Single bunch measurements in ALBA and ongoing kicker studies

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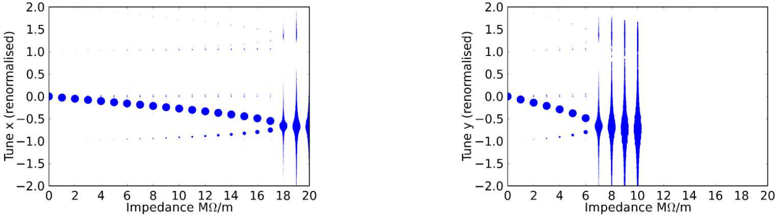
Motivation

- Transverse impedance budget studies for the CLIC damping rings
- Single bunch simulations with the HEADTAIL code and a rough impedance model since the DR are under design
- Single bunch measurements in an existing light source in Barcelona, ALBA, to
  - benchmark our simulation tools
  - validate the current impedance model

HEADTAIL single bunch simulations to define the instability thresholds for the CLIC DR

- HEADTAIL code simulates single/multi bunch collective phenomena associated with impedances
- A broad-band resonator and several resistive wall contributions (arcs 270m, 9 mm half gap, wigglers 104 m, 6 mm flat, FODO rest 53 m, 9 mm) are considered in the macroparticle simulations
- A uniform 2 μm NEG coating is assumed, beam pipe from stainless steel
- ImpedanceWake2D code is used to compute the transverse wake functions of multilayer structures, cylindrical or flat
- Obtain the tune shift as a function of the transverse shunt impedance to estimate the threshold

Mode spectrum of the horizontal and vertical coherent motion as a function of impedance



- TMCI for 0 chromaticity in the x plane (left) at 18 MΩ/m
- TMCI for 0 chromaticity in the y plane (right) at 7 MΩ/m (remaining impedance budget if just a BBR is considered)

Transverse impedance budget of the DR

Model	ξ_x / ξ_y	Threshold in y [$M\Omega/m$]
BB	0/0	7
BB+RW	0/0	4

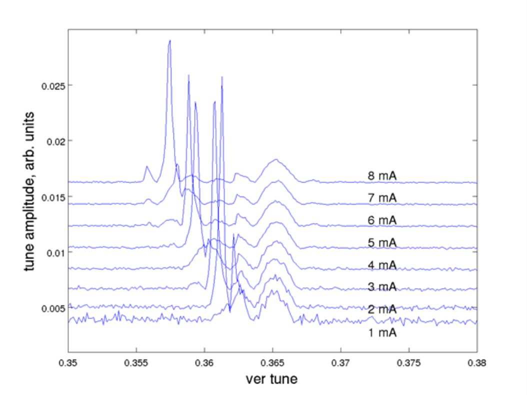
- The impedance budget is further reduced at 4 MΩ/m taking into account broad-band resonator and resistive wall contributions from the arcs and the wigglers of the DR and at 1 MΩ/m for slightly positive chromaticity (*E.Koukovini-Platia, G. Rumolo, IPAC 2014*)
- A collaboration with an existing light source, such as ALBA, would allow the benchmarking of the simulation tools used

Measurements in the ALBA synchrotron light source

- Tune shift with intensity to define the instability thresholds in the vertical plane
- Zero chromaticity
- Measurements performed for closed and open in-vacuum undulators
- Post-analysis with HEADTAIL
- Post-analysis with MOSES (T.F. Günzel et al. *Analysis of single bunch measurements at the ALBA storage ring*, IPAC 2014)

Tune shift with increasing single bunch intensity and closed undulators

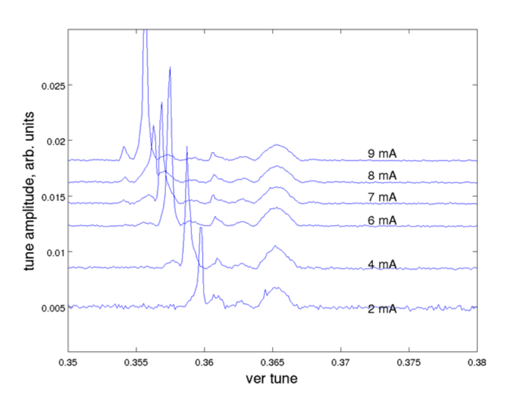
- 1-9 mA single bunch intensity, 2.1 MV, 0 chromaticity, nominal tune $Q_{y0} = 8.362$
- Mode m=-1 very closely to m=0 peak just before the instability onset
- TMCI threshold at 8.8 mA



Courtesy U.Iriso

Tune shift with increasing single bunch intensity and open undulators (aperture from 5.6 to 30 mm)

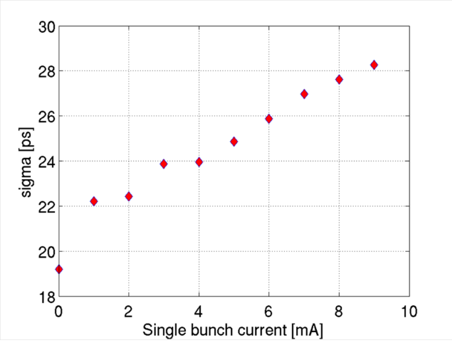
- 2-10 mA intensity, 2.1 MV, 0 chromaticity
- TMCI threshold at 9.8 mA
- Observe higher threshold with open undulators



Courtesy U.Iriso

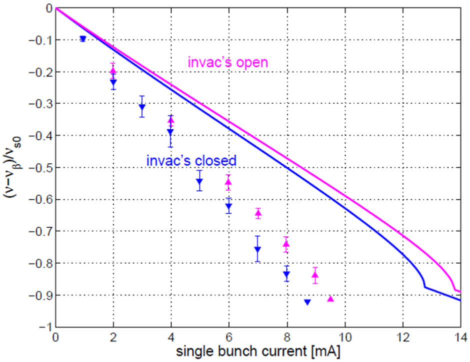
Bunch length parametrization

- Try to reproduce the experimental results with HEADTAIL
- The bunch length was also monitored during the shifts
- A good bunch length parametrization with current contributed essentially to the following results



Current impedance model: MOSES result for 0 chromaticity

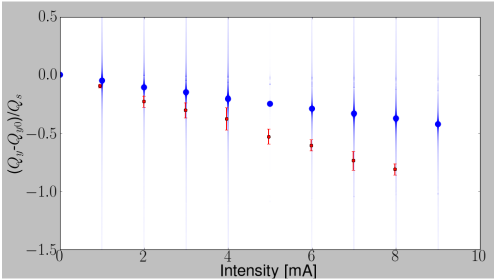
- Current impedance model: 4 BBR, 7 multi-layer RRW (including StSt standard vacuum chamber, IVUs, NEG-coated Al chamber, wiggler etc)
- Measured mode detuning is stronger and TMCI-threshold is lower than the model
- A 55% higher model impedance would be necessary to reproduce the measured values



Courtesy T.F.Günzel

Impedance model 1: HEADTAIL result for 0 chromaticity and closed IVUs

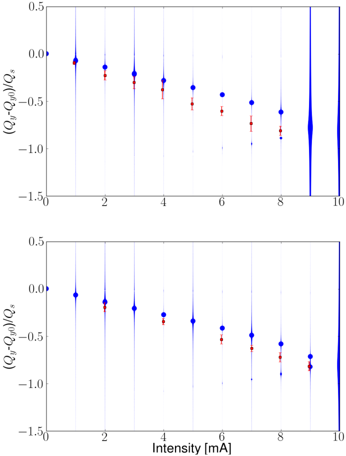
- Impedance model based on T.F.Günzel model: 4 BBR, 6 RRW (injection kickers not included in HEADTAIL)



- No TMCI observed around 8.8 mA. Indication for missing impedance contribution/s

Impedance model 2: adding a 5^{th} BBR

- HEADTAIL matches very well with the measured instability onset by adding a 5^{th} BBR with f_r = 1 GHz, Q = 1 and $R_s = 1.6M\Omega/m$
- The effect of the open IVUs was also predicted
- HEADTAIL TMCI threshold
    - **9 mA for closed IVUs** (found at 8.8 mA)
    - **10 mA for open IVUs** (found at 9.8 mA)



Impedance model 2: adding a 5^{th} BBR (2)

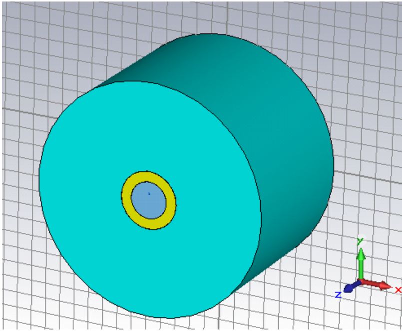
- Measuring an impedance 55% larger than the current impedance budget
- Around 85% of the found mode detuning is explained if a 5^{th} BBR is added in the model
- Physical explanation to add this 5^{th} BBR still to be studied
- First attempts are focused on the injection kickers

Two different approaches for the kickers' contribution

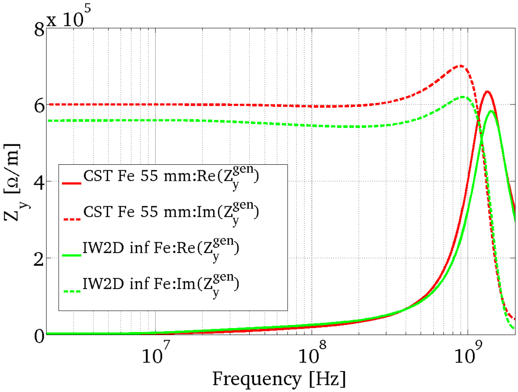
- CST Particle Studio
  - Can simulate the exact geometry of the component
  - The implemented coating feature has to be tested
  - Problem with calculation of wakes of very short bunches due to the huge number of meshcells (same problem had been faced with the CLIC DR kickers at high frequencies)
- ImpedanceWake2D (IW2D) code (computes the transverse impedance/wake functions of infinitely long multilayer structures)
  - Can calculate the wake functions needed in HEADTAIL
  - Cannot simulate the real kicker geometry
- Comparison of CST and IW2D at lower frequencies (faster)

CST and IW2D comparison for round multilayer structure

- CST
  - Vacuum with r=11.5 mm
  - Ceramic 6.5 mm thick (yellow)
  - Ferrite 55 mm thick (blue)
  - Offset source and test in y plane to calculate the generalized impedance
  - Background PEC
- IW2D 2 layers, round, r=11.5 mm
  - Ceramic: $\sigma = 10^{-12}$ S/m, $\varepsilon' = 9.3$, d=6.5 mm
  - Ferrite: $\sigma = 10^{-4}$ S/m, $\varepsilon' = 12$, $\mu = 460$, $f_{rev} = 20$ MHz, d=infinity



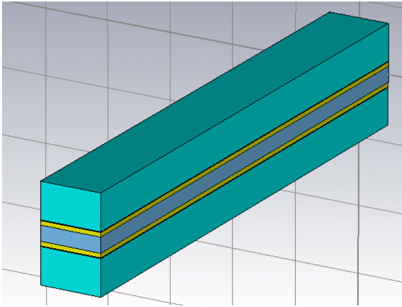
CST and IW2D comparison for round multilayer structure



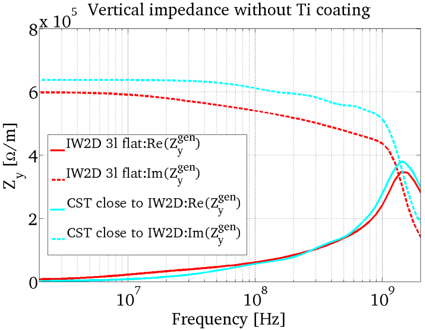
- Good agreement between CST and IW2D within 5%

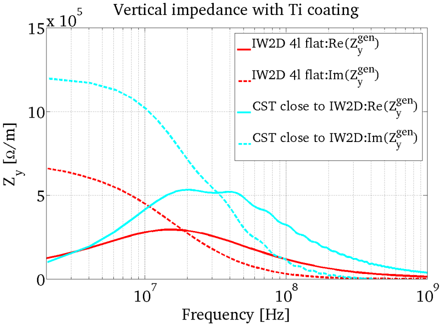
CST and IW2D comparison for multilayer flat structure (1)

- CST
  - Vacuum, r=11.5 mm
  - with and without the Ti of 0.4 μm
  - Ceramic 6.5 mm thick (yellow)
  - Air 1 mm
  - Ferrite 55 mm thick (blue)
  - Background normal
- IW2D 3 or 4 layers (depending if there was coating of Ti or not), flat, r=11.5 mm



CST and IW2D comparison for multilayer flat structure (2)

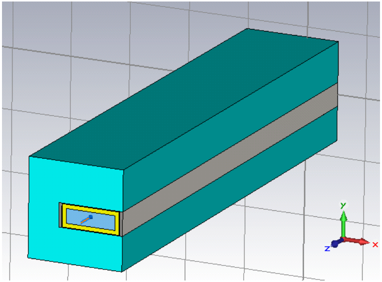




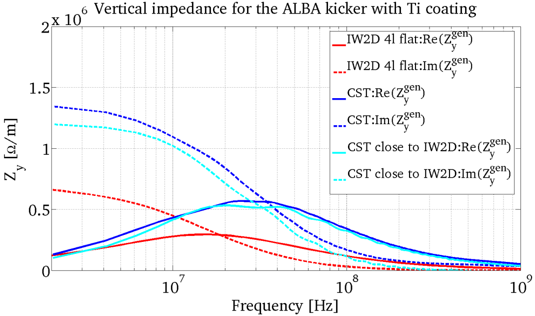
- Much better agreement between CST and IW2D without the Ti coating. Factor of 2 difference in the case of Ti coating

CST and IW2D comparison for the real kicker (1)

- CST C-shape kicker
  - Vacuum, r=11.5 mm
  - Ti of 0.4 μm
  - Ceramic 6.5 mm thick (yellow)
  - Ferrite 55 mm thick (blue)
  - 2 electrodes as PEC
  - Background normal
- IW2D 4 layers, flat, r=11.5 mm
  - Ti: $\sigma = 2.38 \times 10^6$ S/m, d= 0.4 μm
  - Ceramic: $\sigma = 10^{-12}$ S/m, $\varepsilon' = 9.3$, d=6.5 mm
  - Air: $\sigma = 5 \times 10^{-17}$ S/m, d= 1 mm
  - Ferrite: $\sigma = 10^{-4}$ S/m, $\varepsilon' = 12$, $\mu = 460$, $f_{rev} = 20$ MHz, d=infinity



CST and IW2D comparison for the real kicker (2)



- Check the coating feature of CST
- Do some convergence studies
- Use ImpedanceWake2D to calculate the wake function
- Implement the kicker's contribution in the current model

Future steps

- Study the missing impedance contribution to match HEADTAIL simulations and measurements
- Implement the kickers' contribution in HEADTAIL simulations and see the effect in the budget
- Shift planned in November for single bunch measurements with intensity with a pinger-magnet installed in ALBA. Evaluate its contribution and benchmark simulations with machine studies