DEELS 2019,
ESRF June 3-5

Kees SCHEIDT ESRF

will we ever stop developing "BPM-electronics" … ?

what are the real reasons and motivations in the instrumentation community to continue to spend so much efforts in developing their own home-made BPM electronics ?

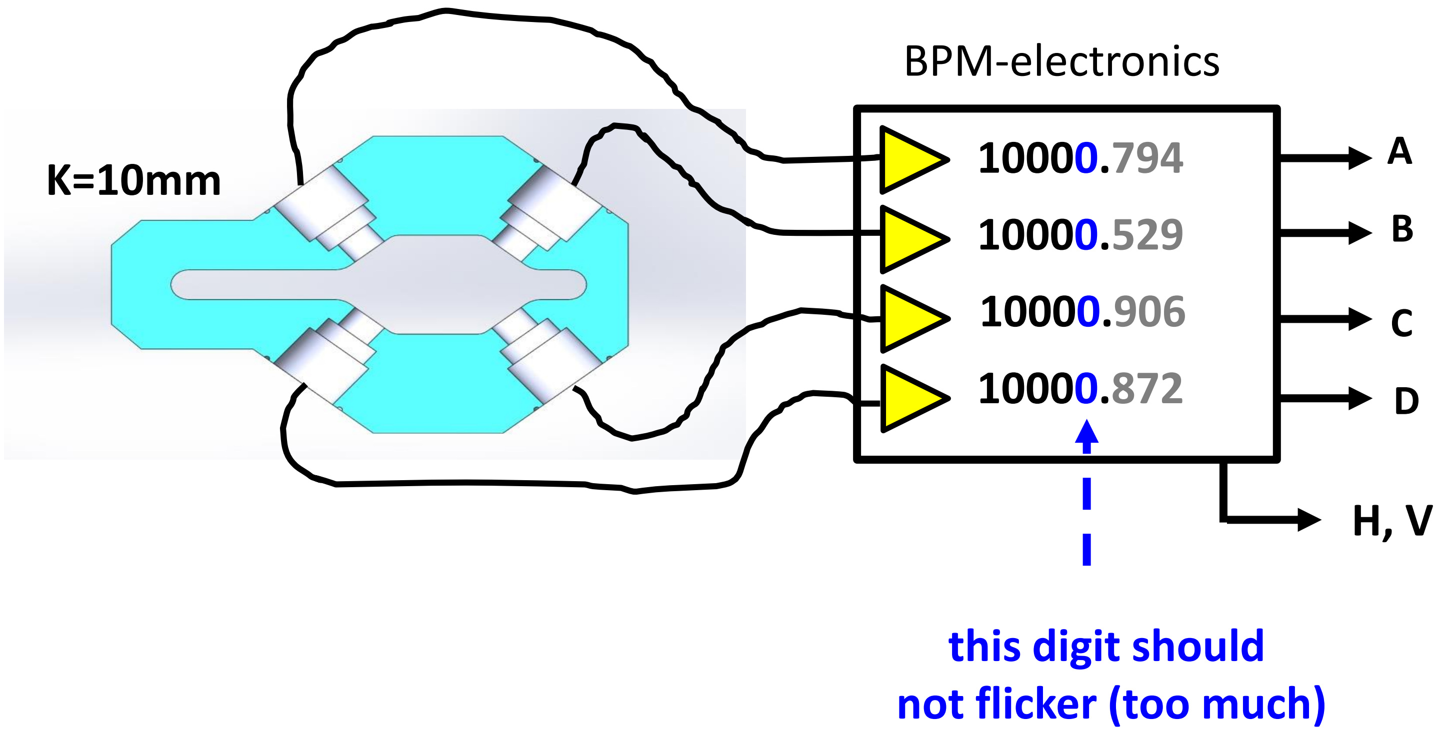
by Kees :
- 15 min presentation on the EBS-BPM-electronics
- emphasis on the basic **stability (or drift) requirements** for the Ring
- and comparison with that obtained with the simple "Sparks"

with Guenther :
- 45 min time for discussing the above question(s)

BPM-electronics are simply **4 channel digitizers** of weak **RF signals**
the **relative stability** of these **4 channels** → the **stability** of the **position result**

a relative variation of **1E-4** (rms) produces **0.5um** (rms) variation of position

H, V, = 10mm x δ/Σ



how to achieve that relative stability of 1E-4 ?

how to achieve that relative stability of 1E-4 ?

by internal RF-cross-bar multiplexing (Libera)

or

by pilot-tone injection

or

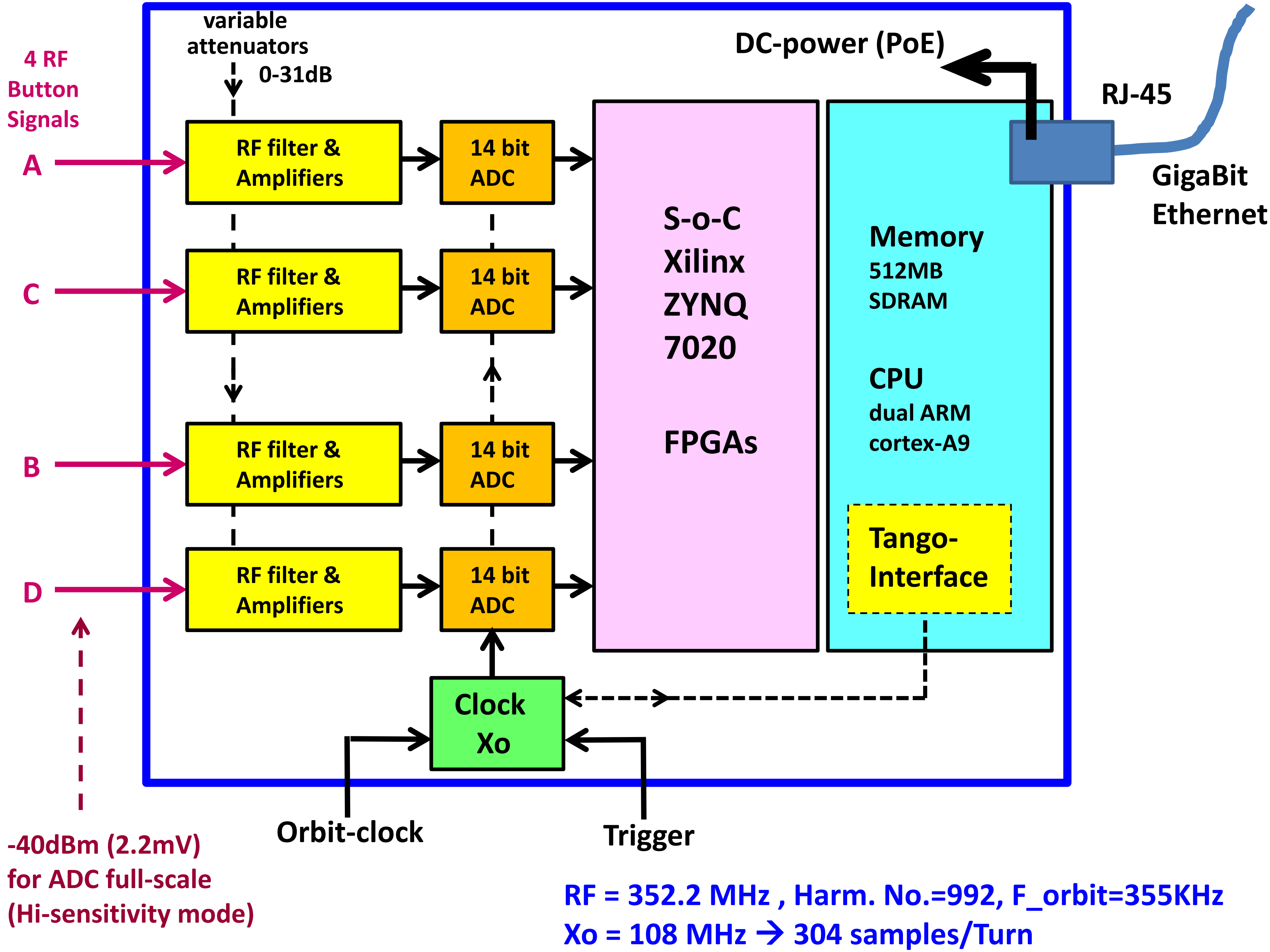
by high quality active temperature stabilization

or

by doing …. NOTHING ….

doing NOTHING ….

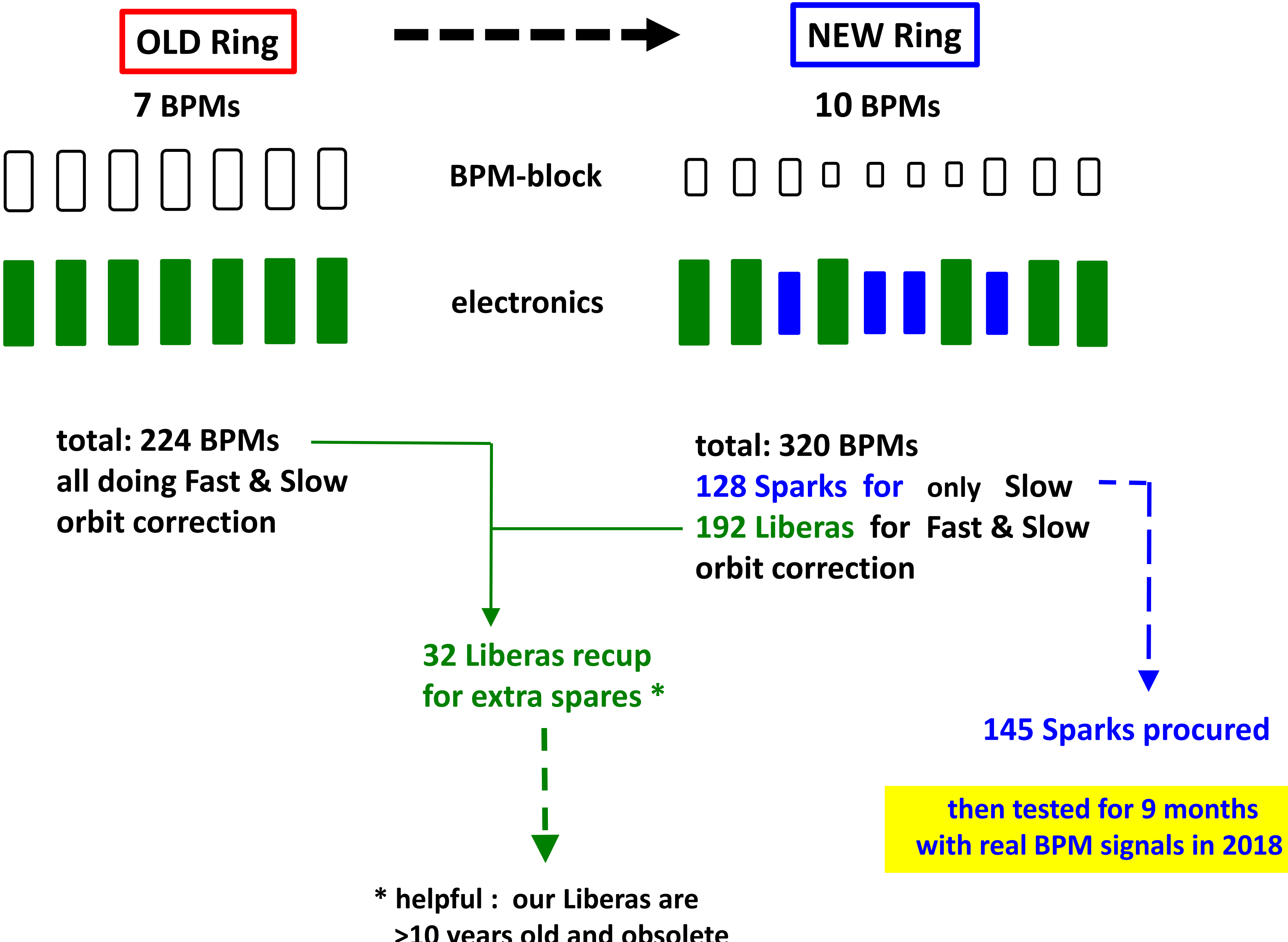
… is already a lot !


4 RF Button Signals
variable attenuators
0-31dB
A
C
B
D
RF filter & Amplifiers
RF filter & Amplifiers
RF filter & Amplifiers
RF filter & Amplifiers
14 bit ADC
14 bit ADC
14 bit ADC
14 bit ADC
S-o-C Xilinx ZYNQ 7020
FPGAs
DC-power (PoE)
RJ-45
GigaBit Ethernet
Memory
512MB SDRAM
CPU
dual ARM cortex-A9
Tango-Interface
Clock Xo
Orbit-clock
Trigger
-40dBm (2.2mV) for ADC full-scale (Hi-sensitivity mode)
RF = 352.2 MHz , Harm. No.=992, F_orbit=355KHz
Xo = 108 MHz → 304 samples/Turn

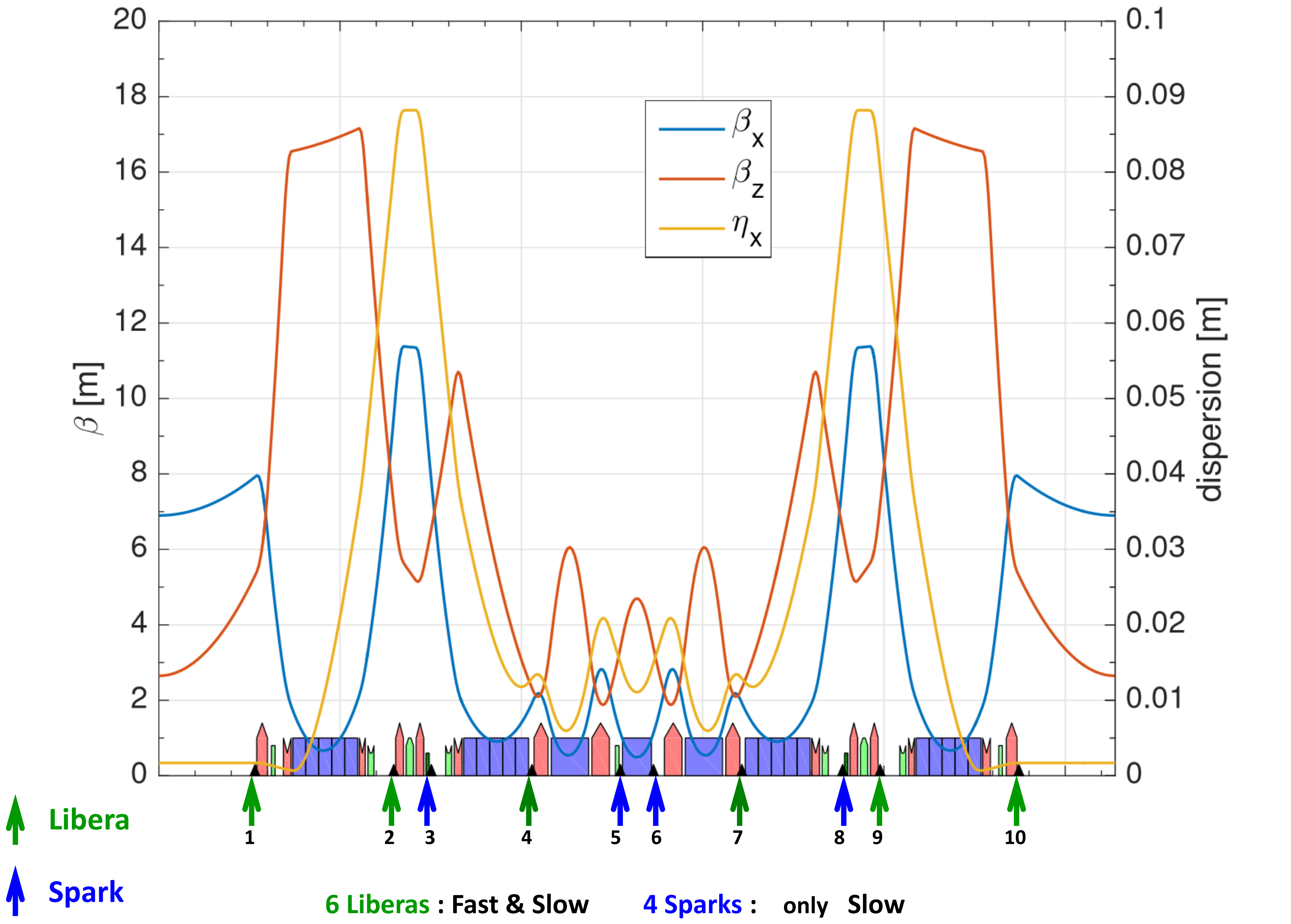
**just a few words on
the ESRF BPM system & orbit correction**

and why we opted for :

- **hybrid system**
- **economic choice**
- **reliability**
- **not “full-blast” functionalities**

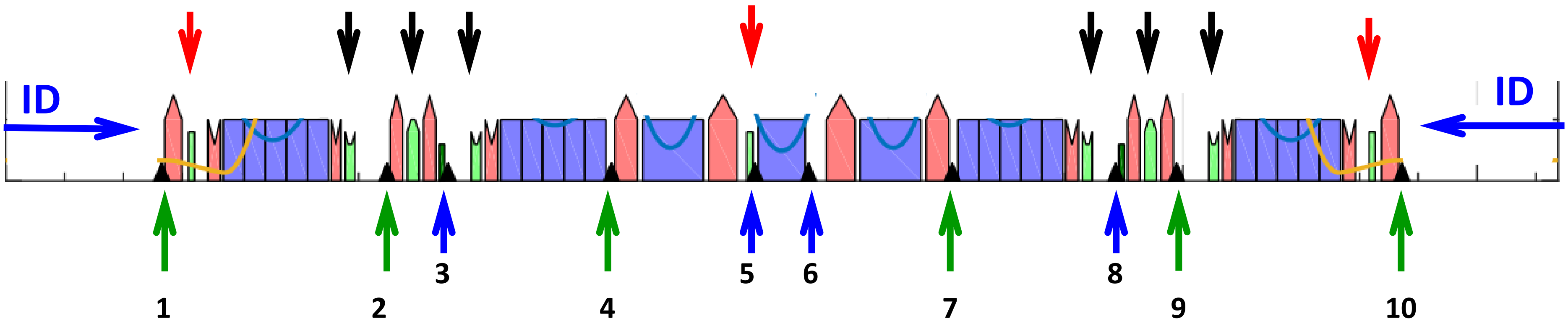


OLD Ring
NEW Ring
7 BPMs
10 BPMs
BPM-block
electronics
total: 224 BPMs
all doing Fast & Slow
orbit correction
total: 320 BPMs
128 Sparks for only Slow
192 Liberas for Fast & Slow
orbit correction
32 Liberas recup
for extra spares *
145 Sparks procured
then tested for 9 months
with real BPM signals in 2018
* helpful : our Liberas are
>10 years old and obsolete


20
18
16
14
12
10
8
6
4
2
0
β [m]
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
dispersion [m]
β_x
β_z
η_x
1
2
3
4
5
6
7
8
9
10
Libera
Spark
6 Liberas : Fast & Slow
4 Sparks : only Slow

correctors Slow : 6

correctors Fast & Slow : 3



Libera : BPMs :	1	2	.	4	.	.	7	.	9	10
Spark : BPMs :	.	.	3	.	5	6	.	8	.	.

in less critical positions

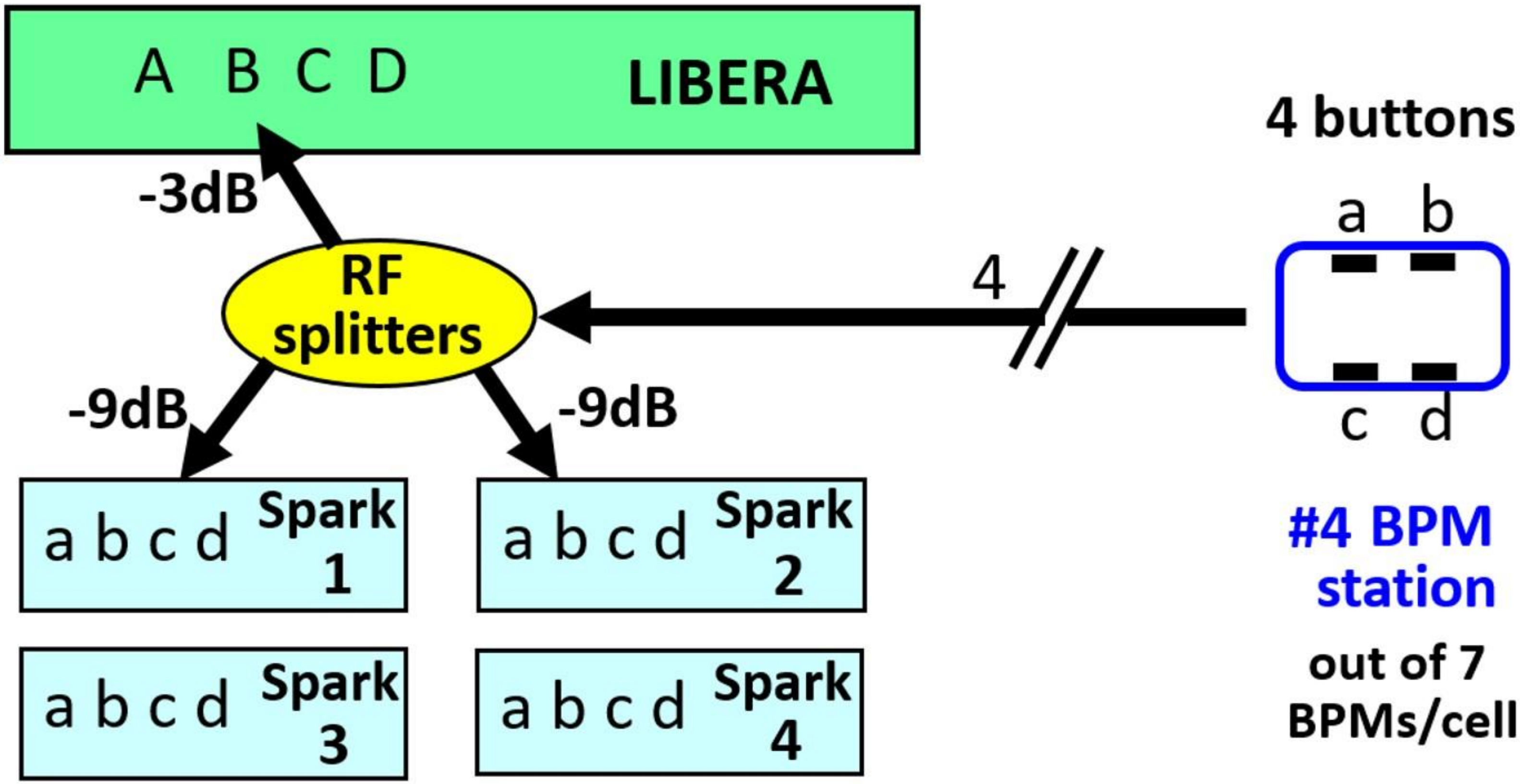
6 Liberas : Fast & Slow

4 Sparks : only Slow

145 Sparks procured

then tested for 9 months
with real BPM signals in 2018

IBIC-2018
TUPB02



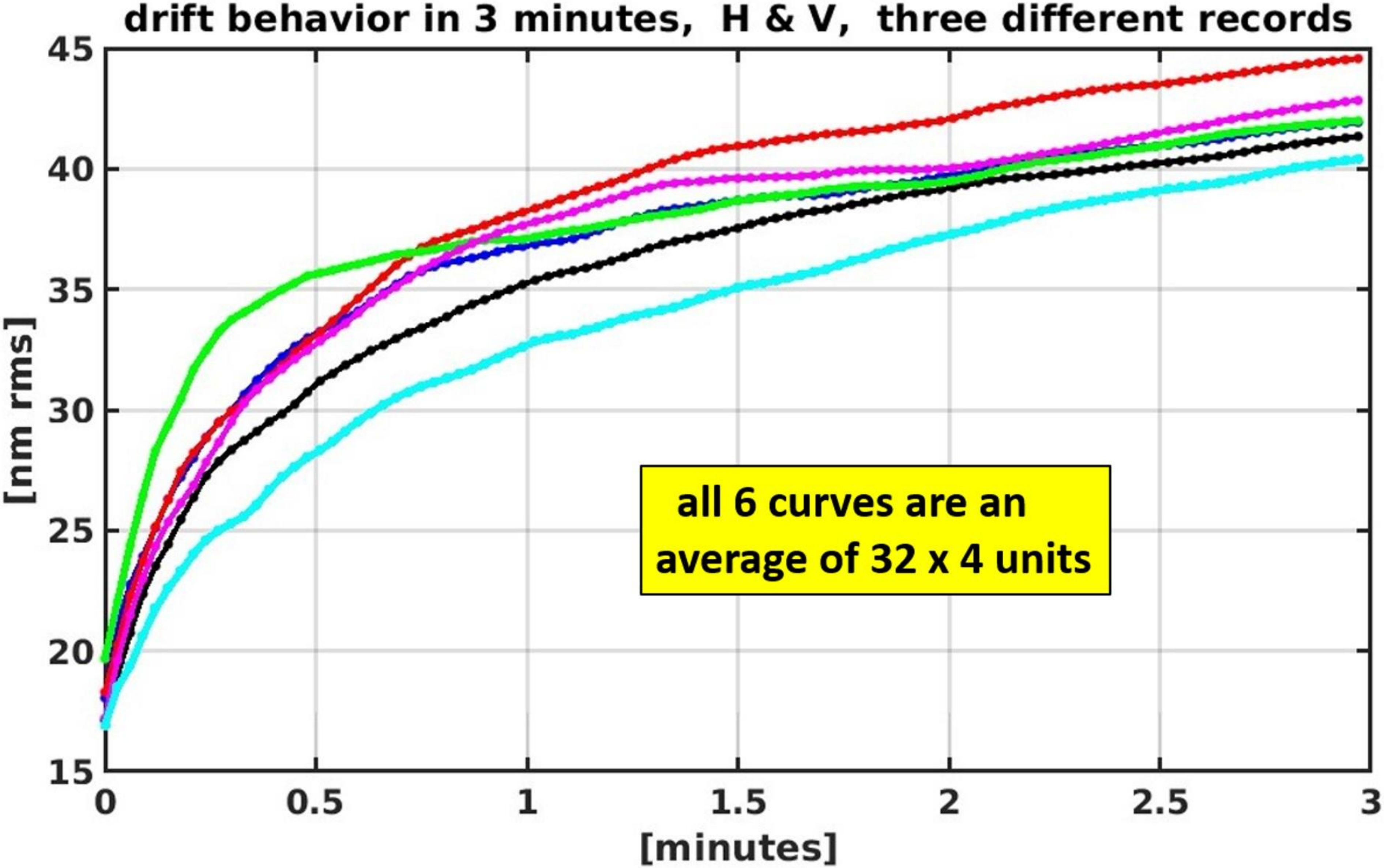
The general method was to detect any deviation
in H & V position data, with K=10 mm
between each of the 4 units,
being themselves in strict parallel & identical conditions.

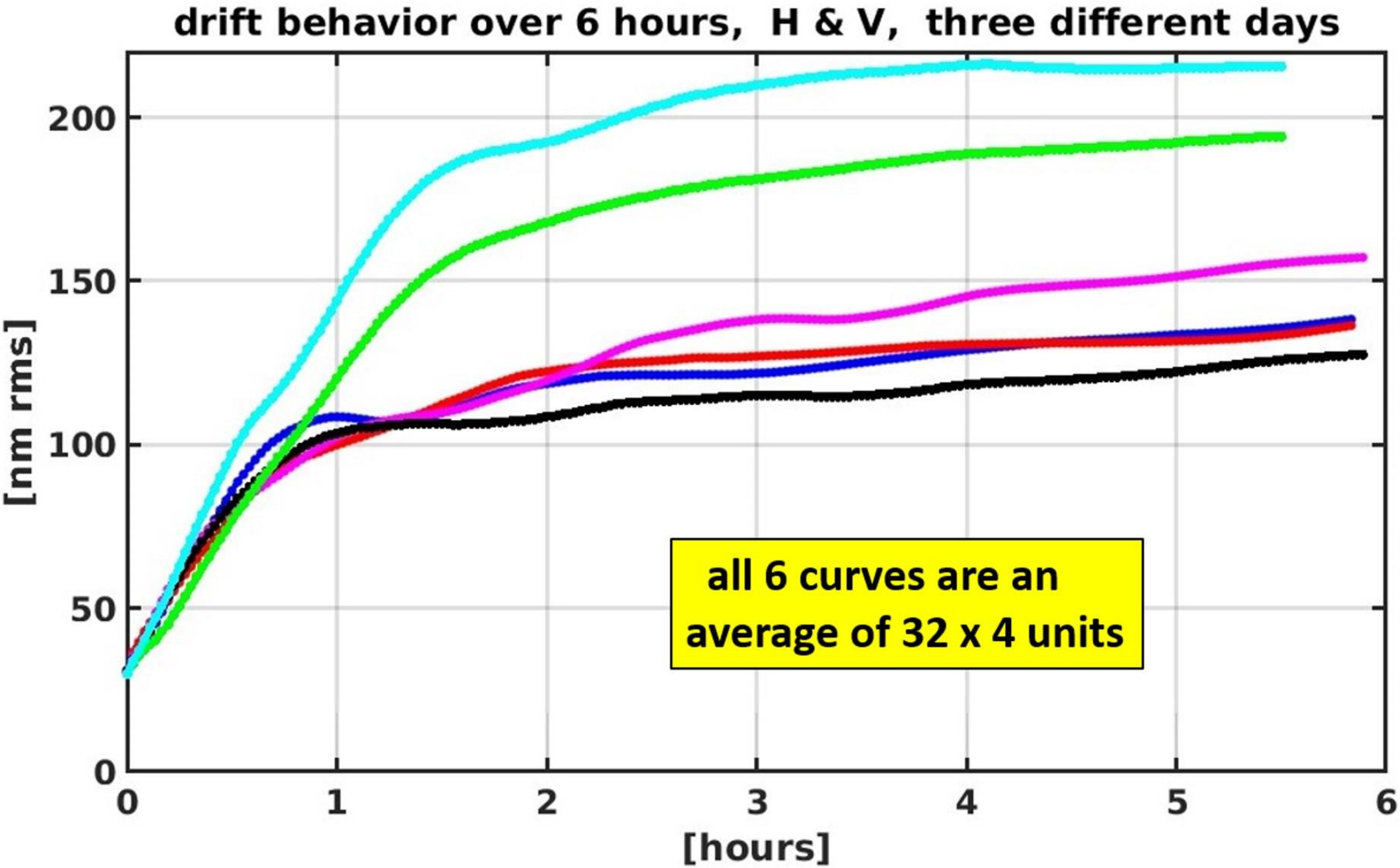
The RF-splitters themselves are supposed without any drift,
so any deviation (drift) detected is fully attributed to the Spark devices.

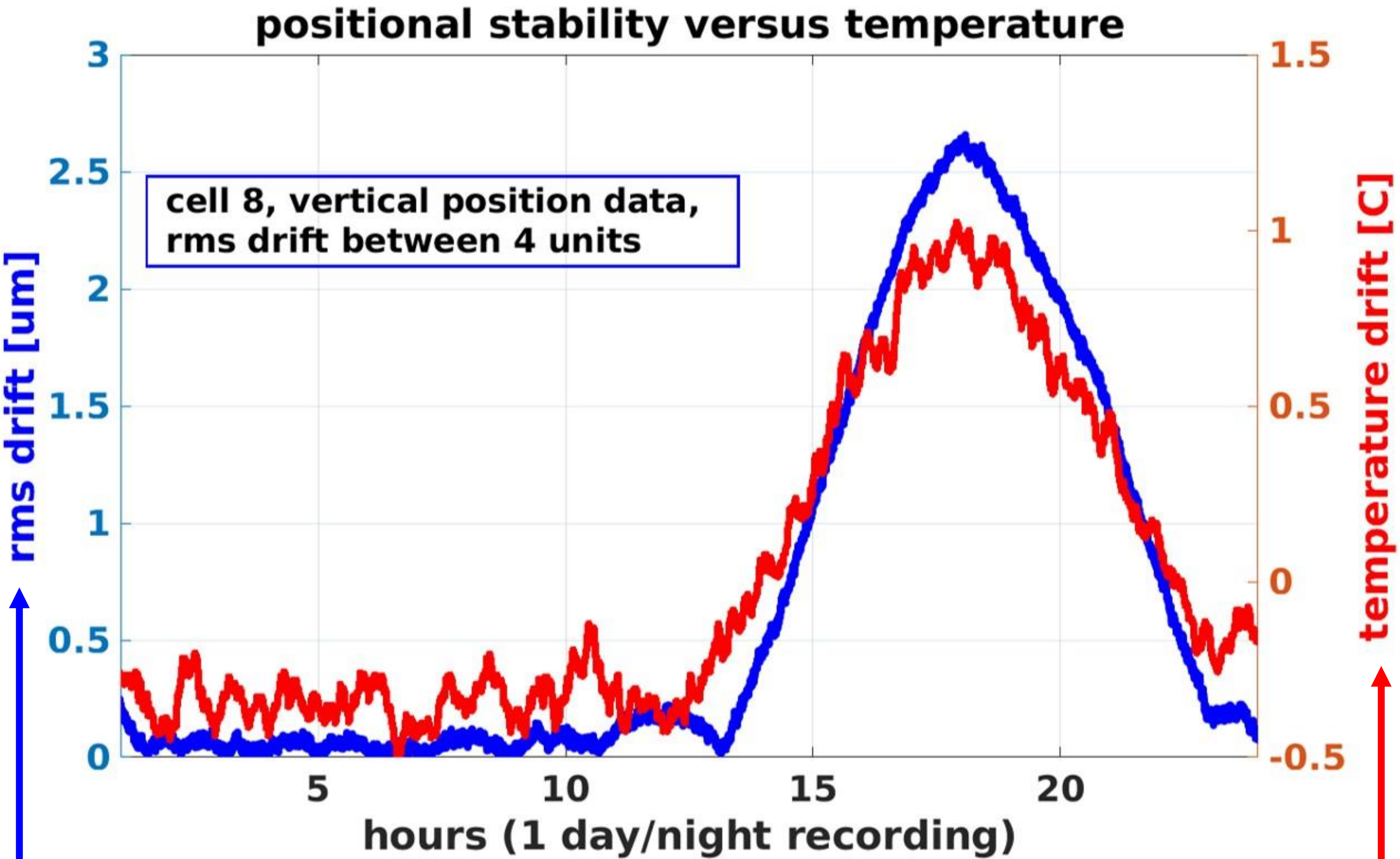
The initial position offsets (at To) of each on the 4 units were removed,
and the rms drift is then recorded from there on.

the next 2 slides show this drift behaviour over periods of respect.
3 minutes and 6 hours.
a total of 6 curves are shown : 2 planes (H & V) and 3 different recordings
to simply illustrate that such behaviour
is not strictly identical or very reproducible.

However, to be noted are the small values:
after **3 minutes** the rms drift is below **45 nm** and
after **6 hours** below **200 nm**

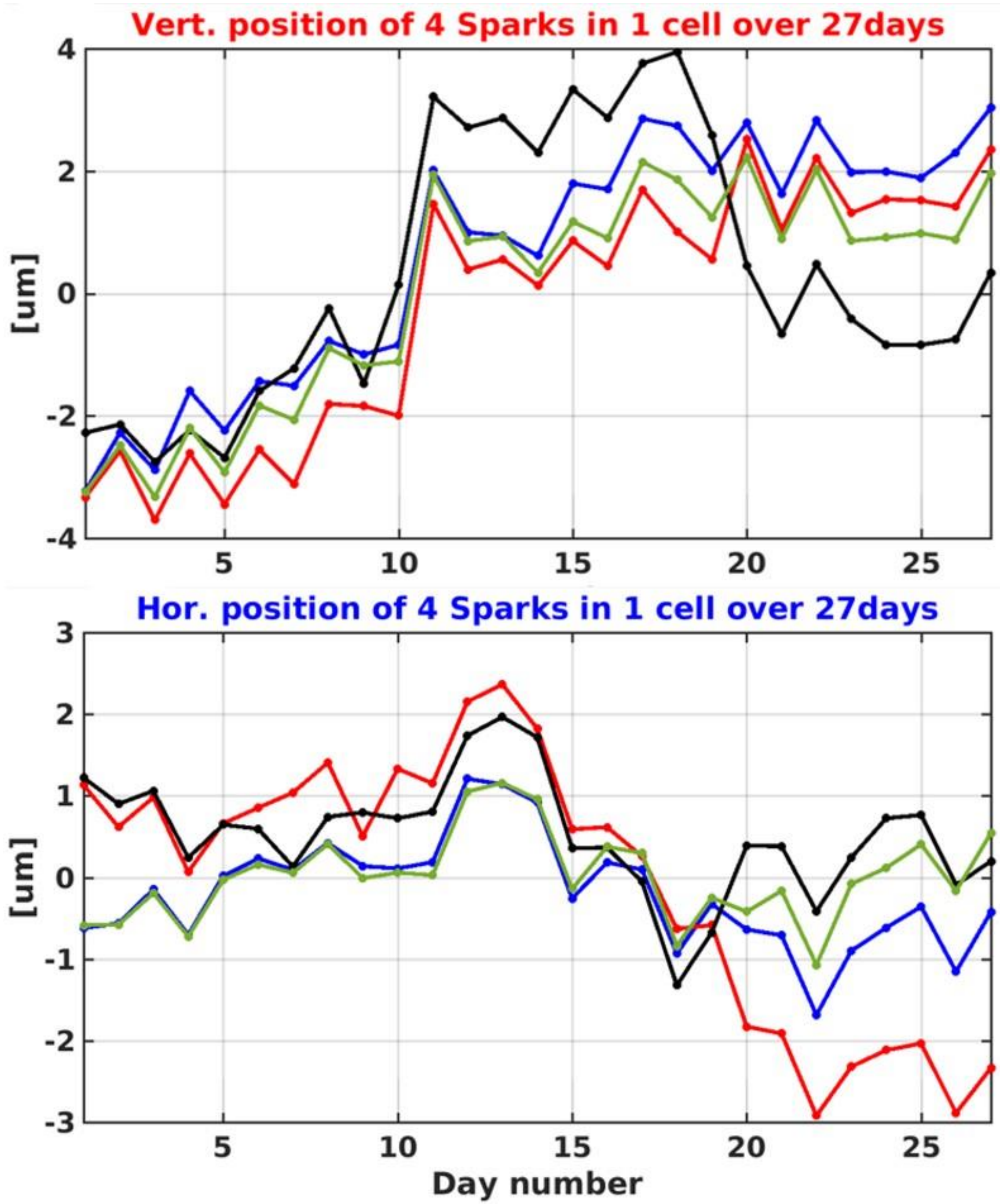

drift behavior in 3 minutes, H & V, three different records
45
40
35
30
25
20
15
[nm rms]
0
0.5
1
1.5
2
2.5
3
[minutes]
all 6 curves are an
average of 32 x 4 units


drift behavior over 6 hours, H & V, three different days
[nm rms]
[hours]
0
50
100
150
200
0
1
2
3
4
5
6
all 6 curves are an
average of 32 x 4 units



however, the Sparks are sensitive to temperature fluctuation
in our ***none-conditioned*** **cubicles** can have **2 degrees variation in 24hrs**

so to assess long-term stability (i.e. many days) I cut-out
the part with temperature fluctuations



stability over 27 days of
4 such Sparks in one cubicle.

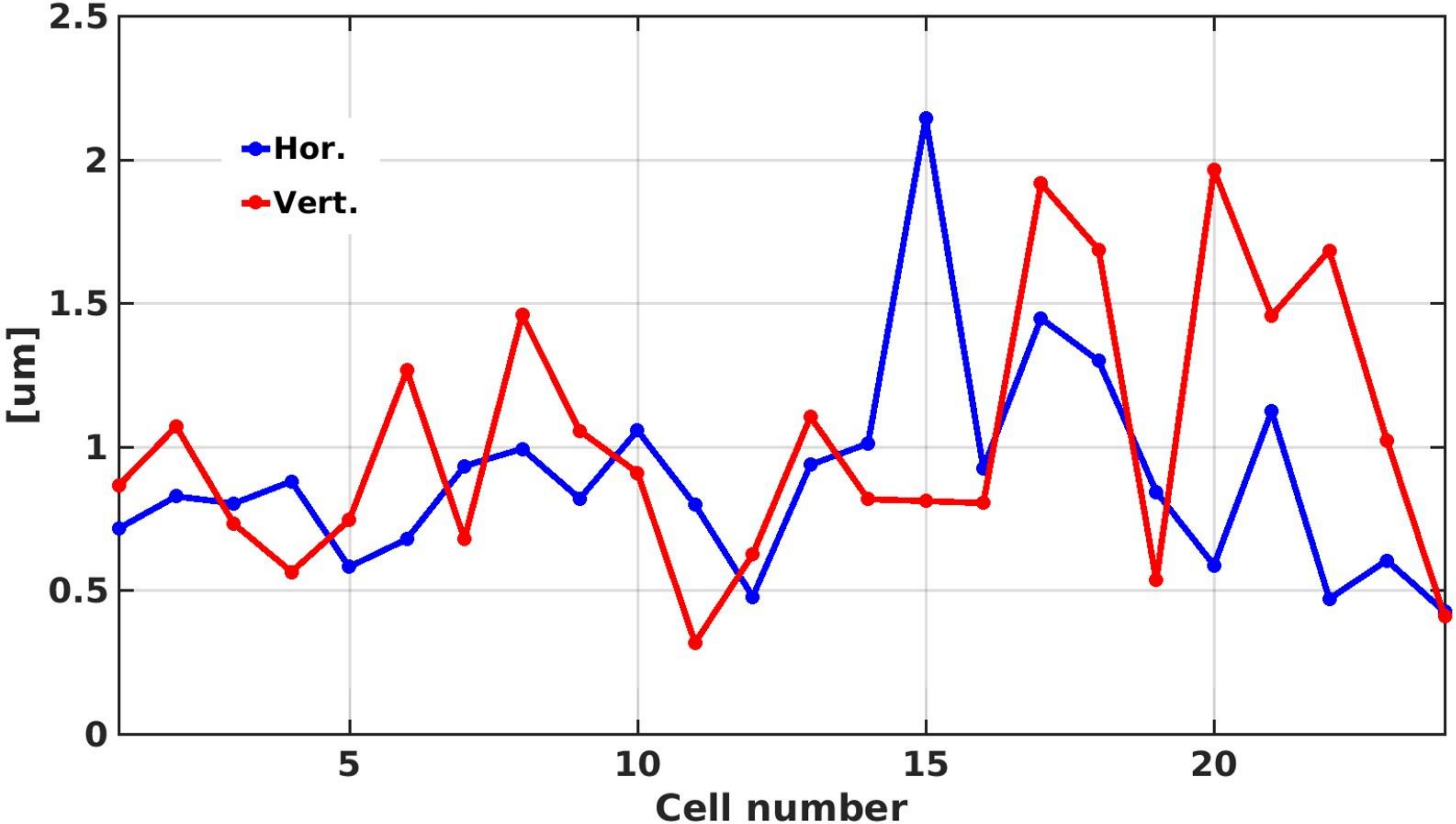
the curves show :

a) some <u>common</u> variation attributed to motion of the beam in that common BPM

and

b) the <u>non-common</u> part that can be attributed to <u>drifts of the Sparks</u>

rms drift between the 4 parallel Sparks per cell, over 27 days



Conclusion : typical long-term stability is about 1um *
by doing NOTHING …

* if temperature fluctuations in cubicle are suppressed

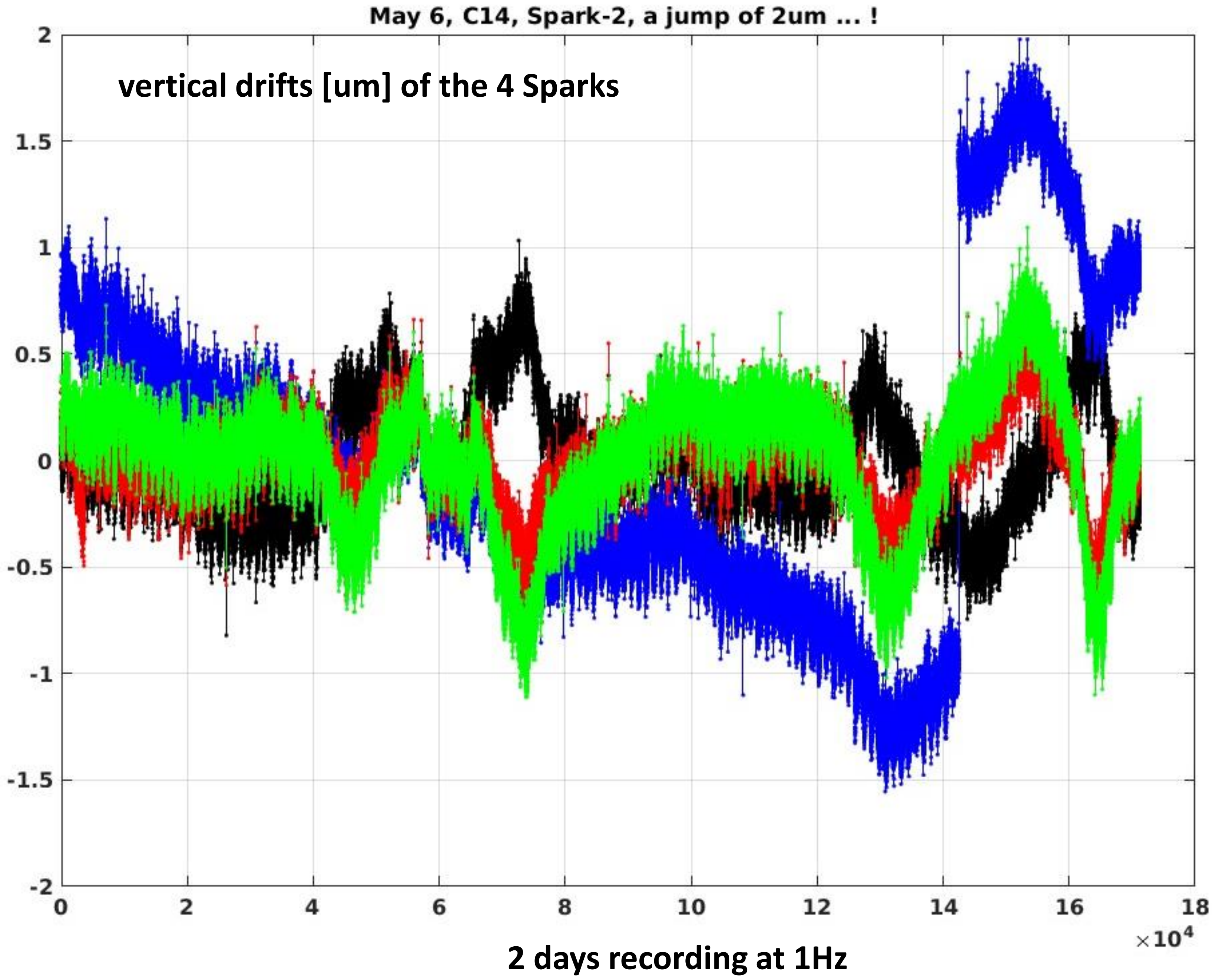
~~will we ever stop developing "BPM-electronics" … ?~~

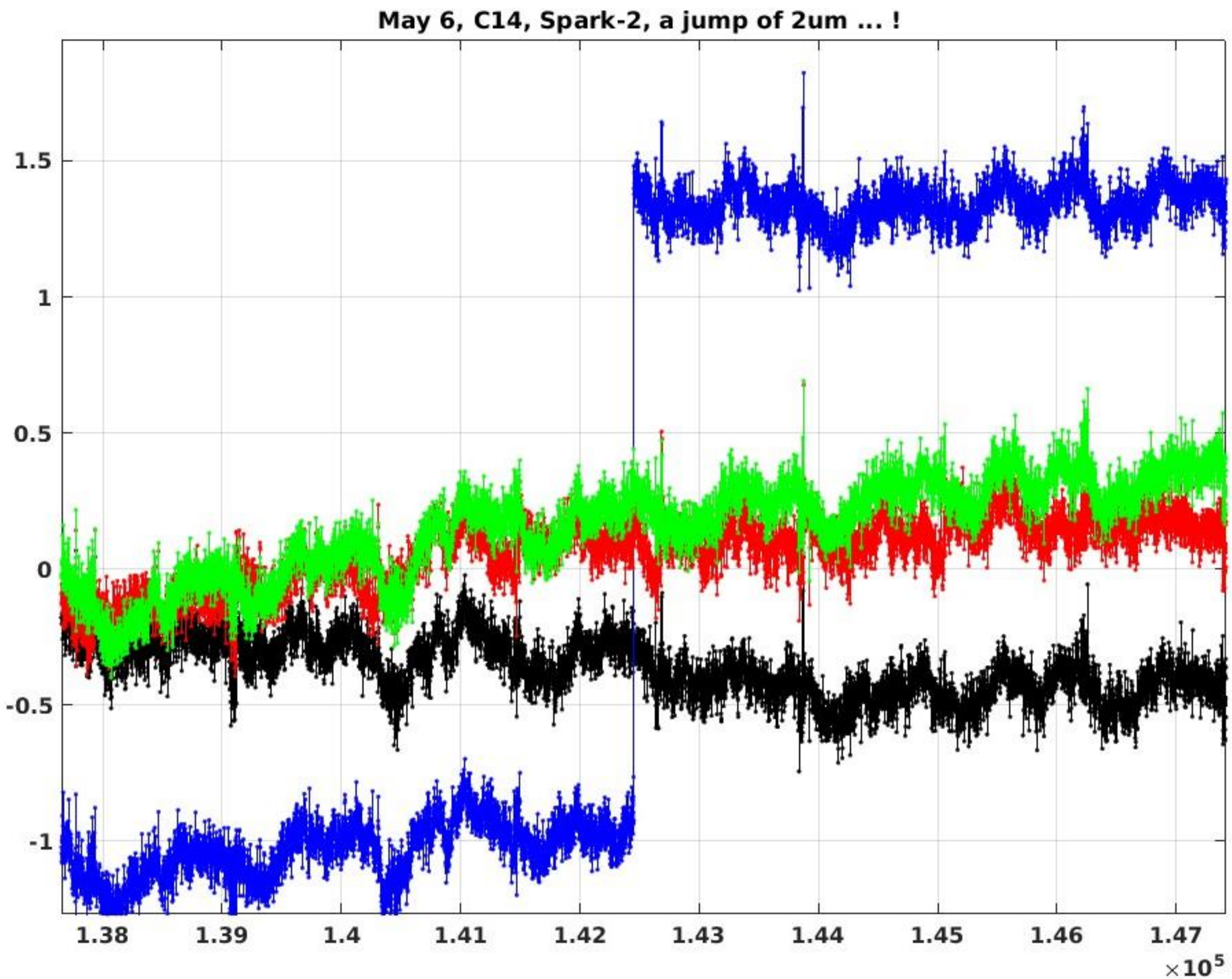
later …

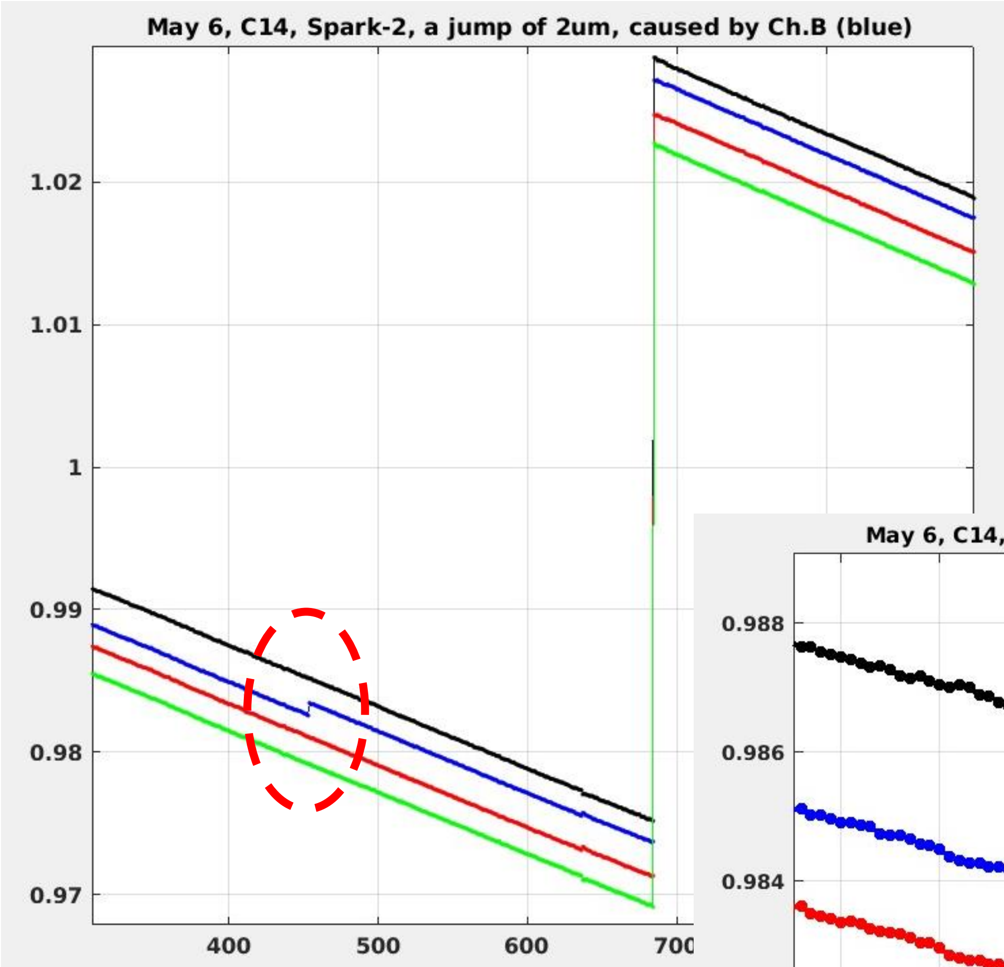
do I now feel 100% happy & relieved with these Sparks … ?

no, there is a snake ….

throughout 2018 we stored in our data base 1Hz data,
of all active Sparks of the 4 A - B - C - D signals
this allowed also assessment of reliability issues

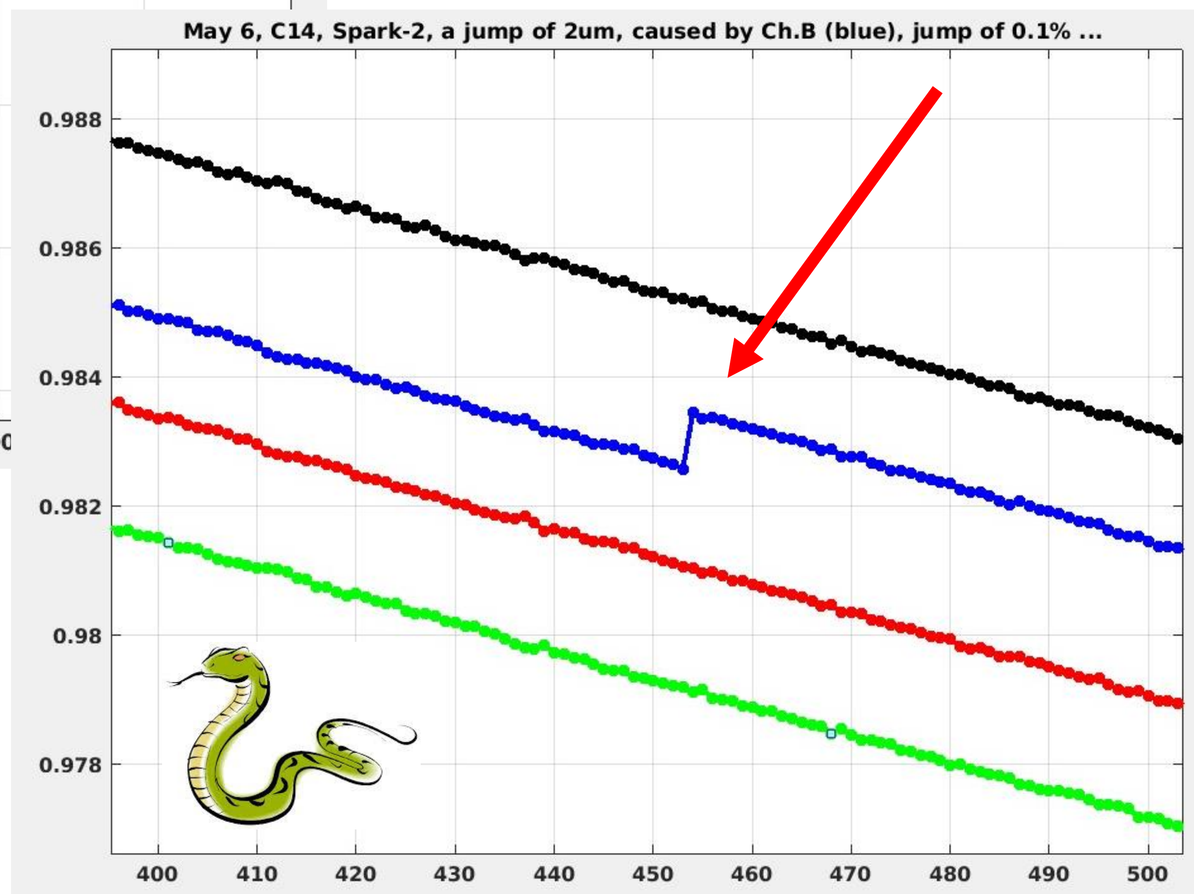

May 6, C14, Spark-2, a jump of 2um ... !
vertical drifts [um] of the 4 Sparks
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
0
2
4
6
8
10
12
14
16
18
×10^4
2 days recording at 1Hz


May 6, C14, Spark-2, a jump of 2um ... !
1.5
1
0.5
0
-0.5
-1
1.38
1.39
1.4
1.41
1.42
1.43
1.44
1.45
1.46
1.47
×10^5

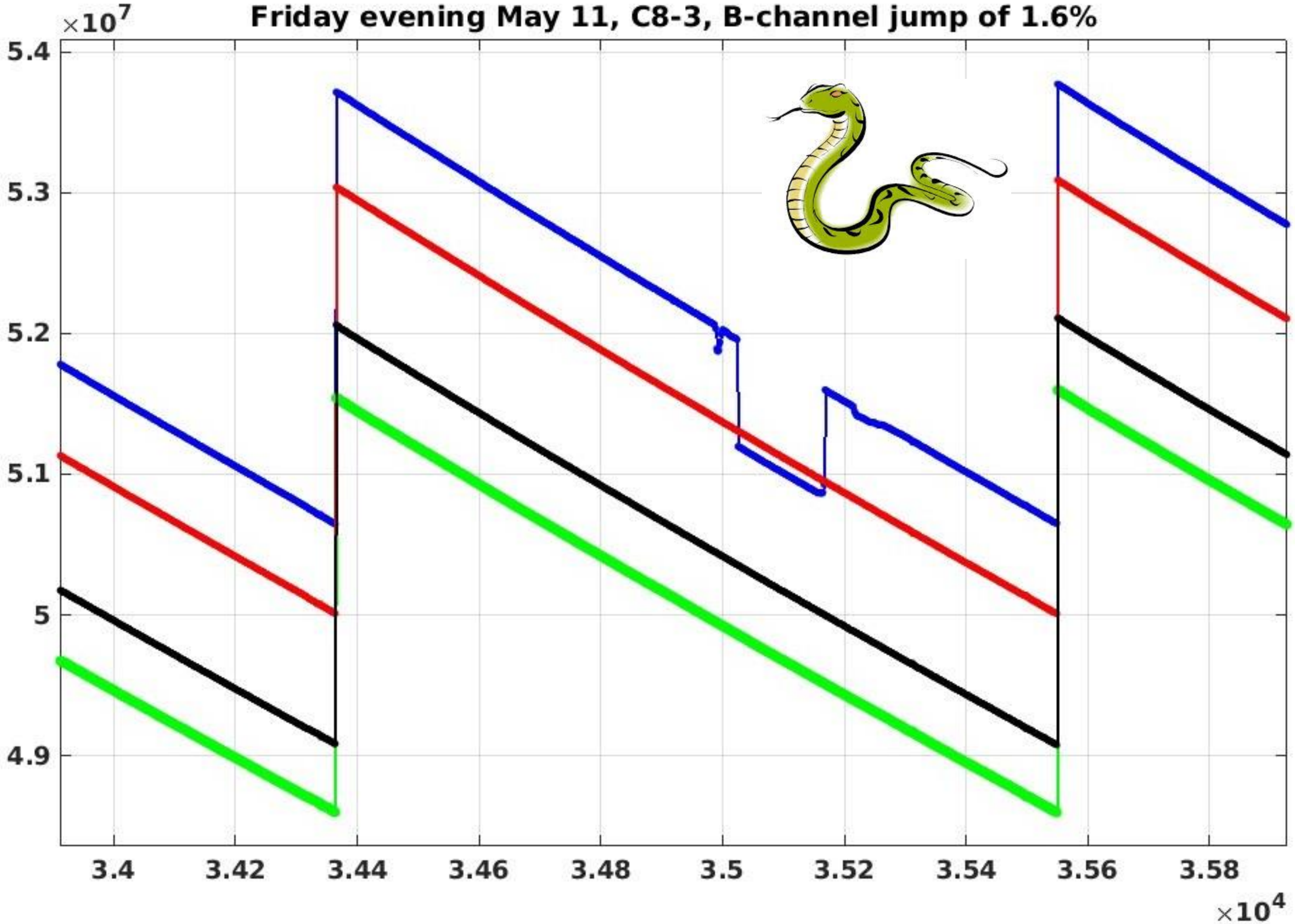


then we look at the
A B C D data
of that Spark ....

0.1% jump at Ch. B



latest events (May 11), another unit ….



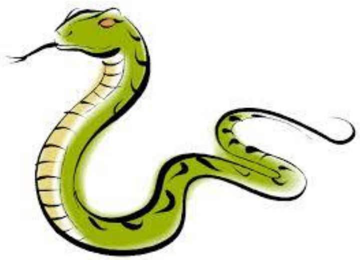
- in total now : 88 Sparks in operation = 352 channels
- started in February with 20 Sparks, followed by progressive installation
- A B C D data stored at 1Hz

→ estimation of 4500 Spark • Days recordings
→ equals : 4500 x 24 x 3600 x 4 = **1.5 E9 samples**

we found about **8 "jumps"** : twice on C14-2, Ch.**B**
*twice on C8-3, Ch.**B***
*and 4 other units (Ch.**A** or Ch.**B** …)*

these "jumps" are tiny or small (a um to 100um)

RF-splitters and/or RF-cabling an unlikely possible cause
(but not 100% excluded)



how to deal with this ? :

1) keep on checking in 2018, some units may be removed/repaired

2) once with beam (2020 and beyond) any detection of these jumps
will be difficult, i.e. to clearly distinguish from real beam motion,
but **surveying** the **Q** * will allow to detect the worst ones

3) trouble-shooting the real cause by **the company, by lab tests & manipulations**

*** Q = A+C-B-D / (A+B+C+D)** → does NOT vary (much) with beam motion
→ but jumps when one channel jumps

will we ever stop developing “BPM-electronics” … ?

what are the real reasons and motivations in the instrumentation community to continue to spend so much efforts in developing their own home-made BPM electronics ?

as a senior engineer (group head ?) in your institute,
do you have nothing else to do then …
“making your own BPM electronics” ???

do you also want to make your own cameras ?
your own network switches ? , or optics, or cables … ?

is um stability/drift really still an issue for the (existing) BPM-electronics ?

are other sources of drift not at least as important,
and today largely ignored and/or left aside ?

1) is sub-um (mid- and long-term) stability/drift really still an issue for the (existing) BPM-electronics ?

2) are other sources of drift not at least as important, and today largely ignored and/or left aside ?

3) how can we better assess these and then possibly counter-act ?

4) in the end, would X-BPMs not be the ultimate judge, and are collaborations between institutes (diagnostics groups) possible to define, develop and test an X-BPM that focuses on such slow stability issues (only) ?

Related questions :

5) how to handle upgrades during the lifetime of the product ?

6) how to ensure reliability ?

7) ultra-fast data-streams, how far to go ?

8) should BPMs be like: **smart phones**, or more like **self built PCs** ?

extra slides, only in cases of questions

ADC	Att.	Input	Current	Resolution	Resolution
[cnts]	[dB]	[dBm]	[mA]	T-b-T rate	SA-rate (40Hz)
				[um]	[nm]
3000	10 .. 31	> -30	> 25	< 0.3	< 10
3000	5	-35	15.4	0.44	11
3000	0	-40	8.7	0.72	13
1687	0	-45	4.9	1.27	16
949	0	-50	2.7	2.26	27
533	0	-55	1.5	4.01	39
300	0	-60	0.9	7.14	73
169	0	-65	0.5	12.7	117
95	0	-70	0.3	22.7	209

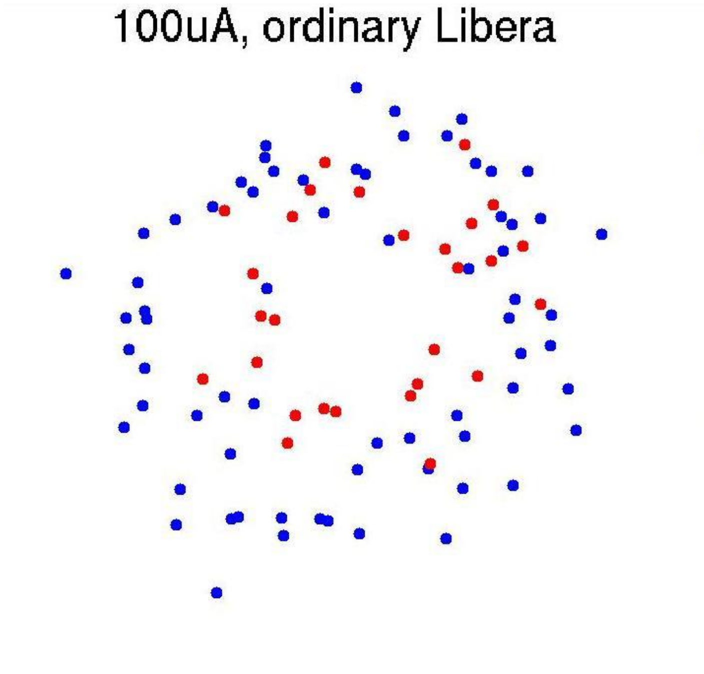
BPM rms resolution versus beam current

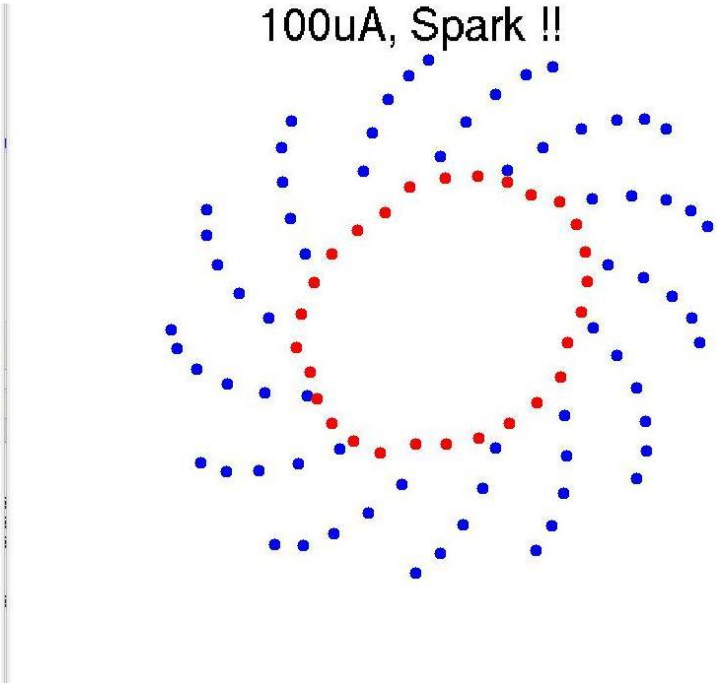
in short : 40Hz SA stream : < 15nm
T-b-T (355KHz) : < 1um

} with current >5mA

Libera vs **Spark** :

Phase/Space* plots from Turn-by-Turn data (at 0.1mA, **single-bunch**)

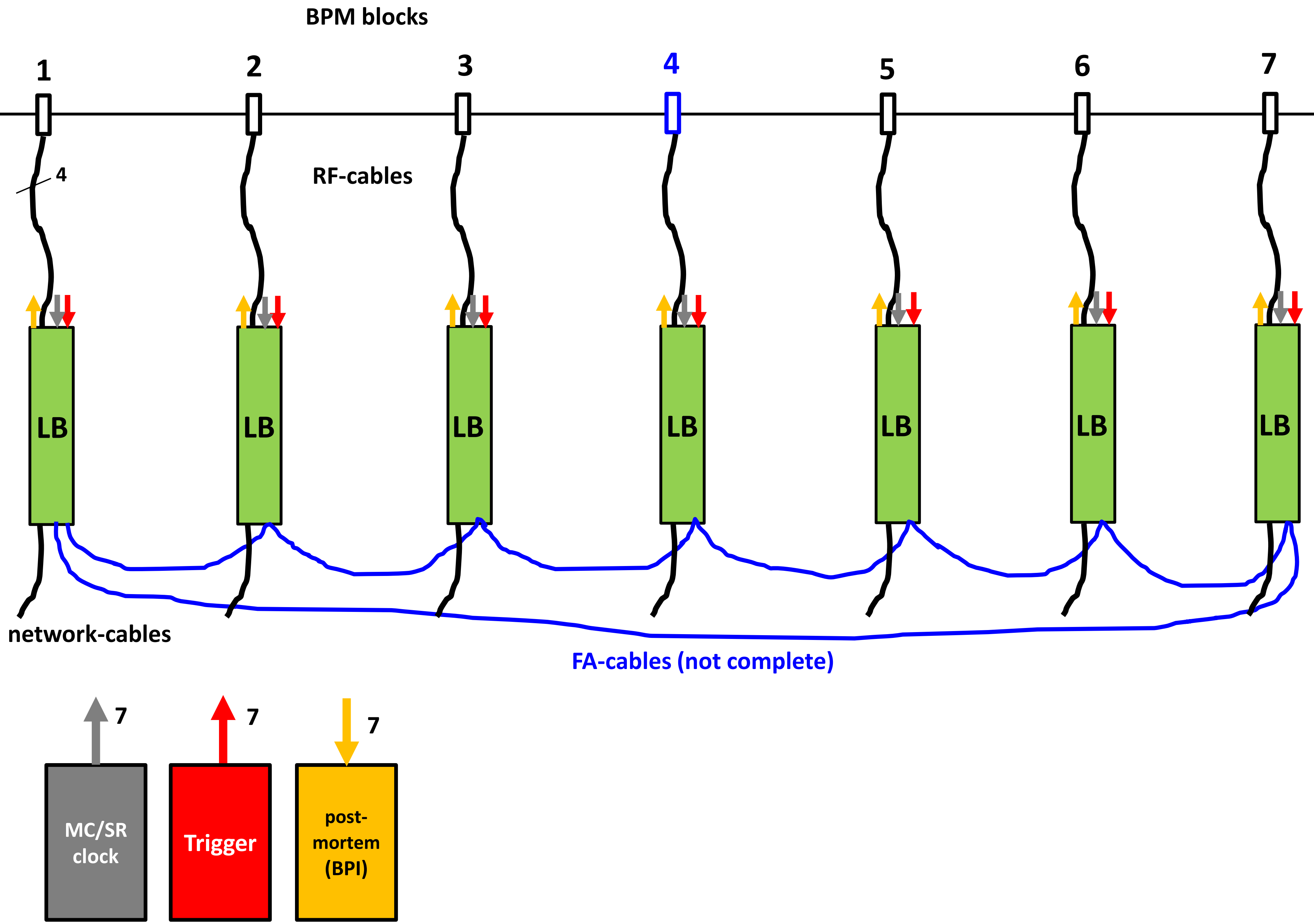




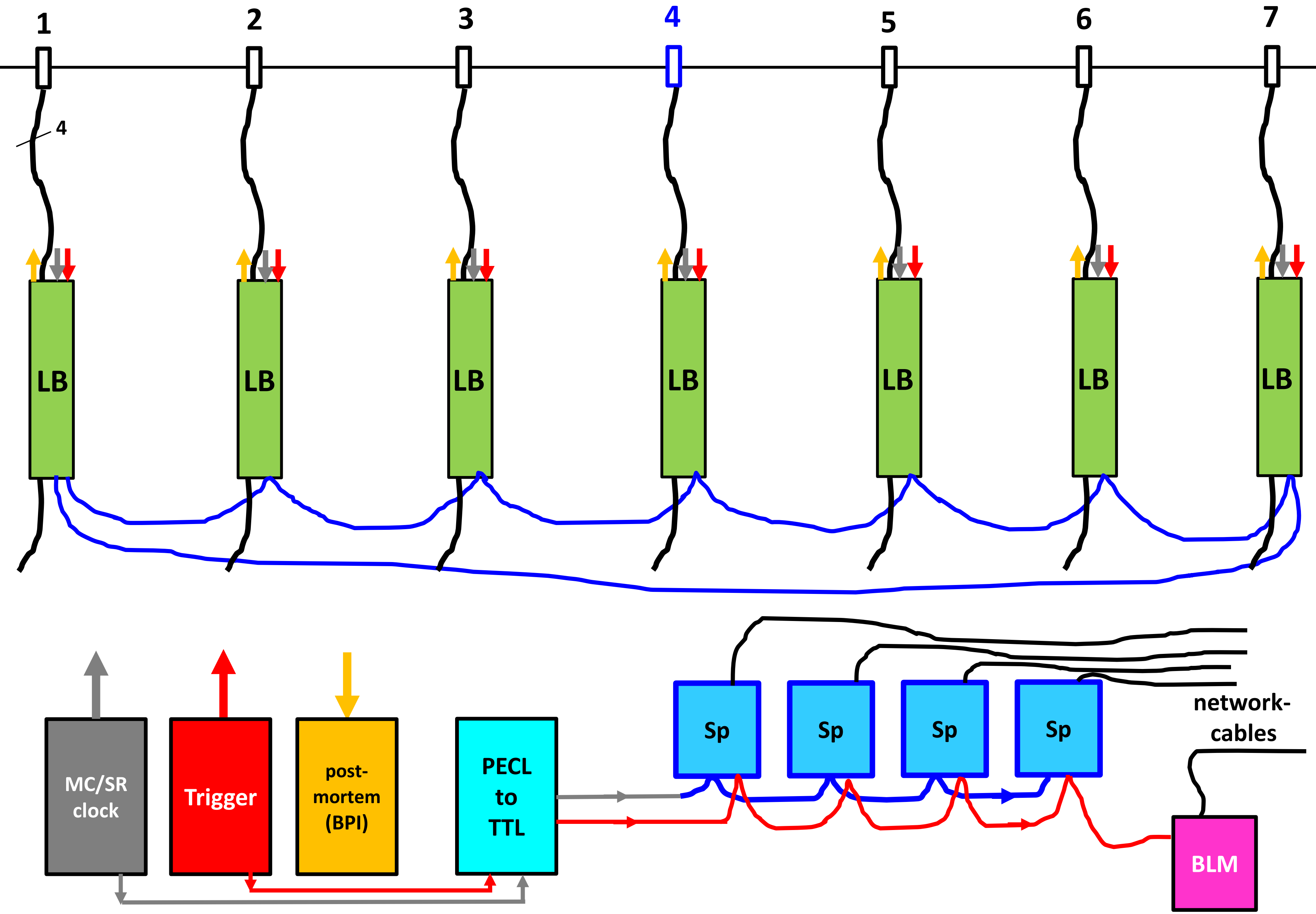
25m RF cable, standard DDC

3m RF cable, Time-Domain-Processing

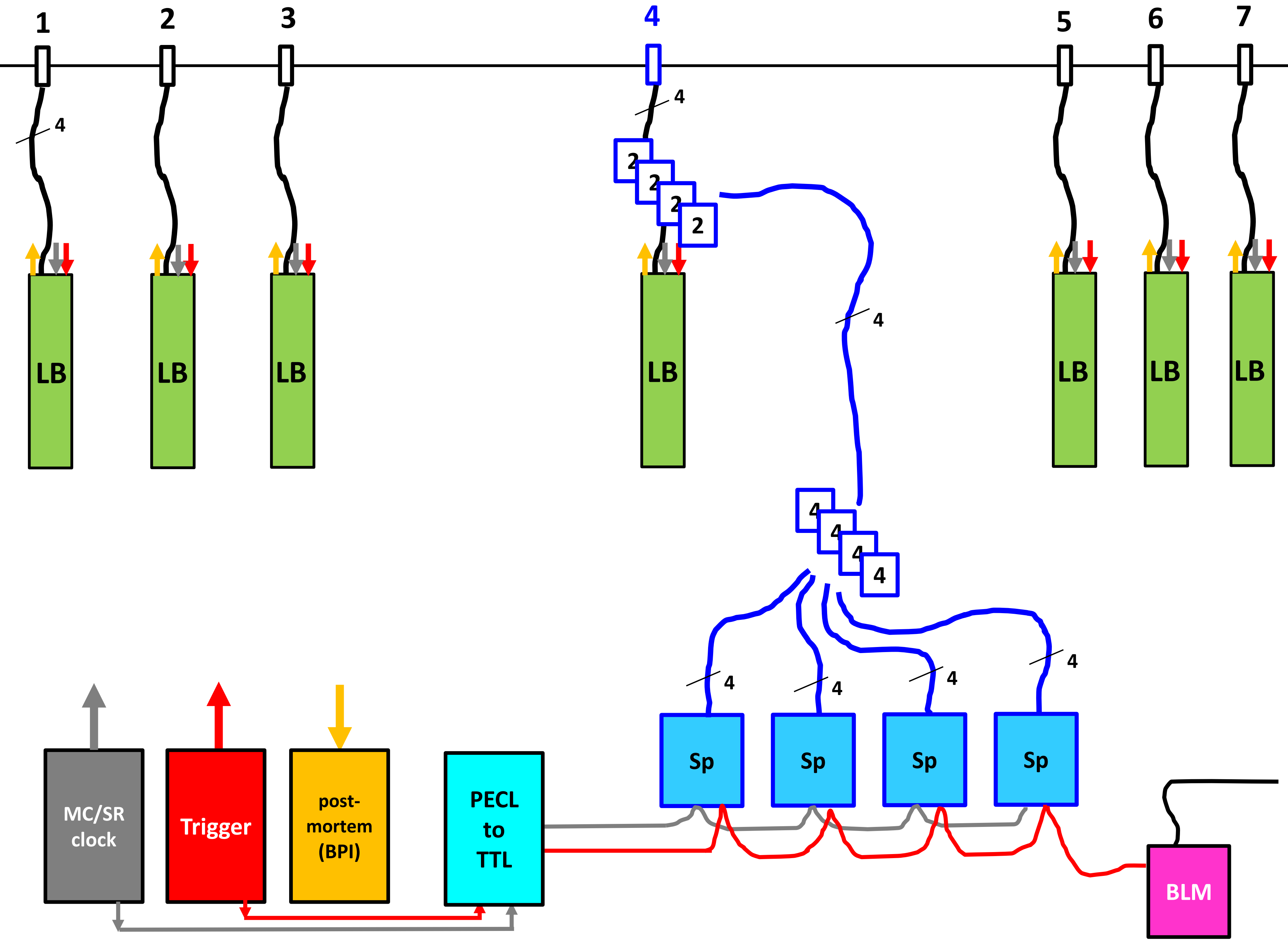
*** poor man's**



BPM blocks
1
2
3
4
5
6
7
RF-cables
4
LB
LB
LB
LB
LB
LB
LB
network-cables
FA-cables (not complete)
7
7
7
MC/SR clock
Trigger
post-mortem (BPI)



1
2
3
4
5
6
7
4
LB
LB
LB
LB
LB
LB
LB
MC/SR clock
Trigger
post-mortem (BPI)
PECL to TTL
Sp
Sp
Sp
Sp
network-cables
BLM



1
2
3
4
5
6
7
4
4
2
2
2
2
LB
LB
LB
LB
LB
LB
LB
4
4
4
4
4
4
4
4
4
4
Sp
Sp
Sp
Sp
MC/SR clock
Trigger
post-mortem (BPI)
PECL to TTL
BLM