Elettra Sincrotrone Trieste

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Home Made Button Type BPMs: simulations, real results and failures

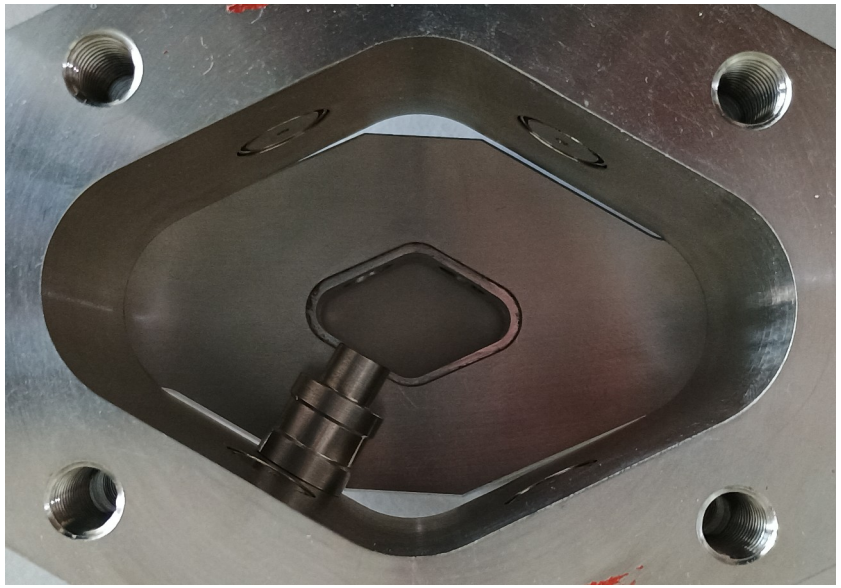
S. Cleva – Elettra Sincrotrone Trieste

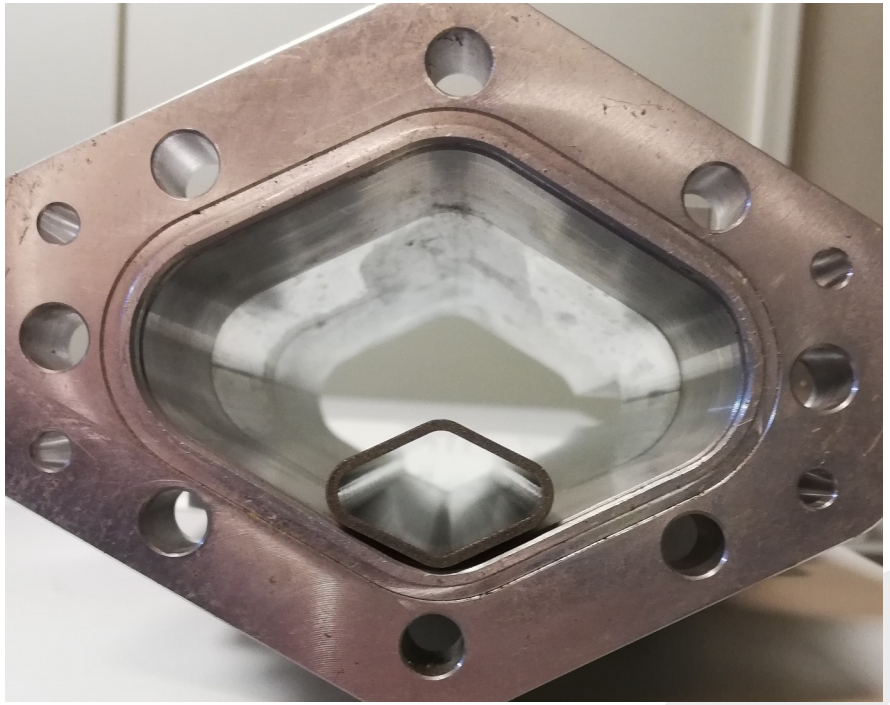
Recap of the previous episode

- The full preamble can be found in the presentation that was given at ALBA, Button BPMs for Synchrotron Light Sources workshop, “Home Made Button Type BPMs: demo antennas or real diagnostics tools?”, https://indico.cells.es/event/1542/contributions/2942/
- ElectroMagnetic design of a 6-port device (button type BPM)
- Beam dynamic constraints – Beam Coupling Impedance (ideally only RW)
- Diagnostics design goals – Transfer Impedance (high pass nature), port matching (over the full beam spectrum), centered bridge (0,0)
- Materials constraints: $\mu_r = 1$, ε_r = as low as possible, σ as high as possible, $\tan(\delta)$ negligible
- Ancillary goals: heat losses, machine operating condition (i.e. beam current, bunch length σ_{RMS}, fill pattern, …)
- Practical limitations: costs, reliability, manufacturability, time schedule, etc.

BPM design in view of Elettra 2.0

- The practical design of the BPMs for Elettra 2.0 started taking into account the available room for the pick-ups
- Compared to Elettra, the transverse size of Elettra 2.0 BPMs is rescaled by 1/3 and ...
- … the longitudinal free room between the different machine elements is almost zero
- → A very compact BPM body is mandatory!
- Side effect: button size must be scaled (½)





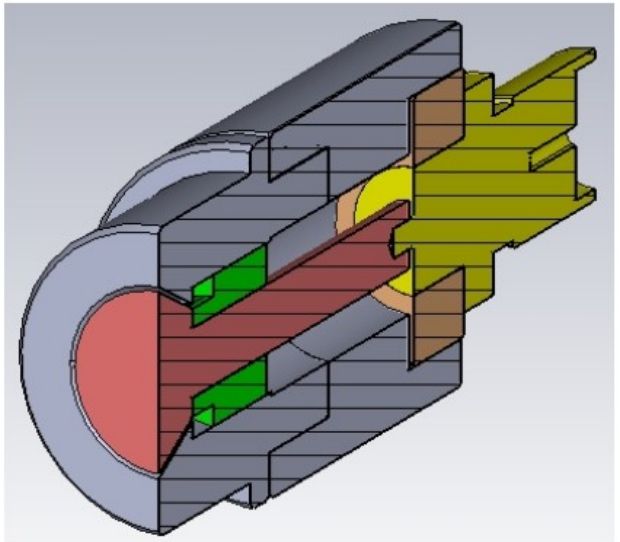
From simulations to reality

- Simulation of various types of materials and geometries can be applied to the BPM design using EM numerical tools such as CST MWS and Ansys HFSS
- BPM body size and material (AISI316L) are fixed by mechanical design
- Once a "nominally" manufacturable BPM assembly is found, it should be tested for EM simulation validation
- Interacting with the manufacturers can be a cumbersome and time-consuming process
- For rapid prototyping and testing, a home made “quick&dirty” approach could be a reasonable way to get in short time cheap and “reliable enough” diagnostics devices
- “reliable enough” is strictly related to the available vacuum sealing technology
- Once a home made prototype has been manufactured, it must be tested on the real machine in real operating conditions

The first generation of HMBPM

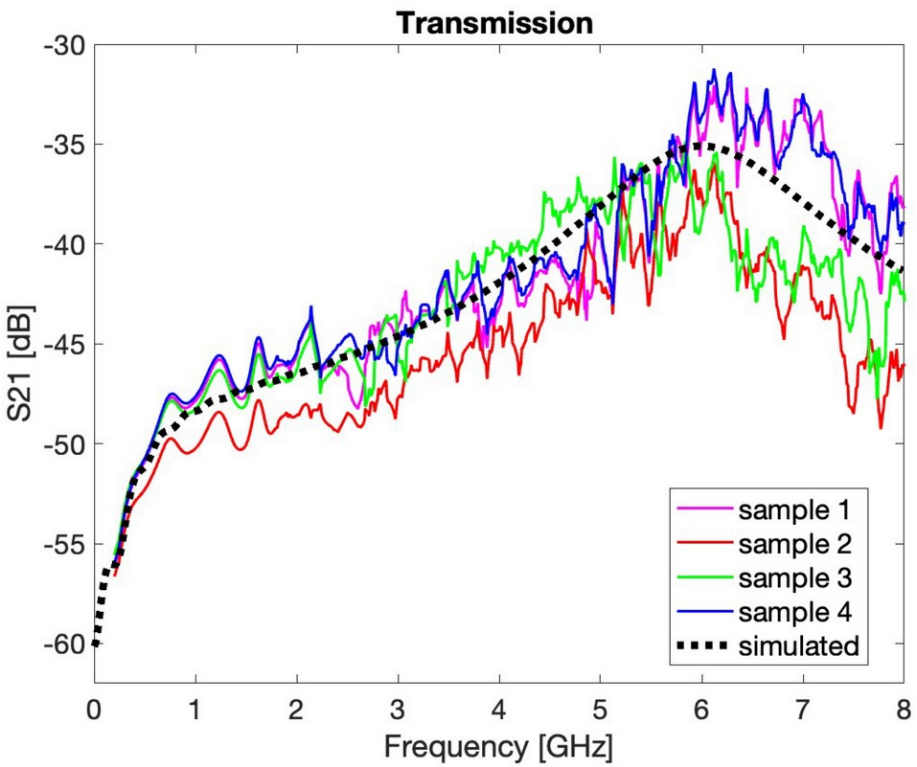
- The first generation of the Home Made BPM was designed to be machined in the company's own workshop using only commercially available materials
- The material of the central pin of the pickups (Cu) was chosen to test the feasibility of the conical shape of the button with the available machining tools
- In order to simplify the gluing process, the housing of the pickups (stainless steel) has been divided into parts that are screwed together
- The size of the pickups has been chosen to match the old “bazooka” coaxial test bench

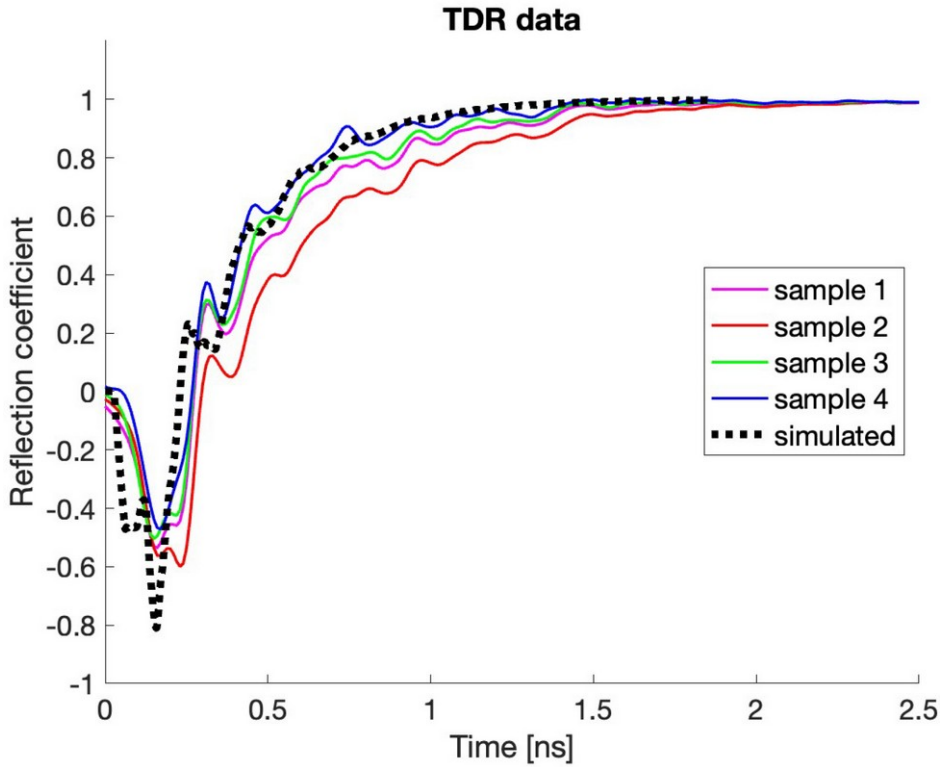
- Dielectric: steatite + vacuum sealant glue
- SMA Female Press Mount Connector



The first generation of HMBPM

- Measurements on the test bench match the simulated behavior

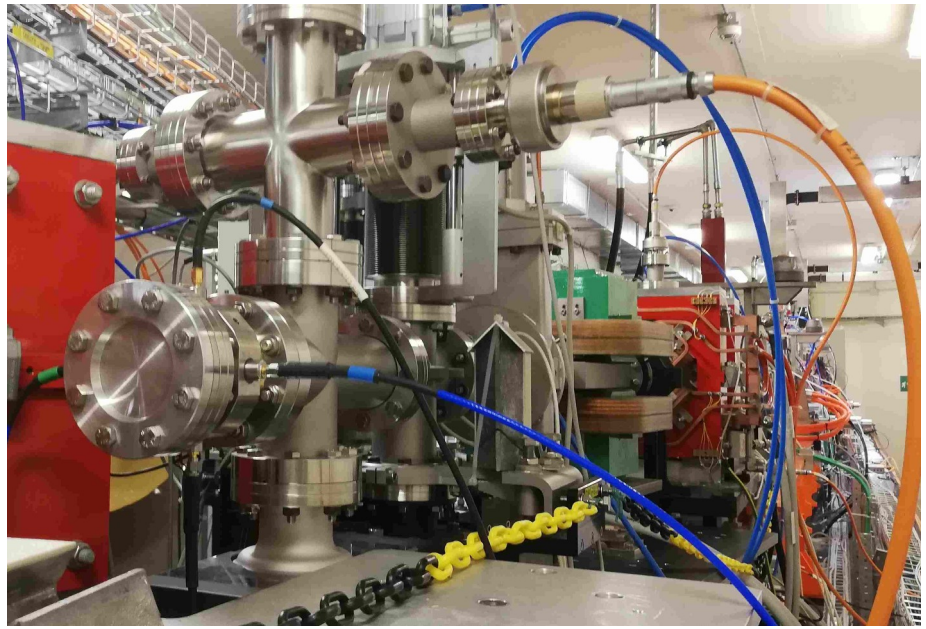


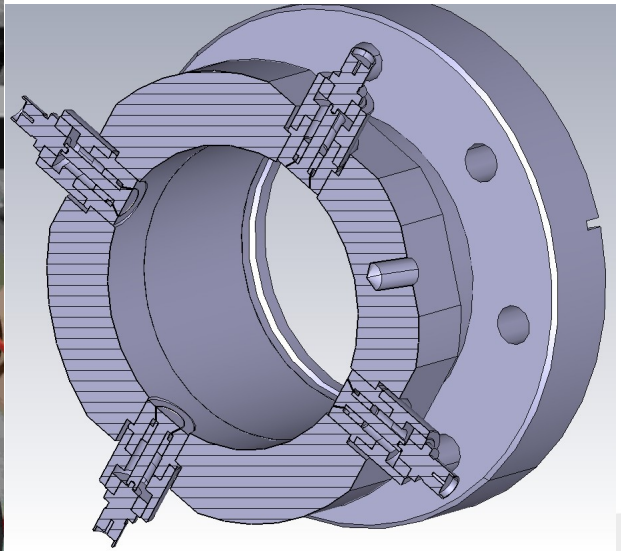


Cleva, S.; Bassanese, S.; Comisso, M.; El Ajjouri, M.; Sergo, R.; Morello, C.; Passarelli, A. Button-Type Beam Position Monitor Development for Fourth-Generation Synchrotron Light Sources: Numerical Modeling and Test Bench Measurements. Sensors 2024, 24, 2726. https://doi.org/10.3390/s24092726

The first generation of HMBPM

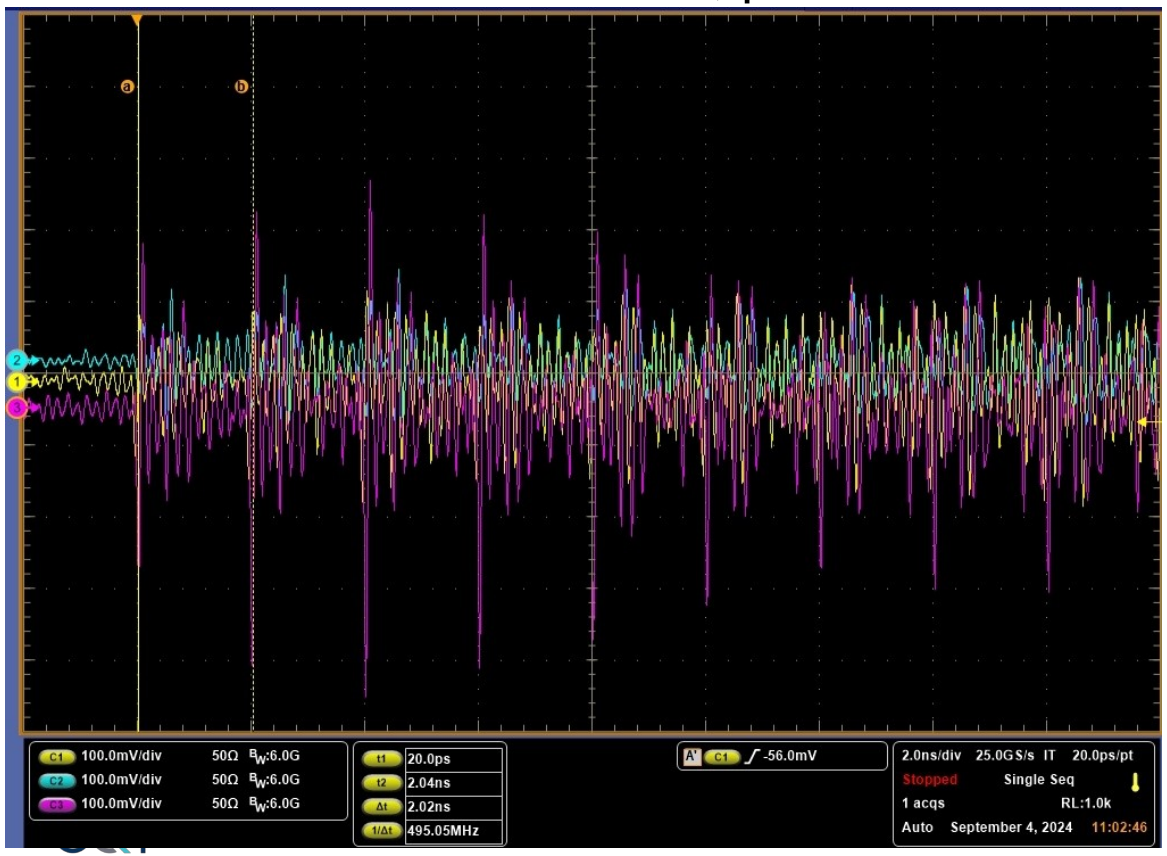
- Once validated on the RF test bench, the pickups have been tested for vacuum leaks
- Then the pickups have been glued on a dedicated BPM body to be mounted at the end of the small linac that fills the booster

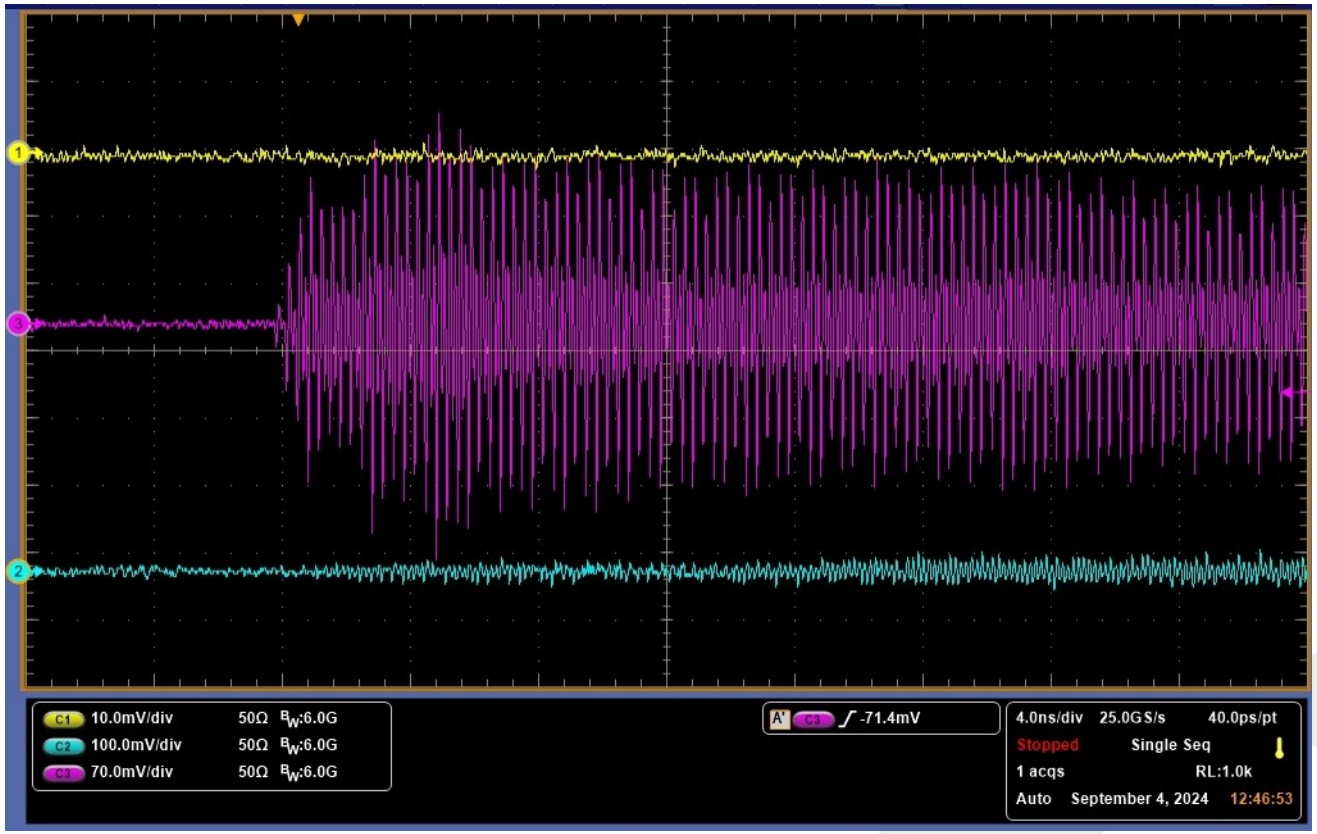




The first generation of HMBPM

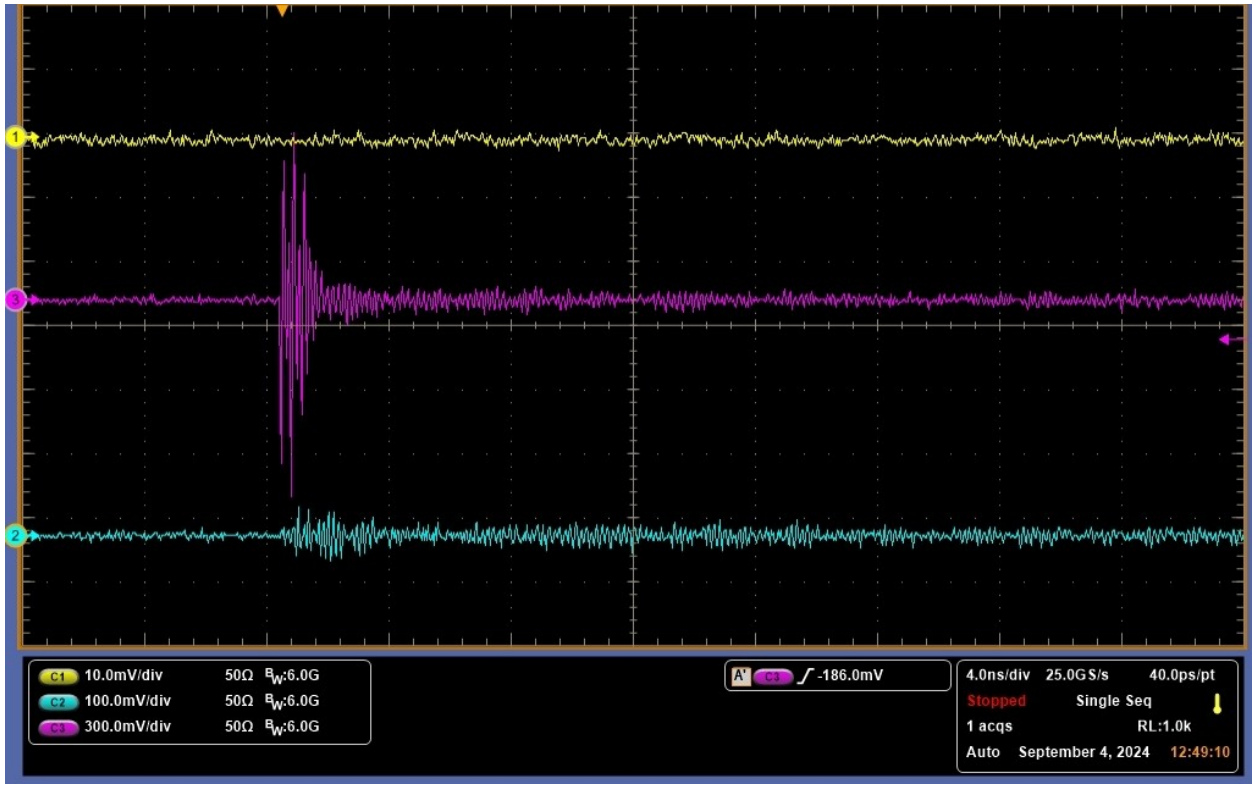
- Several measurements have been done in order to evaluate the RF performance of the first generation. A full beam simulation (wakefield solver) has not been performed due to the low energy of the electrons at the end of the short linac (3GHz acc. cav.)
- Multi bunch measure, prebuncher ON and OFF

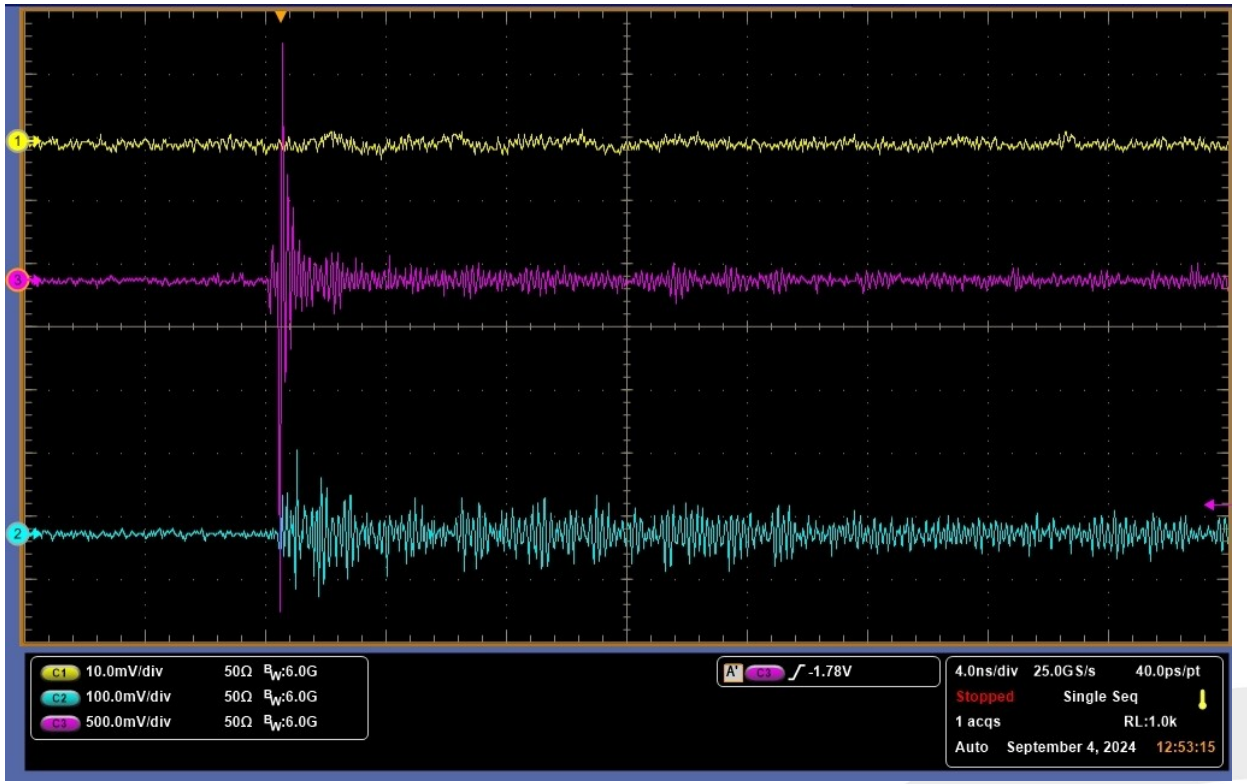




The first generation of HMBPM

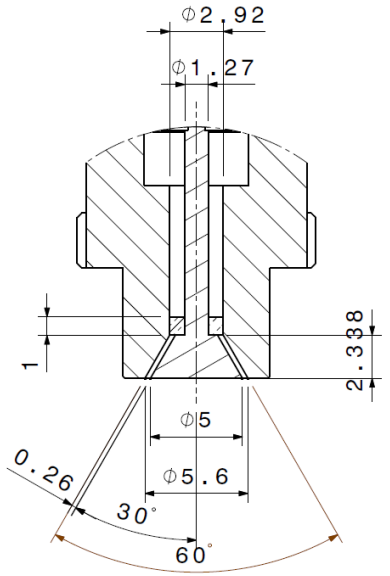
- Single bunch measurements, prebuncher OFF and ON
- Disadvantage: After 6 months of use the pickups started to leak (non destructive)

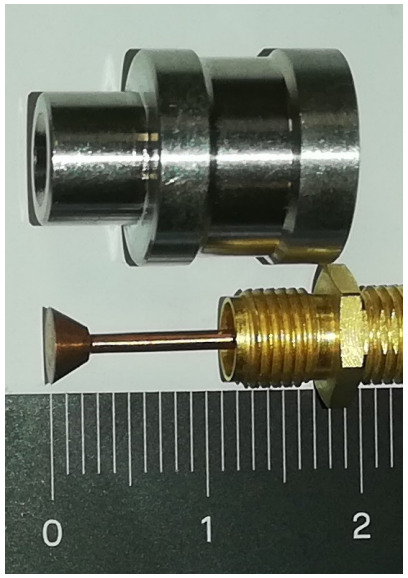




The second generation of HMBPM

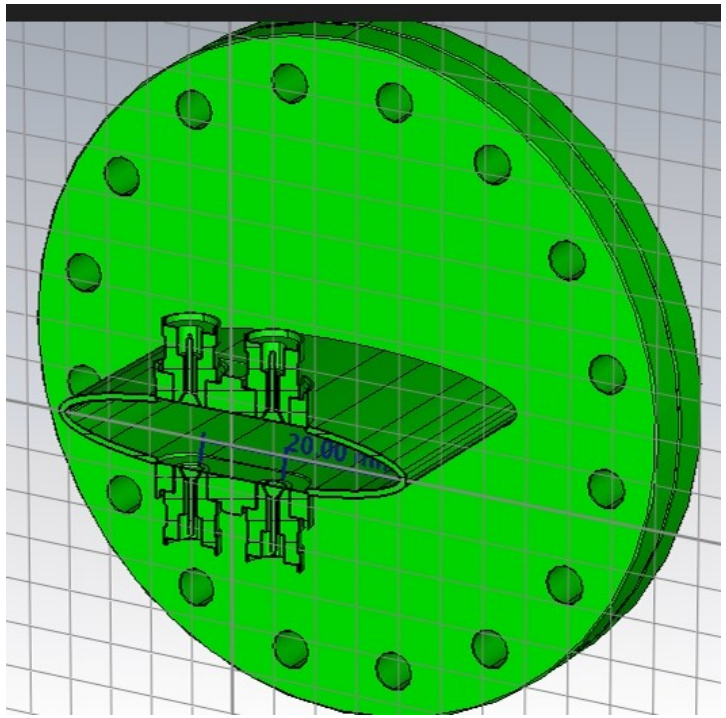
- The first generation behaved as expected, which encouraged the design and realization of the second generation
- Due to their reduced size, both electric insulation and vacuum sealing are performed by glue, whose target thickness is 1 mm
- The BPM body size is chosen as close as possible to the one of Elettra 2.0 (27 x 17 mm). Only the vertical dimension is matched according to low profile ID vacuum pipe (14 mm)
- Materials: stainless steel and Al
- Vacuum tight epoxy glue
- 2.92 mm like RF connector
- Completely HM

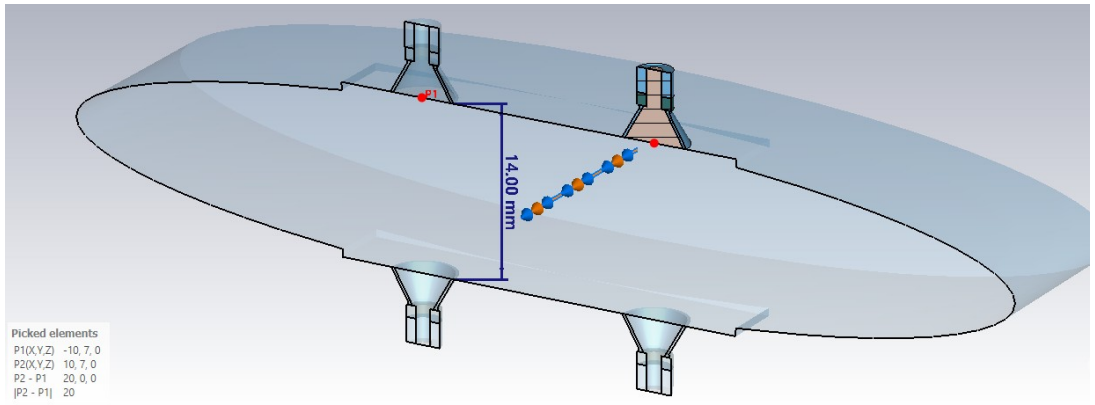


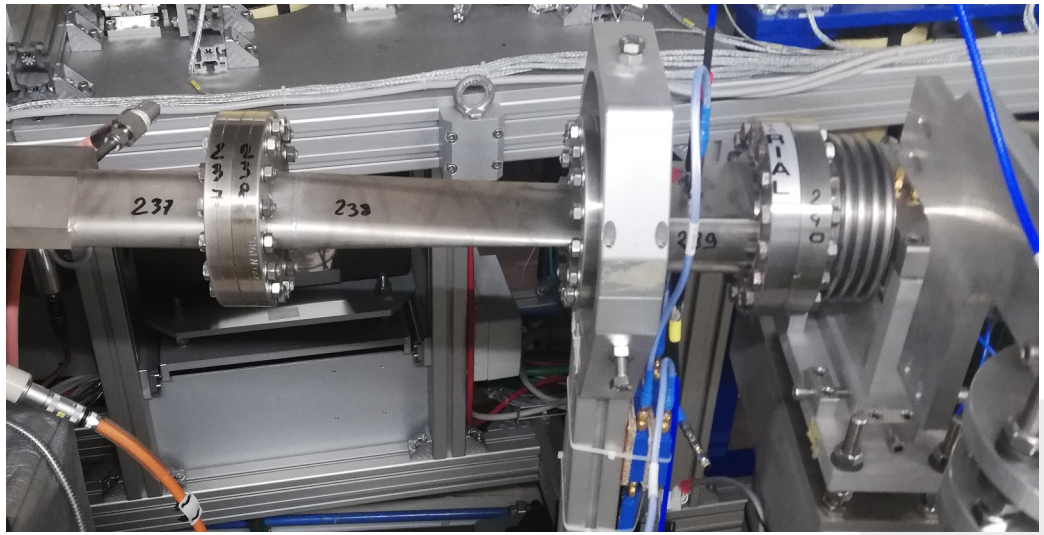


The second generation of HMBPM

- The internal shape of this HMBPM was chosen in order to replace a spare low gap BPM in front of an undulator

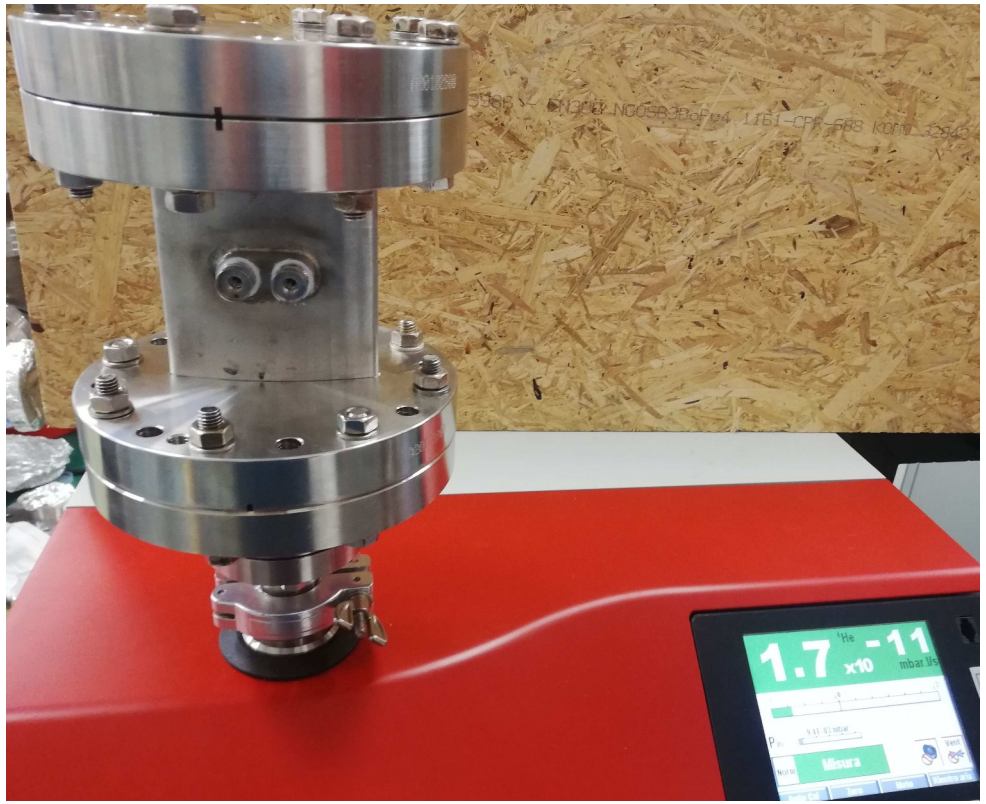






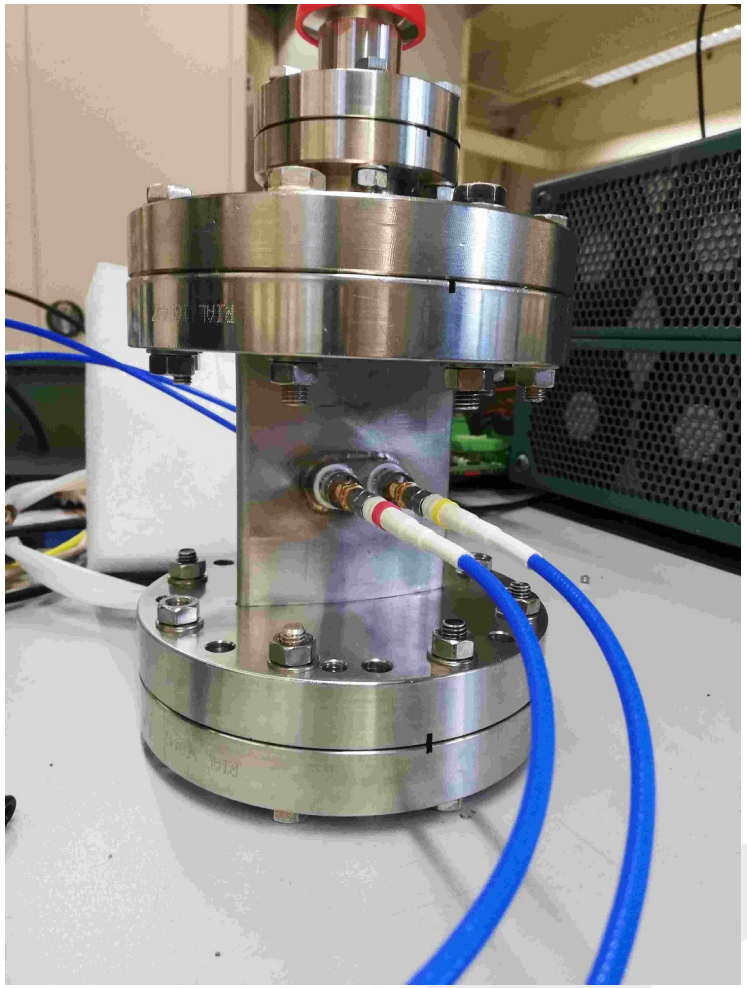
The second generation of HMBPM

- The pickups were tested against vacuum leak and tightness
- Then the pickups were glued on the BPM body
- Finally, the BPM assembly has been subject to vacuum compliance testing



The second generation of HMBPM

- TDR measurement before mounting



The second generation of HMBPM

Sistema di misura temperature installato su E2.0 BPM S7

Per info: stefano.cleva@elettra.eu, francesco.tripaldi@elettra.eu

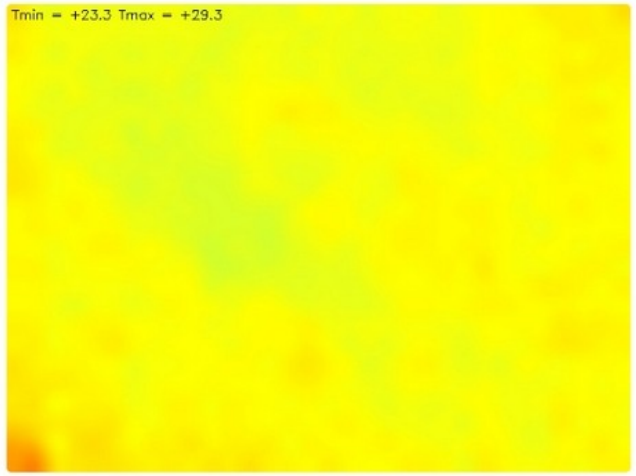


Immagine termocamera FOV=110deg MLX90640. 32x24 upscaled 640x480 with cubic interpolation

Immagine webcam FOV=50deg.

Real Time values

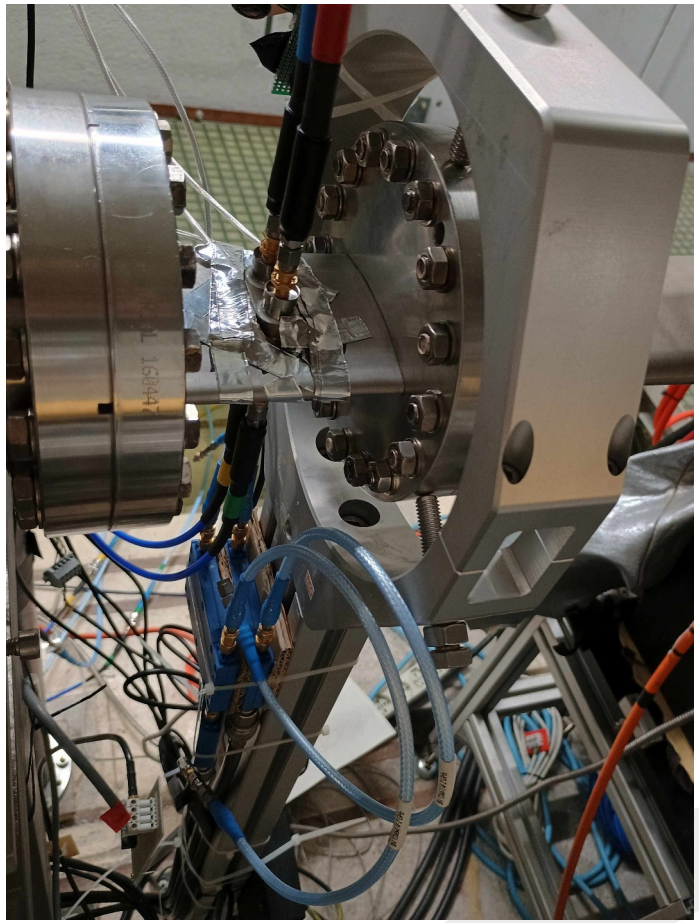
T1: 25.396°C

T2: 25.396°C

T3: 25.092°C

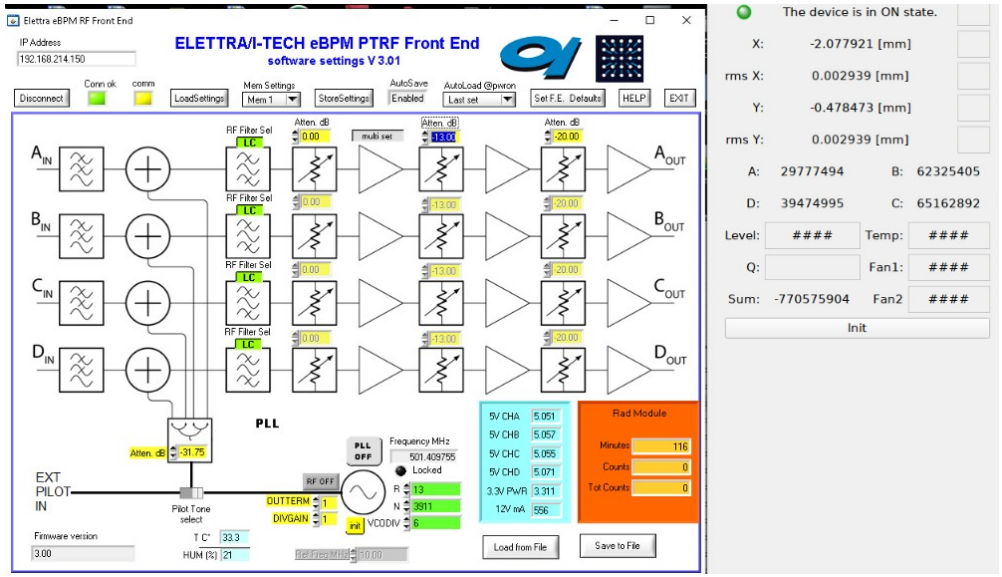
T4: 25.092°C

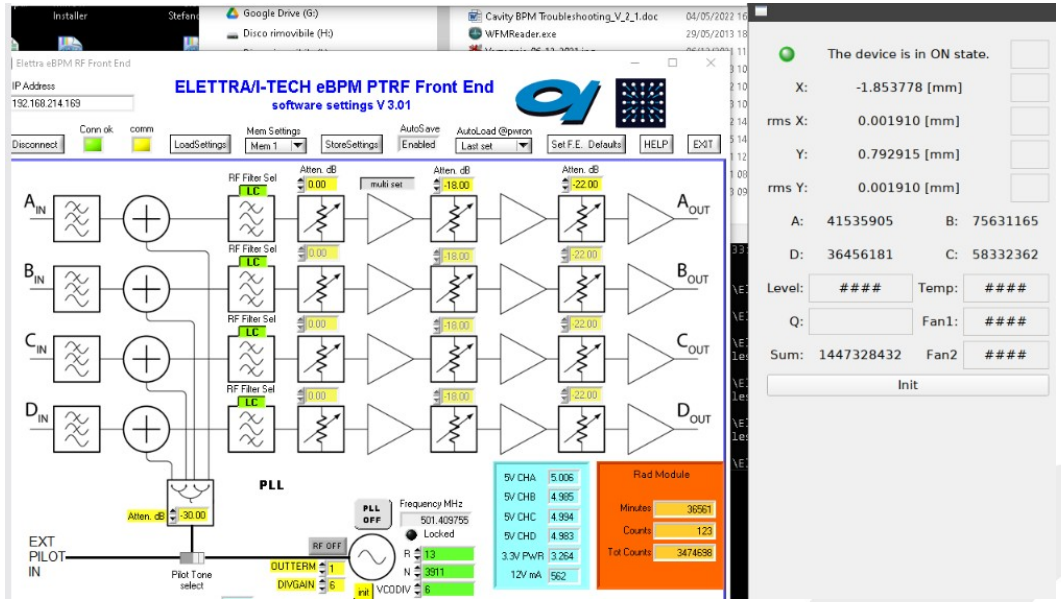
Ir_Sensor: 24.300°C



The second generation of HMBPM

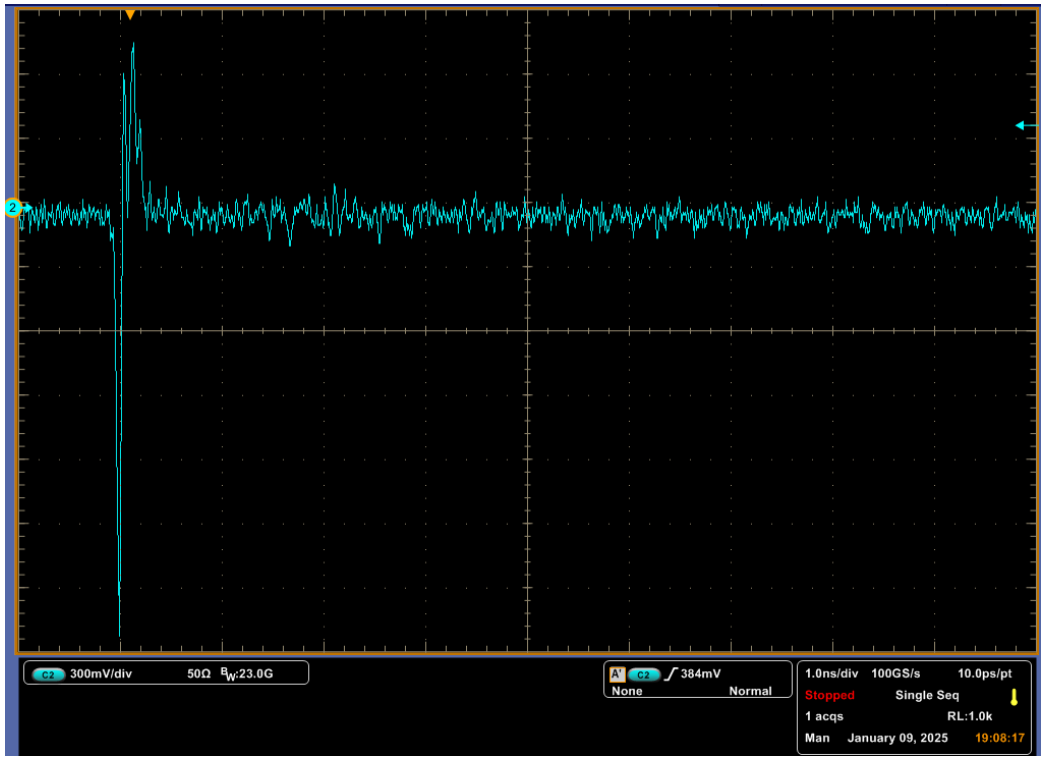
- Several measurements were performed on Elettra in different operating conditions: SingleBunch, MultiBunch, 2 GeV, 2.4 GeV
- A comparison with the close Low Gap BPM 7.1 was performed by X-Y trajectory scanning: the difference in signal amplitudes was around 6 dB
- Such kind of measurements need to be confirmed by the new third generation PU because an alignment error was found in the H plane (around 1.7 mm) during the scanning process. Now the offset error is around 0 mm

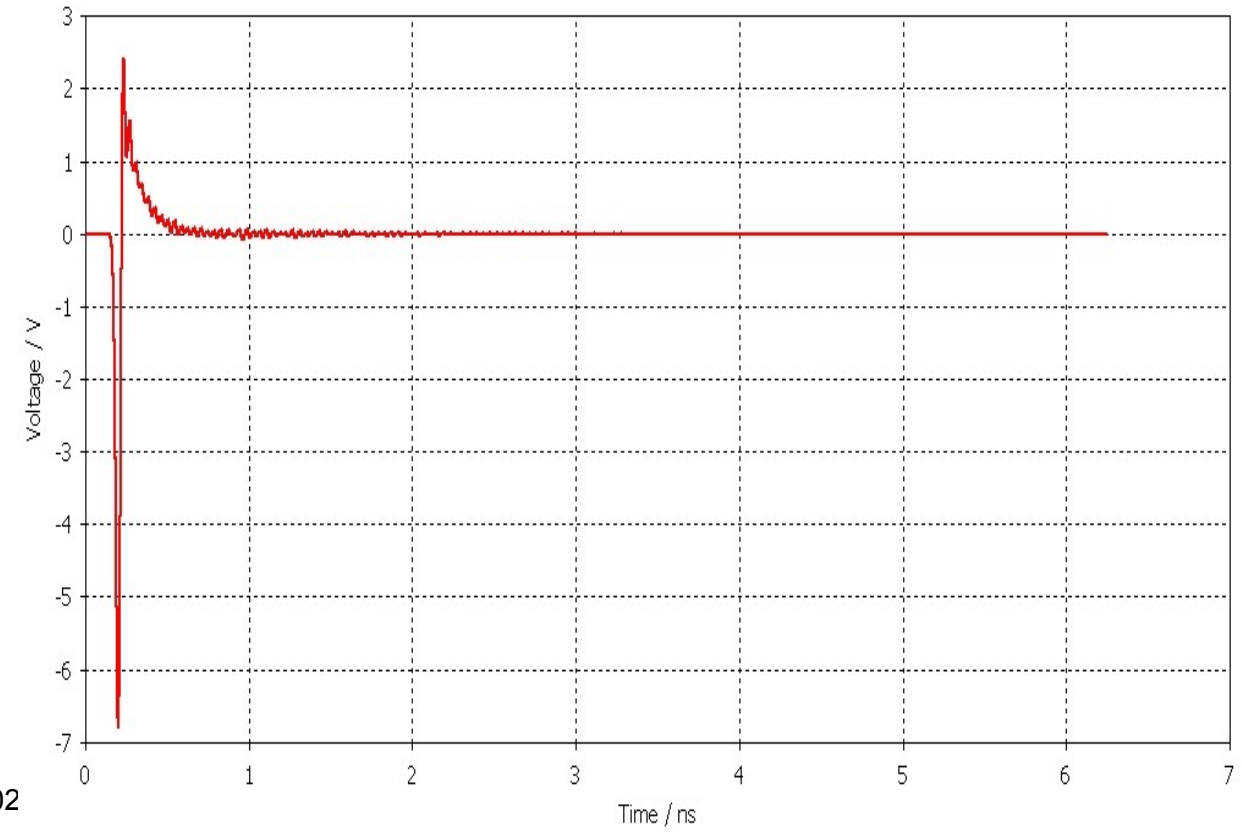




The second generation of HMBPM

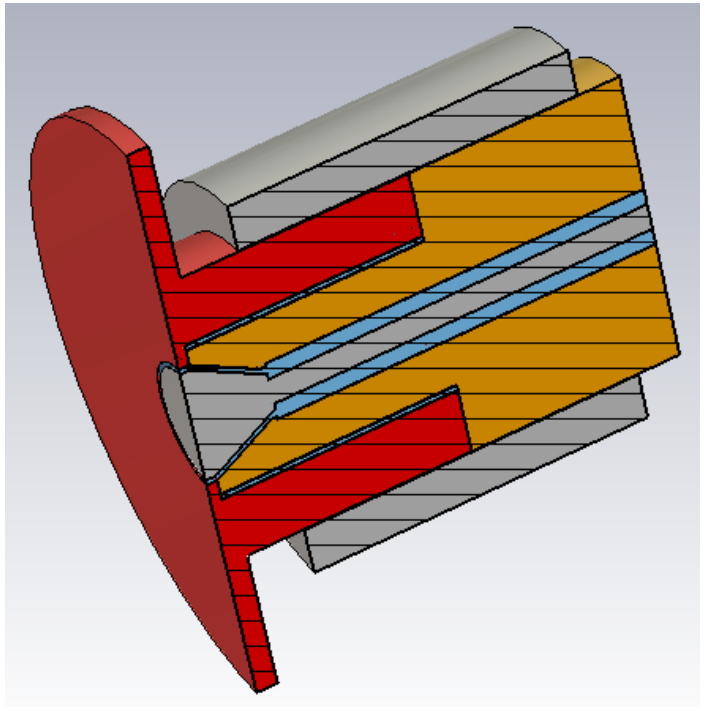
- Measured 0.3 mA SB against simulated 1 nC (Elettra harmonic number = 432)
- The full signal chain from beam to the control system has been validated for Elettra 2.0
- Disadvantage: After a run of use, during the shutdown, the pickups started to leak (non destructive)





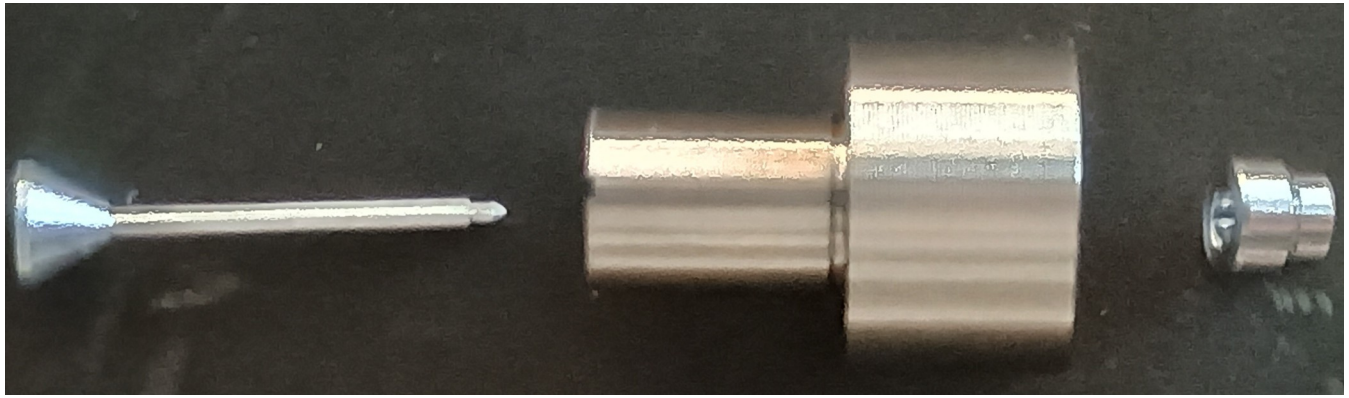
The third generation of HMBPM

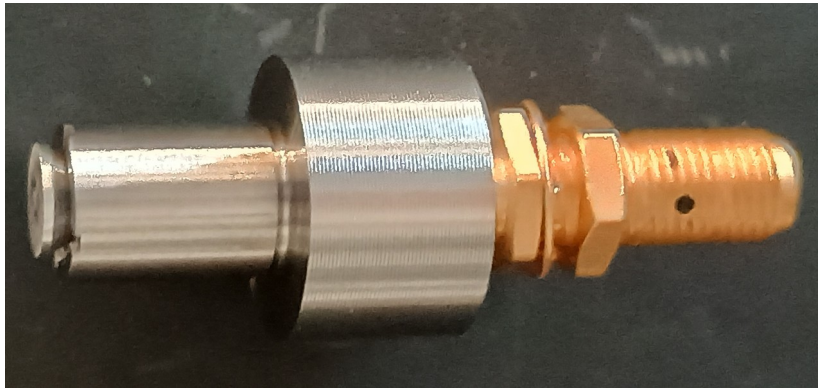
- With a geometry very close to the final one, the second generation allowed to validate the design of the pickups foreseen for Elettra 2.0
- For special diagnostic tasks, it might be useful to be able to replace the pickups of specific BPMs
- SMA (shape memory alloy) technology has been adopted for such kind of applications



The third generation of HMBPM

- Pickup components

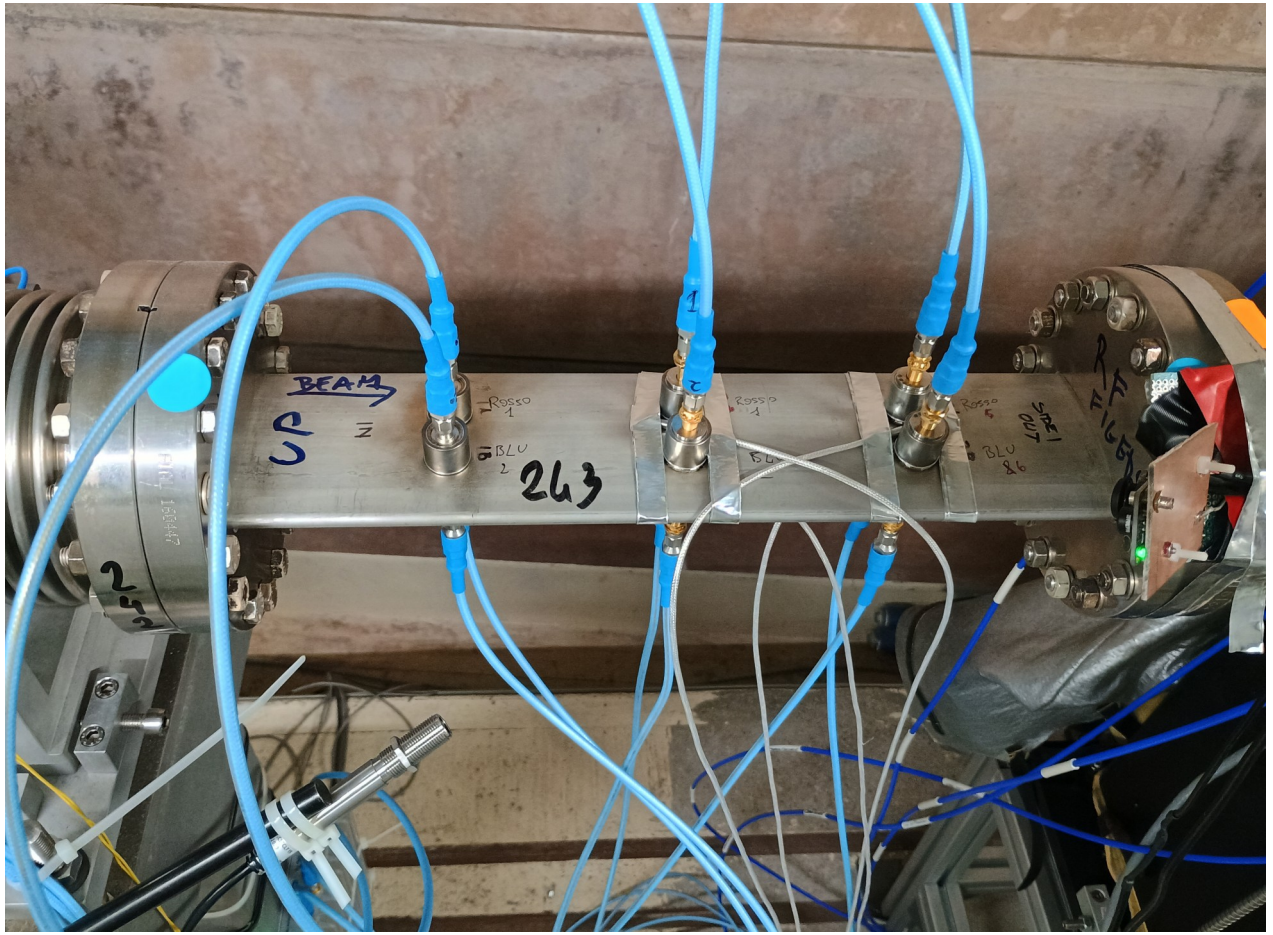




- Pickup comparison

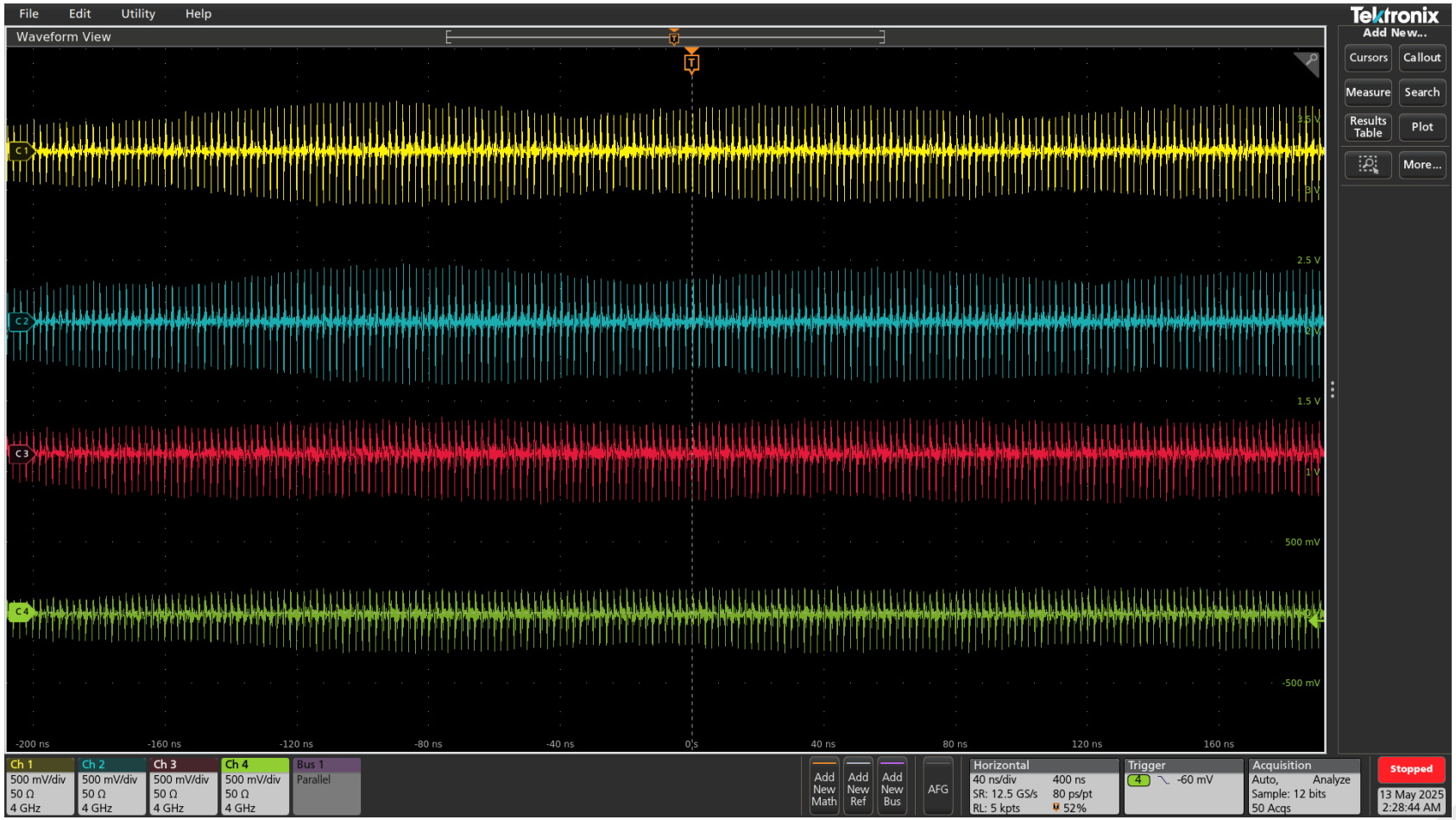
The third generation of HMBPM

- The full group of pickups based on SMA technology



The third generation of HMBPM

- First real measurement (12/02/2025)



The third generation of HMBPM

- First real measurement (12/02/2025)

Conclusions

- The company's workshop has been able to machining the three families of pickups and BPM bodies
- The full BPMs have been tested in real conditions
- The real drawback is the vacuum sealing technology based on vacuum specific glue
- Thanks to the "quick and dirty" approach followed, the full signal chain from the beam to the delivery of the calculated position has been validated

Involved people (random order)

E.Karantzoulis, S. Bassanese, R. Sergo, C. Morello, G. Bortoletto, I. Cudin, G. Pangon, G. Loda, M. Barnaba, E. Busetto, D. Pozzecco, S. Fracassi, S. Krecic, G. Brajnik, R. De Monte, M. Milloch, F. Gelmetti, A. Gambitta, R. Sauro, L. Rumiz, L. Novinec, F. Zudini, R. Umer, A. Carniel, F. Tripaldi, A. Passarelli, M. Comisso

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Thank you!

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