Non-Scaling FFAG Lattices with Chromaticity Correction

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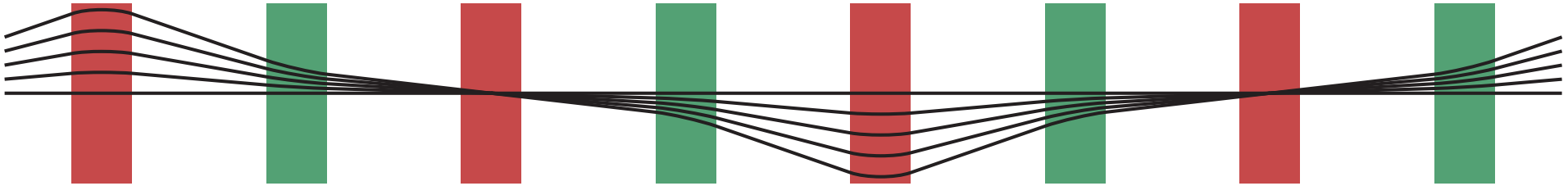
Why Correct Chromaticity?

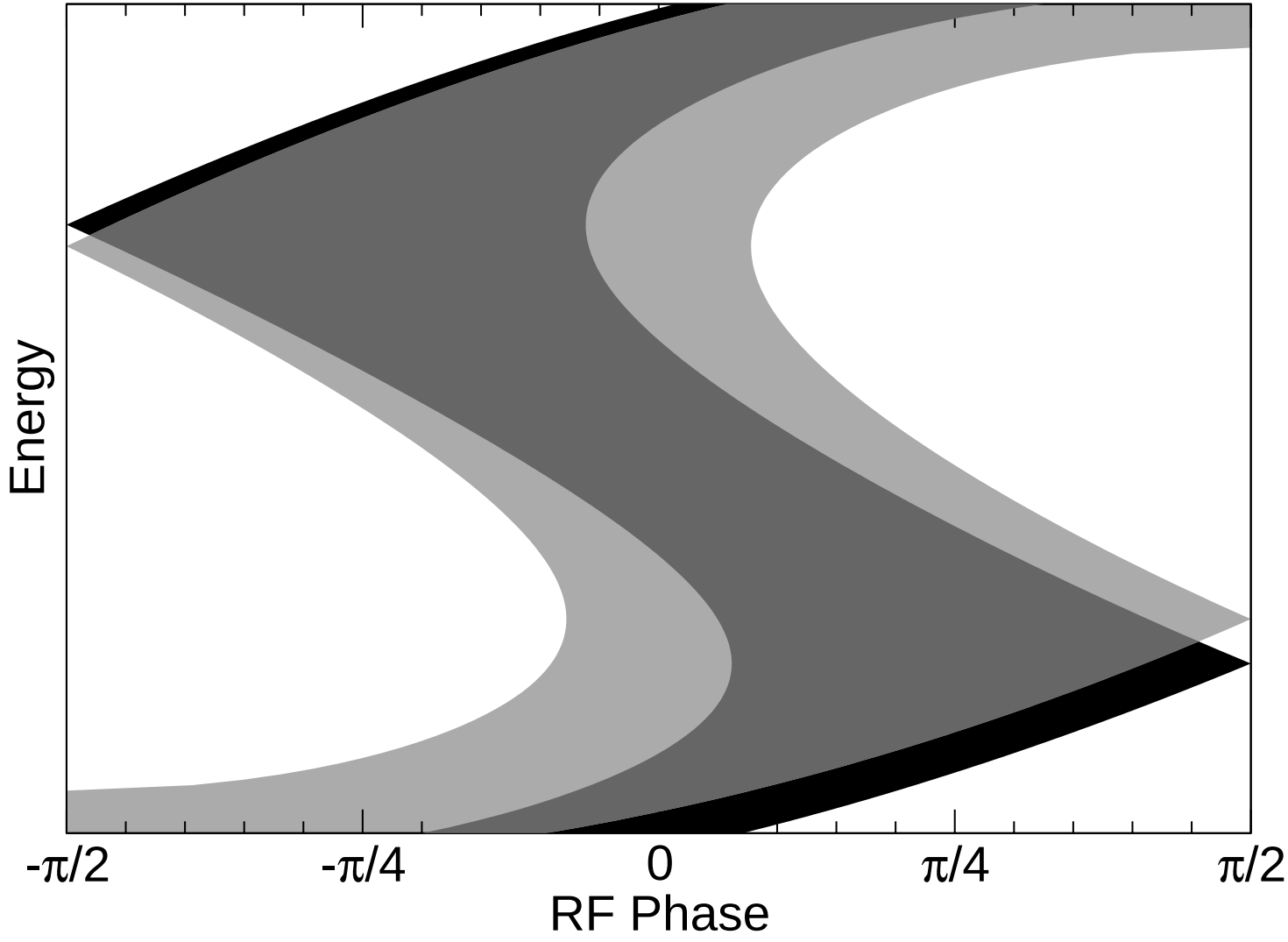
- Time of flight depends on transverse amplitude
- Reason: larger amplitudes, angles make longer path length



- Different times of flight for different amplitudes create acceleration problems in FFAGs
- Time of flight dependence on amplitude related to chromaticity

$$\frac{d\bar{t}}{ds} = -\partial_E H_T - \frac{2\pi(\partial_E \boldsymbol{\nu}) \cdot \boldsymbol{J}_n}{L} + O(\boldsymbol{J}_n^{3/2}).$$

Acceleration Channels in FFAGs



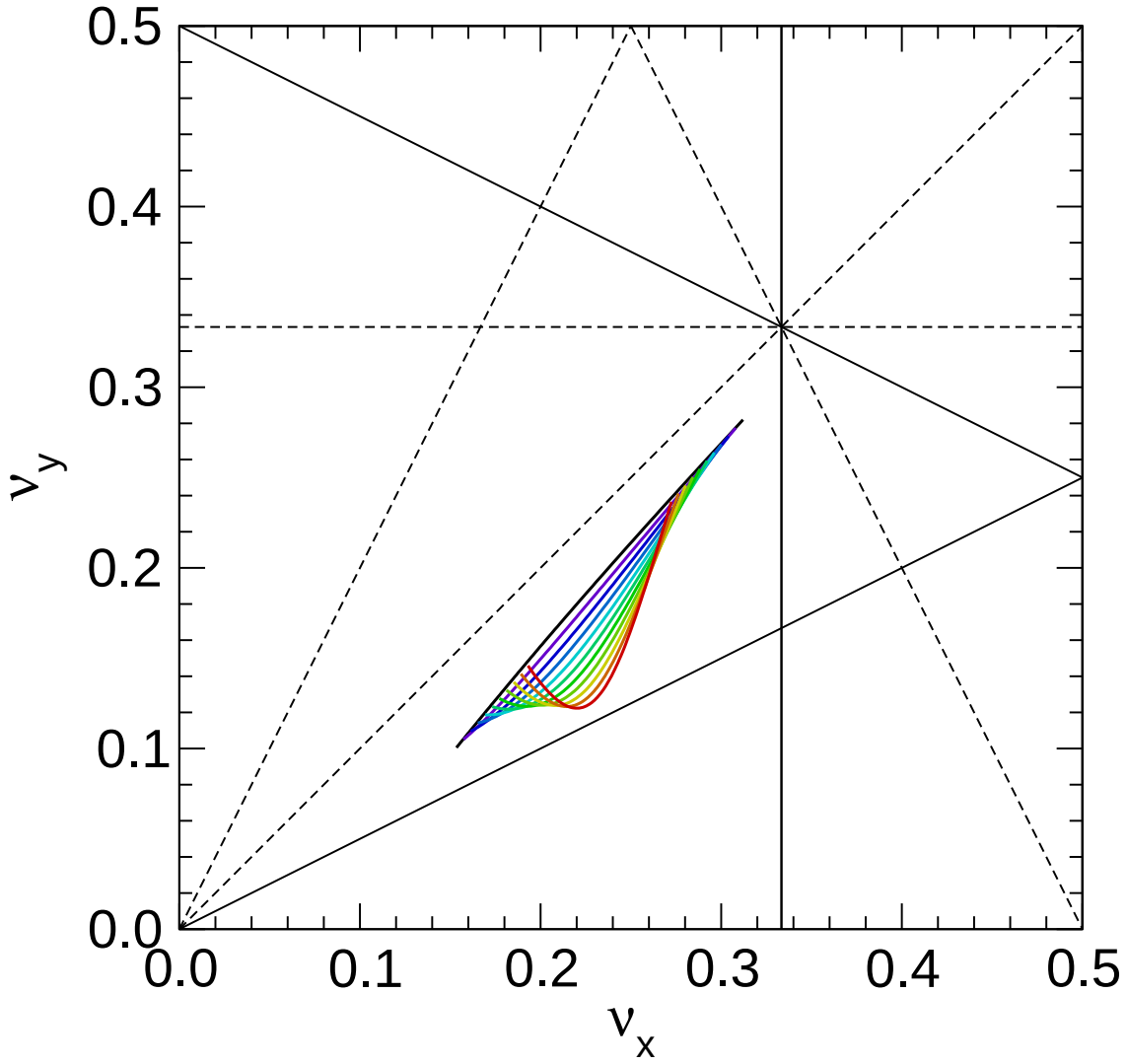
Chromaticity Correction Method

- Correct chromaticity with a sextupole component to magnets as follows
  - Construct a linear lattice where
    - ⋆ Magnet lengths, drift lengths, and the number of cells are fixed
    - ⋆ Time of flight is the same at low and high energy
    - ⋆ The following three distances in the tune plane are equal
      - ➢ Low energy tune ($\boldsymbol{\nu}_{\mathrm{lo},0}$) to $3\nu_x = 1$ line
      - ➢ Low energy tune to $\nu_x - \nu_y = 0$ line
      - ➢ High energy tune ($\boldsymbol{\nu}_{\mathrm{hi},0}$) to $\nu_x - 2\nu_y = 0$ line

Chromaticity Correction Method

- Chromaticity correction procedure (cont.)
  - Add sextupole components, and modify dipole and gradient components so that
    - Magnet lengths, drift lengths, and the number of cells are fixed
    - Time of flight is the same at low and high energy
    - If x is the fraction of chromatic correction
      - $\boldsymbol{\nu}_{\mathrm{lo}} = (1 - x/2)\boldsymbol{\nu}_{\mathrm{lo},0} + (x/2)\boldsymbol{\nu}_{\mathrm{hi},0}$
      - $\boldsymbol{\nu}_{\mathrm{hi}} = (x/2)\boldsymbol{\nu}_{\mathrm{lo},0} + (1 - x/2)\boldsymbol{\nu}_{\mathrm{hi},0}$
- Choice of tune range to avoid third order resonances which sextupole will drive
- Plot shows to $x = 0.5$

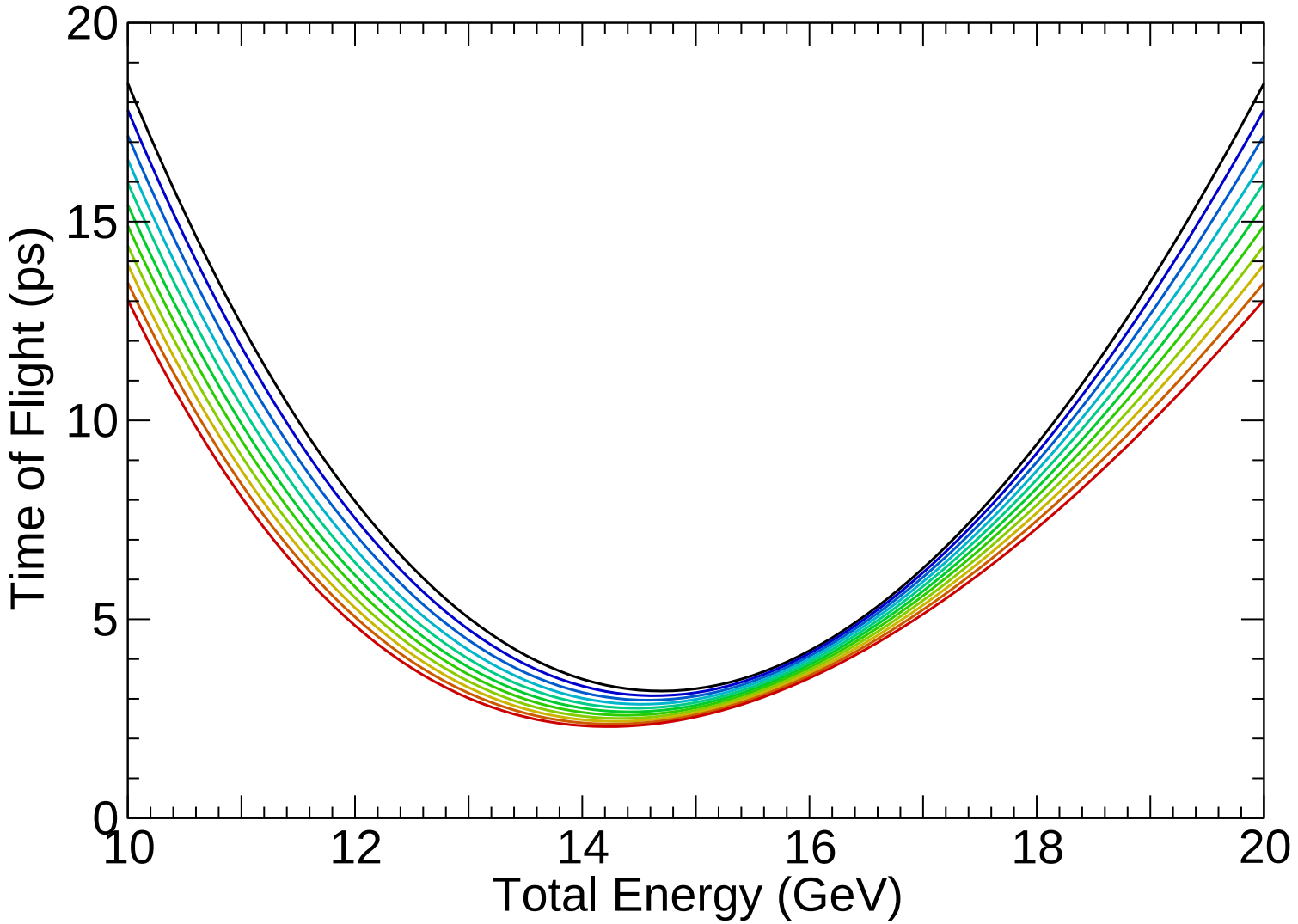
Tune Range with Chromaticity Correction



Observations

- Note chromaticity is locally higher!
- However, for uniform acceleration, what matters is the total change in tune
  - However, increased chromaticity may affect phase space locally!
- Time of flight range actually improves with more sextupole
- Must determine if dynamic aperture is sufficient
  - Losses likely on $4\nu_x = 1$ resonance
  - Should ascertain if we have decent dynamic aperture except for that
- Full chromaticity correction (to $x = 1$)
  - Still have significant actual chromaticity
  - Could add octupole to reduce the range, if there is any dynamic aperture in the first place

Time of Flight Variation with Chromaticity Correction



Tune Range with Full Chromaticity Correction