RELATIVE ALIGNMENT WITHIN THE MAX IV 3 GeV STORAGE RING MAGNET BLOCKS

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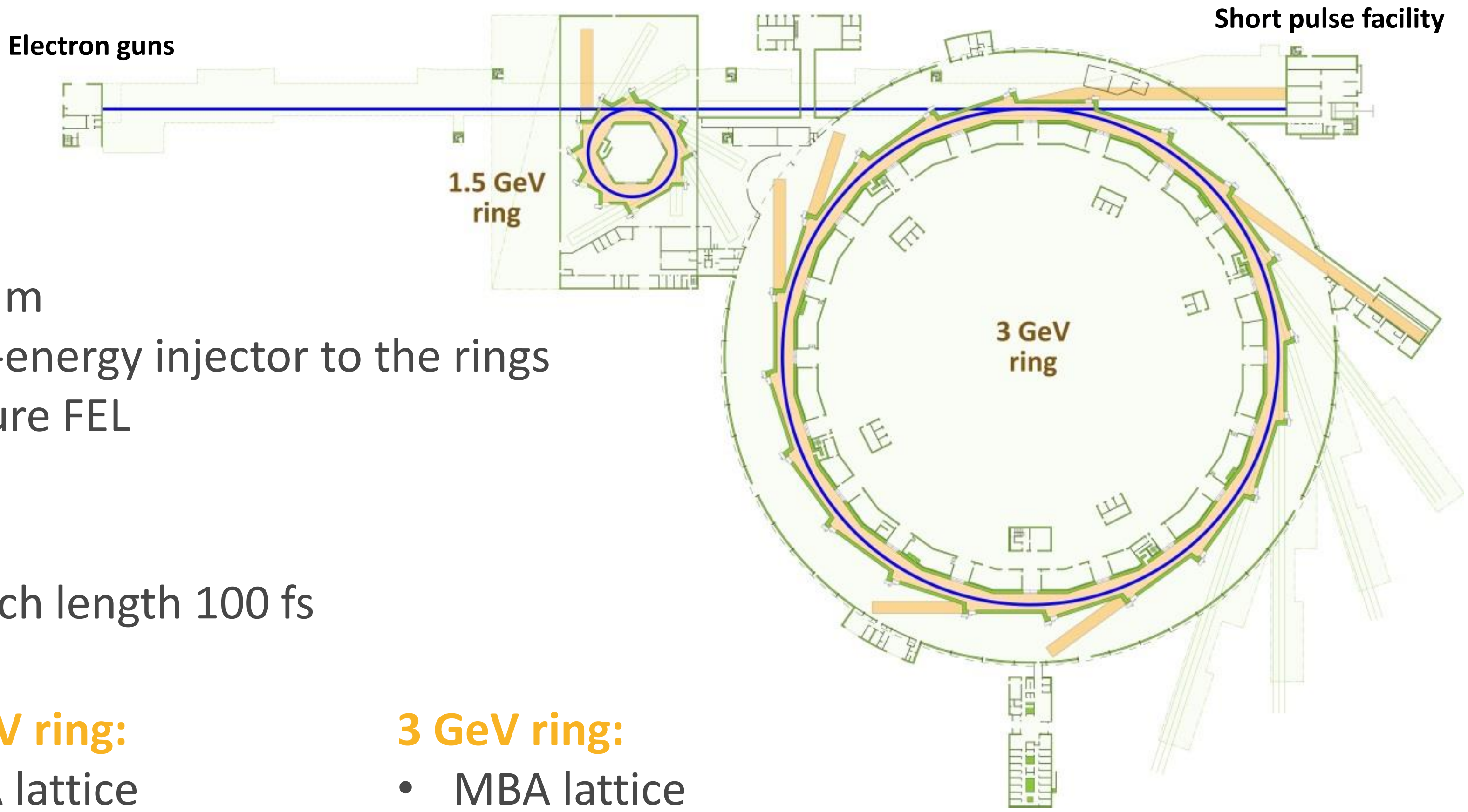
MAX IV

Outline

- Overview of the MAX IV facility
- Magnet design concept
- Displacements of magnetic centers from rotating coil data
- Compensating for rotating coil shaft sag
- Total results
- Summary and conclusions

Overview of the MAX IV facility



Linac:

- 250 m
- Full-energy injector to the rings
- Future FEL

SPF:

- Bunch length 100 fs

1.5 GeV ring:

- DBA lattice
- Emittance 6 nm rad
- Soft X-ray users

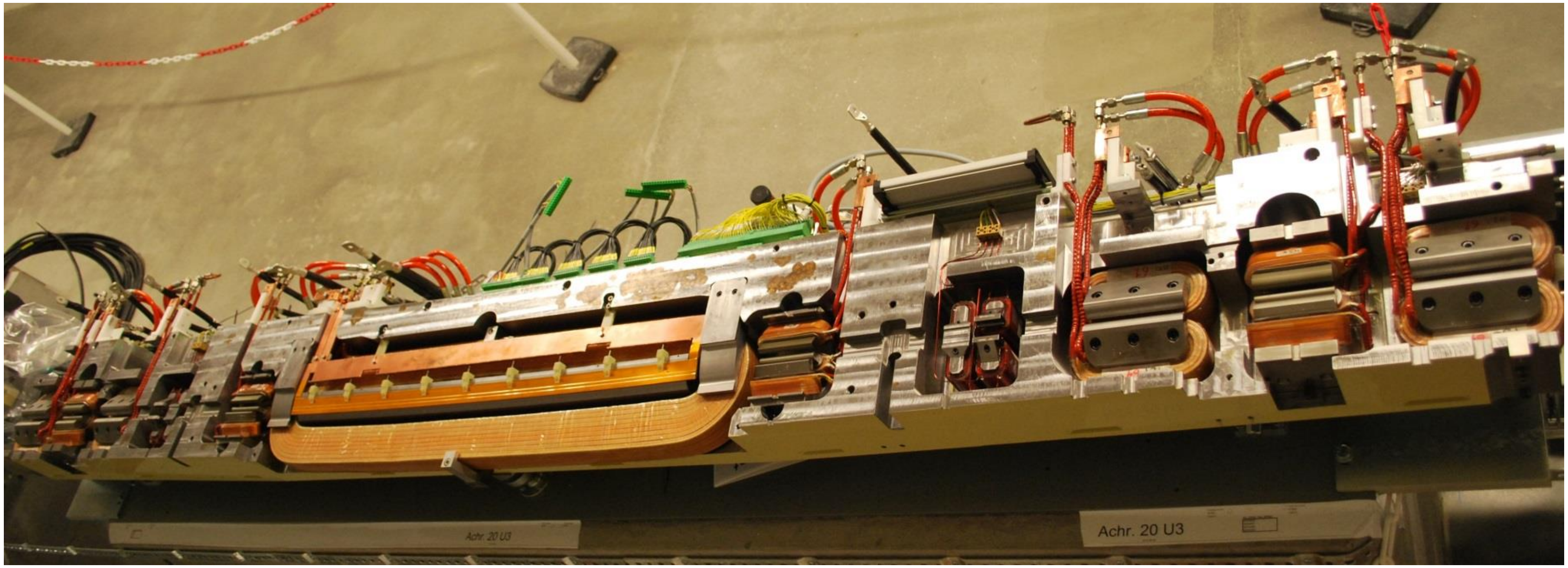
3 GeV ring:

- MBA lattice
- Emittance ~0.3 nm rad (bare)
- Hard X-ray users

Overview of the MAX IV facility

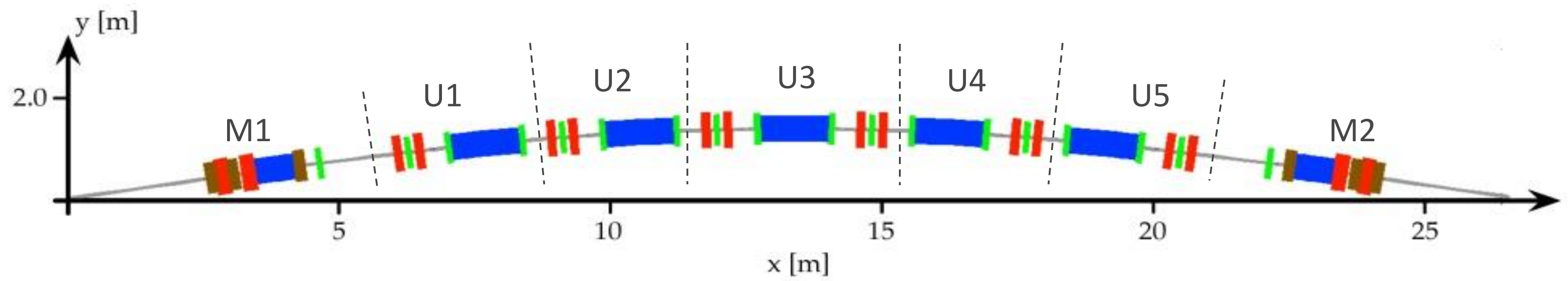
Magnet design concept

- Precision machined magnet blocks (2.3-3.4 m) containing several different magnets – both return yoke and support structure
- Assumes magnetic centers only depend on pole surface position – depend on manufacturing tolerances



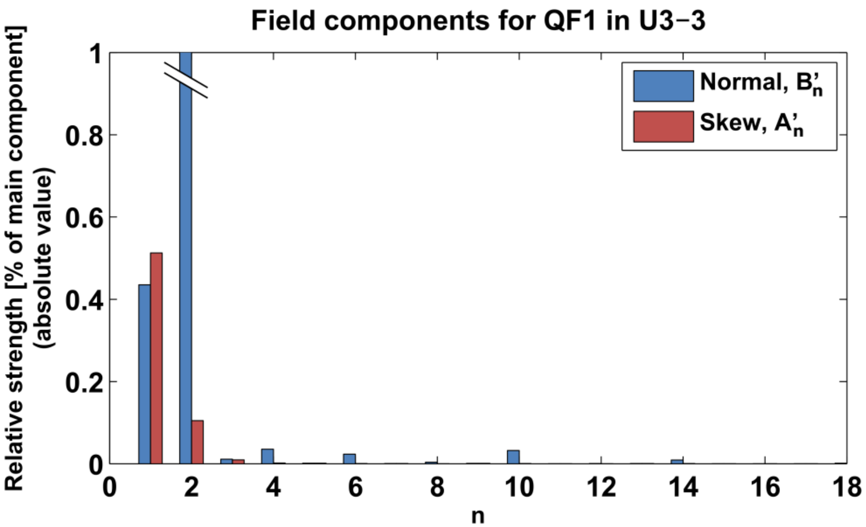
Magnet design concept

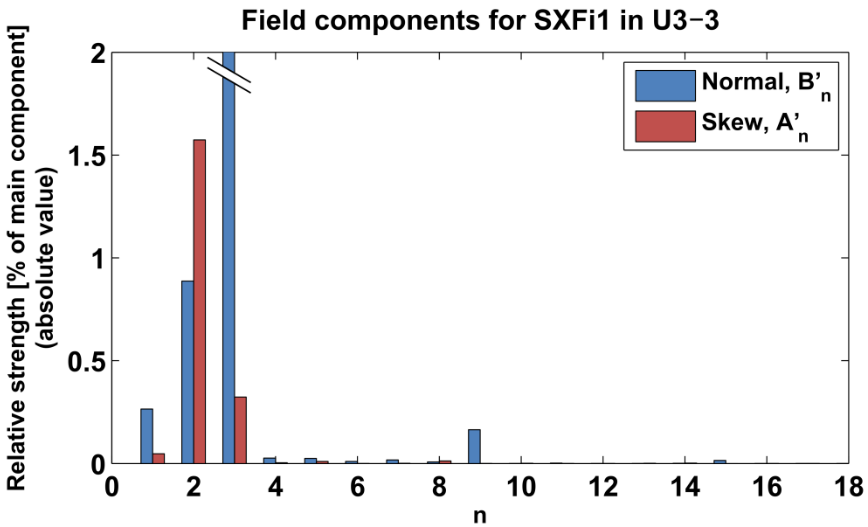
- Seven block types: M1, U1-U5, M2, making up one achromat
- Both production and measurements outsourced to industry (Scanditronix Magnet AB and Danfysik A/S)
- MAX-lab provided technical specification and drawings



First order feed-down

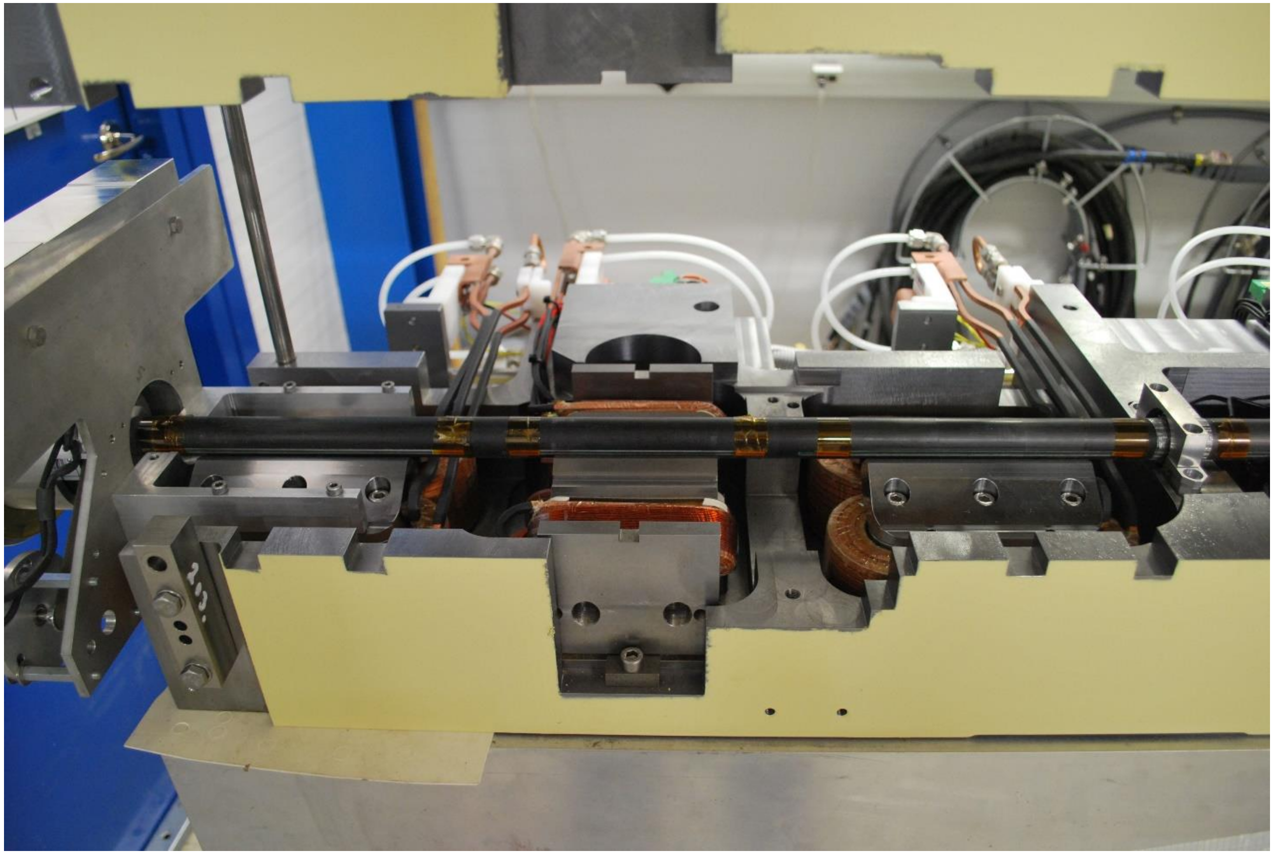
- Going off center in a quadrupole introduces a dipole field, off center in a sextupole introduces a quadrupole and dipole field, etc.
- First order means neglecting all but the first term below, i.e. only keeping the quadrupole term from the sextupole





Displacements from harmonic content

- Manufacturers decided on rotating coils for harmonic content
- Multiple, longitudinally spaced rotating coils on common shaft



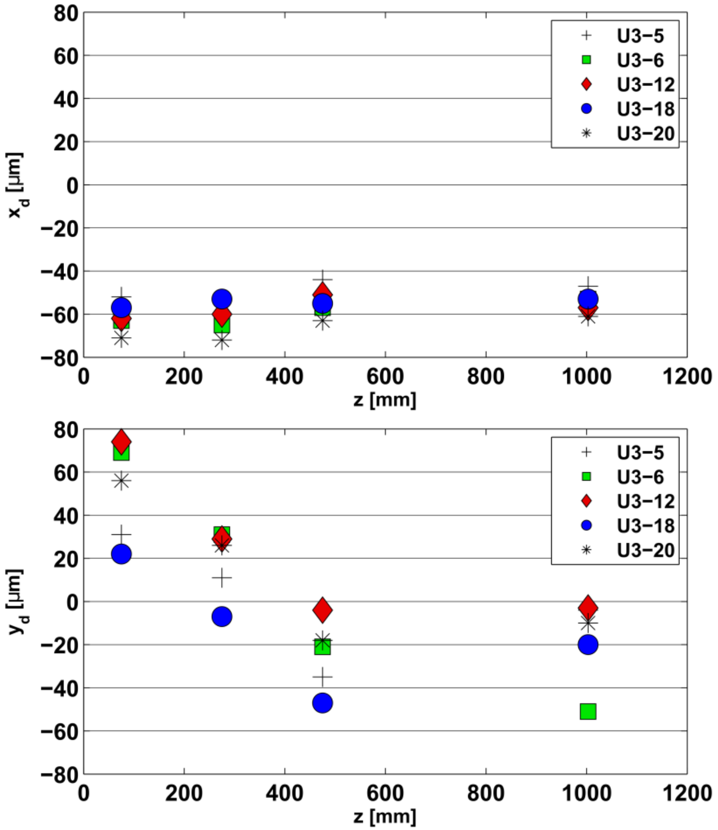
Displacements from harmonic content

MAX IV

Displacements from harmonic content

- Displacements calculated with first order feed-down
- $x_d \propto \frac{B'_{m-1}}{B'_m}$,
- $y_d \propto \frac{A'_{m-1}}{B'_m}$, m is the main component
- We plot the displacements as a function of longitudinal position in the magnet block:

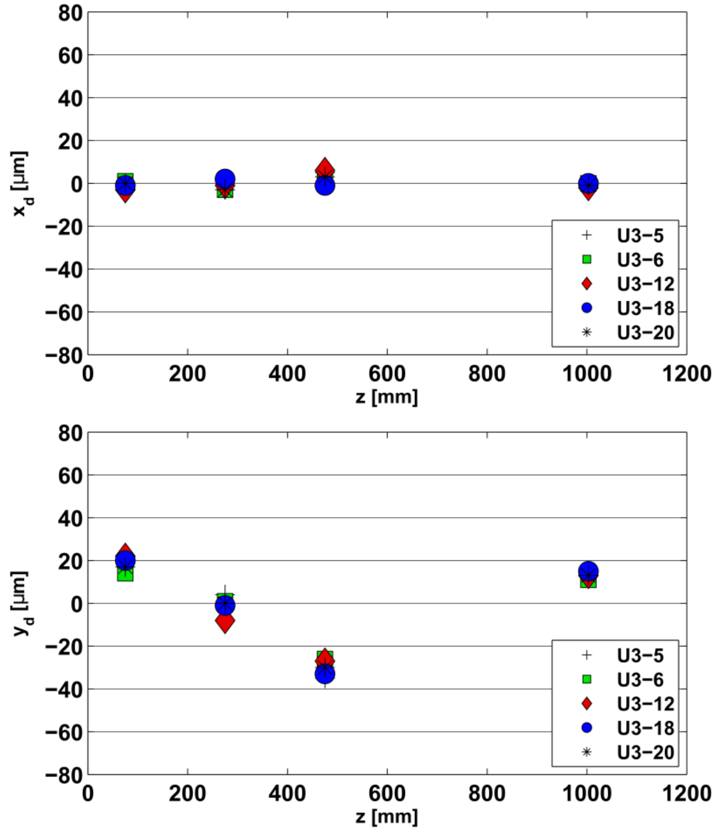
Displacements from harmonic content



- Raw data from feed-down calculations consistent with positioning accuracy for rotating coil shaft (spec. ±0.1 mm)
- Data appears to be on a common line – calculate and subtract a linear fit from raw data (results in relative alignment)

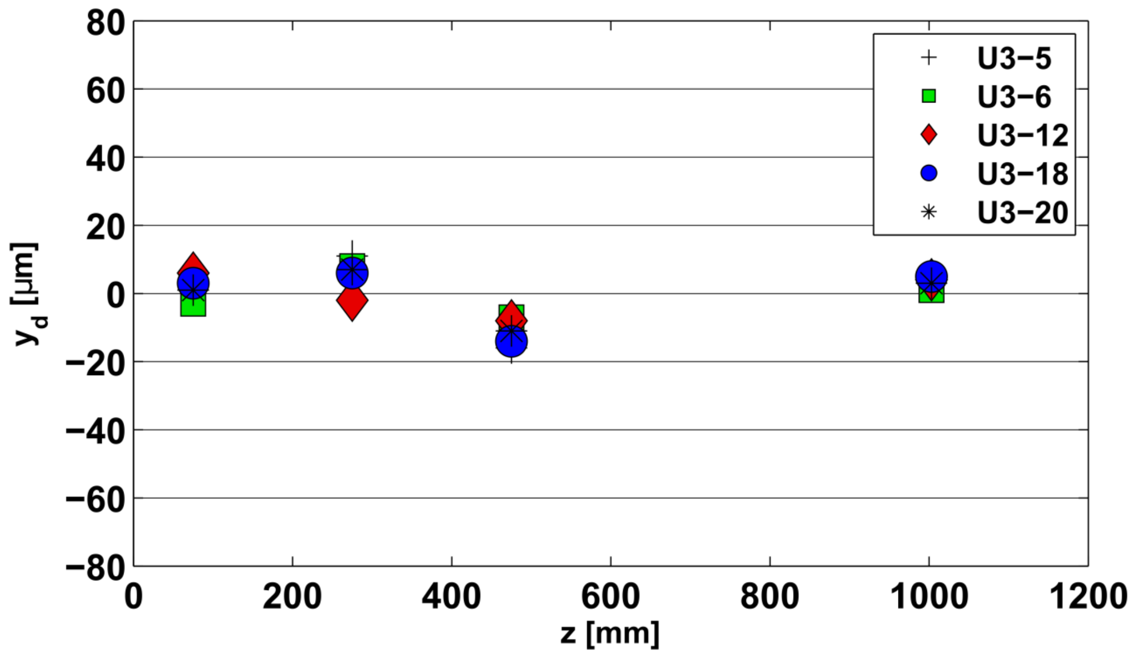
Displacements from harmonic content

- U-shape (vertical) is ascribed to sag of the coil shaft under its own weight

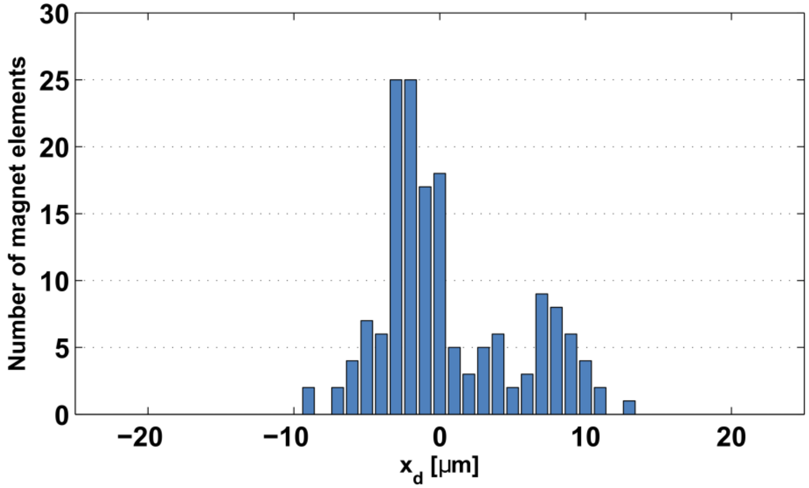


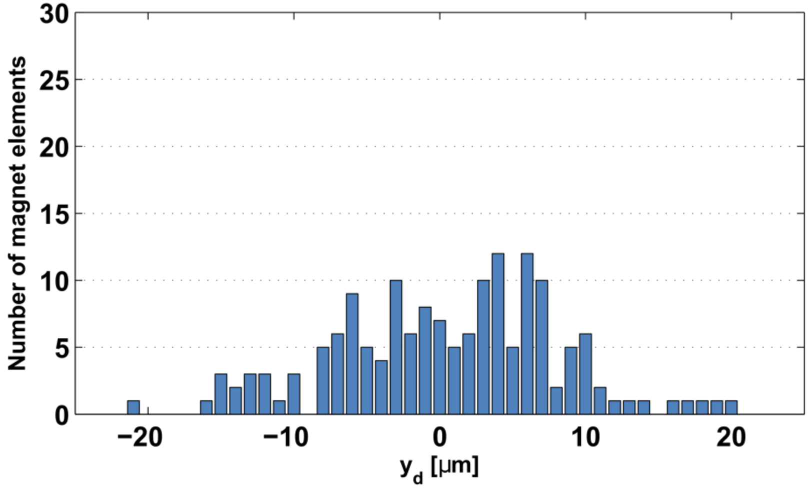
Compensating for shaft sagging

- Subtracted theoretical deflection of the shaft from the raw data and made new linear fit



Total results





Total results

- Relative alignment <10 µm RMS for all magnet block series

Block series	Rel. align.	Min [µm]	Max [µm]	RMS [µm]	Compensated for sag
M1, M2	dx dy	-10 -24	12 18	3.2 9.1	No
U1, U2, U4, U5	dx dy	-16 -24	12 30	4.3 6.4	No
U3	dx dy	-10 -21	13 19	4.7 7.6	Yes

Summary and conclusions

- Obtained information on magnet-to-magnet (relative) alignment from rotating coil data
- Results are a combination of tolerance stack-up and any inhomogeneous magnetization effects
- Relative alignment over whole block length: RMS values ± 20 µm (transverse tolerance over whole block length)
- Simulations have included an internal relative alignment of 25 µm RMS over one block
- **From the perspective of magnet-to-magnet alignment, we are on track for achieving design performance!**

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MAX IV