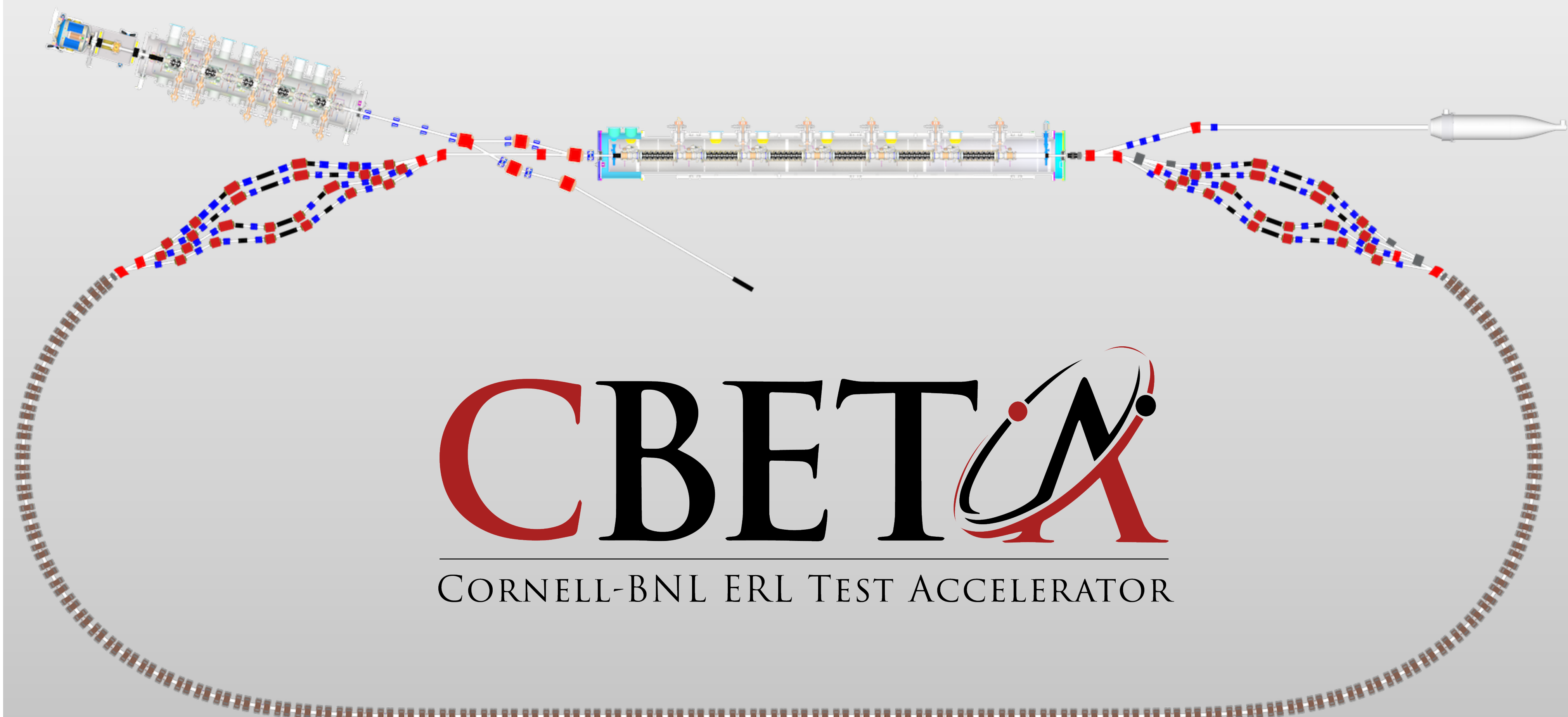
Cornell Laboratory for Accelerator-based Sciences and Education (CLASSE)

BROOKHAVEN NATIONAL LABORATORY

CBETA Multipass Lattice Design



CBETA

CORNELL-BNL ERL TEST ACCELERATOR

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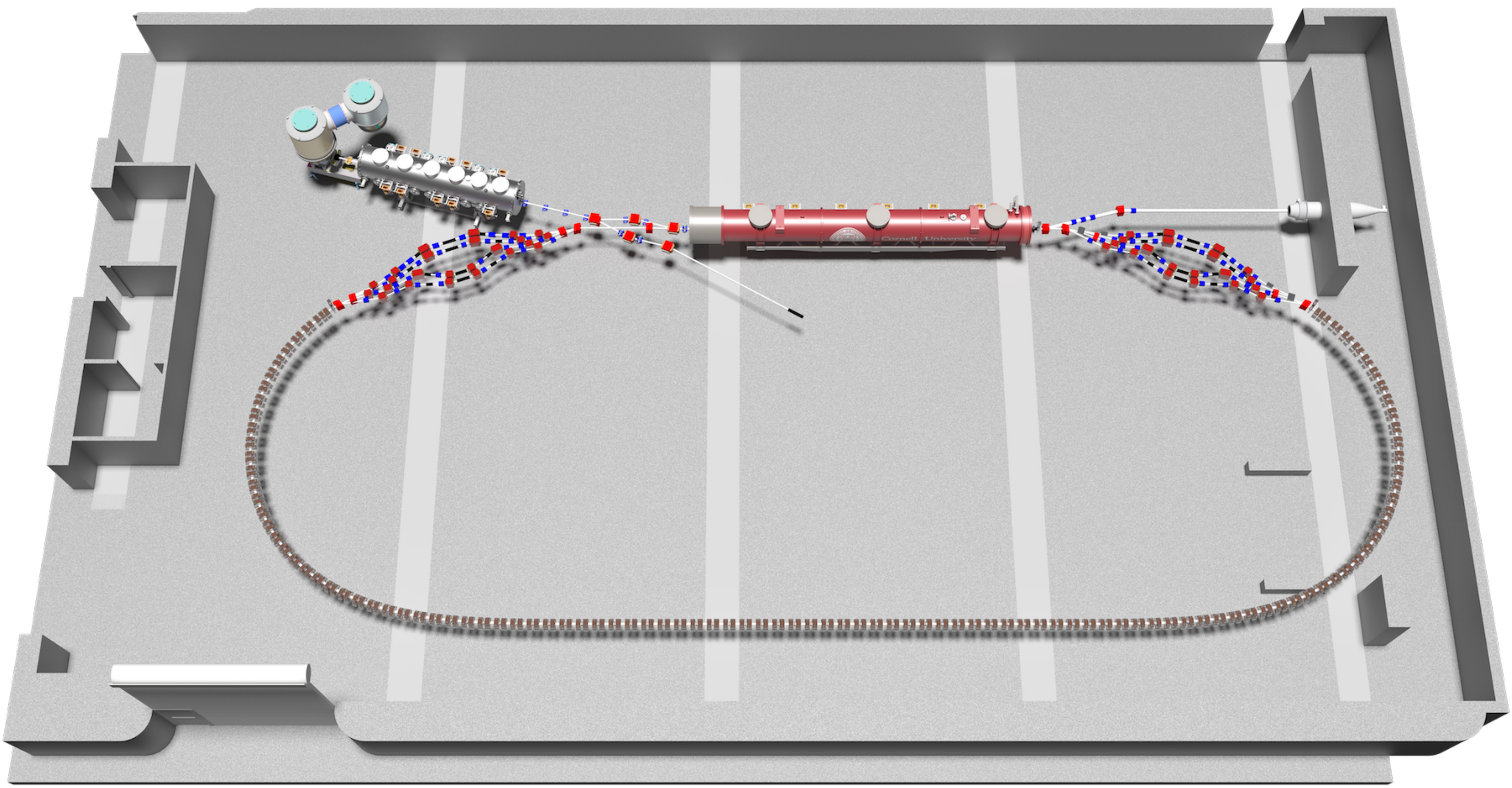
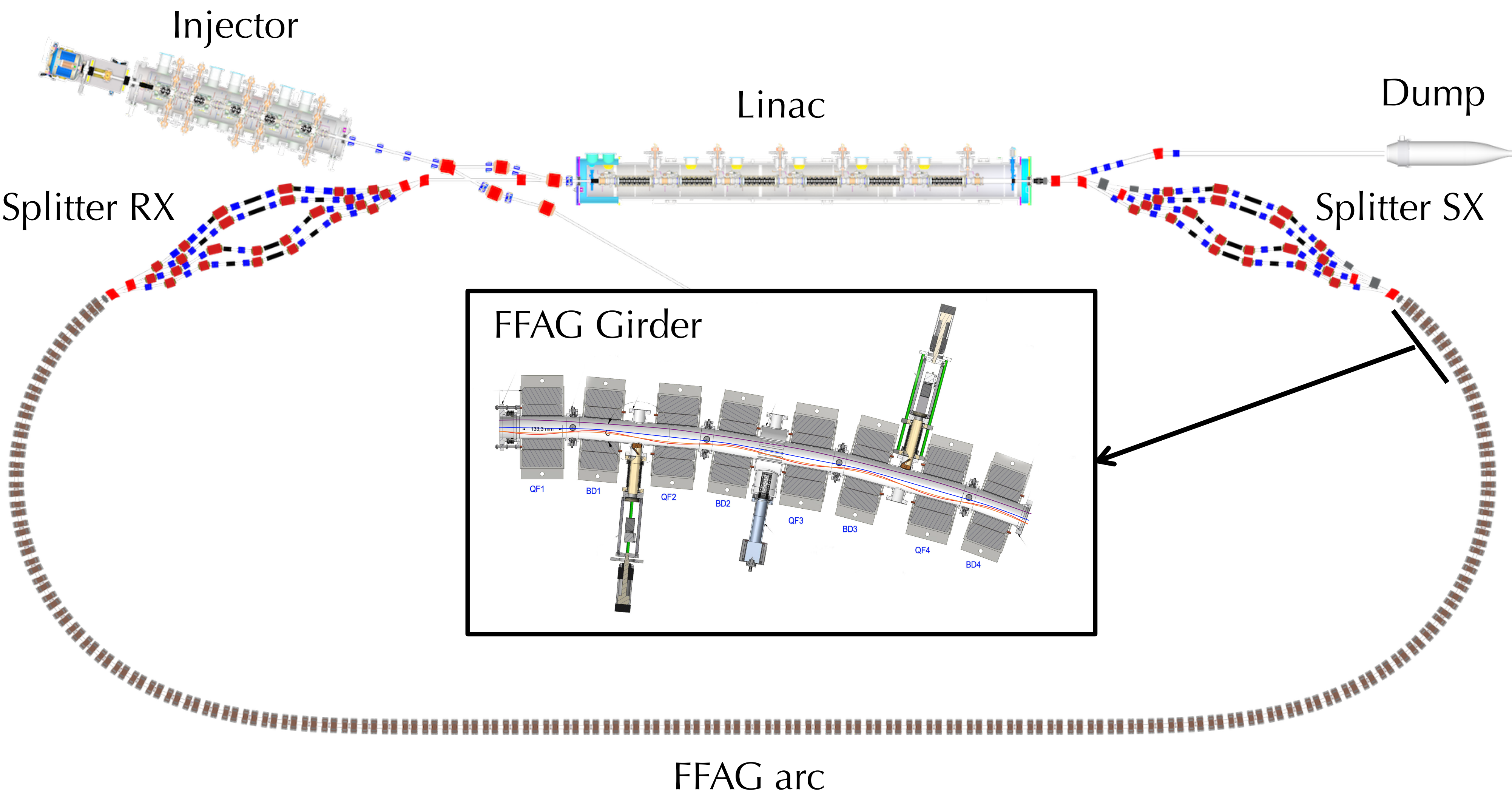
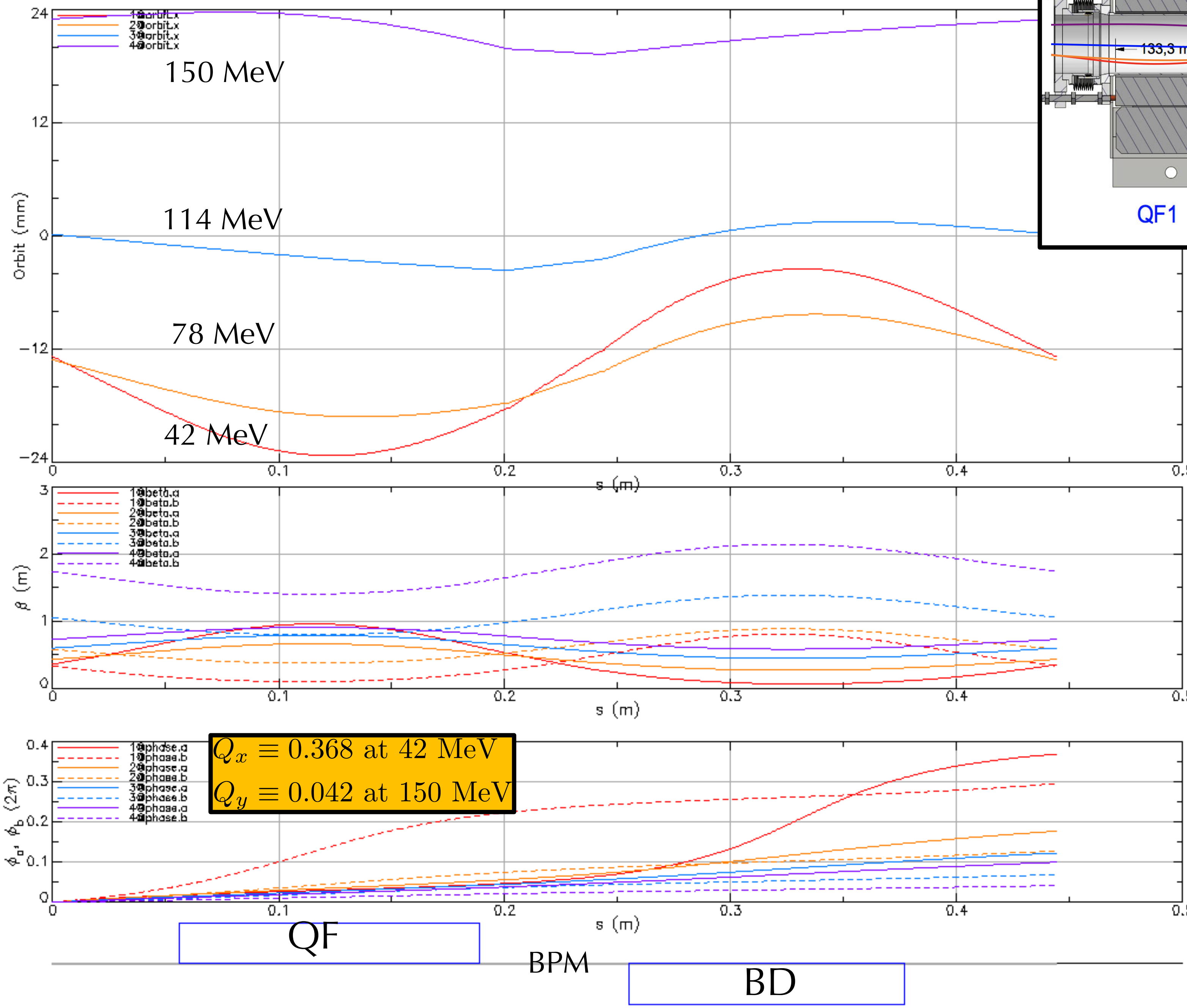
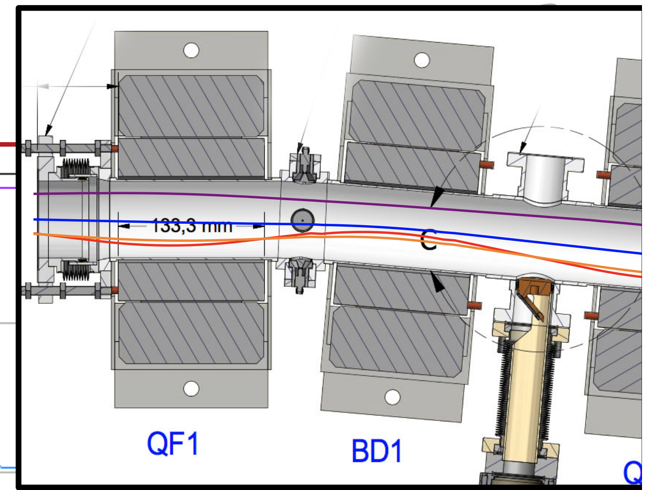


CBETA Layout in L0E

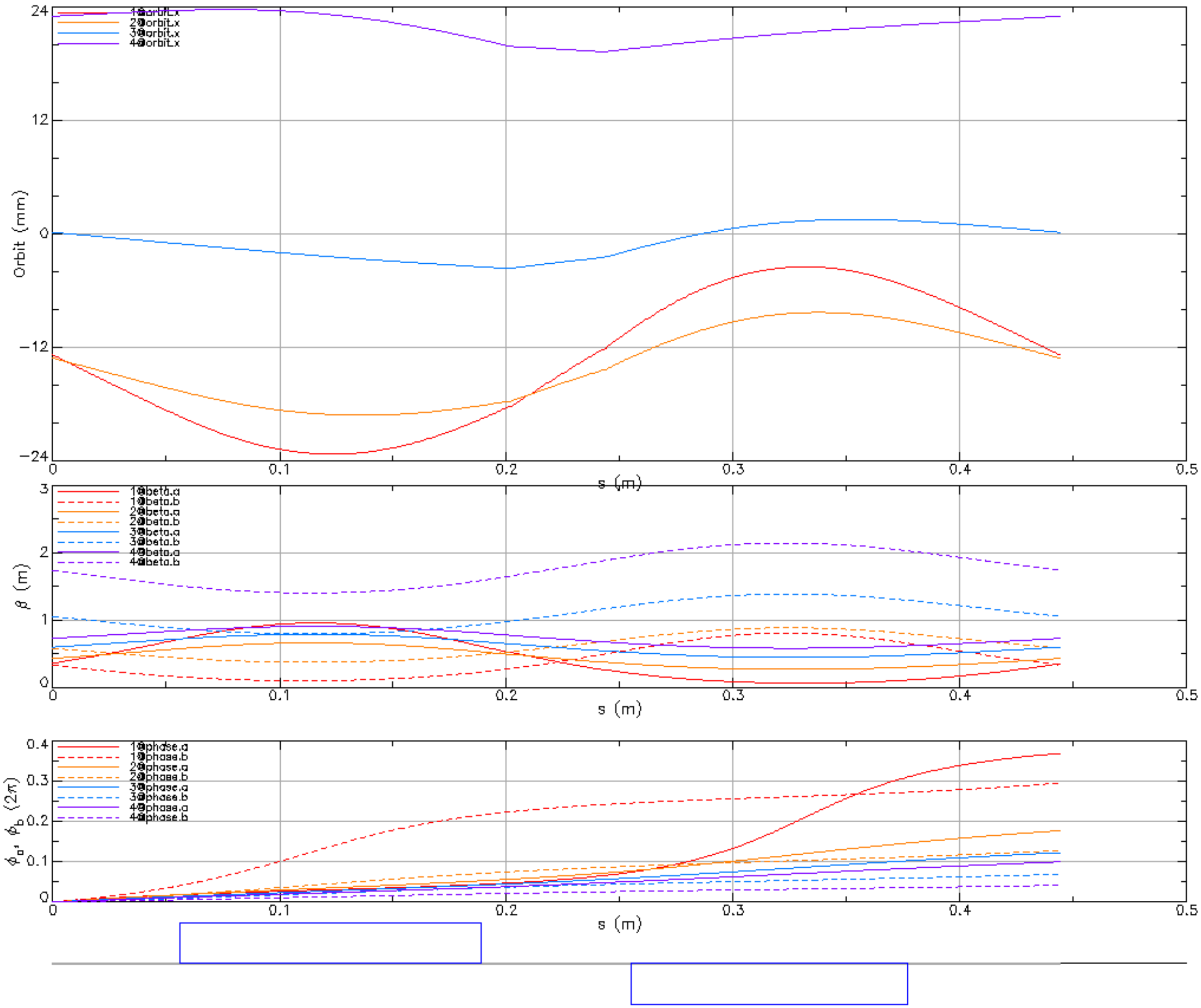


FFAG Arc Cell (5 deg)

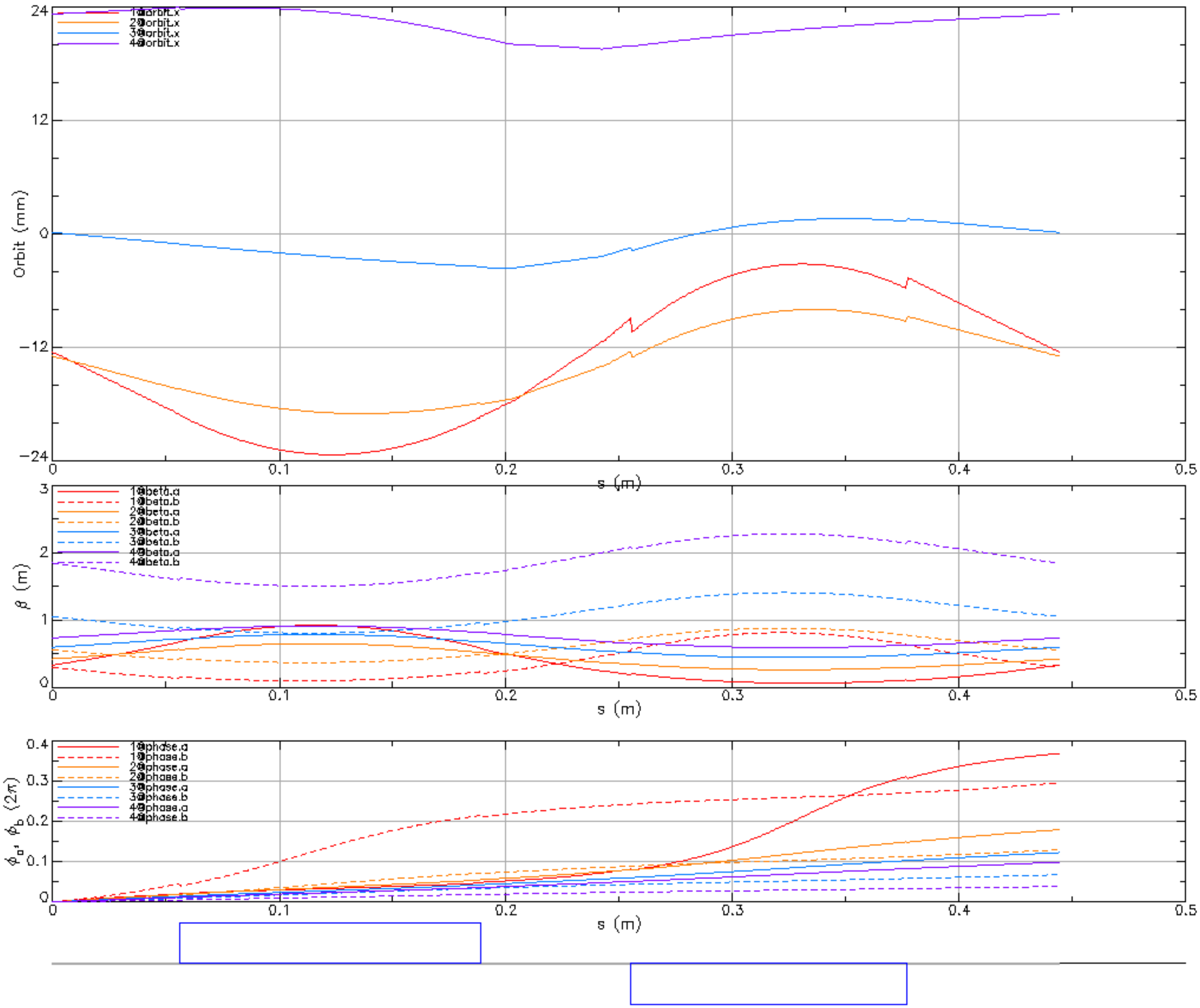




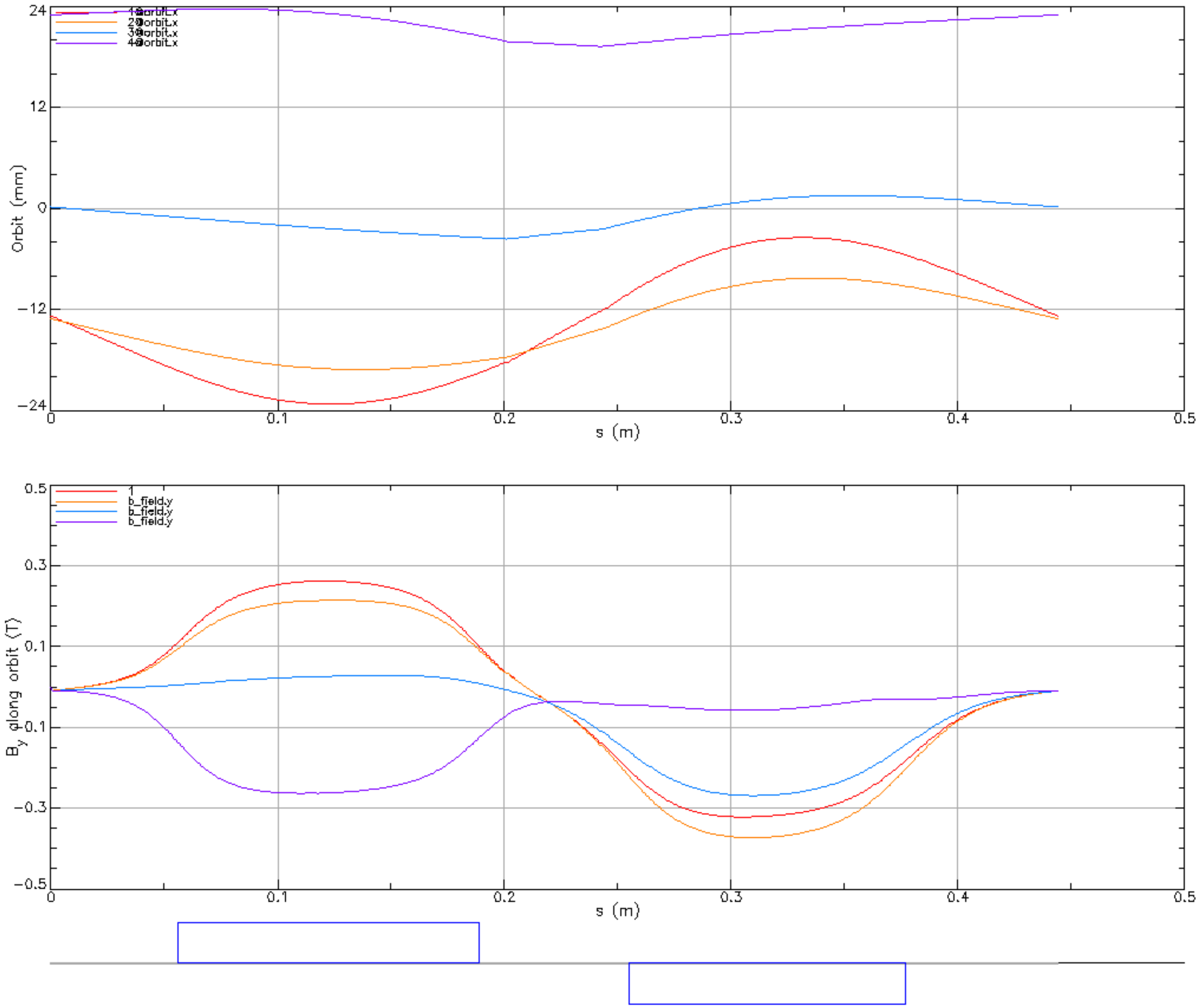
Cell designed with fieldmaps



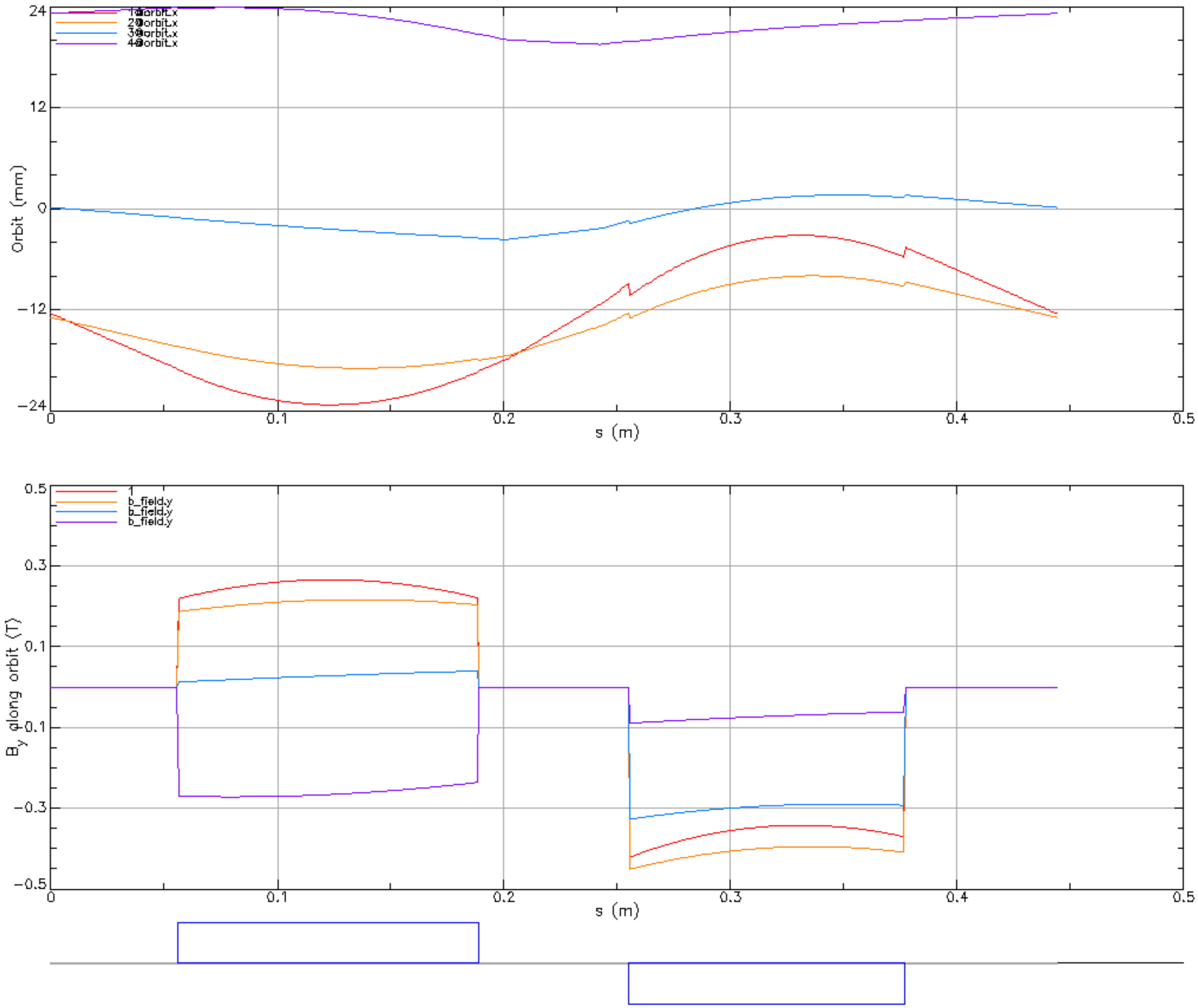
Cell modeled with Bmad_standard



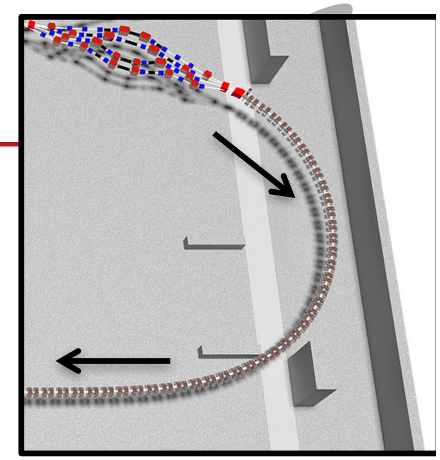
Fields seen: fieldmaps

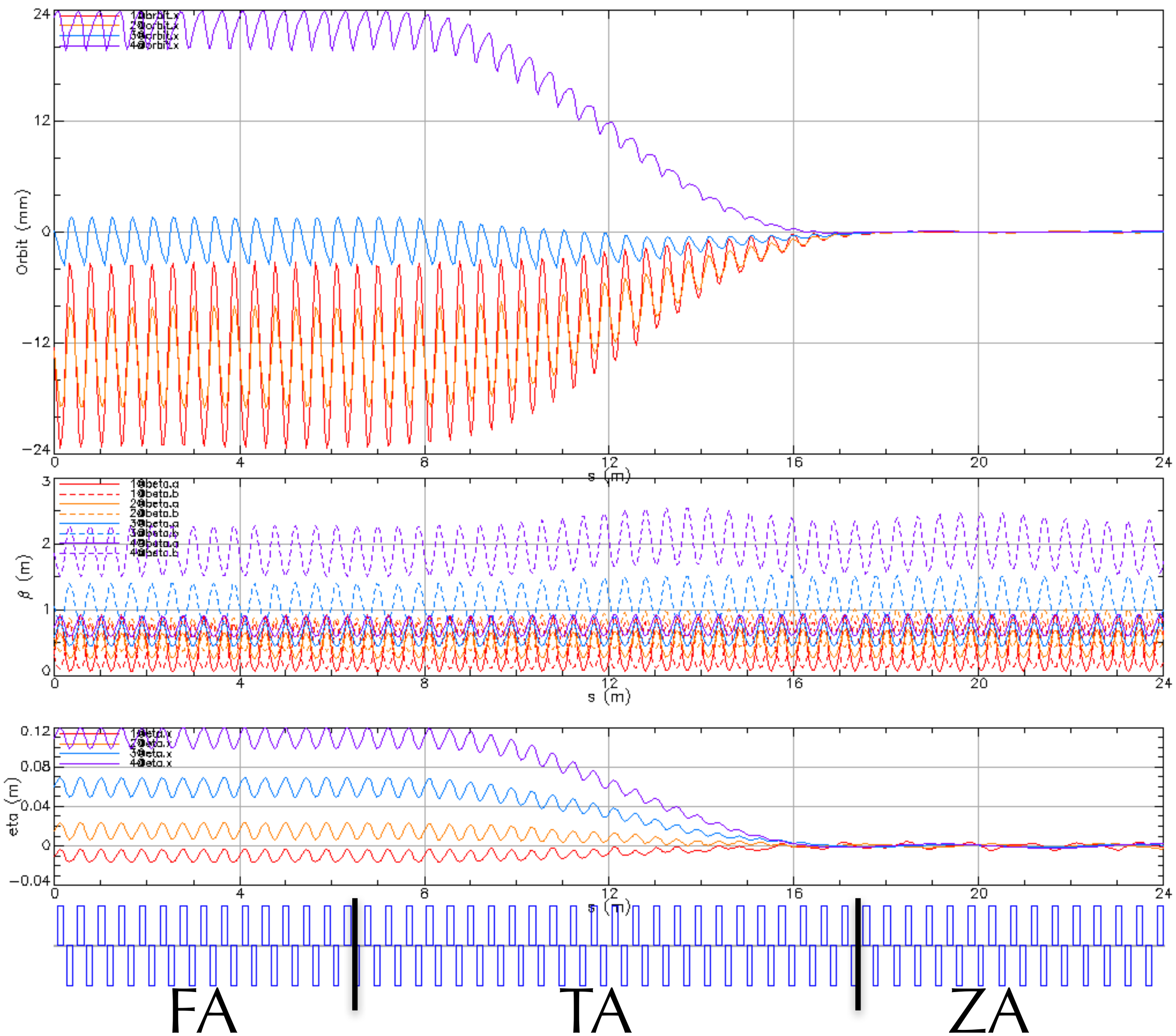


Fields seen: bmad_standard



Designed FFAG Arc, transition, straight

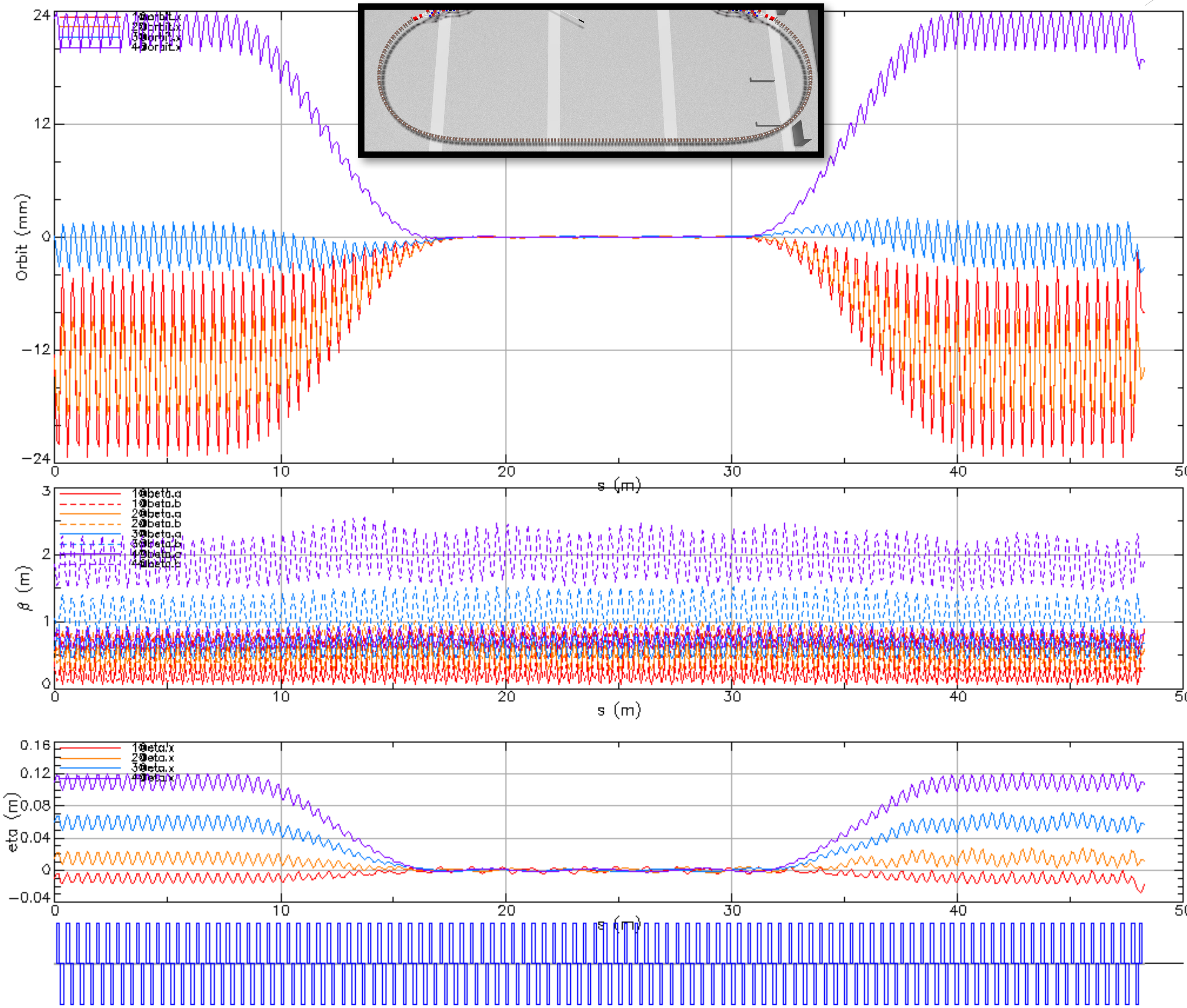




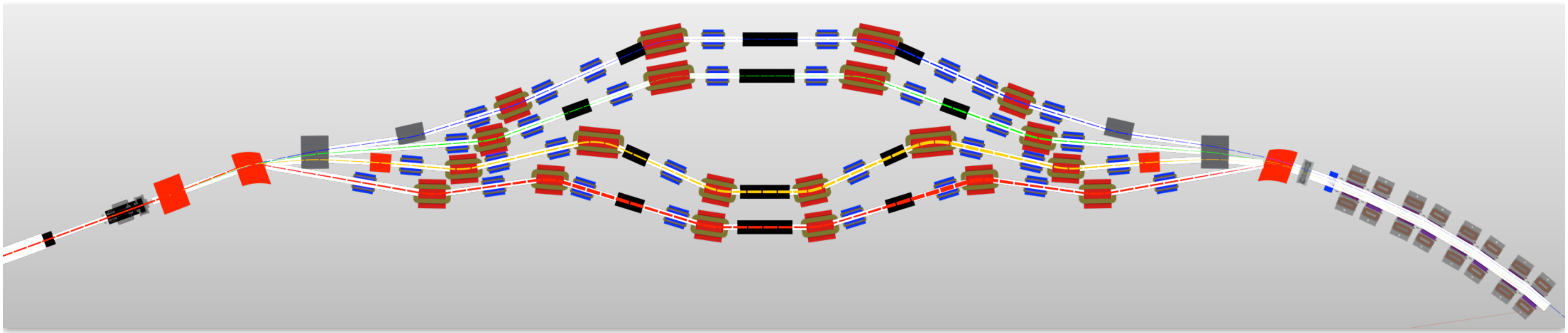
Offsets, angles scaled by factor:

$$f(x) = 1 - x + (1/2 - x)x(1-x)[1.788 + 3.954x(1-x) + 6.58x^2(1-x)^2]$$

Full FFAG Arc

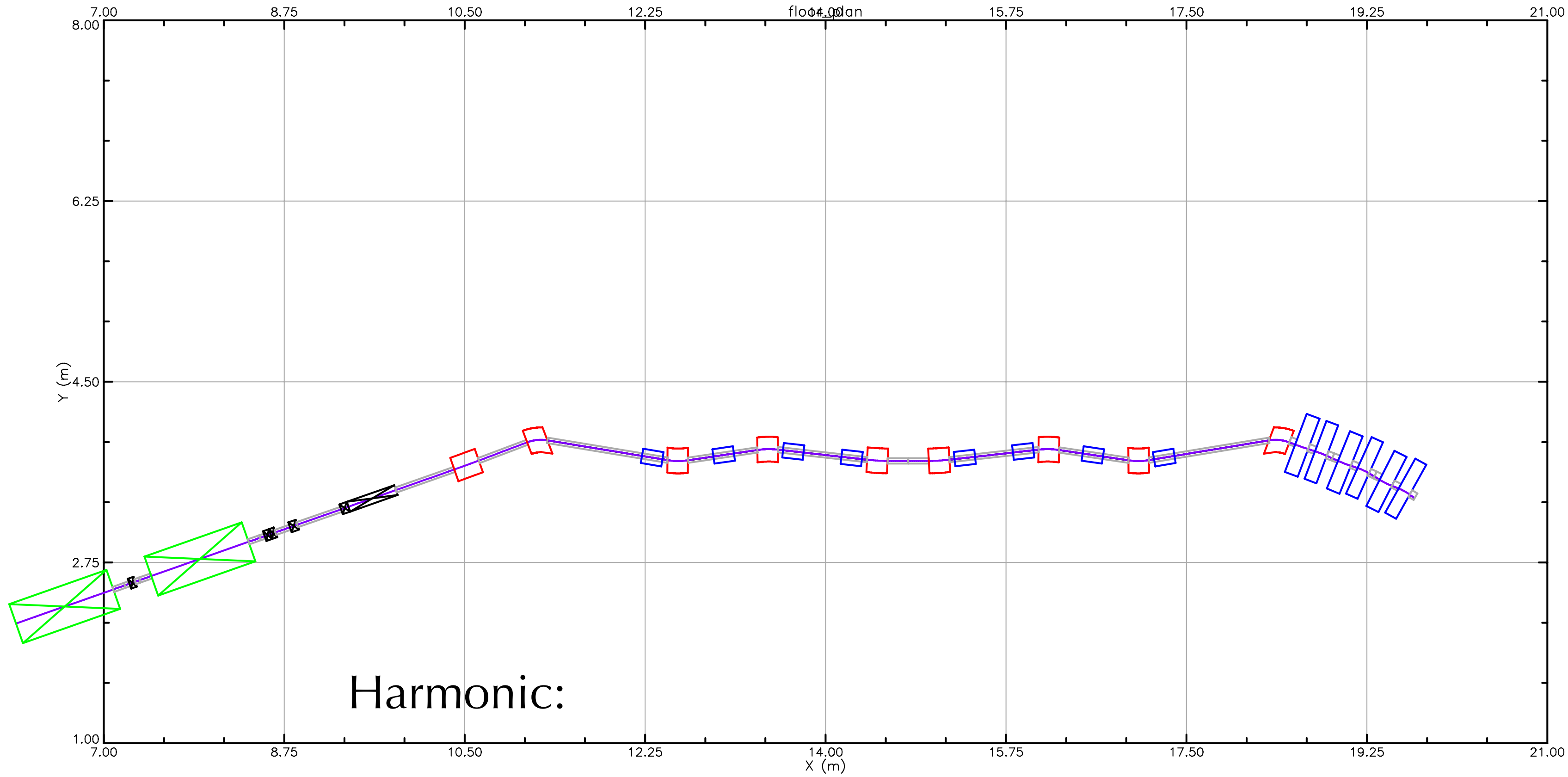


Splitters (SX, RX)



- Receive beams on-axis from the linac
- Match each energy beam onto its stable orbit in the FFAG arg
- Match optics for each energy beam into the FFAG arc
- Momentum compaction (r56) adjustment
- Path lengths: (S1 + FA pass 1) = (S2 + FA pass 2) =(S3 + FA pass 3)
- Allow path length adjustment by sliding joints, ±10 deg rf phase adjustment
- Dipole fields < 0.6 T
- Quad fields < 4 T/m
- Realistic transverse element sizes

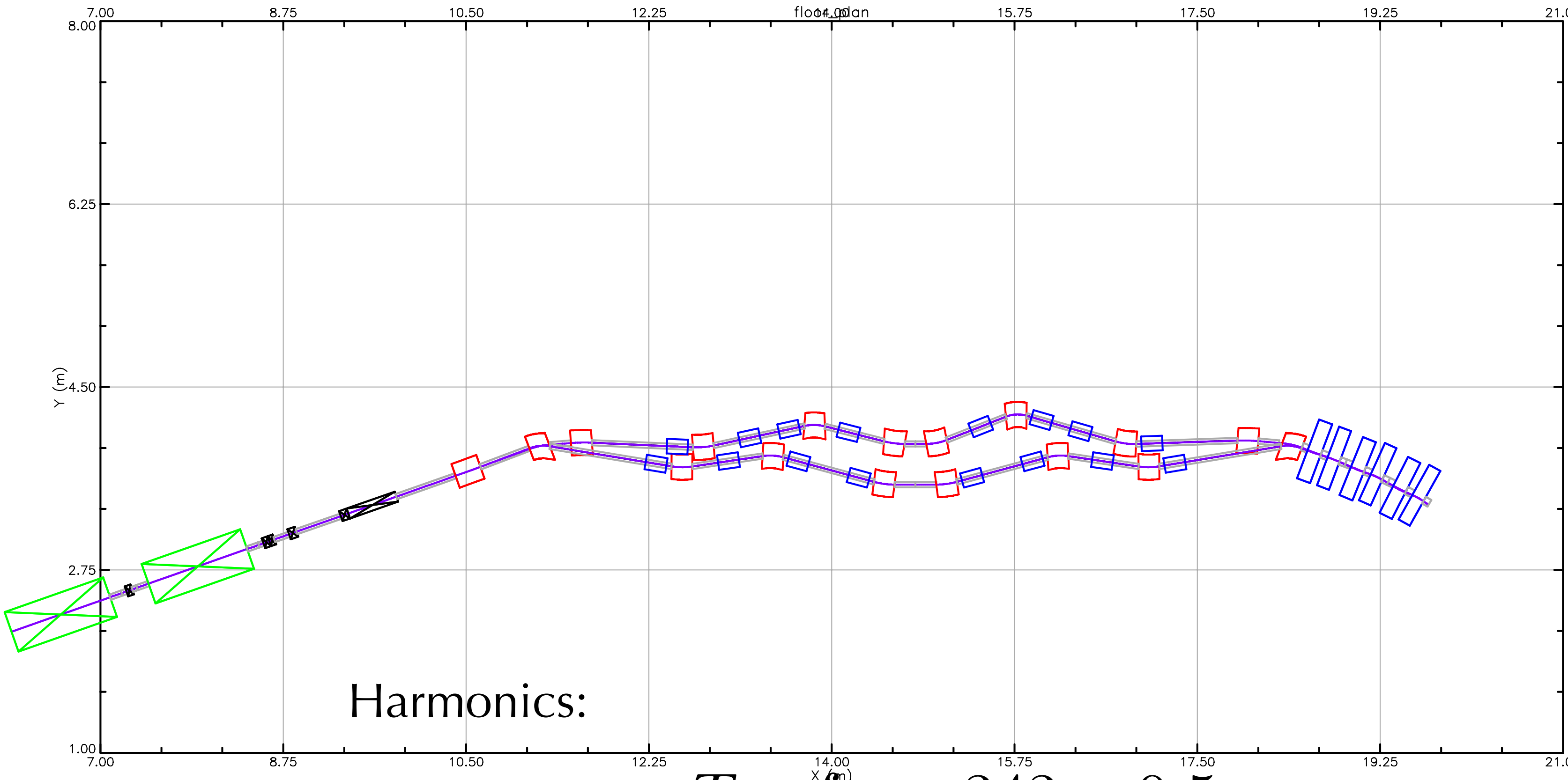
Path length: 1-pass ERL



Harmonic:

$$T_1 \cdot f_{\rm rf} = 343 - 0.5$$

Path length: 2-pass ERL

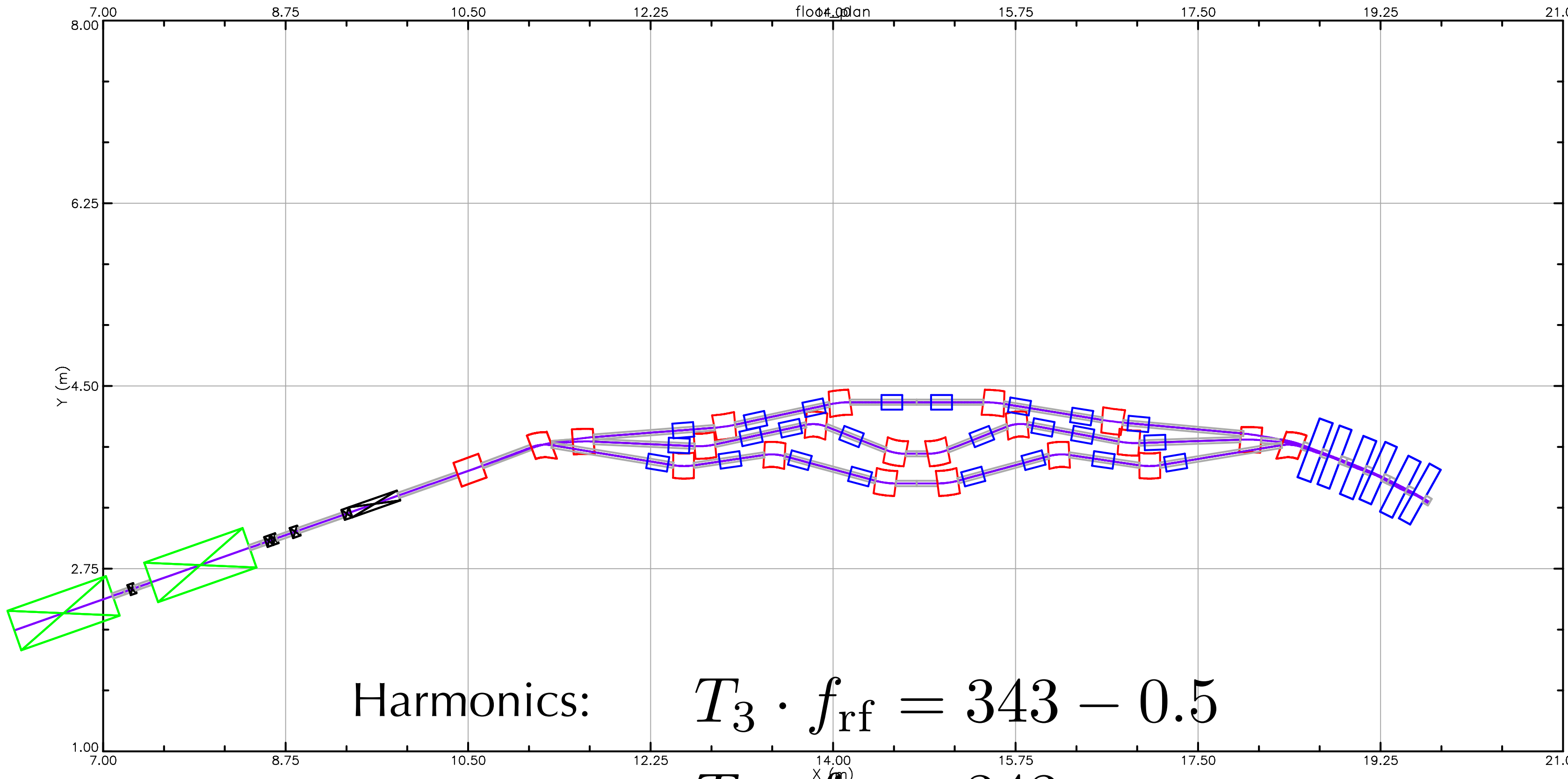


Harmonics:

$$T_2 \cdot f_{\mathrm{rf}} = 343 - 0.5$$

$$T_1 \cdot f_{\mathrm{rf}} = 343$$

Path length: 3-pass ERL



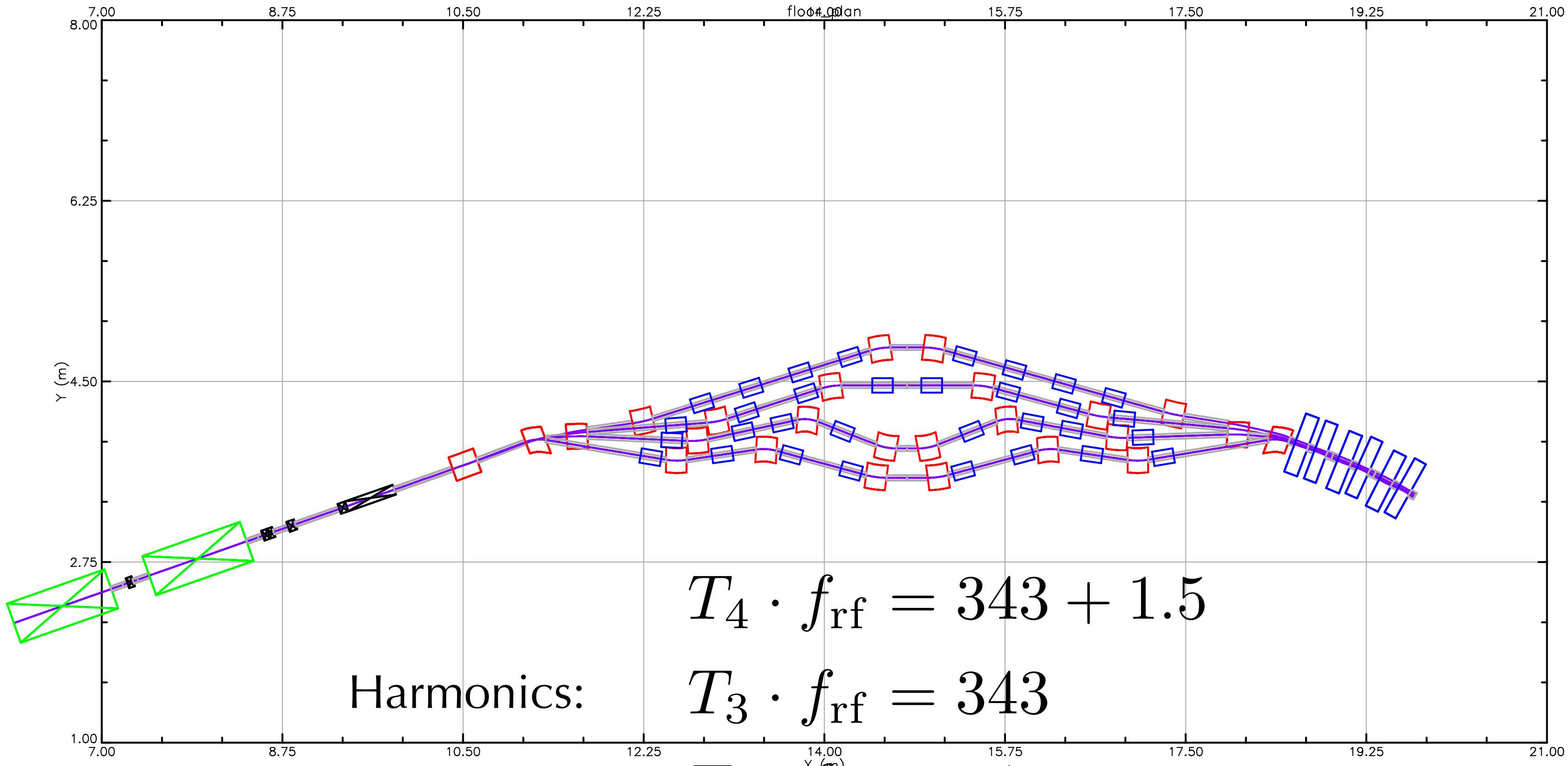
Harmonics:

$$T_3 \cdot f_{\mathrm{rf}} = 343 - 0.5$$

$$T_2 \cdot f_{\mathrm{rf}} = 343$$

$$T_1 \cdot f_{\mathrm{rf}} = 343$$

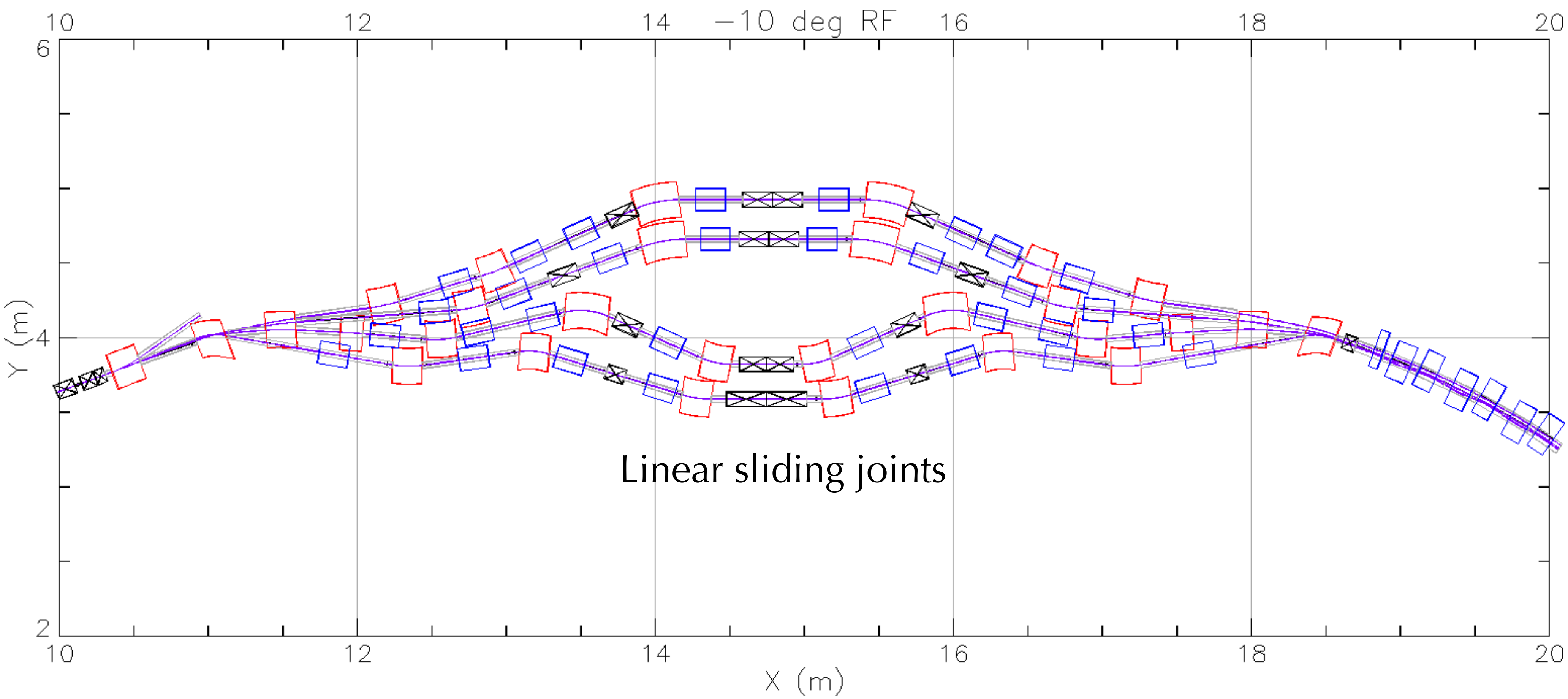
Path length: 4-pass ERL



Harmonics:

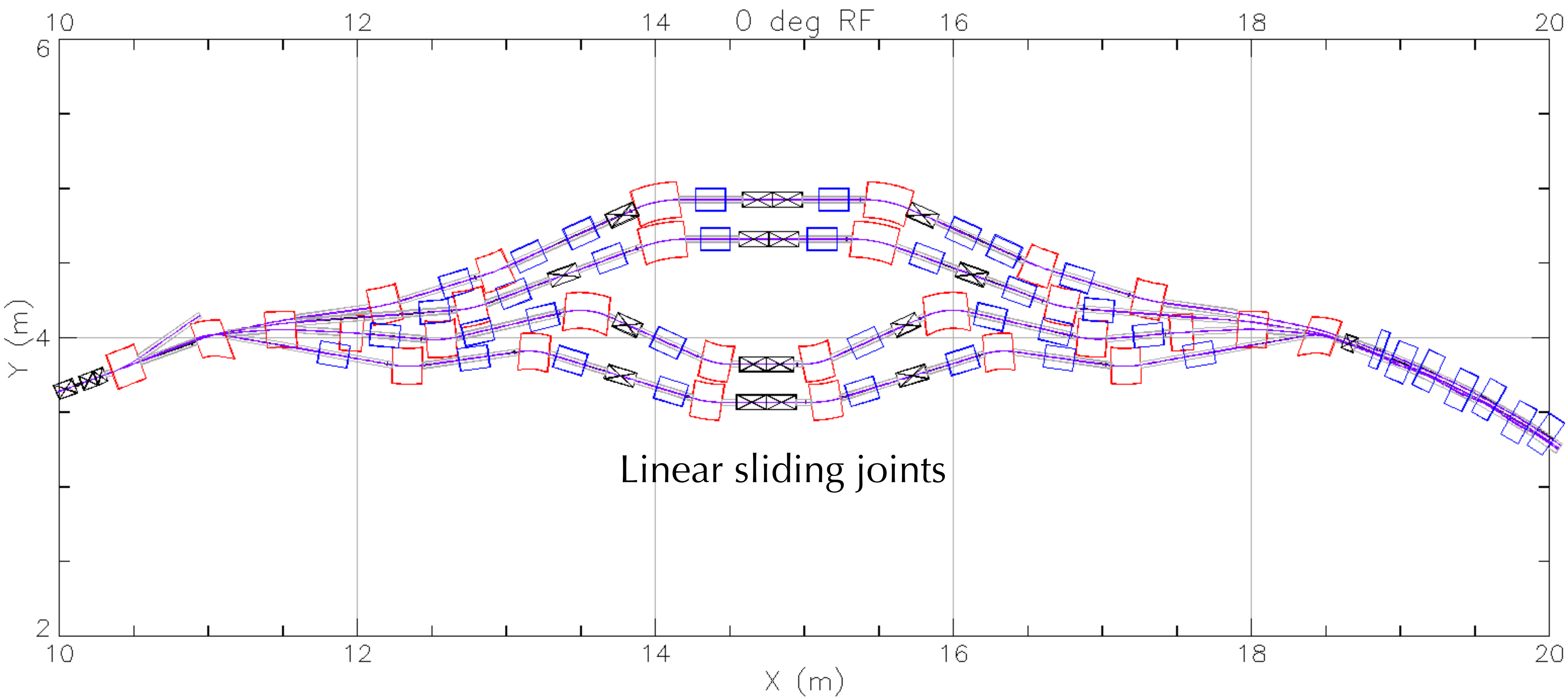
$$T_4 \cdot f_{\text{rf}} = 343 + 1.5$$
$$T_3 \cdot f_{\text{rf}} = 343$$
$$T_2 \cdot f_{\text{rf}} = 343$$
$$T_1 \cdot f_{\text{rf}} = 343$$

Pass 1 length adjustment



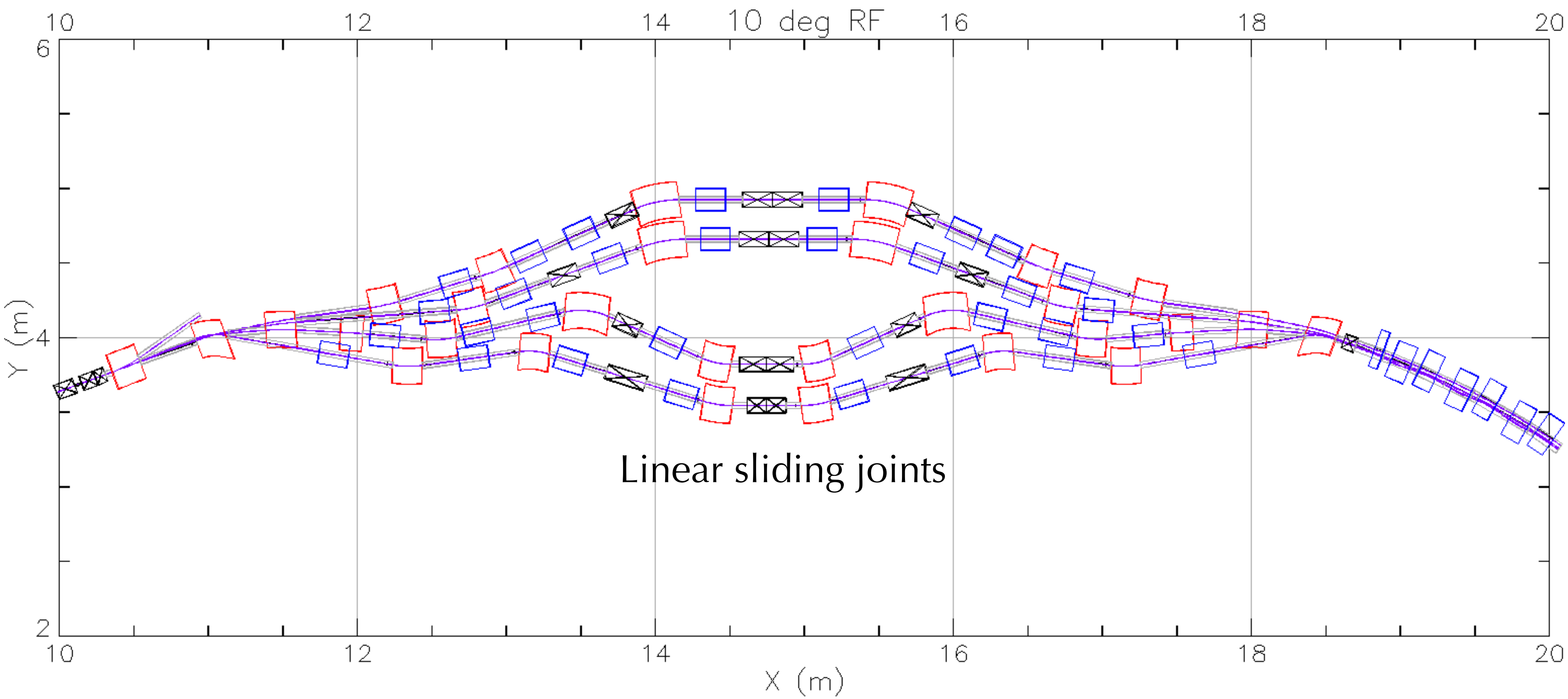
Linear sliding joints

Pass 1 length adjustment

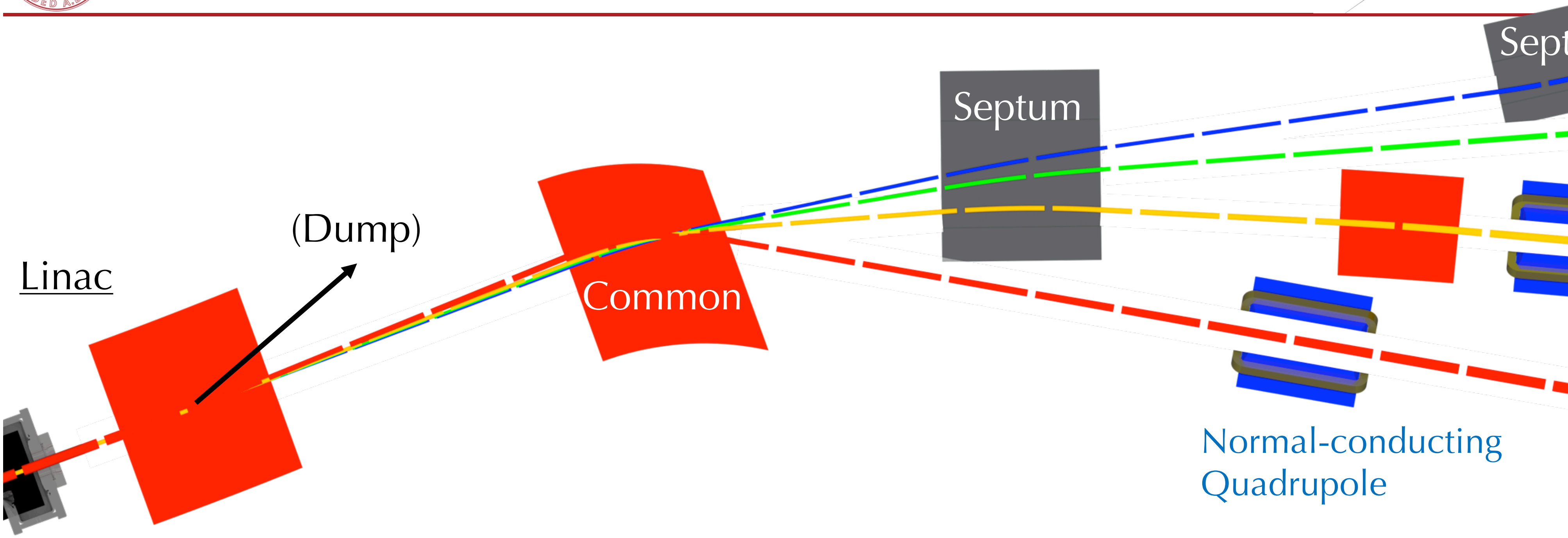


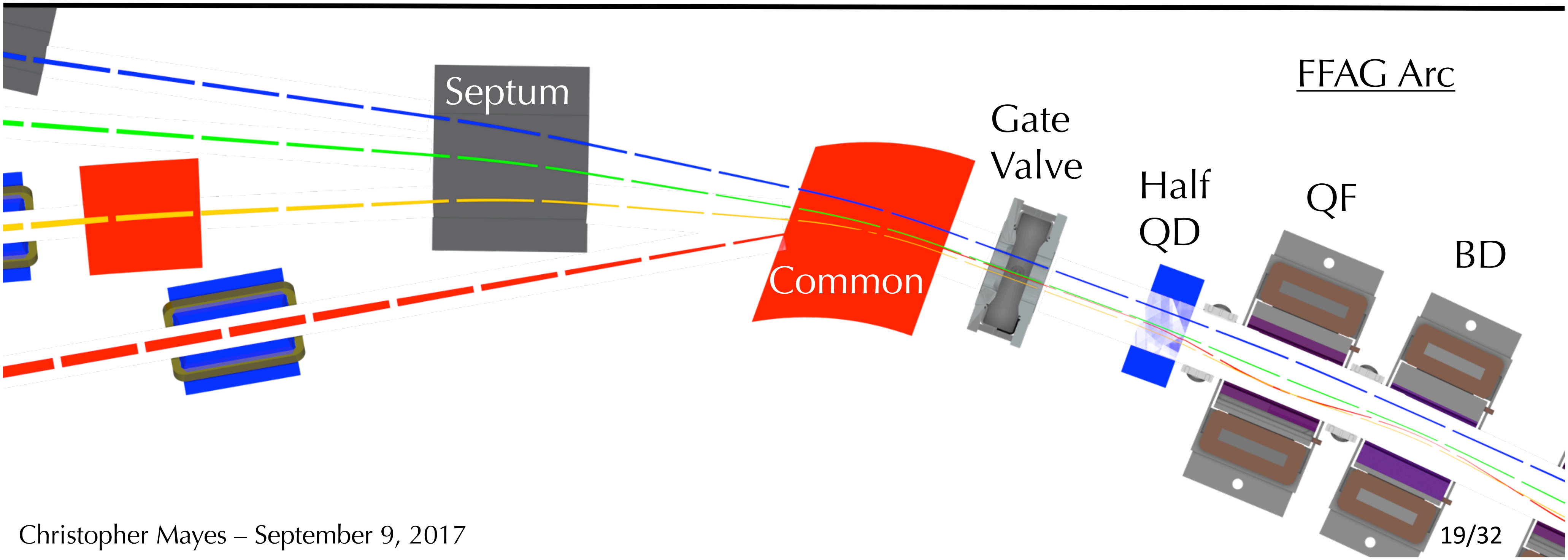
Linear sliding joints

Pass 1 length adjustment

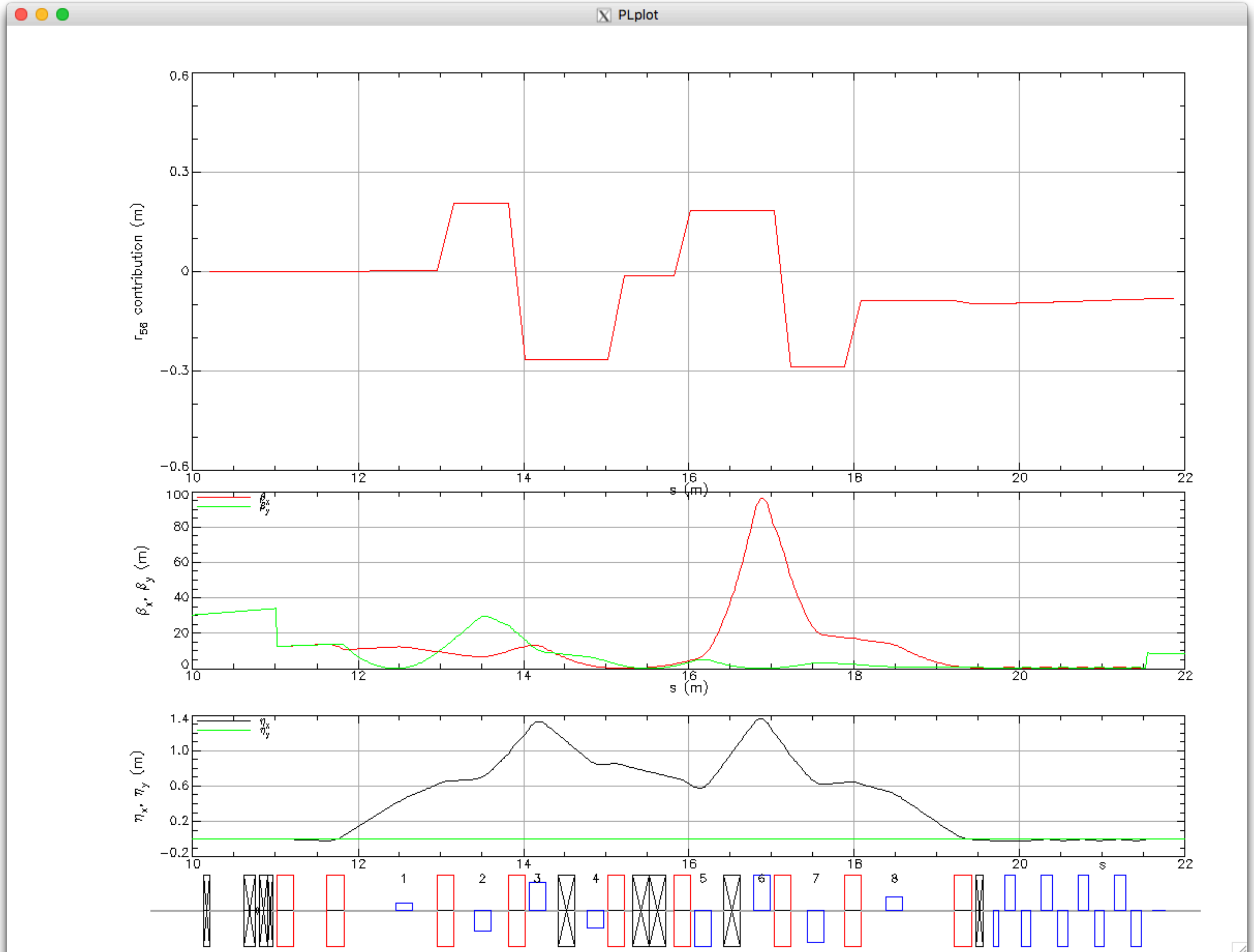


Splitter entrance and exit detail

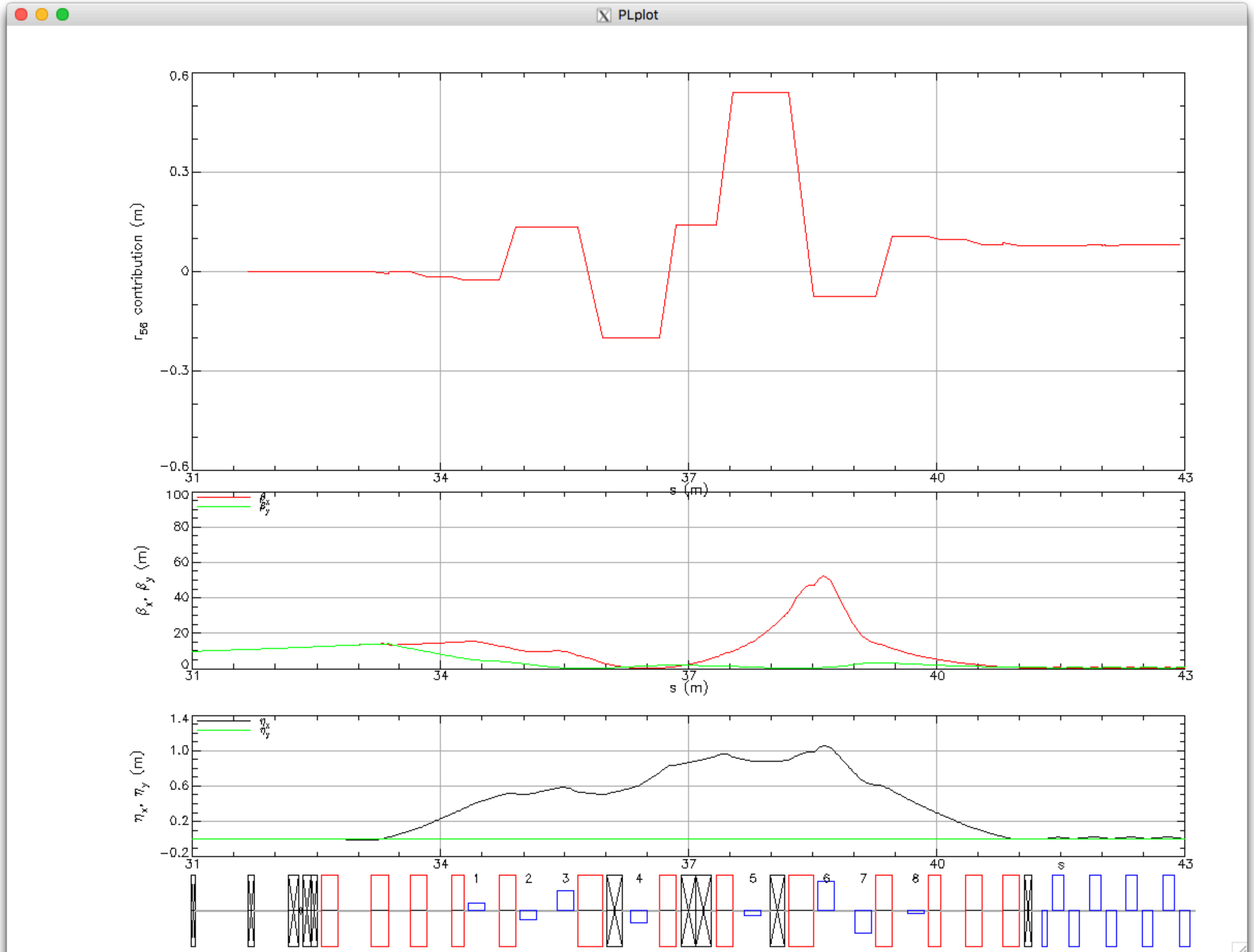




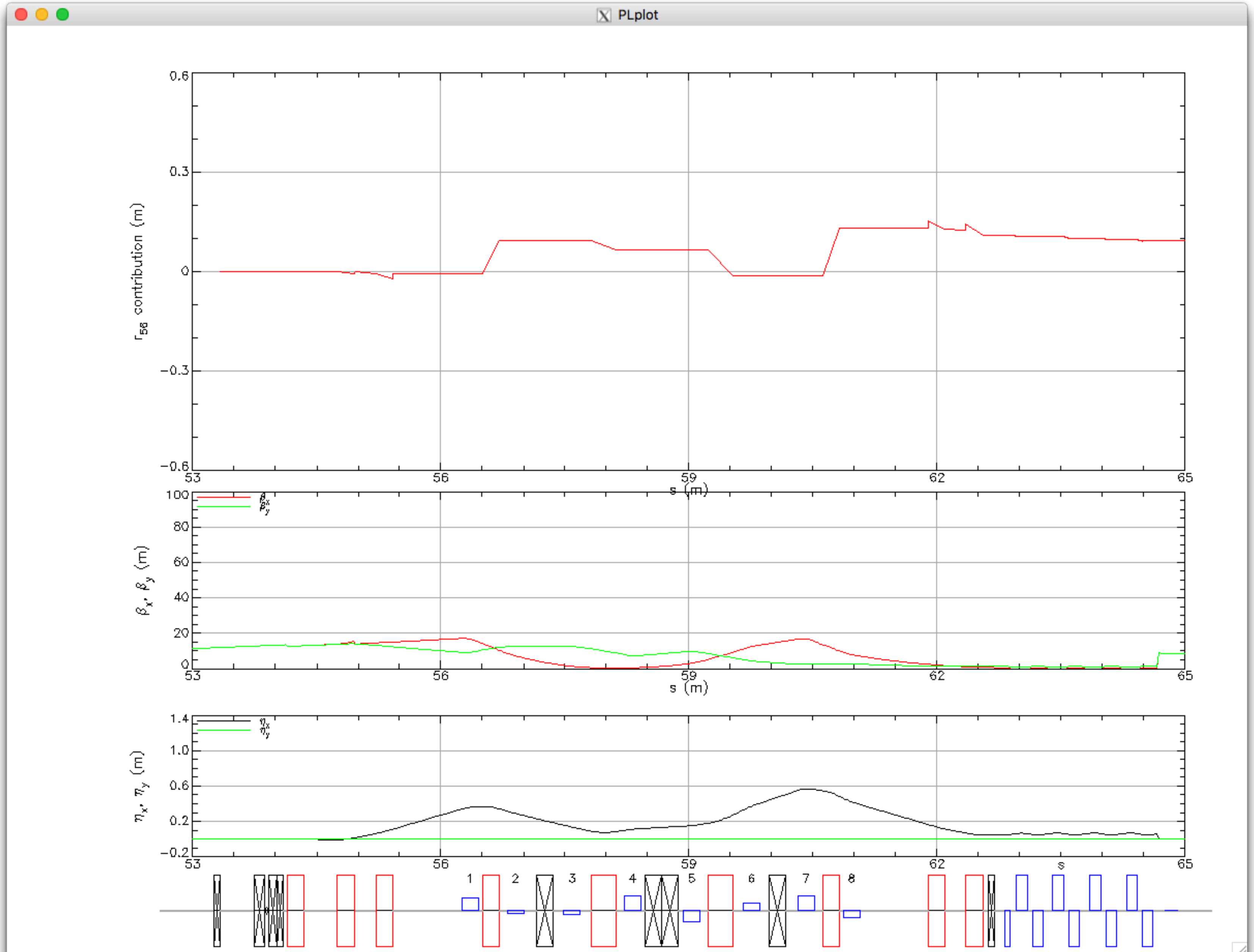
S1 optics (42 MeV)



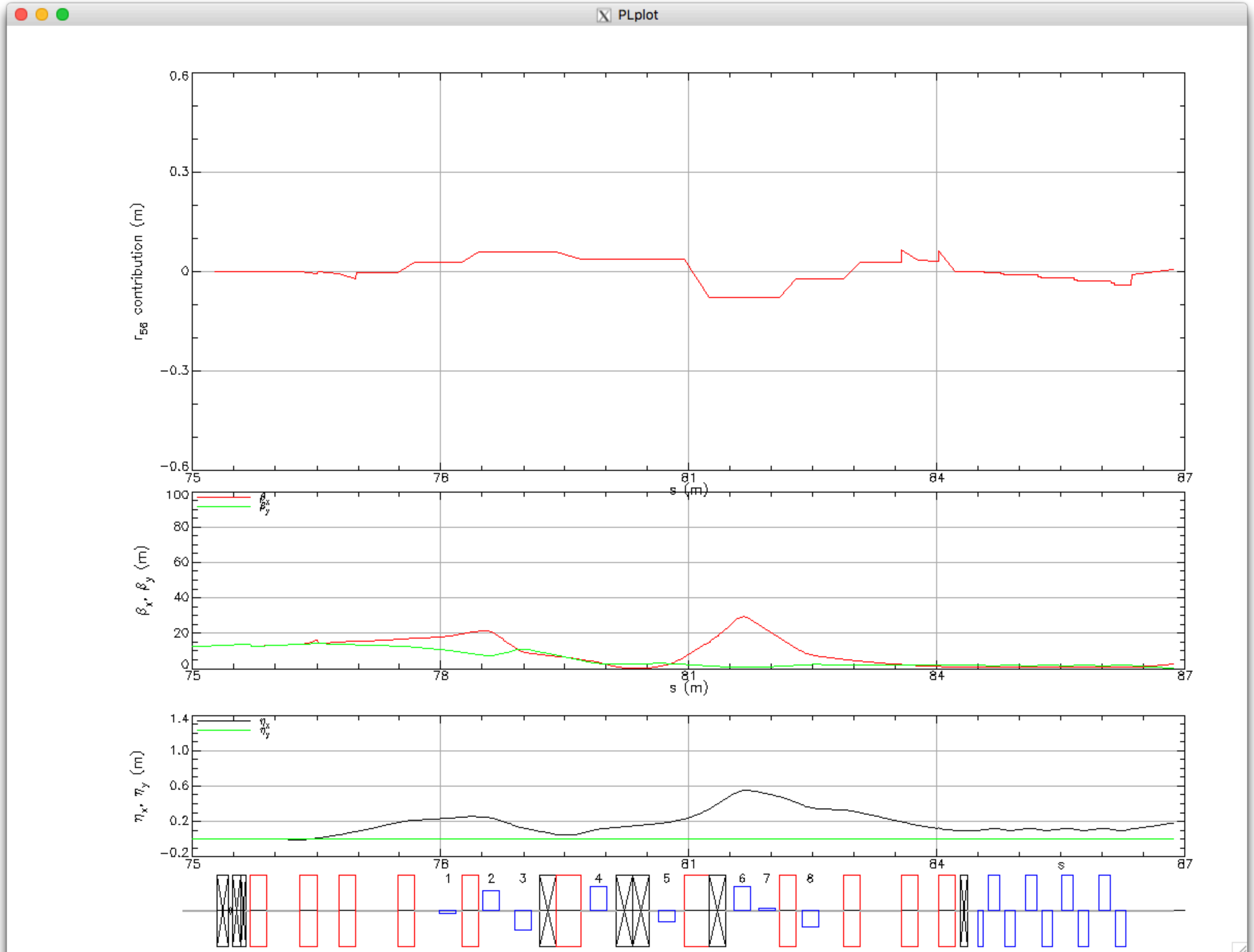
S2 optics (78 MeV)



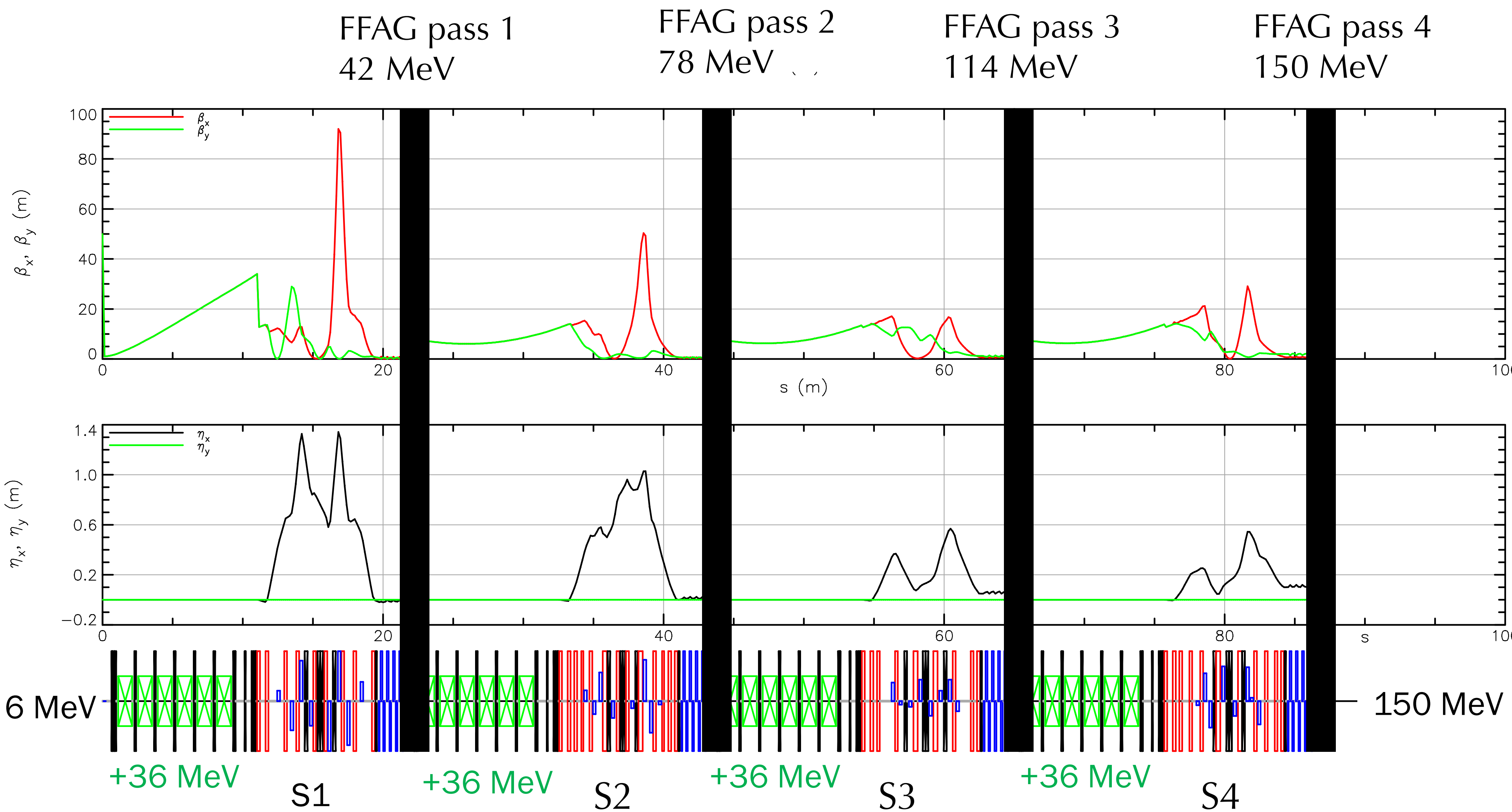
S3 optics (114 MeV)



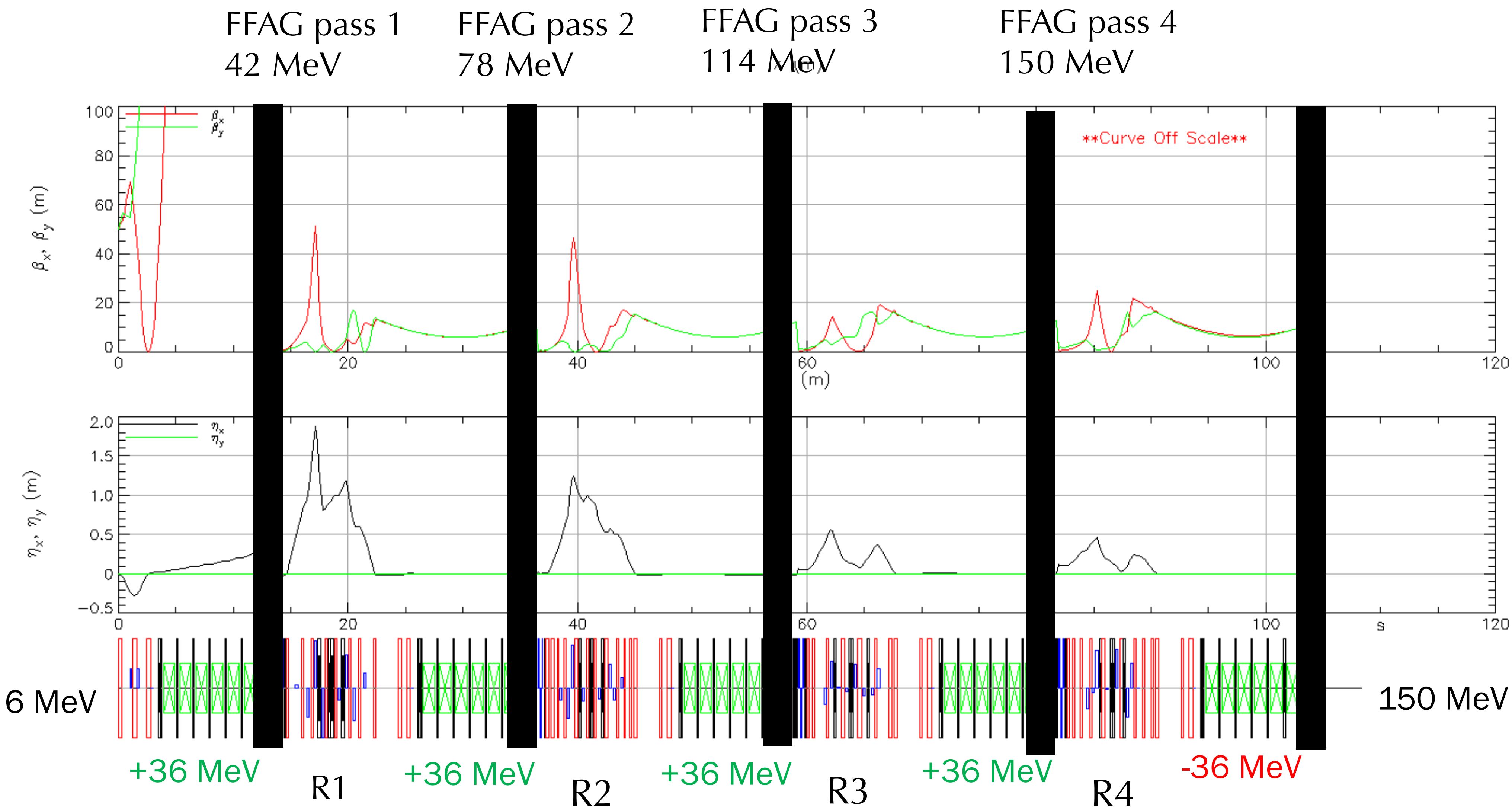
S4 optics (150 MeV)



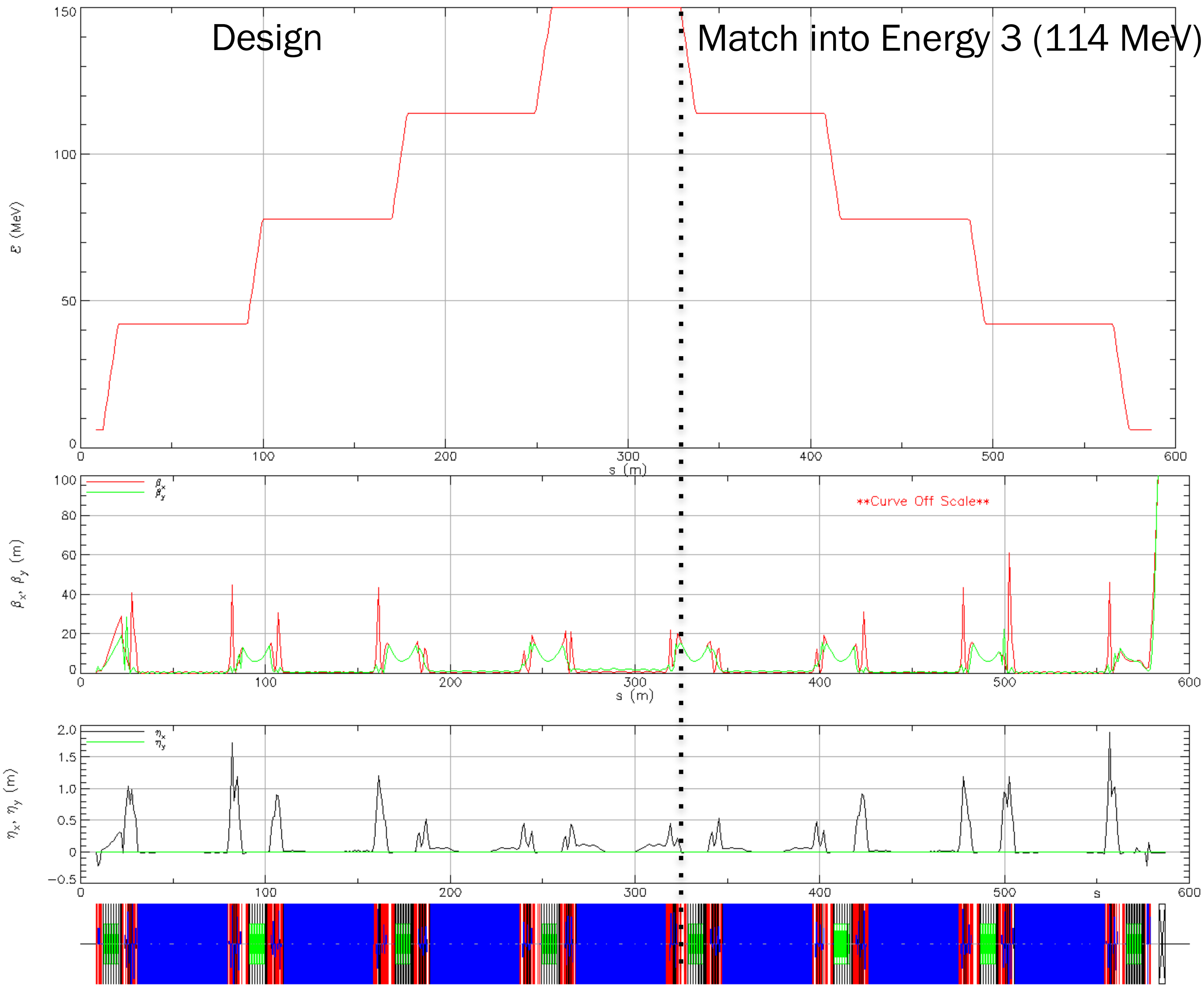
SX optics for each pass



RX optics for each pass

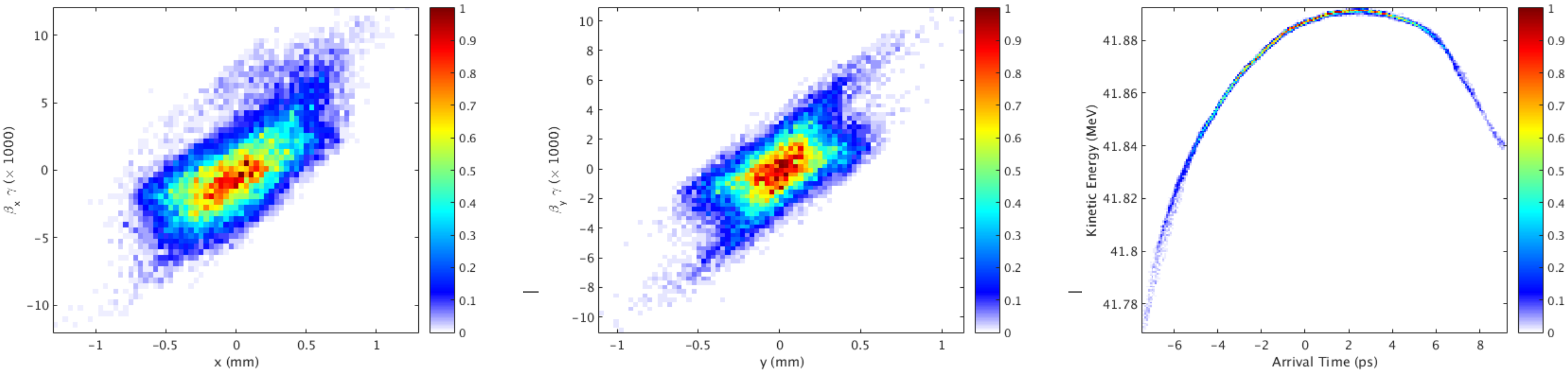


4-pass Optics Design



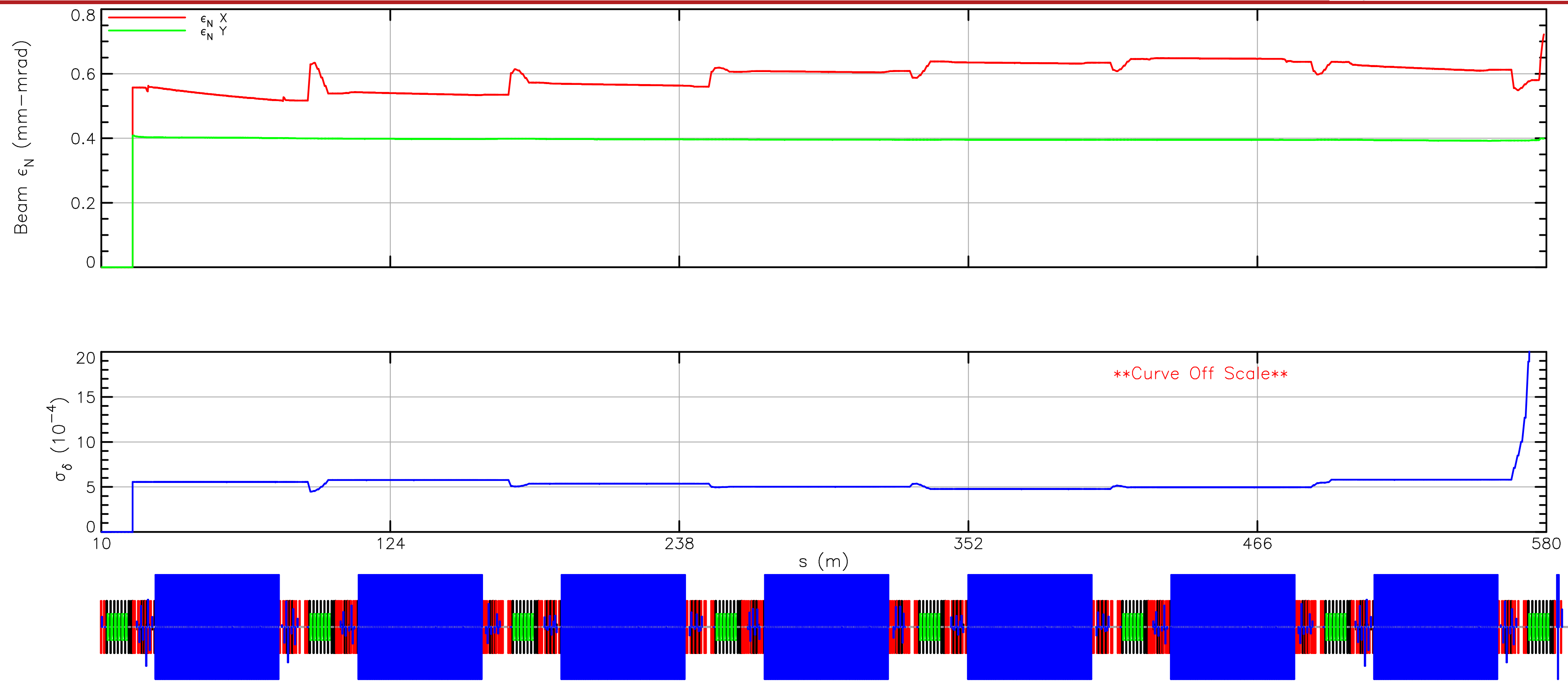
Start-to-End tracking

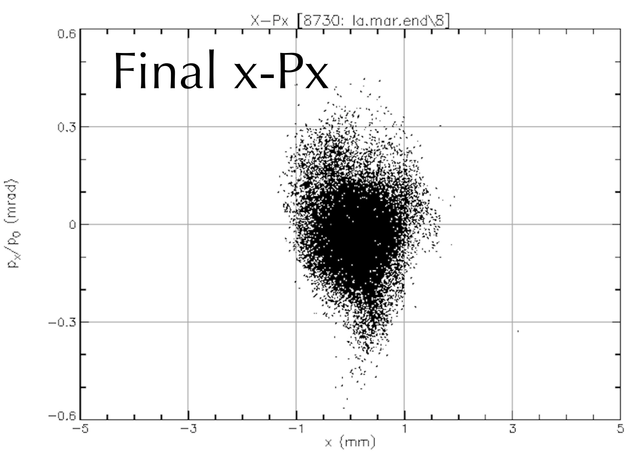
100 pC bunch calculated from GPT with space charge

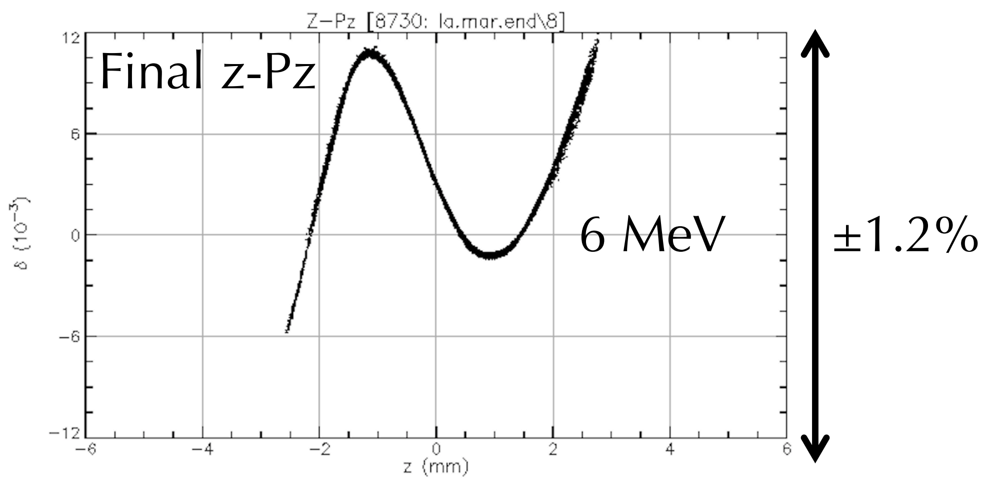


…spliced into Bmad 4-pass model

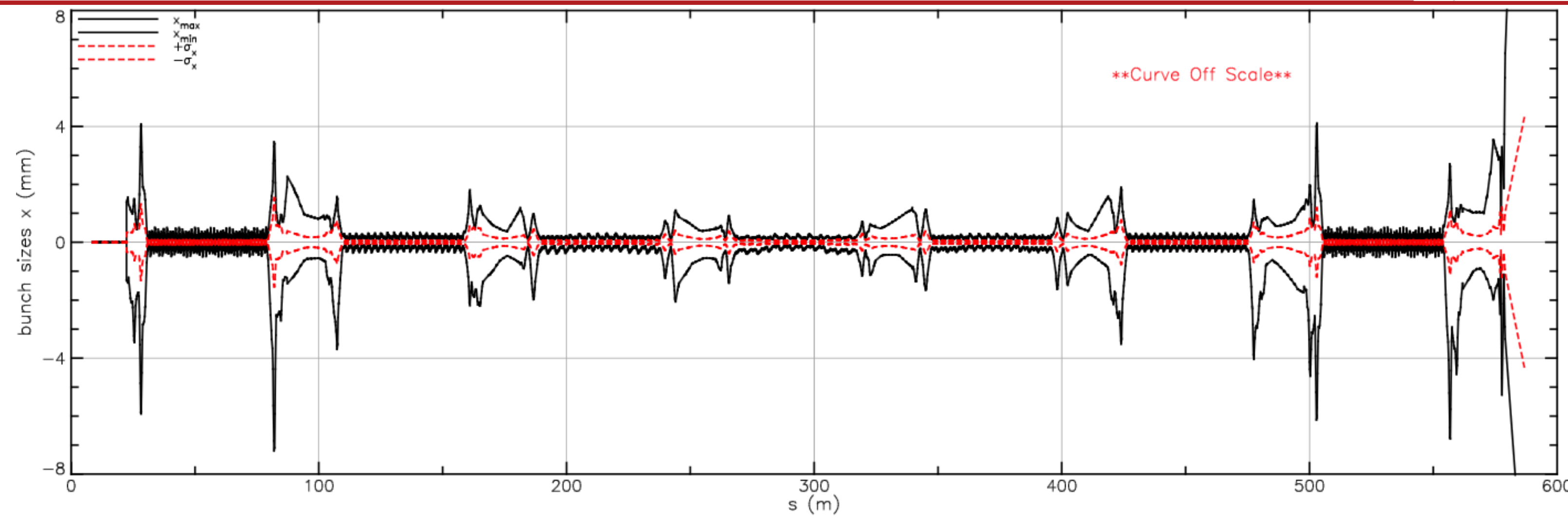
Start-to-End tracking

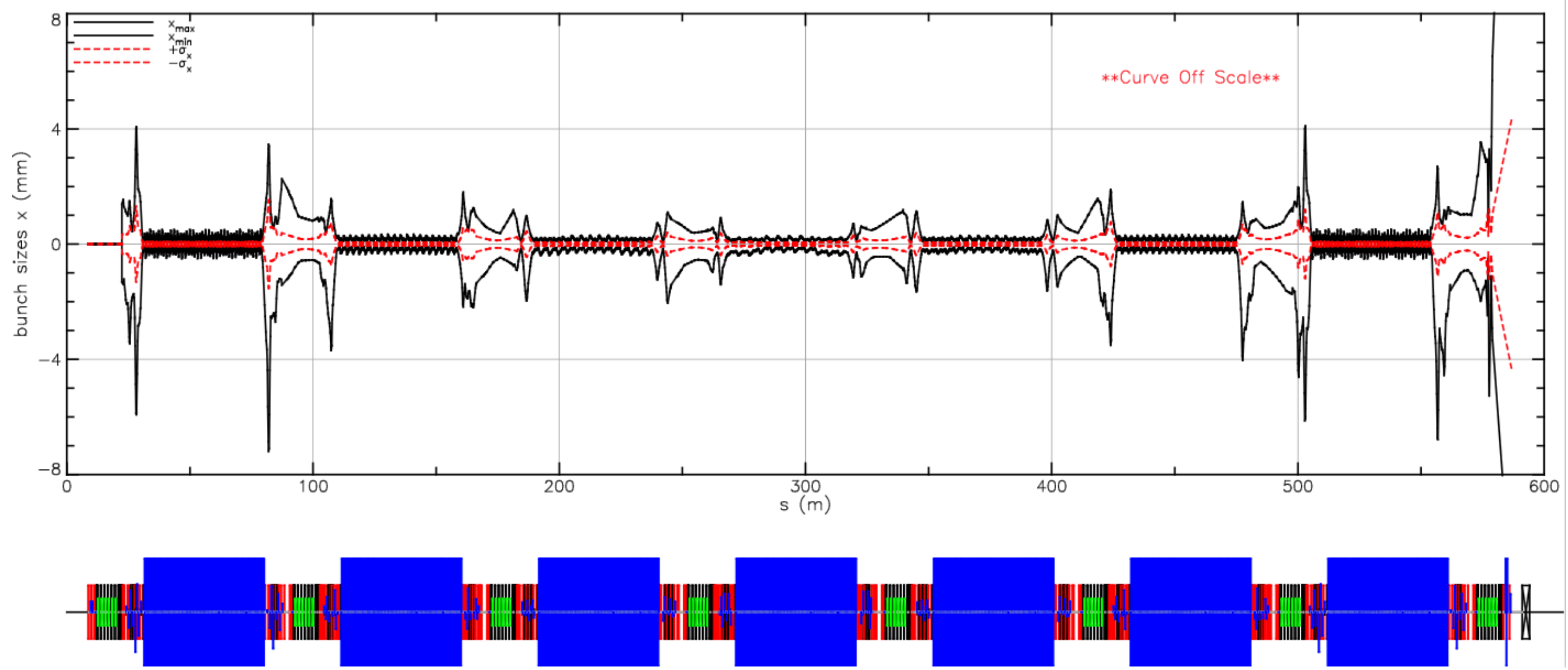




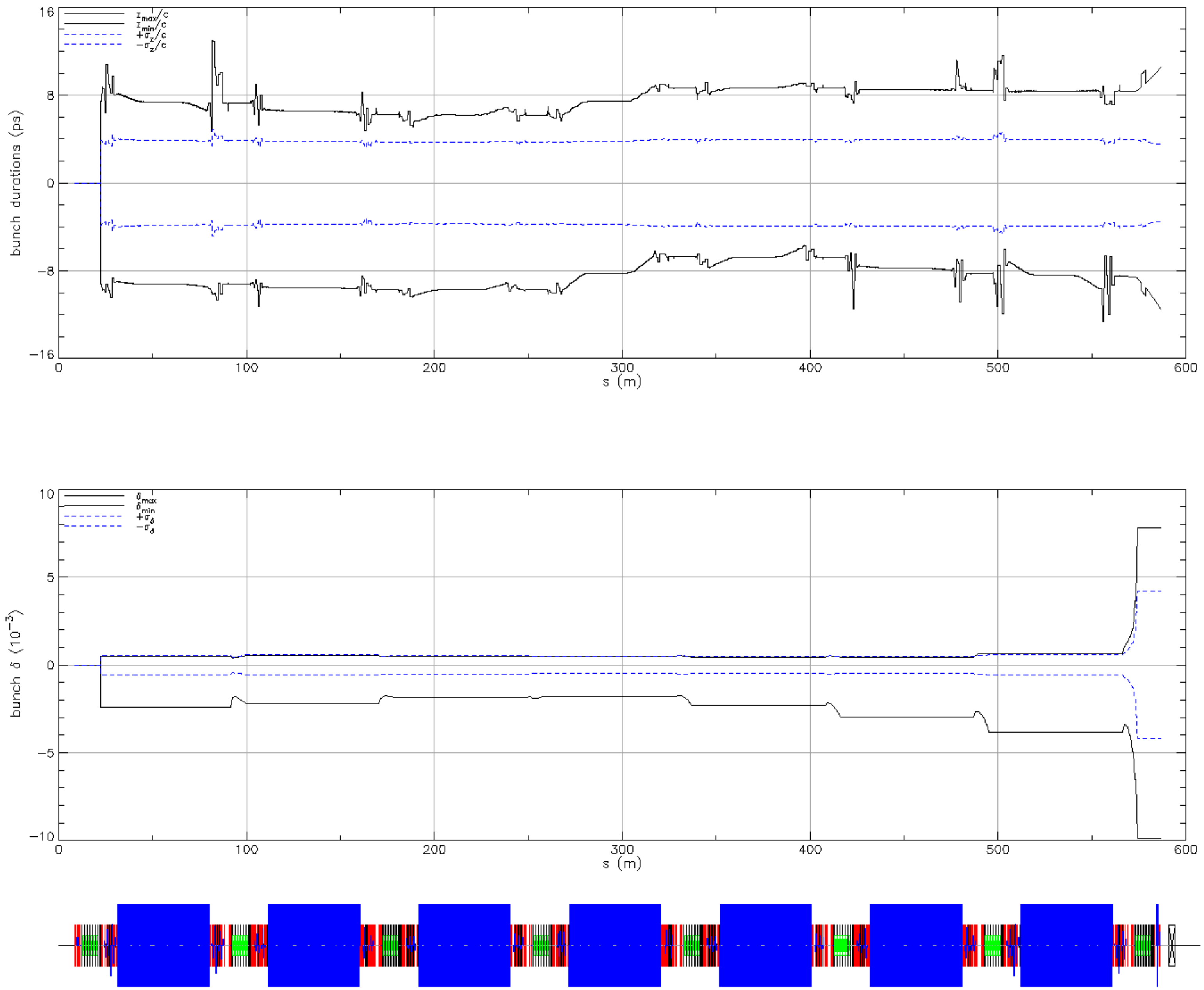


Start-to-End tracking envelopes





Start-to-End tracking



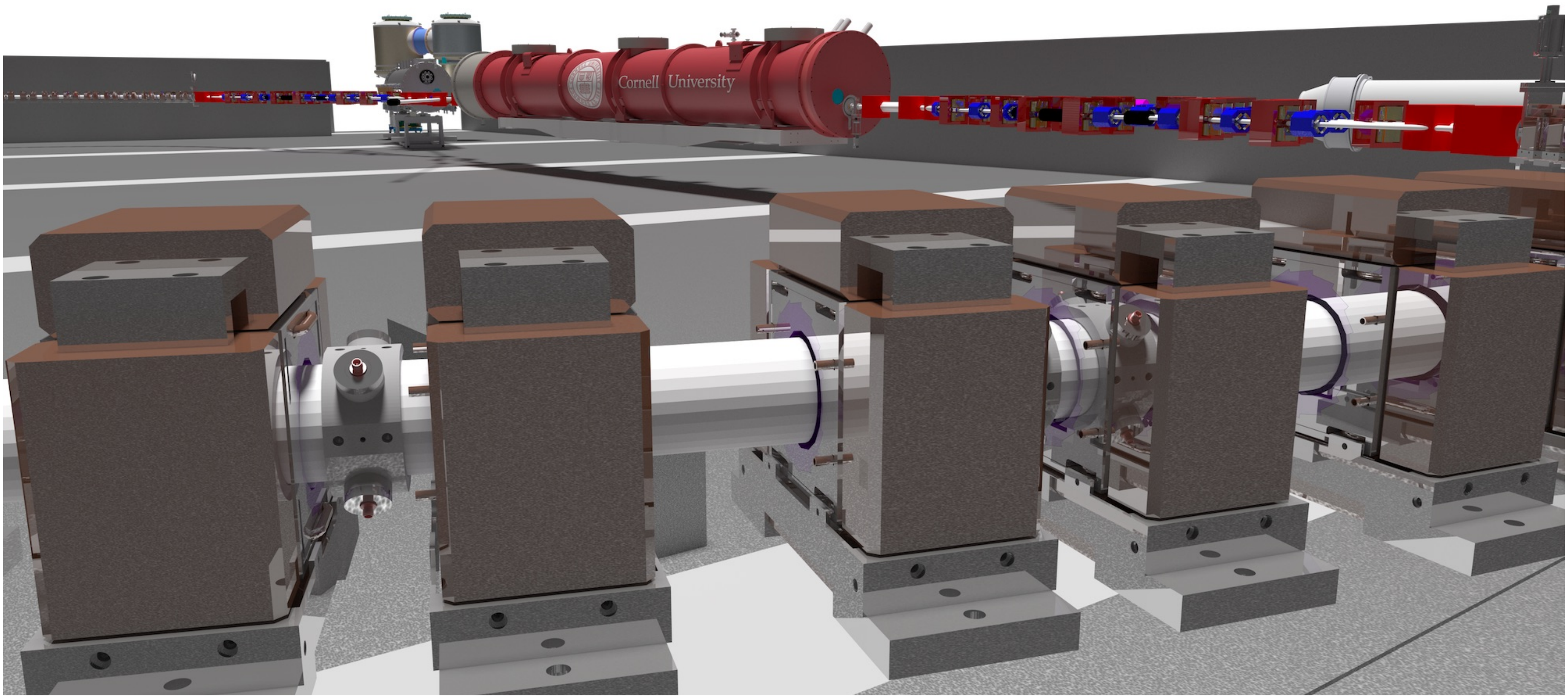
Summary

- CBETA Lattice is finalized
- FFAG designed with fieldmaps, well-modeled in Bmad for fast tracking.
- Splitters designed for:
  - possible 1,2,3,4-pass ERL configuration
  - Match orbit and linear optics into FFAG arc for each beam
  - $\pm 10^{o}$ RF phase shift adjustment via linear sliding joints.
- 4-pass start-to-end ERL tracking:
  - Negligible emittance growth
  - Well-controlled RMS and full (100%) beam envelope (both transverse and longitudinal)
  - Excellent energy at the dump ±1%

END

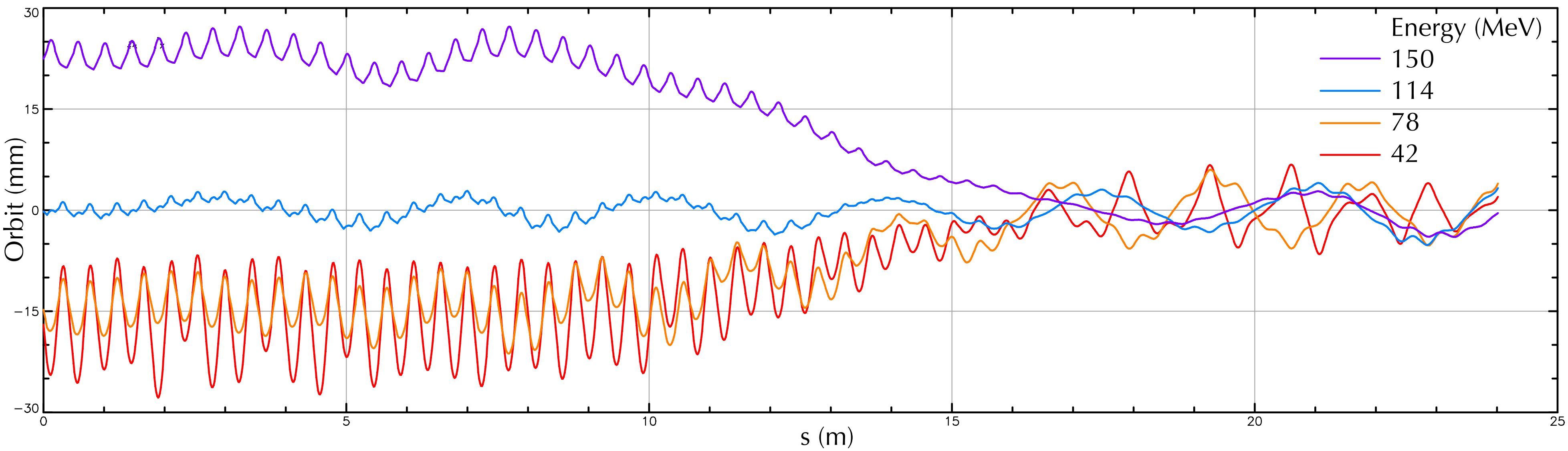
CBETA

CORNELL-BNL ERL TEST ACCELERATOR

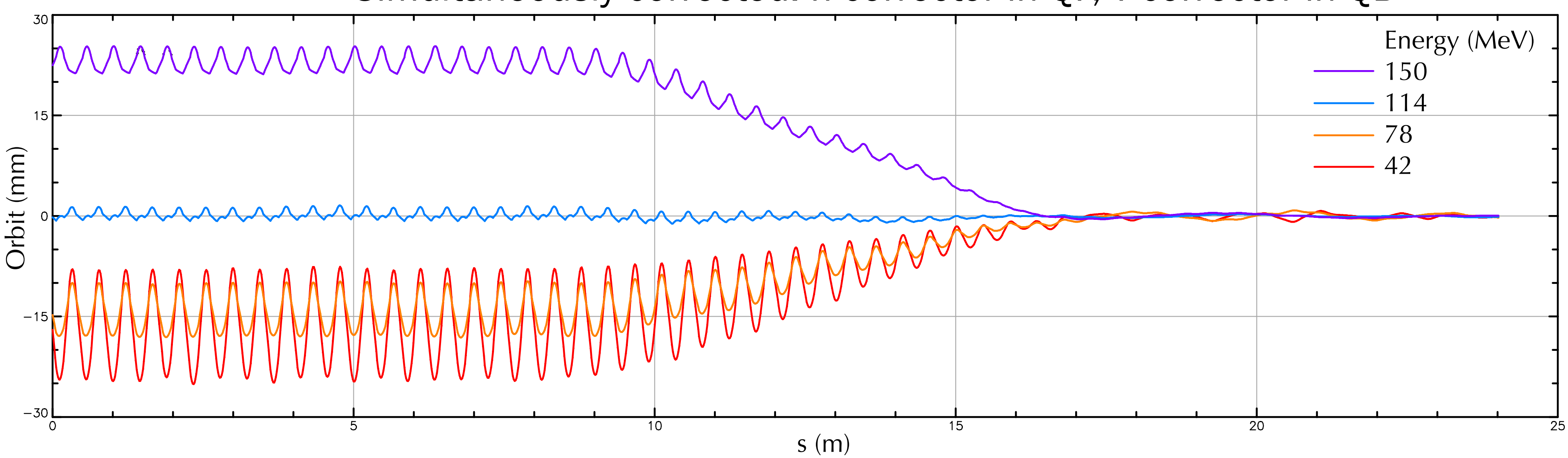


Orbit correction simulation

200 um offset errors in all quads



Simultaneously corrected: h corrector in QF, v corrector in QD



Corrector strength scaling for offsets

Table 2.13.1: Orbit correction analysis procedure. Typically this procedure is iterated for $N = 100$ times.

Step	Procedure
1	Initialize design lattice
2	Calculate orbit and dispersion response matrices
3	Perturb the lattice with random set of errors
4	Apply the SVD orbit correction algorithm
5	Save this perturbed lattice
6	Track particles through, and save statistics
7	Reset the lattice
8	Repeat steps 3-7 N times