Energy Distribution in FCC-ee with Beamstrahlung

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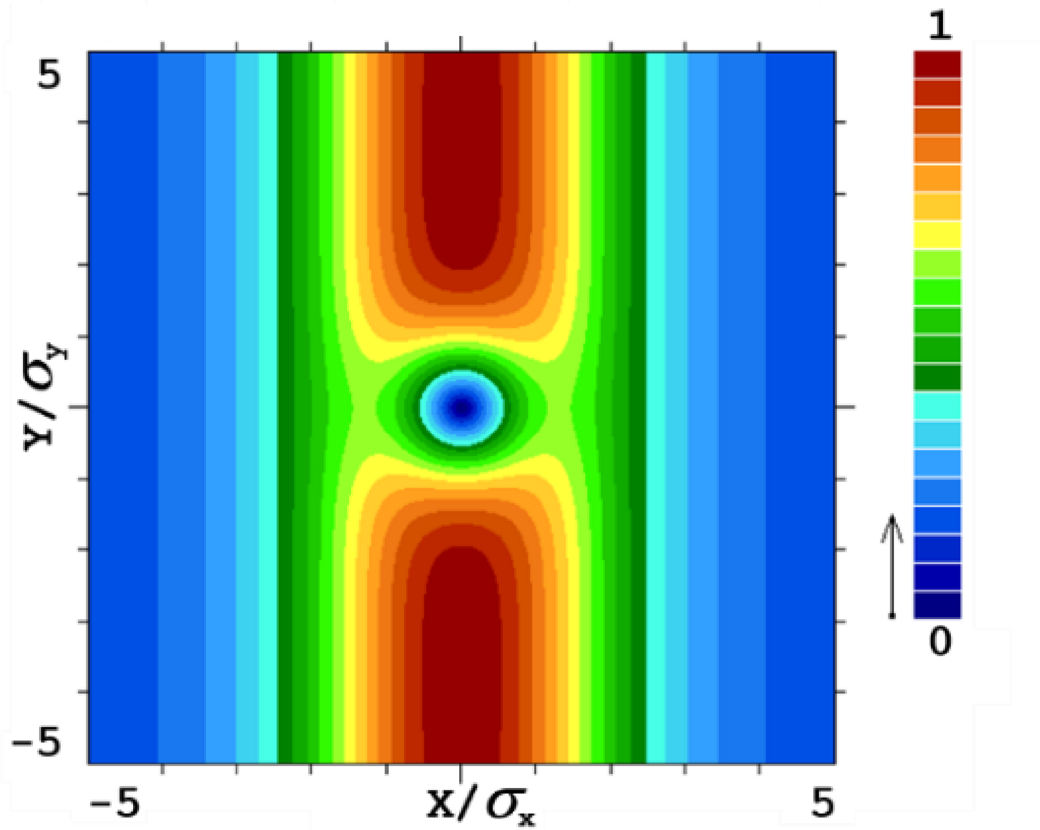
The Model

- Due to symmetry, “half ring” collider is considered with one IP.
- At this stage we used linear lattice with damping and Gaussian noise. No explicit energy loss in the arcs!
- IP is located symmetrically between RF sections, so we assume the energy at the IP is the “mean energy”. In fact, IR region is not symmetrical.
- There is no dispersion at the IP, thus there is no correlations between dE/E and transverse coordinates. However, correlations between σ_E and transverse coordinates appear due to beamstrahlung.
- In simulations, particles collide with the slices of the opposite bunch, not with particles. So we account only energies of the test particles.
- To find out the details of energy distribution in collision, new features were recently implemented in the tracking code. Further we will discuss the results for Z only (45.6 GeV).

Absolute Value of Transverse Force for Flat Beams



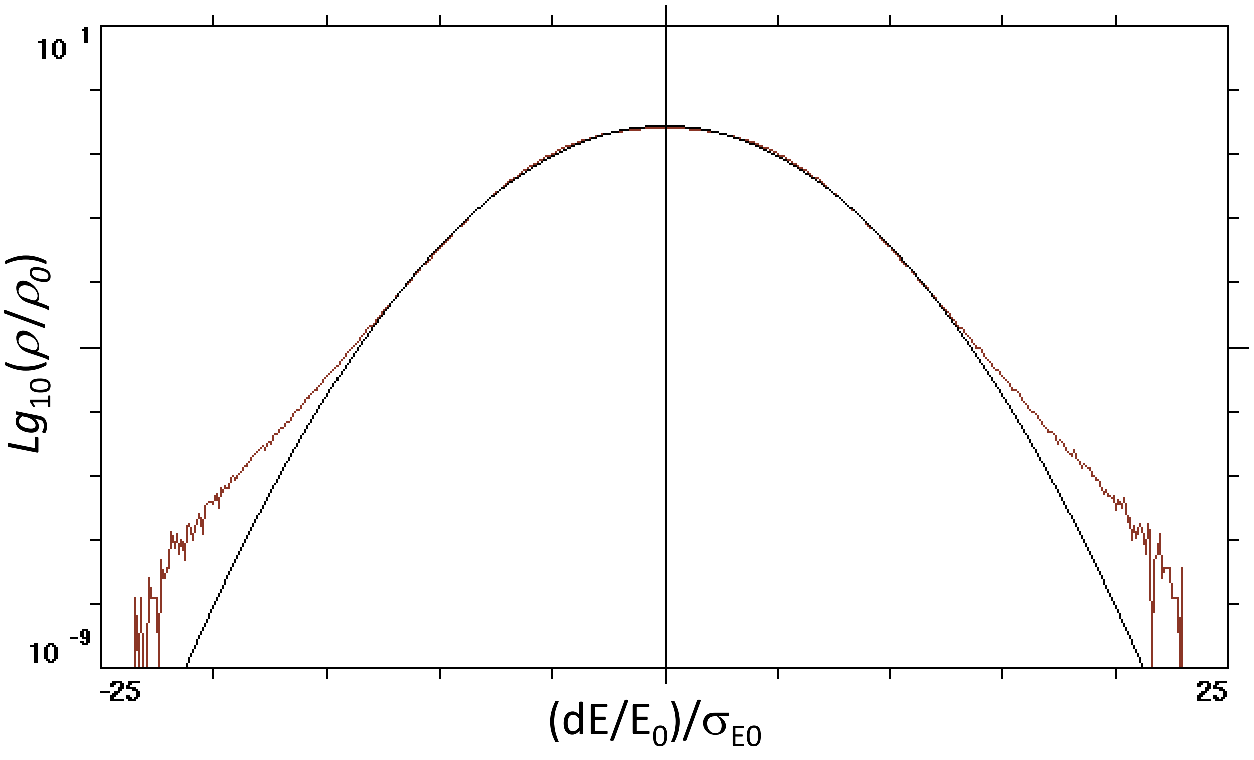
Due to the crossing angle, particles traverse the opposite bunch horizontally.

Maximum beamstrahlung: $|y| > 2\sigma_y$

Maximum luminosity: $|y| < 2\sigma_y$

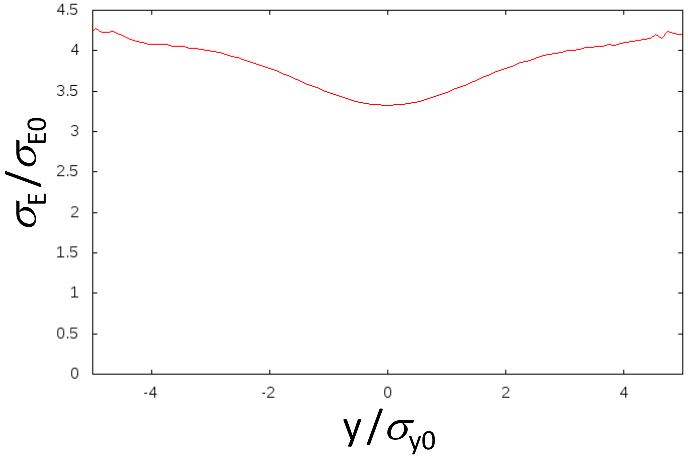
Equilibrium Energy Distribution

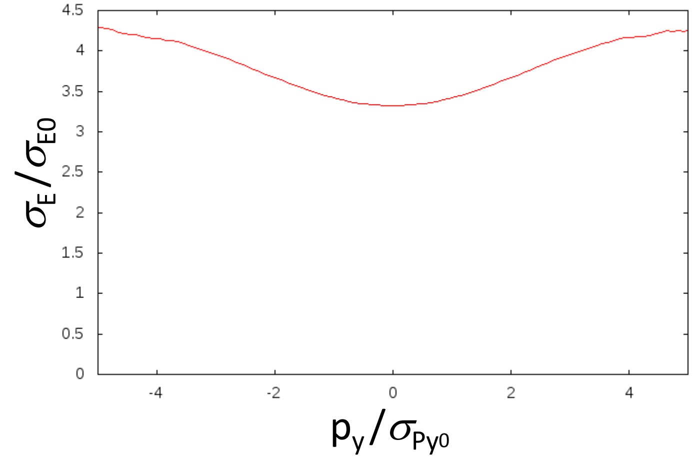
σ_{E0} = 0.00038, σ_E = 0.00132, Black line: Gauss with σ_E = 0.00129 = 3.4 σ_{E0}



Energy acceptance: 1.3% = 34.2 σ_{E0}

Energy Spread vs. Other Coordinates

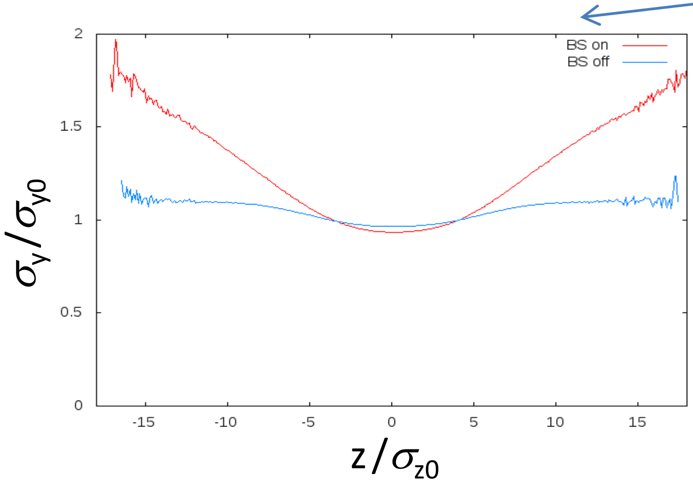


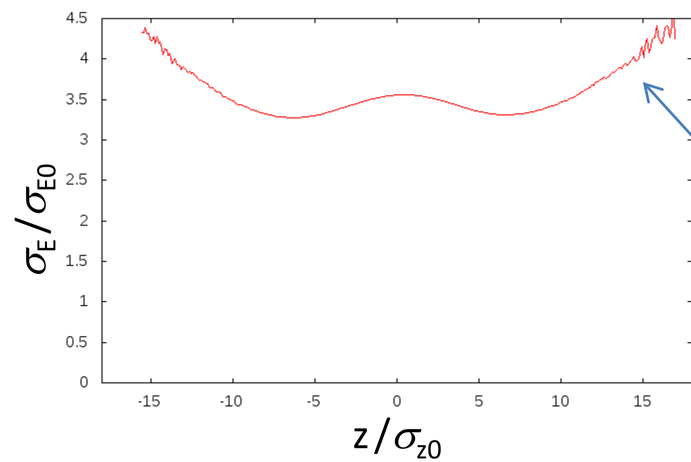


Beamstrahlung depends on Y-coordinate, but it is “fast” variable. “Slow” variable is betatron amplitude, so we have similar σ_E dependence on P_y.

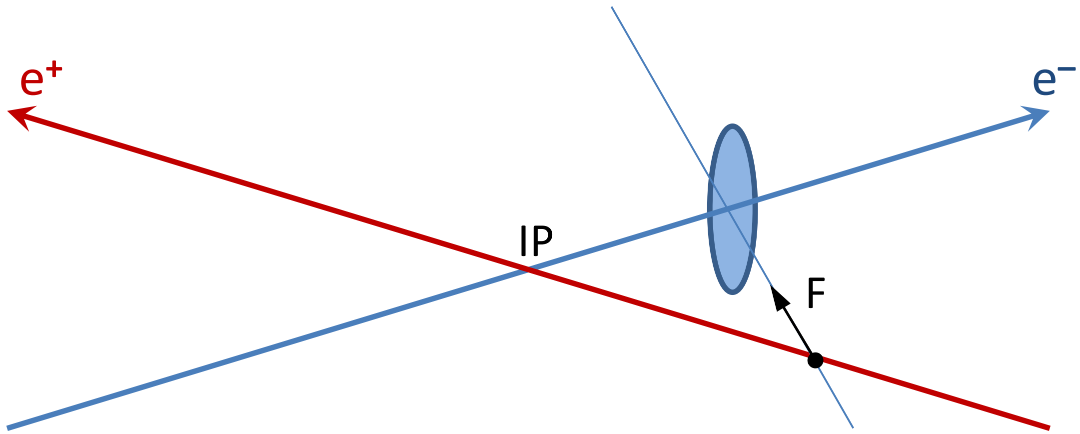
The tails of energy (and longitudinal) distribution are formed by particles with large vertical betatron amplitudes. As a result, σ_y is larger at the longitudinal tails.

As a result, the energy spread also increases at the longitudinal tails.



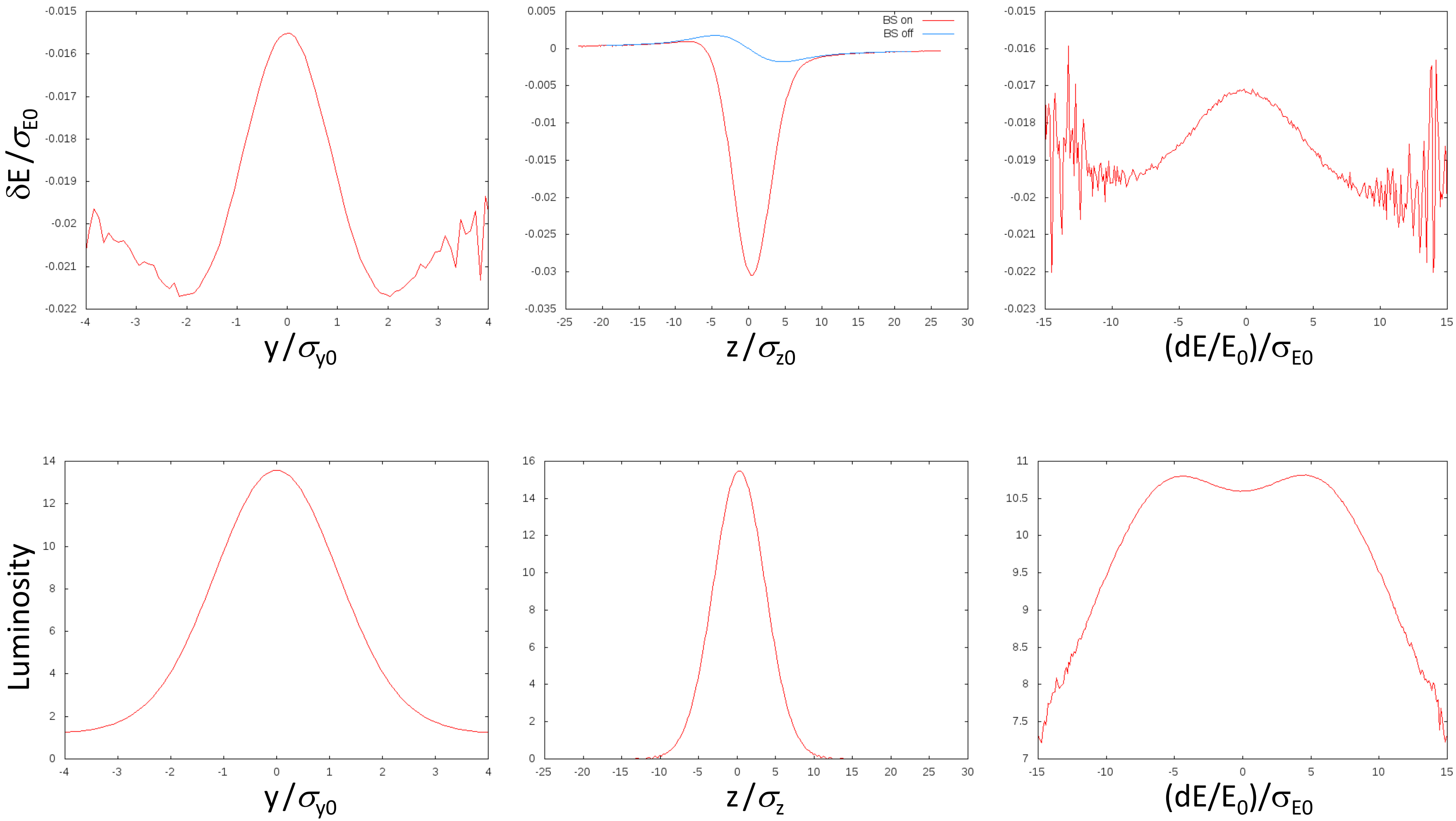


Energy Change due to Crossing Angle

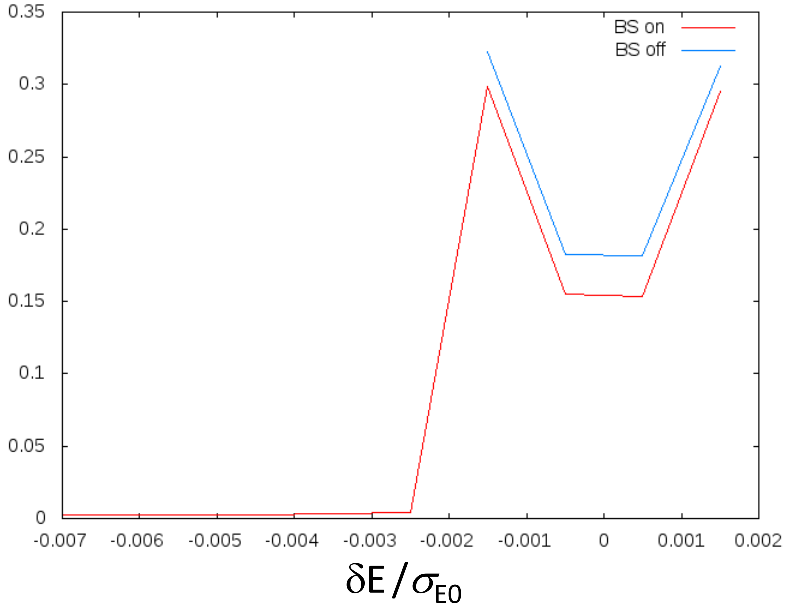


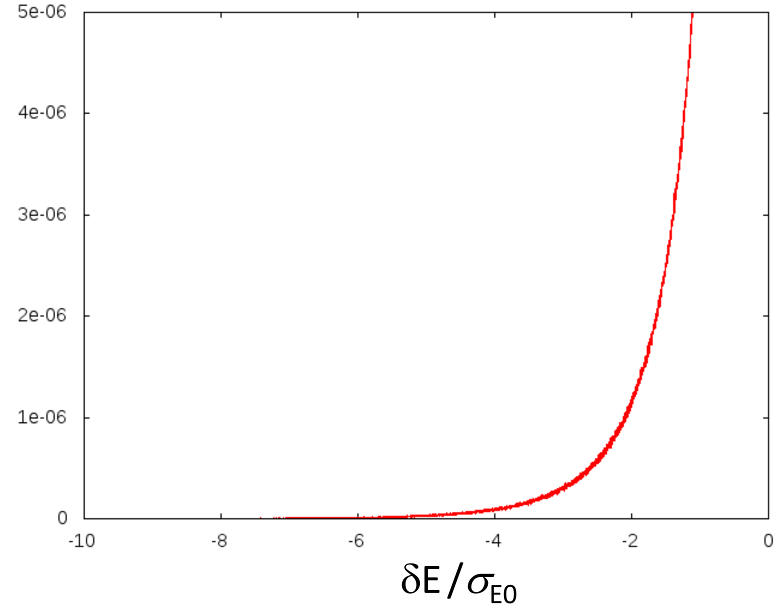
- Transverse kick from a charged "slice" of the opposite bunch is perpendicular to its trajectory (in ultra-relativistic case).
- Due to the crossing angle (actually, large Piwinski angle), transverse kicks have longitudinal components for the particles, and therefore affect their energy.
- The signs of energy change are different "before" and "after" IP.
- The whole energy change depends on the particle's Z-coordinate.
- Thus, beam-beam interaction acts as nonlinear RF cavity and results in a decrease of synchrotron tune. This effect was observed and measured at DAFNE (article in PRST-AB, 2011) .

Energy Loss & Luminosity per Collision



Energy Loss Distribution





Mean energy loss per collision: 6.77E-6 · E_0 = 1.78E-2 · $\sigma_{E0} \approx$ 309 KeV

Mean collision energy: (1+1.3E-6) · E_0.

Without beamstrahlung – the same!

Calculated as: $$< E >= \frac{\sum E_c L_c}{\sum L_c}$$

Collisions with every slice of the opposite bunch