CLIC Ring to Main Linac Transport

- Status
- Simulations
- Plans

Beam parameters

Toler-ance = allowed deviation within one filling time of 60 ns

Property	Symbol	Value	Unit	Toler-ance
Particle energy	E_0	2.86	GeV	10^{-5}
Bunch charge	Q_0	0.65	nC	1%
RMS bunch length	σ_s	1600	µm	1%
RMS energy spread	σ_E / E_0	0.13	%	1%
uncorr. energy spread	σ_E / E_0	0.13	%	1%
Energy chirp	u	0	1/m	
Normalized emittance	$\varepsilon_{n,x}$	500	nm rad	5%
	$\varepsilon_{n,y}$	5	nm rad	5%
Polarization	P	?	%	
Phase offset 2GHz	$\Delta\phi$	0	deg	0.1 deg

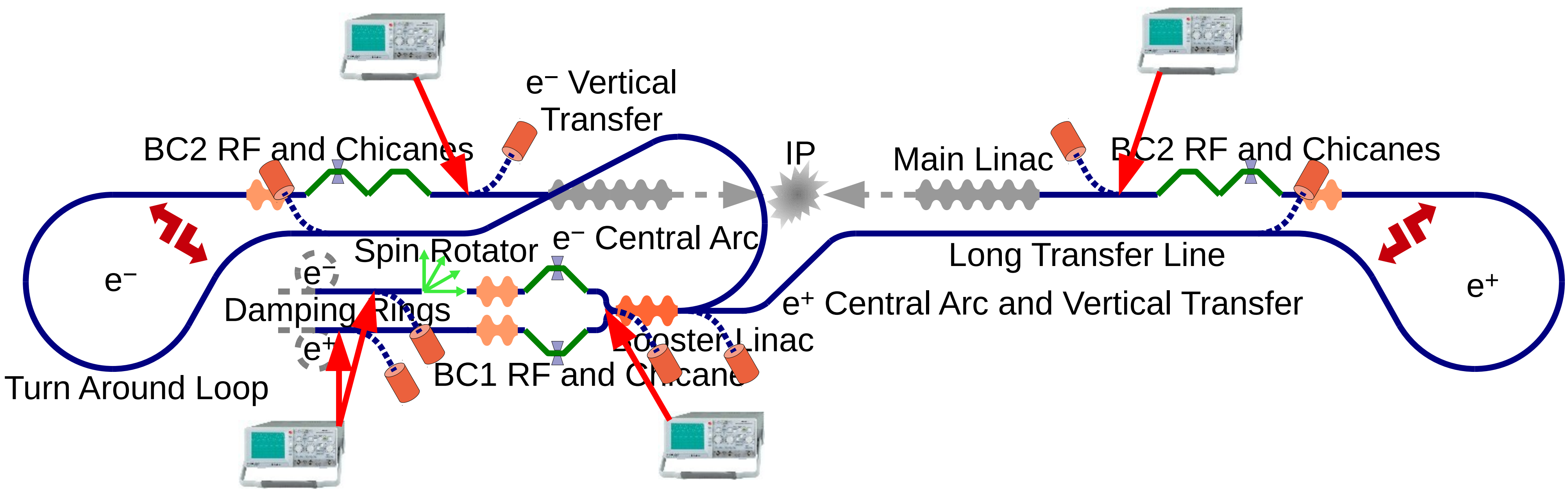
@ exit of damping rings

Property	Symbol	Value	Unit	Toler-ance
Particle energy	E_0	9	GeV	0.2%
Bunch charge	Q_0	> 0.6	nC	0.1%
RMS bunch length	σ_s	44	µm	0.5%
RMS energy spread	σ_E / E_0	< 1.7	%	
uncorr. energy spread	σ_E / E_0	< 1.7	%	
Energy chirp	u	0	1/m	
Normalized emittance	$\varepsilon_{n,x}$	< 600	nm rad	5%
	$\varepsilon_{n,y}$	< 10	nm rad	5%
Polarization	P	?	%	
Phase offset 12 GHz	$\Delta\phi$	0	deg	0.1 deg

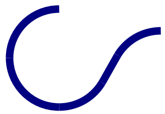
@ entrance of main linac

"General" Layout

an almost complete but messy version...

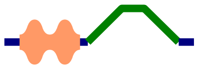


Sub-Systems



Transfer Lines, Loops and Arcs: connection of damping rings and main linac, including the vertical transfer to tunnel level

Booster Linac: acceleration to main linac injection energy

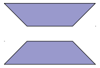


Bunch Compressor RF and Chicanes: two staged longitudinal compression

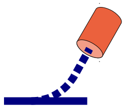
Spin Rotator: rotation from vertical spin orientation to longitudinal orientation

Diagnostics: characterization of beams especially at damping ring exit and main linac entrance

Feedback and Feed-Forward Systems: correction of slow and fast dynamic errors



Collimators, Spoilers: scraping of tails, machine protection



Commissioning Dumps: for setting up parts of the machine, also used as spectrometers

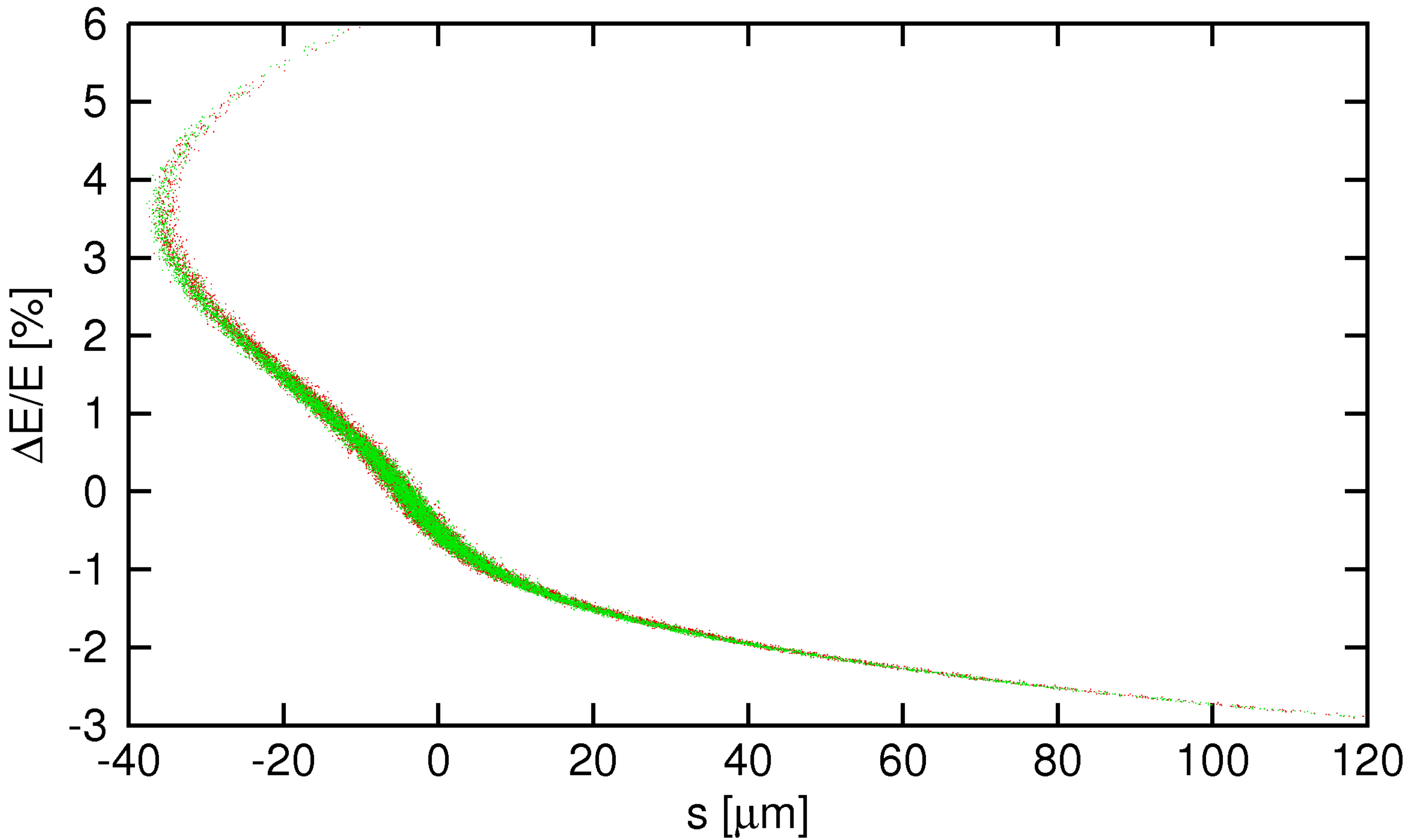
Status

- Lattices have been created for the codes Elegant and Placet.
  A simplified MAD-X lattice can be converted from Placet (useful only for Twiss and survey).
- The lattices follow my “general” layout but deviate in some cases.
  For example merging and splitting of the two beam lines around the booster linac is missing. Diagnostics beam lines are for the moment replaced by place holders, dumps and collimators are not included.
- My layout itself deviates from the civil engineering layout,
  e.g. a few smaller arcs, which are included in the CE layout to match the CERN site, are missing, the path length difference between electron beam lines and positron beam lines is not tuned to the correct value.
- On the other hand, the lattices include the bend of the spin rotator which is not taken into account in my layout and the CE layout.
- Despite these differences and despite the fact that there is some room for improvements or clean-up, the lattices are considered complete and sufficient for beam dynamics studies.

Simulations

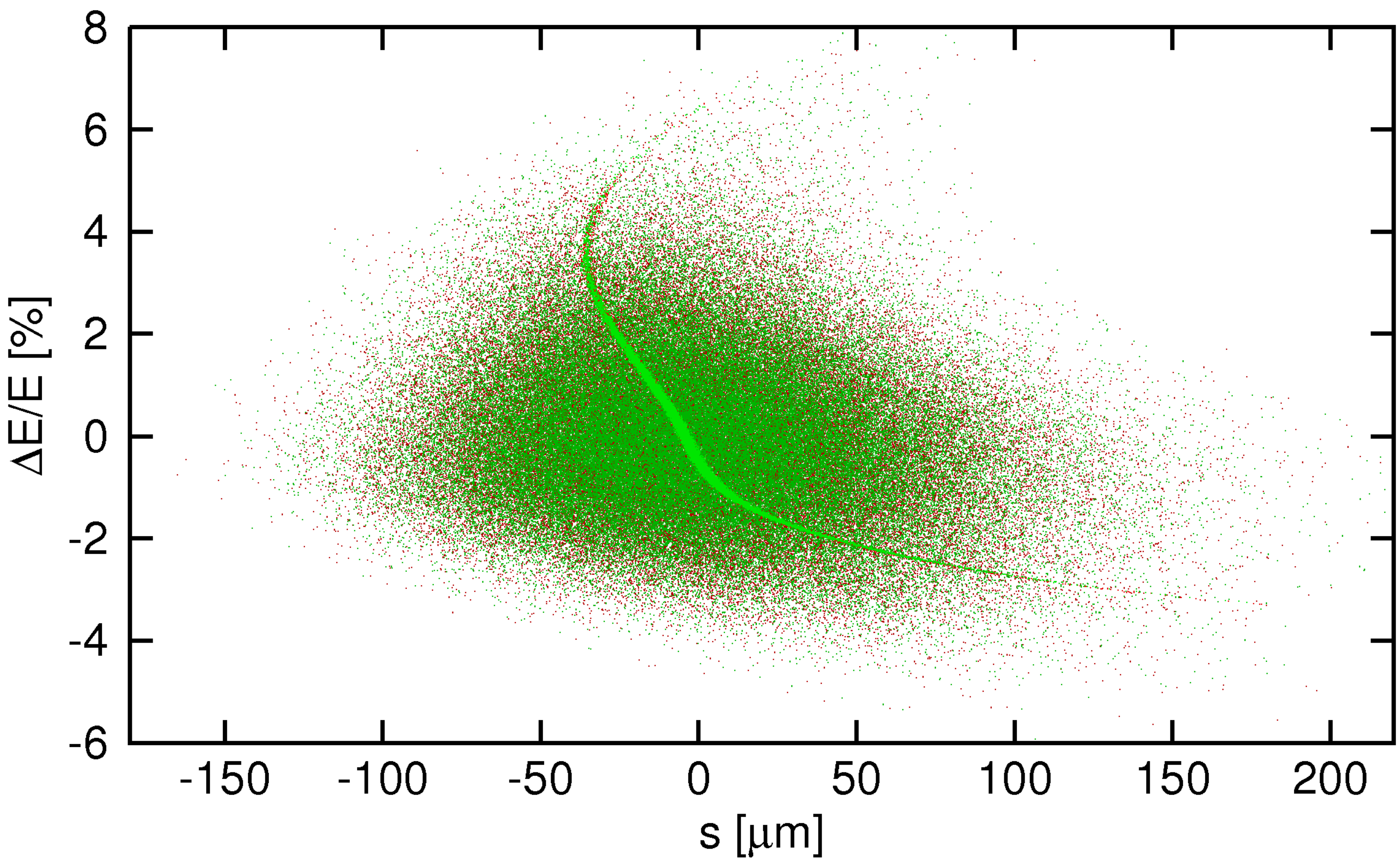
- Simulations are performed using a perfect lattice, i.e. no magnet misalignment, no magnet field errors, no incoming bunch jitter.
- The incoming bunch has a 6D Gaussian charge distribution.
- Single bunch wake fields and incoherent synchrotron radiation (ISR) are included. Emittance plot also includes coherent synchrotron radiation (CSR) (no shielding).
- Only electrons are shown since positron lattices are simpler and thus better in terms of performance.
- Phase space plots show distributions at the end of the RTML.

Simulations, longitudinal phase space



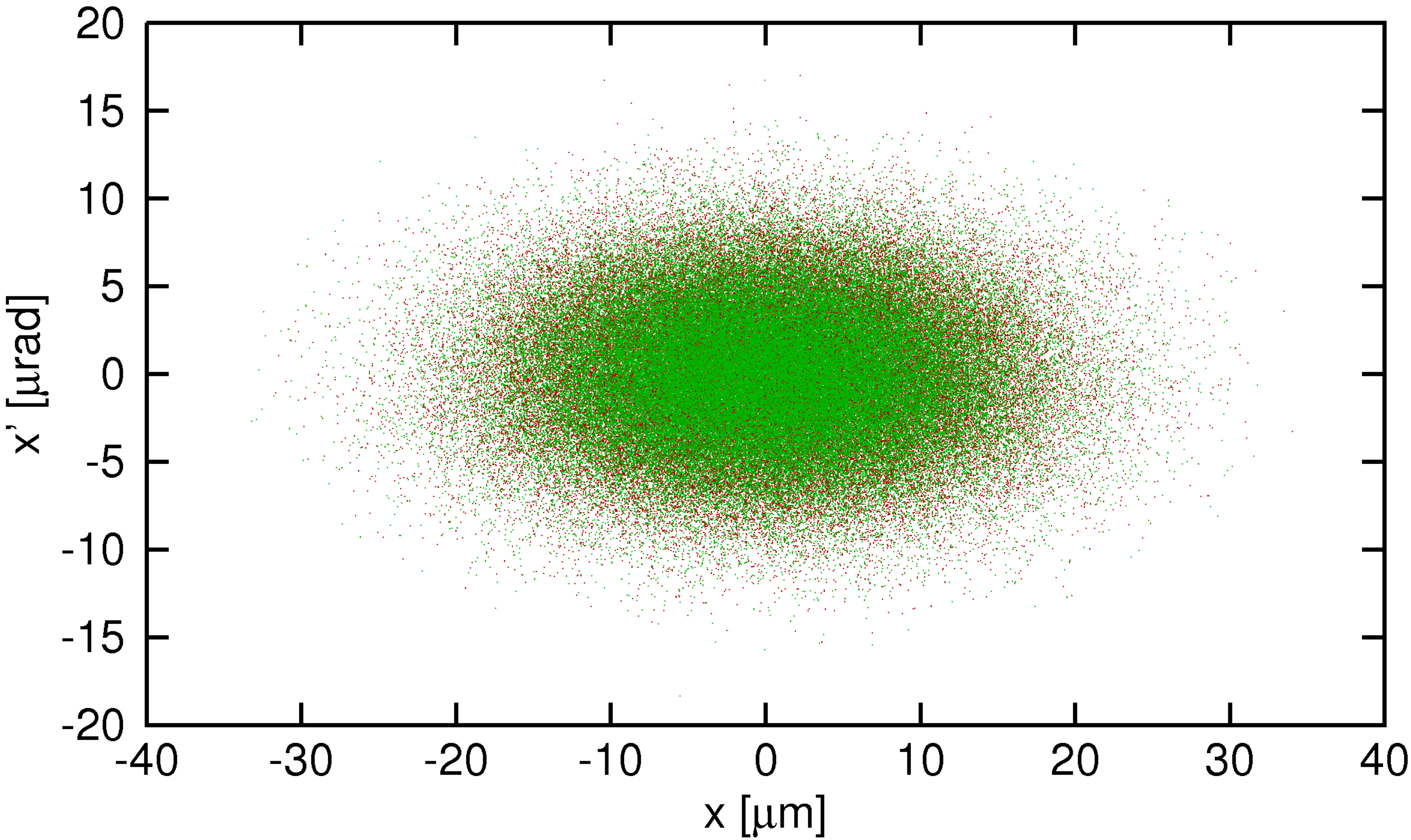
Elegant (green), Placet (red)
zero initial energy spread, with single bunch wakes and ISR

Simulations, longitudinal phase space



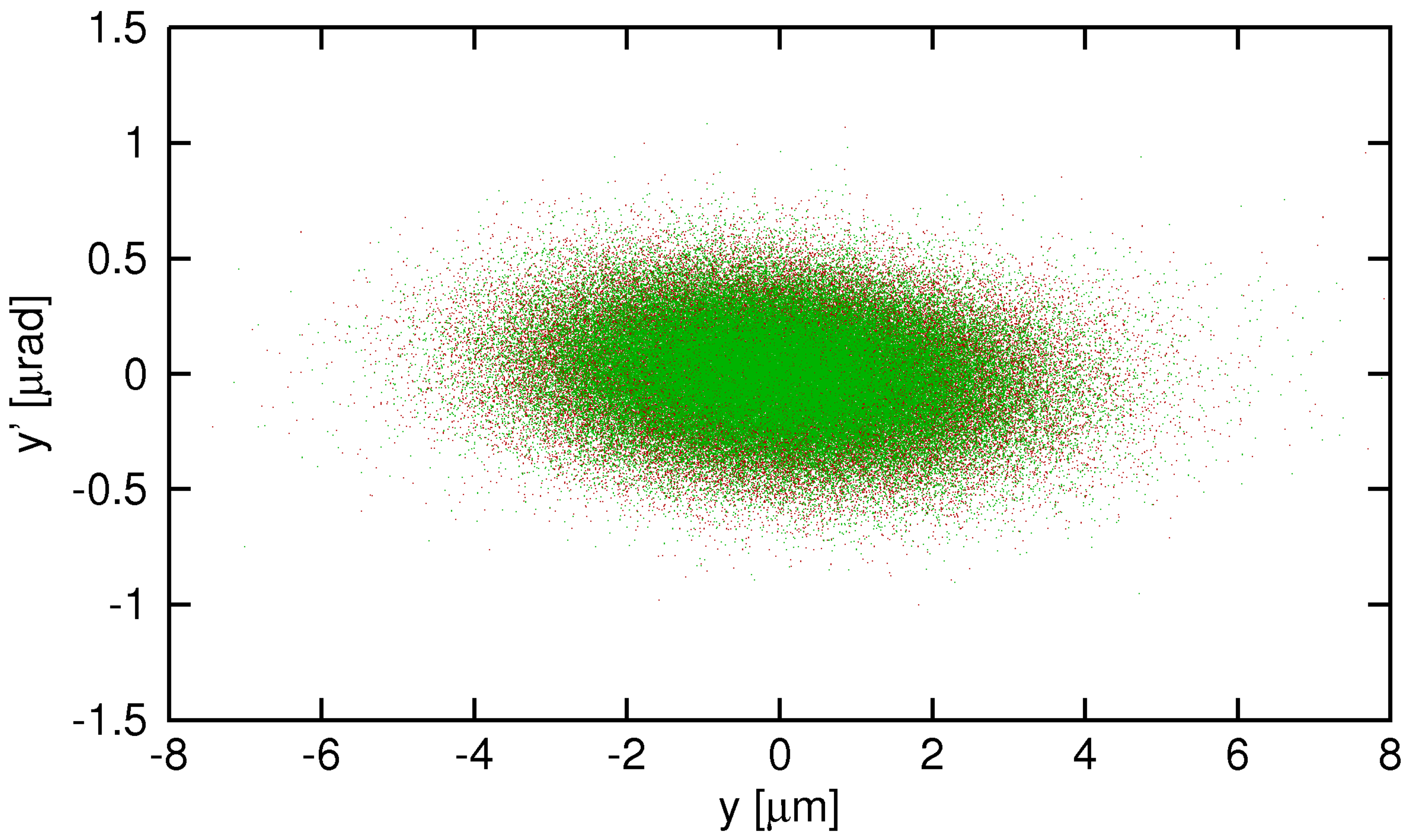
Elegant (green), Placet (red)
with single bunch wakes and ISR

Simulations, horizontal phase space



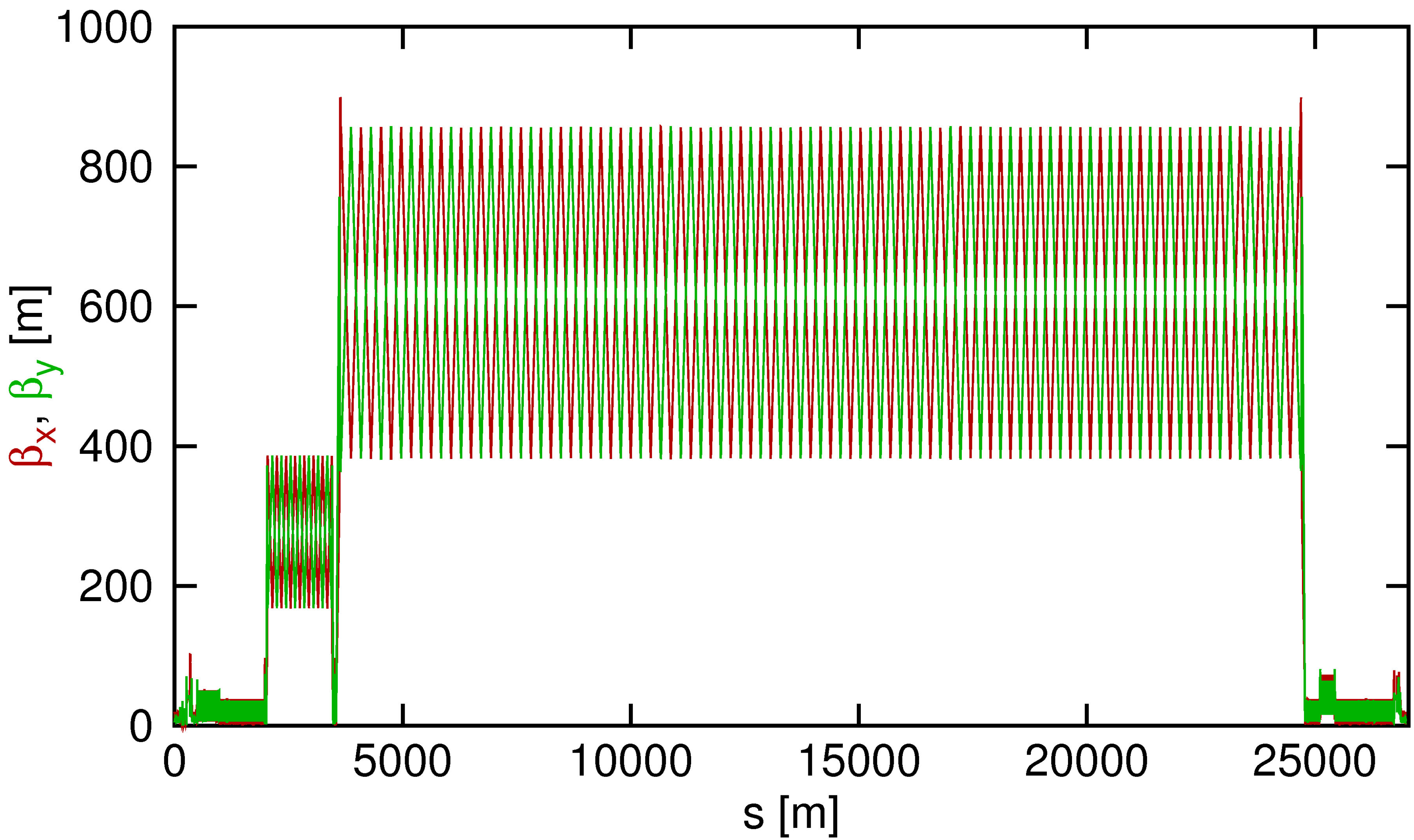
Elegant (green), Placet (red)
with single bunch wakes and ISR

Simulations, vertical phase space



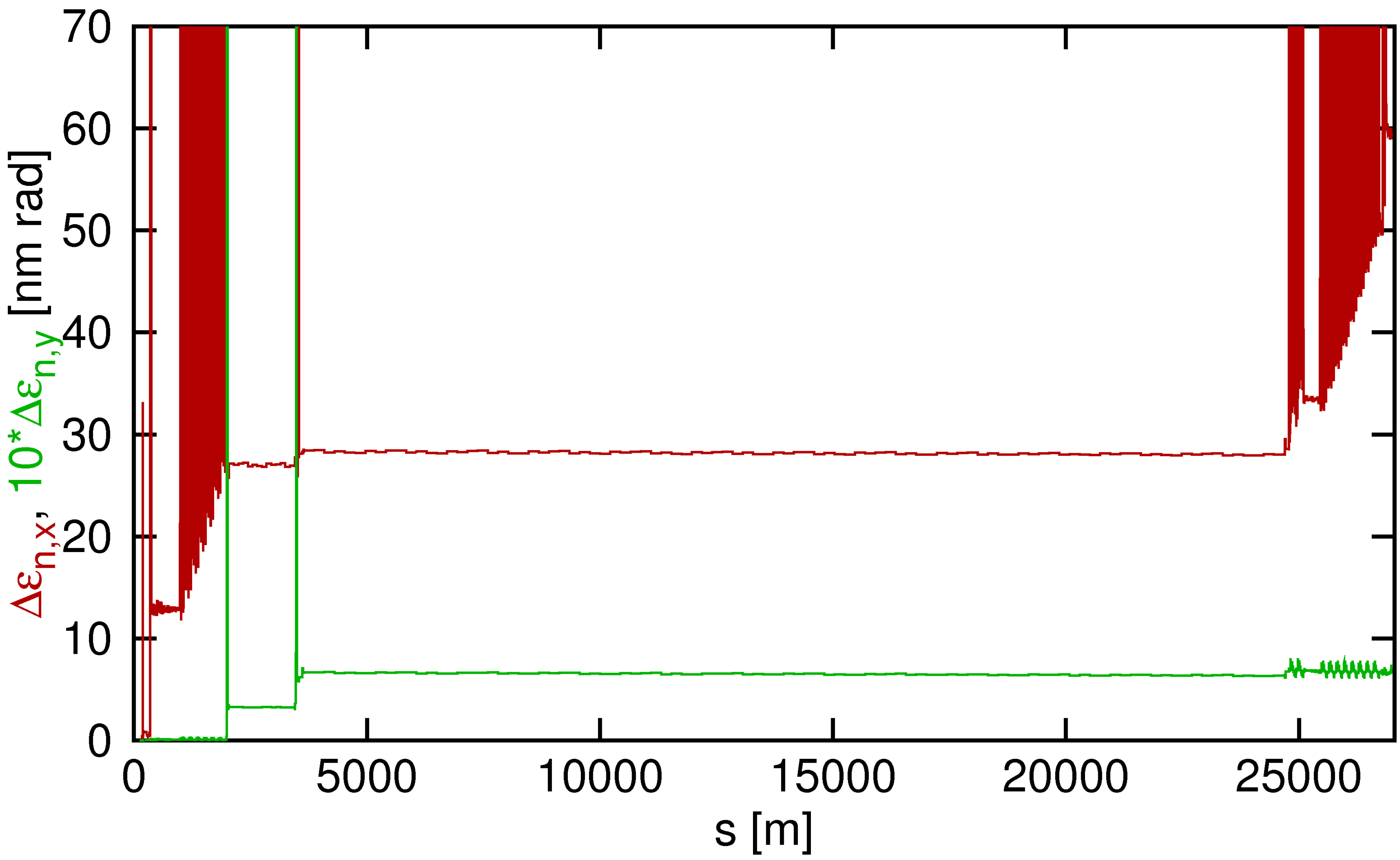
Elegant (green), Placet (red)
with single bunch wakes and ISR

Simulations, beta functions



beta x (red), beta y (green)

Simulations, emittances



Growth of normalized emittances $\varepsilon_{n,x}$ (red), $\varepsilon_{n,y}$ (green)
with single bunch wakes, ISR and CSR

Simulations, first conclusion

- Agreement of Elegant and Placet is almost perfect.
- Performance of the perfect RTML is good.
- Largest emittance dilution due to ISR in arcs and loops.
- CSR in chicanes is second largest contribution. This could be improved by utilizing the shielding effect of narrow vacuum chambers.
- But before improving the perfect RTML we urgently need to study imperfections, i.e. magnet misalignment, magnet field errors, incoming bunch jitter, … and we have to study multi bunch wake fields.
- In previous studies we saw already that the error acceptance of the turn around loop was not sufficient. Its lattice has been improved, but there might be other surprises.

Simulations, misalignment

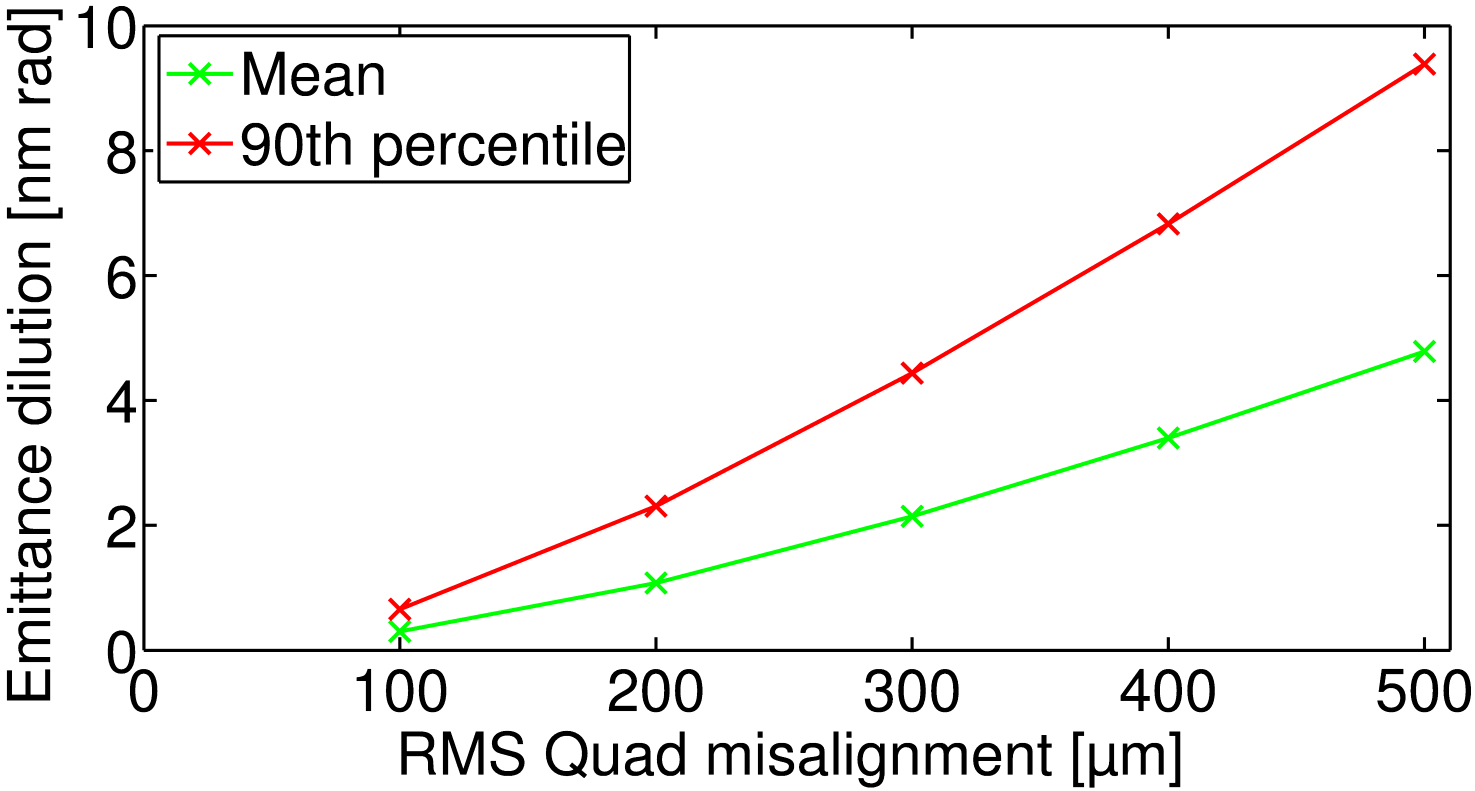
Method

- Load a perfect lattice.
  - Add a BPM & X/Y corrector upstream of each magnet
    - BPM, and corrector are zero-length
    - BPM, corrector, and magnet “tied together” for misalignments
  - Randomly misalign magnets
    - BPMs move with magnets
      - Simulates perfect beam-based alignment
  - Apply one-to-one steering
    - Steer beam to centre of next BPM

by S. Molloy

Simulations, misalignment

Long Transfer Line



by S. Molloy

Simulations, misalignment

Turnaround loop

- Still ***very*** sensitive to magnet misalignments
- Quadrupoles & sector bends
  - 10 um random misalignments → several um of emittance growth (in vertical plane)
  - Larger misalignments result in beam loss
- This is after two rounds of one-to-one steering
  - Have not yet tested DFS or kick minimisation yet
    - (that process has begun)

by S. Molloy

Simulations, second conclusion

- Misalignment studies are on-going.
- Long transfer line is o.k.
- But turn around loop is more challenging.
- A huge emittance contribution seems to be due to coupling.
- Also residual dispersion might be important.
- That means, coupling and dispersion correction could be vital.
- These will be studied.
- But unfortunately for the CLIC CDR these studies will come too late.