Shielded RF Lattice

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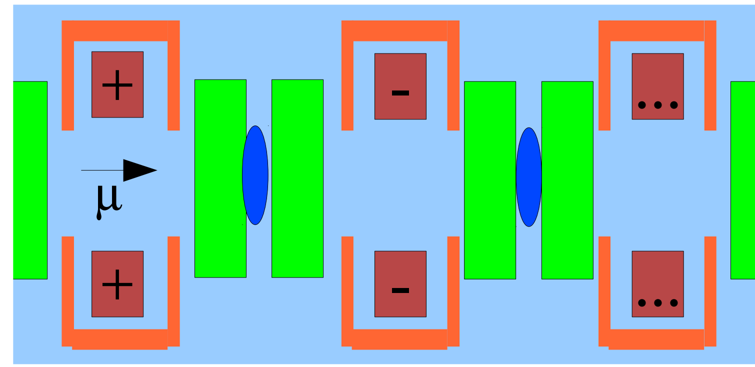
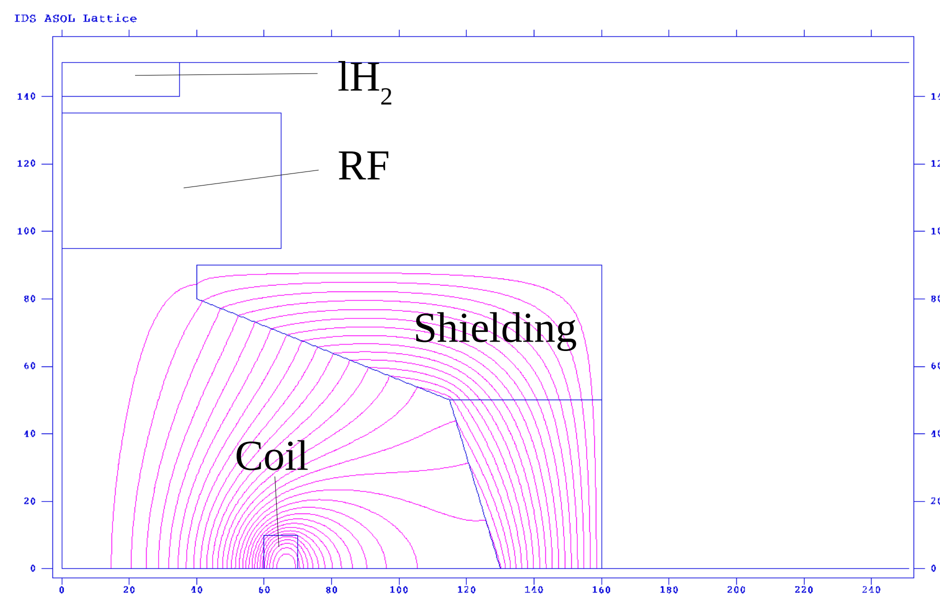
Shielded RF Status

- Shielded RF Lattice was developed until ~ April 2010
- April 2010, we decided to stick with existing baseline front end in lieu of results from MTA for IDR
- Subsequently, problem with secondaries came up and my work shifted to design of chicane system
- Need to soon make the same decision for RDR
  - Time to dust the design off

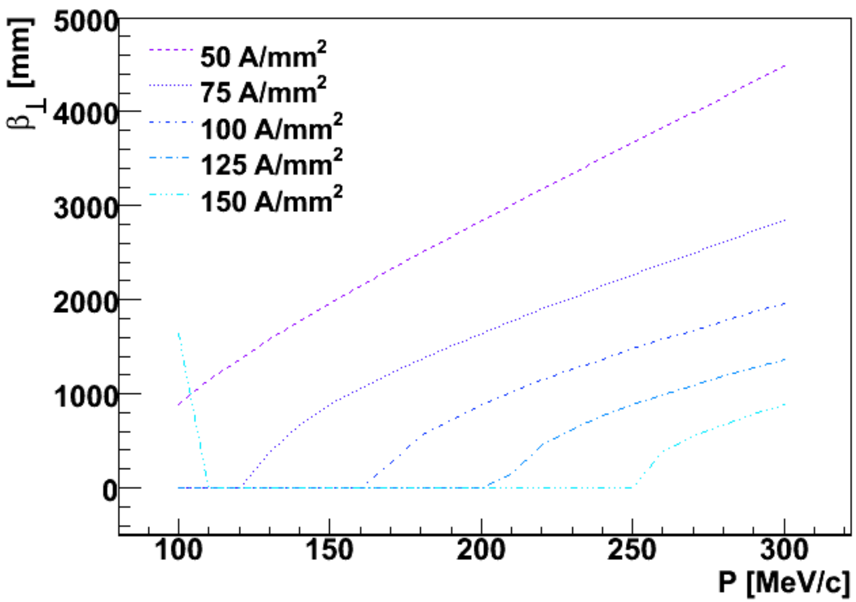
Shielded RF - Reminder

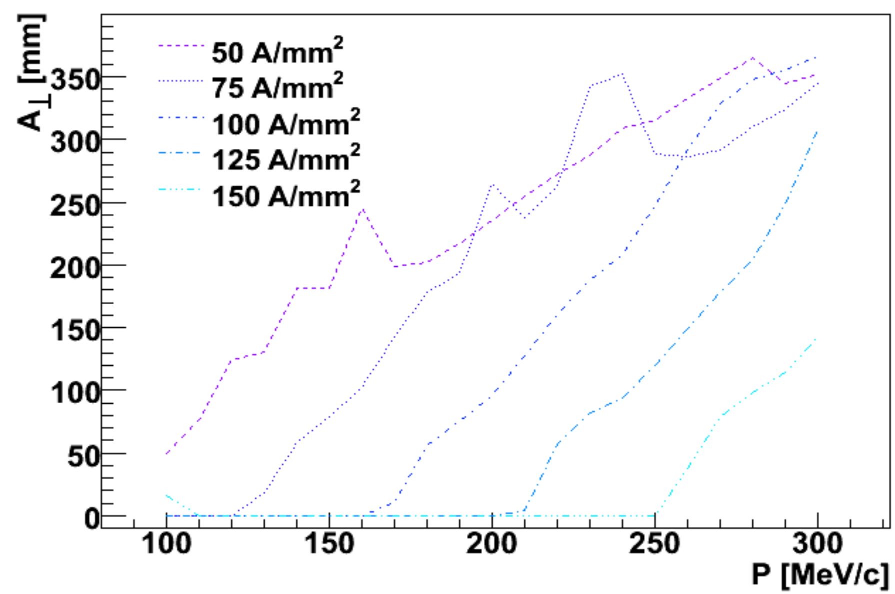
- Increase cell length to remove RF from solenoid fringe fields
  - Add shielding using iron or bucking coils
  - Try to keep good acceptance and focusing
- Look at cooling section
  - This is where the RF is most limited
  - This is where optics are most demanding
- How well can we cool in this shielded scenario?
- How well can we optimise the cooling lattice?
- Try to keep RF cavities in < ~~0.1~~ 0.5 T fields
- Liquid Hydrogen absorbers





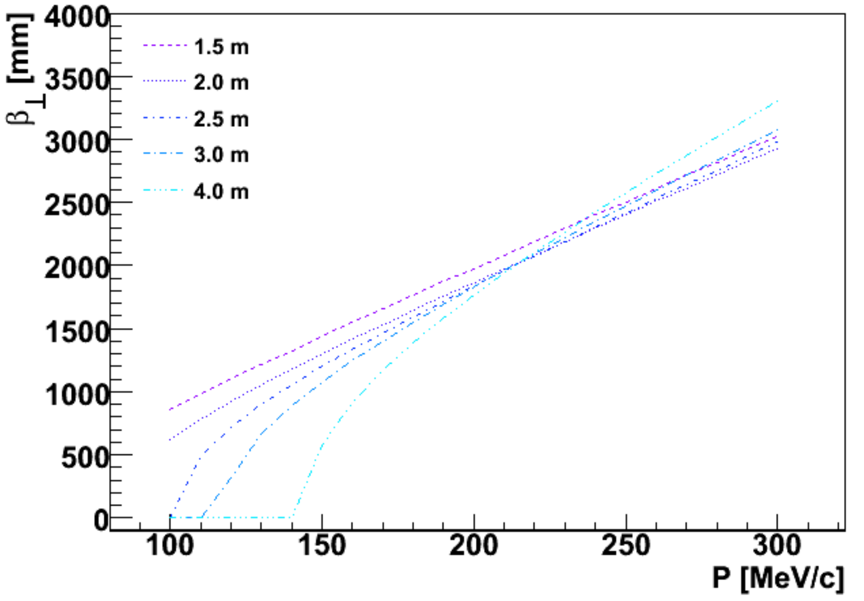
Lattice quality





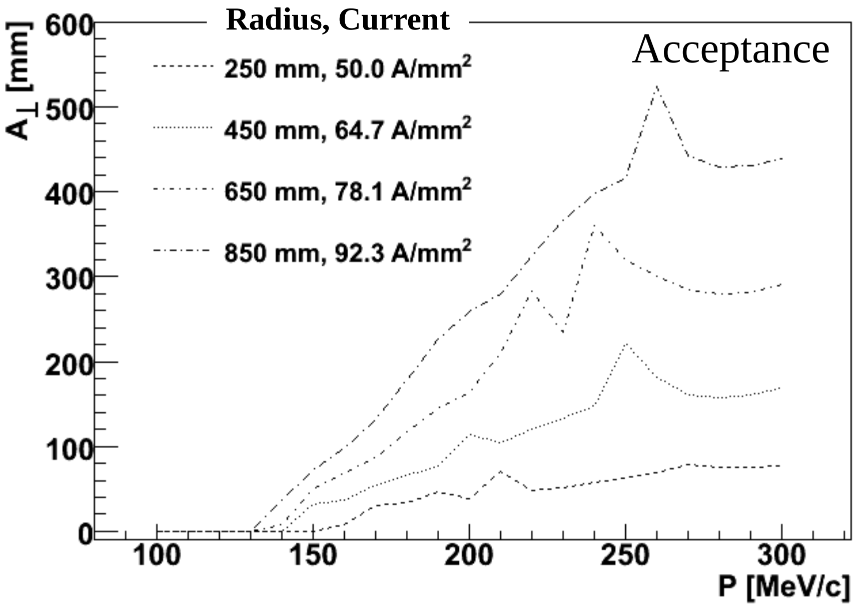
- Two criteria for lattice quality
- β function => how tightly focussed the beam is at the absorber
  - Determines how much cooling we get
  - Require good β function over a large momentum range
- Acceptance => the beam emittance that makes it through the lattice
  - Determines how much beam we get through
- Scale as ~ $\langle B_z^2 \rangle / p$

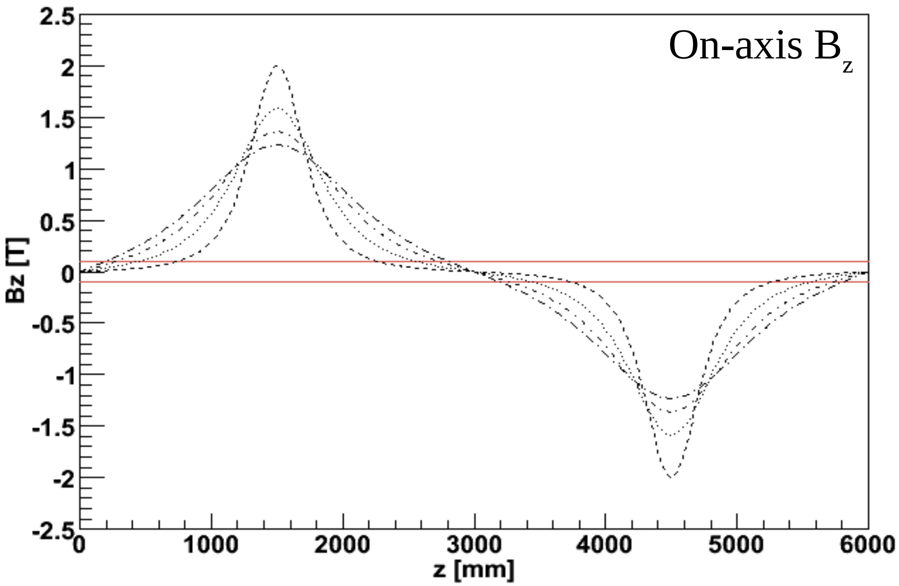
β vs Cell Length



- We want tight focussing on the absorbers for good cooling performance
  - Tight focussing => more cooling
  - Aim for β <~ 1500 mm over ~150 - 300 MeV/c (liquid Hydrogen)
- As cell length gets longer dβ/dp gets worse
  - Making it hard to contain a beam with a large momentum spread
- Keep cell as short as possible
  - To keep B_z off RF, need to reduce solenoid fringe field

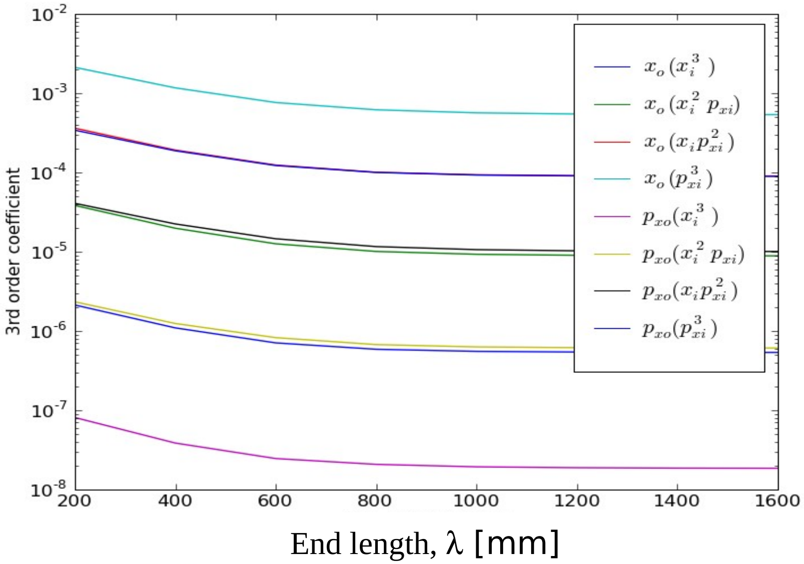
Dynamic Aperture vs Radius

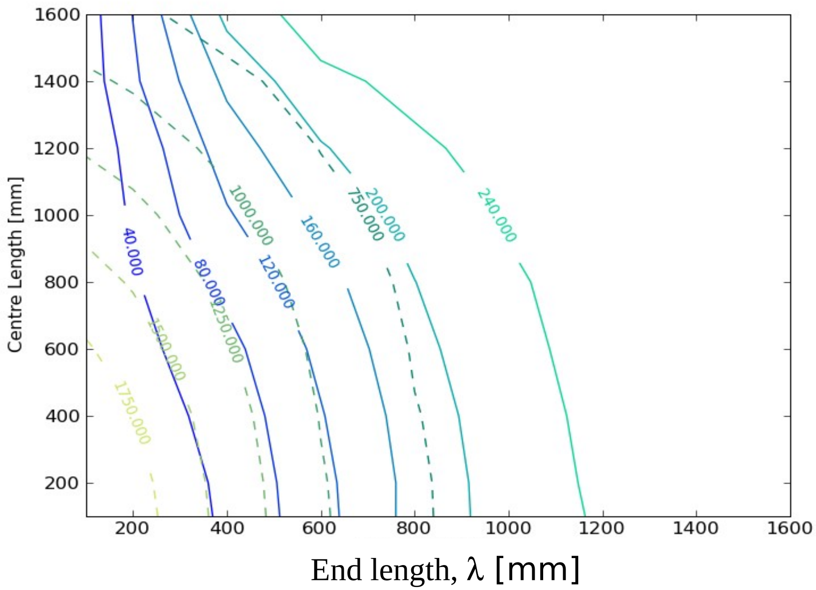




- Reducing radius of coil reduces lattice acceptance
  - Aim for acceptances >~ 100 mm
  - Naively “expect” that reducing coil radius decreases acceptance
  - “Particles travel through region of poor field quality near the coils”
- In solenoid, optics is uniquely defined by on-axis field
  - So any attempt to curtail the fields is like reducing the coil radius
  - What does “poor field quality” really mean?

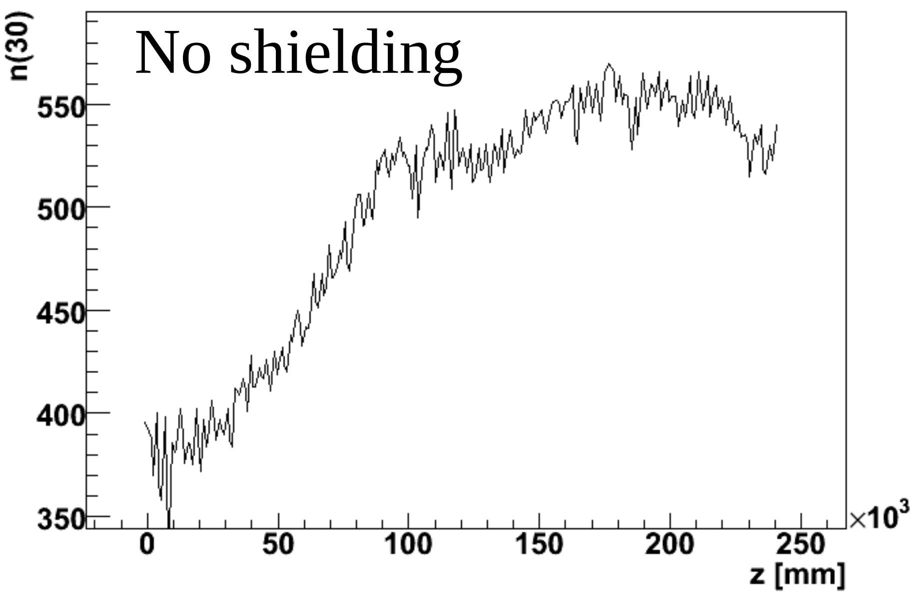
Non-Linear Terms

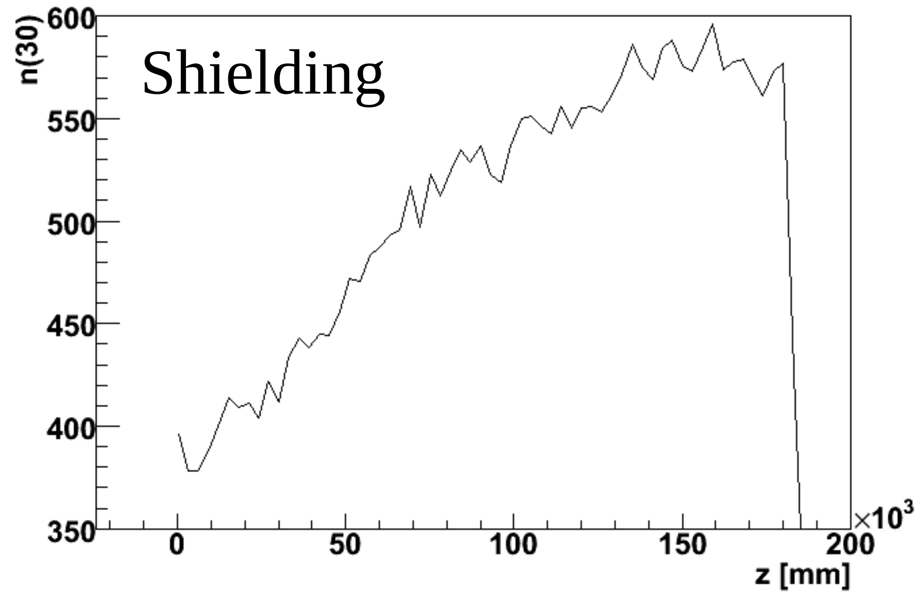




- Non-linear terms => $x_{out} = a_{ij}\, x_{in}^i p_{in}^j$
- 2nd order terms have i+j=2
  - Purely chromatic, can be ignored
- 3rd order terms have i+j=3
  - Increase by order of magnitude in short fringe field
  - In theory go as d^2B_z/dz^2
- For very short fringe fields 3rd order terms become large
  - d^2B_z/dz^2 becomes large
  - e.g. consider tanh model for $B_z(r=0)$
  - $B_z = \tanh[(z-z_0)/\lambda] + \tanh[(z-z_0)/\lambda]$
- Introducing bucking coils etc is equivalent to reducing coil radius

Cooling Performance

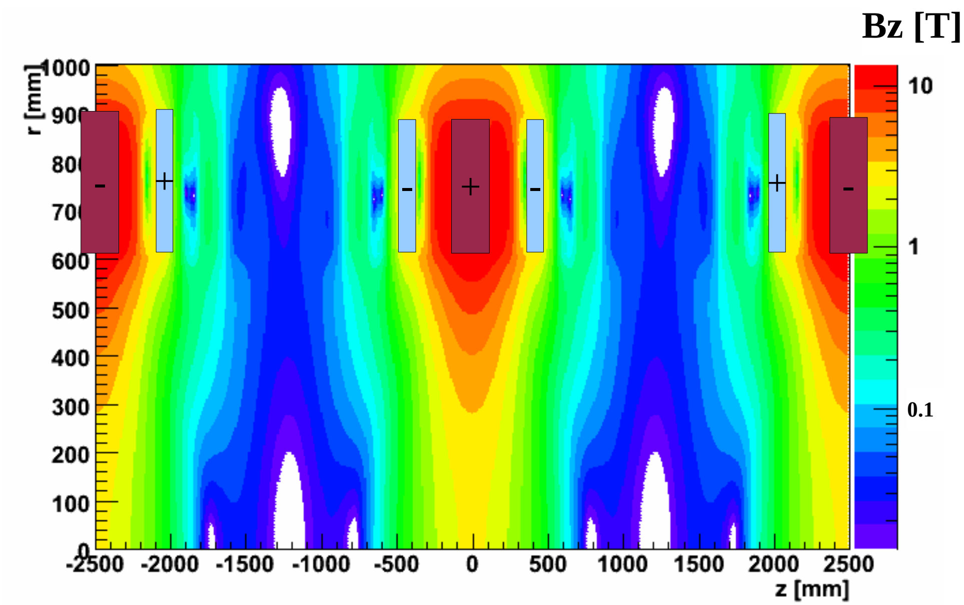


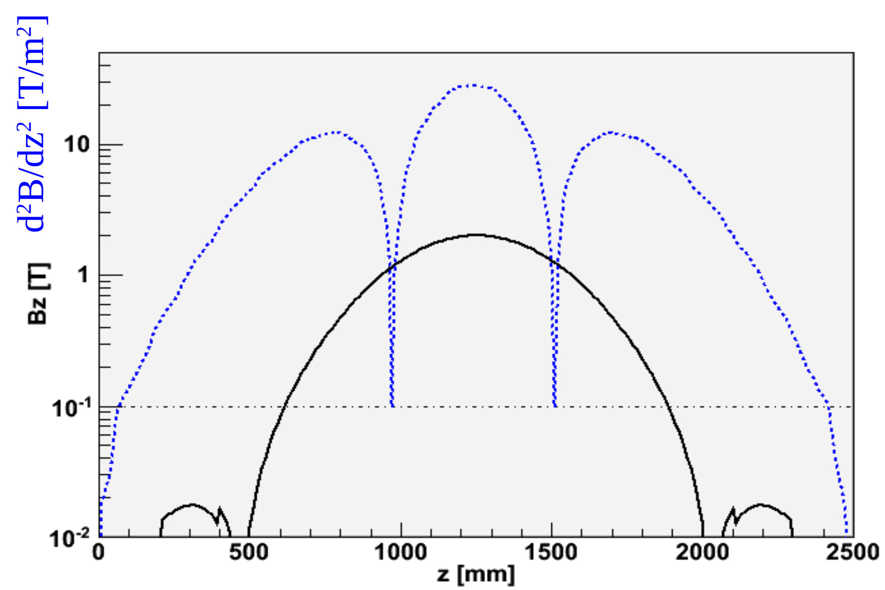


- Transmission into momentum bite 100-300 MeV/c and acceptance of 30 mm
- Shielding gets increase of ~ 52% (better than no-shielding!)
- No-shielding gets increase of ~ 45%

Bucked Magnet Design

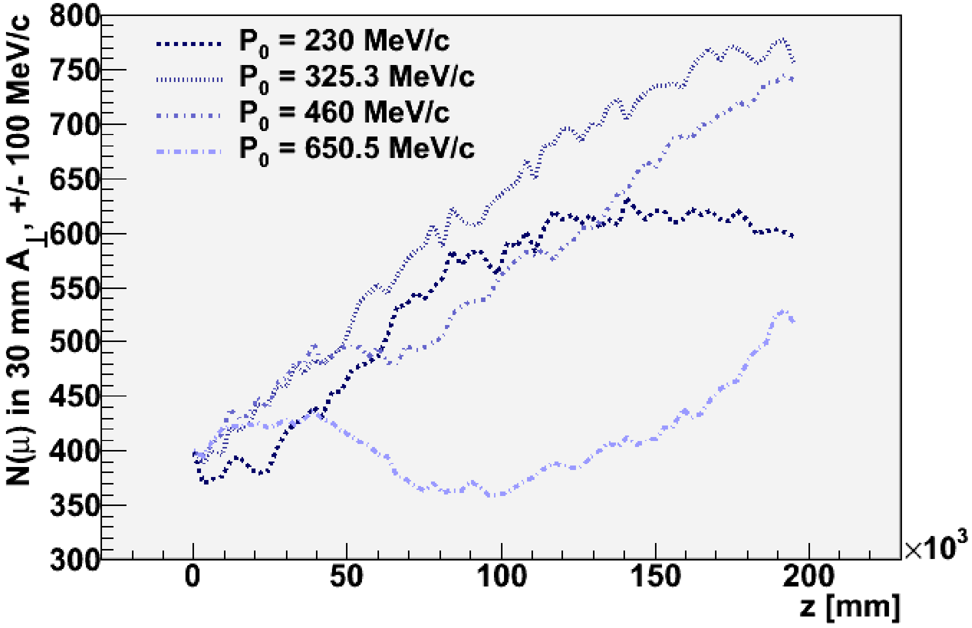
- "Bucking magnet design"
  - Use a coil with opposite current
  - Shield the RF cavities
- Nb field flips as normal
  - Absolute value of Bz plotted
- Magnet design reasonable
  - B_z on coil may be a bit high
  - May be better to use "shells" as in linac
- Move to 2.5 m cell
  - Get ~ 1.2 m with $B_z < 0.1$ T
  - But never tracked successfully



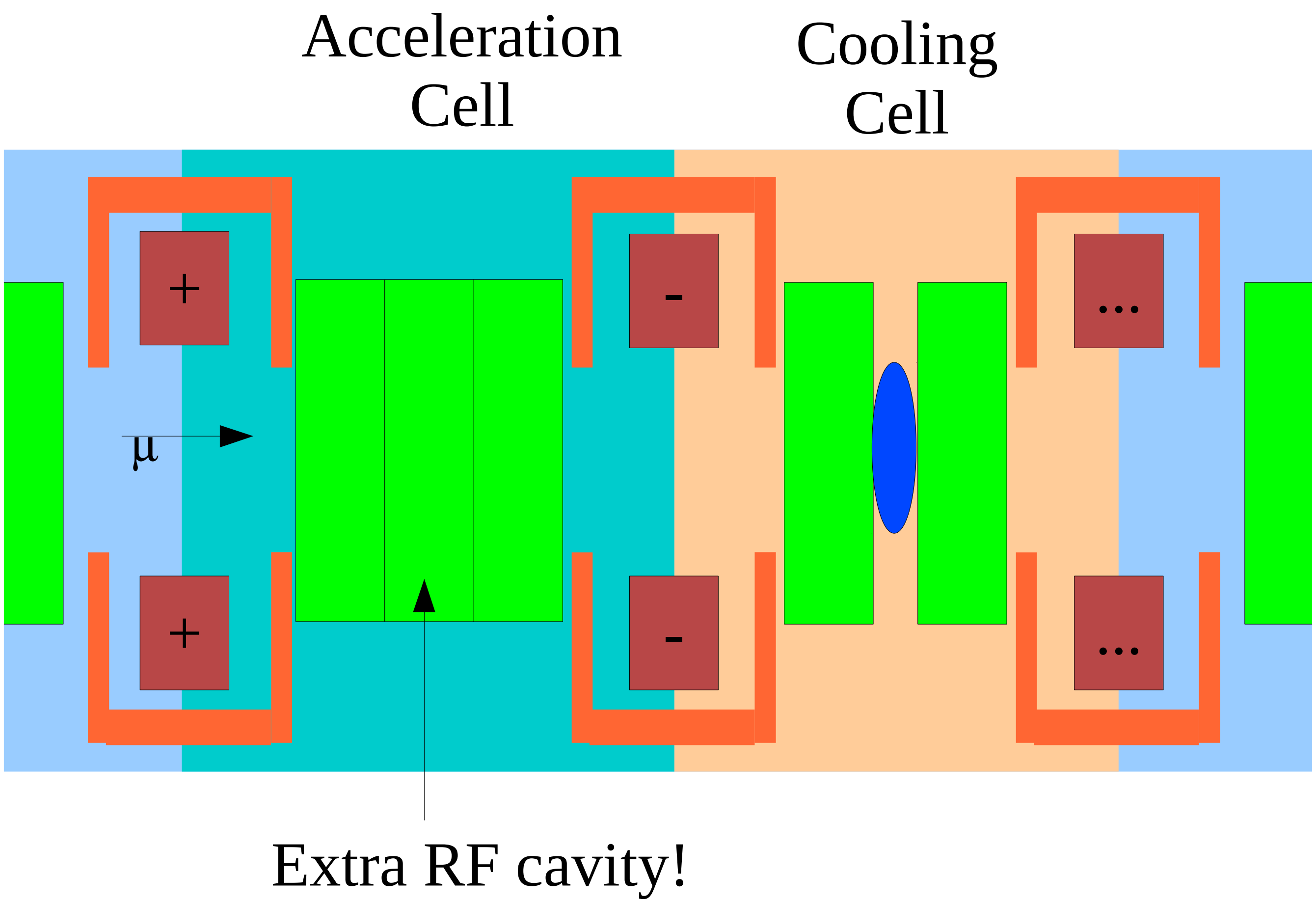


Dynamic Aperture vs Energy

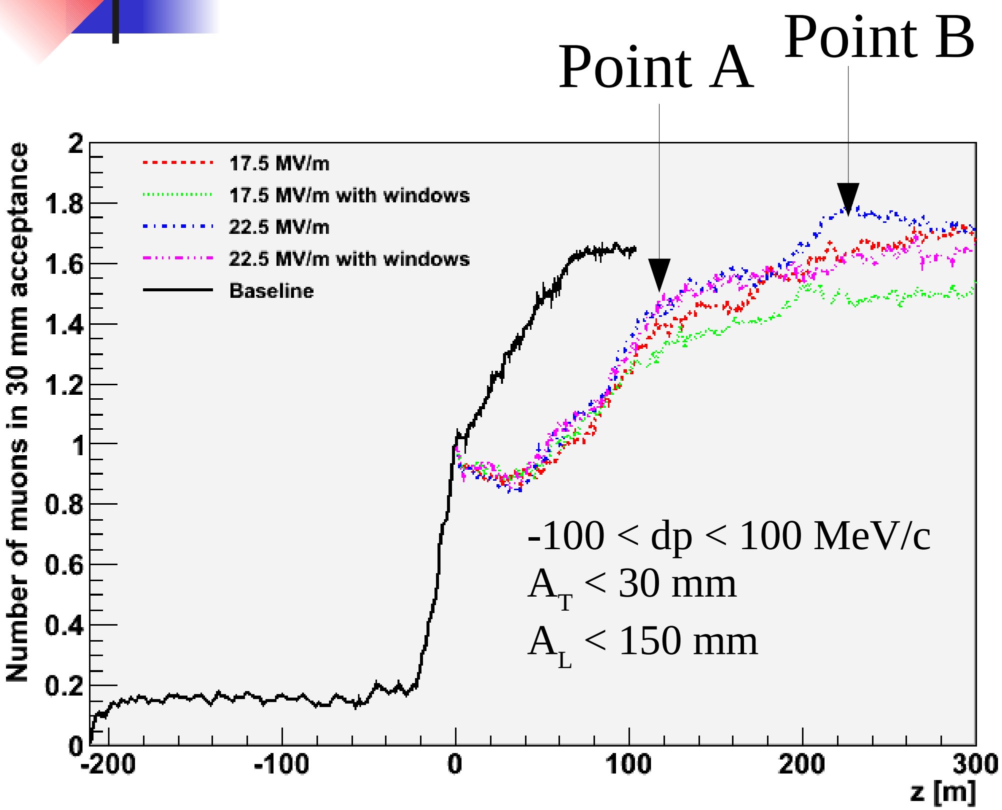
- How does cooling performance respond to energy?
  - "Geometric emittance effect"
  - Require smaller aperture to get the same beam through
  - Might expect to improve acceptance by increasing energy
  - Indeed this can be seen in simulation – to a point



Introduce “acceleration cell”



Higher Momentum Beam



- Fairly large transmission losses
  - >~ 50%
- Most of the remaining beam is inside the 30 mm acceptance
- Getting increase in rate of ~ 70 %
  - But with more hardware
  - Performance quite similar to baseline
- If I stop at point A - I use roughly the same amount of hardware as the baseline (RF packing fraction ~ 1/2 that of the baseline)
  - And lose a few muons
- I can recover baseline performance if I go to Point B
  - But those last few muons are expensive!

Using Baseline Phase Rotation System

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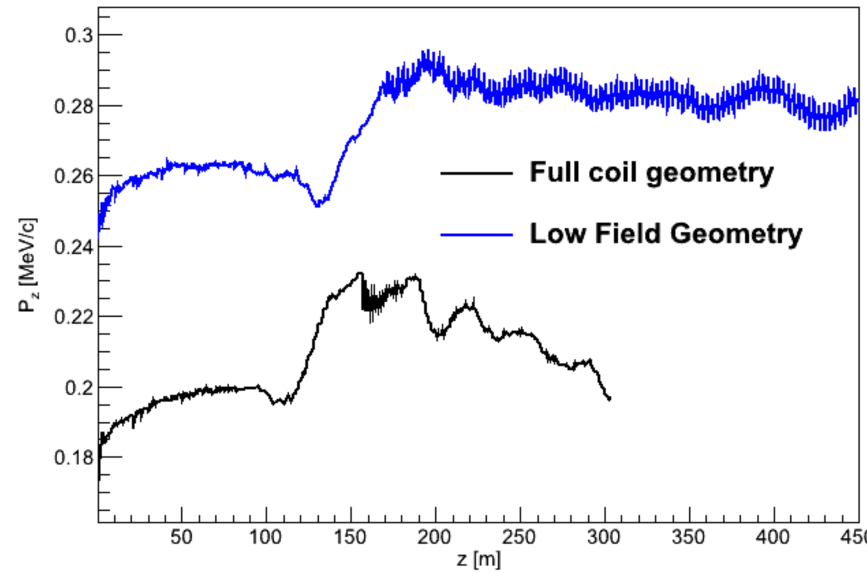
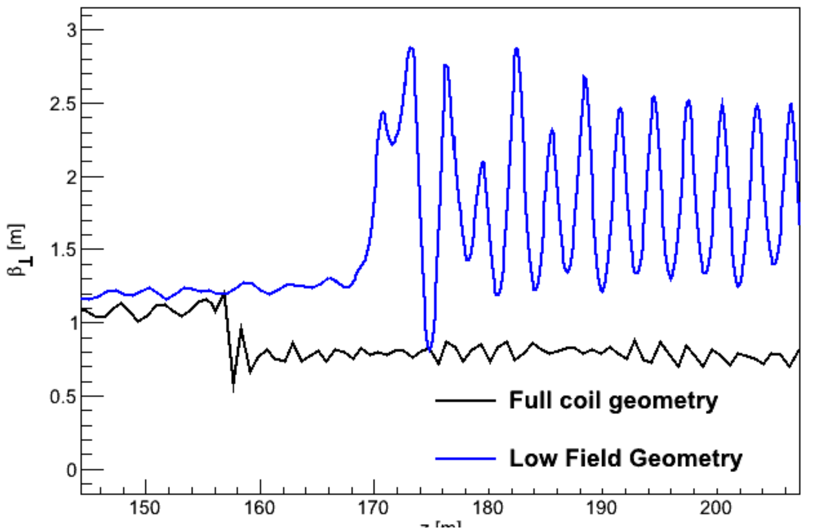
Capture at Higher P

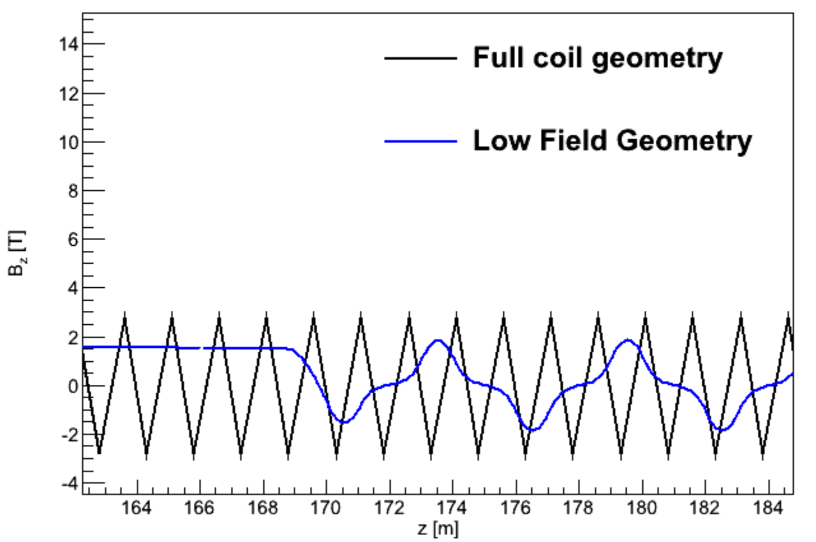
- Try using existing capture scheme for acceleration
  - Rather than special Normal Conducting linac
  - Expensive!
- Keep peak field same
  - Change phasing to bring both reference particles in at higher momentum
  - Still phase with 233 MeV/c particle
  - Needs ~ 6 degrees phase to bring to 273 MeV/c
- Cut 273 MeV/c < Pz < 373 MeV/c
- All simulations done in g4bl v2.06
- No windows on RF/lH2
- Probably needs some jostling for space (1m long coil)



Matching from RF Capture

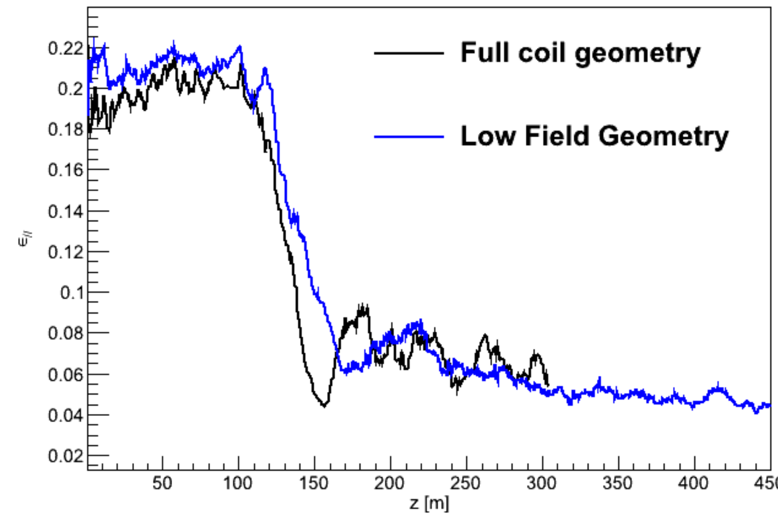
- Bring into flipping lattice
- Okay match
  - Could probably do better
- Note higher beta function
  - Needs Liquid Hydrogen!

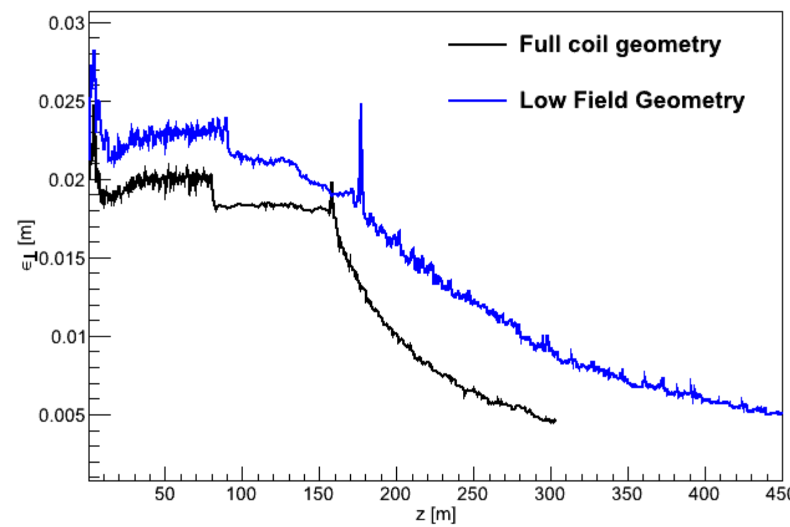




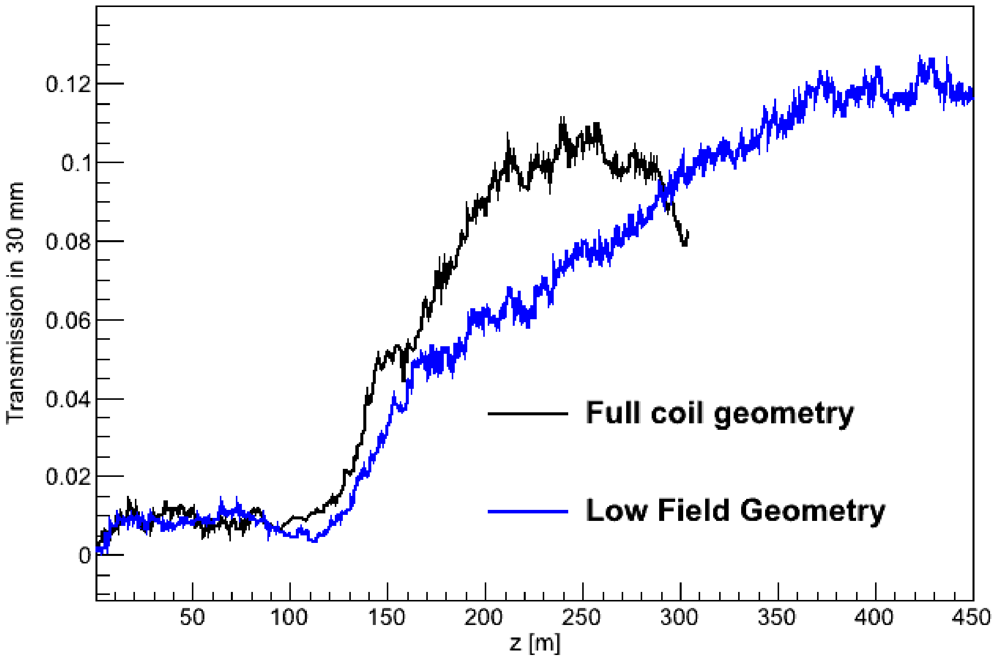
Emittances

- Longitudinal match looks quite good
- Transverse get a big emittance spike round matching point
  - Mismatch?
  - Beam loss?
- But general transverse emittance performance looks good





Capture Performance



- Transmission inside usual cuts:
  - 30 mm normalised transverse acceptance
  - 150 mm normalised longitudinal acceptance
- Note however momentum cut is
  - 173 < Pz < 373 MeV/c for low field geometry
  - 100 < Pz < 200 MeV/c for baseline

Shielded RF Status

- Full simulation in G4BL
- Includes reoptimisation of phase rotation to capture at higher energy
- Looks encouraging
- Needs windows adding