Outcome of yesterday's brainstorming on the potential of using CALIFES or CTF3 electron beam for impedance studies

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for the impedance team

Acknowledgments :
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CLIC Project Meeting #19
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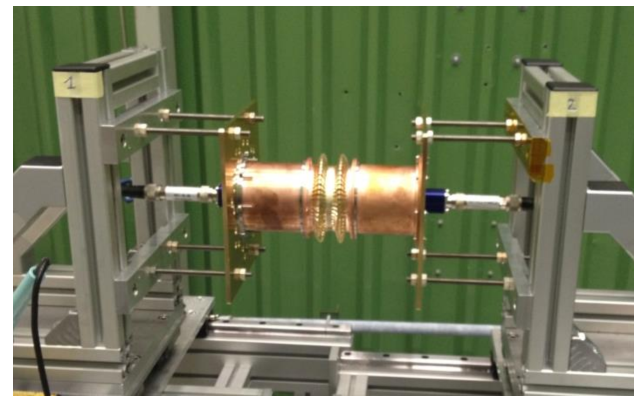
Context

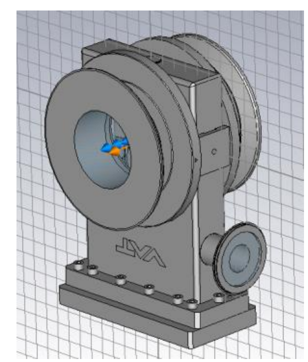
- Impedance team involved in design and approval of new and modified equipment in all CERN circular machines (in particular PSB, PS, SPS and LHC, but also AD, ELENA and CLIC damping rings)



- Tools at our disposal:
  - Bench measurements with wires and probes

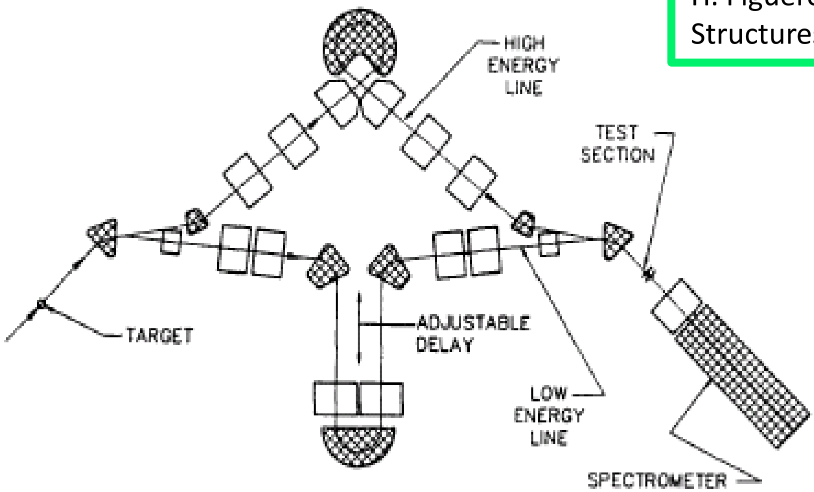
    → problem: not direct measurement of impedance or wake, and possibly strong perturbation of the EM fields
  - Numerical simulations

    → problem: difficulty to reproduce reality with a model (e.g. design errors, small features, coatings, matching errors) , simulated exciting bunch is not a delta function.



→ Measurement with electron bunches could be an interesting complement to these existing tools

Previous attempt: Argonne test facility

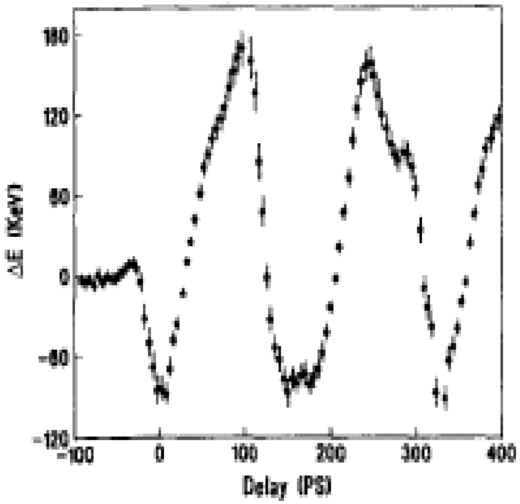


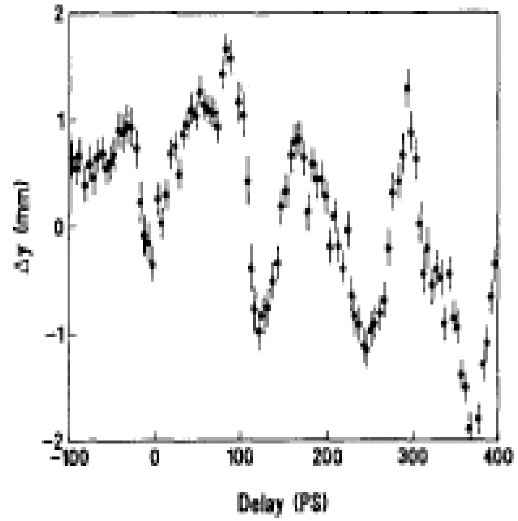
H. Figueroa et al., "Direct Measurement of Beam-Induced Fields in accelerating Structures", Physical Review Letters, Vol.60, N. 21, p.2144, (1988).

Beams

Two bunched beams of different energy and intensity with adjustable delay

Energy change and transverse offset induced on the trailing bunch





The change of energy of the trailing bunch (low intensity and energy) is mainly due to the effect of the wake fields because its own losses are negligible.

What would we be interested to measure?

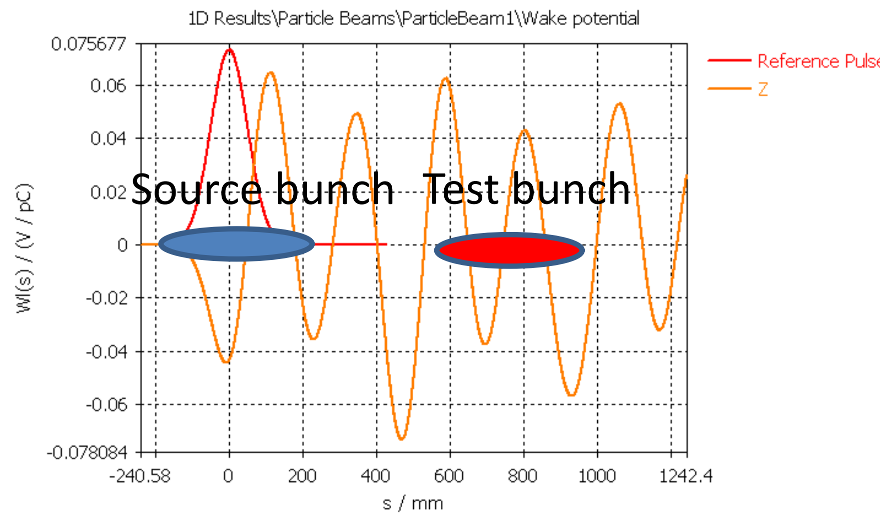
With a realistic exciting source:

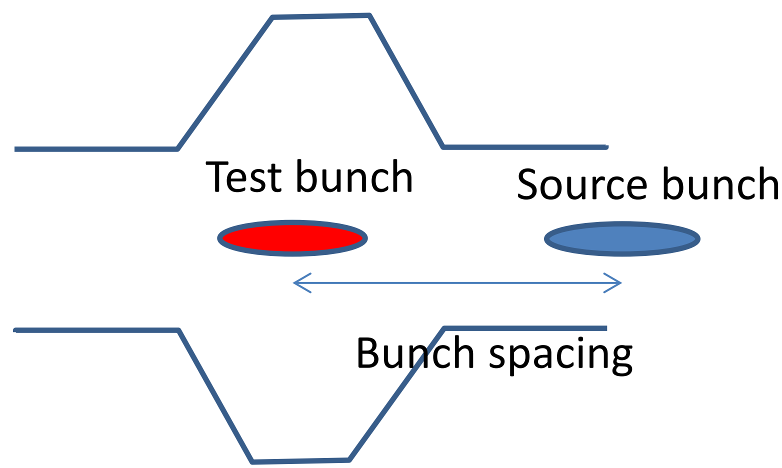
- Direct measurement of “wake function”
- Direct measurement of coherent effects between bunches
- Direct measurement of heating
- Direct measurement of generated electromagnetic fields

→ This is what we would like, but the feasibility is yet to be proven

Direct measurement of “wake function”

- Measurement of energy loss as a function of source/test bunch spacing → longitudinal wake
- Measurement of kick as a function of source/test bunch spacing → transverse wake
- In simulations, difficult to reach source bunch below 1 mm for standard devices due to mesh size.
- Very small bunch length achievable with electron beams (of the order of 10 ps)? → “wake function” could be measured provided the sampling is sufficient. Feasible?

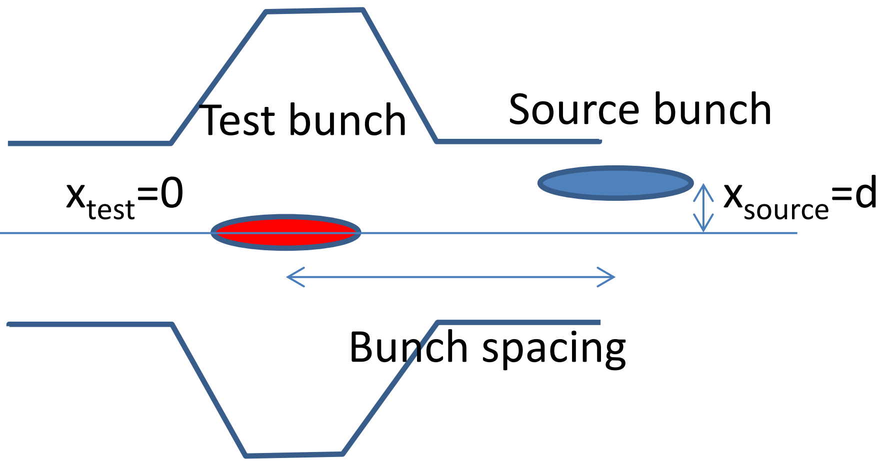




Direct measurement of “wake function”

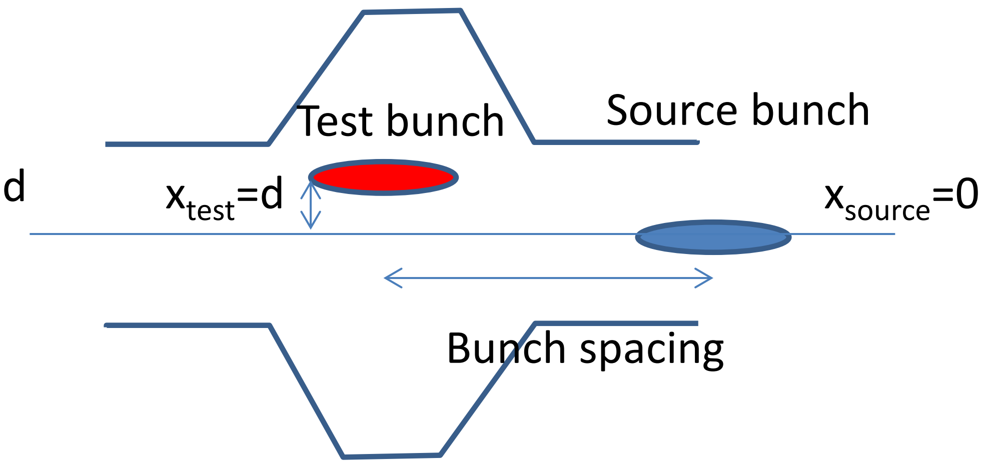
- Important to disentangle the “dipolar” impedance contribution from the “quadrupolar” contribution to assess the impact on collective effects

Dipolar contribution



→ All particles in the test bunch receive the same kick
→ Coherent effect
→ Drives instabilities

Quadrupolar contribution

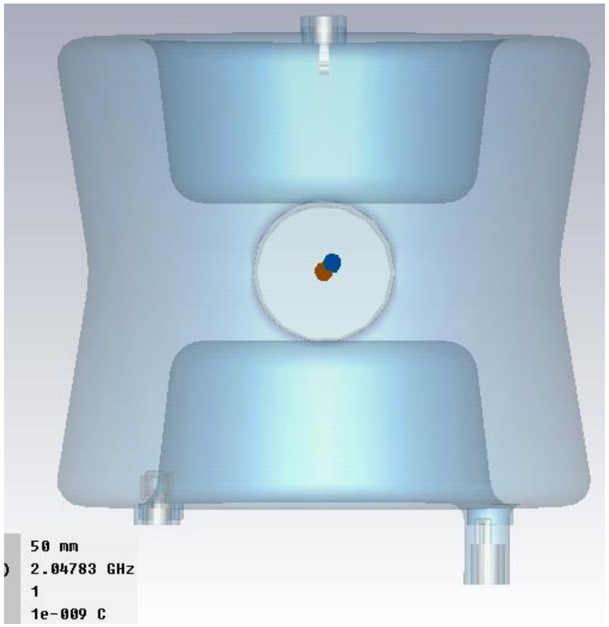


→ All particles in the test bunch receive a kick proportional to their position
→ Incoherent effect
→ Impact on instability depends on the type of instability

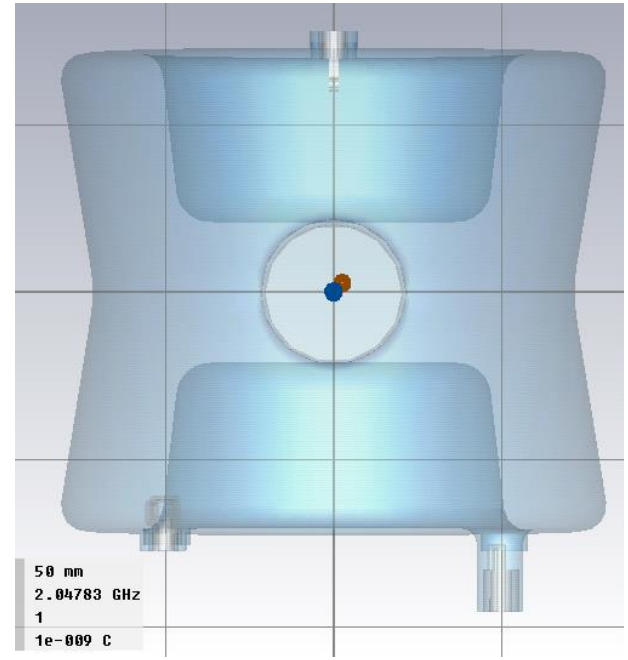
→ Can the orbits of the source and test bunches be controlled separately?

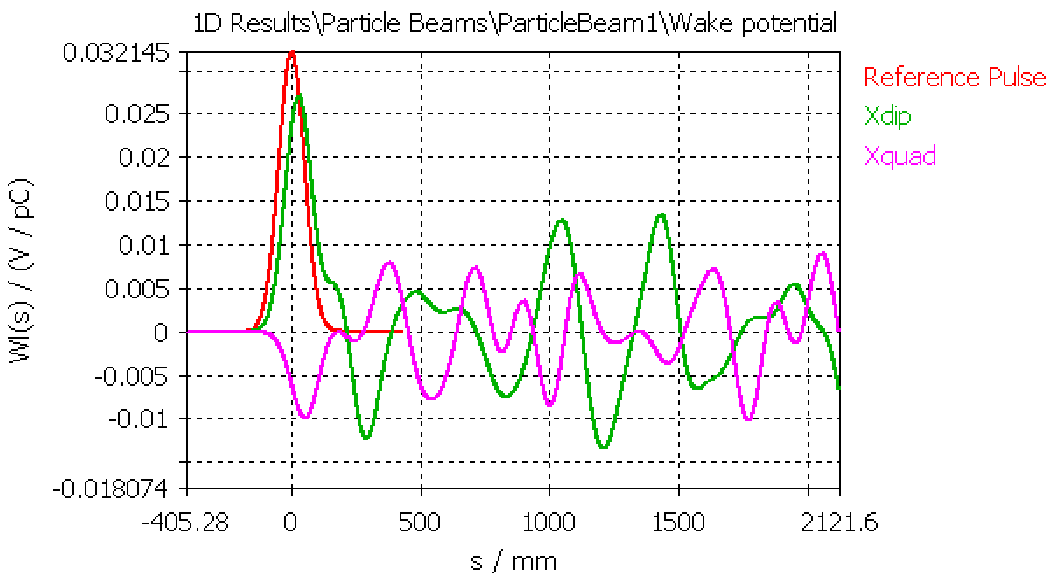
Example: crab cavities

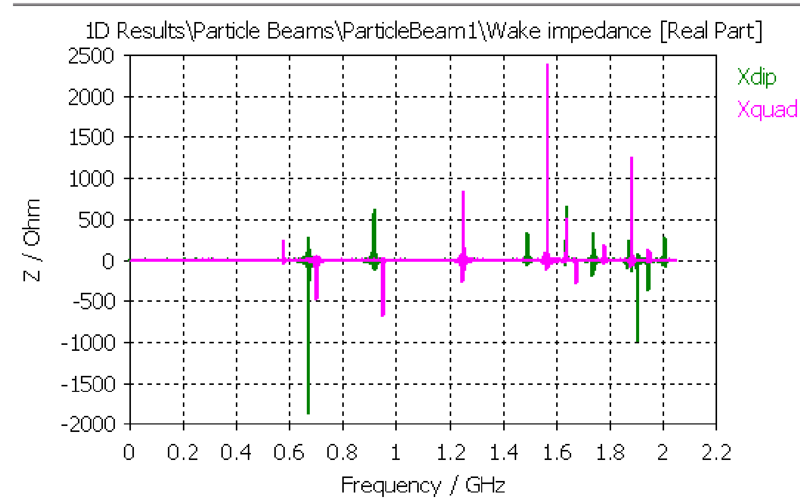
dipolar



quadrupolar







→ Very different features between dipolar and quadrupolar impedance.

Potential limitations

- Minimum kick strength observable with the BPM resolution
  → Many components are in the 1 to 10 kOhm/m range for the transverse impedance, in the mOhm range for the longitudinal impedance
- Control of the orbit/spacing of test vs source
- Control of intensity of both bunches (highest on source and low on test)
- Available length (for both device installation and for observation) → some critical elements are very long (SPS septa, LHC TDI and kickers).
- Need for large flexibility in length and radius of input device → the facility may become a tapering factory.
- Contribution from the BPMs and tapers from 40 mm radius to the aperture of the element should not dominate

Hardware changes during LS1 that may impact impedance

- Consolidation:
  - TDI beam screen consolidation
  - TCP replacement with spare
  - BSRT mirror design change
  - RF fingers consolidation, carroussel
- Upgrade:
  - Tertiary collimators with BPMs (TCTP and TCSP)
  - ATLAS-ALFA
  - “TOTEM consolidation” of existing Roman pots
  - MKI screen conductor upgrade
  - New experimental beam pipe in CMS and ATLAS
  - Schottky
- New equipment:
  - New TCL4 and TCL6
  - 3rd TCDQ module
  - BGV on B2
  - New “TOTEM upgrade” pots
  - New UA9 goniometer
- Non conformities:
  - Contacts in triplets
  - ~~RF fingers next to TCTH and TCTV in pt 5~~

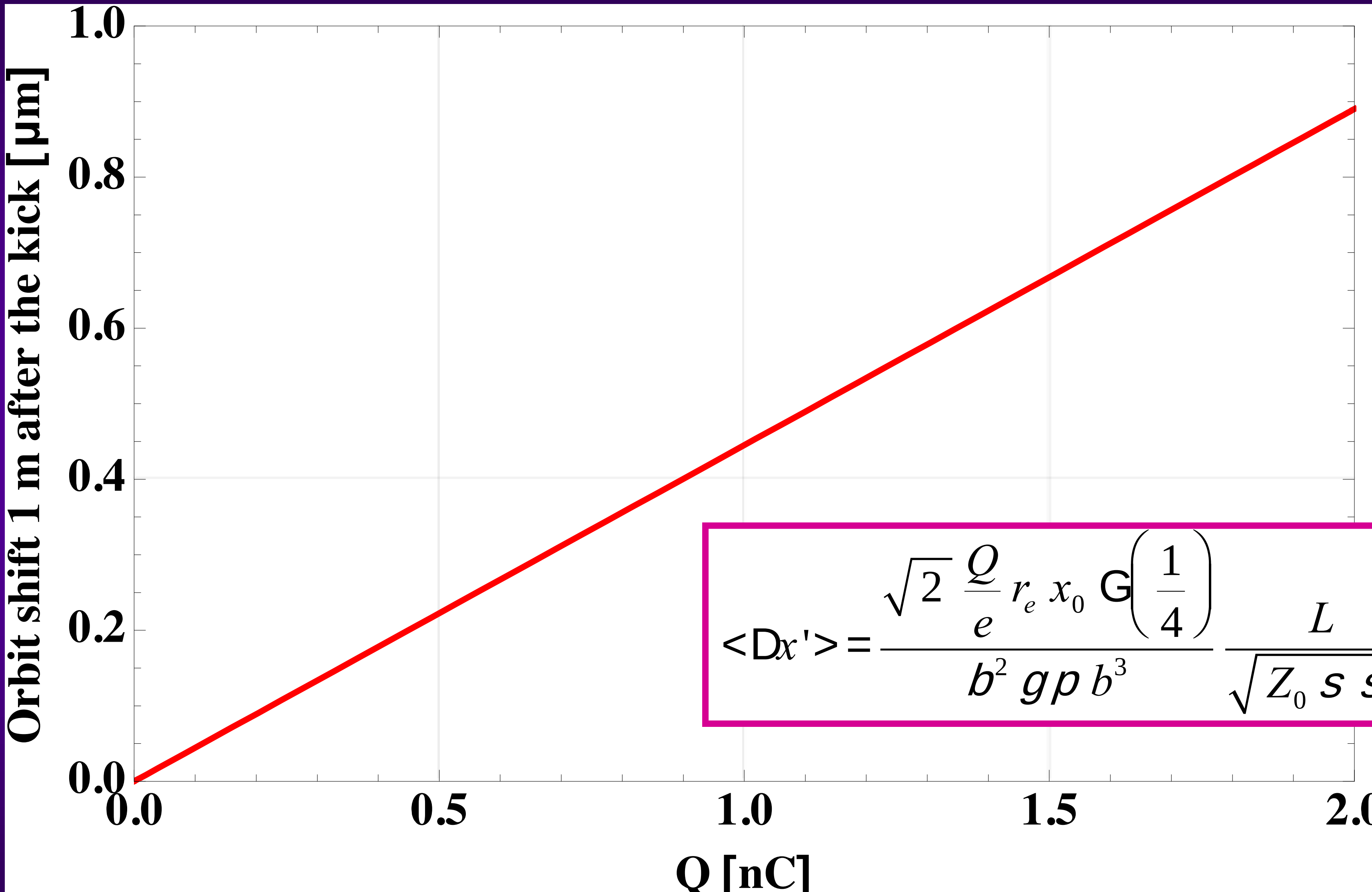
SOME IMPEDANCE COMPUTATIONS WITH CALIFES

Elias Métral

ASSUMPTIONS / CONDITIONS

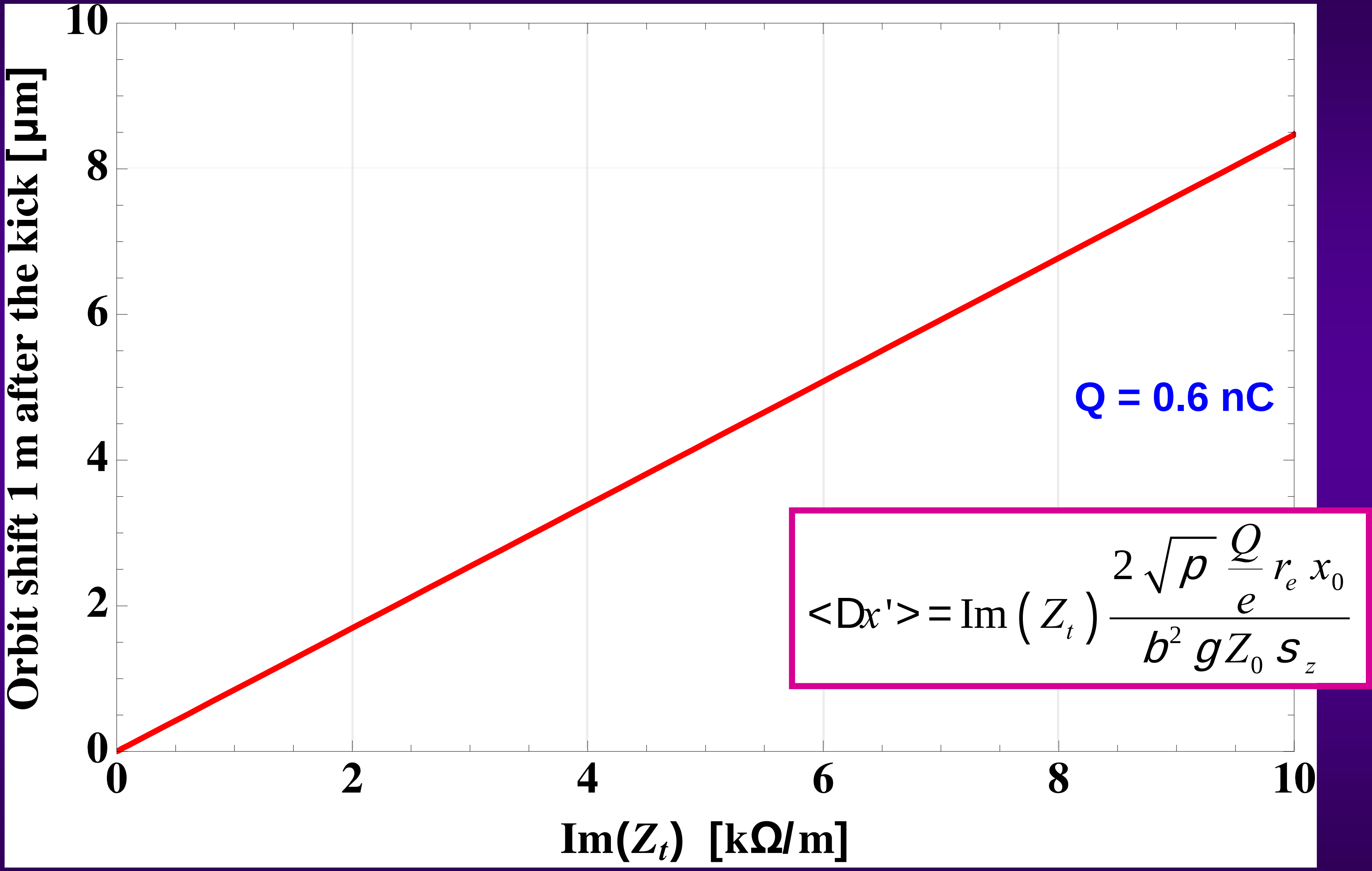
- **Conditions**
  - 1 bunch of e-
  - E = 200 MeV
  - σ_t = 1 ps
  - ε = 20 µm (rms. norm.)
  - Initial beam transverse offset x_0 = 1 mm
- **Case 1: Resistive-wall impedance from a copper collimator**
  - Length L = 1 m
  - Resistivity = 17 nΩm (Copper)
  - Half gap b = 4 mm
- **Case 2: Equipment with constant imaginary impedance**
  - $Z_t = K\,j$

CASE 1



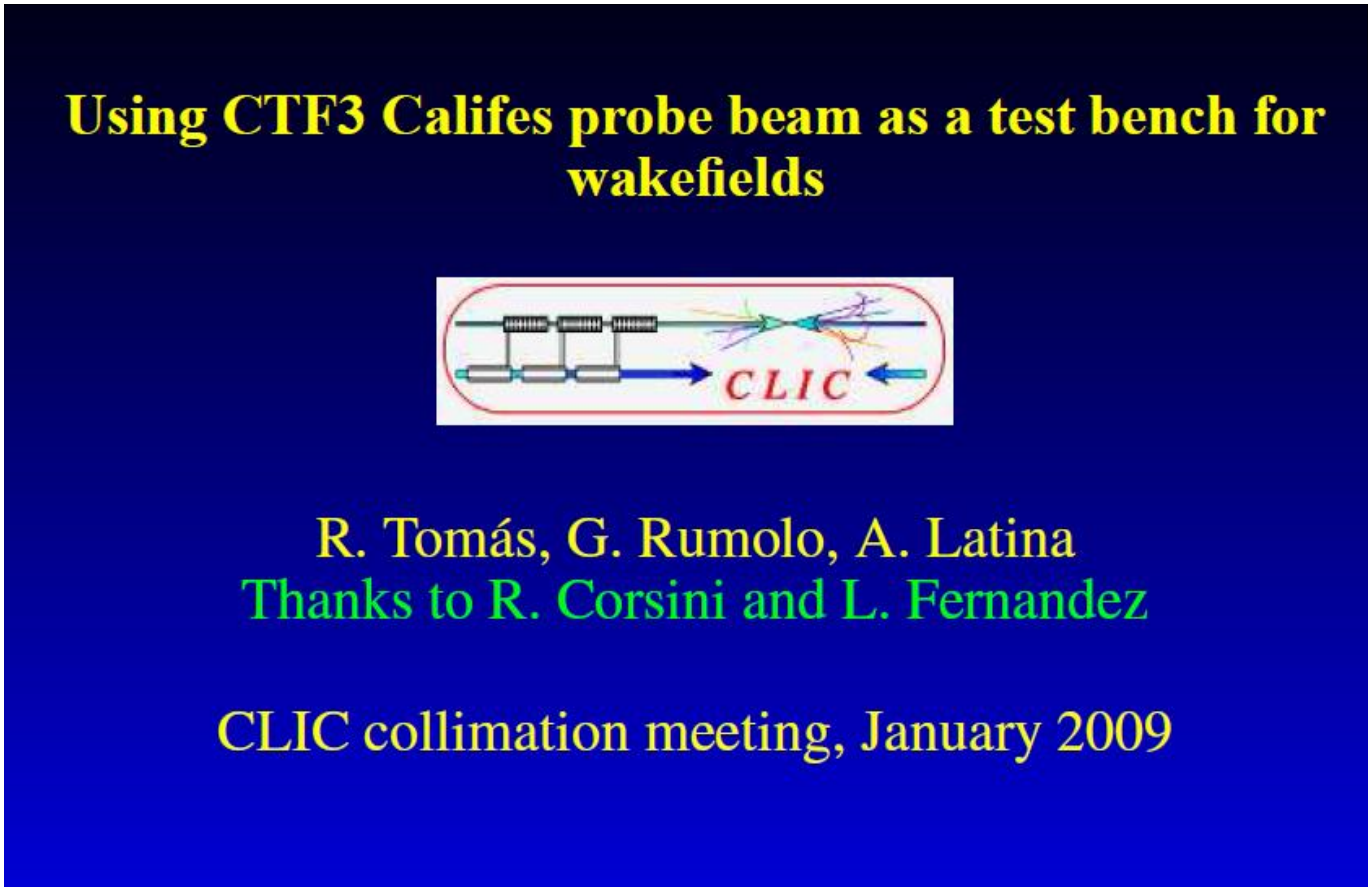
$$\langle \Delta x' \rangle = \frac{\sqrt{2}\,\frac{Q}{e}\, r_e\, x_0\, \Gamma\left(\frac{1}{4}\right)}{\beta^2 \gamma \pi\, b^3} \frac{L}{\sqrt{Z_0\, \sigma\, \sigma_z}}$$

CASE 2

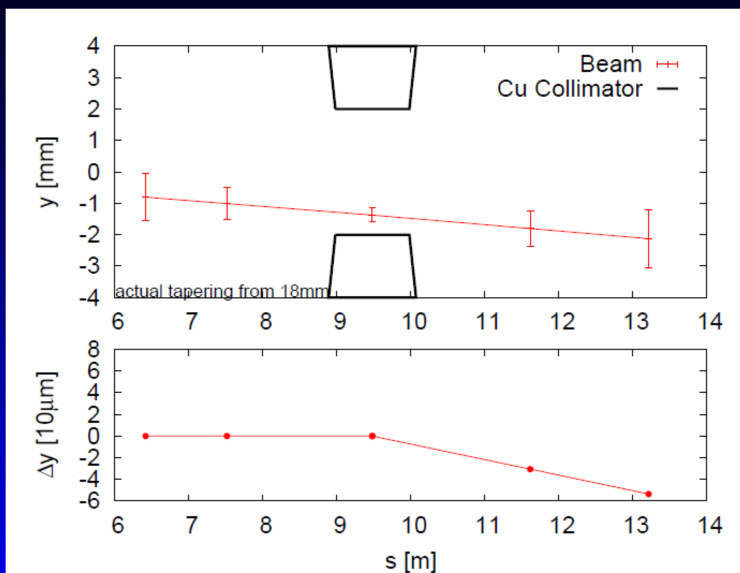


$$\langle \Delta x' \rangle = \mathrm{Im}\left(Z_t\right)\frac{2\sqrt{\pi}\,\frac{Q}{e}\,r_e\,x_0}{\beta^2\,\gamma\,Z_0\,\sigma_z}$$

Transverse displacement from previous work:



Cu collimator pushed example



Califes probe beam parameters

Energy	200 MeV
Energy spread	2%
Normalized emittances	20μm
Bunch charge	0.6nC
Bunch length	0.75ps

Same bunch charge as CLIC.

Bunch length is 5 times longer than CLIC.

Summary

- Existing set-up with almost 8m free distance
- Order of magnitude of position shift due to wakefield 10 μm.
- Therefore BPMs requirement in the 1μm level
- Non-linear wakefields?
- Reproducibility?

What would we be interested to measure?

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- Direct measurement of coherent effects between bunches
- Direct measurement of heating
- Direct measurement of generated electromagnetic fields

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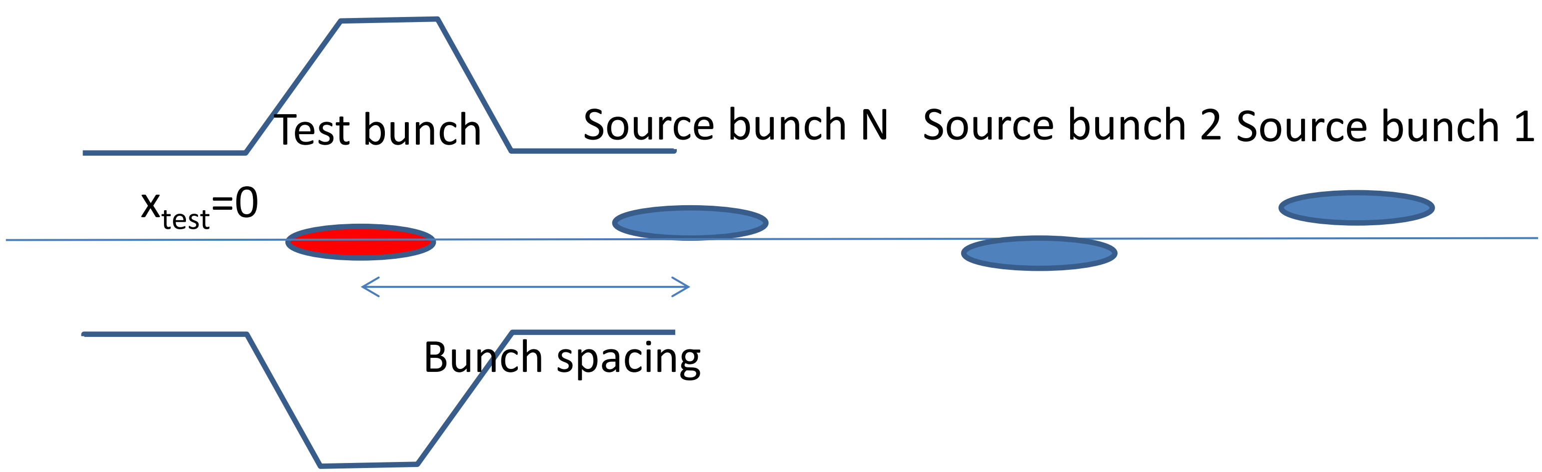
Direct measurement of coherent effects between bunches

- In case of high Q resonances, wake fields do not decay fast and another bunch comes when the fields have not yet decayed → coherent effects could therefore be checked.

- Need to generate several source bunches and one test bunch and to be able to adjust the spacing between the bunches.

→ Very interesting to study the coherent heat deposition: $P_{loss} \alpha M^2 Nb^2$

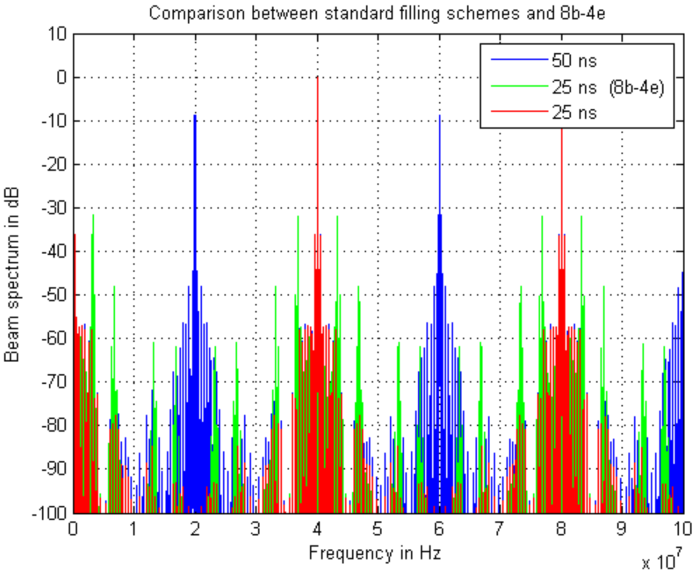
→ And the impact of coherence on transverse kicks



Direct measurement of beam induced temperature increase

- Monitor temperature of the device with many bunches

- Questions:
  - is the available intensity enough to generate enough power loss?
  - Need to be able to adjust the beam spectrum lines (therefore adjust the spacing to e.g. 25 ns)



Direct measurement of generated electromagnetic fields

- Possibility to measure EM fields from available antennas, buttons, striplines, wires, all mode couplers already in the device (or installed just for that reason).
- Possibility of direct benchmark CST Particle Studio simulations and check their validity (probe measurements only validate eigenmode simulations, and wire measurements can perturb significantly the modes).
- For the case of the wirescanners, possibility to directly measure the signals on the wire during the passage of the beam → would be very important, and the only direct way of measuring the heat load to the wire (besides installing it in the SPS or the LHC).
- For other devices, it would be an indirect measurement that could validate the model, meshing and simulation.

Conclusions from the brainstorming

- Using CALIFES or CTF3 beam to measure impedance may not work in many cases due to constraints:
  - need to tune the spacing/orbit between the source and the test bunches
  - Lower limit of detectable impedance kick/energy loss (due to available intensity, resolution of BPM and other impedance contributions that need to be added)
  - Available space and flexibility

- However, some reachable features can not be obtained with other means so far and we think it would be interesting to investigate further the feasibility of such measurements
  - "Wake function" with very short bunches (longitudinal/dipolar/quadrupolar)
  - Direct measurement of impact of field coherence
  - Direct measurement of EM fields
  - Direct measurement of heating (even though it looks difficult)