Acceleration Systems

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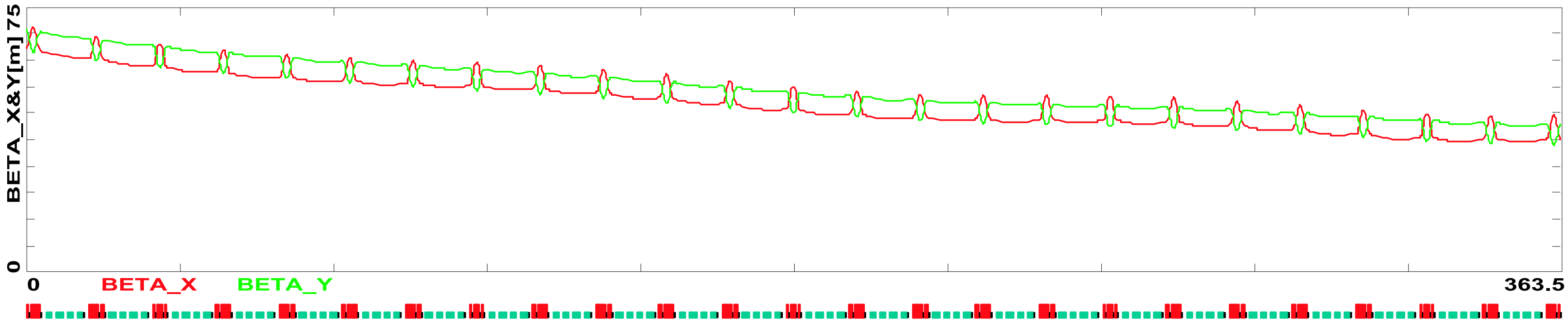
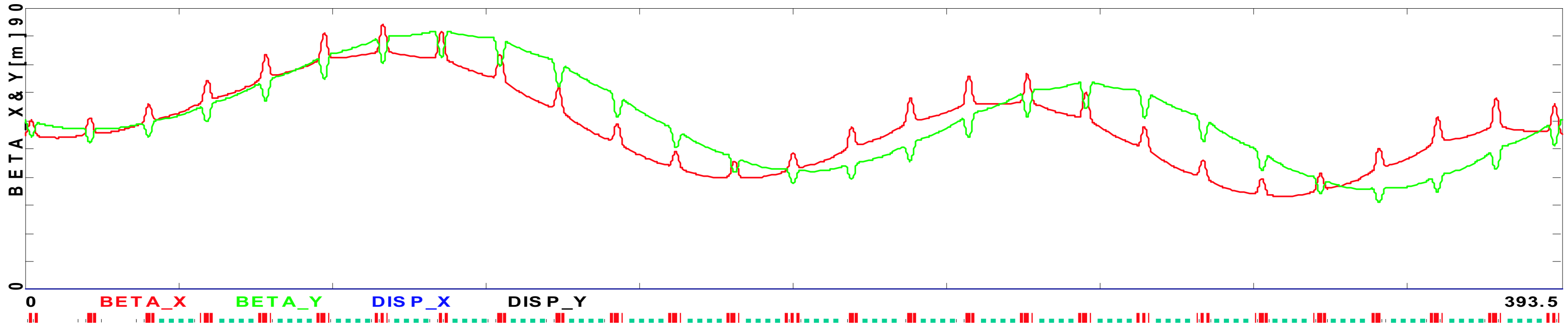
Multiple-arc Recirculator Improvements from Study II (Bogacz)

- Emittance blowup now negligible (formerly 100%!)
- Linac optics improved
  - Use beta-beat to keep beta low at entrance to linac
  - Transitions from arc to linac less severe
- Three families of sextupoles in arcs
  - Groups of 4 instead of 2, improving nonlinearity cancellation

Multiple-arc Recirculator Final-Pass Linac Beta Functions



Original



New

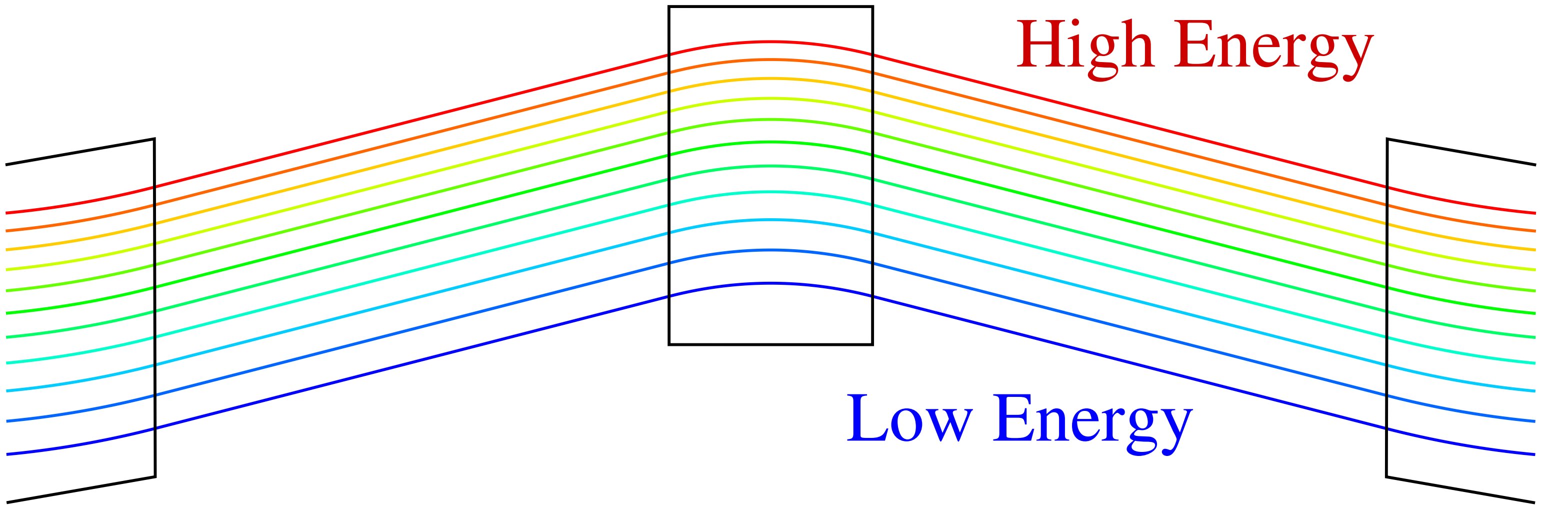
FFAGs

- Single arc transmits wide energy range: factor of 2 or more
  - Don’t pay for a new arc for each pass
  - Avoid switchyards, easily go to many passes
  - Need more stages than multiple arc: smaller energy range per stage
- Much progress has been made in FFAG understanding and design
  - Recent two week workshop at LBL
  - Continuing monthly video conferences
  - We now have a greater understanding of how to optimize FFAG designs

FFAGs: RF Voltage Requirements

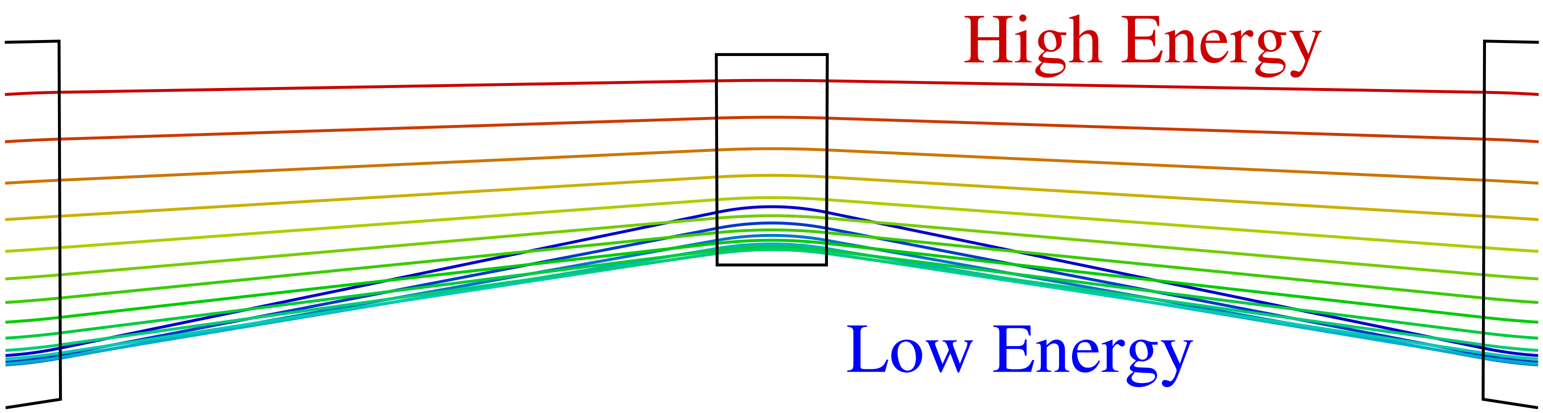
- There is a minimum RF voltage requirement for a given energy range
  - Lower voltage translates to more turns
  - Shortening cells reduces required RF voltage
  - Reducing energy range reduces RF voltage faster than linearly
  - Voltage required proportional to RF frequency
  - Increasing number of cells per ring reduces required RF voltage
    - Arc costs increase with increasing number of cells
    - There is a cost optimum number of cells
- Different types of lattices give different RF voltage requirements
  - Would like to find the optimal type of lattice

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 lattices being studied
  - May have even lower RF voltage requirement

FFAGs: RF Cavities

- Superconducting cavities, compared to room temperature
  - Low power requirements, lower cost (for given voltage)
  - Must leave space between cavity and magnet for field to drop down

- ⋆ Field must be down to around 0.1 Gauss
- ⋆ Cell lengths must be longer: more RF voltage
- ⋆ Required magnet-cavity space must be studied
  - ➢ Initial estimates were 1 m, giving 3 m drift w/ cavity
  - ➢ Some calculations give as low as 0.5 m
- ⋆ Potentially field could be as high as 0.1 T
  - ➢ Cool cavities first, then power magnets
  - ➢ Nb on Cu cavities won't quench, no concern of long downtimes

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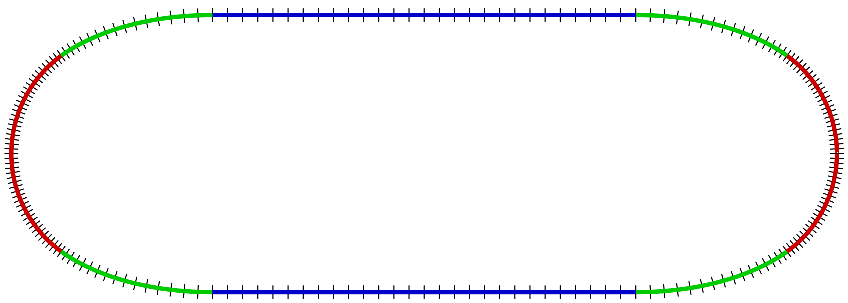
FFAGs: Racetrack

Muon Collaboration

- Distributed RF
  - Each cell (or every couple cells) has an RF cavity
  - Highly adiabatic system



- Consider racetrack shape instead:
  - Lower RF voltage requirement
    - Arcs have short cells, since no space needed for RF
    - Straights have longer drifts for RF, but don’t add to voltage requirement
  - Transition sections
    - Must match dispersion, beta over large energy range
    - Long transitions have been designed (Keil, Sessler), and work
    - Working on making shorter ones

FFAGs: Examination of Designs

- Many appear to be less costly than multiple-arc racetrack
- Reducing drift length in FODO gives significant cost savings
  - Achieve savings even if required to go from superconducting RF to room-temperature
  - Less RF voltage required
  - Magnet apertures go down
- Switching to a racetrack design improves things even more
- Reducing the energy range (e.g., to 10–20 GeV from 6–20 GeV) gives significant improvement
  - Cost per GeV decreases
  - Going from 2 stages to 3 stages will probably save money

Conclusions

- We have brought emittance dilution in multiple-arc recirculating accelerators under control
- We have developed signifiant understanding in FFAG design
- We have begun to look at and optimize various FFAG designs
- FFAGs appear to be a promising way to reduce acceleration costs

Future Work

- Study possibility of going to more turns in multiple-arc racetrack
  - Potentially more cost-optimal
- See how far we can push scaling FFAG designs
- Develop cost-optimized FFAG designs
  - Determine costing algorithms for magnets, RF
- Determine minimum magnet-cavity spacing requirements for SCRF
- Continue study of matching in racetrack FFAG
- Explore other FFAG lattices more thoroughly
- Study injection/extraction (break symmetry)
- Study longitudinal dynamics in FFAGs
- Work on validating/developing codes which handle these large energy spreads well