6D Merge

R. B. Palmer (BNL)
3/20/12

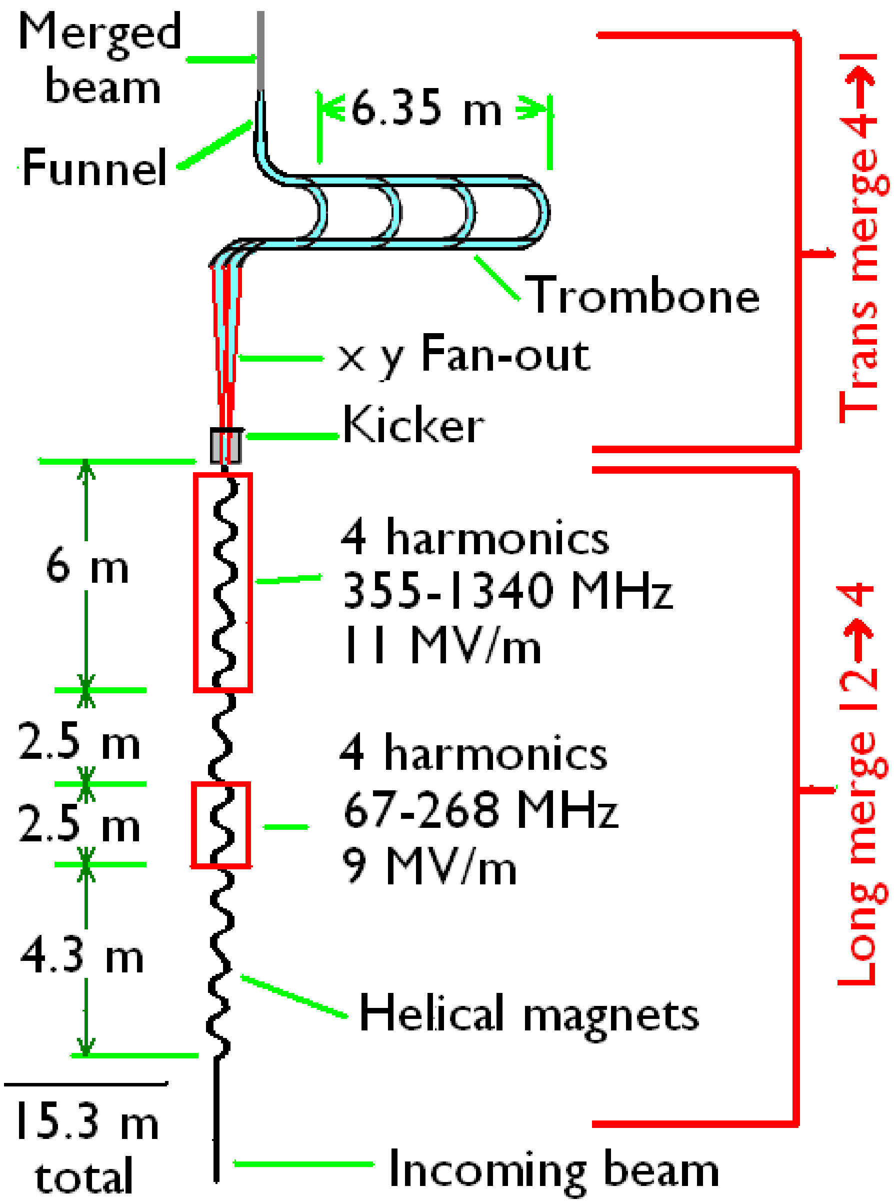
Last week

- Achieved 12$\longrightarrow$ 4 longitudinal merging with good efficiency, using a helical channel, proposed by Neuffer et al, that gave a linear relation between energy and longitudinal motion
- This required rf with multiple frequencies down to 135 MHz
- That would be very hard to locate inside such a channel

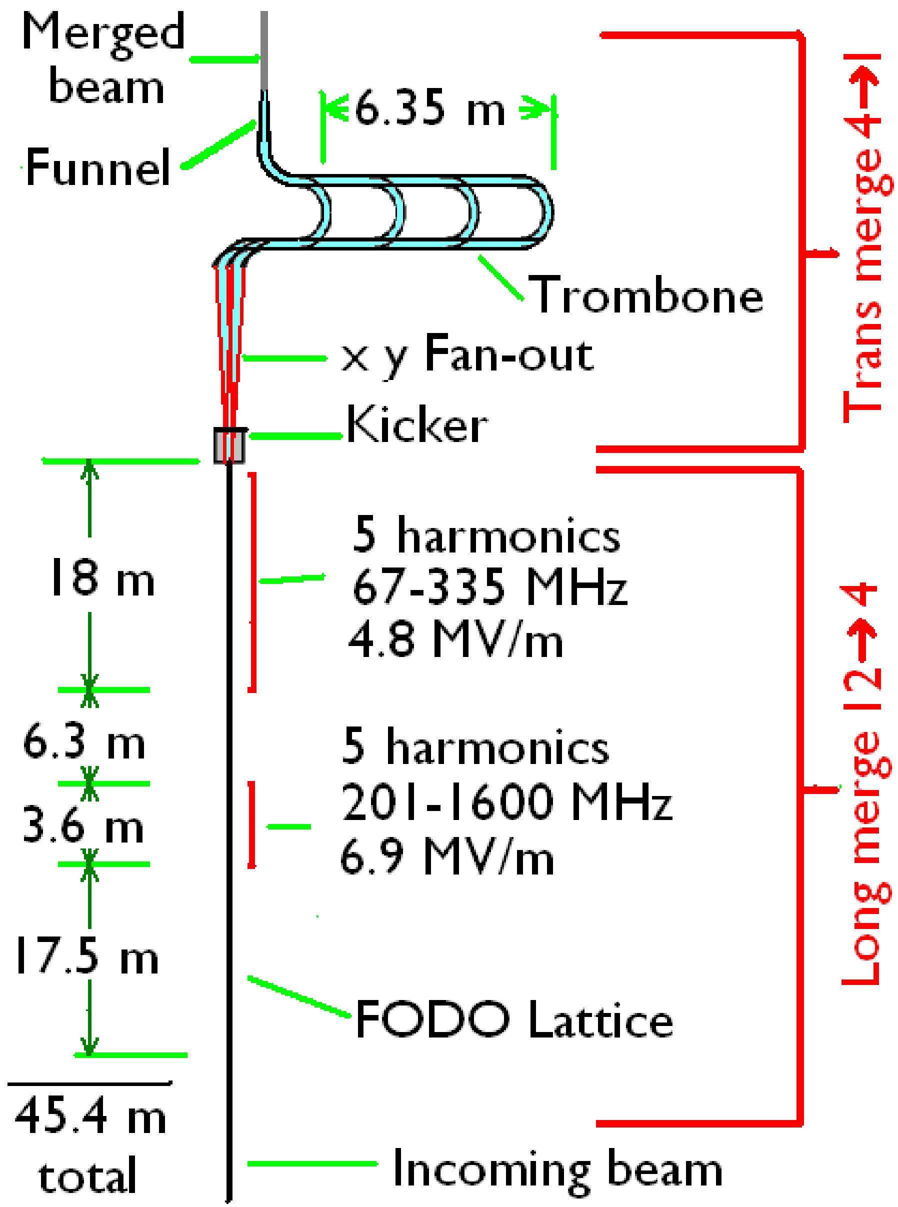
This week

- Design a system using a simple linear FODO Lattice
- The relation between energy and longitudinal motion is now highly non-linear
- Requiring non-linear and asymmetrical energy modulation

Last week



This week



Last week		This week
Helical Channel	$\longrightarrow$	Linear FODO lattice
4 harmonic frequencies/stage	$\longrightarrow$	5 harmoic frequencies
11 and 9 MV/m	$\longrightarrow$	5 and 7 MV/m
220 $\pm$ 50 MeV	$\longrightarrow$	130 +35/ -25 MeV
15 m length for long merge	$\longrightarrow$	45 m length for long merge

Method

- Use an inverse Neuffer phase rotation:
  1. Keep bunches contained by rf whose phase changes as the bunches move in time
  2. Give additional phase shifts to accelerate one bunch and decelerate the other
  3. Use a sawtooth rf to bring the bunches close together
  4. Let them drift together in time, for recapture at 201 MHz
- To work for multiple groups of 3, all rf must be a harmonic of $201/3{=}67$ MHz
- So we:
  1. Cook the arbitrary non-linear waveforms needed,
  2. Fourier analyze them, and
  3. Use 4-5 rf harmonics to generate them
  4. use a saw tooth rf to line the bunches during the drift

Frequencies and phases

Z m	m	freq MHz	grad MV/m	phase deg
0.9	1	67	0.31	14.7
0.9	2	134	0.85	8.3
0.9	3	201	6.52	4.0
0.9	4	268	1.16	12.0
0.9	5	335	0.41	10.3
1.8	1	67	0.32	14.7
1.8	2	134	0.89	8.2
1.8	3	201	6.50	3.9
1.8	4	268	1.23	12.0
1.8	5	335	0.43	10.1
2.7	1	67	0.33	14.7
2.7	2	134	0.90	8.2
2.7	3	201	6.48	3.9
2.7	4	268	1.25	12.0
2.7	5	335	0.44	10.1
3.6	1	67	0.34	14.8
3.6	2	134	0.94	8.2
3.6	3	201	6.45	3.9
3.6	4	268	1.33	11.9
3.6	5	335	0.46	9.9
4.5	1	67	0.37	14.8
4.5	2	134	1.00	8.1
4.5	3	201	6.39	3.8
4.5	4	268	1.46	11.9
4.5	5	335	0.50	9.5
5.4	1	67	0.40	14.9
5.4	2	134	1.09	7.9
5.4	3	201	6.30	3.6
5.4	4	268	1.64	11.7
5.4	5	335	0.54	9.0
6.3	1	67	0.44	14.9
6.3	2	134	1.18	7.7
6.3	3	201	6.18	3.4
6.3	4	268	1.87	11.6
6.3	5	335	0.60	8.3

Z m	m	freq MHz	grad MV/m	phase deg
7.2	1	67	0.49	14.9
7.2	2	134	1.28	7.5
7.2	3	201	6.00	3.1
7.2	4	268	2.16	11.4
7.2	5	335	0.66	7.4
8.1	1	67	0.53	14.8
8.1	2	134	1.37	7.1
8.1	3	201	5.77	2.7
8.1	4	268	2.51	11.1
8.1	5	335	0.73	6.1
9.0	1	67	0.57	14.5
9.0	2	134	1.45	6.6
9.0	3	201	5.46	2.2
9.0	4	268	2.92	10.8
9.0	5	335	0.79	4.3
9.9	1	67	0.60	13.9
9.9	2	134	1.50	5.8
9.9	3	201	5.07	1.4
9.9	4	268	3.38	10.3
9.9	5	335	0.83	1.9
10.8	1	67	0.60	12.7
10.8	2	134	1.50	4.7
10.8	3	201	4.57	0.4
10.8	4	268	3.90	9.8
10.8	5	335	0.86	178.4
11.7	1	67	0.58	10.7
11.7	2	134	1.43	2.9
11.7	3	201	3.97	178.9
11.7	4	268	4.46	9.1
11.7	5	335	0.85	173.3
12.6	1	67	0.53	6.7
12.6	2	134	1.29	0.2
12.6	3	201	3.25	176.4
12.6	4	268	5.04	8.4
12.6	5	335	0.80	165.1

Z m	m	freq MHz	grad MV/m	phase deg
15.3	1	67	0.27	114.3
15.3	2	134	0.46	133.2
15.3	3	201	0.74	132.2
15.3	4	268	6.49	4.9
15.3	5	335	0.71	88.0
16.2	1	67	0.41	74.6
16.2	2	134	0.50	71.8
16.2	3	201	0.77	52.5
16.2	4	268	6.69	3.2
16.2	5	335	1.07	58.5
17.1	1	67	0.64	58.1
17.1	2	134	0.86	42.7
17.1	3	201	1.47	24.9
17.1	4	268	6.62	1.3
17.1	5	335	1.65	41.1
18.0	1	67	0.86	50.5
18.0	2	134	1.24	31.8
18.0	3	201	2.08	15.6
18.0	4	268	6.23	178.9
18.0	5	335	2.37	30.0
13.5	1	67	0.43	178.6
13.5	2	134	1.06	175.1
13.5	3	201	2.43	172.2
13.5	4	268	5.60	7.4
13.5	5	335	0.71	151.0
14.4	1	67	0.31	159.0
14.4	2	134	0.76	164.2
14.4	3	201	1.55	163.1
14.4	4	268	6.11	6.2
14.4	5	335	0.63	125.2

Z m	m	freq MHz	grad MV/m	phase deg
25.2	3	201	0.22	13.1
25.2	6	402	7.65	31.9
25.2	12	804	3.44	63.8
25.2	18	1206	1.78	95.8
25.2	24	1608	0.96	127.7
26.1	3	201	0.22	13.1
26.1	6	402	7.65	31.9
26.1	12	804	3.44	63.8
26.1	18	1206	1.78	95.8
26.1	24	1608	0.96	127.7
27.0	3	201	0.22	13.1
27.0	6	402	7.65	31.9
27.0	12	804	3.44	63.8
27.0	18	1206	1.78	95.8
27.0	24	1608	0.96	127.7
27.9	3	201	0.22	13.1
27.9	6	402	7.65	31.9
27.9	12	804	3.44	63.8
27.9	18	1206	1.78	95.8
27.9	24	1608	0.96	127.7

Phase Space Plots

- The following plots show particle phase spaces for 6 (of 12) initial bunches, as they are merged to 2 (of 4) final merged bunches
- These four bunches will then be merged in transverse phase space using kickers and trombones

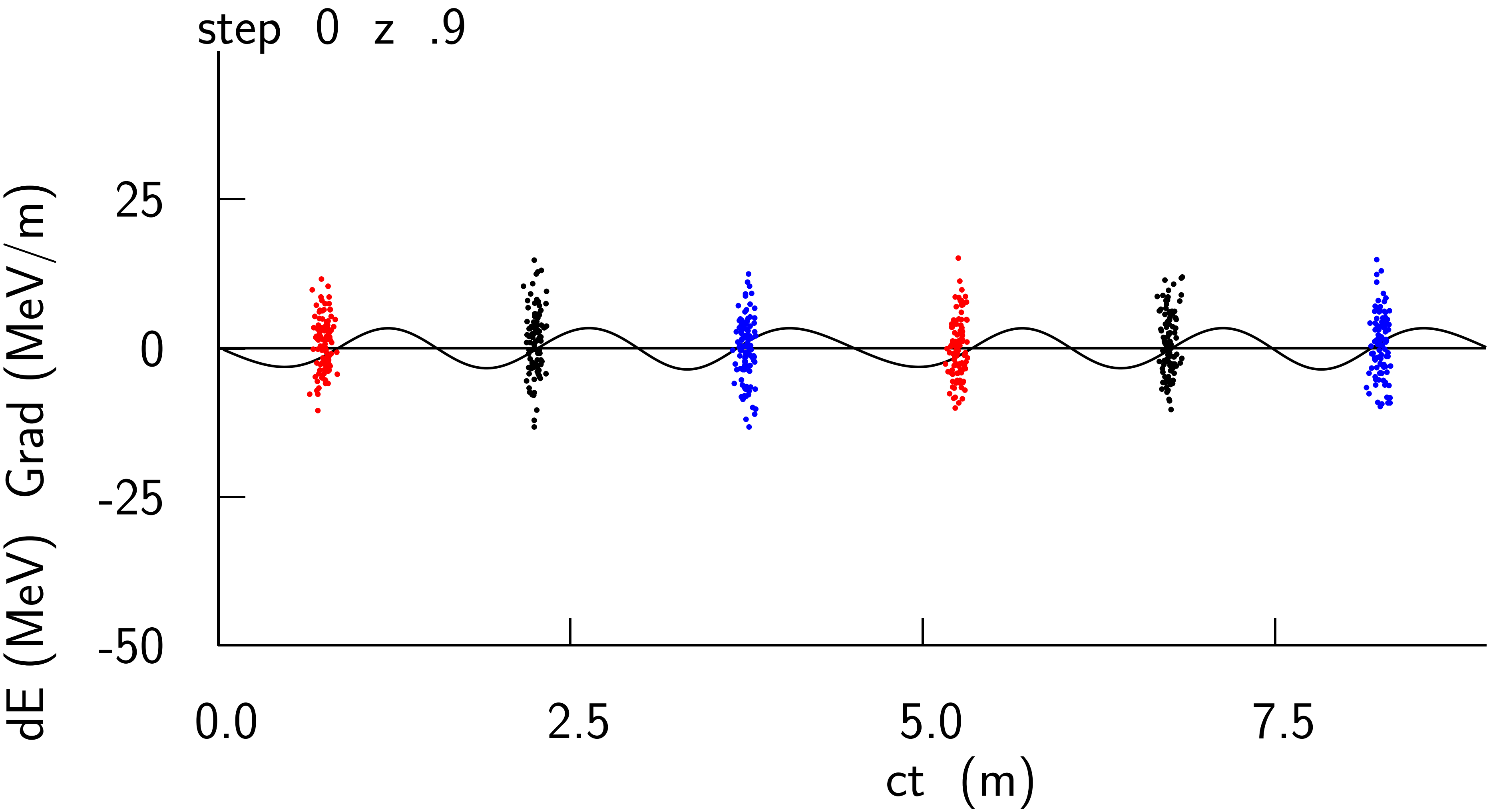


Fig. 1

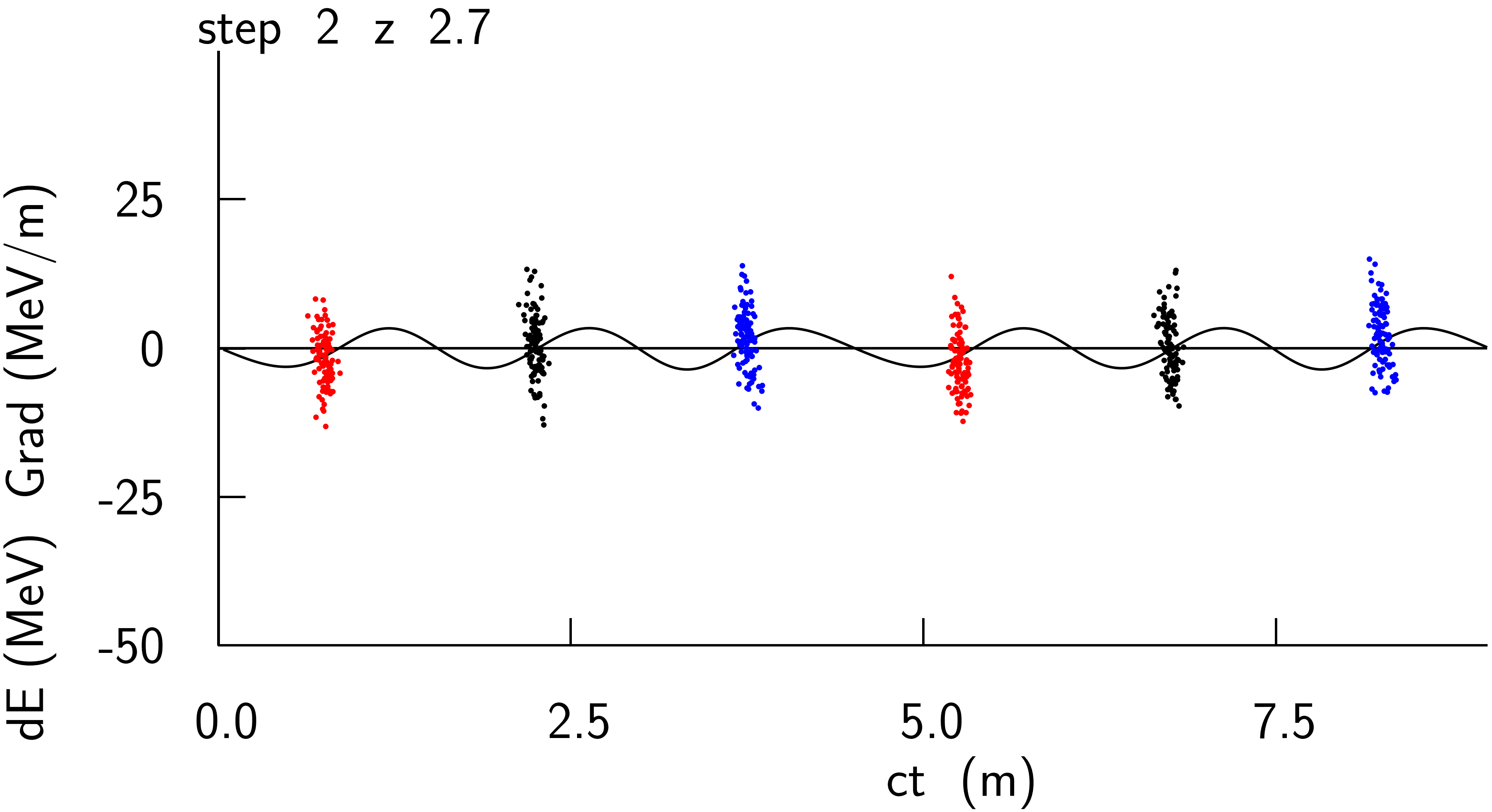


Fig. 2

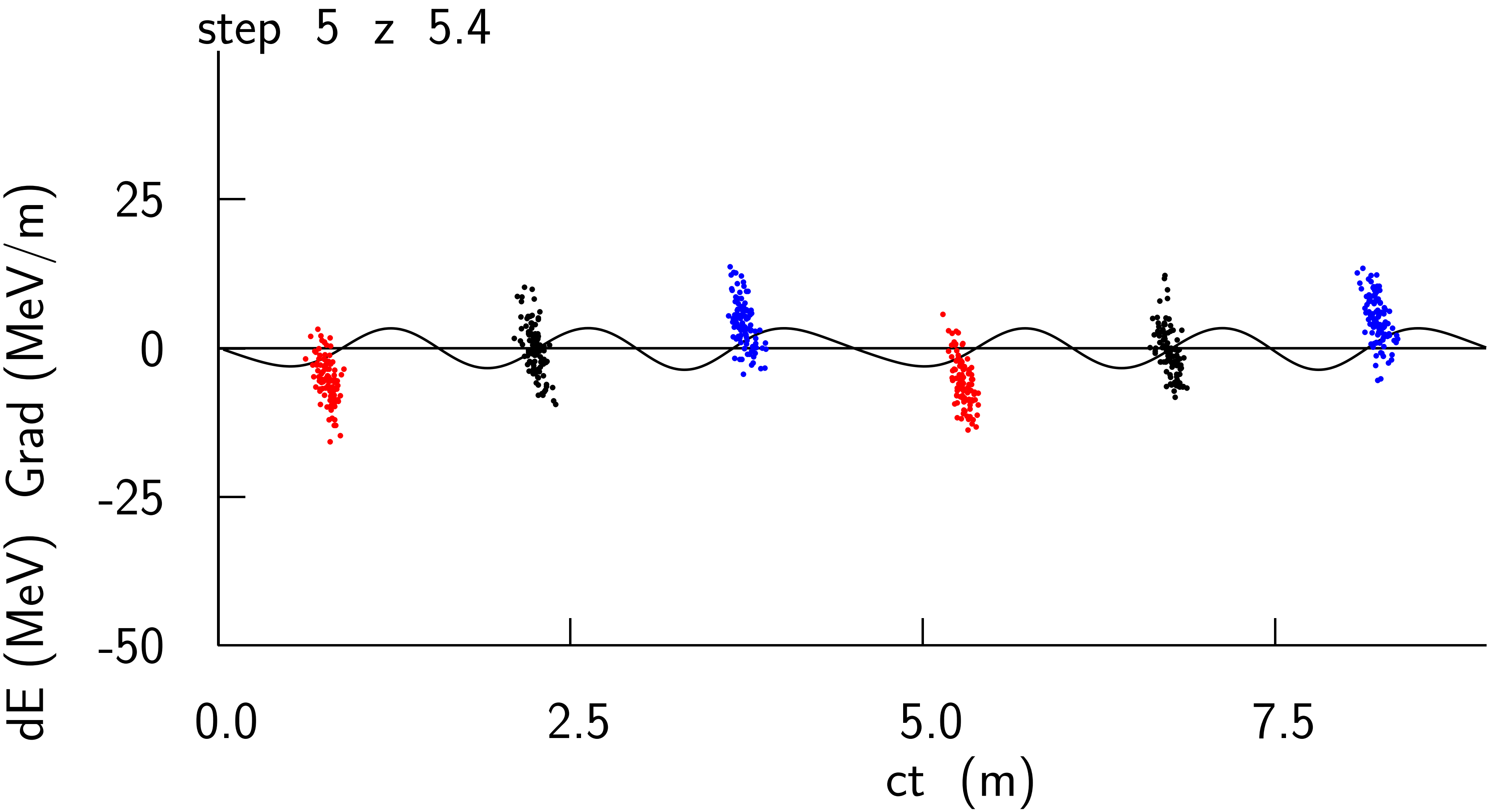


Fig. 3

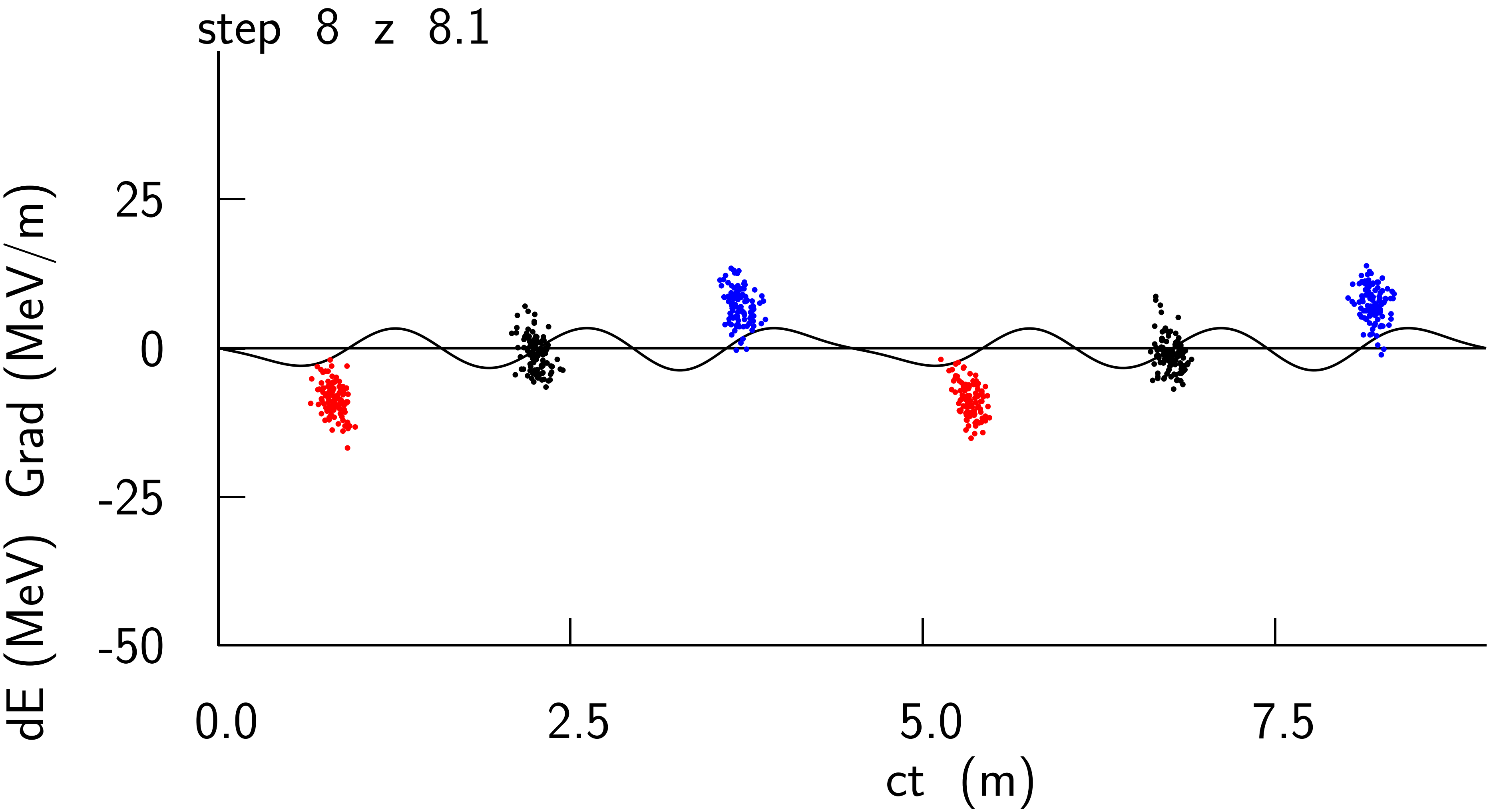


Fig. 4

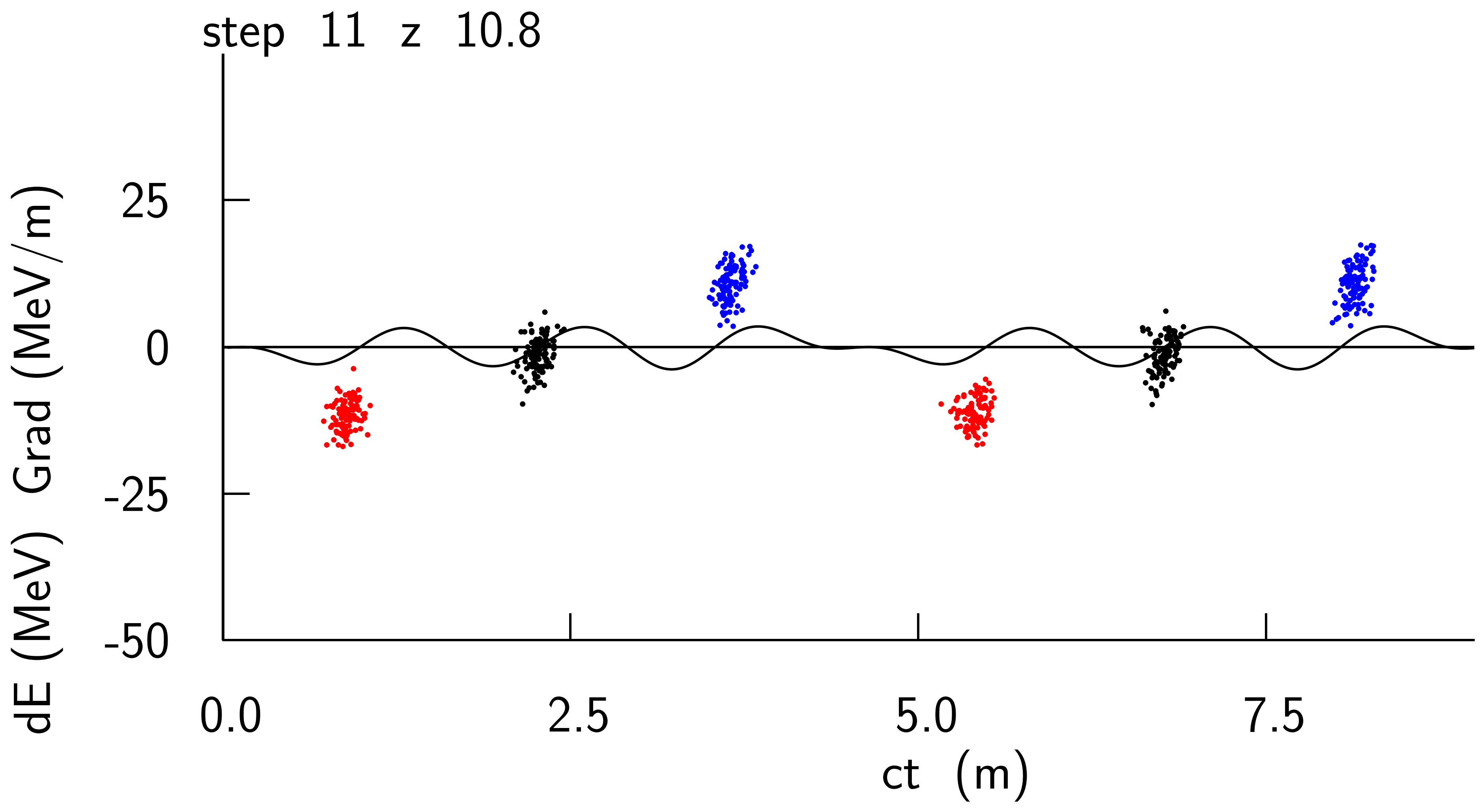


Fig. 5

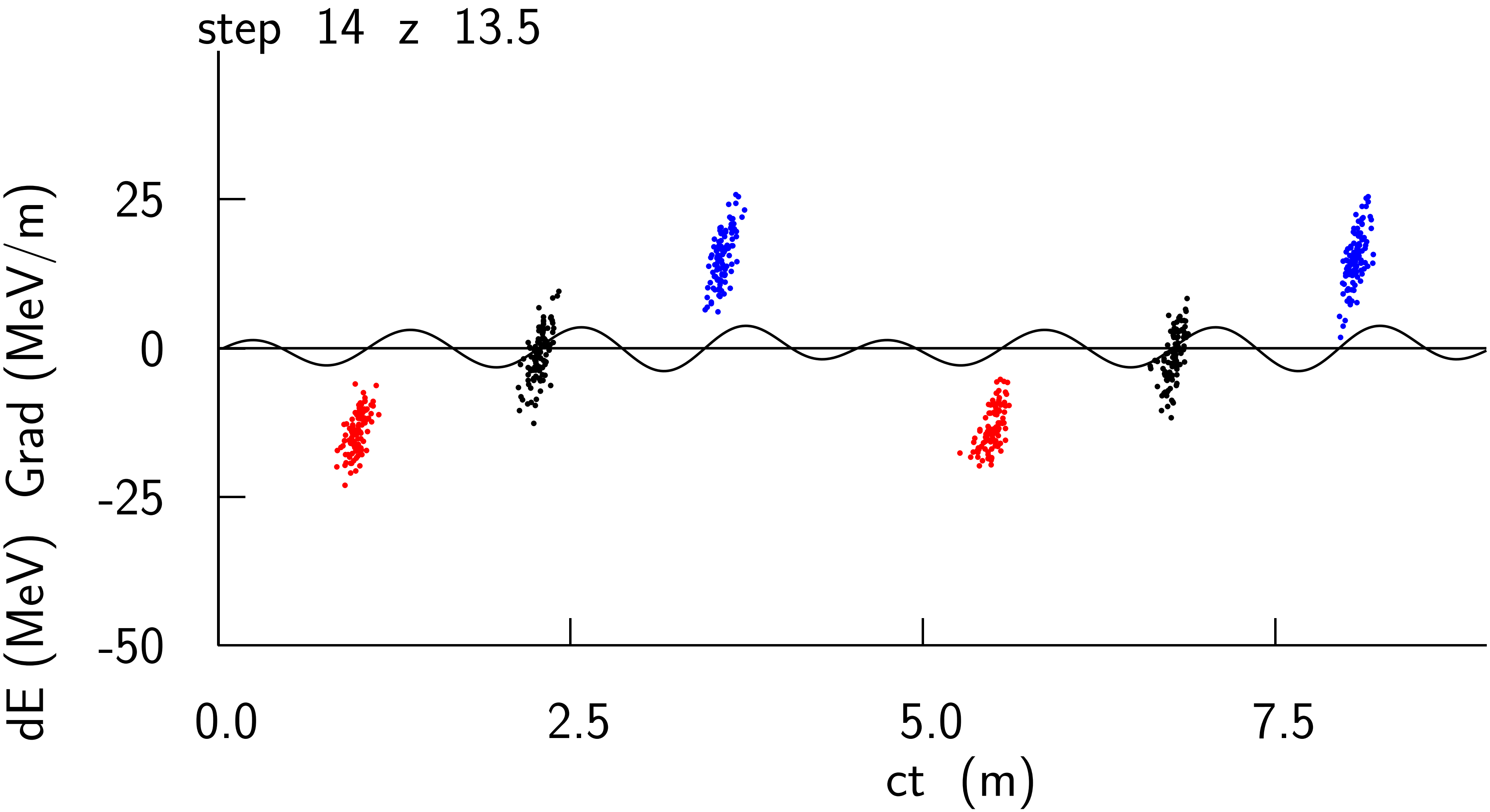


Fig. 6

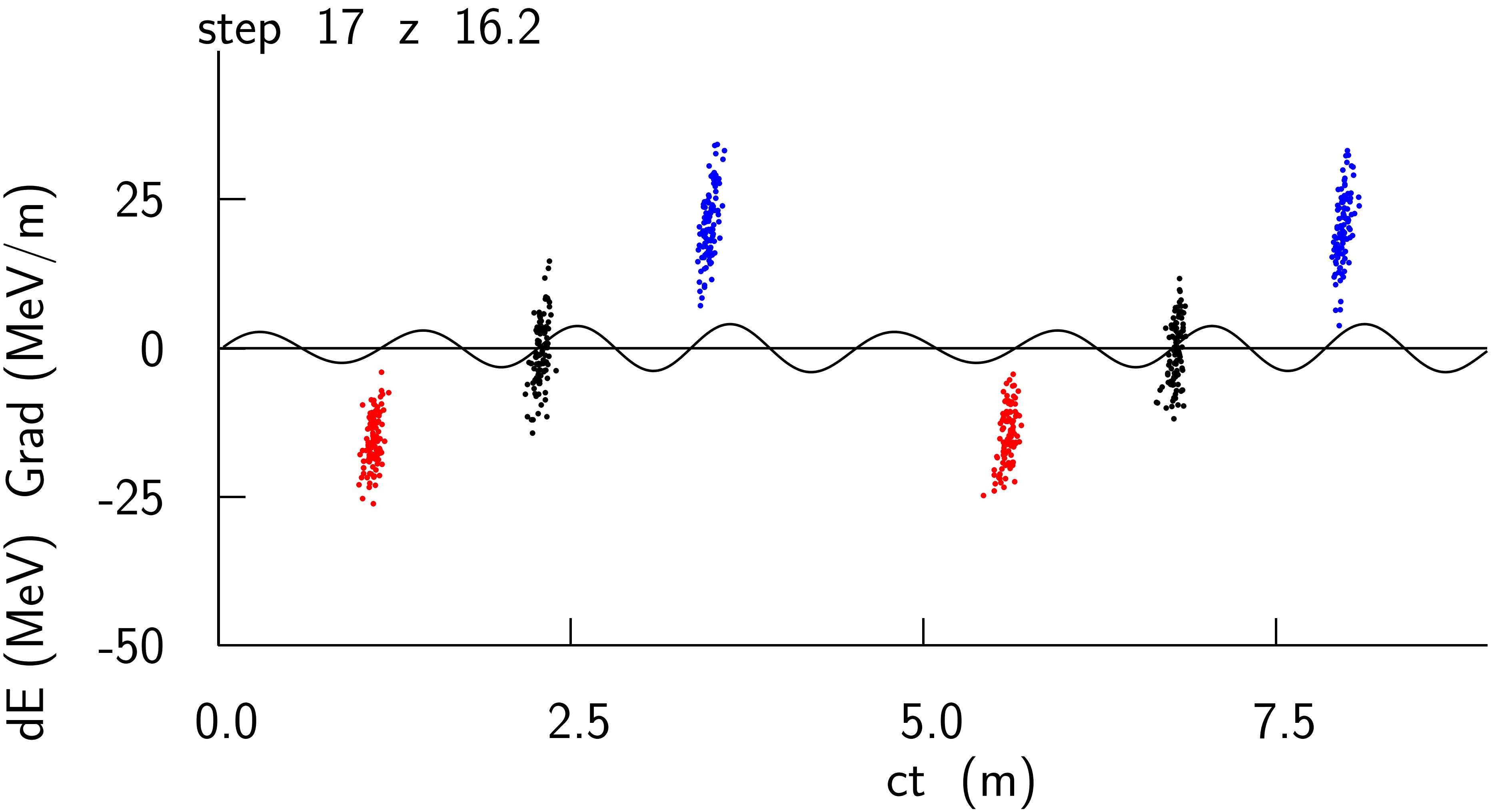


Fig. 7

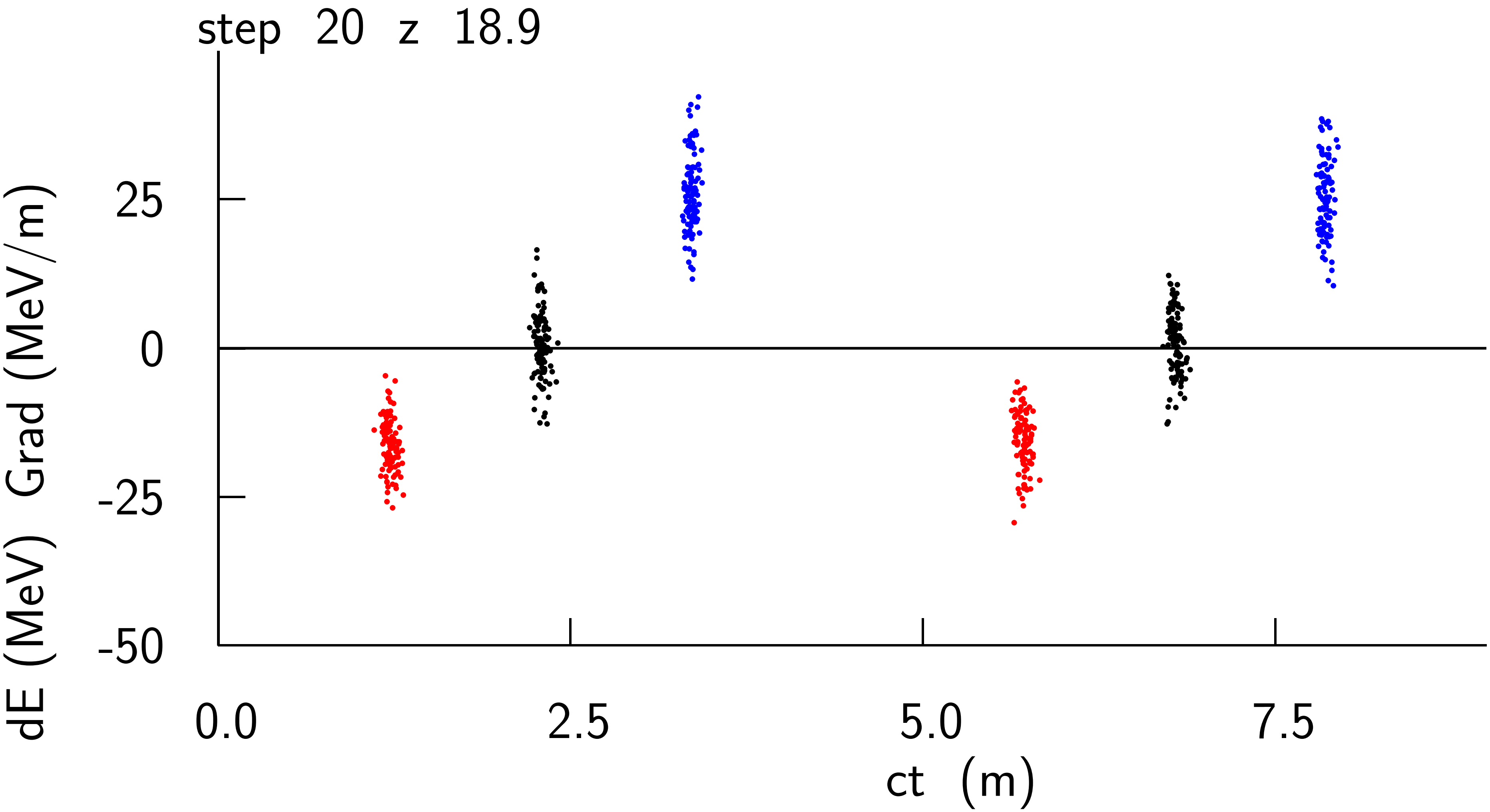


Fig. 8

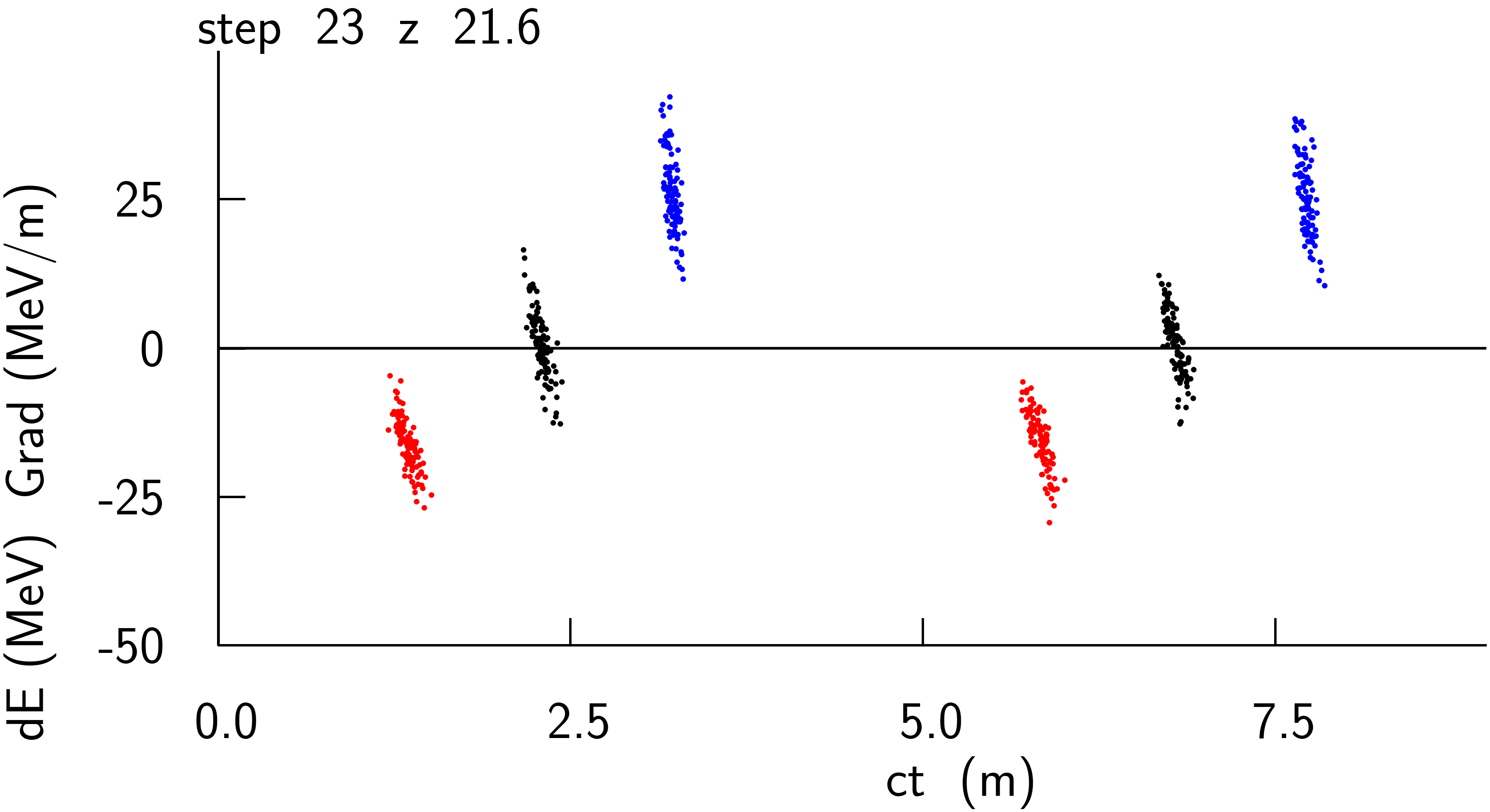


Fig. 9

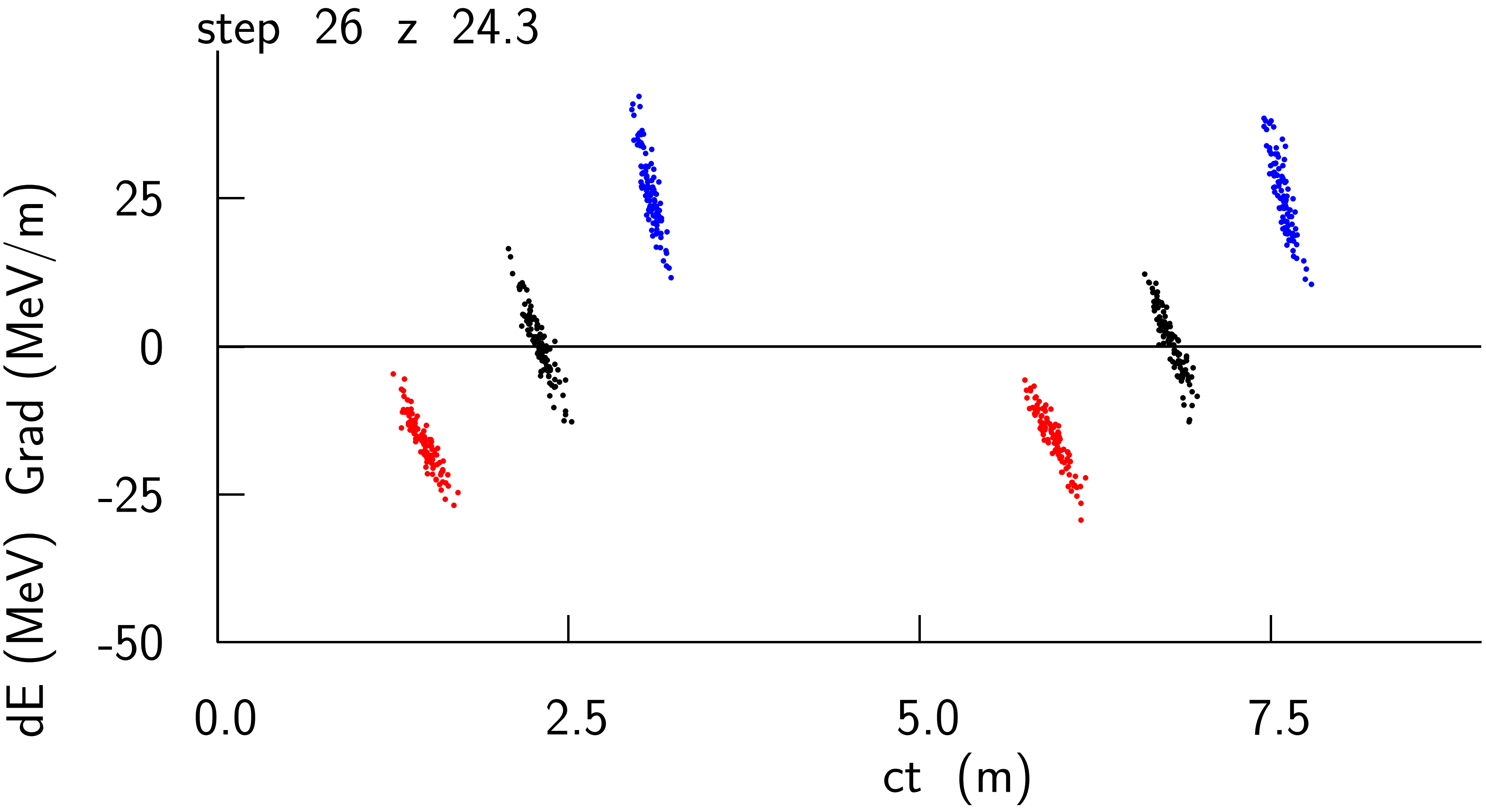


Fig. 10

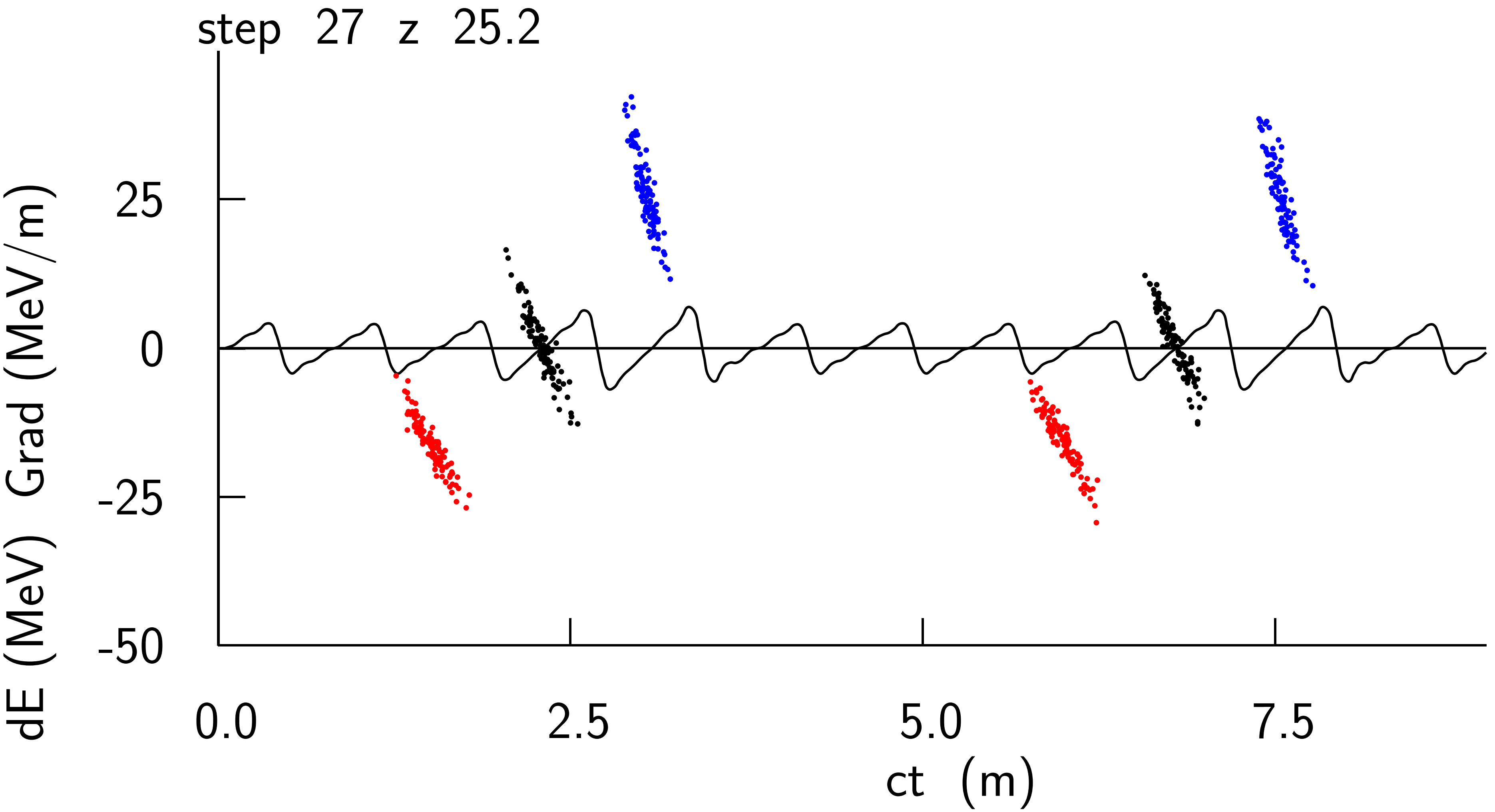


Fig. 11

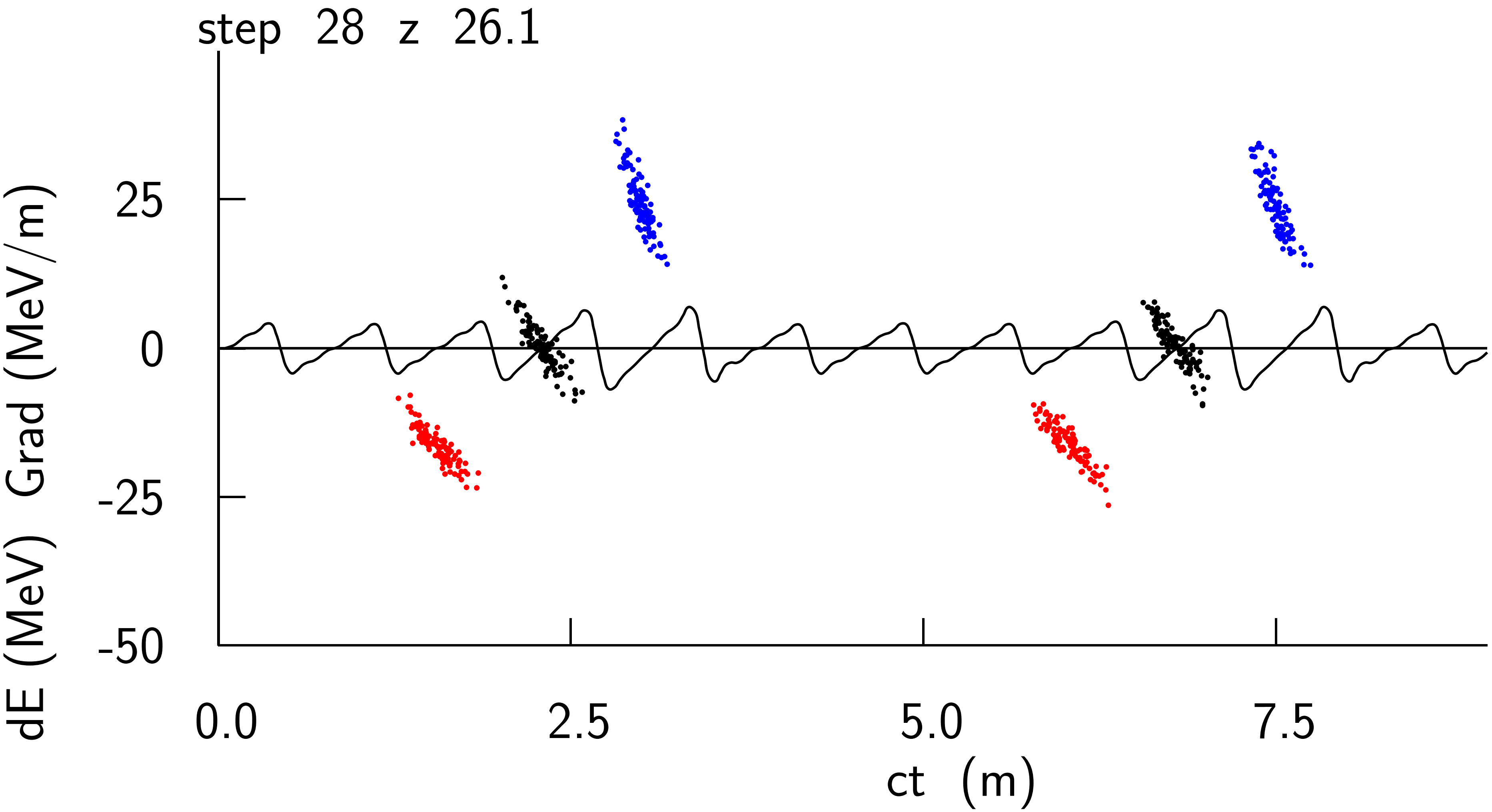


Fig. 12

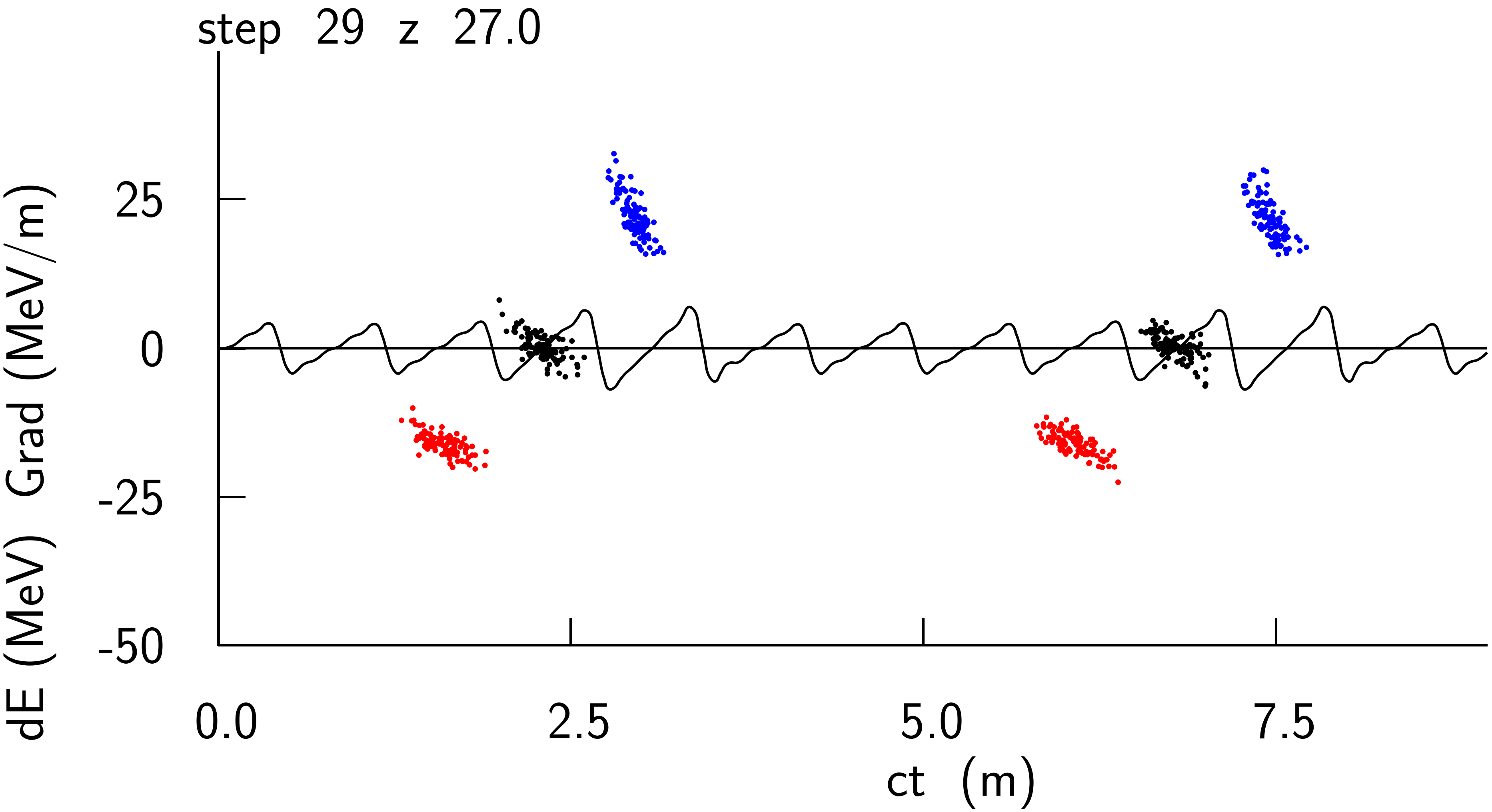


Fig. 13

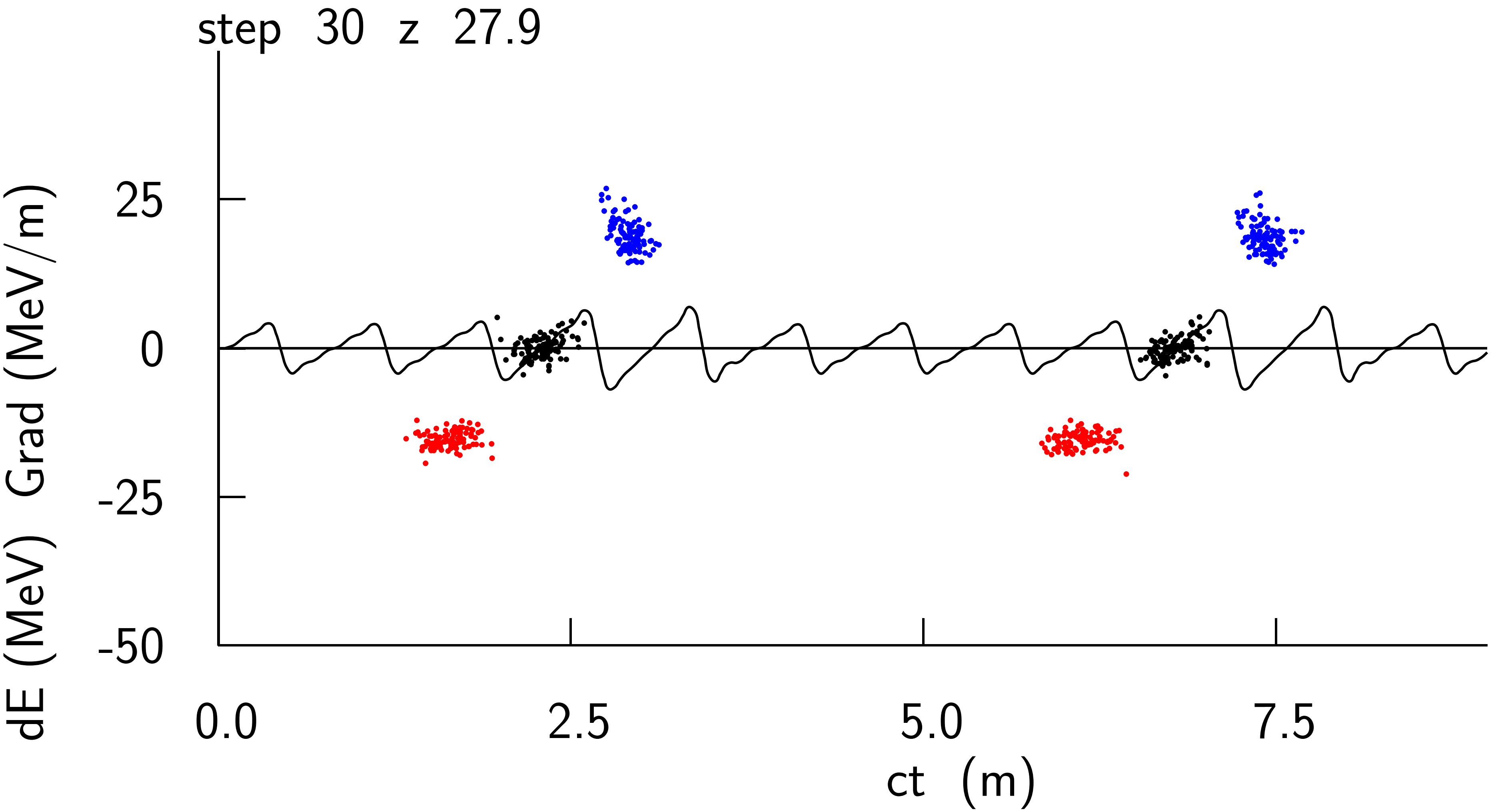


Fig. 14

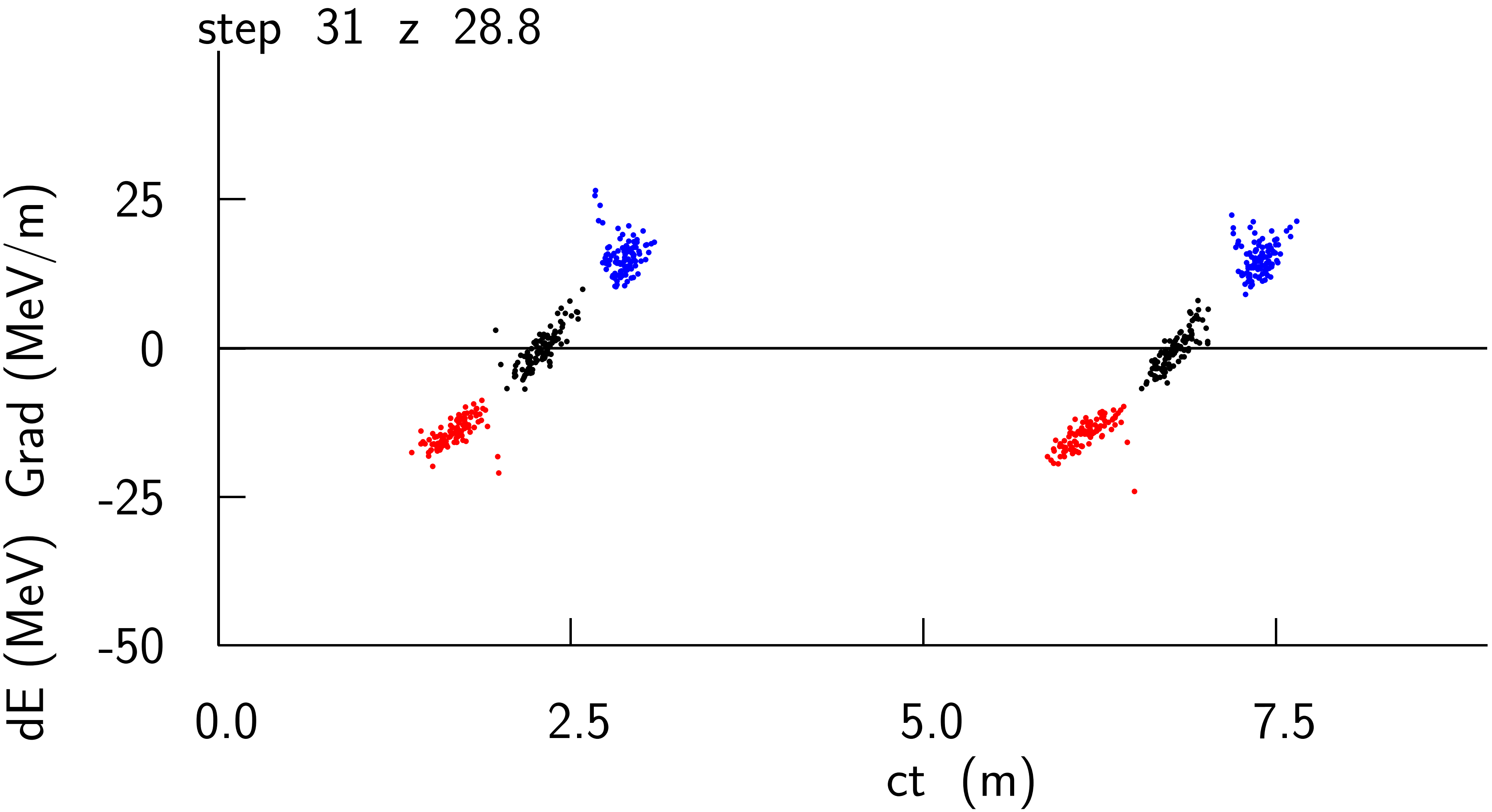


Fig. 15

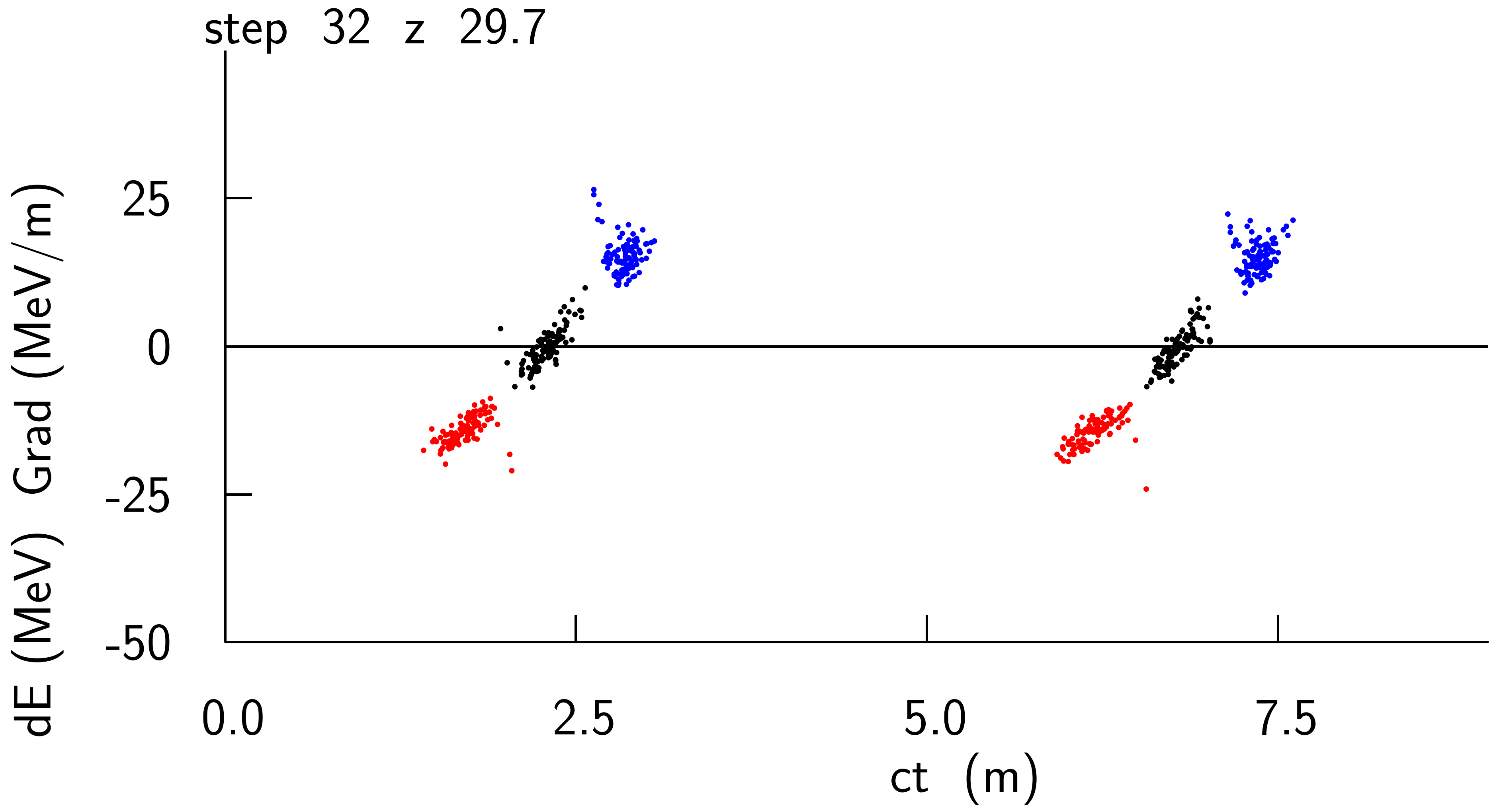


Fig. 16

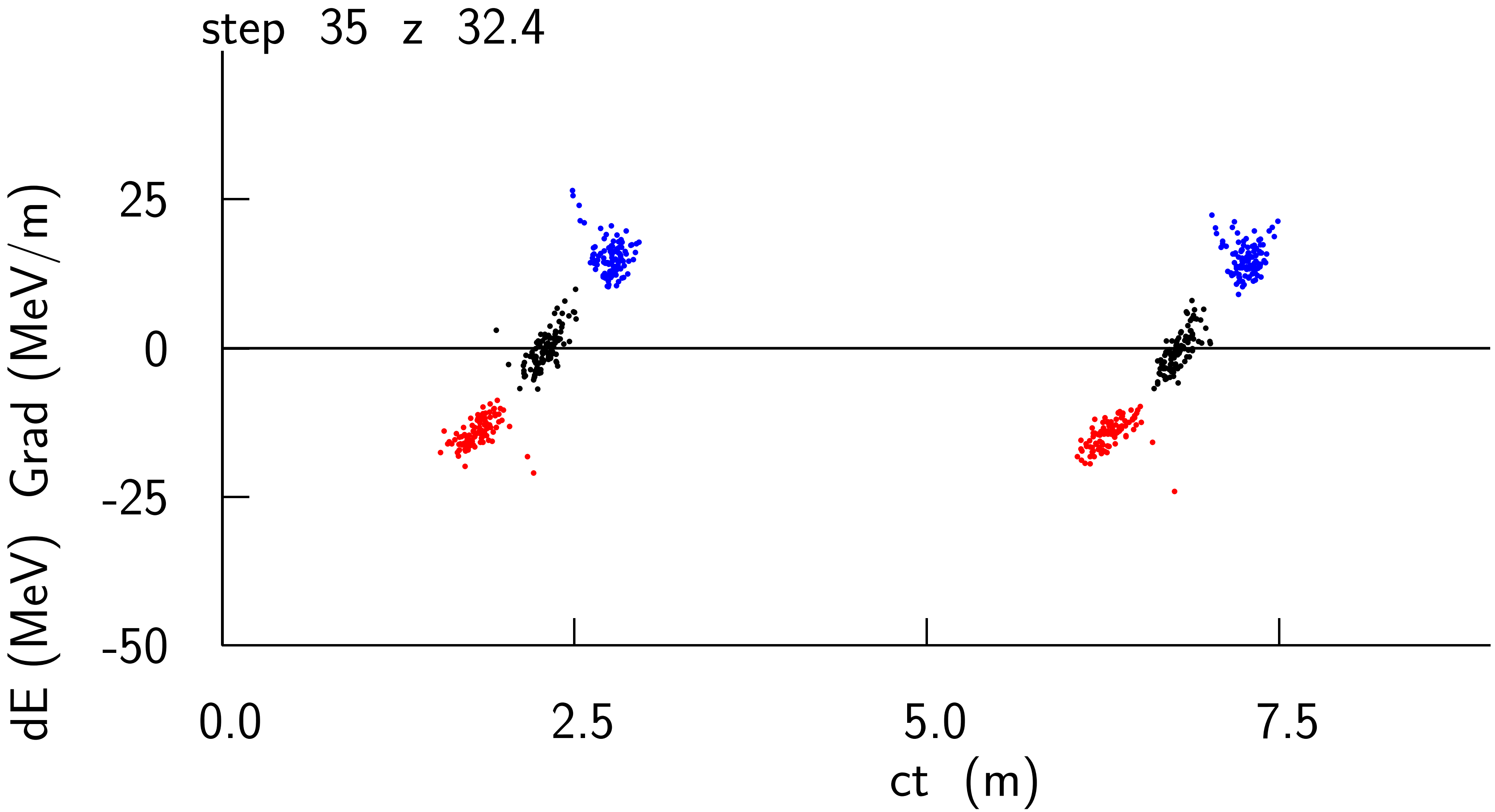


Fig. 17

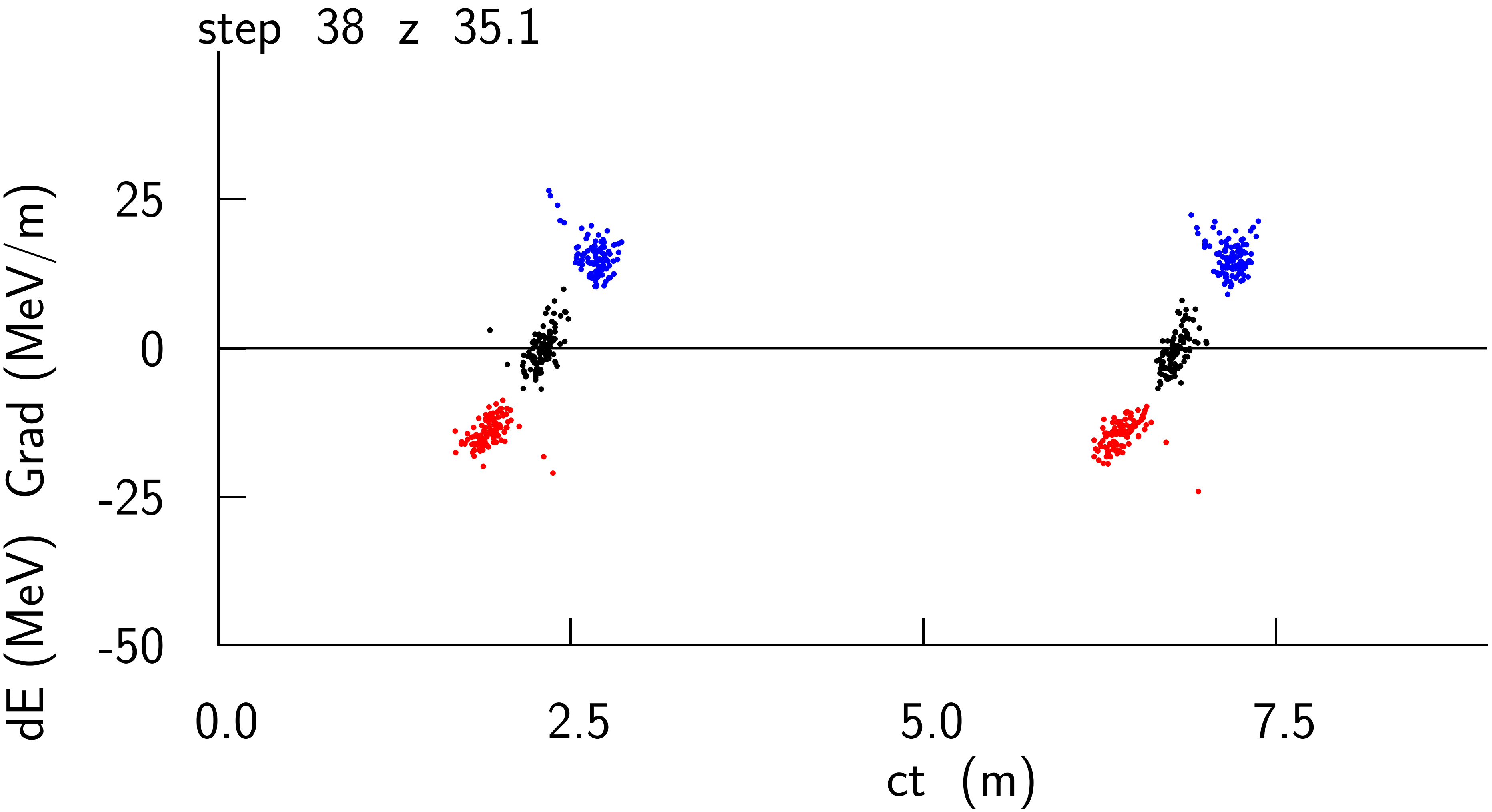


Fig. 18

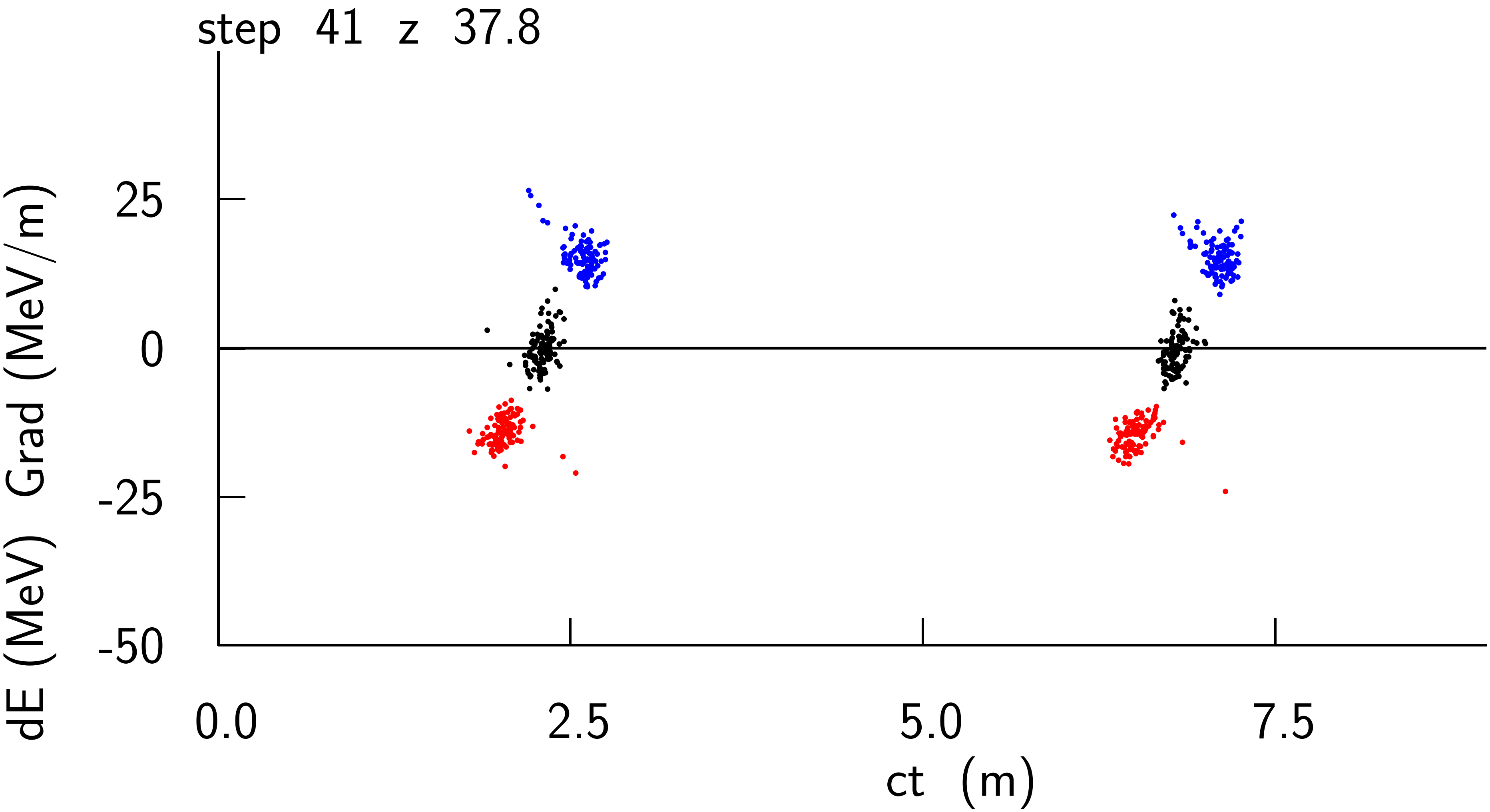


Fig. 19

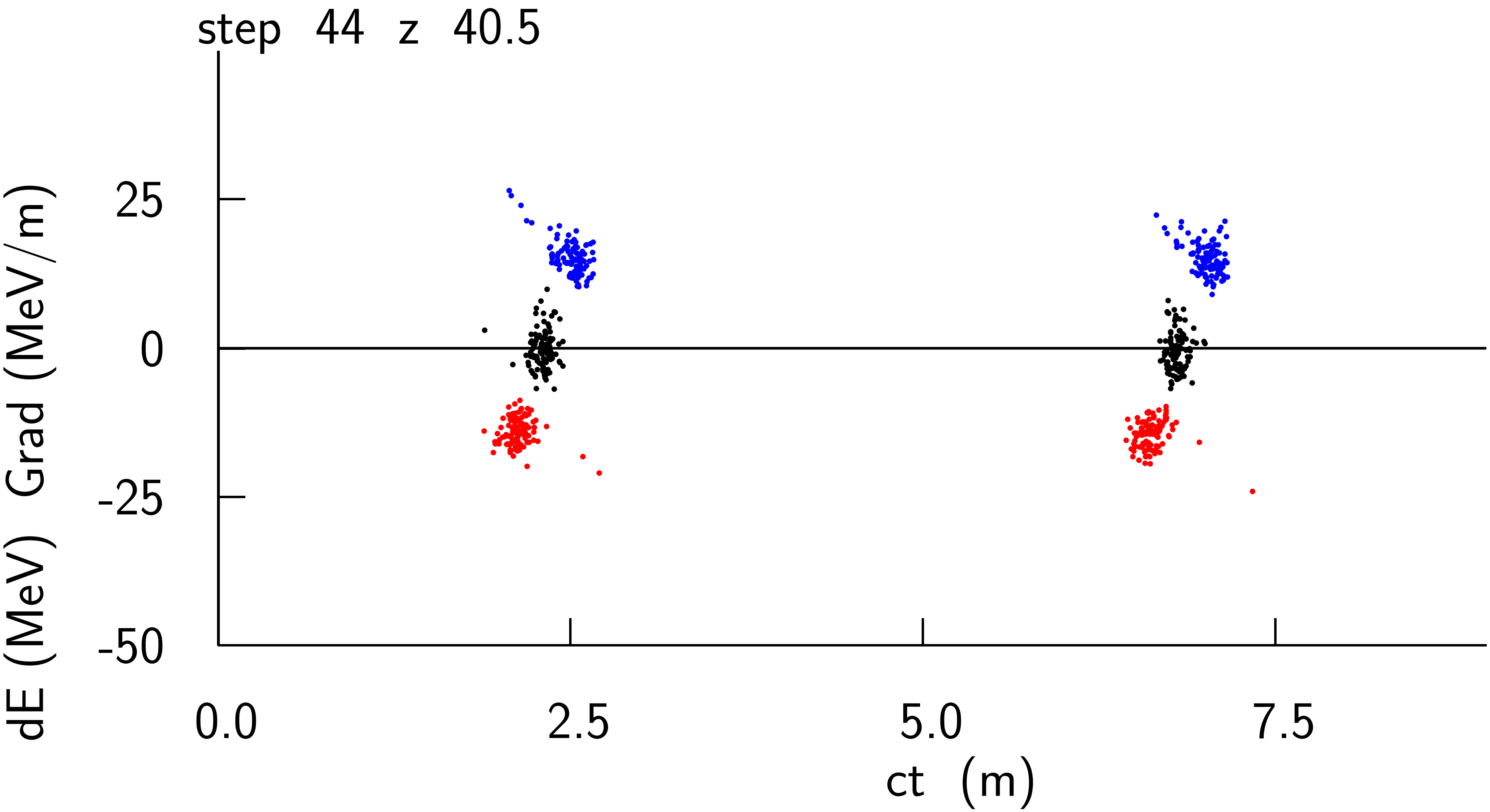


Fig. 20

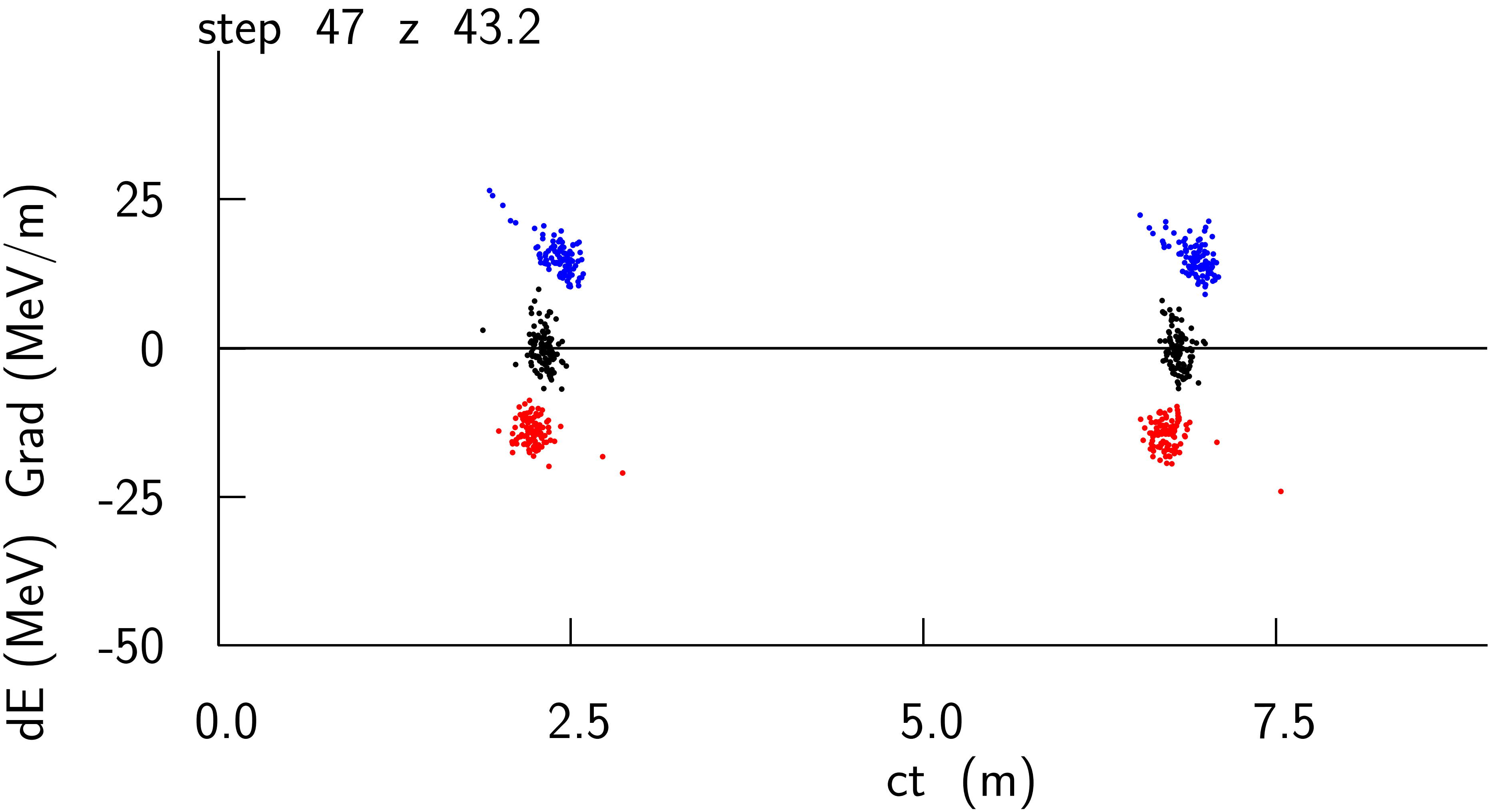


Fig. 21

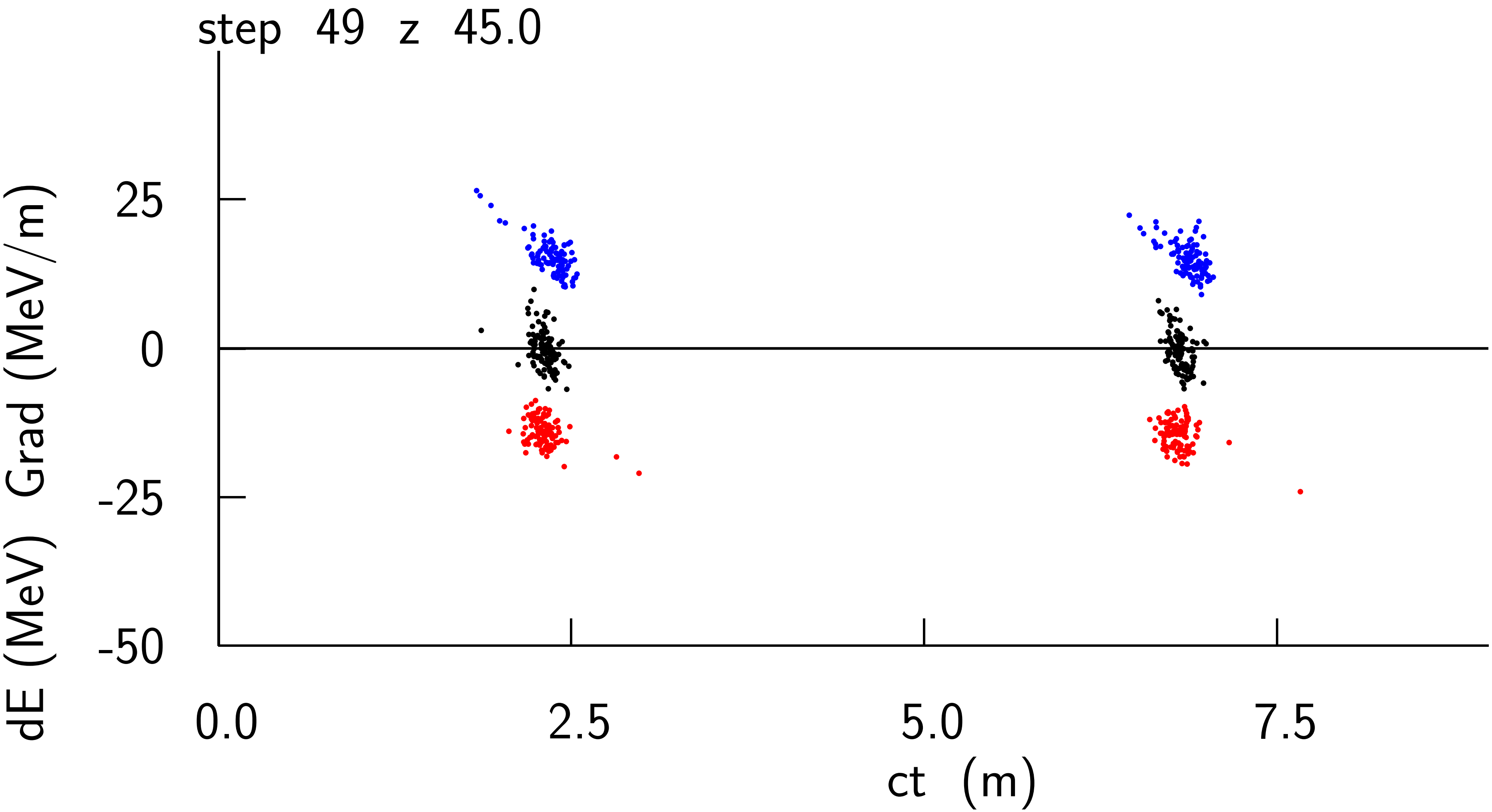


Fig. 22

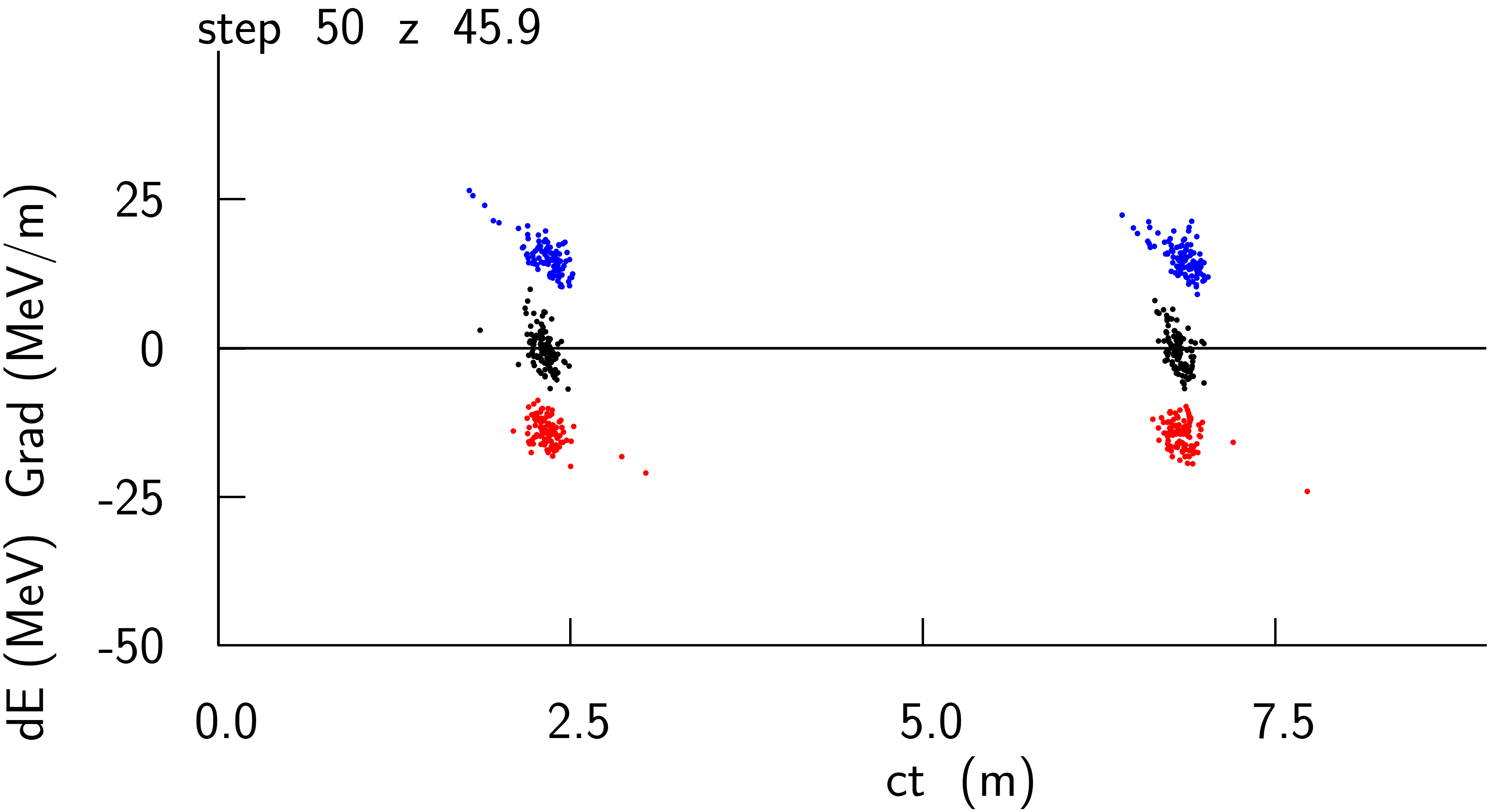
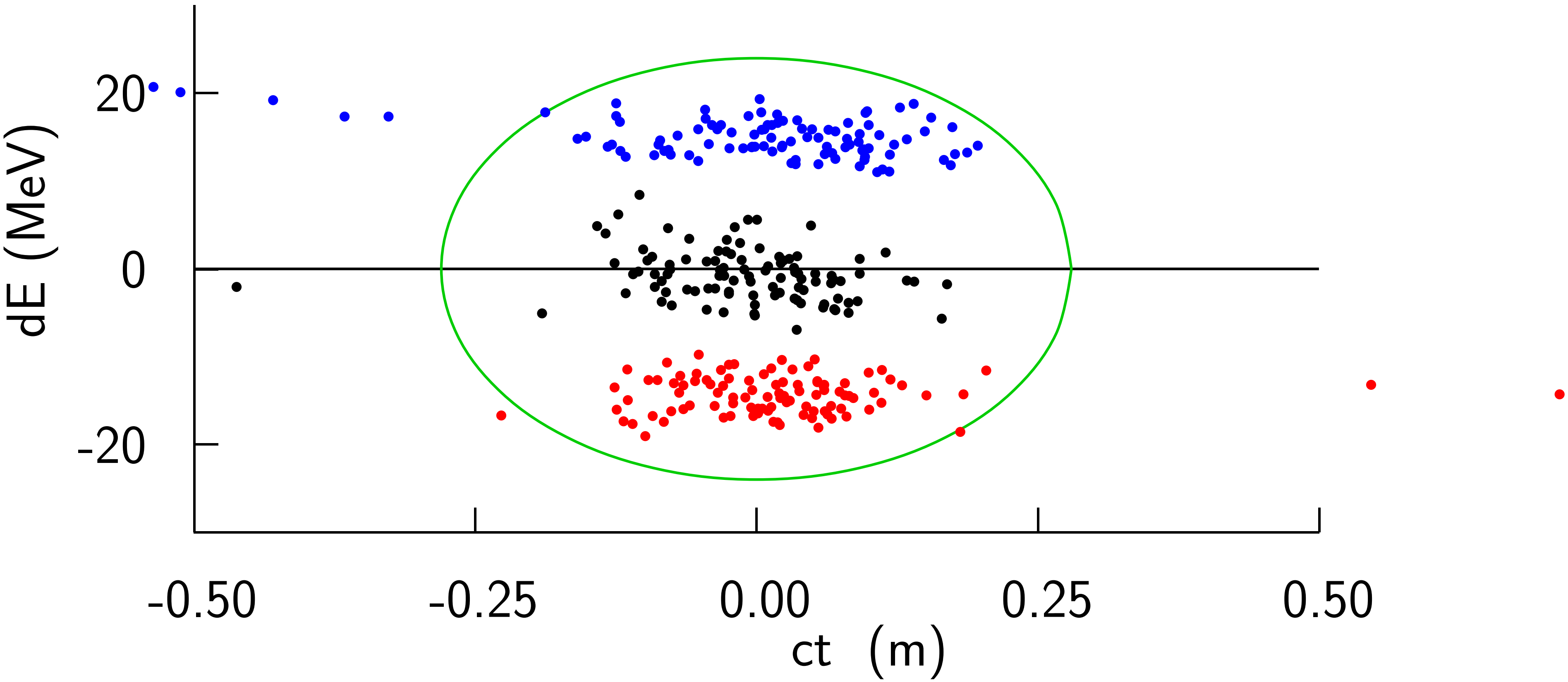


Fig. 23

Detail at end



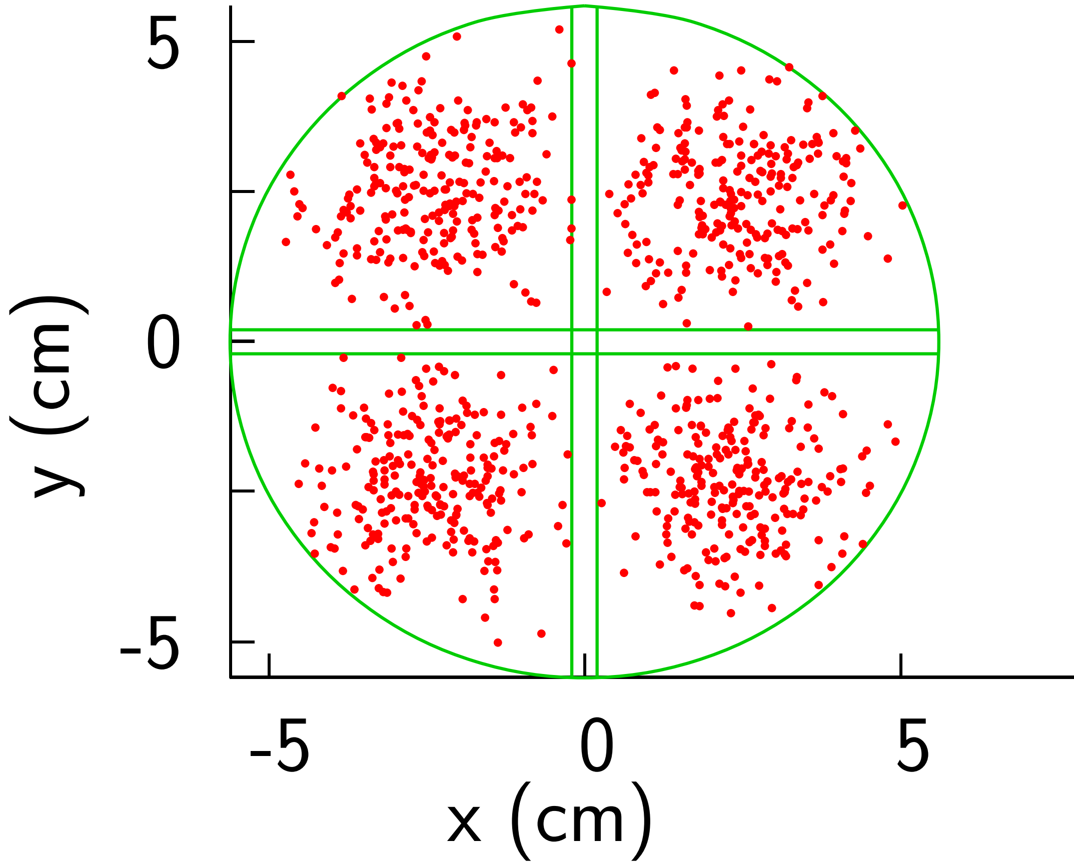
old emitz=1.7 (mm) new emit=8.81 (mm) transm=0.97

old emitz=1.7 (mm) new emit=7.44 (mm) transm=0.98

Almost as good Further optimization will help Already acceptable

Transverse

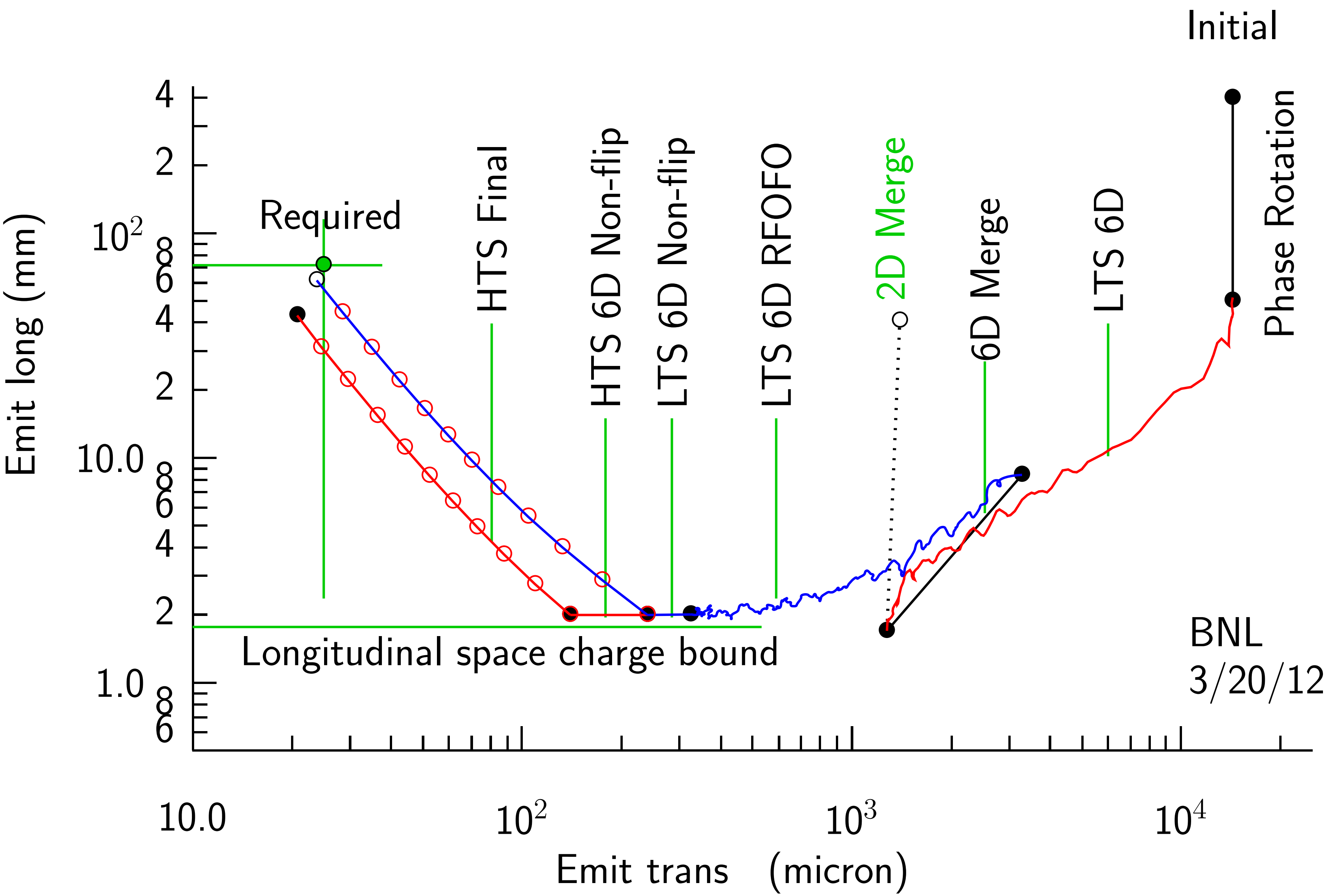
- There are now 12/3=4 bunches spaced by ct=4.5 m
- x and y kickers send these bunches into 4 different channels
- that transport them different lengths (trombone) to bring them to the same time
- where they can be captured into one larger channel



new emit x = 2.57 $\times$ old emit x
new emit y = 2.57 $\times$ old emit y
Transmission 95 %
But aberrations in the Fan-Out has not yet been simulated

New (3/20/12) Cooling Sequence

ICOOL Simulations of 6D cooling are for Guggenheim lattices



Next Tasks

- Simulate merge using files from end of 6D before merge
  quick
- Simulate RFOFO 6D cooling after merge using output from merge
  quick
- The same using Non-flip lattices
  a little longer
- See if this can be done in a simple lattice
  this should be possible - just needs a crazier wave form $\surd$
- Simulate merge with ICOOL or G4Beamline
  This will take time