Spin Rotator Design for the SuperKEKB High Energy Ring in a Proposed Polarization Upgrade

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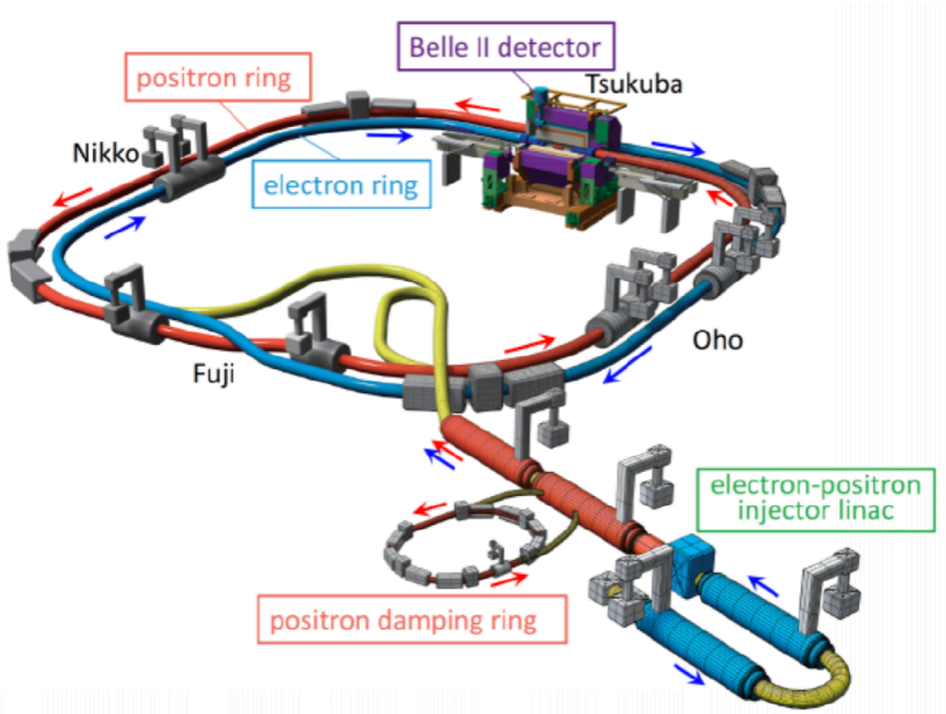
SuperKEKB

Location: Japan

Circumference: 3km



Collides 7 GeV electron – 4 GeV positron for precision flavour studies, CP violation, and searches for new physics beyond the Standard Model

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Purpose and Physics Motivation

Design a spin rotator for SuperKEKB High Energy Ring (Electron Ring), to polarize the spin of the electron beam in the longitudinal direction at the interaction point (IP)

- Study of asymmetry between the identical processes with different electron beam handedness, which provides high precision electroweak measurements (requires longitudinal polarization at the IP)

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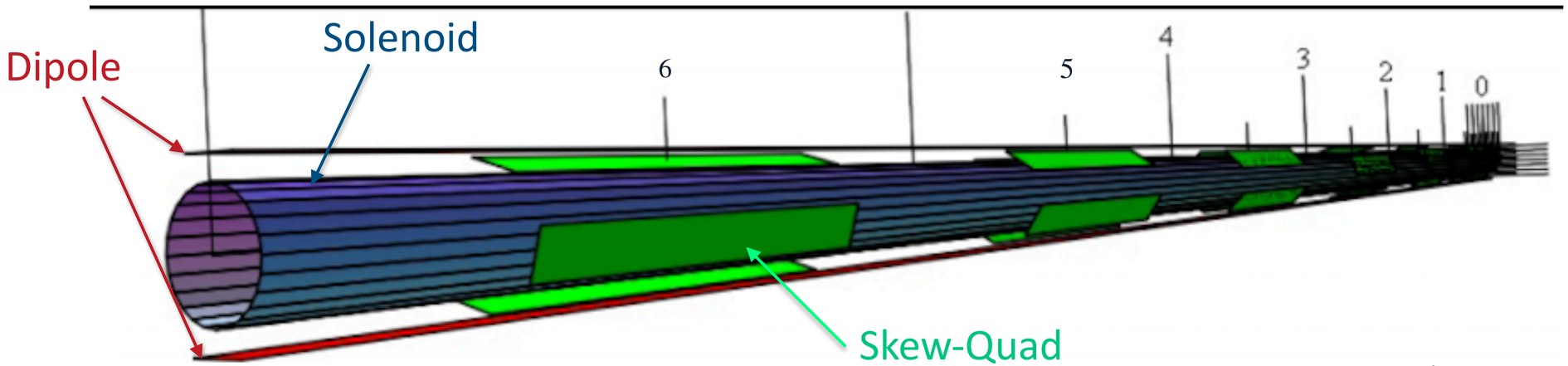
Rotator Magnet

Follows Uli Wienands's idea (at Argonne National Laboratory):

- Replace some existing ring dipoles near the IP with the solenoid-dipole combined function magnets and maintain the original dipole strength
- Install 6 skew-quadruple on top of each rotator section to compensate for the x-y plane coupling caused by solenoids



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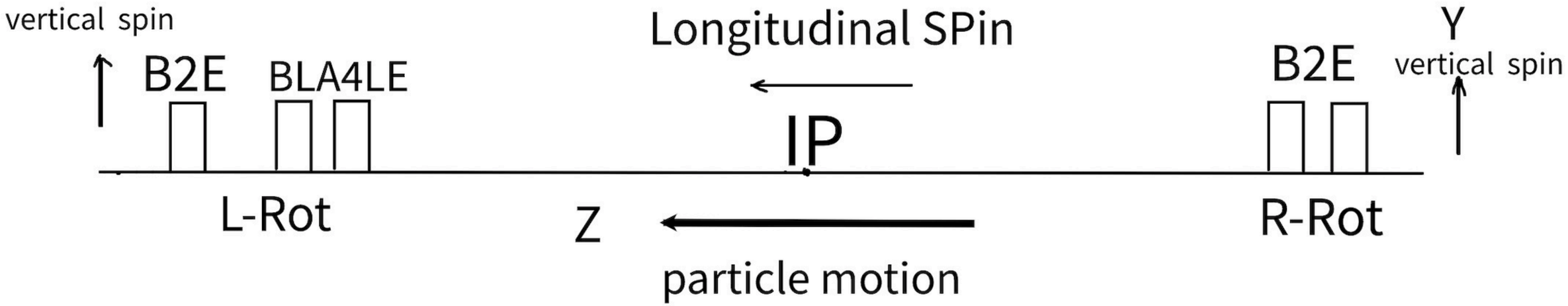
Spin rotator Structure



Right rotator is to rotate the vertical spin to the longitudinal direction

Left rotator is to rotate the longitudinal back to vertical

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Constraints of the Design

- **Transparency**: Need to maintain the original **beam dynamics,** make the spin rotator transparent to the ring as much as possible

- Physical constraints: All new magnets must be manufacturable and installable

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Simulation Tool

- **Bmad** is an open-source software library created/maintained by David Sagan at Cornell University for simulating charged particles and X-rays, also allows full tracking studies for the lattice

- Optimization Algorithm: **LMDIF** is to minimize the sum of the squares of nonlinear functions by a modification of the Levenberg-Marquardt algorithm

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Procedure of Design and Maintaining Transparency

- Design:
  - Find the appropriate dipoles to replace
  - Fit the strength of solenoids
- Transparency:
  - Decouple the x-y plane with skew quads
  - Rematch the optics by tuning ring quads near/in the rotator region
  - Tune the chromaticity with ring sextupoles
  - Maintain Tune value Q

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Current status

The BMAD simulation shows the rotator is working properly

- The longitudinal spin alignment at the IP is achieved
- Transparency is guaranteed

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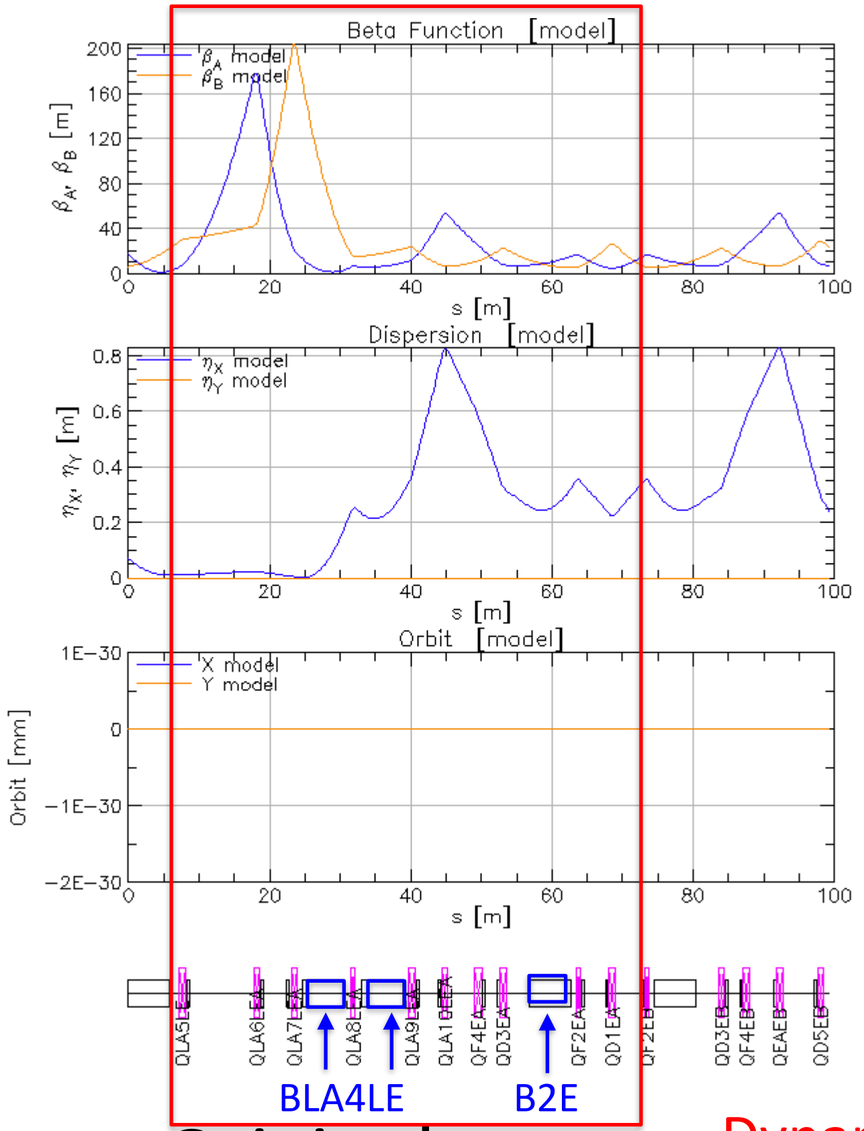
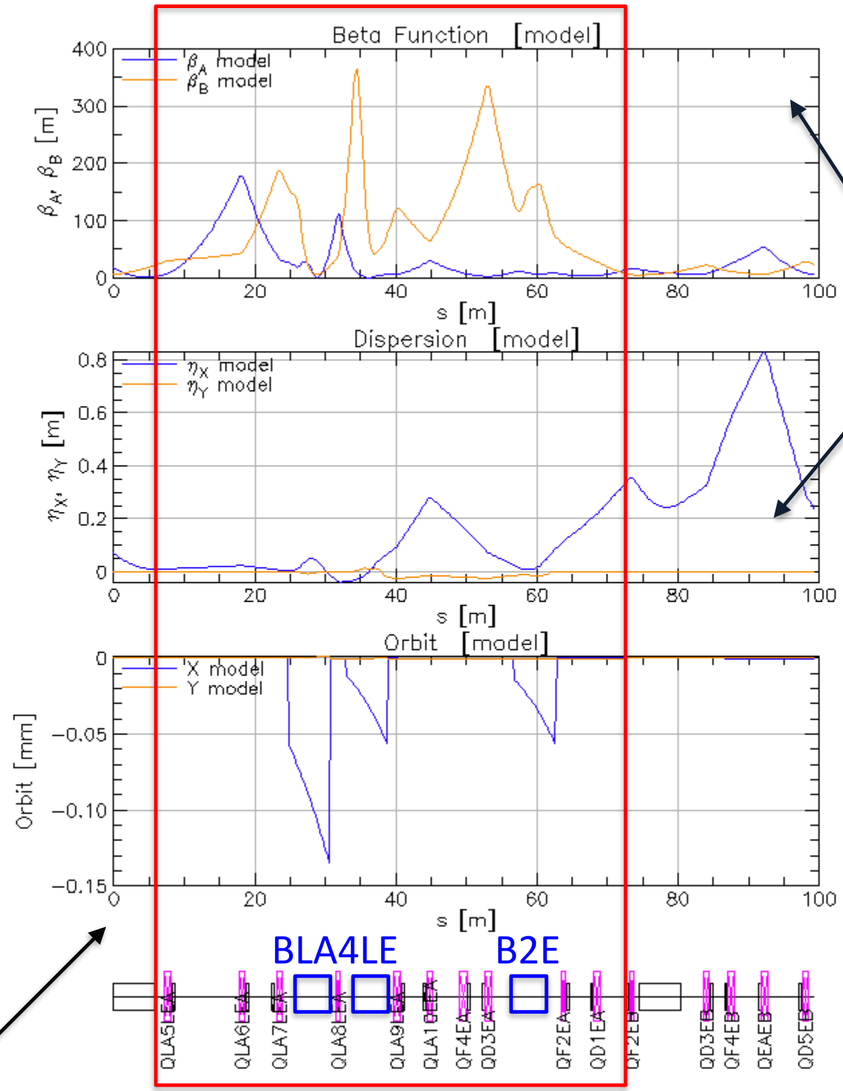
Lattice Comparison at L-Rot Tuning Region



Original

Dynamics changed



L-Rot

Outside the red box, dynamics maintained as the original

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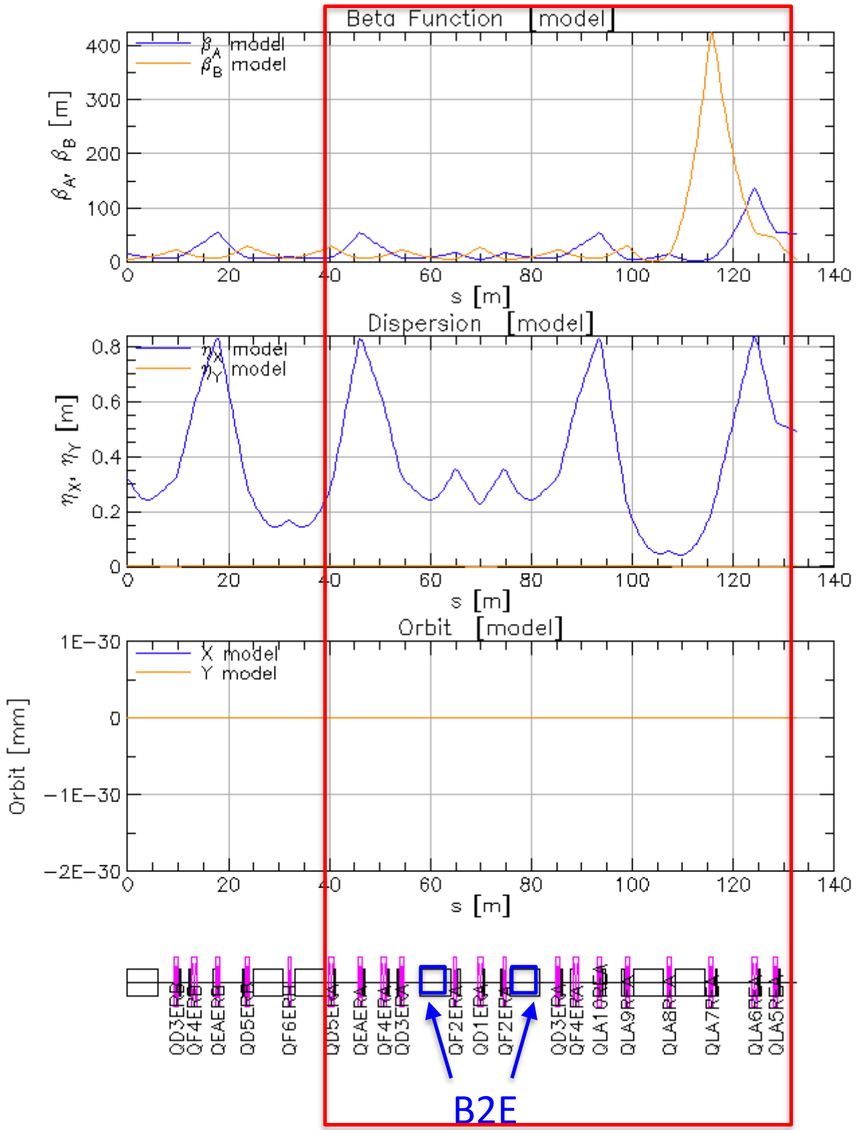
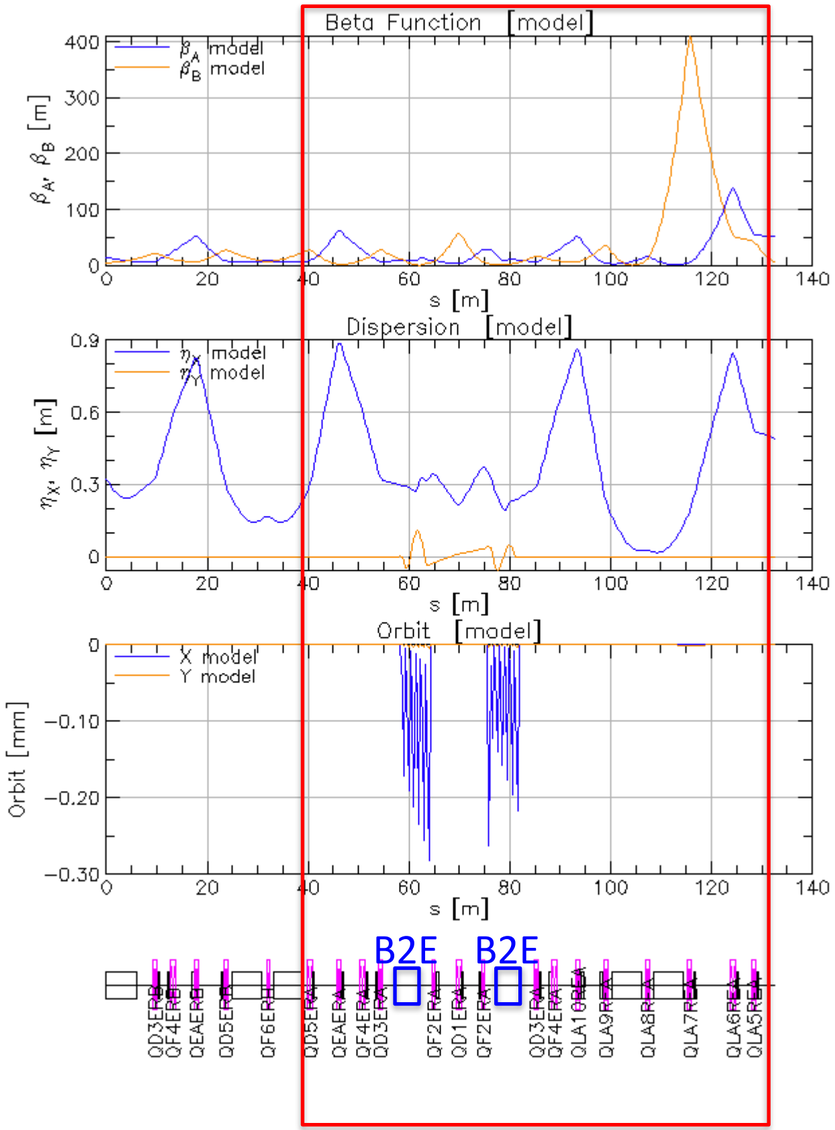
Lattice Comparison at R-Rot Tuning Region



Original



R-Rot

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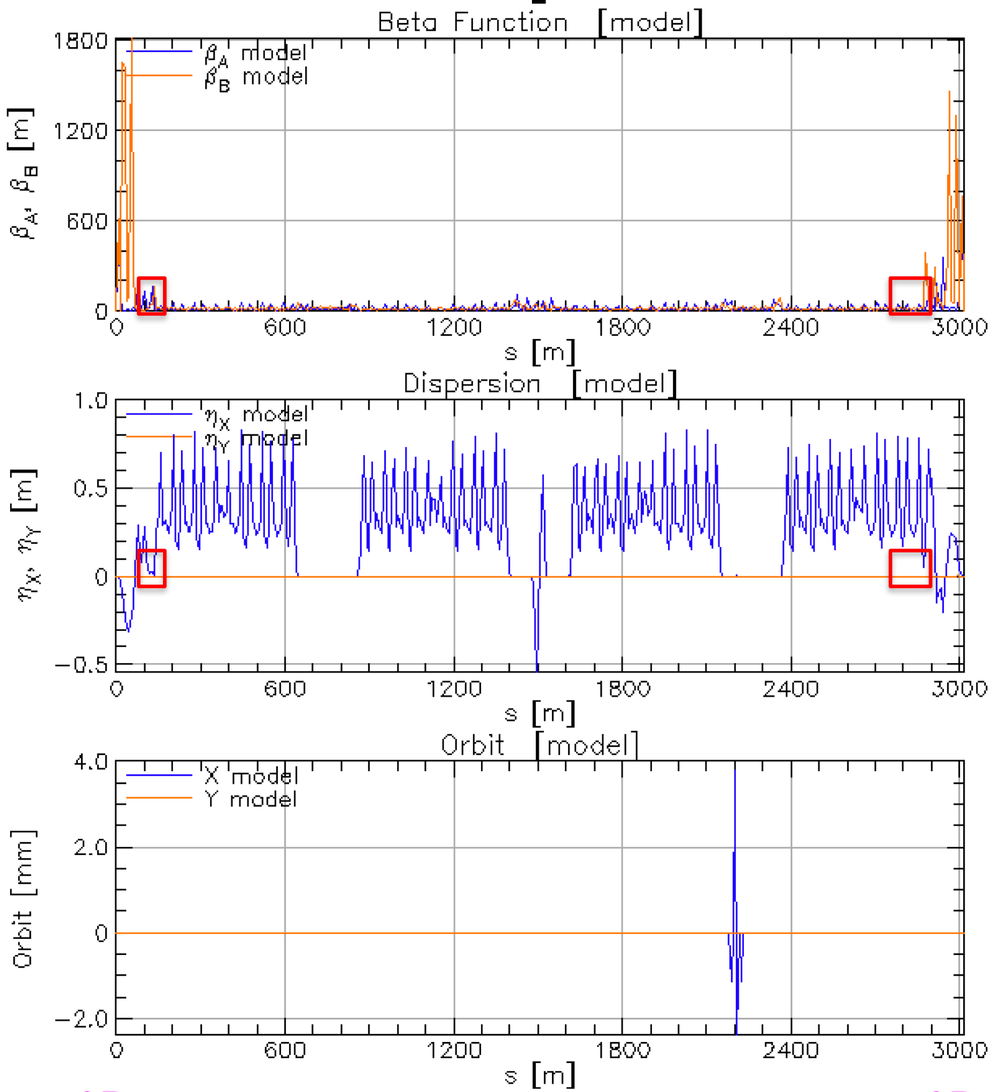
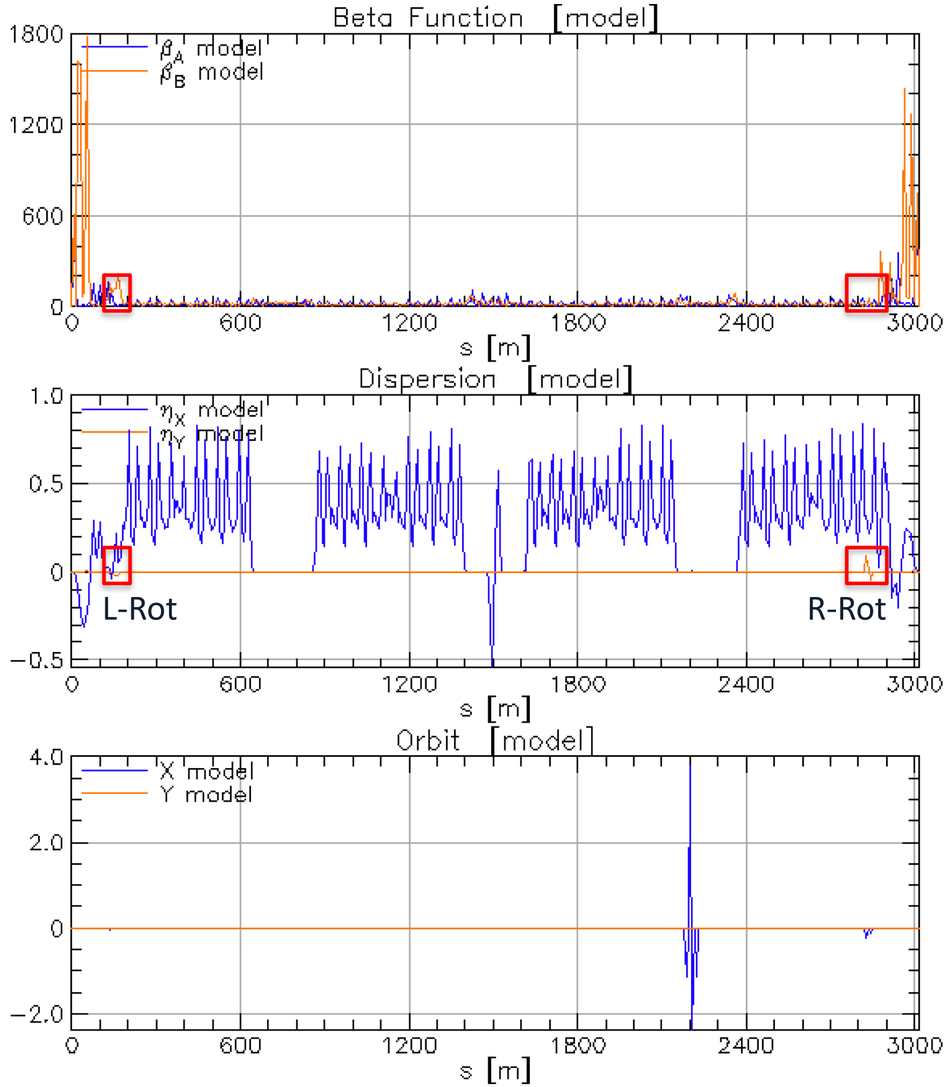
Comparison of full-lattice



IP

Original

IP



Rotator Installed

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Longitudinal spin alignment

- The spin track result shows a longitudinal spin alignment >99.99% with the rotator installed in the High Energy Ring

Spin Component	Spin at the entrance of the Rotator	Spin at the IP	Spin at the exit of the Rotator
X	0.00139185	0.00094458	−0.00284127
Y	**0.99999508**	−0.00115044	**0.99999508**
Z	0.00281270	**0.99999889**	−0.00133075

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Future Steps

- Do the multi-turn beam tracking with BMAD to figure out beam lifetime, and maintain the Tune value Q
- Modify the design if beam lifetime does not meet the expectation

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