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Libera Spark integration in Elettra Booster BPM system

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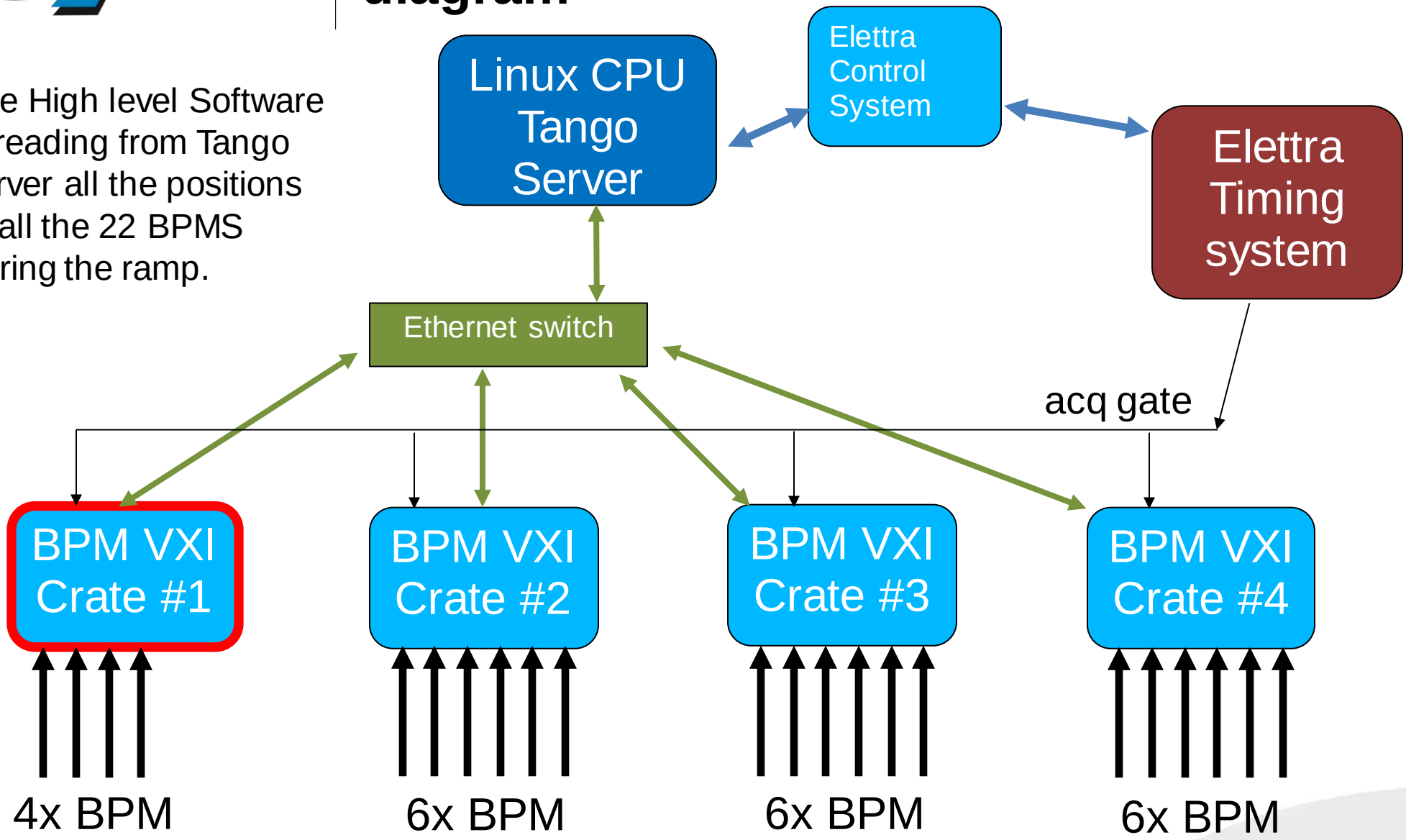
Elettra Booster BPM system overview

The Elettra Booster is a part of the Elettra injection system.
The BPM system of the Booster is a part of the old Elettra BPM system that is based on a VXI Crates. The position detection is based on the multiplexing of the 4 electrodes in a single RF channel, converted from 500MHz to 10.7 MHz, followed by an AM demodulation acquired by 12bit ADC at 1KhZ. All the 8 BPM data was processed by a VME CPU (Eltec E6, with 68030 CPU @25MHz).
The nominal current for the booster is 4mA .
To reduce the radiations, the usual current during users operations is between 0,2 and 0,4mA to maintain safety margins in top-up mode.
During machine physics shifts the current is approximately 1,5 mA maximum.

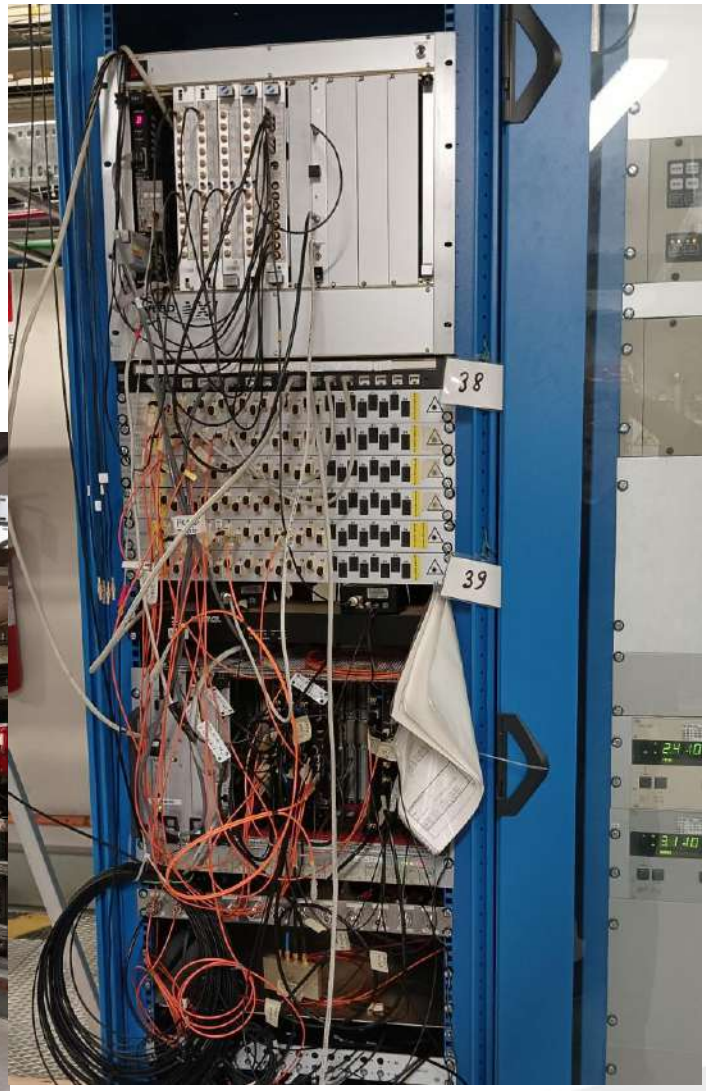
Elettra Booster BPM system block diagram

The High level Software is reading from Tango server all the positions of all the 22 BPMS during the ramp.

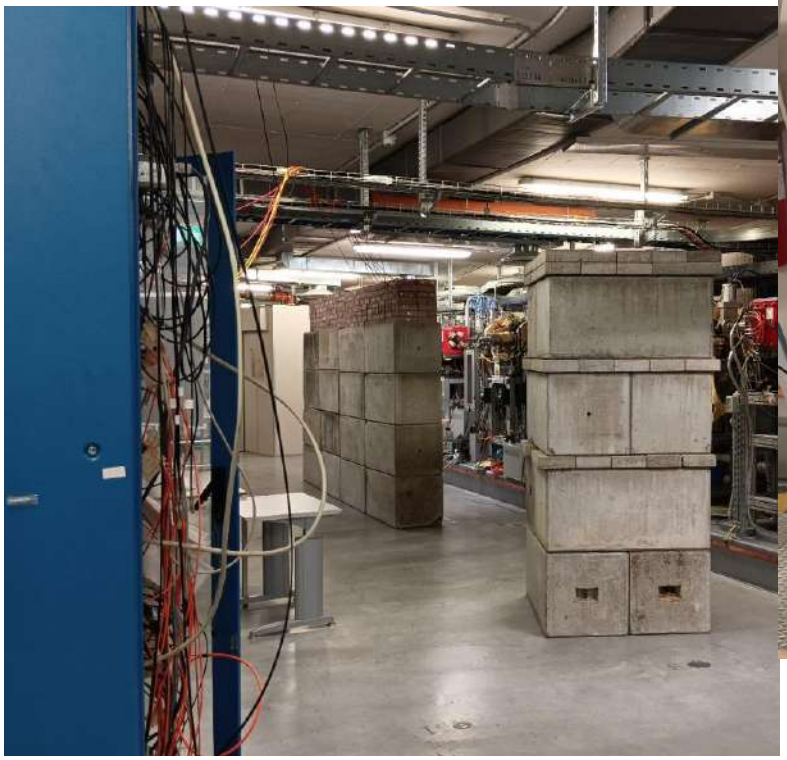


Elettra Booster BPM system
VXI Crate #1 problem

One of the VXI crates is placed in a position where the radiation from the injections is not negligible, even with a concrete wall.



After about ten years, the acquisition electronics of unit #1 failed, and replacement boards are no longer available.



Elettra Booster BPM system problem

The Elettra 2.0 upgrade project also included an upgrade of the BPM system of the transfer lines and the Booster, as well as that of the storage ring.

For the upgrade to Elettra 2.0 at the end of 2022, it was also necessary to perform full orbit measurements to verify that the Booster could inject with the correct emittance into the future Elettra 2.0 ring.

However, when the perfectly functioning BPM Booster system was needed, the radiation-induced failure of the power supply and numerous boards made it impossible to carry out the planned and necessary measurements..

Unfortunately, at that time, the new eBPM electronics, developed at Elettra and part of a partnership with I-Tech, weren't ready at that time.

Elettra Booster BPM system solution

After receiving instructions from Instrumentation Technologies (thanks to Matjaz Znidarcic !) on how to configure the Libera Sparks to receive data in a form similar to current BPM electronics, we decided to **replace the functionality** of the first VXI crate, which managed 4 BPM, with 4 Libera Spark units.

This was possible because the units communicate with each other using a simple TCP/IP or UDP network protocol over standard Ethernet, even though they are 30 year old systems.

In the near future, when we upgrade all BPM Booster systems with new electronics, these Libera Spark units can be easily reused in other machines such as Fermi Linac or Booster pre-injector.

Libera Spark setup

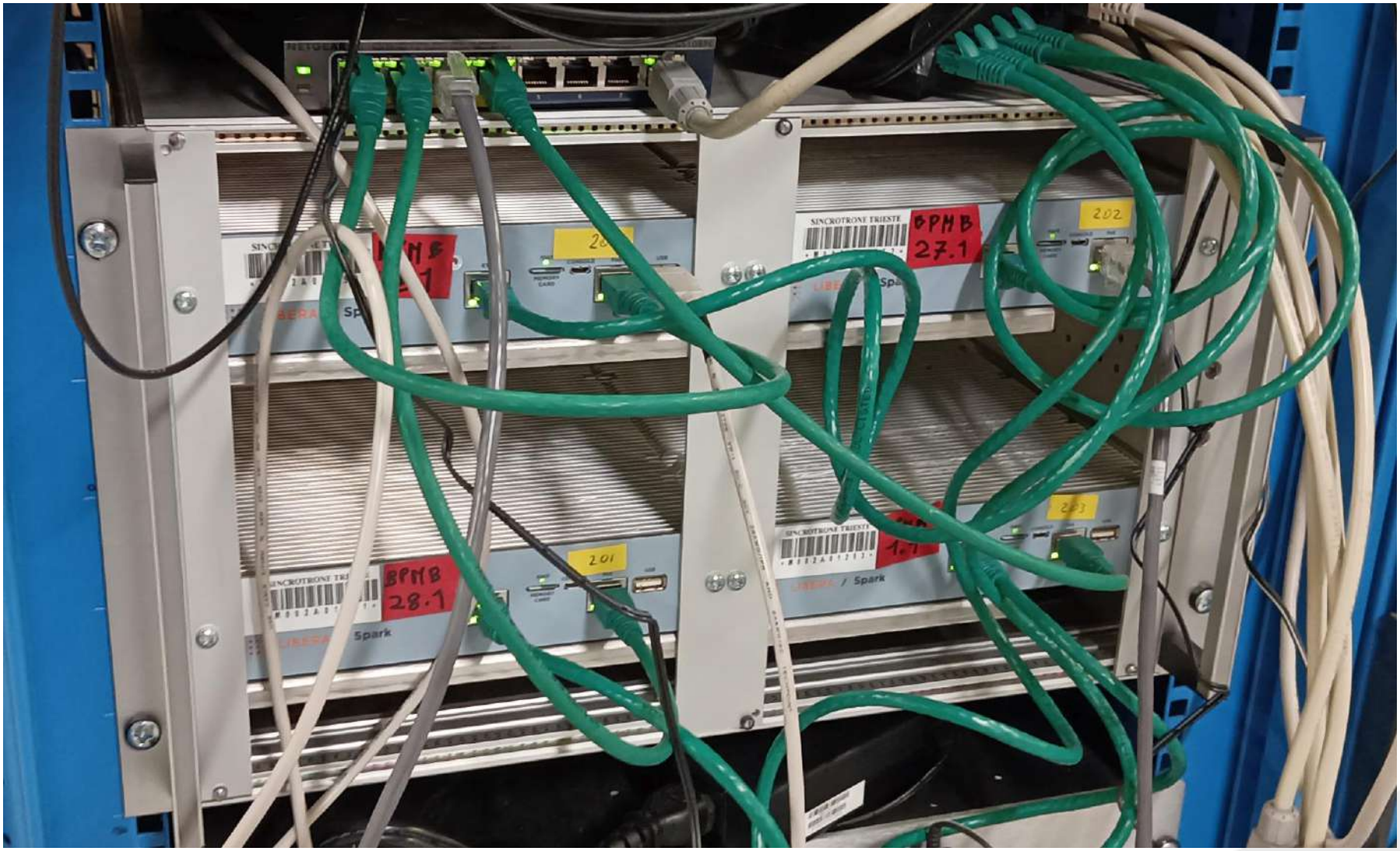
Libera Spark does not have a gated acquisition function, but it does have a trigger input.

With the appropriate settings, it is possible to have the Tango server deliver a predetermined number of positions (from 30 to 40) following a trigger pulse calculated every 5 or 4 ms.

It is also possible to set the Gigabit port to send a UDP packet every 4 ms containing the average of N samples (usually 200) sent after a trigger as long as the ADC values exceed a predefined value, thus avoiding data transmission when there is no beam in the booster.

This means that the receiving process of the Libera Spark data stream does not know when the last packet was received, also because it could happen that not all the data is sent if electrons are lost during the ramp.

Libera Spark setup



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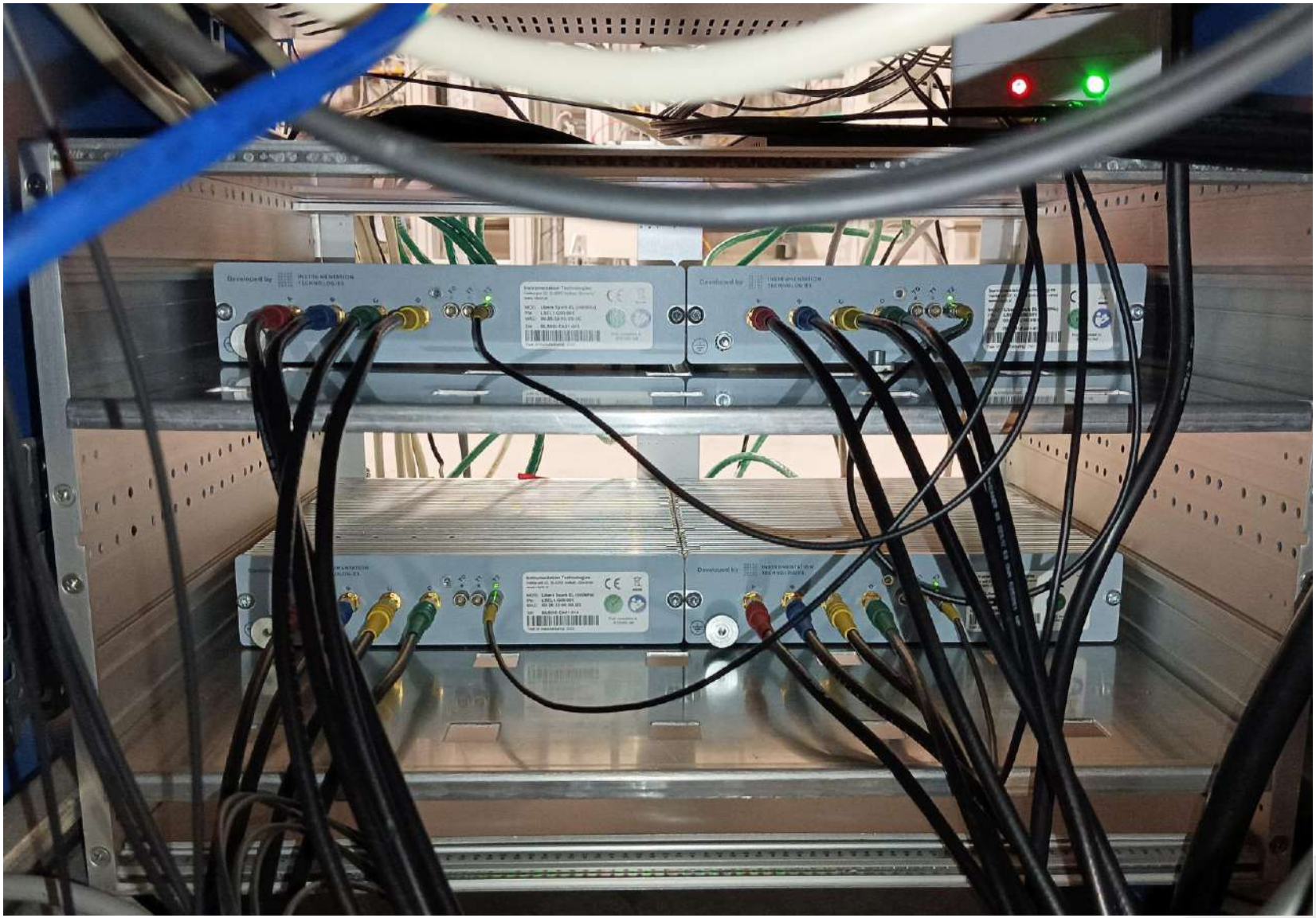
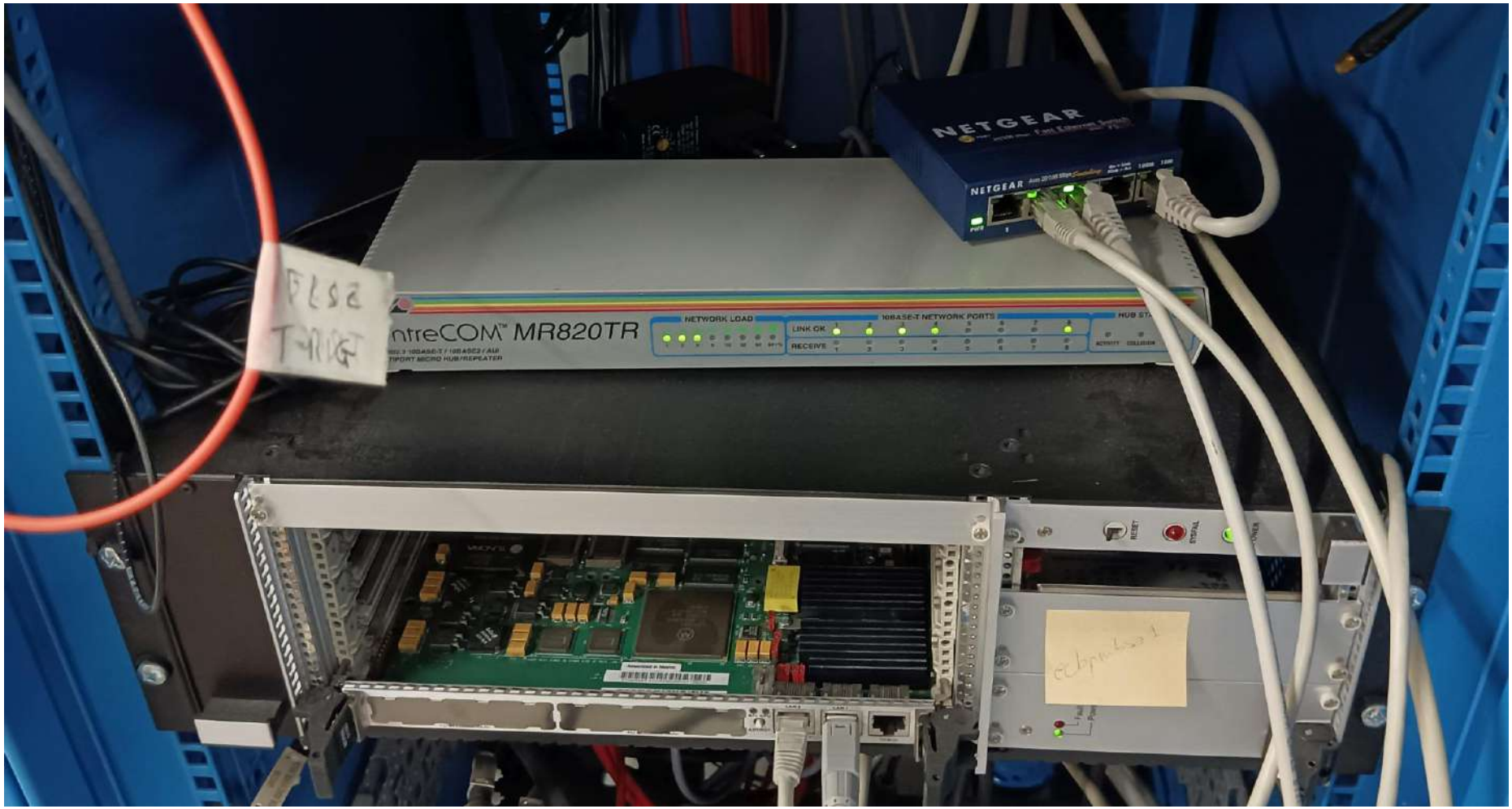
Libera Spark setup

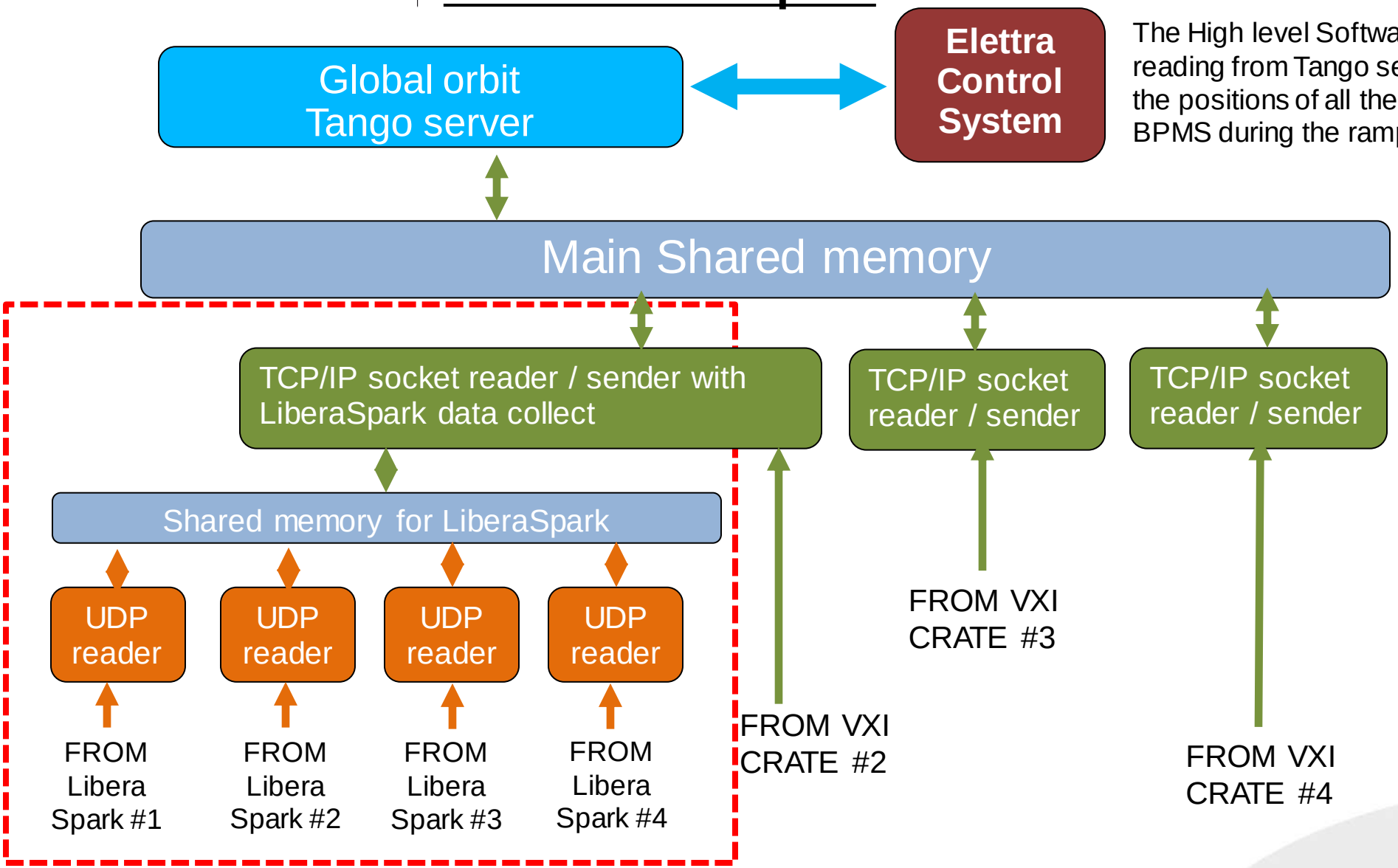


Libera Spark setup



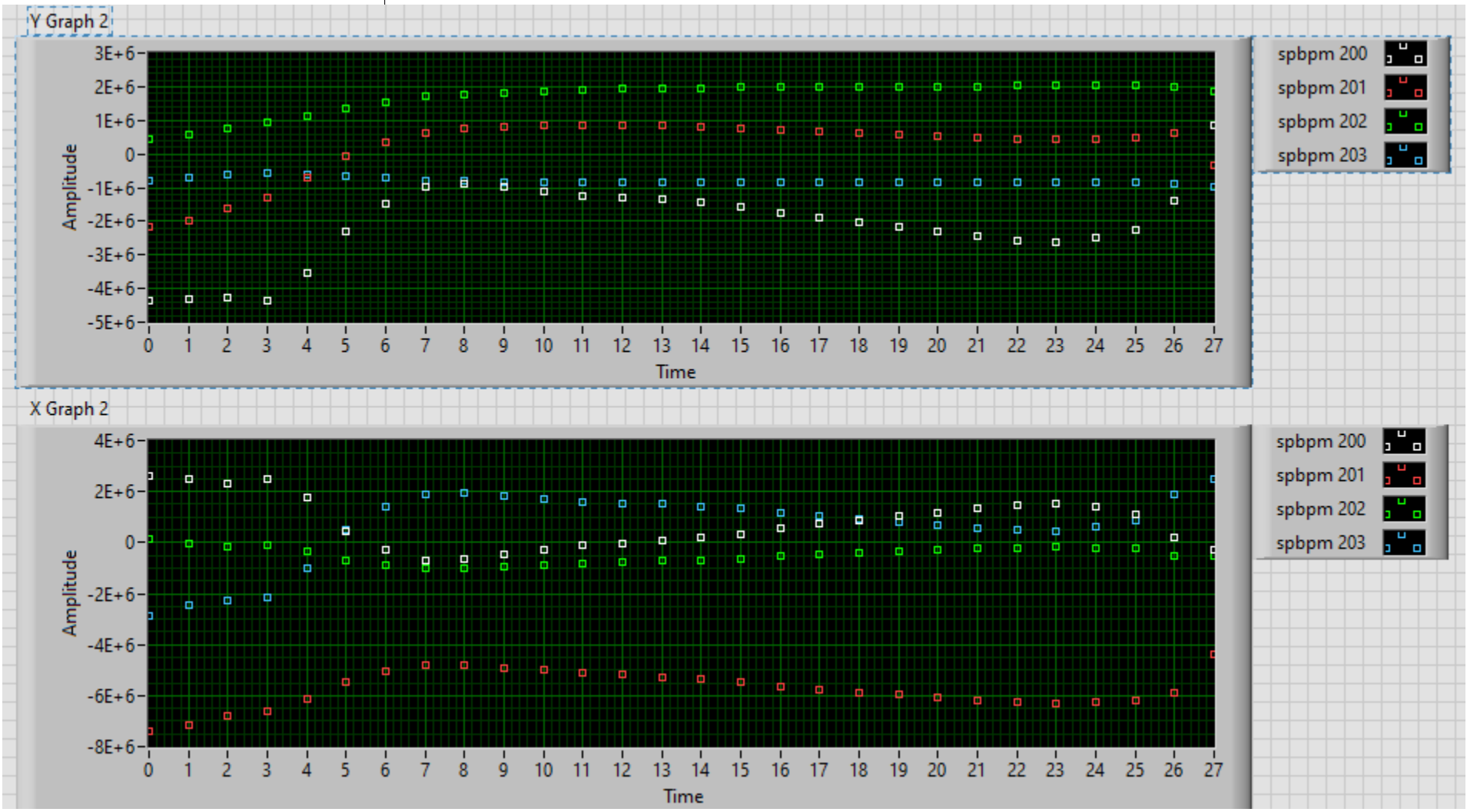
VME Crate with tango server and two ethernet interfaces that collect all the data

Elettra Booster BPM system Global orbit software diagram with 4 Libera Spark



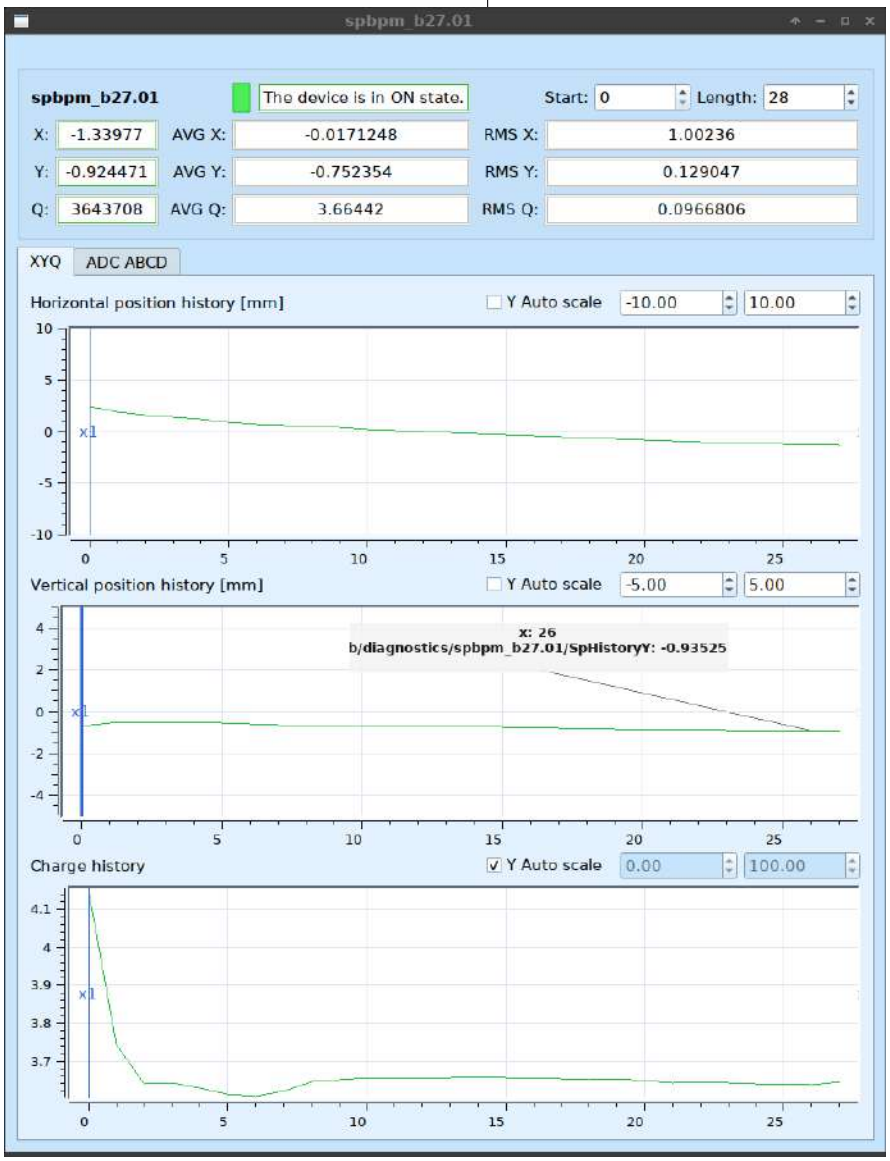
The High level Software is reading from Tango server all the positions of all the 22 BPMS during the ramp.

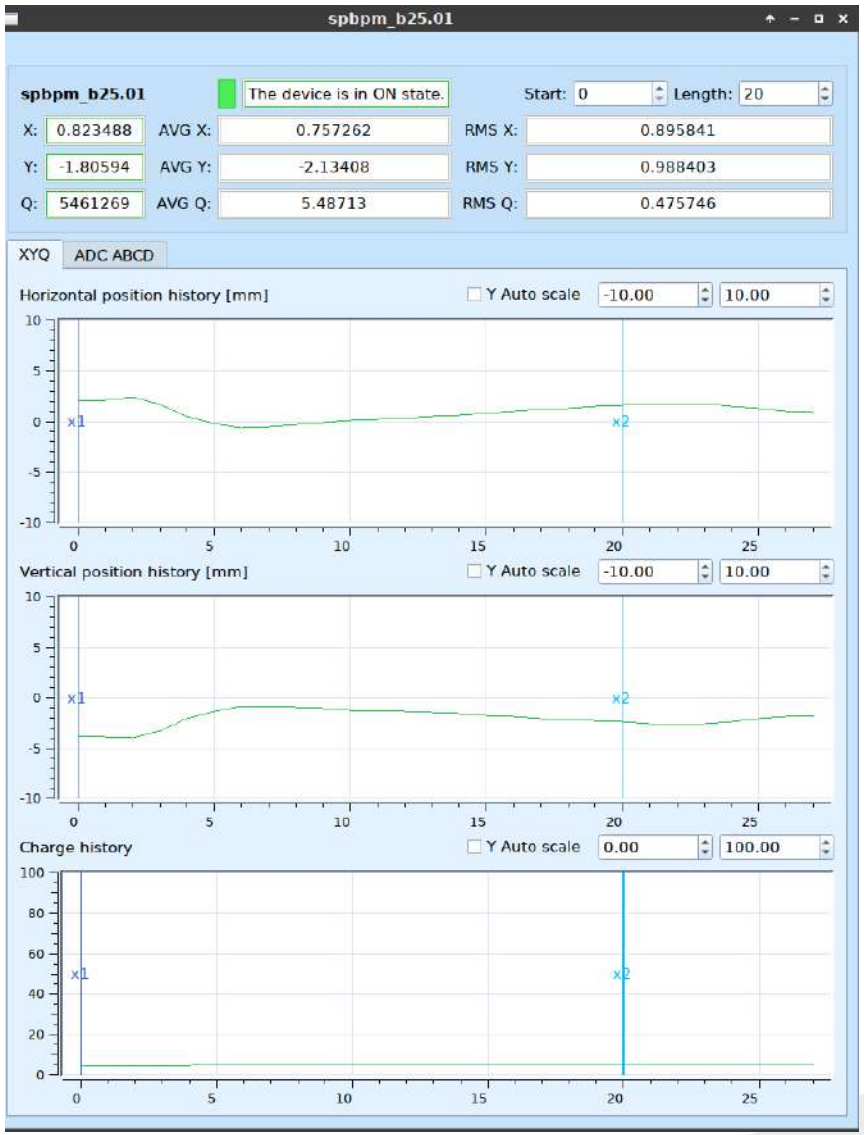
Libera Spark in Booster
First results



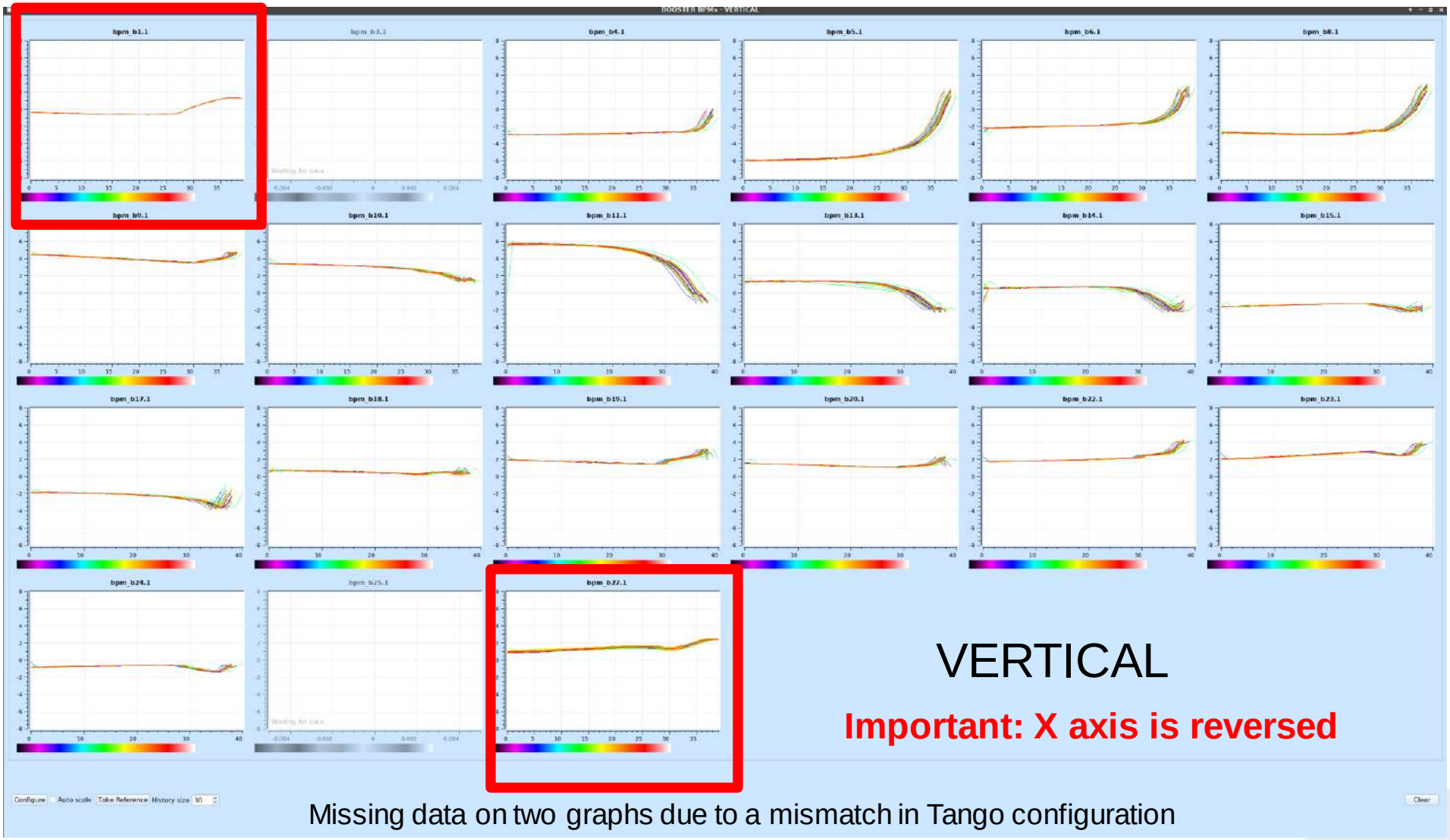
Using remote exec and LabView program, firs tests on 02 Feb 2023

Libera Spark in Booster Control room panels



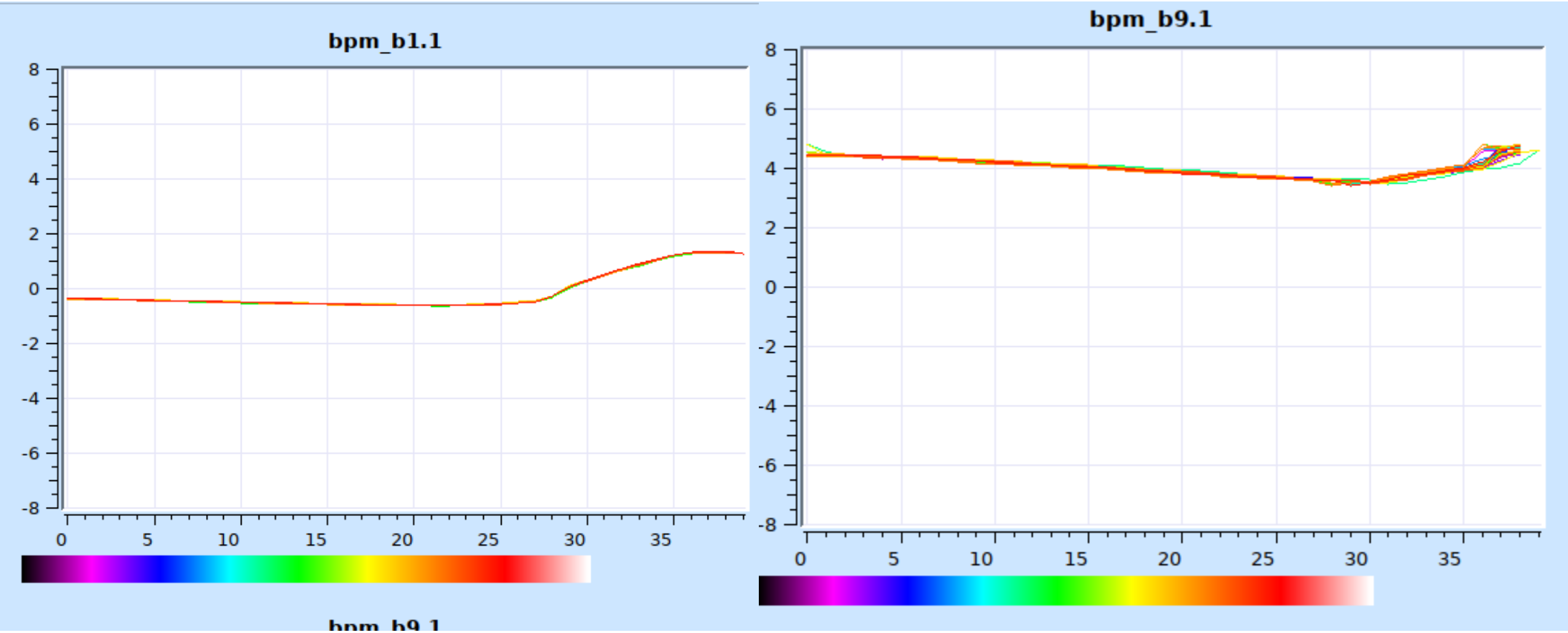


Results with Elettra Booster BPM system with Libera Spark integration



Missing data on two graphs due to a mismatch in Tango configuration

Results with Elettra Booster BPM system with Libera Spark integration

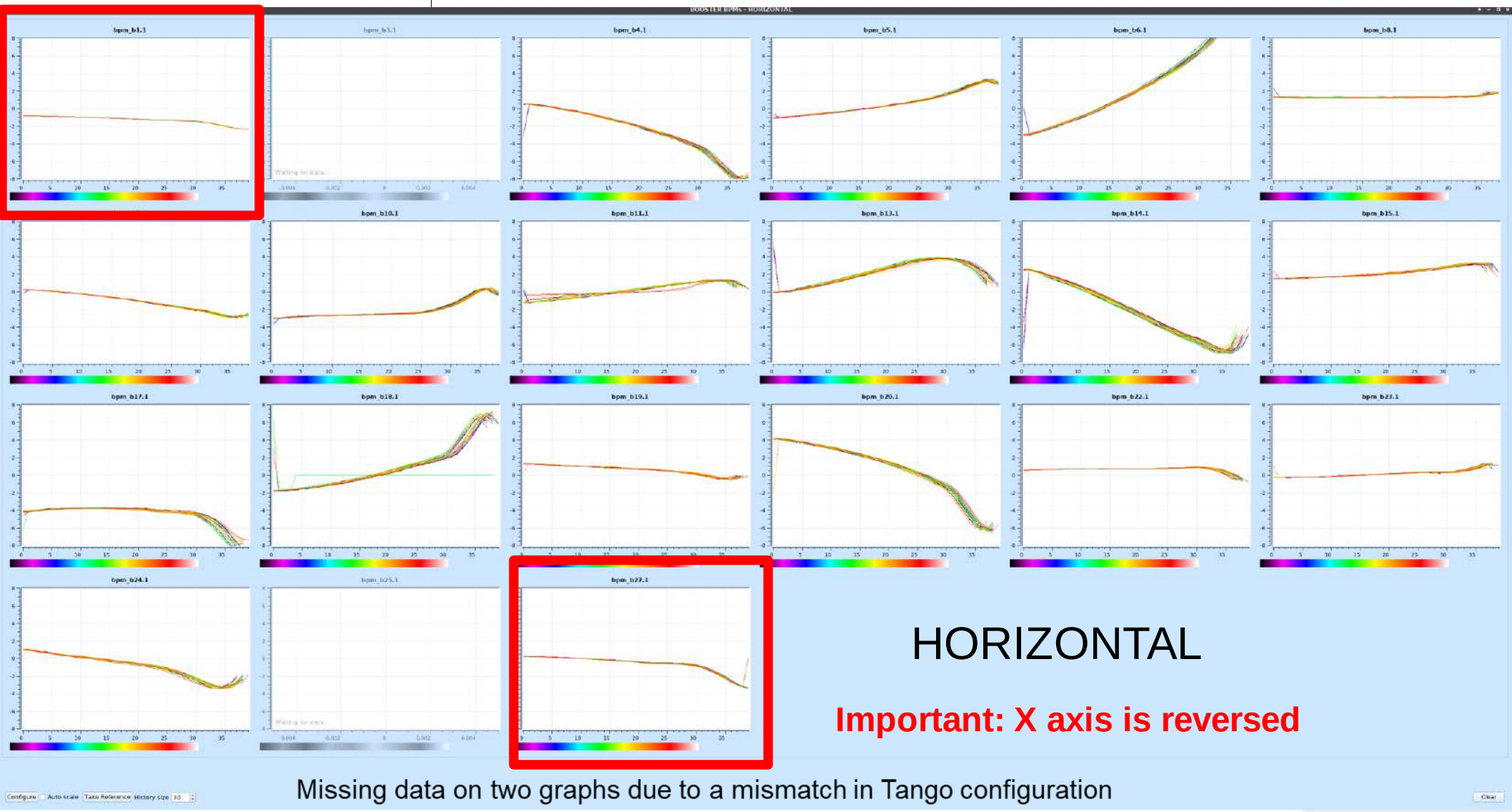


Data from Libera Spark unit

Data from old BPM system unit

Detail view

Results with Elettra Booster BPM system with Libera Spark integration



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Results with Elettra Booster BPM system with Libera Spark integration

BPM	SAMPn	X	Y	A	B	C	D	:Errn	GC1	GC2	GCRF
25.1	40	-0.05	1.69	235	318	236	228	: 0	0	0	0
27.1	40	0.03	1.62	236	316	234	229	: 0	0	0	0
28.1	40	-1.03	-0.20	453	518	583	447	: 0	0	0	0
1.1	39	1.02	-1.17	639	577	645	890	: 0	0	0	0
3.1	39	-1.68	-2.67	1098	1377	1986	1679	: 0	3648	191	1
4.1	39	0.48	-4.71	1271	1110	2532	2505	: 0	3648	191	1
5.1	39	1.61	-0.41	3573	3135	3316	3719	: 0	3648	179	1
6.1	39	0.30	-0.29	3559	3552	3609	3748	: 0	3648	172	1
8.1	39	-0.86	2.22	3759	3932	3149	2569	: 0	3648	190	1
9.1	39	-1.73	2.68	1859	2600	1620	1339	: 0	4032	191	1
10.1	39	-0.00	2.34	3847	3772	2744	2663	: 0	3648	225	1
11.1	38	0.21	-0.38	3777	3689	3789	3901	: 0	3785	212	1
13.1	39	-0.80	-0.18	3614	4037	4095	3730	: 0	3648	224	1
14.1	38	0.42	-0.37	3787	3681	3758	3955	: 0	3784	207	1
15.1	39	-3.14	-1.79	1967	3113	3896	2542	: 0	3648	224	1
17.1	39	-0.08	0.46	2671	2934	2611	2612	: 0	3648	225	1
18.1	38	-0.07	0.46	3890	3991	3752	3773	: 0	3712	190	1
19.1	38	-0.45	0.43	3752	3998	3765	3622	: 0	4032	187	1
20.1	38	0.15	0.51	3627	3583	3431	3493	: 0	3904	177	1
22.1	38	0.04	0.68	3567	3556	3351	3330	: 0	3840	178	1
23.1	38	-0.61	-0.68	1756	1875	2079	1905	: 0	4032	169	1
24.1	38	1.39	-1.53	3082	1989	3114	3151	: 0	3648	225	1

Results with Elettra Booster BPM system with Libera Spark integration

```
trgN: 54539   bncN: 0     A:   58b2a6     B:   4291e0     C:   4b71bb     D:   84f492     x:  2196099    y: -1461235
trgN: 54539   bncN: 1     A:   527db2     B:   3d6454     C:   457d94     D:   7b657b     x:  2226853    y: -1454961
trgN: 54539   bncN: 2     A:   4dfa2d     B:   3b072c     C:   42f0d6     D:   73b865     x:  2118112    y: -1428081
trgN: 54539   bncN: 3     A:   45a9d9     B:   35c16a     C:   3ce0c1     D:   66918c     x:  2006366    y: -1394708
trgN: 54539   bncN: 4     A:   38c662     B:   2cd076     C:   3266eb     D:   52f316     x:  1892619    y: -1351205
trgN: 54539   bncN: 5     A:   3589be     B:   2b61ed     C:   307697     D:   4d2c1f     x:  1746469    y: -1290323
trgN: 54539   bncN: 6     A:   365bff     B:   2d0629     C:   31cc9d     D:   4ce1a4     x:  1611088    y: -1207622
 . . . . . .
trgN: 54539   bncN: 16    A:   4249fd     B:   3723aa     C:   3bb0b4     D:   5b473a     x:  1568934    y: -1084455
trgN: 54539   bncN: 17    A:   43070d     B:   37537c     C:   3bc196     D:   5c2187     x:  1607189    y: -1076917
trgN: 54539   bncN: 18    A:   439803     B:   378f66     C:   3bdf4e     D:   5cc9a7     x:  1629685    y: -1069783
trgN: 54539   bncN: 19    A:   4404a3     B:   37dd72     C:   3c1a15     D:   5d2c64     x:  1631721    y: -1060487
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trgN: 54539   bncN: 21    A:   44ae50     B:   385ae0     C:   3c8e05     D:   5ddf3b     x:  1633249    y: -1051692
trgN: 54539   bncN: 22    A:   44f10d     B:   3895ac     C:   3cc706     D:   5e1b88     x:  1629290    y: -1046988
trgN: 54539   bncN: 23    A:   452531     B:   38d0cb     C:   3ced0f     D:   5e55cb     x:  1626432    y: -1041888
trgN: 54539   bncN: 24    A:   45559e     B:   38f97f     C:   3d21e4     D:   5e847c     x:  1622398    y: -1040608
trgN: 54539   bncN: 25    A:   456cc1     B:   392003     C:   3d47ee     D:   5ea7b5     x:  1616857    y: -1040270
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trgN: 54539   bncN: 27    A:   4588b1     B:   3952e2     C:   3d77d9     D:   5ec051     x:  1607098    y: -1037232
trgN: 54539   bncN: 28    A:   4587f6     B:   395d1e     C:   3d87e7     D:   5ec4d7     x:  1603329    y: -1038329
trgN: 54539   bncN: 29    A:   4589a6     B:   395440     C:   3d7fb6     D:   5ebded     x:  1605454    y: -1037556
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trgN: 54540   bncN: 2     A:   565100     B:   41afe3     C:   4aa927     D:   7fb3a6     x:  2078292    y: -1420935
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trgN: 54540   bncN: 4     A:   3d4e3a     B:   30a2c5     C:   36bdea     D:   592a06     x:  1853301    y: -1337390
trgN: 54540   bncN: 5     A:   3a8fba     B:   2fc08f     C:   35676f     D:   5409b6     x:  1700449    y: -1277157
```

Issues to be fixed

Software:

- Some problems with the Libera Spark Tango server need to be fixed to improve the reliability of the system: sometimes the Tango server crashes when there are multiple connections. A version update should solve this problem.
- After a reboot an important parameter (SpHistoryEnable) need to be set again to 'True' value.
- Already fixed: "device name" to "device hardware" association

Hardware:

- Replace the POE switch with a more robust one
- Move the 4 new devices in a more radiations protected position (i.e. in a rack at few meters distance, that is better shielded by a concrete wall)

Conclusions

The integration of Libera Spark 4 into the old BPM system was successful.

It was therefore possible to measure the orbit of the Booster despite the failure that occurred.

A low emittance orbit suitable for the new Elettra 2.0 storage ring has been verified and created.

The knowledge of hardware and software, and the use of standard network protocols for communication, allowed the integration of a new system with a 30 year old one.

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Many thanks to:

- ✓ Matjaz Znidarcic for the Libera Spark programming parameters support
- ✓ All the Elettra diagnostics team.
- ✓ G. Strangolino for BPM panels

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Thank you!

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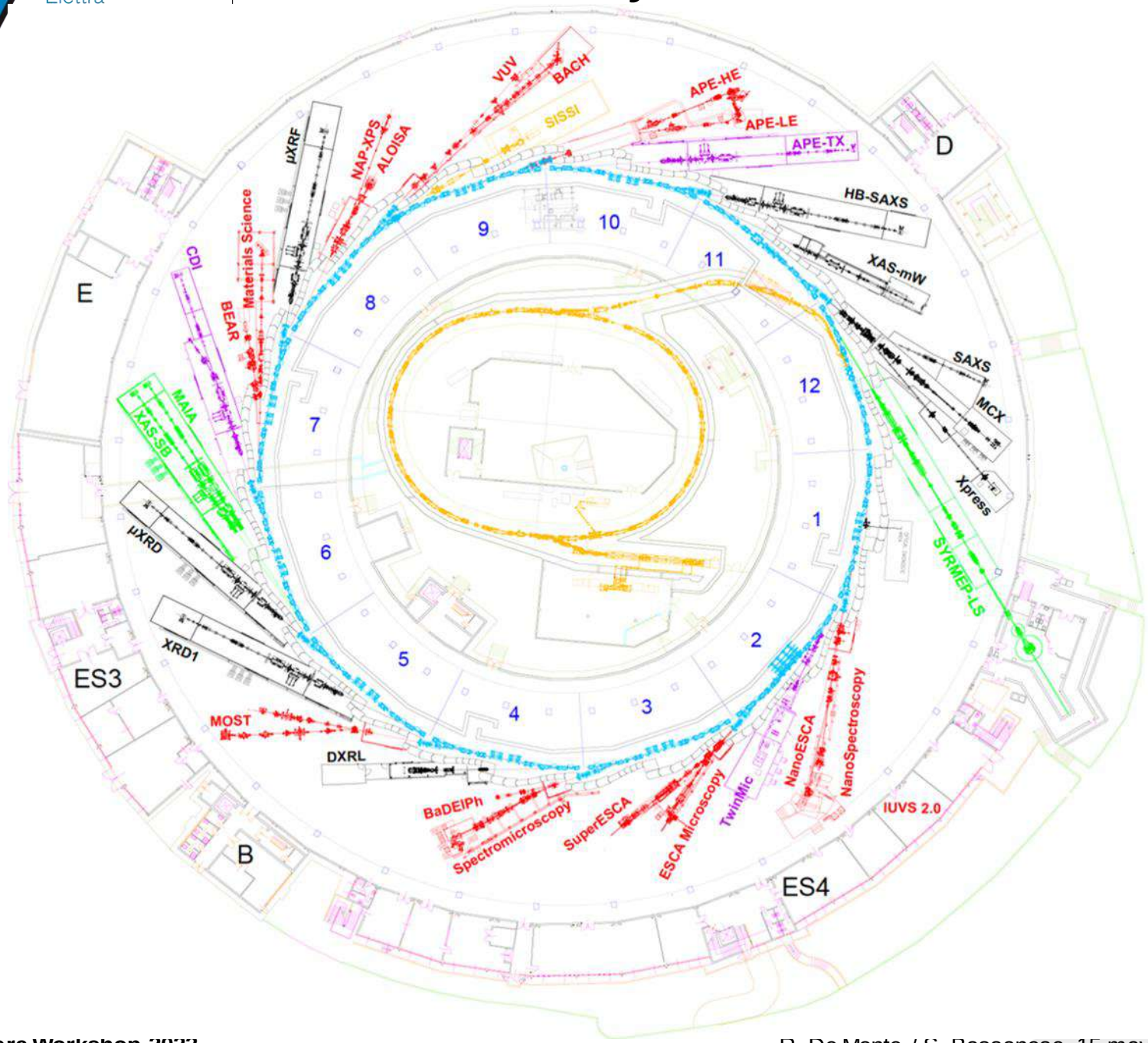
ELETTRA2 Layout



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