Acceleration Studies for MAP

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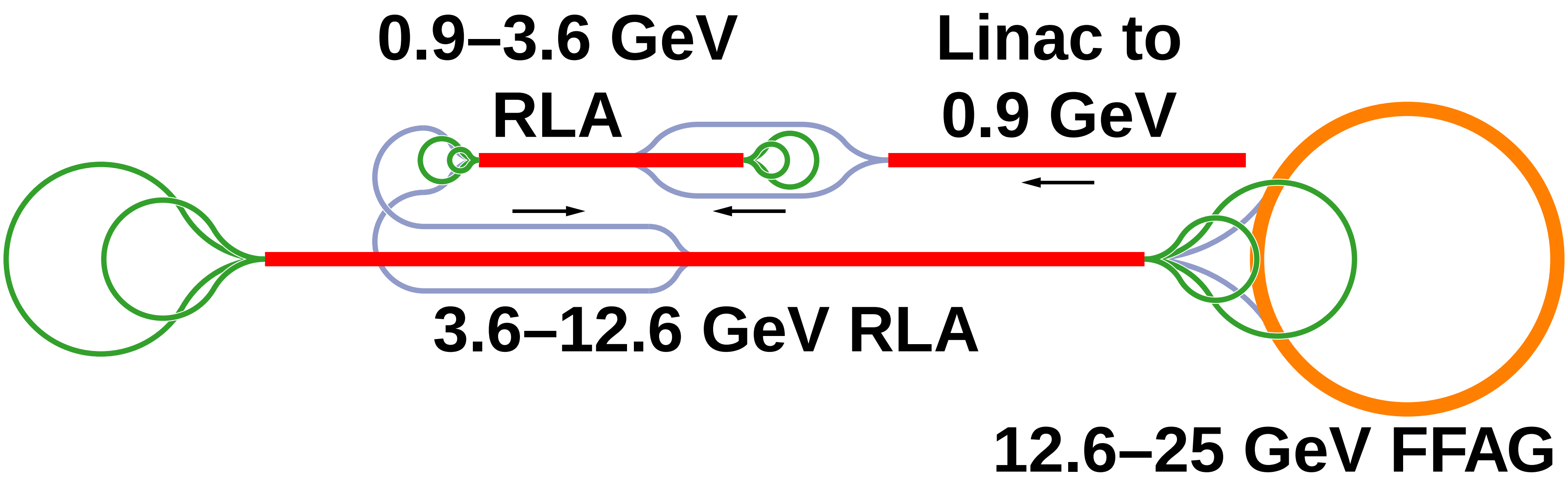
Muon Accelerator Program Winter Meeting
March 2, 2011

Outline

- IDS-NF acceleration
  - FFAG design updates
- The EMMA experiment
- Acceleration for a muon collider
- Acceleration workshop

IDS-NF Acceleration Scenario

- Linac to 0.9 GeV
- Two RLAs, to 3.6 and 12.6 GeV
- FFAG to 25 GeV
- Each stage most efficient for its energy range



IDS-NF FFAG Basics

- Single beamline accepting a wide energy range
  - Avoid switchyard, get large number of passes: more efficient, lest costly
  - Need injection and extraction systems
- Consists of (ideally) identical FDF triplets
- RF cavities in most long drifts
  - More efficient, lest costly if drifts are shorter

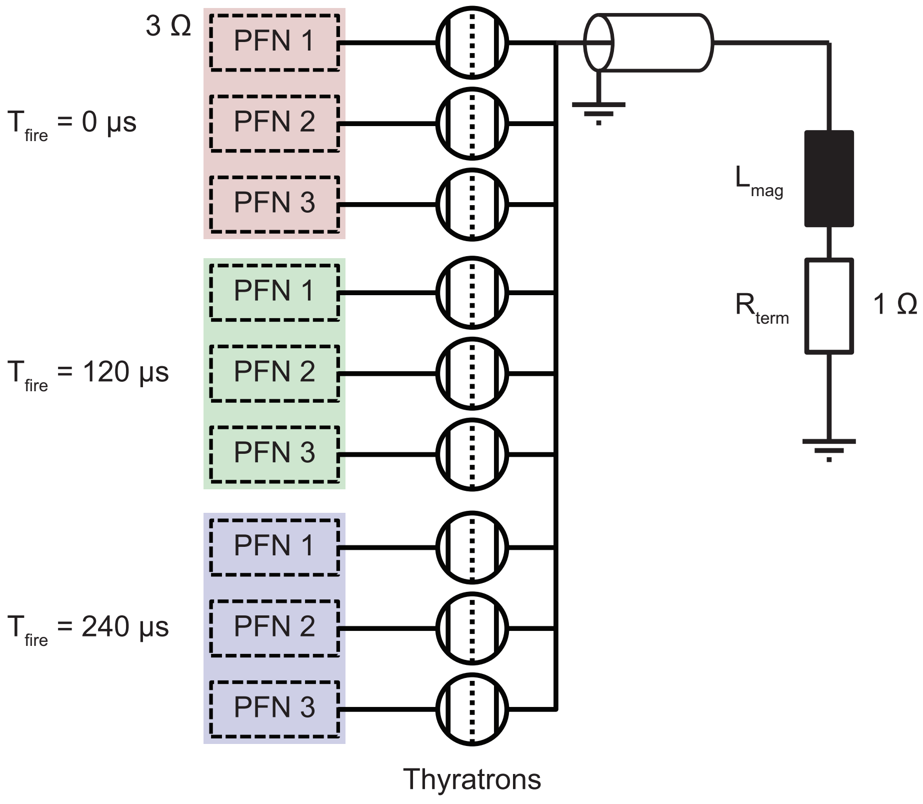
IDS-NF FFAG Design Updates

- Have designs for injection/extraction systems
  - 6 kickers (2 injection, 4 extraction), 4 septa
- Septum field below 2 T to control stray fields
  - Required increasing drift length to 5 m
  - Impacted cost and efficiency of FFAG

Cells	64	Circumference	667 m
Long drift	5.0 m	Short drift	0.5 m
RF cavities	48	RF voltage	1214 MV
Turns	11.6	Decay	6.7%
D max field	6.1 T	F max field	4.3 T

IDS-NF FFAG Design Updates

- Design of kickers and power supplies
  - Traveling wave kicker with 4 sub-kickers
  - 3 PFNs per sub-kicker to produce required current
  - 3 sets for 3 bunches from proton driver
  - 6 kickers: yes, multply these numbers. . .



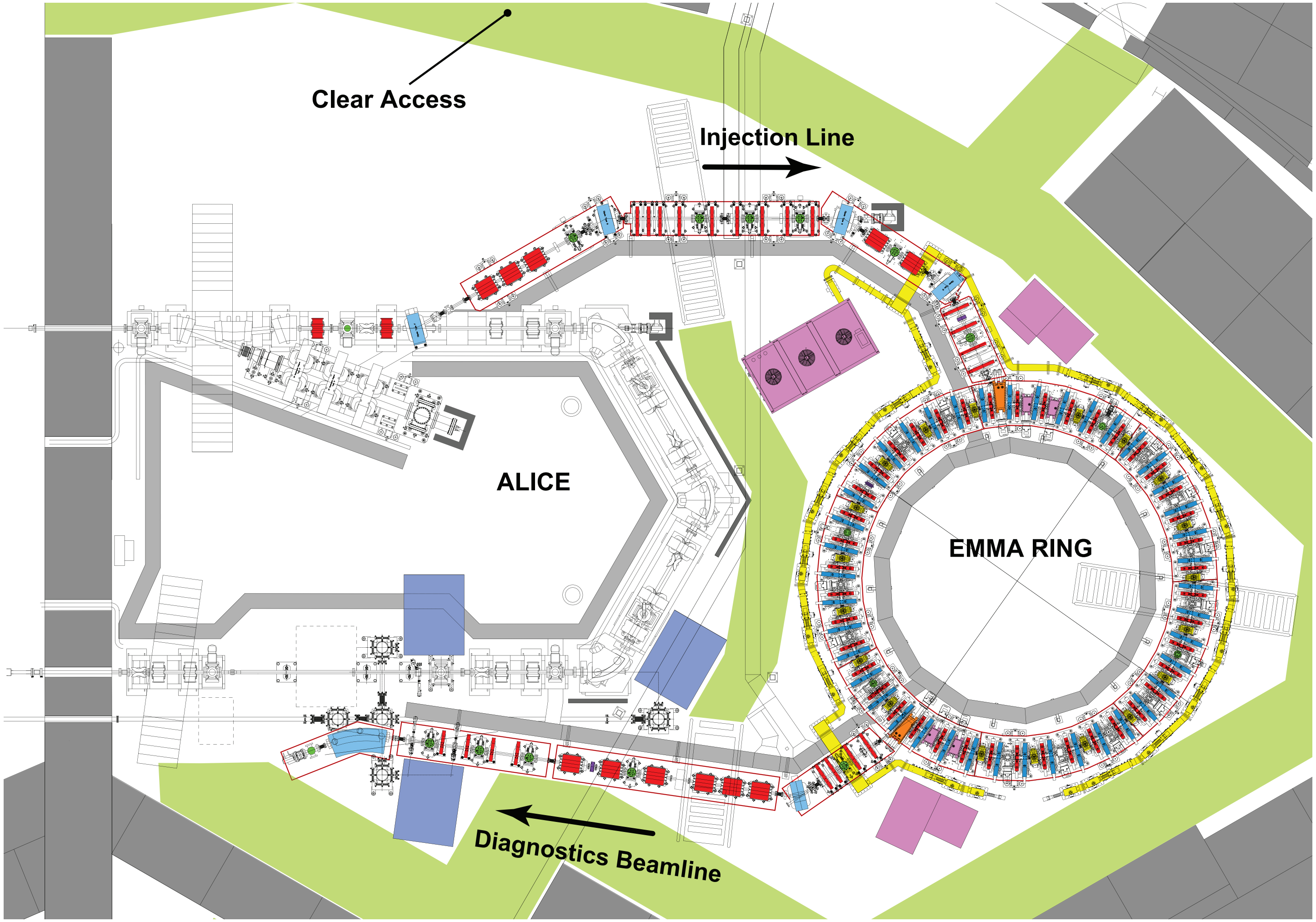
IDS-NF FFAG Design Updates

- First pass at main magnet designs
- First look at engineering layout: need more space between magnets in triplet
  - Will update design with 75 cm between magnets
- Tasks getting to RDR
  - Beam dynamics studies to tweak parameters, define longitudinal matching
  - Transfer lines to/from FFGA
  - Decide on chromaticity correction

The EMMA Experiment Introduction

- Purpose: beam dynamics studies on a linear non-scaling FFAG
- Accelerate electrons from 10 to 20 MeV
- 1.3 GHz RF, accelerate in 10 turns
- 42 cells, 16.6 m circumference

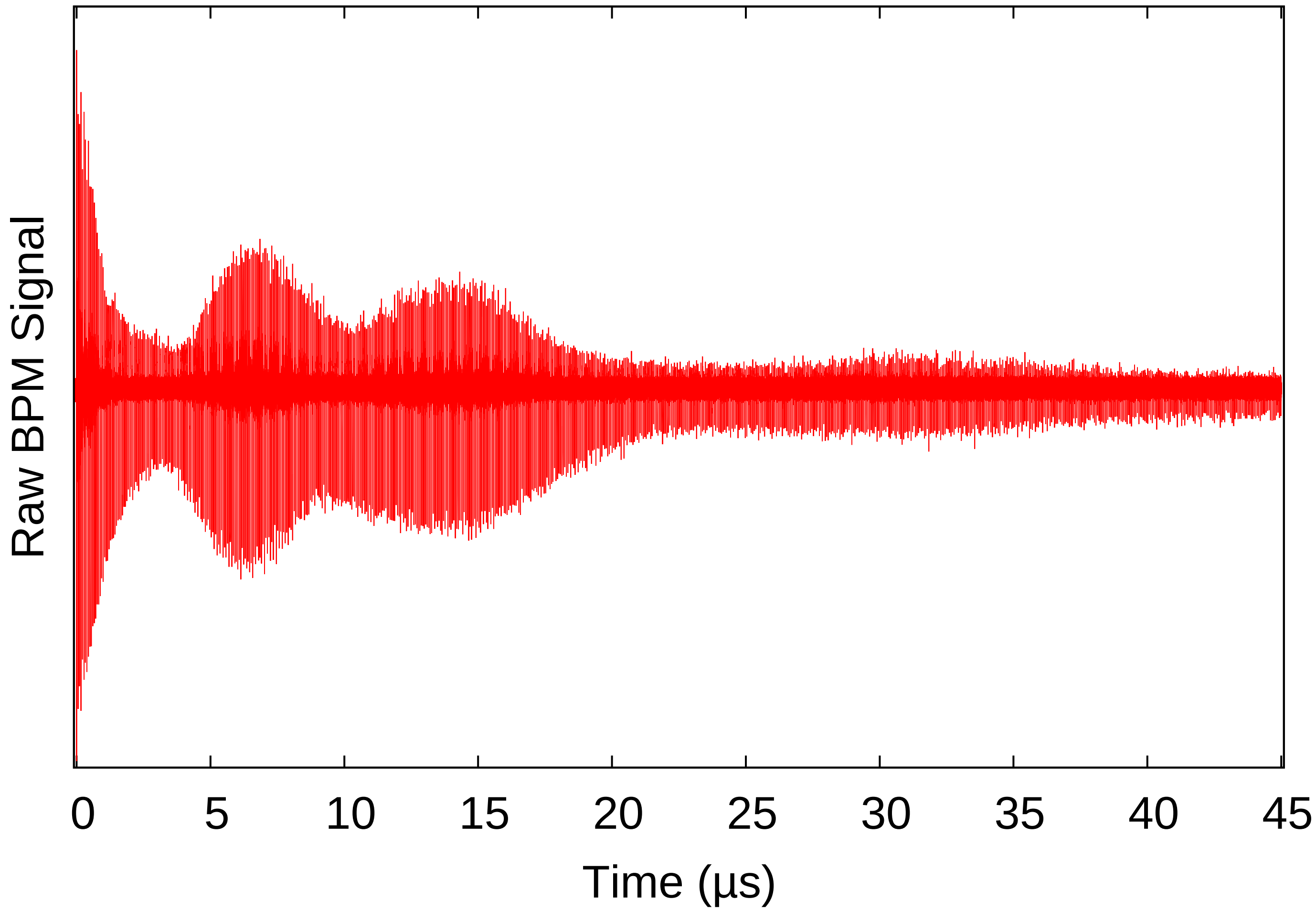
The EMMA Experiment Introduction



The EMMA Experiment Current Status

- Have stored beam for 100s of turns at several energies
  - Measured time of flight, closed orbit
  - Tune measurements are more challenging (decoherence from chromaticity)

The EMMA Experiment Current Status



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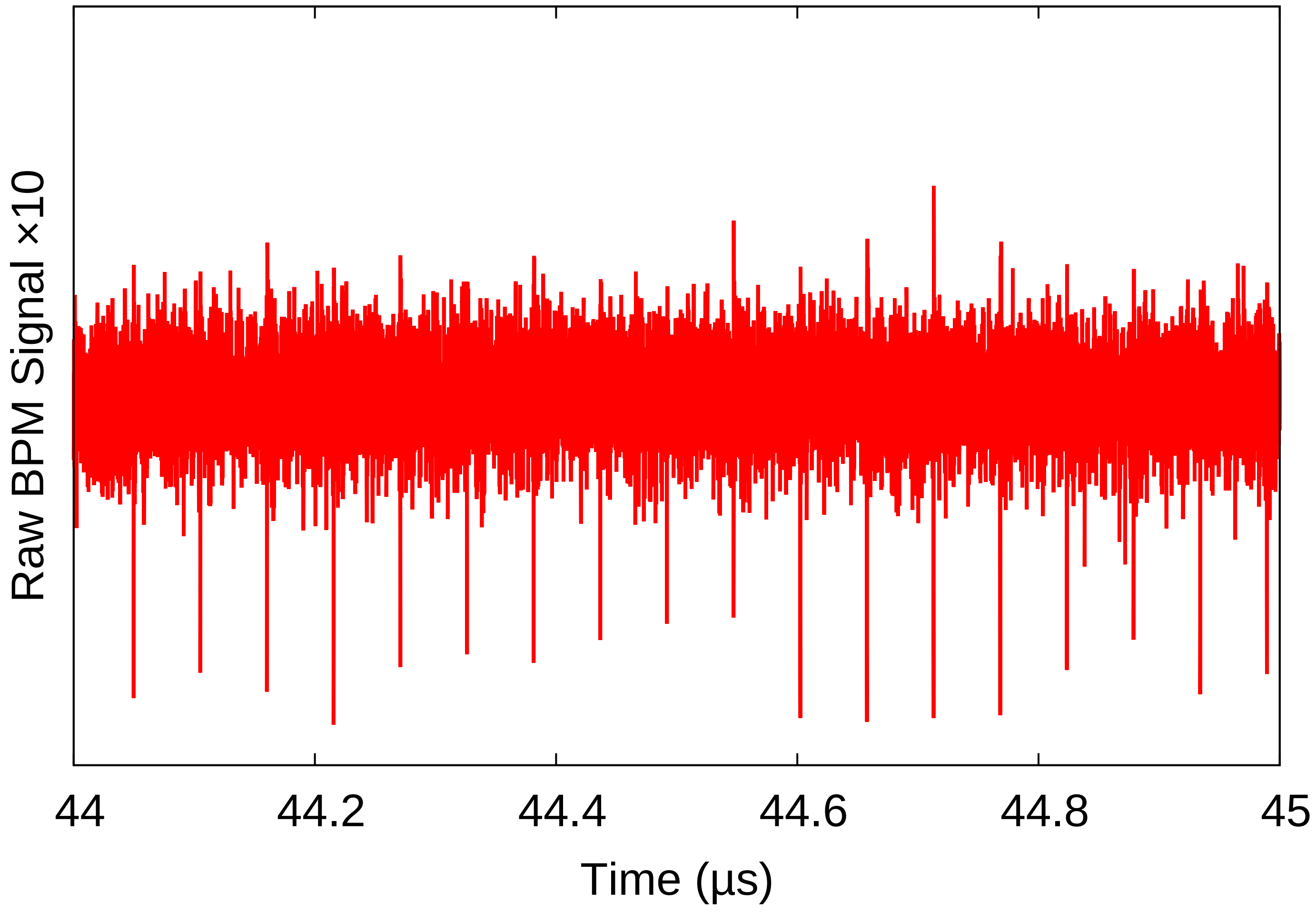
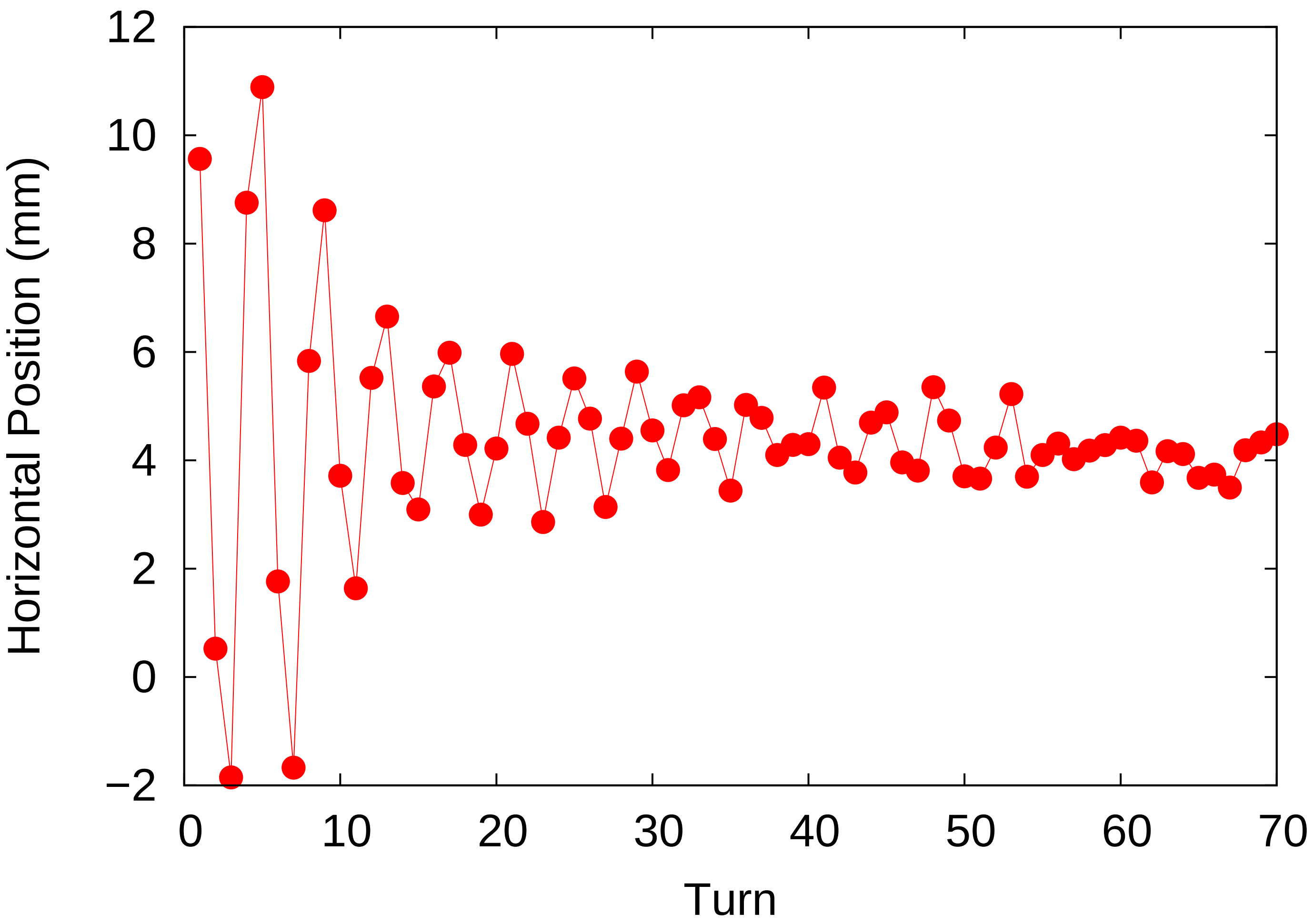


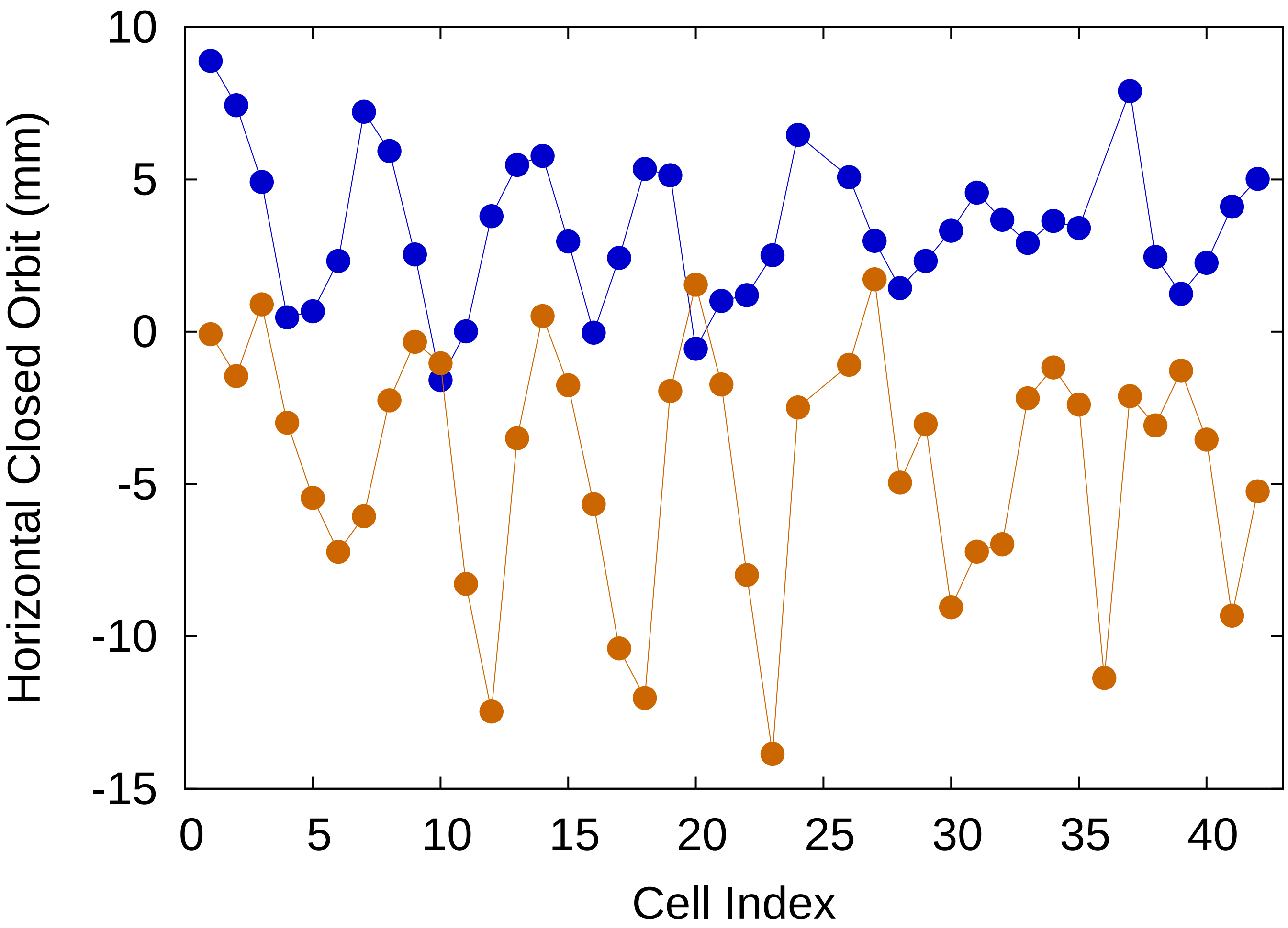
The EMMA Experiment
Current Status



The EMMA Experiment Current Status

- Have accelerated over small energy ranges
- Biggest problem: large closed orbit distortion
  - Caused by magnetic lattice asymmetry
  - Does not appear to be magnet misalignments
    - But possibly correctable with magnet misalignments, vertical correctors
  - Asymmetry likely preventing acceleration over larger range

The EMMA Experiment Current Status



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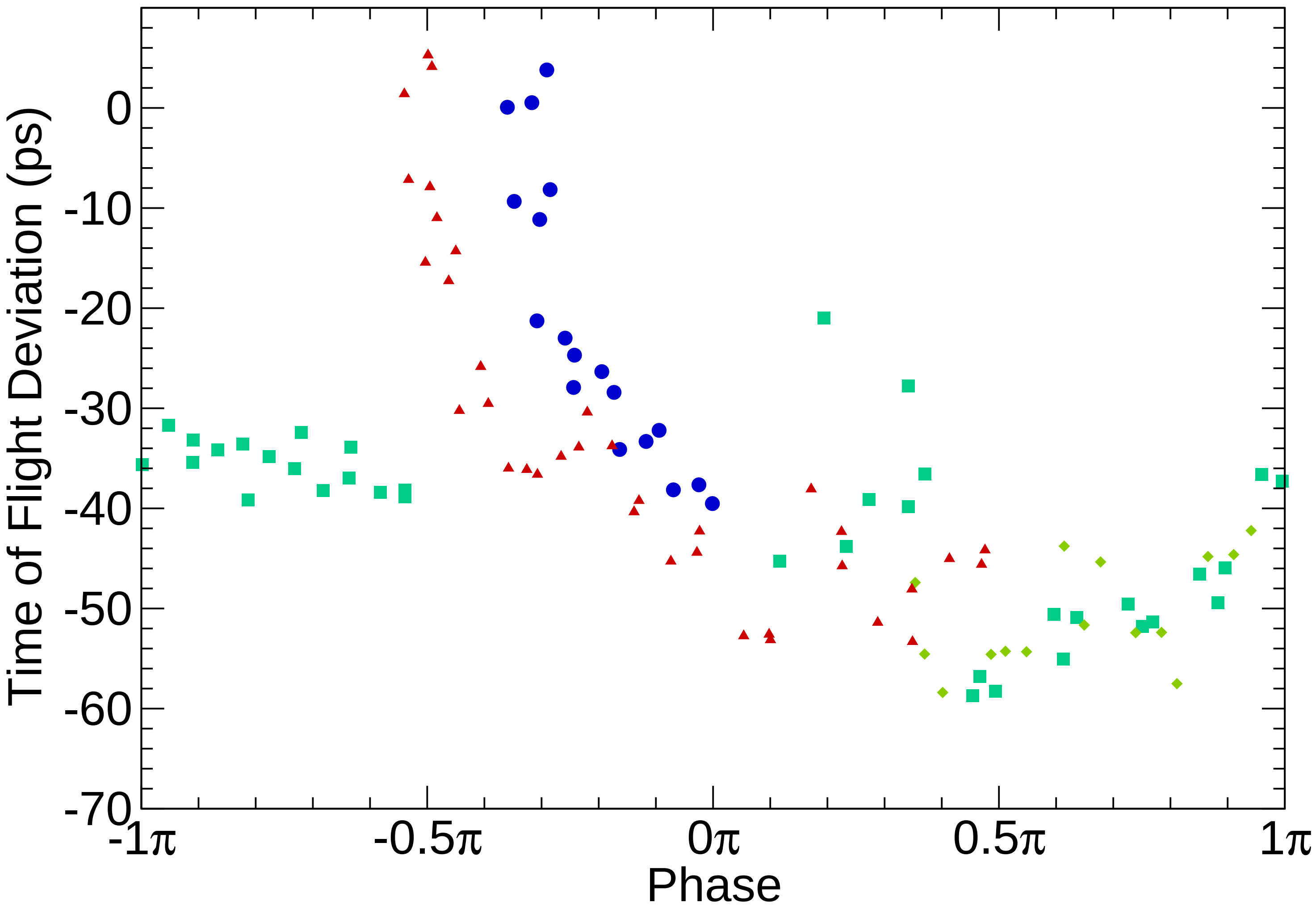
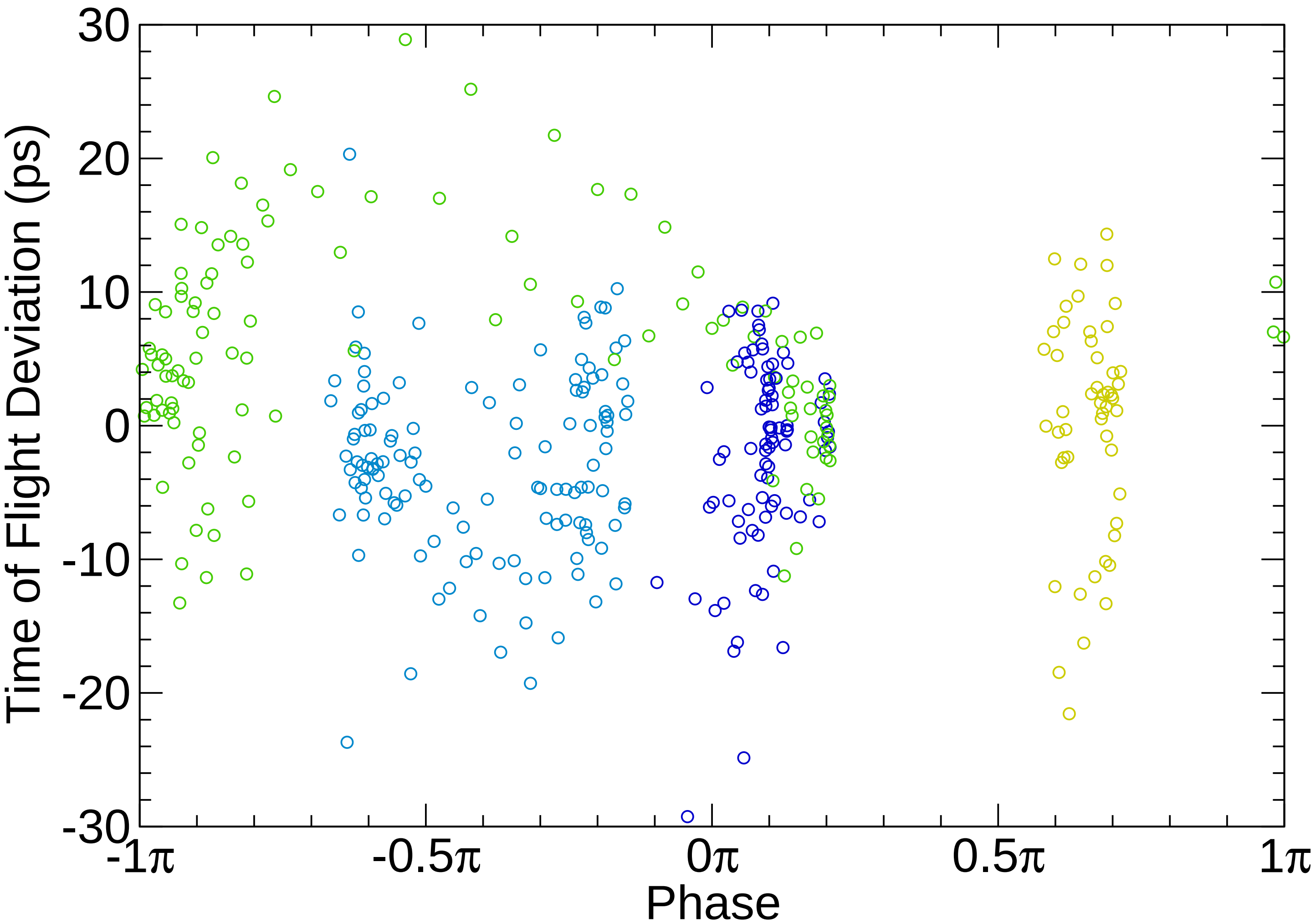


The EMMA Experiment
Current Status



Muon Collider
Initial Design Configuration

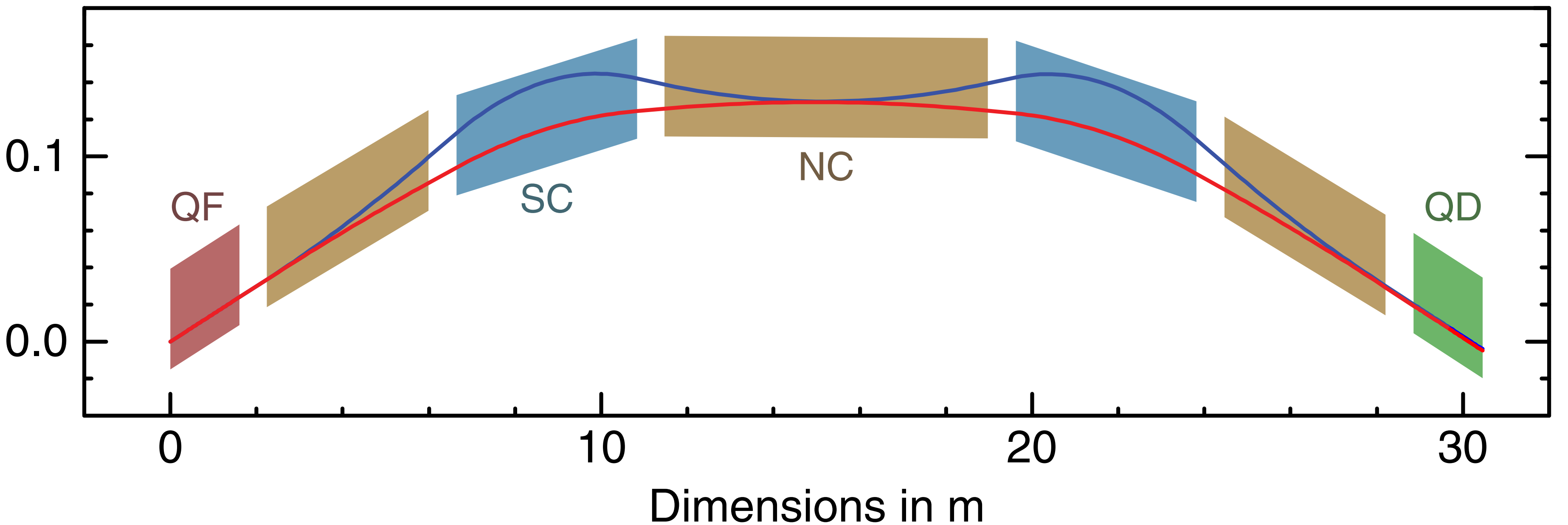
- After ν factory acceleration, fast ramping synchrotrons to 750 GeV
  - Large number of passes through RF
  - Efficient use of RF power and hardware
  - Can create high synchrotron tune: stabilize collective effects
  - Higher energy, longer ring: time to ramp magnets and top off RF
- Two stages
  -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

Muon Collider 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

- Study designs for fast ramping synchrotrons, in particular hybrid lattice
  - Magnet ramping functions that best maintain tunes, time of flight, minimize orbit excursion
  - Determine best way to insert RF
    - Space allocated (not necessarily filled) in each cell
    - Special RF sections
      - Suppress dispersion?
      - Suppress reference orbit shift with energy?
- Collective effects, constraints on lattice design
- Limits/costs of ramping magnets, power supplies

Muon Collider Acceleration Decays and Power

- Palmer analyzed collider acceleration for decay losses, power consumption
- Baseline has about 40% decay loss
  - Only includes SC acceleration portion
  - Spec was 30%, including warm acceleration from final cooling
- Largest contribution to decay: low initial energy in first RCS, which has relatively low average gradient

Decays and Power Baseline Scenario

	E_f GeV	n	f_{RF} MHz	V_{avg} MV/m	Decay %	P_{pk} MW	P_{wall} MW
Linac	1.2	1.0	201	5.7	2.7	33	2.5
RLA	4.2	5.0	201	2.4	7.4	25	1.9
RLA	15.0	5.0	201	3.3	5.6	90	6.8
FFAG	30.0	9.0	201	2.7	4.1	70	5.2
RCS	400.0	28.0	805	2.0	19.0	401	5.9
RCS	750.0	44.0	805	1.2	8.1	241	5.5
					39.2		27.8

Decays and Power
Low Decay Scenario

- Update acceleration scenario to reduce decays
- Stretch linac and RLAs to get to 100 GeV
  - Average gradient increased
  - Drop FFAG stage
  - Cost: much more RF
- Also increase average gradient in second RCS
- Decays down to 27% (but 16% decays in warm means still don't meet spec)
- Much more RF (and peak RF power), increased plug power

Decays and Power
Low Decay Scenario

	E_f GeV	n	f_{RF} MHz	V_{avg} MV/m	Decay %	P_{pk} MW	P_{wall} MW
Linac	1.5	1.0	201	7.9	2.4	46	3.4
RLA	12.5	4.4	201	4.0	7.6	105	7.8
RLA	100.0	6.5	402	5.6	5.4	469	11.7
RCS	400.0	23.0	805	2.1	10.2	396	4.7
RCS	750.0	27.0	805	2.1	4.8	393	7.2
					27.1		34.8

MAP Acceleration Workshop

- 13–15 April, Oxford, MS
- Covering *only* two topics
  - Lattice design of a hybrid synchrotron to 750 GeV
  - Review of the IDS-NF linac and RLA designs
- Meeting is for people working on these two topics: others please read our output. . .

MAP Acceleration Workshop

- No talks, only discussion and planning
- Output will be two documents
  - Hybrid synchrotron: plan to get to a complete lattice design, including finite list of options to consider
  - IDS-NF designs: specification of existing lattice, list of necessary additions and updates

IEEE Pulsed Power Conference

- MAP needs expertise in pulsed power systems
  - Kickers
  - Induction linacs
  - Fast ramping magnets
  - RF systems
- Upcoming conference on the subject: