Research supported by the High Luminosity LHC project
HiLumi LHC:
DA for D2 Specification

F.F. Van der Veken and M. Giovannozzi
Aim

- Effect of D2 errors on DA seemingly under control
- Need to be sure it isn’t due to internal compensations
- Orders $b_3$ and $b_5$ might have larger values
- Random errors should be sampled from $[-4\sigma, 4\sigma]$ uniformly
- Existing routines only sample from $[-3\sigma, 3\sigma]$ and Gaussian
Approach

- Magnetic errors have 3 components:
  - **systematic** error $\xi_M$
  - **uncertainty** error $\xi_U$ per magnet family
  - **random** error $\xi_R$ per magnet

- Total error given by $\xi_{tot} = \xi_M + \xi_U \frac{\sigma_{1.5}}{1.5} + \xi_R \sigma_3$
  - $\sigma_{1.5}$ is a Gaussian random variable capped at 1.5$\sigma$
    sampled once per magnet family
  - $\sigma_3$ is a Gaussian random variable capped at 3$\sigma$
    resampled for every magnet

- By doubling the value of $\xi_R$ we can make sure to have enough cases at $\pm 4\sigma$
Doubling $\xi_R$ indeed gives more representative sampling.

However, in specification: errors are truncated at $4\sigma$ while in this approach seeds beyond $4\sigma$ are not discarded.

$\Rightarrow$ actual DA will be slightly higher than reported here.
DA

Beam 1

Beam 2

DA [σ]

Baseline
Baseline
Baseline
Baseline

D2 errors:
D2 errors:
double random
double random
no systematic
no systematic

Baseline
Baseline
Baseline
Baseline

Without D2
Without D2
Without D2
Without D2

F.F. Van der Veken

DA for D2 Specification
DA

- Baseline: all errors assigned except MCBXF and MCBRD
- Removing systematic D2 errors improves DA for most seeds

⇒ as expected!

hence no compensation effects due to random part
DA from $b_3$ of D2

Beam 1

Beam 2

$\sigma$ (DA)

$b_3$ (systematic)

-6 -4 -2 0 2 4 6

-6 -4 -2 0 2 4 6

• no corr

• $b_3$ corr
DA from $b_3$ of D2

- D2 with double randoms assigned, only systematic $b_3$
- Strong impact at high values, more so for positive values
- Best DA achieved at $-3, 0, \text{ or } +3$, depending on seed
  $\Rightarrow$ seed-dependent compensation from systematic part

- Remember that seeds beyond $4\sigma$ are not discarded
  $\Rightarrow$ actual DA will increase

- If we use the non-linear corrector package to correct the $b_3$ error of the D2 (averaged over both beams), the DA can be fully recovered
$b_3$ corrector strengths for D2

- $kcsx3.l1$
- $kcsx3.r1$
- $kcsx3.l5$
- $kcsx3.r5$

(systematic $b_3$ error vs. corrector strength [%])
$b_3$ corrector strengths for D2

- Correcting a systematic $b_3 = \pm 6$ uses $\pm 11.5\%$ of the corrector budget
  - safe margin, leaving room to correct other magnets
  - probably even for potentially higher values of $b_3$

- Do the correctors introduce seizable beta-beating (via feed-down)?
Beta-Beating from Correctors

Beam 1

Beam 2

F.F. Van der Veken

DA for D2 Specification 7/10
Beta-Beating from Correctors

Beam 1

Beam 2

\( \Delta \theta / \text{RMS} \)

systematic \( b_3 \) of D2

\( \Delta \theta / \text{RMS} \)

systematic \( b_3 \) of D2

- no corr
- corr

F.F. Van der Veken

DA for D2 Specification 7/10
Beta-Beating from Correctors

- For $b_3 = \pm 6$, beta-beating increases slightly ($< 1\%$)
  - $\Rightarrow$ under control

- Is D2 correction compatible with e.g. MCBXF correction?
- Can we estimate (theoretical) budget needed for MCBXF?
  - $\Rightarrow$ depends on sign configuration!
  - $\Rightarrow$ test a few (625) configurations, only MCBXFAH, seed 1
  - $\Rightarrow$ avoid feasibility discussion . . .
Strengths for MCBXF correction

- MCBXFA.3L1
- MCBXFA.3R1
- MCBXFA.3L5
- MCBXFA.3R5
- MCBXFB.a2L1
- MCBXFB.a2R1
- MCBXFB.a2L5
- MCBXFB.a2R5
- MCBXFB.b2L1
- MCBXFB.b2R1
- MCBXFB.b2L5
- MCBXFB.b2R5
Strengths for MCBXF correction
Strengths for MCBXF correction

- Correctors are uncorrelated, on each side of each IP
  ⇒ we can safely “ignore” internal compensations...
  ⇒ only sign of MCBXF closest to corrector matters
- Note that this is worst-case, not assuming FRAS...

- Effect of (weak) MCBXFB is $\pm 2.1\%$ of budget
- Effect of MCBXFA is $\pm 8.6\%$ of budget
  ⇒ how does this influence total budget (MCBXF + D2)?
Strengths for MCBXF correction

[kcsx3.l1 plots]

[kcsx3.r1 plots]

[kcsx3.l5 plots]

[kcsx3.r5 plots]
Strengths for MCBXF correction

Graphs showing the impact of MCBXF correction on systematic $b_3$ error for different scenarios.

- kcsx3.l1
- kcsx3.r1
- kcsx3.l5
- kcsx3.r5
Strengths for MCBXF correction

- Total corrector budget (60 seeds):
  
  \[ \text{kcsx3.l1} : [-37\%, 44\%] \]
  \[ \text{kcsx3.r1} : [-42\%, 33\%] \]
  \[ \text{kcsx3.l5} : [-40\%, 48\%] \]
  \[ \text{kcsx3.r5} : [-48\%, 34\%] \]

- Adding D2 to correction algo does not limit other magnets!
DA from $b_5$ of D2
DA from $b_5$ of D2

- D2 with double randoms assigned, only systematic $b_5$
- Very little impact on DA
Conclusion

- Random part does not lead to compensations (most seeds)
- Systematic part clearly leads to compensations
- DA strongly influenced by (large) systematic $b_3$
- DA not really influenced by systematic $b_5$

$\Rightarrow$ perfect!

$b_3$ can be corrected

(while for $b_5$ no good algorithm exists yet)