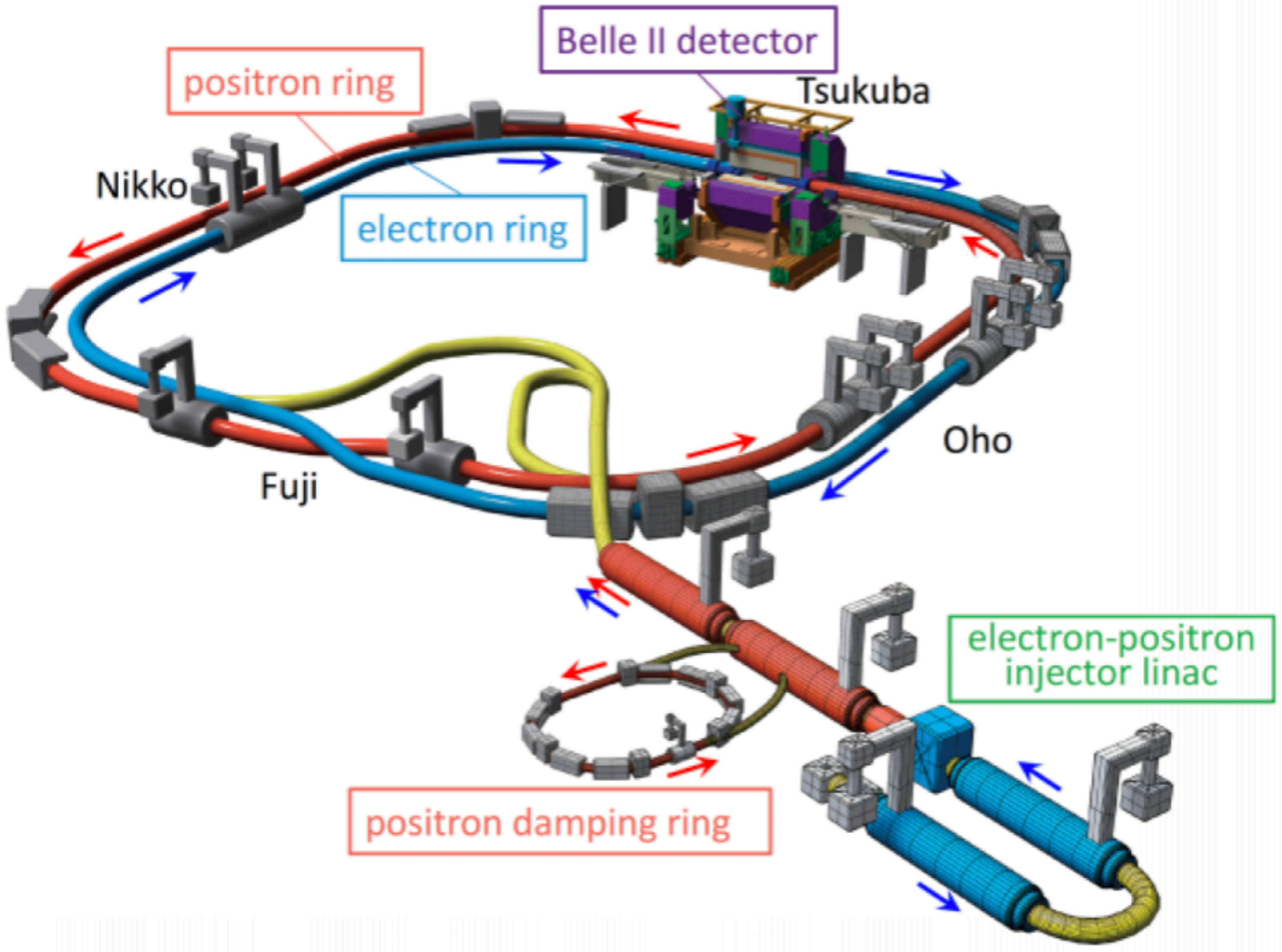
Spin Rotator Design for SuperKEKB HER



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Outline

- Quick review of the previous work and corresponding unsolved problem
- Modification of right rotator design
- Comparison between the old and new design
- Future Steps

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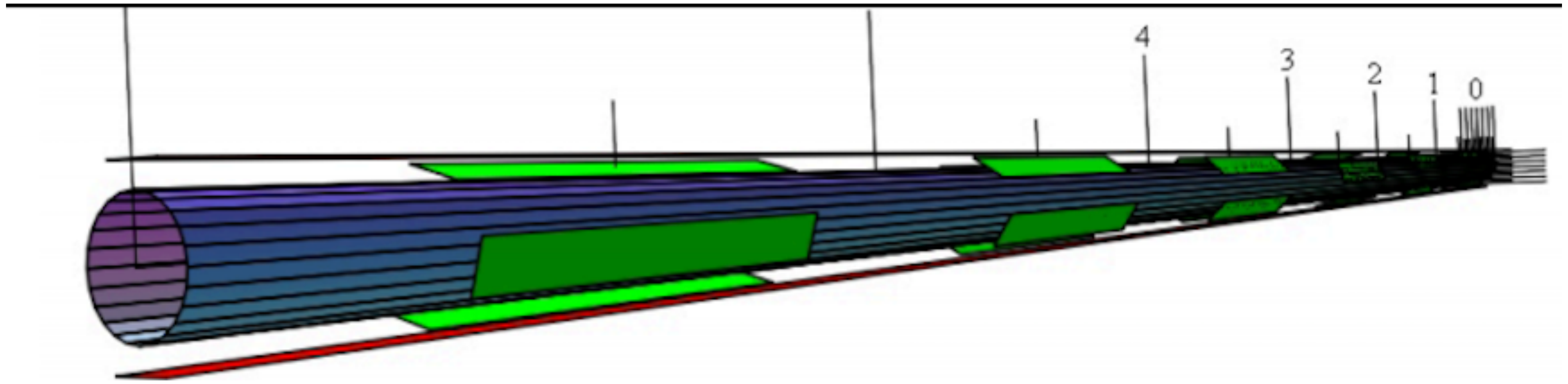
Rotator Design

- Design spin rotator for the High Energy Ring to longitudinally polarize the electron beam at the interaction point (IP)

- Following Uli Wienands's design, use dipole-solenoid overlapping fields to replace existing dipoles in the ring with extra 6 skew-quads on top of each section to decouple the plane caused by solenoids



- Constrain: Transparency

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Fitting Procedure

Simulation tool: Bmad (details show in Appendix)

- Choose ring dipoles on both sides of the IP to install the rotator
- Find the solenoids strength for rotator
- Decouple the plane with skew quads
- Use ring quads to rematch the optics
- Apply the slice Model
- Put the full rotator into the ring and do sanity check
- Tune the Chromaticity with the Sextupole

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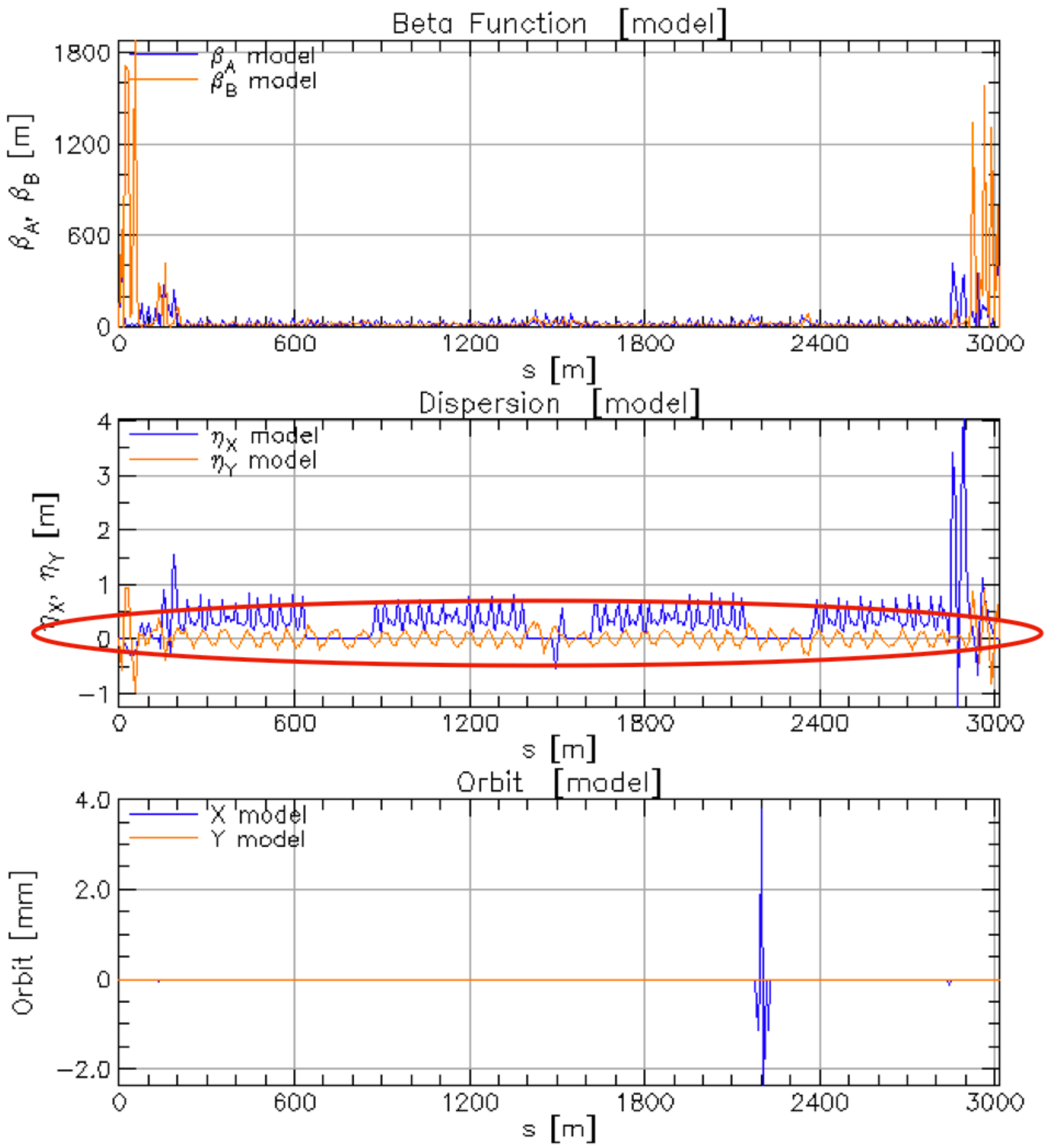
Unsolved Problem



- Vertical dispersion is too big which creates large vertical emittance

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Basic Idea of the Solution

- Modify the design of right rotator, choose different dipoles as the rotator magnets

- In new design, the weaker solenoids, skew-quads, the less change of optical functions will be

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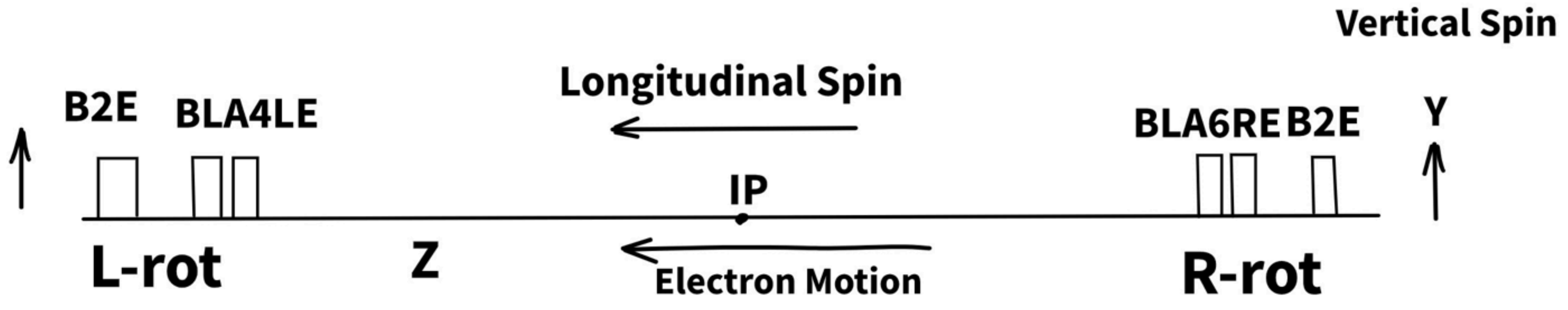
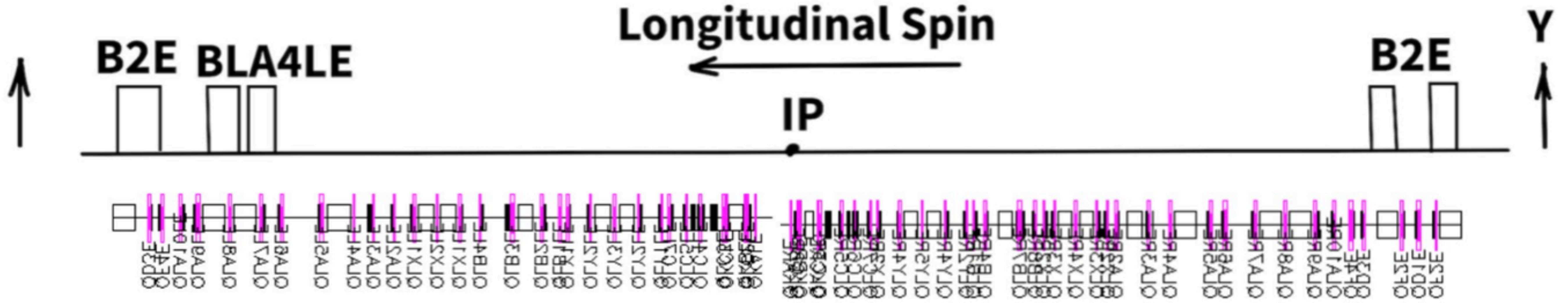
Modification of the design



- Old design



- New design

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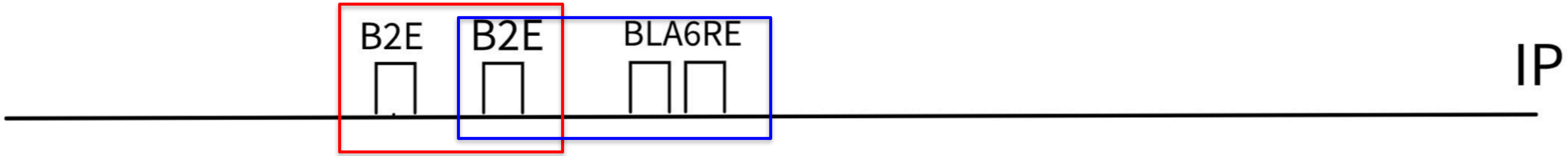
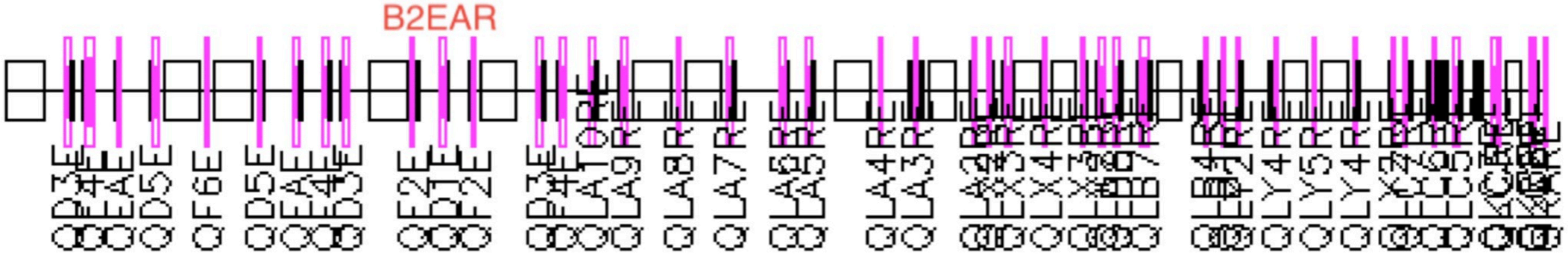
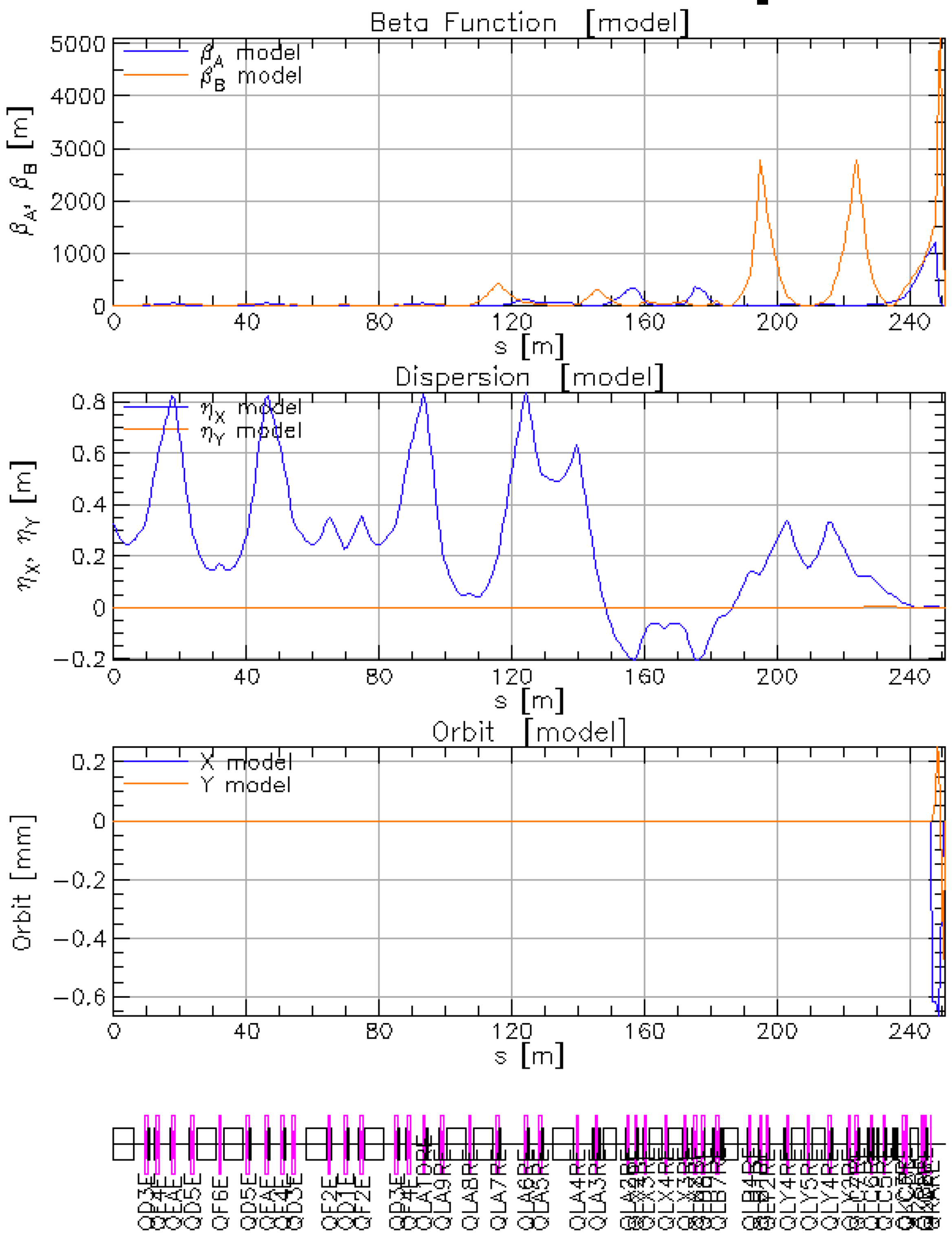
Details of modification



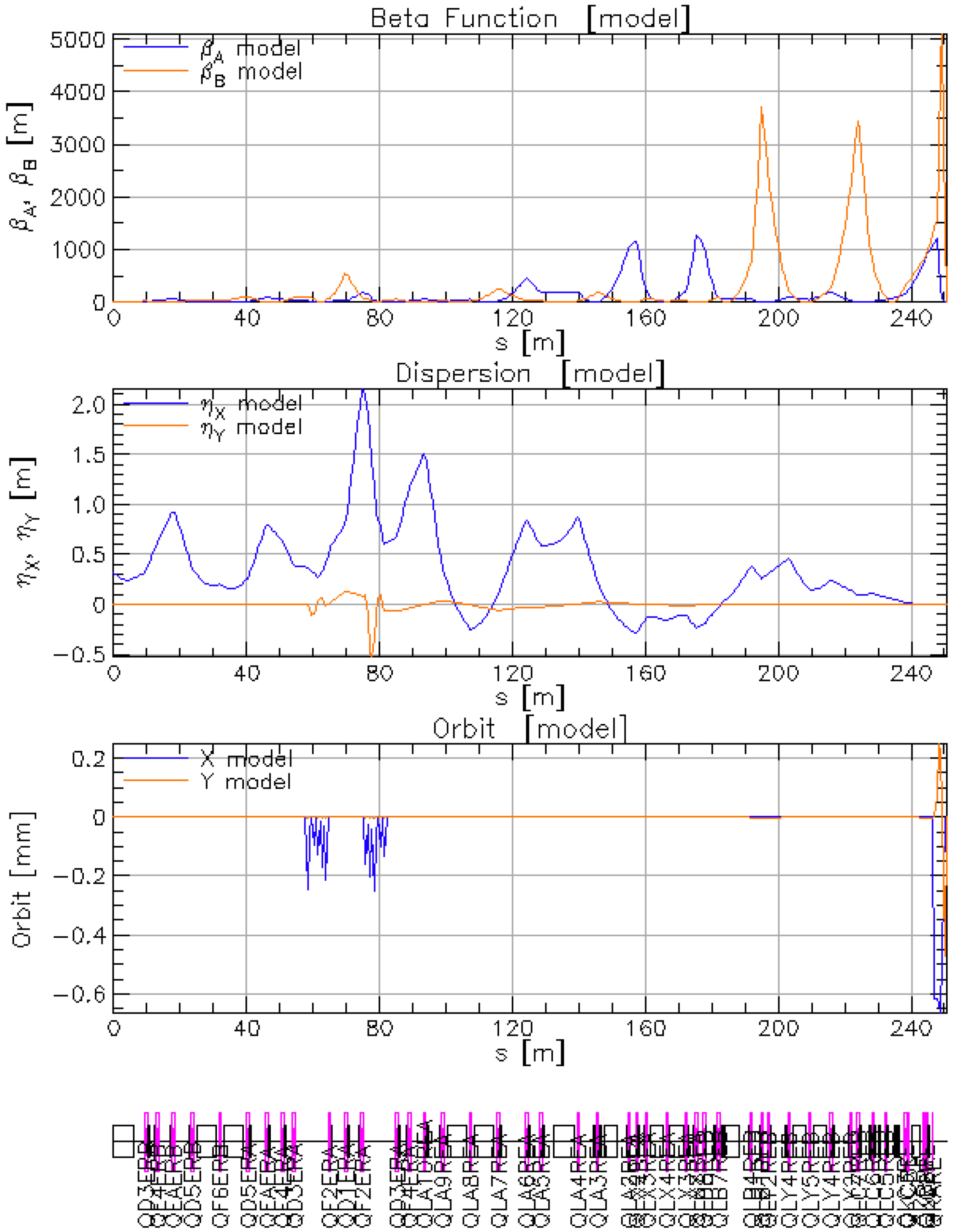


Solenoid	Old design	New design
B2E:	-5.77 T	-3.78 T
BLA6RE:	3.57 T	0 T

Optical Rematch



original



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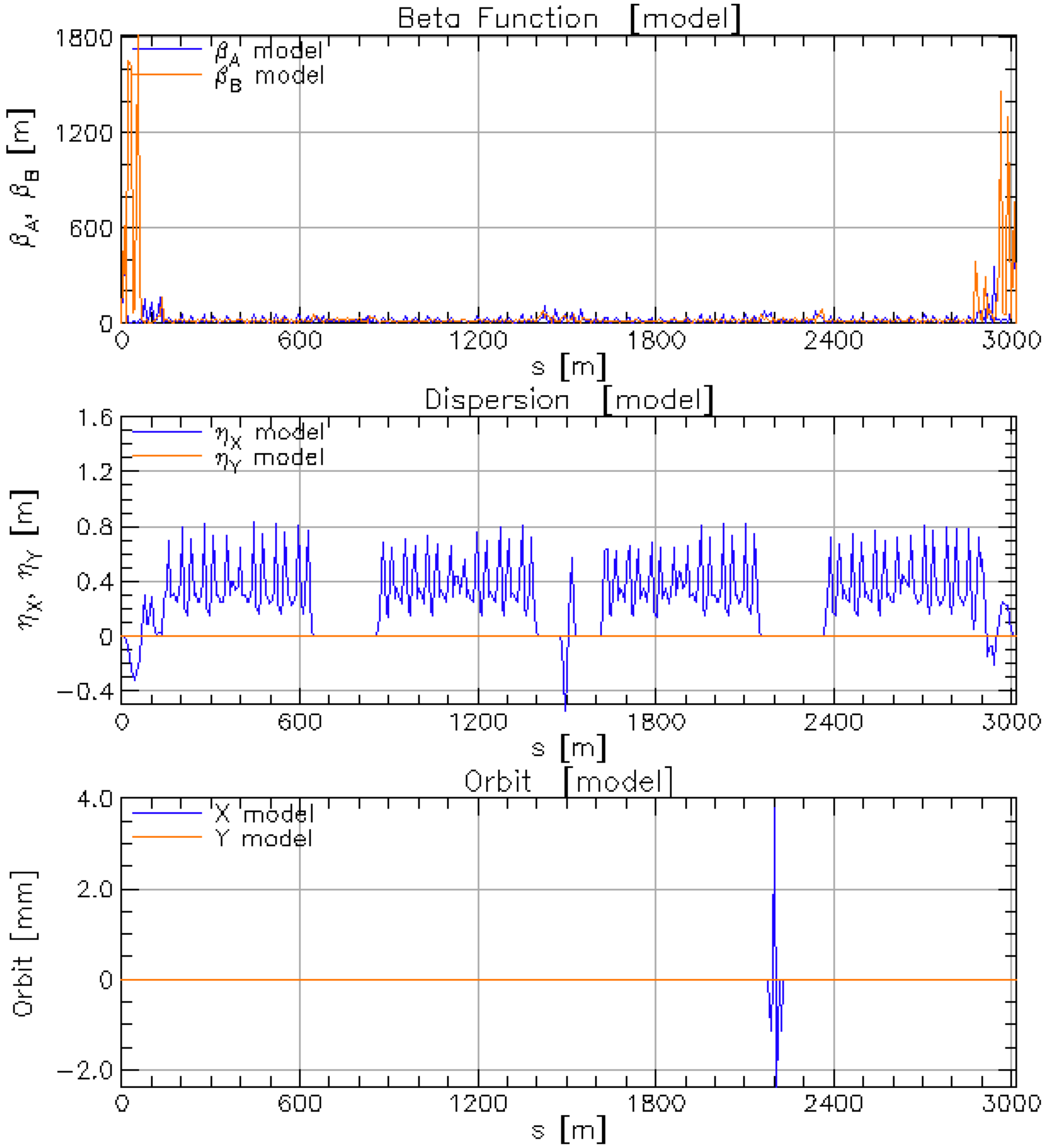
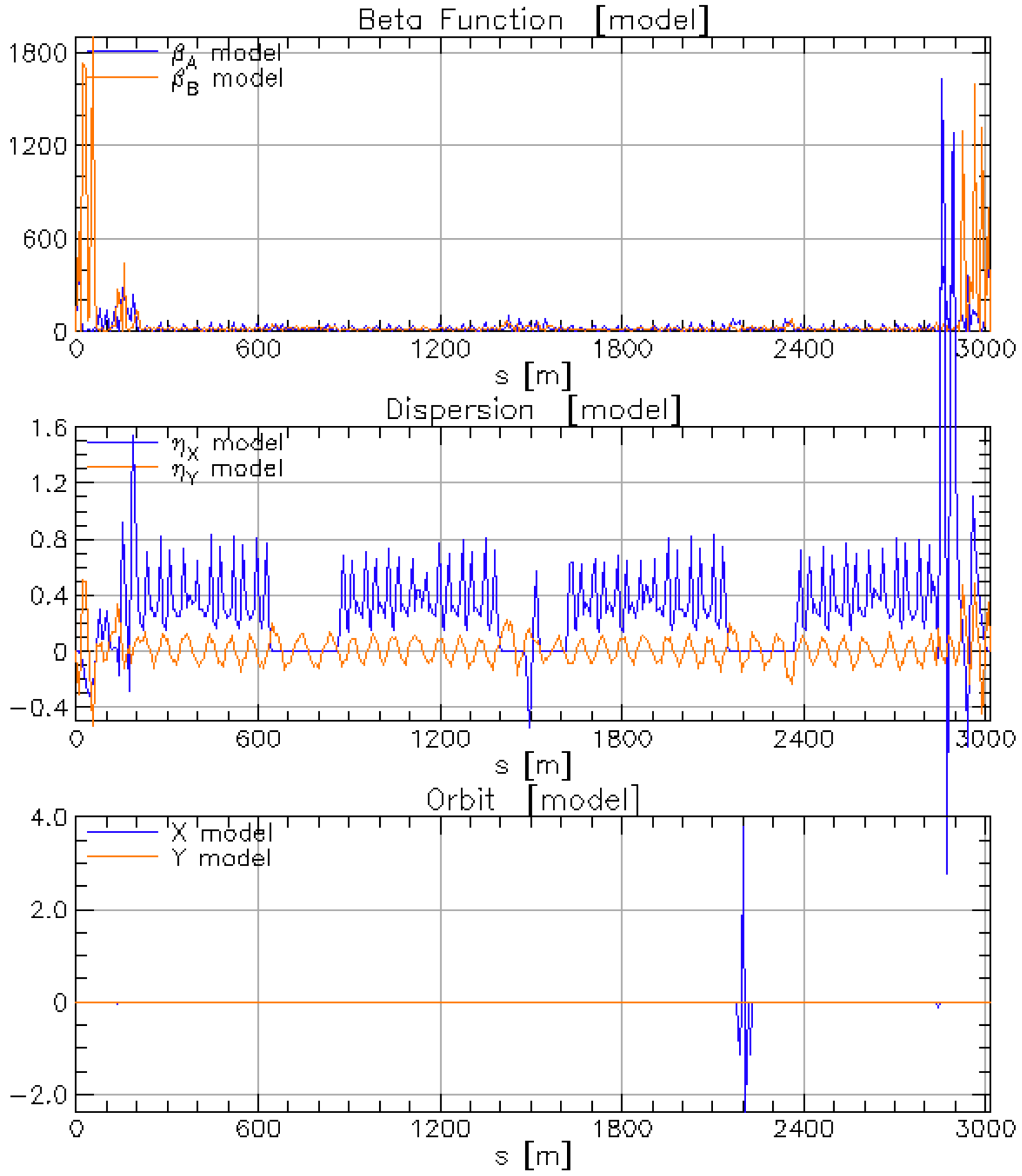
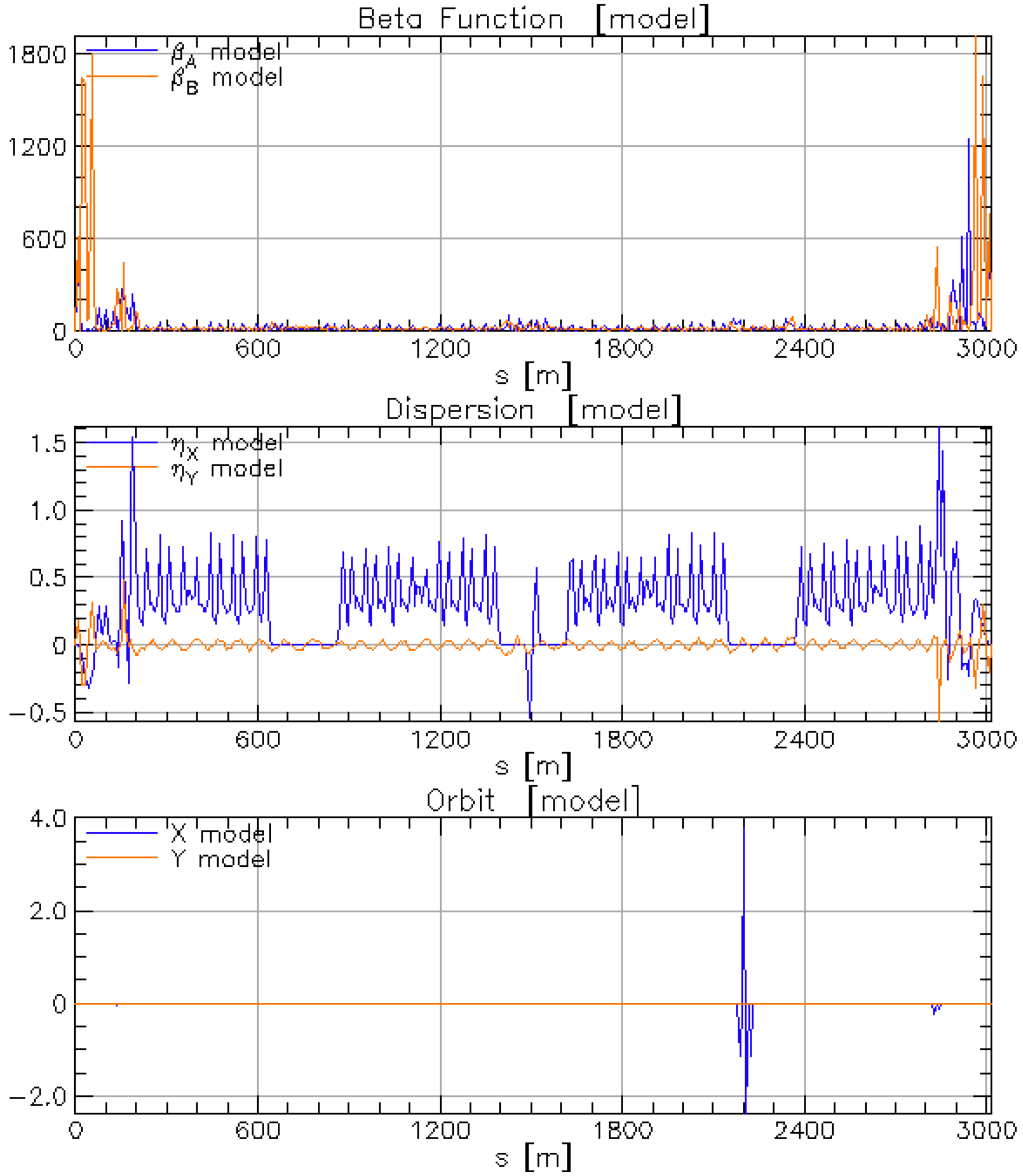
Full lattice Comparison



original



old rot



new rot

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Spin direction at the IP

- Old design

	Spin
X:	-0.09132510
Y:	0.13826504
Z:	0.98617570

- New design

	Spin
X:	0.00236735
Y:	-0.00186309
Z:	0.99999546

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Important properties of the Lattice/Beam

	X Model	X Design	Y Model	Y Design	
Q	45.529986	45.529986	43.569032	43.569032	! Tune
Chrom	3.953515	3.953515	6.595477	6.595477	! dQ/(dE/E)
J_damp	1.000065	0.999667	1.001851	1.001851	! Damping Partition #
Emittance	4.43516E-09	4.43705E-09	1.87884E-12	1.87783E-12	! Meters

- Original full-lat

	X Model	X Design	Y Model	Y Design	
Q	46.596972	46.596972	45.203369	45.203369	! Tune
Chrom	18.733235	18.733326	302.129135	302.129190	! dQ/(dE/E)
J_damp	2.338819	2.313369	0.981808	0.975191	! Damping Partition #
Emittance	4.58538E-09	4.64867E-09	1.58275E-10	1.45140E-10	! Meters

- Full lat with rot without sextupole tuning

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Conclusion So far…

- The new design successfully reduces the vertical dispersion but still need to improve

- The new design reaches higher spin alignment at the IP

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Next Steps

- Further reduce the vertical dispersion/emittance
- Horizontal damping partition larger than 2, needs to be addressed
- Tune the chromaticity with sextupole

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Appendix

- Bmad is an open-source software library created/maintained by David Sagan at Cornell University (aka toolkit) for simulating charged particles and X-rays. (https://www.classe.cornell.edu/bmad/manual.html)

- The disadvantage of Bmad is that, as a toolkit, one cannot perform any calculations without first developing a program.

- Tao is a user friendly interface to Bmad which gives general purpose simulation, based upon Bmad. Tao can be used to view lattices, do Twiss and orbit calculations, nonlinear optimization on lattices

- 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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Patch

- Bmad has solen-quad combined function magnet but does not have solen-dipole-quad combined function magnet
- Following the idea of David Sagan, we use the hkick to simulate the dipole
- The hkick is not in the co-moving coordinate
- Use patch to do the orbit correction(x’, x, y, y’), which is not physical

```
                          X              |               Y
               Model        Design       |      Model        Design
         Q   45.529986    45.529986         43.569032    43.569032   ! Tune
     Chrom    3.953515     3.953515          6.595477     6.595477   ! dQ/(dE/E)
    J_damp    1.000065     0.999667          1.001851     1.001851   ! Damping Partition #
 Emittance  4.43516E-09  4.43705E-09      1.87884E-12  1.87783E-12   ! Meters
Alpha_damp  1.78625E-04  1.78554E-04      1.78944E-04  1.78944E-04   ! Damping per turn
        I4 -4.82222E-06  2.45310E-05     -1.36511E-04 -1.36510E-04   ! Radiation Integral
        I5  4.53913E-06  4.53925E-06      1.90717E-09  1.90614E-09   ! Radiation Integral
I6/gamma^2                                8.09897E-11  8.09820E-11   ! Radiation Integral

               Model        Design
   Z_tune:  -0.0000000    0.0281617     ! The design value is calculated with RF on
  Sig_E/E:  6.42414E-04  6.42350E-04
  Sig_z:    1.00000E+30  4.97739E-03    ! Only calculated when RF is on
Energy Loss: 2.50319E+06  2.50319E+06   ! Energy_Loss (eV / Turn)
   J_damp:  1.99808E+00  1.99848E+00    ! Longitudinal Damping Partition #
Alpha_damp: 3.56884E-04  3.56955E-04    ! Longitudinal Damping per turn
  Alpha_p:  4.54454E-04  4.54462E-04    ! Momentum Compaction
      I0:   9.87010E+04  9.87025E+04    ! Radiation Integral
      I1:   1.37078E+00  1.37080E+00    ! Radiation Integral
      I2:   7.37417E-02  7.37417E-02    ! Radiation Integral
      I3:   8.43876E-04  8.43876E-04    ! Radiation Integral
Spin Tune:  9.77416E-02  9.77416E-02    ! Spin Tune on Closed Orbit (Units of 2pi)
    <pz>:   0.00000E+00  0.00000E+00    ! Average closed orbit pz (momentum deviation)
```

Original full lattice

```
                          X               |              Y
                Model         Design      |      Model         Design
          Q    46.596972     46.596972          45.203369     45.203369   ! Tune
      Chrom    18.733235     18.733326         302.129135    302.129190   ! dQ/(dE/E)
     J_damp     2.338819      2.313369           0.981808      0.975191   ! Damping Partition #
  Emittance  4.58538E-09   4.64867E-09        1.58275E-10   1.45140E-10   ! Meters
 Alpha_damp  4.17653E-04   4.13083E-04        1.75326E-04   1.74133E-04   ! Damping per turn
         I4 -9.87053E-02  -9.68229E-02        1.34119E-03   1.82893E-03   ! Radiation Integral
         I5  1.09727E-05   1.10024E-05        1.58972E-07   1.44783E-07   ! Radiation Integral
 I6/gamma^2                                   9.03384E-11   1.02214E-10   ! Radiation Integral

                Model         Design
    Z_tune:   -0.0000000     0.0287592    ! The design value is calculated with RF on
   Sig_E/E:  1.10169E-03   1.07656E-03
   Sig_z:    1.00000E+30   8.26649E-03    ! Only calculated when RF is on
Energy Loss: 2.50265E+06   2.50249E+06    ! Energy_Loss (eV / Turn)
    J_damp:  6.79373E-01   7.11440E-01    ! Longitudinal Damping Partition #
Alpha_damp:  1.21319E-04   1.27037E-04    ! Longitudinal Damping per turn
   Alpha_p:  4.45745E-04   4.46274E-04    ! Momentum Compaction
        I0:  9.86892E+04   9.87039E+04    ! Radiation Integral
        I1:  1.34451E+00   1.34610E+00    ! Radiation Integral
        I2:  7.37256E-02   7.37210E-02    ! Radiation Integral
        I3:  8.43653E-04   8.43585E-04    ! Radiation Integral
 Spin Tune: -1.84481E-01  -1.84481E-01    ! Spin Tune on Closed Orbit (Units of 2pi)
      <pz>:  0.00000E+00   0.00000E+00    ! Average closed orbit pz (momentum deviation)
```

full lat with full-rot