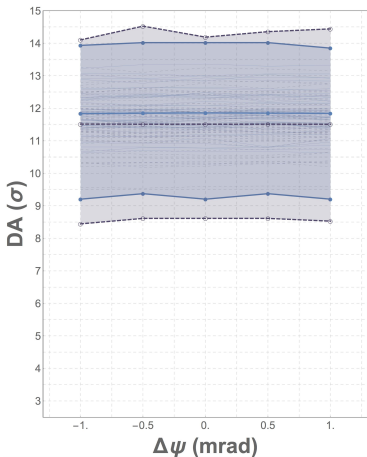


$E = 7000 \text{ GeV}$
 $\epsilon_n = 2.5 \mu\text{m}$
 $\beta_1^* = 0.15 \text{ m}$
 $\beta_2^* = 10 \text{ m}$
 $\beta_5^* = 0.15 \text{ m}$
 $\beta_8^* = 3 \text{ m}$
 $\theta_c^{1,5} = 590 \text{ mrad}$
 $d_{sep}^{1,5} = 4 \text{ mm}$
 $Q_x = 62.31$
 $Q_y = 60.32$
 $Q' = 3$
 $I_{MO} = 0 \text{ A}$
 $\mu_x^{1 \rightarrow 5} = 31.210$
 $\mu_y^{1 \rightarrow 5} = 30.373$
 $\phi_1 = 90^\circ$
 $\phi_5 = 0^\circ$
 $b_3 \text{ of D2} = 1.0$

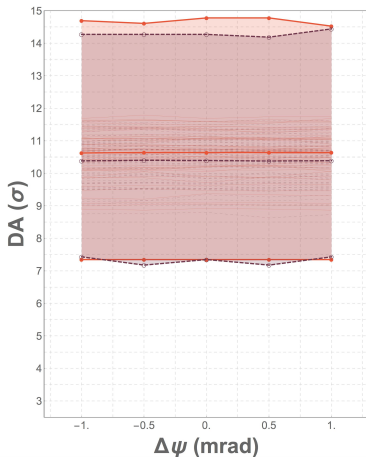
— D2 correction
 - - - no D2 correction

Misrotation of octupole correctors

Beam 1



Beam 4

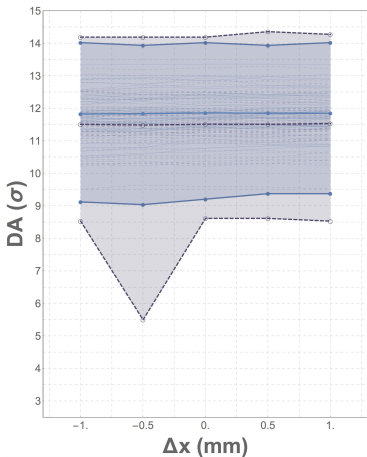


$E = 7000$ GeV
 $\epsilon_n = 2.5 \mu\text{m}$
 $\beta_1^* = 0.15$ m
 $\beta_2^* = 10$ m
 $\beta_5^* = 0.15$ m
 $\beta_8^* = 3$ m
 $\theta_c^{1,5} = 590$ mrad
 $d_{sep}^{1,5} = 4$ mm
 $Q_x = 62.31$
 $Q_y = 60.32$
 $Q' = 3$
 $I_{MO} = 0$ A
 $\mu_x^{1 \rightarrow 5} = 31.210$
 $\mu_y^{1 \rightarrow 5} = 30.373$
 $\phi_1 = 90^\circ$
 $\phi_5 = 0^\circ$
 b_3 of D2 = 1.0

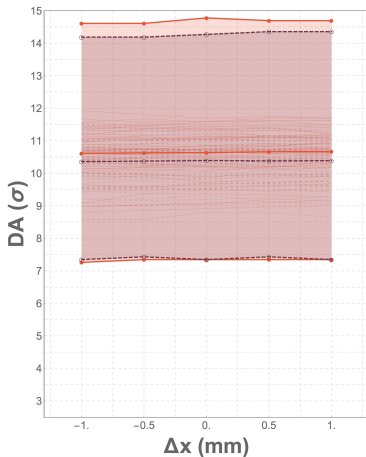
— D2 correction
 - - - no D2 correction

Misalignment of skew octupole correctors

Beam 1



Beam 4

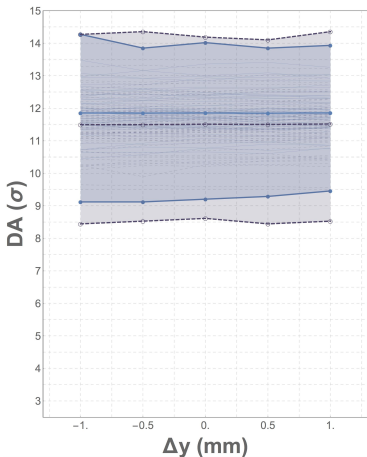


$E = 7000 \text{ GeV}$
 $\epsilon_n = 2.5 \mu\text{m}$
 $\beta_1^* = 0.15 \text{ m}$
 $\beta_2^* = 10 \text{ m}$
 $\beta_5^* = 0.15 \text{ m}$
 $\beta_8^* = 3 \text{ m}$
 $\theta_c^{1,5} = 590 \text{ mrad}$
 $d_{sep}^{1,5} = 4 \text{ mm}$
 $Q_x = 62.31$
 $Q_y = 60.32$
 $Q' = 3$
 $I_{MO} = 0 \text{ A}$
 $\mu_x^{1 \rightarrow 5} = 31.210$
 $\mu_y^{1 \rightarrow 5} = 30.373$
 $\phi_1 = 90^\circ$
 $\phi_5 = 0^\circ$
 $b_3 \text{ of } D2 = 1.0$

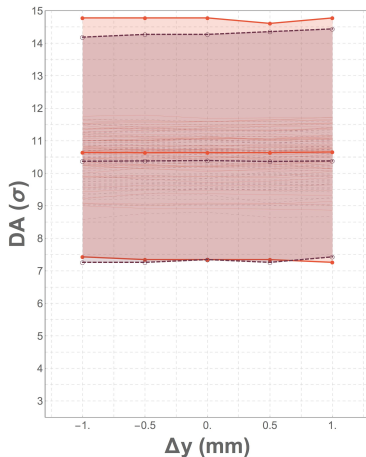
— D2 correction
 - - - no D2 correction

Misalignment of skew octupole correctors

Beam 1



Beam 4

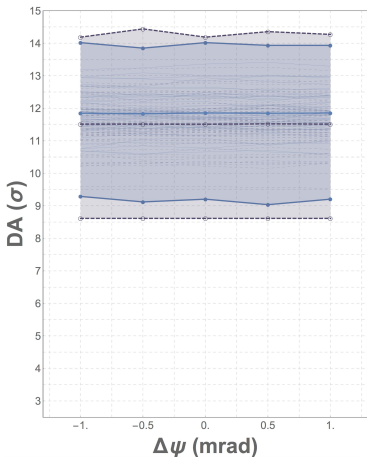


$E = 7000$ GeV
 $\epsilon_n = 2.5 \mu\text{m}$
 $\beta_1^* = 0.15$ m
 $\beta_2^* = 10$ m
 $\beta_5^* = 0.15$ m
 $\beta_8^* = 3$ m
 $\theta_c^{1,5} = 590$ mrad
 $d_{sep}^{1,5} = 4$ mm
 $Q_x = 62.31$
 $Q_y = 60.32$
 $Q' = 3$
 $I_{MO} = 0$ A
 $\mu_x^{1 \rightarrow 5} = 31.210$
 $\mu_y^{1 \rightarrow 5} = 30.373$
 $\phi_1 = 90^\circ$
 $\phi_5 = 0^\circ$
 b_3 of D2 = 1.0

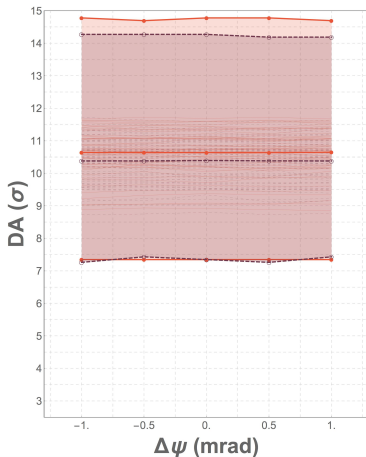
— D2 correction
 - - - no D2 correction

Misrotation of skew octupole correctors

Beam 1



Beam 4

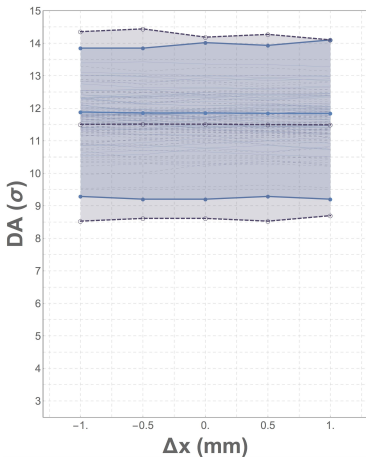


$E = 7000$ GeV
 $\epsilon_n = 2.5 \mu\text{m}$
 $\beta_1^* = 0.15$ m
 $\beta_2^* = 10$ m
 $\beta_5^* = 0.15$ m
 $\beta_8^* = 3$ m
 $\theta_c^{1,5} = 590$ mrad
 $d_{sep}^{1,5} = 4$ mm
 $Q_x = 62.31$
 $Q_y = 60.32$
 $Q' = 3$
 $I_{MO} = 0$ A
 $\mu_x^{1 \rightarrow 5} = 31.210$
 $\mu_y^{1 \rightarrow 5} = 30.373$
 $\phi_1 = 90^\circ$
 $\phi_5 = 0^\circ$
 b_3 of D2 = 1.0

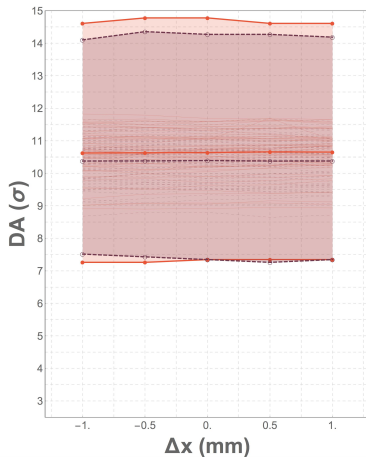
— D2 correction
 - - - no D2 correction

Misalignment of decapole correctors

Beam 1



Beam 4

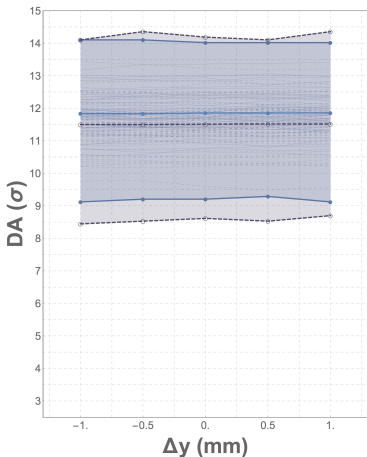


$E = 7000$ GeV
 $\epsilon_n = 2.5 \mu\text{m}$
 $\beta_1^* = 0.15$ m
 $\beta_2^* = 10$ m
 $\beta_5^* = 0.15$ m
 $\beta_8^* = 3$ m
 $\theta_c^{1,5} = 590$ mrad
 $d_{sep}^{1,5} = 4$ mm
 $Q_x = 62.31$
 $Q_y = 60.32$
 $Q' = 3$
 $I_{MO} = 0$ A
 $\mu_x^{1 \rightarrow 5} = 31.210$
 $\mu_y^{1 \rightarrow 5} = 30.373$
 $\phi_1 = 90^\circ$
 $\phi_5 = 0^\circ$
 b_3 of D2 = 1.0

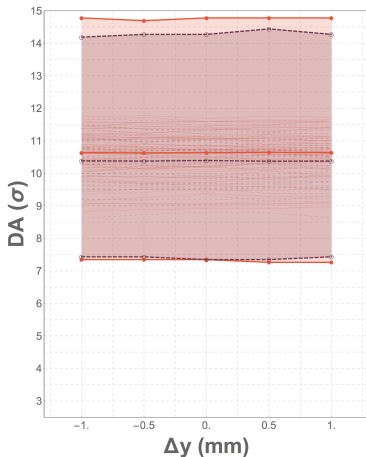
— D2 correction
 - - - no D2 correction

Misalignment of decapole correctors

Beam 1



Beam 4

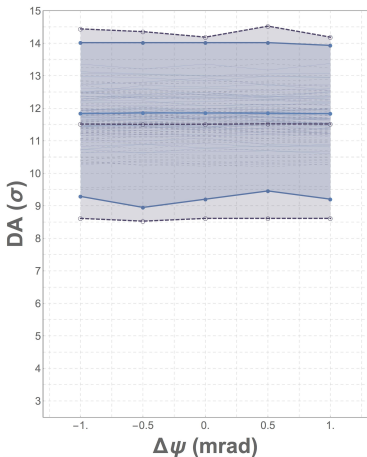


$E = 7000$ GeV
 $\epsilon_n = 2.5 \mu\text{m}$
 $\beta_1^* = 0.15$ m
 $\beta_2^* = 10$ m
 $\beta_5^* = 0.15$ m
 $\beta_8^* = 3$ m
 $\theta_c^{1,5} = 590$ mrad
 $d_{sep}^{1,5} = 4$ mm
 $Q_x = 62.31$
 $Q_y = 60.32$
 $Q' = 3$
 $I_{MO} = 0$ A
 $\mu_x^{1 \rightarrow 5} = 31.210$
 $\mu_y^{1 \rightarrow 5} = 30.373$
 $\phi_1 = 90^\circ$
 $\phi_5 = 0^\circ$
 b_3 of D2 = 1.0

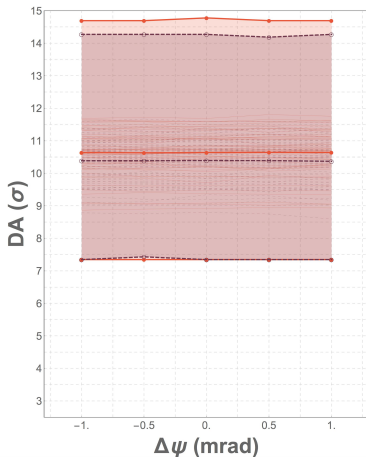
— D2 correction
 - - - no D2 correction

Misrotation of decapole correctors

Beam 1



Beam 4

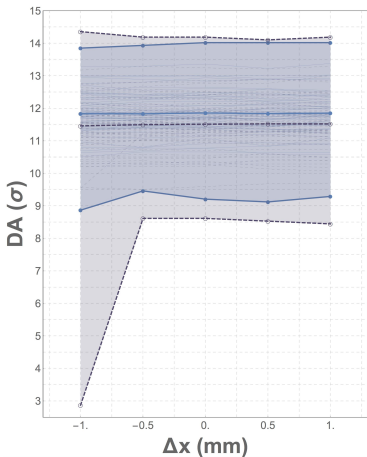


$E = 7000$ GeV
 $\epsilon_n = 2.5 \mu\text{m}$
 $\beta_1^* = 0.15$ m
 $\beta_2^* = 10$ m
 $\beta_5^* = 0.15$ m
 $\beta_8^* = 3$ m
 $\theta_c^{1,5} = 590$ mrad
 $d_{sep}^{1,5} = 4$ mm
 $Q_x = 62.31$
 $Q_y = 60.32$
 $Q' = 3$
 $I_{MO} = 0$ A
 $\mu_x^{1 \rightarrow 5} = 31.210$
 $\mu_y^{1 \rightarrow 5} = 30.373$
 $\phi_1 = 90^\circ$
 $\phi_5 = 0^\circ$
 b_3 of D2 = 1.0

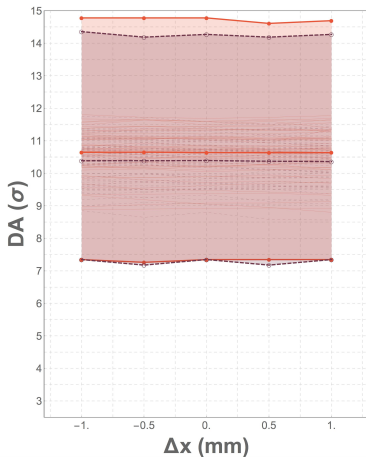
— D2 correction
 - - - no D2 correction

Misalignment of skew decapole correctors

Beam 1



Beam 4

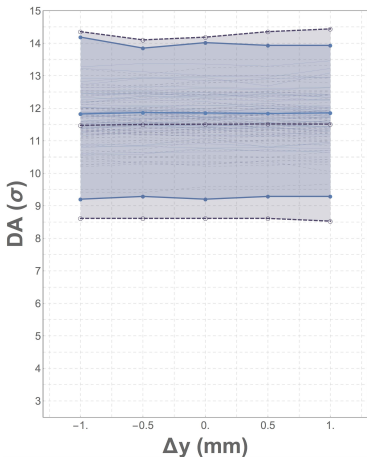


$E = 7000 \text{ GeV}$
 $\epsilon_n = 2.5 \mu\text{m}$
 $\beta_1^* = 0.15 \text{ m}$
 $\beta_2^* = 10 \text{ m}$
 $\beta_5^* = 0.15 \text{ m}$
 $\beta_8^* = 3 \text{ m}$
 $\theta_c^{1,5} = 590 \text{ mrad}$
 $d_{sep}^{1,5} = 4 \text{ mm}$
 $Q_x = 62.31$
 $Q_y = 60.32$
 $Q' = 3$
 $I_{MO} = 0 \text{ A}$
 $\mu_x^{1 \rightarrow 5} = 31.210$
 $\mu_y^{1 \rightarrow 5} = 30.373$
 $\phi_1 = 90^\circ$
 $\phi_5 = 0^\circ$
 $b_3 \text{ of D2} = 1.0$

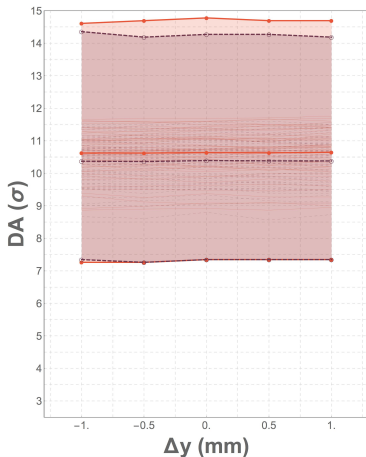
— D2 correction
 - - - no D2 correction

Misalignment of skew decapole correctors

Beam 1



Beam 4

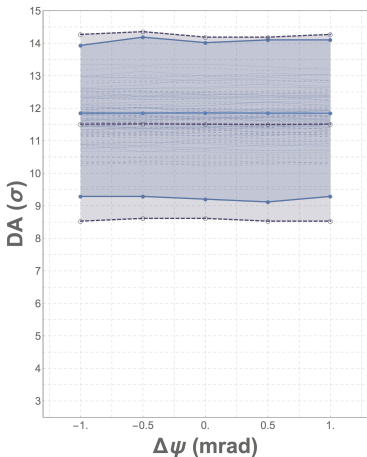


$E = 7000$ GeV
 $\epsilon_n = 2.5 \mu\text{m}$
 $\beta_1^* = 0.15$ m
 $\beta_2^* = 10$ m
 $\beta_5^* = 0.15$ m
 $\beta_8^* = 3$ m
 $\theta_c^{1,5} = 590$ mrad
 $d_{sep}^{1,5} = 4$ mm
 $Q_x = 62.31$
 $Q_y = 60.32$
 $Q' = 3$
 $I_{MO} = 0$ A
 $\mu_x^{1 \rightarrow 5} = 31.210$
 $\mu_y^{1 \rightarrow 5} = 30.373$
 $\phi_1 = 90^\circ$
 $\phi_5 = 0^\circ$
 b_3 of D2 = 1.0

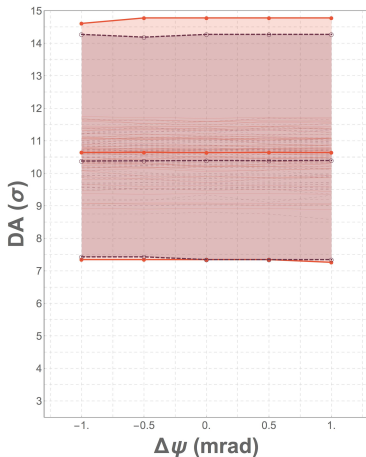
—•— D2 correction
 - - - - no D2 correction

Misrotation of skew decapole correctors

Beam 1



Beam 4

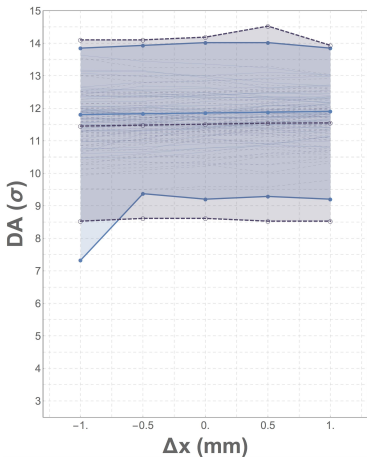


$E = 7000$ GeV
 $\epsilon_n = 2.5 \mu\text{m}$
 $\beta_1^* = 0.15$ m
 $\beta_2^* = 10$ m
 $\beta_5^* = 0.15$ m
 $\beta_8^* = 3$ m
 $\theta_c^{1,5} = 590$ mrad
 $d_{sep}^{1,5} = 4$ mm
 $Q_x = 62.31$
 $Q_y = 60.32$
 $Q' = 3$
 $I_{MO} = 0$ A
 $\mu_x^{1 \rightarrow 5} = 31.210$
 $\mu_y^{1 \rightarrow 5} = 30.373$
 $\phi_1 = 90^\circ$
 $\phi_5 = 0^\circ$
 b_3 of D2 = 1.0

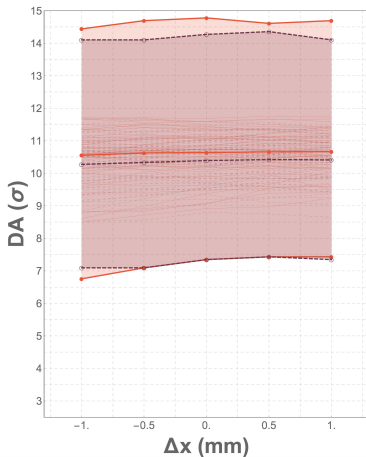
— D2 correction
 - - - no D2 correction

Misalignment of dodecapole correctors

Beam 1



Beam 4

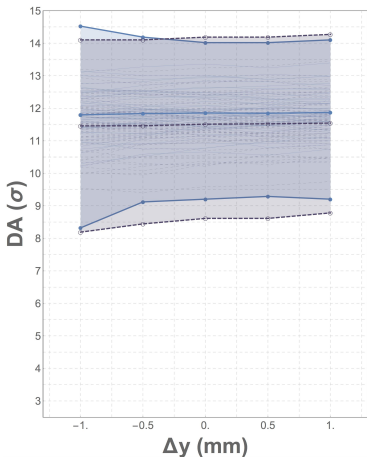


$E = 7000$ GeV
 $\varepsilon_n = 2.5 \mu\text{m}$
 $\beta_1^* = 0.15$ m
 $\beta_2^* = 10$ m
 $\beta_5^* = 0.15$ m
 $\beta_8^* = 3$ m
 $\theta_c^{1,5} = 590$ mrad
 $d_{sep}^{1,5} = 4$ mm
 $Q_x = 62.31$
 $Q_y = 60.32$
 $Q' = 3$
 $I_{MO} = 0$ A
 $\mu_x^{1 \rightarrow 5} = 31.210$
 $\mu_y^{1 \rightarrow 5} = 30.373$
 $\phi_1 = 90^\circ$
 $\phi_5 = 0^\circ$
 b_3 of D2 = 1.0

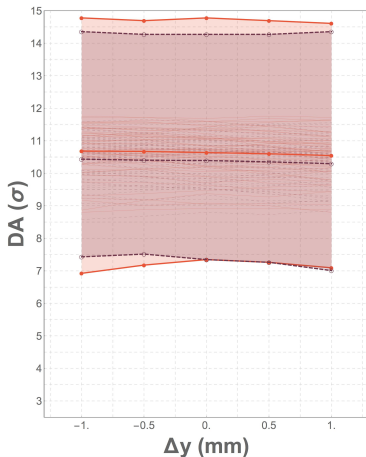
— D2 correction
 - - - no D2 correction

Misalignment of dodecapole correctors

Beam 1



Beam 4

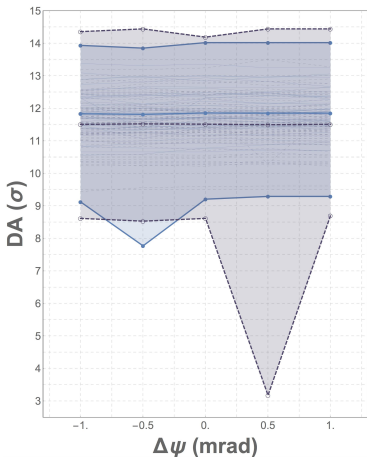


$E = 7000 \text{ GeV}$
 $\varepsilon_n = 2.5 \mu\text{m}$
 $\beta_1^* = 0.15 \text{ m}$
 $\beta_2^* = 10 \text{ m}$
 $\beta_5^* = 0.15 \text{ m}$
 $\beta_8^* = 3 \text{ m}$
 $\theta_c^{1,5} = 590 \text{ mrad}$
 $d_{sep}^{1,5} = 4 \text{ mm}$
 $Q_x = 62.31$
 $Q_y = 60.32$
 $Q' = 3$
 $I_{MO} = 0 \text{ A}$
 $\mu_x^{1 \rightarrow 5} = 31.210$
 $\mu_y^{1 \rightarrow 5} = 30.373$
 $\phi_1 = 90^\circ$
 $\phi_5 = 0^\circ$
 $b_3 \text{ of D2} = 1.0$

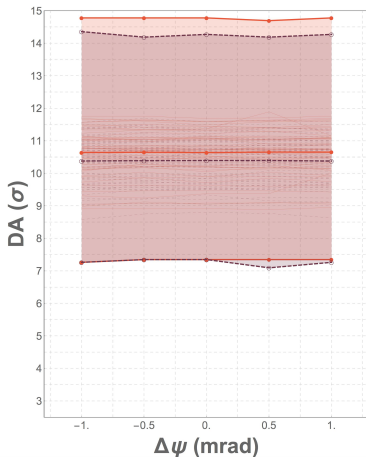
—•— D2 correction
 - - - - - no D2 correction

Misrotation of dodecapole correctors

Beam 1



Beam 4

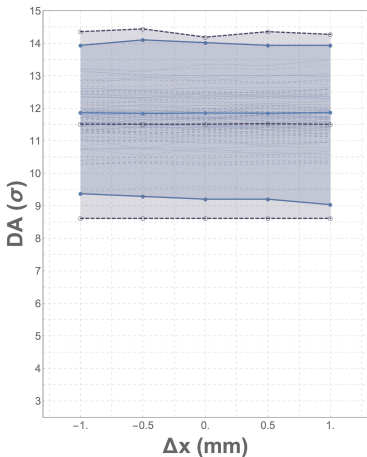


$E = 7000$ GeV
 $\epsilon_n = 2.5 \mu\text{m}$
 $\beta_1^* = 0.15$ m
 $\beta_2^* = 10$ m
 $\beta_5^* = 0.15$ m
 $\beta_8^* = 3$ m
 $\theta_c^{1,5} = 590$ mrad
 $d_{sep}^{1,5} = 4$ mm
 $Q_x = 62.31$
 $Q_y = 60.32$
 $Q' = 3$
 $I_{MO} = 0$ A
 $\mu_x^{1 \rightarrow 5} = 31.210$
 $\mu_y^{1 \rightarrow 5} = 30.373$
 $\phi_1 = 90^\circ$
 $\phi_5 = 0^\circ$
 b_3 of D2 = 1.0

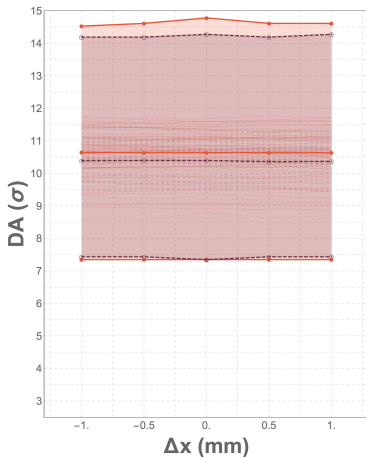
— D2 correction
 - - - no D2 correction

Misalignment of skew dodecapole correctors

Beam 1



Beam 4

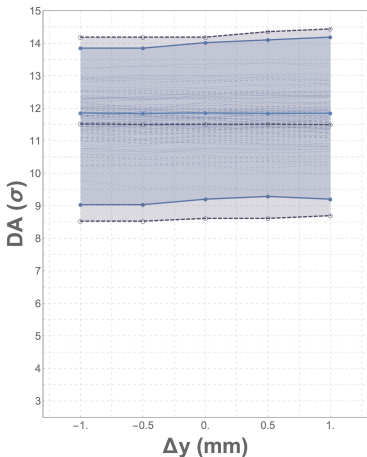


$E = 7000$ GeV
 $\epsilon_n = 2.5 \mu\text{m}$
 $\beta_1^* = 0.15$ m
 $\beta_2^* = 10$ m
 $\beta_5^* = 0.15$ m
 $\beta_8^* = 3$ m
 $\theta_c^{1,5} = 590$ mrad
 $d_{sep}^{1,5} = 4$ mm
 $Q_x = 62.31$
 $Q_y = 60.32$
 $Q' = 3$
 $I_{MO} = 0$ A
 $\mu_x^{1 \rightarrow 5} = 31.210$
 $\mu_y^{1 \rightarrow 5} = 30.373$
 $\phi_1 = 90^\circ$
 $\phi_5 = 0^\circ$
 b_3 of D2 = 1.0

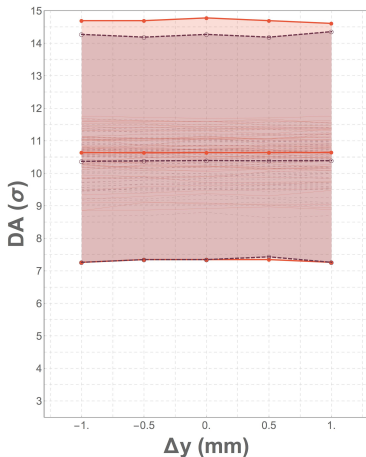
— D2 correction
 - - - no D2 correction

Misalignment of skew dodecapole correctors

Beam 1



Beam 4

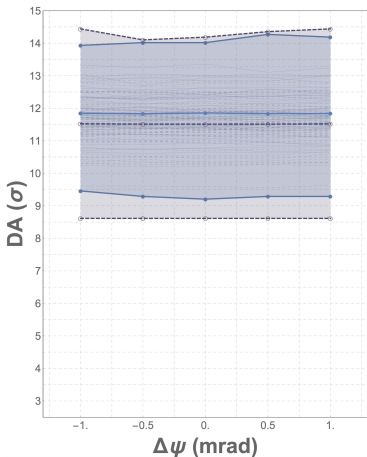


$E = 7000 \text{ GeV}$
 $\epsilon_n = 2.5 \mu\text{m}$
 $\beta_1^* = 0.15 \text{ m}$
 $\beta_2^* = 10 \text{ m}$
 $\beta_5^* = 0.15 \text{ m}$
 $\beta_8^* = 3 \text{ m}$
 $\theta_c^{1,5} = 590 \text{ mrad}$
 $d_{sep}^{1,5} = 4 \text{ mm}$
 $Q_x = 62.31$
 $Q_y = 60.32$
 $Q' = 3$
 $I_{MO} = 0 \text{ A}$
 $\mu_x^{1 \rightarrow 5} = 31.210$
 $\mu_y^{1 \rightarrow 5} = 30.373$
 $\phi_1 = 90^\circ$
 $\phi_5 = 0^\circ$
 $b_3 \text{ of } D2 = 1.0$

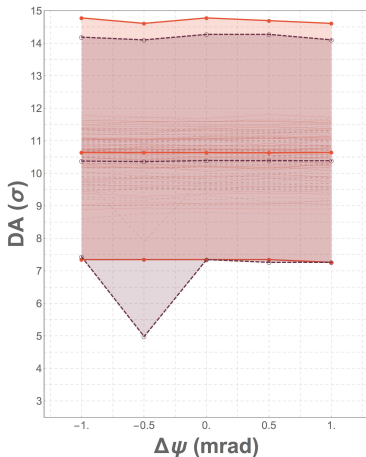
— D2 correction
 - - - no D2 correction

Misrotation of skew dodecapole correctors

Beam 1



Beam 4



$E = 7000$ GeV
 $\epsilon_n = 2.5 \mu\text{m}$
 $\beta_1^* = 0.15$ m
 $\beta_2^* = 10$ m
 $\beta_5^* = 0.15$ m
 $\beta_8^* = 3$ m
 $\theta_c^{1,5} = 590$ mrad
 $d_{sep}^{1,5} = 4$ mm
 $Q_x = 62.31$
 $Q_y = 60.32$
 $Q' = 3$
 $I_{MO} = 0$ A
 $\mu_x^{1 \rightarrow 5} = 31.210$
 $\mu_y^{1 \rightarrow 5} = 30.373$
 $\phi_1 = 90^\circ$
 $\phi_5 = 0^\circ$
 b_3 of D2 = 1.0

— D2 correction
 - - - no D2 correction



www.cern.ch