Update on Ne^{+1} pulse and RF acceleration

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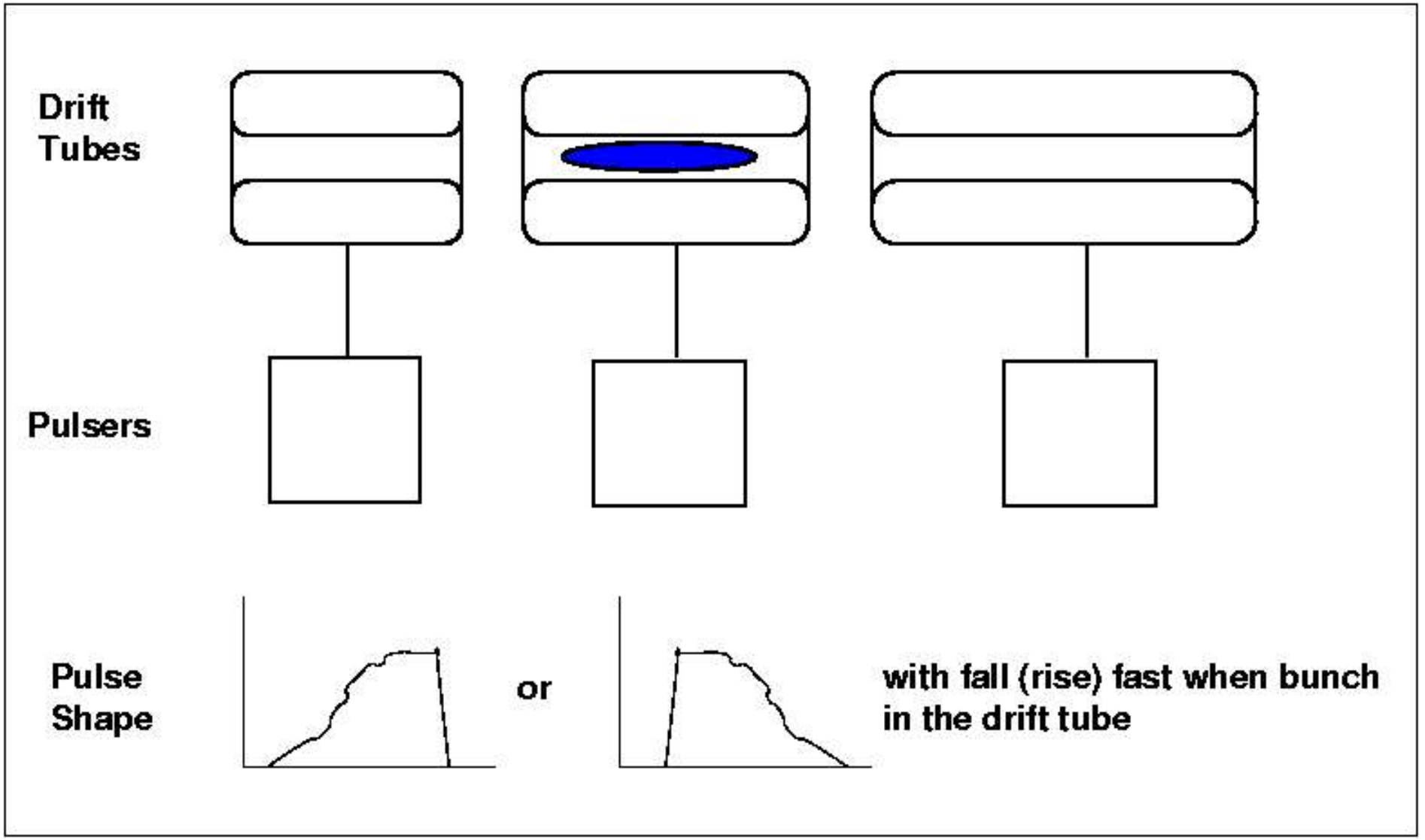
Take another look at a 1-bunch Ne^{+1} structure

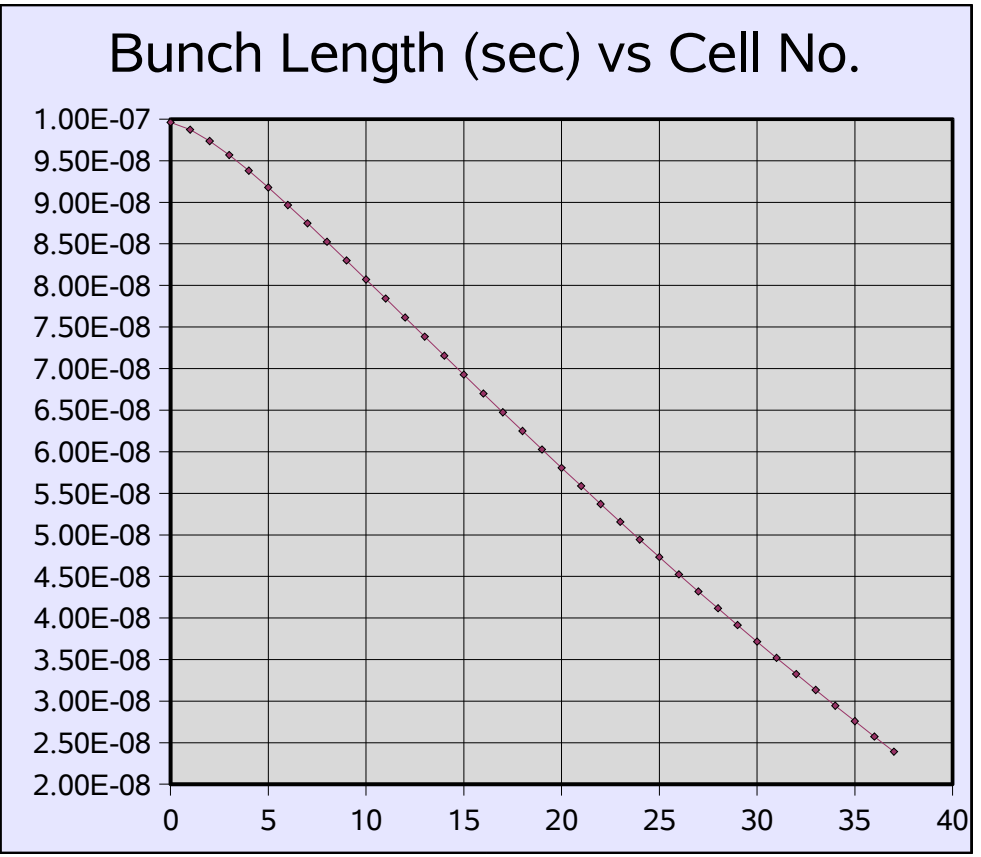
- Assume 500 kV/gap
- 100 nsec risetime of field
- longitudinal dynamics only
- 20 MeV total final energy
- Two cases
  - no bunch compression
  - with compression with tilt on field

Basic drift-tube configuration



Q	1		Cell	KE tot	KE/nuc	Beta	Bunch lth	risetime	Gap lth	DT c-c spa	Accum lth
Amu	20			(eV)	(eV/n)		(m)	(m)	(m)	(m)	(m)
Vinj	1.00E+006										
I	0.05	Amp	0	1.00E+06	50000	0.0103	0.31	0.31	0.05	0.67	0.00
Risetime	1.00E-07	Sec	1	1.50E+06	75000	0.0126	0.38	0.38	0.05	0.81	0.67
Bunch time	1.00E-07	Sec	2	2.00E+06	100000	0.0146	0.44	0.44	0.05	0.93	1.48
Q/bunch	5.00E-09	Coul	3	2.50E+06	125000	0.0163	0.49	0.49	0.05	1.03	2.40
Total charge	1.00E-006	Coul	4	3.00E+06	150000	0.0179	0.54	0.54	0.05	1.12	3.43
Num beams	200		5	3.50E+06	175000	0.0193	0.58	0.58	0.05	1.21	4.56
volts/gap	5.00E+05	V	6	4.00E+06	200000	0.0207	0.62	0.62	0.05	1.29	5.77
Pmass	9.38E+08	MeV	7	4.50E+06	225000	0.0219	0.66	0.66	0.05	1.36	7.05
Clight	3.00E+08	m/sec	8	5.00E+06	250000	0.0231	0.69	0.69	0.05	1.44	8.42
Max gradient	1.00E+007	V/m	9	5.50E+06	275000	0.0242	0.73	0.73	0.05	1.50	9.85
			10	6.00E+06	300000	0.0253	0.76	0.76	0.05	1.57	11.36
			11	6.50E+06	325000	0.0263	0.79	0.79	0.05	1.63	12.92
			12	7.00E+06	350000	0.0273	0.82	0.82	0.05	1.69	14.55
			13	7.50E+06	375000	0.0283	0.85	0.85	0.05	1.75	16.24
			14	8.00E+06	400000	0.0292	0.88	0.88	0.05	1.80	17.99
			15	8.50E+06	425000	0.0301	0.90	0.90	0.05	1.86	19.79
			16	9.00E+06	450000	0.0310	0.93	0.93	0.05	1.91	21.65
			17	9.50E+06	475000	0.0318	0.95	0.95	0.05	1.96	23.56
			18	1.00E+07	500000	0.0327	0.98	0.98	0.05	2.01	25.52
			19	1.05E+07	525000	0.0335	1.00	1.00	0.05	2.06	27.53
			20	1.10E+07	550000	0.0342	1.03	1.03	0.05	2.10	29.58
			21	1.15E+07	575000	0.0350	1.05	1.05	0.05	2.15	31.69
			22	1.20E+07	600000	0.0358	1.07	1.07	0.05	2.20	33.84
			23	1.25E+07	625000	0.0365	1.10	1.10	0.05	2.24	36.03
			24	1.30E+07	650000	0.0372	1.12	1.12	0.05	2.28	38.27
			25	1.35E+07	675000	0.0379	1.14	1.14	0.05	2.33	40.56
			26	1.40E+07	700000	0.0386	1.16	1.16	0.05	2.37	42.88
			27	1.45E+07	725000	0.0393	1.18	1.18	0.05	2.41	45.25
			28	1.50E+07	750000	0.0400	1.20	1.20	0.05	2.45	47.66
			29	1.55E+07	775000	0.0407	1.22	1.22	0.05	2.49	50.11
			30	1.60E+07	800000	0.0413	1.24	1.24	0.05	2.53	52.60
			31	1.65E+07	825000	0.0419	1.26	1.26	0.05	2.57	55.13
			32	1.70E+07	850000	0.0426	1.28	1.28	0.05	2.60	57.69
			33	1.75E+07	875000	0.0432	1.30	1.30	0.05	2.64	60.30
			34	1.80E+07	900000	0.0438	1.31	1.31	0.05	2.68	62.94
			35	1.85E+07	925000	0.0444	1.33	1.33	0.05	2.71	65.62
			36	1.90E+07	950000	0.0450	1.35	1.35	0.05	2.75	68.33
			37	1.95E+07	975000	0.0456	1.37	1.37	0.05	2.79	71.08
			38	**2.00E+07**	1000000	0.0462	1.39	1.39	0.05	2.82	**73.87**

Cell	Tot tilt	KE front	KE mid	KE rear	Beta f	Beta m	Beta r	Lgap	Lth due t	Lbunch	Ldrift	t to next gap	t thru gap	Lbunch	accum l	energy sprea	% energ	dtilt/dtime	drise/dtime
	(volts)								risetime	before	(m)	(sec)	(sec)	after gap			spread	(V/sec)	(V/sec)
0	1.50E+04	9.93E+05	1.00E+06	1.01E+06	0.0103	0.0103	0.0104	0.05	0.31	0.310	0.67	0.00E+00	9.96E-08	0.377	0.00	1.50E+04	1.50	1.51E+11	5.00E+12
1	1.50E+04	1.49E+06	1.50E+06	1.51E+06	0.0126	0.0126	0.0127	0.05	0.38	0.376	0.80	7.73E-08	9.87E-08	0.431	0.67	1.50E+04	1.00	1.52E+11	5.00E+12
2	1.50E+04	1.99E+06	2.00E+06	2.02E+06	0.0145	0.0146	0.0147	0.05	0.44	0.428	0.92	8.57E-08	9.74E-08	0.475	1.47	3.00E+04	1.50	1.54E+11	5.00E+12
3	1.50E+04	2.48E+06	2.50E+06	2.52E+06	0.0163	0.0163	0.0164	0.05	0.49	0.471	1.01	9.05E-08	9.57E-08	0.511	2.39	4.50E+04	1.80	1.57E+11	5.00E+12
4	1.50E+04	2.97E+06	3.00E+06	3.03E+06	0.0178	0.0179	0.0180	0.05	0.54	0.506	1.09	9.36E-08	9.38E-08	0.541	3.40	6.00E+04	2.00	1.60E+11	5.00E+12
5	1.50E+04	3.46E+06	3.50E+06	3.54E+06	0.0192	0.0193	0.0194	0.05	0.58	0.535	1.16	9.57E-08	9.18E-08	0.565	4.49	7.50E+04	2.14	1.63E+11	5.00E+12
6	1.50E+04	3.96E+06	4.00E+06	4.05E+06	0.0205	0.0207	0.0208	0.05	0.62	0.559	1.23	9.72E-08	8.97E-08	0.586	5.66	9.00E+04	2.25	1.67E+11	5.00E+12
7	1.50E+04	4.45E+06	4.50E+06	4.55E+06	0.0218	0.0219	0.0220	0.05	0.66	0.578	1.29	9.83E-08	8.75E-08	0.602	6.89	1.05E+05	2.33	1.71E+11	5.00E+12
8	1.50E+04	4.94E+06	5.00E+06	5.06E+06	0.0229	0.0231	0.0232	0.05	0.69	0.594	1.34	9.92E-08	8.53E-08	0.616	8.17	1.20E+05	2.40	1.76E+11	5.00E+12
9	1.50E+04	5.43E+06	5.50E+06	5.57E+06	0.0241	0.0242	0.0244	0.05	0.73	0.607	1.38	9.99E-08	8.30E-08	0.626	9.51	1.35E+05	2.45	1.81E+11	5.00E+12
10	1.50E+04	5.93E+06	6.00E+06	6.08E+06	0.0251	0.0253	0.0254	0.05	0.76	0.616	1.43	1.00E-07	8.07E-08	0.633	10.89	1.50E+05	2.50	1.86E+11	5.00E+12
11	1.50E+04	6.42E+06	6.50E+06	6.58E+06	0.0262	0.0263	0.0265	0.05	0.79	0.623	1.46	1.01E-07	7.84E-08	0.639	12.32	1.65E+05	2.54	1.91E+11	5.00E+12
12	1.50E+04	6.91E+06	7.00E+06	7.09E+06	0.0271	0.0273	0.0275	0.05	0.82	0.628	1.50	1.01E-07	7.61E-08	0.642	13.78	1.80E+05	2.57	1.97E+11	5.00E+12
13	1.50E+04	7.40E+06	7.50E+06	7.60E+06	0.0281	0.0283	0.0285	0.05	0.85	0.630	1.53	1.02E-07	7.38E-08	0.643	15.28	1.95E+05	2.60	2.03E+11	5.00E+12
14	1.50E+04	7.90E+06	8.00E+06	8.11E+06	0.0290	0.0292	0.0294	0.05	0.88	0.631	1.56	1.02E-07	7.15E-08	0.642	16.81	2.10E+05	2.63	2.10E+11	5.00E+12
15	1.50E+04	8.39E+06	8.50E+06	8.61E+06	0.0299	0.0301	0.0303	0.05	0.90	0.630	1.58	1.02E-07	6.93E-08	0.639	18.36	2.25E+05	2.65	2.17E+11	5.00E+12
16	1.50E+04	8.88E+06	9.00E+06	9.12E+06	0.0308	0.0310	0.0312	0.05	0.93	0.627	1.61	1.02E-07	6.70E-08	0.635	19.94	2.40E+05	2.67	2.24E+11	5.00E+12
17	1.50E+04	9.37E+06	9.50E+06	9.63E+06	0.0316	0.0318	0.0320	0.05	0.95	0.622	1.63	1.02E-07	6.47E-08	0.630	21.55	2.55E+05	2.68	2.32E+11	5.00E+12
18	1.50E+04	9.87E+06	1.00E+07	1.01E+07	0.0324	0.0327	0.0329	0.05	0.98	0.616	1.65	1.02E-07	6.25E-08	0.623	23.18	2.70E+05	2.70	2.40E+11	5.00E+12
19	1.50E+04	1.04E+07	1.05E+07	1.06E+07	0.0332	0.0335	0.0337	0.05	1.00	0.609	1.66	1.03E-07	6.03E-08	0.615	24.82	2.85E+05	2.71	2.49E+11	5.00E+12
20	1.50E+04	1.09E+07	1.10E+07	1.12E+07	0.0340	0.0342	0.0345	0.05	1.03	0.601	1.68	1.03E-07	5.81E-08	0.606	26.49	3.00E+05	2.73	2.58E+11	5.00E+12
21	1.50E+04	1.13E+07	1.15E+07	1.17E+07	0.0348	0.0350	0.0353	0.05	1.05	0.591	1.69	1.03E-07	5.59E-08	0.595	28.16	3.15E+05	2.74	2.68E+11	5.00E+12
22	1.50E+04	1.18E+07	1.20E+07	1.22E+07	0.0355	0.0358	0.0360	0.05	1.07	0.580	1.70	1.03E-07	5.37E-08	0.584	29.86	3.30E+05	2.75	2.79E+11	5.00E+12
23	1.50E+04	1.23E+07	1.25E+07	1.27E+07	0.0363	0.0365	0.0368	0.05	1.10	0.569	1.71	1.03E-07	5.16E-08	0.572	31.56	3.45E+05	2.76	2.91E+11	5.00E+12
24	1.50E+04	1.28E+07	1.30E+07	1.32E+07	0.0370	0.0372	0.0375	0.05	1.12	0.556	1.72	1.03E-07	4.94E-08	0.559	33.27	3.60E+05	2.77	3.03E+11	5.00E+12
25	1.50E+04	1.33E+07	1.35E+07	1.37E+07	0.0377	0.0379	0.0382	0.05	1.14	0.542	1.73	1.03E-07	4.73E-08	0.545	35.00	3.75E+05	2.78	3.17E+11	5.00E+12
26	1.50E+04	1.38E+07	1.40E+07	1.42E+07	0.0384	0.0386	0.0389	0.05	1.16	0.528	1.74	1.03E-07	4.53E-08	0.530	36.73	3.90E+05	2.79	3.31E+11	5.00E+12
27	1.50E+04	1.43E+07	1.45E+07	1.47E+07	0.0390	0.0393	0.0396	0.05	1.18	0.513	1.74	1.03E-07	4.32E-08	0.515	38.46	4.05E+05	2.79	3.47E+11	5.00E+12
28	1.50E+04	1.48E+07	1.50E+07	1.52E+07	0.0397	0.0400	0.0403	0.05	1.20	0.497	1.75	1.03E-07	4.12E-08	0.498	40.21	4.20E+05	2.80	3.64E+11	5.00E+12
29	1.50E+04	1.53E+07	1.55E+07	1.57E+07	0.0404	0.0407	0.0409	0.05	1.22	0.481	1.75	1.03E-07	3.92E-08	0.482	41.95	4.35E+05	2.81	3.83E+11	5.00E+12
30	1.50E+04	1.58E+07	1.60E+07	1.62E+07	0.0410	0.0413	0.0416	0.05	1.24	0.464	1.75	1.03E-07	3.72E-08	0.464	43.70	4.50E+05	2.81	4.04E+11	5.00E+12
31	1.50E+04	1.63E+07	1.65E+07	1.67E+07	0.0416	0.0419	0.0422	0.05	1.26	0.446	1.75	1.03E-07	3.52E-08	0.446	45.46	4.65E+05	2.82	4.26E+11	5.00E+12
32	1.50E+04	1.68E+07	1.70E+07	1.72E+07	0.0423	0.0426	0.0429	0.05	1.28	0.428	1.75	1.03E-07	3.33E-08	0.428	47.21	4.80E+05	2.82	4.51E+11	5.00E+12
33	1.50E+04	1.73E+07	1.75E+07	1.77E+07	0.0429	0.0432	0.0435	0.05	1.30	0.409	1.75	1.03E-07	3.13E-08	0.409	48.96	4.95E+05	2.83	4.79E+11	5.00E+12
34	1.50E+04	1.77E+07	1.80E+07	1.83E+07	0.0435	0.0438	0.0441	0.05	1.31	0.390	1.75	1.03E-07	2.95E-08	0.390	50.72	5.10E+05	2.83	5.09E+11	5.00E+12
35	1.50E+04	1.82E+07	1.85E+07	1.88E+07	0.0441	0.0444	0.0447	0.05	1.33	0.370	1.75	1.03E-07	2.76E-08	0.370	52.47	5.25E+05	2.84	5.44E+11	5.00E+12
36	1.50E+04	1.87E+07	1.90E+07	1.93E+07	0.0447	0.0450	0.0453	0.05	1.35	0.350	1.75	1.03E-07	2.57E-08	0.350	54.23	5.40E+05	2.84	5.83E+11	5.00E+12
37	1.50E+04	1.92E+07	1.95E+07	1.98E+07	0.0453	0.0456	0.0459	0.05	1.37	0.330	1.75	1.03E-07	2.39E-08	0.329	55.98	5.55E+05	2.85	6.27E+11	5.00E+12
38	1.50E+04	1.97E+07	**2.00E+07**	2.03E+07	0.0458	0.0462	0.0465	0.05	1.39	0.309	1.74	1.03E-07	**2.21E-08**	0.000	**57.72**	5.70E+05	2.85	6.78E+11	5.00E+12


Bunch Length (sec) vs Cell No.
1.00E-07
9.50E-08
9.00E-08
8.50E-08
8.00E-08
7.50E-08
7.00E-08
6.50E-08
6.00E-08
5.50E-08
5.00E-08
4.50E-08
4.00E-08
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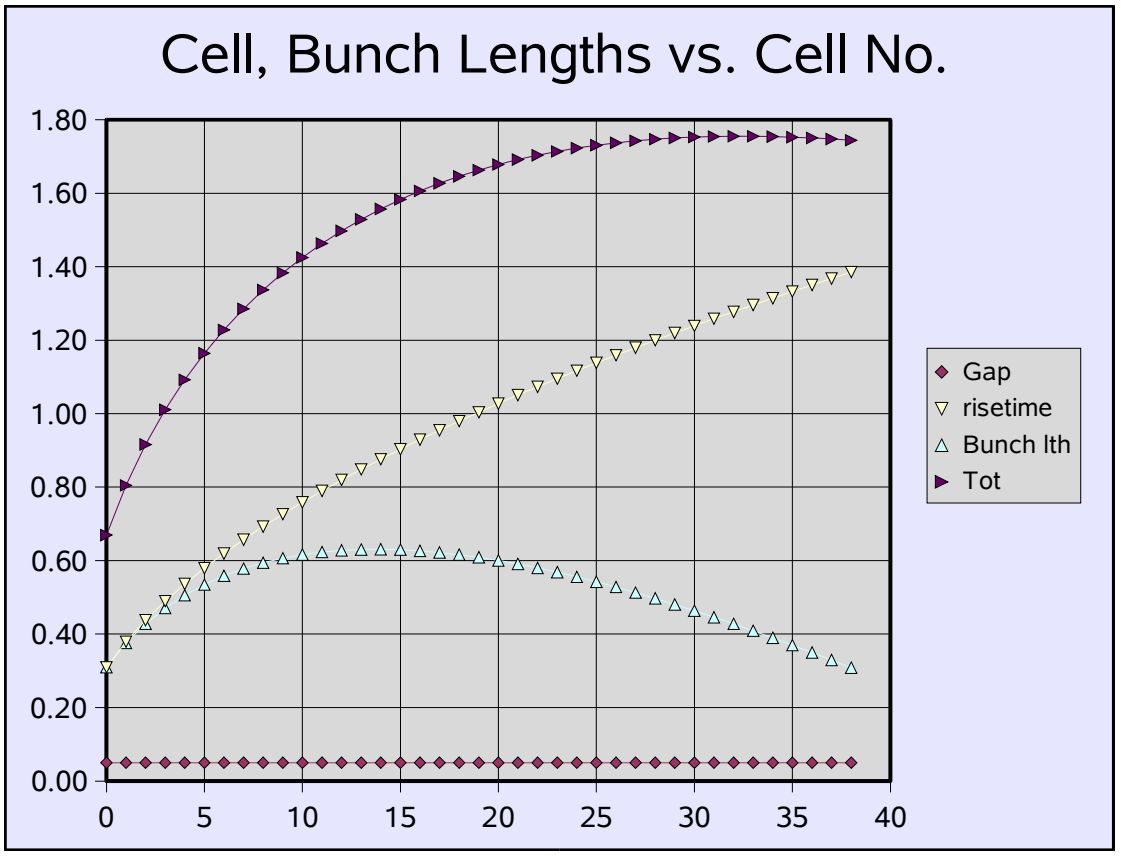
0
5
10
15
20
25
30
35
40


Cell, Bunch Lengths vs. Cell No.
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
0
5
10
15
20
25
30
35
40
Gap
risetime
Bunch lth
Tot

Won't work

- dV/dt values unrealistic
- bunching in structure doesn't reduce overall length that much
- length dominated by risetime of pulse

Upgrade to RF Scenario

- Still Ne^{+1}
- Increase injector to 1 MV
- Model a 50 MHz Alvarez structure
- Assume a perfect pre-buncher
- Model transverse and longitudinal dynamics with parmila

Drift Tube Linac

- Alvarez – easist to calculate quickly
  - 1 MV injector, Ne^{+1} : this helps a lot
  - 50 MHz, still pretty low
    - replace with IH-mode structure
  - 100 mA – perhaps 7 parallel beamlets
  - quad gradient still high, but possibly doable

Drift Tube Table

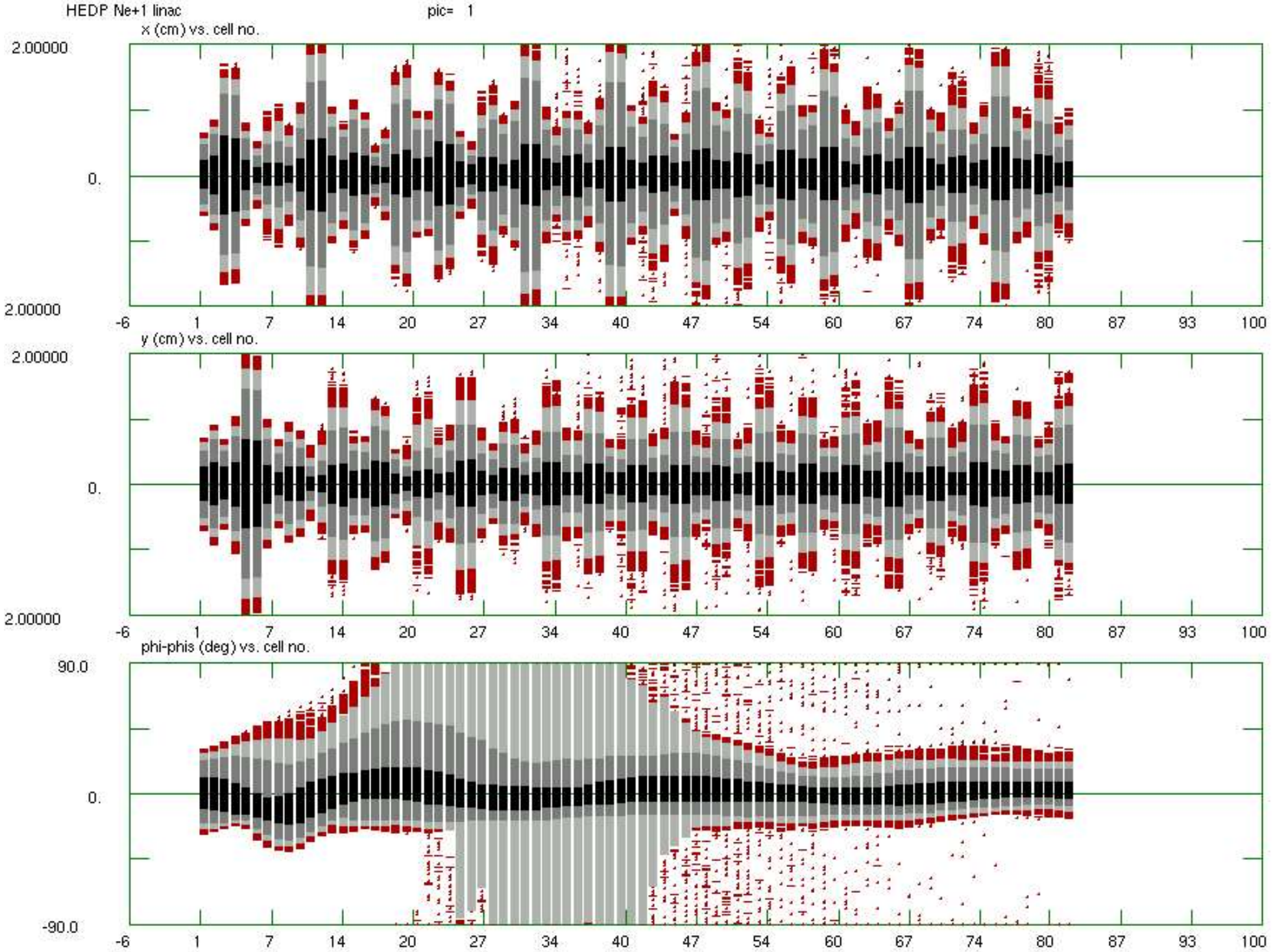
tank no. 1 tank length 1396.212 centimeters 82 cells power= 0.304 MW frequency= 50.00 MHz

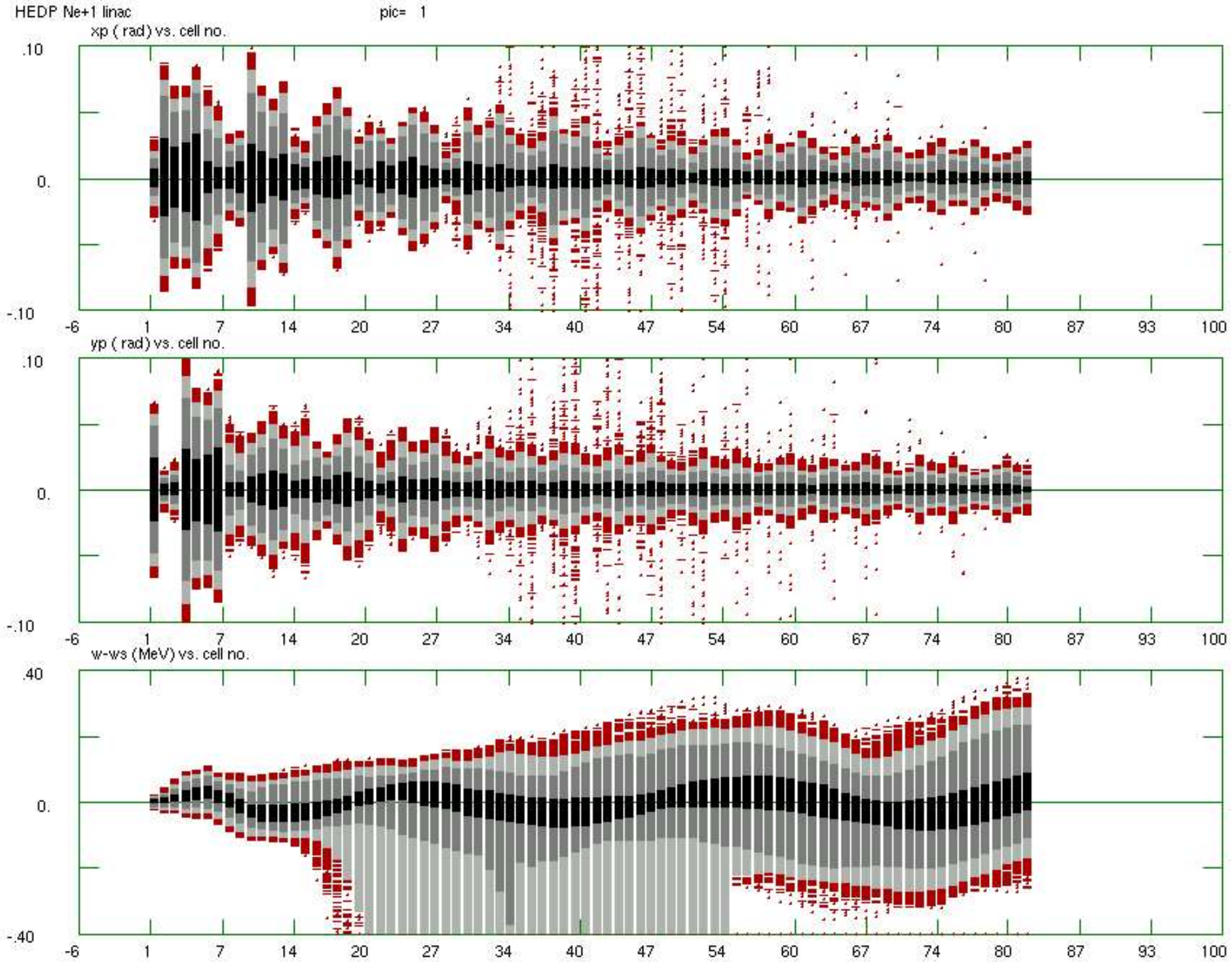
cell number	kinetic energy	beta	length	t	tp	s	sp	quad length	quad gradient	ezero MV/m	phis	total length
)initial	1.0000	0.0103						2.4759	30.0736			0.000
1	1.0872	0.0108	6.3127	0.7974	0.0500	0.4000	0.0500	2.5815	-28.4908	2.0000	-30.00	6.313
4	1.3707	0.0121	7.1054	0.7977	0.0500	0.4000	0.0500	2.8987	24.5706	2.0000	-30.00	26.836
7	1.6872	0.0134	7.8984	0.7979	0.0500	0.4000	0.0500	3.2159	21.5650	2.0000	-30.00	49.738
10	2.0367	0.0147	8.6917	0.7981	0.0500	0.4000	0.0500	3.5332	-19.1935	2.0000	-30.00	75.020
13	2.4191	0.0161	9.4851	0.7983	0.0500	0.4000	0.0500	3.8506	-17.2780	2.0000	-30.00	102.682
16	2.8346	0.0174	10.2788	0.7984	0.0500	0.4000	0.0500	4.1681	15.7009	2.0000	-30.00	132.725
19	3.2830	0.0187	11.0725	0.7985	0.0500	0.4000	0.0500	4.4856	14.3812	2.0000	-30.00	165.148
22	3.7645	0.0200	11.8664	0.7986	0.0500	0.4000	0.0500	4.8032	-13.2615	2.0000	-30.00	199.954
25	4.2789	0.0214	12.6603	0.7987	0.0500	0.4000	0.0500	5.1208	-12.3003	2.0000	-30.00	237.141
28	4.8263	0.0227	13.4543	0.7988	0.0500	0.4000	0.0500	5.4384	11.4666	2.0000	-30.00	276.710
31	5.4068	0.0240	14.2483	0.7989	0.0500	0.4000	0.0500	5.7560	10.7369	2.0000	-30.00	318.661
34	6.0202	0.0253	15.0424	0.7989	0.0500	0.4000	0.0500	6.0736	-10.0932	2.0000	-30.00	362.994
37	6.6667	0.0266	15.8364	0.7990	0.0500	0.4000	0.0500	6.3912	-9.5212	2.0000	-30.00	409.709
40	7.3462	0.0280	16.6304	0.7990	0.0500	0.4000	0.0500	6.7088	9.0098	2.0000	-30.00	458.806
43	8.0587	0.0293	17.4244	0.7991	0.0500	0.4000	0.0500	7.0265	8.5499	2.0000	-30.00	510.285
46	8.8041	0.0306	18.2184	0.7991	0.0500	0.4000	0.0500	7.3440	-8.1342	2.0000	-30.00	564.147
49	9.5826	0.0319	19.0124	0.7992	0.0500	0.4000	0.0500	7.6616	-7.7566	2.0000	-30.00	620.390
52	10.3941	0.0333	19.8063	0.7992	0.0500	0.4000	0.0500	7.9792	7.4122	2.0000	-30.00	679.015
55	11.2386	0.0346	20.6001	0.7992	0.0500	0.4000	0.0500	8.2967	7.0969	2.0000	-30.00	740.021
58	12.1161	0.0359	21.3939	0.7992	0.0500	0.4000	0.0500	8.6142	-6.8071	2.0000	-30.00	803.409
61	13.0266	0.0372	22.1876	0.7993	0.0500	0.4000	0.0500	8.9317	-6.5399	2.0000	-30.00	869.178
64	13.9701	0.0386	22.9812	0.7993	0.0500	0.4000	0.0500	9.2491	6.2928	2.0000	-30.00	937.328
67	14.9465	0.0399	23.7747	0.7993	0.0500	0.4000	0.0500	9.5666	6.0635	2.0000	-30.00	1007.859
70	15.9560	0.0412	24.5682	0.7993	0.0500	0.4000	0.0500	9.8839	-5.8503	2.0000	-30.00	1080.770
73	16.9984	0.0425	25.3615	0.7994	0.0500	0.4000	0.0500	10.2013	-5.6516	2.0000	-30.00	1156.061
76	18.0738	0.0439	26.1548	0.7994	0.0500	0.4000	0.0500	10.5186	5.4658	2.0000	-30.00	1233.732
79	19.1822	0.0452	26.9479	0.7994	0.0500	0.4000	0.0500	10.8358	5.2919	2.0000	-30.00	1313.783
82	20.3235	0.0465	27.7409	0.7994	0.0500	0.4000	0.0500	11.1530	-5.1286	2.0000	-30.00	1396.212

Beam Parameters at exit: 90% transmission

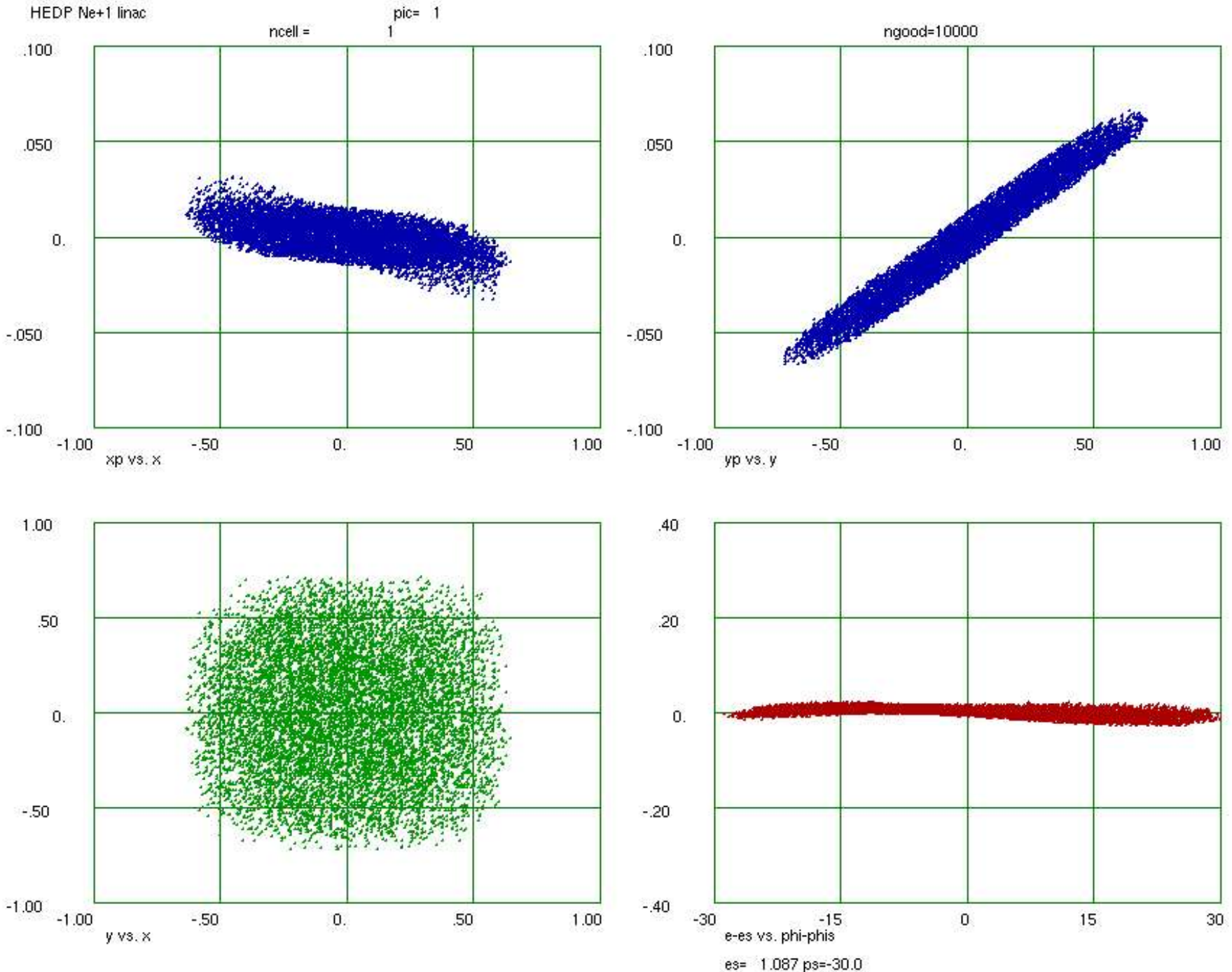
```
 Starting DTL cell  82
 scheff dist=  27.7409152
 scheff beam current=  100.
 pbar(deg)= -27.5104149
 phimc(deg)= -30.

 82    8993     x-xp      1.3403     0.3990     0.0789   -1.280      0.056811
                y-yp      1.0292     0.3016     0.0586    1.598      0.210924
                phi-w  5542.7929     0.0000     2.1409   -0.070     32.160210
Emittance       100%/RMS    90%/RMS
         X        16.99       5.06
         Y        17.55       5.14
         Z      2588.96       0.00
Matched beam phase advance from rms beam size:
  deg/cm, deg/two beta lambda, +-RMS size(cm), sig.emit, Bore/RMS,  Bore(cm)
     0.607166    33.858618     0.310306     2.671552     6.445259     2.000000
     0.451206    25.161519     0.515429     1.475363     3.880264     2.000000
     0.564989    31.506618     0.642673     5.986740     3.615434     2.323541
Long. rms (cm/mrad)(cm mrad) alpha beta(u) emittance(n)=
     0.069599      0.101410      0.190015
RMS X,Y,averageX+Y eV energy=     1597.72053      430.62822     1014.17437
RMS Z eV energy=                                             1158.62540
    end of run    1
 Average beam center(...deg MeV)= -0.000186857474 -0.0001247873 -0.001616648
-1.59543996E-06 -27.6772247  20.353509
 Parmila finished at Wed Sep  8 13:49:12 2004
```

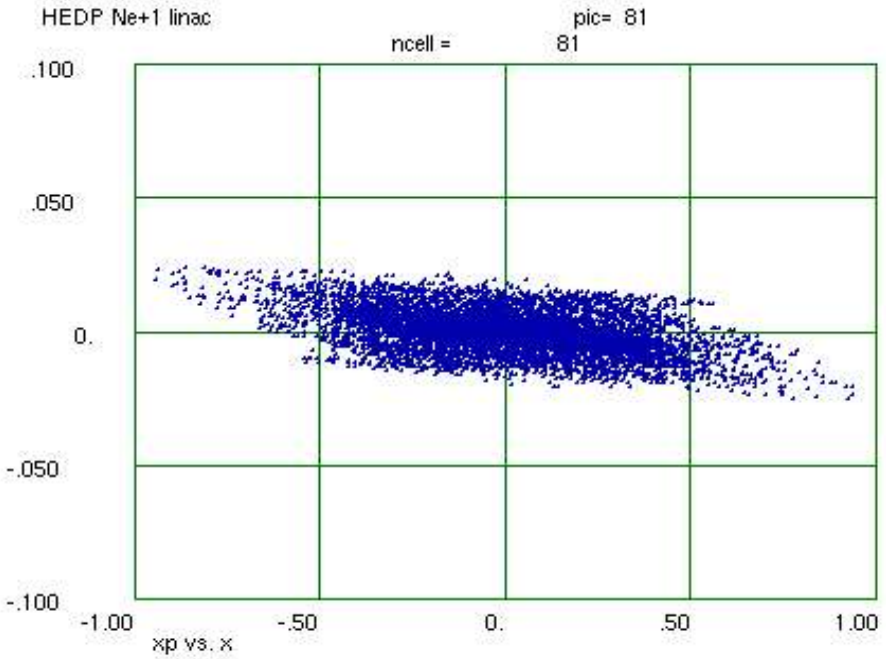

HEDP Ne+1 linac
pic= 1
x (cm) vs. cell no.
2.00000
0.
2.00000
-6
1
7
14
20
27
34
40
47
54
60
67
74
80
87
93
100
y (cm) vs. cell no.
2.00000
0.
2.00000
-6
1
7
14
20
27
34
40
47
54
60
67
74
80
87
93
100
phi-phis (deg) vs. cell no.
90.0
0.
-90.0
-6
1
7
14
20
27
34
40
47
54
60
67
74
80
87
93
100

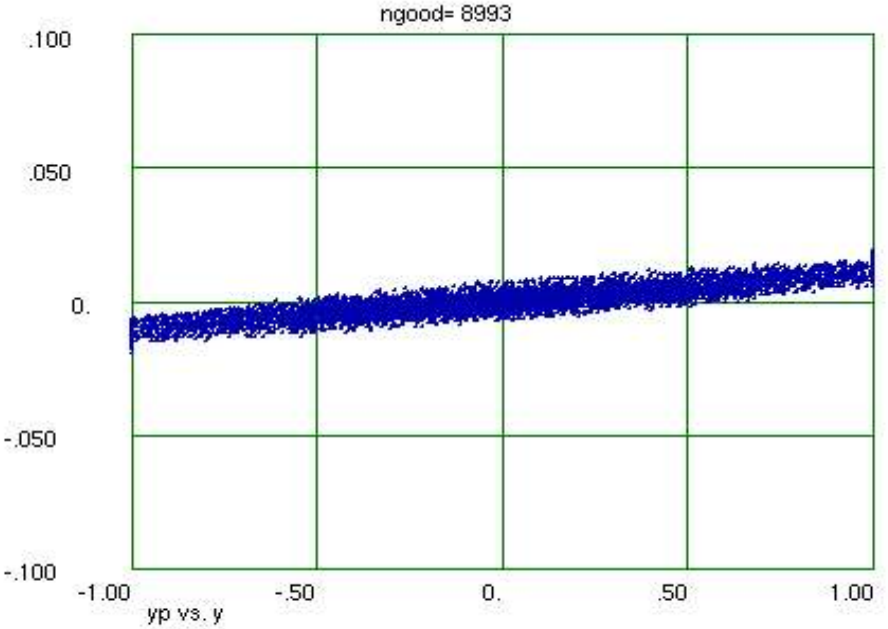

HEDP Ne+1 linac
pic= 1
xp (rad) vs. cell no.
.10
0.
-.10
-6
1
7
14
20
27
34
40
47
54
60
67
74
80
87
93
100
yp (rad) vs. cell no.
.10
0.
-.10
-6
1
7
14
20
27
34
40
47
54
60
67
74
80
87
93
100
w-ws (MeV) vs. cell no.
.40
0.
-.40
-6
1
7
14
20
27
34
40
47
54
60
67
74
80
87
93
100

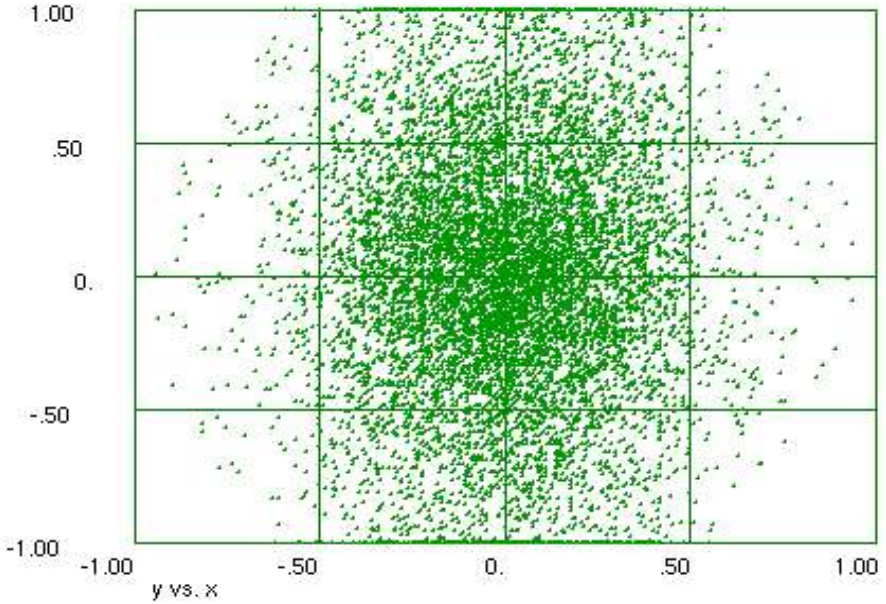
Beam after first gap

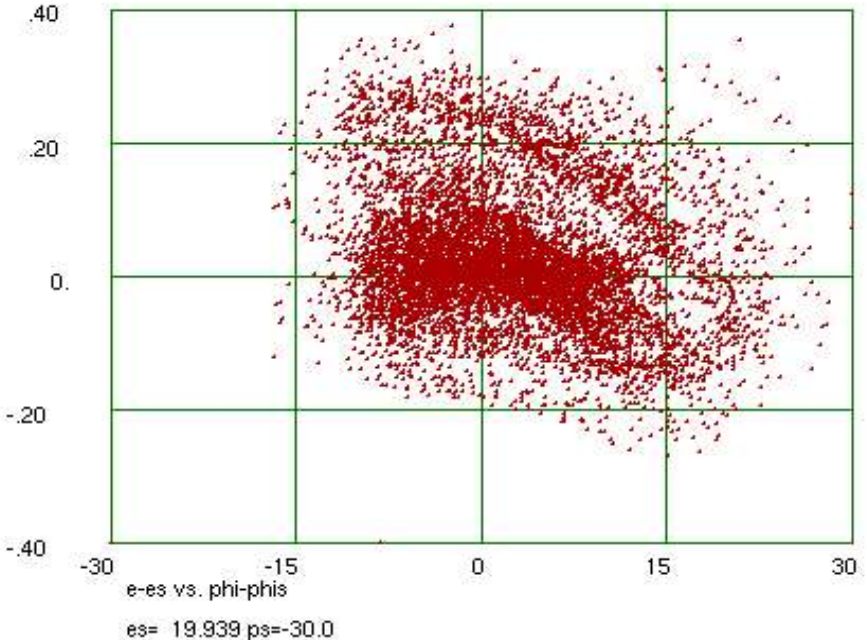


20 MeV Beam at exit of accelerator





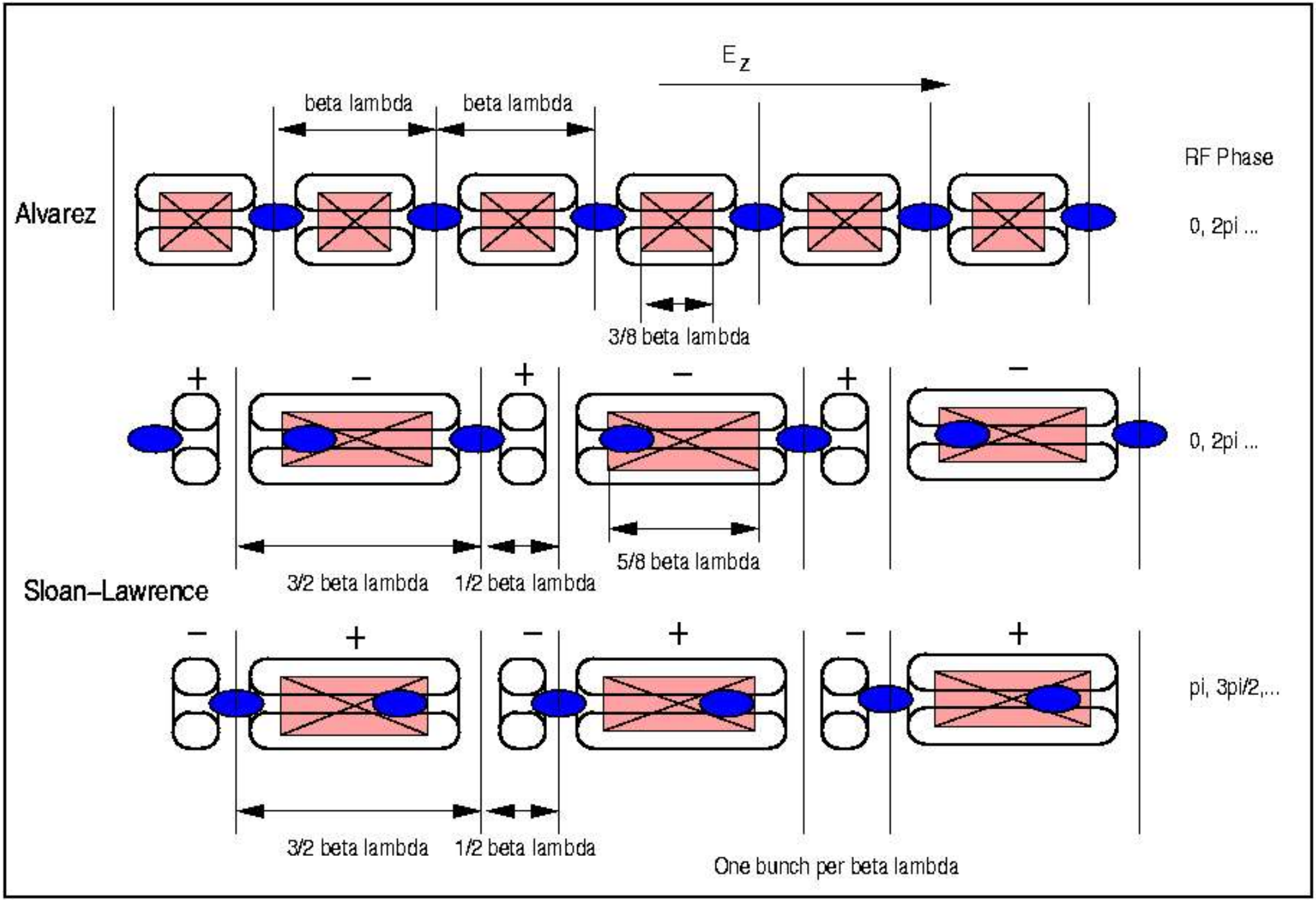




Surprise

- Linac 14 meters long
- 90% of 100 mA beam survives to end
- Exit energy spread about 1%
- Significant reduction in number of parallel beamlets (7 would be good)
- Would probably use a pi-3pi interdigital config

Transition from Alvarez to Sloan-Lawrence Structure



Advantage of S-L Structure

- Heavily loaded – smaller size for 50 MHz
- half as many quadrupoles, each almost twice as long
- Same number of bunches per beta lambda
- Higher shunt impedance at this frequency
- But: less convenient to calculate

To be done...

- Model Sloan-Lawrence machine with DYNAC
- 3 space charge algorithms:
  - scheff – assumes symmetry
  - scherm – no symmetry, Hermite polynomials, several ellipsoids in z, but poor convergence
  - hersc – uses Hermite polynomials (Linac2002), full 3-D representation of bunch, more terms
- Tedious to set up model – not a design program