IR Update (v8a)

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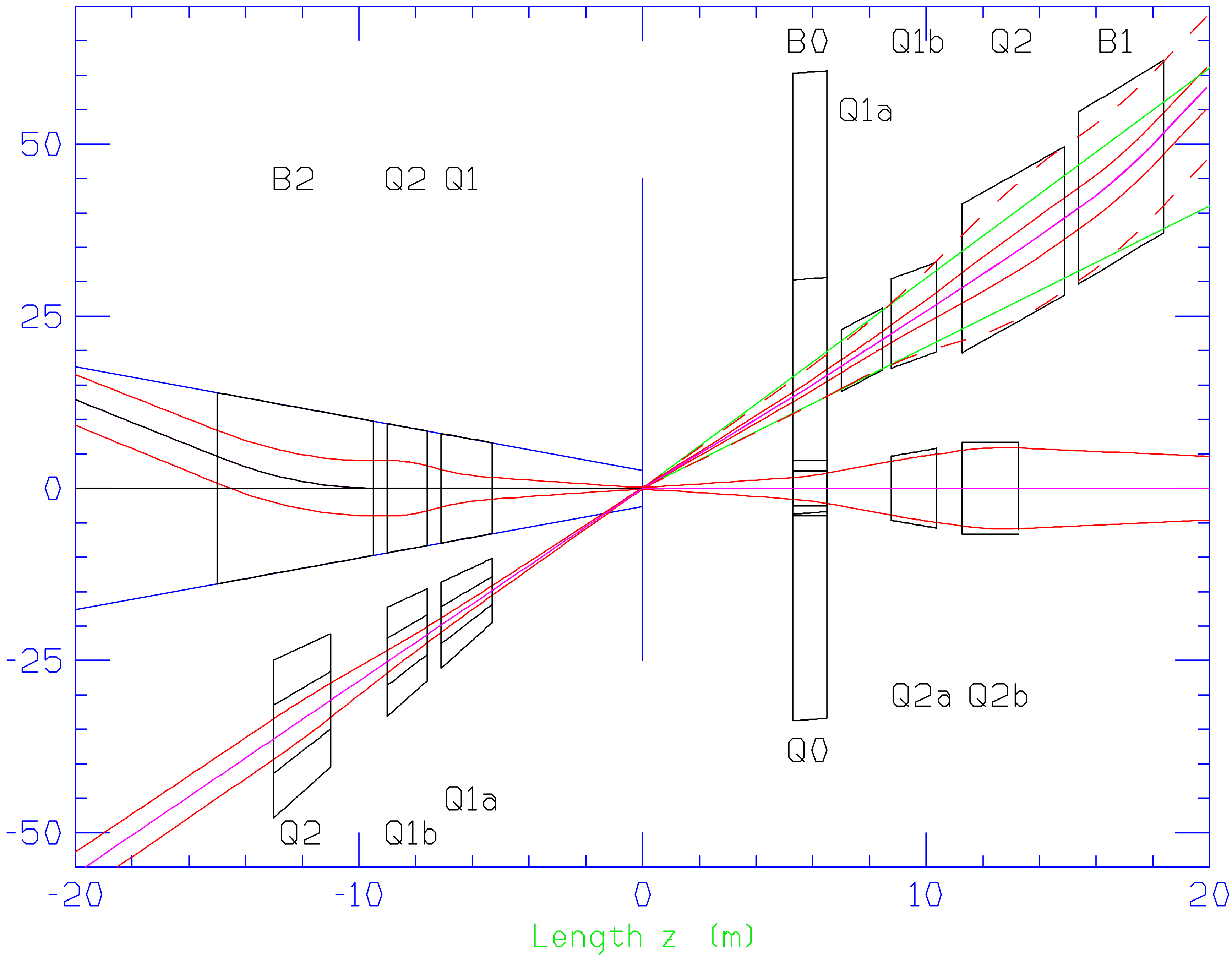
10/5/2018

1. IR changes to lower cost by using NbTi vs. Nb_3Sn conductors: forward e and hadron focus magnets side-by-side instead of alternating.
2. Moving rear electron focus magnets closer to each other to reduce the rear x chromaticity and maximum β
3. Consideration of use of Forward e quad inside detector to reduce the SR fan, forward x and y chromaticities, and maximum βs


B0
Q1b
Q2
B1
Q1a
50
25
0
-25
-50
B2
Q2 Q1
Q2a Q2b
Q0
Q1a
Q2
Q1b
-20
-10
0
10
20
Length z (m)

1.1 Lower Grad. IR Magnets

Too reduce IR cost, these designs are intended to have lower forward gradients allowing use of NbTi (vs. Nb3Sn).

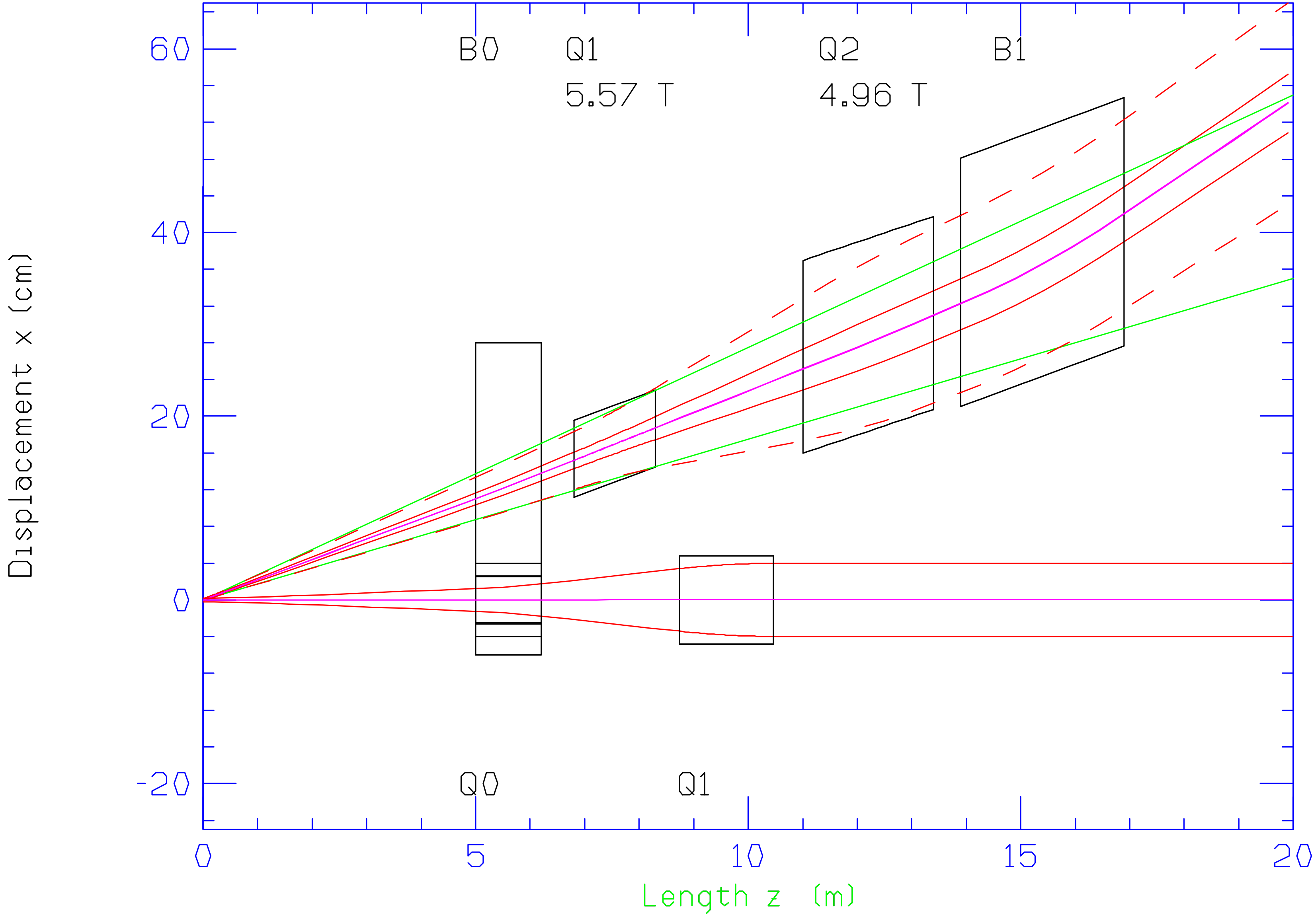
In the pCDR version, the pole tip fields (gradient $\times$ aperture) for Q1pF and Q2pF were 5.57 T and 4.96 T respectively and required the use of Nb_3Sn conductor.

These have been reduced by locating e and p magnets beside each other, instead of alternating along the axis. This require a somewhat larger crossing angle (25 vs. 22 mrad), but allows longer, and weaker, quadrupoles with lower fields and smaller radial coil thicknesses.

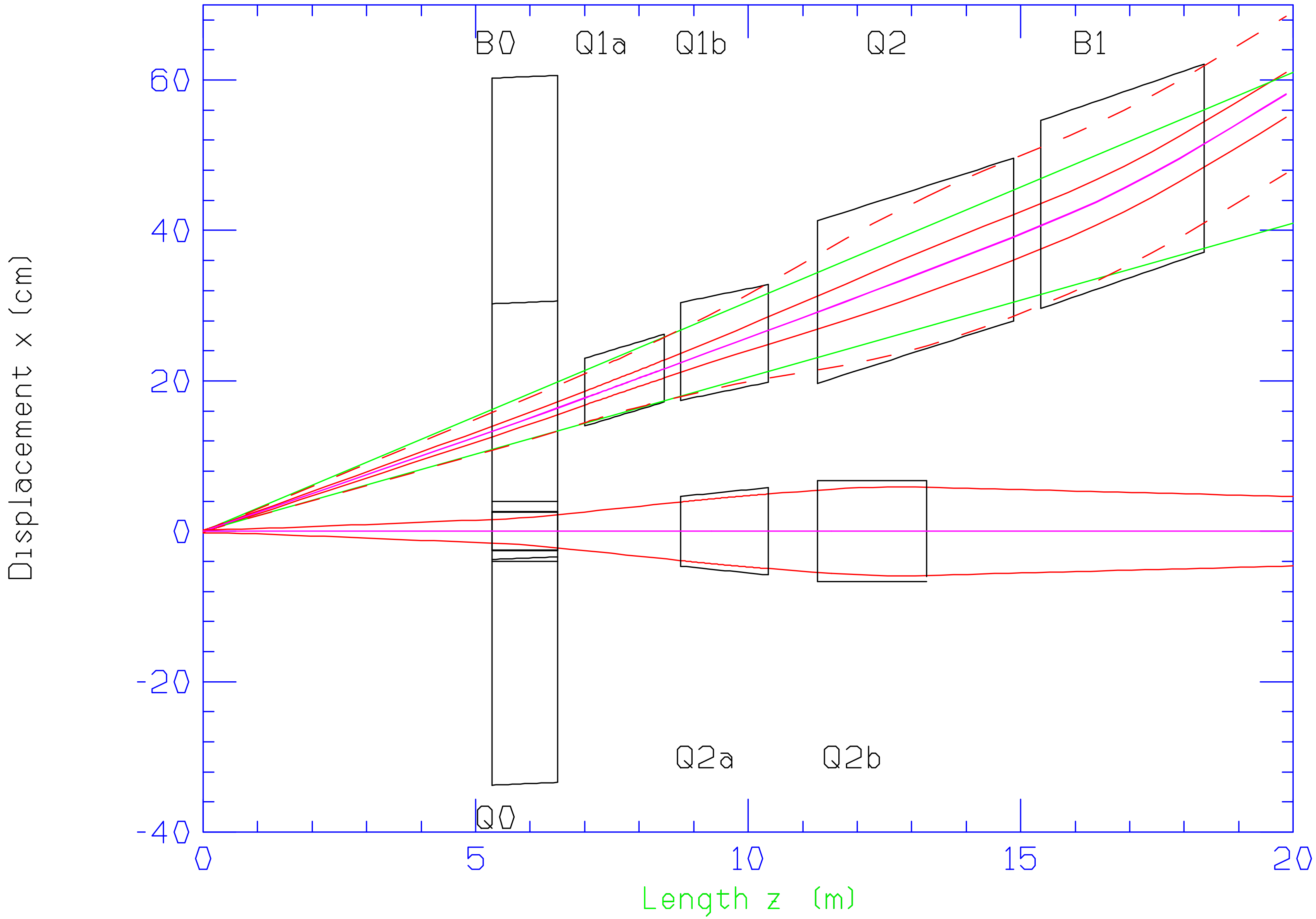
The lowest fields can be achieved using tapered magnets with reverse tapered gradients to achieve constant pole tip fields along the magnet, but stepped shorter straight magnets appear acceptable for all higher pole tip magnets.

c.f. Old pCDR Alternating Quads Layout

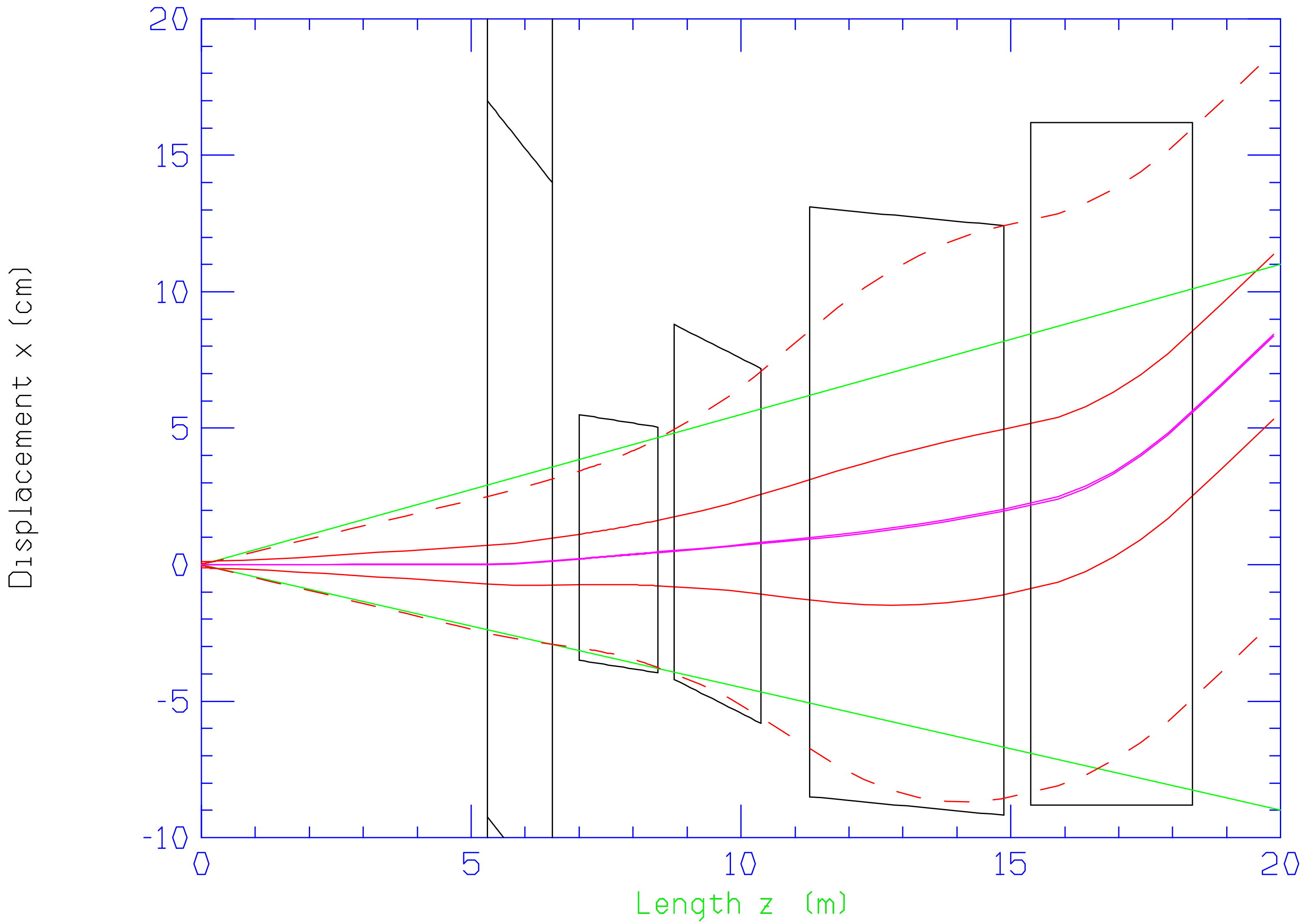
(dnnb3iw)



NEW Stepped side-by-side Quads) (dnnbF)



Forward Hadron Tilts (dnnp336w.eps)



Tilting gives much of the space gain provided by tapering

Pre-CDR Hadrons Parameters for (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 Stepped Side-by-side Magnets (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	0.00	17.00	17.00	30.0	0.000	0.000	1.300	0.000	0.000
Q1a	5	7.00	1.46	0.30	18.5	21.85	4.50	4.50	0.0	3.506	3.506	0.000	-77.903	-77.903
Q1b	7	8.76	1.61	0.90	24.2	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	30.5	23.11	10.80	10.80	0.0	4.291	4.291	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

Comments

The rising pole tip fields with successive magnets was found to minimize the local peak fields in their designs.

In all cases, these appear doable with NbTi conductors.

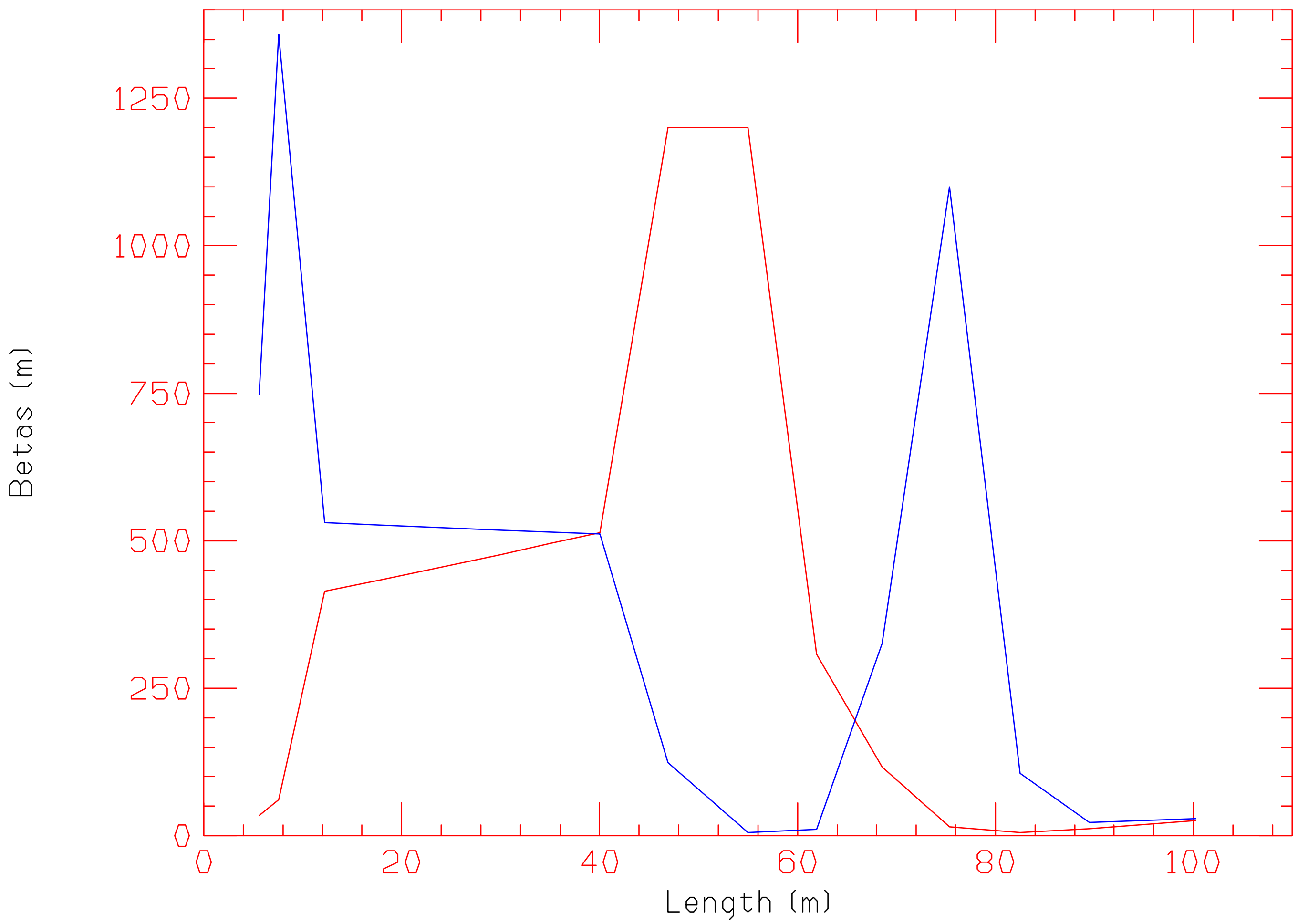
Text file using Brett Conventions

z coordinate along hadron IR axis, x horizontal

```
File: pF336
10/5/18 Hadron forward 275

 beta*_x  beta*_y  gm emit_x gm emit_y  angle_x  angle_y
  [m]      [m]      [nm]      [nm]      [mrad]   [mrad]

 0.9440   0.0420    16.1000    6.1000      25       0

 mag_name center_z center_x center_y radius   length   angle      B       gradient  Mom
           [m]      [m]      [m]      [m]      [m]    [mrad]     [T]       [T/m]    [GeV/c]

  B0pF     5.900  -0.0150    0.00   0.1700    1.200   -25.00   -1.300      0.00      275
  Q1apF     7.730   0.0077    0.00   0.0450    1.460    -3.15    0.000    -77.90      275
  Q1bpF     9.565   0.0149    0.00   0.0650    1.610   -10.00    0.000    -63.03      275
  Q2pF    13.070   0.0196    0.00   0.1080    3.600    -1.89    0.000    39.74      275
  B1pF    16.870   0.0370    0.00   0.1250    3.000     0.00   -4.570      0.00      275
```

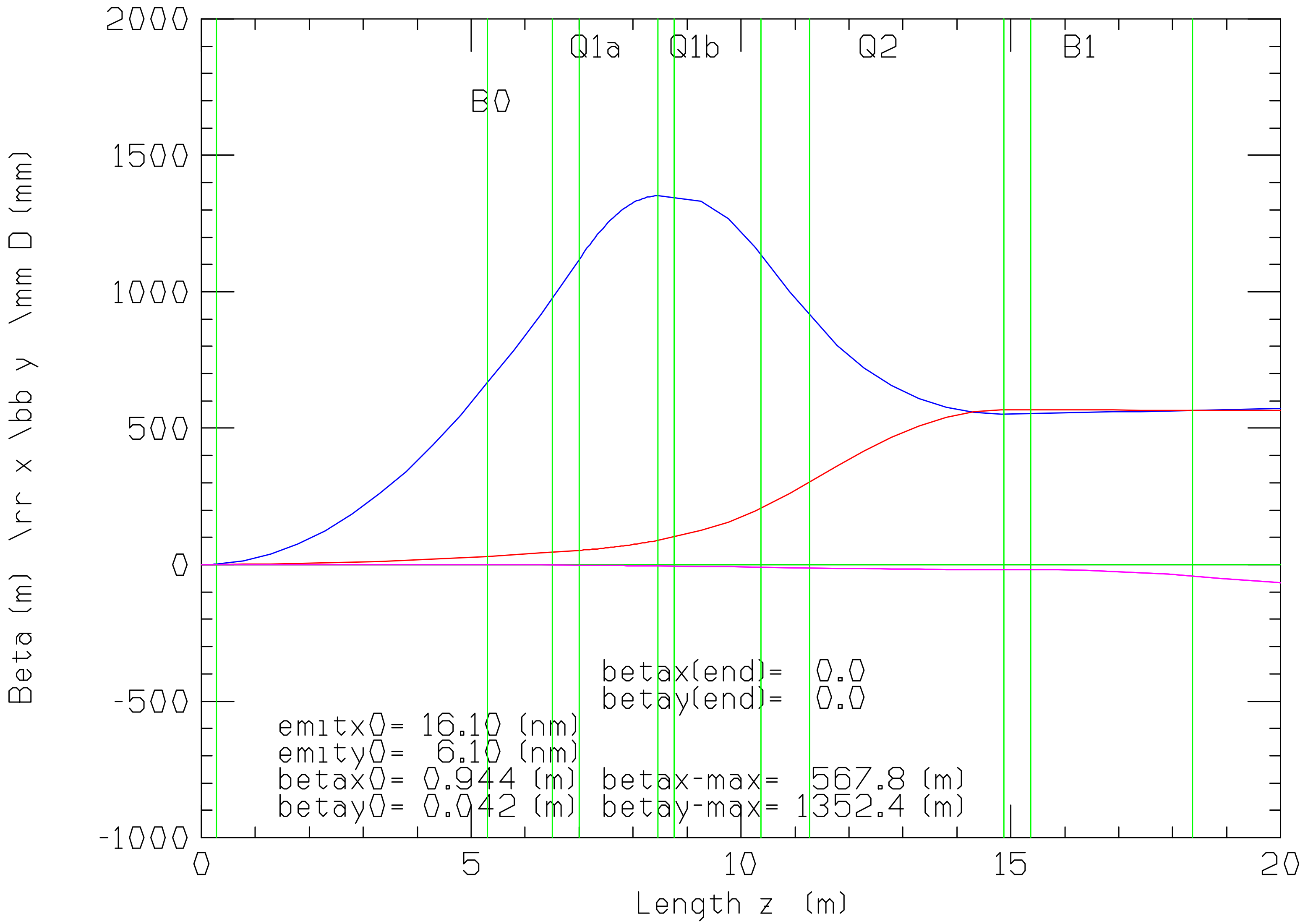
pCDR Forward Hadron Betas (pfbetas3.eps)

From Guillaume's matched data:



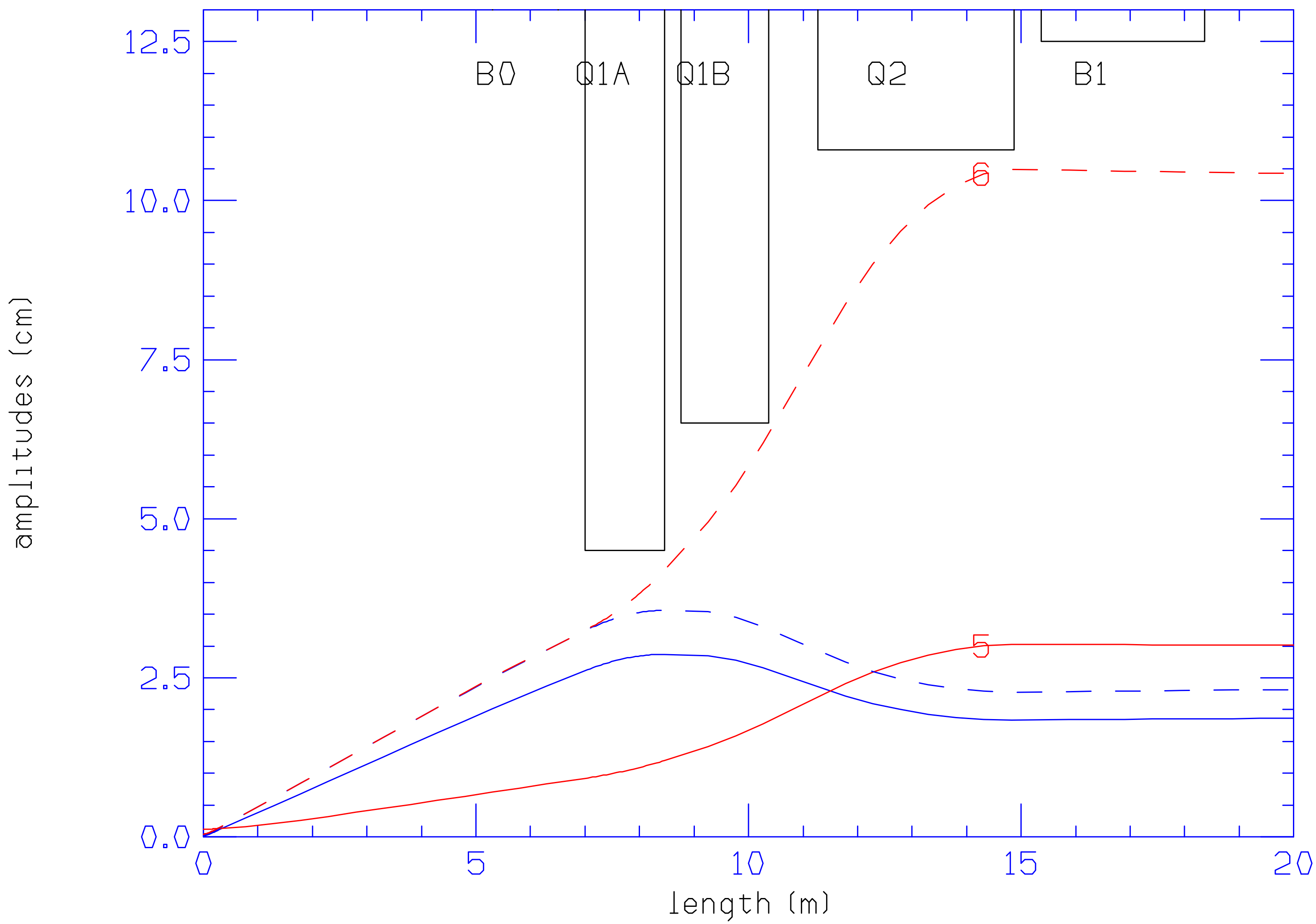
Both betas flattish heading for ≈500 m at z≈ 40 m

Forward Hadron Betas (bnnp335.eps)



Betas flat heading for ≈580 m, similar to pCDR

Forward Hadron amplitudes (annp335.eps)



1.2 Forward Electrons

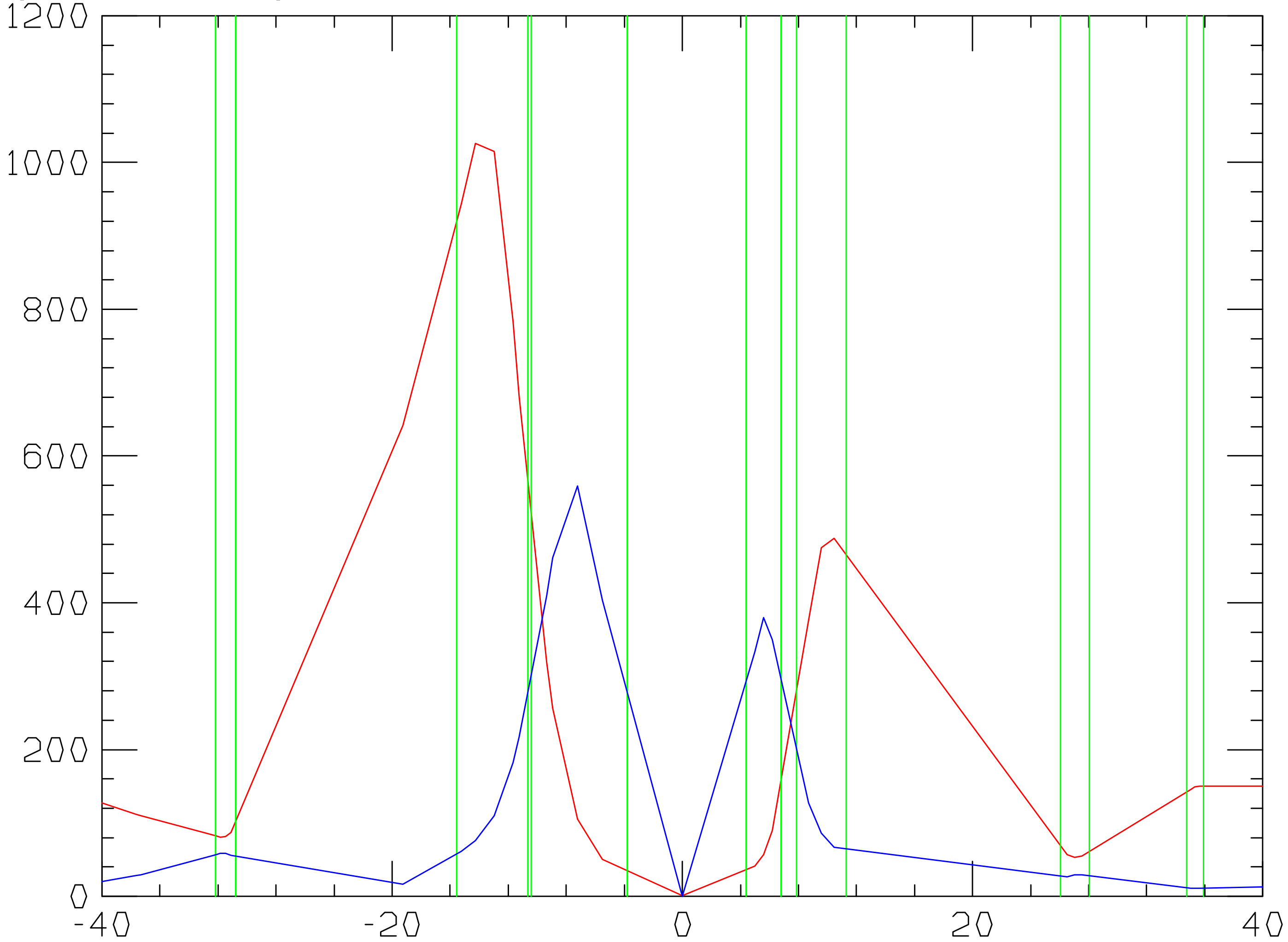
The focus magnets are designed to give betas that roughly match Steve's pCDR lattice.

The low β_y* inevitably gives a high y chromaticity (6.6)

The spacing between the focus and defocus magnets is relatively large to minimize the angles of the SR fan. Unfortunately this gives rise to relatively large x chromaticity (6.3).

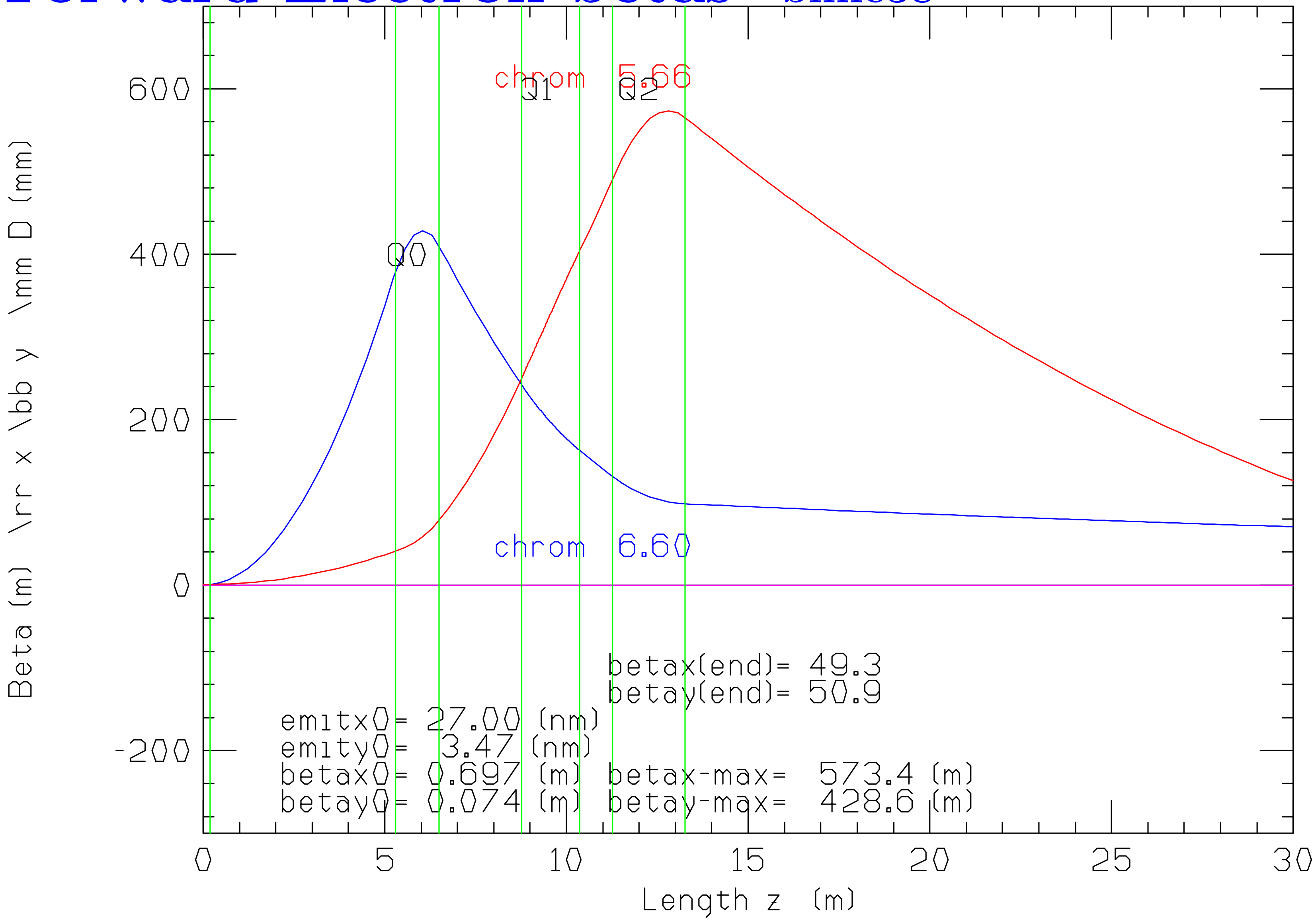
c.f. pCDR electron betas from Steve

(xyebet.eps)

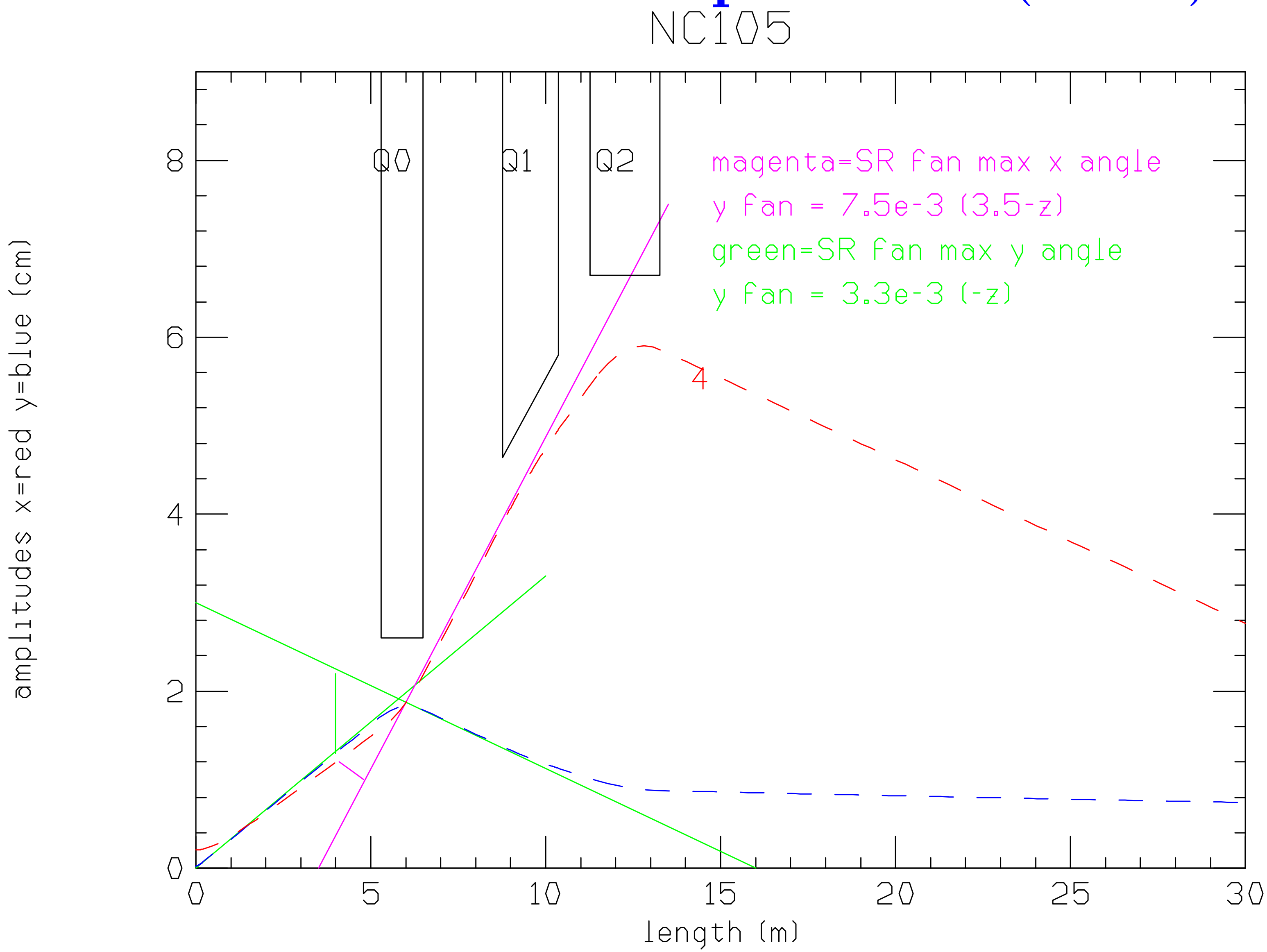


betas are converging to about 150 (x) 80 (y) m at z=27 m and much the same at -33 m in the rear.

Forward Electron betas bnne38



Forward Electrons amplitudes (anne38)



These are for the 105 GeV case with its larger divergences

c.f. Pre-CDR Forward Electron Magnets

Gradients from Steve multiplied by 1.8 for 18 GeV/c

chrom y 5.88 Chrom x??? E 18 GeV

		L1	DL	gap	x	θ	IR	Bpt	Grad)
		m	m	m	cm	mrad	cm	T	T/m
Q0eF	3	5.00	1.20	2.54	0.0	0.00	2.85	0.494	-17.33
Q1eF	5	8.74	1.72	7.02	0.0	0.00	5.00	0.376	7.79

New Forward Electron Magnets **mnne39**

Chrom y 5.66 ' Chrom x 6.30 ' mom = 18

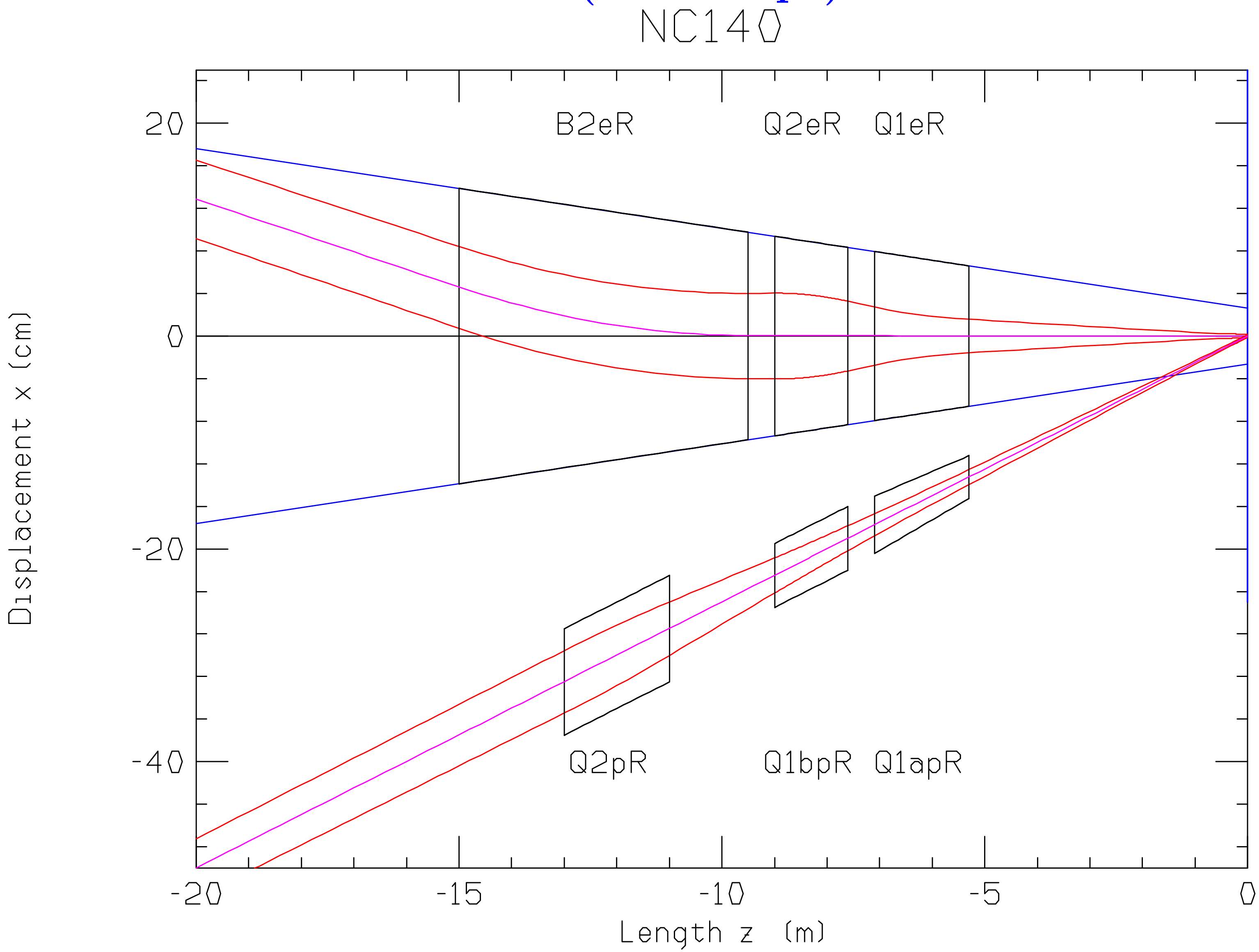
		L1	DL	gap	x	θ	IR1	IR2	OR	B1	B2	B	Grad1	Grad2
		m	m	m	cm	mrad	cm	cm	cm	T	T	T	T/m	T/m
Q0eF	3	5.30	1.20	2.26	0.0	0.00	2.60	2.60	0.0	0.331	0.331	0.0	-12.713	-12.713
Q1eF	5	8.76	1.61	0.90	0.0	0.00	4.64	5.80	0.0	0.078	0.097	0.0	1.675	1.675
Q2eF	7	11.27	2.00	20.40	0.0	0.00	6.35	6.35	0.0	0.244	0.244	0.0	3.846	3.846

The longer magnets have lower fields and less SR

Text file in Brett format

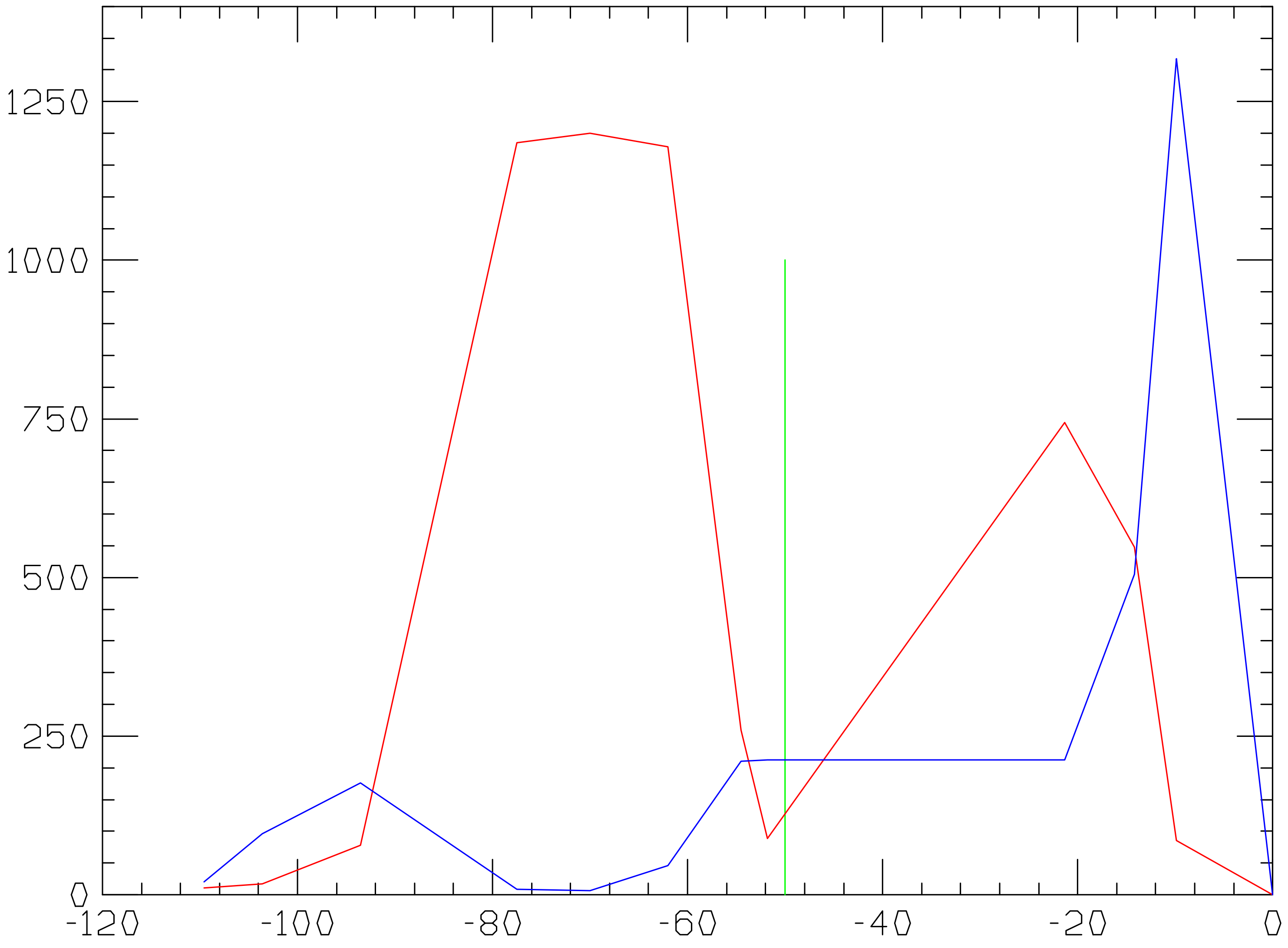
```
## File: eF39 electrons forward HD 3

 beta*_x  beta*_y  gm emit_x gm emit_y  angle_x  angle_y   Mom
  [m]      [m]      [nm]      [nm]      [mrad]   [mrad]   {GeV/c]

 0.6250   0.0740    30.4920   3.4600      25       0       18

Nnehadron forward 275
mag_name center_z center_x center_y radius   length   angle     B      gradient   mom
           [m]      [m]      [m]      [m]      [m]     [mrad]    [T]     [T/m]   [GeV/c]

  Q0ef     5.900  -0.1298    0.00   0.0260    1.200   -25.00   0.000    -12.71      18
  Q1ef     9.565  -0.2104    0.00   0.0464    1.610   -25.00   0.000      1.67      18
  Q2ef    12.270  -0.2699    0.00   0.0635    2.000   -25.00   0.000      3.85      18
  Q3ef    34.170  -0.7517    0.00   0.0500    1.000   -25.00   0.000      0.00      18
  Q4ef    53.690  -1.1812    0.00   0.0600    0.600   -25.00   0.000      0.39      18
```

REAR LAYOUT (rearv8.eps)



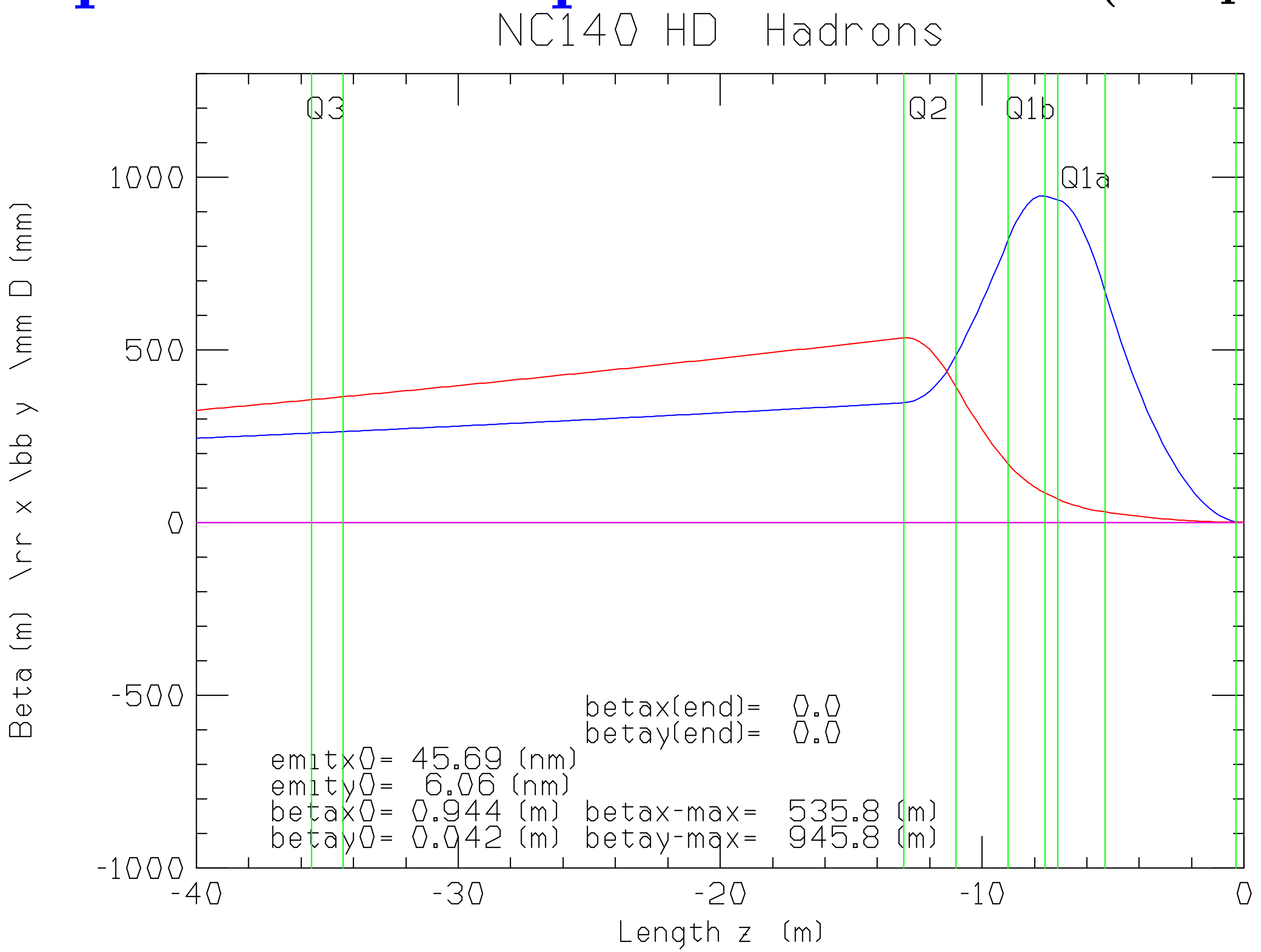
Outlines show the required apertures, not the magnet sizes

1.3 Rear Proton Magnets
pCDR matched betas from Guillaume (PRbetask)



both heading to ≈200 m at z≈-50 m

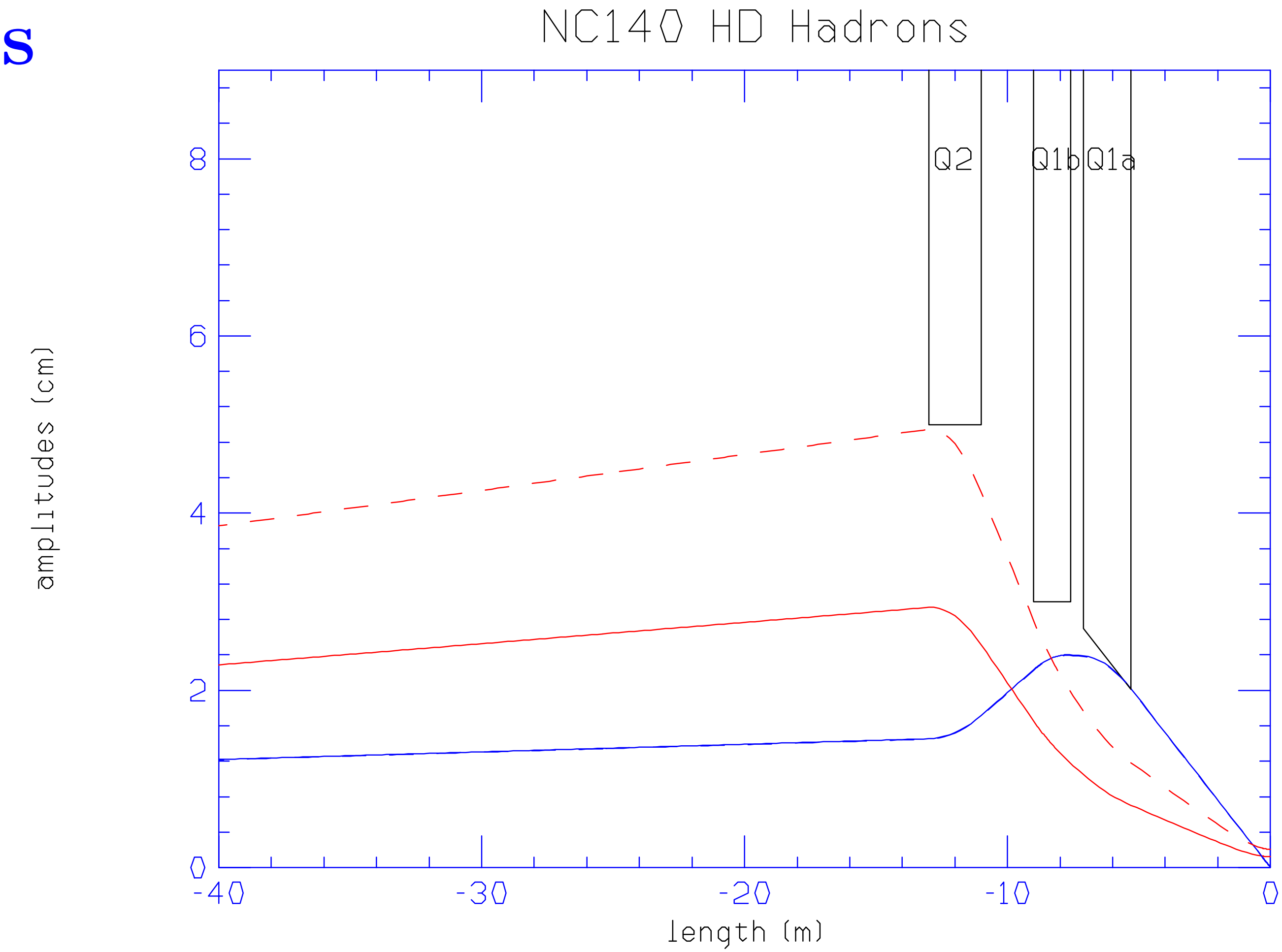
Updated rear proton betas (bnnp3R7a)



Q1pR is split to match the lengths of electron Q1eR & Q2eR

both x & y betas heading to ≈250 m at z≈-50 m as in matched pCDR case

Apertures
(annp3R7k)



The dashed line shows apertures scaled by the maximum beam divergence for all cases, over that for this particular case: Correct only if the betas are the same for those cases. What is required will only be really known when matched solutions are known for all cases.

Rear Proton Magnets mnnp3R7a

Non Tapered Q1ApR (mnnp3R7a)

Chrom y 13.82 ' Chrom x 4.66 ' mom = 275

		L1	DL	gap	x	θ	IR_1	IR_2	B	Bpt_1	Bpt_2	$Grad_1$	$Grad_2$
		m	m	m	cm	mrad	cm	cm	T	T	T	T/m	T/m
Q1ApR	3	5.30	1.80	0.50	-14.8	-25.00	2.40	2.40	0.0	1.892	1.892	-78.833	-78.833
Q1BpR	5	7.60	1.40	2.00	-21.3	-25.00	3.00	3.00	0.0	2.365	2.365	-78.833	-78.833
Q2pR	7	11.00	2.00	21.40	-30.8	-25.00	5.00	5.00	0.0	3.713	3.713	74.250	74.250

Tapered Q1ApR (mnnp3R7t) betas the same as shown above

		L1	DL	gap	x	θ	IR_1	IR_2	B	Bpt_1	Bpt_2	$Grad_1$	$Grad_2$
		m	m	m	cm	mrad	cm	cm	T	T	T	T/m	T/m
Q1ApR	3	5.30	1.80	0.50	-14.8	-25.00	2.01	2.77	0.0	1.585	2.187	-78.833	-78.833
Q1BpR	5	7.60	1.40	2.00	-21.3	-25.00	3.00	3.00	0.0	2.365	2.365	-78.833	-78.833
Q2pR	7	11.00	2.00	21.40	-30.8	-25.00	5.00	5.00	0.0	3.713	3.713	74.250	74.250

Lower pole tip fields should allow direct wind & tapered Q1ApR

Text file in Brett format (non Tapered)

File: pR7a Protons rear HD 10/5/18

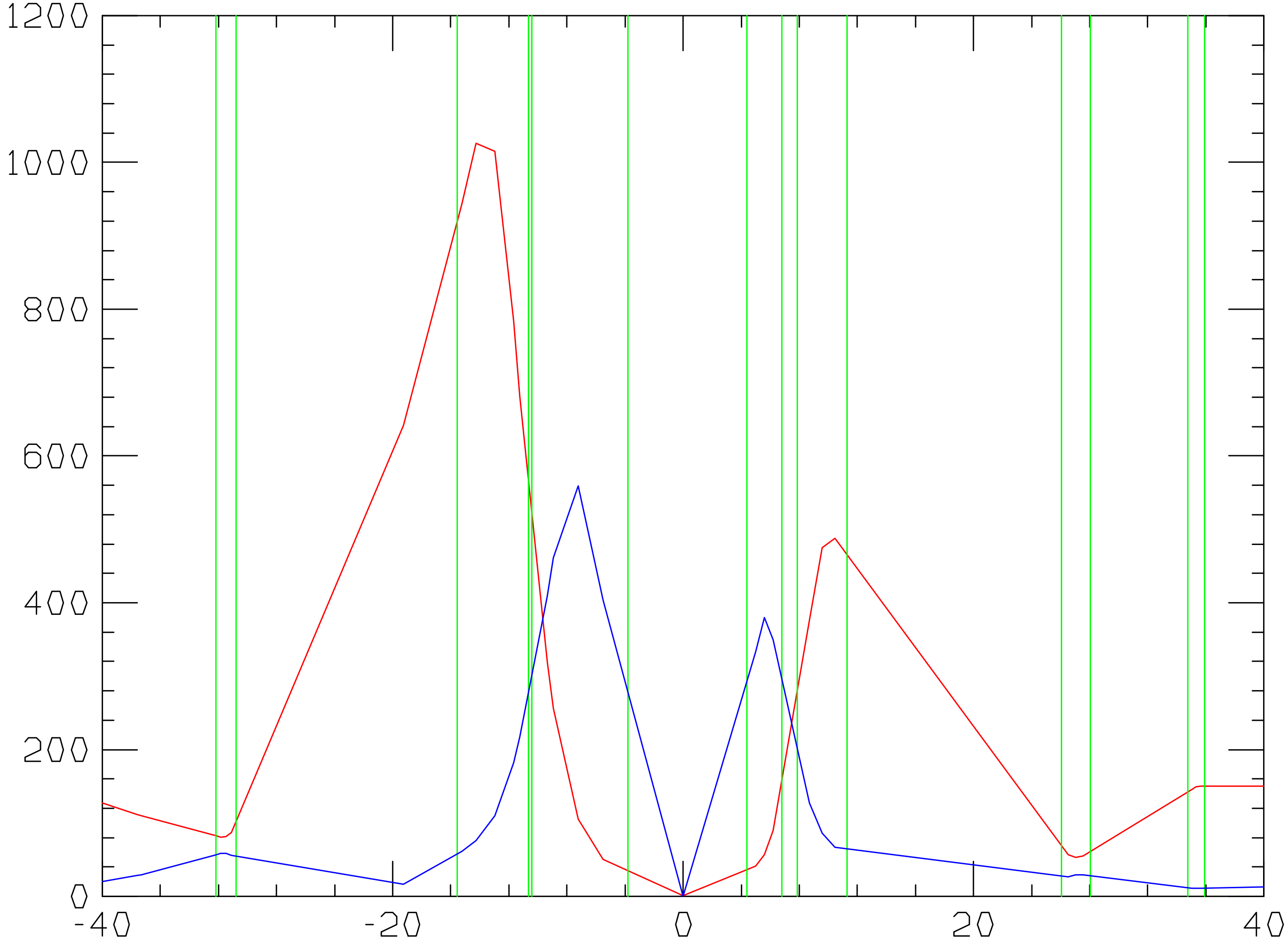
beta*_x	beta*_y	gm emit_x	gm emit_y	angle_x	angle_y	Mom
[m]	[m]	[nm]	[nm]	[mrad]	[mrad]	[GeV/v]
0.9440	0.0420	16.1000	6.1000	25	0	275

Nnphadron forward 275

mag_name	center_z	center_x	center_y	radius	length	angle	B	gradient
	[m]	[m]	[m]	[m]	[m]	[mrad]	[T]	[T/m]
Q1ApR	-6.199	0.0000	0.00	0.024	1.800	0.00	0.000	-78.83
Q1BpR	-8.298	0.0000	0.00	0.03	1.400	0.00	0.000	-78.83
Q2pR	-11.997	-0.0000	0.00	0.05	2.000	0.00	0.000	74.25

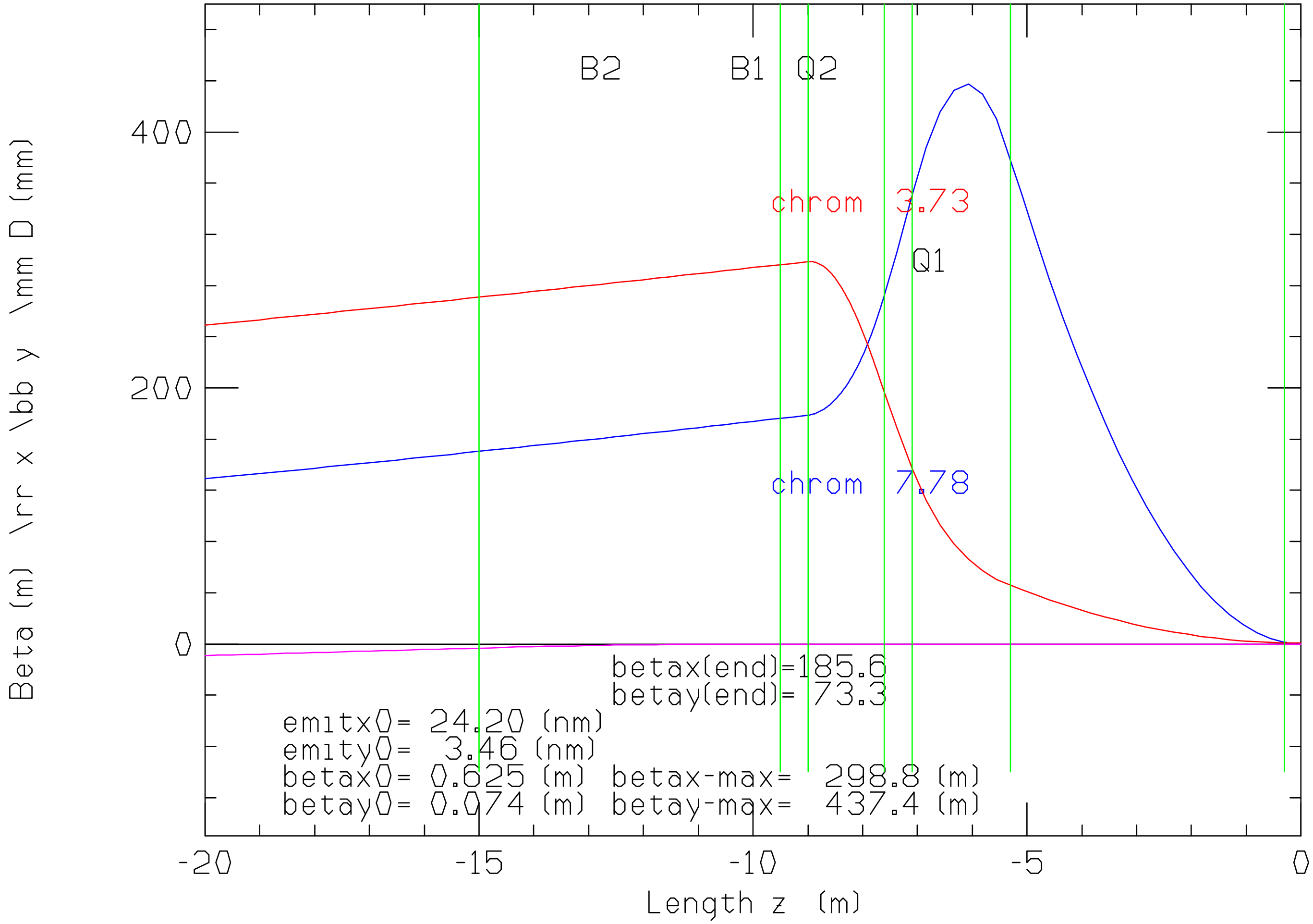
1.4 Rear Electron magnets (bnne3R7w)
c.f. pCDR electron betas from Steve

(xyebet.eps)



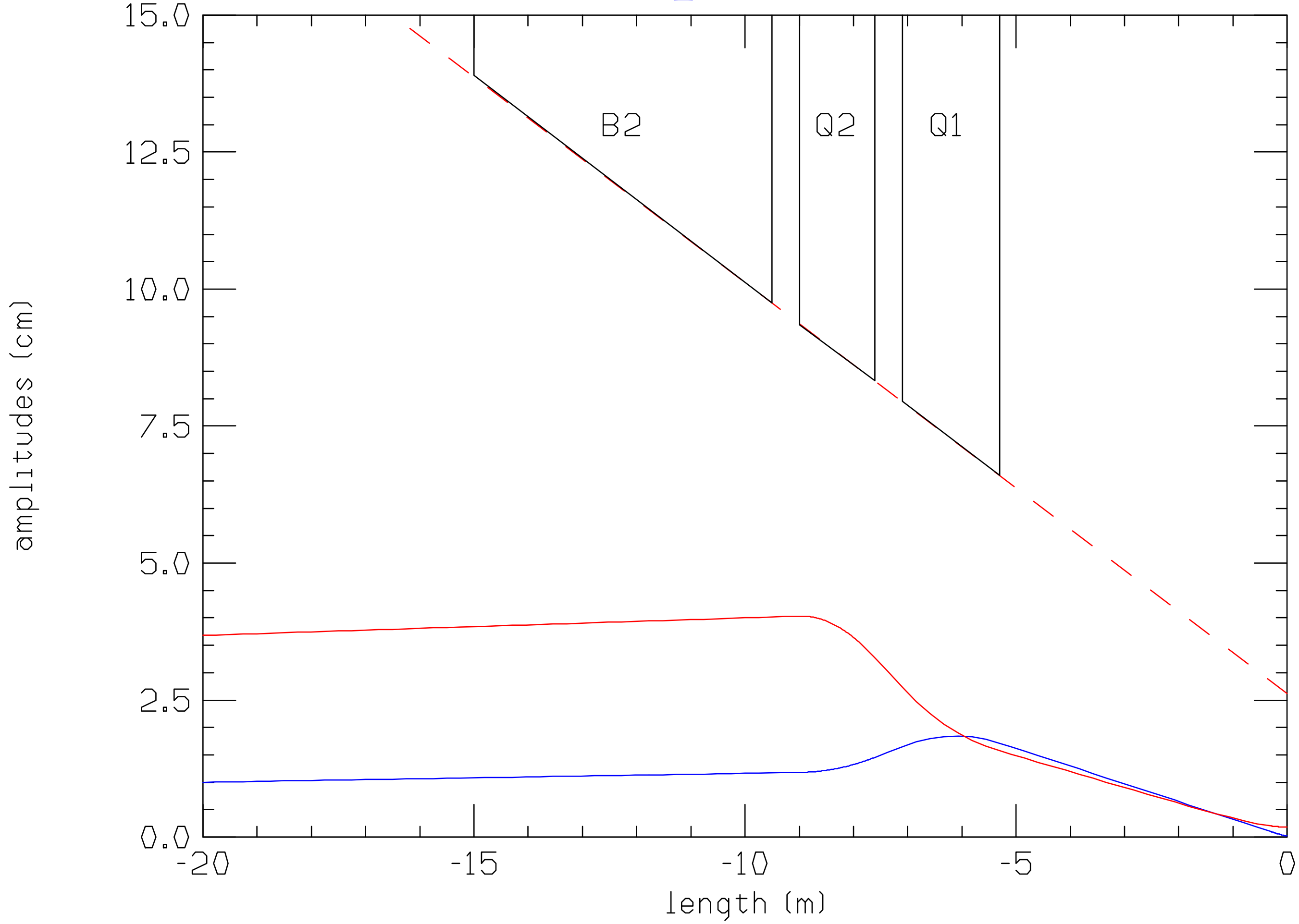
betas are converging to about 150 (x) 80 (y) m at z=-33 m

Rear Electron Betas (bnne3R7w)



Q1eR and Q2eR are made stronger and shorter than those in pCDR to reduce the max betax from 1000 to 300 m, and betay from 530 to 440 m

Rear Electron amplitudes (anne3R7k)



the apertures are set purely by the SR fan: a=7.5 10^{-3} (-Z +3.5)

Rear Electron magnets

Chrom y 7.75 ' Chrom x 3.81 ' mom = 18

		L1	DL	gap	x	θ	IR_1	IR_2	B	Bpt_1	Bpt_2	Grad)
		m	m	m	cm	mrad	cm	cm	T	T	T	T/m
Q1eR	3	5.30	1.80	0.50	0.0	0.0	6.60	7.95	0.000	0.851	1.026	-12.900
Q2eR	5	7.60	1.40	0.50	0.0	0.0	8.32	9.38	0.000	1.048	1.181	12.600
B2eR	9	9.50	5.50	15.98	0.0	0.0	9.75	13.88	0.180	0.00	0.000	0.000

Q1eR is tapered with constant gradient

Text file

```
## File eR7w.txt  electrons rear HD  10/5/18
 beta*_x  beta*_y  gm emit_x gm emit_y  angle_x  angle_y     Mom
  [m]      [m]      [nm]      [nm]      [mrad]   [mrad]       [GeV/c]

 0.6250   0.0740    24.2000    3.4600      25       0      18

mag_name center_z center_x center_y radius   length   angle      B      gradient
           [m]      [m]      [m]      [m]      [m]    [mrad]     [T]      [T/m]

  Q1er   -6.200   0.1364    0.00   0.0795    1.800    22.00    0.000    -12.90
  Q2er   -8.300   0.1826    0.00   0.0938    1.400    22.00    0.000     12.60
  B2er  -12.250   0.2695    0.00   0.1388    5.500    22.00   -0.013      0.00

## Radii given are for straight magnets.
## If tapered, radii nearer IP are 0.066, 0.082, and 0.0975 m
```

Summary

	pCDR	New
FORWARD		
$\beta *_x$ (m)	480	560[1]
$\beta *_y$ (m)	360	420[1]
REAR		
$\beta *_x$ (m)	1000[3]	300[3]
$\beta *_y$ (m)	560	460[4]

Notes

1 Worse because magnets further from IP for warm-cold transition

3 Gain by bringing rear quads close together - not possible forward because it increased SR fan

4 Gain by bringing quad closer and shorter