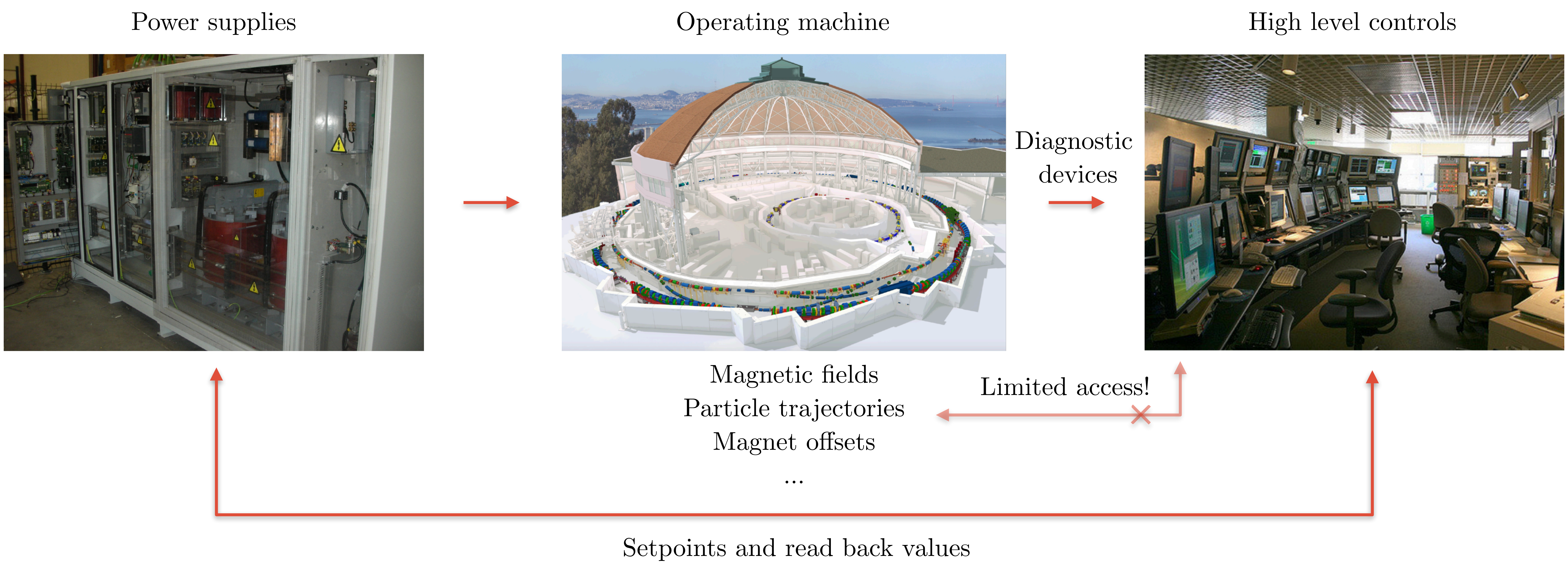
PETRA IV.
NEW DIMENSIONS

SC - A Toolkit for Simulated Commissioning

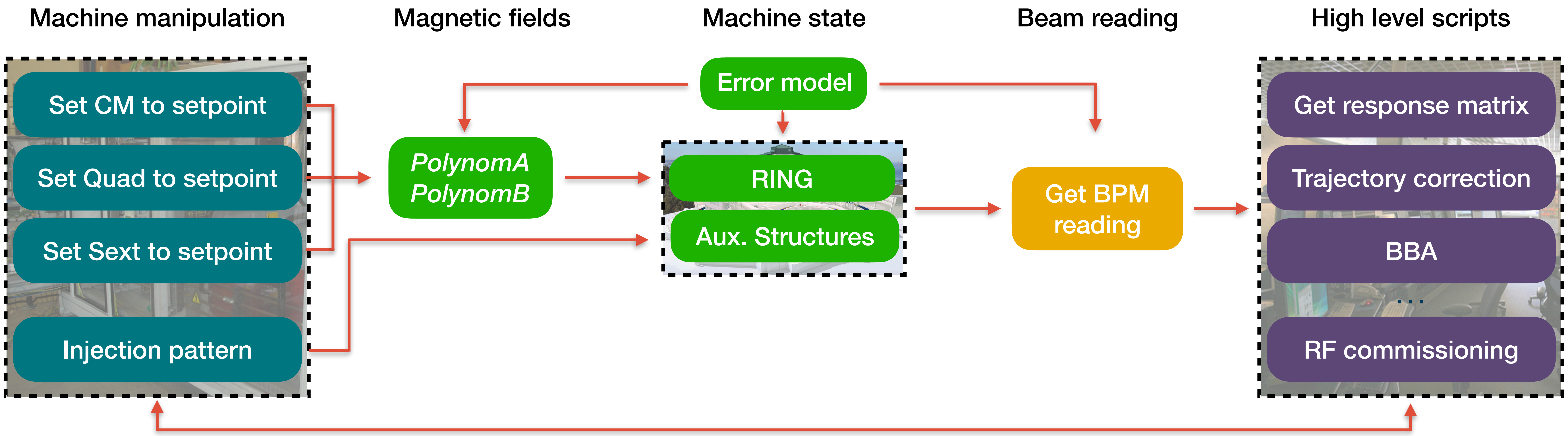
Thorsten Hellert
Eurizon WP 4.1 Meeting
DESY, 23.02.23

Toolkit Design Features

Limited Accessibility of Machine Parameters



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

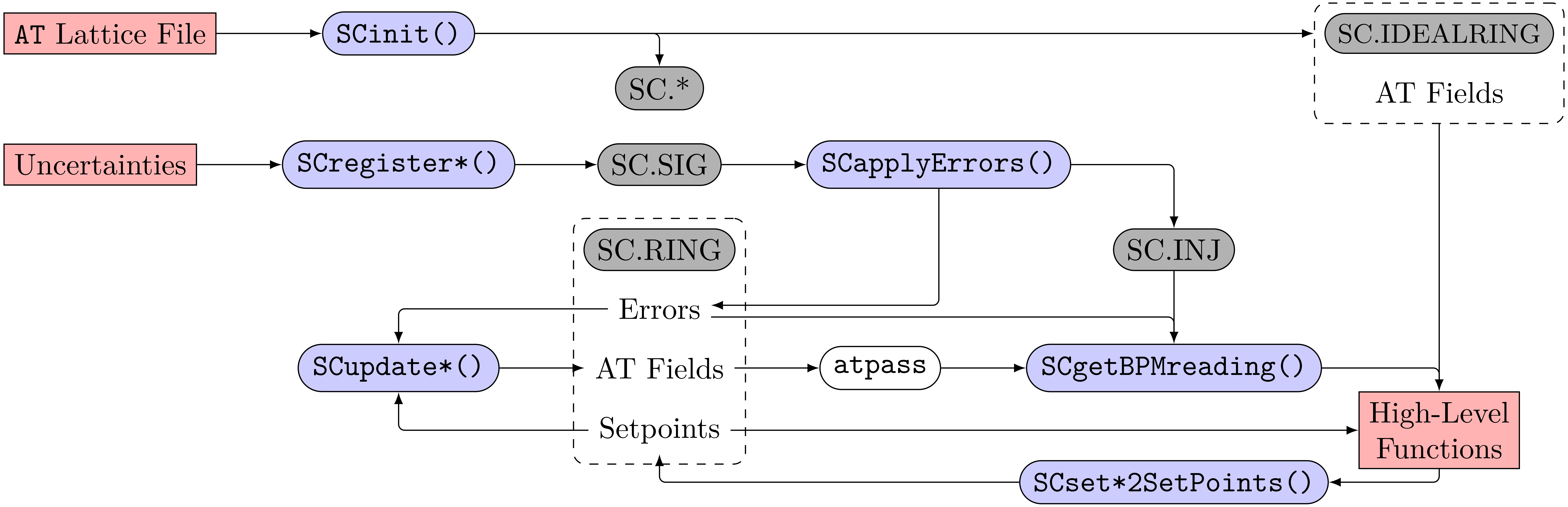
Get BPM reading

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

High level

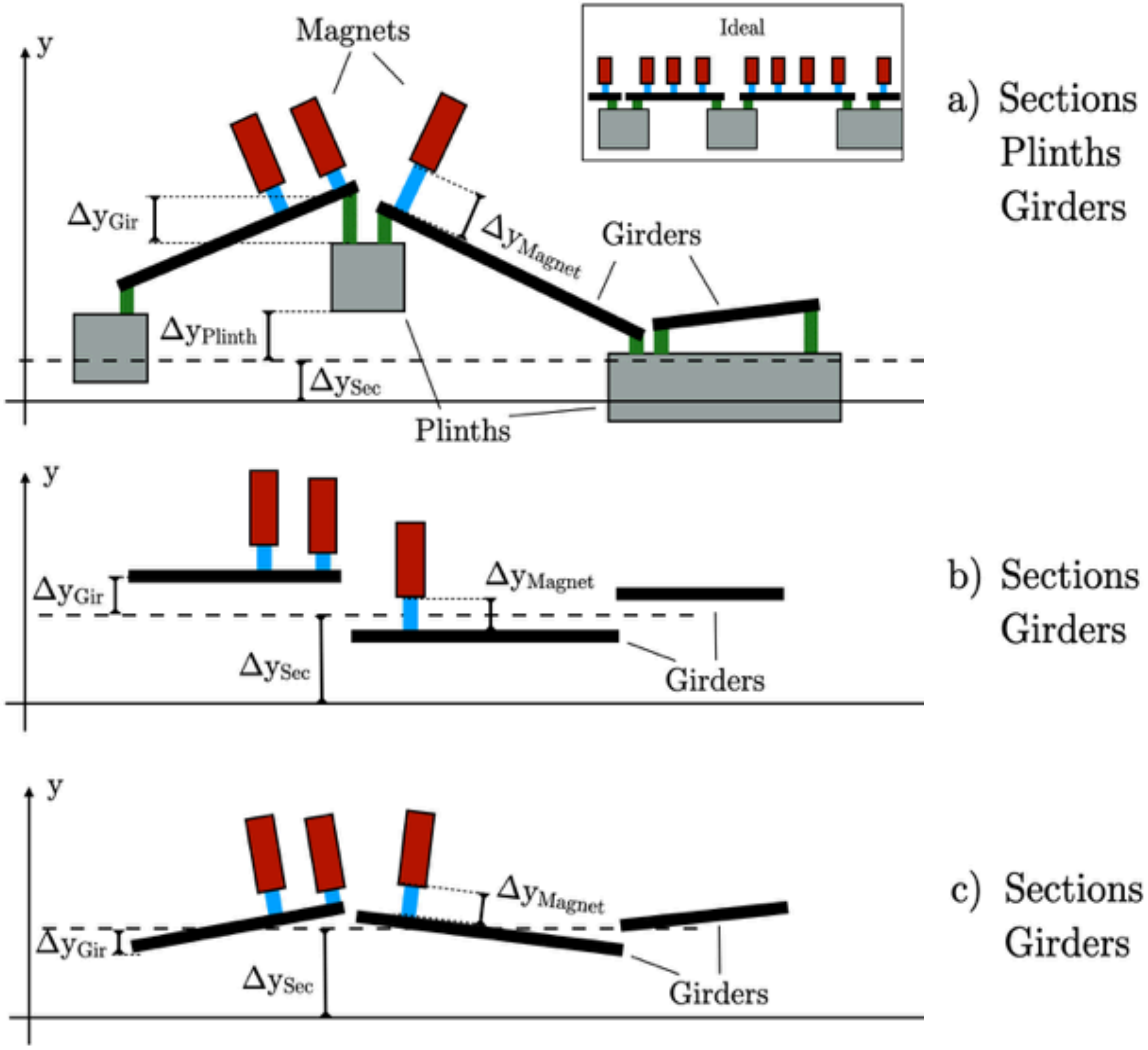
- High level functions use only BPM and setpoints as input
- High level functions write only setpoints

Workflow of Toolkit



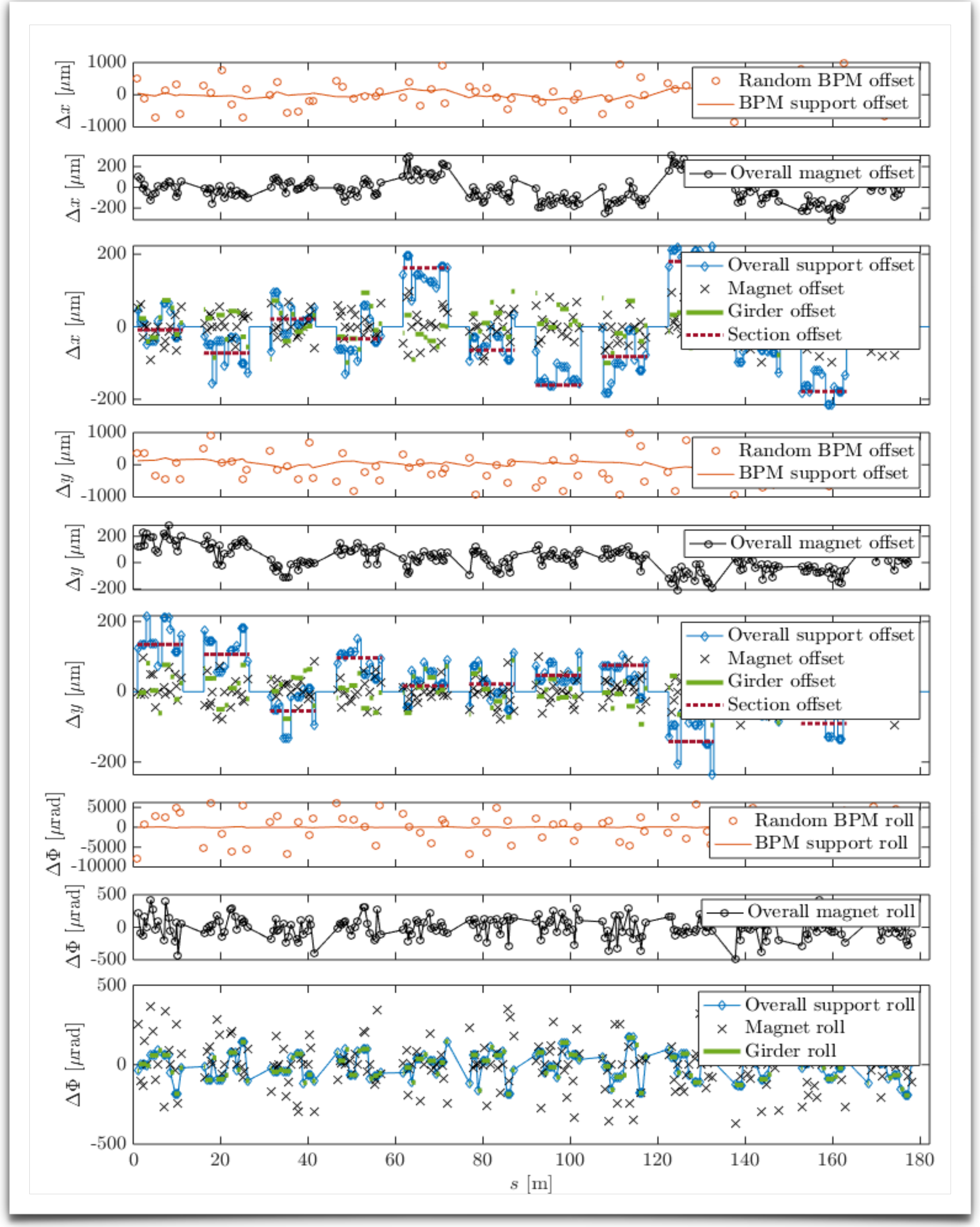
Large Numbers of Error Sources Included

- **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

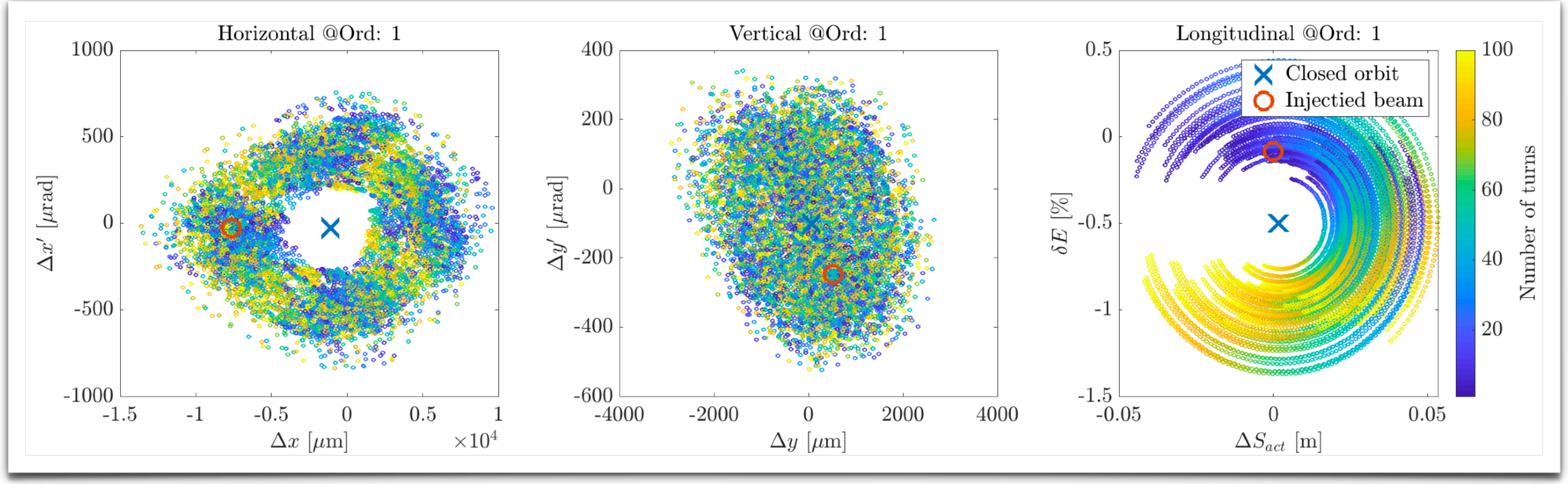


Various Visualisation Tools for Easy R&D

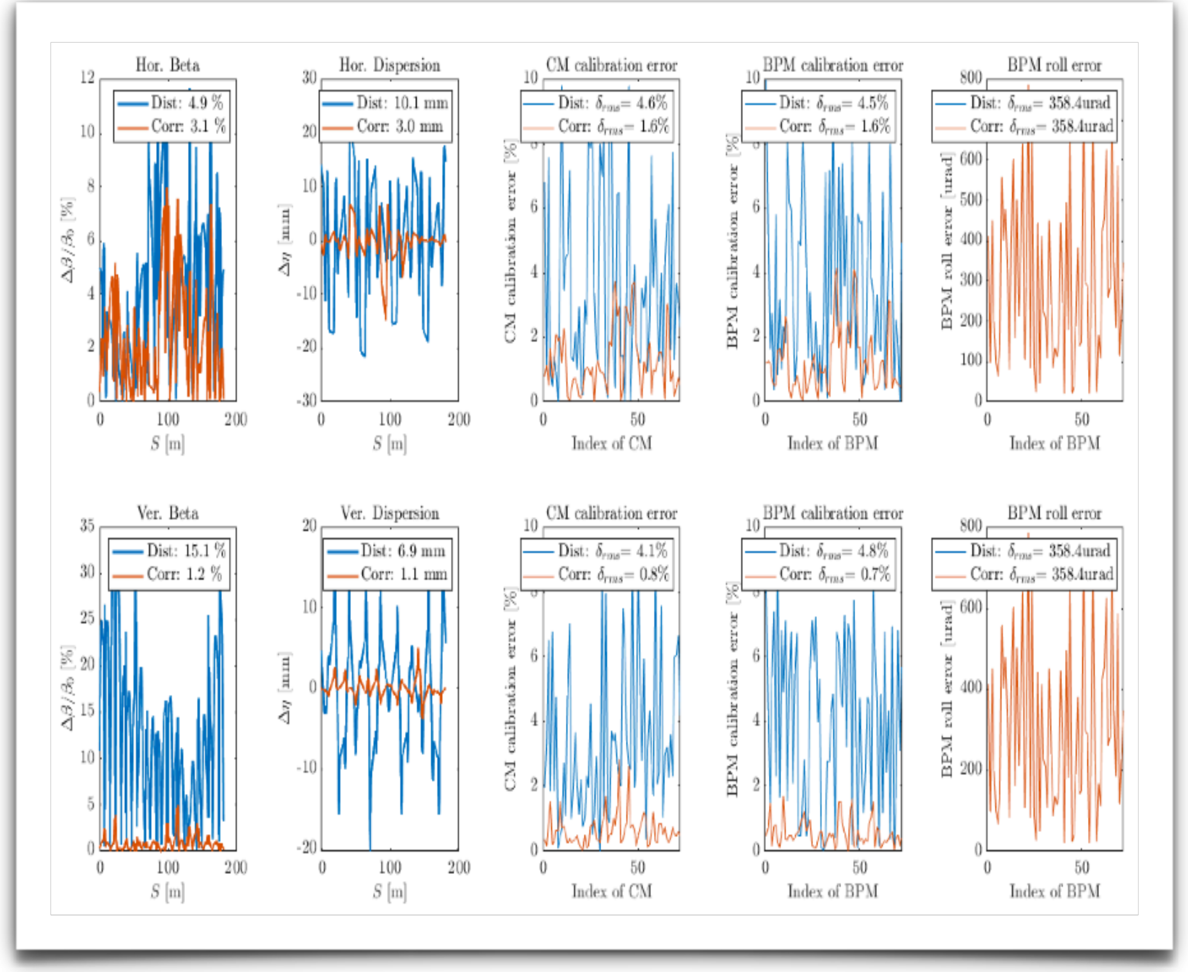
Misalignments



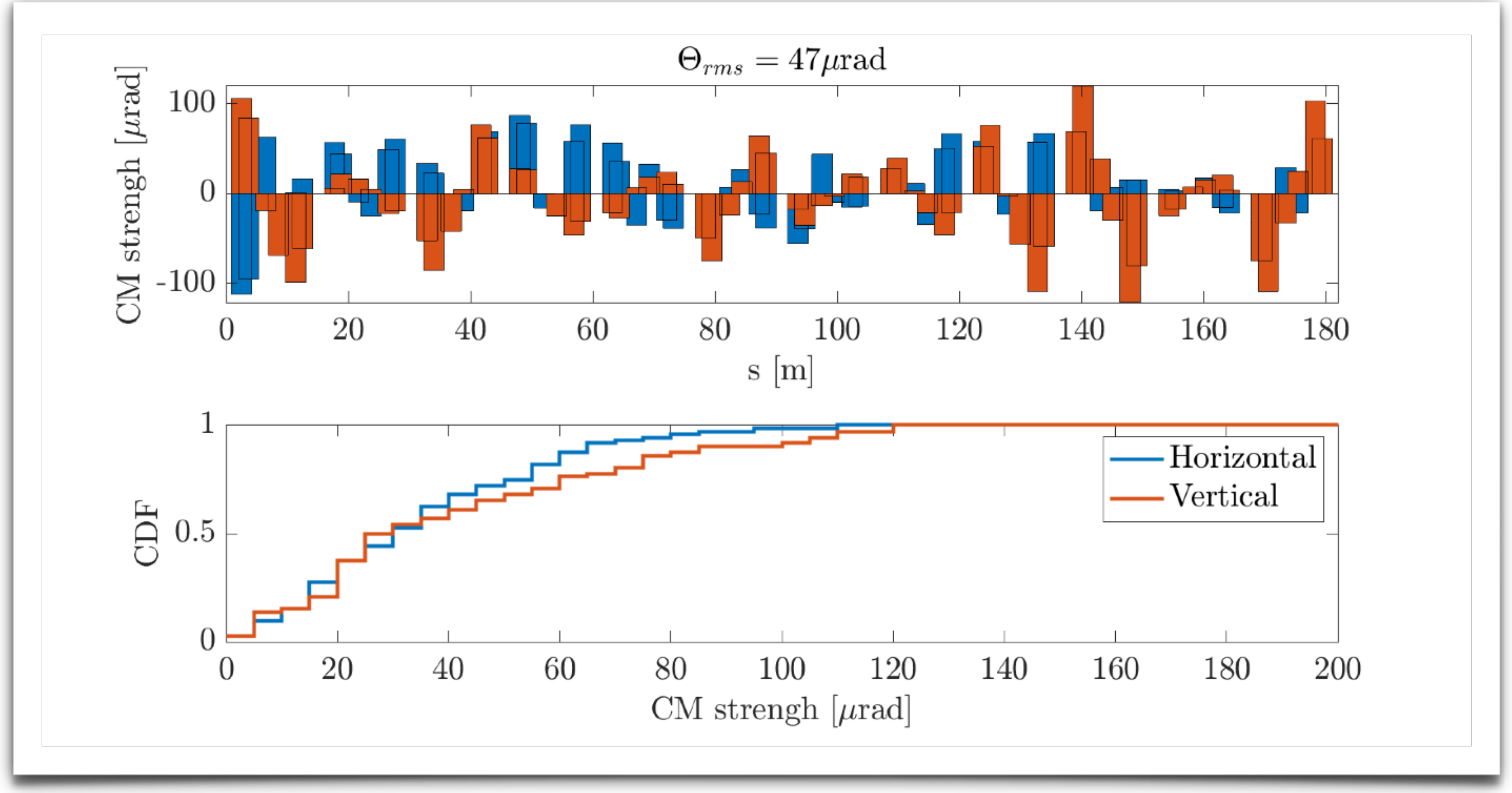
Turn-by-turn Phase Space



LOCO Status

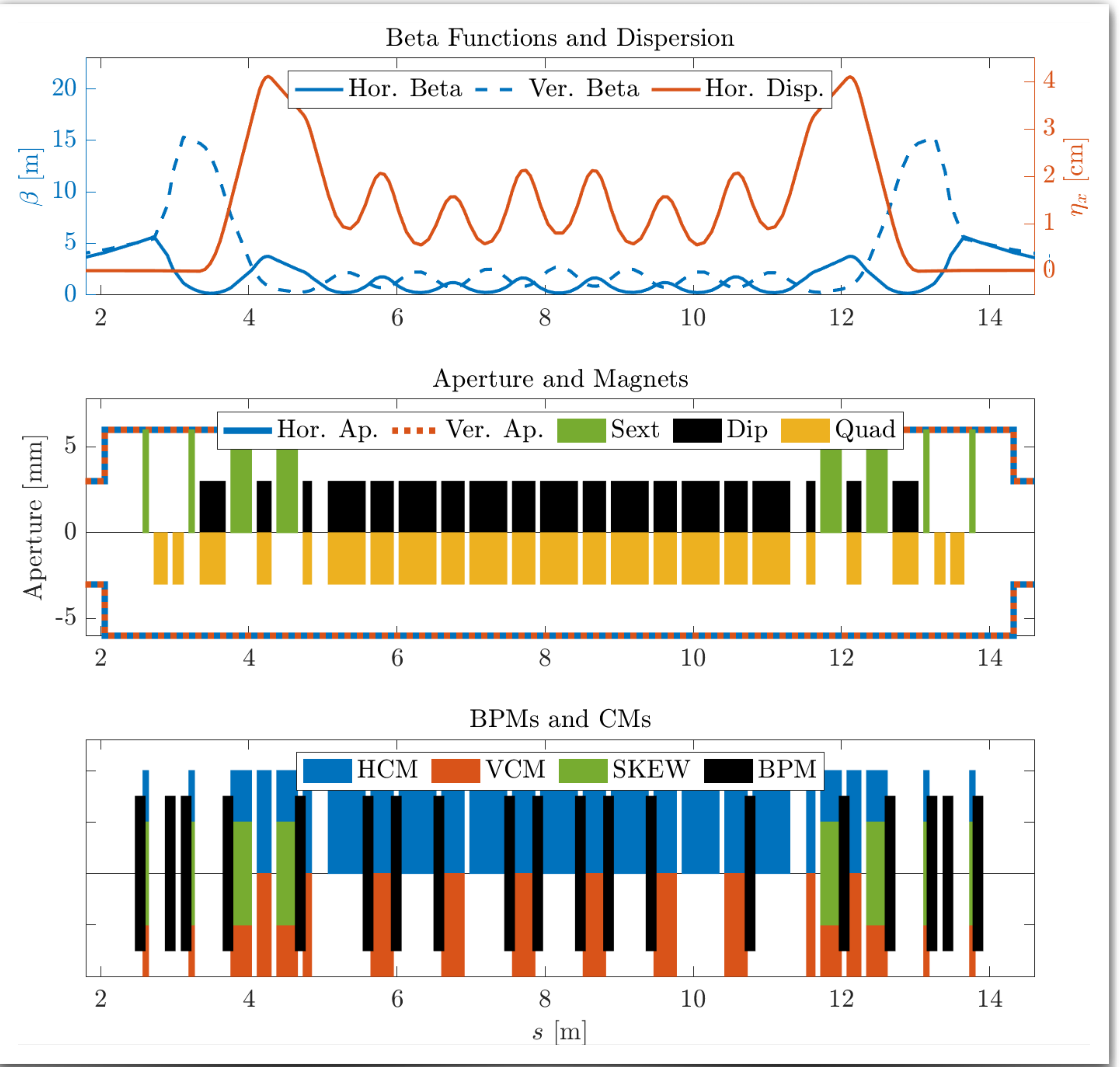


Corrector Strength

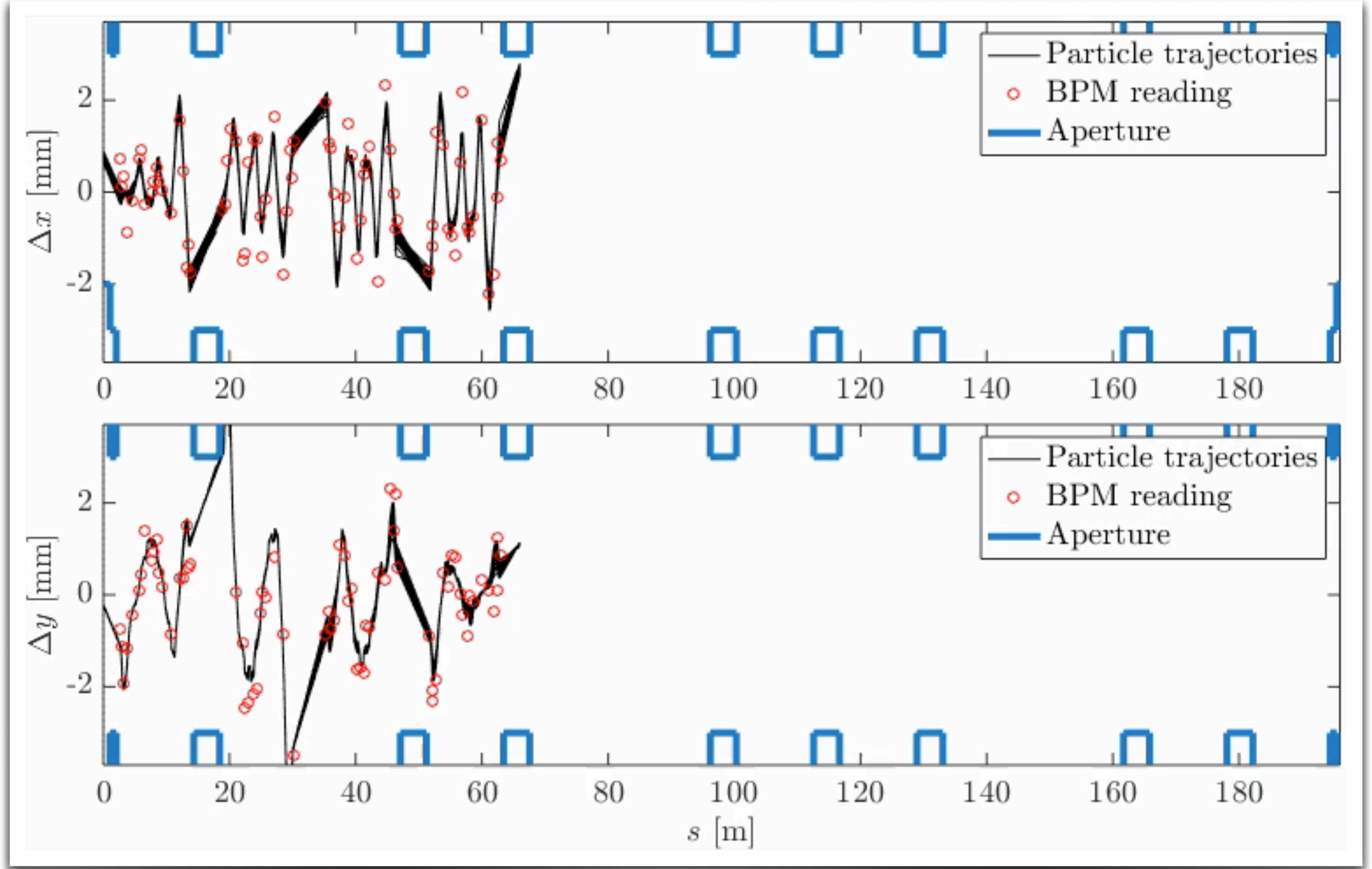


Various Visualisation Tools for Easy R&D

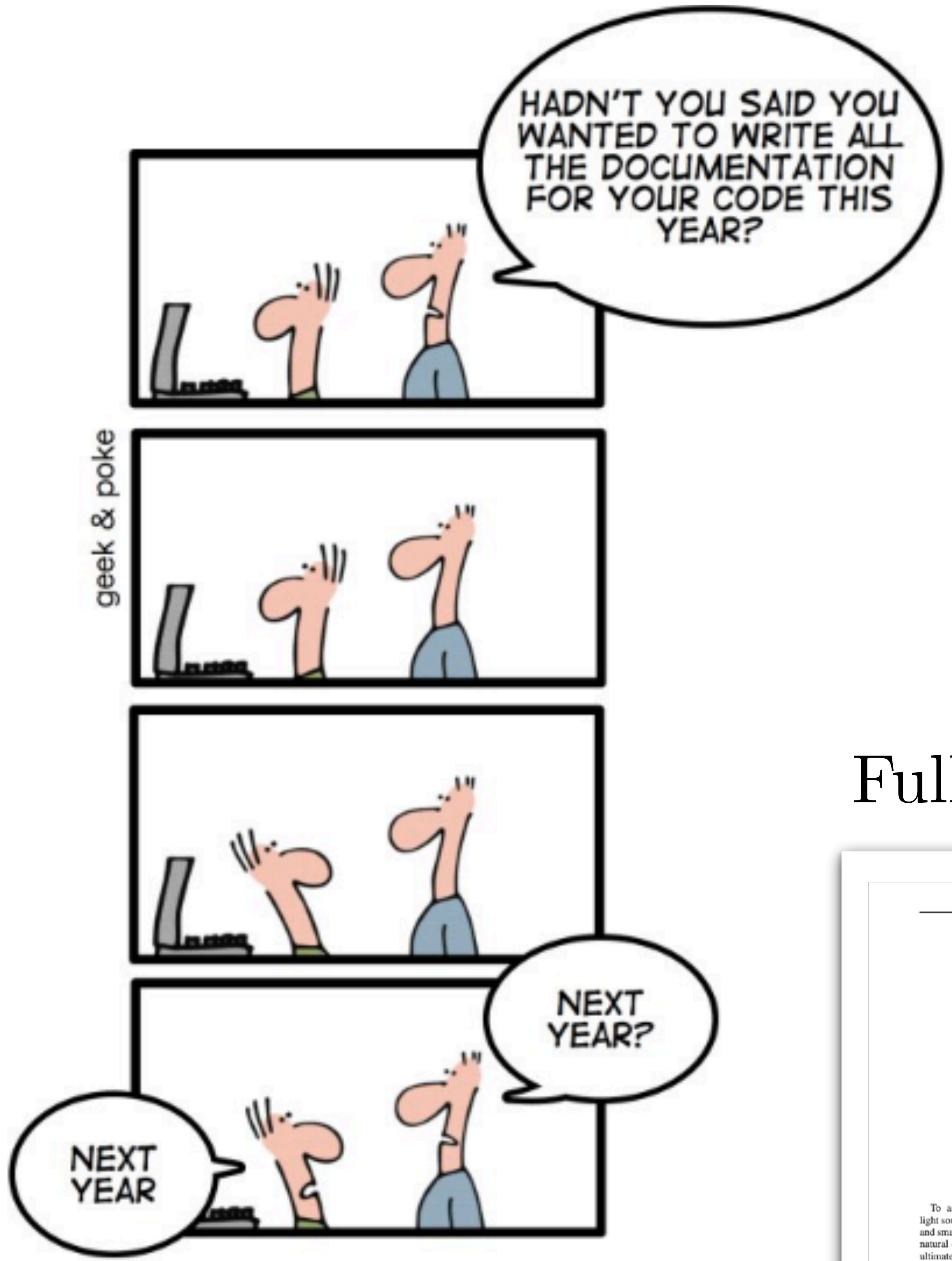
Lattice and Element Registration in Toolkit



Trajectories/Orbit and BPM Readings



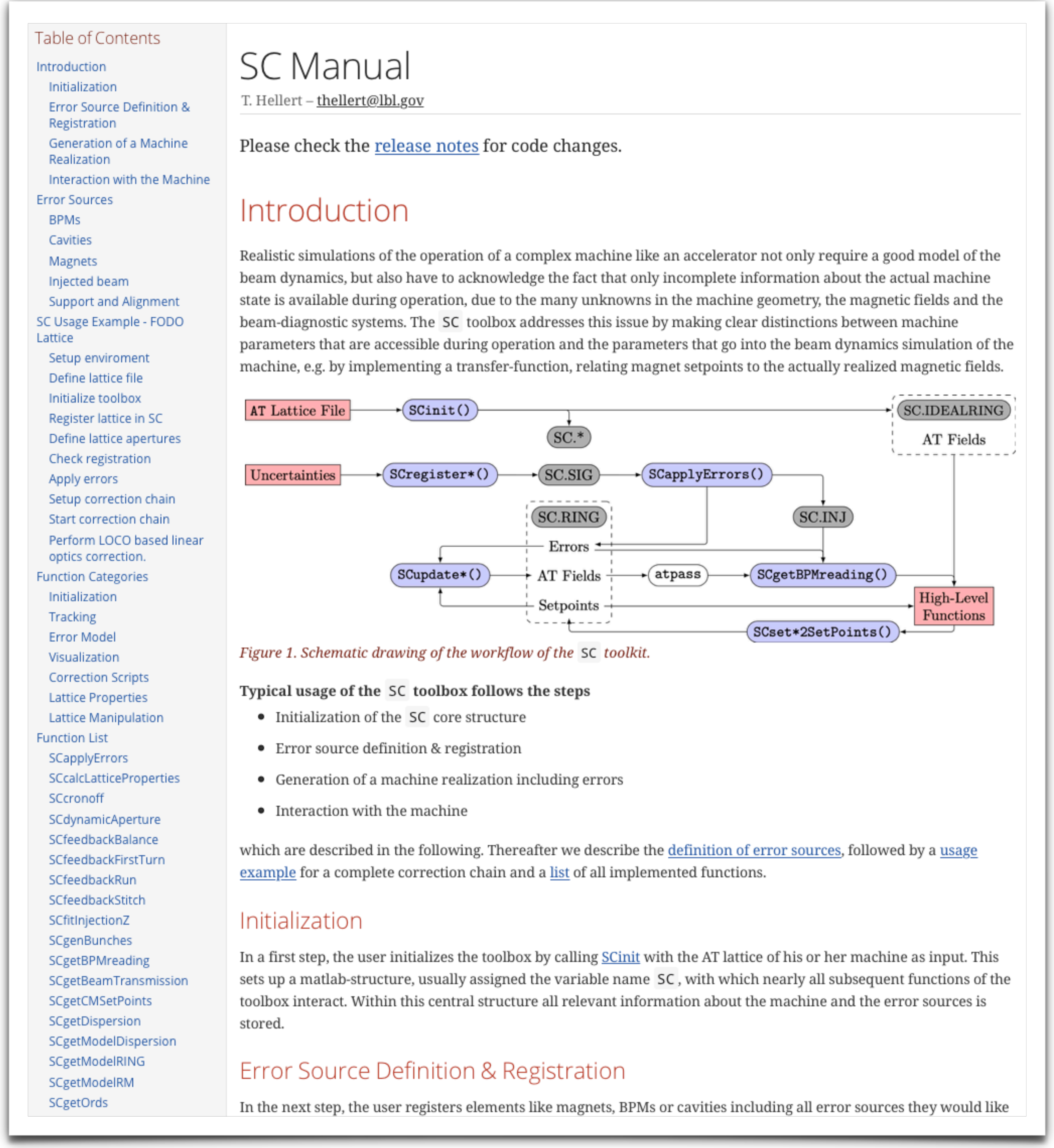
Comprehensive Source Code Documentation



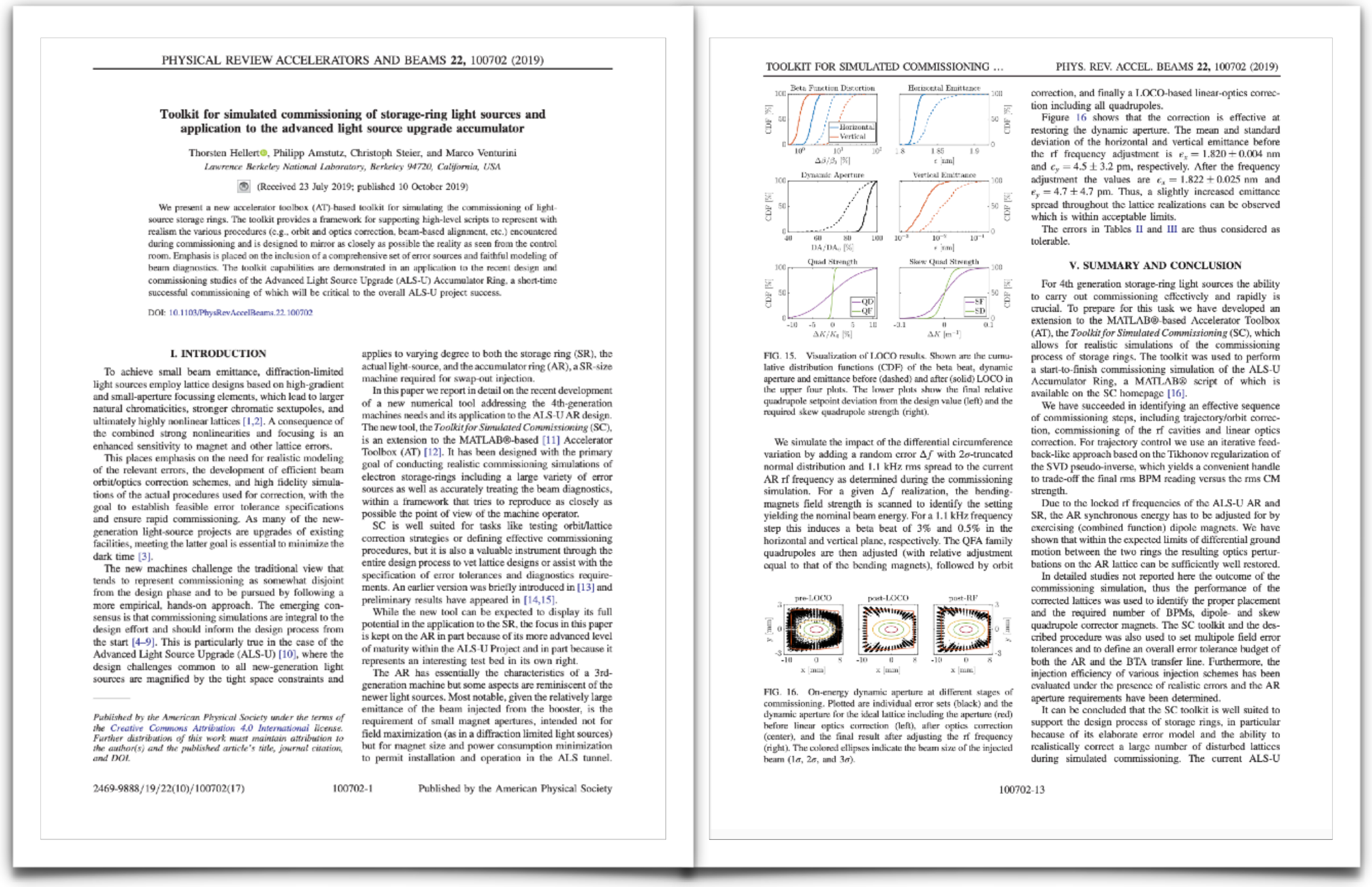
Extensive Code Comments

```
% 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{id

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

    % Set dipole setpoint accordingly.
    [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);
```

Online Manual



Full ALS-U Examples (PRAB 22/100702)



Version Control

git

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

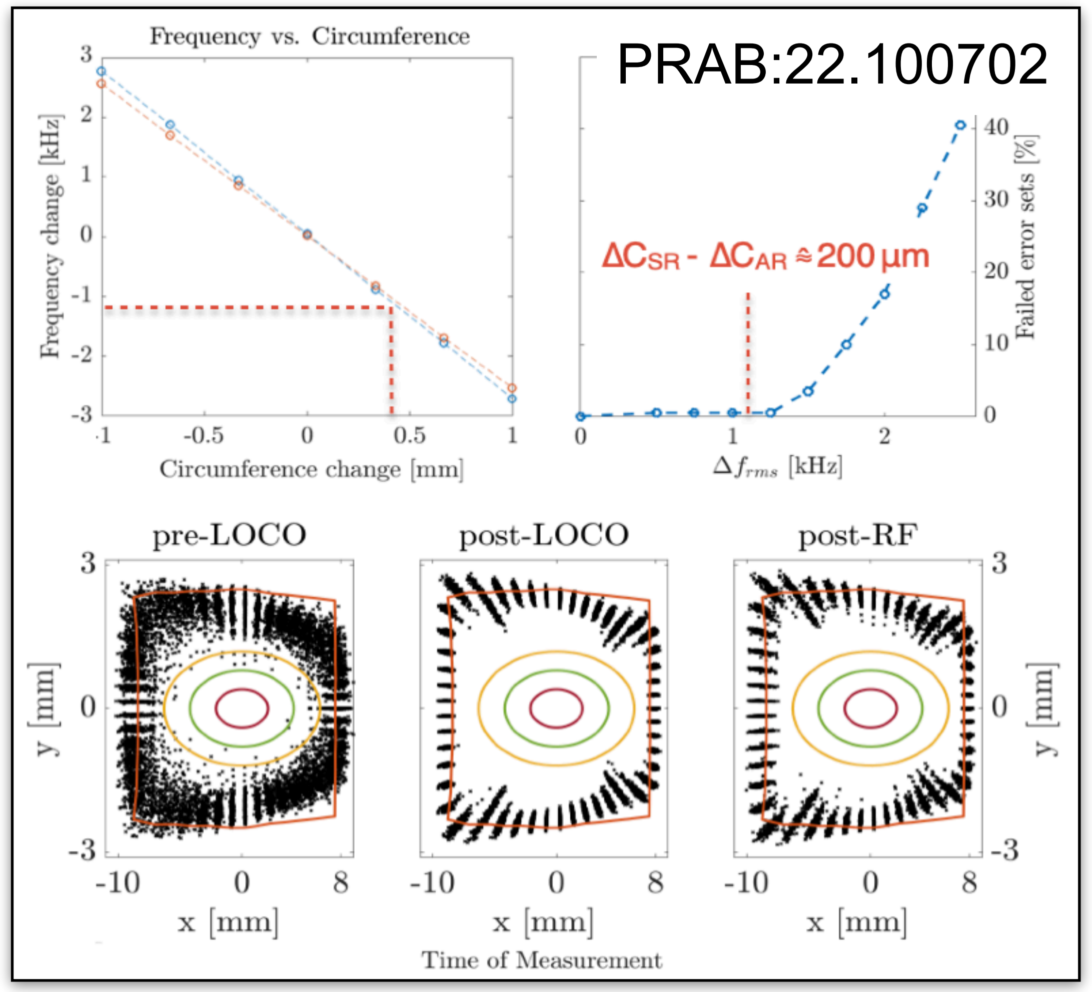
..	
IDLibrary	Custom ID pass metho
Multipoles	Initial commit: ALS-U S
Studies	Adjusted injection sce
lattices	Added CM calibration
calcLatticeProperties_ALSU_SR.m	Initial commit: ALS-U S
crawlClusterJob.m	Initial commit: ALS-U S
getBPM2QuadPairing_ALSU_SR.m	Initial commit: ALS-U S
locoTH.m	Initial commit: ALS-U S
locoresponsematrixFull.m	Initial commit: ALS-U S

Annotated Scripts

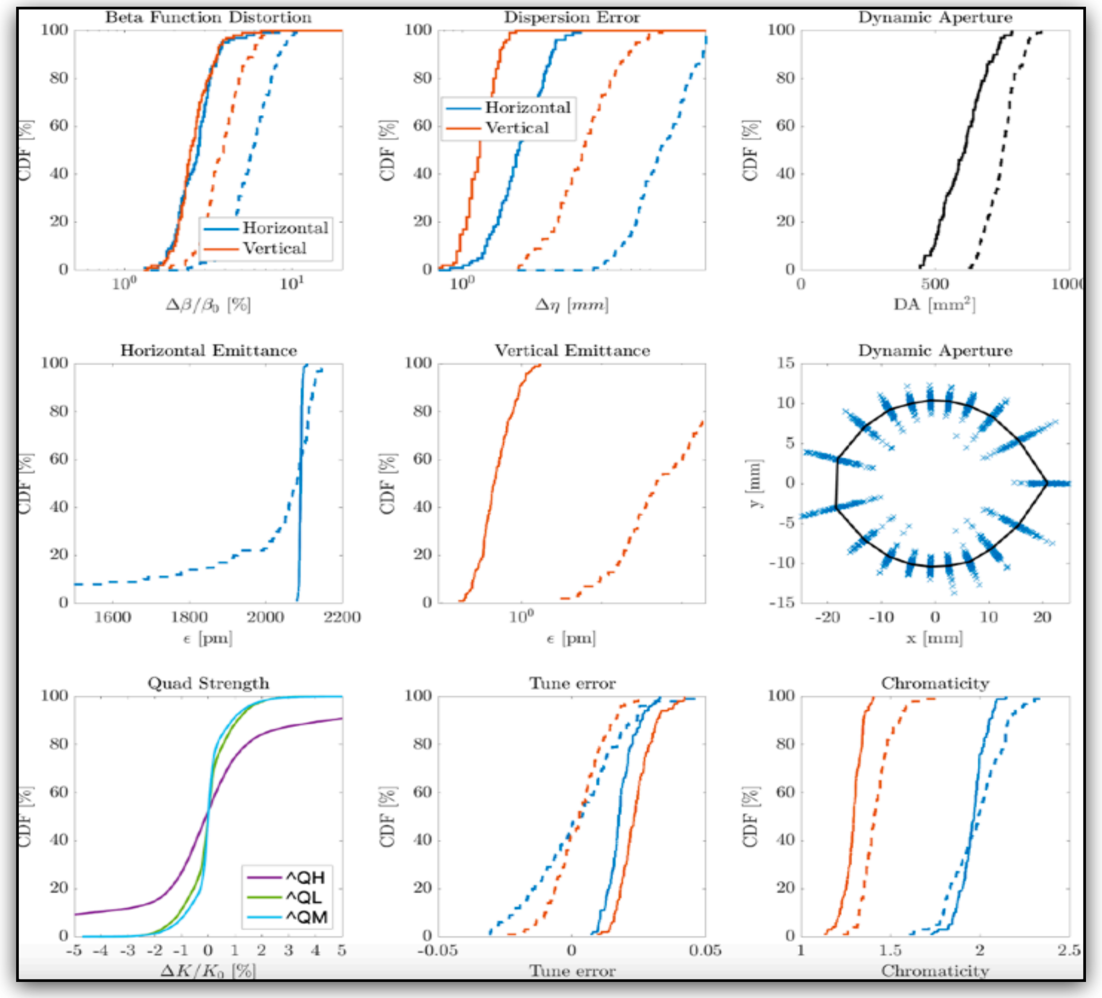
```
% Initialize toolkit
SC = SCinit(RING);

% Register ALSU-SR
[SC,BPMords,CMords] = register_ALSU_SR(SC);
% Save ideal SC state for ID compensation calculat
results.SCrefID = SC;
% Save BPM and CM ords used in orbit correction
results.BPMords = BPMords;
results.CMords  = CMords;

% Define apertures
SC.RING = setApertures_ALSU_SR(SC.RING);
```

Toolkit Used for Guiding Design Process at Various Laboratories

ALS-U (*T. Hellert*)



NSLS-II (*A. Khan*)



Diamond-II (*D. Amorin*)

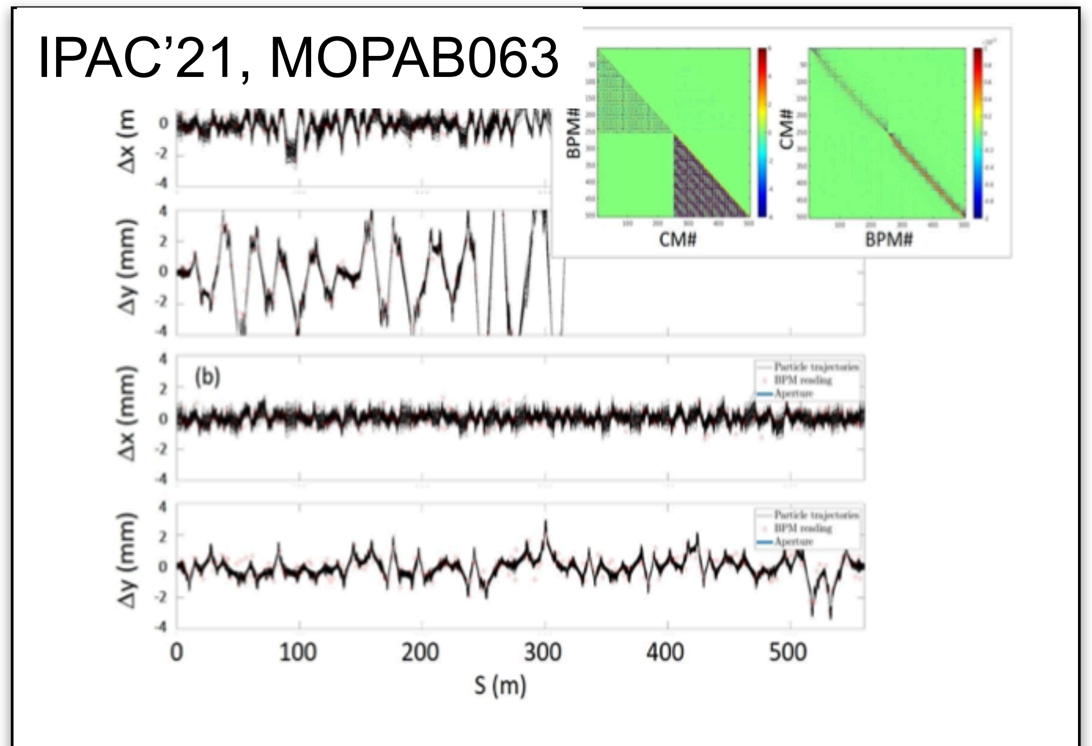
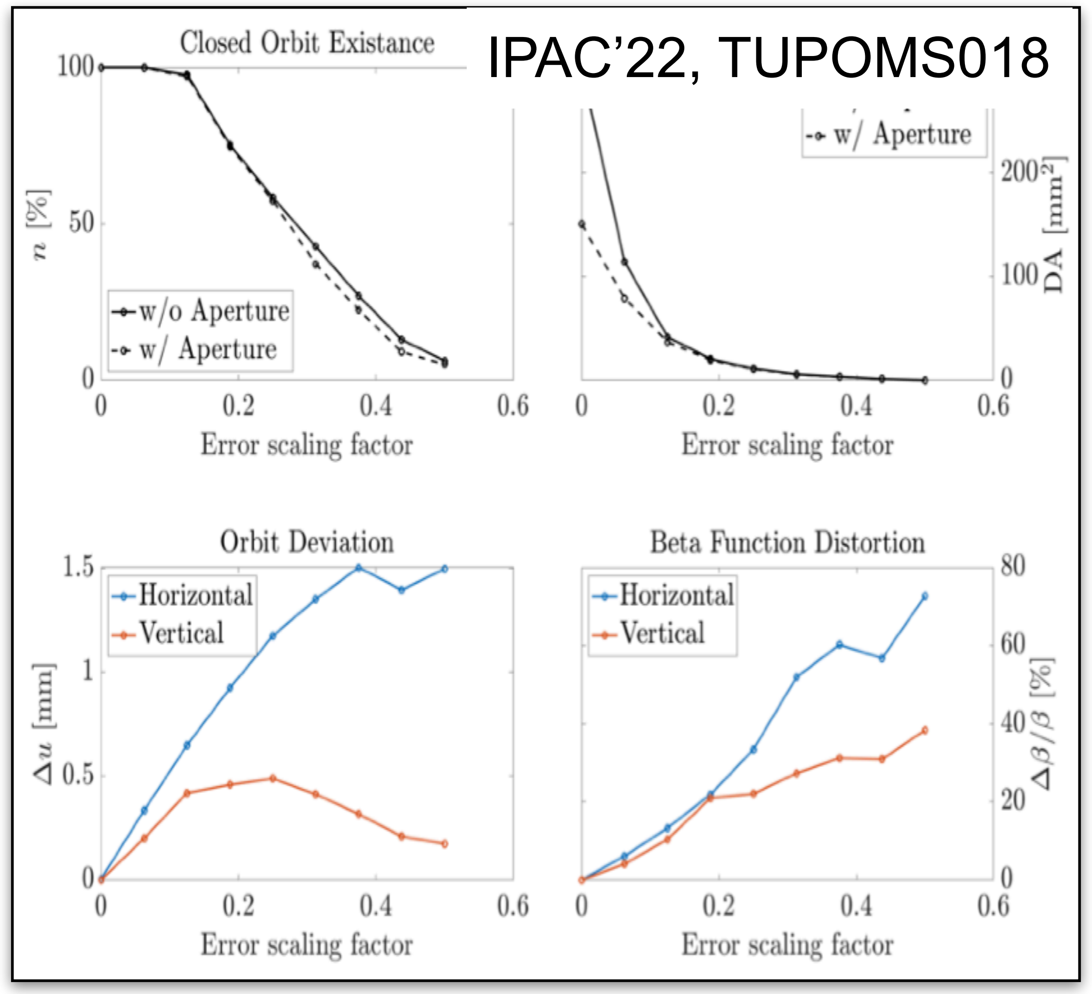


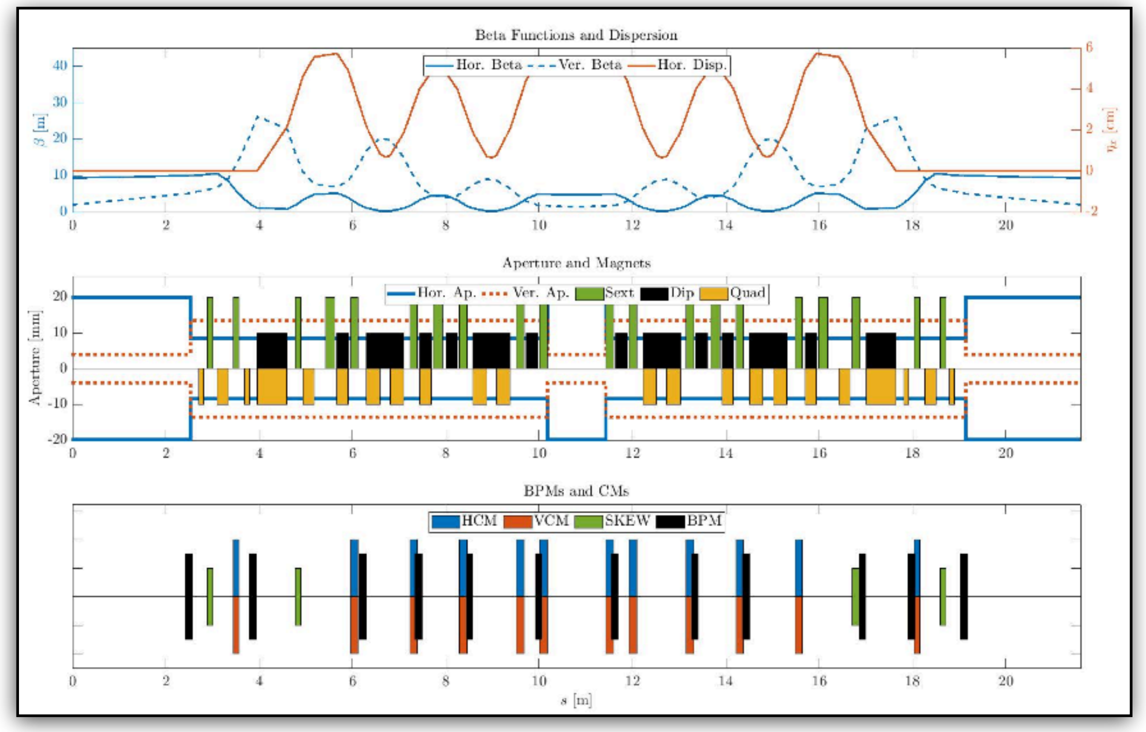
Figure 3: First turn threading in the Diamond-II SR. (Top) initial attempt with total loss of the beam, (bottom) 1st turn transmission completed with beam ready for a 2-turn threading. Inset: 1-turn RM and its pseudo-inverse.

PETRA IV (*T. Hellert*)

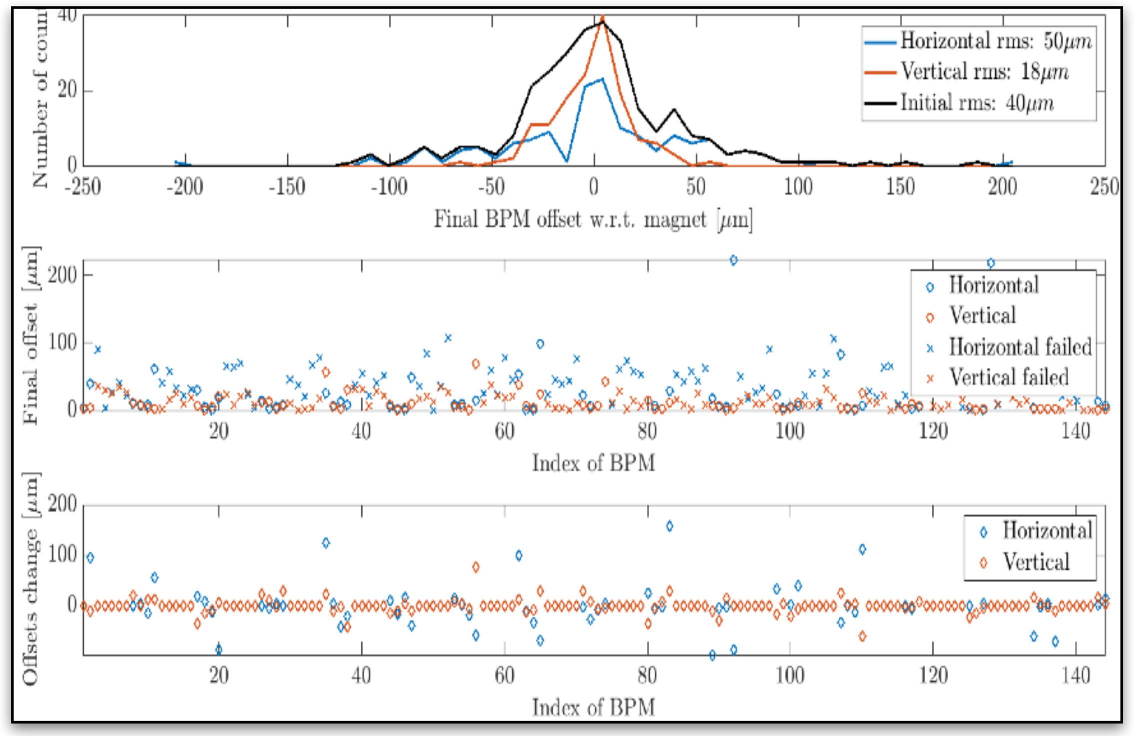


BESSY III (*P. Goslawski*)

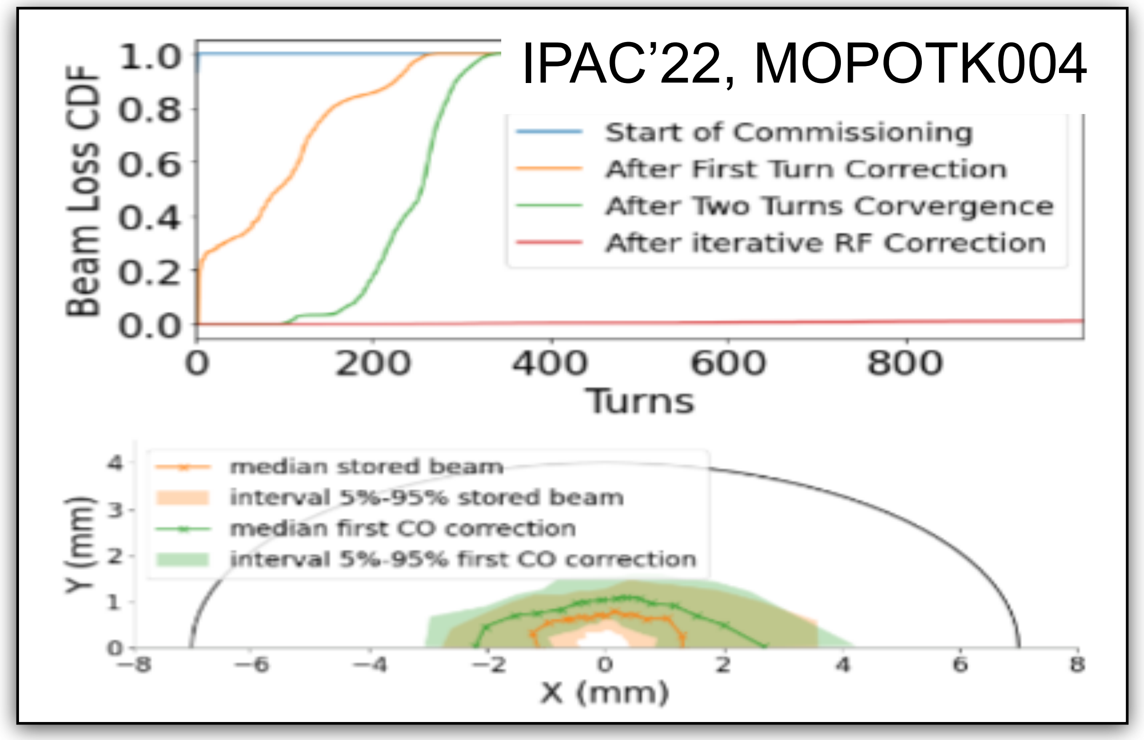
Elettra 2.0 (*S. Dastan*)



ALBA-II (*Z. Marti Diaz*)

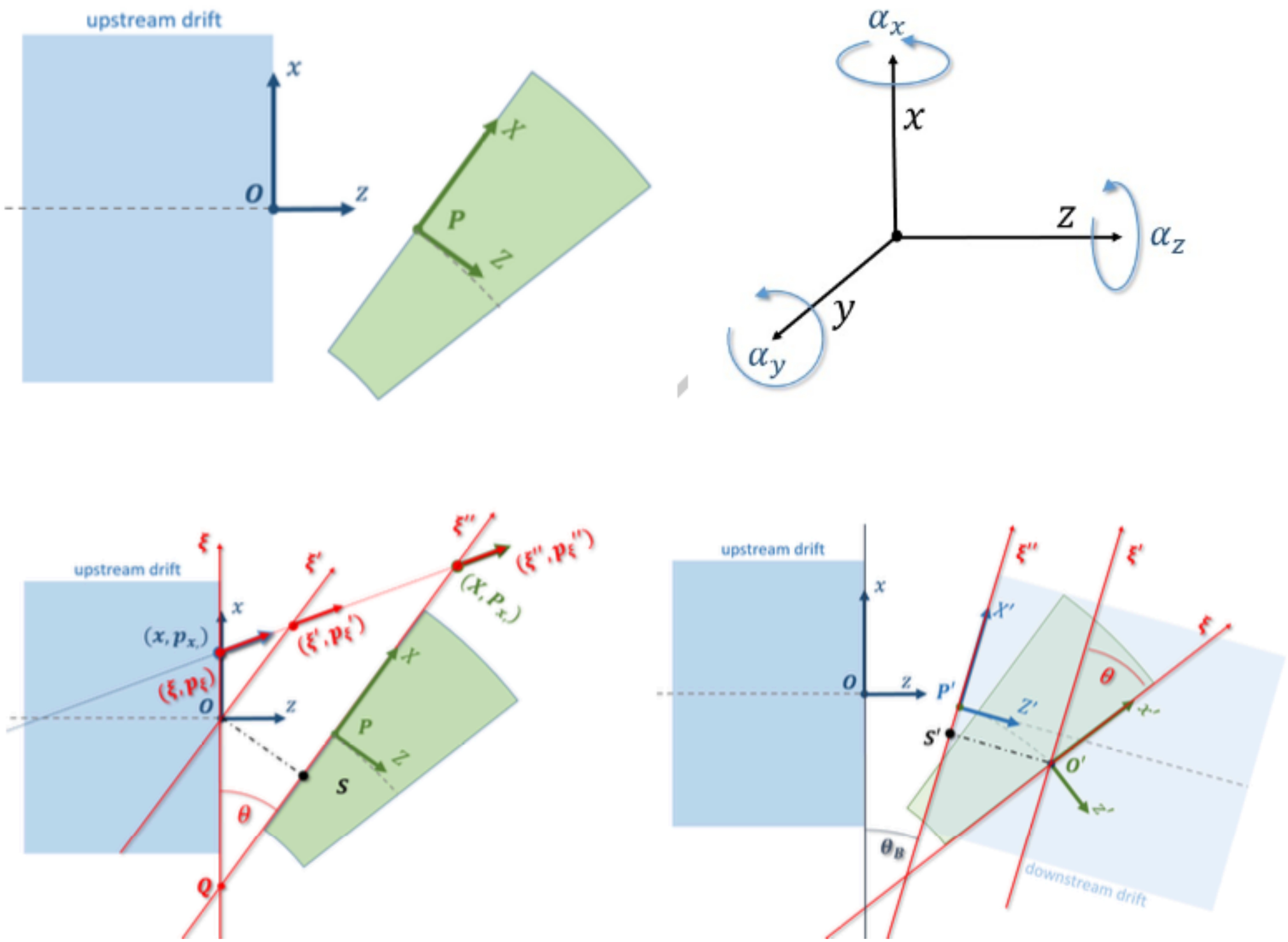


SOLEIL Upgrade (*O. Garcia*)

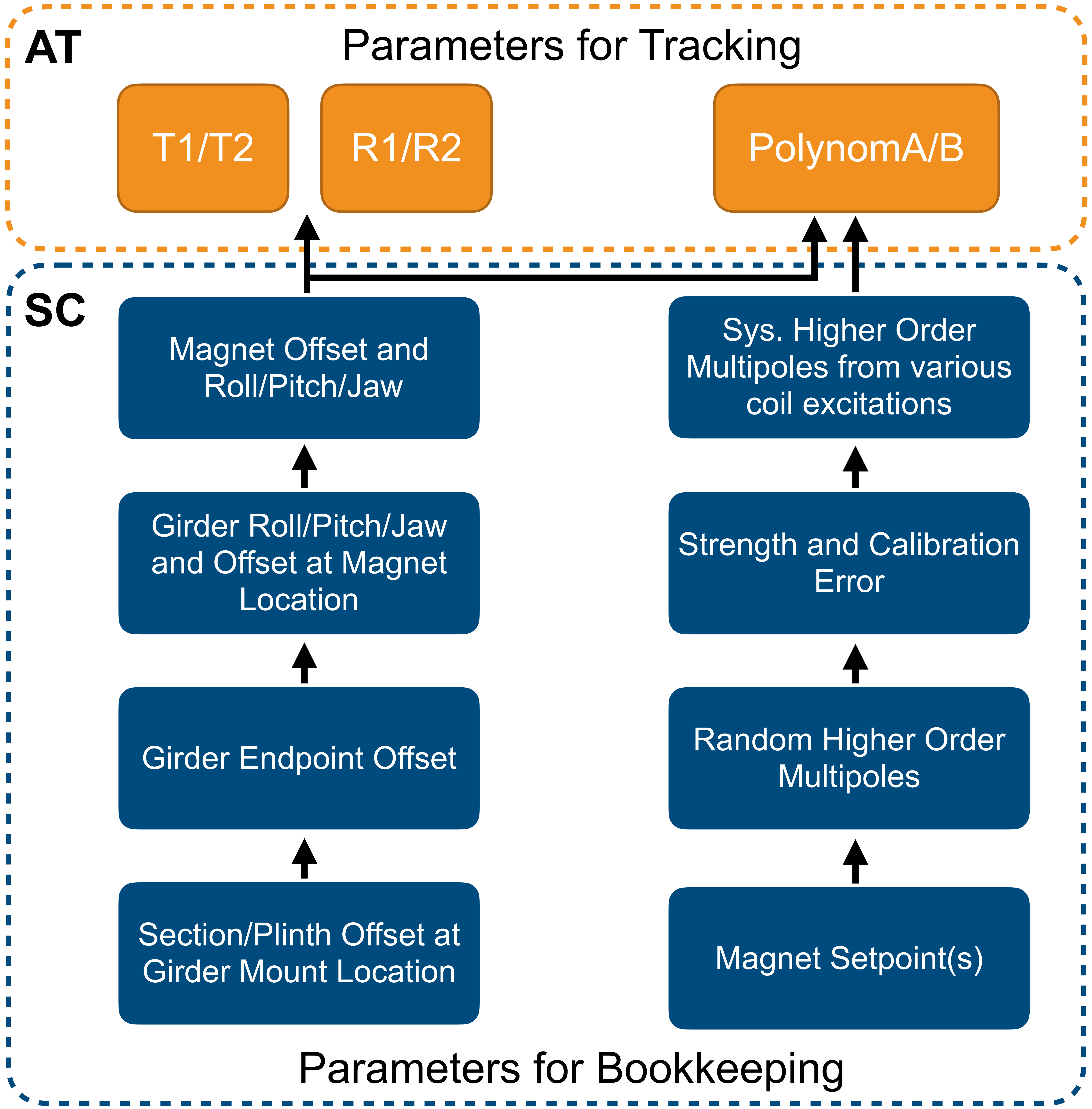


https://sc.lbl.gov

SC -> ELEGANT Corrected Lattice Converter

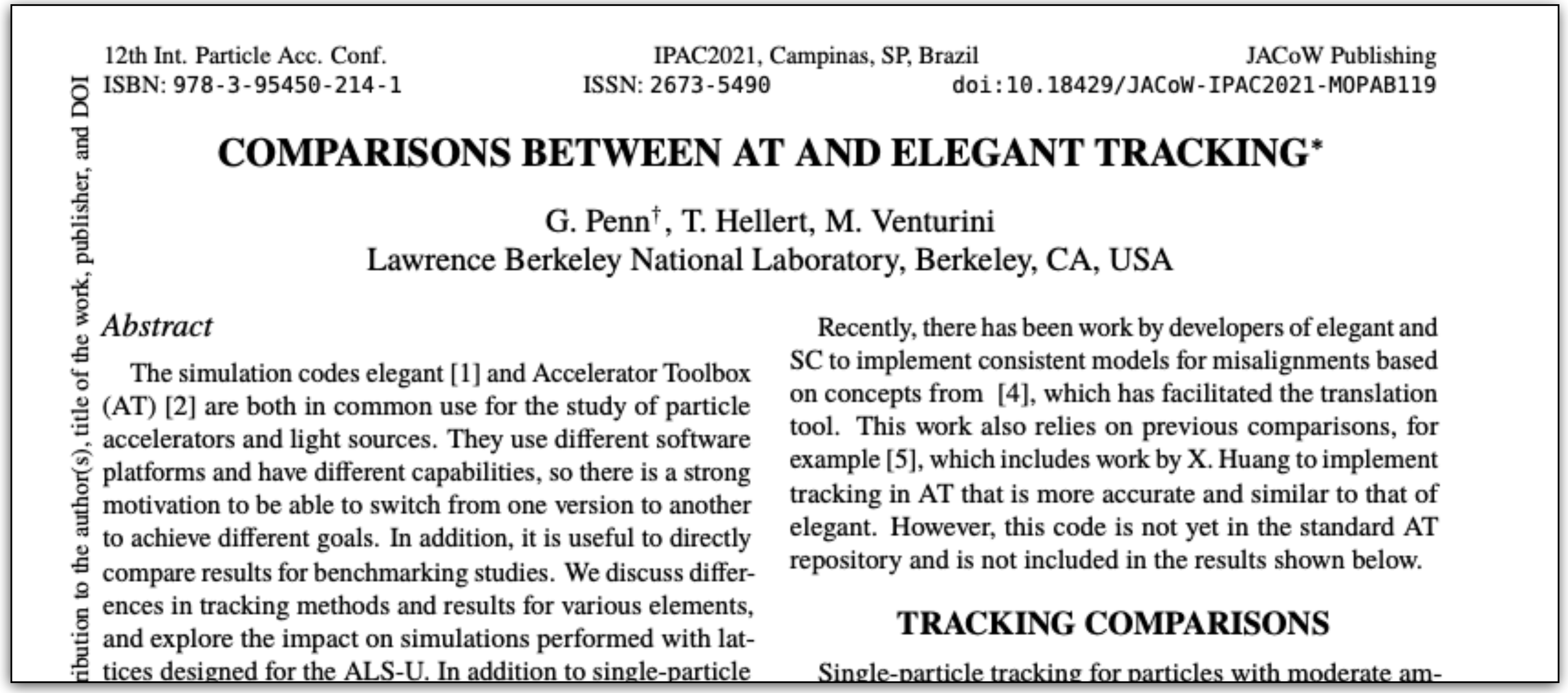


M. Venturini et al., 'Particle dynamics and misaligned lattice elements', ALS-U Tech-Note



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. IPAC2021, Campinas, SP, Brazil JACoW Publishing
ISBN: 978-3-95450-214-1 ISSN: 2673-5490 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