EMMA – The World's First Non-Scaling FFAG

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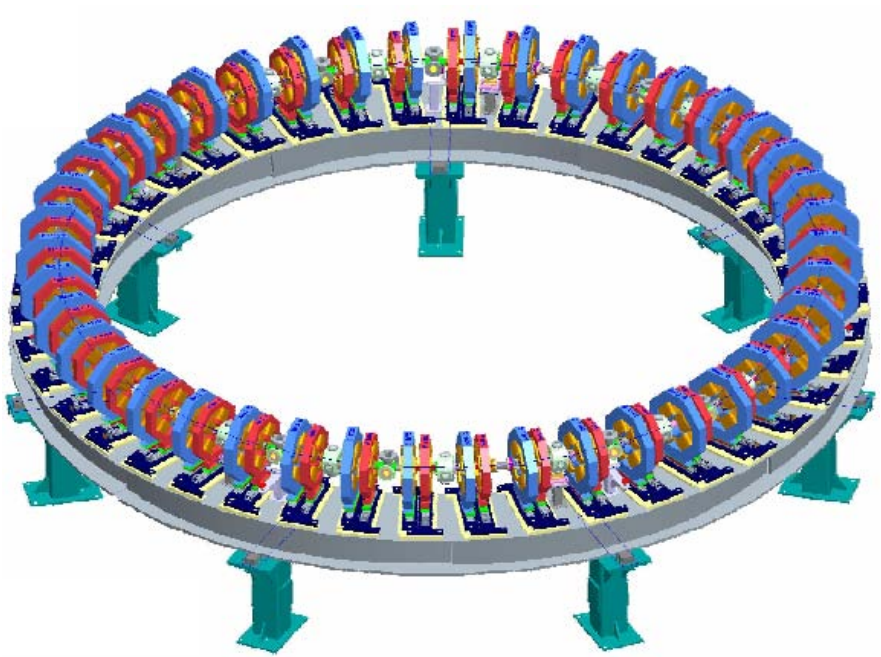
for the EMMA Collaboration*



*BNL, CERN, CI, FNAL, JAI, LPSC Grenoble, STFC, TRIUMF

EMMA

Outline

- Introduction
- Aims of the EMMA project
- Lattice studies and tracking
- Hardware status
- Time schedule
- Conclusions

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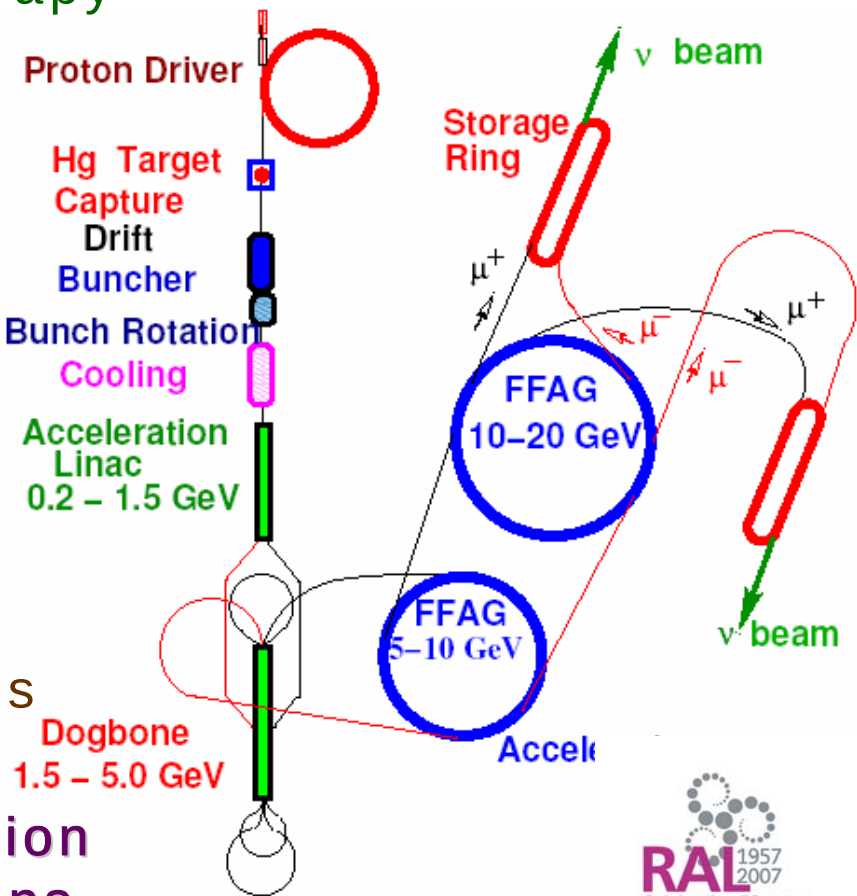
Introduction

- NS-FFAGs:
  - originally invented for muon acceleration
  - since then: high power proton driver
    proton/carbon therapy
- No such machine ever built:
  - resonance crossings
  - asynchronous acceleration
  - tiny momentum compaction
- Proof-of-principle NS-FFAG:
  - prove NS optics work!
  - study features in detail
- Funding: generic as possible
- Simplicity: model muon machines



Electron Model of Muon Acceleration
Many Applications

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Aims

- 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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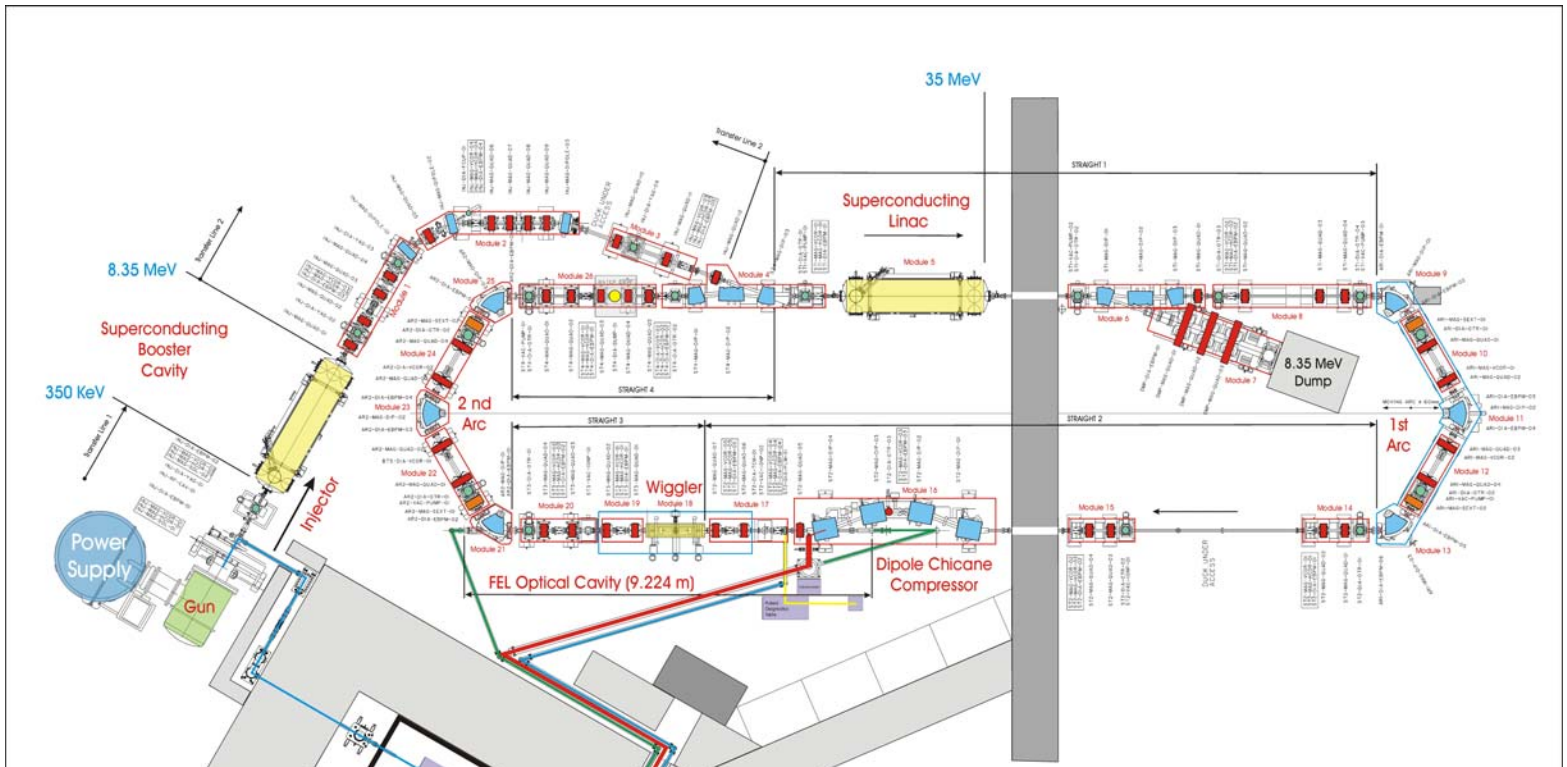
Injector

- 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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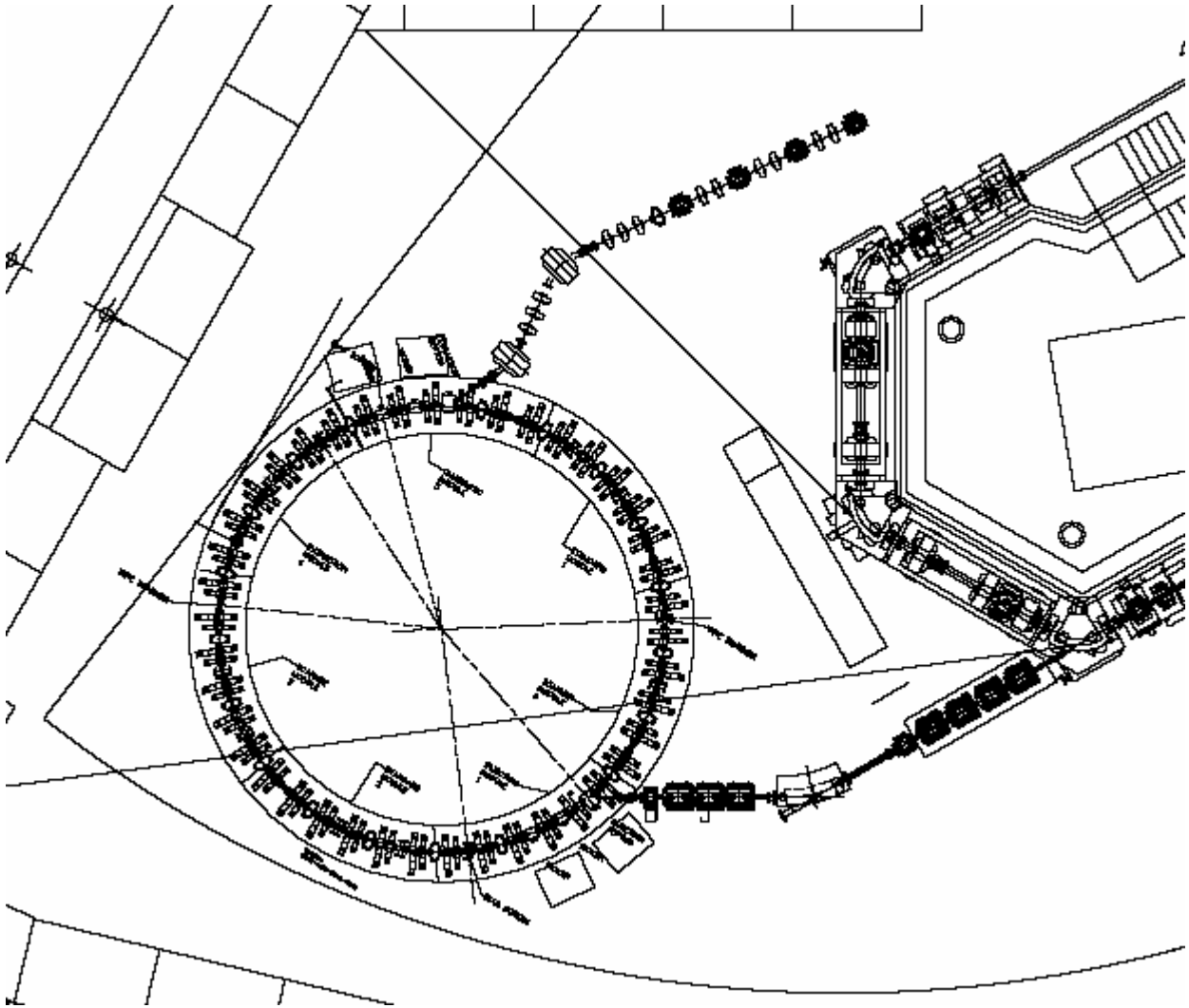
Injector



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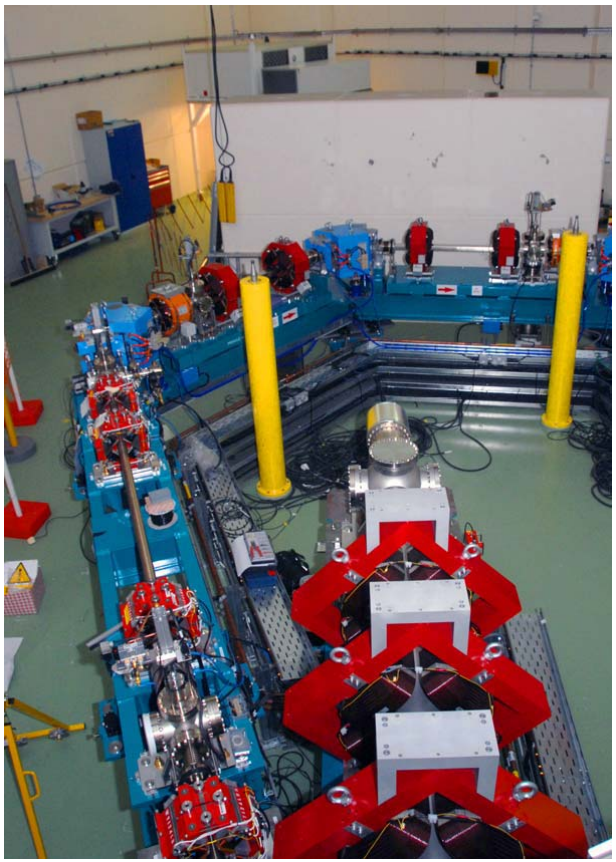
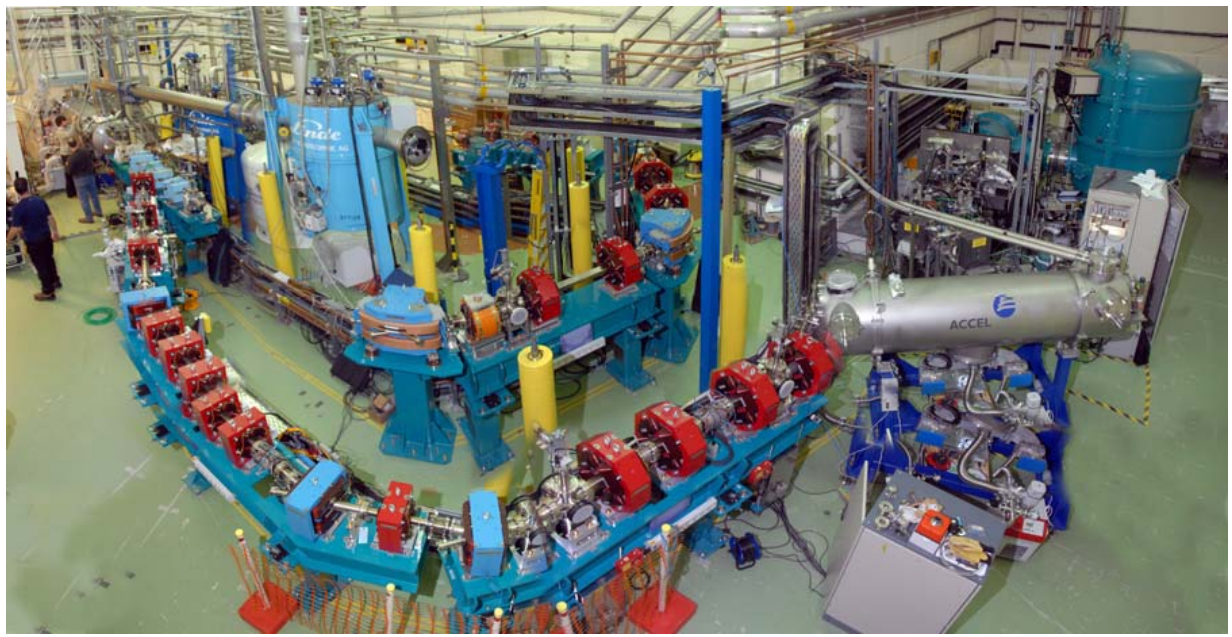
ERLP

- ERLP has been built
- Is currently being commissioned





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Funding

- Consortium called CONFORM created
- Proposal to UK Basic Technology Fund:
  - for studies of basic technology
  - generic as possible
  - three WPs
    - EMMA
    - charged particle therapy
    - other applications
- Successful!
- Funding started 1st April
- Work already started
- Total: £8.2M
- For EMMA construction: £5.6M

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EMMA Lattices

- Basic lattice:
  - 10-20 MeV (scaling)
  - Doublet (cost)
  - 42 cells (number of cell.turns)
  - 1.3GHz RF (scaling + ERLP)
  - 19 cavities (inj. & ext.)
  - 394.481mm cell length
  - 16.57m circumference
- EMMA operation mode:
  - 10-20Hz
  - 1 bunch
  - 80pC
  - $\varepsilon_{n,rms} = 3\pi$ mm mrad
  - 2ps rms length
  - scan aperture
- Documentation at:
  - http://www.conform.ac.uk/documents/emma

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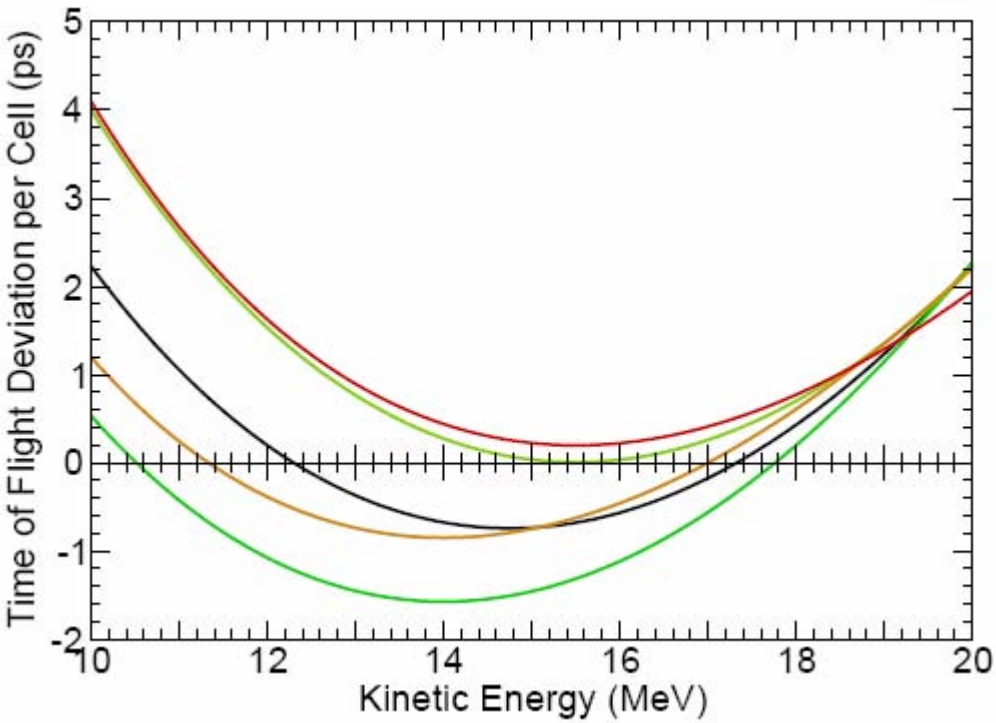
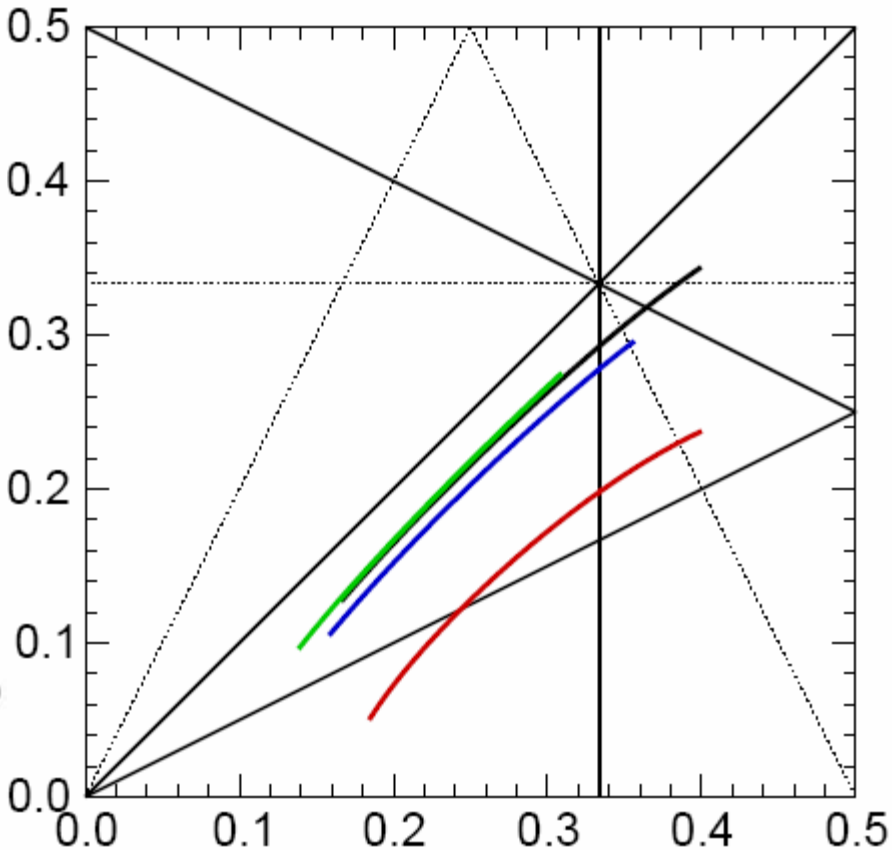
Different Lattices





Requires:

- indep. dipole & quadrupole fields
- sufficient magnet aperture
- RF frequency: -4.0 to 1.5MHz
- RF gain: ~20kV to 180kV/cavity

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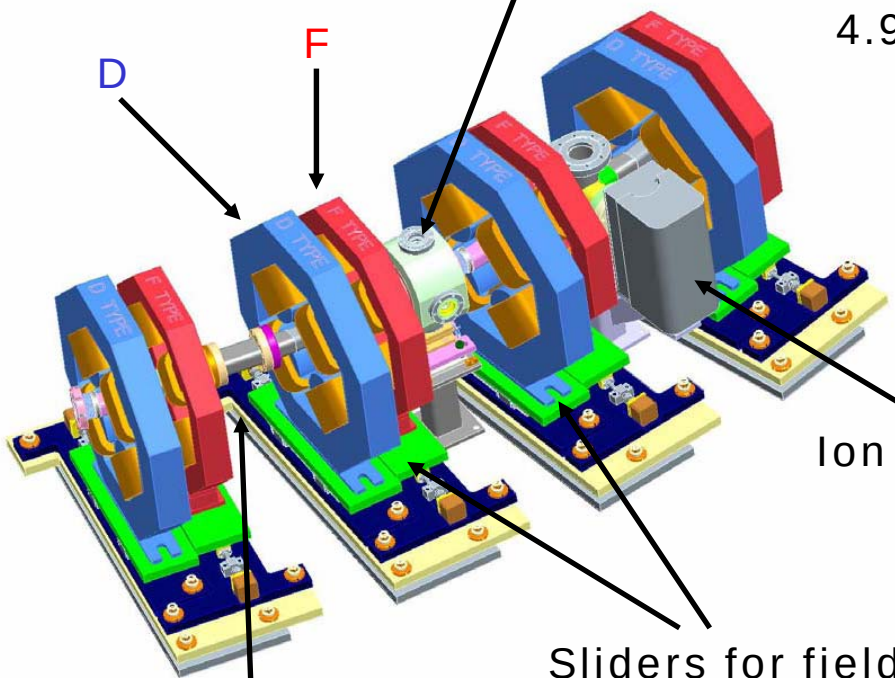
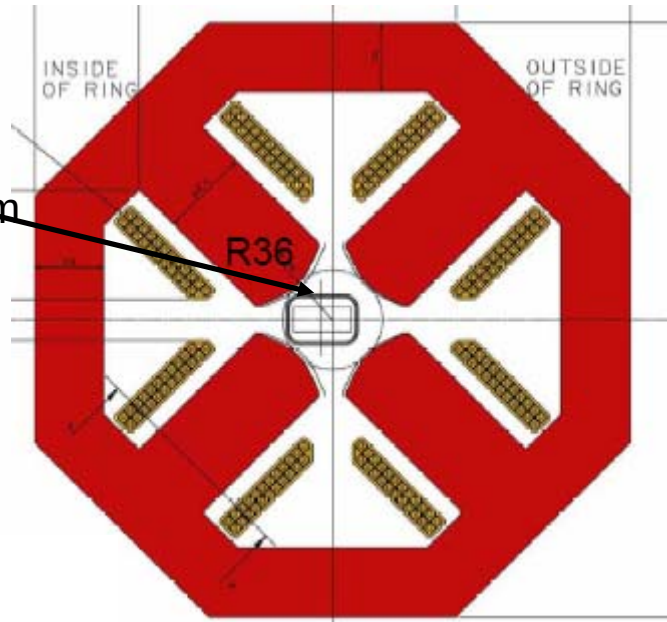
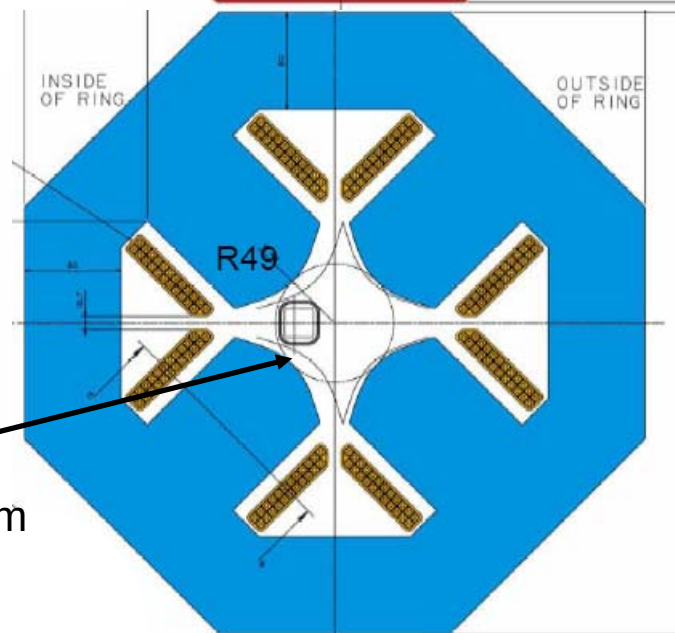
Cells

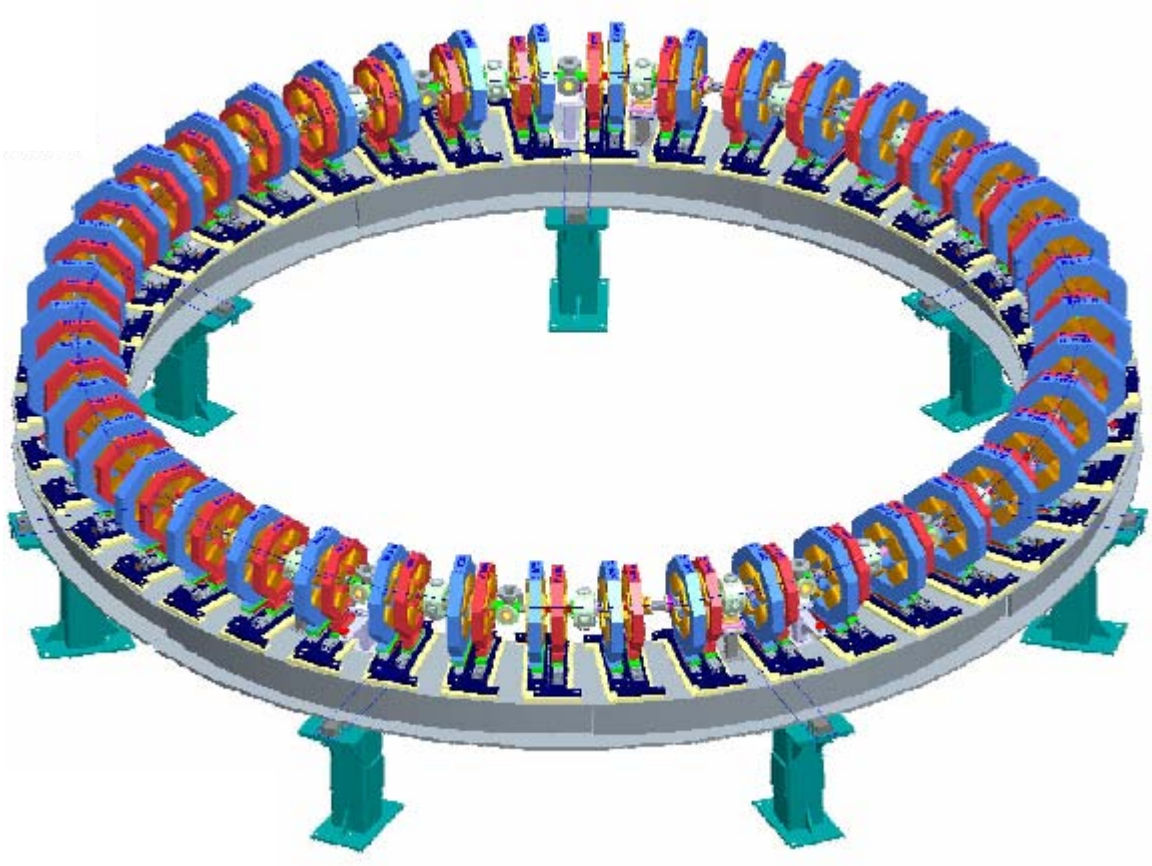

Cavity
D
F
Ion pump
Sliders for field variation
Resistive wall monitor


INSIDE OF RING
OUTSIDE OF RING
7.5mm
4.9mm to 10.2mm
R36


INSIDE OF RING
OUTSIDE OF RING
R49
34.0mm
28.6mm to 48.6mm

EMMA

EMMA Ring



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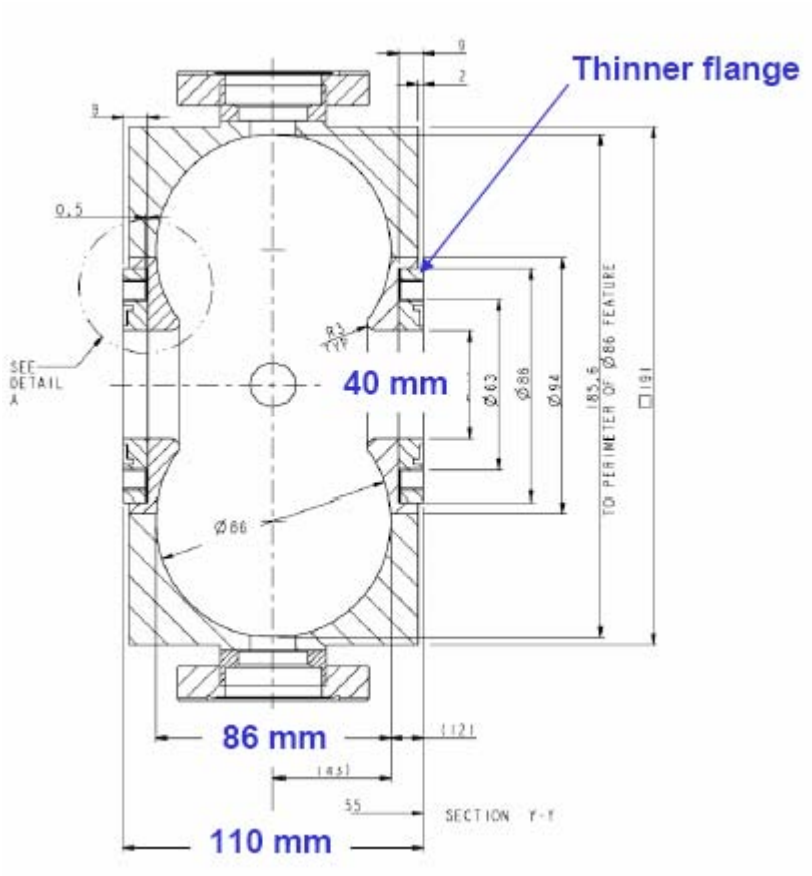
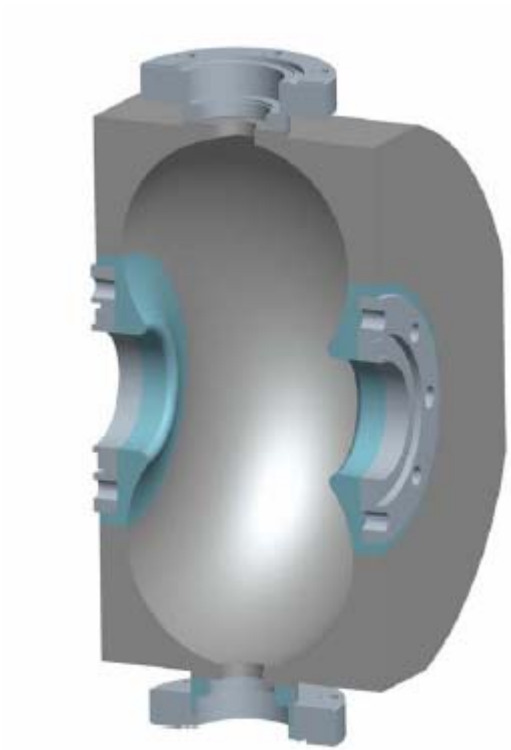
RF Cavity Design

- Started with ELBE cavity: Ω_s=1.4MΩ
- Evolved to toroidal design: Ω_s=4.3MΩ





3D Section

- Various power options under consideration

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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

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Status

- Simulations:
  - lattice design complete
  - tracked in 2 codes
  - preliminary injection/extraction scheme
  - injection/extraction lines being designed
- Magnets:
  - 3D modelling on-going
  - prototypes ordered
  - PSU design underway
- RF:
  - 3D modelling complete
  - thermal and structural analysis underway
  - power system design advanced
- Diagnostics:
  - BPM solution found
  - screens/wires on-going
  - others under study
- Others:
  - engineering/services/controls advancing

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Timescale

ID	Task Name	Duration	Start	Finish
1	**Funding available**	**0 days**	**Mon 02/04/07**	**Mon 02/04/07**
23	**EMMA Project Plan**	**1363 days**	**Fri 01/04/05**	**Fri 09/07/10**
24	Conception	9.8 mons	Fri 01/04/05	Fri 30/12/05
25	Feasibility Phase	16.25 mons	Mon 02/01/06	Fri 30/03/07
26	**Project approval notified**	**0 days**	**Fri 01/12/06**	**Fri 01/12/06**
27	Design	12 mons	Mon 02/04/07	Mon 10/03/08
28	Design review 1	1 day	Mon 12/11/07	Mon 12/11/07
29	Design review 2	1 day	Tue 29/01/08	Tue 29/01/08
30	Procurement	16.2 mons	Mon 30/04/07	Fri 01/08/08
31	**All major components on site**	**0 days**	**Fri 01/08/08**	**Fri 01/08/08**
32	Infrastructure upgrade	10 mons	Tue 01/04/08	Wed 14/01/09
33	Off line assembly and test sub systems	8.2 mons	Mon 09/06/08	Mon 02/02/09
34	Installation in Accelerator Hall	4.1 mons	Tue 03/02/09	Wed 27/05/09
35	Test systems in Accelerator Hall	2 mons	Thu 28/05/09	Wed 22/07/09
36	Construction project close out review	1 day	Thu 23/07/09	Thu 23/07/09
37	**EMMA construction complete**	**0 days**	**Thu 23/07/09**	**Thu 23/07/09**
38	Commission with electrons	2 mons	Fri 24/07/09	Thu 17/09/09
39	Construction project post implementation review	1 day	Fri 18/09/09	Fri 18/09/09
40	Detailed experimental programme	0 days	Fri 18/09/09	Fri 18/09/09
41	Full ring studies	6 mons	Mon 21/09/09	Fri 05/03/10
42	Advanced ring studies	4.5 mons	Mon 08/03/10	Fri 09/07/10
43	**EMMA phase 1 beam studies complete**	**0 days**	**Fri 09/07/10**	**Fri 09/07/10**

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Conclusions

- EMMA will
  - prove the principle of NS-FFAGs
  - investigate dynamics for future designs
- Now funded as part of the CONFORM project
- Designed by international collaboration
- Machine design is well-advanced
- Prototypes have/are being ordered
- Construction complete & commissioning started
  ~2 years
- For more details, see the posters!

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