Demonstrator Magnetic Lattice

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MUON Collider
Collaboration

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Science & Technology Facilities Council
ISIS

Lattice design process

- Understand basic parameter dependencies
  - Solenoid optics ← I am here
  - RF/longitudinal optics
  - Dipole field/dispersion
  - Introduce wedge (maybe cooling without stochastics?)
- Lattice design
  - Choose working point based on parameter dependencies
  - By-hand optimisation based on reasoned arguments
- Final optimisation
  - Throw into some optimiser

Last time…

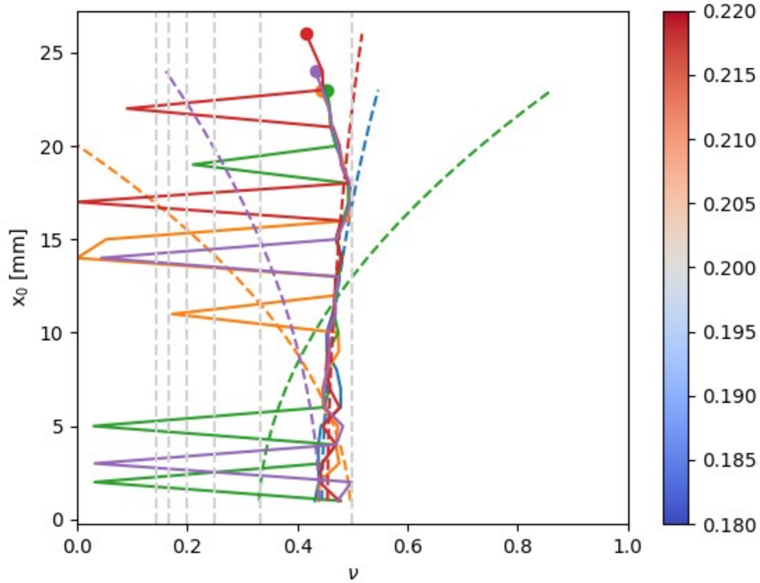
- Discussed new magnet parameters
  - Terrible performance, with no good reason
  - Bad lattice/physics?
  - Numerical issue (step size/etc)?
  - G4BL bug?

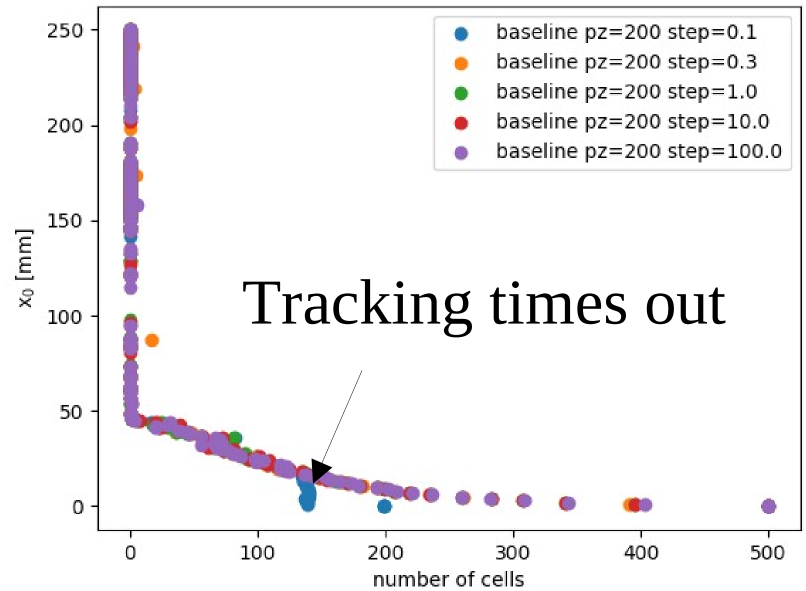
Discuss Three Lattice Baselines

- 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 – former baseline**
  - 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 – current baseline, not discussed here
- **2024-03-28-prerelease**
  - L = 0.8, b_0 = 7.0/0.8, b_1 = 1.0/0.8
  - Tracking not very satisfactory
- **2024-04-16-prerelease**
  - L = 0.8, b_0 = 7.0/0.8, b_1 = 1.0/0.8

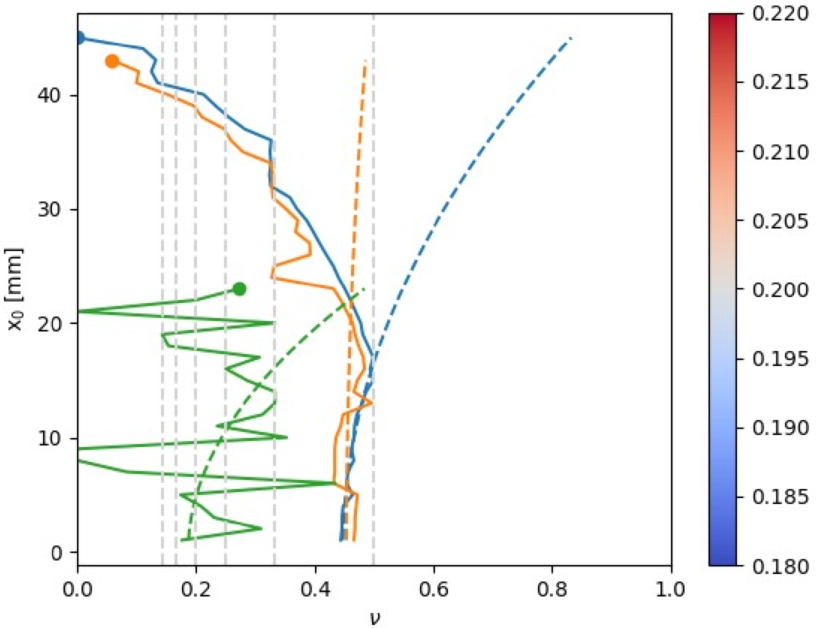
Step Size

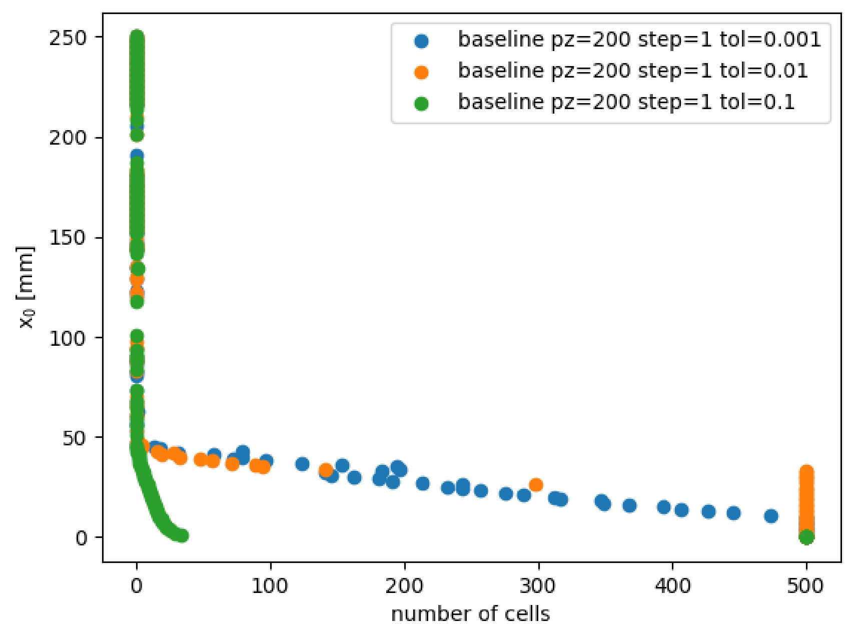




- No improvement with step size

Field map tolerance





- Some change with field map "tolerance"
- Very bad with tolerance "0.1" (0.7 T absolute)
- Better with tolerance "0.01" (0.07 T absolute)
- Worse again with tolerance "0.001" (0.007 T absolute)
- No clear behaviour

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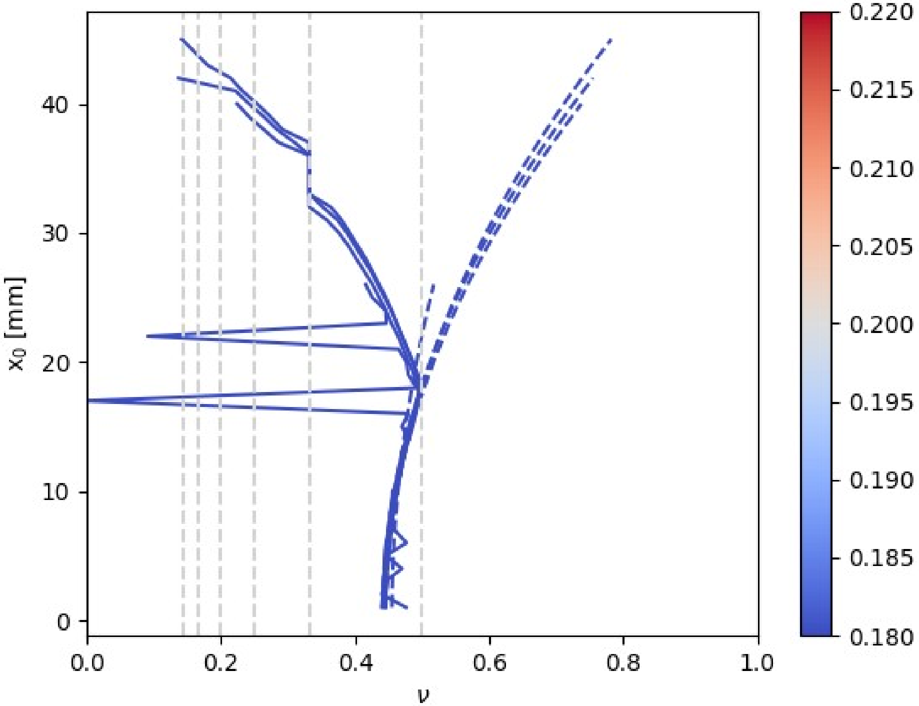
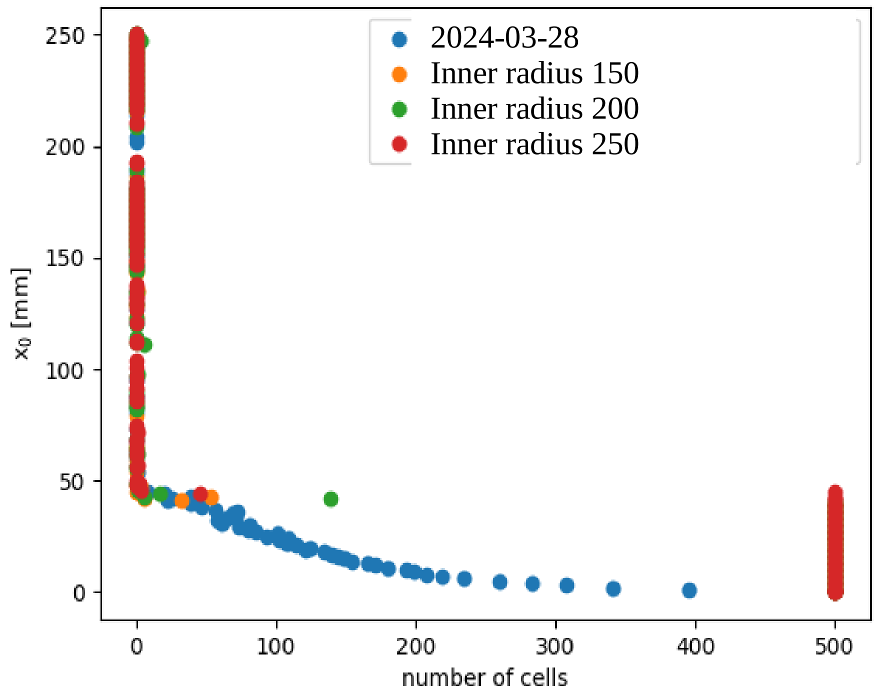
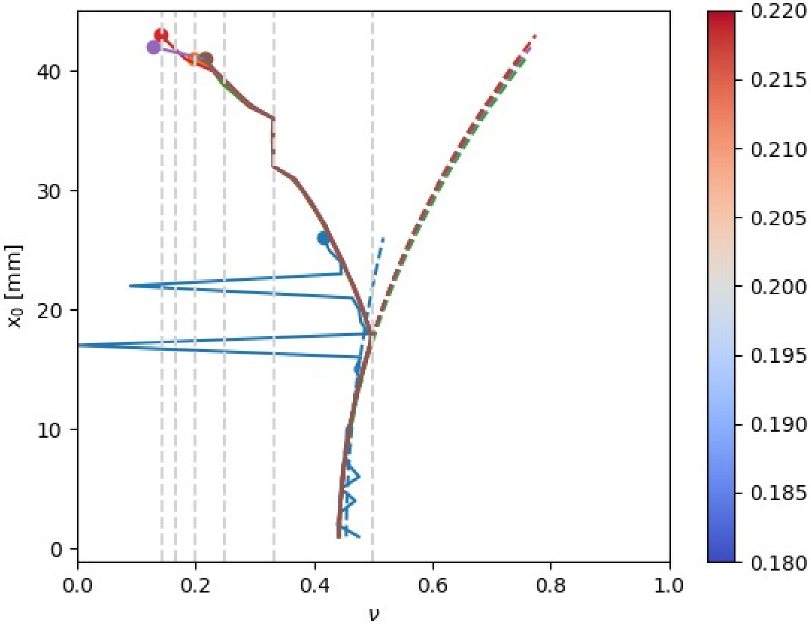
Magnet radius

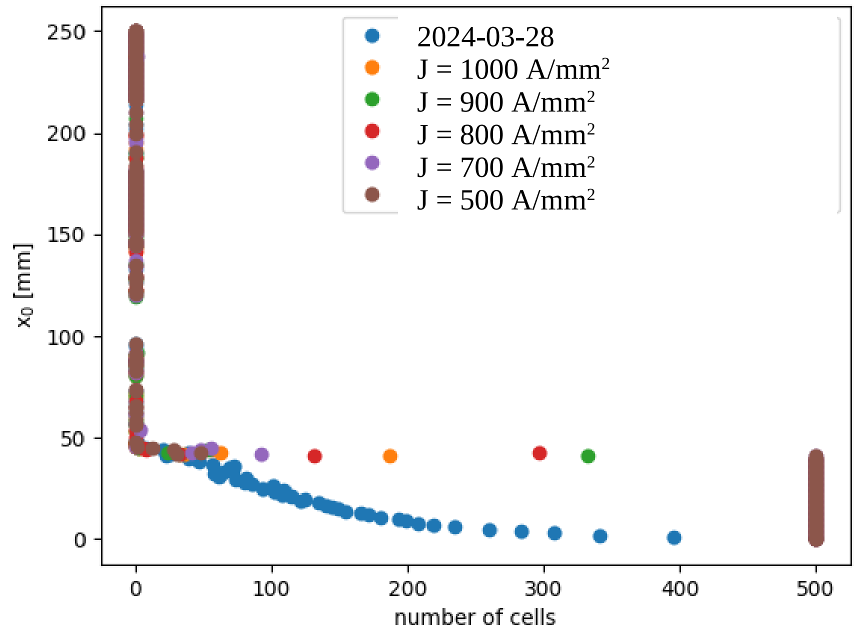




- Try scanning inner radius 150 – 250 mm
  - Length fixed at 140 mm
  - Allow z position of the coil, current density and thickness to move
  - Optimise for match to desire field profile
- Improved performance for all other solenoids?!

Magnet current





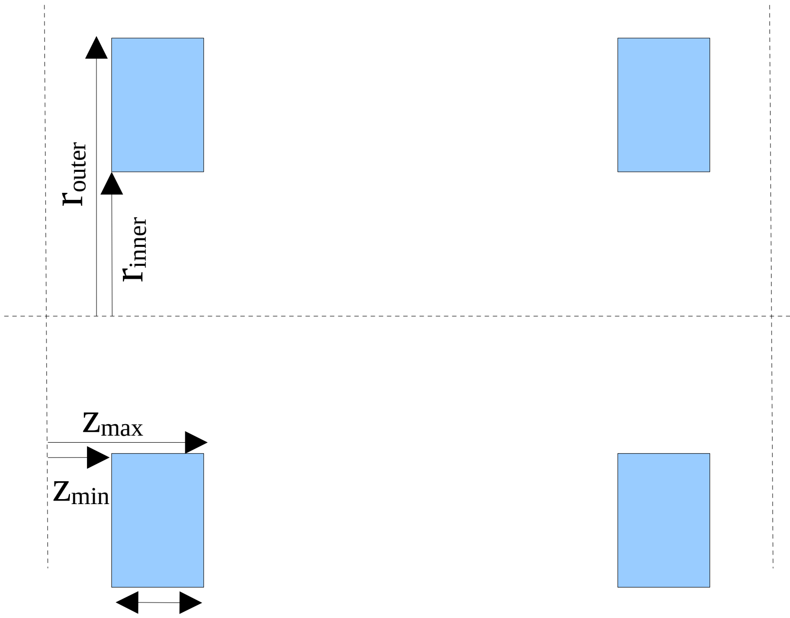
- Fix length and inner radius
- Scan current density
- Allow radial thickness and z position to move to get optimal field profile
- Improved performance for all other solenoids?!

New baseline

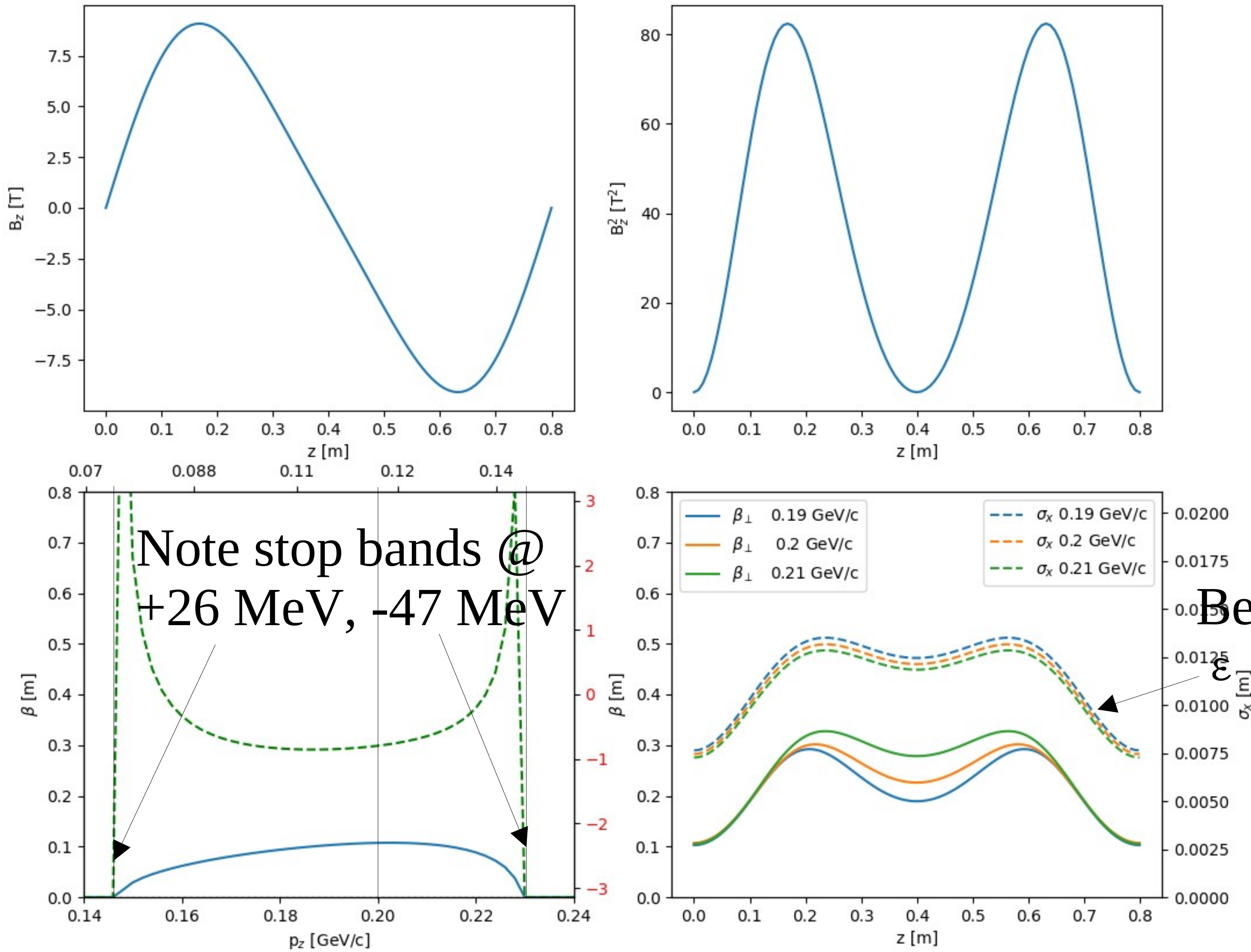
- Propose new baseline:

2024-04-16-prerelease

R inner	0.25 m
R outer	0.419 m
Z min	0.029 m
Z max	0.169 m
Length	0.14 m
Current density	500 A/mm2
Absorber separation	0.8 m



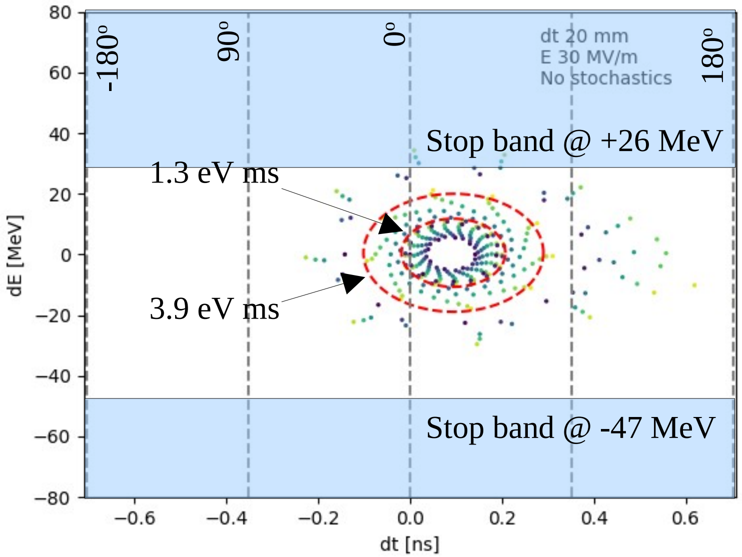
Reminder – linear optics

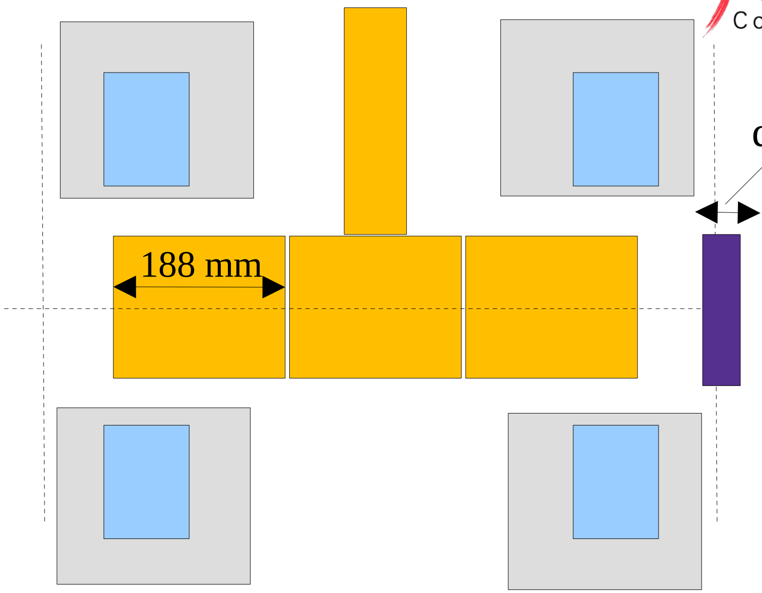


Note stop bands @ +26 MeV, -47 MeV

Beam RMS ε = 1 mm

RF – 30 MV/m, 704 MHz





- Start looking at RF
  - Consider pi mode RF
  - 3 RF cavities each 188 mm long
- Look at performance
  - Look at “bucket” size vs absorber thickness
  - Compare with $\varepsilon_{//}$ = 3.61 mm = 1.3 eV ms & ε_{trans} = 0
    - Nominal demo input emittance
  - Consider different voltage – 30 MV/m & 50 MV/m
  - No windows

RF – 30 MV/m, 704 MHz

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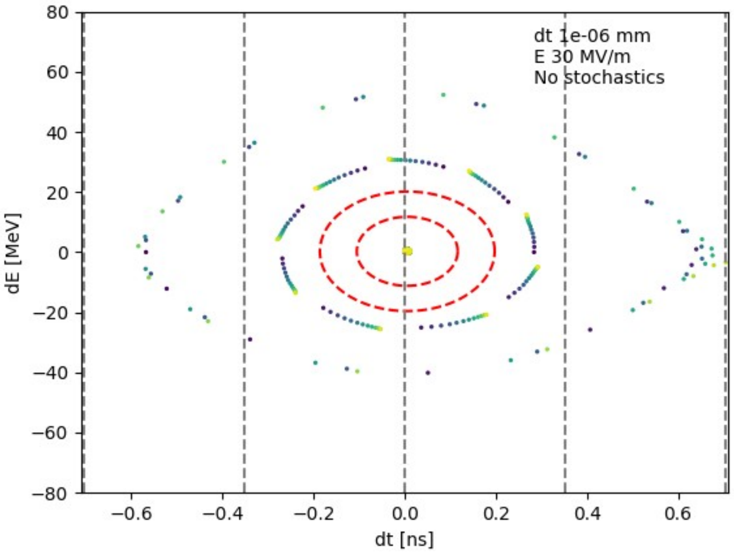
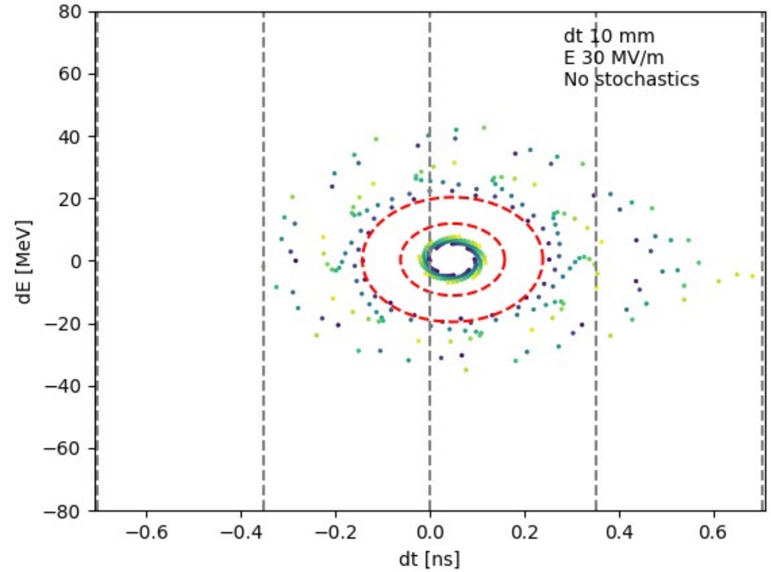
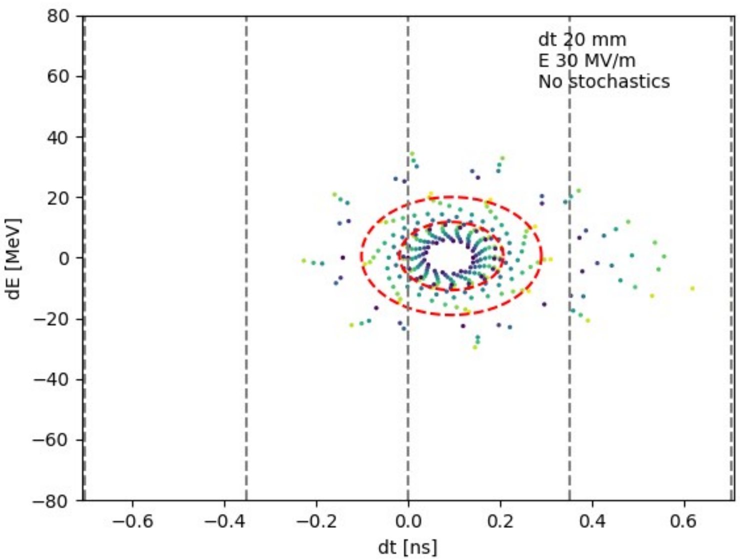
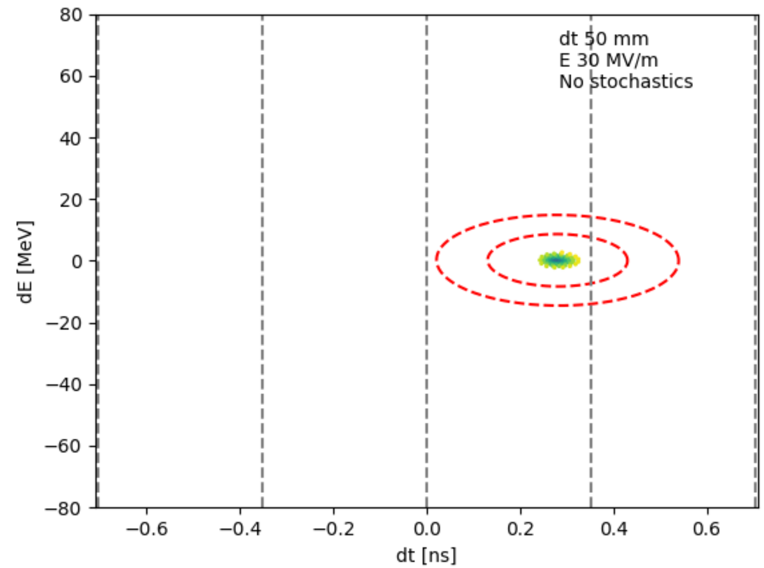
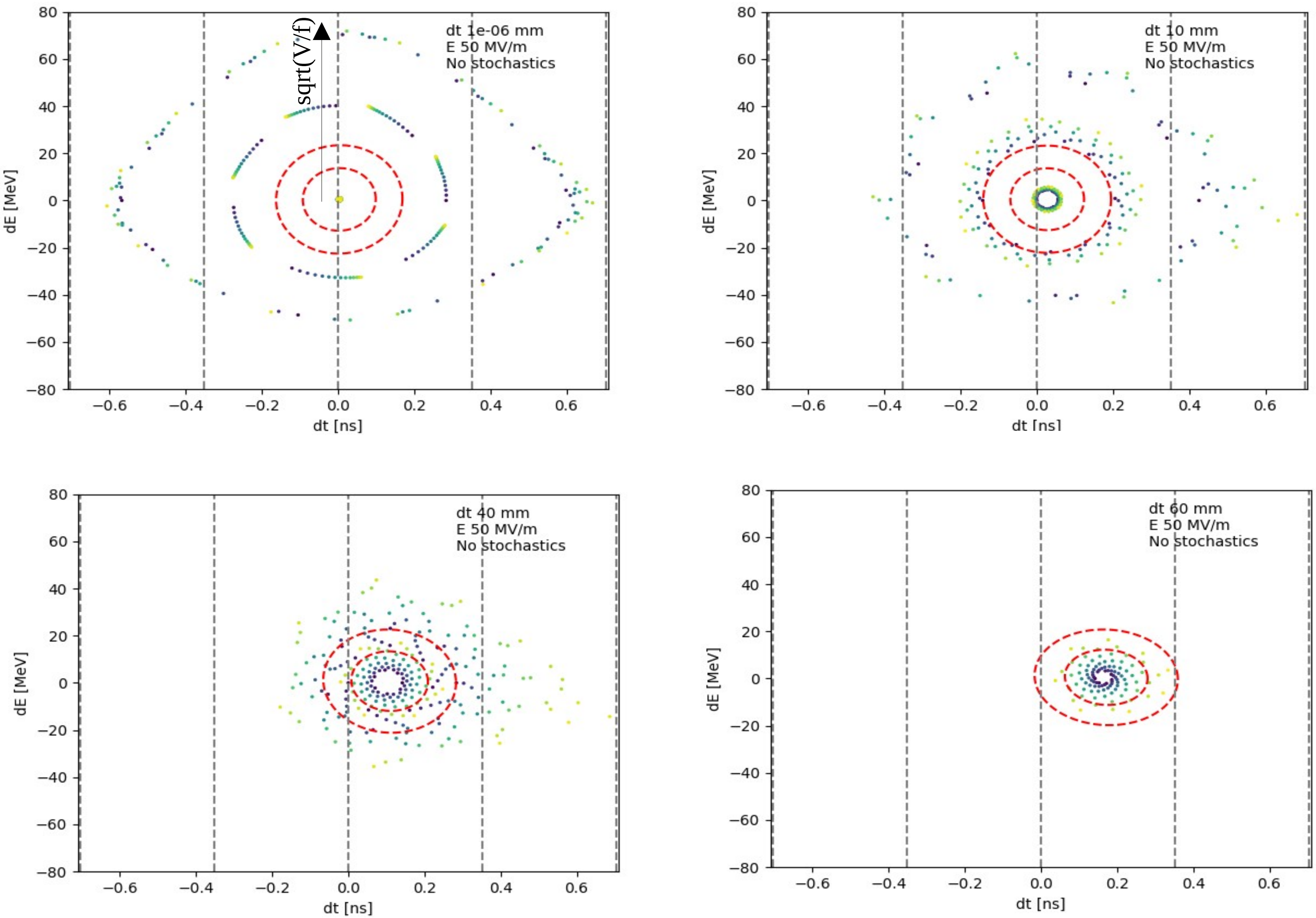








RF – 50 MV/m, 704 MHz

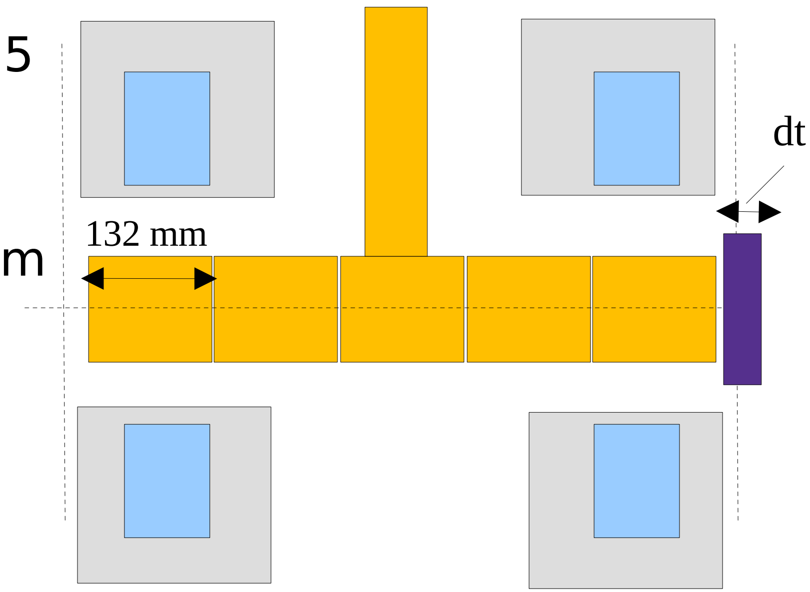


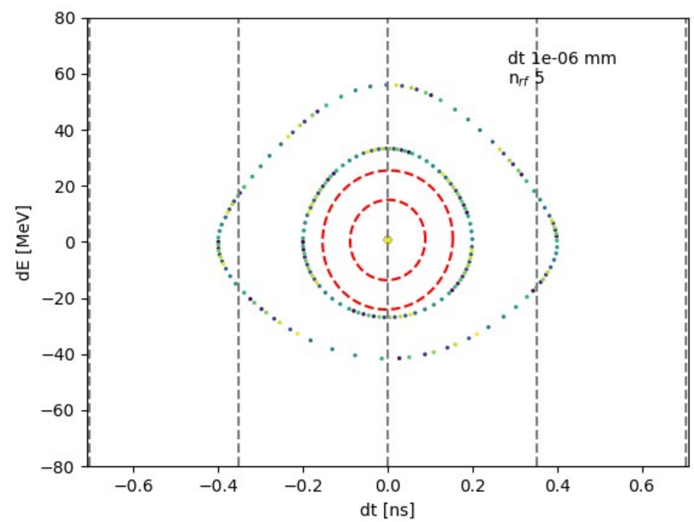
Interpretation

- Slight emittance growth even with no absorber
  - Probably can improve tracking accuracy
- Quite some emittance growth with LiH absorber
  - This is just Bethe Bloch curve
- As we increase the absorber thickness, the beam is less well contained
  - RF has to do more re-acceleration, bucket gets smaller
- At 30 MV/m, 1.3 eV ms beam is well contained for 20 mm LiH absorber
- At 50 MV/m, 1.3 eV ms beam is well contained for 40 mm LiH absorber
- Need to check with tracking of full beam
  - How much “tail” does the beam have?
  - Any non-linear stuff (e.g. when we include transverse emittance)
    - E.g. stop bands will surely be important
- At some point it becomes a cost optimisation
  - Trade-off between loss and cost
  - Trade-off between RF and magnets [cost]
  - Trade-off between transmission and decay

1 GHz

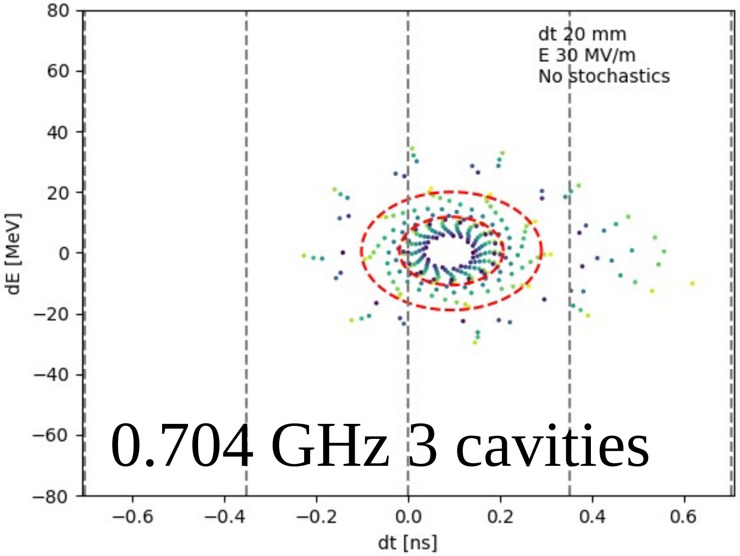
- Shorten cavity by 0.704/1.0
- Increase voltage by (1.0/0.704)^0.5
- 5 cavities may be possible
  - 5 cavities@1 GHz ~ 660 mm
  - 3 cavities@0.704 GHz ~ 564 mm
- Is this practical?
  - Tuners
  - Cooling
  - Vacuum?
  - Any other services?

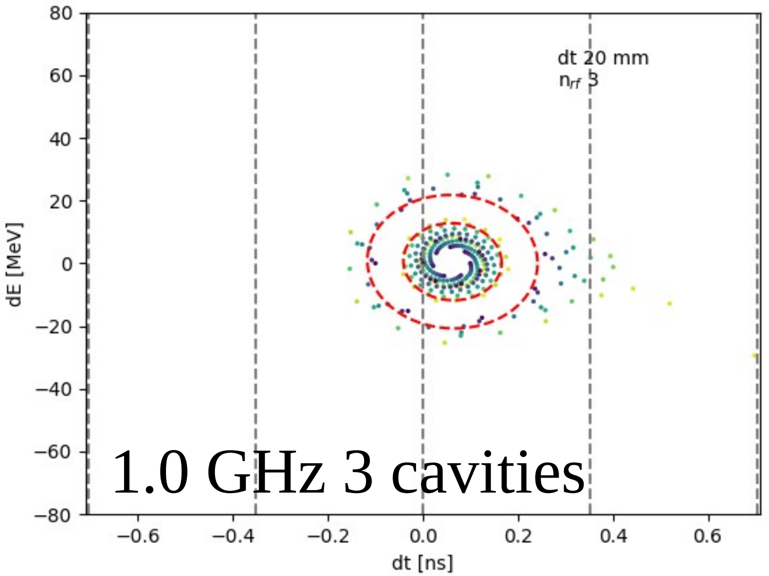


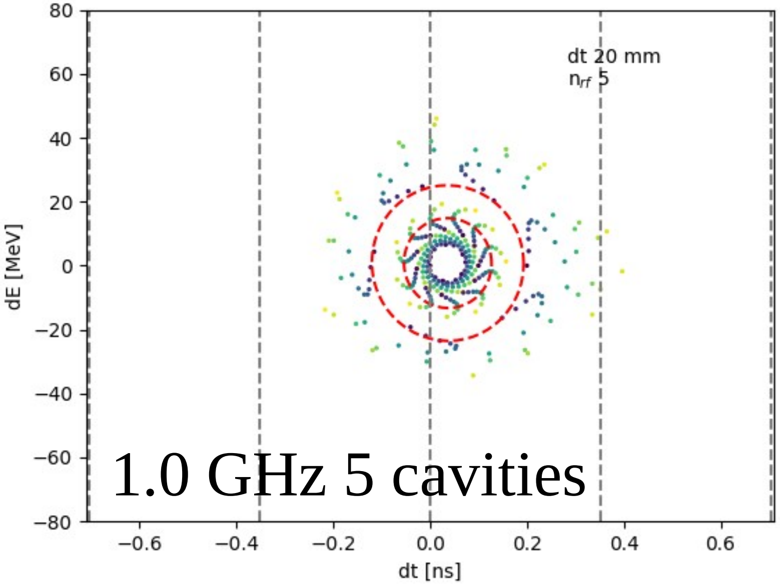


1 GHz - tracking

- V = 30 * (1.0/0.704)**0.5 MV/m

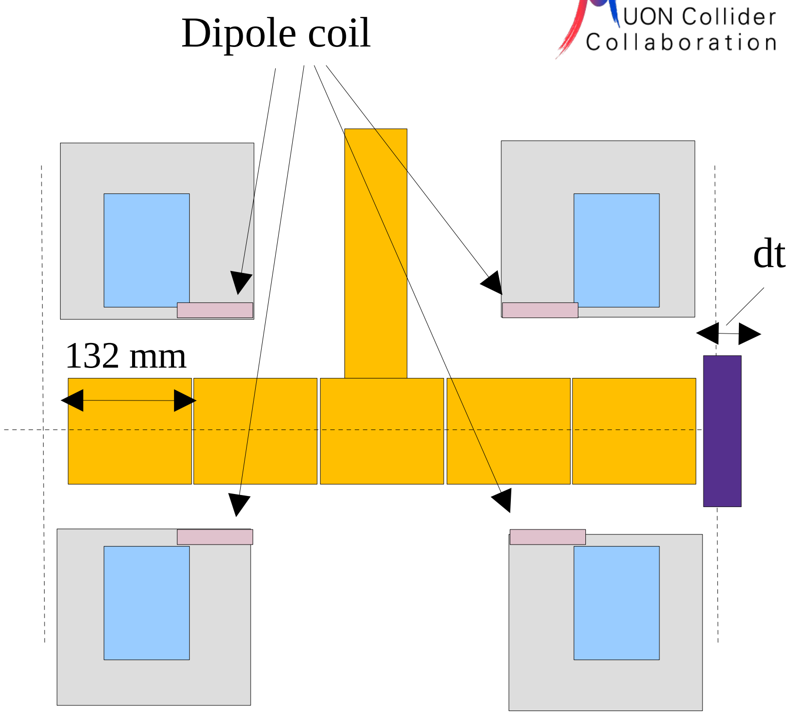






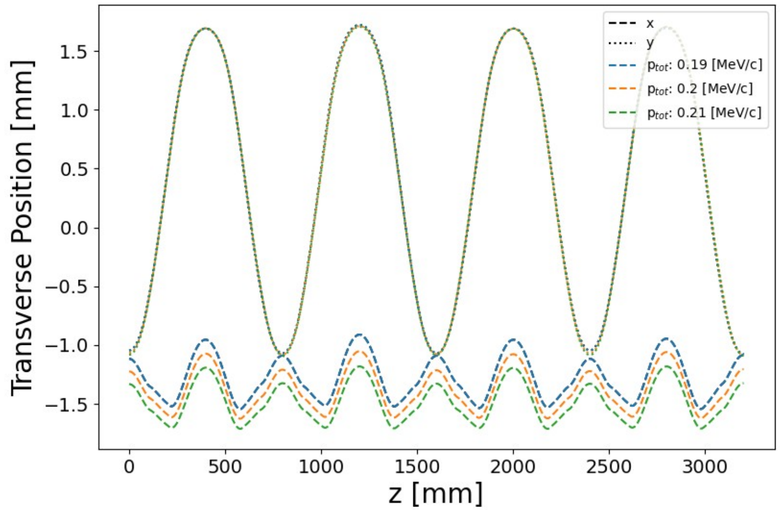
Dipole

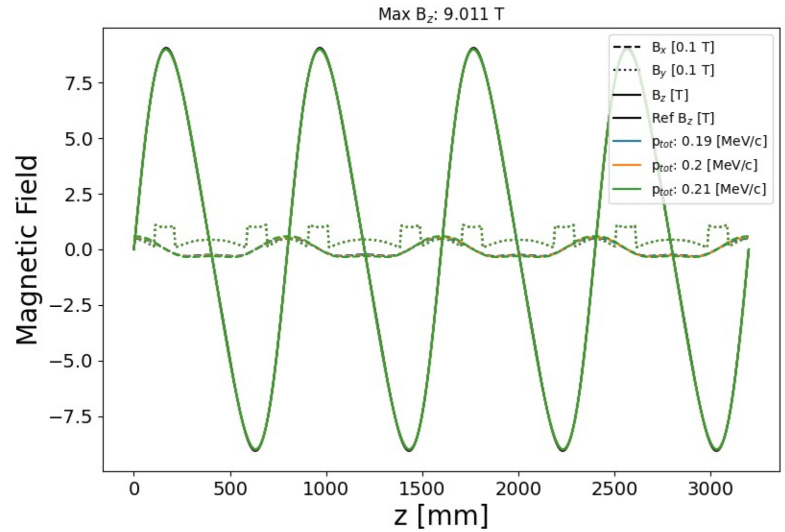
- Look at dipole field **(work in progress)**
  - Aim is to excite a dispersion
  - Different configurations
- For now, no RF/absorber, just solenoid and dipole in tracking
  - Excite a dispersion
  - Depends on phase advance between the dipoles
- Two options considered
  - Length = 0.1 m
  - By = 0.1 T everywhere
  - By = 0.1 T, -0.1 T, -0.1 T, 0.1 T
  - Small variation in z position
- Aim is to exploit phase advance to make more dispersion
  - Scott noted (previously) resonance may be excited

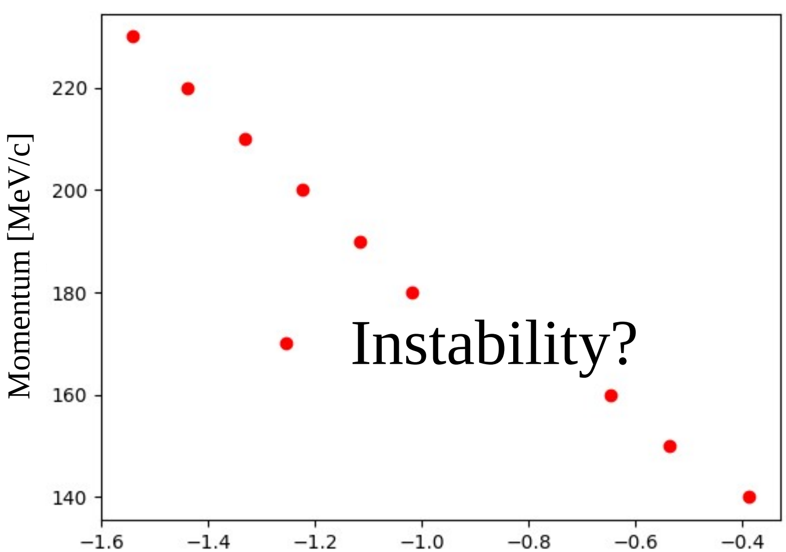


Dipole +0.1 T eveywhere

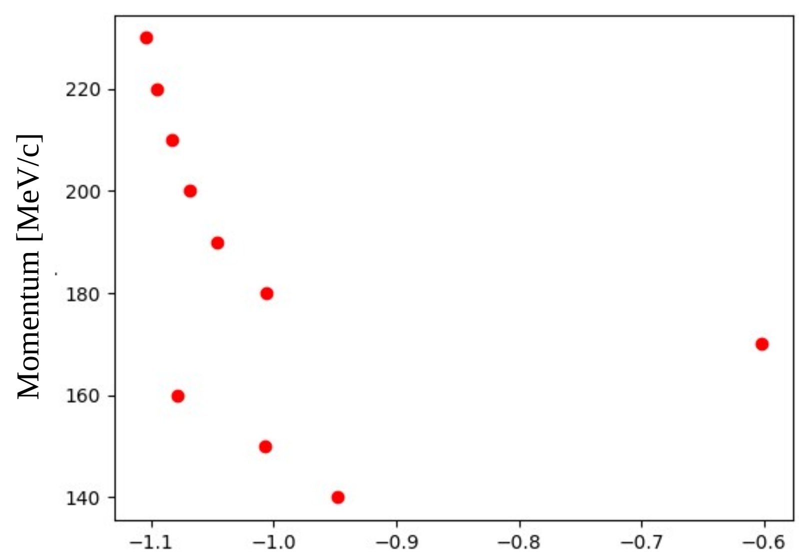
Periodic trajectory "closed orbit" vs z





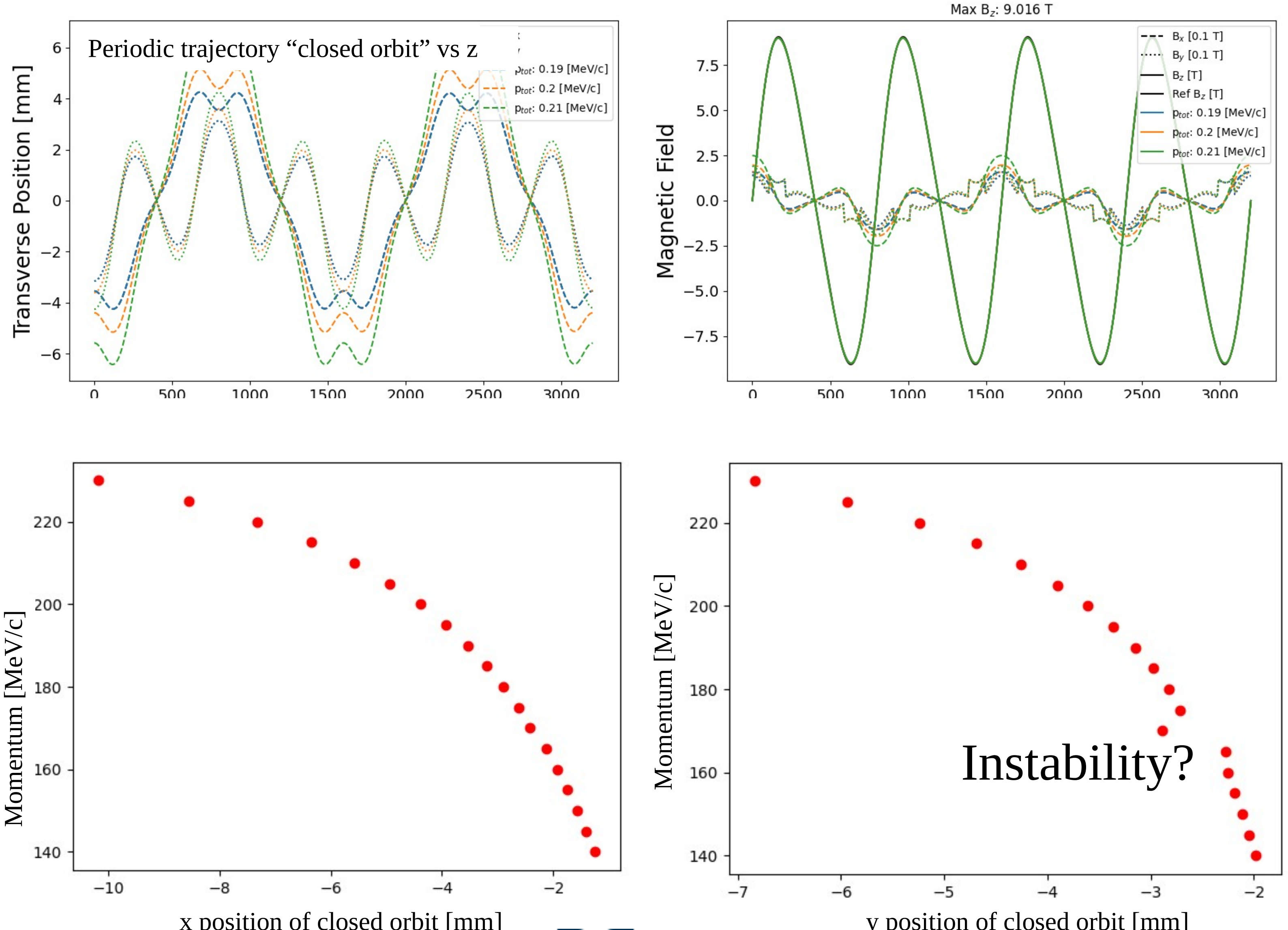


x position of closed orbit [mm]



y position of closed orbit [mm]

Dipole 0.1, -0.1, +0.1, -0.1 T



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