SuperKEKB Lattice translation

Demin Zhou

Acknowledgements:

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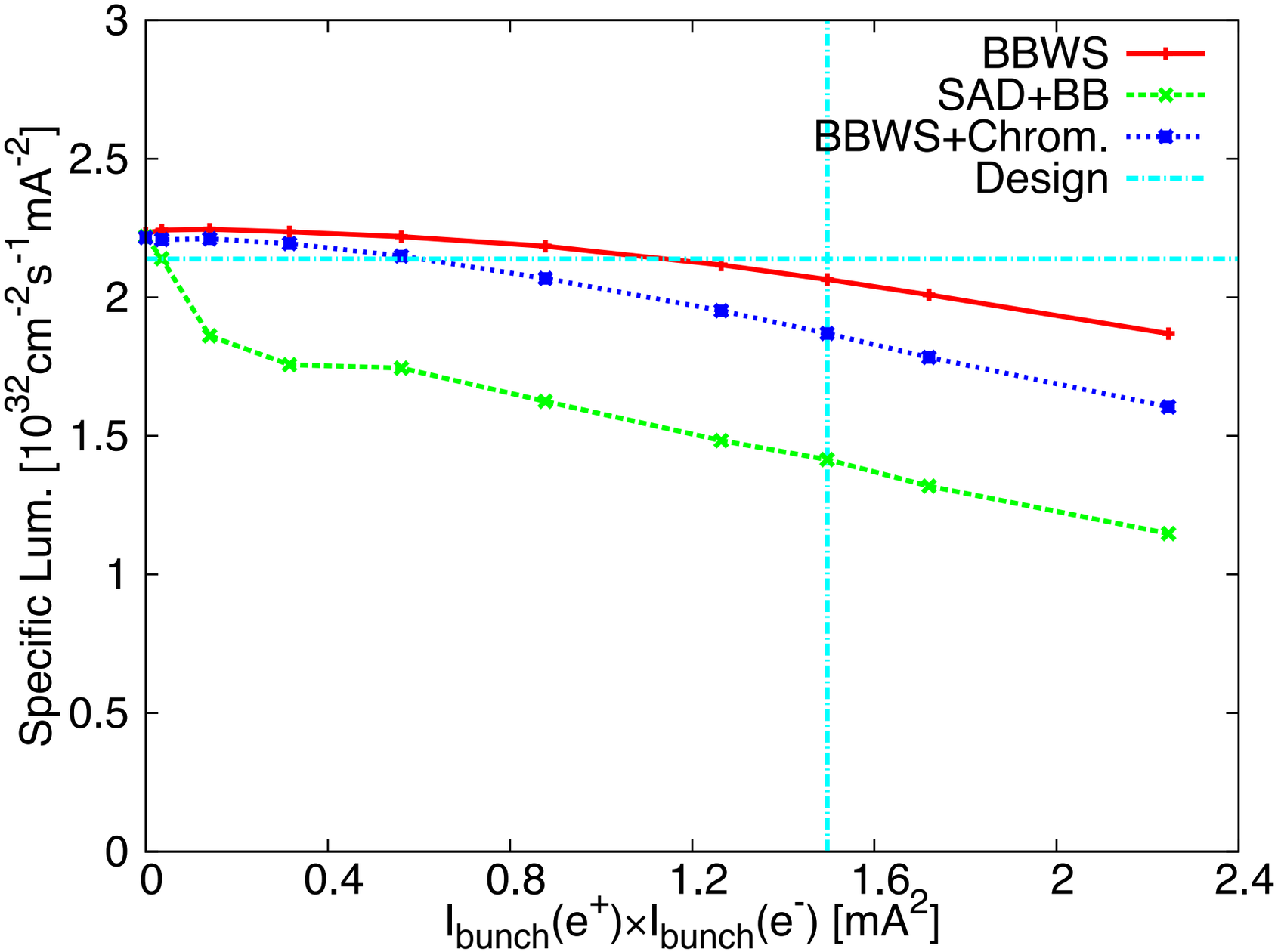
Outline

- ➤ Introduction
- ➤ Current status
  - Lattice translation without solenoid
- ➤ SuperKEKB lattice translation
  - With solenoid
  - Without solenoid
- ➤ Summary

1. Introduction

➤ Motivation

● **Accelerator physics challenges in SuperKEKB: DA, lifetime, luminosity, background, etc.**



Ref. D. Zhou et al., IPAC'13, TUPME016.

1. Introduction

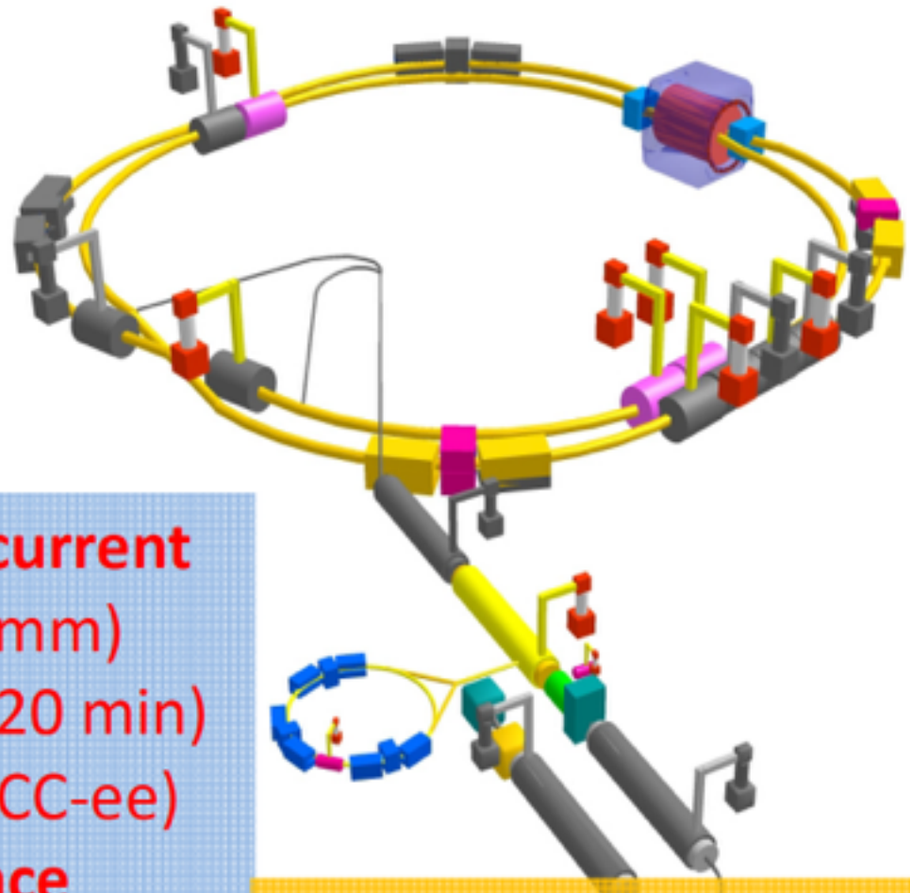
➤ Motivation

- **SuperKEKB as a demonstrator for FCC-ee**

SuperKEKB = *FCC-ee* demonstrator

beam commissioning will start in early 2015

N. Ohuchi et al., IPAC2014, WEOCA01



top up injection at high current
β_y^* =300 μm (FCC-ee: 1 mm)
lifetime 5 min (FCC-ee: ≥20 min)
$\varepsilon_y/\varepsilon_x$ =0.25% (similar to FCC-ee)
off momentum acceptance
(±1.5%, similar to FCC-ee)
e^+ **production rate** (2.5×10^{12}/s,
FCC-ee: $<1.5\times10^{12}$/s (*Z* cr.waist)

***SuperKEKB* goes beyond *FCC-ee*, testing all concepts**

Ref. F. Zimmermann et al., IPAC'14, MOXAA01.

1. Introduction

➤ Advantages of SAD

- Symplectic integrator, optics matching, beam envelope, …
- Advanced programming using mathematica-like script language
- Handling complicated IR (MULT elements, Arbitrary map, etc.)
- Collective effects (IBS, beam-beam, beamstrahlung, etc.)
- Other fancy features (refer to http://acc-physics.kek.jp/SAD/index.html)

Structural Definitions of Beam Line & Component

Since 1986
SAD
Strategic Accelerator Design

Optics Matching

Optical/Geometrical matching
Off-momentum matching
Finite-amplitude matching
Spin matching

SADScript Programming Interface in *Mathematica* Style

Built-in, system- and user-defined
functions for accelerators
SAD/Tkinter/KBFrame
Tcl/Tk interface

Particle Tracking

6D full-symplectic tracking
Dynamic aperture survey
Synchrotron radiation

Nonlinear Analysis

Taylor map by automatic differentiation
Lie algebraic map

Emittance Calculation

6D Beam-matrix method
Anomalous emittance
Spin depolarization(SODOM)

2. Current status

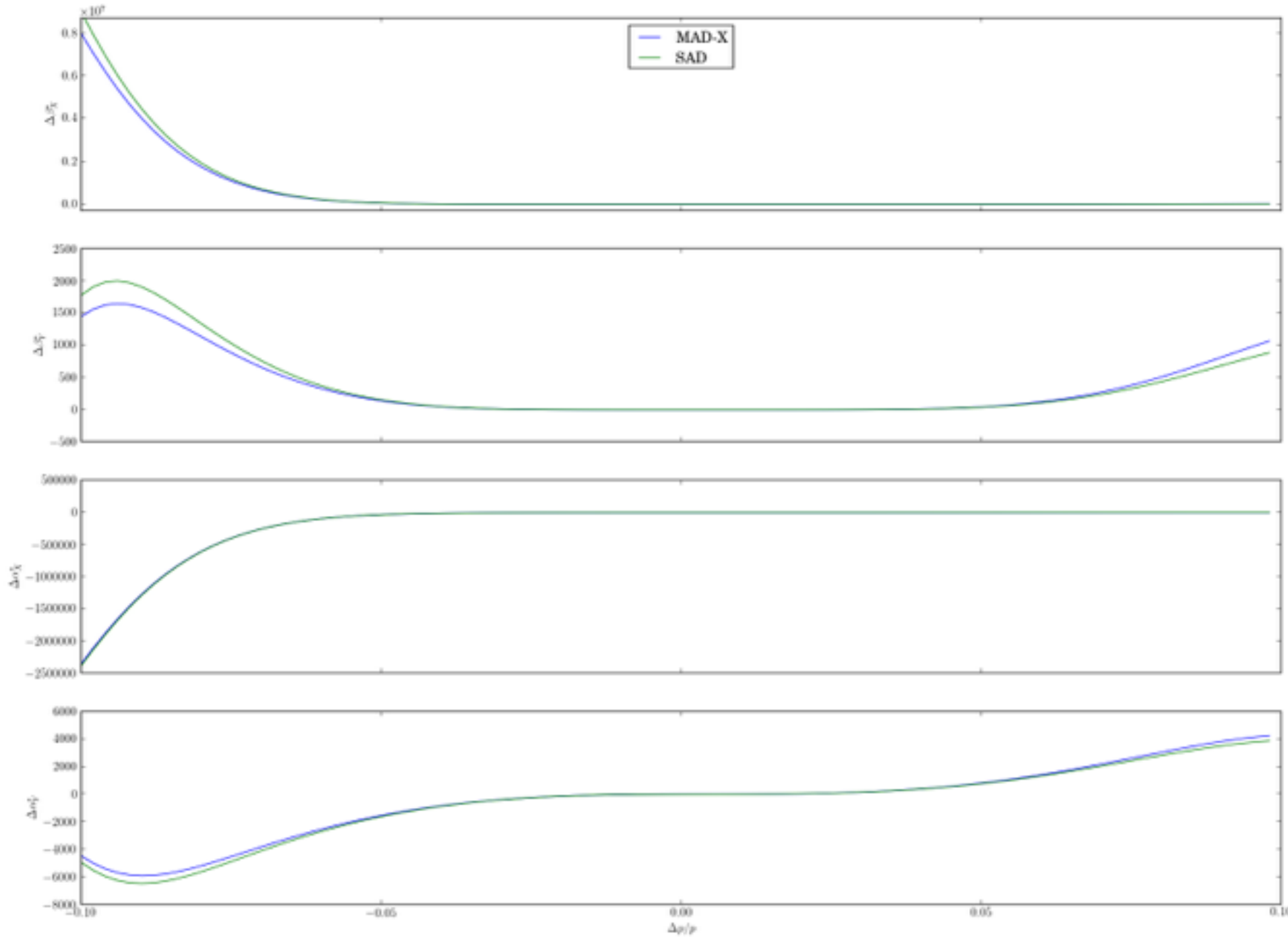
➤ Lattice translation: MAD-X to SAD

- MAD-X input and sequence to SAD input
- Various elements: Mostly straightforward (personal understanding)
- Translating a CLIC FFS beam line to SAD looks successful (Working with Paul Thrane). Other cases: BEPC, ILC DR, etc.
- For large files, we need a translator. SAD script from H. Koiso is available, but to be generalised and improved

2. Current status

➤ A comparison of MAD-X and SAD: CLIC FFS

- Linear Twiss functions perfectly agree
- Momentum dependence of Twiss functions

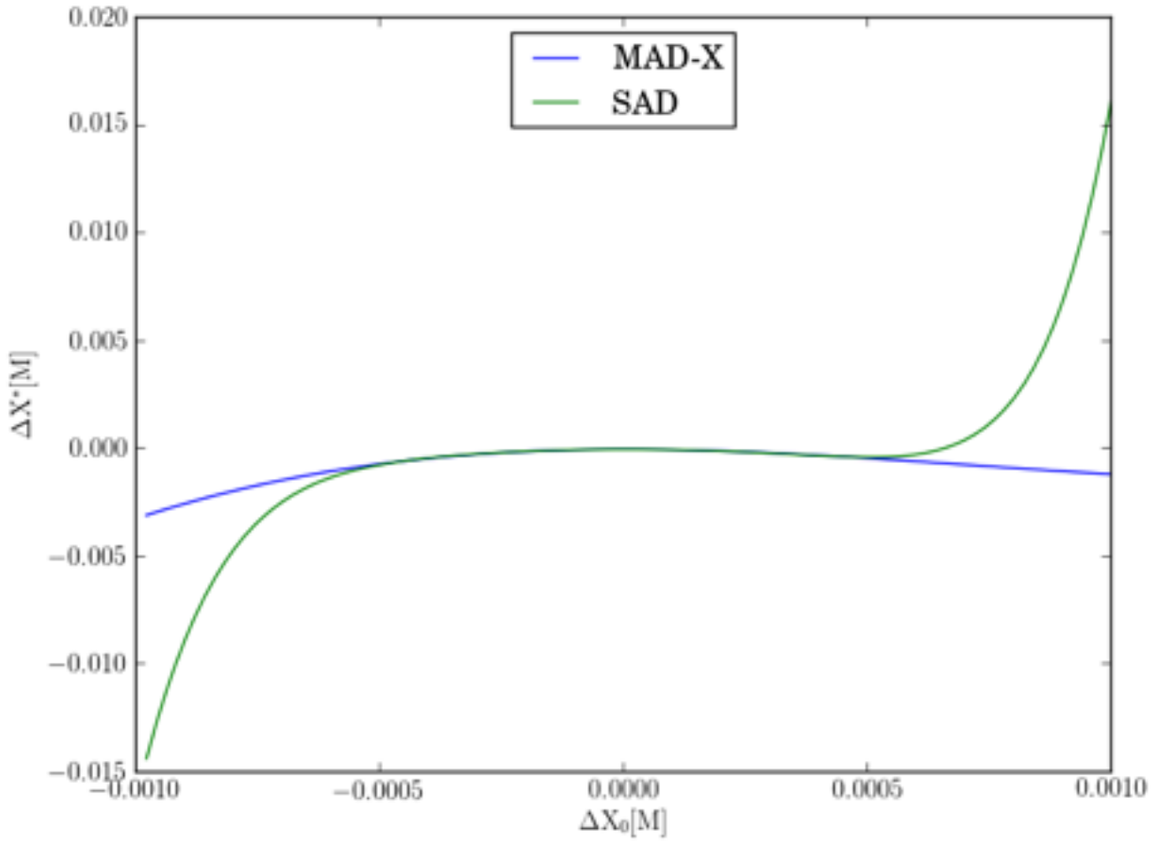


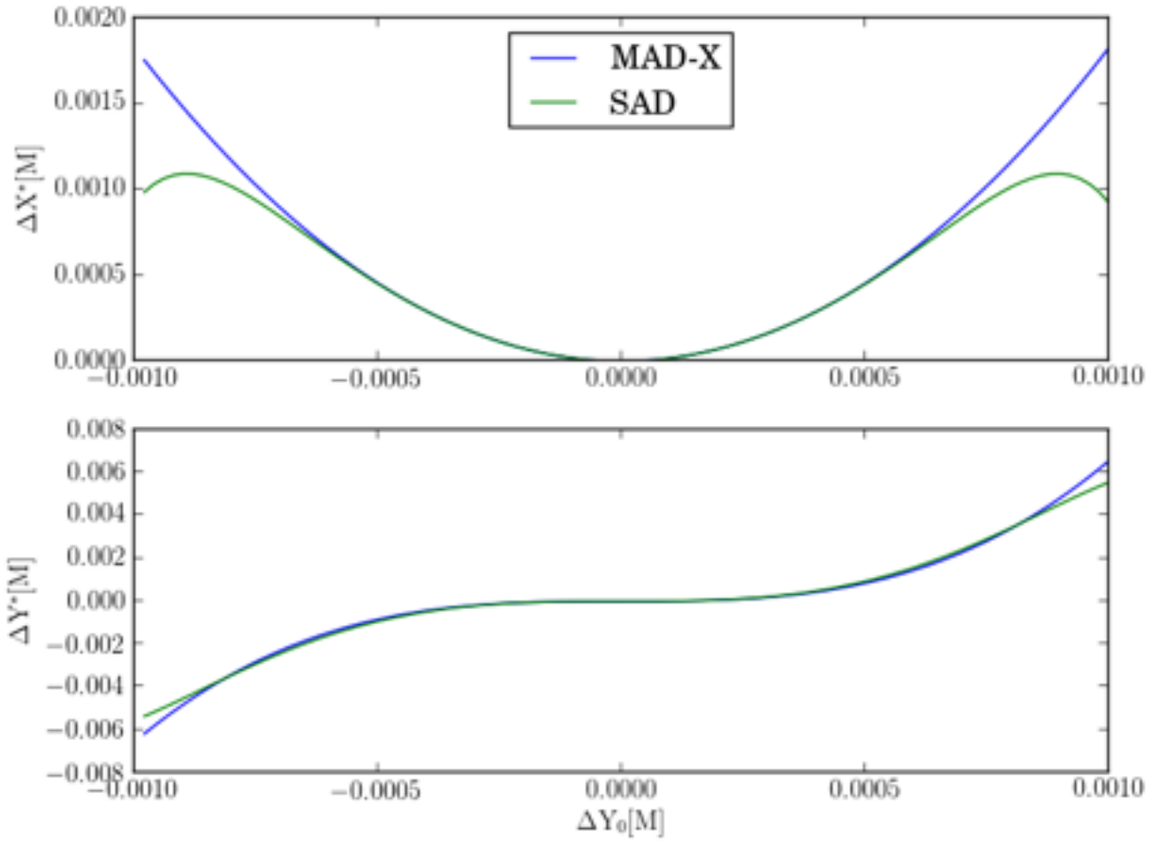
Courtesy of Paul Thrane

2. Current status

➤ A comparison of MAD-X and SAD: CLIC FFS

- Tracking: Coordinates at IP as a response to the initial offset (by Paul Thrane)
- Nonlinear transformations for normal components differ?
- Fringe field effects may make difference (my understanding)





Courtesy of Paul Thrane

2. Current status

➤ Lattice translation: SAD to MAD-X

- A translator written in SAD script is available, and used to publish FCC-ee lattices. To be extended (K. Oide)
- MULT element with Kn (n=1,2,…) superimposed by solenoid field is the most difficult (A. Morita). Not successful in the case of KEKB/ SuperKEKB
- Without solenoid field: mostly straightforward. Succeeded in FCC-ee (K. Oide)

➤ SAD manual is under preparation

- Not easy but should be available in 2017
- Requests from users are always welcome

3. SuperKEKB lattice translation

➤ Normal components

- If L=0, K_n(SAD)=K_n(MAD-X)
- If L≠0, K_n(SAD)=K_n(MAD-X)*L

➤ DRIFT

- SAD uses exact Hamiltonian/transformation for tracking
- MAD-X uses second-order map (?)
- Need extra MATRIX element for better approximation when the angle of the closed orbit is large. For large amplitude particles, this still has limitations

➤ BEND element

- BEND with ANGLE≠0 defines layout, equivalent to RBEND or SBEND in MAD-X
- BEND with ANGLE=0 but K_0≠0 works as a kicker or steering magnet. Hybrid component with K_0≠0 and K_n≠0(n≥1) need special treatment

3. SuperKEKB lattice translation

➤ Fringe fields

- Hard- (or Maxwellian fringe field) and soft-edge fringes (induce linear and nonlinear effects) are important in SuperKEKB
- Treatments of MAD-X are different from SAD
- PTC in MAD-X is similar to SAD but has tiny differences.

➤ SOL element

- Tilted with crossing angle
- Fringe fields
- Reference trajectory is aligned with the solenoid axis to simplify the transformation

➤ SAD MULT element

- Very general type: include field components of solenoid, multipole (K_0 to K_{21}, SK_0 to SK_{21}), fringes, and even RF fields.
- No equivalent element in MAD-X
- Very important in SuperKEKB (superimposed fields of detector solenoids, FF quads and others)

3. SuperKEKB lattice translation

➤ **Shift in longitudinal z coordinate of a particle**

- Automatically done in SAD to counteract a difference between the length of the reference orbit and the closed orbit
- Likely no similar treatment in MAD-X (?)

➤ **For phase-3 lattice (w/ IR)**

- D. Sagan tried SAD => Bmad => MAD-X
- Use MAD-X MATRIX element (contains nonlinear map in second order of phase space coordinates?) to approximate fringes and SAD MULT components
- Need PTC integrated into Bmad to construct the MAD-X MATRIX element

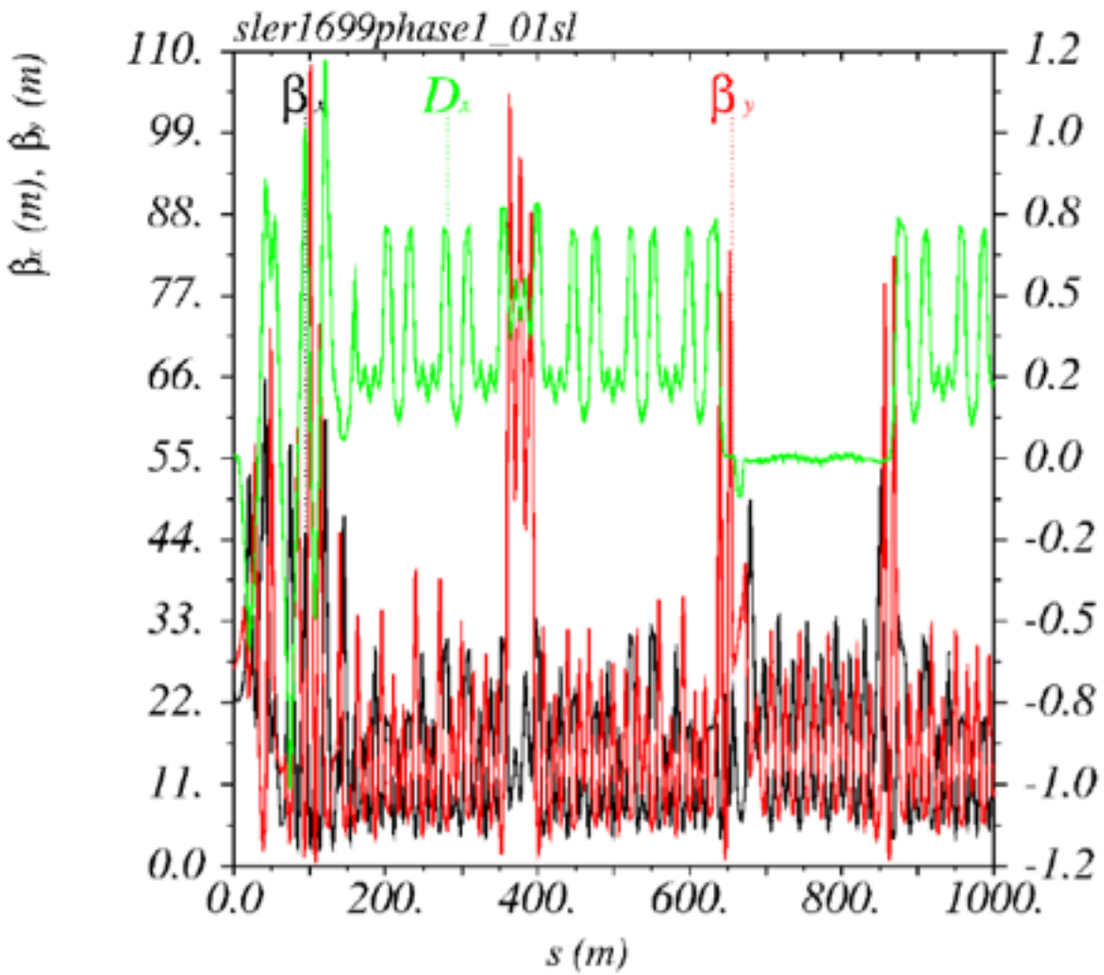
➤ **For phase-1 lattice (w/o IR)**

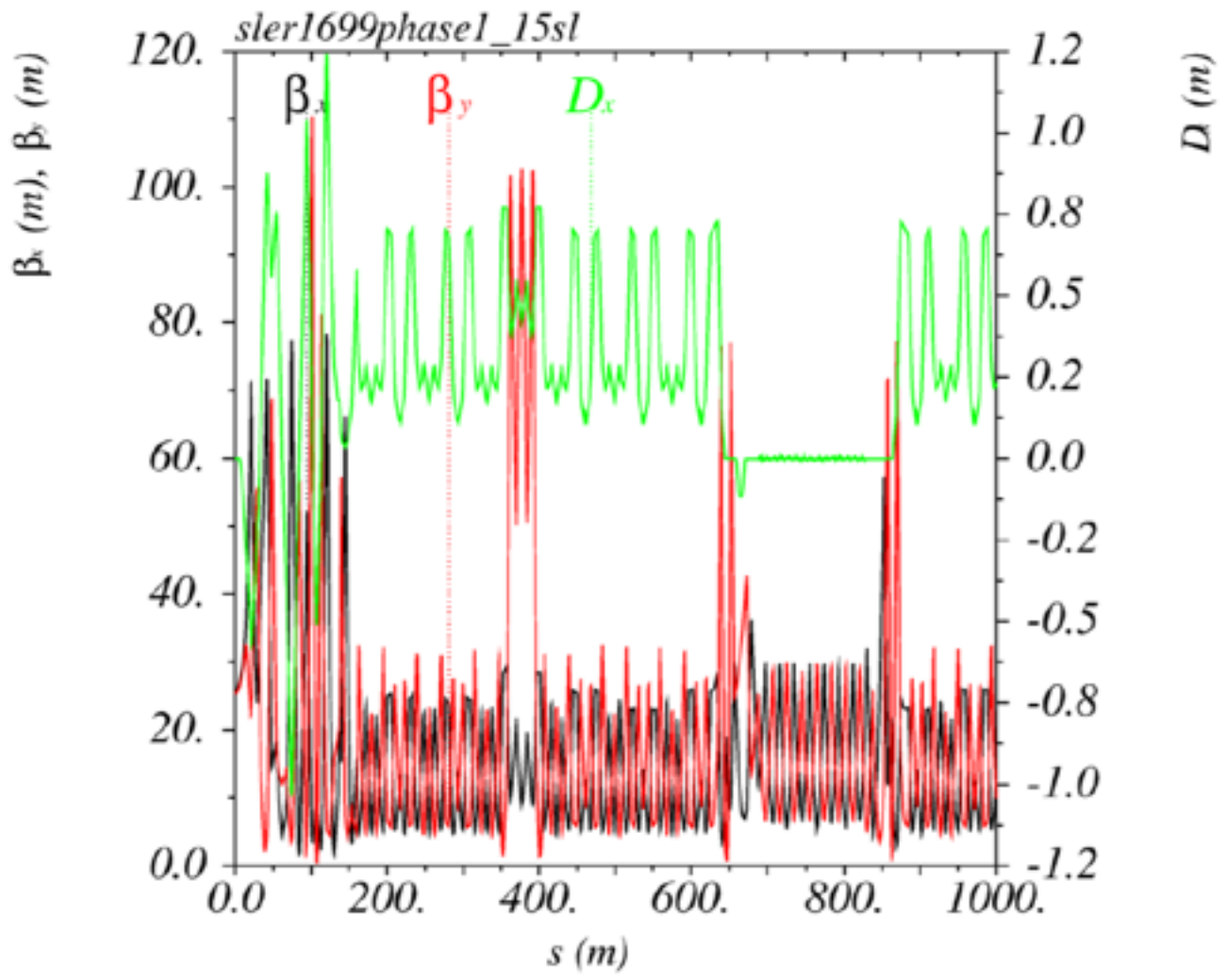
- S.M. Liuzzo(ESRF) tried SAD => AT => MAD-X
- Almost OK except treatment of quad soft-edge fields
- Direct SAD => MAD-X is possible (not tried yet)

3. SuperKEKB lattice translation

➤ MAD-X model of phase-1 lattice (w/o IR)

- Close to SAD
- Expected better agreement if quad soft-edge fringes included



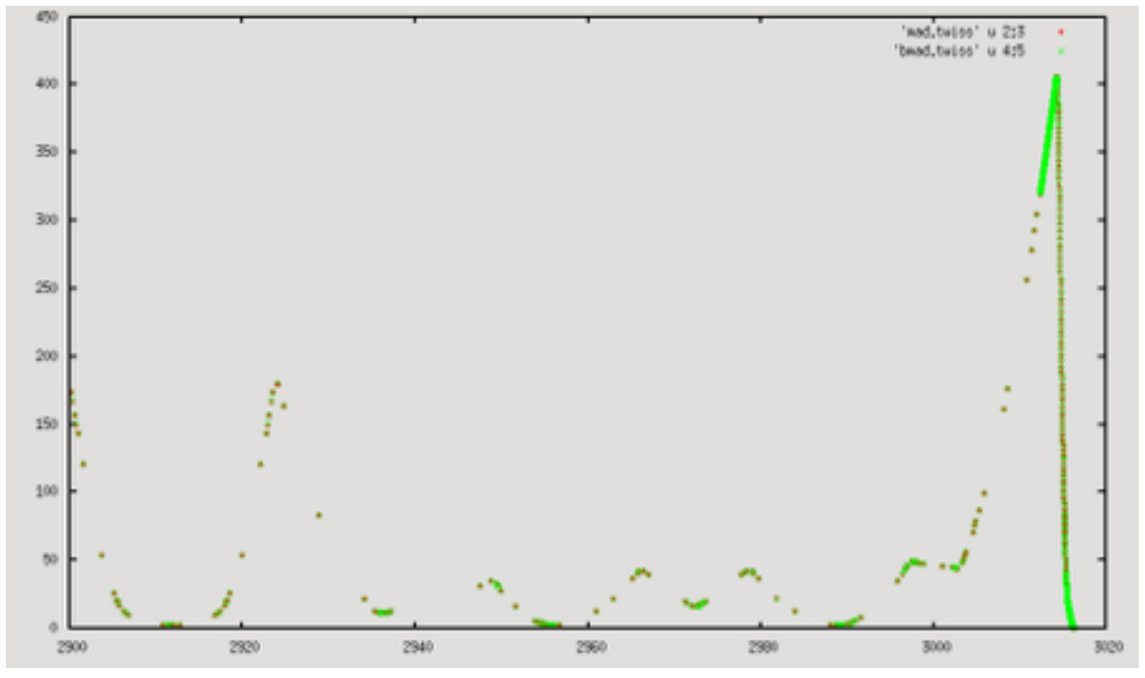


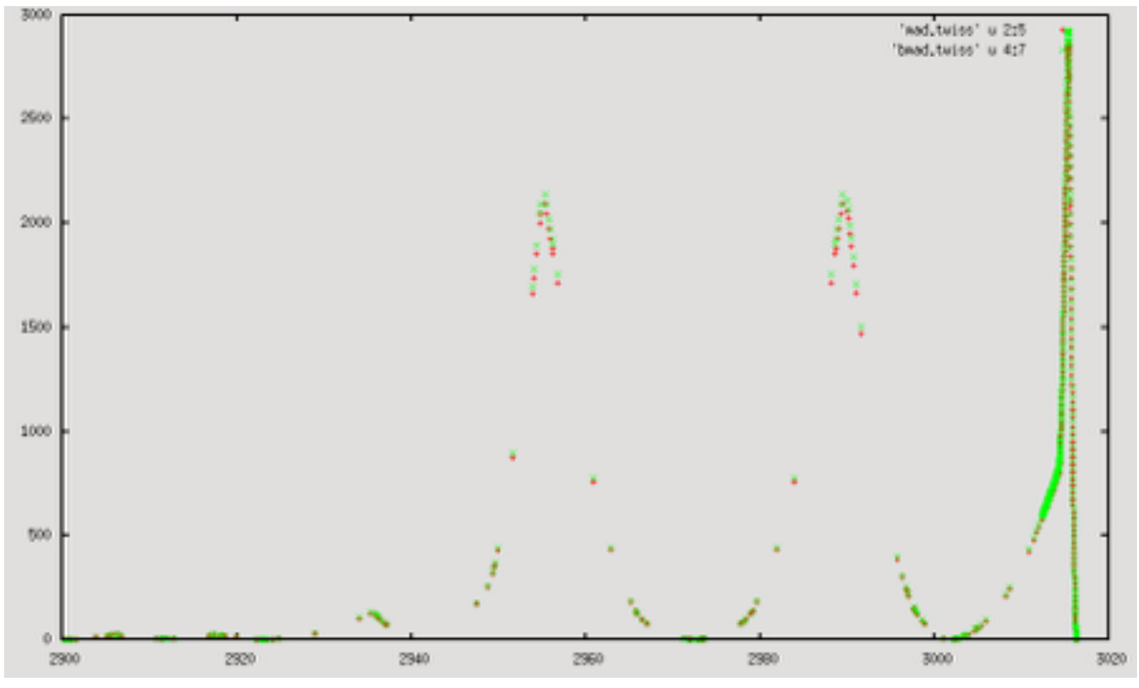
Courtesy of S.M. Liuzzo

3. SuperKEKB lattice translation

➤ MAD-X model of phase-3 lattice (w/ IR)

- Close to Bmad (≈SAD) as a beam line (not a ring)
- Not good for a ring to do optics tuning and advanced studies





Courtesy of D. Sagan and M. Biagini

4. Summary

➤ MAD-X <=> SAD lattice translation

- Multi-purpose: to support collaborations between labs (KEK, CERN, INFN, IHEP, etc.) on different projects (SuperKEKB, FCC-ee, CEPC, LHC, etc.)
- Undergoing smoothly
- Welcome requests and collaborators (Great for PhD candidates and postdocs to improve future communications)
- Need help from MAD-X experts for special elements (fringes, solenoid, etc.)

➤ SuperKEKB lattice translation

- Looks good w/o solenoid (except quad soft-edge fringes)
- Not satisfying w/ solenoid