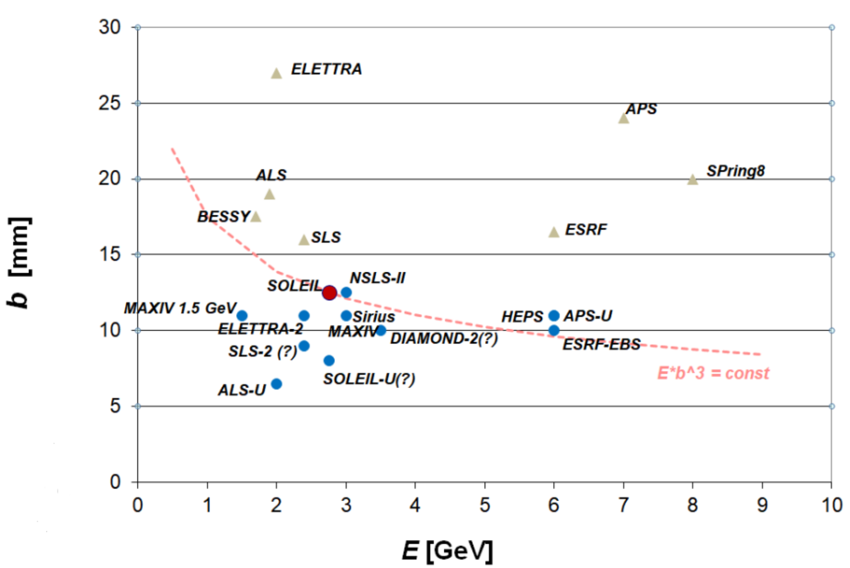
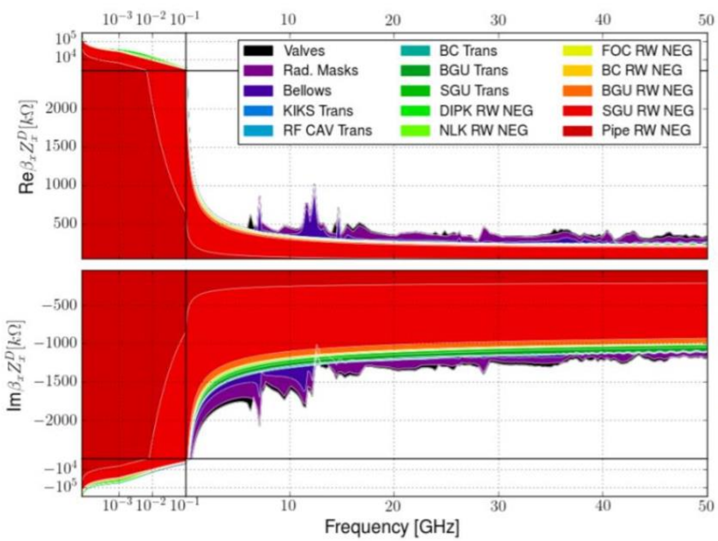
1. Impedance and instabilities of low gap chambers (Ryutaro Nagaoka, SOLEIL)

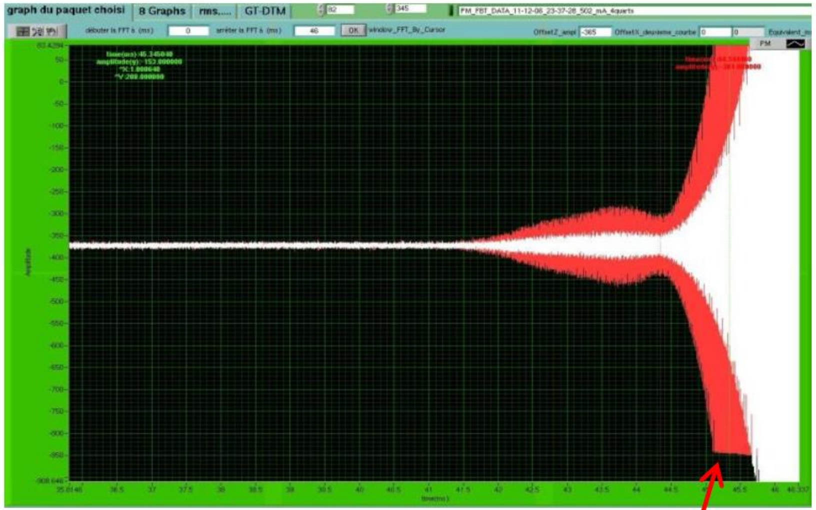
- A clear trend that future LERs adopt vacuum chambers with significantly reduced aperture b
- As the wakefields scale as b^{-n} ($n \geq 1$), whether geometric or resistive-wall, their sensitivity to the sources of impedance can only be larger.

  → A big effort required if we want to keep the machine impedance on the same level as before
- Innovative vacuum components designs, including coating technology, needed in collaboration with machine physicists to keep machine heating and beam instability under control
- Special efforts required to;
  - avoid heating due to ceramic chambers and trapped modes
  - develop means to cleverly evacuate generated heat without damaging vacuum components

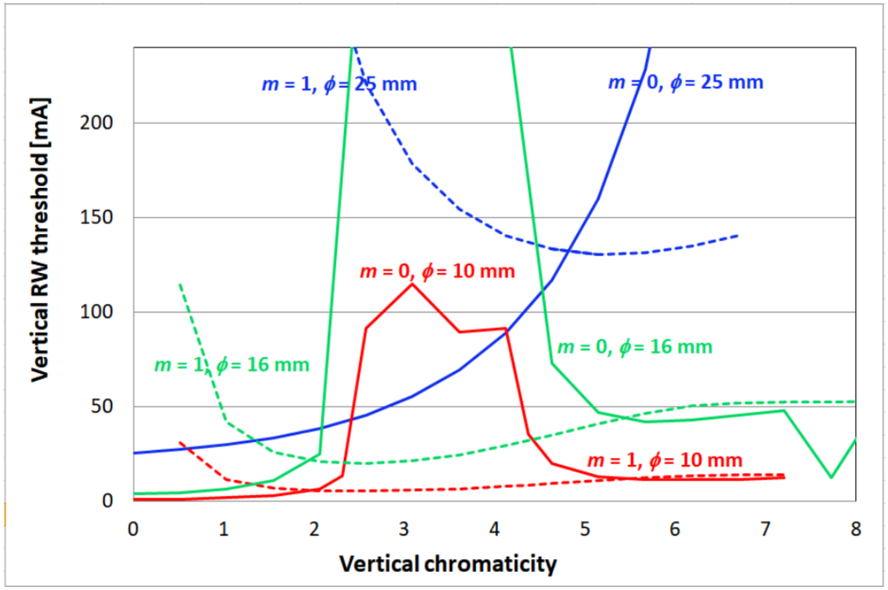




- Gravity of the enhanced Z would depend on the operation modes (beam filling, total current) and on the desired beam quality
  → Most challenging if high bunch current without bunch lengthening is targeted
  → If $\sigma_\varepsilon = \sigma_{\varepsilon 0}$ is to be met, efforts needed to push $(I_{th})_{microwave} > I_{ope}$
- RW and transverse single bunch instabilities are likely to get strongly excited
  → Bunch-by-bunch TFB would be indispensable for machine operation
- Advanced beam instability simulation that can handle
  Bunch by bunch feedback / Single particle nonlinear dynamics (incoherent tune shifts) / Element-by-element transformation (instead of 1-turn) / Arbitrary beam filling
  become important to assure high beam current operation against strong RW effects
- NEG coating would significantly enhance Z, but its impact should be mostly appear on ImZ (i.e. bunch lengthening, coherent tune shifts, …) as long as the beam is only sensitive to $Z_{low\_frequency}$

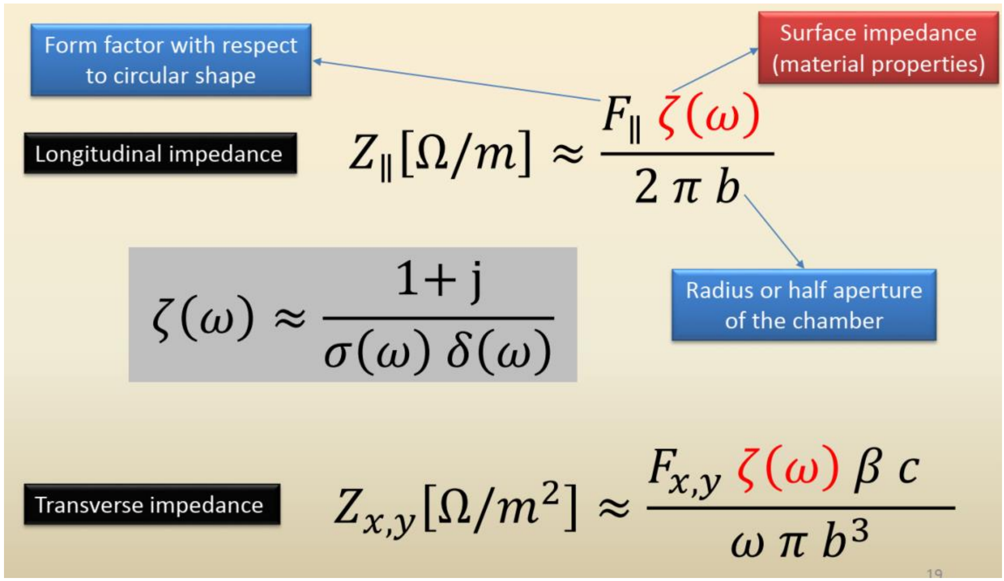


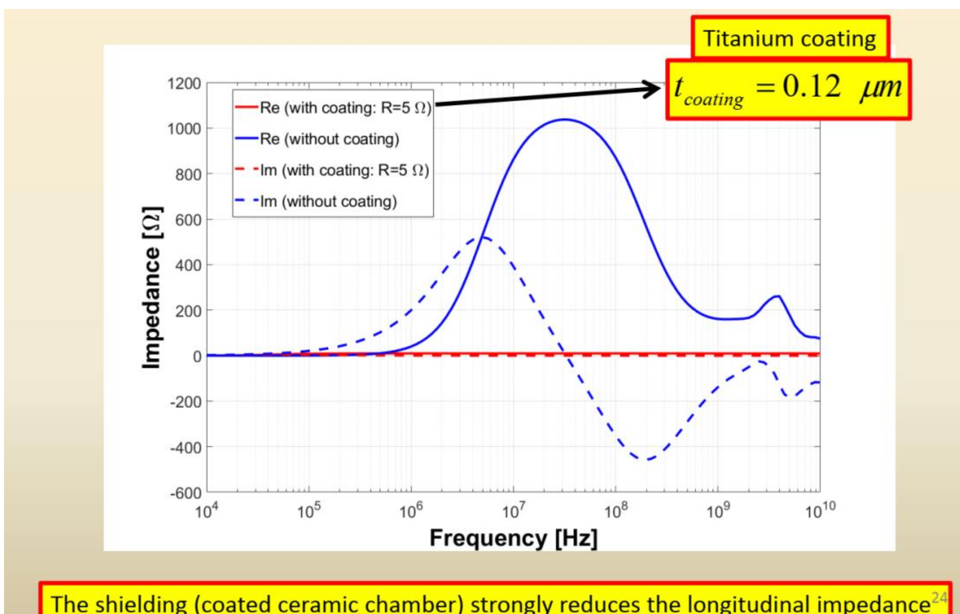
Measured beam loss at 500 mA
***White**: Beam,* ***Red**: TFB kick*

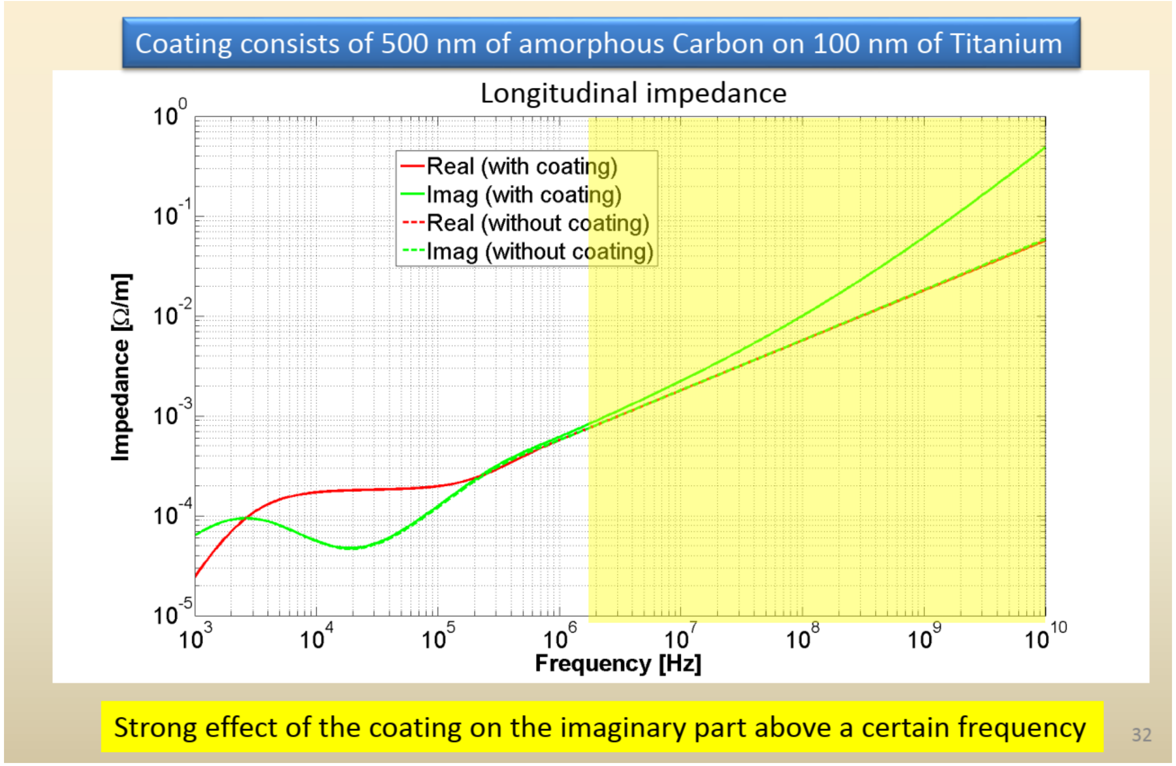


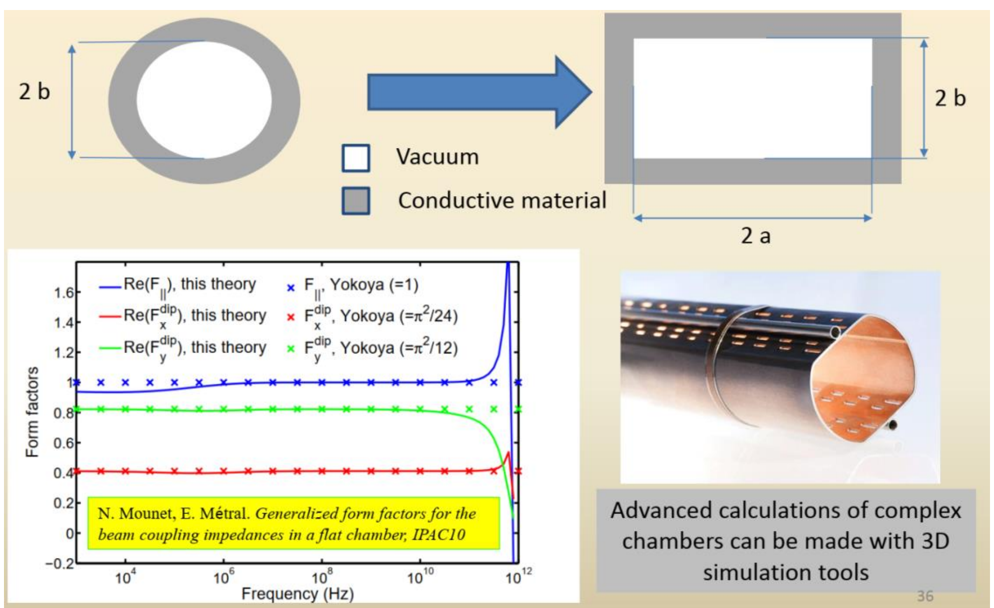
2. Impedance aspects on beam chamber specifications (Carlo Zannini, CERN)

- A review of was on the different important physical ingredients that determine the impedance of a vacuum components in view of minimising them, demonstrated with a few typical examples









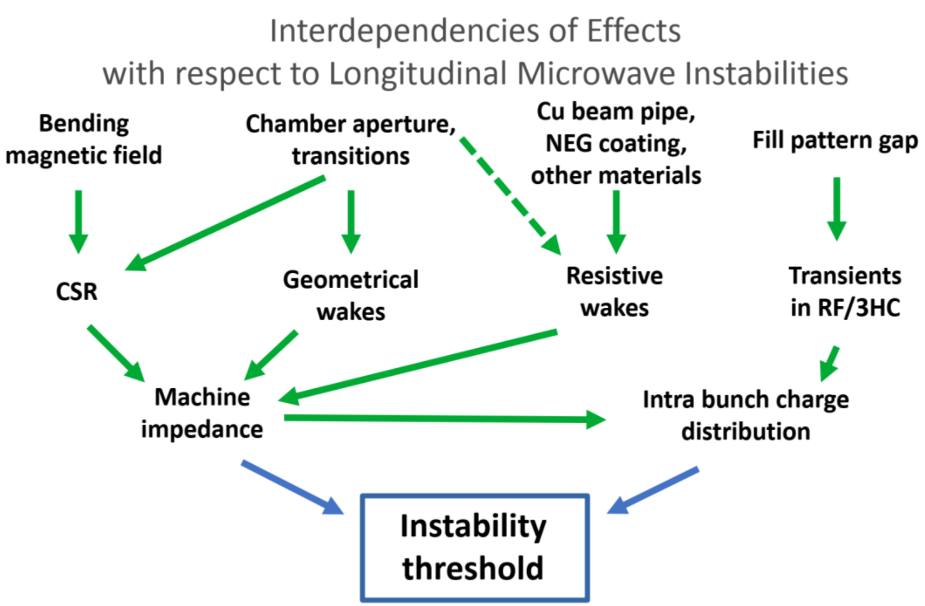
- Dependence of form factor in terms of Yokoya factor along with its general extension including frequency dependence

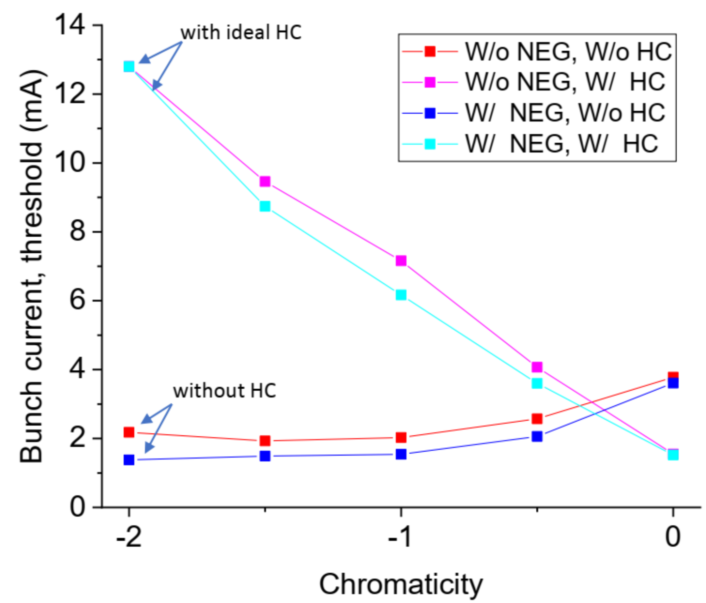
3. Overview of the collective effects in SLS 2.0 (Alessandro Citterio, PSI)

- Systematic studies of instabilities most concerned for SLS-II (microwave, single bunch transverse, ions, …) made by paying attention to “inter-dependency” of different effects

- Most studies made with an assumption “a < 0”, following the ultra low-emittance lattice developed with this characteristics for SLS-II (due to use of reversed-bends, …)

- As a rule of thumb, **we assume to require a margin of safety of two between predicted and required threshold currents**. For the current baseline parameters as described above, this is fulfilled and **the accelerator is expected to run stable at nominal current**. **The harmonic cavity is mandatory** for both longitudinal and transverse instabilities

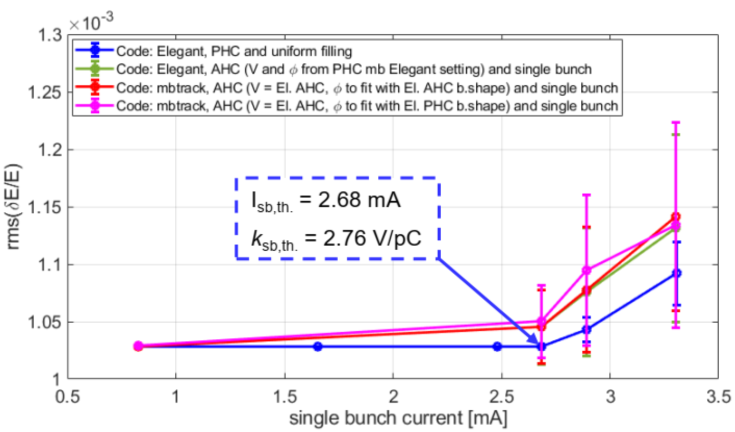




● **The thickness of the NEG coating is an important issue**. Strong efforts are strongly suggested in order to **make the coating as transparent (= thin) as possible: we are now looking towards 200 nm NEG thickness** (vs 500 nm reference in the simulations).

● The **good correspondence of the threshold curves and of the bunch shapes for ELEGANT and Mbtrack** prove the consistency of our approach
both in terms of the impedance preparation and of the tracking calculations for the analysis of the longitudinal microwave instabilities.

● **An experimental validation is under way using SLS 1**, which, together with the results above and a refined impedance model, may allow to
apply a smaller margin of safety for the calculated thresholds.
Lot of efforts in impedance simulations and design cross-checking of SLS 1 !!!



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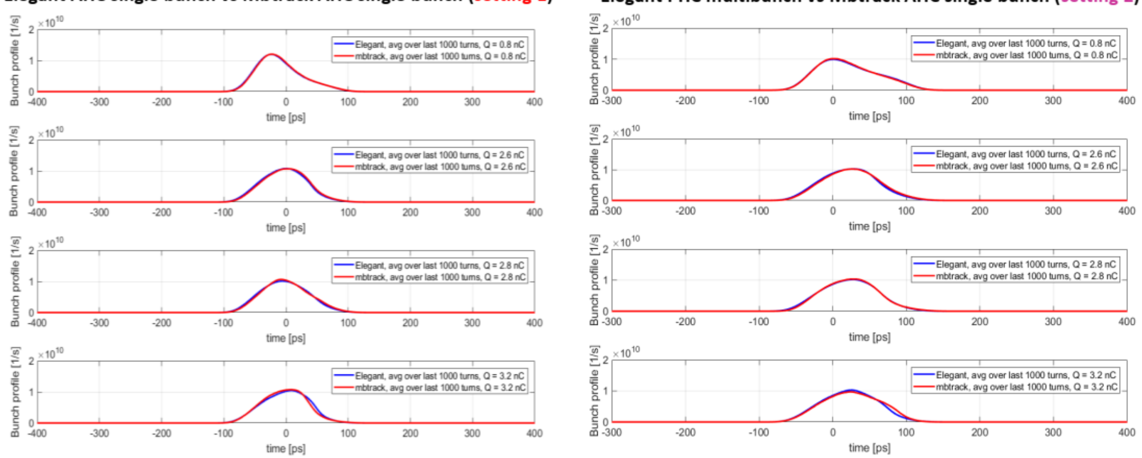
Elegant AHC single bunch vs Mbtrack AHC single bunch (setting 1) **Elegant PHC multibunch vs Mbtrack AHC single bunch (setting 2)**



4. Analytical impedance estimates for coated surfaces (Sergey Arsenyev, CERN)

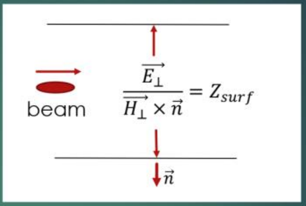
Estimates of wall impedance

- Fully analytical: explicit formulas for impedance
- Semi-analytical: involves numerically finding integrals, roots, etc
  - Example: IW2D (field matching)
  - TLWall (transmission line theory)
- Numerical: numerically solving for the fields with a mesh
  - BI2D
  - CST

4

Surface impedance method

Step 1:
Find the surface impedance Z_{surf} (Leontovich boundary condition)
Applicable if $|\epsilon_1\mu_1| >> \epsilon_0\mu_0$



Step 2:
Relate the surface to the beam coupling impedance

$$Z_{surf}(\omega) \Rightarrow Z_{||}(\omega),\ Z_\perp(\omega)$$

We will start with the second step

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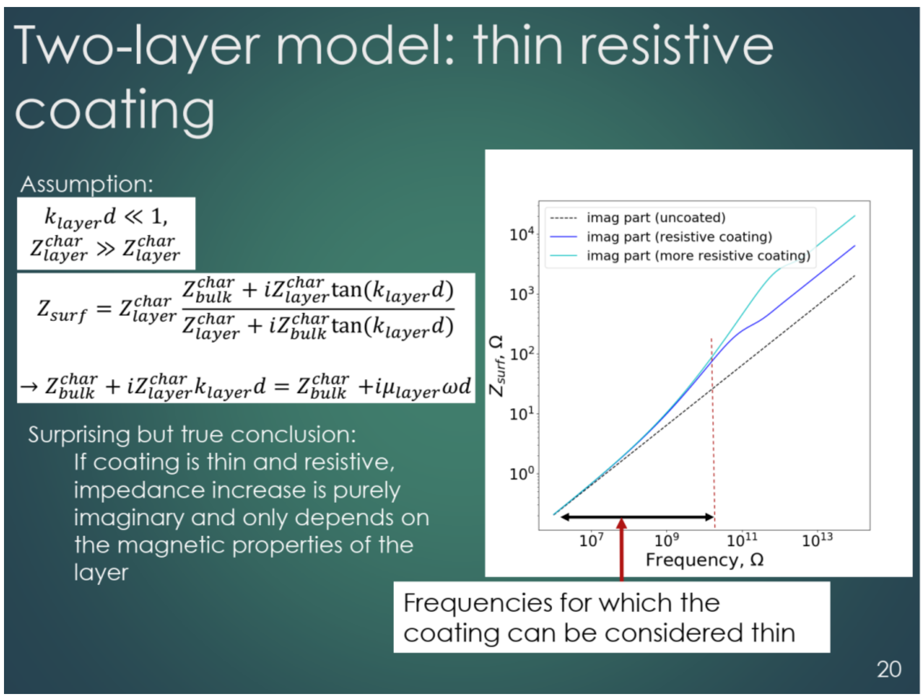
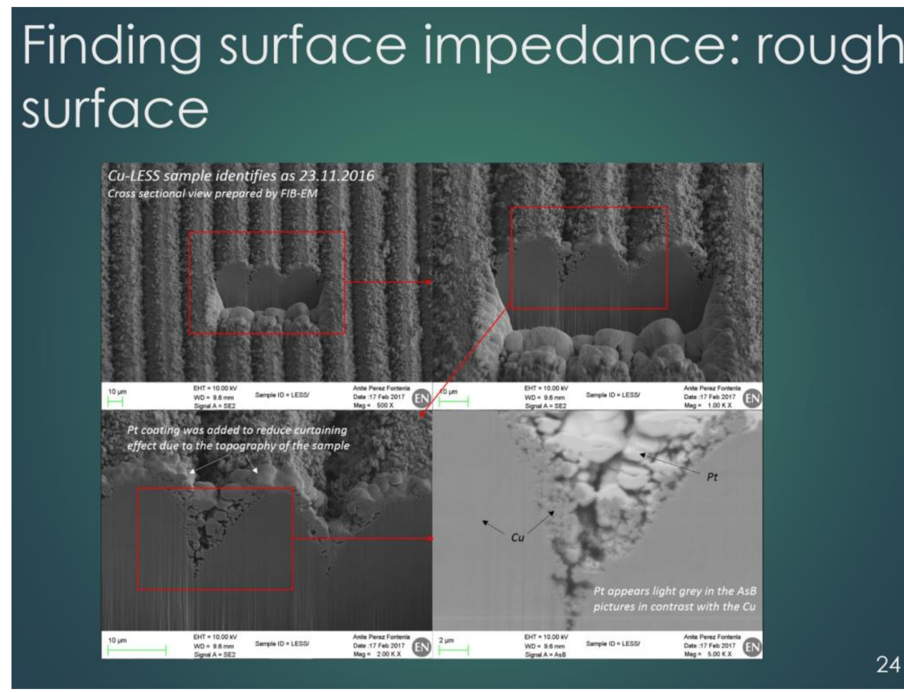
Under certain assumptions, we arrive to incredibly simple relations between surface impedance and coupling impedance

	Relation	Assumption
	Length of the pipe; Pipe inner radius	$Z_0 = 377\Omega$; $\omega_b = c/b$
Longitudinal	$Z_{\|\|}(\omega) = \frac{L}{2\pi b} Z_{surf}(\omega)$	$\|Z_{surf}(\omega)\| \ll 2Z_0 \frac{\omega_b}{\omega}$
Transverse dipolar	$Z_{dip}(\omega) = \frac{Lc}{\omega\pi b^3} Z_{surf}(\omega)$	$\|Z_{surf}(\omega)\| \ll Z_0 \times \min\left(\frac{\omega_b}{\omega}, \frac{\omega}{\omega_b}\right)$

- Analytical derivations of the surface impedance were shown for
  - Two-layer model
  - Linear conductivity model
  - Rough surface model





5. Sub-THz measurements for electromagnetic characterization of coating materials (Andrea Passarelli, INFN, Napoli)

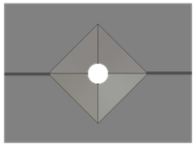
- An experimental setup developed to measure systematically the frequency dependence of the conductivity of coated materials was presented, along with the measured results

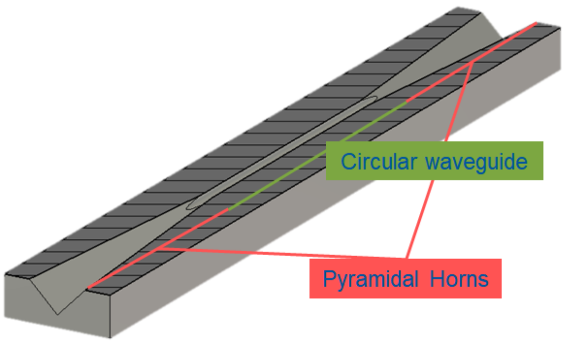
- Goal of the study: To develop a reliable, handy and inexpensive system for the electromagnetic characterization of Coating material in Sub-THz range.

TERA K15

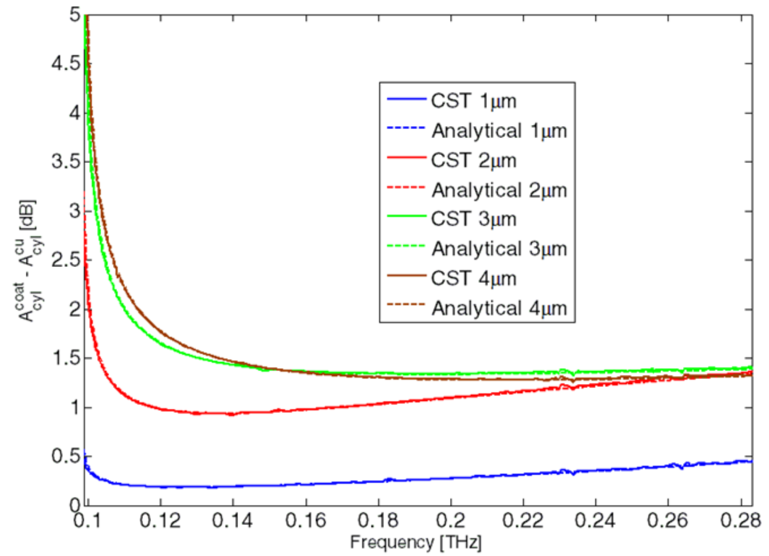
Time-Domain THz Spectrometer

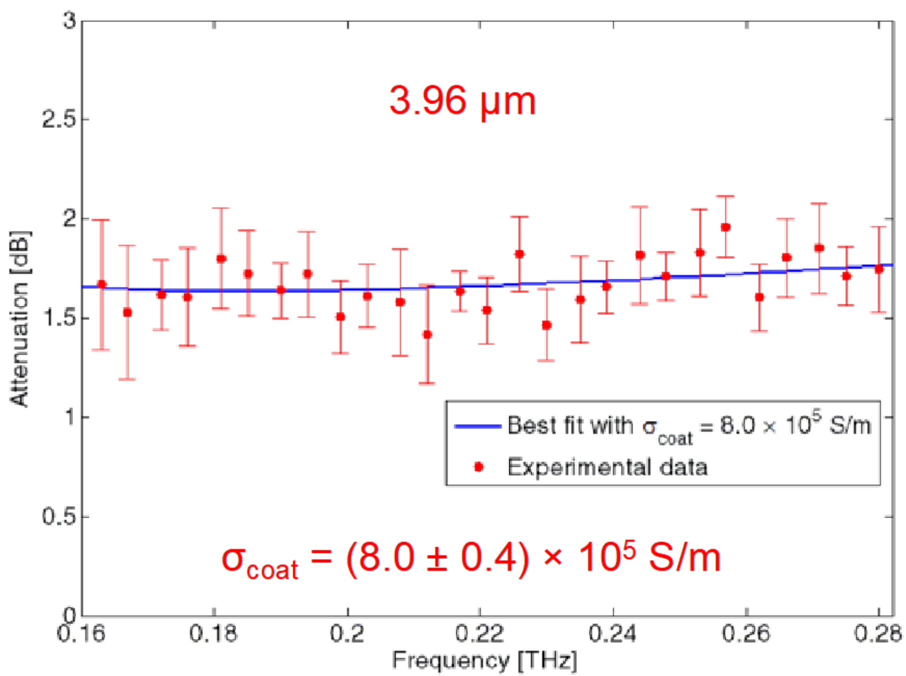
The DUT

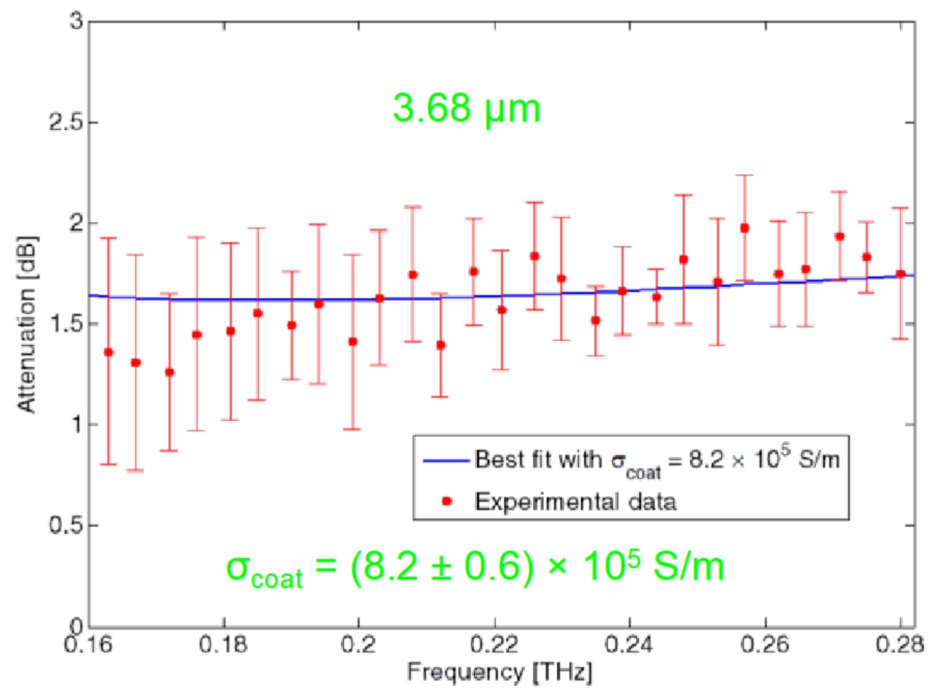
Dimension in mm	
Material	Iron
Waveguide	Circular
Length	42
Radius	0.9
Horns	Pyramidal
Length	39
External side	6
Total Length	120



- Prior to the measurement, good agreement was confirmed with CST calculations and analytical estimates for the setup







Main experimental results obtained for two different NEG coated slabs

Summary of the summaries:

- With decreasing gaps of the future ring vacuum chambers, the beam coupling impedance $Z(\omega)$ is expected to get furthermore increased, enhancing beam collective effects (beam-induced heating and beam instabilities)

- Impedance arising from thin metallic coating either of
  - Poor conducting materials on good conducting walls or
  - Good conducting materials on poor conducting (dielectric) walls

  must be well understood and controlled both theoretically, numerically and experimentally

- Works presented in the session go well along this direction showing the forefront progress

- Simulation studies using different codes have shown good ways to benchmark codes and better assurer obtained results

- Effects of NEG and surface roughness on beam collective effects and instabilities require further thorough studies