# Dynamic Aperture studies for LHeC and FCC-eh

**Emilia Cruz-Alaniz**

Special thanks to: R. Tomas, R. Martin and B. Parker

**June 27th, 2018**

# DA and Status of Lattices

## LHeC

- Based on HL-LHC lattice (round optics β*=15 cm in IR1 and IR5)
- New low-β* IR (IR2)
- ATS-scheme implemented in 3 low-β* IRs
- Previous DA studies were implemented for different IR options
- Update: Studies with errors in IR1/IR5 magnets and new magnet design for IR2

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- Based on FCC-hh lattice (β*=30 cm in IRA and IRG)
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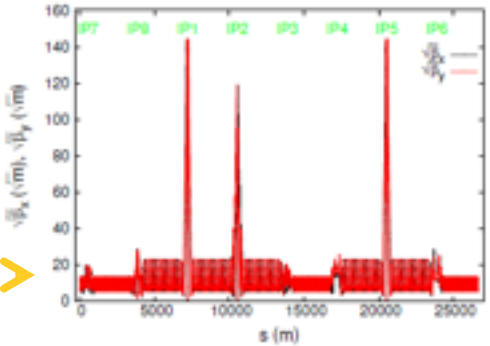

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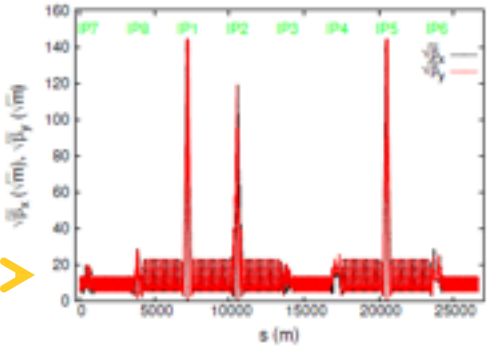


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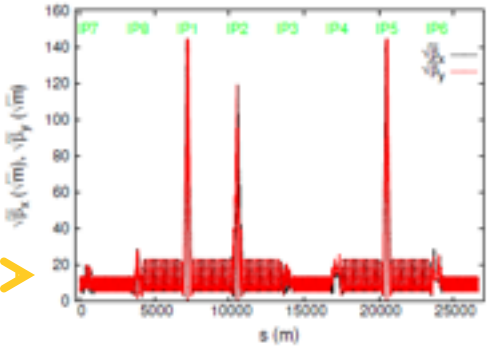


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## Chromaticity correction

- Previous method: Allow all families to vary independently
- Updated method: Allow ATS families vary independently while non-ATS families vary by same amount.
- Chromaticity correction achieved for almost all cases. However case for β*= 5cm seems to be over the limit of chromaticity correction.

# DA studies

- DA studies: $10^5$ turns, 60 seeds, 5 angles, collision energy.
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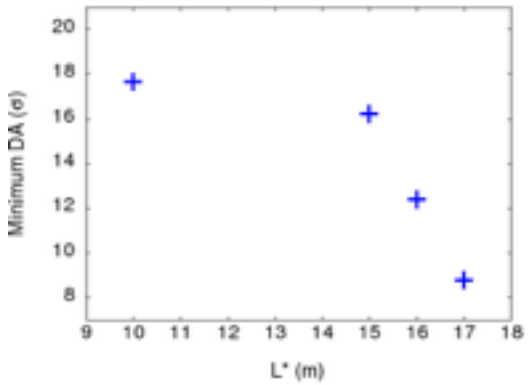


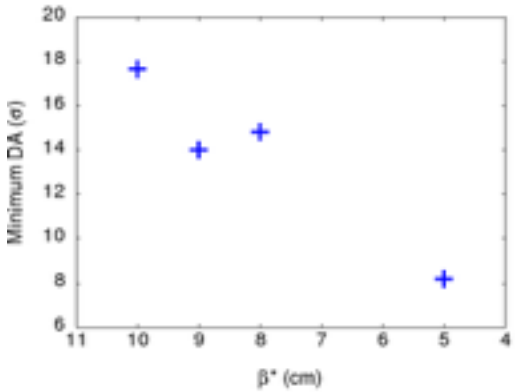

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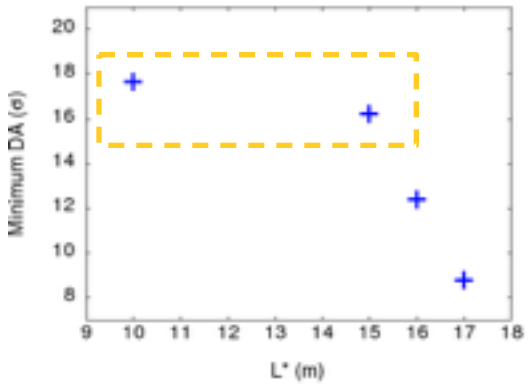


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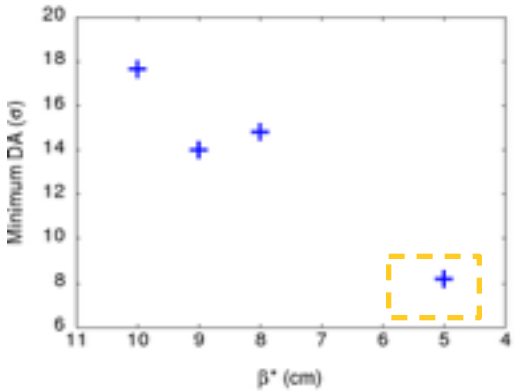


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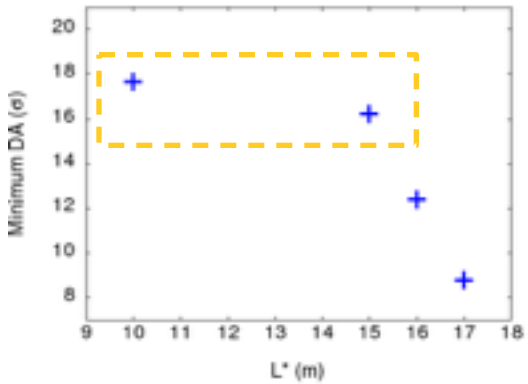


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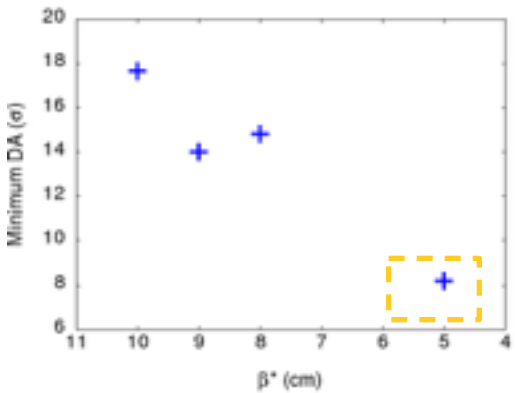


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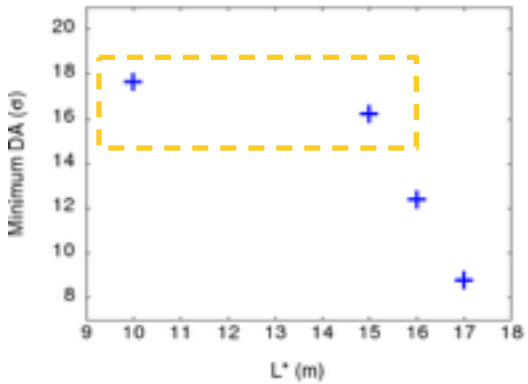


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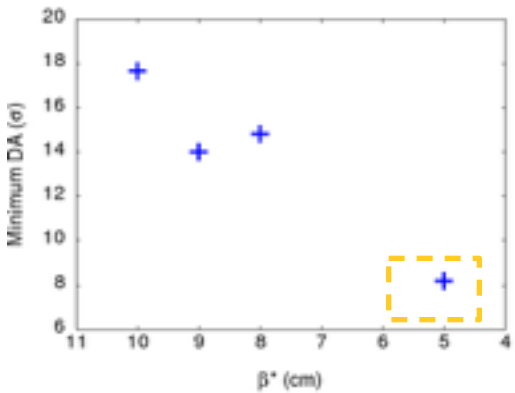


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## Following work

- Repeat previous DA studies with **errors in IR1 and IR5**.
  - Same conclusion? (L*=15 m best compromise?)
- Validate new default with magnet design/aperture/SR (problems with present design)
  - DA with errors on IR1 and IR5 for **new design,** compare to old design
- Impact on **lowering β***
- Impact of **non-linear correctors**. Necessary?

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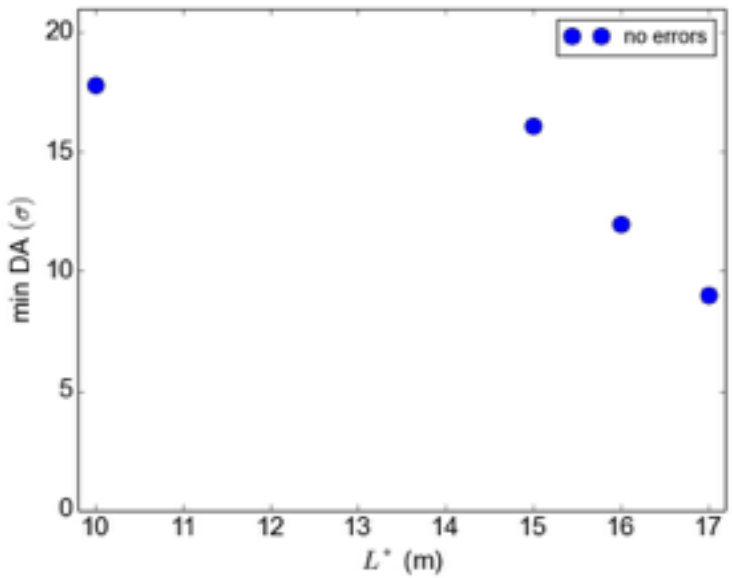


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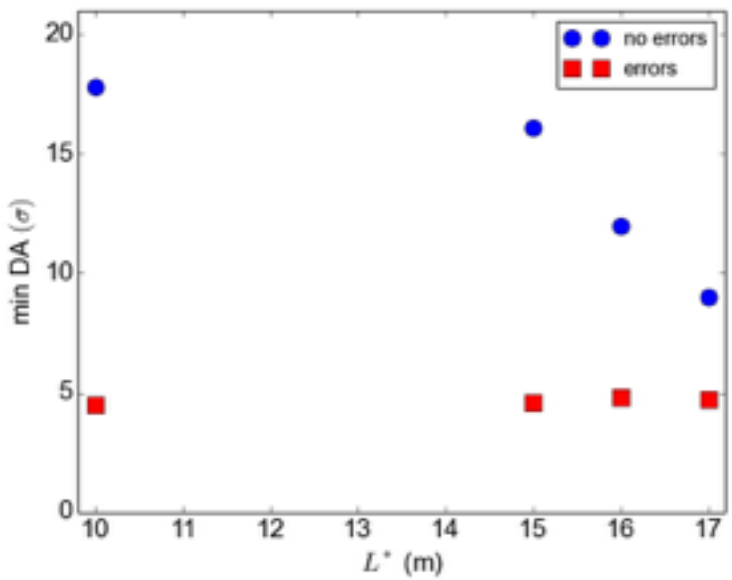


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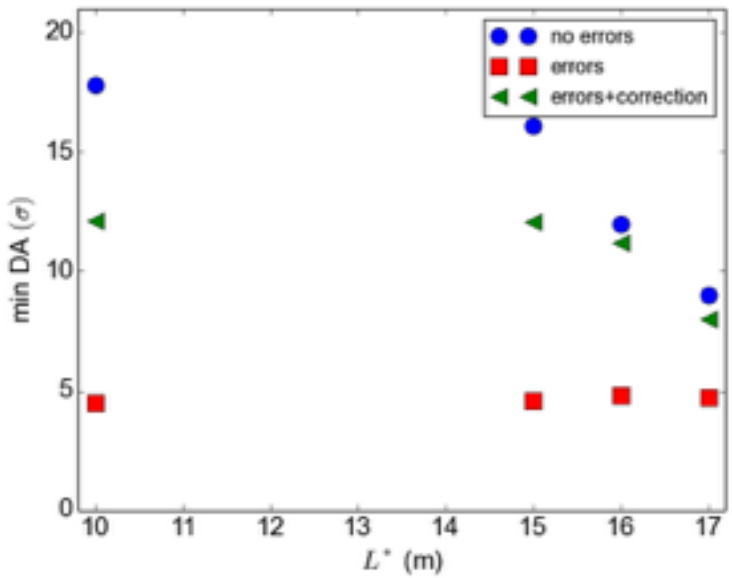


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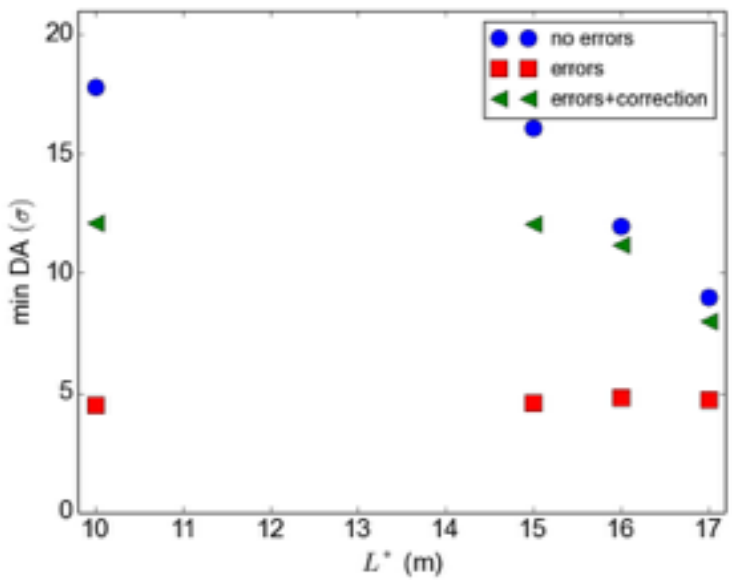


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- Studies with HL errors and non-linear correctors show again that L*=15 m is a good option with very similar min DA values than for L*=10 m.
- Non-linear correctors necessary to achieve an acceptable DA.

# NEW IR

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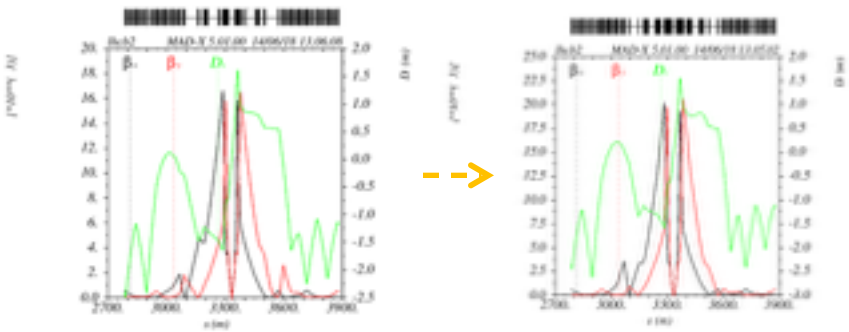

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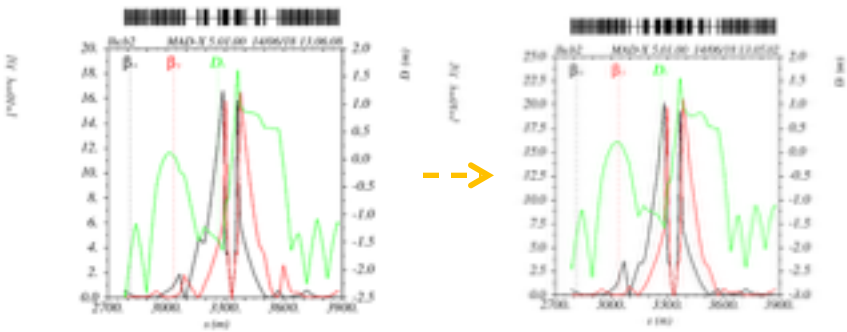

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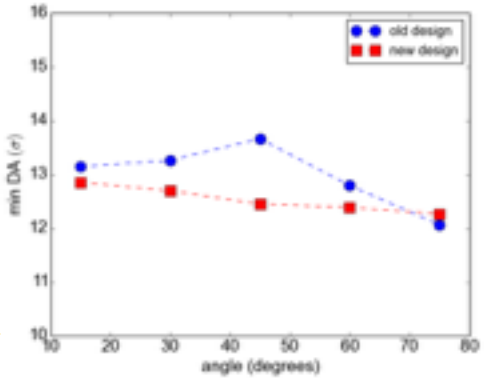

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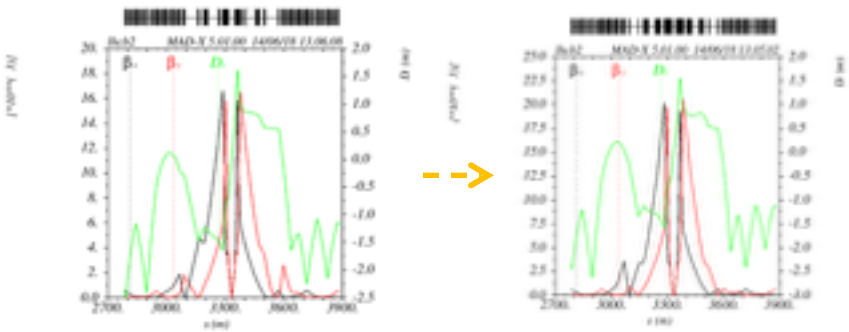

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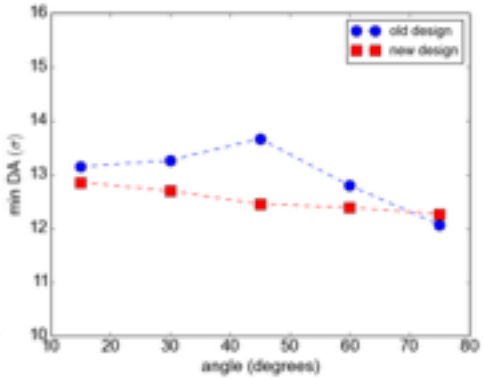


- New design show acceptable DA with the use of non-linear correctors
- Studies for previous lattices with **errors on HL IR,** although not validated with magnet design, give a good indication of how the DA would look like.

# New IR with errors

- Estimate impact of triplet errors and non-linear correctors in LHeC IR

  -> No LHeC triplet errortables yet but use **HL error tables** as an estimate and implement them in the LHeC IR triplet

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How about the case for **lower β*?**

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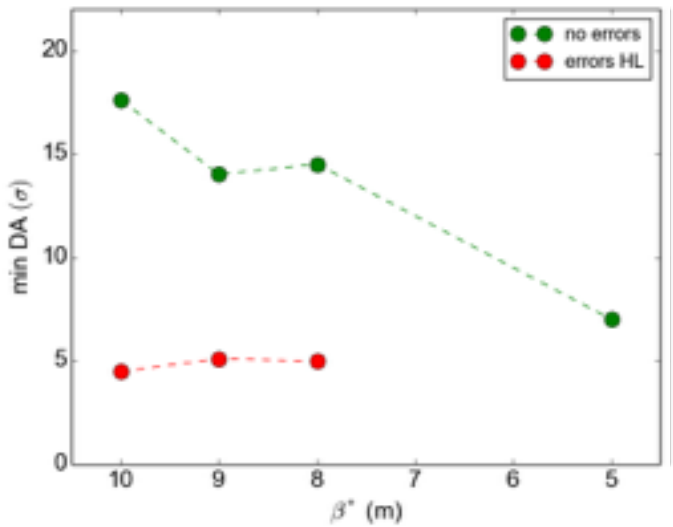


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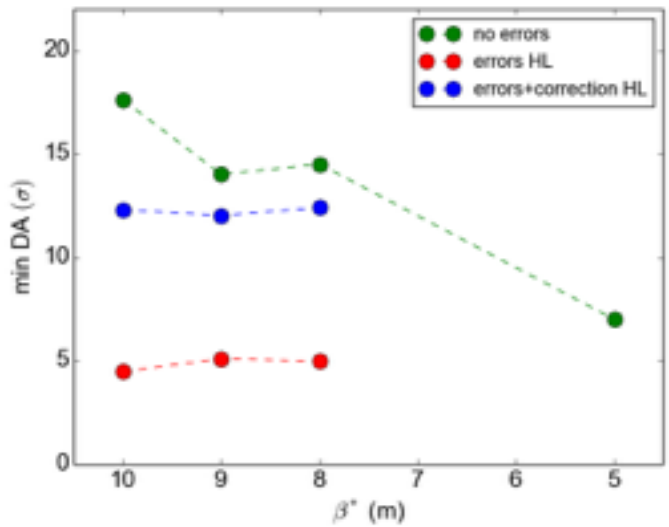


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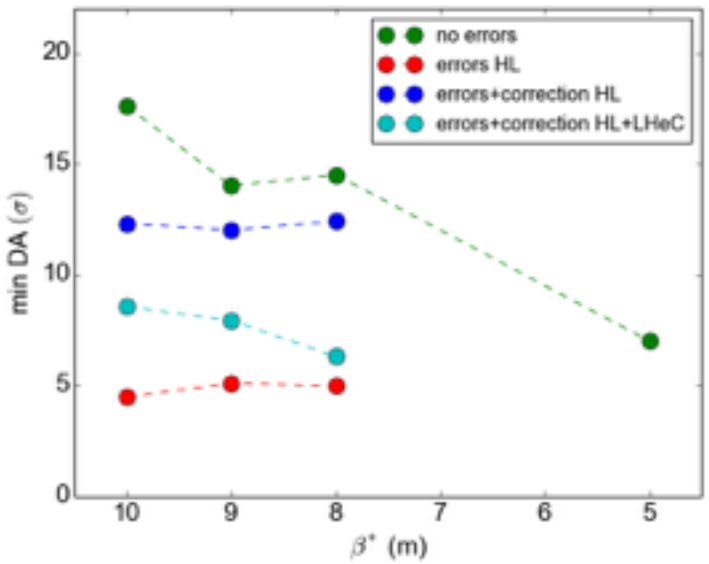


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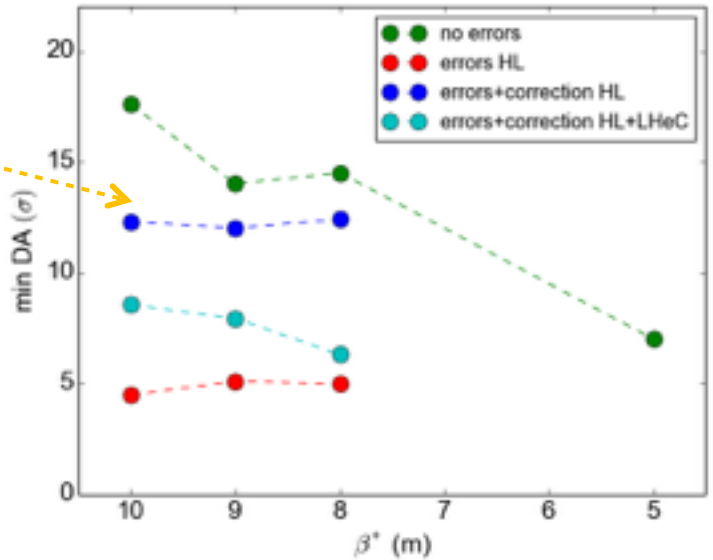


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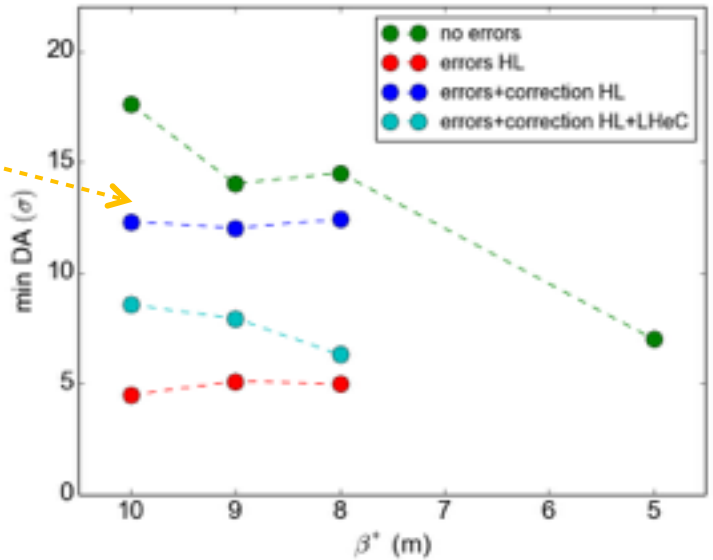


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- Decrease on DA with lower β*, although not large.
- New triplet works slightly better with errors.
- Biggest challenge for lower β* likely to start instead from elsewhere: optics matching/ aperture, magnet design and chromaticity correction.

# DA studies FCC-hh

- DA studies have been performed for FCC –hh studies
- 60 seeds/$10^5$ turns/5 angles no beam-beam
- Errors on arcs and IR magnets
  - Corrections →
    - Chrom+tune correction
    - Spurious dispersion (SSC and HL-LHC like)
    - Crossing IPA and IPG
    - Coupling correction

(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
- **Non-linear correctors**
- **Phase between main IPs**

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- DA studies have been performed for FCC –hh studies
- 60 seeds/$10^5$ turns/5 angles no beam-beam
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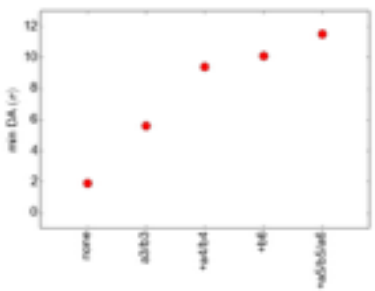
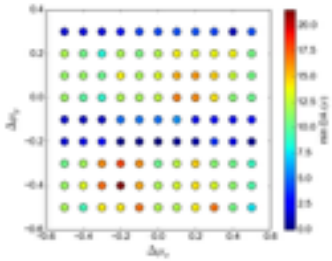
Main corrections

- **Non-linear correctors** show steady increase:



- **Phase between main IPs** have a major impact on DA



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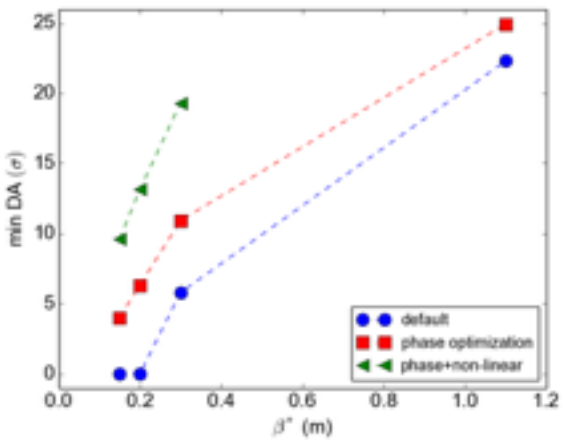
- Results for different ß* options and impact of main corrections




- DA of 10.6 σ with phase optimization and no non-linear correctors

- Large DA 19.7 σ for default case (ß*=30 cm) with phase optimization and non-linear correction

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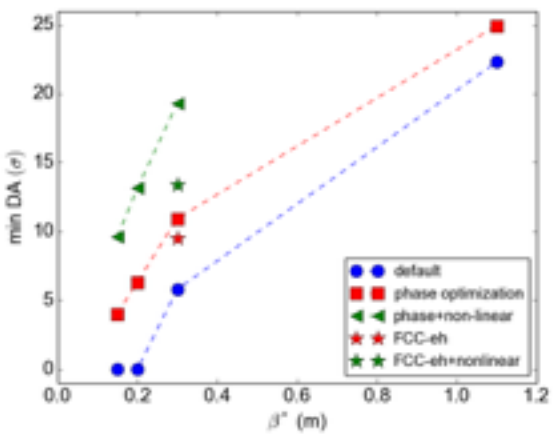
  - **Phase between main IPs**

(Based on scripts of A. Chance, R. Martin and experience LHC: R. Tomas, E. Maclean and T. Persson)

- Impact of FCC-eh : new low-β* of 30 cm in IRL. **No errors** yet on new IR




- DA of 10.6 σ with phase optimization and no non-linear correctors
  - 9.5 σ for FCC-eh
- Large DA 19.7 σ for default case (β*=30 cm) with phase optimization and non-linear correction
  - 13.4 σ for FCC-eh

# DA studies FCC-eh

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- 60 seeds/$10^5$ turns/5 angles no beam-beam
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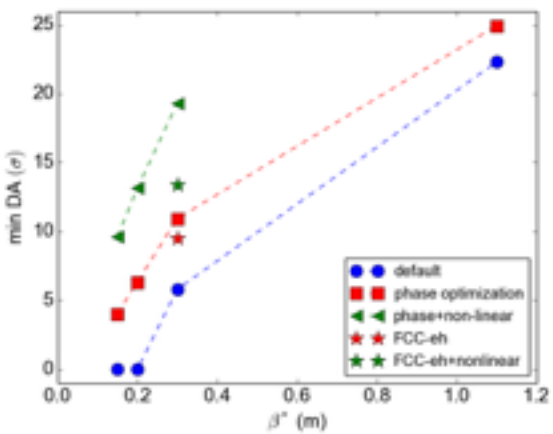


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  - 13.4 σ for FCC-eh

- Acceptable DA with phase optimization. Increased DA with non-linear correctors
- Non-linear correctors are necessary in case errors on IRL have an impact.

# Conclusions

## LHeC

- **A new IR design for the case L*=15 m** and β*=10 cm has been made with validation of magnet design and benefits on SR. Chromaticity correction is achievable.

- New design shows a DA of **12σ** including errors and non-linear correctors on HL. **Acceptable DA but only with the use of non-linear correctors on HL IR**.

- DA with an **estimation on LHeC errors** (using HL errortables) lowers the DA to **9.4σ**. Non-linear correctors crucial for HL IR and useful for LHeC IR. More iterations to be tested.

- **Studies for lower β*** (lattices with no magnet validation and L*=10m) show DA decreases when adding LHeC errors, but real **challenge** might come from somewhere else (**chromaticity correction).** Good news: new triplet shows better results for DA.

## FCC-eh

- DA studies for the FCC-hh show that an acceptable DA of 10.6 σ was obtained with phase optimization but a bigger increase up to 19.7 σ was obtained with non-linear correctors.

- When including FCC-eh IR results without non-linear correctors show a similar value of 9.5 σ, and an increase up to 13.4 σ was obtained when including non-linear correctors. **Non-linear correctors are therefore necessary** to ensure an acceptable DA in case error in LHeC IR affect the DA.