Study IIa FFAG Simulations

Scott Berg, Steve Kahn, Bob Palmer, Dejan Trbjevic

Version 2 for Video 03/09/04

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- Off-line 1D Longitudinal Distortion Calculation
- Conclusion

Introduction

Lattice parameters taken from Scott's Friday 27 Feb talk

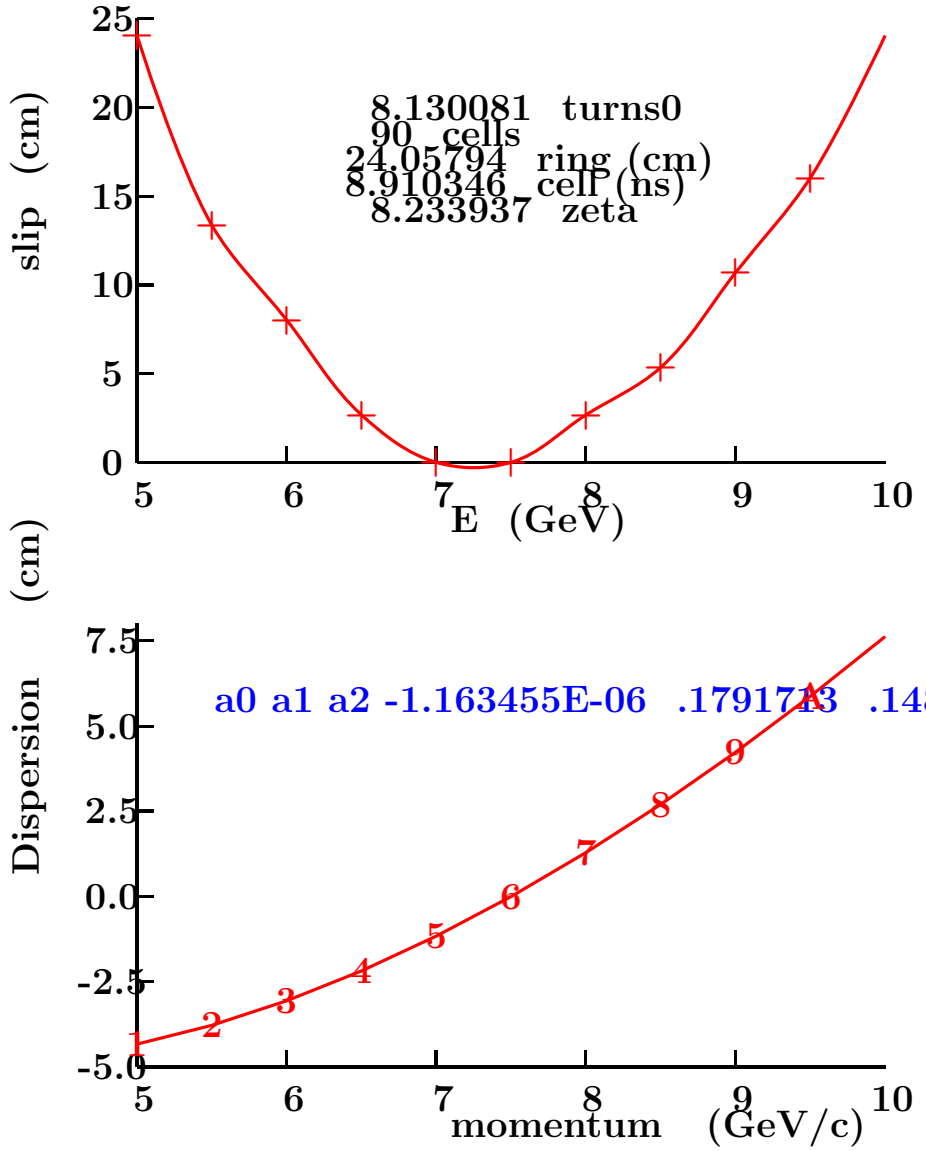
$E_{\min}$ (GeV)	5		10	
$E_{\max}$ (GeV)	10		20	
$V/\omega\Delta T\Delta E$	1/8		1/12	
$A_{\perp n}$ (mm)	30			
L_0 (m)	2			
L_Q (m)	0.5			
V per cell (MV)	7.5			
Empty cells	8			
ν_x, ν_y at $E_{\min}$	0.35			
n	90		105	
C (m)	606.918		767.953	
V total (MV)	675.0		787.5	
	QD	QF	QD	QF
L (m)	1.612338	1.065600	1.762347	1.275747
ρ (m)	15.2740	-59.6174	18.4002	-70.9958
$x_{\rm O}$ (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

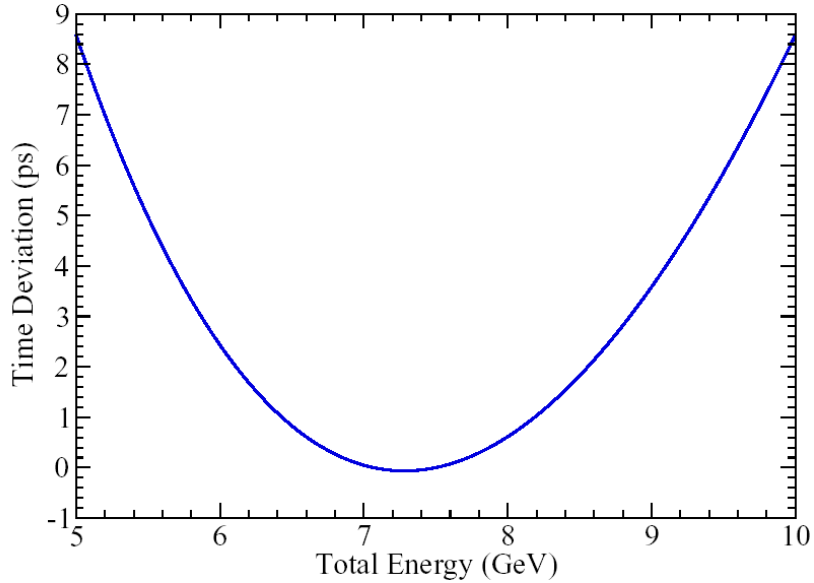
$$\frac{1}{\zeta} = \frac{V}{\omega\ \Delta t\ \Delta E}$$

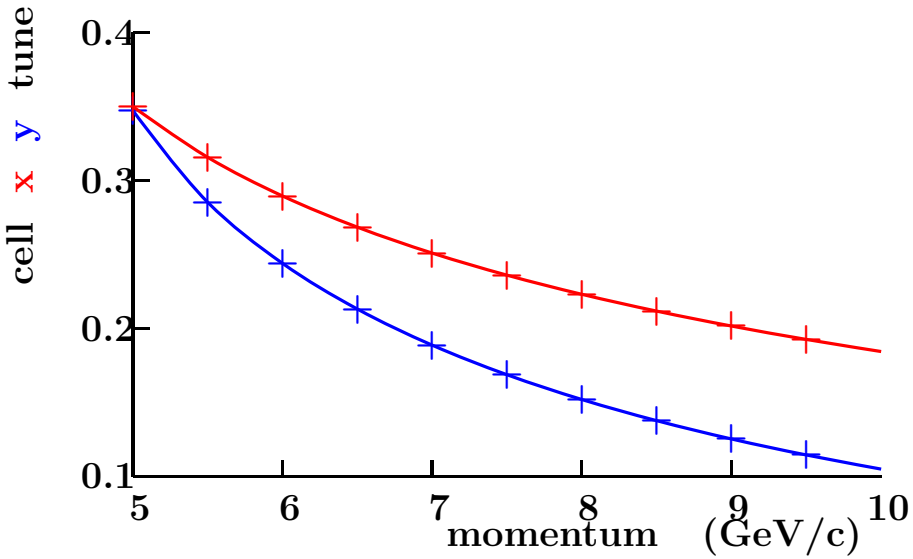
$\zeta = 8$ and 12 for 5-10 and 10-20 respectively

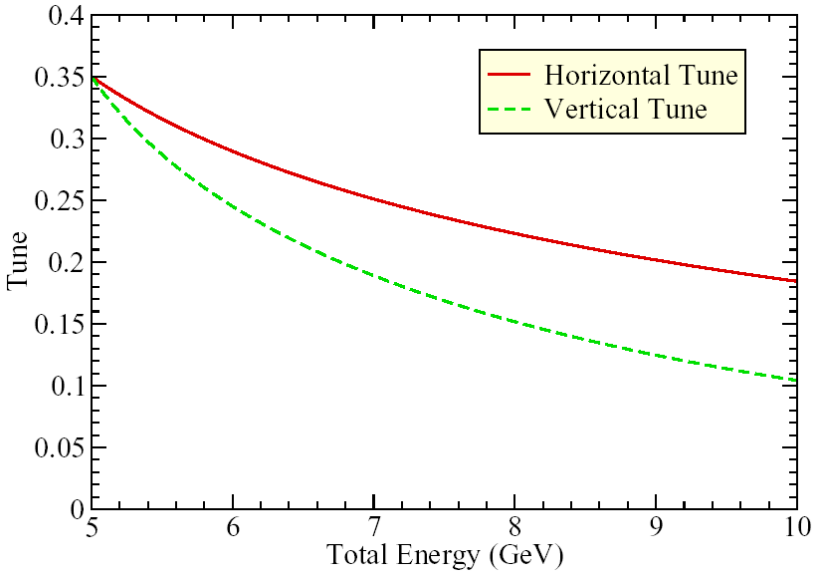
Small amplitude hard edged ICOOL Simulation

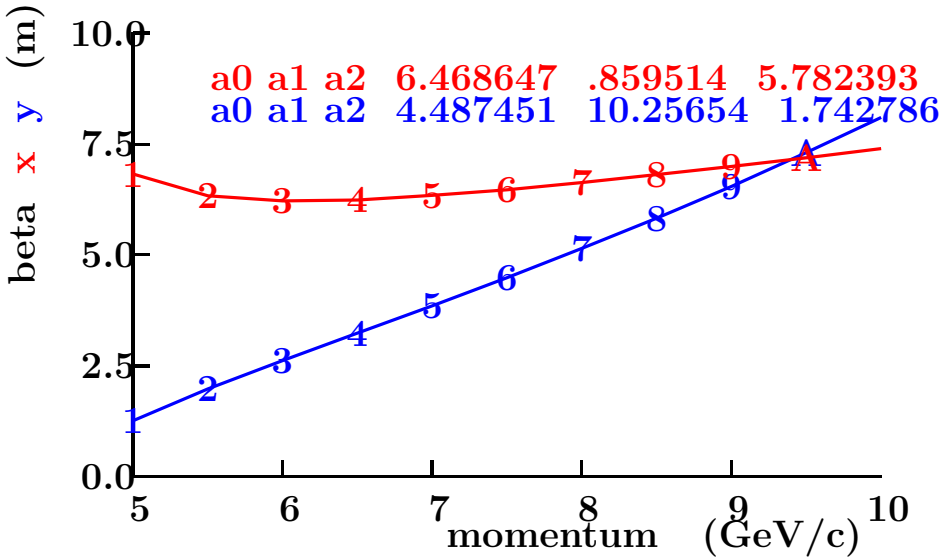
5-10 GeV



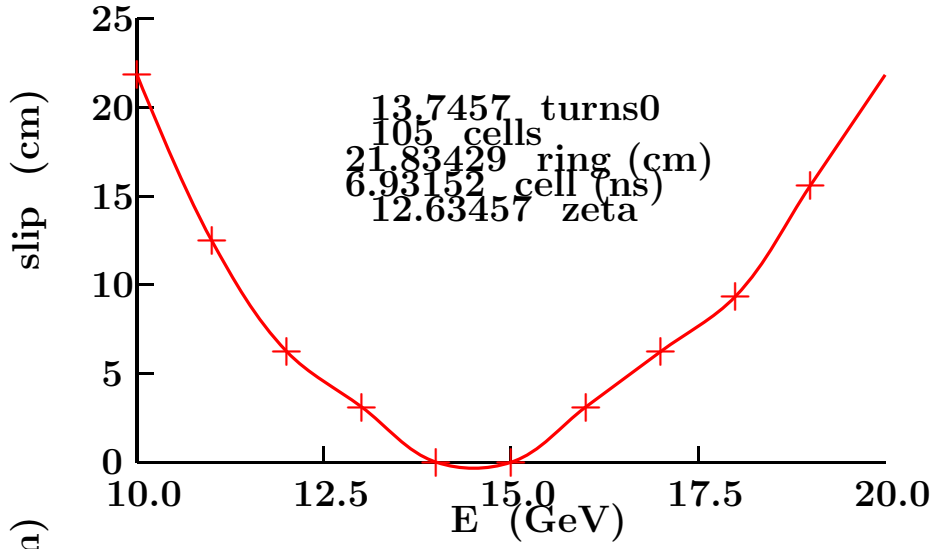


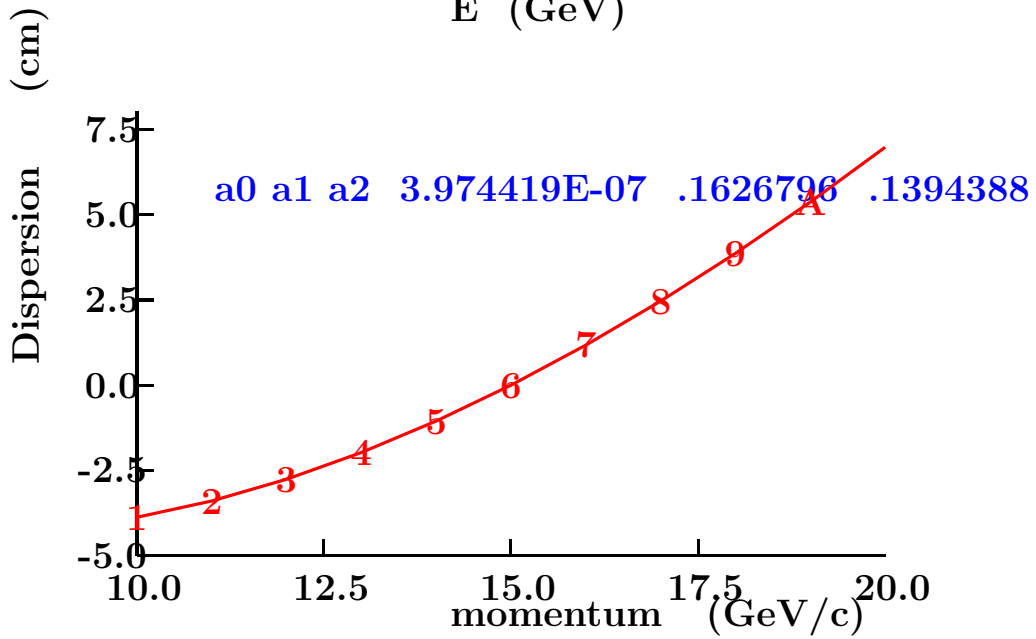

cell x y tune
0.4
0.3
0.2
0.1
5
6
7
8
9
10
momentum (GeV/c)

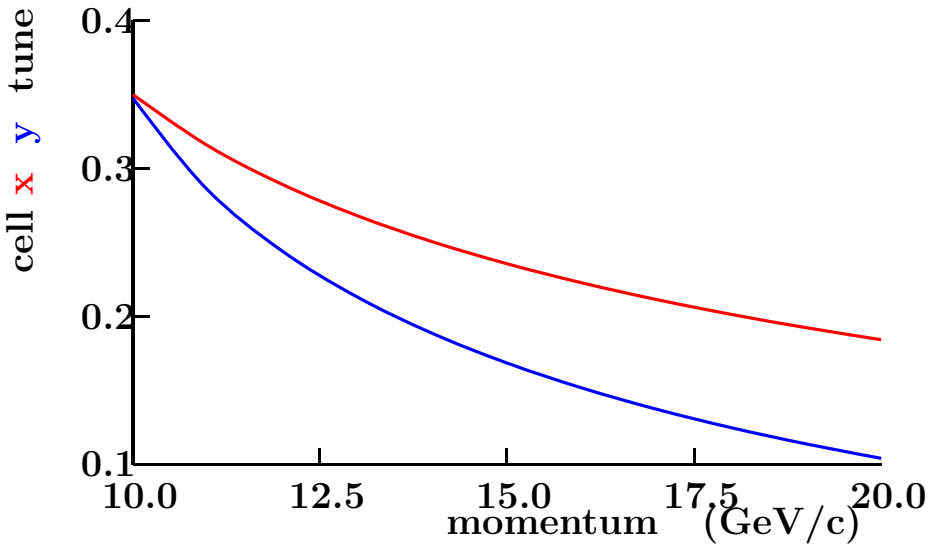

Horizontal Tune
Vertical Tune
Tune
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
5
6
7
8
9
10
Total Energy (GeV)

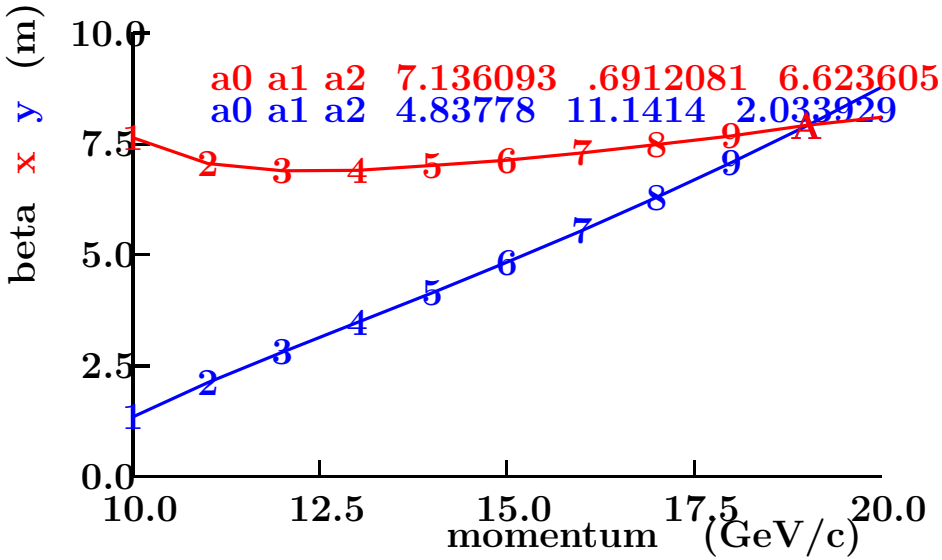

beta x y (m)
a0 a1 a2 6.468647 .859514 5.782393
a0 a1 a2 4.487451 10.25654 1.742786
10.0
7.5
5.0
2.5
0.0
5
6
7
8
9
10
momentum (GeV/c)

10-20 GeV


13.7457 turns0
105 cells
21.83429 ring (cm)
6.93152 cell (ns)
12.63457 zeta
slip (cm)
E (GeV)
25
20
15
10
5
0
10.0
12.5
15.0
17.5
20.0


a0 a1 a2 3.974419E-07 .1626796 .1394388
Dispersion (cm)
momentum (GeV/c)
7.5
5.0
2.5
0.0
-2.5
-5.0
10.0
12.5
15.0
17.5
20.0
1
2
3
4
5
6
7
8
9
A

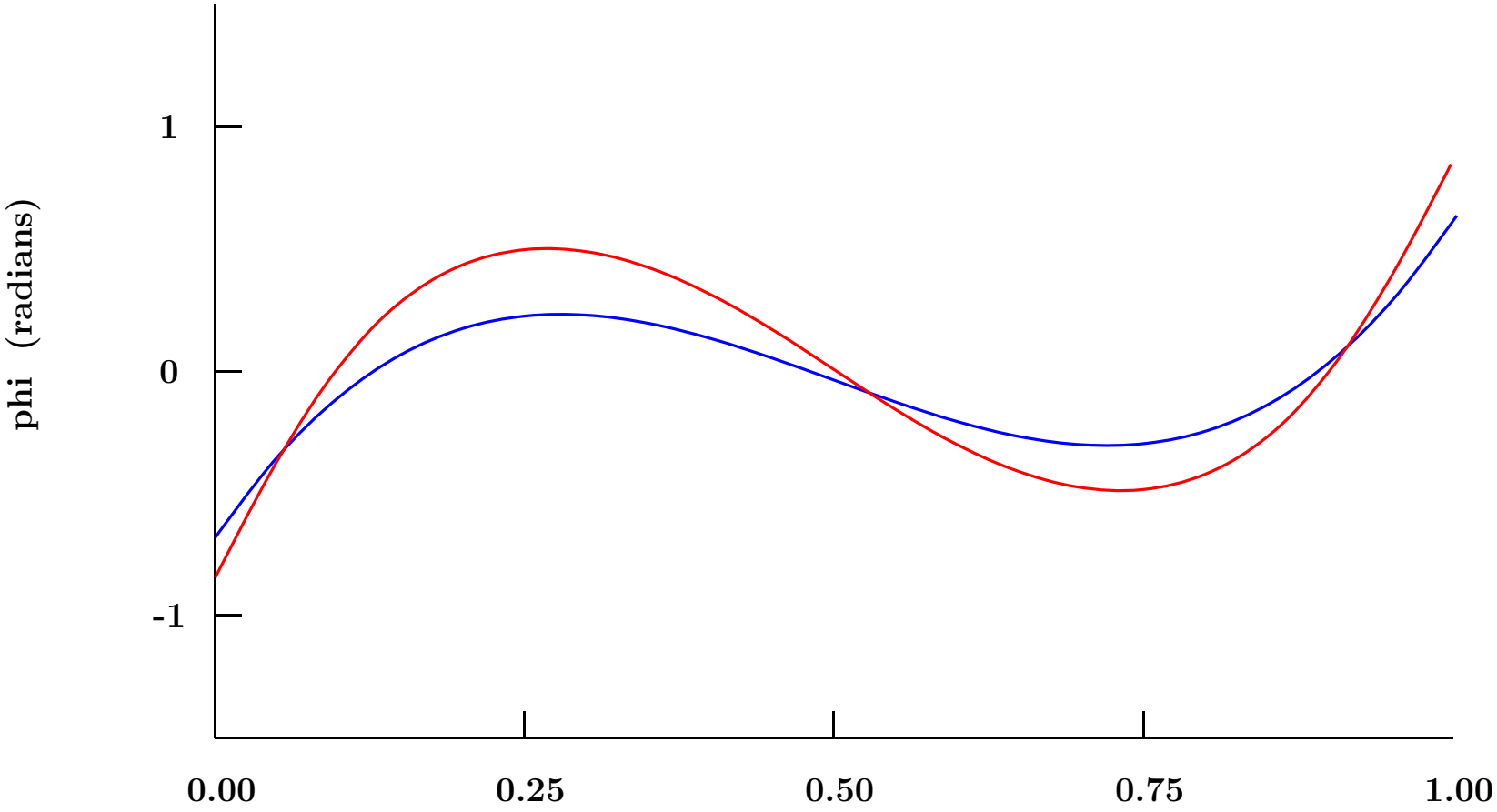

cell x y tune
0.4
0.3
0.2
0.1
10.0
12.5
15.0
17.5
20.0
momentum (GeV/c)


beta x y (m)
10.0
7.5
5.0
2.5
0.0
a0 a1 a2 7.136093 .6912081 6.623605
a0 a1 a2 4.83778 11.1414 2.033929
10.0
12.5
15.0
17.5
20.0
momentum (GeV/c)

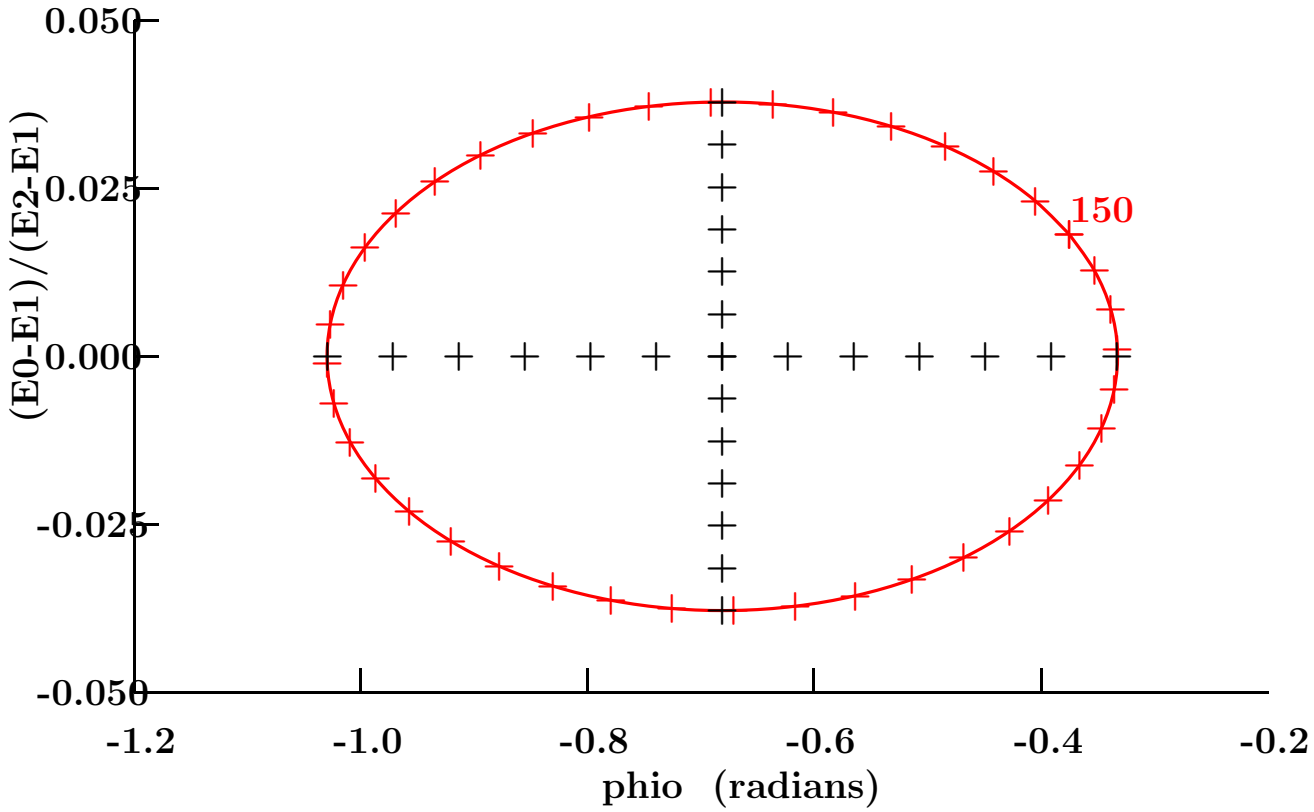
Off-line Longitudinal Distortion Calculation

Selected central phase vs acceleration for:

5-10 GeV
10-20 GeV



5-10 GeV
Initial Particles

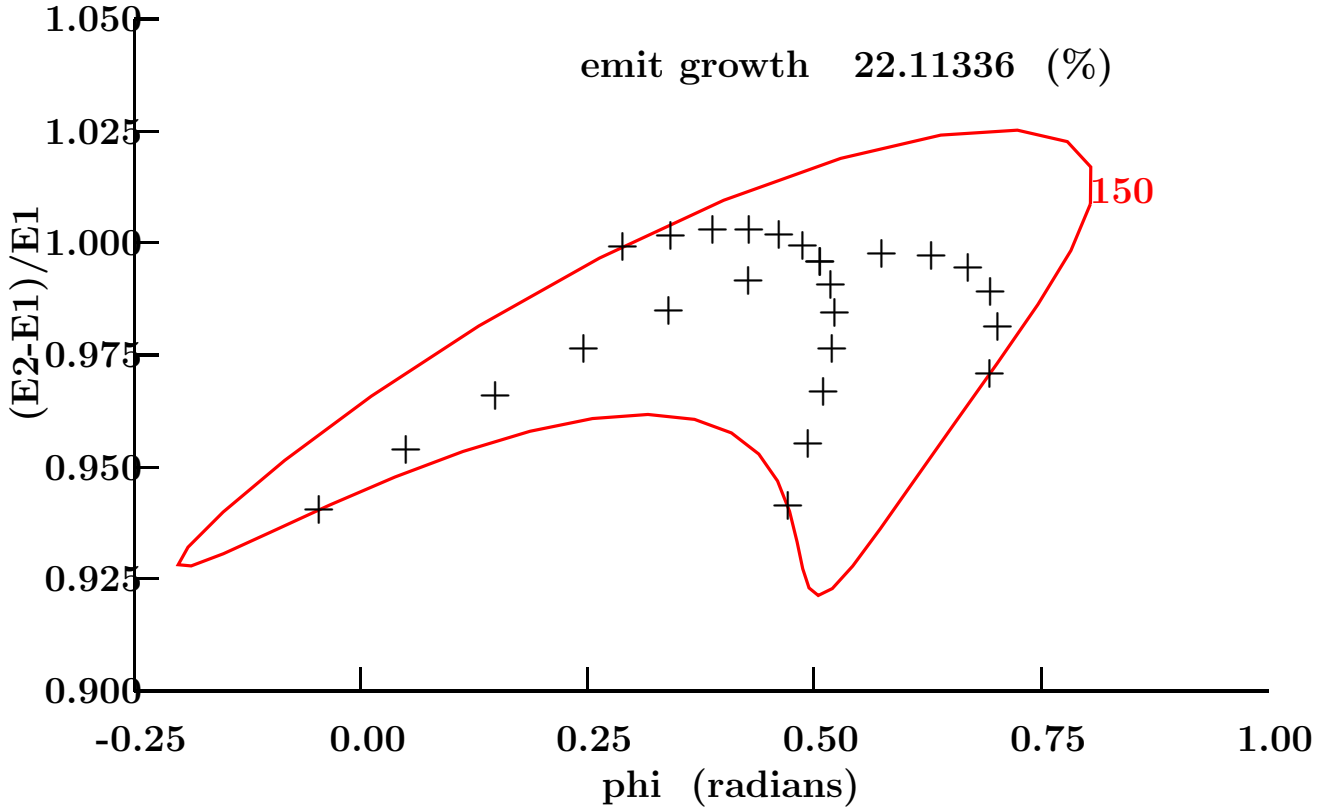


Without Harmonic RF

After adjusting:

- **Long beta ($\Delta\phi/\Delta E$)**
- **Starting Phase**
- **Number of turns**
- **Offset of phase slip vs. E**

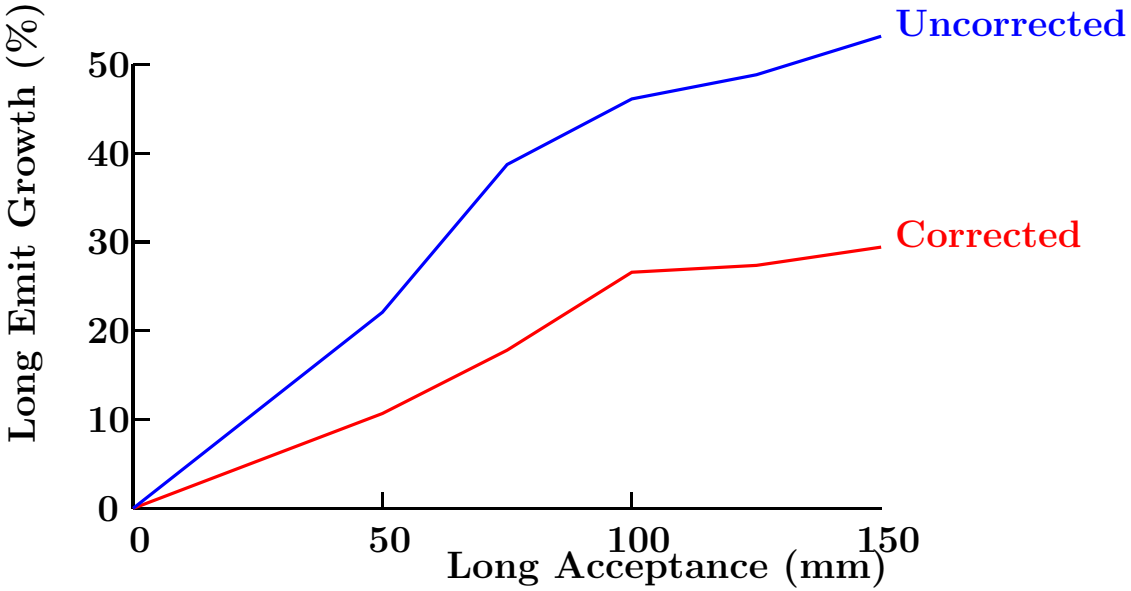
n/n0=1.02 zeta= 8.0 phi0=-.68 shift=0.19 2nd= 0.000 3rd= 0.000



Emittance growth vs. acceptance for

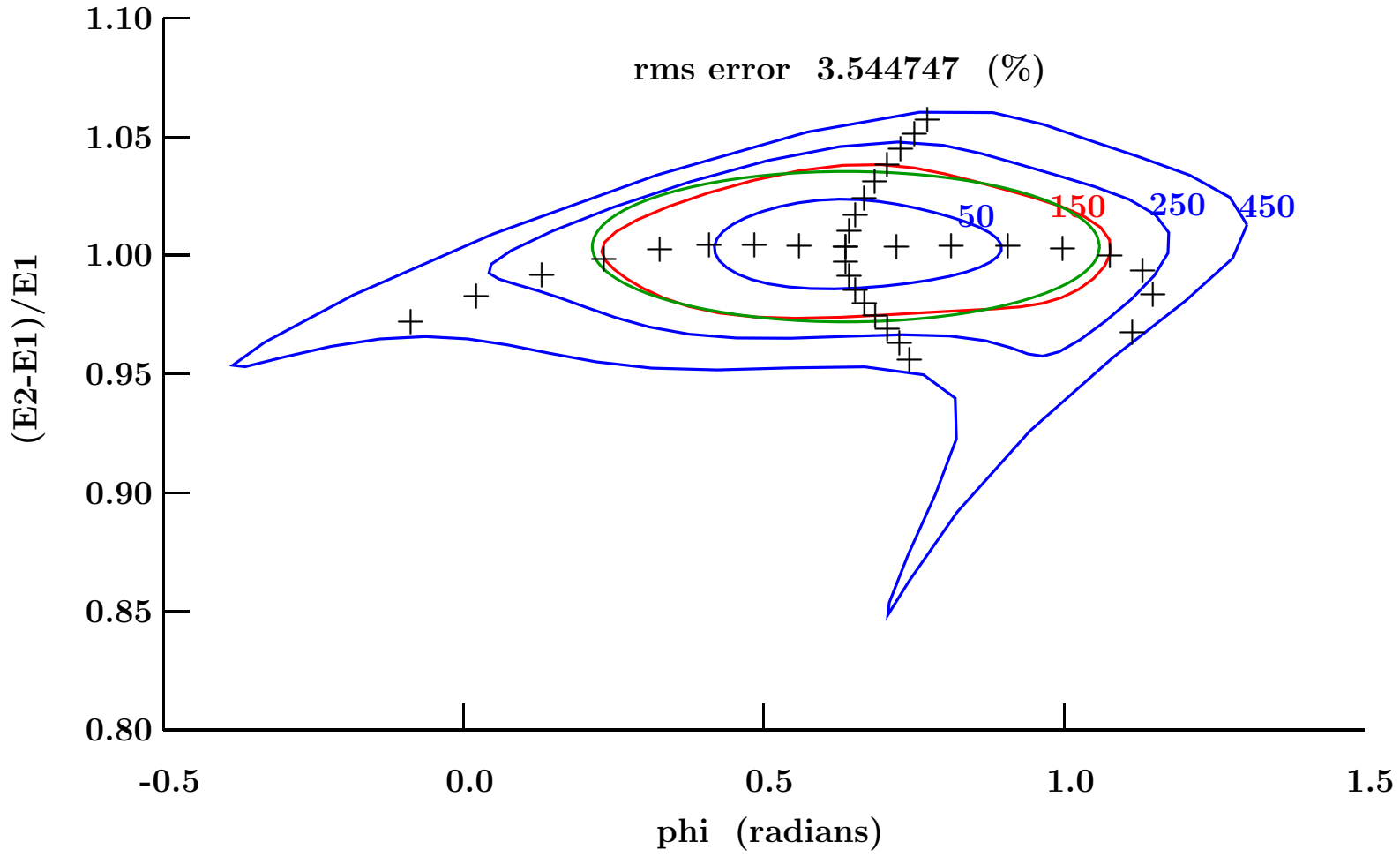
- 1000 particles with emittance=acceptance/3
- Truncated at acceptance boundary
- Corrected (or not) for phi-E correlation

Statistical error +/- 3 %



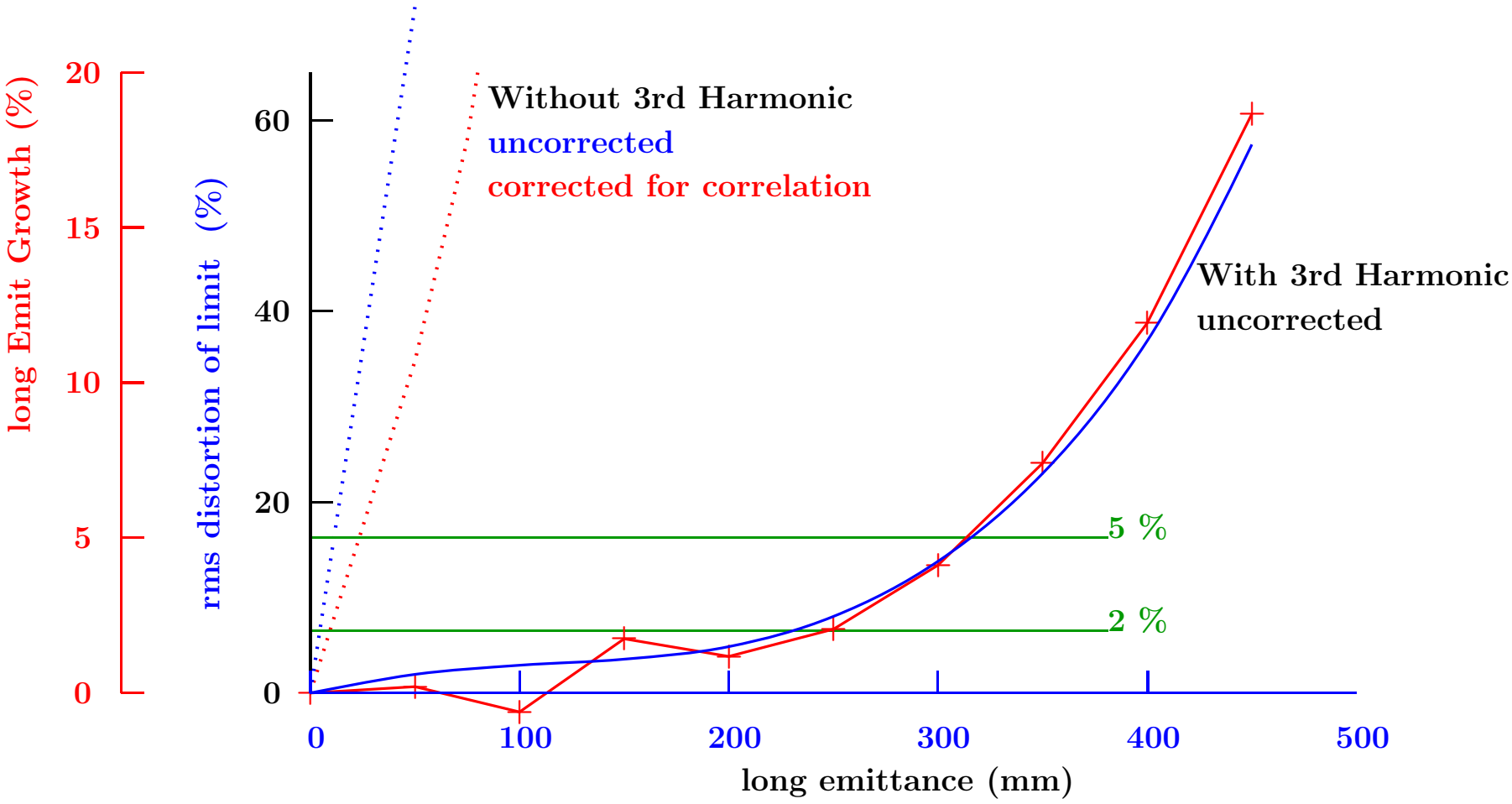
With 3rd Harmonic RF

n/n0=1.17 zeta= 8.0 phi0=-.68 shift=0.19 2nd= 0.000 3rd=-0.150



1. Rms variation in radius of distorted acceptance

2. Emittance growth for 10,000 particles with emittance=acceptance/3
   Statistical error +/- 1 %

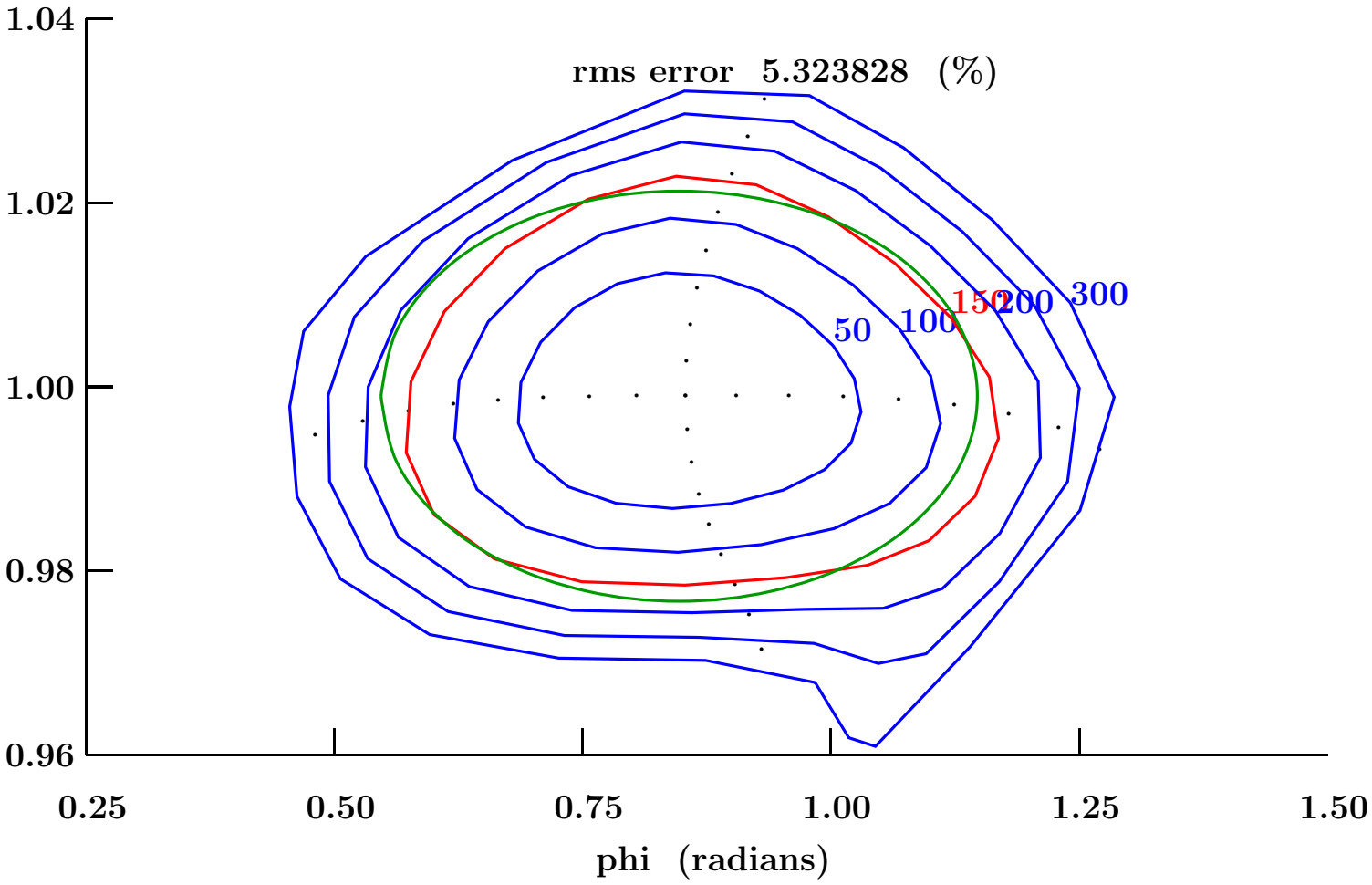


Acceptable Emittance Growth with Acceptances $\approx 2\times$ Req. 150 (mm)

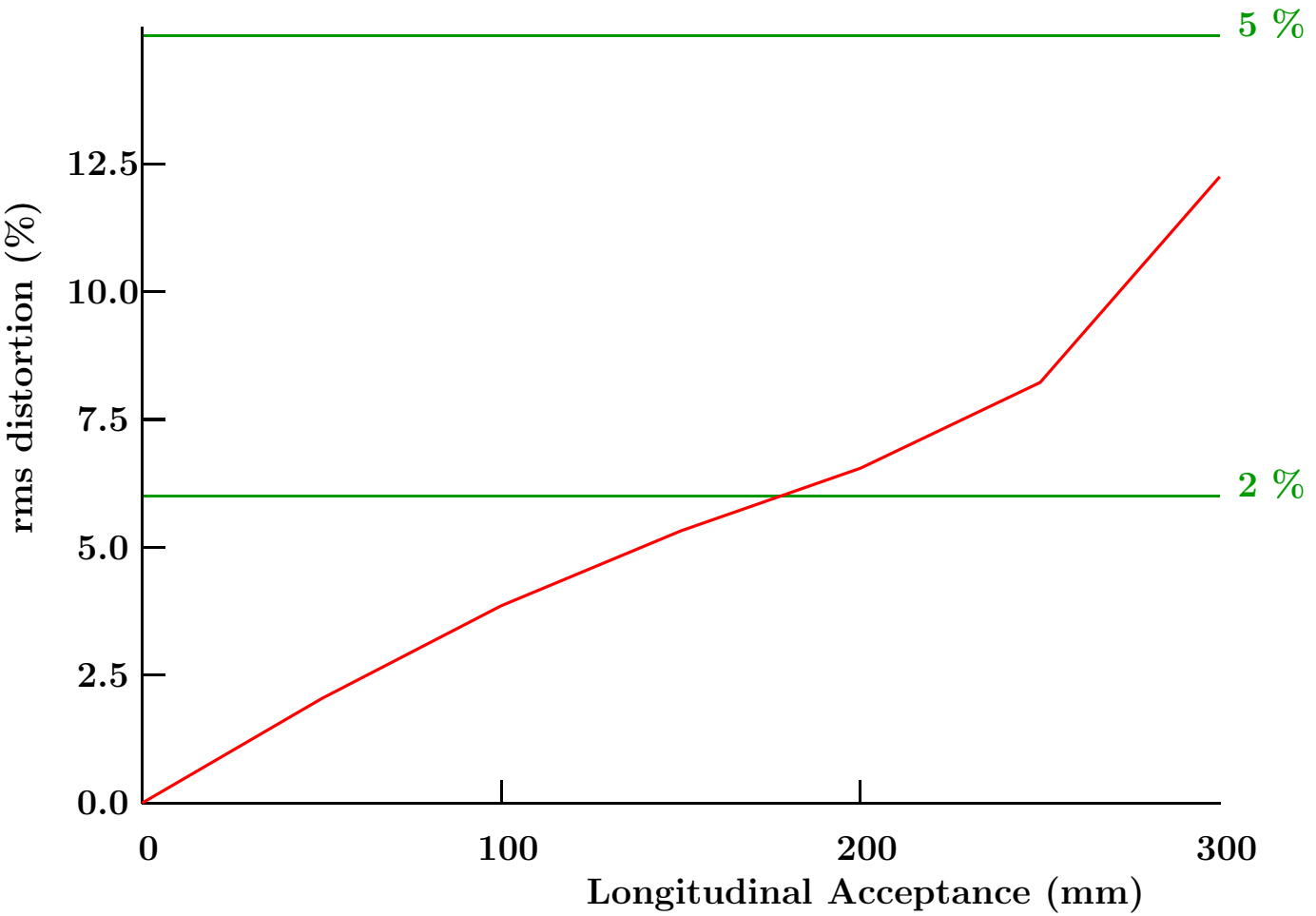
10-20 GeV

off line long distortion 10-20 GeV

n/n0=1.22 zeta=12.0 phi0=-48 shift=0.21 2nd= 0.000 3rd=-0.230



Rms variation in radius of distorted acceptance
And emittance dilutions estimated from 5-10 GeV case



Conclusion

- Good Agreement with Scott Calculations of lattice parameters
  except for some non parabolic behaviour in phase slip vs energy
- Unacceptable emittance growth (>20%) without harmonic RF
- With 3rd harmonic RF:
  1D Longitudinal calcs suggest Scott zeta assumptions are conservative
  For 2 % emit growth acceptance is 230 and 170 (mm) for 5-10 and 10-20
  For 5 % emit growth acceptance is 320 and 350 (mm) for 5-10 and 10-20
  and my 10-20 case is less optimized - the acceptances are probably larger

- ICOOL Simulation with soft ends started

- It will be interesting to have more radical designs to compare with these such designs might:
  - Use higher zetas (e.g. 12 and 14 vs. 8 and 12)
  - Higher tunes at injection (e.g. 0.4 vs. 0.35)
  - Shorter gaps in triplet (e.g. 35 cm vs. 50)
  - Higher SRF Gradient (e.g. 15 MV/m as in Study II vs. 10 MV/m)
- It will be interesting to see how much money would be saved