

# Study IIa FFAG Simulations

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Version for FFAG Workshop  
Triumpf 4/21/04

- Introduction
- Fit end fields from Tosca
- Track with ICOOL with these fields
- Include acceleration
- Conclusion

# Introduction

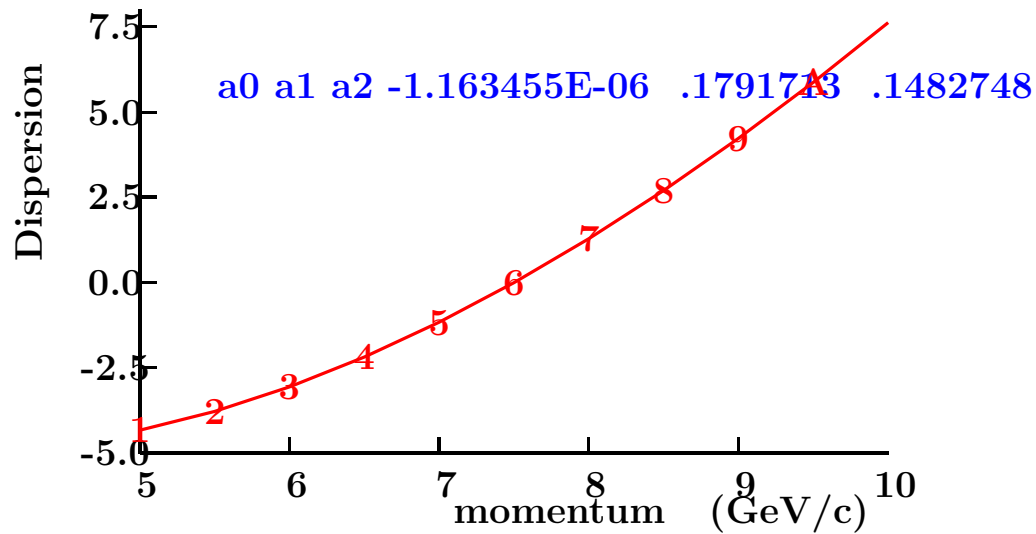
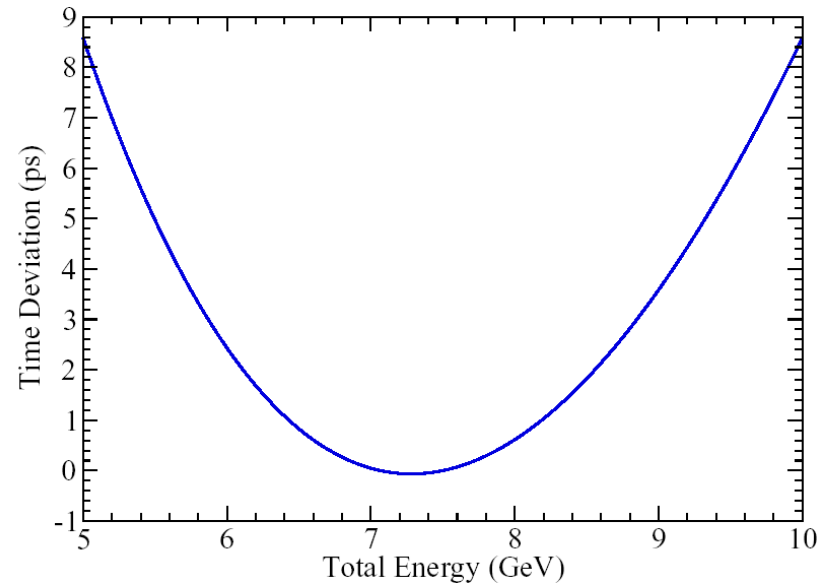
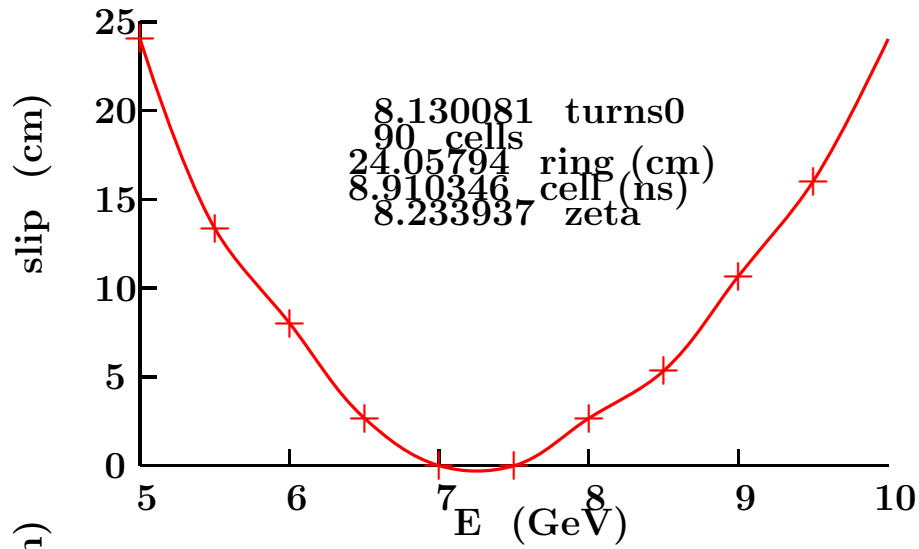
Lattice parameters taken from Scott's Friday 27 Feb talk

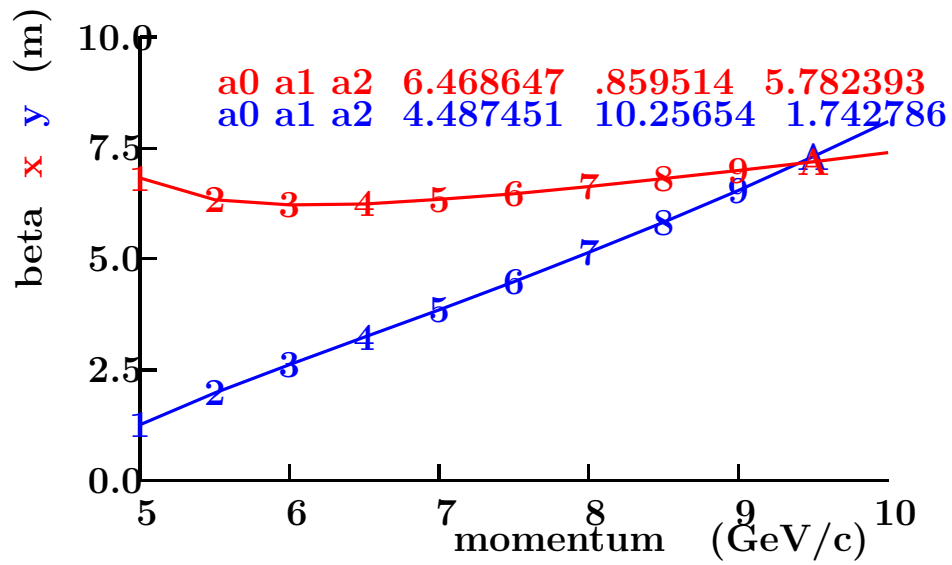
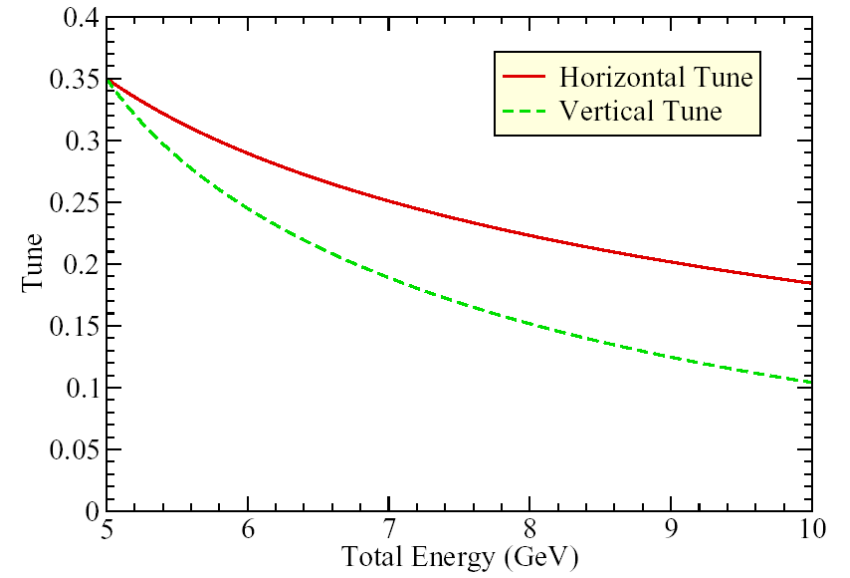
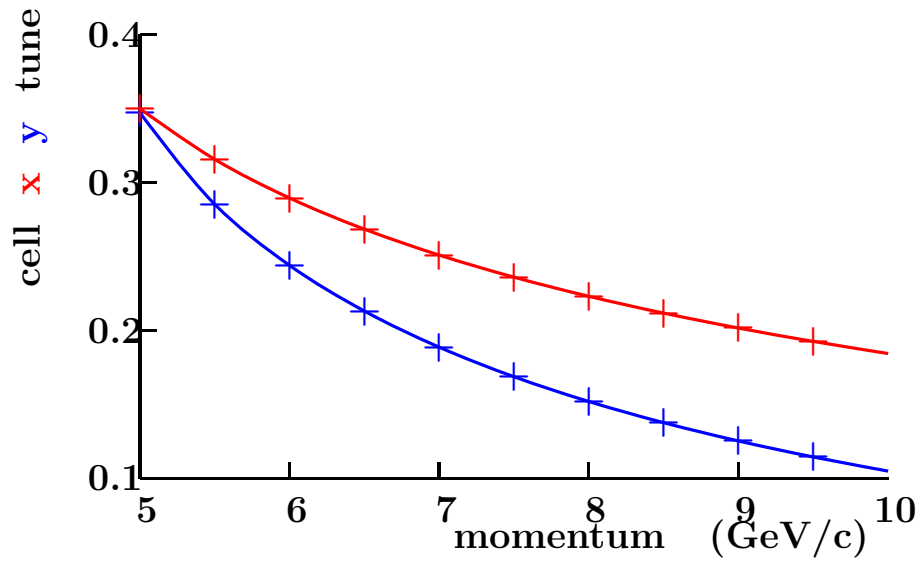
$E_{\min}$ (GeV)	5		10	
$E_{\max}$ (GeV)	10		20	
$V/\omega\Delta T\Delta E$	1/8		1/12	
$A_{\perp n}$ (mm)	30			
$L_0$ (m)	2			
$L_Q$ (m)	0.5			
$V$ per cell (MV)	7.5			
Empty cells	8			
$\nu_x, \nu_y$ at $E_{\min}$	0.35			
$n$	90		105	
$C$ (m)	606.918		767.953	
$V$ total (MV)	675.0		787.5	
	QD	QF	QD	QF
$L$ (m)	1.612338	1.065600	1.762347	1.275747
$\rho$ (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

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

$\zeta = 8$  and  $12$  for  $5-10$  and  $10-20$  respectively

# Small amplitude hard edged ICOOL Simulation 5-10 GeV

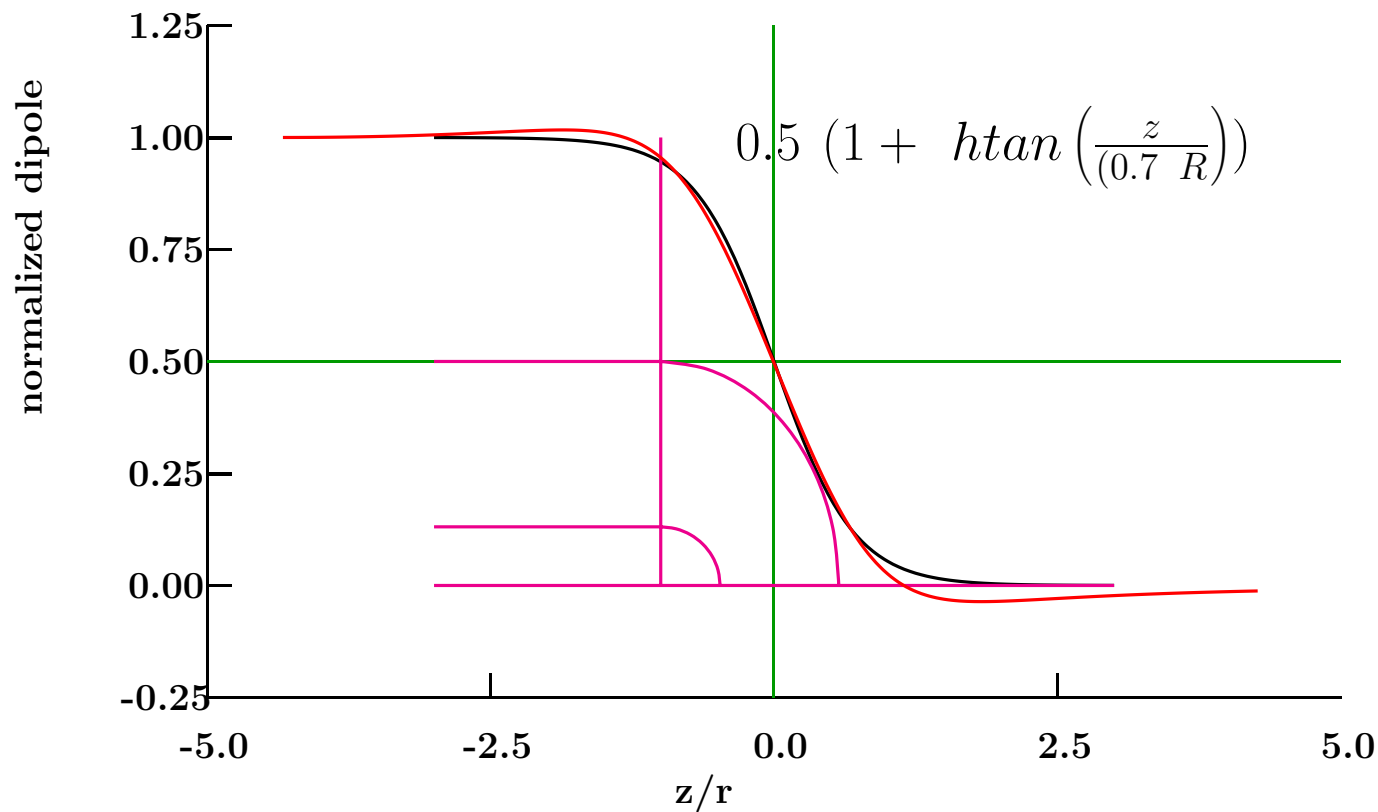




# Ends

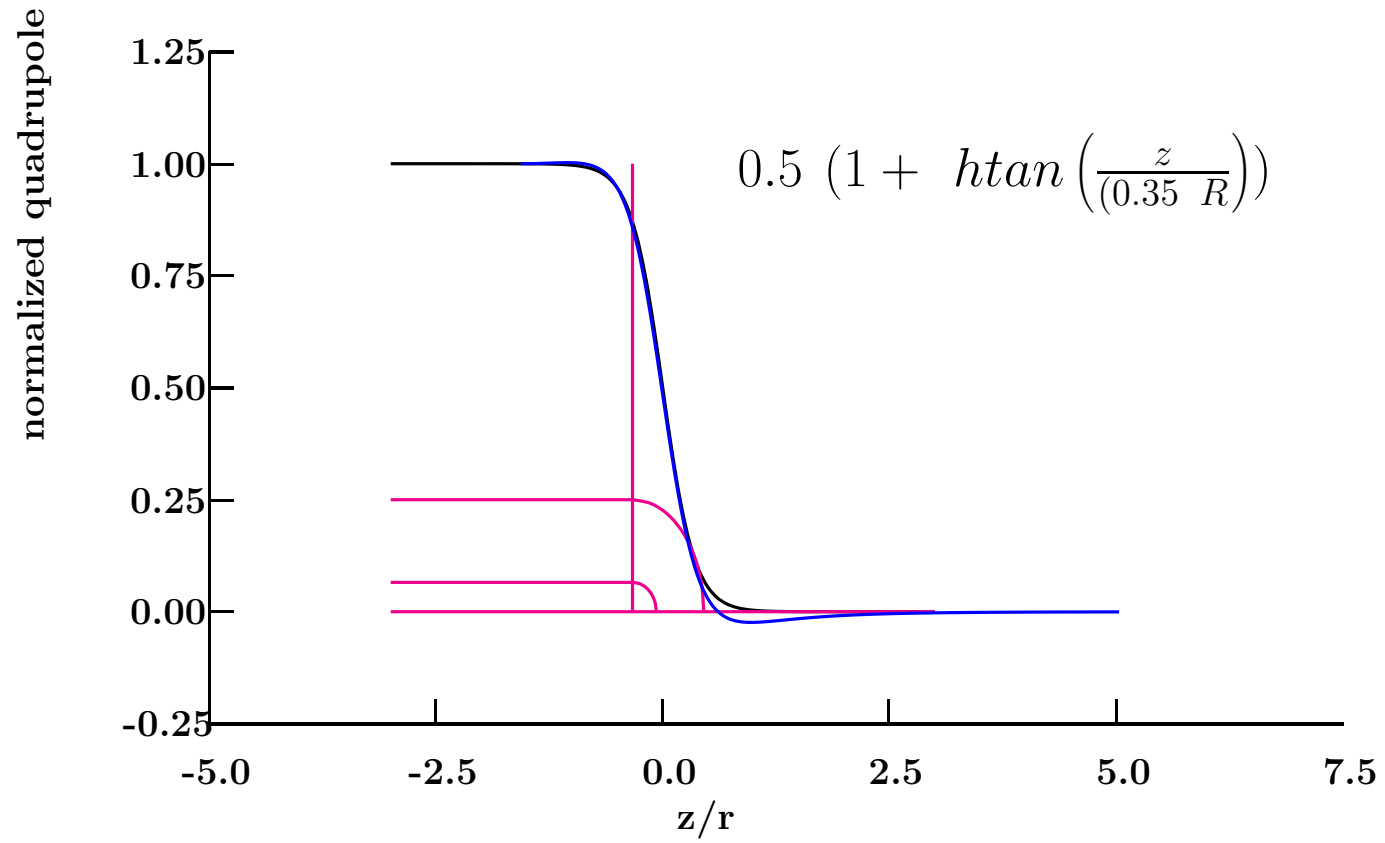
From TOSCA calculation of cos theta magnet (without iron)  
Iron is expected to remove the overshoots

Fit as shown

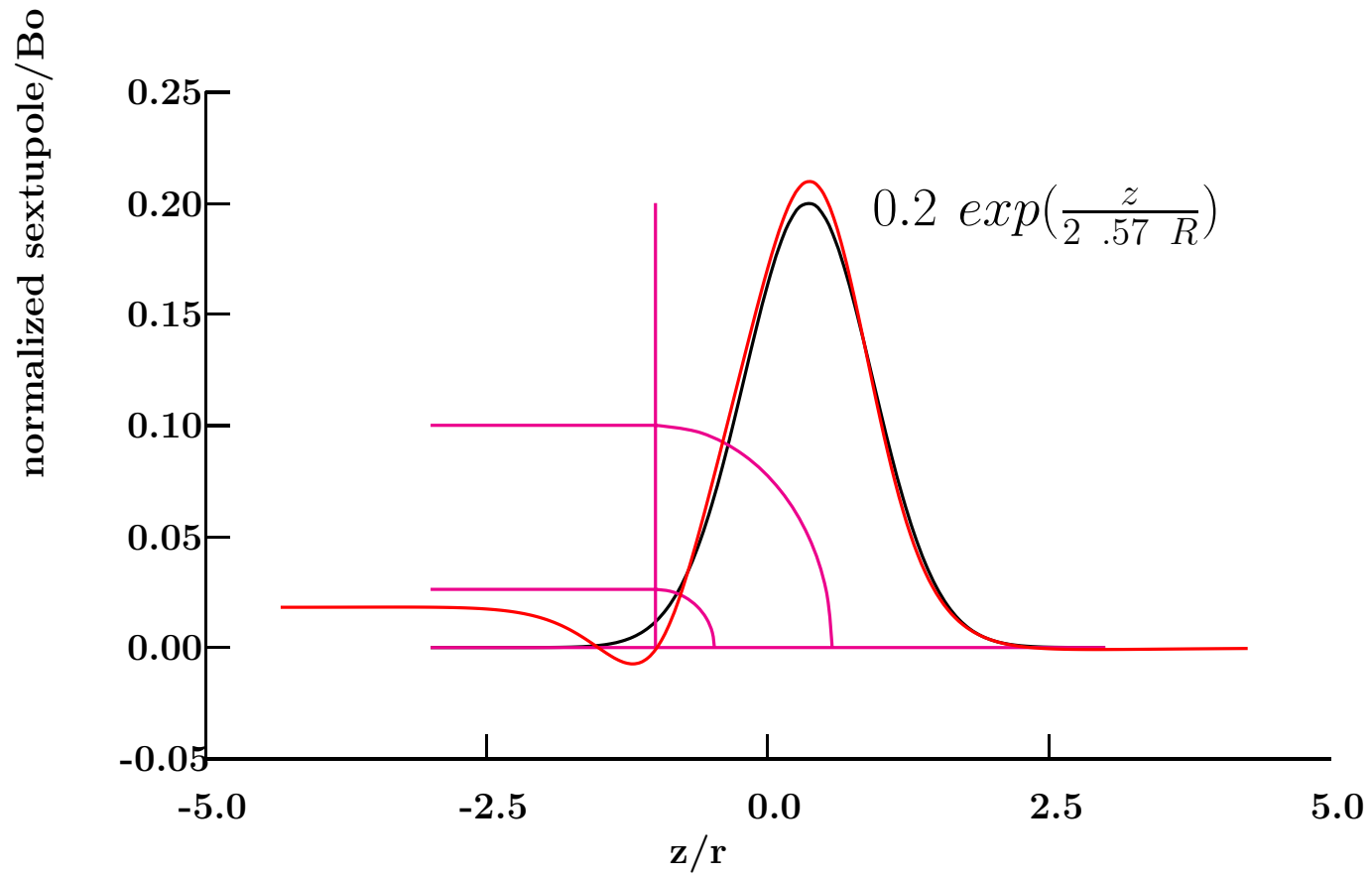


Coil extends little beyond effective length

# Quads Fall off twice as fast

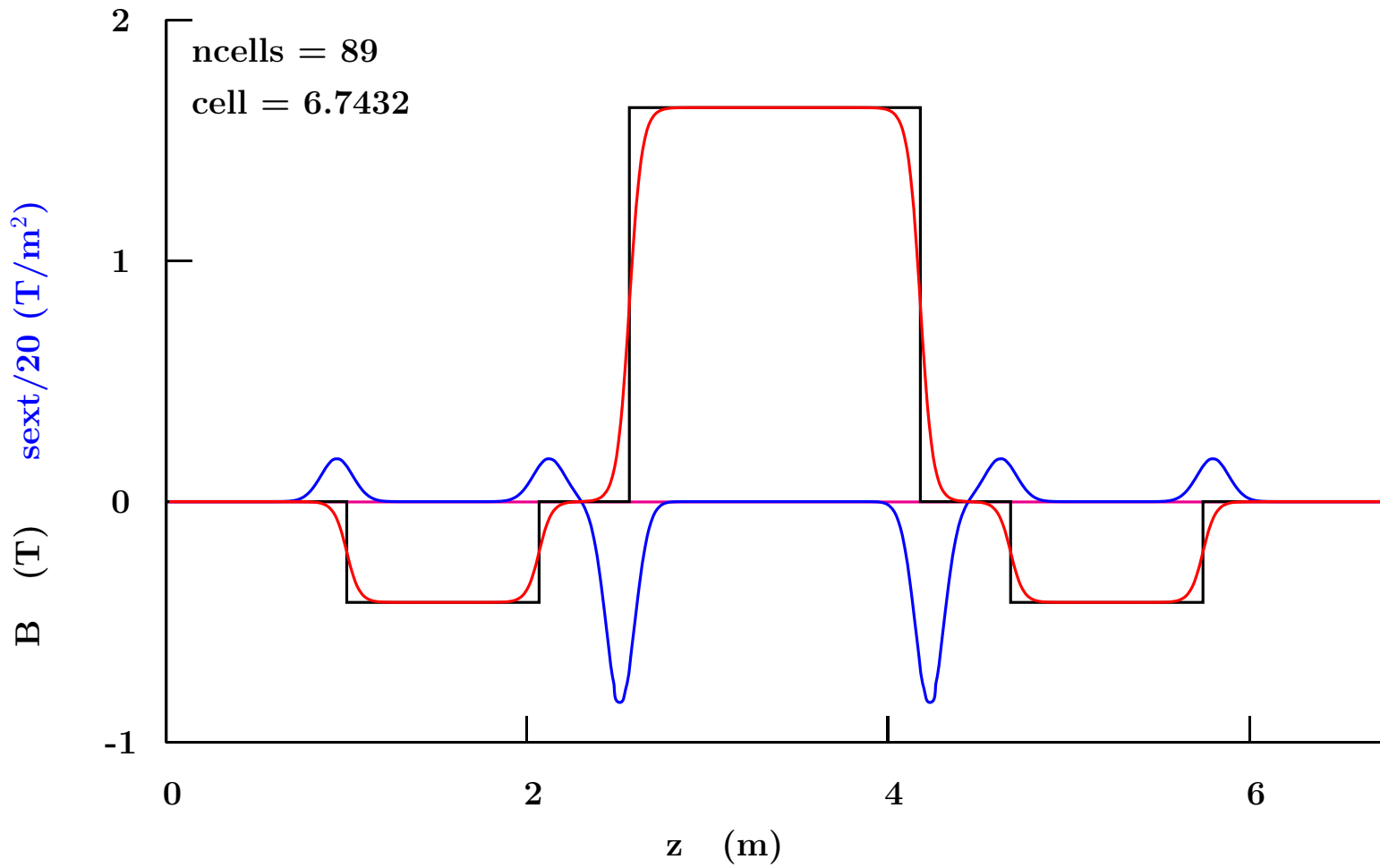


## Sextupole peaks at very end



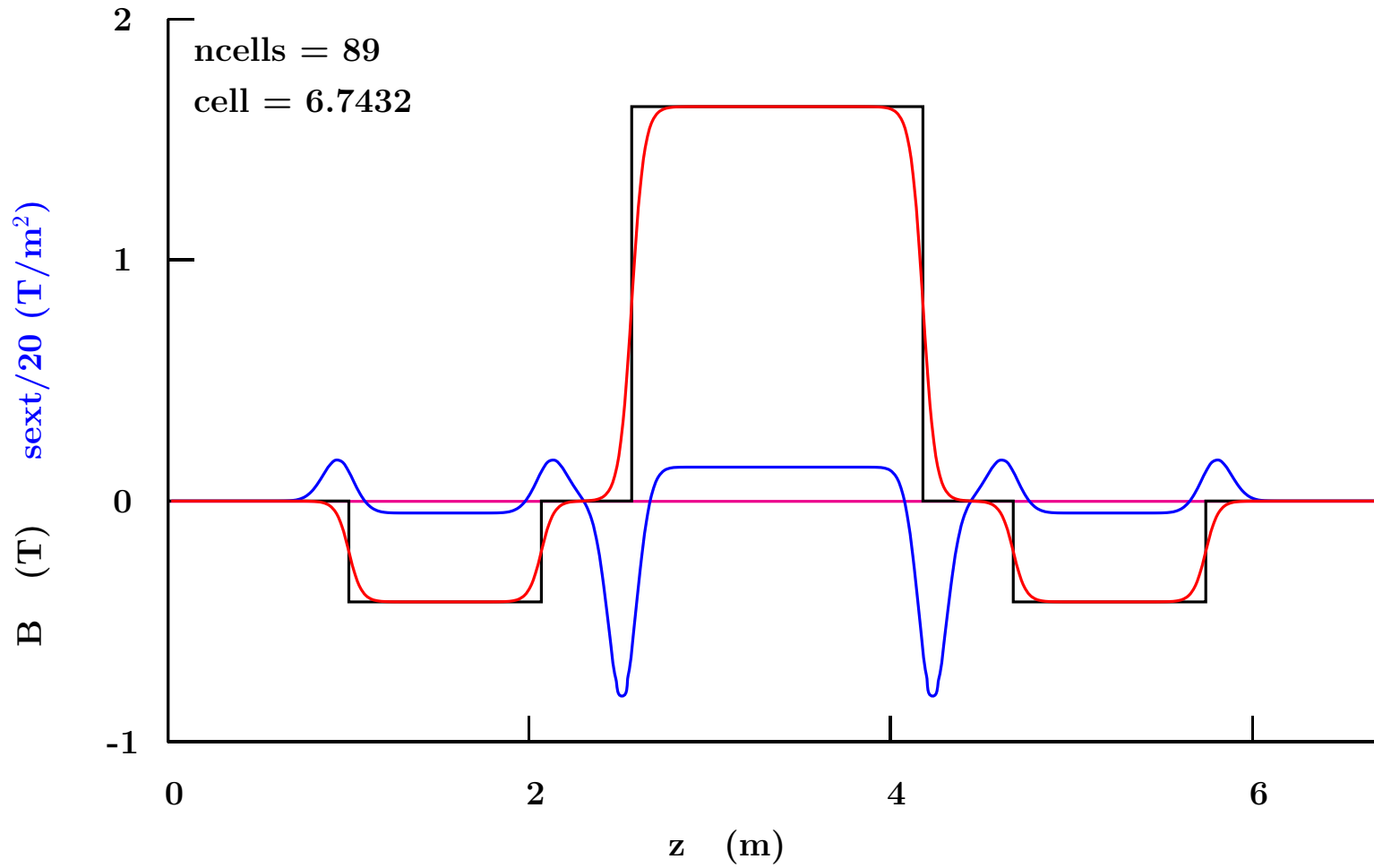
# 5-10 GeV Lattice

Without body sextupoles





## With body sextupoles



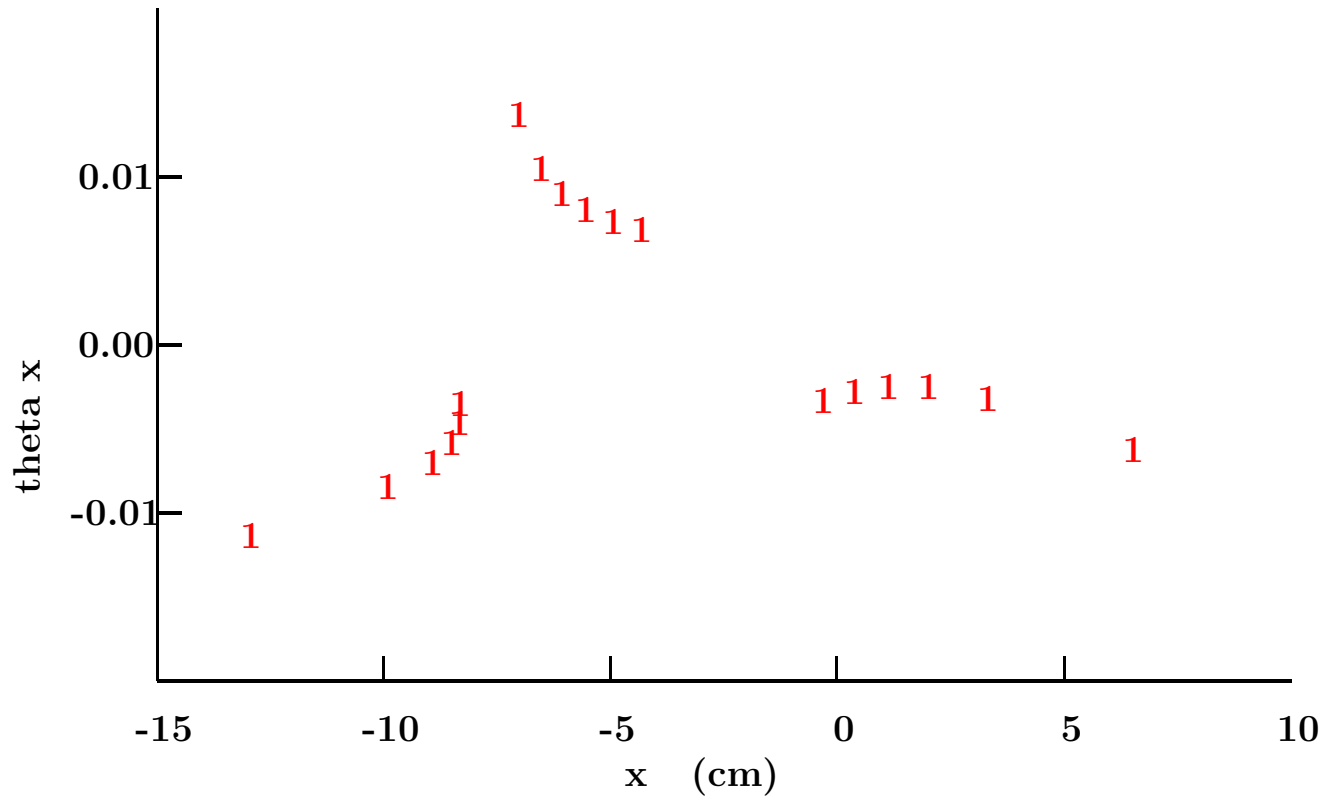
## ICOOL Tracking

- ICOOL uses 'transport coordinates'
- Allows fields to be described by sums of  $s$  dependent multipoles about reference (closed at a ref momentum) orbit
- In particular, the  $s$  dependence can be given as a Fourier sum **This eliminates discontinuities between cells and can include overlaps of fields from neighbours**
- ICOOL calculates Maxwellian fields at all off reference orbit locations from the above description on the orbit
- Off momenta are not approximated
- with the end sextupoles removed, xy mixing is observed, but no prominent resonances
- 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 sextupoles through the magnets.

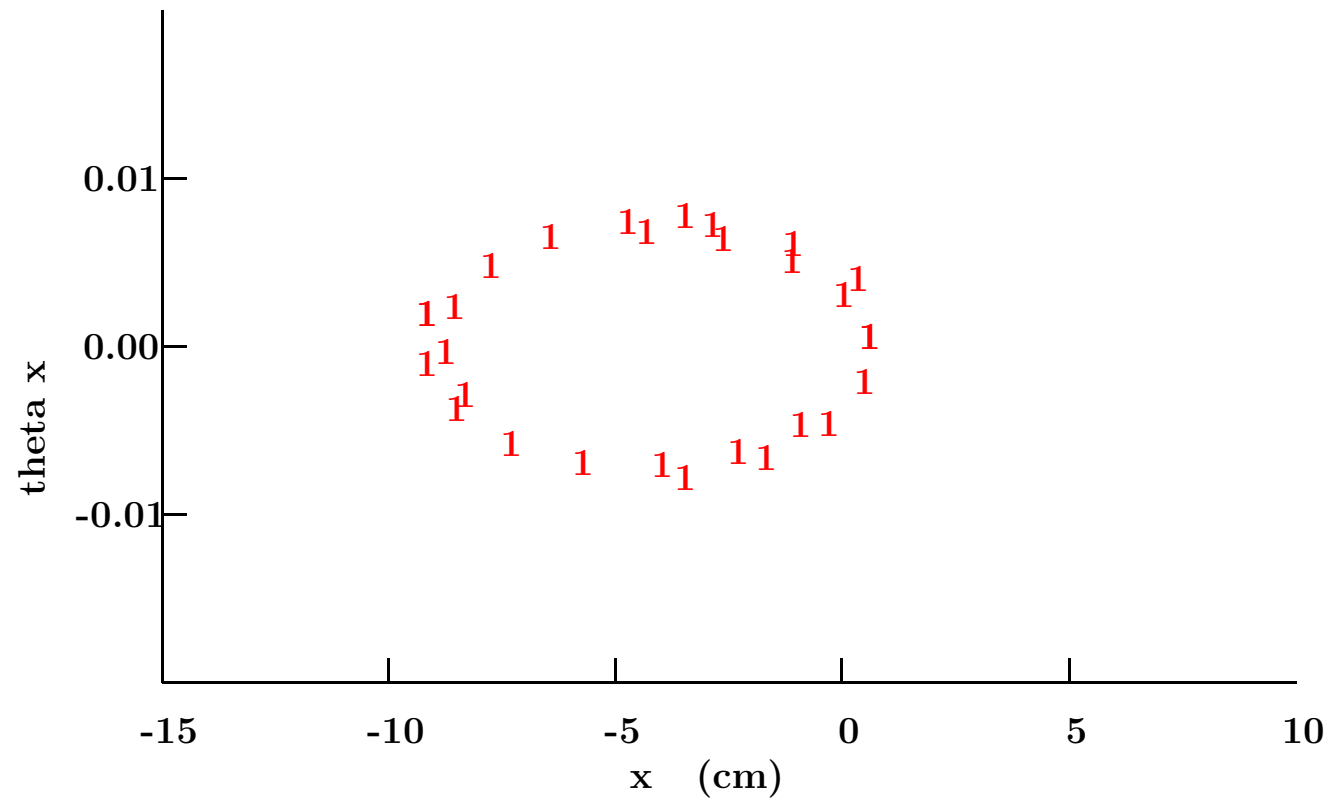
## 3rd order resonance at 5.1 GeV

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

without body sextupoles

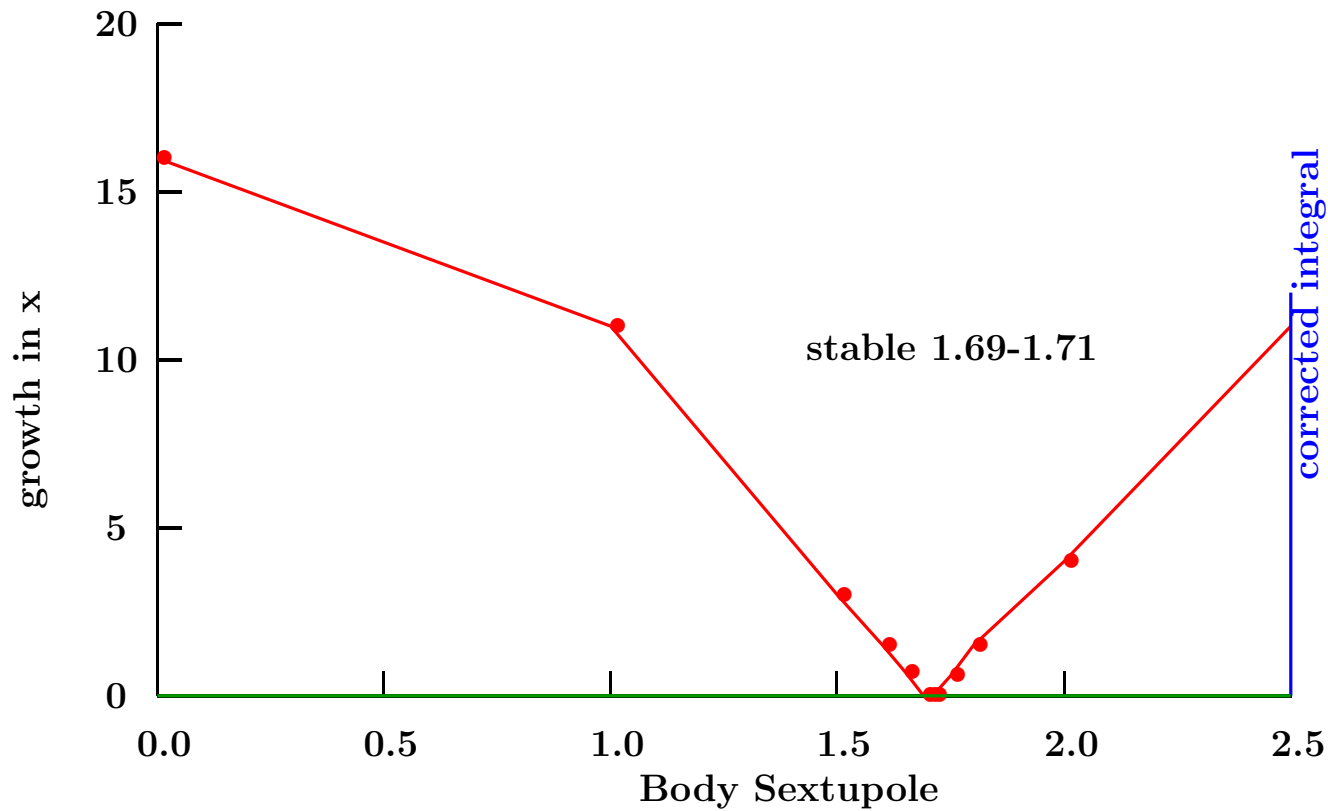


with body sextupoles



# Dependence on body sextupole

Resonance removed with less than correction of integral  
No need to adjust F and D separately

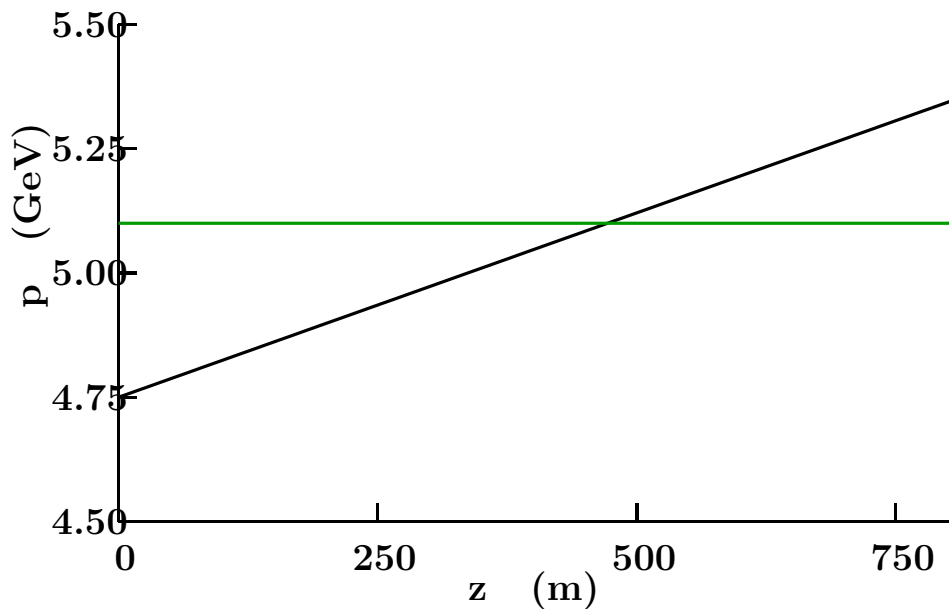


# Add Acceleration

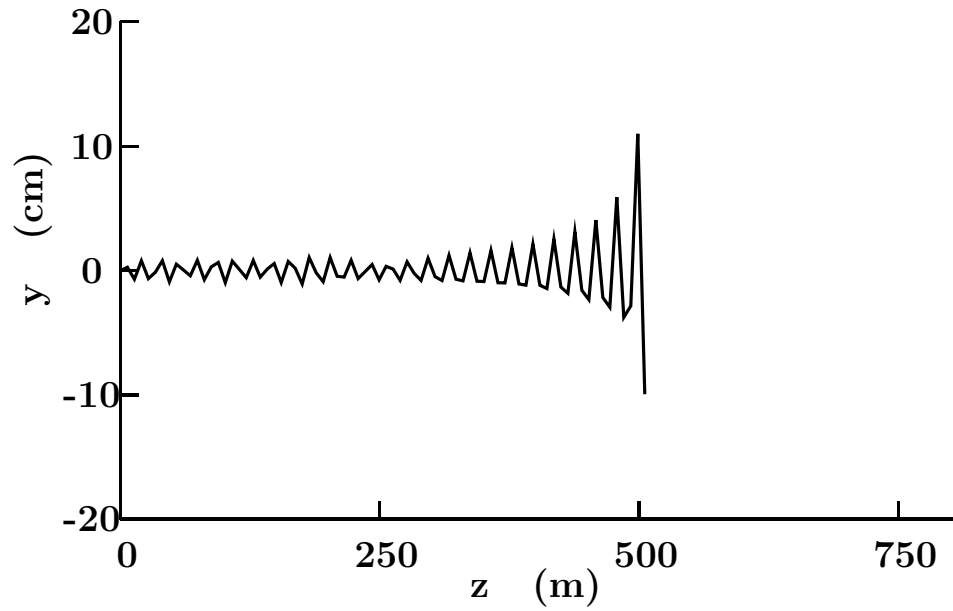
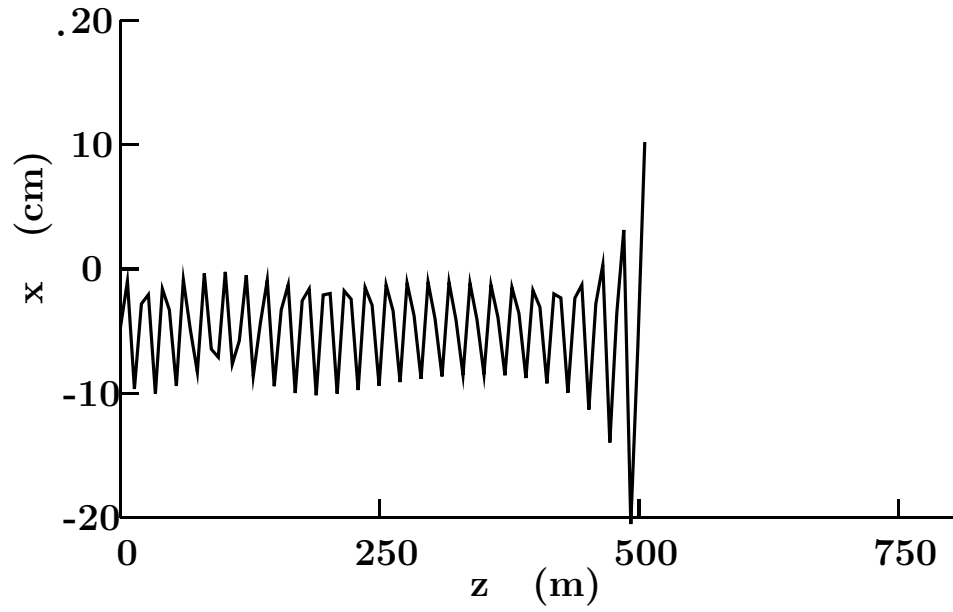
Zero Frequency 10 MV/cell

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

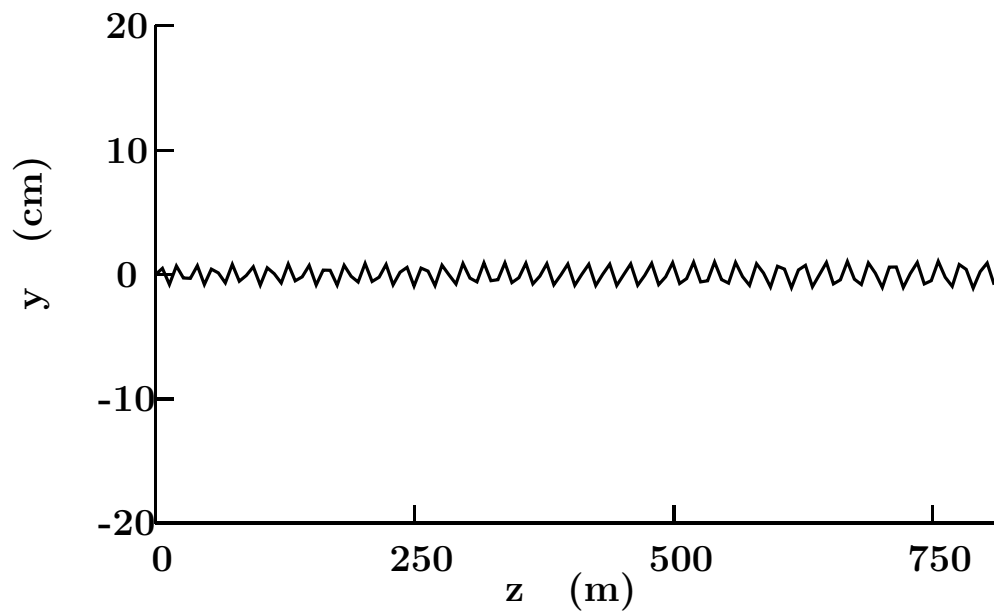
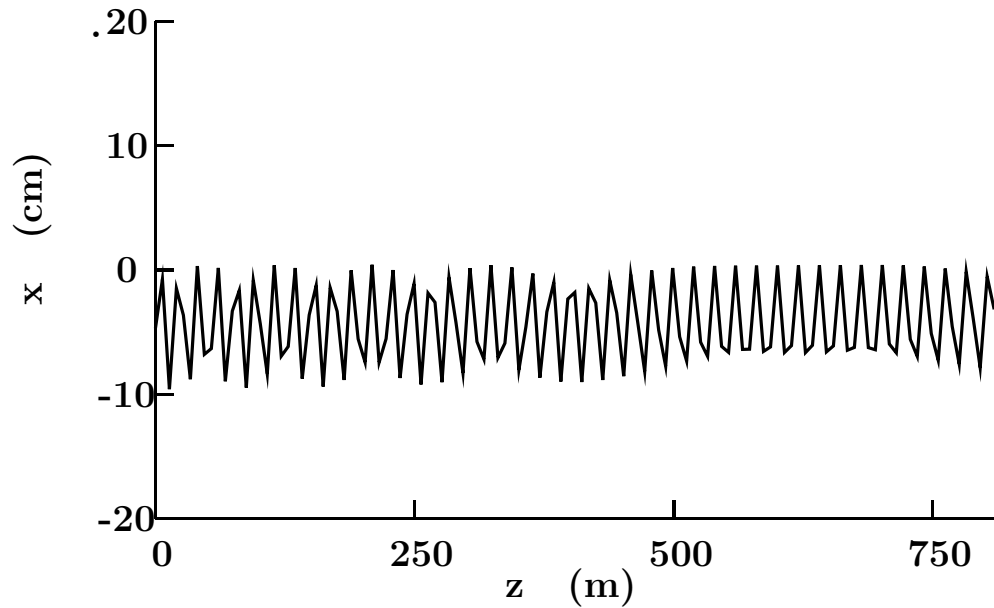
Accelerate accross resonance (4.75 to 5.25 GeV)



# without body sextupoles



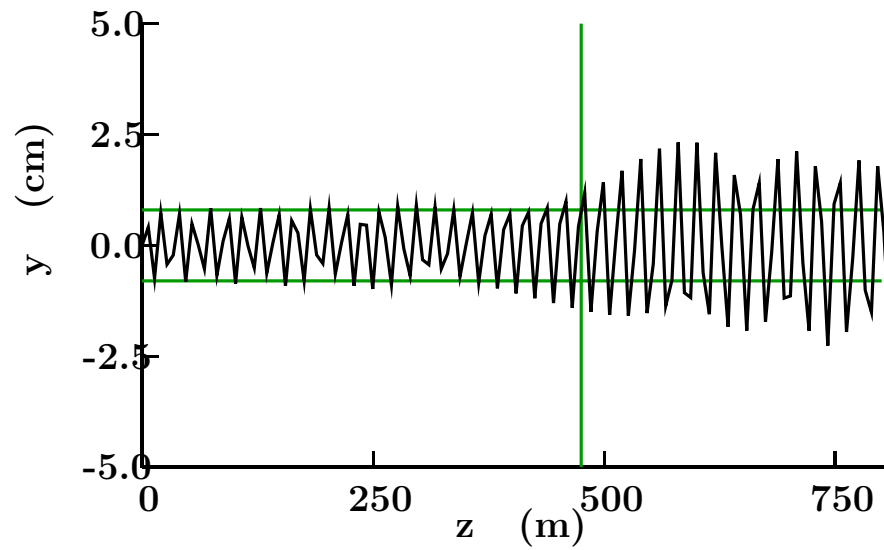
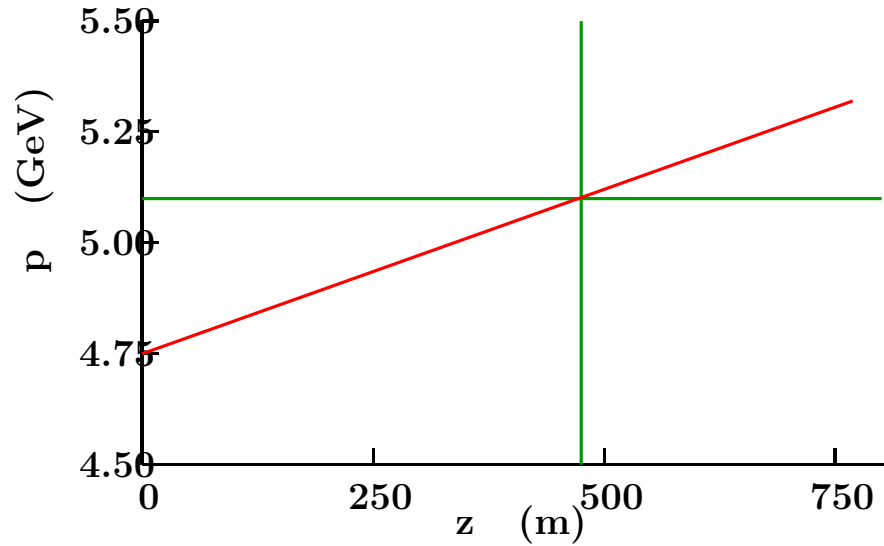
# with body sextupoles





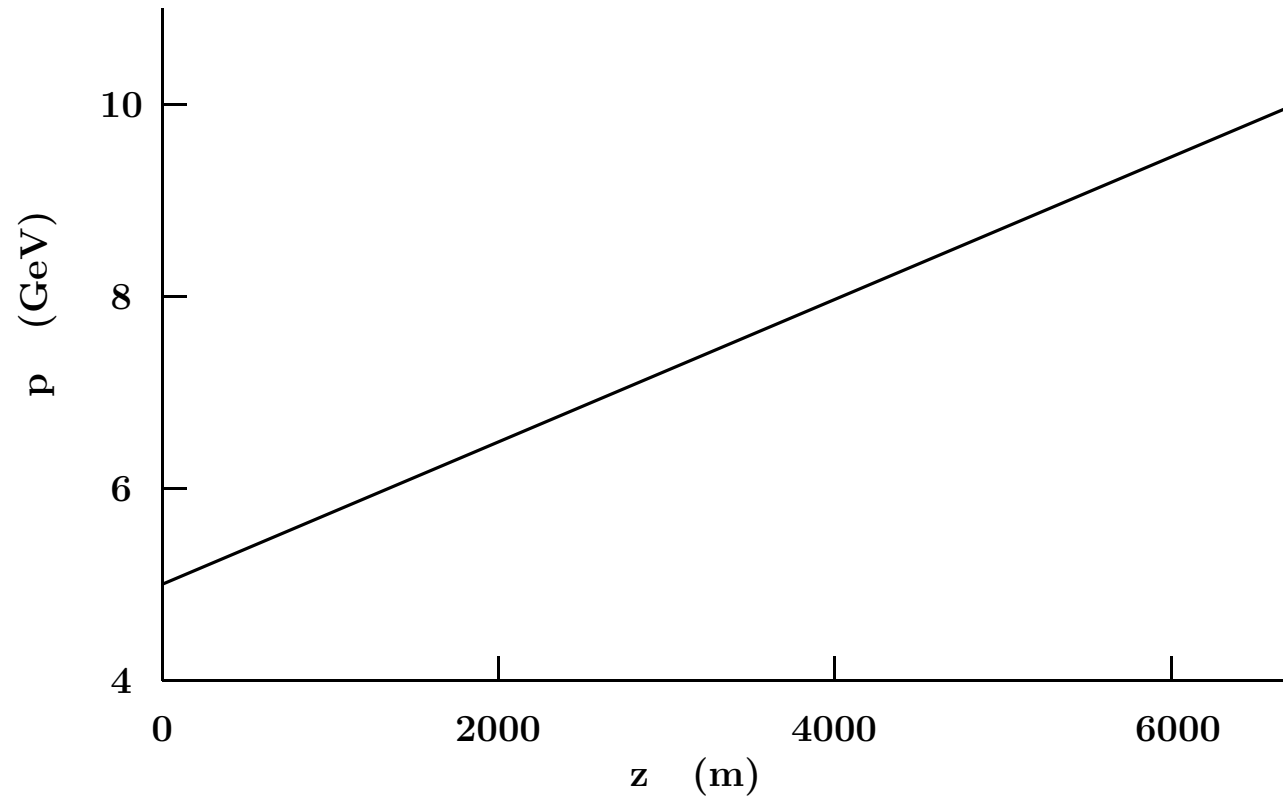
# Partial Correction (-1 vs -1.7)

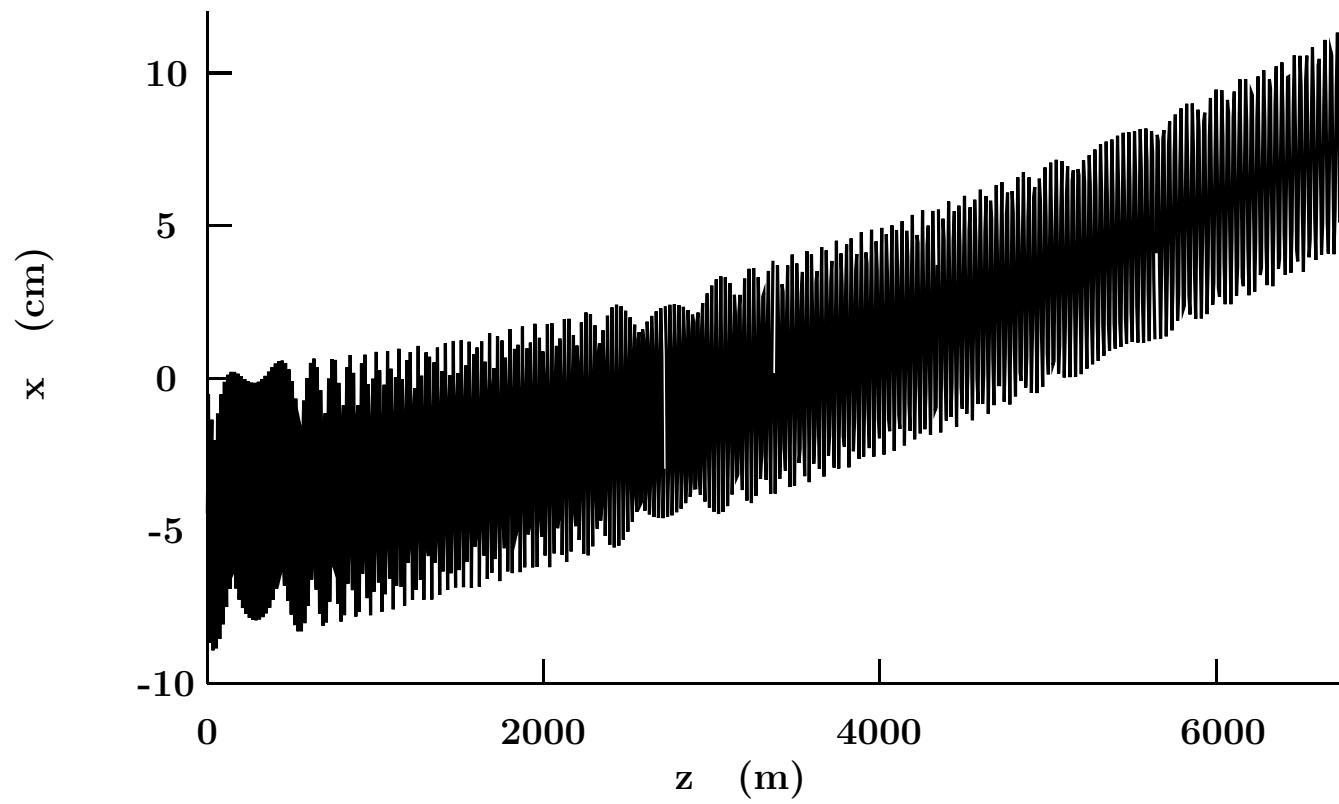
Inject single particle at edge (in x and y) of 30 pi mm

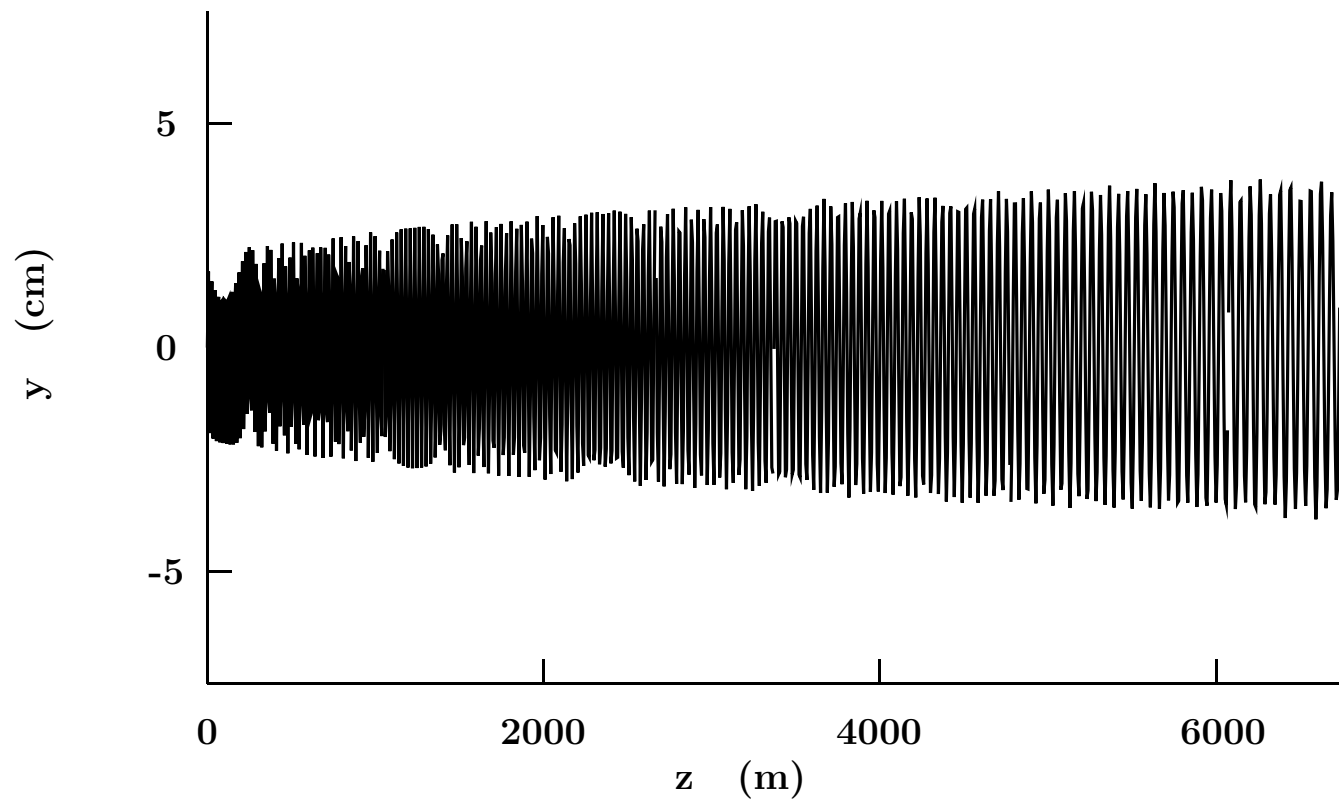


## Acceleration 5 to 10 GeV

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





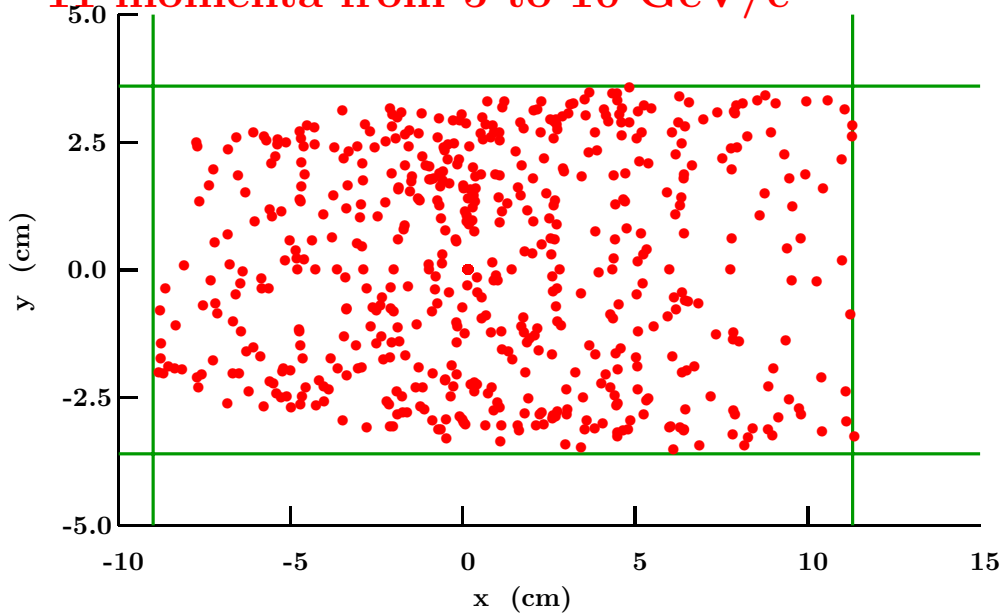


# Emittance Growth

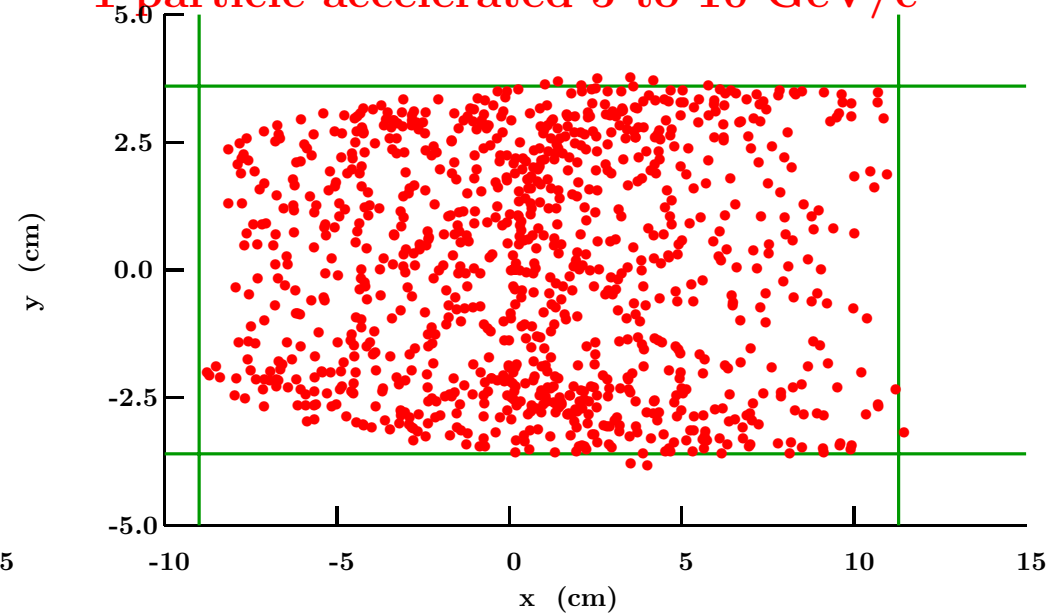
Not yet Calculated

But look at xy plot for 10 fixed energies compared with accelerated particle

11 momenta from 5 to 10 GeV/c



1 particle accelerated 5 to 10 GeV/c



## 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