

FFAG Lattice Design of eRHIC and LHeC

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Dejan's slides go here

This file only contains Stephen's
slides

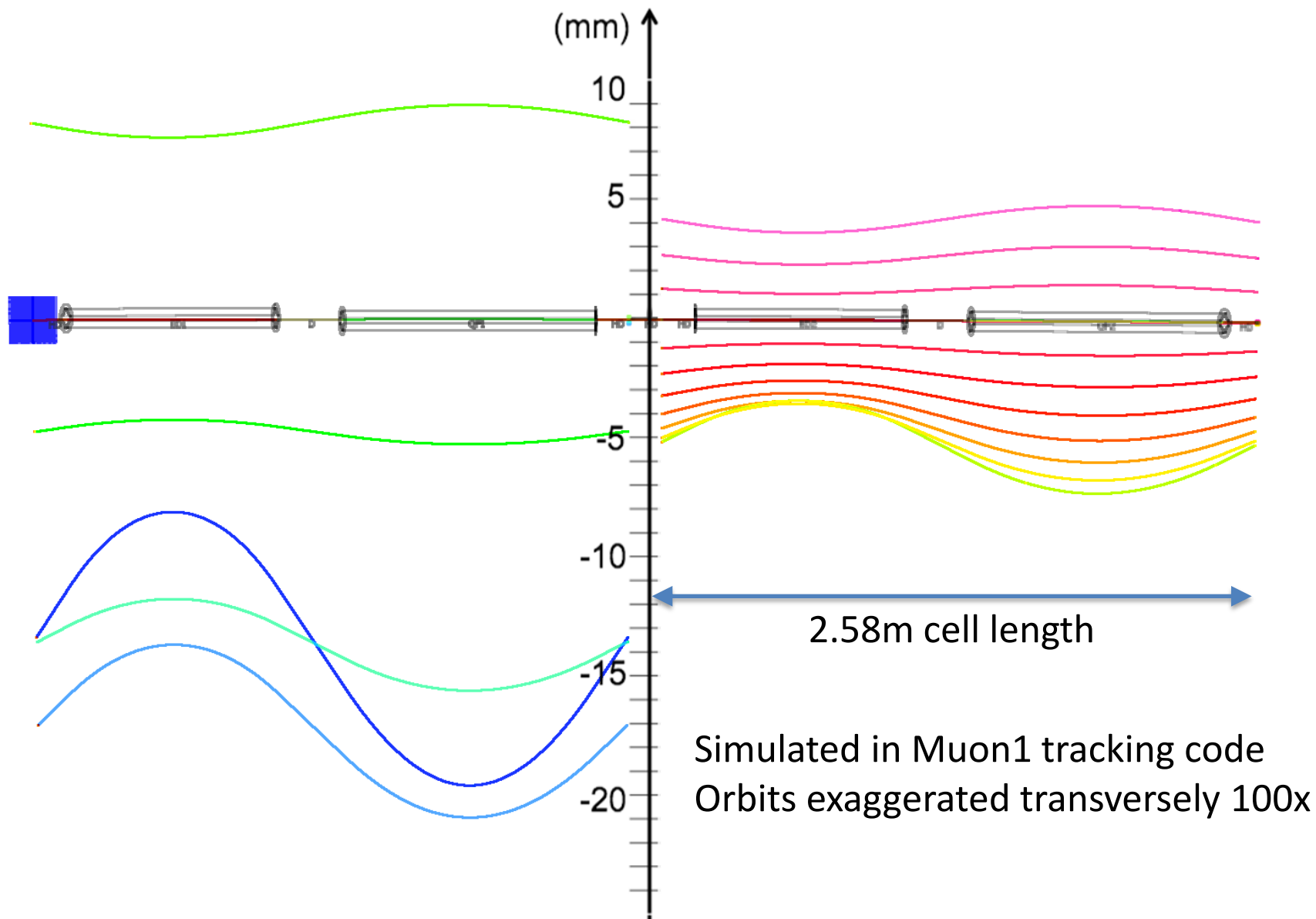
eRHIC FFAG Arc Cells: Parameters and Lattice

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 10.2MW @ 15.8GeV, 50mA 3.2MW @ 10.5GeV, 50mA
TOF range	54.7ppm (12cm)	22.4ppm (5cm)
Drift space	28.8cm	28.8cm
Tune range	0.036 – 0.424	0.035 – 0.369
Orbit range (quads)	31.3mm ($r_{\max} = 23.6\text{mm}$)	12.6mm ($r_{\max} = 9.1\text{mm}$)
Max $ \mathbf{B} $ on orbit	0.227 T	0.451 T
Max quad strength	9.986 T/m	49.515 T/m

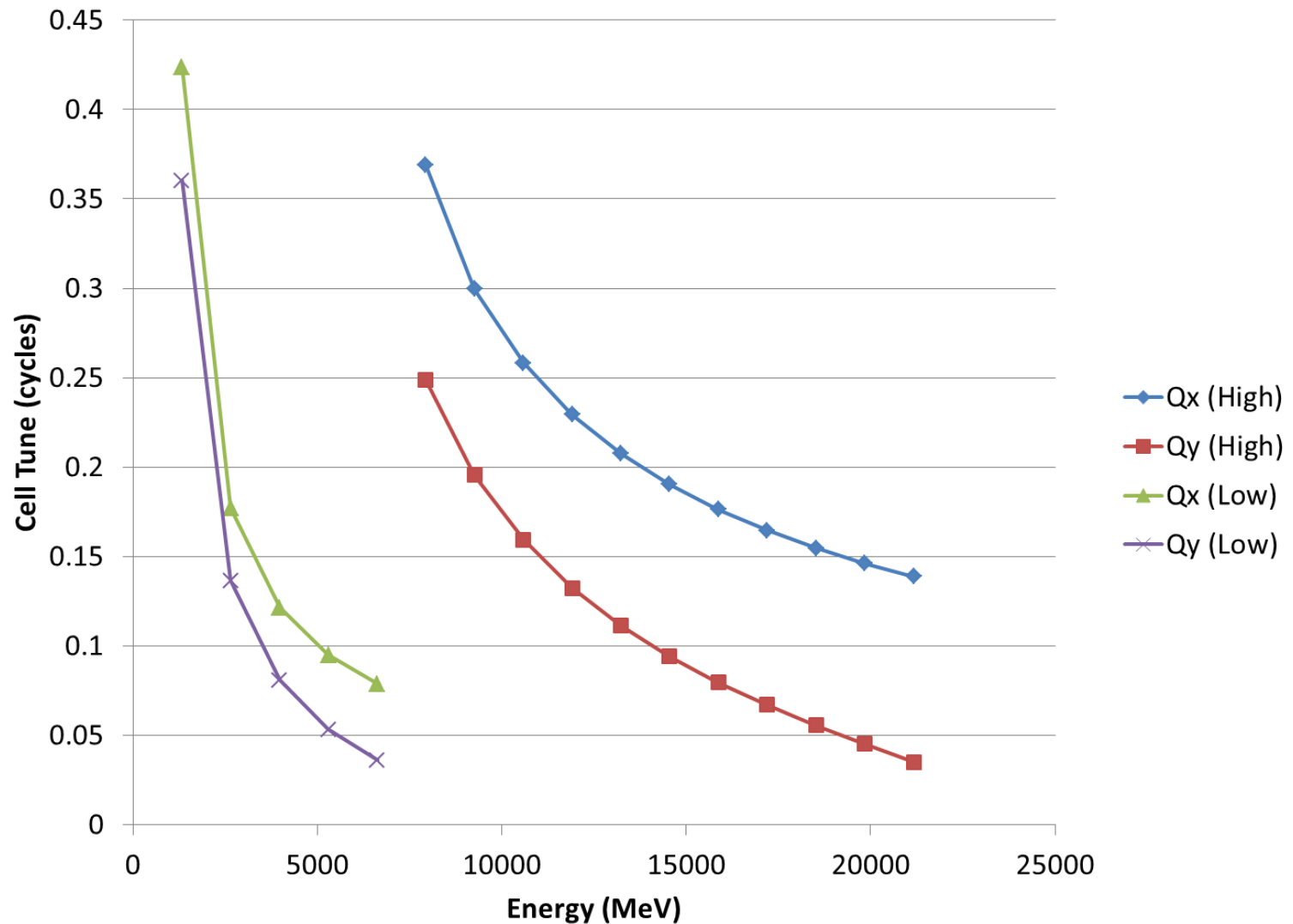
Element	Length (m)	Angle (mrad)	Gradient (T/m)	Offset (mm)
All Drifts	0.287643623	0		
BD (Low)	0.90805 = 35¾"	3.057567	9.986	-6.946947
QF (Low)	1.09855 = 43¾"	3.699017	-9.006	6.946947
BD (High)	0.90805	3.057567	49.515	-3.901098
QF (High)	1.09855	3.699017	-49.515	3.901098

Lattice cell:
½D, BD, D, QF, ½D

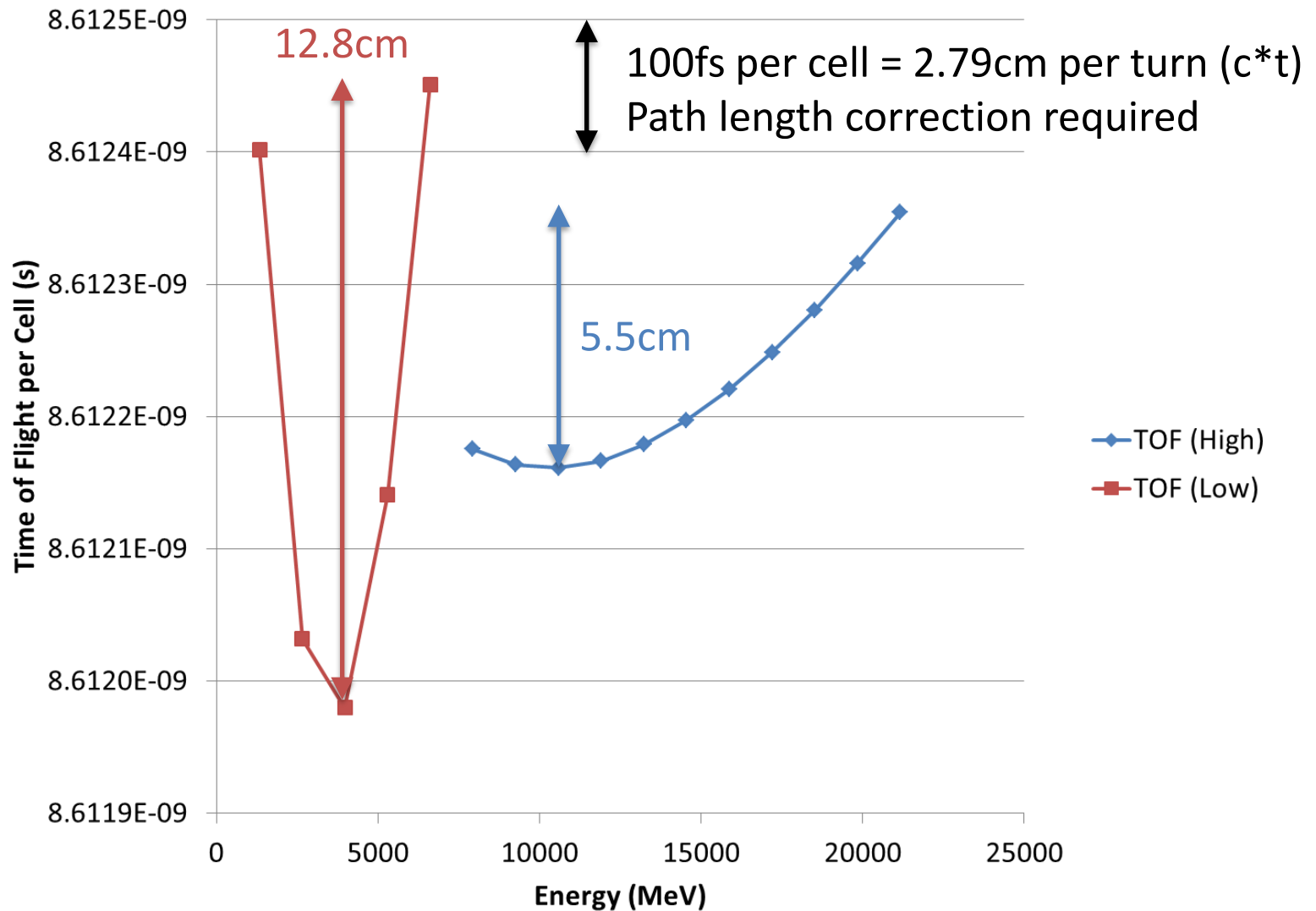
eRHIC: Low (left) and High (right) Energy FFAG Orbits



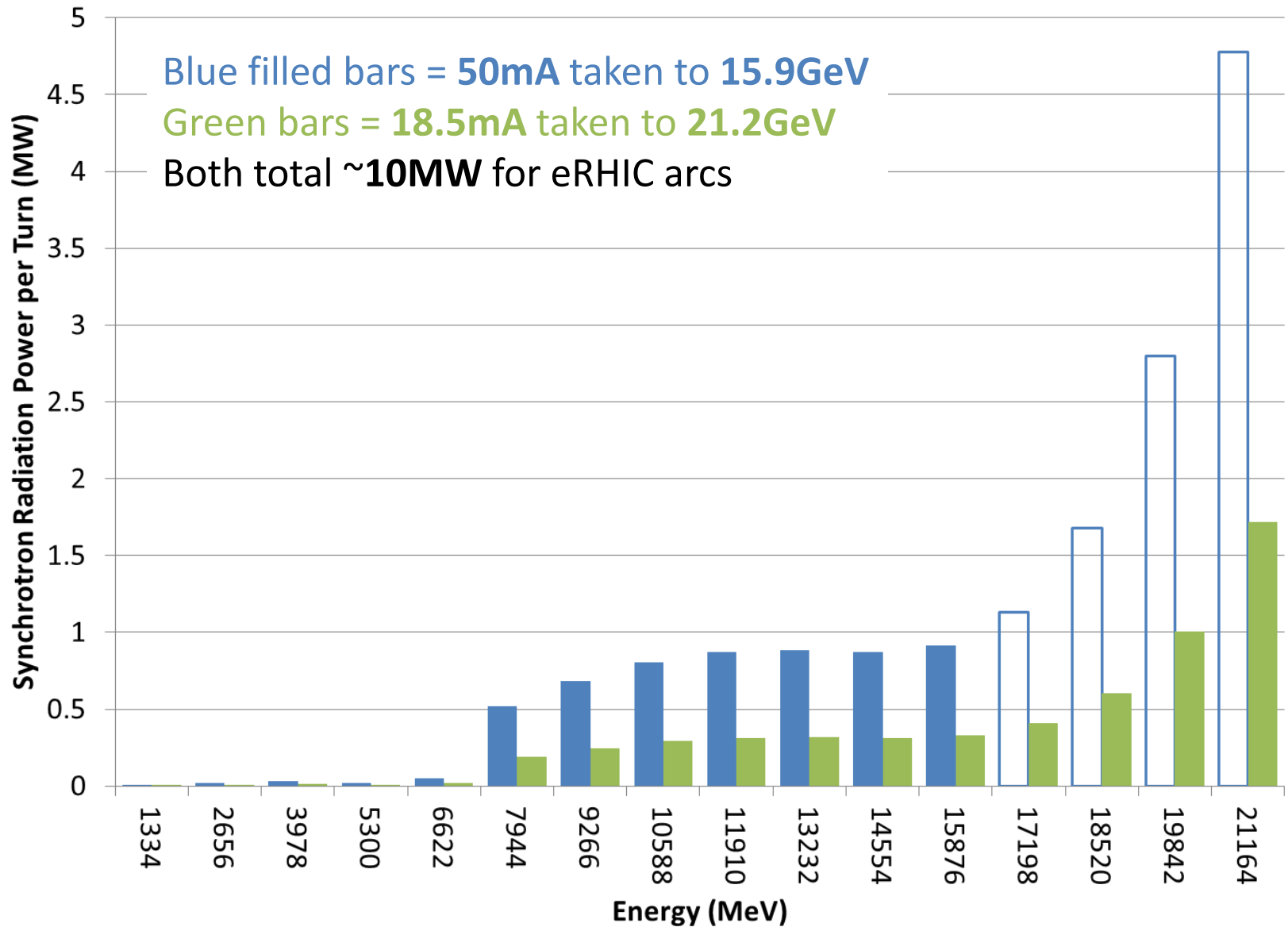
eRHIC Tune per Cell vs. Energy (both rings)



eRHIC Time-of-Flight Variation with Energy (both rings)



eRHIC Synchrotron Radiation per Turn (both rings)



eRHIC FFAG Straight Sections (both rings)

High energy FFAG

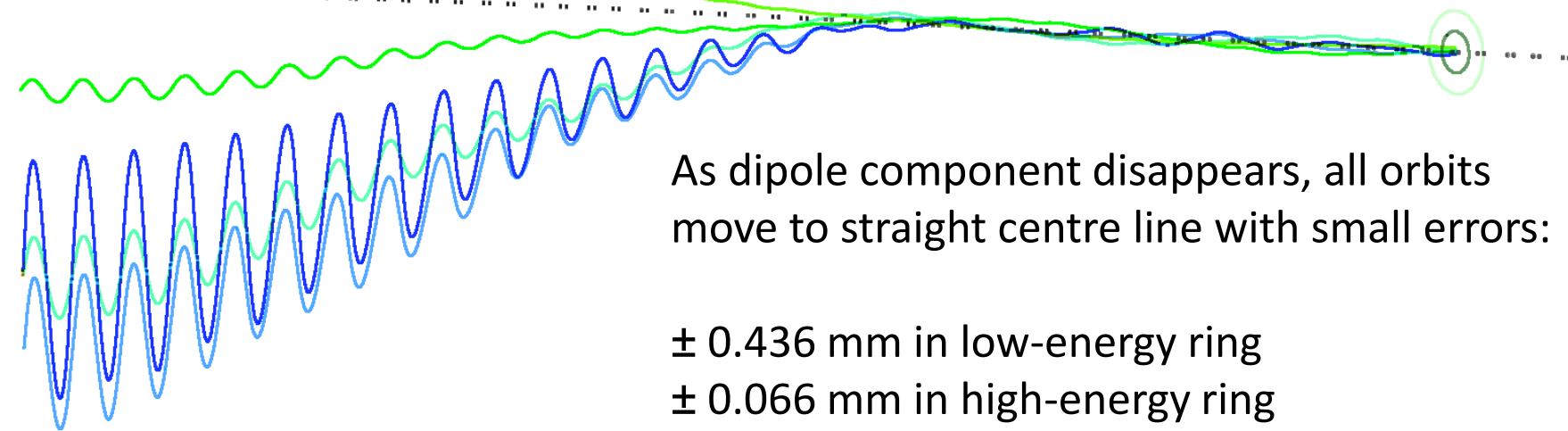
Orbits exaggerated transversely 1000x



1cm

Low energy FFAG

Quadrupole offsets and curvature adiabatically removed over 17 transition cells.



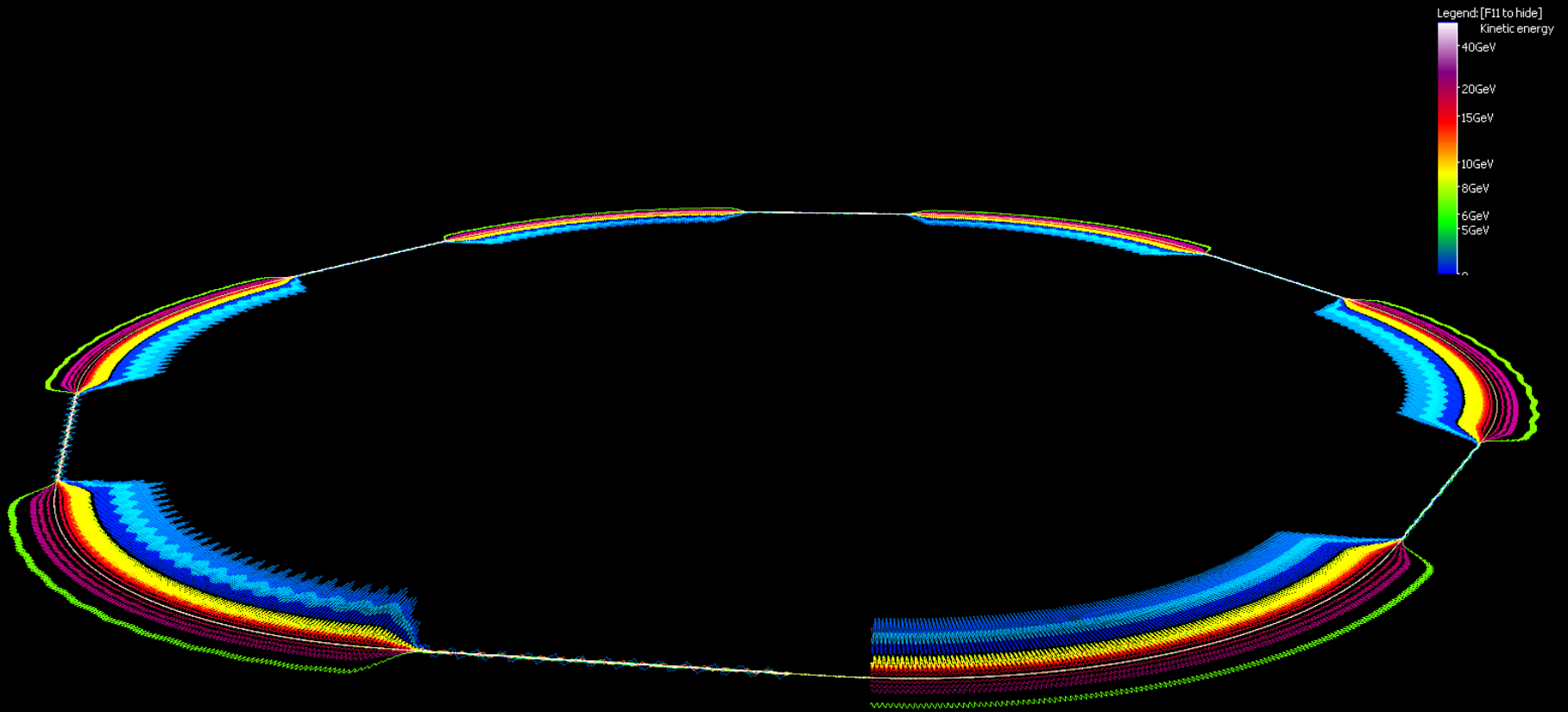
As dipole component disappears, all orbits move to straight centre line with small errors:

± 0.436 mm in low-energy ring

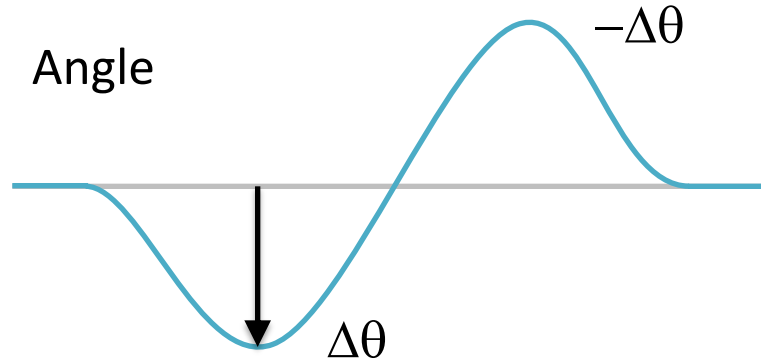
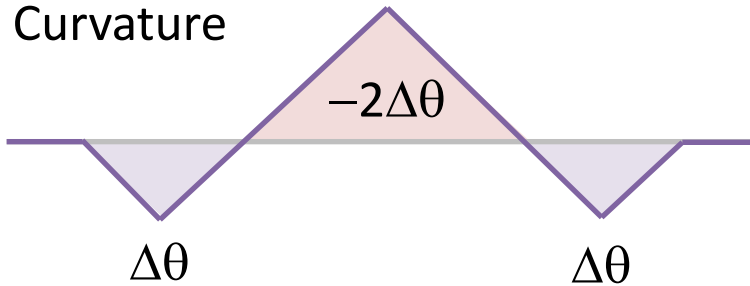
± 0.066 mm in high-energy ring

eRHIC FFAG Rings in Perspective

Orbits exaggerated transversely 5000x, shape of hexagonal RHIC is evident



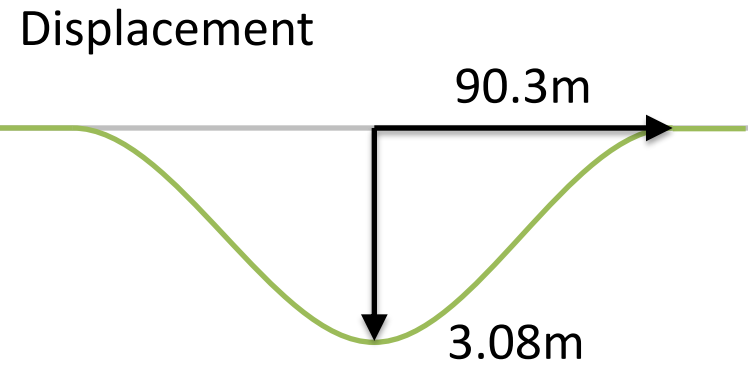
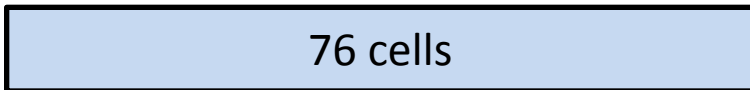
Detector Bypass Scheme: a Flexible FFAG



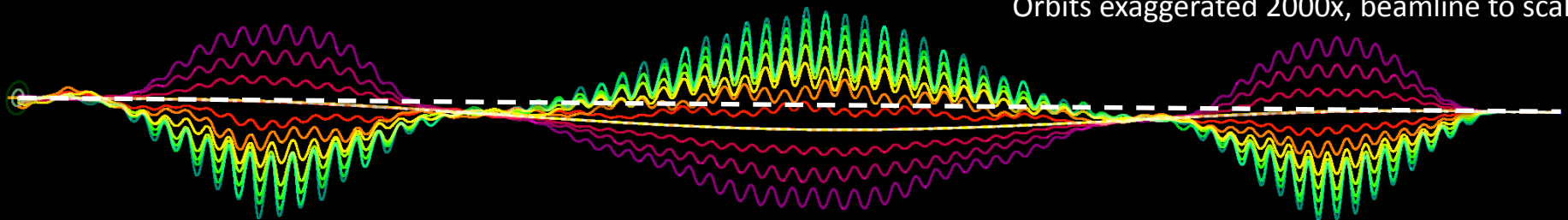
Bypass straight



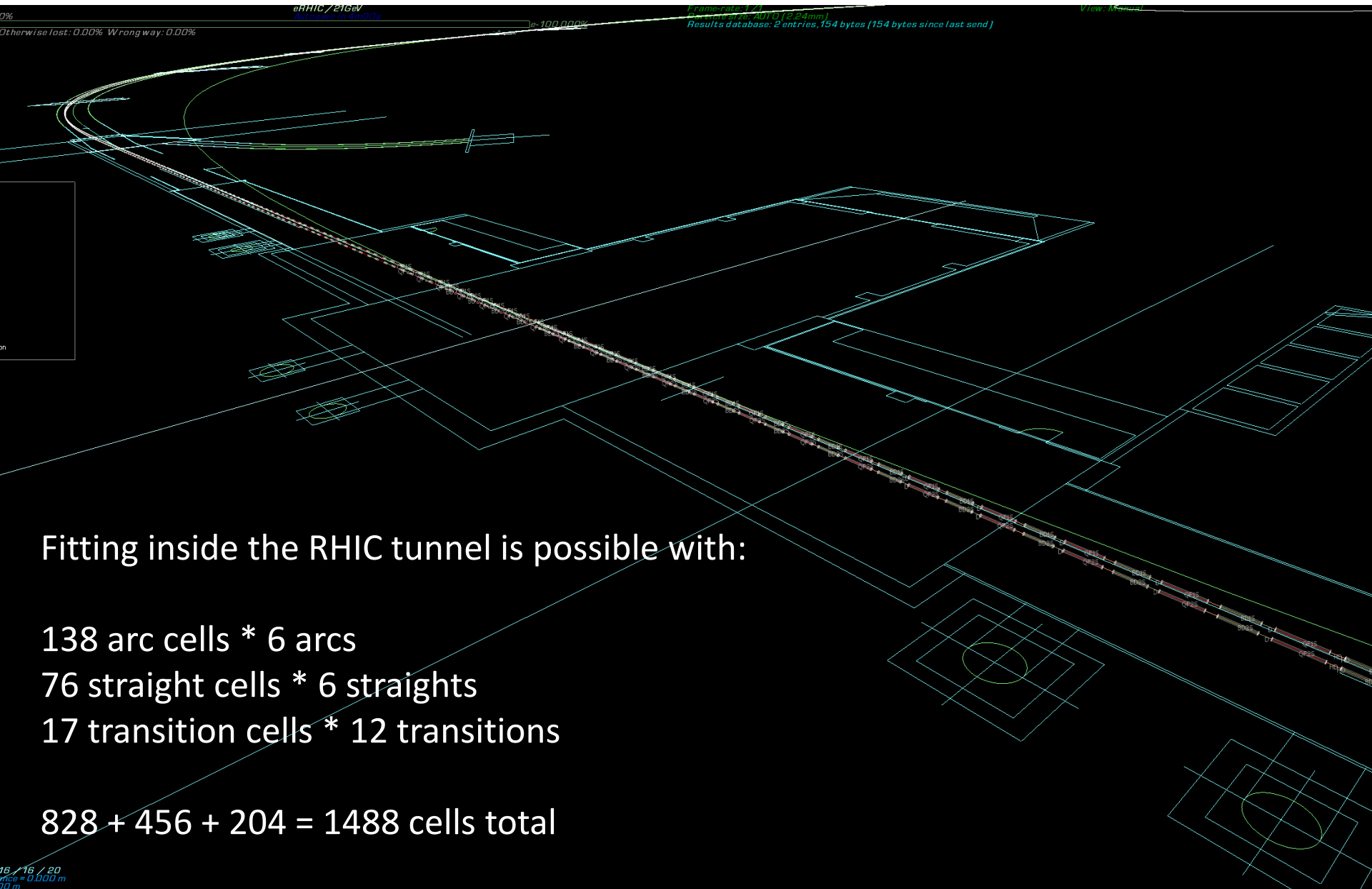
Normal straight



Orbits exaggerated 2000x, beamline to scale



Layout Superimposed on CAD of RHIC Tunnel



Fitting inside the RHIC tunnel is possible with:

138 arc cells * 6 arcs

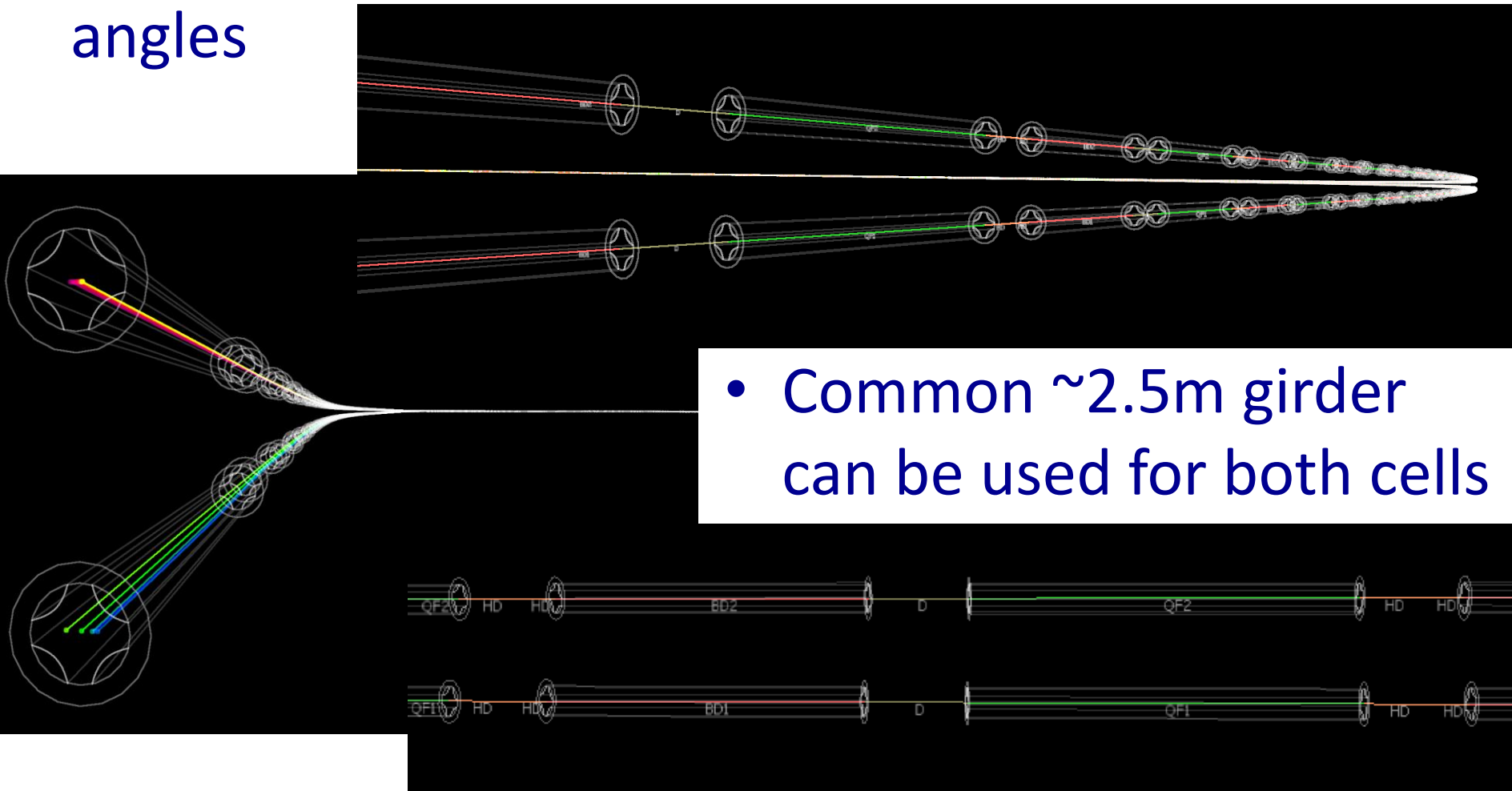
76 straight cells * 6 straights

17 transition cells * 12 transitions

$828 + 456 + 204 = 1488$ cells total

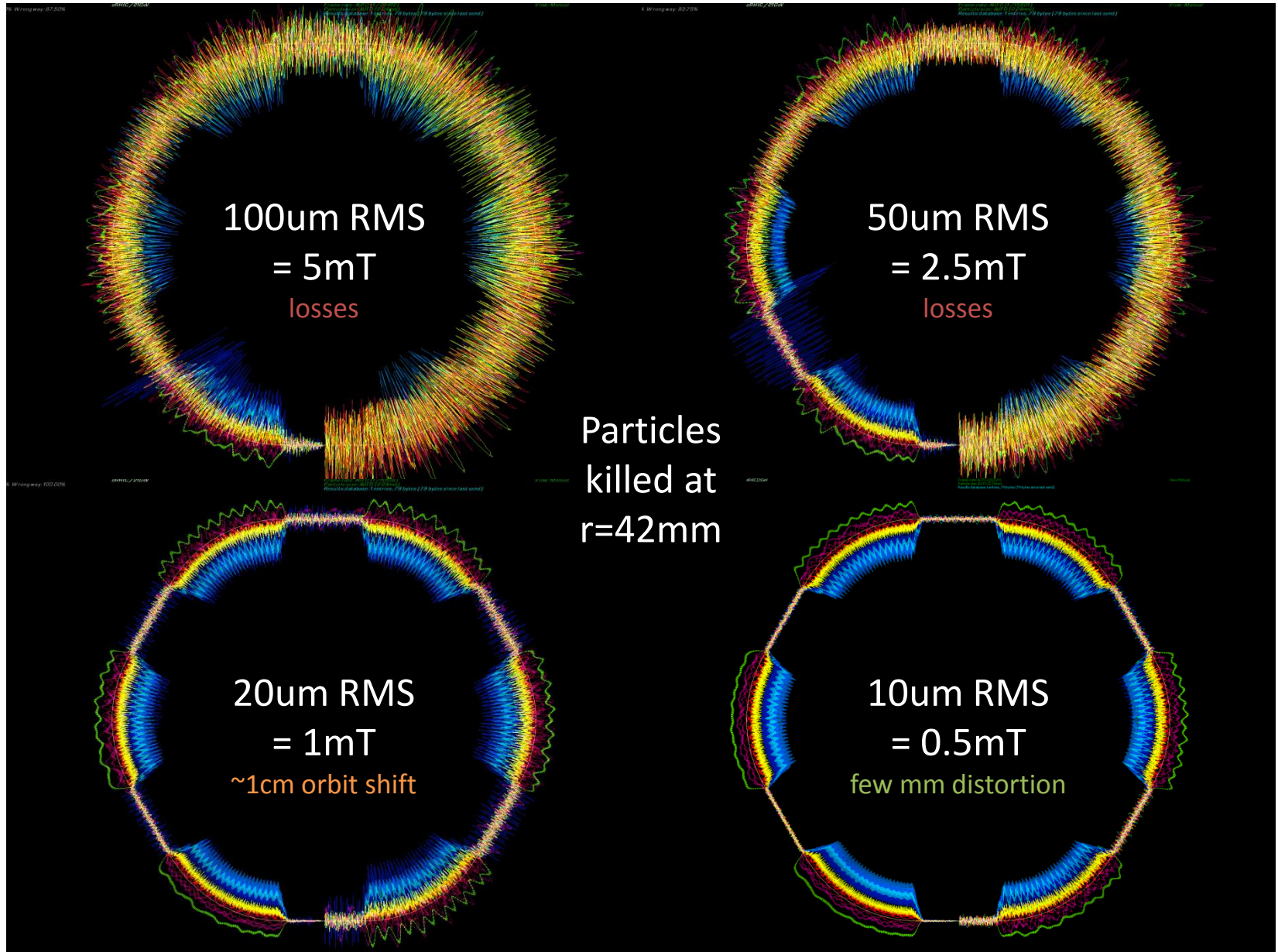
Girder Stacking

- Both rings have the same element lengths and angles

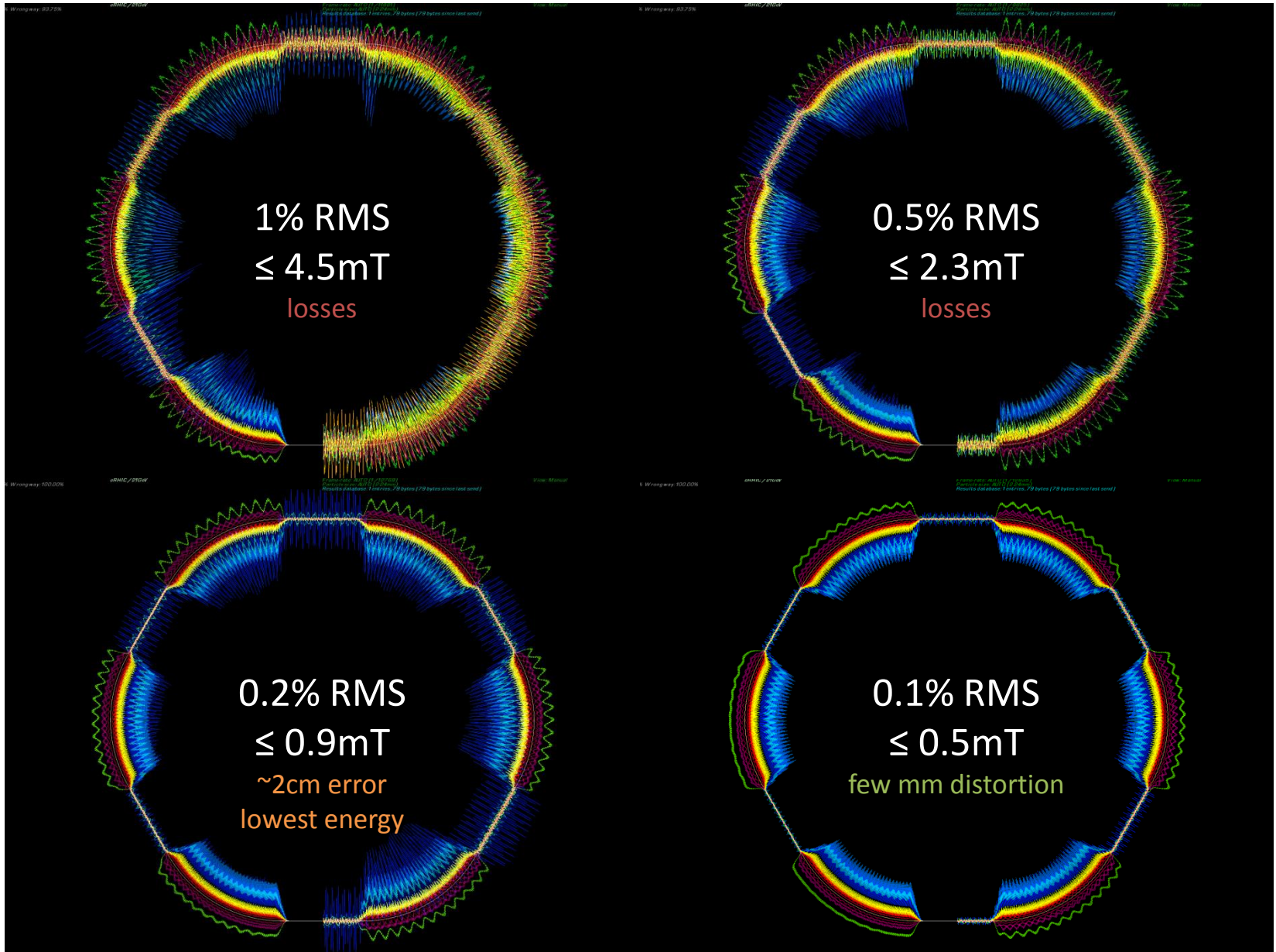


- Common $\sim 2.5\text{m}$ girder can be used for both cells

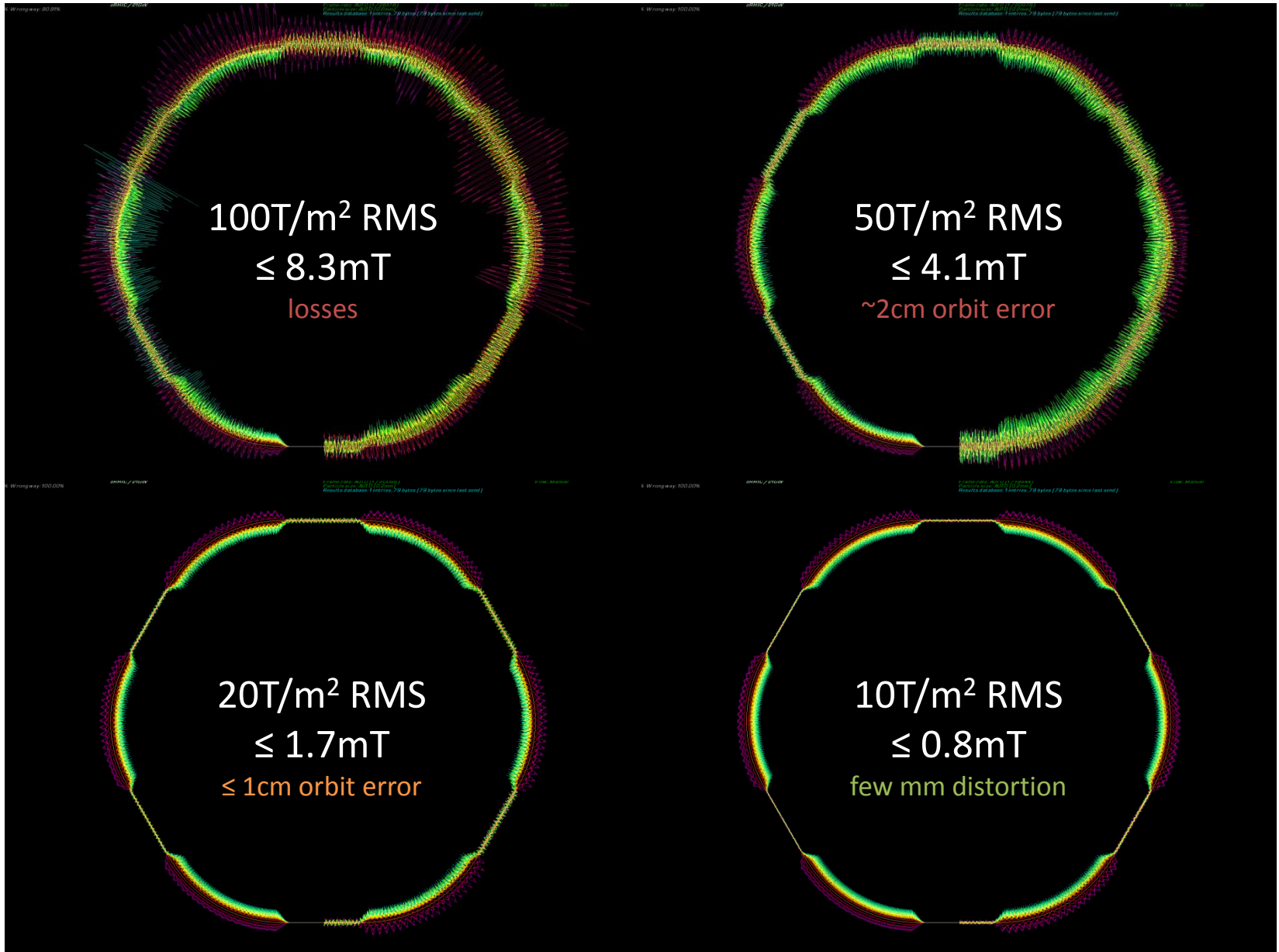
Quadrupole Displacements = Dipole Errors (both rings)



Quadrupole Errors (both rings)



Sextupole Errors (high-energy ring only)



Optimised FFAG LHeC Design in Muon1

Parameter	Low-Energy FFAG	High-Energy FFAG
Energy range	10 – 30 GeV	40 – 60 GeV
Energy ratio	3.00×	1.50×
Turns (10GeV linac)	3	3
Synchrotron power	<2MW @ 6.4mA (not simulated)	21.1MW @ 6.4mA 14.8MW @ 4.5mA
TOF range		28.3ppm (18cm)
Drift space		30.0cm
Tune range		0.050 – 0.399
Orbit range (magnets)		41.6mm
Max $ \mathbf{B} $ on orbit		0.309 T
Max quad strength		8.258 T/m

- R=1km tunnel arcs, tunnel contains a single 10GeV linac, so synchrotron radiation evaluated for 40,50,60,50,40GeV full turns.
- Achieves ~15MW goal for reduced current 4.5mA at 60GeV, or scaled energy ~54GeV at 6.4mA with 9GeV linac.

Optimised FFAG LHeC Design Lattice

Element	Length (m)	Angle (mrad)	Gradient (T/m)	Offset (mm)
Q (High)	5.22623	5.22623	8.25826	-24.5345
Drift D	0.3	0.3		
R (High)	9.09660	9.09660	-6.45646	24.5345
Drift E	0.301702	0.301702		

Orbits stay on positive curvature side in all magnets (exaggeration is misleading!), so can use half-quads. 50GeV orbit is central.

Orbits exaggerated transversely 100x

