

# Effective of Systematic $b_6$ errors on beam-beam

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Hilumi-LHC WP2 Meeting  
11.12.2018

# Introduction

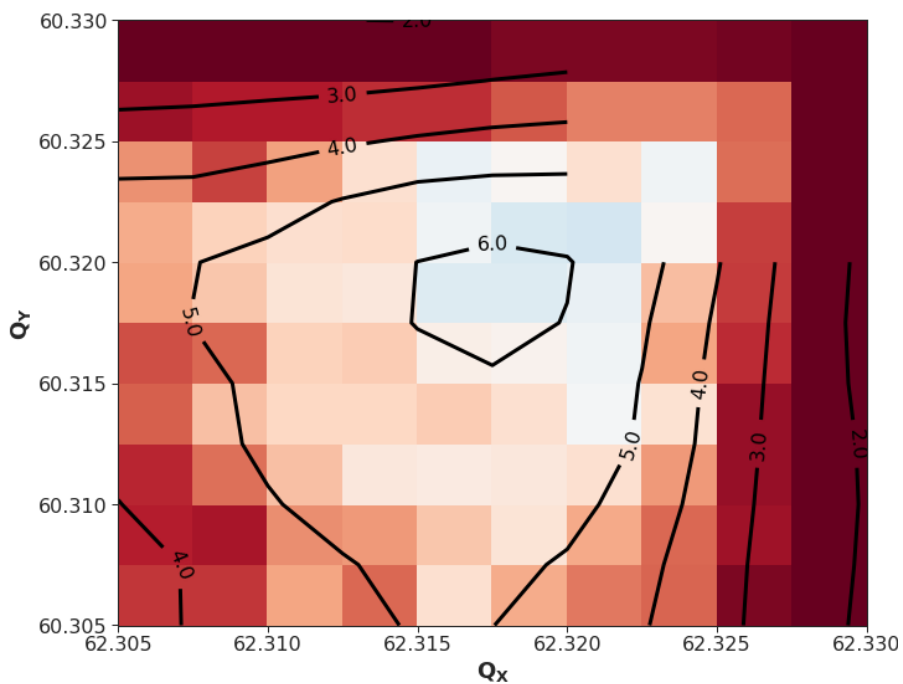
- We evaluate the impact of  **$b_6$  in the presence of BB** under the present operational scenario.
- The study is based around **Frederik's results**:
  - **$b_6=-4$**  & statistical analysis shows the worst performing seed to be **Seed 13**.
- 1. Selecting Seed 13 we evaluate DA in the **worst case scenario for BB**:
  - End of levelling: BBLR dominated, small area of DA available according to the operational scenario.
- 2. Repeat the scan using  **$b_6=-4$**
- 3. Test the impact on the result if **all the available  $b_6$  correctors fail**.
- 4. Select the optimal WP at  $\beta^*=15\text{cm}$  and **scan the 60 seeds**.
- 5. Repeat step 4 at the HO dominated regime: the **start of levelling**.

- N.B.: All simulations performed with  $10^6$  turns over 5 amplitude ranges and 5 angles in the 1<sup>st</sup> quadrant of the configuration space, using the HL-LHC v1.3 optics under the optimized operational scenario (CERN-ACC-NOTE-2018-0002).

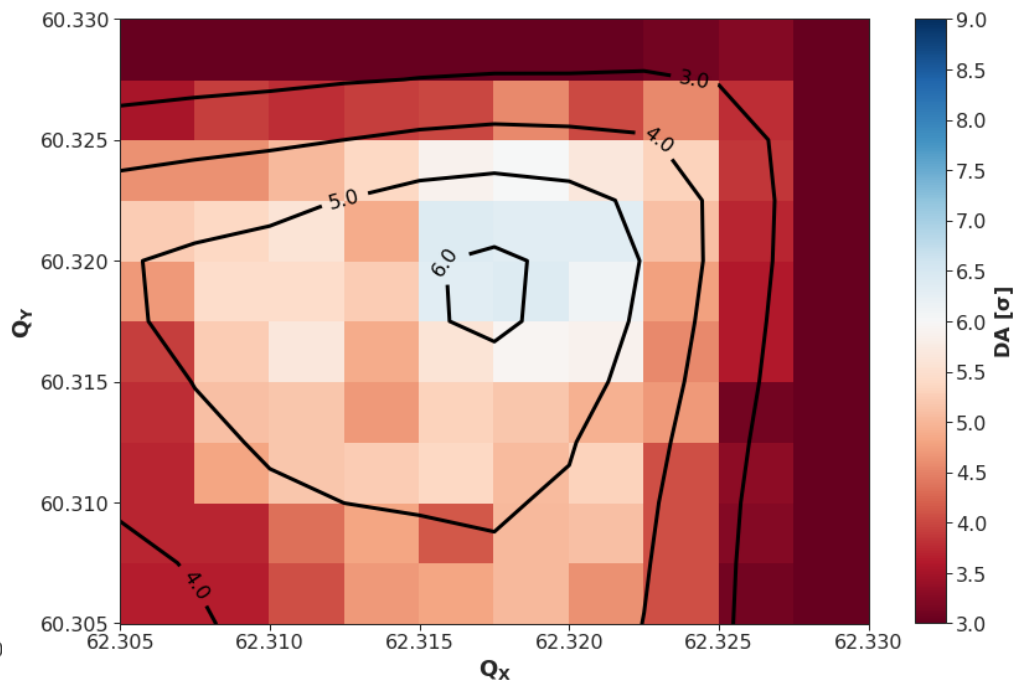
# Seed 1 vs Seed 13

- Comparison of our "no errors" results with the "no errors with seed 13".

Min DA HL-LHC v1.3,  $I=1.2 \times 10^{11}$  ppb,  $\beta^*=0.15\text{m}$   
 $\phi/2=250\mu\text{rad}$ ,  $\epsilon_n=2.5\mu\text{m}$ ,  $Q'=15$ ,  $I_{MO}=-300\text{A}$



Min DA HL-LHC v1.3, Seed 13,  $I=1.2 \times 10^{11}$  ppb,  $\beta^*=0.15\text{m}$   
 $\phi/2=250\mu\text{rad}$ ,  $\epsilon_n=2.5\mu\text{m}$ ,  $Q'=15$ ,  $I_{MO}=-300\text{A}$

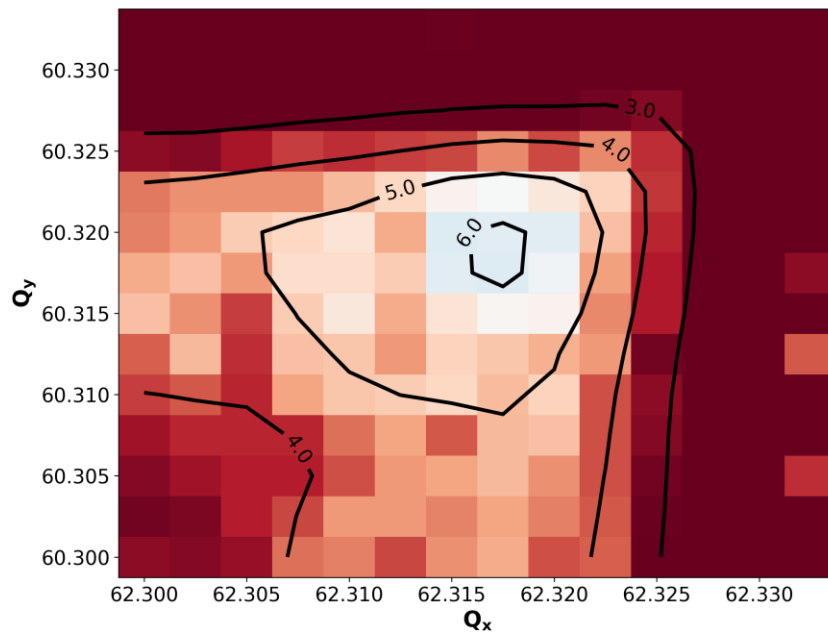


- Not significant change in the nominal scenario.

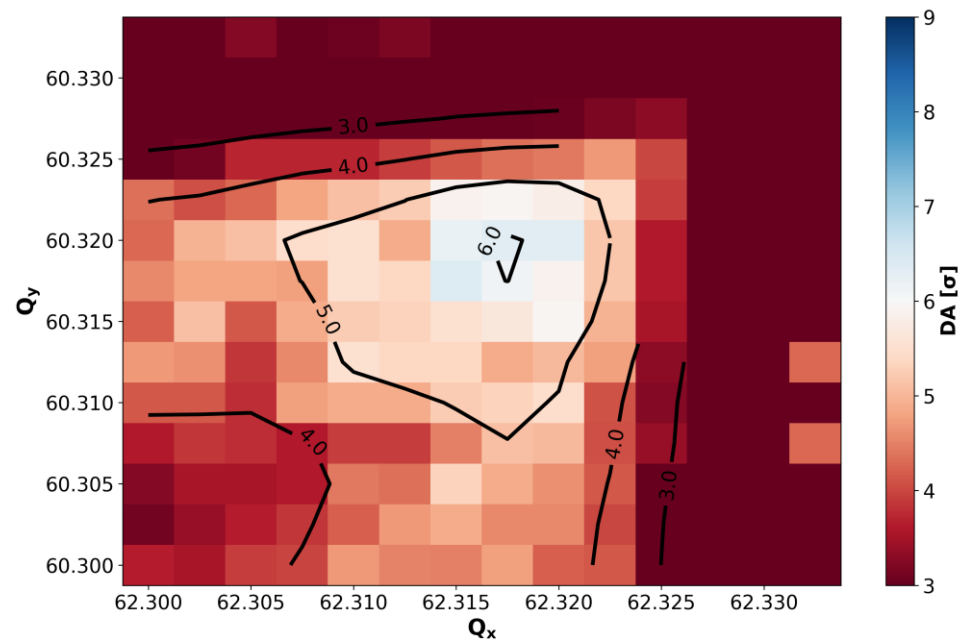
# Impact of $b_6=-4$ on Seed 13

- For the same seed compare the nominal  $b_6$  setting and the  $b_6=-4$  (worst case)

Min DA HL-LHC v1.3, Seed 13, Nominal  $b_6$ ,  $I = 1.2 \times 10^{11}$  ppl  
 $\beta_{IP1}^* = 0.15\text{m}$ ,  $\phi/2 = 250\mu\text{rad}$ ,  $\varepsilon = 2.5\mu\text{m}$ ,  $Q' = 15$ ,  $I_{MO} = -300\text{A}$



Min DA HL-LHC v1.3, Seed 13,  $b_6 = -4$ ,  $I = 1.2 \times 10^{11}$  ppb  
 $\beta_{IP1}^* = 0.15\text{m}$ ,  $\phi/2 = 250\mu\text{rad}$ ,  $\varepsilon = 2.5\mu\text{m}$ ,  $Q' = 15$ ,  $I_{MO} = -300\text{A}$



- The overall impact is small.

# Failure of all correctors

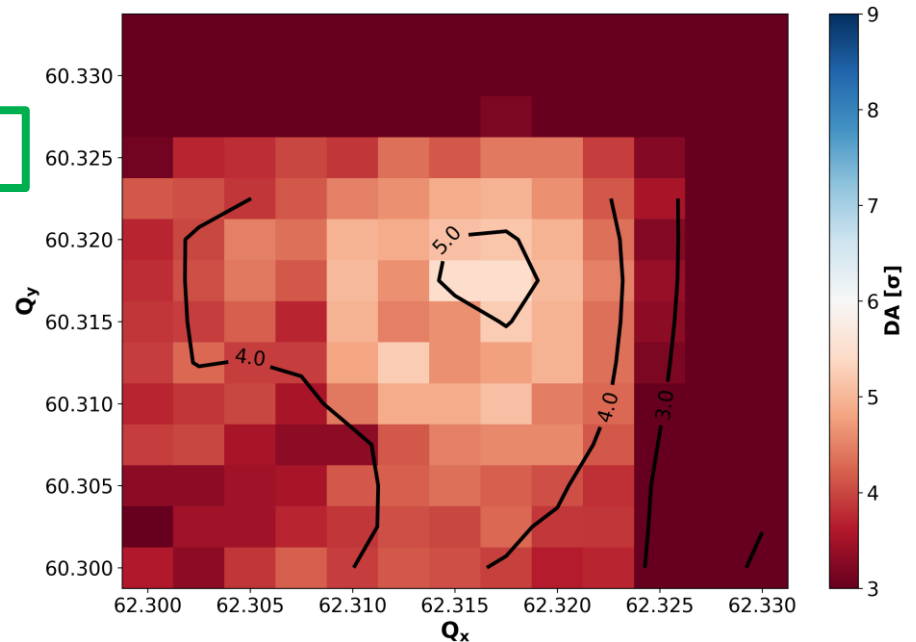
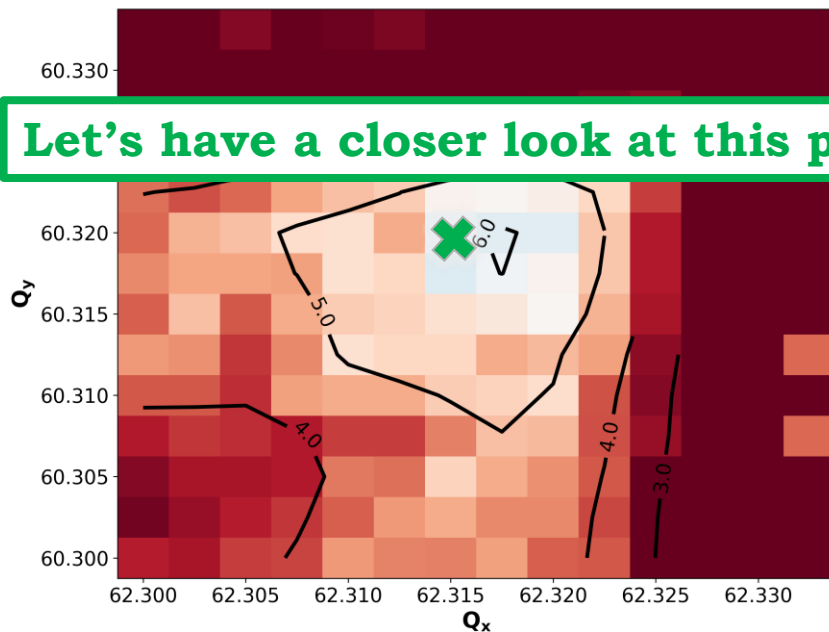
- In this case we compare the case for the seed 13 under a  $b_6 = -4$  in case of all correctors working properly versus if **all correctors fail**.

$$KCTX3.L1 = KCTX3.R1 = KCTX3.L5 = KCTX3.R5 = 0$$

Min DA HL-LHC v1.3, Seed 13,  $b_6 = -4$ ,  $I = 1.2 \times 10^{11}$  ppb  
 $\beta_{IP1}^* = 0.15\text{m}$ ,  $\phi/2 = 250\mu\text{rad}$ ,  $\epsilon = 2.5\mu\text{m}$ ,  $Q' = 15$ ,  $I_{M0} = -300\text{A}$

Min DA HL-LHC v1.3, Seed 13,  $b_6 = -4$  & All IT Correctors Failed  
 $I = 1.2 \times 10^{11}$  ppb,  $\beta_{IP1}^* = 0.15\text{m}$ ,  $\phi/2 = 250\mu\text{rad}$ ,  $\epsilon = 2.5\mu\text{m}$ ,  $Q' = 15$ ,  $I_{M0} = -300\text{A}$

Let's have a closer look at this point



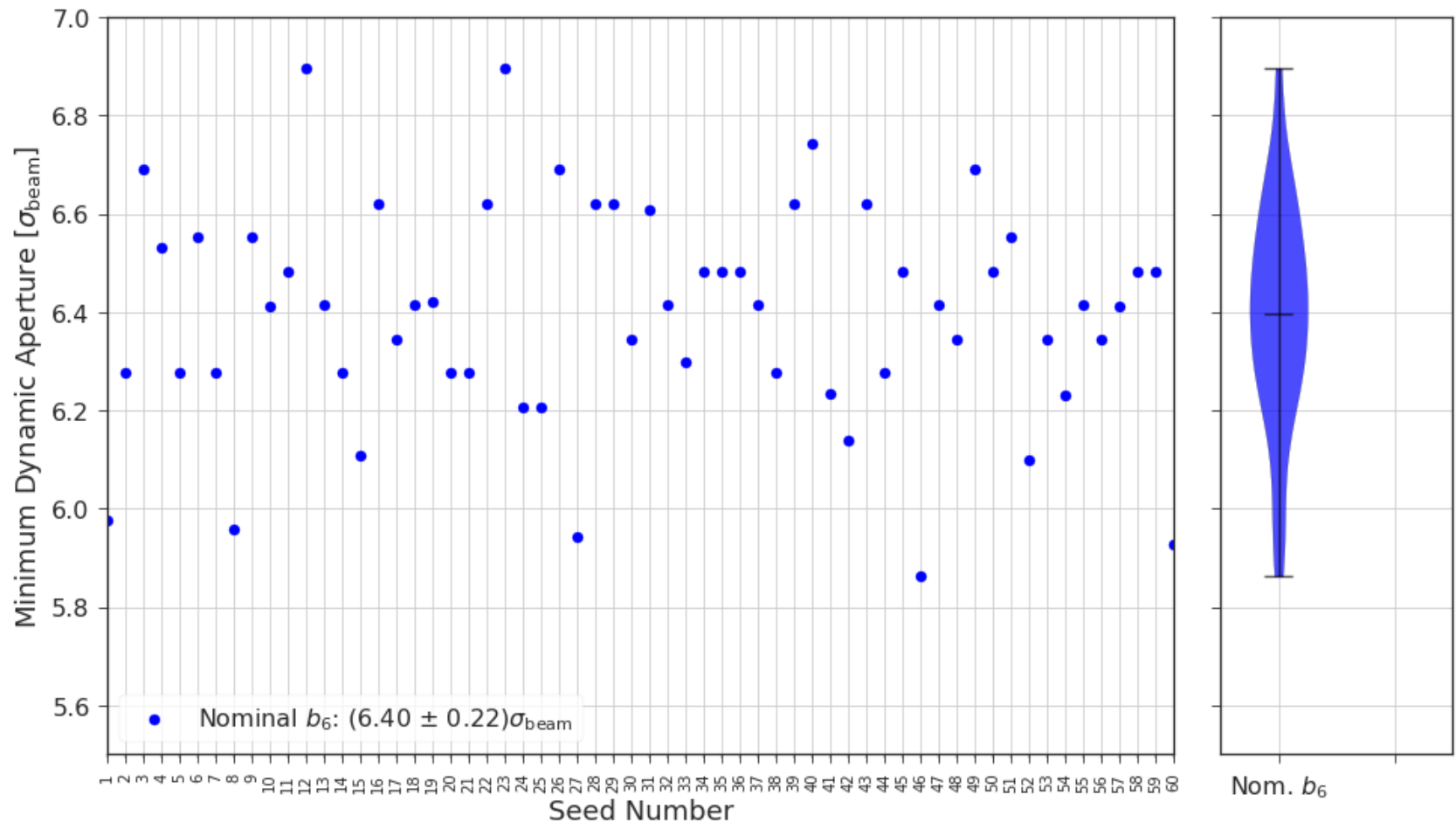
- A reduction of about  $1\sigma$  of DA if all MCTX3 correctors fail in IT of IR1/5.

# Impact of $b_6 = -4$ on all Seeds

- For fixed the WP (62.315, 60.320) compare **across all 60 seeds** the **min DA** for the nominal and the -4 case of  $b_6$

Minimum DA Distribution of  $(Q_x, Q_y) = (62.315, 60.320)$  for 60 seeds

$\beta^* = 15\text{cm}$ ,  $N_b = 1.2 \times 10^{11}$  ppb,  $\phi/2 = 250\mu\text{rad}$ ,  $\varepsilon_n = 2.5\mu\text{m}$ ,  $Q' = 15$

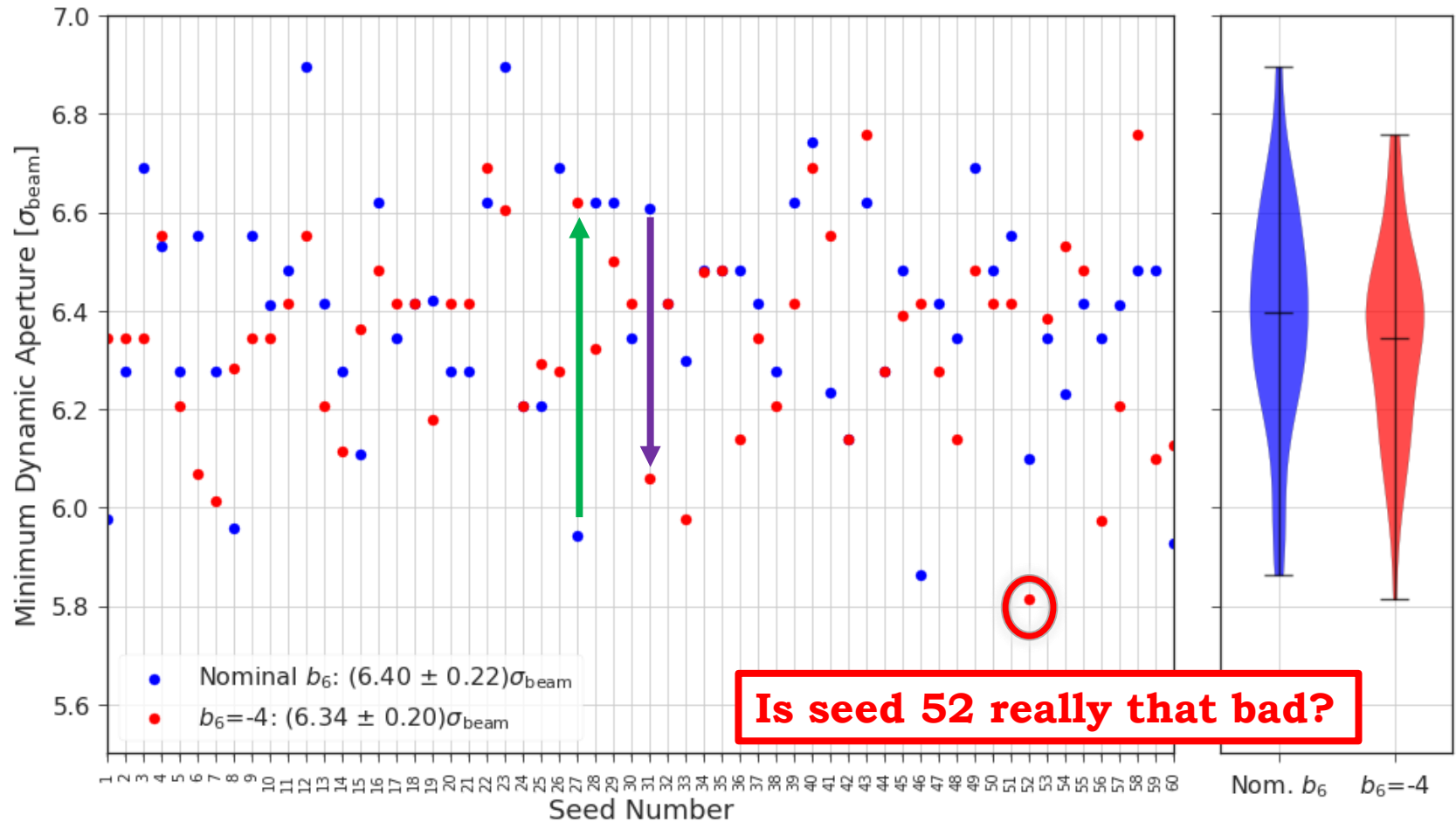


# Impact of $b_6=-4$ on all Seeds

Max gain: Seed 27 by  $+0.68\sigma$

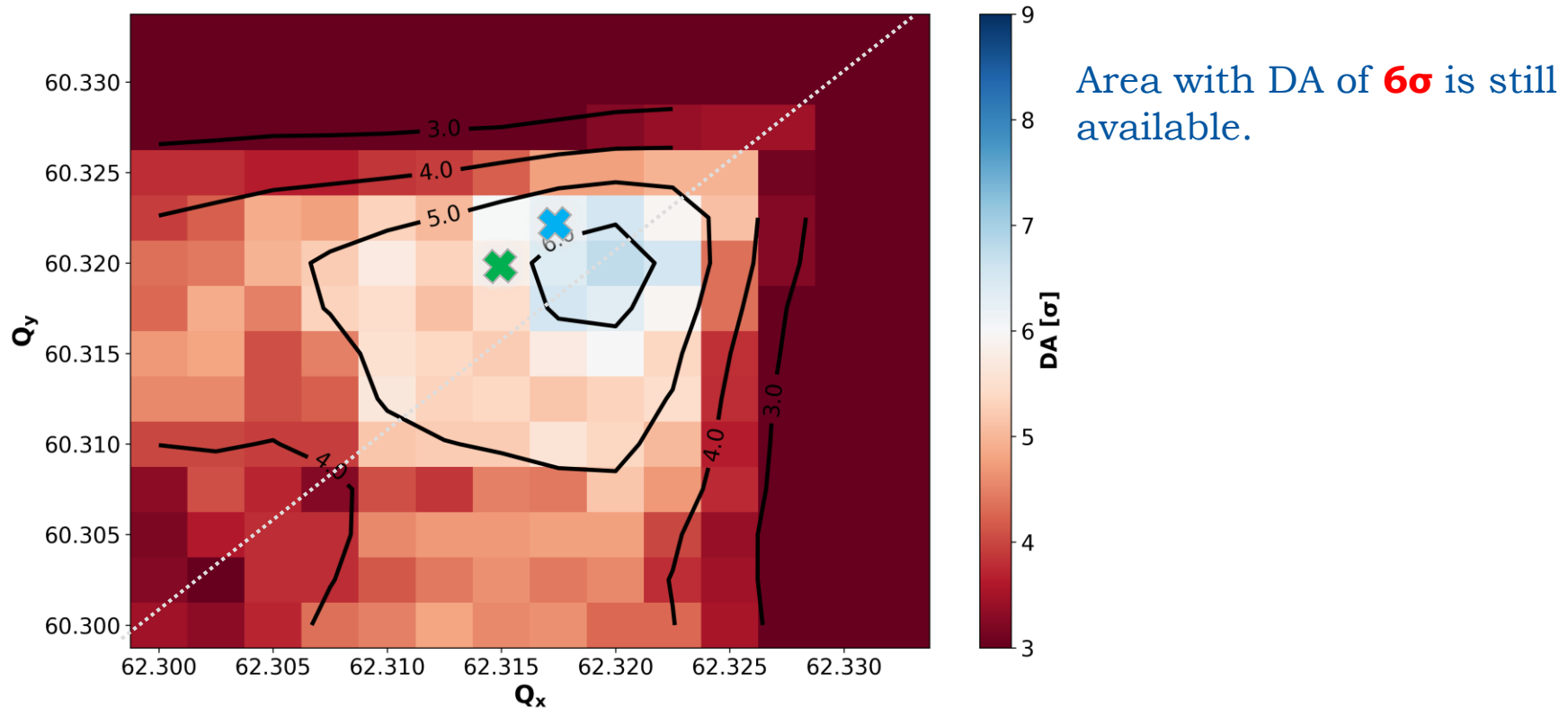
Max drop: Seed 31 by  $-0.55\sigma$

Minimum DA Distribution of  $(Q_x, Q_y)=(62.315, 60.320)$  for 60 seeds  
 $\beta^* = 15\text{cm}$ ,  $N_b = 1.2 \times 10^{11}$  ppb,  $\phi/2 = 250\mu\text{rad}$ ,  $\epsilon_n = 2.5\mu\text{m}$ ,  $Q'=15$



# Impact of $b_6 = -4$ on Seed 52

Min DA HL-LHC v1.3, Seed 52,  $b_6 = -4$ ,  $I = 1.2 \times 10^{11}$  ppb  
 $\beta_{IP1}^* = 0.15\text{m}$ ,  $\phi/2 = 250\mu\text{rad}$ ,  $\epsilon = 2.5\mu\text{m}$ ,  $Q' = 15$ ,  $I_{M0} = -300\text{A}$



The optimal WP has slightly shifted "upwards" along the diagonal (**increased tune shift**).



# Impact of $b_6=-4$ on all Seeds @ Start of Leveling

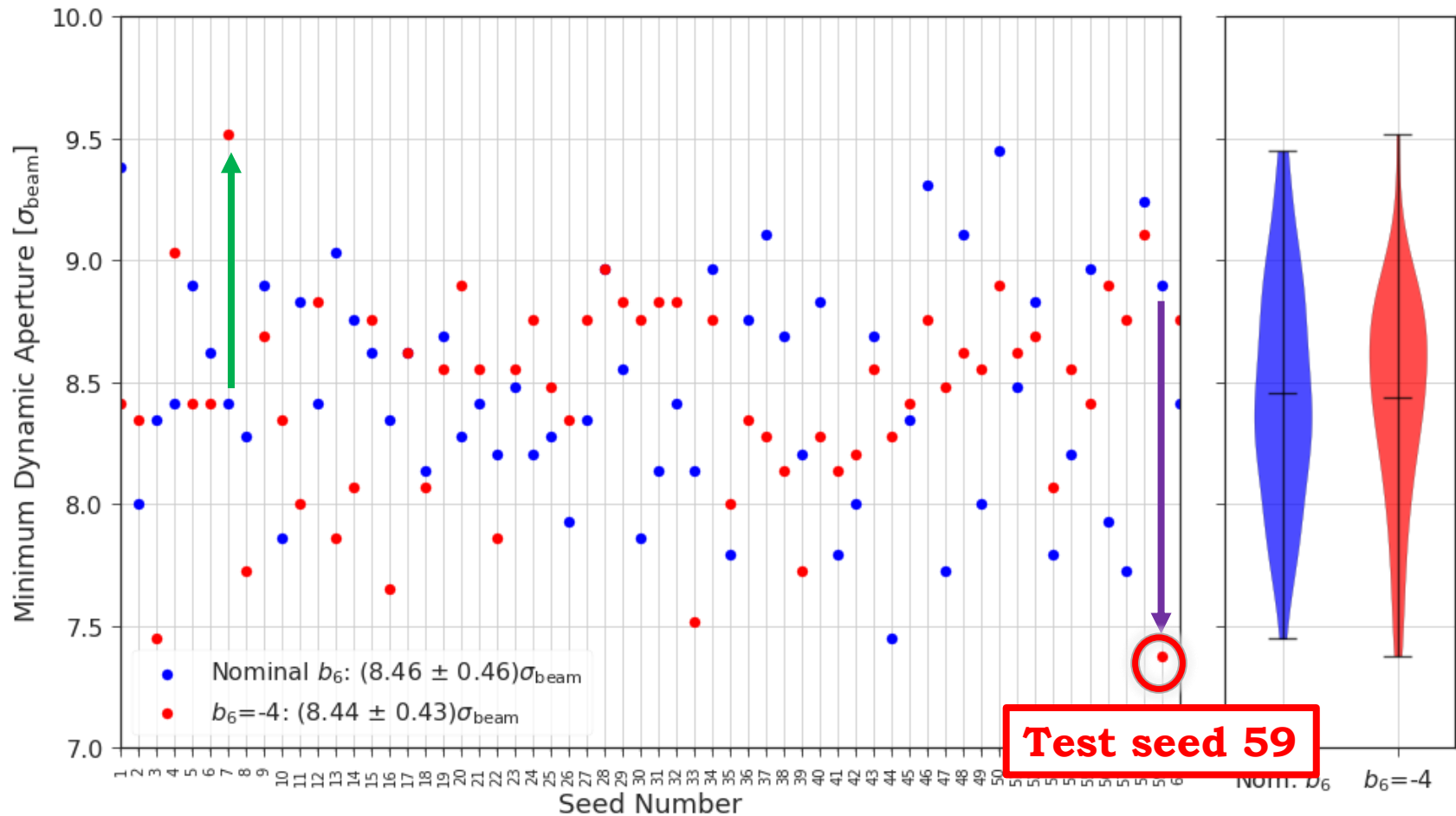
All points well above  $7.0\sigma$  DA  $\rightarrow$  Larger spread between seeds.

Max gain: Seed 7 by  $+1.10\sigma$

Max drop: Seed 59 by  $-1.52\sigma$

Minimum DA Distribution of  $(Q_X, Q_Y)=(62.320, 60.325)$  for 60 seeds

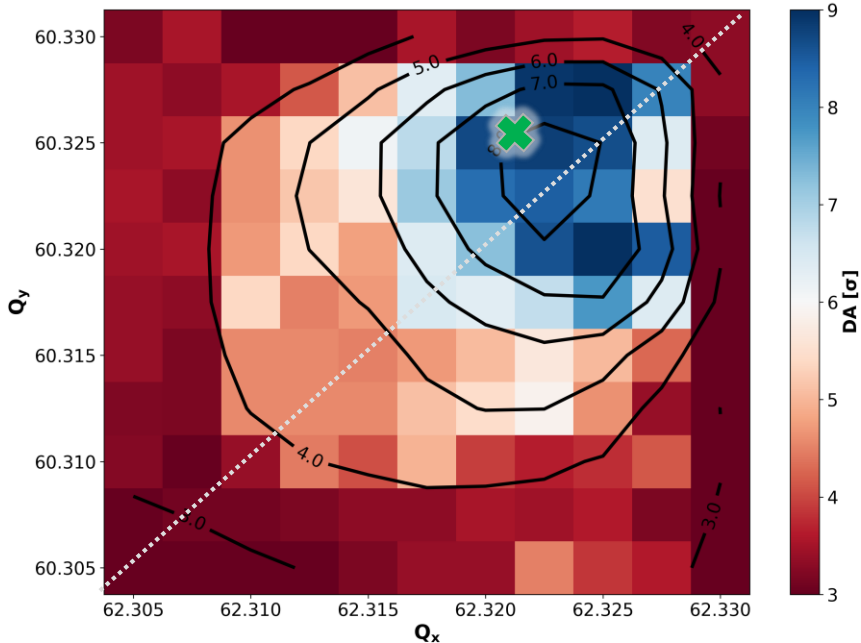
$\beta^* = 64\text{cm}$ ,  $N_b = 2.2 \times 10^{11}$  ppb,  $\phi/2 = 250\mu\text{rad}$ ,  $\epsilon_n = 2.5\mu\text{m}$ ,  $Q'=15$



# Impact of $b_6 = -4$ on Seed 59

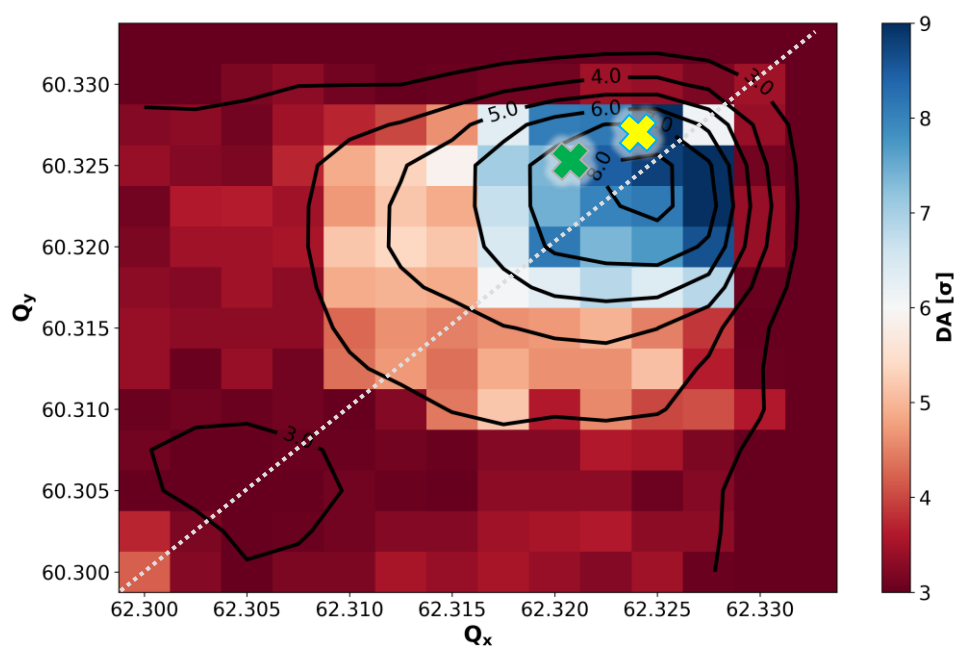
## Nominal

Min DA HL-LHC v1.3,  $I = 2.2 \times 10^{11}$  ppb,  $\beta_{IP1}^* = 0.60$  m  
 $\phi/2 = 250 \mu\text{rad}$ ,  $\epsilon = 2.5 \mu\text{m}$ ,  $Q' = 15$ ,  $I_{MO} = -300$  A



## $b_6 = -9$ | Seed 59

Min DA HL-LHC v1.3, Seed 59,  $b_6 = -4$ ,  $I = 2.2 \times 10^{11}$  ppb  
 $\beta_{IP1}^* = 0.64$  m,  $\phi/2 = 250 \mu\text{rad}$ ,  $\epsilon = 2.5 \mu\text{m}$ ,  $Q' = 15$ ,  $I_{MO} = -300$  A



Still a large area of  $DA > 7.0 \rightarrow$  Again, optimal WP slightly “shifted”.

# Summary

- As expected, **the impact of b<sub>6</sub> is in the shadow of the beam-beam.**
- Taking the **worst case for the scenario** without beam-beam (Frederik's result) and "switching-on" the beam-beam interactions observe that the **DA > 6.0σ** area is still available with small impact on the global result.
- **Collapsing all the b<sub>6</sub> correctors** affects the result by a reduction at the **1σ** level in minimum DA.
- Taking some statistics over all **60 seeds** for the optimal WP, we observe for the impact of b<sub>6</sub>:
  - when we are LR dominated ( $\beta^*=15\text{cm}$ ) :
    - **Maximum Increase or reduction** of minimum DA by **~0.6σ**
    - On **average** (over the **min DA**) the impact of the reduced b<sub>6</sub> is **less than 0.1σ**
    - The **spread** among the seeds is at the level of **0.2σ**
  - when we are HO dominated ( $\beta^*=64\text{cm}$ ):
    - **Maximum increase or reduction** of minimum DA by **~1.3σ** (at a spot well >7σ)
    - On **average** (over the **min DA**) the impact of the reduced b<sub>6</sub> is **less than 0.1σ**
    - The **spread** among the seeds is at the level of **0.45σ**
- Overall, the combination of the increased b<sub>6</sub> together with the BB induces an **additional tune-shift**, which can be mitigated by **properly adjusting the WP** → **no significant DA reduction**, when the IT correctors are working properly.