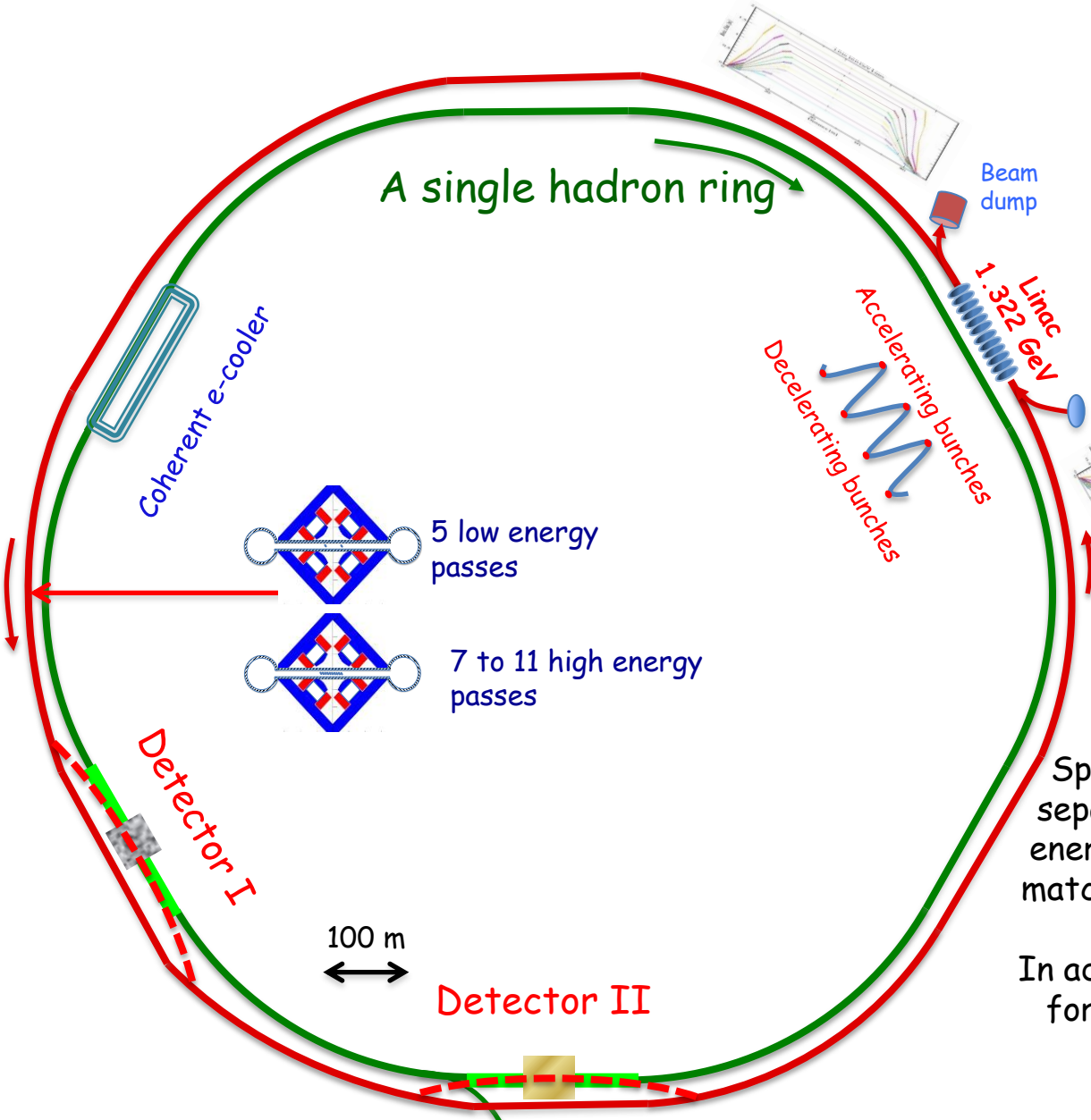
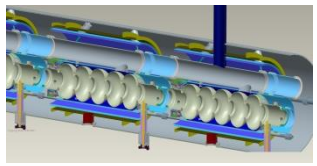
eRHIC FFAG Design for 21GeV

Energy Choices, Number of Passes

- VL recently found a 1.322GeV linac preserved longitudinal spin between IR6 and 8
- VP has found optimal split of energy range between two FFAGs for synchrotron radiation
- Combining these things, I found lattices for:
  - FFAG1. 5 turns, 1.3 – 6.6 GeV
  - FFAG2. 7 turns, 7.9 – 15.9 GeV, 50mA, ~10MW SR
    - *Or* 11 turns, 7.9 – 21.2 GeV, 18mA, ~10MW SR

eRHIC with 15.8/21.16 GeV FFAG ERL

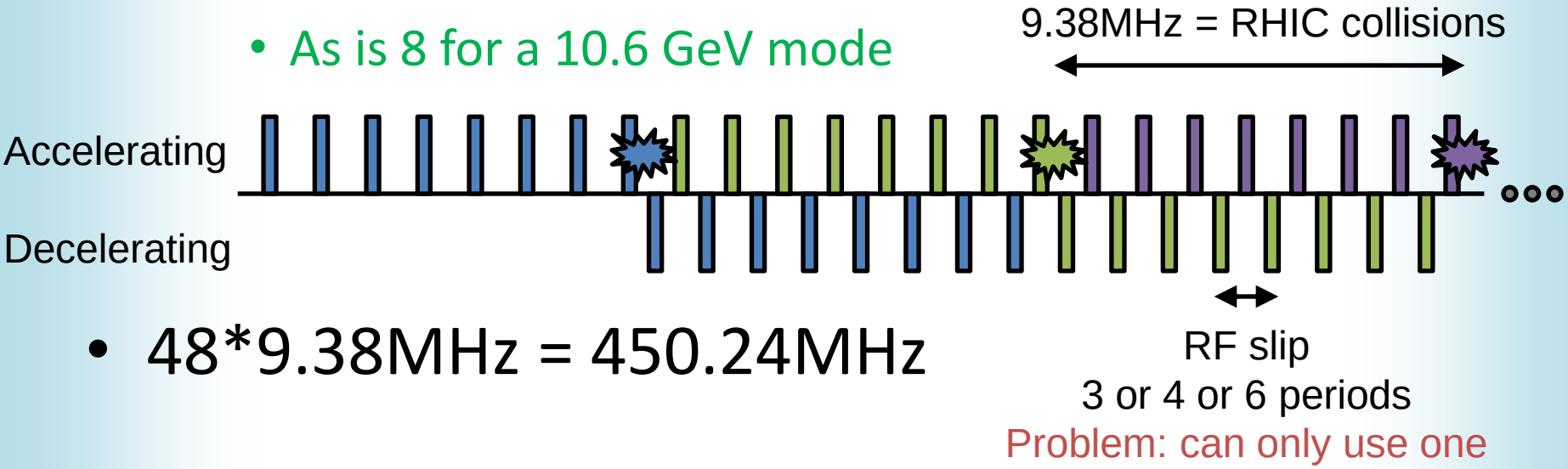




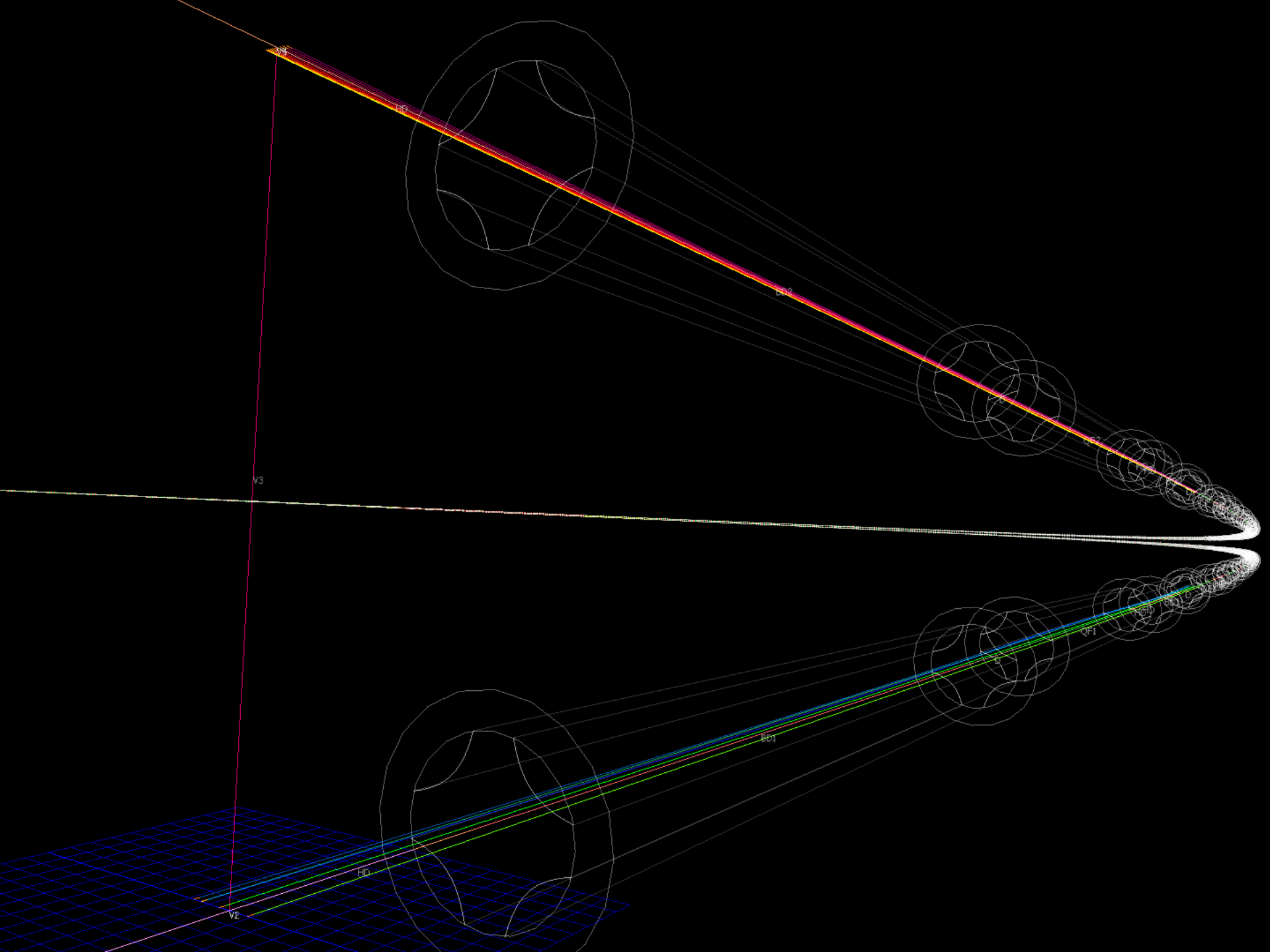
Grand-Central Spreaders/combiners separate 16 beams with energies and are used to match the beam optics of linac and FFAGs.
In addition, they are used for the rough and fine time of flight adjustments

RF and ERL Bunch Structure

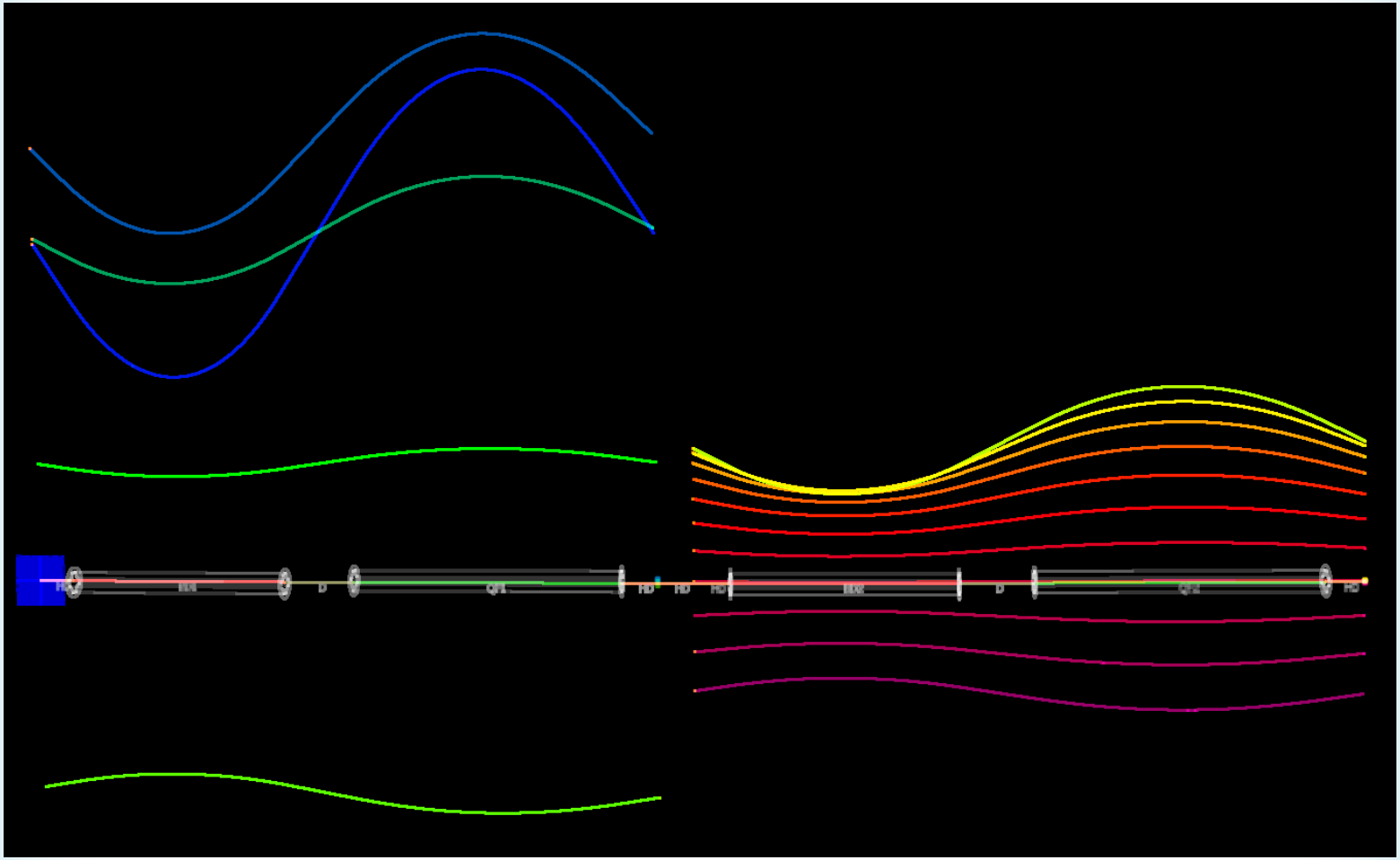
- Operating modes with 5+7=12 or 5+11=16 turns suggest a harmonic such as h=48
  - (RF buckets slip) * (N turns) = h, regular spacing
  - 12 and 16 are factors of 48
    - As is 8 for a 10.6 GeV mode



- 48*9.38MHz = 450.24MHz


V3
V2
HD
BDT
QF1

Orbits Exaggerated 100x



15/21GeV eRHIC (SJB 2013-Dec-26)

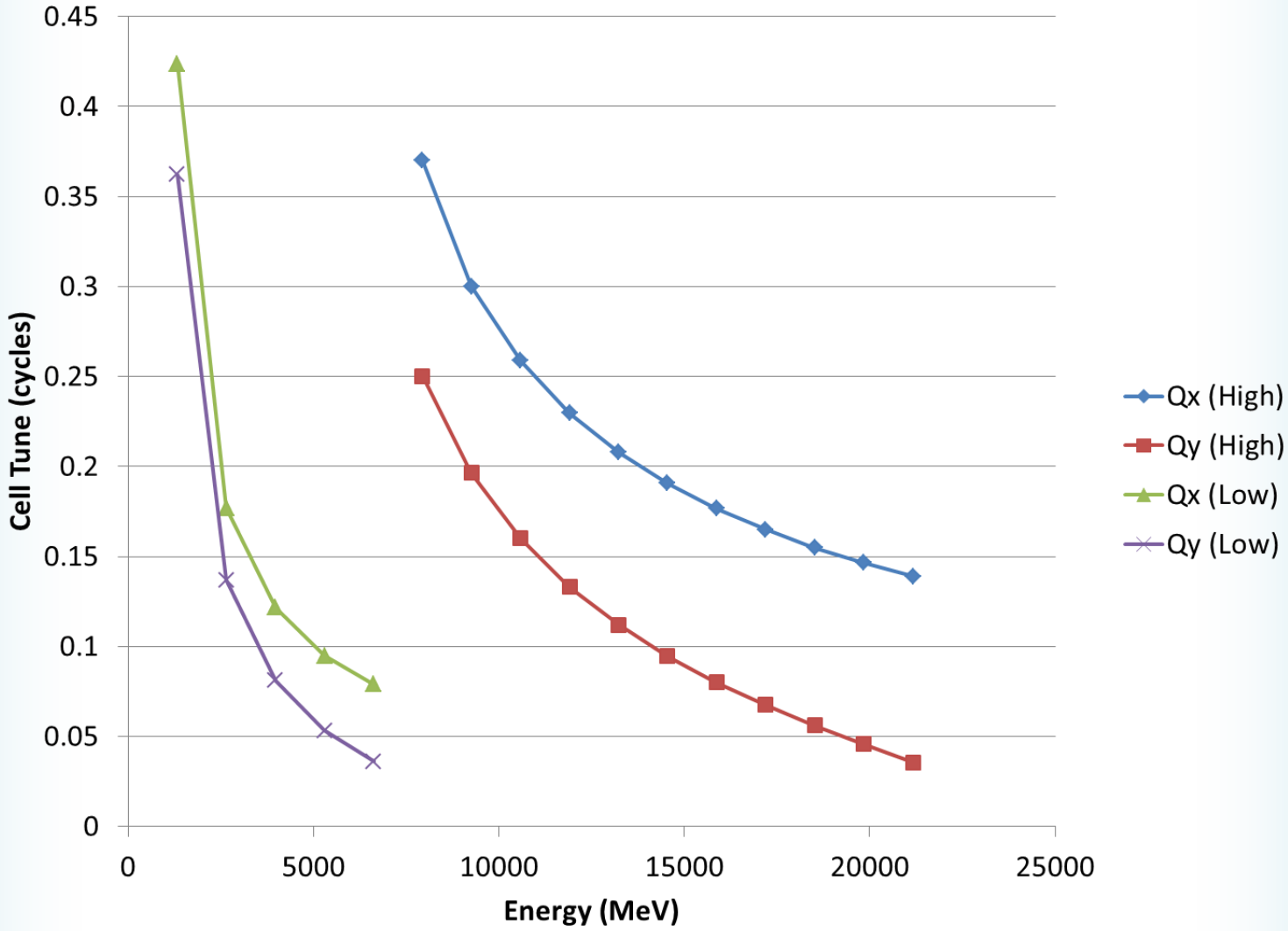
Parameter	Low-Energy FFAG	High-Energy FFAG
Energy range	1.334 – 6.622 GeV	7.944 – 21.164 GeV
Energy ratio	4.96×	2.66×
Turns (1.322GeV linac)	5	11
Synchrotron power	0.26MW @ 50mA	9.8MW @ 21.1GeV, 18mA 10.3MW @ 15.8GeV, 50mA 3.2MW @ 10.5GeV, 50mA
TOF range	54.7ppm (12cm)	22.3ppm (5cm)
Drift space	29.1cm	29.1cm
Tune range	0.036 – 0.424	0.036 – 0.370
Orbit range (quads)	31.3mm (r_{max} = 23.5mm)	12.5mm (r_{max} = 9.1mm)
Max $\|\mathbf{B}\|$ on orbit	0.228 T	0.448 T
Max quad strength	10.1 T/m	50 T/m

Lattice Description

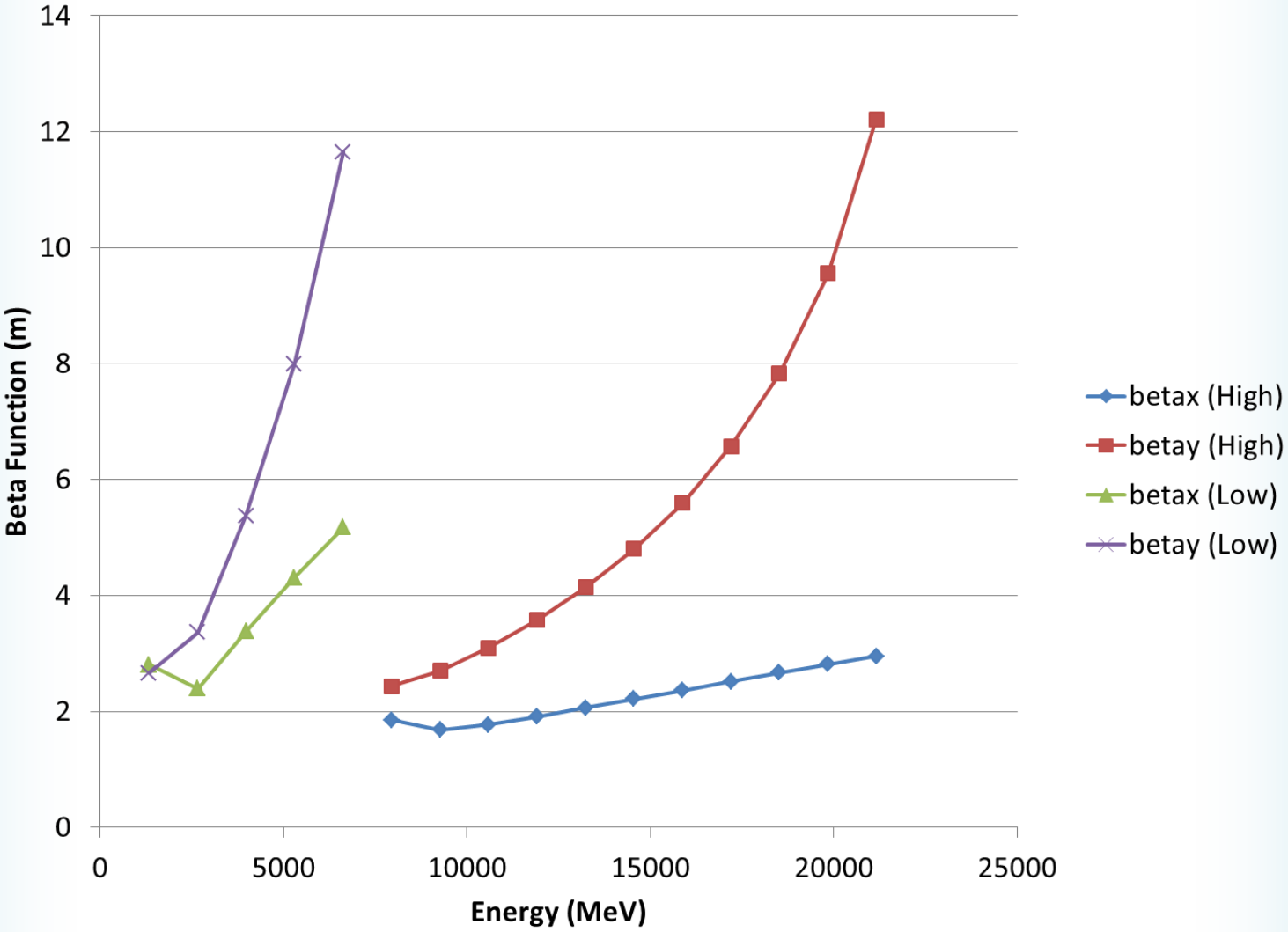
Element	Length (m)	Angle (mrad)	Gradient (T/m)	Offset (mm)
All Drifts	0.2909436	0		
BD (Low)	0.9	3.014379	10.07508	-6.946947
QF (Low)	1.1	3.742197	-8.993994	6.946947
BD (High)	0.9 (as above)	3.014379	50	-3.913914
QF (High)	1.1	3.742197	-49.49950	3.913914

- Cell: ½D,BD,D,QF,½D
- Cells stack exactly, allowing common girder
- First 2 columns fixed, last 2 optimised
  - 50 T/m value was at upper limit of allowed range

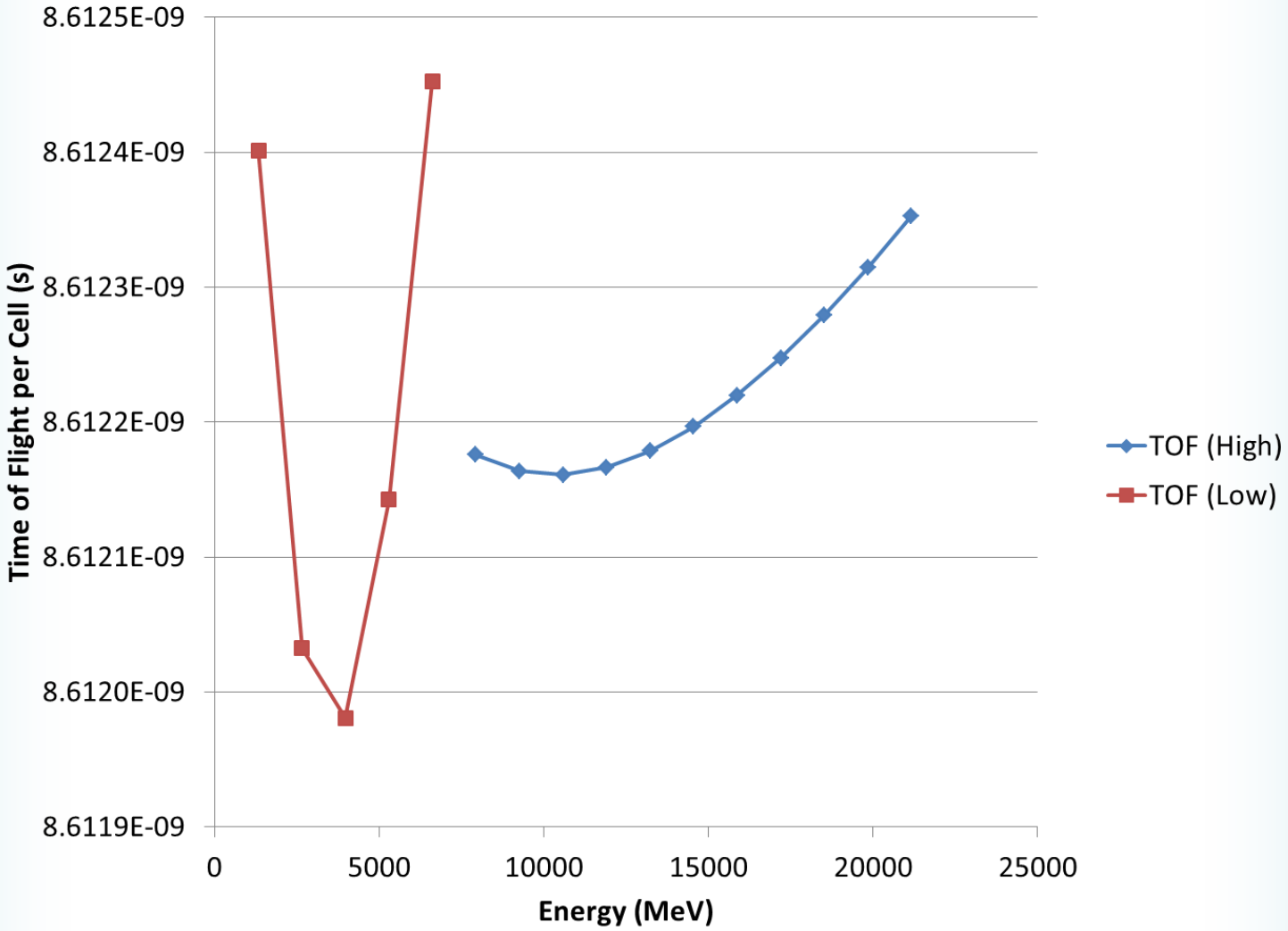
Tunes


0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
Cell Tune (cycles)
0
5000
10000
15000
20000
25000
Energy (MeV)
Qx (High)
Qy (High)
Qx (Low)
Qy (Low)

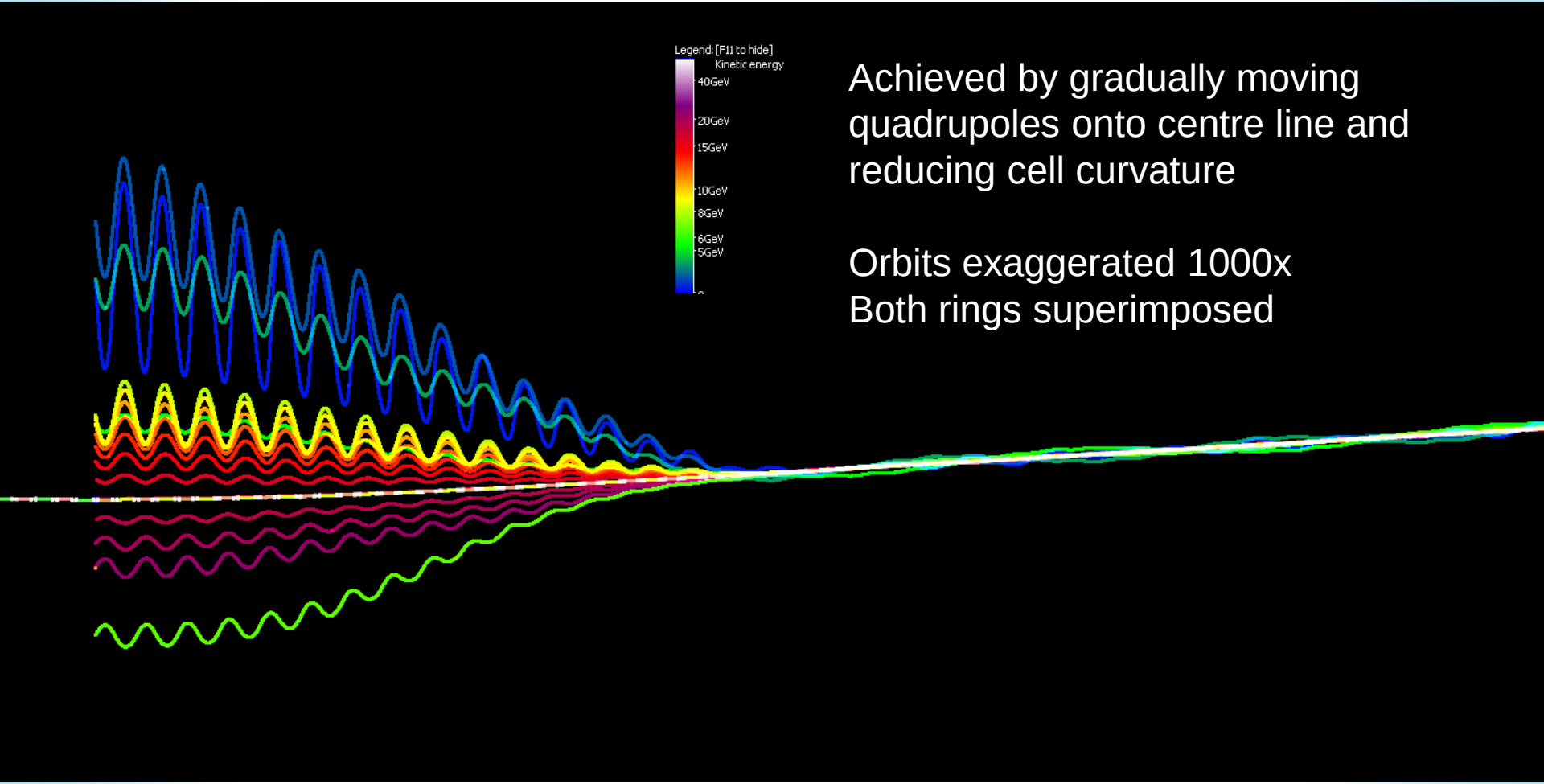
Betas at Matching Plane



Time of Flight Variation



Arc-to-Straight Matching



Achieved by gradually moving quadrupoles onto centre line and reducing cell curvature

Orbits exaggerated 1000x
Both rings superimposed

Whole Rings in Perspective