U.S. DEPARTMENT OF ENERGY
Office of Science

BERKELEY LAB

ALS-U
ADVANCED LIGHT SOURCE

Automated Startup and Commissioning Tests at ALS

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AT Workshop,
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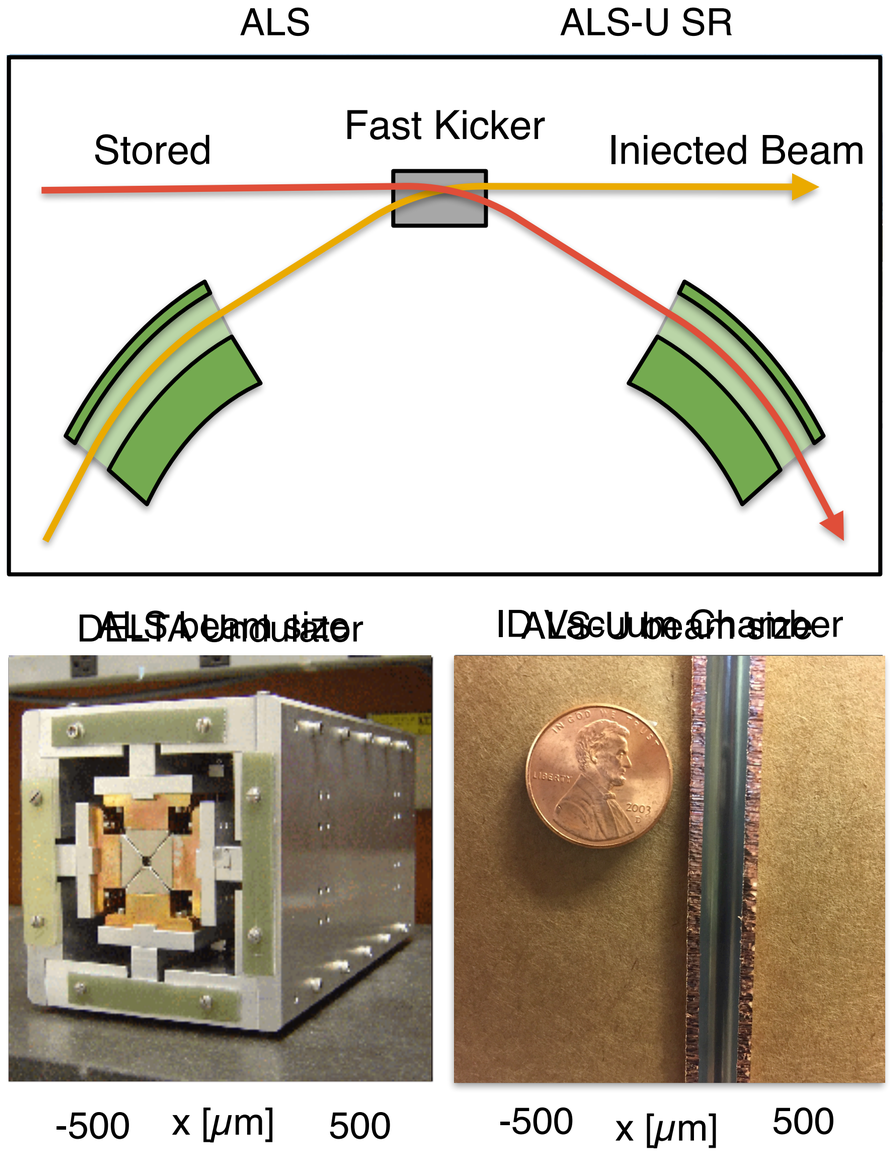
ESRF,
Grenoble,
France

Outline

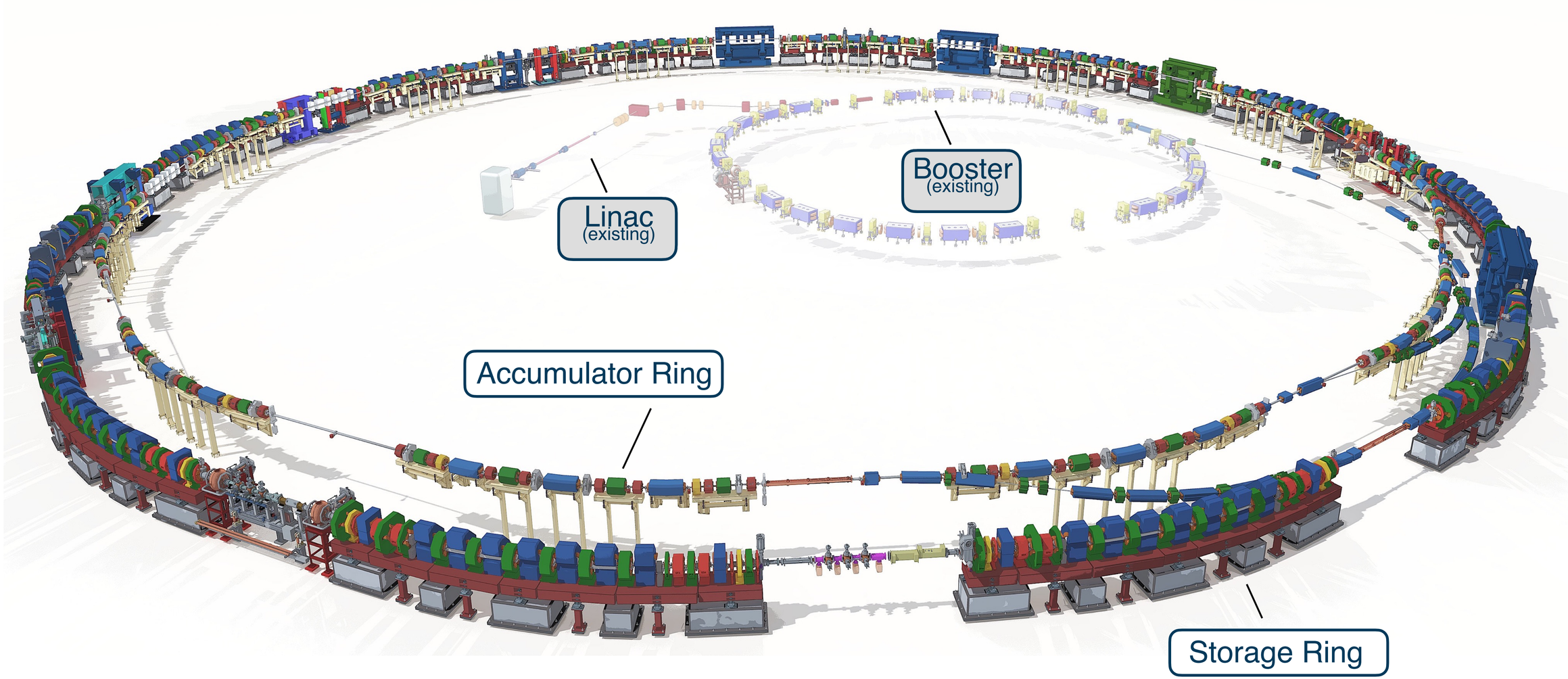
- Introduction
  - Overview of Advanced Light Source Upgrade Project
  - Integration of SC Toolkit into ALS Control System
- Commissioning Tests at ALS
  - First turn threading
  - Pseudo-orbit correction
  - Turn-by-turn BBA

Design Choice of the Advanced Light Source Upgrade

- Goal: Diffraction Limited Light Source
  - Brightness increase: $B_{ALS} = 2*10^{19}$ => $B_{ALSU} = 2*10^{21}$
  - Emittance decrease: $\varepsilon_{ALS} = 2000\,pm$ => $\varepsilon_{ALSU} \sim 100\,pm$
- Space Constraint
  - Use of current building and 12-fold symmetry
- Requires Strong Focusing Elements
  - Quadrupole strength: $K_{ALS} \sim 3$ => $K_{ALSU} \sim 15$
  - Sextupole strength: $M_{ALS} \sim 90$ => $M_{ALSU} \sim 800$
- Requires Small Aperture
  - Magnet aperture: $d_{ALS} = 65\,mm$ => $d_{ALSU} = 40\,mm$
  - Undulator aperture: $d_{ALS} = 30\,mm$ => $d_{ALSU} = 6\,mm$
- Requires on-Axis Swap Out
  - Dynamic aperture: $DA_{ALS} = 120\,mm^2$ => $DA_{ALSU} = 3\,mm^2$
- Requires Accumulator Ring
  - Injected beam: $\sigma_{ALS} = 2\,mm$ => $\sigma_{ALSU} = 60\,\mu m$



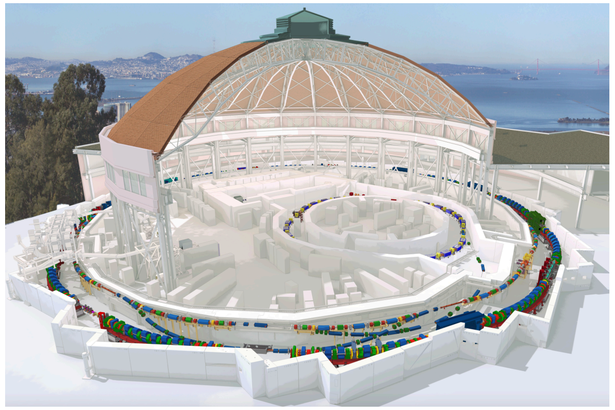
Overview of ALS-U Accelerator Facility



Limited Accessibility of Machine Properties

Power supplies

Operating machine



Diagnostic devices

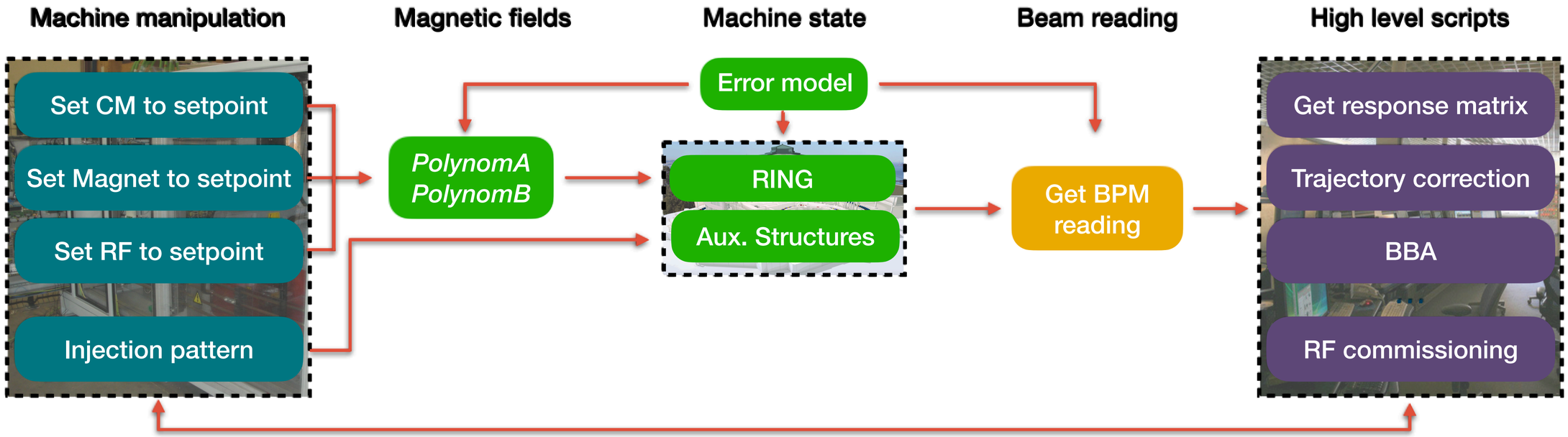
High level controls

Magnetic fields
Particle trajectories
Magnet offsets
…

Limited access!

Setpoints and read back values

Realistic Workflow of Toolkit Important



Set Quad to setpoint

- Compensates bending angle difference by setting horizontal CM
- Checks for CM range (clipping)

Calculate fields

- Calibration errors of all components
- Includes dipole kick from bending angle (set-point & roll)

Auxiliary structures

- Diagnostic errors
- Injected beam trajectory
- Injection pattern

Get BPM reading

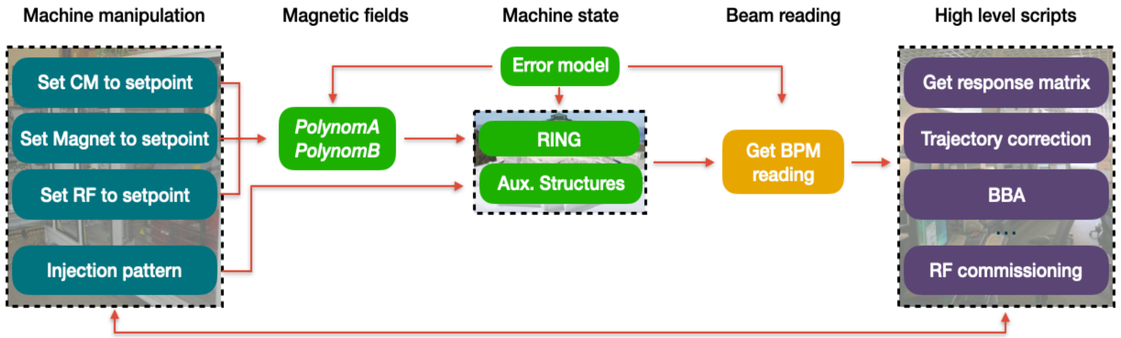
- Performs tracking including aperture
- Gets BPM signal from ensemble of particle trajectories

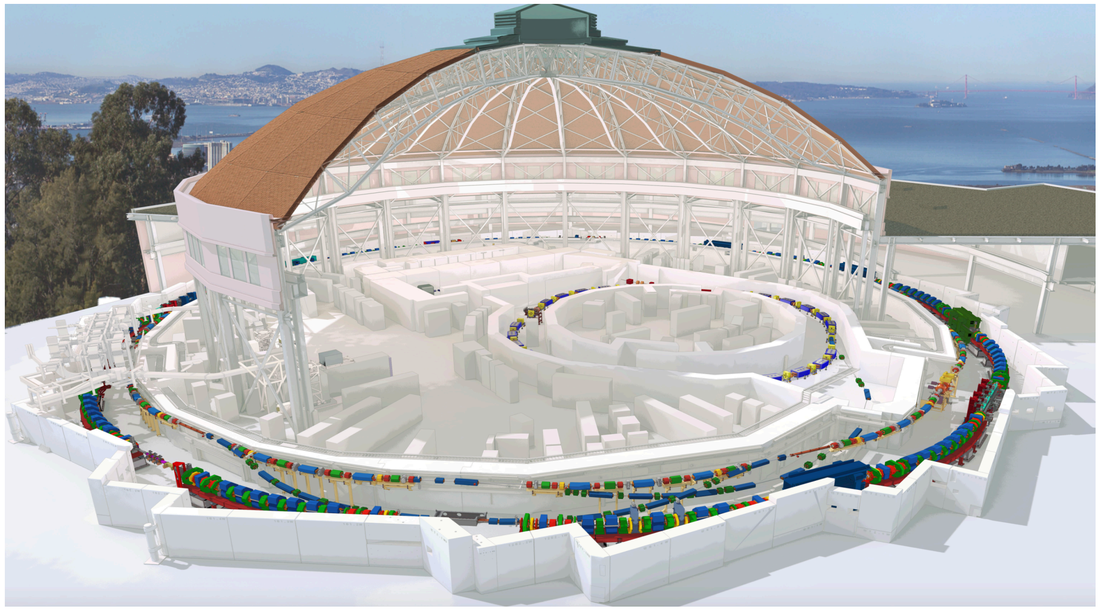
High level

- High level functions use only BPM and setpoints as input
- High level functions write only setpoints

Automated Startup and Commissioning Tests at ALS

- Automated startup and commissioning scripts will be essential for ALS-U
  - Lattice too non-linear to achieve stored beam with conventional methods
  - Scheduled commissioning time for AR and SR very short compared to the operational complexities
- SC Toolkit developed for simulated commissioning and error analysis studies
  - Comprehensive automated lattice correction tools to get from first injection to stored beam
  - Workflow mimics machine operation from the control room





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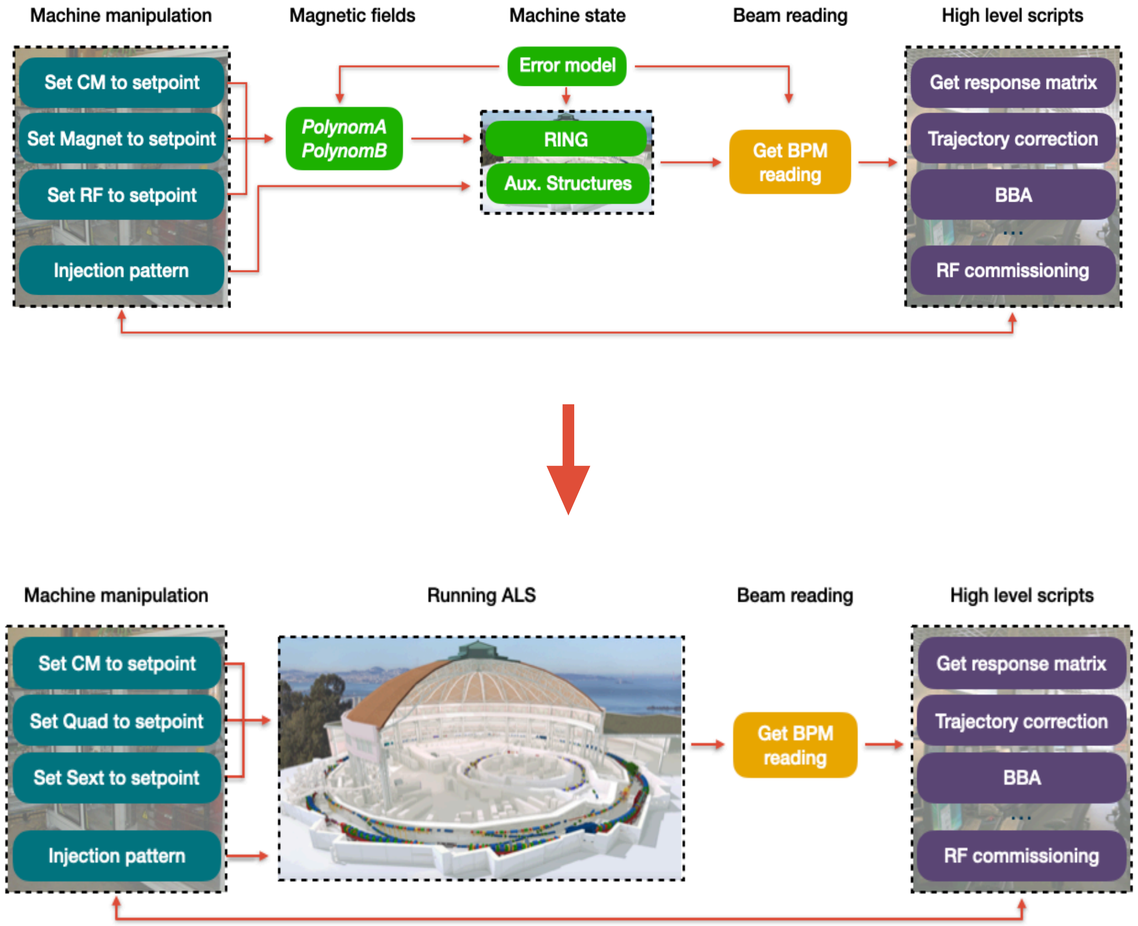
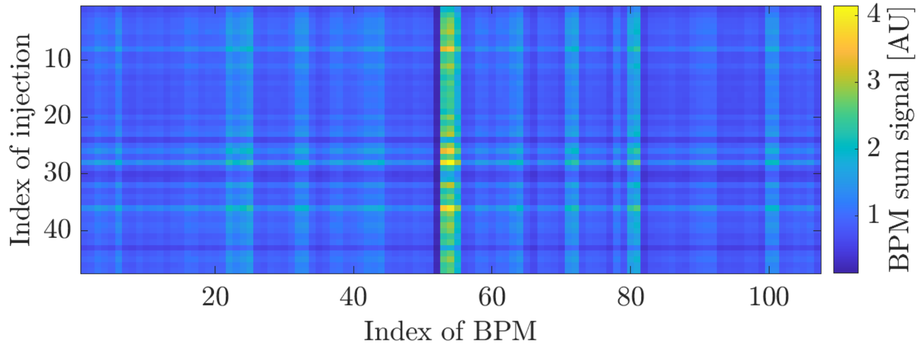
  - Comprehensive automated lattice correction tools to get from first injection to stored beam
  - Workflow mimics machine operation from the control room
- Integrating SC Toolkit into the control system
  - ALS and ALS-U operated with MML, toolkit written in Matlab
  - ALS lattice very similar to ALS-U AR lattice



Commissioning Tests at ALS

BPM Sum Signal Normalisation

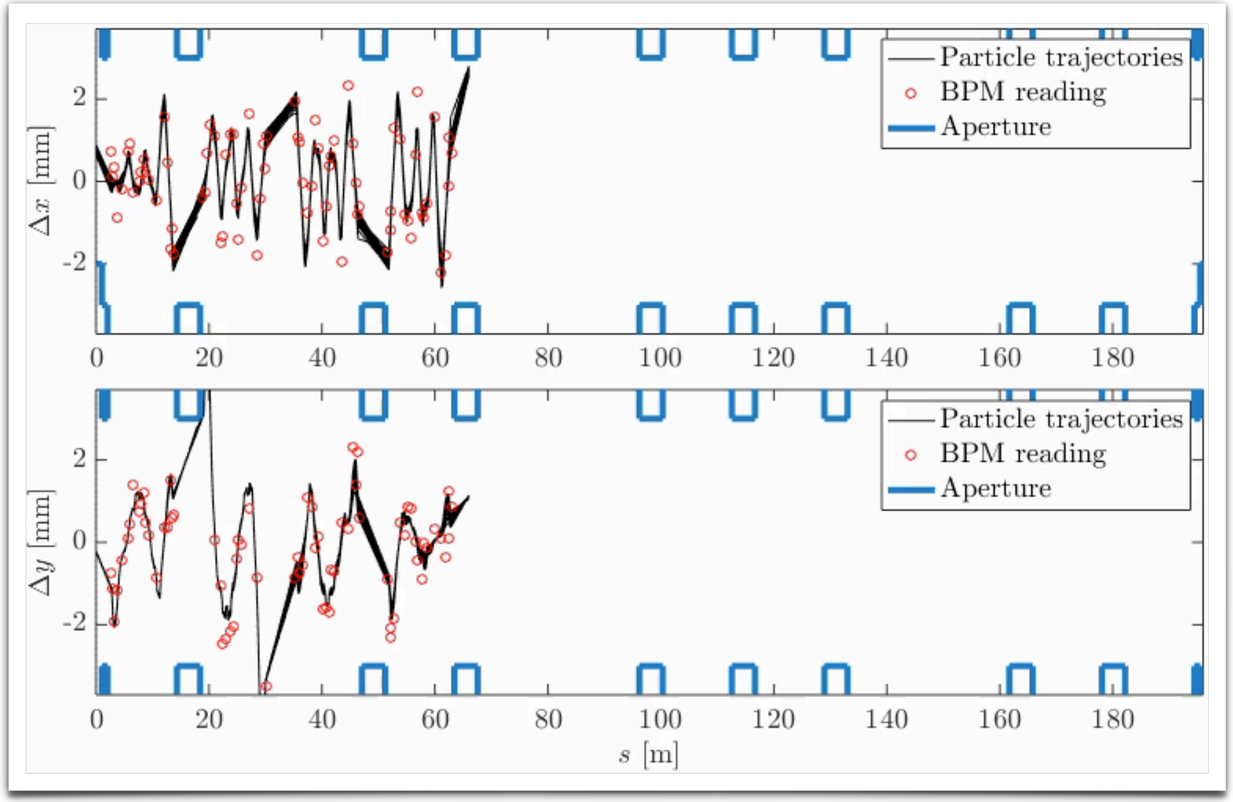
- Reliable BPM Sum Signal Key for First Turn Threading
  - Beam loss detection is very important during early commissioning
  - Turn by turn BPM sum signal provides best path for beam loss detection
- Large Shot-to-Shot and BPM-to-BPM Sum Signal Variation
  - Variation of BPM first turn sum signal over 50 injections and all BPMs is 400% with no beam losses
- BPM Sum Signal Calibration Procedure:
  - 1) use first storage ring BPM to normalize all sum signals with injected bunch charge
  - 2) calculate BPM sensitivity by averaging over many nominal injections and save into file
- Satisfactory Sum Signal Homogeneity:
  - Final sum signal variation below 10%
  - Sufficient for accurate beam loss detection



First Turn Threading

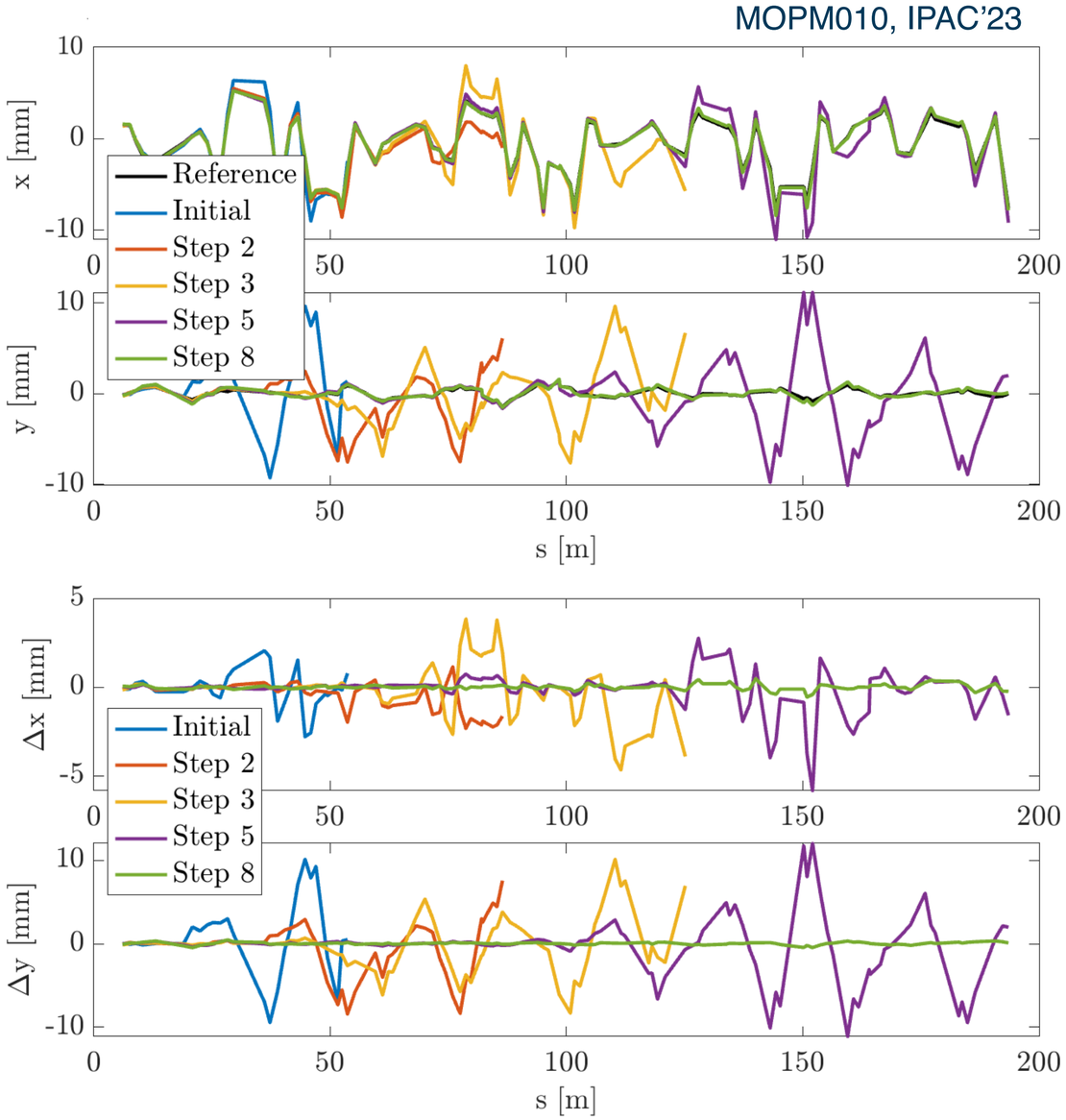
- First Turn Threading at ALS-U:
  - Commissioning simulations show that automated first turn threading algorithm needed to reliable perform regular start up in the storage ring

First Turn Threading in Commissioning Simulation at ALSU-SR



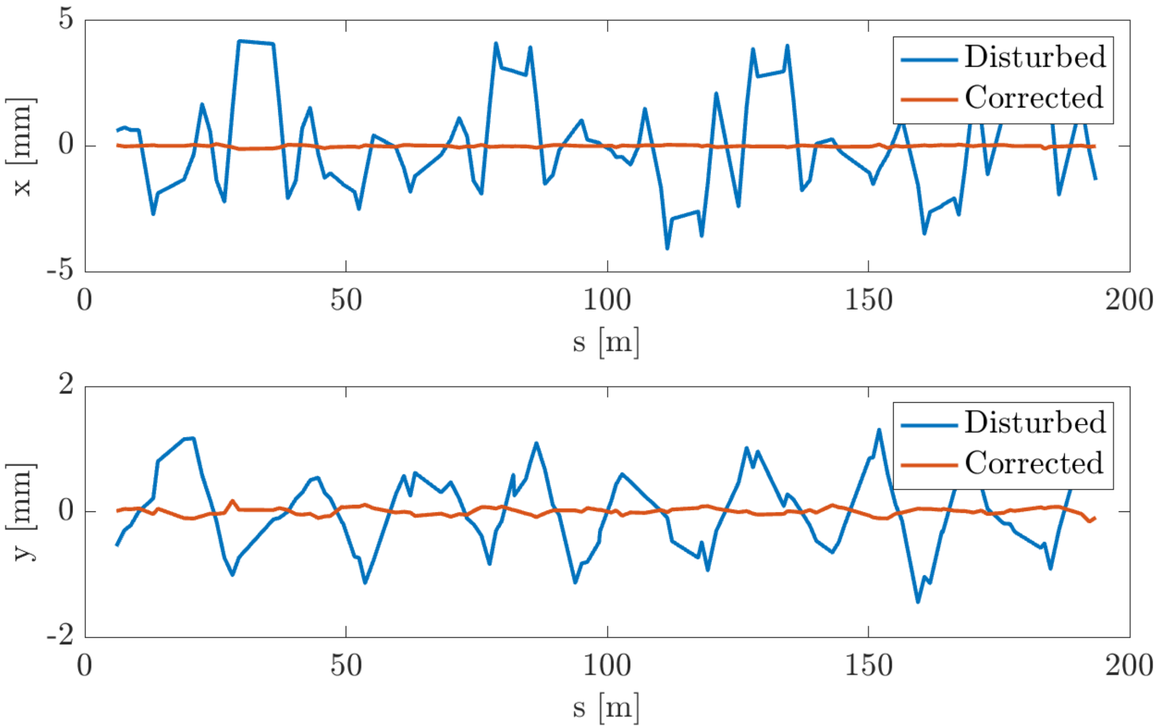
First Turn Threading

- First Turn Threading at ALS-U:
  - Commissioning simulations show that automated first turn threading algorithm needed to reliable perform regular start up in the storage ring
- Off Axis Injection at ALS
  - ALS-U AR/SR commissioning will be done using on-axis injection
  - On axis injection at ALS not possible, thus injected beam trajectory must be corrected towards reference trajectory
  - Reference trajectory recorded during nominal injection
- First Turn Threading Test:
  - Add random CM excitations with 3mrad amplitude
  - Threading algorithm reliably restores reference injected beam trajectory



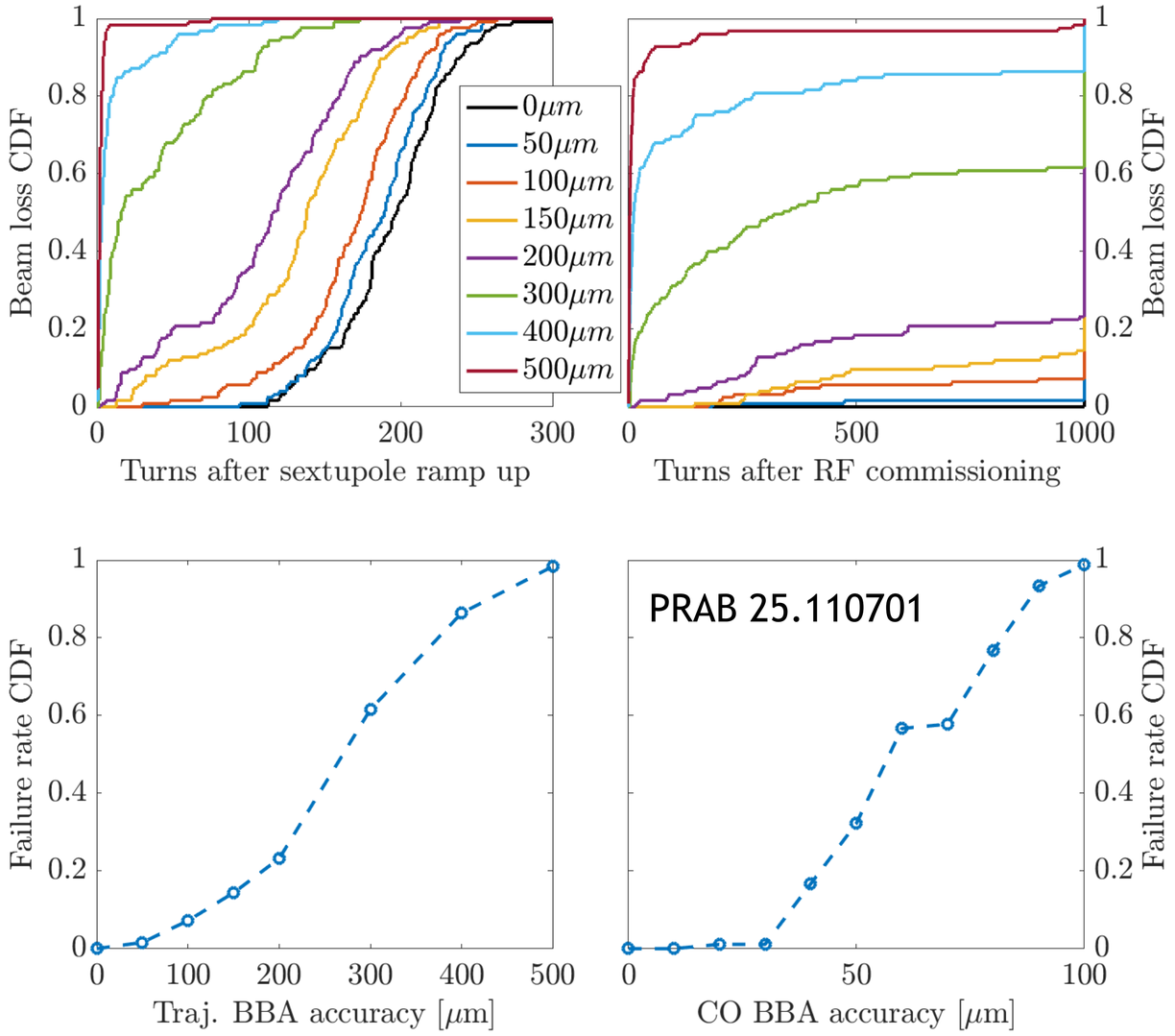
Achieving Stored Beam

- Pseudo-Orbit Correction
  - The orbit BPM readings can be reliably calculated by averaging the BPM turn-by-turn data over >10 turns
  - For off-axis injection a reliable way to achieve stored beam from multi-turn transmission is to correct the pseudo-orbit
- Pseudo Orbit Correction Test:
  - Add random CM excitations with 1mrad amplitude
  - Calculate orbit from turn-by-turn BPM readings taking 50 turns into account
  - Pseudo orbit correction reliably restores initial orbit



Turn-by-Turn Beam Based Alignment

- Turn-by-Turn BBA Required for ALS-U
  - Commissioning simulations for ALS-U Storage Ring show that without ~100um rms BPM offsets reliable beam capture can not be expected
  - Initial BPM offsets to be expected at ~500um rms
  - Turn by turn BBA routine mandatory for successful beam capture at ALS-U SR



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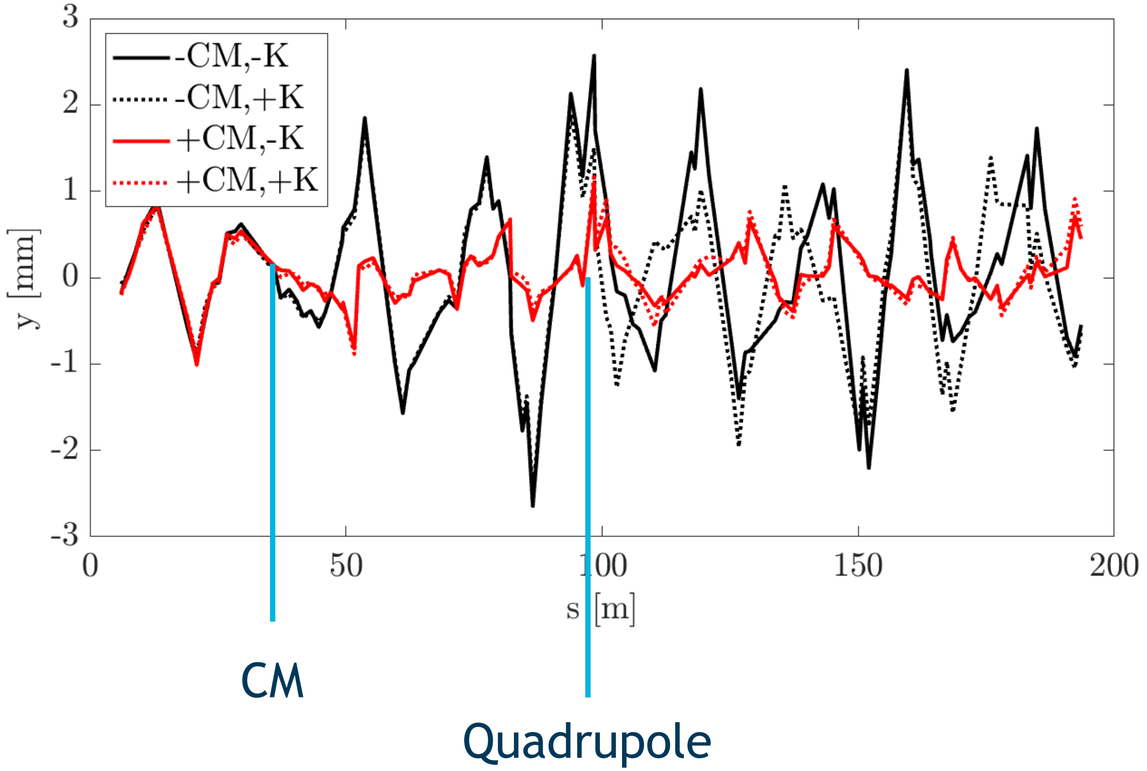

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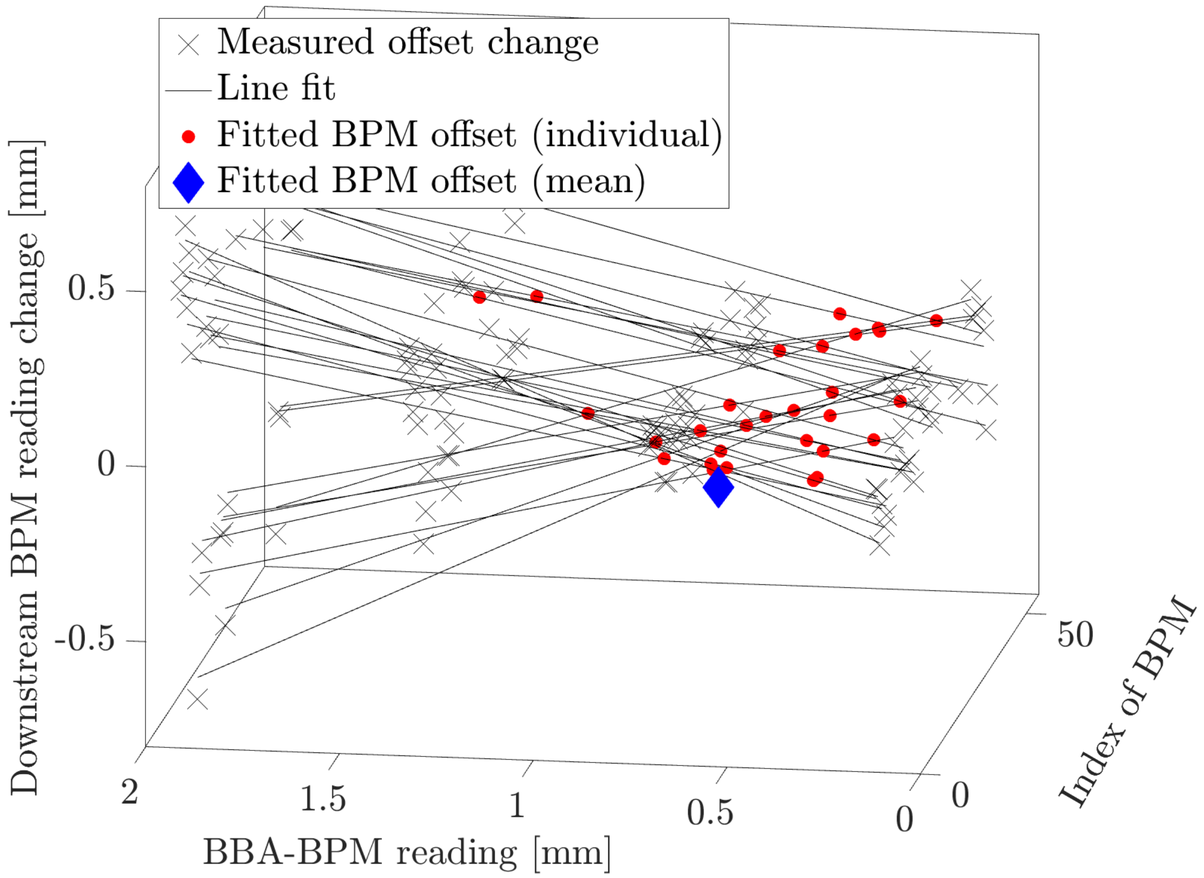
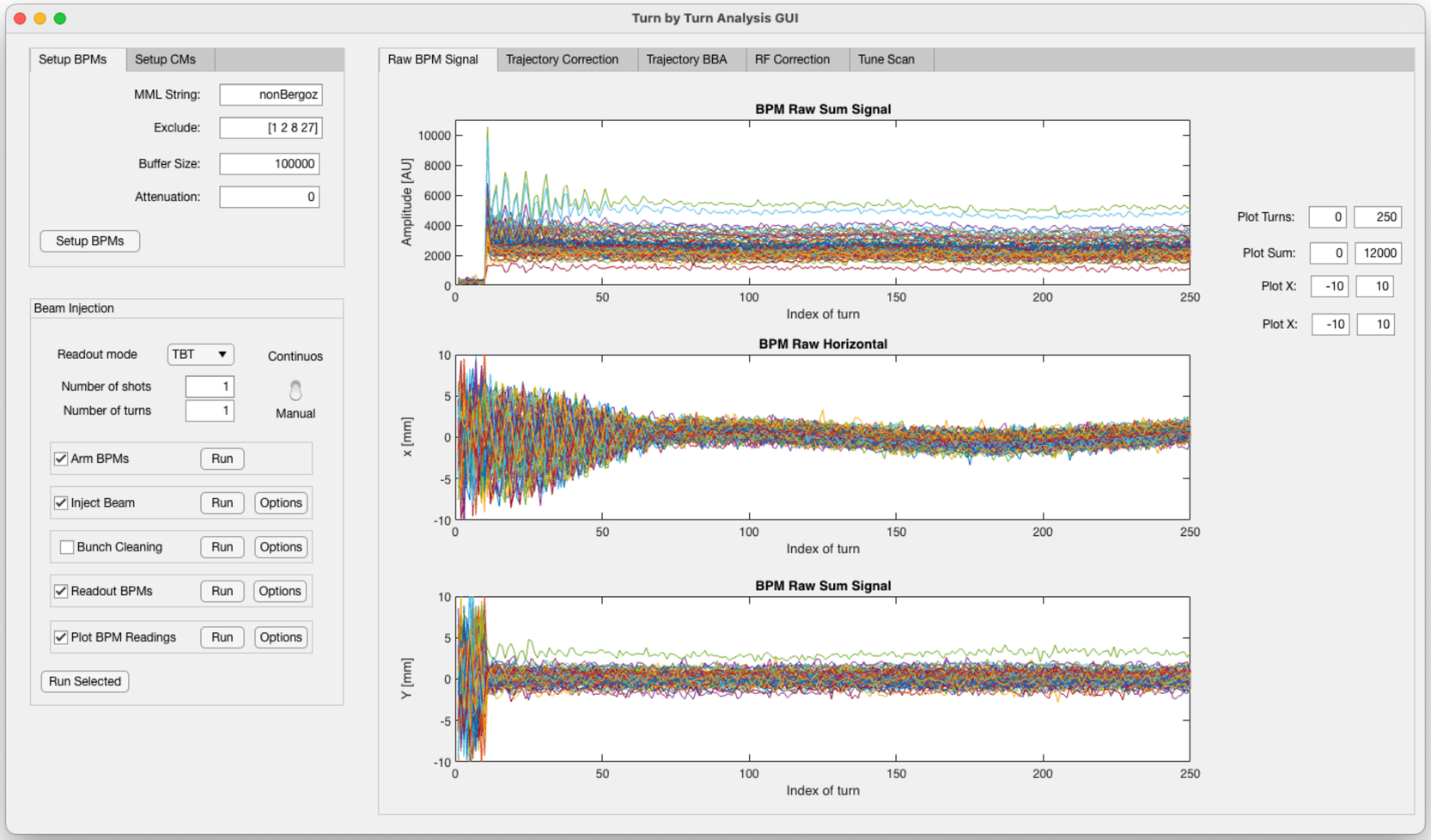
  - Found offset was within 40um of the one determined by stored beam BBA



MOPM010, IPAC'23

GUI Development Underway

- Focus on Accessibility
  - Graphical user interface crucial for easy access to turn by turn tools
  - Operator level desirable
- GUI Development:
  - First prototype of turn by turn GUI available and to be tested in upcoming physics shifts
  - Due to significant delays during latest startup no further studies have been possible



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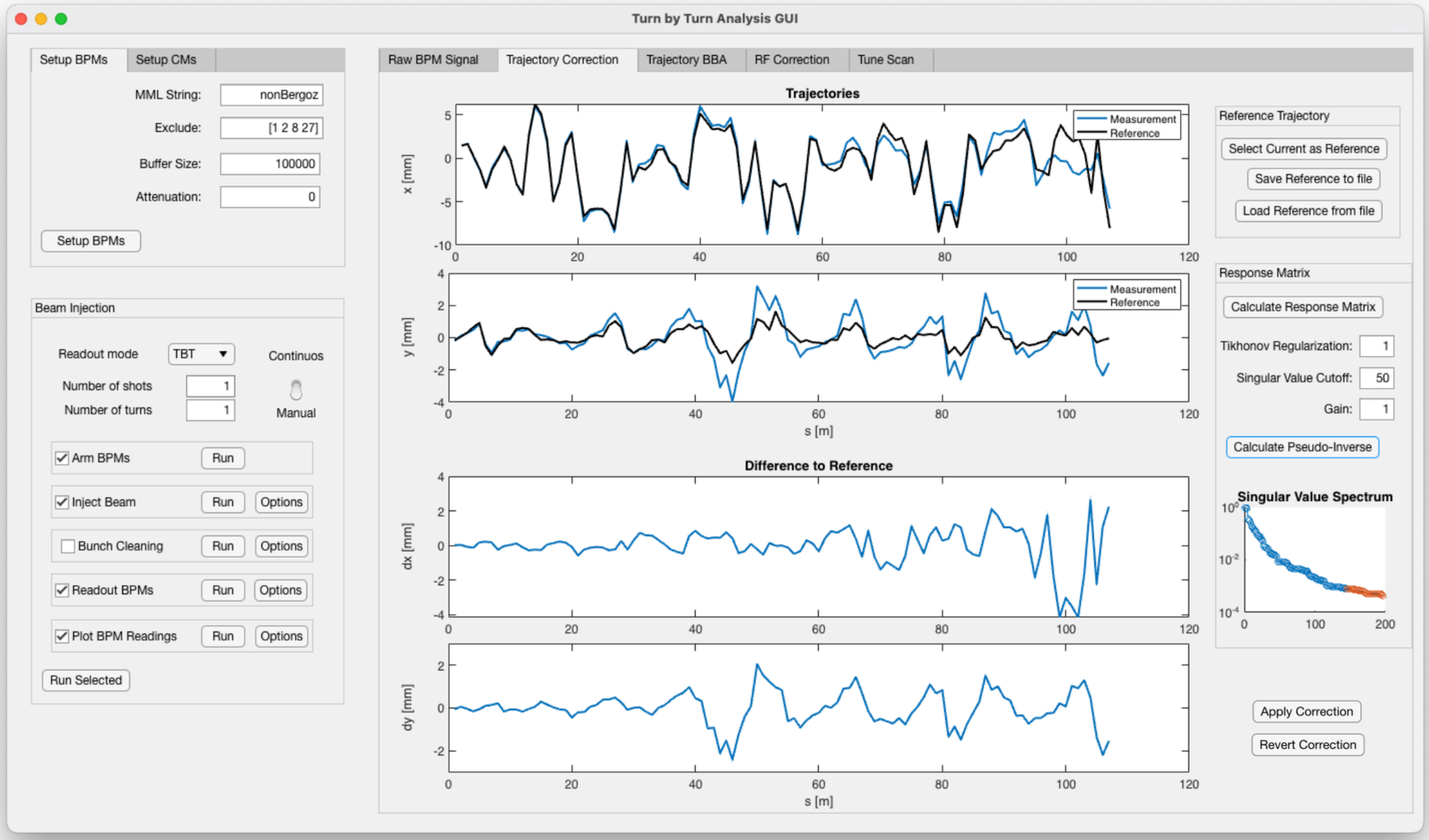

Summary and Conclusion

- Advanced Light Source Upgrade
  - 9 bend achromat lattice with 70pm-rad emittance
  - Very fast commissioning process required
- Commissioning Tests at ALS
  - Integration of SC toolkit into ALS control system underway
  - First turn threading, pseudo-orbit correction and turn-by-turn BBA successfully demonstrated at ALS
  - GUI development for easy accessibility underway