Current status of Elettra 2.0 eBPM system

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A brief history

- At Elettra, in 2014, an internal project started in order to investigate the possibility to develop an electron beam position monitoring system based on **pilot tone compensation**

- The aim was to use it for the **future machine upgrade, Elettra 2.0**

- Specifications:
  - Sub-micron resolution @ 10 kHz
  - Long-term stability better than 2 μm in 24 hours
  - Compensation of thermal drifts, channel variations, cables response

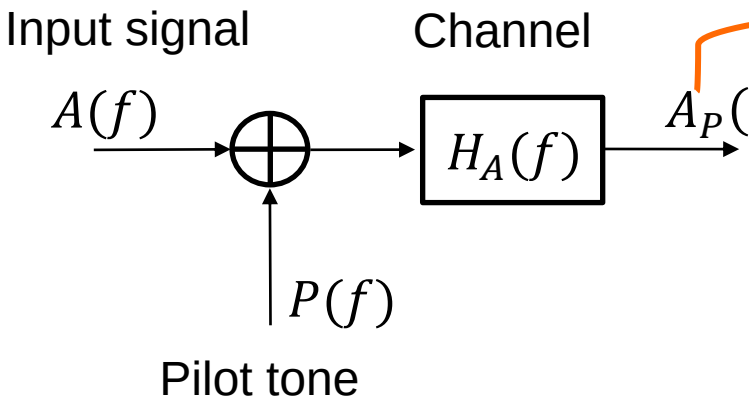
Pilot tone concept

- Well-known technique since ‘50s, used in telecommunications to compensate the **channel response**
  - *M. J. Kelly, et al., "A transatlantic telephone cable," in Transactions of the American Institute of Electrical Engineers, Part I: Communication and Electronics, vol. 74, no. 1, pp. 124-139, March 1955*
  - *Y. Niiro, System equalization for repeated submarine cable system, 1975 Patent*

- Various institutes proposed their implementation:
  - *M. Dehler, et al., "New digital BPM System for the **Swiss Light Source**", Proceedings of DIPAC 1999, pp. 168-170.*
  - *J. Mead, et al., "**NSLS-II** RF Beam Position Monitor Commissioning Update", Proceedings of IBIC 2014, pp. 500-504.*
  - *R. Baron, et al., "Development of the RF Front-End Electronics for the **Sirius** BPM System", Proceedings of IBIC 2013, p. 670.*
  - *G. Portmann et al., "BPM Electronics With Self-Calibration at the **ALS**", Proceedings of IBIC2020*

Proposed implementation at Elettra

- A fixed sinusoidal tone is added to the original signal coming from the beam: the 4 channels use the same tone as reference
- Every channel variation affects in the same way both the carrier and the pilot



$$A_P(f) = H_A(f) \cdot P(f)$$
$$A_M(f) = H_A(f) \cdot A(f)$$
$$A(f) = \frac{A_M(f)}{A_P(f)} \cdot P(f)$$

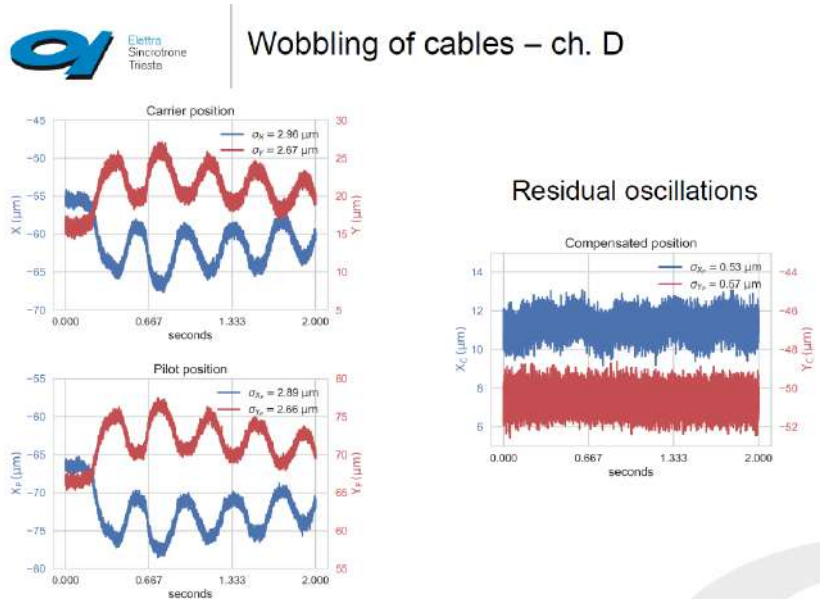
$$x = K_x \cdot \frac{A_M/A_P - B_M/B_P - C_M/C_P + D_M/D_P}{A_M/A_P + B_M/B_P + C_M/C_P + D_M/D_P}$$

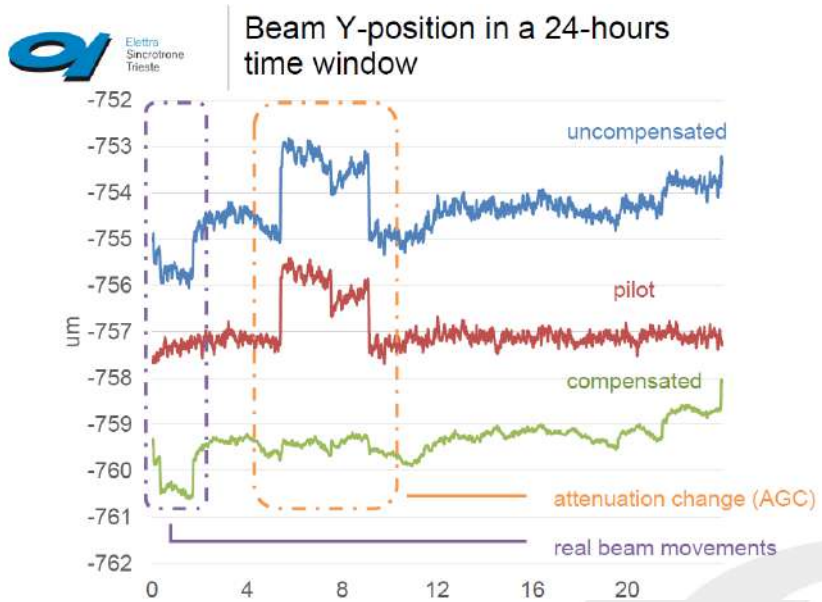
Compensated position in classical Difference-over-Sum (DoS) equation

Proposed implementation at Elettra

- Modular approach:
  - analog front end in the tunnel machine
  - digitizer in service area

- Successfully integrated in Elettra orbit feedback (IBIC 2018)
- Compensation of cables and drifts





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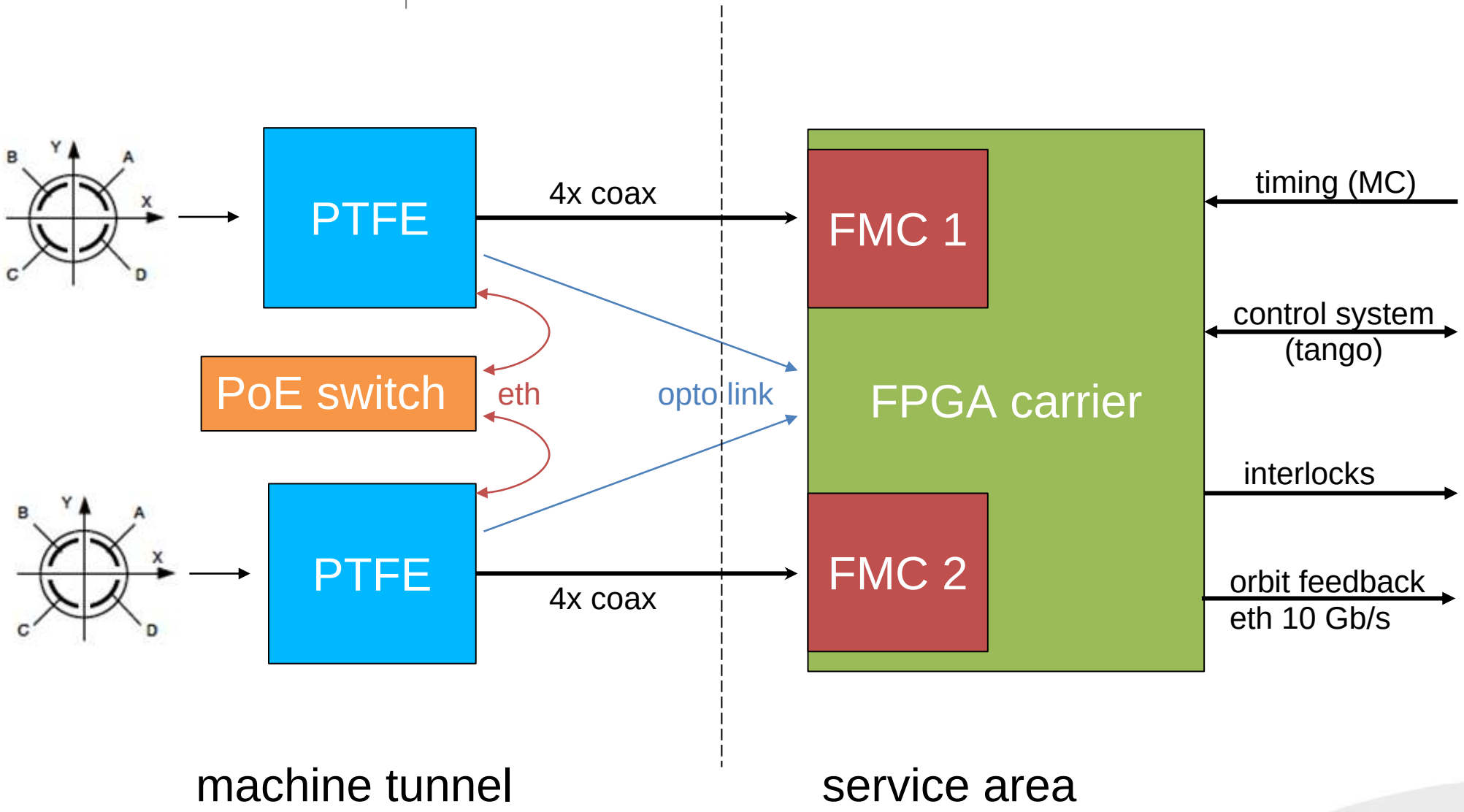
Current status

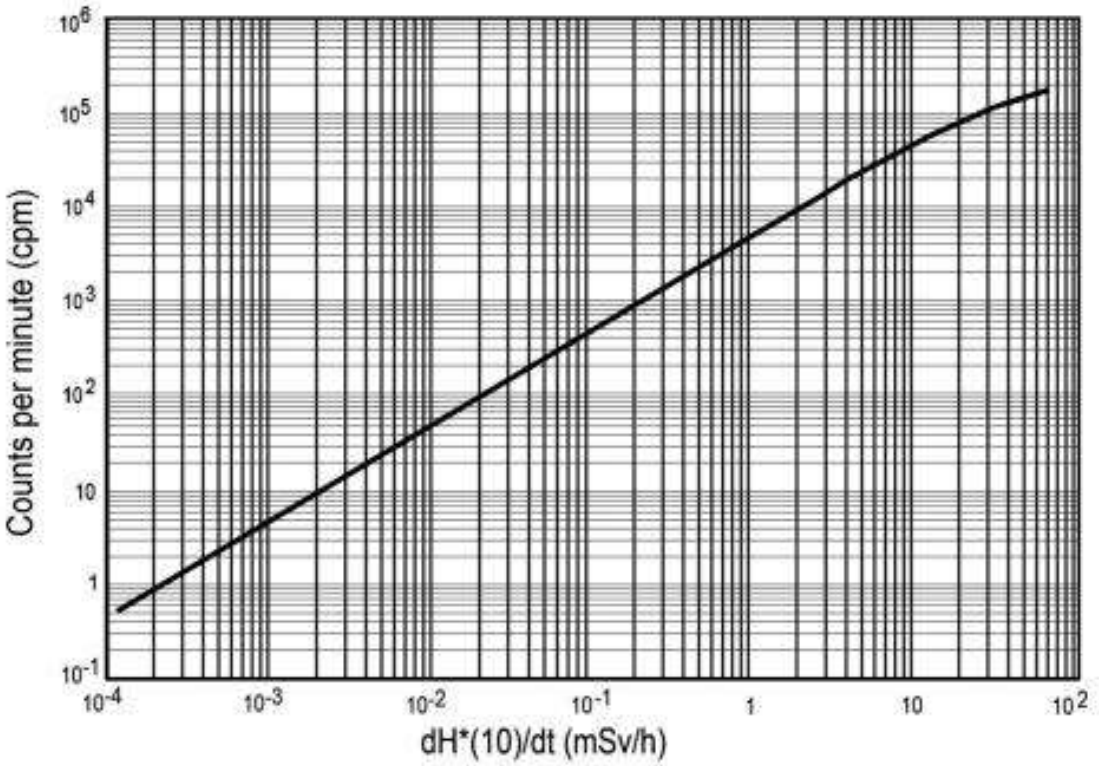
- In the last years we focused on the new digital carrier board and FMC A/D conversion cards (IBIC2019)
- The front end is still a prototype: now it’s time for improvements, towards the final version
- Partnership with Instrumentation Technologies for the production of 200 units of BPMs planned for Elettra 2.0
- Constructive dialogue: continuous revisions thanks to their expertise in product engineering and industrialization

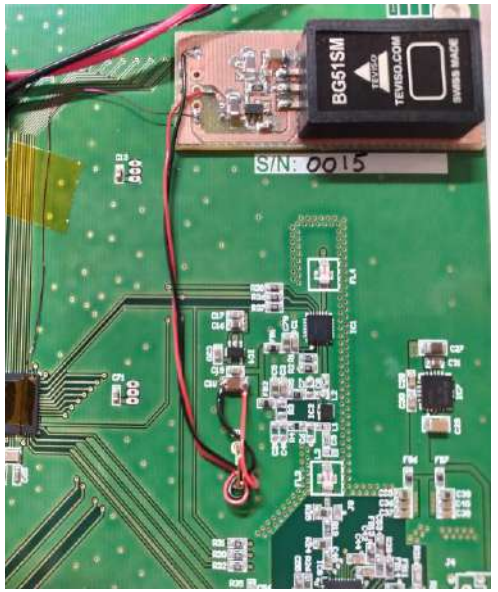
Overall block diagram



Front end improvements

- Radiation sensor onboard (BG51SM)
  - Monitor electronics health
  - Datasheet behaviour confirmed with radioactive sources

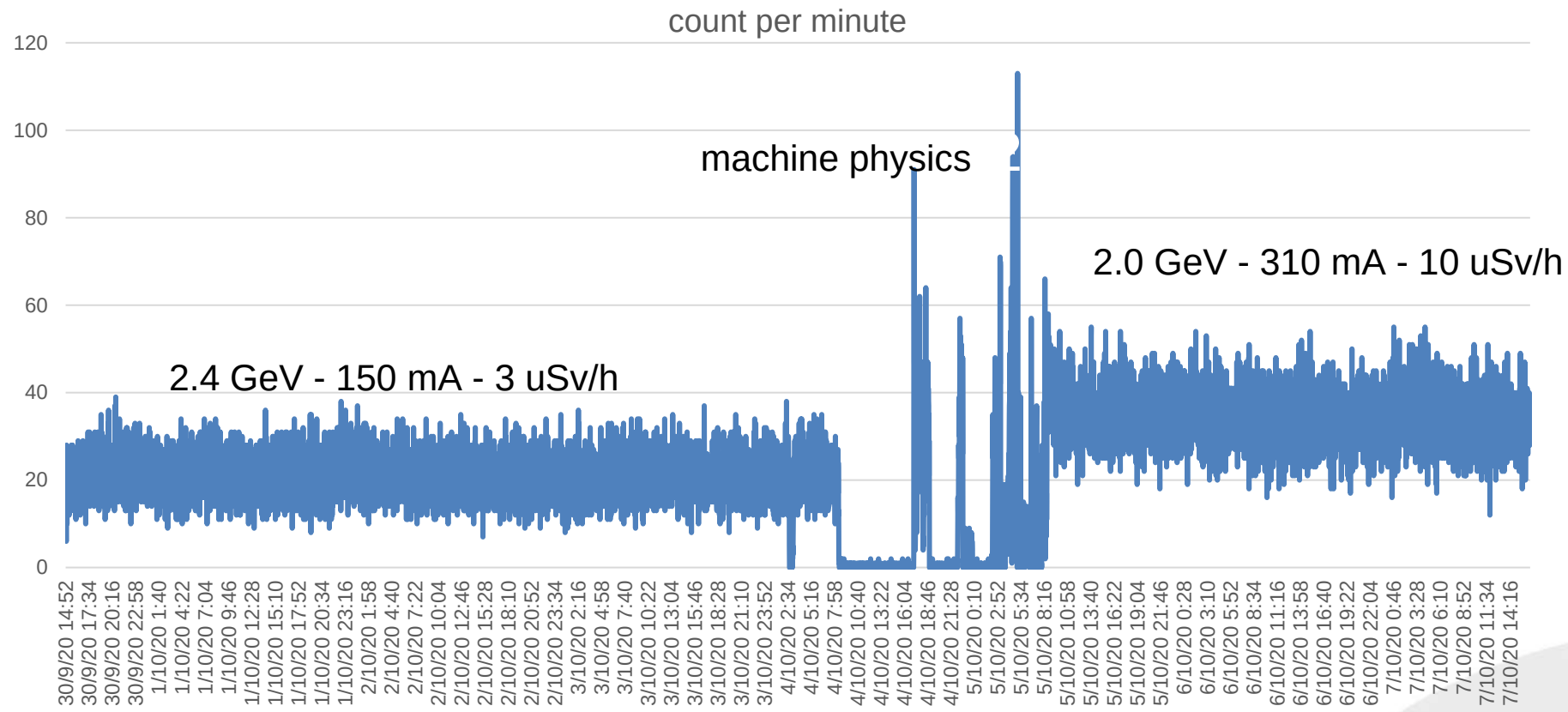




dH*(10) / dt = Radiation dose equivalent rate for Cs-137 and Co-60 (mSv/h)

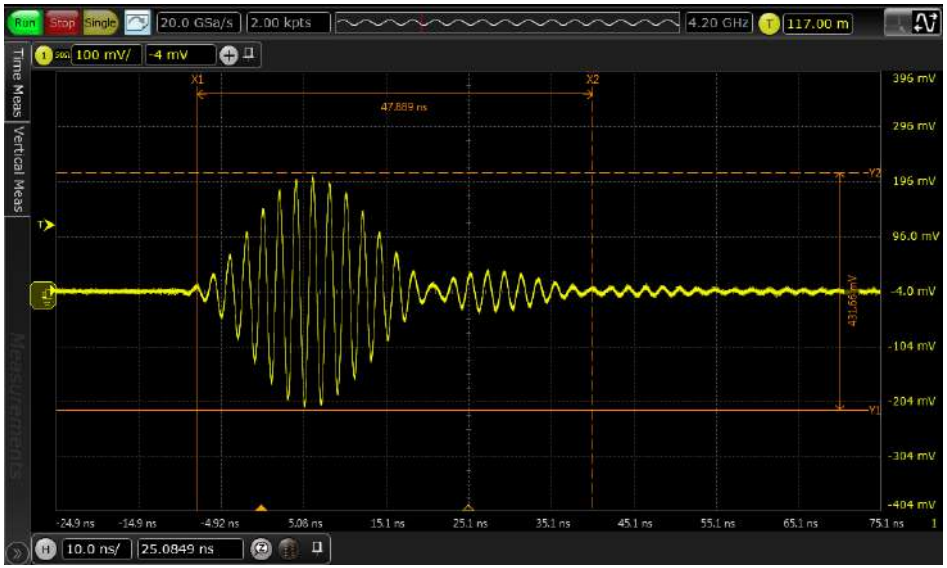
Front end improvements

- Placed in machine tunnel, about 1m below the bpm block (is not intended to be a BLM)



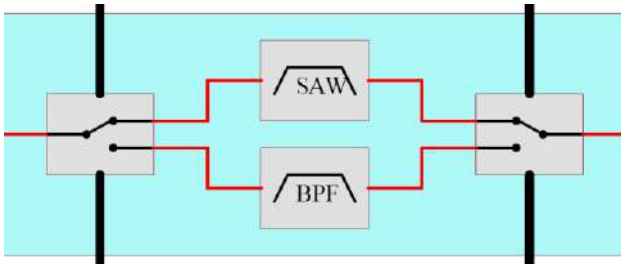
Front end improvements

- Low sensitivity in single bunch operation, due to wide bandwidth of the LC filter (short pulse response)



40 ns
about 7 samples @ 150 MS/s

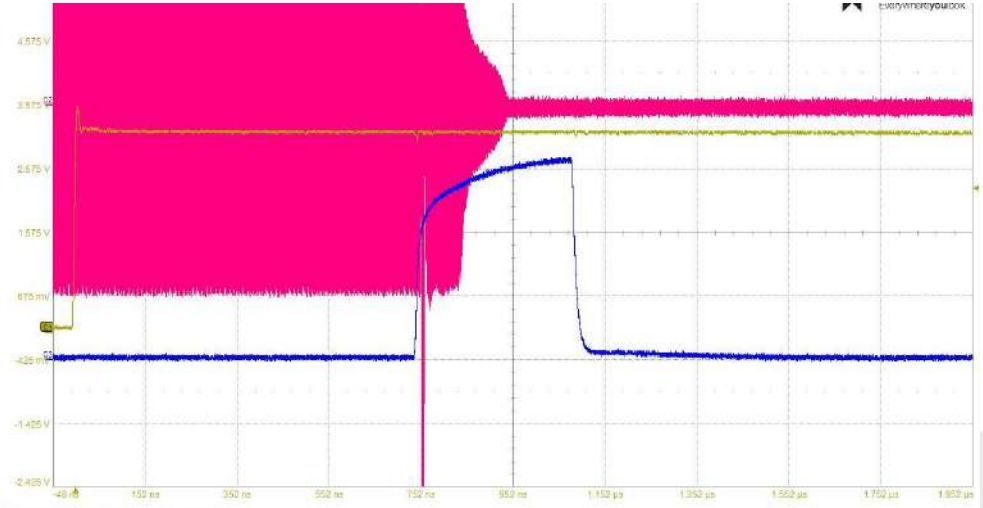
- Added a switchable SAW filter in the signal path



Front end improvements

- Low sensitivity with low currents (1 mA)
  - Added an extra gain stage (20 dB)

- Fiber optic output on attenuators changes
  - Communicates glitches to FPGA



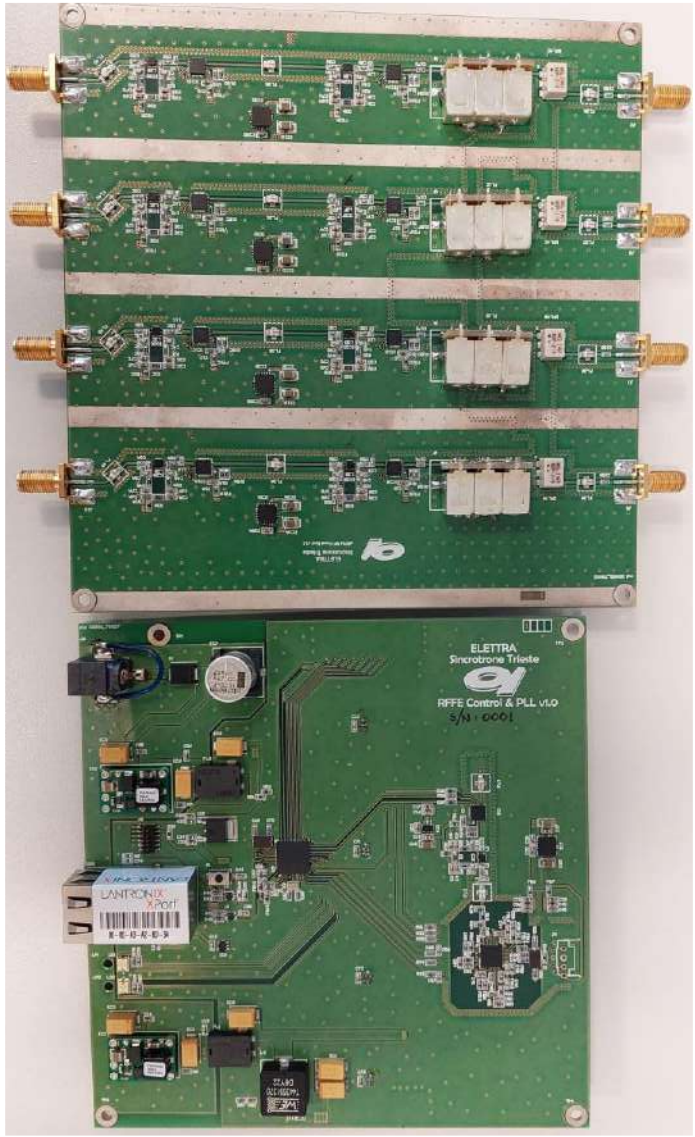
Partnership Elettra - I-Tech

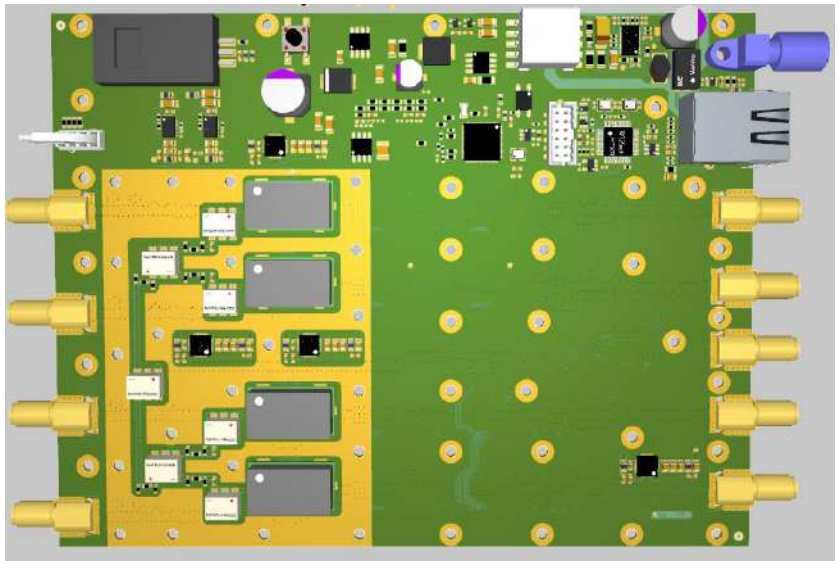
- Result of tender procedure for industrialization of prototype
- Allows open communication on all project aspects
- Regular weekly communication on progress
- Cross-reviewing of designs
- Great expertise balance between the two parts (synchrotron machine on one side, 20 years of experience on the other side)

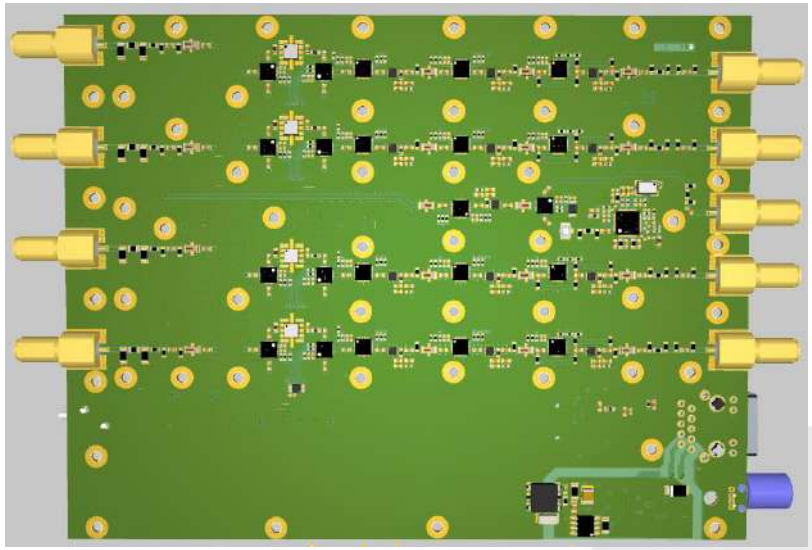
Pilot Tone Front End industrialization

- Design for manufacturing & testing
- Control module + RF module becomes single board
- Less connections - higher reliability
- Passive cooling - maintenance free
- Introducing shields – better isolation
- Miniaturizazion – space issue near pick-up
- PoE - no external components required + remote power cycle posibility
- Remote FW upgrade

Pilot Tone Front End industrialization







Digital acquisition unit

- Design of the electronics provided by Elettra.
- Design of industrial grade enclosure is on I-Tech.
- Cooling challenge - with fans but designed for easy maintenance.
- Isolated RF inputs - preventing DC ground currents.
- Design optimisation for manufacturing and maintenance.

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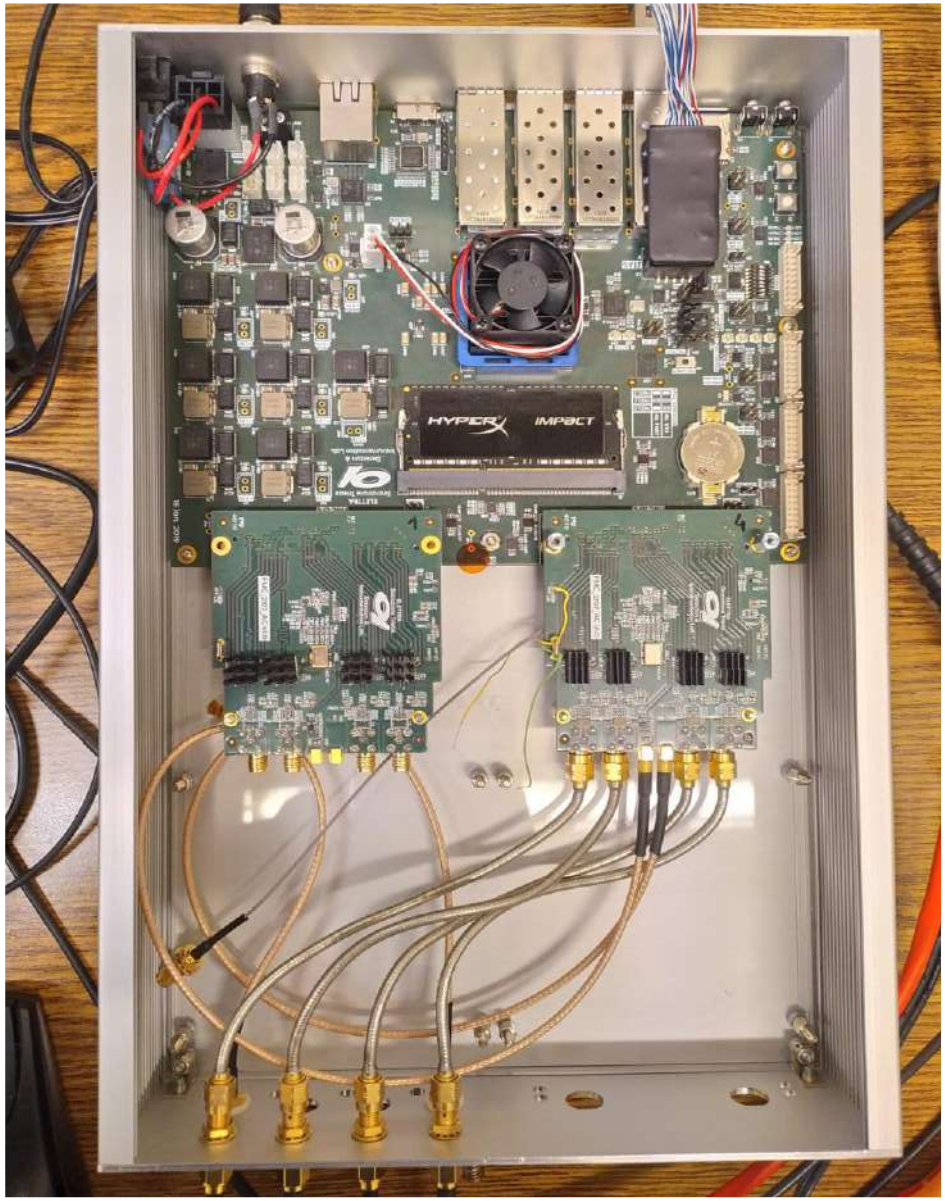
Digital acquisition unit



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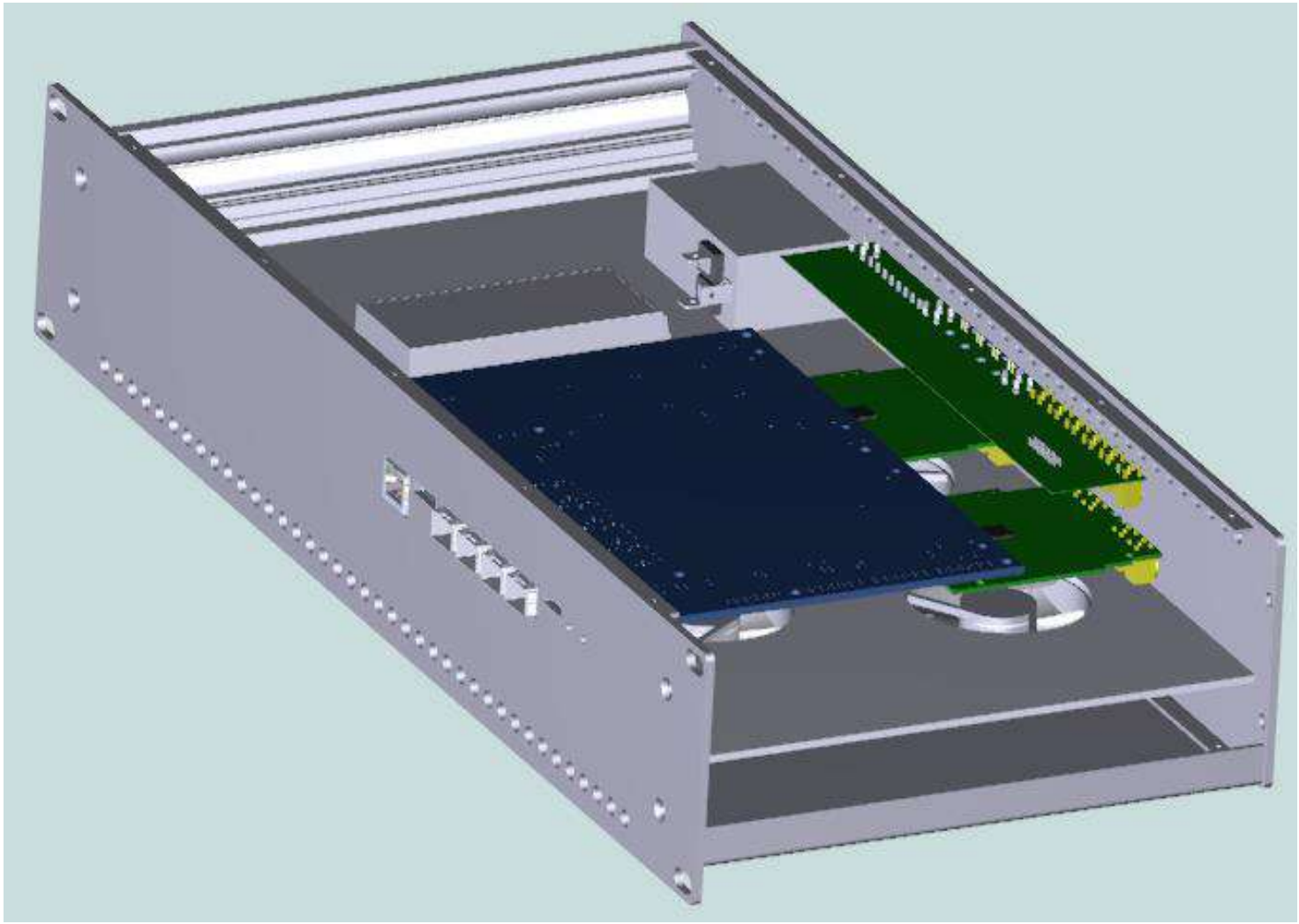
Digital acquisition module



Project next steps

- Prototype series - potentially some tuning is required
- First series of 10 BPMs
- Second series of 130 BPMs
- Last series of 60 BPMs

- Big problem with component availability!

Pilot tone front end unit will be developed and available also for other machines.

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Thank you!

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