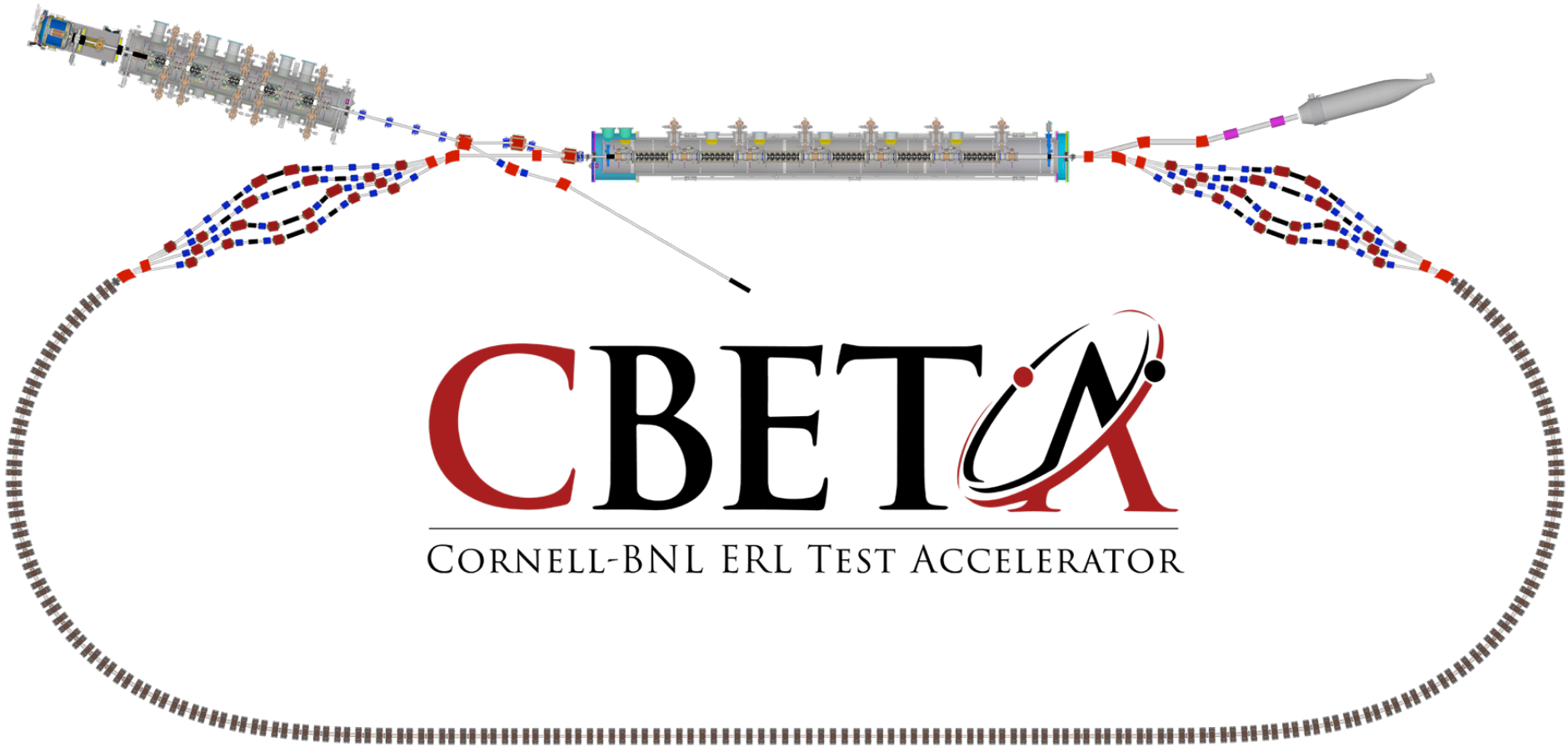
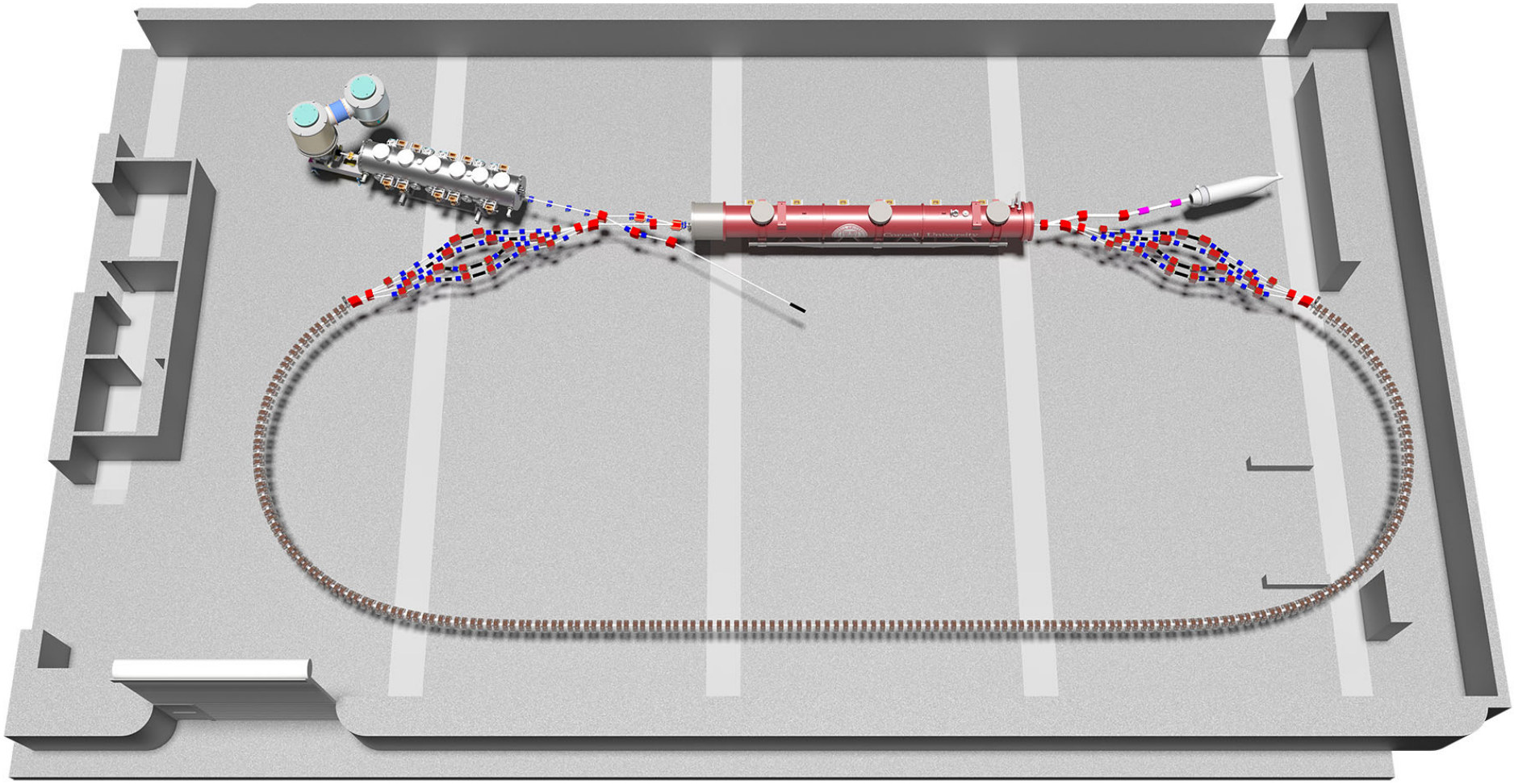
Baseline: Lattice & Studies

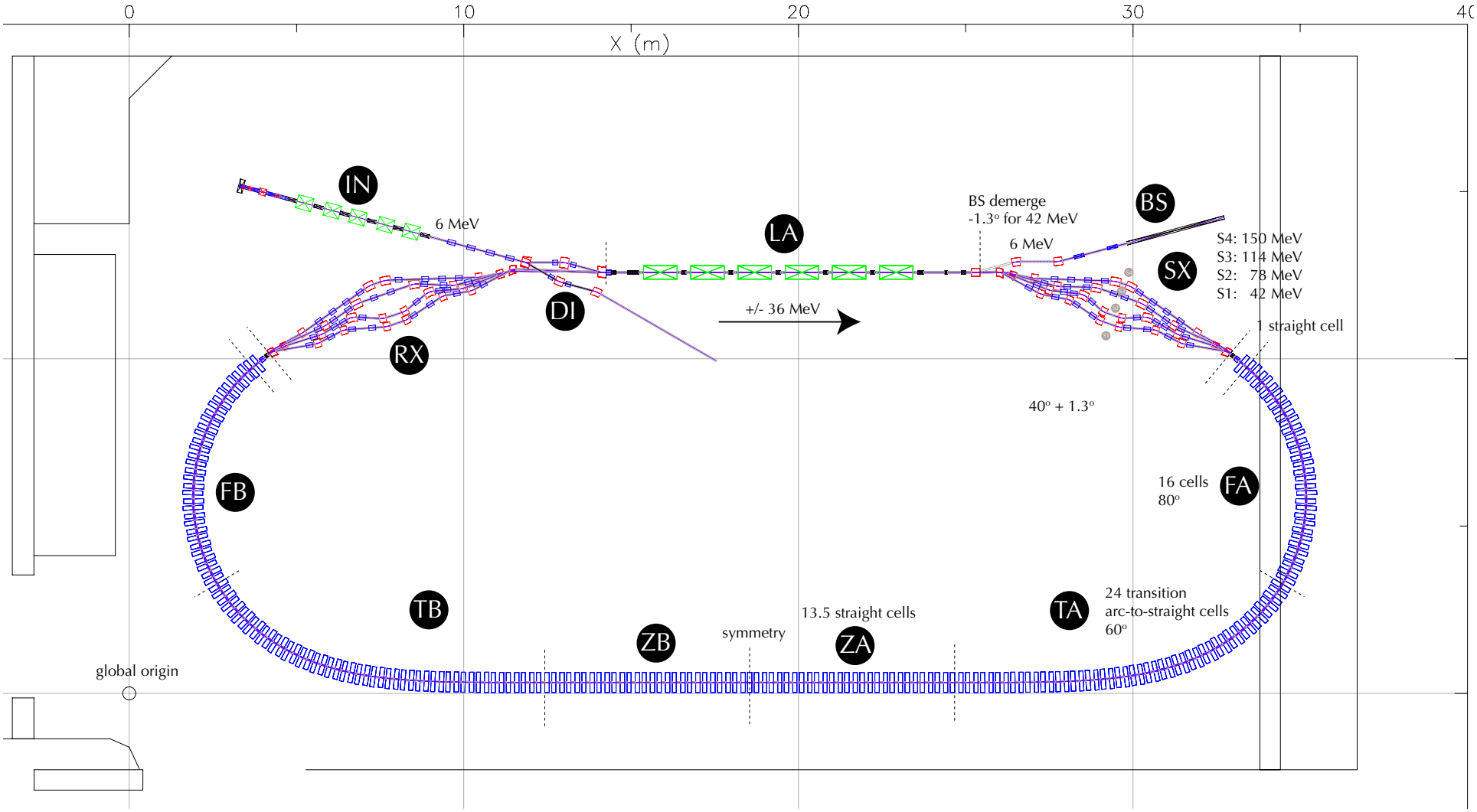


CBETA

CORNELL-BNL ERL TEST ACCELERATOR



CBETA Layout in L0E

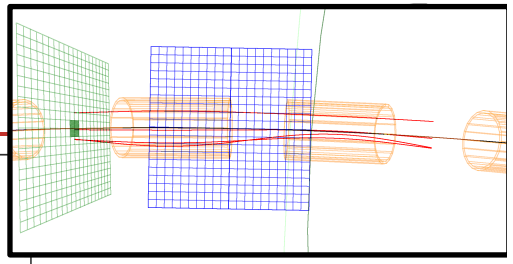


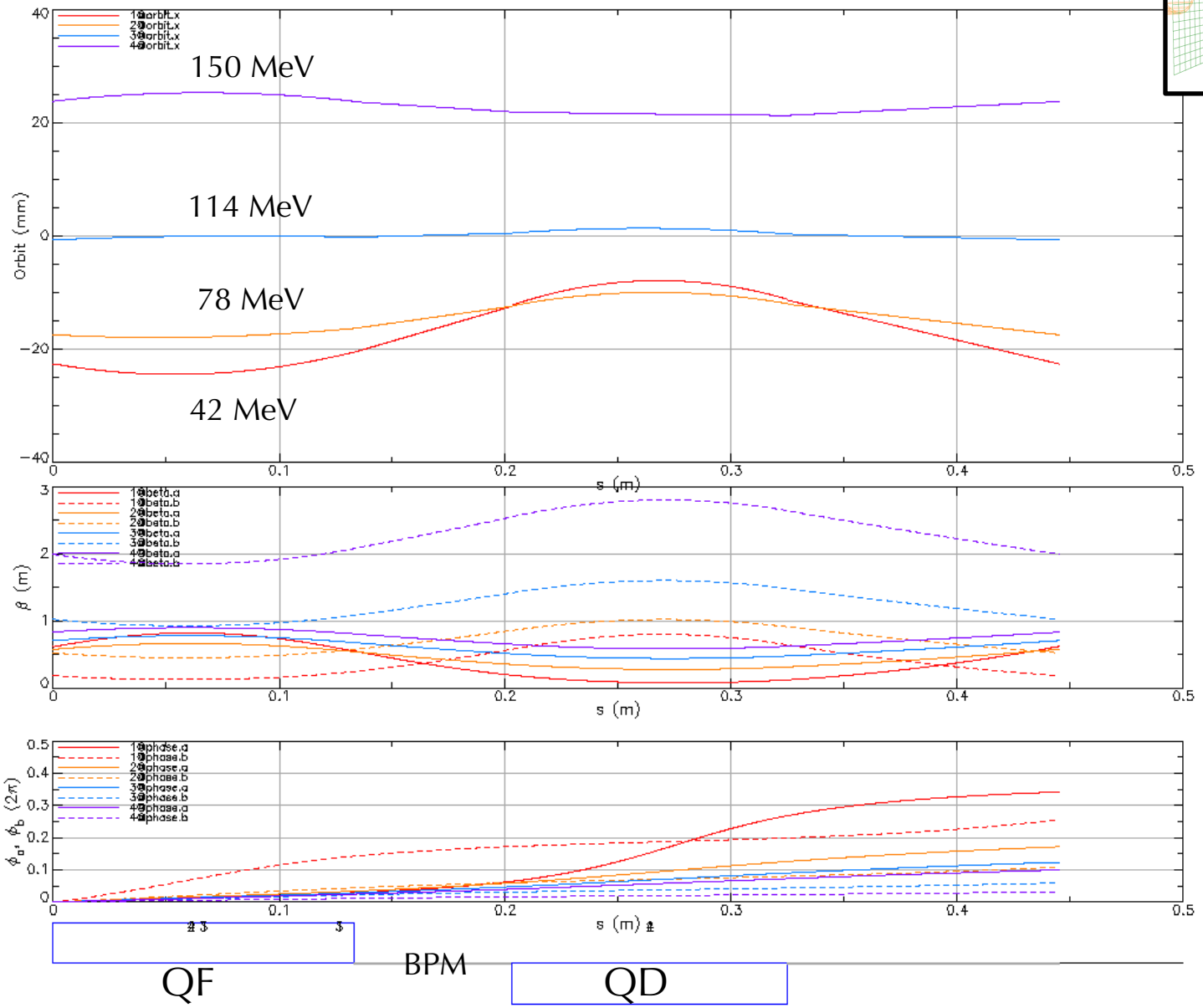
Basic Parameters

Table 1.2.1: Primary parameters of the Cornell-BNL ERL Test Accelerator.

Parameter	Value	Unit
Largest energy	150	MeV
Injection energy	6	MeV
Linac energy gain	36	MeV
Injector current (max)	40	mA
Linac passes	8	4 accel. + 4 decel.
Energy sequence in the arc	$42 \rightarrow 78 \rightarrow 114 \rightarrow 150 \rightarrow 114 \rightarrow 78 \rightarrow 42$	MeV
RF frequency	1300.	MHz
Bunch frequency (high-current mode)	325.	MHz
Circumference harmonic	343	
Circumference length	79.0997	m
Circumference time (pass 1)	0.263848164	μs
Circumference time (pass 2)	0.263845098	μs
Circumference time (pass 3)	0.263844646	μs
Circumference time (pass 4)	0.265003298	μs
Normalized transverse rms emittances	1	μm
Bunch length	4	ps
Typical arc beta functions	0.4	m
Typical splitter beta functions	50	m
Transverse rms bunch size (max)	1800	μm
Transverse rms bunch size (min)	52	μm
Bunch charge (min)	1	pC
Bunch charge (max)	123	pC

FFAG Arc Cell (5 deg)





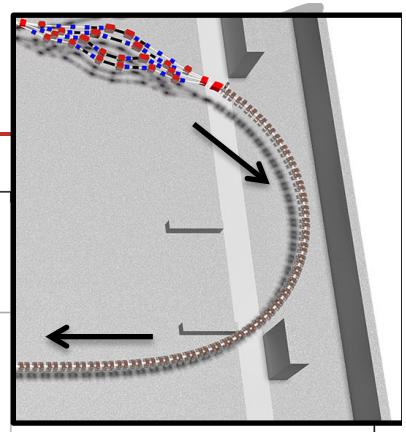
QF
(focusing)
13.3 cm
-11.5 T/m

QD
(defocusing)
12.2 cm
11.0 T/m
-0.311 T in center

Short Drift
7 cm
BPM

Long Drift
12 cm
Pump or screen

Designed FFAG Arc, transition, straight

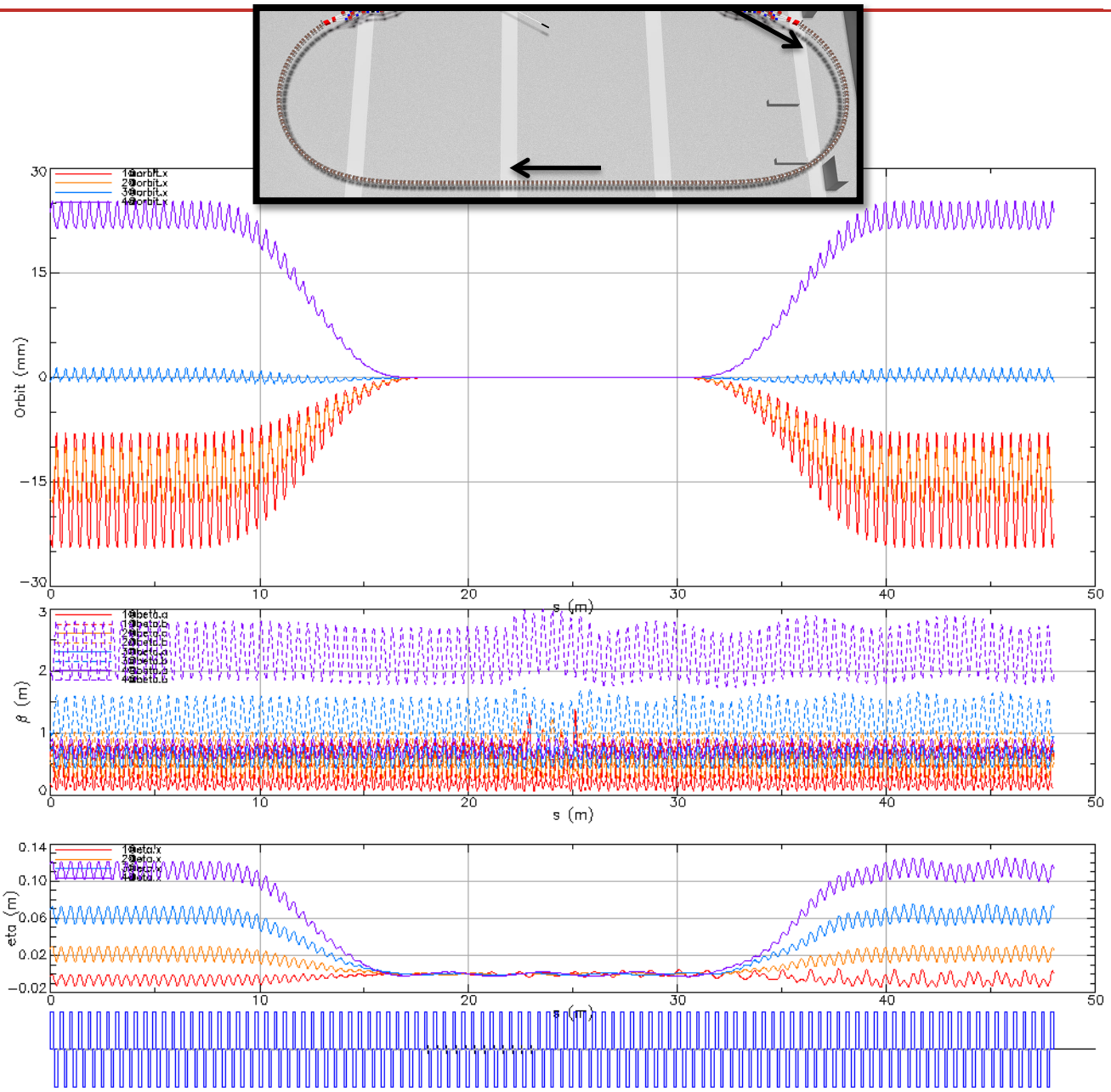


Offsets, angles scaled by factor:

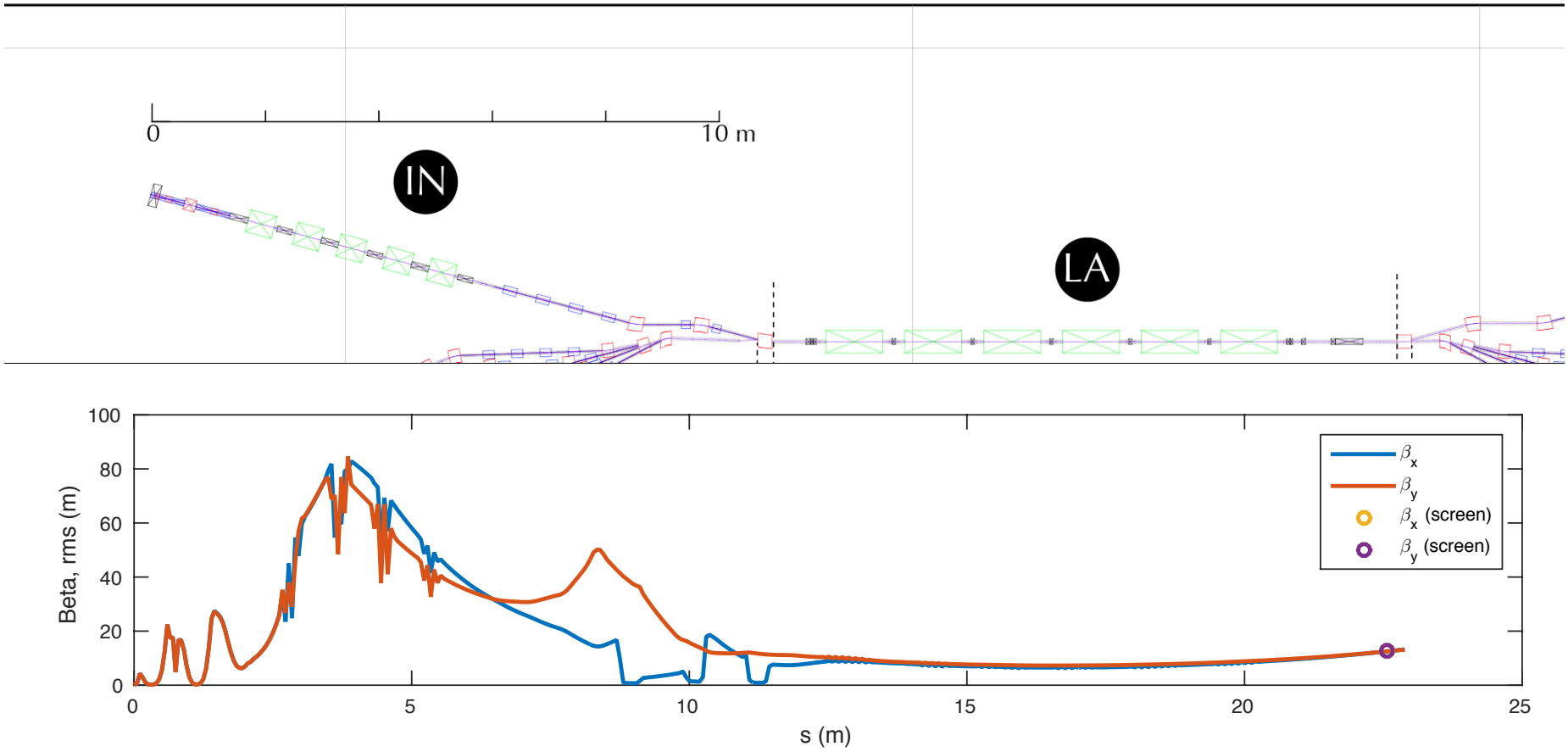
$$f(x) = 1 - 3x^2 + 2x^3 + \ldots$$

FA TA ZA

Full FFAG Arc

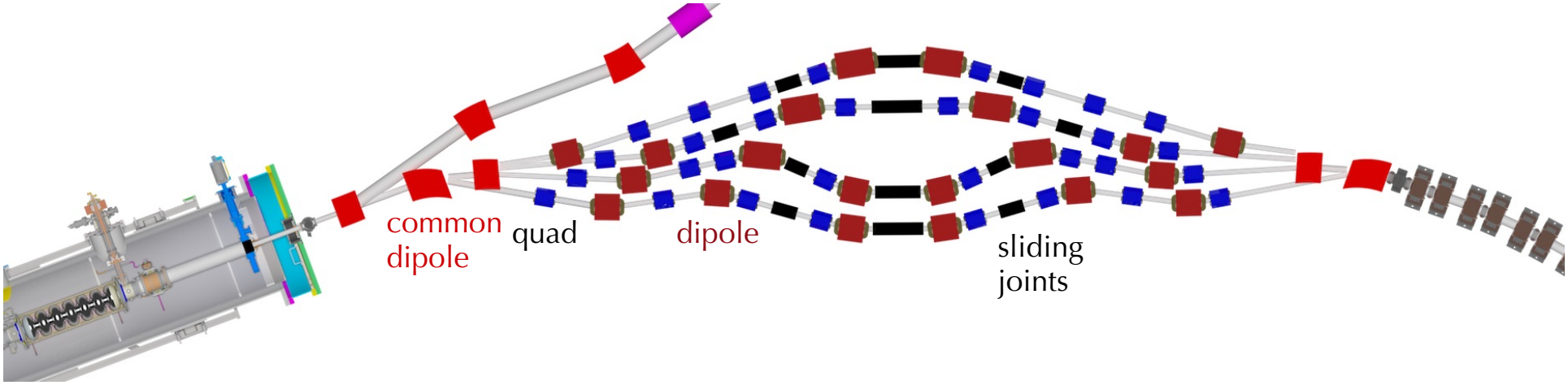


Space Charge optimization through LA



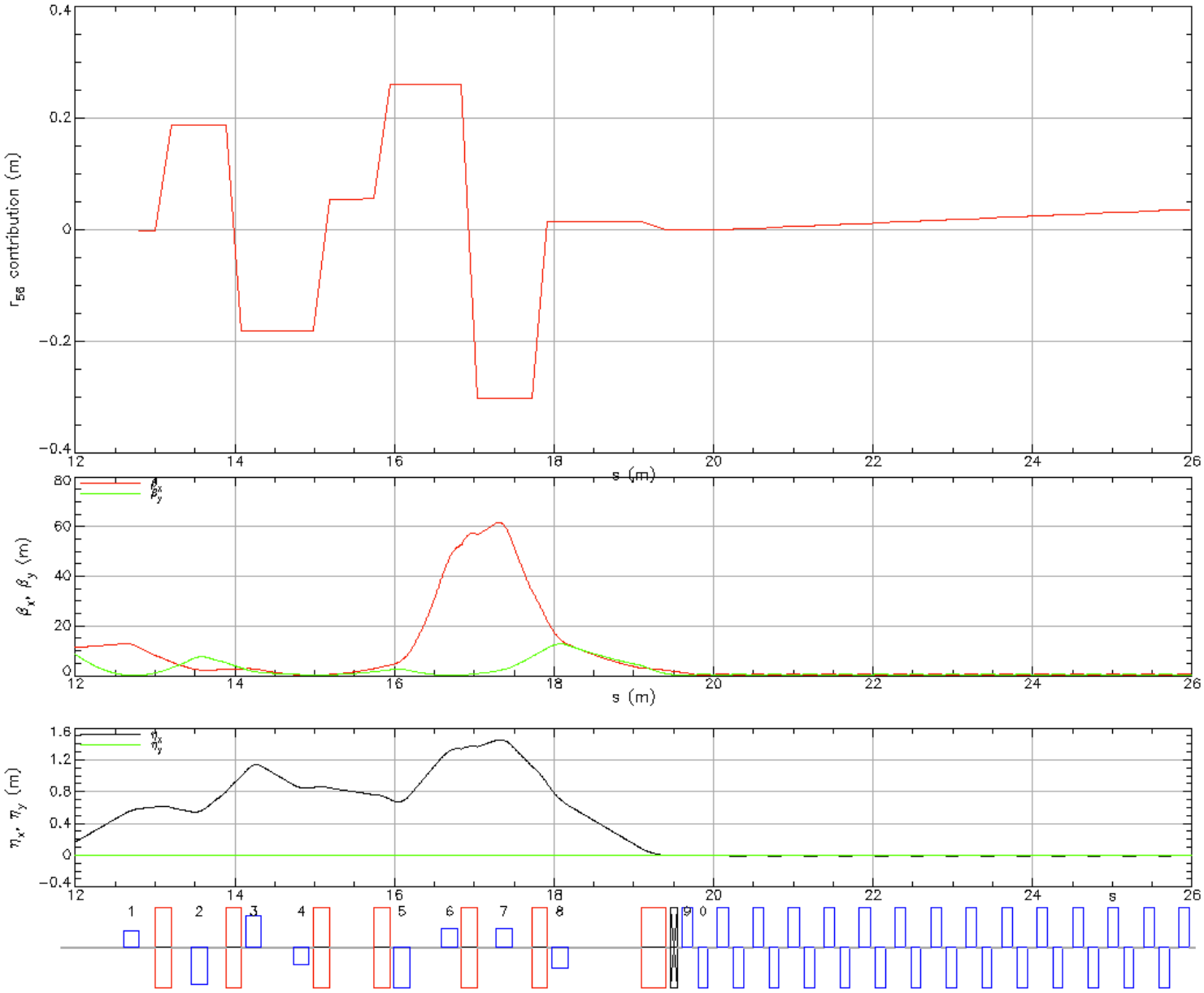
The beam is optimized with space charge using GPT to match specified beam sizes and divergence at the end of the first pass of the Linac.

Splitters (SX, RX)

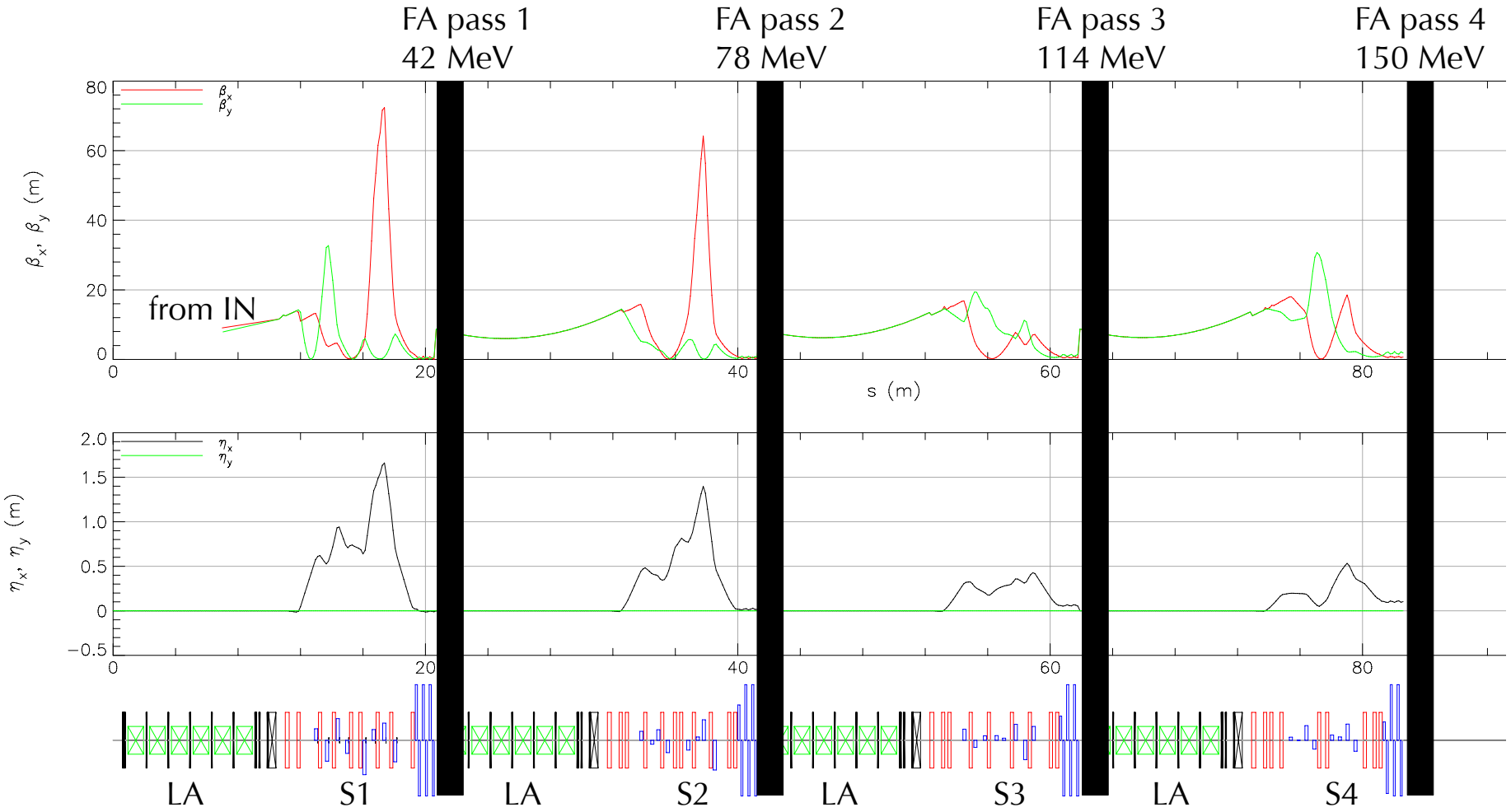


- Receive beams on-axis from LA
- Match each energy beam onto its stable orbit in FA
- Match optics for each energy beam
- Momentum compaction (r56) adjustment
- Path lengths: (S1 + FA pass 1) = (S2 + FA pass 2) =(S3 + FA pass 3)
- Allow path length adjustment by sliding joints
- Dipole fields < 0.6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

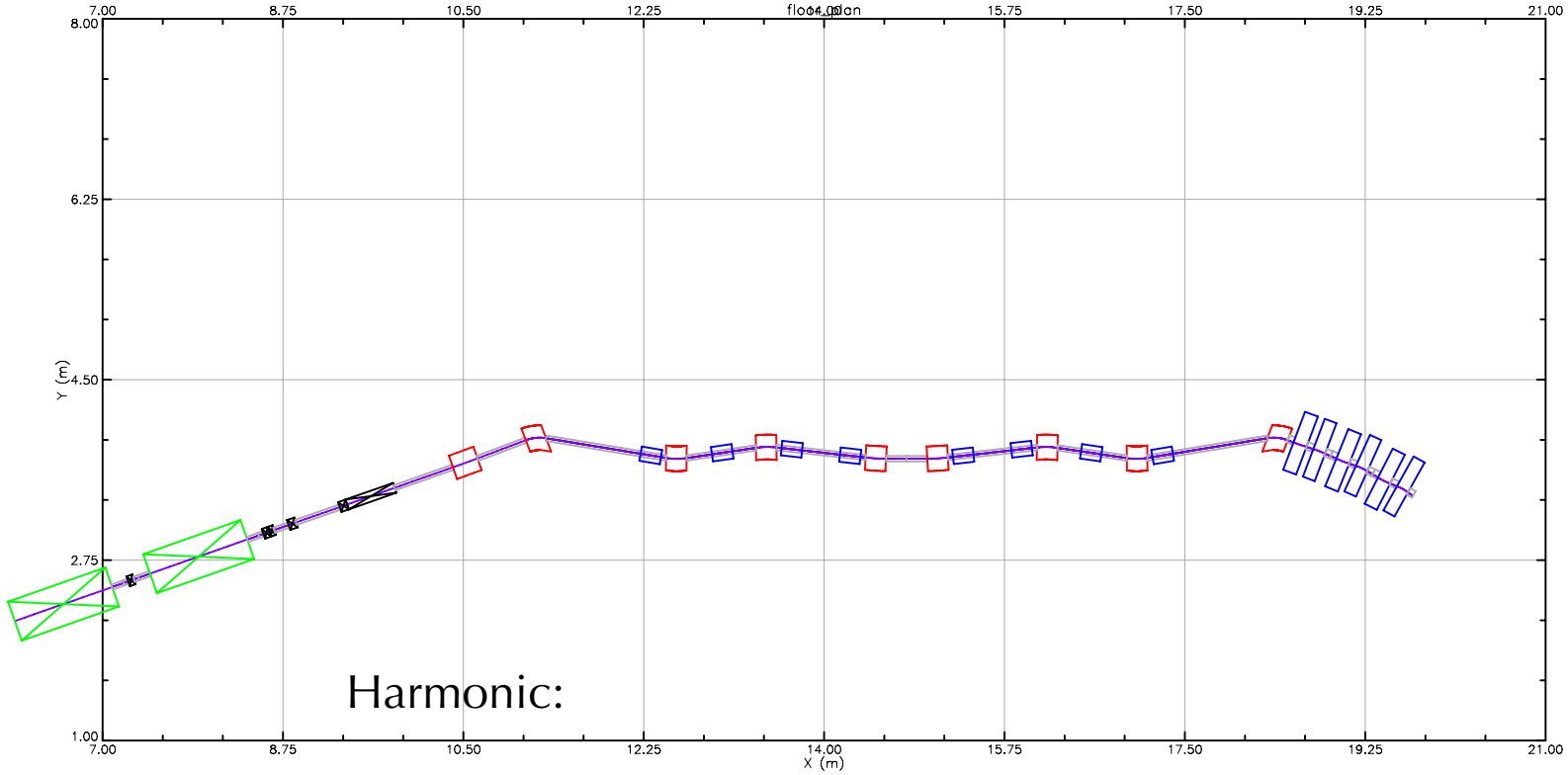
S1 optics (42 MeV)



Splitter optics for each pass

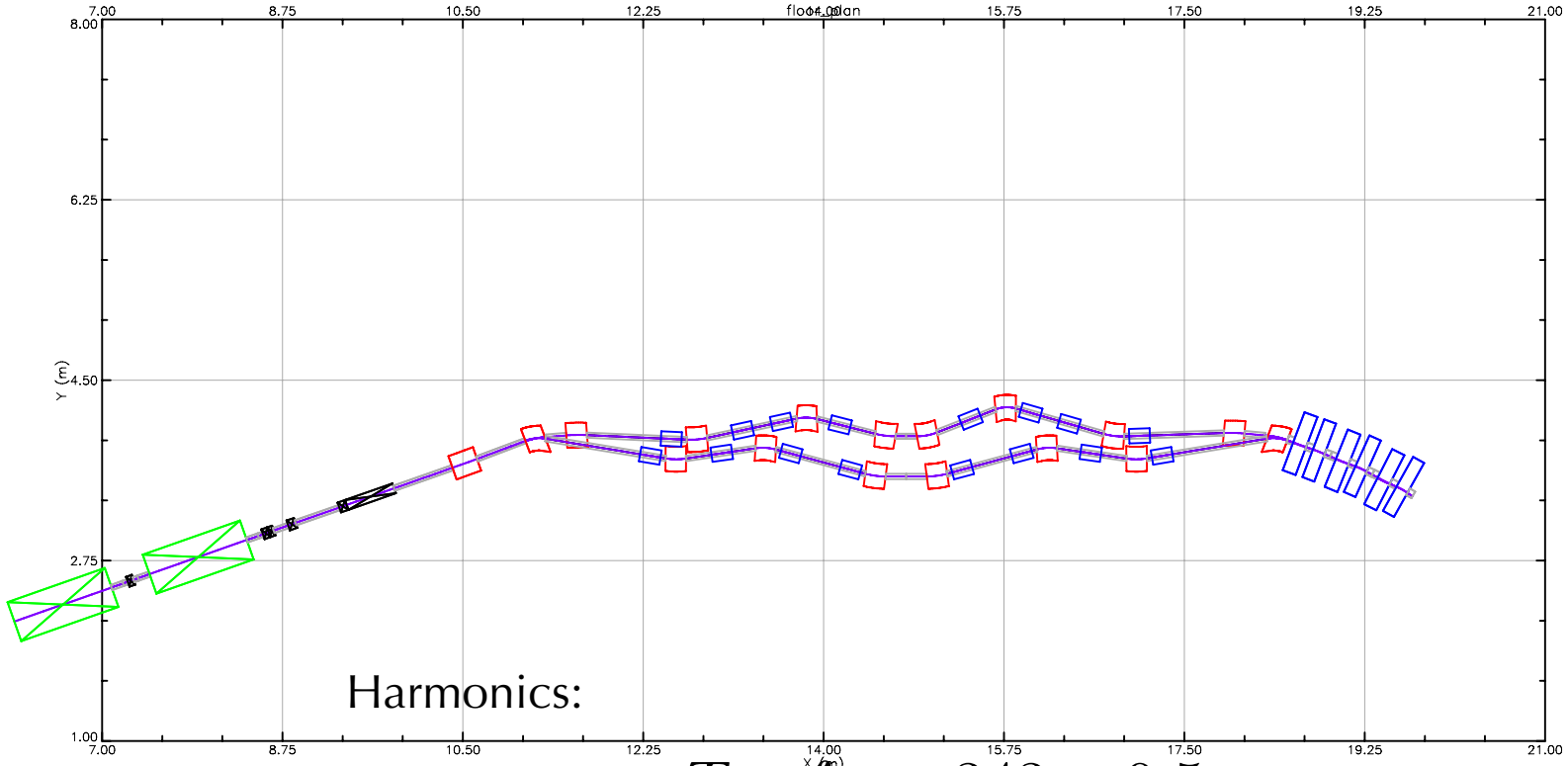


Path length: 1-pass ERL



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

Path length: 2-pass ERL

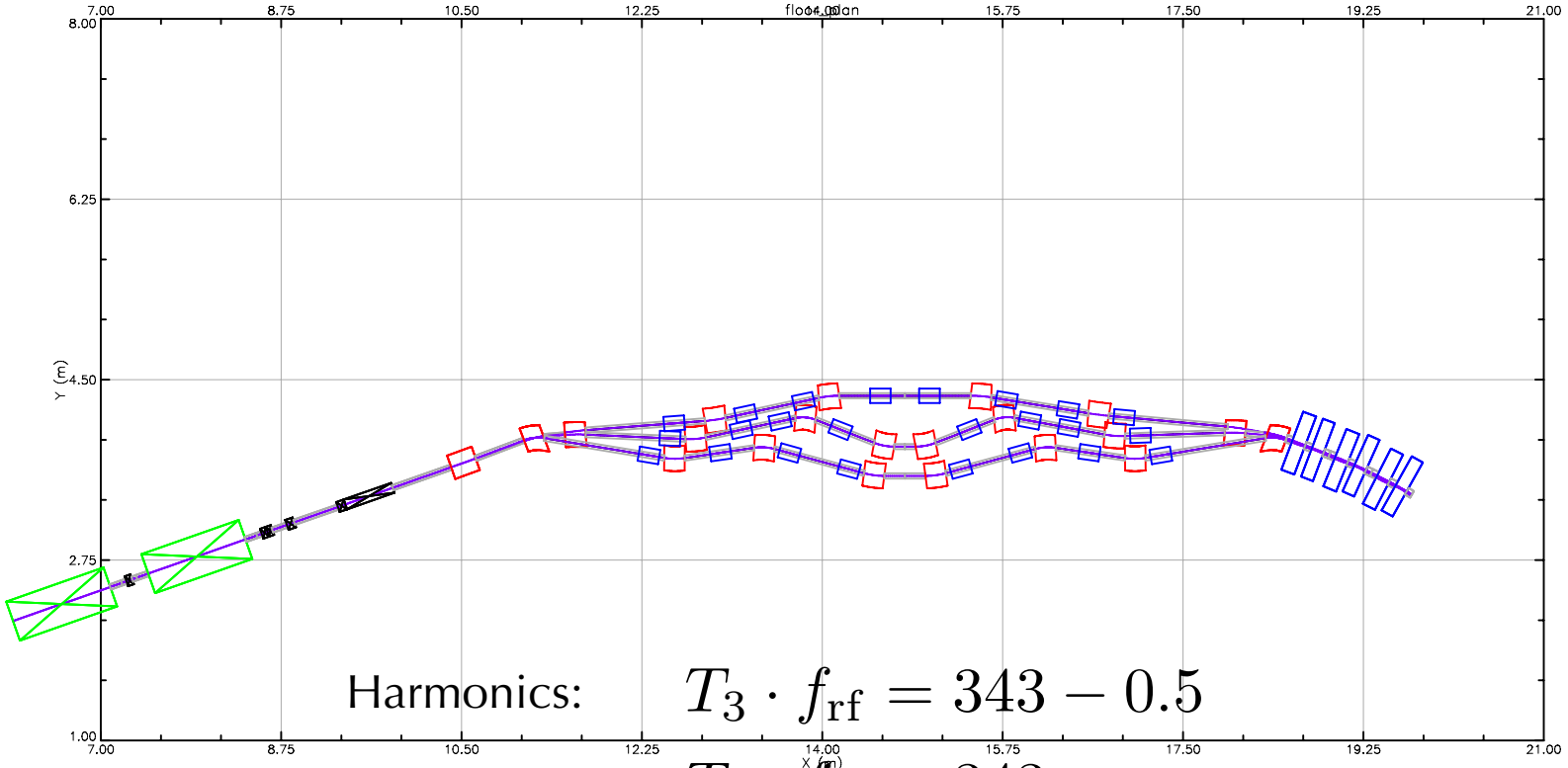


Harmonics:

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

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

Path length: 3-pass ERL

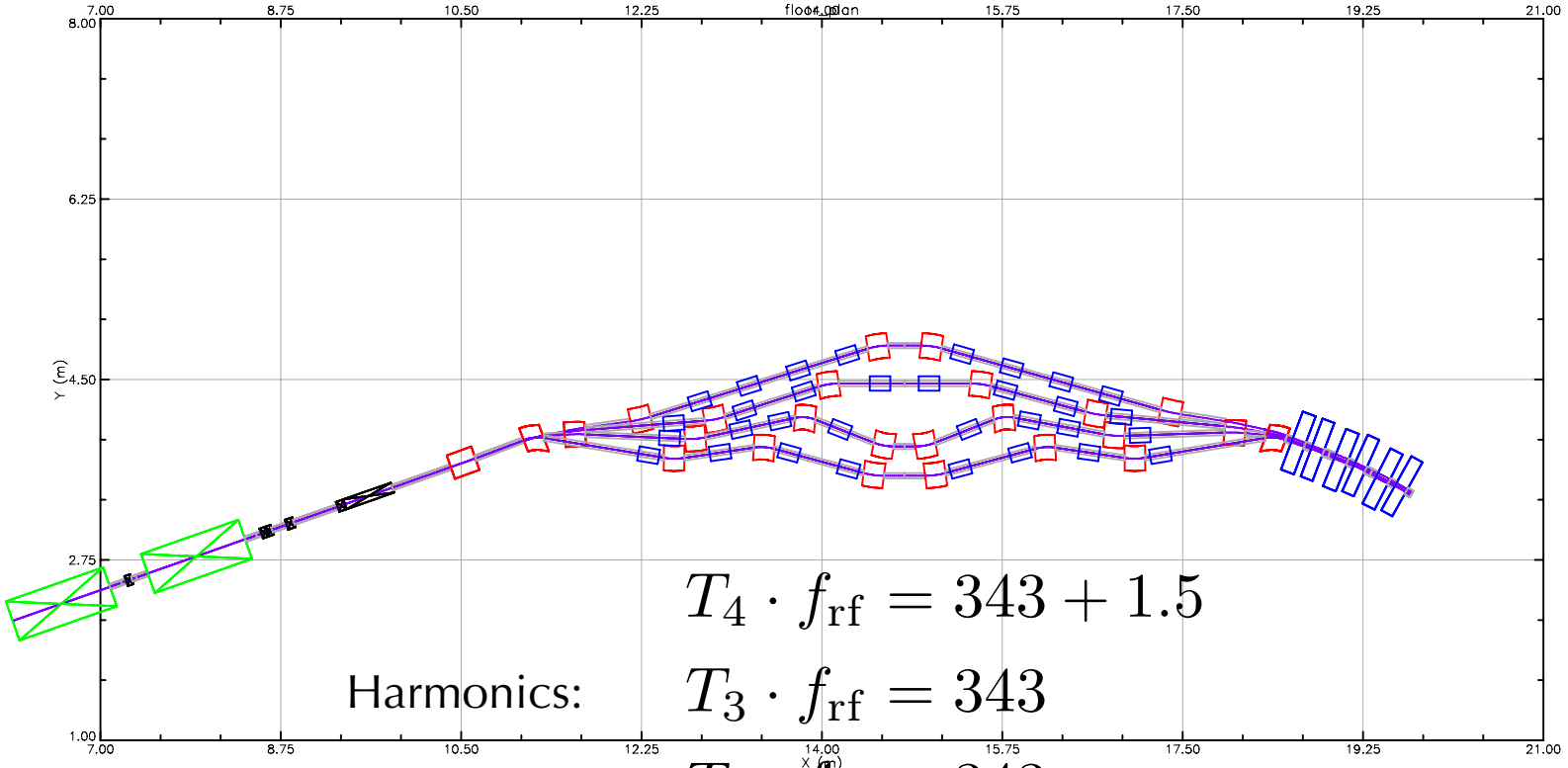


Harmonics: $T_3 \cdot f_{\mathrm{rf}} = 343 - 0.5$

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

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

Path length: 4-pass ERL



Harmonics:

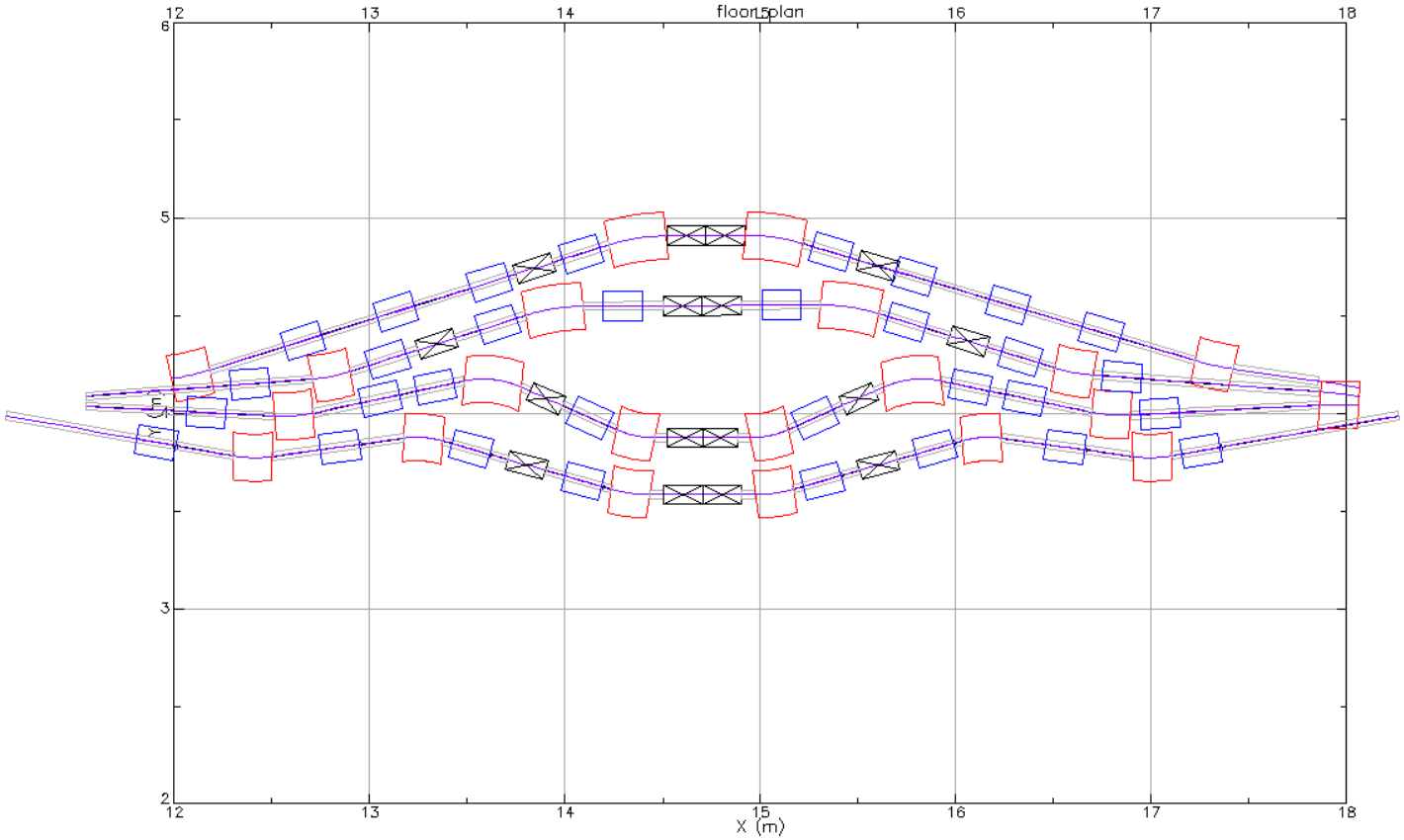
$$T_4 \cdot f_{\mathrm{rf}} = 343 + 1.5$$

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

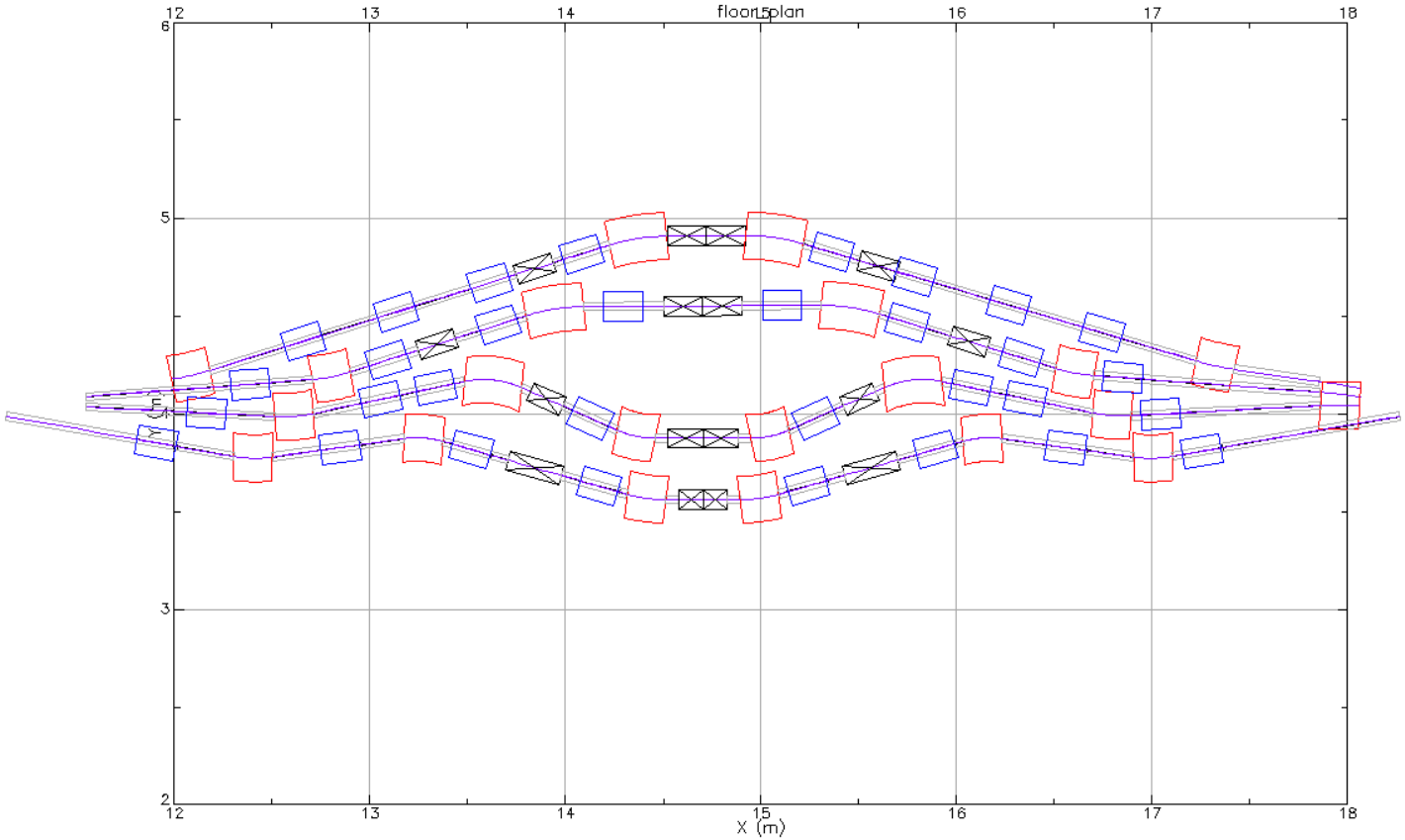
$$T_2 \cdot f_{\mathrm{rf}} = 343$$

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

Path length tuning: pass 1

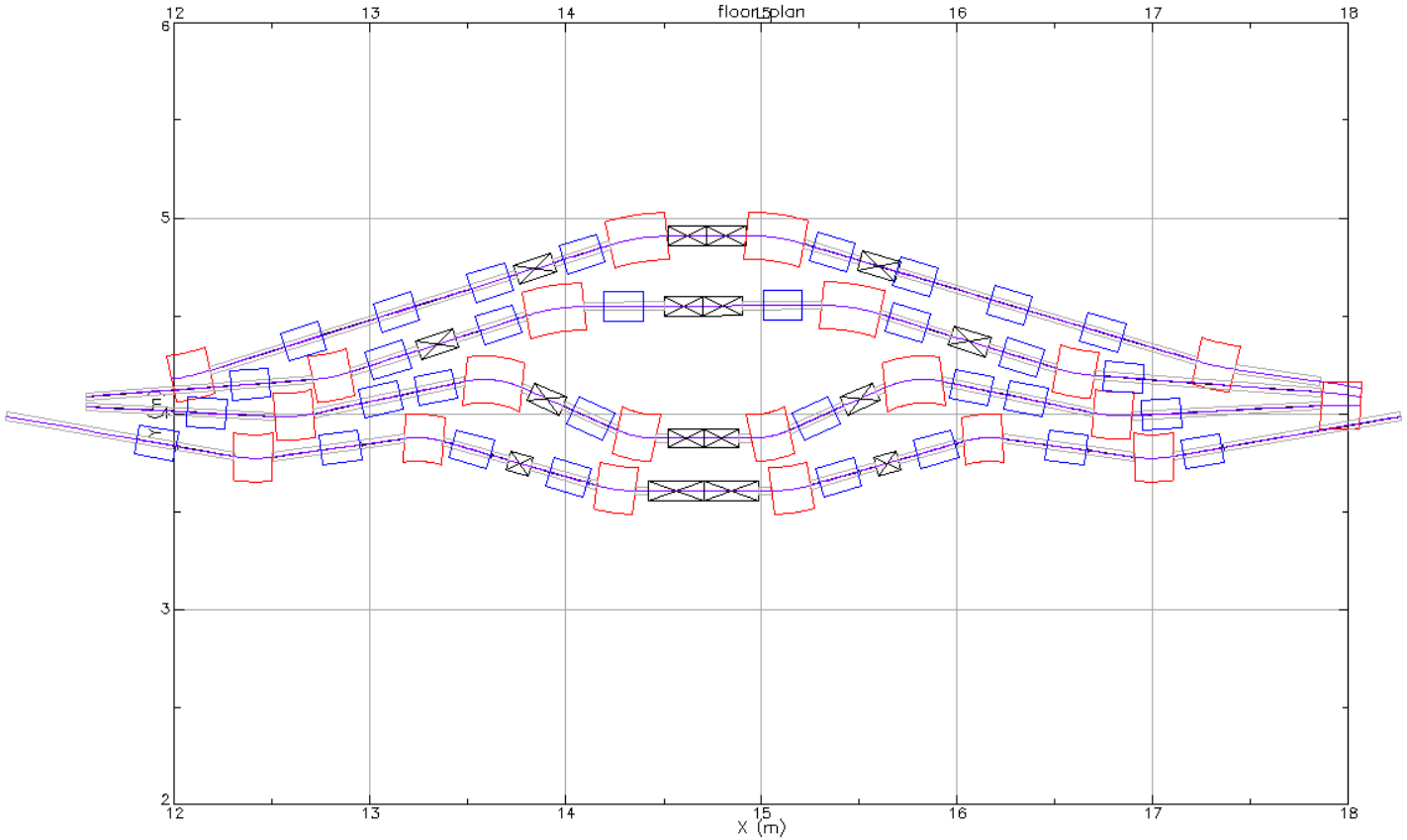


Path length tuning: pass 1



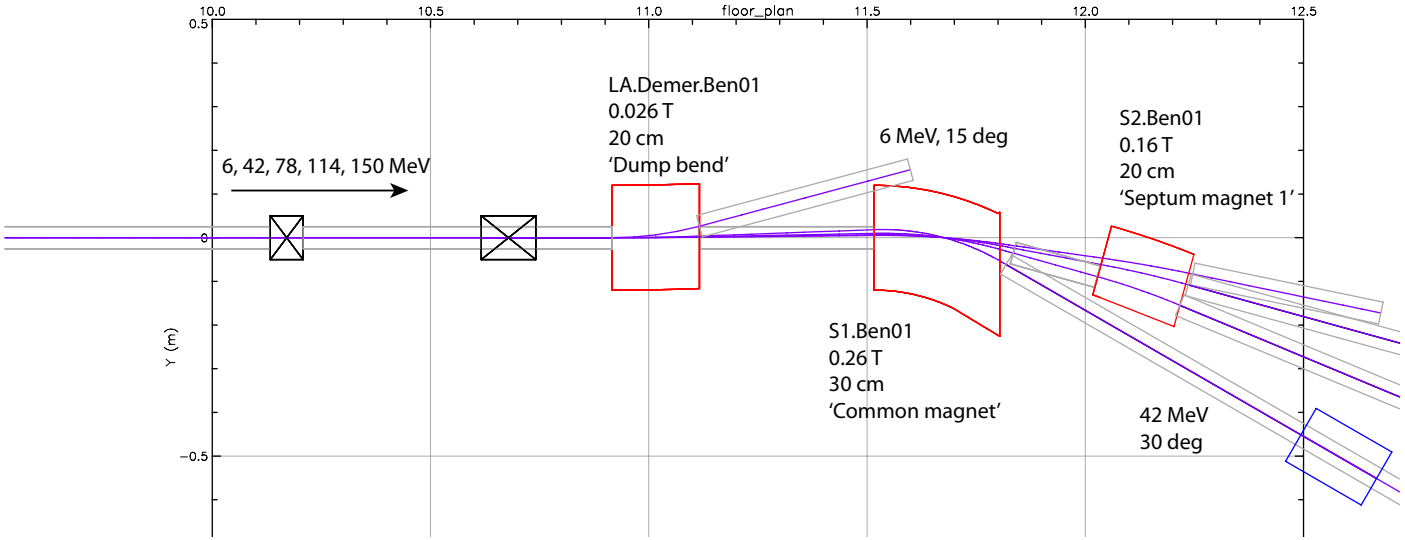
+ 10/360 * rf wavelength

Path length tuning: pass 1



- 10/360 * rf wavelength

SX demerge and merge detail

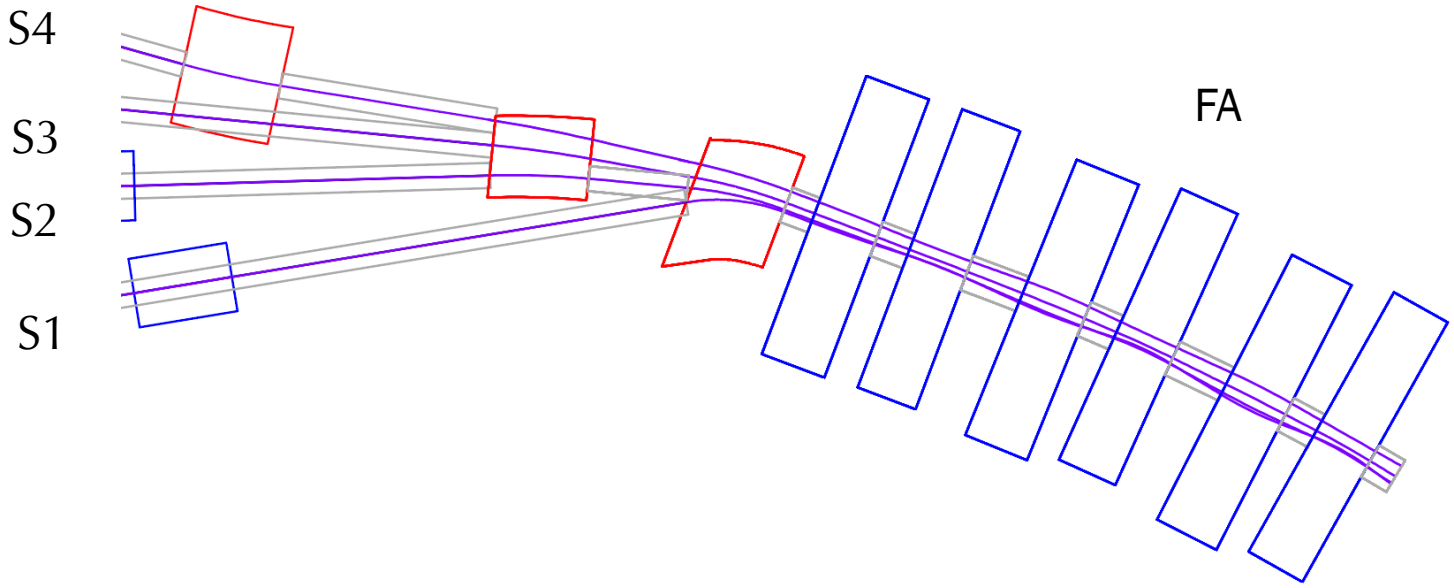


S4: 150 MeV

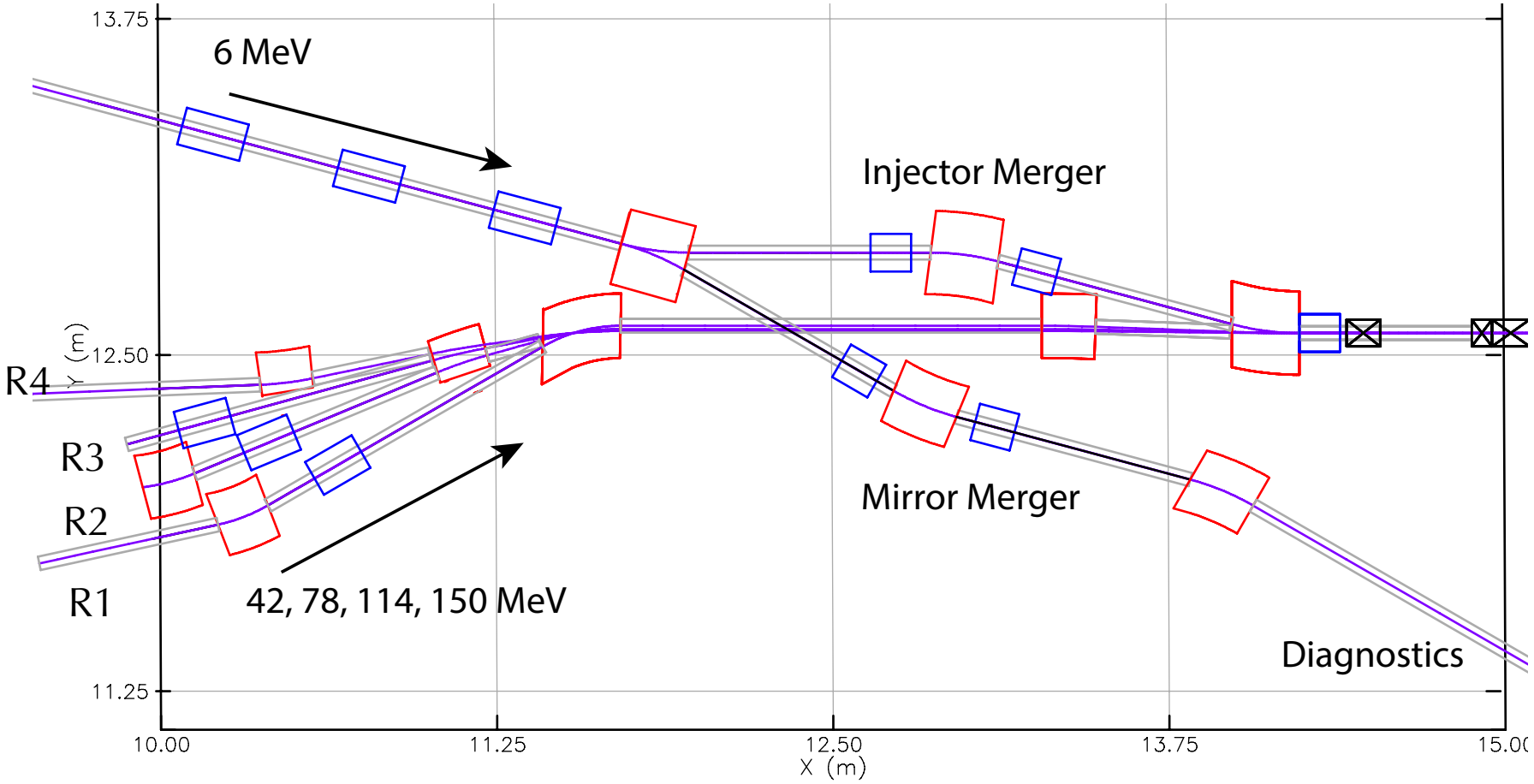
S3: 114 MeV

S2: 78 MeV

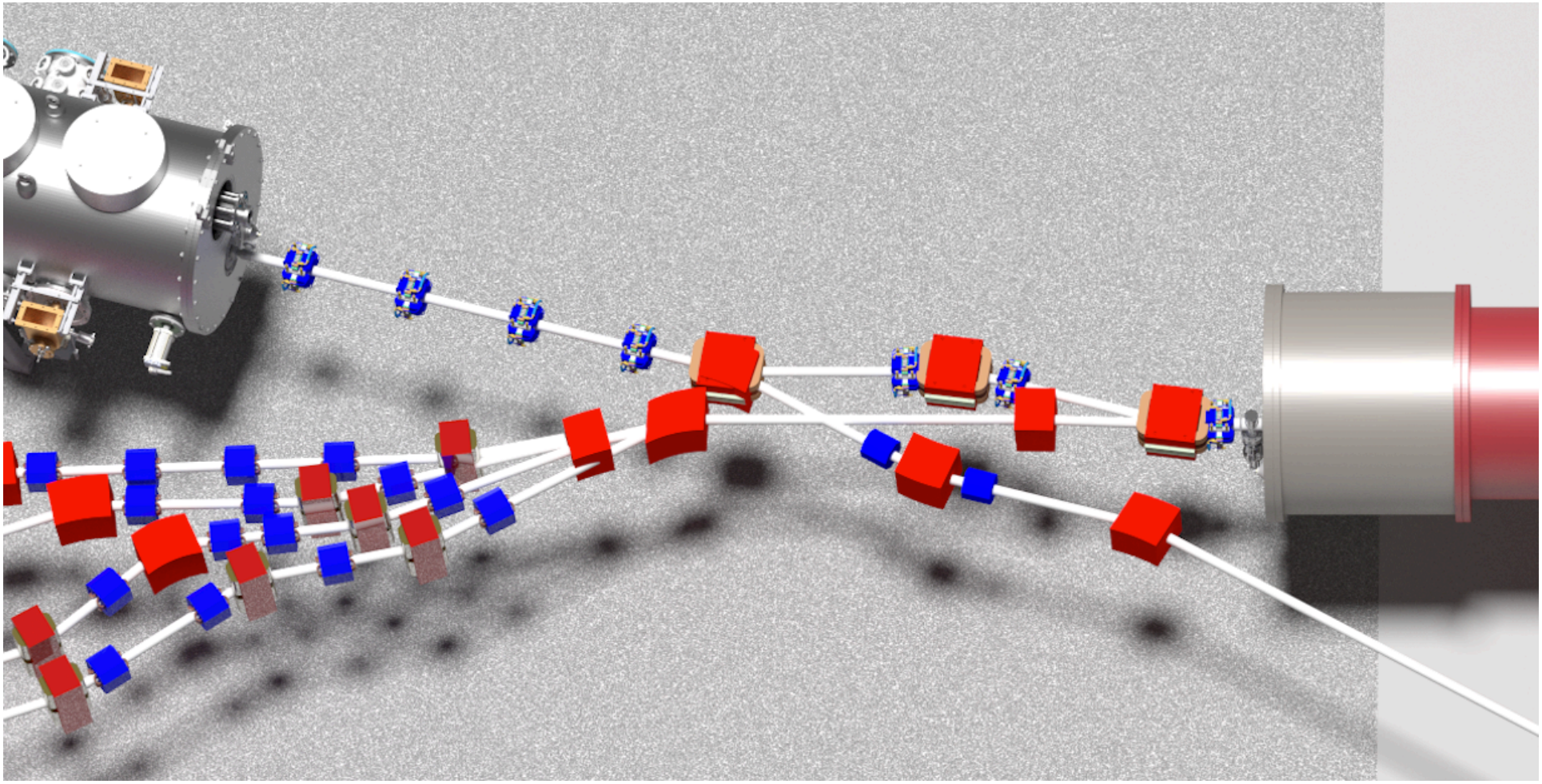
S1: 42 MeV



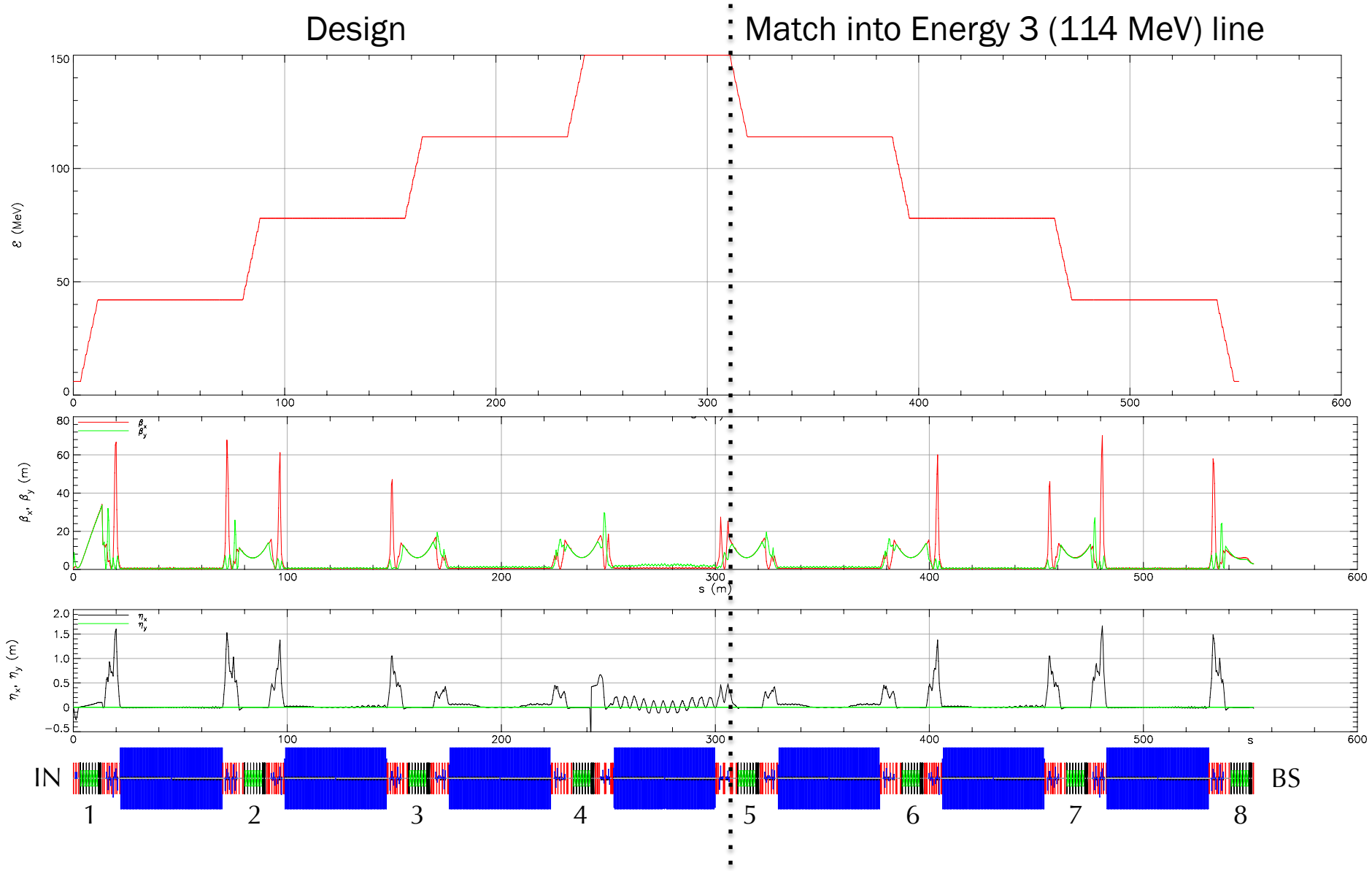
RX Merge and Mirror Merger detail



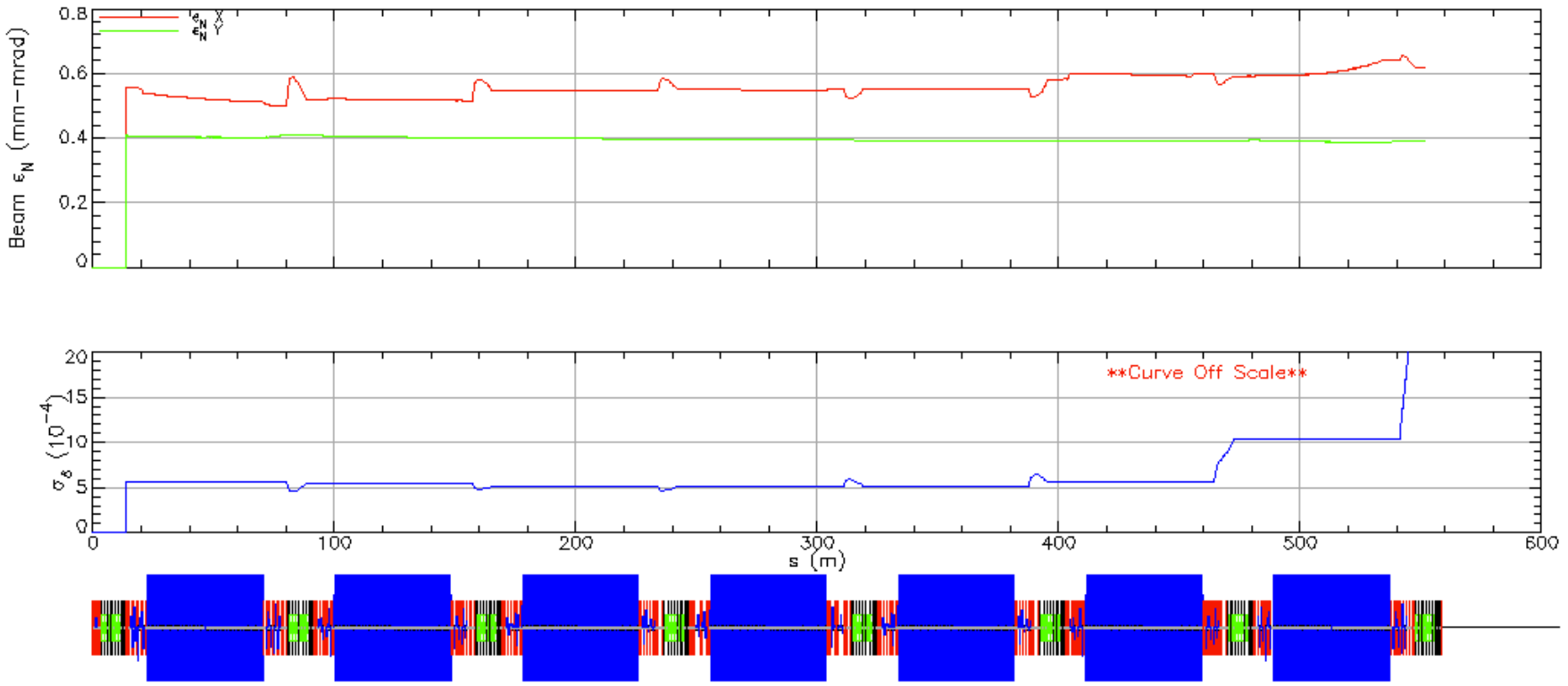
RX Merge and Mirror Merger



4-pass Optics Design

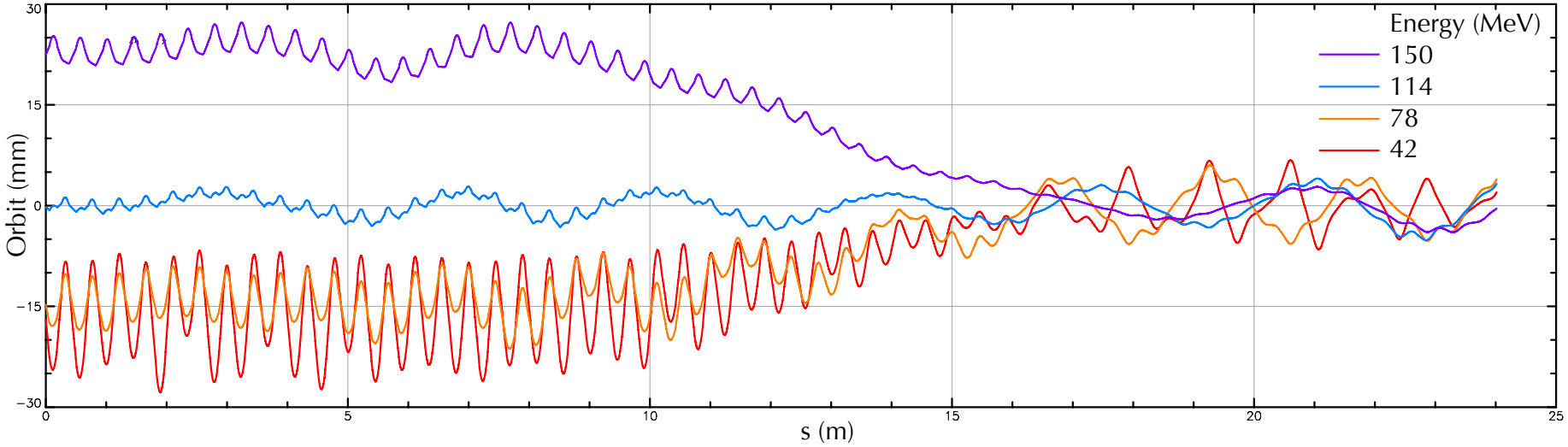


Start-to-End tracking

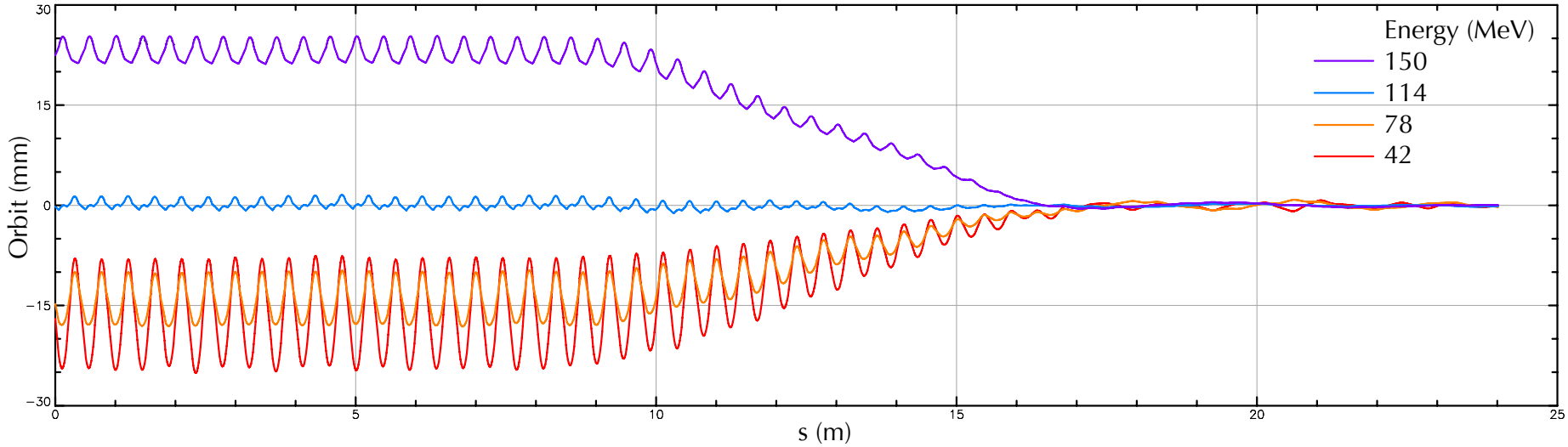


Orbit correction simulation

200 um offset errors in all quads



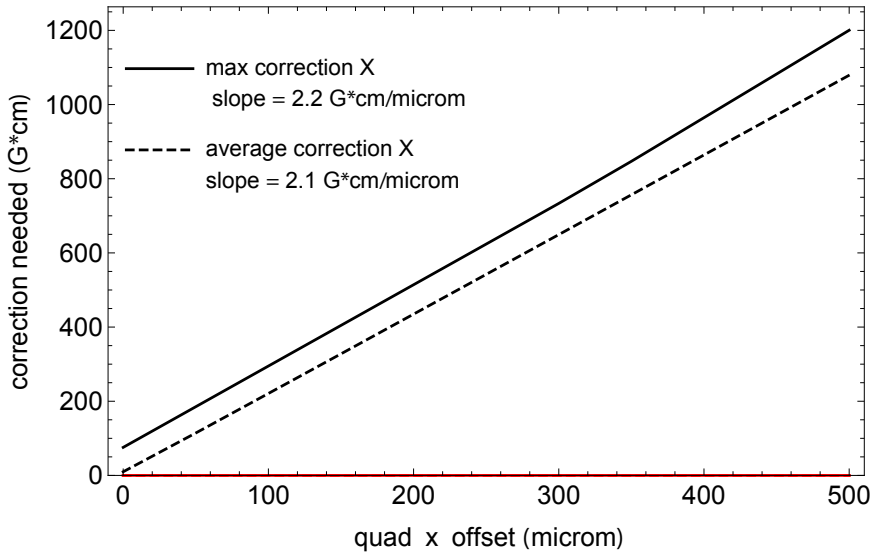
Simultaneously corrected: h corrector in QF, v corrector in QD

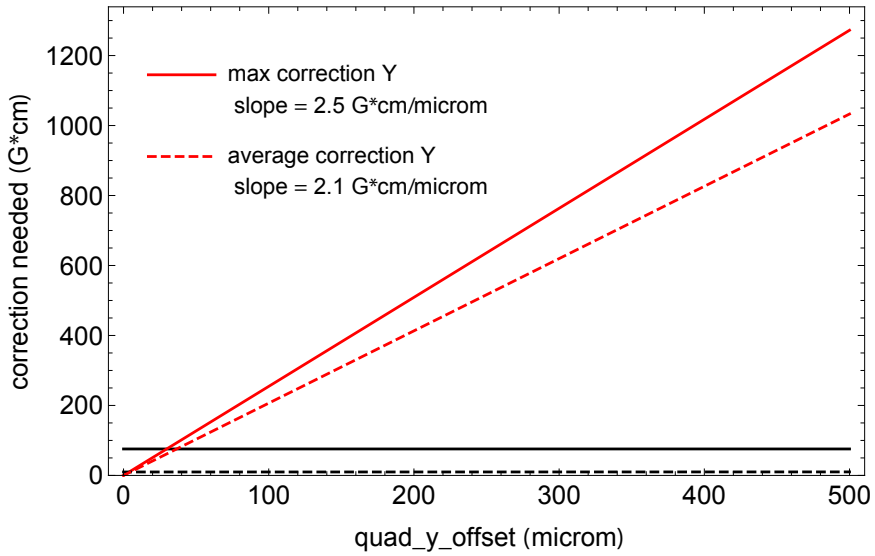


Corrector strength scaling for offsets

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





Accelerator Physics Topics

Injector + Linac space charge optimization
Complete 4-pass start-to-end lattice
Fieldmap tracking in FFAG cell (many codes)
Start-to-end tracking with no collective effects
CSR 1-pass tracking

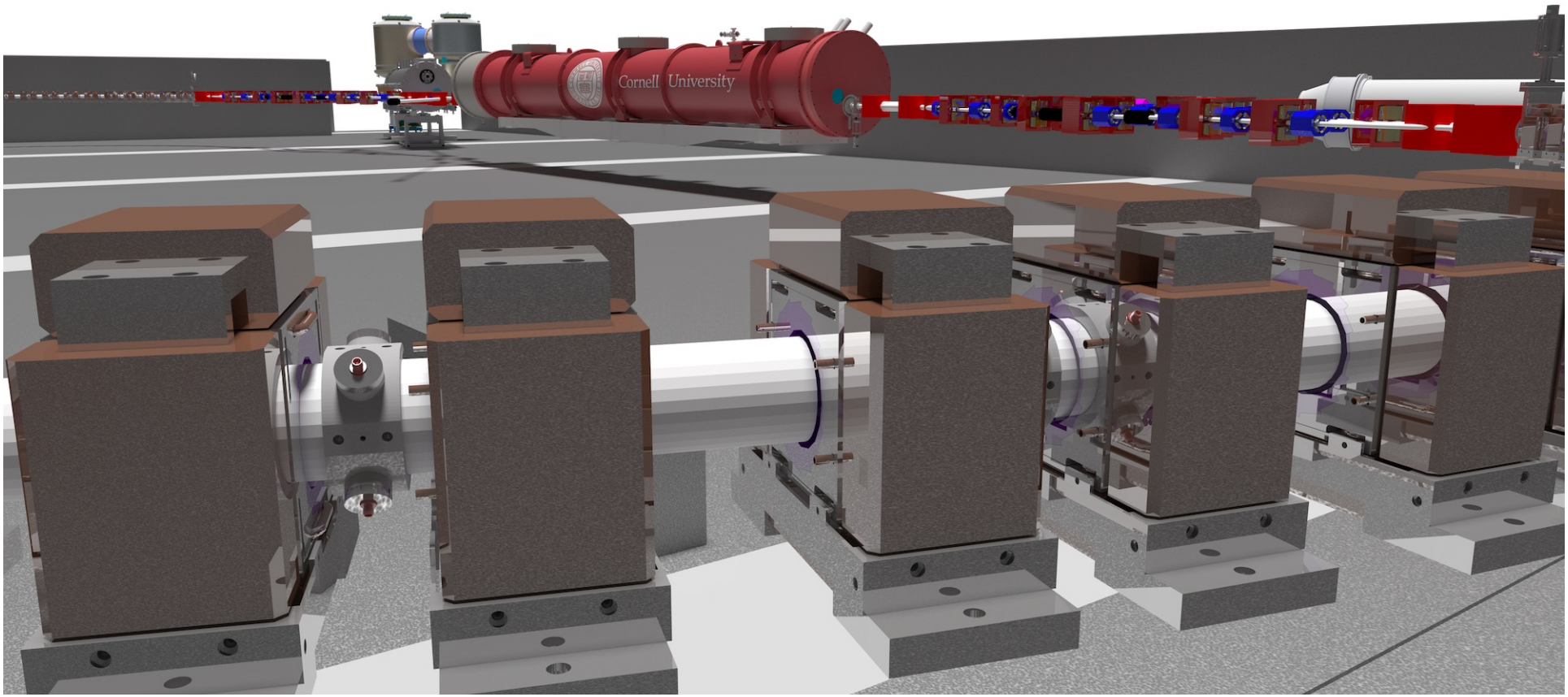
Resistive wall and roughness wakefields
Orbit and optics correction
Tolerance & stability analysis
BBU
RGS
Touschek scattering
Longitudinal Tails
Dark current tracking & collimation
Ion trapping
Realistic Splitter magnet design
Online model

CSR 4-pass tracking, with longitudinal phasing/shaping
Halo from cathode
microbunching

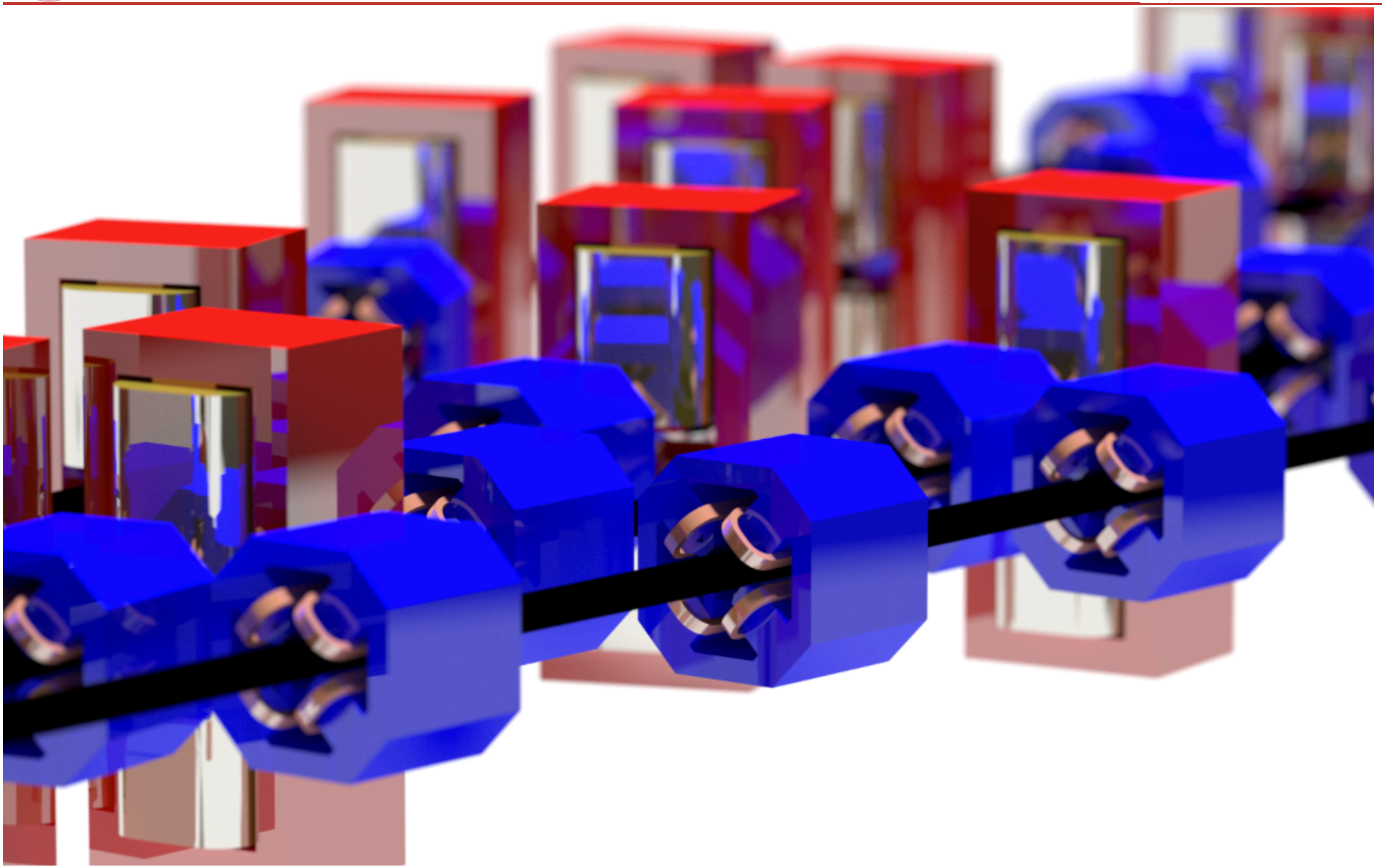
Well under control
Straightforward but not done
Difficult
Caution

CBETA

CORNELL-BNL ERL TEST ACCELERATOR

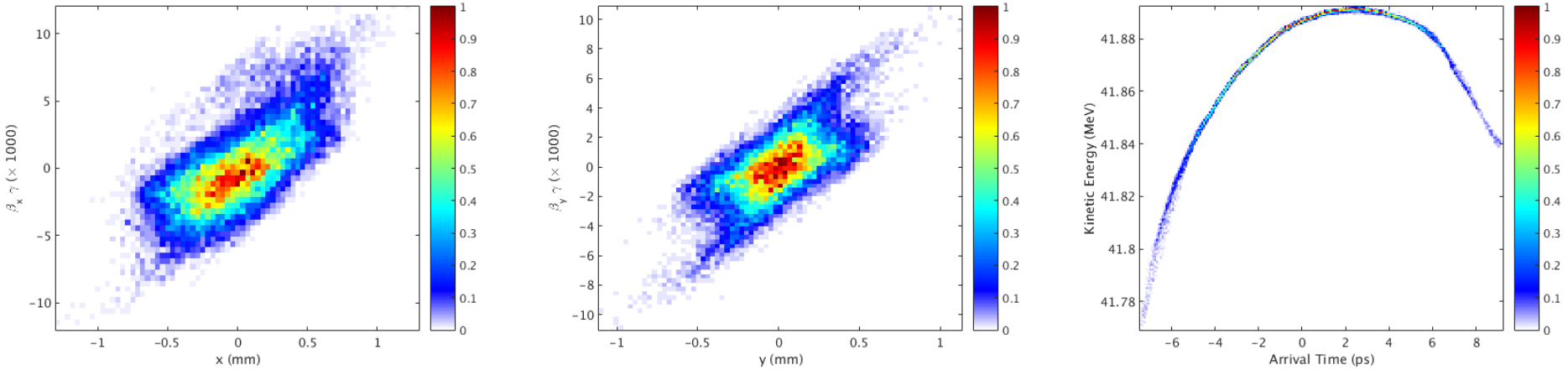


Splitter render



Start-to-End tracking

100 pC bunch calculated from GPT with space charge



…spliced into Bmad 4-pass model