Matching and Extraction using Muon1 Response Matrix Output

Studies using eRHIC Oct'14 lattice, using double beams for dispersion

eRHIC Structure

Clock position	FFAG Lattice	Clock position	FFAG Lattice
2	Linac	8 = PHENIX IR	Straight + Bypass
	Splitter		Transition
1	Arc	7	Arc
	Transition		Transition
12	Straight	6 = STAR IR	Straight + Bypass
	Transition		Transition
11	Arc	5	Arc
	Transition		Transition
10	Straight + Crossover	4	Straight + Crossover
	Transition		Transition
9	Arc	3	Arc
	Transition		Splitter

Extraction?

Un-extraction?

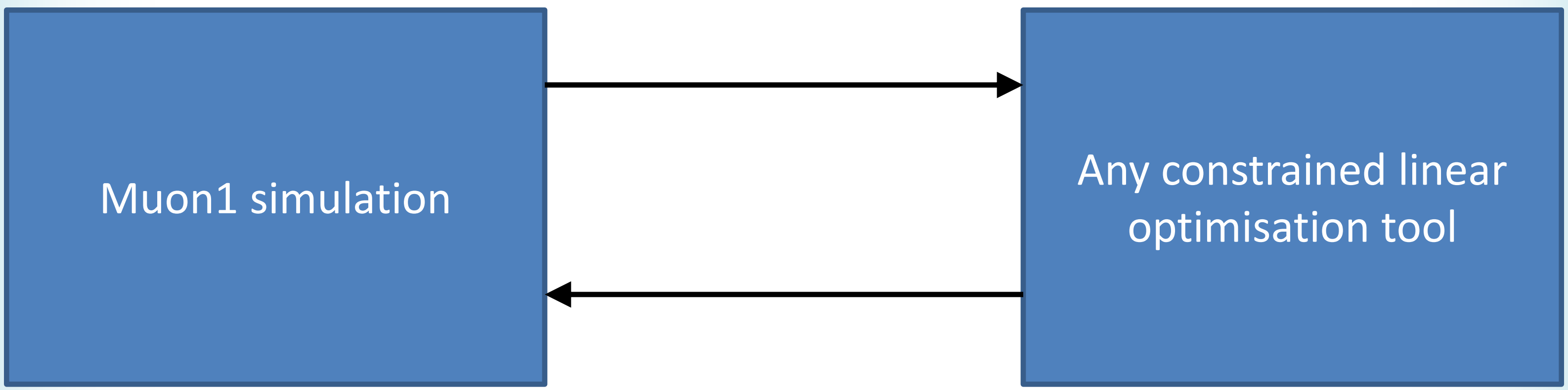
Muon1 Response Output

For each “ResponseBPM” j,
a CSV file containing the matrix:

$$\frac{\partial(x,x',y,y')_{Particle\ n,BPM\ j}}{\partial Corrector_i}$$

…and the uncorrected positions:

$$(x,x',y,y')_{Particle\ n,BPM\ j}$$



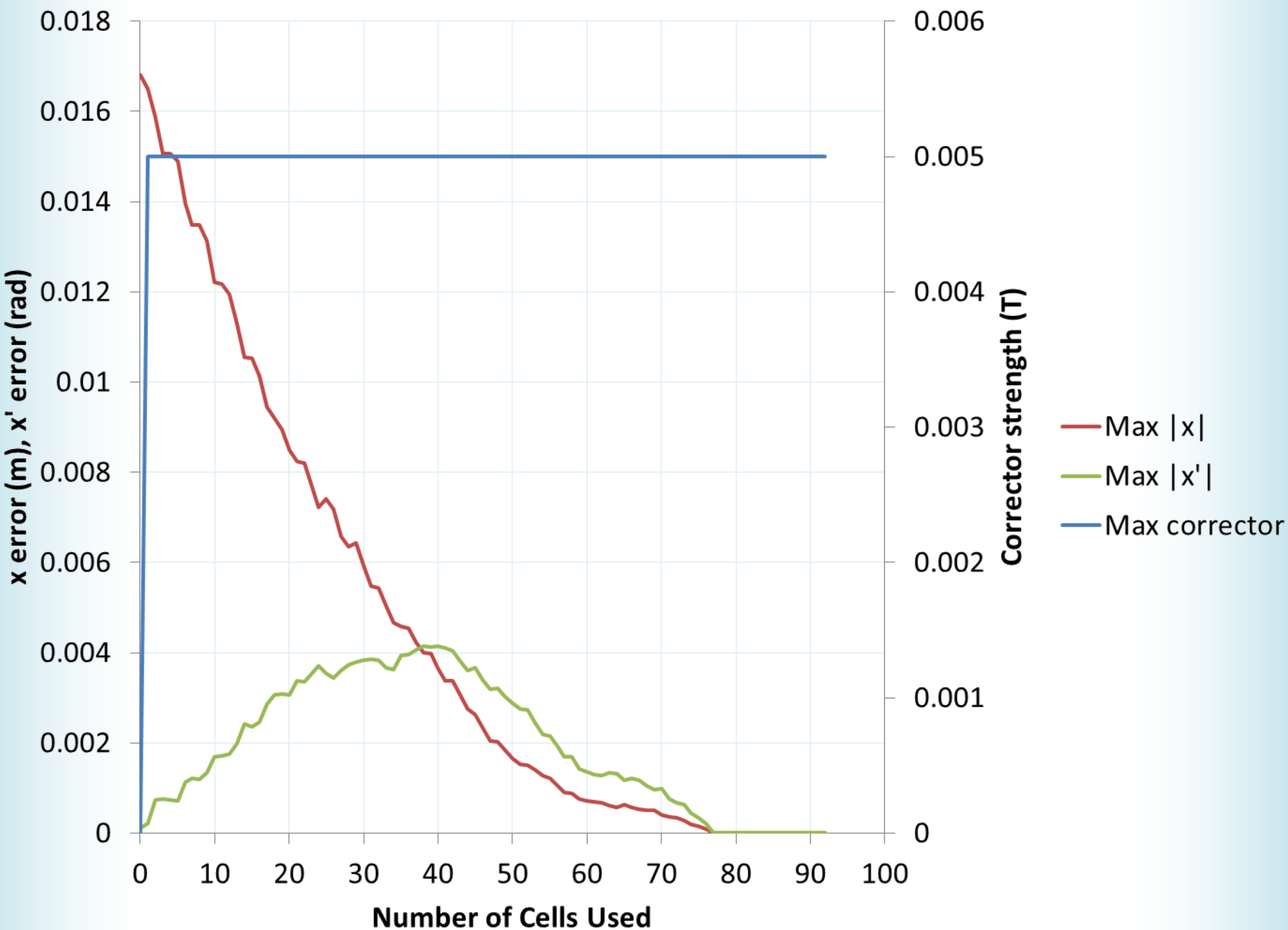
Corrector vector
as lattice input

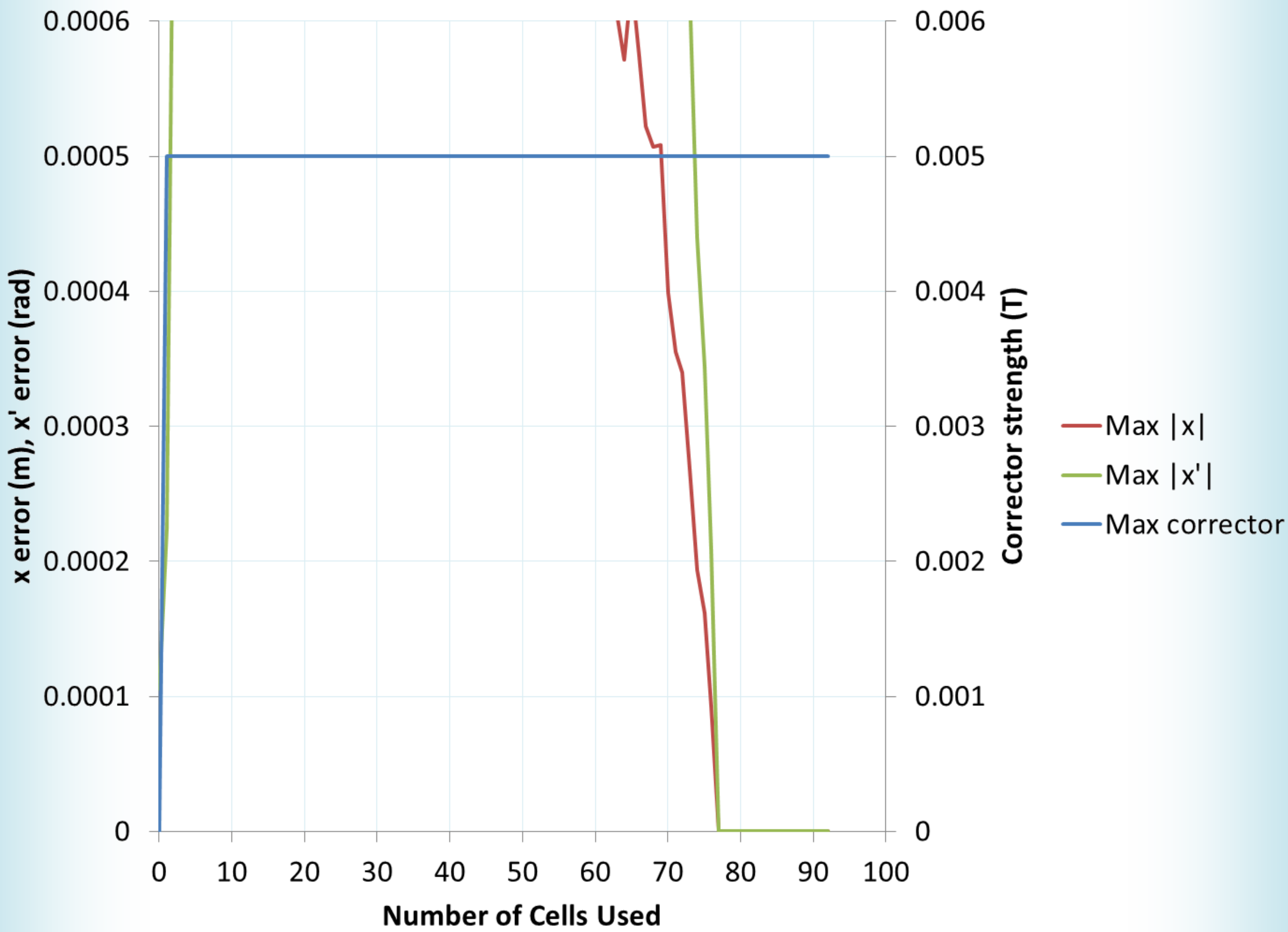
Any attribute can become a corrector, e.g. adding a ResponseDipole=1e-6 attribute will vary that Dipole by 1e-6 Tesla in the numerical differentiation.

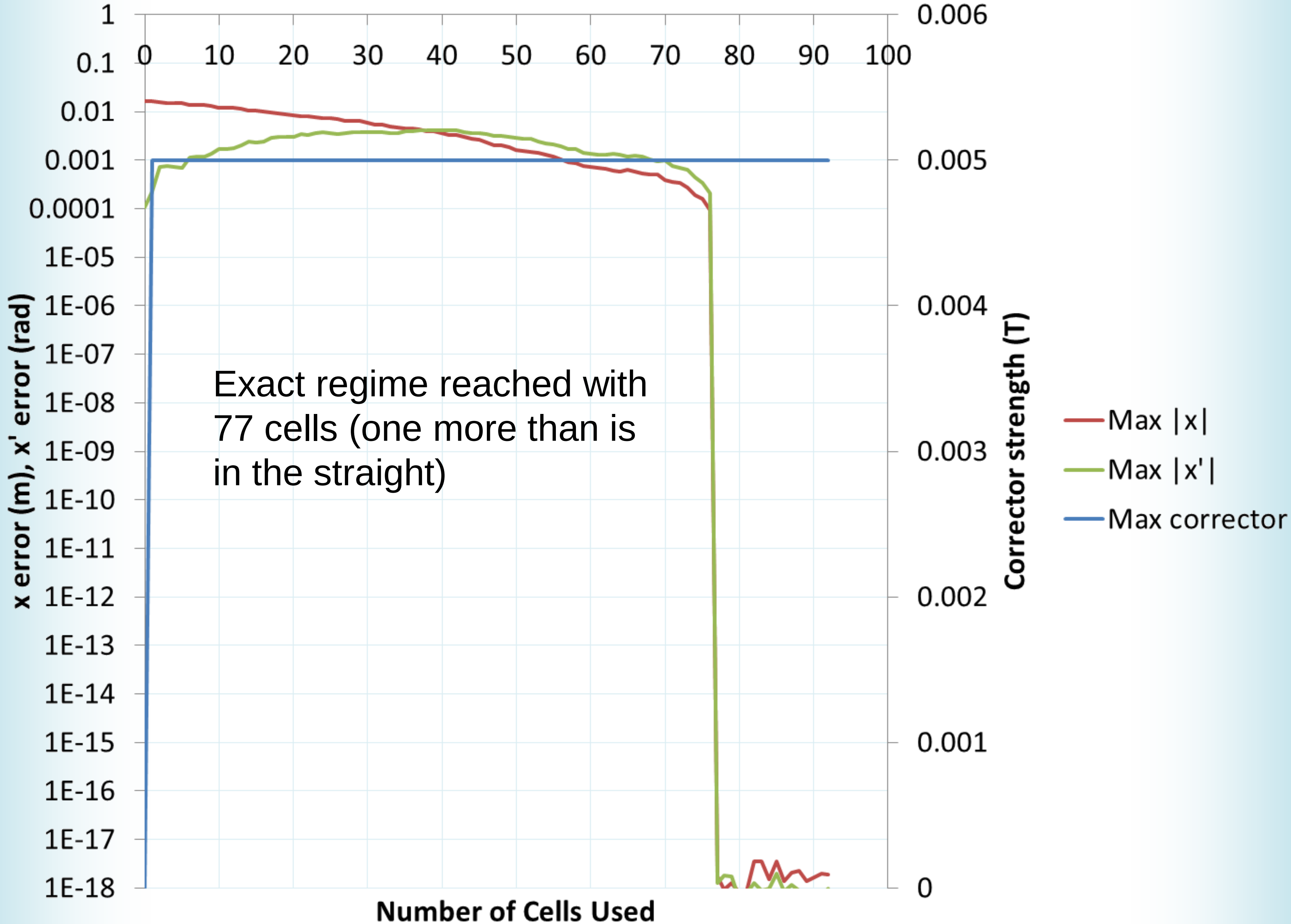
Extraction Matching x, x’ Only

- Uses cells from the FFAG2 straight section
- Goal is x=x’=0 except for one beam where x>0
- Dipole correctors limited to ±0.005T as before

- Corrector program tries to minimise RMS x, x’ error subject to corrector strength constraint
- Results presented for allowing varying number of cells’ correctors to be used

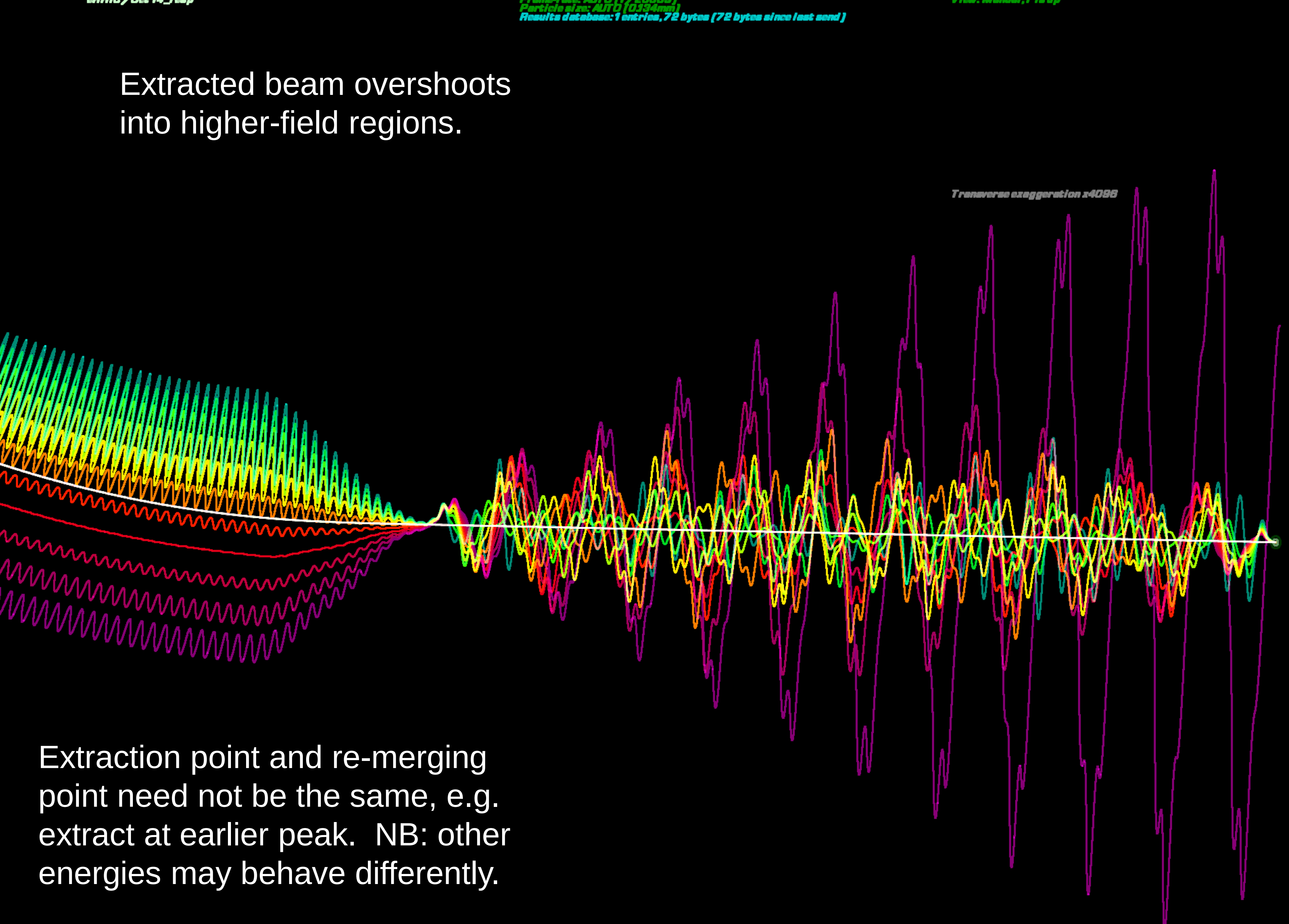

0.018
0.016
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0
x error (m), x' error (rad)
0.006
0.005
0.004
0.003
0.002
0.001
0
Corrector strength (T)
0
10
20
30
40
50
60
70
80
90
100
Number of Cells Used
Max |x|
Max |x'|
Max corrector


0.0006
0.0005
0.0004
0.0003
0.0002
0.0001
0
0.006
0.005
0.004
0.003
0.002
0.001
0
0
10
20
30
40
50
60
70
80
90
100
Number of Cells Used
x error (m), x' error (rad)
Corrector strength (T)
Max |x|
Max |x'|
Max corrector



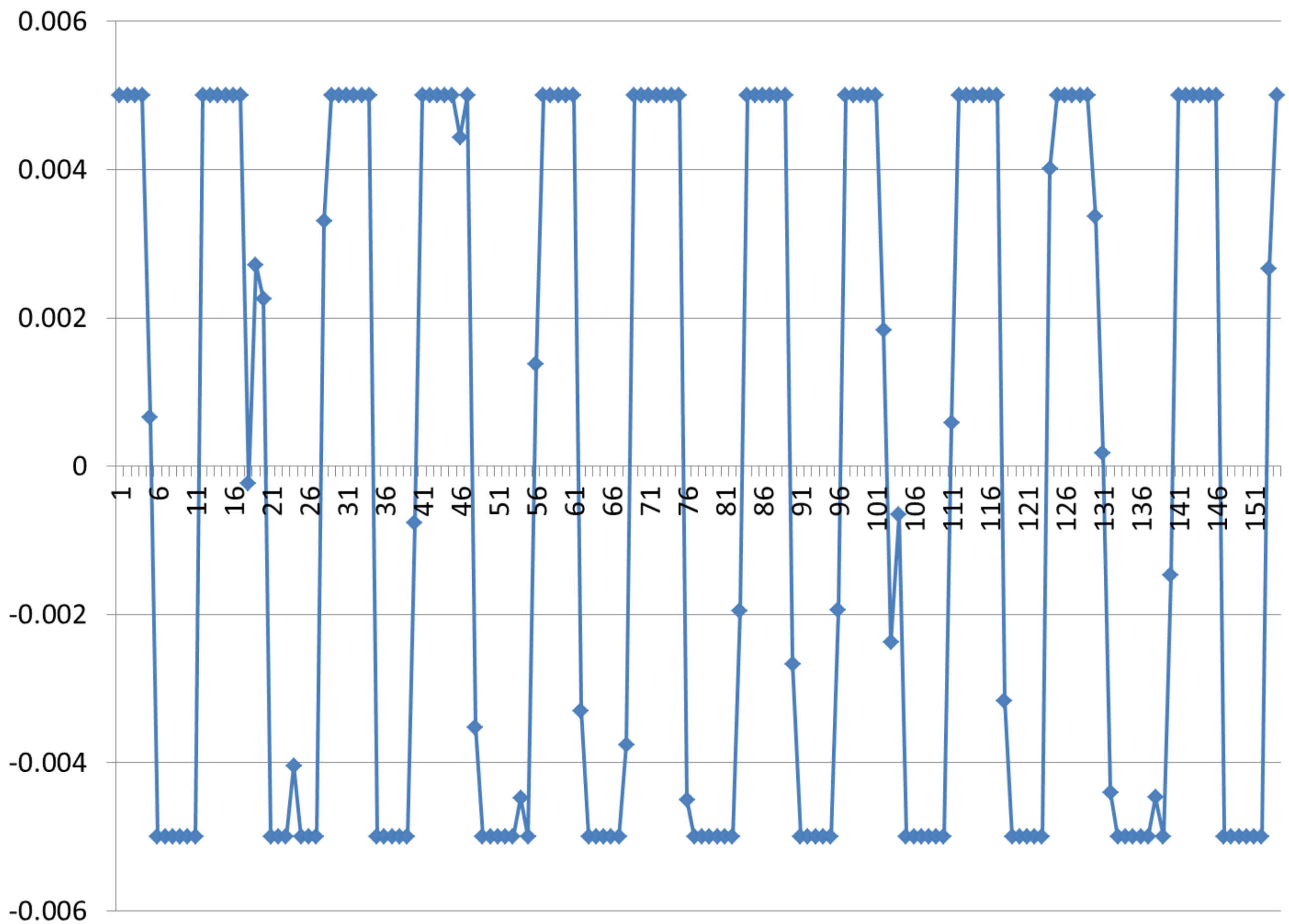
Exact regime reached with
77 cells (one more than is
in the straight)
x error (m), x' error (rad)
Corrector strength (T)
Number of Cells Used
Max |x|
Max |x'|
Max corrector
1
0.1
0.01
0.001
0.0001
1E-05
1E-06
1E-07
1E-08
1E-09
1E-10
1E-11
1E-12
1E-13
1E-14
1E-15
1E-16
1E-17
1E-18
0
10
20
30
40
50
60
70
80
90
100
0.006
0.005
0.004
0.003
0.002
0.001
0

Extracted beam overshoots
into higher-field regions.

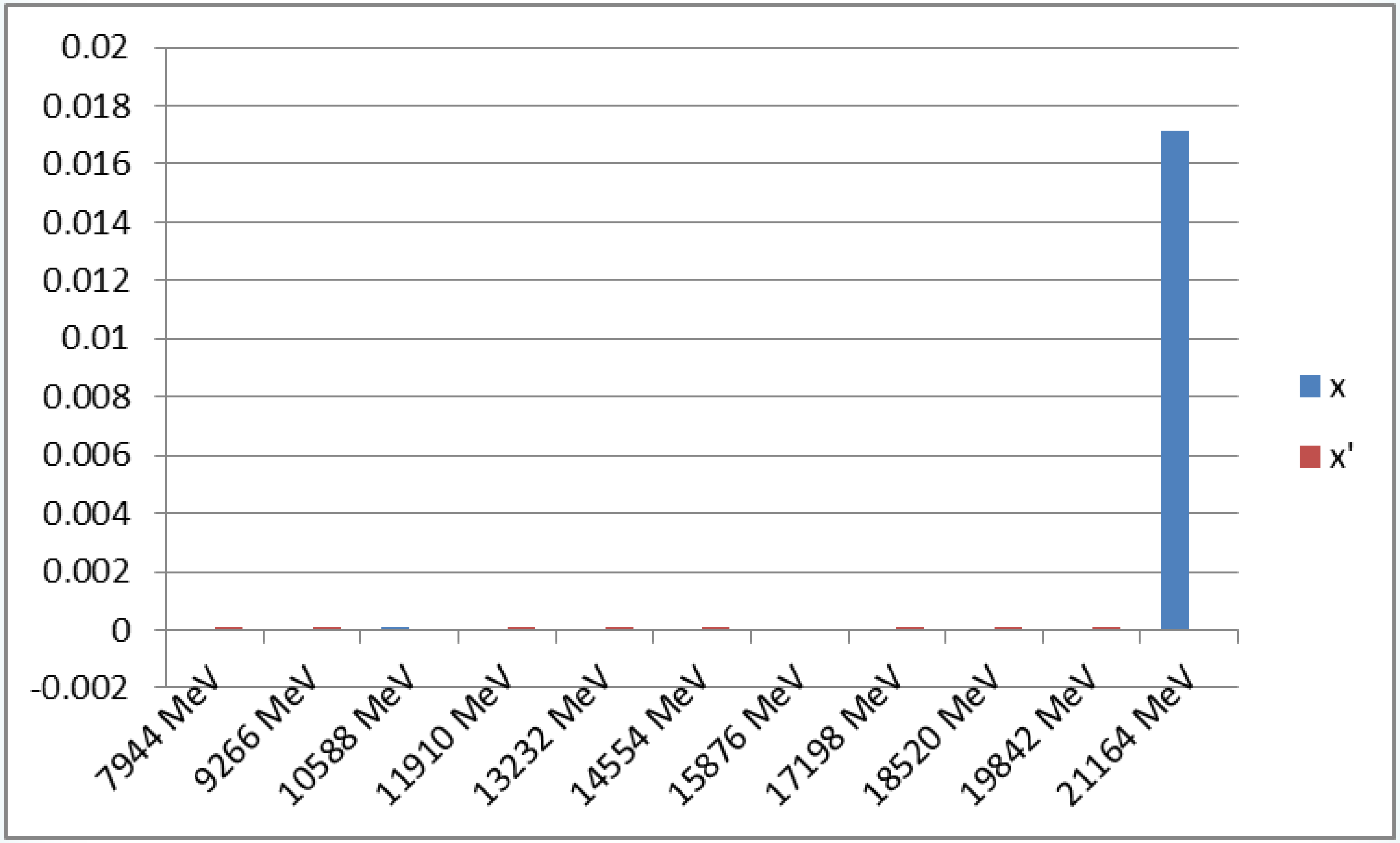


Extraction point and re-merging point need not be the same, e.g. extract at earlier peak. NB: other energies may behave differently.

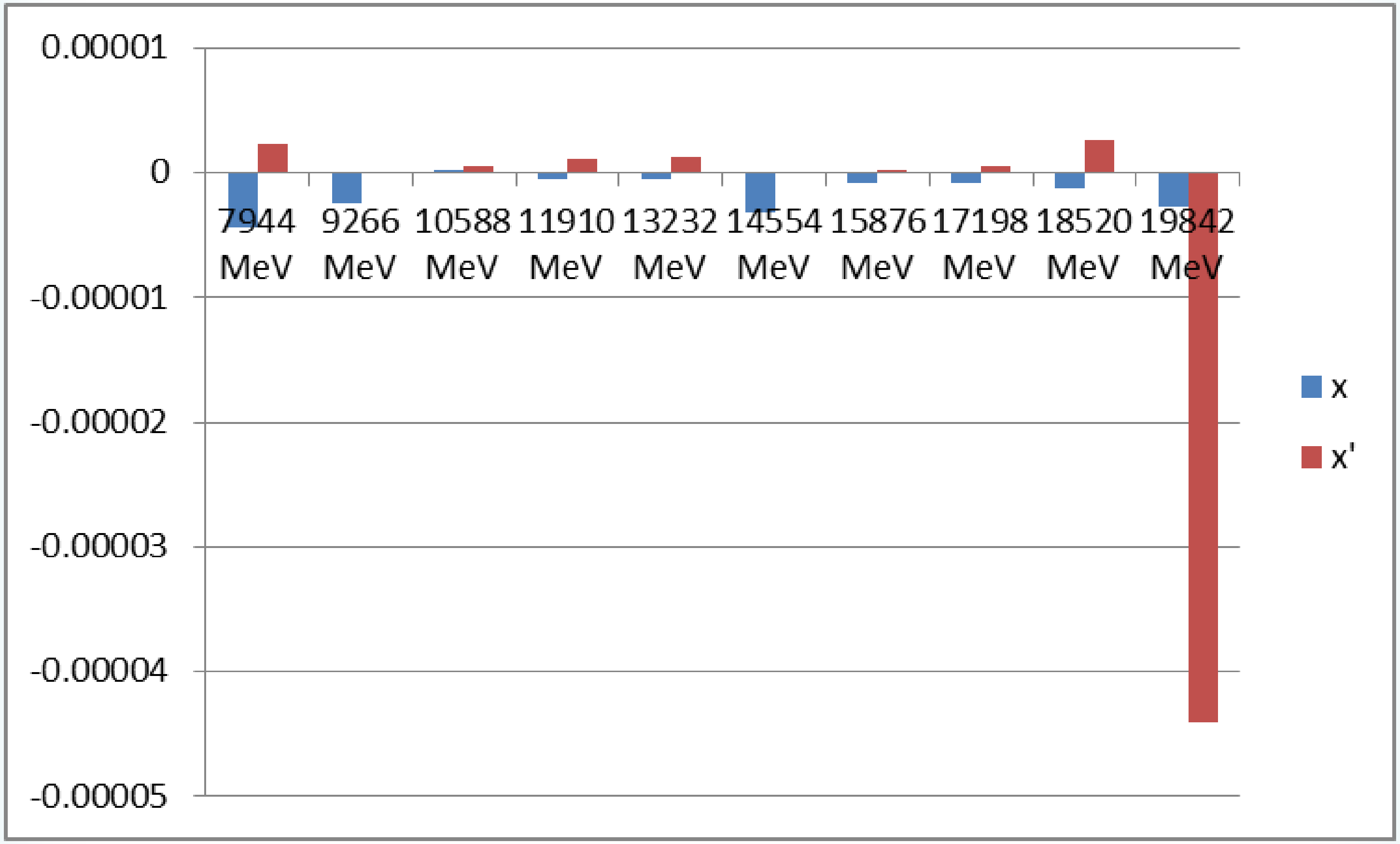
Corrector Dipole Fields (T)



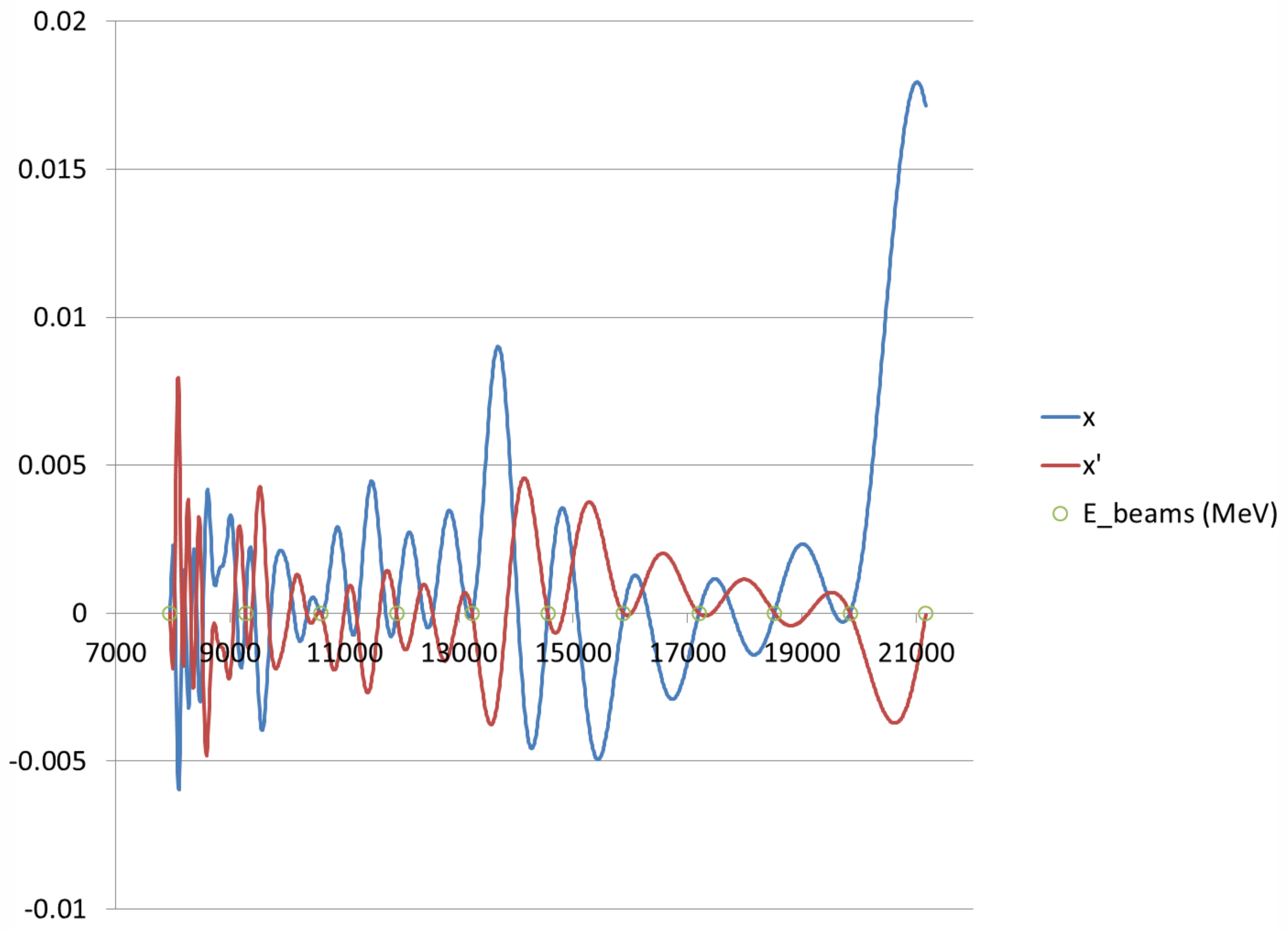
x and x' for Beam Energies



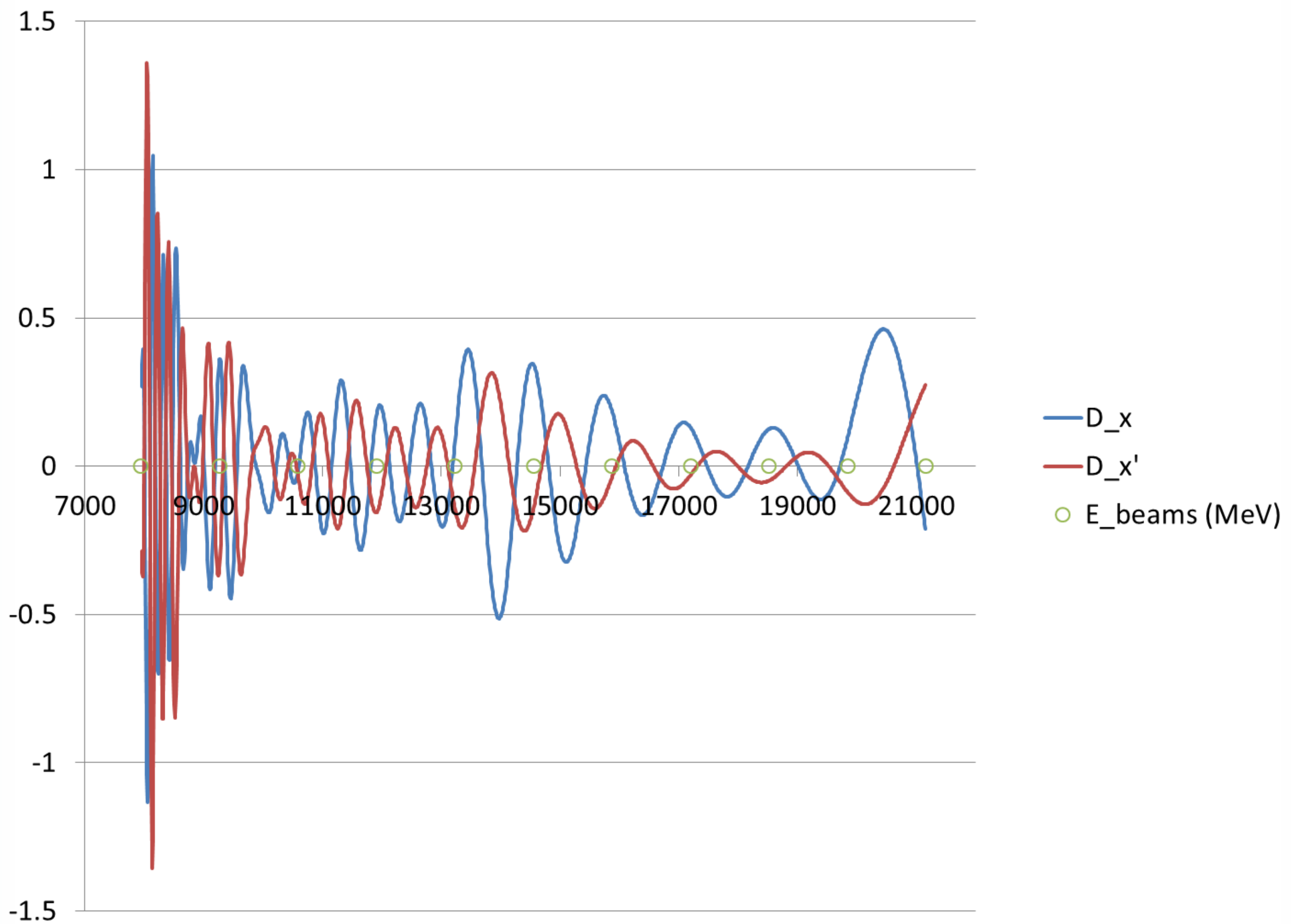
x and x’ for Beam Energies (zoom)



x and x’ as a Function of Energy

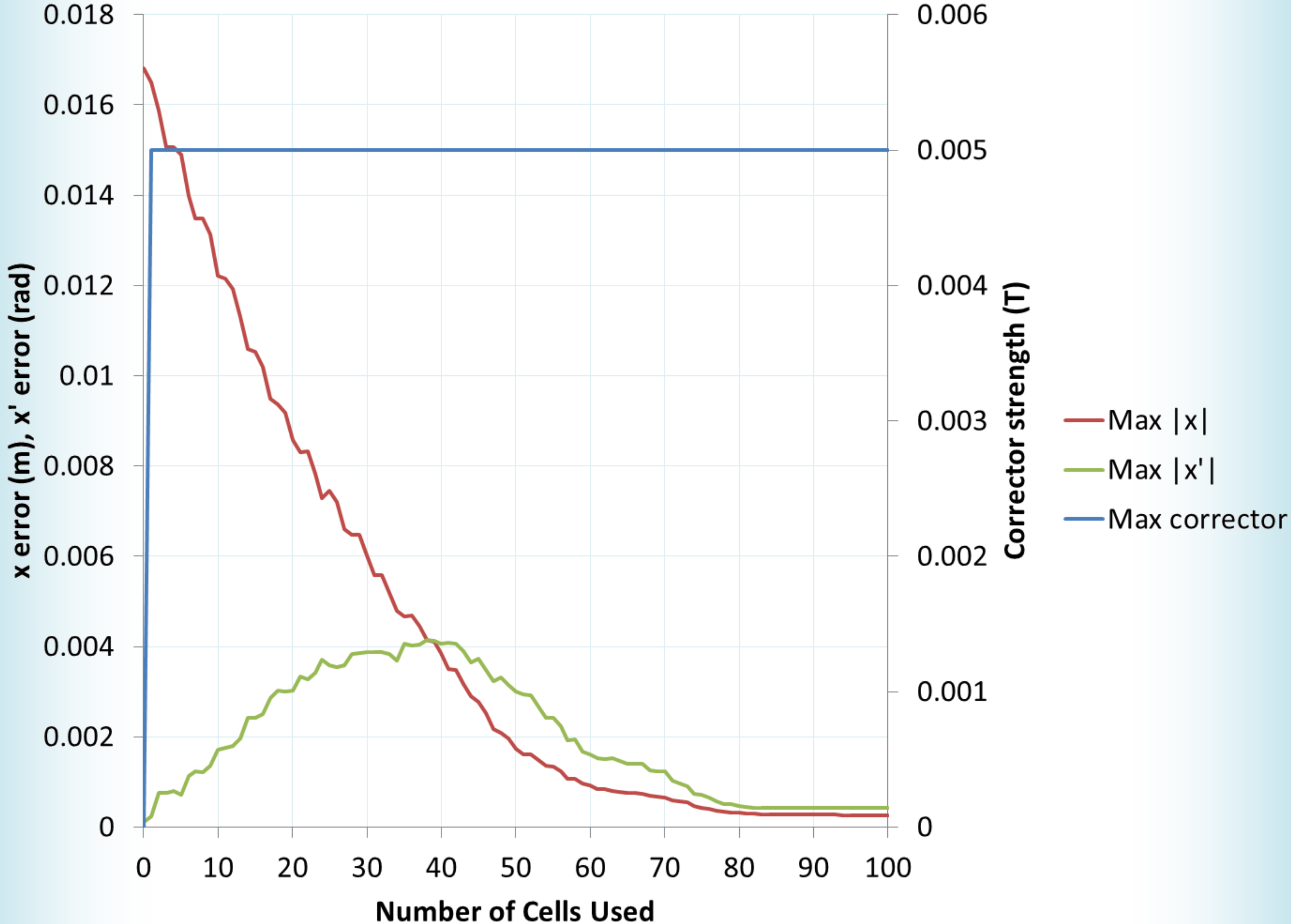


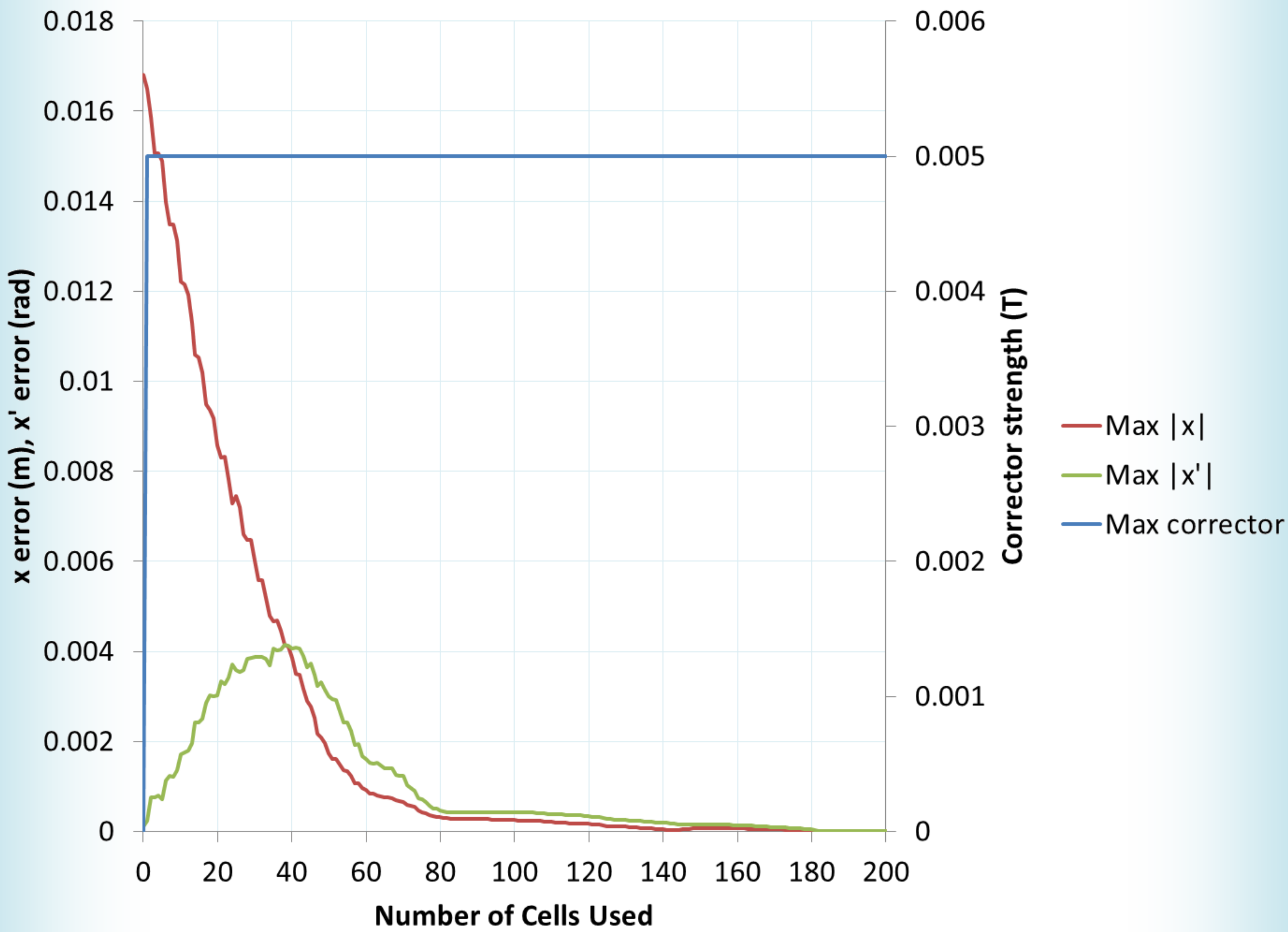
D_x and $D_{x'}$ as a Function of Energy

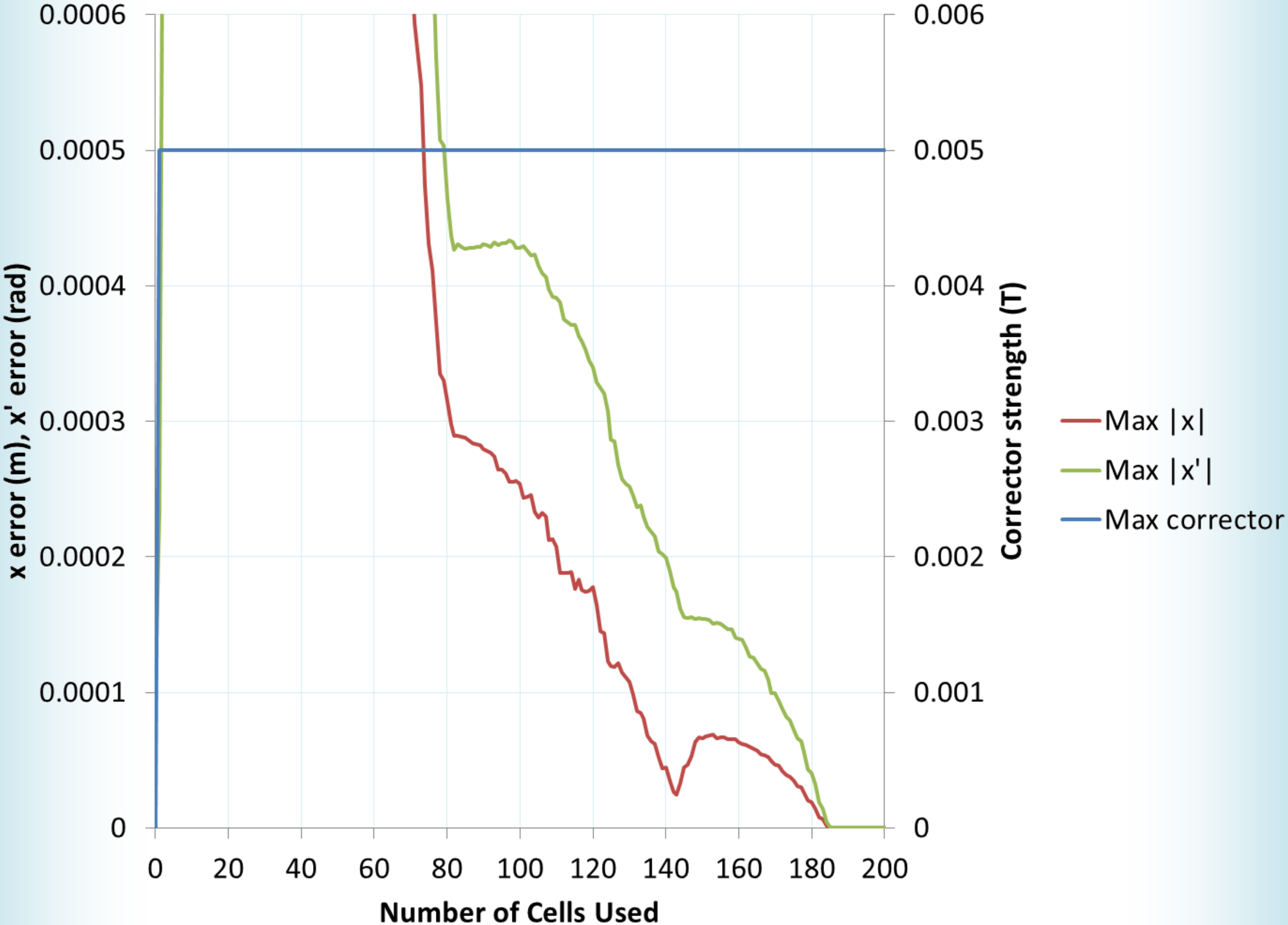


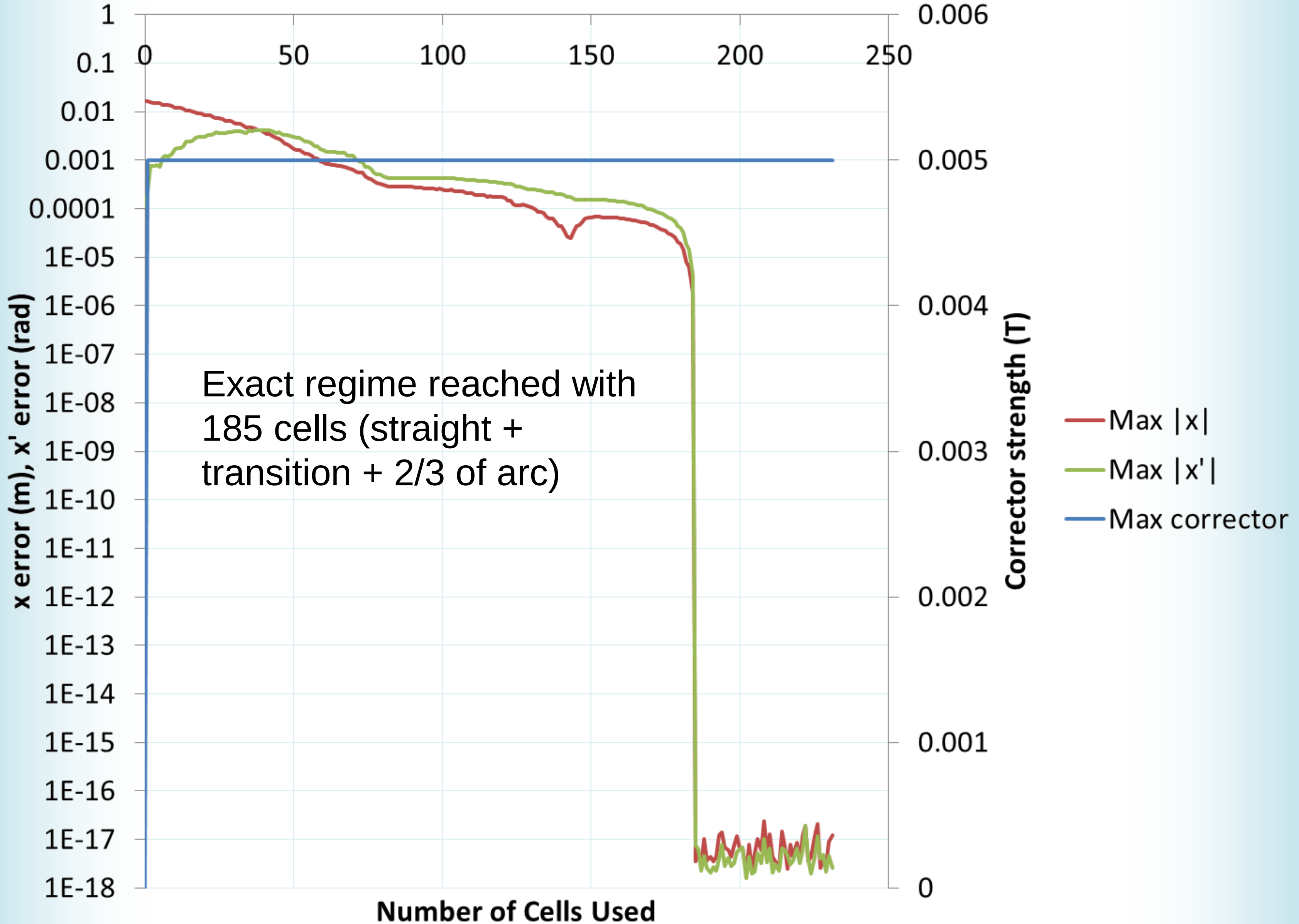
Extraction Including Dispersion

- Want gradient of x(E), x'(E) approximately zero around the beam points
- Add another set of beams 50MeV above the original 11
  - With the same goal x, x'
- "Double root" should force x(E), x'(E) to vary quadratically rather than linearly near the beam energies (D_x, $D_{x'}$ approximately zero)

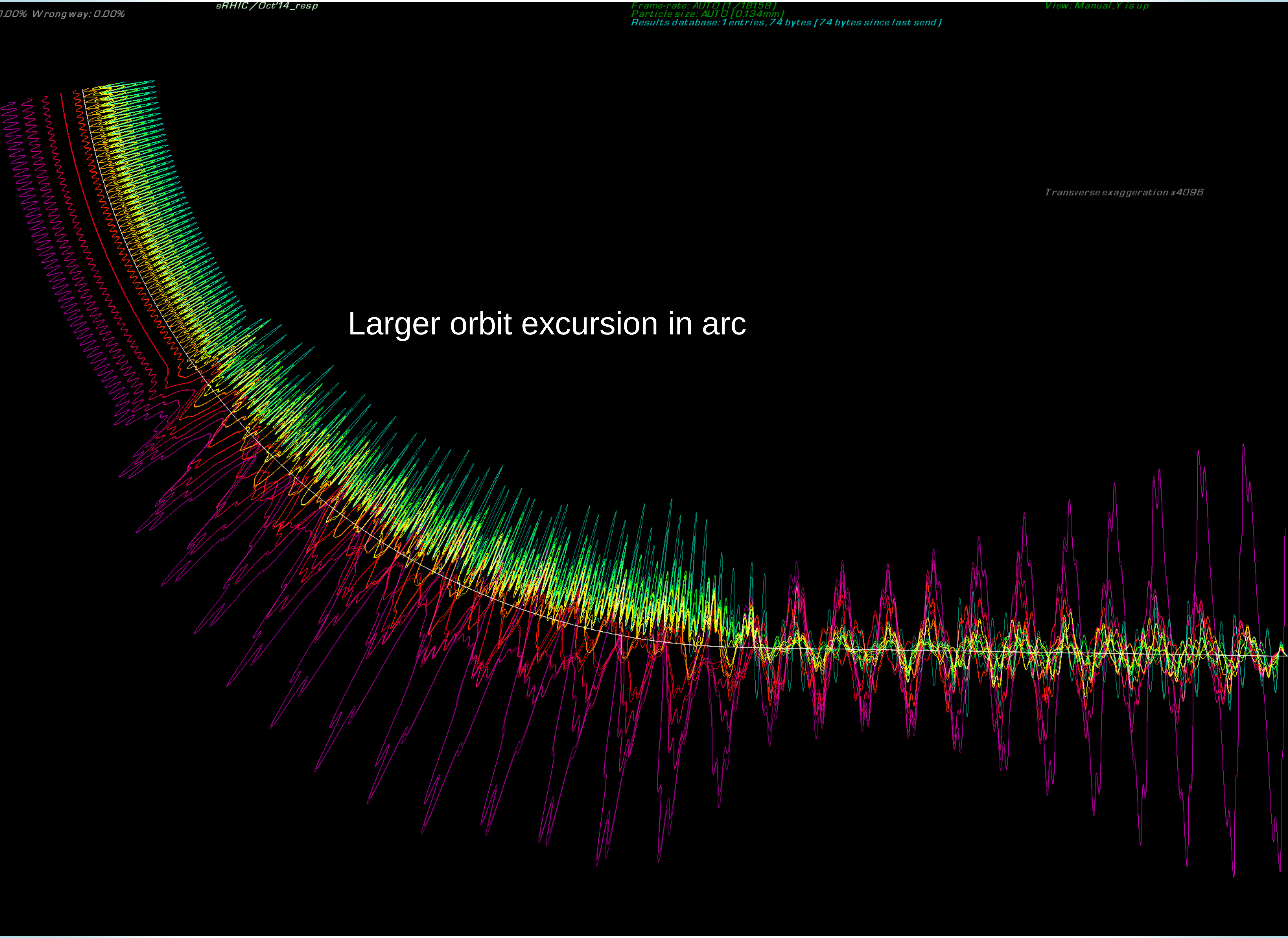

0.018
0.016
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0
x error (m), x' error (rad)
0.006
0.005
0.004
0.003
0.002
0.001
0
Corrector strength (T)
0
10
20
30
40
50
60
70
80
90
100
Number of Cells Used
Max |x|
Max |x'|
Max corrector


0.018
0.016
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0
x error (m), x' error (rad)
0.006
0.005
0.004
0.003
0.002
0.001
0
Corrector strength (T)
0
20
40
60
80
100
120
140
160
180
200
Number of Cells Used
Max |x|
Max |x'|
Max corrector


0.0006
0.0005
0.0004
0.0003
0.0002
0.0001
0
x error (m), x' error (rad)
0.006
0.005
0.004
0.003
0.002
0.001
0
Corrector strength (T)
0
20
40
60
80
100
120
140
160
180
200
Number of Cells Used
Max |x|
Max |x'|
Max corrector

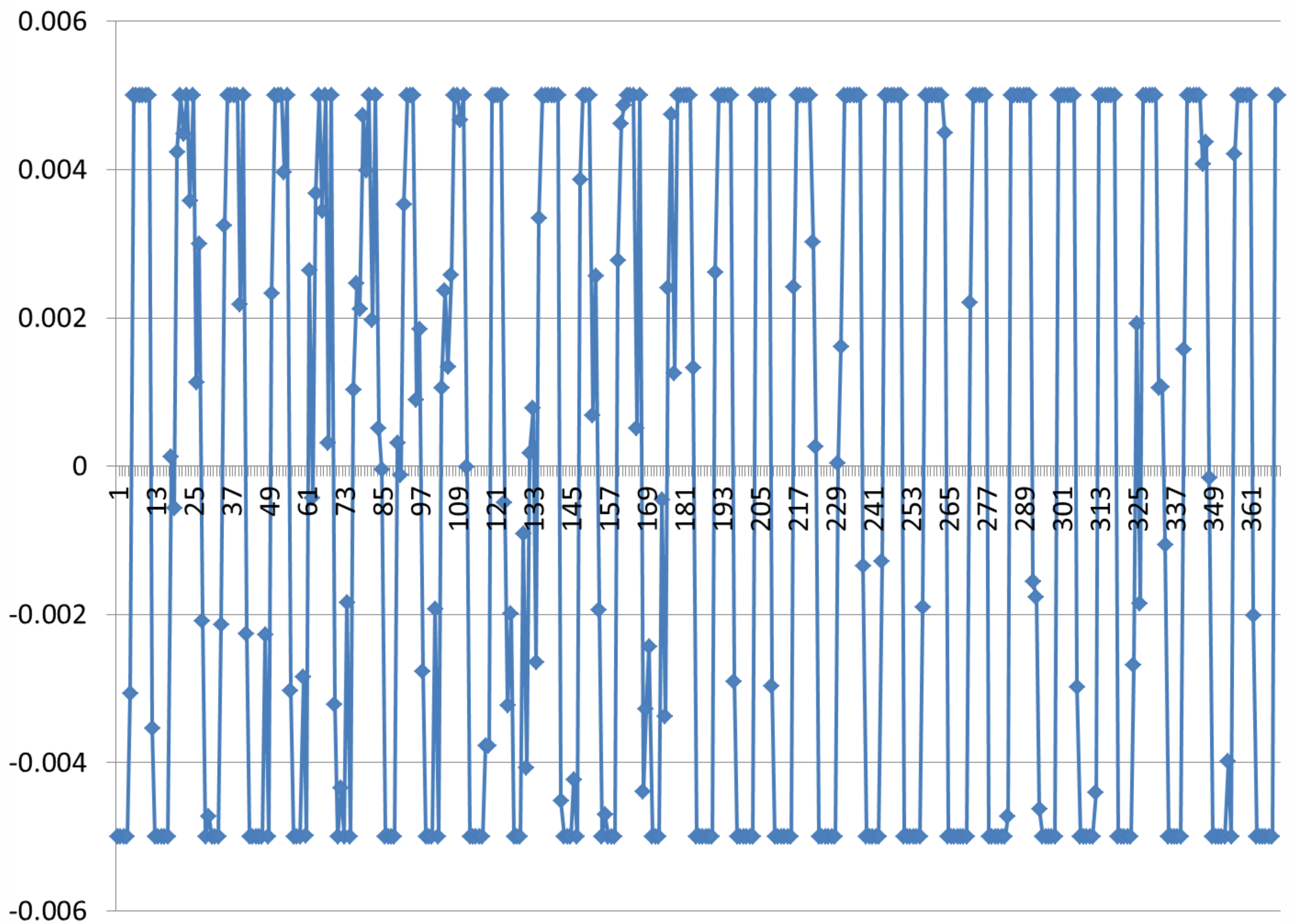


1
0.1
0.01
0.001
0.0001
1E-05
1E-06
1E-07
1E-08
1E-09
1E-10
1E-11
1E-12
1E-13
1E-14
1E-15
1E-16
1E-17
1E-18
0
50
100
150
200
250
0.006
0.005
0.004
0.003
0.002
0.001
0
x error (m), x' error (rad)
Corrector strength (T)
Number of Cells Used
Exact regime reached with 185 cells (straight + transition + 2/3 of arc)
Max |x|
Max |x'|
Max corrector

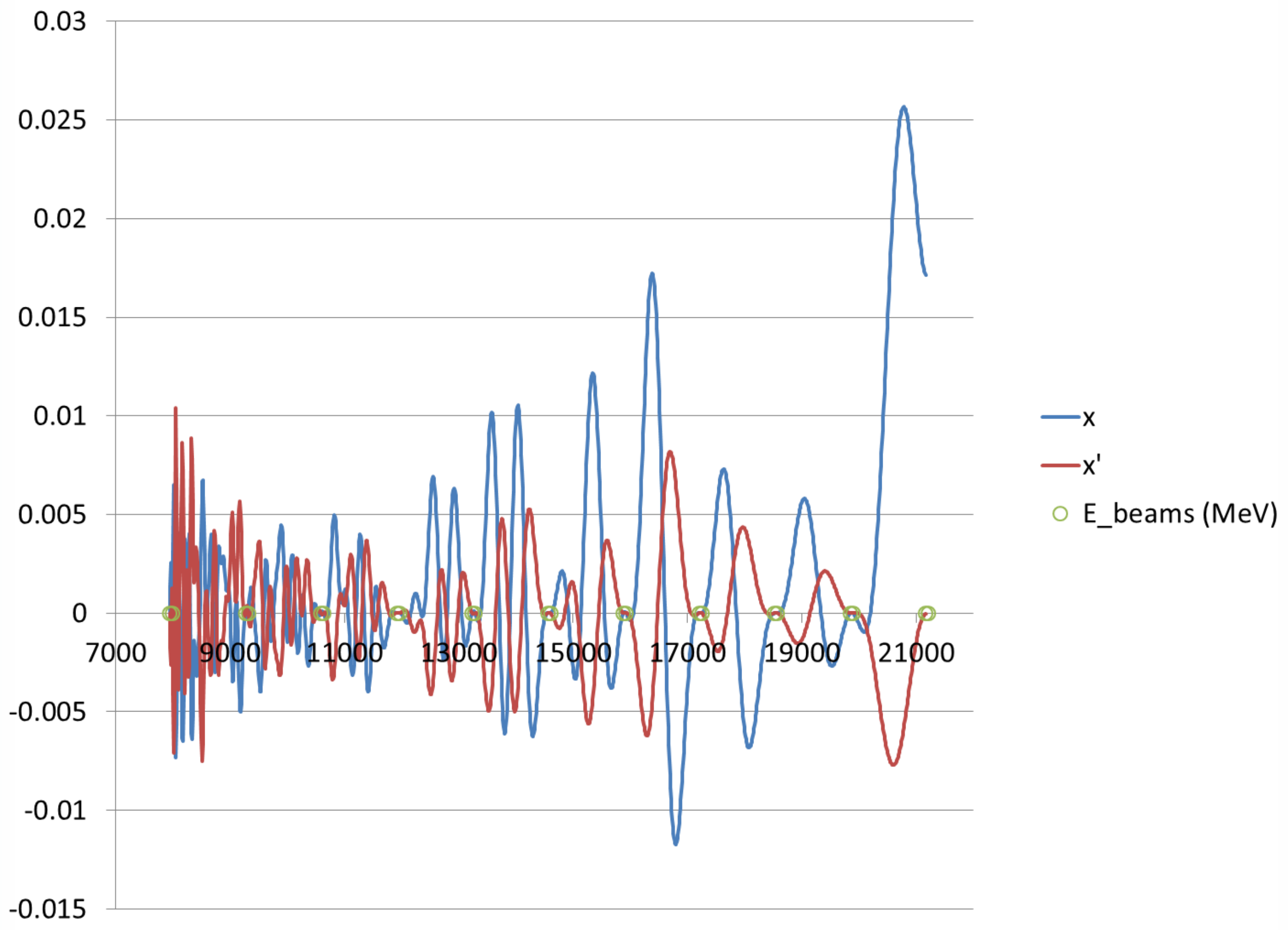


0.00% Wrongway: 0.00%
eRHIC/Oct'14_resp
Frame-rate: AUTO (1/18158)
Particle size: AUTO (0.134mm)
Results database: 1 entries, 74 bytes (74 bytes since last send)
View: Manual, Y is up
Transverse exaggeration x4096
Larger orbit excursion in arc

Corrector Dipole Fields (T)

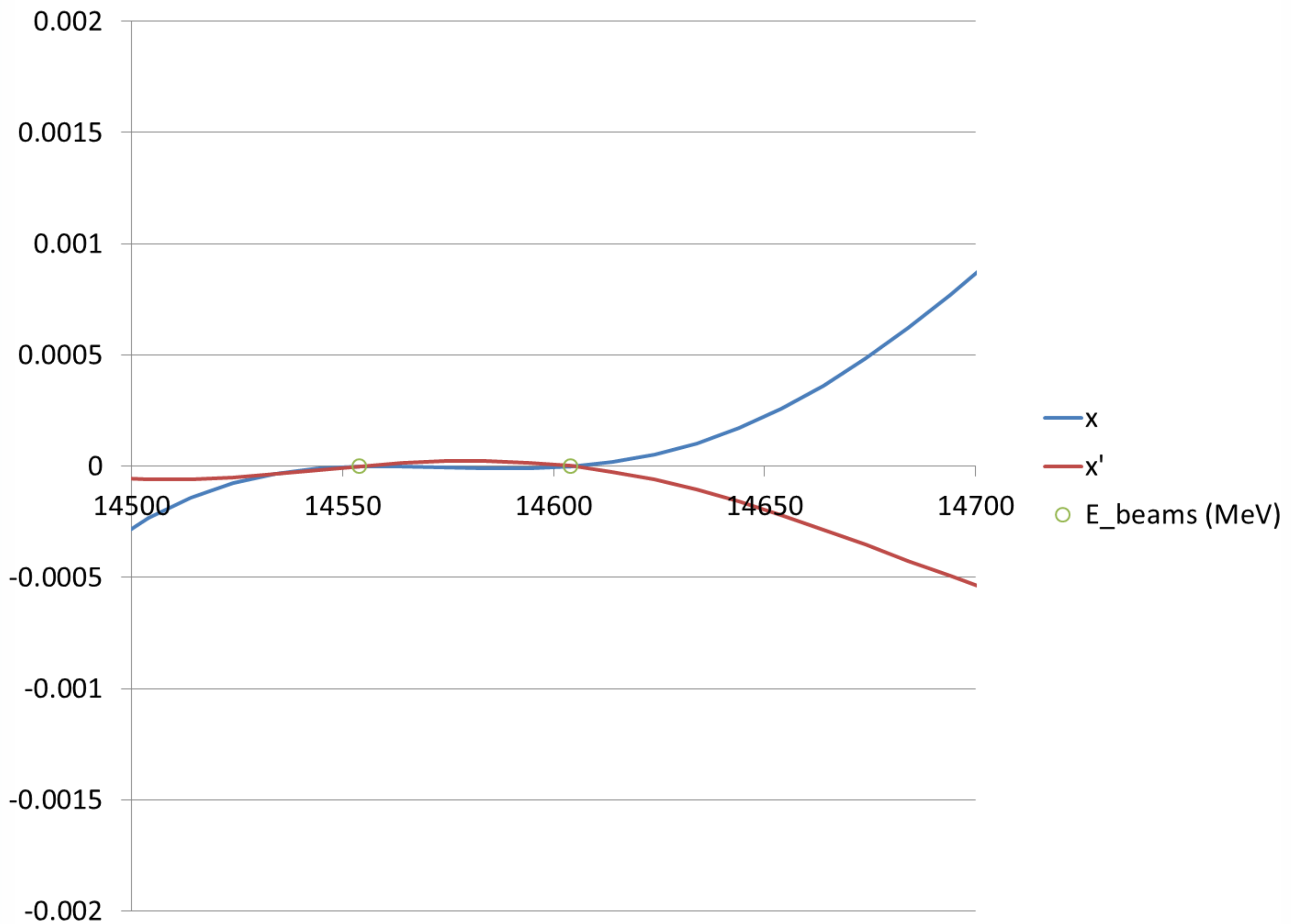


x and x’ as a Function of Energy

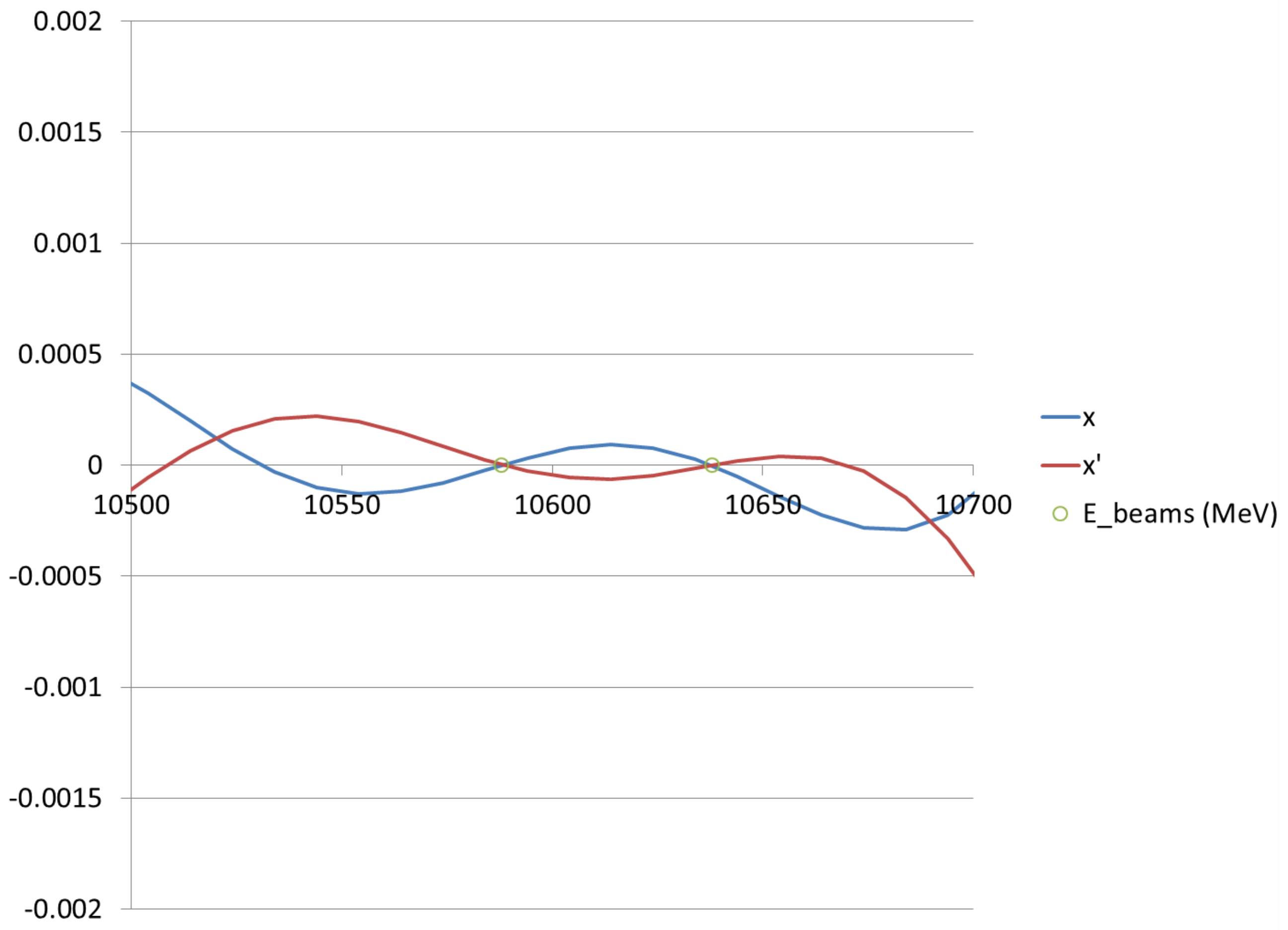


Zoom: 19.8GeV beams

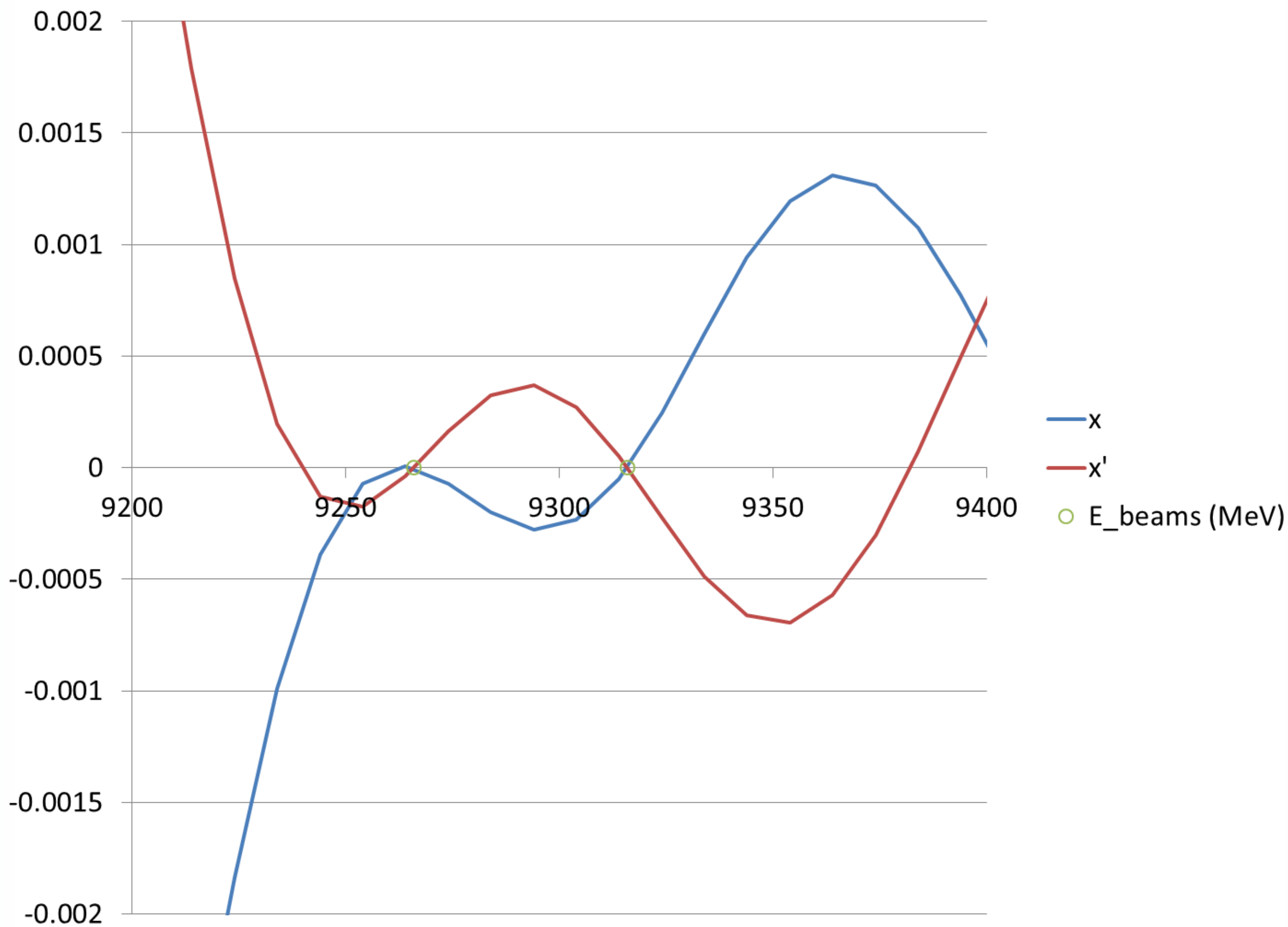
Zoom: 14.6GeV beams



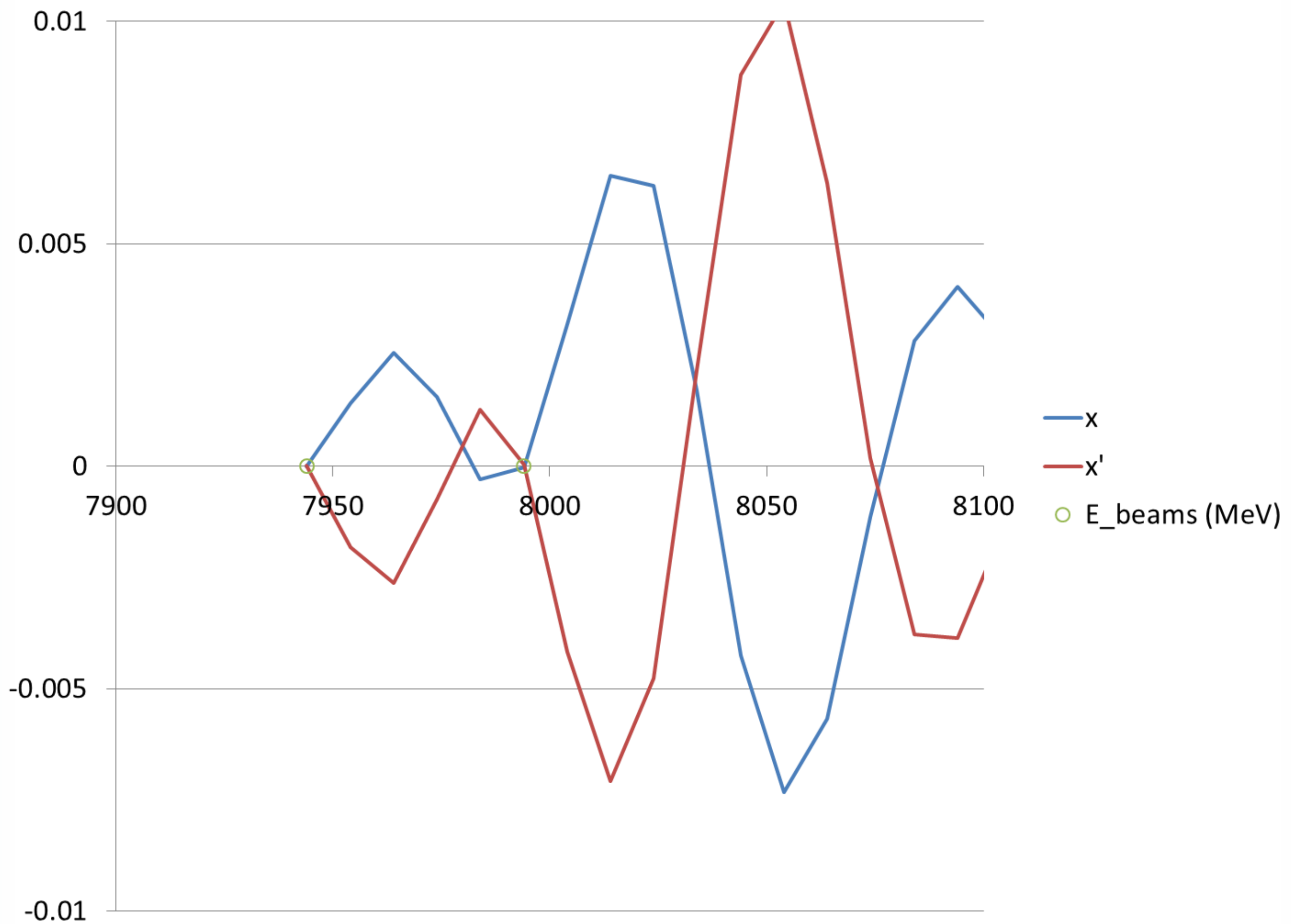
Zoom: 10.6GeV beams



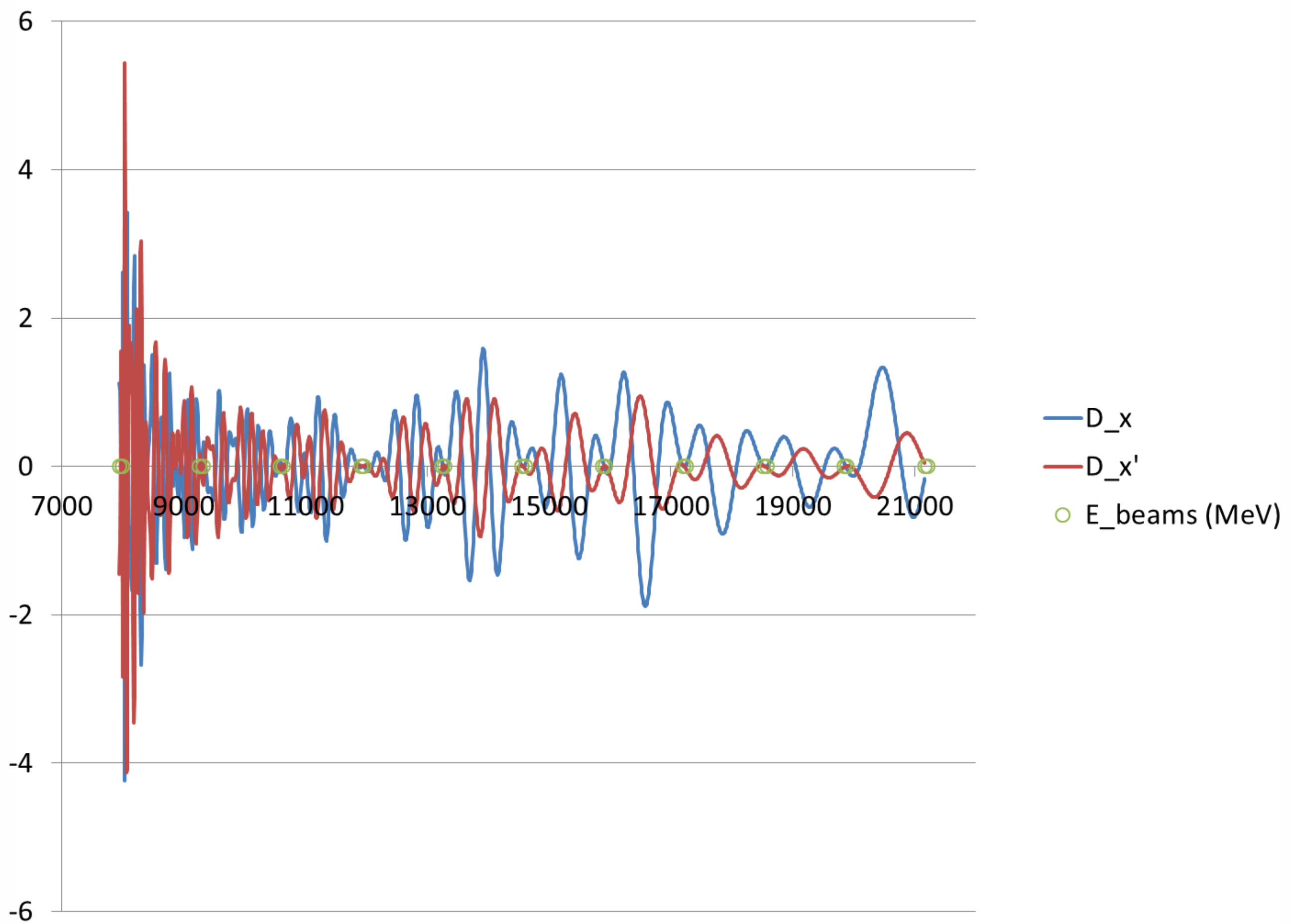
Zoom: 9.3GeV beams



Problem: 7.9GeV beams



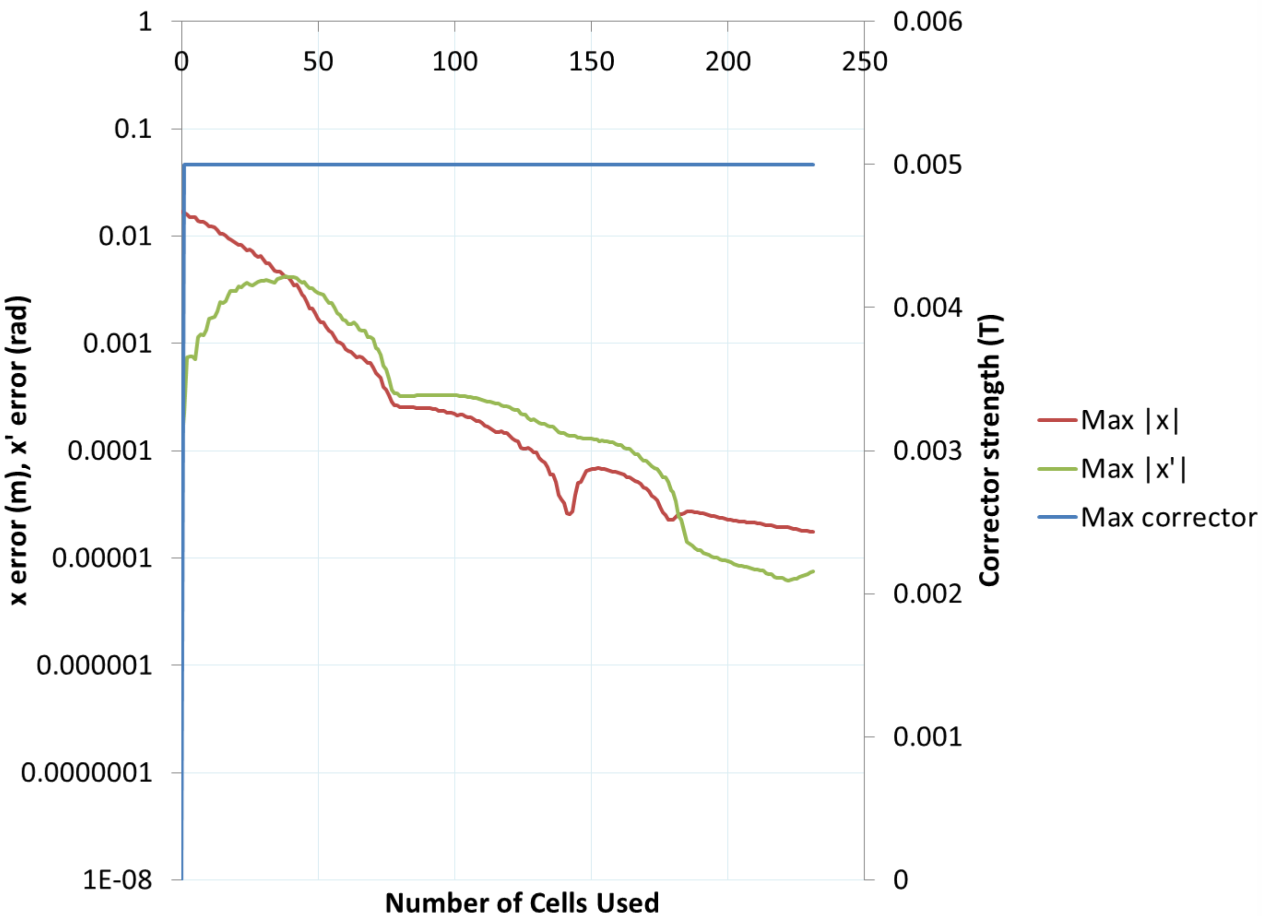
D_x and $D_{x'}$ as a Function of Energy



Dispersion Using 5*11 Beams

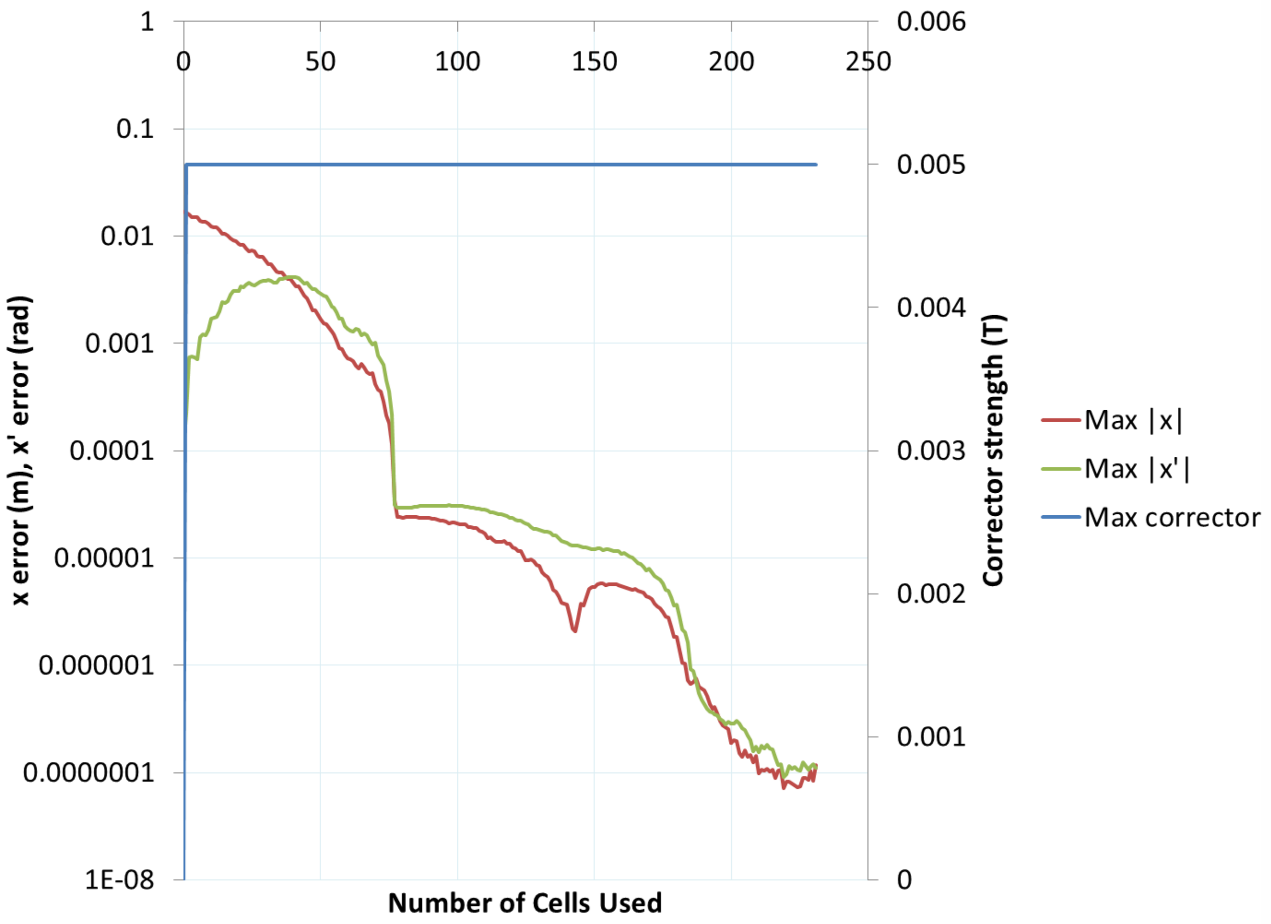
- For each beam energy E, use five particles:
  - $E(1-\delta)$
  - $E(1-\delta/2)$
  - E
  - $E(1+\delta/2)$
  - $E(1+\delta)$
- This should force higher-order dispersions to zero in the relevant momentum ranges

With δp/p=1e-3



0
50
100
150
200
250
1
0.1
0.01
0.001
0.0001
0.00001
0.000001
0.0000001
1E-08
x error (m), x' error (rad)
0.006
0.005
0.004
0.003
0.002
0.001
0
Corrector strength (T)
Number of Cells Used
Max |x|
Max |x'|
Max corrector

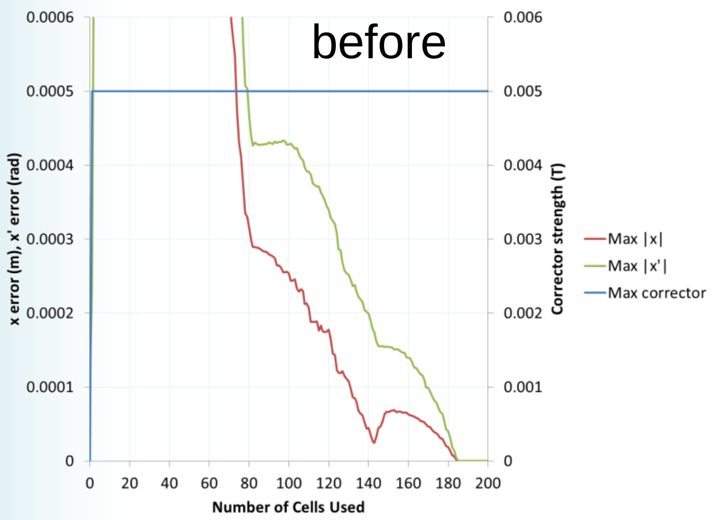
With δp/p=1e-4

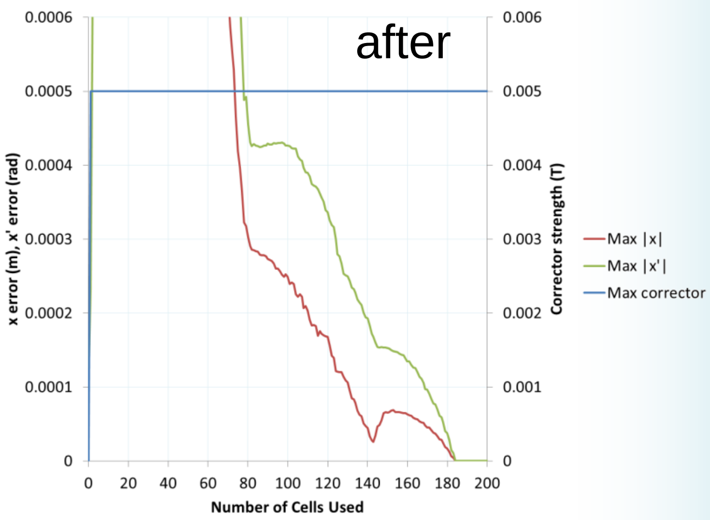


1
0.1
0.01
0.001
0.0001
0.00001
0.000001
0.0000001
1E-08
0
50
100
150
200
250
0.006
0.005
0.004
0.003
0.002
0.001
0
x error (m), x' error (rad)
Corrector strength (T)
Number of Cells Used
Max |x|
Max |x'|
Max corrector

Idea #1: two correctors per magnet

- Put different correctors in front and back halves of each magnet, beams will have different phase advances in each
  - Might help if problem is just "lacking in variables"





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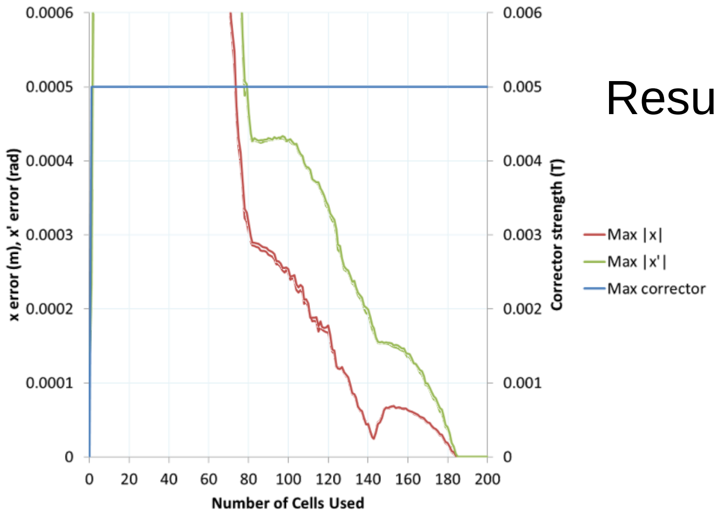
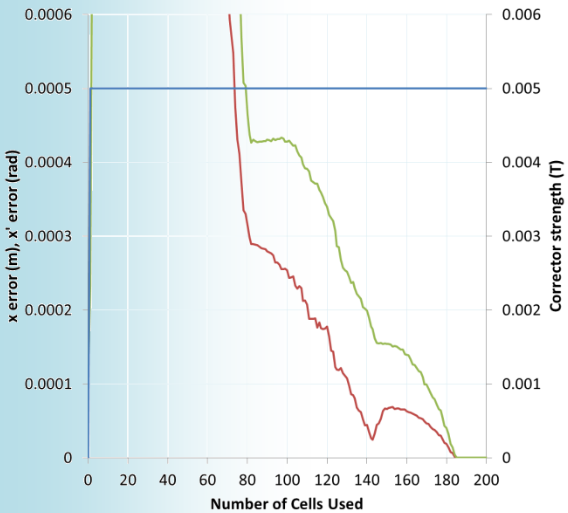


Result: almost no change!

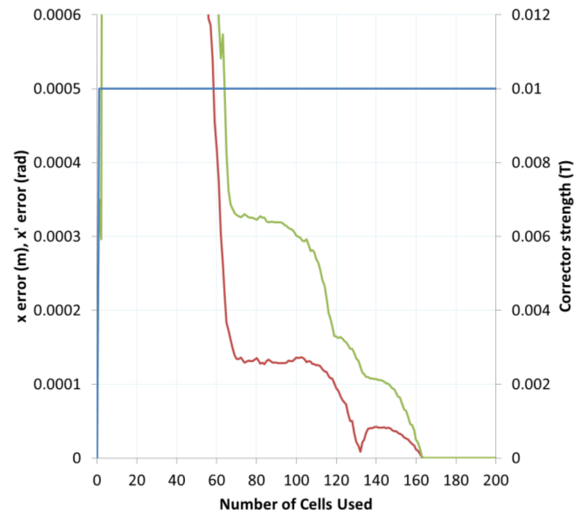
Idea #2: stronger correctors

- What if correctors are lacking in power?
  - 0.05T is achievable with ±2mm magnet offsets
    - Or partial shorting of PM blocks with iron shunts

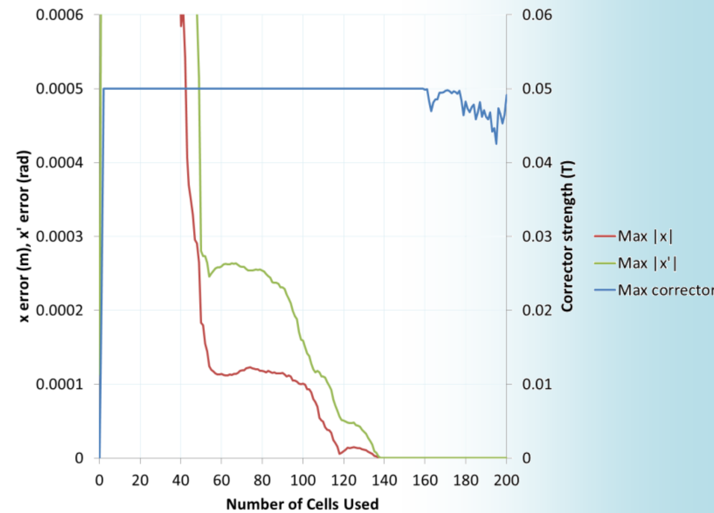
Before (0.005T)



0.01T



0.05T



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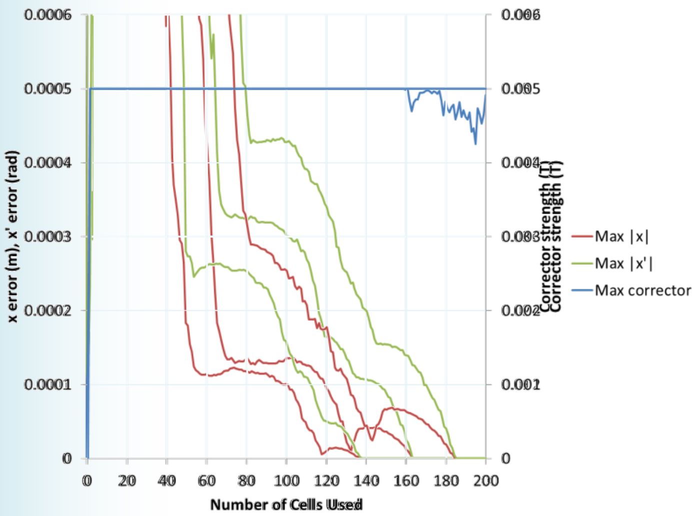

Max Corrector Strength (T)	Cells Needed for Exact Correction
0.005	185
0.01	164
0.05	140

Future Work

- Extraction point does not have to be merging point for rest of the beams
  - Only condition is beam well-separated from rest
  - Could try to find optimal location
- Yue: really only symmetry to un-extraction point is necessary rather than exact merging
- Dejan: what about changing the gradients?
  - Introduces constraints ($\beta_{x,y}$) as well as variables