CLIC integrated studies

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IWLC 2010
Geneva, October 2010

Contents

Introduction

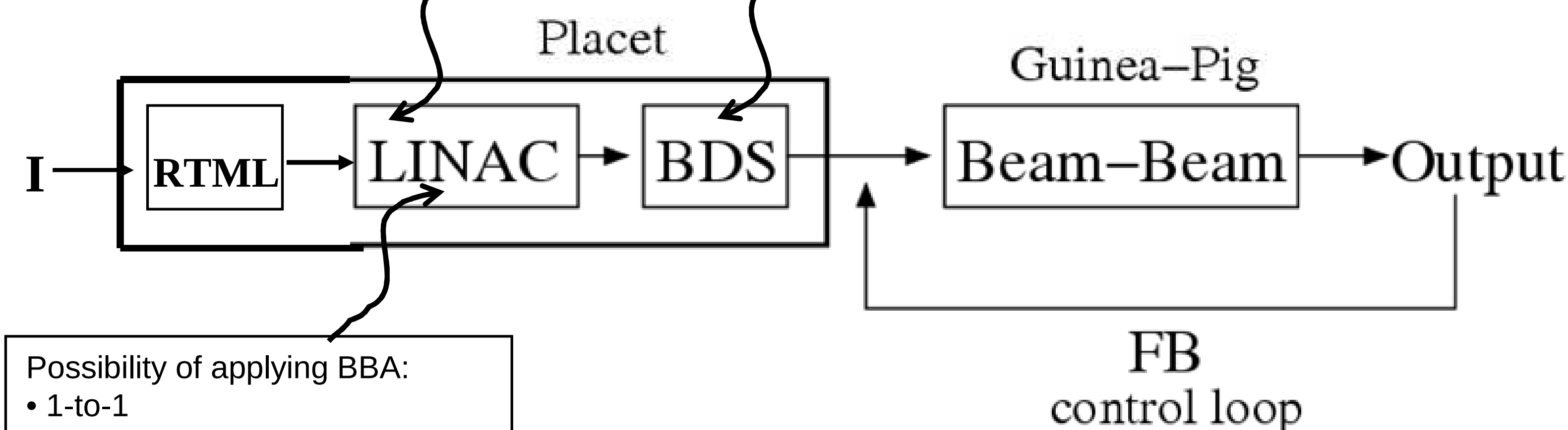
- In order to achieve the design luminosity of the future linear colliders (ILC and CLIC):
  - Preservation of ultra low vertical emittance from the DR to the IP
  - Subnanometre level beam stabilisation at the IP
- In this context, integrated simulations, covering different subsystems and time-scales of the collider are important for assessing the reliability of the design luminosity
- CLIC lattices and tracking code repository for integrated simulations:

http://isscvs.cern.ch/cgi-bin/viewcvs-all.cgi/clic-integrated-simulations/?root=placet

Simulation procedure

- Sliced bunches tracked along the LINAC
- Including long- and short-range transverse and longitudinal wakefield functions
- Alignment survey errors
- Dynamic imperfections: GM

- Macroparticle tracking
- Alignment survey errors
- Dynamic imperfections : GM
- Collimator wakefields
- Crab cavity wakefields



Possibility of applying BBA:
- 1-to-1
- DFS
- RF alignment
- Wakefield, dispersion bumps …

- FB systems
- Intra-train
- Inter-train
- Others … (Under development)

CODES:

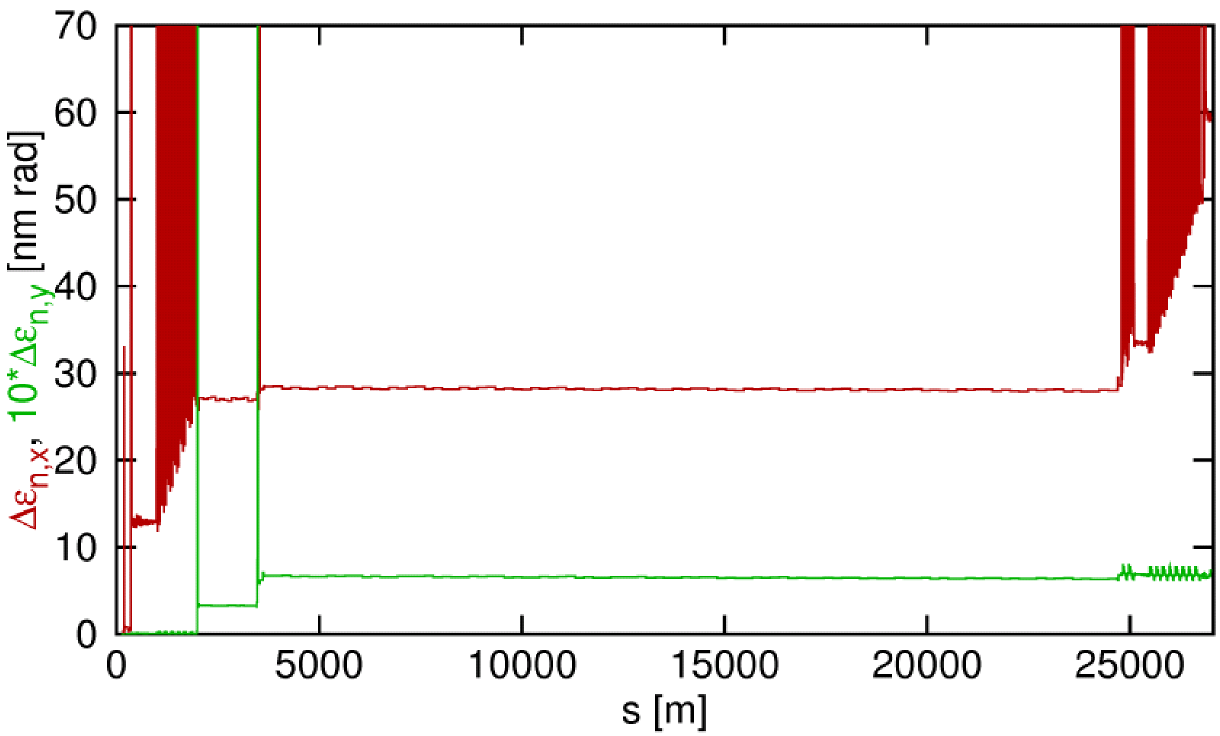
PLACET: allows the simulation of the different LC subsystems in a modular fashion

GUINEA-PIG: performs realistic simulations of the beam-beam interaction

LET studies

RTML

Example of emittance growth in the RTML for the electrons without imperfections (misalignment or field errors):



[Frank Stulle]

$\Delta\varepsilon_y < 5$ nm

- For the horizontal plane the largest contribution is due to ISR in central arc and turn around loop. Second largest is due to CSR in the bunch compressor chicanes.
- For the vertical plane largest contribution is due to ISR in the arcs of the vertical transfer.

LET studies
Main linac

Simulation of survey alignment process:

- Recently simulated for the ILC main linac by the LiCAS group [J. Dale, PhD Thesis, Oxford University, 2010]

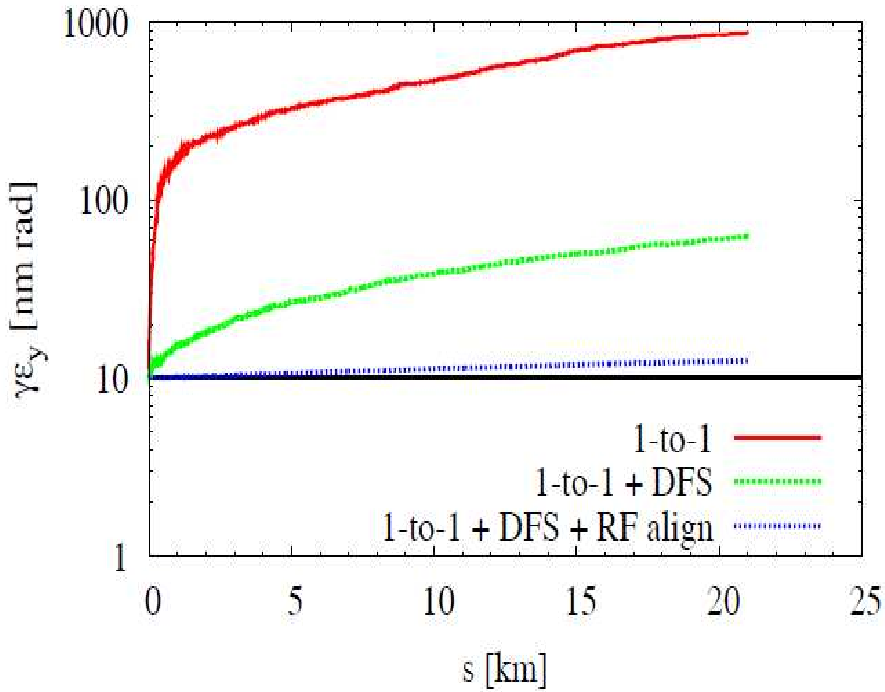
- In a similar way it could be applied to CLIC (work in progress) in order to generate a realistic list of survey alignment errors

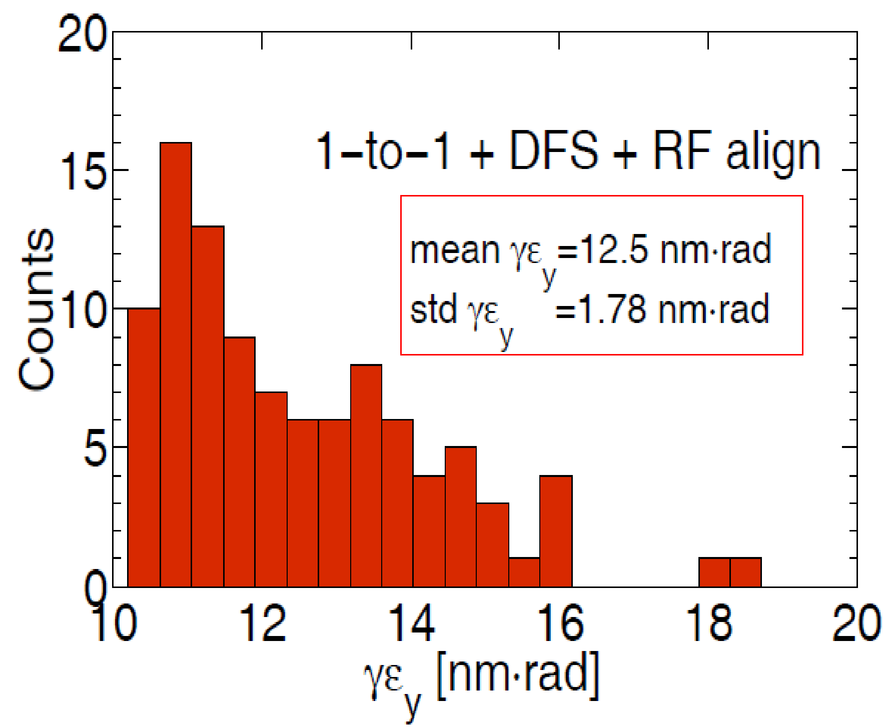
Static misalignment errors in the CLIC main linac

Imperfection	Respect to	Value
BPM offset	Survey line	14 μm
BPM resolution		0.1 μm
RF cavity offset	Girder axis	10 μm
RF cavity tilt	Girder axis	200 μrad
Quadrupole offset	Survey line	17 μm
Quadrupole roll	Longitudinal axis	100 μrad
Girder intersection offset	Survey line	12 μm
Girder intersection mismatch	Articulation point	5 μm

LET studies
Main linac

- Beam based alignment:
  - 10 nm initial vertical normalised emittance (injection from RTML).
  - Results from simulation of 100 machines.
  - Applying survey alignment errors and beam-based alignment correction.





90% of events below the emittance growth budget $\Delta(\gamma\varepsilon_y)$ ~< 5 nm for static imperfections

LET studies
BDS

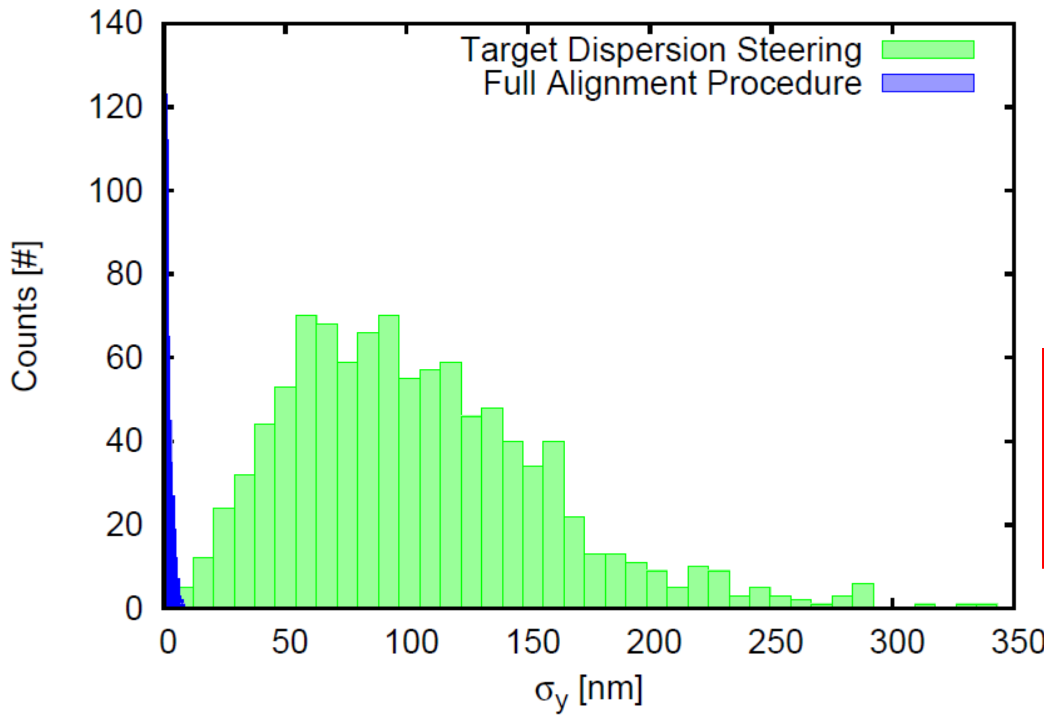
- Beam based alignment:

[A. Latina]

Errors applied:

10 µm x and y error for all the elements

10 nm BPM resolution



- 1000 random seeds
- Case without synchrotron radiation (optimistic)

Result after full alignment procedure:

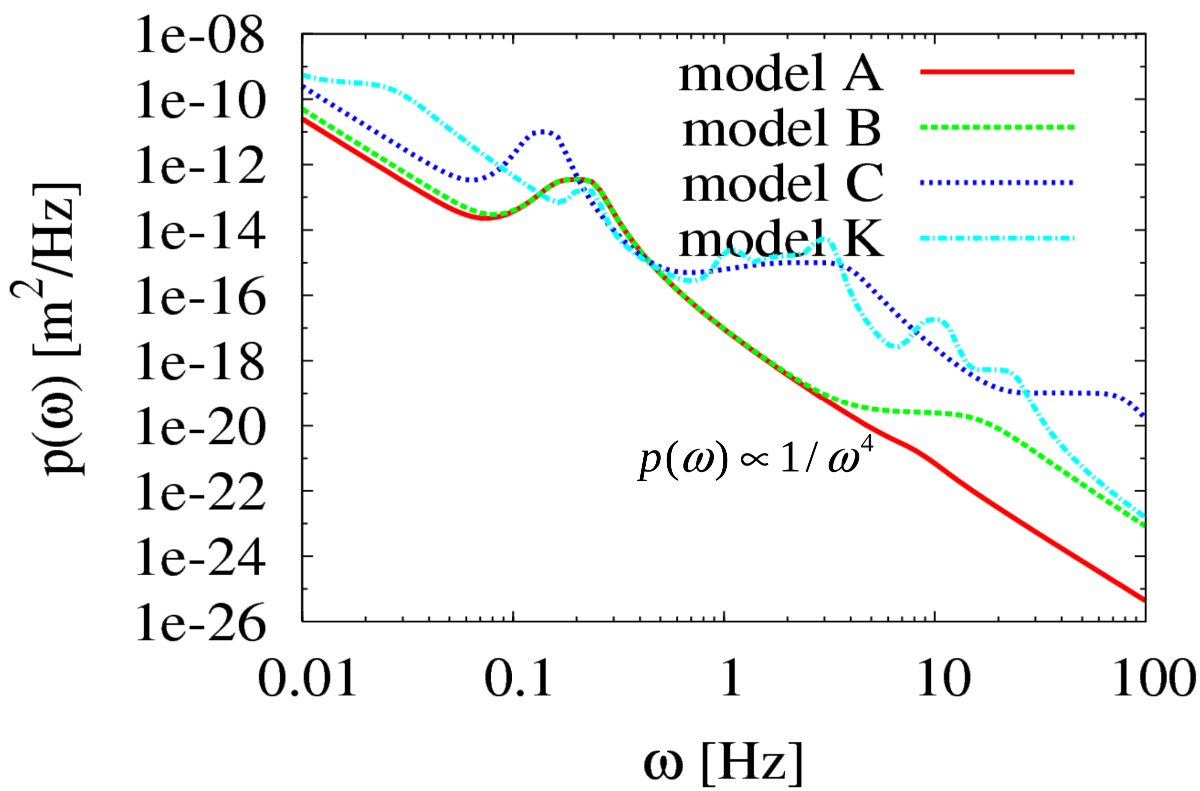
σ_y= 2.6+/- 1.3 nm

Luminosity stability

Dynamic imperfections

- Ground motion: Andrei Seryi's models:

Power spectrum: $$p(\omega) = \frac{B}{2\omega^4} + \sum_{i=resonances} \frac{a_i}{1 + \left[d_i \left(\omega - \omega_i \right) / \omega_i \right]^4}$$



Model A=CERN
Model B=Fermilab
Model C=DESY
Model K=KEK

Slow motion: emittance growths
Beam size effects

Fast motion: beam jitters
Beam-beam offsets

Luminosity stability
Dynamic imperfections

- Ground motion:
  - What is the RMS vertical beam-beam offset at the IP we have to deal with?
    - In the following simulations we apply 0.02 s (corresponding to f_{rep}=50 Hz) of GM in the CLIC BDS
    - Simulation of 100 random seeds:

GM model	rms Δy^* [nm] (in units of σ_y^*)
A (CERN)	0.035 (0.04)
B (SLAC and FNAL)	0.47 (0.52)
C (DESY)	8.9 (9.9)
K (KEK)	6.4 (7.1)

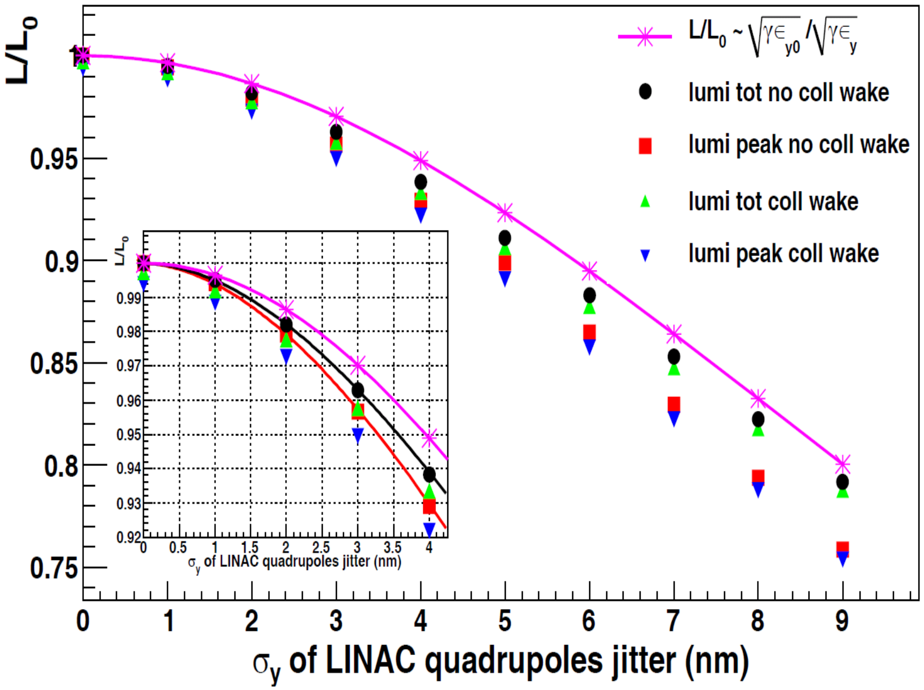
X 250

Luminosity stability
Quadrupole position offset tolerance

- Main linac quad position jitter tolerance:

[B. Dalena]

RMS quadrupole jitters in the Main linac
+
tracking through a perfectly aligned BDS
+
Collimator wakefields
(100 simulated machines)



- Tolerance for 1% dynamic luminosity loss ≈ 1.3 nm
- Collimator wakefields add a static luminosity loss of ≈ 0.6 %

Luminosity stability

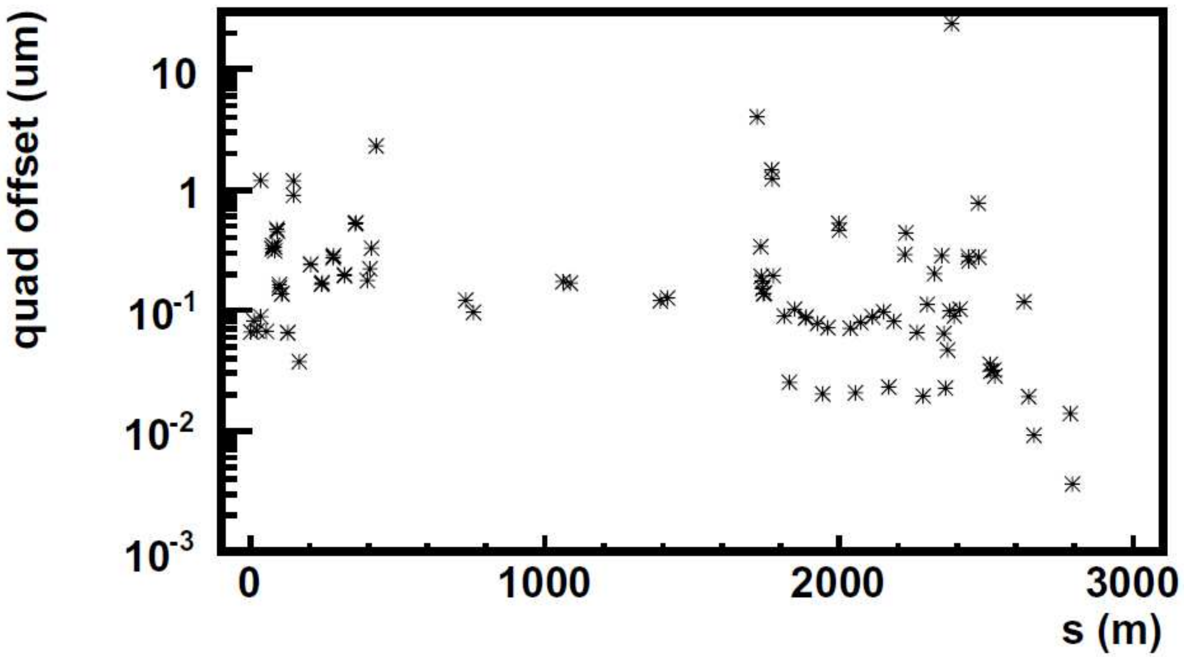
Quadrupole position offset tolerance

- BDS quad position offset tolerance:

[J. Snuverink]

- For every single quadrupole in the BDS the offset that corresponds to a 2% luminosity loss has been calculated

- Tolerances of few nanometres for the FD quads.



Luminosity stability

Mitigation of beam orbit jitter

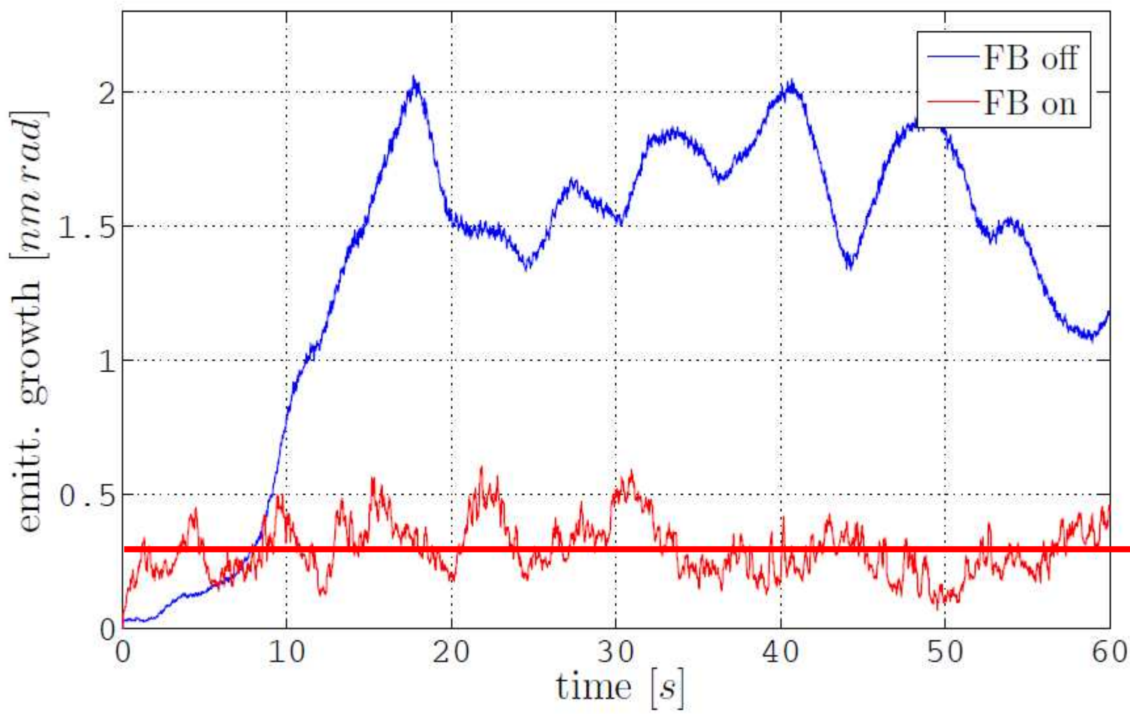
- General strategy:
  - Selection of a site with sufficiently small ground motion.
  - Well-engineered detector environment for low vibration.
  - Careful magnet and support design to minimise the impact on the beam-beam jitter.
  - FB systems operating to different time scales:
    - Active stabilisation of the FD using a mechanical FB based on ground motion sensors
    - Beam based pulse-to-pulse FB/FF systems for orbit correction in the linac and the BDS
    - Very fast beam-based intra-train FB system to keep the beams into collision

Luminosity stability
Feedback systems

- Adaptive FB system for the CLIC main linac:

  To attenuate GM effects

[J. Pfingstner, IPAC10]



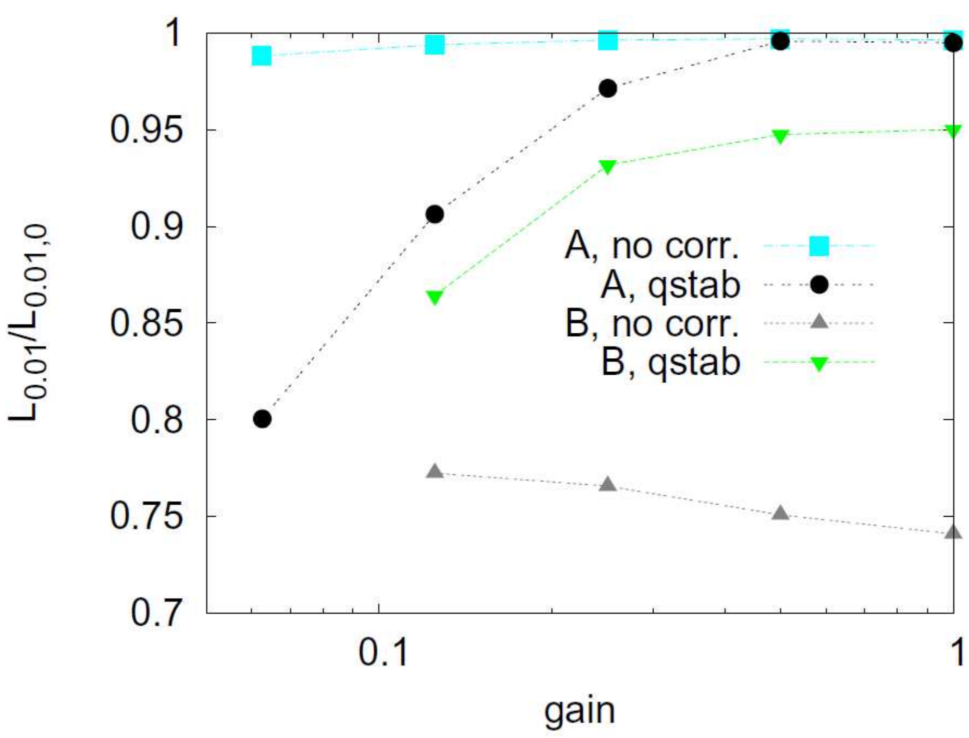
$\langle \Delta\varepsilon_y \rangle$ ~ 0.3 nm-rad

Luminosity stability
Feedback systems

- Beam-based orbit FB for the CLIC BDS:

Comparing impact of ground motion models A and B

[Daniel Schulte]

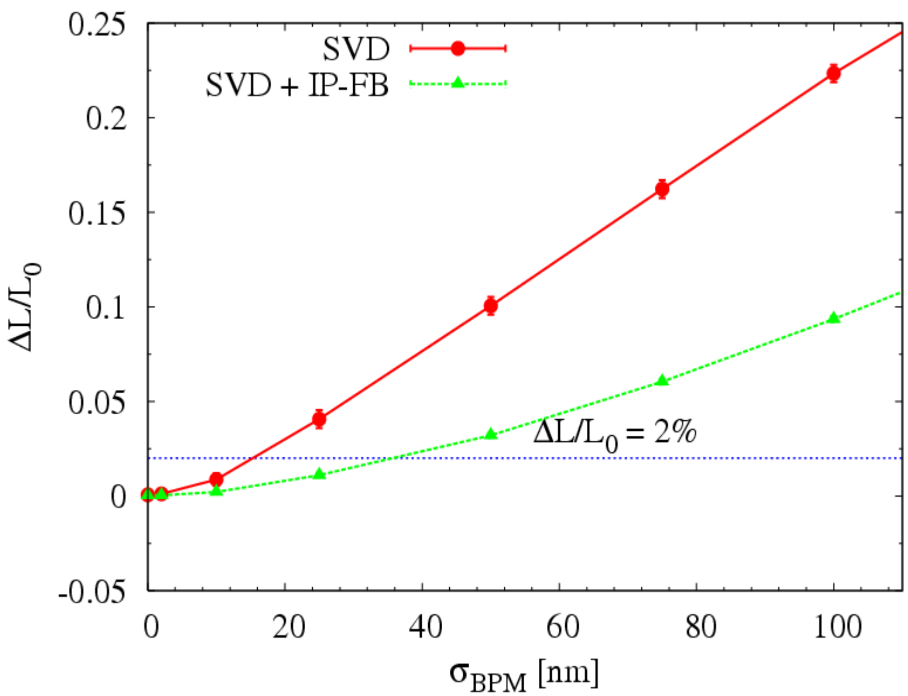


- Assumed a direct one-to-one transfer to beam line elements (neglecting any amplification of the GM by the elements or their supports).
- Loss dominated by the motion of the FD
- If FD magnets are stabilised perfectly, luminosity loss reduced to ~ 5% for high gains on the beam-based FB
- For model A stabilisation can increase luminosity loss as machine drifts away from stabilised FD magnets

Luminosity stability
Feedback systems

- Beam-based orbit FB for the CLIC BDS:
  - BPM resolution scan for SVD orbit correction (using BPMs and correctors available in the BDS):

Using CLIC lattice version L^*=4.3 m

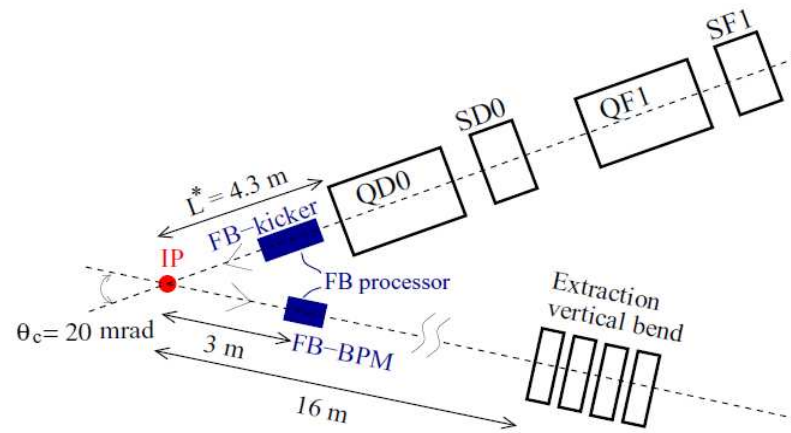


Preliminary results show that the BPM resolution for SVD orbit correction should be better than 30 nm for fast FB

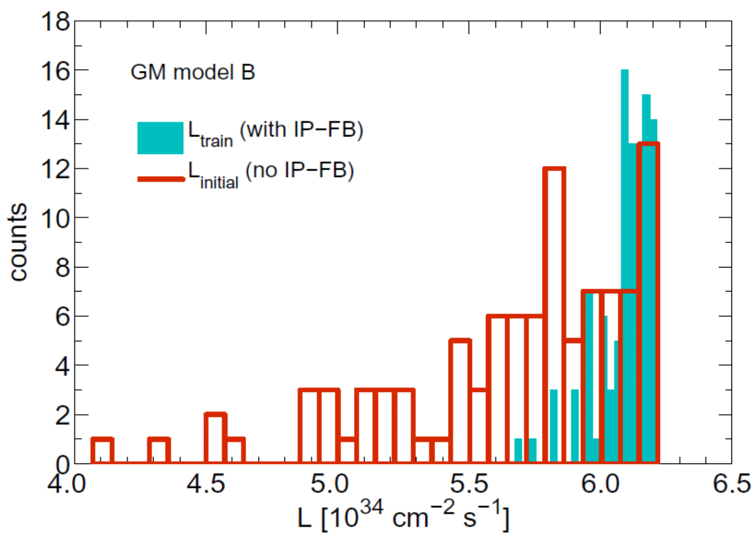
Luminosity stability

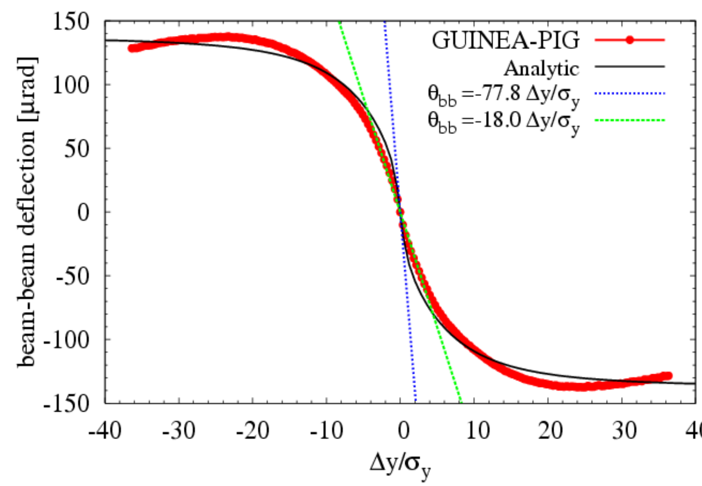
Feedback systems

- Intra-train FB system at the IP
  - Based on measurements of beam-beam deflection angle
  - ~30-40 ns latency
  - ~ micron BPM resolution



Simulation of 100 random seeds of GM model B





One can hope for a factor 2 gain in tolerance

Summary

- In the context of LET and luminosity stability studies, the development of a start-to-end simulation model of CLIC is in progress
- This model is based on the tracking code PLACET, and allows the addition of the accelerator subsystems in a modular way, from the exit of the DR to the IP
- This model allows to study the influence of static and dynamic imperfections on the emittance/luminosity.
- In order to combat those imperfection effects, BBA, feedback systems (covering different time scales) and tuning methods have been implemented.
- The work is in progress and it is necessary a complete simulation to understand the interplay between the different FB systems

Summary

• The first steps towards a fully integrated start-to-end simulation of CLIC have been made