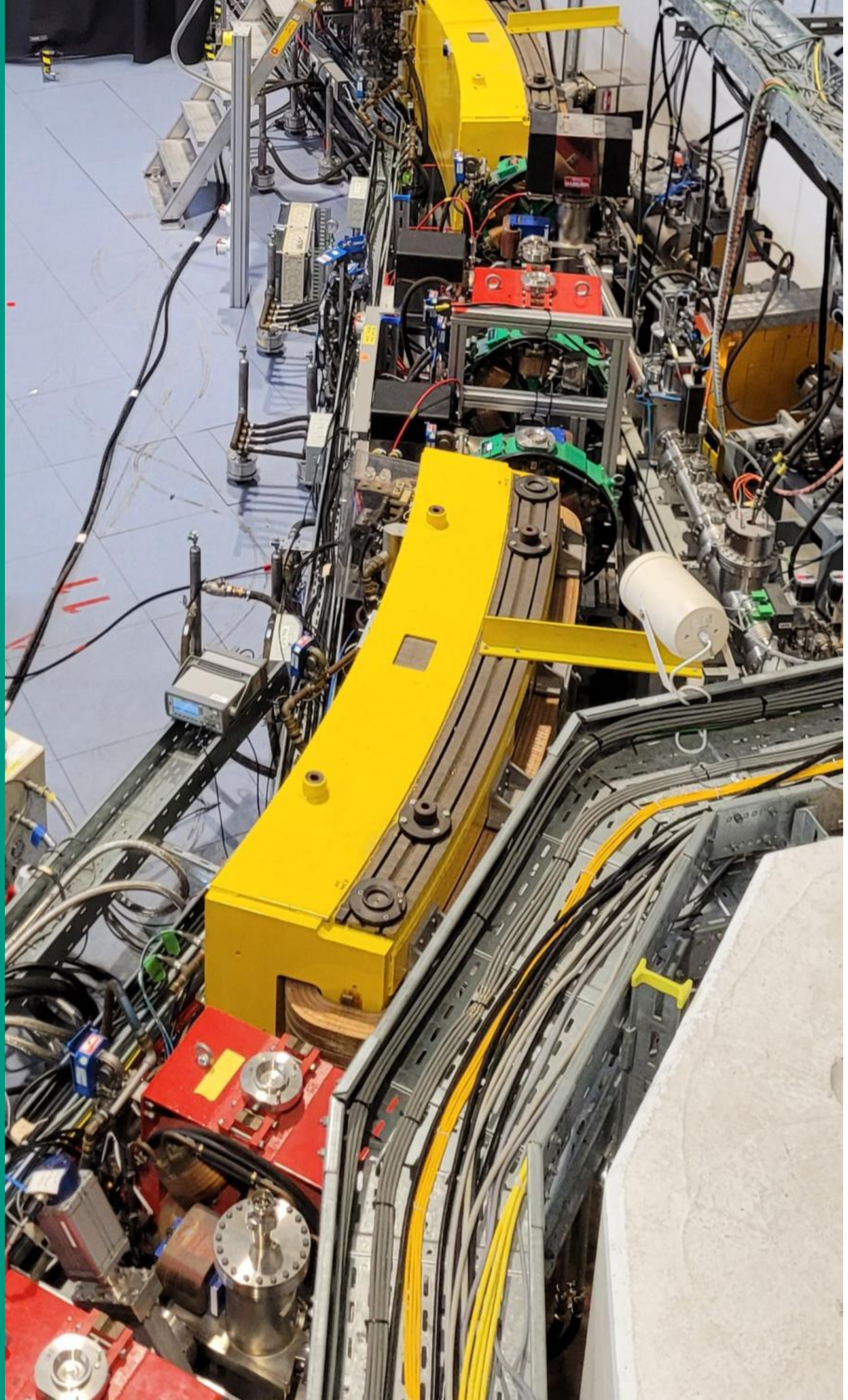
Beam-based alignment and measurement possibilities at KARA



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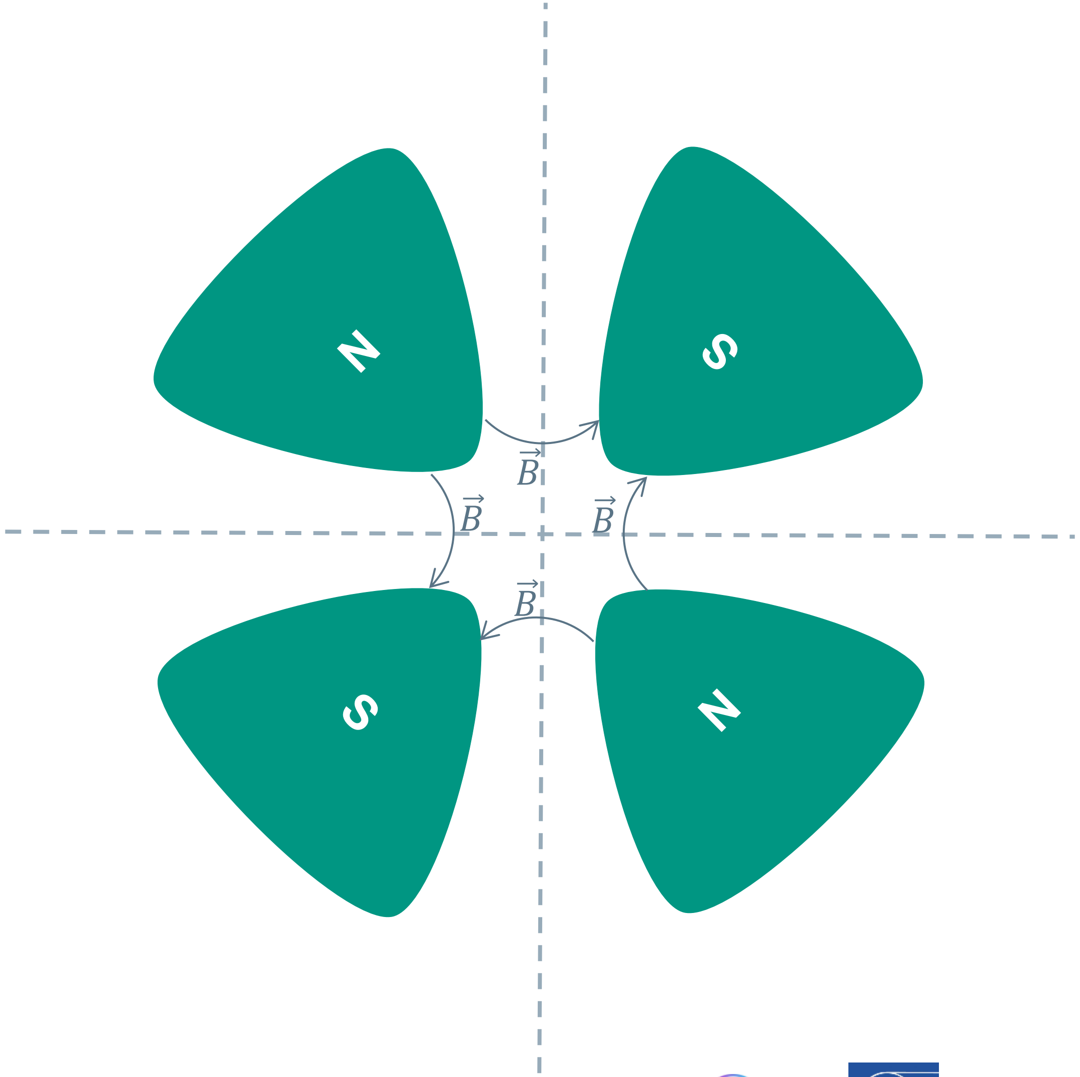
Why is beam-based alignment required?

Some misalignment of accelerator elements unavoidable

For magnets feed-down effects

- Quadrupoles
  - Additional deflection
- Sextupoles
  - Additional deflection
  - Focussing/defocussing
  - Change of coupling



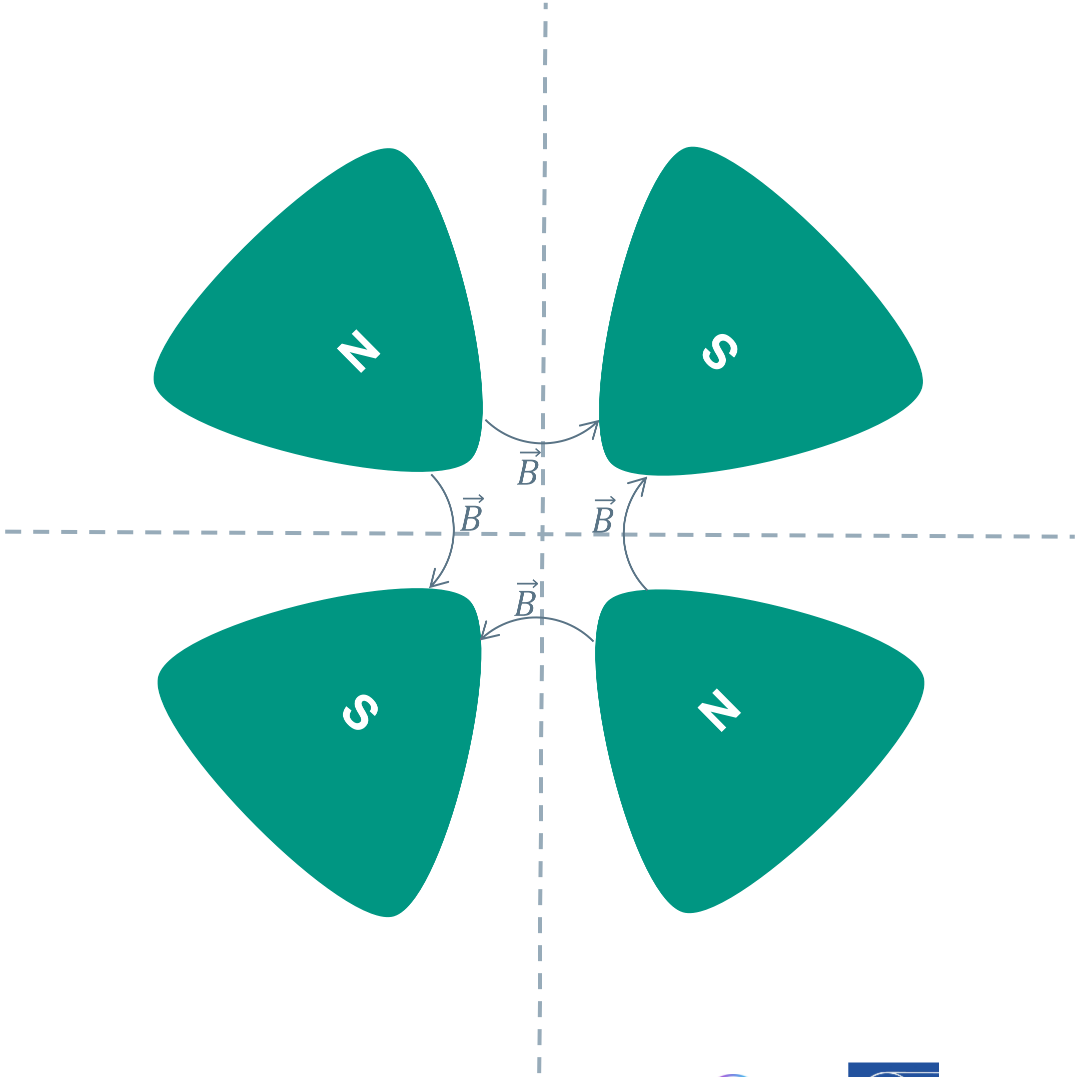
Why is beam-based alignment required?

Change of accelerator optics

- Orbit deviations
- Beta beating
- Tune change
- Change of coupling

Reduce effective misalignment by steering beam towards centre of magnets

Knowledge of position of magnetic centre required for orbit correction



What is beam-based alignment?

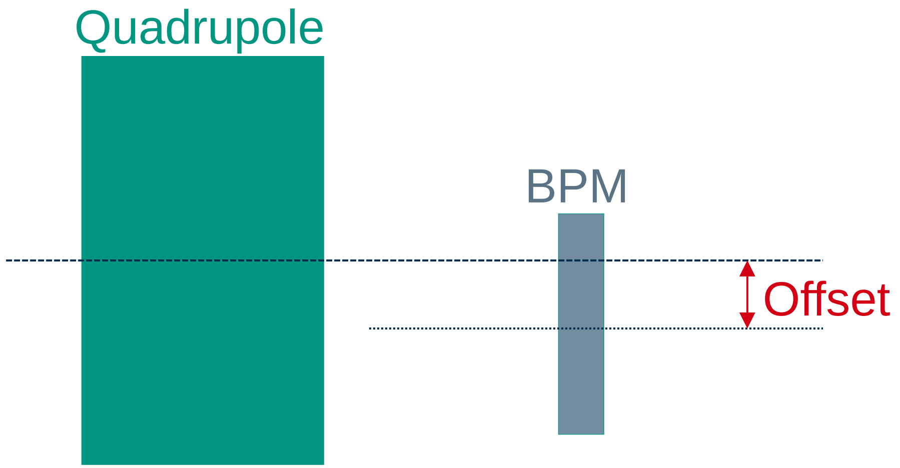
Beam position monitors used as reference for orbit correction

Define reference orbit through the magnetic centres

Knowledge of offset between BPM and quadrupole required for orbit correction

Beam-based alignment for estimation of the offsets

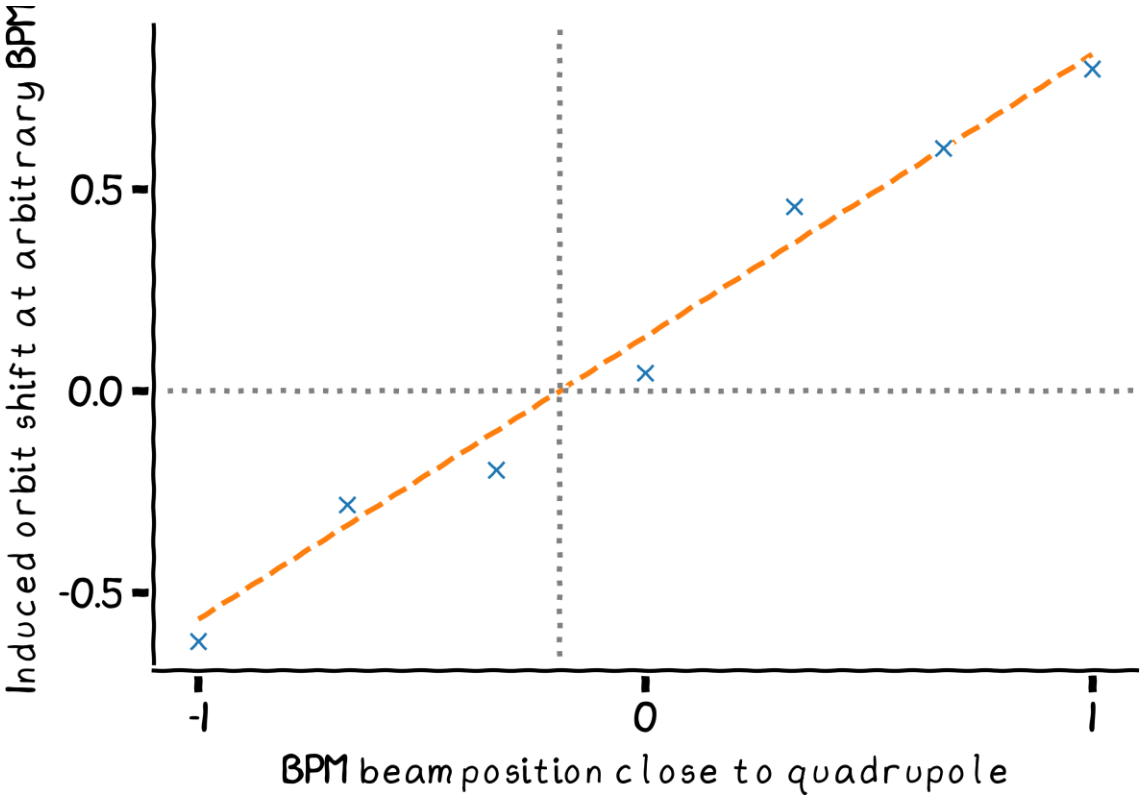
Use of optics deviations for offset estimation



Individual beam-based alignment

Quadrupole modulation scheme (QMS)

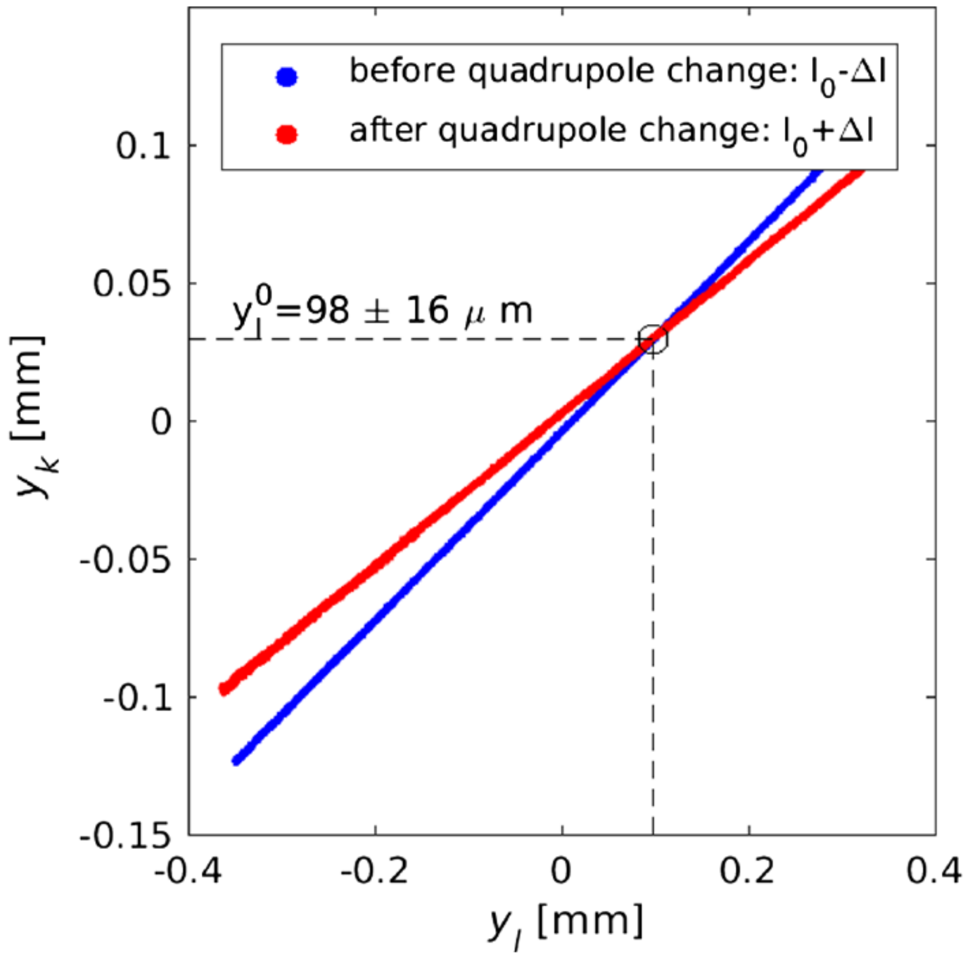
- Repeat measurements for different orbits
- Vary quadrupole strength
- Record changes of closed orbit for different quadrupole strengths
- Measure beam position with BPM nearby modulated quadrupole
- Plot closed orbit change over beam position for different orbits
- Estimate offset using fit



Fast beam-based alignment

Fast beam-based alignment

- Comparable approach like individual BBA
- Modulate orbit corrector strength with a sinus wave
- Change quadrupole strength
- Significant time reduction due to fast position measurement



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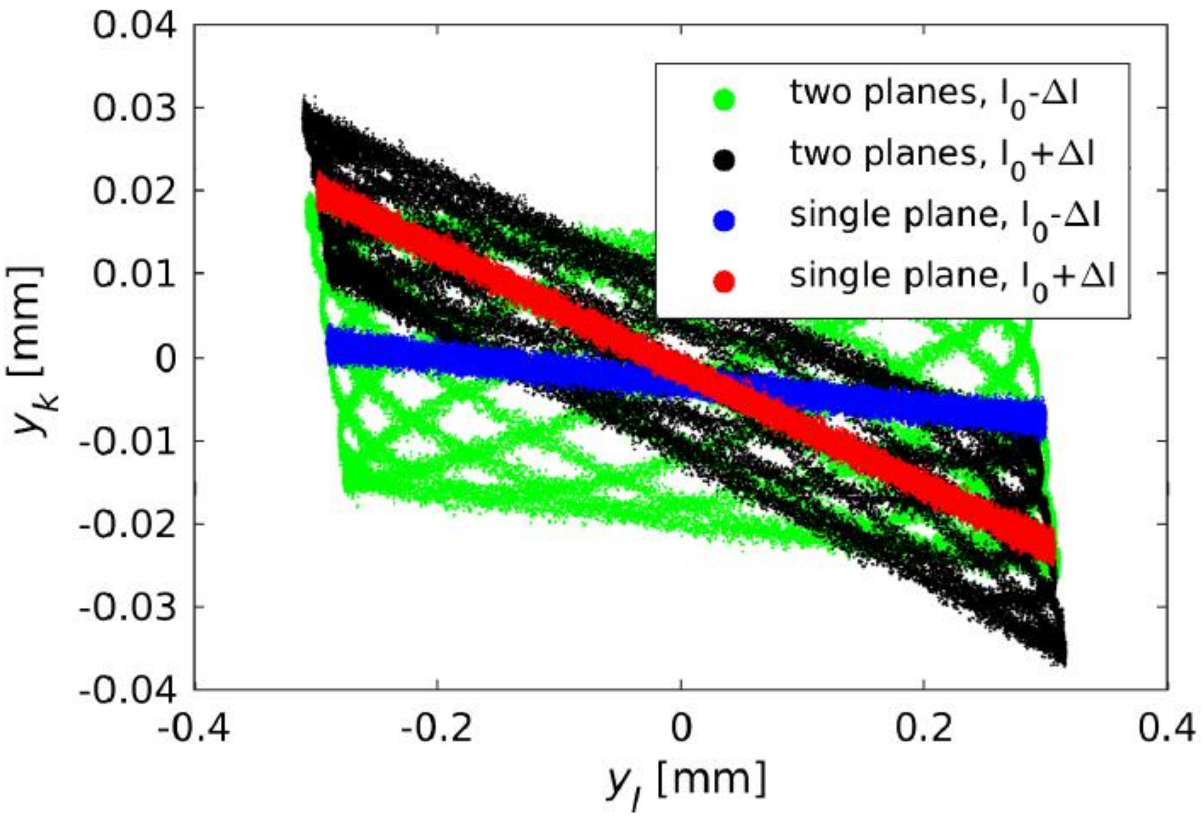
Fast beam-based alignment

Fast beam-based alignment

- Could be extended to both planes using different frequencies for excitation
- Fourier analysis to separate contributions from horizontal and vertical excitation
- Frequency analysis of beam position data
- Simultaneously offset estimate in both planes



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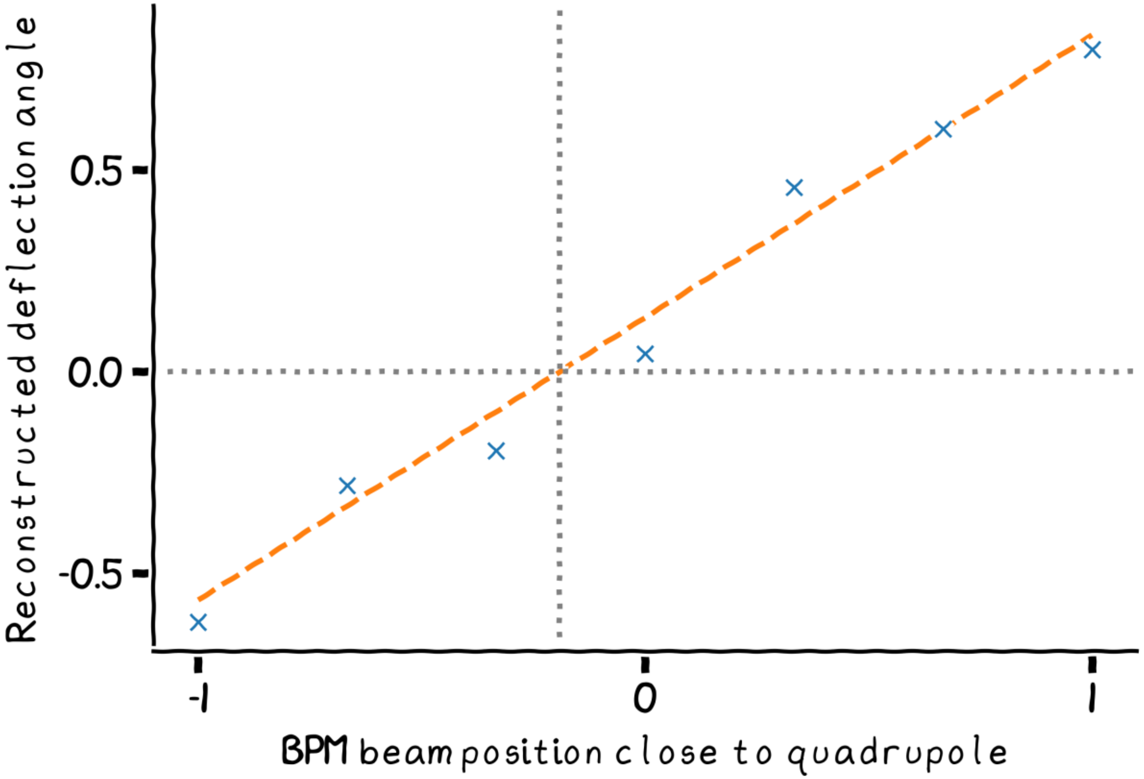
Parallel beam-based alignment

Parallel QMS

- Similar approach as for QMS
- Modulation of a group of magnets instead of a single magnet
- Multiple magnets contribute to closed orbit changes
- Use orbit response matrix to estimate individual dipole kick strength from individual quadrupoles
- Estimate offset using reconstructed kick strength and beam position for different orbits



Individual or parallel beam-based alignment

Individual:

- Orbit variation at one magnet
- Change of individual quadrupole strength
- Model independent
- Time consuming, faster with fast approach
- Required time scales linear with number of magnets
- Established method for majority of synchrotron light sources

Parallel:

- Orbit variation at all modulated magnets
- Usable for in series powered magnets
- Model dependent orbit response matrix
- Simultaneous offset determination for multiple magnets
- Scales linearly with number of magnet groups
- Advantageous for large accelerators and for accelerators within series powered magnets without possibility of change of individual magnet strength

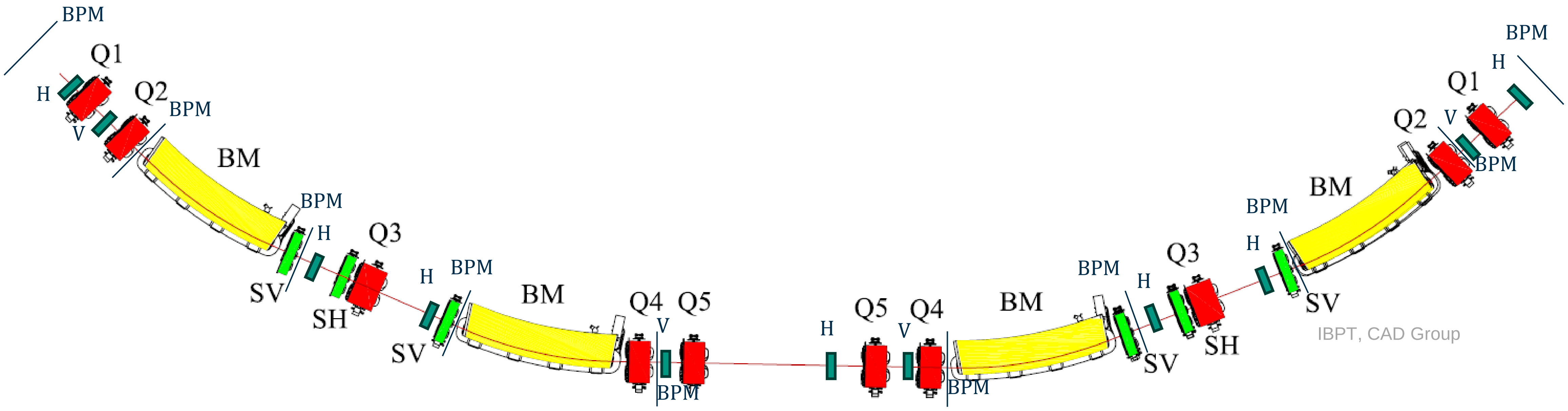
KArlsruhe Research Accelerator (KARA)

Individual BBA

- Orbit corrector on other side of storage ring
- Additional power supply for change of quadrupole strength

Parallel BBA

- Two correctors for different orbits
- Change of magnet currents for the whole family



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Parallel BBA at KARA

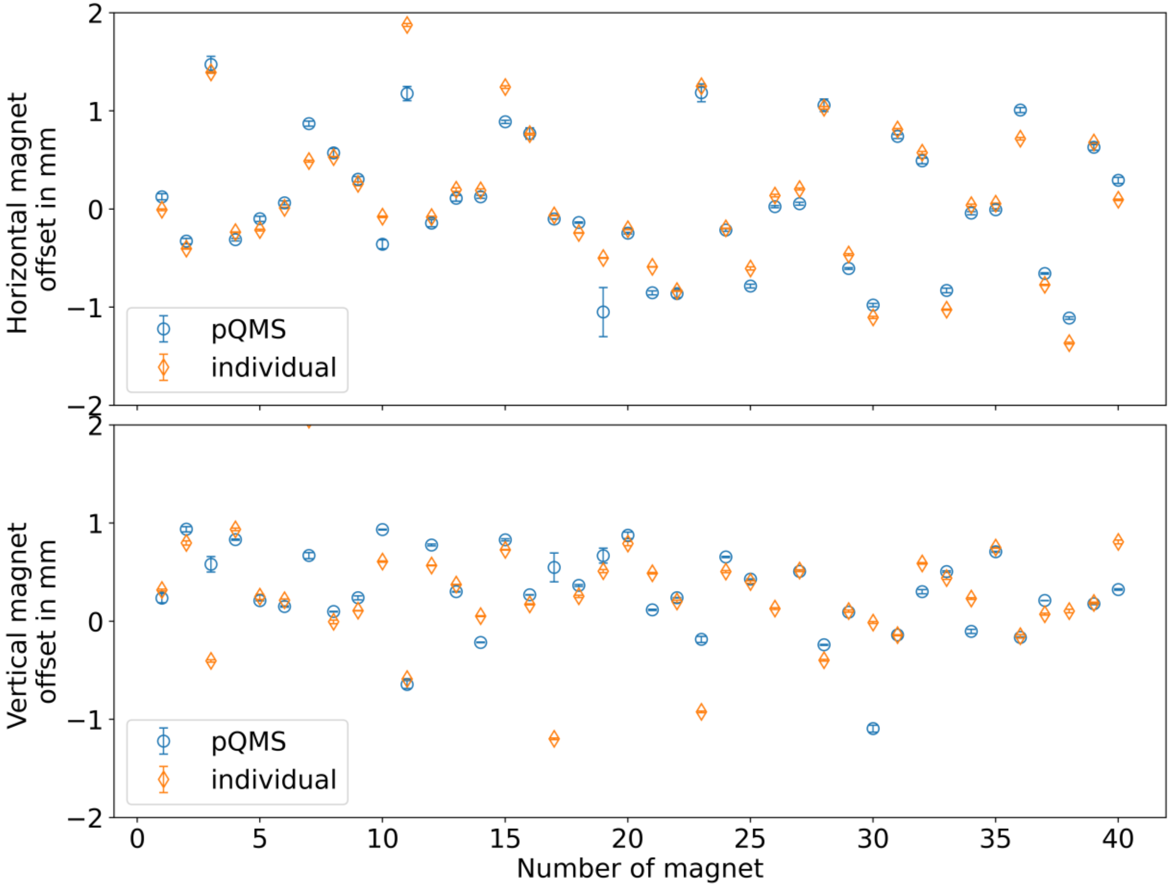
Use of two orbit correctors to change beam position at all modulated quadrupoles

Measure beam position with BPM next to the modulated quadrupoles

For each orbit variation of quadrupole strengths

Measure change of closed orbit between different quadrupole strength

Estimate beam deflection angle in each modulated quadrupole using a response matrix

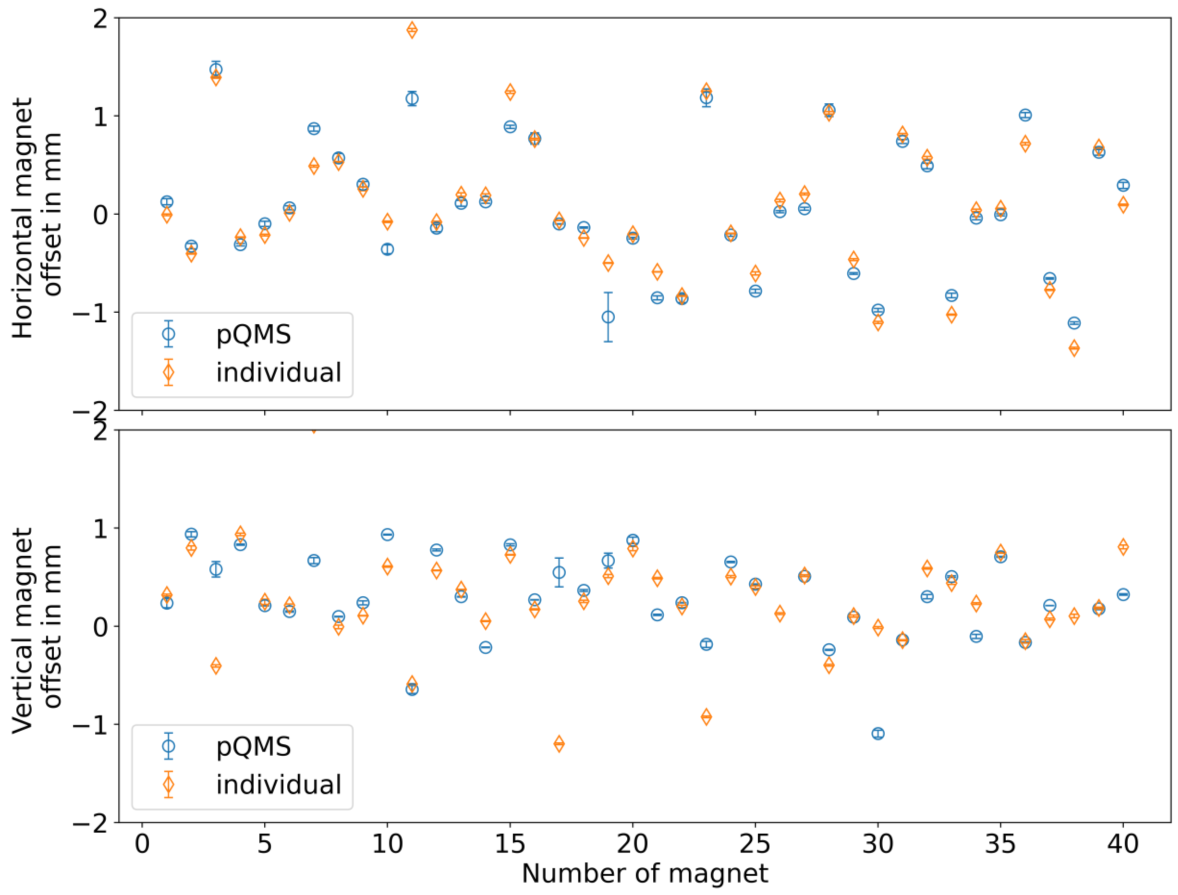


Parallel BBA at KARA

Calculate offset based on estimated kick strength and beam position

Orbit response matrix

- Estimated with simulation
- Model dependent
- Most probable cause of deviations from the individual BBA



Parallel BBA at KARA

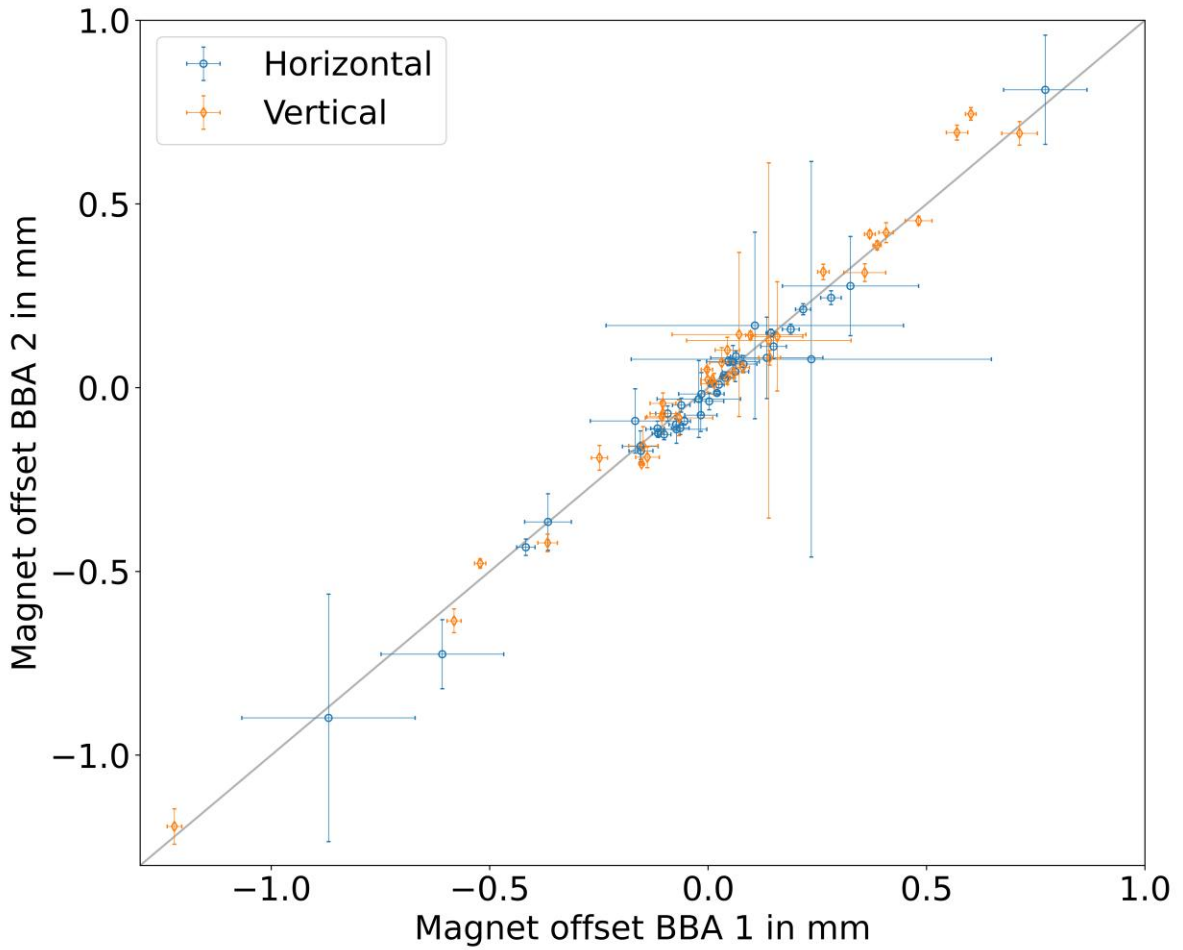
Reduction of time compared to individual BBA

- Parallel BBA: around 10 minutes
- Individual BBA: around 2 hours

Smaller changes of quadrupole strength

- Less hysteresis effects
- No pre-cycle of magnets required

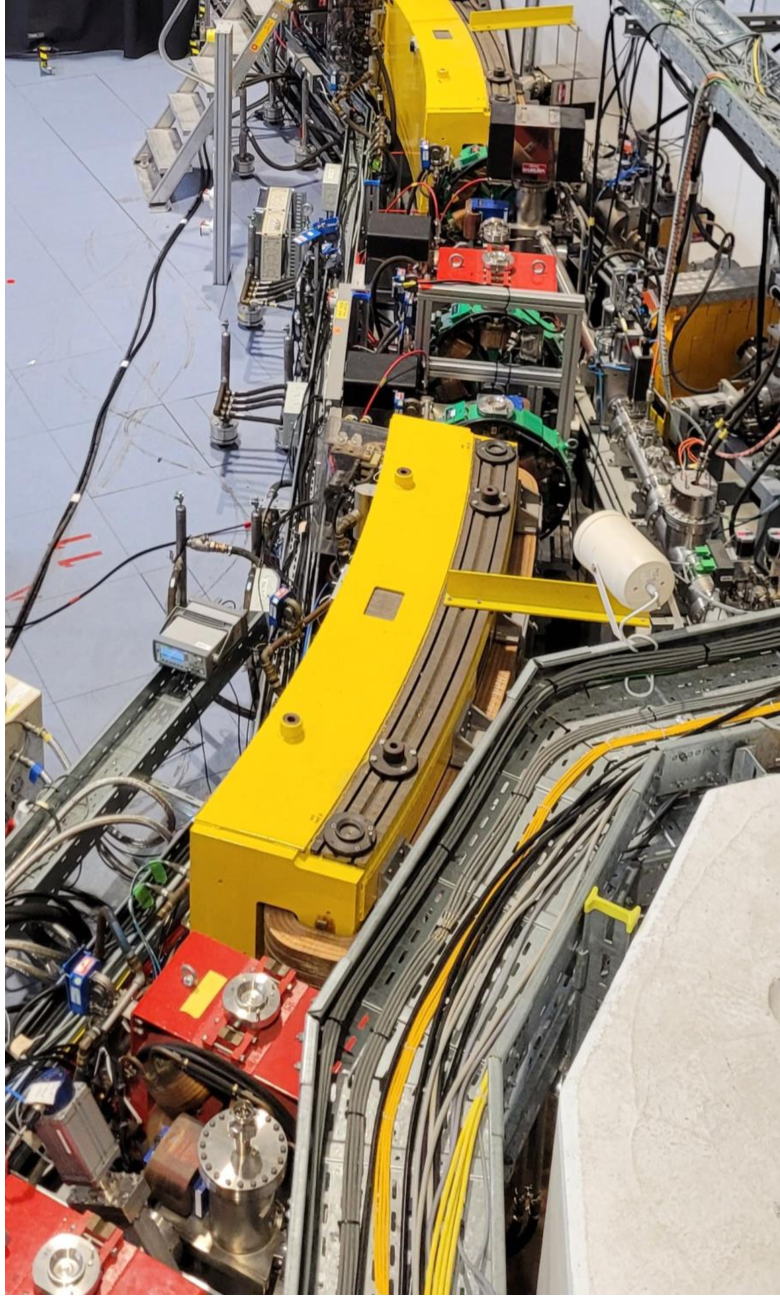
Reproducibility of magnet offsets 30 µm - 50 µm RMS between two different fills



Joint Experiment

Measurements:

- Parallel Quadrupole BBA
- Optics measurements
  - Tune
  - Orbit
  - Chromaticity
  - Beta functions and beta beating
  - Dispersion



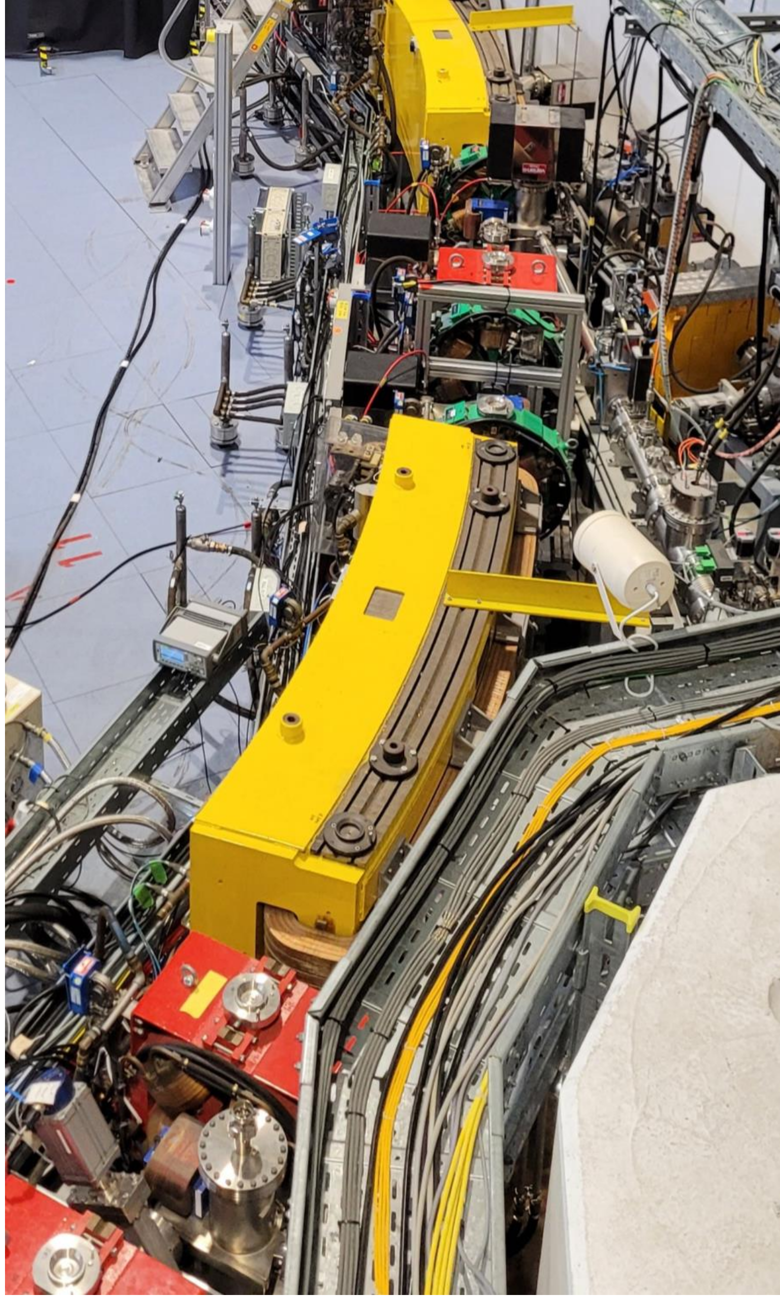
Joint Experiment - Thursday

2.5 GeV, multi-bunch:

- Inject high current, ramp up energy
- BBA and optics measurements
- Reduction of beam current
- Repeat BBA and optics measurements

2.3 GeV and 2.2 GeV, multi-bunch:

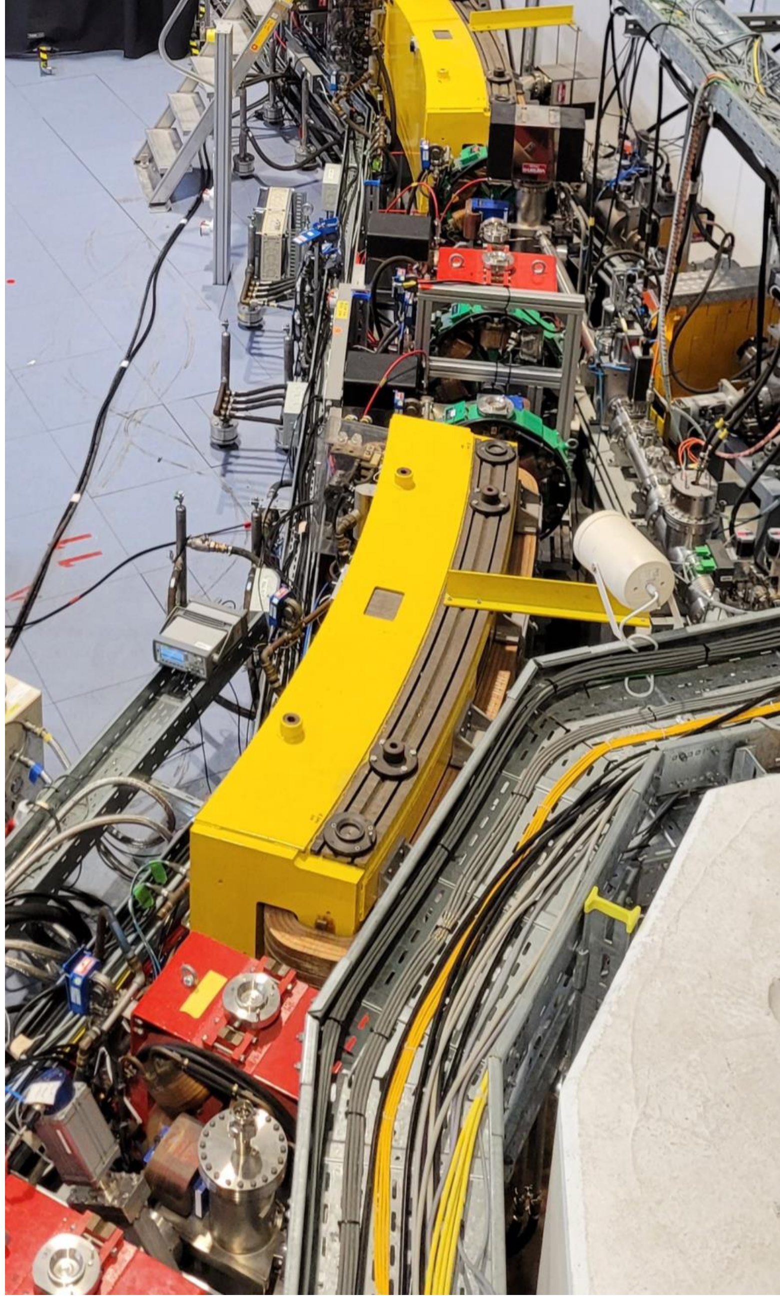
- Inject beam and ramp up energy
- BBA and optics measurements
- Estimation of beam offset
- Use offset estimates for orbit correction
- Repeat optics measurements
- Analyse beam position data from BPMs and beamlines



Joint Experiment - Friday

2.5 GeV, multi-bunch:

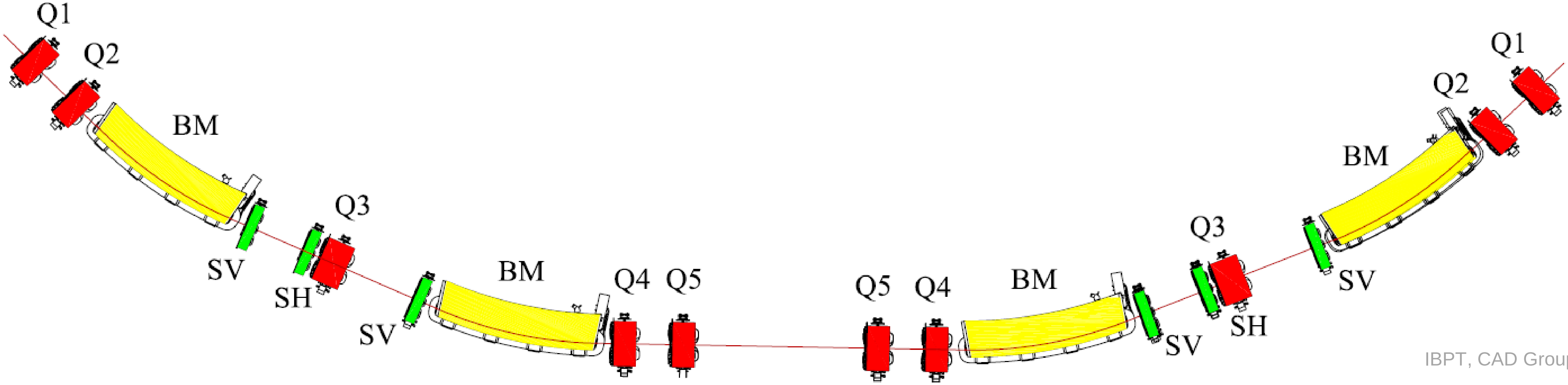
- Inject beam and ramp up energy
- BBA and optics measurements
- Start changing cooling water temperature
- Repeat BBA and optics measurements



KArlsruhe Research Accelerator (KARA)

- Test facility
- Synchrotron
- 110.4 m circumference
- Double Bend Achromat (DBA) lattice
- Energy 0.5 GeV – 2.5 GeV

- 40 quadrupoles
- Organised in 5 families
- Each family contains 8 magnets
- Magnets in each family powered in series
- Additional power supply for change of an individual quadrupole strength



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