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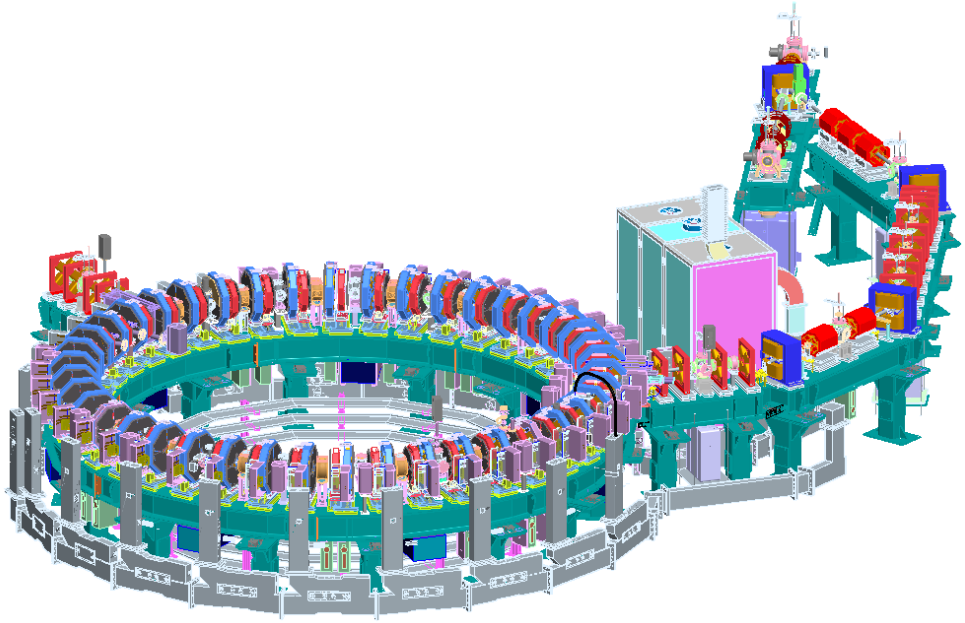
Commissioning of the EMMA non-scaling FFAG

Rob Edgecock
STFC Rutherford Appleton Laboratory
For the EMMA Collaboration*



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

Outline

One small problem……

- Introduction
- Motivation for EMMA
- EMMA design
- Status of construction
- Status of commissioning
- Next steps
- Conclusions

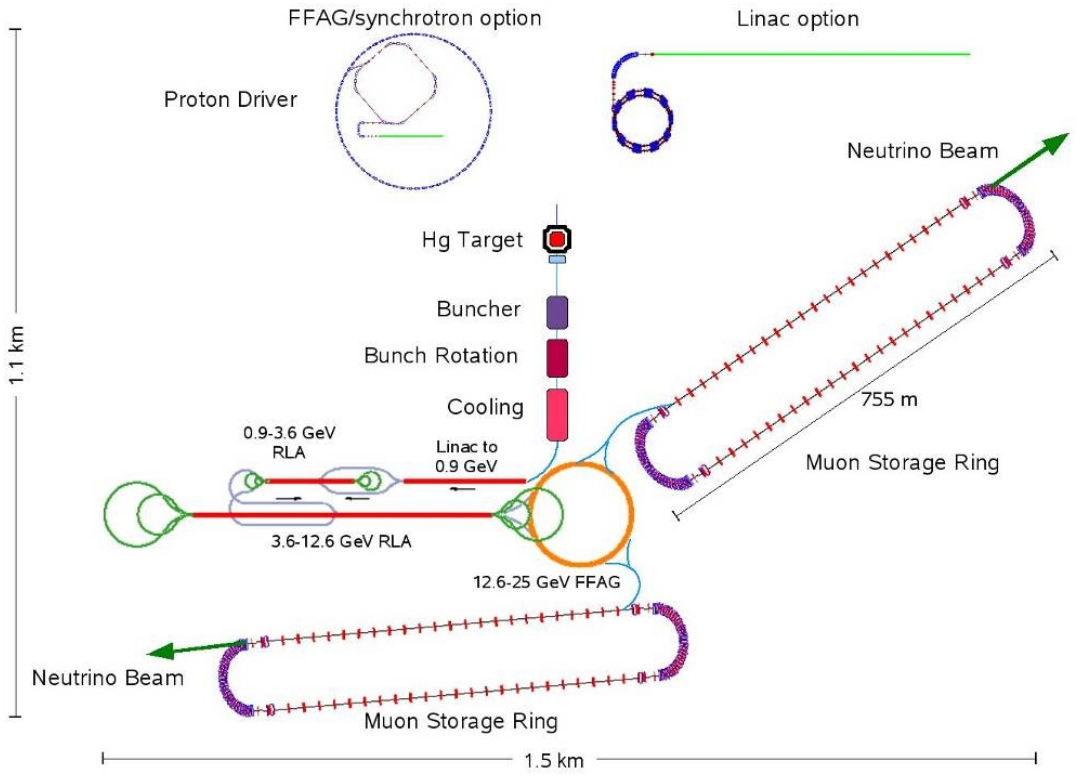
Introduction

$$B = B_0\left(1 + \frac{k}{r_0} r\right)$$

- Linear non-scaling FFAGs:

invented 1997/9

for muon acceleration in a Neutrino Factory



Neutrino Factory

Introduction

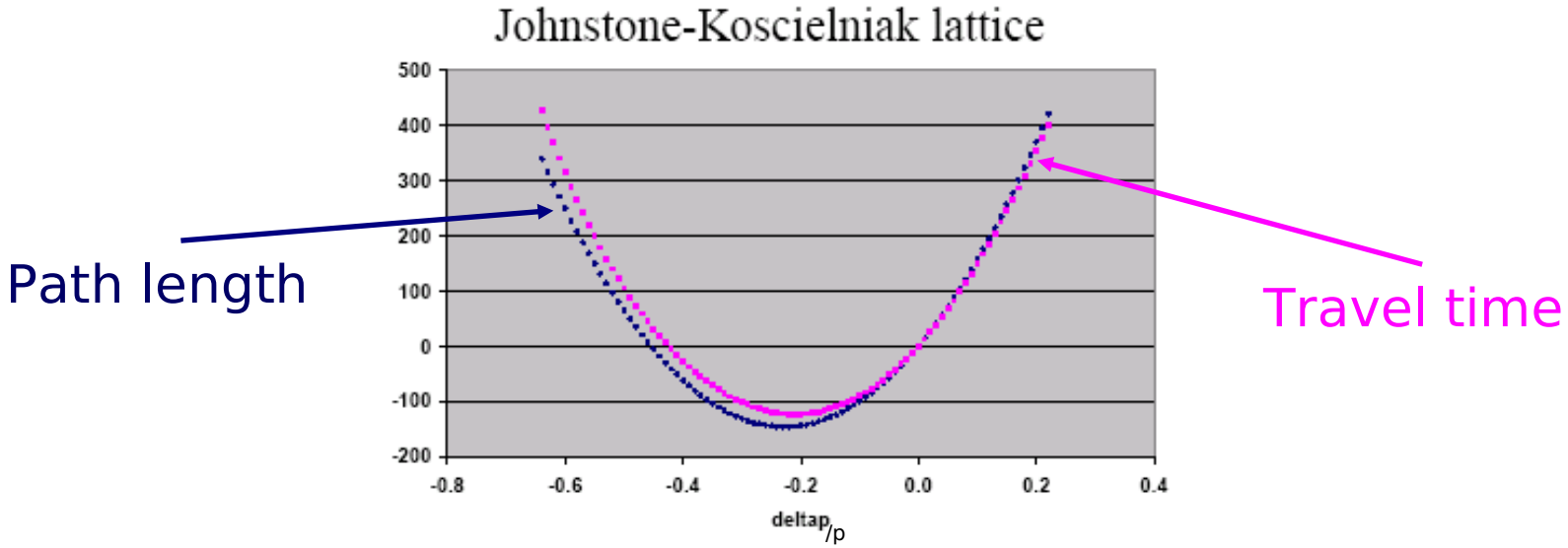
$$B = B_{\square}\left(1 + \frac{k}{r_{\cdot}} r\right)$$

- Linear non-scaling FFAGs:

invented 1997/9

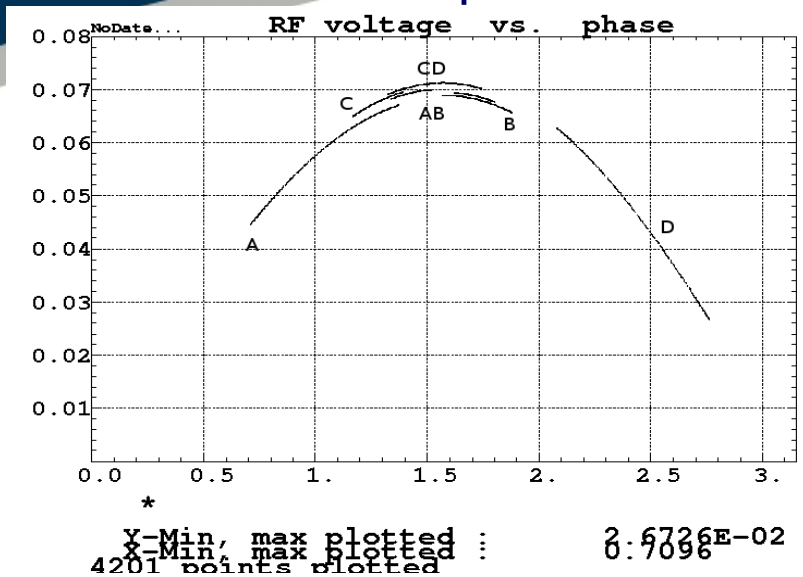
for muon acceleration in a Neutrino Factory

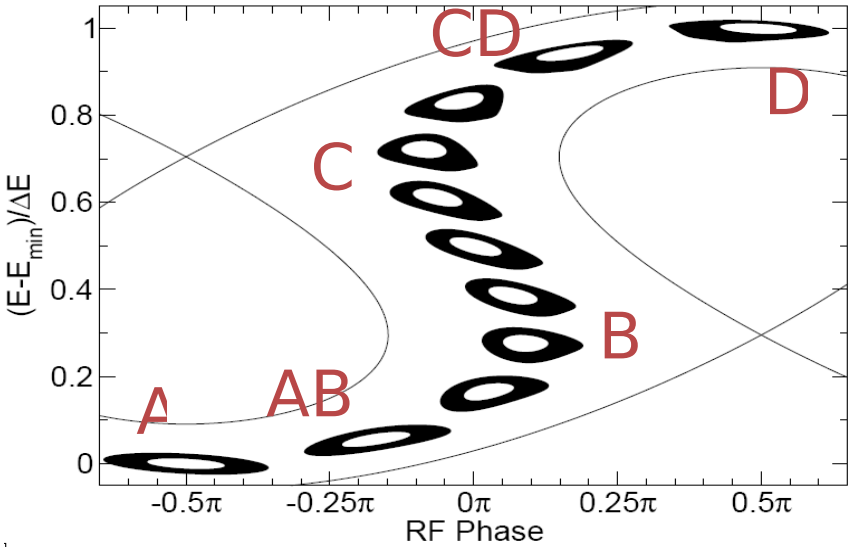
- large dynamic aperture
- small orbit excursion – higher frequency RF
- CW acceleration



Introduction

Serpentine, bucketless, asynchronous acceleration





Isochronism (measured)

Take the previous graph, imagine that there is a mirror image at $\phi \rightarrow \phi + \pi$, and rotate it 180 deg.

Here is a longitudinal trajectory as measured by time-of-flight (Craddock et al, 1977 PAC).

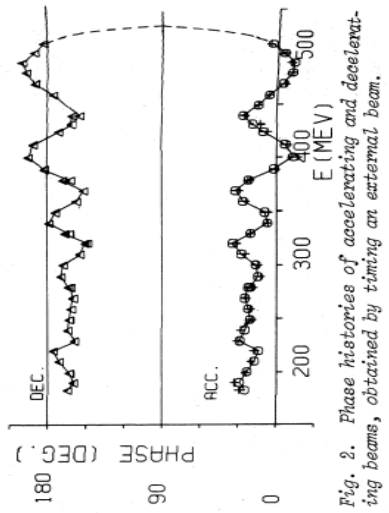
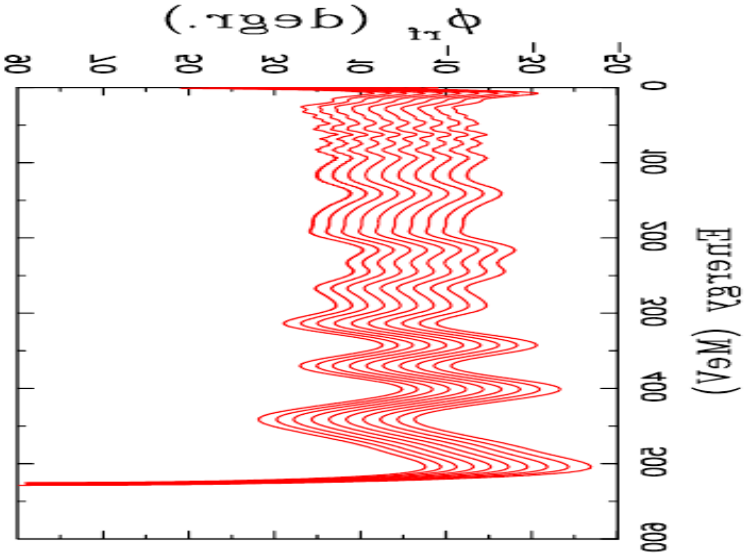


Fig. 2. Phase histories of accelerating and decelerating beams, obtained by timing an external beam.



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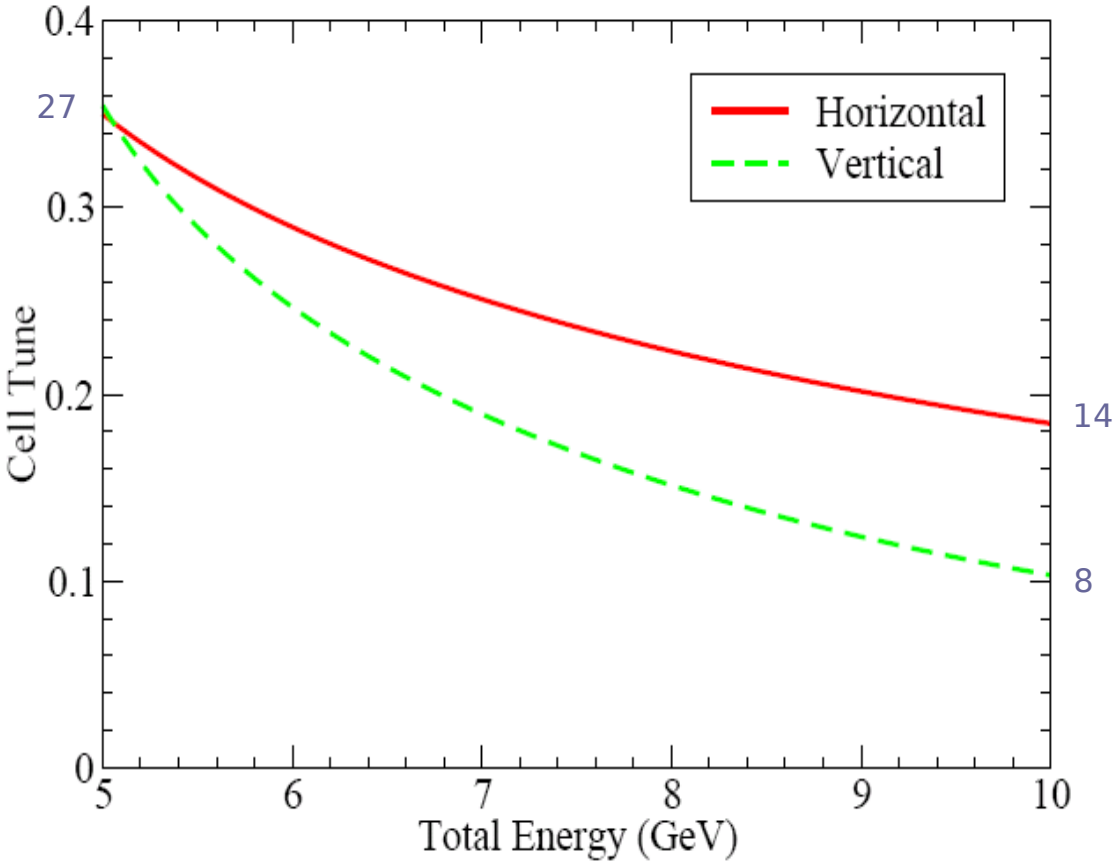
Introduction

Fast resonance crossings



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Motivation for EMMA

- Realised early on:
  - Other potential applications:

    hadron therapy

    ADSR

    other high power proton beam applications

    MOPEA021

    MOPEC047
  - One or two issues:
    - tiny momentum compaction
    - unique longitudinal dynamics
    - possible transverse dynamics problems
    - resonance crossings
    - constraints on construction
    - standard tracking codes not applicable
    - purpose built codes need benchmarking
- Must build one!
- Hence, EMMA

EMMA Design

- A linear non-scaling machine
- Main parameters taken from muon accelerator:
  - electrons, 10-20MeV
  - linear magnets, cw RF
  - 42 cells, doublet lattice
- In addition
  - very flexible
  - injection into full muon acceptance
  - lots of diagnostics
  - need flexible (10-20 MeV) injector with hall space
  - small
  - not too expensive!

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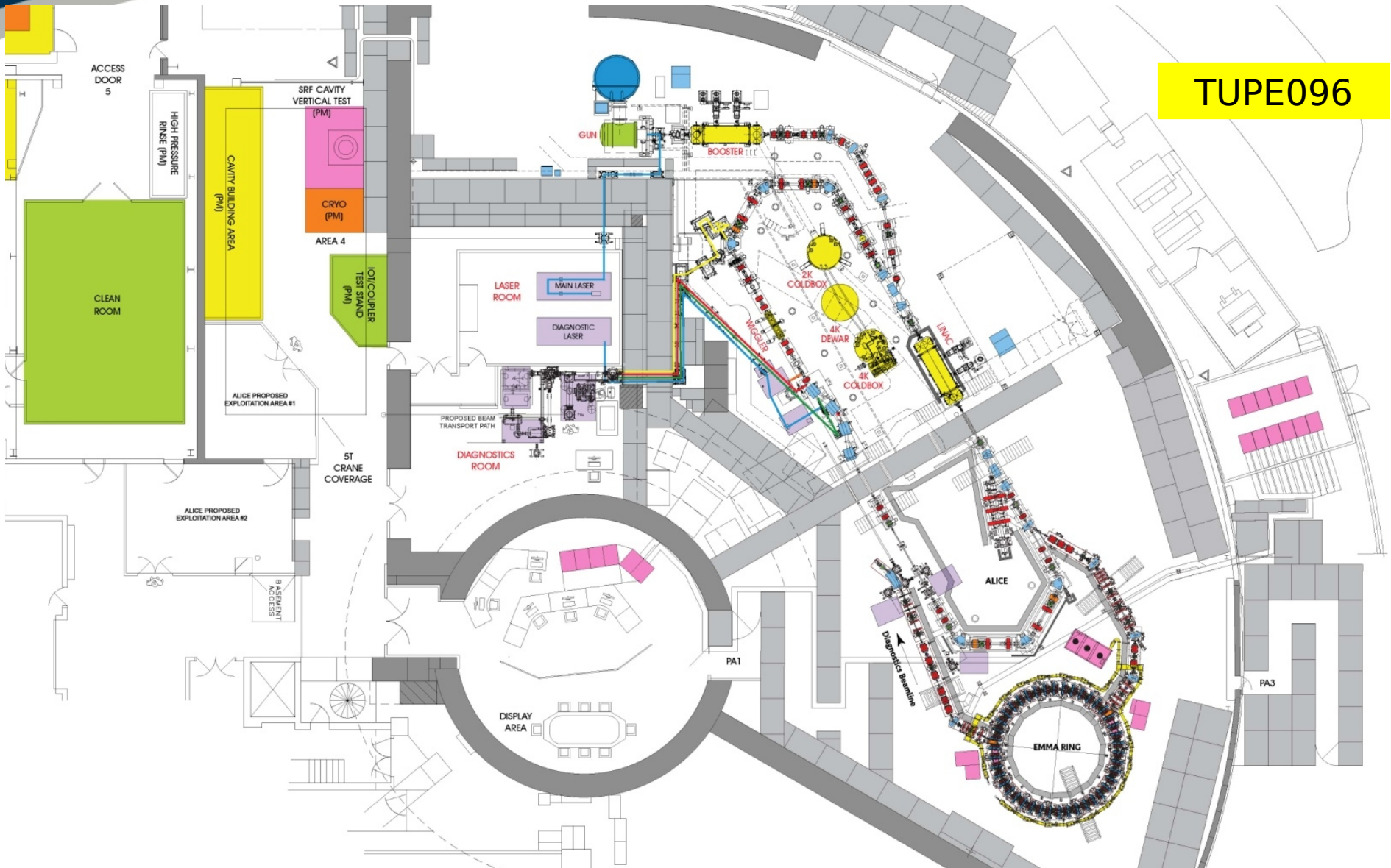
EMMA Location

TUPE096



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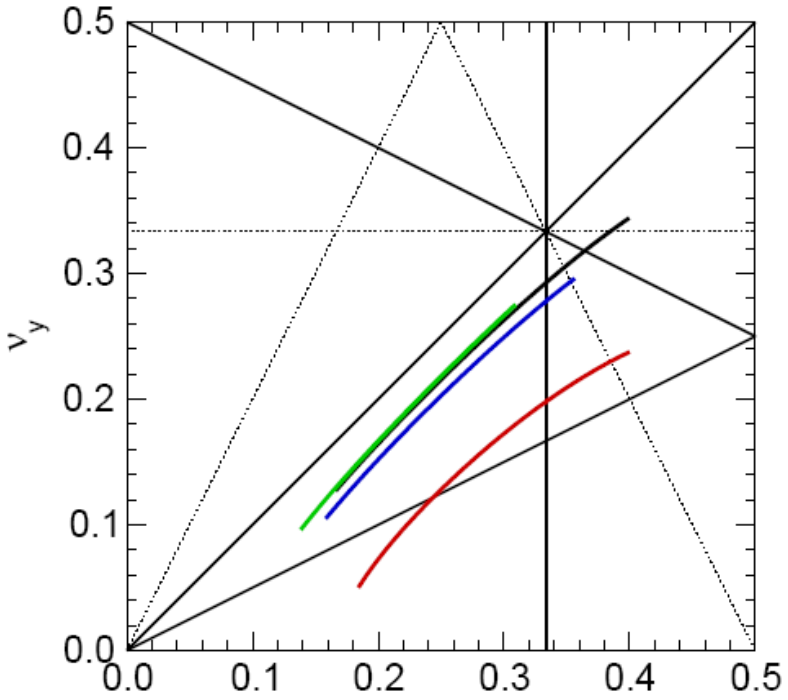
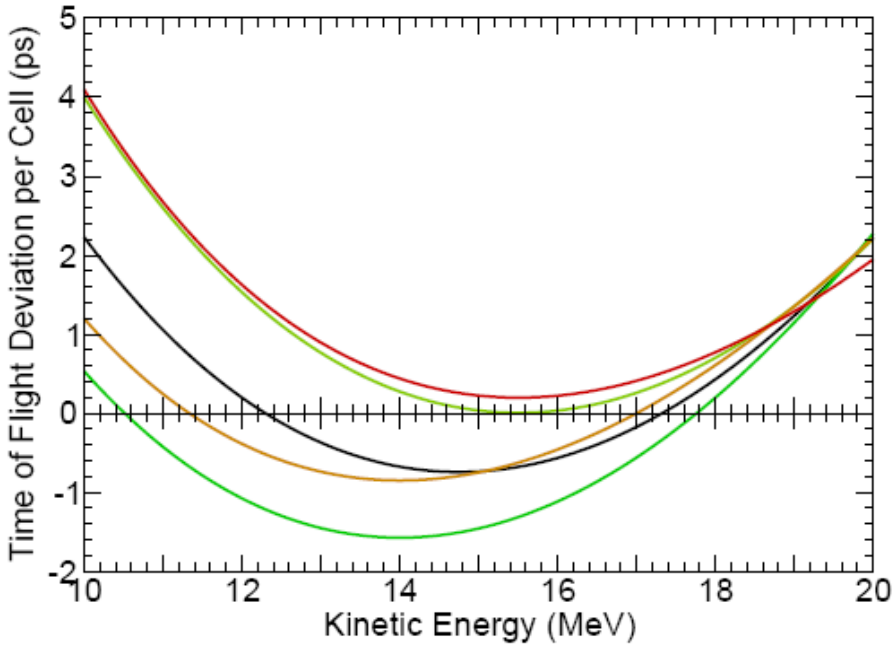
EMMA Specifications

- Driven by experimental nature
- 8 lattices to explore long. & trans. dynamics





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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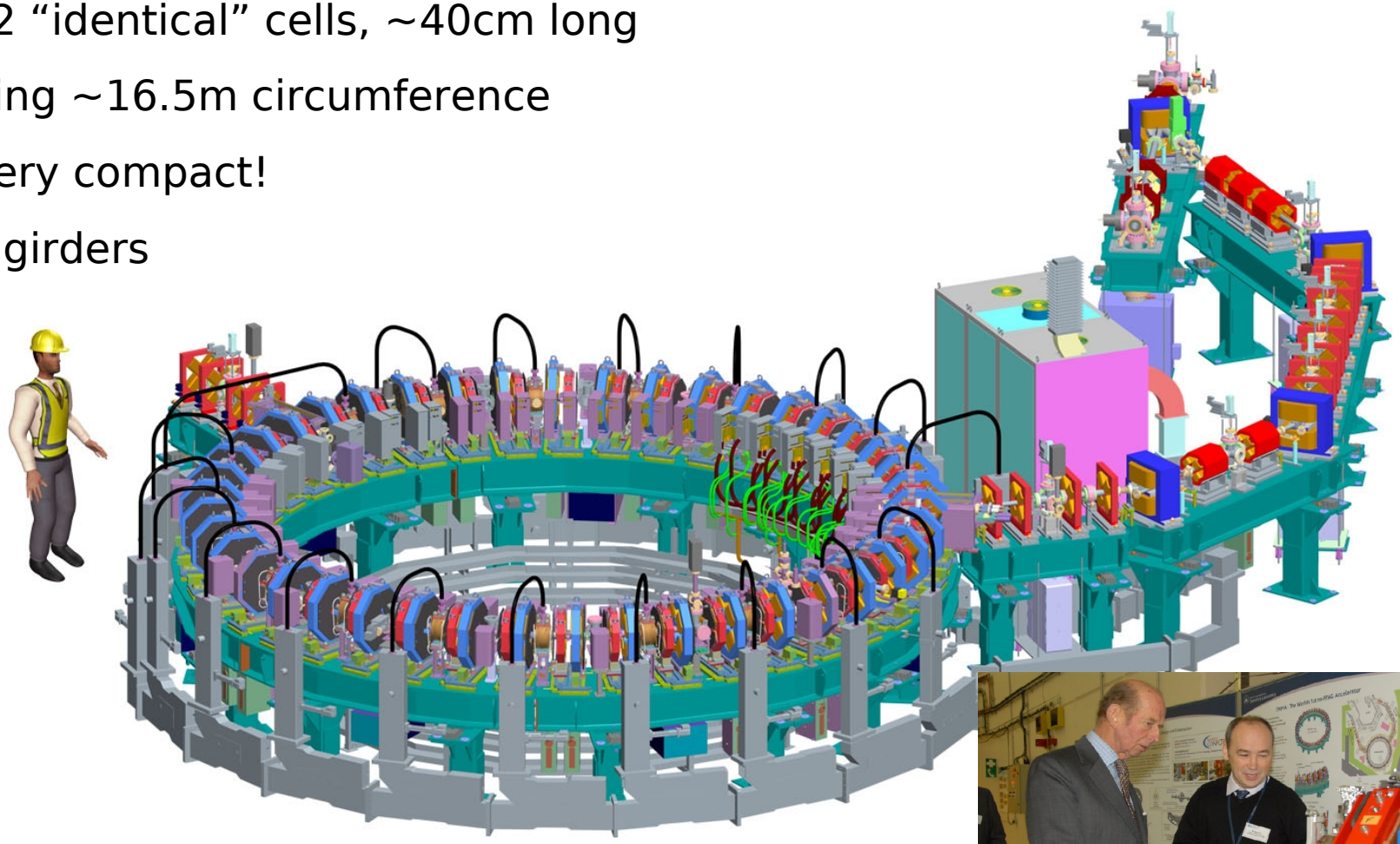
EMMA Design

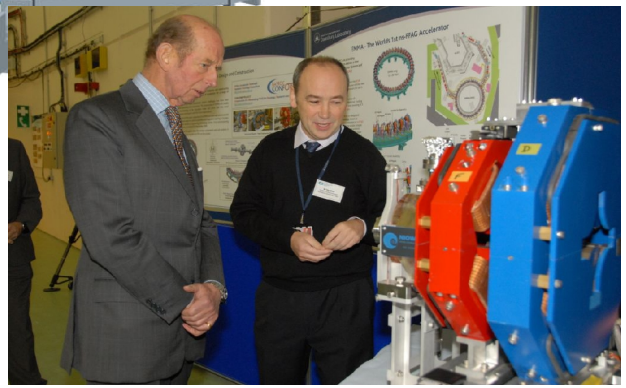
42 “identical” cells, ~40cm long

Ring ~16.5m circumference

Very compact!

7 girders





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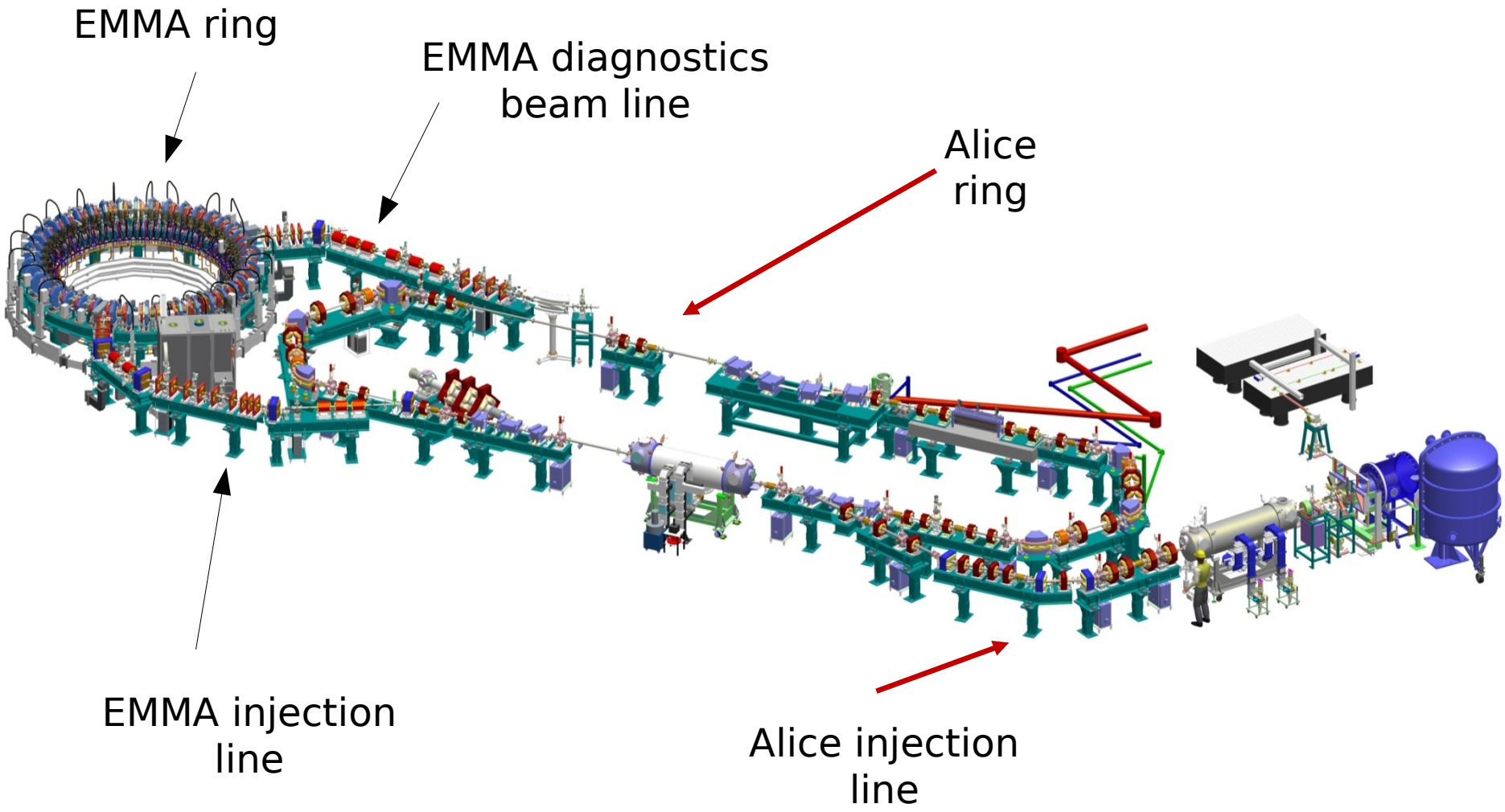
Status of Construction



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Injection line

Transport beam to EMMA.

Matching.

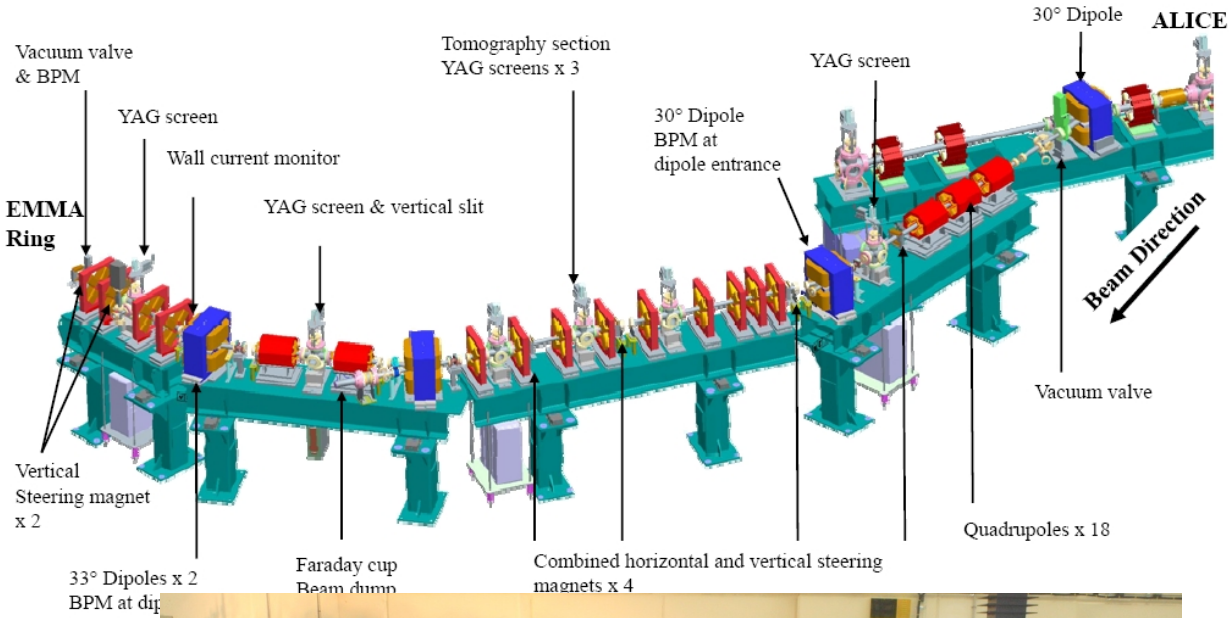
Measure beam parameters on entry to EMMA.

Completed ~2 months.

Beam transported to end.

First measurements made.

MOPEC046



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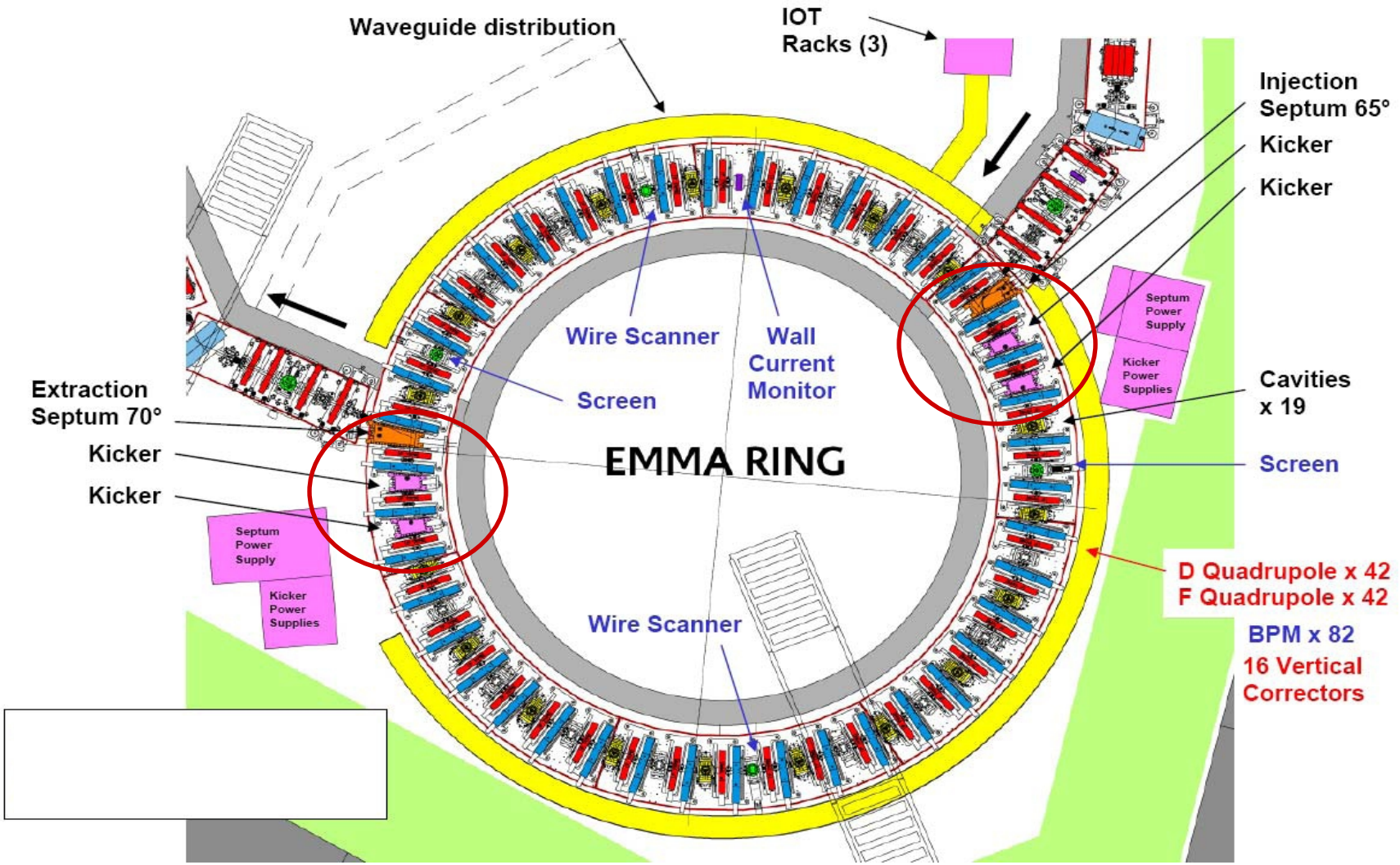
EMMA Ring



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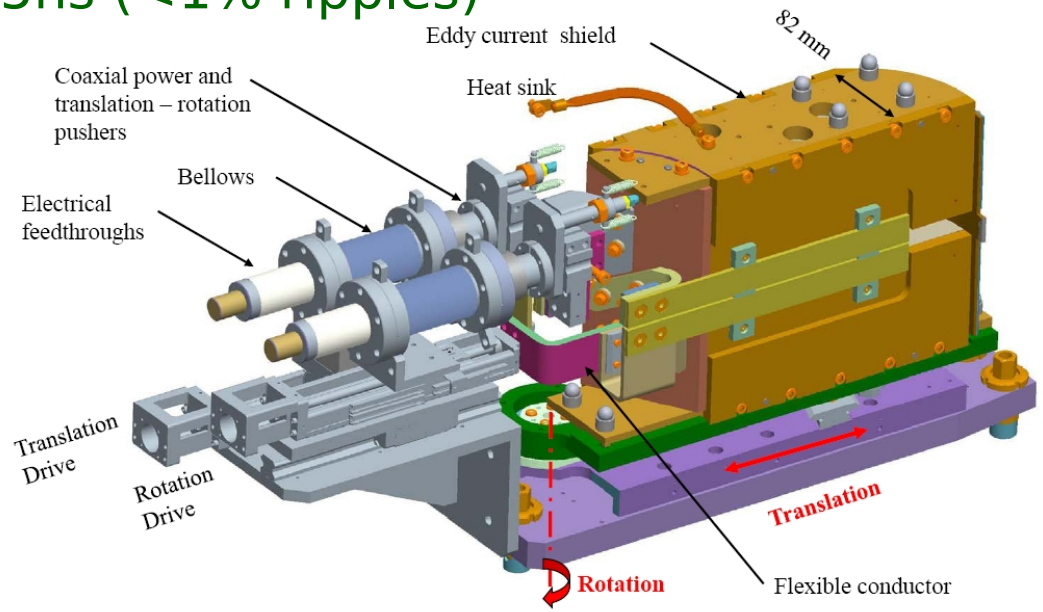
Injection & Extraction

Requirements

- Injection of:
  - all 8 lattices
  - all energies between 10 and 20 MeV
  - into 3π m mrad
- Minimal impact on next turn:
  - leakage field from septum < 0.01%
  - kickers off before 55ns (<1% ripples)
- Slot length: ~10cm



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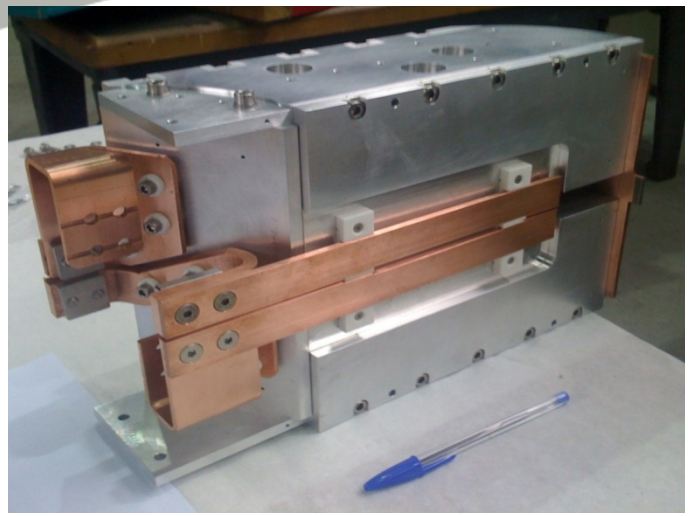
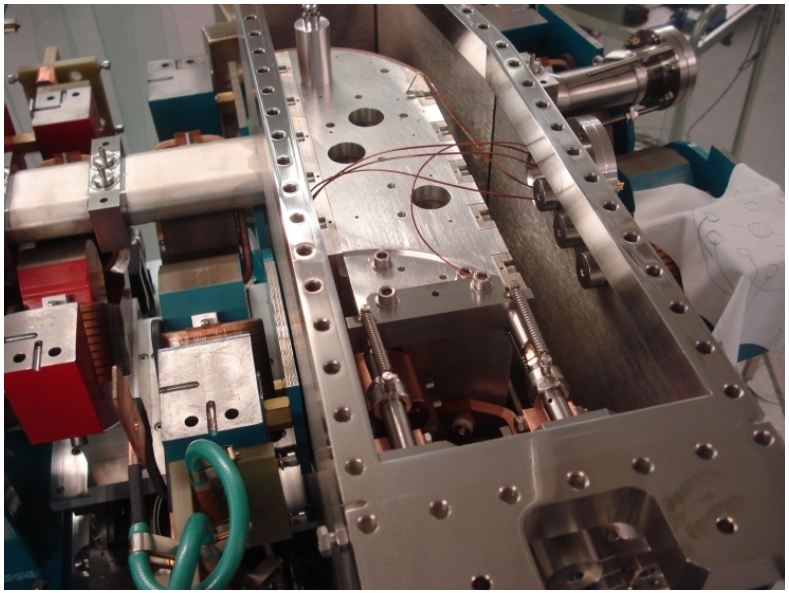
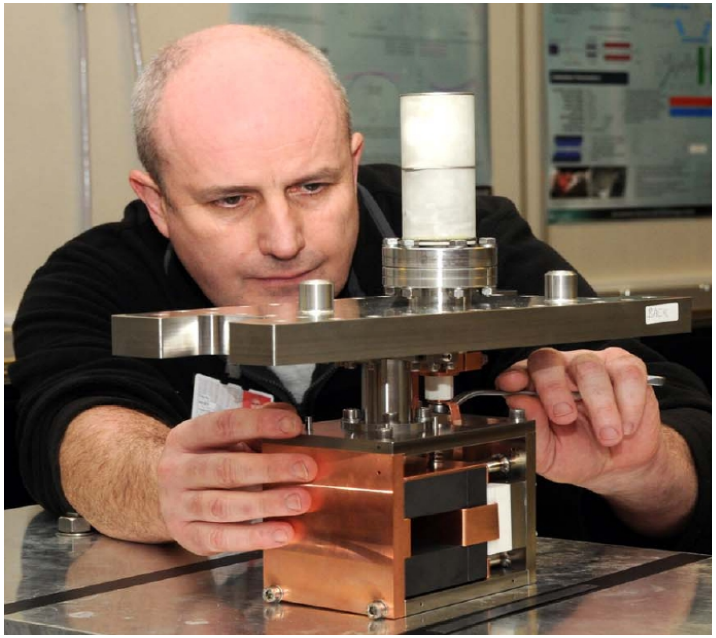
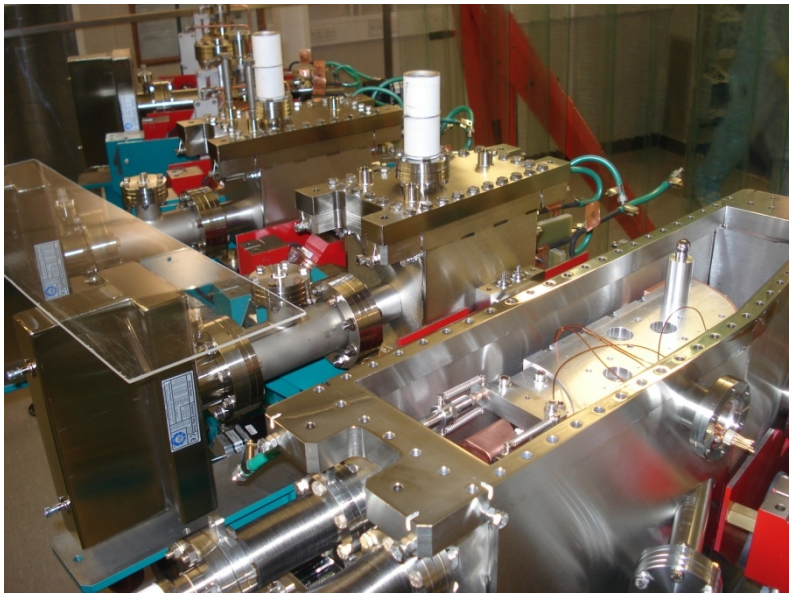
Injection & Extraction









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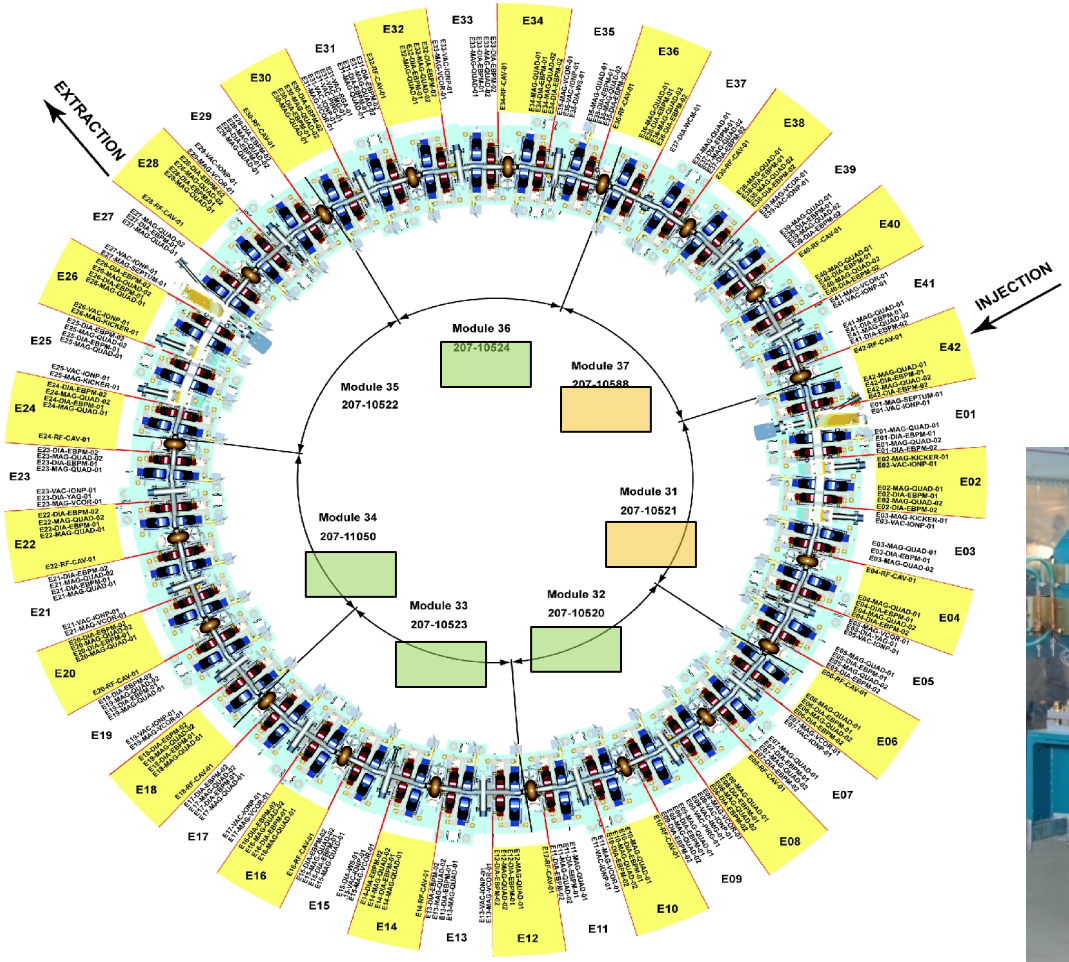
EMMA Ring

- 42 cells mounted on 7 girders:



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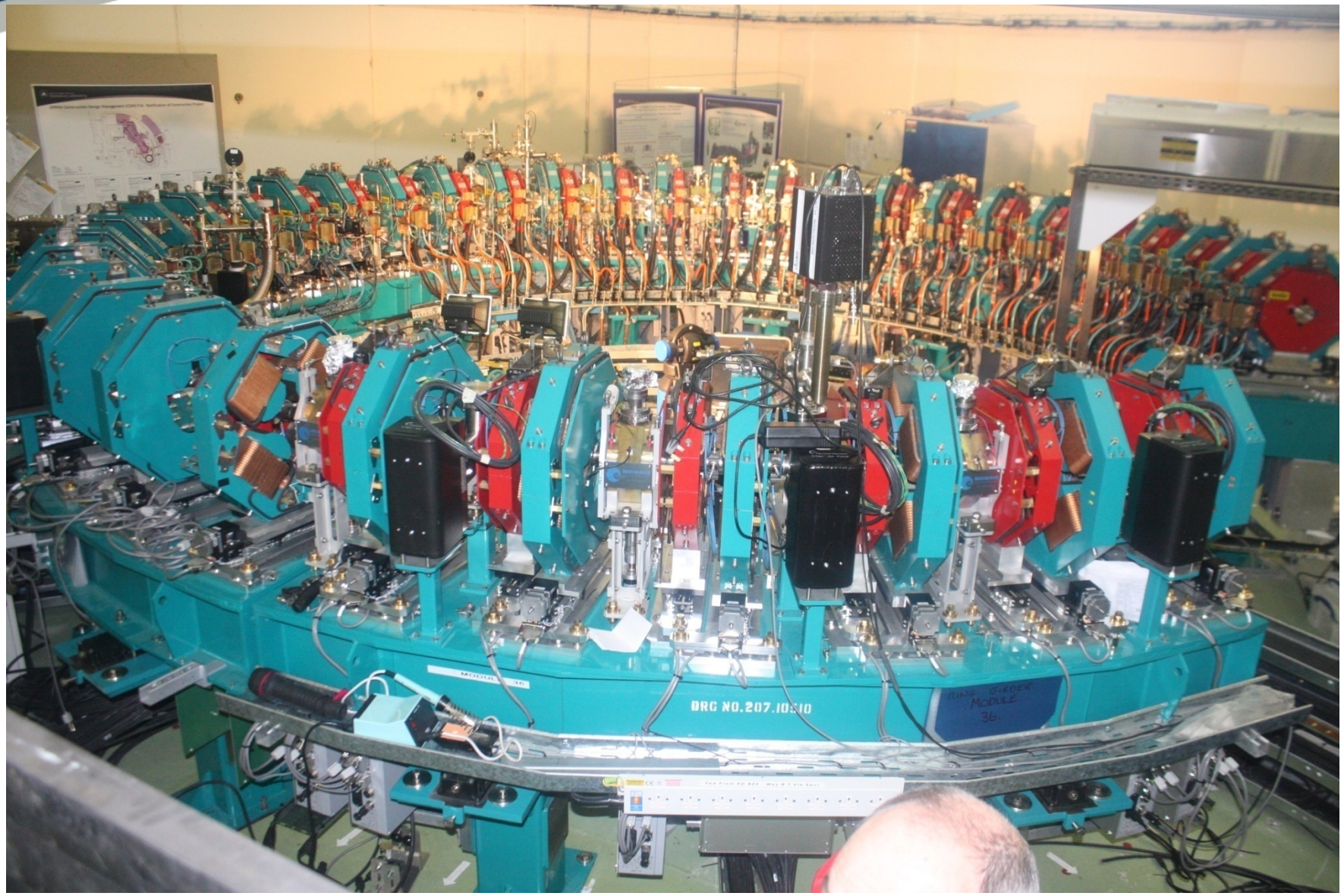
EMMA Ring



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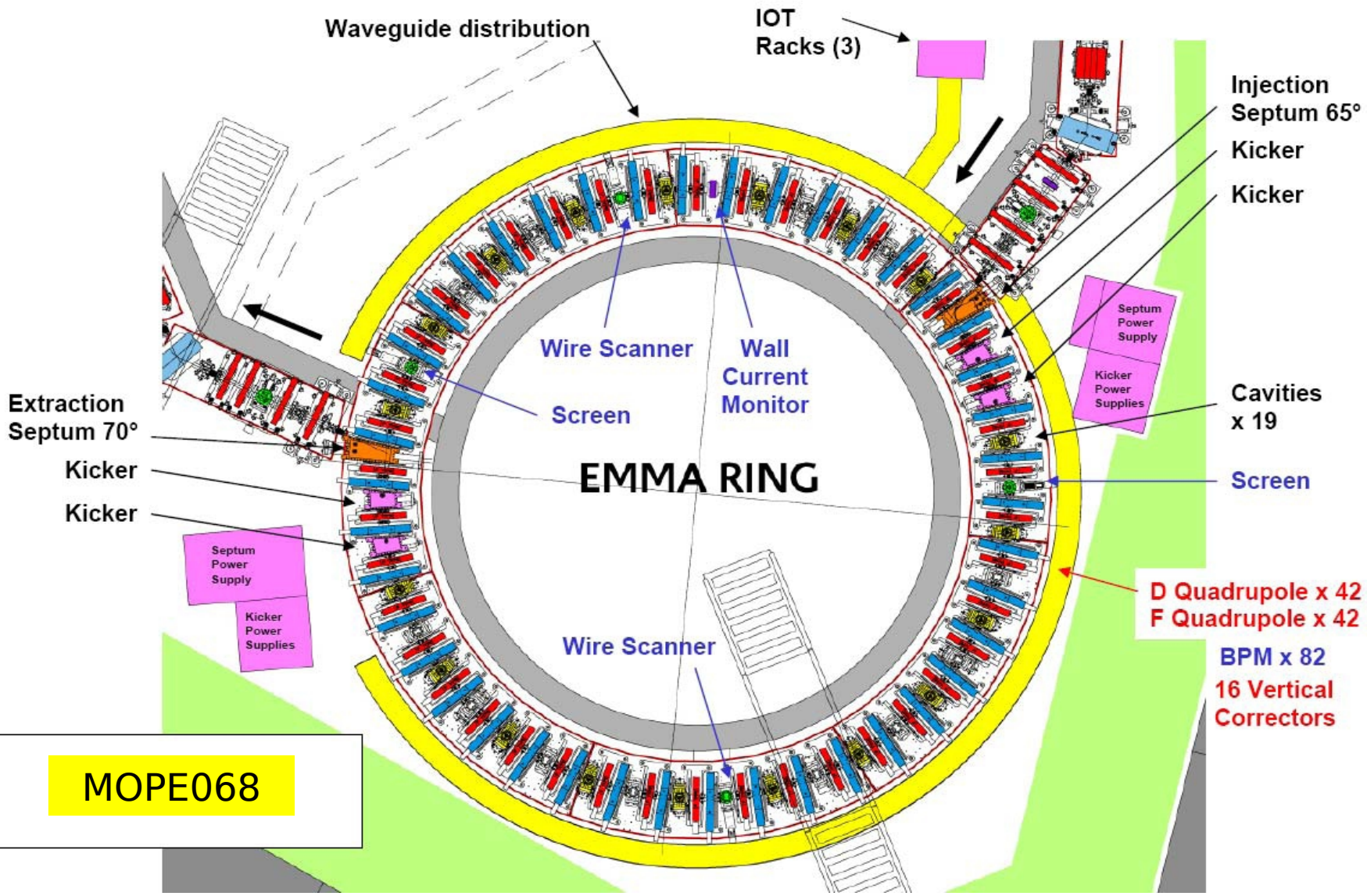
Diagnostics



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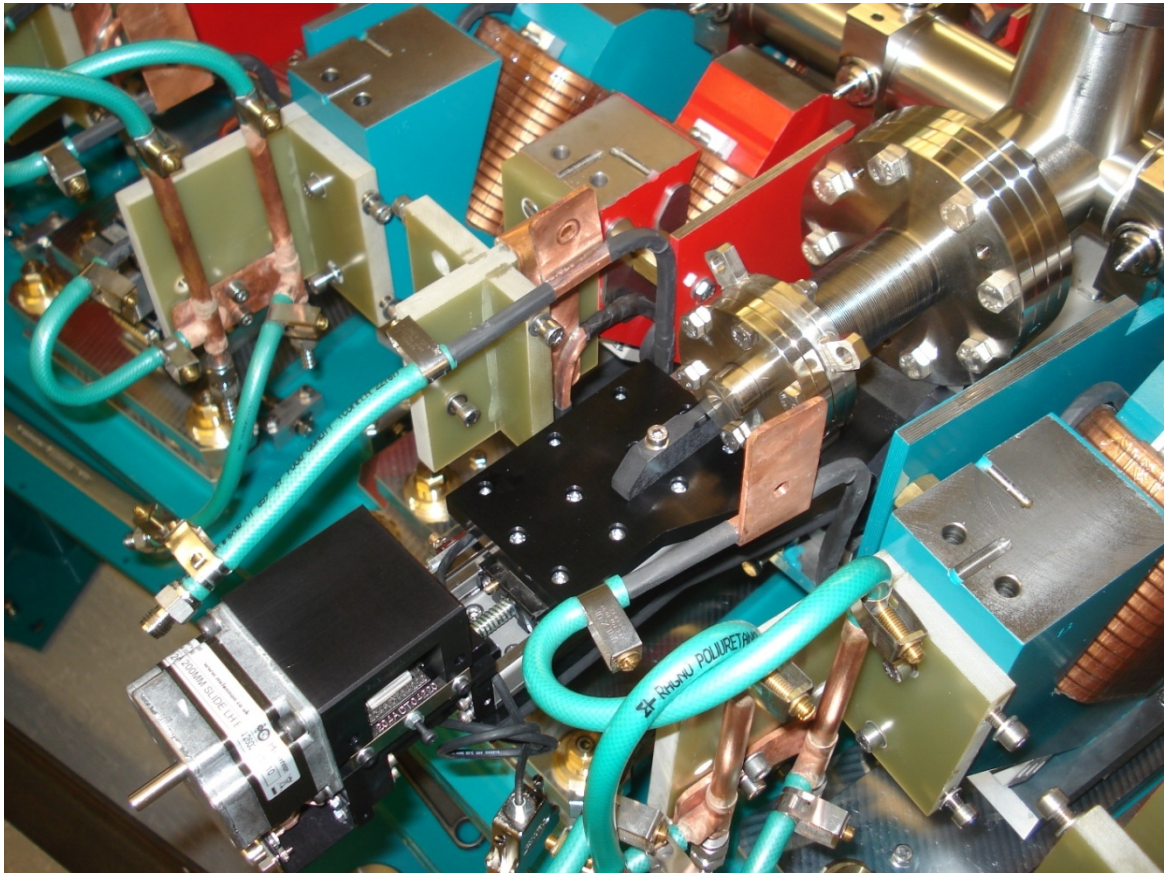
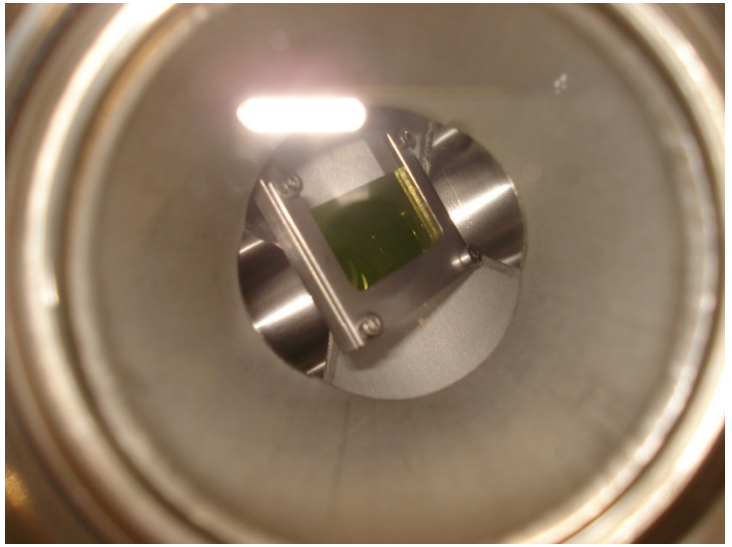
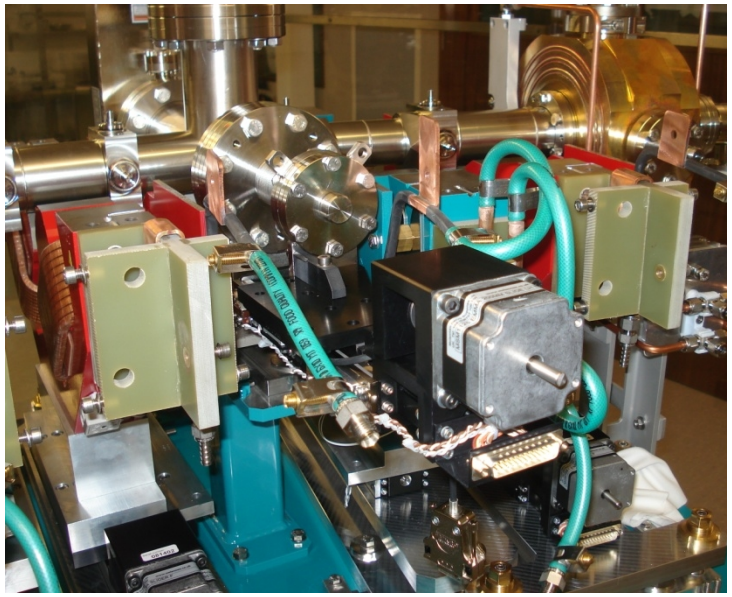
Diagnostics



YAG screen





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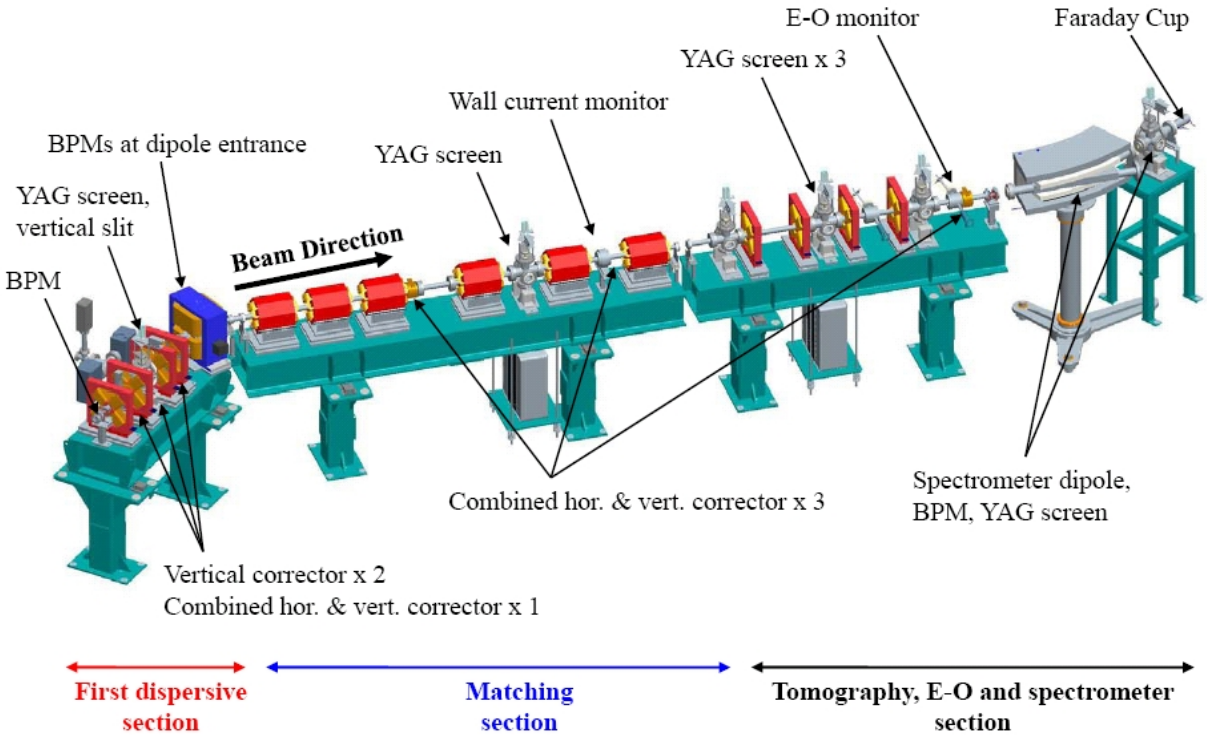
Diagnostics Beam Line



"Destructive" diagnostic devices.
Beam can be extracted at any energy for measurement

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Commissioning Status

Stages in commissioning

- ALICE:
  - settings required for EMMA beam parameter measurements

Started

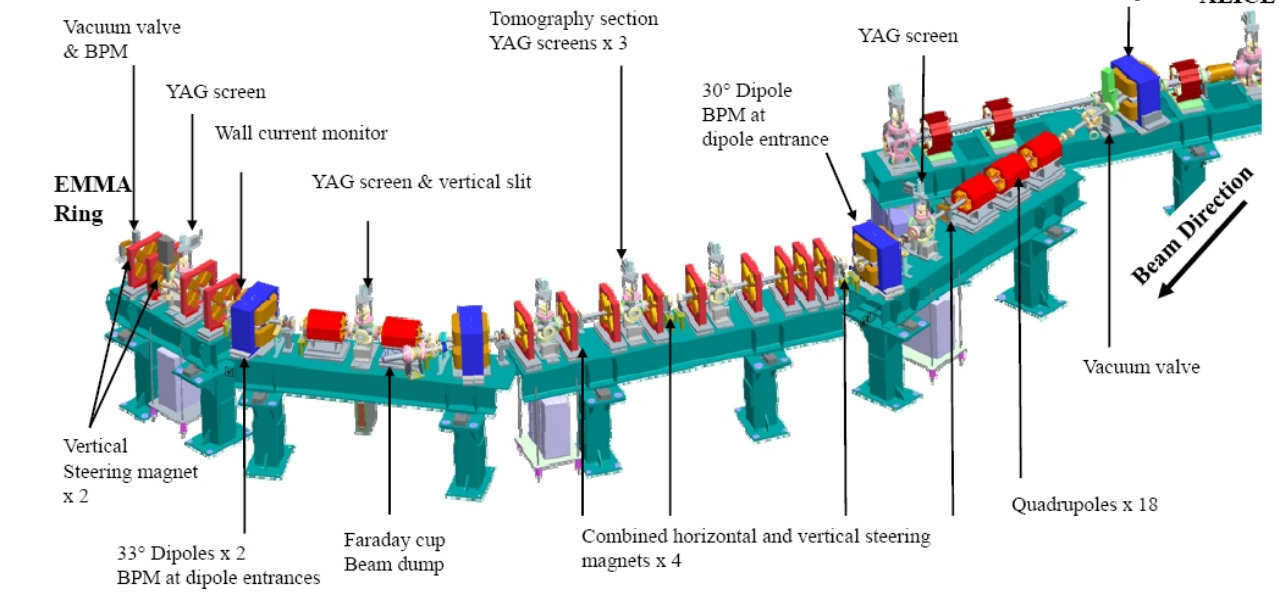
- Injection line:
  - transmission of beam
  - diagnostics commissioning

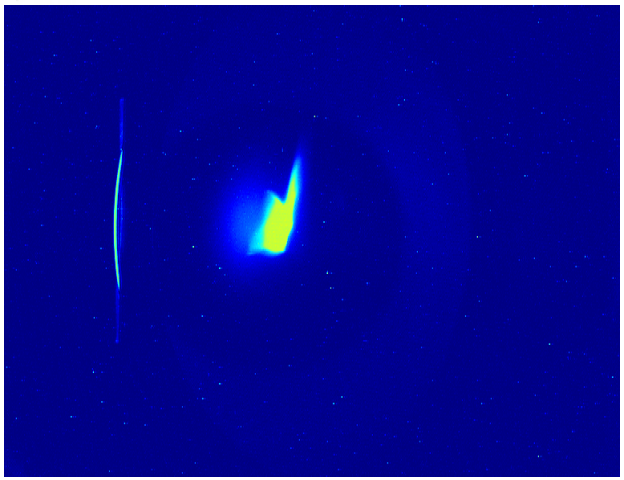
Started

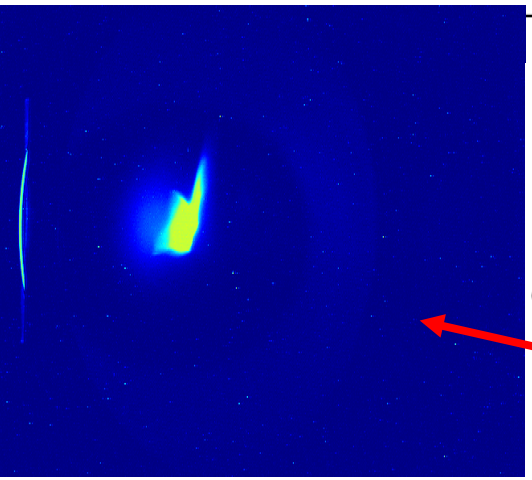
- 4 sector commissioning:
  - injection & setting beam on orbit
  - check lattice(s)
  - tune measurements

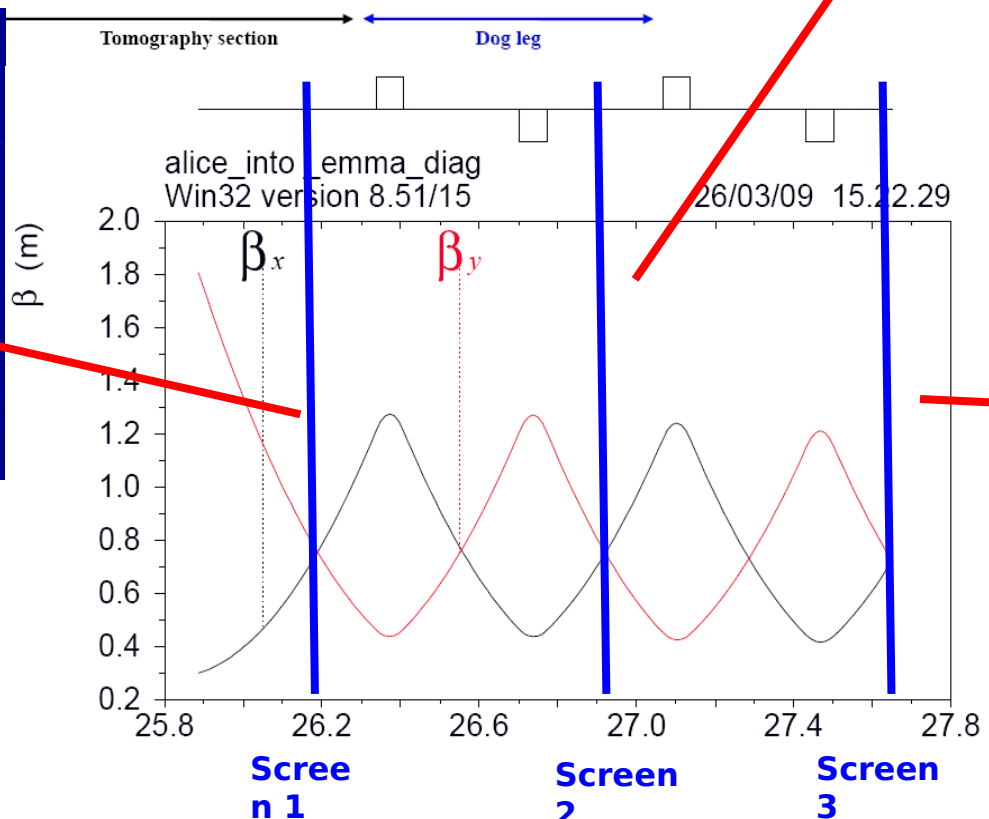
Very soon!

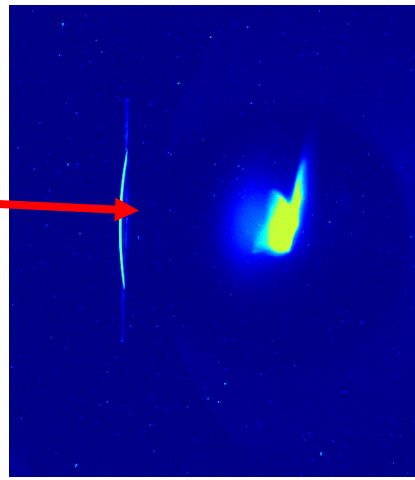
- Full ring
- Extraction and external beam measurements











First emittance measurement. See THPD028

Conclusions

- EMMA is the proof-of-principle non-scaling FFAG
- Construction has been a challenge
  - novel machine
  - very compact: “…everything takes 5 times longer in EMMA…”, Neil Bliss, project manager
- Construction of ring is almost complete
- Commissioning has started
- Commissioning of ring will start soon