SR fan using Steve's MAD output
and
Modified e lattice for Crab location

At IR meeting

19/08/23

Bob Palmer

Machine parameters v6

Initial HD

PARAMETERS	Proton	Electron		Proton	Electron		Proton	Electron		Proton	Electron		Proton	Electron
energy, GeV	275	18		275	10		100	10		100	5		41	5
relativistic factor	293.1	35225.1		293.1	19569.5		106.6	19569.5		106.6	9784.8		43.7	9784.8
bunch_intensity,E10	10.014	2.099		9.789	22.02		7.64	22.02		6.145	22.02		6.892	22.02
number_of_bunches	290			290			290			290			290	
beam_current,A	0.36	0.076		0.36	0.8		0.28	0.8		0.22	0.8		0.25	0.8
rms_normaliz._emittance,h/v_um	5.9/2.50	845/96.6		5.9/2.50	391/96.6		3.1/2.50	391/100.0		2.7/2.50	196/100.0		2.5/2.50	196/113.3
rms_emittance,h/v_nm	20.3/8.5	24.0/2.7		20.3/8.5	20.0/4.9		29.2/23.5	20.0/5.1		25.4/23.5	20.0/10.2		57.2/57.2	20.0/11.6
emittance_y/emittance_x	0.421	0.114		0.421	0.247		0.805	0.256		0.922	0.511		1	0.579
beta,h/v_cm	90/5.9	76/18.4		90/5.9	91/10.2		90/16.2	131/74.6		90/16.2	115/37.3		118/39.6	338/195.9
IP_beam_size,h/v_um	135/22.4	135/22.4		135/22.4	135/22.4		162/61.7	162/61.7		151/61.7	151/61.7		260/150.6	260/150.6
K=sgm_y/sgm_x	0.166			0.166			0.381			0.408			0.579	
IP_rms_ang_spread,h/v_urad	150/380	178/122		150/380	148/220		180/380	123/83		168/380	132/166		220/380	77/77
beam-beam_parameter,h/v	0.001/0.000	0.046/0.066		0.008/0.003	0.096/0.065		0.013/0.006	0.063/0.095		0.014/0.006	0.100/0.080		0.014/0.008	0.100/0.100
long._bunch_area,evs	0.8			0.8			0.6			0.6			0.5	
rms_bunch_length,cm	9.9	0.85		9.9	0.83		11	0.83		11	0.85		13	0.85
rms_energy_spread,e-4	4.7	10.9		4.7	5.8		8.7	5.8		8.7	6.8		14.9	6.8
max_space_charge	0.001	neglig.		0.001	neglig.		0.004	neglig.		0.004	neglig.		0.021	neglig.
Piwinski_angle,rad	8.1	0.7		8.1	1.6		7.5	1.4		8	1.5		5.5	0.8
Longit._IBS_time,h	8			8			8.28			9.44			17	
Transv._IBS_time,h	18.6			18.61			8			8			8	
lumi_factor	0.83			0.81			0.89			0.88			0.9	
luminosity,E33	0.1			1.05			0.27			0.23			0.06	

... Initial Scope-HD | Moderate Lumi Scope-HA | Moderate Lumi Scope-HD | Fl ...

Medium HD

PARAMETERS	Proton	Electron		Proton	Electron		Proton	Electron		Proton	Electron		Proton	Electron
energy, GeV	275	18		275	10		100	10		100	5		41	5
relativistic factor	293.1	35225.1		293.1	19569.5		106.6	19569.5		106.6	9784.8		43.7	9784.8
bunch_intensity,E10	15.782	7.294		10.357	34.407		7.64	26.365		6.028	26.365		6.892	24.256
number_of_bunches	290			580			580			580			580	
beam_current,A	0.57	0.265		0.75	2.5		0.56	1.916		0.44	1.916		0.5	1.762
rms_normaliz._emittance,h/v_um	5.9/2.50	845/100.9		4.7/2.50	391/96.6		3.1/2.50	391/100.0		3.1/2.50	196/99.5		2.5/2.50	196/113.3
rms_emittance,h/v_nm	20.3/8.5	24.0/2.9		16.1/8.5	20.0/4.9		29.2/23.5	20.0/5.1		29.2/23.5	20.0/10.2		57.2/57.2	20.0/11.6
emittance_y/emittance_x	0.421	0.119		0.53	0.247		0.805	0.256		0.805	0.509		1	0.579
beta,h/v_cm	90/5.9	76/17.6		90/5.9	72/10.2		90/16.2	131/74.6		90/16.2	131/37.5		118/39.6	338/195.9
IP_beam_size,h/v_um	135/22.4	135/22.4		120/22.4	120/22.4		162/61.7	162/61.7		162/61.7	162/61.7		260/150.6	260/150.6
K=sgm_y/sgm_x	0.166			0.186			0.381			0.381			0.579	
IP_rms_ang_spread,h/v_urad	150/380	178/128		134/380	166/220		180/380	123/83		180/380	123/165		220/380	77/77
beam-beam_parameter,h/v	0.003/0.001	0.072/0.100		0.015/0.005	0.100/0.076		0.015/0.007	0.063/0.095		0.015/0.007	0.100/0.075		0.015/0.009	0.100/0.100
long._bunch_area,evs	0.8			0.8			0.6			0.6			0.5	
rms_bunch_length,cm	7	0.9		7	2		11	2		11	2		13	2
rms_energy_spread,e-4	6.6	10.9		6.6	5.8		8.7	5.8		8.7	6.8		14.9	6.8
max_space_charge	0.002	neglig.		0.001	neglig.		0.004	neglig.		0.003	neglig.		0.021	neglig.
Piwinski_angle,rad	5.7	0.7		6.4	1.8		7.5	1.4		7.5	1.4		5.5	0.8
Longit._IBS_time,h	8			10.7			8.28			10.5			16.98	
Transv._IBS_time,h	9.67			10.3			8			10.14			8.05	
lumi_factor	0.91			0.9			0.89			0.88			0.9	
luminosity,E33	**0.63**			**4.28**			**0.54**			**0.51**			**0.14**	

Moderate Lumi Scope-HD | Full Scope-HA | Full Scope-HD | Initial Scope-HA ...

Full Scope HD

PARAMETERS	Proton	Electron		Proton	Electron		Proton	Electron		Proton	Electron		Proton	Electron
energy, GeV	275	18		275	10		100	10		100	5		41	5
relativistic factor	293.1	35225.1		293.1	19569.5		106.6	19569.5		106.6	9784.8		43.7	9784.8
bunch_intensity,E10	20.444	7.294		6.881	17.203		6.881	17.203		4.658	17.203		2.639	13.294
number_of_bunches	290			1160			1160			1160			1160	
beam_current,A	0.74	0.265		1	2.5		1	2.5		0.68	2.5		0.38	1.932
rms_normaliz._emittance,h/v_um	4.6/0.74	845/71.2		2.8/0.45	391/23.9		4.0/0.22	391/25.4		2.7/0.27	196/20.0		1.9/0.45	196/34.2
rms_emittance,h/v_nm	15.8/2.5	24.0/2.0		9.6/1.5	20.0/1.2		37.1/2.1	20.0/1.3		25.1/2.6	20.0/2.0		43.6/10.3	20.0/3.5
emittance_y/emittance_x	0.159	0.084		0.158	0.061		0.056	0.065		0.102	0.102		0.236	0.175
beta,h/v_cm	90/4.0	59/5.0		90/4.0	43/5.0		90/4.0	167/6.4		90/4.0	113/5.0		90/7.1	196/21.0
IP_beam_size,h/v_um	119/10.1	119/10.1		93/7.8	93/7.8		183/9.1	183/9.1		150/10.1	150/10.1		198/27.1	198/27.1
K=sgm_y/sgm_x	0.084			0.084			0.05			0.067			0.137	
IP_rms_ang_spread,h/v_urad	133/251	201/201		103/195	215/156		203/227	109/143		167/253	133/202		220/380	101/129
beam-beam_parameter,h/v	0.004/0.002	0.100/0.100		0.014/0.007	0.073/0.100		0.010/0.009	0.075/0.057		0.015/0.010	0.100/0.066		0.015/0.009	0.053/0.042
long._bunch_area,evs	0.68			0.68			0.4			0.4			0.2	
rms_bunch_length,cm	6	0.9		6	2		7	2		7	2		7.5	2
rms_energy_spread,e-4	6.6	10.9		6.6	5.8		9	5.8		9	6.8		10.4	6.8
max_space_charge	0.006	neglig.		0.003	neglig.		0.028	neglig.		0.019	neglig.		0.05	neglig.
Piwinski_angle,rad	5.5	0.8		7.1	2.4		4.2	1.2		5.1	1.5		4.2	1.1
Longit._IBS_time,h	2.1			3.41			2			2.6			3.8	
Transv._IBS_time,h	2			2			2.32/2.36			2/4.8			3.4/2.1	
lumi_factor	0.86			0.86			0.85			0.83			0.93	
luminosity,E33	**1.93**			**10.05**			**4.35**			**3.16**			**0.44**	

... | Moderate Lumi Scope-HD | Full Scope-HA | **Full Scope-HD** | Initial Scope-HA ...

Maximum Angular spreads vs. Scopes

	Init.(E) μrad(GeV)	Mod.(E) μrad(GeV)	Full(E) μrad(GeV)	Worst (E) μrad(GeV)	Case
ang x	178 (140)	178(140)	215(106)	215(105)	Full Scope HD
ang y	220(105)	220(105)	202(45)	220(105)	Moderate Scope HD

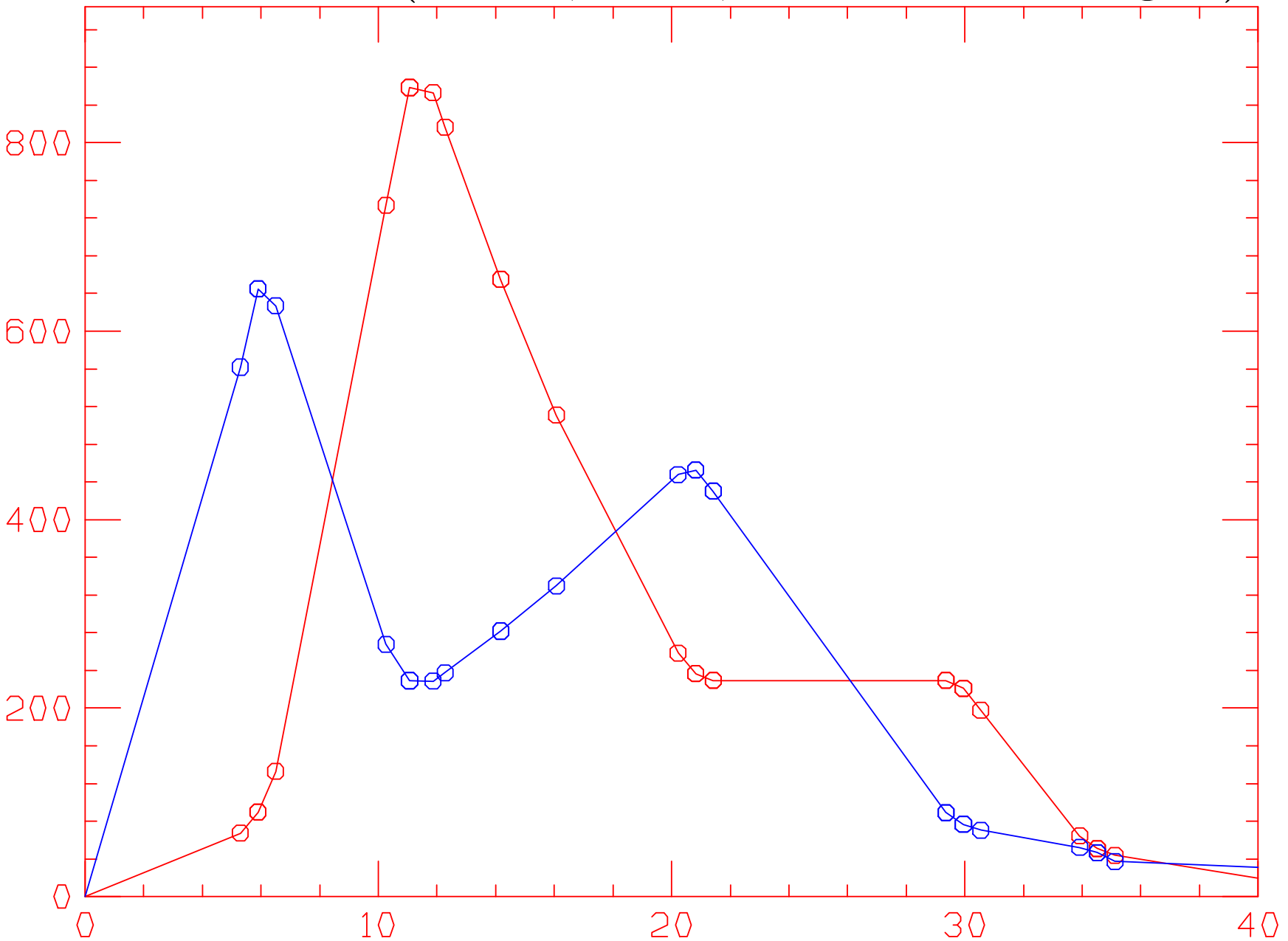
- The maximum x electron divergence = 215 μrad (close to the allowed of 220 μrad) It is for E (c of m)=105 GeV for the Full Scope, with β*=43 cm, ϵ=20 nm
- The maximum y electron divergence = 220 μrad (equal to the allowed of 220 μrad) It is for E (c of m)=105 GeV for the Moderate Scope, with β*=10.2 cm and ϵ=4.9 nm)
- Steve, used β_x^*=42 cm, which with ϵ=19.7 nm gives 215 μrad and β_y^*=5 cm which with ϵ=1.7 nm gives 220 μrad

Note that by using geometric emittances, these parameters are independent of the beam energies

Betas and beam sizes vs. length

- I note that Steve's v6 simulations use Q0eF strength and locations and Q2eF locations that are identcal to mine.
- I use Steve's MAD output to get betas in x
- These are very close to mine.
- I use an emittance of 20 e-9 (near enough to 19.7) to calculate beam sizes for two cases:
  1. 15 sigma and
  2. 12.5 sigma (used to find synchrotron fans assuming 12.5 sigma collimation elsewhere in the ring

Steve's betas (at start, center, and end of each magnet)

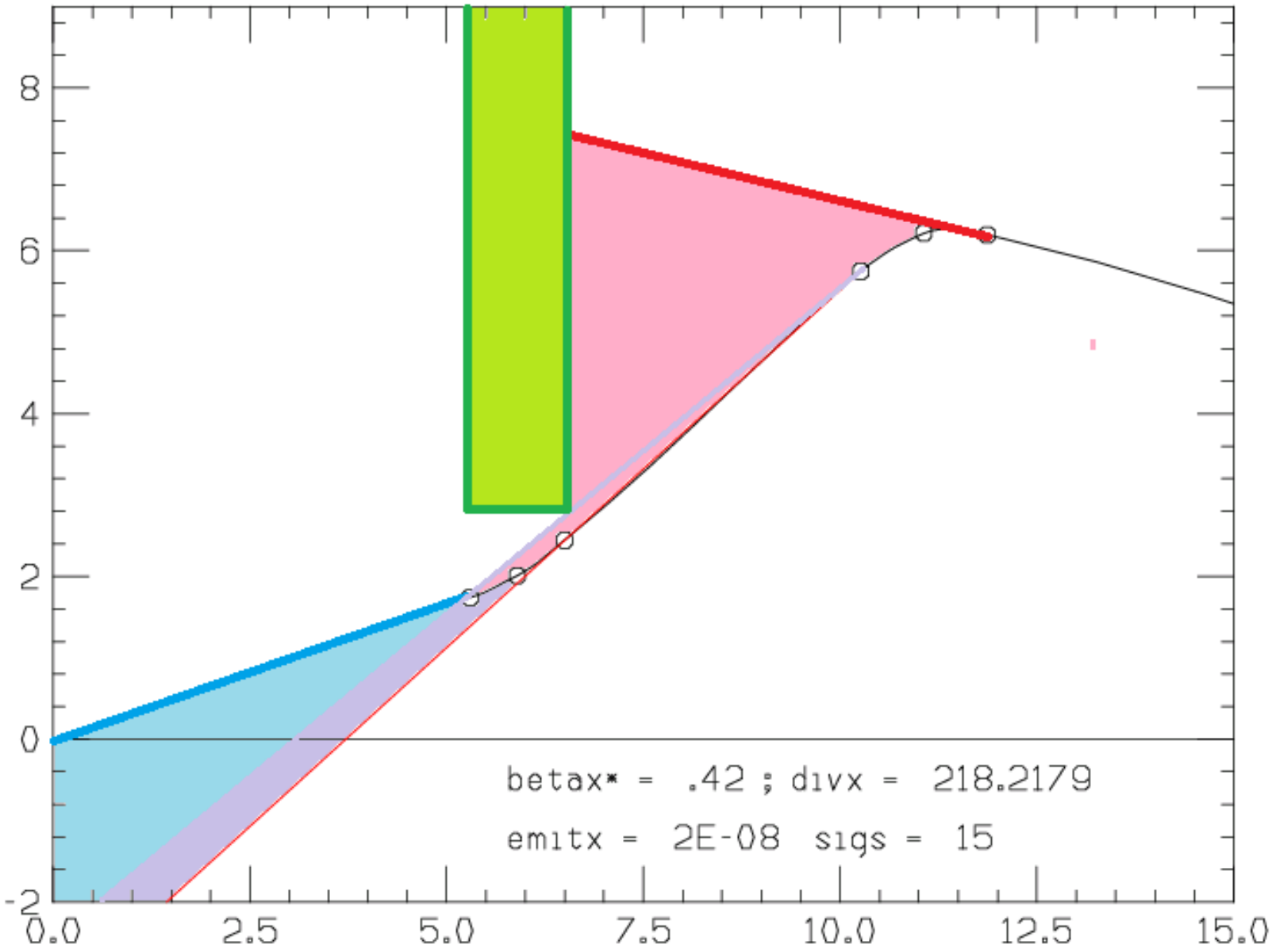


1) 15 sigma parameters

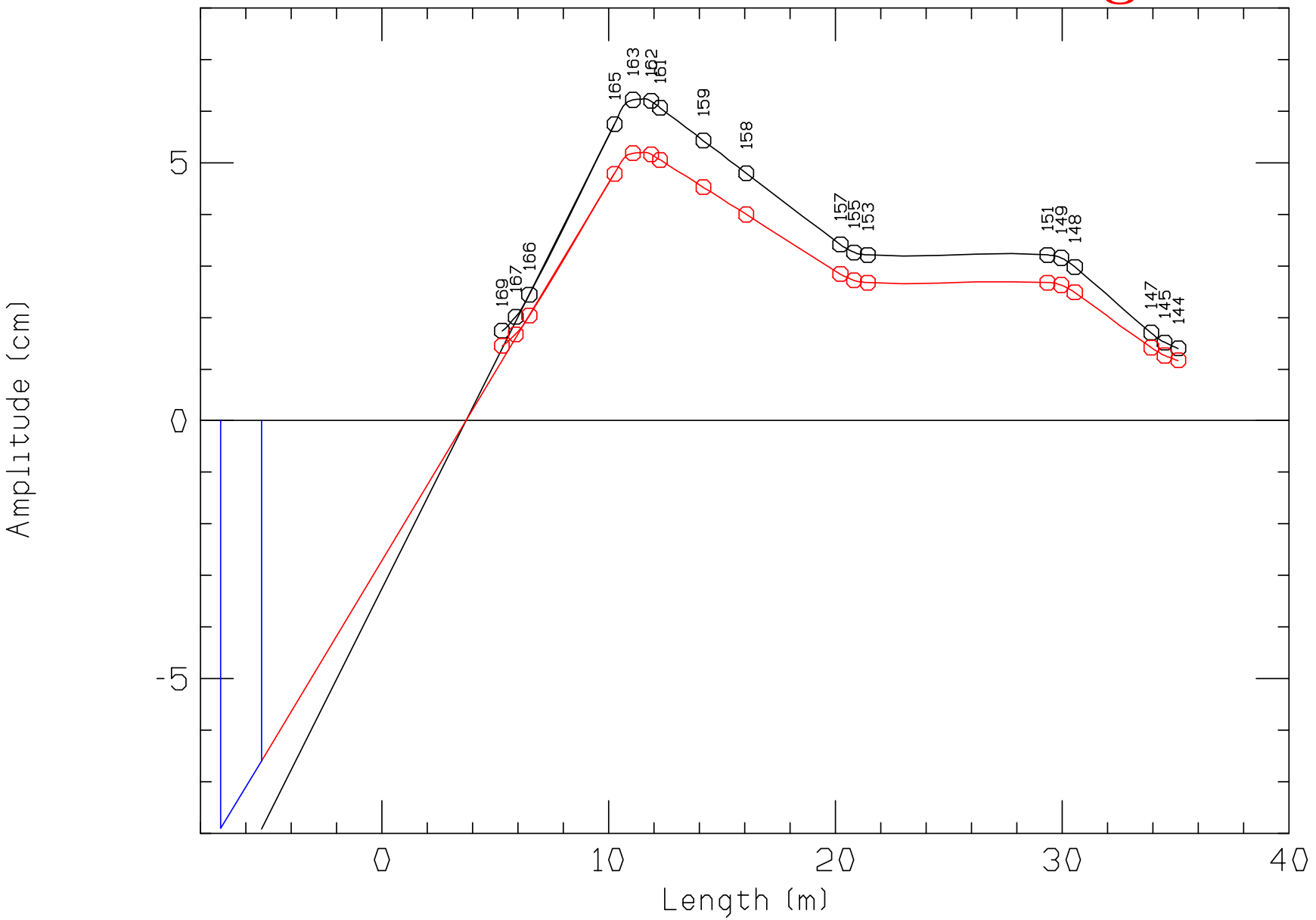
```
emitx =  2E-08   sigs =  15
betax* =  .42 ; divx =  218.2179 ’

 i    strt    L      bx     by      K1L   grad   betax  app(cm)
144   35.115  7.700   43.7  37.45  0.00   0.00   43.7   1.40  ODE7F DRIFT
145   34.515  0.600   51.0  46.71 -0.08  -8.20   51.0   1.51  HQ5EF_5 QUADRUPOLE
147   33.915  0.600   64.4  52.06 -0.08  -8.20   64.4   1.70  HQ5EF_5 QUADRUPOLE
-------------------------------------------------------------------------------
148   30.550  3.365 197.6  70.36  0.00   0.00 197.6   2.98  ODE6F DRIFT
149   29.950  0.600 221.1  76.63  0.06   6.07 221.1   3.15  HQ4EF_5 QUADRUPOLE
151   29.350  0.600 229.3  89.11  0.06   6.07 229.3   3.21  HQ4EF_5 QUADRUPOLE
-------------------------------------------------------------------------------
153   21.420  7.930 229.3 430.14  0.00   0.00 229.3   3.21  ODE5F DRIFT
155   20.820  0.600 236.4 452.66 -0.05  -5.08 236.4   3.26  HQ3EF_5 QUADRUPOLE
157   20.220  0.600 258.5 447.96 -0.05  -5.08 258.5   3.41  HQ3EF_5 QUADRUPOLE
-------------------------------------------------------------------------------
158   16.070  4.150 510.8 329.76  0.00   0.00 510.8   4.79  ODE4F DRIFT
159   14.170  1.900 654.8 281.71  0.00   0.00 654.8   5.43  HQ2EF_5 QUADRUPOLE
161   12.270  1.900 816.6 237.46  0.00   0.00 816.6   6.06  HQ2EF_5 QUADRUPOLE
-------------------------------------------------------------------------------
162   11.870  0.400 853.0 228.63  0.00   0.00 853.0   6.20  ODE3F DRIFT
163   11.065  0.805 858.6 229.09  0.10   7.36 858.6   6.22  HQ1EF_5 QUADRUPOLE
165   10.260  0.805 733.5 267.74  0.10   7.36 733.5   5.75  HQ1EF_5 QUADRUPOLE
-------------------------------------------------------------------------------
166    6.500  3.760 132.7 626.92  0.00   0.00 132.7   2.44  ODE2F DRIFT
167    5.900  0.600  89.8 644.89 -0.14 -13.53  89.8   2.01  HQ0EF_5 QUADRUPOLE
169    5.300  0.600  67.3 561.85 -0.14 -13.53  67.3   1.74  HQ0EF_5 QUADRUPOLE
-------------------------------------------------------------------------------
170   -0.000         0.42   0.05  0.000  0.000  0.137  IR
```

Fans from Q0eF and Q2eF



Beam size and fans for 15 and 12.5 sigma



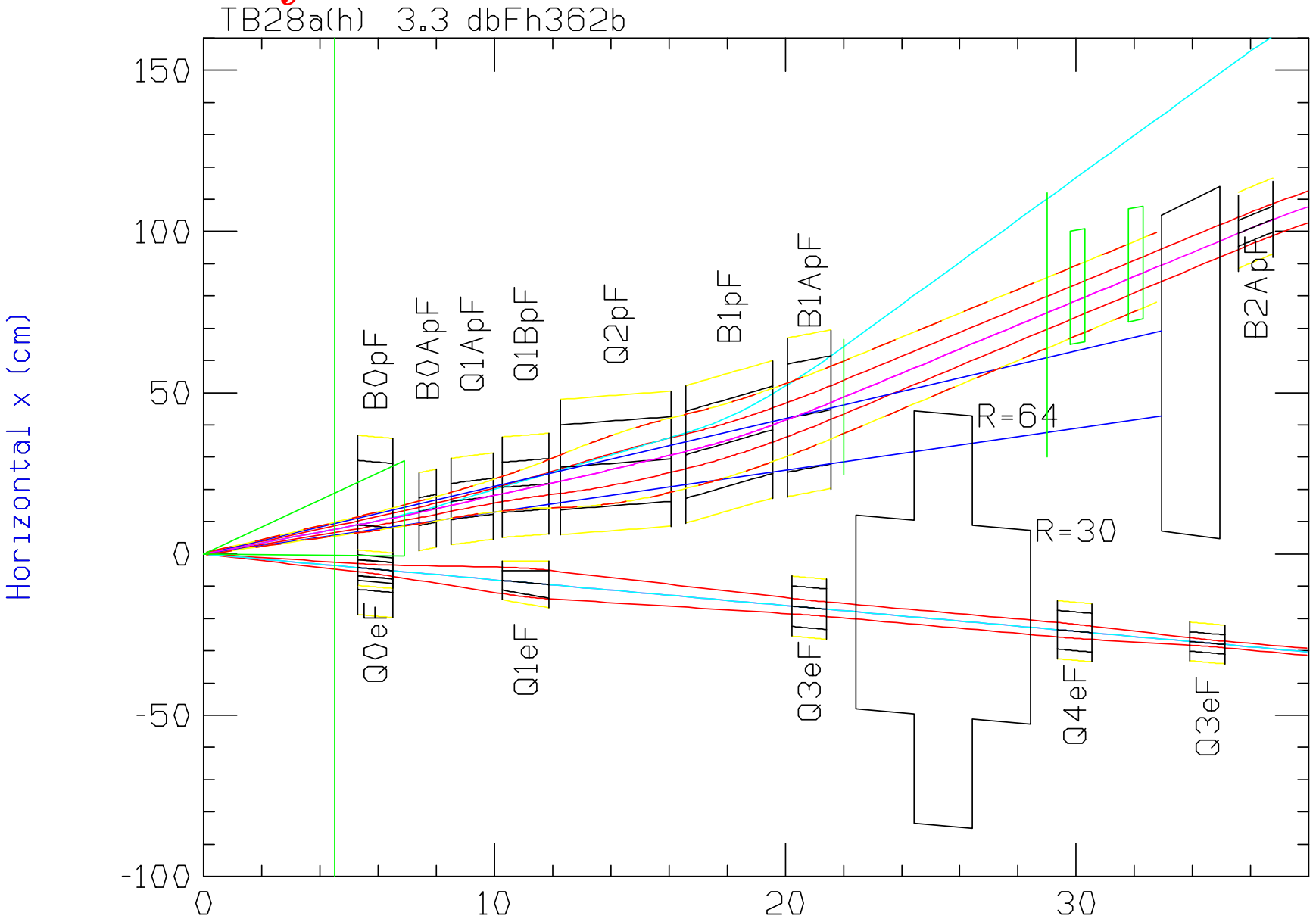
Conclusion on SR

- In Steve's MAD simulation The location and strength of Q0eF is the same as in mine
- Using his betas I calculate beam apertures at
  1)15 sigma and
  2) 12.5 sigma
- I use the divergence between Q0eF and Q2eF to define the SR fan
- The results agree with my earlier simulations showing that the apertures of the rear Q1eR and Q2eR match the fan for 12.5 sigmas.
- This is really just a crosscheck using MAD instead of my program.

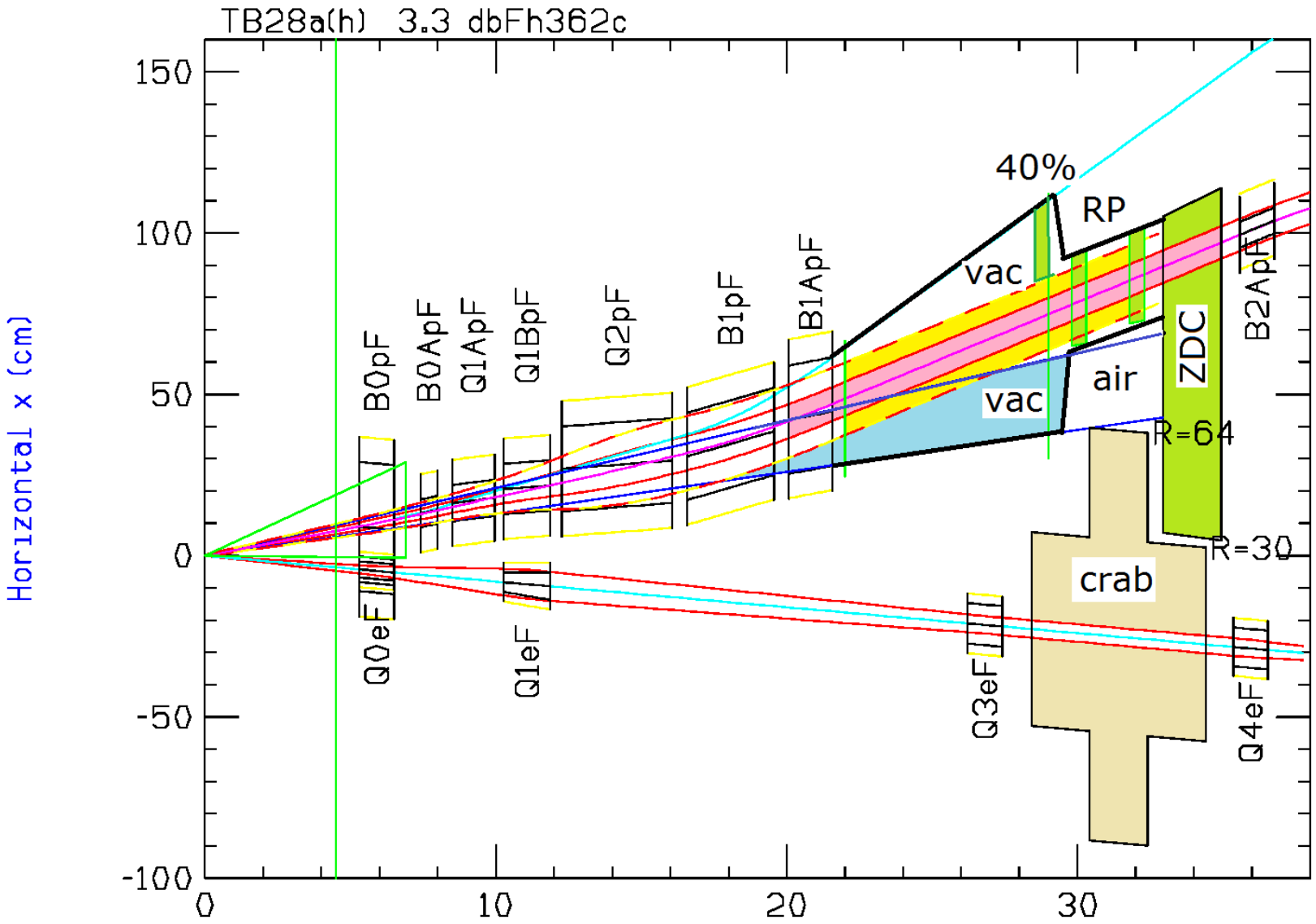
Location for Forward e crab

- With Steve's version 6 there is:
  1. a severe conflict with a 200 MHz crab (R$\approx$ 85 cm)
  2. a finite conflict with a 400 MHz crab (R$\approx$ 64 cm)
- With suggested changes:
  1. a finite conflict with a 200 MHz crab (R$\approx$ 85 cm)
  2. but no conflict with a 400 MHz crab (R$\approx$ 64 cm)

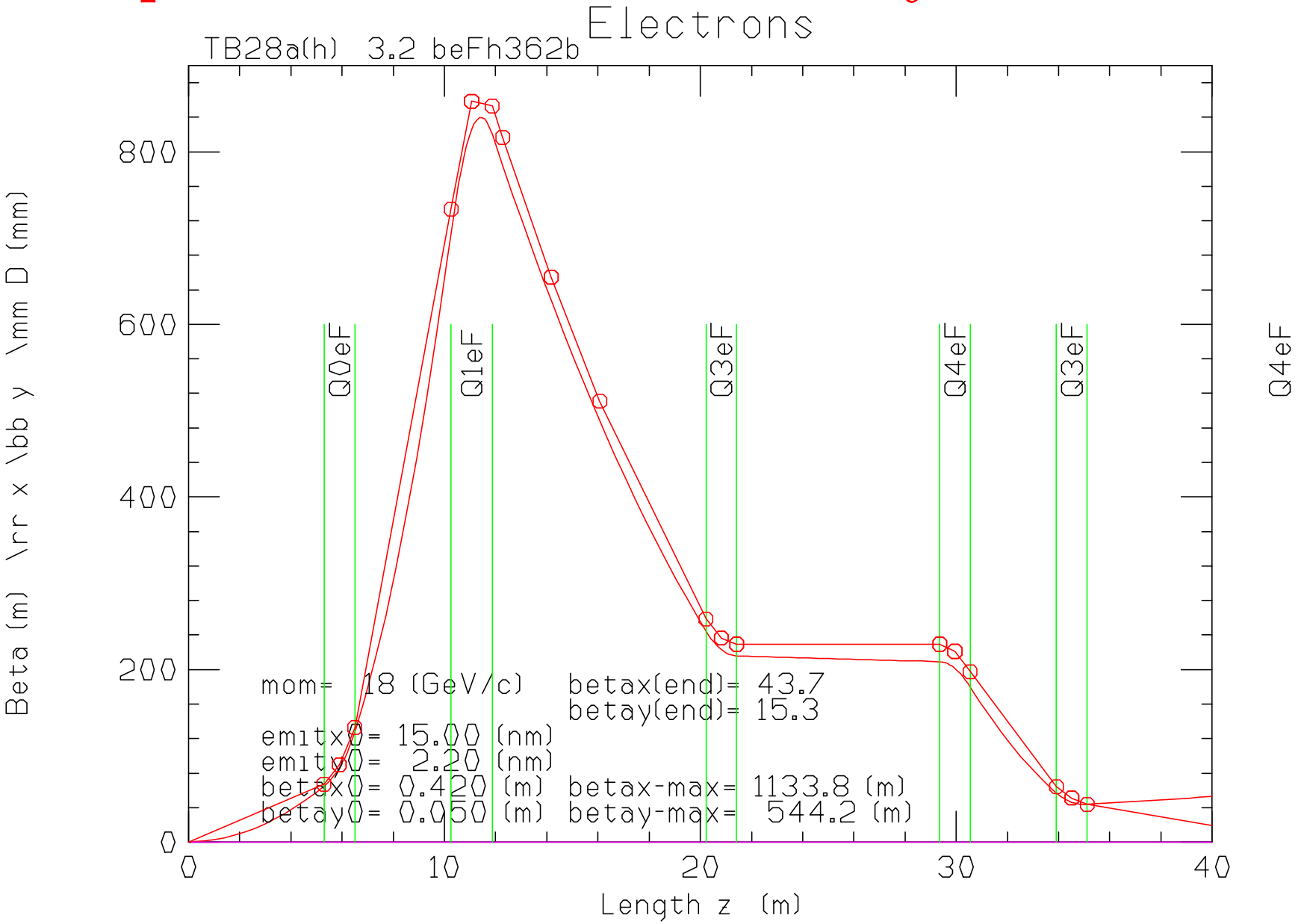
Sreve's layout with 400 MHz



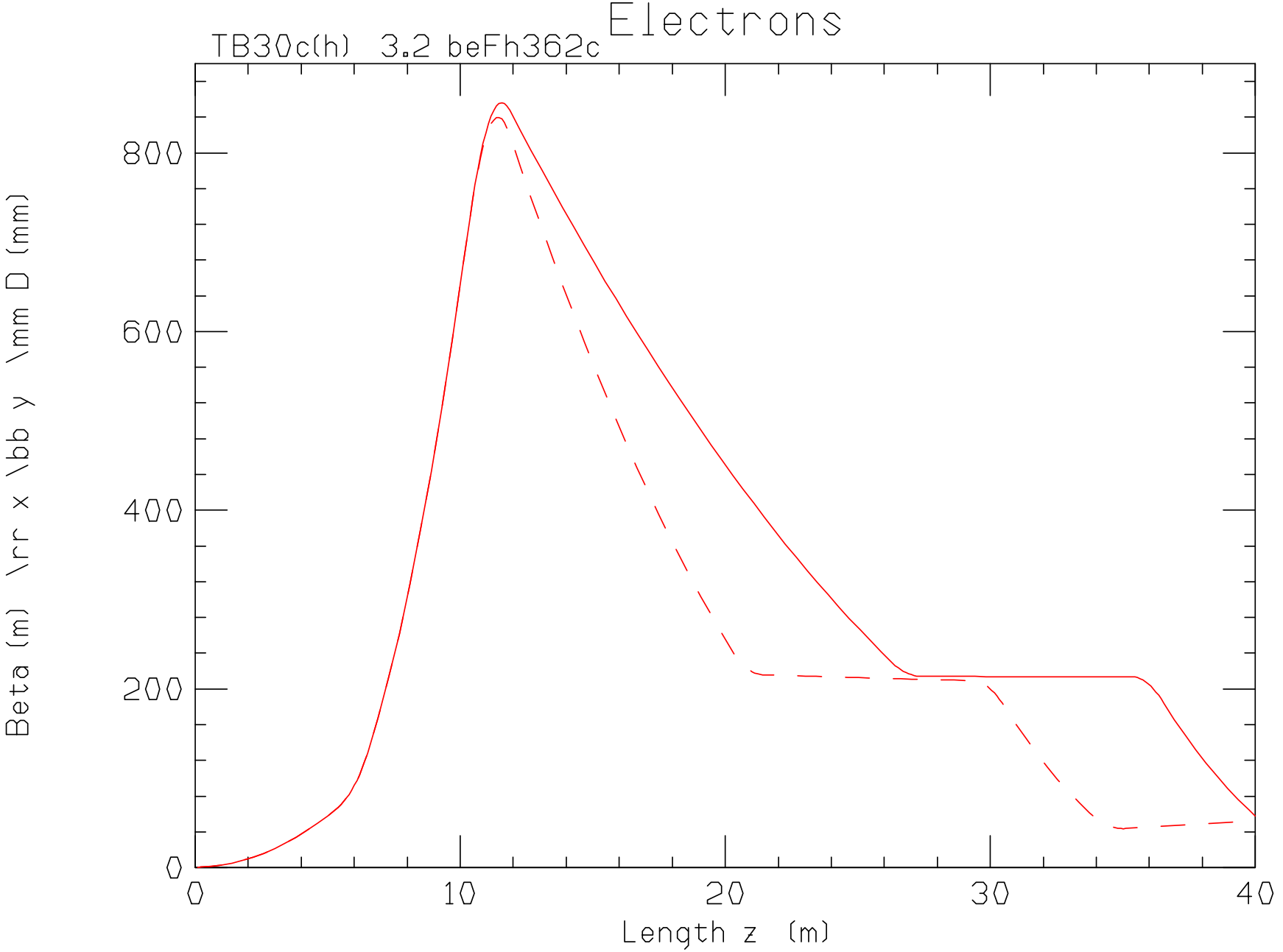
Modified layout with 400 MHz



Compare Steve's MAD with my unmodified



Sreve's and modified betas



Parameters

```
OLD
# TB30b(h)  zeFh362b Electron Forward  18
#
# beta*_x  beta*_y  gm emit_x gm emit_y  angle_x  angle_y    mom
#  [m]      [m]      [nm]     [nm]      [mrad]    [mrad]     GeV/c
 0.4200   0.0500     15.0000    2.2000      25       0        18
#
# name    center_z center_x rad1  rad2  length  angle     B      grad  ap x grad    x1      x2      cc1      cc2
#           [m]      [m]     {m}   [m]    [m]    [mrad]    [T]    [T/m]     [T]     [m]     [m]      [m]      [m]
  Q0eF    5.900  -0.1475  0.025  0.025   1.20    25.0   0.000   -13.540    -0.338   0.0000   0.0000   0.1325   0.1625
  Q1eF   11.065  -0.2766  0.030  0.042   1.61    25.0   0.000     7.365     0.309   0.0000   0.0000   0.2565   0.2968
  Q3eF   20.820  -0.5205  0.063  0.063   1.20    25.0   0.000    -5.084    -0.320   0.0000   0.0000   0.5055   0.5355
  Q4eF   29.950  -0.7488  0.060  0.060   1.20    25.0   0.000     6.074     0.364   0.0000   0.0000   0.7338   0.7638
  Q3eF   34.515  -0.8629  0.030  0.030   1.20    25.0   0.000   -13.475    -0.404   0.0000   0.0000   0.8479   0.8779
  Q4eF   42.645  -1.0661  0.030  0.030   1.20    25.0   0.000   -16.170    -0.485   0.0000   0.0000   1.0511   1.0811
  Q5eF   51.545  -1.2886  0.050  0.050   1.20    25.0   0.000     4.023     0.201   0.0000   0.0000   1.2736   1.3036
#

NEW
# ------------------------------------
# TB30c(h)  zeFh362c Electron Forward  18
#
# beta*_x  beta*_y  gm emit_x gm emit_y  angle_x  angle_y    mom
#  [m]      [m]      [nm]     [nm]      [mrad]    [mrad]     GeV/c
 0.4200   0.0500     15.0000    2.2000      25       0        18
#
# name    center_z center_x rad1  rad2  length  angle     B      grad  ap x grad    x1      x2      cc1      cc2
#           [m]      [m]     {m}   [m]    [m]    [mrad]    [T]    [T/m]     [T]     [m]     [m]      [m]      [m]
  Q0eF    5.900  -0.1475  0.025  0.025   1.20    25.0   0.000   -13.540    -0.338   0.0000   0.0000   0.1325   0.1625
  Q1eF   11.065  -0.2766  0.030  0.042   1.61    25.0   0.000     6.555*    0.275   0.0000   0.0000   0.2565   0.2968
  Q3eF   26.820* -0.6705  0.063  0.063   1.20    25.0   0.000    -3.254*    -0.205   0.0000   0.0000   0.6555   0.6855
  Q4eF   35.950* -0.8988  0.060  0.060   1.20    25.0   0.000     6.074#    0.364   0.0000   0.0000   0.8838   0.9138
  Q3eF   40.515# -1.0129  0.030  0.030   1.20    25.0   0.000   -13.475#    -0.404   0.0000   0.0000   0.9979   1.0279
  Q4eF   48.645# -1.2161  0.030  0.030   1.20    25.0   0.000   -16.170#    -0.485   0.0000   0.0000   1.2011   1.2311
  Q5eF   57.545# -1.4386  0.050  0.050   1.20    25.0   0.000     4.023#     0.201   0.0000   0.0000   1.4236   1.4536
#
                        * on modified values     # will need tuneing for match
```