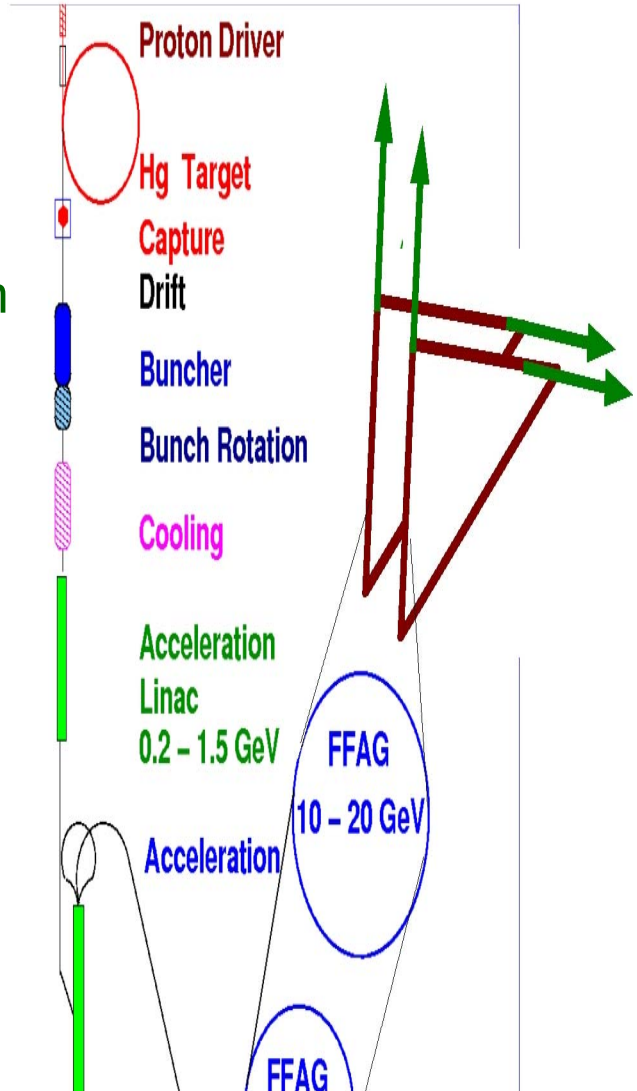
EMMA

- Introduction
- Requirements
- Funding
- Machine design
- Hardware status
- Conclusions

Introduction

- NS-FFAGs: part of baseline
- No such machine ever built:
  - resonance crossings
  - asynchronous acceleration
  - tiny momentum compaction
- Need EMMA
- Funding: generic as possible
- Study proton, carbon, etc
- Proof-of-principle NS-FFAG
- Main emphasis: still muons



Requirements

- Demonstrate that non-scaling optics work
- Study resonances in detail:
  - emittance growth vs acceleration rate
  - " " vs tune variation
  - " " vs parabola shape
  - effect of errors
  - detailed probe using injector
- Study longitudinal dynamics in detail:
  - transmission vs parameter values
  - emittance growth vs parameter values
  - tof behaviour; effect of non-parabolic nature
  - effect of moving parabola
  - effect of errors
- Check effect of transverse dynamics
- Compare with predictions
- .....

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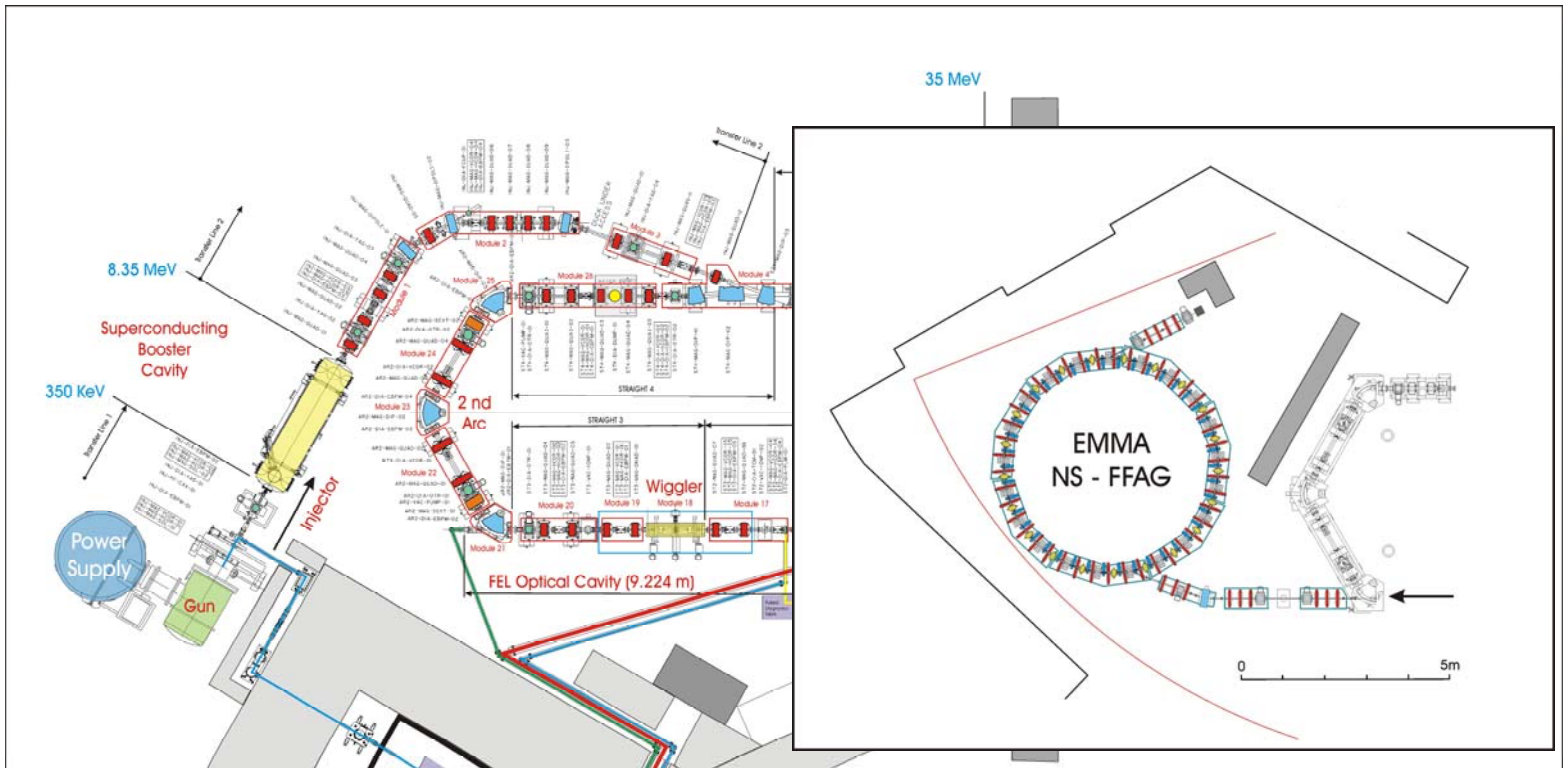
UK Involvement

- Needs a flexible injector:
  - injection at any energy
  - small emittance
  - sufficient intensity in a single bunch

Energy Recovery Linac Prototype at DL



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Funding

- EMMA collaboration: Adams, BNL, CCLRC, CERN, Cockcroft, Grenoble, FNAL, Rostock, TRIUMF
- EU FP6 – too big
- UK Basic Technology:
  - generic as possible
  - three WPs
    - EMMA
    - charge particle therapy
    - other applications
- Successful!
- Funding starts 1st March
- Work already started
- Total: £8.2M
- For EMMA construction: £5.6M

EMMA

Funding

Item	Cost / £k
RF cavity system	1641
Diagnostics	492
Magnets	502
Mechanical and vacuum chamber	391
Vacuum equipment	134
Controls	122
Electrical	443
Cooling and services	70
Civil engineering	34
Hardware sub-total	*3830*
Staff	1808
TOTAL	**£5638k**

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EMMA Design

- 1st attempt: July 2006 (for BT proposal)
- Design Reviews:
  - 30th November
  - 4th-5th January: fixed some parameters
    nothing is easy!
  - 26th-28th February: start of change control
- Basic lattice:
  - 10-20 MeV (scaling)
  - Doublet (cost?)
  - 42 cells (number of cell.turns)
  - 1.3GHz RF (scaling + ERLP)
  - 19 cavities (see later!)
  - 394.481mm cell length
  - 16.57m circumference
- EMMA operation:
  - 20Hz
  - 1 bunch
  - 80pC
  - $\varepsilon_{n,rms} = 3\pi$ mm mrad
  - 2ps rms length
  - scan aperture
- Documentation at:
  http://www.conform.ac.uk/documents/emma

EMMA

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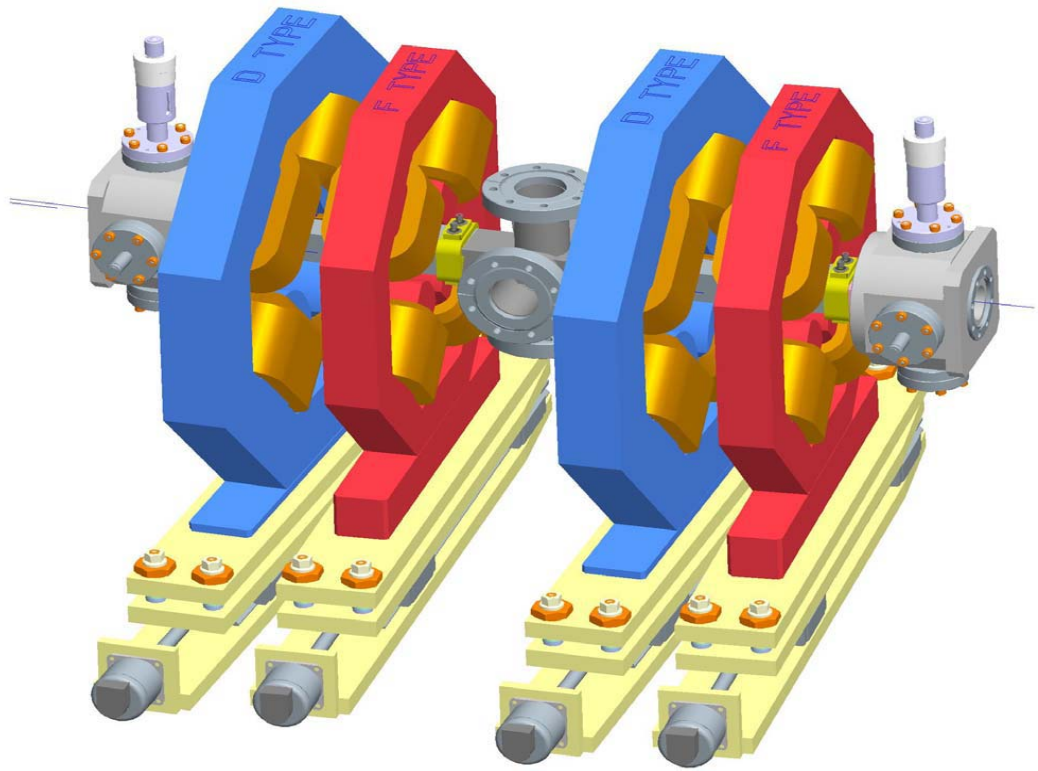

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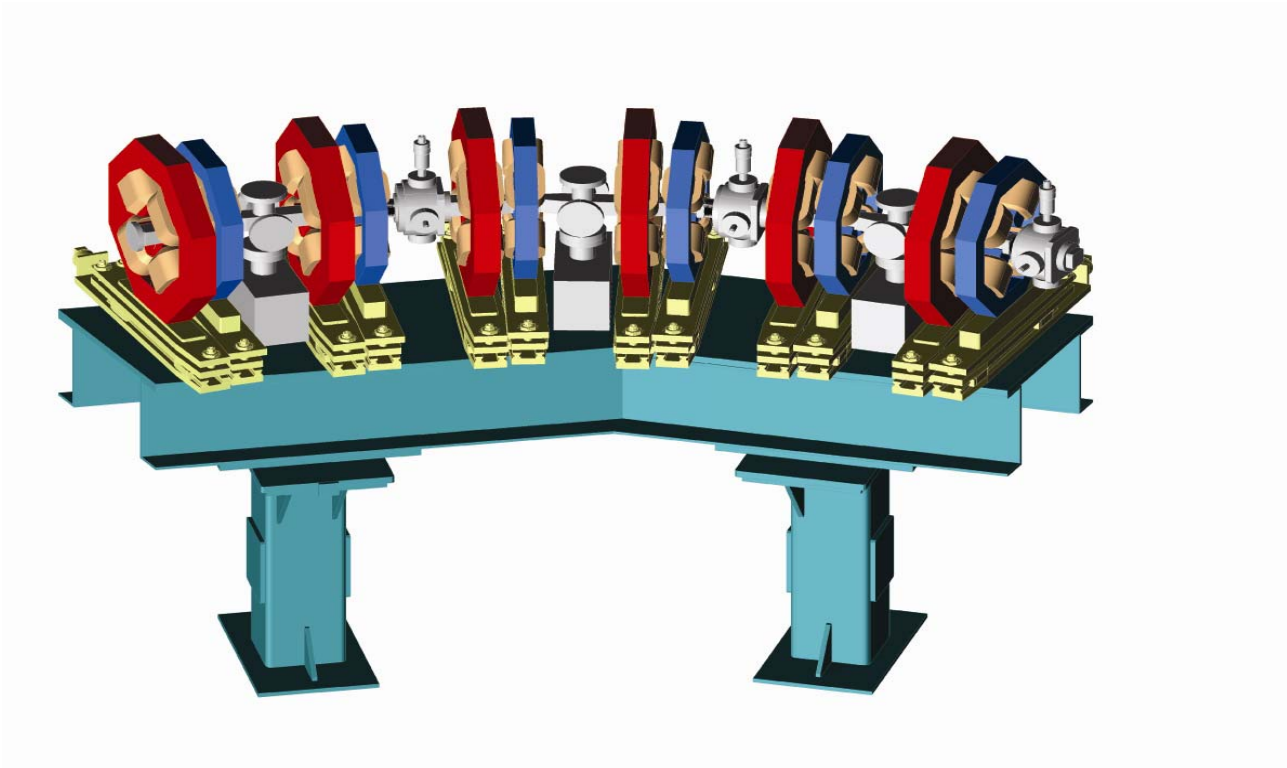

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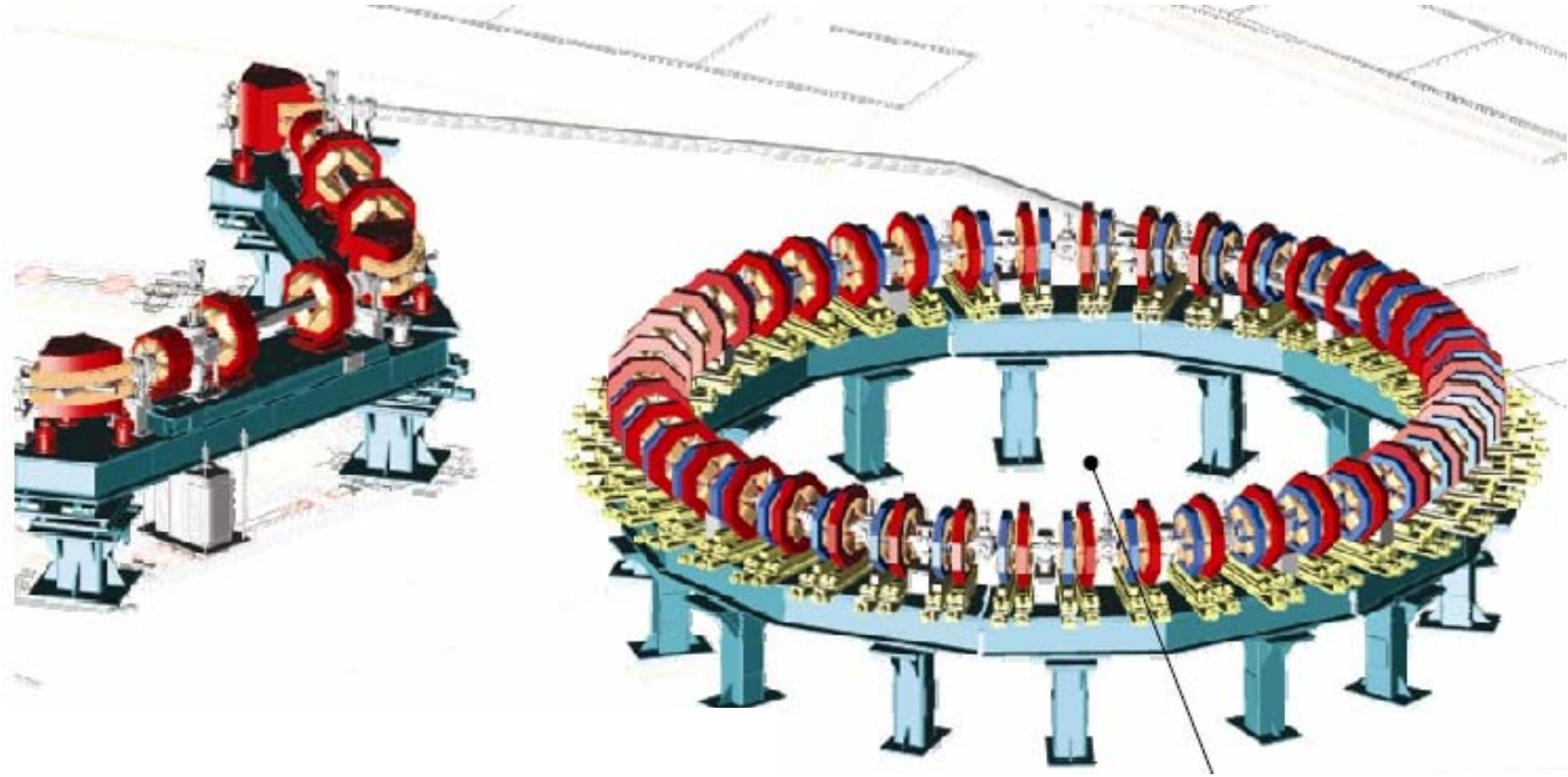

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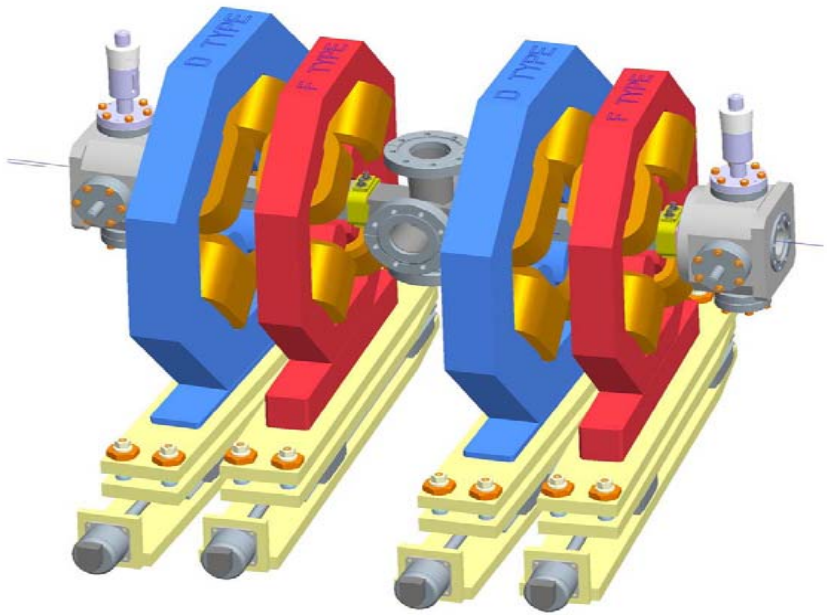
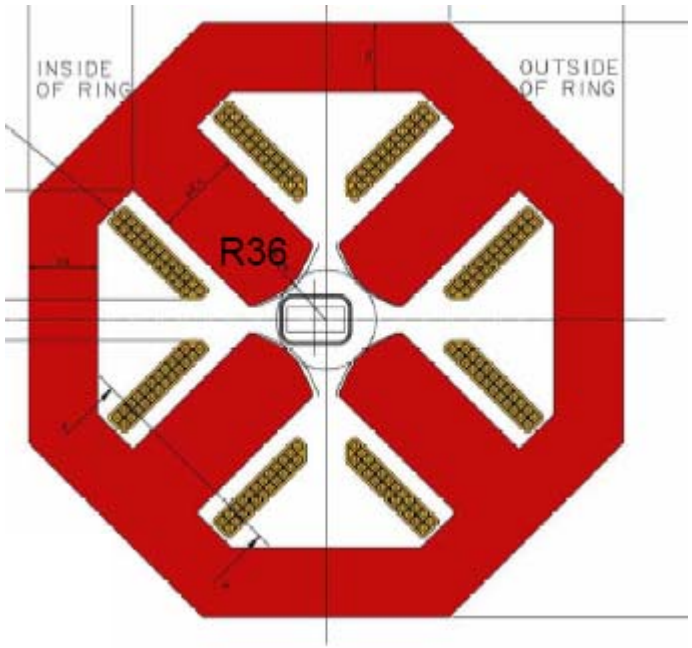
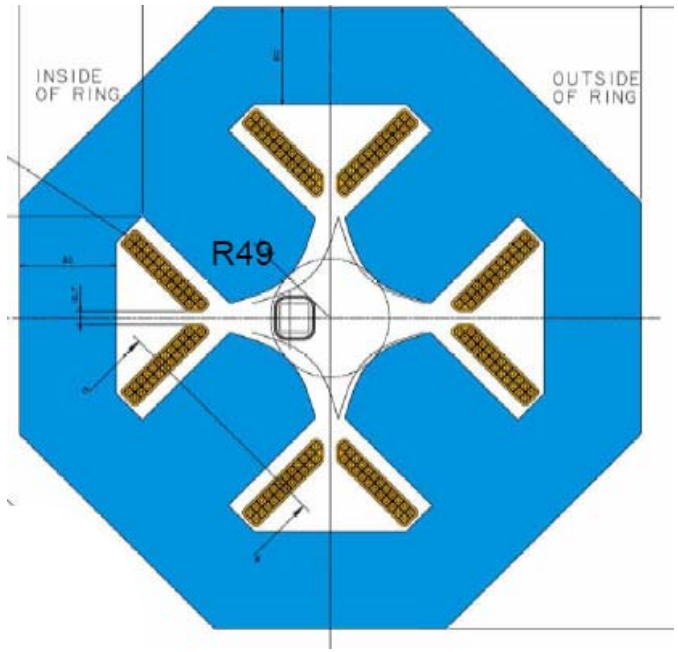
Magnets

- Main requirement: independent di- and quadrupoles
- Magnets are mainly quads



Magnets



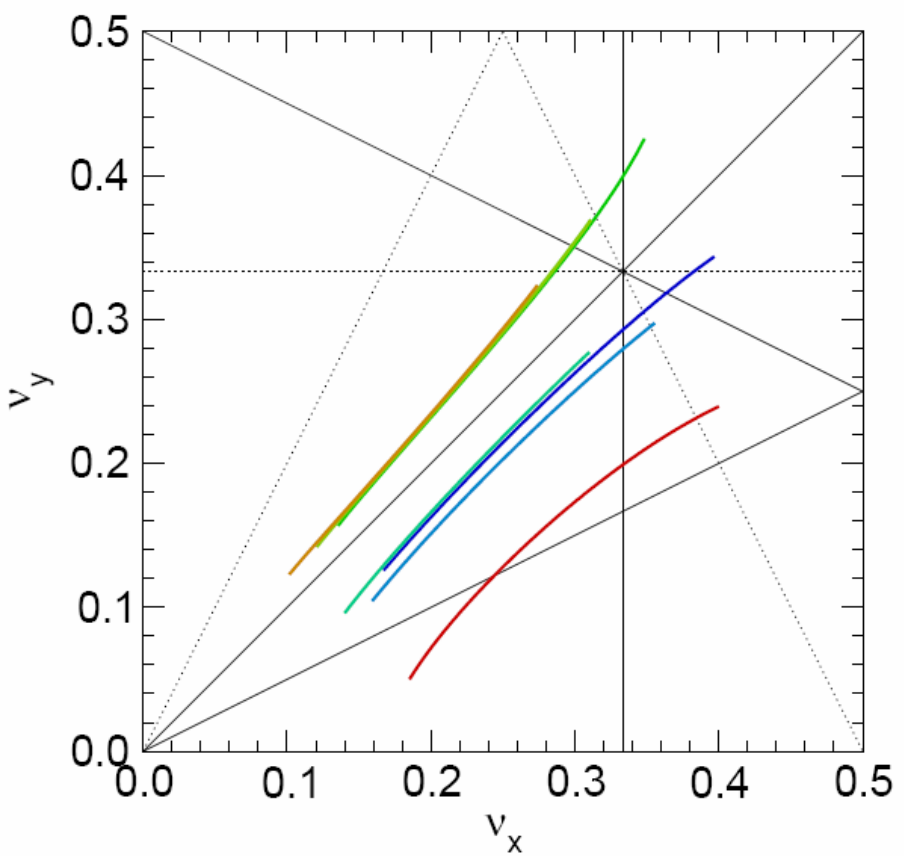


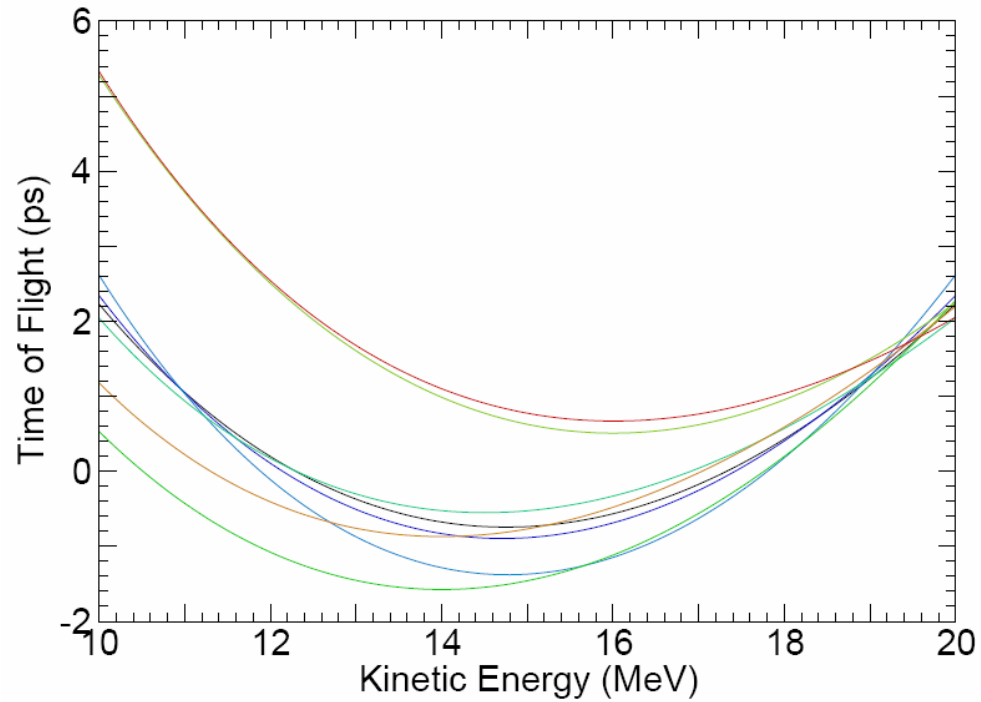
Pipe apertures:	-21.6 to 20.7	-6.1 to 18.8
Vertical:	17.8	23.4
Shifts:	4.9 to 10.2	28.7 to 48.6

3D modelling underway

Prototypes to be ordered soon

Different Lattices





RF

Requirements:

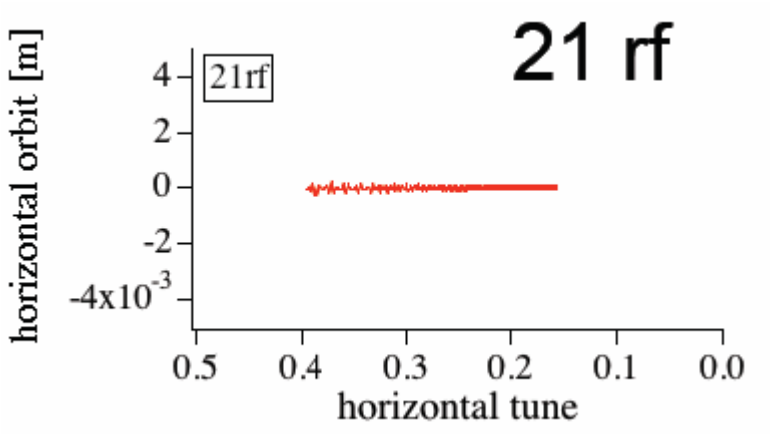
- Maximum total voltage: 5MV(!)
- Allowable max voltage: >2.5MV
- Frequency: 1300.000, variable by -4.028 to +1.554
- Aperture: ~38mm

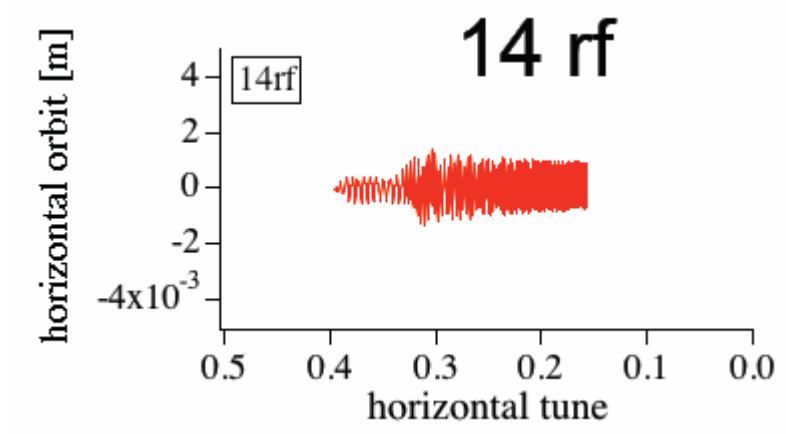
Original solution:

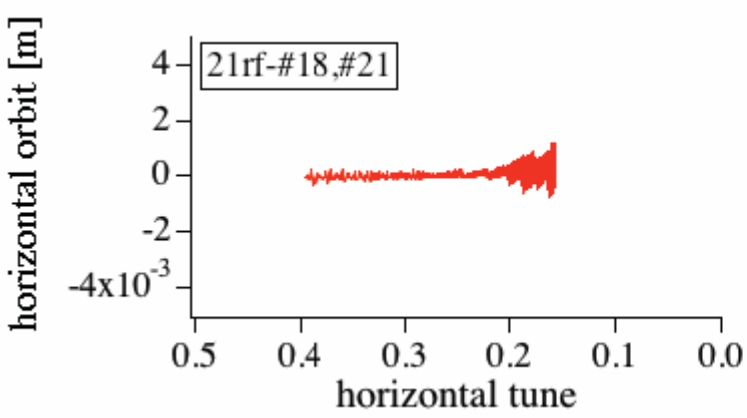
- 1 cavity every 2 cells
- 7 IOTs for power, distributed by cables
- Difficult to inject or extract
- Two possibilities:
  - 1 cavity every 3 cells
  - 1 cavity every 2 cells minus 2

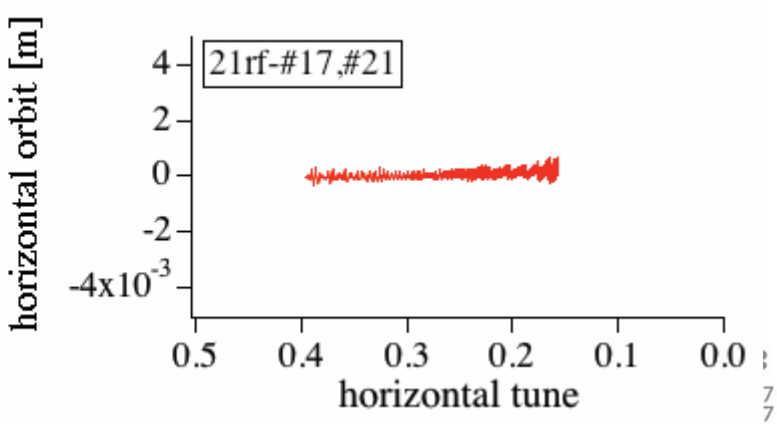
RF

Studied orbit distortion



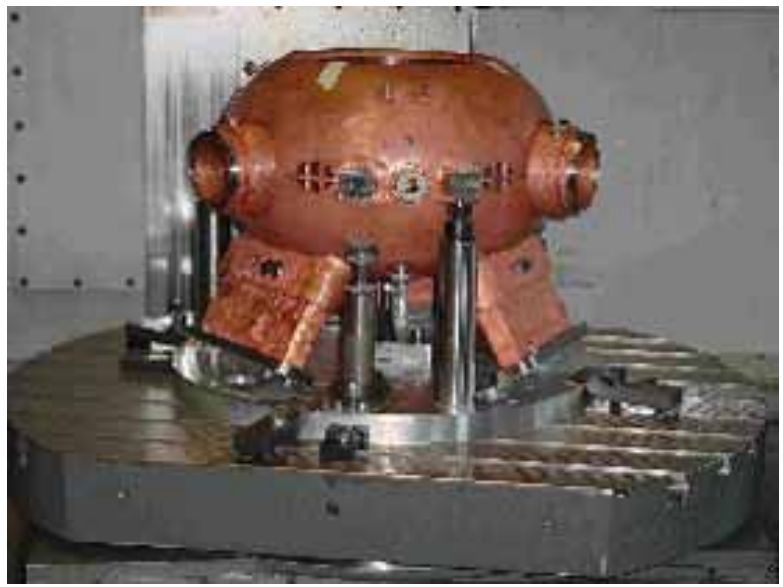


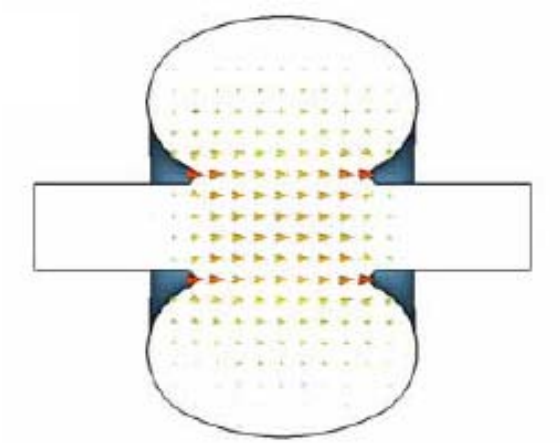




RF Cavities

- Maximising shunt impedance very important





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RF IOT

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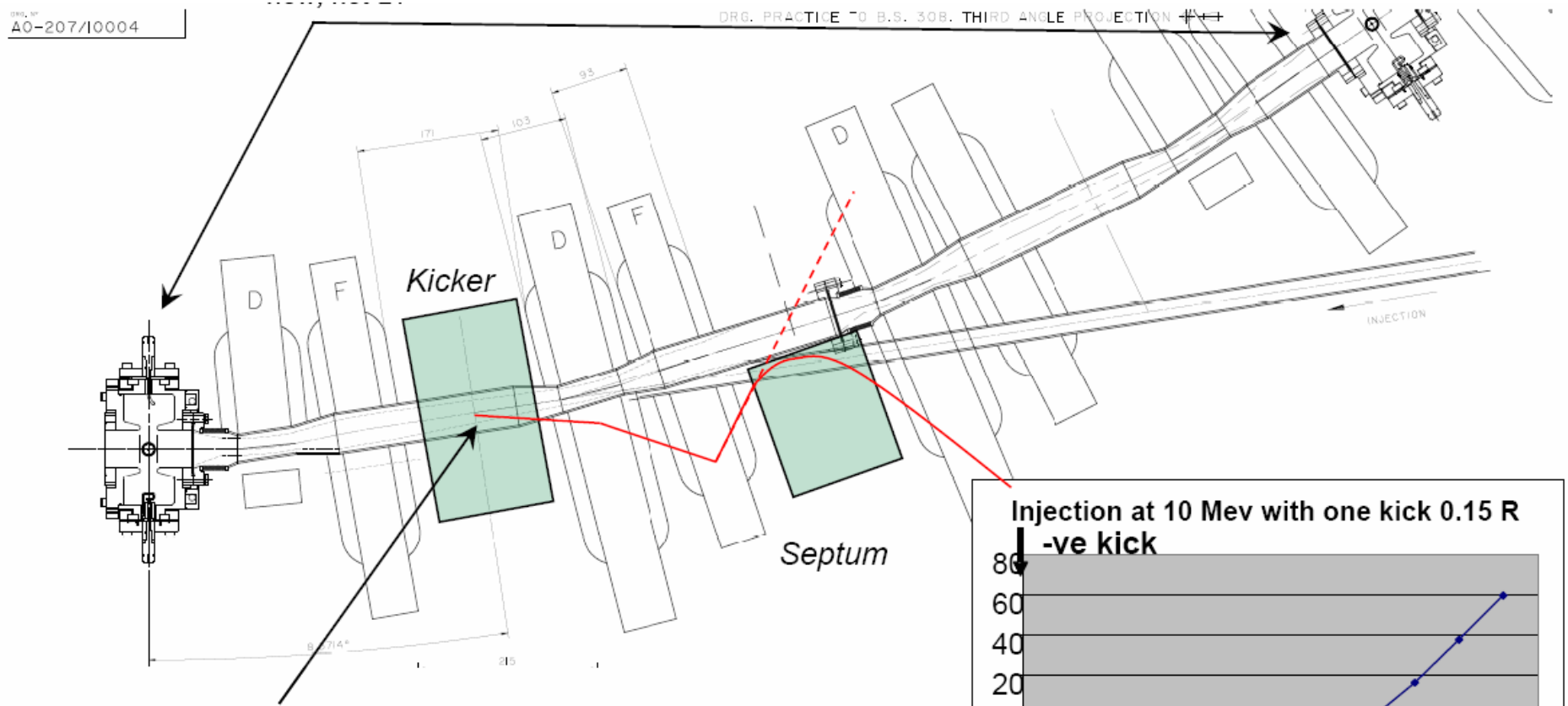
Injection and Extraction

Requirements:

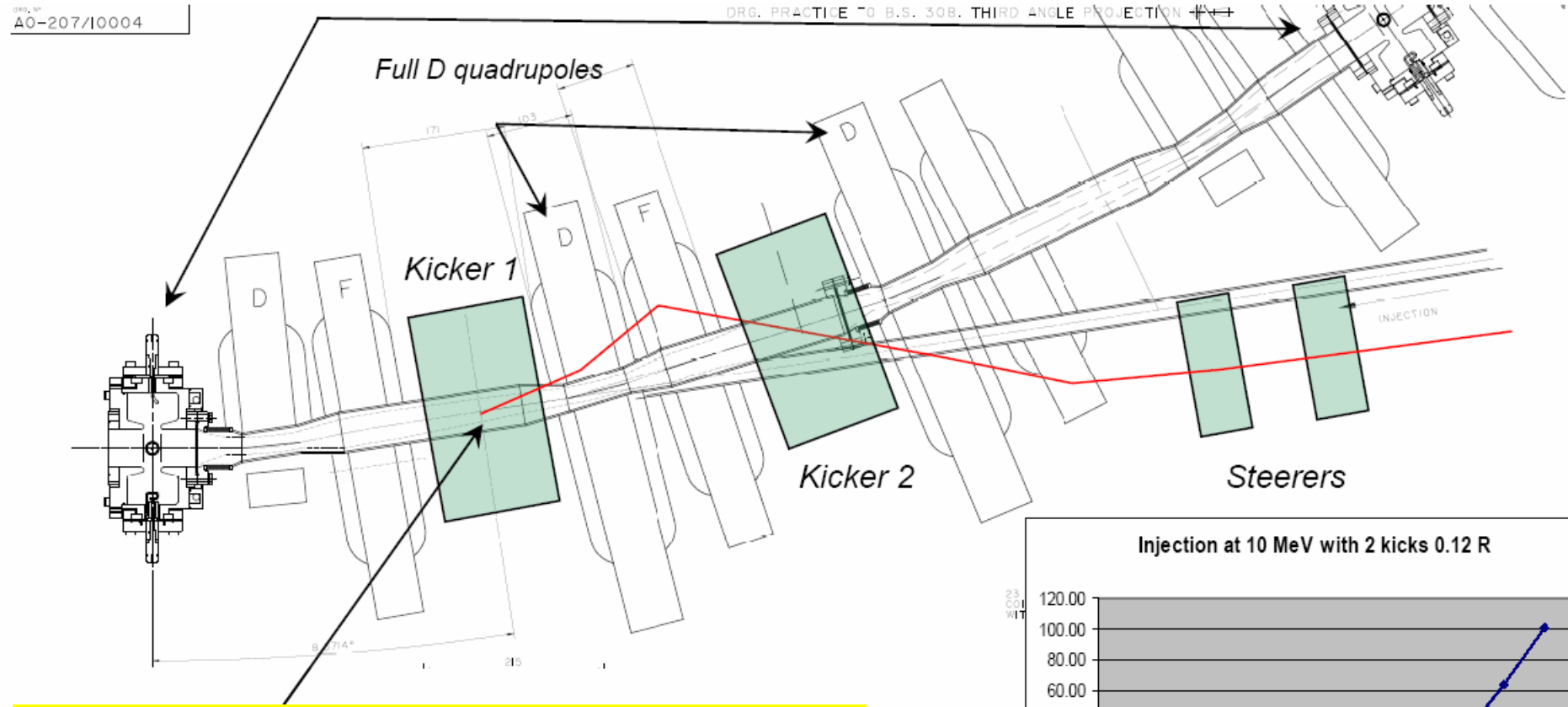
- 55ns revolution time
- Inject & extract at any energy
- Scan EMMA dynamic aperture
- 1 & 2 kicker options studied for practicality
- 1 looks difficult

Injection and Extraction



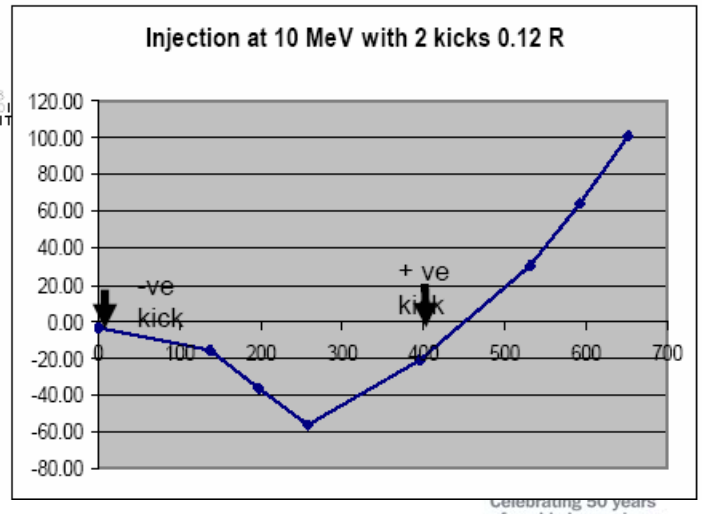
2 parameters to control at injection point:
position and angle
Angle done with kicker
Position done with upstream steerers
This allows the incoming transfer line pipe to be fixed.

Injection and Extraction



Injection and extraction lines being worked on.

Results soon.



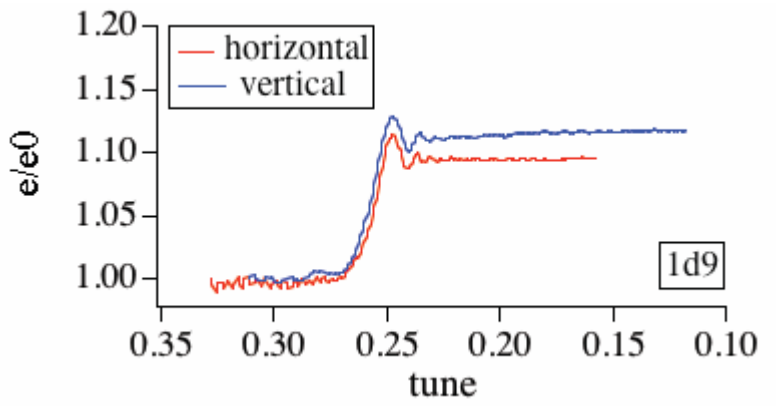
Diagnostics

Measurement	Device	Number	Required resolution
Beam position	4 button BPM	2/plane/cell in ring 4 in injection & diagnostics lines	50μm
Beam profile	OTR screens	3 in ring, 1 in injection and diagnostics lines	100μm pixel size
	Wire scanners	≥4	
Beam current	Resistive wall monitor	4 RWMs 1 scope	2%
Phase	Resistive wall monitor	As above	10 degrees
Transmission	Resistive wall monitor Faraday cup	As above 1	2%
Beam loss	Beam Loss Monitor	4	2%
Momentum	BPMs and TOF from RWMs		100keV
Emittance	Screens	3 in diagnostics line	10%
Extracted momentum	Spectrometer	1 in diagnostics line	1%
Longitudinal profile	Transverse deflecting cavity and screen	1 in diagnostics line	20keV and 5 degrees

- Requirements agreed
- Hardware under study, but.....

Space Charge!

- EMMA operation:
  - 1 bunch
  - 80pC
  - $\varepsilon_{n,rms}$= 3π mm mrad
  - 2ps rms length
- Linear tune shift ΔQ=-0.68 per turn!
- Linear part can be corrected; non-linear is a problem



4th order resonance

Can be corrected:
- reduced charge
- increase pulse length
- increase emittance
- increase # of bunches

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Conclusions

- EMMA is a crucial R&D project for the NF
- Now funded in the UK
- Funding starts on 1st March:
  - construction complete Q3 2009
  - commissioning complete Q2 2010
- Design work already started
  - lattice done
  - magnet modelling advanced
  - RF modelling started
  - injection & extraction being designed
  - diagnostics specified
  - electrical, civil, etc investigated
- Basic design parameters complete by end February