Swiss Accelerator Research and Technology

A multicode comparison

First steps towards a collaborative software framework for the FCC-ee simulations

Félix Carlier

On behalf of the collaboration:

M. Benedikt, R. Bruce, X. Buffat, R. De Maria, A. Faus-Golfe, W. Herr, G. Iadarola, K. Oide, T. Pieloni, F. Schmidt, D. Schulte, M. Seidel, R. Tomas, S. White, F. Zimmermann

Overview

1. Introduction to project
2. Initial results for optics codes
3. New functionalities
4. Lattice manager
5. Outlook

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Introduction to project

Swiss Accelerator Research and Technology

The FCC-ee requires simulations that can no longer be provided by single codes.

CHART funded project to develop a modern and maintainable simulation framework to address the key FCC-ee challenges.

Overview of project and goals (T. Pieloni):

https://indico.cern.ch/event/923801/

https://indico.cern.ch/event/1018475/

Project started in December 2020 with initial review of optics, tracking, and beam-beam codes (F. Carlier):

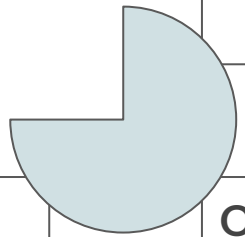
https://indico.cern.ch/event/1018475/

This talk will summarize initial results and progress, and provide short term outlook.

Three main areas of study for the project

Team will grow as project advances.

- New topics such as collimation, and spin dynamics, are foreseen in the future.



Code benchmarking and lattice management tools for FCC-ee

Develop comprehensive lattice manager connecting multiple optics codes, enabling benchmarking of codes for the FCC-ee.

- Current focus

Beam-beam modeling for FCC-ee

Develop tools for BB with detailed lattice descriptions, and self-consistent optics

https://indico.cern.ch/event/1022415/

- Recently started

Optics and tracking models for FCC-ee

Treat 6D symplectic beam dynamics, adding synchrotron radiation, and realistic modeling of insertion region optics.

https://indico.cern.ch/event/1022415/

- Starting in October

Exploring other codes creates new possibilities for FCC-ee simulations

There is no do-it-all code at the moment. Enabling a larger field of optics codes creates opportunities for new types of FCC-ee simulations.

Large effort at CERN to benchmark these two codes
(L. van Riesen-Haupt, T. Persson, K. Oide)

Exploration of other codes opens up new functionalities
(S. White, M. Rakic, D. Sagan, F. Carlier)

MAD-X

Prefered tool at CERN for accelerator design

- Powerful lattice descriptions
- Large community
- PTC connection

SAD

Currently the code of choice to create the FCC-ee lattice

- Expertise in KEK

Bmad

Accelerator simulation library

- Spin tracking
- Photon tracking
- Large library of functionalities
- PTC connection

pyAT

Python simulation framework

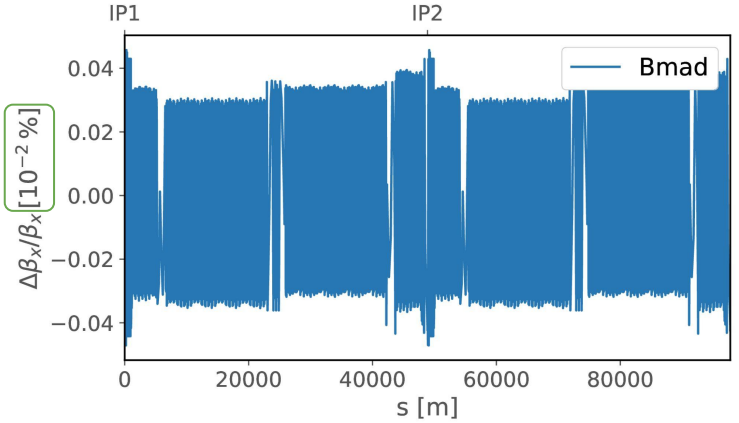
- Lightsource tools
- Fast development
- Interfaceable with ML tools

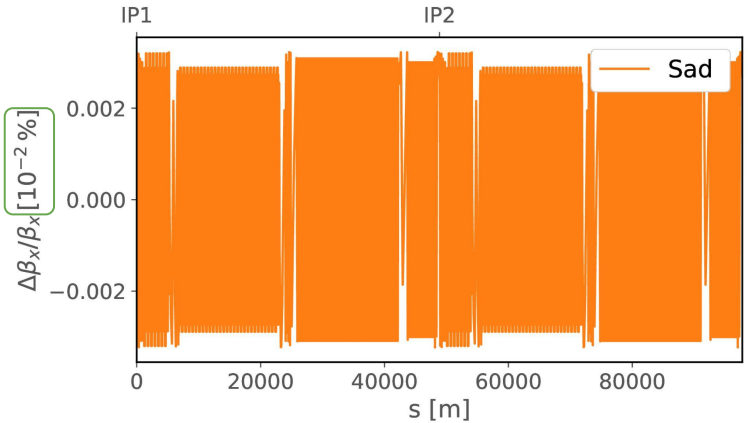
Optics variations compared to MAD-X

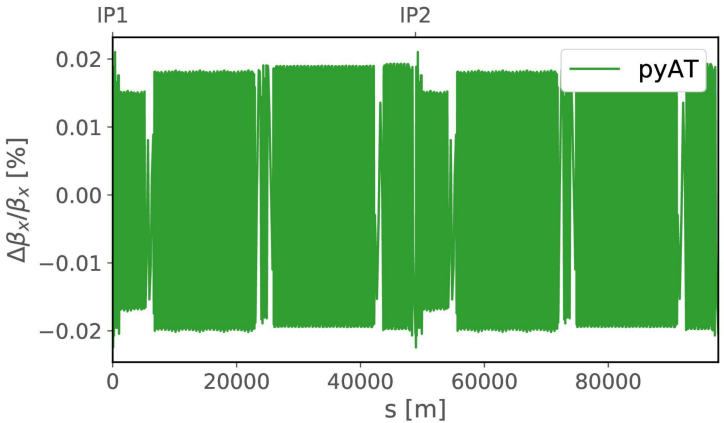
Results for Higgs physics '217' lattice without radiation

Excellent agreement between SAD, Bmad and pyAT

- Larger discrepancy with pyAT. Perhaps:
  - Fringe fields, nr. of slices? Under study.







Tapering was developed for Bmad and pyAT

Tapering schemes adjust magnetic strengths of elements to compensate for energy loss due to synchrotron radiation.

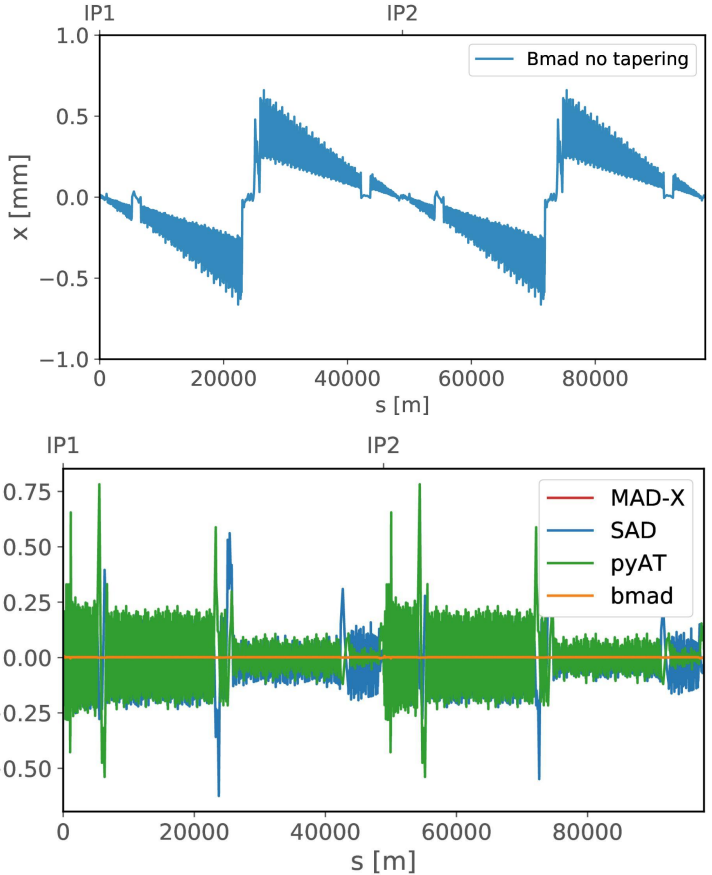
Some results already presented:

- SAD comparison (L. van Riesen-Haupt) https://indico.cern.ch/event/923801/
- Bmad (F. Carlier) https://indico.cern.ch/event/1018475/
- pyAT (S. White, M. Rakic, F. Carlier) https://indico.cern.ch/event/1018475/

Good 'ideal tapering' schemes now available for MAD-X, SAD, Bmad, and pyAT

- Very similar orbits after tapering in pyAT and SAD
- Bmad orbit after tapering now at nm level

MAD-X tapered orbit is practically zero (element-by-element)

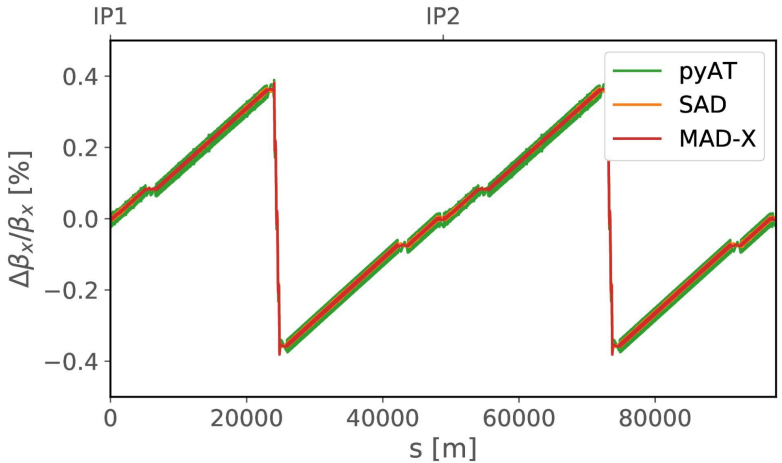


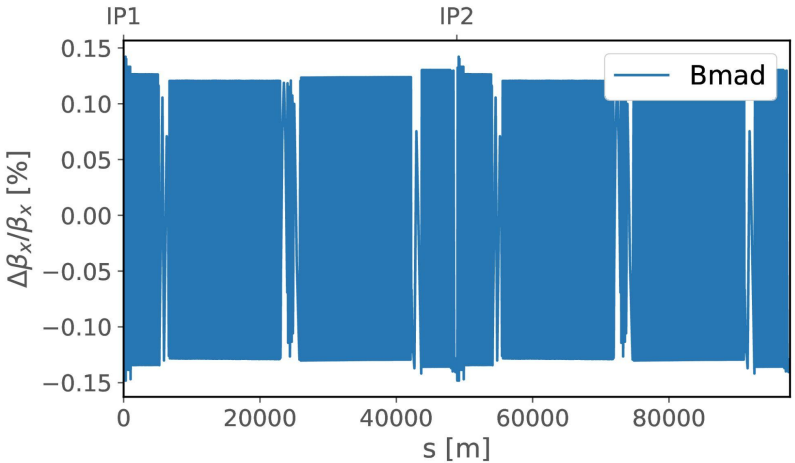
Optics after tapering compared to MAD-X reference without tapering

Results for Higgs physics '217' lattice with rad. & tapering

In general good agreement between the different tapering schemes

- Bmad already takes into account the energy loss during optics calculations -> Flat deviation

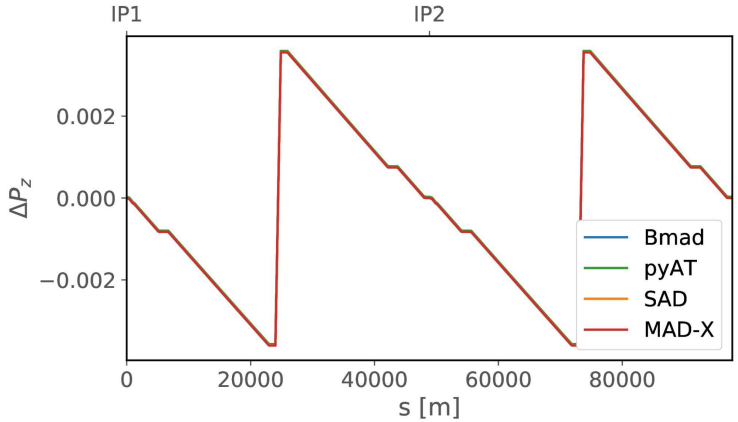


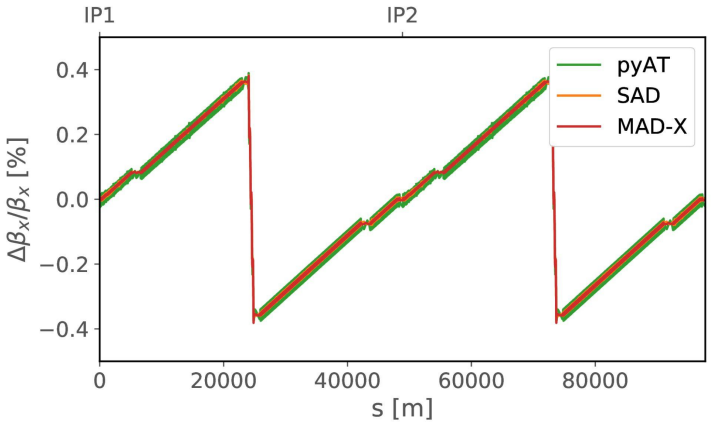


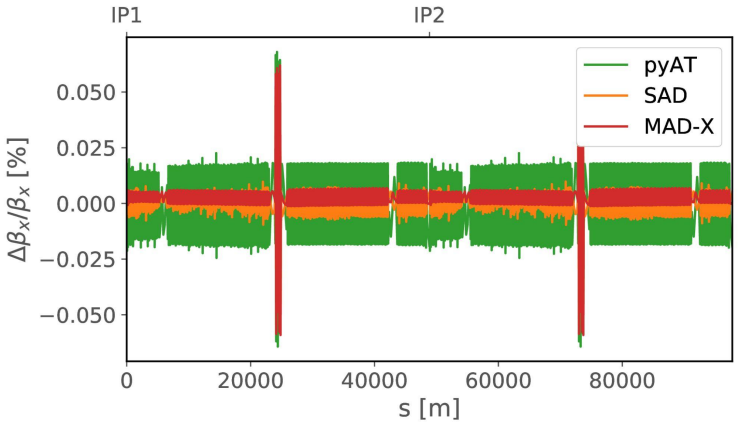
Compensating optics functions for energy loss yields flat optics deviations

Results show that optics calculation results of Bmad vs. MAD-X/SAD/pyAT are equivalent when energy loss is taken into account.

- Energy losses from synchrotron radiation the optics codes are equivalent







New functionalities available for FCC-ee spark new studies

Bmad:

- Among many Bmad features, spin tracking is the most interesting:
  - EPFL Master project starting in July on exploration of spin tracking for FCC-ee (EPFL)

pyAT:

- Exploration of pyAT for collimation studies (A. Abramov)
  - https://indico.cern.ch/event/1042425/
  - https://indico.cern.ch/event/995850/
- Study of simplified tapering schemes to reduce number of power supplies (M. Rakic)
  - https://indico.cern.ch/event/1022018/
- Low threshold Python simulation code now available for FCC-ee community.
  - Access to TensorFlow, Keras, Scikit-learn, as well as plotting libraries

First step towards simulation framework: Lattice manager

Many different conversion scripts and programs can lead to loss of information!

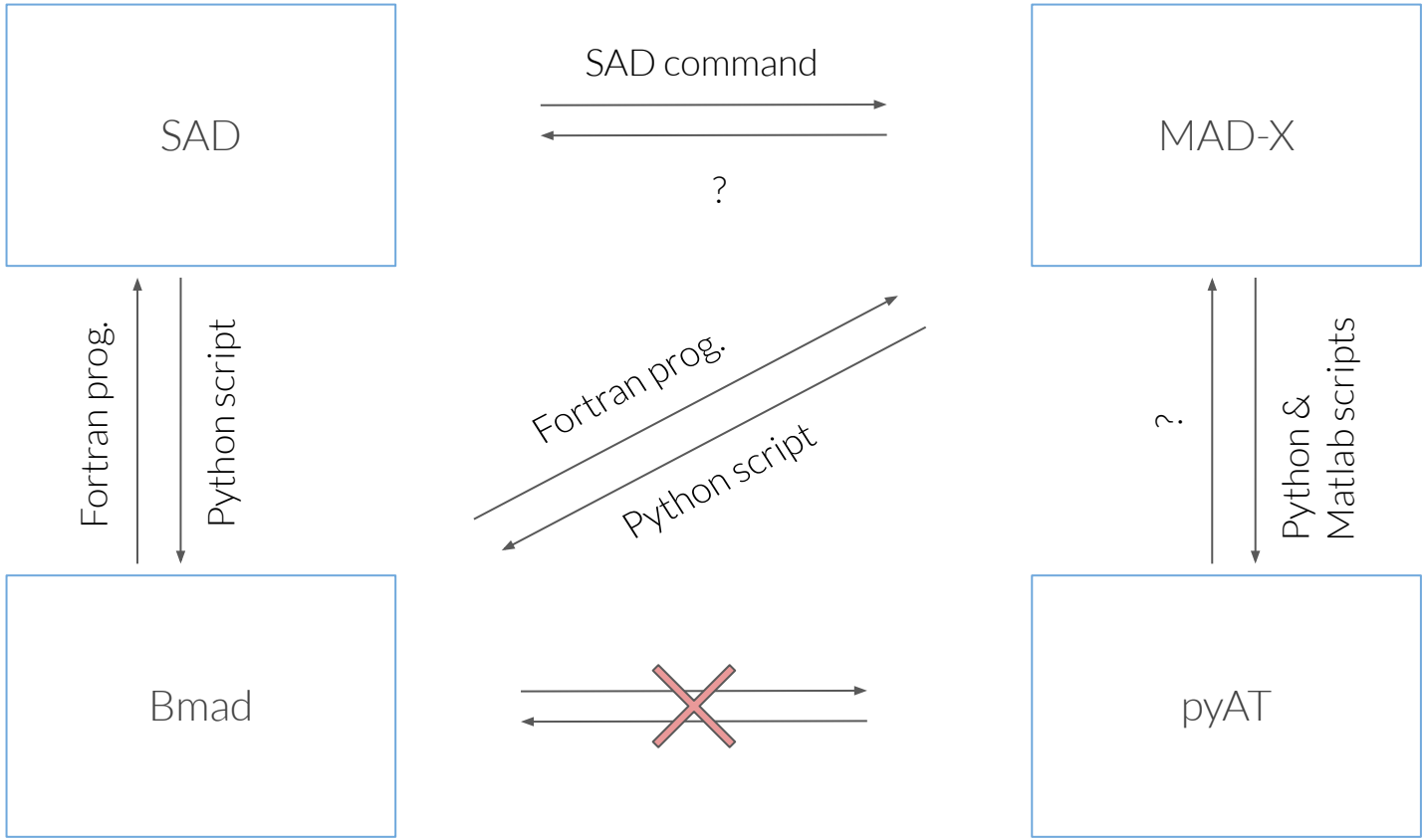
Goal is **to create a centralized Python representation of the FCC-ee sequence and the state of the lattice**.

- This will allow efficient conversions between codes as first step towards merging functionalities (i.e. optics, beam-beam, tracking, spin dynamics, ..)
- Allows controlled benchmarking between codes
- Start with MAD-X, SAD, Bmad, pyAT and later expand if needed.

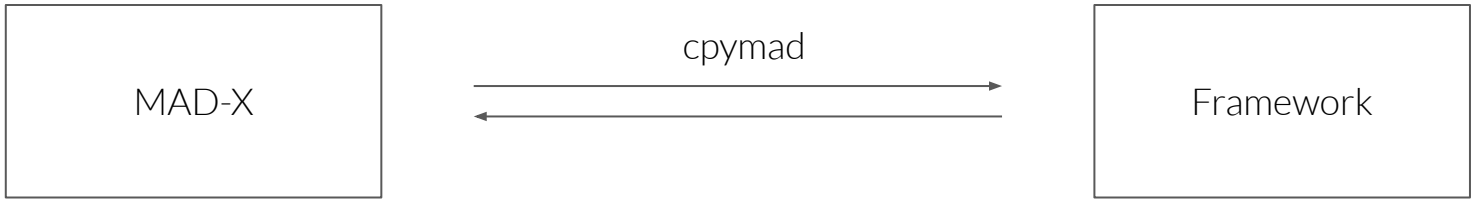
Synergetic with efforts to:

- modernize optics repository (G. Roy) https://indico.cern.ch/event/1014448/
- develop new tracking tools (R. de Maria, G. Iadarola) https://github.com/xsuite

Current lattice conversions



Simulation framework: Lattice manager

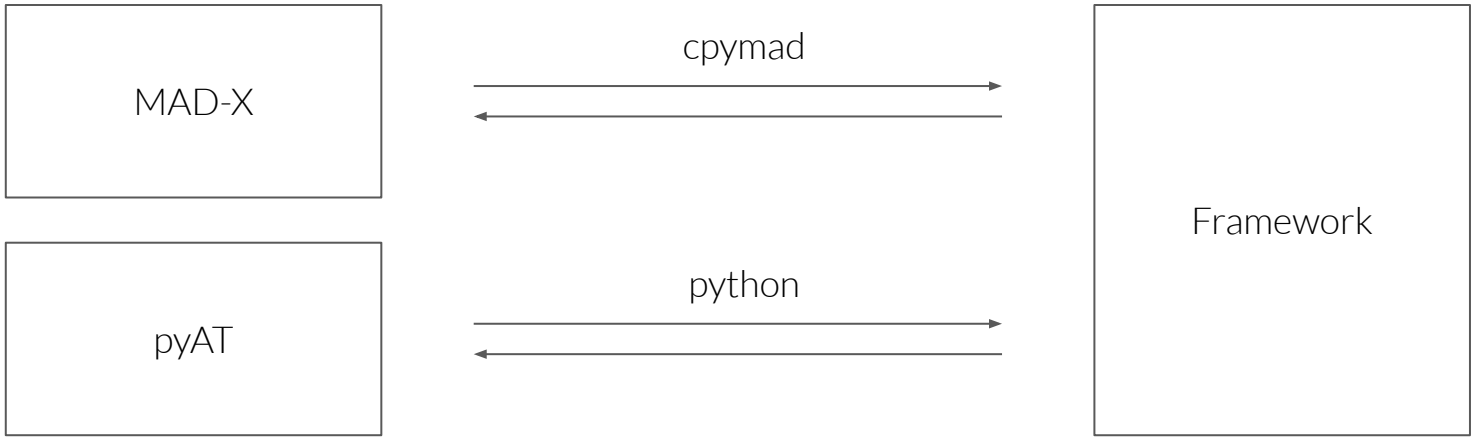


Interfacing through cpymad allows import and export of MAD-X lattices.

- No loss of precision after import + export
- Currently loss of circuit dependencies

  (to be addressed this summer together with R. de Maria)

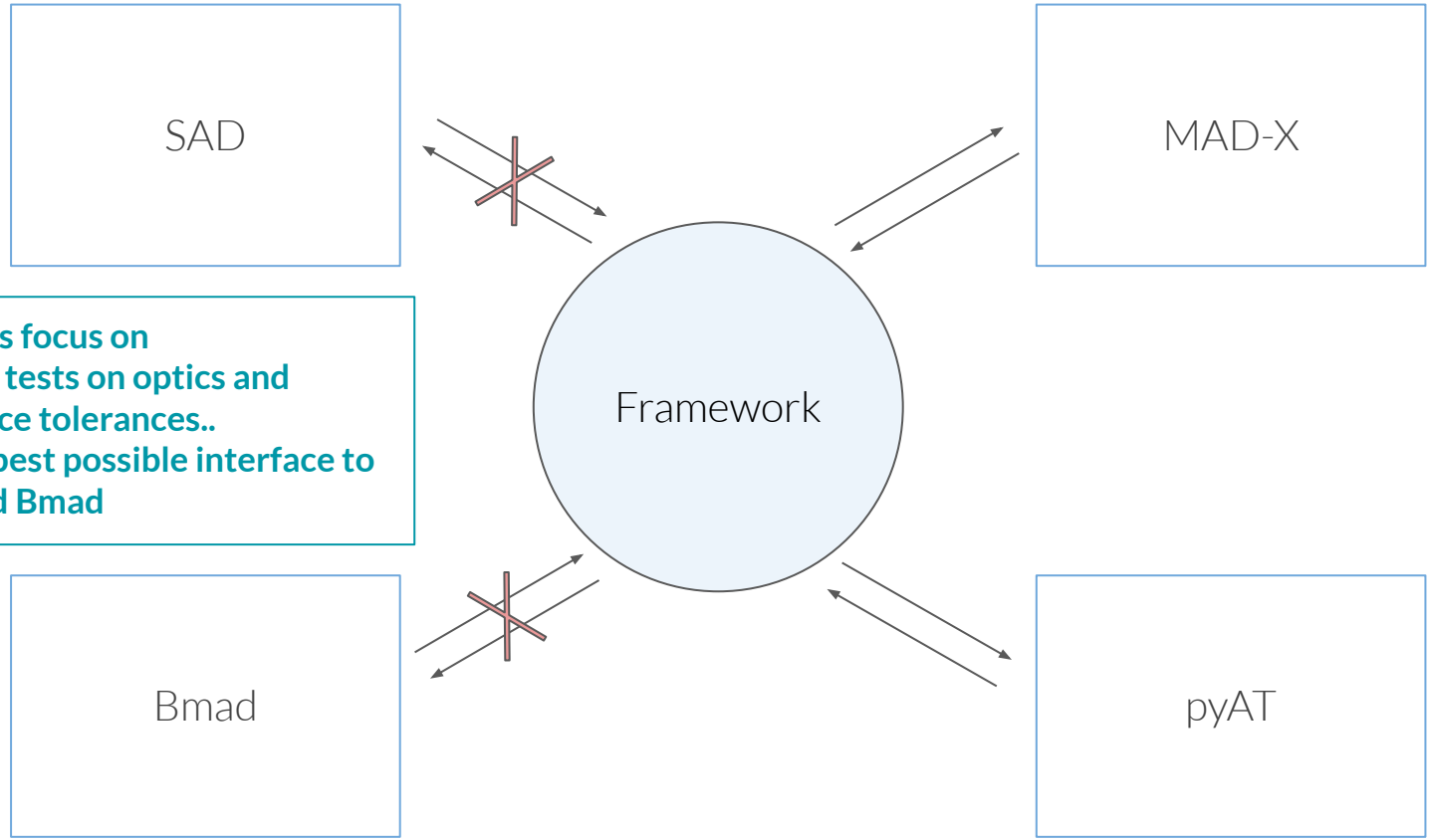
Simulation framework: Lattice manager



Interface through Python is simple.

- Presented results obtained with this approach
- Custom slicing and PassMethod specifications still needed

Lattice manager conversions



Current efforts focus on

1. **develop tests on optics and emittance tolerances..**
2. **finding best possible interface to SAD and Bmad**

Conclusions

1. The CHART funded project for a new simulation framework for the FCC-ee has started and is picking up pace with addition of new students.
2. New functionalities are now available for the FCC-ee with addition of Bmad and pyAT, and are sparking new studies.
3. First results of lattice manager show more efficient lattice conversions between MAD-X and pyAT.

Outlook

1. Integrate SAD and Bmad to framework for efficient lattice conversions.
2. Include basic optics calculations through framework as first step towards framework based simulations.
3. Explore circuits and knobs descriptions in Python for advanced lattice options (together with R. de Maria).
4. Studies on beam-beam modeling started recently and will pick up pace.
5. Master student on spin dynamics in FCC-ee using Bmad starting in July.