IR Update

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6/9/2017

1. Corrections since last week
2. Part I) Latest parameters
3. Part II) IR Magnets

Corrections

- Corrected coordinates for x and θ
- Small correction to High Acceptance Parameters
- Correct electron bending fields (thanks Holger)
- Rear electrons back to initial axis (thanks Brett)
- New Rear design with 4.5 T vs. 6 T hadron pole tip fields at Brett's request

Parameters

This part of the study was done with earlier electron emittance assumptions, but the differences will be small.

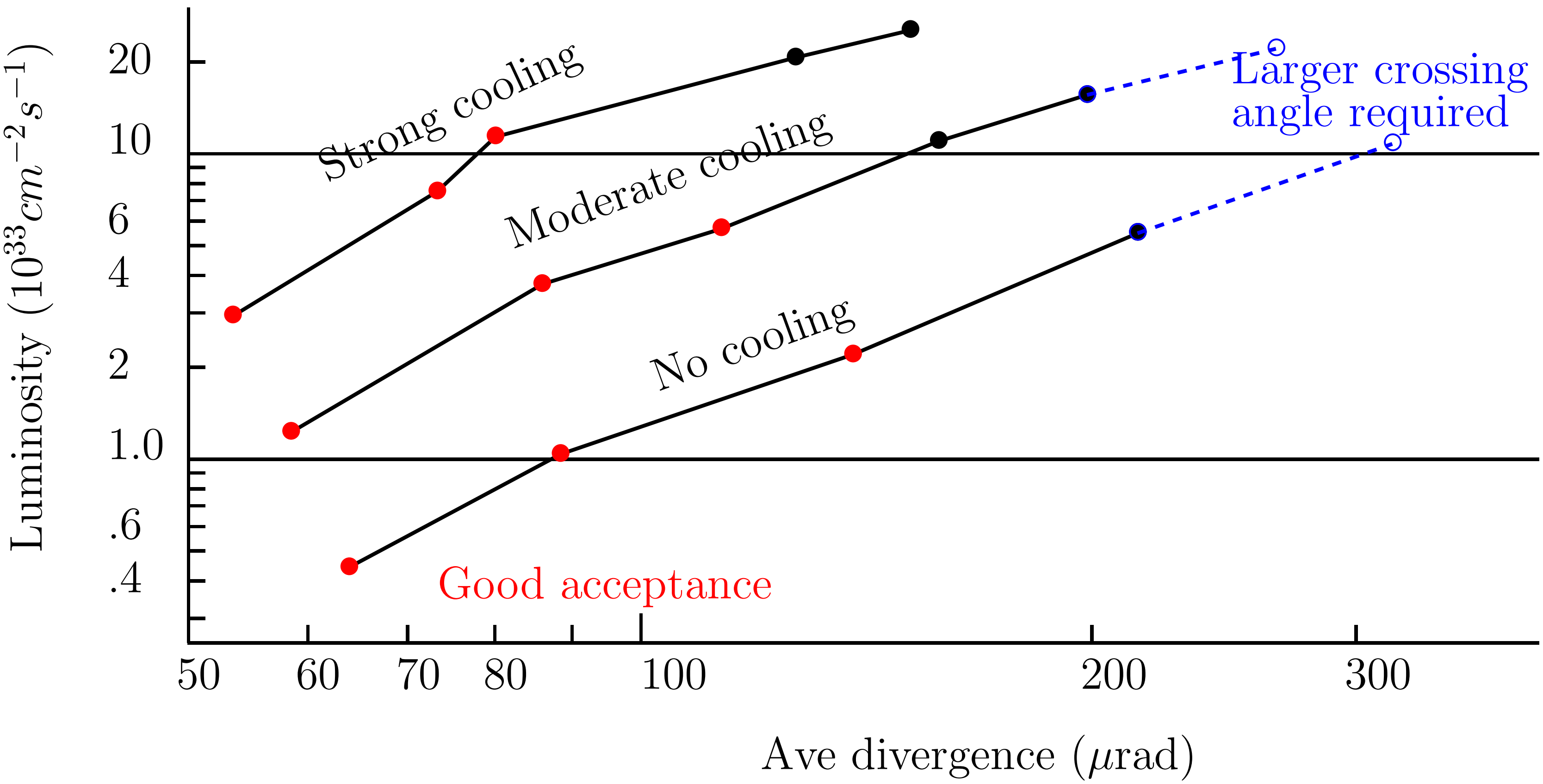
Parameters found for 3 cooling assumptions:

1. No Cooling (NC) assuming normalized emittances down to 1.8 μm
2. Moderate cooling (MC) assuming normalized emittances down to 0.4 μ
3. Strong cooling (SC) with normalized emittances down to 0.1 μm

And different divergence choices:

1. With no real limit
2. Only limited by aperture in current IR (High Divergence)
3. With hadron x divergence to give good acceptance of Pt=200 MeV/c forward protons (High Acceptance)
4. With all divergences lowered to reduce uncertainties in initial state (Low Divergence)

Lum vs. Ave Divergences



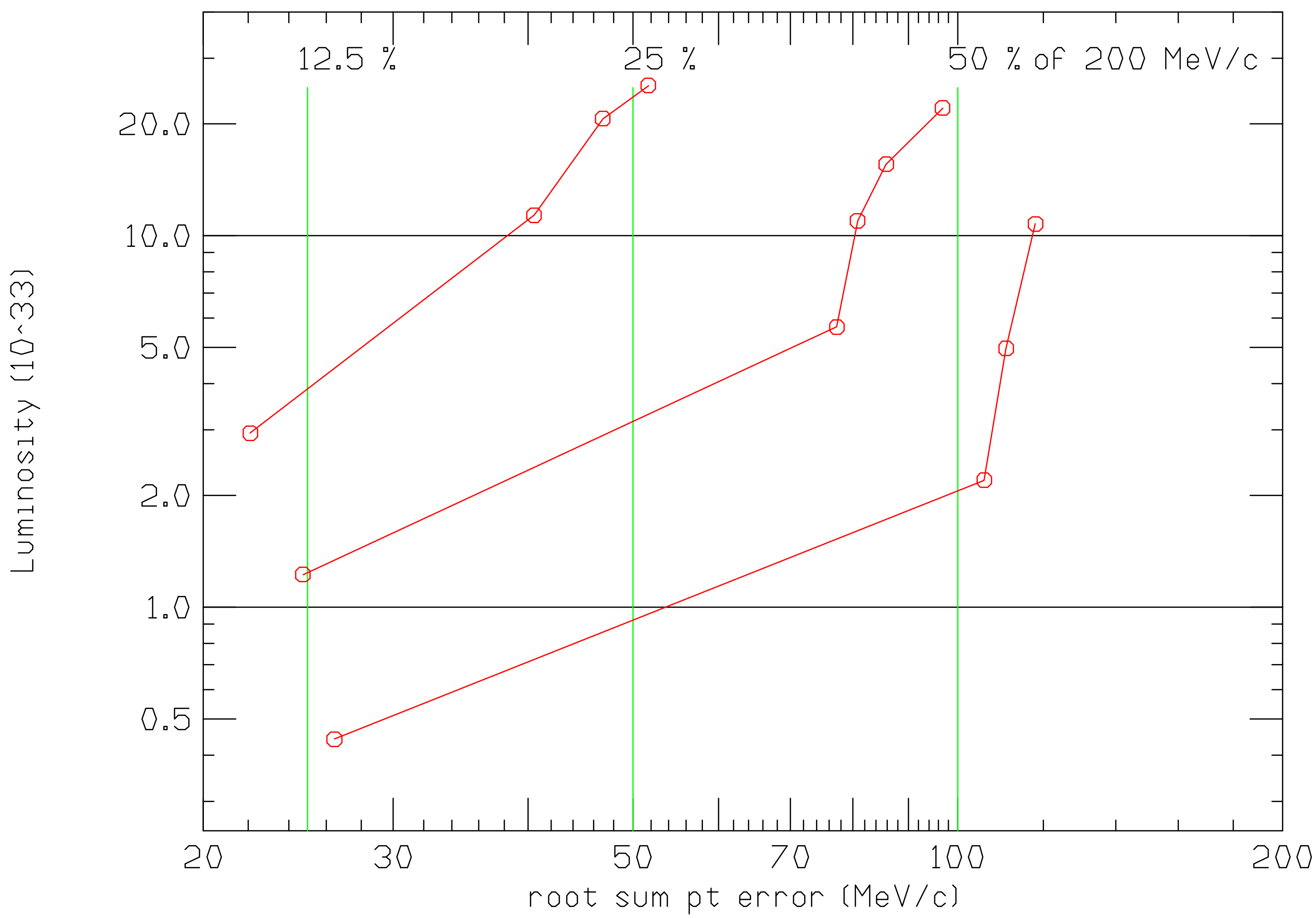
Ave used is geometric: $(\theta_{xp}\theta_{yp}\theta_{xe}\theta_{ye})^{1/4}$

Without hourglass, Luminosity $\propto$ (Geometric Ave)^2

For comparison, even without cooling, beam currents are assumed $\approx$ double the baseline

All are for center of mass energy 105 GeV (275 GeV p on 10 GeV e)

Luminosities vs $P_\perp$ error



$$dP_\perp \;=\; \sqrt{(P_p\theta xp)^2 + (P_p\theta yp)^2 + (P_e\theta xe)^2 + (P_e\theta ye)^2}$$

Again, all beam currents are assumed $\approx$ double the baseline

All are for center of mass energy 105 GeV (275 GeV p on 10 GeV e)

New electron horizontal Emittances

- The above calculations used ideal electron emittances chosen by me
- Steve has given me approximate realizable emittances that I have used for what follows
- More accurate values will have to be used later

No Cooling High Divergence

New parameters for No Cooling High Acceptance (NC-HA) and No Cooling High Divergence (NC-HD) solutions use the new electron estimated emittances as given below

Ep GeV	Ee GeV	Ecom GeV	emit$_{xe}$ nm	Lum HA 10^{33}	Lum HD 10^{33}
50	5	32	48 (37.5)	.16	.16
100	5	45	48 (37.5)	.47	.51
100	10	63	27 (24.7)	.64	.78
275	10	105	27 (24.7)	1.16	2.37
275	18	140	24.4 (17.3)	.34	.78

Earlier emittances in parentheses

The 5 GeV electrons assume a 60 deg advance giving 3 x 16.0 $=$ 48 nm
The 10 GeV electrons assume 60 deg advance giving 3 x 9.0 $=$ 27 nm
The 18 GeV electrons assume 90 deg advance giving $=$ 24.4 nm

High Acceptance Parameters

		E GeV	N 10^{10}	Nb	$\epsilon_x(\epsilon_{Nx})$ nm(μm)	$\epsilon_y(\epsilon_{Ny})$ nm(μm)	β_x cm	β_y cm	σ_x μm	σ_y μm	σ'_x μrad	σ'_y μrad	ξ_x	ξ_y	ΔQ	σ_s cm	I A	SR MW	HG %	lum 10^{33}
1	com	31.6																		
	p	50	10.7	330	111.1(5.9)	33.8(1.8)	130.0	22.0	380	86.2	292	392	.010	.008	.022	17.8	0.44		75	0.16
	e	5.0	31.1	330	48.0(470)	9.20(90)	301.0	80.9	380	86.3	126	107	.083	.098	.000	1.0	1.28	0.3		
2	com	44.7																		
	p	100	11.6	330	55.6(5.9)	16.9(1.8)	252.8	10.6	375	42.3	148	399	.012	.004	.008	13.2	0.48		81	0.38
	e	5.0	31.1	330	48.0(470)	7.58(74)	293.8	23.9	375	42.6	128	178	.100	.071	.000	1.0	1.28	0.3		
3	com	63.2																		
	p	100	13.4	330	39.1(4.2)	16.9(1.8)	175.6	11.6	262	44.2	149	382	.015	.006	.009	13.2	0.56		78	0.55
	e	10.0	29.5	330	27.0(528)	5.97(117)	253.0	32.7	261	44.2	103	135	.098	.074	.000	1.0	1.22	6.5		
4	com	104.9																		
	p	275	12.2	330	18.0(5.3)	6.1(1.8)	631.9	4.2	337	16.0	53	381	.014	.002	.002	8.0	0.50		83	1.18
	e	10.0	30.5	330	27.0(528)	3.47(68)	418.4	7.4	336	16.0	80	217	.099	.037	.000	1.0	1.26	6.5		
5	com	139.9																		
	p	275	15.0	330	16.1(4.7)	6.1(1.8)	566.4	4.2	302	16.0	53	381	.003	.000	.003	7.0	0.62		86	0.35
	e	17.8	6.3	330	24.2(843)	3.46(121)	375.0	7.4	301	16.0	80	216	.076	.028	.000	1.0	0.26	10.0		

	γ	N_b	freq MHz	Volts MV	ϵ_{xN} μm	ϵ_{yN} μm	σ_z cm	dp/p 10^{-4}	evsec eV sec	N_p 10^{11}	$\tau_{\parallel}$ hr.	$\tau_{\perp}$ hr.	Q_{100m} nC	β^4_{crab} m	f_{crab} MHz	V^5_{crab} MV	HG %	Lum 10^{33}	eff %	lum*eff 10^{33}
1	53	330	394	2.11	5.92	1.80	17.8	14.00	0.80	1.1	16.5	24.4	4.7^1	225	336	4.57	75	0.16	69^4	0.11
2	107	330	394	4.18	5.92	1.80	13.2	9.50	0.80	1.2	11.8	18.6	28^2	450	336	4.63	81	0.38	66^4	0.25
3	107	330	394	4.18	4.16	1.80	13.2	9.50	0.80	1.3	8.3	10.9	25^2	640	336	4.66	78	0.55	59^4	0.33
4	293	330	394	15.20	5.26	1.79	8.0	6.50	0.92	1.2	10.9	12.3	196^3	1392	336	4.58	83	1.18	62	0.73
5	293	330	394	19.86	4.72	1.79	7.0	6.50	0.80	1.5	7.3	7.7	224^3	1553	336	4.58	86	0.35	55	0.19

Warning: The data in the second table above give only approximate estimates of rf, IBS, and electron cooling charges, and are given for qualitative understanding only

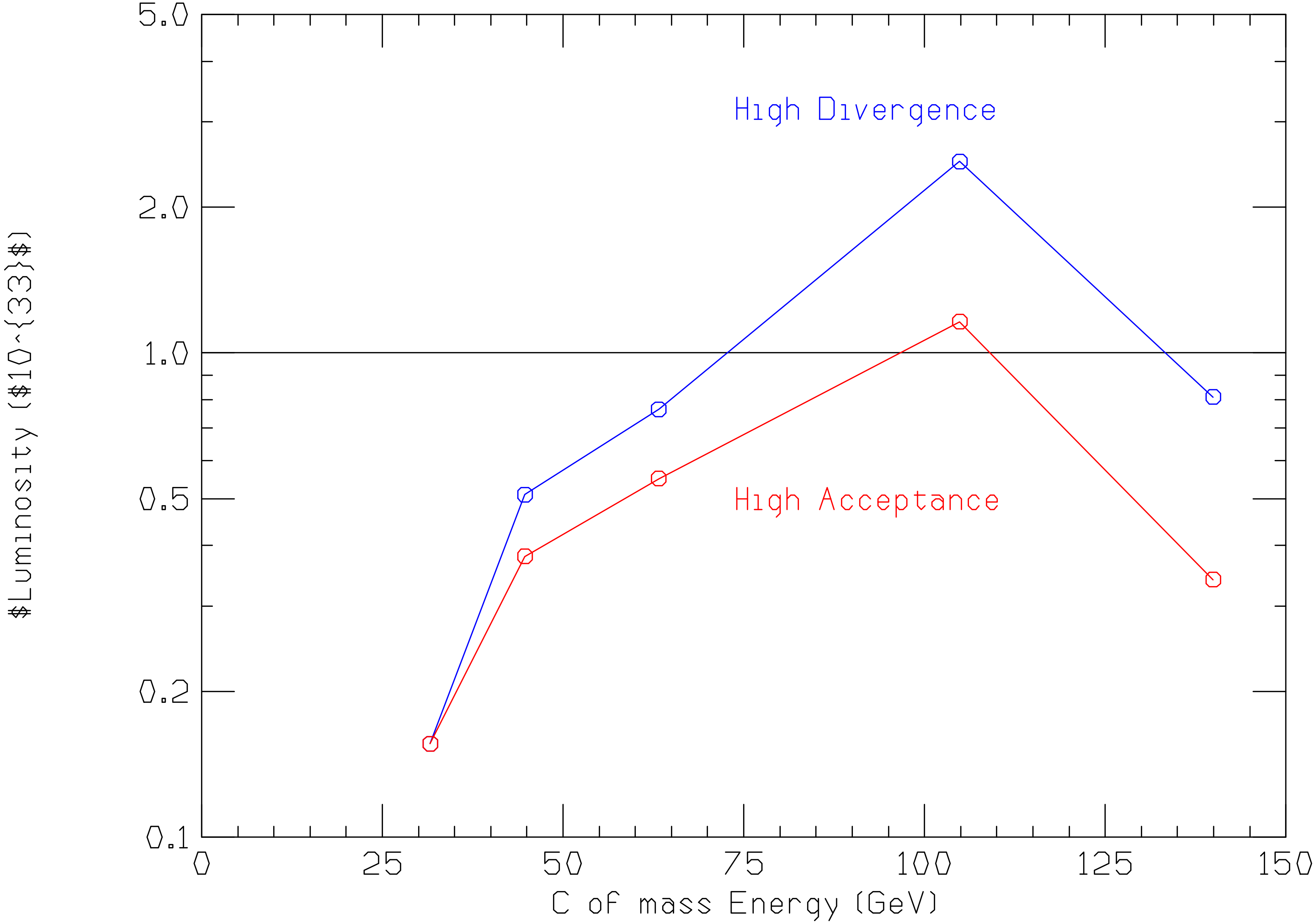
High Divergence Parameters

		E GeV	N 10^{10}	Nb	$\epsilon_x(\epsilon_{Nx})$ nm(μm)	$\epsilon_y(\epsilon_{Ny})$ nm(μm)	β_x cm	β_y cm	σ_x μm	σ_y μm	σ'_x μrad	σ'_y μrad	ξ_x	ξ_y	ΔQ	σ_s cm	I A	SR MW	HG %	lum 10^{33}
1	com	31.6																		
	p	50	10.7	330	111.1(5.9)	33.8(1.8)	130.0	22.0	380	86.2	292	392	.010	.008	.022	17.8	0.44		75	0.16
	e	5.0	31.1	330	48.0(470)	9.20(90)	301.0	80.9	380	86.3	126	107	.083	.098	.000	1.0	1.28	0.3		
2	com	44.7																		
	p	100	10.9	330	55.6(5.9)	16.9(1.8)	107.2	10.6	244	42.3	228	399	.011	.006	.008	13.2	0.45		76	0.51
	e	5.0	31.1	330	48.0(470)	7.58(74)	124.5	23.9	245	42.6	196	178	.088	.097	.000	1.0	1.28	0.3		
3	com	63.2																		
	p	100	12.8	330	39.1(4.2)	16.9(1.8)	79.8	11.6	177	44.2	221	382	.015	.008	.009	13.2	0.53		73	0.76
	e	10.0	31.1	330	27.0(528)	5.97(117)	115.0	32.7	176	44.2	153	135	.087	.098	.000	1.0	1.28	4.9		
4	com	104.9																		
	p	275	11.1	330	18.0(5.3)	6.1(1.8)	105.3	4.2	138	16.0	131	381	.013	.004	.002	8.0	0.46		79	2.48
	e	10.0	30.5	330	27.0(528)	3.47(68)	69.7	7.4	137	16.0	197	217	.084	.076	.000	1.0	1.26	4.8		
5	com	139.9																		
	p	275	15.0	330	16.1(4.7)	6.1(1.8)	94.4	4.2	123	16.0	131	381	.003	.001	.003	7.0	0.62		82	0.81
	e	17.8	6.3	330	24.2(843)	3.46(121)	62.5	7.4	123	16.0	197	216	.071	.064	.000	1.0	0.26	10.0		

	γ	N_b	freq MHz	Volts MV	ϵ_{xN} μm	ϵ_{yN} μm	σ_z cm	dp/p 10^{-4}	evsec eV sec	N_p 10^{11}	$\tau_{\parallel}$ hr.	$\tau_{\perp}$ hr.	Q_{100m} nC	β^4_{crab} m	f_{crab} MHz	V^5_{crab} MV	HG %	Lum 10^{33}	eff %	lum*eff 10^{33}
1	53	330	394	2.11	5.92	1.80	17.8	14.00	0.80	1.1	16.5	24.4	4.7[1]	225	336	4.57	75	0.16	69[4]	0.11
2	107	330	394	4.18	5.92	1.80	13.2	9.50	0.80	1.1	12.6	20.0	26[2]	450	336	7.12	76	0.51	67[4]	0.34
3	107	330	394	4.18	4.16	1.80	13.2	9.50	0.80	1.3	8.7	11.5	24[2]	640	336	6.92	73	0.76	60[4]	0.46
4	293	330	394	15.20	5.26	1.79	8.0	6.50	0.92	1.1	12.0	13.5	178[3]	1392	336	11.23	79	2.48	63	1.57
5	293	330	394	19.86	4.72	1.79	7.0	6.50	0.80	1.5	7.3	7.7	224[3]	1553	336	11.23	82	0.81	55	0.45

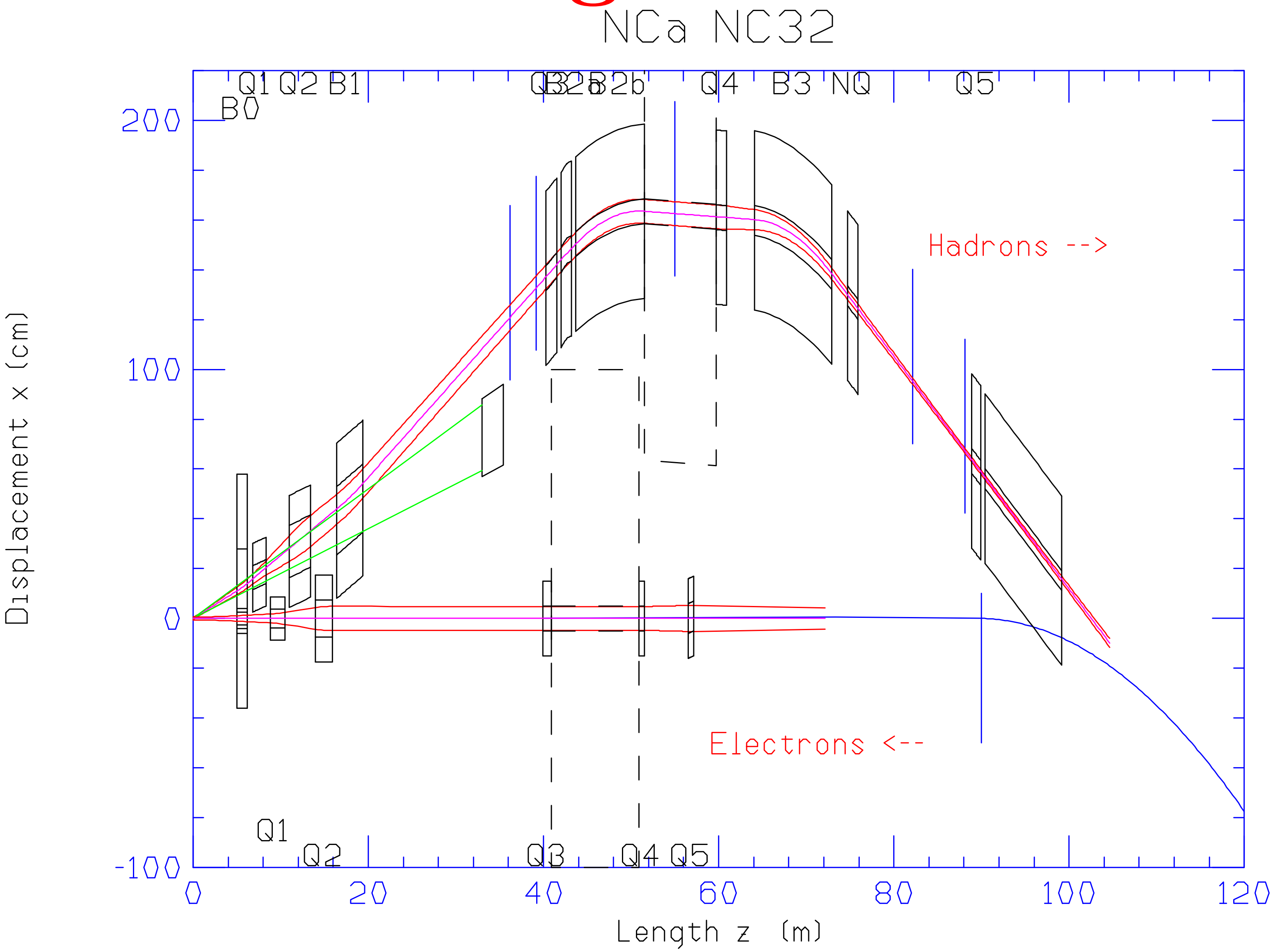
Warning: The data in the second table above give only approximate estimates of rf, IBS, and electron cooling charges, and are given for qualitative understanding only

Luminosity vs. Energy



(II) IR Design

Forward Magnets

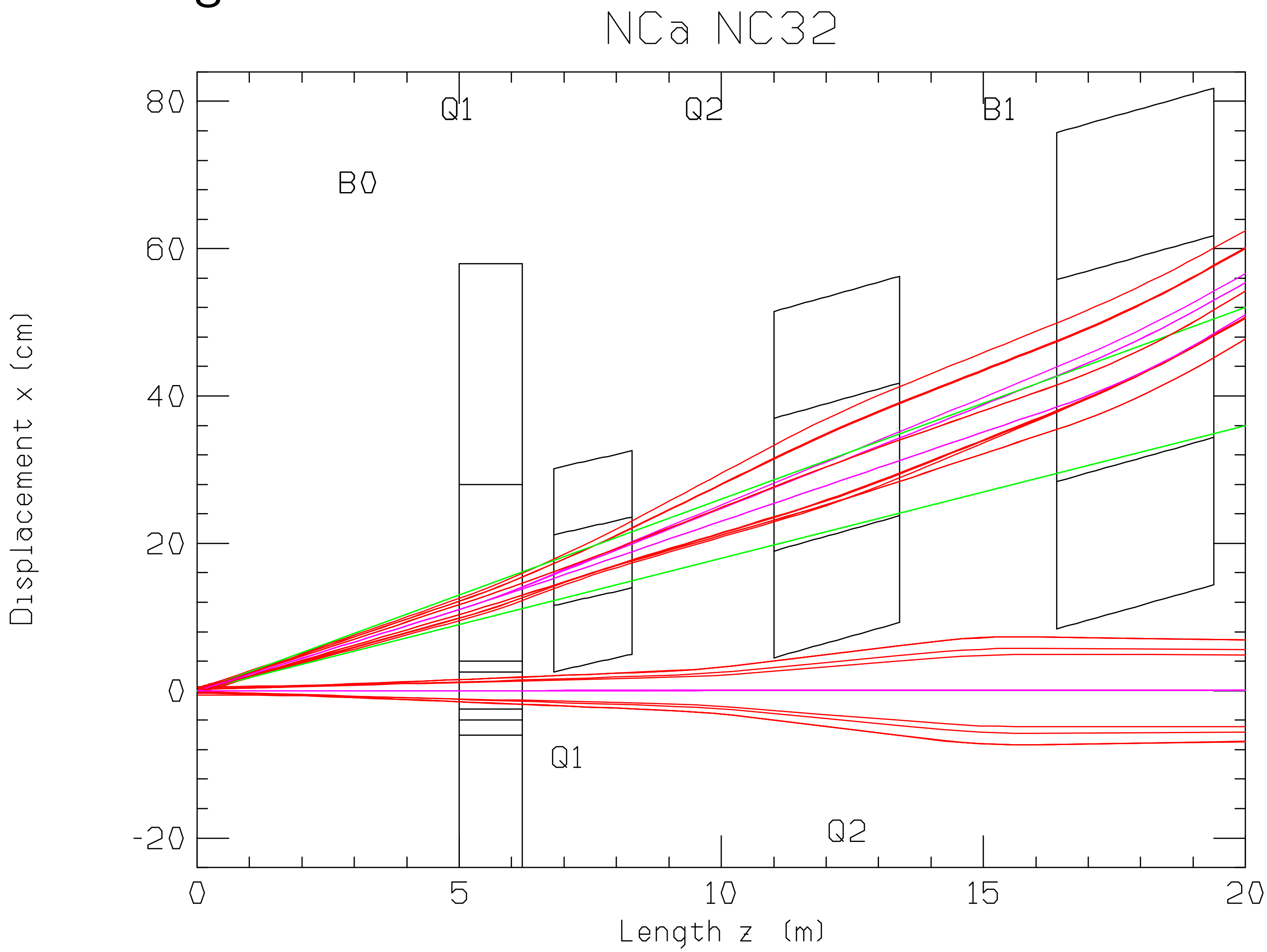


Dashes indicate space for Crab Cavities

Forward Magnets Detail

Showing 10 and 15 sigma of beams for all 5 NC-HD cases

All divergences for NC-HA cases are smaller than those for NC-HD



Green shows 4 mrad neutron cone

Forward Proton Magnets

and fields for Ecom=105 GeV - fields for other cases below

Protons mom=275 GeV/c

		L1	DL	gap	x	θ	IR	OR	B	Grad)
		m	m	m	cm	mrad	cm	cm	T	T/m
B0	3	5.00	1.20	0.60	11.0	0.00	17.00	47.0	1.70	0.00
Q1	5	6.80	1.50	2.70	16.4	16.00	4.80	13.8	6.69	-139.35
Q2	7	11.00	2.40	3.00	26.9	17.00	10.50	22.5	4.62	44.02
B1	9	16.40	3.00	20.90	39.3	30.39	13.70	31.2	5.50	0.00
Q3	11	40.30	1.20	0.50	136.6	42.22	5.00	35.0	0.57	11.46
B2a	13	42.00	1.20	0.50	143.8	39.21	5.10	35.1	-3.02	0.00
B2b	15	43.70	7.80	8.20	150.3	16.71	5.00	35.0	-4.58	0.00
Q4	17	59.70	1.20	3.20	161.1	-2.79	5.00	35.0	1.78	35.65
B3	19	64.10	8.80	1.80	159.9	-24.79	6.00	36.0	-4.58	0.00
NQ	21	74.70	1.20	13.00	129.6	-46.77	4.00	34.0	2.93	-73.33
Q5	23	88.90	1.00	0.50	63.2	-46.78	5.00	35.0	2.75	55.00
H1	25	90.40	8.75	5.50	56.2	-46.78	4.00	34.0	0.00	0.00

forward protons

E_{com}	P_p	B0	Q1		Q2		B1	Q3		B2a	B2b	Q4		B3	NQ		Q5	
		B	B	grad	B	grad	B	B	grad	B	B	B	grad	B	B	grad	B	grad
GeV	GeV/c	T	T	T/m	T	T/m	T	T	T/m	T	T	T	T/m	T	T	T/m	T	T/m
NC32	50	1.0000	1.2944	-26.9676	1.1363	10.8218	0.5833	0.0694	-1.3889	-0.4667	-0.8333	0.2894	5.7870	-0.8333	0.2667	-6.6667	0.5000	10.0000
NC45	100	1.7000	2.5778	-53.7037	2.1632	20.6018	1.3533	0.0231	-0.4630	-1.1000	-1.6667	0.5787	11.5741	-1.6667	0.5333	-13.3333	1.0000	20.0000
NC63	100	1.7000	2.5778	-53.7037	2.1632	20.6018	1.3533	0.0231	-0.4630	-1.1000	-1.6667	0.5787	11.5741	-1.6667	0.5333	-13.3333	1.0000	20.0000
NC105	275	1.6958	6.6886	-139.3460	4.6220	44.0191	5.5000	0.5729	11.4583	-4.5833	-4.5833	1.7824	35.6481	-4.5833	2.9333	-73.3333	2.7500	55.0000
NC140	275	1.6958	6.6886	-139.3460	4.6220	44.0191	5.5000	0.5729	11.4583	-4.5833	-4.5833	1.7824	35.6481	-4.5833	2.9333	-73.3333	2.7500	55.0000

Forward Electron Magnets

and fields for Ecom=105 GeV - fields for other cases below

		L1	DL	gap	x	θ	IR	OR	B	Grad)
		m	m	m	cm	mrad	cm	cm	T	T/m
Q1	3	8.79	1.72	3.42	0.00	0.00	3.70	8.7	0.14	-3.70
Q2	5	13.93	2.00	24.00	0.00	0.00	7.50	17.5	0.17	2.23
Q3	7	39.93	1.00	10.00	0.00	0.00	5.00	15.0	0.03	-0.51
Q4	9	50.93	0.60	5.00	0.00	0.00	5.00	15.0	0.05	-1.07
Q5	11	56.53	0.60	15.00	0.00	0.00	6.00	16.0	0.10	1.71

Forward electrons

E_{com}	P_e	Q1		Q2		Q3		Q4		Q5	
		B	grad	B	grad	B	grad	B	grad	B	grad
GeV	GeV/c	T	T/m	T	T/m	T	T/m	T	T/m	T	T/m
NC32	5	0.0685	-1.8506	0.0766	1.0208	0.0011	-0.0214	0.0268	-0.5350	0.0514	0.8561
NC45	5	0.0685	-1.8506	0.0858	1.1443	0.0185	-0.3692	0.0268	-0.5350	0.0514	0.8561
NC63	10	0.1369	-3.7012	0.1620	2.1603	0.0150	-0.2996	0.0535	-1.0701	0.1027	1.7121
NC105	10	0.1369	-3.7012	0.1713	2.2838	0.0364	-0.7277	0.0535	-1.0701	0.1027	1.7121
NC140	18	0.2465	-6.6622	0.3089	4.1193	0.0636	-1.2713	0.0963	-1.9262	0.1849	3.0819

Discussion

L1 is the distance from IP to the start of the magnets, DL is the magnet length, the gap follows that magnet. There are no combined function magnets. When the gradient is zero, the B indicates its field. If not, B indicates the nominal pole tip field (grad times IR).

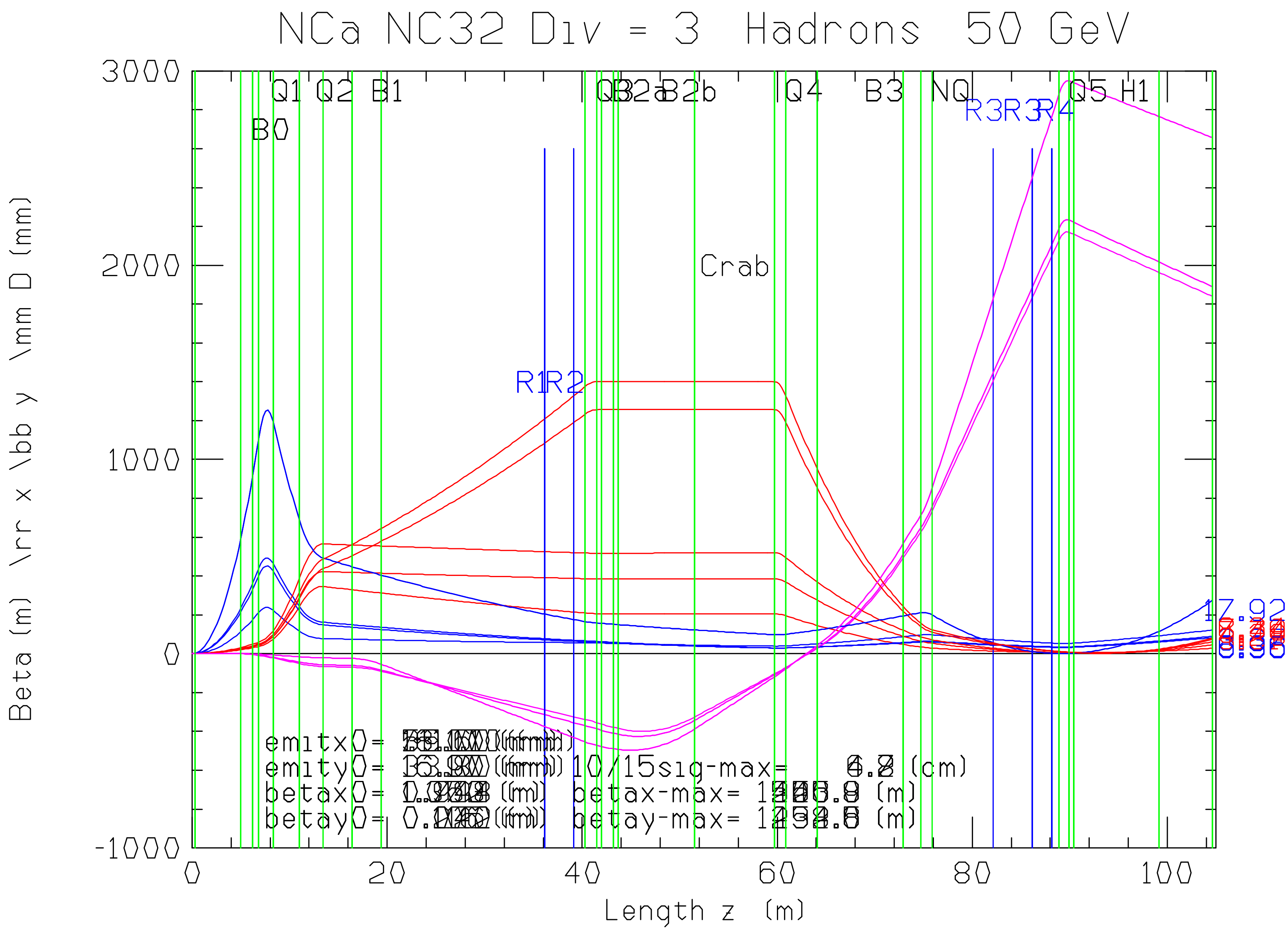
The horizontal displacements x and the angles θ are with respect to the electron direction at the IP.

Magnet locations are fixed independent of beam momenta or settings. For proton magnets Q3 and beyond, the beam center should follow the magnet centres and angles θ, but for the earlier proton magnets this is sometimes far from true.

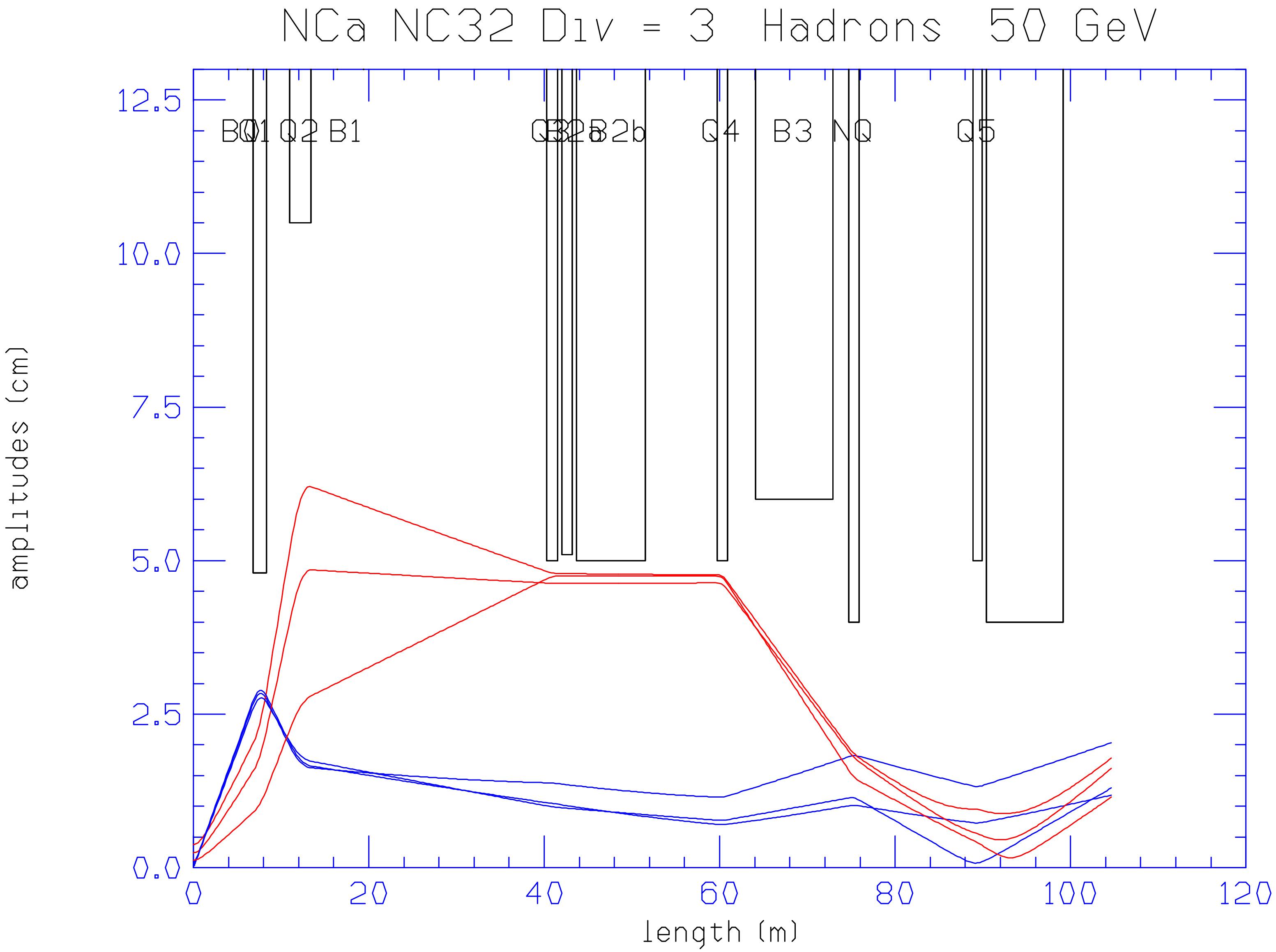
Protons are moving left to right. Electrons right to left.

Gradients and fields in the above tables are for 275 GeV p on 10 GeV e.

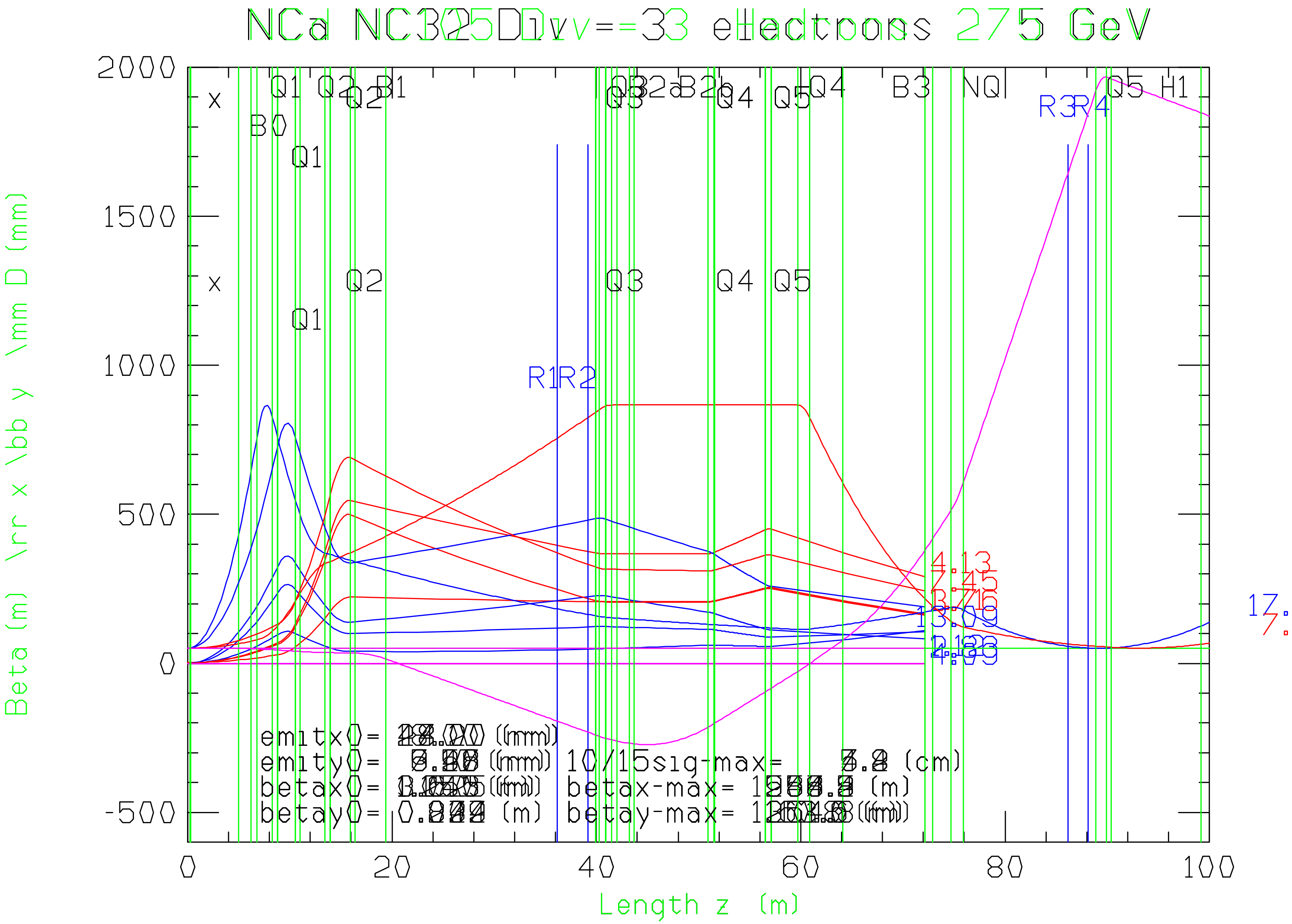
Forward hadron betas



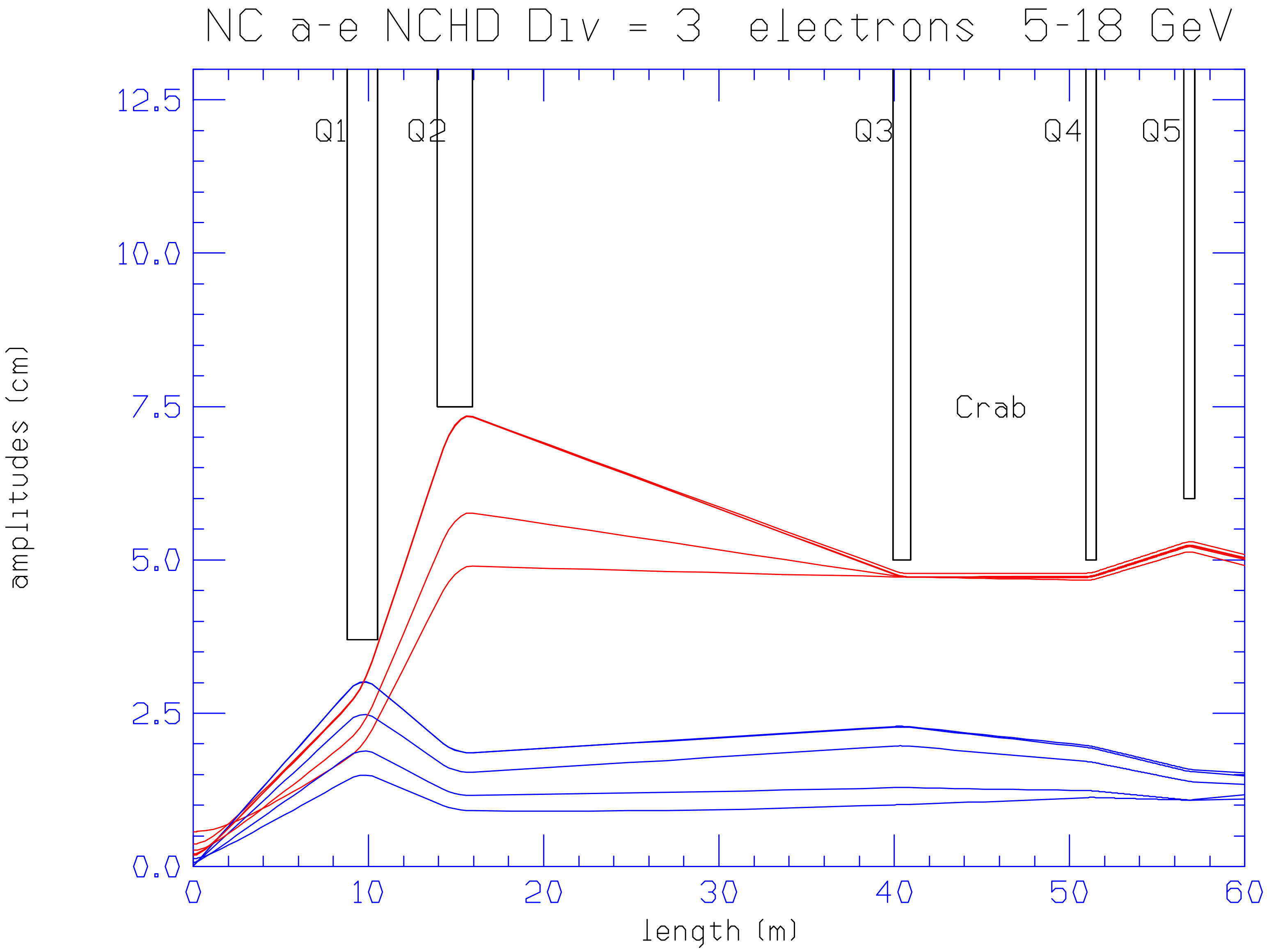
Forward hadron beam sizes



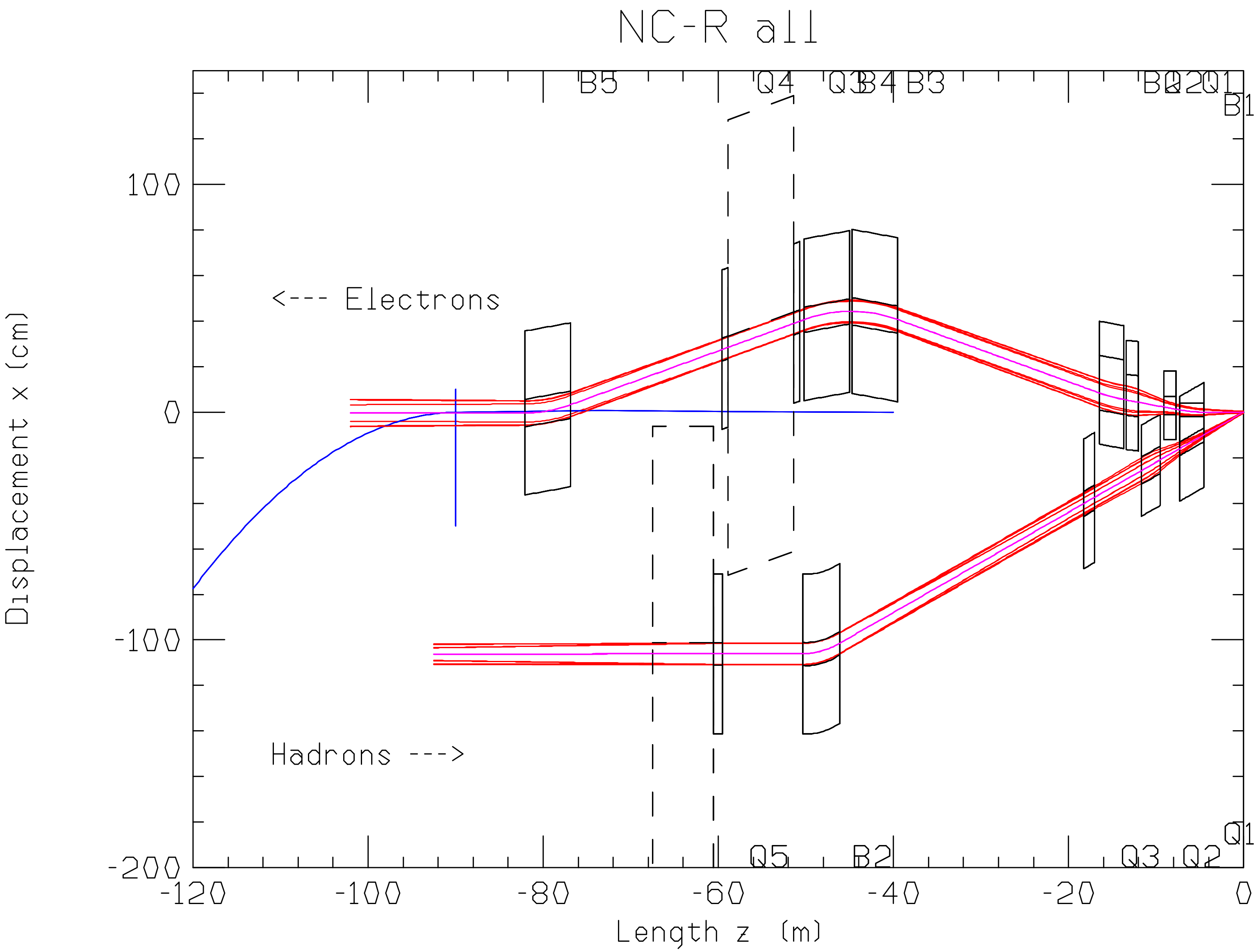
Forward electron betas



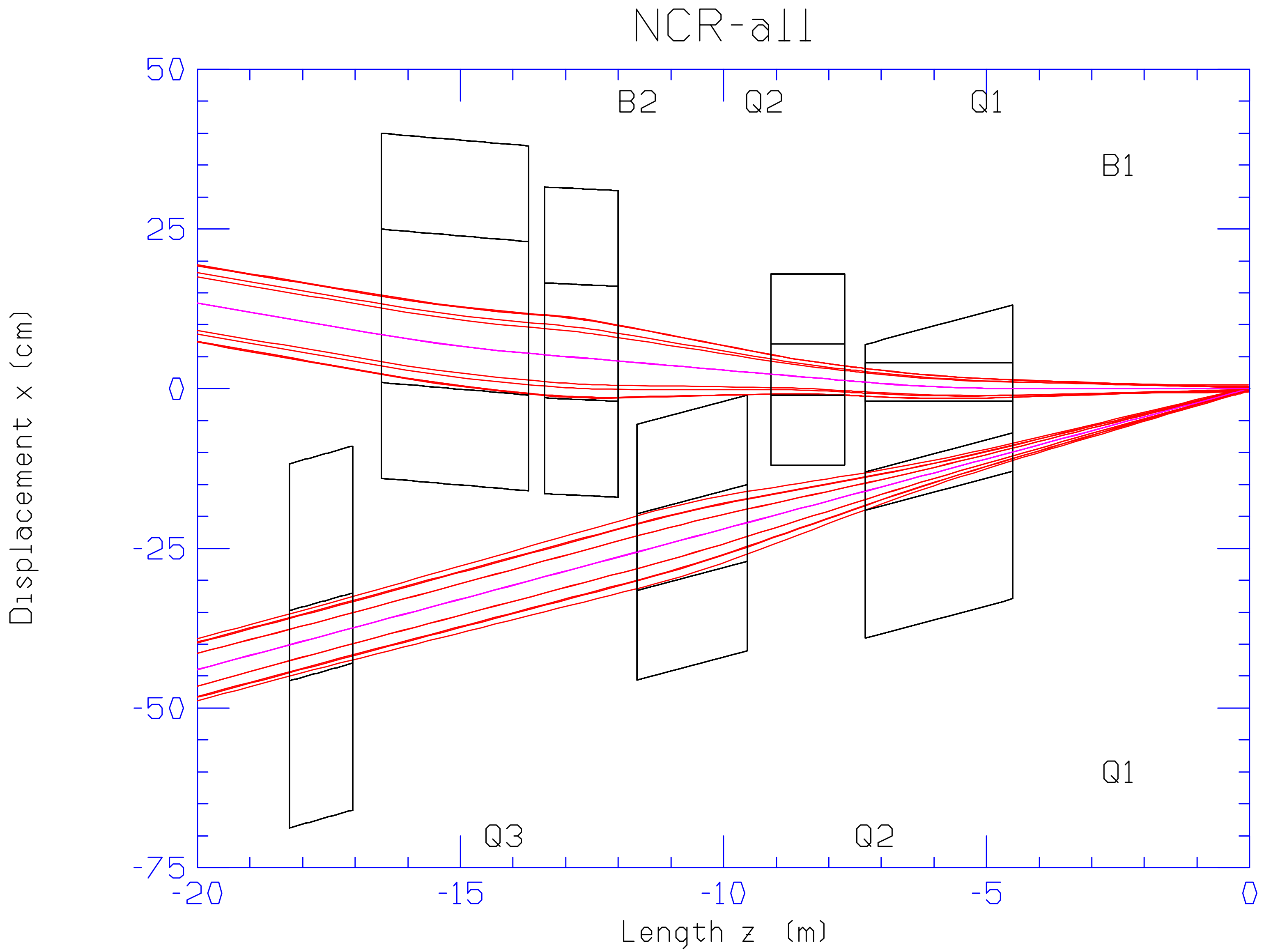
Forward electron beam sizes



Rear Magnets



Rear Detail



NCR-all
B2
Q2
Q1
B1
Q1
Q3
Q2
50
25
0
-25
-50
-75
-20
-15
-10
-5
0
Displacement x (cm)
Length z (m)

Rear Proton Magnets

Protons mom = 275 GeV/c

		L1	DL	gap	x	θ	IR	OR	B	Grad)
		m	m	m	cm	mrad	cm	cm	T	T/m
Q1	3	-4.50	2.80	2.25	-9.9	22.0	3.00	23.0	2.860	-95.333
Q2	5	-9.55	2.10	2.20	-21.0	22.0	6.00	20.0	**4.400**	73.333
Q3	9	-17.05	1.20	21.40	-35.3	22.0	5.50	28.5	1.639	-29.792
B2	13	-46.15	4.19	9.20	-101.5	11.00	5.10	35.1	4.807	3.529
Q5	15	-59.54	1.00	7.00	-106.1	0.00	5.00	35.0	0.568	11.367
Q6	17	-67.54	1.00	24.00	-106.2	0.00	5.00	35.0	0.000	0.000

L1 is location of magnet end furthest from IP

new rear hadrons

E_{com}	P_p	Q1		Q2		Q3		B2	Q5	
		B	grad	B	grad	B	grad	B	B	grad
GeV	GeV/c	B	T/m	B	T/m	B	T/m	B	B	T/m
NC32	50	0.5350	-17.8333	0.8900	14.8333	0.2017	-3.6667	0.8740	0.0117	0.2333
NC45	100	1.0700	-35.6667	1.6000	26.6667	0.1412	-2.5667	1.7480	0.0233	0.4667
NC63	100	1.0700	-35.6667	1.6100	26.8333	0.1742	-3.1667	1.7480	0.0333	0.6667
NC105	275	2.8600	-95.3333	4.4000	73.3333	1.6385	-29.7917	4.8070	3.5292	0.5683
NC140	275	2.8600	-95.3333	4.4275	73.7917	1.6385	-29.7917	4.8070	3.4833	0.5683

Rear Electron Magnets mom = 10 GeV/c

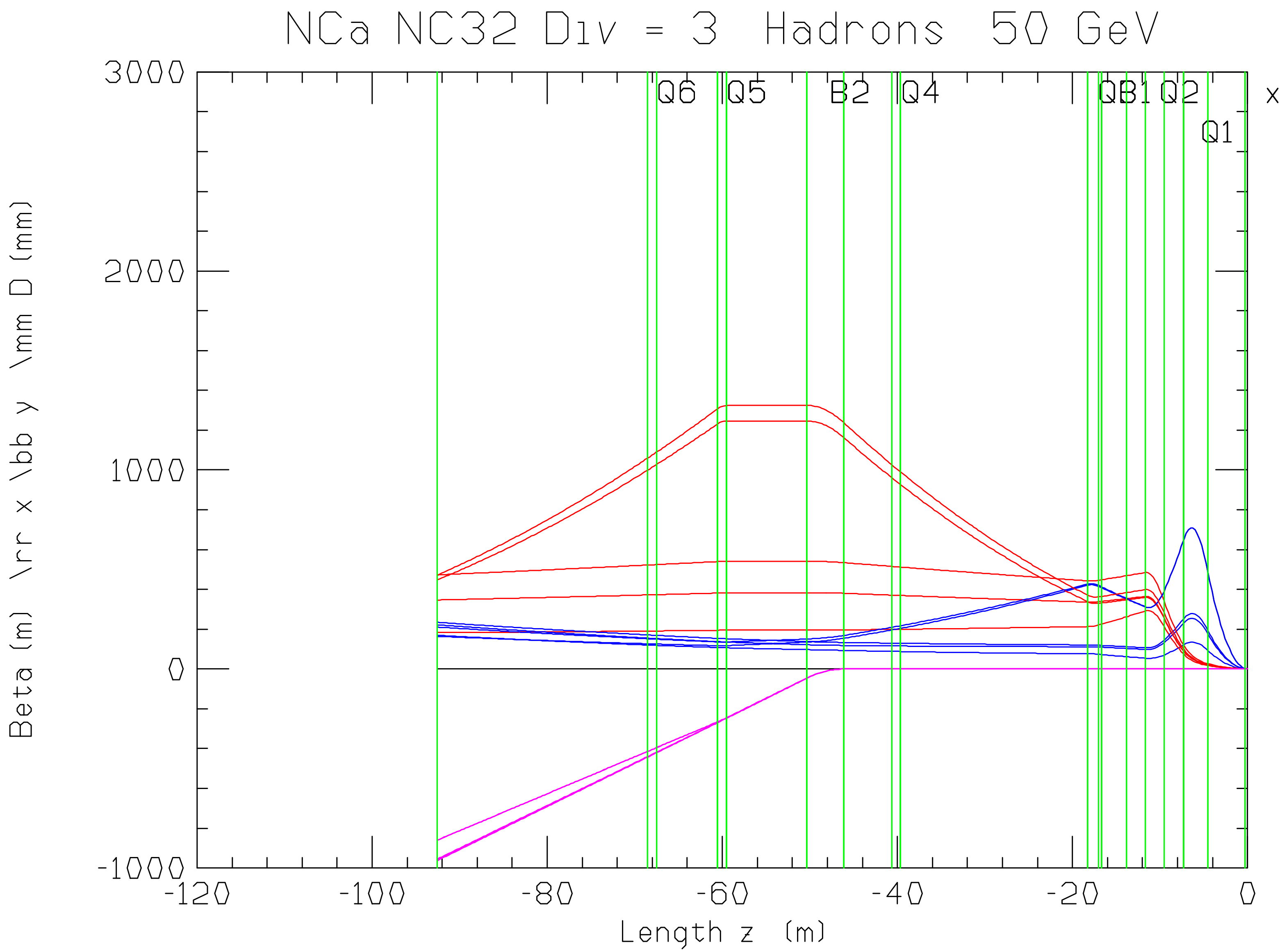
new rear electrons

		L1	DL	gap	x	θ	IR	OR	B	Grad)
		m	m	m	cm	mrad	cm	cm	T	T/m
B1	3	4.50	2.80	0.40	1.0	0.00	3.00	3.0	0.083	0.000
Q1	5	7.70	1.40	2.90	3.0	0.00	5.00	16.0	0.263	-5.267
Q2	7	12.00	1.40	0.30	7.0	4.0	9.00	24.0	0.325	3.617
B2	9	13.70	2.80	23.00	9.0	7.0	12.00	27.0	0.083	0.000
B3	11	39.50	5.20	0.30	40.6	7.0	6.00	36.0	-0.090	0.000
B4	13	45.00	5.20	0.50	44.2	-7.0	5.50	35.5	-0.090	0.000
Q3	15	50.70	0.70	7.50	39.9	-14.0	5.00	35.0	0.020	-0.400
Q4	17	58.90	0.70	17.26	28.4	-14.0	5.00	35.0	0.013	-0.267
B5	19	76.86	5.20	20.00	3.3	-7.0	6.00	36.0	0.090	0.000

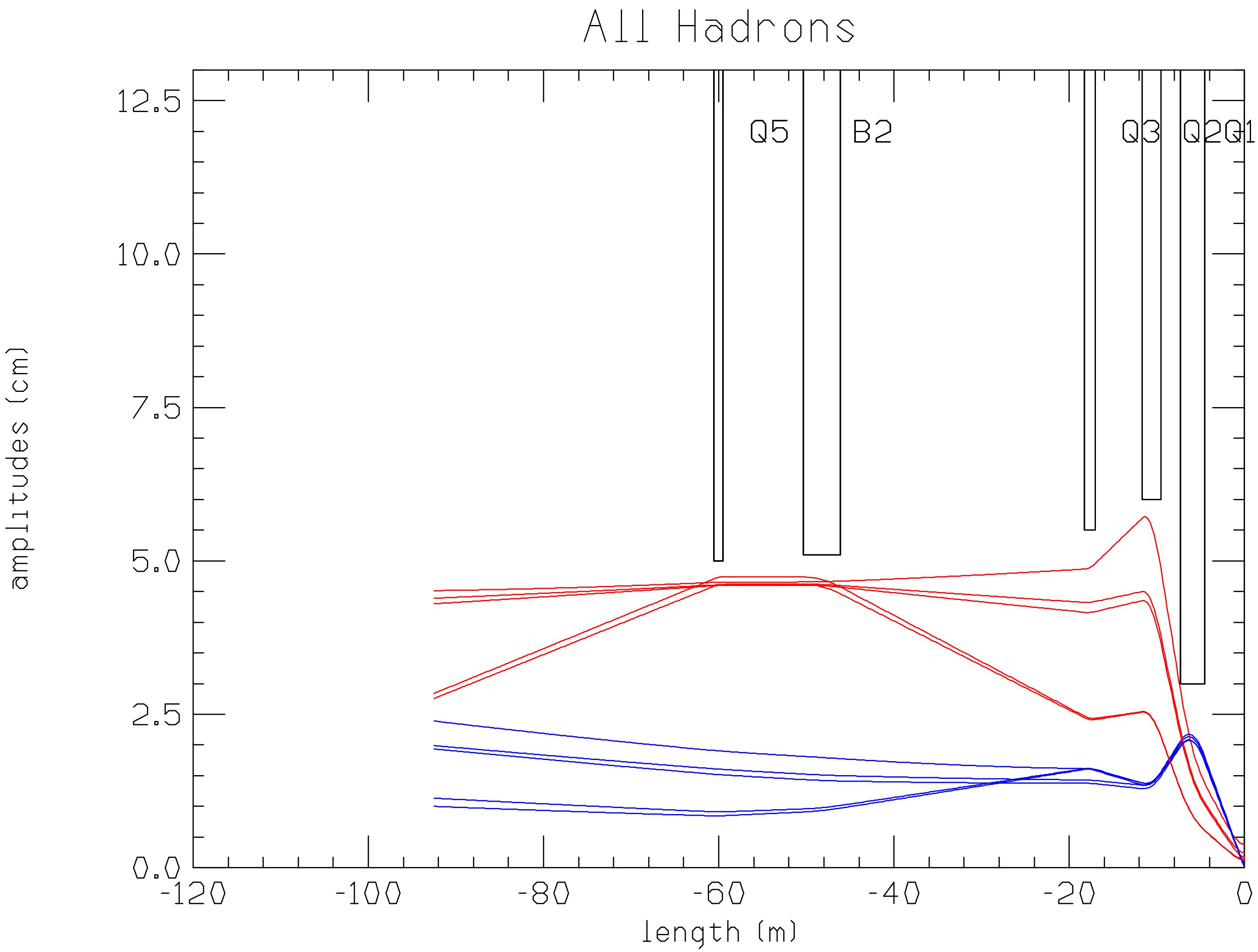
new rear electrons

E_{com}	P_e	B1	Q1		Q2		B2	B3	B4	Q3		Q4		B5
		B	B	grad	B	grad	B	B	B	B	grad	B	grad	B
GeV	GeV/c	T	B	T/m	B	T/m	B	T	T	B	T/m	B	T/m	T
NC32	5	0.0417	0.1317	-2.6333	0.1515	1.6833	0.0417	-0.0449	-0.0449	0.0033	0.0667	0.0067	0.1333	0.0449
NC45	5	0.0417	0.1317	-2.6333	0.1632	1.8133	0.0417	-0.0449	-0.0449	0.0108	-0.2167	0.0067	-0.1333	0.0449
NC63	10	0.0833	0.2633	-5.2667	0.3135	3.4833	0.0833	-0.0897	-0.0897	0.0033	-0.0667	0.0133	-0.2667	0.0897
NC105	10	0.0833	0.2633	-5.2667	0.3255	3.6167	0.0833	-0.0897	-0.0897	0.0200	-0.4000	0.0133	-0.2667	0.0897
NC140	18	0.1500	0.4980	-9.9600	0.5940	6.6000	0.1500	-0.1615	-0.1615	0.0369	-0.7380	0.0240	-0.4800	0.1615

Rear Protons Betas

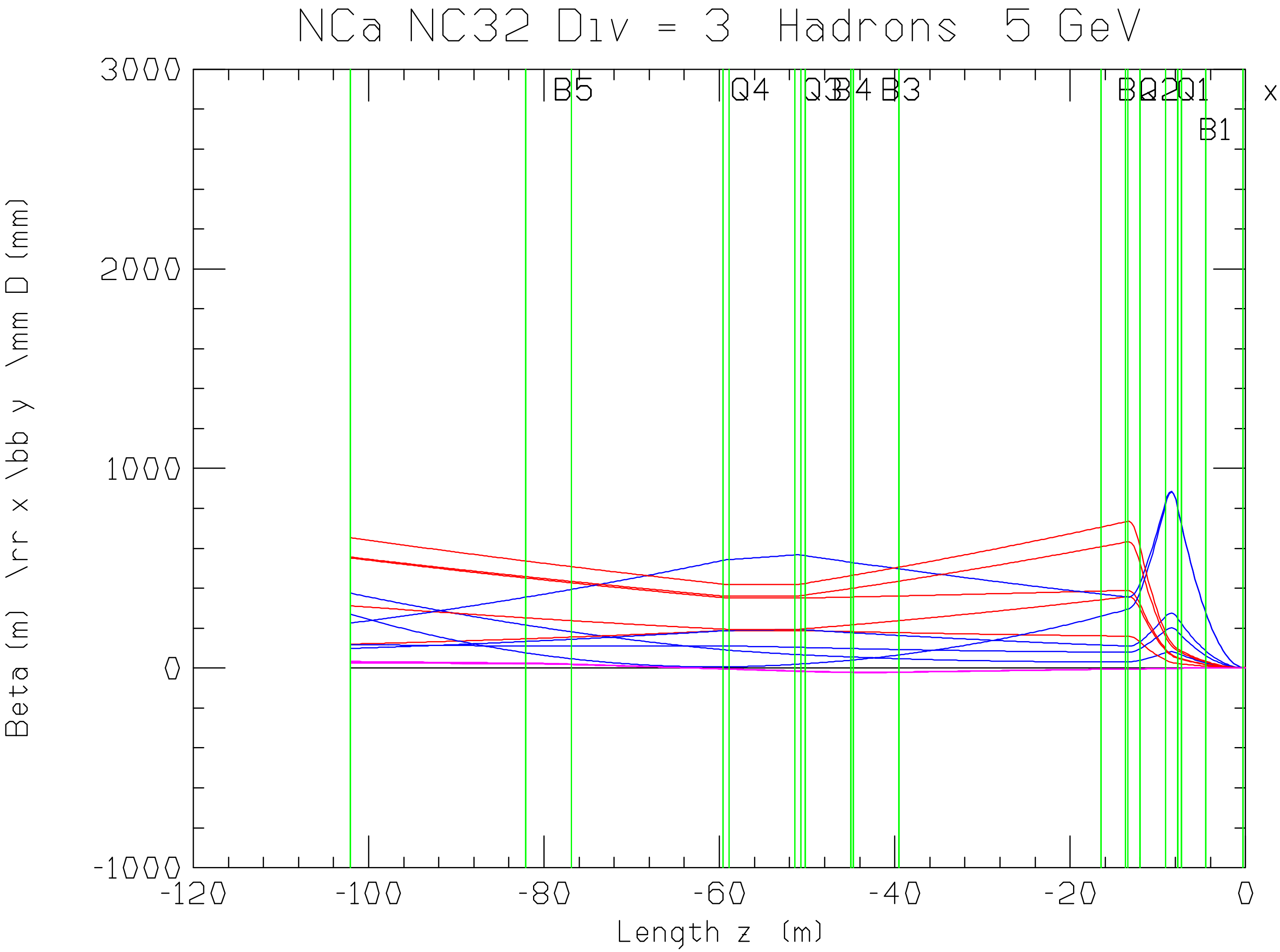


Rear proton beam sizes (all)

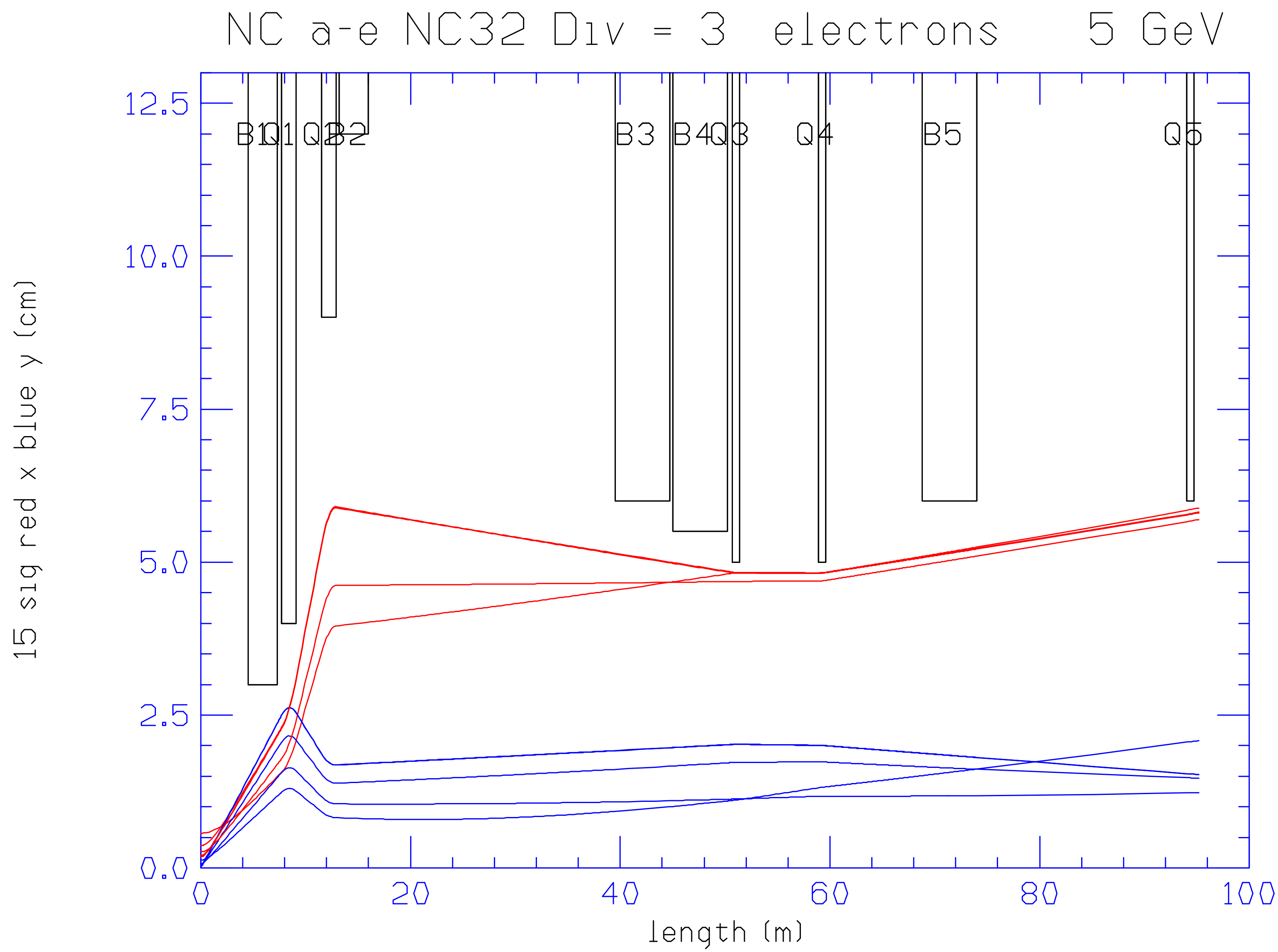


Beam size at crab cavity between Q5 abd Q6 is set just below 5 cm for all cases.

Rear electrons betas



Rear electrons beam sizes



To Be Done

- Include magnet locations in Brett/Elke coordinates
- Clean up the figures
- Generate parameters for Low Divergence cases
- Get parameters for Au-e cases
- get parameters with moderate and strong cooling
- Get magnet settings for a subset of these other cases
- Write this all up
- Re-visit use of Roman Pot data