Front End Simulations

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Collaboration Meeting

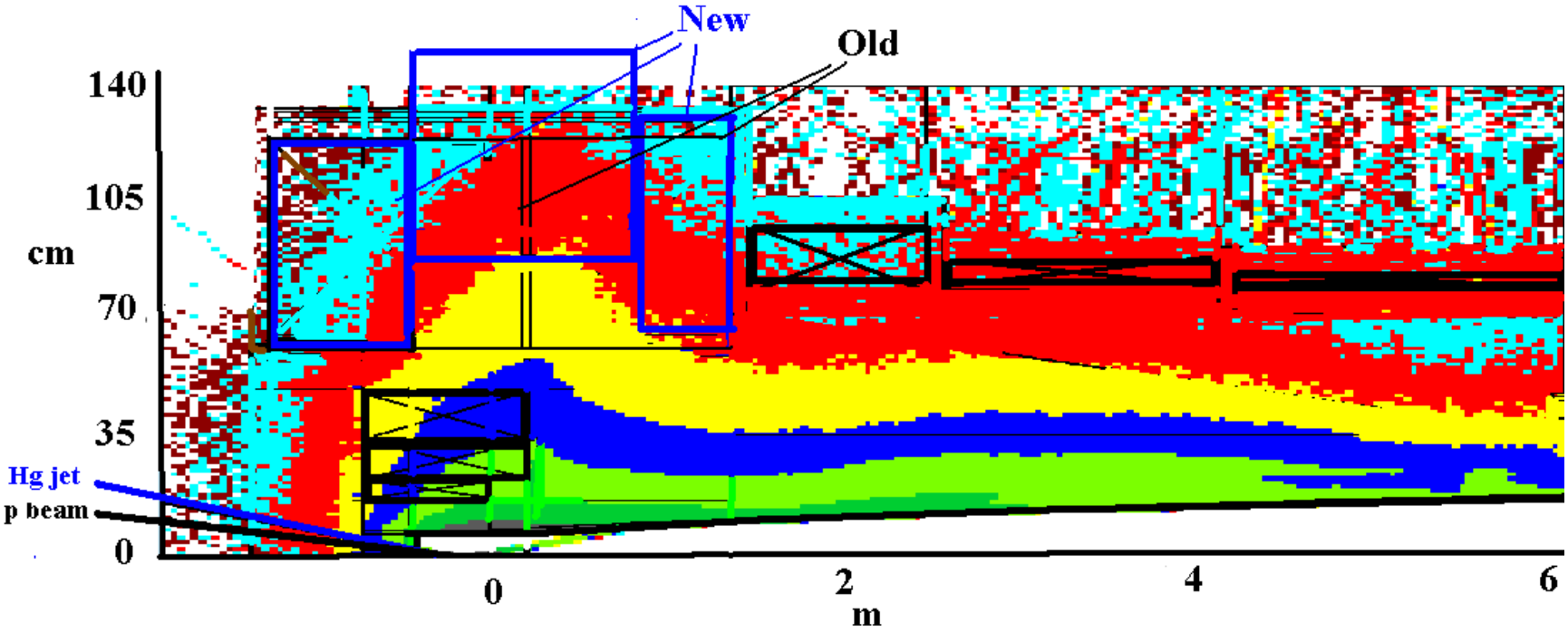
Riverside 0104

- Proposed New Front End for Study IIa
  - Capture
  - Phase Rotation
  - Match
  - New Cooler
- Simulated Performance
- Possible Modifications
- Conclusion

1) Target Production

Production calculated by MARS using Study II geometry

Study 2 Radiation Levels (Mokhov) Note modified coils



Component	radius cm	Dose/yr Grays	Max Dose Grays	1MW Life years	4 MW life years
Inner Shielding (SS)	7.5	5 10^{10}	10^{12}	20	5
Hg Containment (SS)	18	10^{9}	10^{11}	100	25
Hollow Conductor (SS)	18	10^{9}	10^{11}	100	25
Superconducting Coil	80(65)	1(5) 10^{6}	10^{8}	100(20)	25(5)

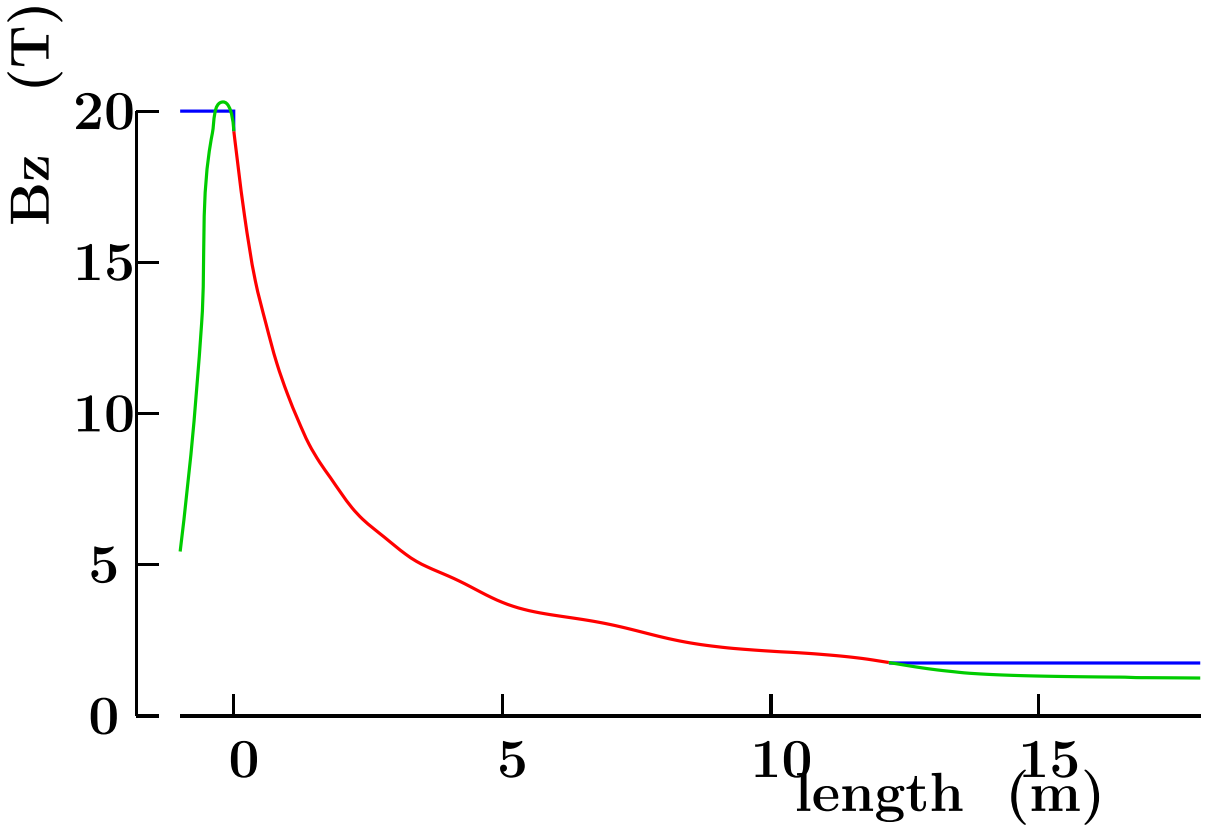
2) Matching Taper 20 to 1.75 T

Real coils aimed at 20 to 1.25 T over 18 m

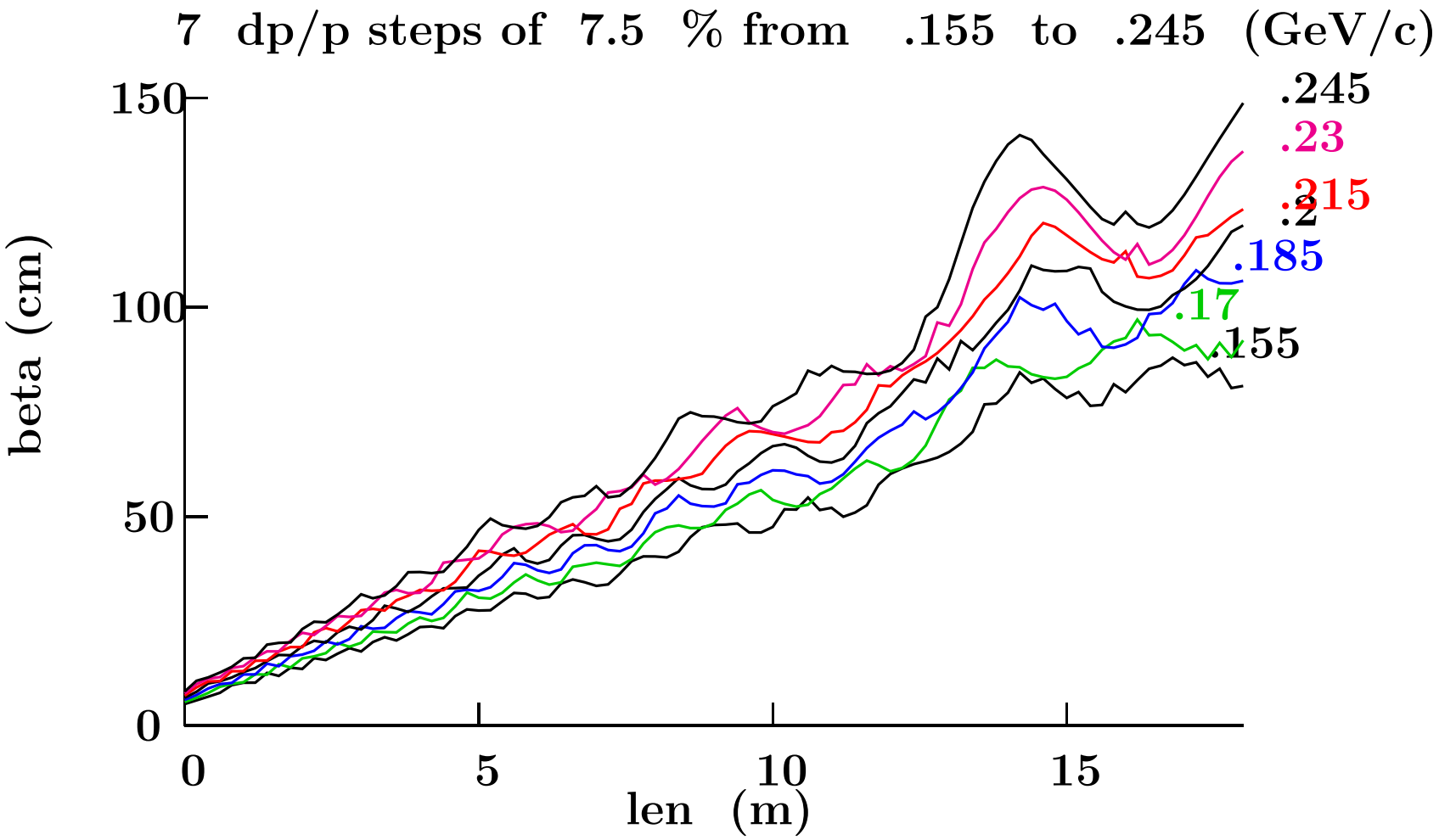
$$B = \frac{B_o}{1 + kz}$$

This is "slow" by Kevin standars, so form probably ok

In simulations I used real fields from 20 to 1.75 T with non-physical hard matches at start and end (needs fixing)

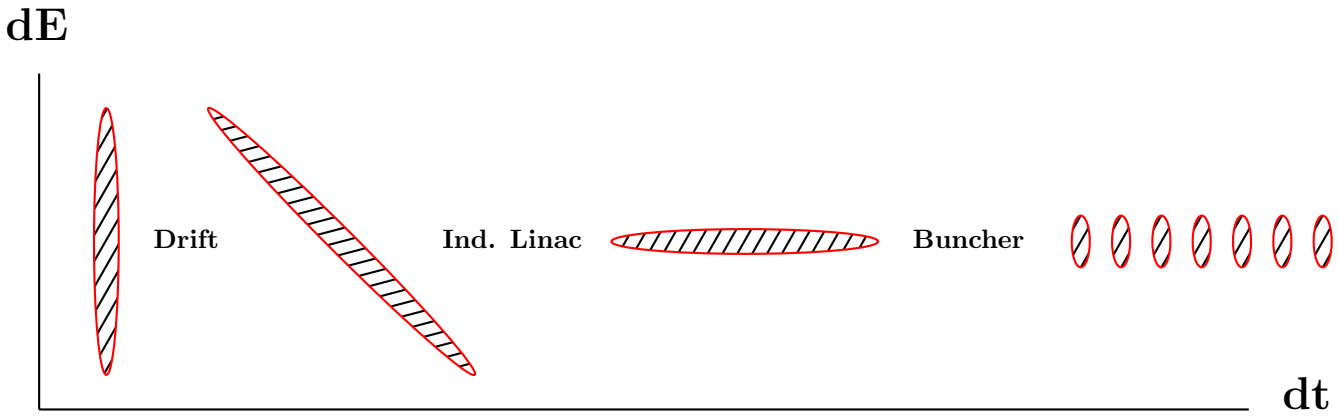


Beta Functions

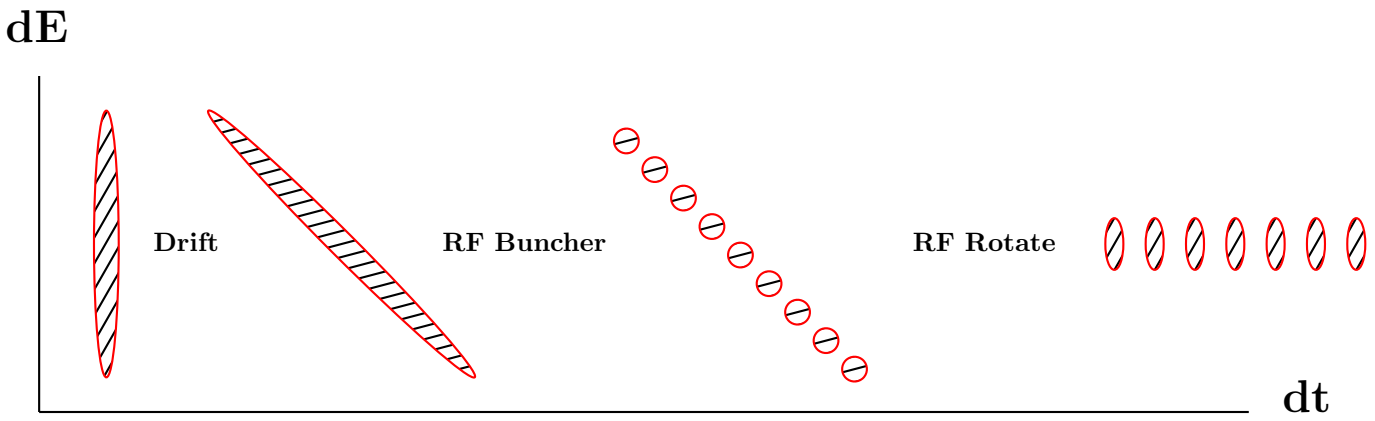


3) Neuffer Phase Rotation (Reduce dp/p prior to Cooling)

Study 2 with Induction Linacs



Neuffer's Bunched Beam Rotation with 200 MHz RF



- 200 MHz RF is cheaper than Induction Linacs
- But RF frequency must vary along bunching channel
  (high mom. bunches move faster than low)

Required Be Window Thickness in Phase Rotator

Scale from Study 2

$$t_{\text{buncher}} = t_{\text{Study 2}} \left(\frac{r}{21\ (cm)}\right)^4 \left(\frac{\mathcal{E}}{16\ (\text{MV/m}}\right)^2$$

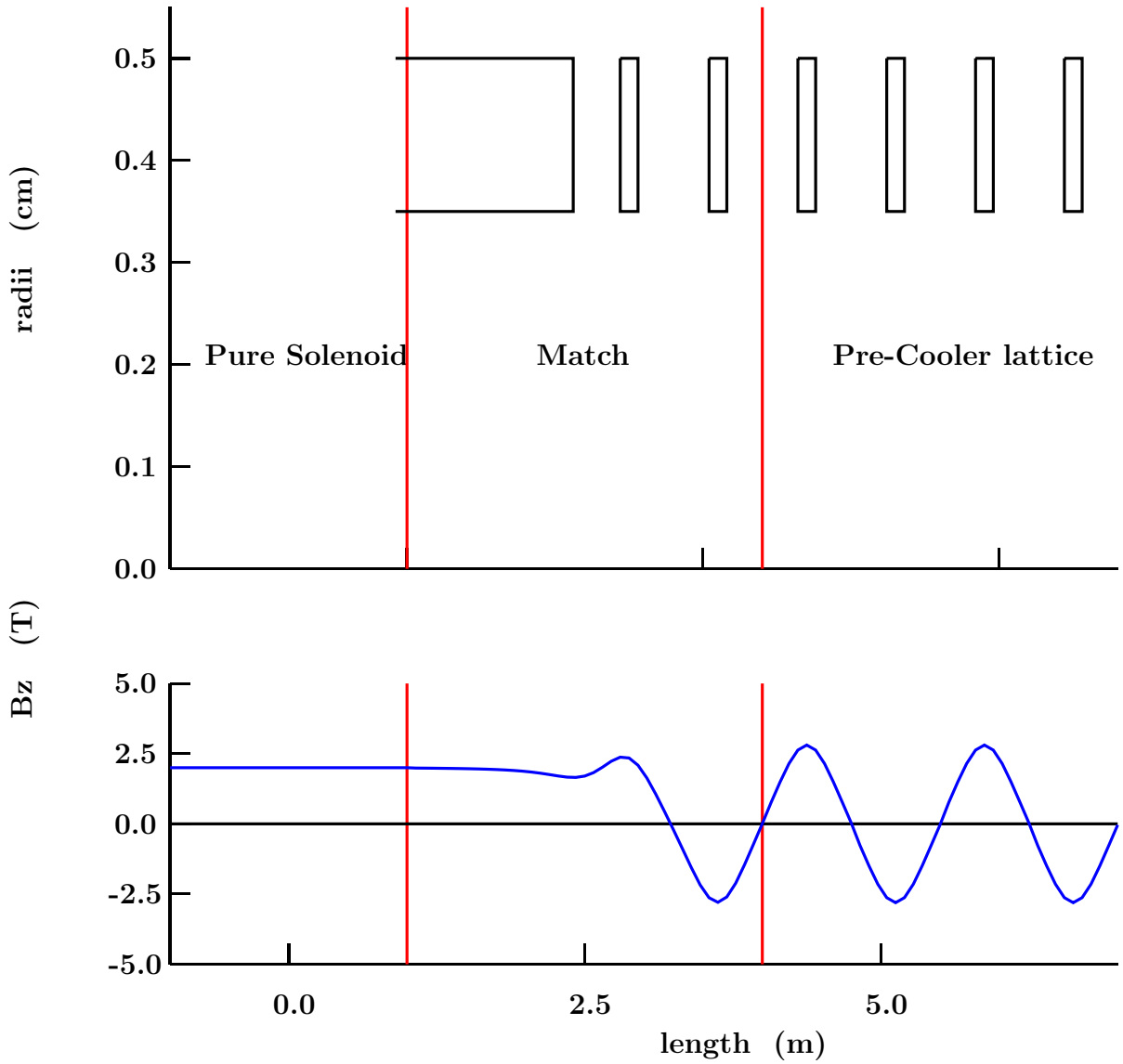
$$= 0.7 \left(\frac{30}{21}\right)^4 \left(\frac{8}{16}\right)^2 = 0.72 \quad \text{mm}$$

Used 0.75 mm 0 to 20 cm, 1.5 mm from 20 to 30 cm:

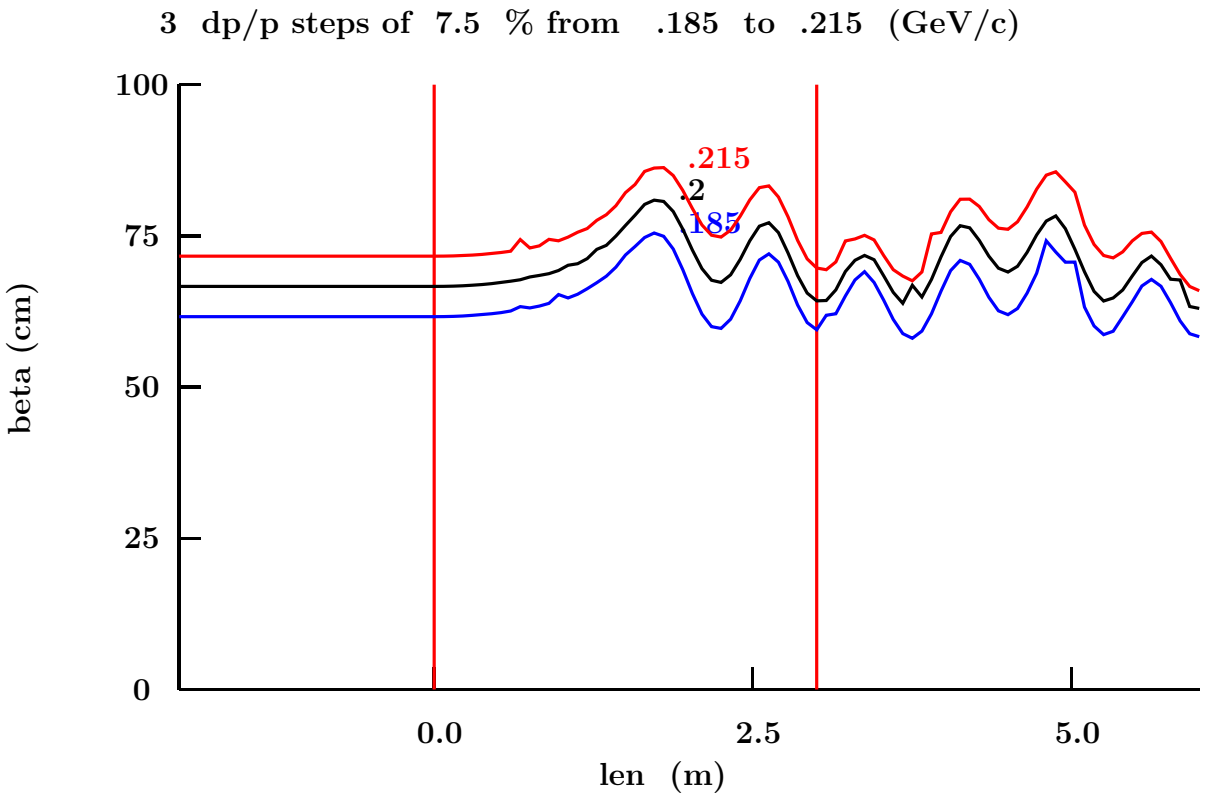
But new curved Be windows for mice are 0.38 mm so we may be able to reduce the above.

4) Match to Pre-Cooler Channel

len1 m	gap m	dl m	rad m	dr m	I/A A/mm^2	n I A	n I l A m	
0.000	0.000	1.500	0.350	0.150	10.72	2.41	6.44	End of contin solenoid
1.500	0.000	1.500	0.350	0.150	10.72	2.41	6.44	
3.000	0.000	1.500	0.350	0.150	10.72	2.41	6.44	Match
4.500	0.000	1.500	0.350	0.150	10.72	2.41	6.44	
6.397	0.397	0.150	0.350	0.150	74.60	1.68	4.48	
7.147	0.600	0.150	0.350	0.150	-106.67	2.40	6.41	
7.897	0.600	0.150	0.350	0.150	106.67	2.40	6.41	
8.647	0.600	0.150	0.350	0.150	-106.67	2.40	6.41	Regular Cooling Lattice
9.397	0.600	0.150	0.350	0.150	106.67	2.40	6.41	
10.147	0.600	0.150	0.350	0.150	-106.67	2.40	6.41	
10.897	0.600	0.150	0.350	0.150	106.67	2.40	6.41	
11.647	0.600	0.150	0.350	0.150	-106.67	2.40	6.41	


radii (cm)
0.5
0.4
0.3
0.2
0.1
0.0
Pure Solenoid
Match
Pre-Cooler lattice
Bz (T)
5.0
2.5
0.0
-2.5
-5.0
0.0
2.5
5.0
length (m)

Beta vs distance through Match



- Match needs improvement

5) Pre-Cooler

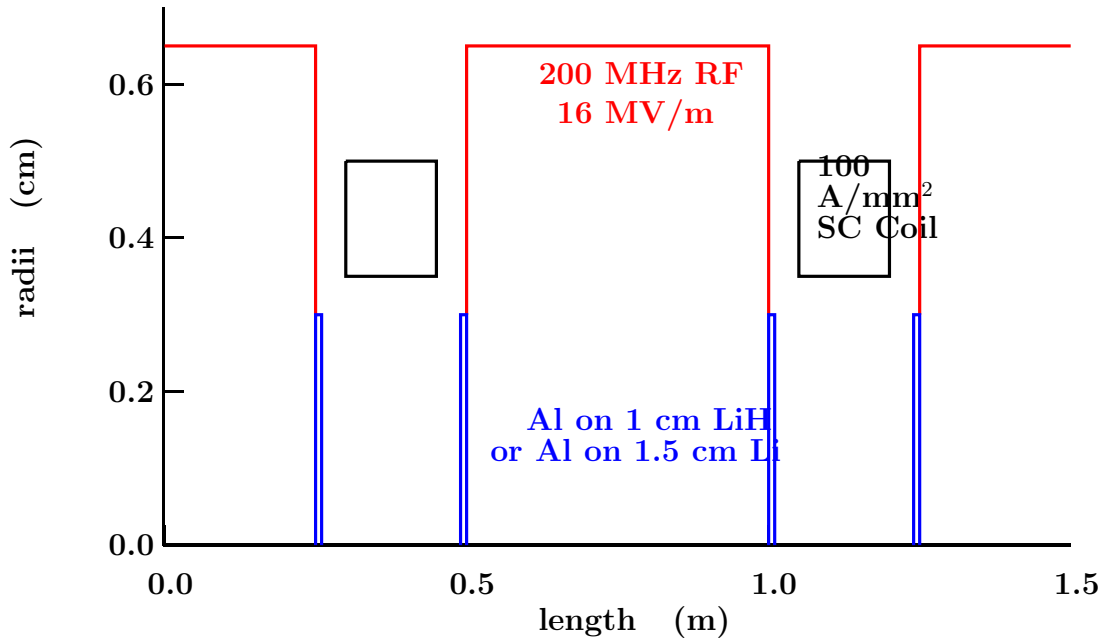
Use the Larger Accelerator Acceptance

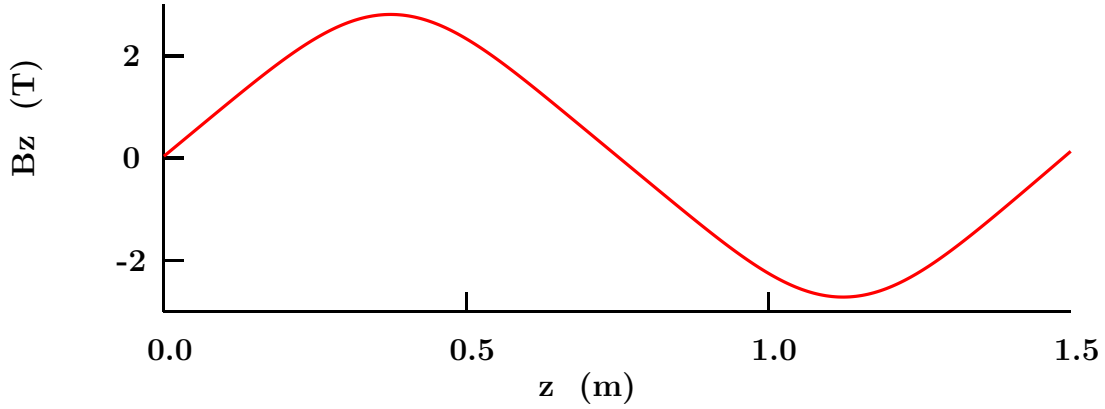
- Less cooling (50 m vs 108 m)
- Weaker focusing: (beta= 70 vs 40 mm)
- No coils outside RF
- No Liquid Hydrogen absorbers

Full Cell Length=1.5 m

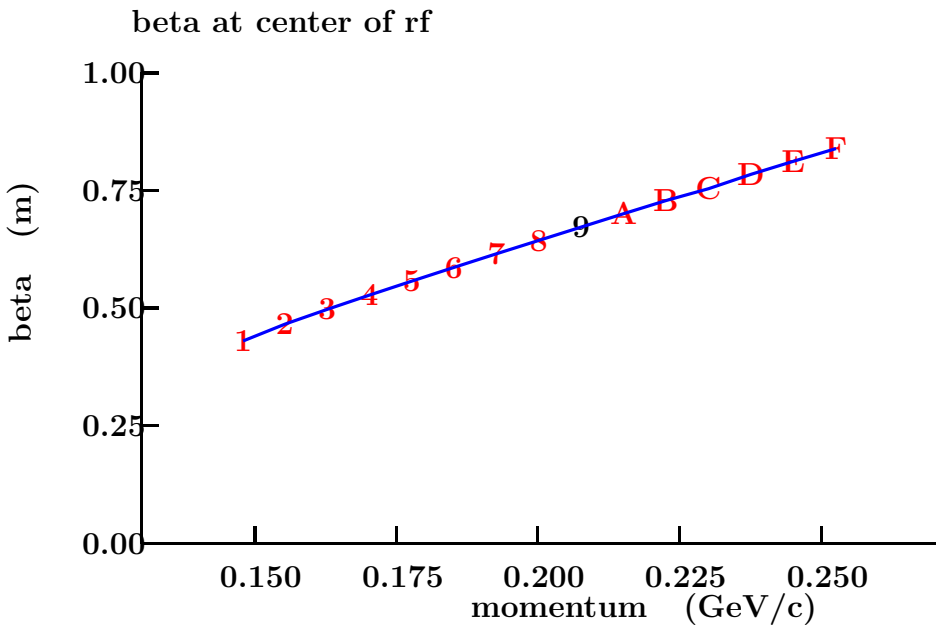
len1 m	gap m	dl m	rad m	dr m	I/A A/mm^2	n I A	n I l A m
0.30	0.300	0.150	0.350	0.150	106.67	2.40	6.41
1.05	0.300	0.150	0.350	0.150	-106.67	2.40	6.41

Pre-Cooler Cells

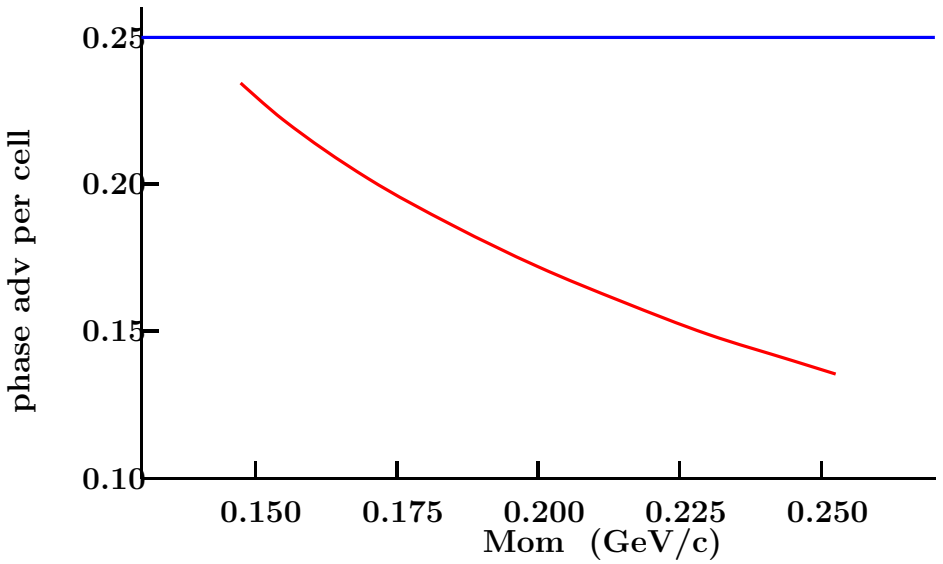




Betas vs. momentum

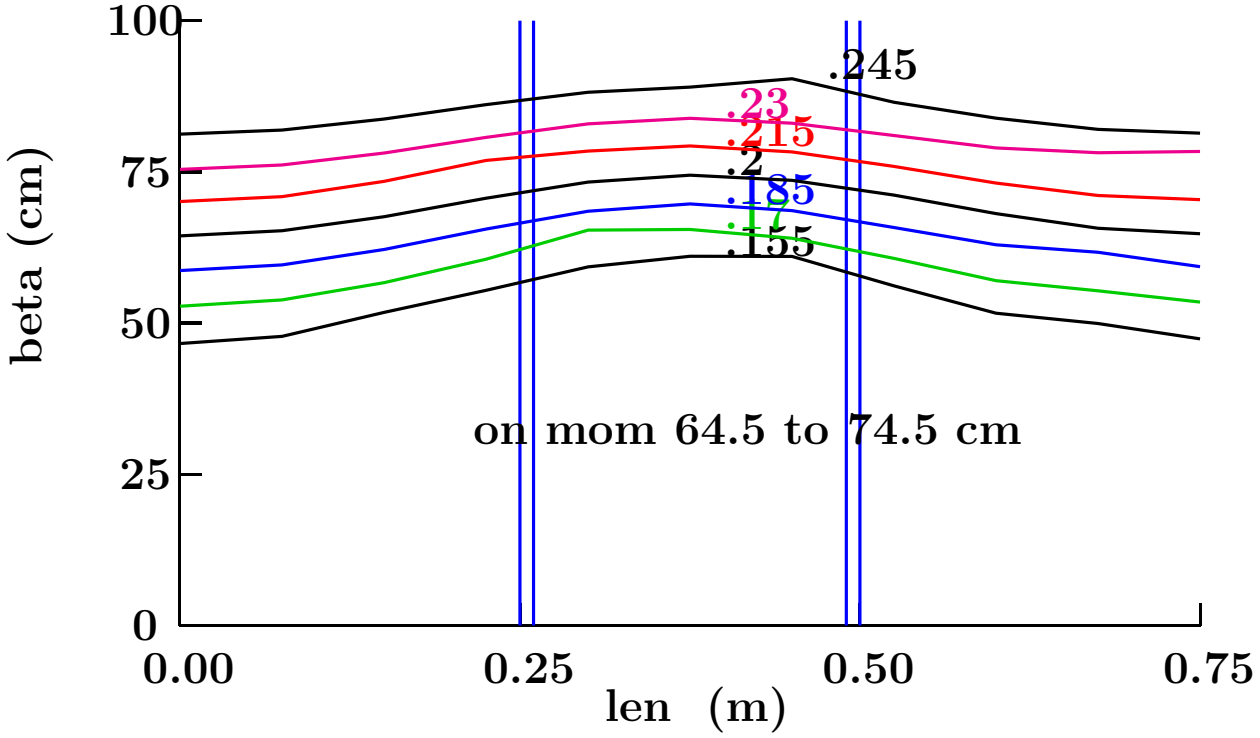


Phase adv/cell vs. momentum



- **Very Large Momentum acceptance (80 MeV/c to infinity)**
- **Small phase advance per cell over range used (150-250 MeV/c)**
- **avoids even 1/4 tune resonance → Large dynamic aperture**

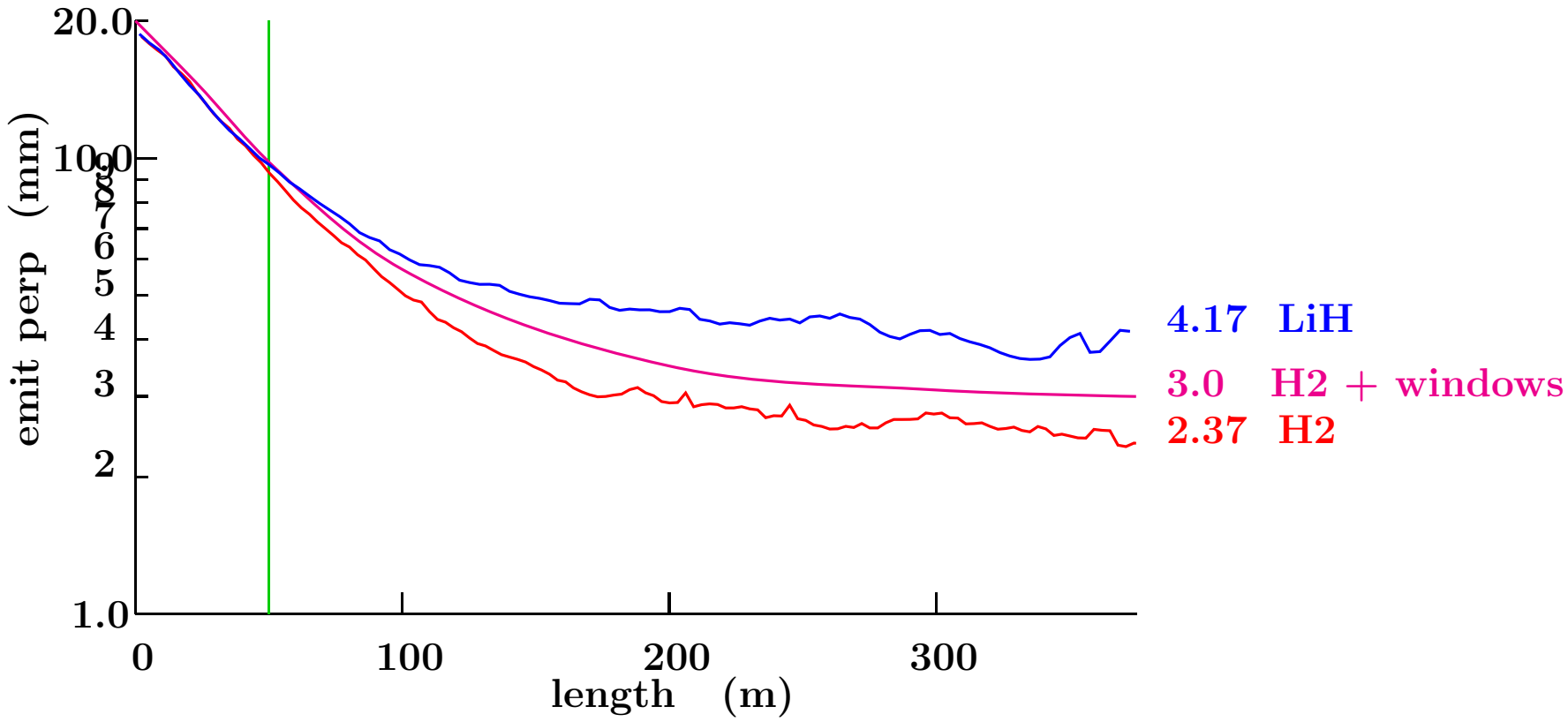
Betas vs. length



- Since beta is almost constant, does not matter where absorber located
- Combine RF windows with absorbers
- Currently prefered solution: Li with thin Be or Al encapsulating windows
  Li has good conduction, so Be can be very thin

Cooling from Gaussian Input

H2 gas, H2 gas plus initial and final windows, LiH plates

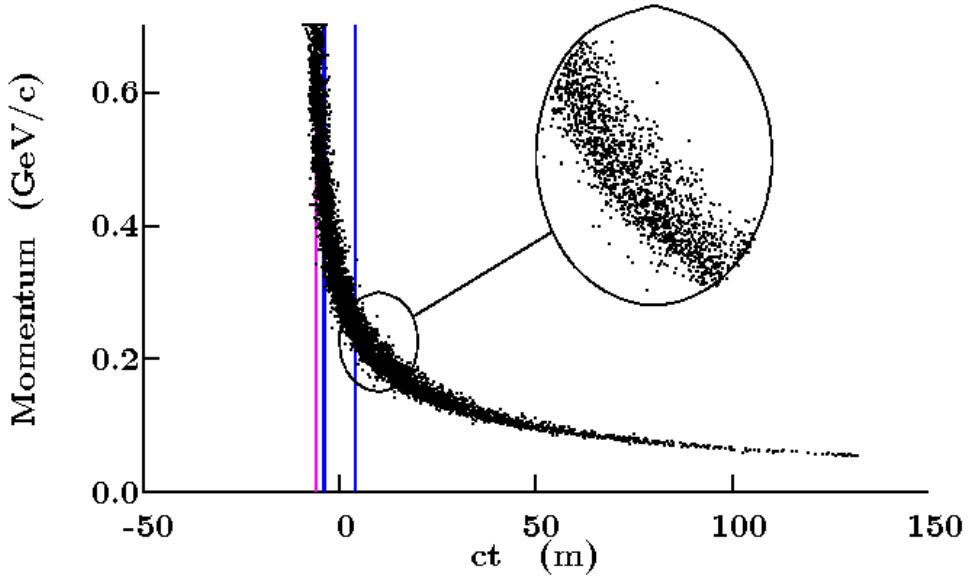


- No difference between LiH and H2 before 50 m
- 50 m being what we can afford (1/2 Study 2)
- The fields in the lattice could be increased with length, but this is not needed.

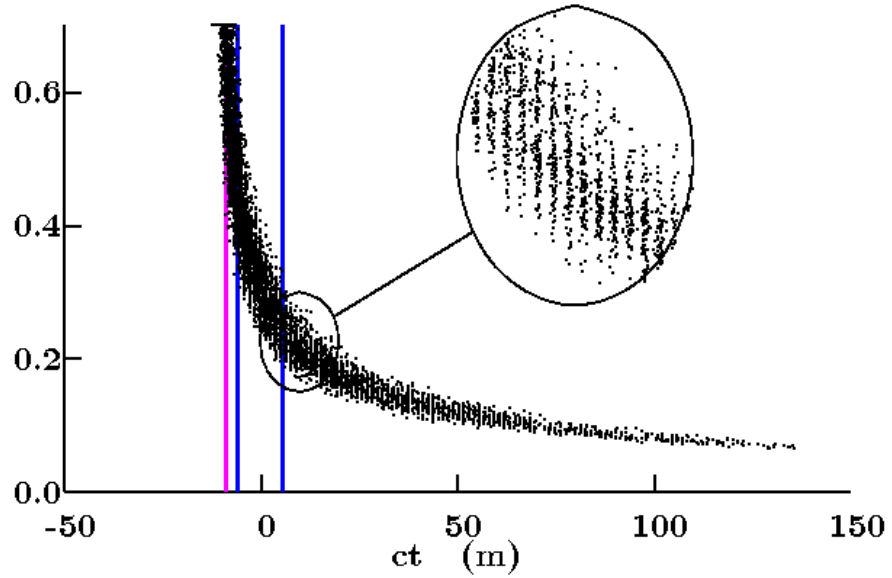
SIMULATIONS

Neuffer Phase Rotation Simulation

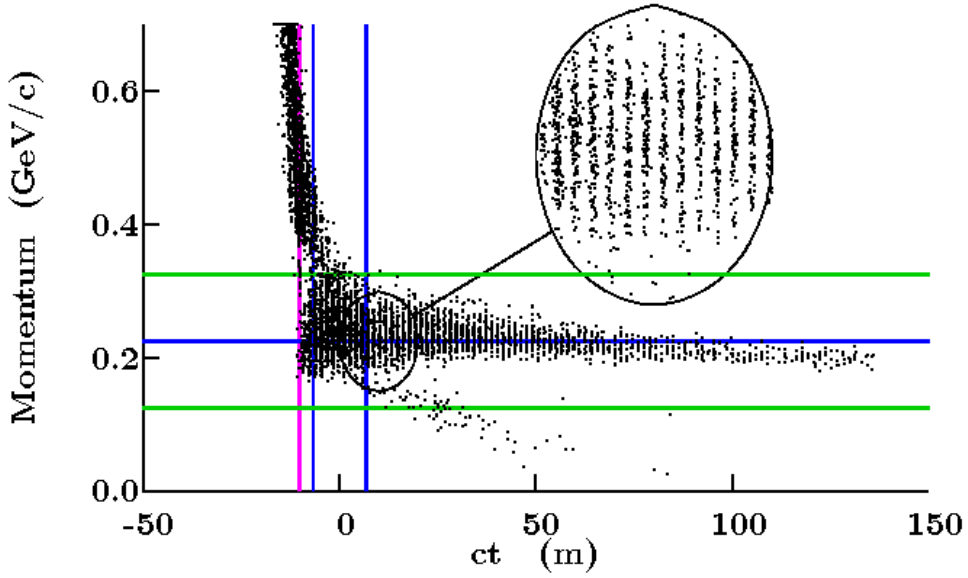
110.7 m End of drift



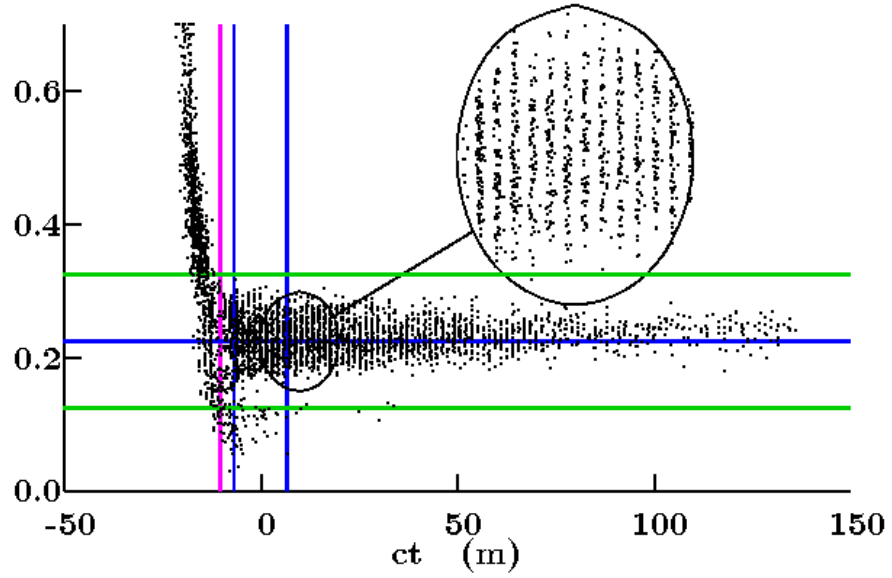
161.7 m End of bunch



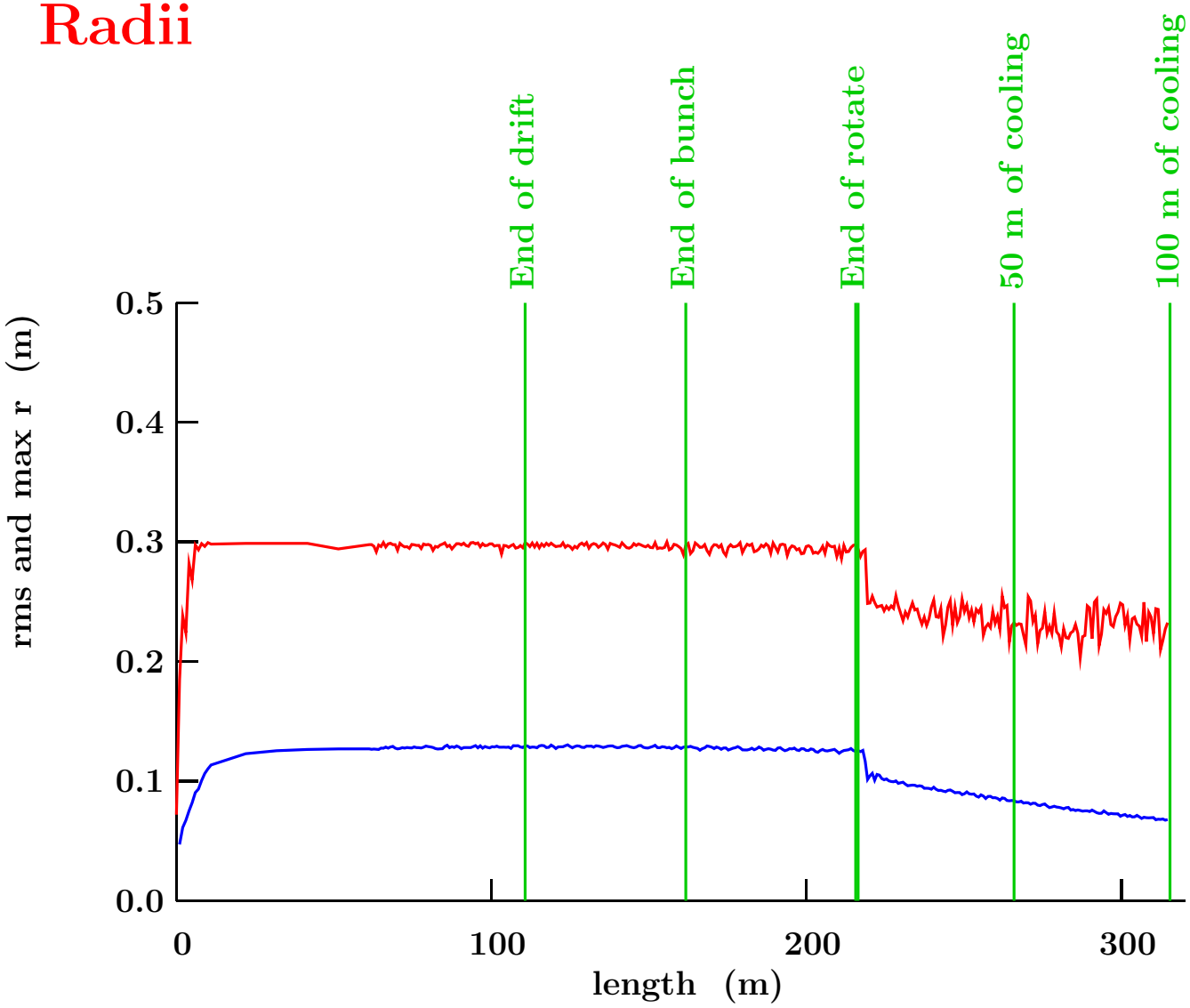
215.63 m End of rotate



265.9 m 50 m of cooling

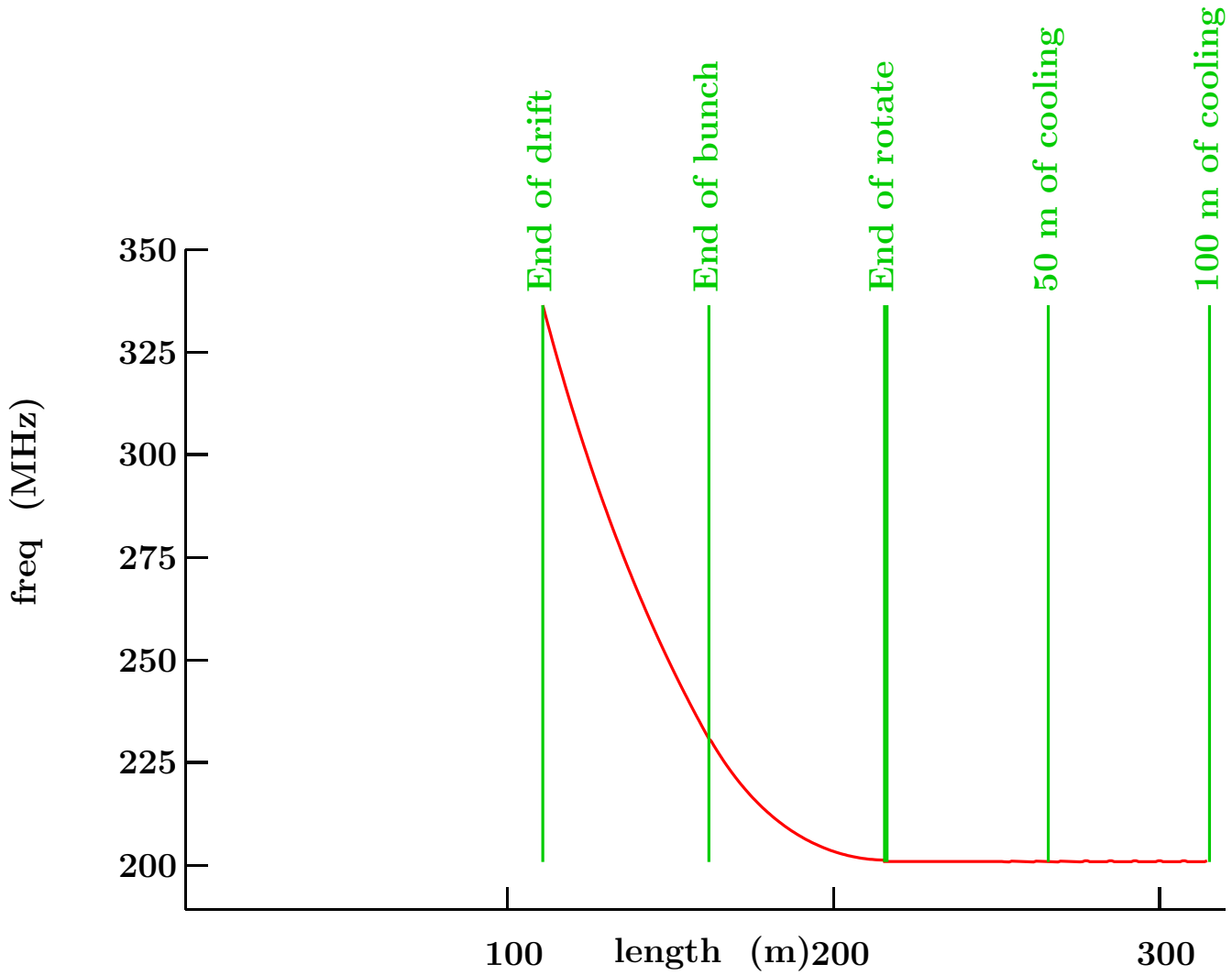


Radii

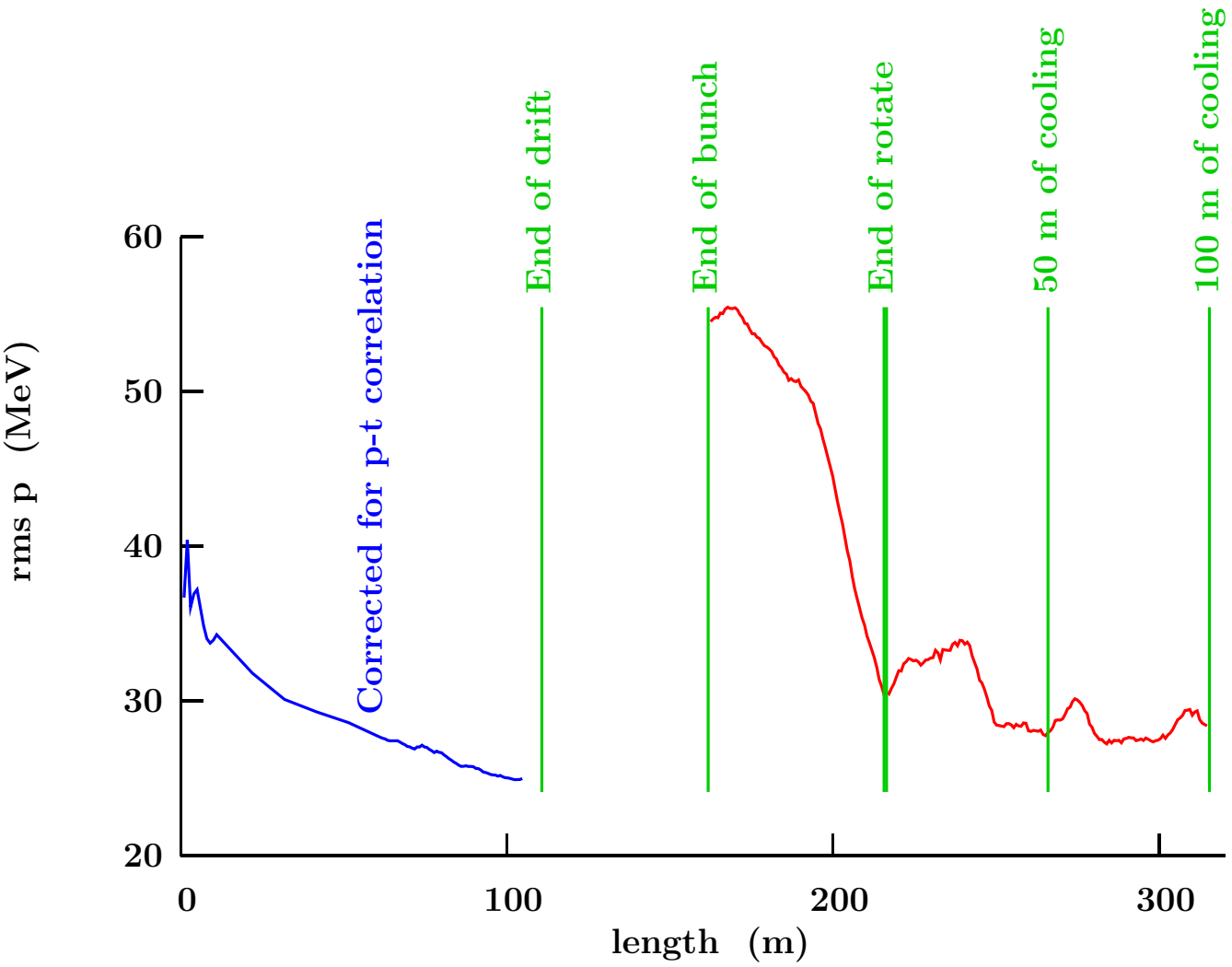

End of drift
End of bunch
End of rotate
50 m of cooling
100 m of cooling
rms and max r (m)
0.0
0.1
0.2
0.3
0.4
0.5
0
100
200
300
length (m)

Frequency

Frequency and phase after phase rotation chosen by Fourier analysis of track times

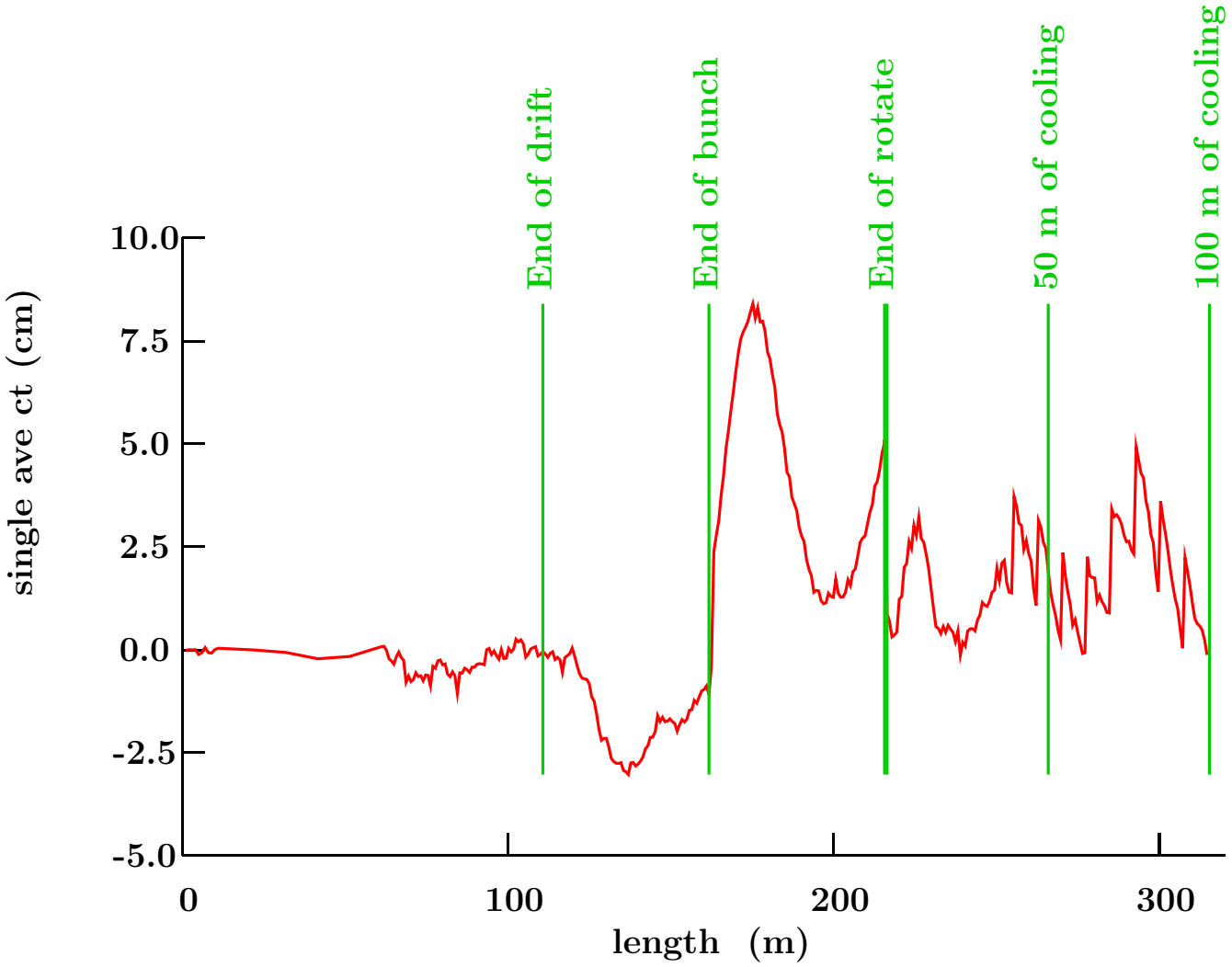


Rms Momentum Spread



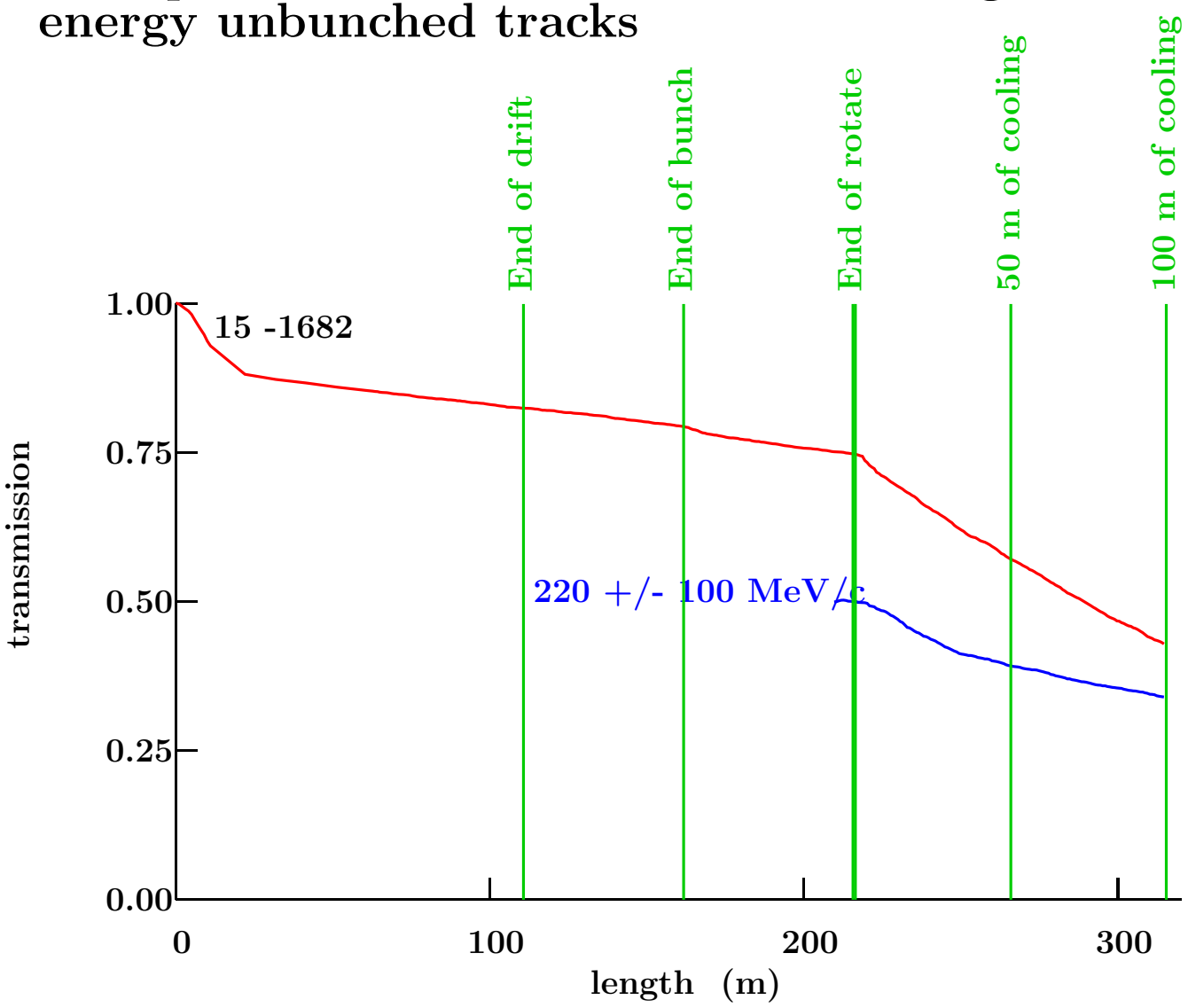
Ave ct (modulo wavelength)

Watch this to check that time and momentum matches are ok



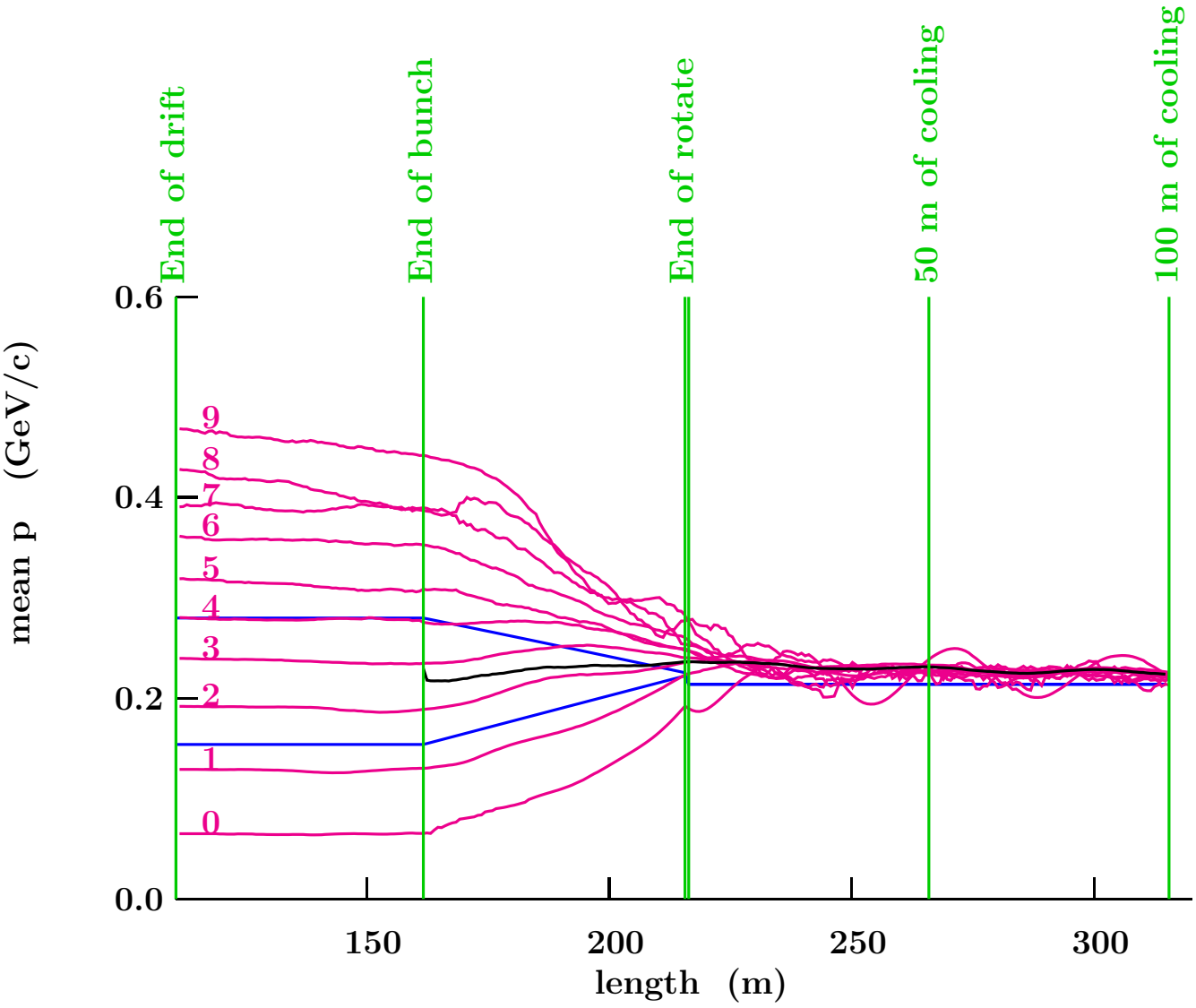
Transmission

Drop in total transmission in cooling is due to loss of high energy unbunched tracks



Mean Momenta

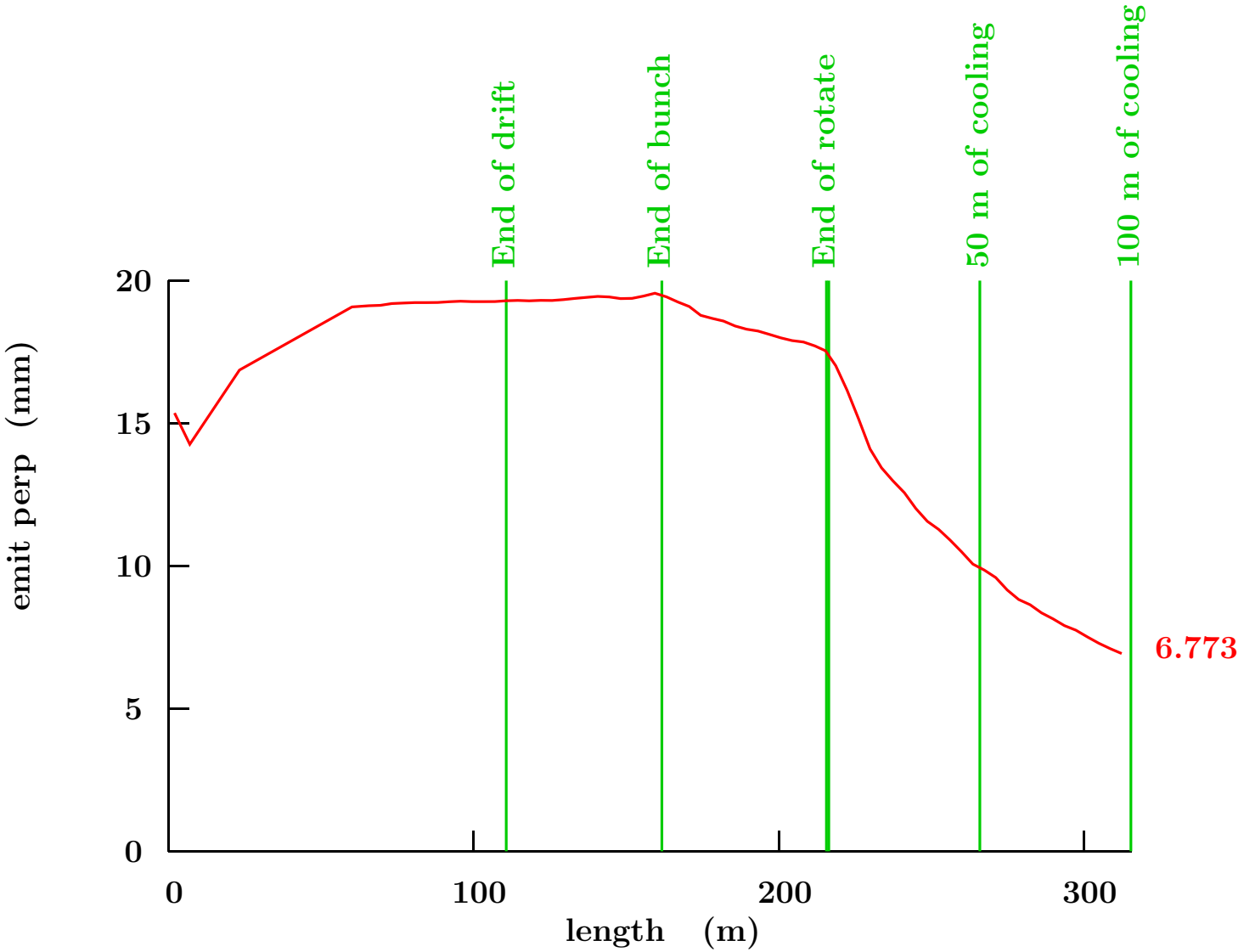
In time slices in fractions of reference time differences (t1-t2)



Transverse Emittance

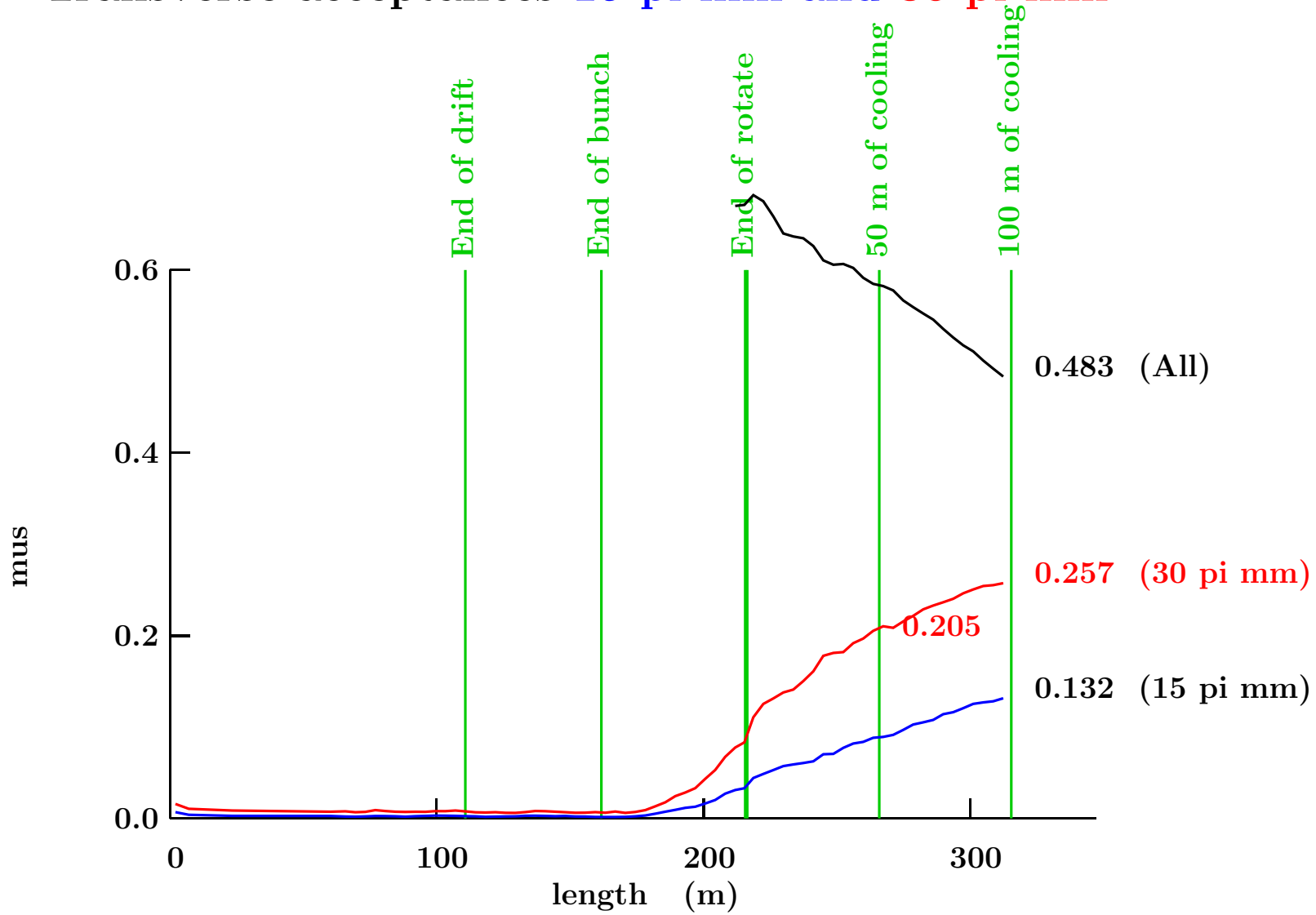
Initial rise from slower decay of higher energy (and emittance) particles

Note significant cooling from Be windows in Phase rotation



Muons per proton in Accelerator Acceptance

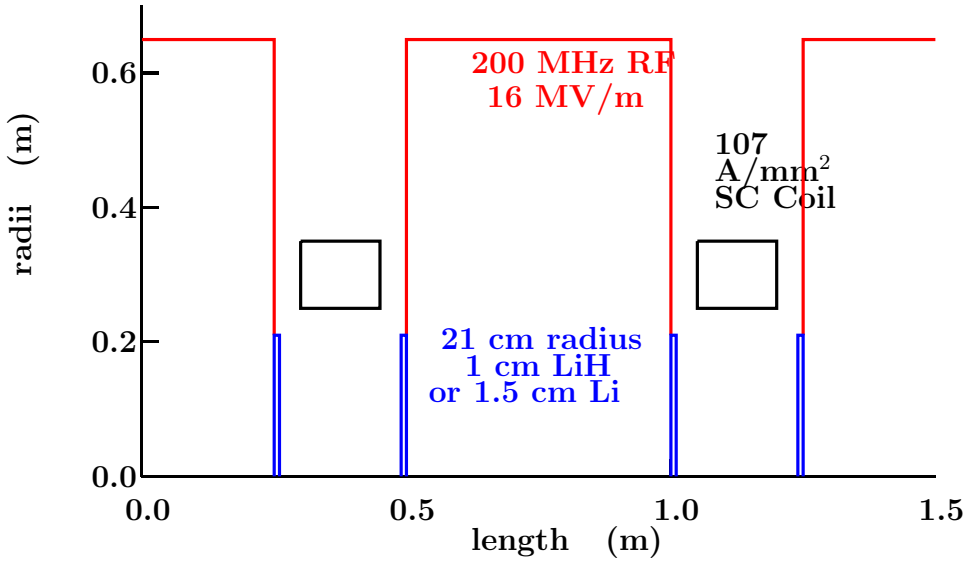
Longitudinal Acceptance 150 pi mm
Transverse acceptances 15 pi mm and 30 pi mm

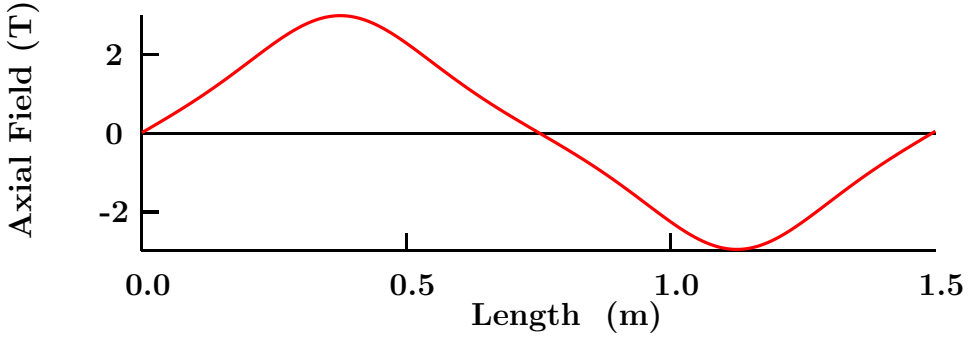


Possible Modification

- Reduce beam window radii to 21 cm (from 30 cm)
  Now same as Study 2
- Bring coils in to 25 cm (from 35 cm)

len1 m	gap m	dl m	rad m	dr m	I/A A/mm^2	n I A	n I l A m
0.300	0.300	0.150	0.250	0.100	107.39	1.61	3.04





Muons per proton
at 50 m now 0.195 (from 0.205)
at 100 m now 0.23 (from .257)

1/2 amp turn meters
Significant saving

Allows use of
Study II Be Windows
plus LiH slab

Field contains significantly more harmonic content
resulting in less dynamic aperture

Other Studies

1. Lower RF gradient from 15.25 MV/m to 10.17 MV/m and increase cooling lengths from 50 and 100 m to 75 and 150 m
   Loss approximately 5% (e.g. 0.205 to 0.195 at 50/75 m)

2. Use periodic fields in drift (period 50 cm)
   and in bunch and rotate (period 75 cm)
   Juan Gallardo
   Loss of performance at 100 m: approx 15%
   Loss of performance at 50 m: approx 15%

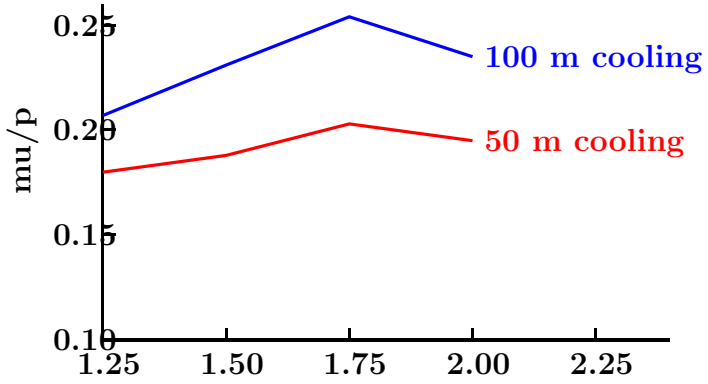
3. Increase solenoid field to 5 T for first 40 m of decay channel
   Should reduce emittance increase form decay good (Kevin)
   But also increases time-amplitude collellations bad
   Observed loss of 10% i.e. Bad wins

4. Vary Solenoid Field in drift,bunch and rotate

Changing length of initial taper and match to pre-cooler

Keeping aperture fixed at 30 cm rad

1.75 T prefered



Lower field better because it reduces amplitude-time, and angular momentum-time, correlations

Conclusion

If

- Acceleration has 30 pi mm transverse acceptance and 150 pi mm longitudinal, then
- Use Neuffer Phase Rotator (somewhat longer than David's)
- And 50 m Pre-cooler

Then

- mu/p for each sign (≈0.20) is about 1.2 times Study 2
- And we have both signs
- i.e. effectively 2.4 times Study 2
- Cost of Rotation & cooling probably less than half Study II's

But Note

- Some of this will be lost with FFAG's that will have more decay losses than the RLA