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Integration of a novel BPM system within the global orbit feedback environment of Elettra

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Introduction to a eBPM Elettra project

- ✓ Goal of the project is the development of the prototype of an innovative device for measuring beam position, for rings such as Elettra, Elettra2 and single-pass machines such as Fermi
- ✓ A measurement system consisting of a RF section, an FPGA-controlled ADC section able to detect the position of the beam with sub-sampling techniques and a section capable of performing high-level processing (position calculation, calibration, system communication control). **Fully integrated in Accelerator Control Systems** (Tango, Epics) and compatible with the "environmental" constraints required by these devices.
- ✓ Spatial resolution less than 1µ @100Hz
- ✓ Long term stability (24hrs) **and** beam current dependance (70% machine range) less than 4µ rms
- ✓ Communication through Gigabit Ethernet connections
- ✓ **MODULAR SYSTEM**: Stand alone FrontEnd, digitizer and timing system.

Replacing only ONE old BPM Electronics

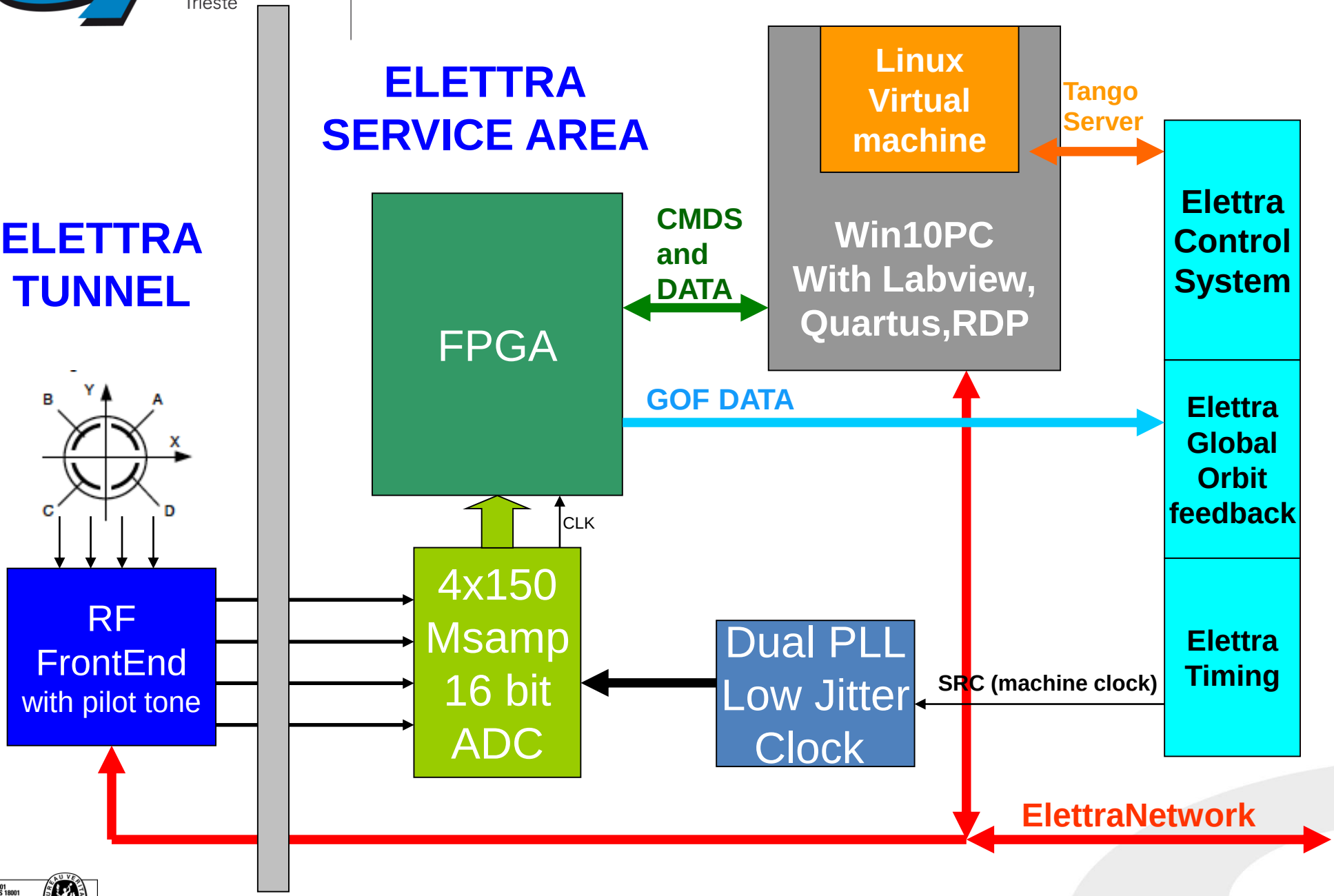
To validate the prototype for the project a test in a real environment, was required.
The prototype has been integrated in the Elettra Control System.

System constrain / interfaces / signals:

- **Timing**:
  - 1.156MHz pecl Storage Ring Clock "**SRC**" (RF/432)
  - Sync Signal to synchronize all the gigabit channels GOF (Global Orbit Feedback)**note1**
- **Data**:
  - Ethernet interface with Tango server data and house-keeping
  - Gigabit Ethernet interface for GOF data (UDP packets)

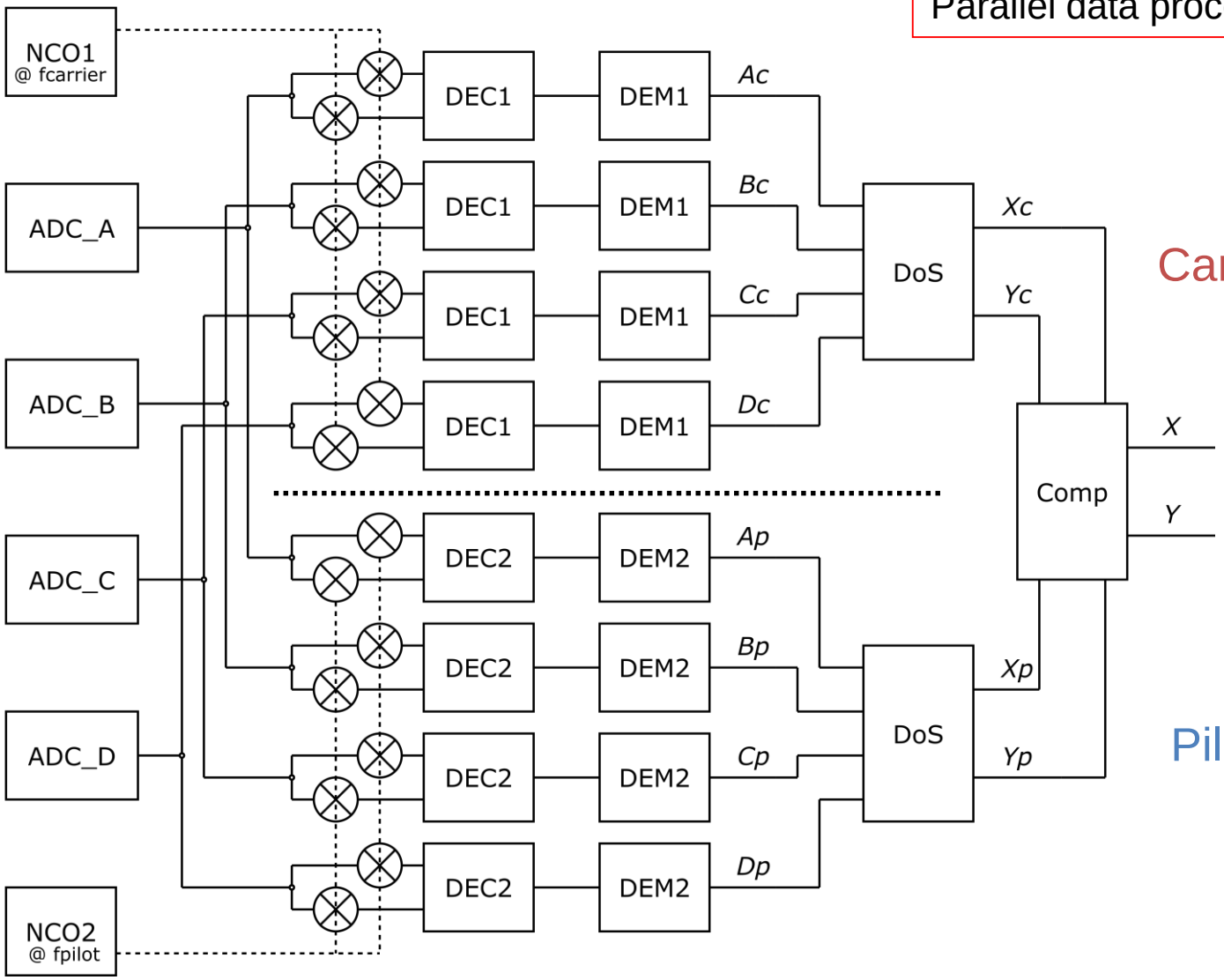
note1: the signal is sent once a time and it is pre-triggered by a software command. It causes all units sending data to GOF inputs at ≈10KHz at the same time (phase) within 20µSec.

System Test block diagram design



FPGA block diagram

Parallel data processing



Carrier demodulation

Pilot demodulation

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Architectural considerations

The main goal of this work was to prove that we are able to replace an existing BPM electronics.

For this reason we had to emulate the two connections to the control system.

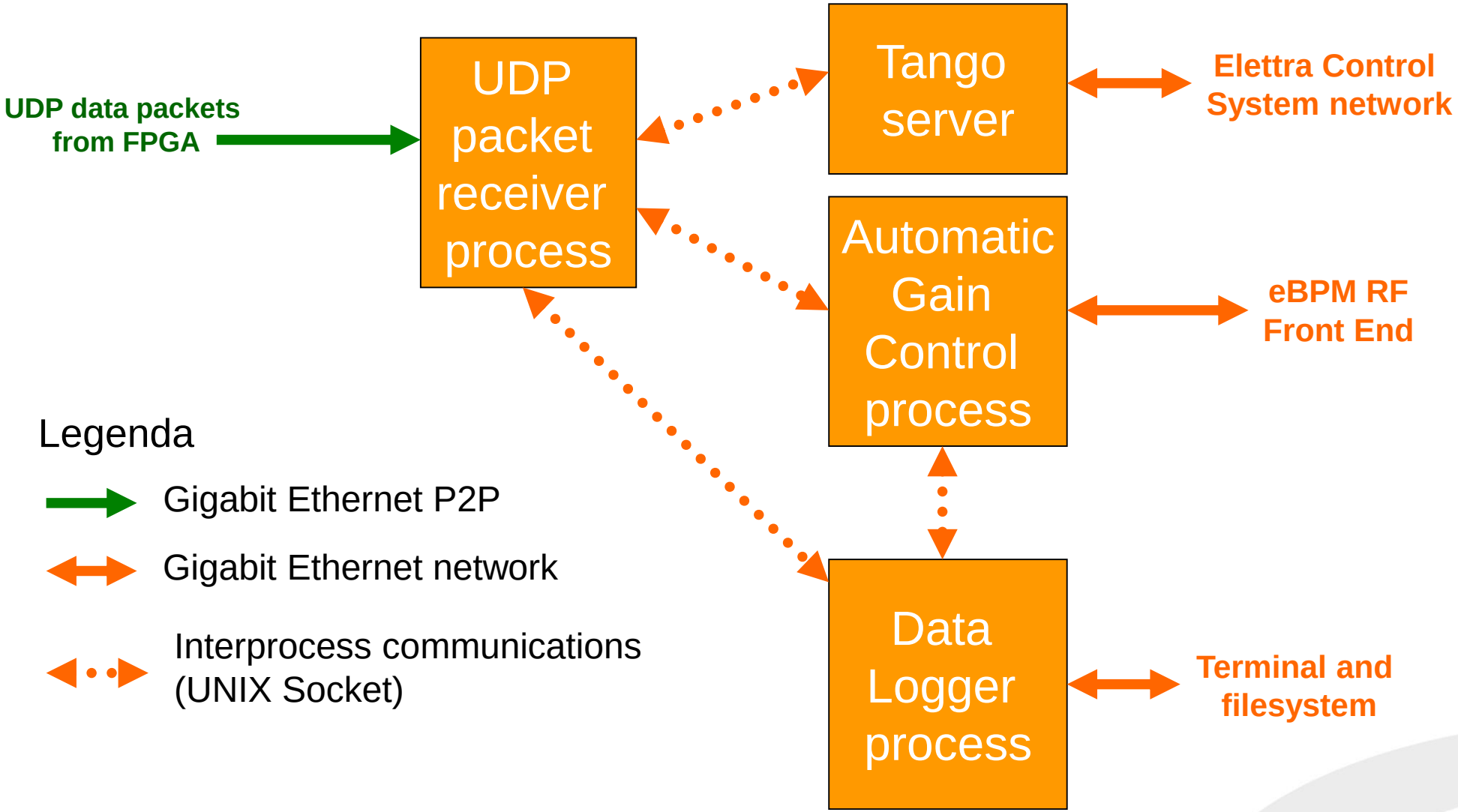
Tango server :

For the Tango server , we made a porting of a standard Tango BPM server into the Linux virtual machine. The greatest difficulty of this work was to have the data read from the software module instead of the hardware directly. This is because the software module receive the data flow from one of the FPGA ethernet ports have to shares it with Tango server , AGC software module and Data Logger software module.

GOF (Global Orbit Feedback) data link:

A UDP packet is formed and sent to the GOF Section manager. It contains the pilot tone compensated position plus the mechanical to electrical BPM offset with respect to the quadrupole. This offset has been measured with BBA (Beam Based Alignment) system.

Linux VirtualMachine: data path and process structure



Synchronization of GOF data packets

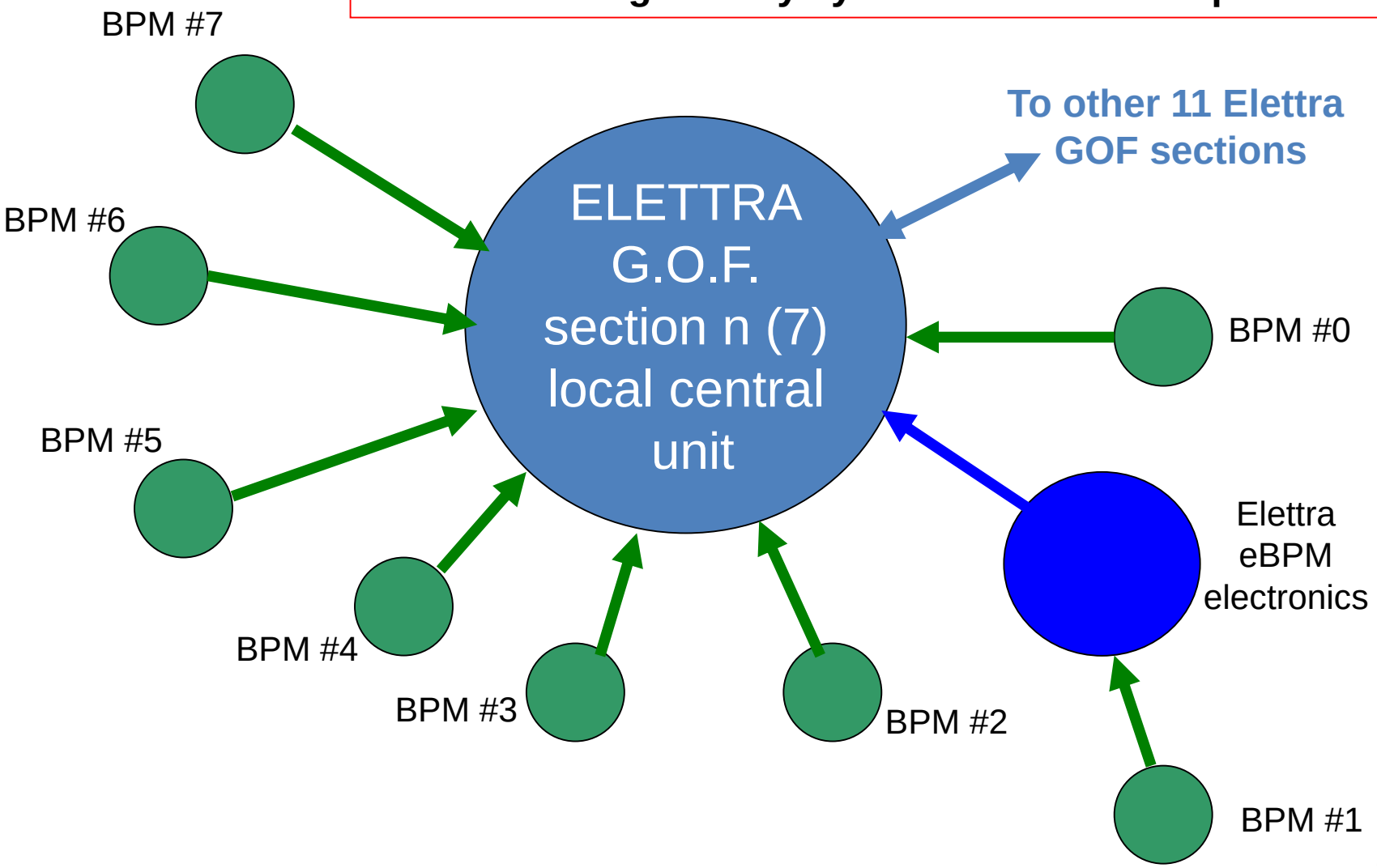
1. The PLL is locked to the SRC clock
2. We program the PLL to pilot the ADC clocks with a fractional part of 500 MHz ≈150.7MHz
3. All the FPGA processing clocks are in phase with the Elettra machine clock
4. The ≈10KHz data rate is derived from 1.156 MHz
5. The exact frequency is fSRC / 116 = 9.9655 KHz…
6. …or not????

Of course not!

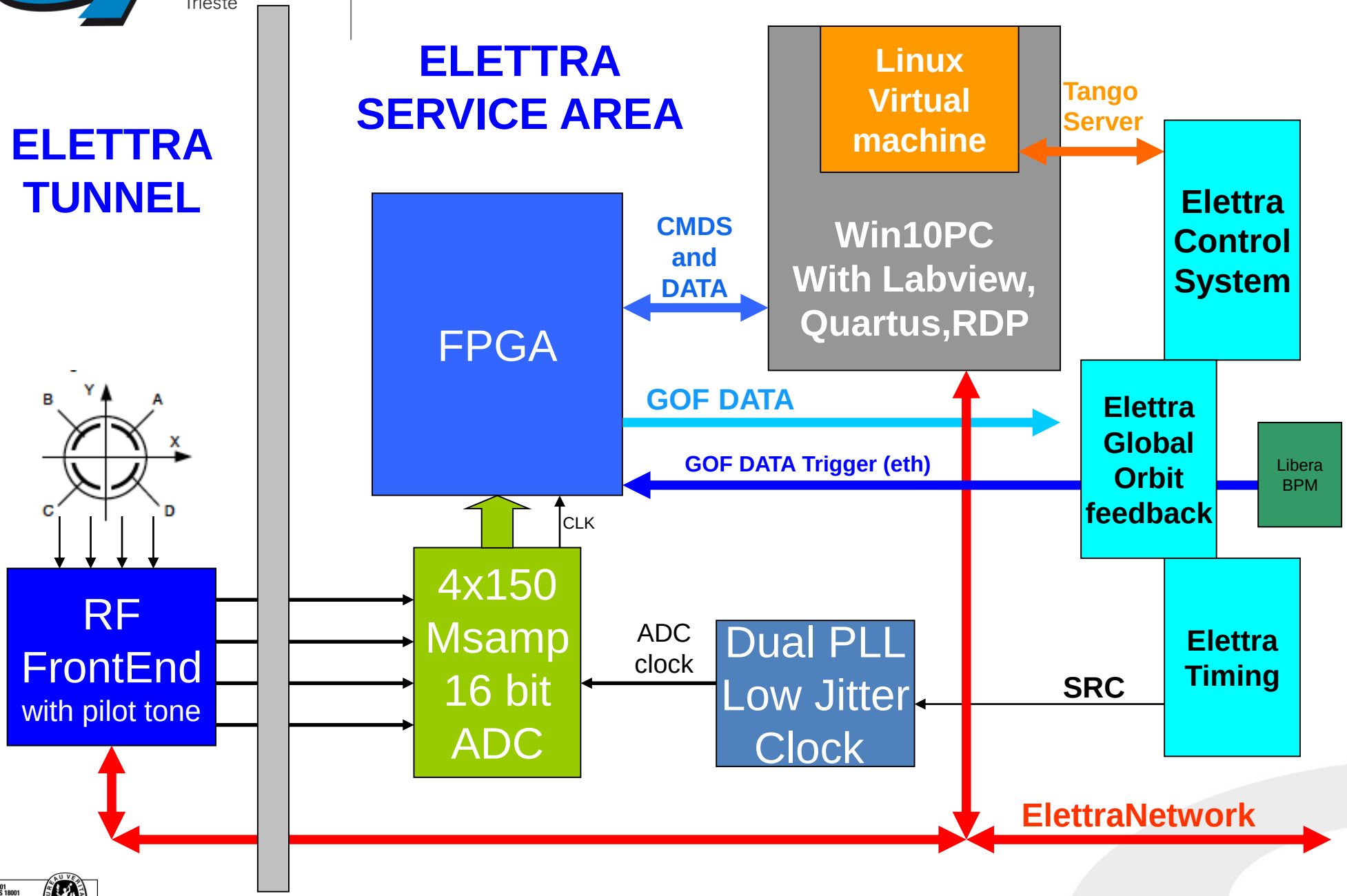
Due to a different internal processing, the data rate that comes from Libera electron is slightly different (0,02 Hz) from 9.9655KHz

A simple workaround

Use the exising already syncronized ethernet packet as a trigger

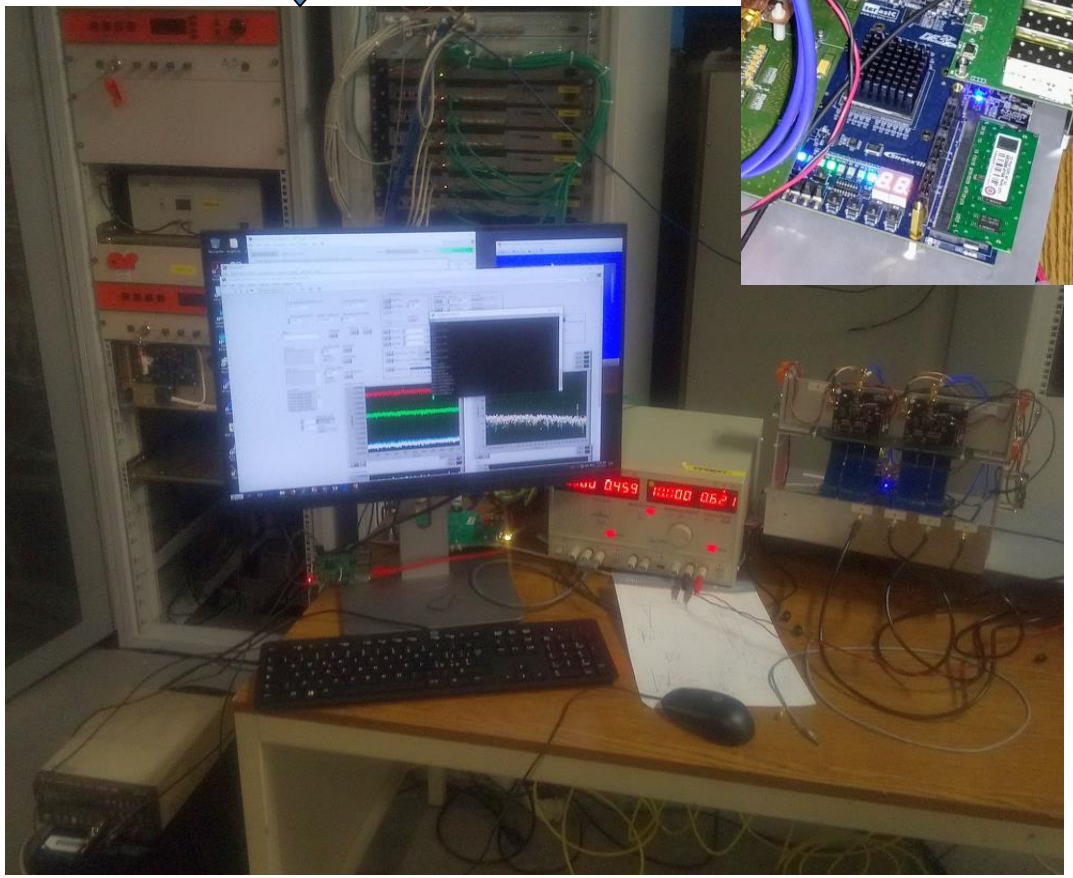


Final system Test block diagram



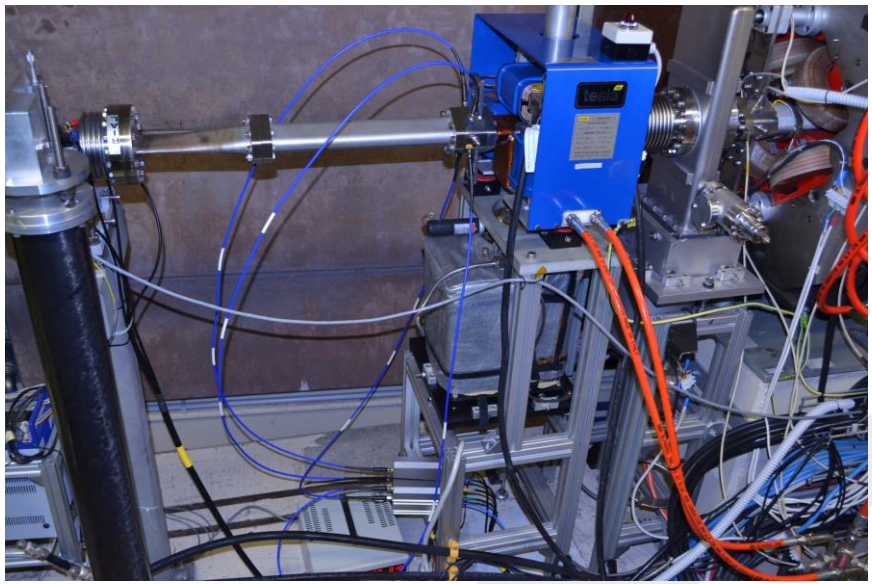
Test the whole electronics in real environment

Elettra Service Area



FPGA and Gigabit Ethernet detail

Elettra Tunnel

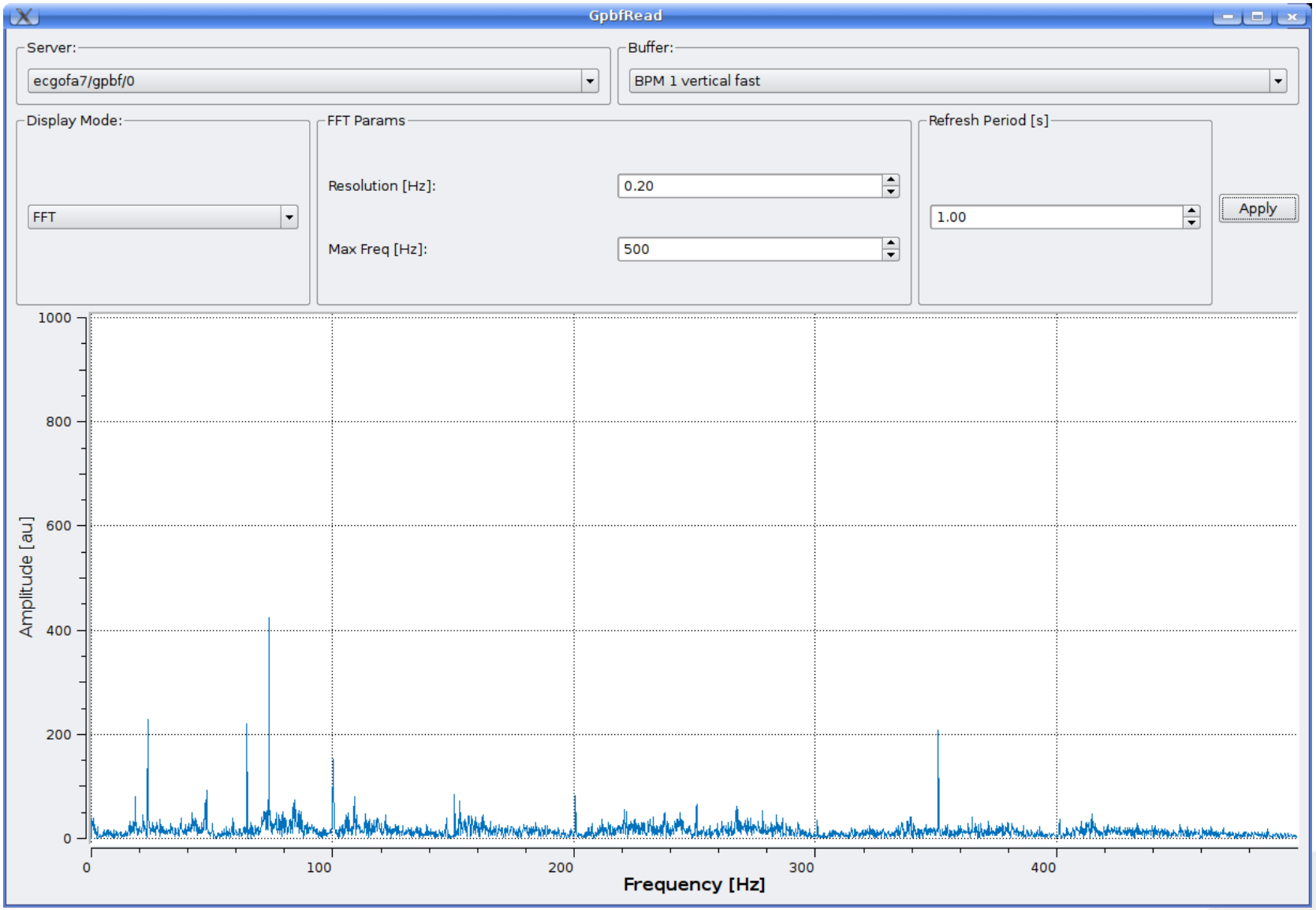


The Logger Output

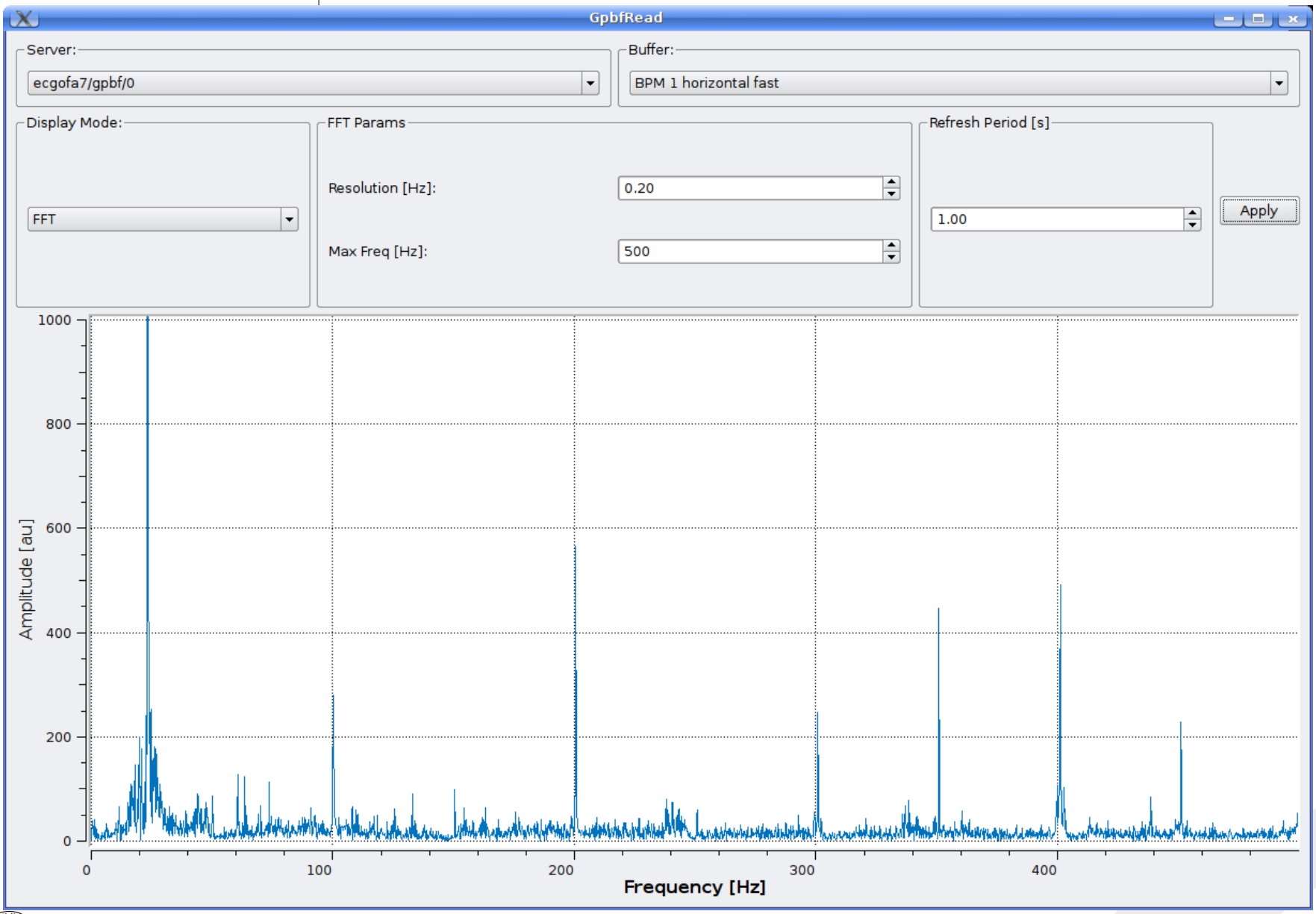
```
Started 18-2-2018 22:7:18 logging to file GofON_1min_mean60_quat.xlt  Now 3 loglines  18-2-2018 22:10:21

Va   =   43065835.4            RMS     21599.18
Vb   =   51906701.7            RMS     27025.16
Vc   =   55702573.9            RMS     25403.22
Vd   =   46934320.0            RMS     29354.82
Sum =  197609431.1             RMS     14998.18
Q    =      -7236.0            RMS       691.59
Xum =       -1754.591          RMS        10.09
Yum =        -754.764          RMS         1.55

PVa   =   53451318.7           RMS      1755.58
PVb   =   54265351.1           RMS      1741.43
PVc   =   53870777.4           RMS      1690.61
PVd   =   53693140.5           RMS      1715.98
PSum =  215280587.7            RMS      5948.55
PQ    =     -58206.8           RMS       184.56
PXum =         -90.701         RMS         0.18
PYum =          13.807         RMS         0.18

Compensated Xum =    -1663.890          TangoXum  =     -771.690      Xoffset=  892.200
Compensated Yum =     -768.571          TangoYum  =      119.429      Yoffset=  888.000

att A  0=    4  1= 94
att B  0=    4  1= 94
att C  0=    4  1= 94
att D  0=    4  1= 94
att Pil  12      freq=502435897
Pil out1   4     out2=     9
TEMP abcdl:  405          407      401      385      412
```

With 20 mm Vacuum Chamber diameter

eBPM frequency response in GOF vertical plane



eBPM frequency response in GOF horizontal plane



eBPM 10hrs data logging while in GOF horizontal plane

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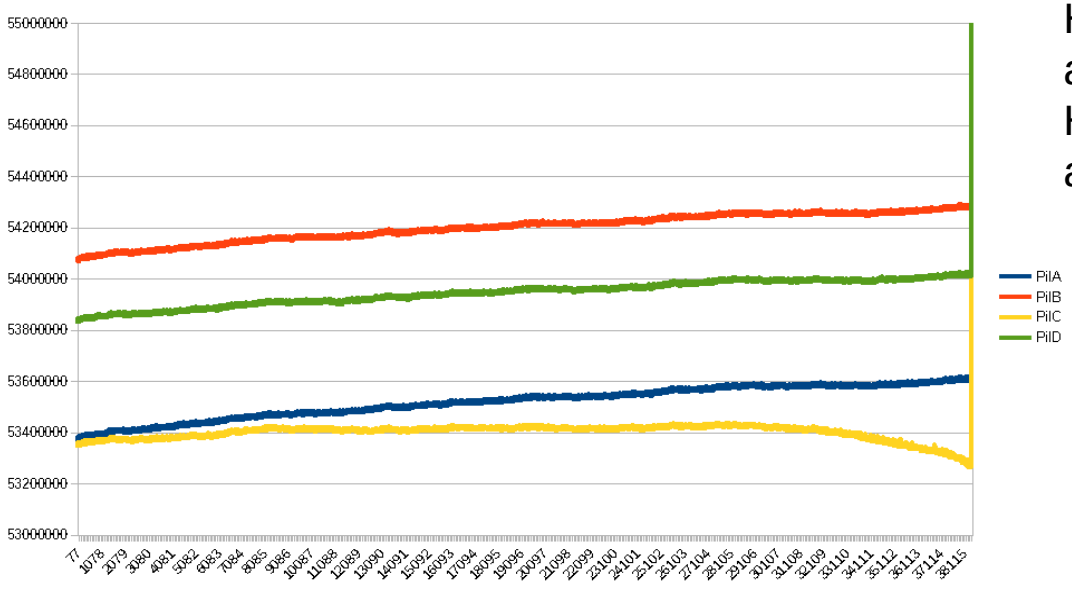
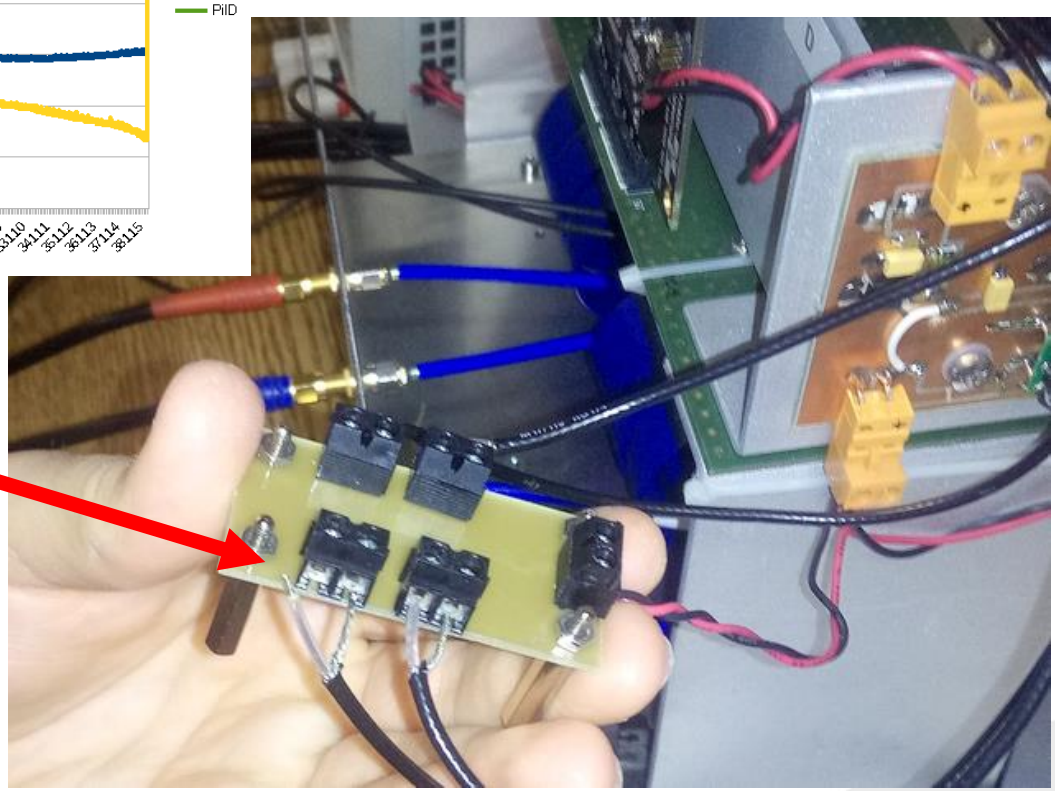
eBPM 10hrs data logging while in GOF vertical plane

Troubleshooting using pilot



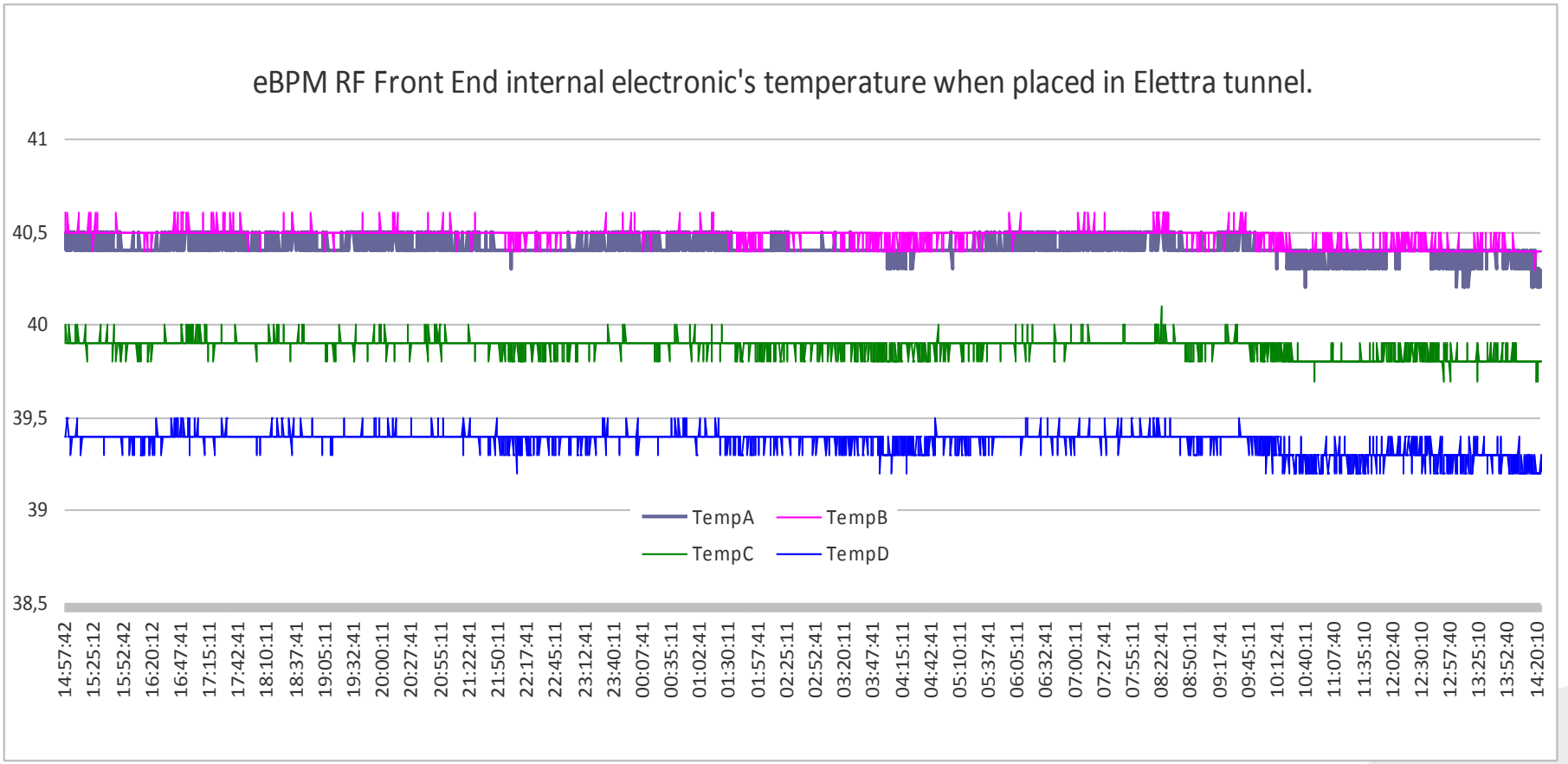
Having a well-known pilot signal can help detect any hardware problems.
Here is an example of "strange" behavior during an 8-hour acquisition.

This is the cause of the strange behavior noted, found after a brief investigation.
One of the four reference voltage signals ADC had a broken contact. So one of the four ADC voltage references was inside the ADC itself rather than the more precise and stable external one.



Temperatures logging

Temperatures in 24 Hrs taken from the internal electronics of a eBPM RF Front End placed inside Elettra's machine tunnel.
Variations in the 24 hours are **less than 0.4° C pk-pk**



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Conclusions

A prototype of the new ***eBPM*** using “pilot tone” compensation technique has been successfully tested and used in Elettra machine.

The test was in a **real** environment within a control system and Global Orbit Feedback, replacing one old BPM electronics.

The **measured “on field”** performances for ***eBPM*** with 20mm chamber are:

Resolution: <200nm @ 10KHz

8hrs stability: < 500nm

This system has been in operations also with a users dedicated machine for more than 10 hrs.

During these tests no packet loss, no software/firmware hangs or structural issues have been detected.

During normal operations is possible to know the quality and the reliability of the measure simply monitoring the pilot tone position.

Thanks to the pilot tone, a sneaky issue (one ADC reference voltage internal instead of external) has been discovered and fixed.

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Thank you!

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