

FCC-ee contributions to SuperKEKB – past, present and future

Frank Zimmermann

CERN-KEK Committee, meeting #19, 26 November 2024

a few relevant agreements & frameworks

KEK member in **FCC collaboration** during CDR phase (2014-2019)
and in **FCC Feasibility Study** phase (2021-25)

KEK partner in **EU projects EuroCirCol, EJADE, FCCIS, EAJADE...**

CERN participation in **KEK MNPP-01** (R&D for high luminosity colliders)

Appendix 22 to ICA-JP-0103

original 2017

1st amendment 2021

2nd amendment 2023

KEK designates the following personnel to manage and coordinate MNPP-01 Project (hereinafter referred to as "Project Manager": Makoto Tobiya, Professor, Accelerator Laboratory, KEK).

1.5.5. CERN

Beam commissioning of SuperKEKB accelerators (Injector, Damping ring, Main ring).
Design study of future circular colliders.

Appendix 14 to ICA-JP-0103, **Halo measurement** for LHC & future colliders

Appendix 25 to ICA-JP-0103, R&D for **SRF cavity production**

SuperKEKB International Task Force

Launched by KEK in 2021, initially chaired by Mika Mazusawa, later by Yuki Yoshi Ohnishi, since April 2024 by the three KEK division heads; most tasks finished by now

collective effects task force

M. Migliorati (Sapienza, FCC-ee coordinator for collective effects and impedance) co-leader and contact person for TMCI subgroup from August 2021 till end 2022 ; updated machine impedance; in 2022, instability was identified as -1 instability due to bunch-by-bunch feedback system; adjusting feedback suppressed the instability. Also N. Mounet (CERN), M. Zobov (INFN) et al. contributed

beam tuning task force

J. Keintzel (CERN), F. Soubelet (CERN) et al. contributed

beam-beam task force

P. Kicsiny (CERN) et al. contributed

secondments from FCC to SuperKEKB

Name	Affil.	Topic(s)	Funded by	Dates	Duration
Frank Zimmermann	CERN	Performance limits and plan for CERN secondments	EAJADE/FCC	13-20 July 2023 6-10 July 2024	13 days
Peter Kicsiny	CERN	Beam-beam modeling	EAJADE/FCC	17 Nov–16 Dec'23	30 days
Marton Ady	CERN	Vacuum related effects	EAJADE/FCC	30 Mar – 29 Jun '24	91 days
Jacqueline Keintzel	CERN	Optics measurement & BBA study	EAJADE/FCC	4 – 18 Feb 2024 6 May – 1 Jun '24	30 days
Giacomo Broggi	CERN	Collimation and background control	EAJADE/FCC	27 Jan – 25 Feb 2024	29 days
Mael LeGarrec	CERN	Nonlinear optics	EAJADE/FCC	3 Feb – 3 Mar '24	30 days
Roxanna Soos	CERN	Beam-beam modeling	EAJADE/FCC	8 May – 9 Jun '24	32 days
John Salvesen	CERN	IP feedback, operation	EAJADE/FCC	6 May – 8 Jun '24	33 days
Ilya Agapov	DESY	CSR emittance growth in SKEB transfer lines, etc.	EAJADE	3 -12 April 2024	10 days
Mauro Migliorati	Sapienza	Impedance & collective effects	KEK	11-26 May 2024	16 days
Barbara Dalena	CEA	Optics measurement & DA	EAJADE	Feb +June 2024	30 days
Quentin Bruant	CEA	Optics measurement & DA	EAJADE	Feb +June 2024	30 days

secondments from KEK to CERN/FCC

Name	Affiliation	Topic	Funded by		Duration
Kazuhito Ohmi	KEK	Beam-beam & electron cloud	CERN/FCC	22 Feb – 14 Apr 2024	53 days
Takumi Arai	KEK	Beam-beam	CERN/FCC	6 – 17 Sept 2024	11 days
Takashi Mori	KEK	Transfer lines & injection (tbc)	KEK	21 Nov 2024 – end March 2025	~3.5 months

Shoji Uno
20 Sept 2024

Mike Lamont
21 Oct 2024



Necessary Accelerator Simulations

Experts shown
in bold already
visited
SuperKEKB
1x or few x;
those in red
might visit again
or newly

- Beam-Beam Interaction
- Weak-Strong Model with Machine Error (X-Y Couplings and Dispersions) **collaboration underway; tools & young experts**
(**Kicsiny**, Soos, **Salvesen**, **Andre**, Buffat, Bartosik, ...)
- Strong-Strong Model with Machine Error, Impedance, Lattice Nonlinearity, Space Charge
- Dynamic Aperture **collaboration underway; tools & young experts**
(**Keintzel**, **LeGarrec**, **Tomas**, **Andre**)
- Comparison between Measurements and Tracking Simulation
- Beam Injection
- Injection Efficiency with Machine Error, Injection Errors and Beam Emittance **collaboration underway; tools & young experts**
- Injection Efficiency without and with Beam-Beam Interaction (Weak-Strong Model) (**Andre**, Buffat, Dutheil)
- Synchrotron Radiation in the Interaction Region **collaboration underway; tools & young experts**
- SR on PXD
- SR in the Strong Sextupole Region (**Andre**)

possible new secondments incl. for other topics

- SR in the IR, injection efficiency, dynamic aperture, beam-beam
Kevin Andre (fellow contract will end January)

- Optics correction, emittance tuning, luminosity tuning
Satya Sai (doctoral student CERN), **Felix Carlier** (CERN staff)

- sudden beam loss and vacuum issues

Roberto Kersevan (the best expert at CERN, retiring right now;
might leave for US or China)

Lotta Mether (multi-species simulations; Lotta studied e-cloud, ion instability and
LHC “16L2 problem”)

Yu Hashimoto in new function for ATLAS & support for CERN/FCC-KEK/SKEKB coll. ?!

recent big achievement 😊

we waited ~18 years for this 😞 since Akio Morita's stay at CERN in 2006/2007

Now, thanks to

J. Salvesen, G. Iadarola, G. Broggi, H. Sugimoto, and K. Oide :
complete model of SuperKEKB LER and HER, including IR with titled solenoid and overlapping elements available in CERN simulation framework xsuite since last week !

With this CERN FCC team could carry out many studies for SuperKEKB:

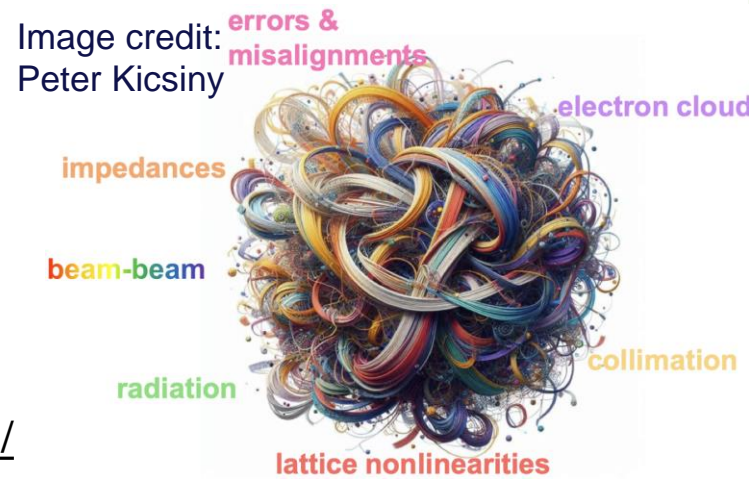
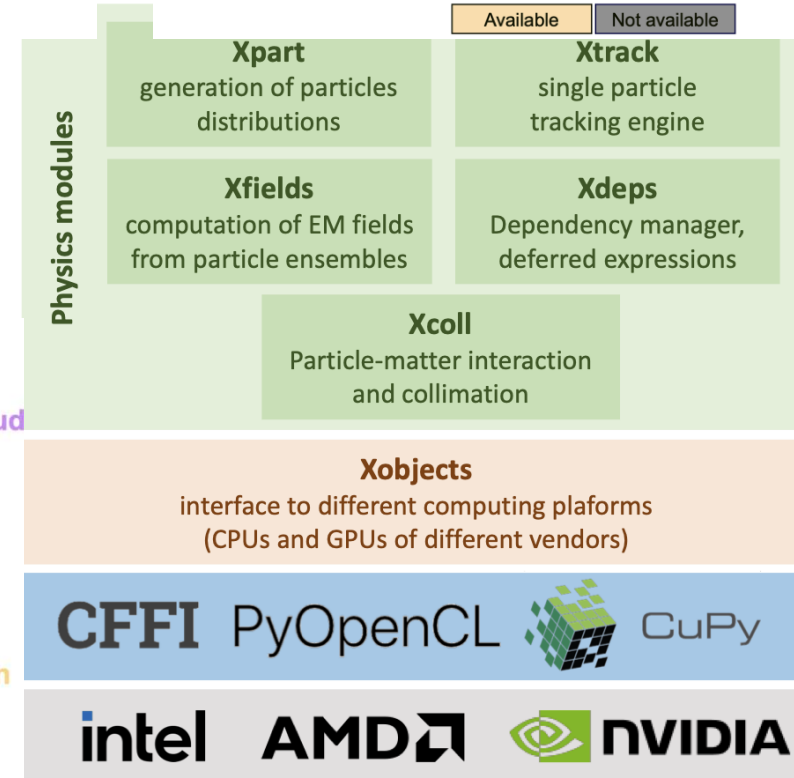
Optics, beam-beam, collimation, SR background, injection, ..

Xsuite simulation toolkit

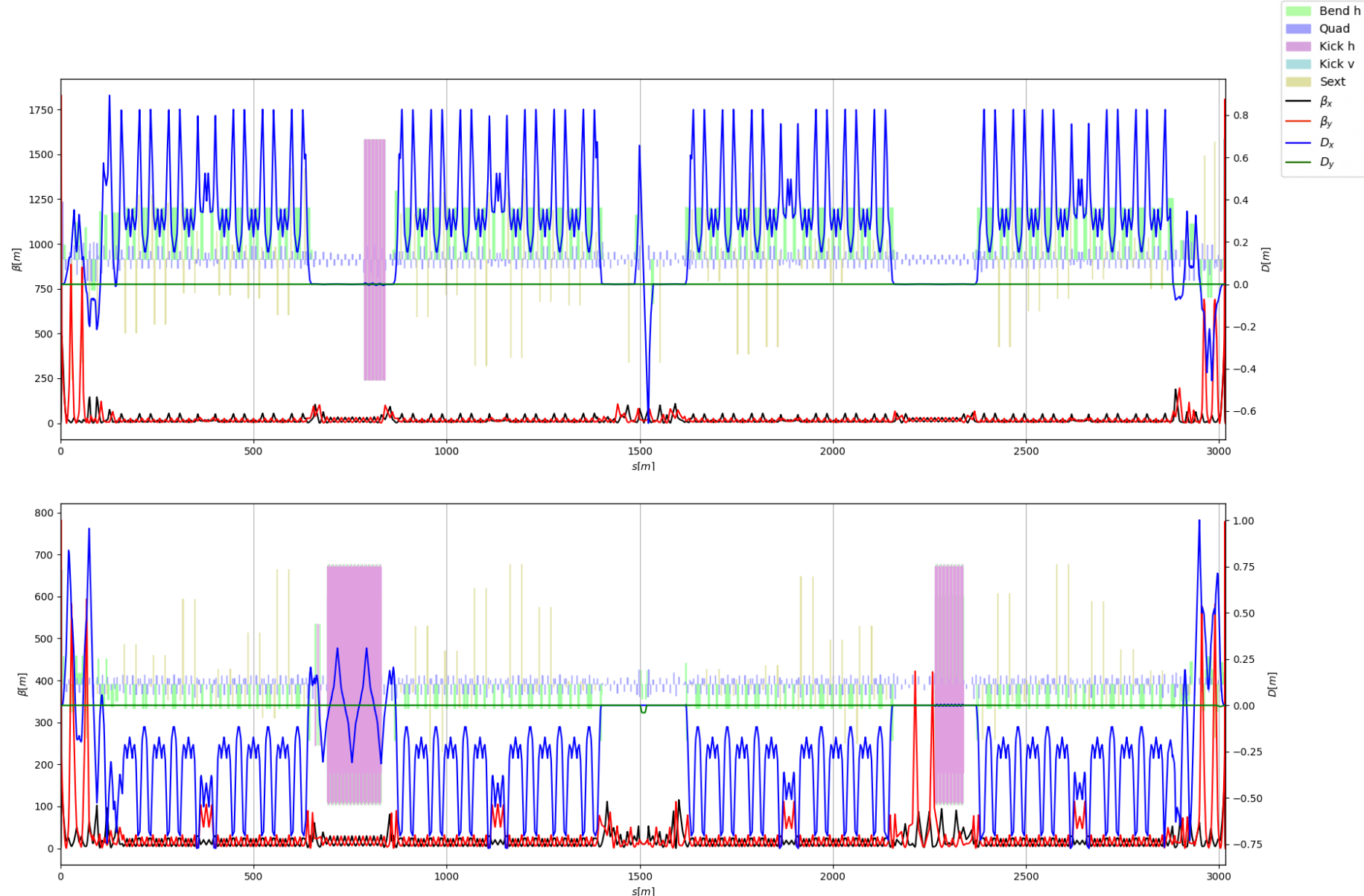
- developed at CERN since 2021
- adopted for beam dynamics simulations by large & diverse user community, > 100 users!
- main goal: bring into a modern Python toolkit the know-how built up while developing MAD, Sixtrack, COMBI, ...
- cover with a single toolkit applications ranging from low-energy hadron rings to high-energy lepton colliders
- applied to PS, SPS, LHC...
- used for FCC design studies



	Weak-strong 6D	Quasi-strong-strong 6D	Strong-strong 6D SG	Strong-strong 6D PIC	Beamstrahlung	Bhabha-scattering	Transverse wakefields	Longitudinal wakefields	Linear tracking	Lattice tracking	Open source	Runs on GPU
GUINEA-PIG [2]	Available	Available	Available	Available	Available	Available	Available	Available	Available	Available	Available	Available
COMBI [3]	Available	Available	Available	Available	Available	Available	Available	Available	Available	Available	Available	Available
BBWS [4]	Available	Available	Available	Available	Available	Available	Available	Available	Available	Available	Available	Available
BBSS [5]	Available	Available	Available	Available	Available	Available	Available	Available	Available	Available	Available	Available
SCTR [6]	Available	Available	Available	Available	Available	Available	Available	Available	Available	Available	Available	Available
IBB [7]	Available	Available	Available	Available	Available	Available	Available	Available	Available	Available	Available	Available
LIFETRAC [8]	Available	Available	Available	Available	Available	Available	Available	Available	Available	Available	Available	Available
BeamBeam3D [9]	Available	Available	Available	Available	Available	Available	Available	Available	Available	Available	Available	Available
Xsuite [10]	Available	Available	Available	Available	Available	Available	Available	Available	Available	Available	Available	Available



- strong collaboration between CERN and KEK
- alternative modelling strategy for IR
- many additional features & improvements to Xsuite have come about as a result of this effort



*J. Salvesen, G. Iadarola,
G. Broggi, H. Sugimoto,
K. Oide*

Studies already underway!

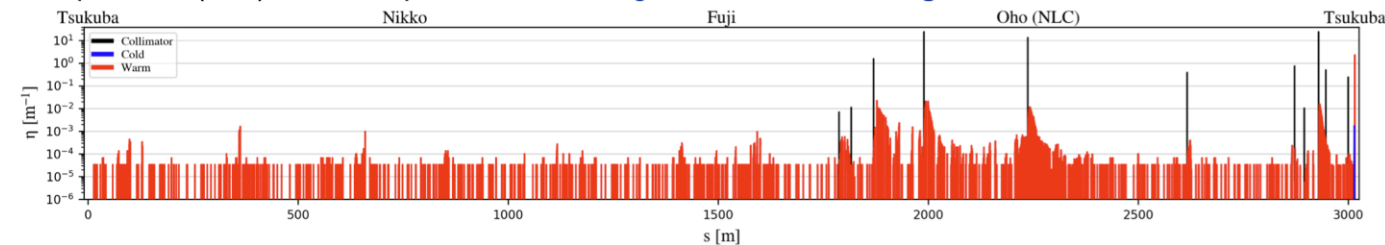
- many interested users:
- large number of studies in CERN ABP on SuperKEKB:
 - IP feedback studies (*J. Salvesen*)
 - machine vibration studies (*J. Salvesen, LAPP collaborators*)
 - collimation studies (*G. Broggi*)
 - optics studies (*J. Keintzel, M. Le Garrec*)
 - beam based alignment studies (*C. Goffing*)
 - impedance studies (*R. Soos*)
 - beam-beam studies (*P. Kicsiny*)
- interest from BELLE-II for IR upgrade model
- and more ..

- G. Broggi: First results on SuperKEKB loss maps
 - Xsuite no-solenoid lattice used

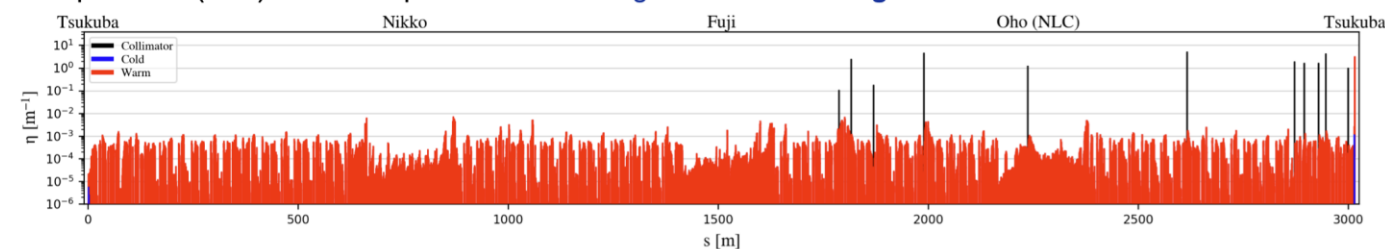
First preliminary SuperKEKB loss maps

$$\eta = \frac{E_{loss,\Delta s}}{E_{loss,tot} \Delta s}$$

- SuperKEKB (LER) beam loss pattern from beam-gas **Coulomb scattering** interactions:



- SuperKEKB (LER) beam loss pattern from beam-gas **bremstrahlung** interactions:



- Flat 1 nTorr pressure profile, Z=7 equivalent gas (from KEKB-SuperKEKB experience)
- Full IR model including solenoid to be added



John Salvesen (“Jack”)



UNIVERSITY OF
OXFORD



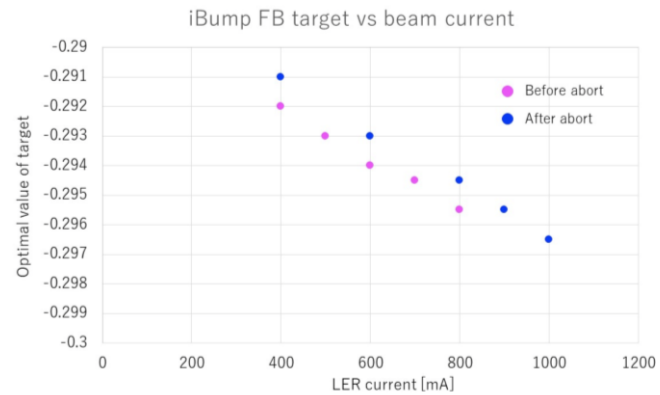
Thesis: *Design of an Interaction Point Collision Feedback System for FCC-ee*

Doctoral Student: CERN BE-ABP-LAF, Oriel College Oxford

Supervisors: *Frank Zimmermann (CERN), Phil Burrows (Oxford)*

- KEK Secondment May-June 2024
 - iBump Feedback studies
 - Start of SuperKEKB Lattice conversion
- KEK Secondment December 2024
 - Xsuite SuperKEKB Lattice testing
 - iBump feedback system modelling in Xsuite
 - Further iBump studies TBD

in collaboration with R. Ueki,
Y. Funakoshi, M. Masuzawa



EAJADE
Europe-America-Japan Accelerator
Development Exchange Programme

Secondment related publications

- iBump Feedback Studies:
 - IPAC 2025 poster (in progress)
- Xsuite Lattice Modelling
 - eeFACT 2025 Invited Talk (in progress)
 - IPAC 2025 poster (in progress)

EAJADE

This work was partially supported by the European Union's Horizon Europe Marie Skłodowska-Curie Staff Exchanges programme under grant agreement no. 101086276.

conclusion

many good ideas, great expertise & excellent tools



FCC team is ready and motivated to work together with
KEK on unravelling the mysteries of SuperKEKB

appendix: solenoid modelling strategy

SAD IR:

- Alternating solenoid and multipole slices
- Along the beamline reference frame
- Strengths from full 3D magnetostatics model

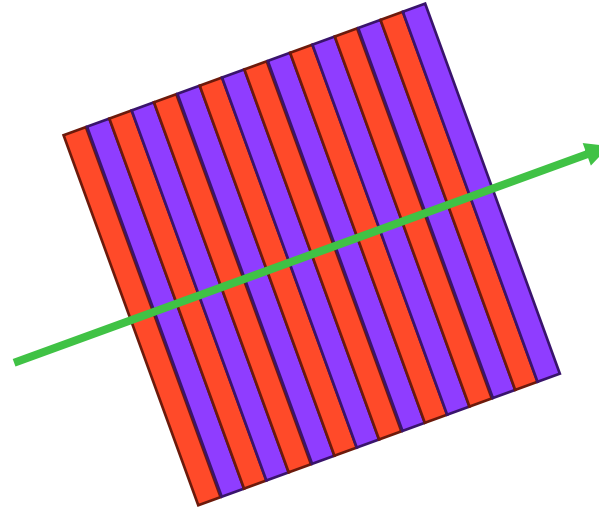
Xsuite IR (nosol):

- Thick final focus quadrupoles
- Along the beamline reference frame
- No: sol, FFQ corrs, FFQ offsets, skew quads

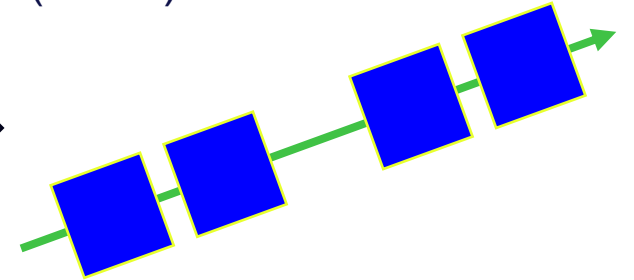
Xsuite IR (sol)

- Solenoid slices, with multipole kicks each slice
- Along BELLE-II reference frame
- Slices built from thick final focus quadrupoles, remaining fully controllable

SAD: sliced 3D IR



Xsuite: Thick Magnet IR (nosol)



Xsuite: sliced IR (sol)

