Neutrino Factory Accelerator Systems

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IDS-NF Overview

- Goal is to produce a reference design report by end 2013
- Need accelerator physics design of entire machine
- Simulations supporting assertion that machine will work
- Cost estimate
- Engineering of systems sufficient for
  - Demonstrating feasibility
  - Estimating cost

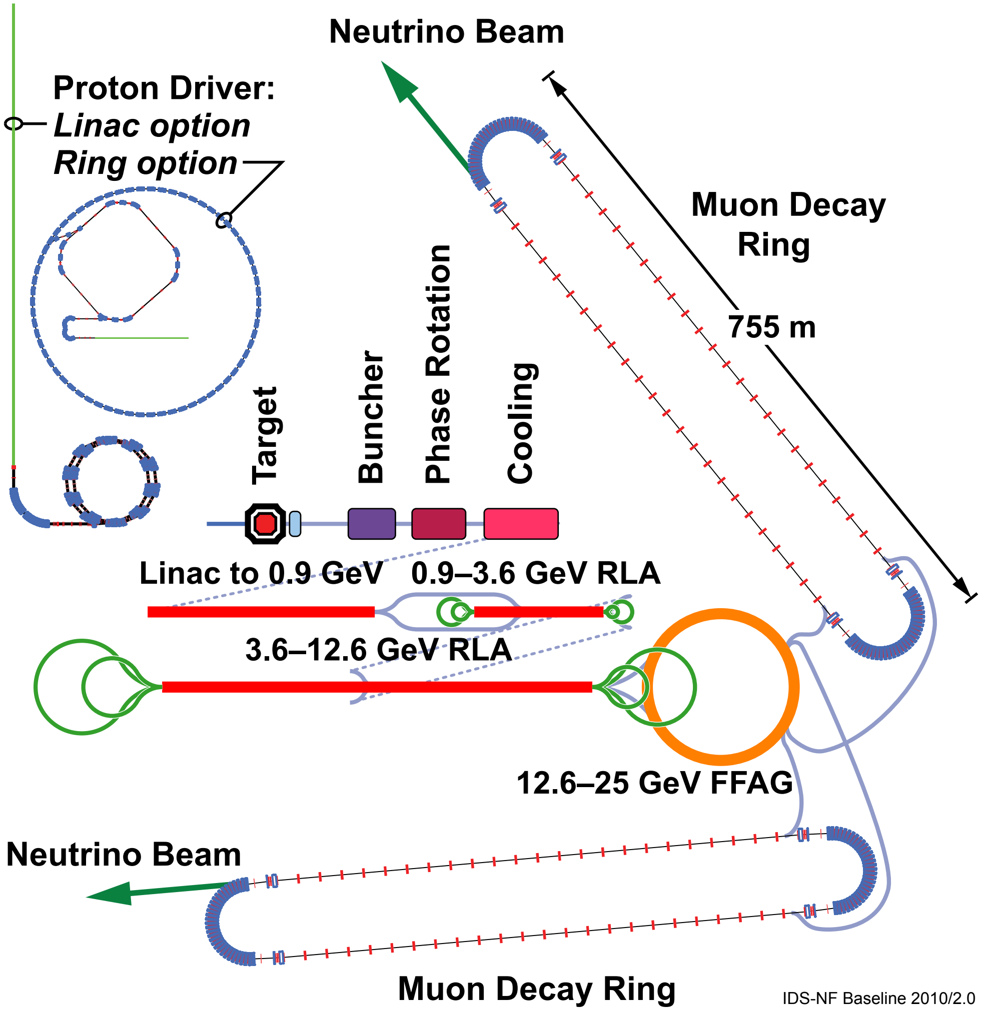
IDS-NF Machine Requirements

- 10^{21} muon decays toward detectors per 10^7 s year
- 25 GeV muons
- Beam divergence $< 0.1/\gamma$
- Two detectors at 2500–5000 km and 7000–8000 km

IDS-NF Accelerator Overview

- Proton driver, makes protons that hit
- Target, produces pions decaying to muons
- Front end, improves beam phase space distribution
- Acceleration, increases muon energy
- Decay ring, stores muons where they decay to neutrinos, directs them toward detector

Neutrino Factory Complex



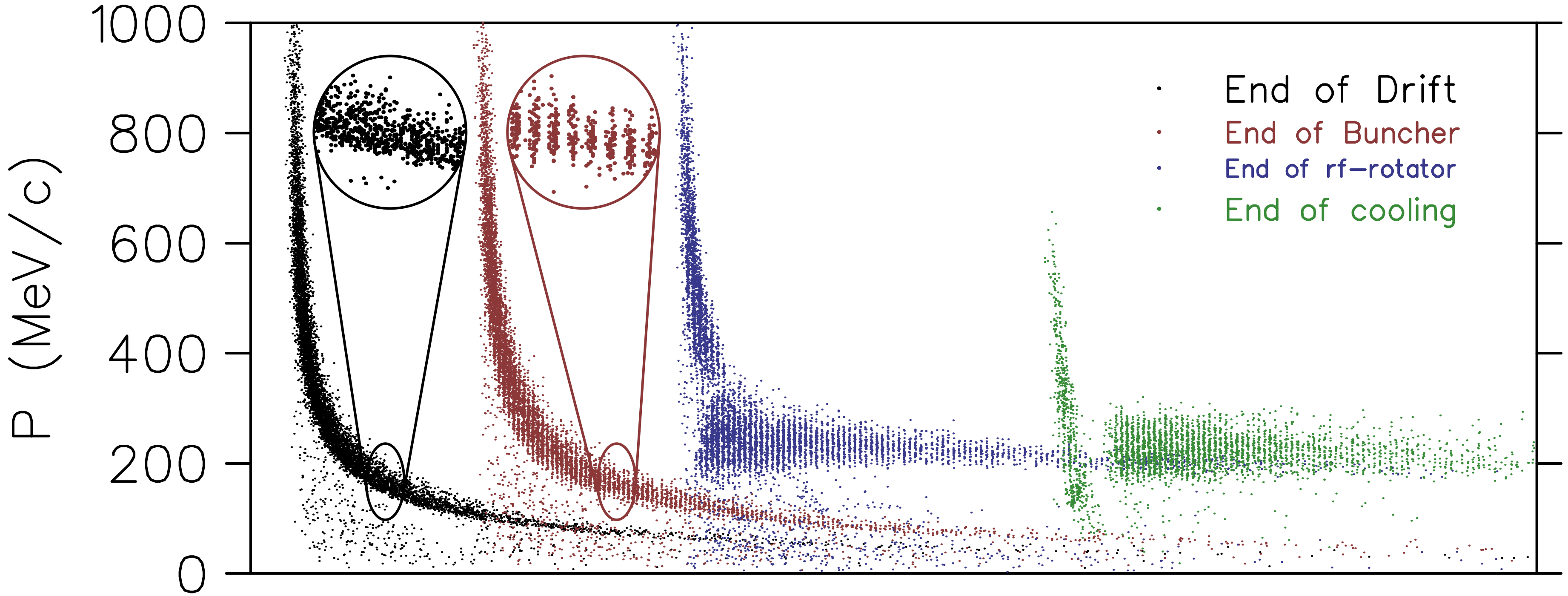
IDS-NF Baseline Accelerator Subsystems

- Proton Driver
  - 4 MW: sufficient flux to get desired muon flux
  - Parameters optimized for capture by front end
  - 50 Hz, 3 bunches, 5–15 GeV, 1–3 ns bunch length
  - Several facility-specific designs
- Target
  - 20 T solenoid capture system
  - Hg jet target

IDS-NF Baseline Accelerator Subsystems

- Front end
  - Constant field (1.5 T) solenoid channel for pions to decay to muons
  - “Neuffer” buncher and phase rotation
    - Create 200 MHz bunch train
    - Reduce large energy spread
  - Transverse ionization cooling channel

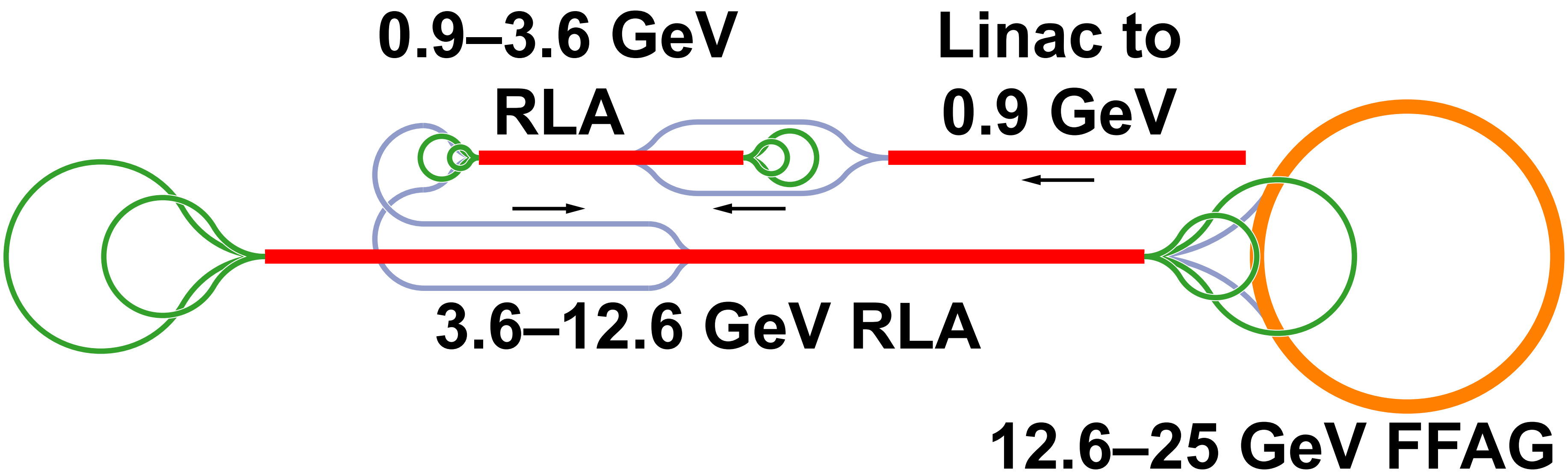
IDS-NF Baseline Accelerator Subsystems



IDS-NF Baseline Accelerator Subsystems

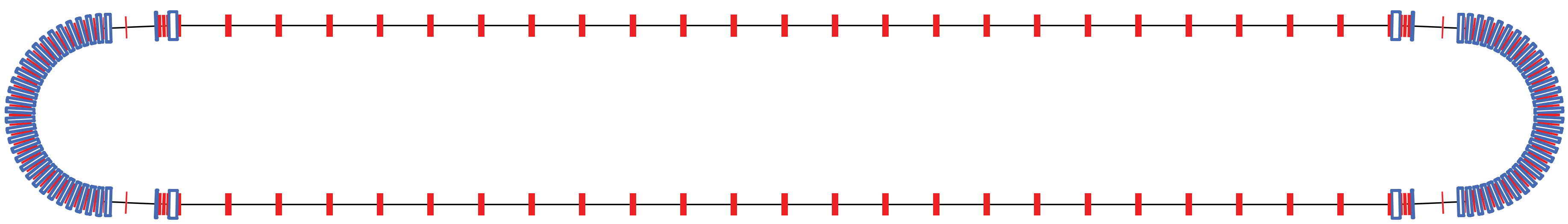
- Acceleration in four stages, 200 MHz SCRF
  - Each stage efficient in its energy range
  - Maximize passes through RF, more difficult at low energies
  - Linac
  - Two recirculating linear accelerators (multiple passes)
  - Fixed field alternating gradient accelerator (more passes, no switchyard)

IDS-NF Baseline Accelerator Subsystems

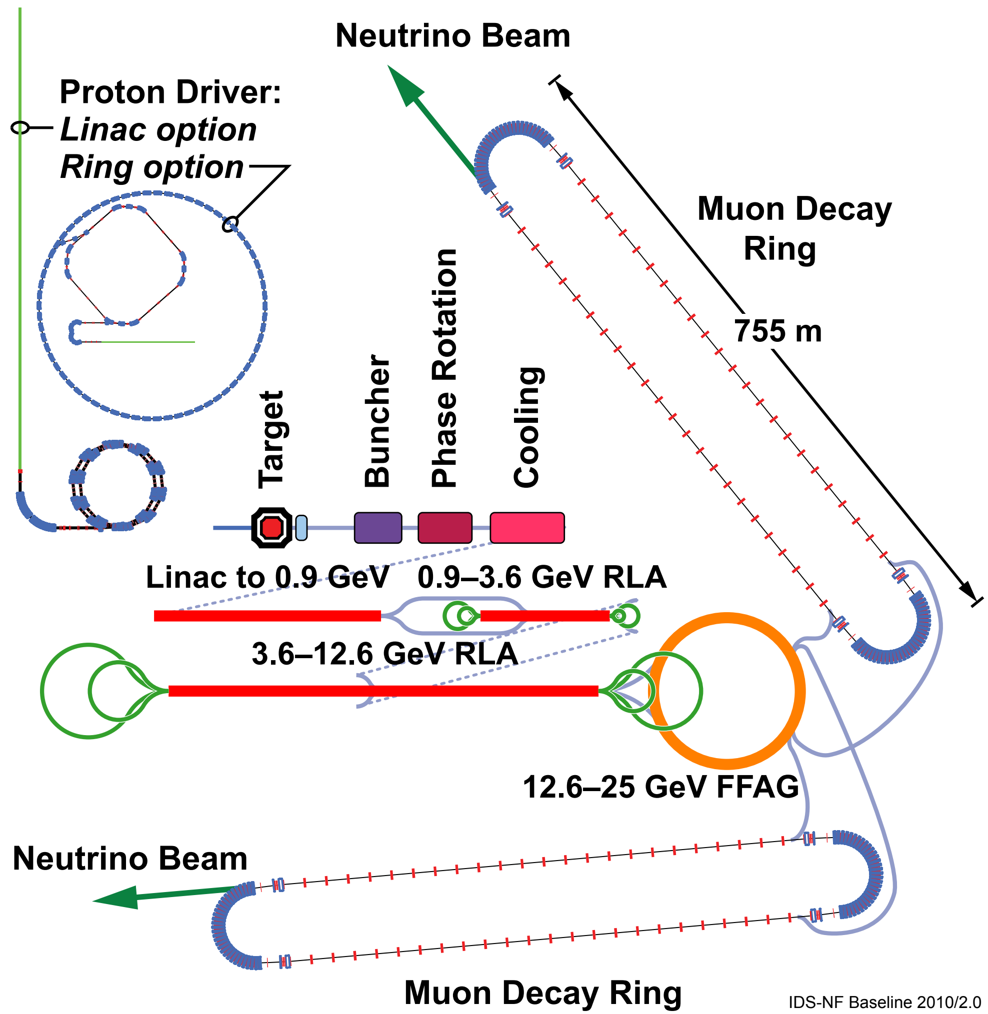


IDS-NF Baseline Accelerator Subsystems

- Two 25 GeV racetrack-shaped decay rings
  - Two detector baselines: 3000–5000 km, 7000–8000 km
  - Racetrack maximally flexible
  - In-ring diagnostics for current, energy and its distribution (polarimeter)



Neutrino Factory Complex



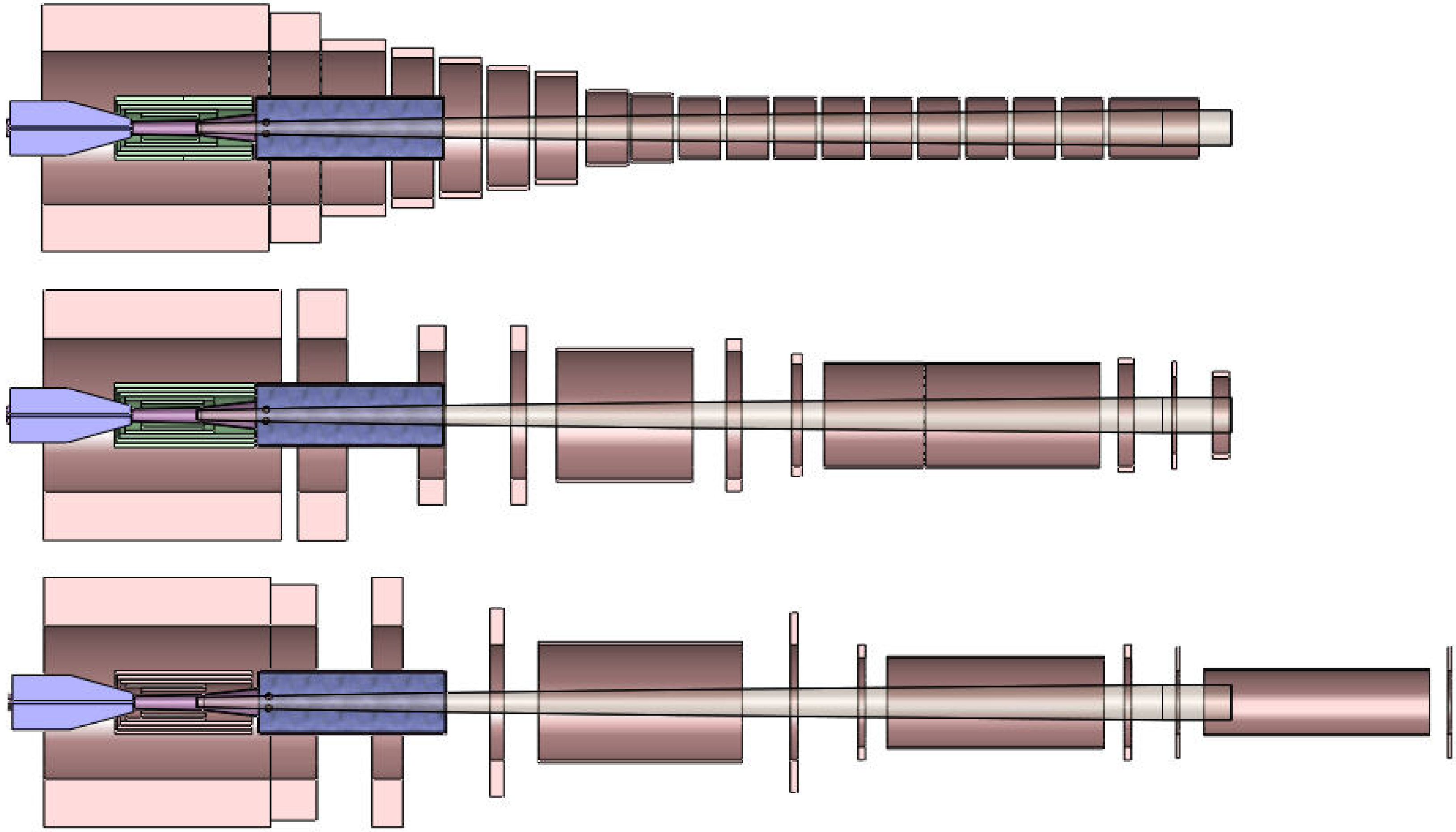
Proton Driver

- Disconnect between IDS-NF and muon collider parameter sets
- Agree on 4 MW
- Effective repetition rate differs by factor of 10: 150 Hz vs. 15 Hz
  - 50 Hz 3 bunches from proton driver requirements
  - Muon collider does proposes combining
- If IDS-NF had 15 Hz, single bunch train, would do little harm
  - Would need to look at collective effects

Target

- Significant progress in target design
  - Energy deposition in SC solenoids too high in earlier design
  - Reconfigured solenoids to enable better shielding
    - Larger aperture solenoids near target
  - Subsequent reconfiguration to make space for cryostats
  - Significant engineering on solenoids
- Studies of (liquid) Ga target in case Hg is unacceptable

Target



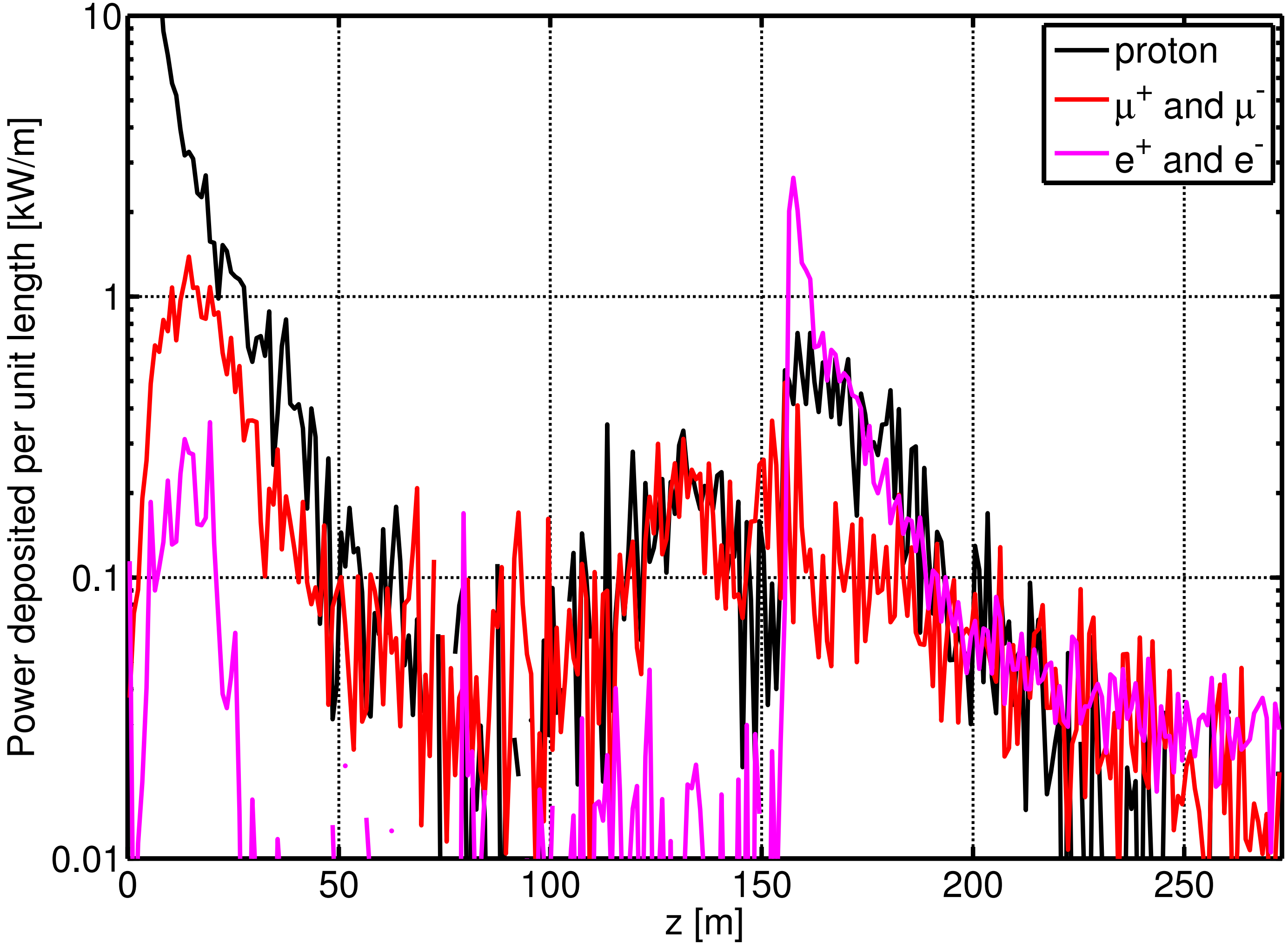
Target

- Important work needed to reach RDR
  - Design of mercury circulation system
  - Layout of target hall
  - Design of remote handling systems
  - Final focus of proton beam to target

Front End

- Energy deposition in front end a significant problem
- Address with a chicane and absorber
  - Chicane bends only lower energy particles
    - High energy particles deposit energy in well-defined location
  - Absorber after chicane stops lower energy undesirables
  - Good performance, some modest loss ($\approx 20\%$)
  - Some lattice modifications required

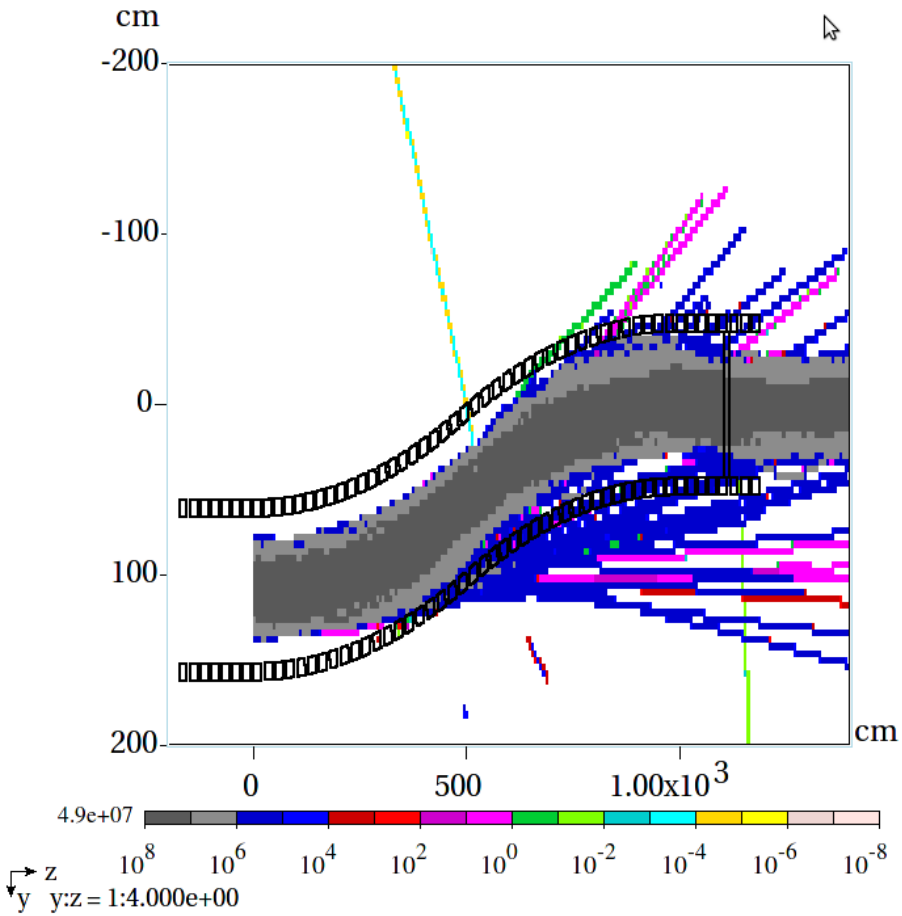
Front End



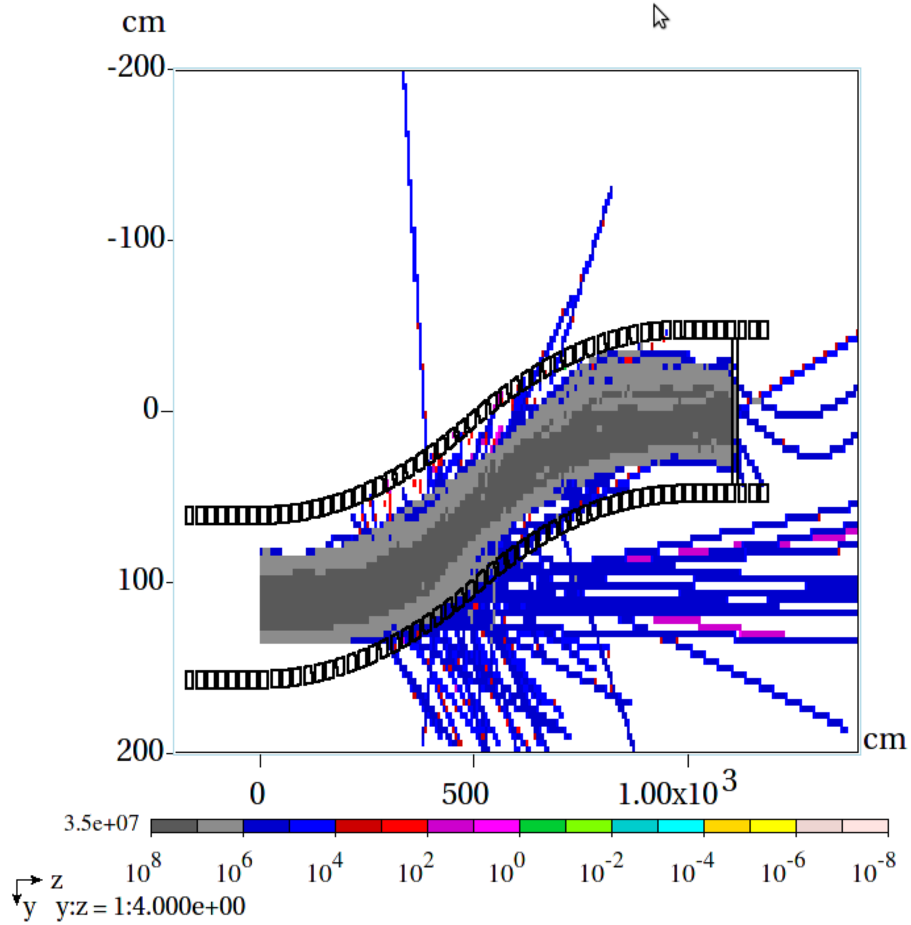
10
1
0.1
0.01
Power deposited per unit length [kW/m]
0
50
100
150
200
250
z [m]
proton
μ+ and μ-
e+ and e-

Front End

Muons



Protons



Front End

- Muon collider delivers very different beam
  - 25 μm vs. 7.5 mm transverse normalized emittance
  - 0.025 eV s emittance vs. 0.05 eV s *acceptance*
    - Collider acceptance must be several times larger than neutrino factory
    - Can't reuse acceleration at same energy
    - Maybe reuse at higher energy: design for this

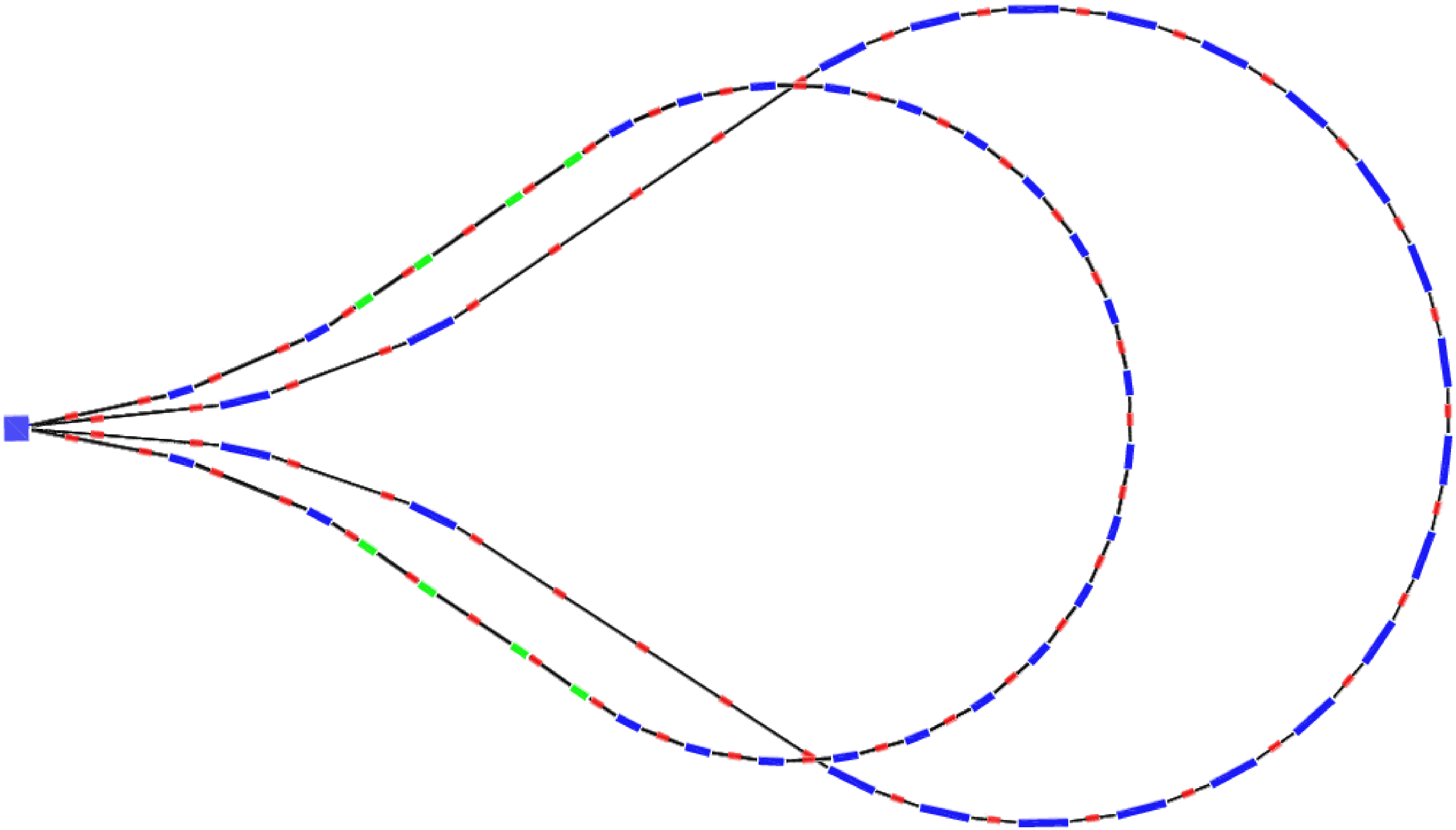
Front End

- Possibility: use collider beam prior to bunch merge for neutrino factory
  - 1 mm normalized emittance in all planes
  - About the same muon flux
  - Could make much less expensive acceleration, decay ring
  - Could have very low flux uncertainty

Low Energy Acceleration

- Updated designs of linac and first RLA
  - Larger transverse acceptance in linac and first RLA
  - Improved handling of arc crossings
  - New matching algorithm requiring less chromatic correction
- More effort needed here
  - Completion of lattice designs
  - 6-D tracking beginning to end
    - Expect transverse/longitudinal coupling issues similar to those in FFAG
    - Matching of distributions between parts
  - Layout of the lattice

Low Energy Acceleration



High Energy Acceleration: FFAG

- Need more work on beam dynamics
  - Adjust lattice parameters to get good transmission, small emittance growth
  - Chromaticity correction
- Beam dynamics issues significantly reduced for smaller transverse emittance, as in collider

Decay Ring

- Relatively stable
- Injection system designed

Low Energy Neutrino Factory

- θ_{13} is looking like it is not so low
- This pushes you to lower energy muons: around 12 GeV
- Quick solution
  - Remove final acceleration stage
  - New decay ring (first pass design done)
- Low flux first machine considered
  - Some physics could be done with reduced flux
  - Little cost savings from full machine if upgradability is desired

Costing

- Getting together component lists
  - Starting point is lattice design
  - Working on defining the supporting bits
  - Schematic of full system
- Key missing part is target support systems

International Collaboration

- UK funding will continue at a similar level through end RDR
- Major areas of work
  - Engineering support for costing: but not target!
  - Costing
  - Front end
  - Some tracking support for linacs and RLAs
  - FFAG, particularly on hardware
  - Decay ring
  - Management

Additional Support for RDR

- Engineering on target systems
  - Essential for making a reasonable estimate of cost
- More support for RLA design and simulation work
  - Completion of designs
  - Tracking through full system
  - Layout and engineering of complex beamline
- Mid through end 2013: writing RDR will become a major distraction

Summary

- Progress on significant issues in IDS-NF
  - New solenoid configuration to reduce energy deposition
  - Chicane to confine energy deposition in front end
  - Update low energy acceleration scheme
- Need additional support to get to RDR
  - Engineering on target systems
  - Linac/RLA design
- The RDR is coming up soon! Time to panic!