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Error Correction Schemes

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On behalf of the JAI FCC Team

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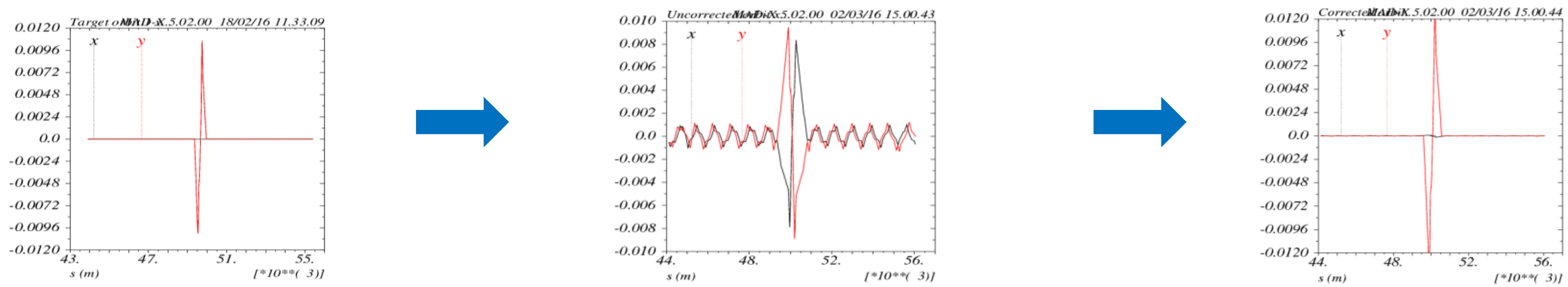
EuroCirCol
A key to New Physics

November 7th, 2016

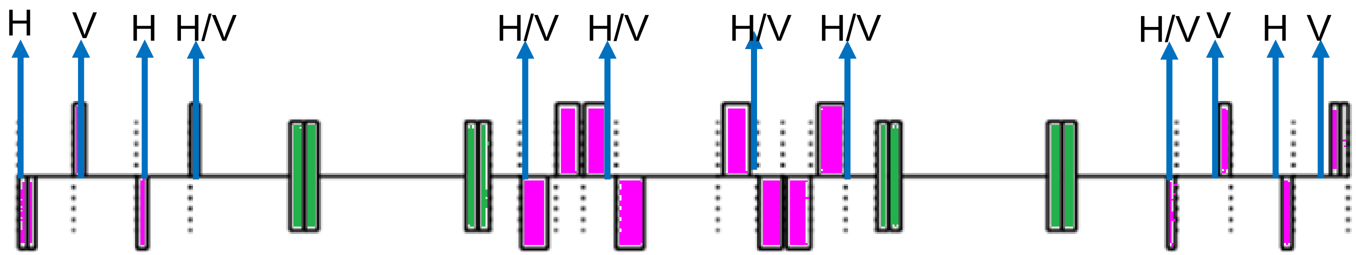
Correction Scheme

- **The objective of the correction scheme in the IR is to correct the orbit due to possible misalignments of the quadrupoles in the inner triplet and the separation dipoles.**

No errors | **Misalignment errors** | **Correction**



- **The correctors scheme used for these studies include:**
  - Use correctors installed next to the IT (also used for the crossing angle). L=0.5 m.
  - Correctors installed in the dispersion suppressor (DS). L=0.647 m
  - New correctors added in the matching section (MS) L=0.647 m.
  - BPM's installed along the IR. Used for correction procedure.



Studies and Procedure

- **Techniques to identify good correction:**
  - **Maximum Deviation**
  - Maximum Angle
  - Beta beating
  - **Corrector Strengths**

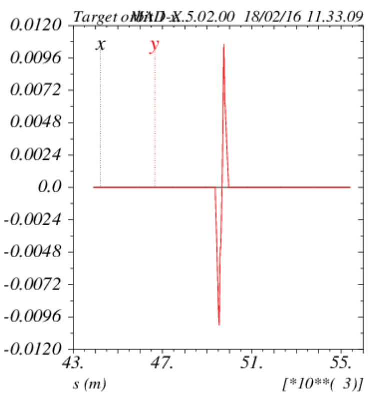
- **Studies for different types of errors:**
  - Quadrupole misalignments in the **IT** and **MS**
    - 0.35 mm
    - 0.5 mm
  - Tilt errors in the **separation dipoles**
    - 1 mrad
    - 2 mrad

- **Different optics**
  - **β^*=110 cm**
  - **β^*=30 cm**

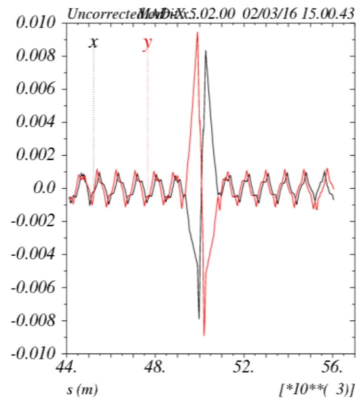
Analyse Results

1. Assign random errors. Gaussian errors 2.5σ.
2. Use CORRECT method in MADX.

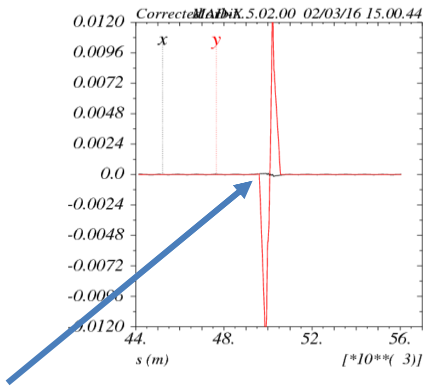
No errors



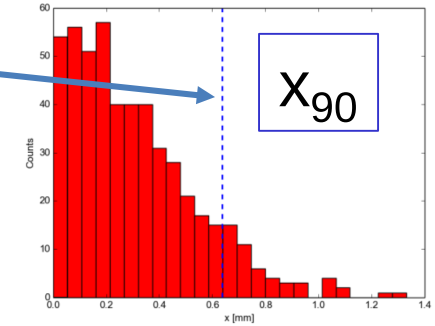
Added IT errors



Correction



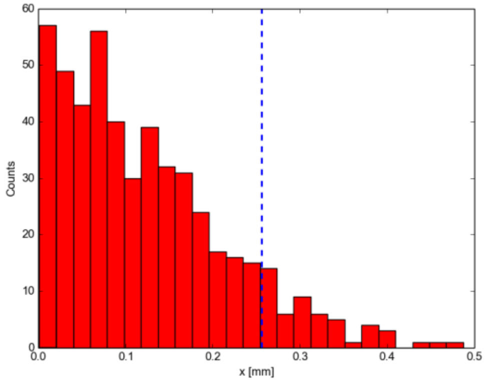
1. Calculate maximum orbit deviation/corrector strengths in IR after correction.
2. Repeat for 500 seeds
3. Calculate value of the maximum orbit deviation or correctors strengths for which 90% of the seeds are included (x_{90})



D. Boutin
Correction arcs

Previous Results

1.1 m



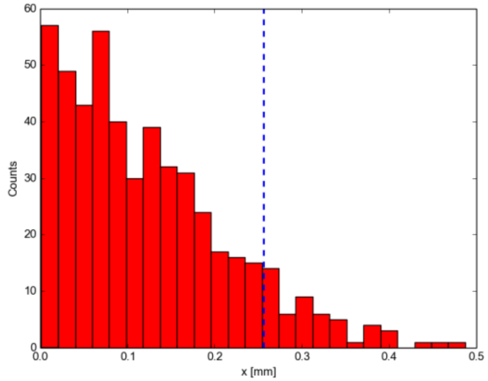
0.3 m

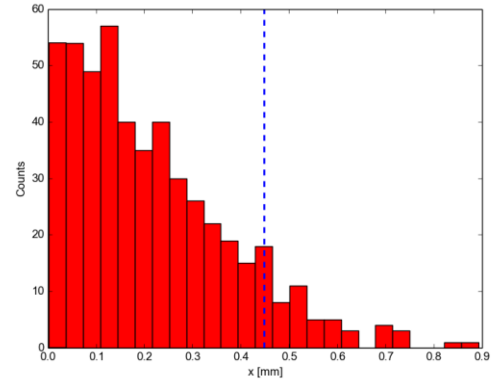
0.2 mm 0.35 mm 0.5 mm

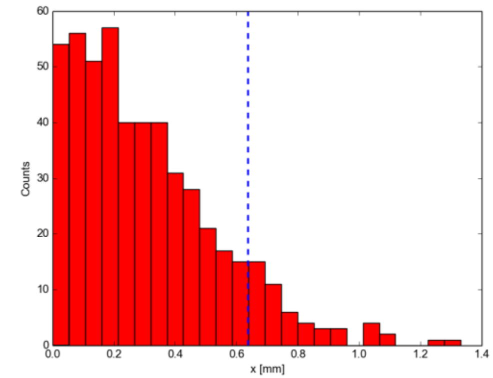
Quad Misalignment

Previous Results

1.1 m







0.3 m

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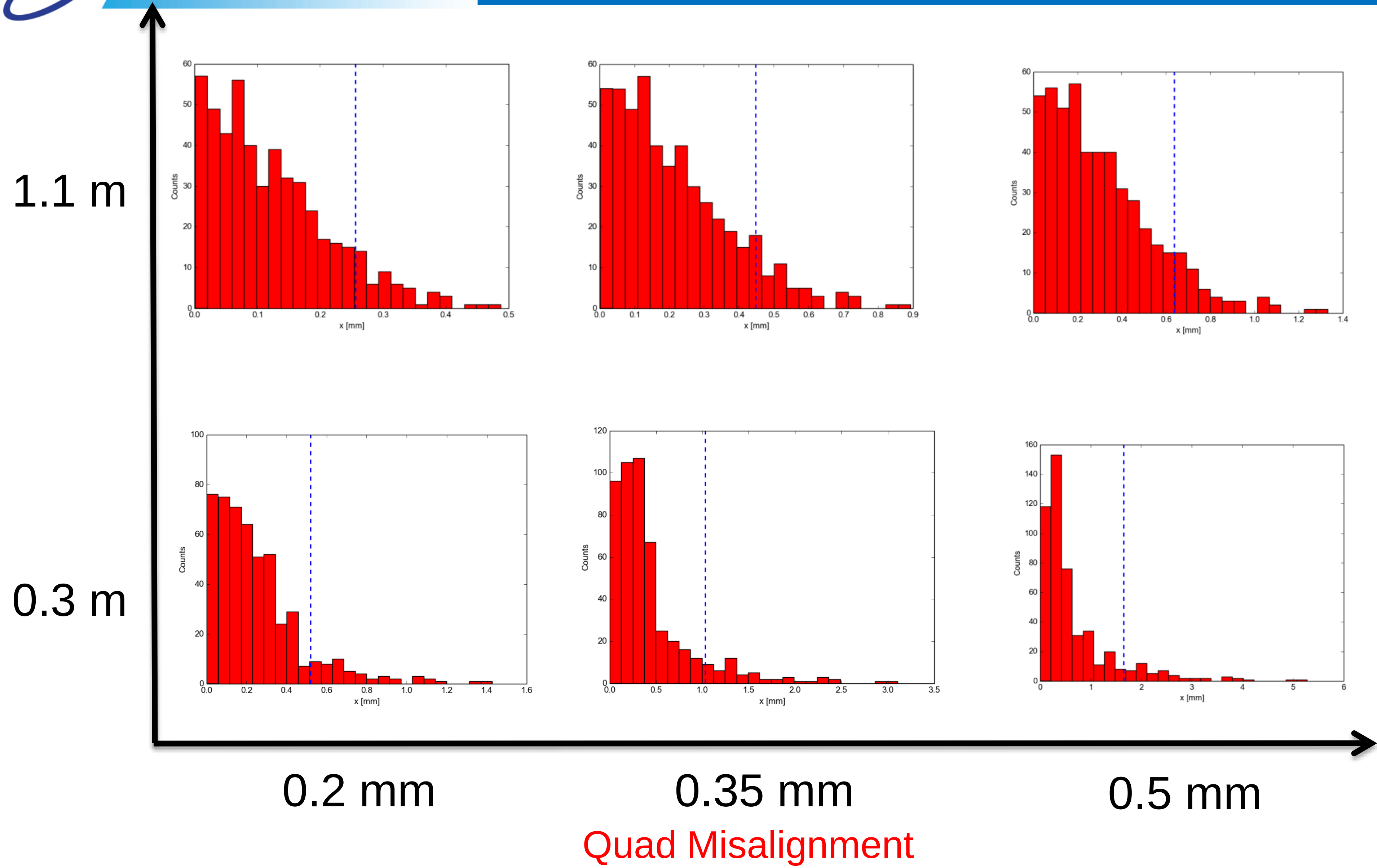
0.5 mm

Quad Misalignment

Previous Results



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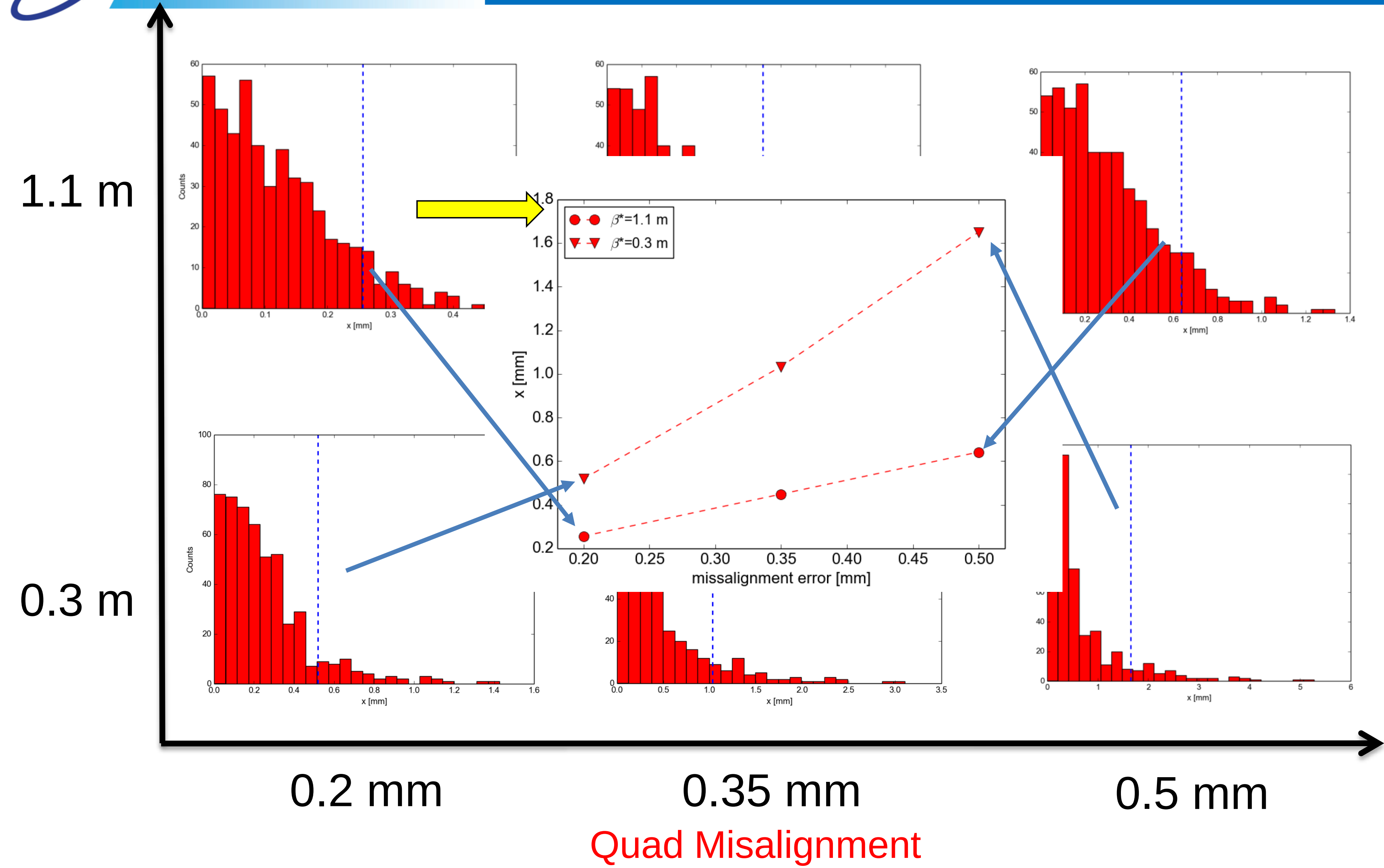
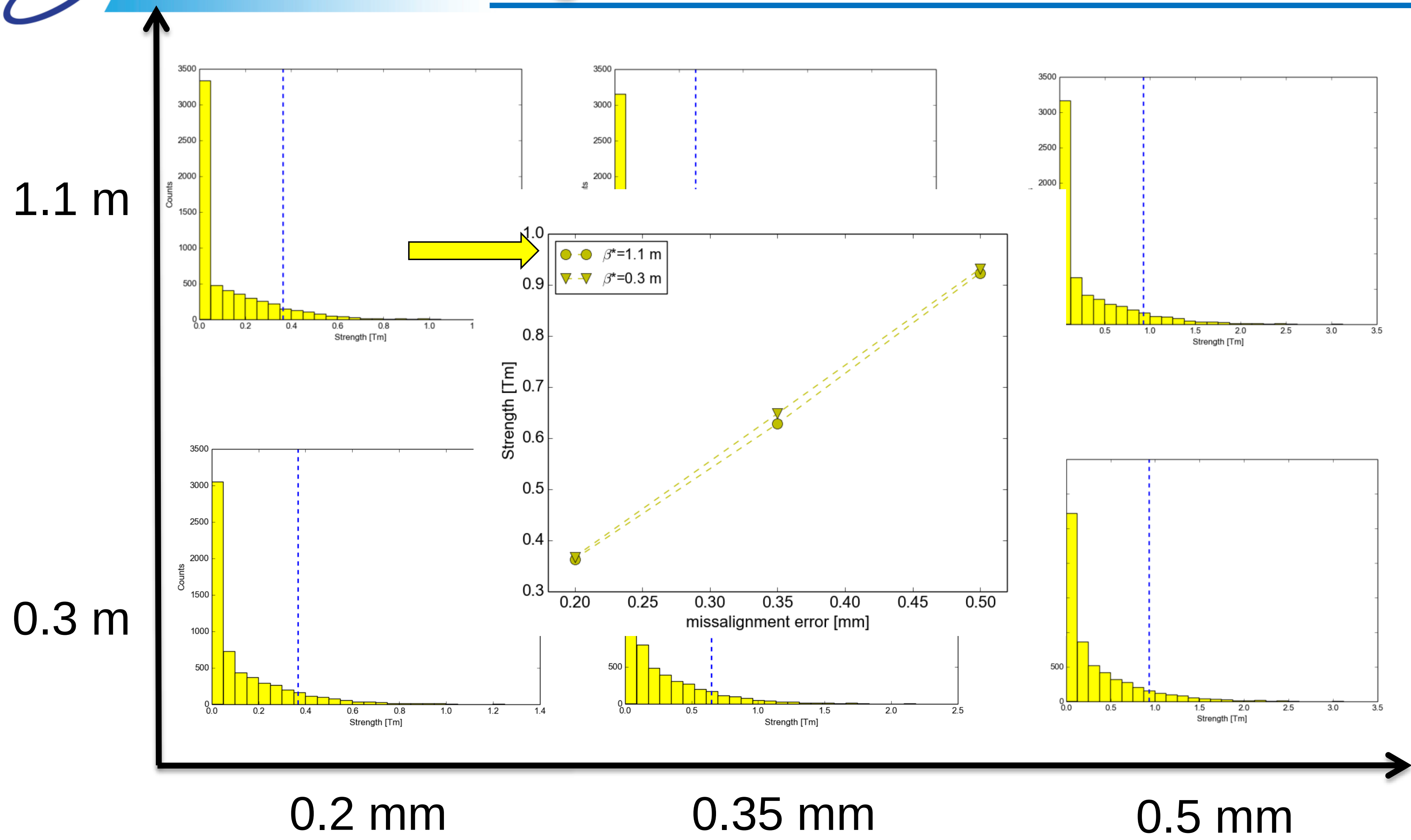


Strength of the Correctors



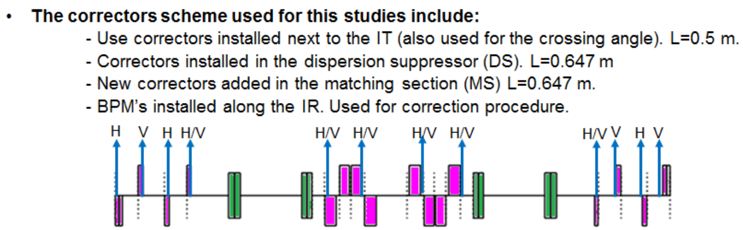
Quad Misalignment

New Lattice, New script

New lattice released by A. Chance with skew quads
New script: make_corr_seq.madx
That creates this task:

- Add lengths to correctors
- New correctors in MS
- Add BPMs in IR
- Groups correctors and monitor in families

(helpful to turn on/off families in correction procedure)

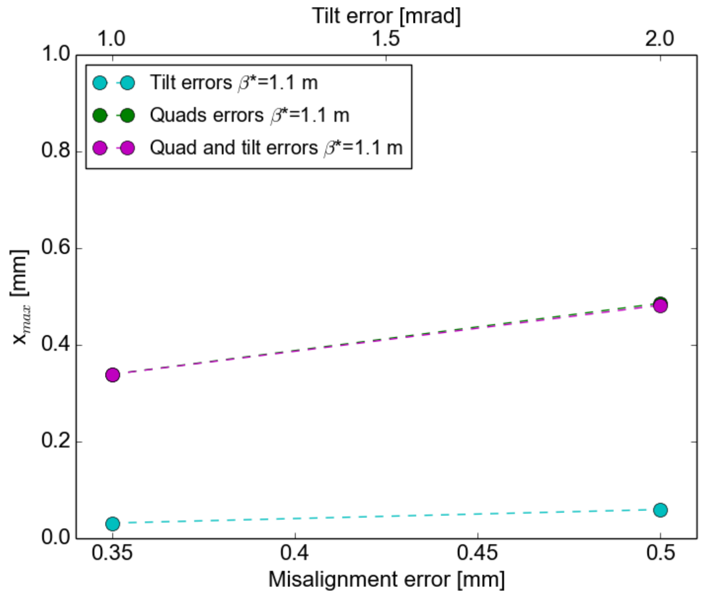


This allows me to:

1. Adapt it easily to new versions of lattice.
2. Track more easily effect of different parameters (length of correctors for example).

Results New Lattice

- Studies of the maximum orbital deviation (90-percentile) after the correction in the non crossing orbit with misalignment errors in the quadrupoles in the IT and the matching section and tilt errors in the separation dipoles.



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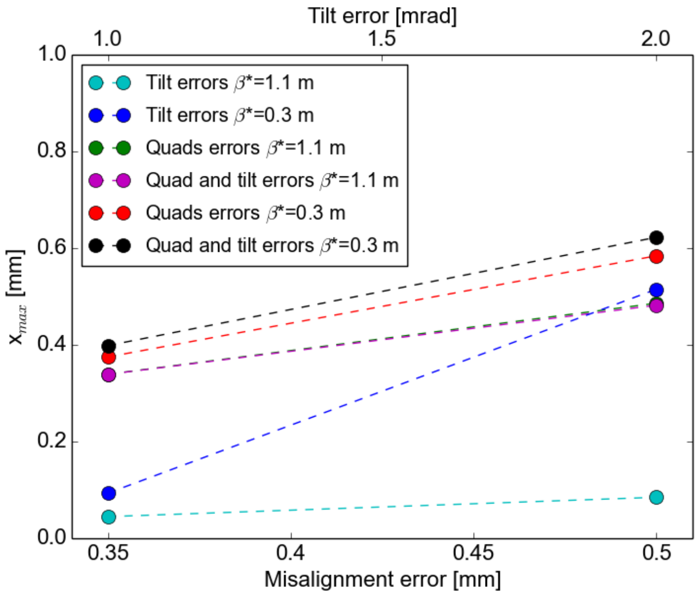
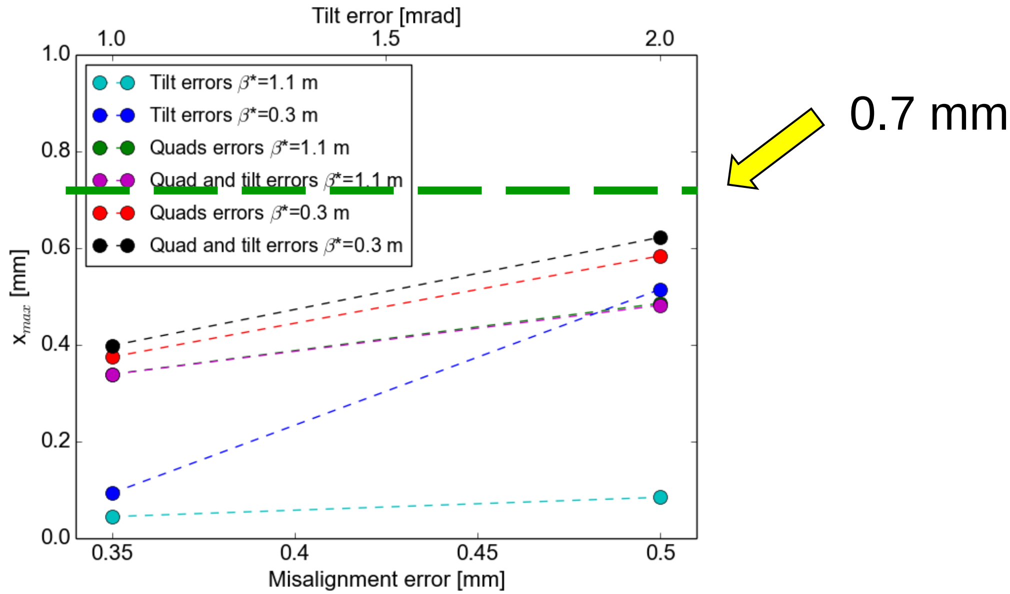


Errors IT+MS

- Studies of the maximum orbital deviation (90-percentile) after the correction in the non-crossing orbit with misalignment errors in the quadrupoles in the IT and the matching section and tilt errors in the separation dipoles.



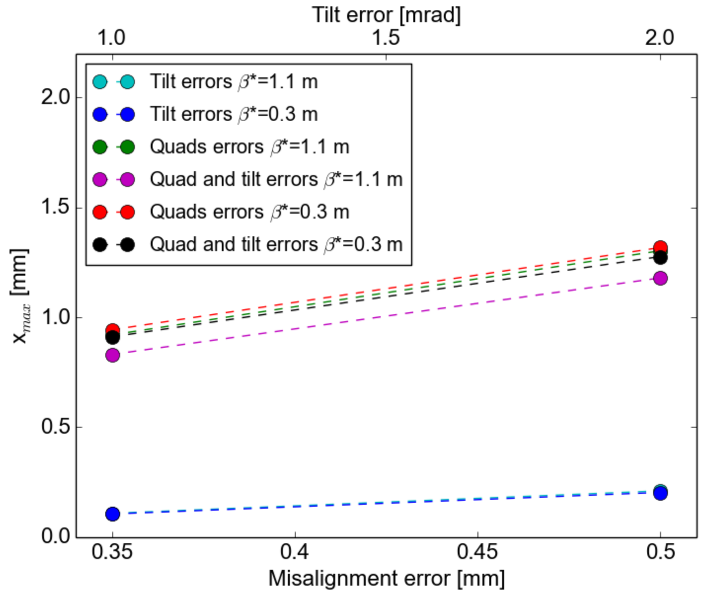
- More challenging cases with β* of 30 cm.

- Tilt errors are corrected very well. Quad+tilt errors almost the same as quad errors only.

- All the studies have a 90-percentile maximum deviation below 0.7 mm. Only the most challenging cases with β* of 30 cm and quad error with a gaussian around 0.50 mm are above 0.5 mm.

Corrector Strengths

- Studies of the corrector strength (90-percentile) needed for correction in the non-crossing orbit with misalignment errors in the quadrupoles in the IT and the matching section and tilt errors in the separation dipoles.



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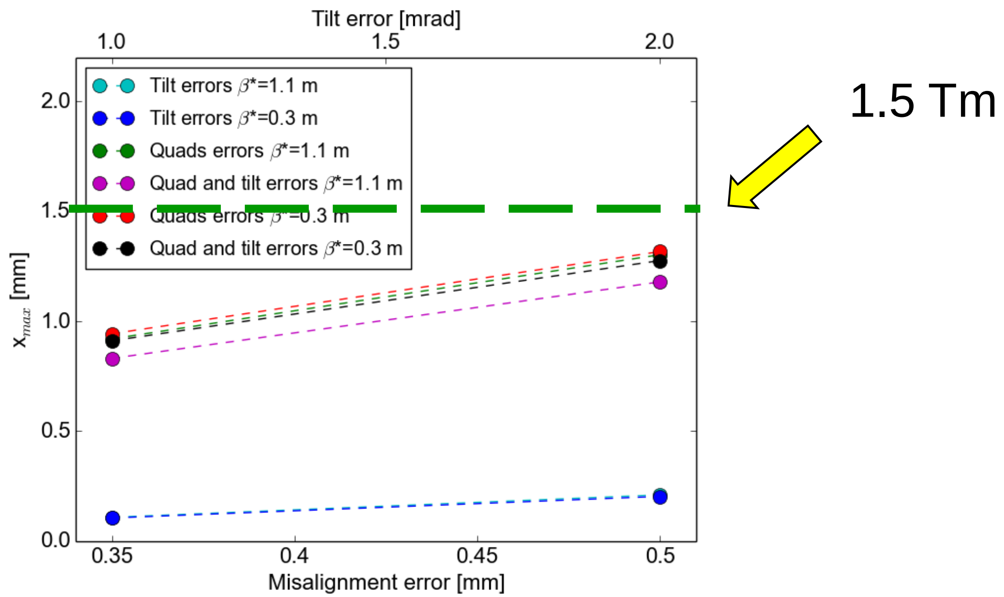

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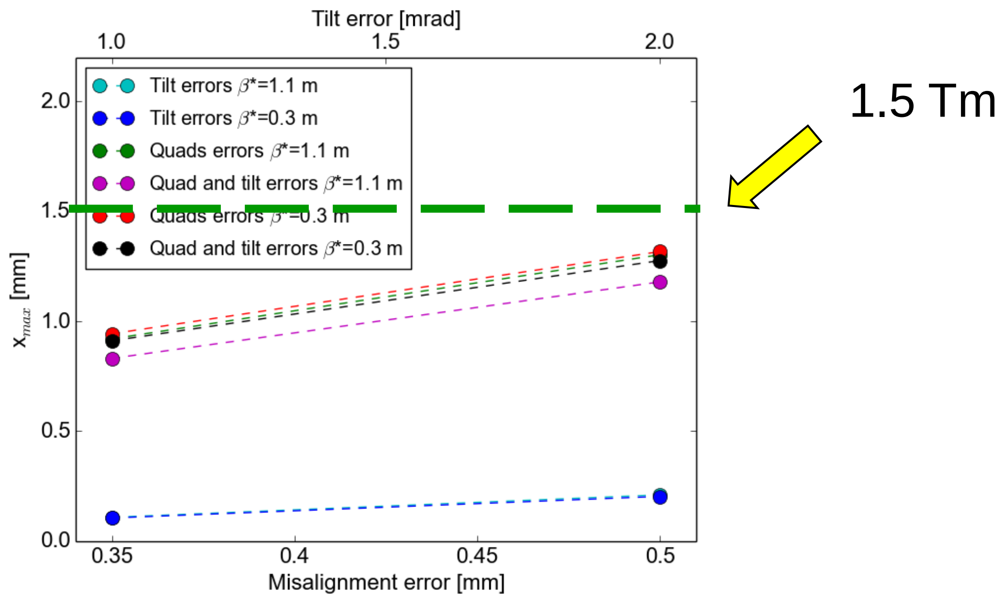

- Strength required increases linearly with error and is higher for the optics with β*=30 cm.

- All cases have a 90-percentile maximum strength of 1.5 Tm, including the most challenging case with β*=30 cm and 0.5 mm misalignment.

Corrector Strengths

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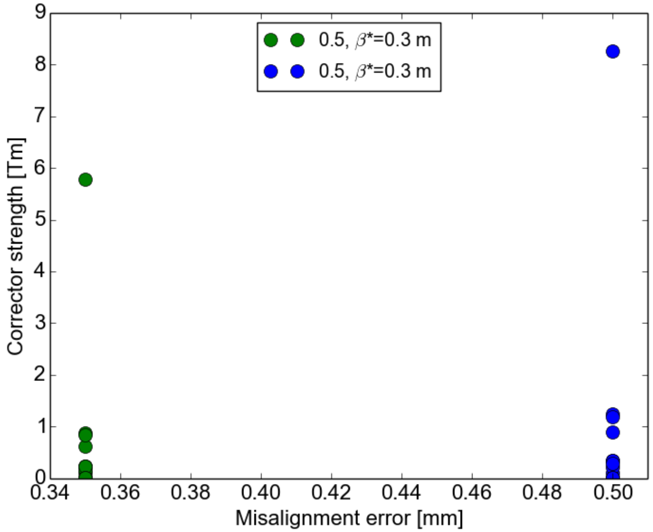

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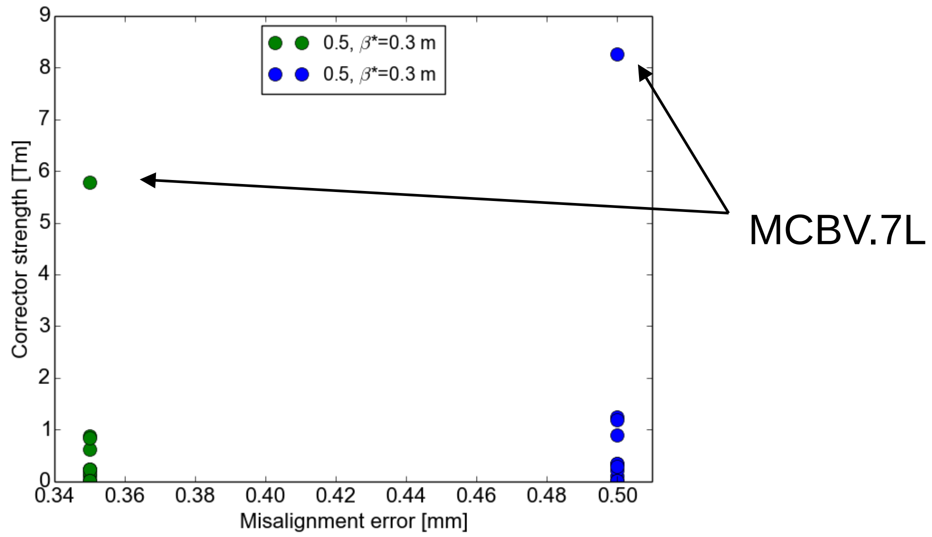

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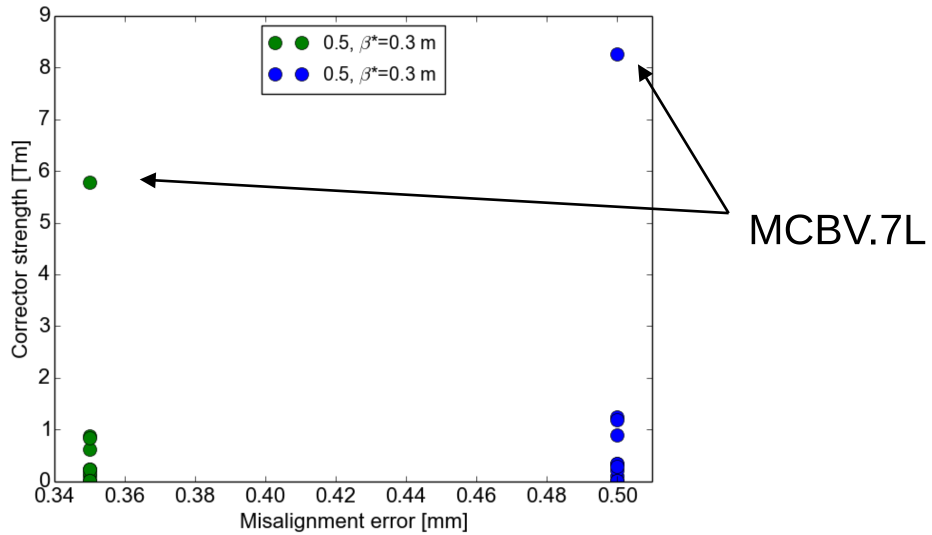
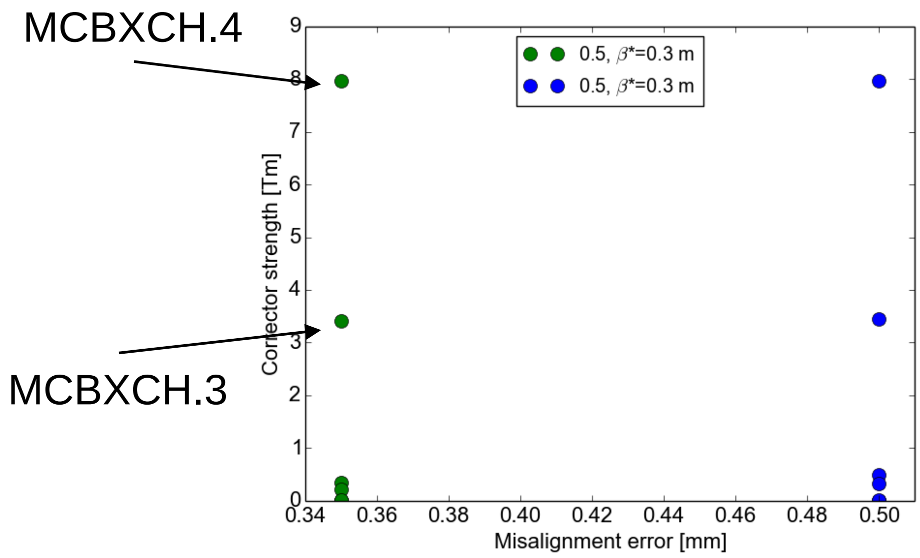


- When adding MS errors all correctors have a 90-percentile corrector strength below 1.5 Tm except for corrector next to MQ7 (MCBV.7L).

- Explore a different correction or make this corrector longer.

Corrector Strengths

- Studies of the IT (and MCB4) corrector strength (90-percentile) needed to correct the errors and provide the crossing angle.



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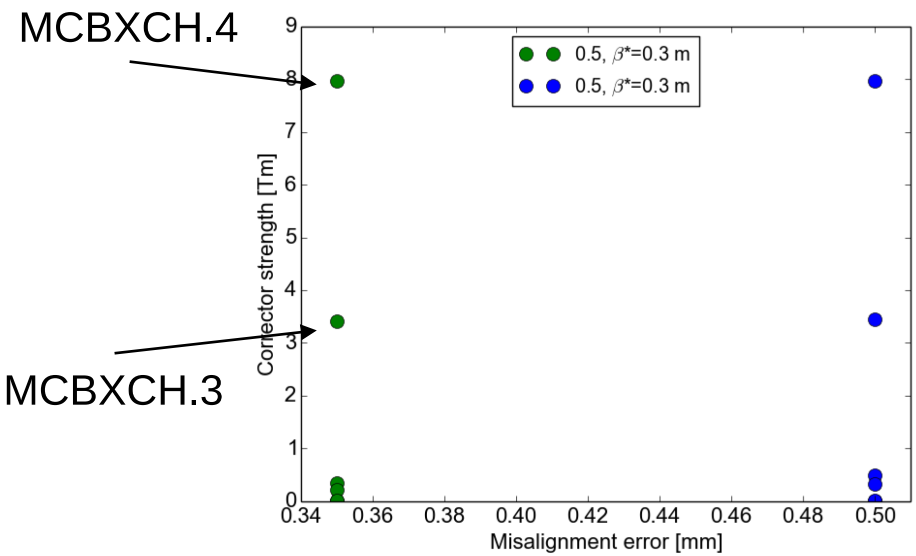

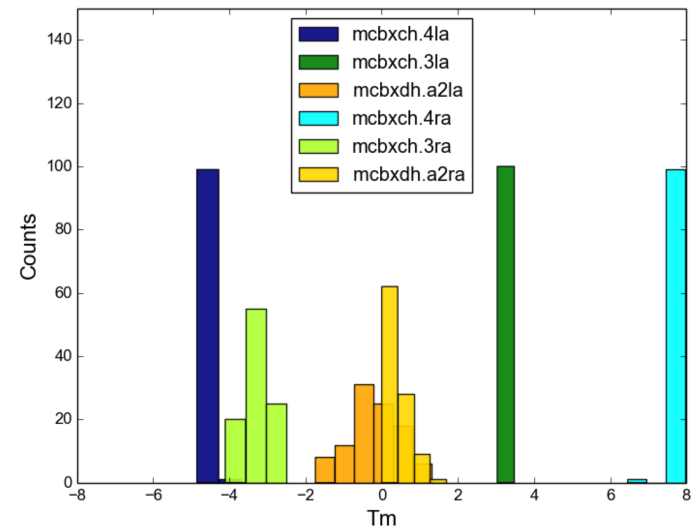

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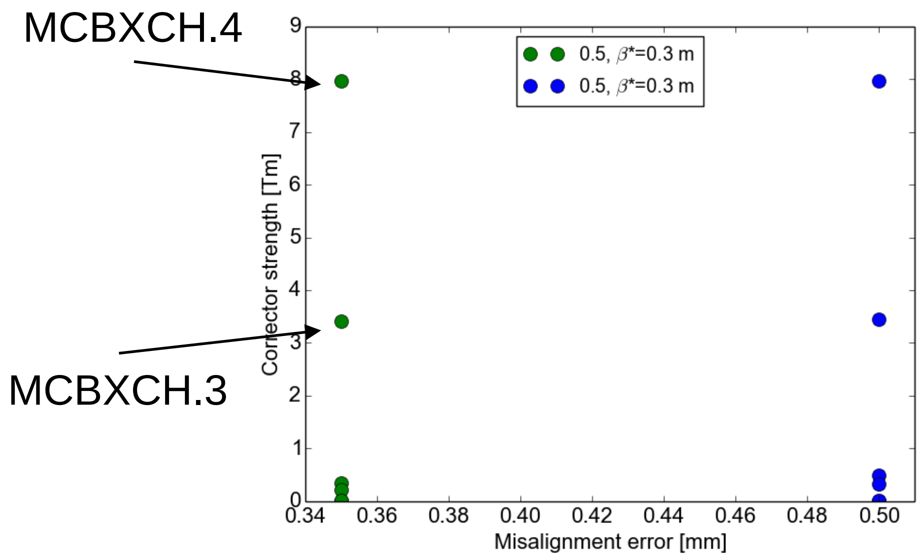
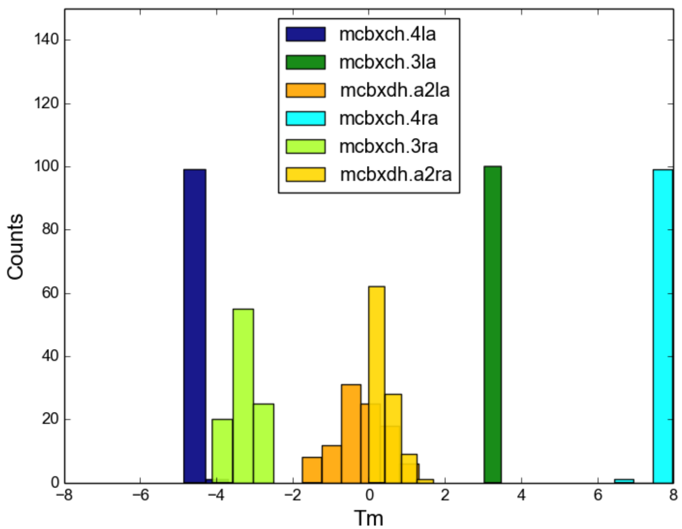
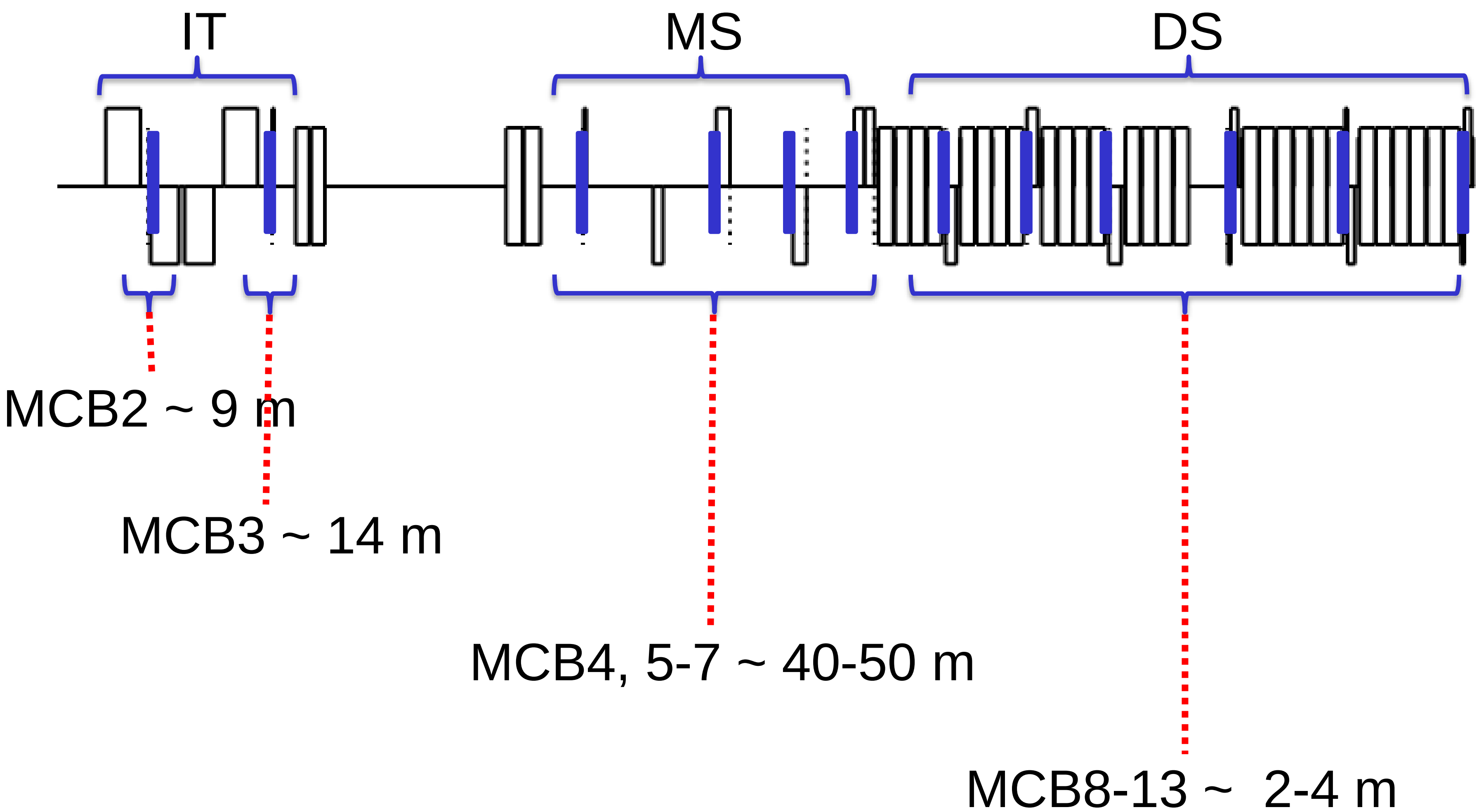




- Higher strength in 4th corrector (MCBXCH.4la and MCBXCH.4ra). This corrector has already a length of 3 m.
- Lower strengths needed for corrector 2 but for corrector 3 a length of 1 m might be required.

Space

- Space available for correctors and BPMs in the current design.



Deviation at location of crab cavities

- Following the example of HL-LHC:

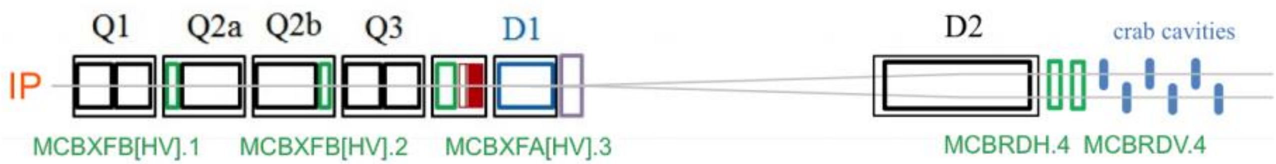
Yi-Peng Sun et al,
Phys. Rev. ST Accel. Beams 12, 101002 (2009).

Possible location of the crab cavities:

1. Need space
2. High beta function
3. Phase advance with respect to IP close to π/2

$$V_1 = \frac{c^2 \cdot p_s \cdot \tan(\frac{\theta}{2})}{q \cdot \omega \cdot \sqrt{\beta^* \cdot \beta_{\text{crab}}} \cdot \sin(\Delta\varphi_0)},$$

$$V_2 = -R_{22} \cdot V_1,$$



- After separation dipole D2 and before MQ4: → $\beta \sim 3000$ m, $\mu \sim 0.2567\ [2\pi]$

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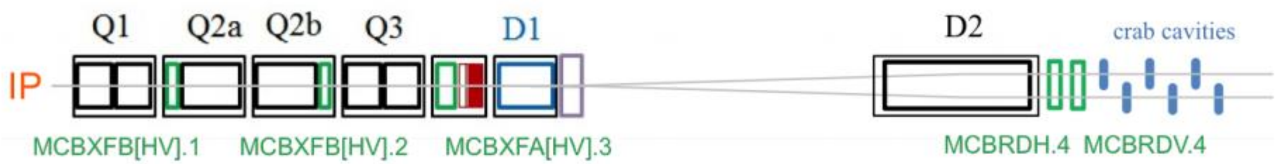

- After separation dipole D2 and before MQ4: → β ~ 3000 m
  μ ~ 0.2567 [2 π]

- Check orbital deviation at this location.

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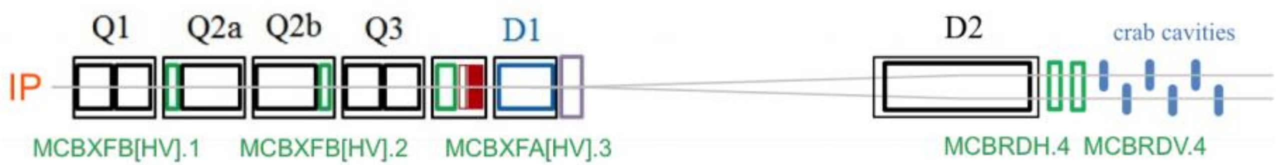

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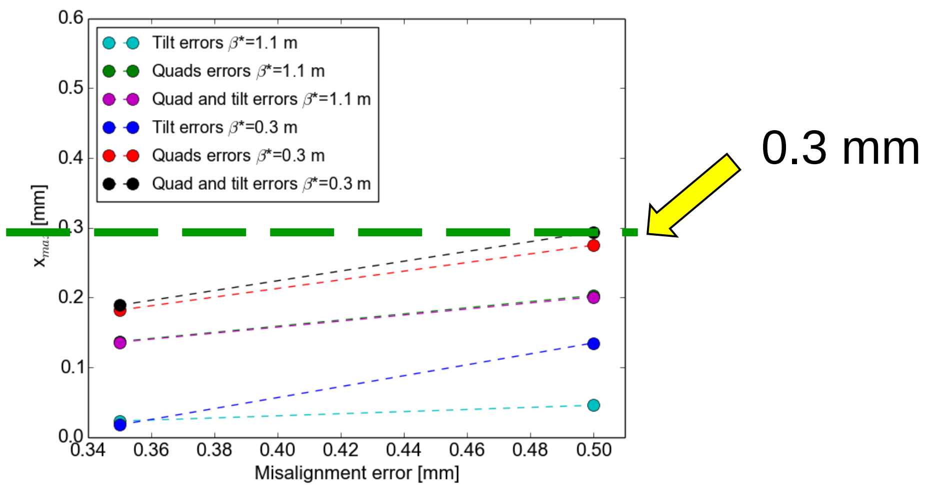

- For all cases the maximum orbital deviation was below 0.3 mm

Conclusions

- Studies were done to check the efficiency of the correction scheme for different alignment errors in the quadrupoles (IT and MS) and tilts in the separation dipoles. Studies were also done for different optics (β^*=110 cm and β^*=30 cm).

- The efficiency of the correction is measured in terms of the maximum orbital deviation after the correction in the non-crossing orbit and the strength of the correctors.

- Only the case with β^*=30 cm and (gaussian around) 0.5 mm misalignment was above a maximum deviation of 0.5 mm after correction.

- The strength of the correctors for the non crossing orbit require values below 1.5 Tm. For the crossing orbit higher strength are needed to provide the crossing angle as well (particularly for the MCB4 corrector) but the values are similar to the nominal ones and contemplated with the length (3 m).

- The maximal orbital deviation at the possible location of the crab cavities is kept below 0.3 mm.

Thank you!