Muon Acceleration

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Muon Accelerator Program Review
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Muon Acceleration Goals & Parameters

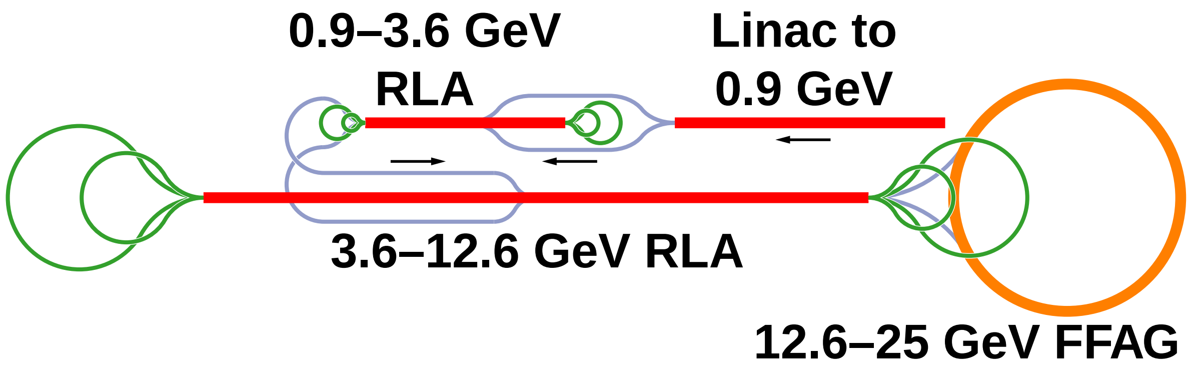
	ν factory	μ collider
p_i (MeV/c)	220	?
p_f (GeV/c)	25	750
$\varepsilon_{n\perp}$ (μm)	6000	25
$\varepsilon_{n\parallel}$ (mm)	25	70
Repetition rate	50	15
Trains/pulse	3	1
Muons/train	4×10^{11}	2×10^{12}
Bunches/train	≈ 23	1

Primary Design Goal
Hardware Efficiency

- Re-use RF systems: multiple passes
  - Cost inversely proportional to passes
- Arcs needed to return beam to RF
  - Cost depends on type of system
- Use different types of accelerators for different energies
  - Choose most efficient type
  - More efficient types won't work (or will be less efficient) at lower energies

Neutrino Factory

- Well-defined acceleration scenario
- Linac to 0.9 GeV
  - Make beam sufficiently relativistic
  - Reduce relative energy spread and beam size
- Two 4.5-pass “dogbone” RLAs to 3.6/12.6 GeV
- FFAG to 25 GeV: 12.5 turns
  - Good efficiency



Neutrino Factory R&D Tasks

- Finalize injection/extraction design for FFAG
  - Kickers and septa very challenging
  - May affect final FFAG lattice parameters
- Full system simulation with realistic magnet fields
- Transfer lines and matching between stages
- Verify that FFAG is more cost-effective than RLA
  - Rough relative costing, from scaling up RLA design
- High gradient in 201 MHz superconducting RF

Muon Collider Initial Design Configuration

- After ν factory acceleration, fast ramping synchrotrons to 750 GeV
  - Large number of passes through RF
  - Efficient use of RF power
  - Can create high synchrotron tune: stabilize collective effects
  - Higher energy, longer ring: time to ramp magnets and top off RF
- Two stages
  - Ramping synchrotron to $\approx$400 GeV
  - Hybrid ramping synchrotron to 750 GeV

Muon Collider Power Efficiency

- 7 MW of muon beam power at end
- Power efficiency

$$\frac{\text{Energy delivered to beam}}{\text{RF energy delivered to cavity}}$$

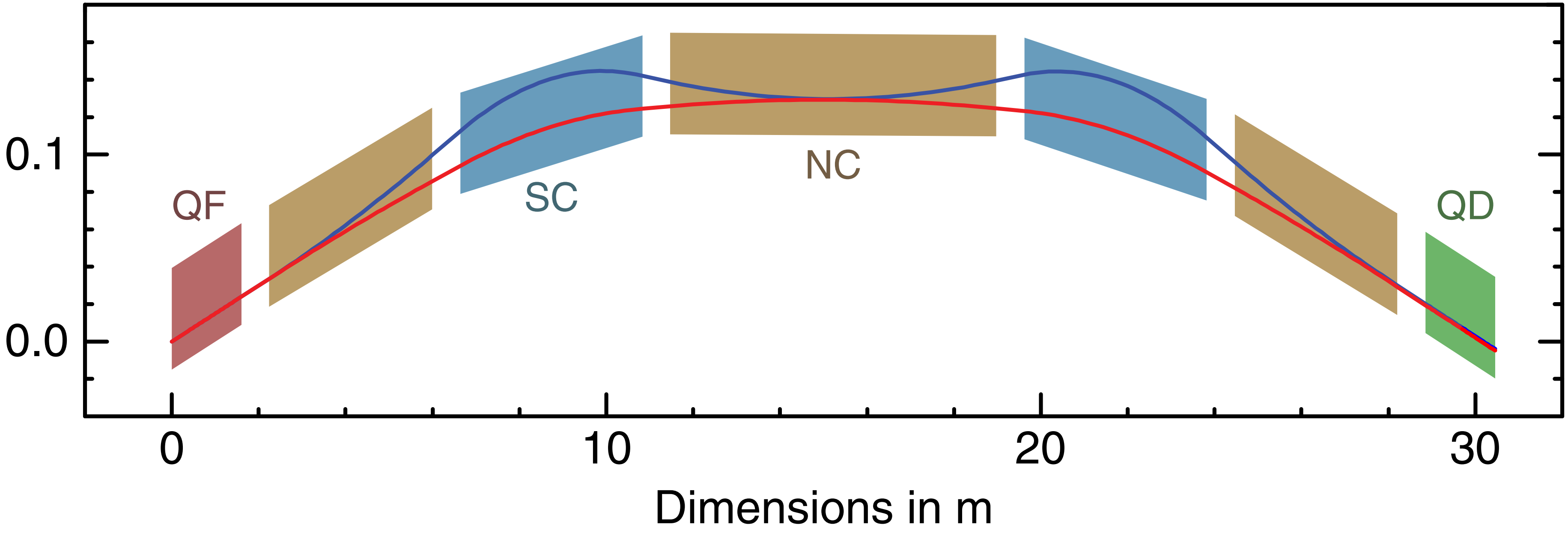
- High efficiency, low RF power requirements
- Efficiency depends on product of
  - Fractional energy extraction per bunch (train)
    - Larger for higher frequency RF
    - Larger with higher charge
  - Number of turns (like hardware efficiency)
- Product ideally $\approx$4 (1.3 GHz RF: $\approx$24 turns)

Collective Effects

- Beam loading w/ high current
  - ≈8.3% energy extraction per pass for 1.3 GHz
- Large additional contribution from HOMs, etc.
- Small vacuum chamber in ramped magnets
- Mitigation
  - Lower frequency RF
  - Strong synchrotron oscillations
    - Distribute RF around ring: arc/ring act like mini-ring
    - Mode coupling viewpoint: higher ν_s separates modes
  - Chromaticity
  - Few turns, growth tolerable?

Hybrid Ramping Synchrotron

- Keep average field high: mix
  - Fixed-field superconducting dipoles
  - Ramped (−1.8 T to +1.8 T) warm dipoles
- Closed orbit changes during acceleration



Muon Collider Acceleration R&D Tasks

- Hybrid lattice design needs to be optimized
  - Time of flight constant (RF synchronization)
  - Tunes constant
  - Minimize orbit variation
    - Smaller aperture, smaller power supply
- Chromatic correction
- Determine best way to insert RF
  - More RF sections better
    - Higher synchrotron tune, collective instability suppression
  - RF/drift in each cell
  - Dispersion suppressed sections
    - Suppress orbit variation also

Muon Collider Acceleration R&D Tasks

- Understand limits/costs of ramping magnets and power supplies
- Study high charge/impedance collective effects

Planning in First Years
Acceleration Milestones

- FY11: Specify ν factory μ acceleration initial configuration
- FY13: Specify μ collider μ acceleration initial configuration

Planning in First Years R&D Goals

- FY11
  - Final details & simulations for ν factory initial configuration
  - Lattice designs for μ collider
  - Basic understanding of collective effects
- FY12
  - Finalize μ collider lattices, incorporating collective
  - μ collider simulations with collective effects
  - Study ν factory acceleration with μ collider beam
- FY13
  - Simulations of full μ collider acceleration

Summary

- ν factory design essentially settled
  - Need to know 201 MHz SCRF capabilities
- Fast ramping synchrotrons are an efficient way to accelerate muons for a μ collider
  - Make many turns
  - Strong synchrotron oscillations to stabilize collective effects
- RLA should be a feasible fallback for the μ collider