

SC - A Toolkit for Simulated Commissioning

Thorsten Hellert
Eurizon WP 4.1 Meeting
DESY, 23.02.23

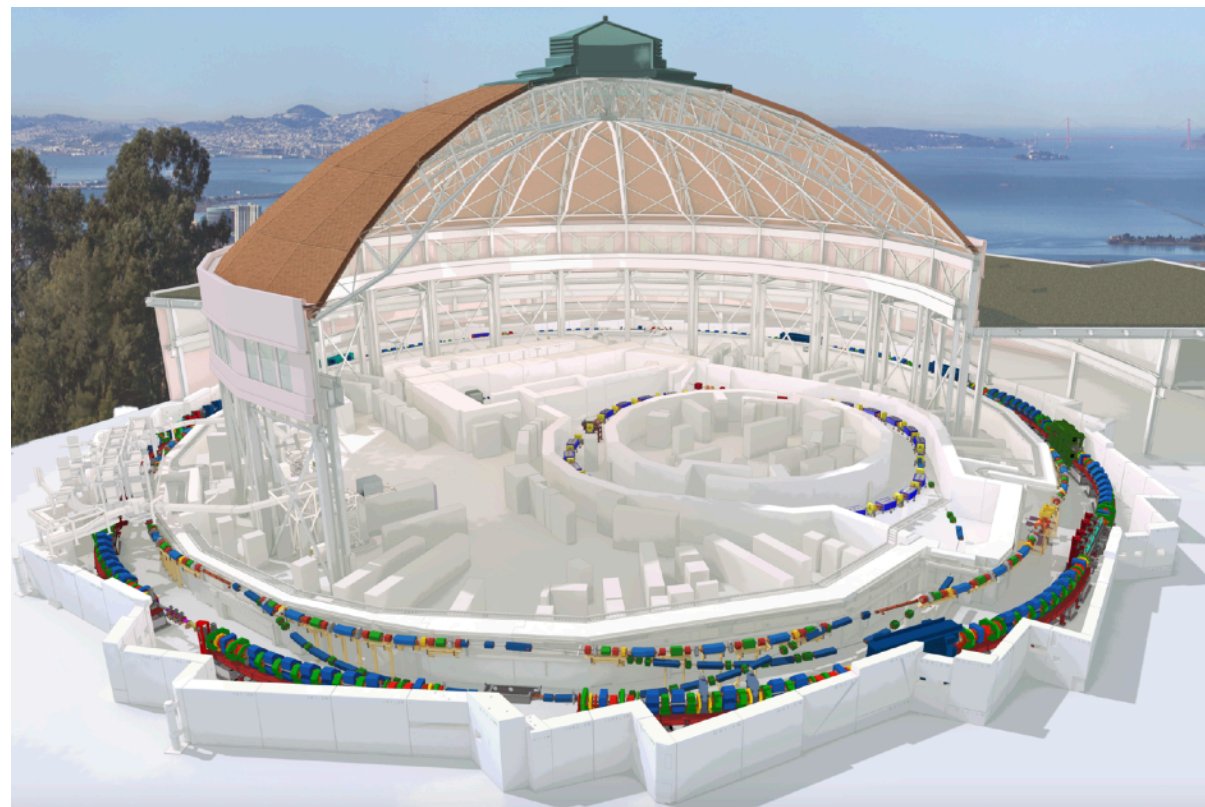
Toolkit Design Features

Limited Accessibility of Machine Parameters

Power supplies



Operating machine



High level controls



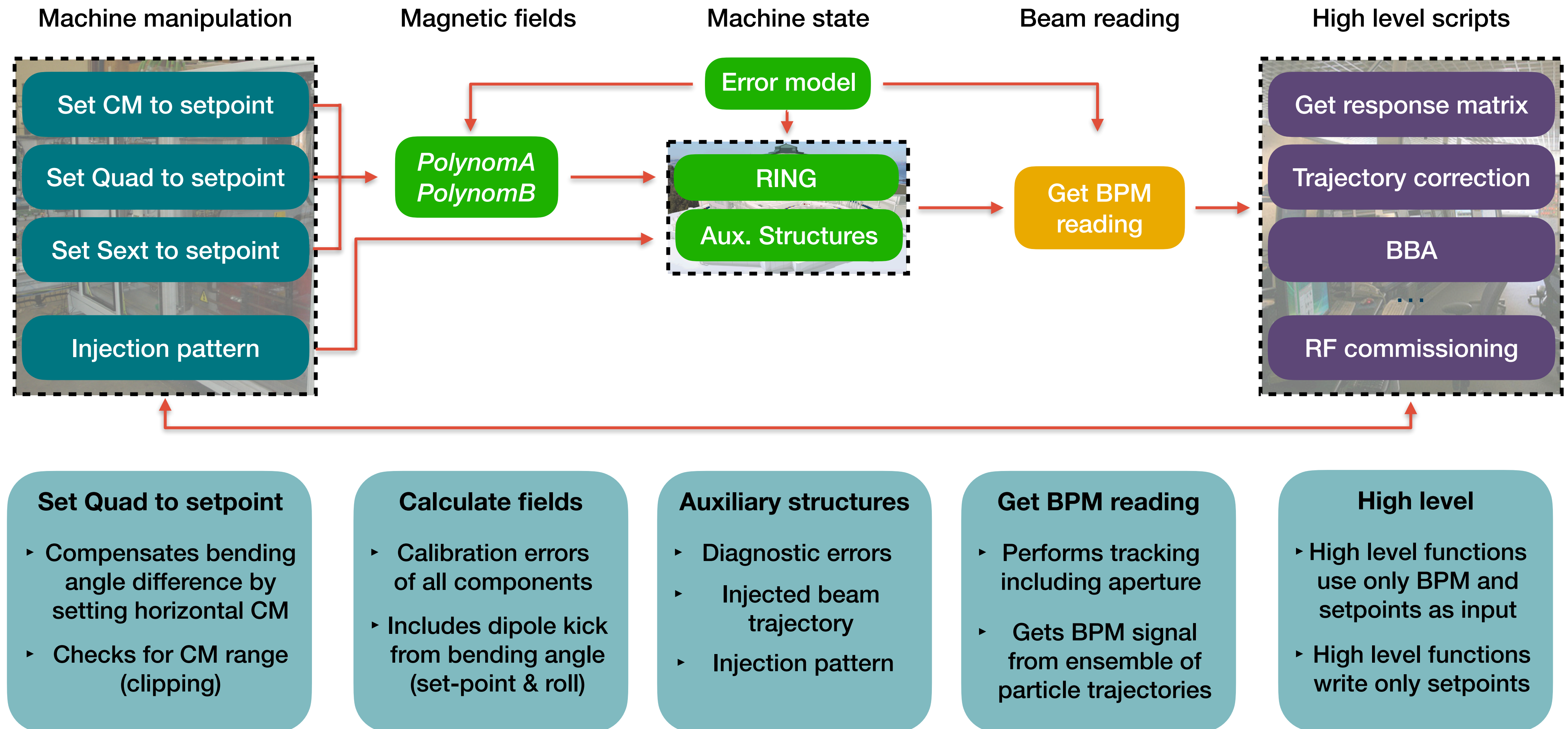
Dagnostic devices

Magnetic fields
Particle trajectories
Magnet offsets
...

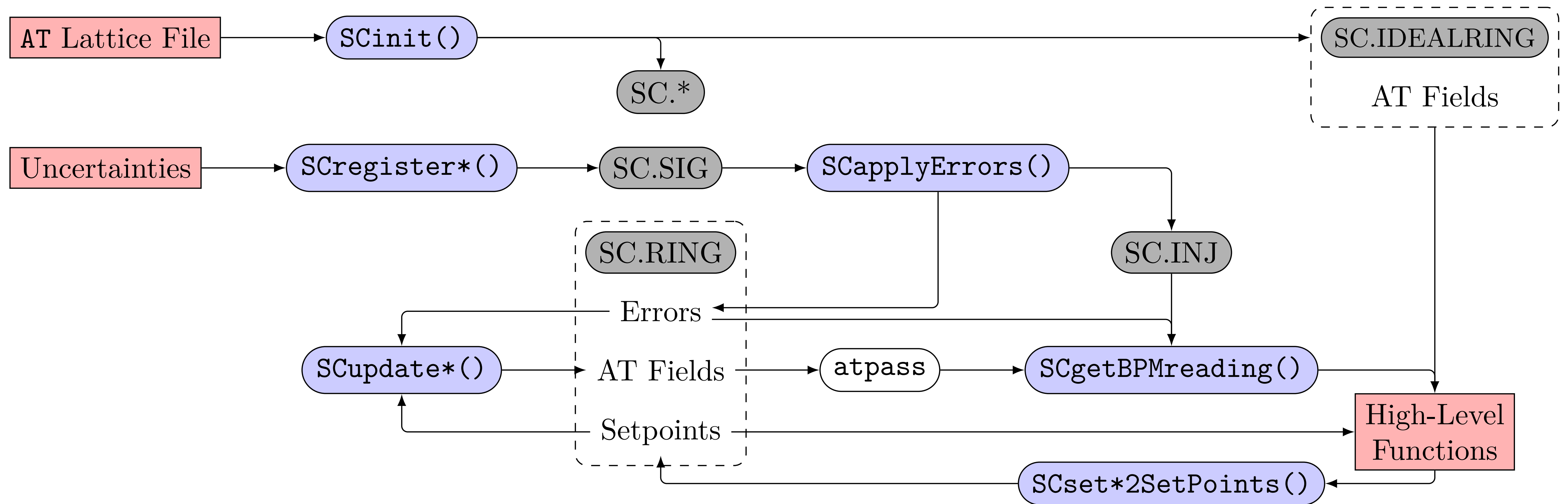
Limited access!

Setpoints and read back values

Realistic Workflow of Toolkit Important

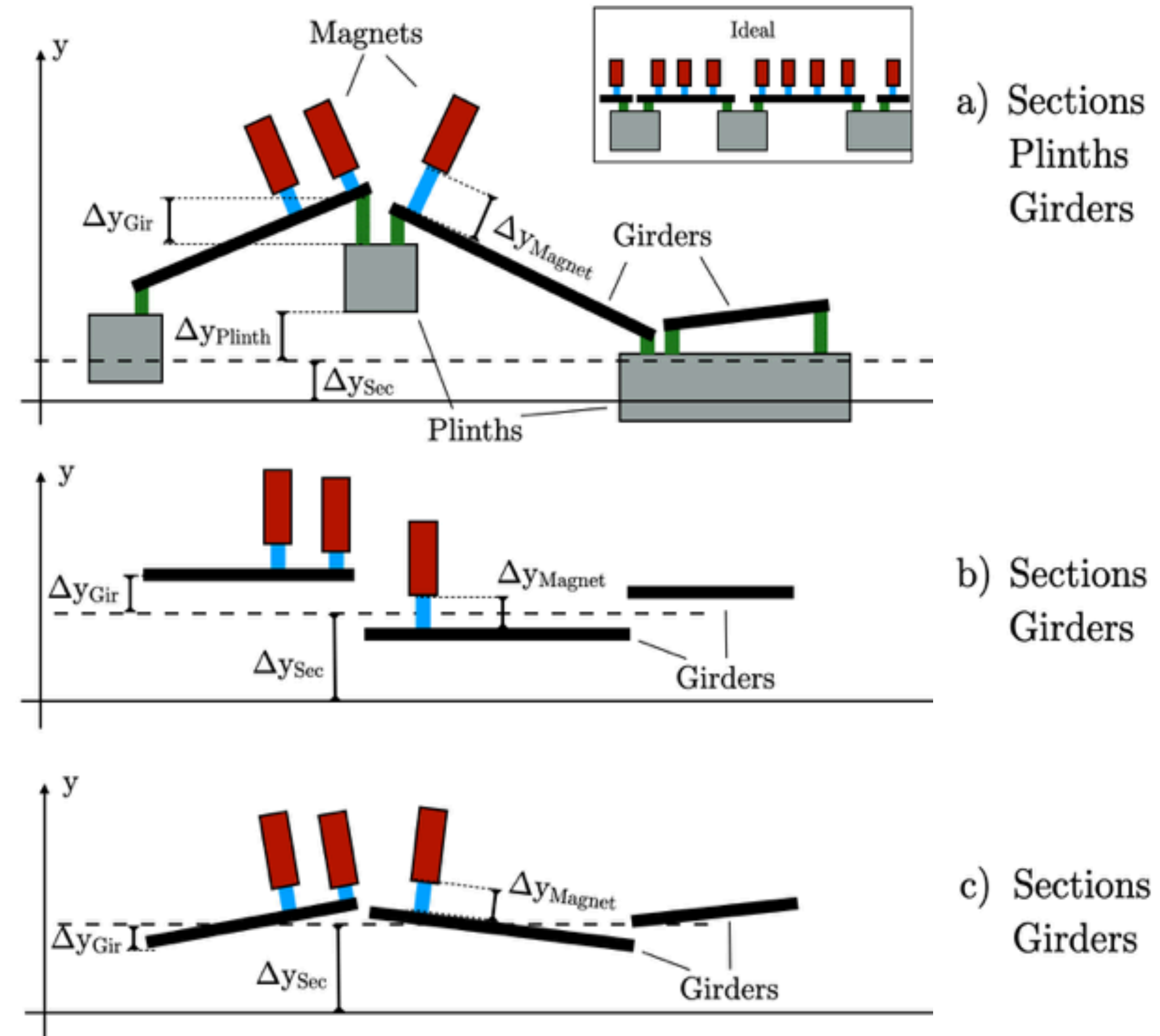


Workflow of Toolkit



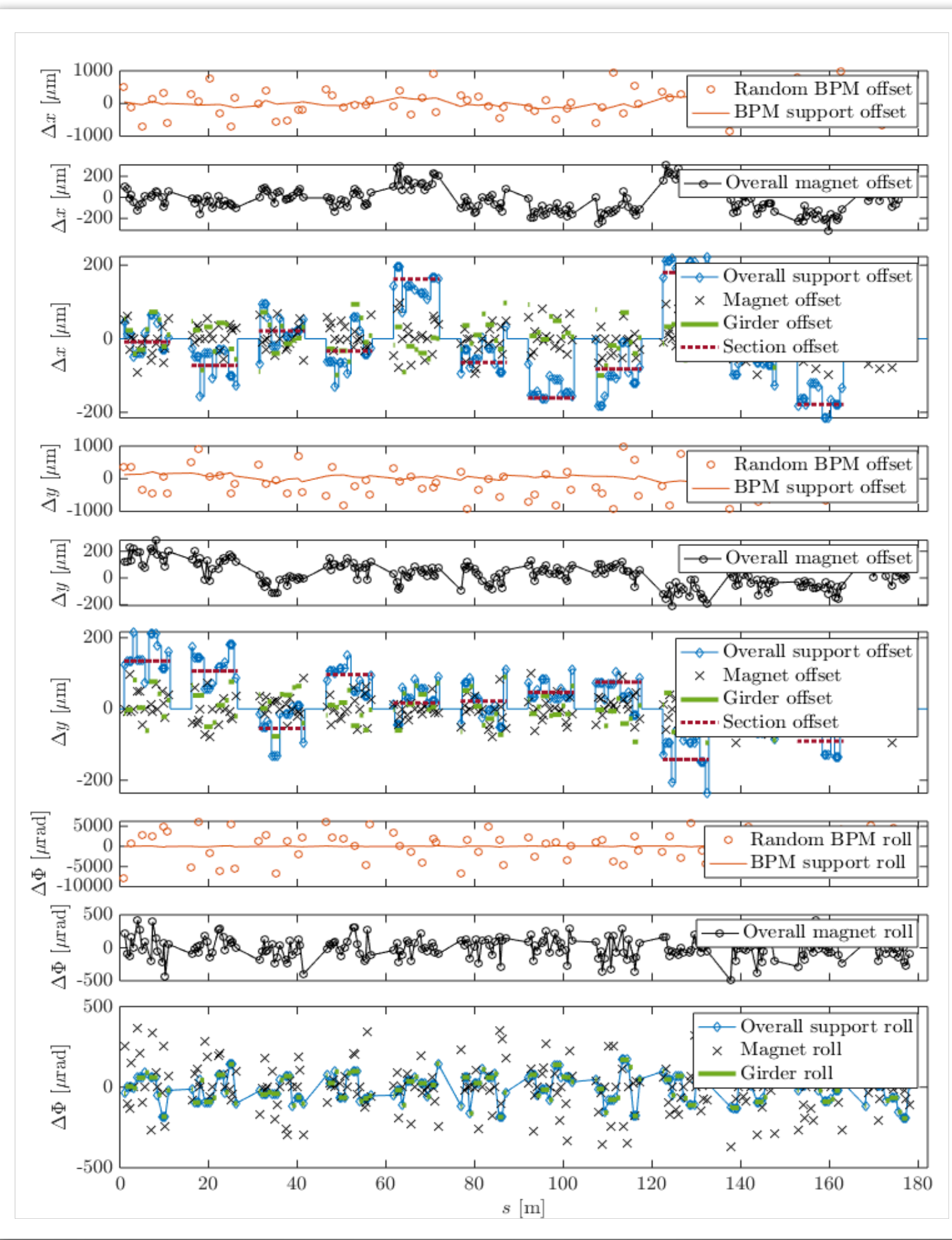
Large Numbers of Error Sources Included

- **Diagnostic errors**
 - BPM offset
 - BPM cal. error
 - BPM noise (TbT/CO)
 - BPM roll
 - CM cal. error
 - CM roll
 - CM / skew-quad limits
- **Support Structure**
 - Rafts, Plinths, Sections
 - Roll & Offsets
 - Pitch & Jaw
- **Circumference**
- **Higher Order Multipoles**
 - Systematic for arbitrary coil excitations
 - Random
- **Magnets**
 - Offset (x/y/z)
 - Roll, pitch, jaw
 - Strength
 - Calibration
- **RF Errors**
 - Phase
 - Frequency
 - Voltage
- **Injection**
 - Static
 - Shot-by-shot jitter

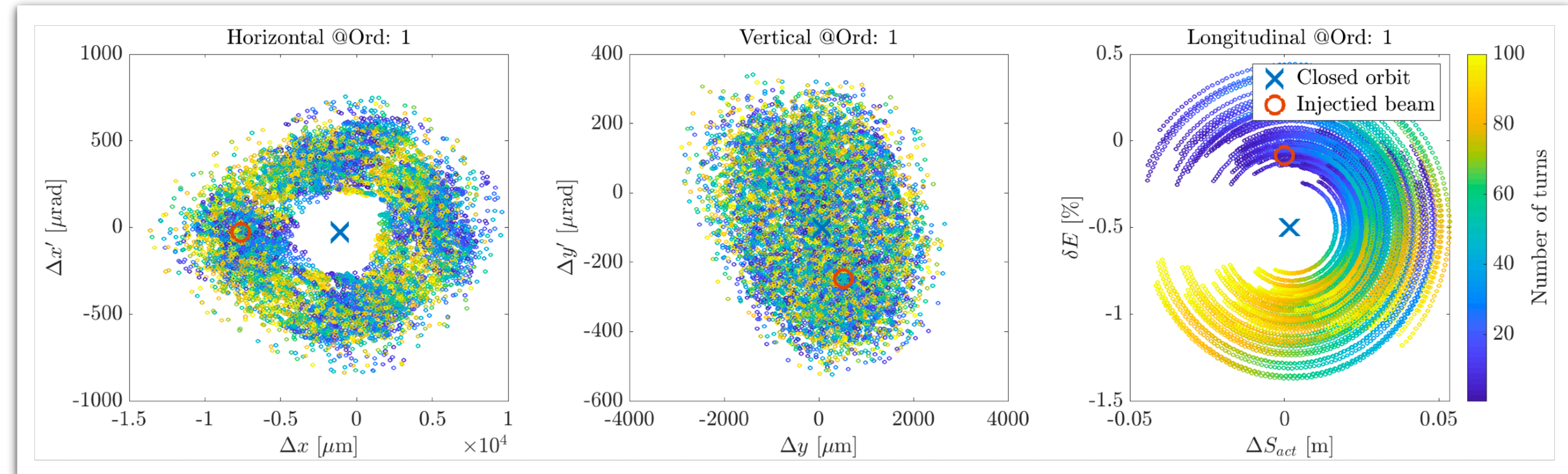


Various Visualisation Tools for Easy R&D

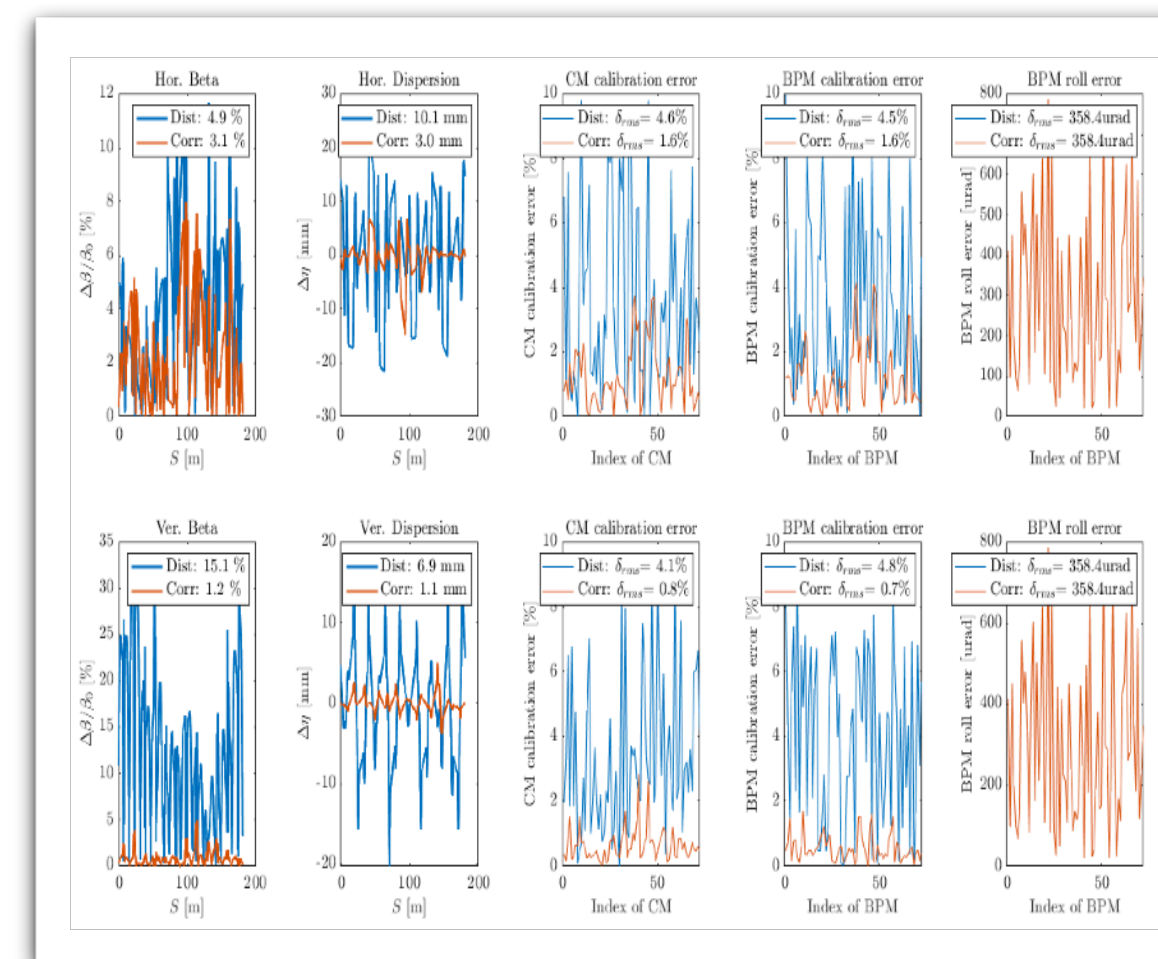
Misalignments



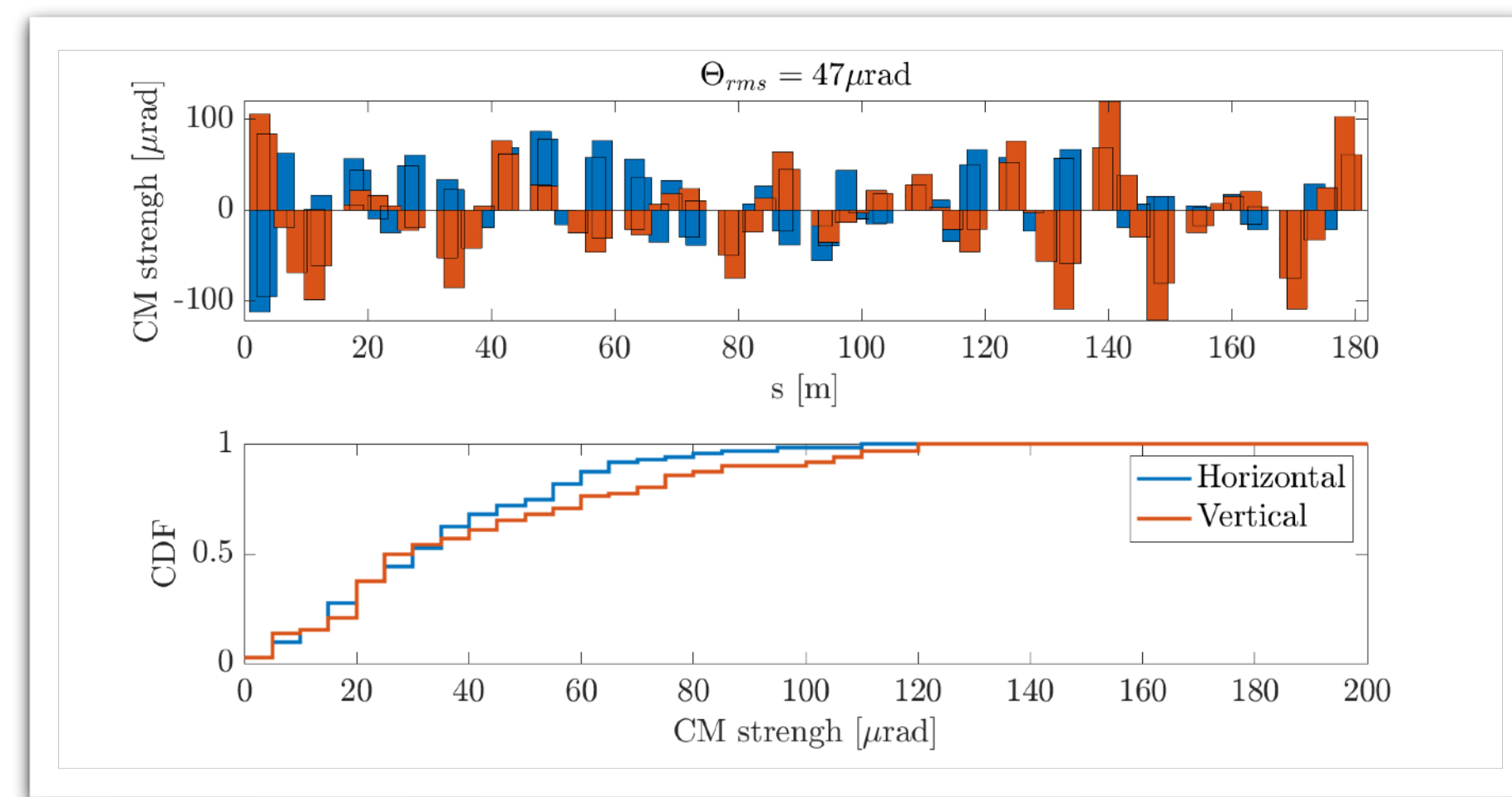
Turn-by-turn Phase Space



LOCO Status

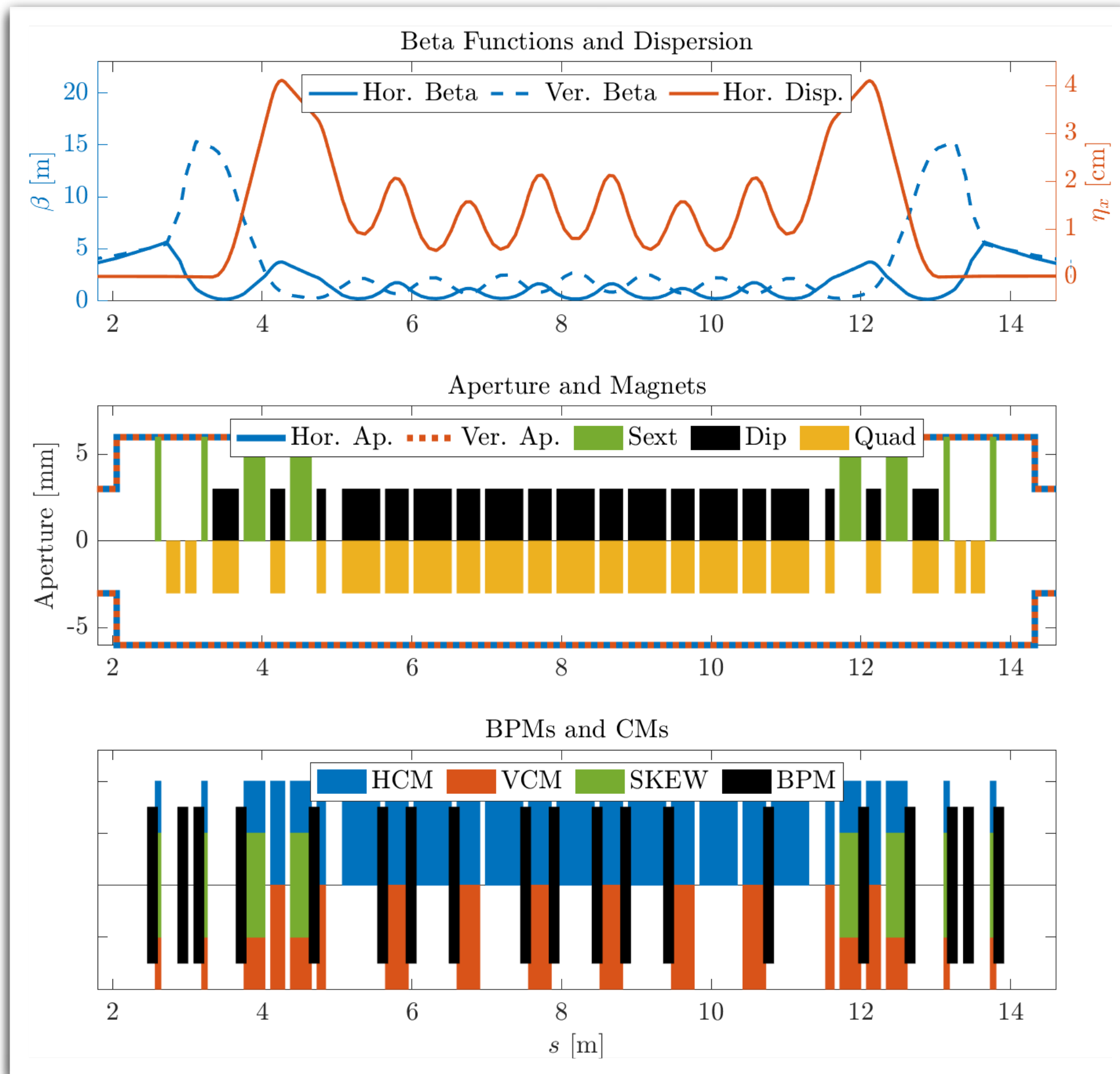


Corrector Strength

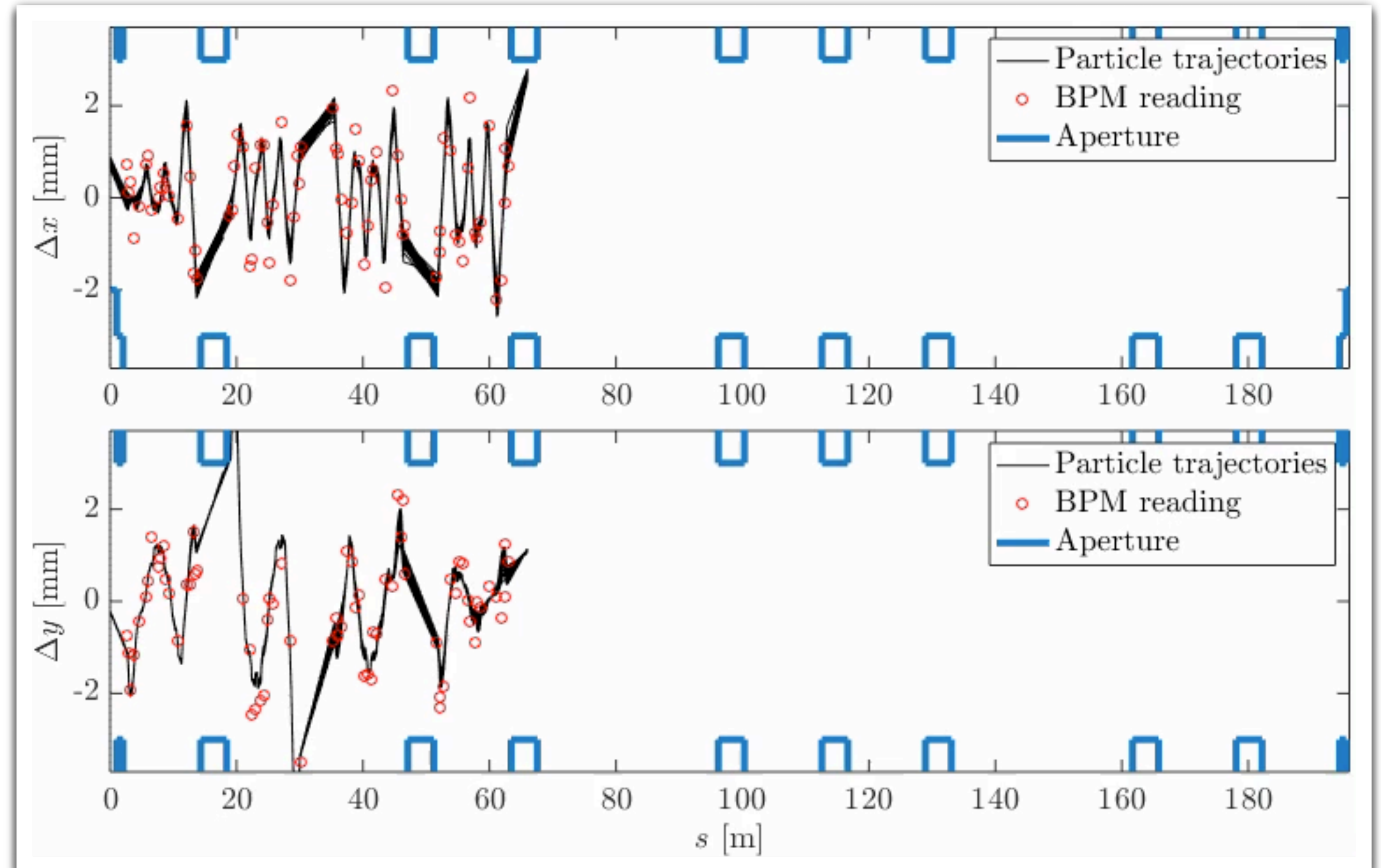


Various Visualisation Tools for Easy R&D

Lattice and Element Registration in Toolkit



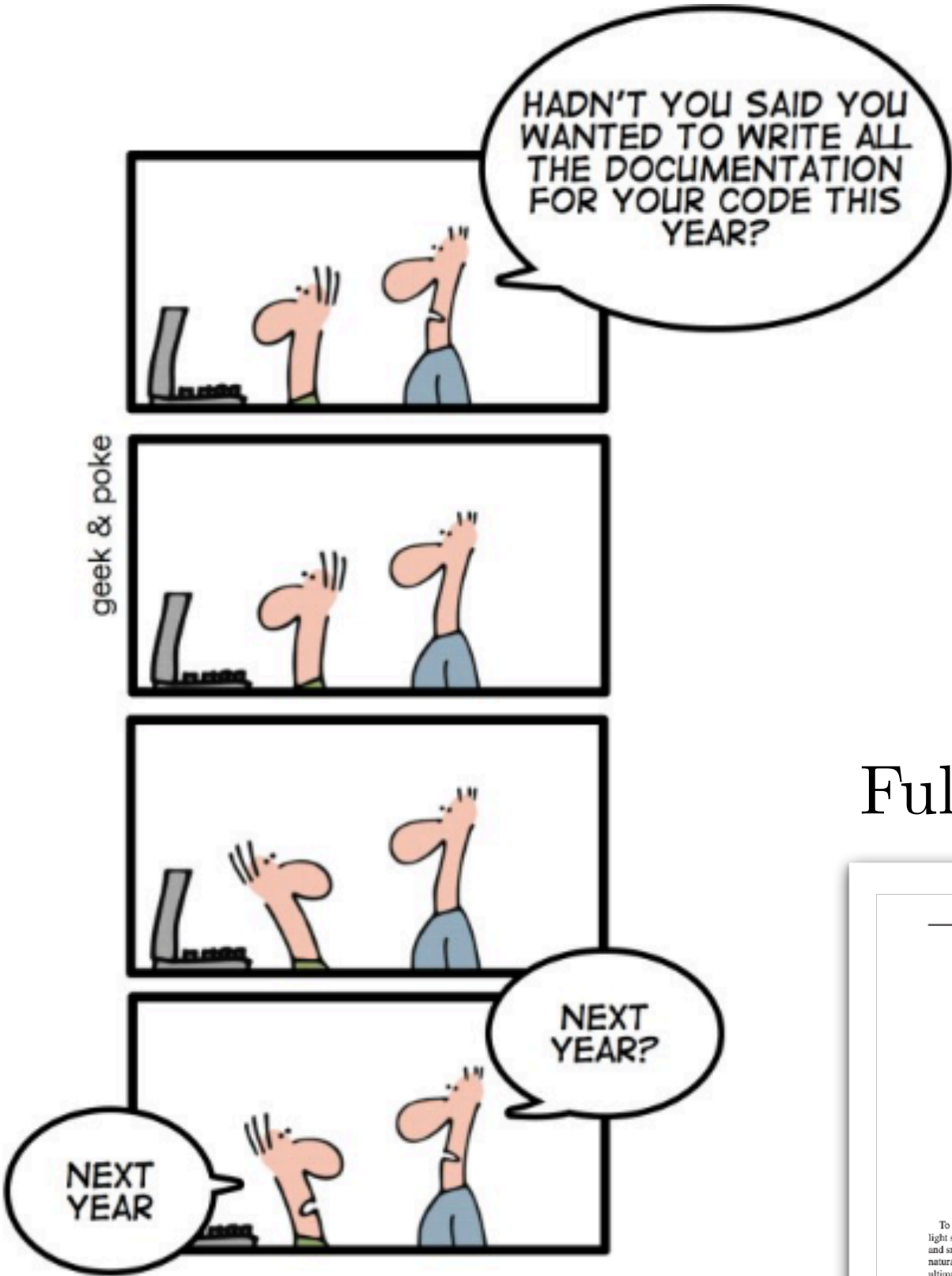
Trajectories/Orbit and BPM Readings



Comprehensive Source Code Documentation

Extensive Code Comments

Online Manual



```
% Compensate for bending kick difference.
if dipCompensation && SC.RING{idx}.BendingAngle ~= 0 && ismember(idx,SC.ORD.

% Calculate bending kick differnece for ideal magnet. See note-y18m08d20
idealKickDifference = ( ( polSP - ( SC.RING{idx}.SetPointB(2)-SC.RING{idx}

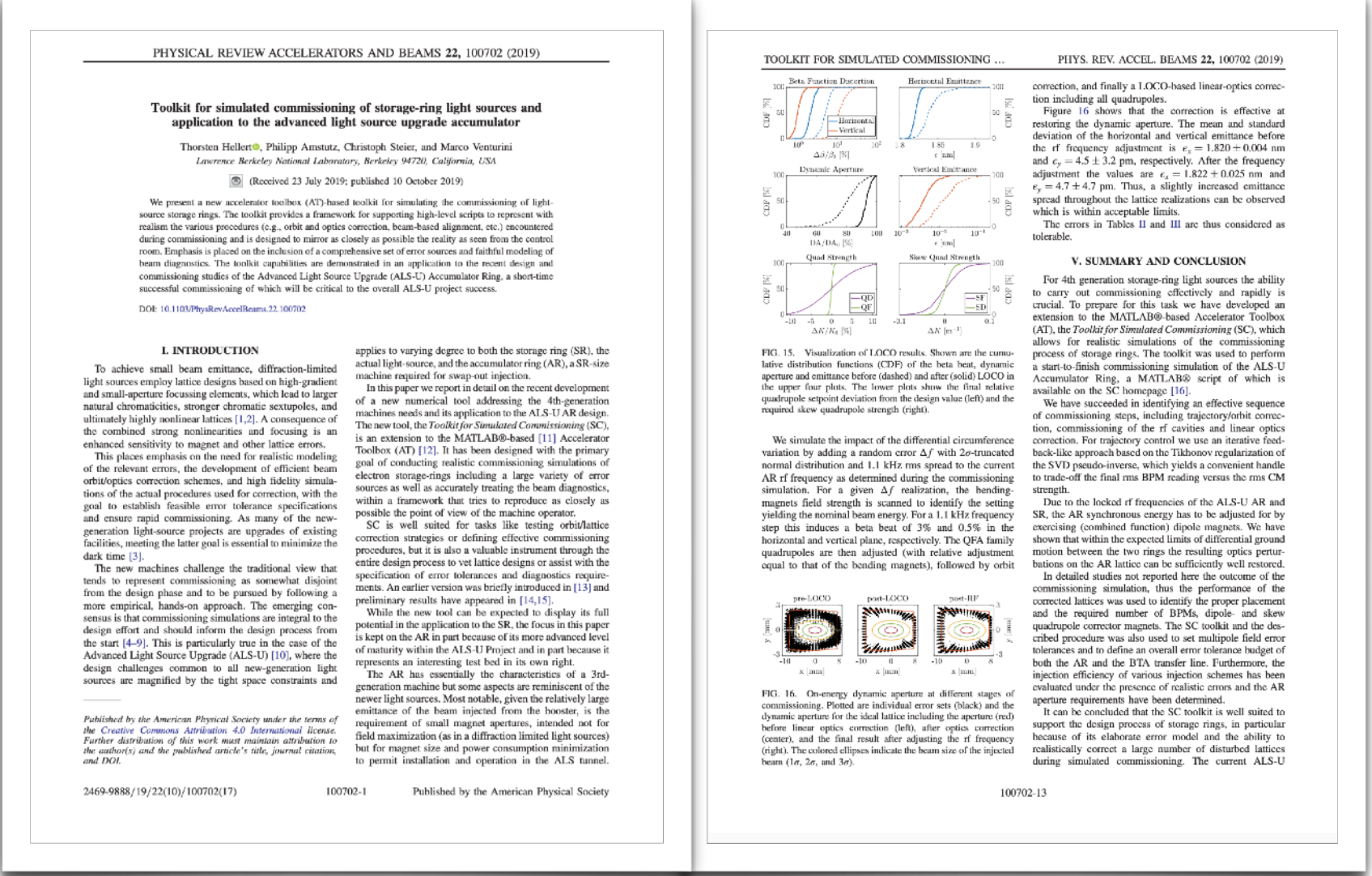
% Apply quadrupole setpoint.
SC.RING{idx}.SetPointB(2) = polSP;

% Set dipole setpoint accordinly.
[SC,~] = SCsetCMs2SetPoints(SC,idx, -idealKickDifference*SC.RING{idx}.Le

else
% Apply quadrupole setpoint.
SC.RING{idx}.SetPointB(2) = polSP;
end

% Update magnets.
SC = SCupdateMagnets(SC,idx);
```

Full ALS-U Examples (PRAB 22/100702)



Version Control



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 - SCgetBeamTransmission
 - SCgetCMSetPoints
 - SCgetDispersion
 - SCgetModelDispersion
 - SCgetModelRING
 - SCgetModelRM
 - SCgetOrds

SC Manual

T. Hellert – thellert@lbl.gov

Please check the [release notes](#) for code changes.

Introduction

Realistic simulations of the operation of a complex machine like an accelerator not only require a good model of the beam dynamics, but also have to acknowledge the fact that only incomplete information about the actual machine state is available during operation, due to the many unknowns in the machine geometry, the magnetic fields and the beam-diagnostic systems. The SC toolbox addresses this issue by making clear distinctions between machine parameters that are accessible during operation and the parameters that go into the beam dynamics simulation of the machine, e.g. by implementing a transfer-function, relating magnet setpoints to the actually realized magnetic fields.

Figure 1. Schematic drawing of the workflow of the SC toolkit.

Typical usage of the SC toolbox follows the steps

- Initialization of the SC core structure
- Error source definition & registration
- Generation of a machine realization including errors
- Interaction with the machine

which are described in the following. Thereafter we describe the [definition of error sources](#), followed by a [usage example](#) for a complete correction chain and a [list](#) of all implemented functions.

Initialization

In a first step, the user initializes the toolbox by calling **SCinit** with the AT lattice of his or her machine as input. This sets up a matlab-structure, usually assigned the variable name **SC**, with which nearly all subsequent functions of the toolbox interact. Within this central structure all relevant information about the machine and the error sources is stored.

Error Source Definition & Registration

In the next step, the user registers elements like magnets, BPMs or cavities including all error sources they would like


Easy Accessibility For New Users with Full Example Scripts

PRAB Paper for ALSU-AR

PHYSICAL REVIEW ACCELERATORS AND BEAMS **22**, 100702 (2019)

Toolkit for simulated commissioning of storage-ring light sources and application to the advanced light source upgrade accumulator

Thorsten Hellert, Philipp Amstutz, Christoph Steier, and Marco Venturini
Lawrence Berkeley National Laboratory, Berkeley 94720, California, USA

 (Received 23 July 2019; published 10 October 2019)

We present a new accelerator toolbox (AT)-based toolkit for simulating the commissioning of light-

PRAB Paper for ALSU-SR (under review)

Lattice Correction and Commissioning Simulation of the Advanced Light Source Upgrade Storage-Ring

Thorsten Hellert, Christoph Steier, and Marco Venturini
Lawrence Berkeley National Laboratory, Berkeley 94720, California, USA
(Dated: May 23, 2022)

The ALS-U is the upgrade of the existing Lawrence Berkeley National Laboratory Advanced Light Source to a diffraction-limited soft X-ray light source. Here we present the lattice correction studies and commissioning simulations demonstrating that the proposed machine design can be expected to deliver the intended performance when realistic errors and perturbations are fully accounted for. Critical to this demonstration are the high-fidelity, realistic simulations of the beam-based alignment process (both in turn-by-turn mode during early commissioning and with stored beam) that are now

Toolkit Webpage

Toolkit for Simulated Commissioning (SC)

We present the *Toolkit for Simulated Commissioning* (SC), which allows for realistic comm as diligently treating beam diagnostic limitations. Please have a look at the [manual](#) for more [Accumulator Ring](#) including all files and error defenitions can be found [here](#).

SC uses the Matlab-based *Accelerator Toolbox* (AT), which can be downloaded [here](#). The rel

Manual

[This is the manual.](#)

Source

[git repository](#)

[Full ALS-U Accumulator Ring example](#)

[Full ALS-U Storage Ring example](#)

Git Repository

master SC / applications / ALSU_SR /

ThorstenHellert Custom ID pass method for running on cluster

..

IDLibrary Custom ID pass metho

Multipoles Initial commit: ALS-U S

Studies Adjusted injection sec

lattices Added CM calibration

calcLatticeProperties_ALSU_SR.m Initial commit: ALS-U S

crawlClusterJob.m Initial commit: ALS-U S

getBPM2QuadPairing_ALSU_SR.m Initial commit: ALS-U S

locoTH.m Initial commit: ALS-U S

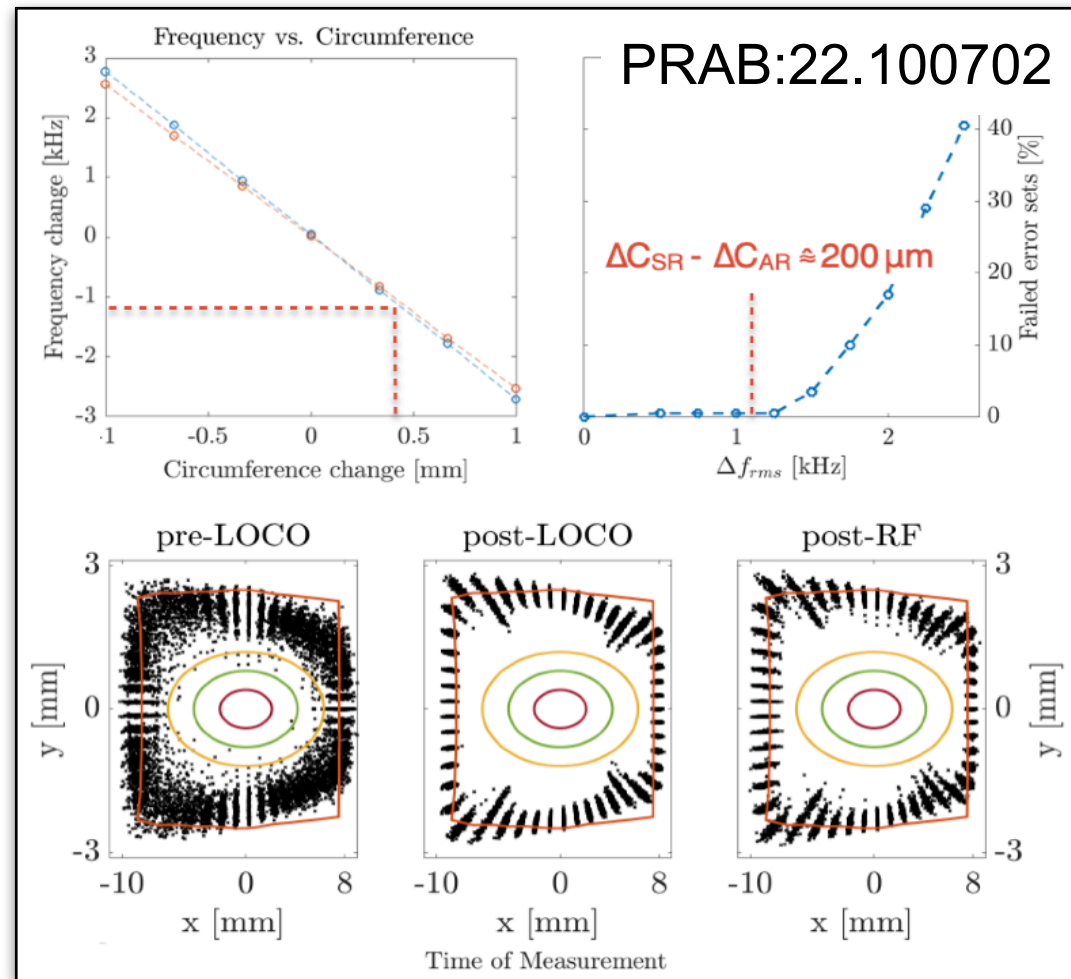
locoresponsematrixFull.m Initial commit: ALS-U S

Annotated Scripts

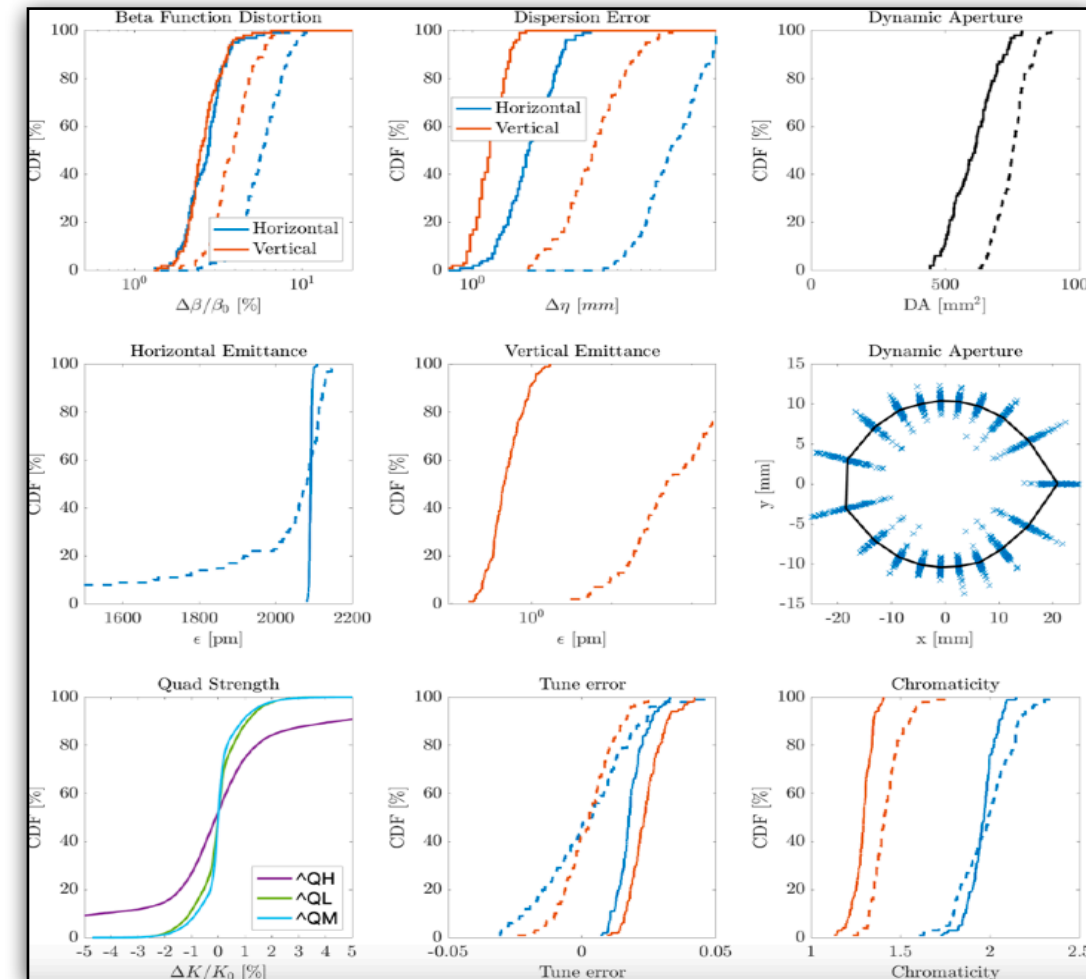
```
64 % Initialize toolkit
65 SC = SCinit(RING);
66
67 % Register ALSU-SR
68 [SC,BPMords,CMords] = register_ALSU_SR(SC);
69 % Save ideal SC state for ID compensation calculat
70 results.SCrefID = SC;
71 % Save BPM and CM ords used in orbit correction
72 results.BPMords = BPMords;
73 results.CMords = CMords;
74
75 % Define apertures
76 SC.RING = setApertures_ALSU_SR(SC.RING);
77
```


Toolkit Used for Guiding Design Process at Various Laboratories

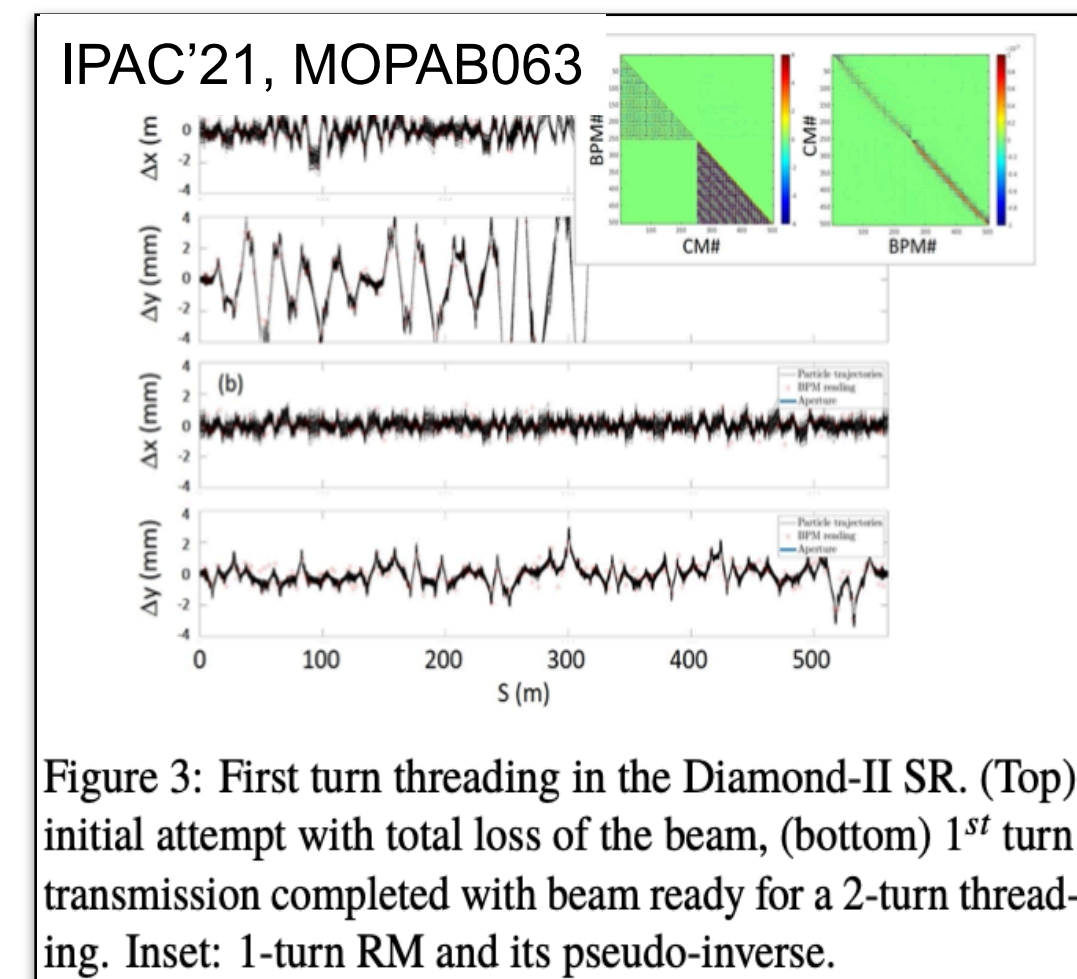
ALS-U (*T. Hellert*)



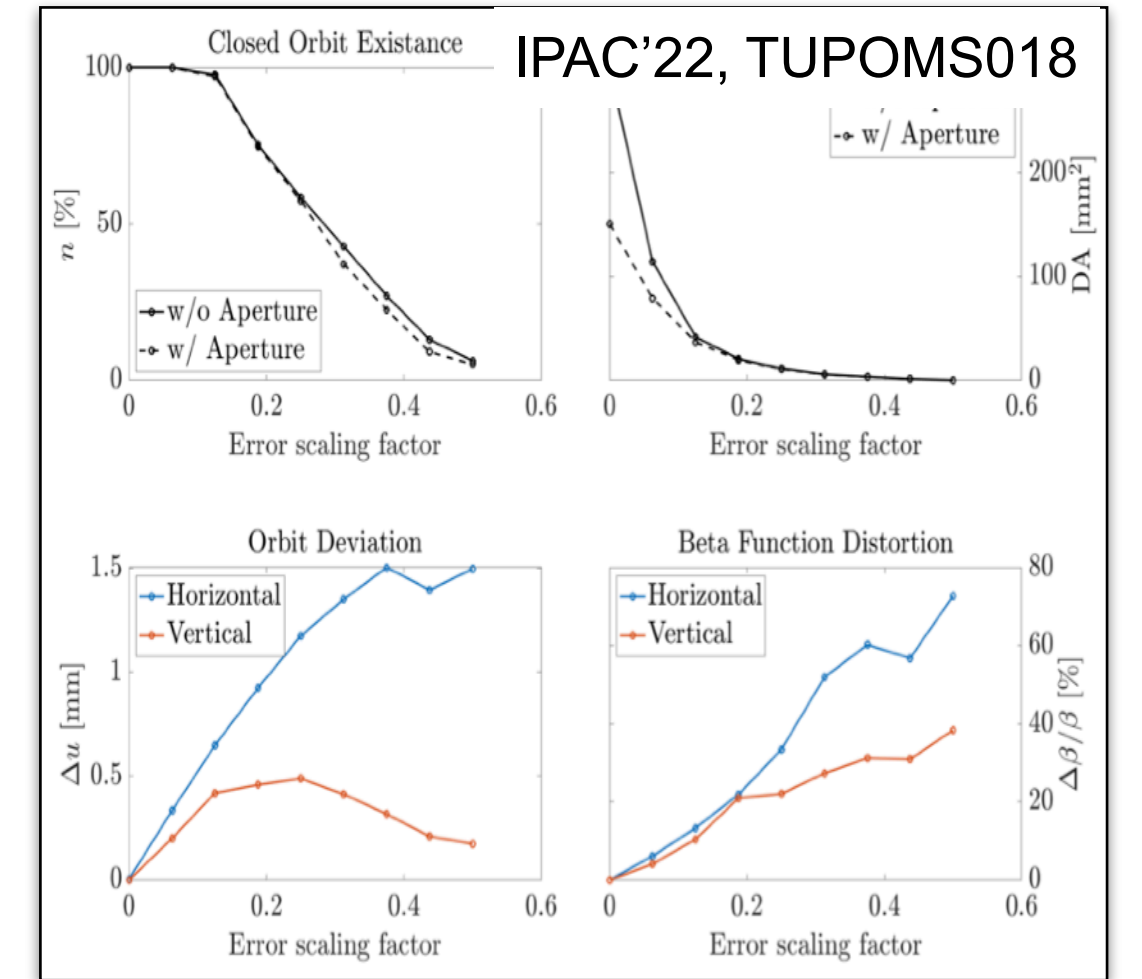
NSLS-II (*A. Khan*)



Diamond-II (*D. Amorin*)



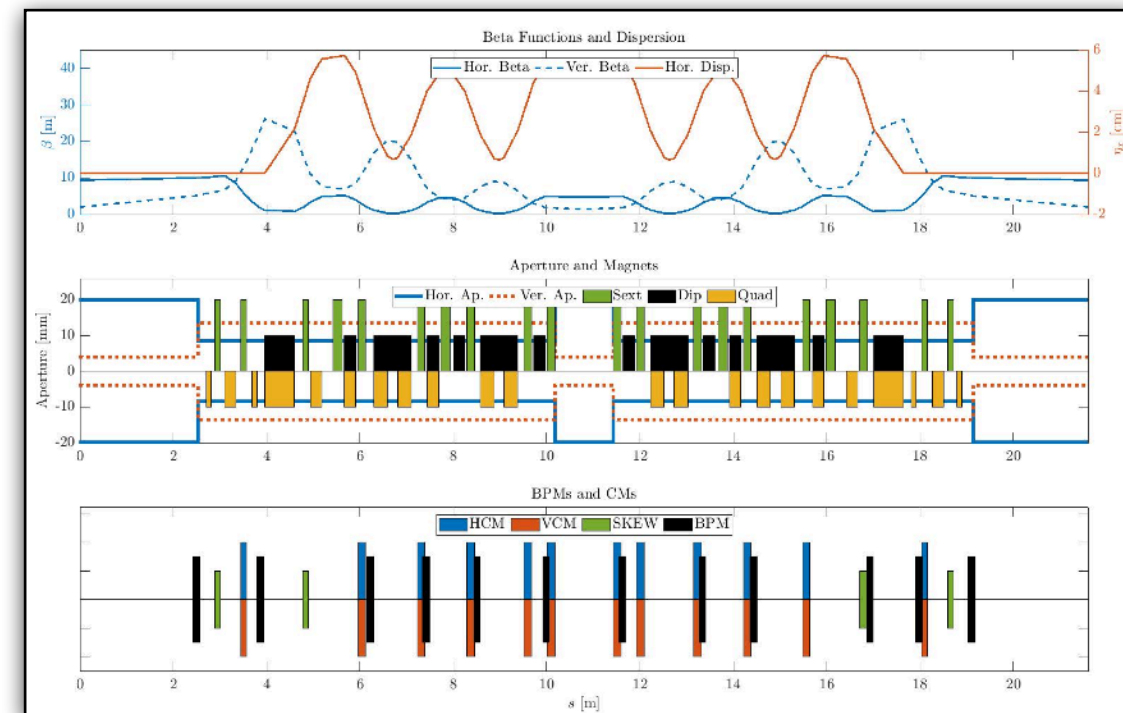
PETRA IV (*T. Hellert*)



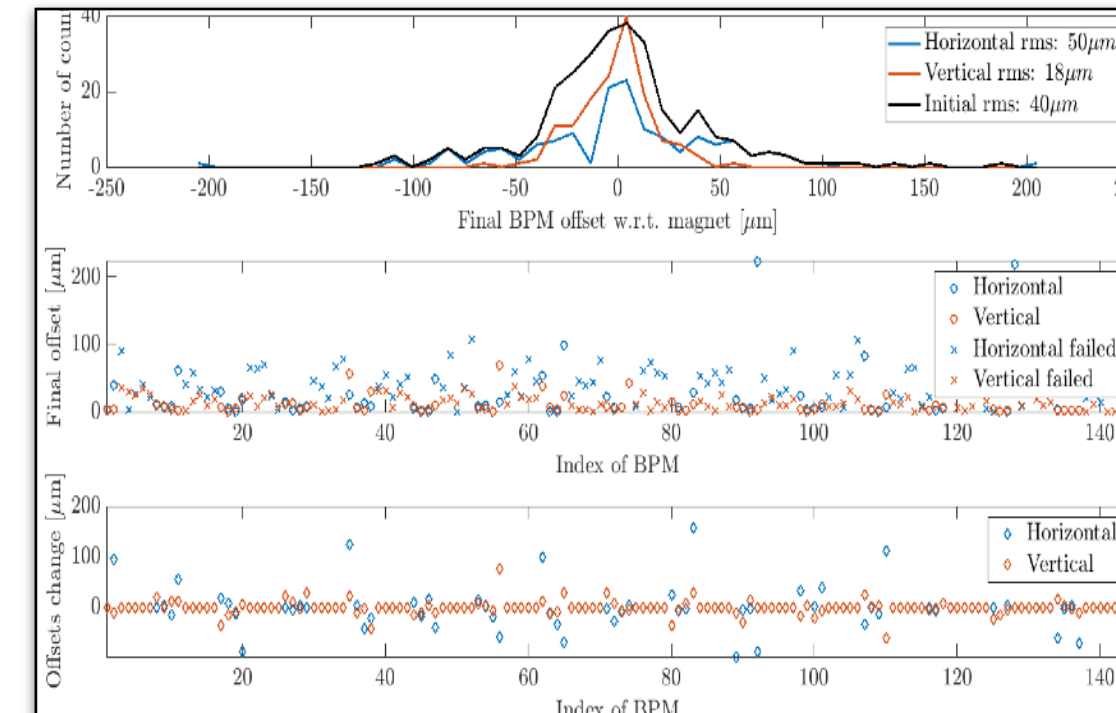
BESSY III (*P. Goslawski*)



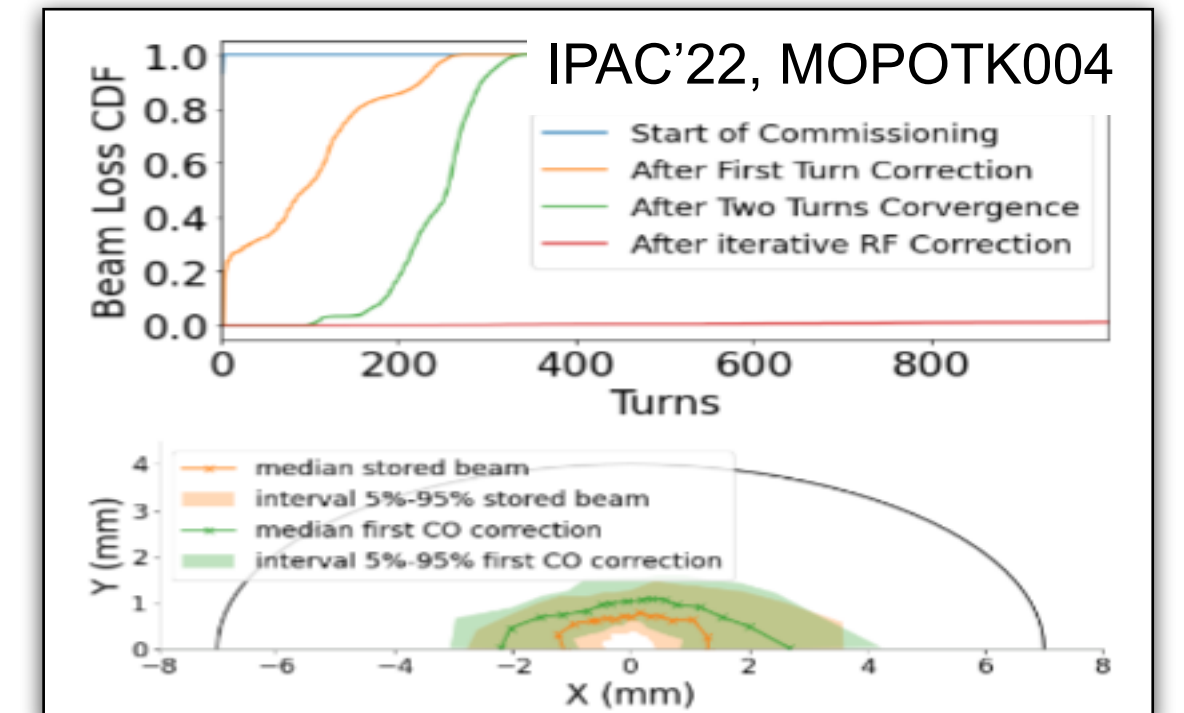
Elettra 2.0 (*S. Dastan*)



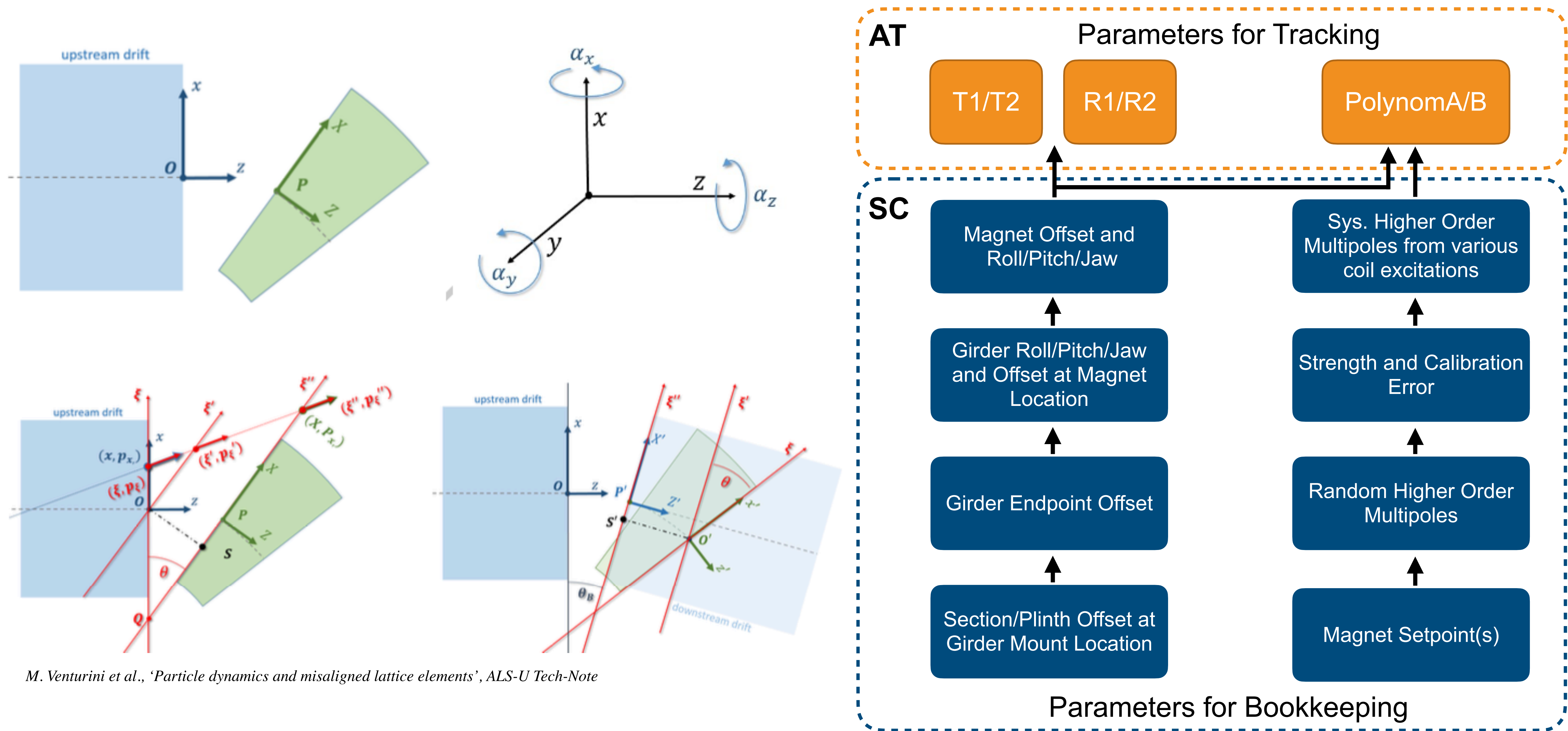
ALBA-II (*Z. Marti Diaz*)



SOLEIL Upgrade (*O. Garcia*)



SC -> ELEGANT Corrected Lattice Converter



M. Venturini et al., 'Particle dynamics and misaligned lattice elements', ALS-U Tech-Note

SC -> ELEGANT Corrected Lattice Converter

- **AT/elegant**
 - SC allows for easy error model- and correction chain setup
 - Elegant allows for more advanced tracking studies than AT
- **Corrected Lattice Converter**
 - Set up errors and correction chain with SC
 - Convert final lattice to elegant
 - Perform e.g. collective effects studies
 - Converter now available on SC webpage

12th Int. Particle Acc. Conf.
ISBN: 978-3-95450-214-1

IPAC2021, Campinas, SP, Brazil
ISSN: 2673-5490

JACoW Publishing
doi:10.18429/JACoW-IPAC2021-MOPAB119

COMPARISONS BETWEEN AT AND ELEGANT TRACKING*

G. Penn[†], T. Hellert, M. Venturini
Lawrence Berkeley National Laboratory, Berkeley, CA, USA

Abstract

The simulation codes elegant [1] and Accelerator Toolbox (AT) [2] are both in common use for the study of particle accelerators and light sources. They use different software platforms and have different capabilities, so there is a strong motivation to be able to switch from one version to another to achieve different goals. In addition, it is useful to directly compare results for benchmarking studies. We discuss differences in tracking methods and results for various elements, and explore the impact on simulations performed with lattices designed for the ALS-U. In addition to single-particle

Recently, there has been work by developers of elegant and SC to implement consistent models for misalignments based on concepts from [4], which has facilitated the translation tool. This work also relies on previous comparisons, for example [5], which includes work by X. Huang to implement tracking in AT that is more accurate and similar to that of elegant. However, this code is not yet in the standard AT repository and is not included in the results shown below.

TRACKING COMPARISONS

Single-particle tracking for particles with moderate am-

G. Penn et al., MOPAB119, IPAC'21

