Electron Quads inside Detector

R.B.Palmer B.Parker H.Witte

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It appears important minimize SR fan by using large spacing between F and D quads.

Plot below and fan is set for 105 GeV without cooling because it has a higher divergence than the 140 GeV case. Fans with cooling are even higher making the fan to be at 13 sigmas for those.

Fans in x:

140 GeV no cool Div=162 15sig: x=6.02 10^{-3}(L+2.1)

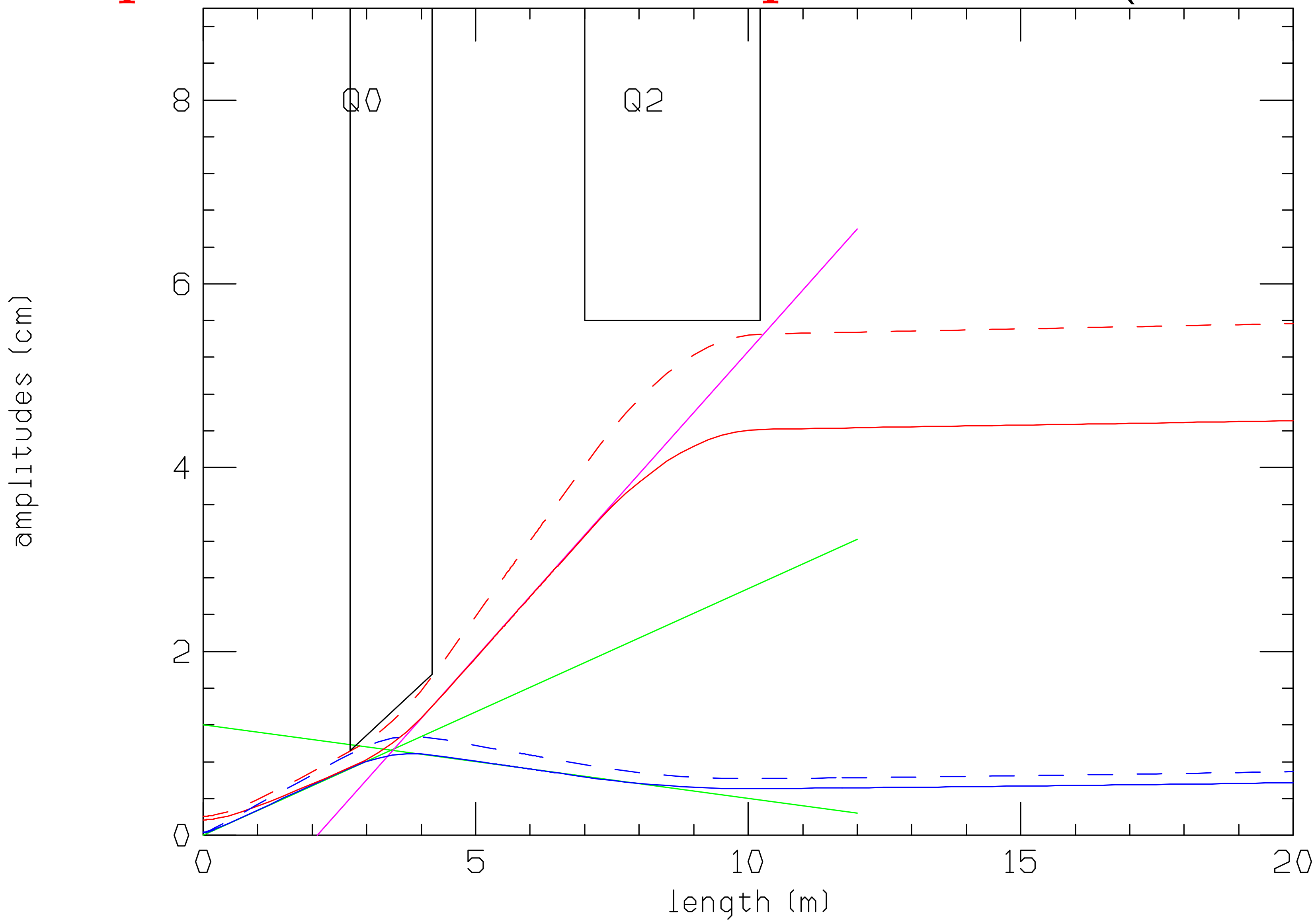
105 GeV no cool Div=179 15sig: x=6.67 10^{-3}(L+2.1) ← USED

140 GeV with cool Div=220 12sig: x=6.67 10^{-3}(L+2.1)

cf old x=0.75 (L+3.5)

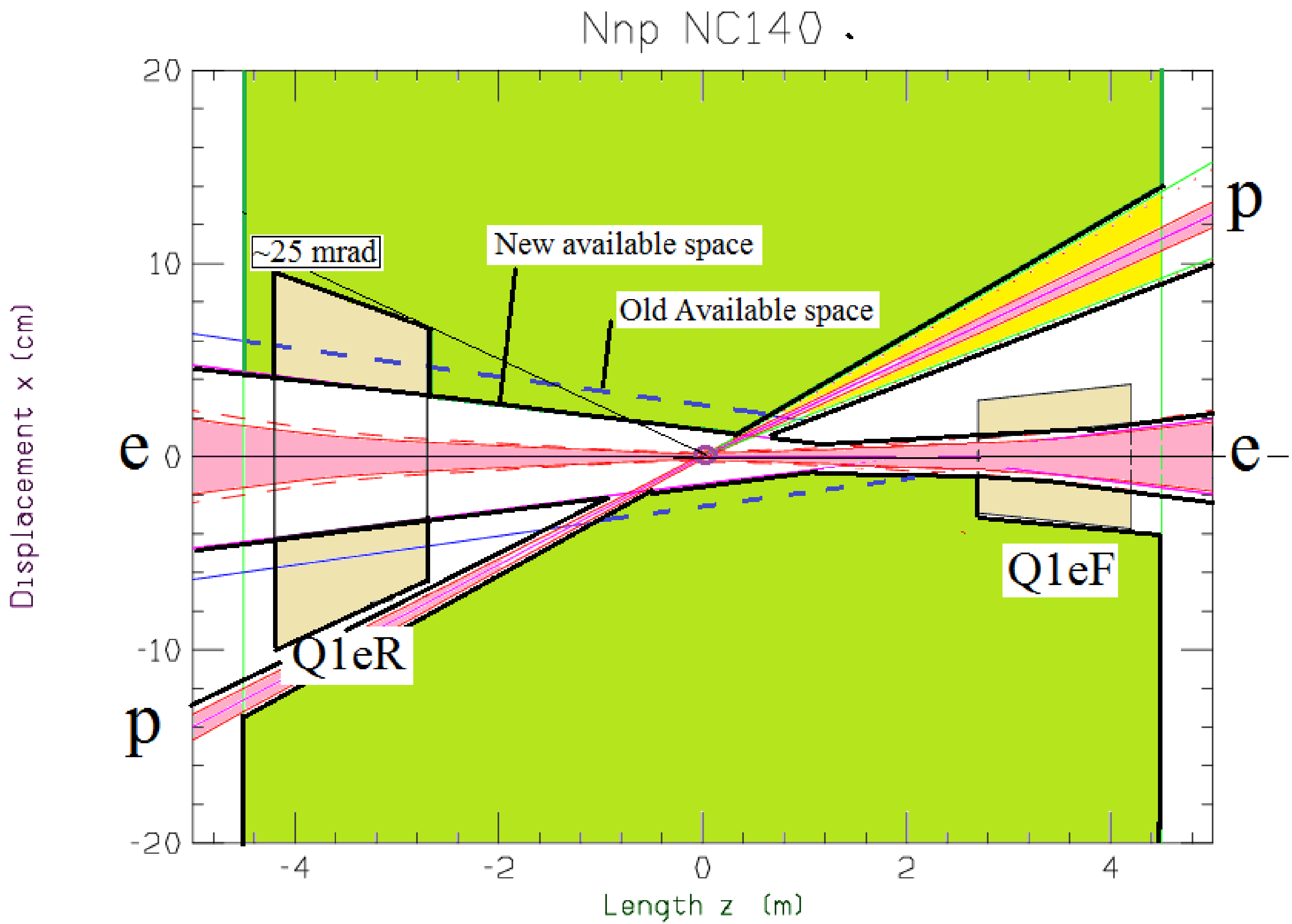
In y: Div=220 15sig: x= maxof [3.3 10^{-3} L & 0.8 10^{-3} (L+15)]

Amplitudes for 105 GeV parameters (anne312)



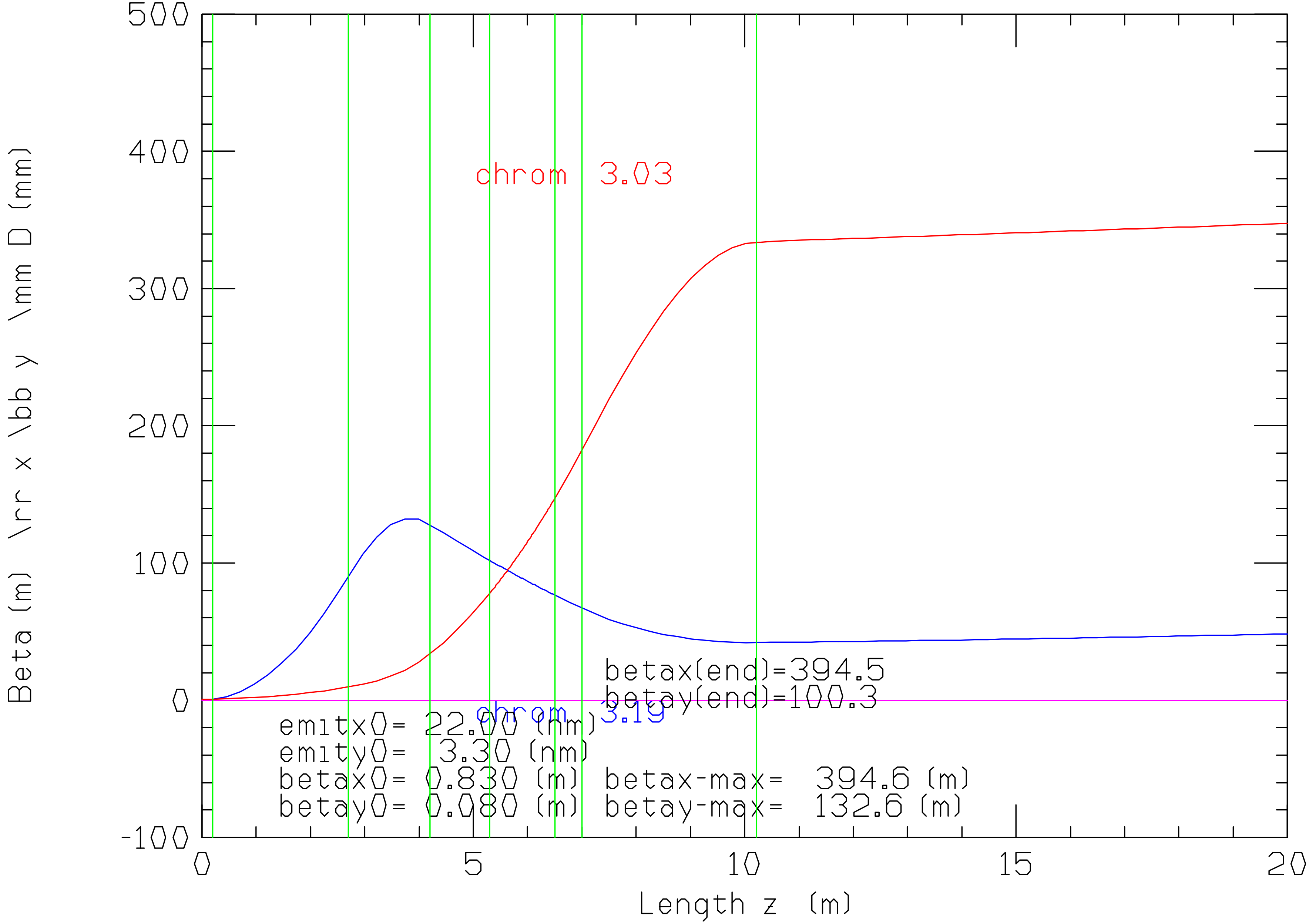
fan shown in magenta

Layout (dnna312k)



This, and the later plots and table are 140 GeV (Ee=18 GeV) with a slightly smaller divergence. Dash=15 sigma with cooling

Electron Betas (bnne312)



Magnets for 140 GeV (Ee=18 GeV)

Forward e

Chrom y 3.16 ' Chrom x 3.15 ' mom = 18 (mnne312.tab)

		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	2.70	1.50	1.10	0.0	0.00	0.92	1.75	0.0	0.145	0.276	0.000	-15.795	-15.795
Q2	7	7.00	3.22	20.40	0.0	0.00	5.60	5.60	0.0	0.170	0.170	0.000	3.034	3.034

Rear e

Chrom y 3.16 ' Chrom x 3.15 ' mom = 18 (mnne314.tab)

		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	2.70	1.50	1.10	0.0	0.00	3.20	4.20	0.0	0.505	0.663	0.000	-15.795	-15.795
Q2	7	7.00	3.22	20.40	0.0	0.00	6.01	8.13	0.0	0.182	0.247	0.000	3.034	3.034

Only apertures and Pole tip Fields have changed

Summary

		New	Old	factor
L*	m	2.7	5.3	.51
β_x(max)	m	394	522	1/1.33
β_y(max)	m	132	423	1/3.2
Chrom$_x$ /side		3.15	3.74	1/1.19
Chrom$_y$ /side		3.16	6.19	1/1.96
Aperture$_x$(o)	cm	1.39	2.6	1.1.87
Aperture$_y$(o)	cm	1.2	3.2	1/2.7
Rear θ_x(min) at -2.7 m	mrad	12	17	1/1.4
Rear θ_x(min) at -4.5 m	mrad	$\approx$ 25	$\approx$ 11	$\times \approx 2$

Conclusion from lattice

1. The Betamax in y is down by 3.2   betamax ix down by 1.3
2. Chromaticity in y is down by 2 Chromaticity in x by 1.2
3. SR fan and thus beam pipe at IP down by 1.9 in x & 2.7 in y
4. Min angular acceptance at -2.7 m is DOWN by 1.5
5. Min angular acceptance at -4.5 m is up by around 2 ($\approx 15 \rightarrow \approx 25$ mrad)
6. Forward acceptances are effectively unchanged

Magnet considerations

The Focus quadrupoles further from the IP, that are outside the detector and are similar in strength and location to those in the current design. There should be no new difficulty with these superconducting magnets, shielded from the hadrons by the presence of iron.

The focus magnets nearer to the IP start 2.7 m from it, extend to 4.2 m, and are fully inside the detector.

If made with coils, normal conducting or superconducting, their stray field could be a problem for the nearby hadrons. Iron shielding cannot be used because they are in the 0.8 T stray field from the detector solenoid.

If made with Halbach permanent magnets, there is essentially no stray field. But how to trim the permanent magnets when the use of iron wires (that would saturate) is a challenge.

Options

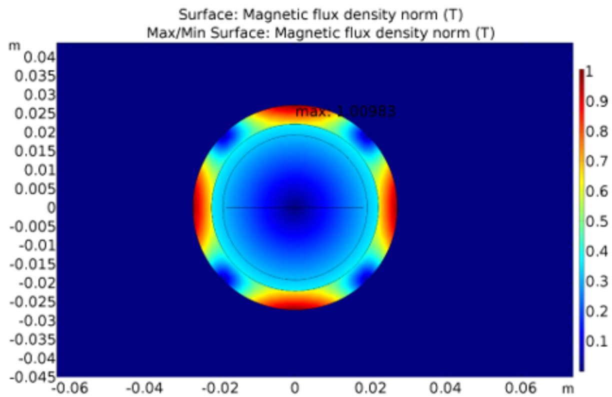
- Magnet designs are still very preliminary
- Many options have been considered but only four are discussed here

		small end mm	large end mm
Forward Options			
Inside Radii		9	18
Outside radii	Halbach plus warm Quad	40	54
Outside radii	Nested rotatable Halbachs	28	32
Rear Options			
Inside radii		32	42
Outside radii	Superconducting	58	68
Outside radii	Nested rotatable Halbachs	73	85

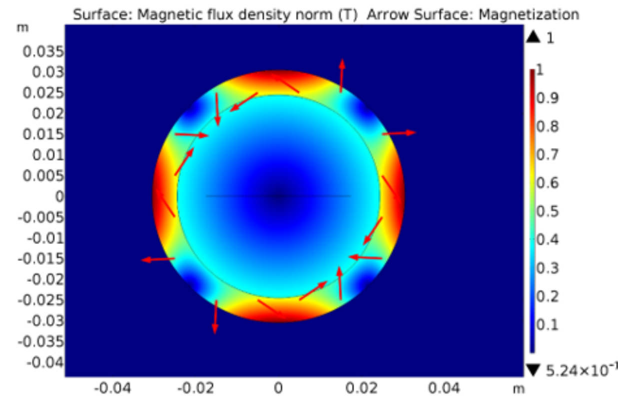
Forward Q0eF

Nested Halbach

Front



Rear



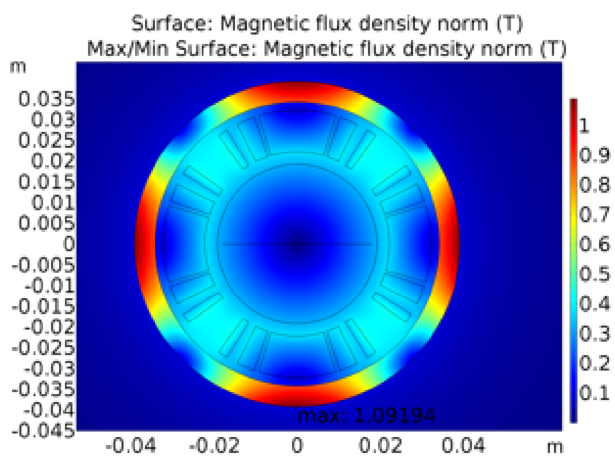
R1=28mm

R2=32mm

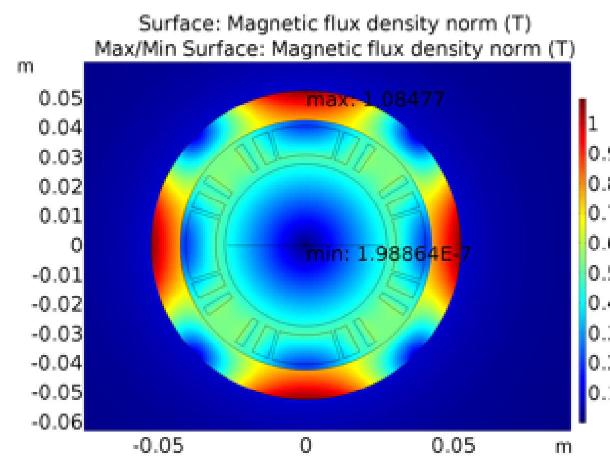
Normal conducting

+ Halbach

Front



Rear



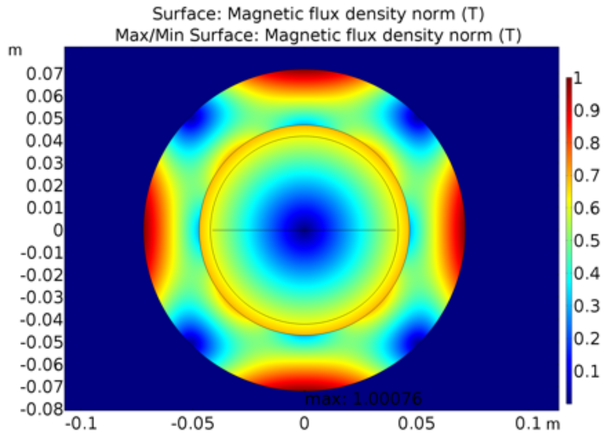
R1=40mm

R2=54mm

Rear Q0eR

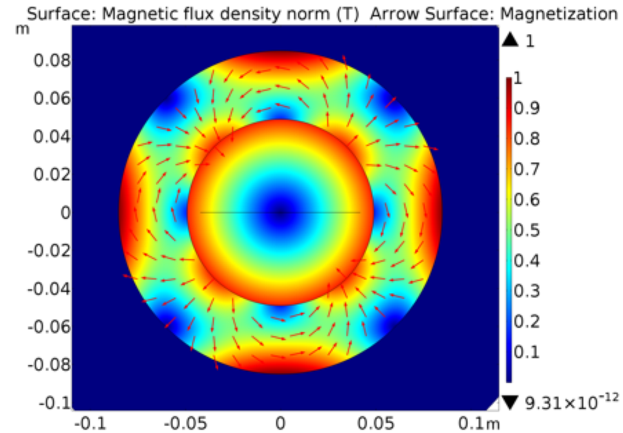
Nested Halbach

Front



R1=73mm

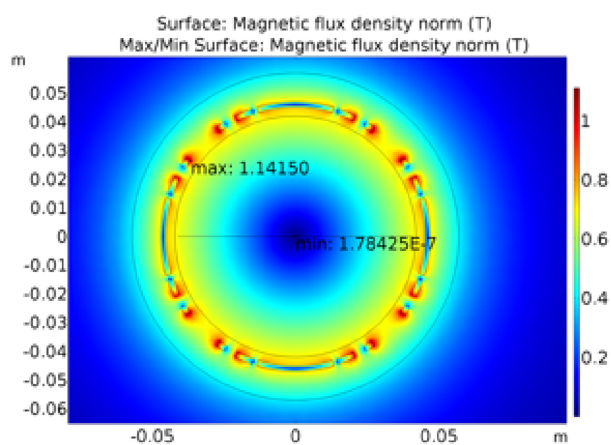
Rear



R2=85mm

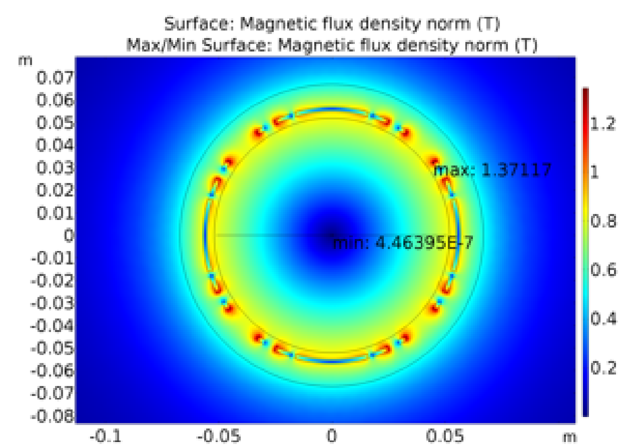
Superconducting

Front



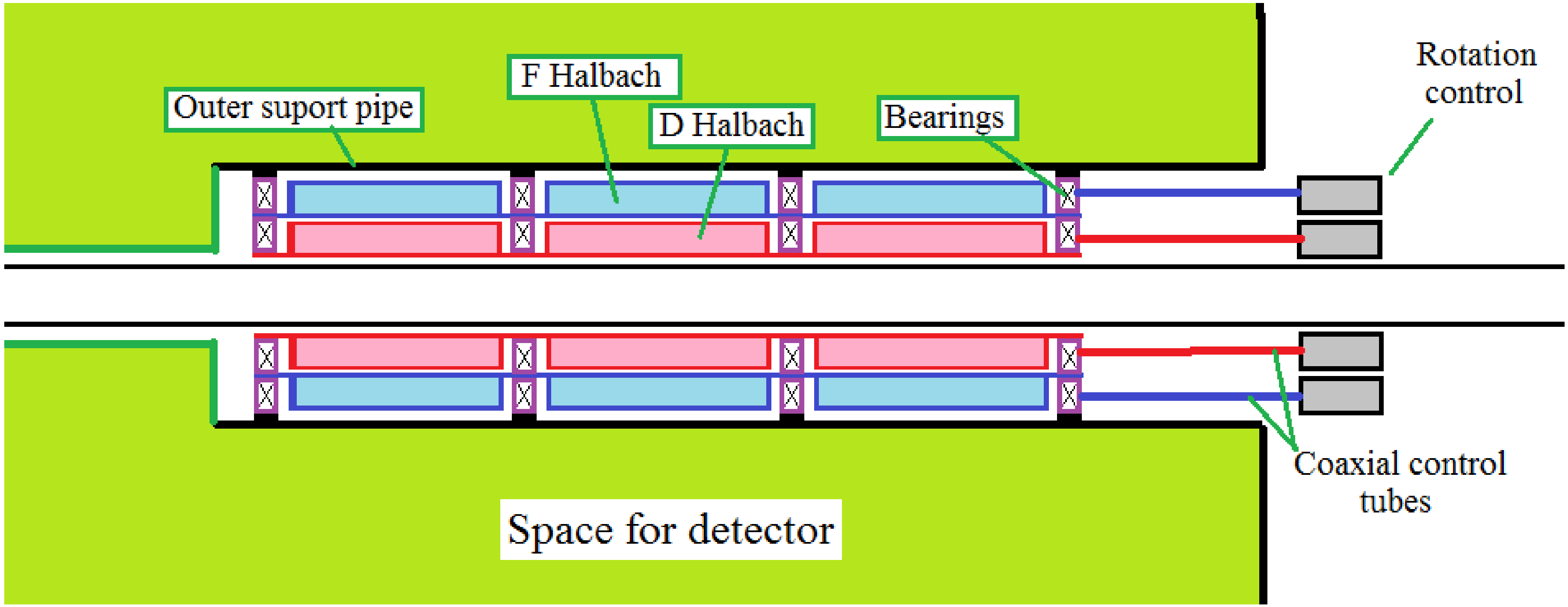
R1=58mm

Rear



R2=68mm

Possible nested Halbach mechanisms



- Tapering not shown
- Not to scale
- This concept has rotation controls outside of detector
- Possibly supported from outside the detector ends
- Needs more study

CONCLUSION

- Placing the first electron IR quad inside the detector:
  - Lowers the maximum y betas
  - Approximately halves the y Chromaticity
  - Approximately halves the beam pipe dimensions at the IP
  - Reduces the minimum electron angle observable before 2.7 m
  - May even reduce the IR magnet costs

BUT

  - Increases the minimum e outgoing angle to reach the detector end calorimeter from around 15 mrad to around 25 mrad

- If not initially installed, but needed later for Luminosity or life-time, then the inside Q0eF and Q0eR could be installed later. The initial electron focus magnets could then probably be tuned to act as the new Q2eF and Q2eR

Appendix of other systems

1. Direct wind design
2. Intro to Lower gradient IR designs

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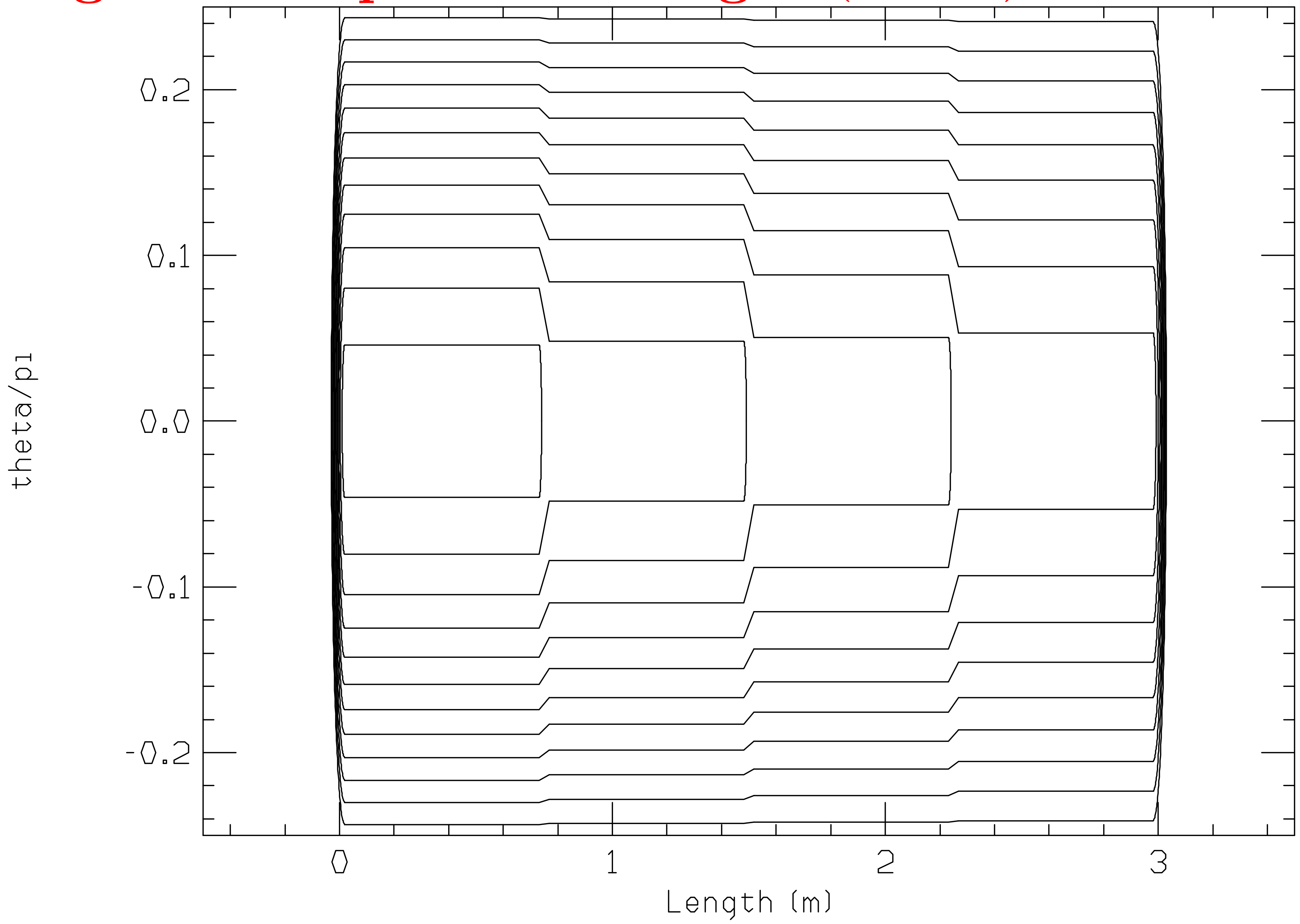
Direct wound tapered Q1apF (taper3a)

R.B.Palmer 8/18/2018

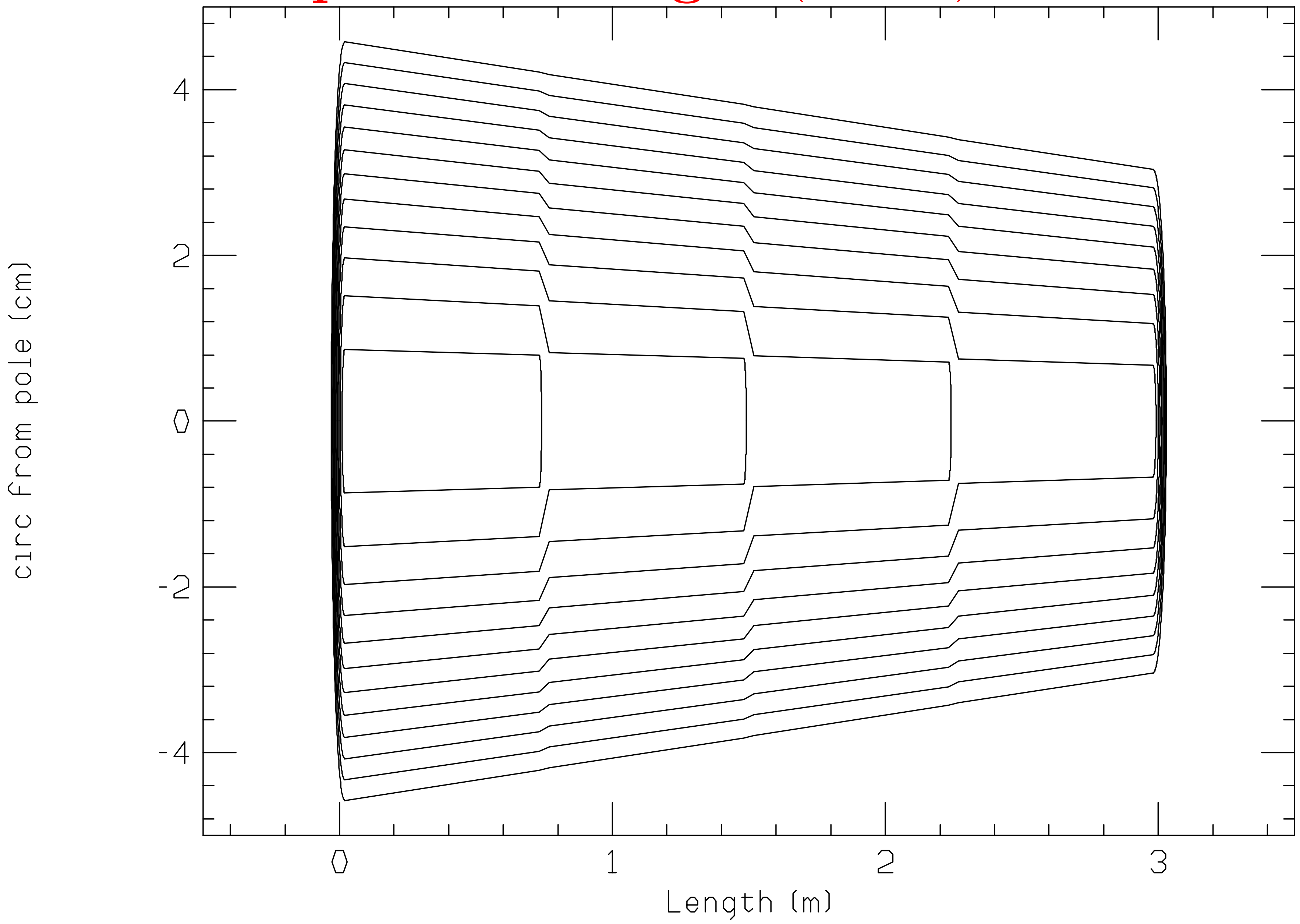
- Example with 12 turns at R=6 cm end for each pole
- 8 turns at R=4 cm end for each pole
- 4 longitudinal sections
- Inner turn crosses over between turns
- Circumferential locations in cos theta distributions
- Minimum spacing between conductors (at mid planes) independent of length ($\approx$ 2.6 mm $\propto$ 1/turns used)
- Minimum bend radius = 9 mm (larger with mini-dog-bones)
- Without iron this gives fixed pole tip fields

- What spacing should I use? What bend radius?
- I can give table of all coil elements
- Can you use these to get 3D fields?

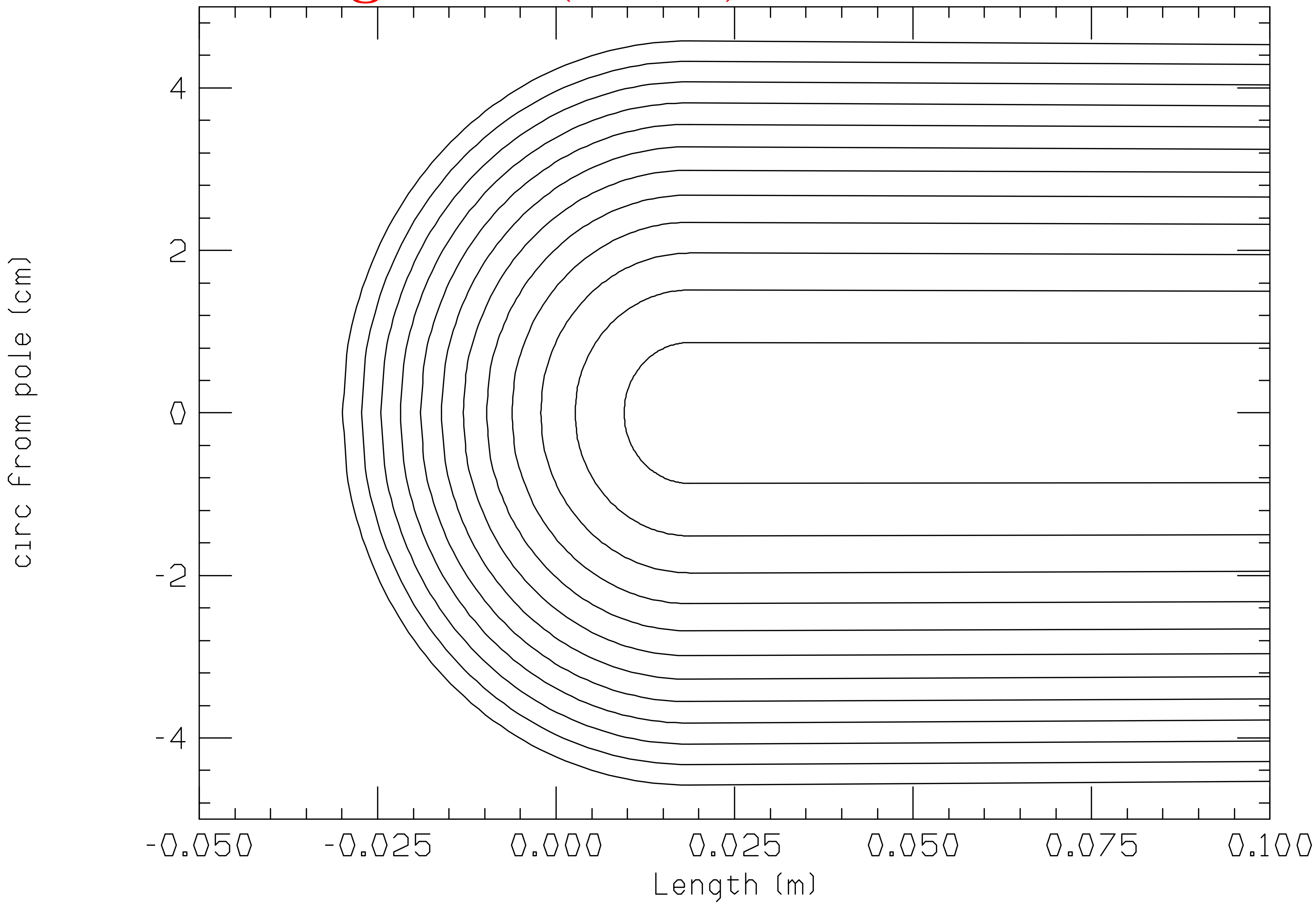
angles from poles vs. length (taper3a)



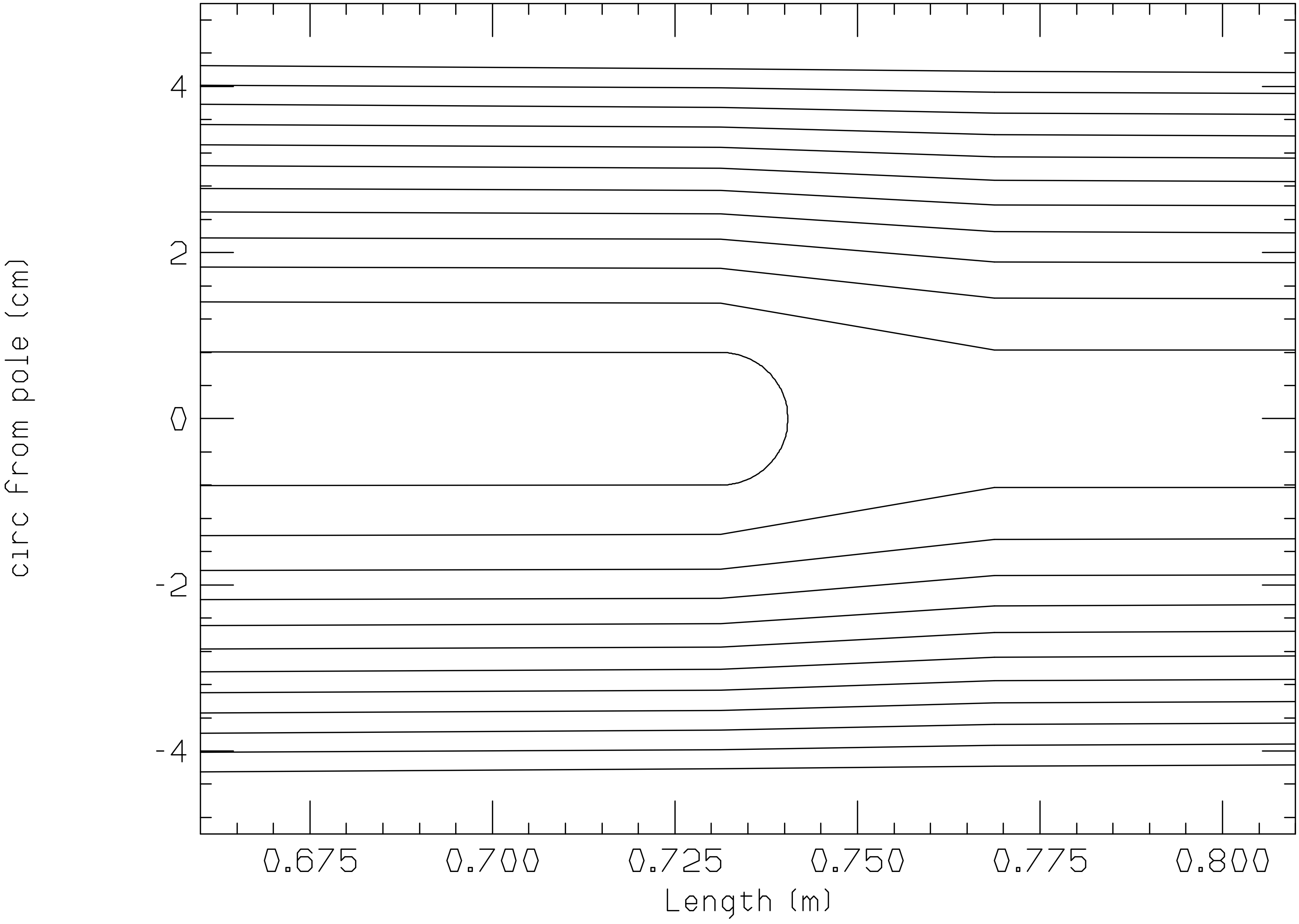
circ. from poles vs. length (taper3c)



Detail at large end (taper3d)



Detail at a cross over (taper3e)



Lower gradient Forward IR (v5)

8/18/18
R.B.Palmer

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 of the inside radii now allows for reversed tapered gradients (in option (A) done in Q1Fp (but not now in Q2pF). This gives a near constant pole tip field.
3. This needs more turns at large magnet ends, but does not need extra layers: see example below.

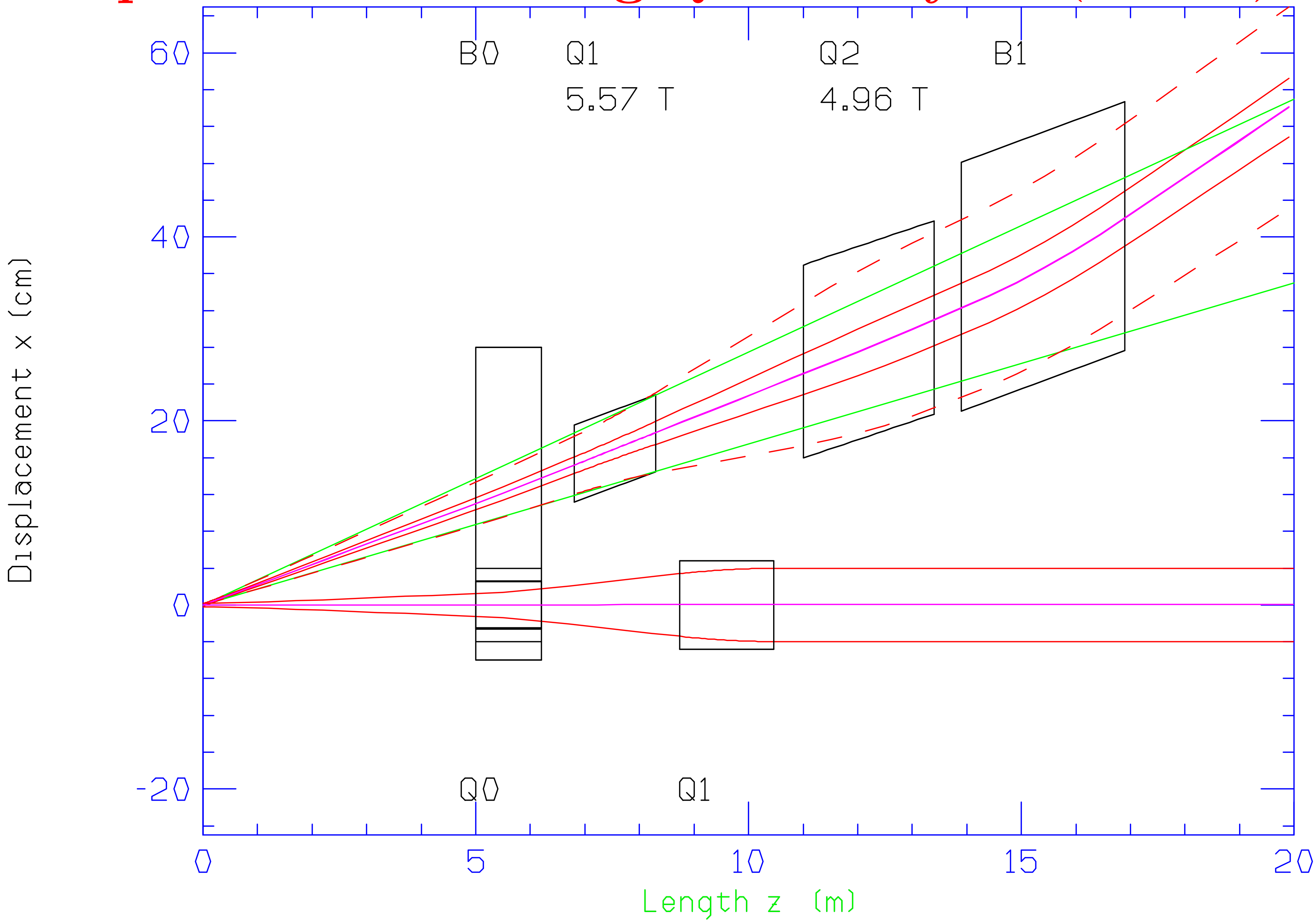
D corrected (Stepped Q1pF-Straight Q2pF):

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 a non-tapered 'straight' alternative.

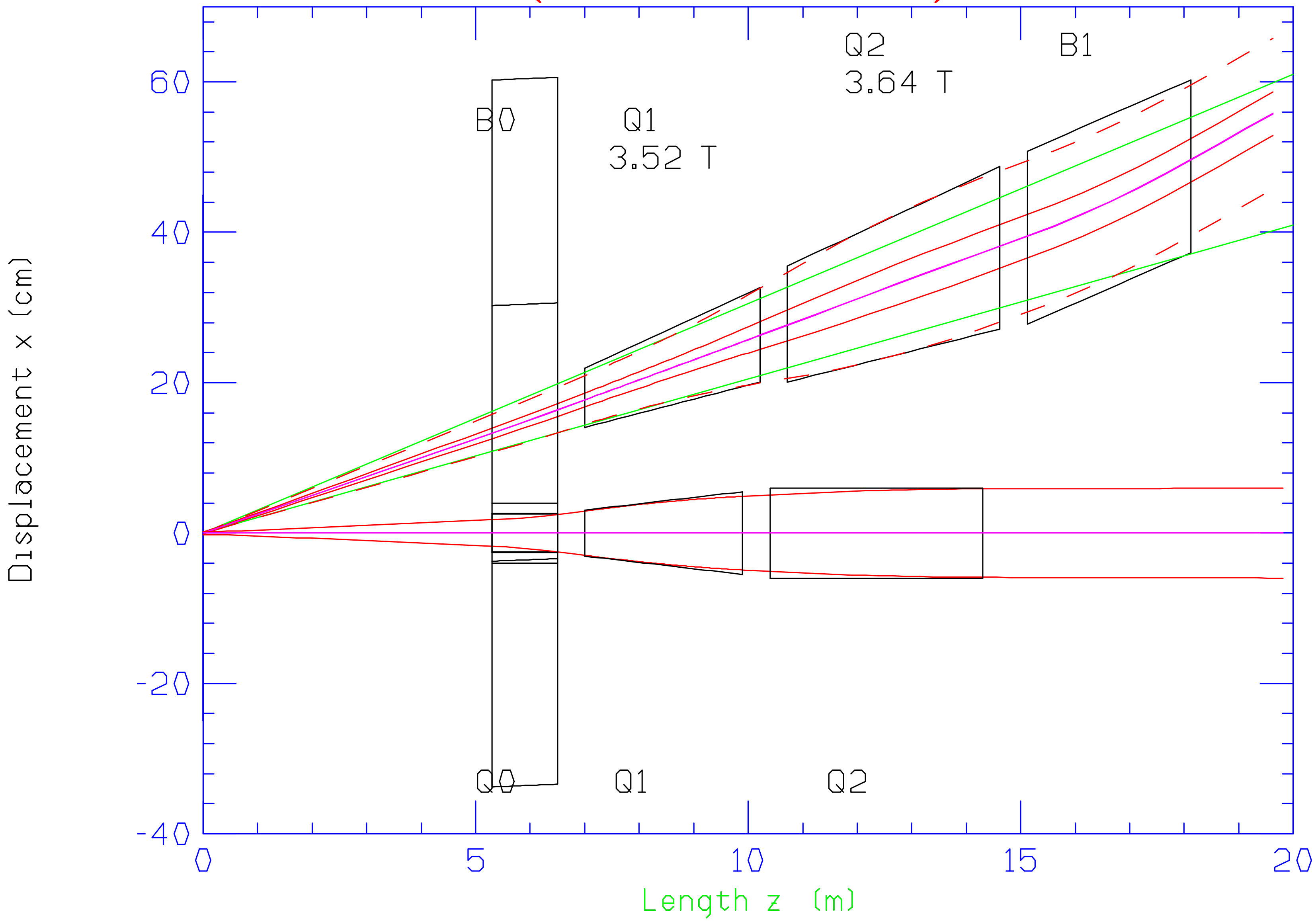
As a poor man's tapers, The first straight magnet Q1Fp is broken into two equal lengths with a possibly optimistic space between their magnetic lengths of 30 cm. Their two apertures are each set to the required beam acceptance at their further ends, while their gradients are chosen to give approximately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

The "correction" lowered the pole tip fields in Q1apF; raised it in Q2pF in response to the greater spacing between p and e magnets further from the IP.

c.f. pCDR Alternating Quads Layout (dnnb3iw)

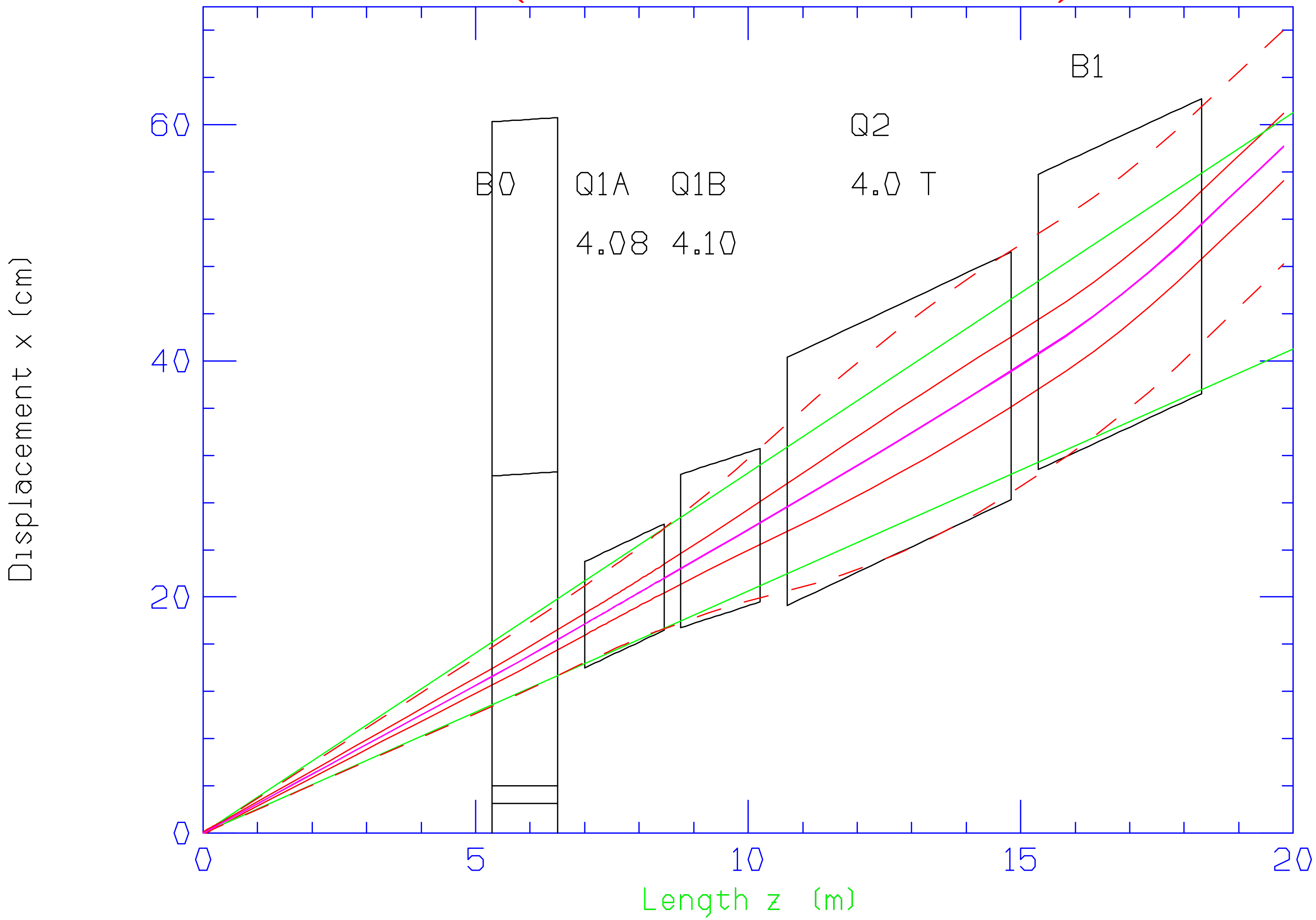


NEW Layout A (Taper-Taper) (dnnb321k)



Dash lines are of 1.3 GeV pt protons

NEW Layout D (Stepped-Straight) (dnnp335k)



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 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

New Stepped-Straight D (corrected) (mnnp335)

Chrom y 15.61 ' Chrom x 3.91 ' mom = 275

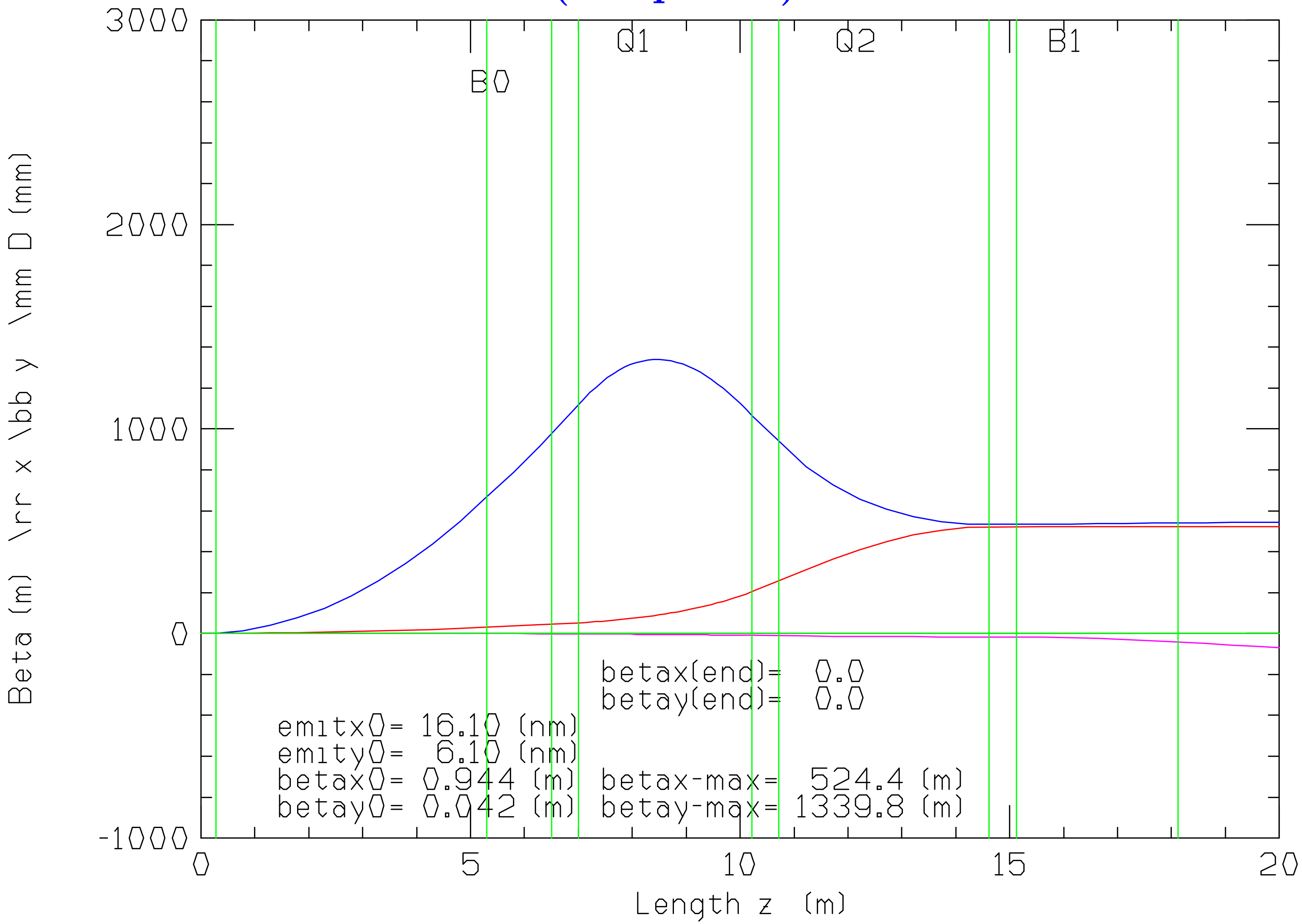
		L1	DL	gap	x	θ	IR1	IR2	OR	B1	B2	B	Grad1	Grad2
		m	m	m	cm	mrad	cm	cm	cm	T	T	T	T/m	T/m
B0	3	5.30	1.20	0.50	13.3	3.00	17.00	17.00	30.0	0.000	0.000	1.300	0.000	0.000
Q1A	5	7.00	1.46	0.30	19.5	15.00	4.50	4.50	0.0	3.506	3.506	0.000	-77.903	-77.903
Q1B	7	8.76	1.61	0.90	23.9	15.00	6.50	6.50	0.0	4.097	4.097	0.000	-63.028	-63.028
Q2	9	11.27	3.60	0.50	34.5	12.00	10.80	10.80	0.0	4.29	4.29	0.000	39.736	39.736
B1	11	15.37	3.00	20.90	42.1	25.00	12.50	12.50	0.0	0.000	0.000	4.570	0.000	0.000

Hadron Betas and amplitudes

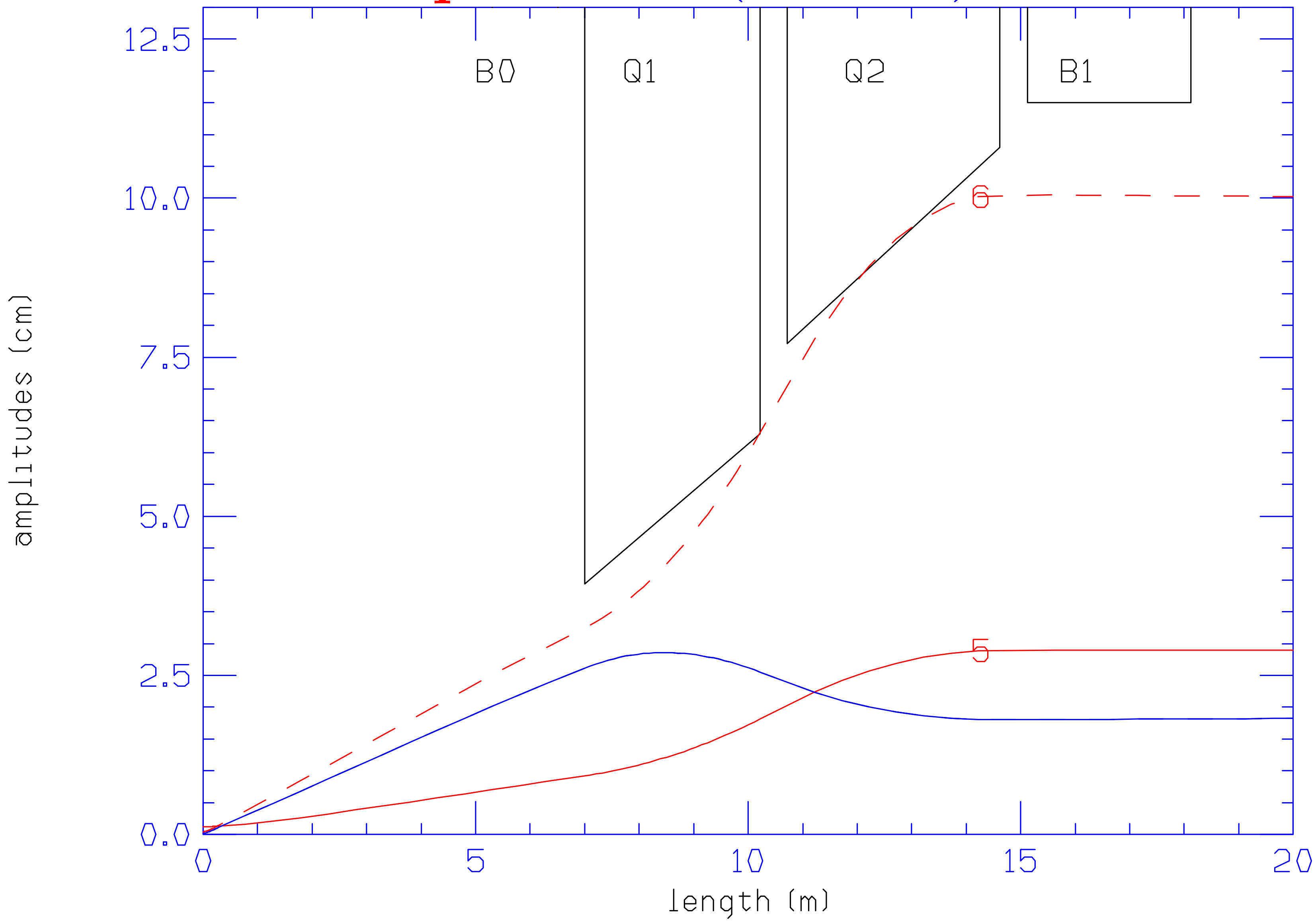
All the examples use the same electron design, whose betas and amplitudes are given below.

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.

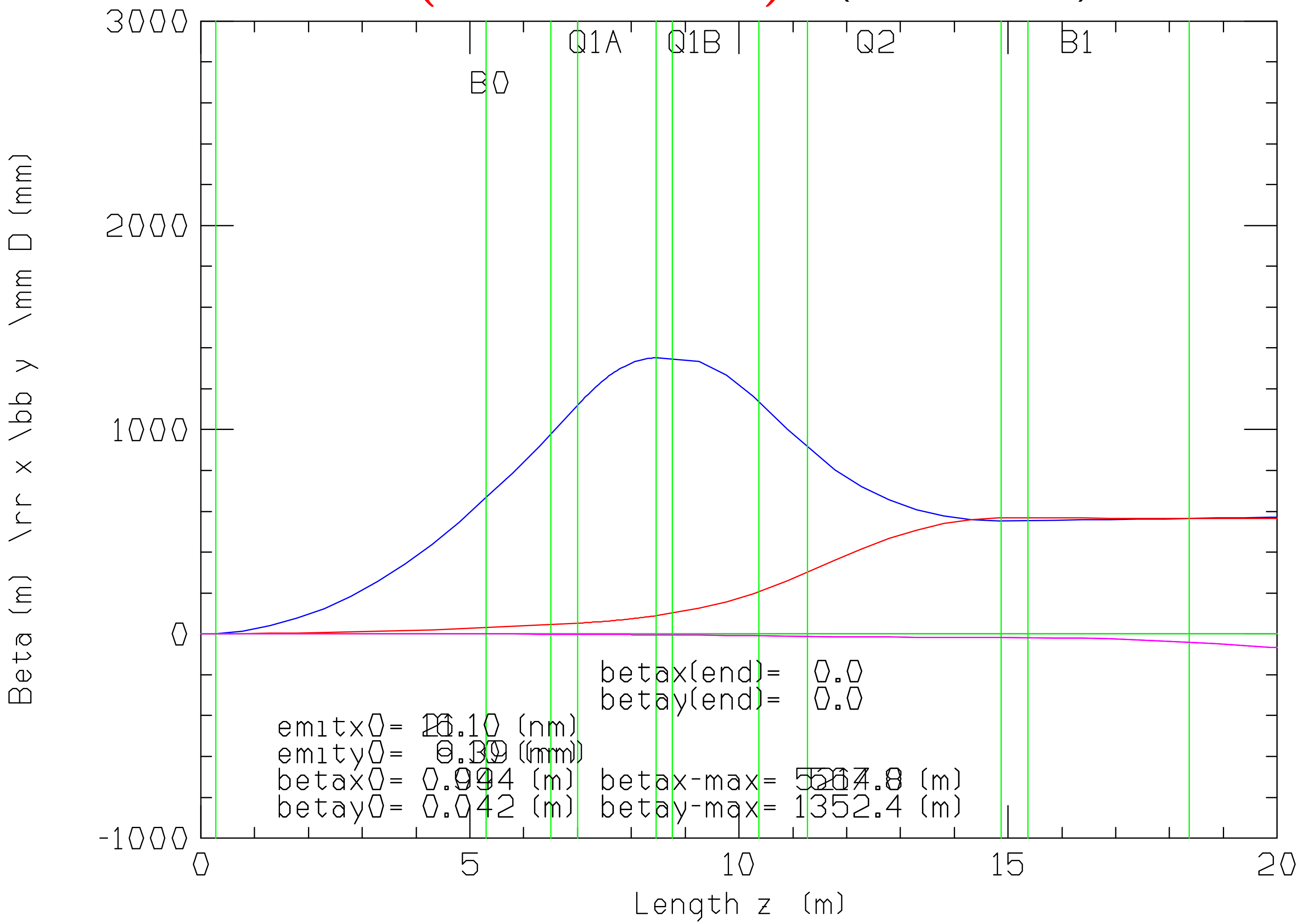
A Hadron betas (bnnp321k)



A Hadron amplitudes (annp321k)



Betas for D (Corrected) (bnnp335.eps)



Betas flat heading for ≈580 m

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

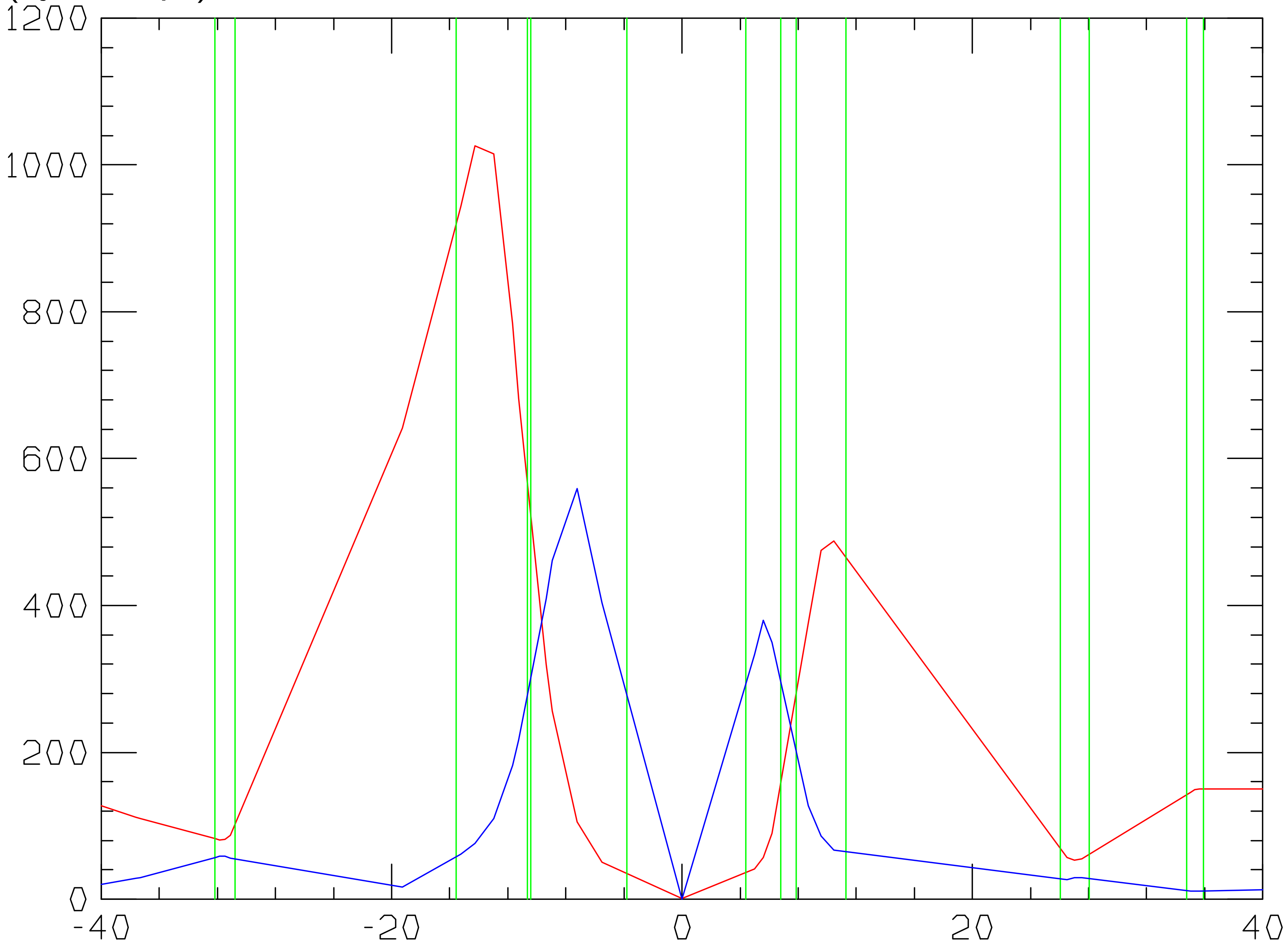
Chrom y 6.12 ' Chrom x 3.93 ' mom = 18

		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

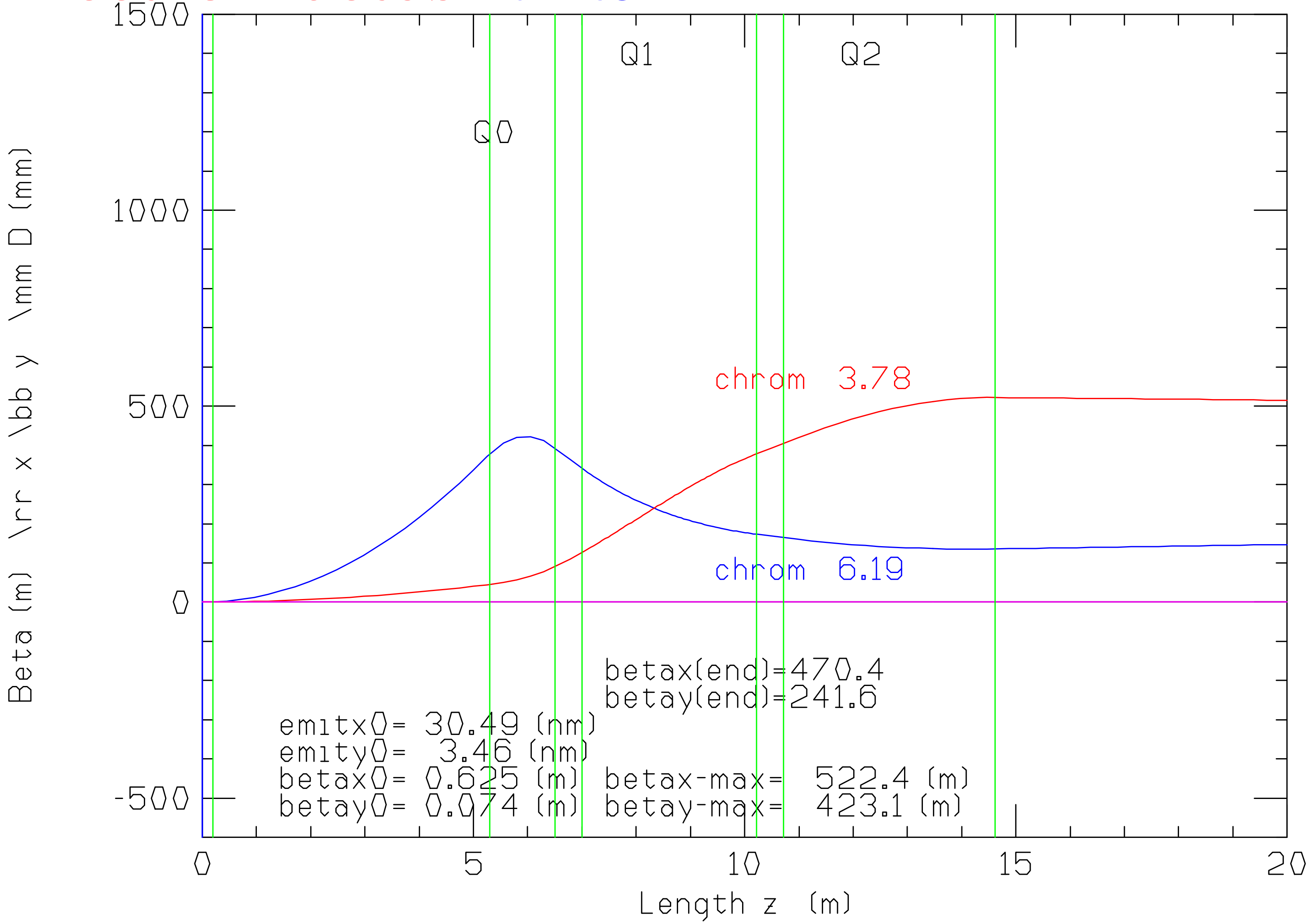
The very Q1Fe and Q2Fe are two parts of the now very weak old Q1Fe

c.f. pCDR electron betas from Steve

(xyebet.eps)



Electron betas bnne34



Electrons amplitudes (anne34k)

crab