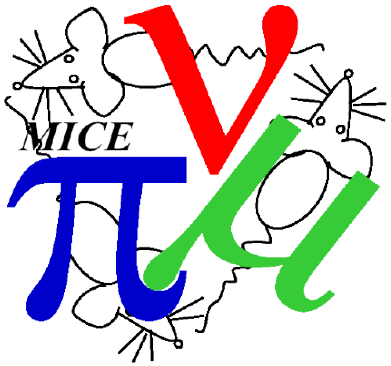
Effect of Reduced Focus Coil Current on Step IV and Step VI



Chris Rogers,
ASTeC,
Rutherford Appleton Laboratory

Overview

- Focus Coil 1 has not reached nominal currents
  - Stuck at around 200 MeV/c required current
  - Even here, need an operating overhead of order 10%
- If FC can't be fixed; how does this limit the performance of Step IV?
- What about Step VI?
- Caveat:
  - All of this is linear optics
  - Great for getting an idea of the parameter space
  - Not sufficient for redefining MICE baseline

Step IV

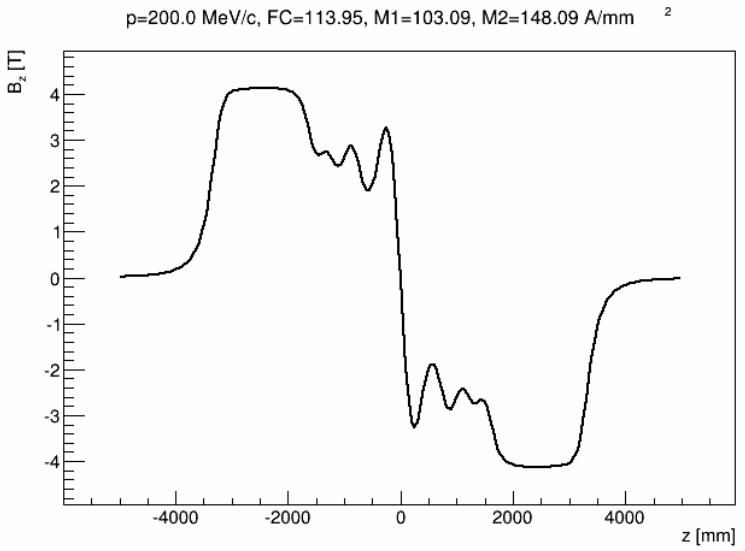
- Step IV has just FC, no coupling coil and no lattice
  - What beta function can be achieved with reduced FC current?
- Coils
  - End coils and Centre coil is fixed for 4 T field on tracker
  - Optimise for matching using Match 2 and Match 1
  - Vary focus coil and look at response

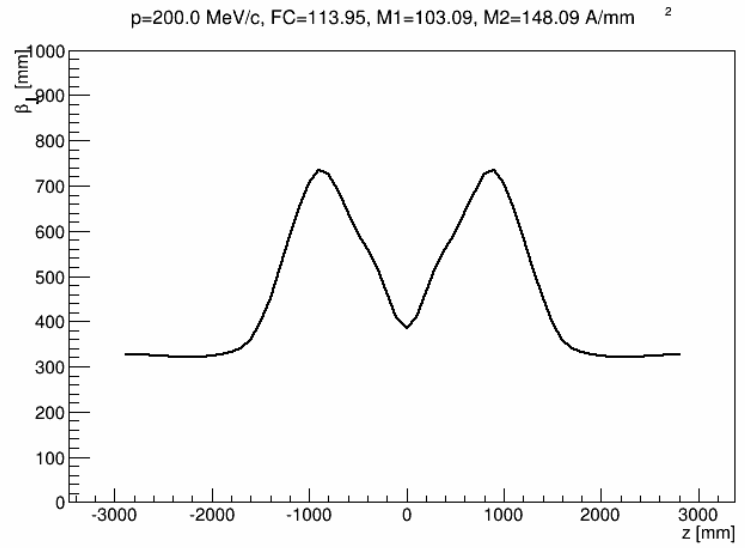
Coil Name	Centre z [mm]	Inner radius [mm]	Radial thickness [mm]	Length [mm]	Current Density [A/mm^2]
End 2	3201	258	68.2	110	135.18 fixed
Centre	2451	258	22	1294	152.44 fixed
End 1	1701	258	60.9	110.6	127.37 fixed
Match 2	1301	258	30.9	199.5	148.09 maximum
Match 1	861	258	46.2	201.3	145.94 maximum
Focus	205	263	84	210	113.95 nominal

Tab. 1: Coil pack used for simulation of MICE Step IV. The field has odd symmetry about z=0; upstream magnets have opposite polarity. Field values and parameters for the Spectrometer Solenoid were sourced from [2].

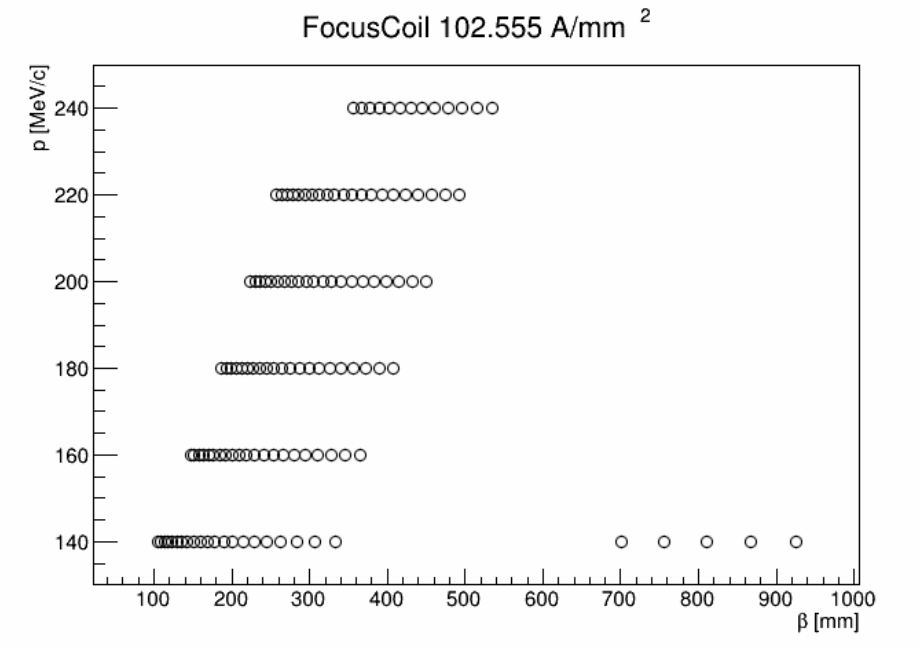
Beta function matching

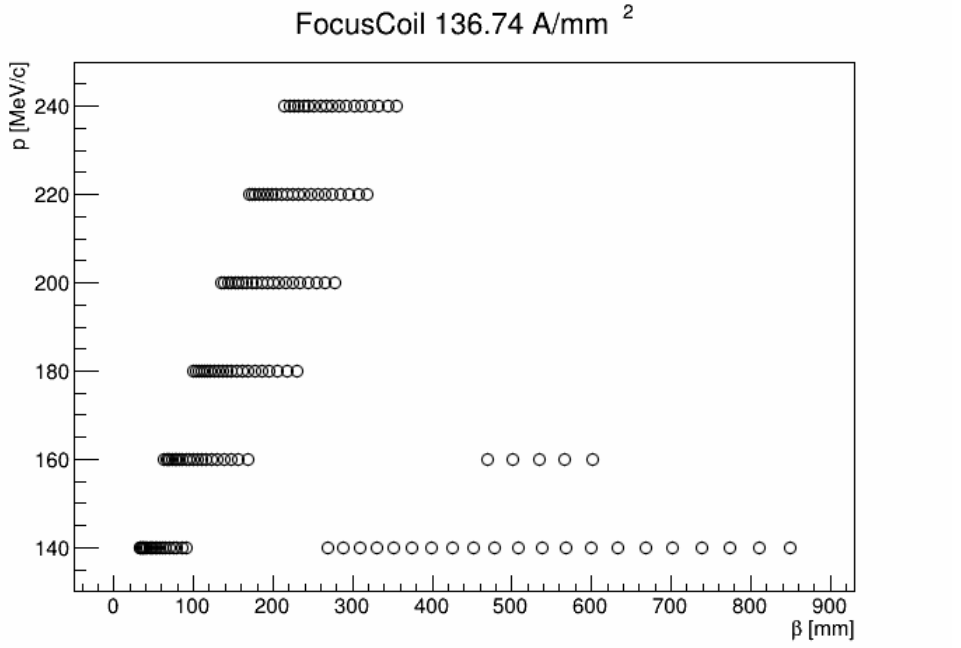
- Standard setting at Step IV is that beta should be symmetric about absorber (z=0)
  - Require dbeta/dz = 0 at the absorber centre
  - Choose dbeta/dz = 0 in the constant solenoid field (analytic solution here)
- Example for 200 MeV/c
  - E2, Centre, E1 set for 4 T
  - M2 set to max current 148.09 A/mm^2
  - M1 varied for matching
  - FC current at nominal 113.95 A/mm^2





Matching vs Momentum





- What is the range of available optics for a given focus coil strength?

Step IV - Conclusions

- Reduced FC current limits accessible range of beta functions
  - Assume FC performance as FC 1
    - e.g. J < 102 A/mm^2 with 10 % operating margin
  - Minimum beta function 32 mm → 104 mm at 140 MeV/c
  - Minimum beta function 136 mm → 224 mm at 200 MeV/c
  - Minimum beta function 215 mm → 356 mm at 240 MeV/c
  - Can still achieve “nominal” beta function (420 mm)
  - Some exotic options are ruled out in flip mode
  - Maximum beta function is unaffected
    - Prefer low FC current for large beta functions

Step VI

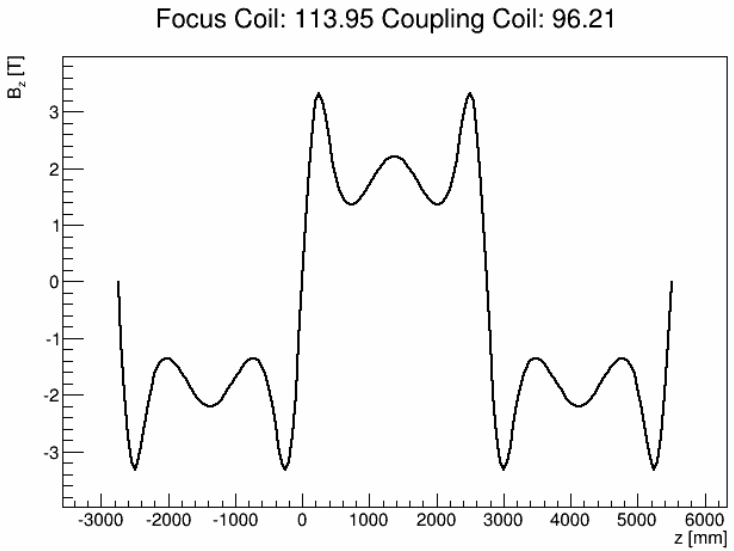
- Consider now Step VI SFoFo lattice only
  - Assume we can match (but see discussion above)
  - Look at how optics scales with Coupling Coil and Focus Coil currents
- Repeat over 5500 mm cell length in flip mode

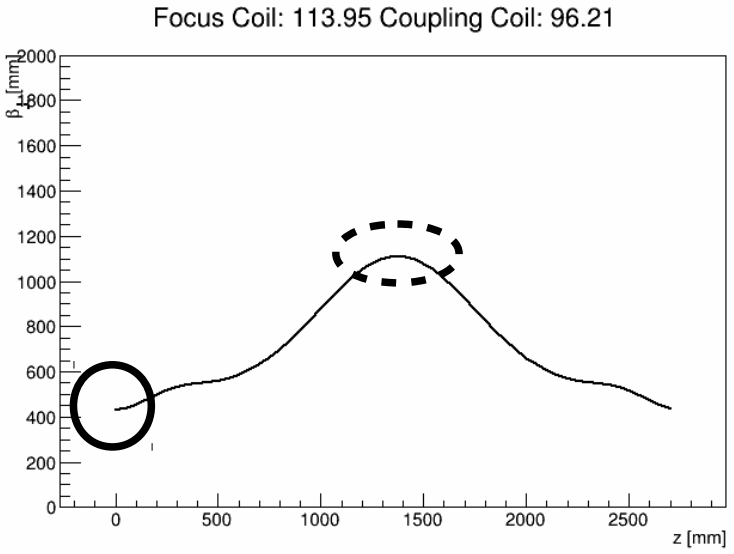
Coil Name	Centre z [mm]	Inner radius [mm]	Radial thickness [mm]	Length [mm]	Current Density [A/mm^2]
Focus	205	263	84	210	113.95 nominal
Coupling	1375	725	116	250	96.21 nominal
Focus	2545	263	84	210	113.95 nominal

Tab. 3: SFoFo lattice used for simulation of MICE Step VI. The lattice was repeated with a cell period of 5500 mm and adjacent half cells having opposite polarity (i.e. flip mode). 3 half cells were placed on either side of the test cell to ensure correct application of fringe fields.

Nominal magnets, 200 MeV/c

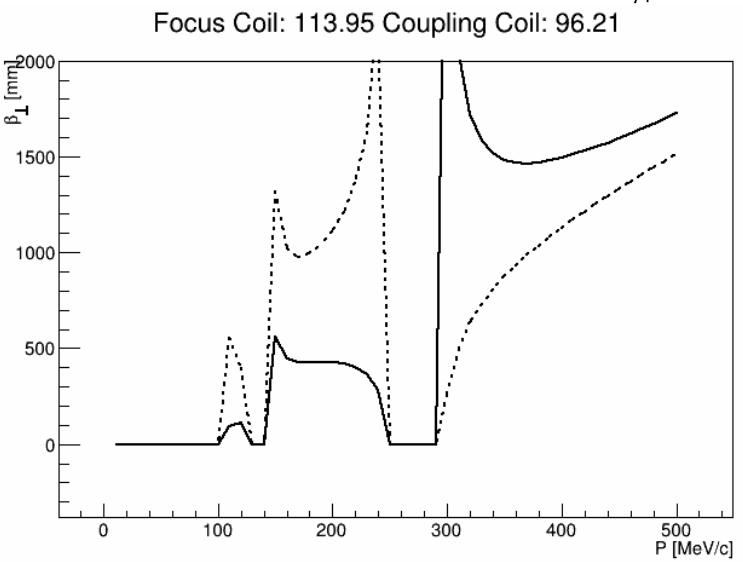
- By way of example
  - Bz as a function of z
  - Beta function for a half cell
- What is momentum dependence of beta function?
  - At focus (absorber)
  - At anti-focus (scraping aperture)

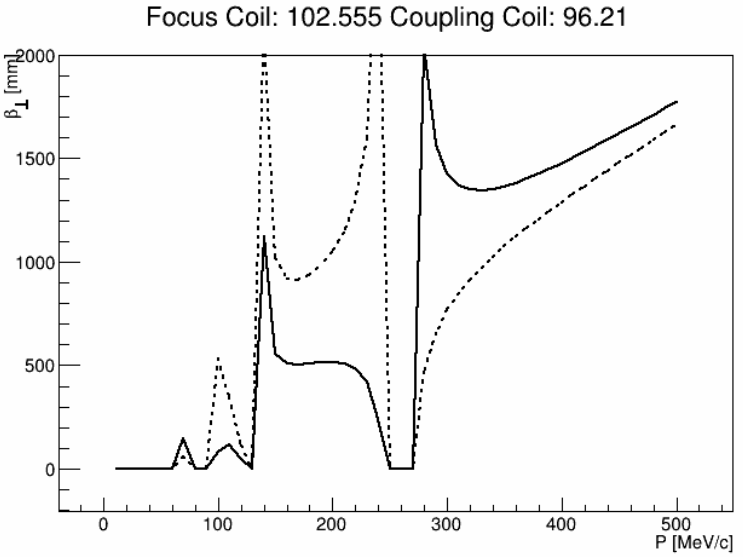




Response to FC – 200 MeV/c

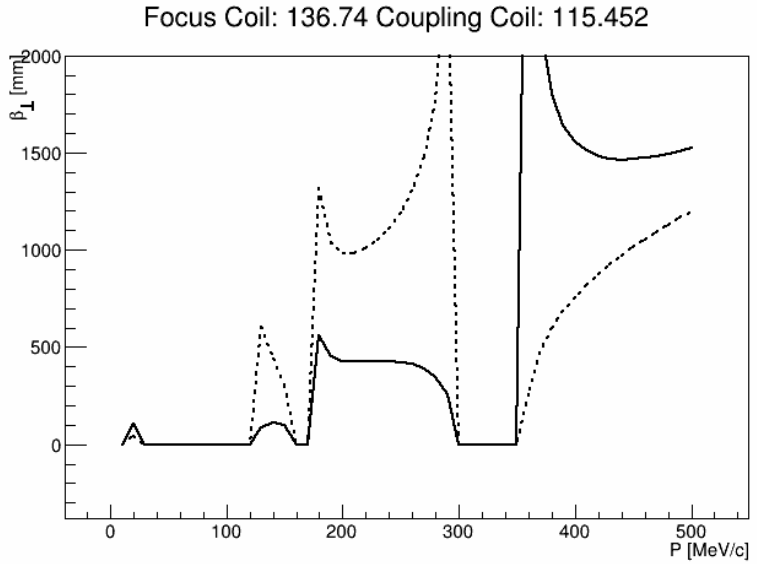
- Assume FC performance as FC 1
  - e.g. J < 102 A/mm^2 with 10 % operating margin
  - Beta function 420 -> 500 mm
  - Equilibrium emittance increases by ~ 20% (proportional to beta)

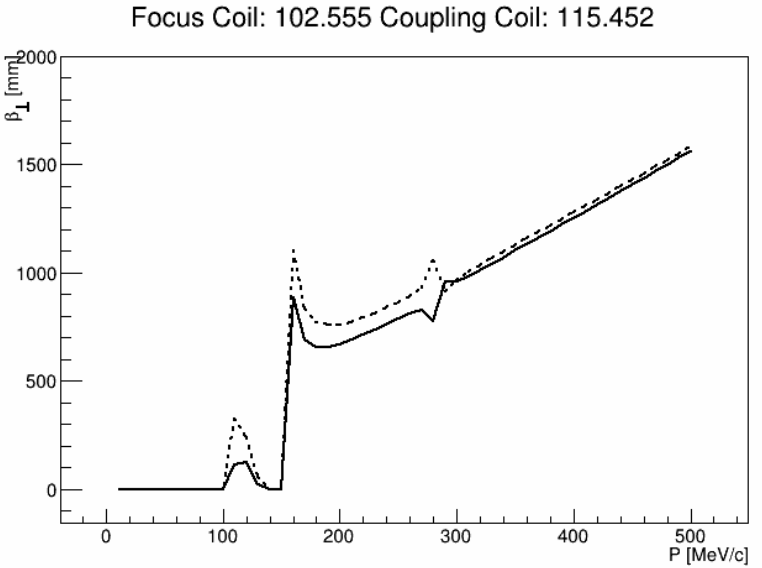




Response to FC – 240 MeV/c

- Assume FC performance as FC 1
  - Beta function ~ 50-100% higher
  - Equilibrium emittance ~ 50-100 % higher
  - Bigger chromatic aberations
  - Weaker (2pi) resonance
  - Possibly slightly better acceptance
    - Beta at midpoint is lower
- Context: current NF baseline operates with
  - Beta ~ 800 mm
  - Central p ~ 230 MeV/c
  - Half cell length ~ 0.86 m
  - Phase advance per cell < 2pi





Conclusions

- MICE is still operable with reduced FC
- But physics performance is slightly reduced
  - Lose low beta function options at Step IV
  - Poor 240 MeV/c performance at Step VI
- Caveat:
  - All of this is linear optics
  - Great for getting an idea of the parameter space
  - Not sufficient for redefining MICE baseline
- MICE Note is written but not committed (awaiting comments)