IT a3, b3 corrector strengths with large a3, b3 IT errors

Y. Nosochkov, M. Giovannozzi

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S. Fartoukh, R. De Maria, A. Mereghetti, E. Todesco, and Boinc volunteers

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Outline

- SixTrack simulations of the IT a3 & b3 corrector's strengths with large a3 & b3 errors in the IT
- Estimate of the maximum "allowed" IT a3 & b3 errors for the present corrector spec, based on high statistics with 600 random seeds
- Evaluation of the effect of D1 a3 & b3 spec errors on the IT corrector's strengths
- a3 & b3 corrector strength distribution in 600 seeds
- Conclusions

DA simulations set-up

- SixTrack
  - HLLHCV1.0 lattice at collision energy (7 TeV)
  - Tune: 62.31, 60.32
  - Chromaticity: +3
  - Arc errors and standard corrections
  - IT non-linear correctors in IR1, IR5
  - 600 seeds for high statistics of the IT corrector strength

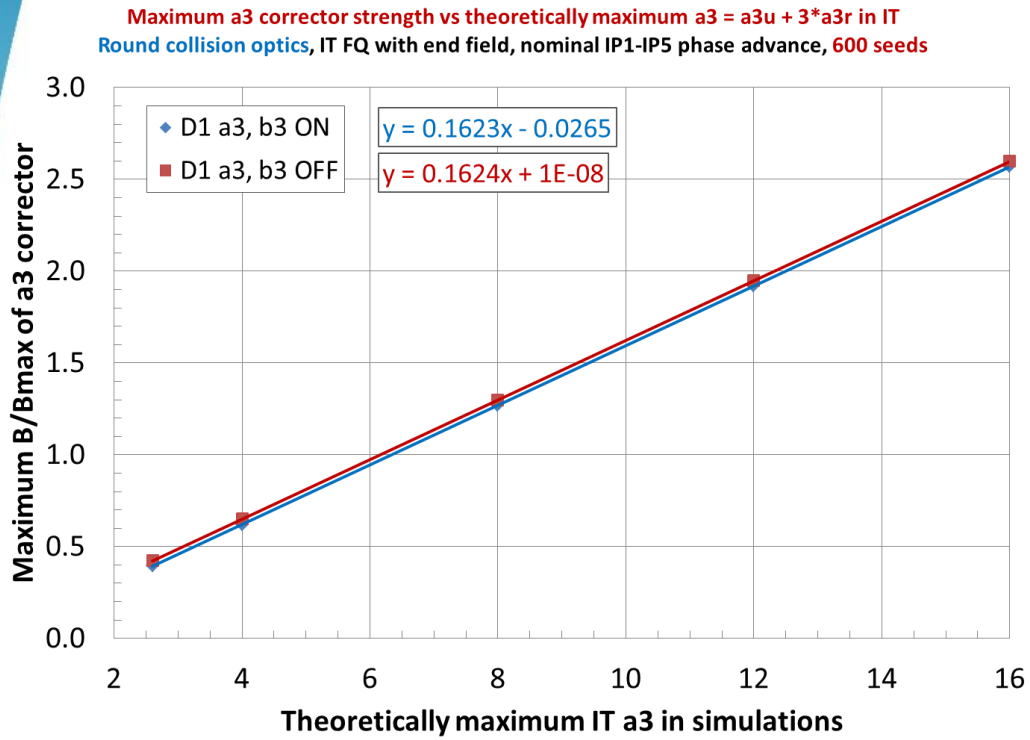
- FQ tables of IT, D1, D2, Q4, Q5 magnets
  - “ITbody_errortable_5”, “ITcs_errortable_v5”, “ITnc_errortable_v5” (with end effects)
  - “D1_errortable_v1_spec”, “D2_errortable_v5_spec”
  - “Q4_errortable_v2_spec”, “Q5_errortable_v0_spec”
  - a2 and b2 terms are set to zero to simulate the linear optics correction

- Beam-beam effects are not included
- **Field errors are randomly generated according to** $b = b_s + (\xi_u / 1.5) b_u + \xi_r b_r$ **, where random** $\xi_u < 1.5$ **and** $\xi_r < 3$ **(with** $\sigma_\xi = 1$**); and similarly for the a-terms**

Evaluation of maximum a3, b3 IT corrector strengths vs IT a3, b3

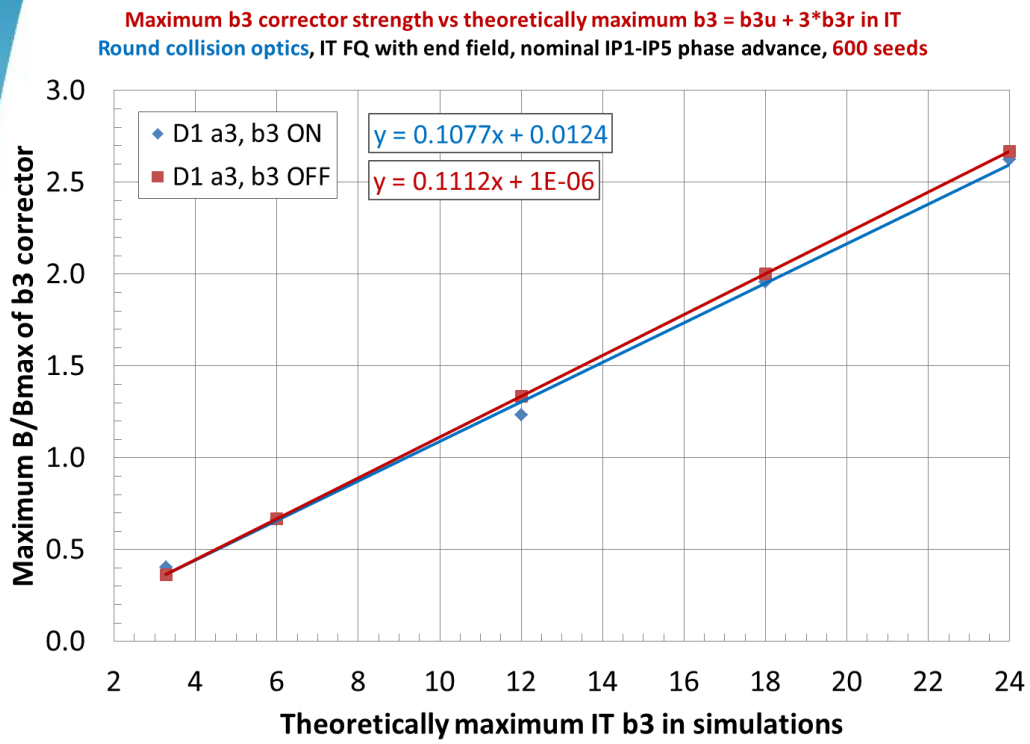
- Field errors are randomly generated according to $b = b_s + (\xi_u / 1.5) b_u + \xi_r b_r$, where random Gaussian $\xi_u < 1.5$ and $\xi_r < 3$ (with $\sigma_\xi = 1$); and similarly for the "a" terms
- According to the above formula, the theoretically maximum generated error value is $b_{max} = b_u + 3*b_r$ ($b_s = 0$) → high statistics is needed to approach this value in simulations
- We use large number of seeds (600) to determine maximum a3 & b3 IT corrector strengths as a function of the theoretically maximum errors a3max & b3max
- This method avoids ambiguity related to the dependence of four a3 (or b3) corrector strengths on the 24 random values of a3 (b3) errors in the 24 IT quadrupoles in IR1 & IR5
- From this dependence, we can determine the maximum allowed a3max & b3max values satisfying the a3 & b3 corrector specifications
  - a3 -> BL_{max} = 0.063 Tm @ 50 mm (new nominal values are 0.095 Tm)
  - b3 -> BL_{max} = 0.063 Tm @ 50 mm (new nominal values are 0.095 Tm)
- Finally, we determine the maximum allowed uncertainty & random a3 & b3 values
  - a3u = a3r = a3max / 4
  - b3u = b3r = b3max / 4

Maximum a3 corrector strength vs the theoretically maximum IT a3 error



- The IT a3 corrector strength is normalized to the spec (**BL_{max} = 0.063 Tm @ 50 mm**)
- Two options: D1 a3, b3 errors turned ON and OFF → The effect on the maximum a3 corrector strength is small
- Based on the linear fit, the a3 corrector spec strength is reached at the theoretically maximum error of a3max = 6.2
- This corresponds to the maximum allowed uncertainty & random values: a3u = a3r = a3max / 4 = 1.55 (as compared to the present spec of a3u,r = 0.65)
- Due to the still limited statistics, this estimate should be considered as optimistic, i.e. the maximum allowed error may be somewhat smaller

Maximum b3 corrector strength vs the theoretically maximum IT b3 error

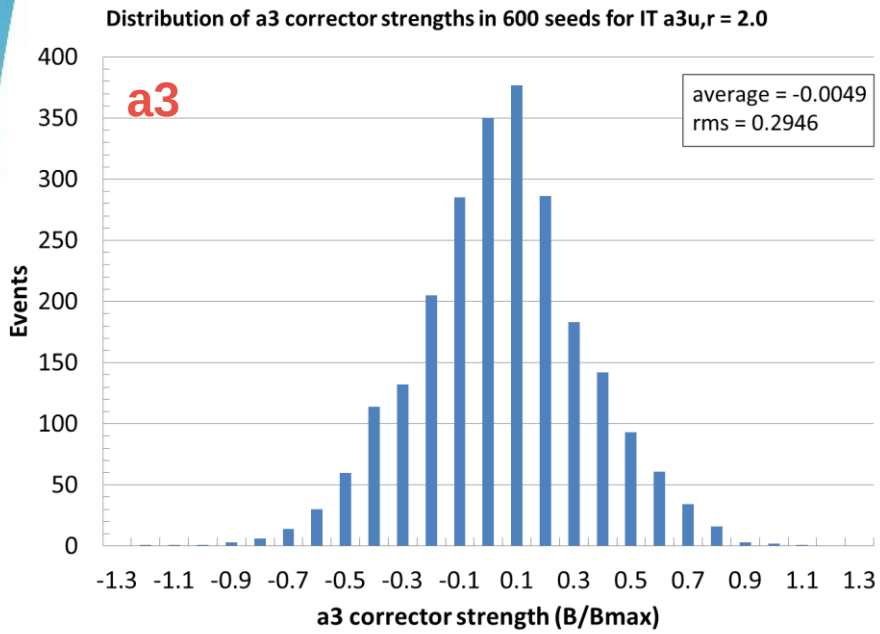


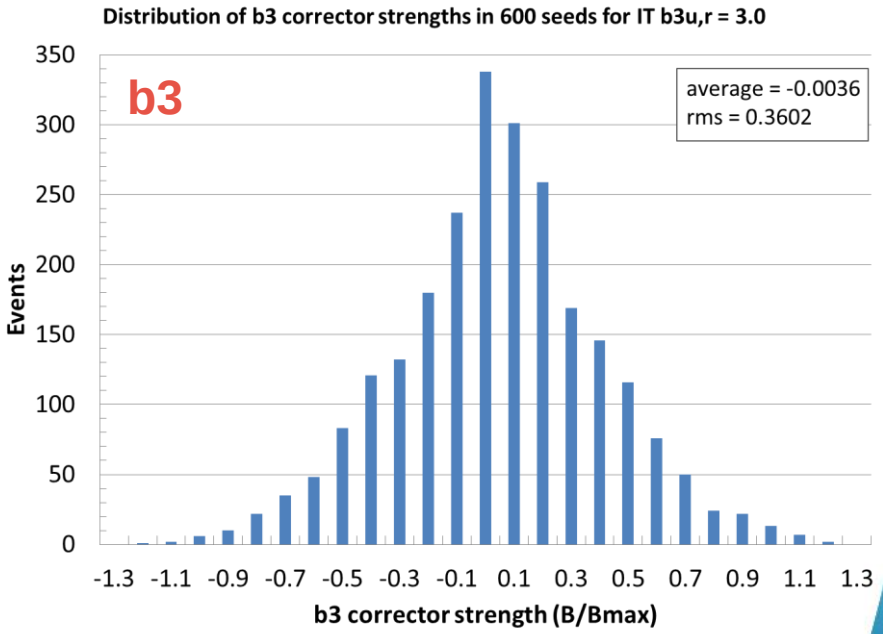
- The IT b3 corrector strength is normalized to the spec (**BL_{max} = 0.063 Tm @ 50 mm**)
- The effect of D1 a3 & b3 errors on the maximum b3 corrector strength is small
- With the D1 b3 errors ON, there are small fluctuations from the linear fit of the b3 corrector strength – this is likely caused by the “worst” seed in presence of the non-zero D1 systematic b3 error
- Based on the linear fit, the b3 corrector spec strength is reached at the theoretically maximum error of b3max = 9.0
- This corresponds to the maximum uncertainty & random values: b3u = b3r = b3max / 4 = 2.25 (as compared to the present spec of b3u,r = 0.82)
- Due to the still limited statistics, this estimate should be considered as optimistic, i.e. the maximum allowed error may be somewhat smaller

Example of a3 and b3 corrector strength distribution

- Distribution of a3 & b3 corrector strengths in 600 seeds for the IT a3u,r = 2 and b3u,r = 3 (where D1 a3 & b3 errors are ON)

In this case, the IT a3 & b3 errors exceed the maximum "allowed" a3u,r = 1.55 and b3u,r = 2.25





Conclusions

- Impact of large a3 & b3 IT errors on the IT a3 & b3 corrector strengths is evaluated for the range of a3u = a3r < 4 and b3u = b3r < 6 (as compared to the present spec of **a3u,r = 0.65 and b3u,r = 0.82**)
- A large number of seeds (600) is used to determine the maximum strengths of IT a3 & b3 correctors vs the a3 & b3 random IT errors
- The maximum "allowed" a3 & b3 errors compatible with the **old** corrector spec are
  - a3max = 6.2 (**for BLmax = 0.063 Tm @ 50 mm**), corresponding to the maximum a3u = a3r = **1.55**
  - b3max = 9.0 (**for BLmax = 0.063 Tm @ 50 mm**), corresponding to the maximum b3u = b3r = **2.25**
- The maximum "allowed" a3 & b3 errors compatible with the **new** corrector spec are
  - a3max = 9.5 (for BLmax = 0.095 Tm @ 50 mm), corresponding to the maximum a3u = a3r = **2.38**
  - b3max = 13.9 (for BLmax = 0.095 Tm @ 50 mm), corresponding to the maximum b3u = b3r = **3.48**
- The recent magnetic measurements of MQXFS4a at 1.9 K (L. Fiscarelli WP3 meeting 11/7/18) gave
  - a3 = **1.18 -> compatible even with old corrector spec**
  - b3 = **2.61 (with shims) -> compatible even with old corrector spec**
- The impact of D1 a3 & b3 spec errors on the maximum IT corrector strengths is small