Lattice Option for ILC Extraction Line with 20 mrad Crossing Angle

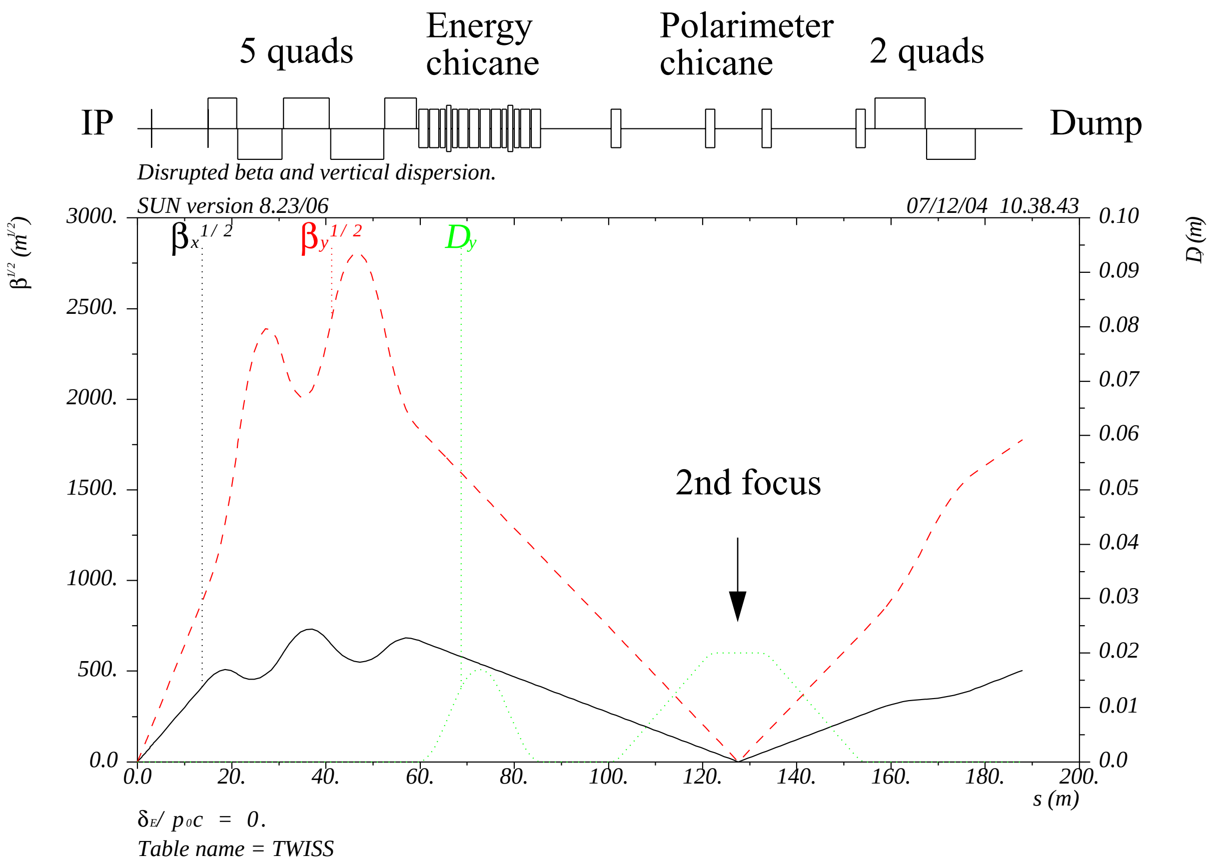
Y. Nosochkov, A. Seryi (SLAC)

Machine Detector Interface Workshop
SLAC, January 6 - 8, 2005

Optics design considerations

- Use the same beamline and a common dump for extracted electron and photon beams.
- Allow a sufficient free space after IP to minimize interference with the opposite incoming beamline.
- Assume no shared field with the opposite incoming beam except detector solenoid.
- Use a system of 5 alternating gradient quadrupoles after IP, rather than a doublet, to reduce overfocusing and particle loss in the low energy tail of disrupted beam.
- Include two dedicated vertical chicanes and a secondary low beta point for downstream energy and polarization measurements.
- Adjust the electron beam at the dump using the final quadrupole doublet.
- Provide magnet apertures for the outgoing photon beam with +/-1 mrad IP divergence, and electron beam size ($7\sigma_x/10\sigma_y$) with large energy spread.
- Use magnet field sufficient for running up to 500 GeV per beam.

Beam optics



- L^*_{ex} = 15 m free space after IP (an 8 m option also exists).
- At the 2nd focus: η_y = 2 cm, $R_{12} = R_{34} = 0$, R_{11} = -3.1, R_{33} = -2.4.
- Dump is assumed at 188 m after IP, but its location may be changed.

Electron beam parameters at IP

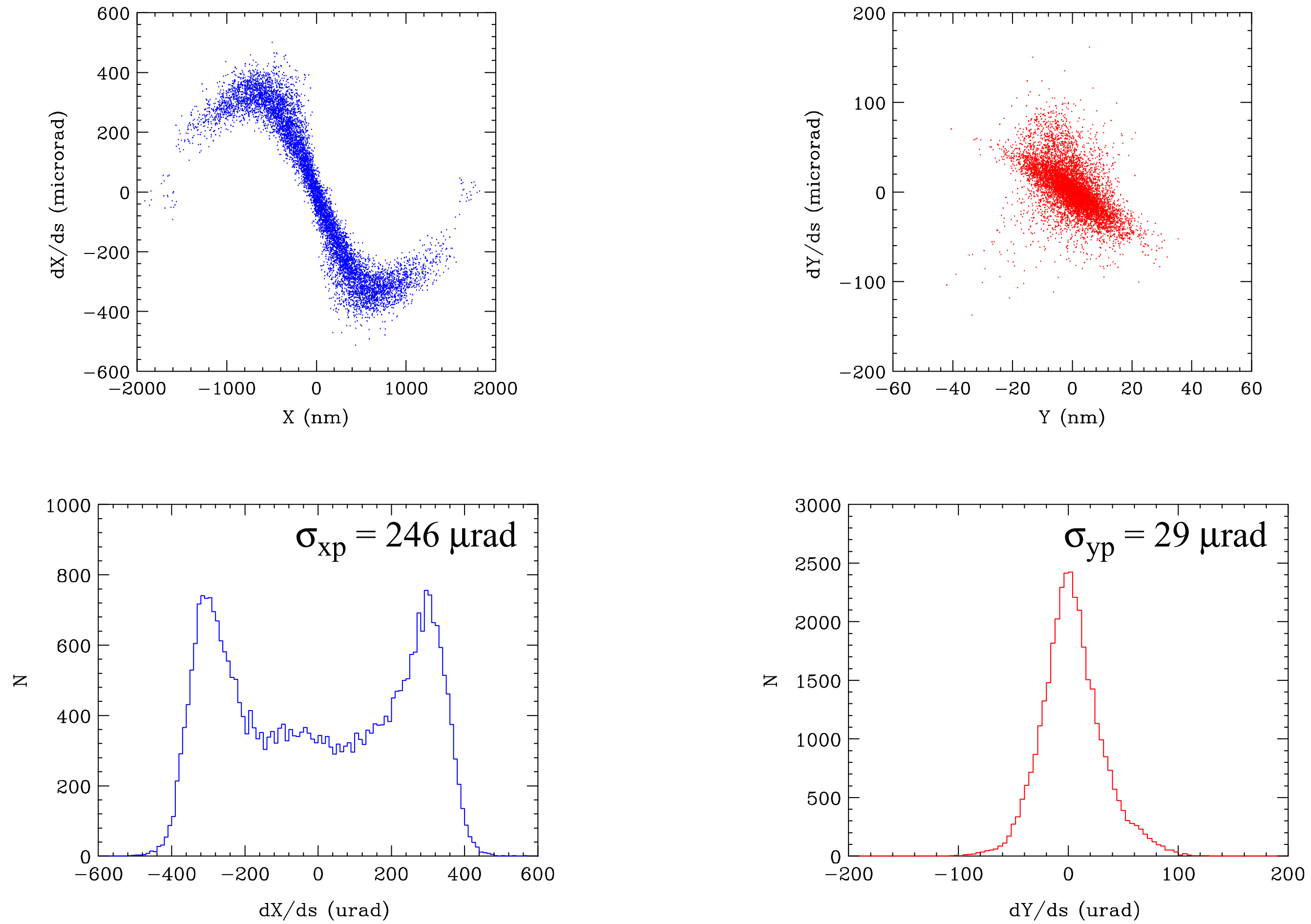
- Assumed the following incoming beam parameters at IP for 250 GeV beams:

  $\gamma\varepsilon_x$ / $\gamma\varepsilon_y$ = 10e-6 / 3e-8 m,
  σ_x / σ_y / σ_z = 553 nm / 5 nm / 300 µm,
  σ_{xp} / σ_{yp} = 36.9 / 12.4 µrad,
  σ_E / E = 0.1%,
  β_x / β_y = 15 / 0.4 mm,
  N = 2e10 particles per bunch.

- Disrupted beam distribution at IP was simulated by the Guinea-Pig code. The rms values for disrupted beam were estimated from the simulated distribution of 3.5e4 particles:

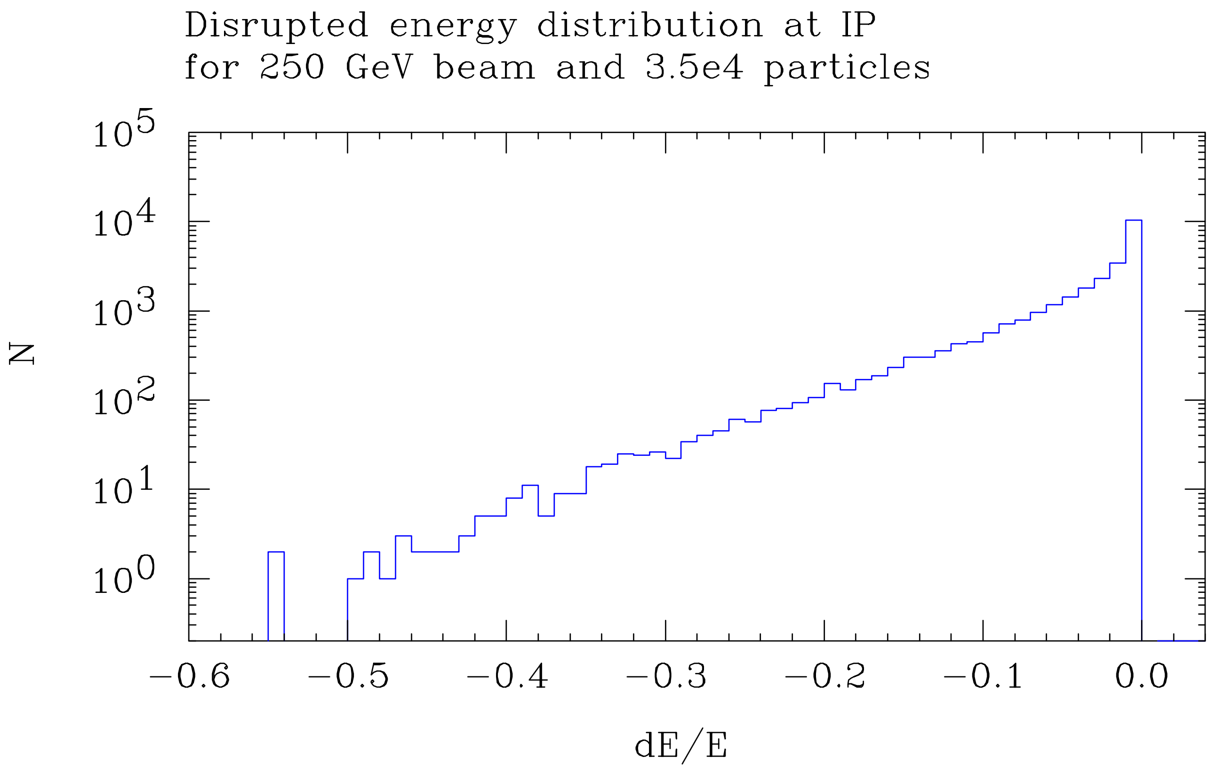
  $\gamma\varepsilon_x$ / $\gamma\varepsilon_y$ = 32.7e-6 / 9.7e-8 m,
  σ_x / σ_y = 549 nm / 8.3 nm,
  σ_{xp} / σ_{yp} = 246 / 29 µrad,
  σ_E / E = 5.5%, $(\Delta E / E)_{ave}$ = -3.3%, $(\Delta E / E)_{max}$ = -55%,
  β_x / β_y = 4.5 / 0.345 mm, α_x / α_y = 1.76 / 0.663.

Disrupted X-Y distribution at IP for primary beam



- Maximum betatron amplitudes in the extraction line will be proportional to IP divergence.
- The characteristic double-peak angular X-distribution at IP will translate to a double peak amplitude X-distribution at the dump.

Disrupted energy distribution at IP for primary beam



- The low energy tail of the disrupted beam is the major cause of particle loss in the extraction line since the deflections in magnets increase as 1/E and then are further amplified due to larger amplitudes in quads.
- The use of a system of multiple alternating gradient quads reduces overfocusing at low energies, while the chicanes provide closed trajectory bumps for all energies.

Tracking of 250 GeV primary beam from IP to dump

- Assumed no errors in the extraction magnets.
- Detector solenoid field was off, but its effect is expected to be small if the orbit is corrected.
- Tracked 1.5e4 particles for the undisrupted beam and 3.5e4 for the disrupted beam using DIMAD code.
- Result: all particles transported to dump without loss on the beamline aperture.

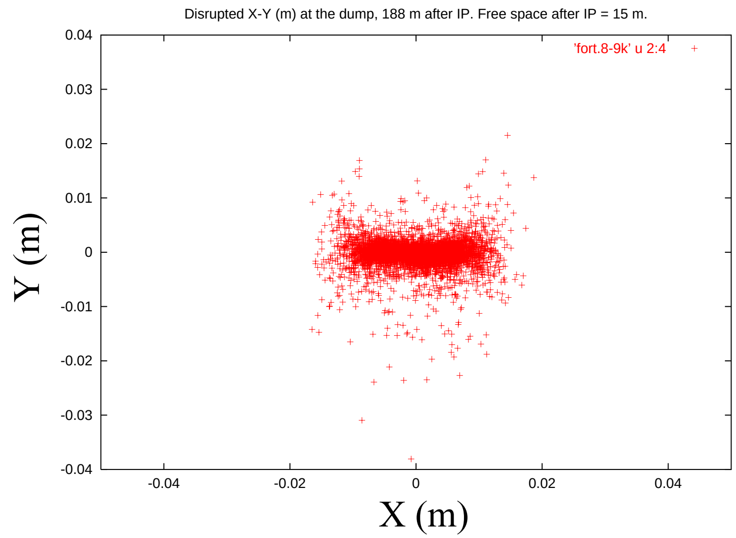
- Undisrupted beam size and divergence at the dump:
  σ_x / σ_y = 0.62 / 0.34 mm, $\sigma_{xp} / \sigma_{yp}$ = 12.4 / 3.5 μrad.
  σ_x / σ_y = 0.73 / 0.32 mm, $\sigma_{xp} / \sigma_{yp}$ = 12.1 / 5.2 μrad - with the last doublet off.

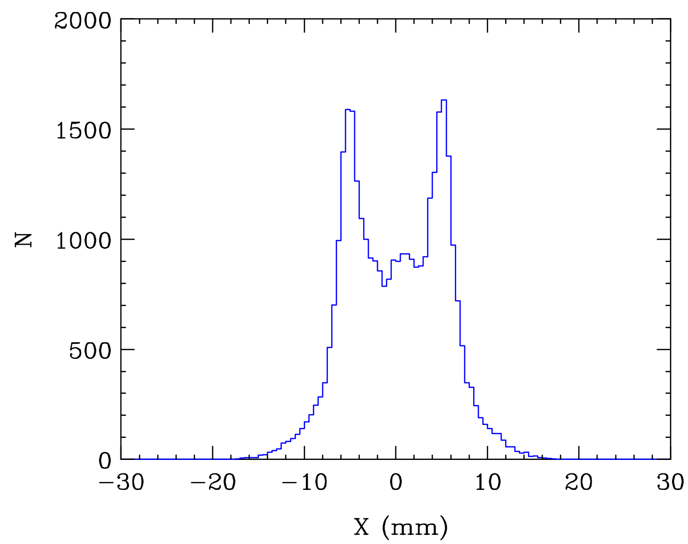
- Disrupted beam size and divergence at the dump:
  σ_x / σ_y = 5.3 / 2.3 mm, $\sigma_{xp} / \sigma_{yp}$ = 79.7 / 9.2 μrad.
  σ_x / σ_y = 6.9 / 1.9 mm, $\sigma_{xp} / \sigma_{yp}$ = 88.8 / 18.7 μrad - with the last doublet off.

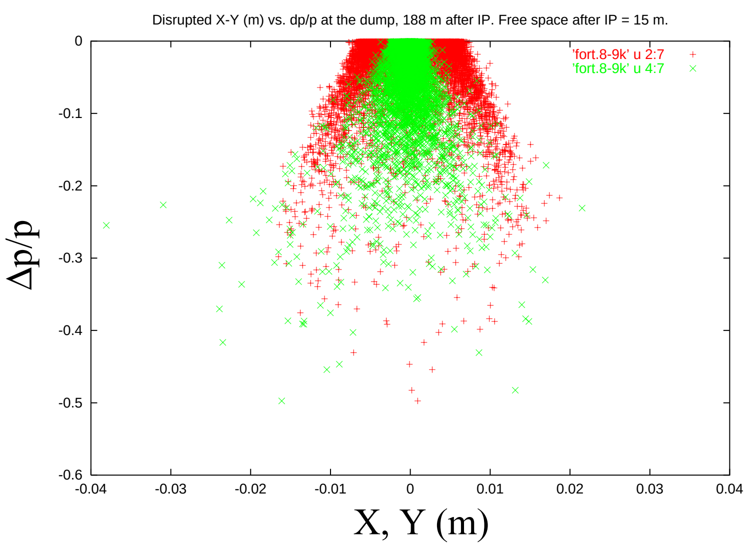
- More tracking is needed including beam and magnet errors, more particles, especially in the tails, and higher beam energy to determine the potential beam loss and to further optimize apertures.

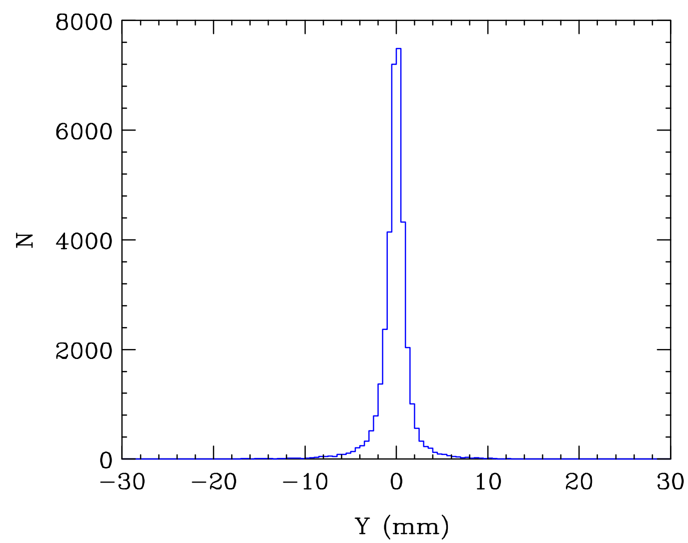
Distribution of primary disrupted beam at the dump

$\sigma_x / \sigma_y = 5.3 / 2.3$ mm









Extraction magnets

Table 1: Quadrupoles.

	L (m)	GL (T)	R (mm)	Δx (mm)
QFEX1	6.004	165.6	29	300
QDEX2	9.392	-216.5	35	426
QFEX3	9.673	185.7	42	620
QDEX4	11.270	-169.3	53	819
QFEX5	6.648	88.4	60	1051
QFEX6	10.717	44.8	167	3132
QDEX7	10.354	-40.7	178	3352

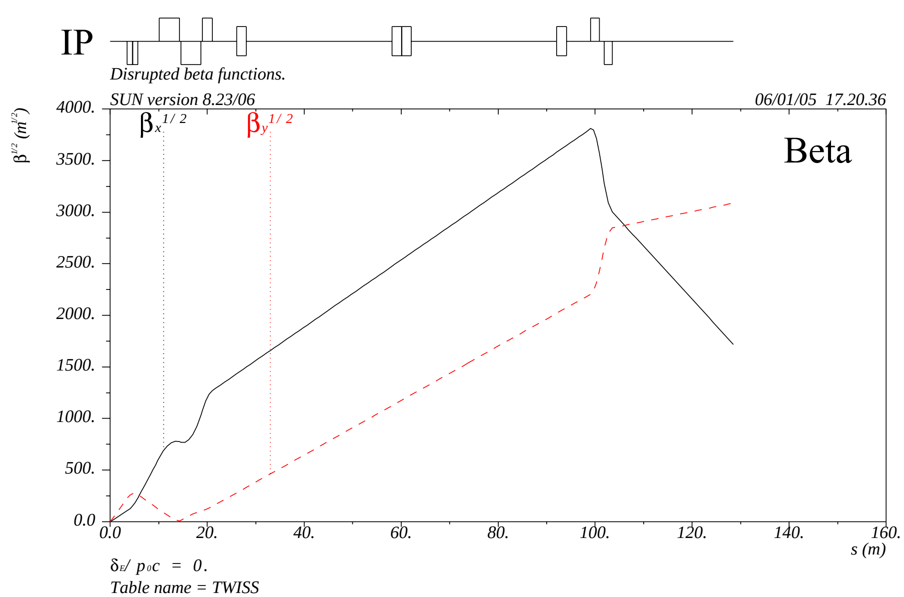
- The field is for 500 GeV beam.
- For realistic design, long quads need to be split in shorter quads.
- Δx is a separation between incoming and extracted beamlines at the front face of a quad.
- R_x / R_y is the maximum half-width aperture in the chicane bends.

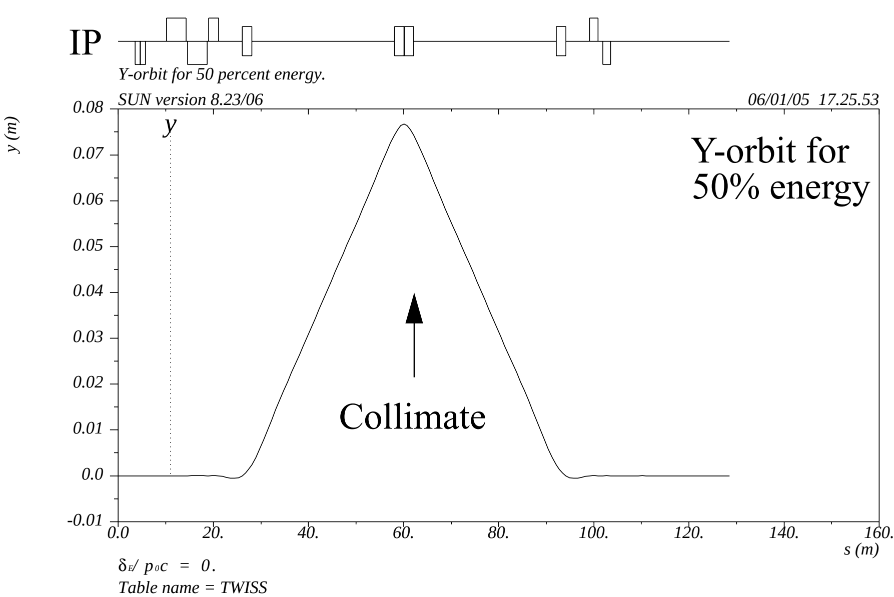
Table 2: Vertical chicane bends.

Chicane	Number	L (m)	B (T)	R_x / R_y (mm)
Energy	8	2.0	0.834	86 / 91
Polarimeter	4	2.0	0.834	155 / 155

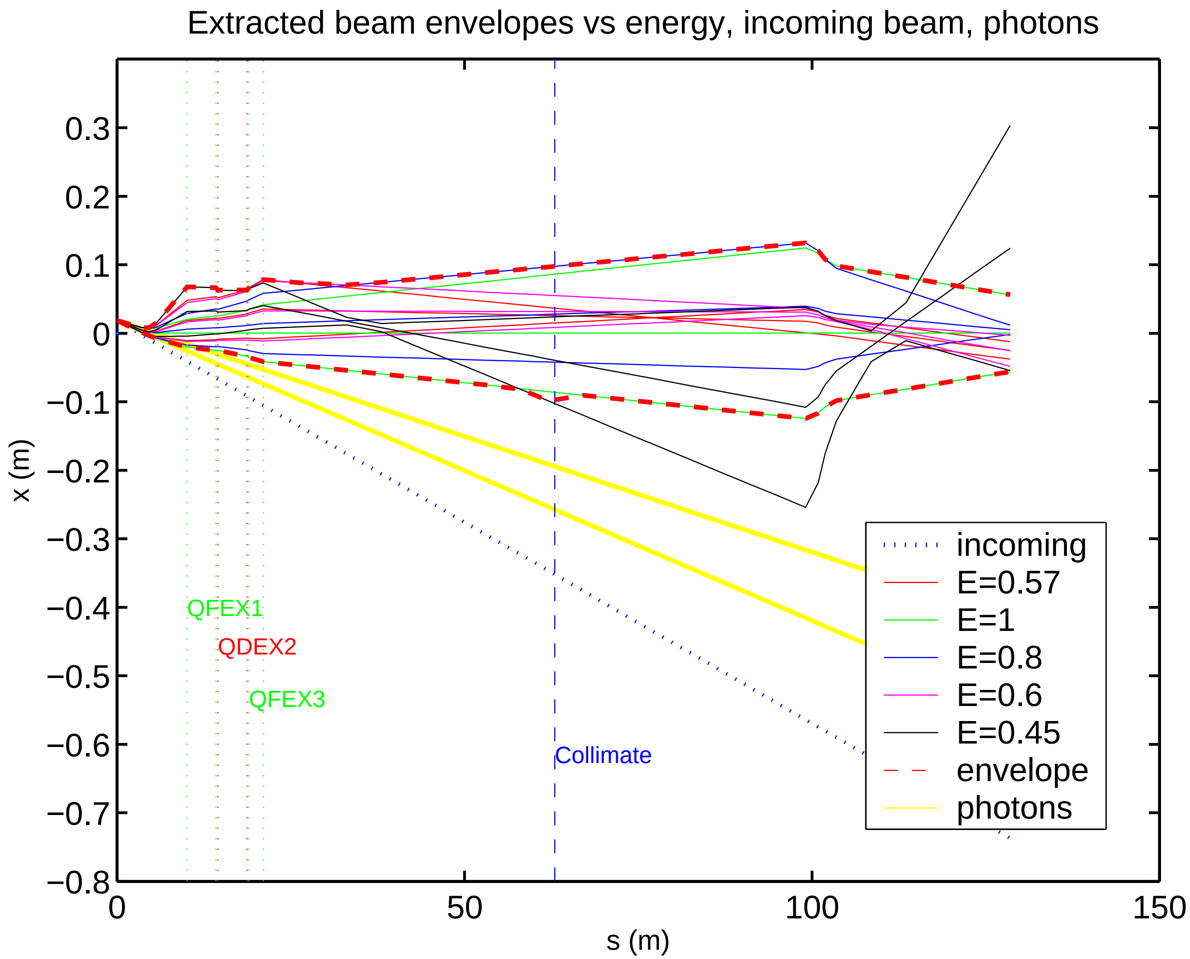
A quick look at 2 mrad option

- The extracted beam passes through the incoming QD0 quad with an X-offset and angle.
- Besides QD0, assumed no other shared fields on the extracted and incoming lines.
- Looked only at initial focusing and electron beam containment in the extraction line.
- Challenges: 1) QD0 is too strong for the low energy particles, creates X-dispersion and further increases the beam X-size, 2) a small separation between the beamlines complicates placement of extraction quads.
- Strategy: 1) assume $4\sigma_x/8\sigma_y$ for extracted beam size, 2) use a quad triplet at 10 m after IP (after QD0 and QF1) for initial focusing, 3) optimize triplet for minimum size of disrupted beam downstream, 4) include a vertical chicane to deflect and collimate particles with less than 50% energy.



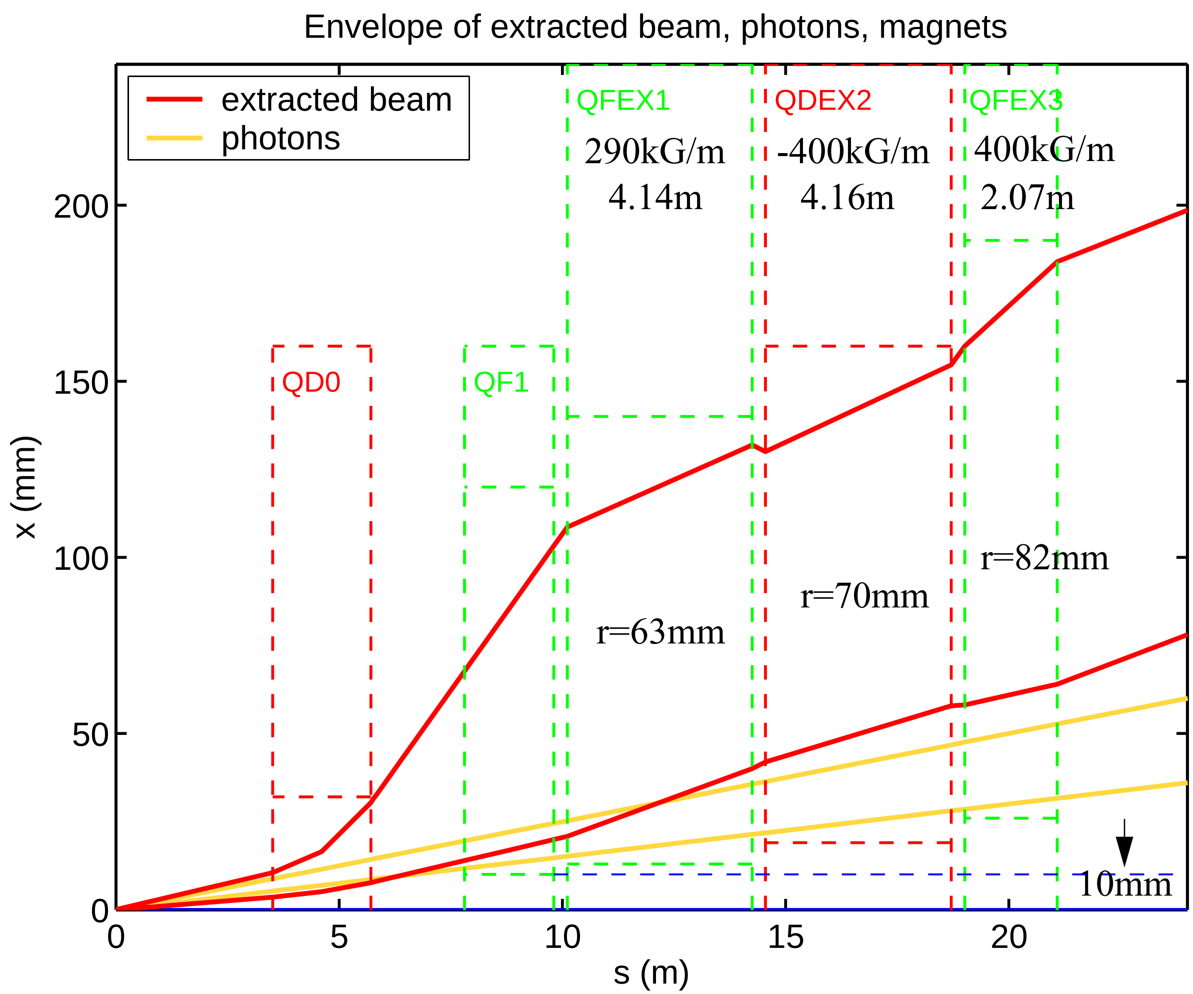


Horizontal envelope of disrupted beam for different energies



- E is the ratio of energy to nominal 250 GeV energy.
- Assumed +/-0.5 mrad photon angle.
- The collimation is to remove particles with less than 50% energy.
- No study of technical details.

Horizontal envelope of disrupted beam near IP



- The shown quad gradient is for 250 GeV beam.

Summary

- Conceptual optics design exists for 20 mrad extraction line.
- The 20 mrad beamline has sufficient aperture to transport the outgoing photons and provides a large energy acceptance for the disrupted electron beam.
- The dedicated vertical chicanes and the secondary beam focus are included for energy and polarization diagnostics.
- Further studies need to include more beam tracking, further optimization of apertures (they may be too conservative) and a detailed magnet design.
- The optics for 2 mrad crossing angle appears to be a challenge.