FFAG Acceleration

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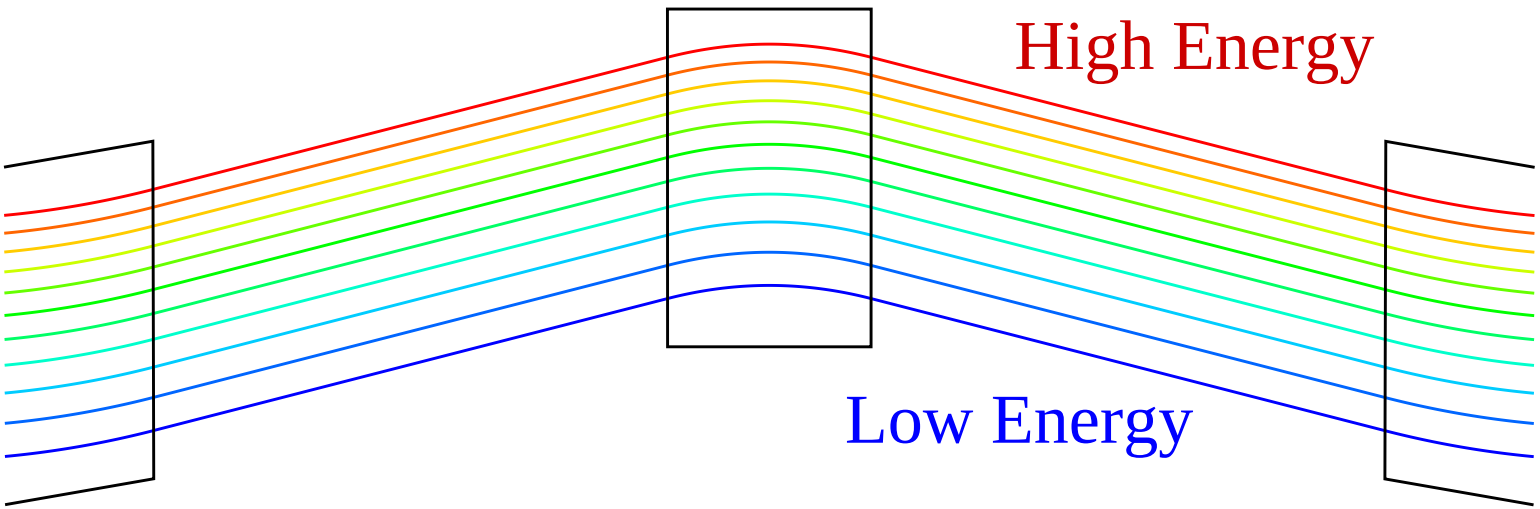
FFAG Basics

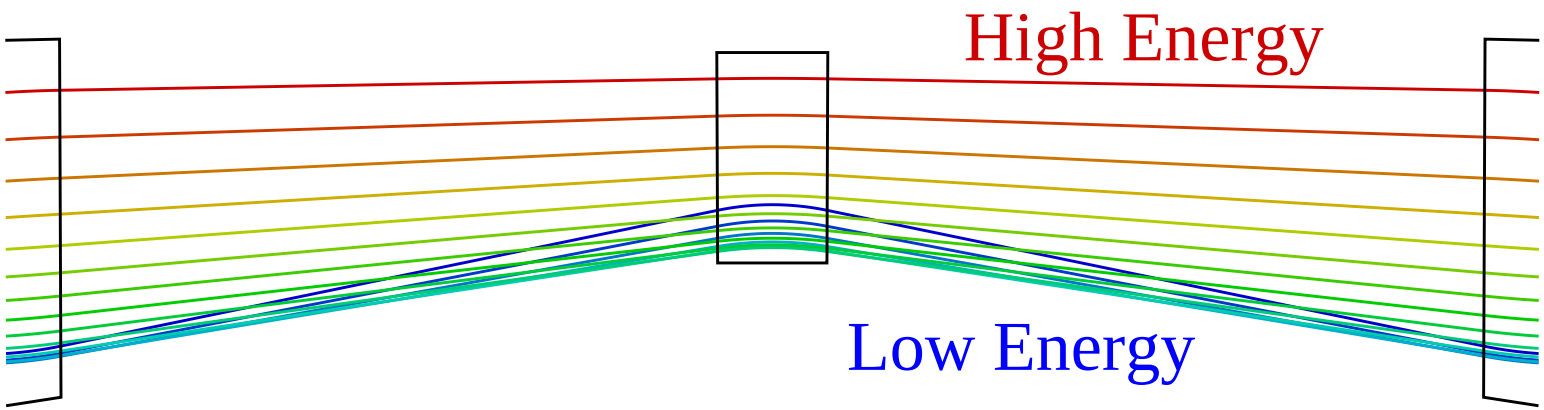
- Recirculating accelerator: pass through same RF cavities many times
- Pass through same arc on every pass
- Magnet fields don't vary with time
- Avoid single-cell linear resonances
- Deal with time-of-flight dependence on energy: RF synchronization
  - Leads to a minimum required voltage
  - Depends on lattice design
    - Minimum voltage decreases with decreasaing cell length
    - Minimum voltage decreases with increasing number of arc cells
    - Different lattice types give different performance

Scaling FFAGs



- What people traditionally think of as an FFAG
  - Tunes, momentum compaction constant
  - Orbits at all energies geometrically similar
- Magnets are highly nonlinear
  - Decreasing orbit swing (aperture required) increases nonlinerities
- Much work being done at KEK

Non-scaling FFAGs



- FODO-based lattices
  - Advantages over scaling FFAGs
    - ⋆ Very linear, large dynamic aperture
    - ⋆ Lower RF voltage requirement
    - ⋆ Aperture in defocusing quadrupole lower
- Other types exist also

Types of Non-Scaling Lattices

- FODO lattice
  - First non-scaling design—Carol Johnstone
  - Combined-function magnets
  - These are very well understood now
    - Keep low-energy tune well below 0.5
    - Time-of-flight varies parabolically with energy
      - Set minimum at central energy to minimize path length variation
- Minimum-emittance lattice (Dejan Trbojevic)
  - Keep dispersion low at bend
  - Very compact lattice with small path length variation
  - Original had poor dynamic aperture; recent modifications have improved substantially
  - Now looks more like a triplet lattice–Carol suggested this at FFAG workshop!

Space for RF

- Need to leave drift space for RF
- Path length improves with smaller drift for RF
- Superconducting RF: extra space must be left for field from magnets to drop down
  - Working on finding out how far that is
  - Could cool RF first, then power magnets
- Warm RF currently gives lower cost
  - Shorter drifts give lower path length variation, allowing fewer cells
  - Increased cost per GeV, but fewer GeV

General Observations

- We are no longer path length limited in our designs
  - Tolerable decay
  - Beam loading
- Some designs are becoming very compact and cost-effective
  - We need to start doing more detailed work on a couple of lattices
  - Often start looking more expensive when we look at real magnets
- Need to start looking at performance details of sample lattices
  - Dynamic aperture, end fields, etc.