Dynamic Aperture at Collision

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April 10th, 2018
Results FCC week @ Berlin

• DA at collision energy with errors on triplets no beam-beam and crossing angle on resulted in very low DA.

\[ \sim 2\sigma \]

• Non-linear correctors:
  \[ a_3/b_3/a_4/b_4/b_6 + b_5/a_5/a_6 \]

\[ \sim 11.7\sigma \]

• Acceptable DA with the use of non-linear correctors
  - Follow progress on its reliability (experiments LHC)
  - Find alternative corrections?
October update

CHANGES IN THE LATTICE

• New integrated lattice (97 km).
  • L* shortened to 40 m.
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WORK TO DO

• check what is causing the difference on DA between the old and new lattice.
  - Will give us an indication of problem with last lattice and what to avoid
  - Will give us more flexibility to include more errors in the DA studies.
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  Phase between main IR ✔

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10.03 σ, 10.02 σ, 1.9 σ
DA Studies

- 60 seeds/10^5 turns/5 angles no beam-beam (Talk: Beam-Beam studies T. Peloni)
- Triplet errors IRA/IRG
- Corrections

(Based on scripts of A. Chance, R. Martin and experience LHC: R. Tomas, E. Maclean and T. Persson)
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  - Chrom+tune correction
  - Spurious dispersion (SSC and HL-LHC like)
  - Crossing IPA and IPG
  - Coupling correction
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Method 1: Double-tuning
1. Change horizontal and vertical phase from IPA to IPG with trim quads on the right.
2. Adjust tune with trim quads on the left.

Method 2: Phasors
1. Install phasors (elements that only change the phase) in IPL and IPB
2. Change phase with phasor on the right (IPB)
3. Recuperate with phasor on left (IPL)

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Phase Study

- Study to analyse impact of phase between main IR on DA

- 10 seeds/$10^5$ turns/5 angles
- Triplet errors, no beam-beam
- Normal corrections
- w/o non-linear correctors
- Double-tuning method
  (Phasors show similar results)
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Results

• Bigger dependency with change in $\mu_y$. Bigger refinement changing $\mu_x$.
• Found two good zones:
  1. $\Delta \mu = [0.2, 0.05]$
  2. $\Delta \mu = [-0.2, -0.4]$
• Run best case for 60 seeds: 16.5 sigma (6.5 $\sigma$ more than original!)
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- Phase dependency also observed in beam-beam (J. Barranco, T. Peloni Talk: beam-beam effects) and in injection (B. Dalena, Talk: Dynamic Aperture at injection and 3.3 TeV energy choice).
- Not necessarily the same ones. Objective: Find the best compromise at different stages of the operation cycle.
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• Not necessarily the same ones. Objective: Find the best compromise at different stages of the operation cycle.
• Higher DA gives flexibility to amplify study: include arc and dipole errors.
• Add Errors:
  - Triplet Errors
  - Arc Errors + correction (B. Dalena, Talk: Dynamic Aperture at injection and 3.3 TeV energy choice)
  - Separation/Recombination dipoles errors (R. Martin)

• Rest of study stays the same: 60 seeds/10^5 turns/corrections

• When adding errors and non-linear correctors ‘colour zones’ stay consistent
Expanded Study

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**Results**

Original case: 5.8 σ

+ Non-linear corr: 7.5 σ
+ Optimize phase: 9.55 σ
+ non-linear+opt phase: 15.9 σ
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• Check other lattice options?
(Even more) expanded Study

Expand study to include:

1. Other lattice options ($\beta^*=0.15, 0.2, 1.1 \text{ m in IPA and IPG}$)
   
   Draw line when non-linear correctors are needed?

Talk: Experimental Insertions
R. Martin
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2. FCC-eh implementation $\beta^*=0.3/0.3/0.3$ m (IPA/G/L) and $\beta^*=3$ m (IPB)

   DA gets affected?

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3. Alternative IR design round and flat
   Phase Dependency? Same pattern?
   Good DA?

Talk: Interaction Region FCC-eh
R. Martin

Talk: Flat beam alternative
J. Abelleira

Poster: An optimised Alternative Triplet for the final Focus of the FCC-hh.
L. Van Riesen-Haupt
1. Other lattice options ($\beta^* = 0.15, 0.2, 0.3, 1.1 \text{ m}$)

- Draw line when non-linear correctors are needed?

- Low DA in $\beta^* = 0.15$ and 0.2 m
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- Once phase is optimized DA grows consistently
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- Adding non linear correctors brings $\beta^*=0.2$ m to more acceptable levels
- $\beta^*=0.15$ m still challenging but likely to improve with improved phase.
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- Using non-linear correctors becomes more crucial for cases $\beta^*=0.15$ and 0.2 m
2. FCC-EH implementation (Roman) $\beta^*=0.3/0.3/0.3$ m (IPA/G/L) $\beta^*=3$ m (IPB)
   Same errors than before, no errors on FCC-EH IR yet.
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3. Alternative IR design (Leon/Jose) $\beta^*=0.3/0.3$ (IPA/G) $\beta^*=3$ m (IPB/IPL)
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   **Quick phase check:**
   
   Follows similar shape
   
   Increase DA to similar values
   
   $10.1 \sigma$

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   - 10.1 $\sigma$
   - Continue study with complete set of errors

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   $13.6 \sigma$
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3b. Alternative IR design (Leon/Jose) Flat optics $\beta^* = 1.2/0.15$ (IPA/IPG)  

$10.6 \sigma$
Conclusions

• Study at collision without beam-beam has been expanded to include further errors: triplet errors, dipole arc errors, separation and recombination dipoles
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\[ 25 \sigma \quad \beta^* = 1.1 \text{ m} \]

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\[ 10-13 \sigma \quad - \quad - \quad - \quad - \quad - \quad \beta^* = 0.3 \text{ normal and alternative design} \]
- Flat beams
- FCC-eh IR

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& - \text{Expected the same for alternative design, flat beams and FCC-eh} \\
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- Check compatibility with beam-beam studies. Find best phase optimization for different stages of operation cycle.
- Non-linear correctors improved results for all cases, useful to give safety margin but particularly important for the β*=0.2 m.
- More extensive study to be done for the challenging case β*=0.15 and for the FCC-eh in case new errors affect DA.
Thanks!