Lower gradient Forward IR (v4)

7/25/18

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Too reduce IR cost, these designs are intended to 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 the initial design here (A), using tapered magnets with counter tapered gradients, the pole tip fields are reduced to 3.4 T and 3.6 T respectively.

Other, more conventional, designs give intermediate fields.

Alternative A: (Taper-Taper)

These reductions are achieved by:

1. Locating e and p magnets beside each other, instead of alternating along the axis. This could require a somewhat larger crossing angle, but allows longer, and weaker, quadrupoles with lower fields and smaller radial coil thicknesses.

2. Tapering the inside radii (of Q1Fp, Q2Fp, and Q1Fe) which with constant gradients reduces the pole tip fields at the smaller magnet end, but leaving the pole tip field at the far end.

3. But tapering of the inside radii now allows for the gradients (in option (A) done in Q1Fp, but not for Q2Fp) to be tapered in the opposite direction, higher at the small, end to give a near constant pole tip field. This further reduces the needed fields.

Alternative designs

Designing a tapered magnet, even with appropriately reverse tapered gradients, appears relatively straightforward using 'Direct Wind' technology. But this would be much more difficult using more conventional collared coils. It is thus useful to consider non-tapered 'straight' alternatives. We have thus looked at two other options:

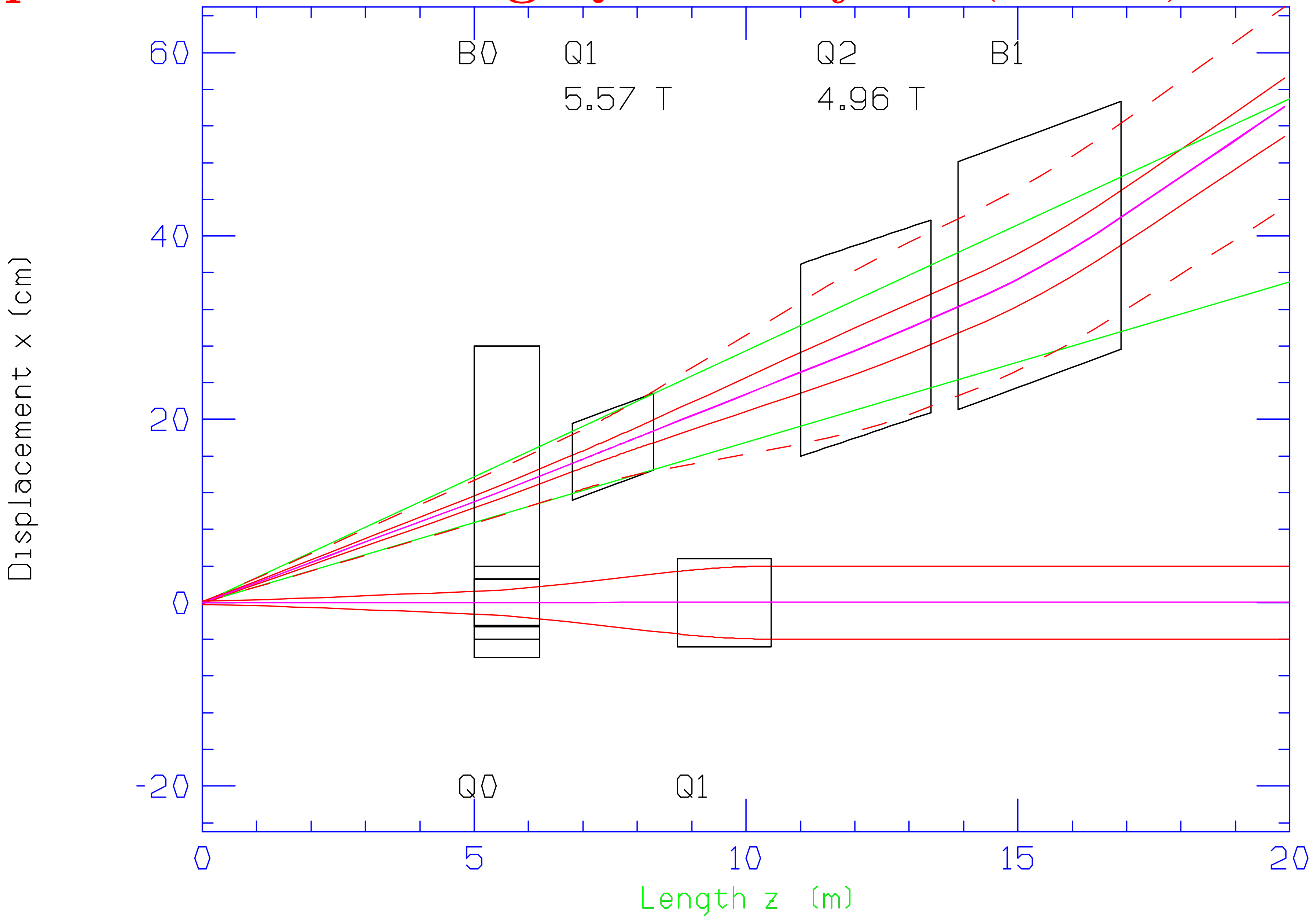
B (Straight-Straight):

Both hadron quadrupoles are made straight, but are allowed to be tilted to maximize the space between them and the electron magnets beside them.

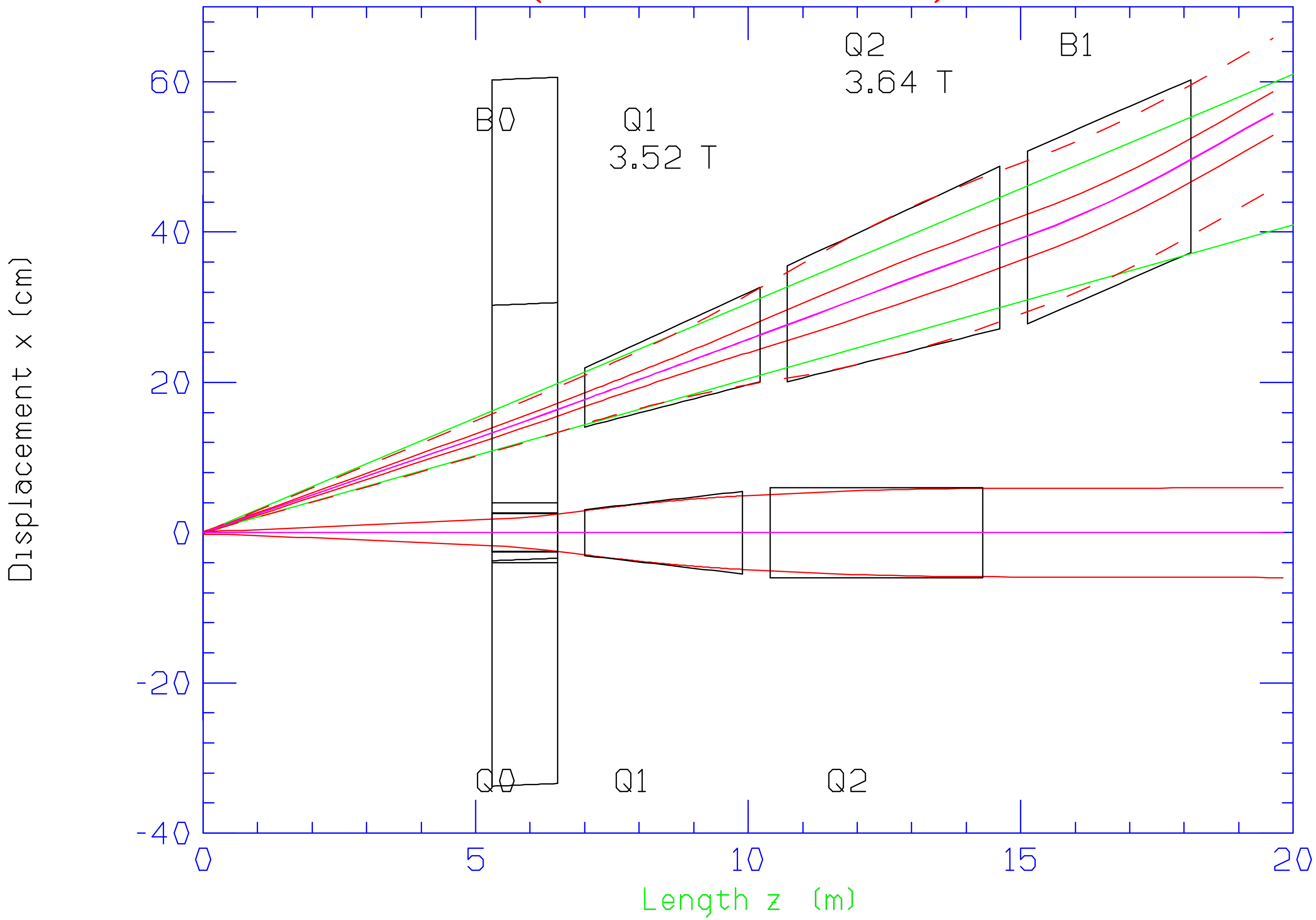
C (Stepped-Straight):

As a poor man's tapers, The first straight magnet Q1Fp is broken into two equal lengths with a possibly optimistic space between their magnetic lengths of 30 cm. Their two apertures are each set to the required beam acceptance at their further ends, while their gradients are chosen to give approximately equal pole tip fields.

pCDR Alternating Quads Layout (dnnb3iw)

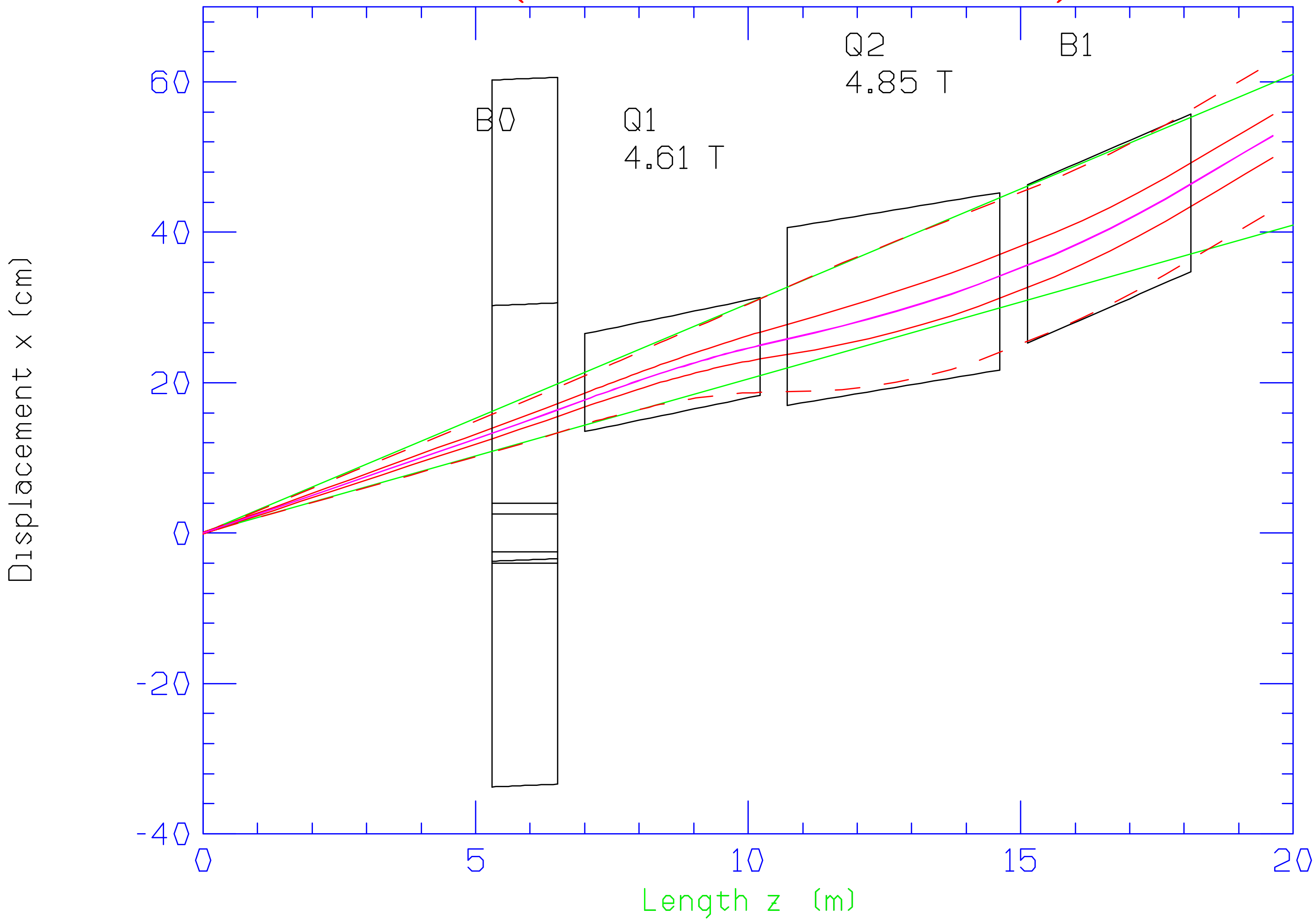


NEW Layout A (Taper-Taper) (dnnb321k)



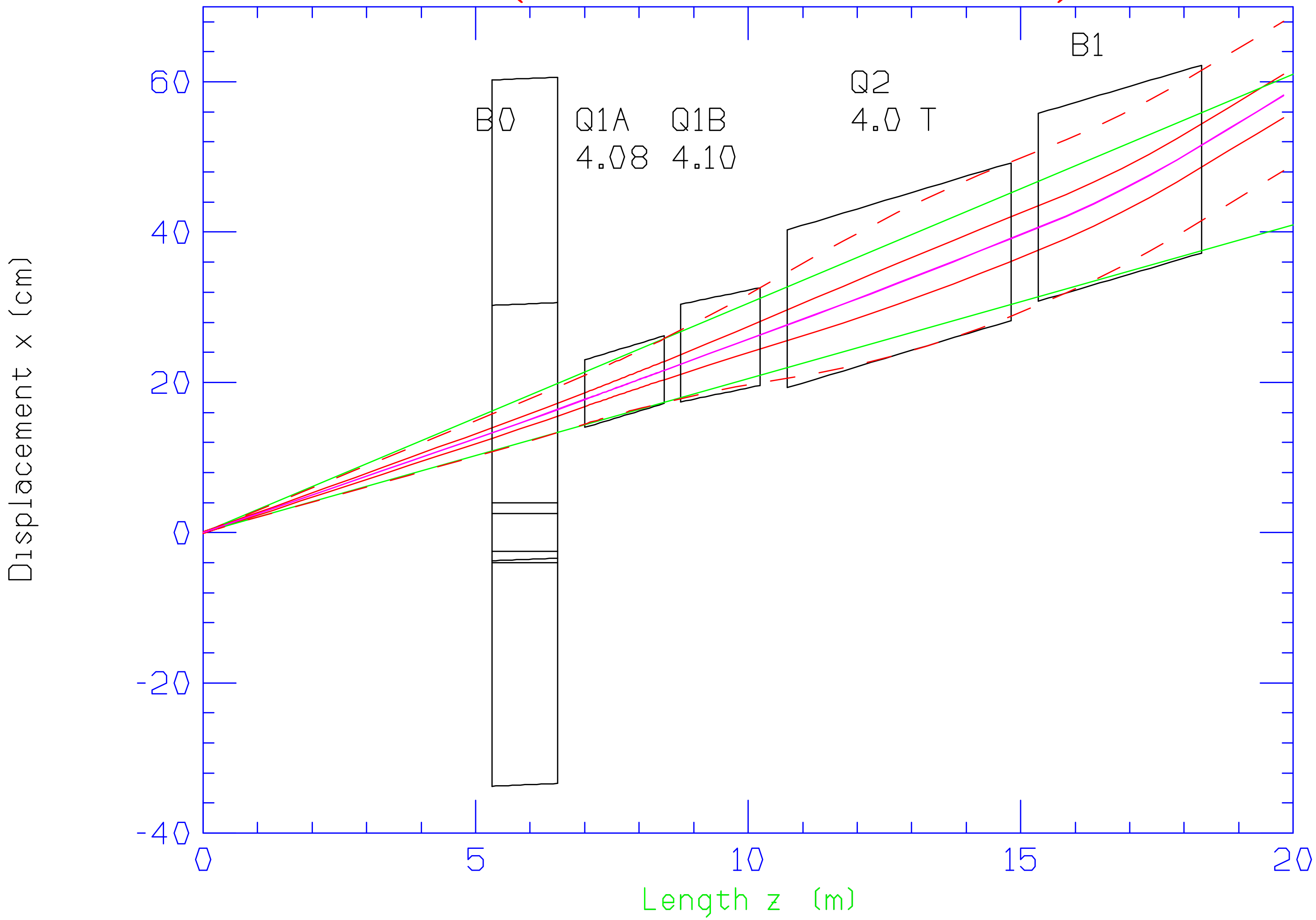
Dash lines are of 1.3 GeV pt protons

NEW Layout B (Straight-Straight) (dnnp332k)



Electrons the same as (1)

NEW Layout C (Stepped-Straight) (dnnp333k)



Electrons the same as (1)

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)

A Taper Taper (mnnp321) Chrom y 21.03 'Chrom x 4.17

		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

B Straight Straight (mnnp332) Chrom y 16.40 ' Chrom x 3.94 '

		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	0.50	13.3	3.00	17.00	17.00	30.0	0.000	0.000	1.300	0.000	0.000
Q1	5	7.00	3.22	0.50	20.0	15.00	6.50	6.50	0.0	4.614	4.614	0.000	-70.979	-70.979
Q2	7	10.72	3.90	0.50	28.8	12.00	11.80	11.80	0.0	4.848	4.848	0.000	41.081	41.081
B1	9	15.12	3.00	20.90	35.8	31.40	10.50	10.50	0.0	0.000	0.000	4.570	0.000	0.000

C Stepped Straight (mnnp332) Chrom y 15.49 ' Chrom x 4.02 '

		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	0.50	13.3	3.00	17.00	17.00	30.0	0.000	0.000	1.300	0.000	0.000
Q1A	5	7.00	1.46	0.30	19.5	15.00	4.50	4.50	0.0	4.084	4.084	0.000	-90.761	-90.761
Q1B	7	8.76	1.46	0.50	23.9	15.00	6.50	6.50	0.0	4.097	4.097	0.000	-63.028	-63.028
Q2	9	10.72	4.10	0.50	33.8	12.00	10.50	10.50	0.0	4.004	4.004	0.000	38.130	38.130
B1	11	15.32	3.00	20.90	43.3	21.40	12.50	12.50	0.0	0.000	0.000	4.570	0.000	0.000

Pre-CDR Forward 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

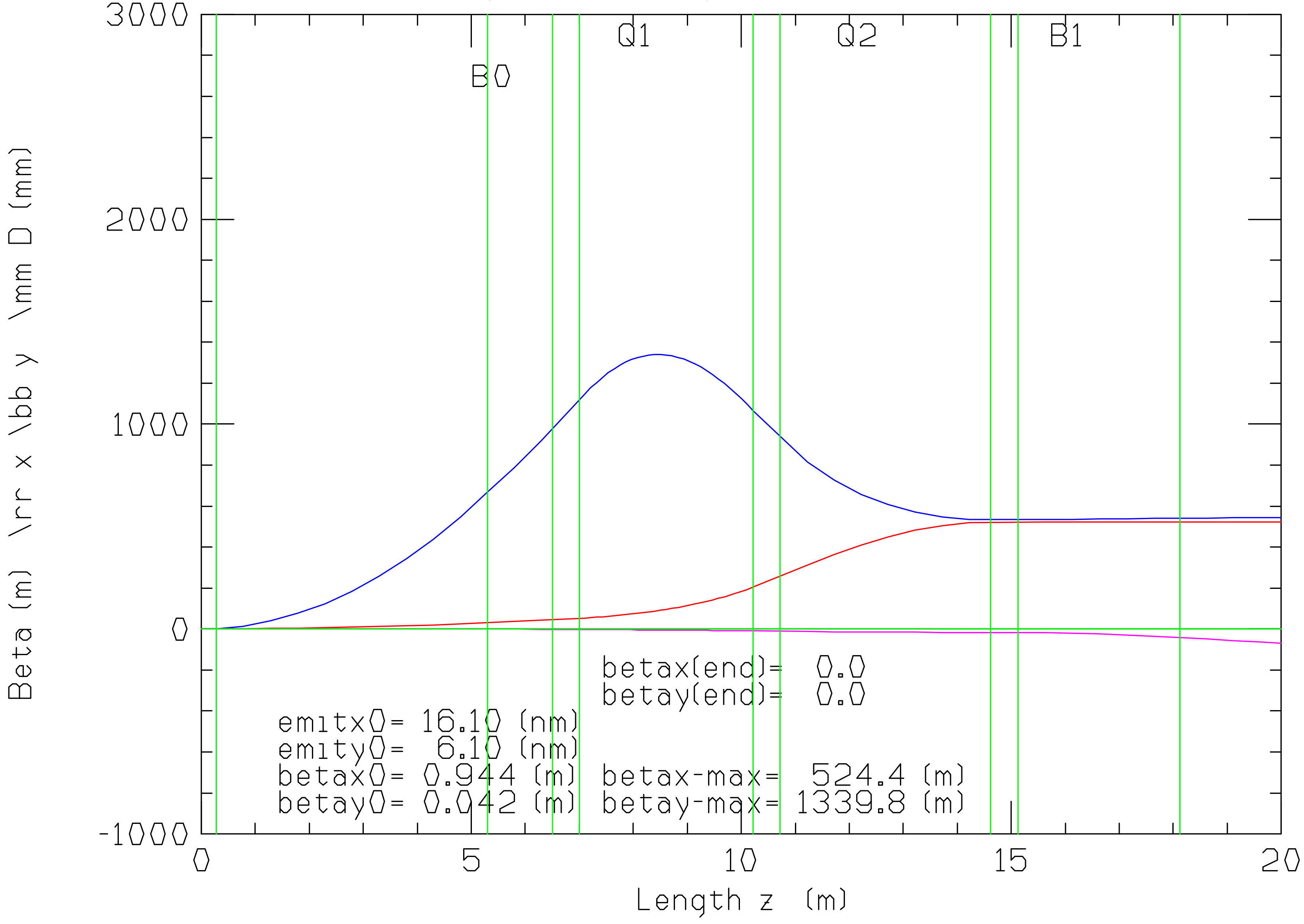
The very Q1Fe and Q2Fe are two parts of the now very weak old Q1Fe

Betas and amplitudes

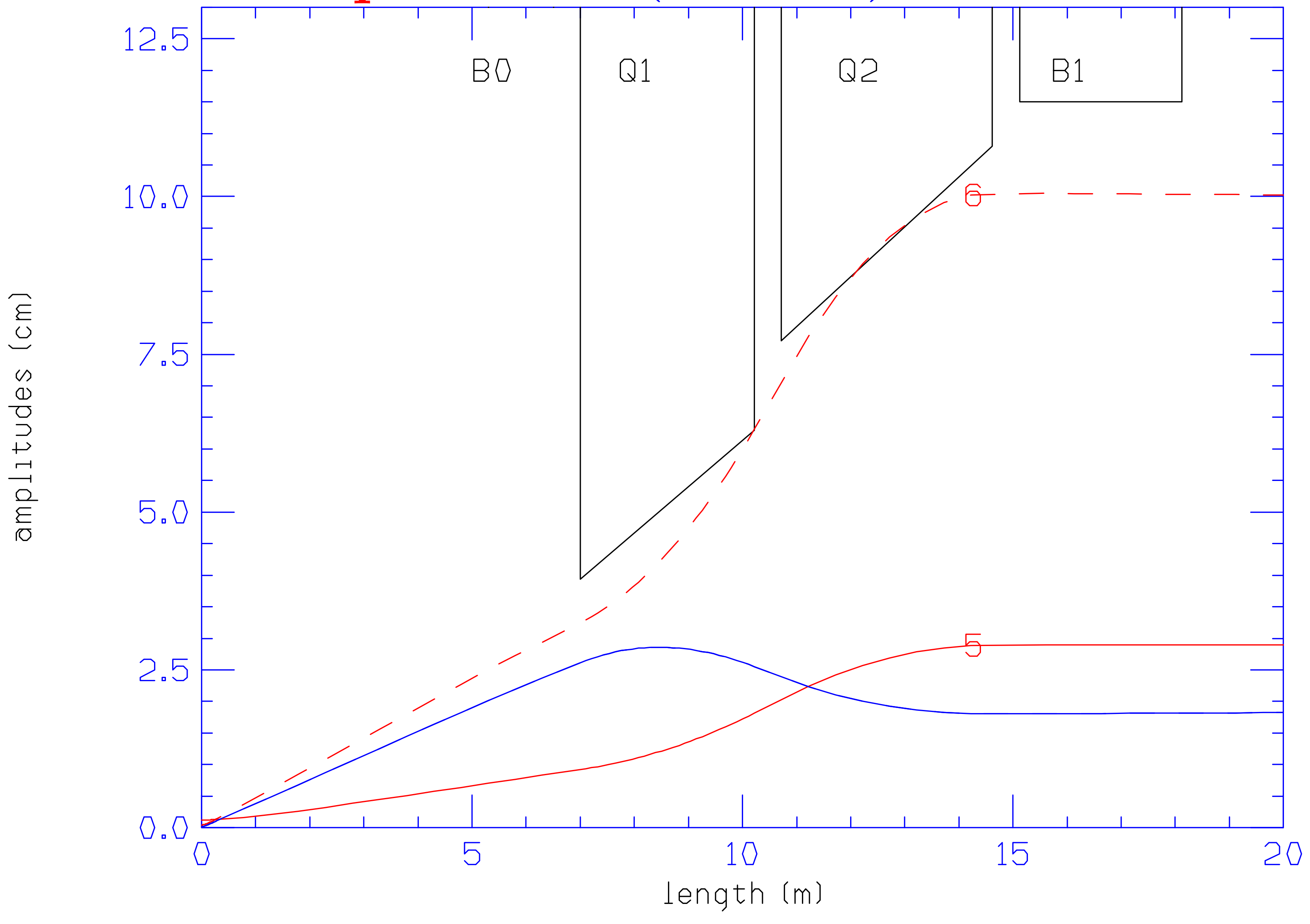
All the examples use the same electron design, whose betas and mplitudes are given below.

The betas and amplitudes for the hadrons are all very similar, and broadly match those in Guillaume's matched design. Those for option A are given below.

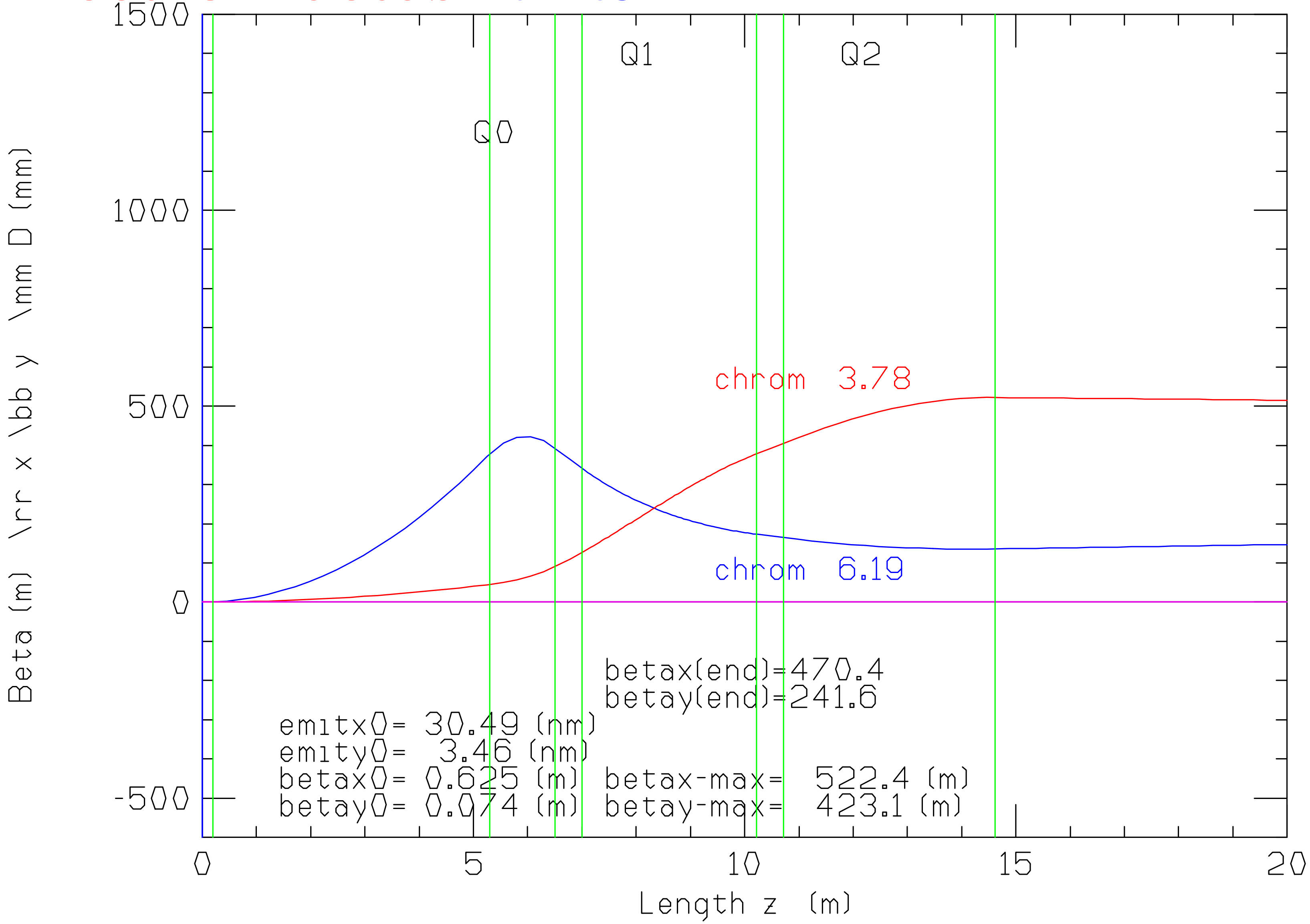
Hadron betas (bnnp321k)



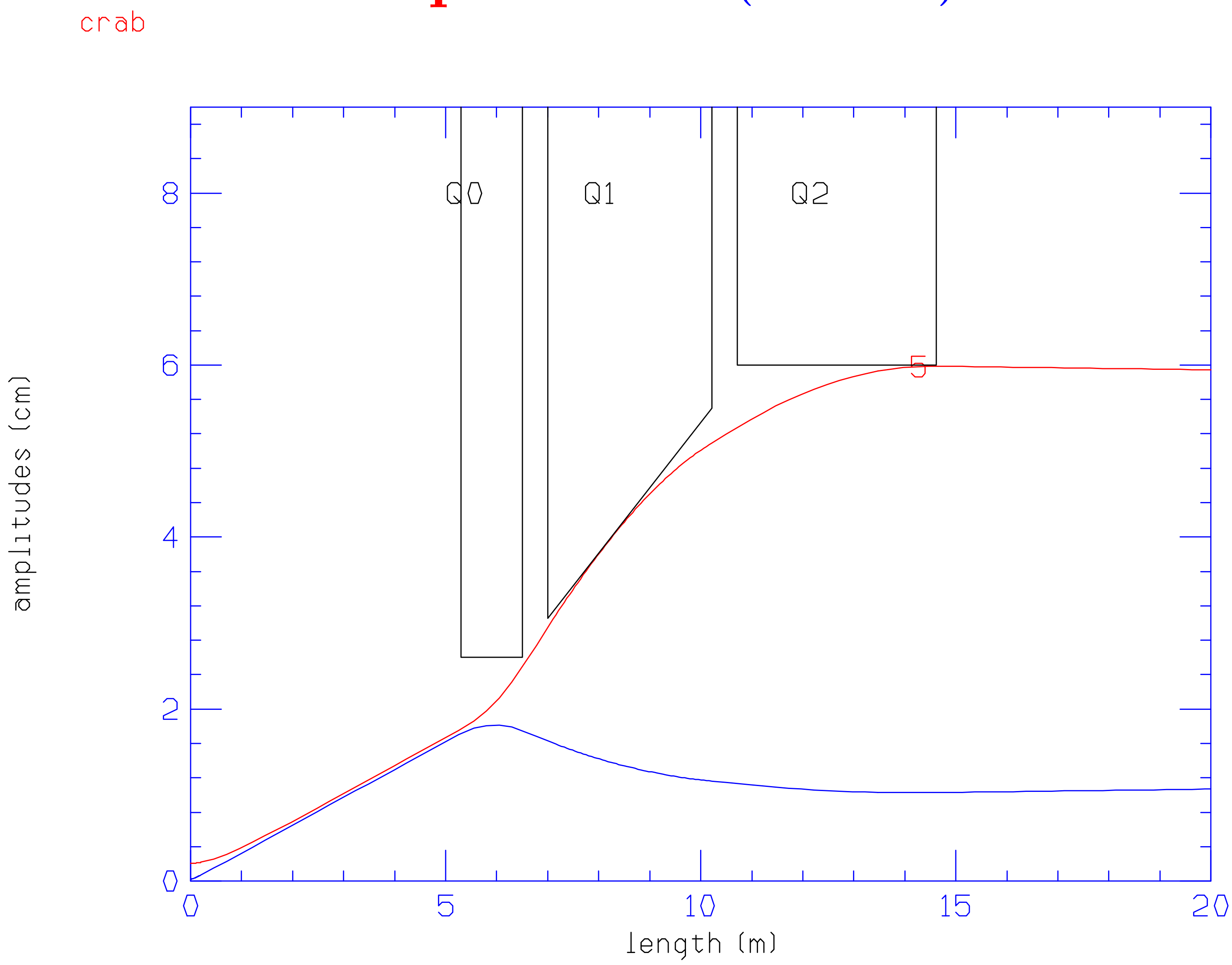
Hadron amplitudes (annp321k)



Electron betas bnne34



Electrons amplitudes (anne34k)



Required aperture of good hadron field

The above slides, at 275 GeV, suggests good field is only required over the quite limited central part of the aperture where the beam is present only in a limited central part of the apertures. But at lower energies the beam will be displaced in the apertures, requiring good field over a much larger part of the apertures reuiring good field everywhere.

At full 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 can get much better momentum determinations by keeping B0 at 1.3 GeV and allow 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.

Hadron beam locations at different energies