A wireless method for beam coupling impedance measurements of the LHC goniometer

C. ANTUONO

M. MIGLIORATI

A. MOSTACCI

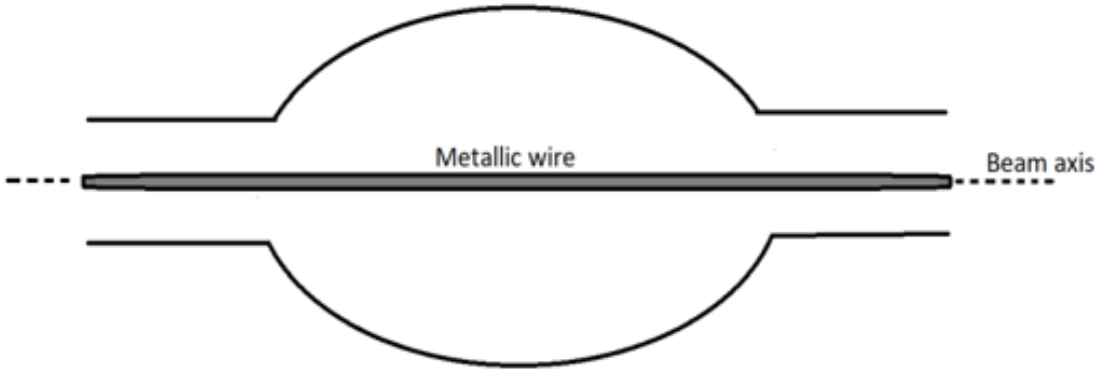
C. ZANNINI

- **PhD student** in ''Physics of particle accelerators'' at **"La Sapienza"** University of Rome
  - Thesis title : methods to evaluate the **beam coupling impedance** of accelerators: **a novel technique for bench measurements** and beam-based measurements at the PSB
- **BE-ABP-CEI** at CERN

A wireless method for beam coupling impedance measurements of the LHC goniometer

Standard impedance bench measurement method

- Ideally the **beam coupling impedance** should be evaluated by exciting the device with **the beam itself**
- Beam based measurements of the **impedance** are not always possible
  - The **stretched wire method** is a well-established **bench measurements** technique *



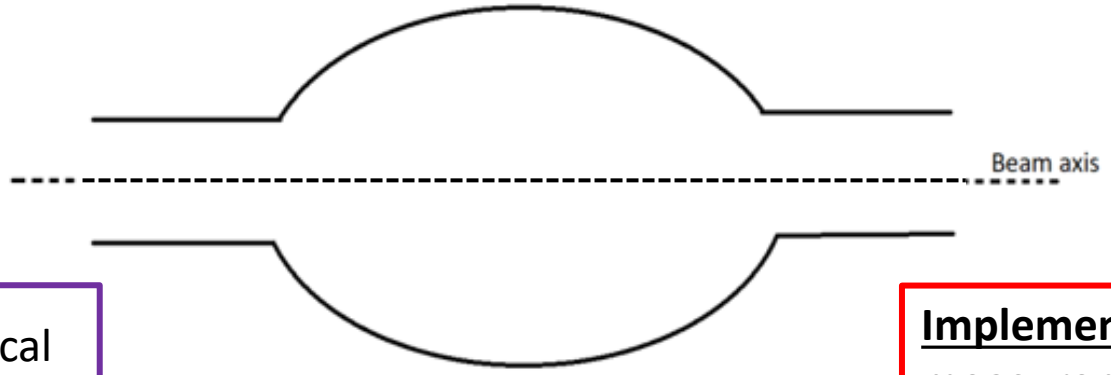
The **wire** simulates the EM behaviour of the particle beam → The **wire perturbs the EM boundary conditions** → **limitations** of this technique **are known** → Techniques **without the modification of the DUT** → **wireless method**

A wireless method for beam coupling impedance measurements of the LHC goniometer

A new Wireless method to measure the impedance

Idea: longitudinal beam impedance**: energy loss of the EM wave** propagating in the structure → ***S*** **parameters of the DUT**

Approach: excite the **appropriate EM fields** in the DUT related to the beam impedance



✓ Simulations and analytical computations work **for RW beam chambers** *

$$Z = \frac{Z_{TM}}{2\pi} \ln \frac{S21^{DUT}}{S21^{REF}}$$

challenges

Implementation of a measurement technique:

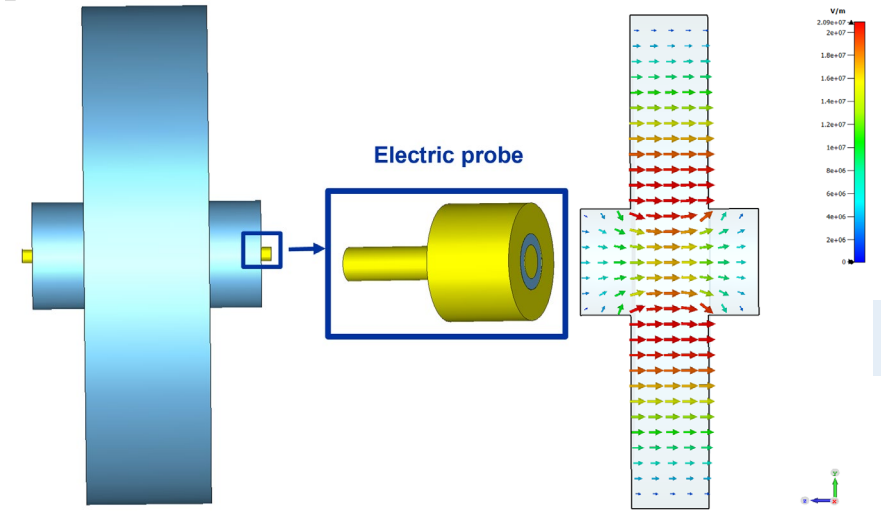
- **real excitation** of the DUT consistent with simulations
- extension to **resonant structures**

*C. Antuono, Improved simulations in frequency domain of the Beam Coupling Impedance in particle accelerators, CERN-THESIS-2021-026

Virtual wireless measurement for resonant structure

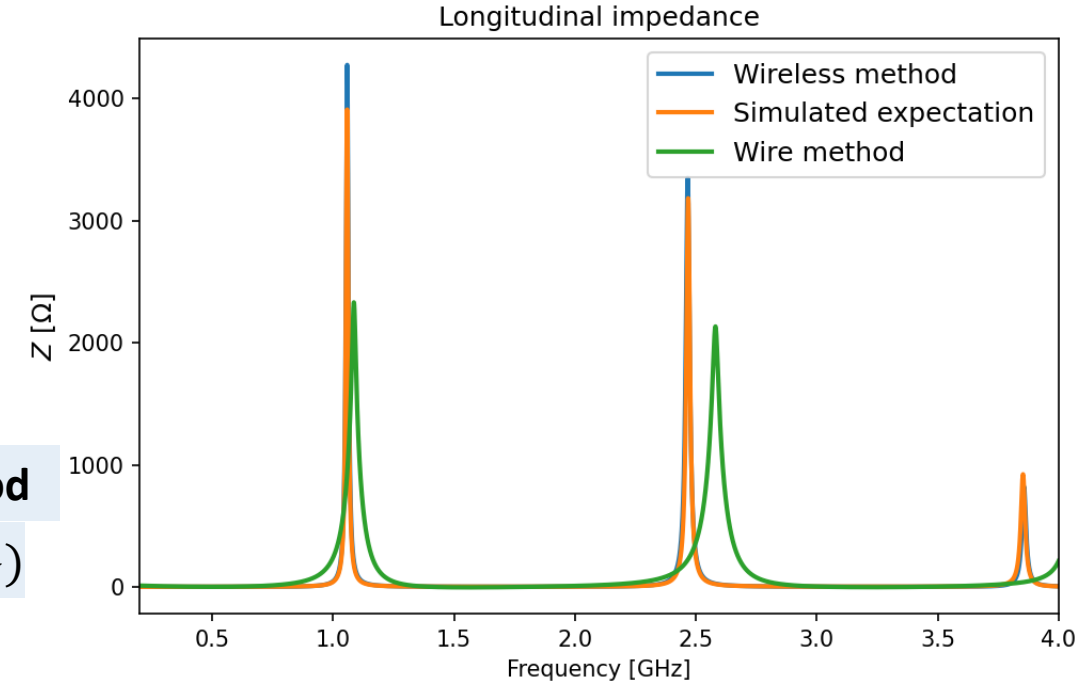
Wireless method implementation:

- Electric probe setup as a **real excitation** of the DUT



Wireless method

$$Z(f, S_{21}, Z_{TM})$$

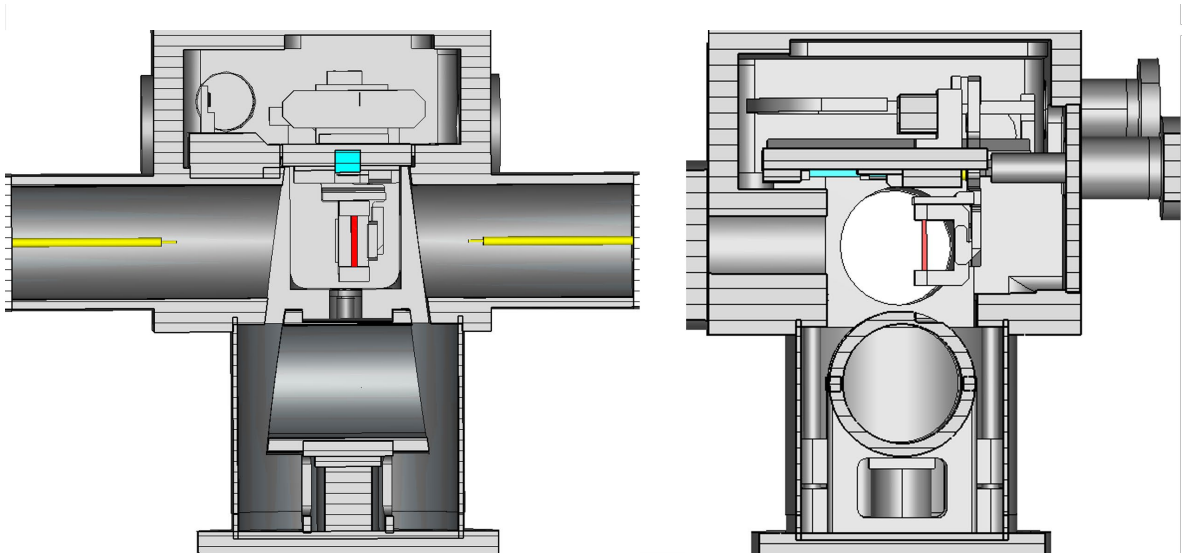


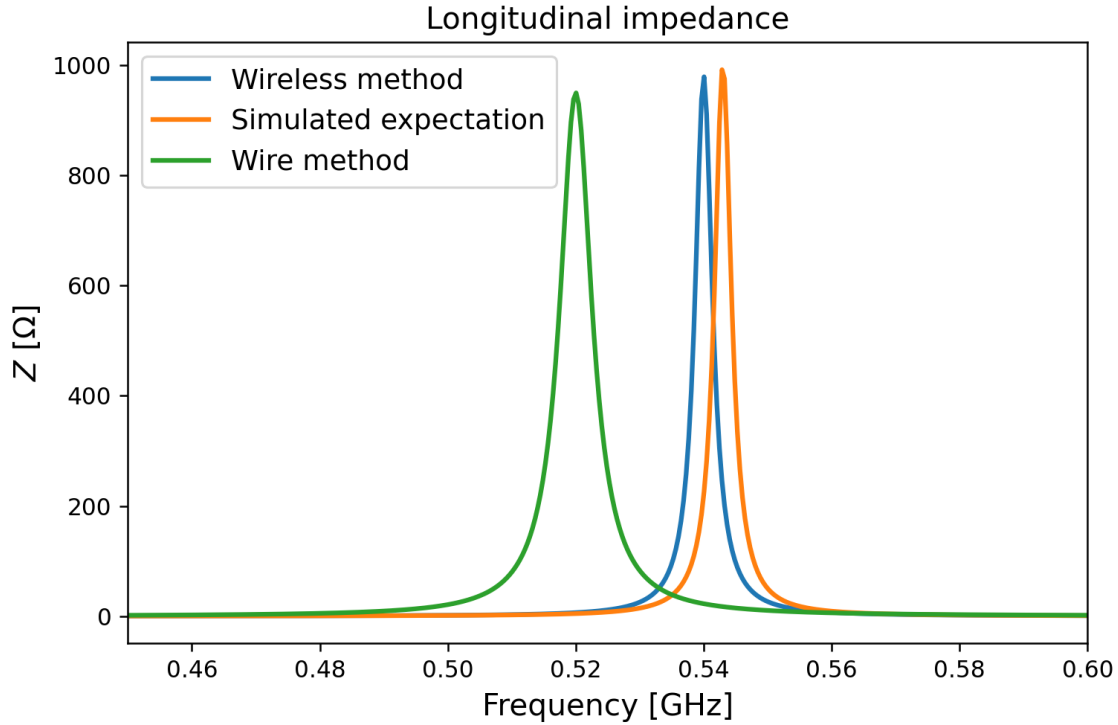
- **Very good agreement** between the wireless method and the expectations
  - The **advantage** compared to the wire method is evident

A wireless method for beam coupling impedance measurements of the LHC goniometer

Wireless method to more complex devices: LHC crystal goniometer

Preliminary test of a complex structure: LHC crystal goniometer





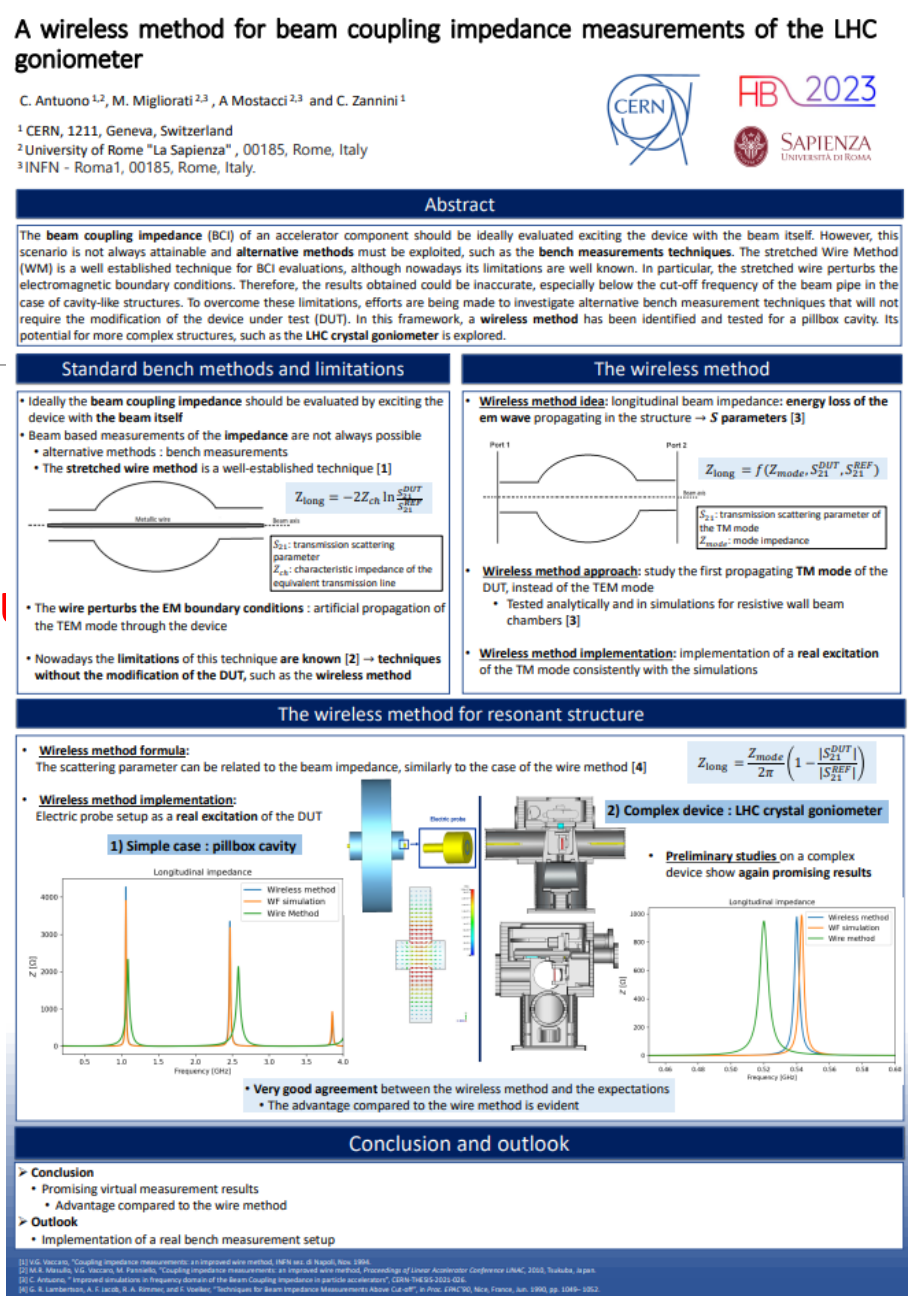
- **Again, very good agreement** between the wireless method and the expectations
  - promising preliminary results

Conclusions and outlook

- Promising virtual measurement results
- Implementation of a real bench measurement setu

Find more on my poster…

Thank you!!!



A wireless method for beam coupling impedance measurements of the LHC goniometer

C. Antuono [1,2], M. Migliorati [2,3], A Mostacci [2,3] and C. Zannini [1]

[1] CERN, 1211, Geneva, Switzerland
[2] University of Rome "La Sapienza", 00185, Rome, Italy
[3] INFN - Roma1, 00185, Rome, Italy.

HB 2023

Abstract

The **beam coupling impedance** (BCI) of an accelerator component should be ideally evaluated exciting the device with the beam itself. However, this scenario is not always attainable and **alternative methods** must be exploited, such as the **bench measurements techniques**. The stretched Wire Method (WM) is a well established technique for BCI evaluations, although nowadays its limitations are well known. In particular, the stretched wire perturbs the electromagnetic boundary conditions. Therefore, the results obtained could be inaccurate, especially below the cut-off frequency of the beam pipe in the case of cavity-like structures. To overcome these limitations, efforts are being made to investigate alternative bench measurement techniques that will not require the modification of the device under test (DUT). In this framework, a **wireless method** has been identified and tested for a pillbox cavity. Its potential for more complex structures, such as the **LHC crystal goniometer** is explored.

Standard bench methods and limitations

- Ideally the **beam coupling impedance** should be evaluated by exciting the device with **the beam itself**
- Beam based measurements of the **impedance** are not always possible
  - alternative methods : bench measurements
  - The **stretched wire method** is a well-established technique [1]

$Z_{long} = -2Z_{ch} \ln \frac{S_{21}^{DUT}}{S_{21}^{REF}}$

S_{21}: transmission scattering parameter
Z_{ch}: characteristic impedance of the equivalent transmission line

- The **wire perturbs the EM boundary conditions** : artificial propagation of the TEM mode through the device
- Nowadays the **limitations** of this technique **are known** [2] → **techniques without the modification of the DUT,** such as the **wireless method**

The wireless method

- **Wireless method idea:** longitudinal beam impedance: **energy loss of the em wave** propagating in the structure → ***S* parameters** [3]

$Z_{long} = f(Z_{mode}, S_{21}^{DUT}, S_{21}^{REF})$

S_{21}: transmission scattering parameter of the TM mode
Z_{mode}: mode impedance

- **Wireless method approach:** study the first propagating **TM mode** of the DUT, instead of the TEM mode
  - Tested analytically and in simulations for resistive wall beam chambers [3]
- **Wireless method implementation:** implementation of a **real excitation** of the TM mode consistently with the simulations

The wireless method for resonant structure

- **Wireless method formula:**
  The scattering parameter can be related to the beam impedance, similarly to the case of the wire method [4]

$Z_{long} = \frac{Z_{mode}}{2\pi}\left(1 - \frac{|S_{21}^{DUT}|}{|S_{21}^{REF}|}\right)$

- **Wireless method implementation:**
  Electric probe setup as a **real excitation** of the DUT

1) Simple case : pillbox cavity

Longitudinal impedance

Wireless method
WF simulation
Wire Method

Z [Ω]

Frequency [GHz]

2) Complex device : LHC crystal goniometer

- **Preliminary studies** on a complex device show **again promising results**

Longitudinal impedance

Wireless method
WF simulation
Wire method

Z [Ω]

Frequency [GHz]

- **Very good agreement** between the wireless method and the expectations
  - The advantage compared to the wire method is evident

Conclusion and outlook

- **Conclusion**
  - Promising virtual measurement results
    - Advantage compared to the wire method
- **Outlook**
  - Implementation of a real bench measurement setup

[1] V.G. Vaccaro, "Coupling impedance measurements: a n improved wire method, INFN sez. di Napoli, Nov. 1994.
[2] M.A. Masullo, V.G. Vaccaro, M. Pannetta, "Coupling impedance measurements: an improved wire method, Proceedings of Linear Accelerator Conference LINAC, 2010, Tsukuba, Japan.
[3] C. Antuono, " Improved simulations in frequency domain of the Beam Coupling Impedance in particle accelerators", CERN-THESIS-2021-026.
[4] G. R. Lambertson, A. F. Jacob, R. A. Rimmer, and F. Voelker, "Techniques for Beam Impedance Measurements Above Cut-off", in Proc. EPAC'90, Nice, France, Jun. 1990, pp. 1069–1052.