Error study of non-scaling FFAG
10 to 20 GeV muon ring

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Definition of errors

• Alignment error
  – Horizontal and vertical directions. No longitudinal or tilt.
  – Assume each QD and QF are on a single support table. QD and QF are aligned (or misaligned) together.
  – Alignment errors produce additional dipole kicks.

• Gradient error
  – Random errors of quadrupole strength.
  – Gradient errors produce additional quadrupole kicks.

• Distribution of both errors is Gaussian and there is a cut at 2 sigma.
• Use 40 seeds to see statistics.
Tracking conditions

• Constant energy gain (independent of RF phase) per turn is assumed to avoid time of flight variation due to transverse amplitude.
• 10 to 20 GeV acceleration is finished in 17 turns.
• 30 pi mm emittance in horizontal and vertical (ellipsoidal in 4-D).
• Distribution of 500 macro particles is Waterbag.
• Nominal initial dp/p and phase spread are assumed.
Initial matching

- Assume the distortion of beta functions are small. Particle distribution is matched unperturbed lattice function.
- To make sure the above assumption is reasonable, choose the initial tune away from half-integer resonance.
- Initial momentum is 9.965 [GeV/c] in the present study.
Note on initial matching

- Results presented at EPAC06 assumed initial momentum at either 9.9 or 10 [GeV/c].
- Tunes of both momentum is very close to an integer and initial matching was bad.
- With proper matching (present study), effects of errors are reduced.

Result presented at EPAC06 when only alignment error exists. Those are improved with proper matching.
Loss criterion

• At every cell, calculate amplitude (single particle emittance) of each macro particle.
• If the amplitude is more than 45 pi mm (1.5 times of the initial emittance), the particle is regarded as lost.
• The “phase space collimation” concept was introduced by Meot.
Tracking results (1)
only alignment error

- No beam loss at 20 μm (rms) or below.
- 50 μm (rms) may be tolerable.
Tracking results (2)
only gradient error

- No beam loss at $dG/G = 2 \times 10^{-4}$ (rms) or below.
- $dG/G = 5 \times 10^{-4}$ (rms) may be tolerable.
Tracking results (3)
gradient error with some alignment error

- Two kinds of errors seem to be added, not multiplied.
Summary

• In 10 to 20 GeV/c muon ring,
  – Alignment error should be 20 to 50 μm (rms).
  – Gradient error should be $dG/G = 2 \times 10^{-4}$ (rms).

• Requirement of gradient error may be a bit hard.