Simulation of electron beam in undulators of e+ source of ILC - Emittance and orbit angle with quad misalignment and corrections - No wakefiled

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ILC-LET meeting, Daresbury

2007.01

Concerns studied here:

- Radiation in undulators may increase transverse emittance if there is dispersion due to misalignment of quads.
- Section by section orbit angle change due to misalignment of quads, then gamma-ray angle change, may make polarization of e+ impossible.

Lattice and assumption

- Undulator:
  - Field 1T
  - Period 14 mm
  - Total undulator length 119 m
    - 11.9 m between quadrupole magnets, 10 sections
  - No field errors, no misalignment
- Lattice:
  - Quadrupole magnet every 12.4 m,
  - x 70 deg. y 90 deg. per FODO cell
  - Quad-BPM-dipole corrector package
- Errors
  - Quad offset 0.3 mm, rotation 0.3 mrad
  - BPM offset 10 micron w.r.t. quad, rotation 0.3 mrad
- No wakefield

Kick Minimization

Quad magnet, BPM and steering magnets should be attached.

$$\text{Minimize } r\sum_i (x_i^2 + y_i^2) + \sum_i \left[\left(\theta_{x,i} + k_i x_i\right)^2 + \left(\theta_{y,i} - k_i y_i\right)^2 \right],$$

$\theta_{x(y)i}$: Additional kick angle (additional to designed kick) of steering at i - th quad

$x(y)_i$: Offset from designed orbit at i - th quad

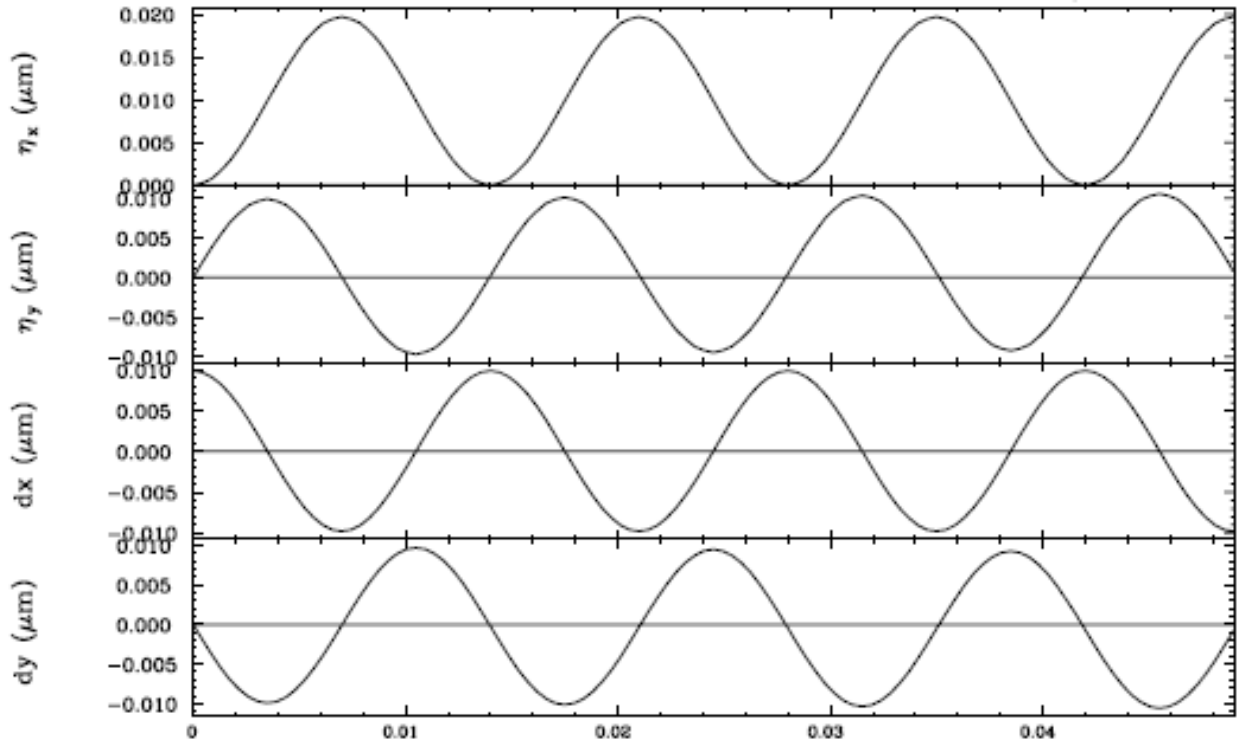
k_i : K - value (inverse of focal length) of the i - th quad

r : Weight ratio : $(\text{Quad - BPM offset})^2 / (\text{Quad offset})^2$

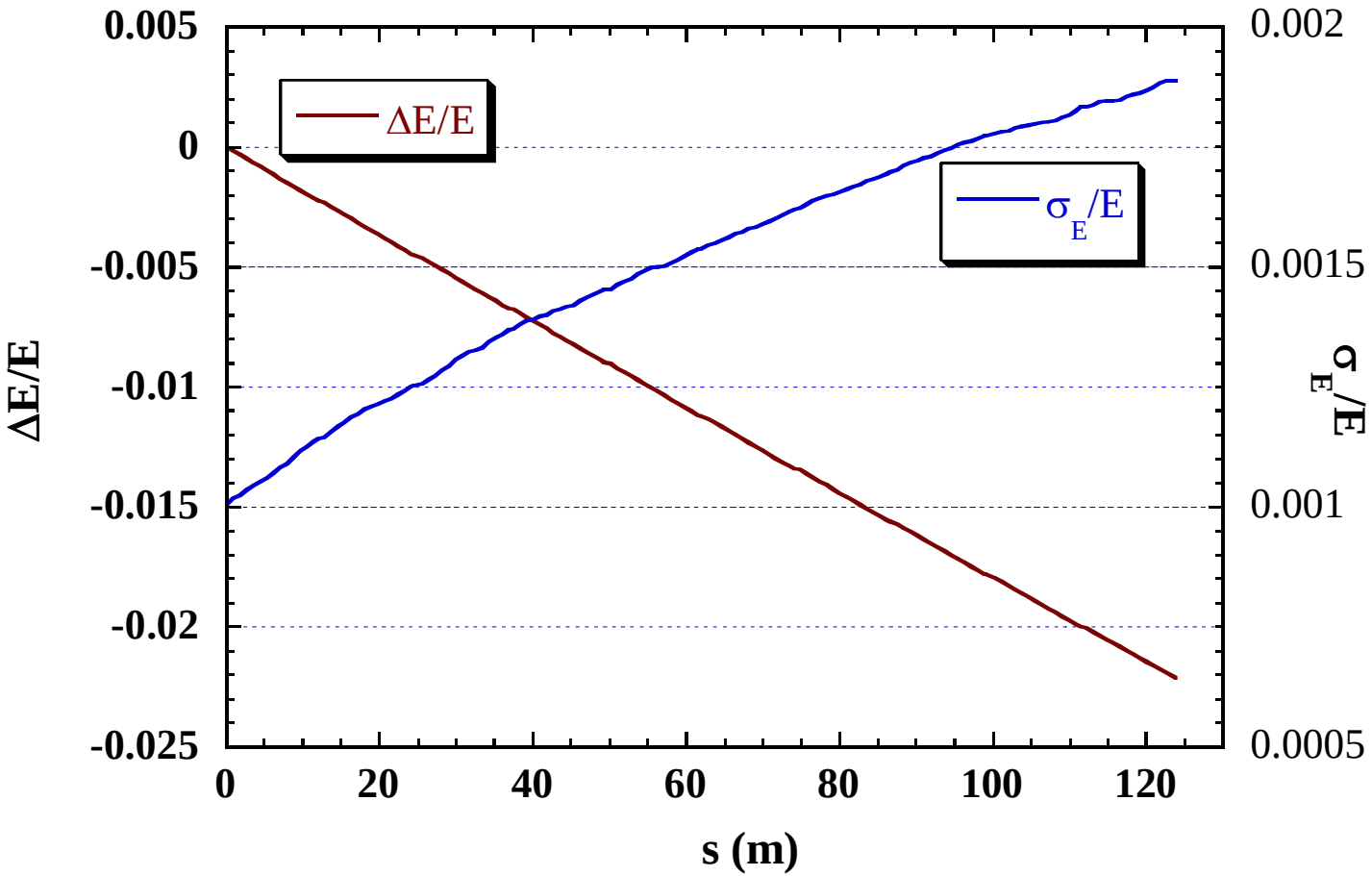
Helical Undulator in SAD

- Simulation used computer code SAD
  - Helical undulator is not supported as a standard magnet.
- Represented by series of bend magnets
  - 16 bend magnets/period (0.875 mm/magnet)
  - Rotate i-th magnet by (360/16)*i deg.

Orbit and dispersion in undulator



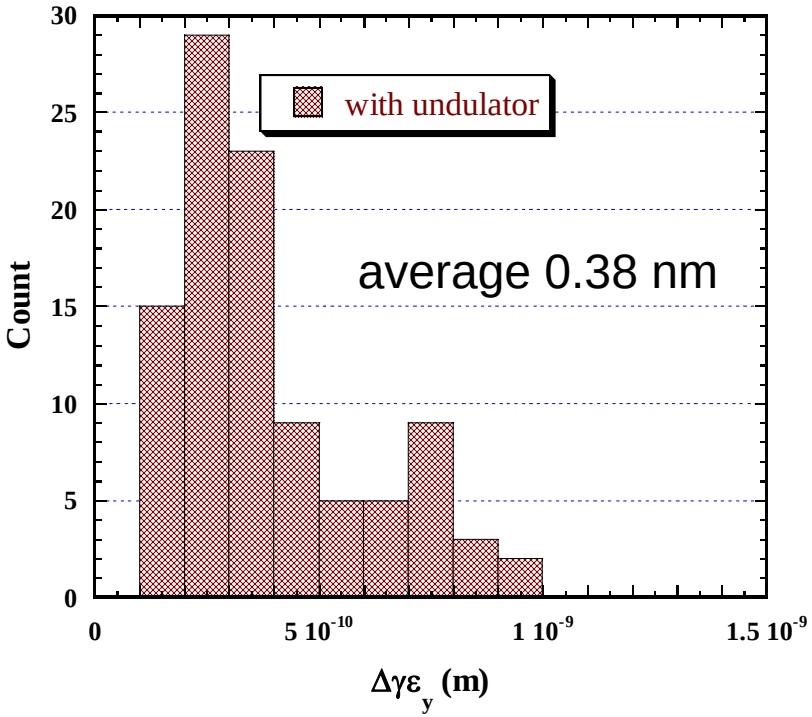
Beam Energy and Energy Spread vs. s



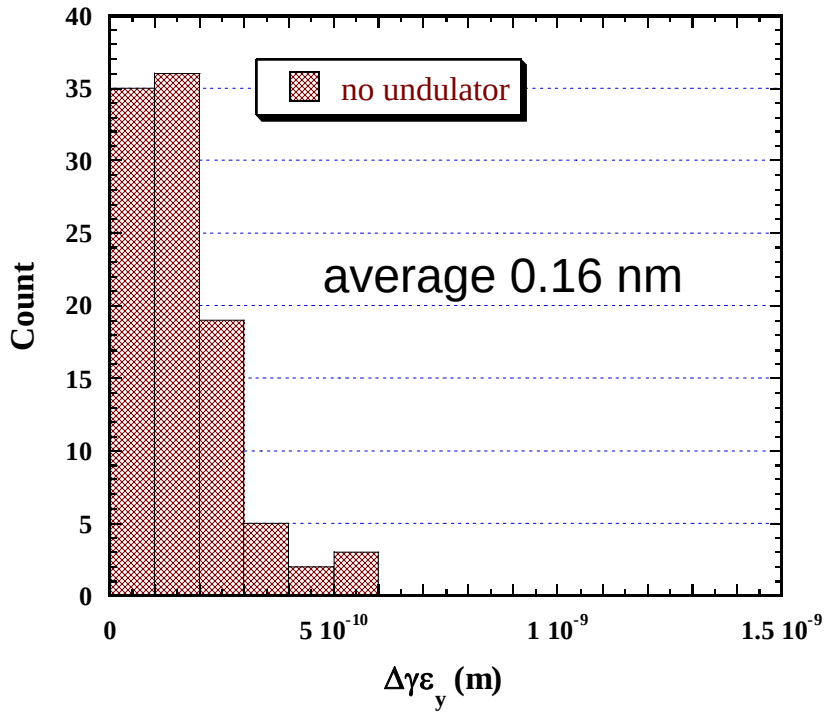
Emittance incraese in the undulator section

Quad offset 0.3 mm, rotation 0.3 mrad
BPM offset 10 micron w.r.t. quad, rotation 0.3 mrad
KM steering, 100 random seeds.

With undulator radiation

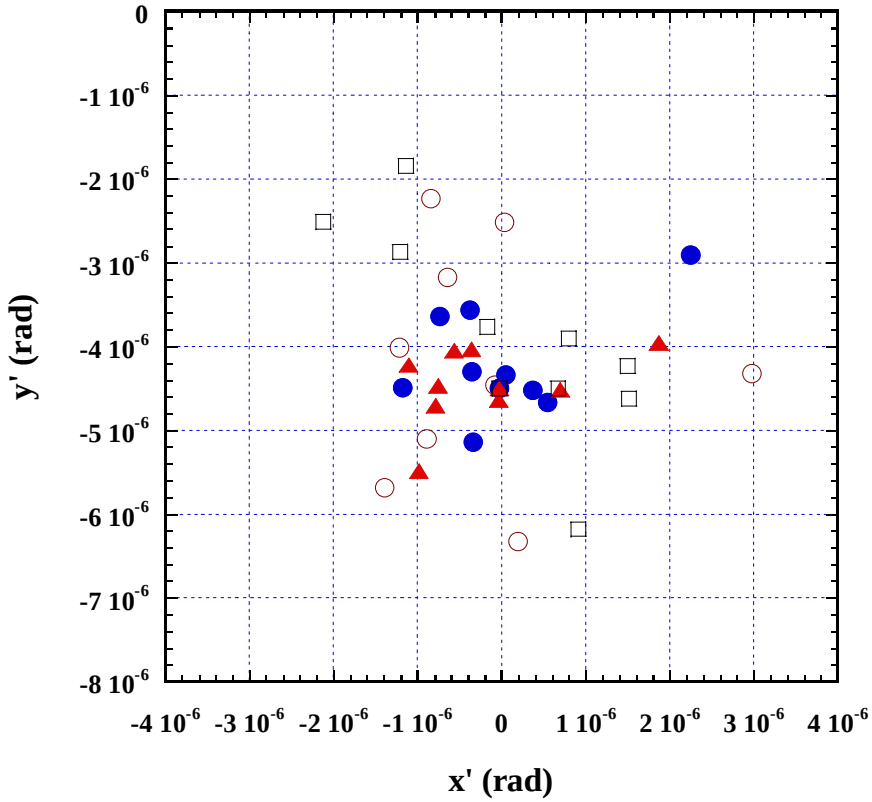


No undulator (replaced by drift space)

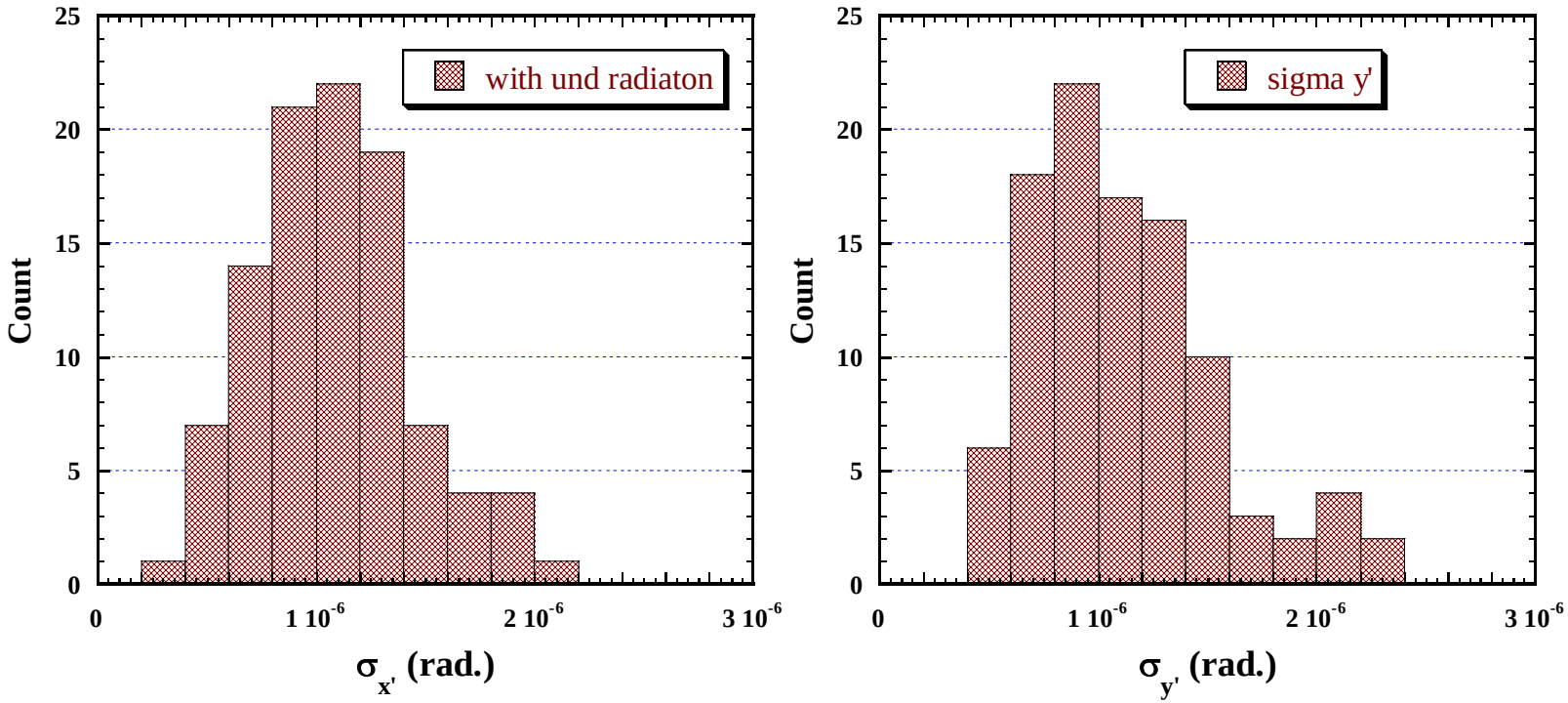


Orbit angle distribution

Each set consists of 10 points. Each point represents orbit angle at the entrance of a quadrupole magnet after each undulator section. Note: 1/gamma = 3.3e-6. $\sigma x'$ ~ 2-3e-6, $\sigma y' << \sigma x'$



Distribution of r.m.s. of orbit angle



Well below 1/gamma

Summary

- Assumptions should be reviewed.
- Radiation in undulators may increase transverse emittance if there is dispersion?
  - Emittance increase ~ 1 nm or less. OK.
- Section by section orbit angle change, then gamma-ray angle change, may make polarization of e+ impossible.
  - Angle distribution ~ 2 μrad or less
    - $1/\gamma \sim 3.3$ μrad,
  - Probably OK.(?)
    - farther correction will be possible, if not.