# Power losses of a CLIC beam in the ILC 20 mrad extraction line

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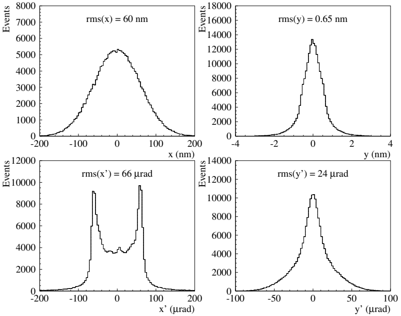
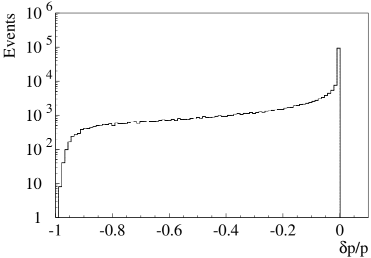
# Incoming CLIC beam parameters

| Parameter | Symbol | Value | Unit |
|---|---|---|---|
| Center-of-mass energy | $E$ | 3 | TeV |
| Particles per bunch | $N_b$ | 2.56 | $10^9$ |
| Bunches per RF pulse | $n$ | 220 | |
| Bunch spacing | $\Delta t_b$ | 0.267 | ns |
| Repetition frequency | $f$ | 150 | Hz |
| Primary beam power | $P_b$ | 20.4 | MW |
| Horizontal normalized emittance | $(\beta\gamma)\epsilon_x$ | 660 | nm.rad |
| Vertical normalized emittance | $(\beta\gamma)\epsilon_y$ | 10 | nm.rad |
| Horizontal rms beam size | $\sigma_x$ | 60 | nm |
| Vertical rms beam size | $\sigma_y$ | 0.7 | nm |
| Rms bunch length | $\sigma_z$ | 30.8 | $\mu$m |
| Peak luminosity | $L$ | 6.5 | $10^{34}$ cm$^{-2}$ s$^{-1}$ |

# Disrupted beam distributions

Strong beam-beam interactions lead to an emittance growth and the apparition of low-energy tails in the disrupted beam.

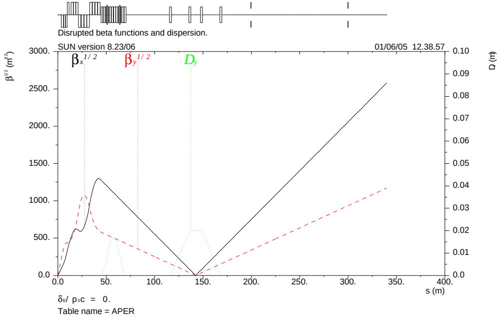



*Distributions for CLIC at 3 TeV*

# The ILC 20 mrad extraction line

The ILC 20 mrad extraction line consists of a DFDF quadruplet, followed by two vertical chicanes for energy and polarization measurements and a field-free region with two collimators at 200 and 300 m downstream of the interaction point.



# Estimation of the power losses

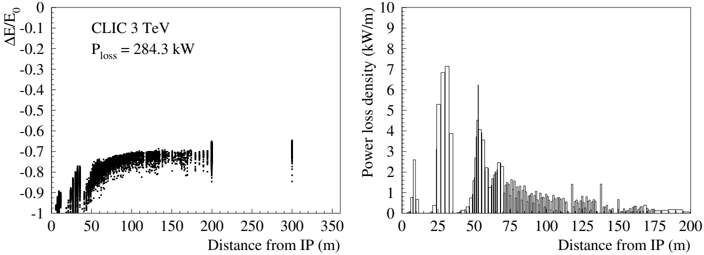
The disrupted beam distributions are tracked with DIMAD, from the interaction point to the dump.
Using the number of lost particles in the extraction line, as well as their energy, one calculates the total beam power loss:

$$P_{loss}[W] = 1.602 \times 10^{-10} \frac{N_b\, n\, f}{N_{tracks}} \sum_{i=1}^{N_{loss}} E_i.$$

- $N_b$ is the number of particles per bunch,
- $n$ is the number of bunches per RF pulse,
- $f$ is the repetition frequency (in Hz),
- $N_{tracks}$ and $N_{lost}$ are the number of tracked and lost particles,
- $E_i$ is the energy of the particle $i$ (in GeV).

# Disrupted beam losses

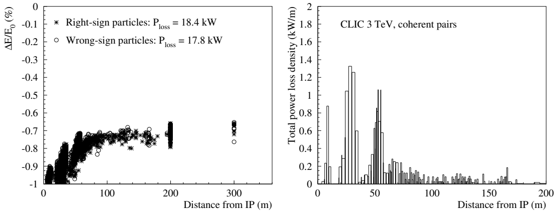
Total power losses (left) and loss density (right) along the 20 mrad extraction line, upstream of the collimators:



# Beamstrahlung photon and coherent pair losses

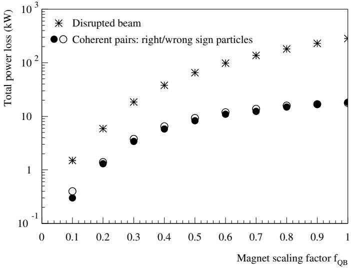
Beamstrahlung photons losses occur on the first collimator, which has an opening angle of 0.44 mrad. However, these losses can be neglected ($P_{loss} = 55$ W).

At CLIC, one expects about $5 \times 10^7$ coherent pairs per bunch crossing. About 80% of these particles do not reach the dump, due to their low energy. The corresponding power loss is one order of magnitude smaller than for the disrupted beam.



# Power losses vs magnet settings

One can reduce the power losses by lowering $f_{QB}$, a common scaling factor for all normalized gradients and bending angles along the 20 mrad extraction line... But one needs to change the settings by at least a factor 5 to reach reasonable power levels.




PROBLEM: the nominal optics is destroyed, no more second focus point! But the spot size at the dump still looks good...

# Conclusion and outlooks

- A scaled-up ILC 20 mrad extraction line was considered for the nominal CLIC machine, but the power losses are too large (284 kW for the disrupted beam and 36 kW for the coherent pairs).
- Power losses are reduced by scaling down the magnetic field of the dipoles and quadrupoles of the post-collision line.
- However, the optics at the nominal energy is destroyed: no post-collision beam measurement seem possible. And the losses in the SC quadrupoles are still a few hundred Watts!

NEXT: design of a CLIC post-collision line based on chicanes to separate beamstrahlung photons and charged particles.