Bunched beam Phase Rotation Optimization

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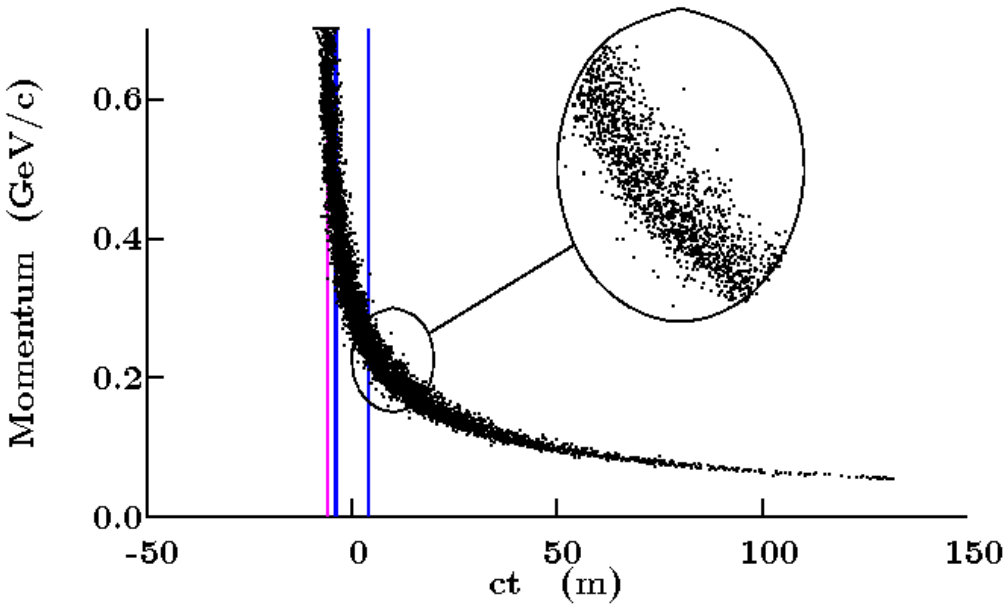
ISS FFAG Workshop

12/16/05

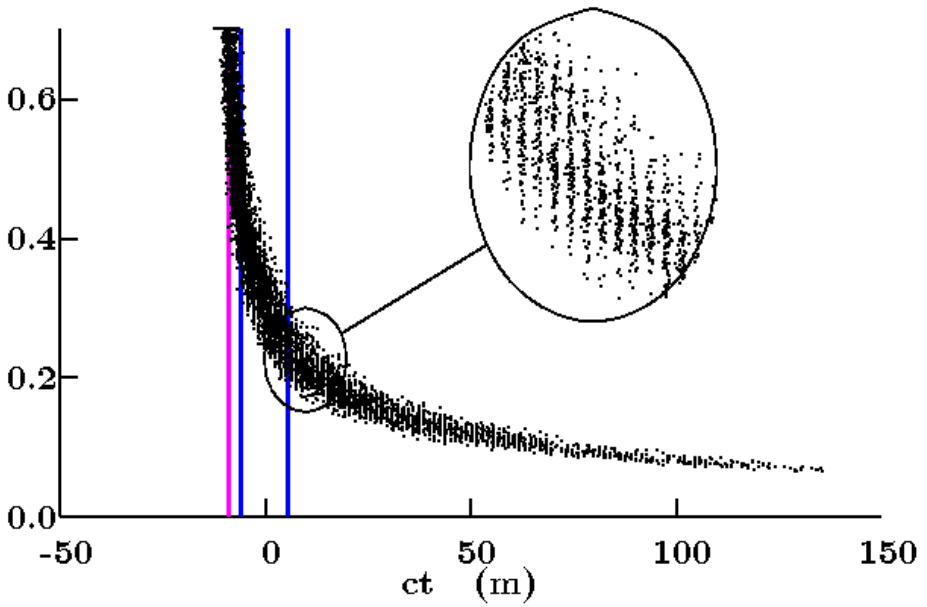
- Study 2a
- Initial Concept
- 1D Model
- Computer Optimization

Study 2a Rotation with ICOOL

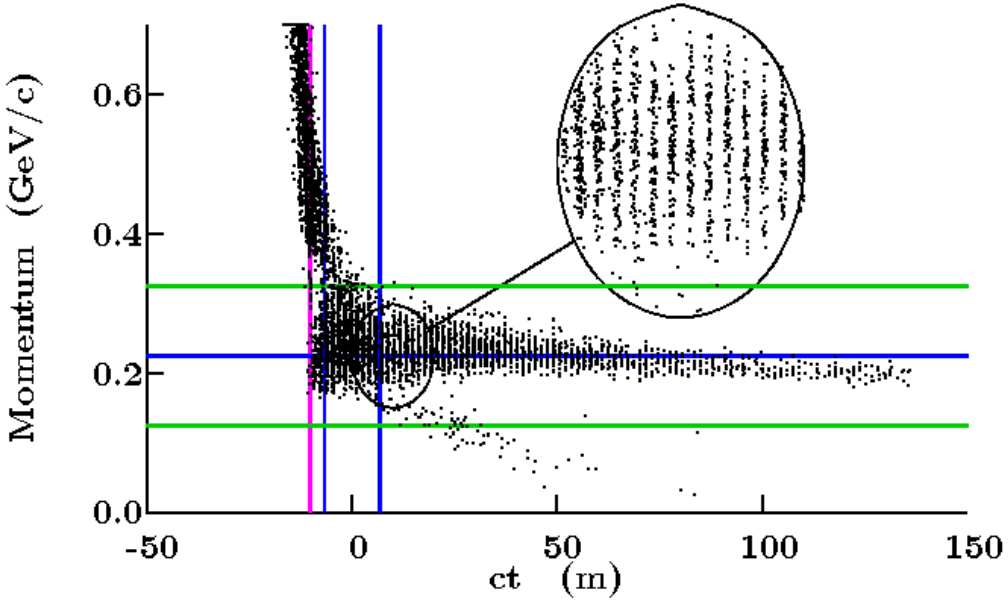
110.7 m End of drift



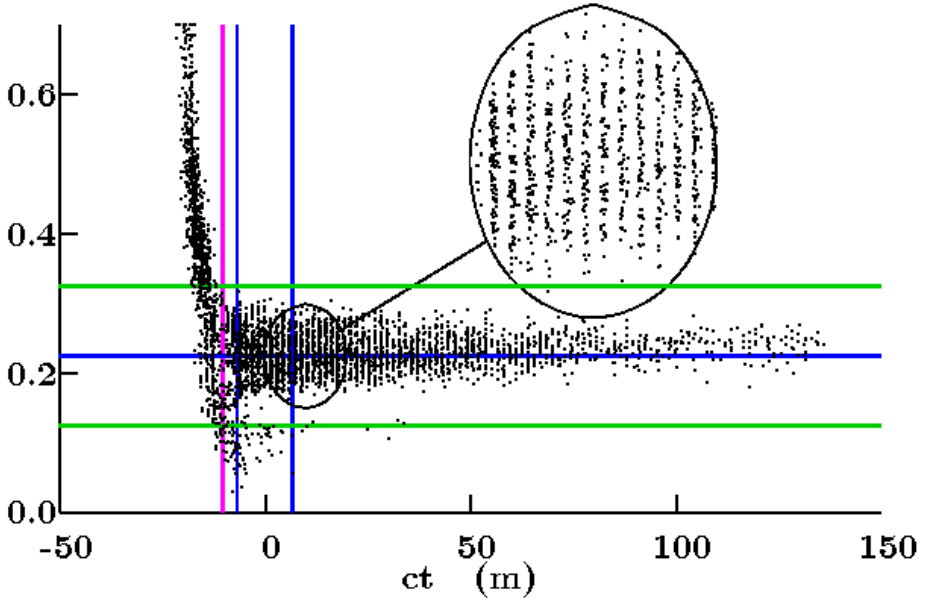
161.7 m End of bunch



215.63 m End of rotate



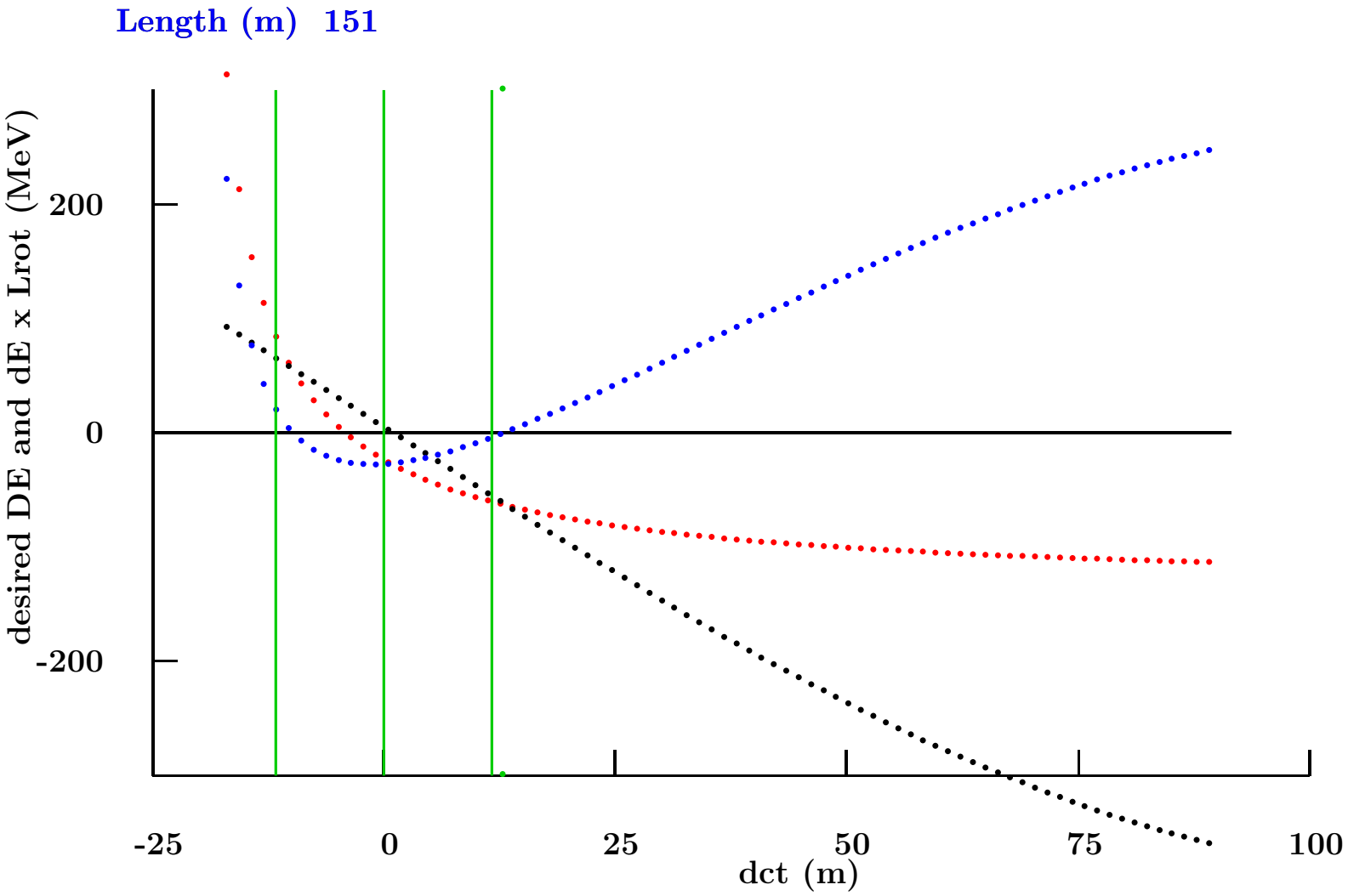
265.9 m 50 m of cooling



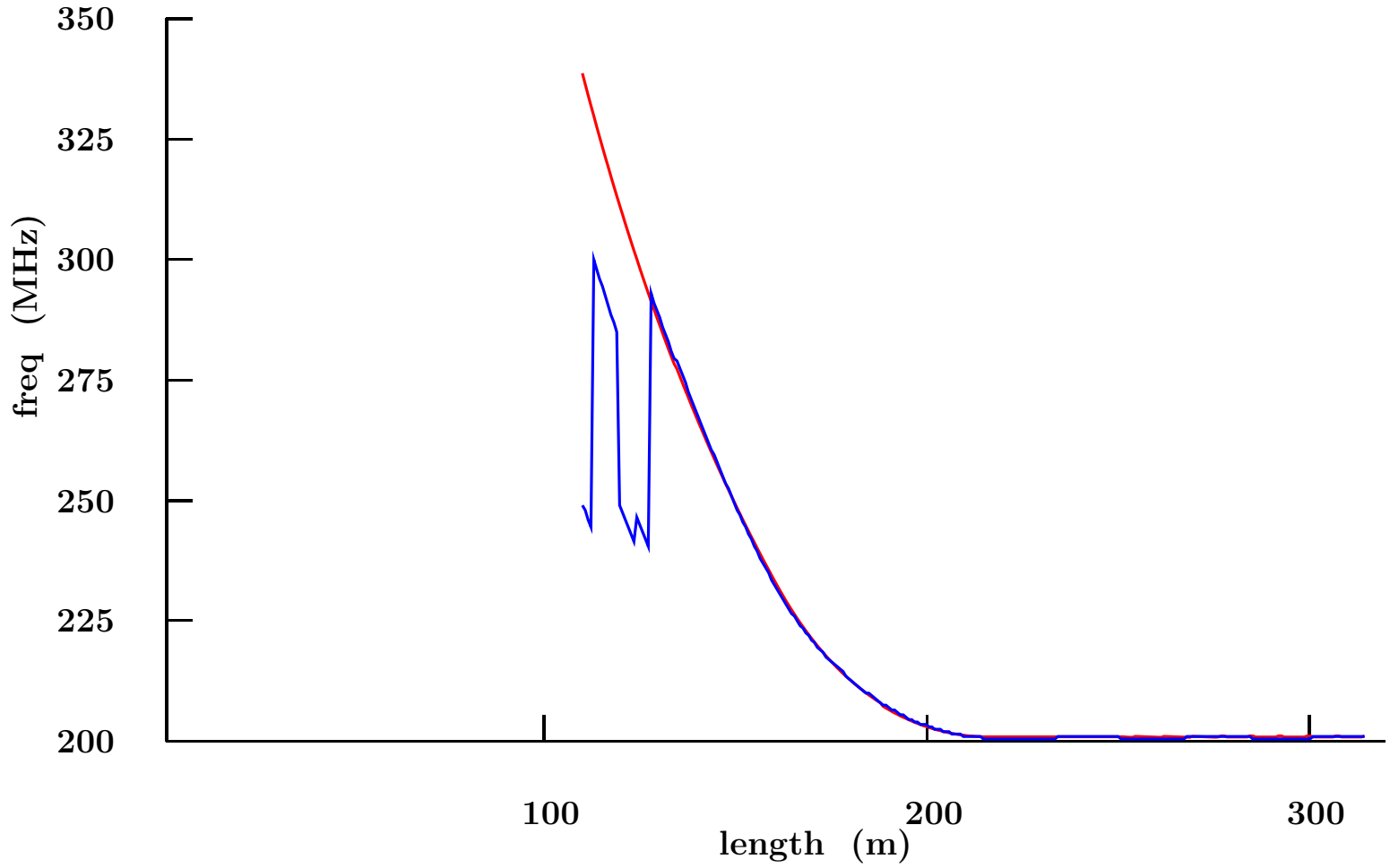
Method

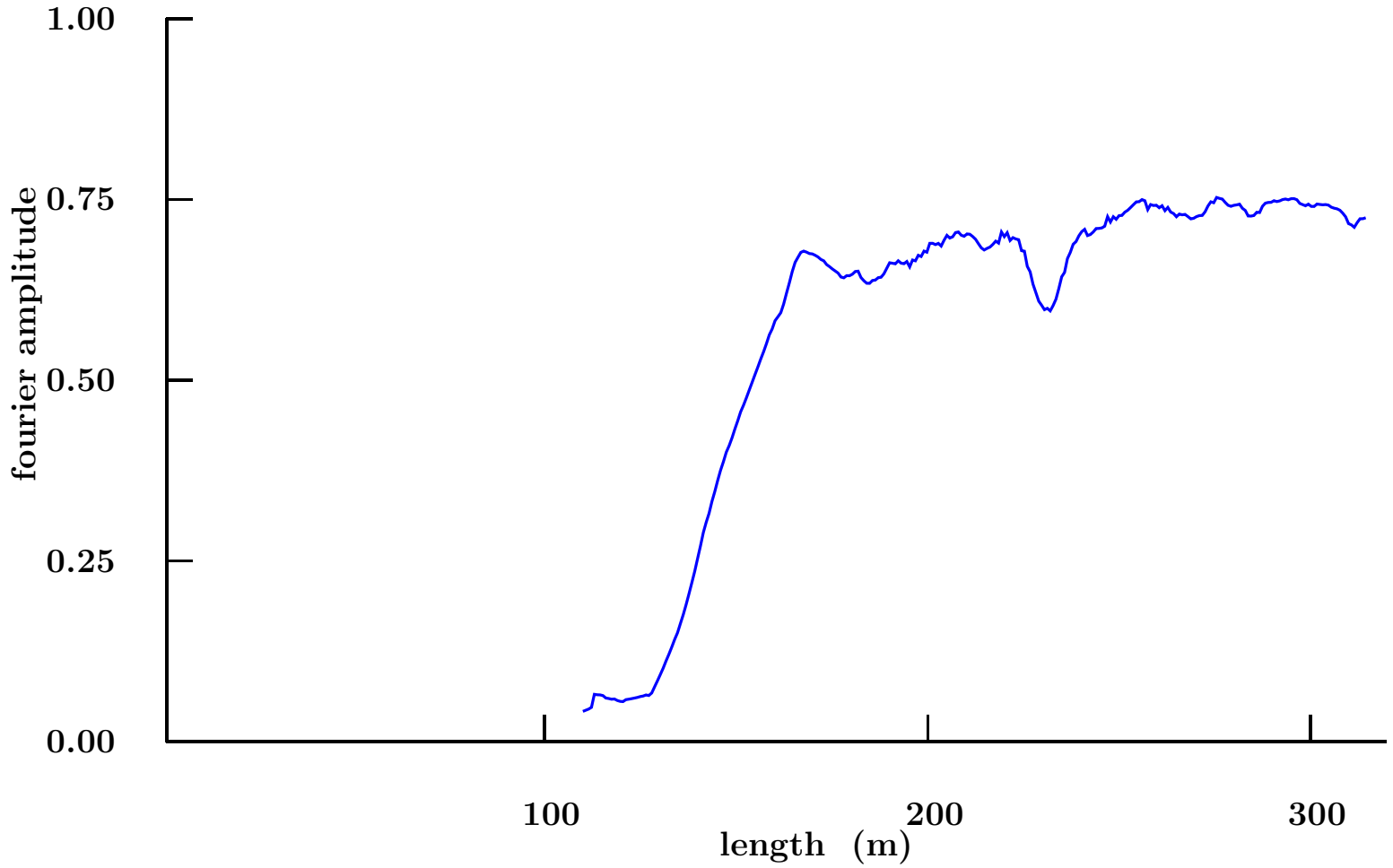
- **Define two reference particles with two momenta p1 and p2 and zero transverse amplitude**
- **Start them off at the target with t=0**
- **Use 18 m of taper 20 T to 1.75 T, and 82 m of drift at 1.75 T**
- **Start RF with** $\lambda = c(t_1 - t_2)/n$ **with n=18**
  where t_1 **and** t_2 **are the times of the two reference particles**
- **Increase the average RF gradient over next 50 m to bunch**
- **Now lower the upper reference energy with z by dE/dz=slope 1**
- **Now increase the lower reference energy with z by dE/dz=slope 2**
- **Set the RF wavelength by** $\lambda = c(t_1 - t_2 + \delta)/n$ **with n=18 and** δ**=.03**
  this shifts the phases at reference 1 and 2 to get real particles at those momenta to follow the changing reference energies
- **When reference 1 = reference 2, go to the fixed wavelength** $\lambda = c(t_1 - t_2)/n$

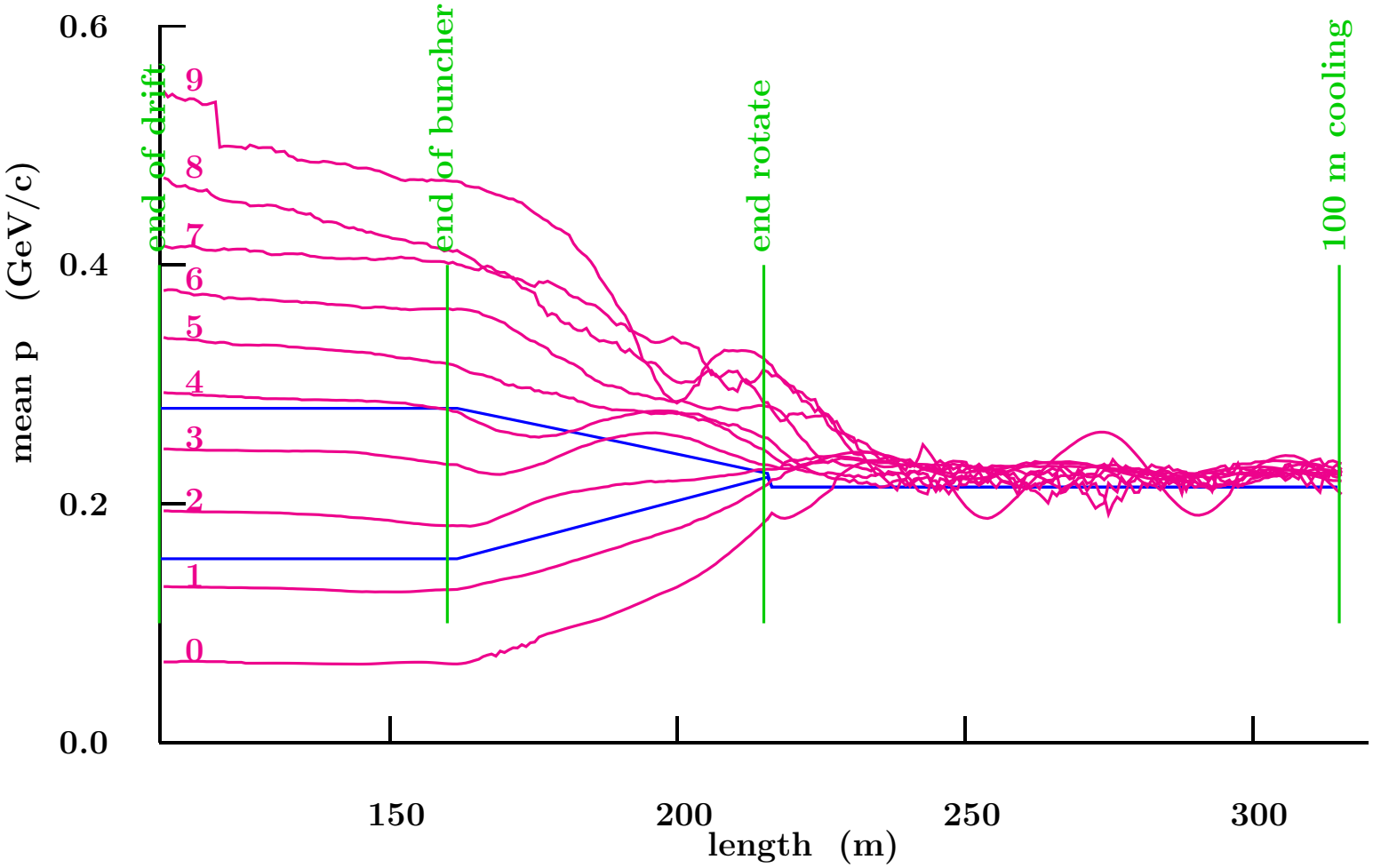
problem


Length (m) 151
desired DE and dE x Lrot (MeV)
200
0
-200
-25
0
25
50
75
100
dct (m)

Study 2a diagnostics



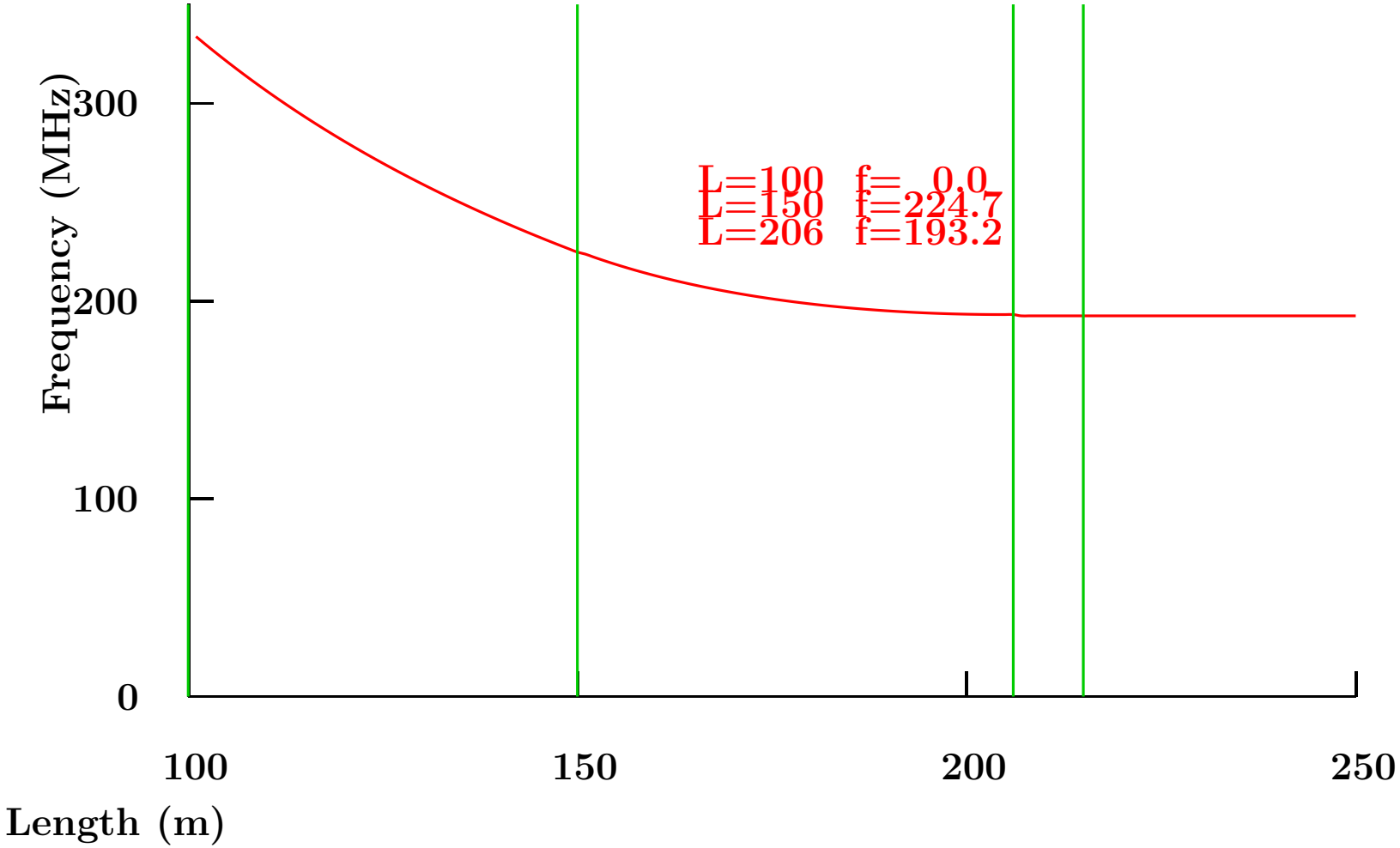

1.00
0.75
0.50
0.25
0.00
fourier amplitude
100
200
300
length (m)



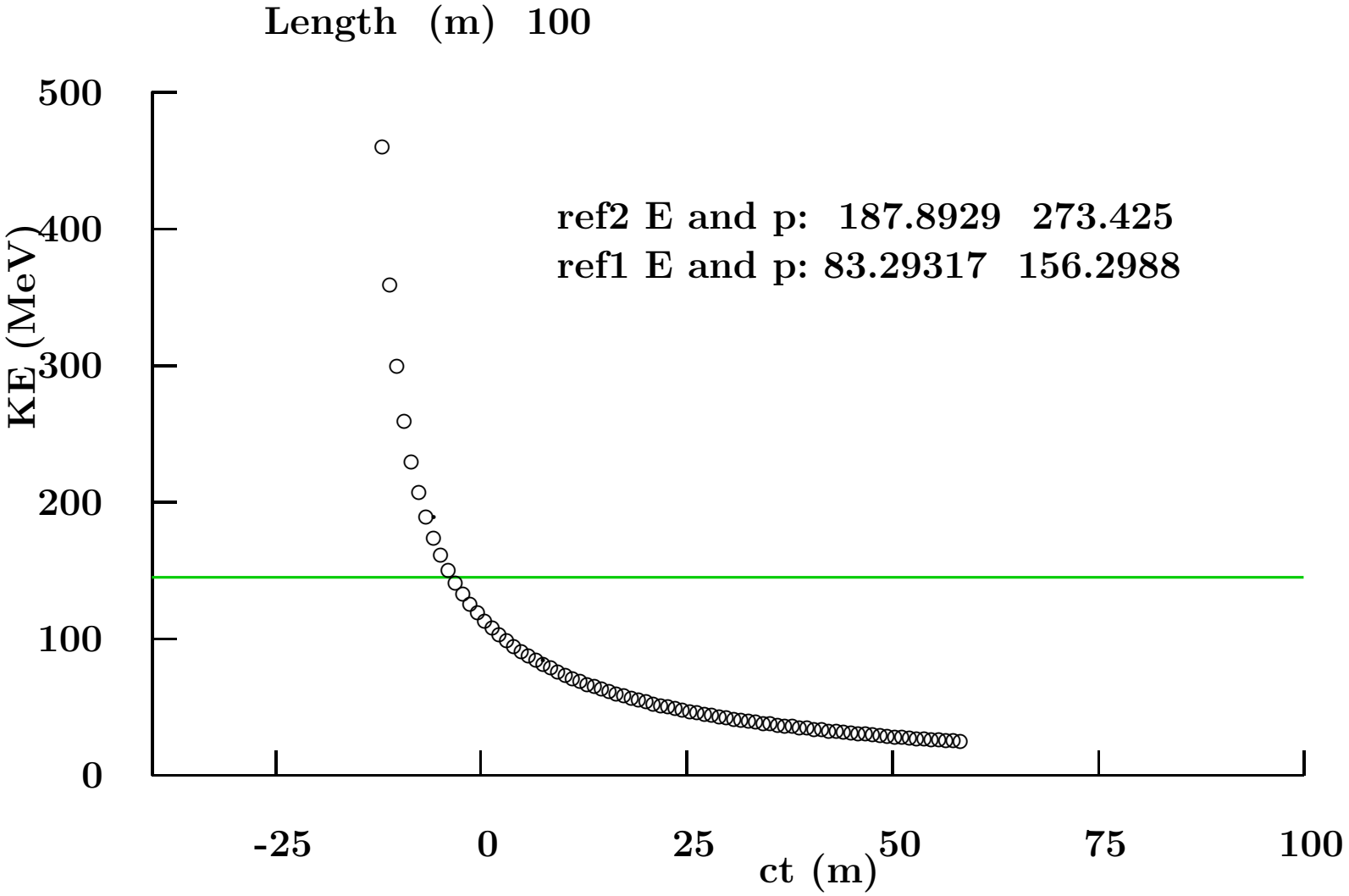
Note delta was not set as theory suggested

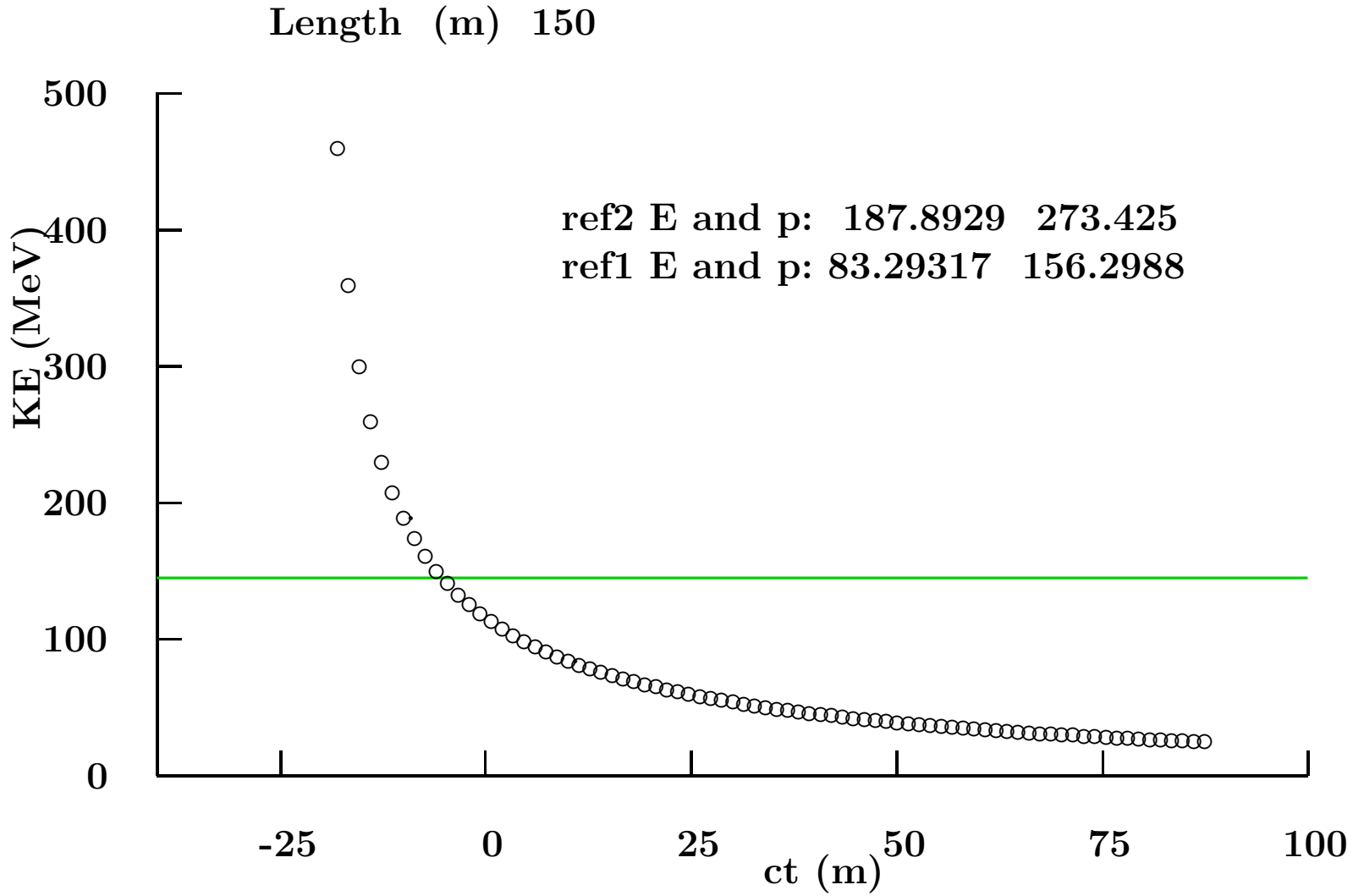
1 D program

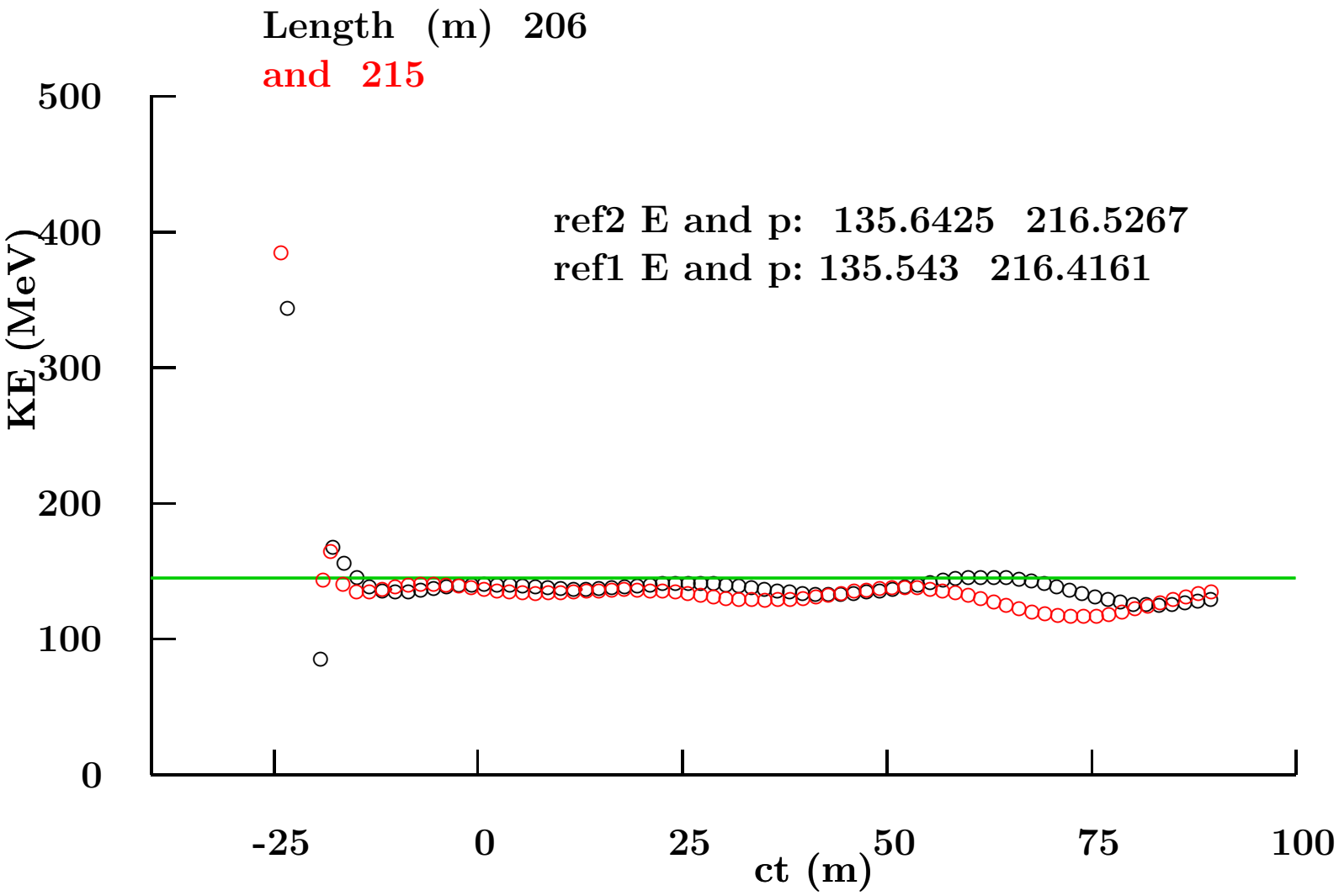
Try as Conceived



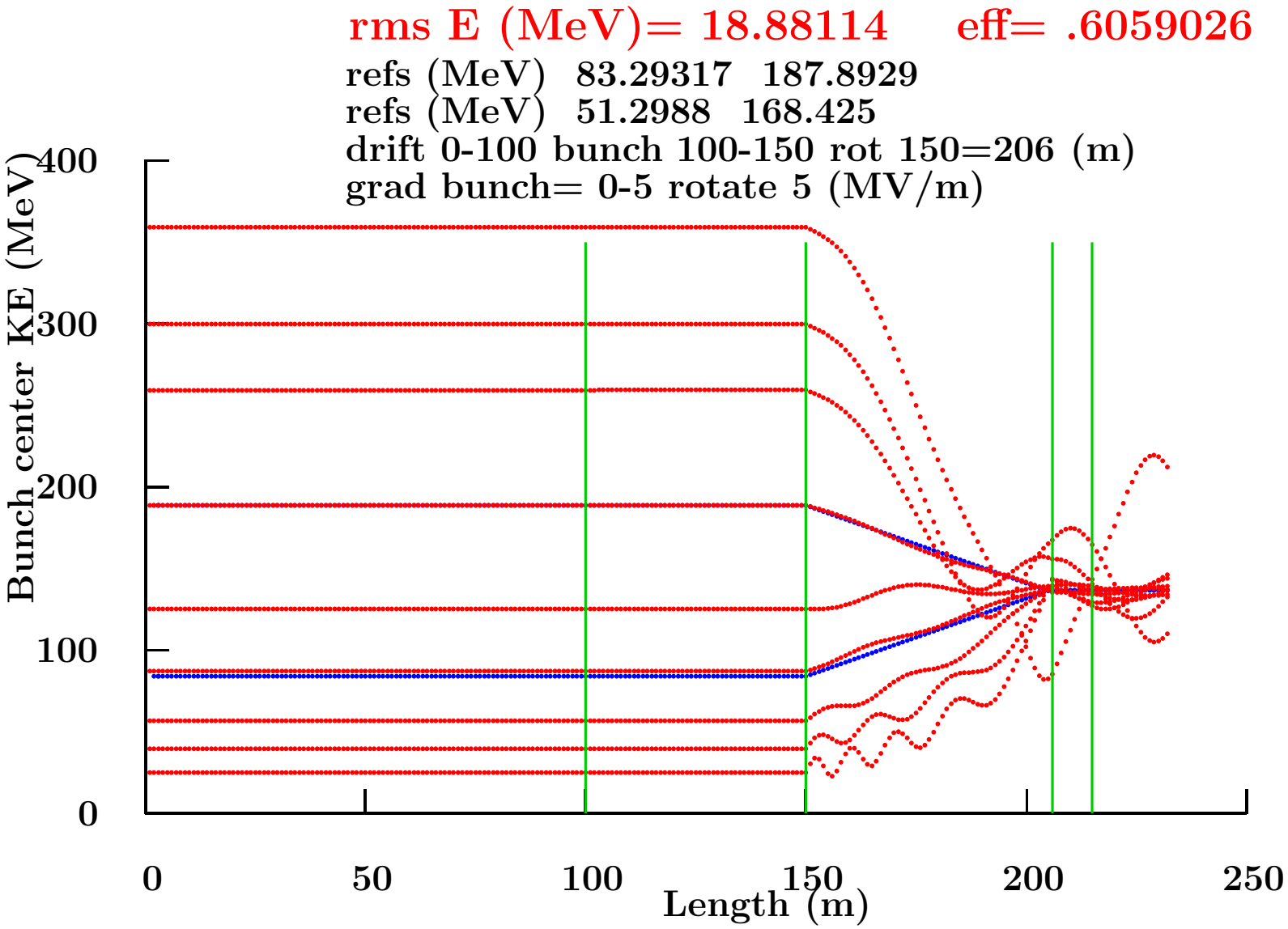
Parameters bucket centers




Length (m) 150
ref2 E and p: 187.8929 273.425
ref1 E and p: 83.29317 156.2988
KE (MeV)
500
400
300
200
100
0
-25
0
25
50
75
100
ct (m)


Length (m) 206
and 215
ref2 E and p: 135.6425 216.5267
ref1 E and p: 135.543 216.4161
KE (MeV)
500
400
300
200
100
0
-25
0
25
50
75
100
ct (m)

Centers of selected energies vs x



Computer Optimized Design

- **First Try**

  Adjust to minimize RMS E spread at end

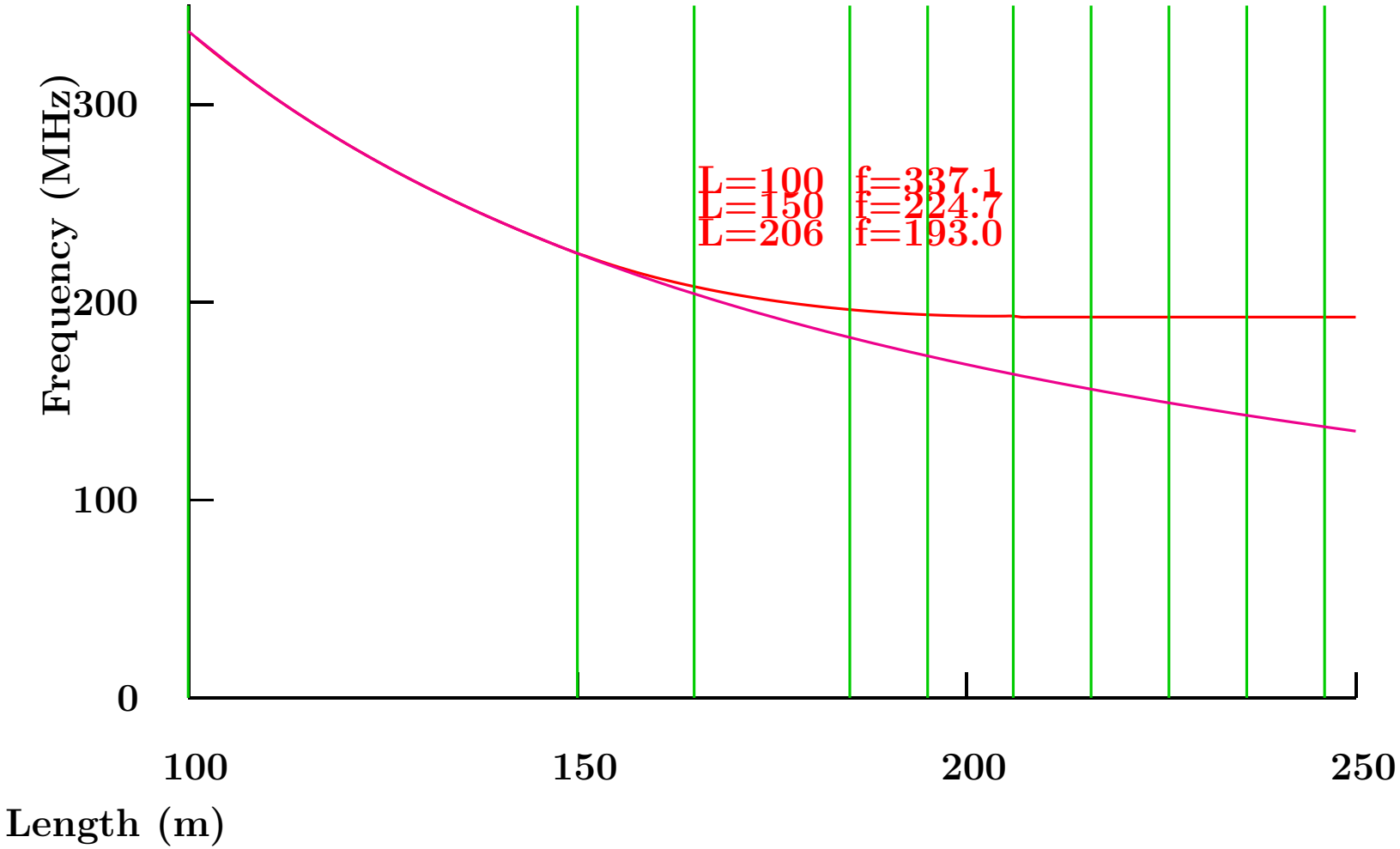
  - **RF Gradient in Phase Rotation**
  - **Slope 1**
  - **Slope 2**
  - **delta**
  - **Final reference momentum**

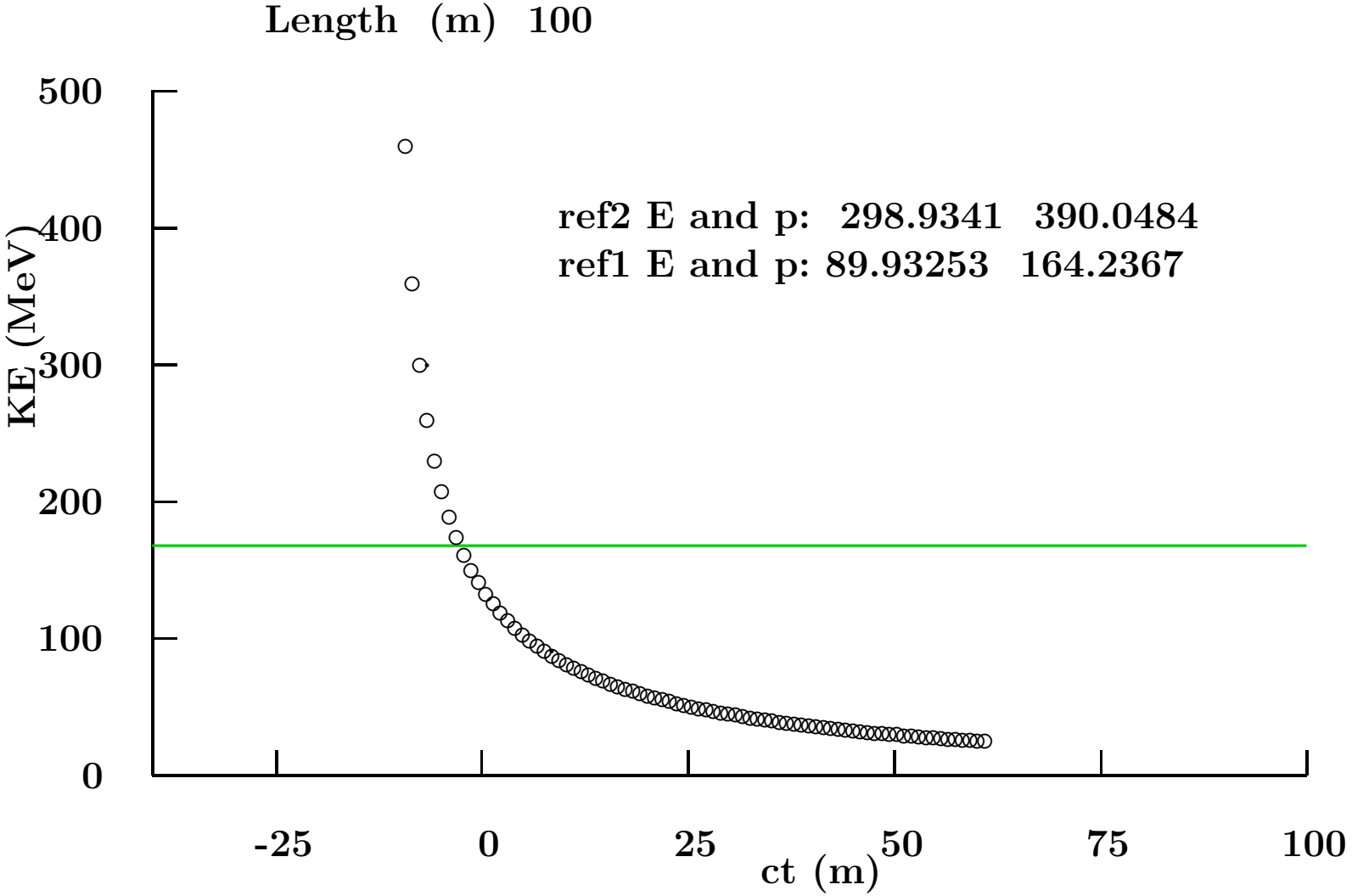
- **Second Try**

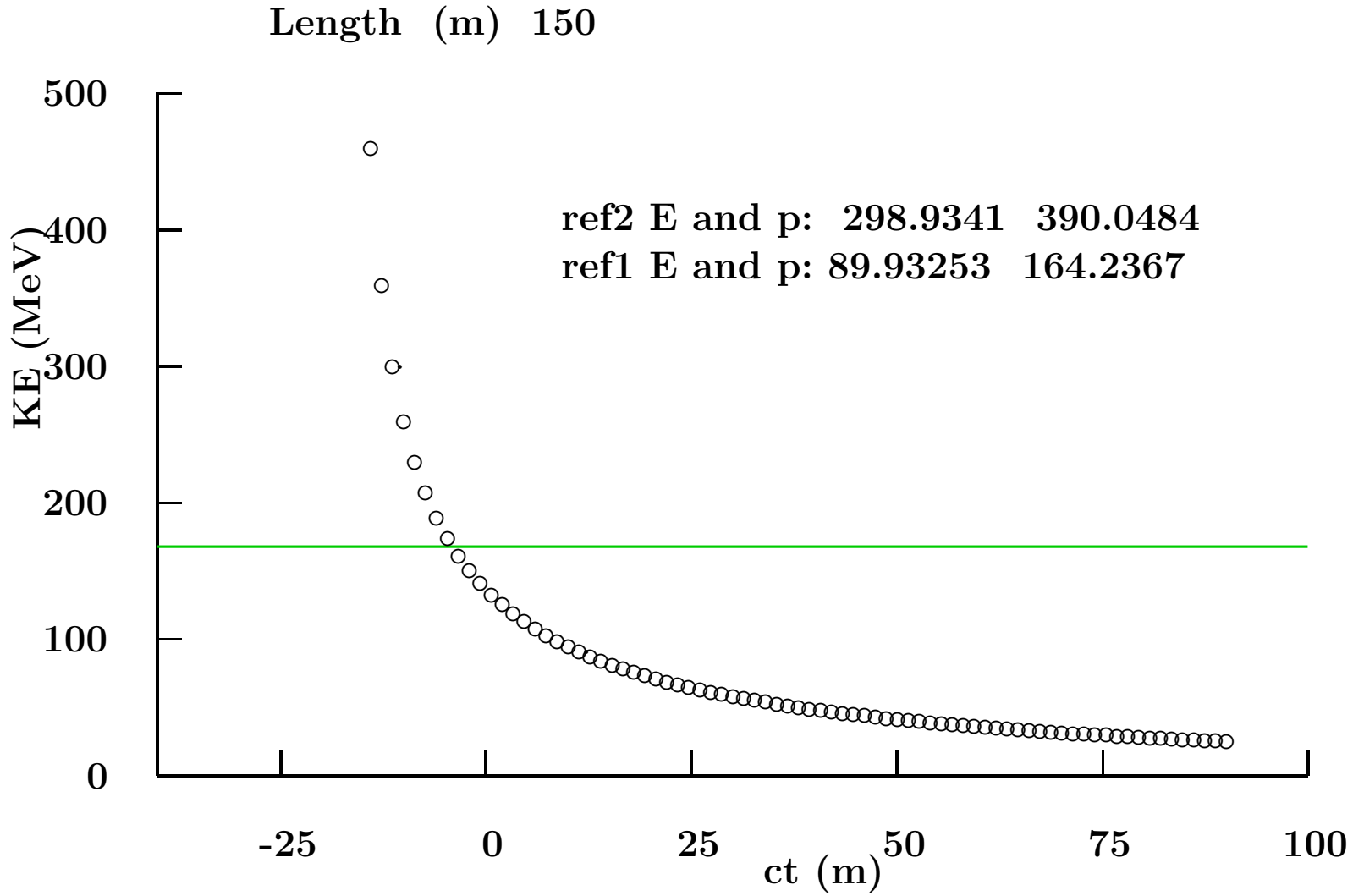
  - **Raise upper and lower Ref momenta**
  - **Use n=17**
  - **repeat above**

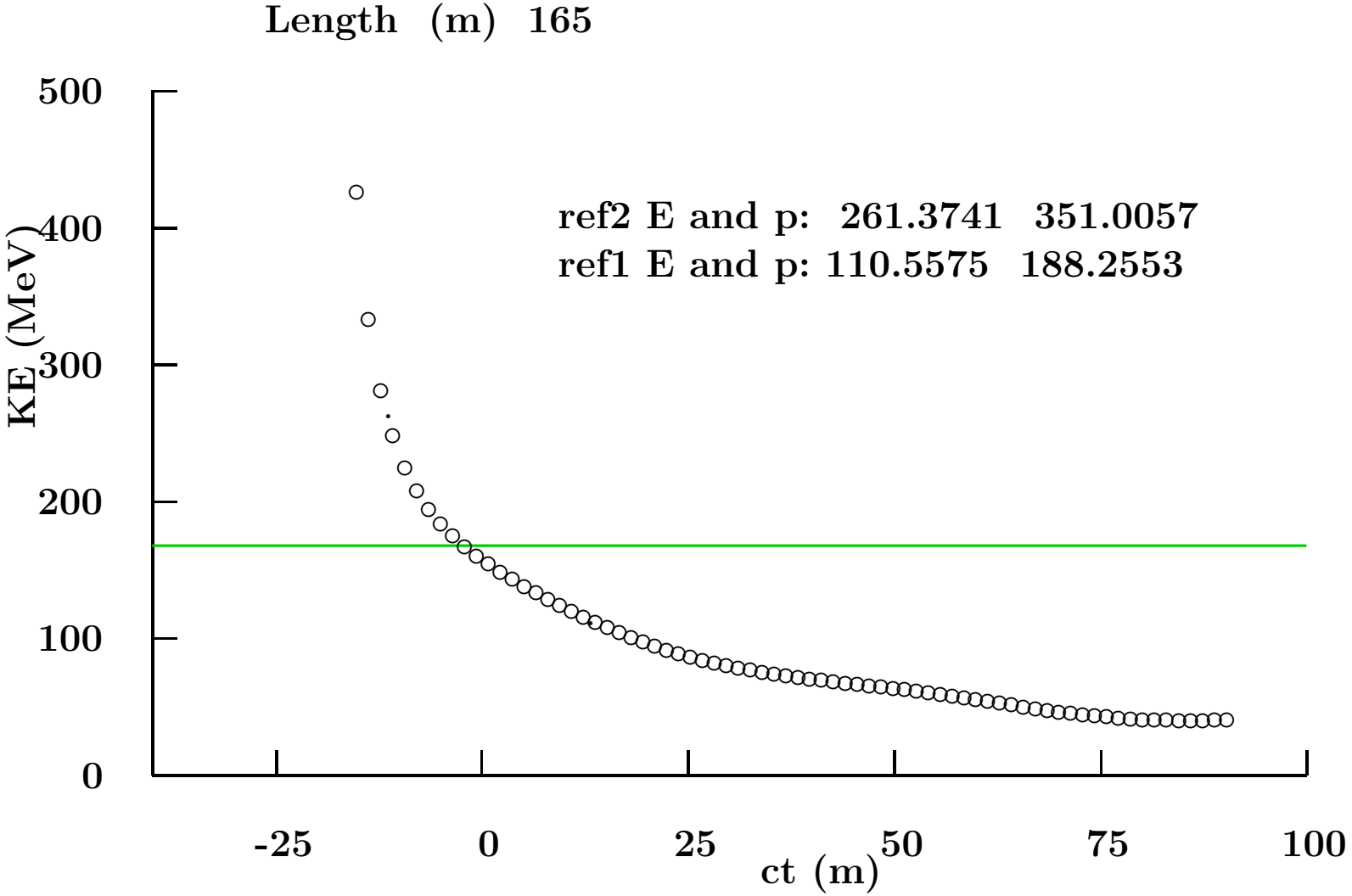
  - **Gradient went up from 12 to 14.7 MV/m**
  - **Delta went down**
  - **Final energy went up**

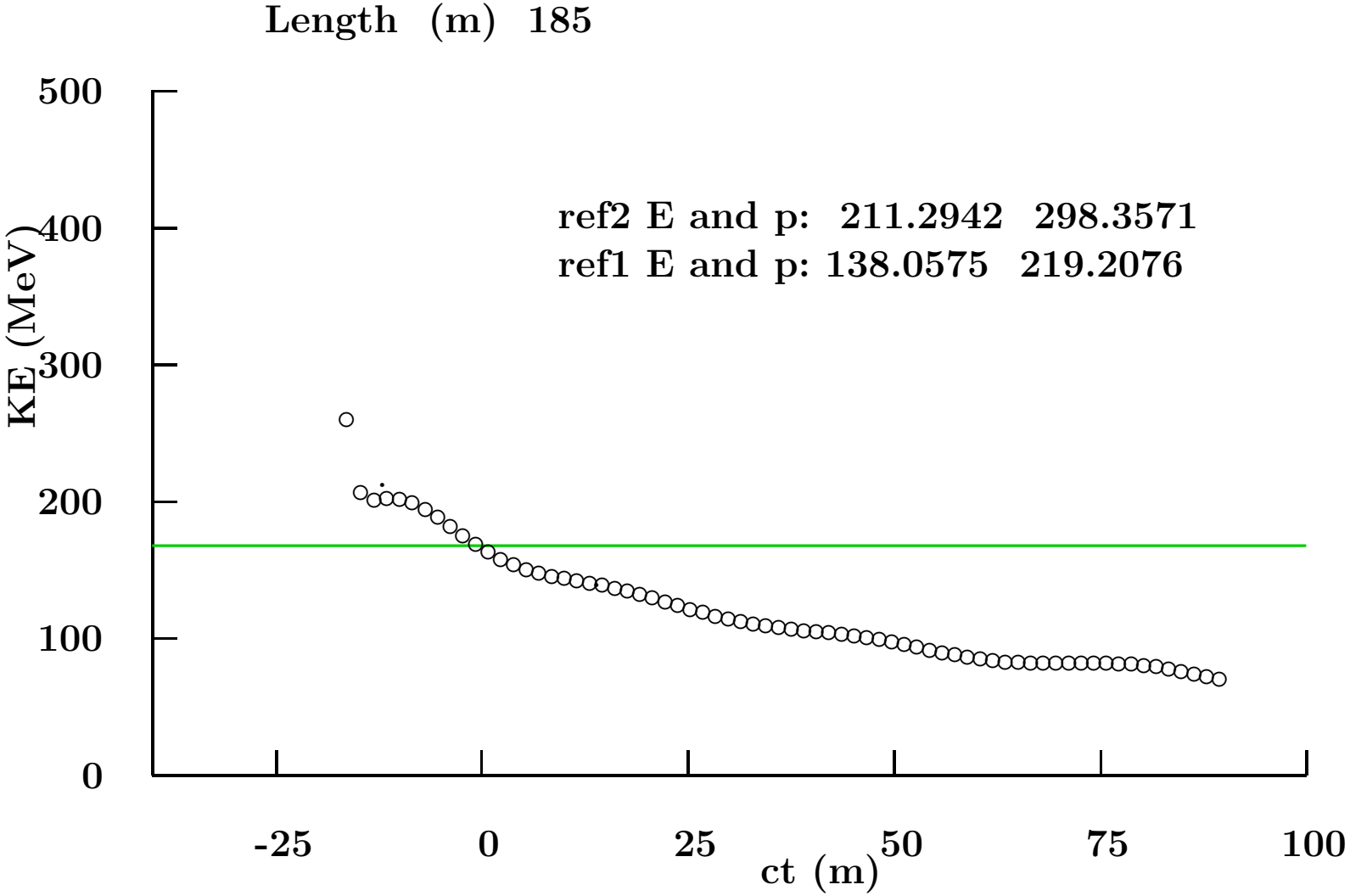
  - **This gave significant gain at high energies**

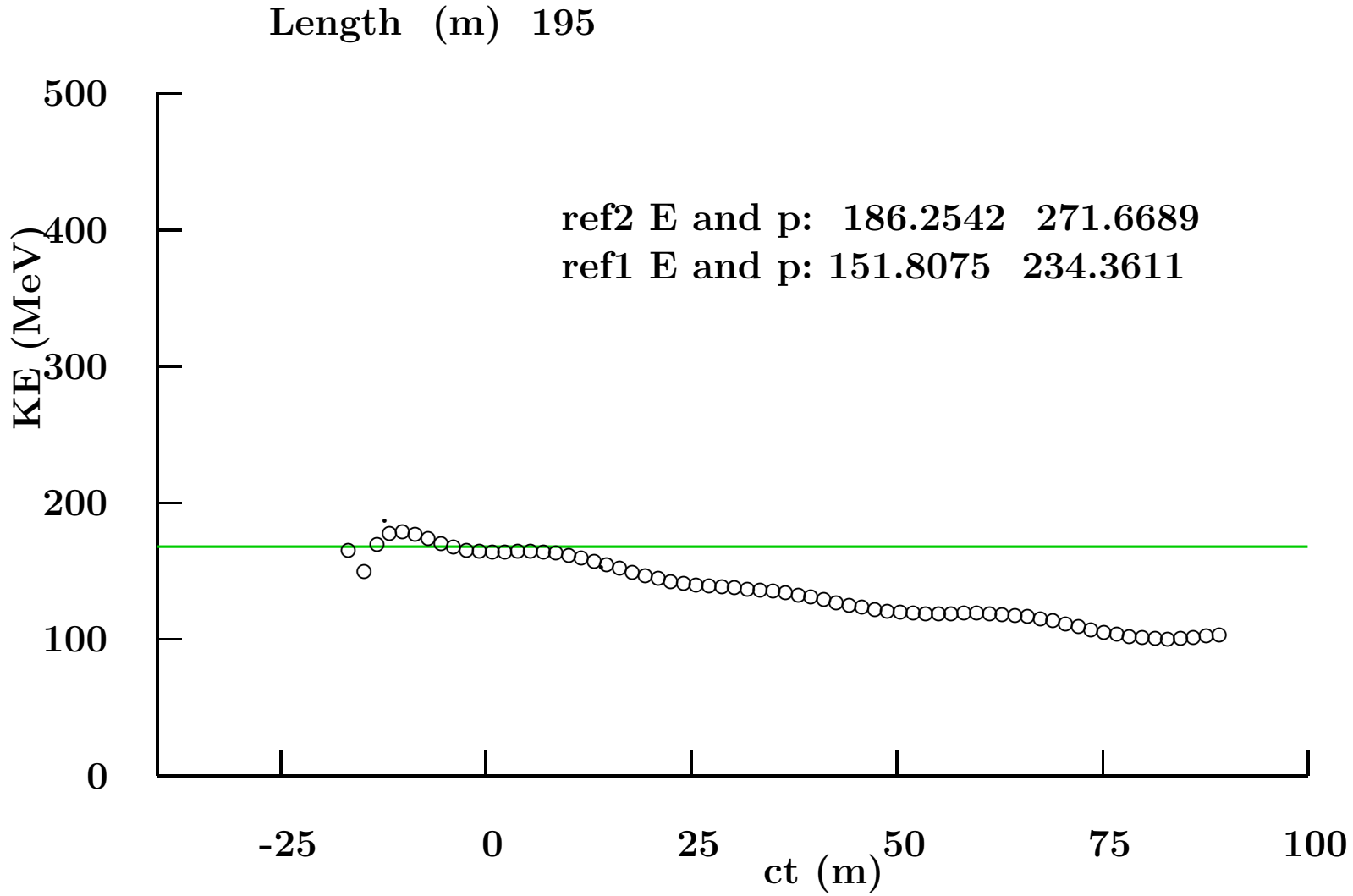

Frequency (MHz)
300
200
100
0
L=100 f=337.1
L=150 f=224.7
L=206 f=193.0
100
150
200
250
Length (m)

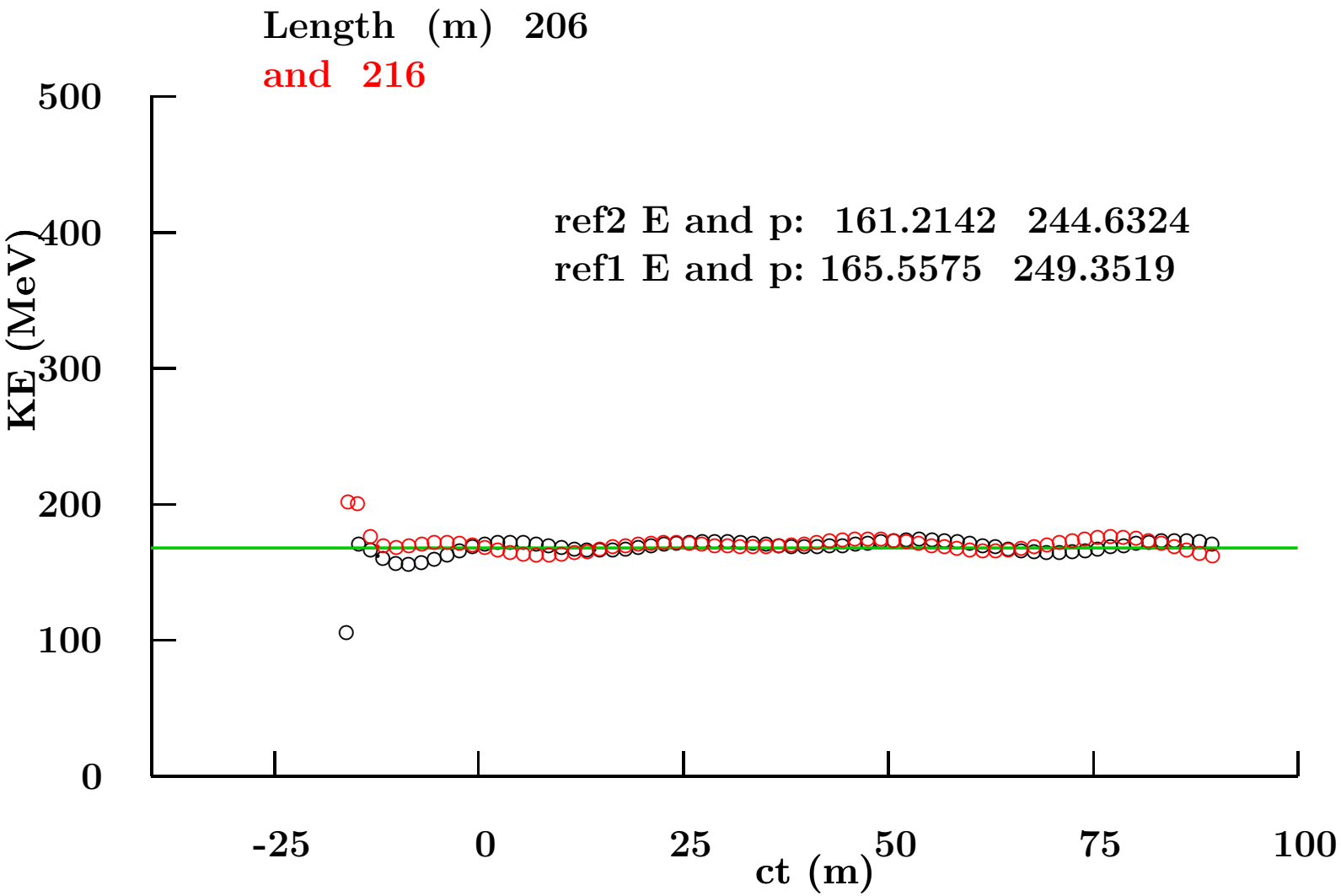

Length (m) 100
ref2 E and p: 298.9341 390.0484
ref1 E and p: 89.93253 164.2367
KE (MeV)
500
400
300
200
100
0
-25
0
25
50
75
100
ct (m)

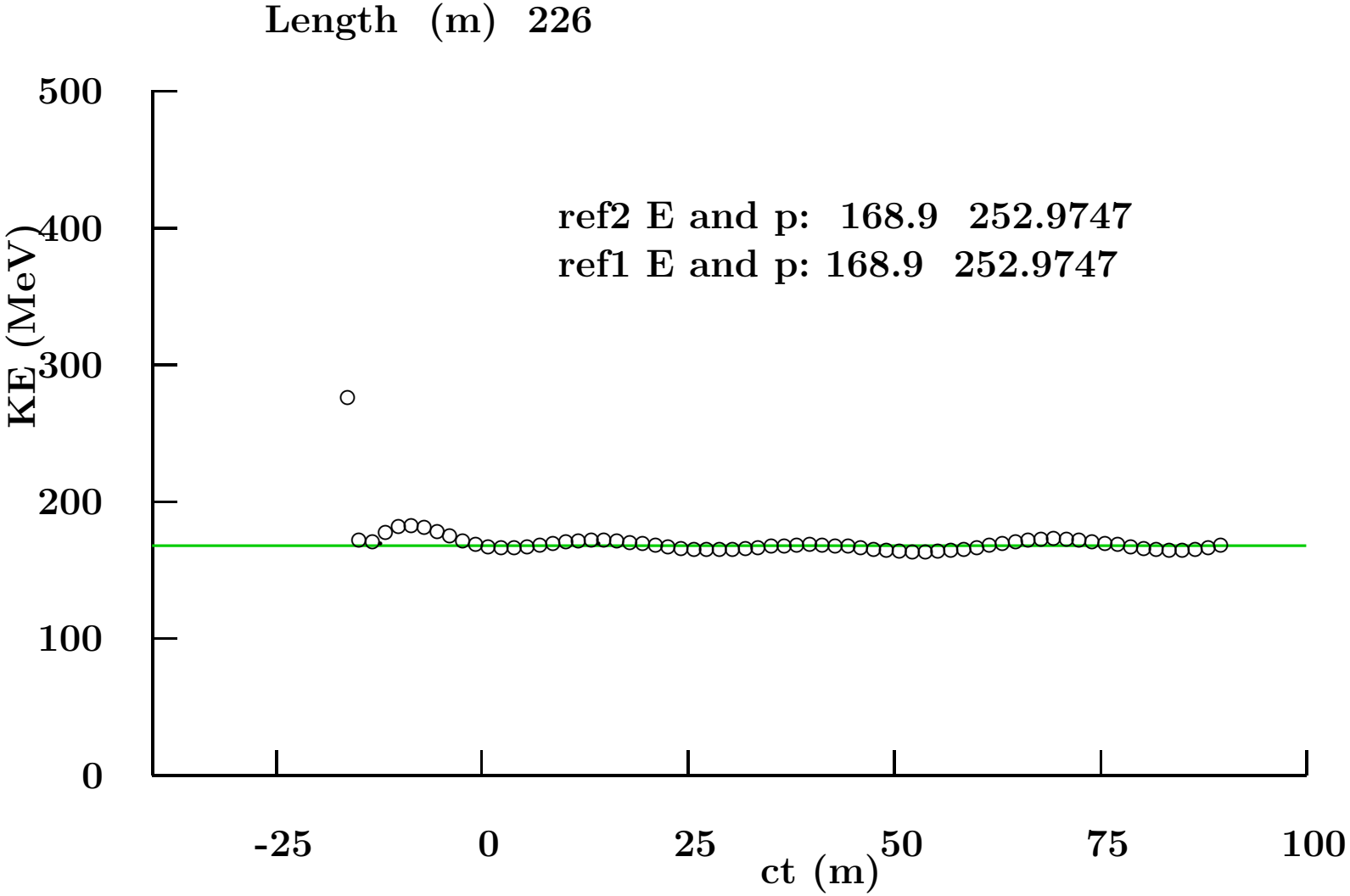

Length (m) 150
ref2 E and p: 298.9341 390.0484
ref1 E and p: 89.93253 164.2367
KE (MeV)
500
400
300
200
100
0
-25
0
25
50
75
100
ct (m)

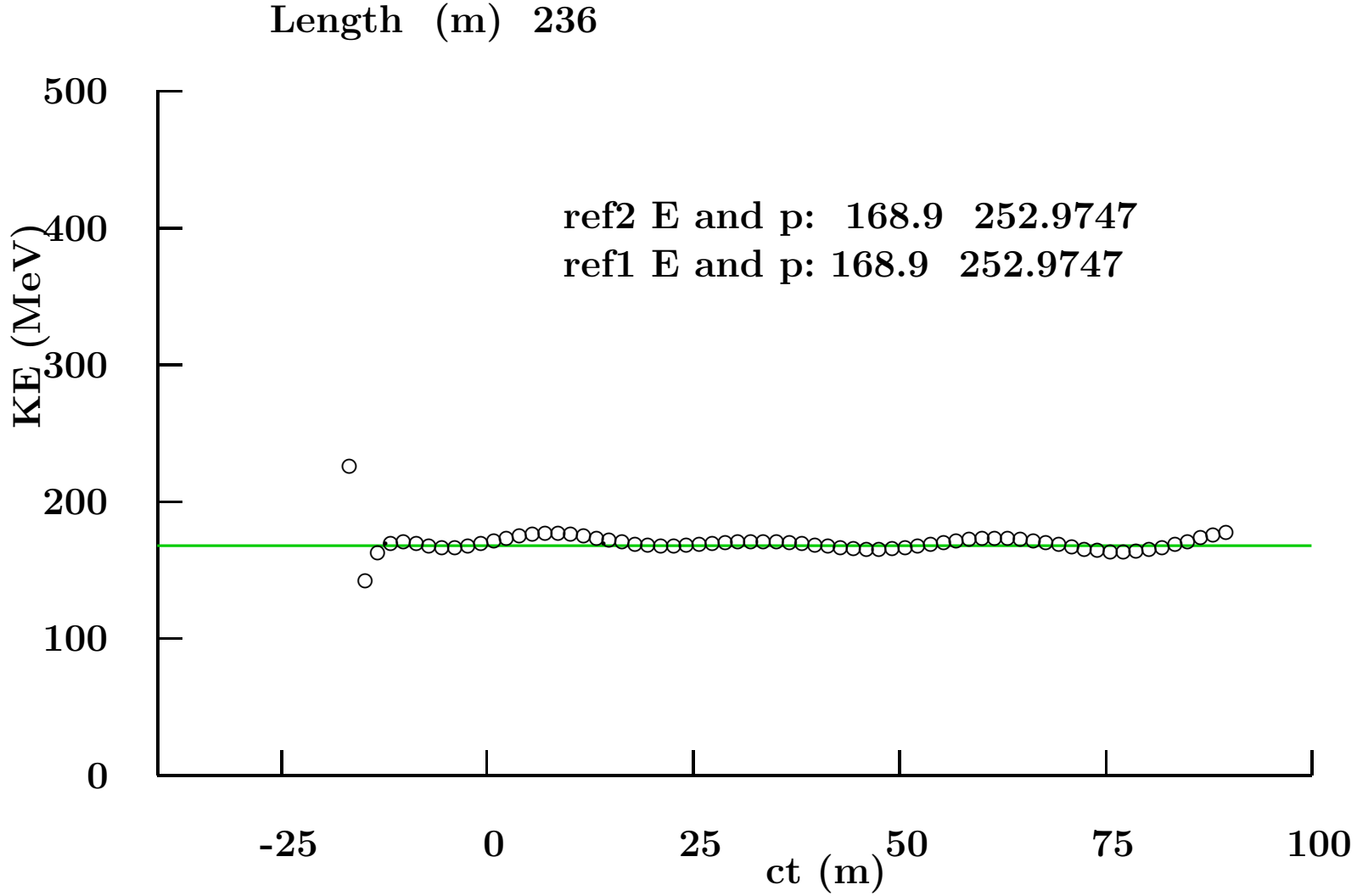

Length (m) 165
ref2 E and p: 261.3741 351.0057
ref1 E and p: 110.5575 188.2553
KE (MeV)
500
400
300
200
100
0
-25
0
25
50
75
100
ct (m)

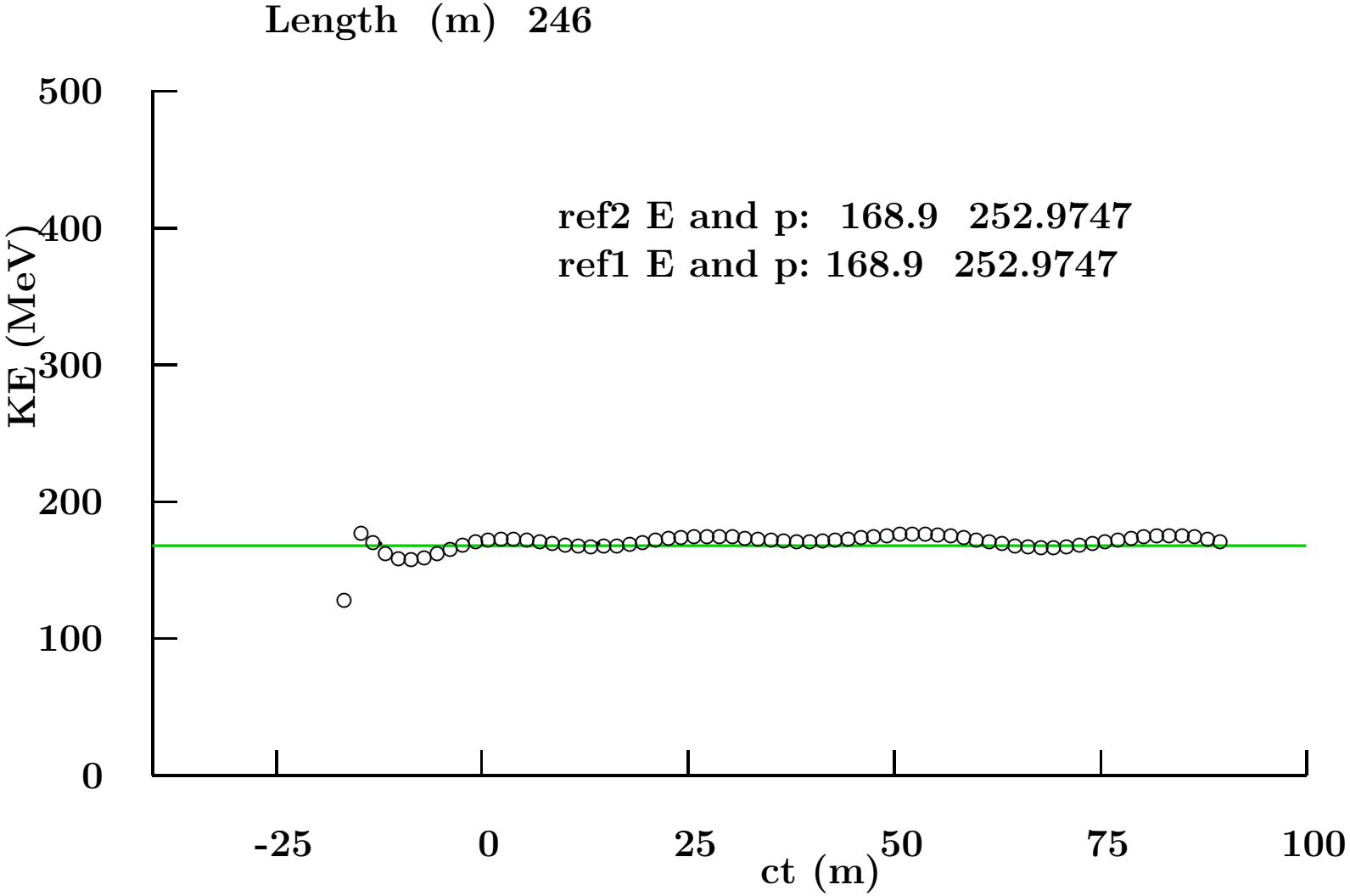

Length (m) 185
ref2 E and p: 211.2942 298.3571
ref1 E and p: 138.0575 219.2076
KE (MeV)
500
400
300
200
100
0
-25
0
25
50
75
100
ct (m)

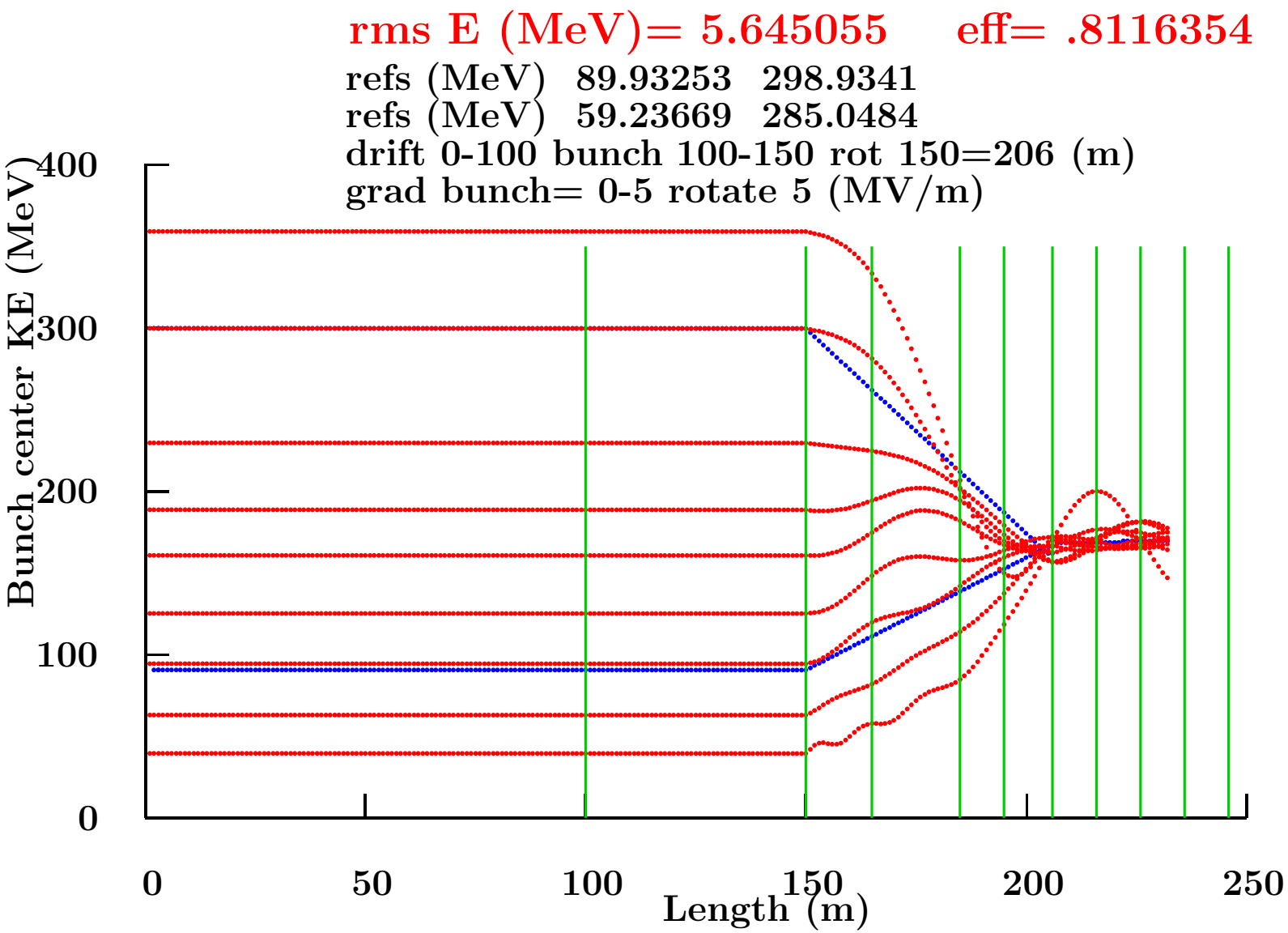

Length (m) 195
ref2 E and p: 186.2542 271.6689
ref1 E and p: 151.8075 234.3611
KE (MeV)
500
400
300
200
100
0
-25
0
25
50
75
100
ct (m)


Length (m) 206
and 216
ref2 E and p: 161.2142 244.6324
ref1 E and p: 165.5575 249.3519
KE (MeV)
500
400
300
200
100
0
-25
0
25
50
75
100
ct (m)

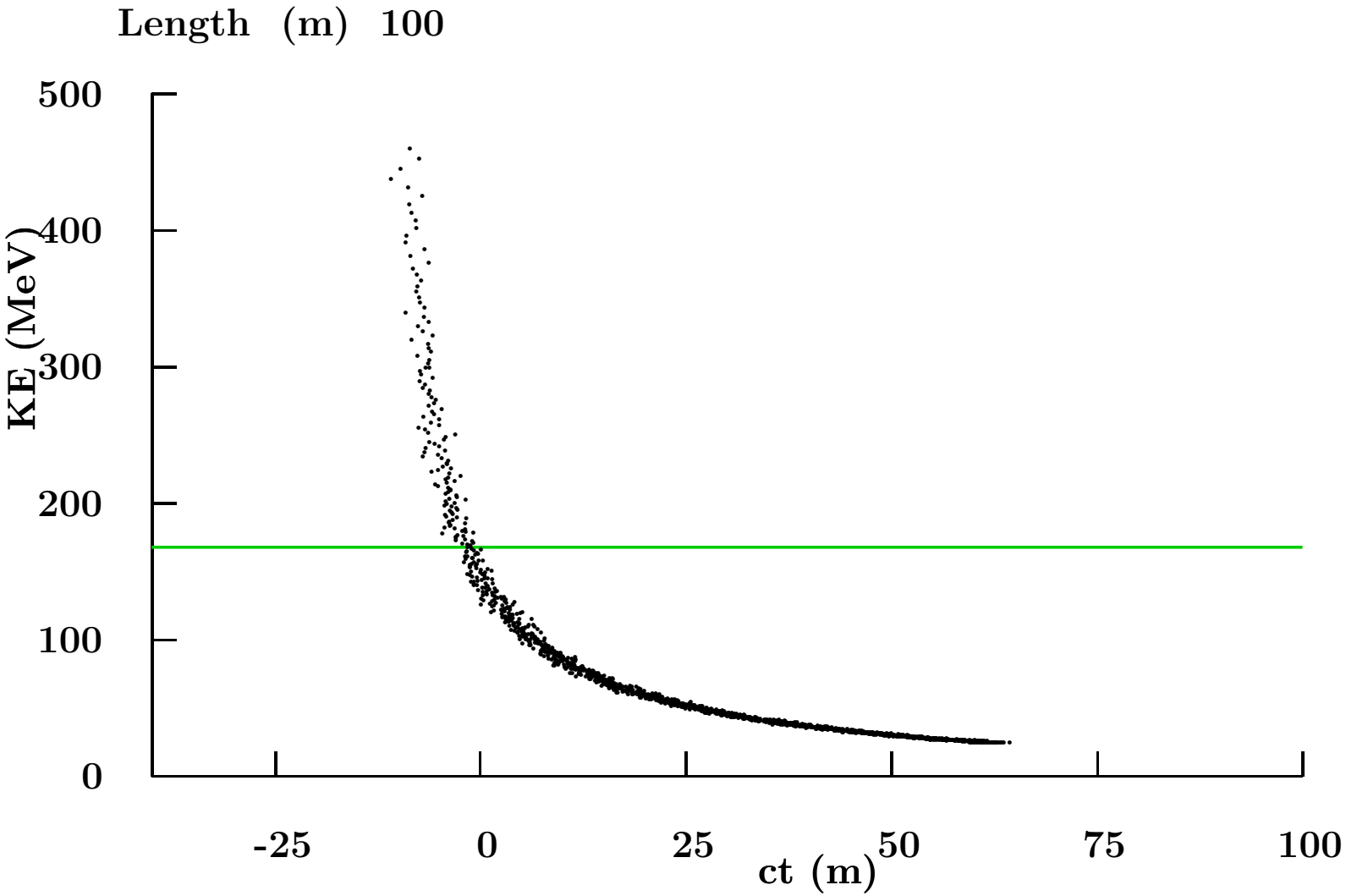

Length (m) 226
ref2 E and p: 168.9 252.9747
ref1 E and p: 168.9 252.9747
KE (MeV)
500
400
300
200
100
0
-25
0
25
50
75
100
ct (m)

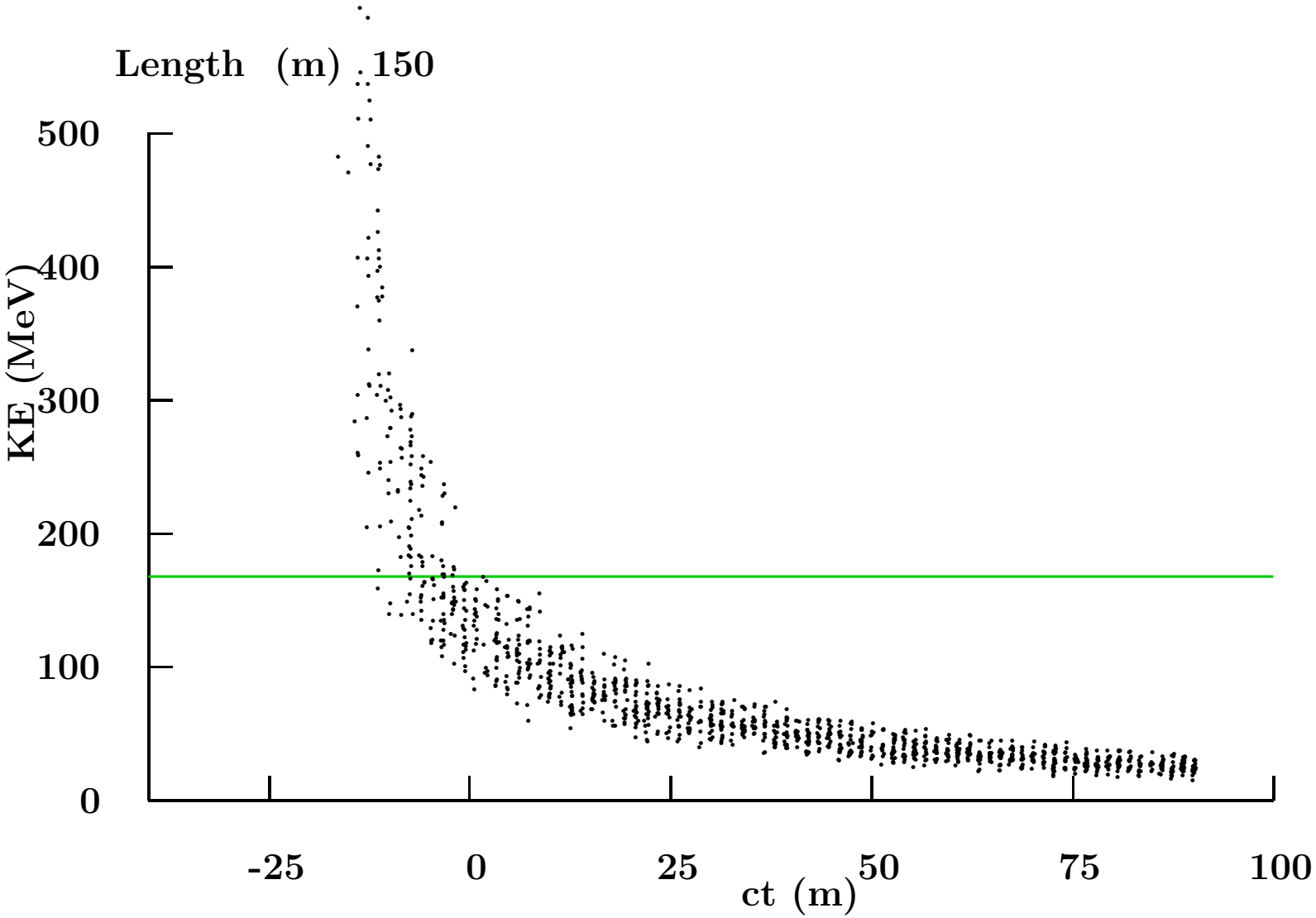

Length (m) 236
ref2 E and p: 168.9 252.9747
ref1 E and p: 168.9 252.9747
KE (MeV)
500
400
300
200
100
0
-25
0
25
50
75
100
ct (m)

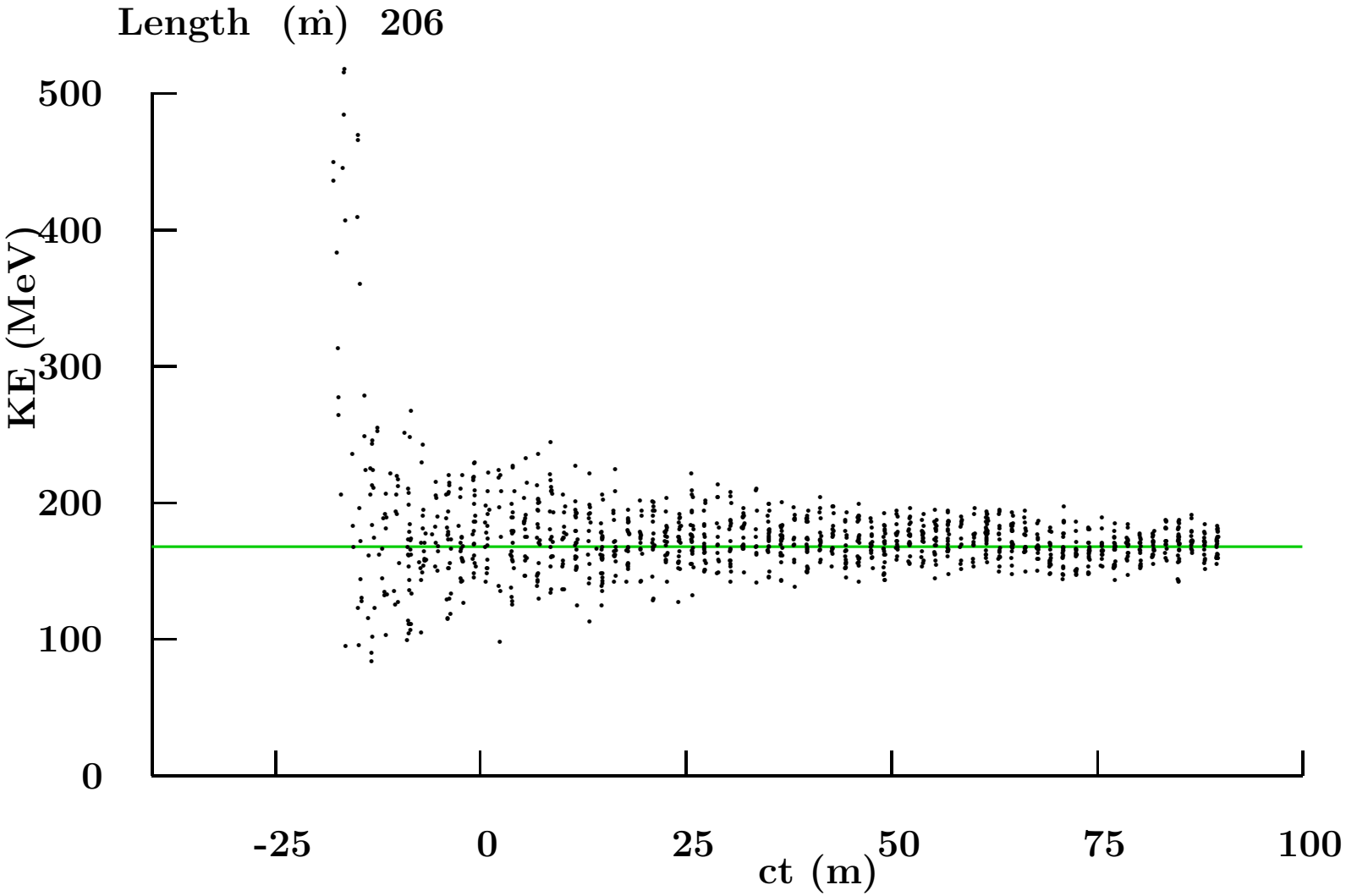

Length (m) 246
ref2 E and p: 168.9 252.9747
ref1 E and p: 168.9 252.9747
KE (MeV)
500
400
300
200
100
0
-25
0
25
50
75
100
ct (m)


rms E (MeV)= 5.645055 eff= .8116354
refs (MeV) 89.93253 298.9341
refs (MeV) 59.23669 285.0484
drift 0-100 bunch 100-150 rot 150=206 (m)
grad bunch= 0-5 rotate 5 (MV/m)
Bunch center KE (MeV)
400
300
200
100
0
0
50
100
150
200
250
Length (m)

Start with 3 nsec scatter - all tracks




Length (m) 150
500
400
300
200
100
0
KE (MeV)
-25
0
25
50
75
100
ct (m)


Length (m) 206
500
400
300
200
100
0
KE (MeV)
-25
0
25
50
75
100
ct (m)

Conclusion

- Neuffer scheme does not work as I imagined
- But is good up to about 250 MeV initial
- It can be optimized
- Now good to 370 MeV
- Further raising the rererences may further improve it
- Try varying rotation length
- I must add material
- Optimize buncher
- I am trying to put the new design back in ICOOL