Electron model for muon acceleration EMMA

Shinji Machida

CCLRC/RAL/ASTeC

15 May, 2006

http://hadron.kek.jp/~machida/doc/nufact/ffag/machida_20060515emma.ppt & pdf

Background

- Electron model of non scaling FFAG was proposed. It is a scaled down model of muon ring from 10 to 20 GeV.
- Beam dynamics aspects are discussed in a regular phone meeting, every two weeks.
- Engineering design recently started at Daresbury Laboratory.
- First iteration of cost estimate has been done.
- Proposal is submitted to BT to obtain funding.

Location

- Daresbury Lab is constructing a ERLP (energy recovery linac prototype?) and electron injector of around 10-30 MeV is available.
- Frequency of e-linac is 1.3 GHz.
- There is a place for EMMA which used to be an experimental hall of Tandem accelerator.

Layout at Daresbury Laboratory

Main parameters

• Energy	10 to 20 MeV electron
• Circumference	~16 m
• Number of cell	42
• RF frequency	1.3 GHz
• Lattice	doublet

Cost estimate

• RF cavity system (only for fundamental)	
– RF cavity	286,000 (pounds)
– Waveguide distribution	331,500
– RF amplifier	960,000
– Cabling	24,000
– HV supply transformer	8,000
• Diagnostics	154,000
• Magnets	
– Main magnets	466,430
– Injection&extraction kicker	40,000
• Mechanical&vacuum chamber	290,400
• Vacuum equipment	134,300
• Controls	121,662
• Electrical (power supply)	298,950
• Cooling&services	70,000
• Civil	42,000

Total 3,227,242 + 1,330,000 (staff)
= 4,557,242
(8.1 M$, 9.5 OkuYen, 6.6 MEuro)

Goals and specifications

Accelerate outside of RF bucket

Resonance crossing

Large acceptance

Commissioning procedure

Goal (accelerate outside of RF bucket)

- Study items
  - Dependence of “a” and “b” parameters.

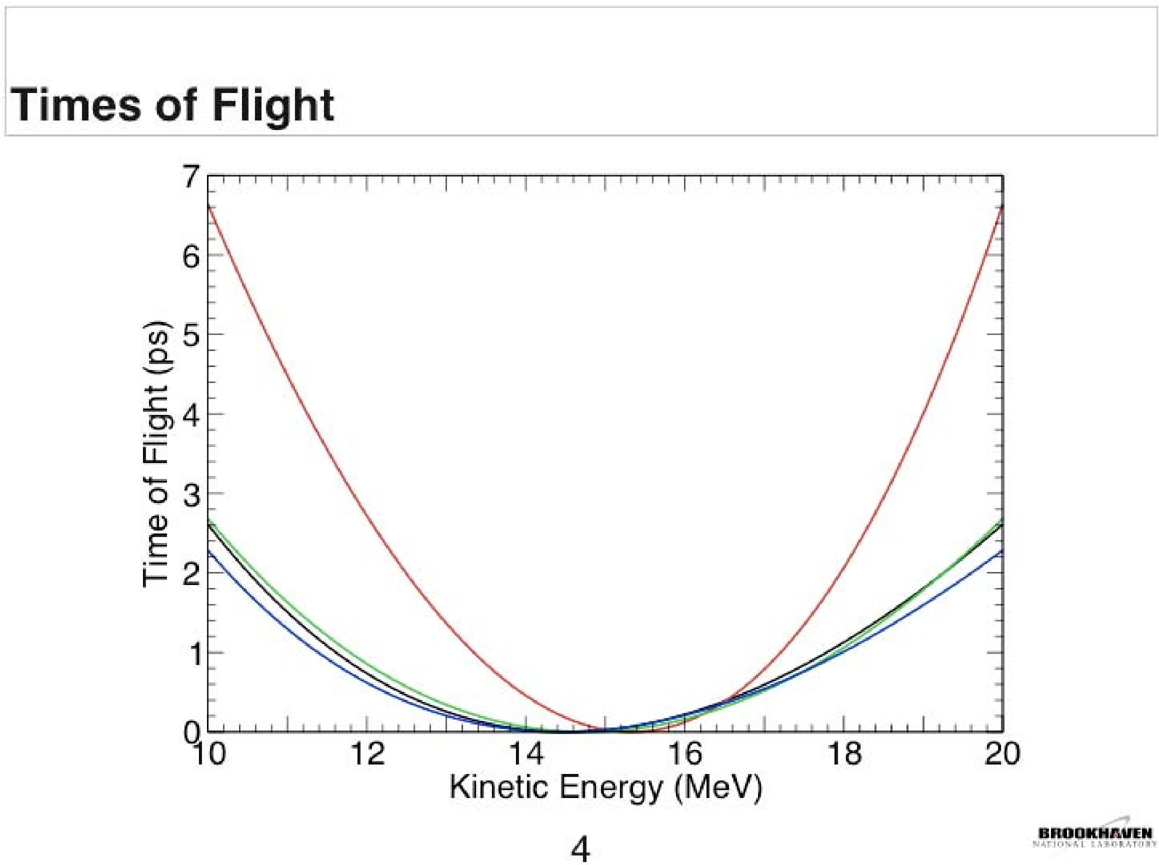
$$a = \frac{qV}{\omega \cdot \Delta T \cdot \Delta E} \left(\text{Energy gain per phase slip} \right) \qquad b = \frac{T_0}{\Delta T} \left(\text{RF frequency relative to revolution f} \right)$$

  - Time of flight variation.
  - Effects of errors in voltage and phase.
  - Effects of injection mismatch in longitudinal phase.

- Requirements for hardware
  - RF frequency: $\Delta f/f = 10^{-3}$?
  - RF voltage: factor of 4 or 6 ?
  - Precision of RF phase:
  - Independent knobs for dipole and quadrupole components

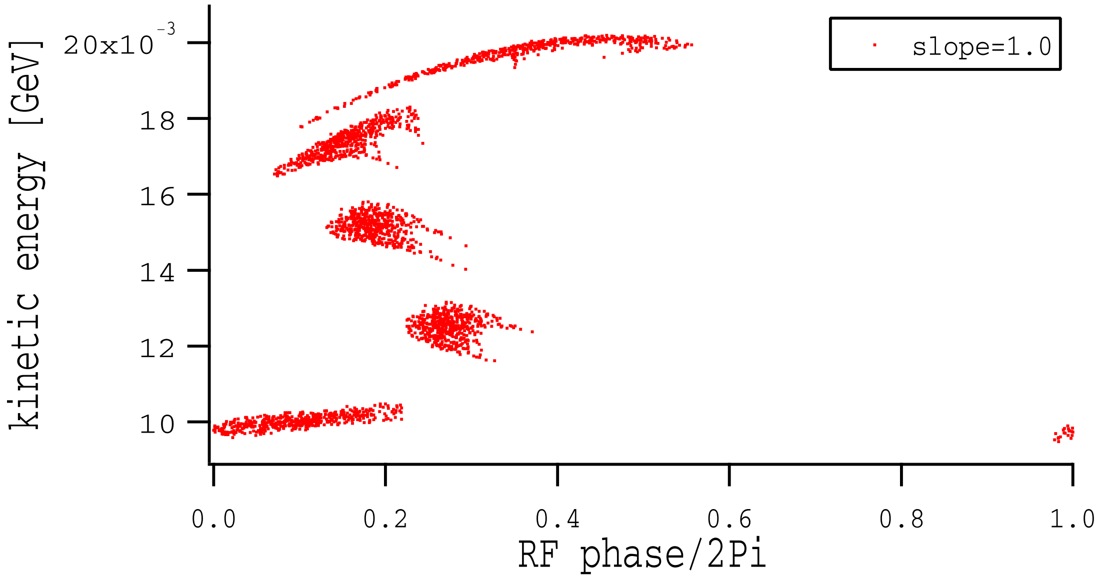
RF frequency range

Calculation by Berg shows we need Df/f = 6×10^{-3} for some operating point.



Phase precision

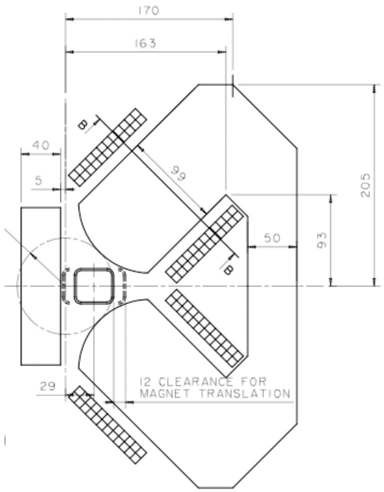
- One RF cycle is 770 ps.
- Precision of 1 degree means 2 ps.

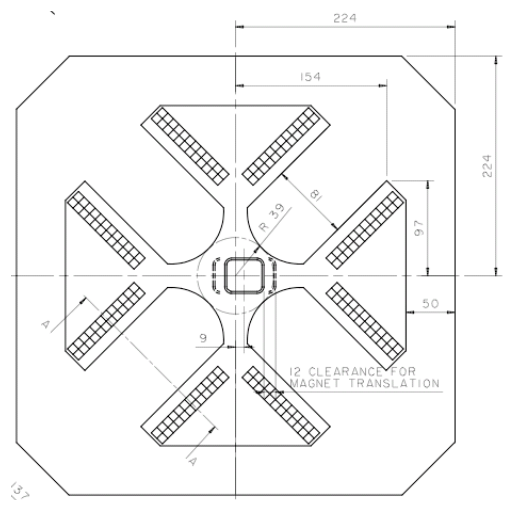


Independent knobs for D and Q

- There was a proposal at Fermilab to combine permanent magnet and coils.

- Daresbury people assume a full and a half quadrupole in a movable table.
- Johnstone has different idea.





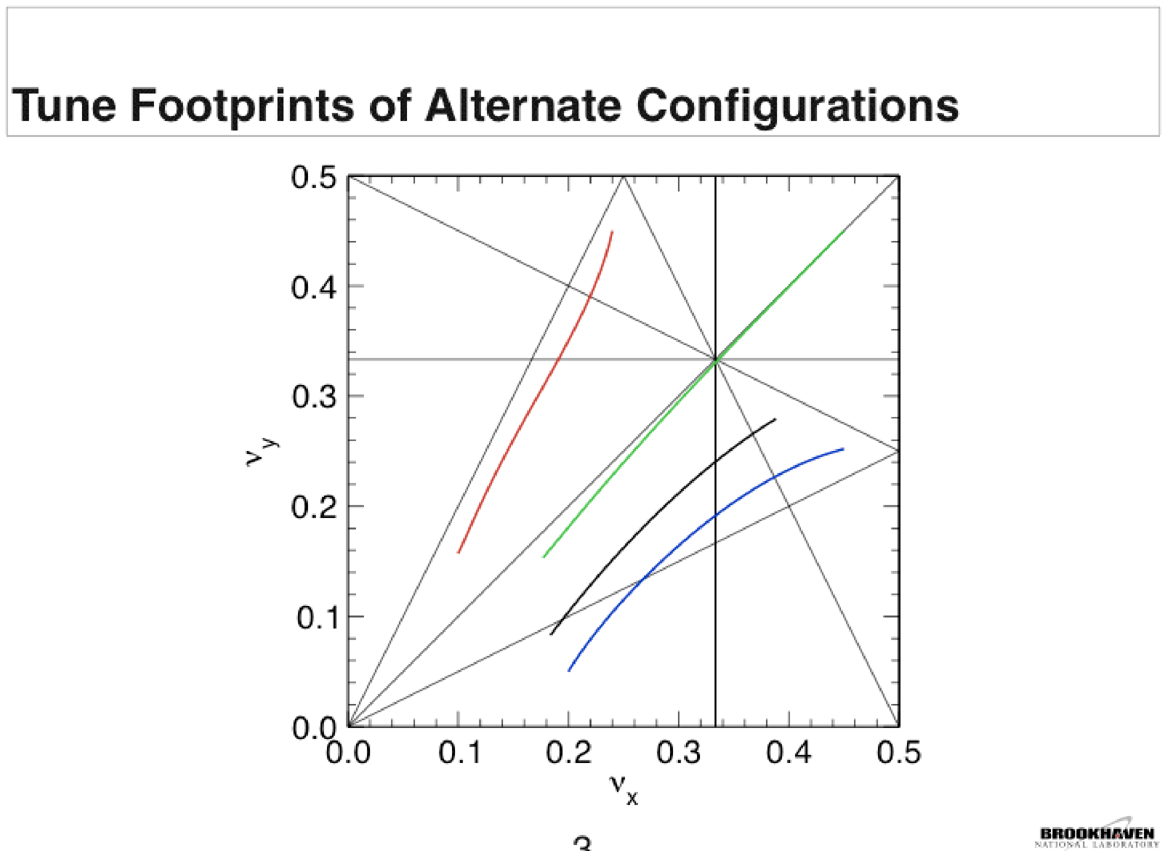
Goal (resonance crossing)

- Study items
  - Tune
  - Different source of resonance lines.
  - Crossing rate.
  - Effects of known misalignments and field errors.
  - Effects of mismatch at injection.

- Requirements for hardware
  - Variable gradient: 25% ?
  - Precision of alignments: 100 μm ?
  - Gradient error: 10^{-3} ?
  - RF voltage: factor of 4 ?

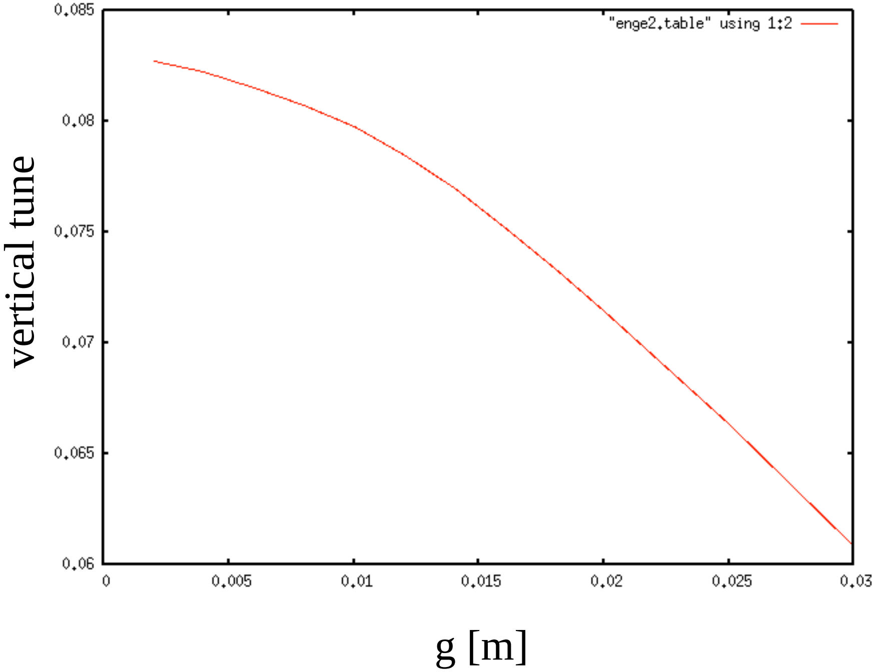
Gradient range

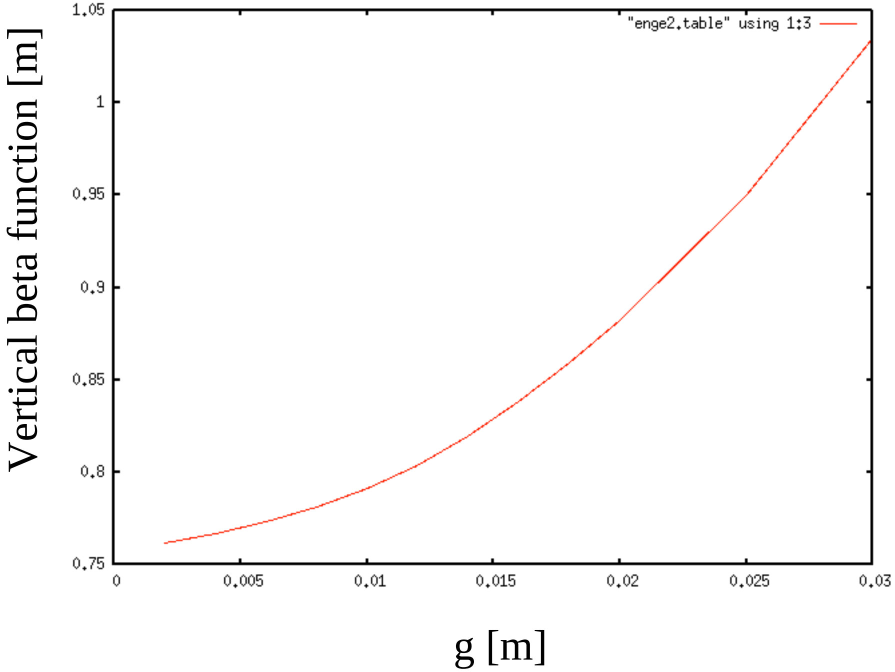
To explore tune space, gradient has a variation of 25%.



Calculation by Berg

ν_y and β_y vs. *g* (scaling parameter of the order of gap)





Beam size increases 10-15% when *g*=20-30 mm.

Alignment errors

- QD
  - Dipole field: 0.13 T
  - Quadrupole field: 4.6 T/m
  - 0.0001 m displacement is 0.46×10^{-3} T or 3.5×10^{-3} of dipole

- QF
  - Dipole field: 0.051 T
  - Quadrupole field: 7.4 T/m
  - 0.0001 m displacement is 0.74×10^{-3} T or 1.5×10^{-2} of dipole

RF voltage

- If it is high enough to demonstrate “fast crossing”?
- How low can we reduce voltage to simulate “slow crossing” with stable operation?

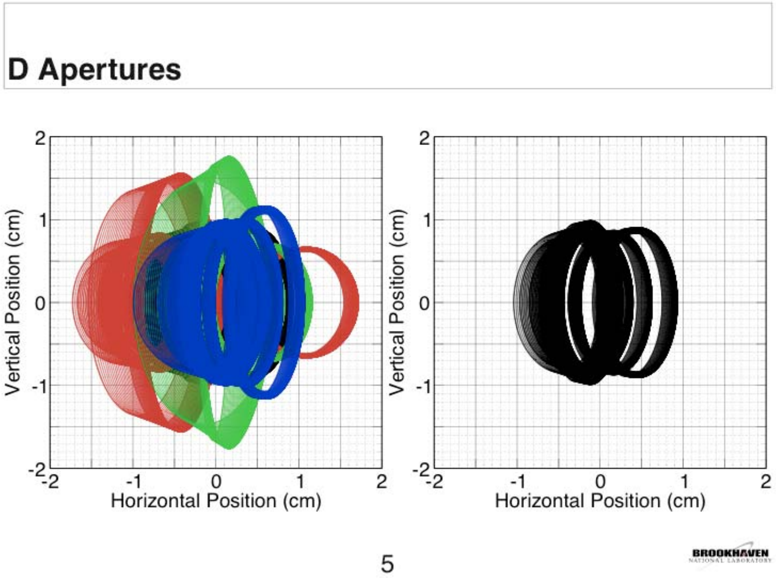
Goal (large acceptance)

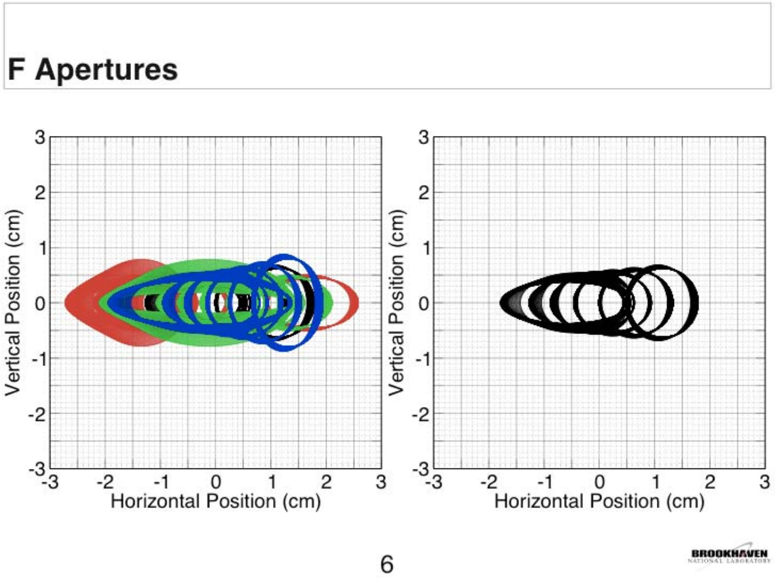
- Study items
  - Aperture survey at fixed energy.
  - Acceleration of large transverse amplitude.

- Requirements for hardware
  - Enough aperture: Main magnet does not have problem. RF cavity may have.
  - RF voltage: factor of 2 ?
  - Second or third harmonic RF ?
  - Scanning magnet

Magnet aperture

Calculation by Berg shows the aperture range of +-20 mm at QD and +-30 mm at QF.

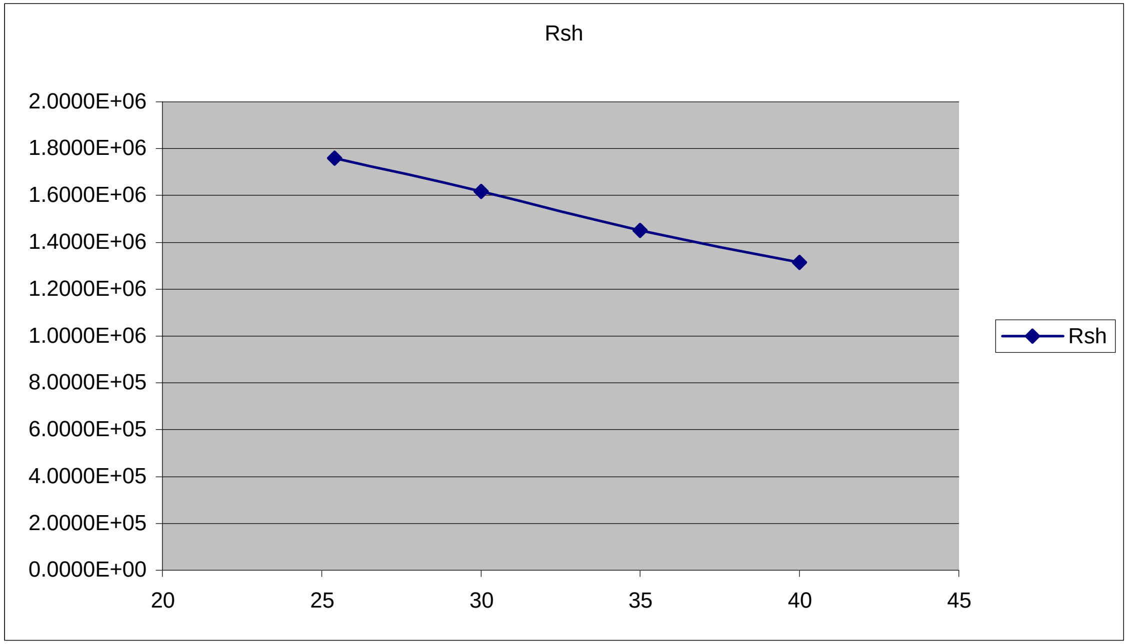




RF cavity aperture

- Cost estimate is based on 25 mm diameter.
- We prefer the aperture more than 45 mm.

Shunt impedance decrease by 33%.



Calculation by C.D.Beard

Goal (commissioning)

- Study items
  - Time of flight measurement.
- Requirements for hardware

Commissioning

- Only an injection momentum beam is available when we start commissioning of muon ring.
  - Parabola curve without high momentum beam.
  - “b” parameter without high momentum beam.
  - How we measure ToF with a single turn?

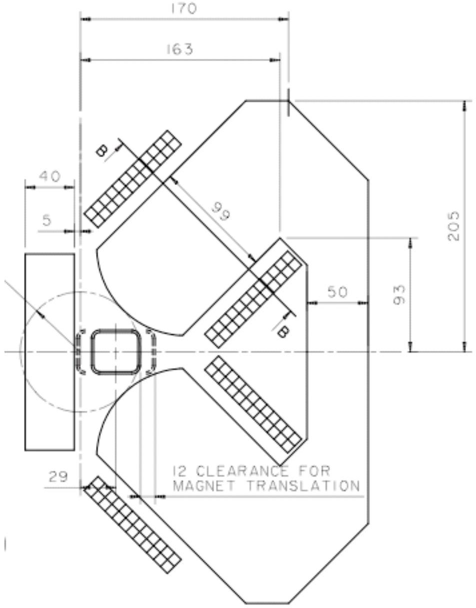
Missing items

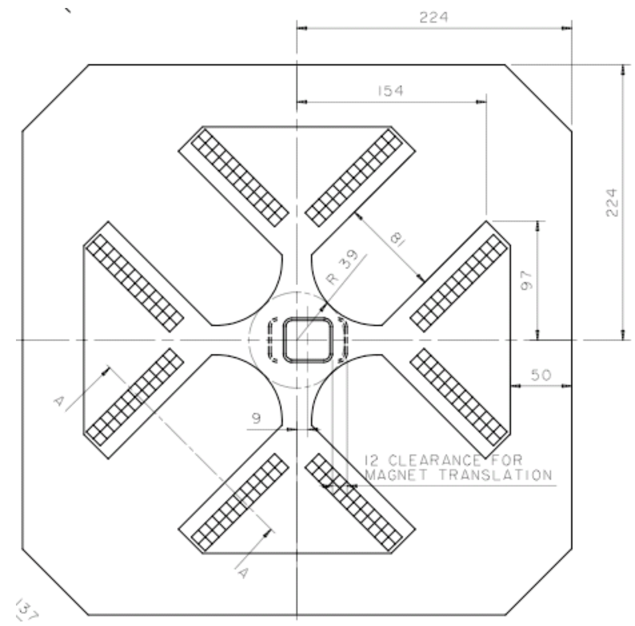
- Injection and extraction
  - Optics
  - Kickers
- Diagnostics
  - Circulating beam
  - Extracted beam
- Alternative (low) frequency RF requirement and design.
- and others

Hardware status

Magnets

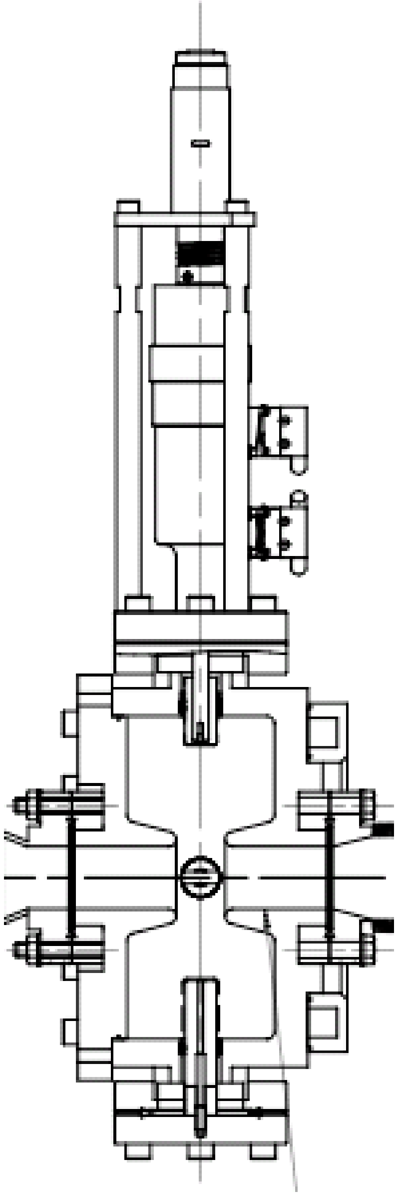
- Gradient is -4.6 T/m for D and 7.4 T/m for F.
- Half a yoke for D and full quadrupole for F.
- Dipole component is controlled by magnet position.



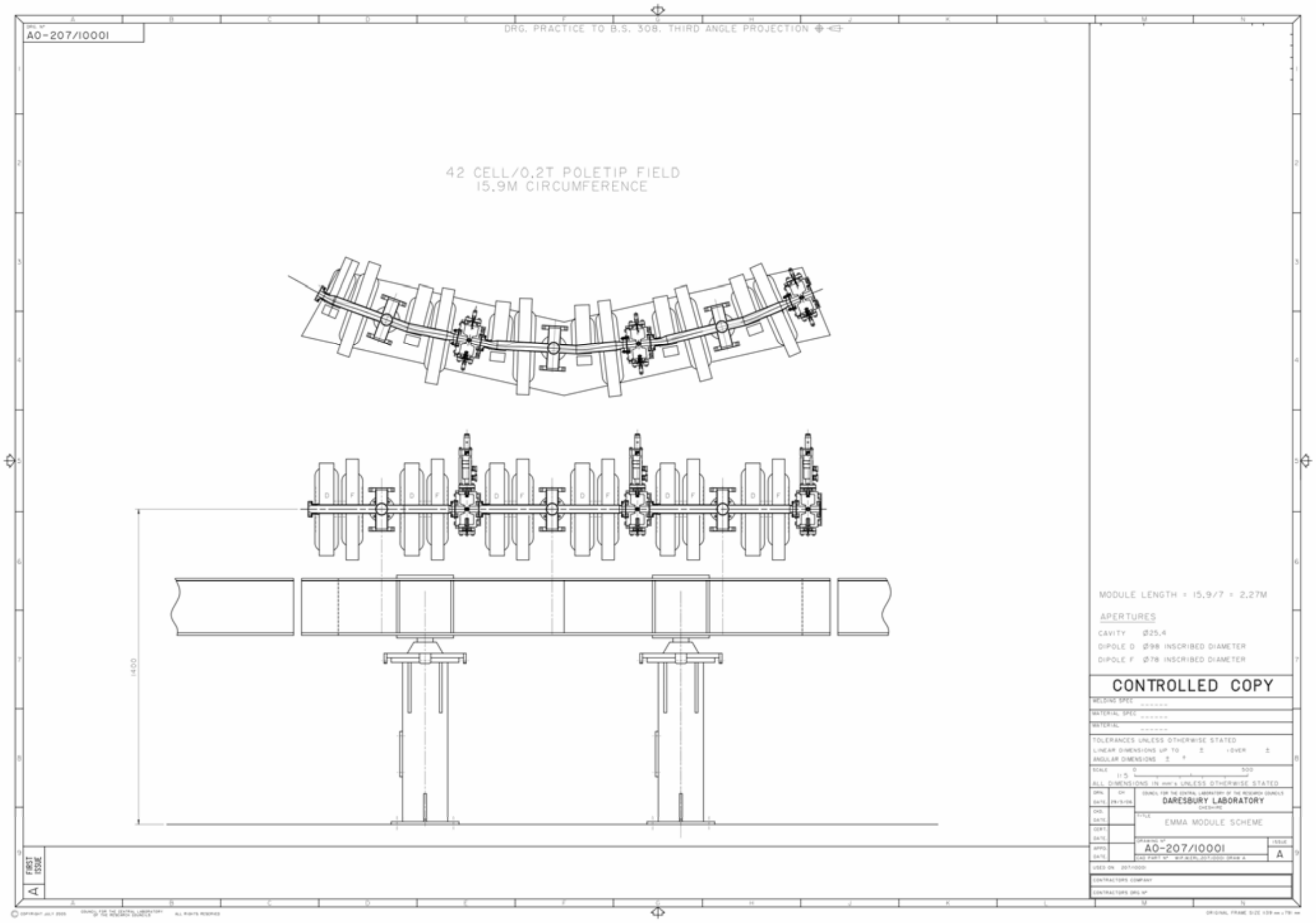


RF cavity

- Frequency is 1.3 GHz.
- Tuning stubs and RF coupler.
- Aperture (diameter) is 25 mm.



A few cells in a stand



Summary

- Physics discussion continues.
- Continuous update of parameters and its range.
  - We need more details discussions: what parameter region we want to study.
  - Iteration between physics requirements and engineering design.
- More precise figure of cost.