Code Development Status

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WORK SUPPORTED BY THE SWISS ACCELERATOR RESEARCH AND TECHNOLOGY (CHART)

Introduction

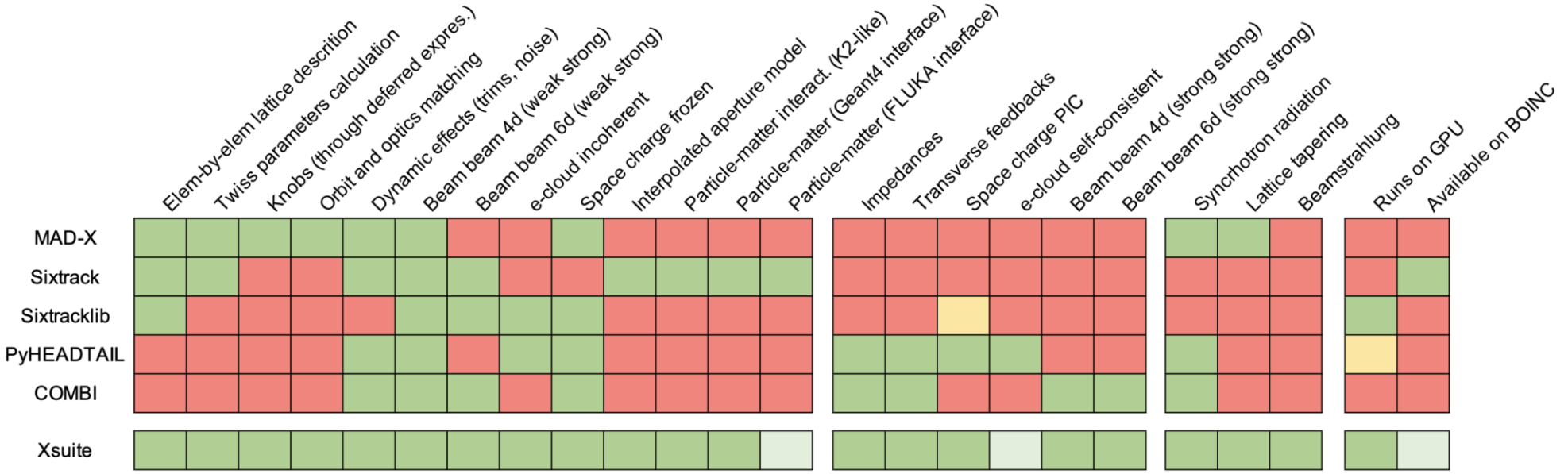
- Large **number of tools** used in FCC study
  - Often **specialised** to one purpose/aspect of beam physics
  - Sometimes tools with **overlapping purpose** used, depending on the **user's expertise**
- Vast and very active community in the **CERN ABP Computing Working Group**
  - Maintenance, improvement, complement **existing codes**
  - **Development** of modern, robust and broad tools for the **entire accelerator community**
- **Large community** outside of FCC and CERN with overlapping interests
  - **Potential for synergies** and **cooperation**

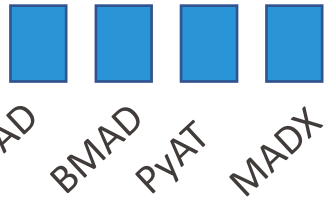
FCC Software Framework Project

- **Understand requirements** for the development and simulation of FCC
  - **Which effects** need to simulated and which **tools exist** or **need to be developed/optimised** for these purposes
  - Identify which simulations need to **interplay/overlap** and understand how they fit together in the **“bigger picture”**
- Ensure that the needs of the FCC study are met by
  1. **Maintaining, benchmarking** and **improving current simulation tools**
  2. Actively contributing to the **development** of **new simulations tools**
  3. Create tools to allow for **interfacing** between different simulation tools
- Work closely with the **ABP Computing WG** and identify synergies and come up with a **common strategy**
- Offer a **first point of contact** for external collaborators that see synergies
- Perform simulations to realistically model FCC using advanced techniques

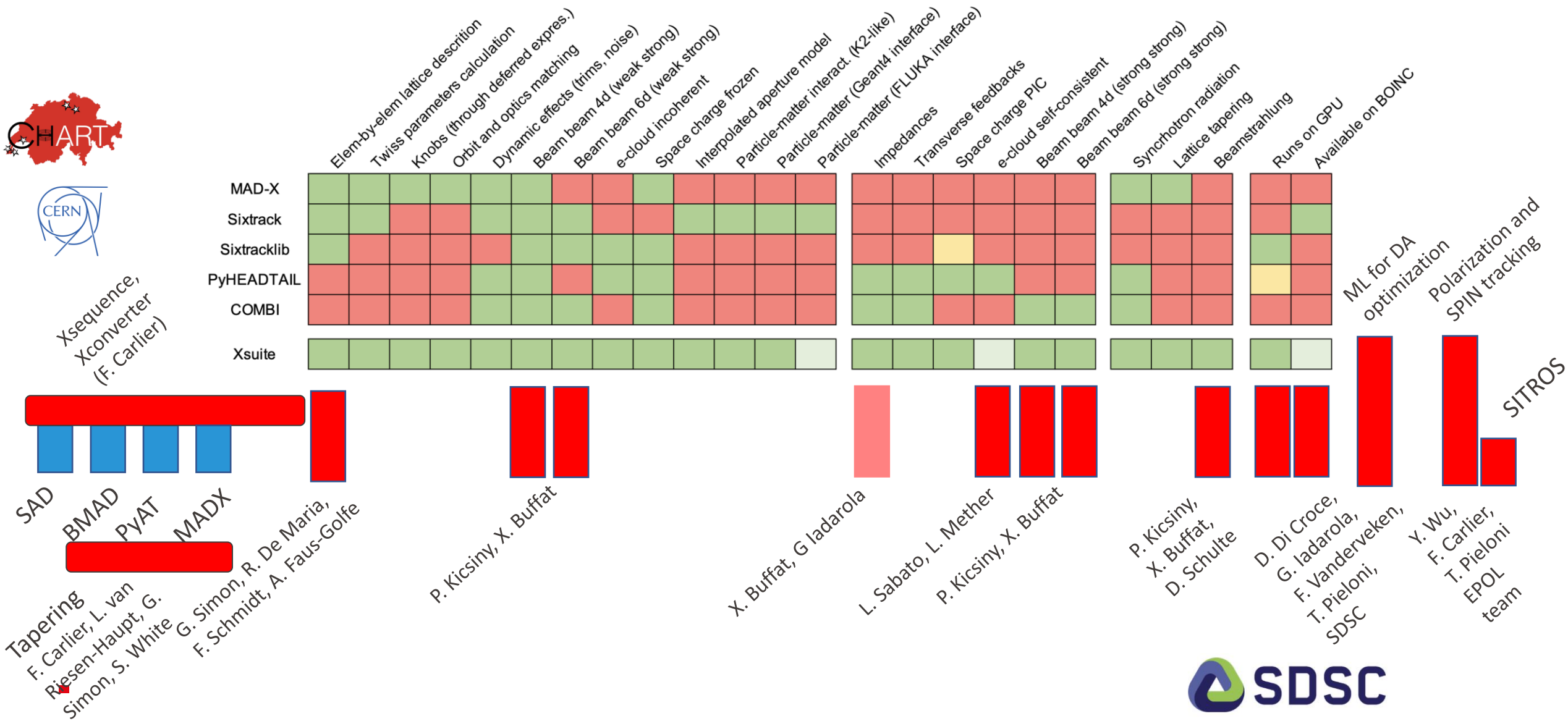
Simulation Tools

Synergies and New Developments





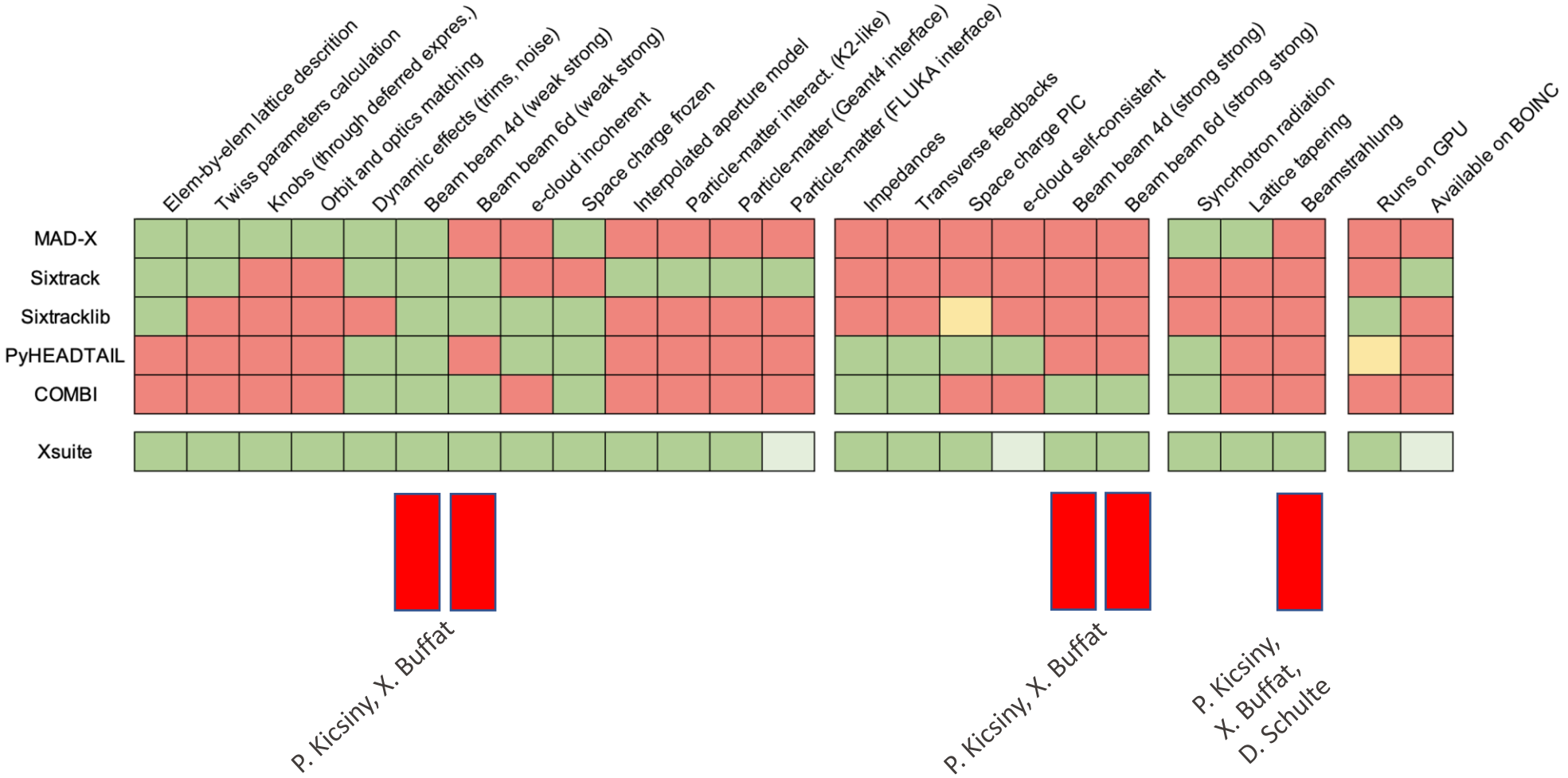
Synergies and New Developments



Software Framework Talks

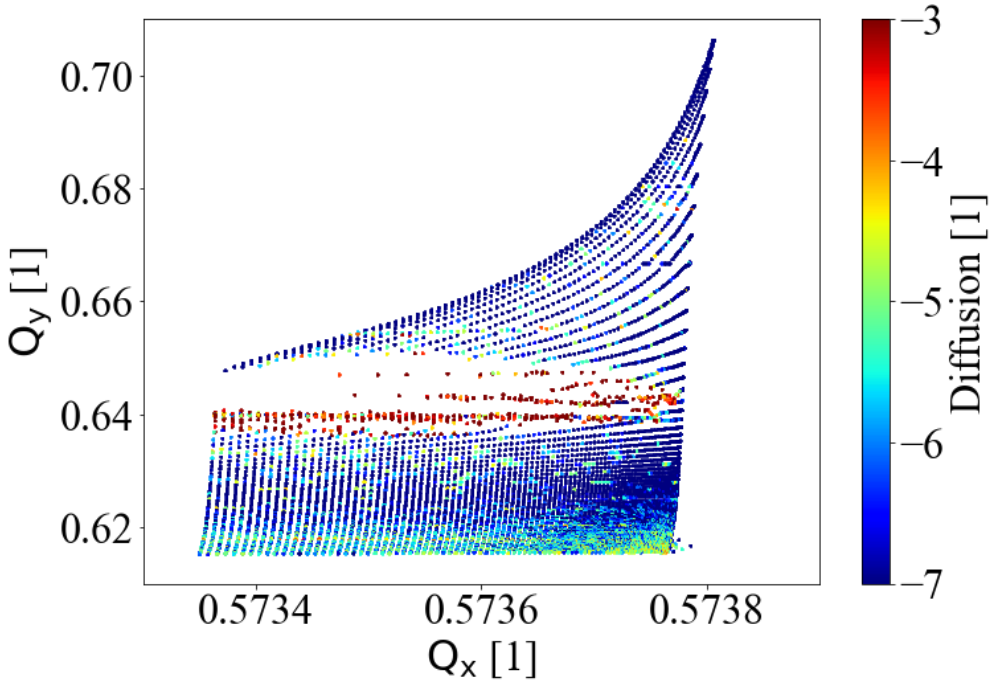
Title	Presenter	Description
Beam-beam Code Progress	Peter Kicsiny	Novel beam-beam, beamstrahlung and bhabha scattering simulation tools for FCC-ee and integration into Xsuite framework.
Review of MAD-X for FCC-ee studies	Guillaume Simon	Accurate simulation of energy loss compensation in arcs (tapering) for MADX optics, tracking and emittance simulation code.
Electron Cloud Studies	Luca Sabato	Improved electron cloud simulations for FCC-ee using pyECLOUD. Integration with other tools. Stability simulations.
Polarisation Studies	Yi Wu	Spin polarisation studies for energy calibration. Simulation of methods to improve polarisation levels.
Accelerating Beam Dynamic Simulations	Davide Di Croce	Speed up dynamic aperture studies for FCC-hh using machine learning and parallelisation

Beam-Beam, Beamstralung, bhabha scattering Code

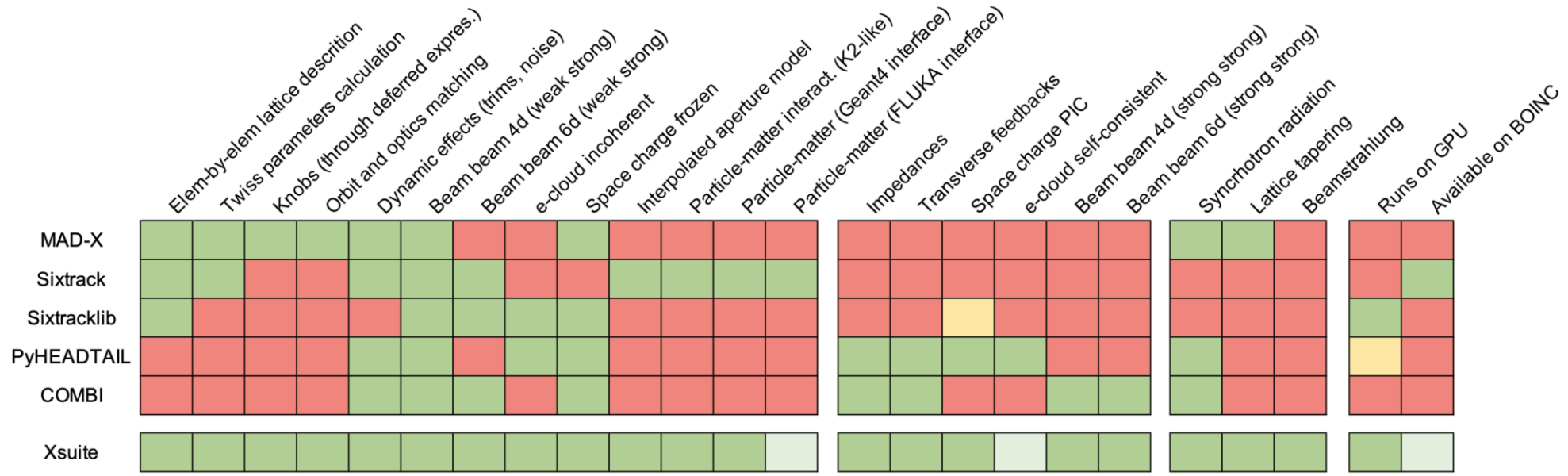


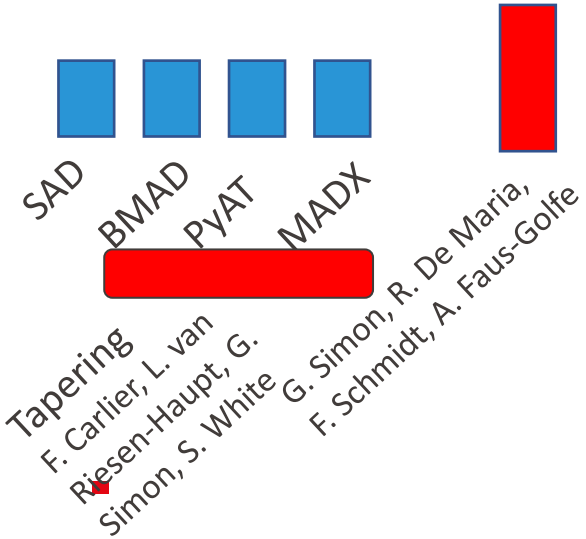
Beam-Beam Code

- Efforts led by **P. Kicsiny**, **X. Buffat, D. Schulte**
- Aim to simulate **beam-beam**, **beamstrahlung**, **bhabha scattering**
- Implement different **beam-beam models** in (WS, QSS, SS)
  - **Benchmarking** against other codes (lifetrac)
  - Make use of modern **technologies** such as **GPUs, open MP**
- Xsuite implementation can be combined with **other effects**
  - E.g. errors, radiation in the arcs, impedance …



MAD-X for FCC-ee



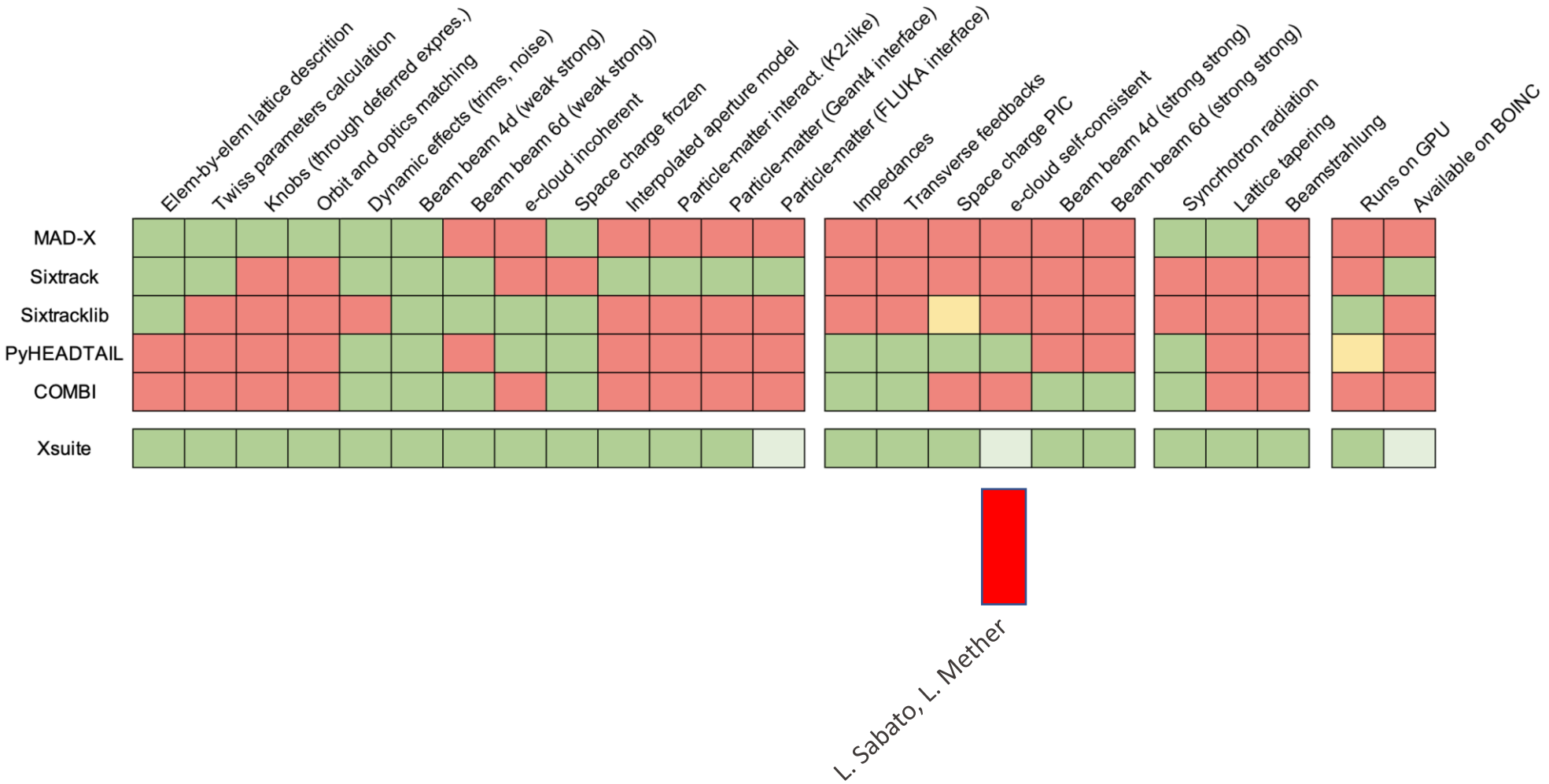


MAD-X for FCC-ee

- Efforts led by G. Simon, R. De Maria, A. Faus-Golfe and F. Schmidt
- Ongoing **review** of **MAD-X** for FCC-ee simulations
  - Investigation of **Twiss**, **Emit** and **Track** modules
  - Improved modeling in presence of energy deviations (**tapering**)
  - Implement more accurate twiss **computation** considering **energy offset**
  - Review of **radiation damping** modelling

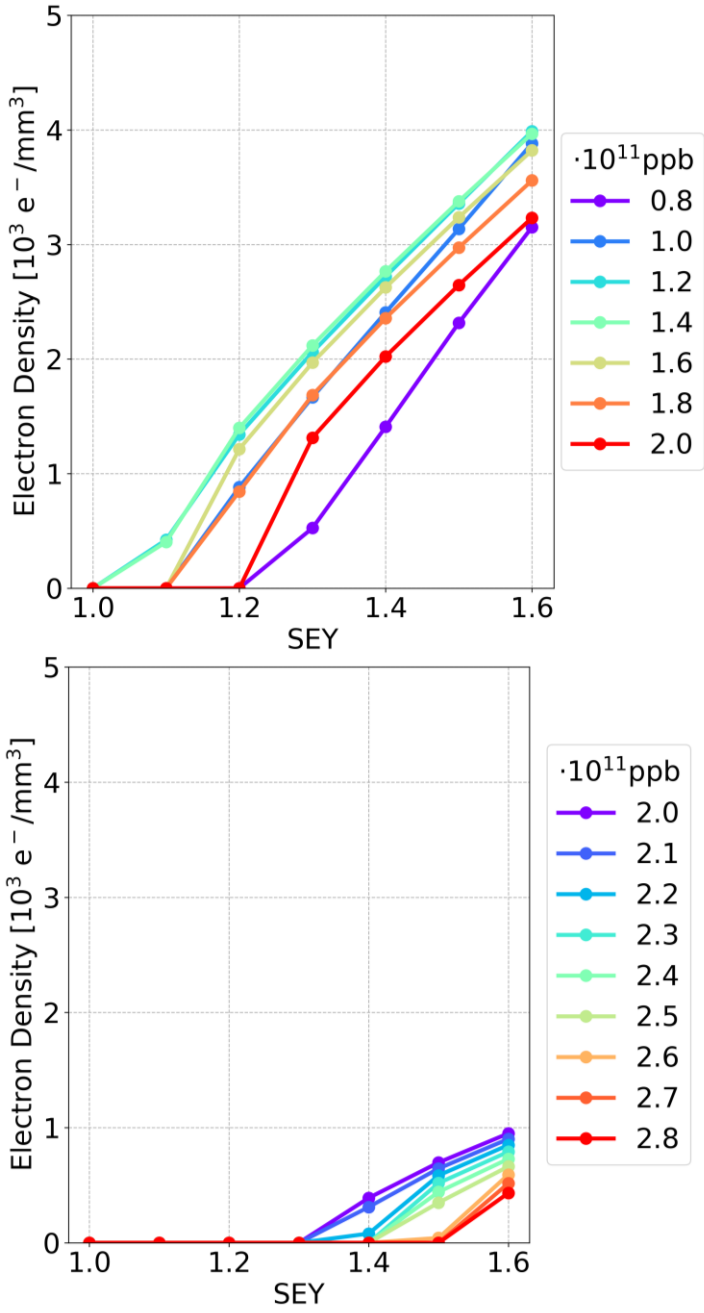
TWISS	No tapering	Tapering
5.07.00	0.2240 0.3600	0.2240 0.3593
5.08.01	0.2240 0.3600	0.2153 0.3509
5.09.00	0.2240 0.3600	0.2153 0.3509
TRACK	**No tapering**	**Tapering**
5.07.00	0.2240 0.3600 0.101	0.1797 0.3942 0.0833
5.08.01	0.2240 0.3600 0.101	0.2236 0.3588 0.0815
5.09.00	0.2240 0.3600 0.101	0.2236 0.3588 0.0815

Electron Cloud



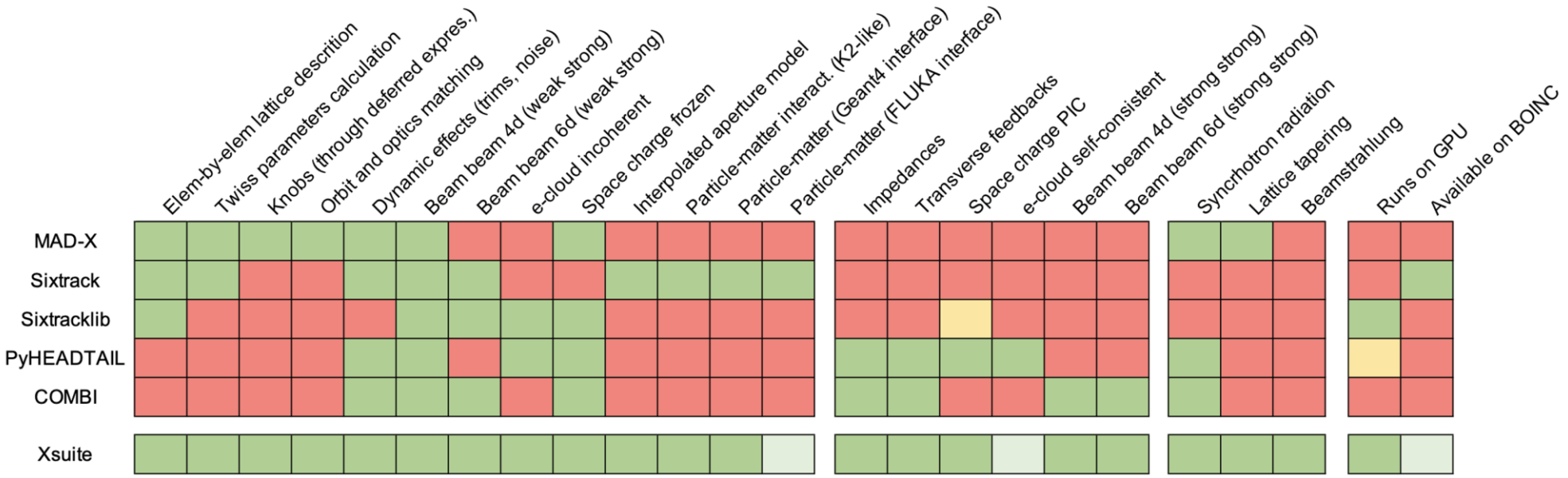
Electron Cloud

- Efforts by **L. Sabato** and **L. Mether**
- Provide **feedback** for **vacuum design**
- Cloud formation using **pyECLOUD**
  - **Improved** electron cloud **models** based on LHC
  - Systematically **reduce computational load** by identifying **parameter range**
- Beam **stability simulations** with **pyHeadTail**
  - Using distributions from pyECLOUD
- Possible aim to **integrate** with other (python) **codes** for **multiple effects**

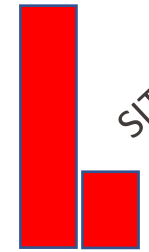


Electron cloud formation in dipoles for two design iterations with different bunch spacing

Spin Polarisation



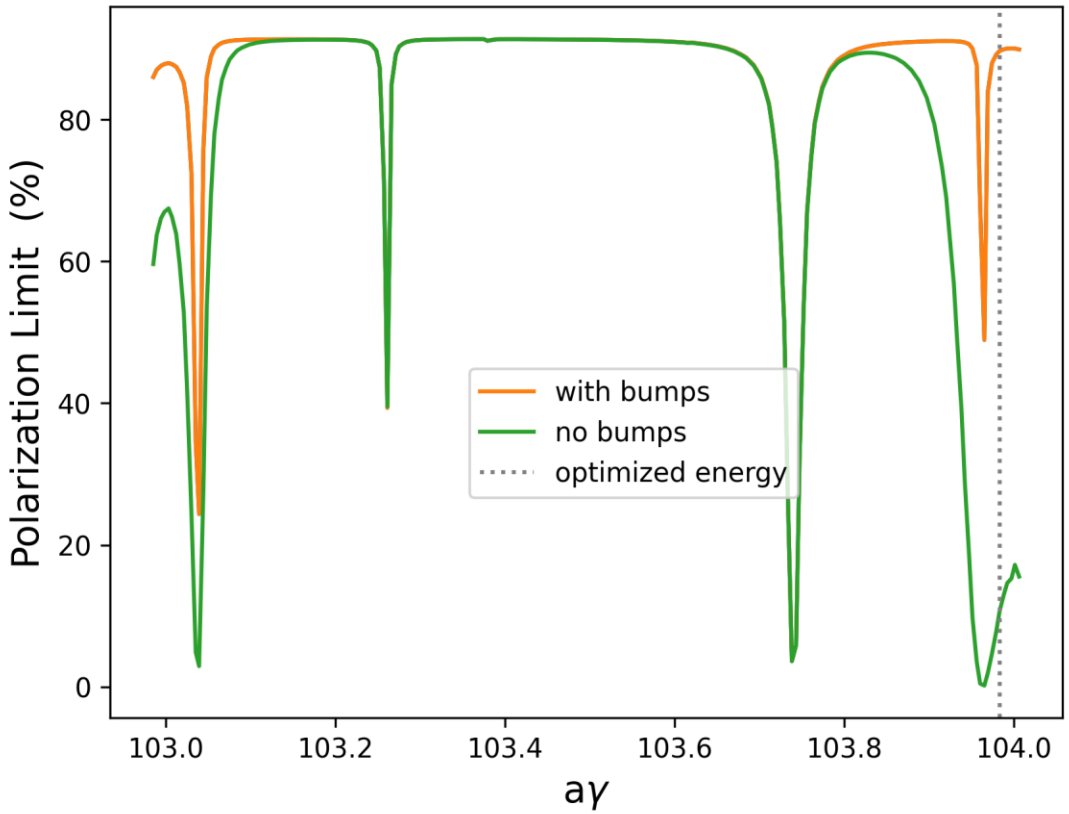
Polarization and SPIN tracking



Y. Wu, F. Carlier, T. Pieloni EPOL team

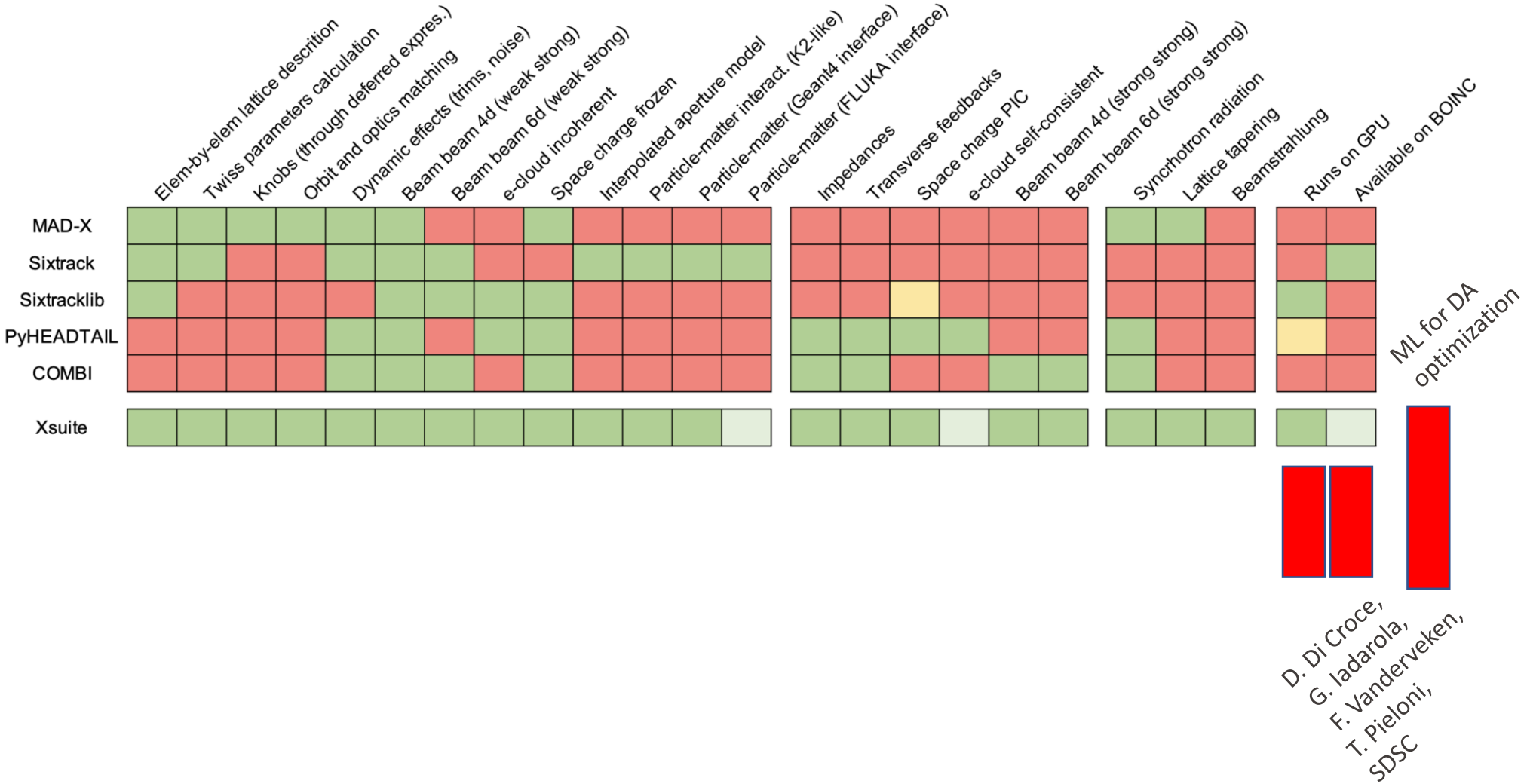
Spin Polarisation

- Lead by **Y. Wu, D. Barber**
- Spin polarisation required for **energy calibration** by spin tune measurement
- **Polarisation levels and times** determined from simulations
  - Currently done in **Bmad**
- Software framework **requirements**:
  - Simulate and optimise polarisation with **realistic lattice errors** and **corrections**
  - Understand how **spin optimisation affects** other **properties**
  - Accurate **representation** and **propagation** of changes between codes



Polarisation levels before and after implementing orbit bumps using harmonic spin matching.

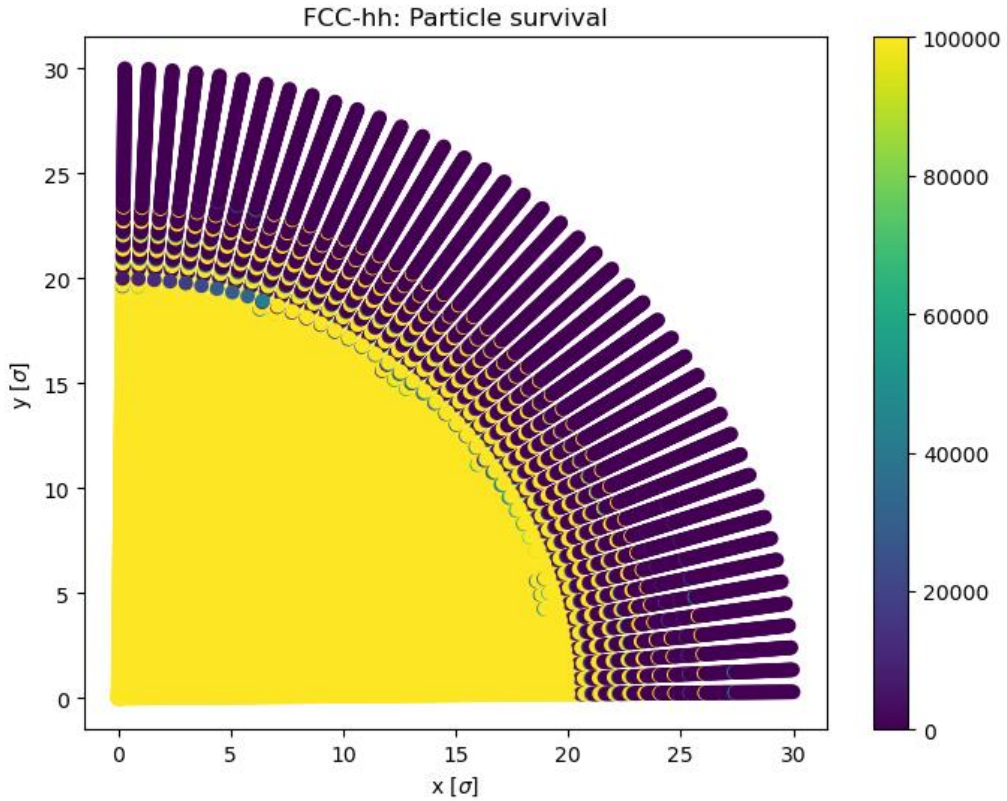
XBoinc and Machine Learning



D. Di Croce,
G. Iadarola,
F. Vanderveken,
T. Pieloni,
SDSC

XBoinc and Machine Learning

- Efforts led by **D. di Croce, F. van der Veken, G. Iadarola, M. Giovannozzi, T Pieloni** and **SDSC**
- Improve efficiency of **dynamic aperture** studies for **FCC-hh** using **machine learning** techniques
  - **Smart sampling** of dynamic range
  - Generate **surrogate models** to predict dynamic aperture and losses
    - Train using **xsuite** jobs submitted to **LHC@home** via **xboinc**
- Potential synergies with FCC-ee

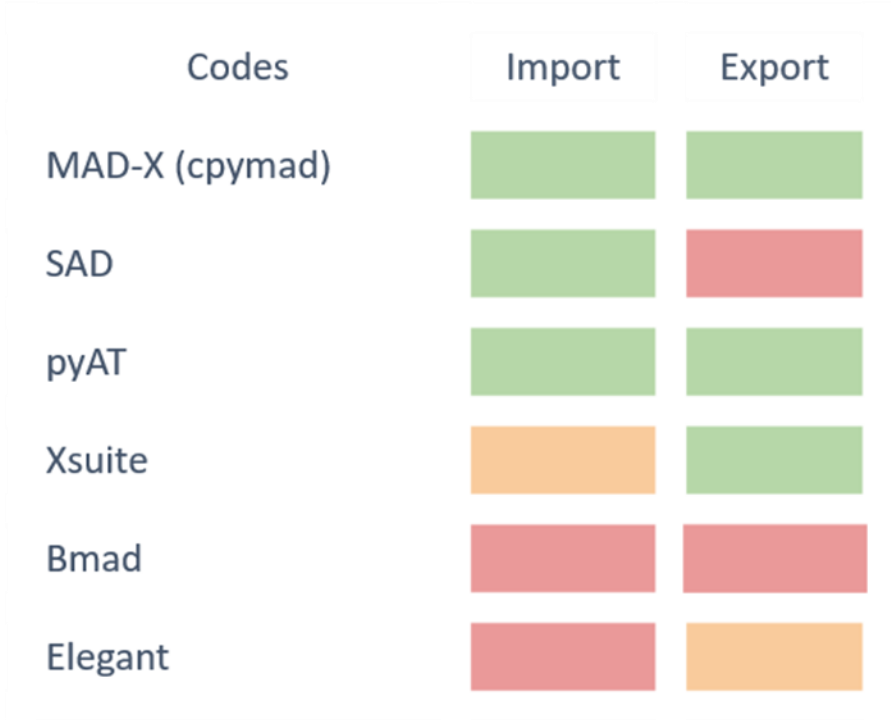


FCC-hh survival plot

Bring it together

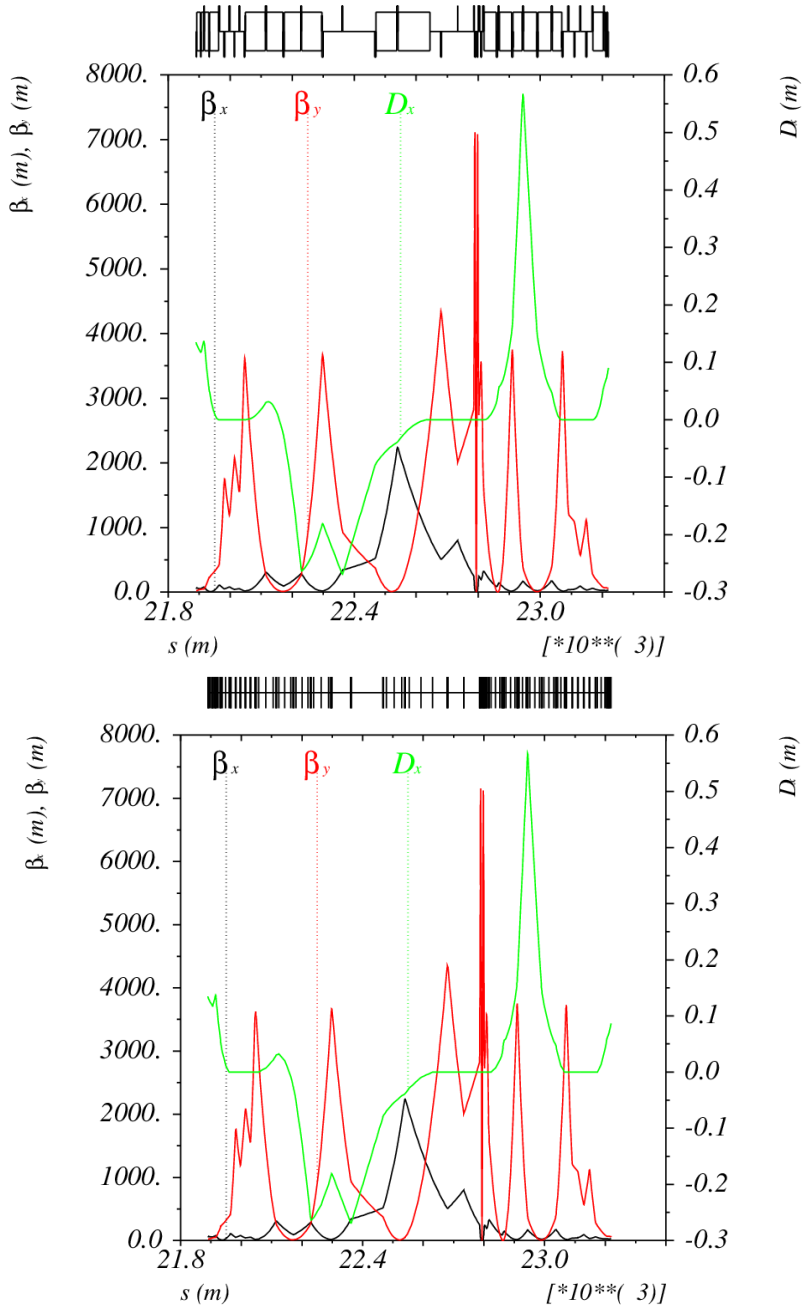
Lattice Conversion and Management

- Lattice conversion and management tools written by F. Carlier
  - XConverter to **convert** to and from different codes
  - XSequence to **manage** sequences in python
- To be **adjusted and augmented** based on user requirements
- Available on **github**



Consistency – Matching after Conversion

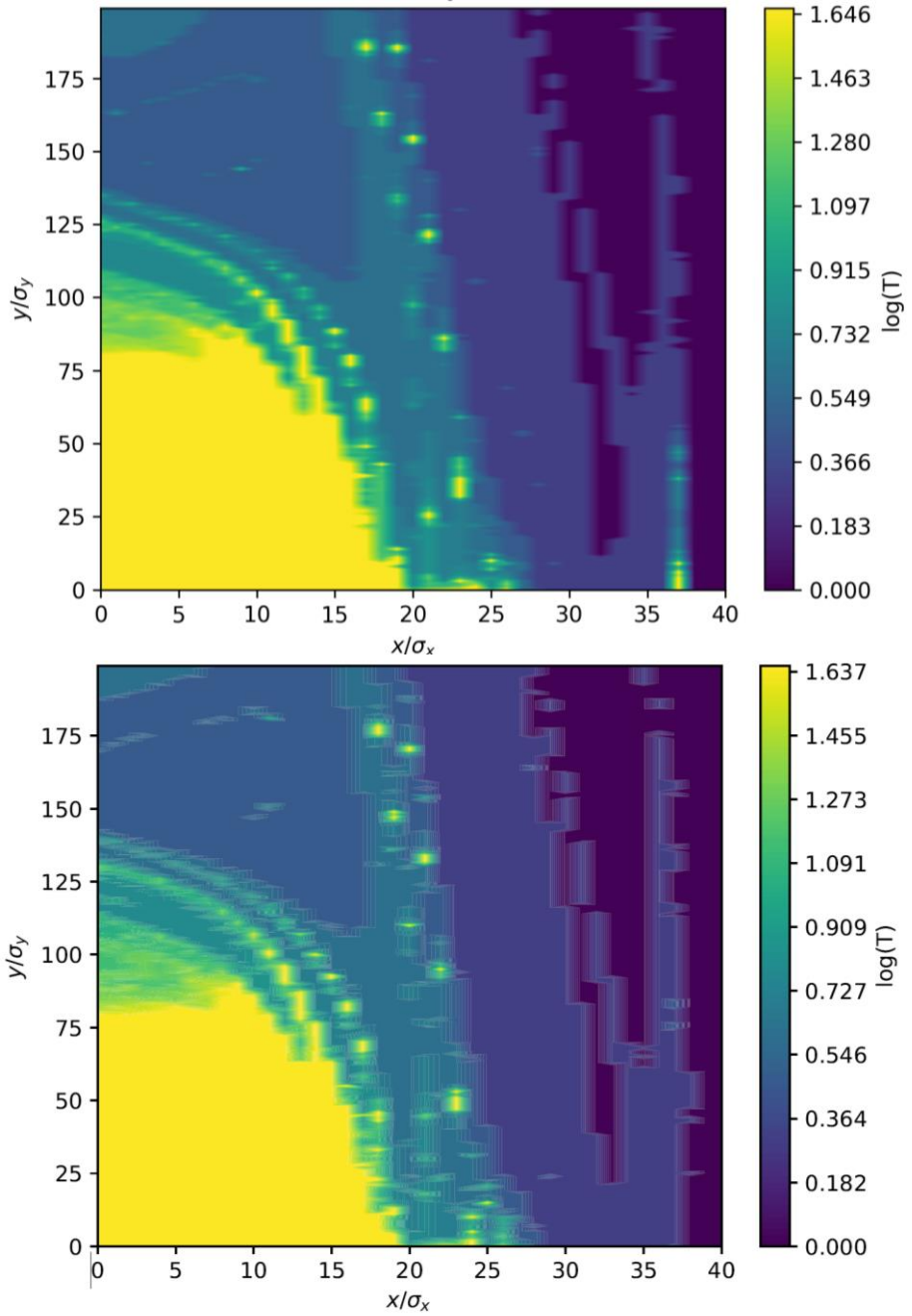
- **Matching** of lattice after **conversion** important to recover accurate physics
- Matching on multiple levels
  - **Global** parameters (tune, chromaticity…)
  - **Local** linear optics (segment-by-segment)
  - Fine **tuning** in specific areas (e.g. IP) using dedicated knobs
    - Knobs creation ongoing
  - **Non-linear** corrects after optics matching
    - Under investigation
- **Synergies** with machine tuning studies



IR Twiss obtained thick elements and with three thin slices per element and matching

Consistency - Benchmarking

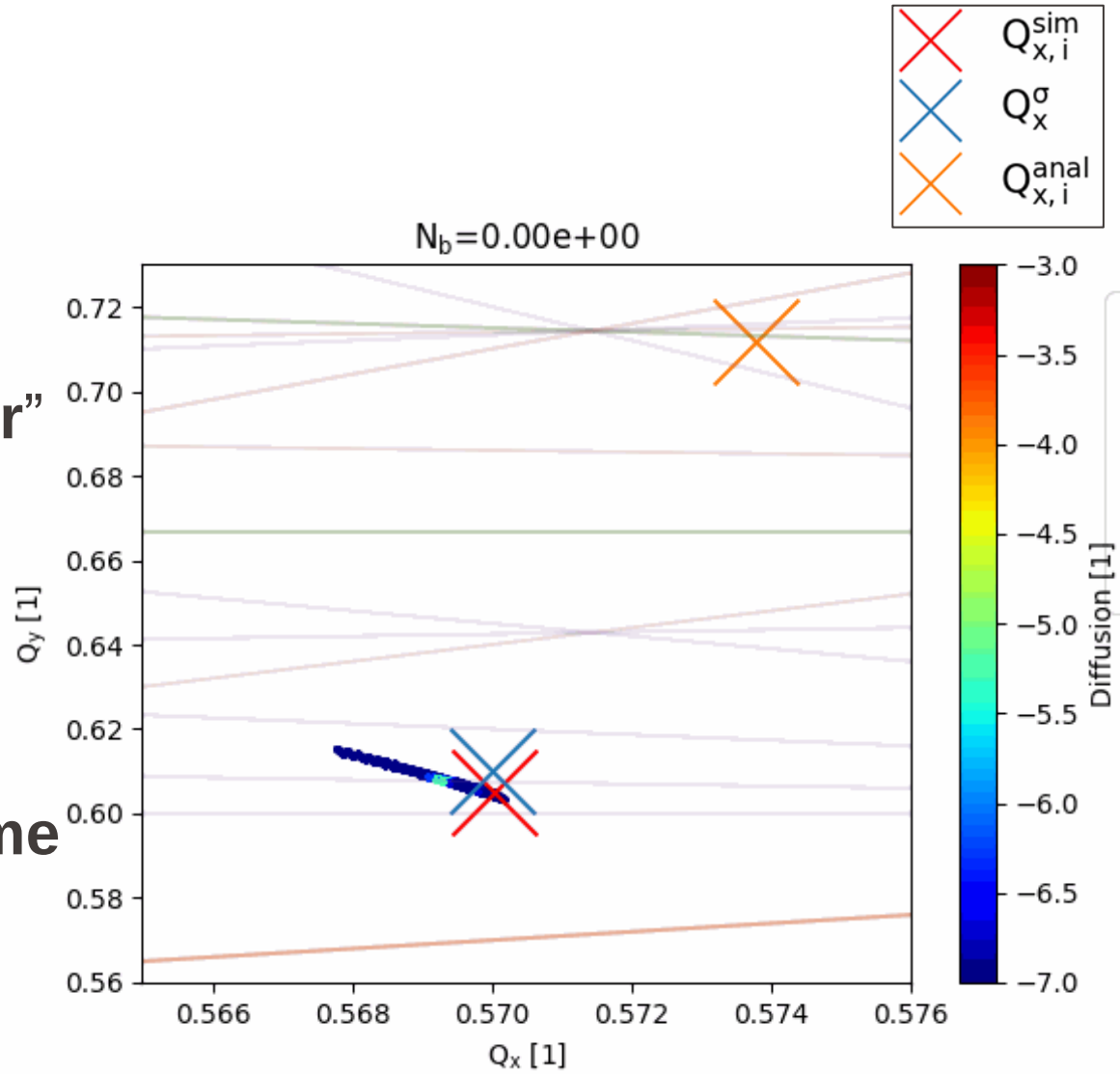
- Important to **benchmark** new tools with existing codes
  - Simple examples before studying **multiple effects**
  - **Understand** sources of possible inconsistencies
- Extensive study benchmarking **xsuite** since this is a primary tool
  - **Optics** with radiation and tapering compared to optics codes (MADX,SAD)
  - **Dynamic** aperture with and without radiation (MADX, SAD, MADX-PTC)
  - **Emittance** from tracking
    - Compared to other **tracking** codes
    - Compared to matrix **methods**



FCC-ee survival plot with radiation using SAD (top) and Xtrack (bottom)

First Results: Beam-beam and full lattice

- First example of “**bringing it together**”
- Installing **beam-beam** model from P. Kicsiny in **full lattice** model
  - E.g. for tune footprint
- Full **benchmarking** underway
- Many studies ahead e.g. beam **lifetime** and **blow-up**



Tune footprint at different intensities simulated using xtrack, including full arcs.

Conclusion

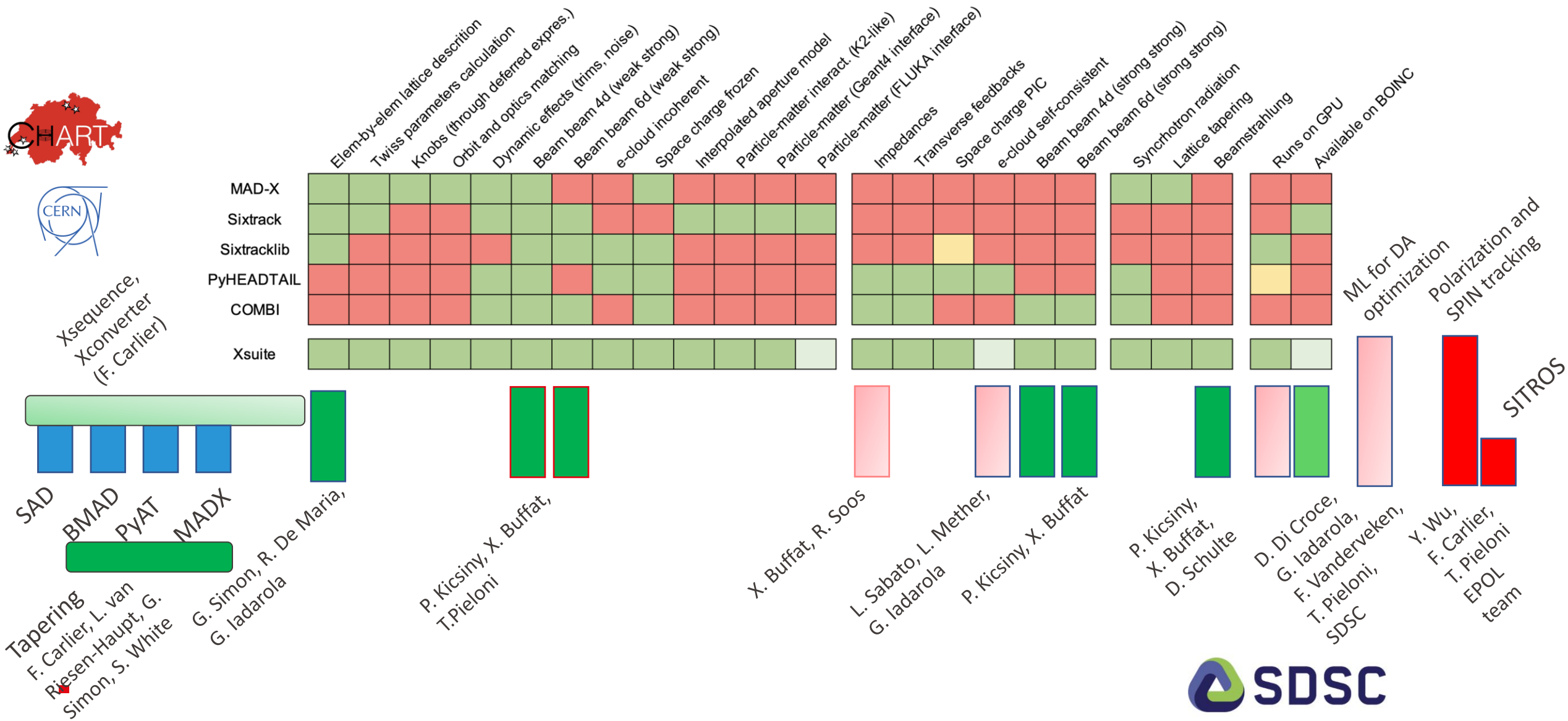
- Lots of **progress** by a large and very **young team**
  - **Synergies** between **CHART** and **CERN** for FCC-ee and FCC-hh studies
  - Beam-beam simulations, optics simulations with radiation, electron cloud and stability, spin polarization, machine learning and xboinc
- Co-ordinated effort to **bring it all together**
  - Help with **conversion** between codes (SAD, MADX, BMAD)
  - **Benchmarking** introducing one effect at a time
  - First example – beam-beam model integrated in with full FCC-ee lattices with radiation and tapering

Outlook

- Finalise **solenoide** implementation in Xtrack (Oide talk)
- **Reproduce** studies by Oide and Shatilov for lattice **DA** and **lifetime** with 2-4 IPs and different **parameter scans** (i.e. tunes, intensities) for baseline optics
- **Incoherent** effects: DA, lifetime, luminosity performance for baseline lattice and optimization studies
- **Coherent** Stability studies with beam-beam, impedance and electron cloud

- Several tools are ready, many studies to come→ see presentations

Synergies and New Developments



Software Framework & Friends