TIARA-SVET Kick-off meeting

CLIC damping rings emittance targets and expectations

Yannis PAPAPHILIPPOU
CERN

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CLIC DR design goals

- Horizontal and **vertical** normalized emittance target of 500 and **5nm** (90 and **0.9pm** geometrical @2.86GeV) is unprecedented
- High bunch charge of 4.1×10^9 electrons (0.7nC), giving a high peak current of 0.7A and average current of 145
- Small longitudinal emittance (rms momentum spread of 0.1% and bunch length of ~1.8mm)
- High bunch density (brightness) triggers large number of collective effects, including intrabeam scattering dominating the steady-state emittance

PARAMETER	VALUE
bunch population (10^9)	4.1
bunch spacing [ns]	1
number of bunches/train	156
number of trains	2
Repetition rate [Hz]	50
Extracted hor. norm. emittance [nm]	<**500**
Extracted ver. norm. emittance [nm]	<**5**
Extracted long. norm. emittance [keV.m]	<**6**
Injected hor. norm. emittance [μm]	63
Injected ver. norm. emittance [μm]	1.5
Injected long. norm. emittance [keV.m]	1240

Damping Ring parameters

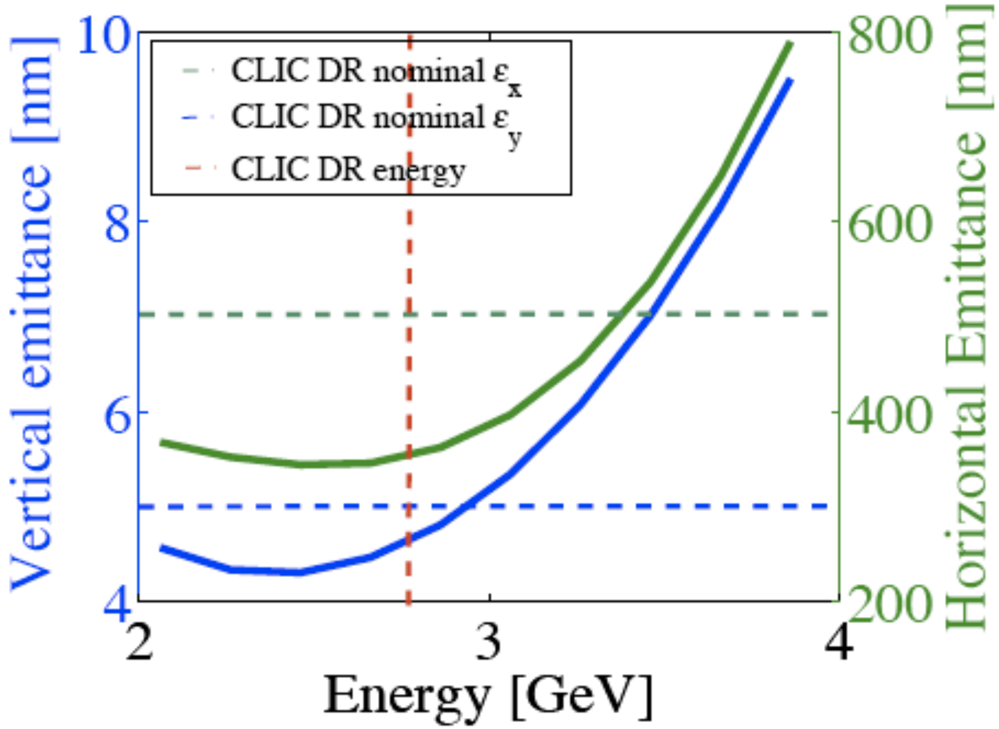
Parameters	1GHz	2GHz
Energy [GeV]	2.86	
Circumference [m]	427.5	
Energy loss/turn [MeV]	4.0	
RF voltage [MV]	5.1	4.5
Stationary phase [°]	51	62
Natural chromaticity x / y	-115/-85	
Momentum compaction factor	1.3e-4	
Damping time x / s [ms]	2.0/1.0	
Number of dipoles/wigglers	100/52	
Cell /dipole length [m]	2.51 / 0.58	
Dipole/Wiggler field [T]	1.0/2.5	
Bend gradient [1/m2]	-1.1	
Phase advance x / z	0.408/0.05	
Bunch population, [e9]	4.1	
IBS growth factor x/z/s	1.5/1.4/1.2	
Hor./ Ver Norm. Emittance [nm.rad]	456/4.8	472/4.8
Bunch length [mm]	1.8	1.6
Longitudinal emittance [keVm]	6.0	5.3
Space charge tune shift	-0.10	-0.11

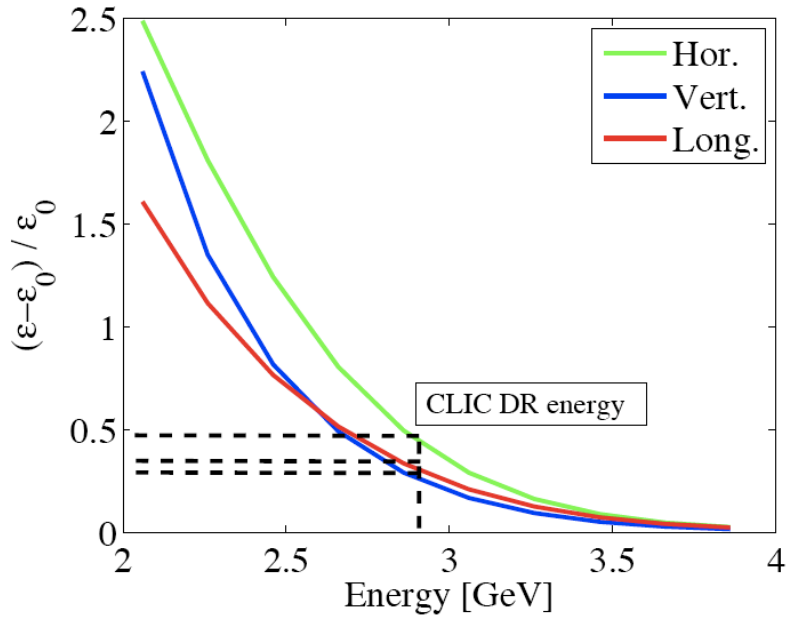
- Reduced circumference
  - Lower space-charge tune-shift and relax collective effects
- Increased momentum compaction factor
  - Longer bunch for reducing space-charge tune-shift and increasing CSR instability threshold
- RF frequency of 1GHz (two trains)
  - Halving peak power and current, thereby reducing transient beam loading
  - Increase harmonic number i.e. longer bunch (see above)
  - Less e-cloud production (bunch spacing doubled)
  - Less pronounced Fast ion instability (doubling critical mass above which particles get trapped)

IBS blow-up versus the ring energy

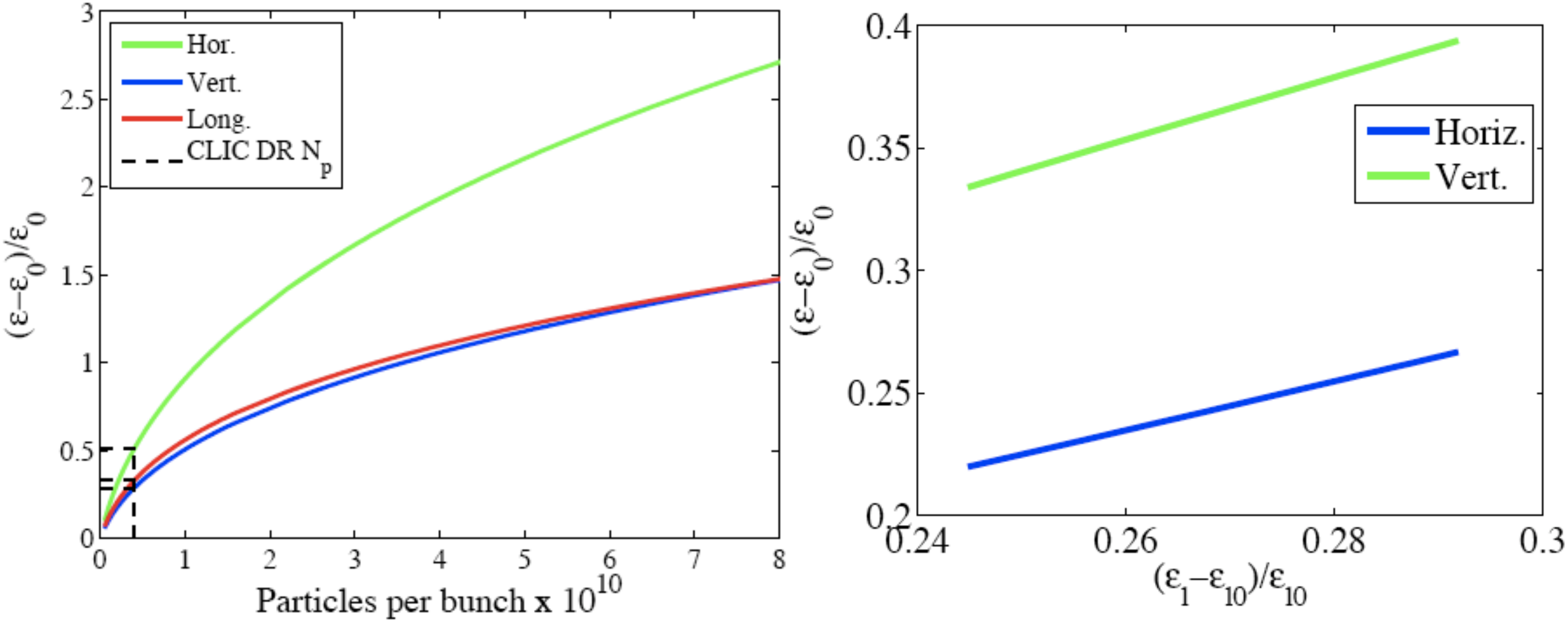
F. Antoniou, et al. IPAC10

- Scaling of emittances growth due to IBS with energy obtained with Piwinski formalism for the same optics and constant output longitudinal emittance
- Broad **minimum** for transverse emittance ~2-3GeV
- Higher energy reduces ratio between zero current and IBS dominated emittance
- Similar results obtained for other rings (e.g. CESRTA)
- This should be verified for SLS as well



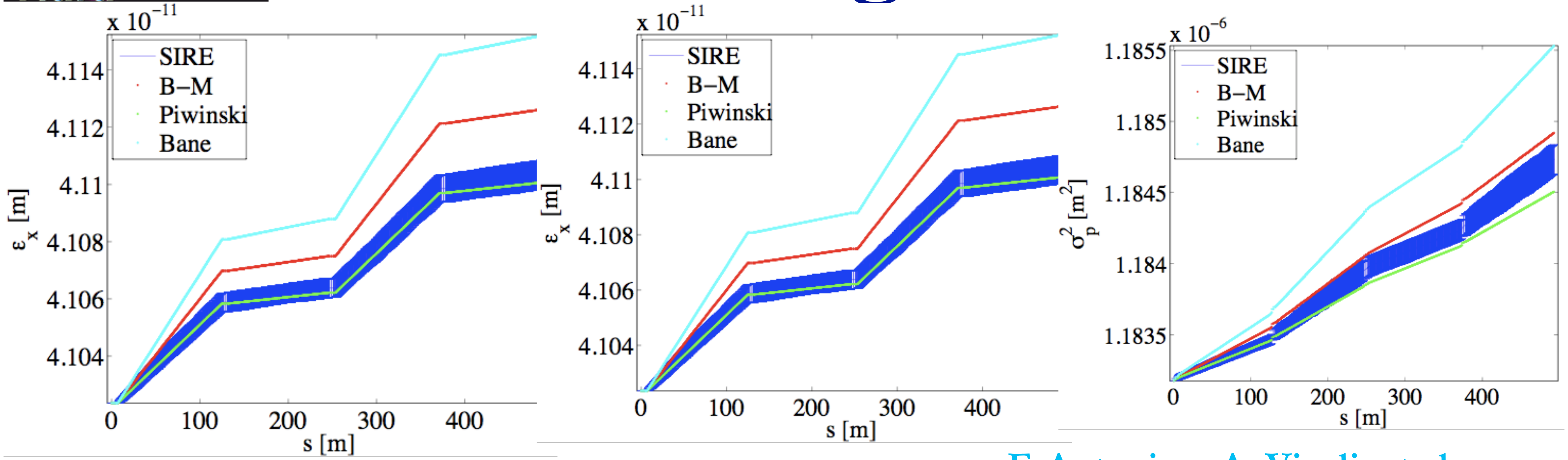


Bunch charge and longitudinal emittance F. Antoniou, et al. IPAC10



- **Emittances** scale as a power law of the bunch charge
- Vertical and **longitudinal emittance** have **weaker dependence** to **bunch charge** (of the same order) confirming that **vertical emittance dominated** by **vertical dispersion.**
- Linear dependence between transverse and longitudinal emittance
- What about SLS?

IBS tracking code

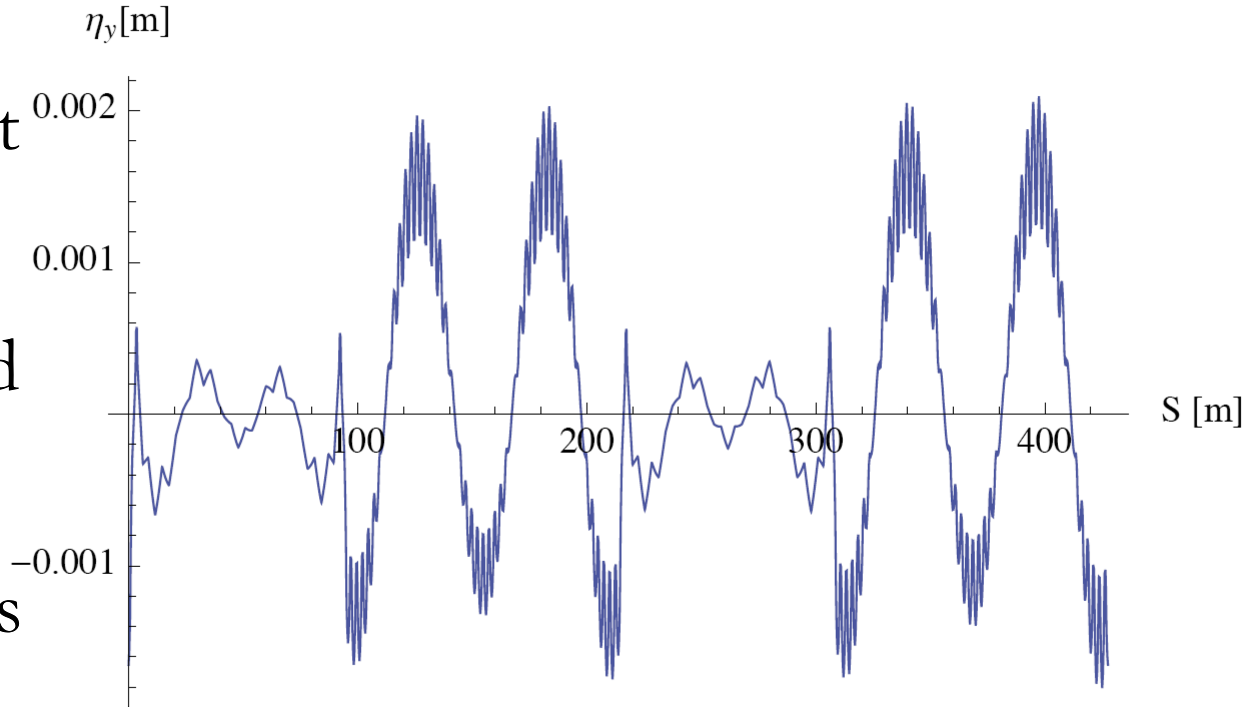


F. Antoniou, A. Vivoli, et al.

- Developed Monte-Carlo tracking code for IBS including synchrotron radiation damping and quantum excitation (**SIRE**, based on MOCAC)
- Agreement between analytical emittance growth (especially Piwinski approach) and the mean values obtained by 20 SIRE runs
- Final emittances obtained by SIRE are within the CLIC DR budget
- Benchmarking with measurements at SLS?

Vertical emittance tuning

- Vertical emittance mostly dominated by vertical dispersion (rms of 0.3mm and coupling of 0.1% provides equilibrium emittance of 4.4nm)
- Good optics and orbit control are essential
- Alignment tolerances close to ones achieved in modern storage rings
- Magnet misalignments seems more critical than rolls



Imperfections	Simbol	1 r.m.s.
Quadrupole misalignment	$\langle \Delta Y_{quad} \rangle$, $\langle \Delta X_{quad} \rangle$	90 μm.
Sextupole misalignment	$\langle \Delta Y_{sext} \rangle$, $\langle \Delta X_{sext} \rangle$	40 μm
Quadrupole rotation	$\langle \Delta \Theta_{quad} \rangle$	100 μrad
Dipole rotation	$\langle \Delta \Theta_{dipole\ arc} \rangle$	100 μrad.
BPMs resolution	$\langle R_{BPM} \rangle$	2 μm.

Diagnostics challenges

- 300PUs, turn by turn (every 1.6μs)
  - **10μm** precision, for linear and non-linear optics measurements.
  - **2μm** precision for orbit measurements (vertical dispersion/ coupling correction + orbit feedback).
- Turn by turn transverse profile monitors with a wide dynamic range
  - Hor. beam size varies from **300μm** @ injection to **30μm** @ extraction and the vertical from **40μm** to **3μm**
  - Capable of measuring tails for IBS and other collective effects
- Longitudinal profile monitors
  - Energy spread of **0.1%** and bunch length from **5** to **2**mm.
  - Note that the dispersion around the ring is extremely small (<5cm)

CERN/CLIC interests and contribution

- IBS theory and simulations
  - IBS effect on emittance at SLS versus different parameters (energy, bunch charge, etc.)
  - IBS simulations for SLS (SIRE)
- Beam measurements
  - Participate in machine developments for correcting vertical emittance
  - Learn/test procedures and numerical tools for reaching ultra-low emittance (orbit control, response matrix and frequency analysis)
  - Understand limitations and refine tolerances for CLIC damping rings (alignment, girder design, magnet errors and instrumentation)
  - Demonstrate ultra-low vertical emittance <1pm in IBS dominated regime (beyond TIARA)
- Beam instrumentation
  - Participate in technical specifications, design and comissioning of profile monitor