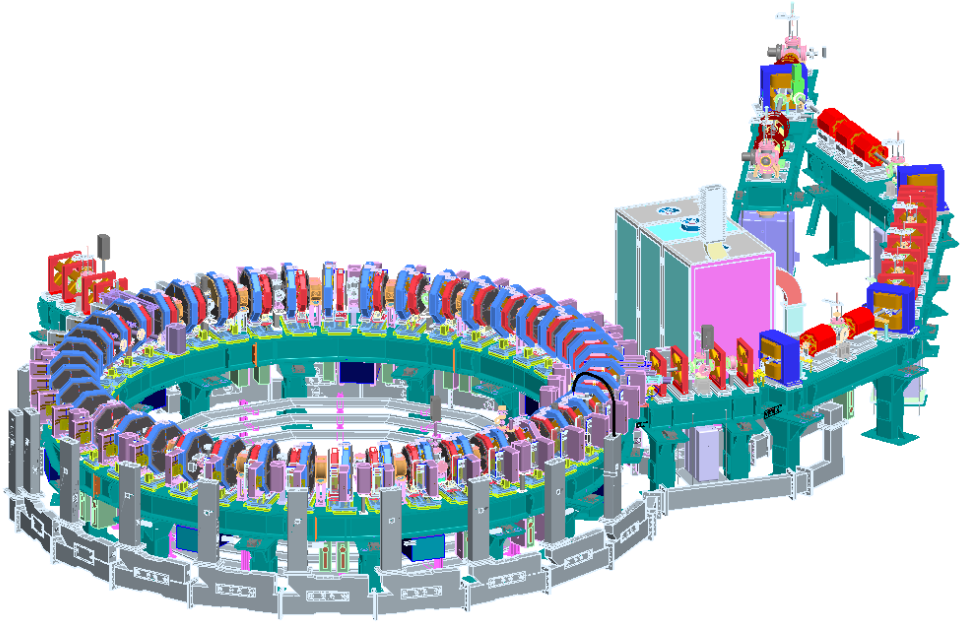
Science & Technology Facilities Council

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

Science & Technology Facilities Council

Outline

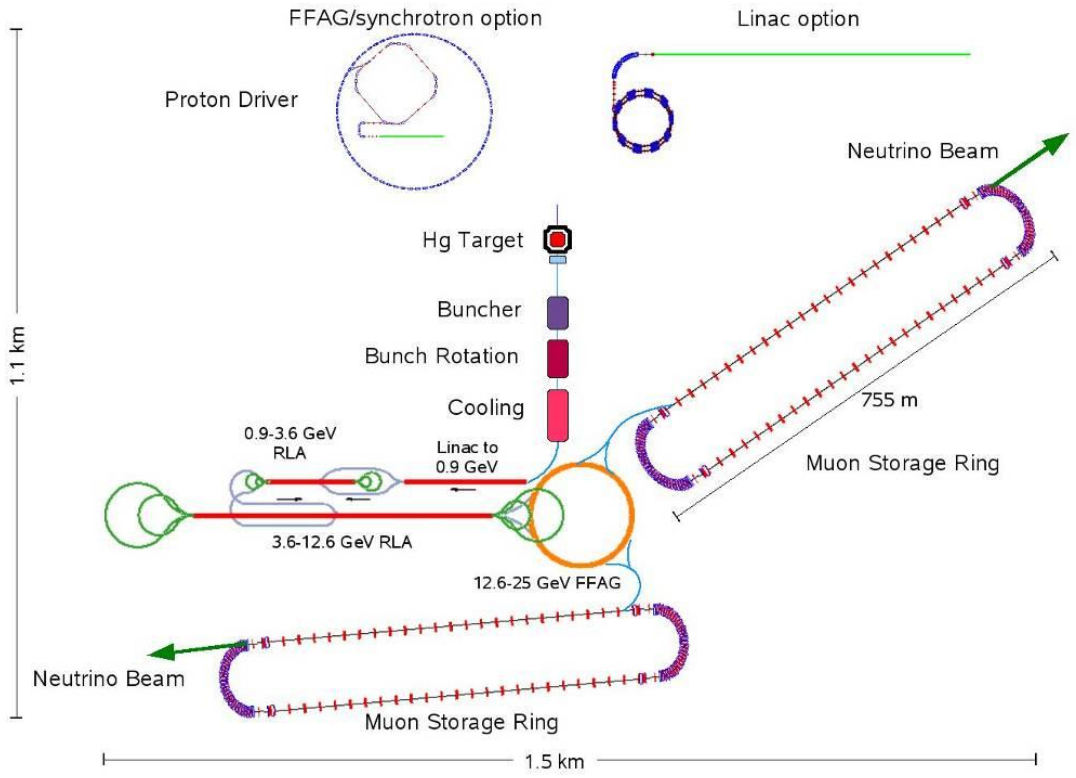
One small problem.....

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

Introduction

- **Linear non-scaling FFAGs:**
  - **invented 1997/9**
  - **for muon acceleration in a Neutrino Factory**

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

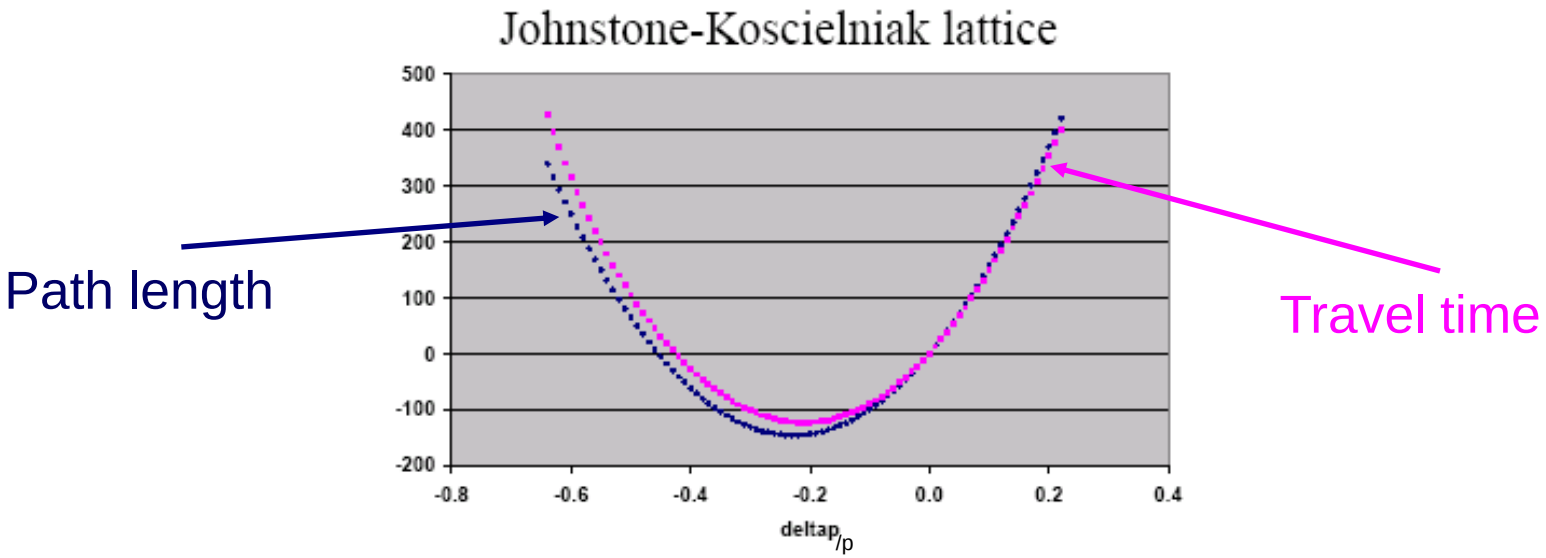


Neutrino Factory

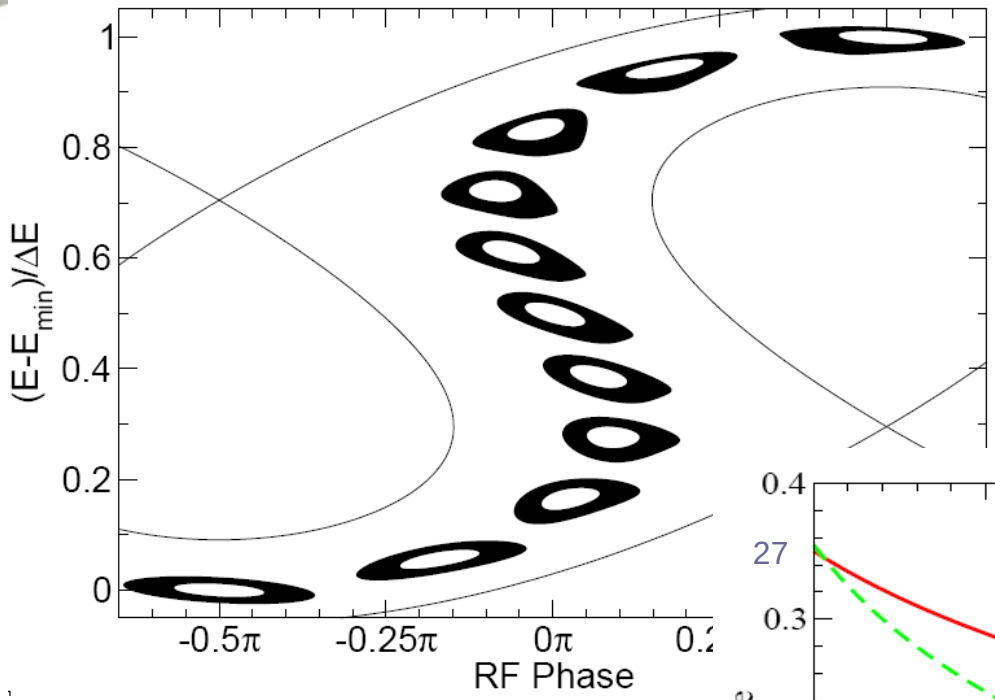
Introduction

- **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**

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

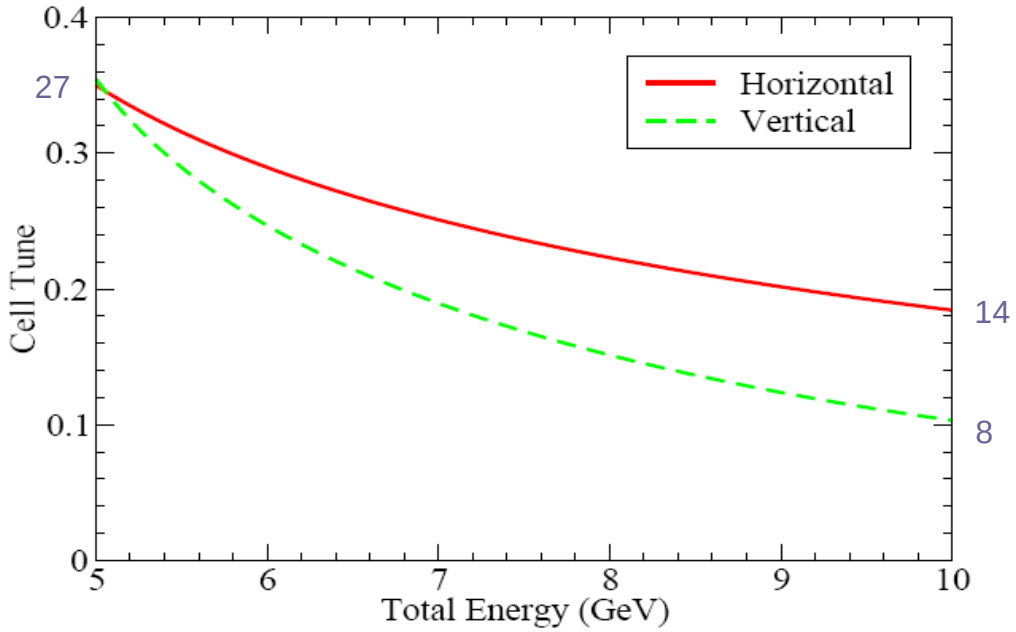


Introduction



Serpentine, bucketless, asynchronous, etc acceleration

Fast resonance crossings



Science & Technology Facilities Council

Motivation for EMMA

- **Realised early on:**
  - **Other potential applications:**
    - **hadron therapy**
    - **ADSR**
    - **other high power proton beam applications**
  - **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**

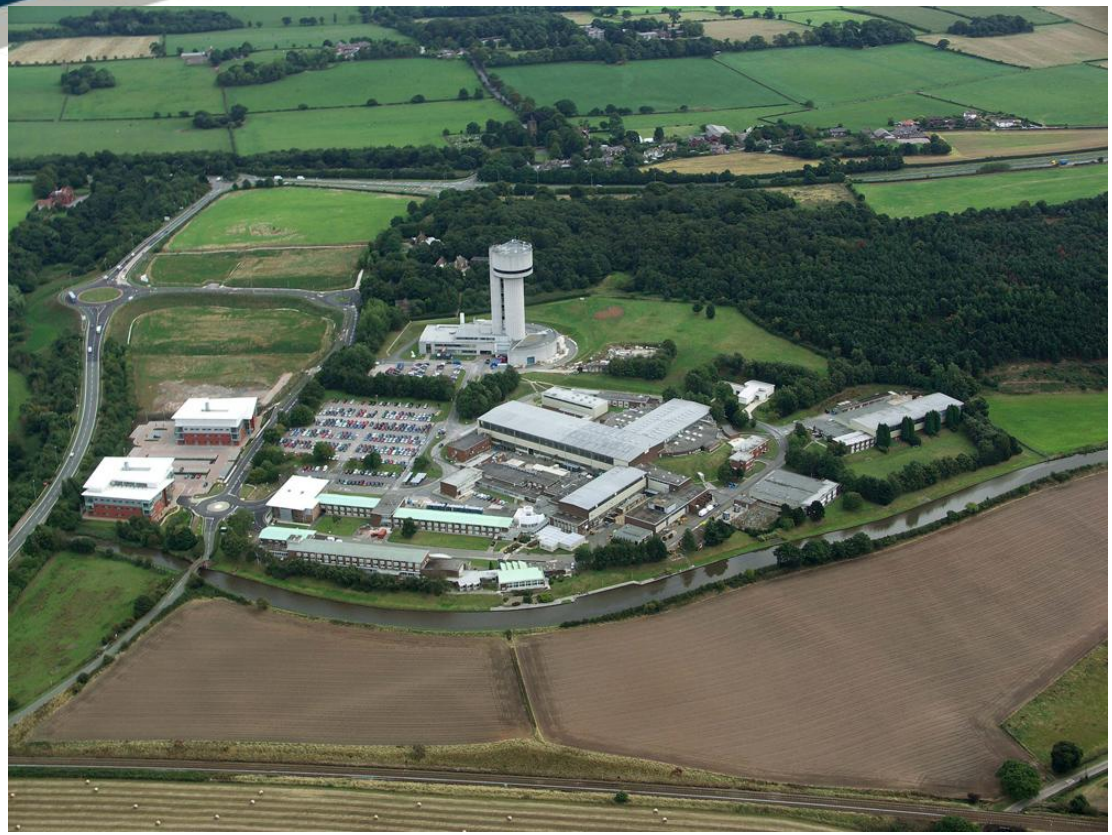
MOPEA021
MOPEC047

EMMA Design

- Simplest to build 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!

Science & Technology Facilities Council

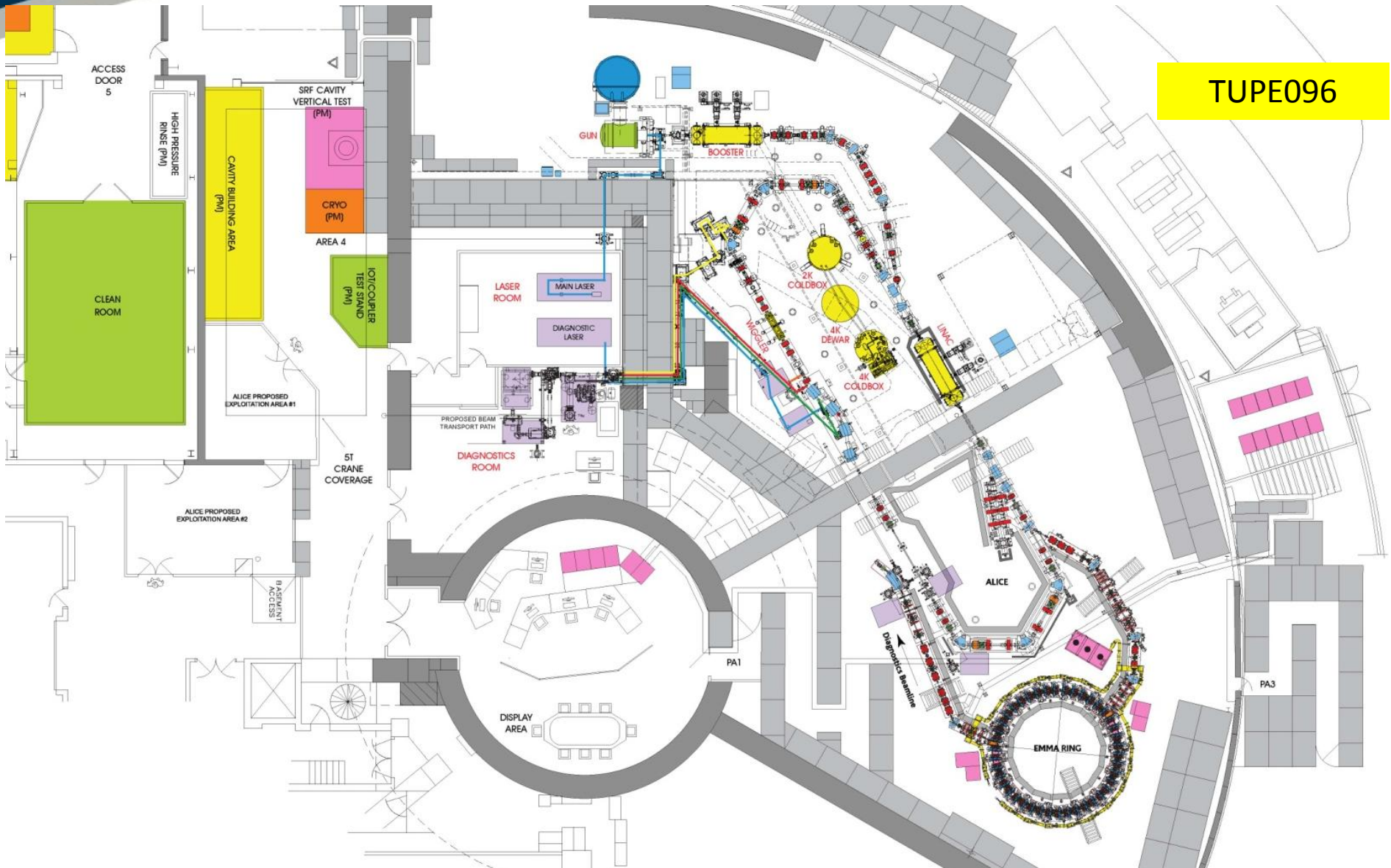
EMMA Location



Science & Technology Facilities Council

EMMA Location

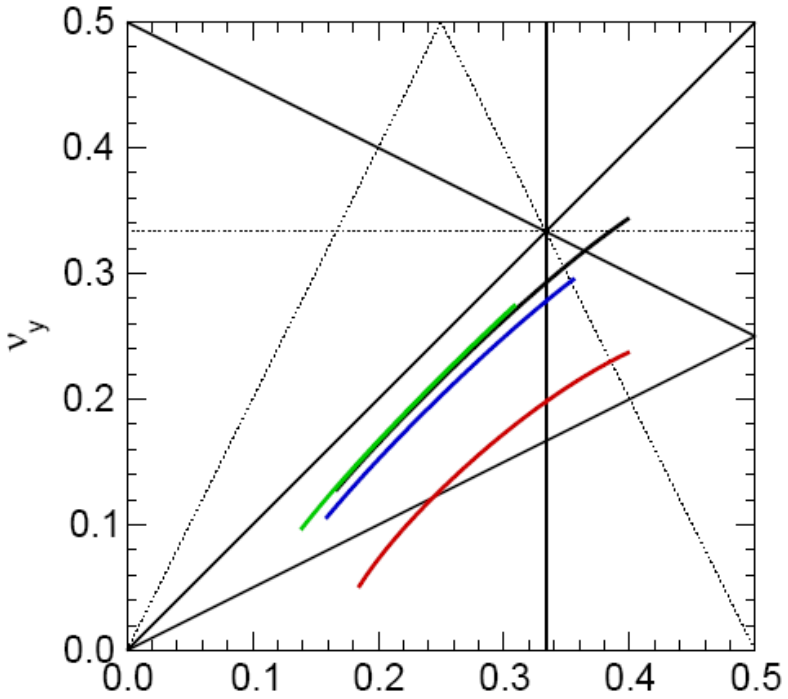
TUPE096

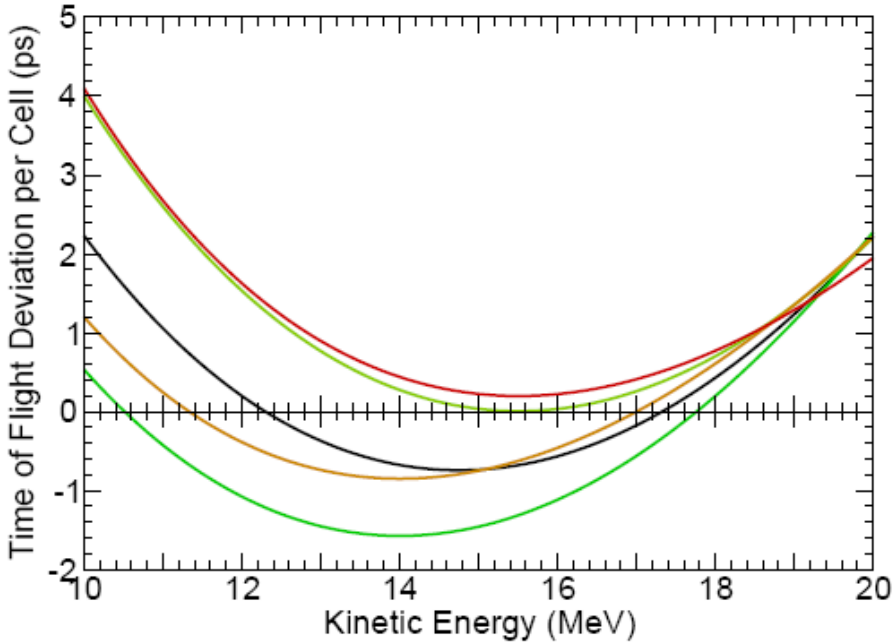


Science & Technology Facilities Council

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

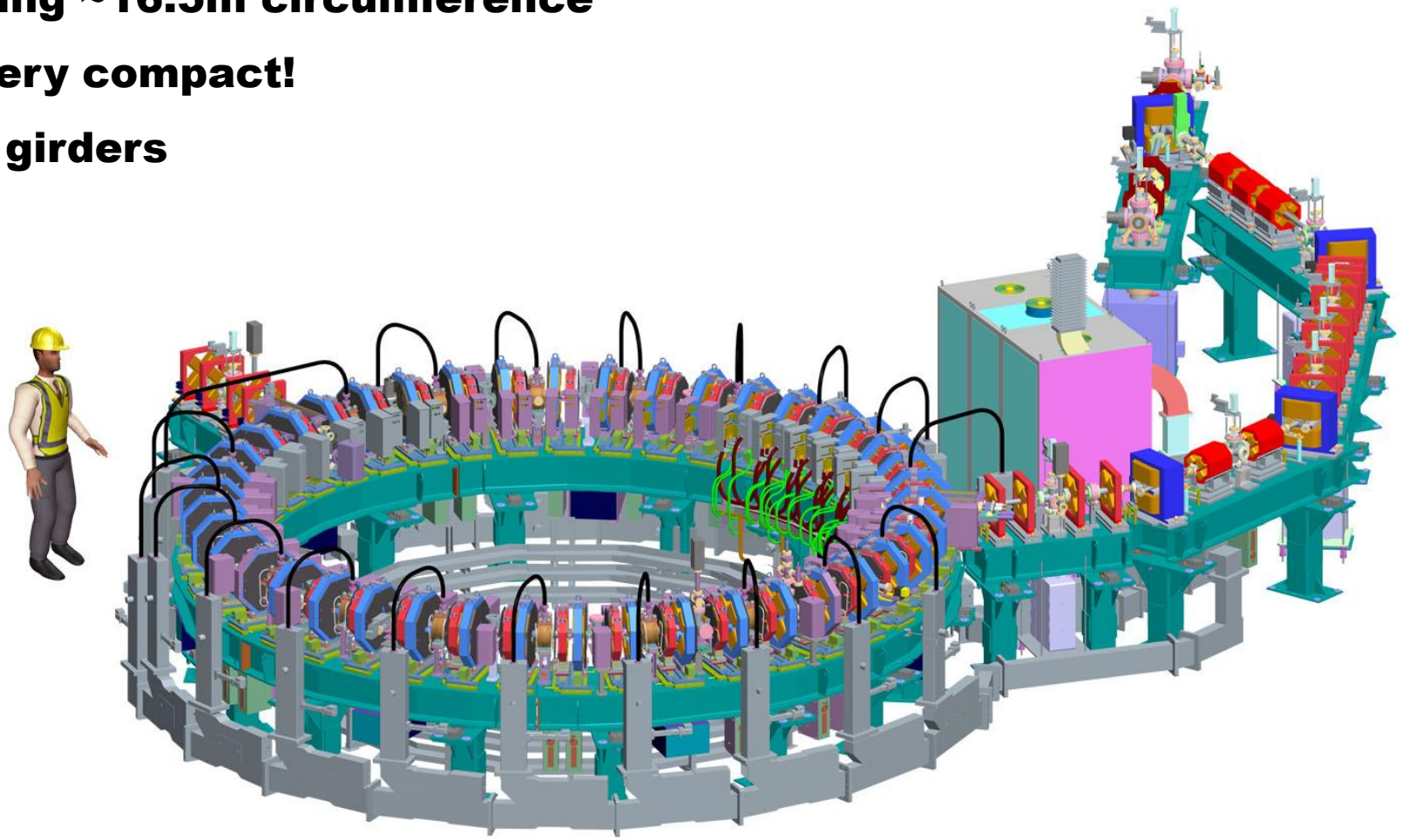
EMMA Design

42 “identical” cells, ~40cm long

Ring ~16.5m circumference

Very compact!

7 girders



Science & Technology Facilities Council

EMMA Design

42 “identical” cells, ~40cm long

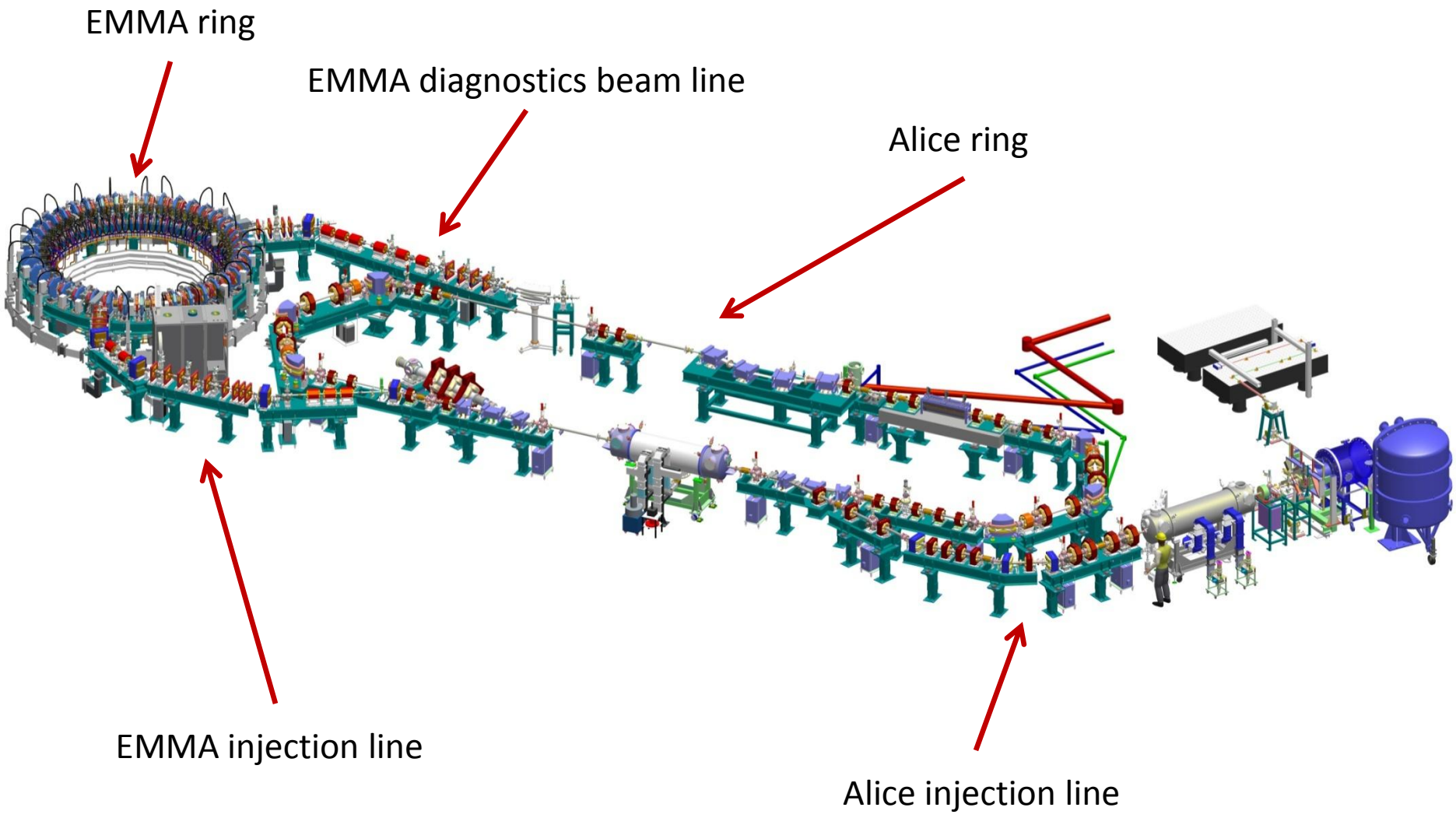
Ring ~16.5m circumference

Very co

7 girde

Science & Technology Facilities Council

Status of Construction



Science & Technology Facilities Council

Injection line

Transport beam to EMMA.

Matching.

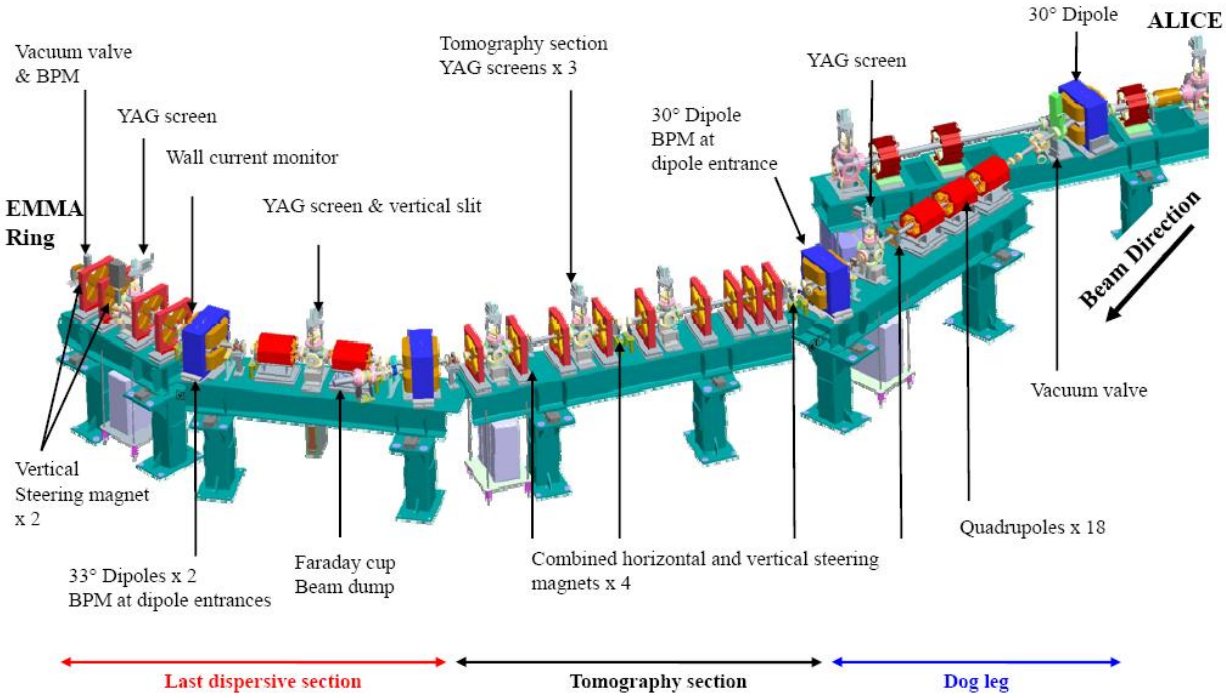
Measure beam parameters on entry to EMMA.

Completed ~2 months.

Beam transported to end.

First measurements made.

MOPEC046



Science & Technology Facilities Council

Injection line

Transport beam to EMMA.

Matching.

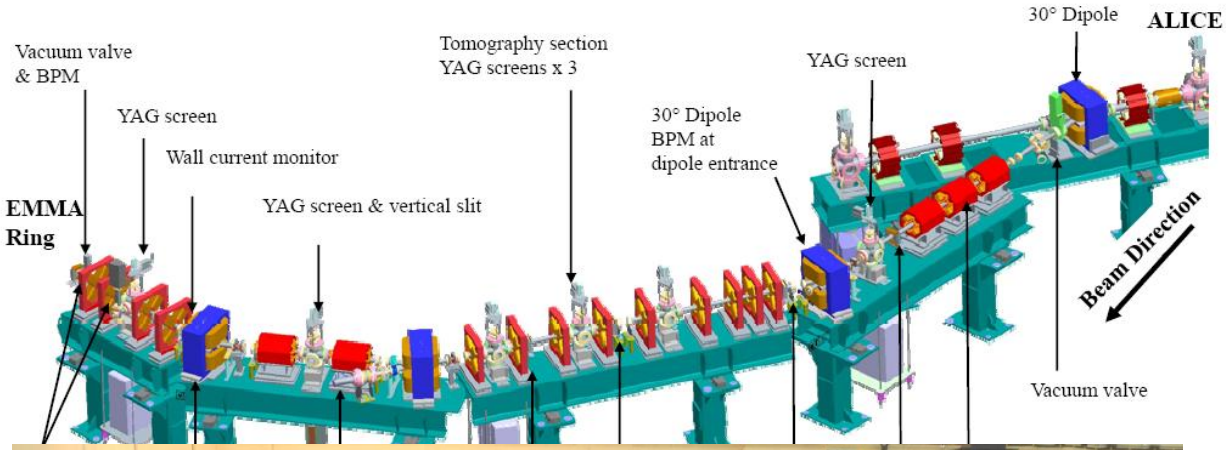
Measure beam parameters on entry to EMMA.

Completed ~2 months.

Beam transported to end.

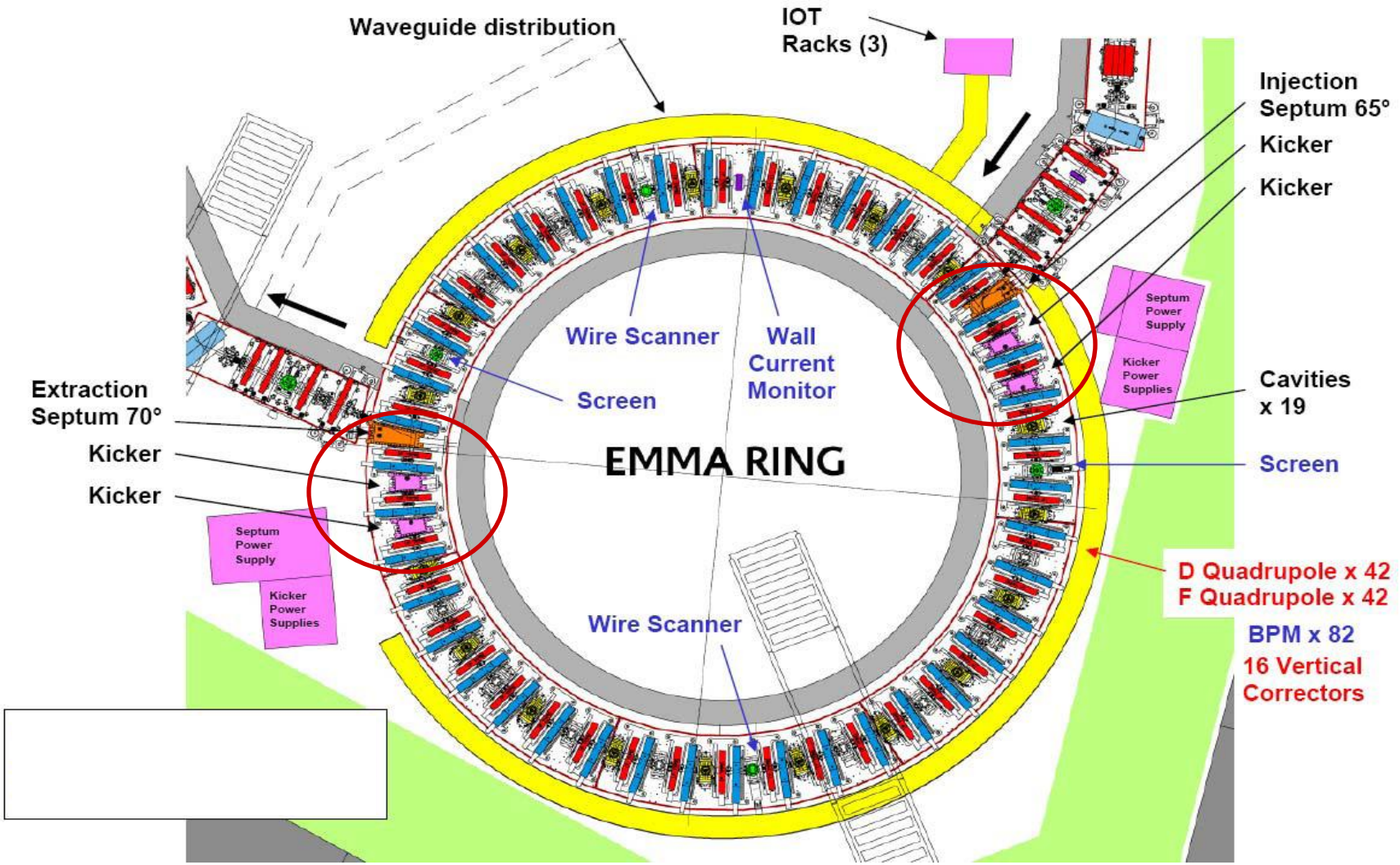
First measurements made.

MOPEC046



Science & Technology Facilities Council

EMMA Ring

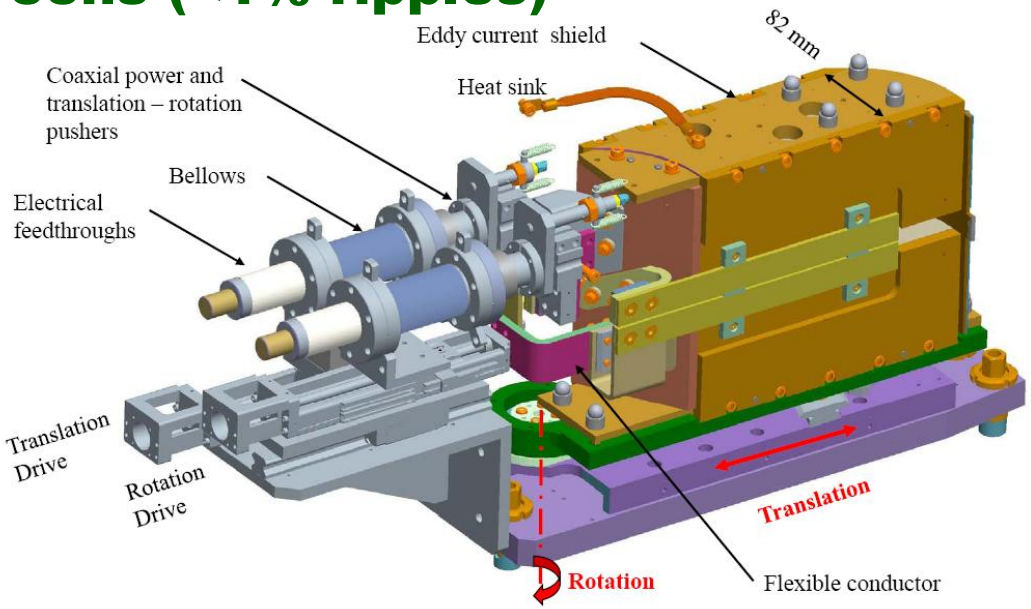


Science & Technology Facilities Council

Injection & Extraction

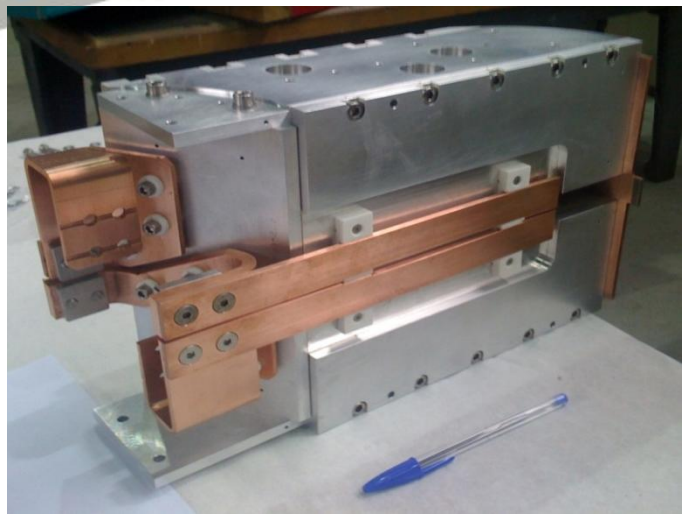
Requirements

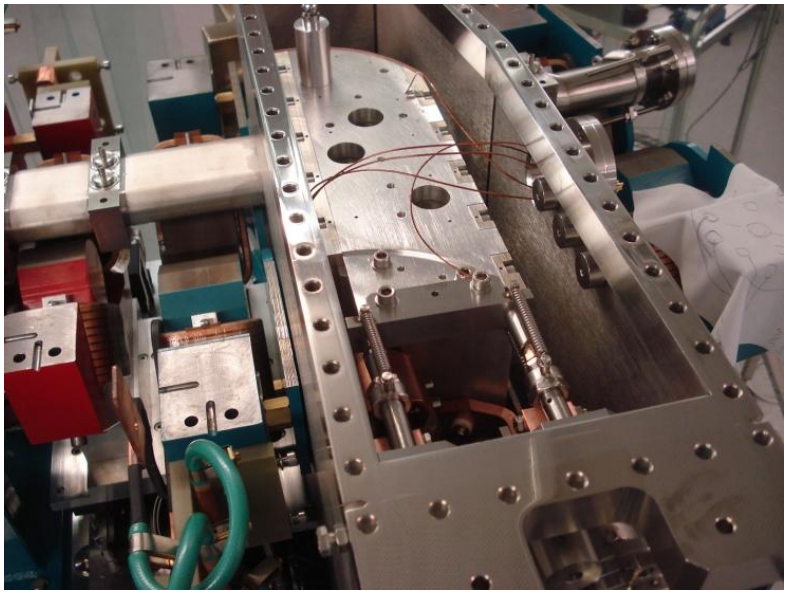
- **Injection of:**
  - **all 8 lattices**
  - **all energies between 10 and 20 MeV**
  - **into 3π m mrad**
- **Minimal impact on next turn:**
  - **leakage field from septum < 0.01%**
  - **kickers off before 55ns (<1% ripples)**
- **Slot length: ~10cm**

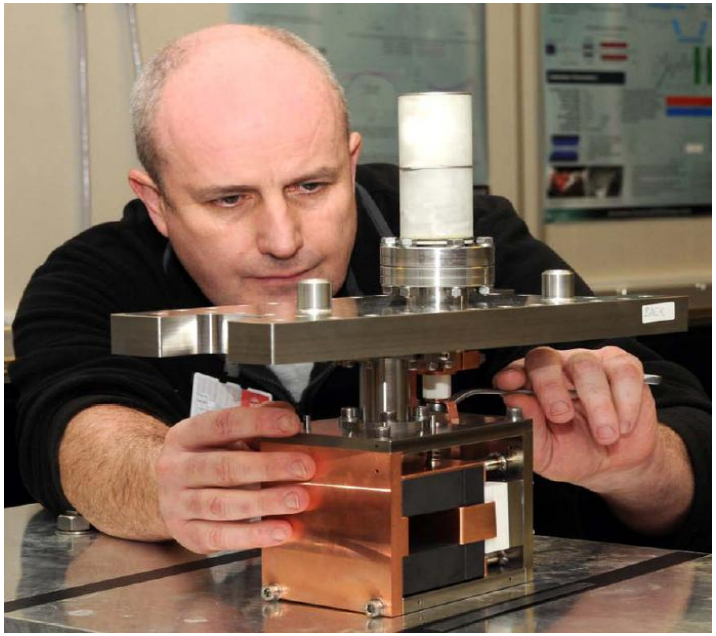


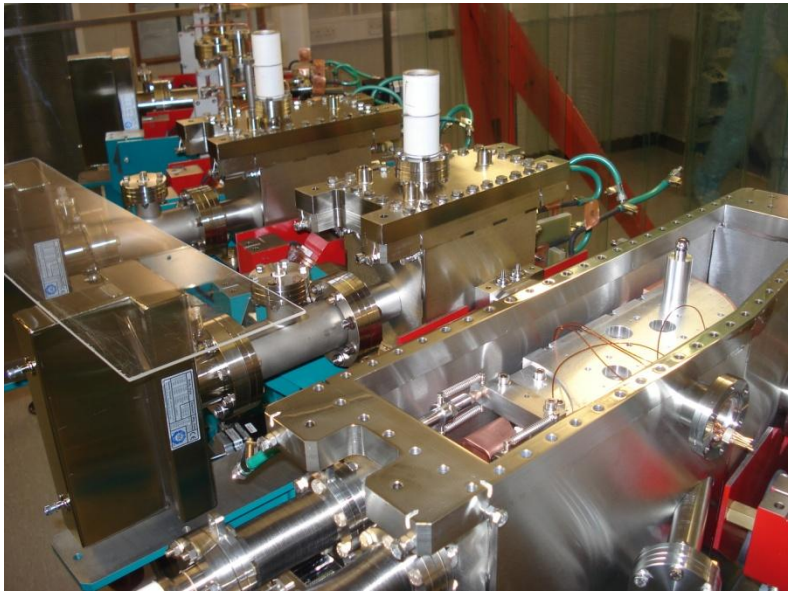
Science & Technology Facilities Council

Injection & Extraction





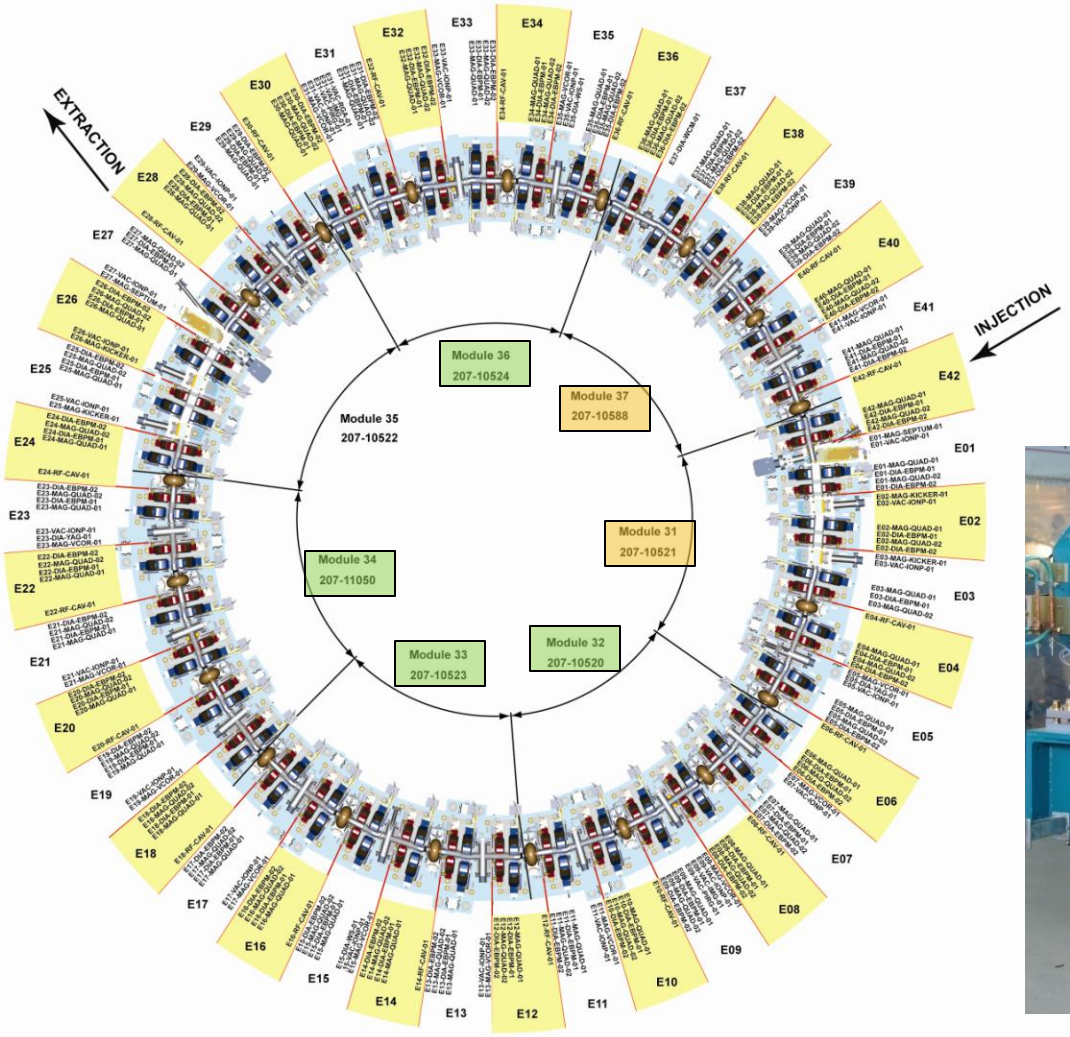




Science & Technology Facilities Council

EMMA Ring

- **42 cells mounted on 7 girders:**

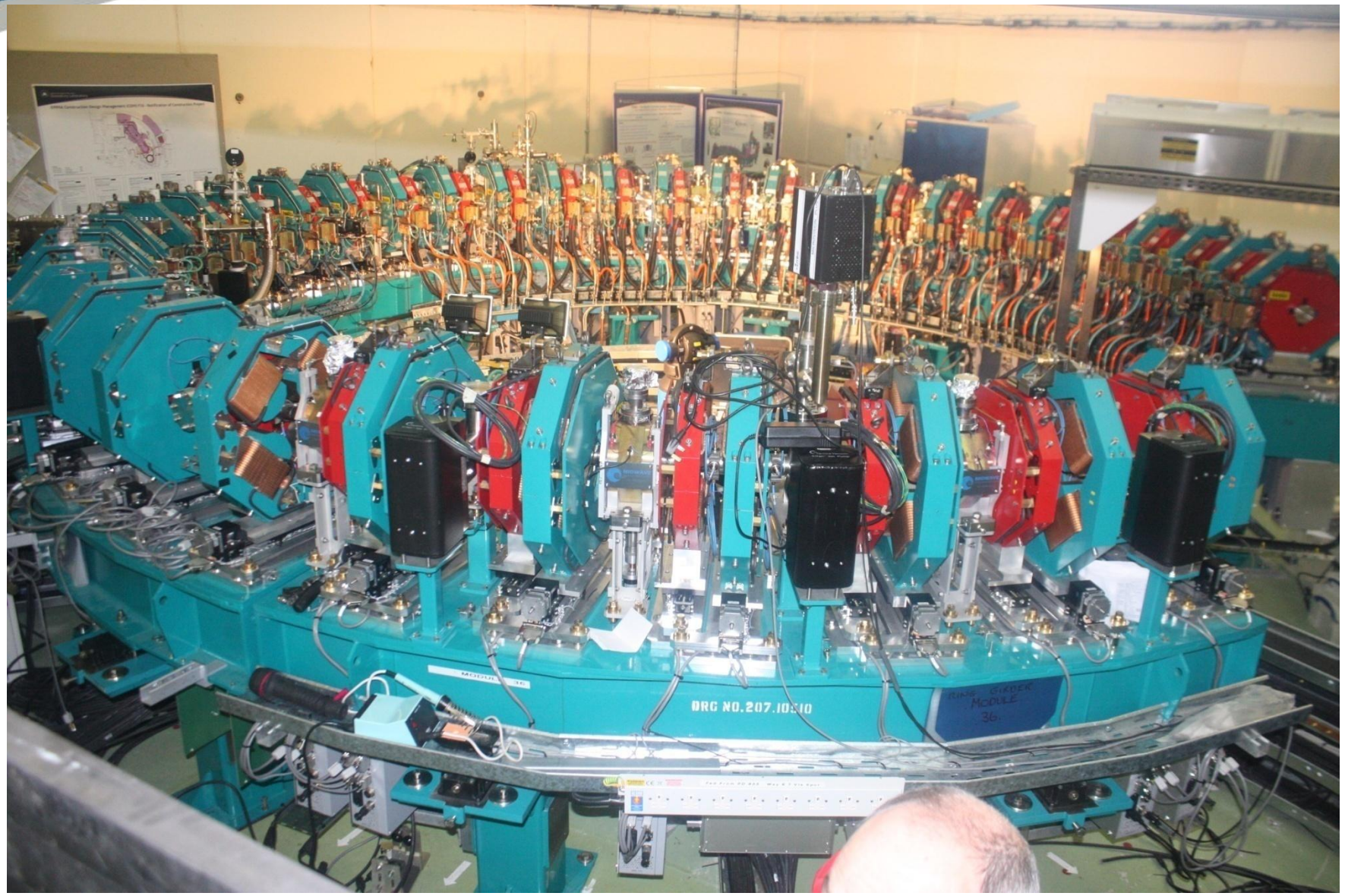


Science & Technology Facilities Council

EMMA Ring

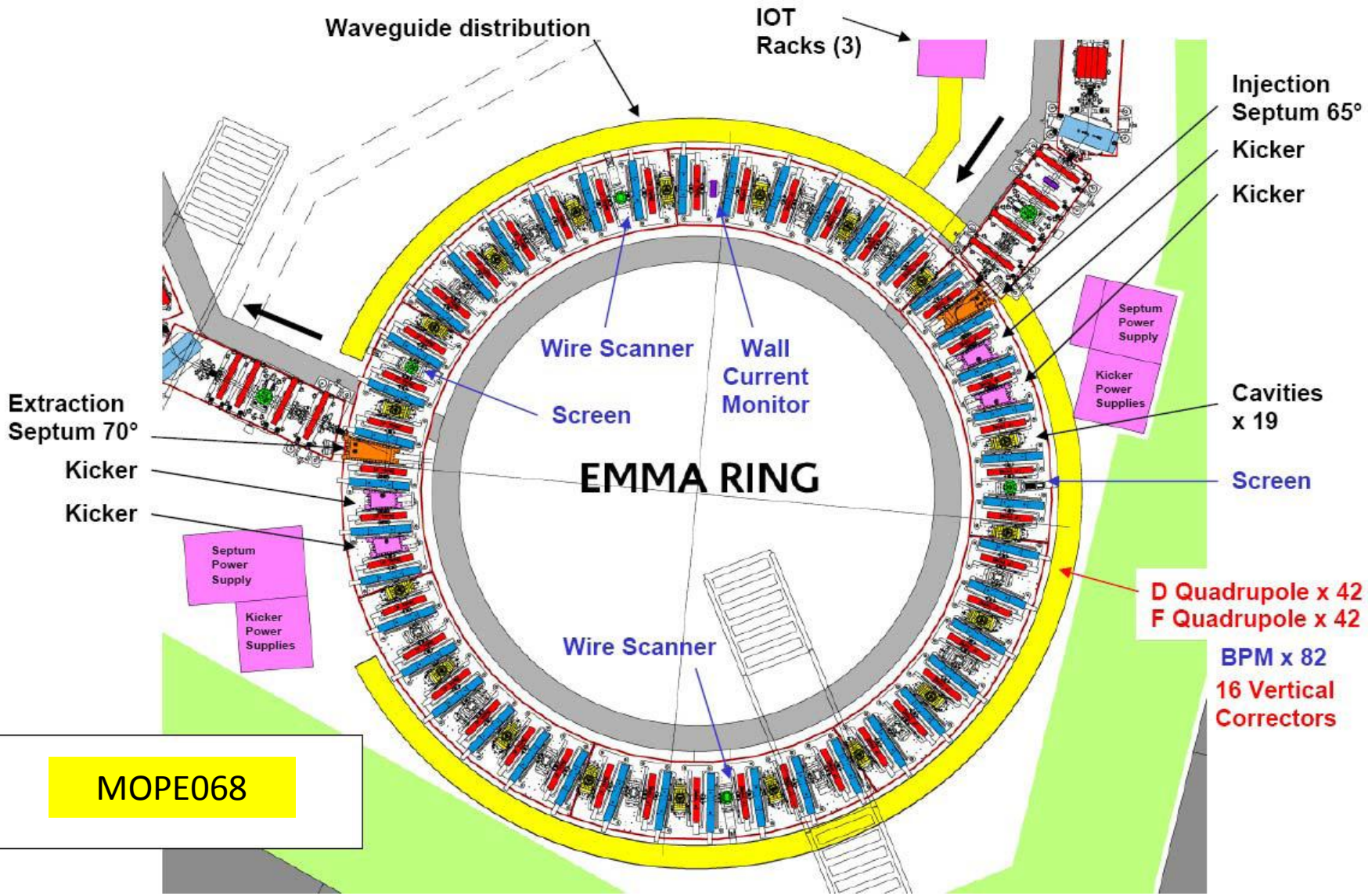
Science & Technology Facilities Council

EMMA Ring



Science & Technology Facilities Council

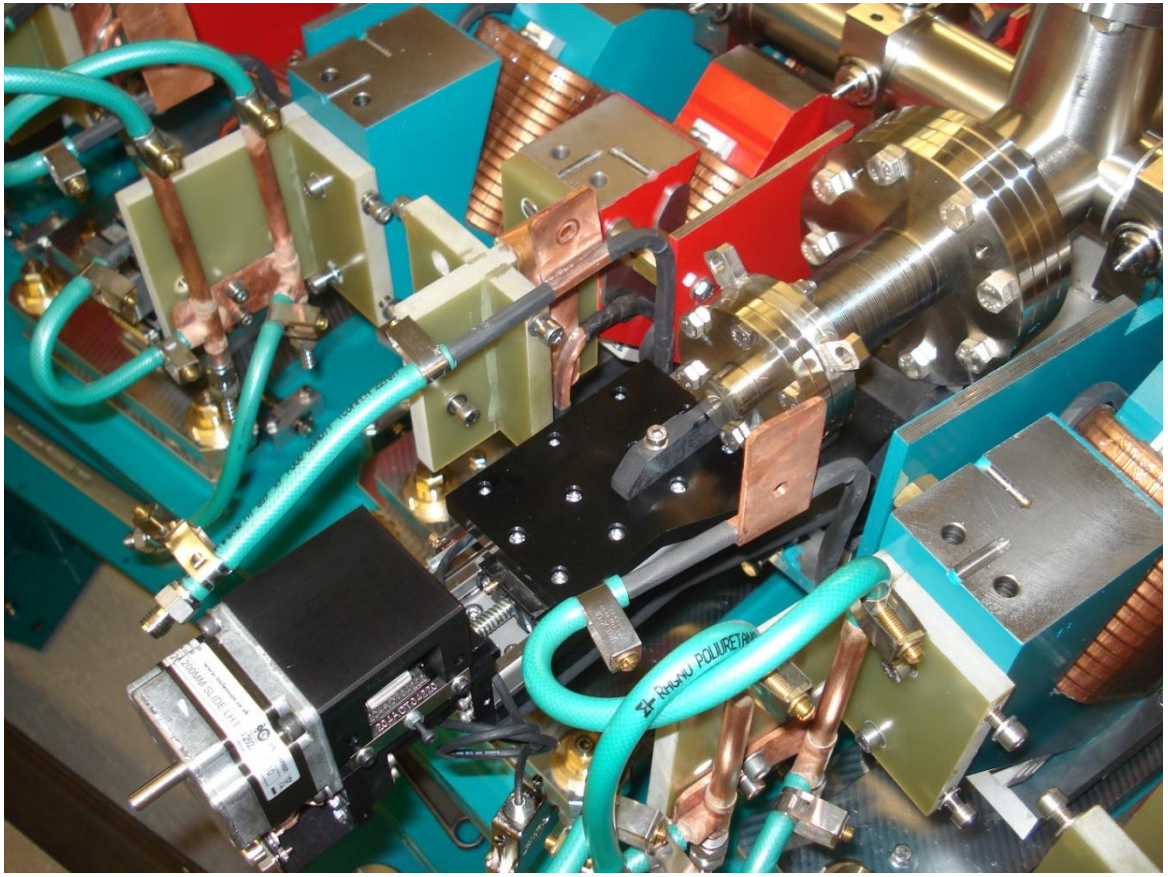
Diagnostics



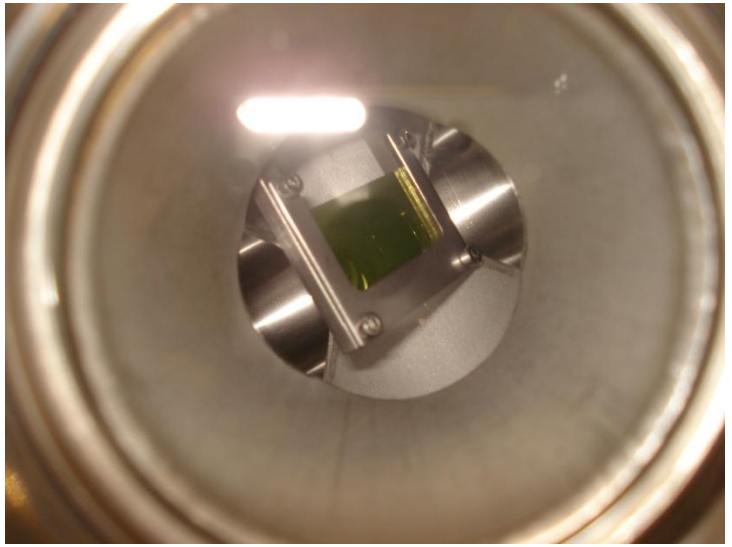
MOPE068

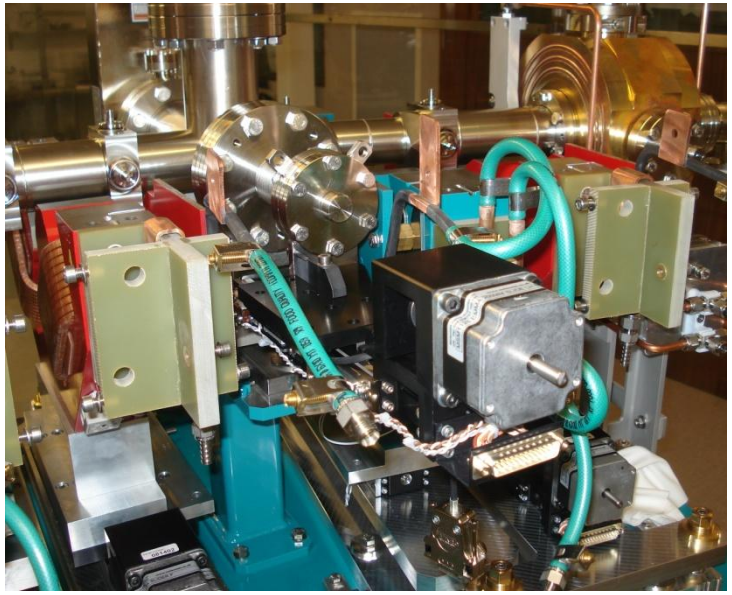
Science & Technology Facilities Council

Diagnostics



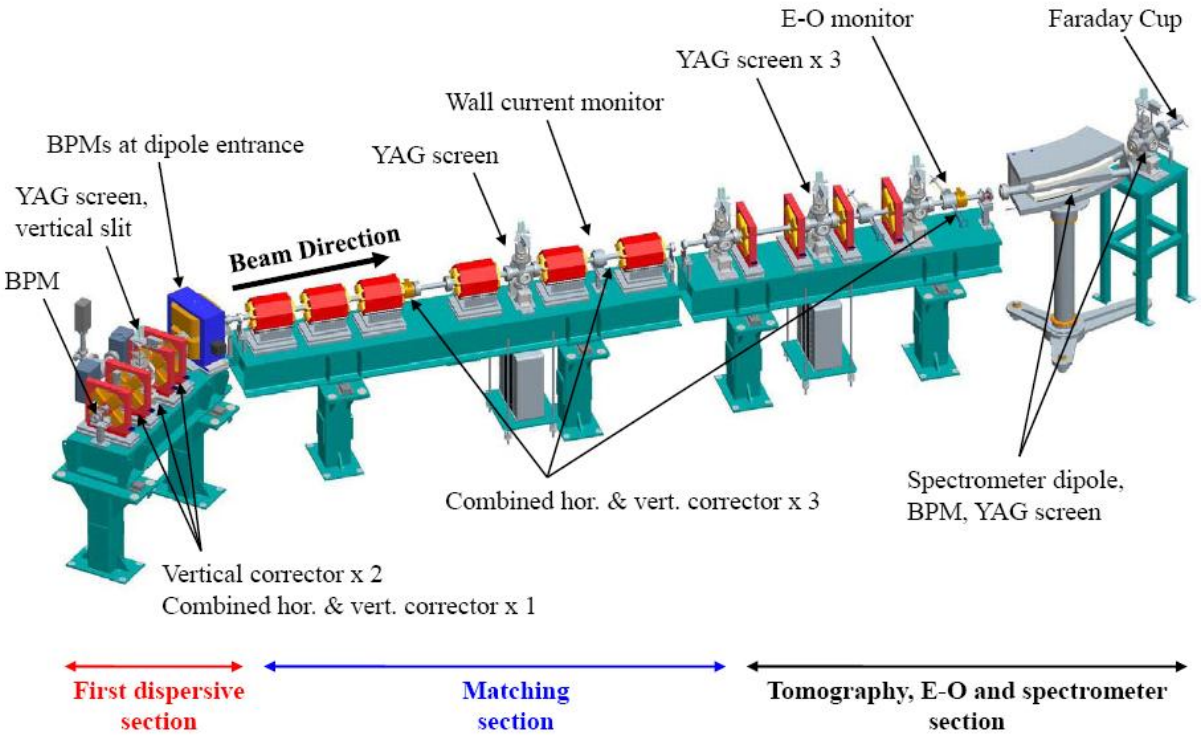
YAG screen





Science & Technology Facilities Council

Diagnostics Beam Line



"Destructive" diagnostic devices.

Beam can be extracted at any energy for measurement

Science & Technology Facilities Council

Commissioning Status

Stages in commissioning

- **ALICE:**
  - **settings required for EMMA**
  - **beam parameter measurements**

  Started

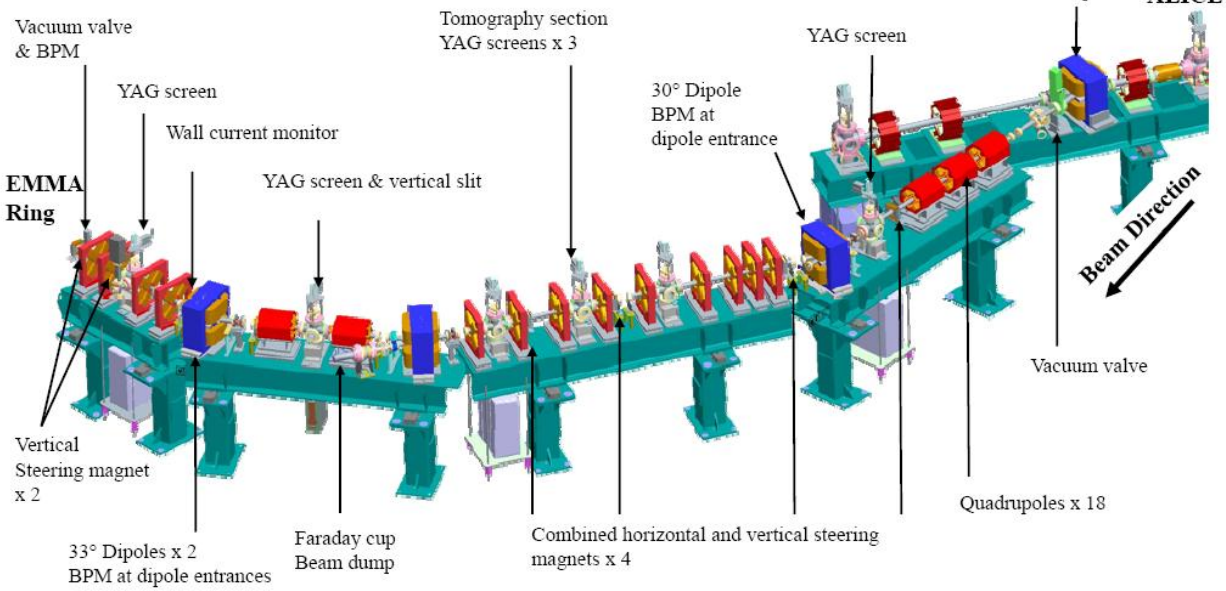
- **Injection line:**
  - **transmission of beam**
  - **diagnostics commissioning**

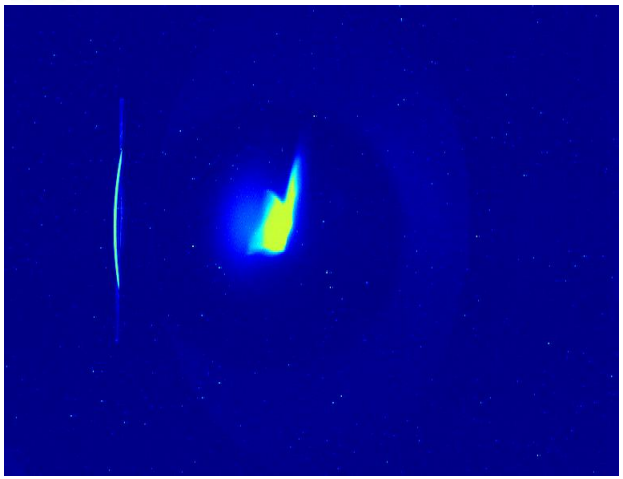
  Started

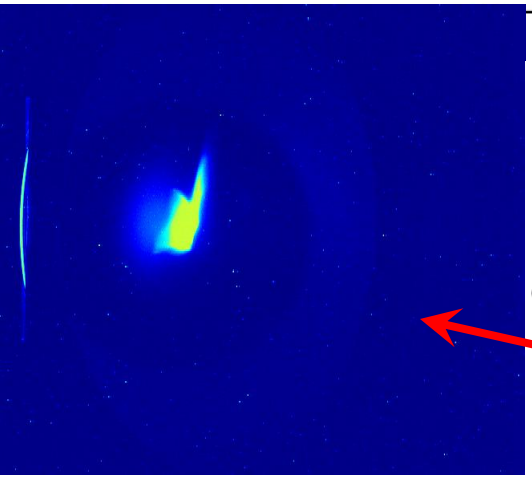
- **4 sector commissioning:**
  - **injection & setting beam on orbit**
  - **check lattice(s)**
  - **tune measurements**

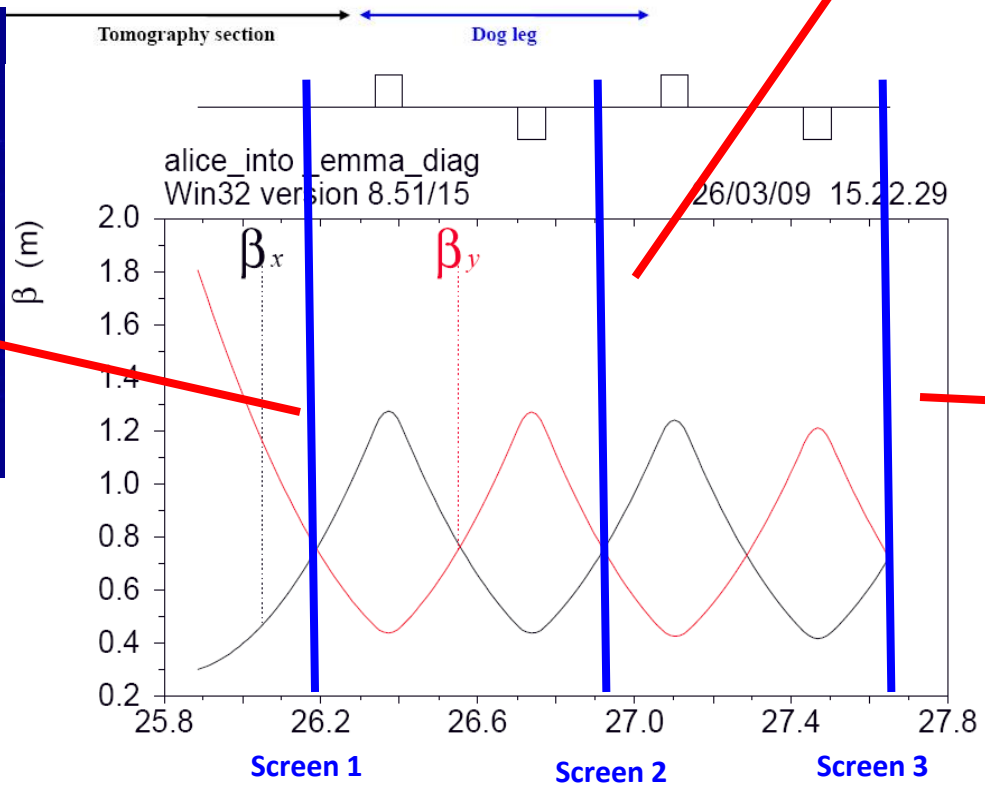
  Very soon!

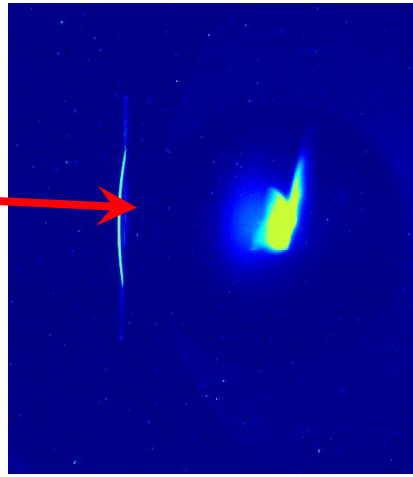
- **Full ring**
- **Extraction and external beam measurements**











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