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BASROC CONFORM

EMMA
recent developments

Shinji Machida

on behalf of the EMMA commissioning team

ASTeC/STFC/RAL

04 August 2011

Contents

- Muon FFAG design and EMMA
- EMMA Commissioning results
- Future plans

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Neutrino factory

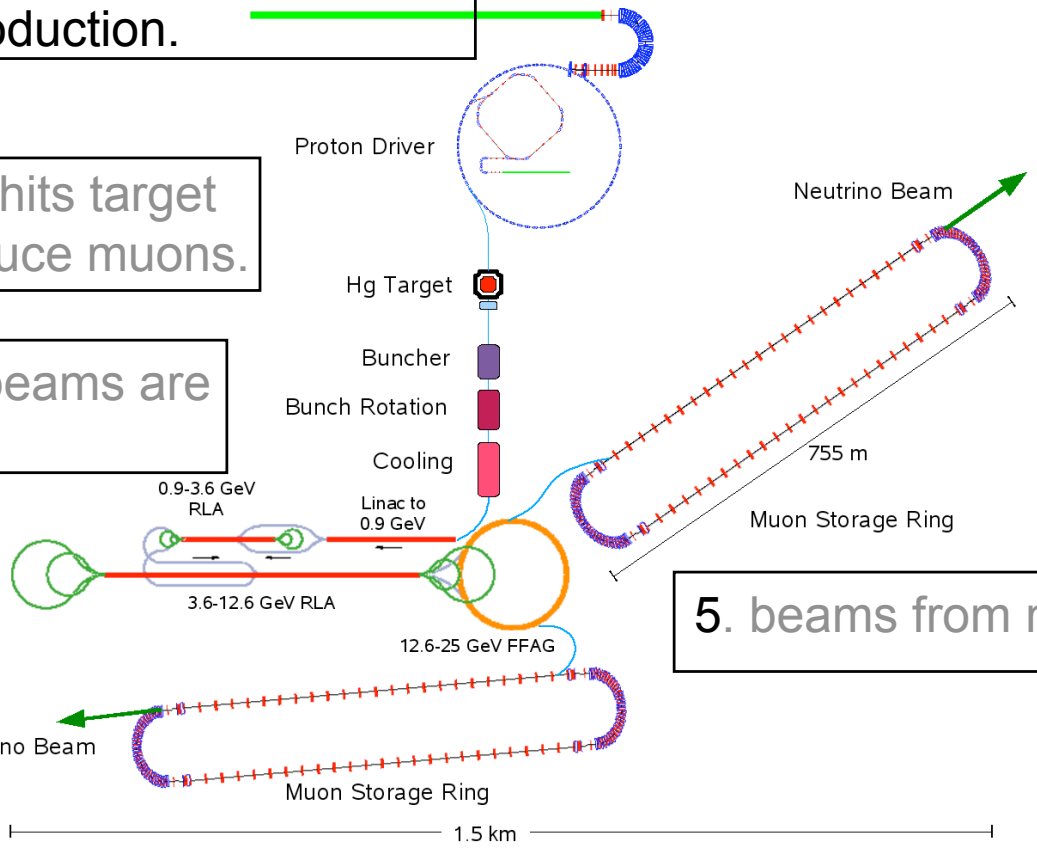
1. High power proton beam for muon production.

2. Proton hits target and produce muons.

3. Muon beams are cooled.

4. Acceleration of muon beams to 20-50 GeV.

5. beams from muon decay.



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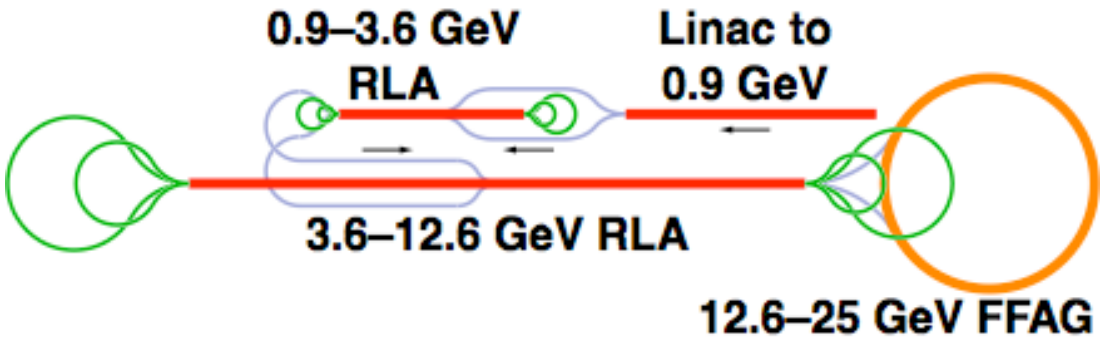
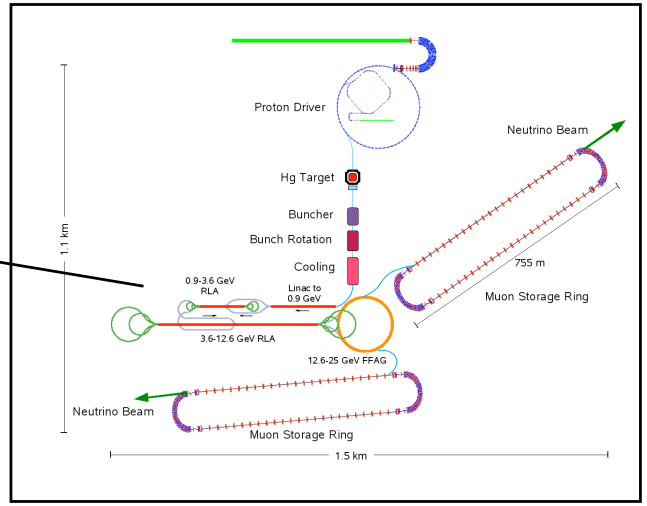
Muon accelerator





- Energy up to 20 - 50 GeV
  - It is ultra relativistic.
- Large acceptance
  - Muon emittance is a few tens of thousand π mm mrad even after cooling. (e.g. 30,000 π mm mrad)
- Quick acceleration
  - Muon's lifetime at rest is 2.2 μs.

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Accelerator for a Muon Collider

Linac:	0.2 to 0.9 GeV
Recirculating Linac (RLA):	0.9 to 12.6 GeV
Linear nonscaling FFAG:	12.5 to 50 GeV
Scaling FFAG:	50 to 400 GeV
Pulsed magnet synchrotron:	400 to 2000 GeV

Shinji Machida, at Topical workshop on the Neutrino Factory and Muon Collider.

Maybe a good starting point because we cannot think of more variety.

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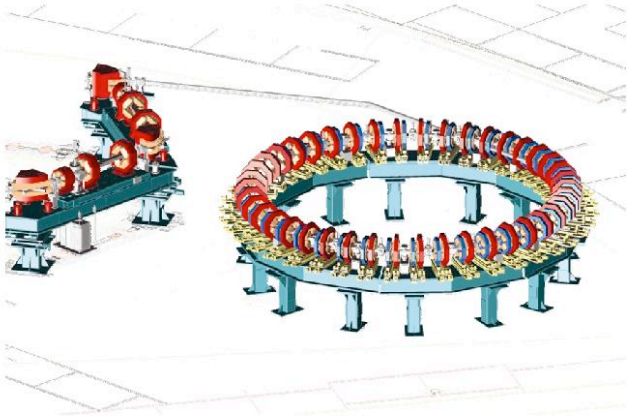
FFAG works as expected?

- Do we have enough knowledge of this new machine?

- Demonstration of a linear nonscaling Fixed Field Alternating Gradient Accelerator; EMMA.
- EMMA was (and still is)

  Electron Model of Muon Accelerator
- Although it is now called

  Electron Model for Many Applications



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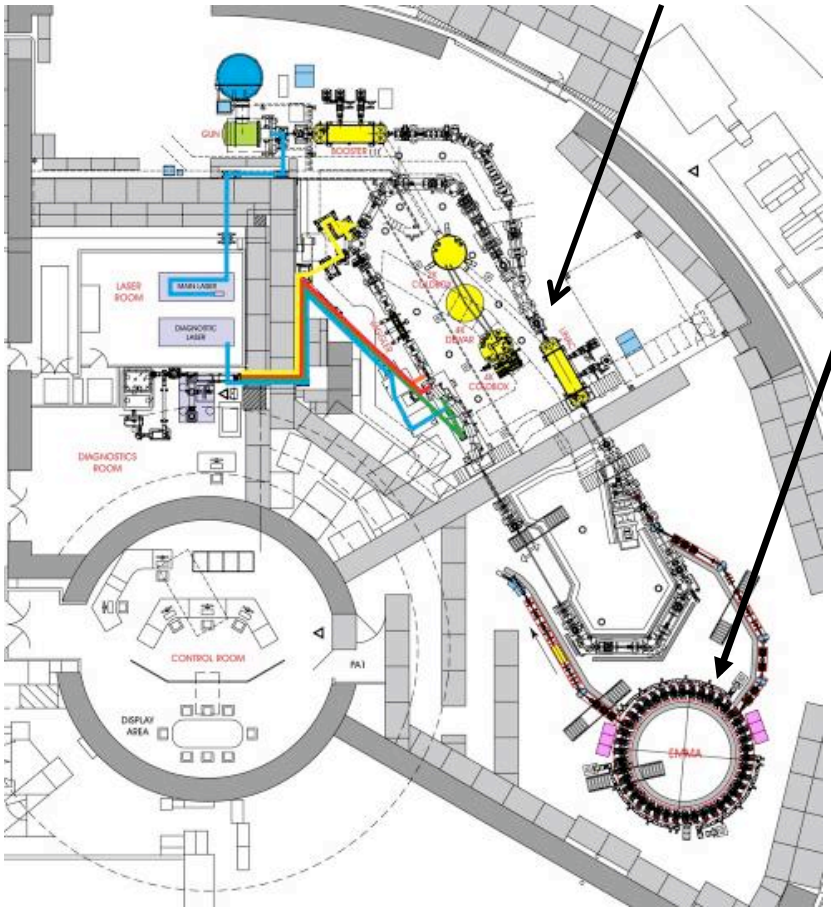
ALICE/EMMA at Daresbury

Accelerators and Lasers in Combined Experiments



EMMA

Parameter	Value
Particle	electron
Momentum	10.5 to 20.5 MeV/c
Cell	42 doublet
Circumference	16.57 m
RF Frequency	1.3 GHz
RF voltage	2 MV with 19 cavities

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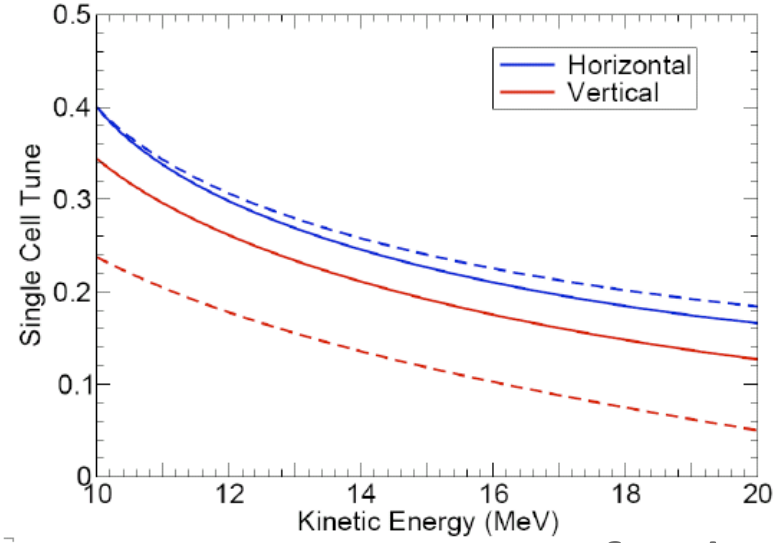
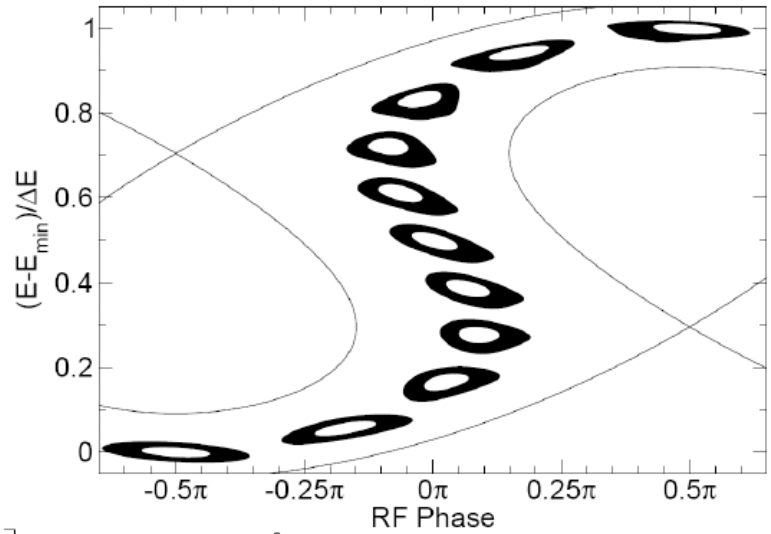
Goals

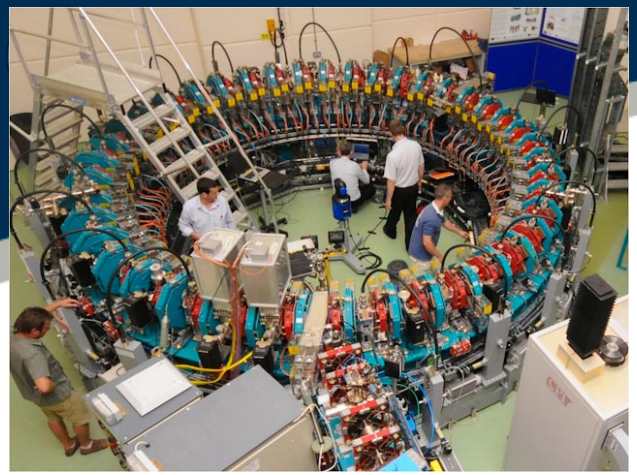
- Rapid acceleration with large tune variation due to natural chromaticity.
- Serpentine acceleration or acceleration outside rf bucket.

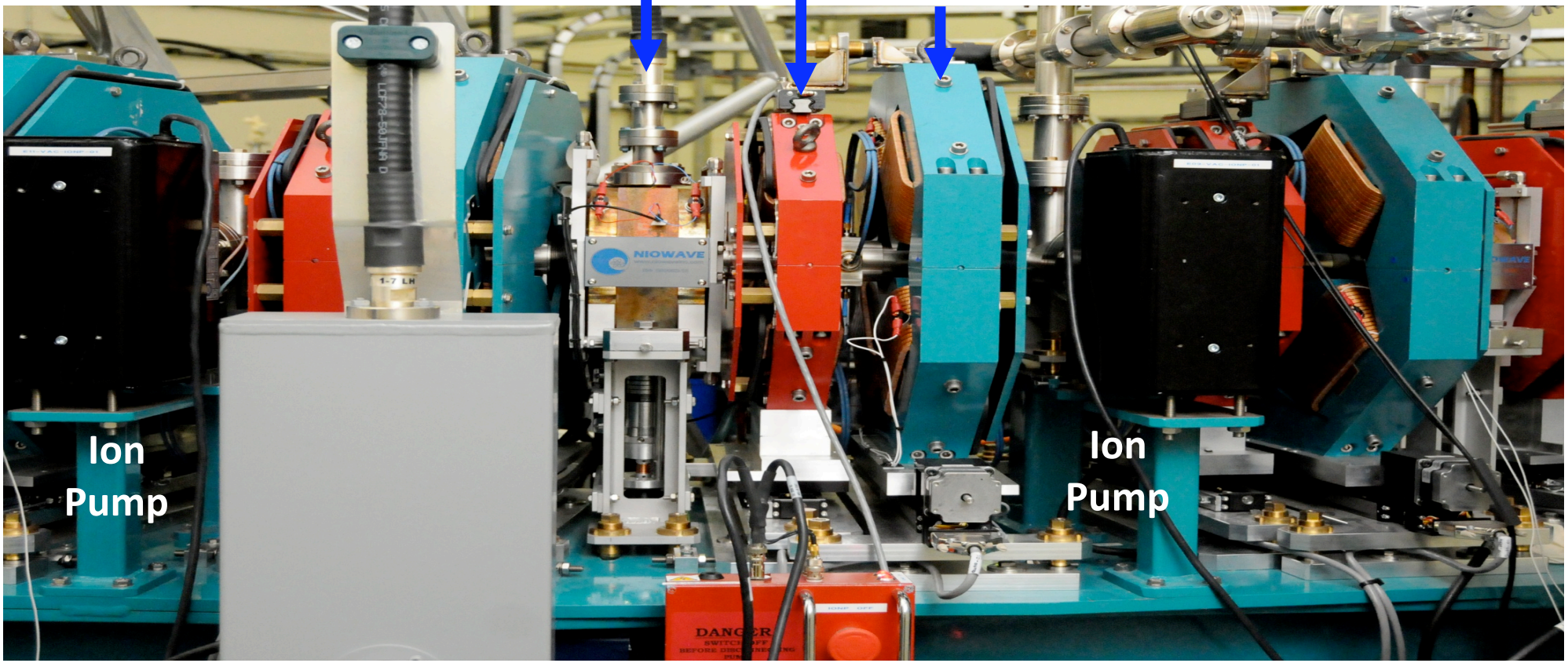




- Large acceptance for huge muon beam emittance.

EMMA in pictures





- Muon FFAG design and EMMA
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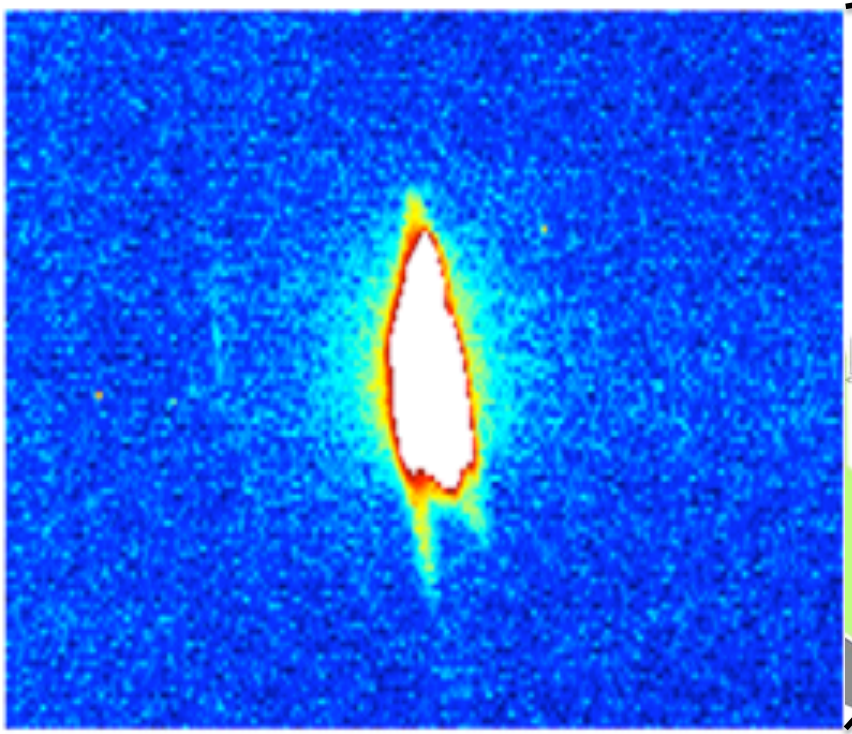
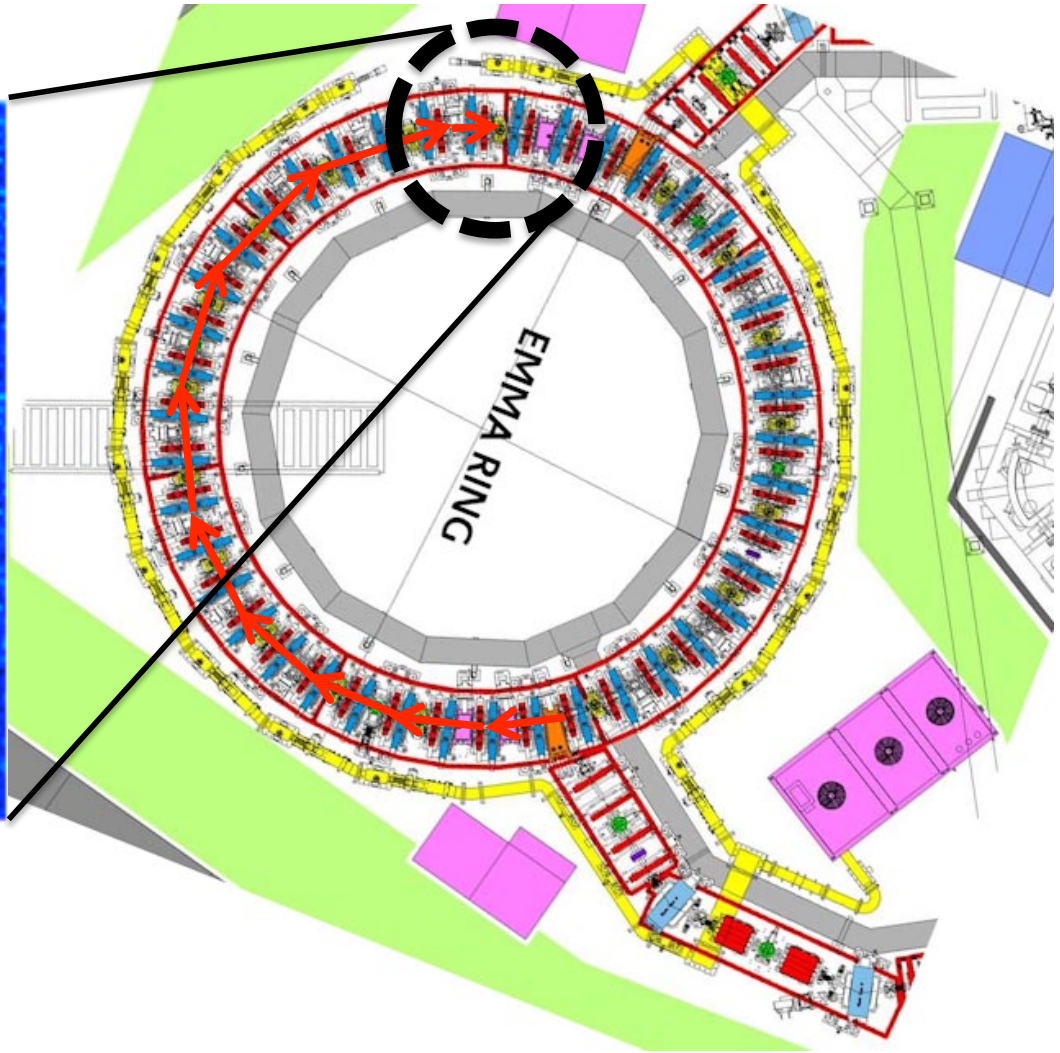
Four sector commissioning

- Beam image on screen at the end of 4 sectors.

  22:37 on 22 June 2010





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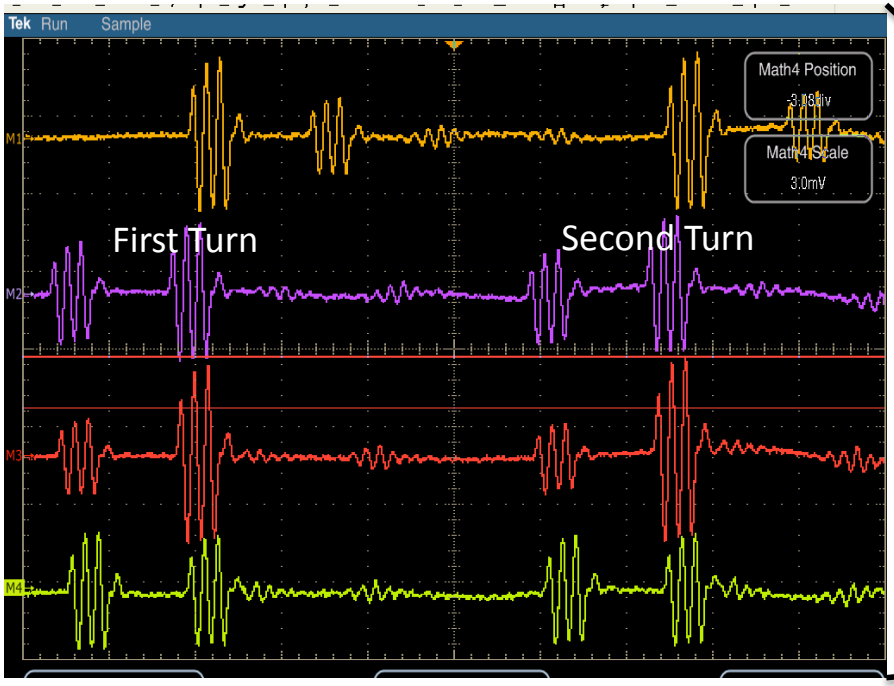
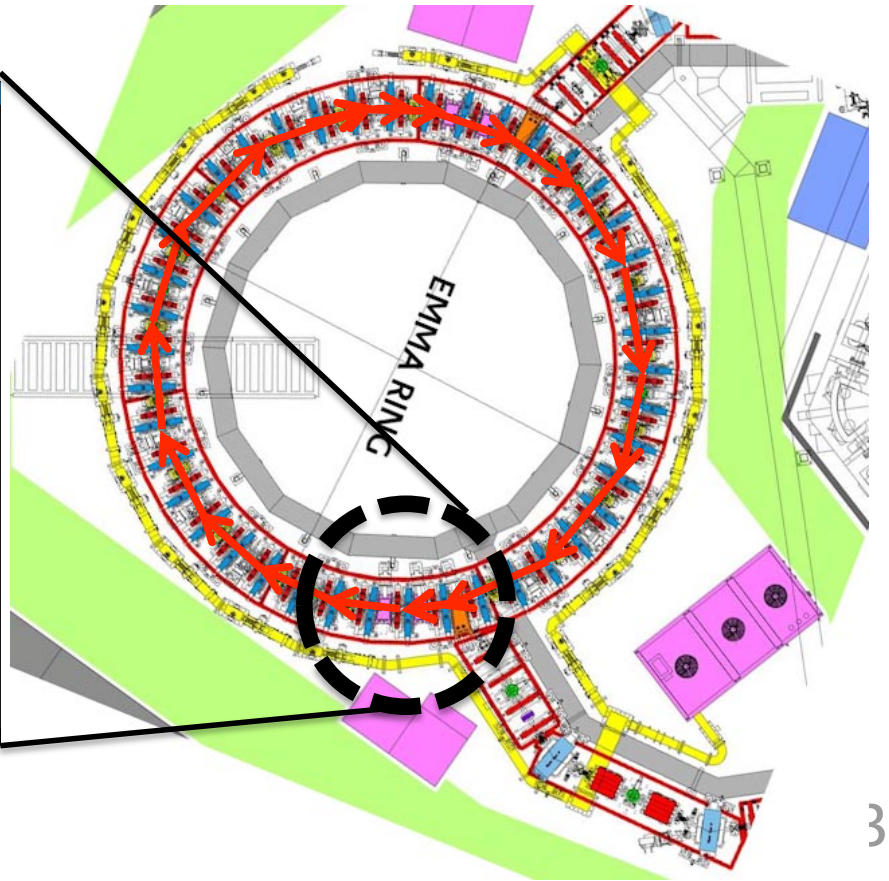
Complete ring

- A beam circulates first for three turns and then for thousands turns a few day later.

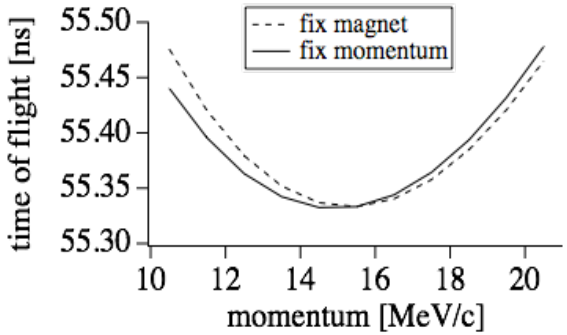
  16 August 2010

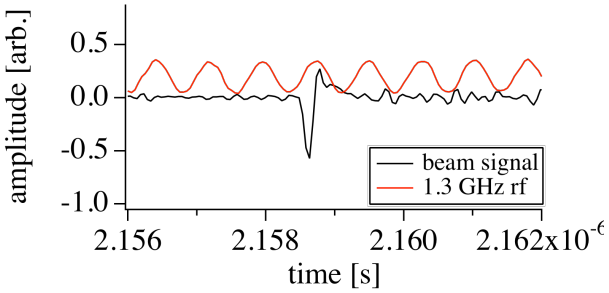




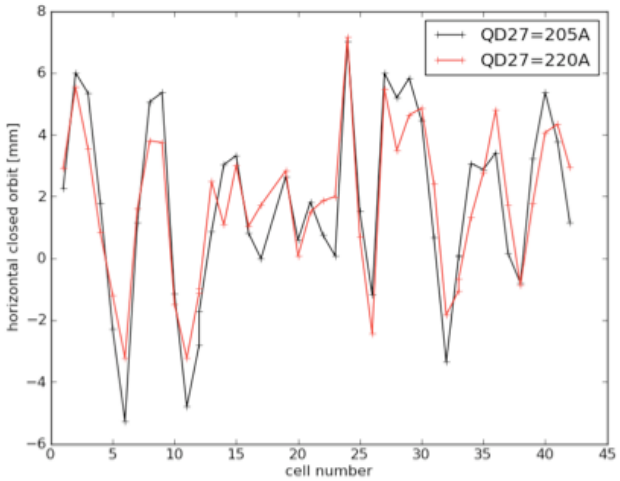
Measurement of basic parameters

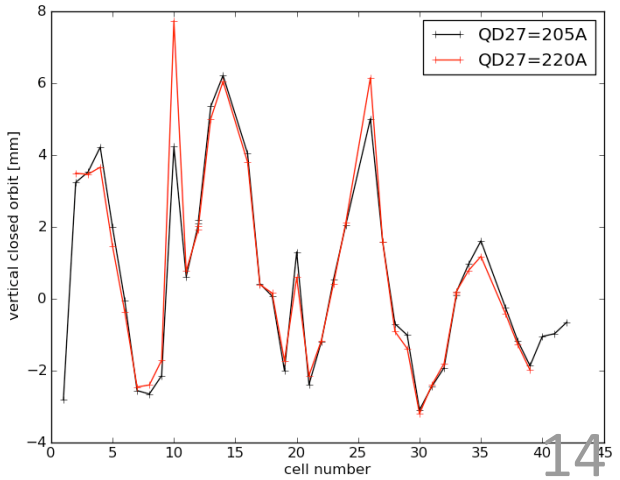
- Orbital period



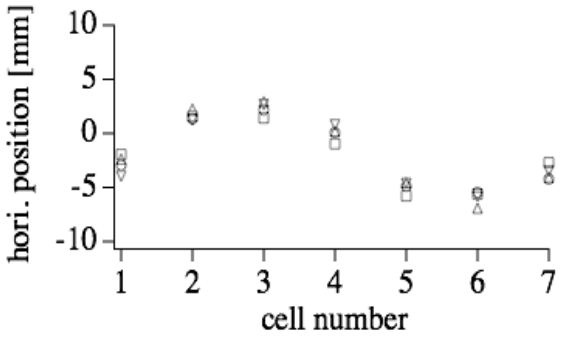


- Closed orbit





- Betatron oscillations



Tune

Dispersion

Two major problems identified

- Closed orbit distortion was rather large (~+/- 5 mm) in both horizontal and vertical.

- rf vector sum of 19 cavities was lower than expected. Cavity phase was not correctly adjusted.

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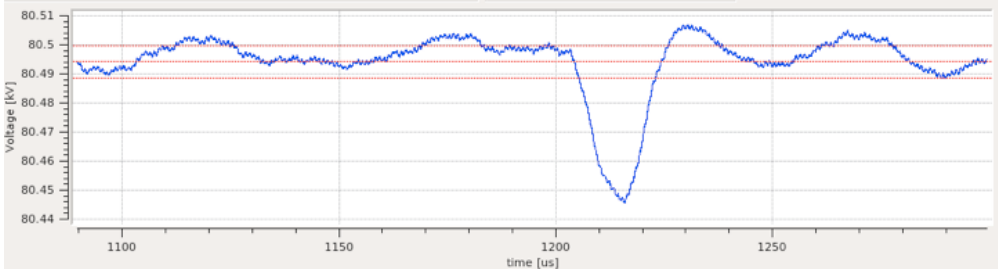
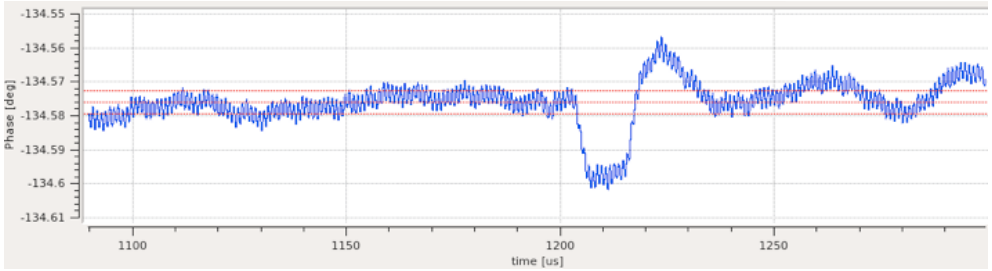
Cavity phase adjustment with beam loading signal

- Monitored amplitude



- Monitored phase



- As a function of rf phase, observe sign of loading signal.

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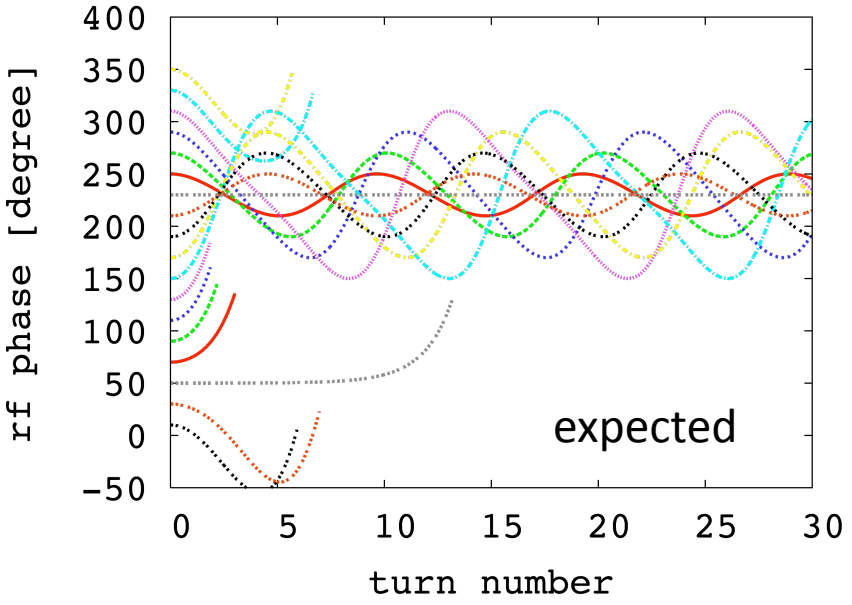
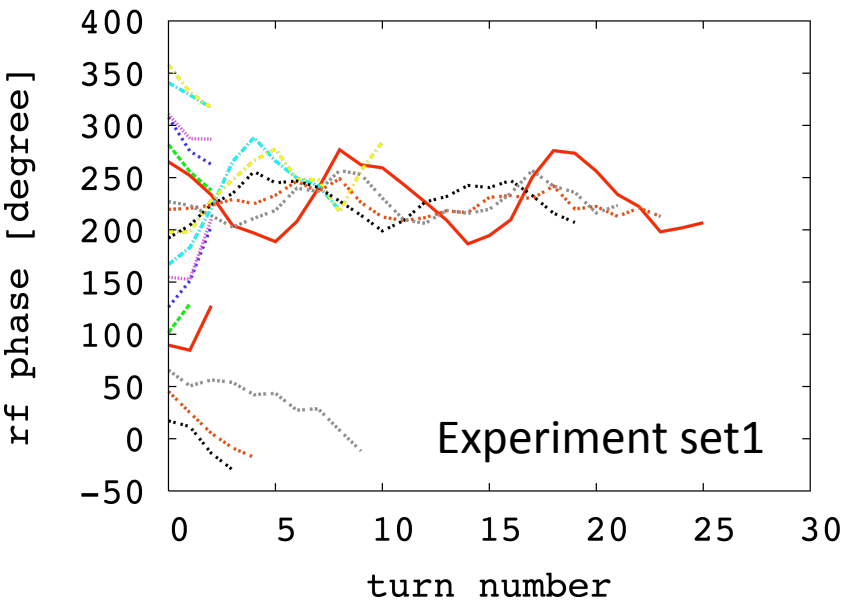
rf voltage

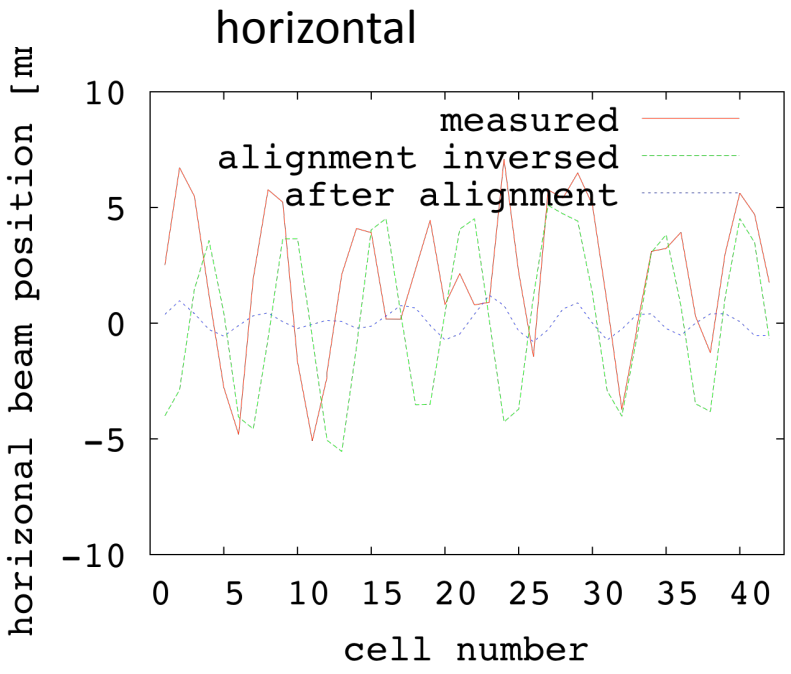
- Consistent synchrotron oscillation period in experiment and simulation suggests there is enough rf voltage.

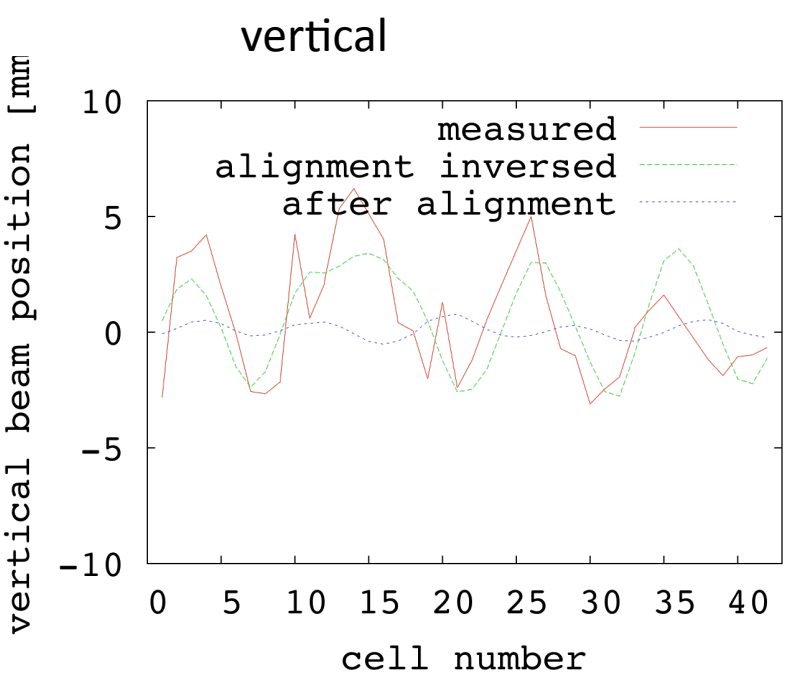




Source of COD

- Misalignment turns out worse than expected.
- Realignment during shutdown should make COD less than +/- 1 mm. But…





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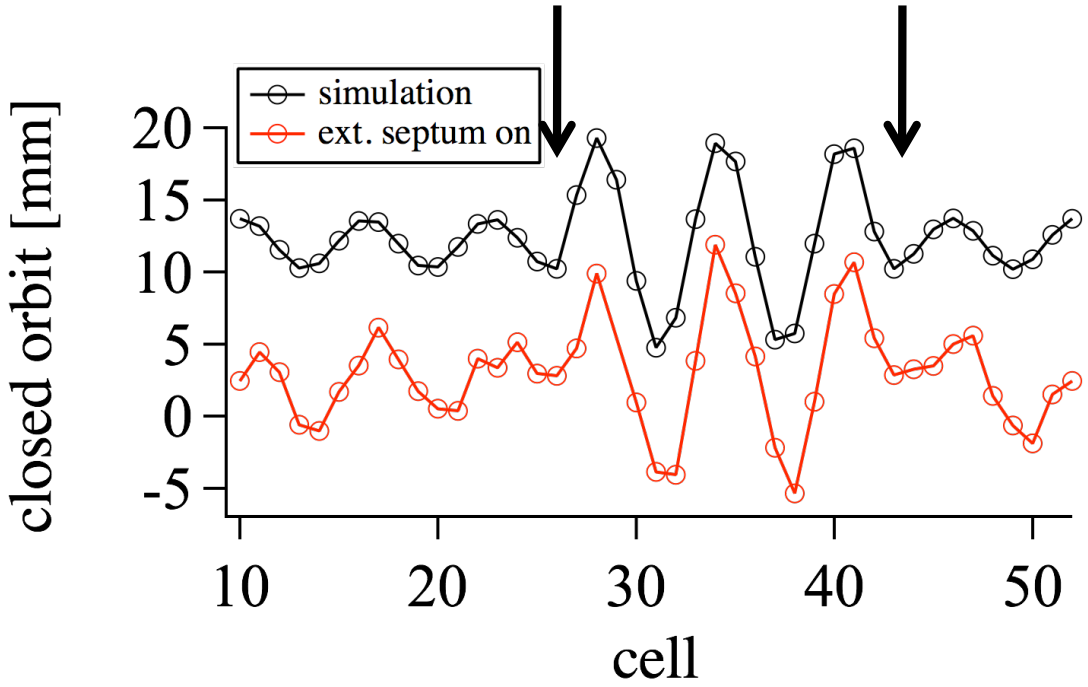
COD by both septa

- Kick with the same strength of 0.0006 [Tm] at both septa makes a similar COD observed with extraction septum on.
- Source of vertical COD is not yet identified.



Previous results

- Stability of optics with very small dispersion function has been shown.
- Dependence of orbital period on beam momentum is confirmed.

  Optics is fine.

- Large COD suggests integer tune crossing can be harder than initially thought.

  Acceleration seems difficult.

Quick and dirty?

- Fast acceleration with maximum possible rf voltage.

  Brute force, but why not.

- Serpentine channel acceleration should be possible with 1 MV per turn.
- Increase the voltage to ~ 2 MV and see what happen.

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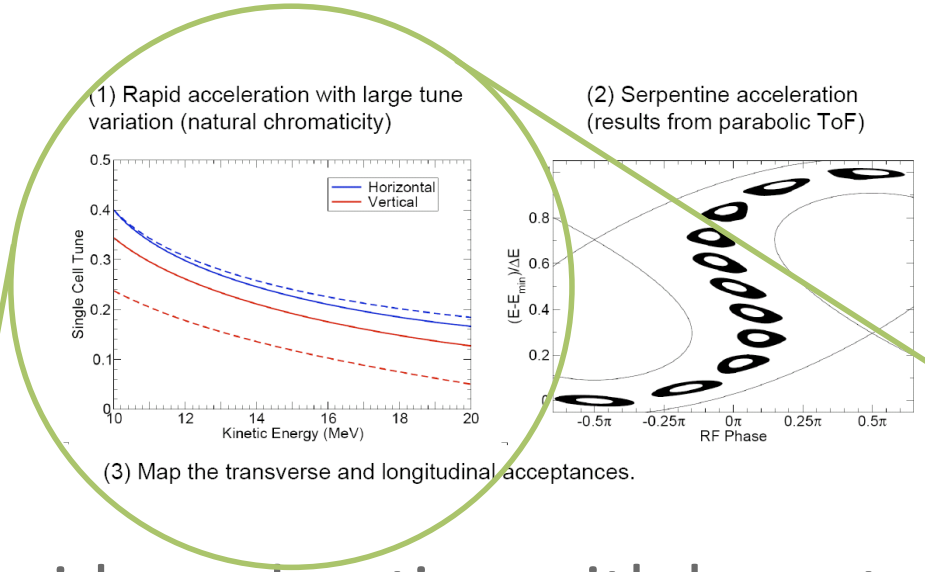
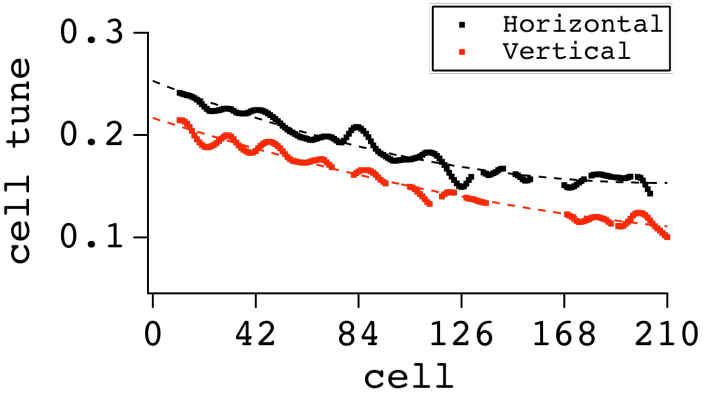
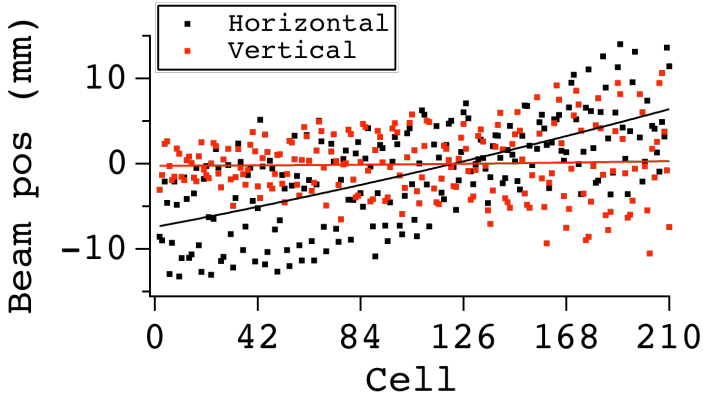
with 1.9 MV rf (1)



- Rapid acceleration with large tune variation.





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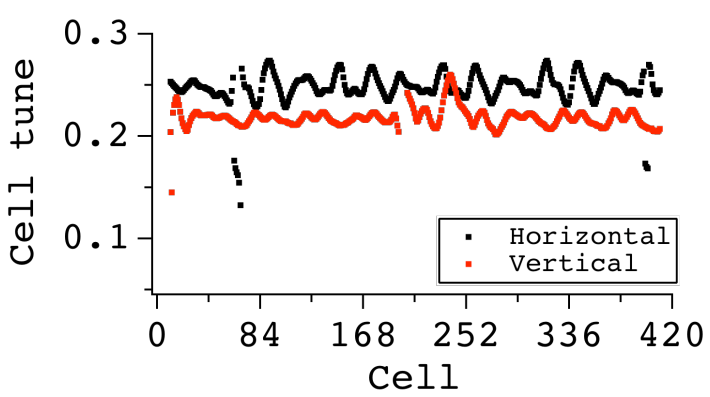
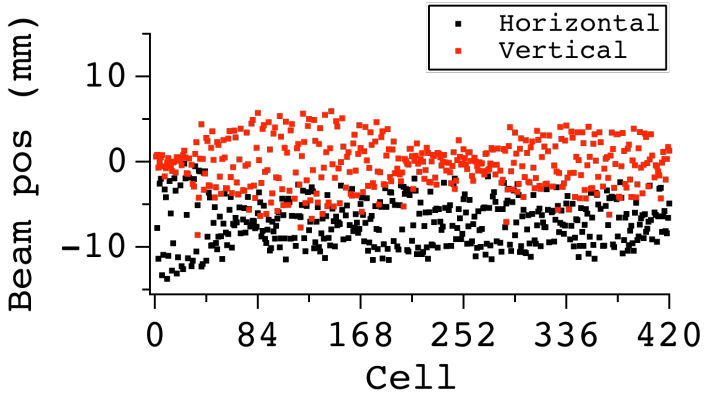
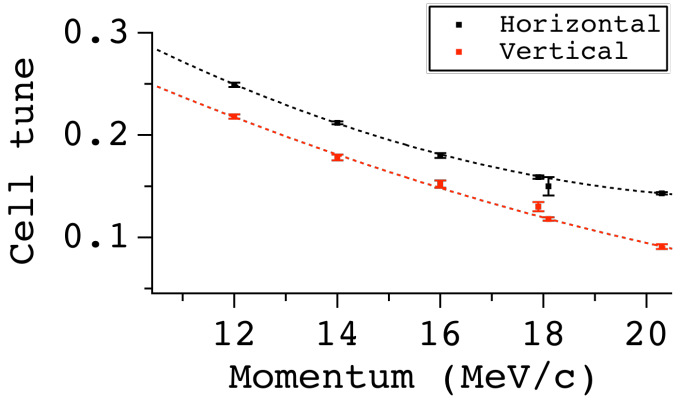
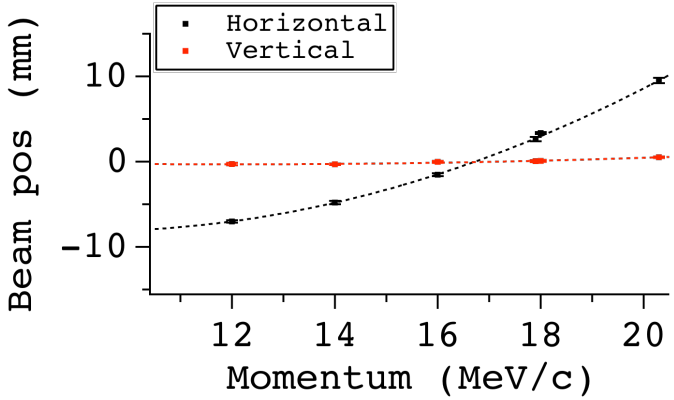
without rf

- Beam position and tune

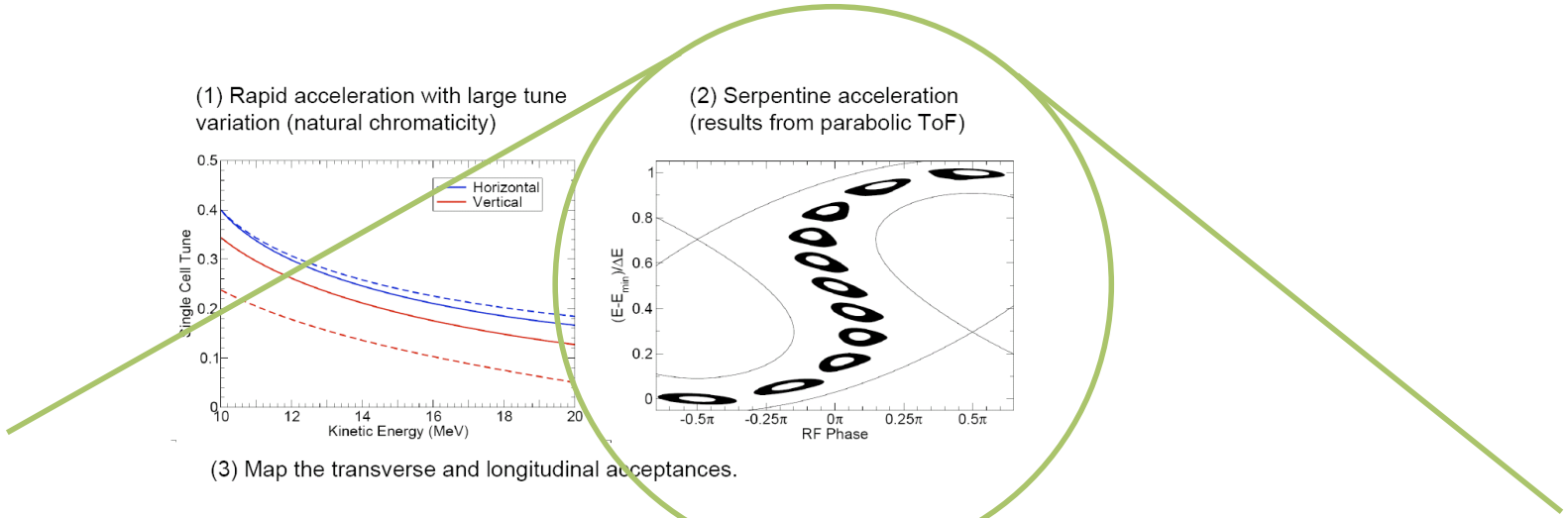




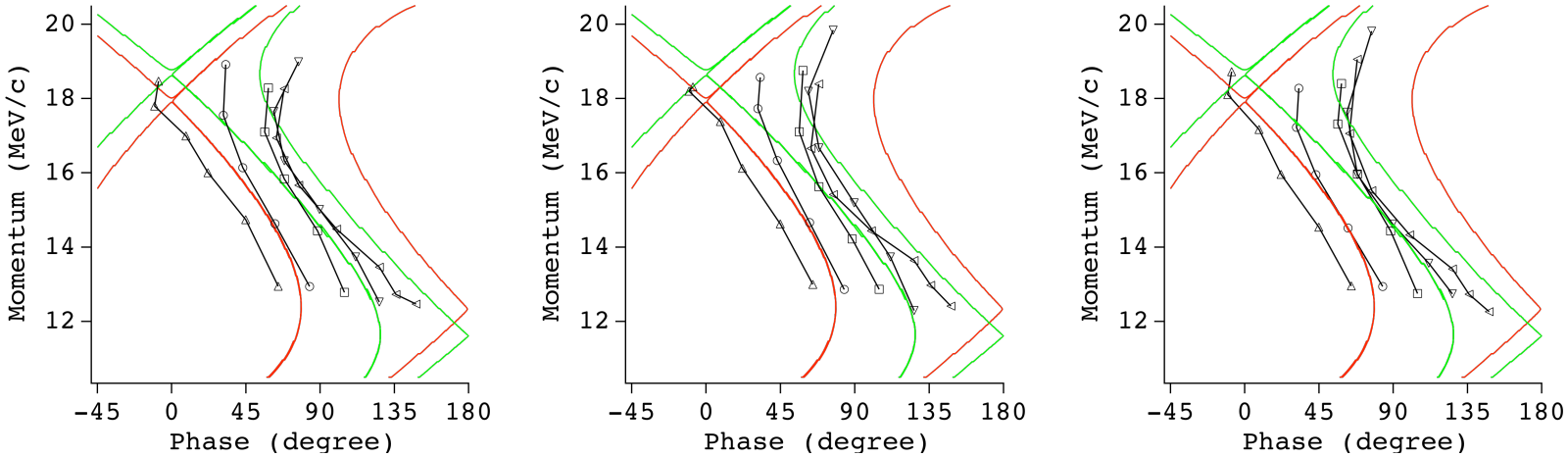




with 1.9 MV rf (2)



- Serpentine channel acceleration



P from H orbit from H tune from V tune

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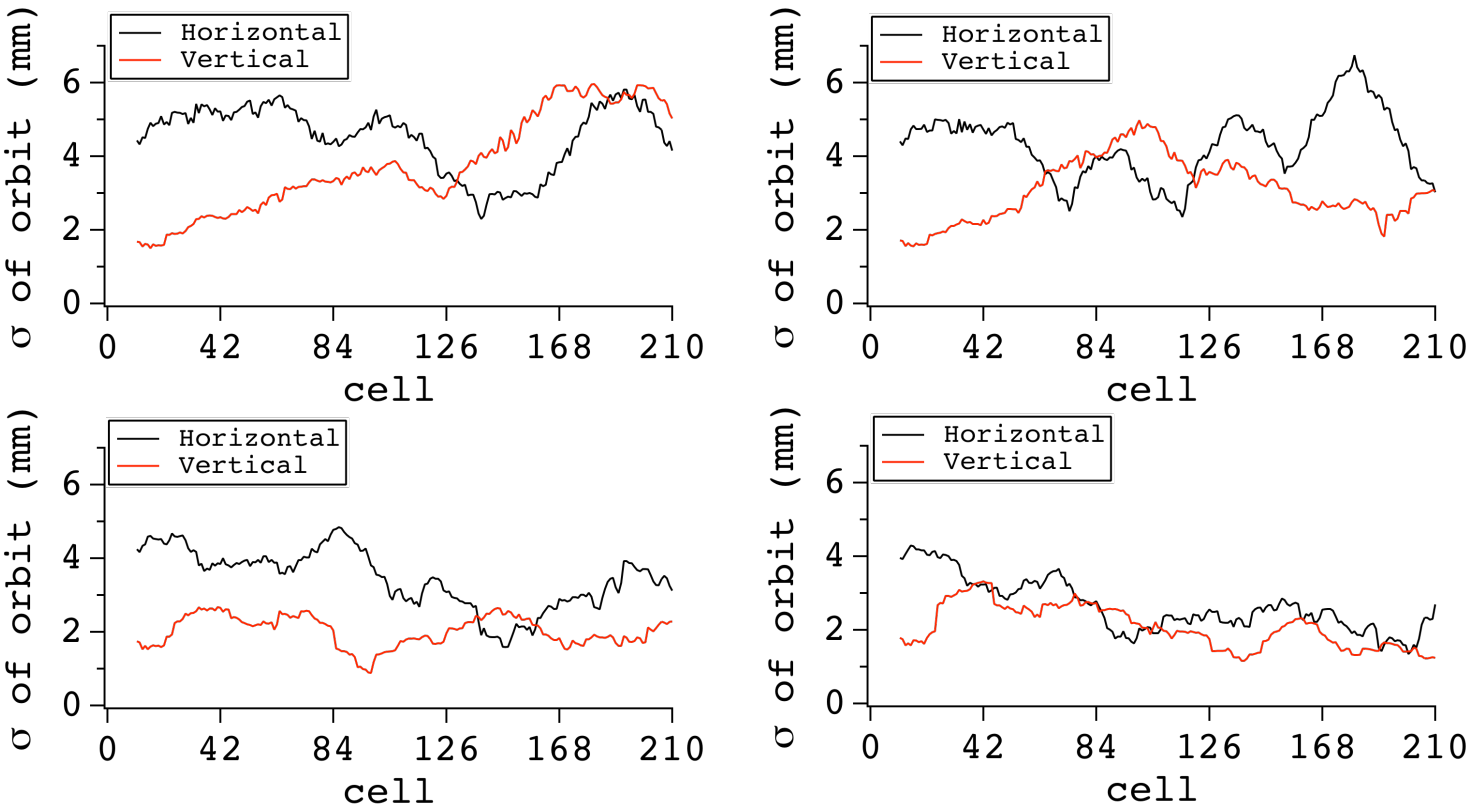
with 1.9 MV rf (3)

- Not much distortion to betatron oscillations with inter tune crossing.

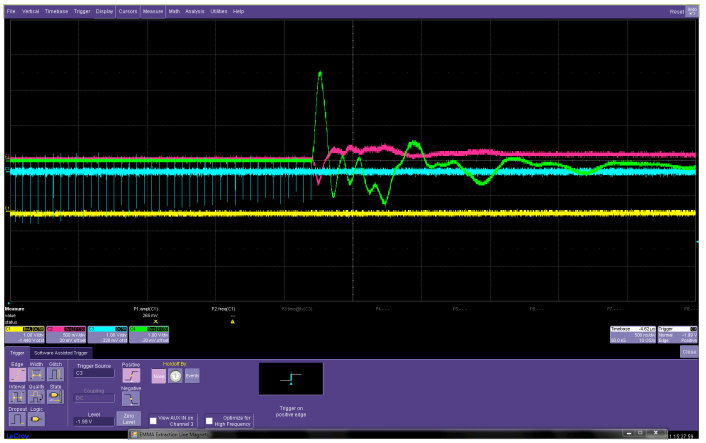


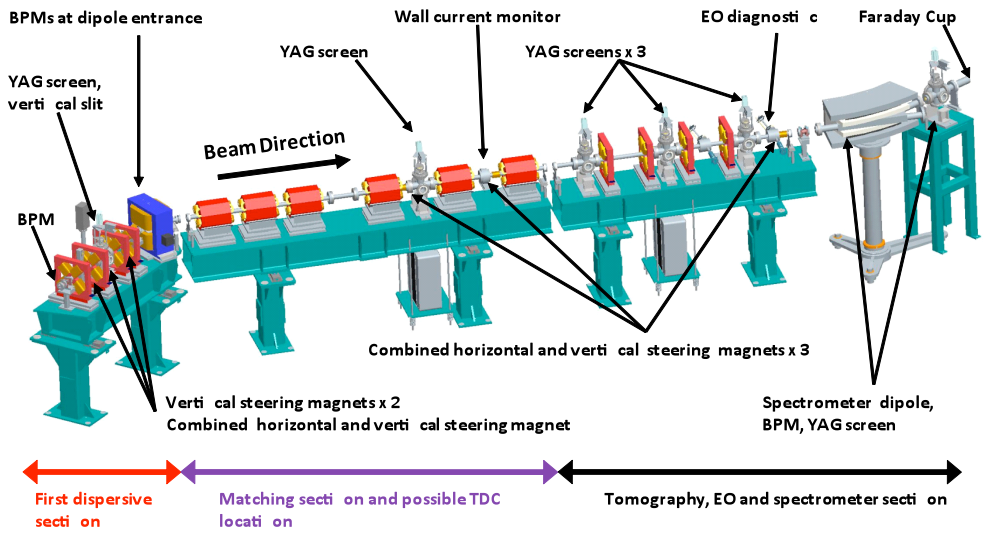
Extracted beam

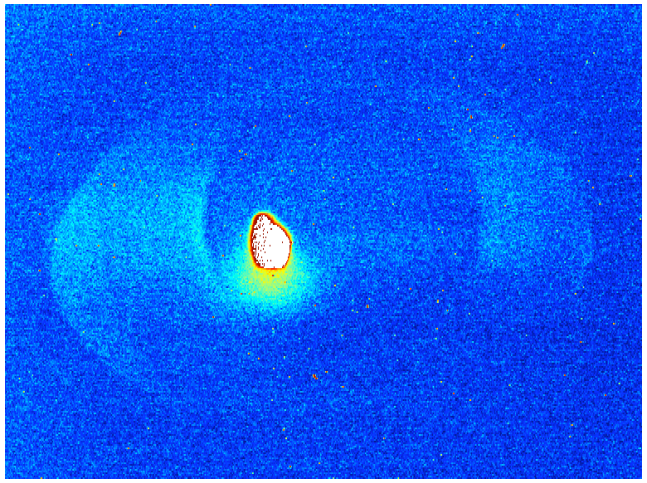
- Beam line after extraction.

  Dipole strength confirms momentum increase.

Green: beam inside
Blue: kicker







YAG screen image

- Muon FFAG design and EMMA
- EMMA Commissioning results
- Future plans and EMMA upgrade

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Where we are now?

- "Proof of principle" phase (~publication of a letter)

  June to October 2010: injection, lattice tuning, measurement of basic parameters, rf setup

  January to March 2011: acceleration/deceleration

- Detailed measurement (~publication of full papers)

  April 2011 to March 2013: list in the following page

Plan for the next 1~2 yrs (1)

more EMMA run

- Serpentine channel acceleration
  - Set frequency and voltage to achieve desired parameters
  - Accelerate point beam
  - Measure mapping of longitudinal phase space
  - Study parameter dependence of longitudinal phase space
  - Dependence of transverse amplitude, etc.
- Acceleration with varying phase advance
  - Effect of magnet errors
  - Slowly cross individual resonance
  - Examine effects of space charge, etc.

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Plan for the next 1~2 yrs (2)

more EMMA run (continued)

- Show large longitudinal and transverse acceptance
  - Scan injected beam in horizontal phase space
  - Scan injected beam in vertical phase space
  - Scan injected beam in longitudinal phase space, etc.

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Plan for the next 1~2 yrs (3)

Installation of peripheral equipments

- Injection line additional diagnostics
  - BPM at end of injection line to optimise septum entry angle
- Install collimators in diagnostics line
  - Better understanding of off closed orbit beam
- Remote control room
  - Give external labs control of EMMA and ancillaries for dedicated experiments
  - Promotes collaboration and expertise exchange

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Summary

- EMMA proves that a linear nonscaling FFAG works. A big step forward to the muon acceleration in NF.

- Main goals are achieved by March 2011.
  - Still need to show large acceptance for NF.
- So far, no big surprise.
- In two years, we will gain much more knowledge, both design and operational view point, on a linear nonscaling FFAG.

Thank you for your attention.

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Muon FFAG and EMMA

	Muon FFAG	EMMA	Ratio
Momentum	12.6 – 25 GeV/c	10 – 20 MeV/c	1 : 0.001
rf voltage	1214 MV	2.28 MV	1 : 0.002
Number of cell	64	42	1 : 0.66
Circumference	667 m	16.6 m	1 : 0.025
QD/QF length	2.251/1.087 m	0.0777/0.0588 m	1 : 0.035/0.054
Straight section	5 m	0.2 m	1 : 0.04
Aperture	~ 300 mm	~ 30 mm	1 : 0.1

- Requirement of rf is much lower, a factor of 1000.
- Space is more packed in longitudinal than in transverse.

  Relatively large aperture magnets.

  Injection/extraction might be harder than Muon FFAG.

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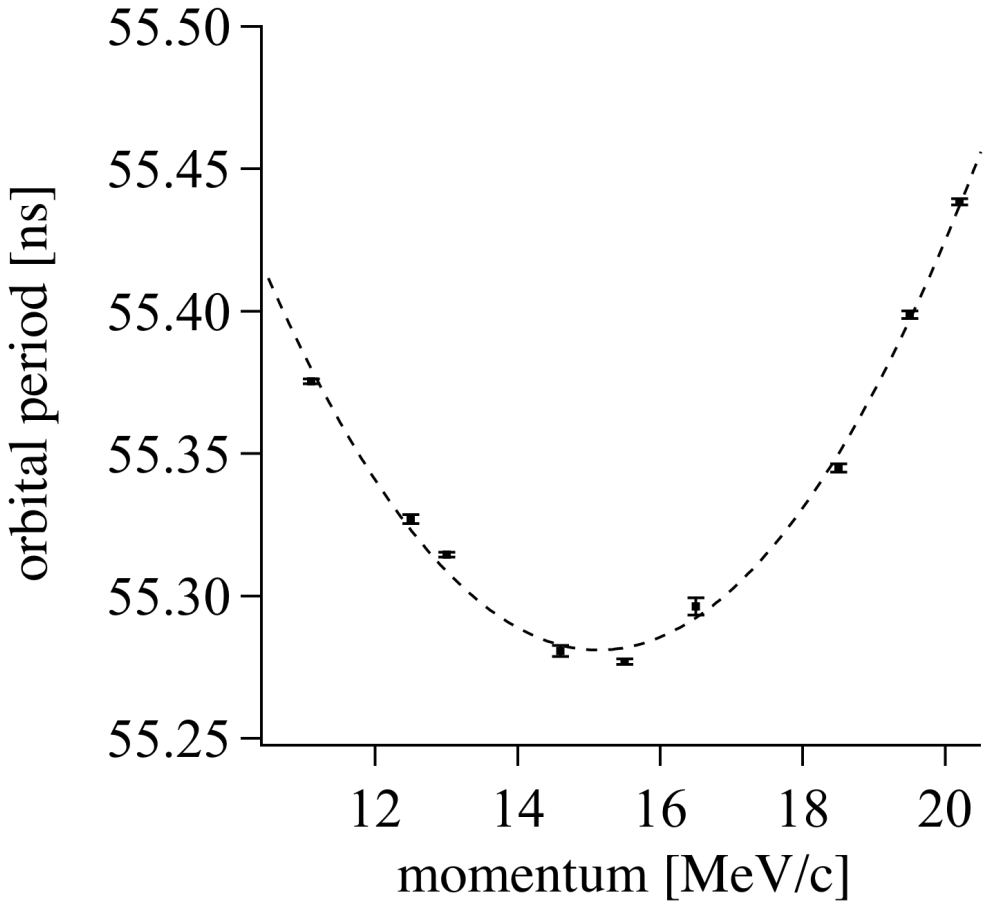
Orbital period

- Error bars are only statistical.



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Toward acceleration

- Signal suggests only a few MeV gain or loss.