The EMMA Lattice

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Linear Non-Scaling FFAGs Motivation from Muon Machines

- Maximize passes through RF
- RLAs limited by switchyard
- Scaling FFAG problems
  - Large apertures and superconducting magnets
  - Forced to low RF frequency

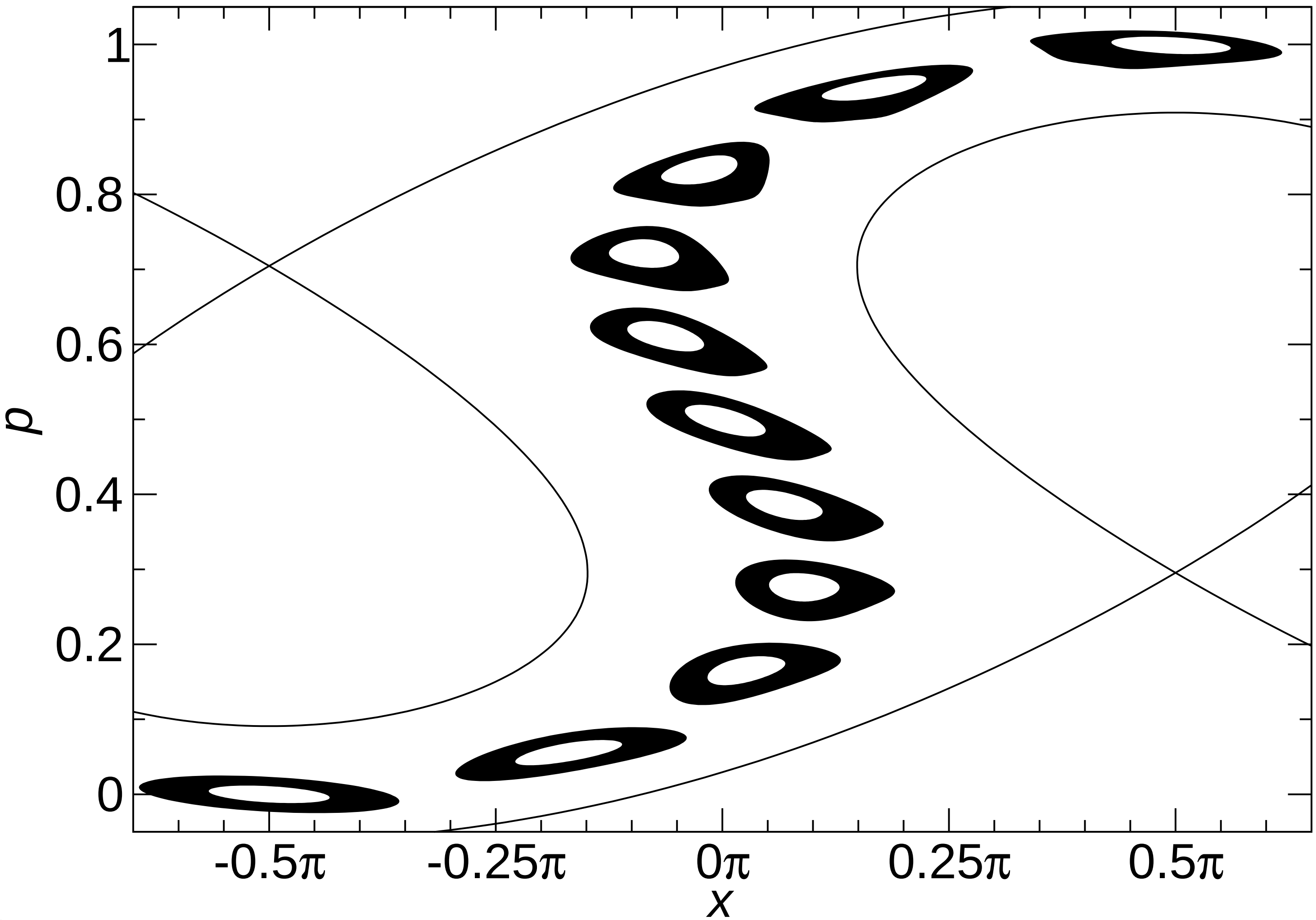
Linear Non-Scaling FFAGs Design Principles

- Avoid resonances by
  - Symmetry: all cells identical
  - Linear magnets: nonlinear resonances weak
- Accelerate rapidly: minimize resonance effects
  - Magnet errors
  - Nonlinearities from kinetic, ends
- Keep horizontal aperture small
  - Muon: minimize time of flight variation

EMMA Goals

- Study Linear Non-Scaling FFAGs with
  - Rapid acceleration
  - Relativistic energies
  - High frequency RF
  - Muon acceleration
- Important characteristics
  - Rapid acceleration thru many resonances
  - Serpentine acceleration

Serpentine Acceleration



Test Understanding of FFAG Beam Dynamics

- Emittance growth vs. which resonances crossed
- Longitudinal dynamics vs. machine parameters
- Coupling of transverse and longitudinal
- Effect of errors

Perforance Parameters

- Cell turns ($>$ 500)
- Maximum magnetic fields ($\sim$ 0.2 T)
- “Reasonable” magnet length-to-width ratio
- Normalized transverse acceptance: 3 mm
- Cost and available space

Basic Machine Parameters

- 10–20 MeV Kinetic Energy
- Combined-function doublet cells
    - Displaced quadrupoles
- 42 cells
- RF frequency 1.3 GHz

Lattice Dimensions

- Magnet and cavity axes parallel
- Horizontally displaced centers

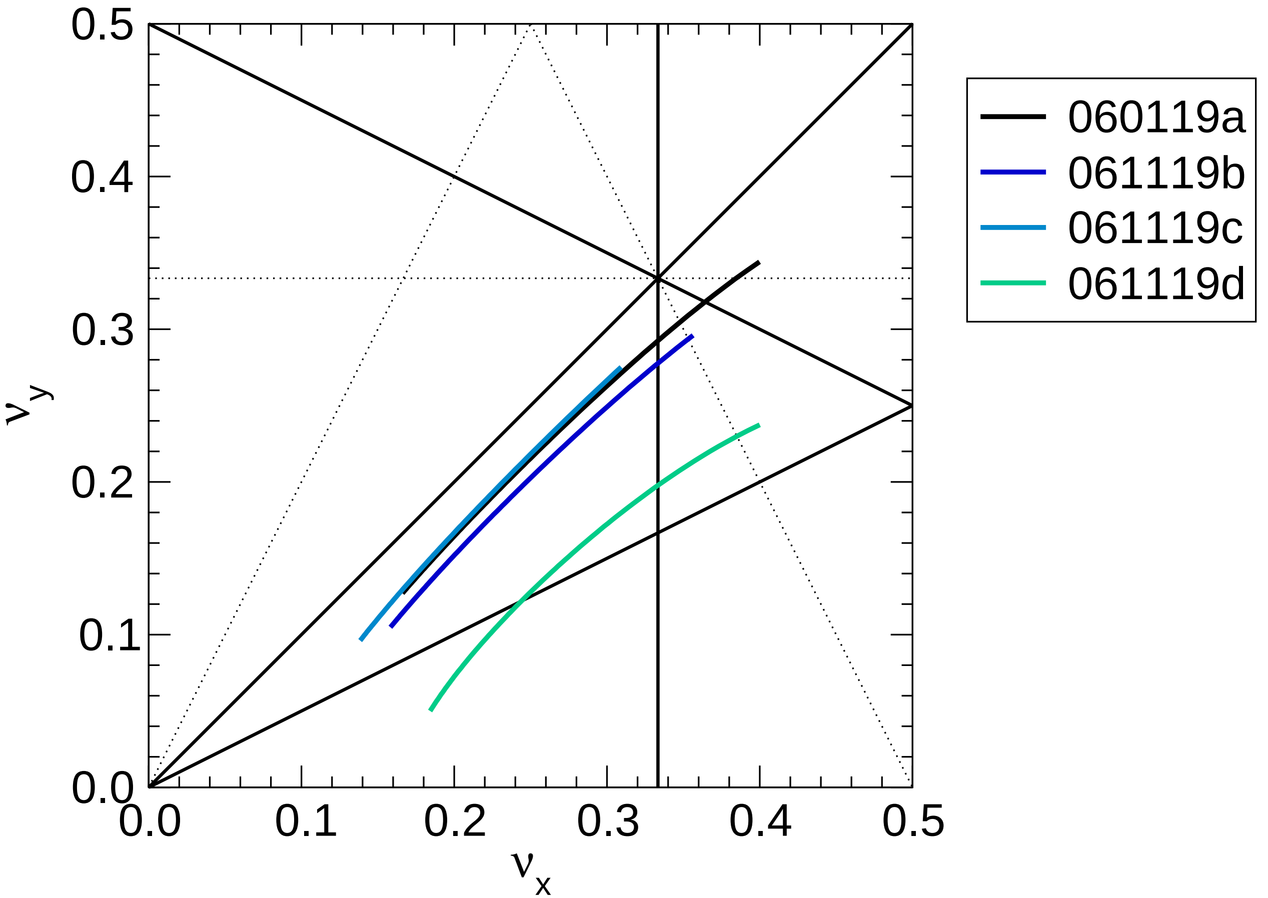
Long drift	210.000 mm
Short drift	50.000 mm
D length	75.699 mm
F length	58.782 mm
Circumference	$\sim$ 16.6 m

Vary Machine Parameters

- Accomplish goals
  - Pass through different resonances
  - Vary longitudinal parameters
- Allowed lattice changes
  - Horizontally displace magnets
  - Magnet gradients
  - RF frequency
  - RF voltage

Lattice Variations
Tune Range

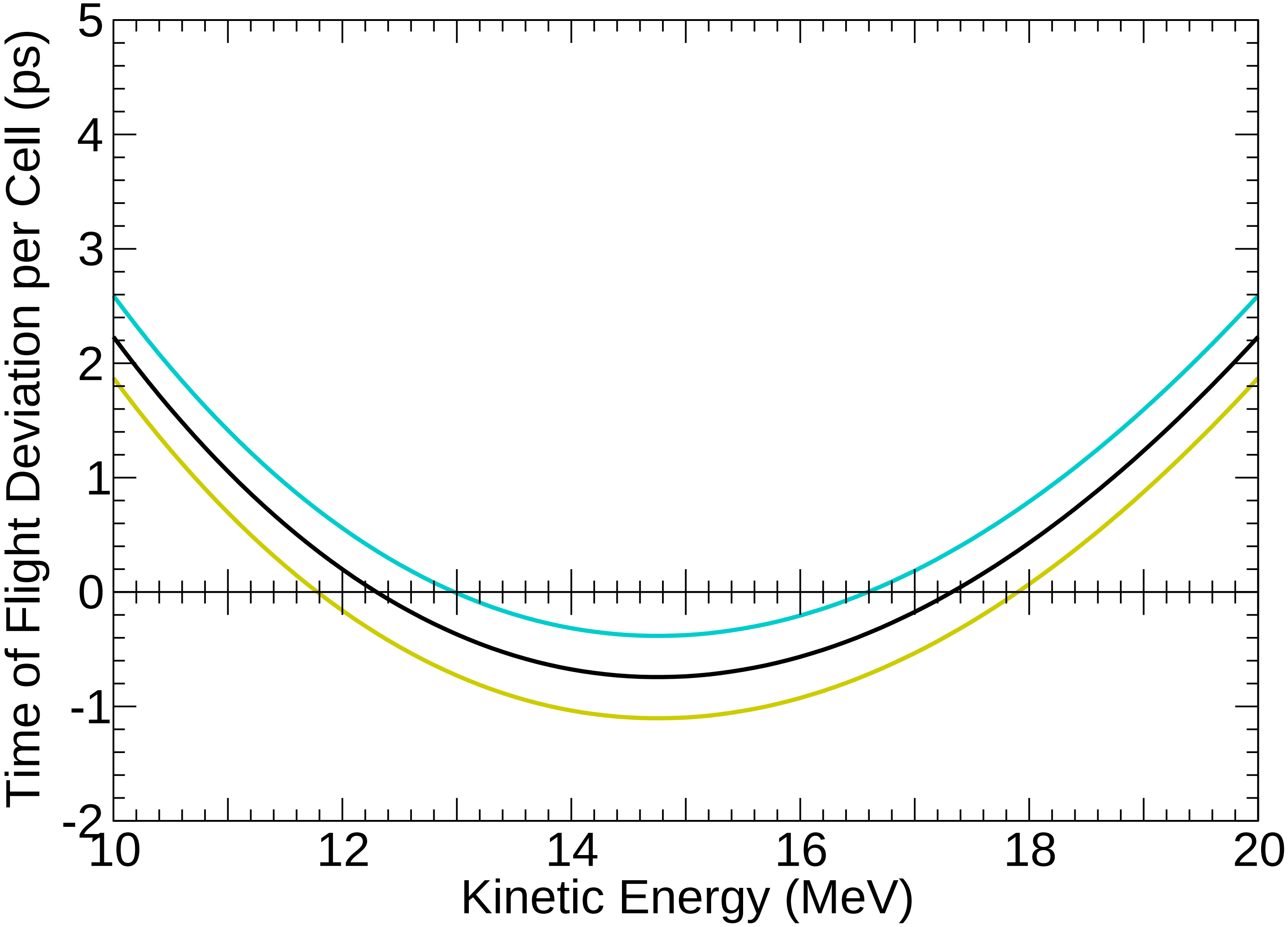
- Vary resonances crossed during acceleration
- Consider upright sextupole driven



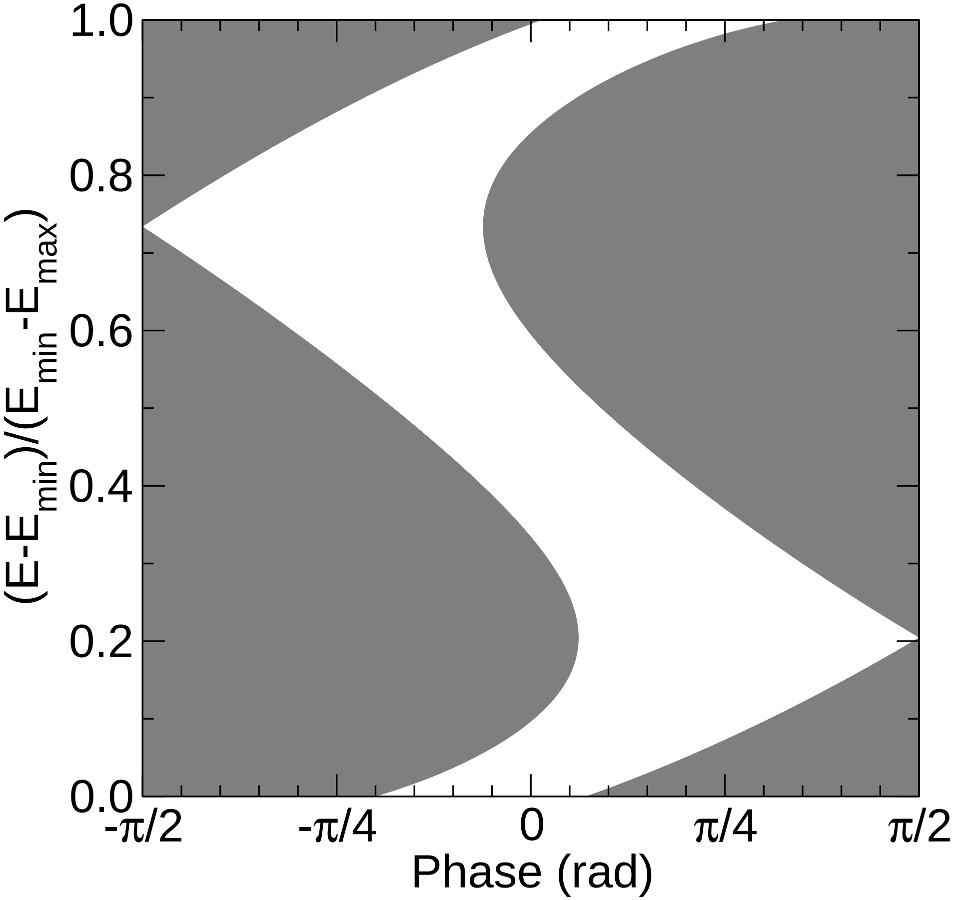
Lattice Variations
Synchronized Energy

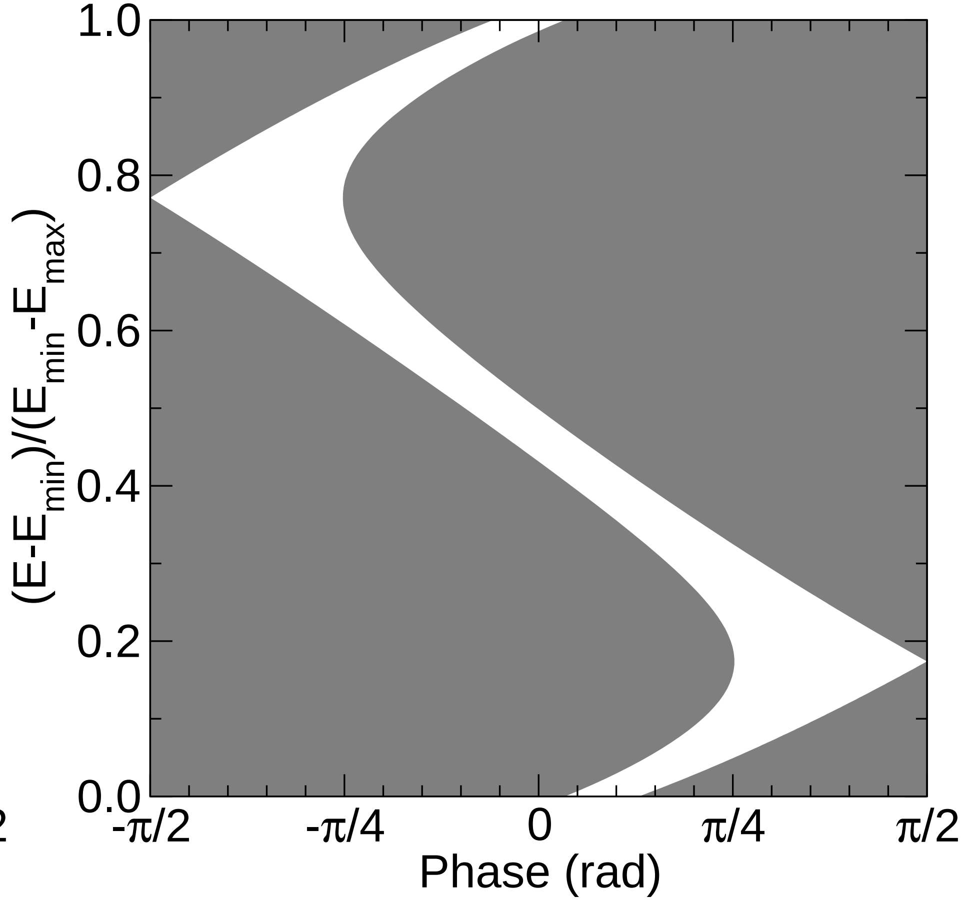
- Purposes
  - Vary longitudinal phase space
  - Fixed energy runs
    - Commissioning
    - Map tunes, time of flight
  - Study individual resonances
- Method: change RF frequency

Lattice Variations
Synchronized Energy



Lattice Variations
Synchronized Energy: Phase Space





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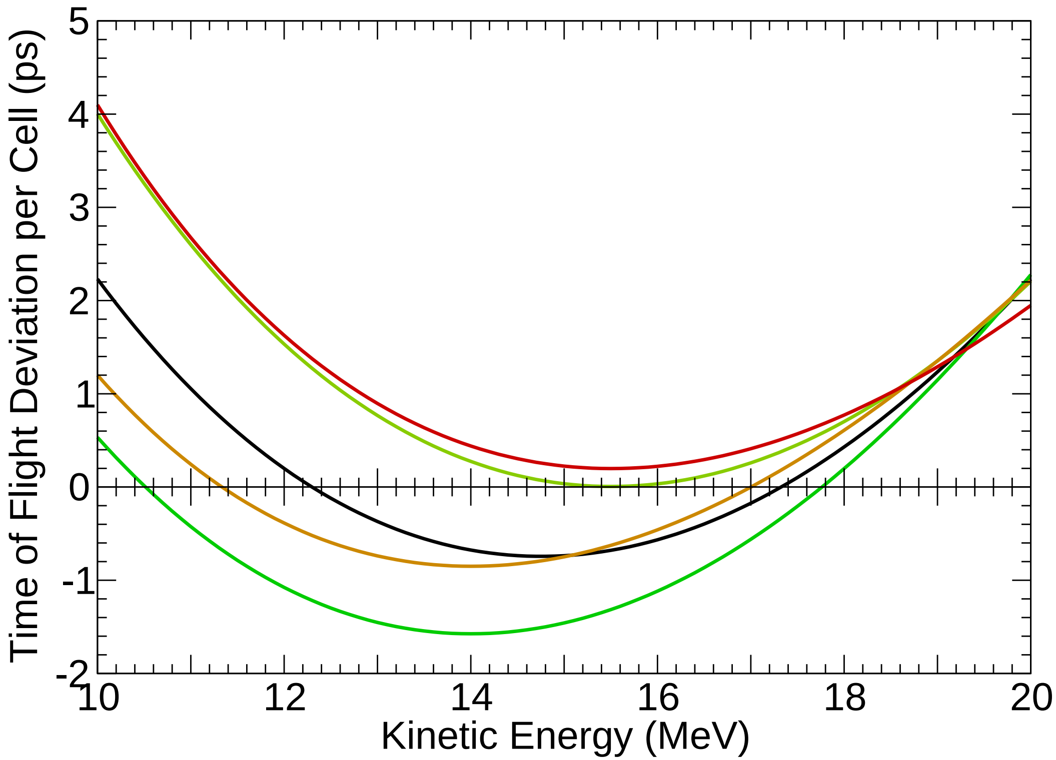
Lattice Variations
Energy for Minimum Time

- Base lattices: same time at high and low energy
  - This is not optimum
- Vary energy of minimum
  - 14–15.5 MeV
  - High horizontal tune only
- Study longitudinal phase space



Lattice Variations
RF Voltage

- Larger voltage increases longitudinal acceptance
- Characterized by dimensionless parameter a
  - a proportional to voltage
  - $a = 1/12$ is baseline
  - Increase to $a = 1/6$
  - Phase space change above $a = 1/6$

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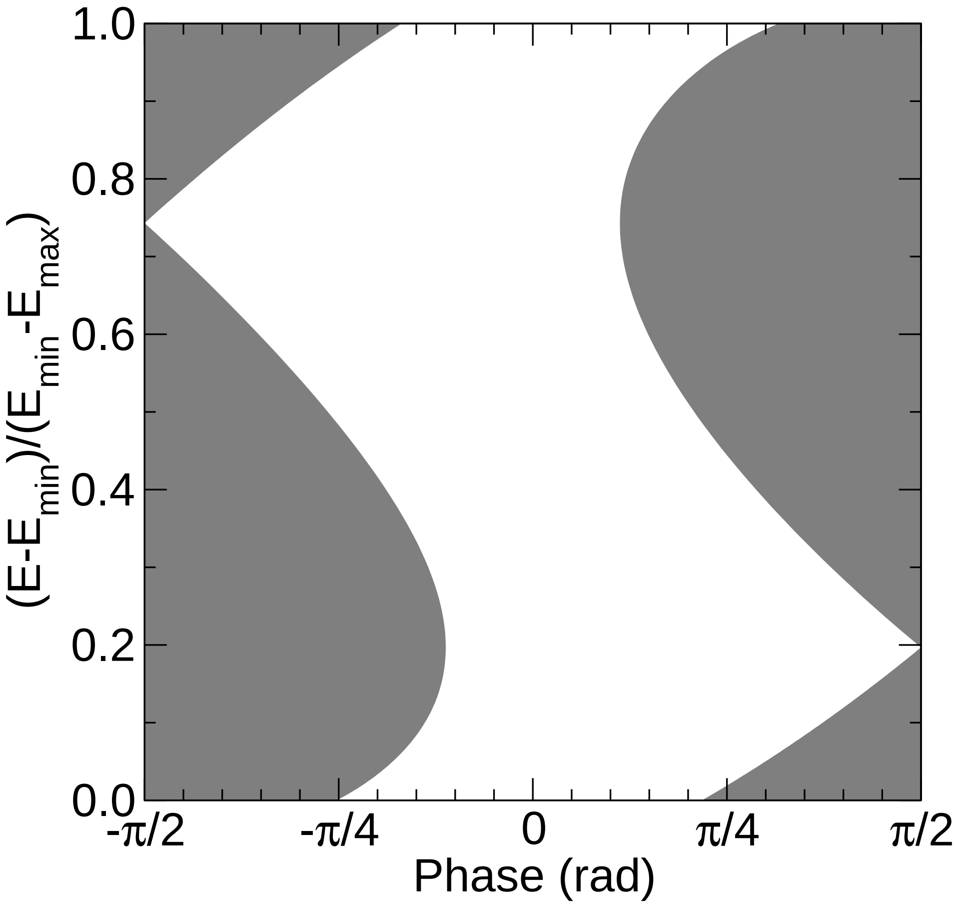
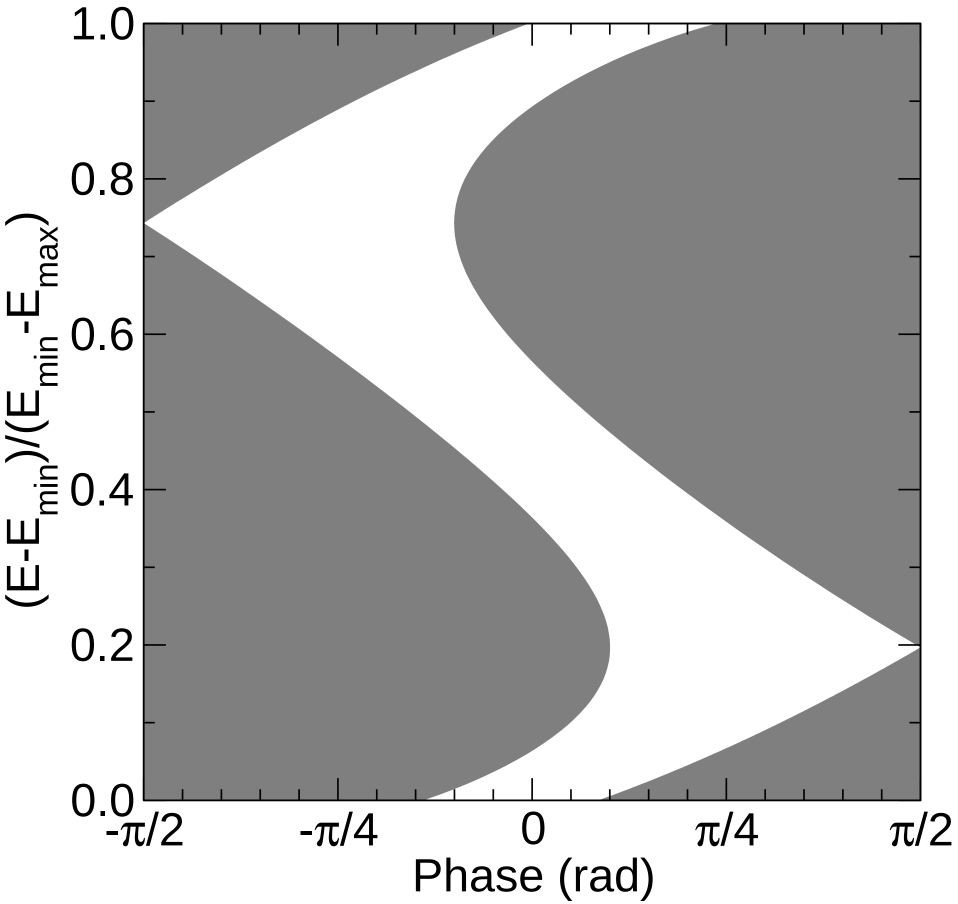
Lattice Variations
RF Voltage: Phase Space





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Magnet Parameters

- Parameters to satisfy all configurations

	D	F
Chamber width (mm)	26	42
Displacement range (mm)	20	5
Max quad horiz (mm)	56	32
Quad length (mm)	76	59
Max gradient (T/m)	4.8	6.8

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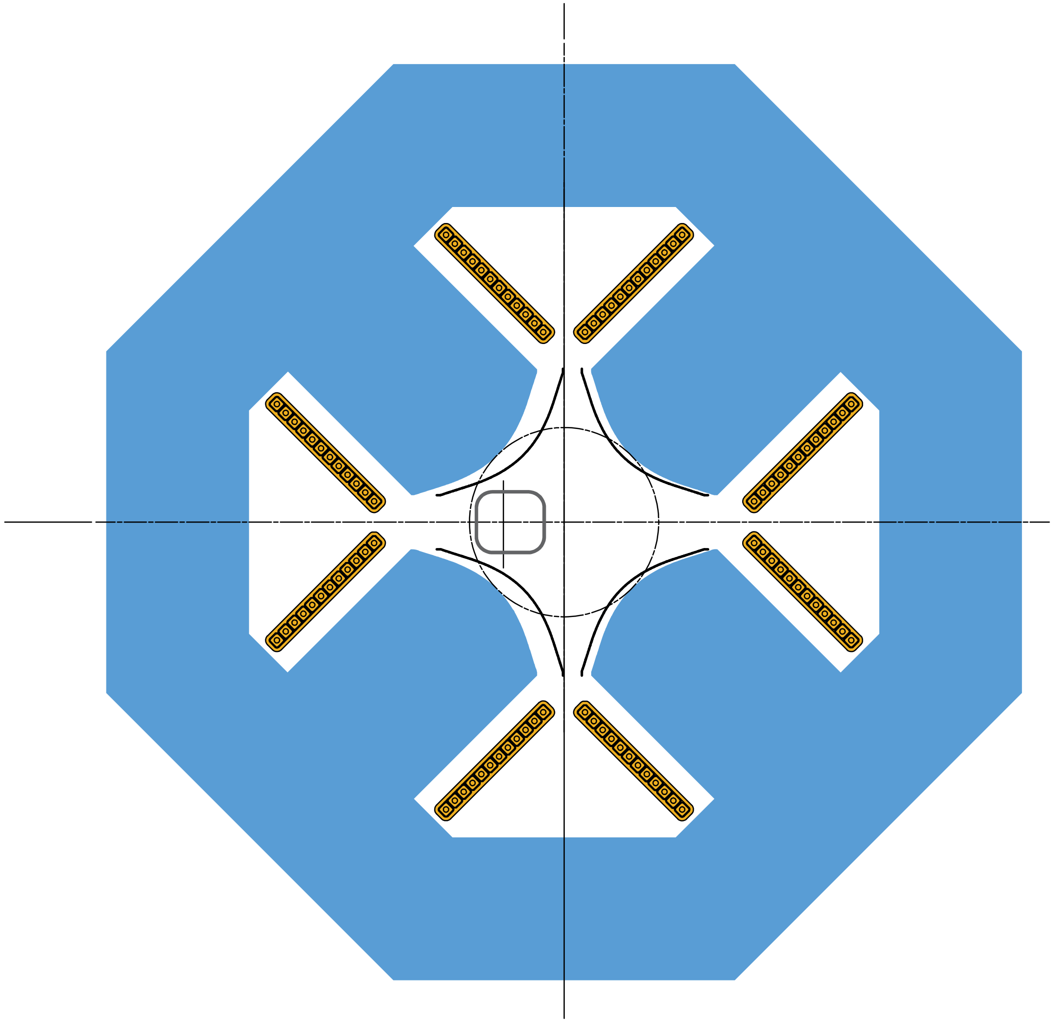
Quadrupole



RF Parameters

- Cavity aperture width: 35 mm
- Frequency tunability range: 5.5 MHz
- Cavities: 19
  - Every third cell: discretization errors
  - Two removed for injection/extraction
- Voltage: 120 kV/cavity ($a = 1/6$)
  - Larger a potentially interesting (upgrade?)

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