ICOOL Acceleration Studoes

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Collaboration Meeting LBNL Feb 05

- FFAG Tracking
- FFAG Injection/Extraction
- Study 2a Matching from Cooling to Linac

I: Study 2a FFAG Simulations

Lattice parameters taken from Scott's Friday 27 Feb talk

$E_{\min}$ (GeV)	5		10	
$E_{\max}$ (GeV)	10		20	
$V/\omega\Delta T\Delta E$	1/8		1/12	
$A_{\perp n}$ (mm)	30			
L_0 (m)	2			
L_Q (m)	0.5			
V per cell (MV)	7.5			
Empty cells	8			
ν_x, ν_y at $E_{\min}$	0.35			
n	90		105	
C (m)	606.918		767.953	
V total (MV)	675.0		787.5	
	QD	QF	QD	QF
L (m)	1.612338	1.065600	1.762347	1.275747
ρ (m)	15.2740	-59.6174	18.4002	-70.9958
x_0 (mm)	-1.573	7.667	1.148	8.745
r (cm)	14.0916	15.2628	10.3756	12.6256
B_0 (T)	1.63774	-0.41959	2.71917	-0.70474
B_1 (T/m)	-9.1883	8.1768	-15.4948	12.5874

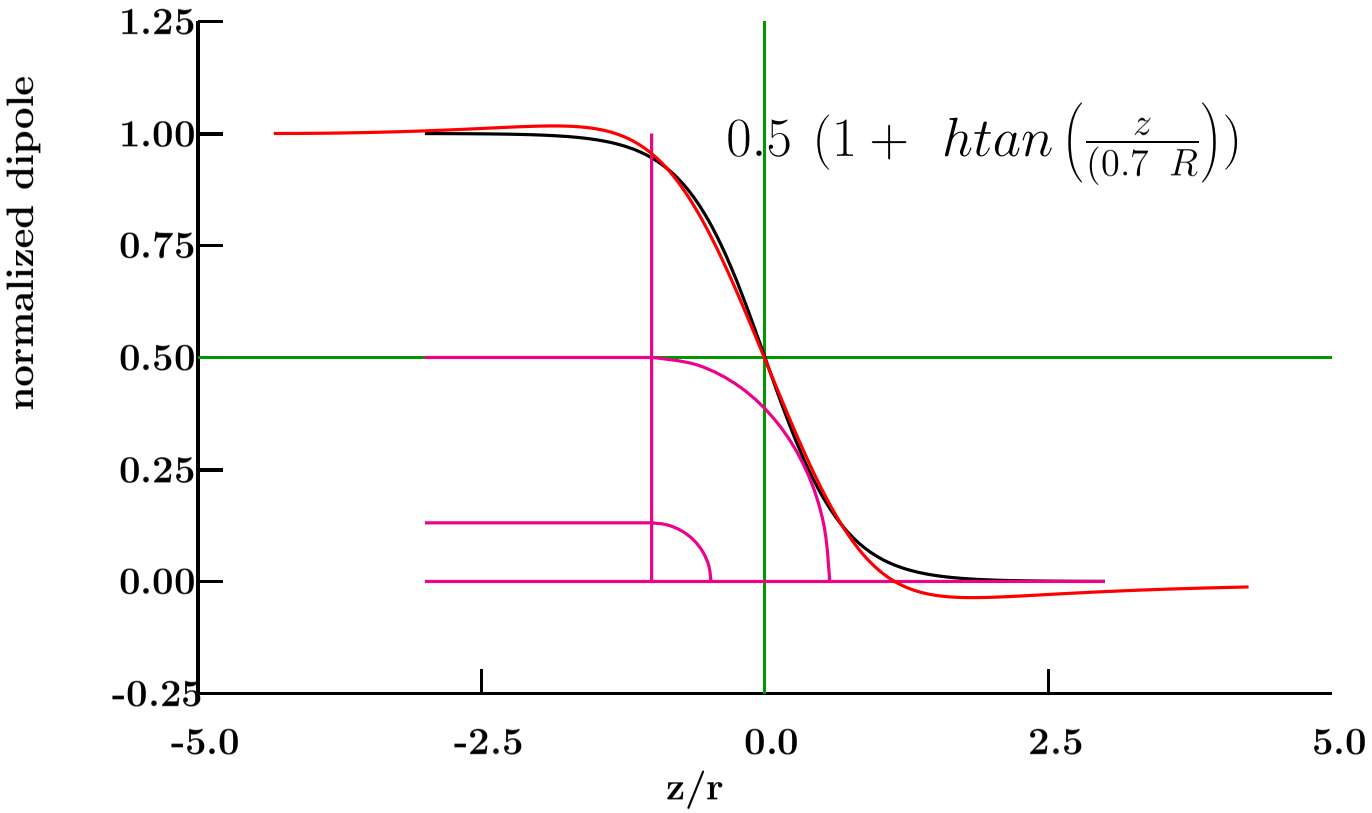
$$\frac{1}{\zeta} = \frac{V}{\omega\ \Delta t\ \Delta E}$$

$\zeta = 8$ **for 5-10**

Model of fields at magnet ends

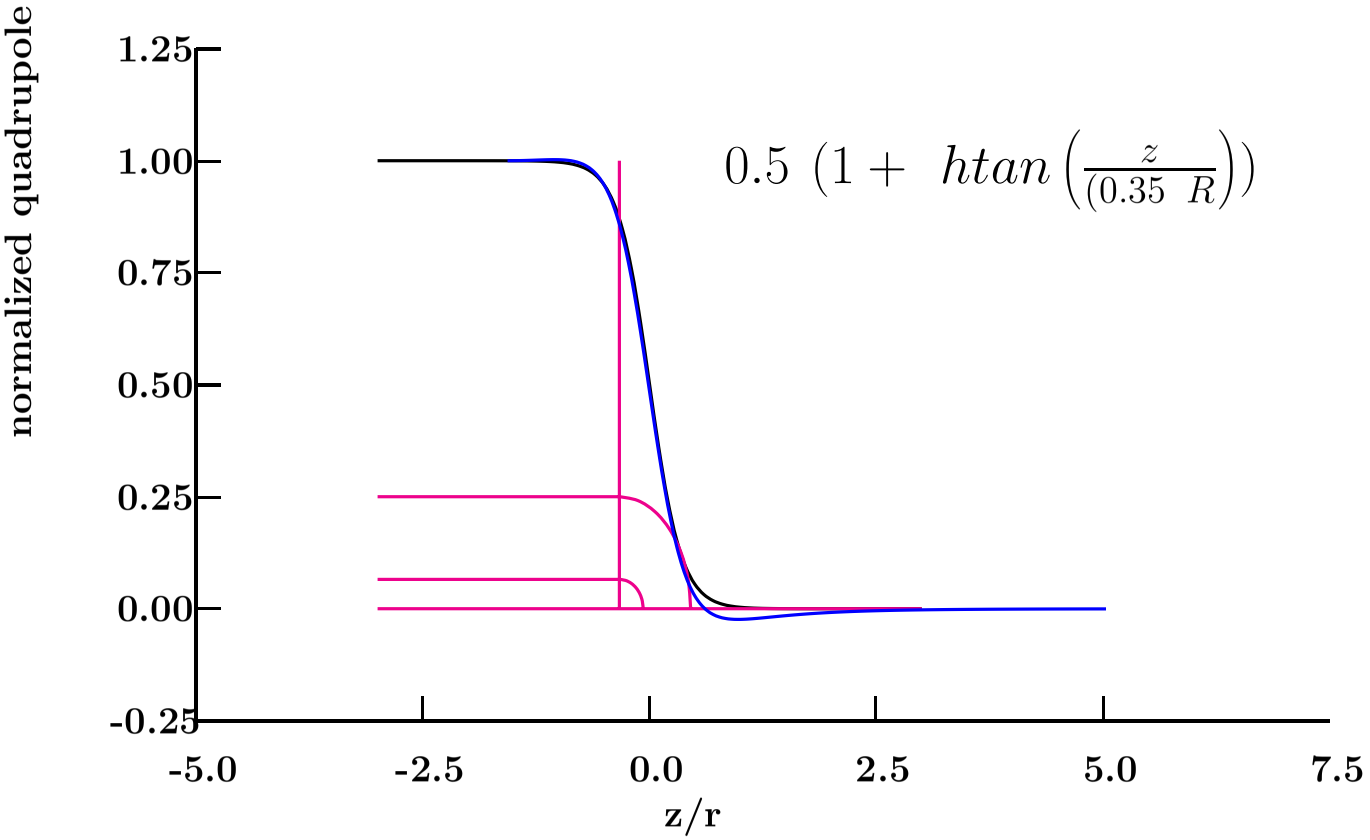
From TOSCA calculation of cos theta magnet (without iron)
Iron is expected to remove the overshoots

Fit as shown

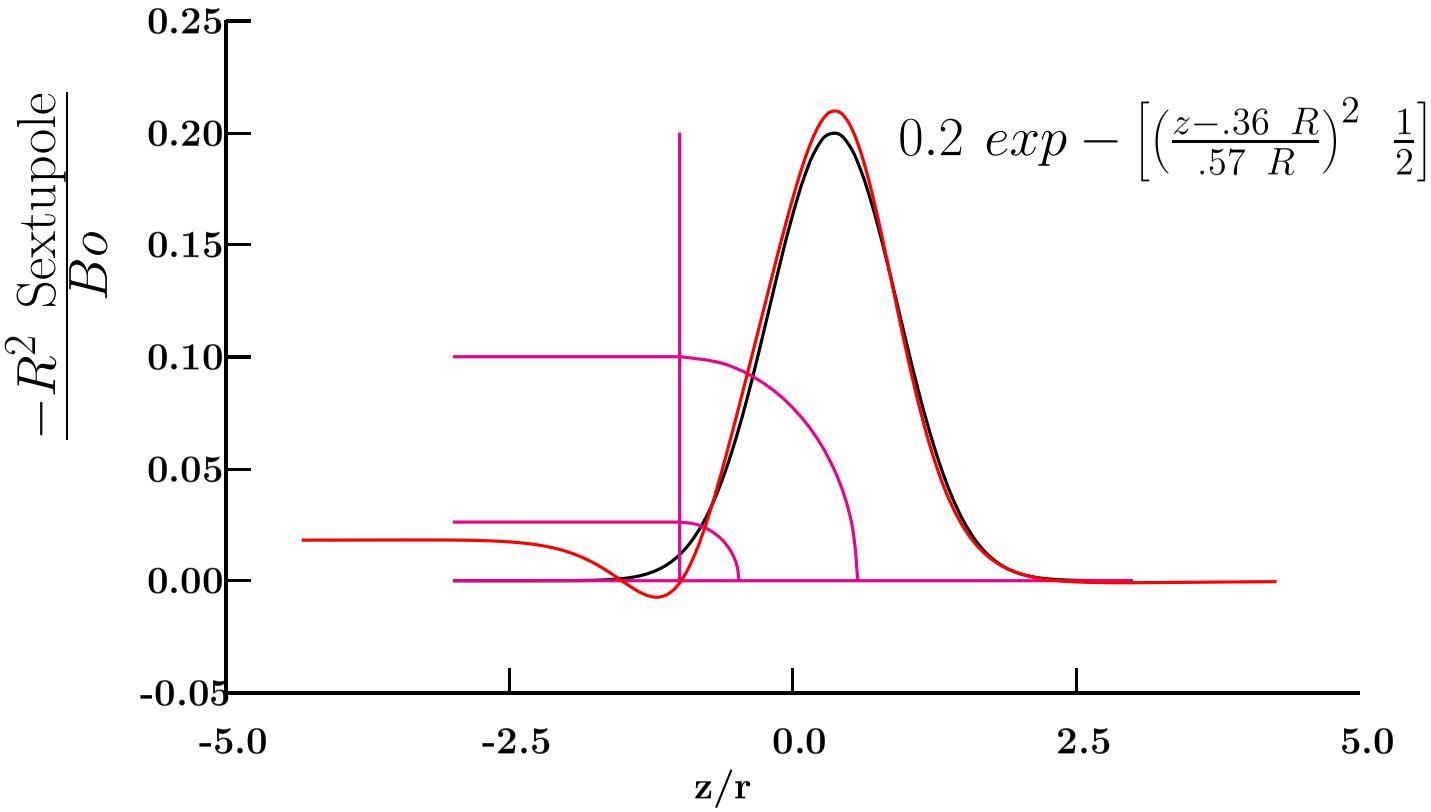


Coil extends little beyond effective length

Quads Fall off twice as fast

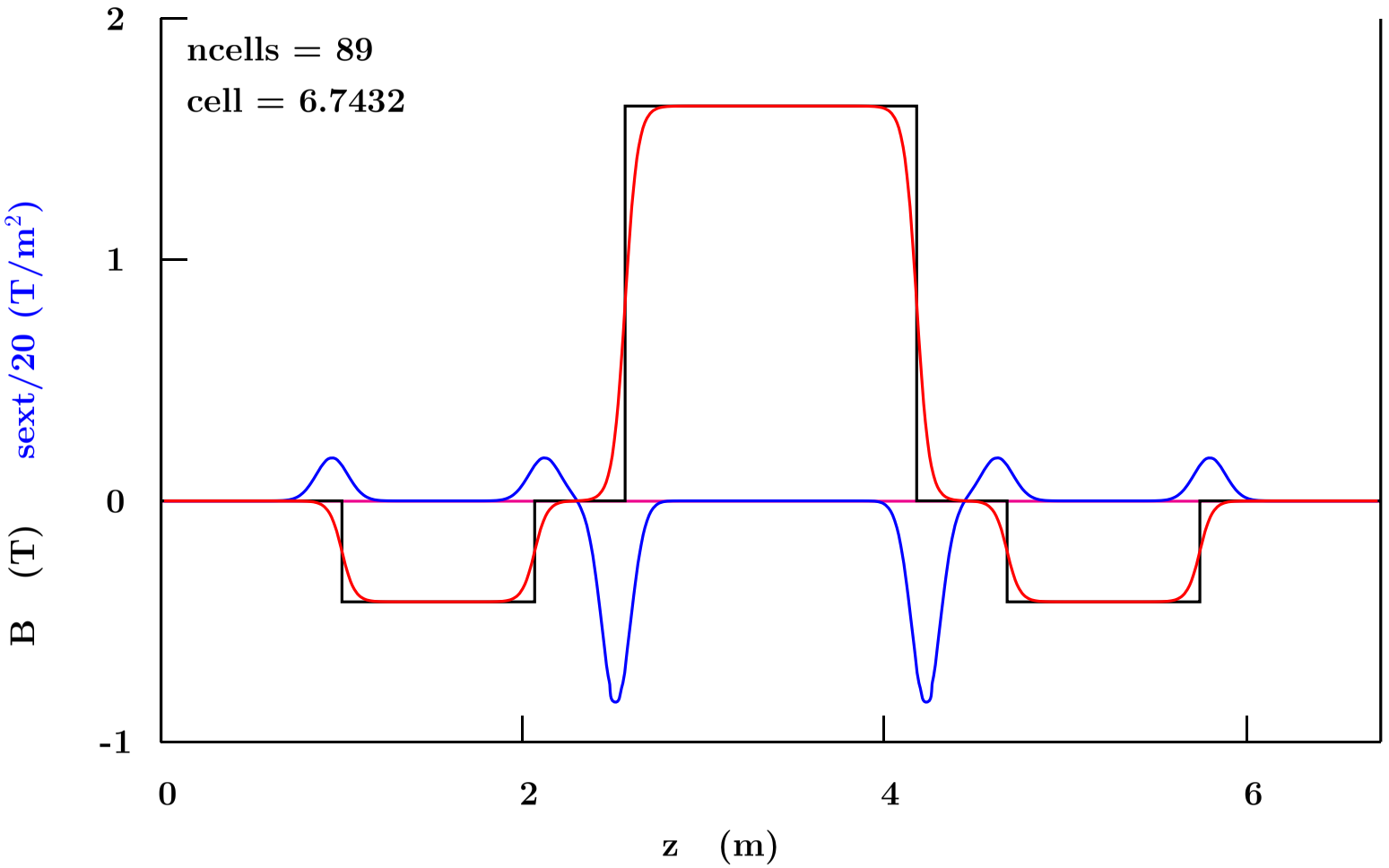


Sextupole peaks at very end

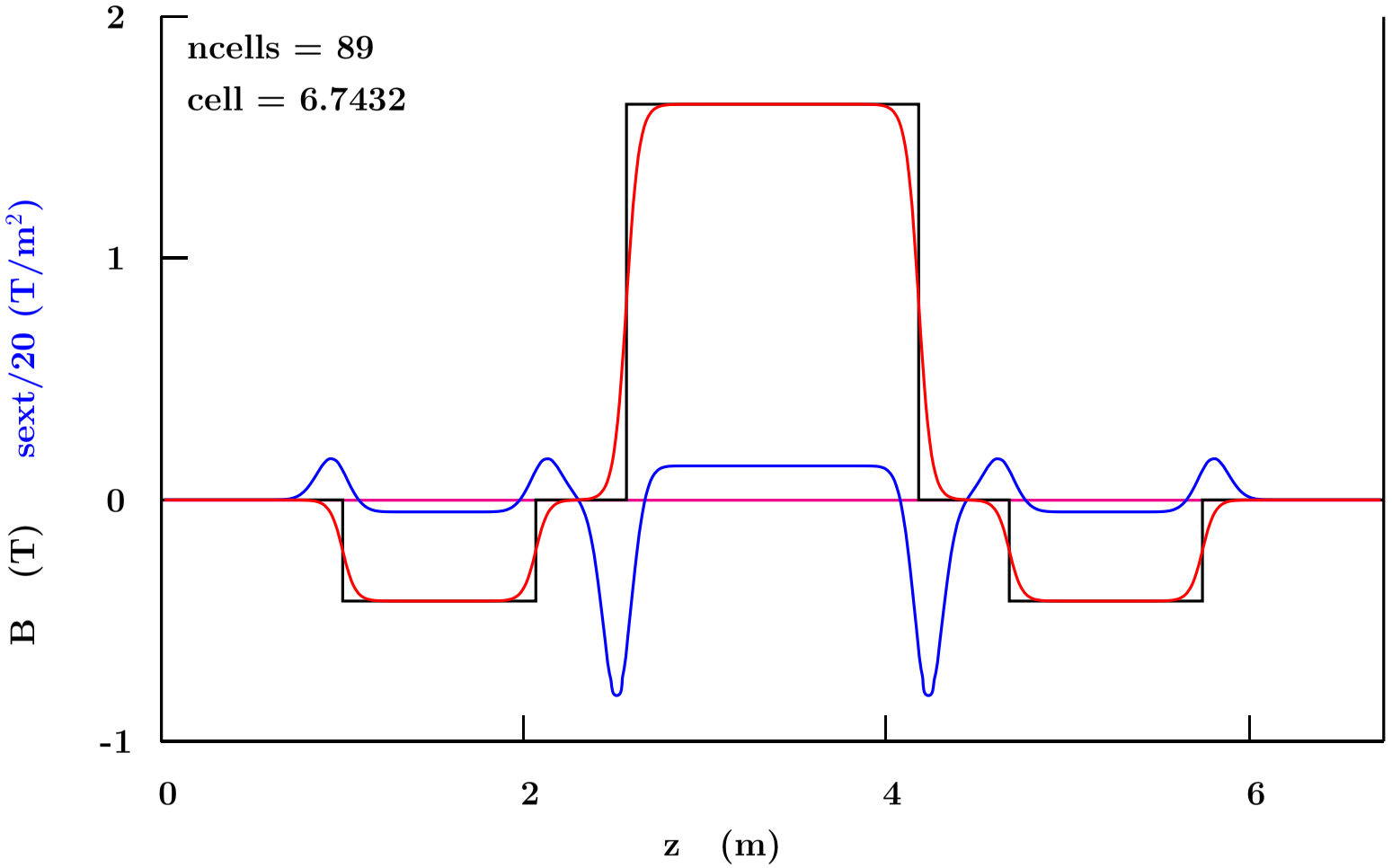


5-10 GeV Lattice

Without body sextupoles

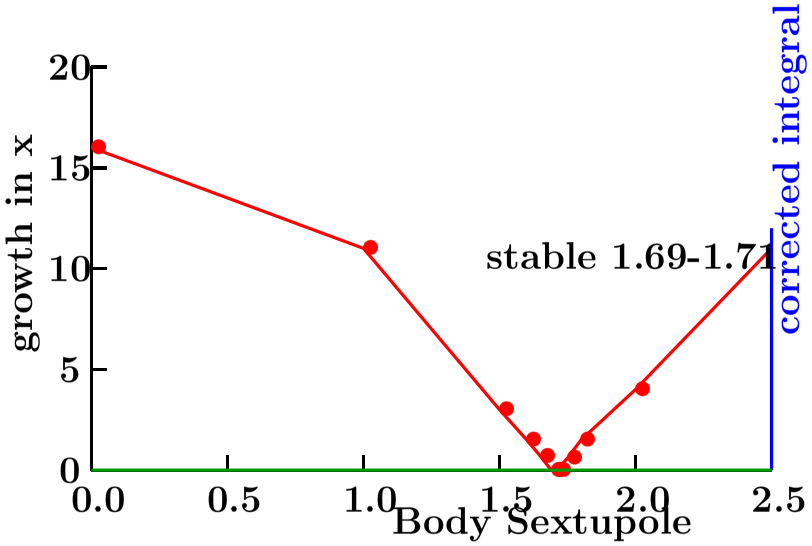


With body sextupoles



ICOOL Tracking

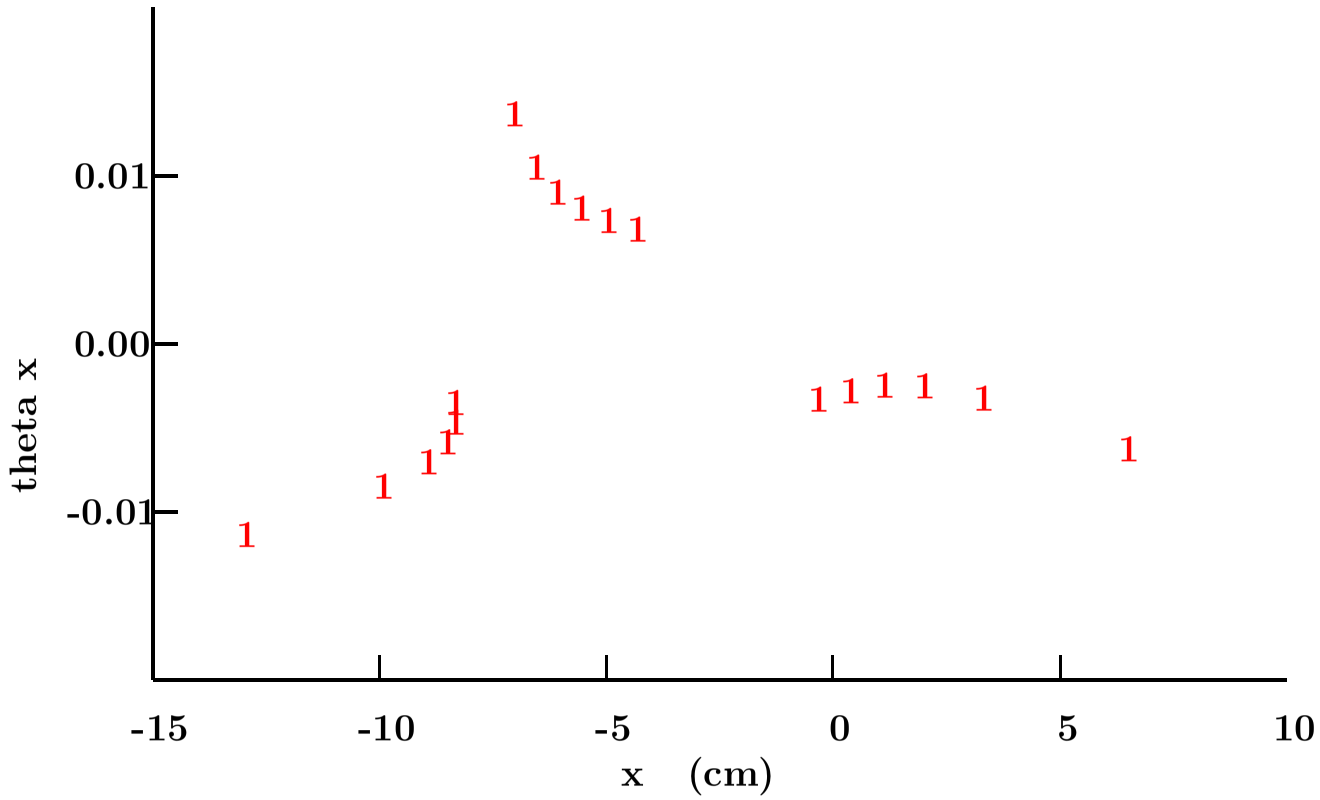
- with the end sextpoles removed, xy mixing is observed, but no prominent resonaces
- With the end sextupoles on there is a strong third order resonance at 5.1 GeV (both tunes approximately 0.33)
- This can be removed by adding body sextupole components that partially correct the integral magnet sextupoles
- No need found to adjust F and D separately



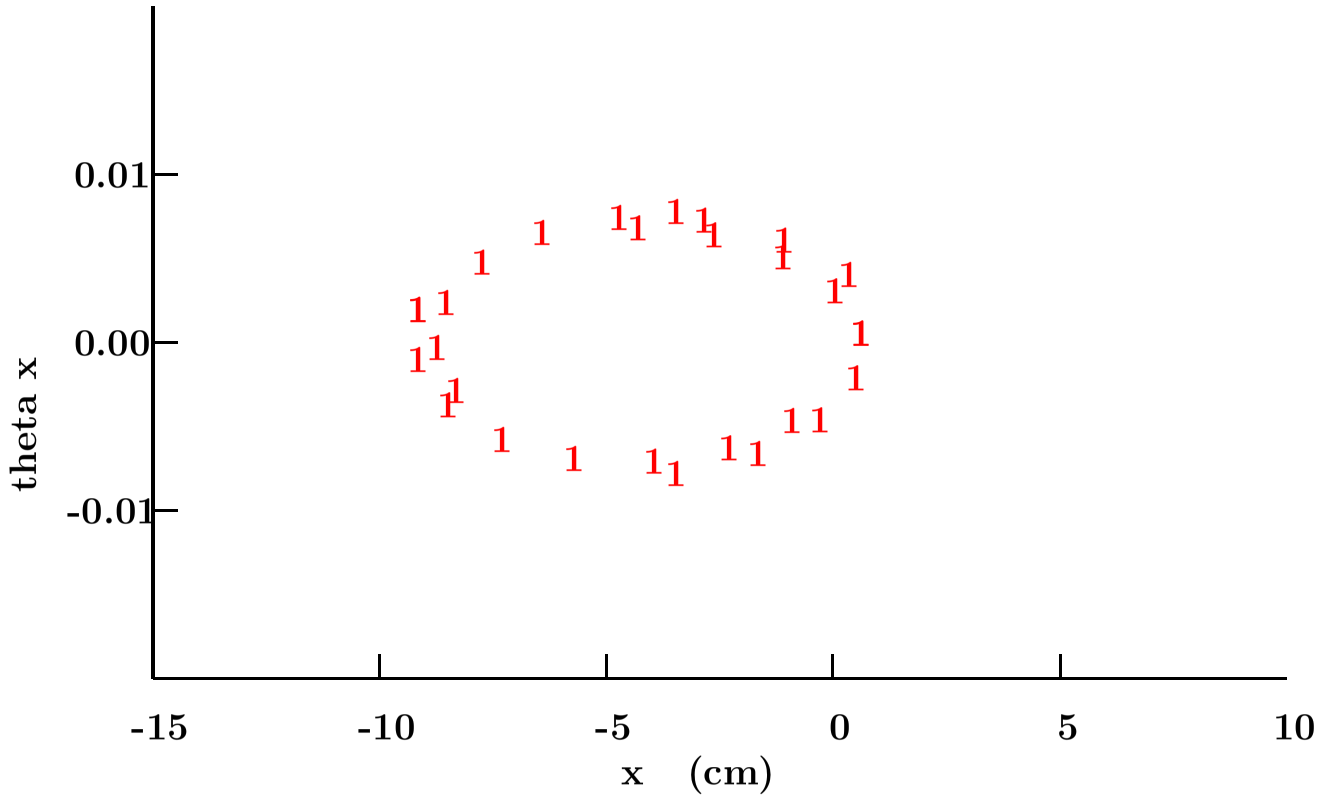
3rd order resonance at 5.1 GeV

e.g. inject single particle at edge (in x and y) of 30 pi mm acceptance. Observe phases after each turn.

without body sextupoles



with body sextupoles

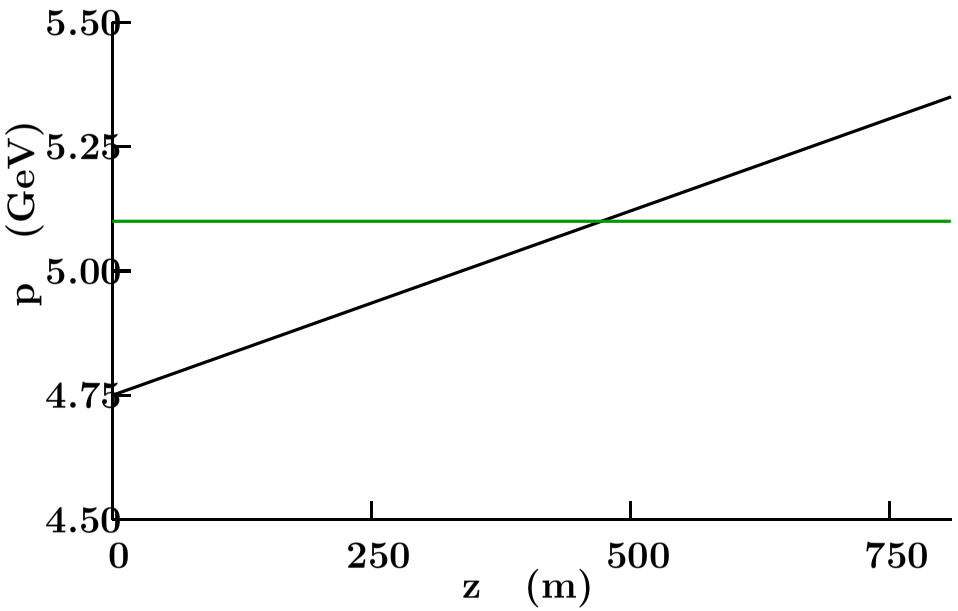


Add Acceleration

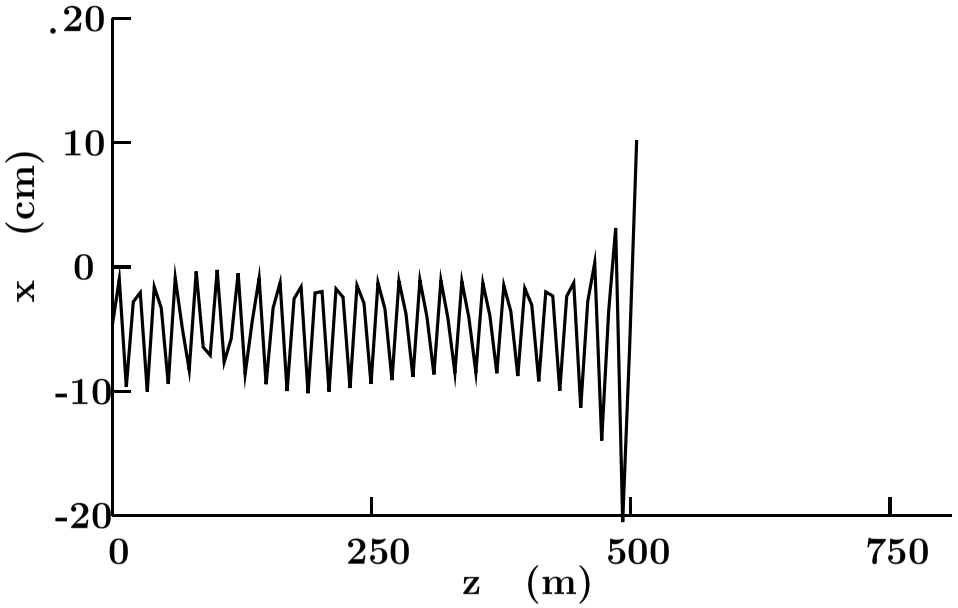
Zero Frequency 10 MV/cell

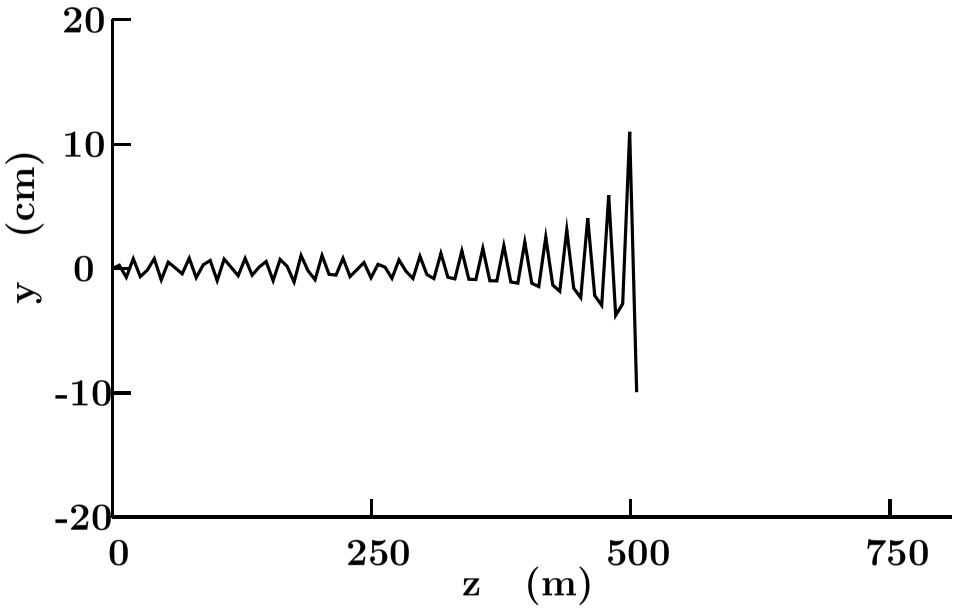
Inject single particle at y edge of 30 pi mm (no initial x amplitude)

Accelerate accross resonance (4.75 to 5.25 GeV)

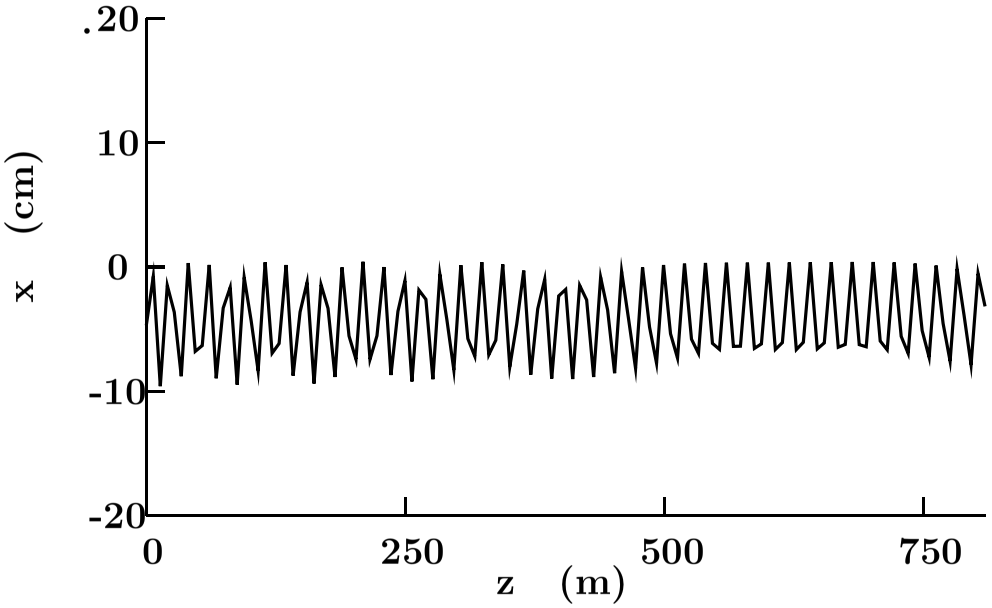


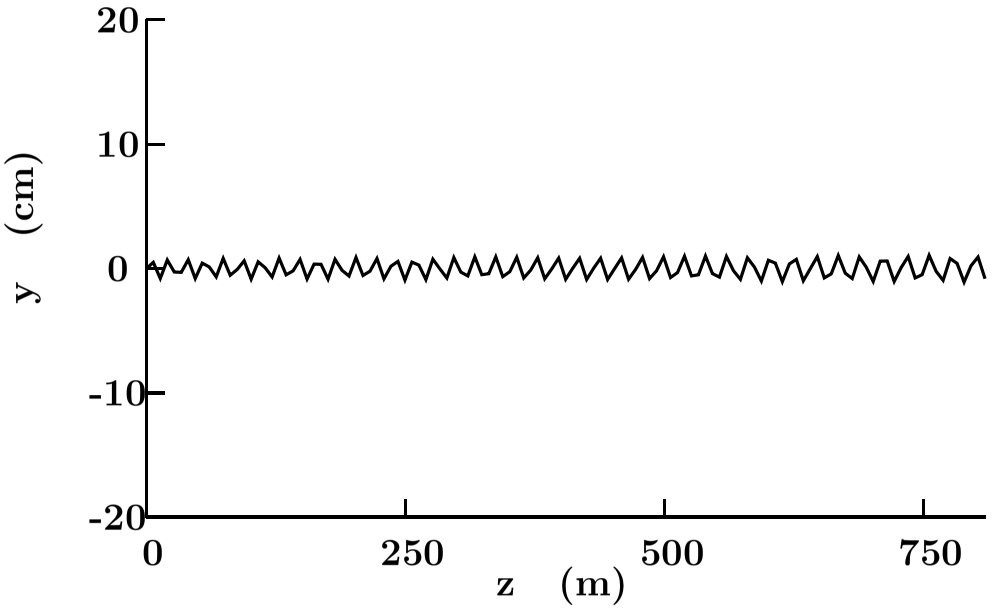
without body sextupoles





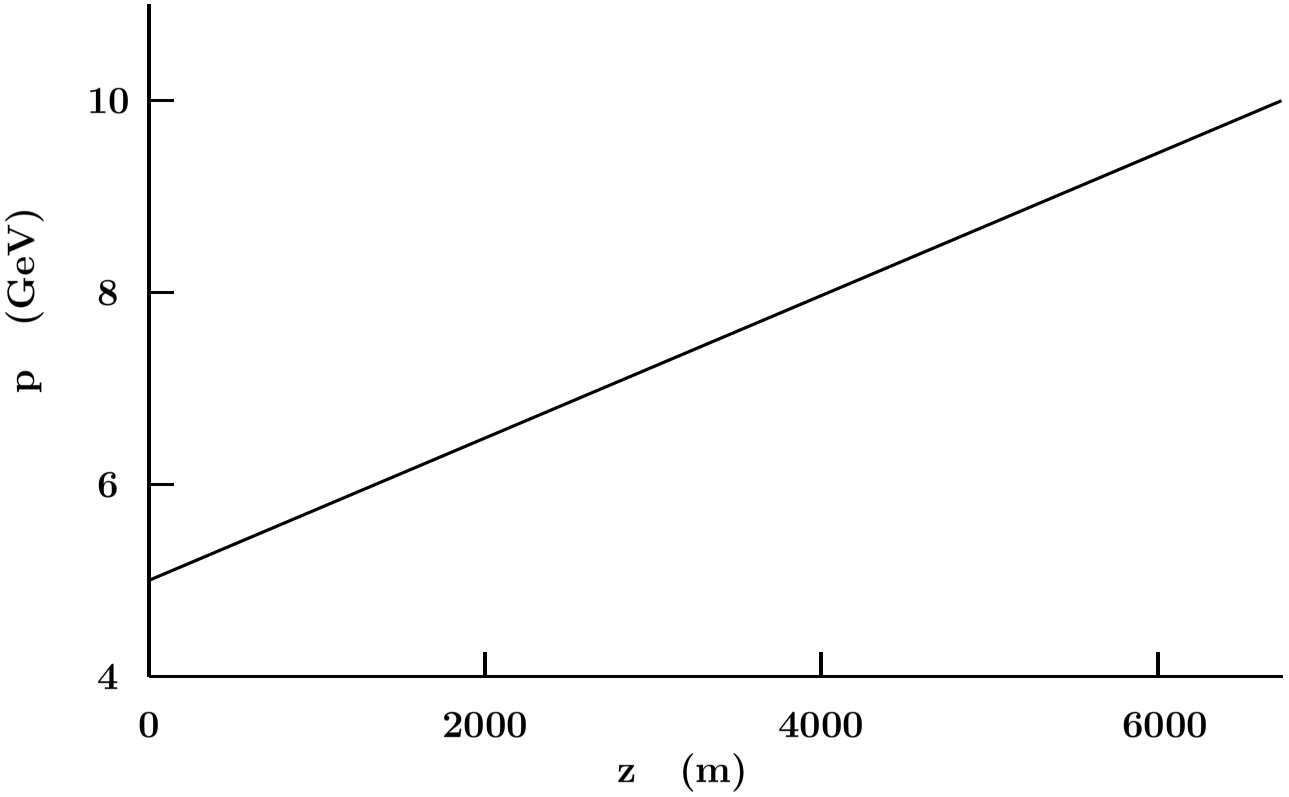
with body sextupoles

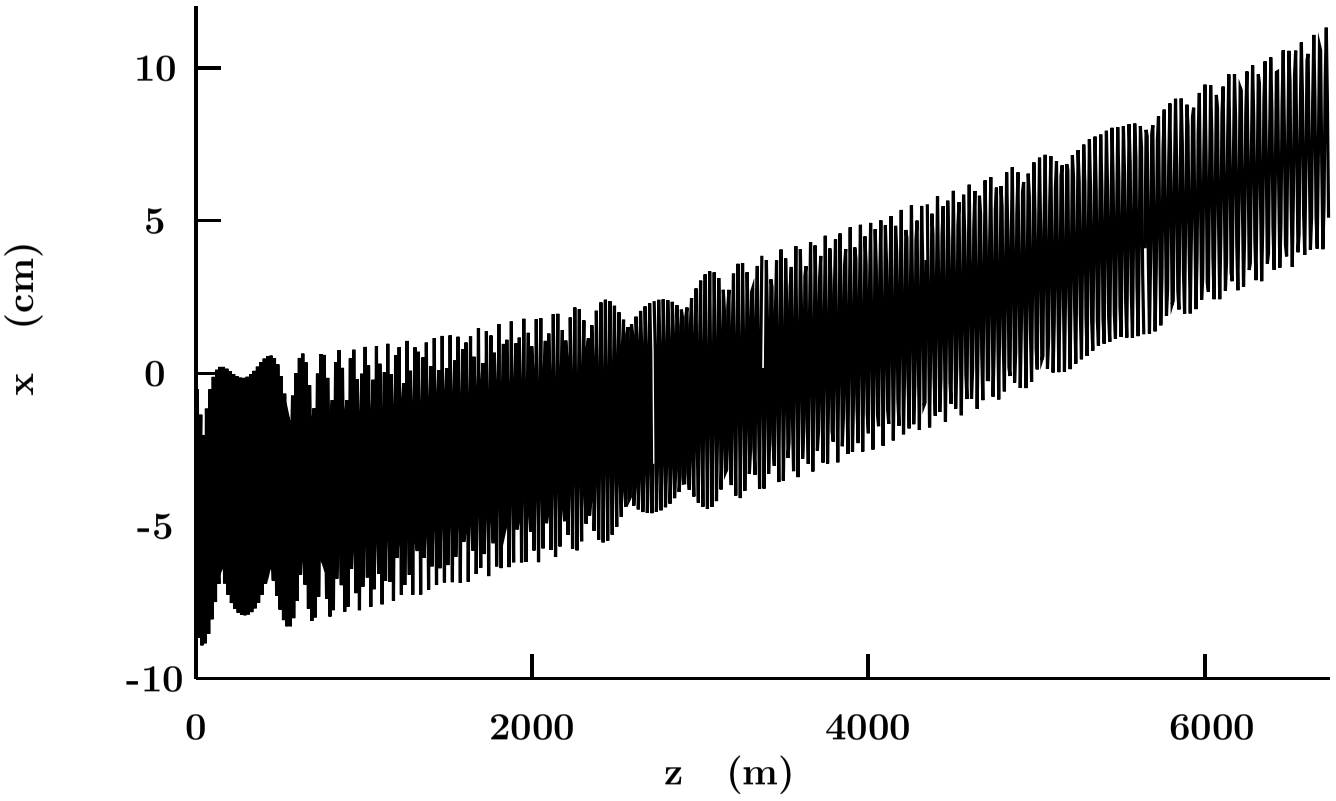


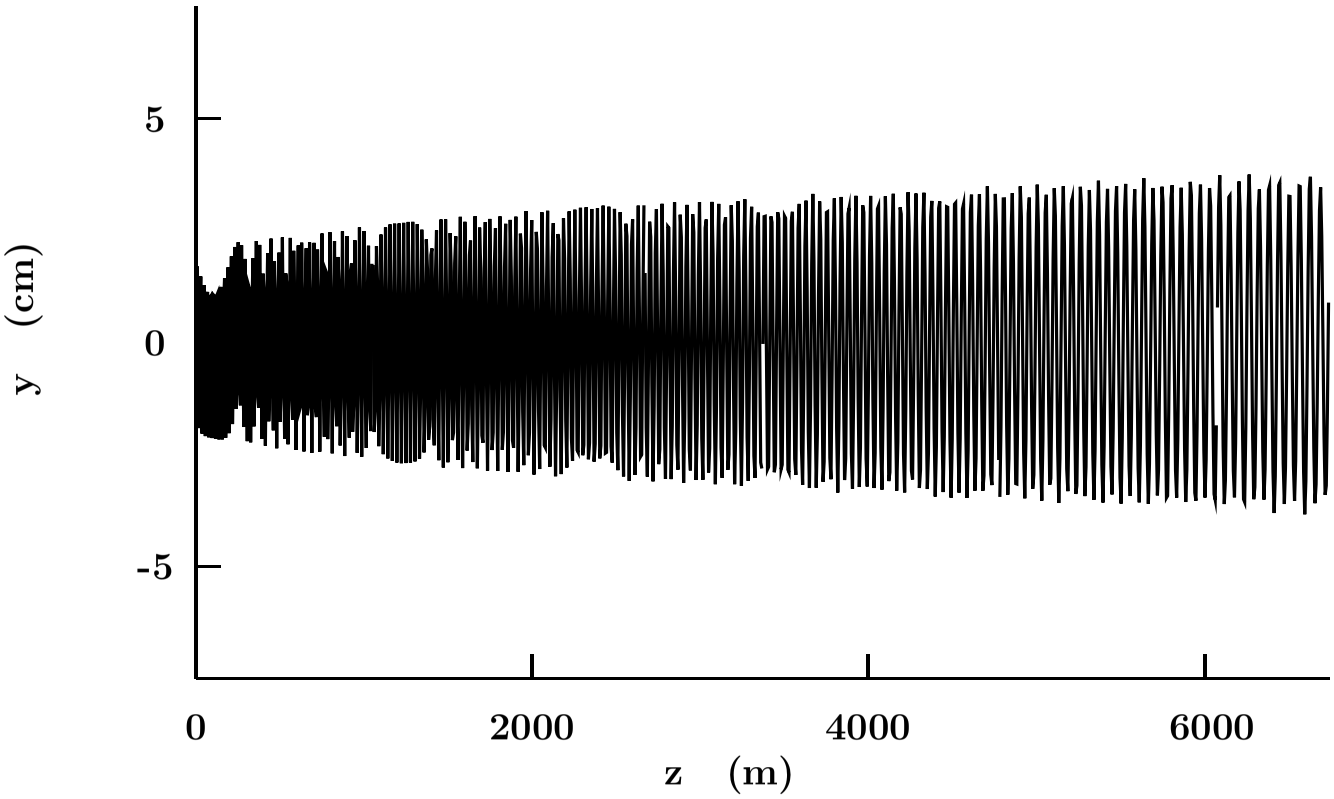


Acceleration 5 to 10 GeV

Inject single particle at edge (in x and y) of 30 pi mm




10
5
0
-5
-10
x (cm)
0
2000
4000
6000
z (m)



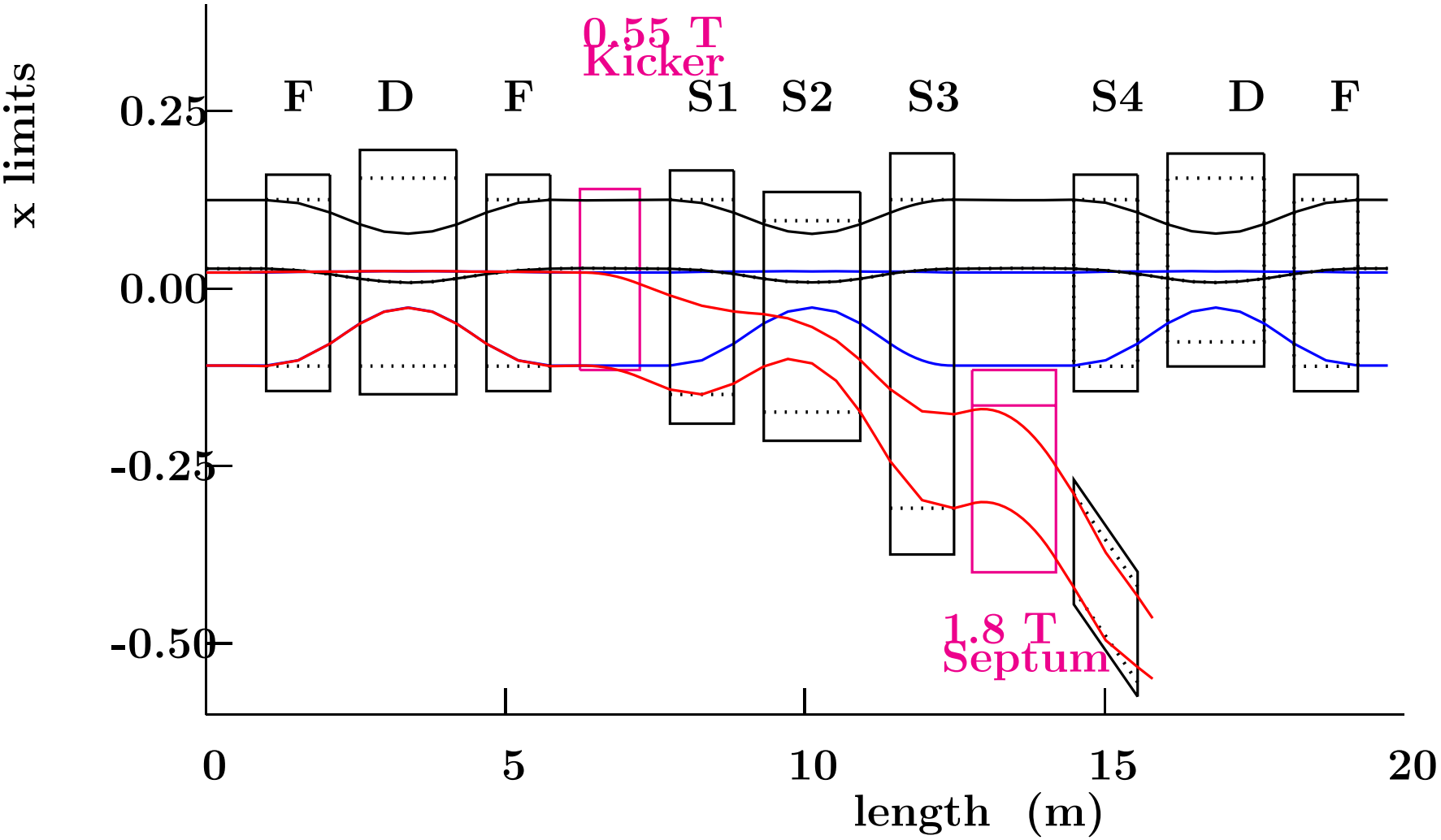
No evidence of emittance growth

Conclusion

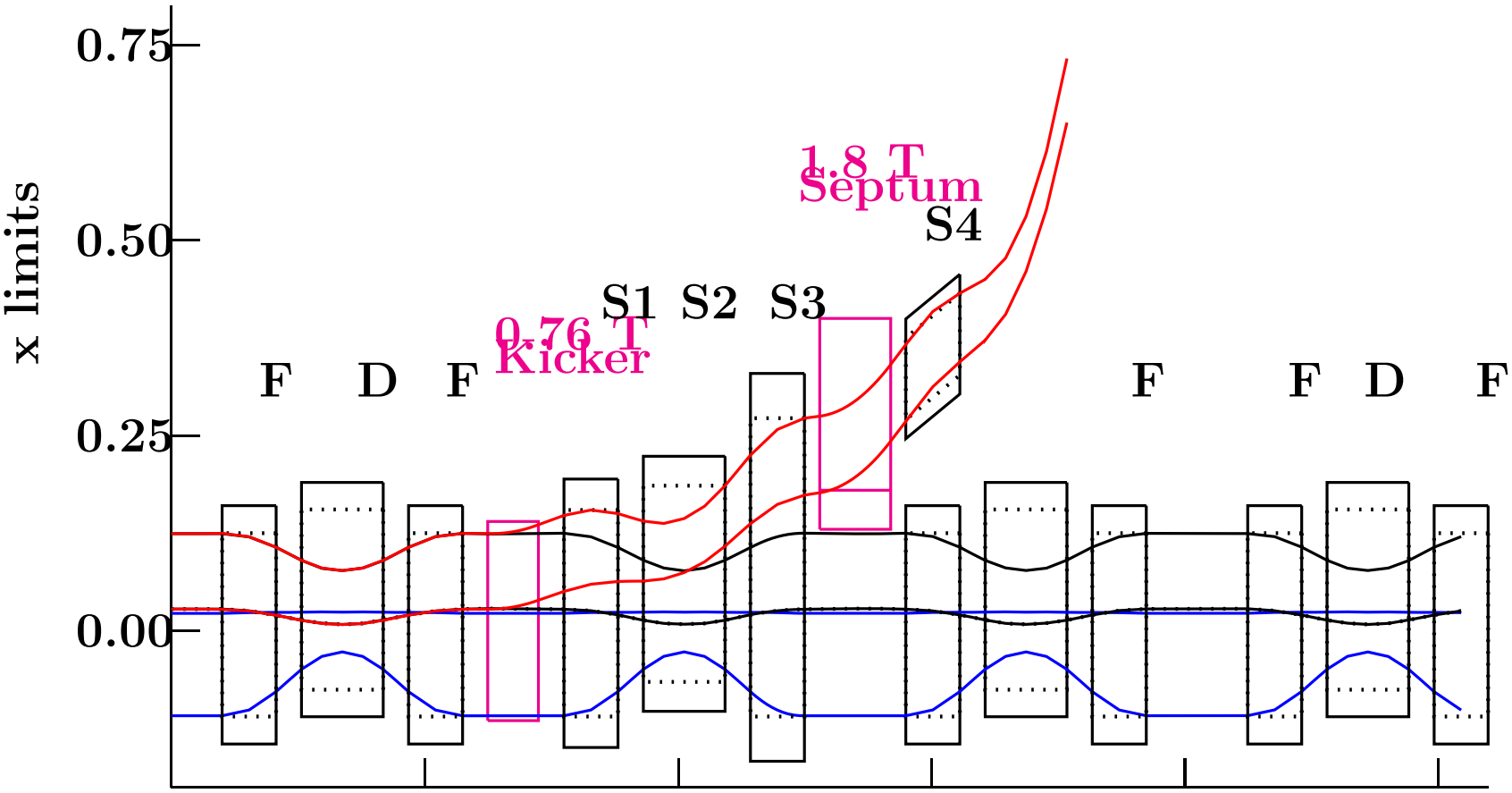
- Adding uncorrected sc magnet ends
  gives fatal 3rd order resonance
- Adding corrective sextupoles in the magnet bodies
  removes the resonance
- Independent adjustment of body sextupole in the different magnets is not required
  May be because x and y tunes are so close
- Acceleration of 30 pi mm particle shows
  no evidence of emittance growth
  But needs more study

II Injection/Extracion

Injection best from inside

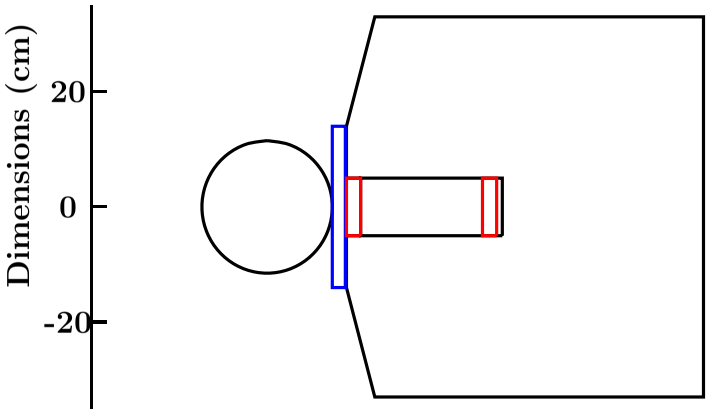


Extraction best to Outside

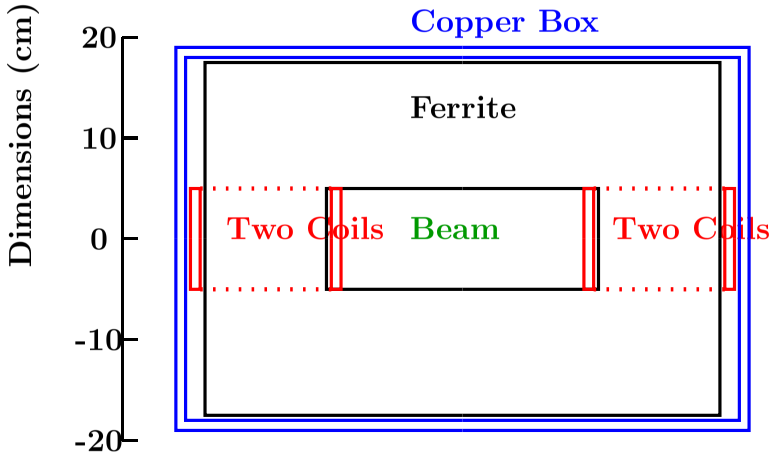


Septums

length	m	1.4
Field	T	1.8
Height	cm	10
.Width	cm	23
septum	cm	5



Kicker



Parameters

		Inj in	Ext out	10-20Ext	10-20Inj	RFOFO	$\bar{p}$	Ind
Length [2]	m	1.5	1.5	1.5	1.5	1.0	≈5	1.0
B $[2]_o$	T	.37	0.51	.78	.58	.42	≈0.018	0.6
Y	m	.1	.1	.076	.076	.42	.08	
X	m	.25	.25	.195	.195	.63	.25	
I	kA	44	60	71	53	105	3.6	
U [2]	J	850	1620	2280	1260	8200	≈13	1600
Max pole B	T	3.6 [1]	2.6	4.2	5.6			
t_{fall}	ns	640	950	875	1270	50	90	40
$t_{pulse\ length}$	ns	300	300	300	300	100	500	100
$V_{1\ turn}$	kV	230	240	208	193	5,700	800	1000
V_{supply}	kV	±58	± 60	± 52	± 48	190	80	190

Note 2: Length 1.5 m (vs 1 m) by using special short quads

Conclusions

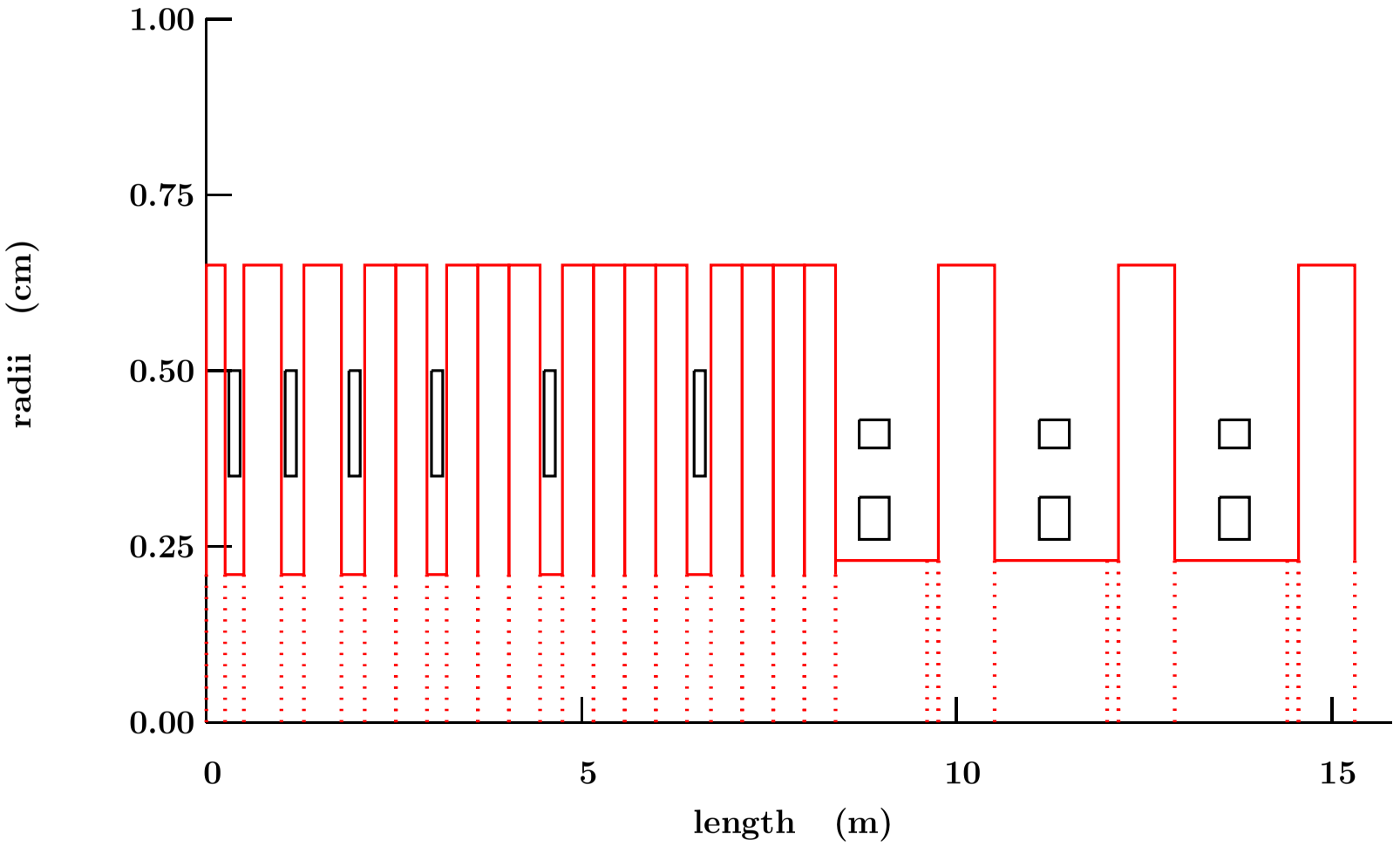
- Injection from inside favored for kicker energy ($> 2\times$)
- Half sin wave (or full sin wave to restore voltage) gives flat enough top
- Stored Energy similar to Induction Linac
- Rise time Much slower
- Voltage moderate

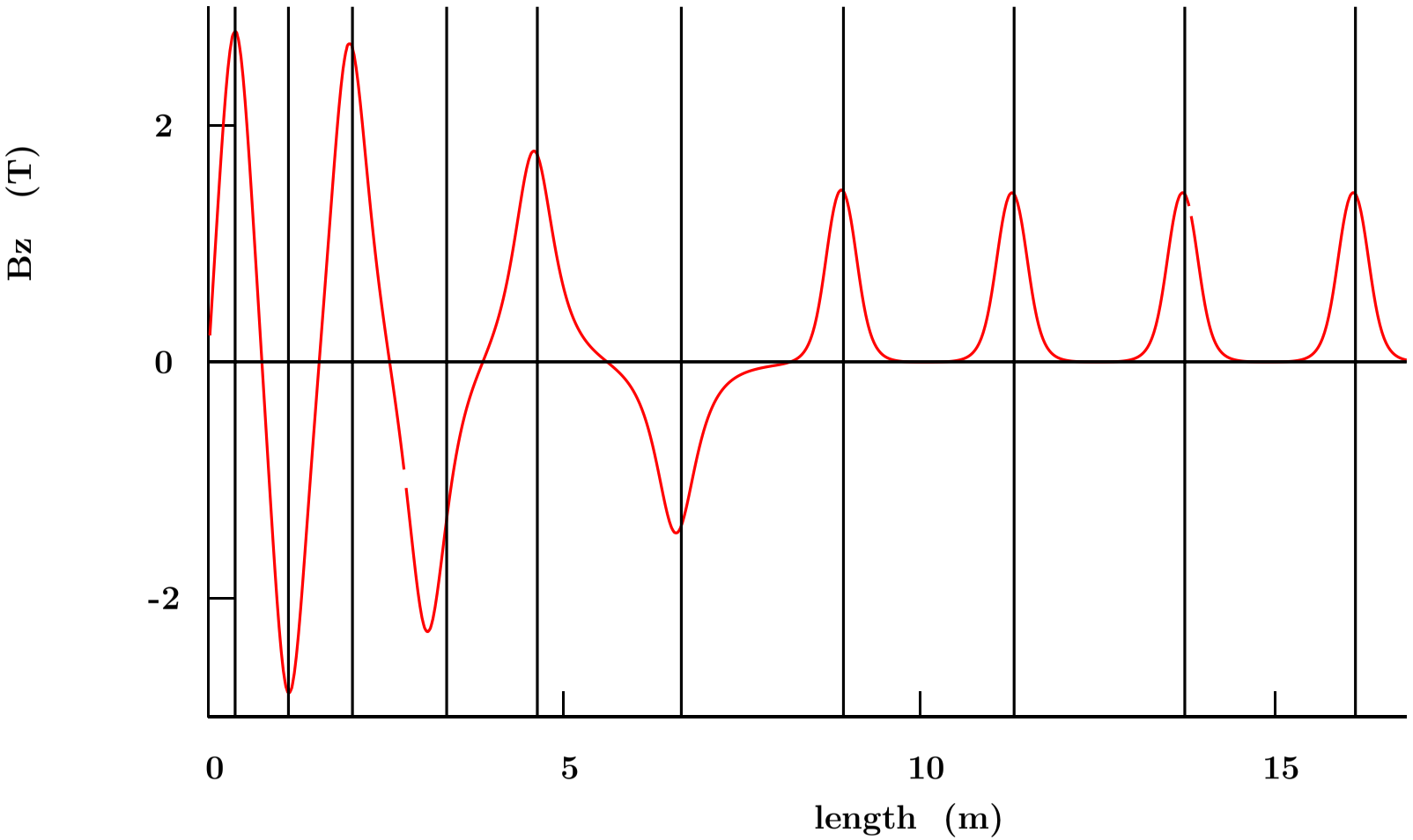
- **Stored Energy $\approx$ 1/4 of RFOFO cooling ring kicker**
- **But Stored energy still $\approx 100\times$ conventional kicker**
- **Pulse rise time 20 times cooling ring making voltage reasonable**

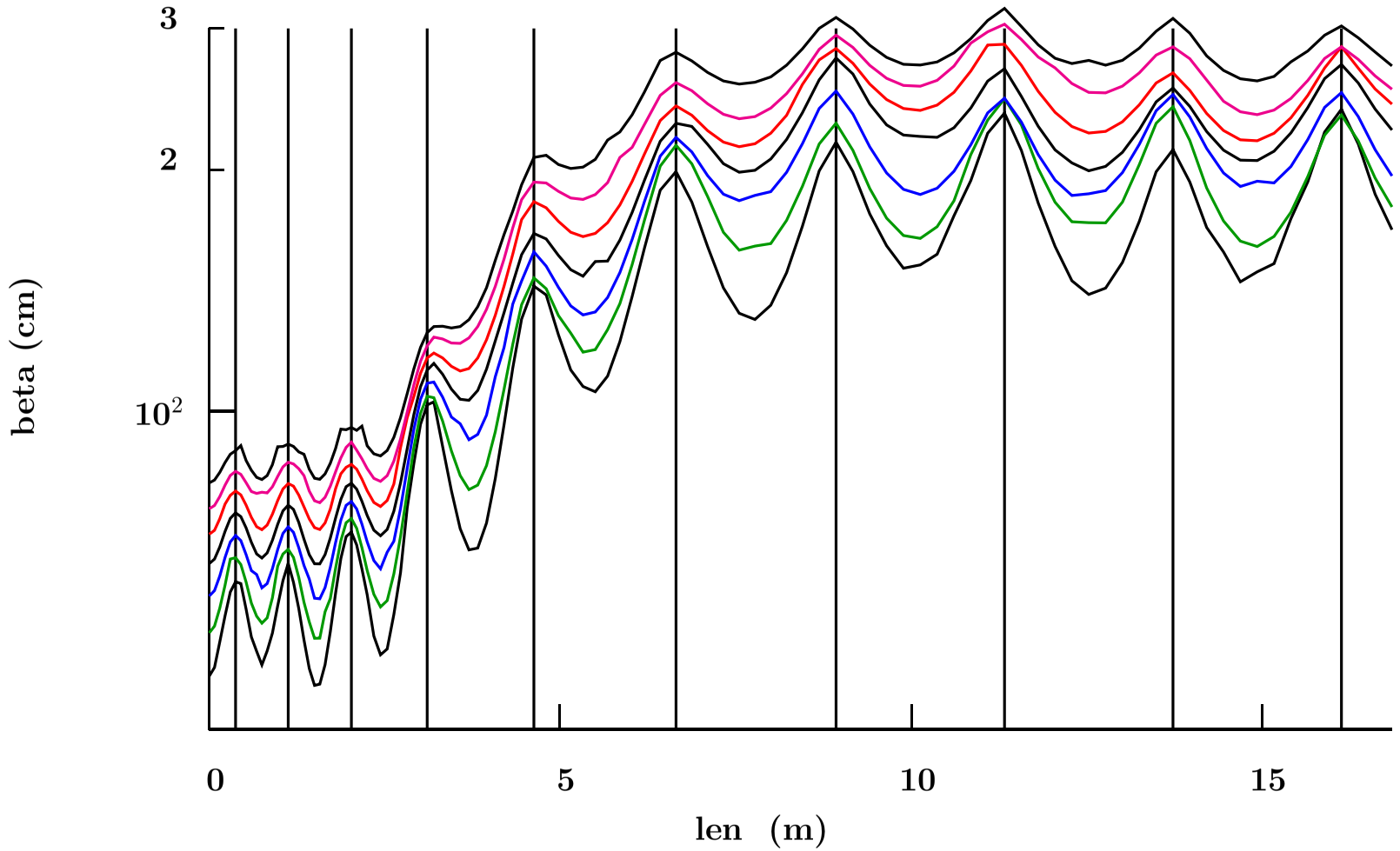
Matching from Study 2a Cooling to Linac

Transverse match at multiple moment

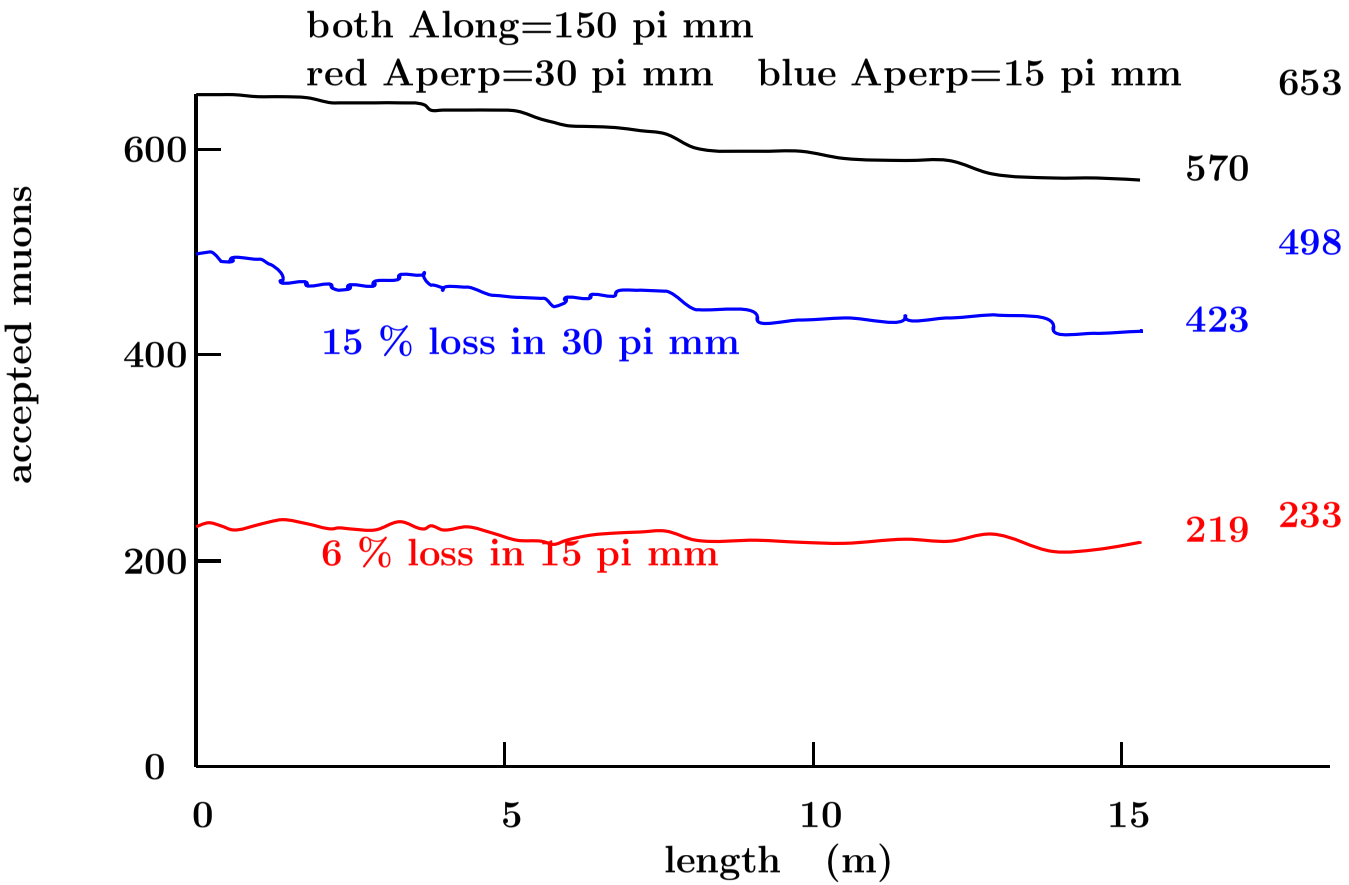
But at small amplitude

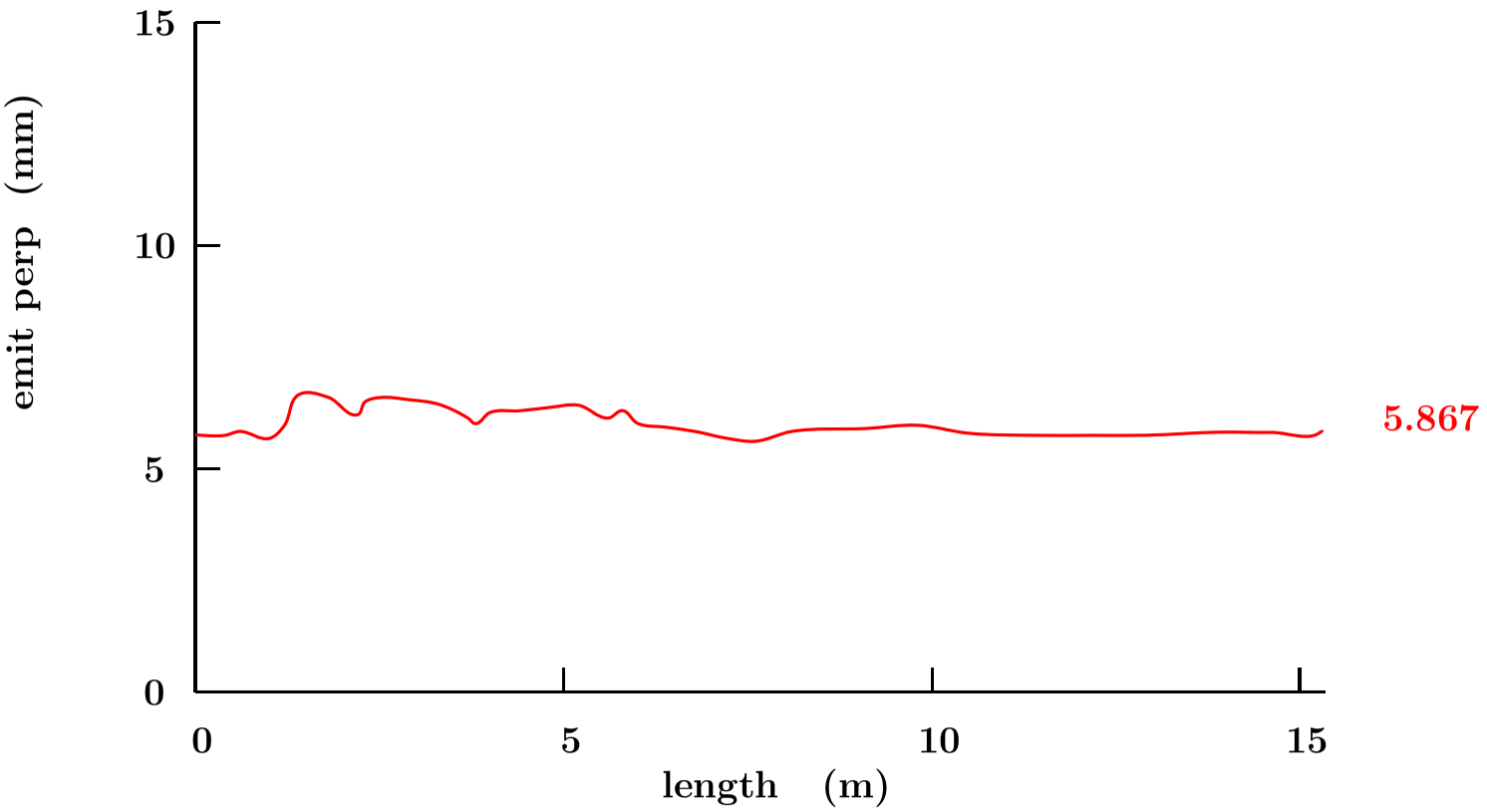



Bz (T)
2
0
-2
0
5
10
15
length (m)


3
2
10^2
beta (cm)
0
5
10
15
len (m)

Track particles from ICOOL sim of Cooling



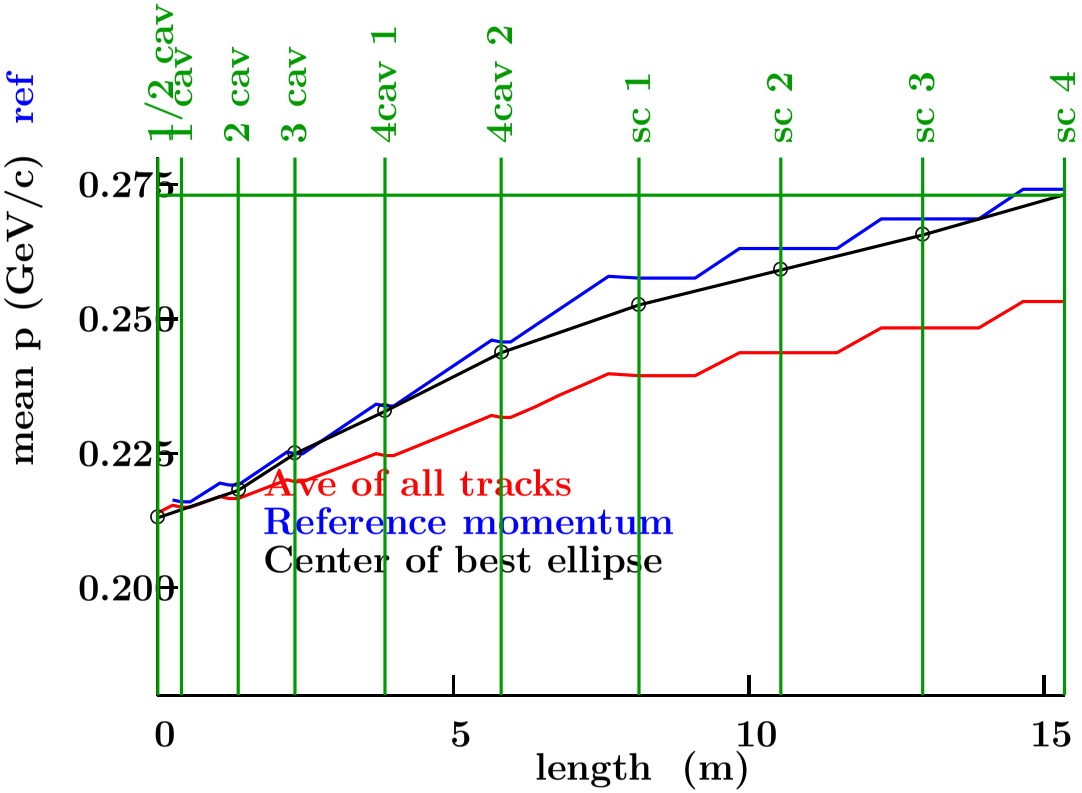


Significant loss and some initial emittance growth

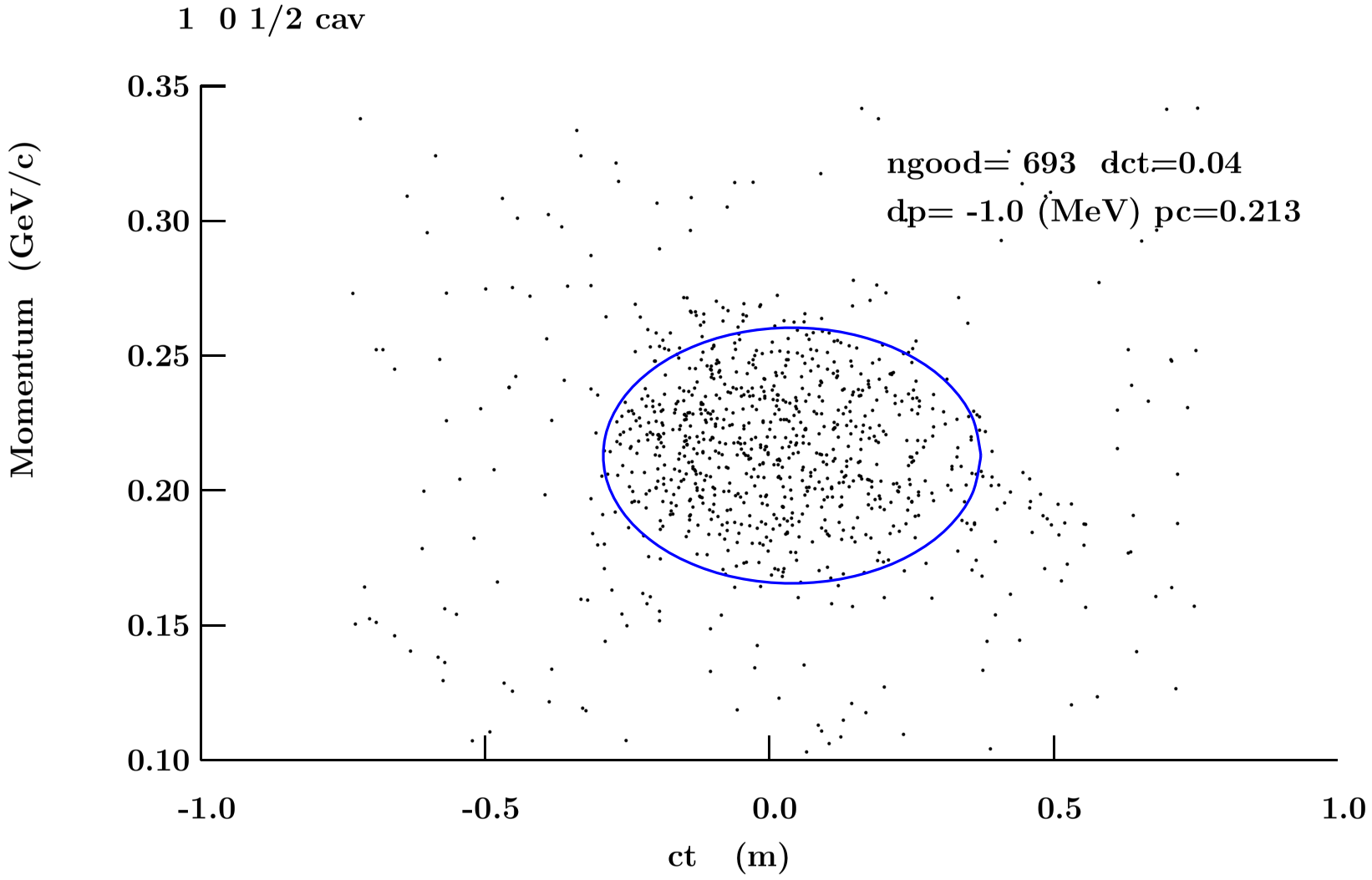
Suggests matching should be done at large amplitude

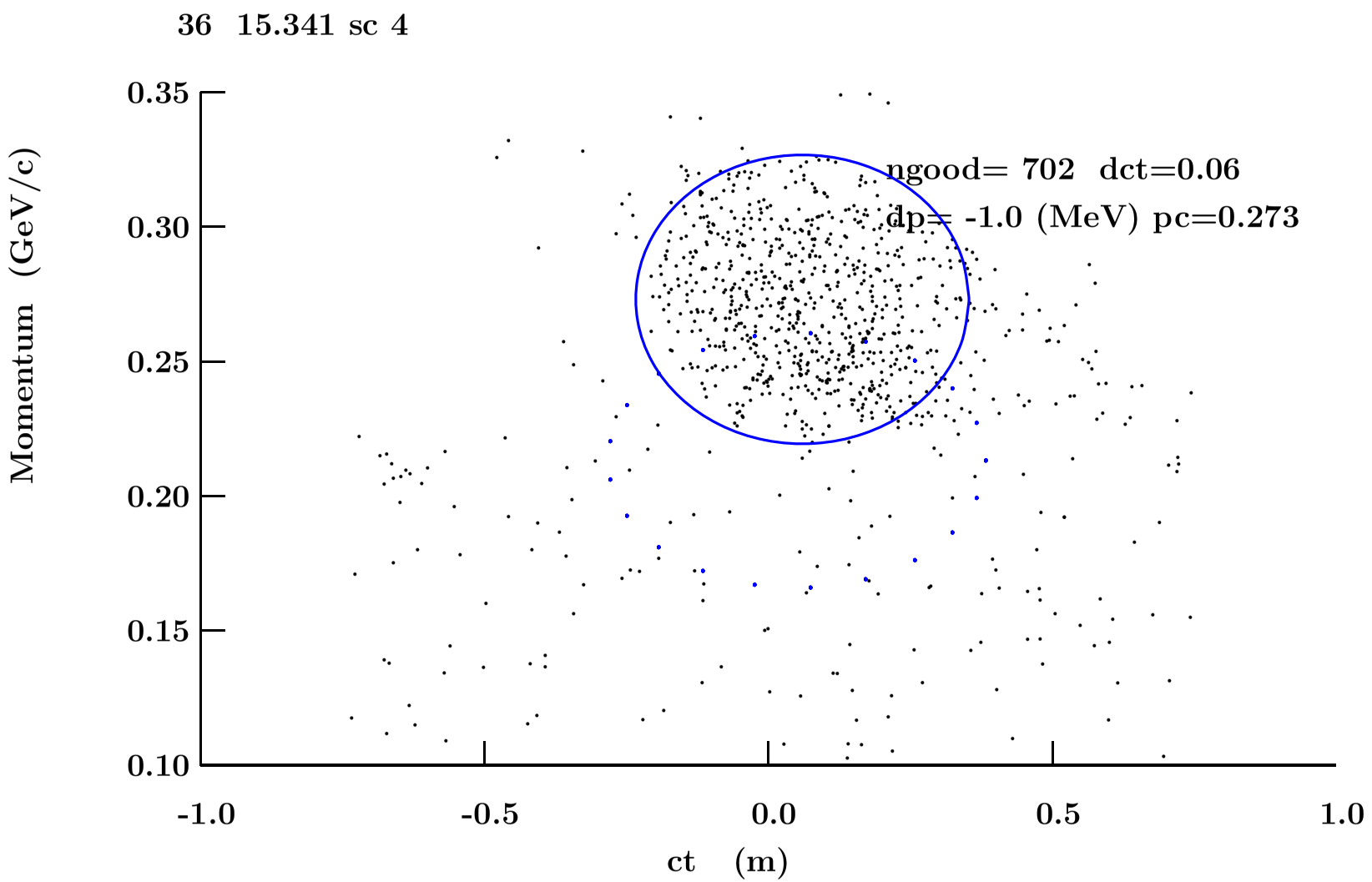
Longitudinal Match at large amplitude

- Early attempts matched small amplitude ellipses but gave significant loss of particles extrnding to 150 pi mm
- Now matching at the 150 pi mm boundary
- adjusting boundry phase and mom for maximum capture

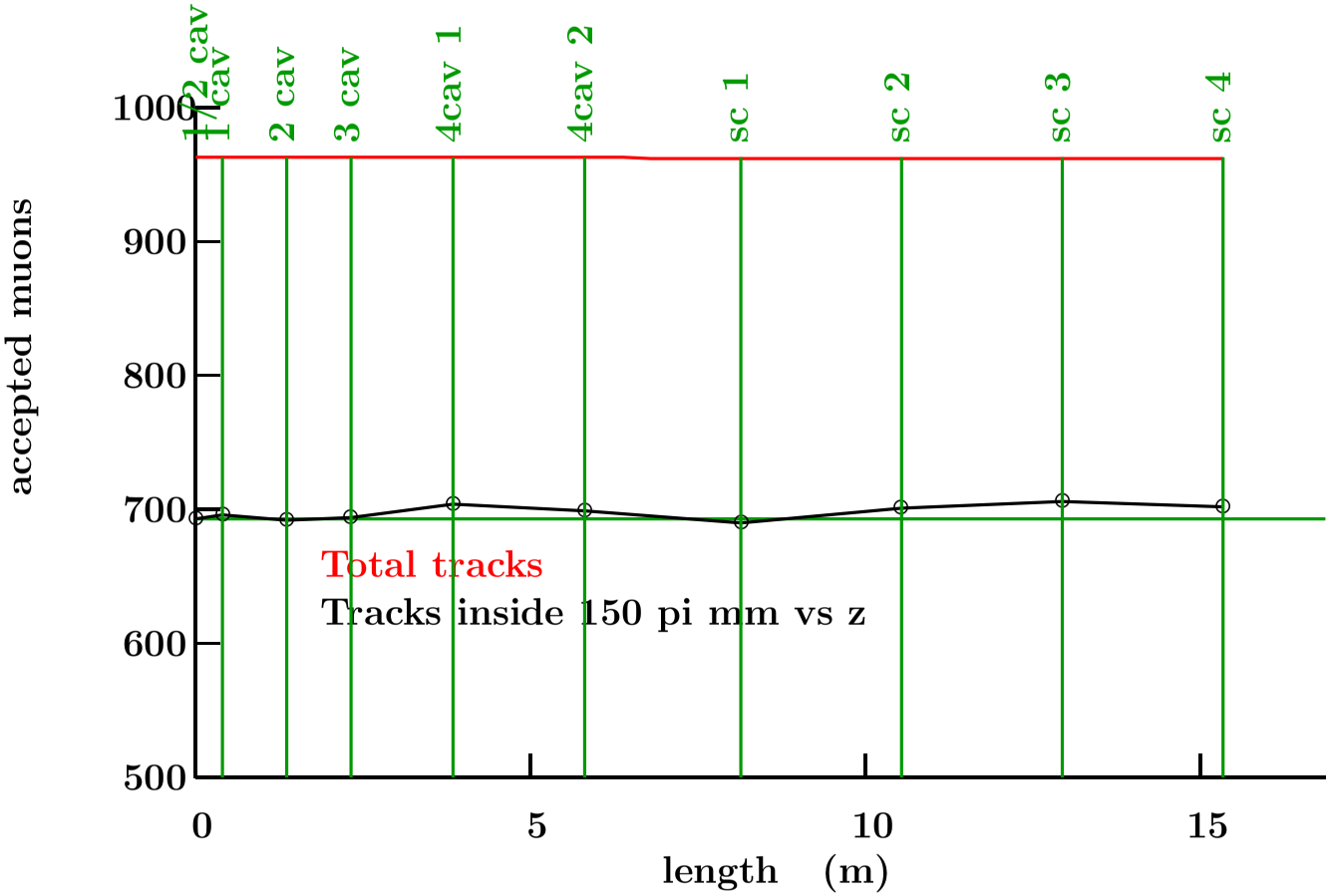


Longitudinal Phase Plots




36 15.341 sc 4
ngood= 702 dct=0.06
dp= -1.0 (MeV) pc=0.273
Momentum (GeV/c)
0.35
0.30
0.25
0.20
0.15
0.10
-1.0
-0.5
0.0
0.5
1.0
ct (m)

Now no loss of tracks in 150 pi mm cut



Conclusion on Match

- If acceptance of tracks is criteria, then matching should be done at the acceptance boundaries
- This was done successfully for longitudinal match
- Has yet to be tried for Transverse match