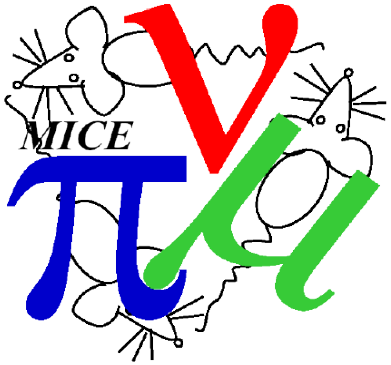
MICE Step Pi



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Plan

- Develop optics by NuFact session 28th August
  - Explore as many lattices as we can
  - Need to fix a set of z positions and currents
- Hand to engineers for first consideration 1st September
  - This should be a good approximation to final lattice
  - May require a little optimisation but no more major changes
  - Is the z positioning reasonable?
  - What is the available RF voltage likely to be?
- Physics cross checks
  - Tracking study
    - What is cooling performance?
    - What is aperture/acceptance?
    - What is momentum acceptance?
  - Shielding scheme for trackers

Design Options

- Magnetic lattice
  - symmetric lattice with various polarities on FCs ++ ++, +- -+. …
  - RF near spectrometer solenoid SS - RF - AFC – RF – AFC – RF – SS
  - Asymmetric magnetic lattice
- Absorber position
  - Between 2 RF cavities i.e. SS – AFC – RF – abs – RF – AFC – SS
  - In AFC
  - In both positions i.e. shielding in AFC and absorber between RF
  - On RF windows
- Tracker radiation shielding
  - Use absorbers
  - Use shielding in/near tracker volume
  - Unshielded tracker
- RF
  - 1 cavity between AFC
  - 2 cavities between AFCs

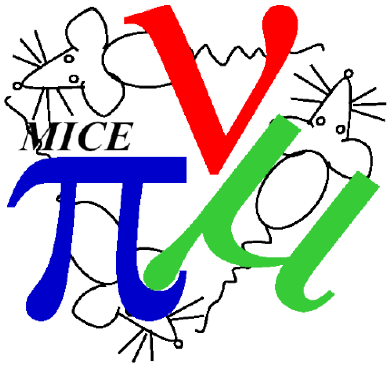
Design Criteria

- Lattice quality
  - Cooling performance
  - Cell optics
  - Momentum restoration
  - Similarity to a buildable cooling channel
  - Quality of match to spectrometer
  - Scraping aperture / transverse acceptance
  - Momentum acceptance
  - Canonical angular momentum effects
- Engineering issues
  - Current limits of magnets
  - Incremental cost of any hardware
  - Radiation load on tracker
  - RF breakdown in magnetic fields

Assumptions

- Geometry
  - AFC dimension 844 mm full length [source: Blackmore]
  - AFC - RF bellows 56 mm [source: Blackmore]
  - single cavity module length - assume 600 mm [source: Yagmur]
  - two cavity module length - assume 1000 mm [source: Yagmur]
- RF
  - RF power available - 4 MW as baseline, with 8 MW as an upgrade with corresponding cost, schedule and technical risk
  - RF volts is sqrt(cavity power)*8 MV/m
- Step IV coil pack – see #1543
  - The spectrometer solenoid coils (Match1 through End2) can be moved bodily away from FC module; but no closer

MICE Step Pi – Symmetric Lattice



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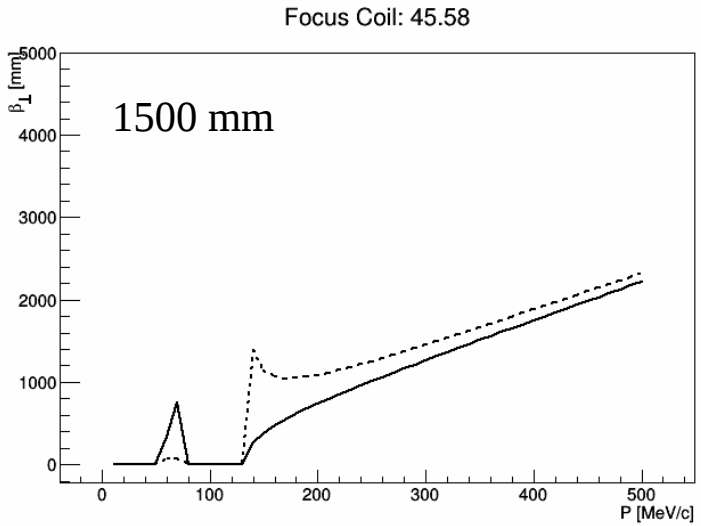
Consider Symmetric Lattice

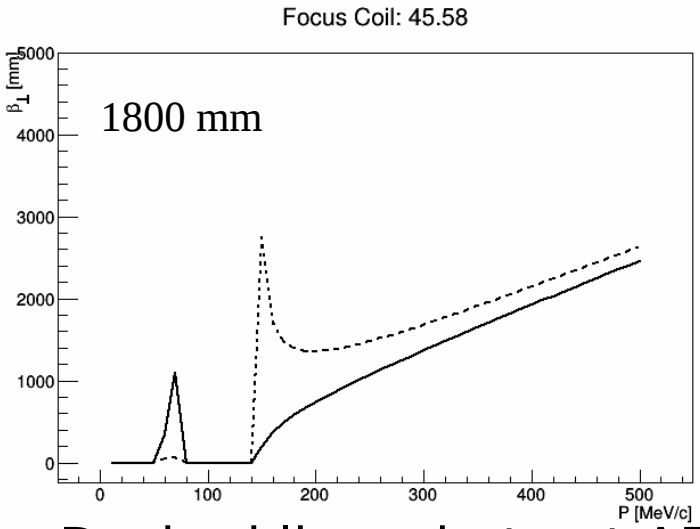
- Lengths
  - AFC = 422 mm
  - Bellows = 56 mm
  - Single cavity module (1xRF) = 600 mm
  - Double cavity module (2xRF) = 900 mm
  - Absorber = 200 mm (complete guess)
- Three lattices to be considered
  - Single cavity: AFC+bellows+1xRF+bellows+AFC ~ 1500 mm
  - Double cavity: AFC+bellows+2xRF+bellows+AFC ~ 1800 mm
  - Double cavity and absorbers: AFC+bellows+RF+absorber+RF+bellows+AFC ~ 2000 mm
- Treat cooling cell and matching from spectrometers as separate problems to first approx

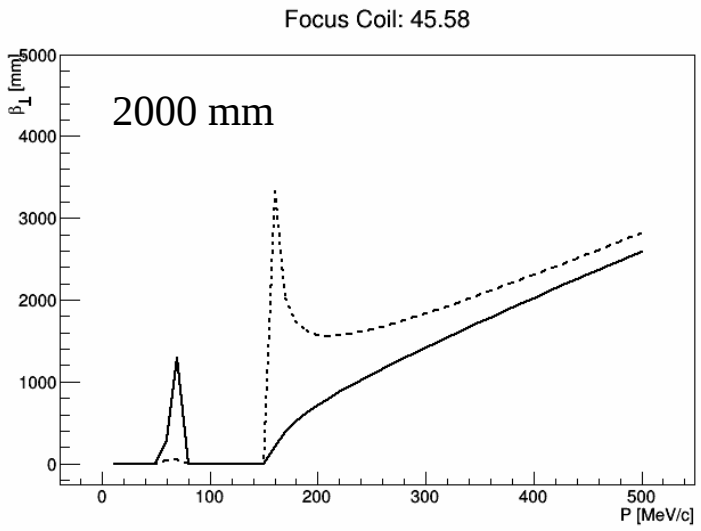
Optics

- 2 Focus coil pairs → four possible arrangements
  - ++++
  - ++-- (not studied yet)
  - +--+
  - +-+-
- Seek a solution for p = 200 MeV/c initially
  - Want beta at absorber < 1 m for reasonable cooling
  - Note that AFC is at the antifocus for this sort of lattice

++++ (solenoid mode)







- Dashed line – beta at AFC
- Full line – beta at centre
- 1500 mm is marginal for beta at AFC
- 1800 mm – probably no cooling
- 2000 mm – okay for beta at centre
- Some fine tuning of FC current possible

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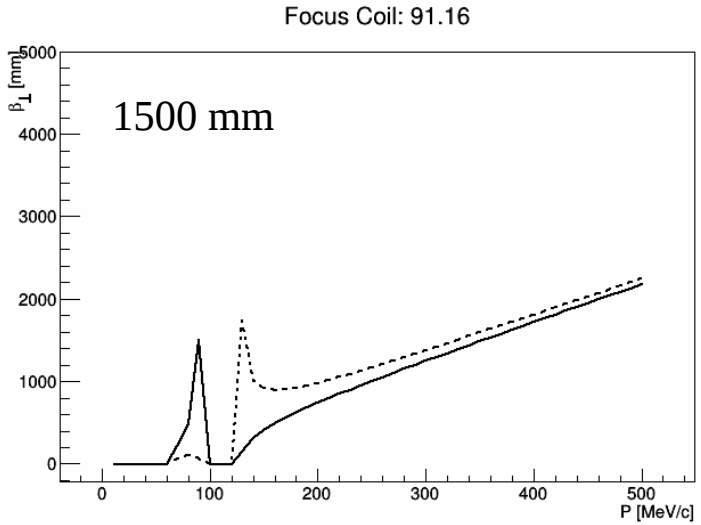
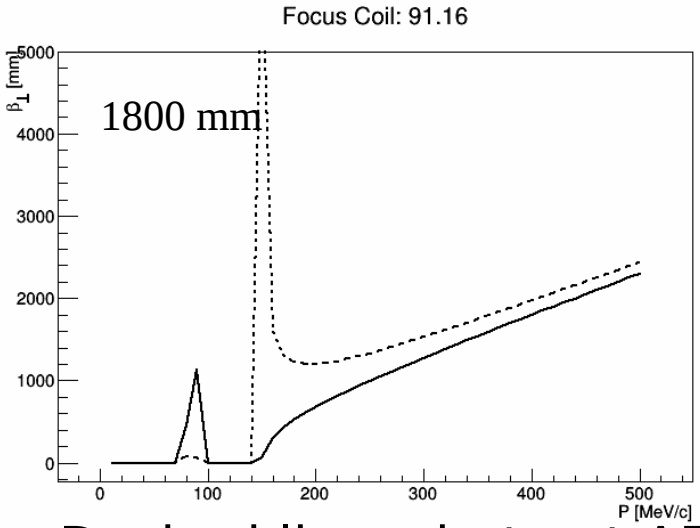
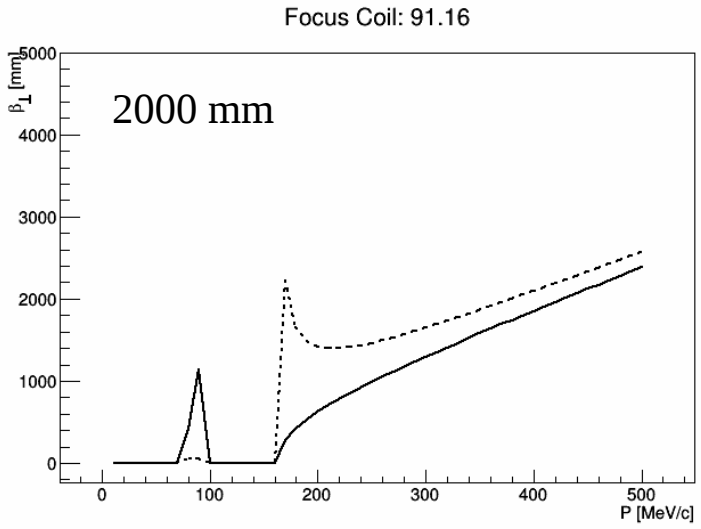
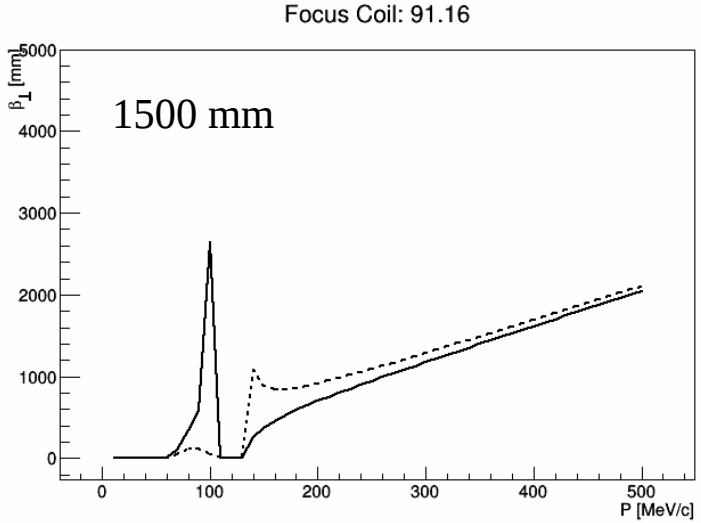


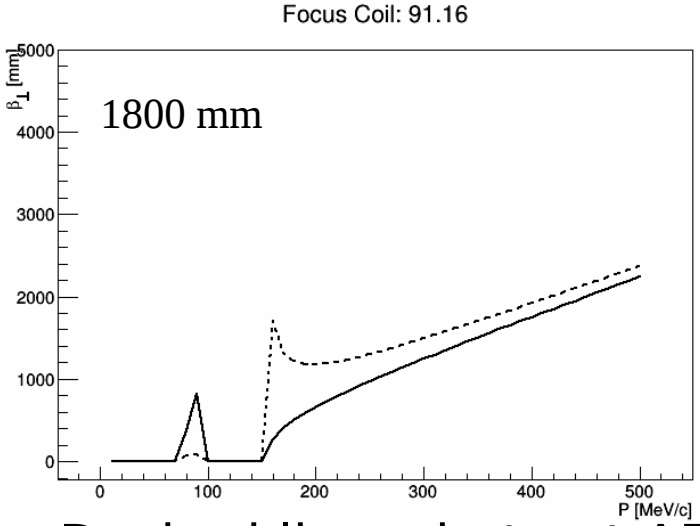


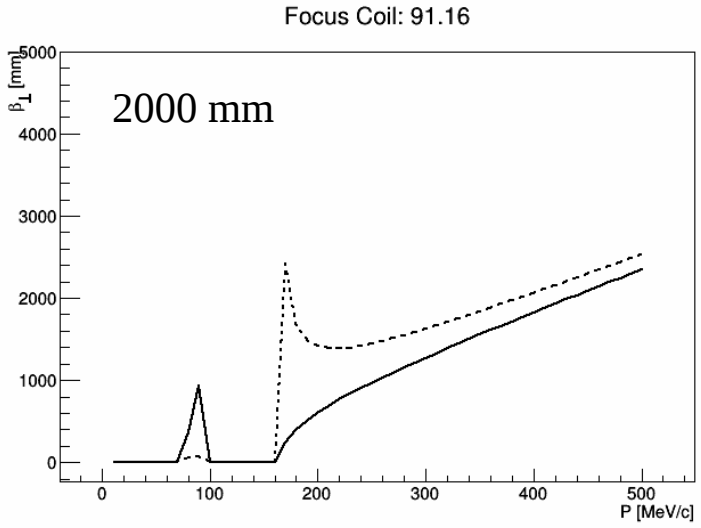


- Dashed line – beta at AFC
- Full line – beta at centre
- 1500 mm is marginal for beta at AFC
- 1800 mm – probably no cooling
- 2000 mm – okay for beta at centre
- Sounds familiar?

+--+







- Dashed line – beta at AFC
- Full line – beta at centre
- 1500 mm is marginal for beta at AFC
- 1800 mm – probably no cooling
- 2000 mm – okay for beta at centre
- Landscape is similar to +-+-

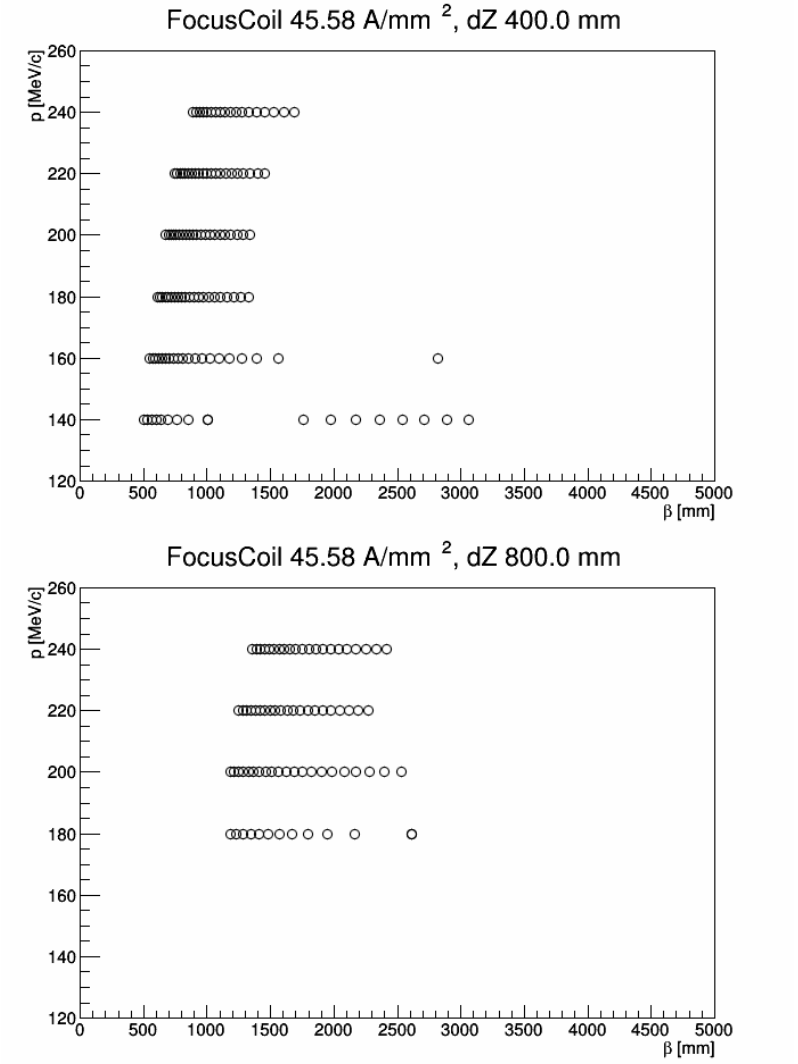
Symmetric Lattice - conclusions

- 1800 mm (double RF lattice)
  - Beta at AFC is too large
  - Probably won't cool very well
- 1500 mm (single RF lattice)
  - Beta at AFC can be reasonably small
  - Probably will cool okay
  - Only one RF cavity → not much reacceleration
  - 7 MeV with step V RF power (4 MW)?
  - 10 MeV with step VI RF power (8 MW)?
- 2000 mm (double RF + absorber)
  - Absorber is now moved to focus
  - Beta at absorber can be reasonable
  - Two RF cavities → better reacceleration
  - Need to consider tracker shielding
  - Need to consider engineering – can absorber really be in centre
  - Need to check apertures

Matching

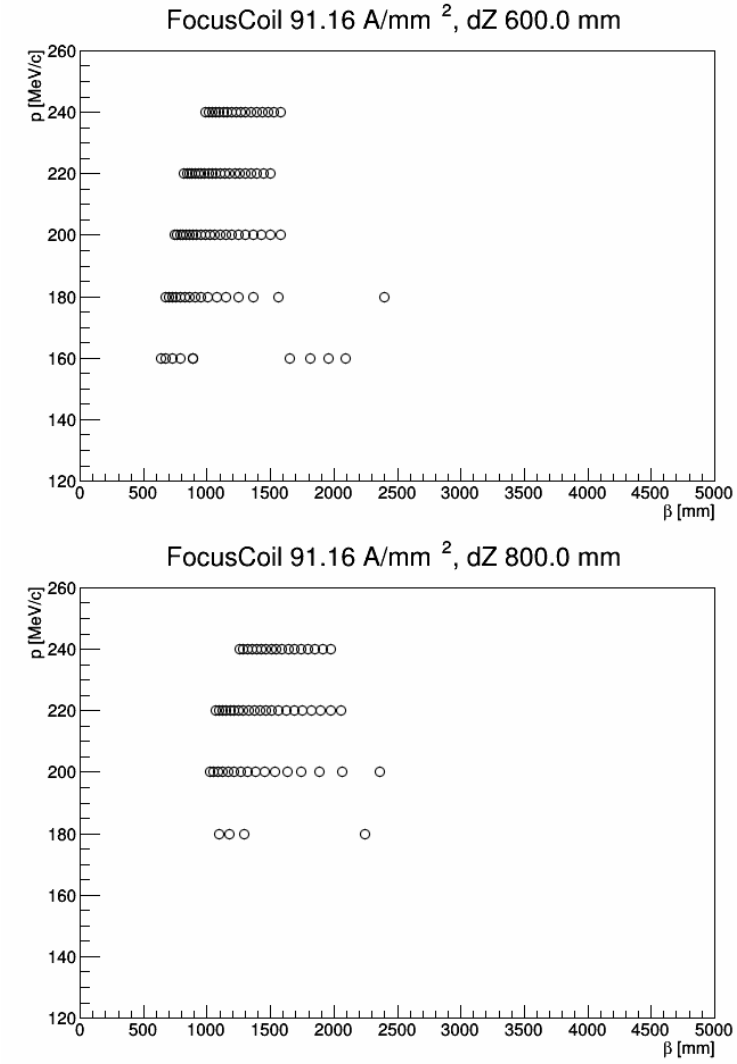
- Can we match into these lattices?
  - For Step V, beta at absorber ~ 400 mm
  - Now beta at absorber ~ 1000 – 2000 mm
  - Previous studies have shown this is out of range for as-designed SS
- Consider inserting gap between SS and AFC
  - Give the beam a chance to grow to get into AFC
- Use Step IV lattice as a matching test-bed
  - Close enough to step pi
  - Follow-up job to match into the step pi lattices properly
- Two cases to match into
  - Flipping mode +-
  - Solenoid mode ++

Solenoid mode



- Seek a match at beta = 1000 mm for cell length 1500 mm
  - Additional 400 mm gap seems about right
- Seek a match at beta = 1500 mm for cell length 2000 mm
  - Additional 800 mm gap seems about right
  - Note that no match was found for p <= 160 MeV/c

Flip mode



- Seek a match at beta = 1000 mm for cell length 1500 mm
  - Additional 600 mm gap seems about right
- Seek a match at beta = 1500 mm for cell length 2000 mm
  - Additional 800 mm gap seems about right
  - Note that no match was found for p <= 180 MeV/c
    - May be a little unstable
    - Some further iteration required

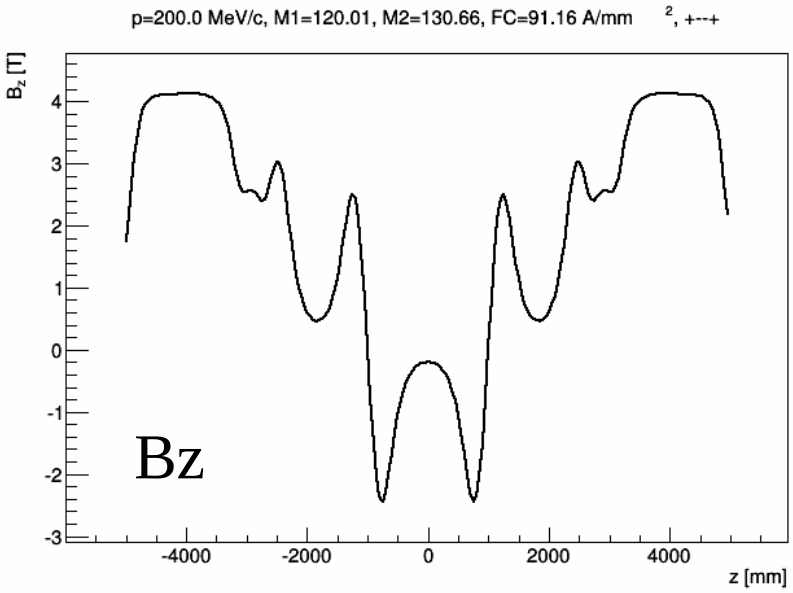
Matching - conclusions

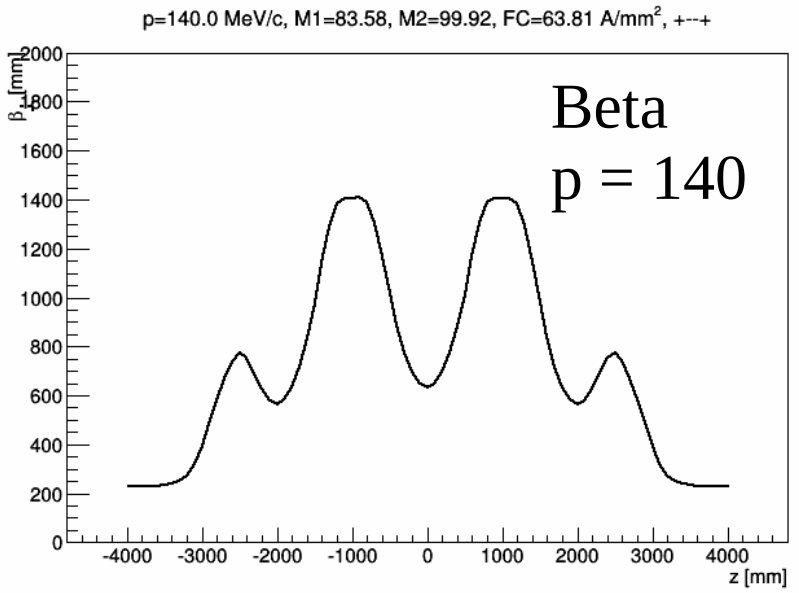
- Can we match into these lattices?
  - Yes, but would require additional spacing between spectrometer solenoid and AFC
  - 400-500 mm seems about right for single RF option
  - 600-800 mm seems about right for double RF + absorber option

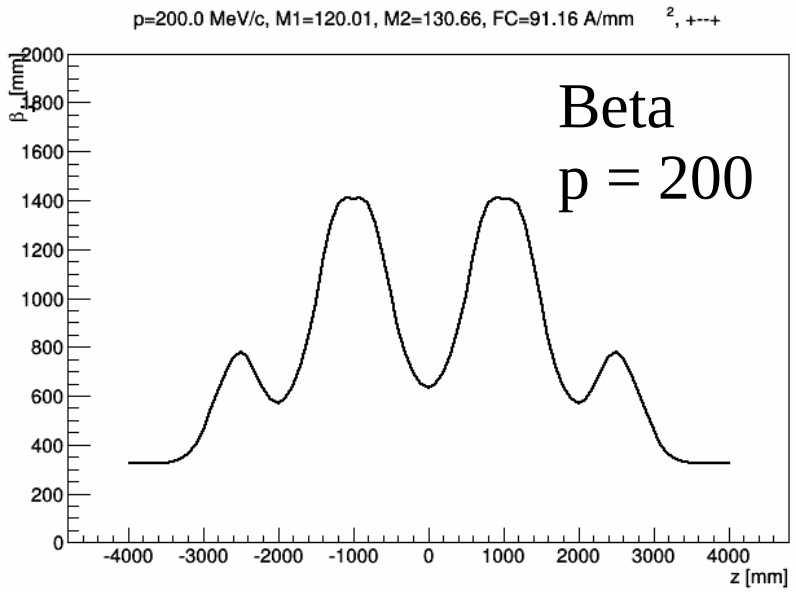
Coil Geometry

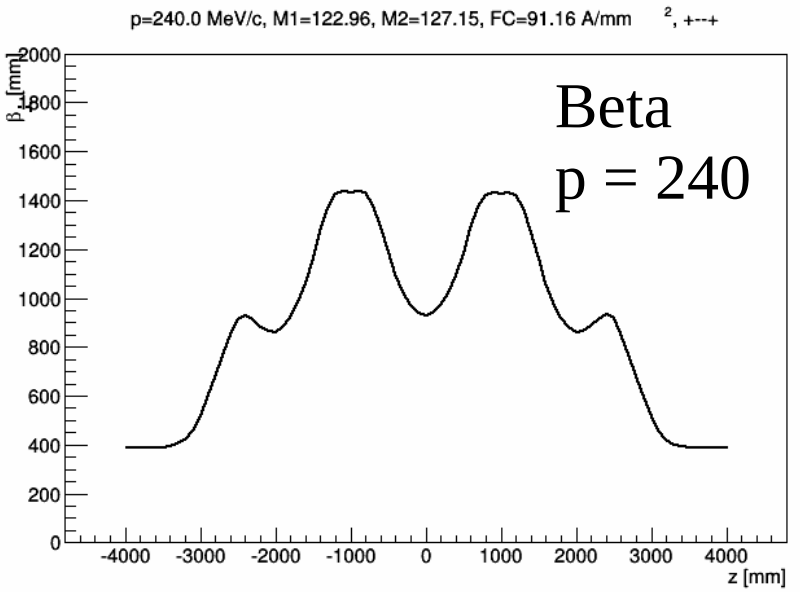
	z(centre)	inner radius	radial thickness	length
EndCoil2	-4800	258	67.8	110.6
CenterCoil	-4050	258	22.1	1314.3
EndCoil1	-3300	258	60.9	110.6
MatchCoil2	-2900	258	30.9	199.5
MatchCoil1	-2461	258	46.2	201.3
FocusCoil	-1202.75	267	94.8	213.3
FocusCoil	-797.25	267	94.8	213.3
FocusCoil	797.25	267	94.8	213.3
FocusCoil	1202.75	263	84	210
MatchCoil1	2461	258	46.2	201.3
MatchCoil2	2900	258	30.9	199.5
EndCoil1	3300	258	60.9	110.6
CenterCoil	4050	258	22.1	1314.3
EndCoil2	4800	258	67.8	110.6

Optics solutions – flip(+--+)

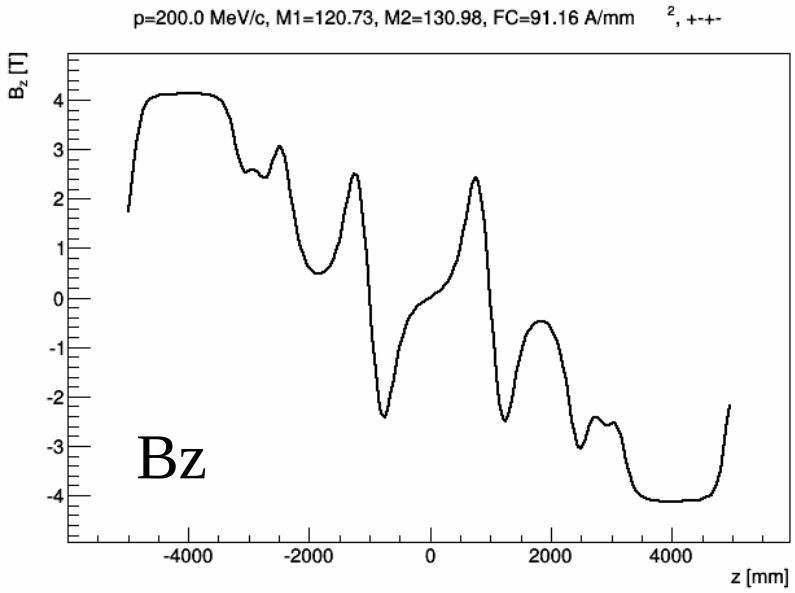


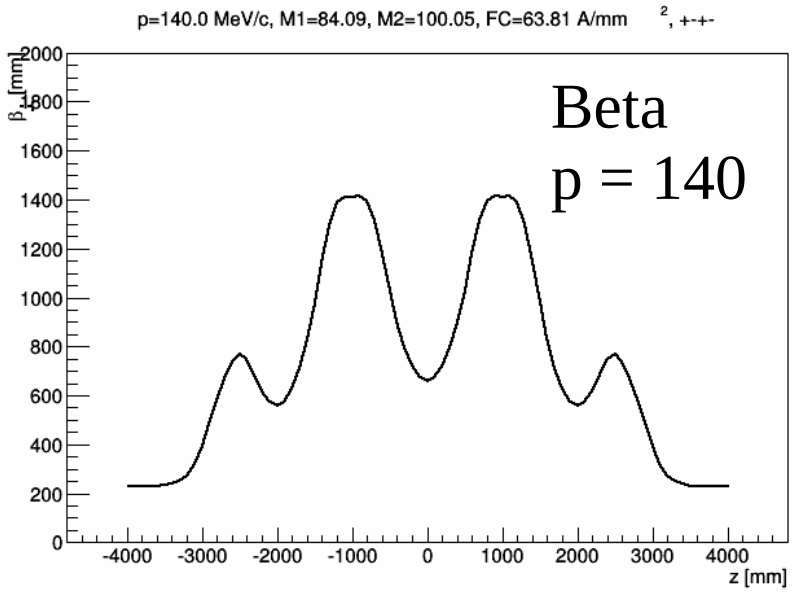


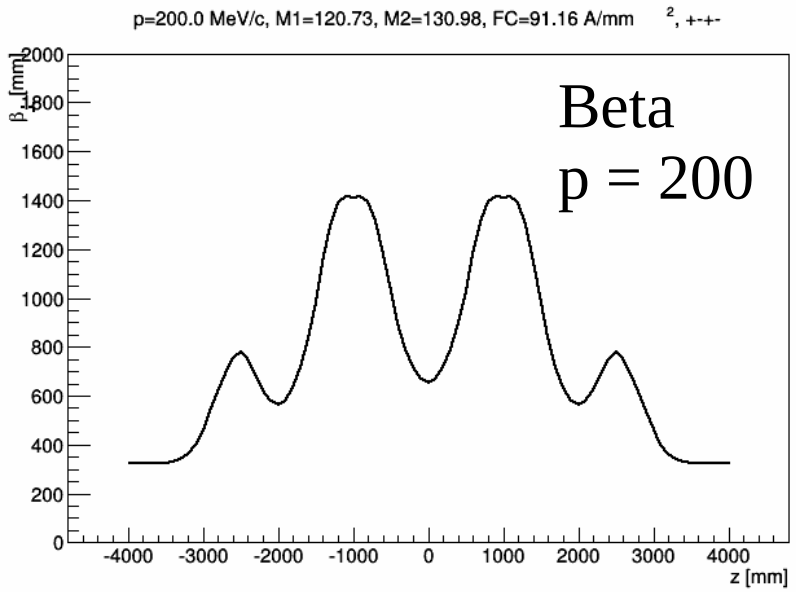


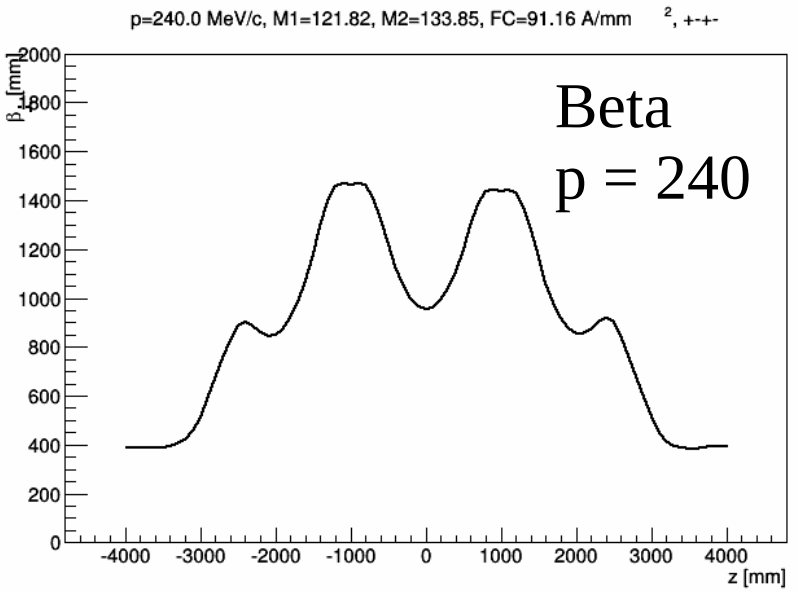


Optics solutions – +-+-

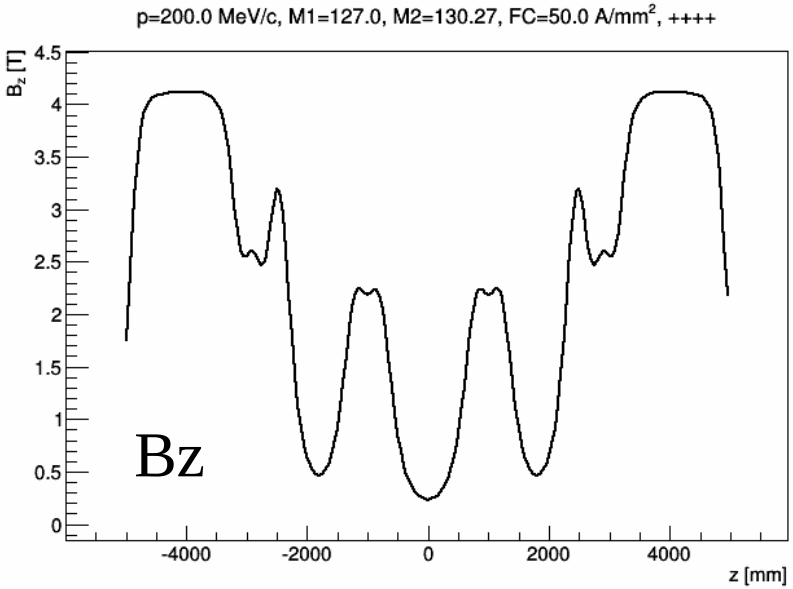


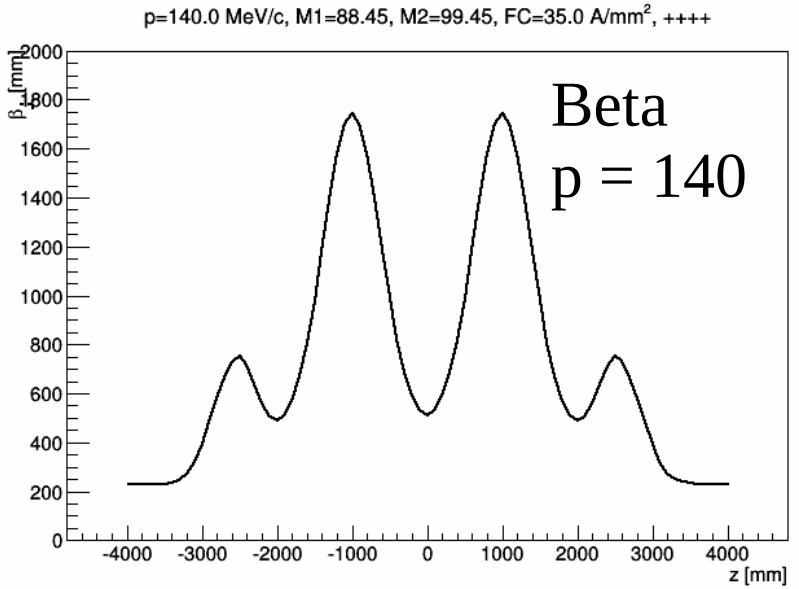


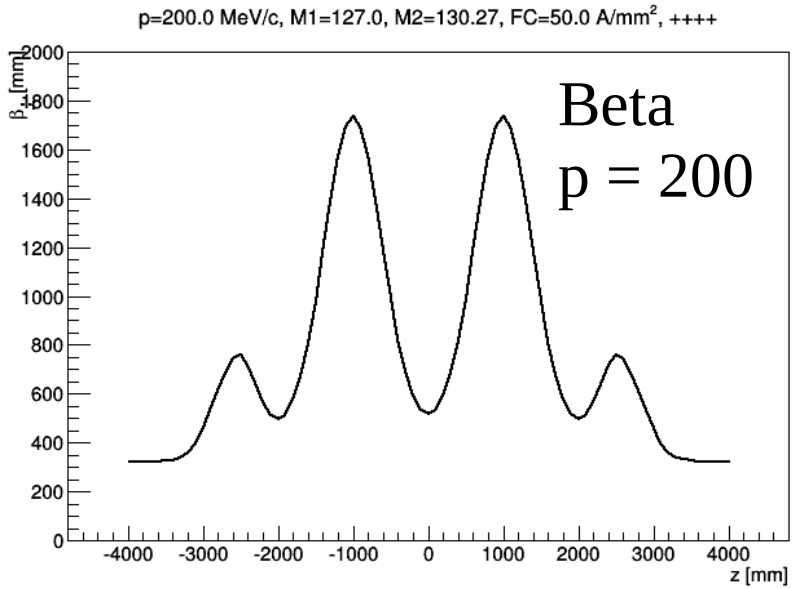


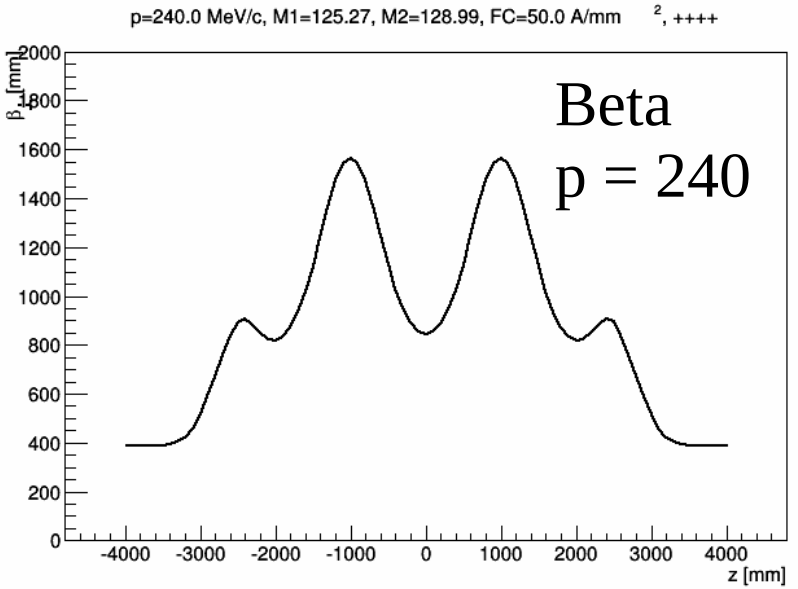


Optics solutions – sol(++++)

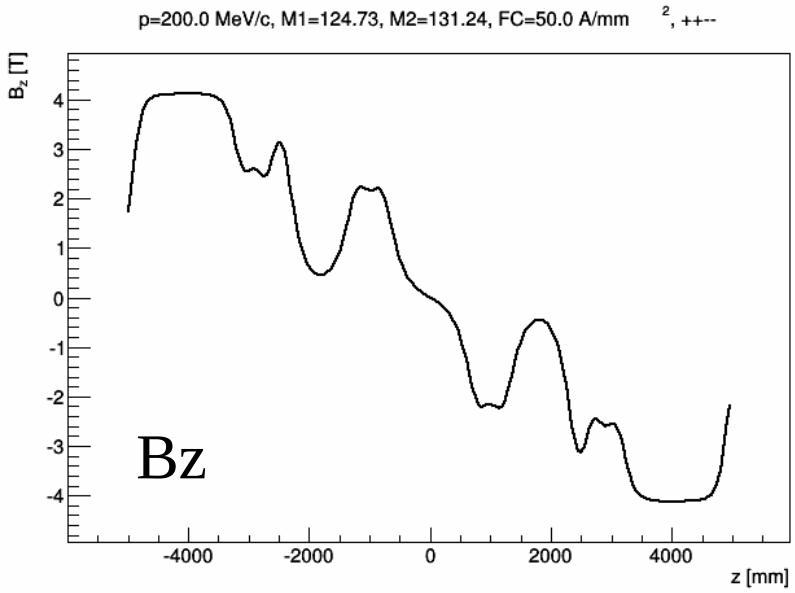


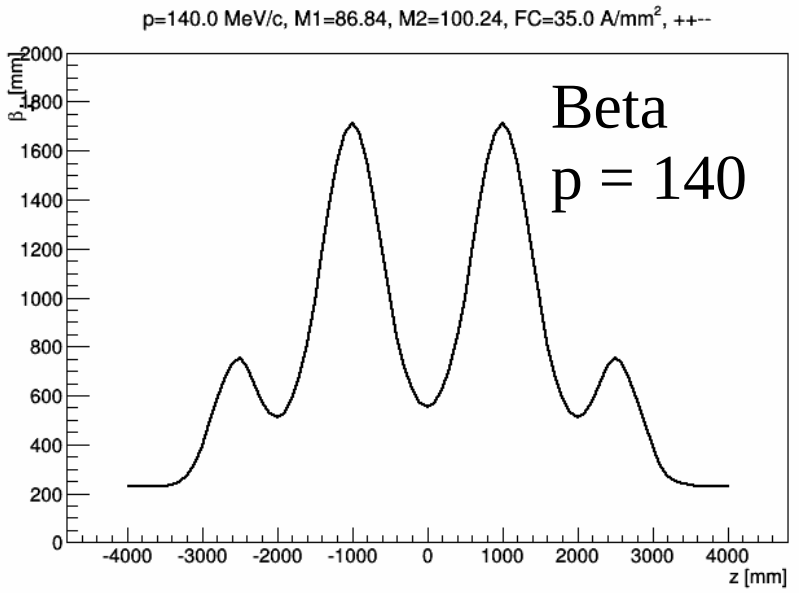


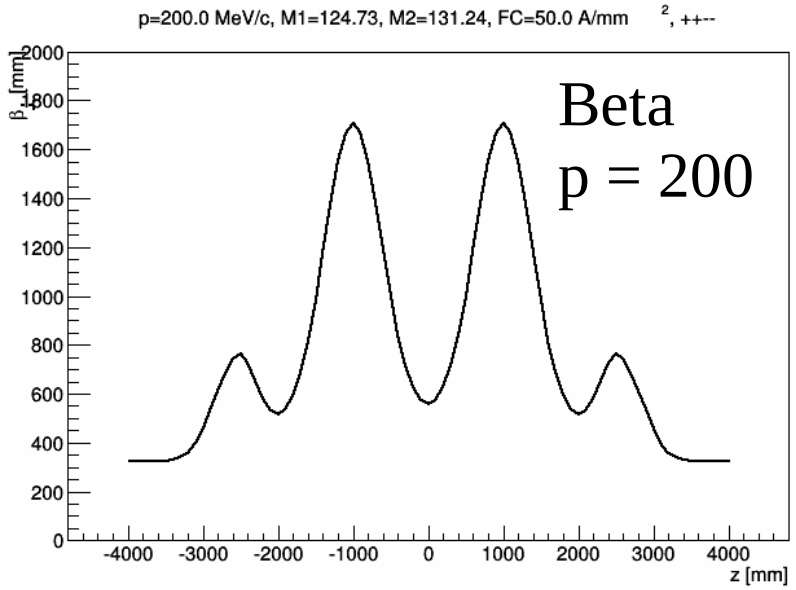


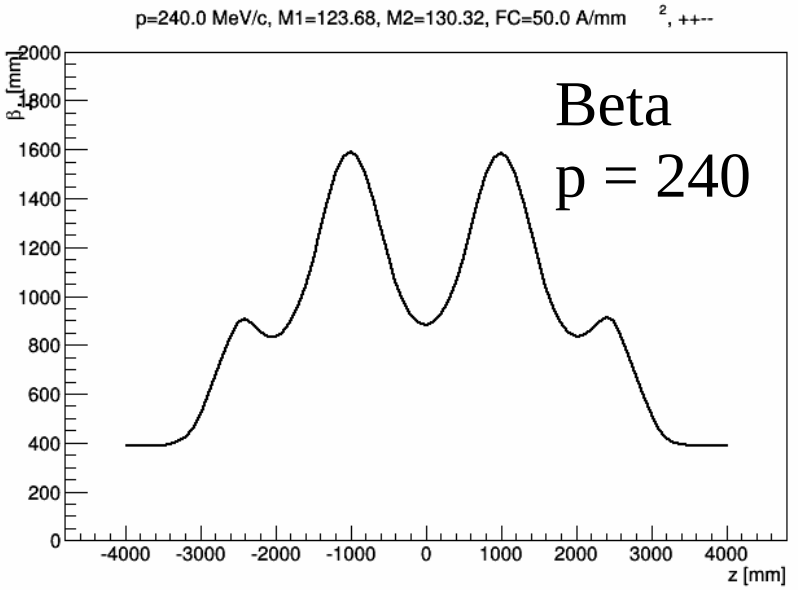


Optics solutions – sol(++--)

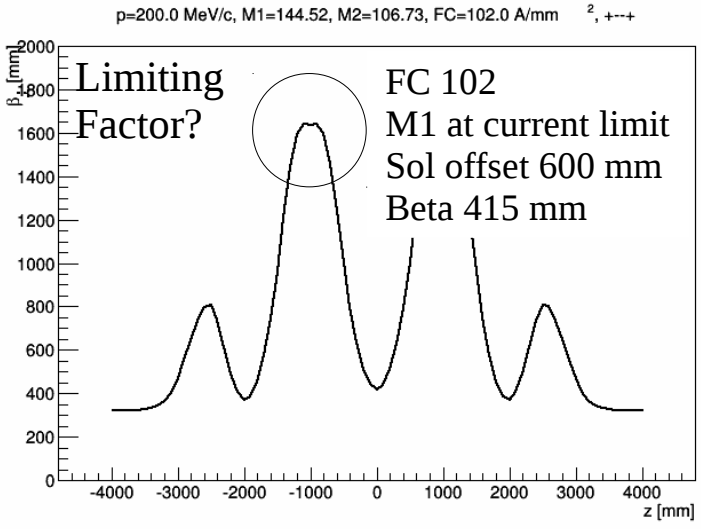


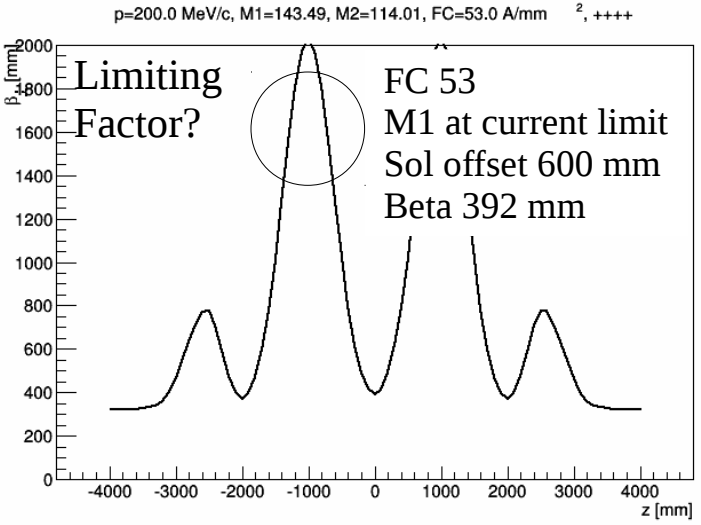






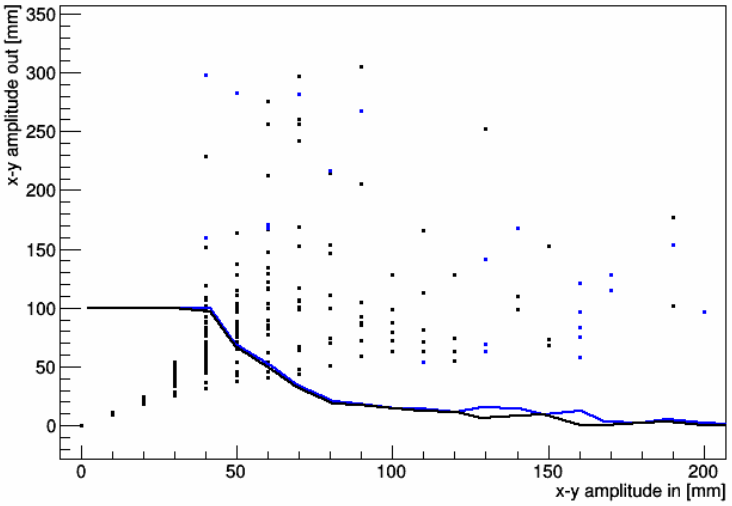
Tightest focus

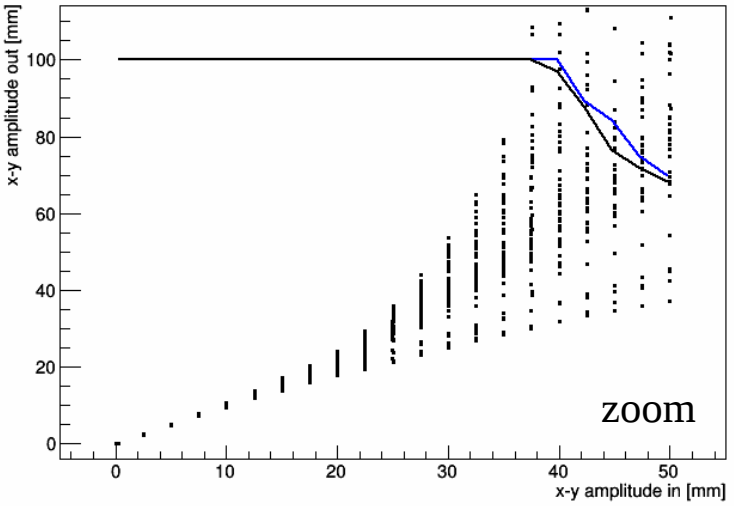




- What is the tightest focus we can get?
  - e.g. 200 MeV/c +--+ (“Classic” case)
  - e.g. 200 MeV/c ++++ (Solenoid case)
  - Limited by match coil currents
  - Appears that changing solenoid offset does not help
  - e.g. seeking solution that does not go through a focus at z = -2000 m
- Solution has beta ~ 400 mm
  - We are close to unstable point in the lattice – no “symmetric” solution exists

Acceptance





- What is the lattice acceptance?
  - Physical aperture is similar to MICE Step V
    - At Step V 1400 mm beta in RF (aperture 21 cm)
    - This lattice 1400 mm beta in FC (aperture 21 cm)
  - Start getting transmission losses around 40 mm 4D amplitude
  - Some concern over optical emittance growth starting at 30 mm

Baseline

- Following discussion Monday pm – propose 2000 mm lattice as baseline (with absorber between 2 RF cavities)
- Lattice quality
  - Cooling performance possibly ok, needs check
  - Cell optics looks ok
  - Momentum restoration 2 cavities is the best we can get?
  - Similarity to a buildable cooling channel yes, very close
  - Quality of match to spectrometer looks ok
  - Scraping aperture / transverse acceptance same as StepV?
  - Momentum acceptance looks ok
  - Canonical angular momentum effects looks ok, flip mode possible
- Engineering issues
  - Current limits of magnets looks ok
  - Incremental cost of any hardware new vacuum tube, absorber
  - Radiation load on tracker may be issue, mitigate with shields
  - RF breakdown in magnetic fields 4 cavities would be better

Conclusions

- From an optics perspective, symmetrical lattice looks okay
  - A 4 cavity lattice would be better
  - Any alterations to the optics (before I track)?
- Next - tracking study to check
  - Cooling performance
  - Scraping aperture / transverse acceptance
  - Momentum acceptance, especially for “low beta” cases