Demonstrator Magnetic Lattice

International
MUON Collider
Collaboration

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Science & Technology Facilities Council
ISIS

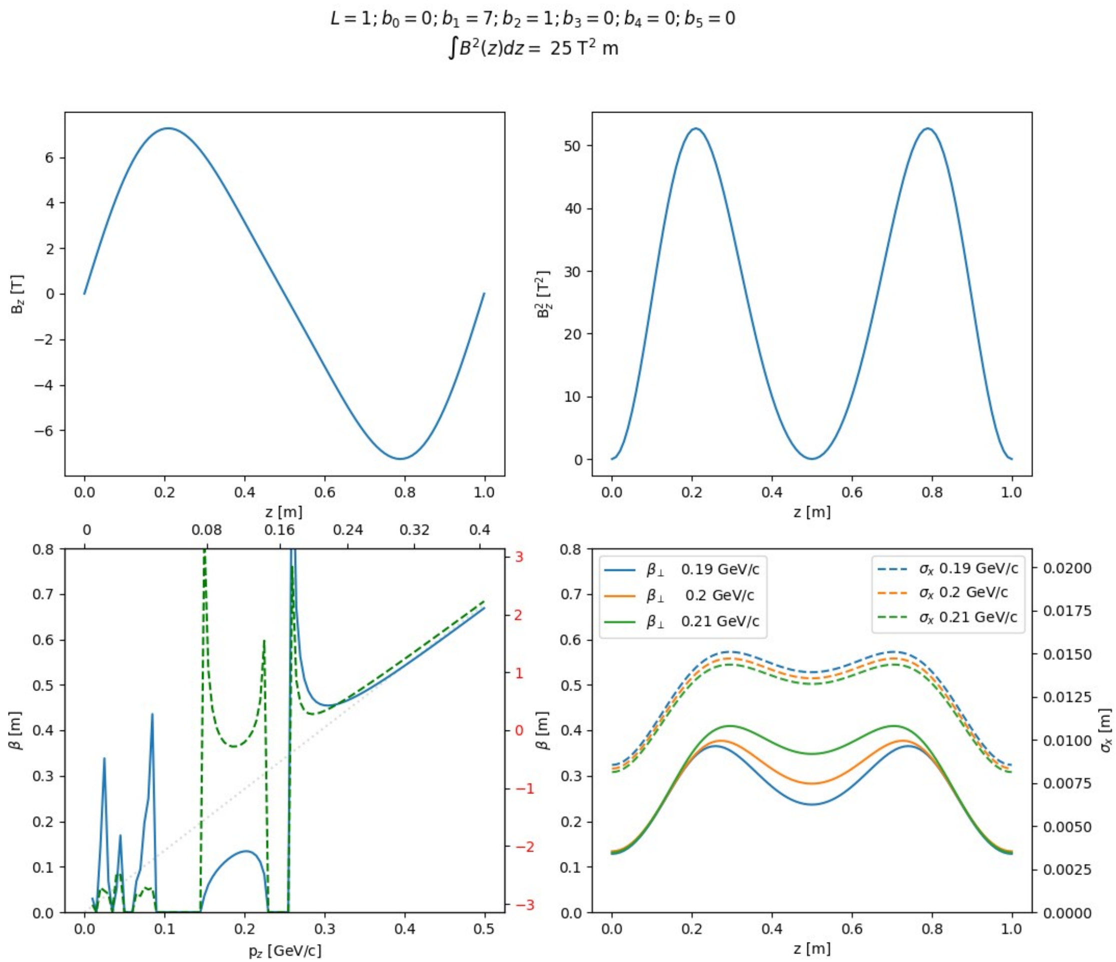
Discuss Three Lattice Baselines

- Looking at solenoid fields
  - Targeting on-axis field of the form

    $Bz = b_0 \sin(2 \pi z/L) + b_1 \sin(4 \pi z/L)$
- **2022-11-01-release**
  - $L = 1.0$, $b_0 = 7.0$, $b_1 = 1.0$
  - Design presented at NuFact22
  - Coils not terribly realistic
  - Baseline lattice to get things going
- **2024-03-01-prerelease**
  - $L = 1.0$, $b_0 = 7.0$, $b_1 = 1.0$
  - Aim to make less unrealistic coils
- **2024-03-28-prerelease**
  - $L = 0.8$, $b_0 = 7.0/0.8$, $b_1 = 1.0/0.8$
  - Following consideration of RF: require odd number of RF cavities
  - Make the lattice shorter suitable for 3 RF cavities
- Only considering solenoids in this talk (no RF, dipoles, wedge)

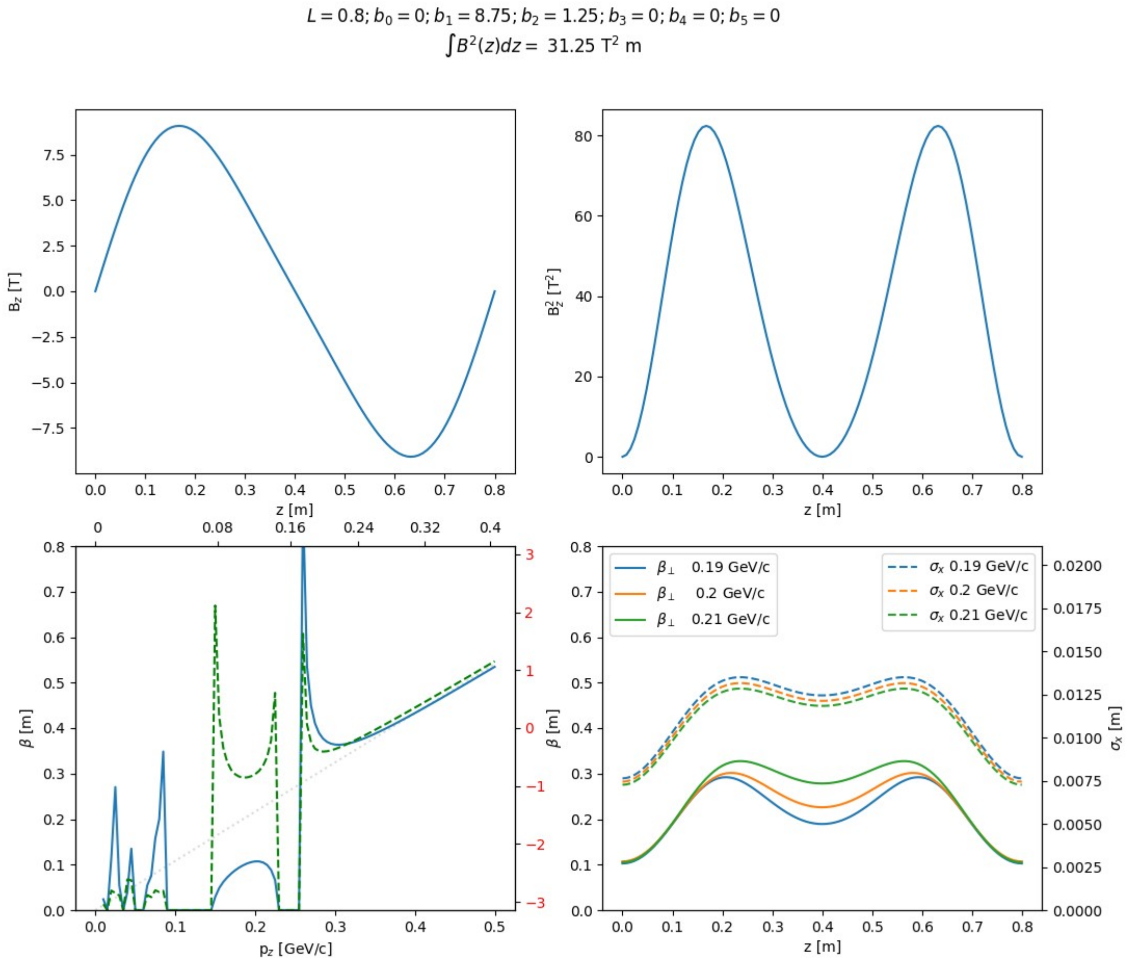
Linear optics (1)

- Linear optics solution for the 2024-03-01 and 2022-11-01 ideal field
  - Nb calculated by integrating transfer matrix from z→ z+dz and juggling to find the transverse beta

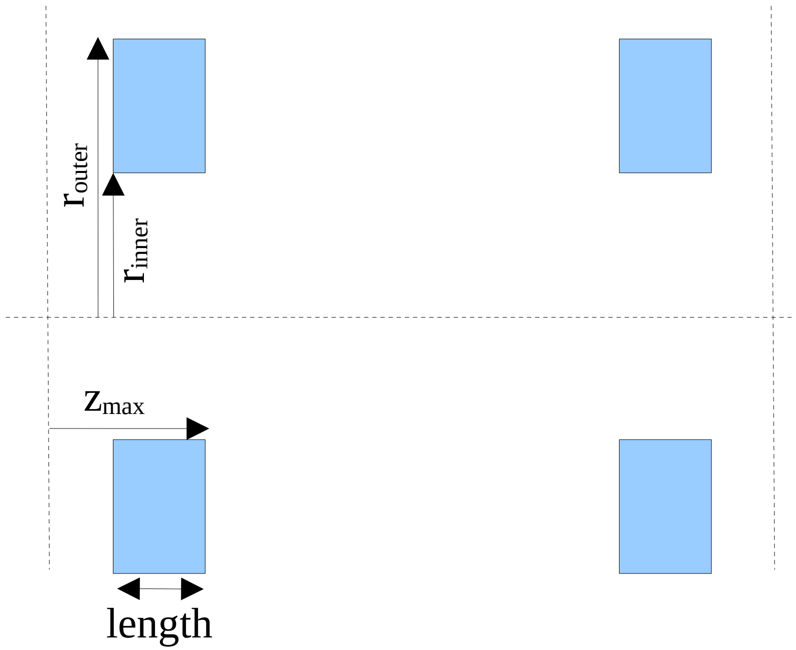


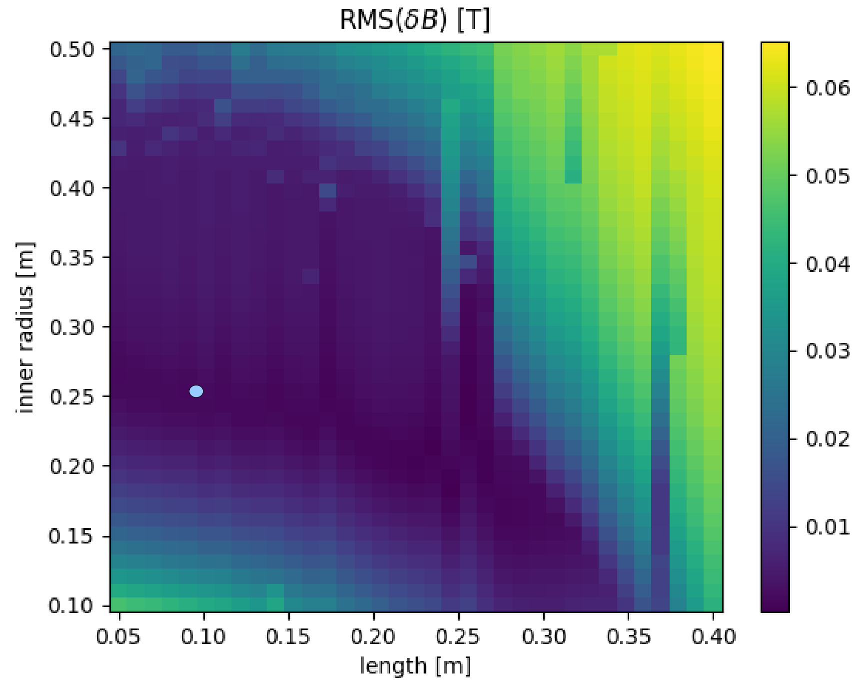
Linear optics (2)

- Linear optics solution for the 2020-03-28 ideal field
  - Should be identical except β and $\sigma(x)$ scales by 0.8



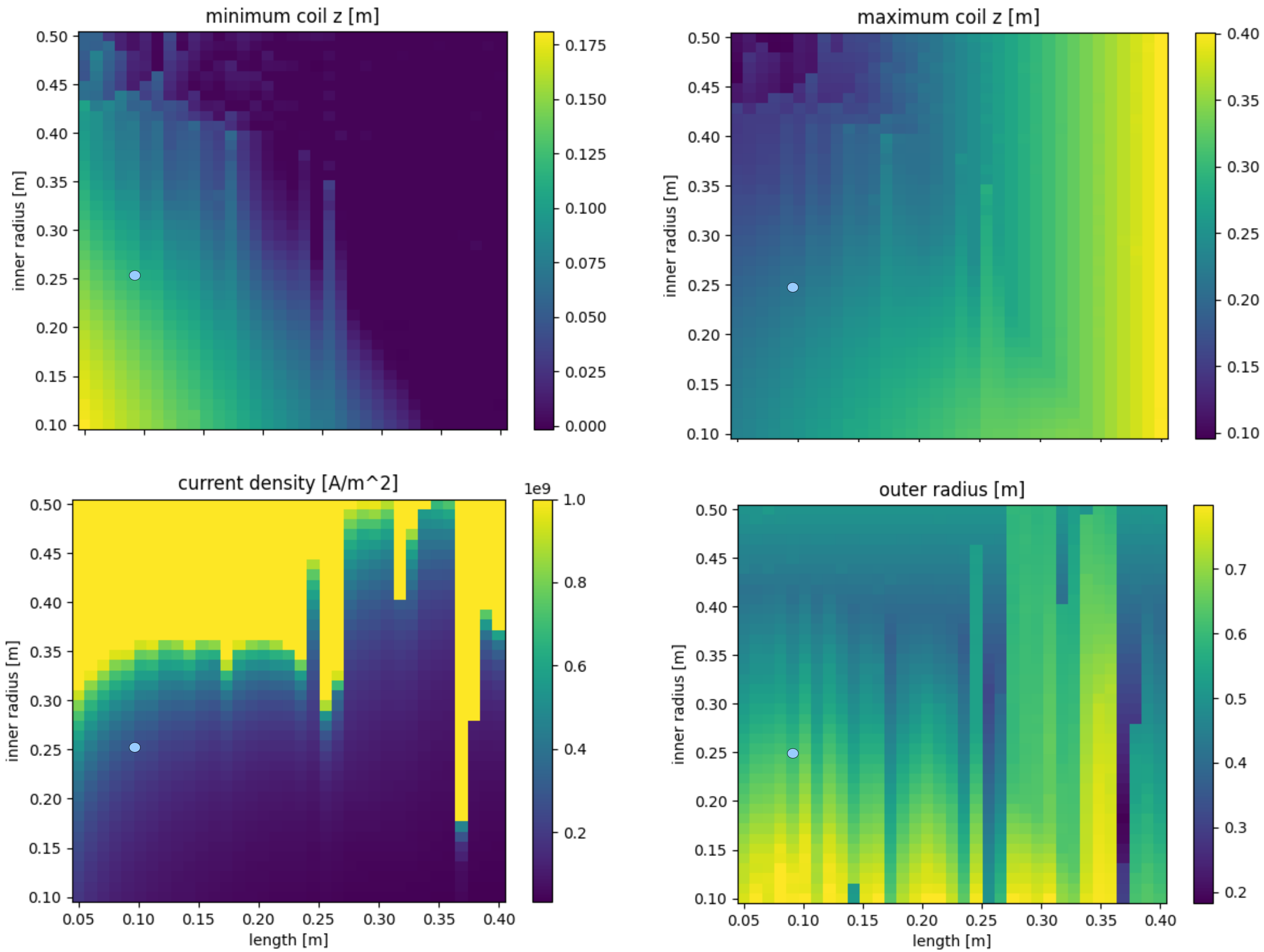
Solenoid 2024-03-01



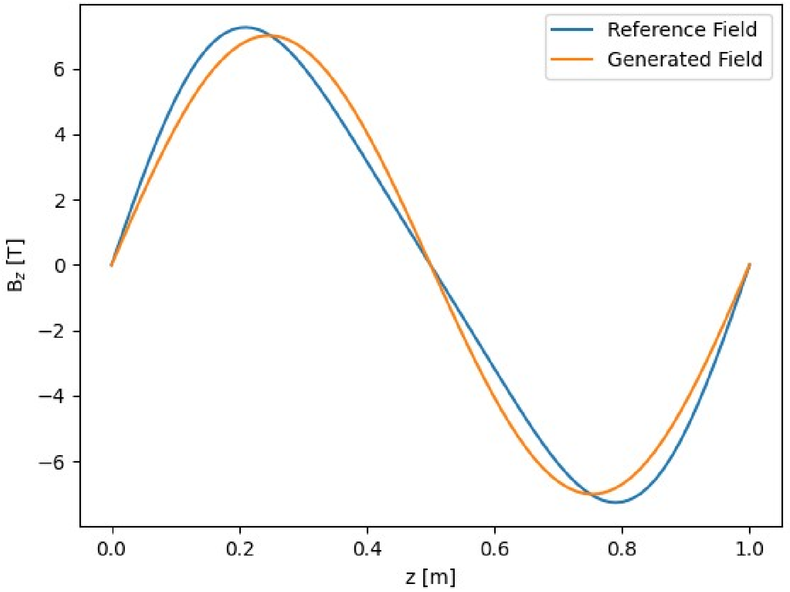


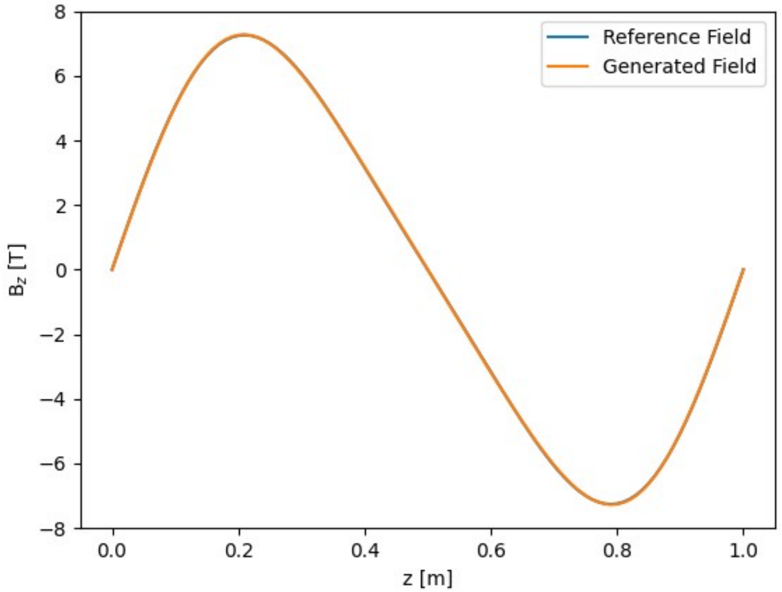
- **Scan** length
- **Scan** inner radius
- Allow r_{outer}, z_{max} and current density to vary
- **At each scan point** minimise Sum[B_{test} – $B_{desired}$]^2, calculated at 100 points
- **Not** checked stresses/stored energy

Geometry 2024-03-01

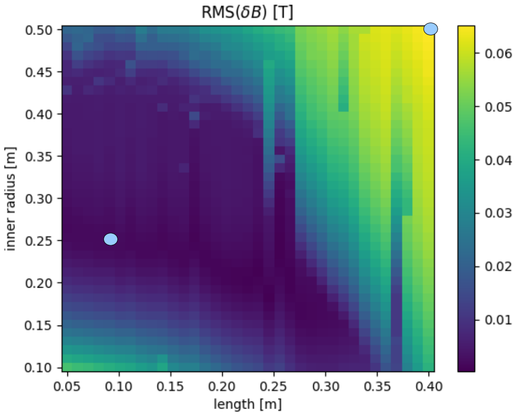


Coil fit quality 2024-03-01

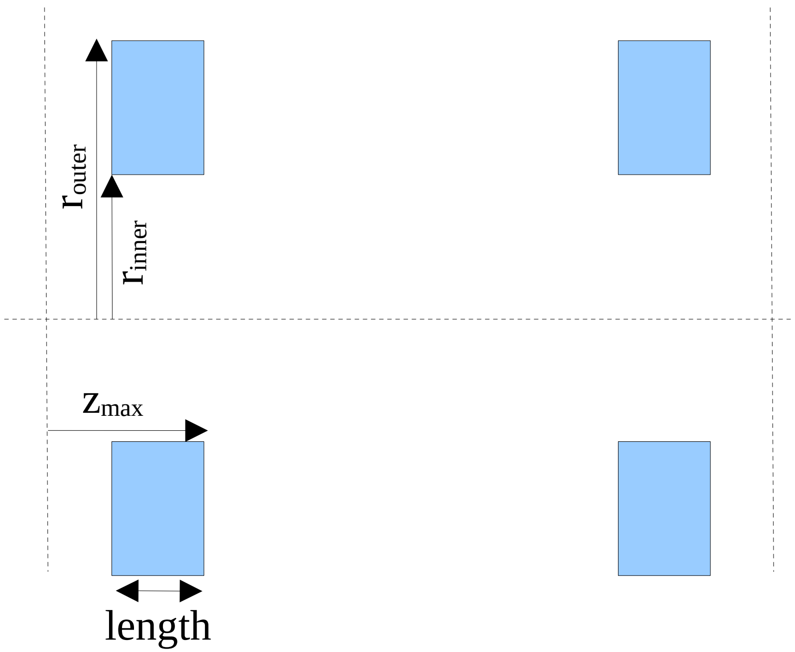


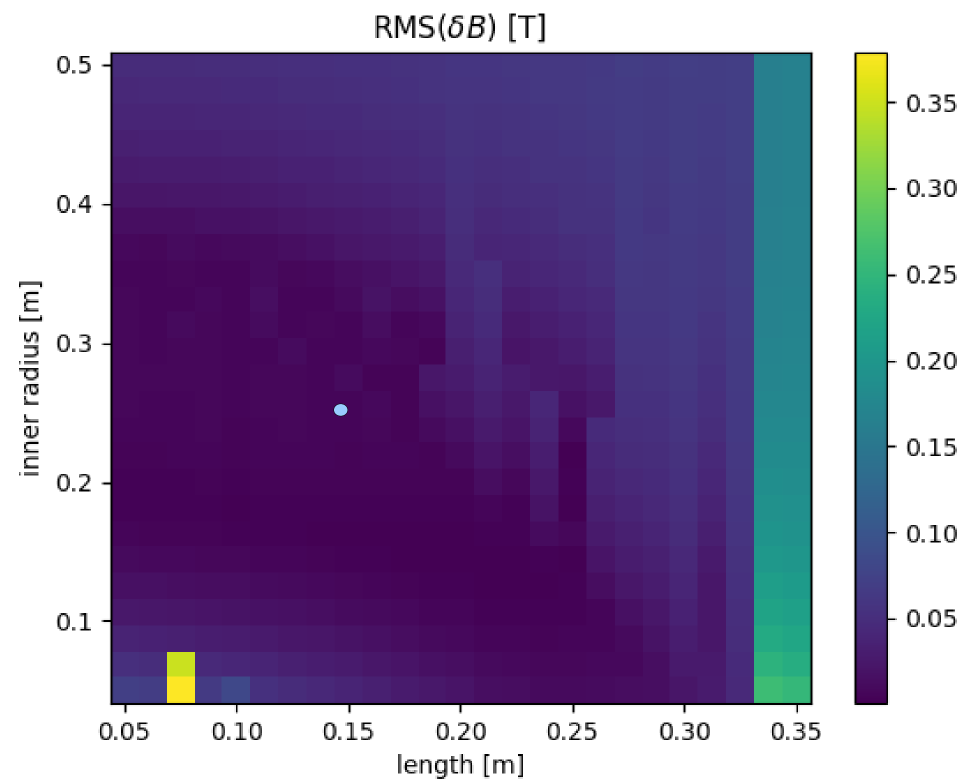


- Show a badly-fitted field (left)
- Show the 2024-03-01 coil (right)

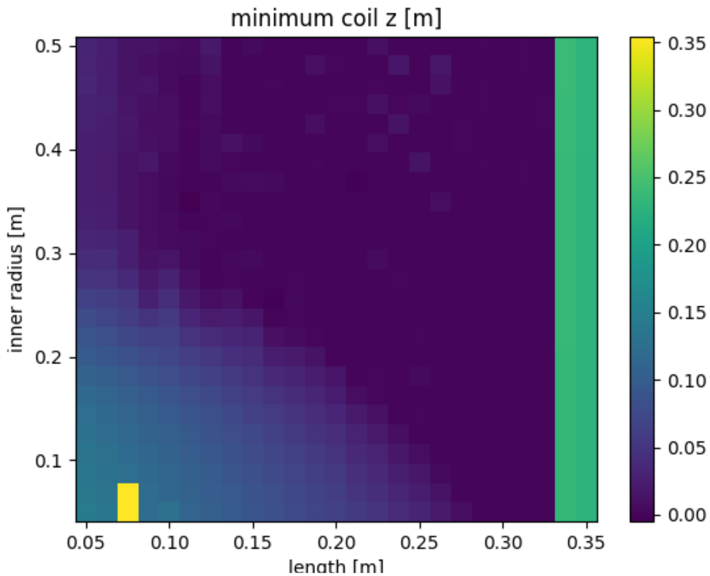


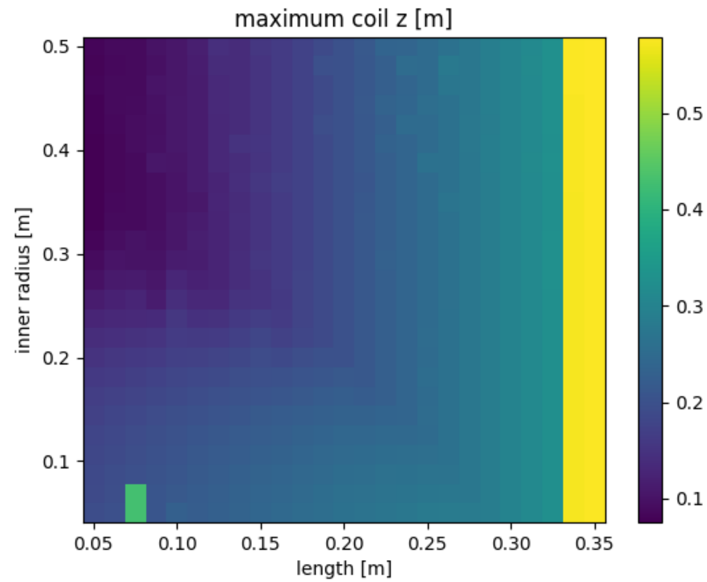
Coil fit quality 2024-03-28

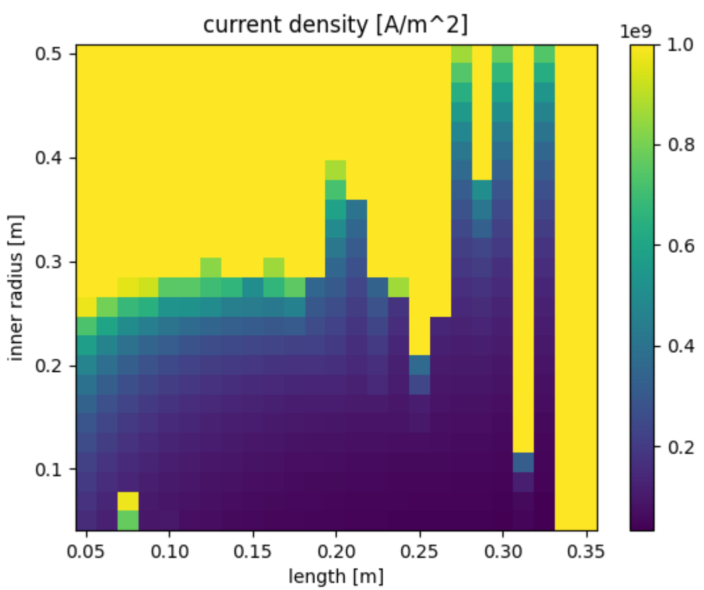


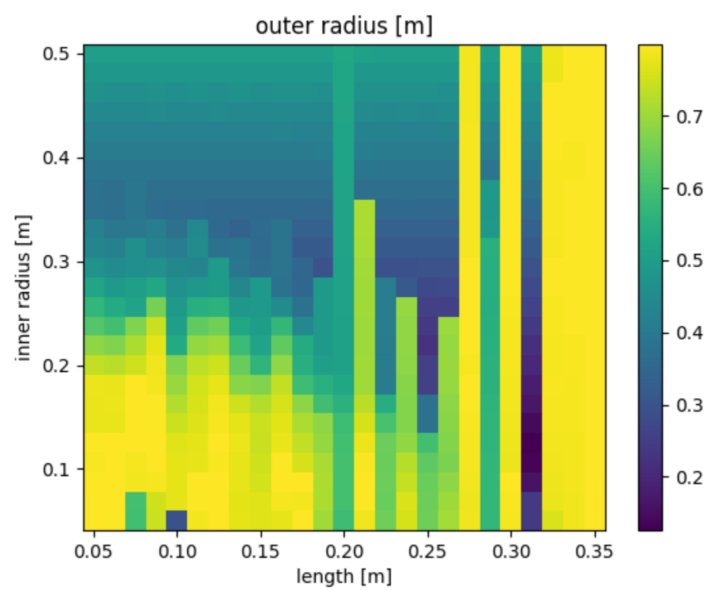


Geometry 2024-03-28

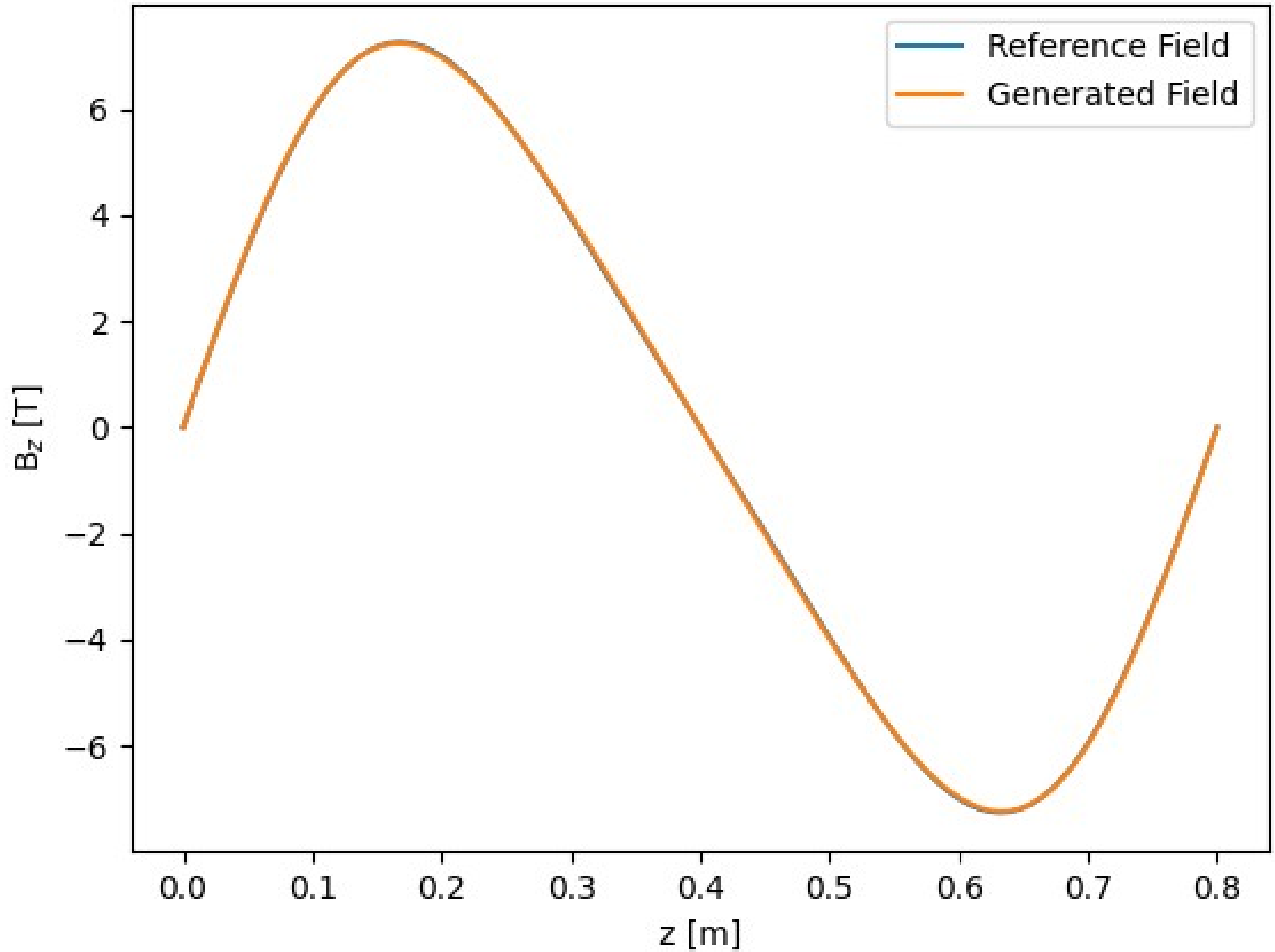








Field on-axis



Parameters

2022-11-01-release

R inner	0.4 m
R outer	0.5 m
Z min	0.05 m
Z max	0.15 m
Length	0.1 m
Current density	3003.45 A/mm2

Non-physical current

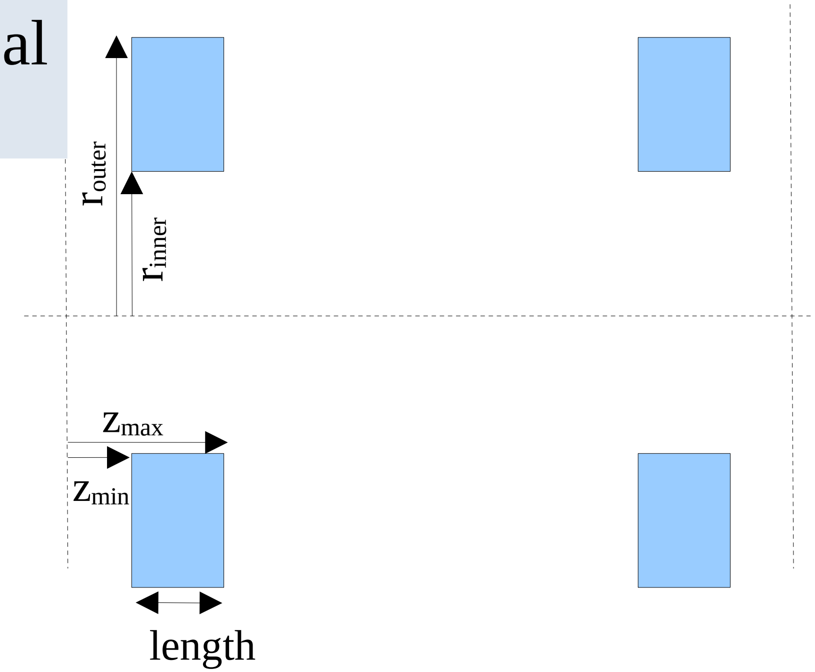
2024-03-01-prerelease

R inner	0.25 m
R outer	0.575 m
Z min	0.1155 m
Z max	0.2155 m
Length	0.1 m
Current density	264.5 A/mm2

2024-03-28-prerelease

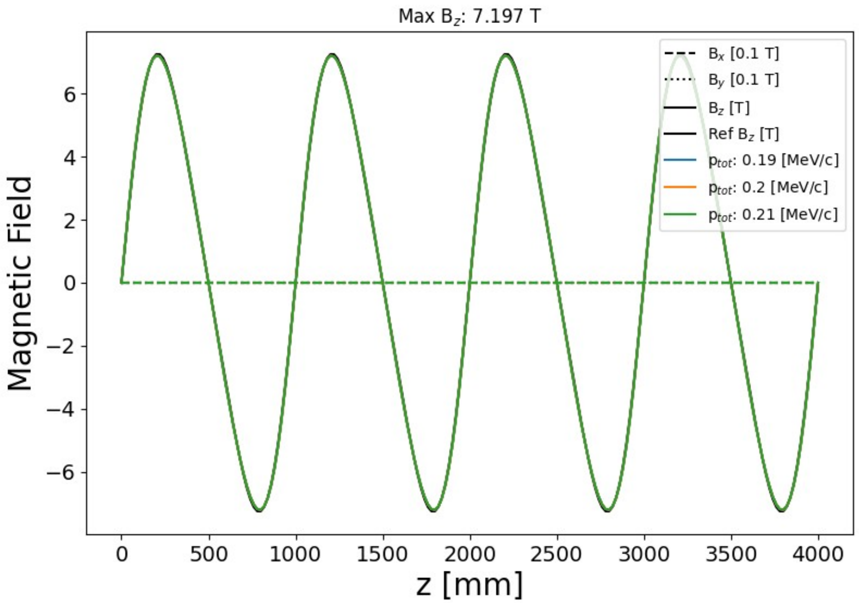
R inner	0.25 m
R outer	0.361 m
Z min	0.042 m
Z max	0.182 m
Length	0.14 m
Current density	594.27 A/mm2

Terrible tracking performance

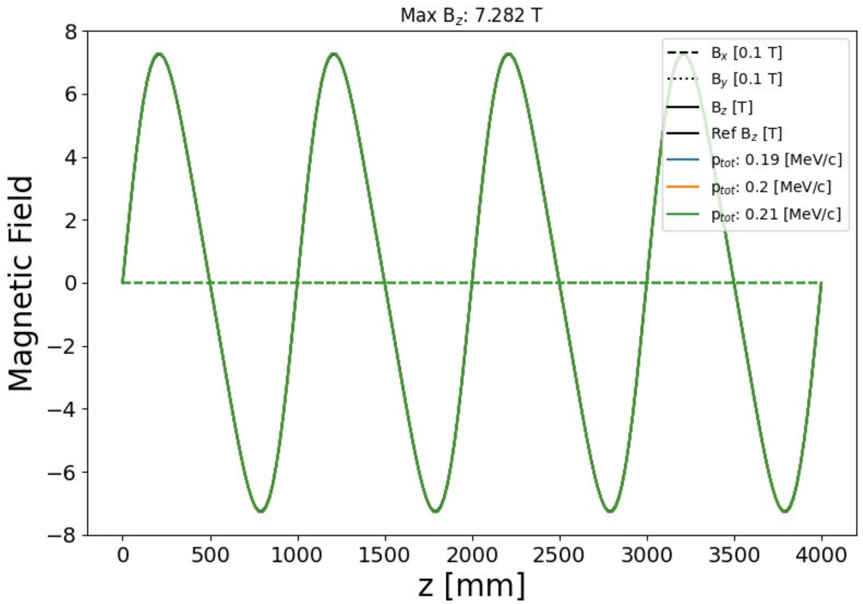


G4BL – Field

2022-11-01



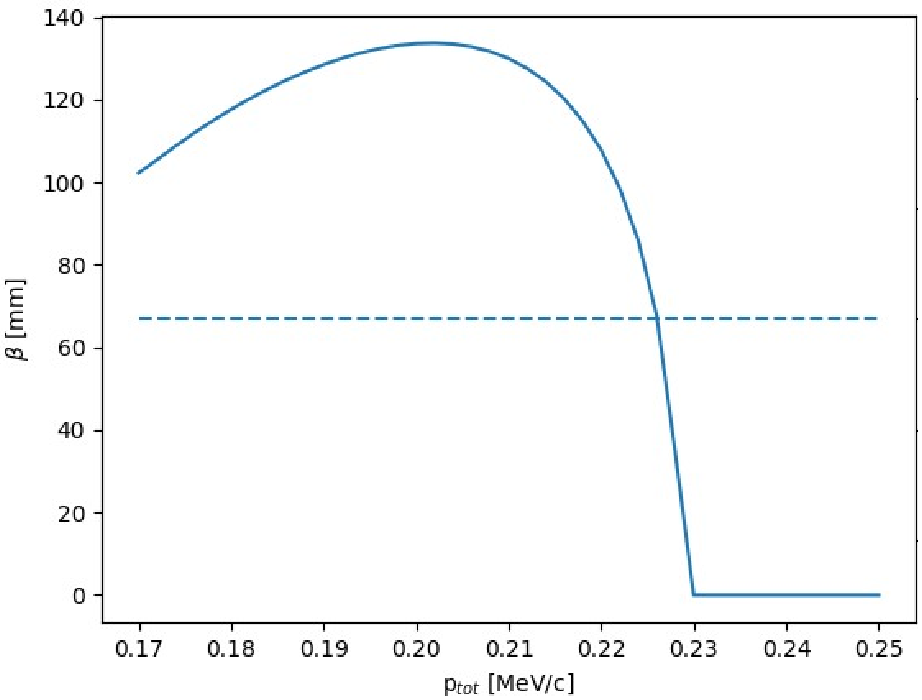
2024-03-01



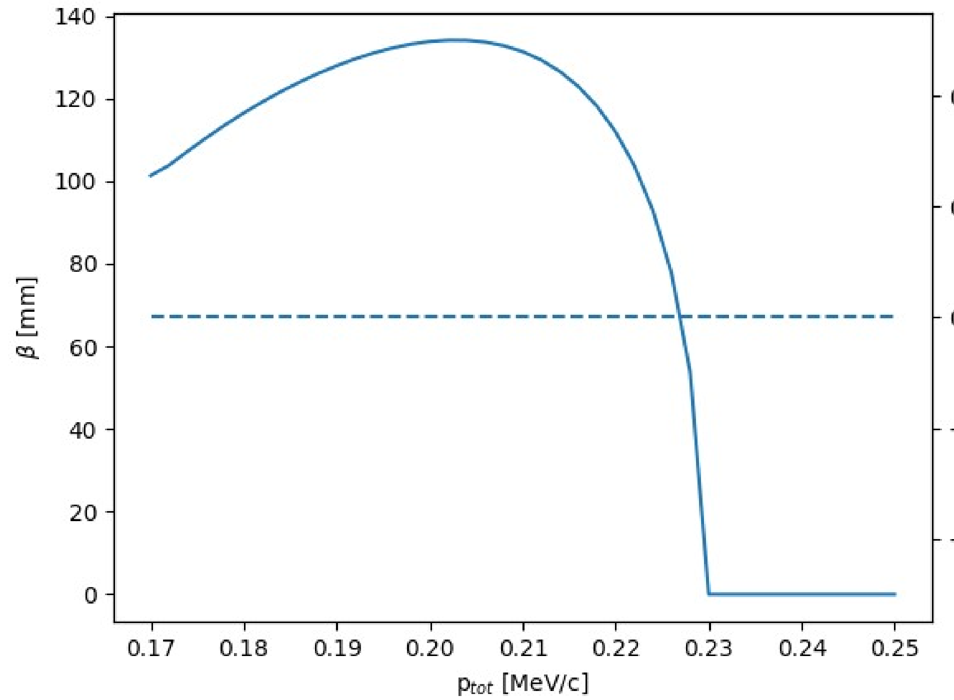
- Implement solenoid fields in G4BL

Tracking – Linear optics

2022-11-01



2024-03-01



- Track particles having small deviations through the solenoids
- Find dx_{out}/dx_{in}, dpx_{out}/dx_{in}, etc (Jacobian)
- Juggle to get transfer matrix and one-cell periodic beta

Tracking – Tune

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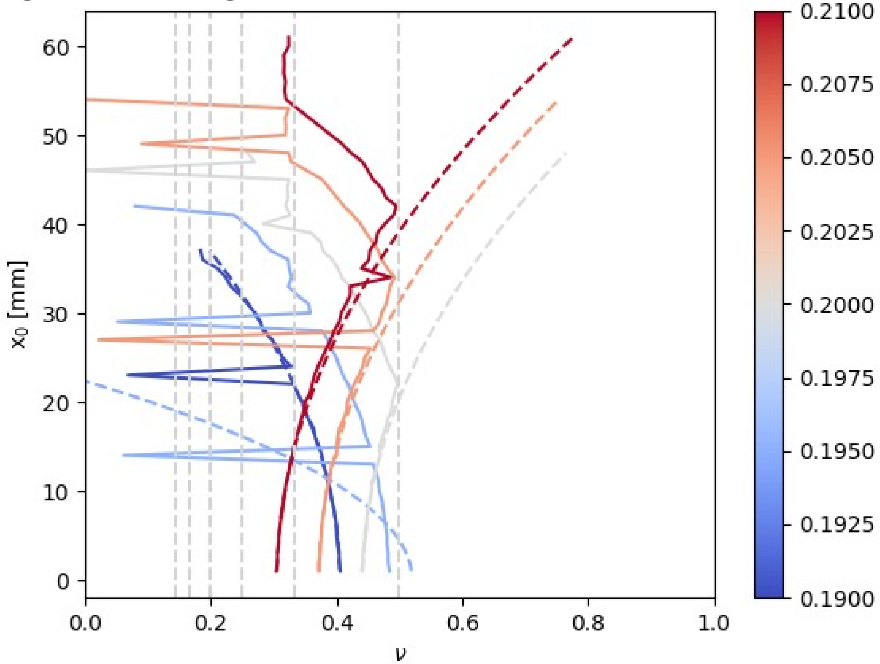
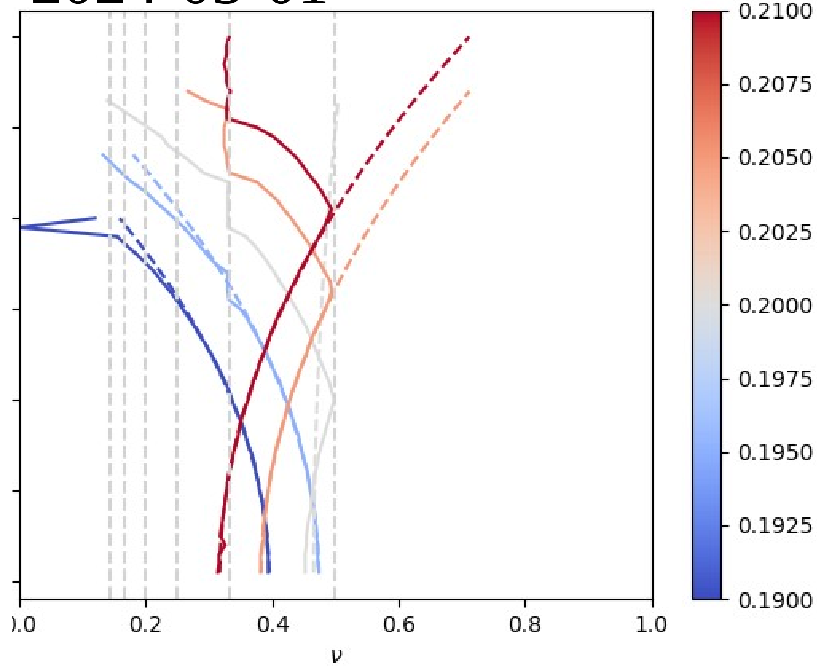
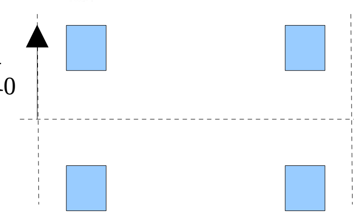
2022-11-01



2024-03-01





- Move particles off the axis
- Calculate tune (FFT)
  - Ps: I may have a factor 2 error – I calculate tune for every other cell
- 2024-03-01 seems better behaved
  - Better fit to the reference field

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Tracking – Tune

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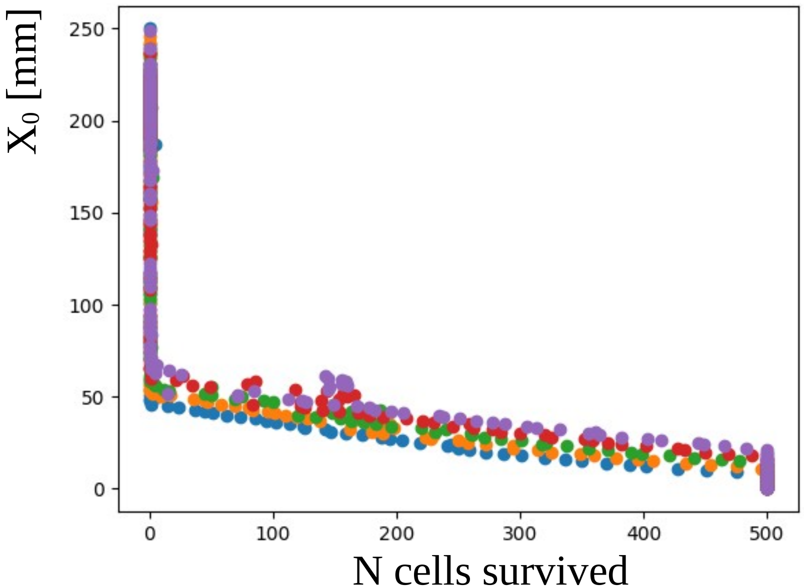
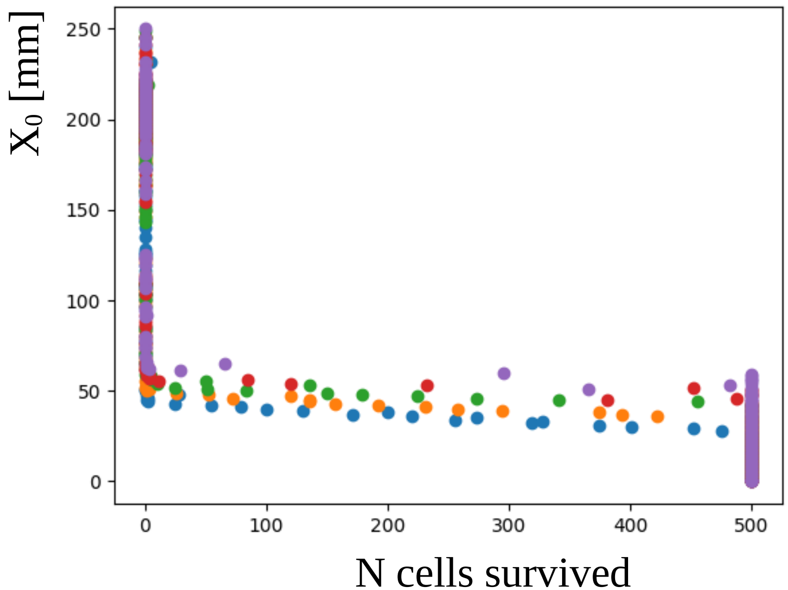
2022-11-01



2024-03-01

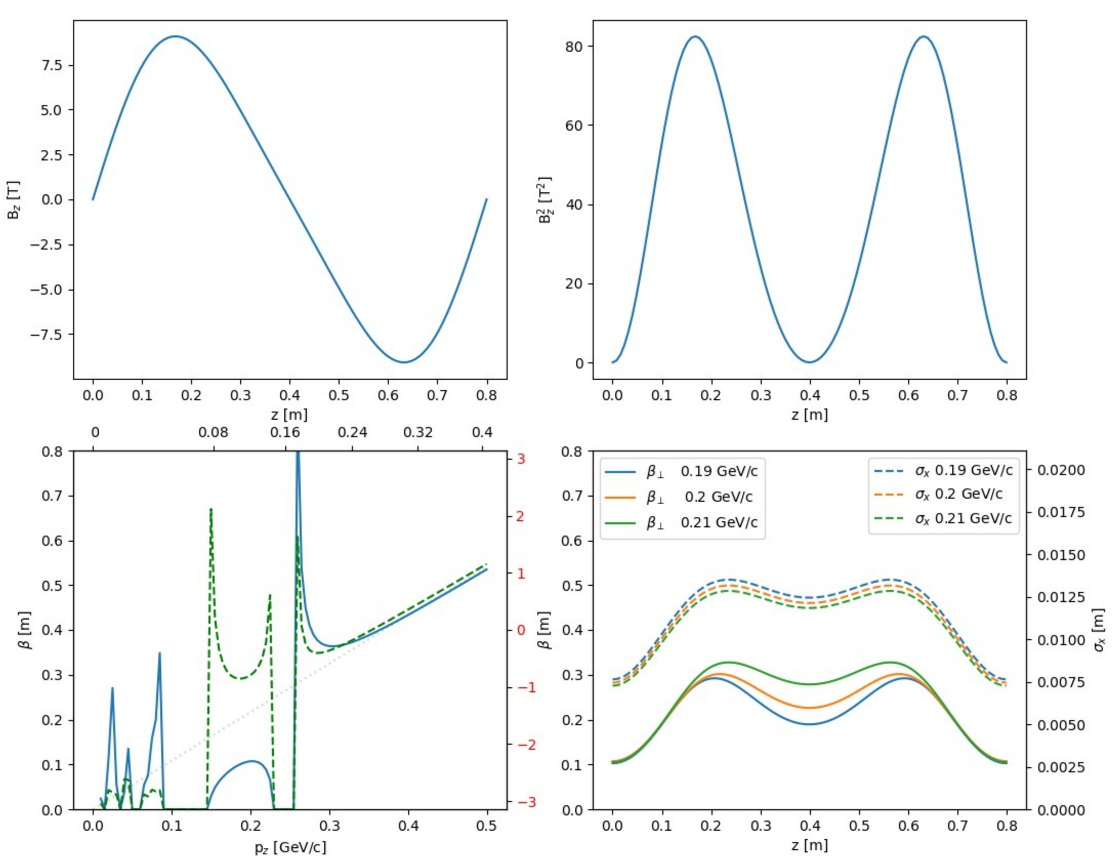


- Look at number of cells survived
  - 2022-11-01 performance significantly worse
  - Why?

2024-03-28 linear optics

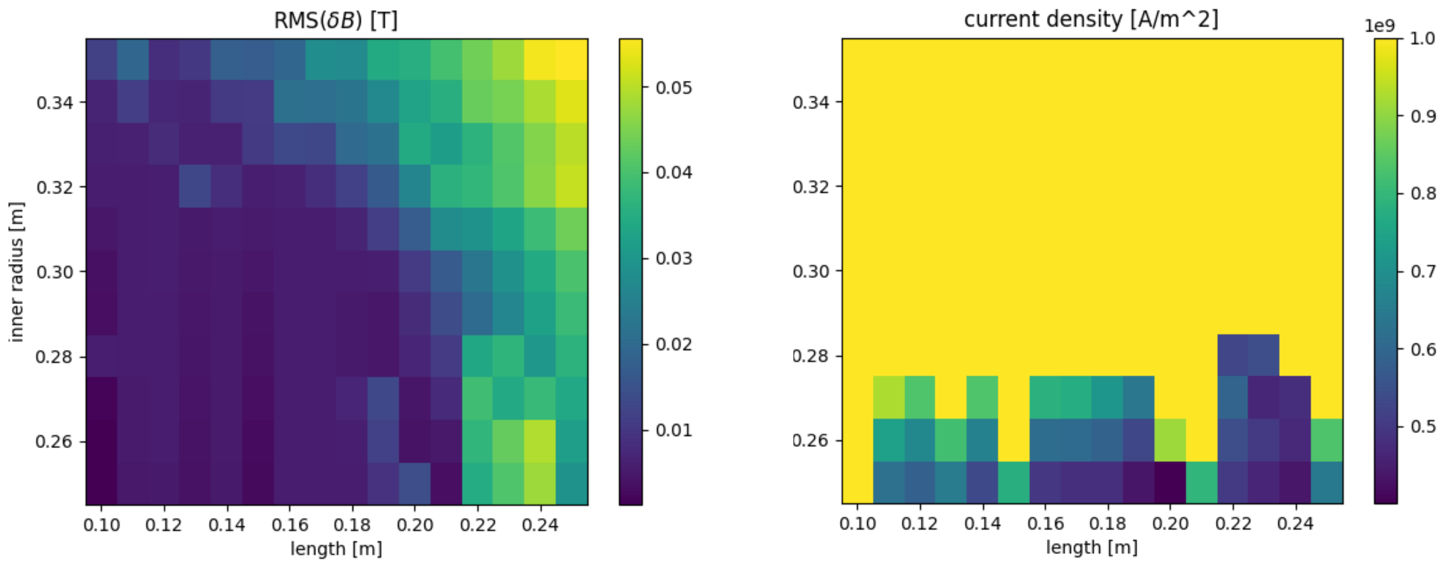
$L = 0.8; b_0 = 0; b_1 = 8.75; b_2 = 1.25; b_3 = 0; b_4 = 0; b_5 = 0$

$\int B^2(z)dz = 31.25\ \mathrm{T^2\ m}$



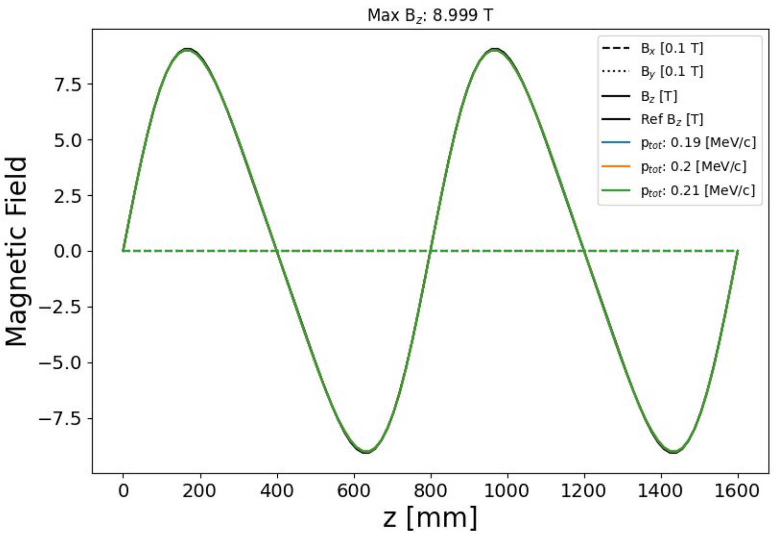
- Momentum dependence does not change
- Fields scale by 1/0.8
- Lengths scale by 0.8

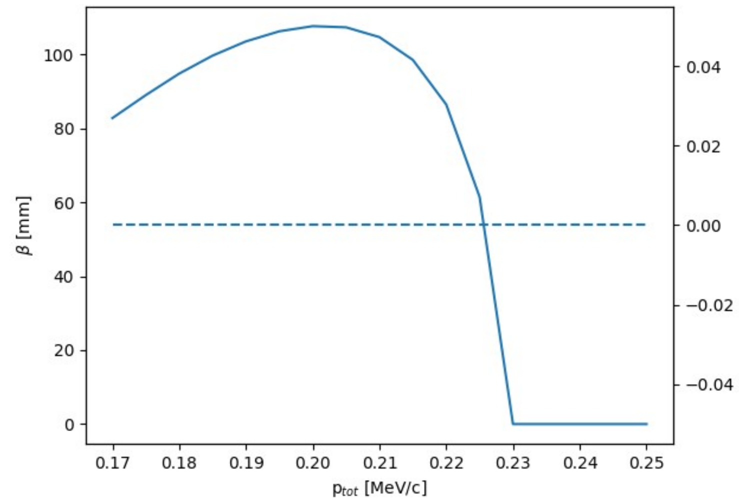
2024-03-28 g4bl vs optics



- Consider now 2024-03-28
- Field is higher and more bucked
  - Current density is more squeezed
  - Coil geometry is more constrained

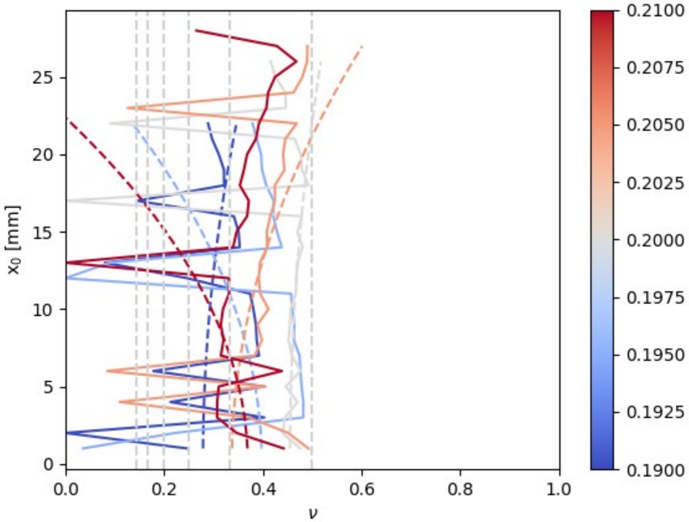
2024-03-28 g4bl vs optics

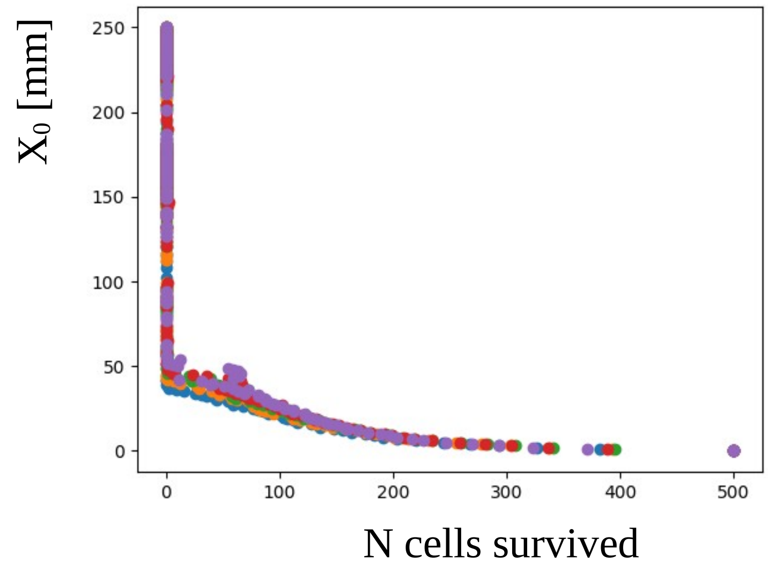




- Momentum dependence does not change
- Fields scale by 1/0.8
- Lengths scale by 0.8
  - Acceptance and emittance scales as a length*momentum
  - Beta scales as a length

2024-03-28 g4bl vs tune





- Terrible tracking performance!
- Terrible survival rate
- Poor Dynamic Aperture
- What is driving Dynamic Aperture?

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Discussion

- There seems to be a loss mechanism that is not exposed by linear optics calculation
- I note that lattices with fields that are slightly less well fitted appear to perform worse
- If losses are attributed to resonance behaviour at high amplitude there are two ingredients
  - Amplitude dependent tune depression
  - Width of the resonance
  - Can higher harmonics of the B_z excite a wider resonance?
- Or is there another loss mechanism altogether?