Spin Rotator ***Slice Studies***

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University of Victoria

Wrapping up FMA

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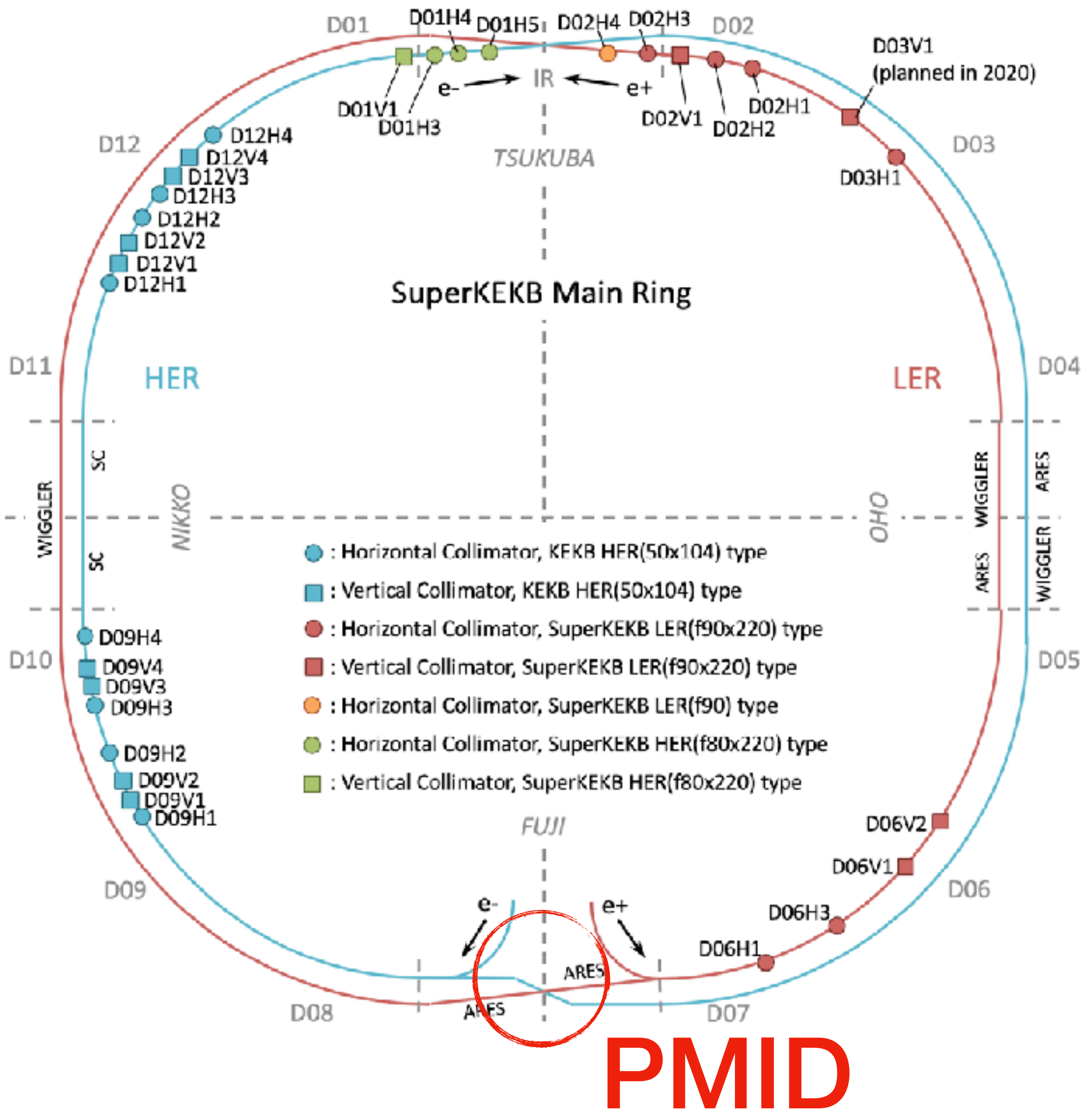
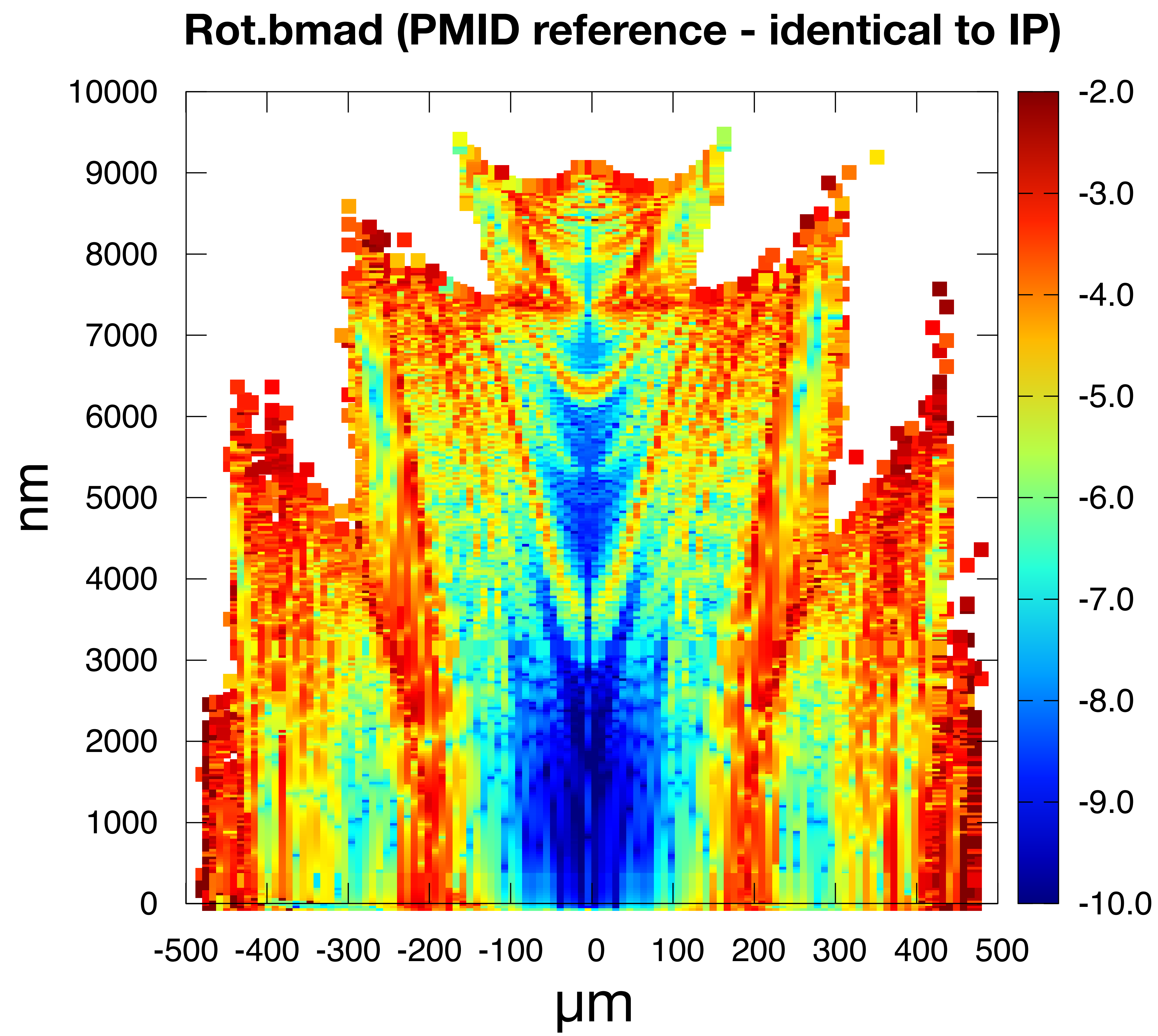


- Some people voiced concerns about the shape of the FMA, and what the reference point should be
  - Demin suggested trying FMA studies at PMID
  - BMAD doesn't let you easily change the reference point, but you can change the order of the lattice such that element 0 is PMID

Wrapping up FMA



- No difference with using PMID
  - Difference in software?

LTT - Reconstructing the Rotator

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- We are testing the stability of the Spin Rotator, and whether or not the loss of particles is due to Bmad's modelling
  - Yuhao has already done 24 slice and 96 slice model
  - I will be checking 120, 144, and 192 to see if the particle loss diminishes with the number of slices
- Checked how optimizer fits floor coordinate data corrections to the number of slices and plotted

Roadmap

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Step	Tuning Parameters	Constraints	Progress
OPEN GEOMETRY		Stay within operational limits of magnets	
1. fit for hkicks describing rot region dipoles	hkick value	x-orbit	Lrot and rrot
	patch	floor	72, 96, 120, 144, 192, validation
2. fit for Sol field	Sol field	spin at exit of L-rot region and exit of R-rot region	Could not optimize 192
with hkicks on & sq quads off	hkick	x-orbit	Lrot and rrot
	vkick	y-orbit	72, 96, 120, 144, validation
3. fit for squew-quad fields and tilt angles	squew quad field (k)	x-y coupling matrix off-diagonal = 0	Could not optimize 192
with hkicks on, Sol field on	tilt angle ('skew angles')	i.e. C matrix = 0	Lrot and rrot
to get rid of x-y coupling	hkick	x-orbit	validation
	vkick	y-orbit	
		beta function reasonable when both L-rot and R-r	Tighter restrictions on k1 and tilt.
4. rematch beta,alpha, dispersion, orbit - all i	Local Ring quad strength	beta, alpha, orbit, dispersion same as HER	
at exit of L-rot region and R-rot Region	squew quad strengths in L-rot and	at exit of L-rot region and R-rot Region	
		C=0 at exit	Done validation
CLOSED GEOMETRY			
		Stay within operational limits of magnet	
5. rematch Tunex, Tuney	NICO quads	Tunex and Tuney same as in HER	
6. rematch Chromaticity	set of ring sextupoles in ARC regior	Chromaticity same as in HER	Done validation

Overview of Slice Model:

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- Each half of the Spin Rotator tested in the design contains 6 magnets, which are each subdivided into slices of magnet and patches
    - The slices subdivide the magnet into components of equal length and magnetic field strength
    - The patches correct the horizontal and vertical position of the particle within the overall sliced spin rotator magnet

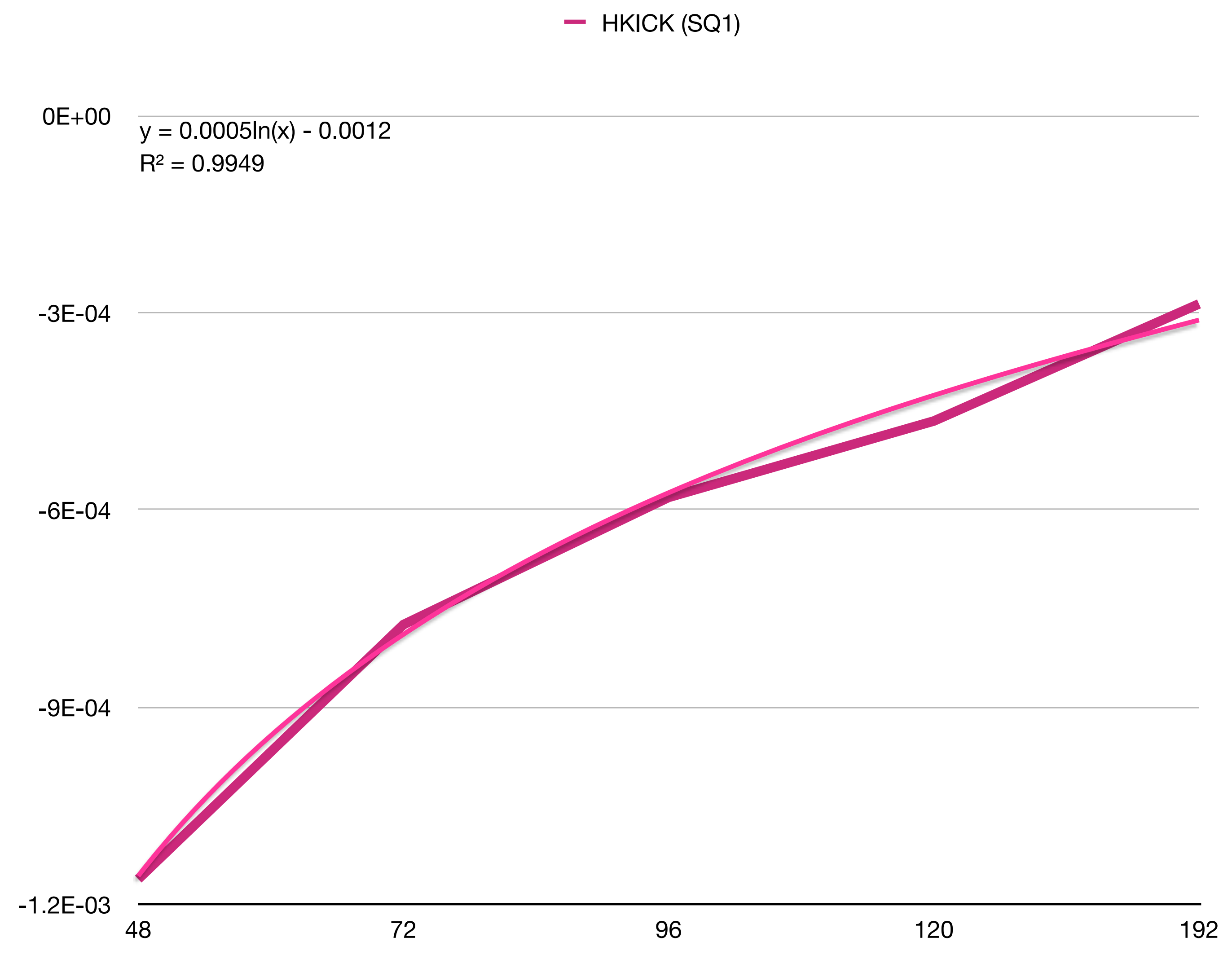
- The general order:

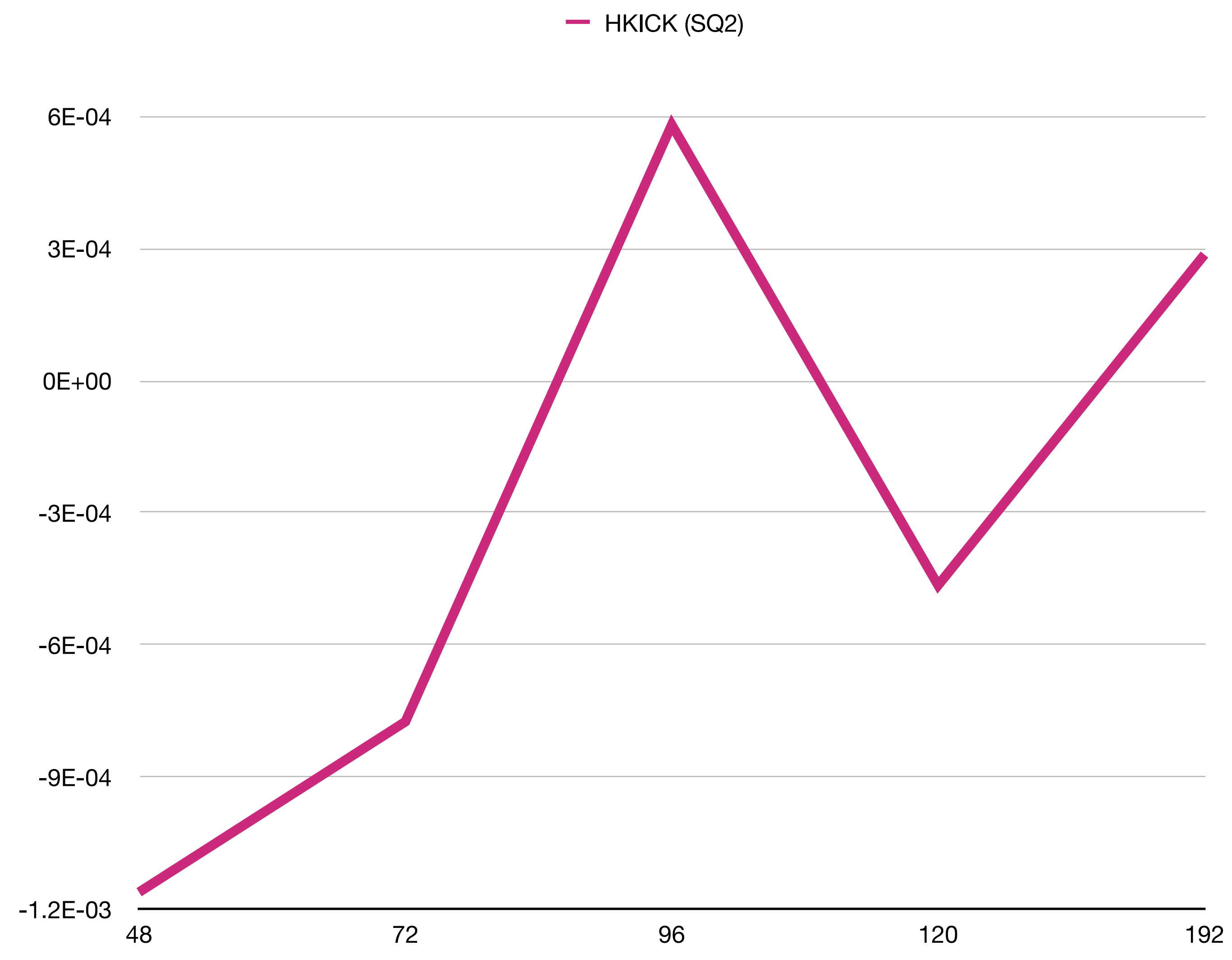
SQ(1) + P(1) + SQ(1) + P(1) + … + SQ(2) + P(2) + ….

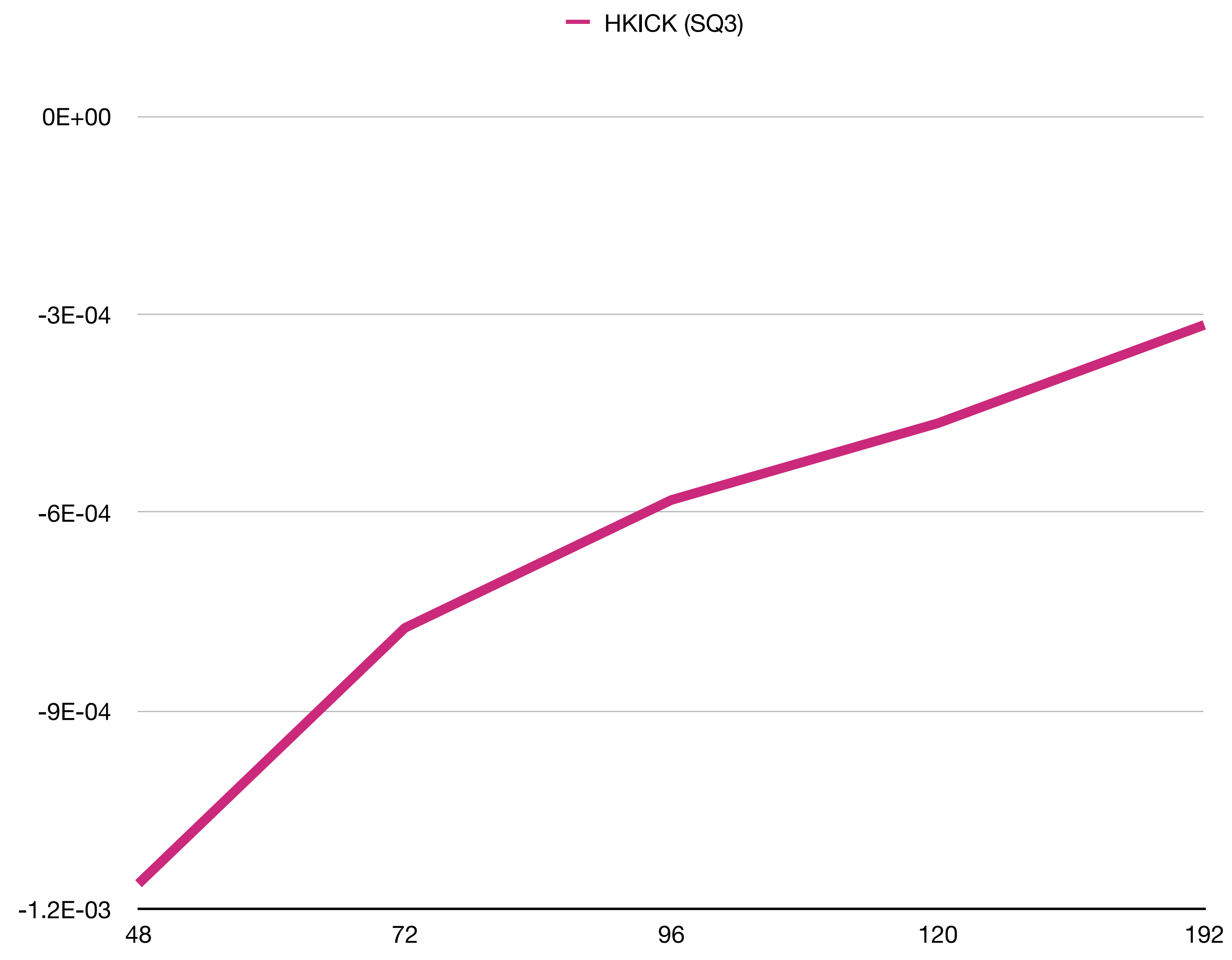
Some technical jargon:

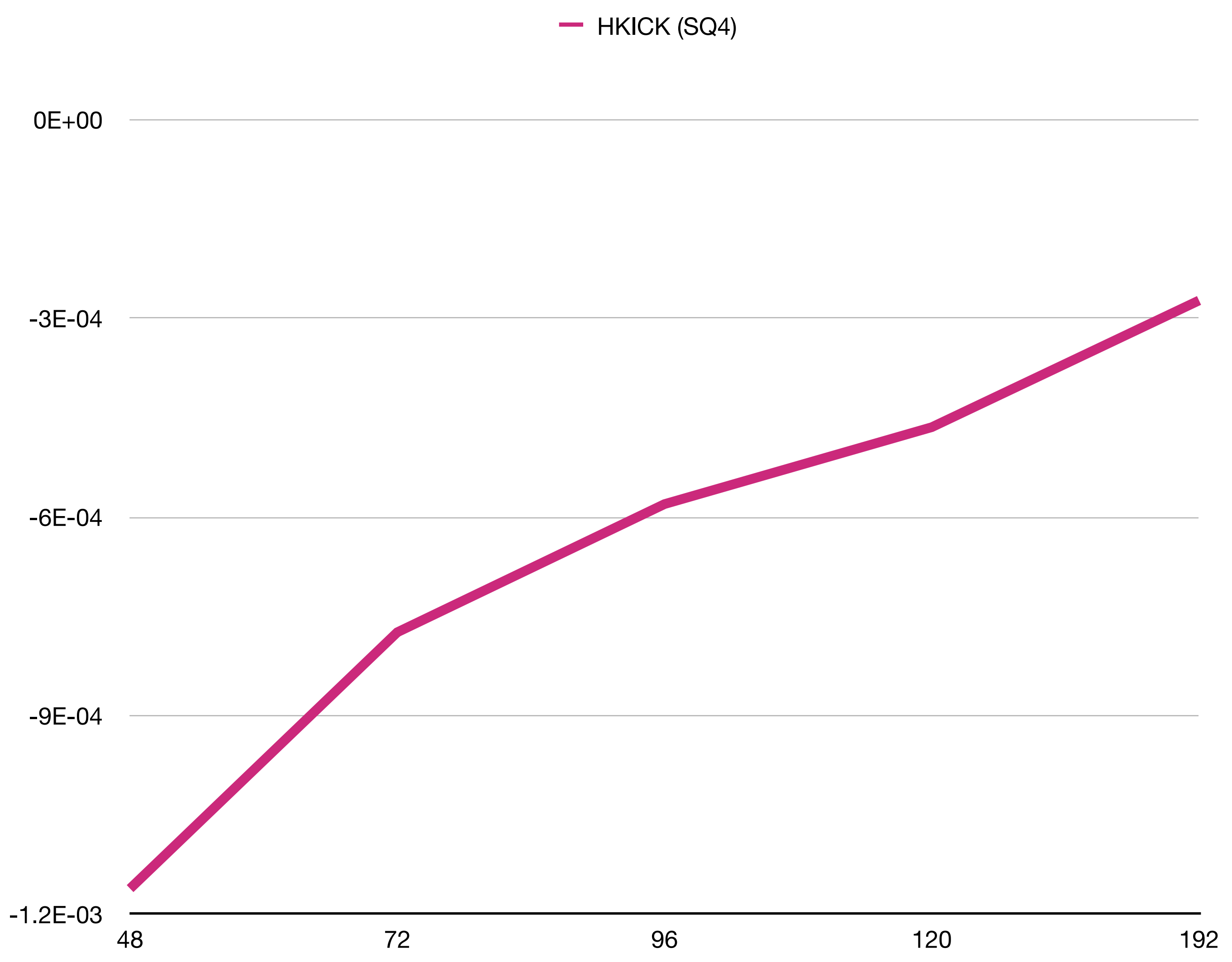
- soqf.bmad: solenoids on, quadrupoles off
- soqo.bmad: solenoids on, quadrupoles on
- Open geometry: looking at only a piece of the ring
- Closed geometry: looking at the entire ring
- hkick/vkick: horizontal or vertical kick elements in Bmad, kicks particle into position instead of a gradually bending.
  - The slicing is important because we need to preserve the geometry of the ring and optical parameters, and using “bend” elements doesn’t do that well in Bmad.
  - The more slices we use, the more “bend” like the simulation behaves, while preserving optical parameters

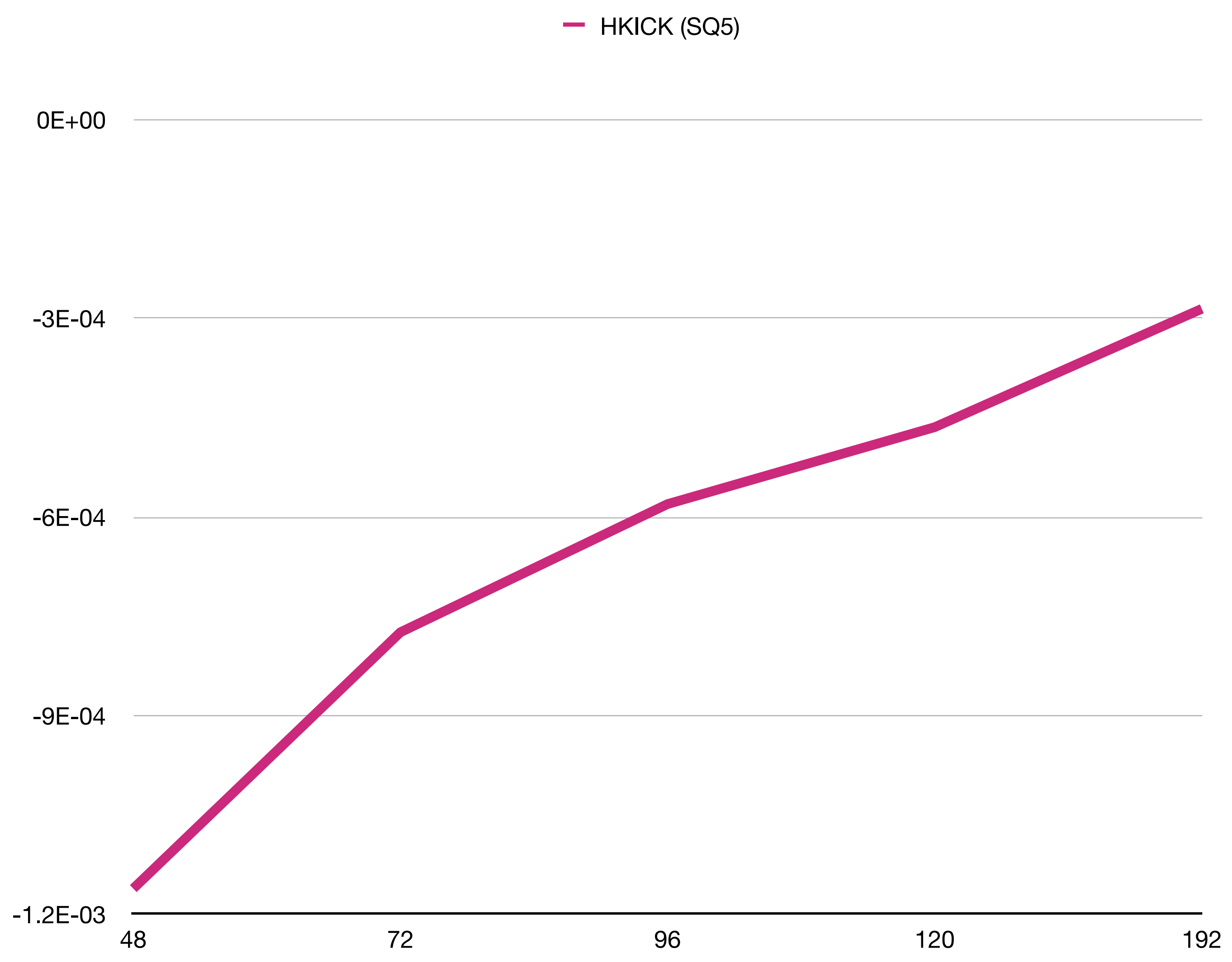
Stage 1: HKICK Fitting

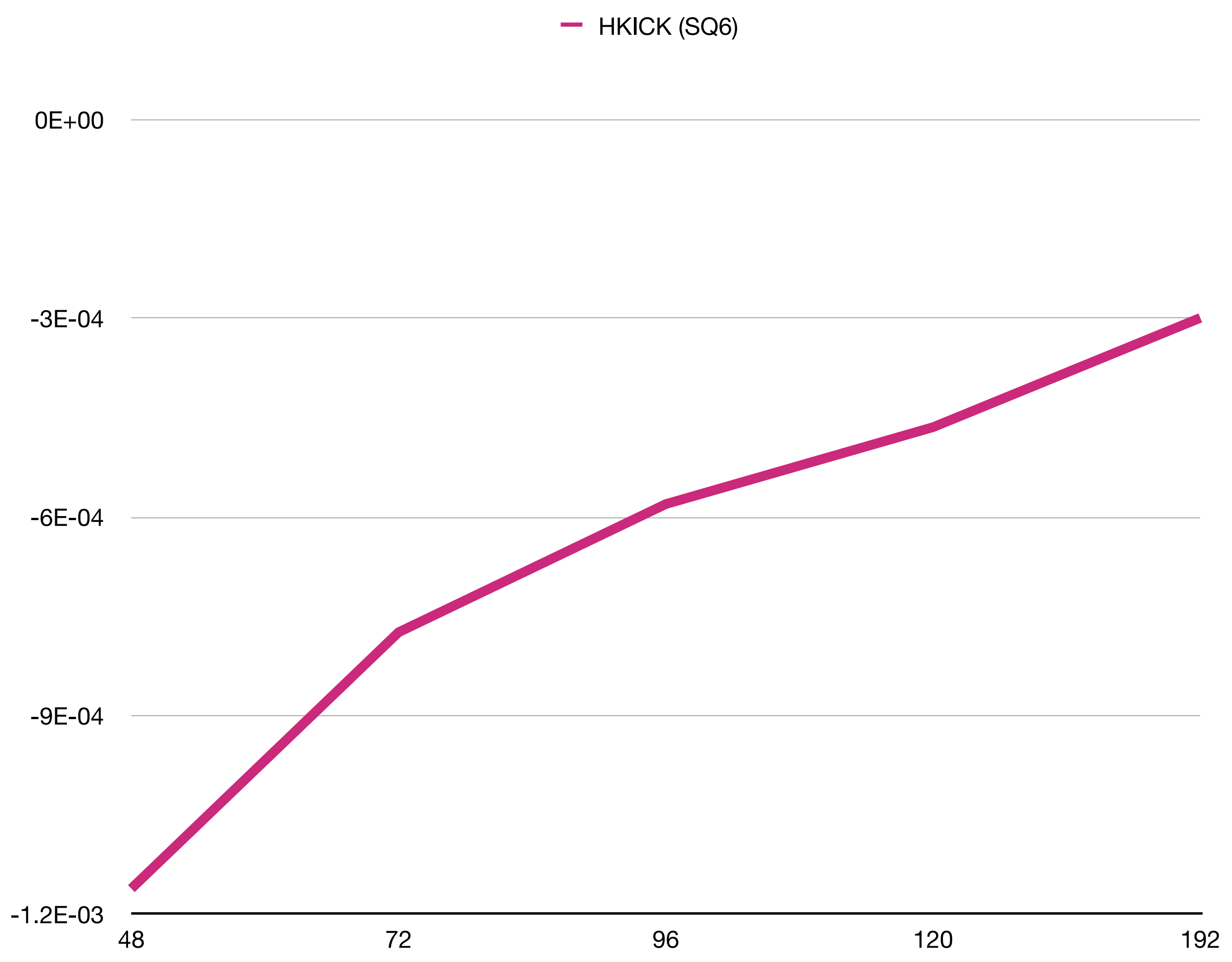




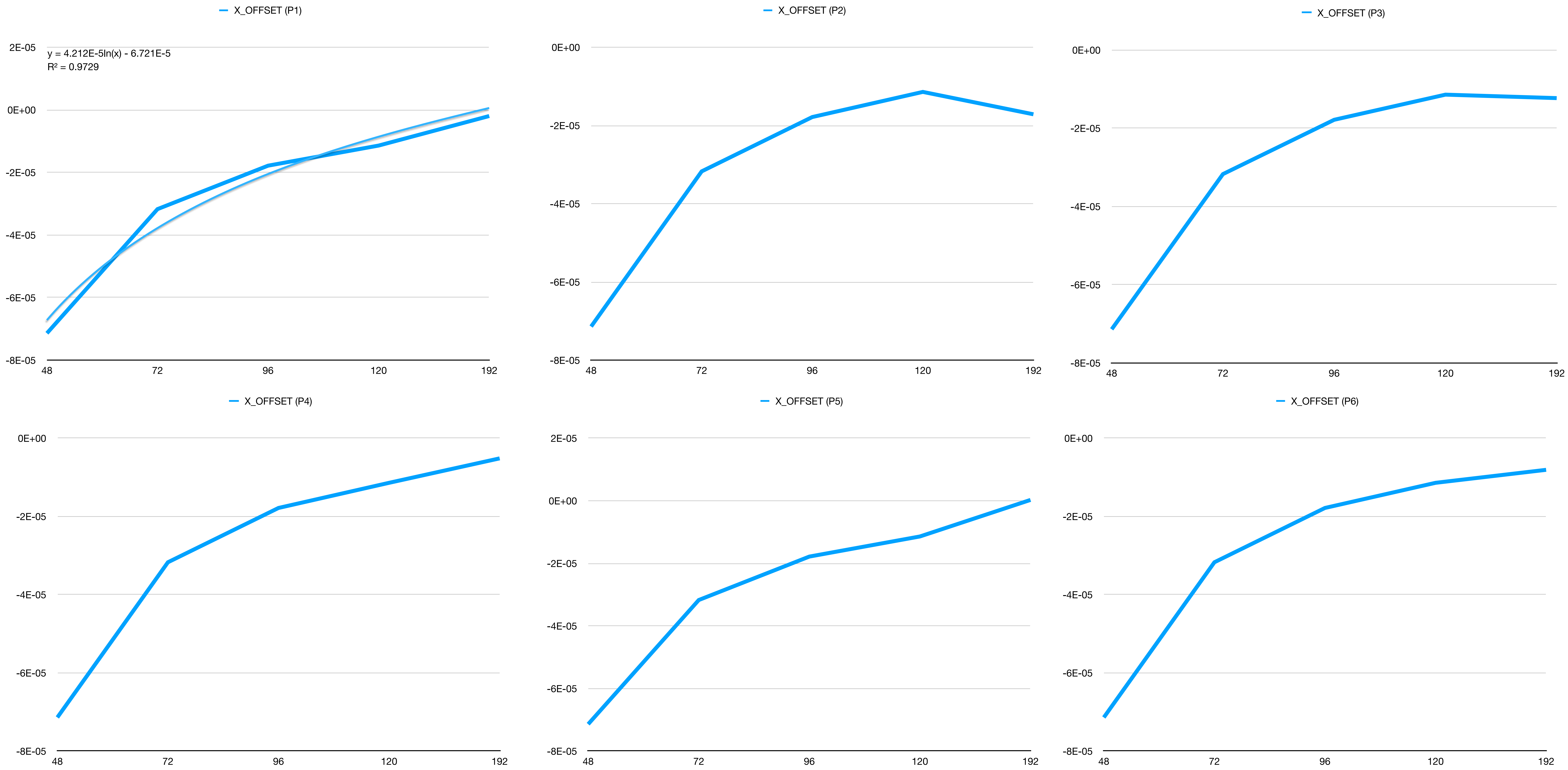








Stage 1: X_OFFSET Fitting



Stage 1: X_PITCH Fitting

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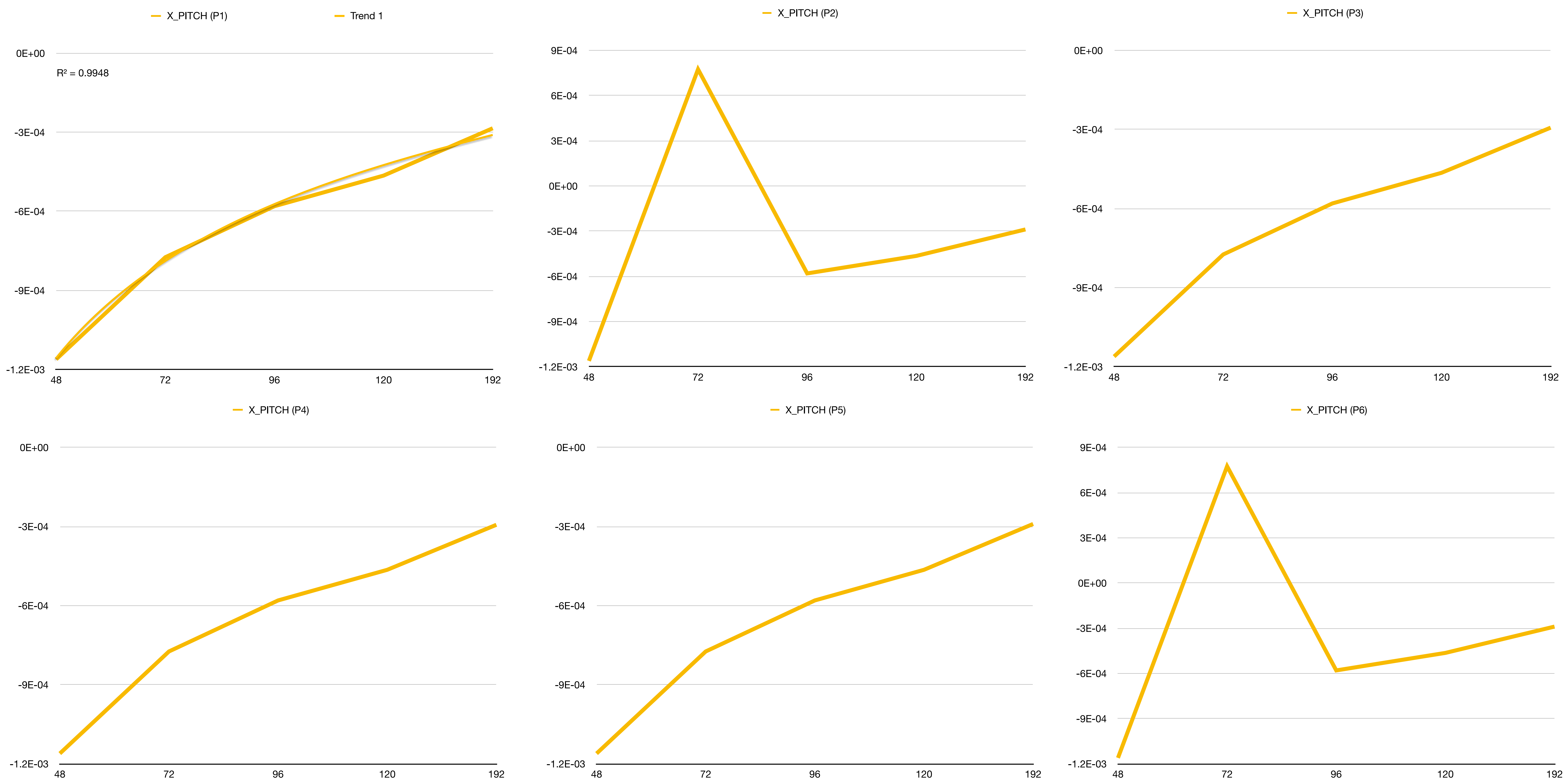
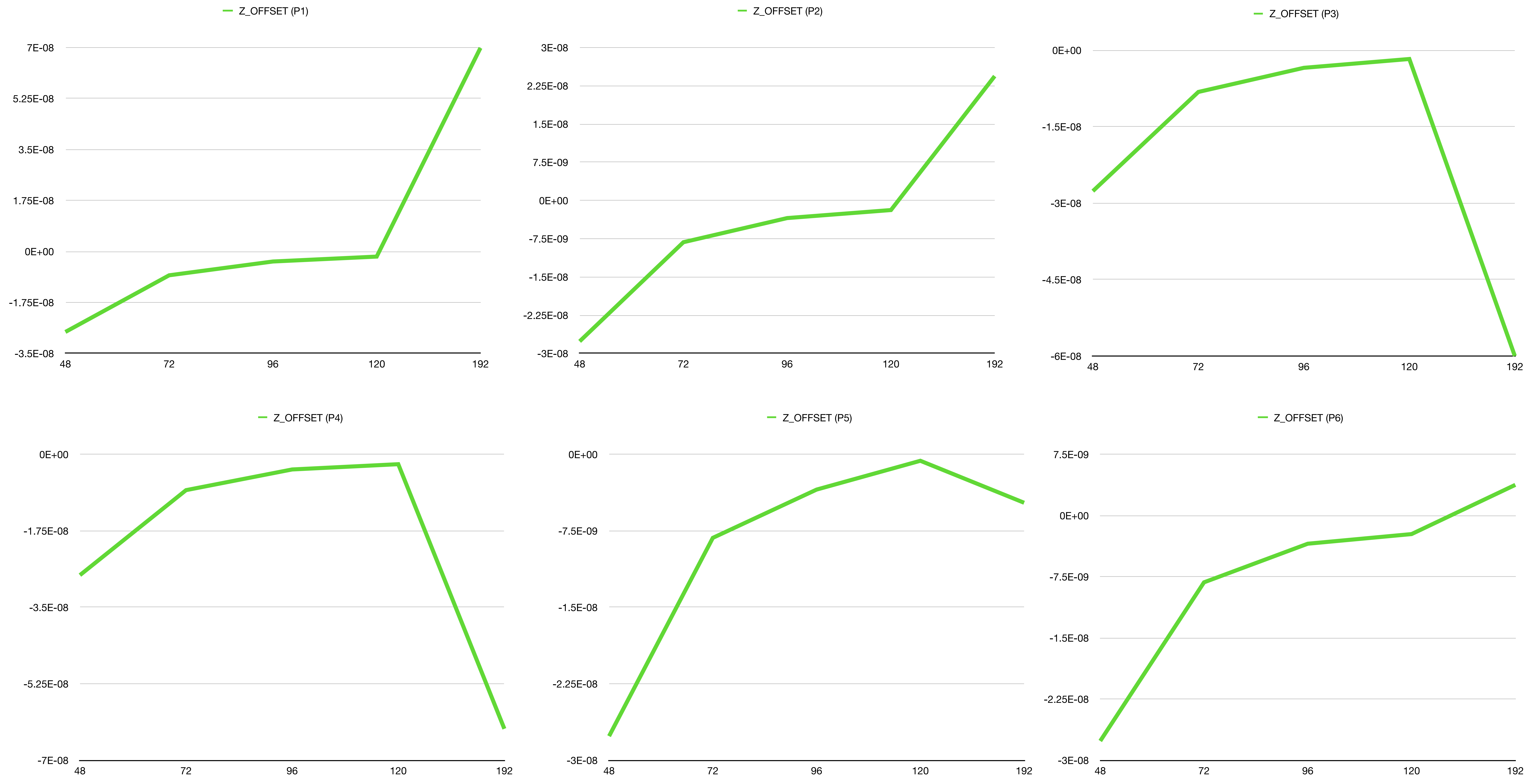
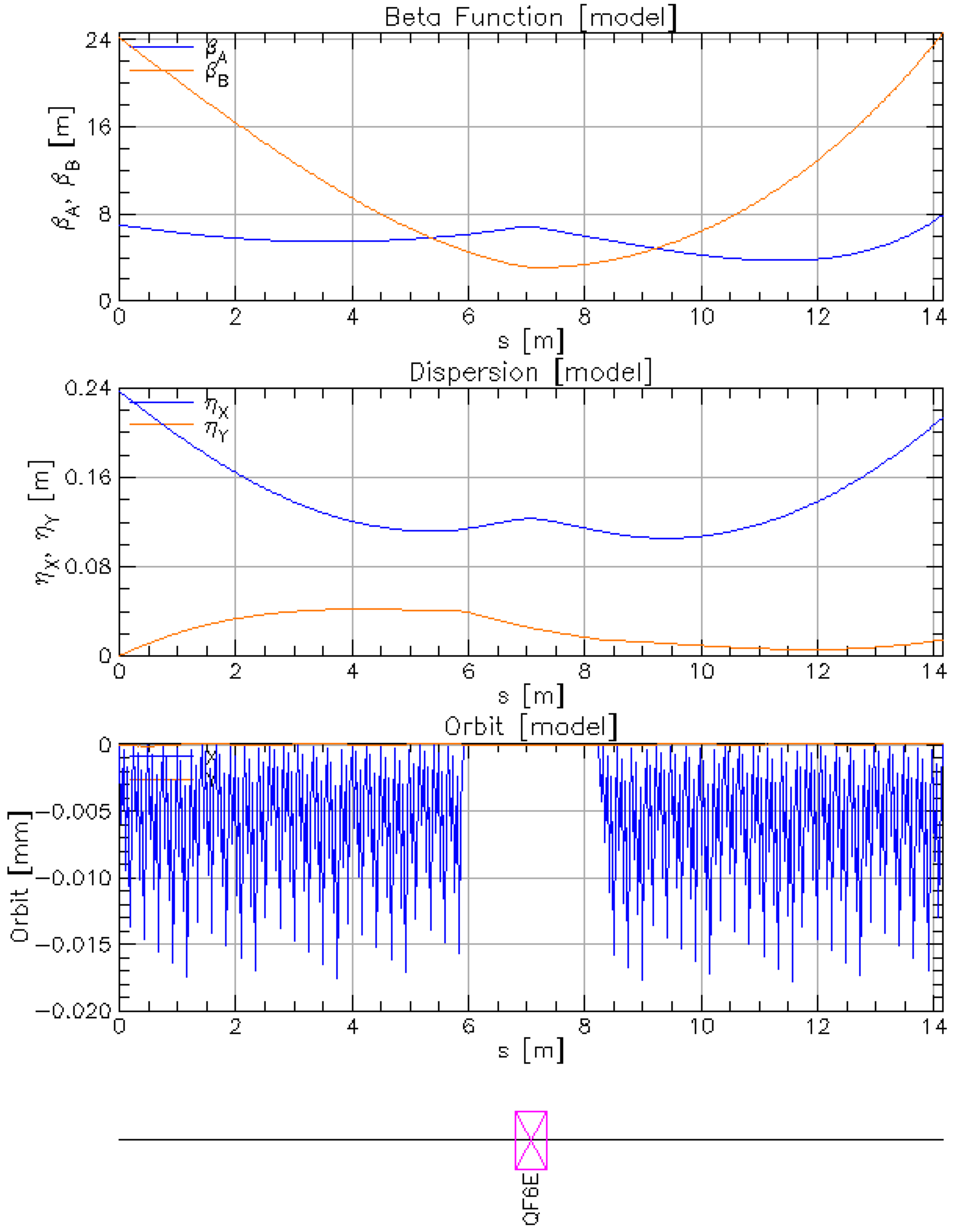


Stage 1: Z_OFFSET Fitting

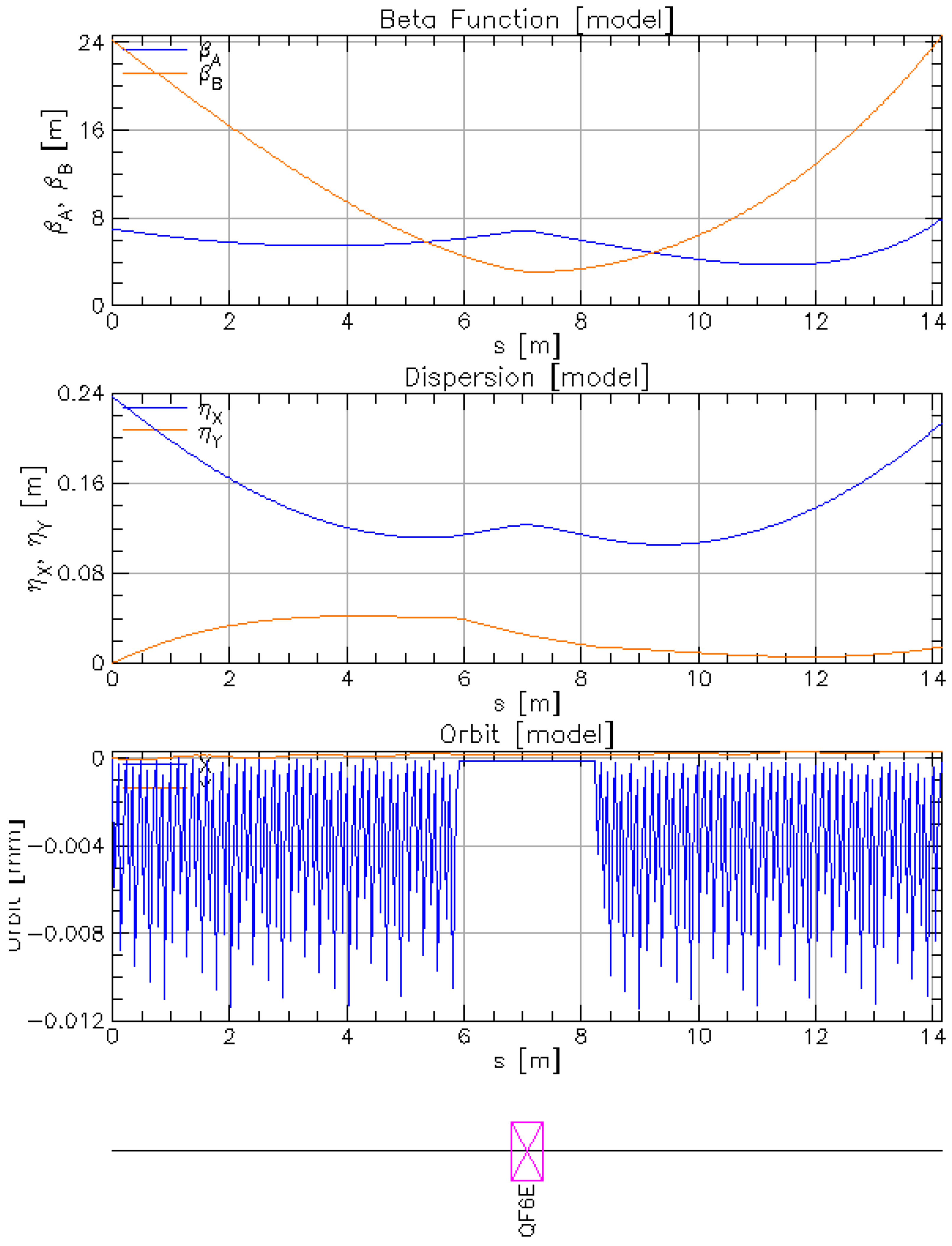


Stage 2: Fitting vkicks in sextupole on / quads off model

96 slice

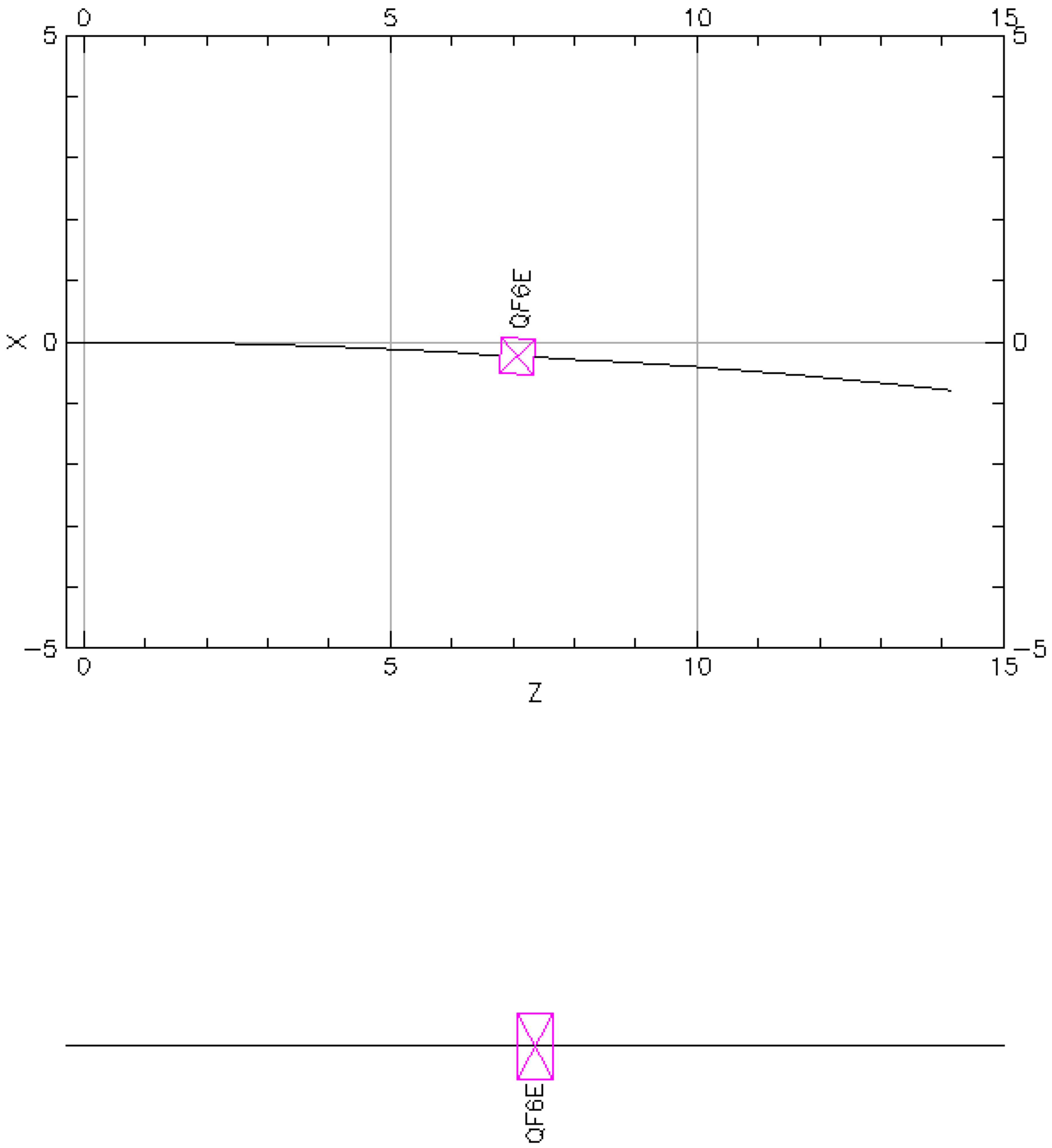


120 slice

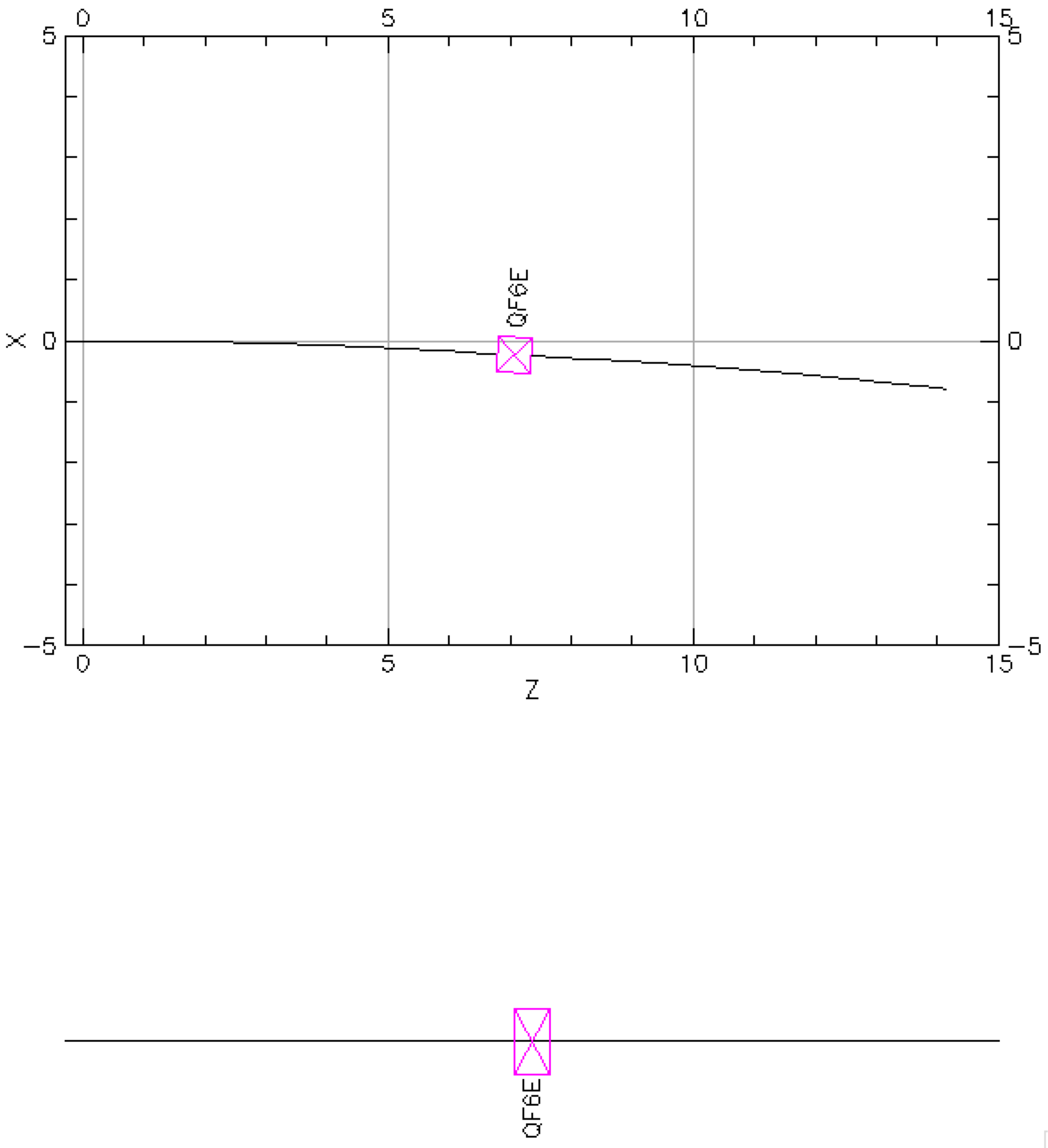


Stage 2: Fitting vkicks in sextupole on / quads off model

96 slice

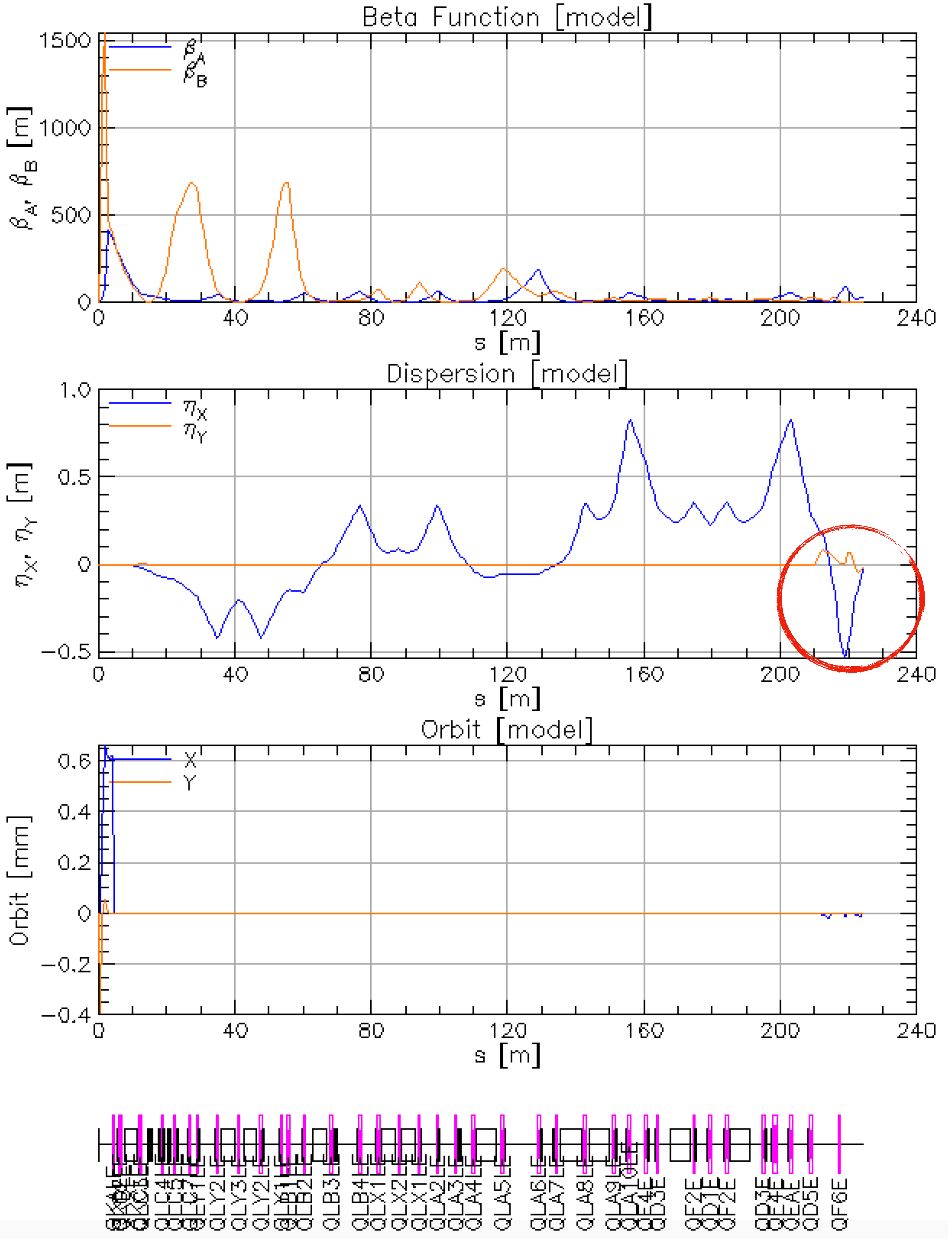


120 slice

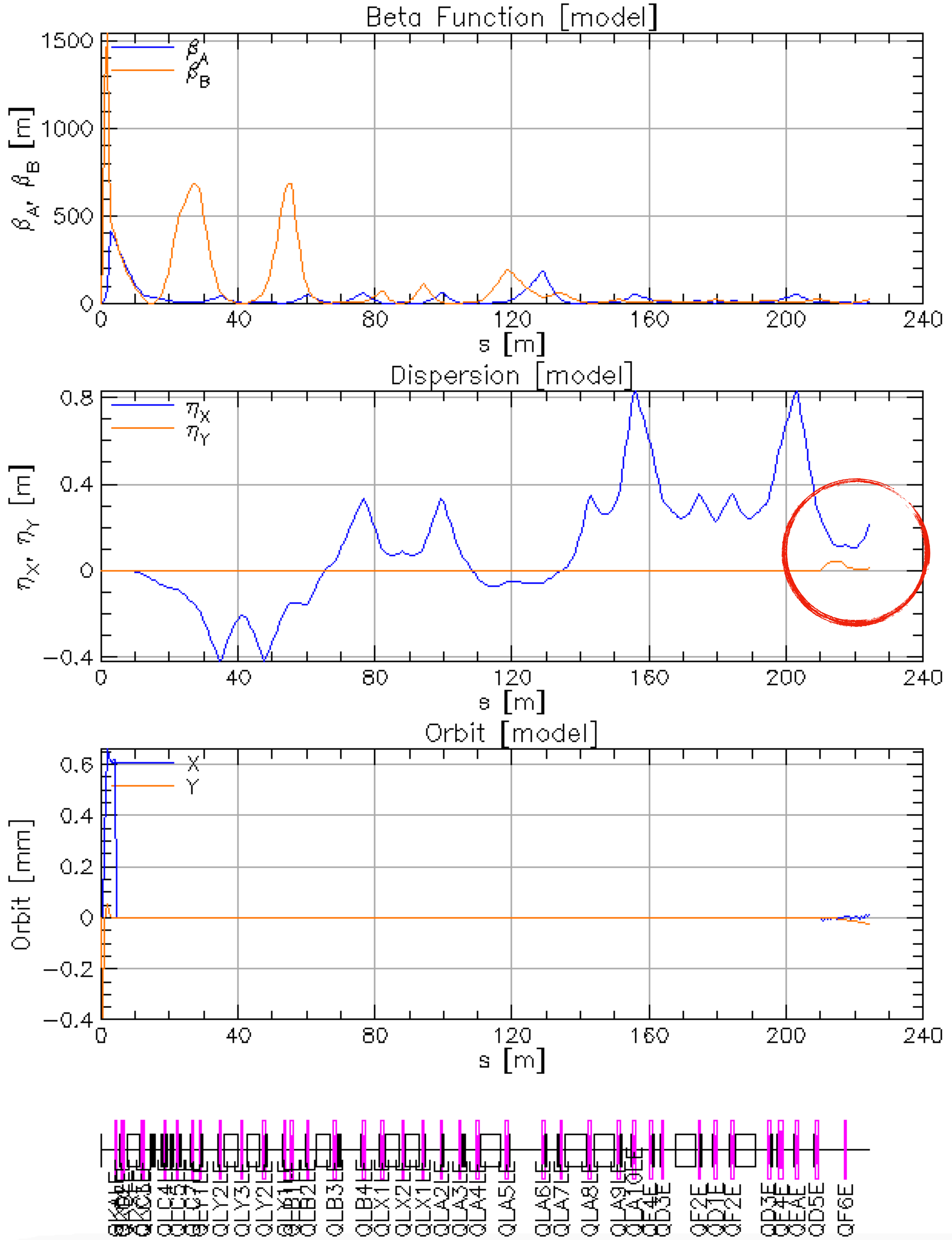


Making sure things look good (lrot soqo.bmad)

96 slice



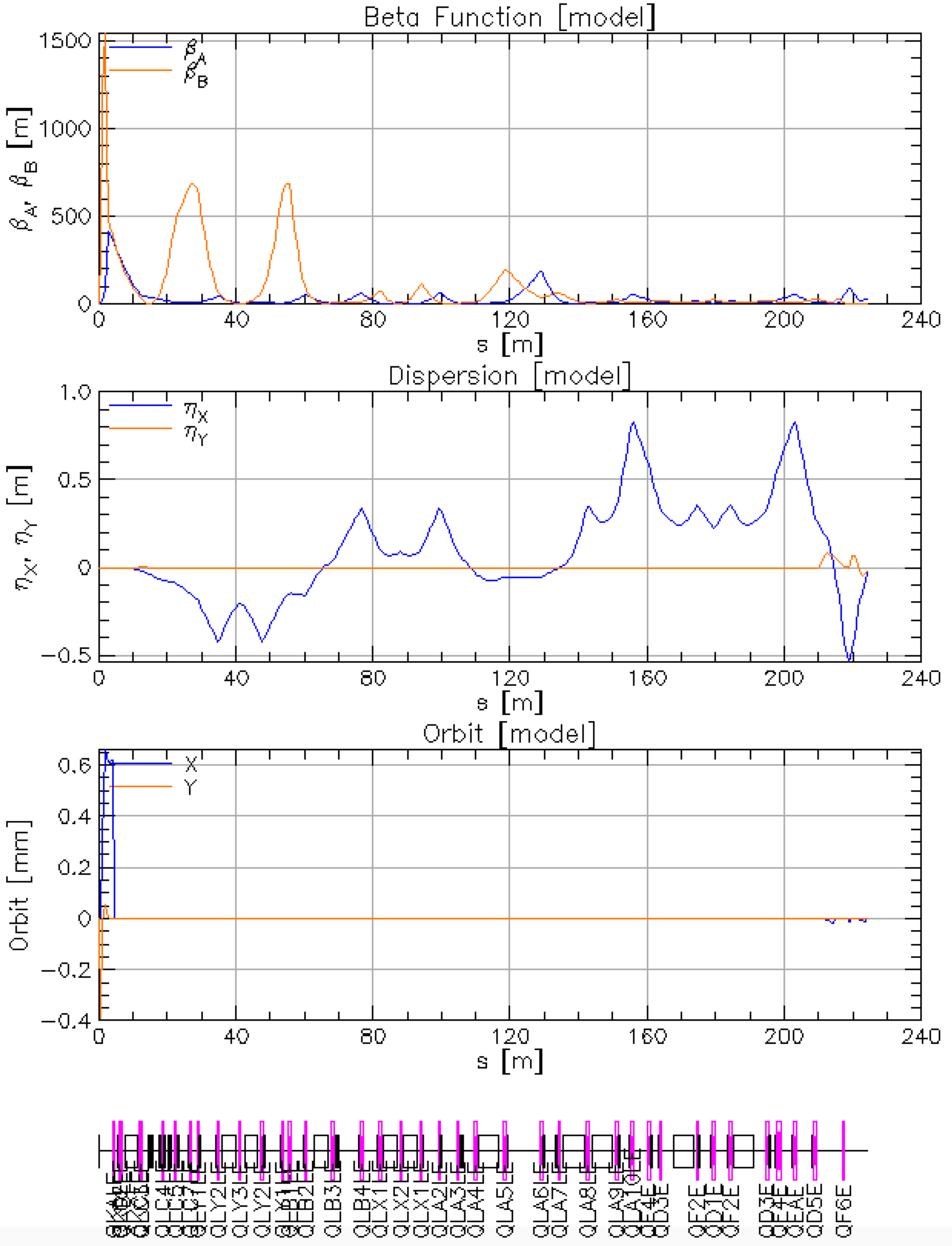
120 slice



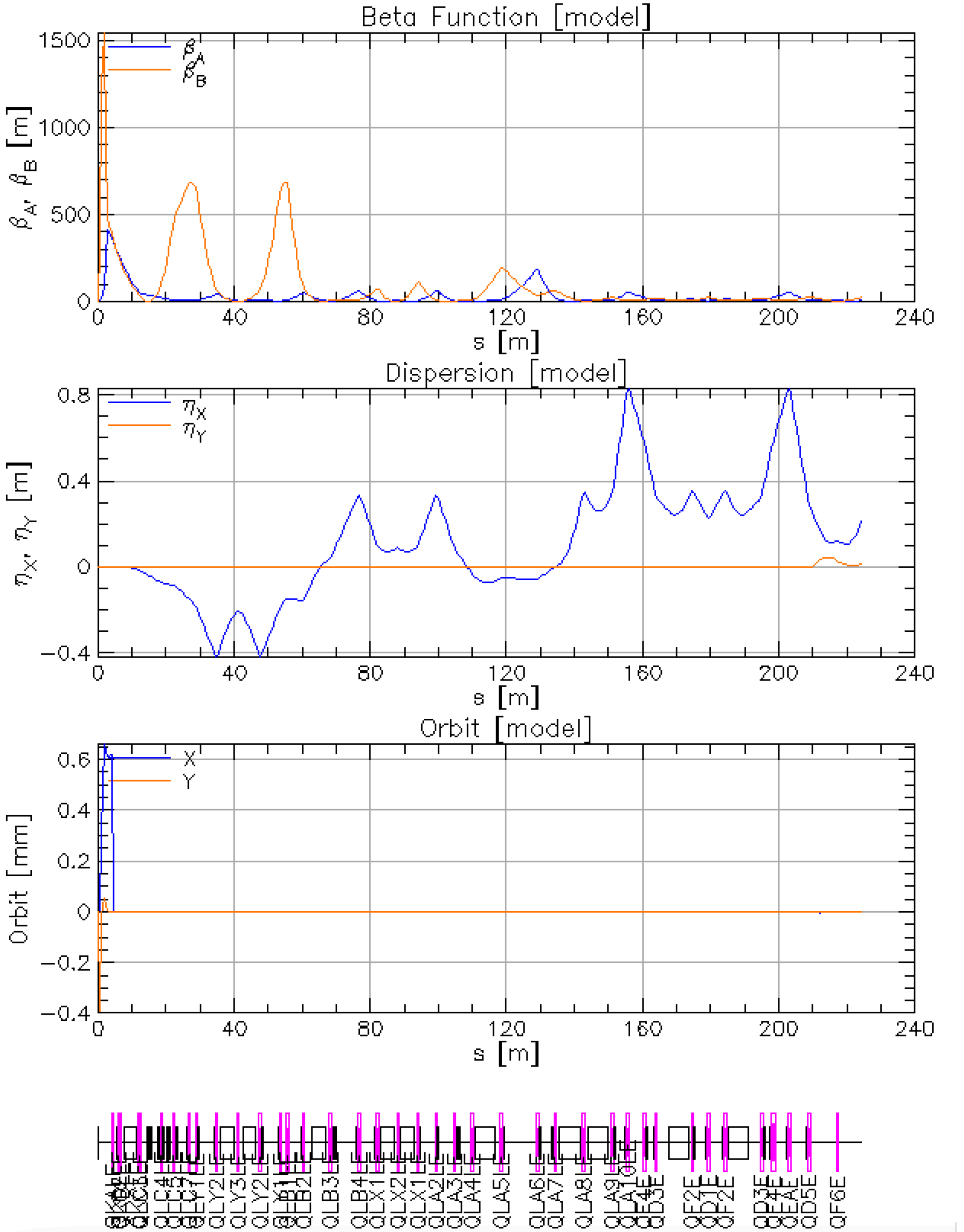
May be caused by final point in optimizer?

lrot soqo.bmad

96 slice

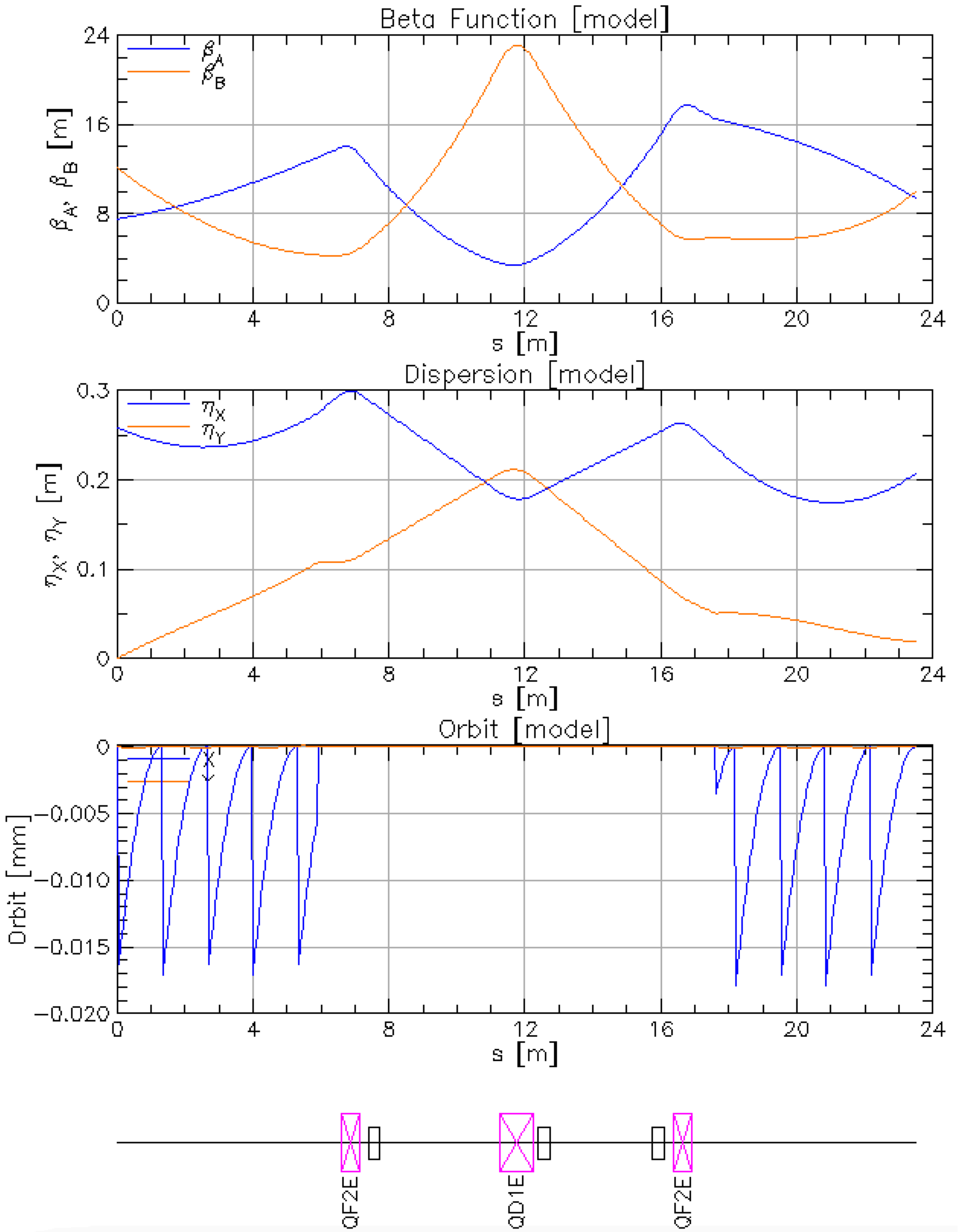


192 slice

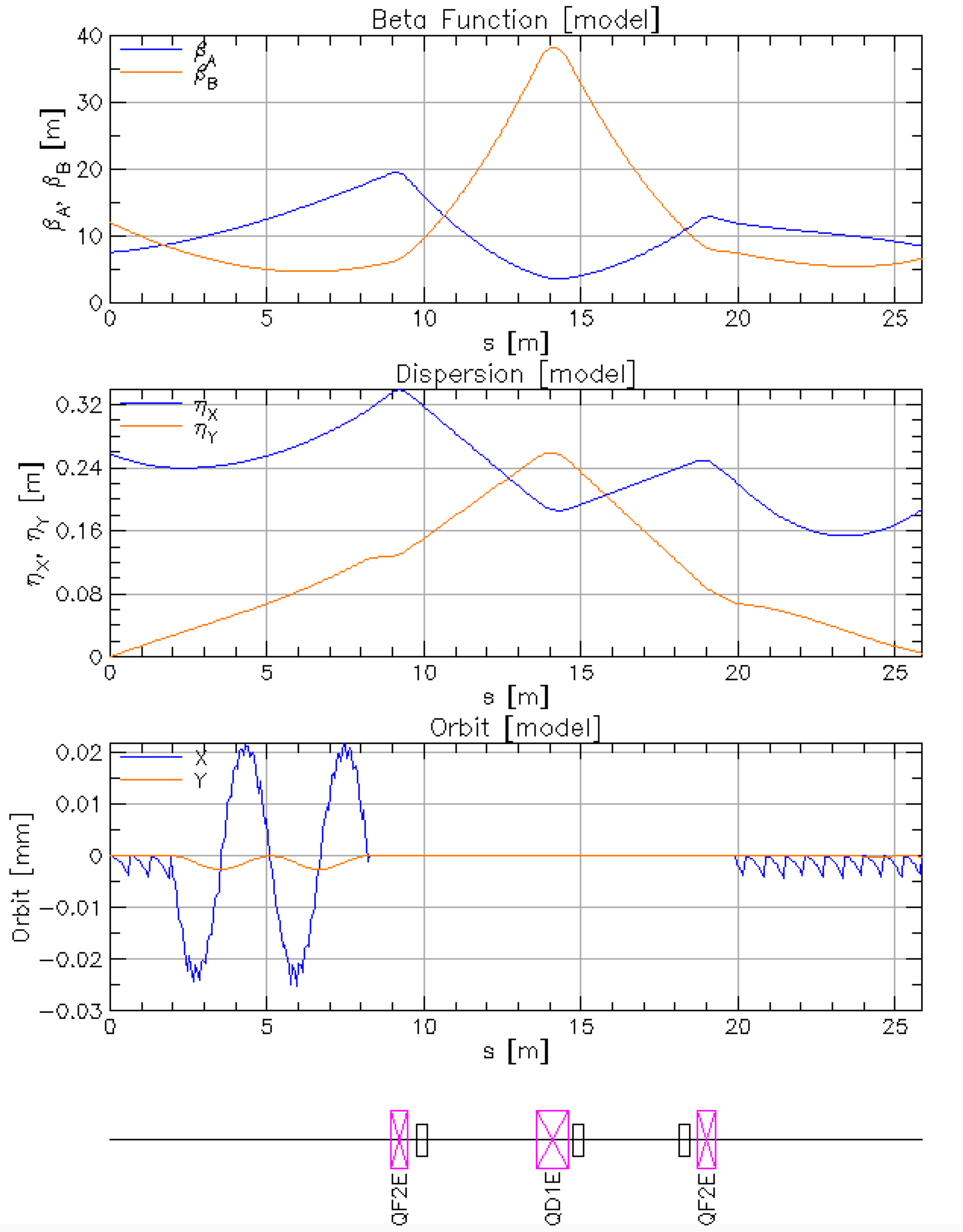


Problem with matching rrot: soqf.bmad

96 slice

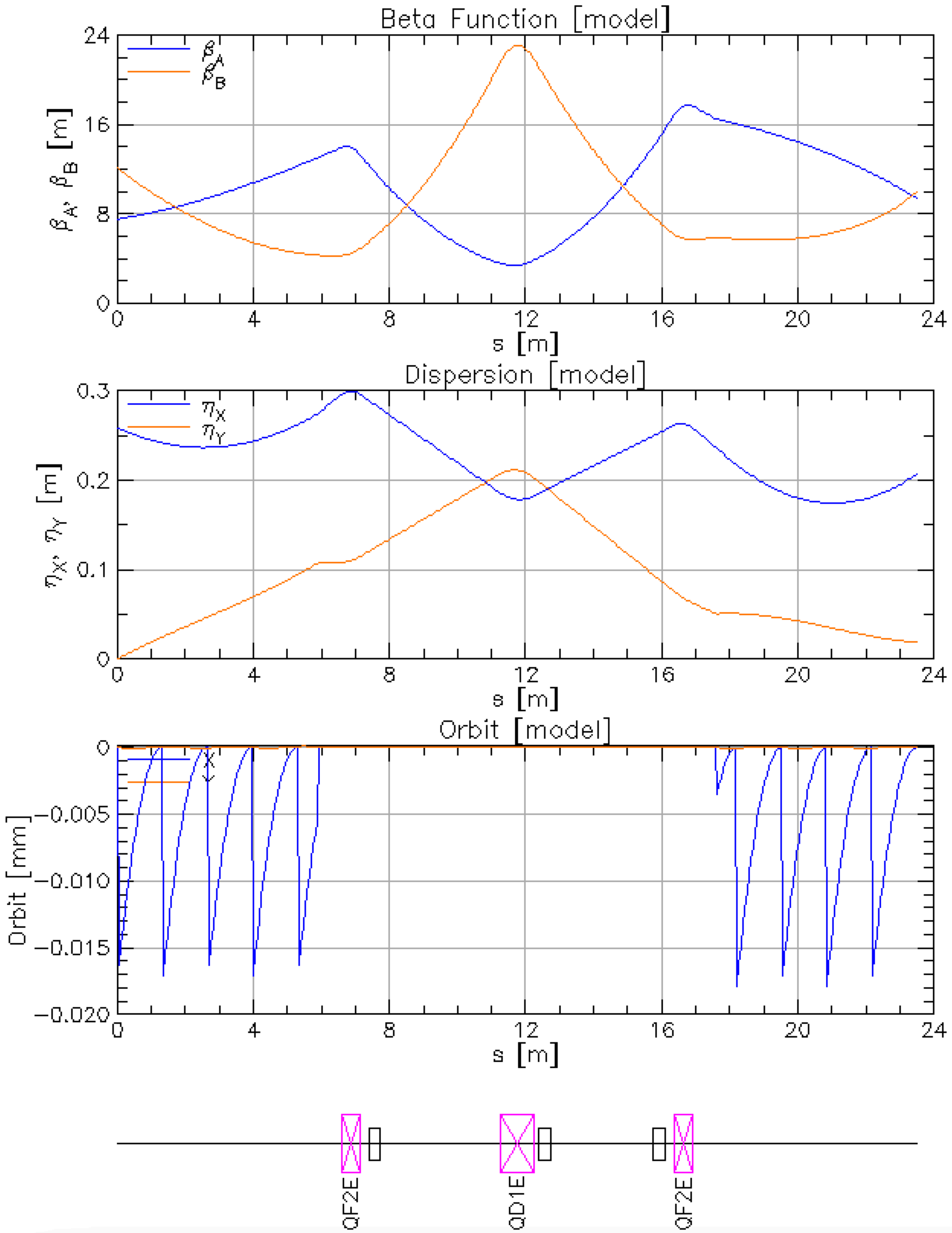


196 slice

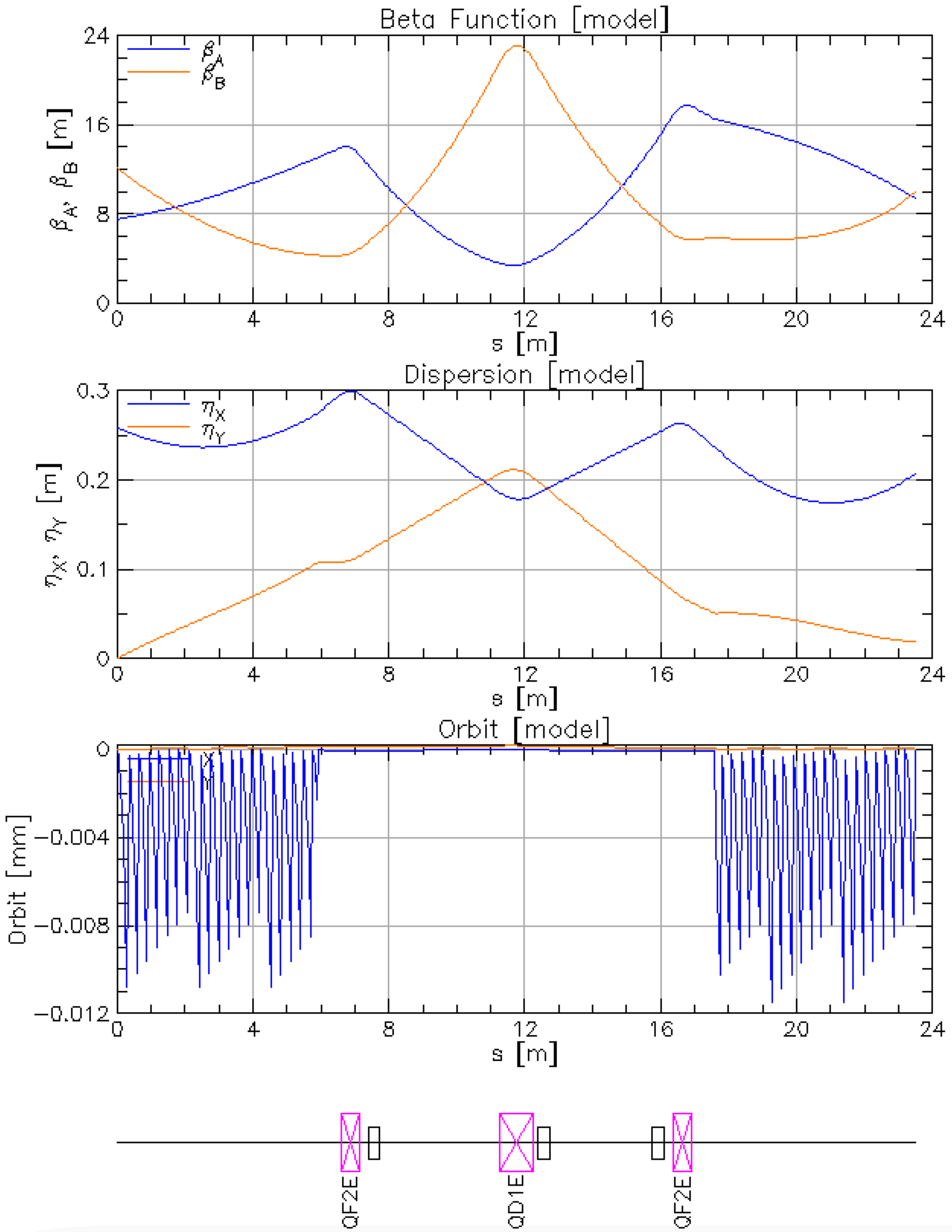


Only had the issue with 192 slice

96 slice

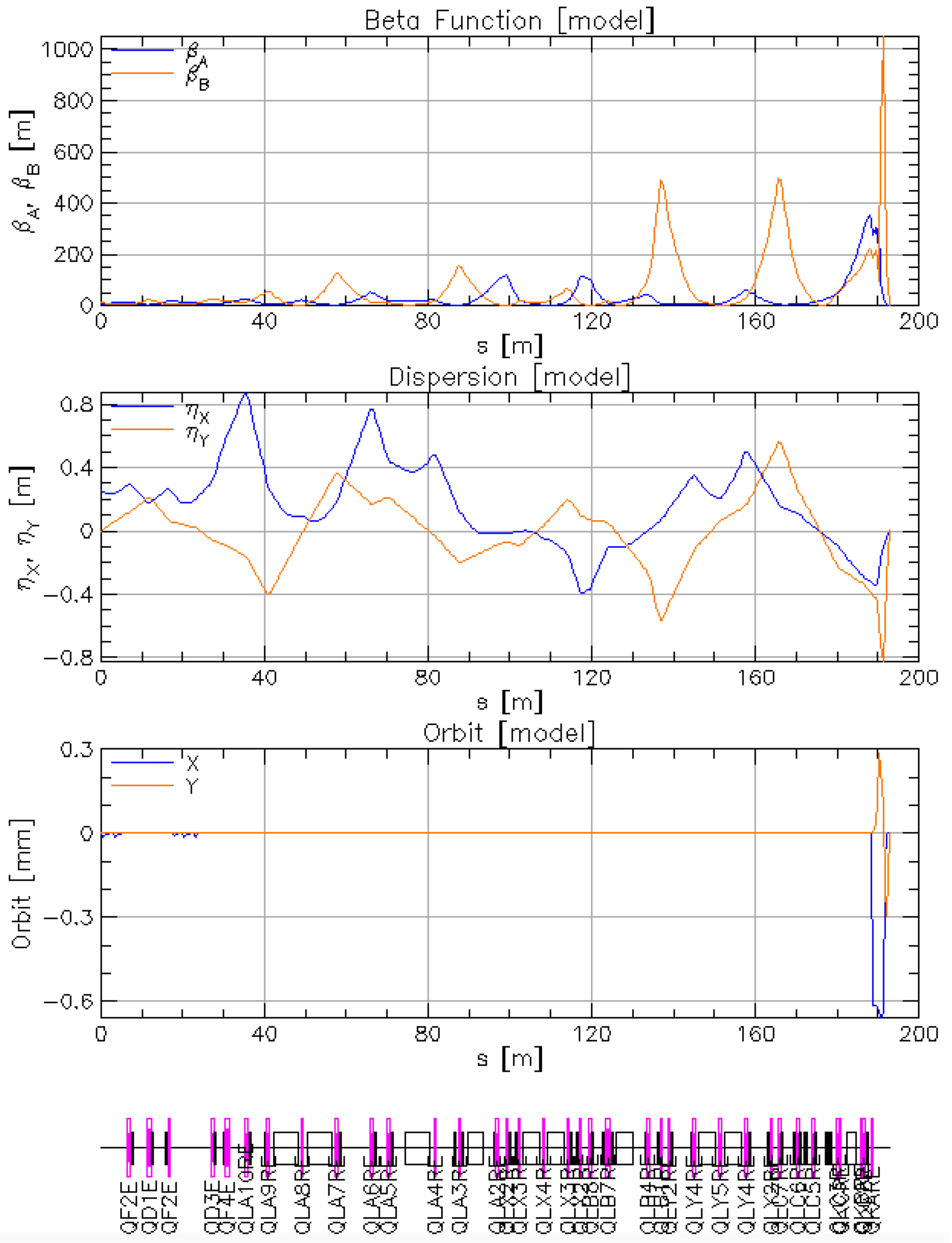


120 slice

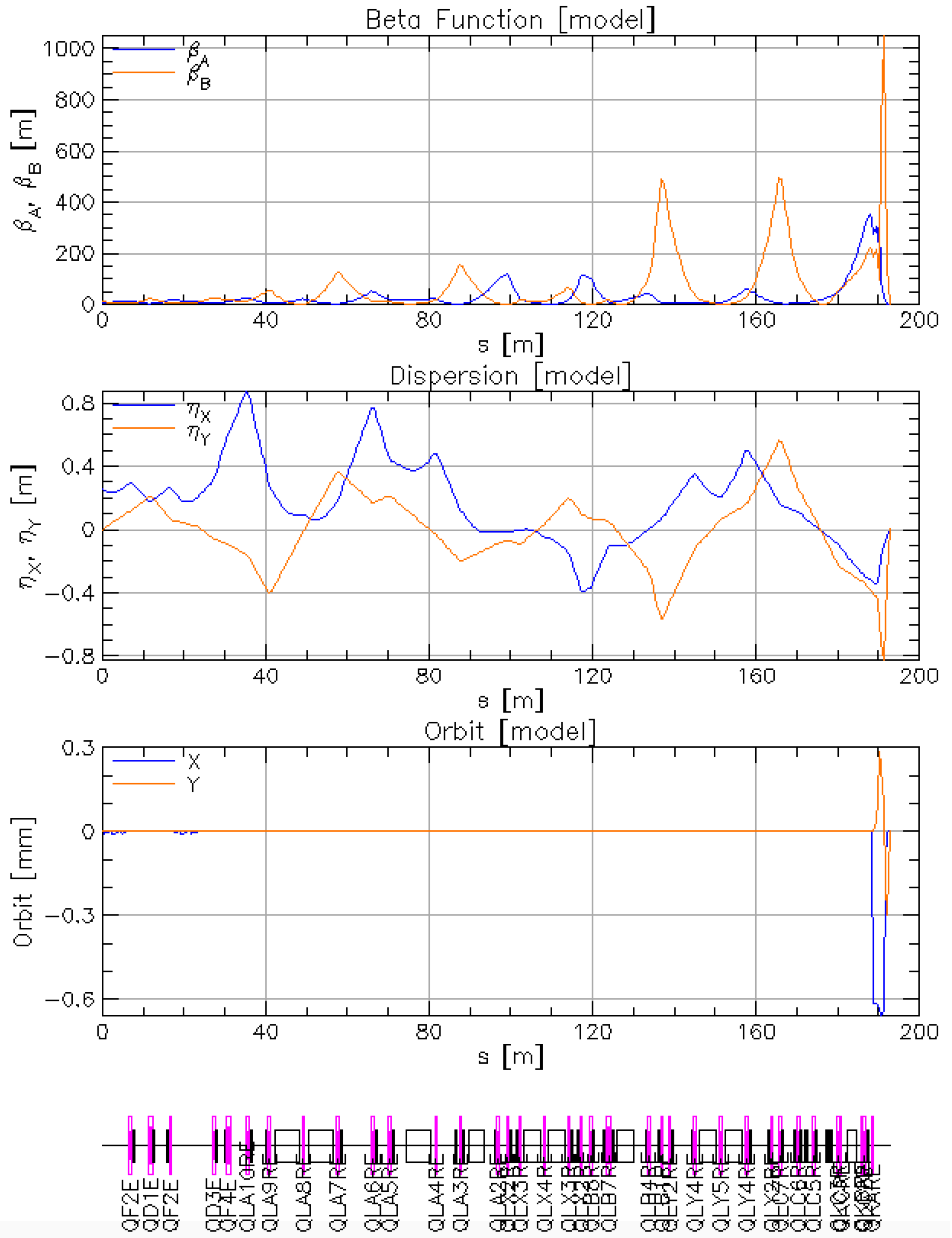


rrot soqo.bmad

96 slice

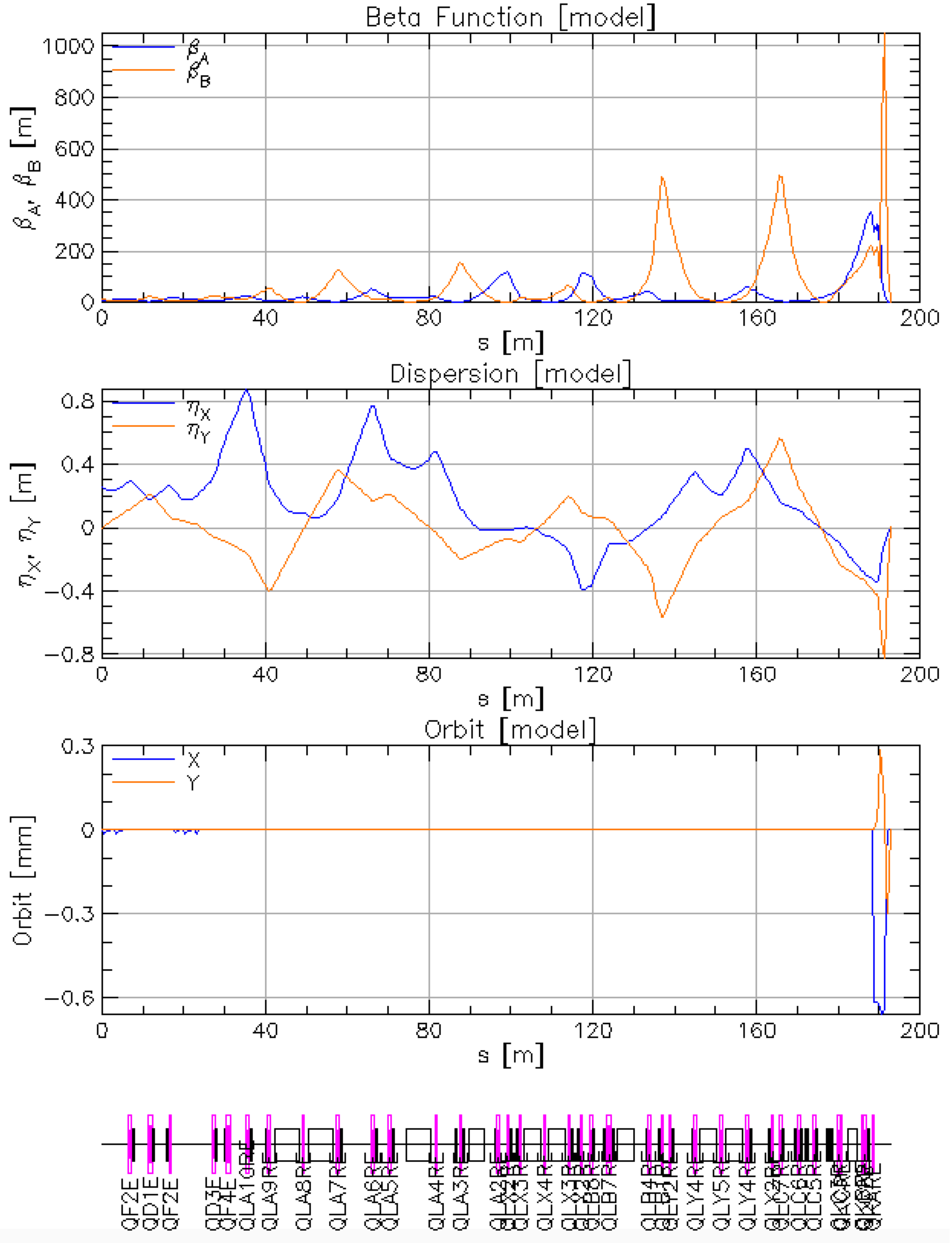


120 slice



rrot soqo.bmad

72 slice

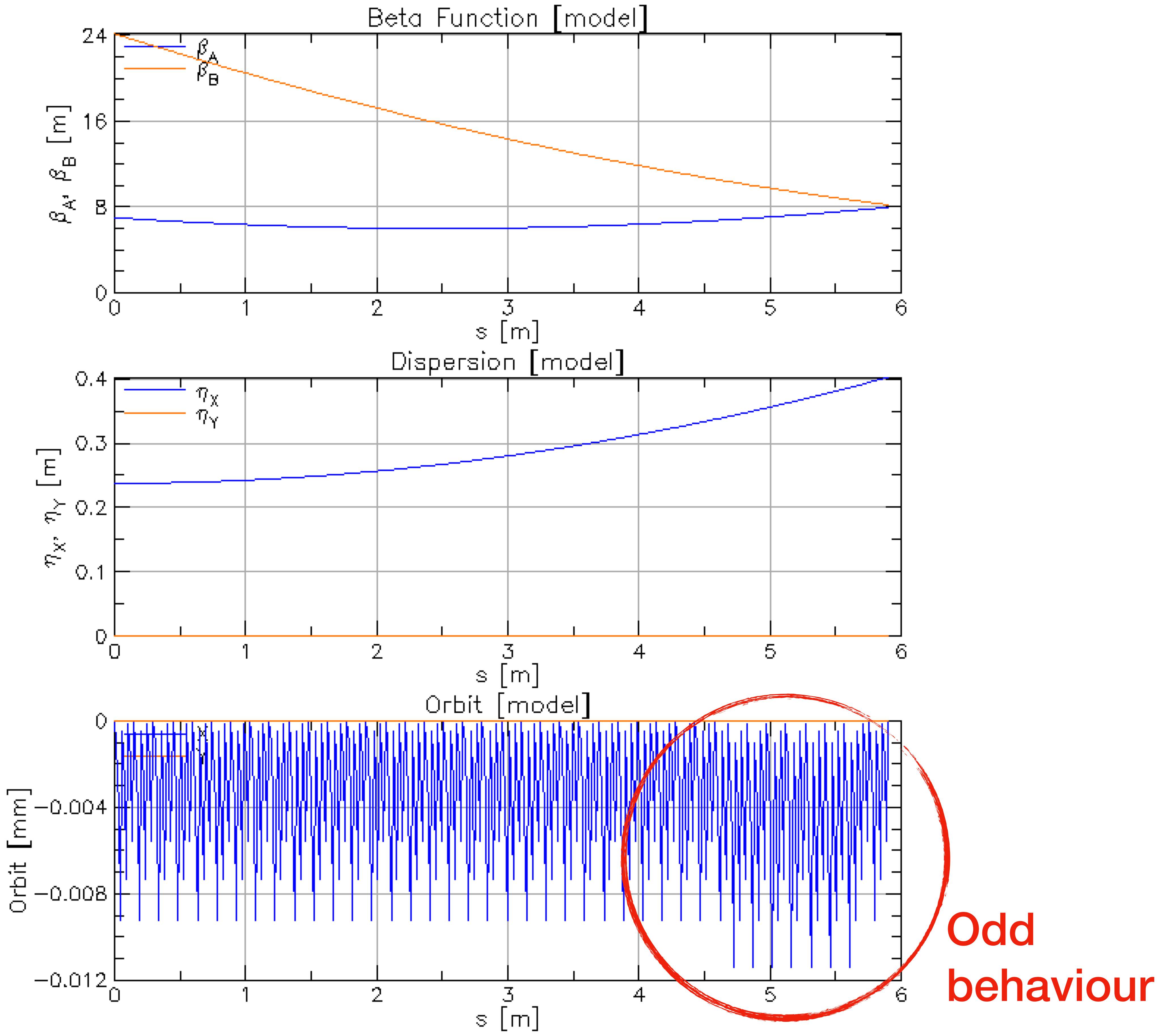


192 slice

Couldn’t optimize (issues in soqf optimization phase)

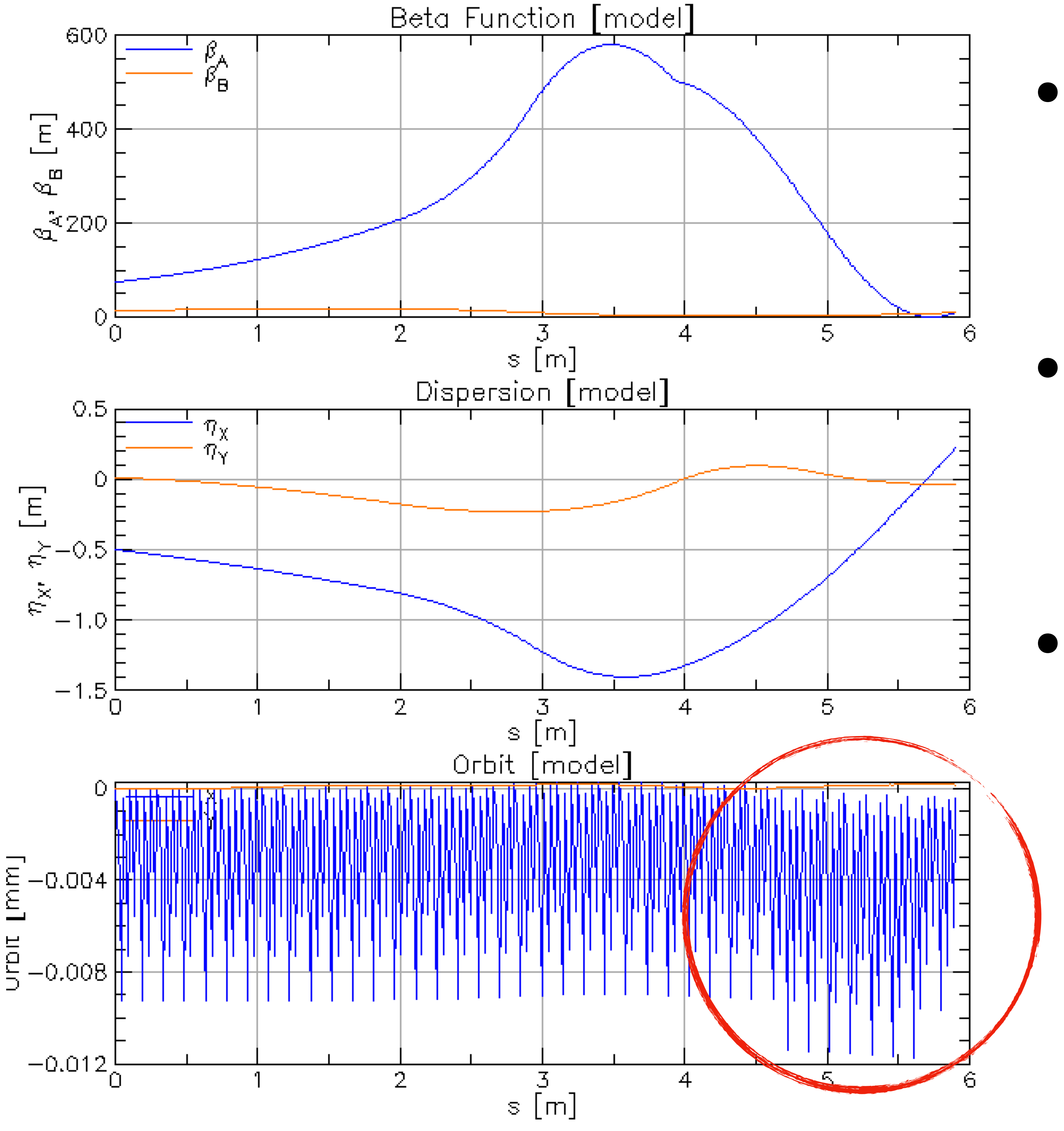
Stage 3: Decoupling Irot

120 slice Irot "b2ea" section




```
Twiss at end of element:
                     A              B       |       Cbar                          C_mat
  Beta (m)         7.97519849     8.20383397  |   0.00000000  -0.00000000     0.00000000  -0.00000000
  Alpha           -0.57226419     0.77456003  |   0.00000000  -0.00000000     0.00000000  -0.00000000
  Gamma (1/m)      0.16645182     0.19502384  |   Gamma_c =    1.00000000     Mode_Flip = F
  Phi (rad)        0.90900592     0.43278477          X              Y              Z
  Eta (m)          0.40224672     0.00000000     0.40224672     0.00000000    -0.01630920
  Etap             0.05574309     0.00000000     0.05574309     0.00000000     0.00000000
```

120 slice Irot "b2eb" section

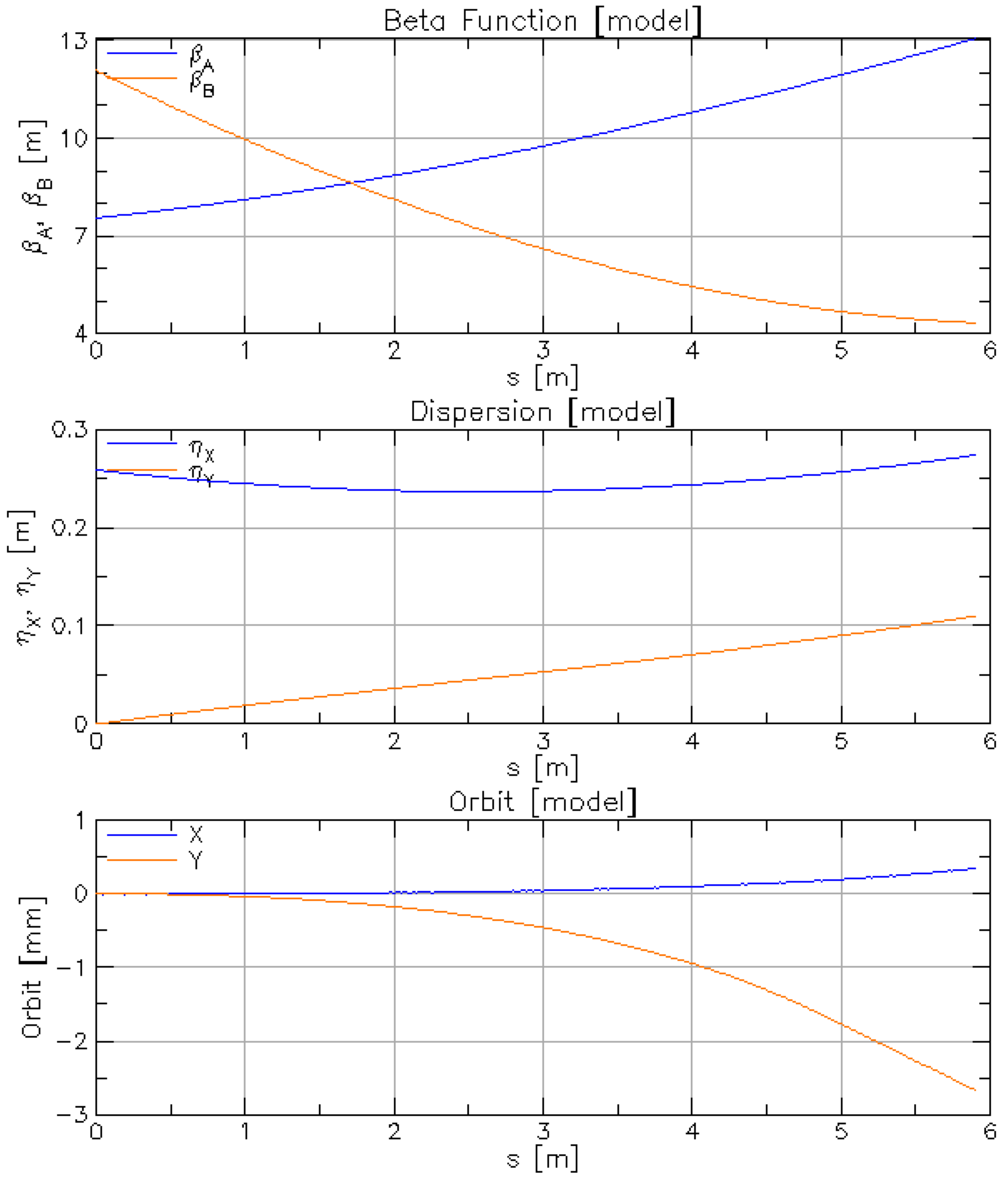



```
Twiss at end of element:
                     A              B       |       Cbar                          C_mat
  Beta (m)         9.99996743     9.99999994  |  -0.00000000   0.00000000    -0.00000000   0.00000000
  Alpha          -60.43733849    -6.97496071  |   0.00000000  -0.00000000     0.00000000   0.00000000
  Gamma (1/m)    365.36837824     4.96500773  |   Gamma_c =    1.00000000     Mode_Flip = F
  Phi (rad)        3.14762822     0.83667147          X              Y              Z
  Eta (m)          0.21865055    -0.04091288     0.21865055    -0.04091288     0.04631295
  Etap             1.05714851    -0.03614519     1.05714851    -0.03614519     0.00000000
```

- Computationally simple yet tricky to get right
- Very weird beta functions after decoupling
- Finding the "sweet spot" between the tilt and skew quad fields is the hard part

Stage 3: Decoupling rrot

120 slice rrot “b2ea” section



Very wrong

```
Twiss at end of element:
                        A                 B         |         Cbar                       C_mat
  Beta (m)       13.06241819       4.32156155  |  -0.25306725   0.00001540    -0.43997171   0.00011568
  Alpha          -0.63507986       0.09984468  |   0.23675945  -0.76492732    -0.00004411  -0.43997012
  Gamma (1/m)     0.10743236       0.23370463  |   Gamma_c =    0.89801202     Mode_Flip = F
  Phi (rad)       0.61170902       0.90852512           X                Y                Z
  Eta (m)         0.29403398      -0.02182498     0.27364712       0.10977033     -0.01370835
  Etap            0.02817868      -0.01132896     0.03029016       0.00221131      0.00000000
```

- Previously was using looser constraints for fitting (+- 0.8m^-2 for both a and b side, lrot and rrot) - worked fine

> not be further lowered. For the L-Rot, the maxim quadrupole strength k_1 of the first and the second rotator magnet is about 0.8, $0.5m^{-2}$, respectively; for the R-Rot, the max of both magnets is about $0.6m^{-2}$.

Yuhao Peng’s Thesis

- Now currently trying to impose tighter restrictions on fitting (based on her ring without rotator, for transparency)
- fitter isn’t reaching desired results for rrot - hits a local minimum possibly
- Tried an iterative approach where I reduce things incrementally and very gradually (tweak tilt and skew quad strength slowly until within imposed limit) - same result no matter my starting targets
- Currently trying the “de” optimizer, a lot slower though

de

The **de** optimizer stands for **differential evolution**[Sto96]. The advantage of this optimizer is that it looks for global minimum. The disadvantage is that it is slow to find the bottom of a local minimum. A good strategy sometimes when trying to find a global minimum is to use **de** in combination with **lm** or **lmdif** one after the other. One important parameter with the **de** optimizer is the **step** size. A larger step size means that the optimizer will tend to explore larger areas of variable space but the trade off is that this will make it harder to find minimum in the locally. One good strategy is to vary the **step** size to see what is effective. Remember, the optimal step size will be different for different problems and for different starting points. The **step** size that is appropriate of the **de** optimizer will, in general, be different from the **step** size for the **lm** optimizer. For this reason, and to facilitate changing the step size, the actual step size used by the **de** optimizer is the step size given by a variable’s **step** component multiplied by the global

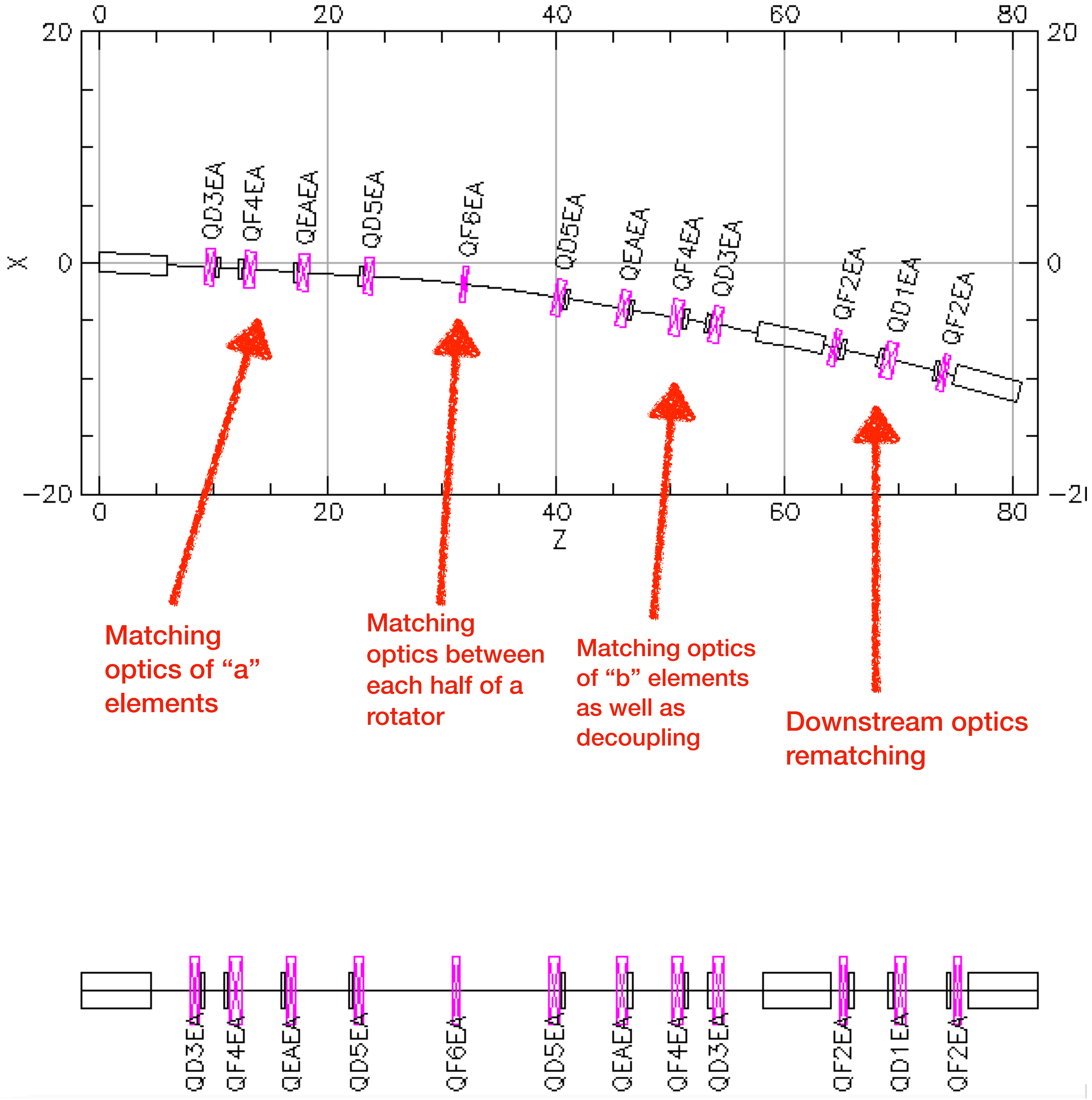
Tao manual, Bmad

Stage 4: Open Geometry Optical Rematch

- Once the tighter restrictions on the tilt have been successfully imposed for both lrot and rrot, we can begin with the open geometry rematch

- As Mike puts it: “8 variables, 12 control knobs”

- Simultaneously rematch dispersion, beta, alpha while keeping orbit fixed at 0 and decoupled at the ends of each half of a rotator



Reproduction tests

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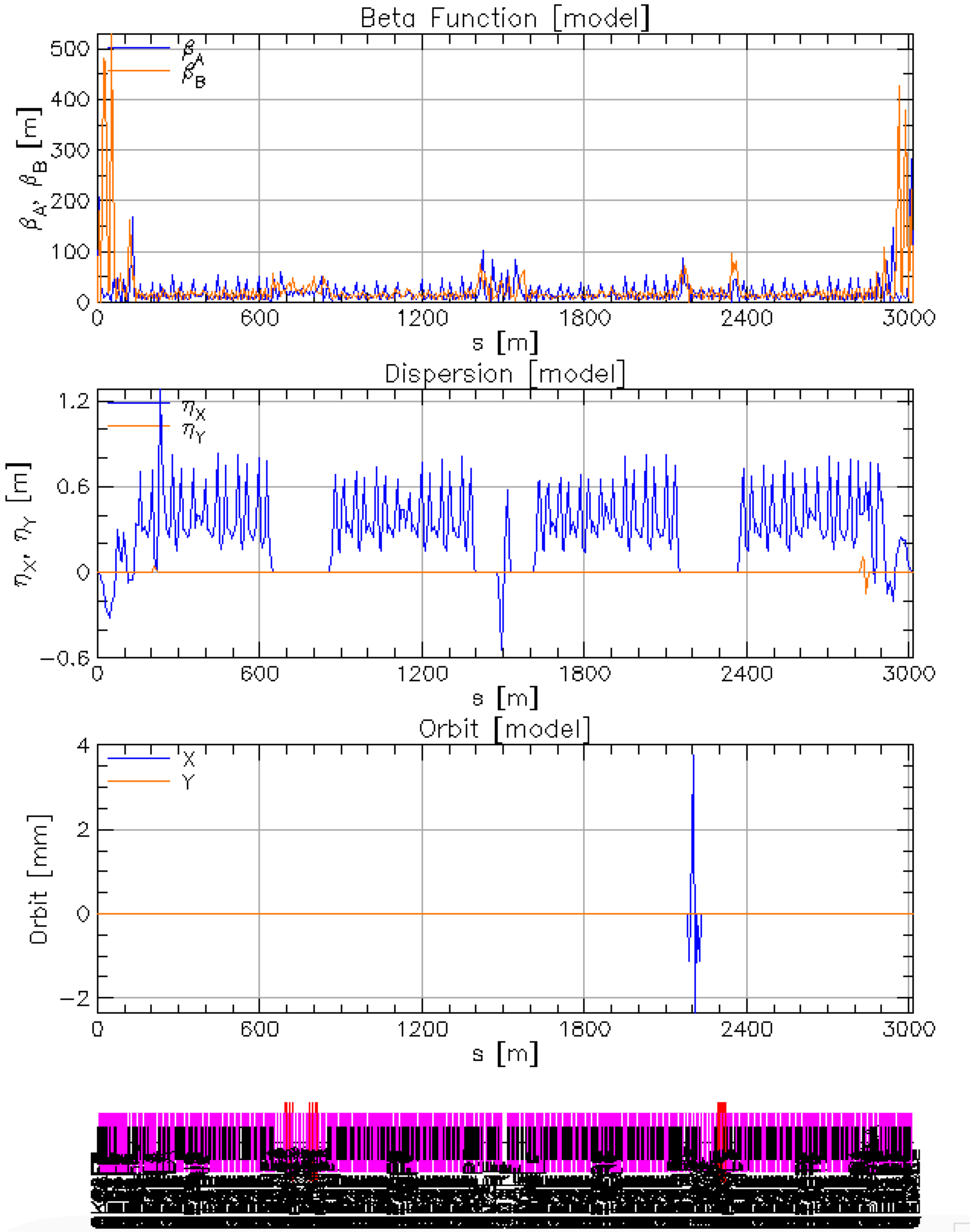
- Run every fitter, unmodified, rebuild 96 slice model rotator
  - Good way to verify that things are being done correctly and BMAD updates not changing how optimizing is done

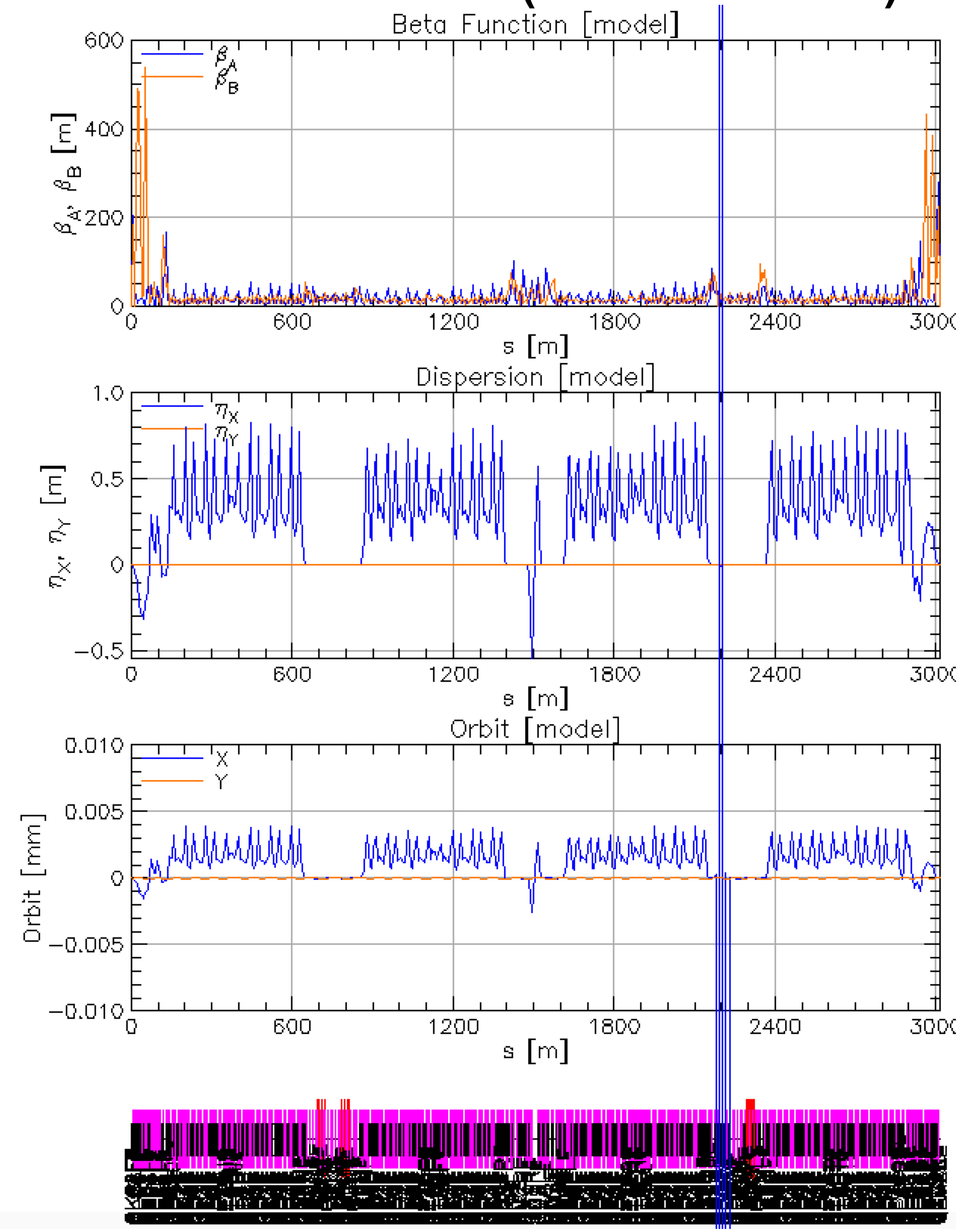
  - Everything is unmodified, except making sure the former fitting results were removed before doing my fitting.

Reproduction Tests

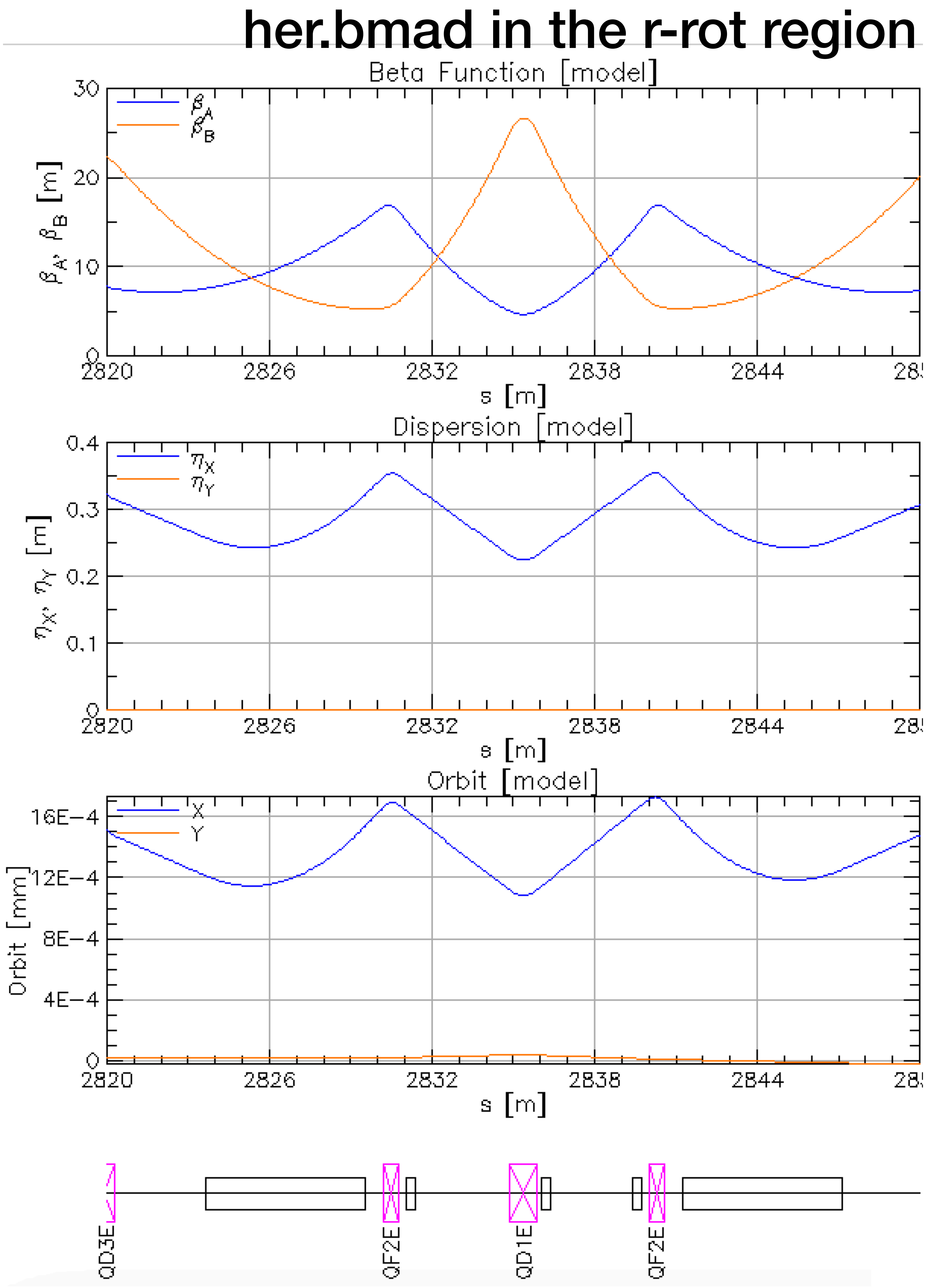
validation 96

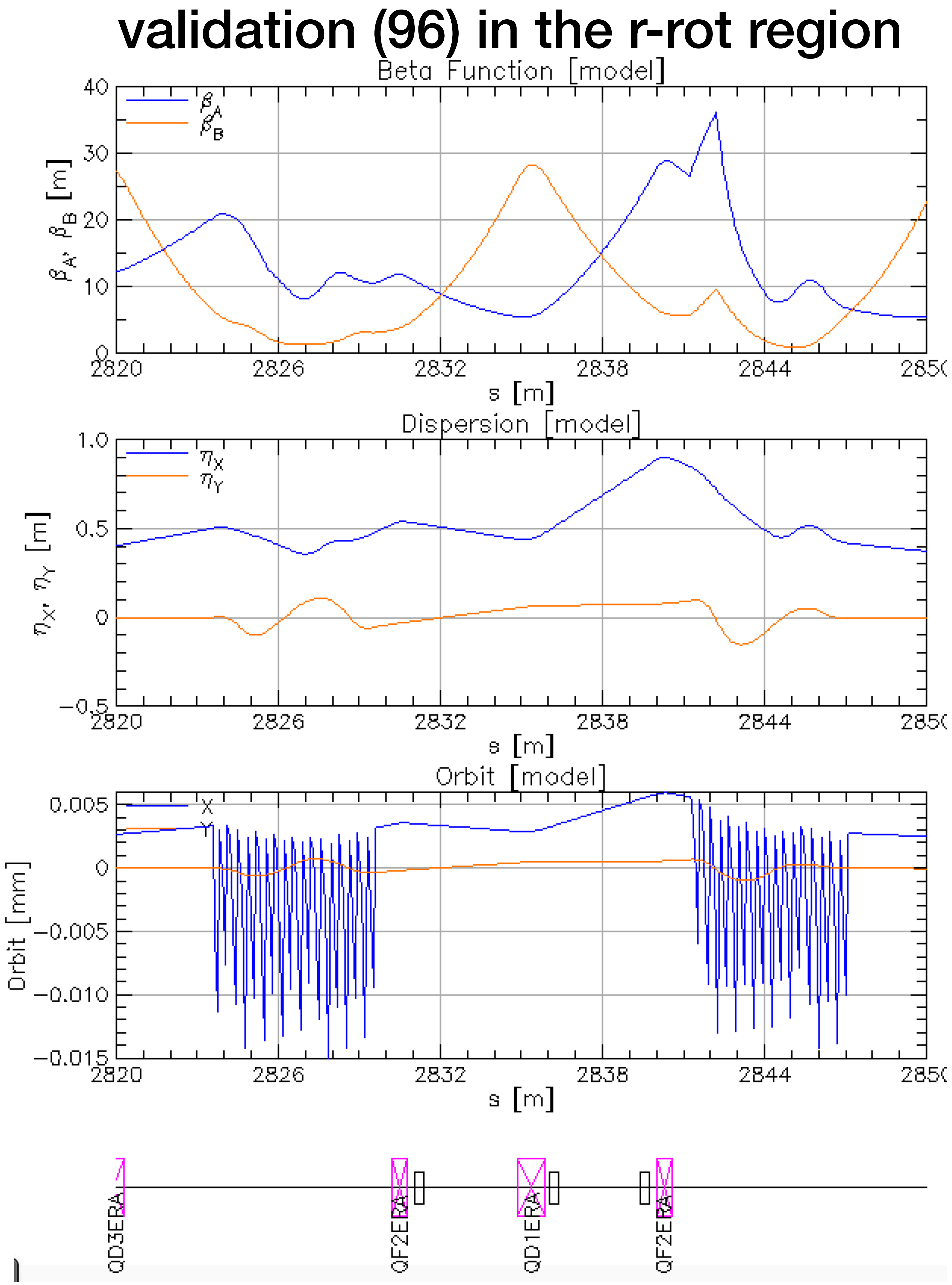


her.bmad (orbit is scaled)



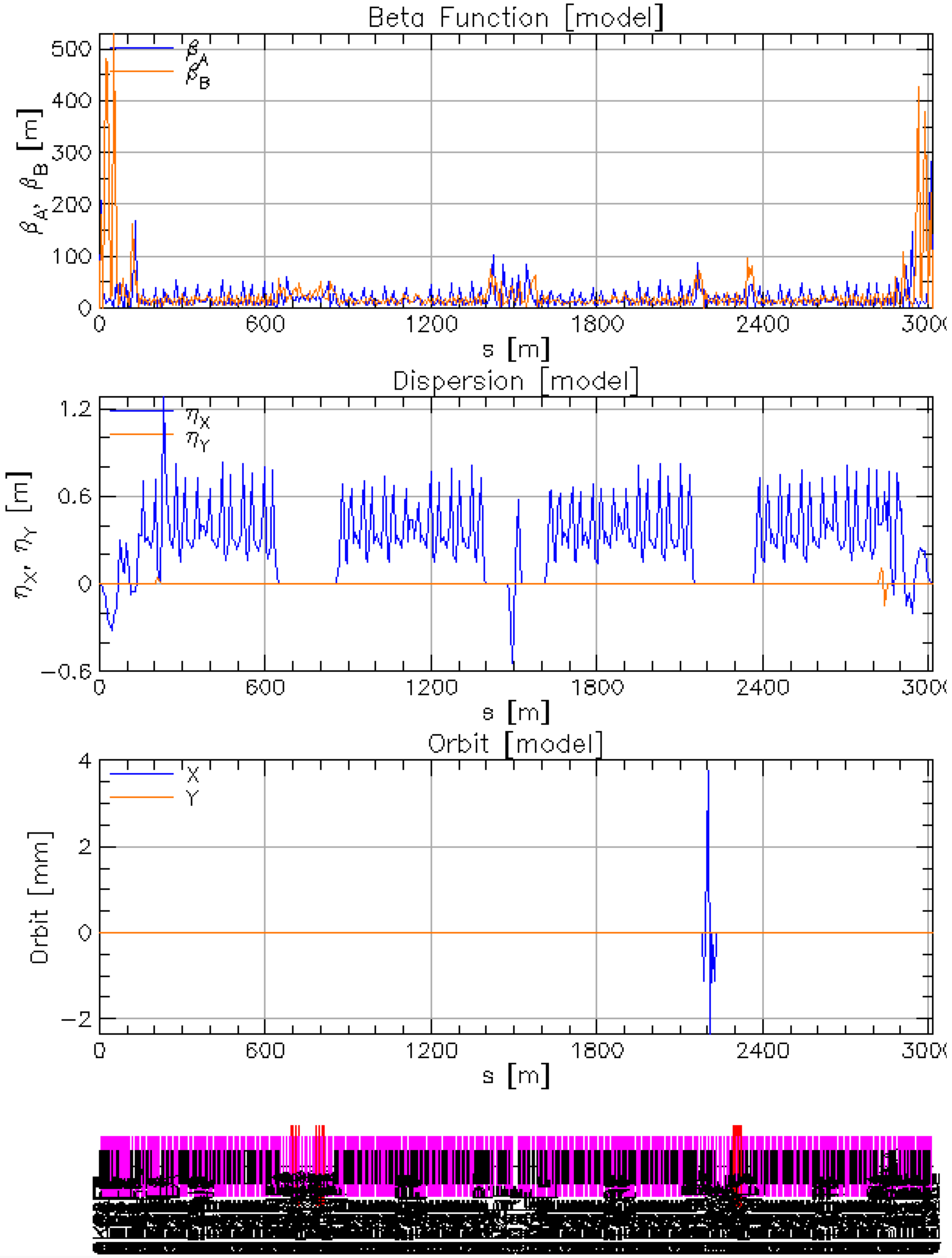
Reproduction Tests



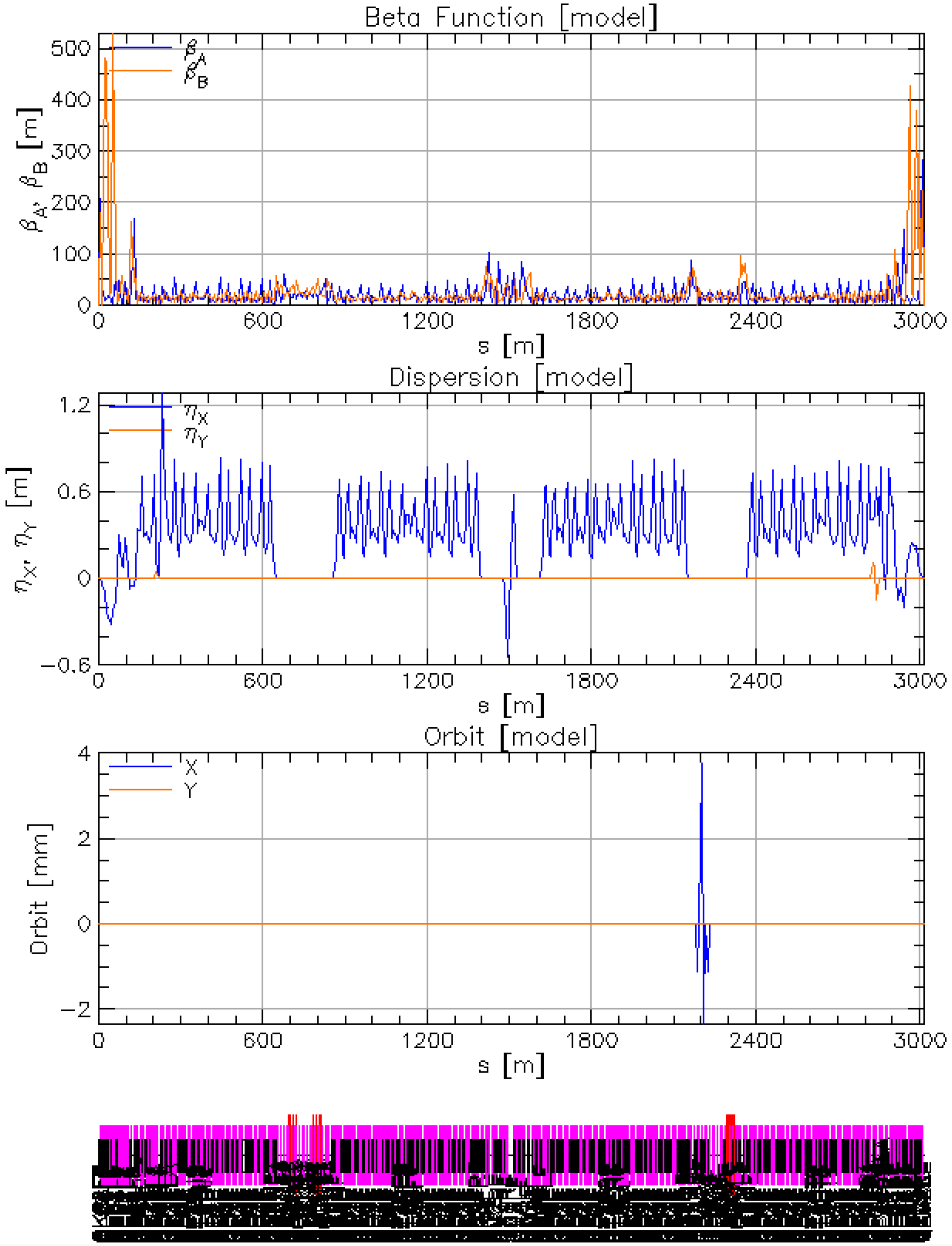


Reproduction Tests

Rot.bmad (uses 96 slice)



validation (96 slice)



What's next

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- Finish the optimizing of the 120 slice model (seems to be the most promising) and 144 slice model once ironed out process and can debug the issues efficiently

- Long Term Tracking of 120 slice model (and 144 slice model) once the above is addressed

Roadmap

University of Victoria

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with hkicks on & sq quads off	hkick	x-orbit	Lrot and rrot
	vkick	y-orbit	72, 96, 120, 144, validation
3. fit for squew-quad fields and tilt angles	squew quad field (k)	x-y coupling matrix off-diagonal = 0	Could not optimize 192
with hkicks on, Sol field on	tilt angle ('skew angles')	i.e. C matrix = 0	Lrot and rrot
to get rid of x-y coupling	hkick	x-orbit	validation
	vkick	y-orbit	
		beta function reasonable when both L-rot and R-r	Tighter restrictions on k1 and tilt.
4. rematch beta,alpha, dispersion, orbit - all i	Local Ring quad strength	beta, alpha, orbit, dispersion same as HER	
at exit of L-rot region and R-rot Region	squew quad strengths in L-rot and	at exit of L-rot region and R-rot Region	
		C=0 at exit	Done validation
CLOSED GEOMETRY			
		Stay within operational limits of magnet	
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6. rematch Chromaticity	set of ring sextupoles in ARC regior	Chromaticity same as in HER	Done validation