Lower gradient Forward IR (v2)

7/12/18
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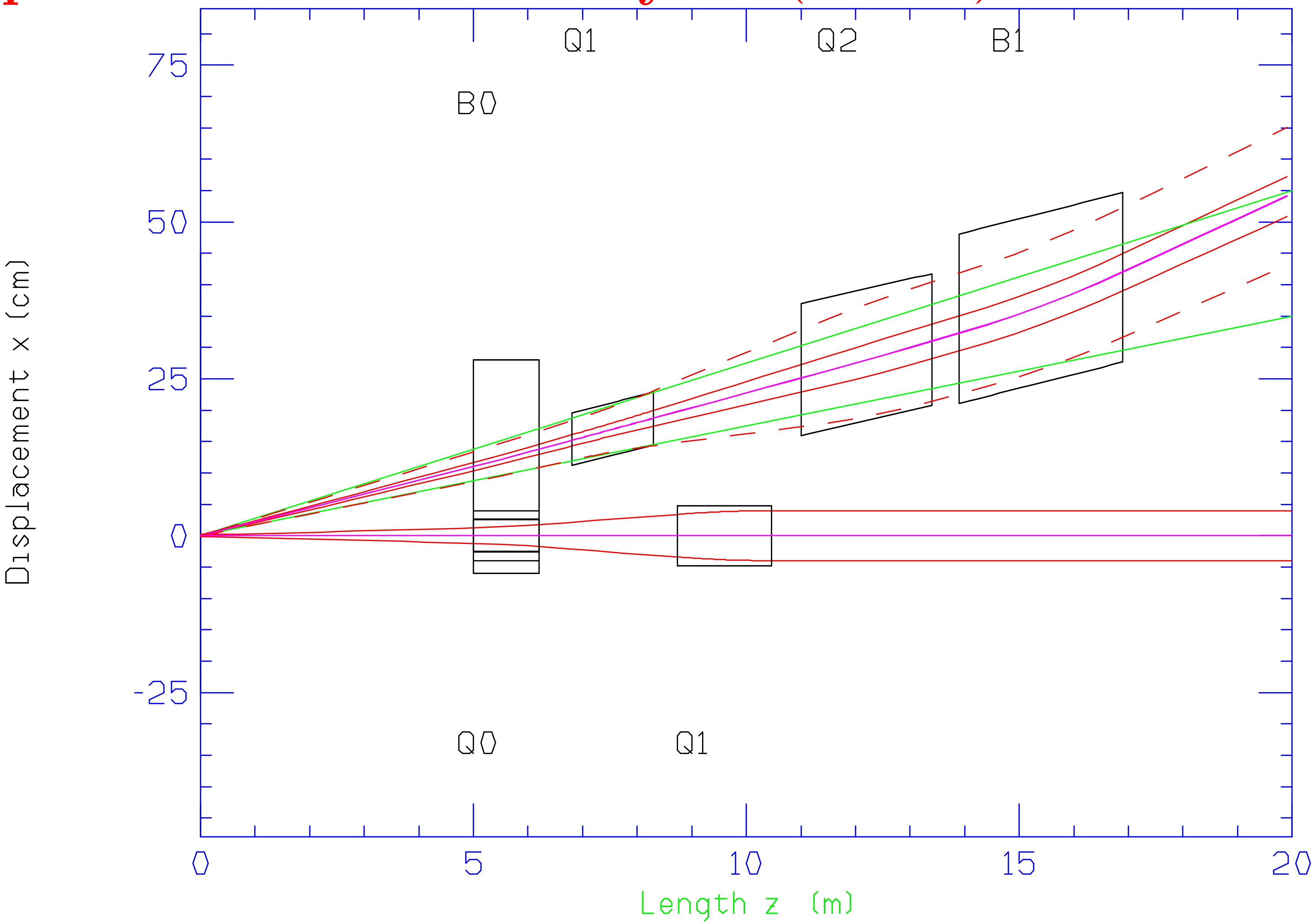
Too reduce IR cost, this design has lower forward gradients hopefully allowing use of NbTi (vs. Nb3Sn).

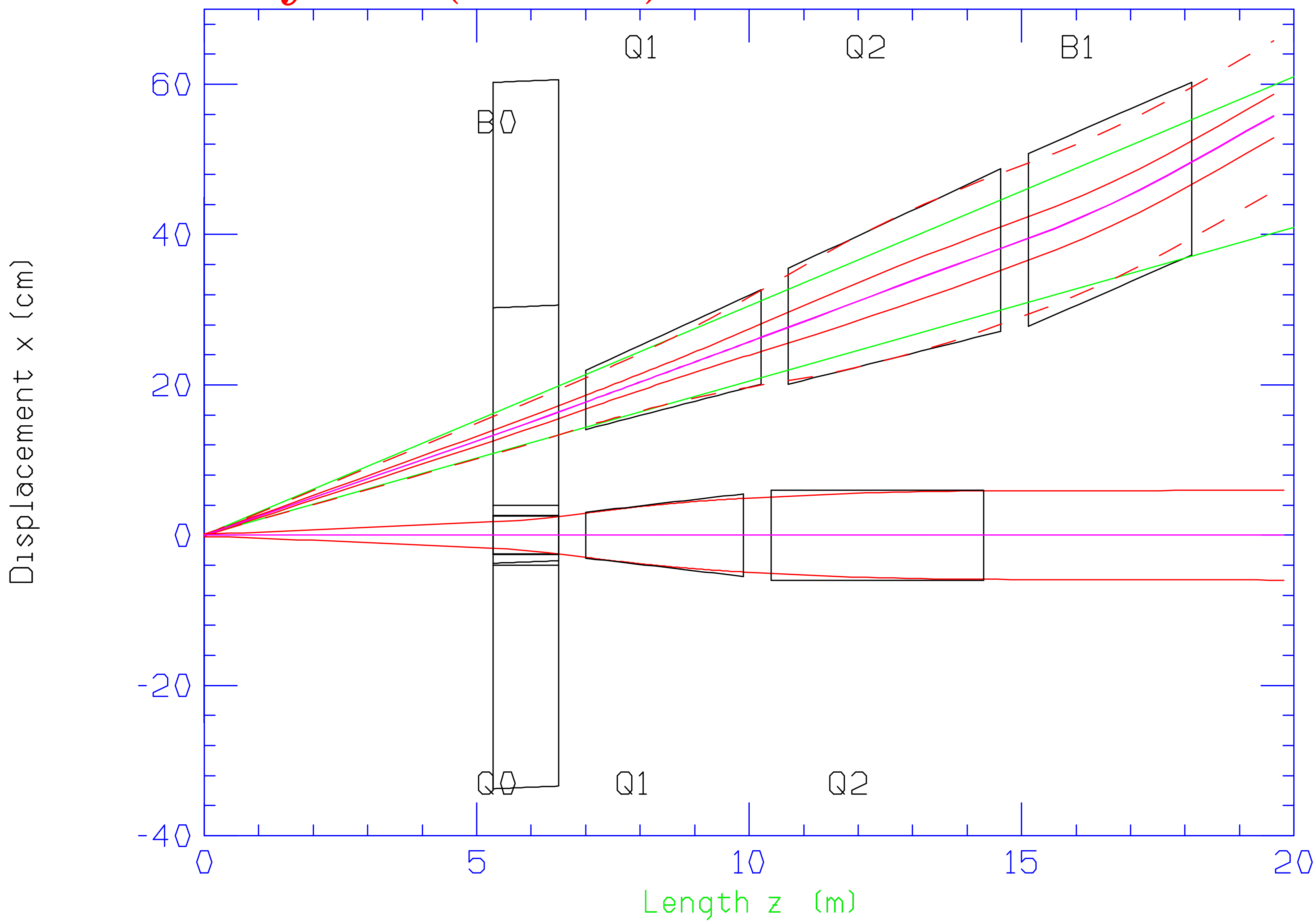
In the pCDR version, the pole tip fields (gradient $\times$ aperture) for Q1pF and Q2pF were 5.57 T and 4.96 T respectively. In this design they are reduced to 3.4 T and 3.6 T. These reductions are achieved by:

1. Locating e and p magnets beside each other, instead of alternating, allows longer, and weaker, quadrupoles for both p and e.
   This reduces the space for the magnets thicknesses and shielding
2. Using crossing angle of 25 mrad (c.f.22) helps.
3. Tapering the inside radii of Q1Fp, Q2Fp, and Q1Fe also helps.
4. Tapering the gradients of Q1Fp to give constant pole tip fields further minimizes needed fields.

pCDR FORWARD Layout (dnnb3iw)



NEW Layout (dnnb321)



Dash lines are of 1.3 GeV pt protons

c.f. Pre-CDR Hadrons (275) GeV

Chrom y 21.17 'Chrom x 3.85 ' mom = 275 GeV/c

		L1	DL	gap	x	θ	IR	Bpt	B	Grad)
		m	m	m	cm	mrad	cm	T	T	T/m
B0Fp	3	5.00	1.20	0.60	11.0	0.00	17.00		1.299	
Q1Fp	5	6.80	1.50	2.70	15.4	22.00	4.20	5.57		-132.649
Q2Fp	7	11.00	2.40	0.50	26.4	20.00	10.50	4.96		47.223
B1Fp	9	13.90	3.00	20.90	34.6	22.00	13.50		4.571	

Subscripts 1 nearer IP, 2 further from IP B_1 & B_2 are pole tip fields

New Hadrons Note: Magnets start at 5.3 m from IP (c.f. 5.0)

Chrom y 21.03 'Chrom x 4.17 ' Mom 275 (GeV/c)

		L1	DL	gap	x	θ	IR1	IR2	OR	B1	B2	B	Grad1	Grad2
		m	m	m	cm	mrad	cm	cm	cm	T	T	T	T/m	T/m
B0	3	5.30	1.20	0.5	13.3	3.0	17.00	17.0	30.0	0.000	0.000	1.300	0.000	0.000
Q1	5	7.00	3.22	0.5	18.0	26.0	3.94	6.3	0.0	3.528	3.528	0.000	-89.597	-55.998
Q2	7	10.72	3.90	0.5	27.8	26.0	7.71	10.8	0.0	3.643	3.643	0.000	47.220	33.729
B1	9	15.12	3.00	20.90	39.3	31.5	11.50	11.5	0.0	0.000	0.000	4.570	0.000	0.000

Pre-CDR ForwardForward Electron (18)

Gradients from Steve multiplied by 1.8 for 18 GeV/c

chrom y 5.88 Chrom x3.69 E 18 GeV

		L1	DL	gap	x	θ	IR	Bpt	Grad)
		m	m	m	cm	mrad	cm	T	T/m
Q0Fe	3	5.00	1.20	2.54	0.0	0.00	2.85	0.494	-17.33
Q1Fe	5	8.74	1.72	7.02	0.0	0.00	5.00	0.376	7.79

New Electrons

Chrom y 6.12 ' Chrom x 3.93 ' mom = 18

		L1	DL	gap	x	θ	IR1	IR2	OR	B1	B2	B	Grad1	Grad2
		m	m	m	cm	mrad	cm	cm	cm	T	T	T	T/m	T/m
Q0	3	5.30	1.20	0.50	0.0	0.00	2.60	2.60	0.0	0.376	0.376	0.000	-14.446	-14.446
Q1	5	7.00	3.22	0.50	0.0	0.00	3.06	5.50	0.0	0.077	0.138	0.000	2.512	2.512
Q2	7	10.72	3.90	20.40	0.0	0.00	6.00	6.00	0.0	0.059	0.059	0.000	0.983	0.983

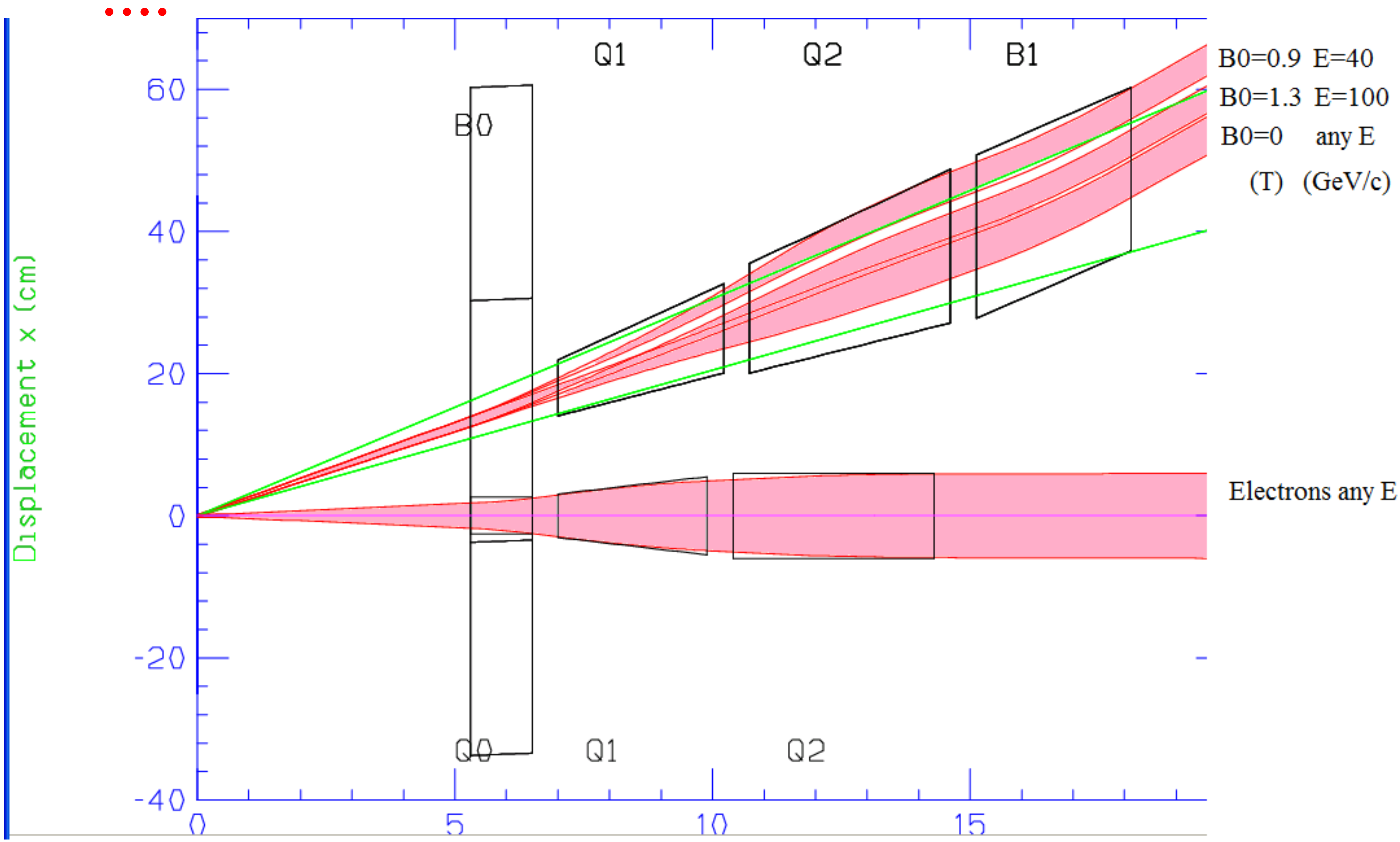
The very Q1Fe and Q2Fe are two parts of the now very weak old Q1Fe

Required aperture of good field

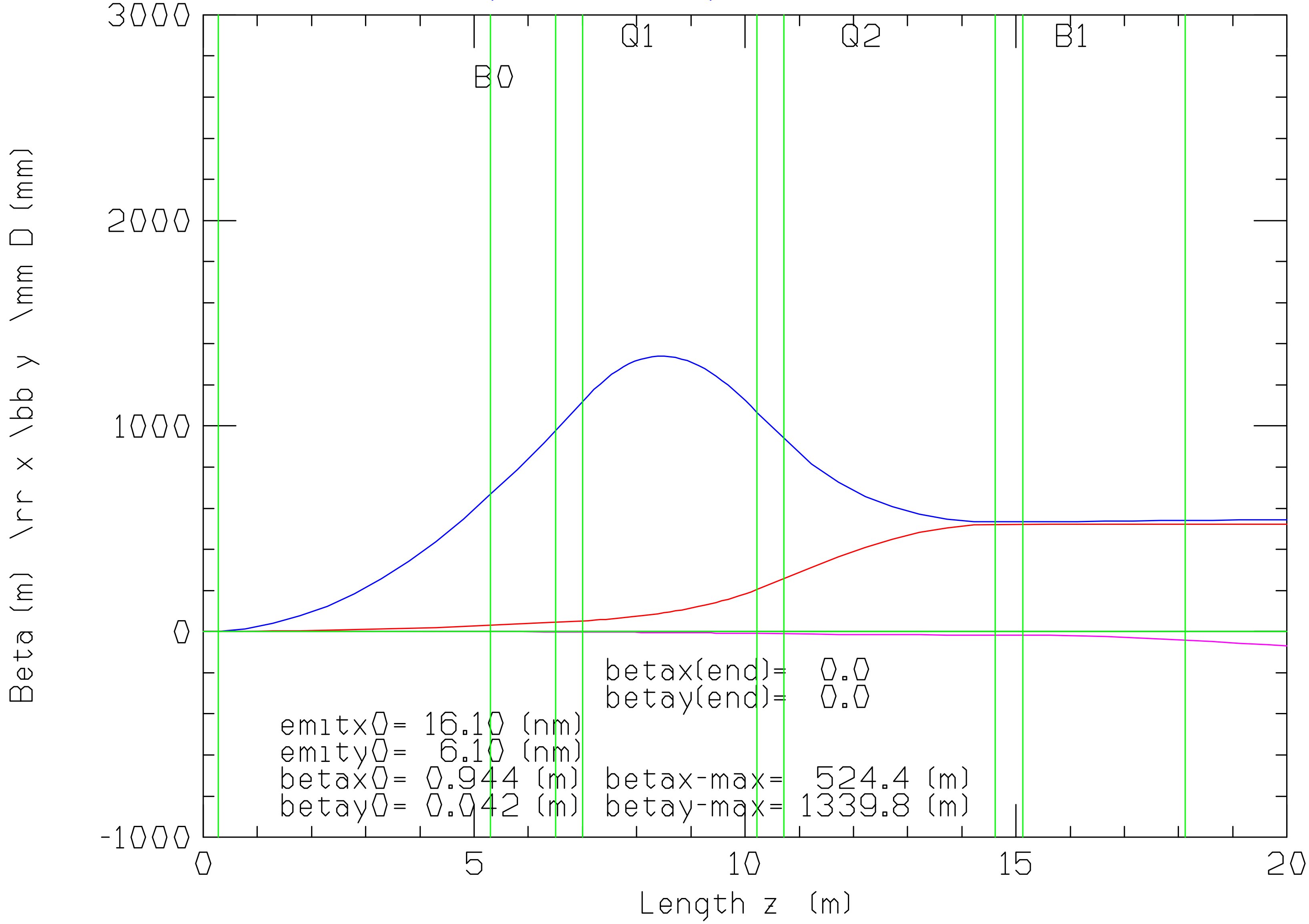
The above slide, at 275 GeV, suggests good field is only required over the quite limited central part of the aperture. At this energy and B0=1.3 T the forward spectrometer momentum determination is poor, but this is not so important because diffracted protons do not get into it.

But at 100 GeV, the spectrometer is more important, and we cam get much better momentum determinations by keeping B0 at 1.3 GeV and allowing the beam to be displaced through Q1, Q2 and B1. The fields of B1 and B2 can be adjusted to return the beam to its nominal center. This requires good field over a wider area (see following slide).

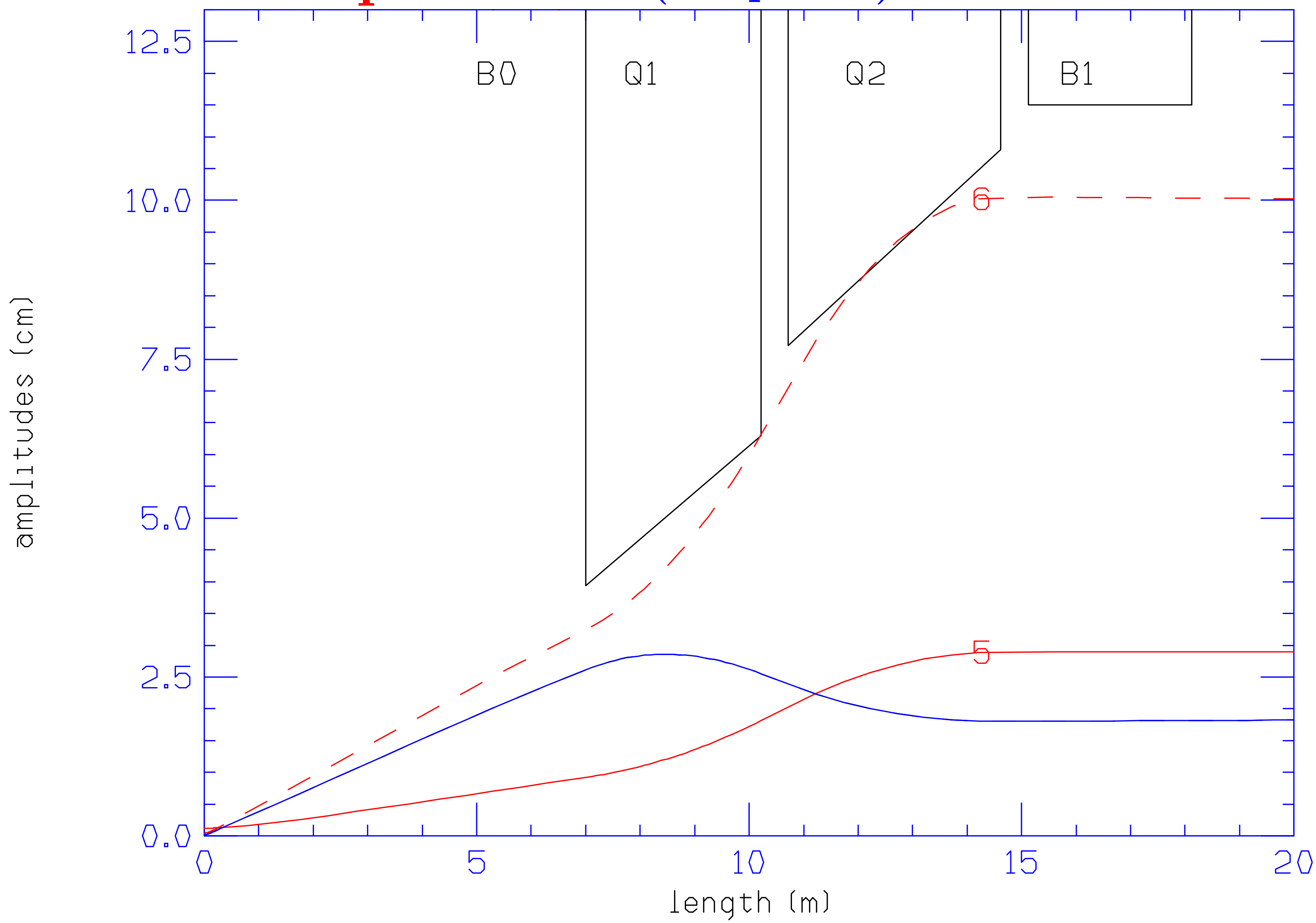
At 41 GeV momentum determinations can be even better with B0=0.9 T and the beam now up against the magnet apertures, needing good field up to that bound: a demanding requirement that could require further lowering the B0 field.

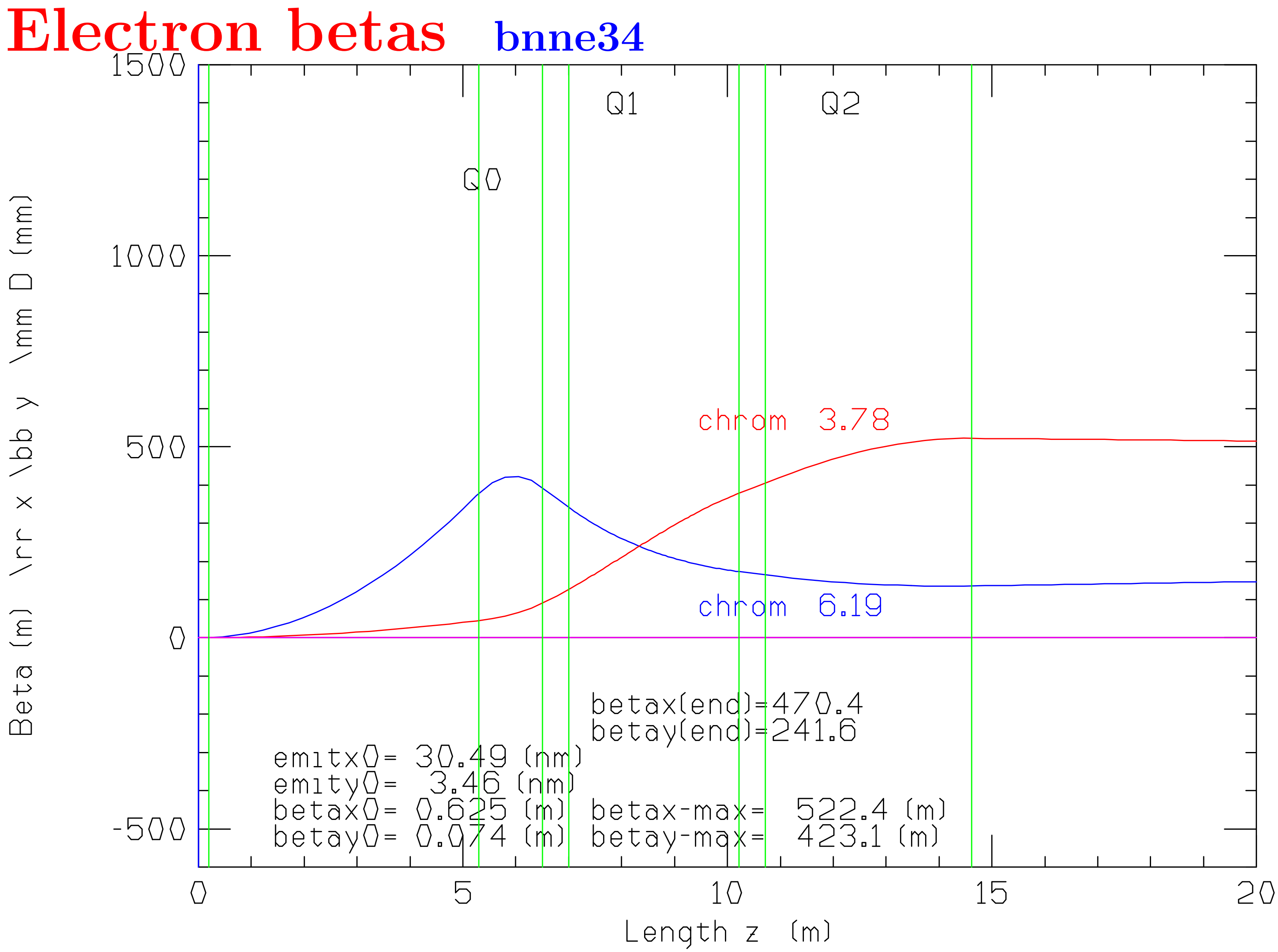

Displacement x (cm)
60
40
20
0
-20
-40
0
5
10
15
B0
Q0
Q1
Q2
B1
Q1
Q2
B0=0.9 E=40
B0=1.3 E=100
B0=0 any E
(T) (GeV/c)
Electrons any E

Hadron betas (bnnp321k)



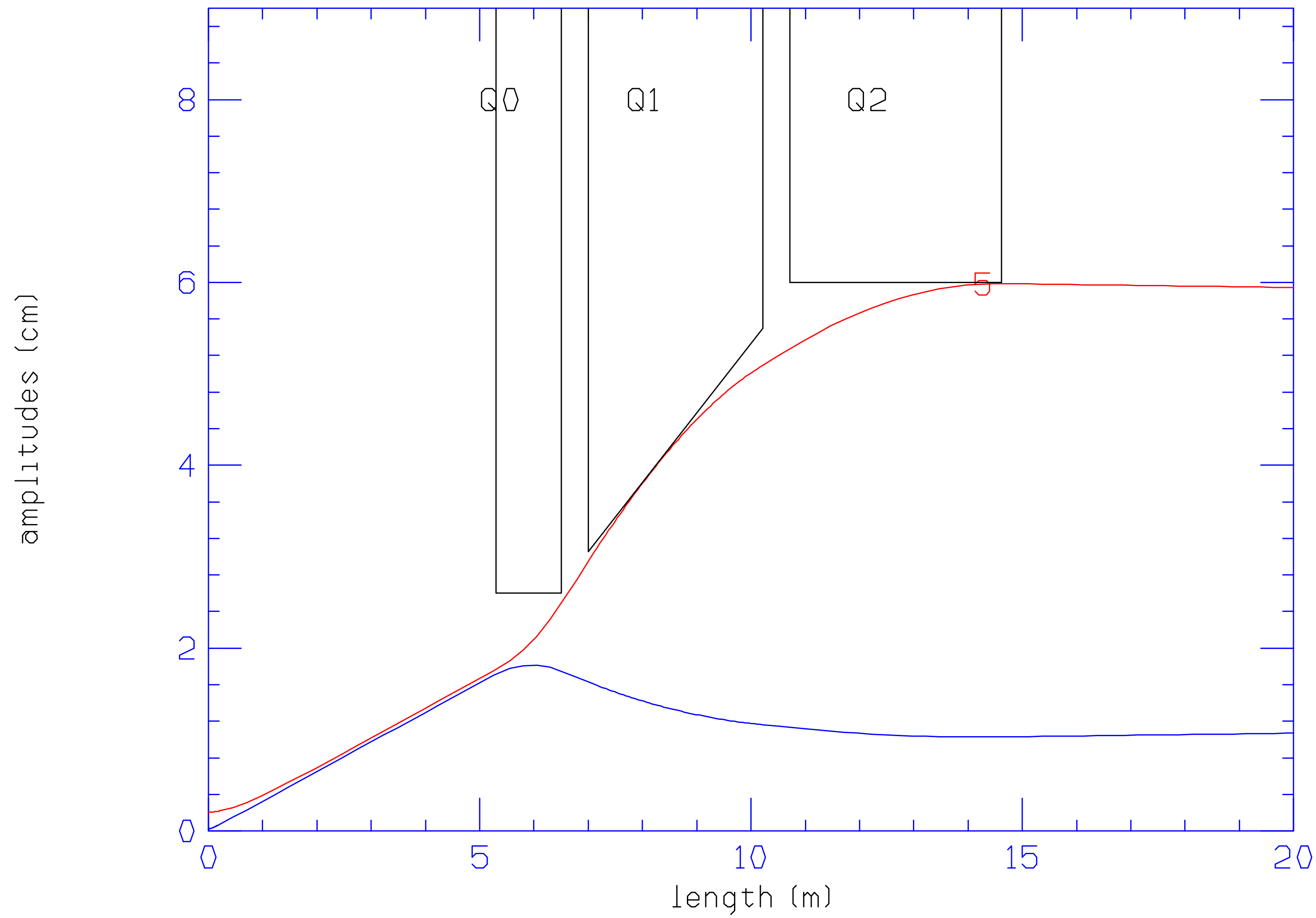
Hadron amplitudes (annp321k)




Electron betas
bnne34
Q0
Q1
Q2
chrom 3.78
chrom 6.19
betax(end)=470.4
betay(end)=241.6
emitx0= 30.49 (nm)
emity0= 3.46 (nm)
betax0= 0.625 (m)
betay0= 0.074 (m)
betax-max= 522.4 (m)
betay-max= 423.1 (m)
Beta (m) \rr x \bb y \mm D (mm)
Length z (m)
1500
1000
500
0
-500
0
5
10
15
20

Electrons amplitudes (anne34k)

crab



Conclusion

- By avoiding the alternations of e & p quads, and having them side by side, magnets can be made longer and weaker:
- Effectively the same focusing is achieved by z=14.3 m (c.f. 13.4 m) requiring B1Fp to be only 0.9 m later.
- Crossing angle 25 mrad (c.f. 22) helps space between bores for conductor & shielding.
- By tapering appropriate magnets, further increases spaces between them: at start of Q1Fp, space between bores is 10.5 cm (vs. 8.6 cm).
- By using higher gradients at the small end of a taper, more focusing is achieved without increasing the pole tip fields needing shielding.
- The question now is whether these lower pole tip field magnets can be built, and shielded one from the other, without the need for Nb3Sn whose R&D cost has been estimated to be too high.