IR-Parameters-5.1

File 190208-IR.pdf and txt

Robert B.Palmer

02/08/2019

This is an update of the 01/25 meeting Parameters 5 Document. That document reflected changes from the 01/11 after a meeting of Bob Palmer, Brett Parker, and Holger Witte that settled on:

- a tilt and aperture choice of Q2pf that resulted in an increased aperture and 20 cm increase in its length and a move of B1pf.
- Abandonment of special electron lower beta forward design for mon-cooled baseline parameters.
- Increase in electron rear bending B2eR

In this 02/08 version, no changes have been made in magnet strengths and lengths. Changes are:

1. The apertures of Q2BeF has increased from 4.4 & 5.7 cm to 4.5 & 5.9 cm at the smaller and larger ends respectively.
2. The Neutron detector and magnet B2Apf have been moved 5.94 m down stream, allowing much better separation of neutrons and hadrons at Roman Pots and neutron detector. This change reflects Guillaume's latest z-x layout.

There is now also a figure showing calculations of the synchrotron fans.

Conventions

The tables use Brett Parker's conventions:

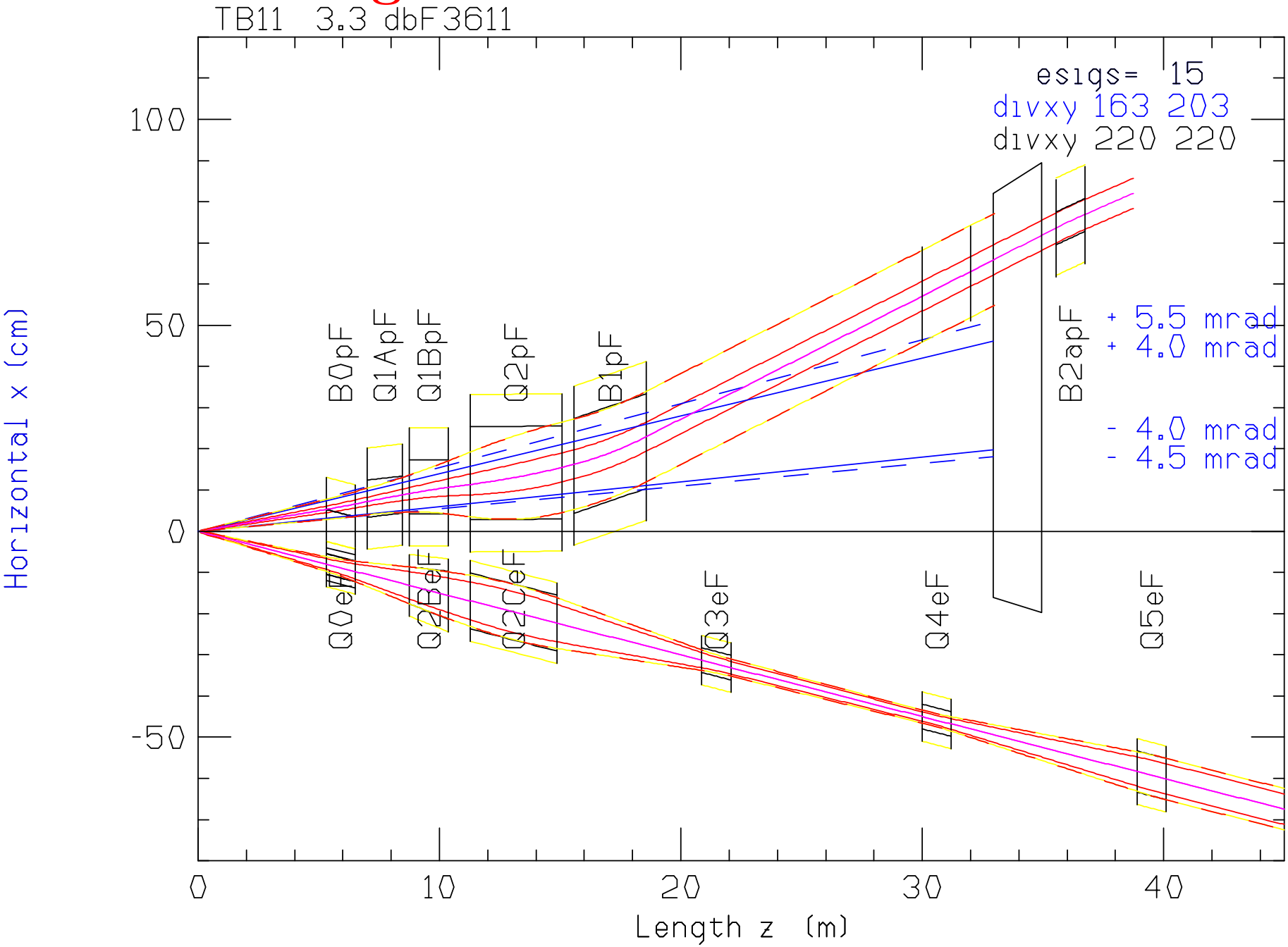
- "rad1" is the minimum inside magnet aperture at the IP end of magnets. "rad2", if tapered, is the larger aperture father from the IP.
- "center-x", "center-y", "center-z" are the horizontal, vertical and distance along the beam, of the magnet centres, with respect to a Z axis passing through the IP parallel with the hadron beam at the IP. x=y=z=0 is at the IP.
- "angle" is the horizontal angle between the magnet axis and the Z axis

Gradients given are only approximate because:

- Matching will likely change them
- My program is not exact

The term "Baseline" is used for 140 GeV c of m, High Divergence, No Cooling.
Apertures for other cases estimated by their greater divergences

Forward magnets



Comments

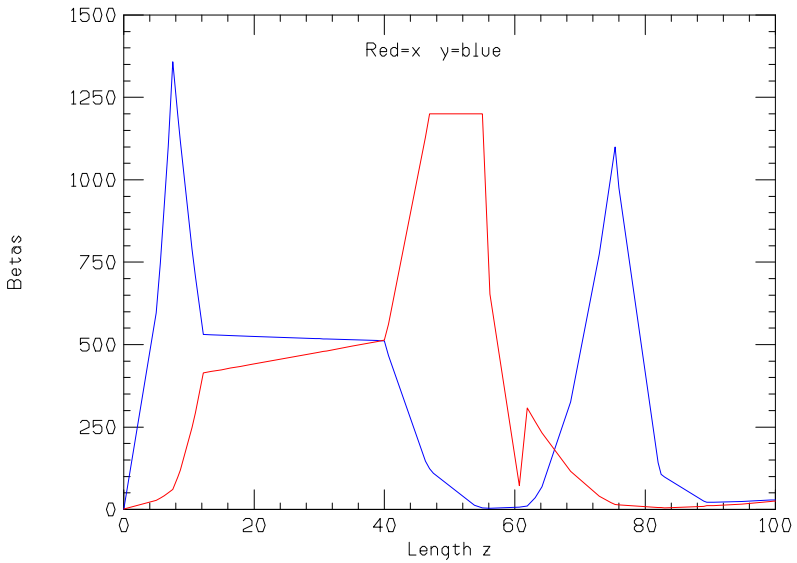
The minimum neutron cone (blue lines) of +/- 4 mrad gives some room for Roman pots on both sides of the beam without blocking the neutrons.

The maximum neutron cone of -4.5 to +5.5 mrad (dashed blue lines), allowed by forward focus magnet apertures, gives almost no room.

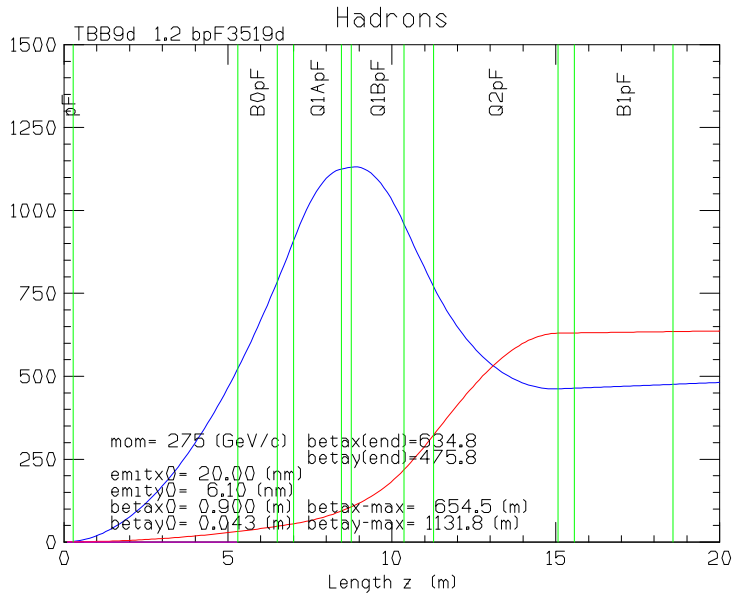
Note that the neutron detector is shown extending 40 cm beyond the neutron cone, as required for good measurement. But this is now beyond the beam, so a hole in is is made for the beam.

The re is just room

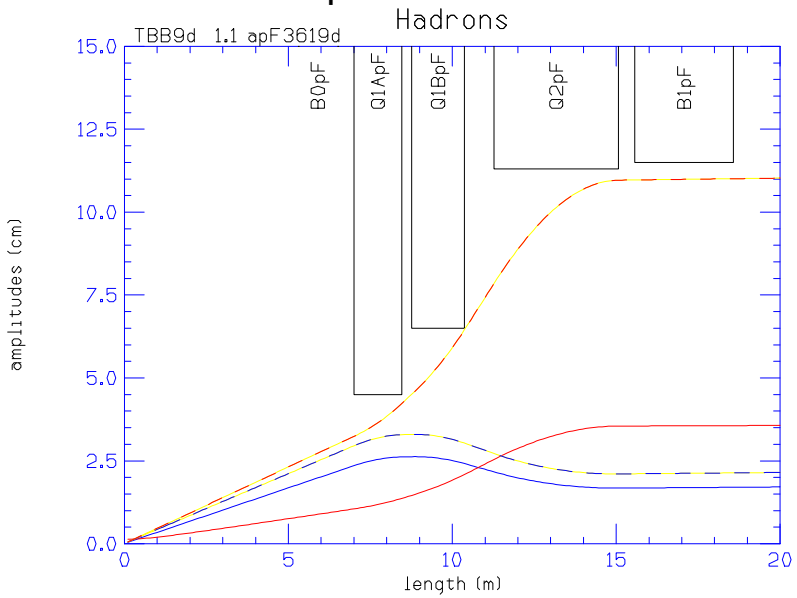
Protons Forward



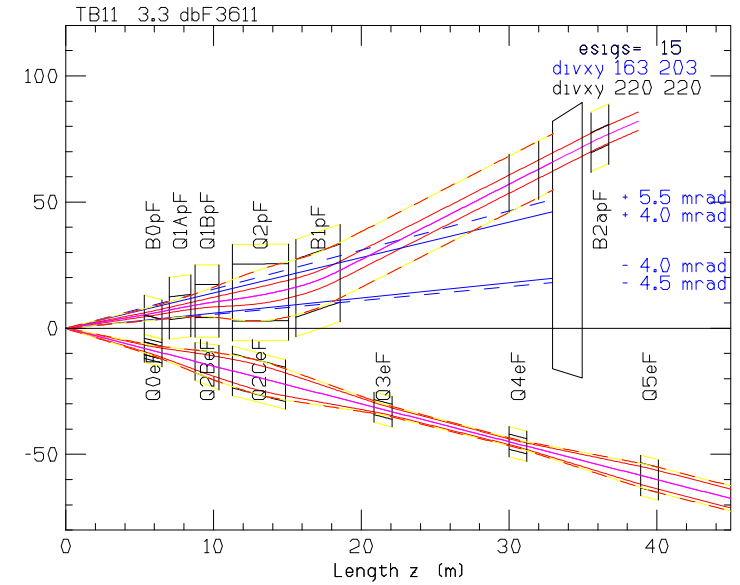
matched pCDR



current



Amplitudes
Red=x Blue=y



x-z Layout
Red=beams Blue=n-cone

Red lines are for x, Blue lines for y

For hadrons:
Red lines are 10 sigma baseline beam radii. Dash lines are apertures of outgoing tracks up to B2ApF.

For electrons:
Red lines are 15 sigma baseline beam sizes. Dashes for larger divergence cases with cooling or lower energies.

Proton Forward Parameters

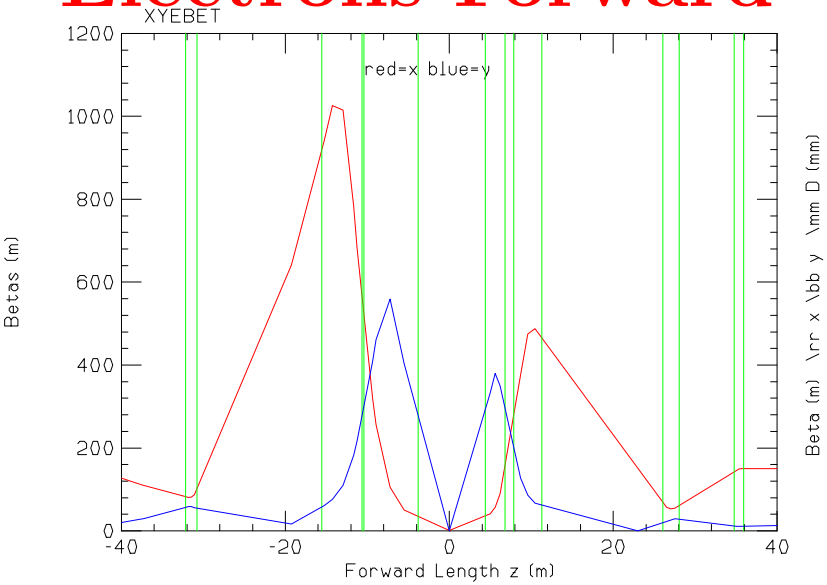
```
#
# ------------------------------------
# zpF3529d  Hadron forward  275
#
# beta*_x  beta*_y  gm emit_x gm emit_y  angle_x  angle_y    mom
#  [m]      [m]      [nm]     [nm]     [mrad]    [mrad]     GeV/c
 0.9000   0.0430     20.0000    6.1000      25       0       275
#
# name    center_z center_x rad1  rad2  length  angle     B      grad  ap x grad   alphax    betax    alphay      betay
#           [m]      [m]     {m}   [m]    [m]   [mrad]    [T]    [T/m]     [T]                [m]                  [m]
  B0pF    5.900  -0.0150  0.170  0.170   1.20  -25.0  -1.30     0.000     0.000    -6.553    39.574  -108.929   647.365
  Q1ApF    7.730   0.0067  0.045  0.045   1.46   -3.2   0.00   -77.903    -0.035   -12.861    70.148   -75.814  1061.777
  Q1BpF    9.565   0.0119  0.065  0.065   1.61  -10.0   0.00   -66.180    -0.043   -33.823   150.758    55.871  1092.779
  Q2pF   13.170   0.0100  0.113  0.113   3.80   -9.5   0.00    37.327     0.042   -44.571   539.185    36.872   525.824
  B1pF   17.070   0.0180  0.115  0.115   3.00   10.0  -4.57     0.000     0.000    -0.673   632.796    -1.954   469.936
  B2apF   30.200   0.2710  0.040  0.040   1.20   17.0   3.30     0.000     0.000    -0.703   650.856    -2.088   523.004
#-------------------------------------
```

We note that the betas in pCDR matched case, and ours stay relatively flat at $\approx$ 500 m out to 35 m. This is required to allow Roman Pot detectors to be sensitive to the angles of outgoing tracks.

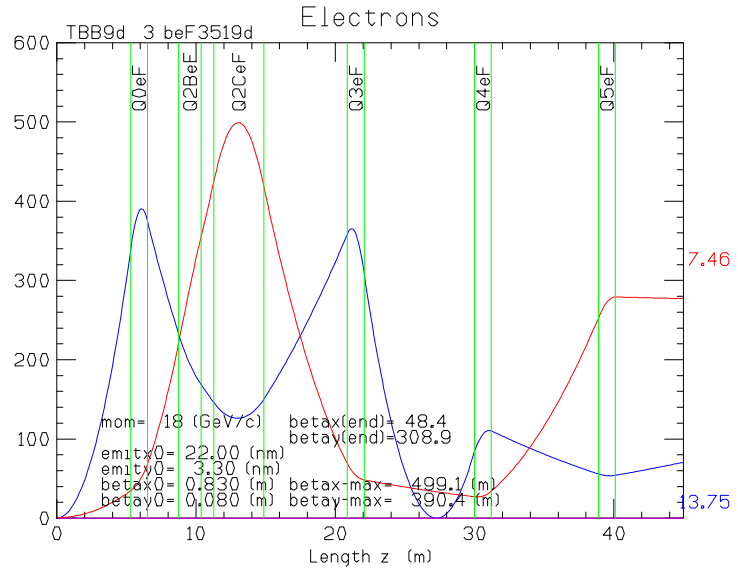
This differs from all the other cases in which the betas drop to much lower values by the next element.

Q1BpF and Q2pF are tilted to increase the space between the fronts of each from the electron magnets Q2BeF and Q2CeF that are close by them. The tilt of Q1BpF bends the p beam closer to the electrons, but the stronger Q2pF bends it by a greater angle away.

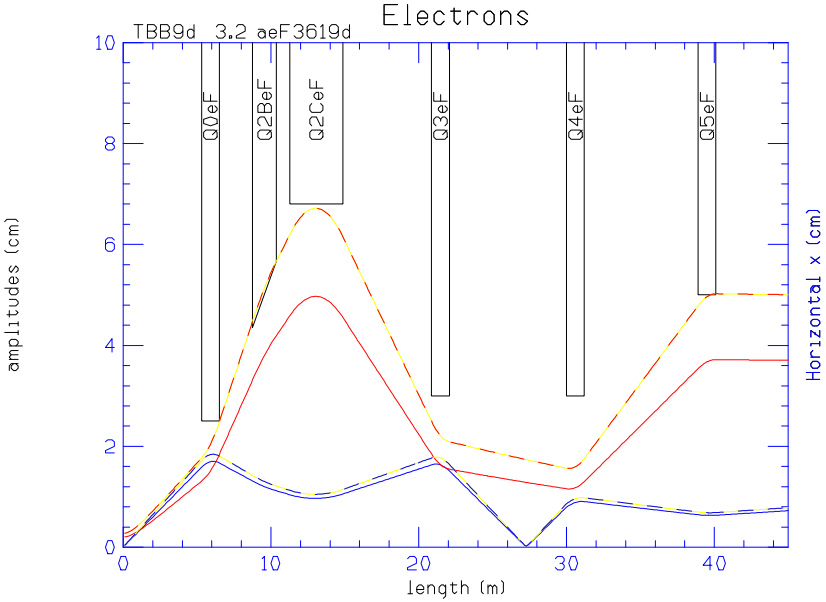
Electrons Forward



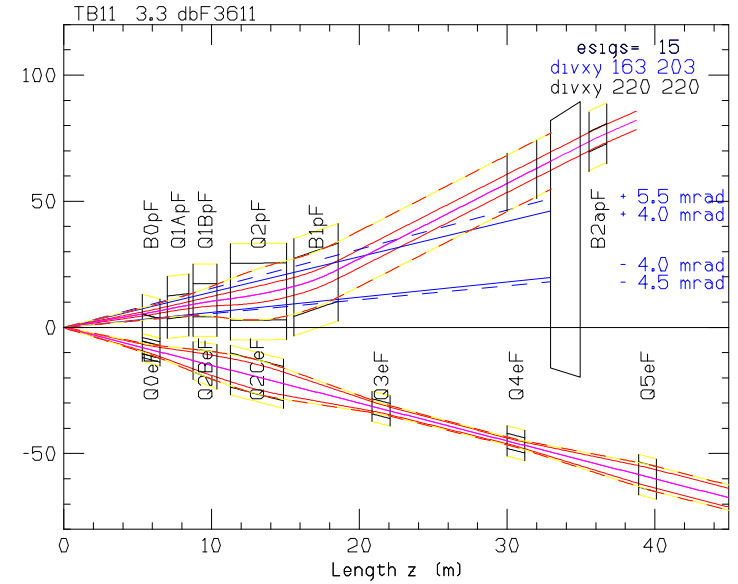
matched pCDR



current



Amplitudes
Red=x Blue=y



x-z Layout
Red=beams Blue=n-cone

Red lines are for x, Blue lines for y

For hadrons:
Red lines are 10 sigma baseline beam radii. Dash lines are apertures of outgoing tracks up to B2ApF.

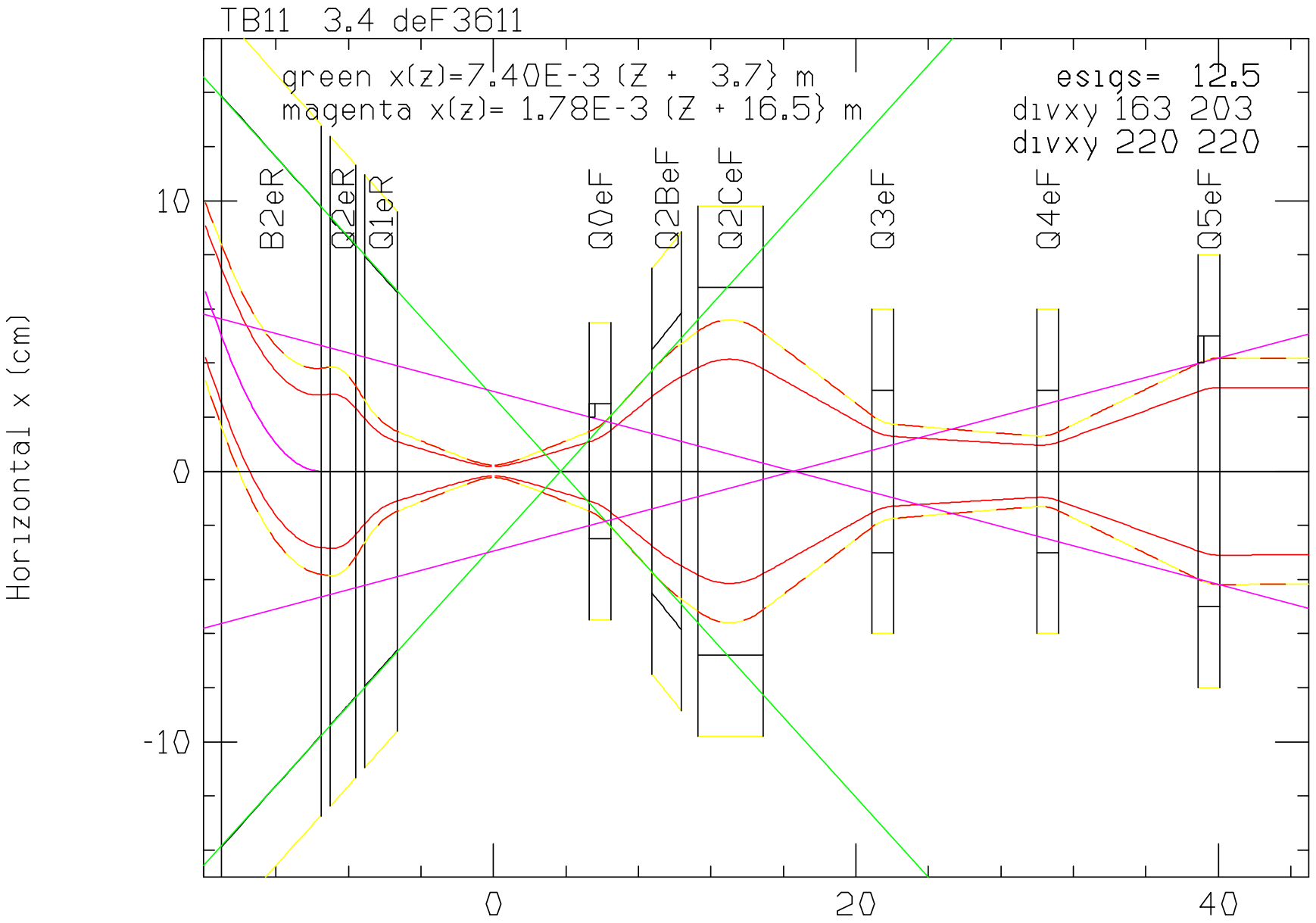
For electrons:
Red lines are 15 sigma baseline beam sizes. Dashes for larger divergence cases with cooling or lower energies.

Electron Forward Parameters

```
#
# ------------------------------------
# zeF3511  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
 0.8300   0.0800     22.0000    3.3000      25       0        18
#
# name    center_z center_x rad1  rad2  length  angle     B      grad  ap x grad   alphax    betax    alphay      betay
#           [m]      [m]     {m}   [m]    [m]   [mrad]    [T]    [T/m]     [T]                [m]                  [m]
  Q0eF    5.900    0.0000  0.025  0.025   1.20   25.0   0.00   -13.540    -0.338   -13.160    46.051   -16.165   387.278
  Q2BeF    9.565   0.0000  0.045  0.059   1.61    25.0   0.00     2.553     0.149   -41.727   292.544    19.130   194.024
  Q2CeF   13.070   0.0000  0.068  0.068   3.60   25.0   0.00     3.043     0.207     1.213   499.042    -0.618   126.296
  Q3eF   21.470   0.0000  0.030  0.030   1.20   25.0   0.00   -12.012    -0.360     8.026    54.079    22.255   358.648
  Q4eF   30.600   0.0000  0.030  0.030   1.20   25.0   0.00   -13.860    -0.416    -2.807    28.137   -10.836   105.963
  Q5eF   39.500   0.0000  0.050  0.050   1.20   25.0   0.00     4.023     0.201   -10.842   272.621     0.647    53.669
#-----------------------------------
#-----------------------------------
```

The matching shown to the crab cavities at 40 m is seen to be significantly different from that in the pCDR, and includes the addition of Q3eF. This was needed to constrain the aperture of Q2CeF. Alternative and simpler designs may be possible. It is shown as an example of possible matching and should not be seen as a constraint in detail.

Synchrotron Radiation Fans in x



Comments

Synchrotron fans from quadrupoles are calculated assuming local beam radii up to 12.5 sigma. This assumes collimation far away at this aperture.

The fan with greatest horizontal angular spread (green) is generated In Q0eF and extends up to the divergence of the beam after that magnet. For a fixed IP divergence (220 mrad rms), the divergence after Q0eF depends only on the gradient of that magnet. The x bound of that fan, as a function of z is given in the top left of the figure.

$$x(z)=7.4E\text{-}3\ (Z + 3.7)\ m$$

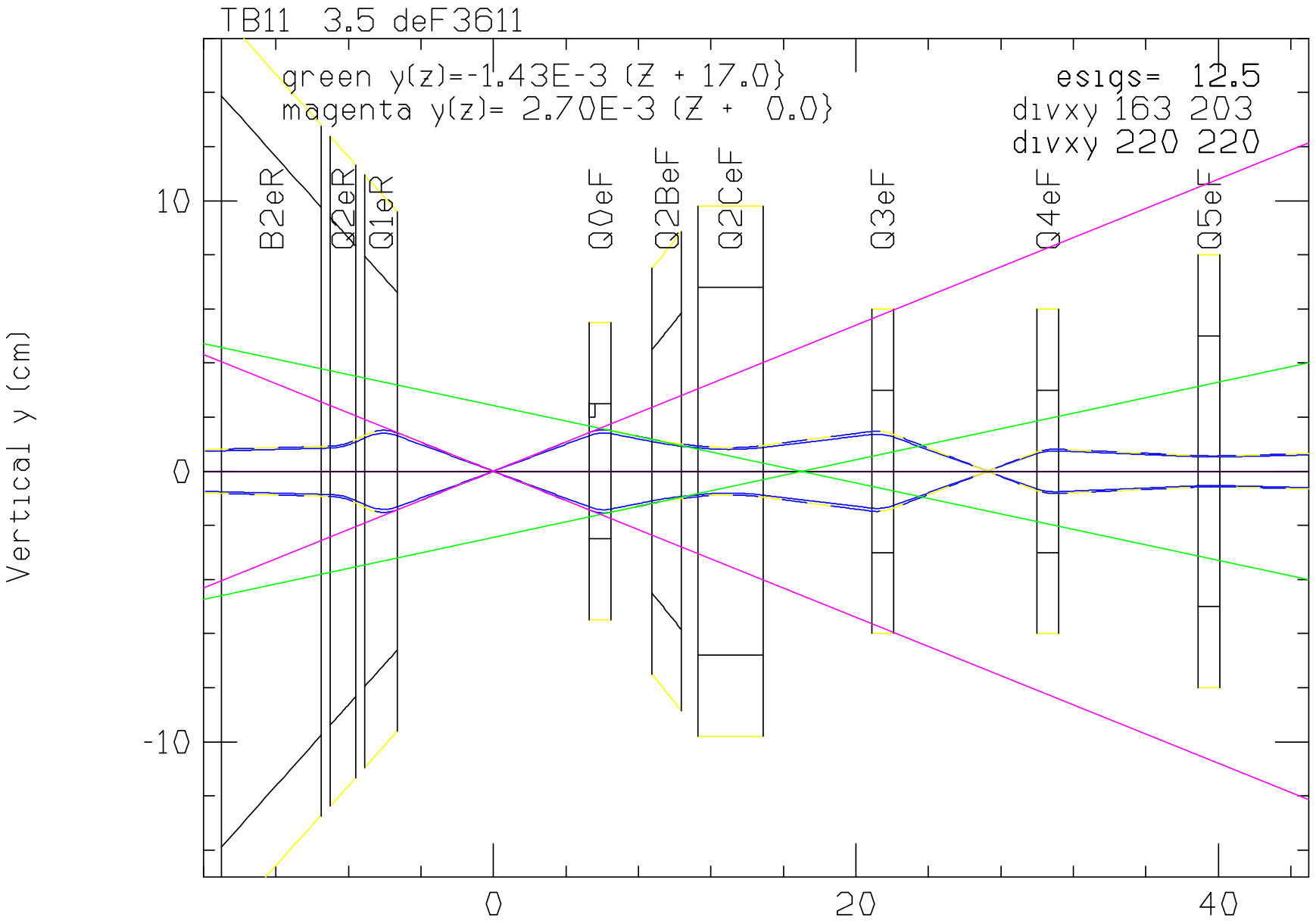
The aperture of Q1eR, Q2eR , and B2eR are currently set at;

$$x(z)=7.5E\text{-}3\ (Z + 3.5)\ m$$

which is always greater than the fan in those magnets. This fan will also set the maximum beam pipe horizontal extent in the rear of the detector.

A fan with smaller angular spread, but greater initial radius, is shown in magenta. It is generated in magnet Q5eF and collimated by a mask inside Q0eF. This will determine the maximum beam pipe horizontal extent in the forward half of the detector.

Synchrotron Radiation Fans in y



Comments

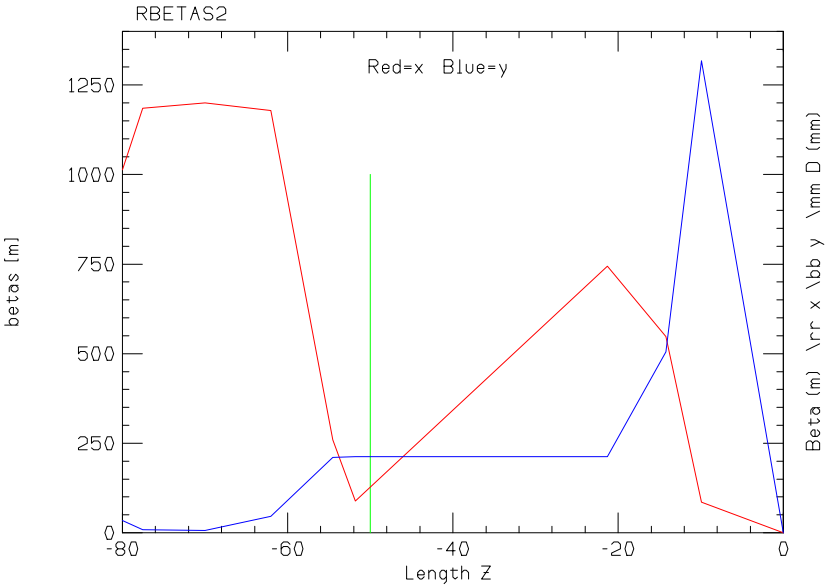
The fan with greatest vertical angular spread (magenta) is generated at the IP end of Q0eF with the IP divergence of the beam (220 mrad rms). But this fan remains smaller than that (green) from the end of Q0eF further from the IP. This fan extends up to the divergence between Q0sF and Q2BeF. Its fan, defined in the top left of the plot is

$$y(z) = 1.43\text{E-}3\ (z + 17)\ \text{m}$$

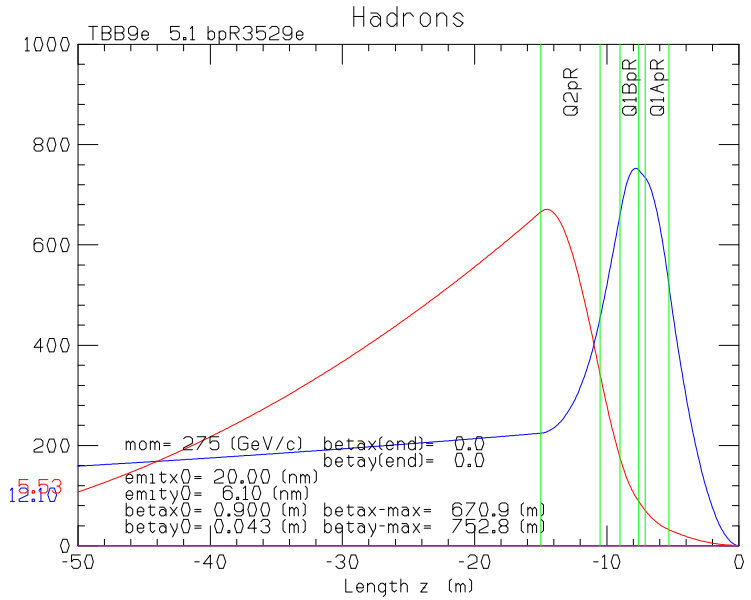
It again depends on the gradient of Q0eF.

The apertures of Q1eR, Q2eR , and B2eR are currently assumed cylindrical and set by the x fan size, but both here and in the beam pipe in the detector they could be elliptical with this vertical extent.

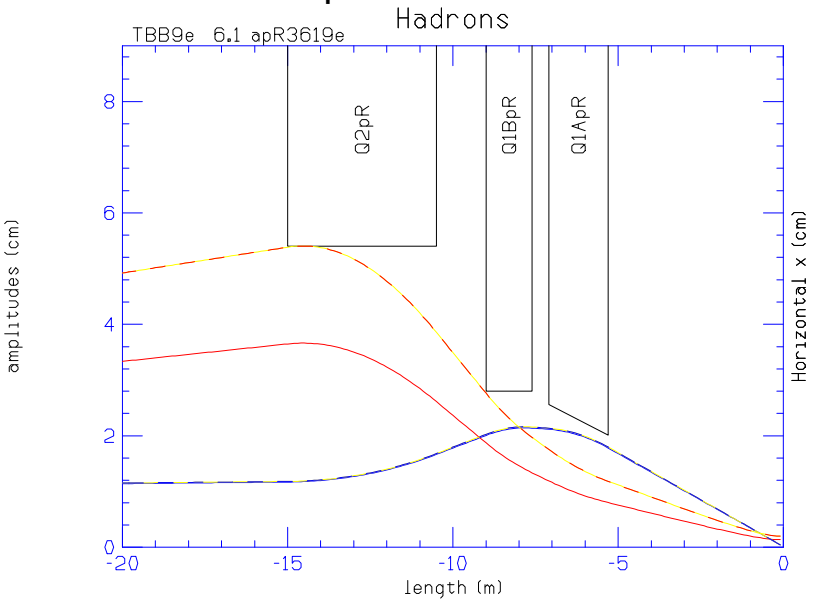
Protons Rear



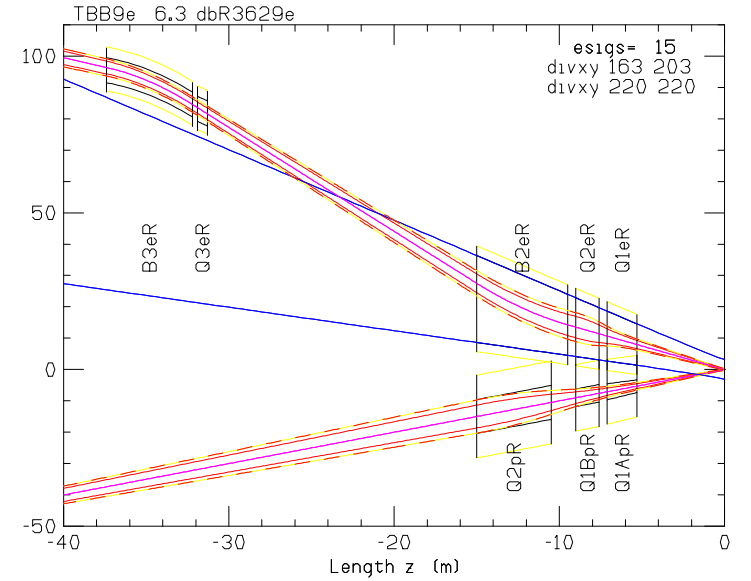
matched pCDR



current



Amplitudes
Red=x Blue=y



x-z Layout
Red=beams Blue=SR fan

Red lines are for x, Blue lines for y

For hadrons:
Red lines are 10 sigma baseline beam radii. Dashes for larger divergence cases with cooling or lower energies.

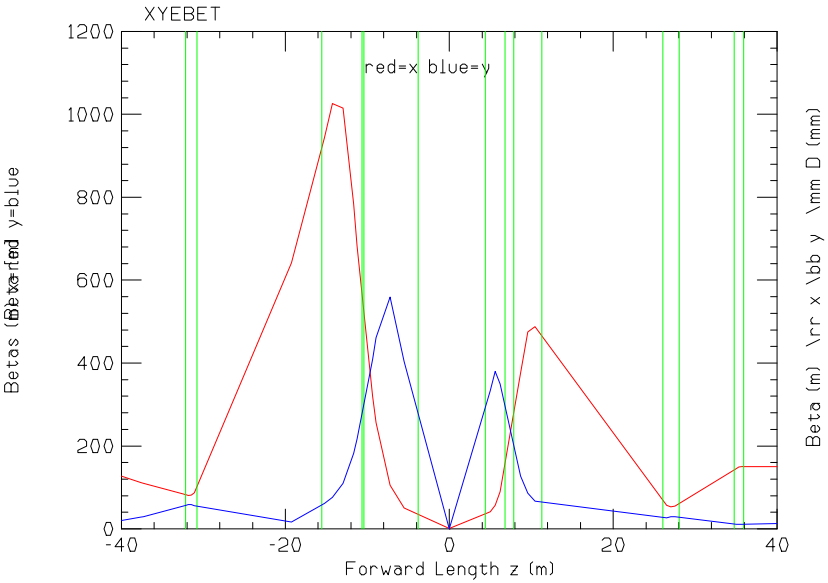
For electrons:
Red lines are 15 sigma baseline beam sizes. Dashes for larger divergence cases with cooling or lower energies.

Proton Rear Parameters

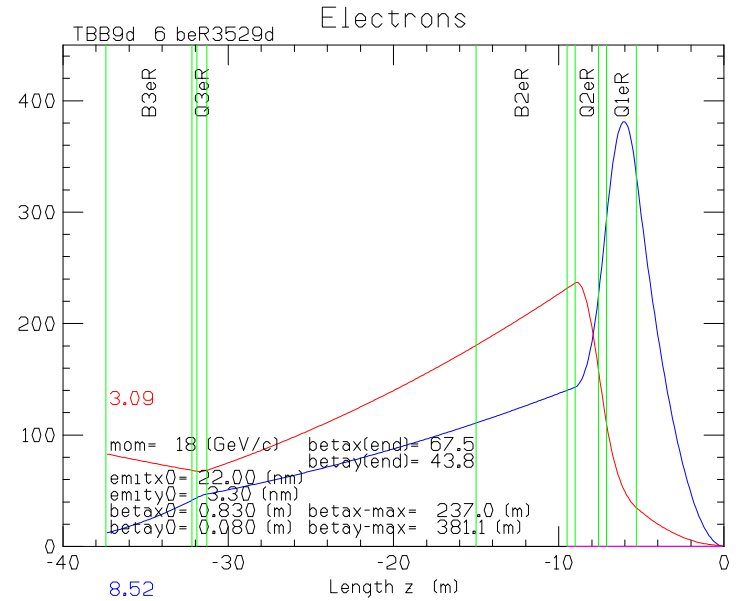
```
#
# ------------------------------------
# zpR35239d  Hadron Rear  275
#
# beta*_x  beta*_y  gm emit_x gm emit_y  angle_x  angle_y    mom
#  [m]      [m]      [nm]     [nm]     [mrad]    [mrad]     GeV/c
 0.9000   0.0430     20.0000    6.1000      25       0       275
#
# name    center_z center_x rad1  rad2  length  angle     B      grad  ap x grad   alphax    betax    alphay      betay
#           [m]      [m]     {m}   [m]    [m]   [mrad]    [T]    [T/m]     [T]                [m]                  [m]
  Q1ApR   -6.200   0.0000  0.020  0.026   1.80    0.0   0.00   -84.150    -0.022   -10.408    46.563   -60.940   665.600
  Q1BpR   -8.300   0.0000  0.028  0.028   1.40    0.0   0.00   -84.150    -0.024   -29.993   123.074    32.917   737.069
  Q2pR  -12.750   0.0000  0.054  0.054   4.50    0.0   0.00    33.843     0.018   -40.819   594.541    22.648   275.049
#-----------------------------------
```

Because the space between the e and p beams is small and tapering, the first proton focus Q1pR is broken into two: Q1ApR and Q1BpR. Q1ApR is shown tapered, but it could also be straight with the larger aperture throughout, giving less space between them at the IP end. The magnet builders can choose.

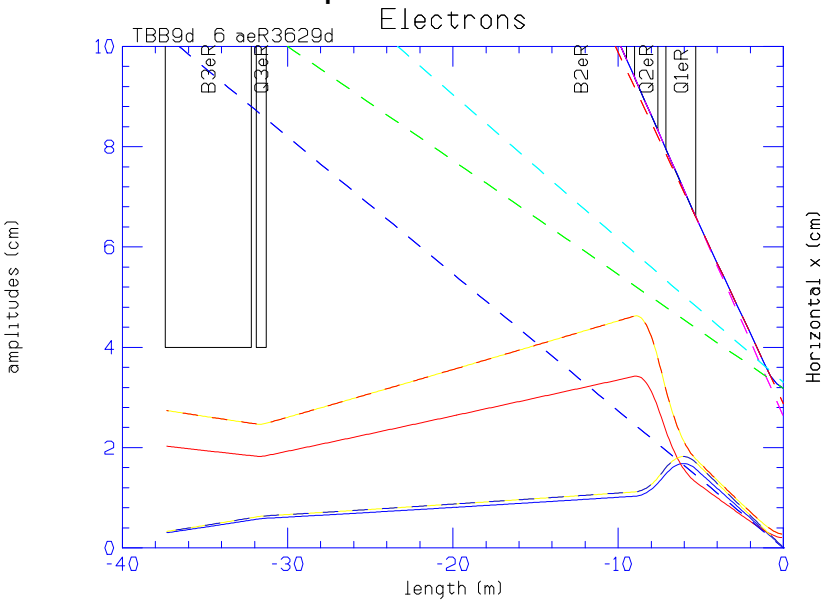
Electrons Rear



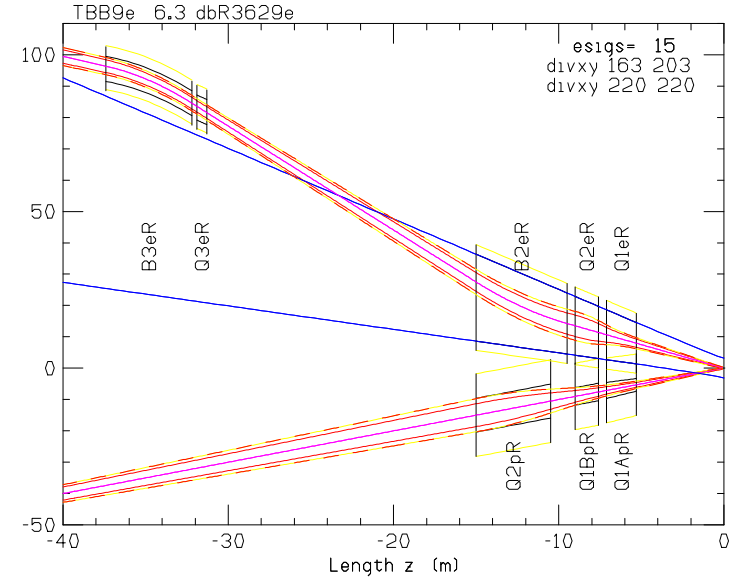
matched pCDR



current



Amplitudes
Red=x Blue=y



x-z Layout
Red=beams Blue=SR fan

Red lines are for x, Blue lines for y

For hadrons:
Red lines are 10 sigma baseline beam radii. Dashes for larger divergence cases with cooling or lower energies.

For electrons:
Red lines are 15 sigma baseline beam sizes. Dashes for larger divergence cases with cooling or lower energies.

Electron Rear Parameters

```
#
# ------------------------------------
# zeR35239d  Electron Rear  18
#
# beta*_x  beta*_y  gm emit_x gm emit_y  angle_x  angle_y    mom
#  [m]      [m]      [nm]     [nm]     [mrad]    [mrad]     GeV/c
 0.8300   0.0800     22.0000    3.3000      25       0        18
#
# name    center_z center_x rad1  rad2  length  angle     B      grad  ap x grad   alphax    betax    alphay      betay
#           [m]      [m]     {m}   [m]    [m]   [mrad]    [T]    [T/m]     [T]                [m]                 [m]
  Q1eR   -6.200    0.0000  0.066  0.079   1.80   25.0   0.00   -15.038    -0.012   -18.779    56.141    13.931   378.985
  Q2eR   -8.300    0.0000  0.083  0.094   1.40   25.0   0.00    14.290     0.013   -29.468   218.668    26.914   163.168
  B2eR  -12.250    0.0000  0.097  0.139   5.50   25.0  -0.20     0.000     0.000     4.641   205.234     2.663   124.969
  Q3eR  -31.600    0.3503  0.040  0.040   0.60   34.0   0.00    -6.000    -0.002     0.558    67.334     2.748    45.753
  B3eR  -34.800    0.3780  0.040  0.040   5.20   31.1   0.25     0.000     0.000    -1.427    75.497     2.826    24.207
#-----------------------------------
```

The further the absorber is from the IP, the less of any reflected radiation comes back to the detector absorber. For this reason, the electron magnet apertures are large enough to transport the synchrotron radiation fan through the magnets to 26 m where the beam separates from the fan.

Since their fields are low, it is assumed that they can be direct wound and tapered.

The parameters and locations given for Q3eR and B3eR will be determined by the overall matching and those given here are only for illustration.

The field in B2eR has been increased to bring the separation of the beam and synchrotron fan further from the next magnet (Q3eF). This will ease the design of the synchrotron absorber.

It may be a good idea to break B2eR into a short lower field B1eR, followed by a shorter B2eR. This would reduce the bend SR entering the luminosity detector

Conclusion

- This design is settling (thanks to Brett, Holger, & Guillaume)
- To be done:
  1. Cross check with MAD
  2. Match betas, alphas, and dispersions with rings
  3. Include B0 dimensions
  4. Include SR absorbers, luminosity measurement, and tagging and consider breaking B2eR into a lower field B1eR followed by a shorter B2eR.
  5. Discuss lower energy parameters for B0pF, B1pF, and B2ApF to keep match into the ring.