Arc to Straight Matching

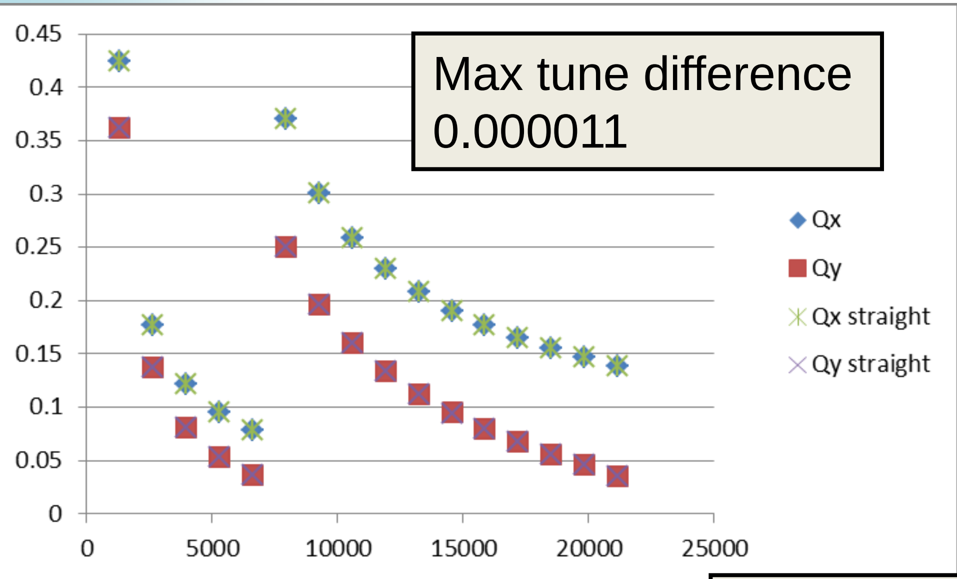
In both eRHIC FFAG rings

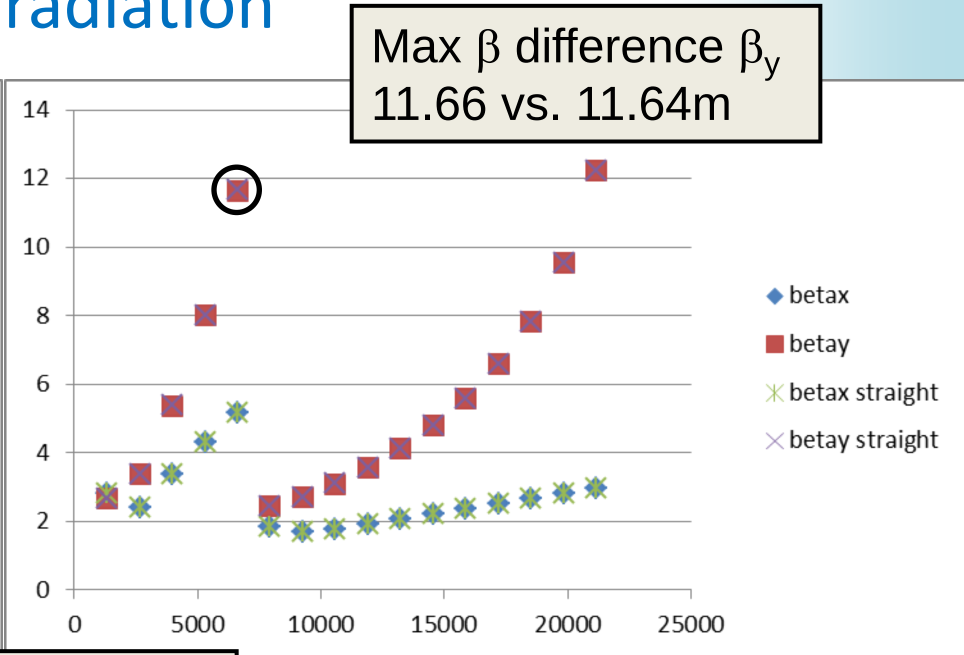
What is the Straight?

- The straight cell is the same as the arc cell but with the following set to zero:
  - Displacements from reference curve
    - “Dipole component” if magnet was combined function
  - Bends in reference curve
    - The magnets have no real bends, they are rectangular
- These are positioning issues only, so actually the straight cell consists of the same ‘part numbers’ as the arc!

Straight Cell Optics

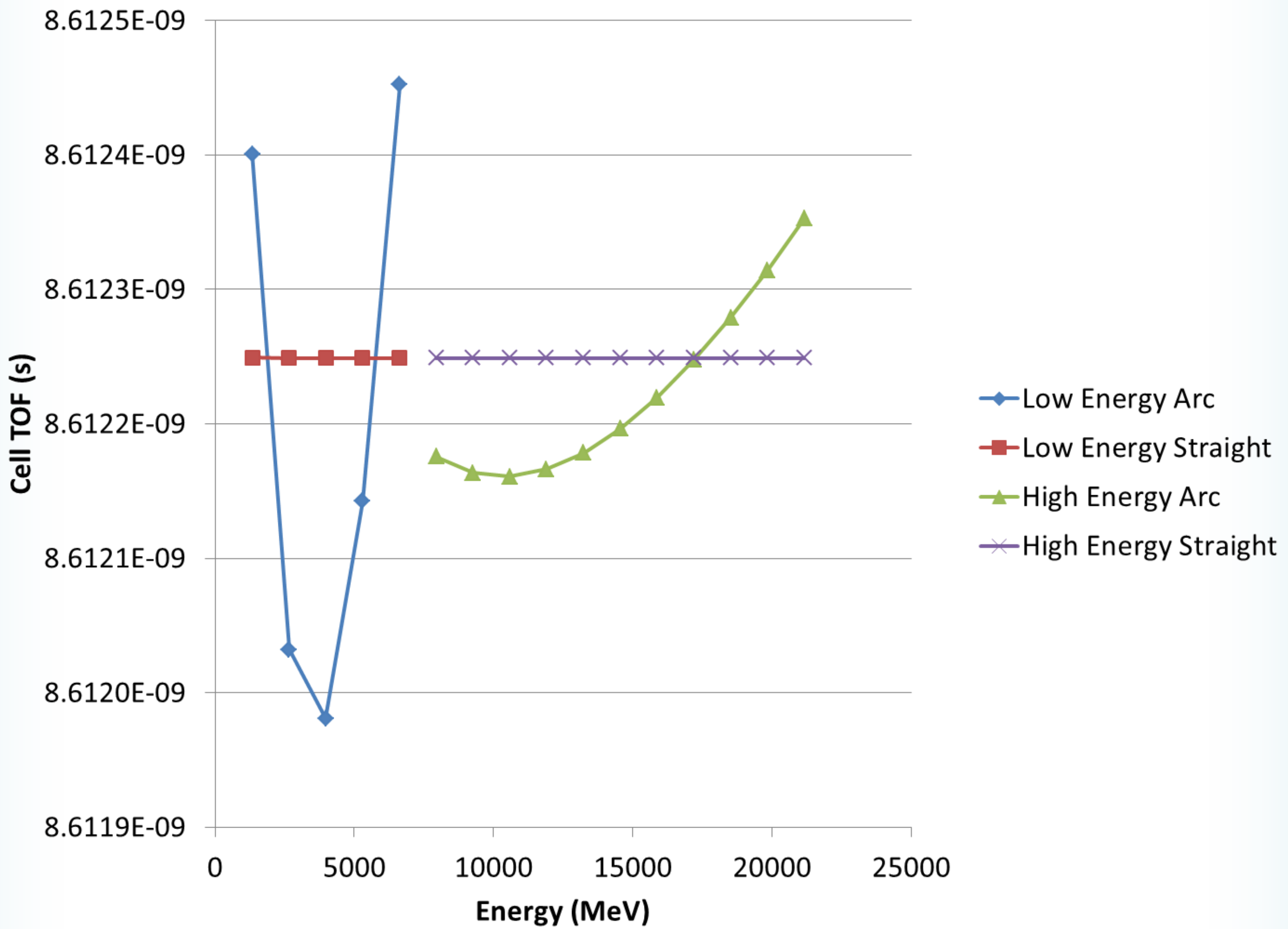
- Non-offset quadrupoles so all matched beams go straight down the middle
  - Very little synchrotron radiation





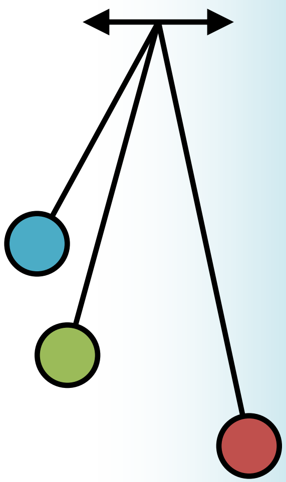
Same "optics" as arc

Straight Cell TOF



Matching Concept

- FFAG matching analogous to trying to move a bunch of pendulums of different lengths from one place to another with minimum disturbance
  - One pendulum for each orbit
  - 1/period ~ tune
  - Sensitive to accelerations (by relativity!)

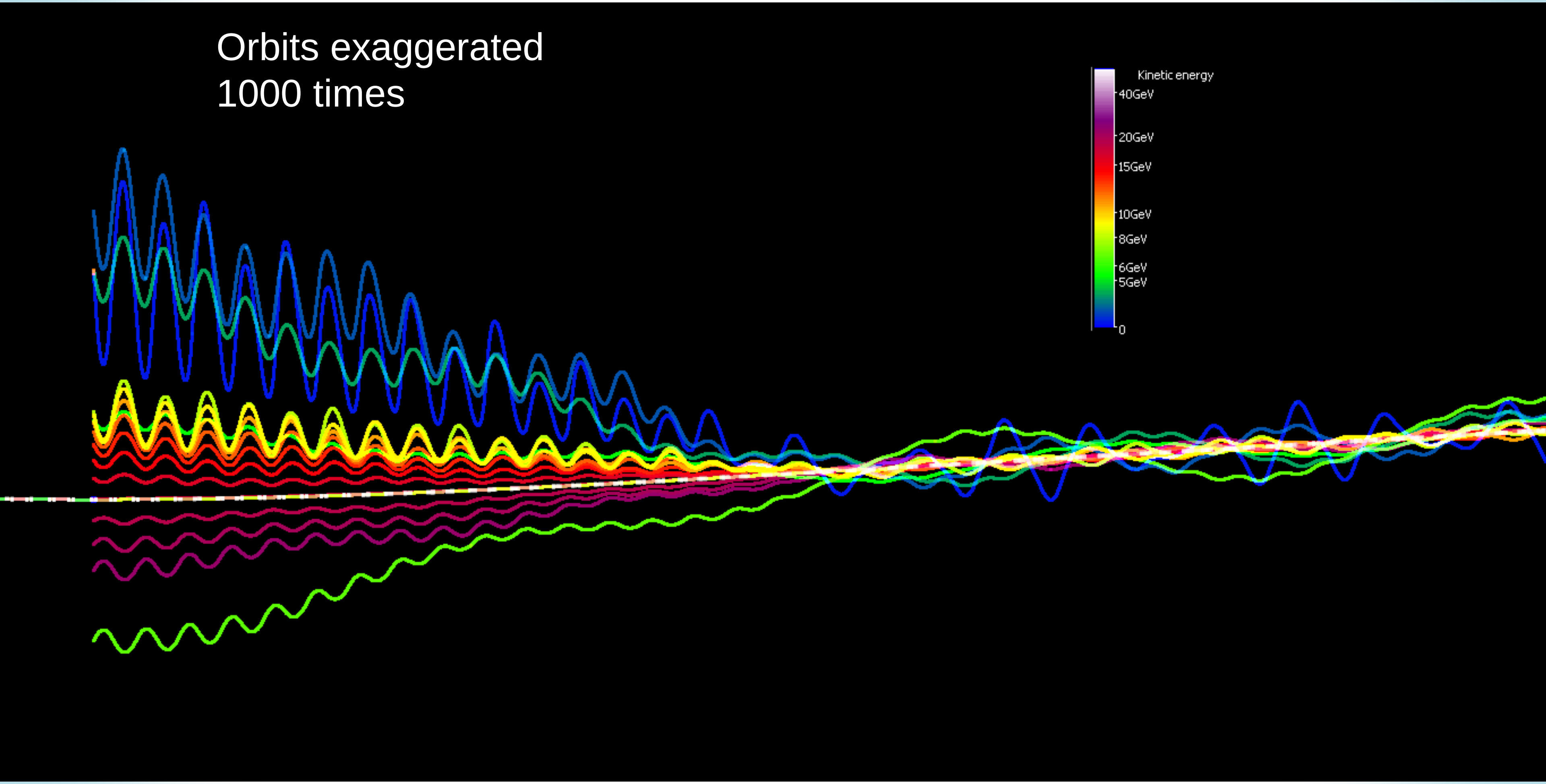


- Doing it adiabatically will always work
  - Non-adiabatic solutions hard for many pendulums

Matching Method

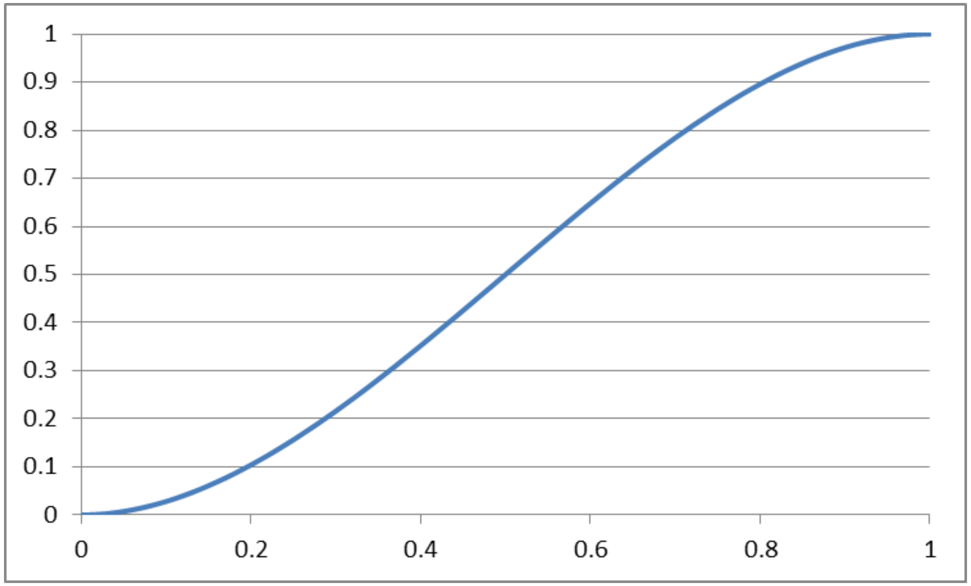
- Used 17 special matching cells (~44m)
- Bend angles and quad offsets in each cell are arc cell's values multiplied by a function w(u)
  - u "coordinate" = cell number(1 to 17)/18
    - $u \leq 0$ in straight, $u \geq 1$ in arc
  - Want w(0)=0 and w(1)=1 to avoid discontinuities
- Simplest choice: w(u)=u (linear)
  - Problem: w'' is effectively infinite at u=0 and 1

Linear Ramp of Both Rings

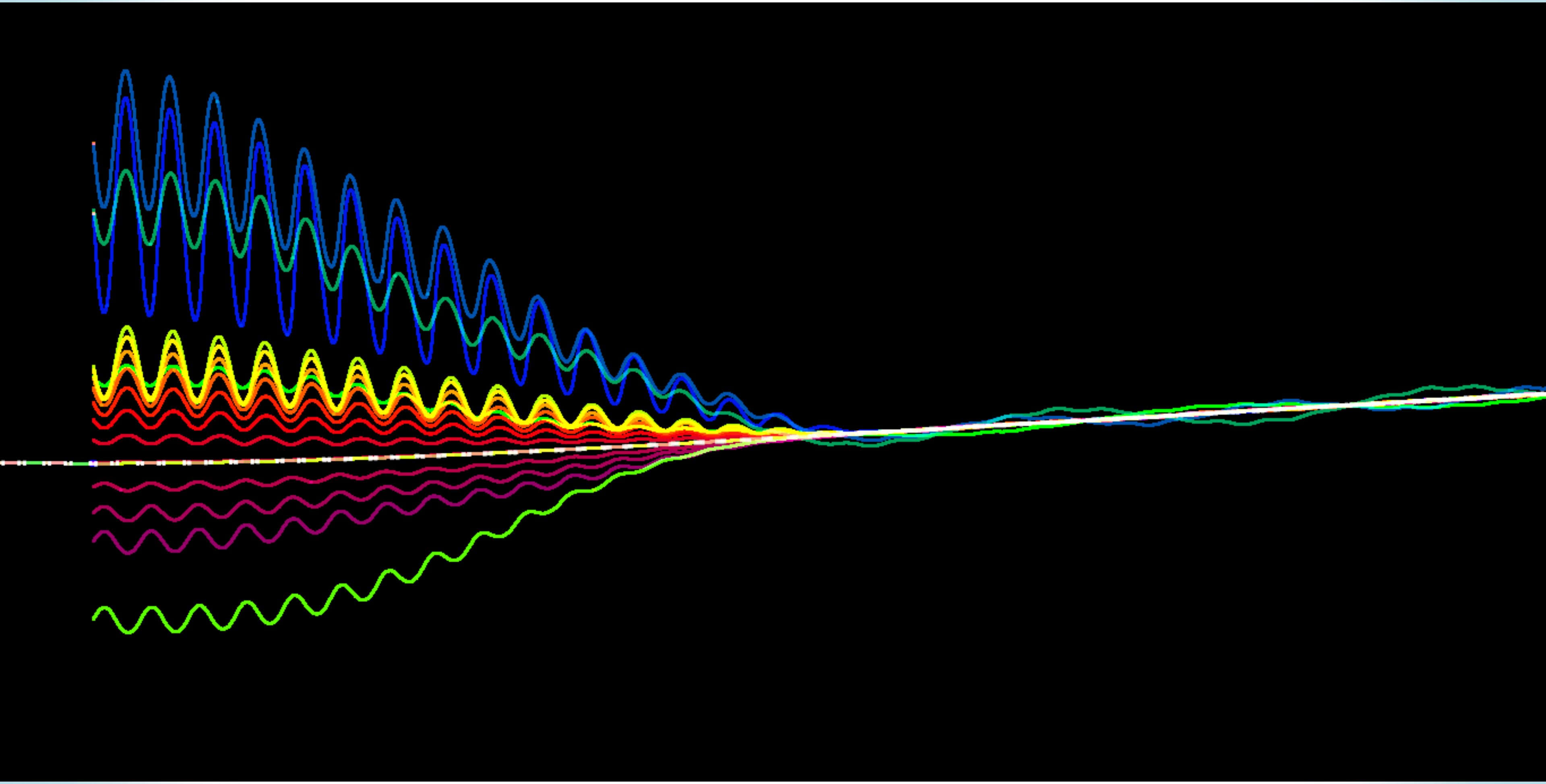


Something Smoother

- The cubic function $w(u) = 3u^2 - 2u^3$
  - $w(0)=0$, $w(1)=1$, $w'(0)=w'(1)=0$
  - Makes a nice ramp with w'' finite

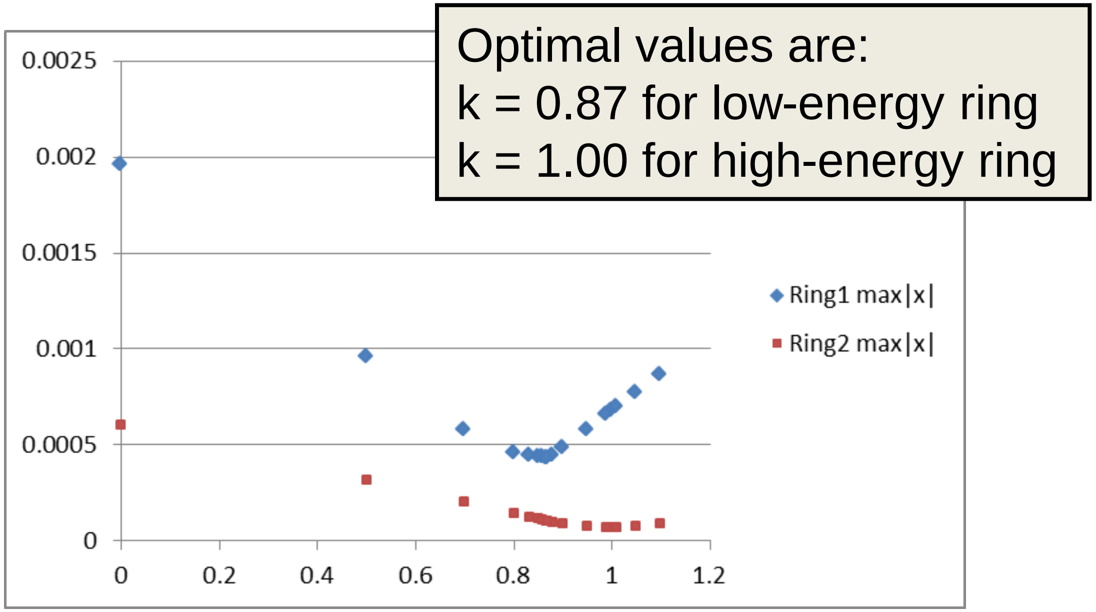


Cubic Ramp of Both Rings

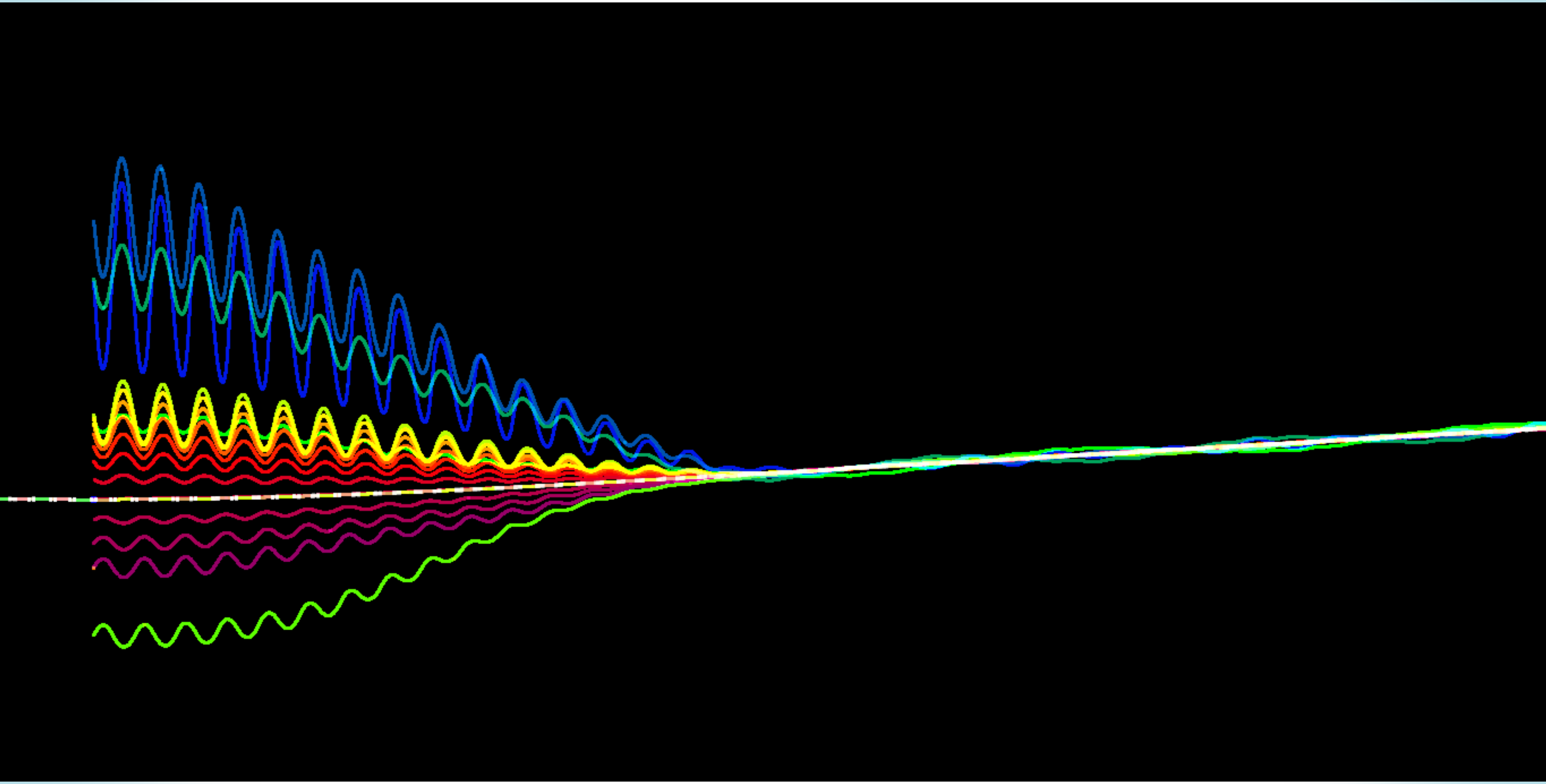


Method Used for MAC-10 Match

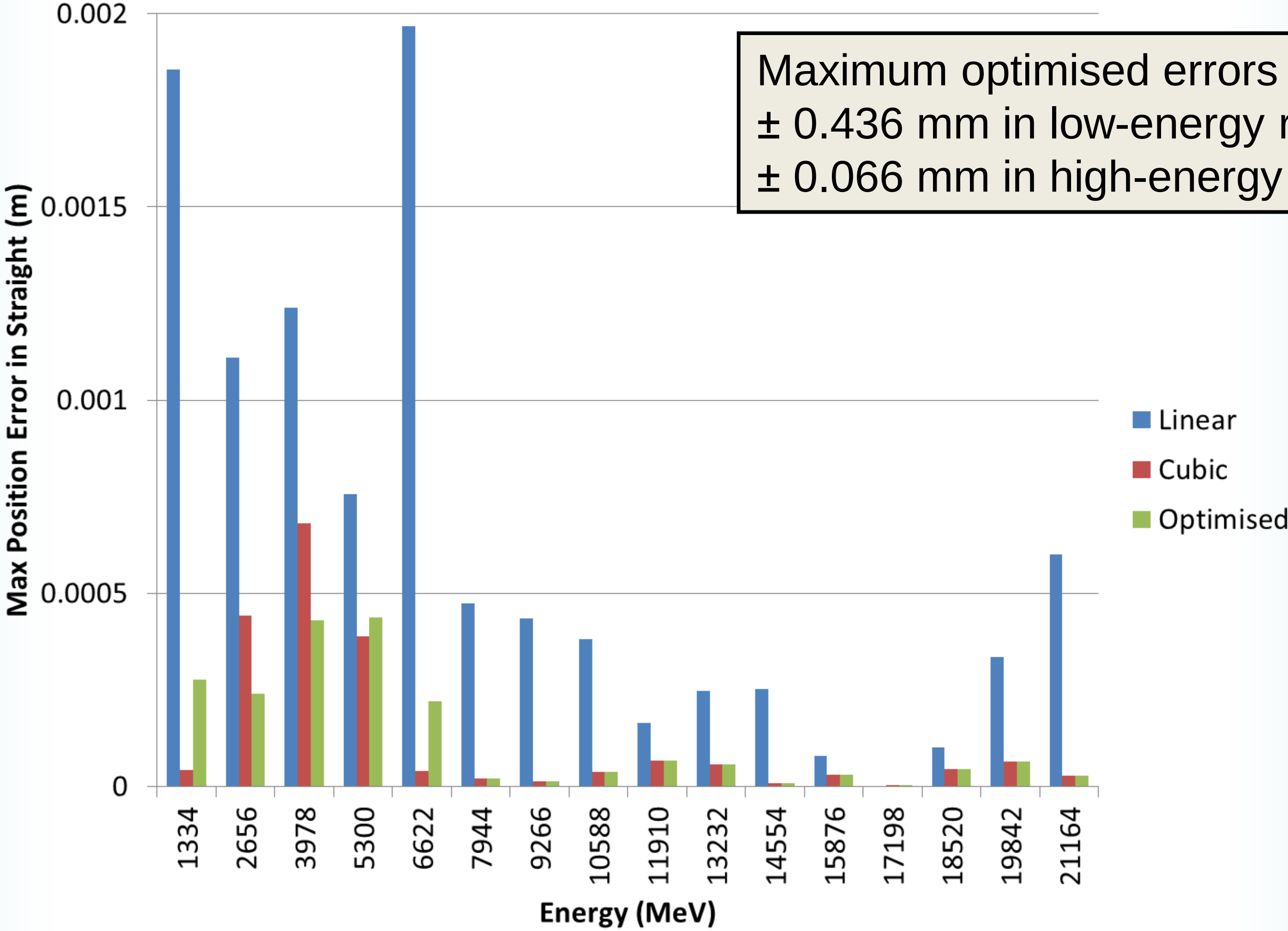
- Sometimes a linear combination is better than either of the above choices
  - $w(u) = (1 - k)\, u + k\, (3u^2 - 2u^3)$



Optimised Ramp of Both Rings

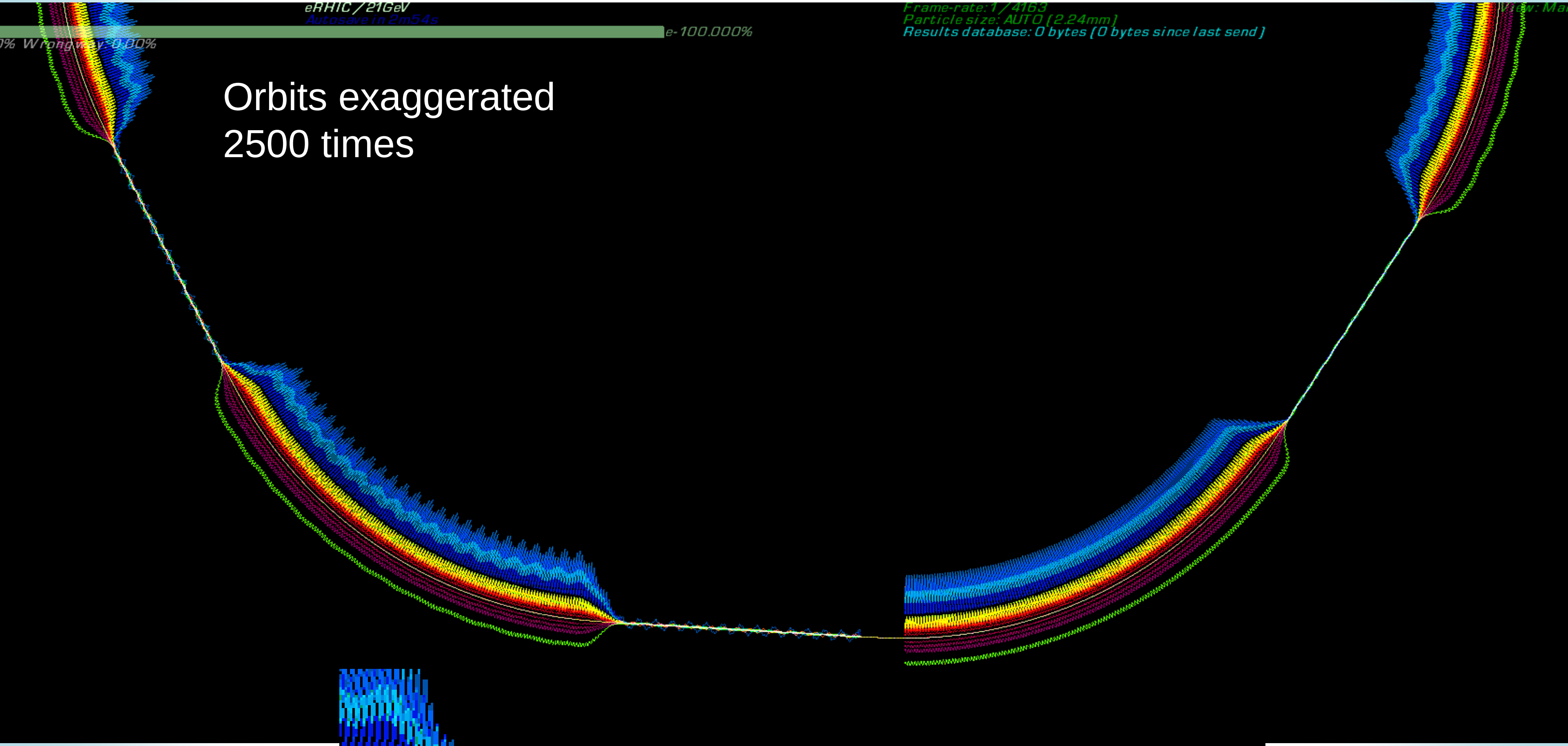


Position Errors in Straight

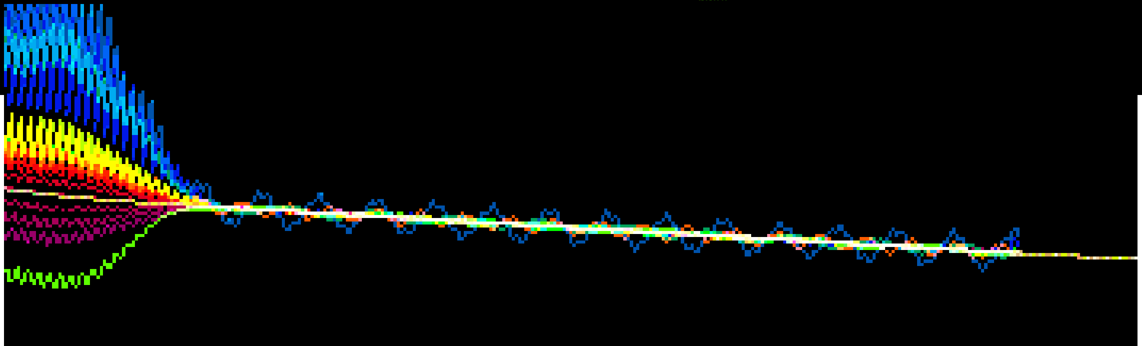


Maximum optimised errors are:
± 0.436 mm in low-energy ring
± 0.066 mm in high-energy ring

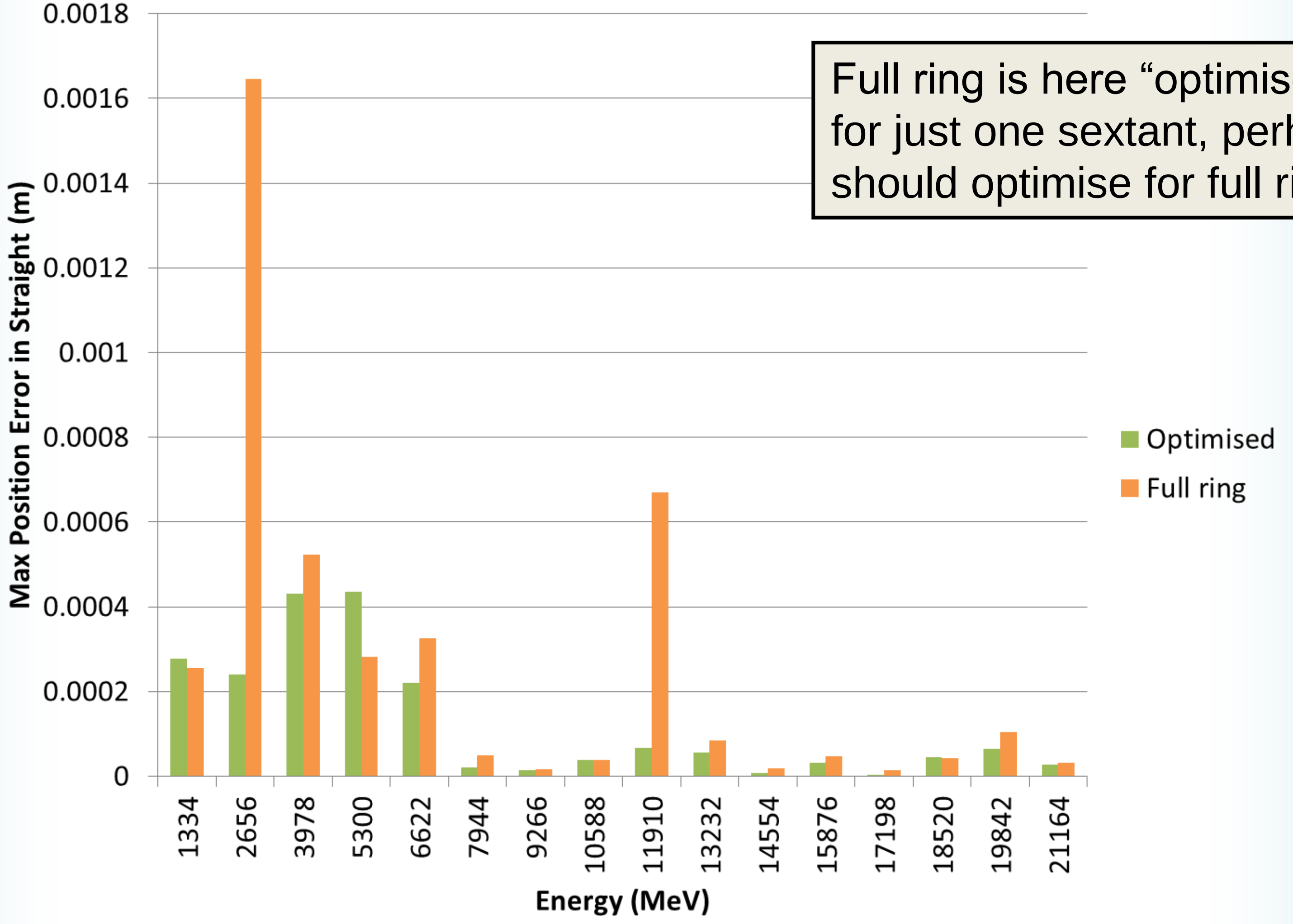
Full Ring



eRHIC / 21GeV
Autosave in 2m54s
Wrong way: 0.00%
e-100.000%
Frame-rate:1/4163
Particle size: AUTO (2.24mm)
Results database: 0 bytes (0 bytes since last send)
Orbits exaggerated
2500 times



Position Errors After Whole Turn



Full ring is here “optimised” for just one sextant, perhaps should optimise for full ring.

To-do List Update (stars = difficulty)

- Find vertical gap size required for synchrotron radiation ★★
  - Feeds into magnet LDRD parameters

> Have asked Oleg Tchoubar about this but he had vacation last week

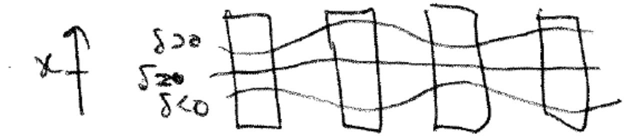
- ~~Arc-to-straight matching sections~~ ★★
  - Similar: detector bypasses
- Splitter/combiner at both ends of linac ★★★
- 10/15/21GeV septum ★★★★
  - With possible optical bumping etc.

The Tunnel: Working Assumptions?

- Will the proton ring in eRHIC be the blue ring, or an “inner” ring without the DX magnets?
  - This determines in-tunnel position of eRHIC rings
    - Which determines the splitter exit coordinates
- Nick Tsoupas suggests horizontally stacked FFAGs would be easier than vertically stacked
  - Path length increase ($2\pi\Delta r$) should then also be compensated in the splitter, if possible 
  - One cell would be *very* slightly longer for ‘stacking’

Scope of February Design Report

- Vadim will/already has clarified ☺
- Seems not too hazardous
  - Arcs + straights + matching + bypasses = 2 pages
  - Splitter in another section

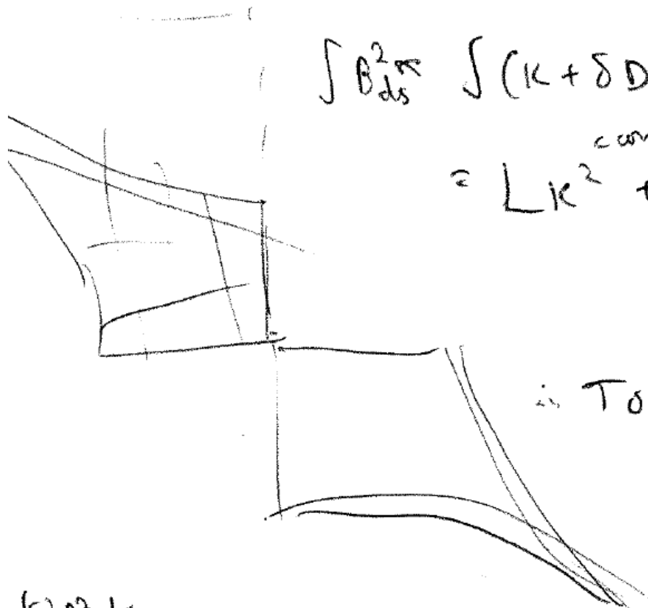


$$x = \tfrac{1}{2}\kappa s^2 + \delta D_x(s)$$

$$x'' = \kappa + \delta D_x''(s)$$

$$\therefore -x_D = \frac{2B_0}{G_F}\delta$$

$$B^2E^2 \propto x''^2(1+\delta)^2$$



$$\int B^2 ds \propto \int (\kappa + \delta D_x'')^2 ds$$

$$= L\kappa^2 + 2\kappa\delta \overbrace{\int D_x'' ds}^{=0 \text{ for periodic cell}}$$ (const.)

$$+ \delta^2 \int D_x''^2 ds$$

∴ To minimize $\int B^2 ds$,
minimize $\int D_x''^2 ds$
or rather $\langle D_x''^2 \rangle_s$

$\int E^2B^2 ds$

$$\Rightarrow (1+\delta)^2 \int B^2 ds \propto L\kappa^2(1+\delta)^2 + \underbrace{\delta^2(1+\delta)^2}_{\geq 0} \int D_x''^2 ds$$