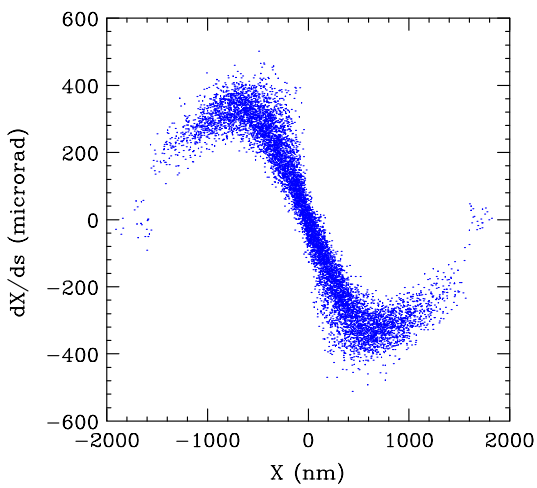
Options for FF quads with head-on collisions

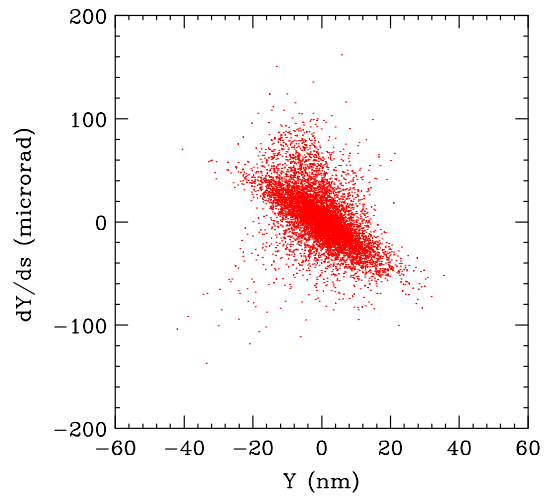
The incoming beam parameters at IP used for disruption calculation:
beam energy E = 250 GeV, normalized emittance $\gamma\varepsilon_x$ / $\gamma\varepsilon_y$ = 10e-6 / 3e-8 m, rms beam size σ_x / σ_y / σ_z = 553 nm / 5 nm / 300 μm, rms beam divergence σ_{xp} / σ_{yp} = 36.9 / 12.4 μrad, rms energy spread σ_E / E = 0.001, beta function β_x / β_y = 15 / 0.4 mm, particles per bunch N = 2e10.

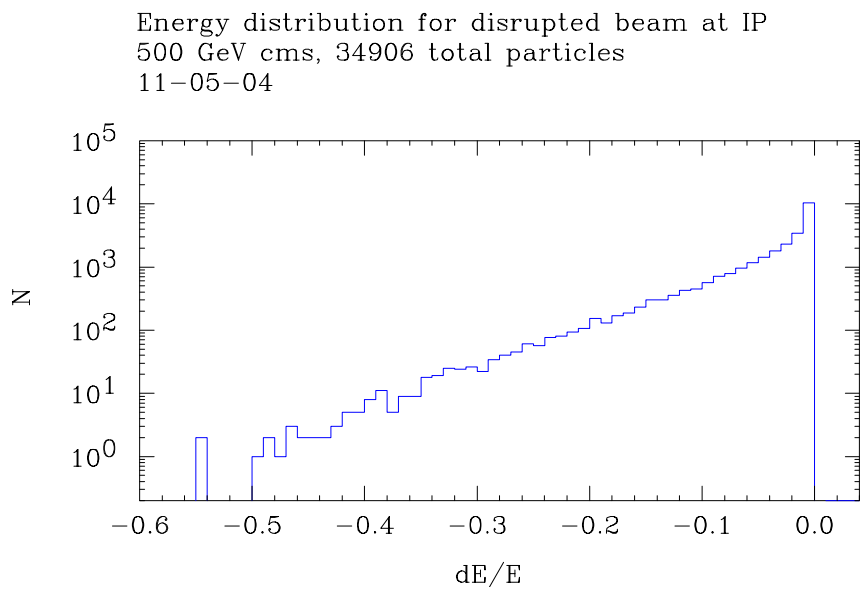
IP parameters for the disrupted beam (by Guinea-Pig):
$\gamma\varepsilon_x$ / $\gamma\varepsilon_y$ = 32.7e-6 / 9.7e-8 m, σ_x / σ_y = 549 nm / 8.3 nm, σ_{xp} / σ_{yp} = 246 / 29 μrad, σ_E / E = 0.055, $(\Delta E / E)_{ave}$ = -0.033, $(\Delta E / E)_{max}$ = -0.55, β_x / β_y = 4.5 / 0.345 mm, α_x / α_y = 1.76 / 0.663.

Disrupted X-X' at IP



Disrupted Y-Y' at IP





Summary of studied options for FF quads

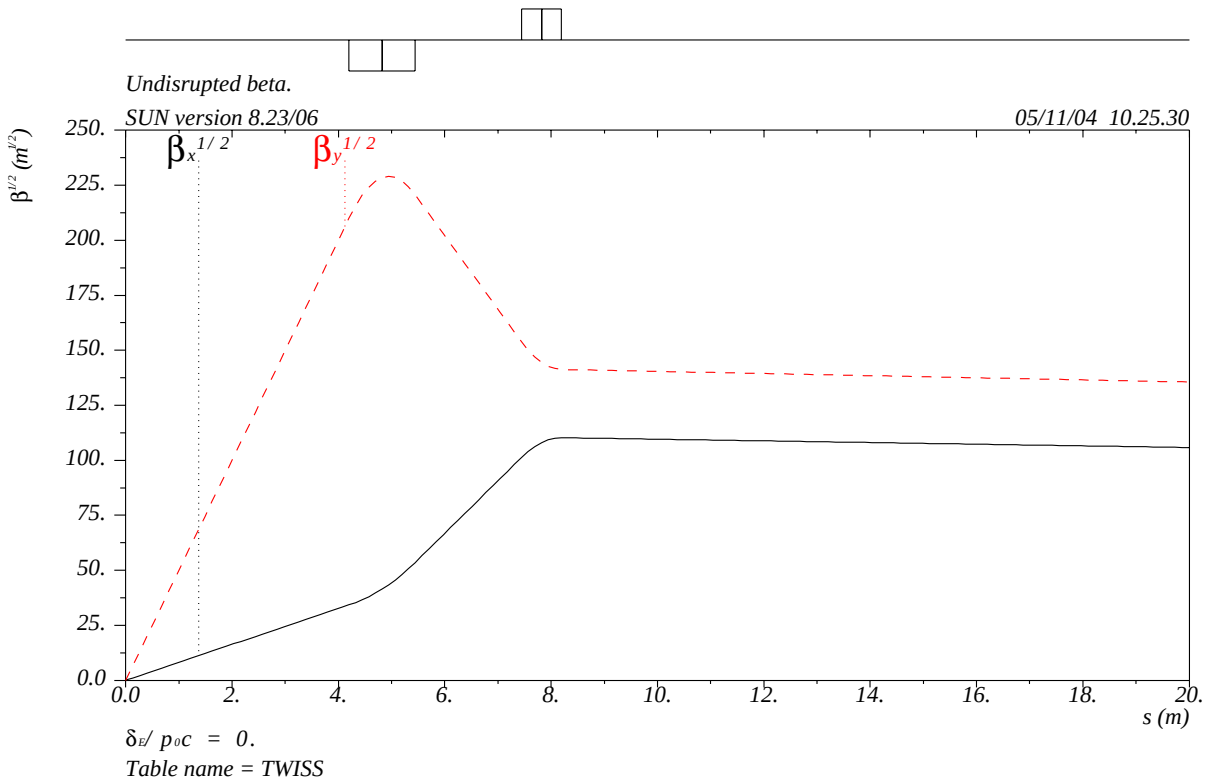
The table below compares rms size of disrupted beam at s = 50 and 80 m after IP for various options of the FF quads. No other magnets were used. The free space at IP is 4.2 m. The FF quads have the same gradient of 250 T/m, and the quad lengths are adjusted to provide an image focal point at 300 m from IP for the nominal energy beam and to minimize beam size for low energy particles after IP. More optimization may be needed.

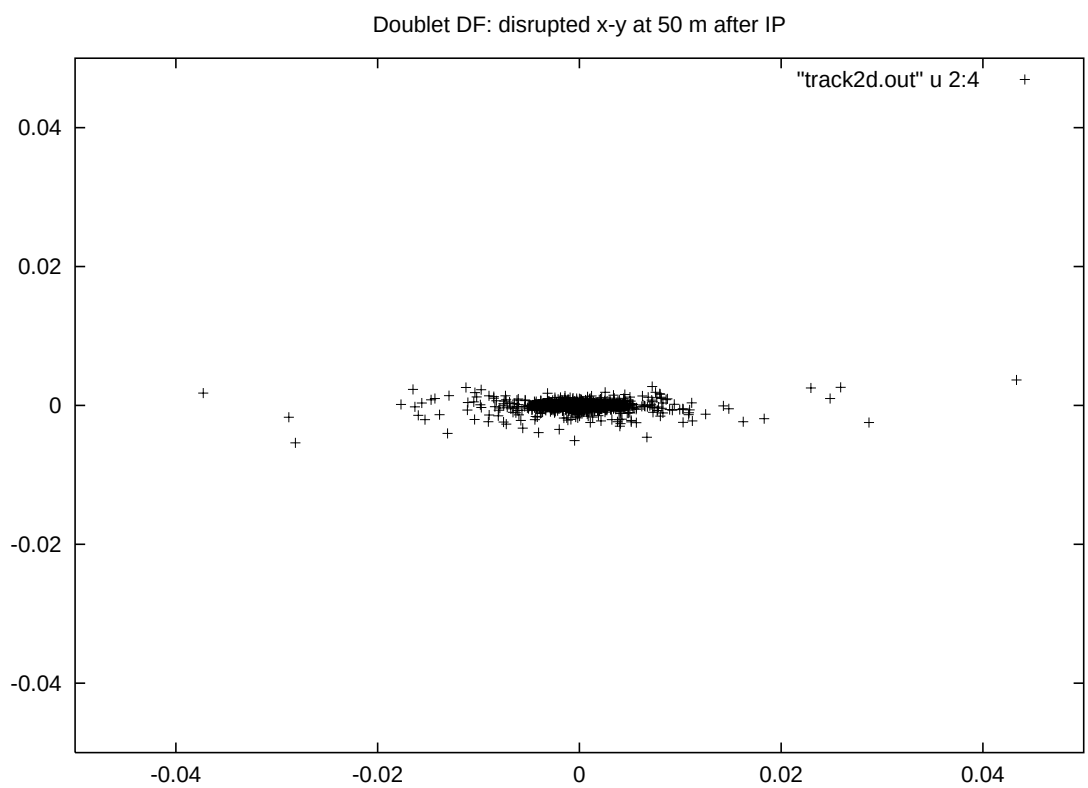
FF quads (from IP)		σ_x / σ_y (mm) at s = 50 m	σ_x / σ_y (mm) at s = 80 m	Space between quads (m)
D-F		2.75 / 0.26	3.75 / 0.46	2.0
D-F-D-F	(1)	2.33 / 0.18	2.62 / 0.31	1.0 - 2.0 - 2.0
	(2)	2.38 / 0.21	2.52 / 0.37	1.0 - 1.0 - 3.0
F-D		2.10 / 0.32	3.66 / 0.46	2.0
F-D-F	(1)	1.55 / 0.43	1.54 / 0.77	1.0 - 3.7
	(2)	1.62 / 0.41	1.66 / 0.74	1.0 - 3.0
	(3)	1.33 / 0.43	1.45 / 0.77	1.0 - 3.0
F-D-F-D	(1)	1.31 / 0.28	1.39 / 0.44	1.0 - 8.0 - 1.0
	(2)	1.45 / 0.31	1.42 / 0.55	1.0 - 8.0 - 1.0
	(3)	1.56 / 0.29	1.45 / 0.49	1.0 - 10.0 - 1.0
F-D-F-D-F	(1)	1.26 / 0.30	1.49 / 0.53	1.0 - 1.0 - 1.0 - 1.0
	(2)	1.39 / 0.31	1.49 / 0.55	1.0 - 1.0 - 1.0 - 1.0
	(3)	1.44 / 0.29	1.43 / 0.51	1.0 - 3.0 - 1.0 - 1.0
	(4)	1.49 / 0.31	1.45 / 0.54	1.0 - 2.0 - 1.0 - 2.0

Additional FF quadrupoles reduce overfocusing of the low energy particles in the extracted beam, but increase the total quad length and nominal beta functions in the FF.

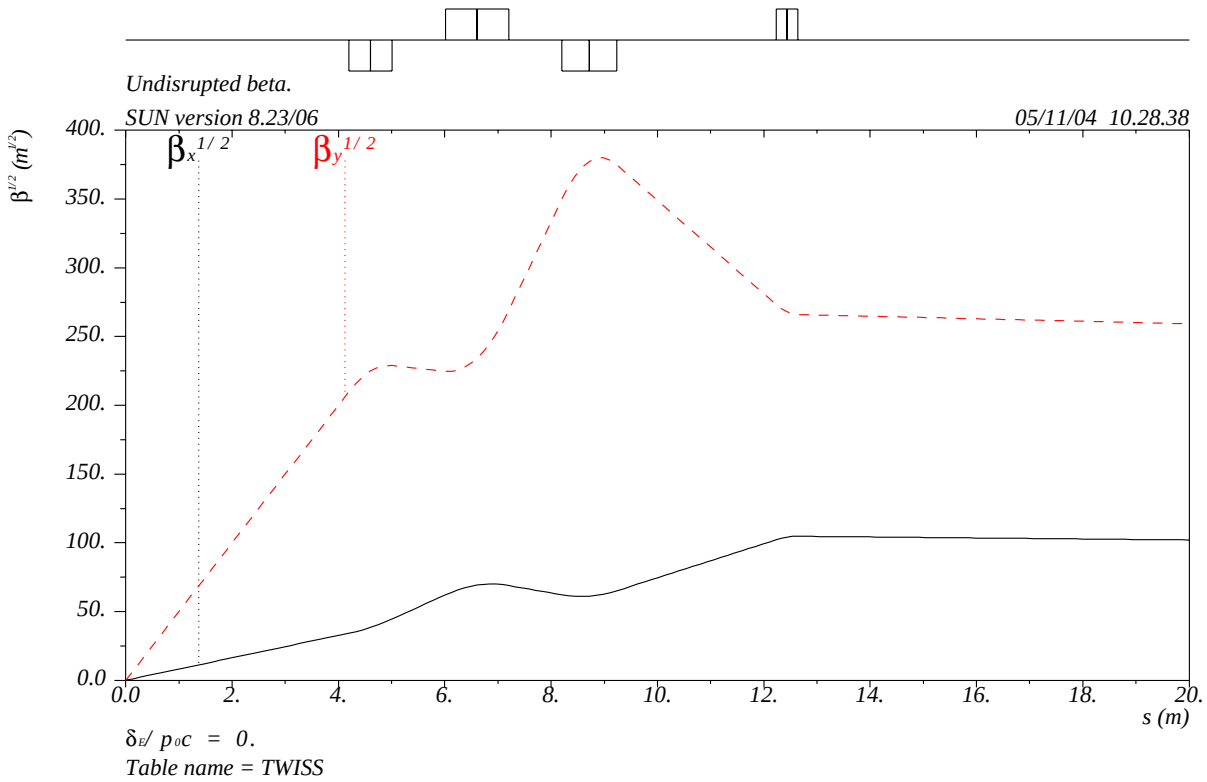
The next slides show the following plots for the selected options (blue and red above):
- Beta functions in the FF quads for nominal energy beam (starting at IP),
- x-y distribution for disrupted beam at s = 50 m after IP.

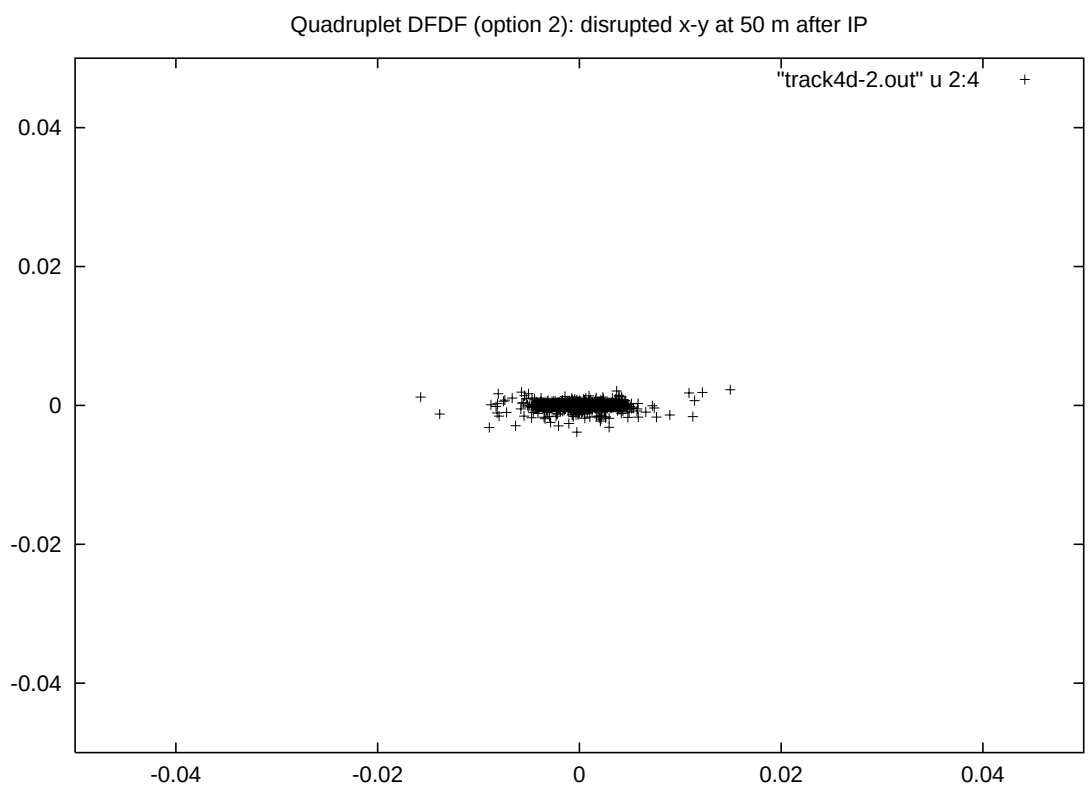
Doublet D-F


Undisrupted beta.
SUN version 8.23/06
05/11/04 10.25.30
$\beta_x^{1/2}$
$\beta_y^{1/2}$
$\beta^{1/2}$ ($m^{1/2}$)
250.
225.
200.
175.
150.
125.
100.
75.
50.
25.
0.0
0.0
2.
4.
6.
8.
10.
12.
14.
16.
18.
20.
s (m)
$\delta_E / p_0 c$ = 0.
Table name = TWISS

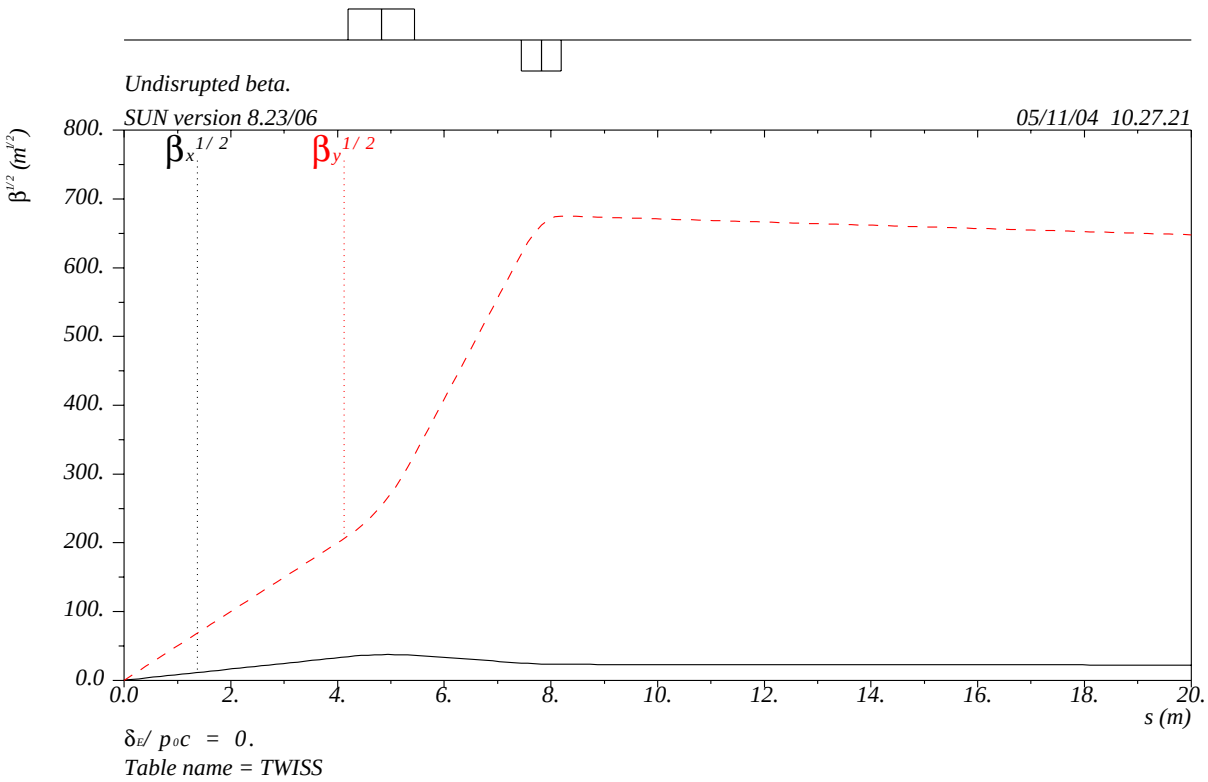

Doublet DF: disrupted x-y at 50 m after IP
"track2d.out" u 2:4
0.04
0.02
0
-0.02
-0.04
-0.04
-0.02
0
0.02
0.04

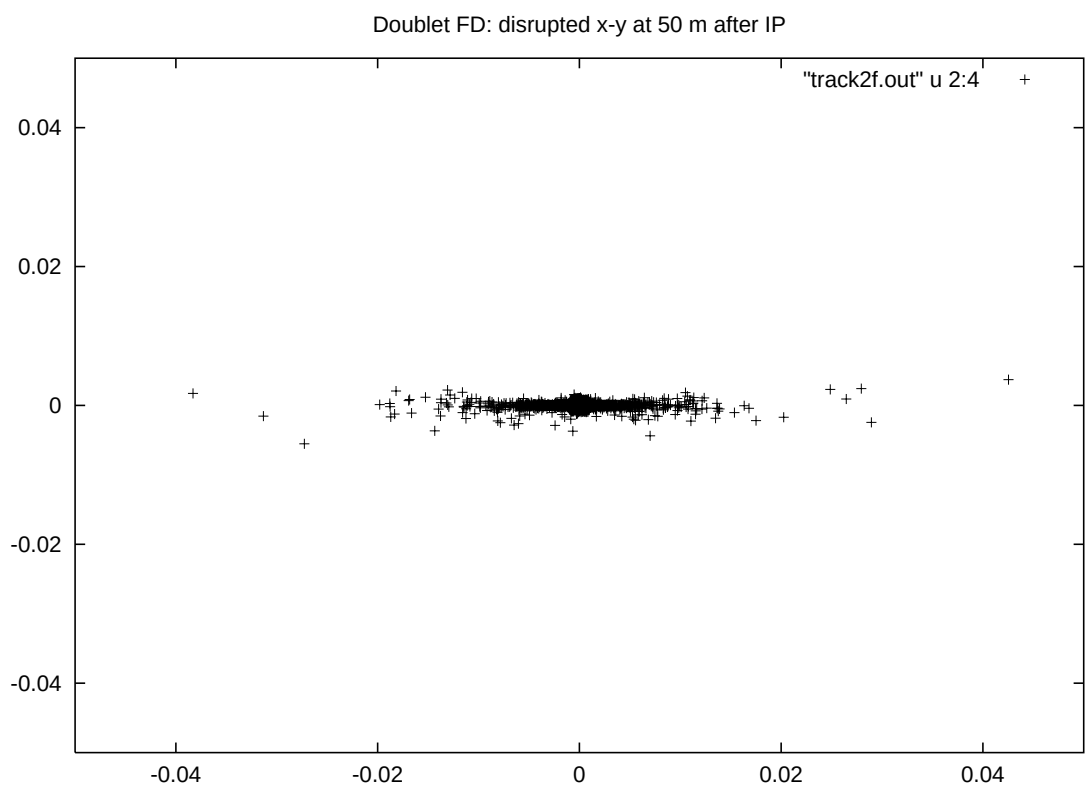
Quadruplet D-F-D-F (option 2)



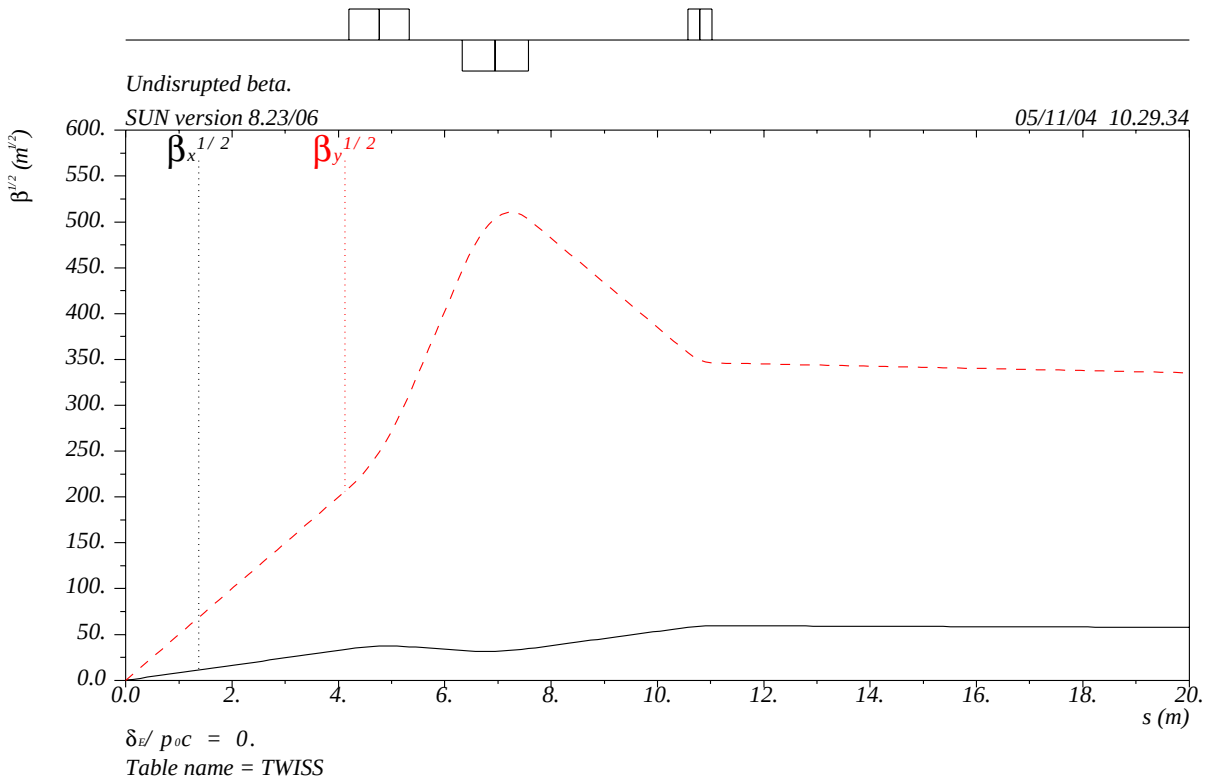


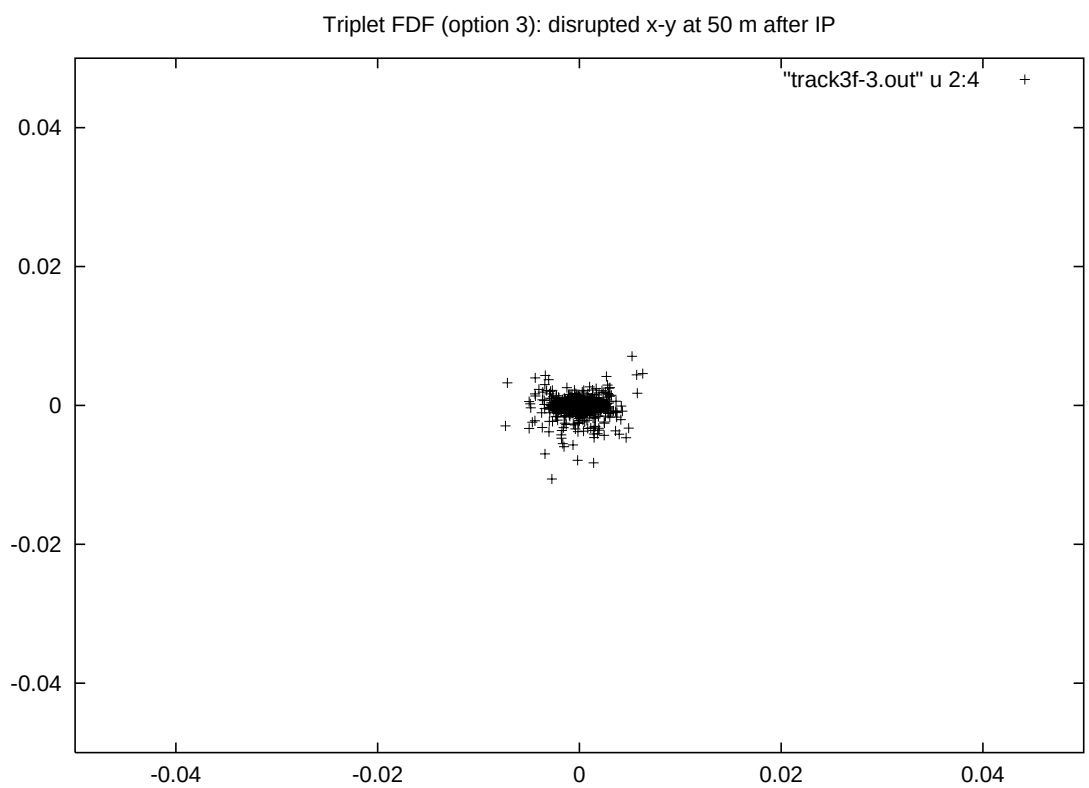
Doublet F-D


Undisrupted beta.
SUN version 8.23/06
05/11/04 10.27.21
$\beta_x^{1/2}$
$\beta_y^{1/2}$
$\beta^{1/2}$ ($m^{1/2}$)
800.
700.
600.
500.
400.
300.
200.
100.
0.0
0.0
2.
4.
6.
8.
10.
12.
14.
16.
18.
20.
s (m)
$\delta_E / p_0 c$ = 0.
Table name = TWISS

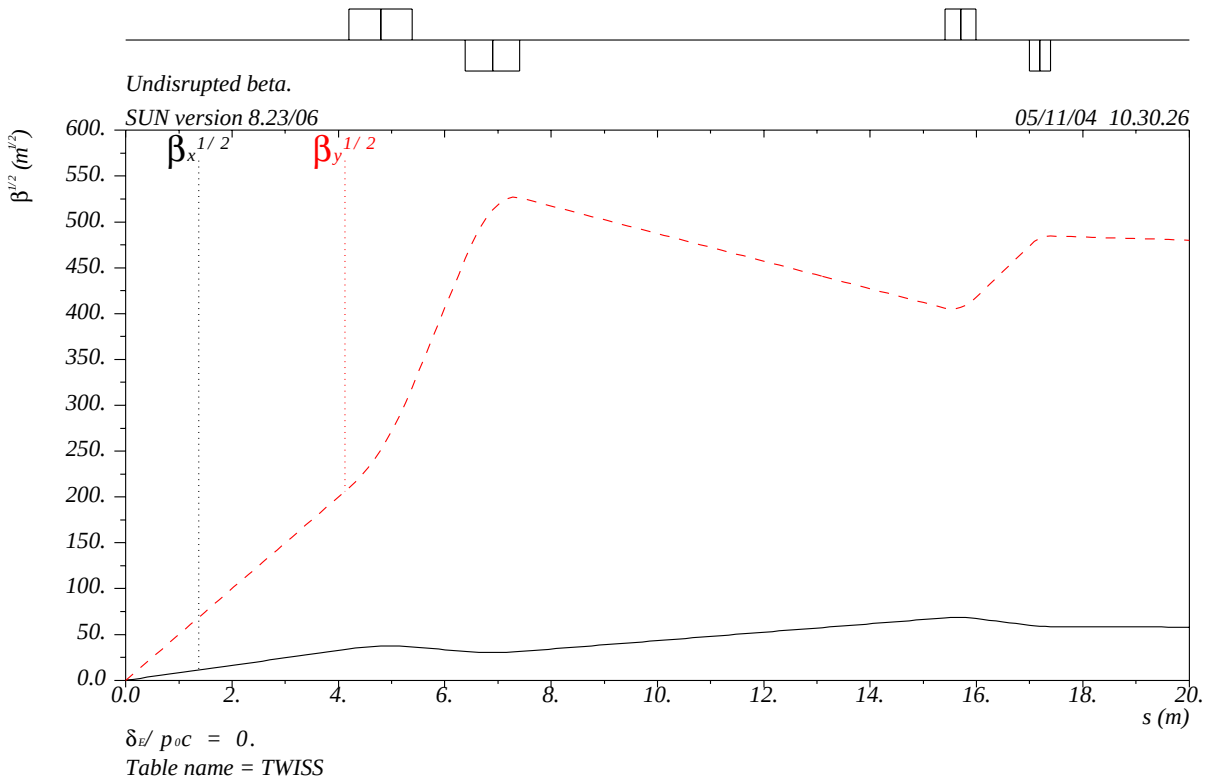

Doublet FD: disrupted x-y at 50 m after IP
"track2f.out" u 2:4
0.04
0.02
0
-0.02
-0.04
-0.04
-0.02
0
0.02
0.04

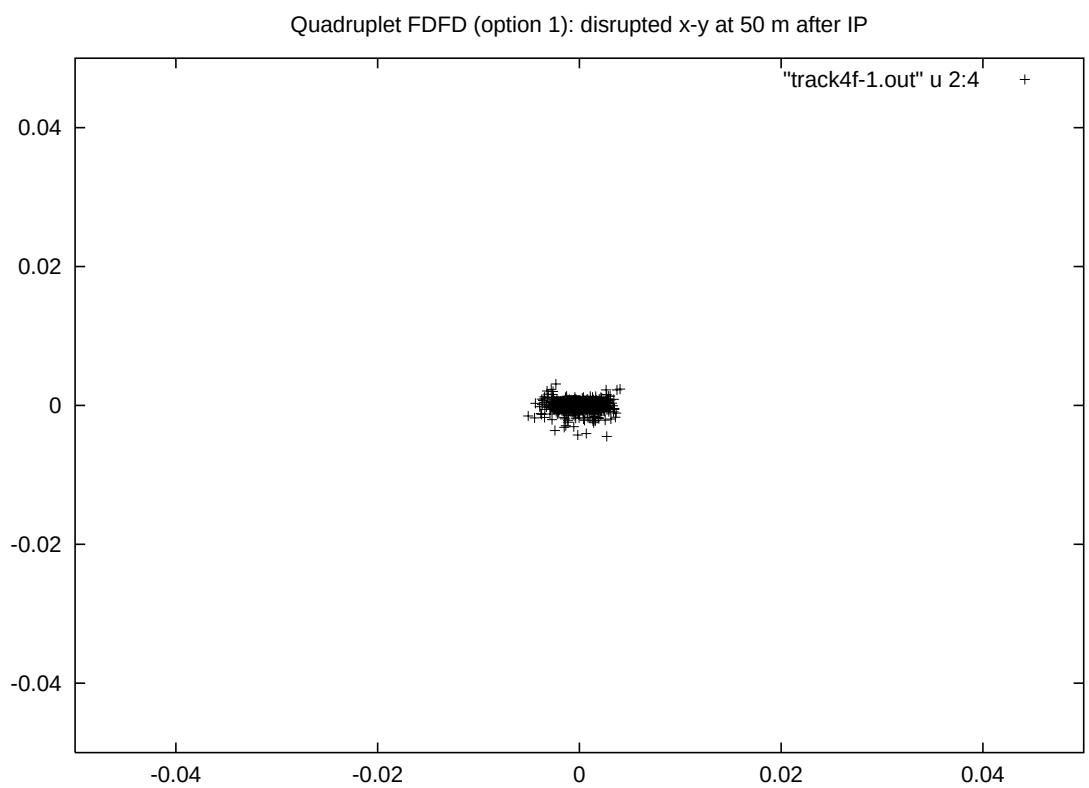
Triplet F-D-F (option 3)



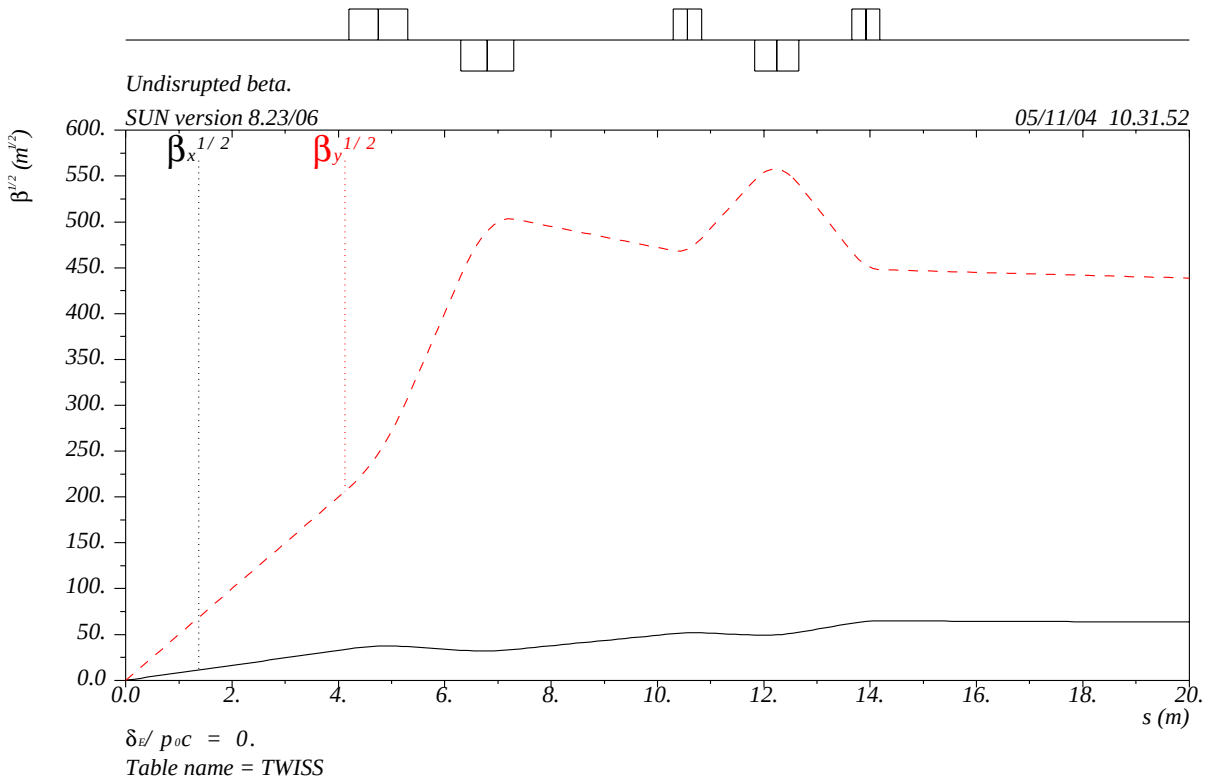


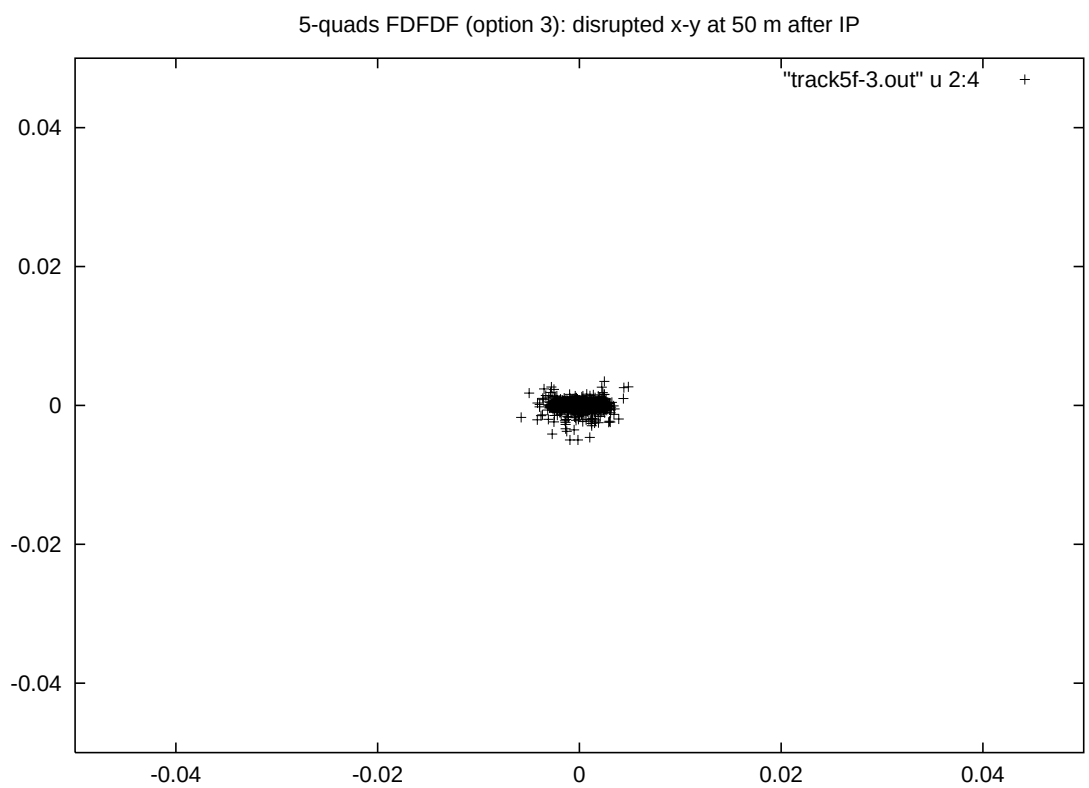
Quadruplet F-D-F-D (option 1)





5 quads F-D-F-D-F (option 3)





Comments

* Schemes with the first x-focusing quad F (nearest to IP) have an advantage of a smaller horizontal beam size in the extraction line.

* Schemes with the first x-defocusing quad D provide a lower vertical beta for the incoming nominal energy beam.

* The quadrupole FDFD scheme tends to converge to the FDF triplet when quad spacing is reduced.

* The desired spacing between the quads needs to be specified for placement of local sextupole, octupole and dipole correctors and possibly for the separators.

* Dispersive effects of the separators and bends on the extracted beam were not included.