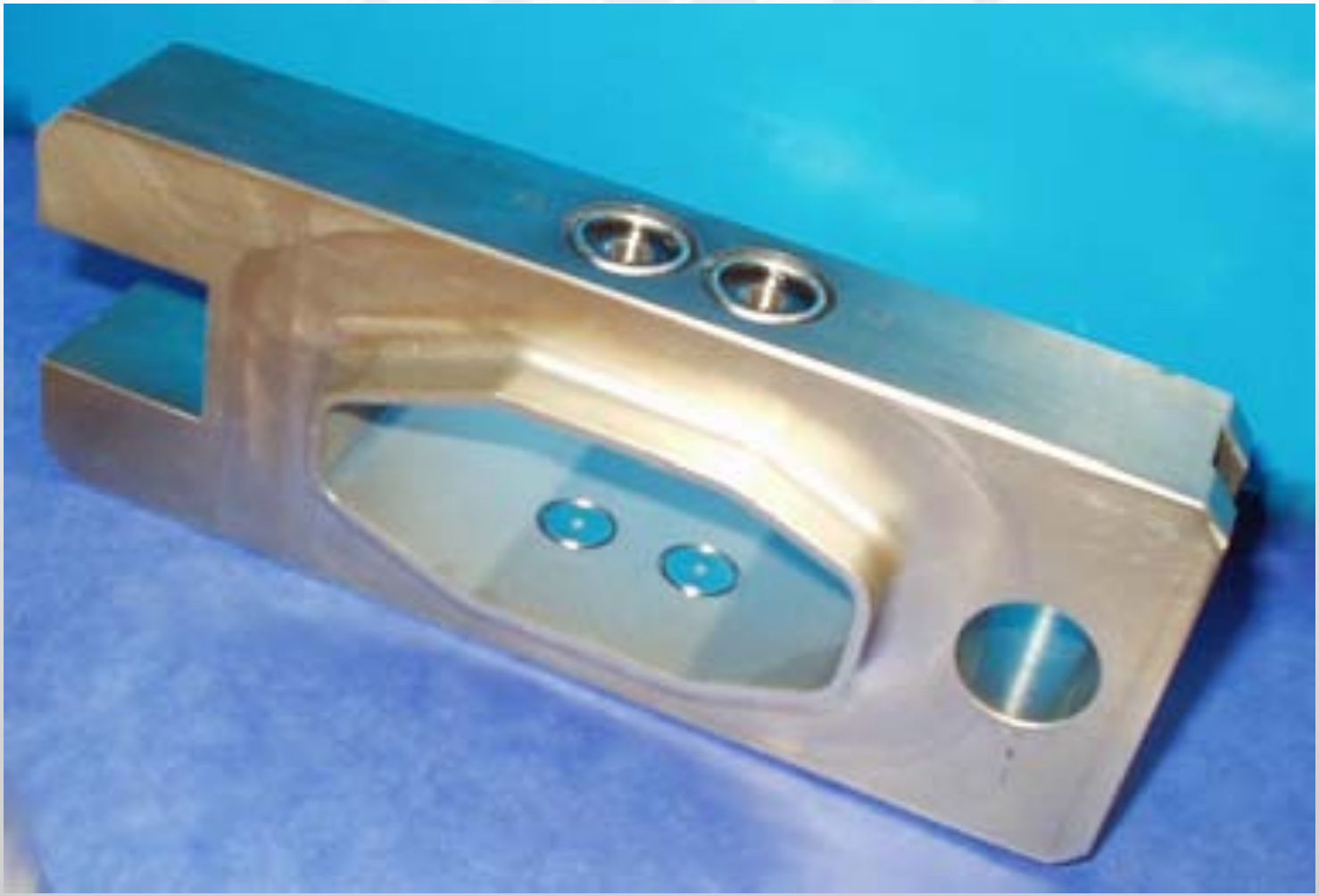
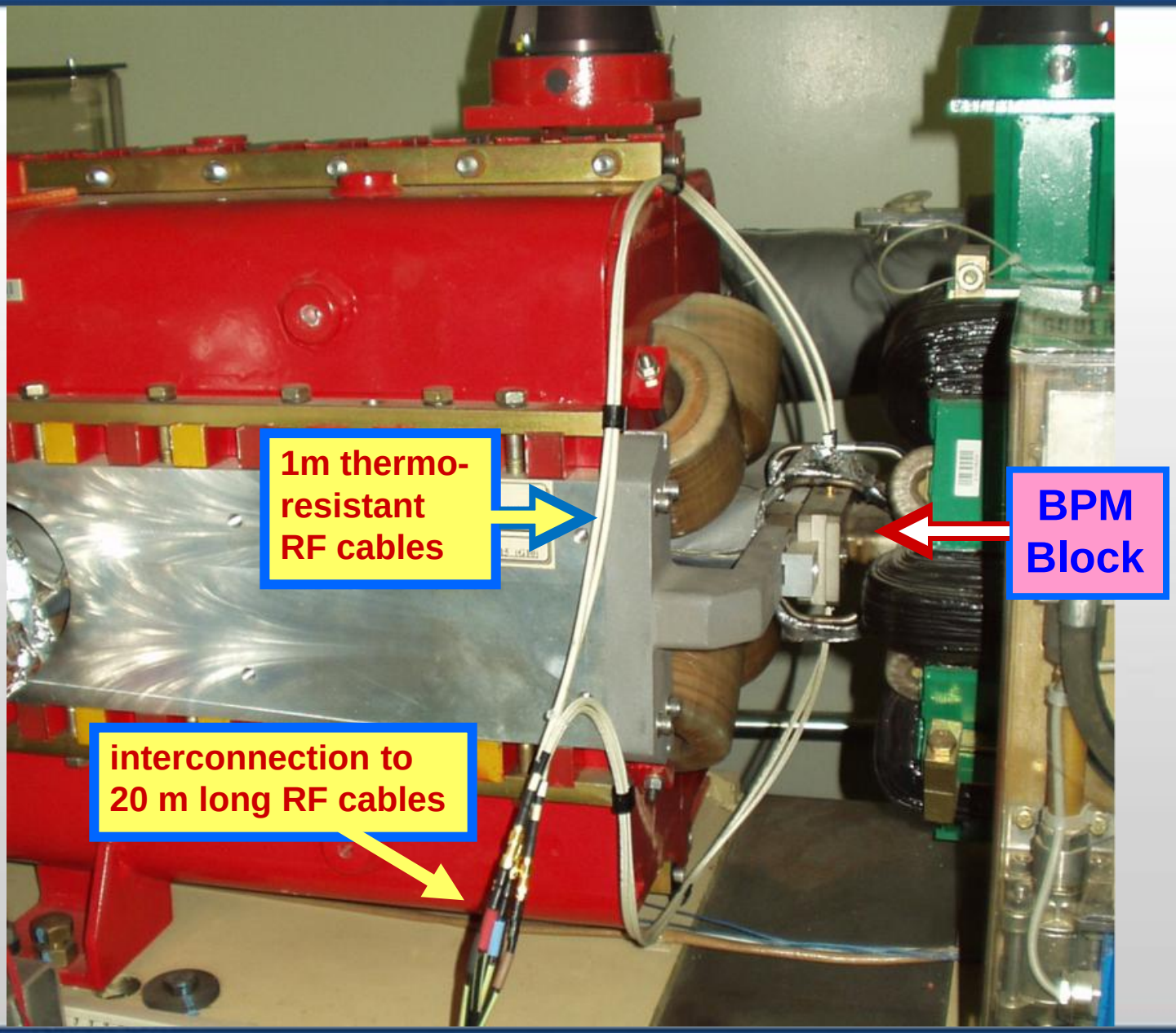
Towards full use of the Libera BPMs in the ESRF Storage Ring

- Using the **ADCs** for verifications on the Kickers — 108 MHz
- Using the T-b-T output with **Standard** & **MAF** T.b.T filter for Injection-Trajectory studies & H.Q. lattice studies — 355 KHz
- Preparing the FA output & distribution network for the near-future's use in Fast/Slow full global orbit stabilization — 10 KHz
- The DD-64 output for precise & strict survey of the beam's AC position stability — 5.5 KHz
- The SA output for the survey & control of the 'slow' beam position stability — 10 Hz
- The SA-**Sum** output for H.Q. Lifetime & 'beam-drop' & 'accumulation' monitoring
- The PM-buffer for detailed analysis of 'events' after 'total beam-cut'

The BPM block with its 4 capacitive buttons



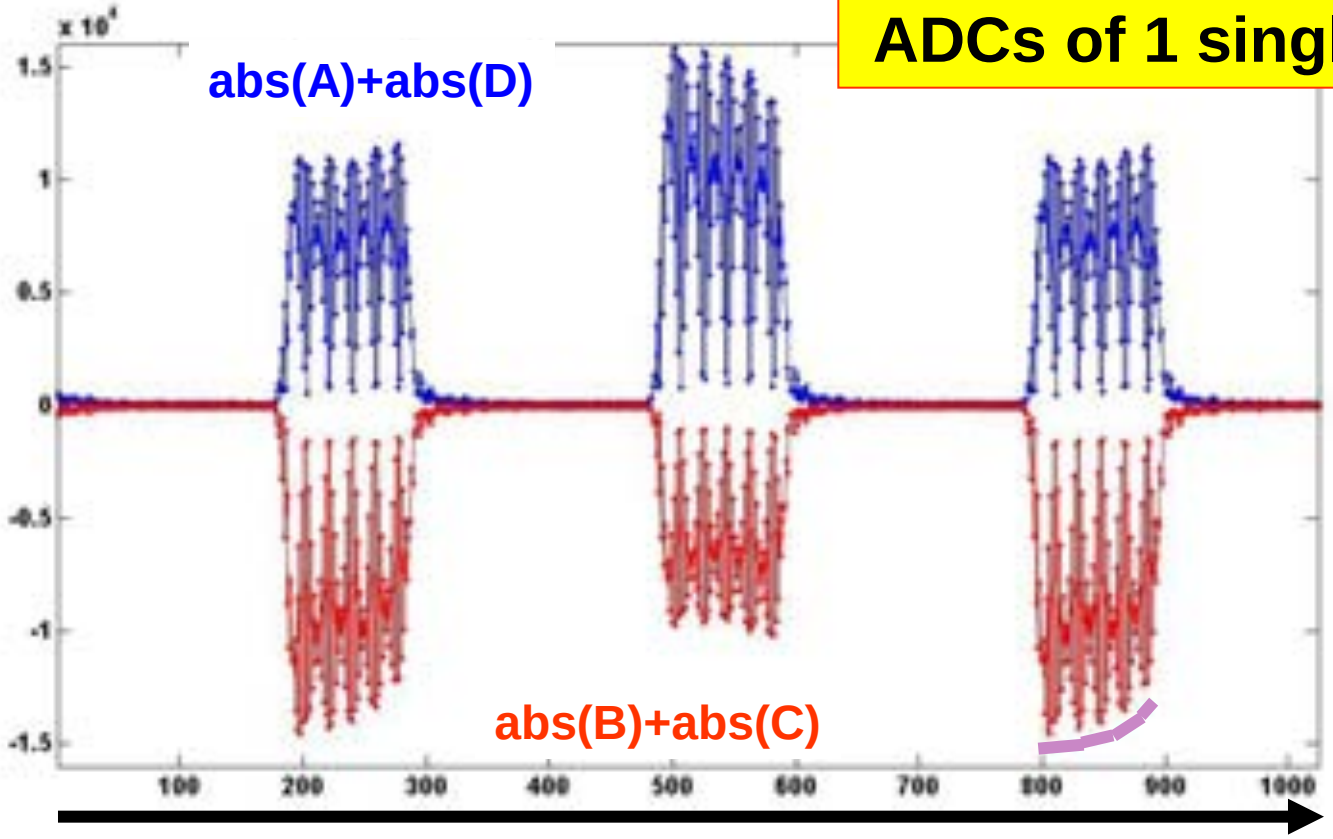

1m thermo-
resistant
RF cables
BPM
Block
interconnection to
20 m long RF cables

108 MHz

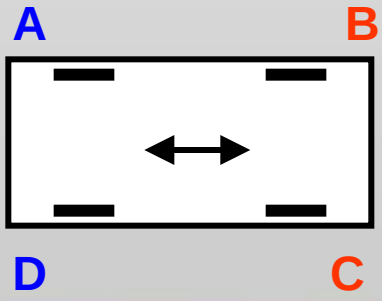
Using the **ADCs** for verifications on the Kickers

- correct timing ,
- ‘skew’ ,
- overshoot & after-pulse etc.

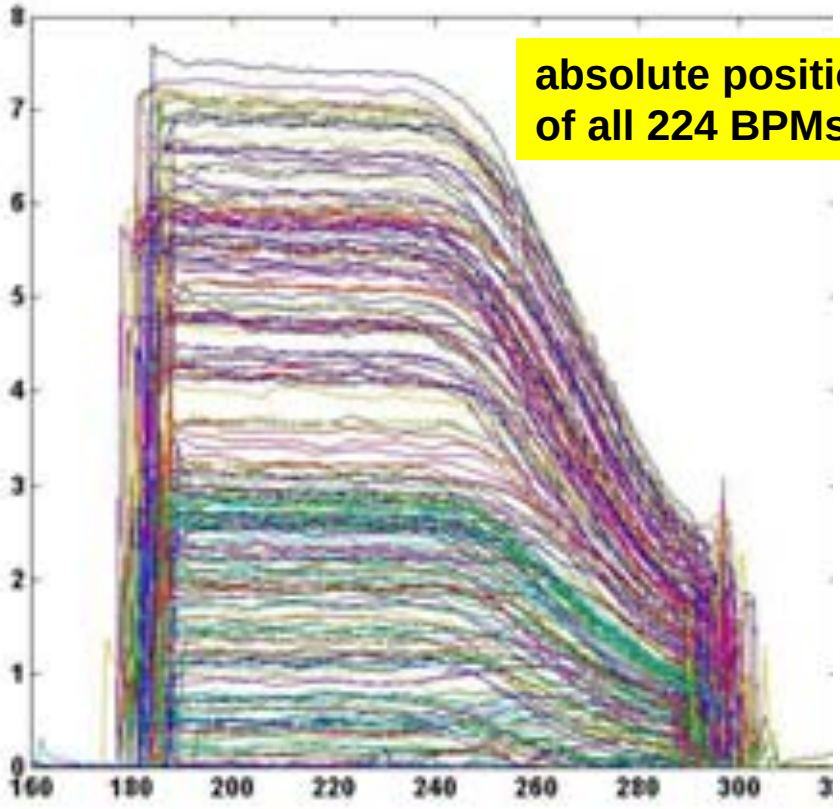
ADCs of 1 single BPM

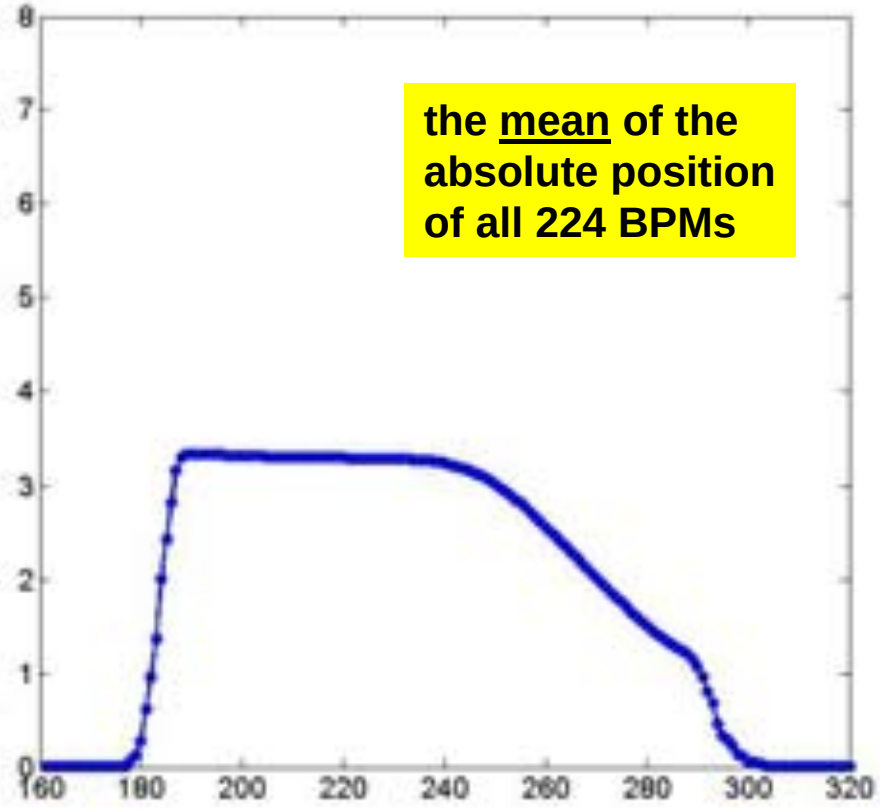


1024 ADC samples (~10nS) → see 3 Turns



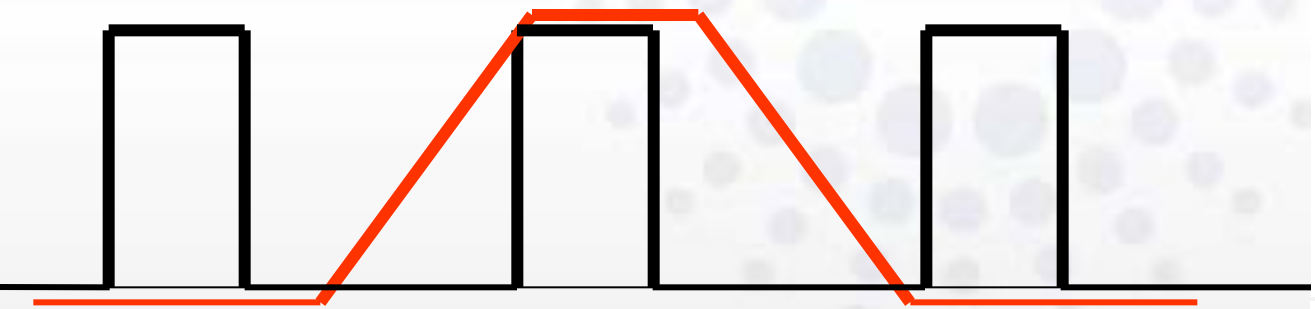
Beam being (single-Turn) kicked,
by 1 single injection kicker
but the kick is NOT flat,
but skewed . . .

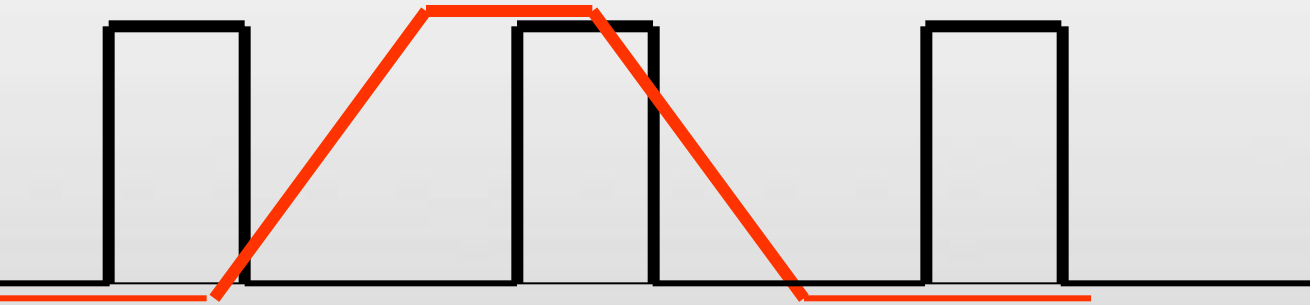


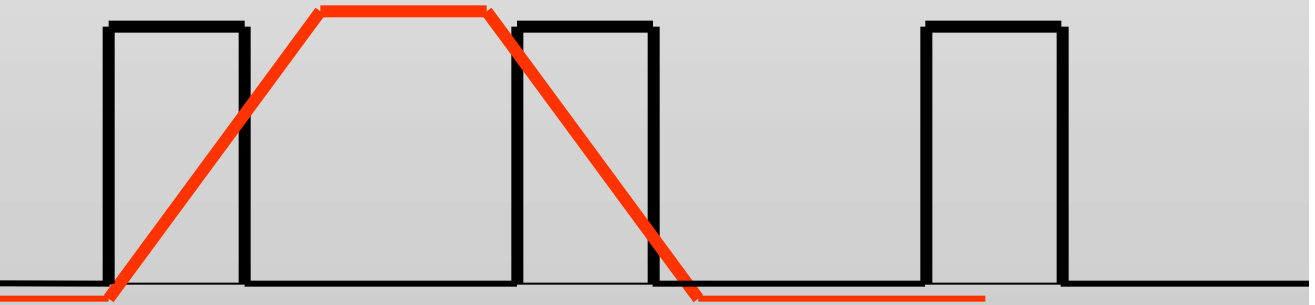


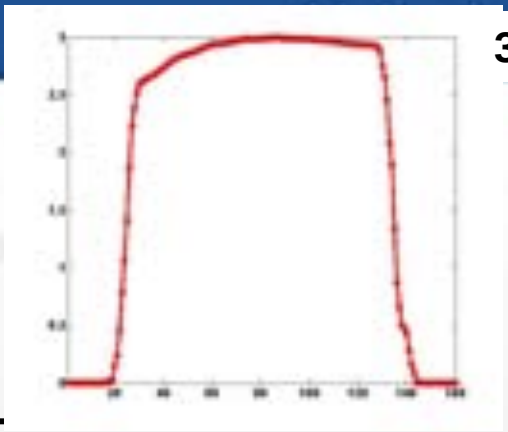
~100 ADC samples (~9.3nS)
(= 1 us = 1/3 fill)

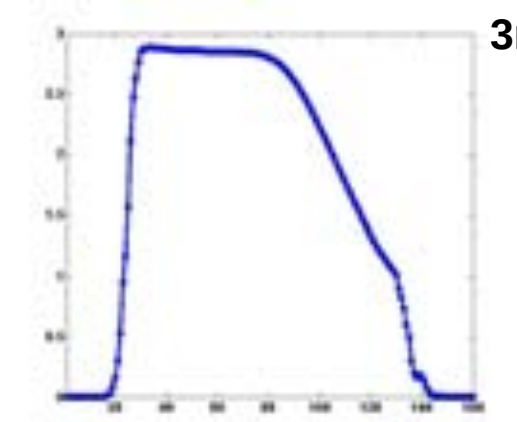
~100 ADC samples (~10nS)
(= 1 uS = 1/3 fill)

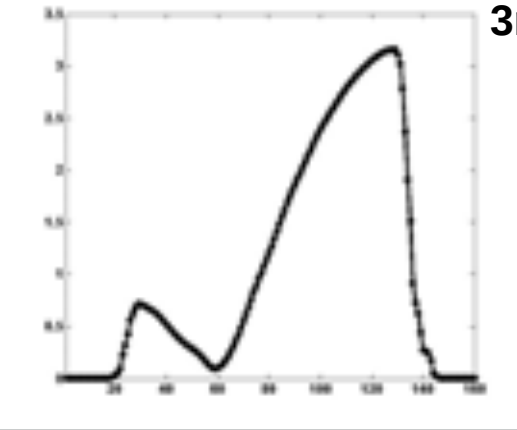


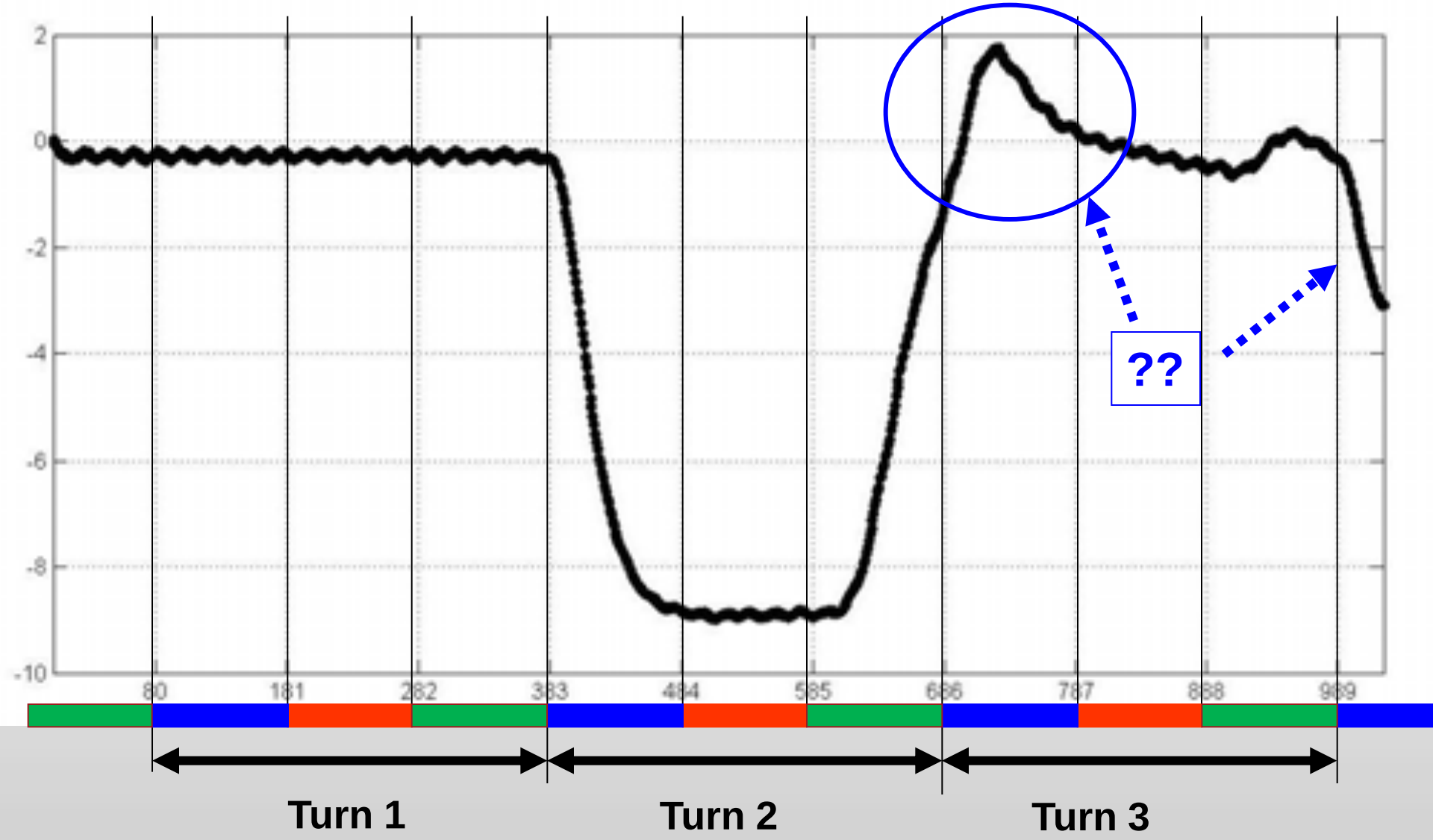





3mm

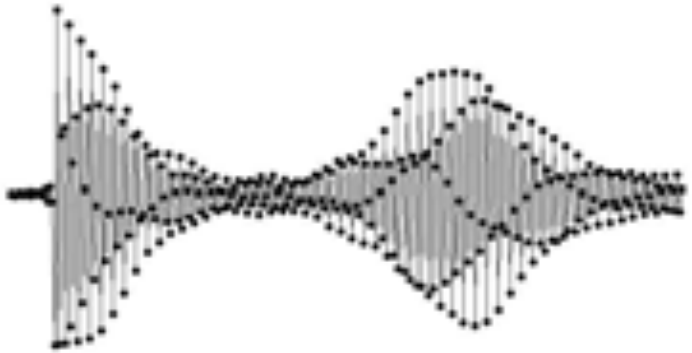

3mm


3mm



Kicker <u>bump</u> seen on a BPM that is <u>inside the bump</u>, with <u>uniform fill</u>, over 3 turns with sub-turn details

355 KHz



Turn-by-Turn measurements :

-- Kick the beam transversely

-- Measure positions on all BPMs at each orbit Turn

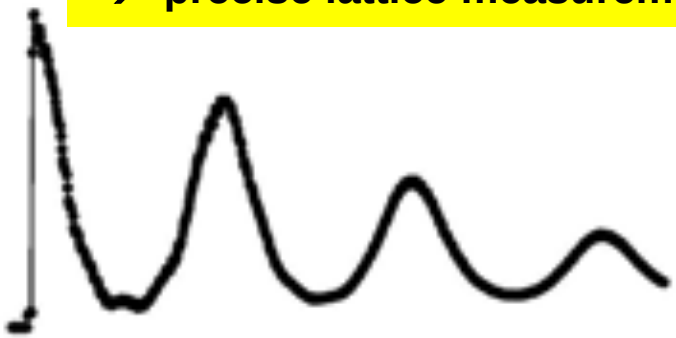
→ precise lattice measurement

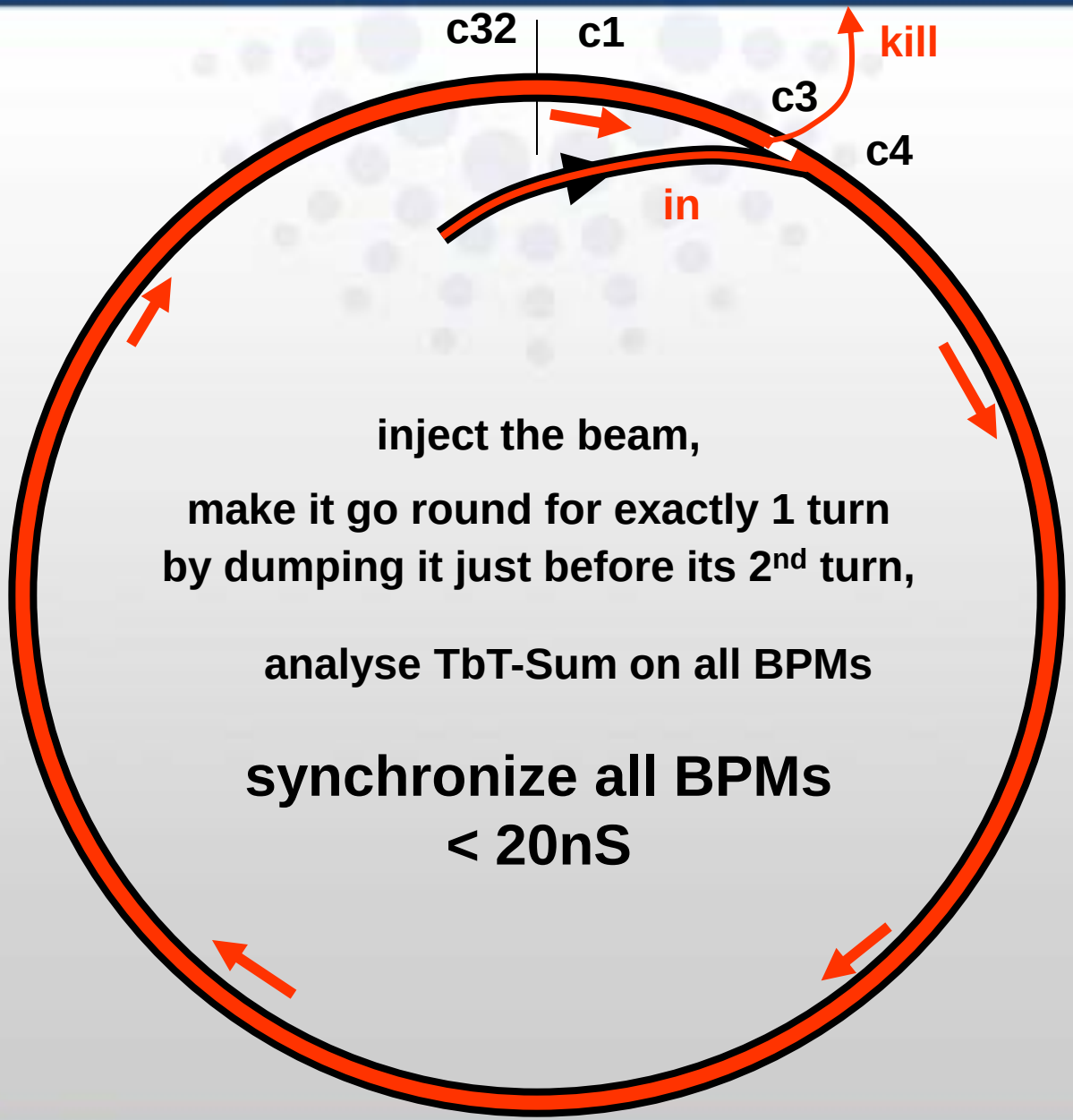
1rst Turn Trajectory measurements :

-- Inject the beam in an empty Ring

-- Measure positions on all BPMs at Turn(s) 1, 2 ,3 or more

→ find errors in the Ring lattice, or in the injector system



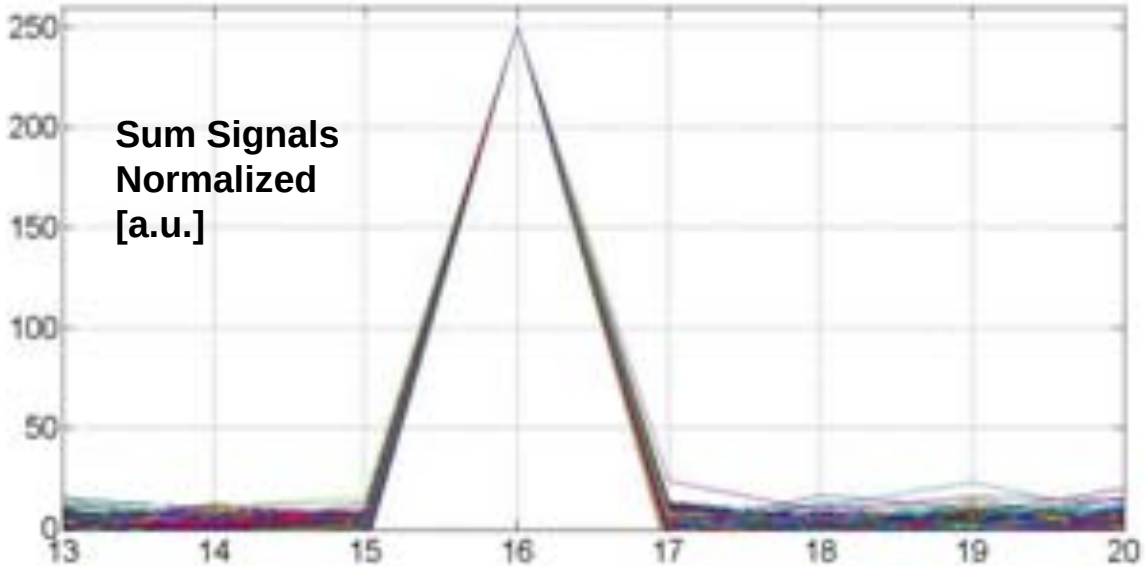


inject the beam,

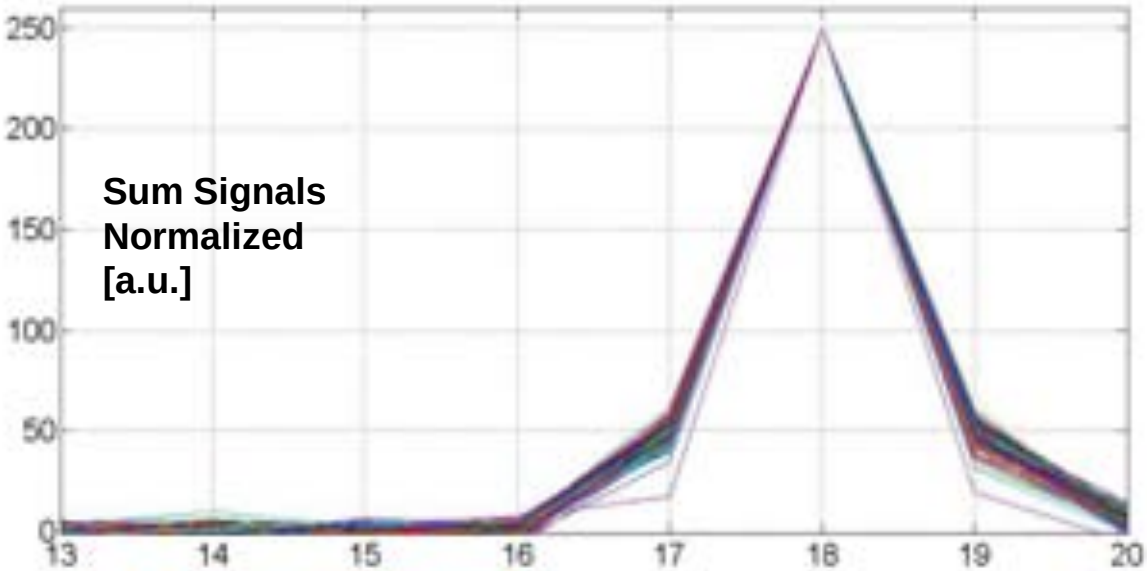
make it go round for exactly 1 turn
by dumping it just before its 2nd turn,

analyse TbT-Sum on all BPMs

synchronize all BPMs
< 20nS

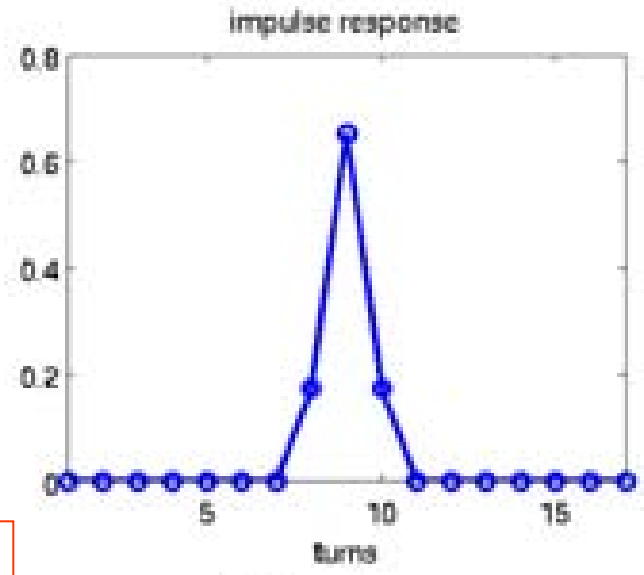


optimized T-b-T filter 'MAF'

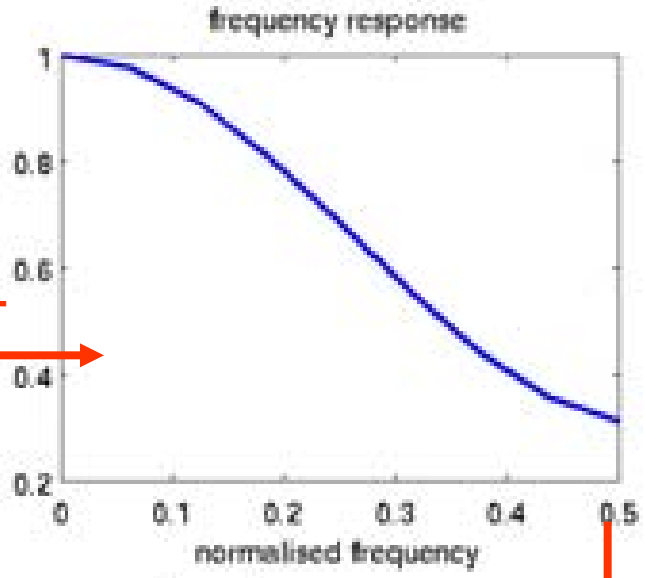


Standard T-b-T filter

a Compensation Filter
courtesy of G.Rehm DLS

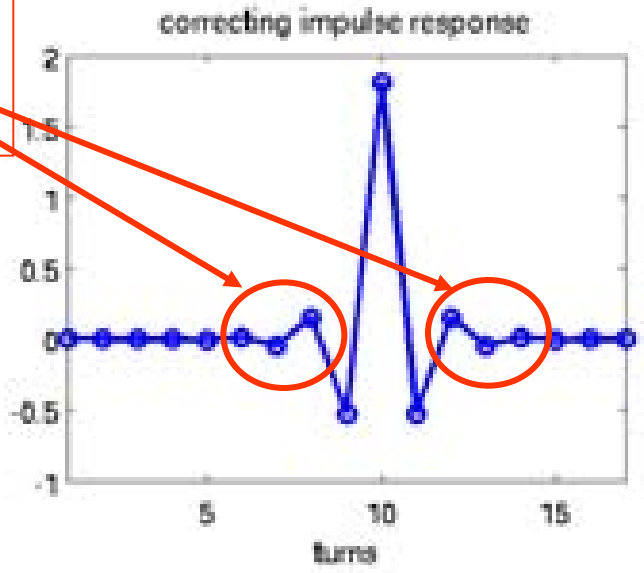


FFT

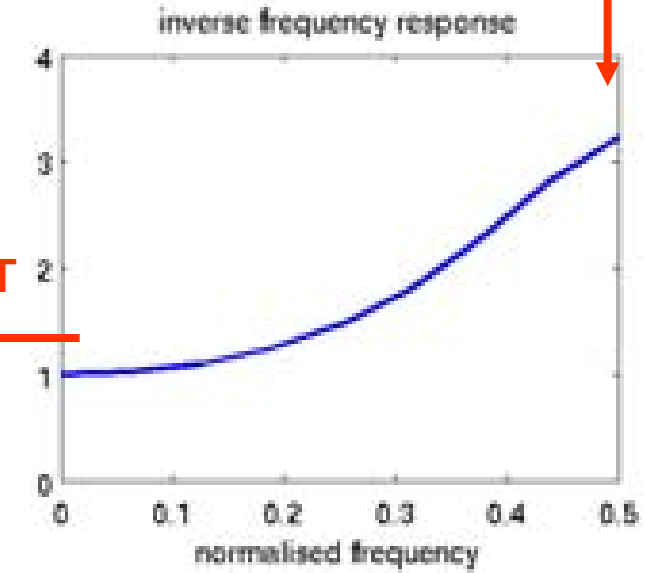


Inverse

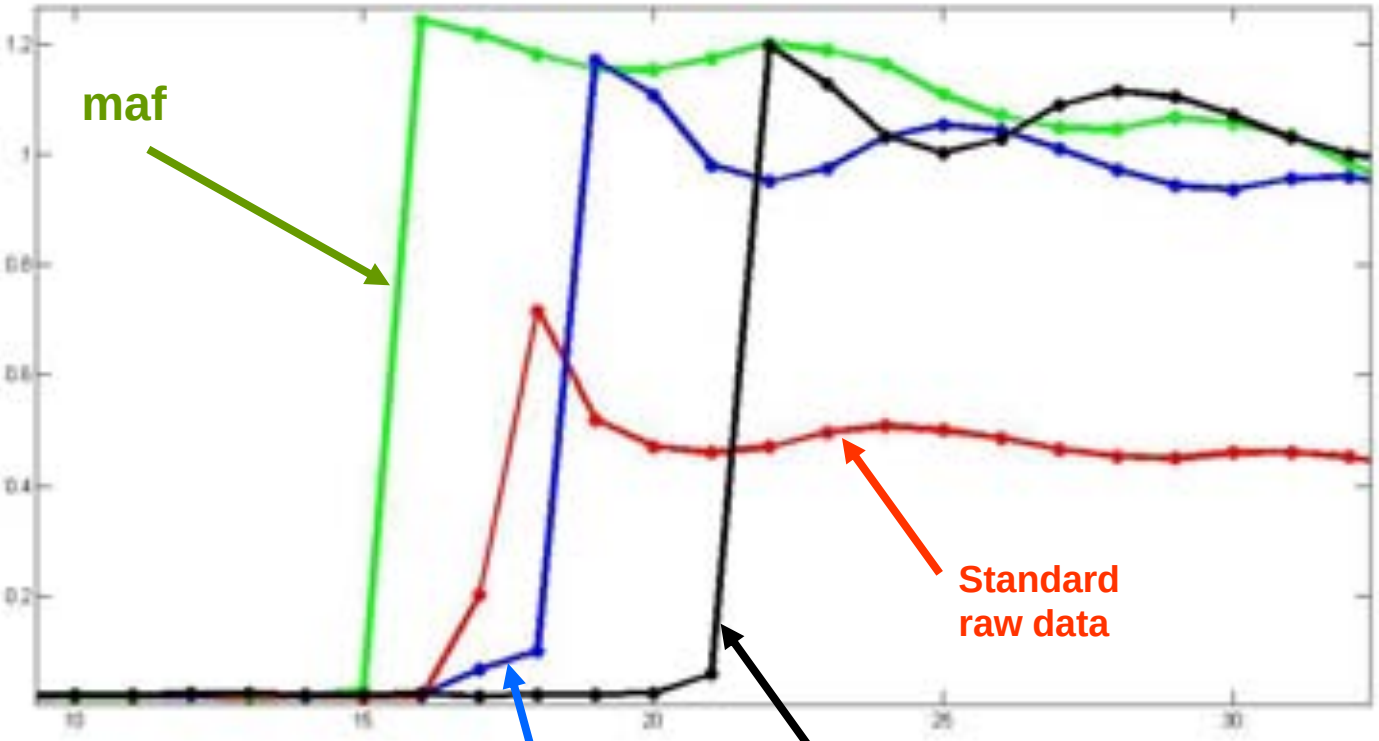
these coeff. at 0 in my first simple anti-smear



IFFT

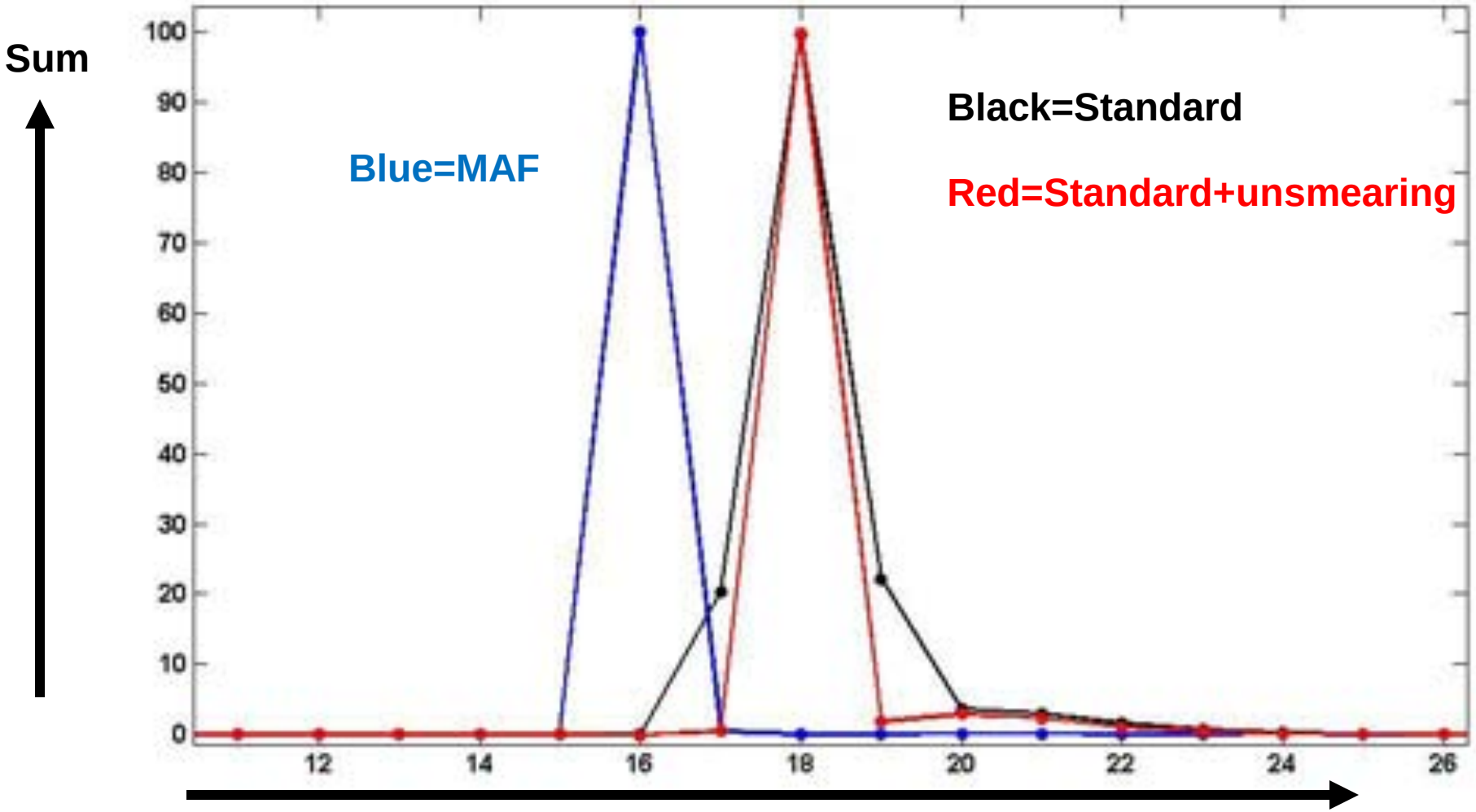


Sum signal [a.u] at Injection, with beam being Stored

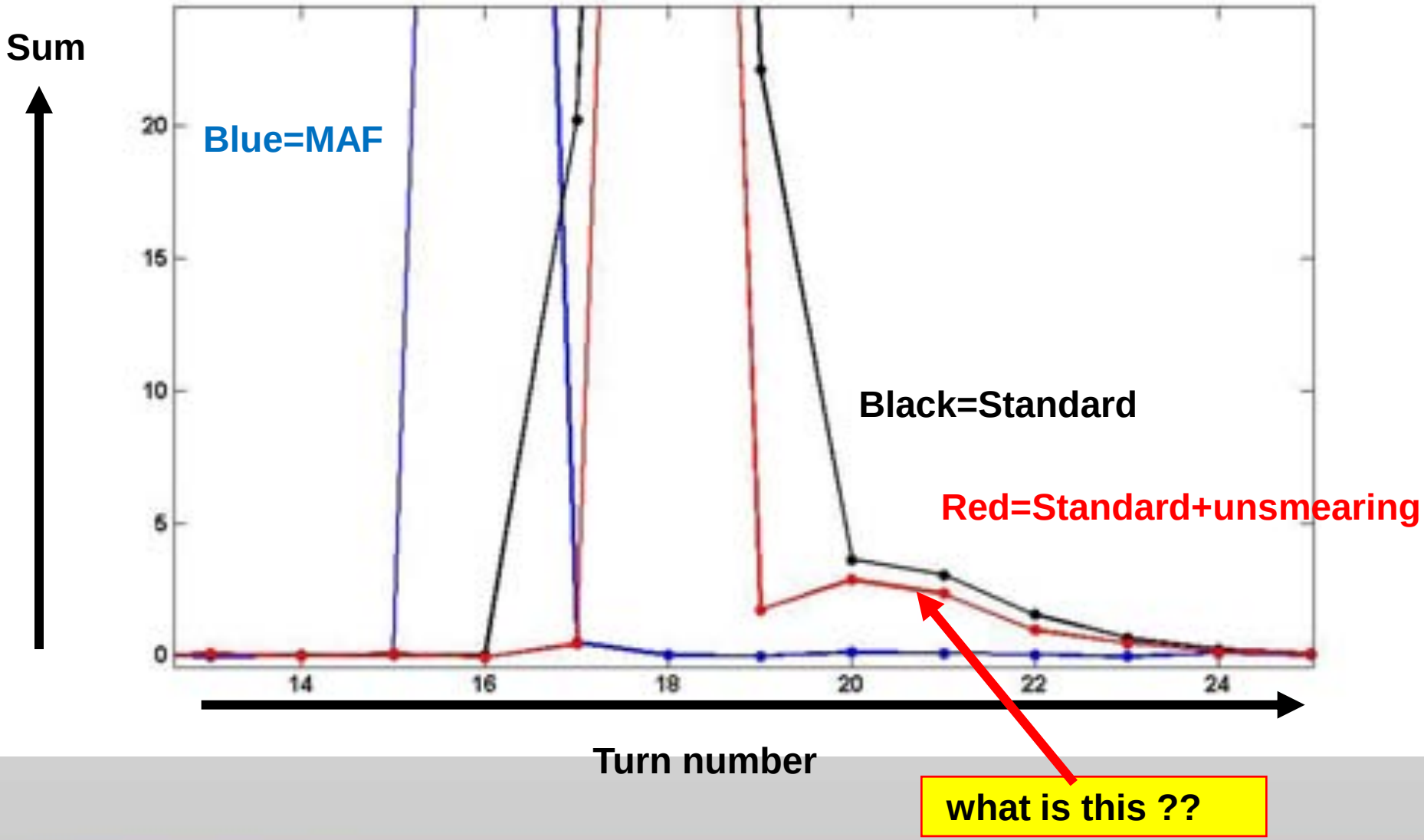


Note : deliberate horizontal shifts between 4 curves to better distinguish the curves

Beam injected, and lost after 1 single Turn



Zoom on the “low-level-smearing”



Turn-by-Turn measurements :

-- Kick the beam transversely

-- Measure positions on all BPMs at each orbit Turn

→ precise lattice measurement

we use the **MAF** filter,

beam experts insists that information on detailed lattice parameters is better & more precise

price to pay :
- 2 x15min switching-over time
- DSC does not work reliably :
  SA outputs have reduced precision & resolution

1rst Turn Trajectory measurements :

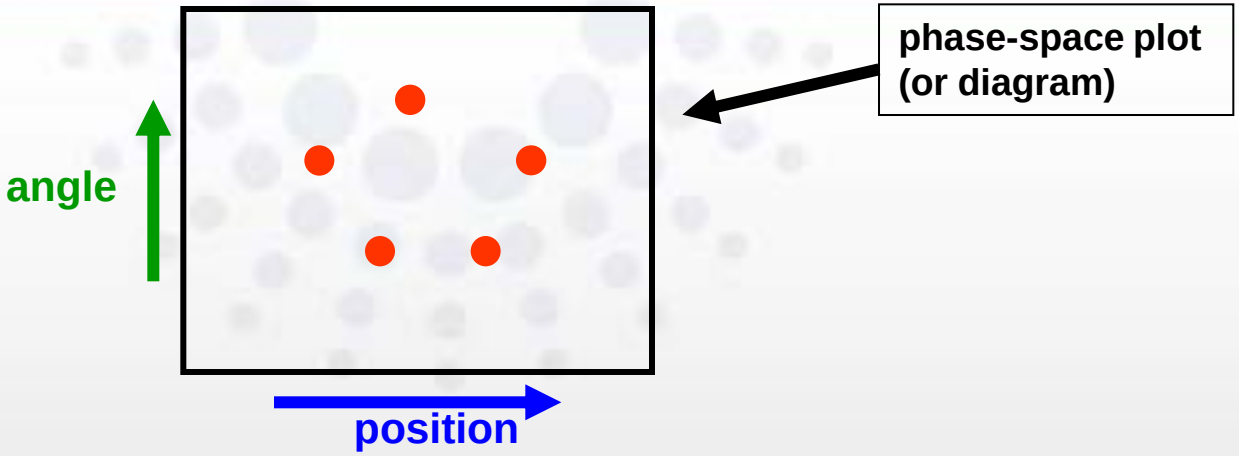
-- Inject the beam in an empty Ring

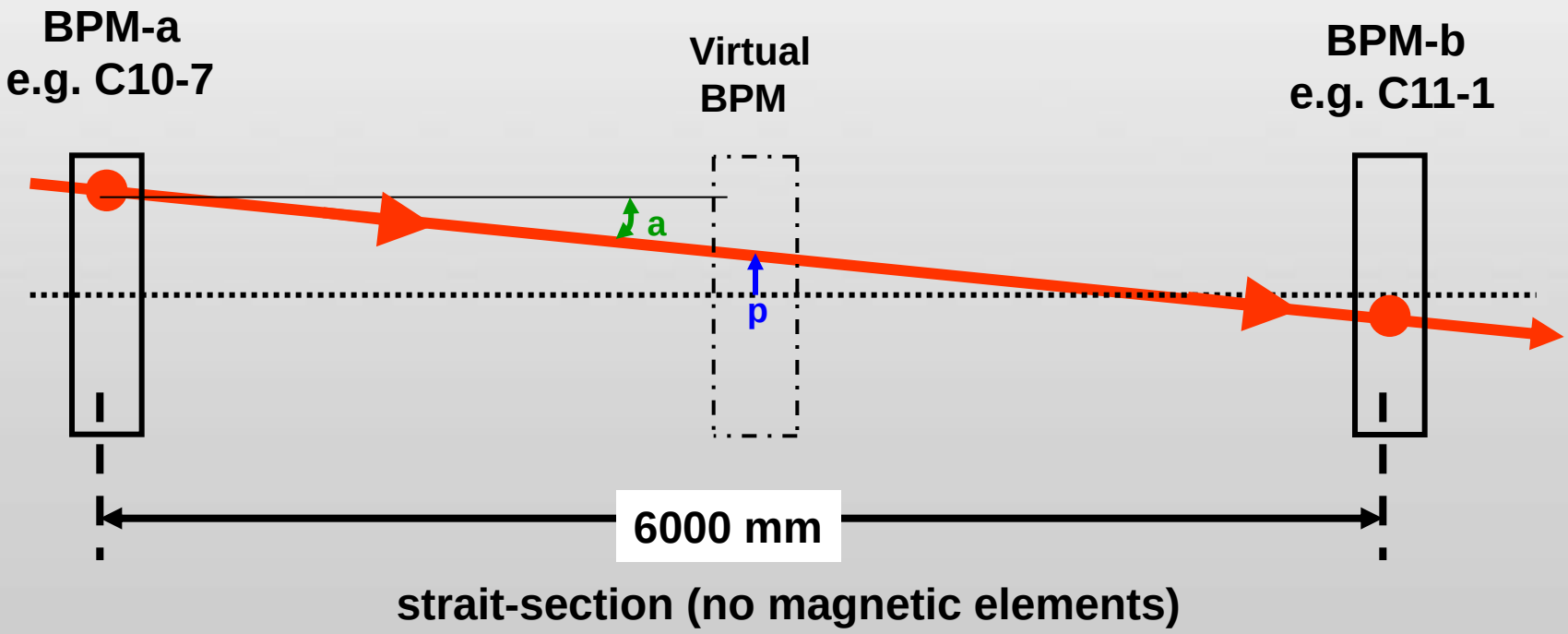
-- Measure positions on all BPMs at Turn(s) 1, 2 ,3 or more

→ find errors in the Ring lattice, or in the injector system

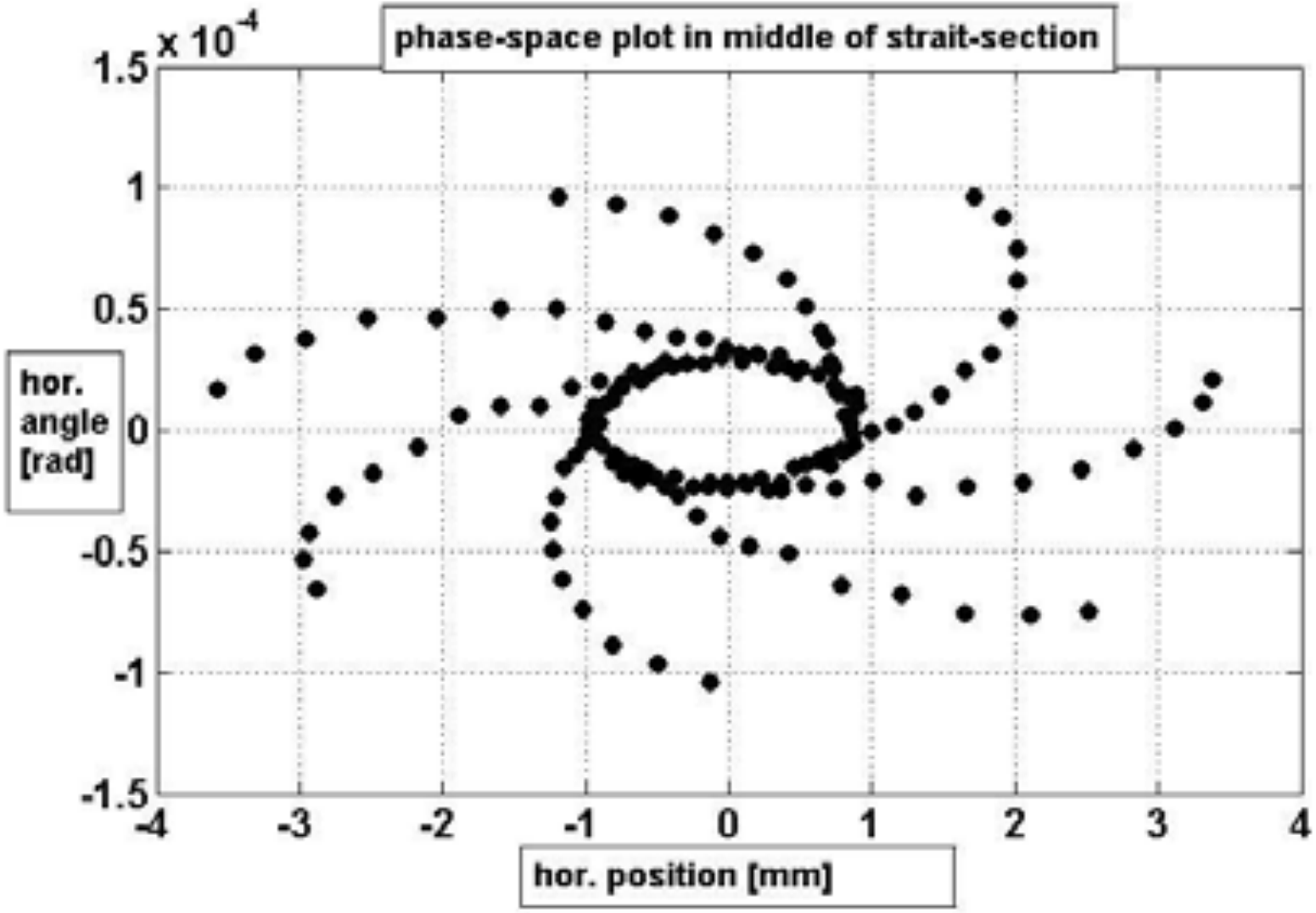
We use the **Standard** filter with 5-points anti-smearing,

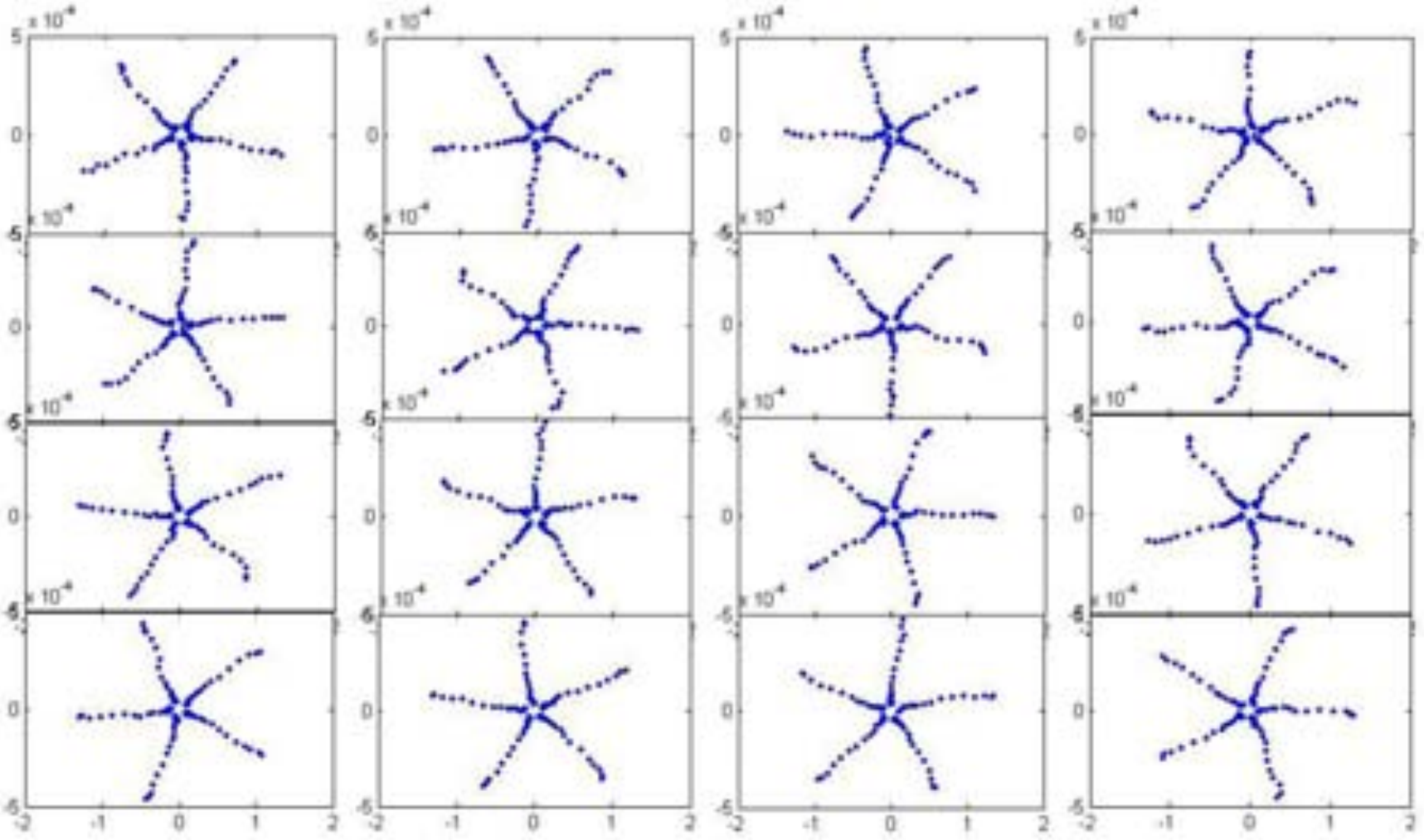
good enough precision,
easy & strait-forward to use,
no complications with DSC etc.





strait-section (no magnetic elements)


phase-space plot in middle of strait-section
x 10^-4
1.5
1
0.5
0
-0.5
-1
-1.5
hor. angle [rad]
-4
-3
-2
-1
0
1
2
3
4
hor. position [mm]



Vertical phase-space plot in 16 (even) strait sections

to follow : some examples of 1rst Turn Trajectory measurements

1rst Turn Trajectory measurements :

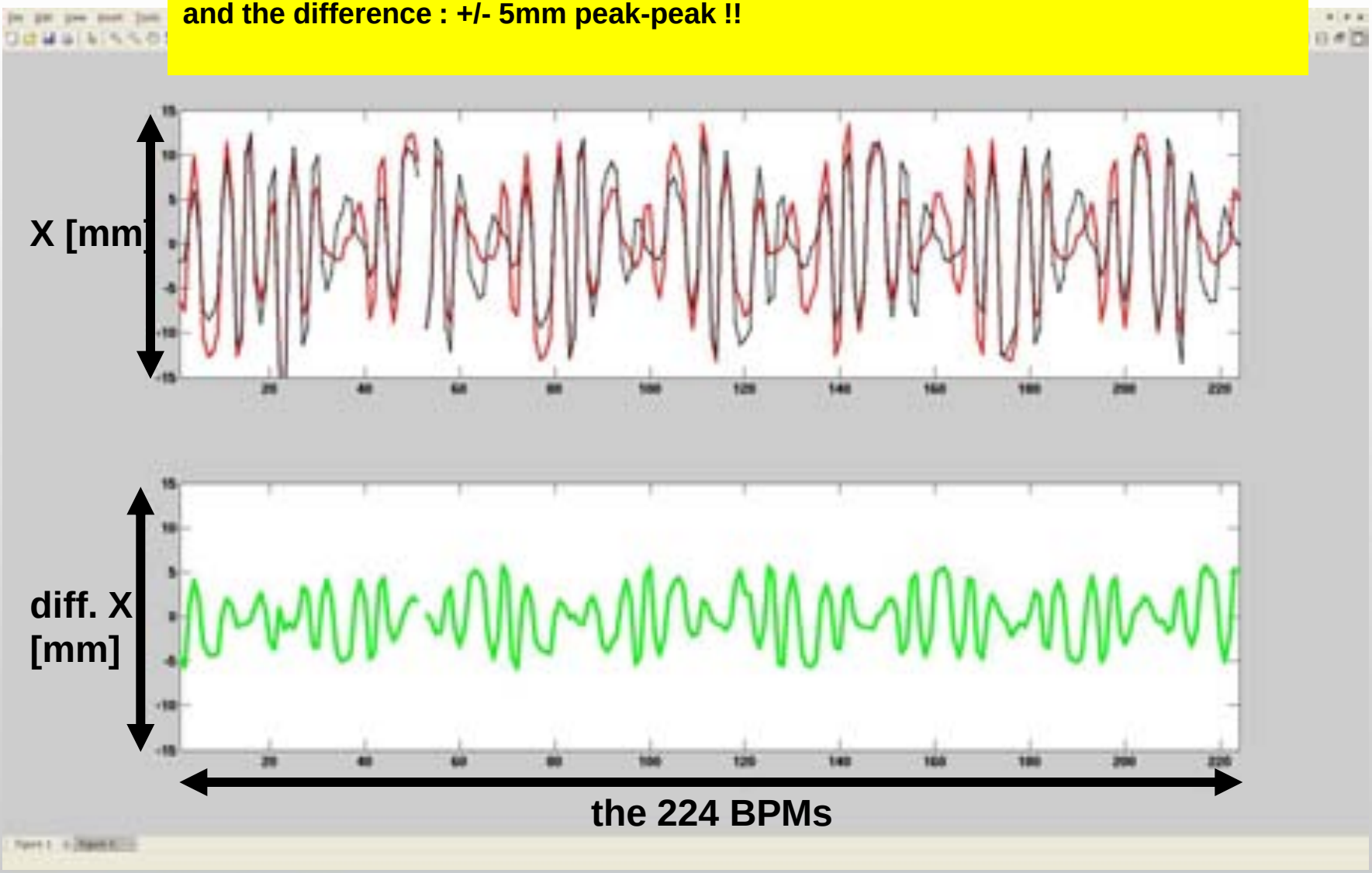
-- Inject the beam in an empty Ring

-- Measure positions on all BPMs at Turn(s) 1, 2 ,3 or more

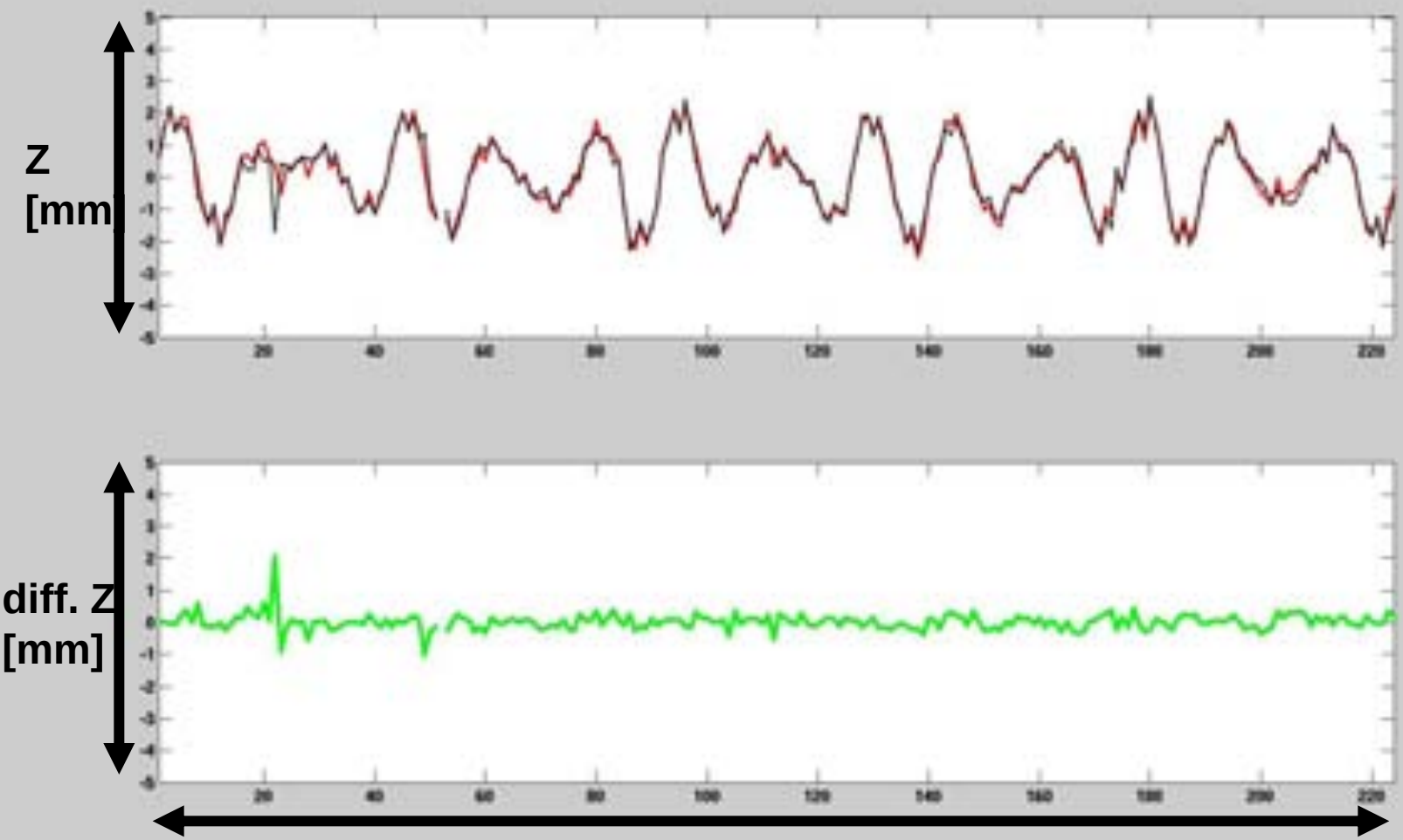
→ find errors in the Ring lattice, or in the injector system

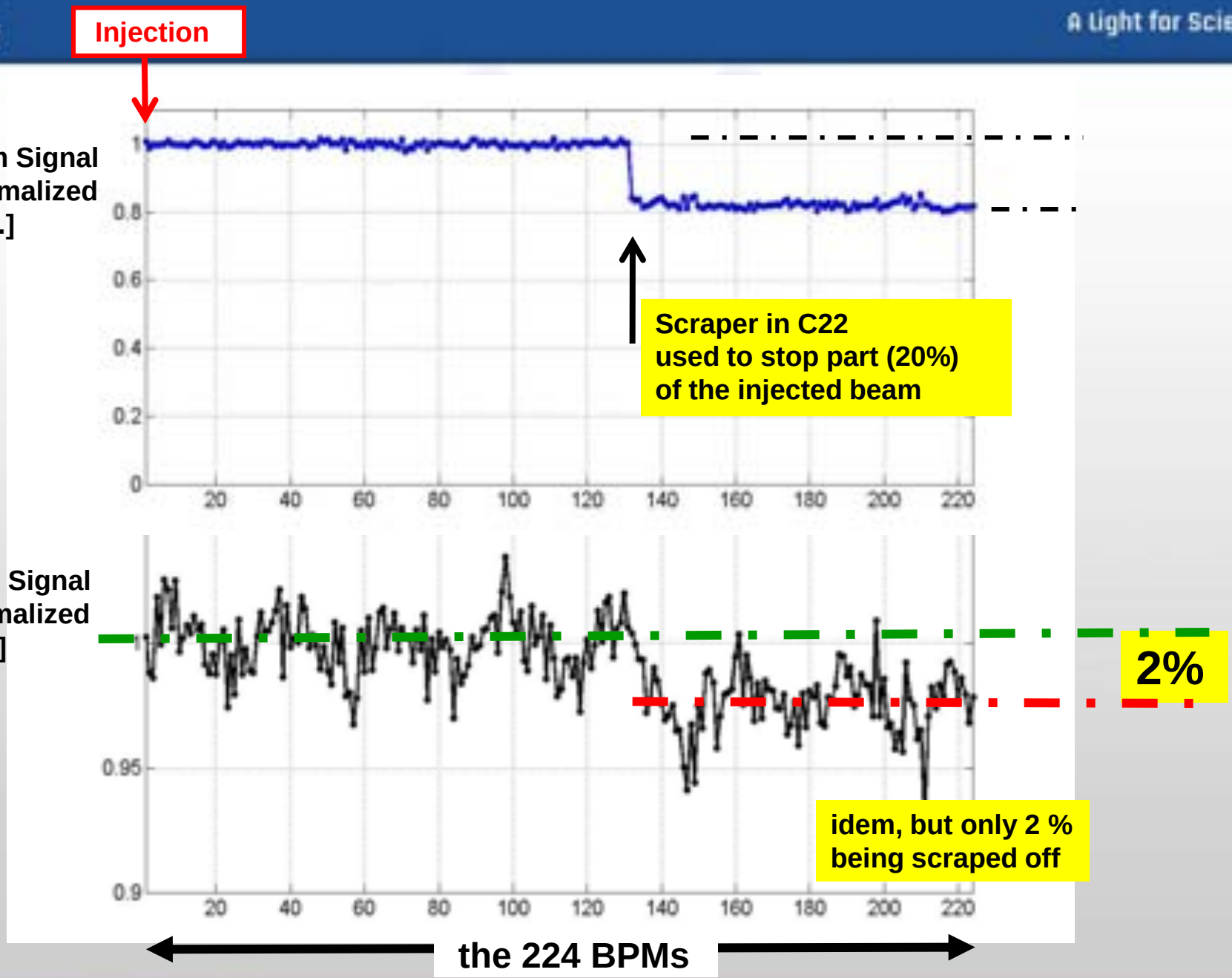
Reproducibility of the first-turn measurement :

2 Horizontal Trajectories of the injected Turn are shown over the whole Ring and the difference : +/- 5mm peak-peak !!



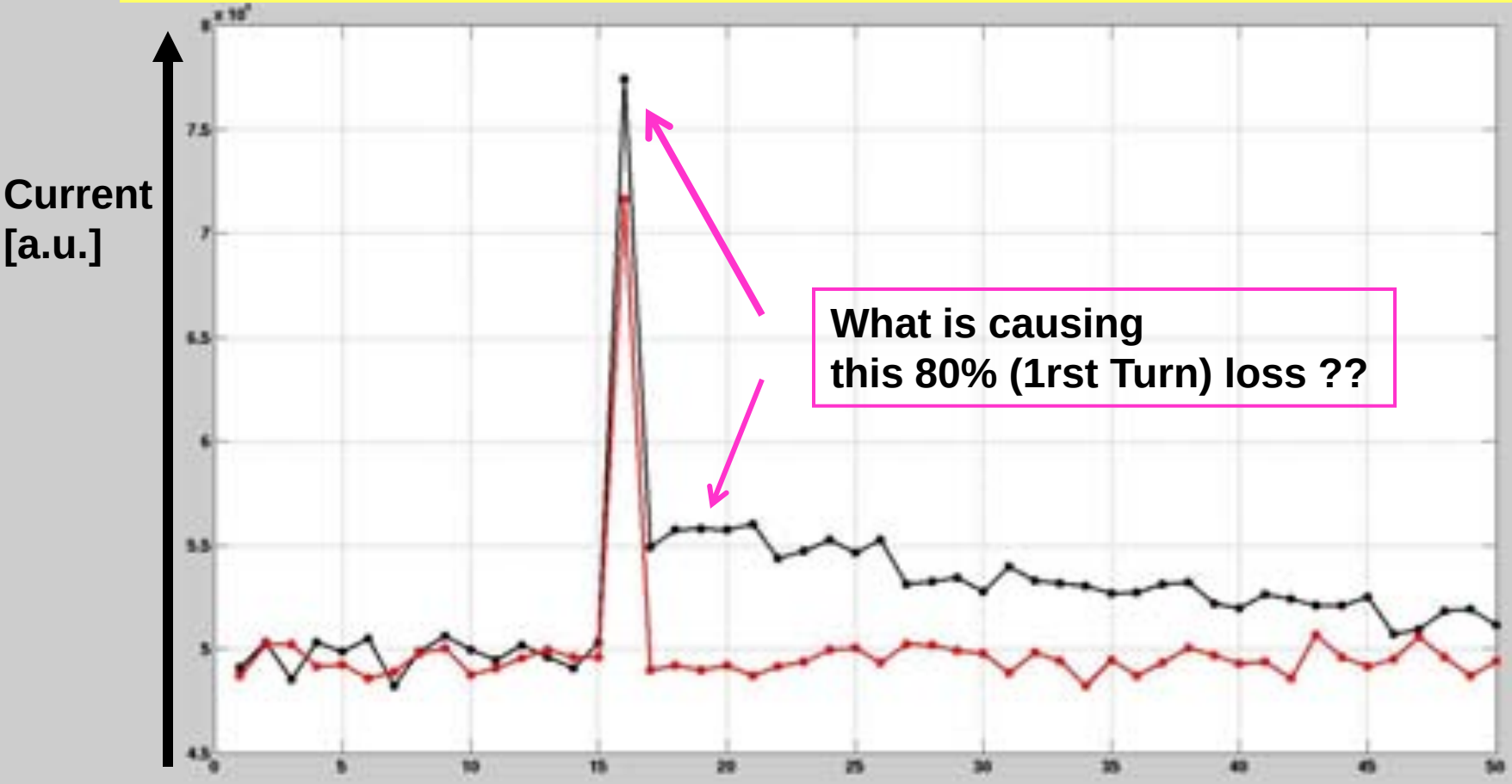
Reproducibility of the first-turn measurement :
The Vertical Trajectories of the injected Turn have a much better reproducibility




Injection
Sum Signal Normalized [a.u.]
Scraper in C22
used to stop part (20%)
of the injected beam
Sum Signal Normalized [a.u.]
2%
idem, but only 2 %
being scraped off
the 224 BPMs

Sum signal (average of all BPMs) at Injection of the Single Bunch :

Black : stored in SR
Red : cut after 1 Turn (C4 scraper-jaw)



Sum signal (average of all BPMs) at Injection of the <u>1us LongPulse</u> :

stored & accumulated in SR, 5 consecutive Injections

Status of Fast-Orbit Feedback

10 KHz

Liberas using the I/O-Rocket ports
+ C.C. + network of copper & fiber links

96 Horizontal &
Vertical steerers
housed in the
Sextupoles

the 7 Liberas / cell in a circular copper link (using 2 ports / libera)

2 Liberas are using 2 more ports (so 4) for fiber links to other cells, and to a few FeedBack Processor cards

+ a 'Sniffer' that surveys the network, with a 'LostPackets' counter implemented

if the topology is perfect (no open links) then all is fine ('LP' counter=0)

BUT : any open link disturbs the network a lot . . .

a remedy is found (Sept.) but not understood :
avoid using 4 ports on a libera,
Instead : re-distribute the links and limit to max. of 3 ports / libera

The complete upgrade of the e-BPM system :

Position measurements with all 224 BPM in the Ring :

in the next few slides some examples of :
the present ESRF beam stability,
in the slow and fast domain,

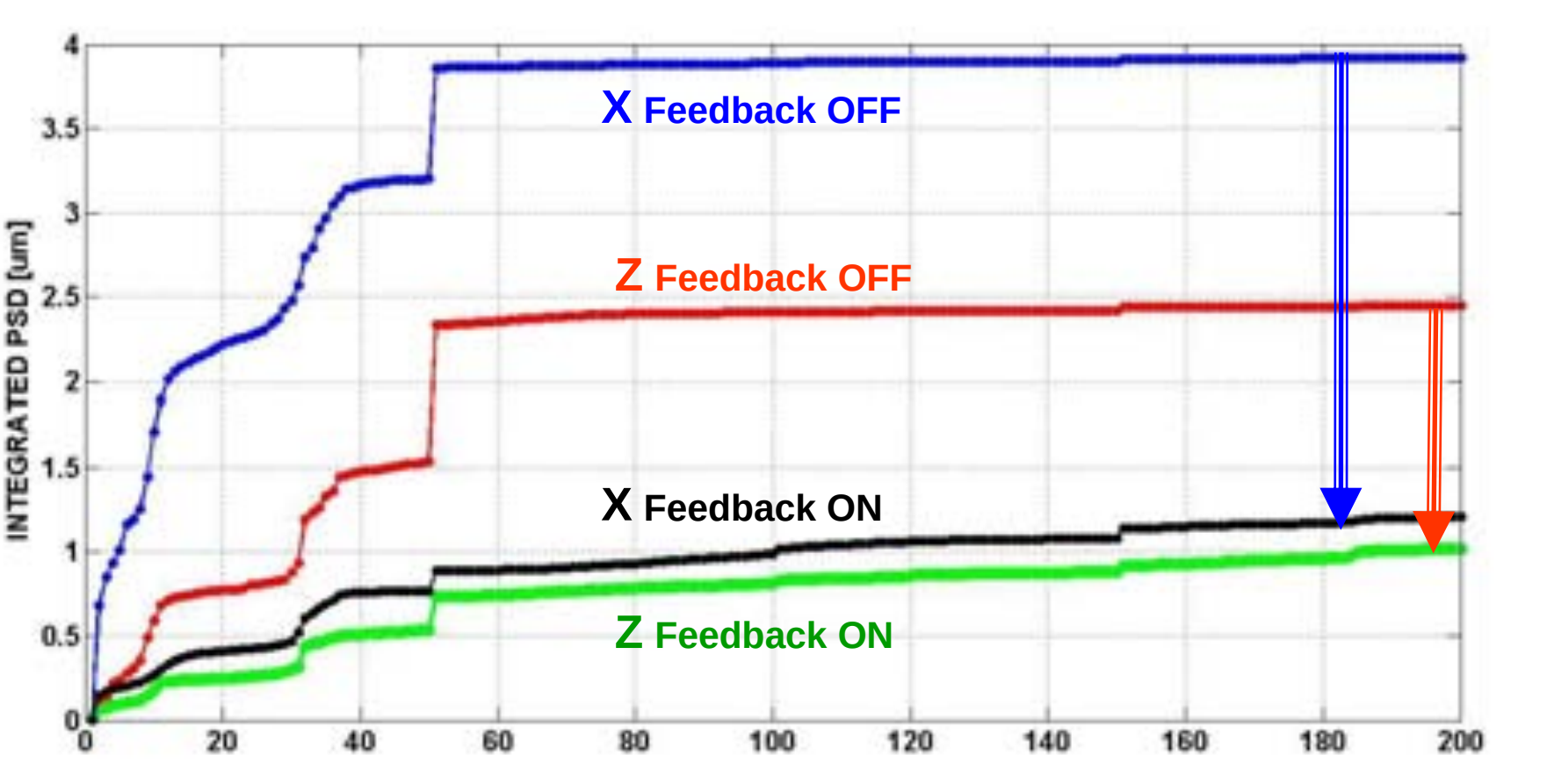
its limitations to fully cope with disturbances
caused by Insertion Device manipulations,

how this new BPM system, together with an
upgrade of 96 fast orbit steerers will remedy this

Stability in the AC domain (1Hz – 2KHz)

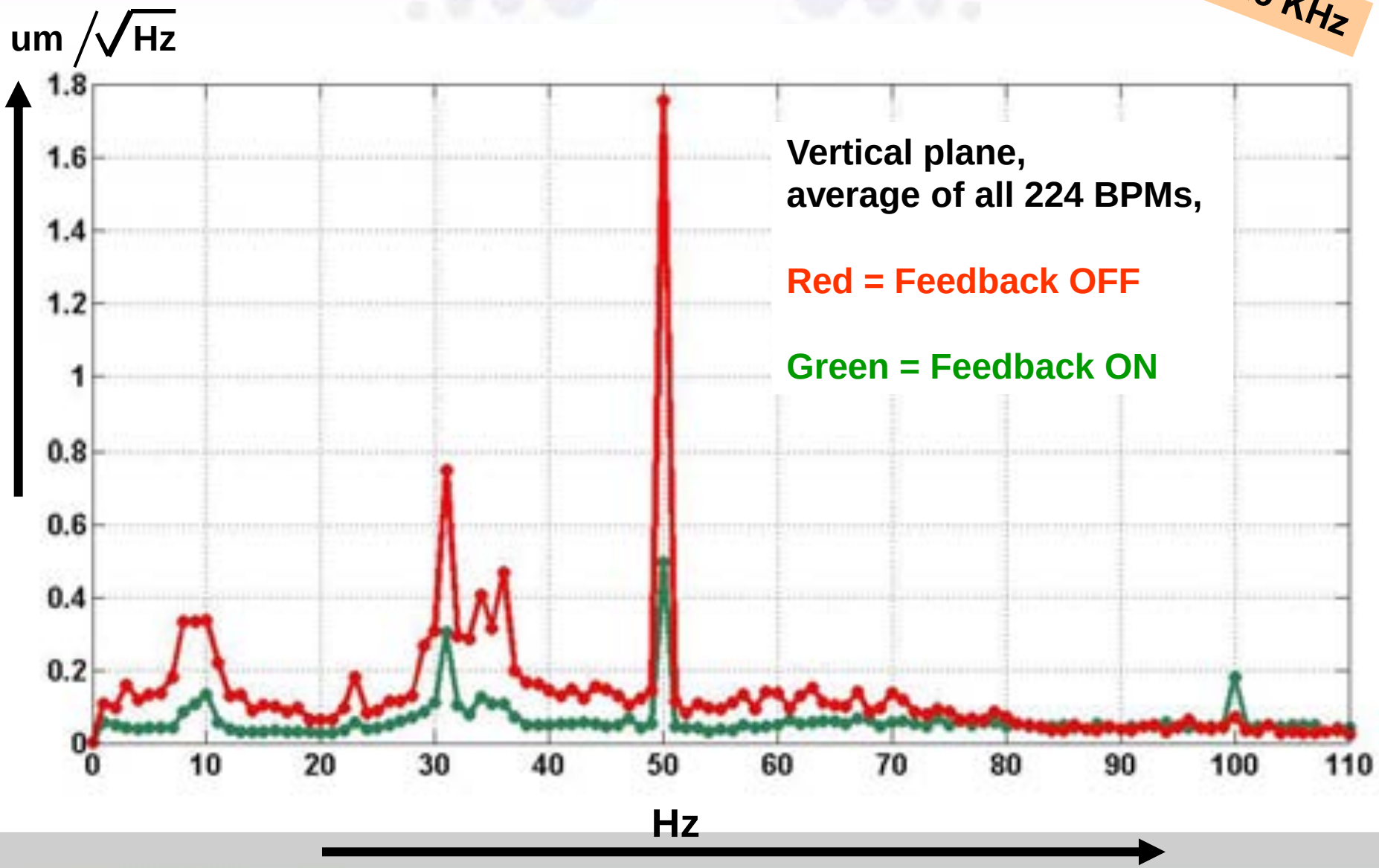
5.5 KHz

Average of all 224 BPMs, X & Z , FastFeedback On & Off

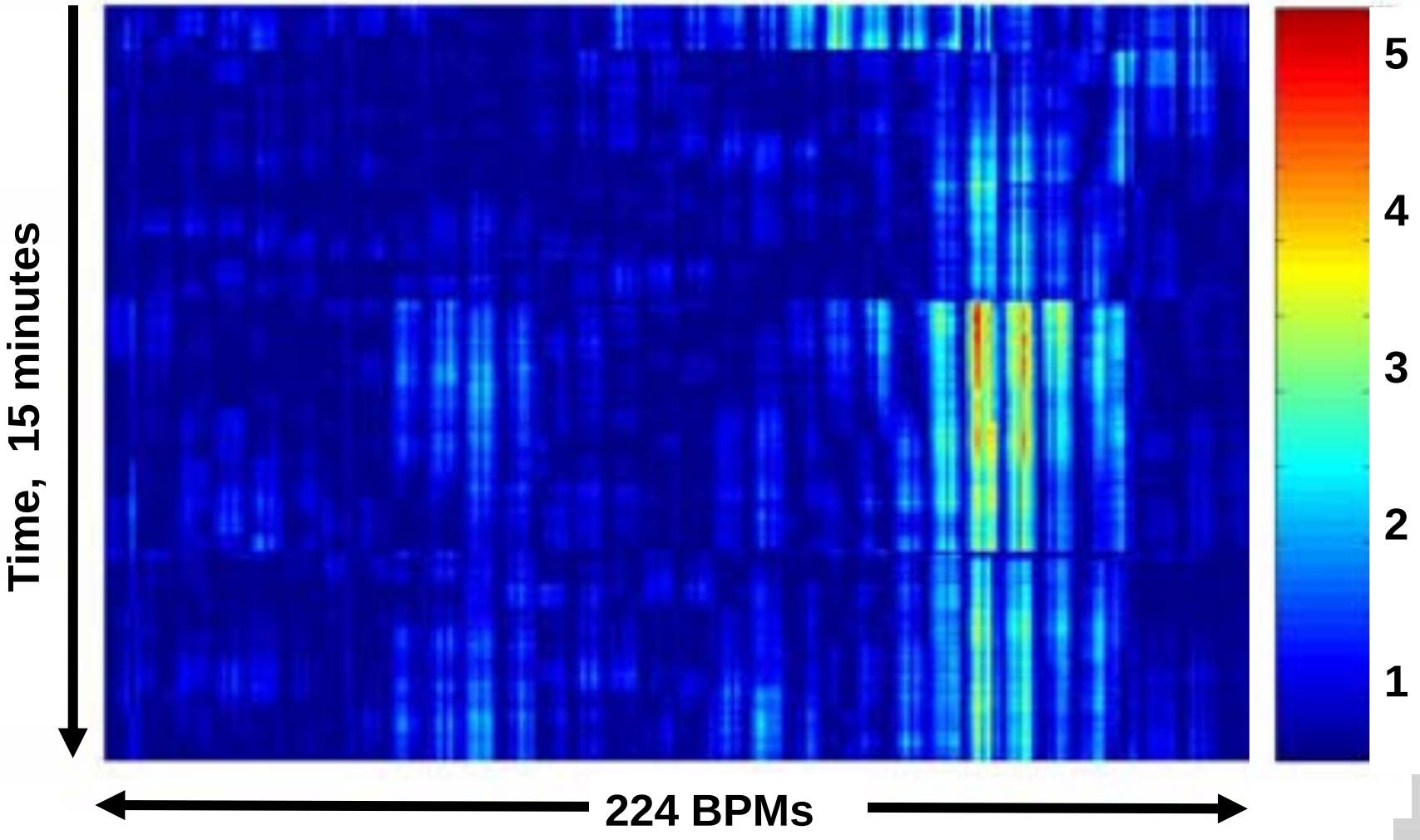


Stability in the low AC domain (1Hz ~ 100Hz)

5.5 KHz

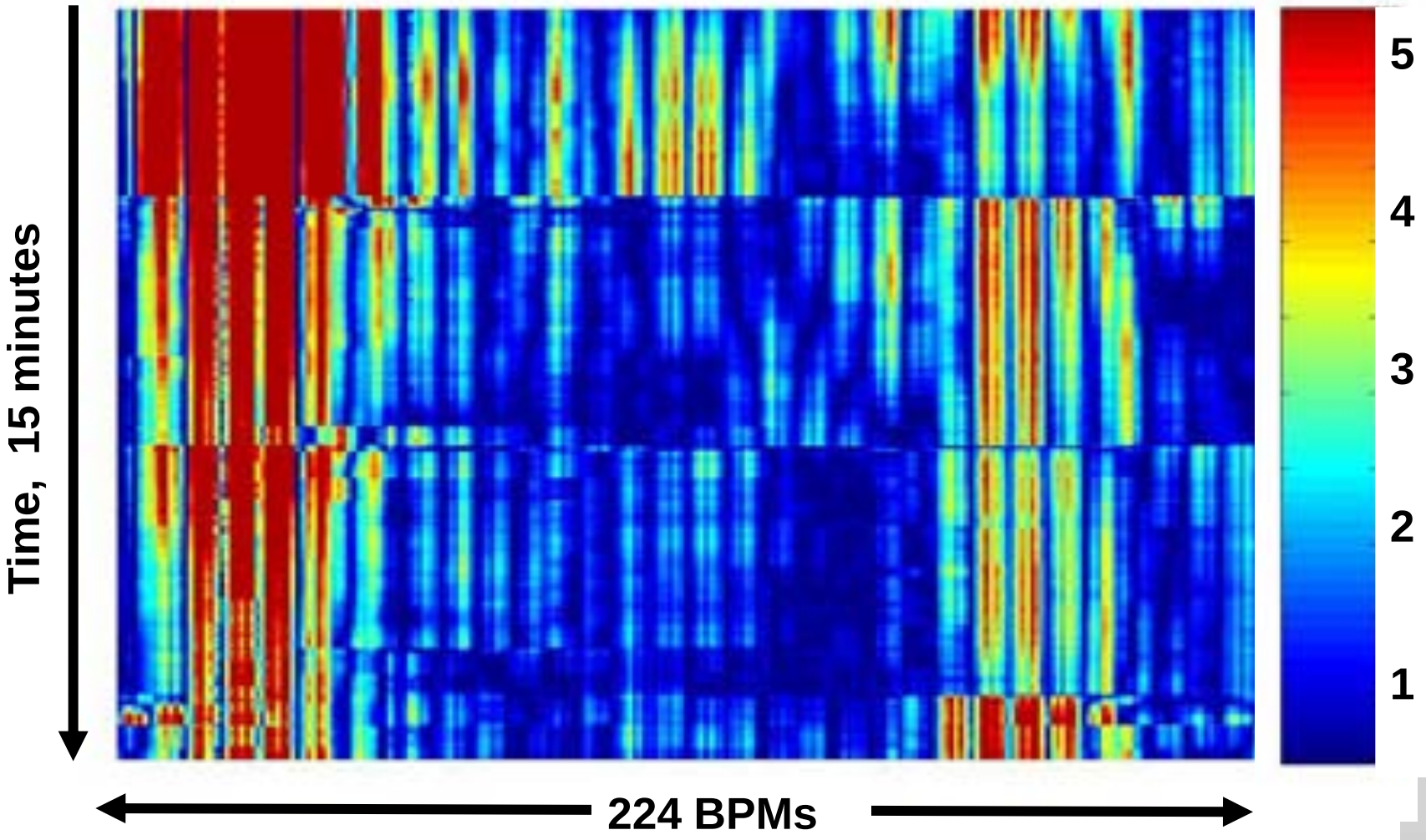


Stability in an intermediate time domain, 0.5sec to 15min



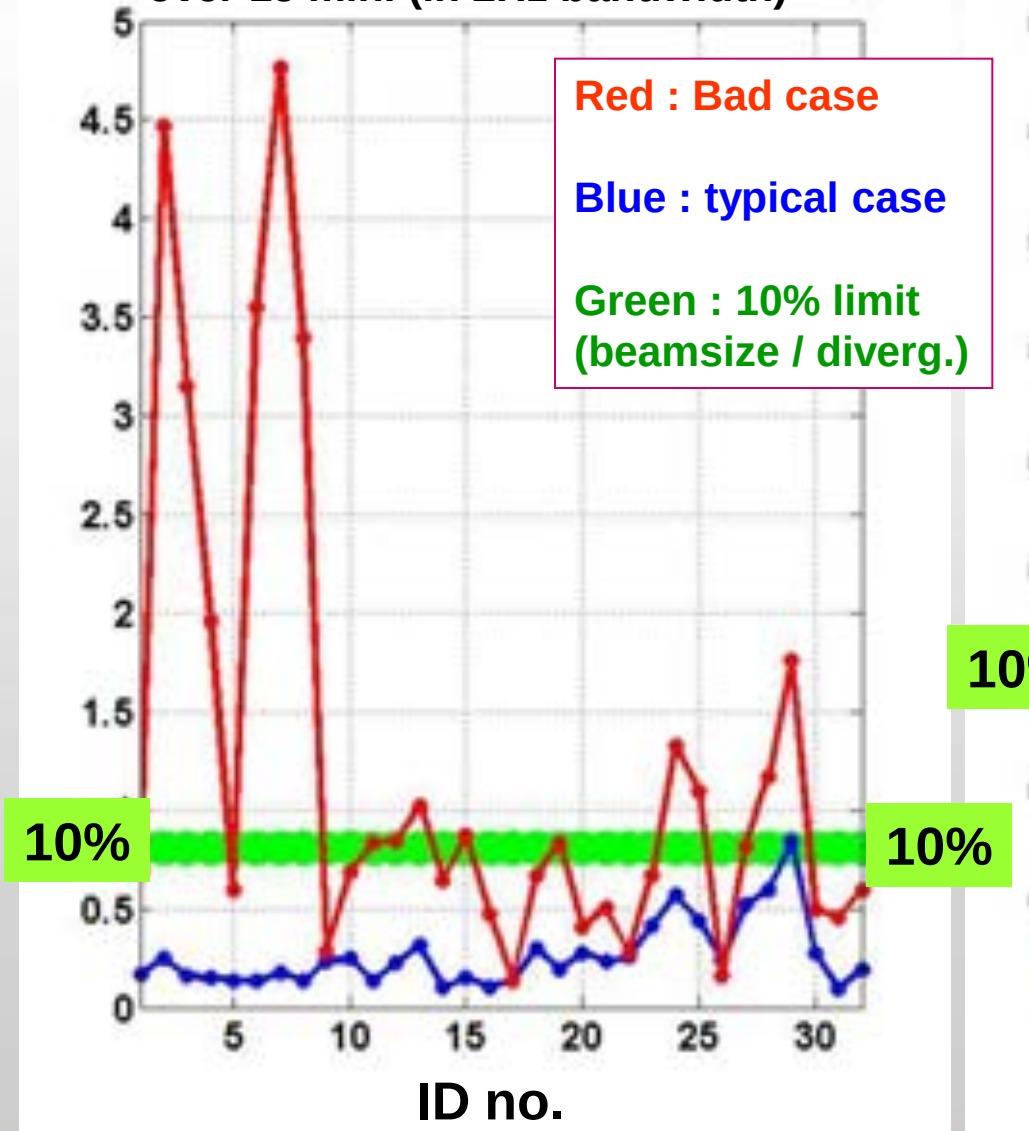
Stability judgment : typical, not too bad . . .

Stability in an intermediate time domain, 0.5sec to 15min

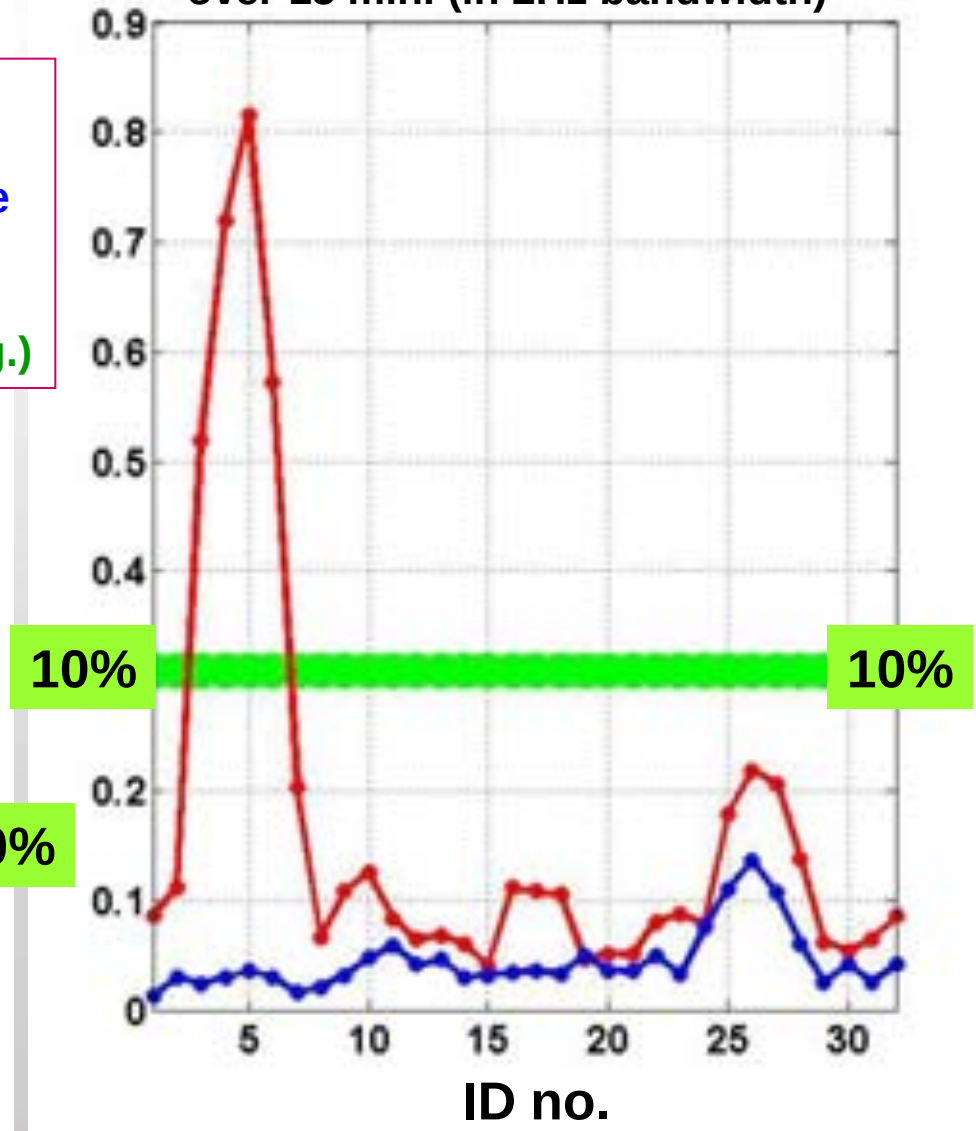


Stability judgment : BAD

IDs Vert. position stability [um rms] over 15 min. (in 2Hz bandwidth)



IDs Vert. angle stability [urad rms] over 15 min. (in 2Hz bandwidth)



The *benefits*, now and in the future, for beam stability

Future : the Fast-Orbit-Stabilization system will use :

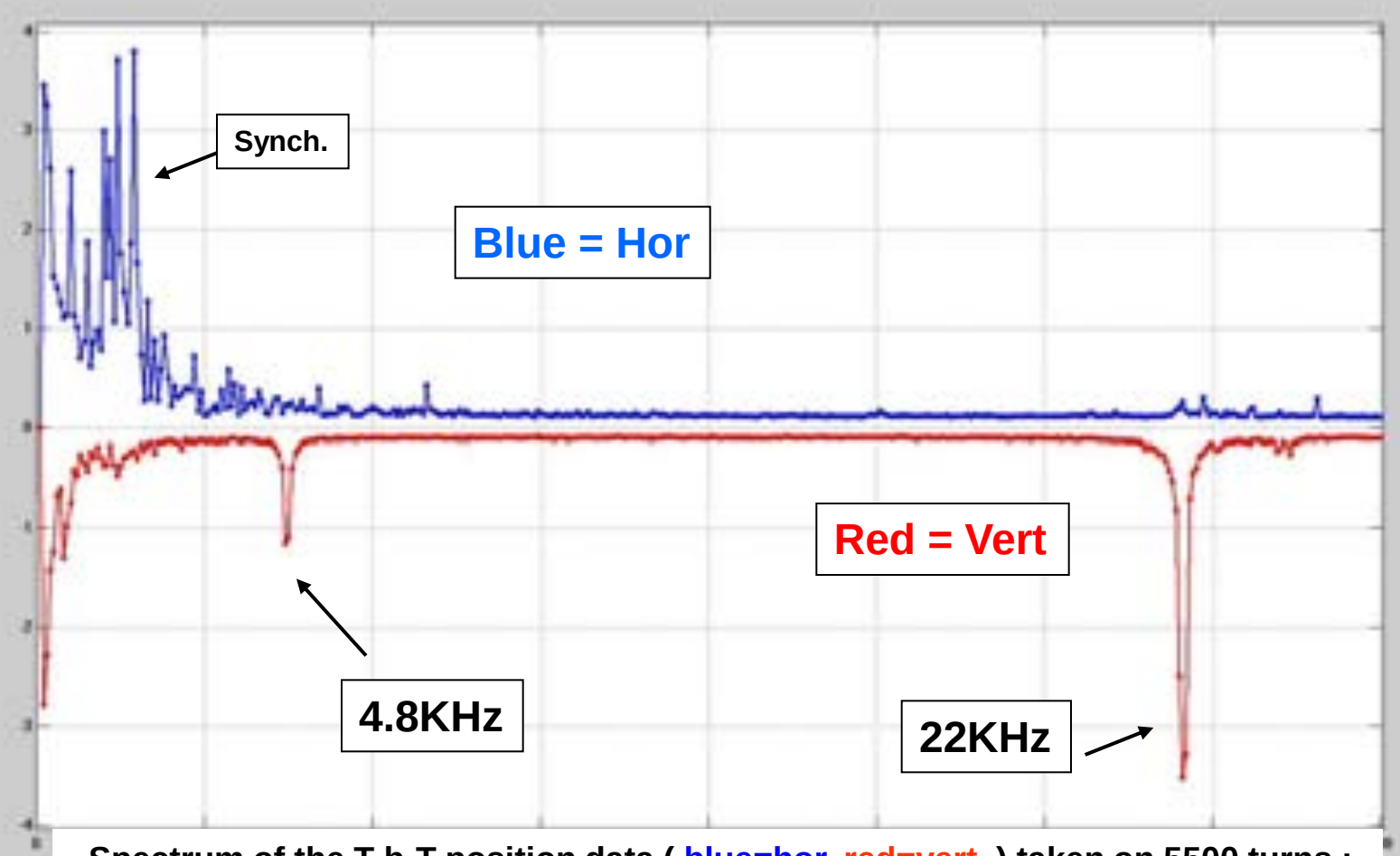
224 Libera BPMs (done)	(today only : 32 Hor-Fast-BPMs 32 Vert-Fast-BPMs)
96 AC-DC Steerers (2011)	(today only : 32 AC Hor-Steerers 16 AC Vert-Steerers

Now : - much better survey of beam motion & stability
- some instabilities & motions have been suppressed

The complete upgrade of the e-BPM system :

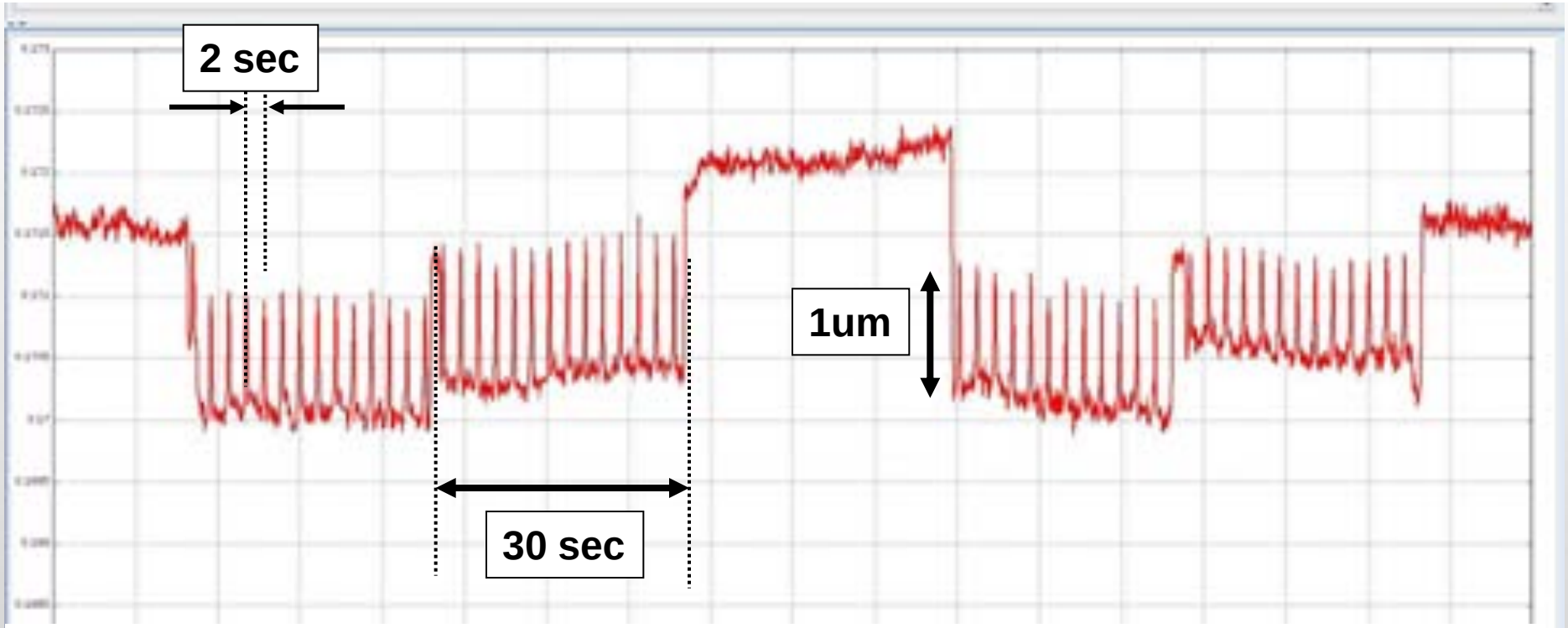
Other benefits now already :

detection & localization of
disturbances to beam position
that have consequently been suppressed



Spectrum of the T-b-T position data (blue=hor, red=vert.) taken on 5500 turns :
the 2 main peaks are : 22 KHz (noise from fast-orbit-correctors)
4.8KHz (noise from tune-shaker)

Vertical oscillation of the Beam, as seen by a single BPM station



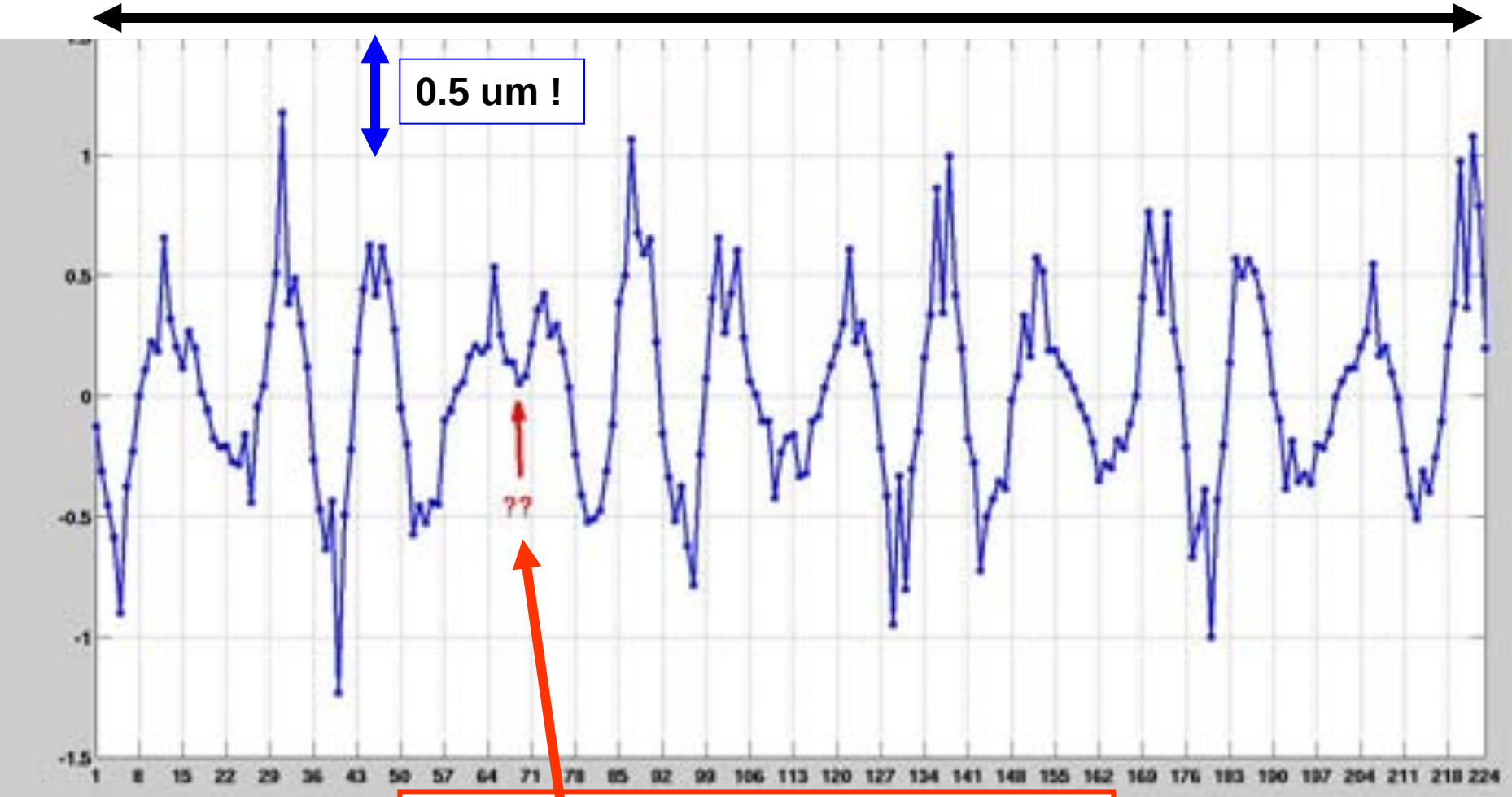
a **0.5Hz** oscillation of **1um pk-pk** comes & goes-away with a 30sec period

this problem came from a slow Steerer, it appears / disappears with a change in current

in this Steerer, the DAC convertor has a problem on its LSB, not detectable in Lab.

The new BPM system allows to pin-point the faulty Steerer among 96 suspects

Orbit plot around the Ring, showing : harmonic number + distortion



faulty steerer found in this zone :

it had LSB noise of 0.0001A ….. !!

Record brilliance at the ESRF achieved thanks to ultra small vertical emittance

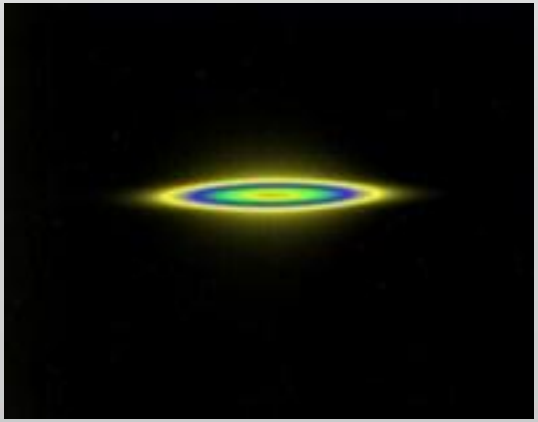
Within the ESRF Upgrade Programmme, the Accelerator Division has increased the brilliance and coherence of the undulator-generated photon beams through a reduction of the electron beam vertical emittance by a factor of six.

A value of 5 picometres is now available in User Service Mode, making possible photon beam brilliance values matched nowhere else in the world.

The 224 electron beam position monitors in the ESRF storage ring have recently been upgraded by replacing their electronics by more modern units that make use of digital electronics (Libera [1]).

The new system provides much improved resolution in the orbit measurement which now makes it possible to measure the lattice functions of the ring (beta functions) with higher accuracy.

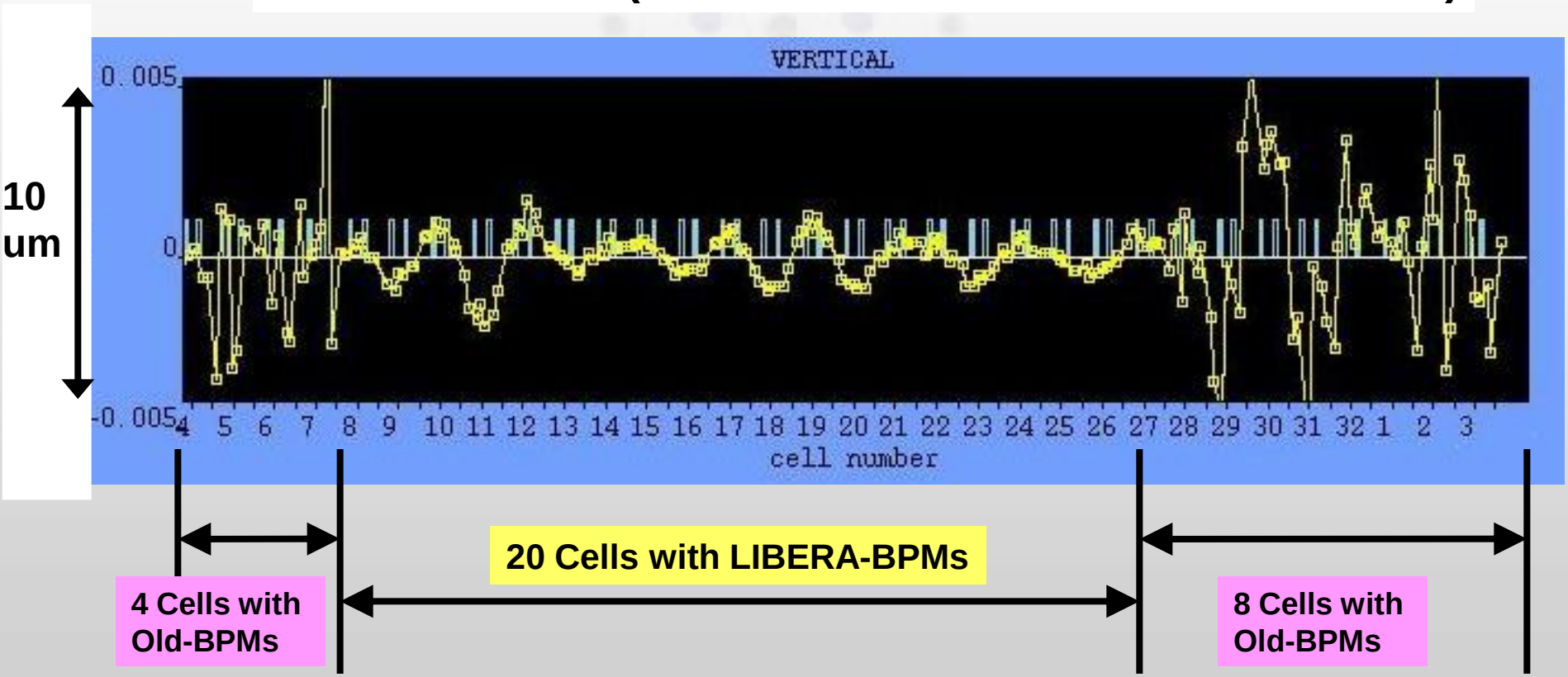
The greater precision combined with an improved algorithm for the coupling correction has resulted in the operation of the ring in User Service Mode with a vertical emittance (rms) as small as 5 pm for several days in a row.
This corresponds to a normalised emittance (rms) of 0.06 mm mrad.



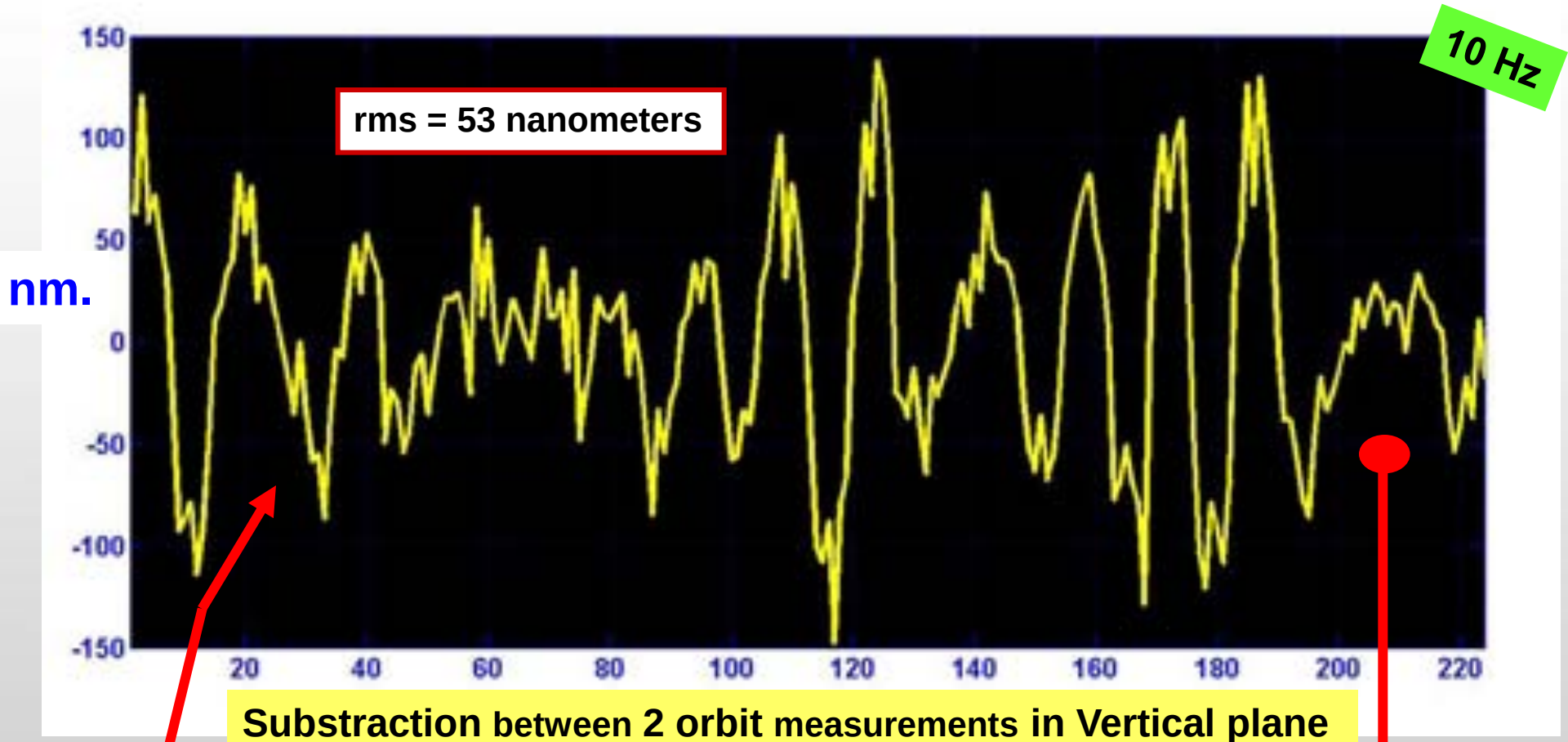
from february 2009 : an intermediate view . . . . .

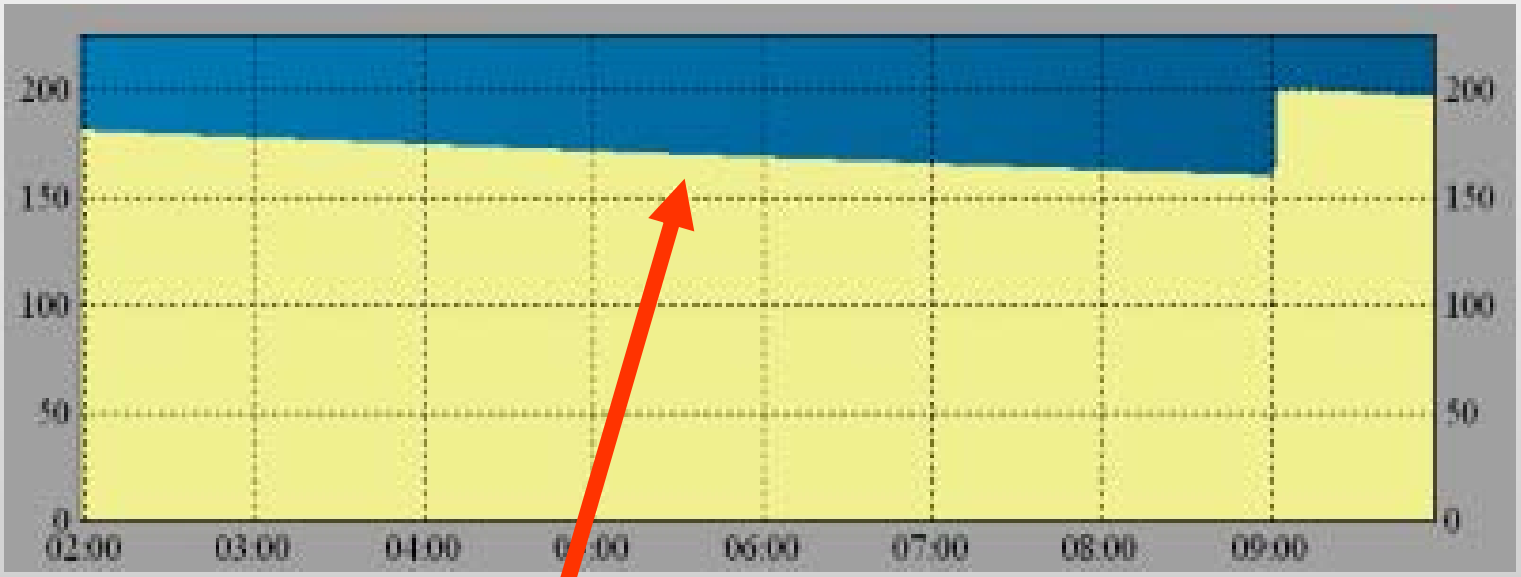
10 Hz

Beam Orbit Plot (i.e. substraction from a reference orbit)

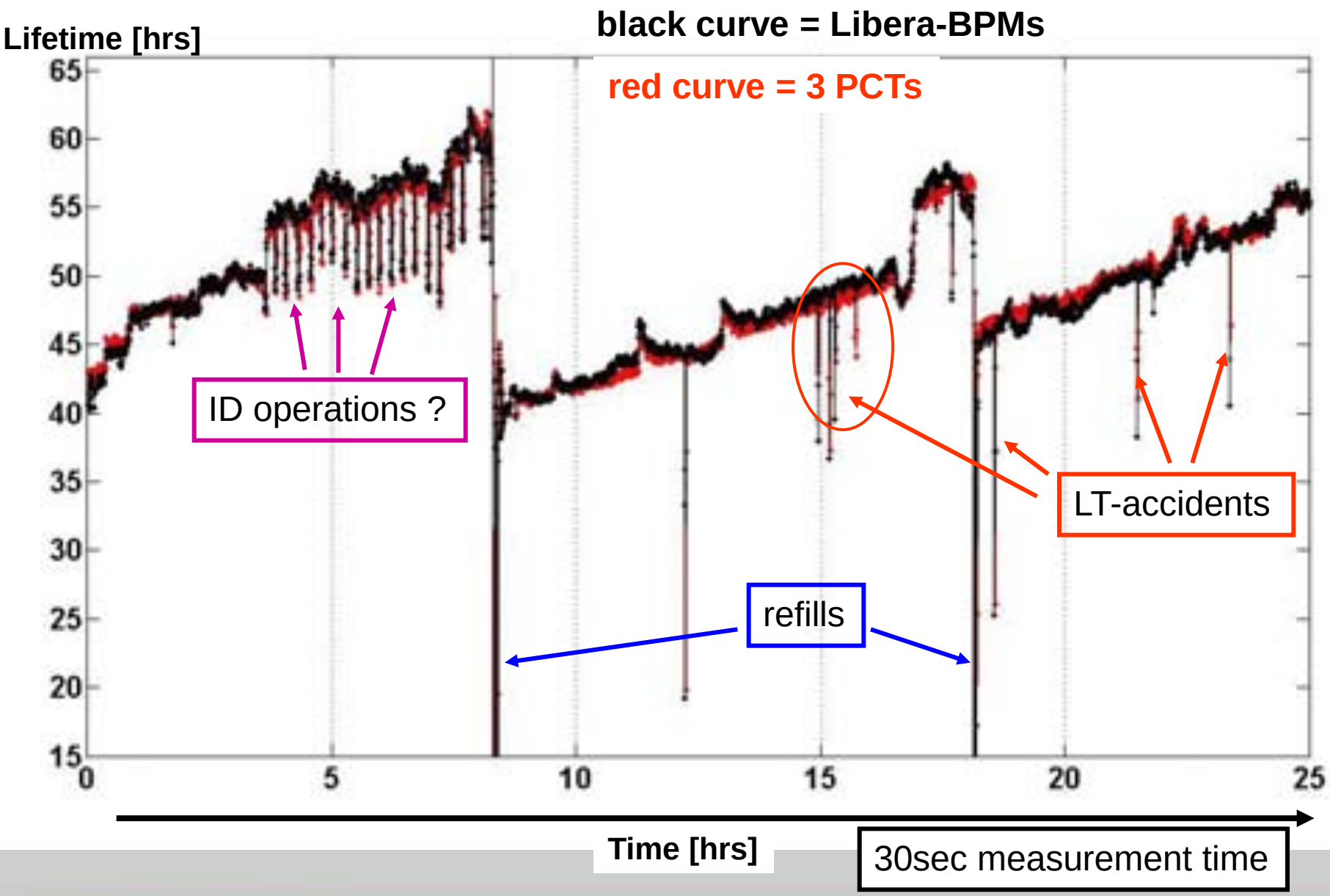


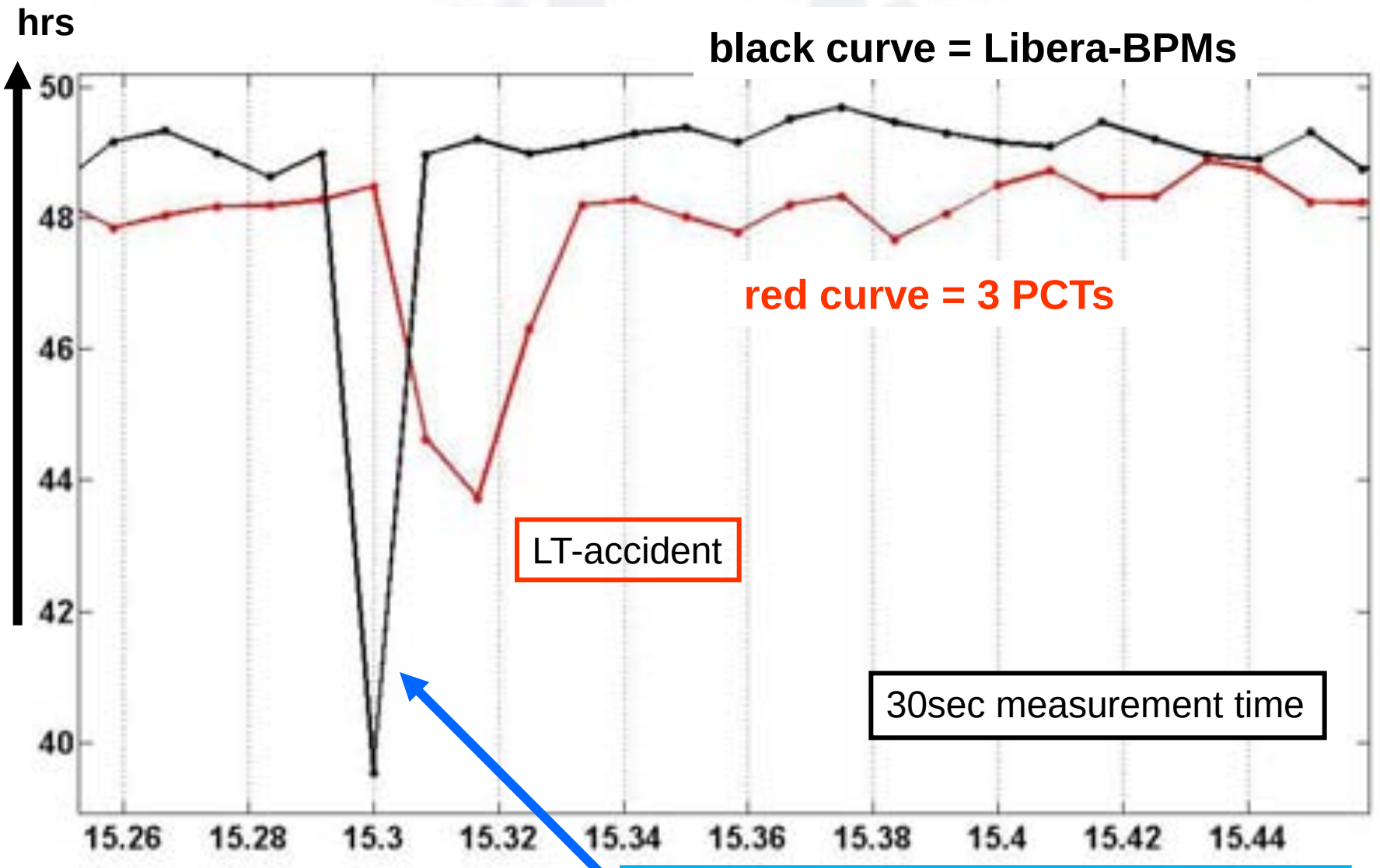
The full picture : all 32 cells equipped with 7 Liberas, = total of 224





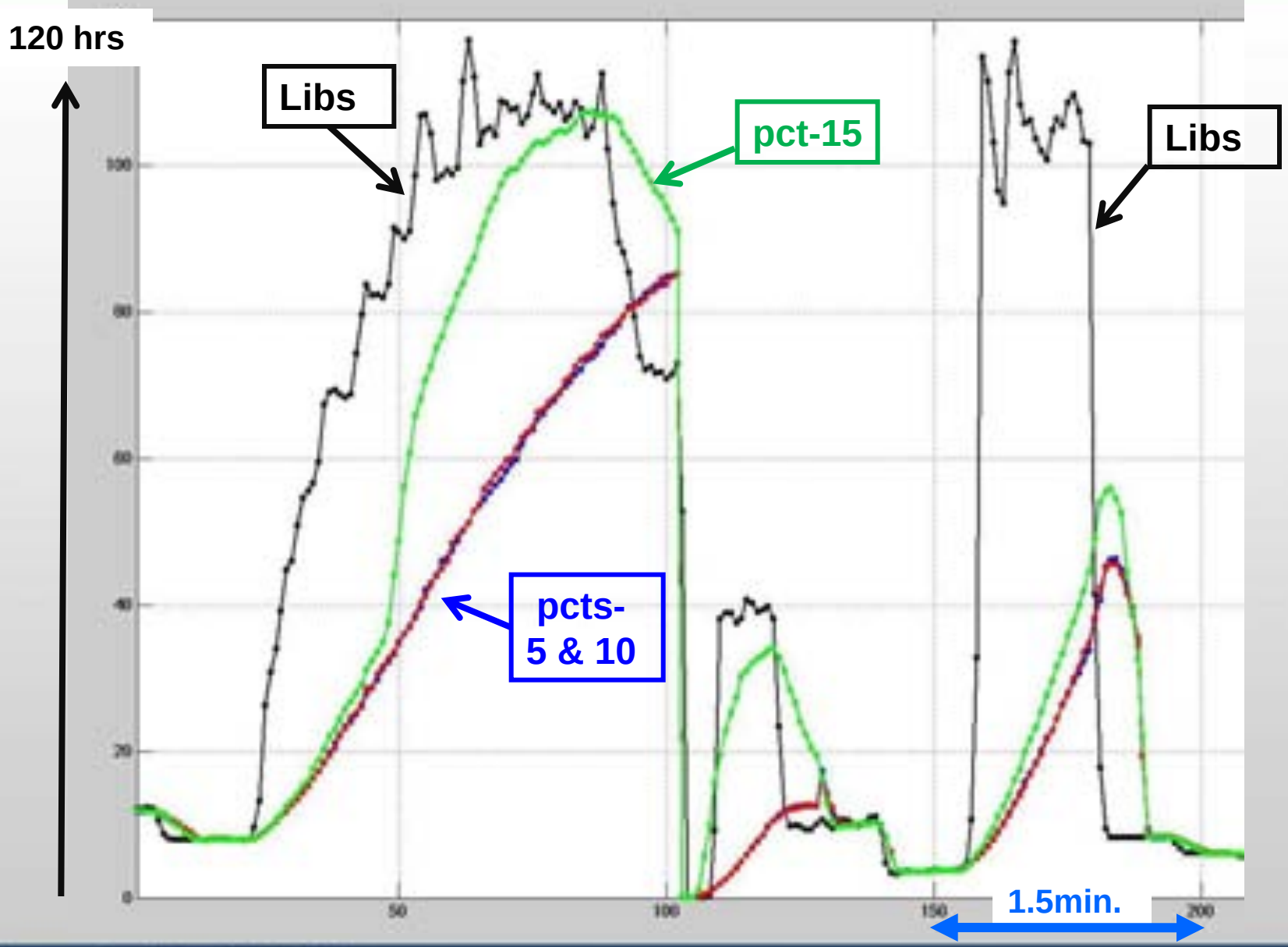
Lifetime is this slope

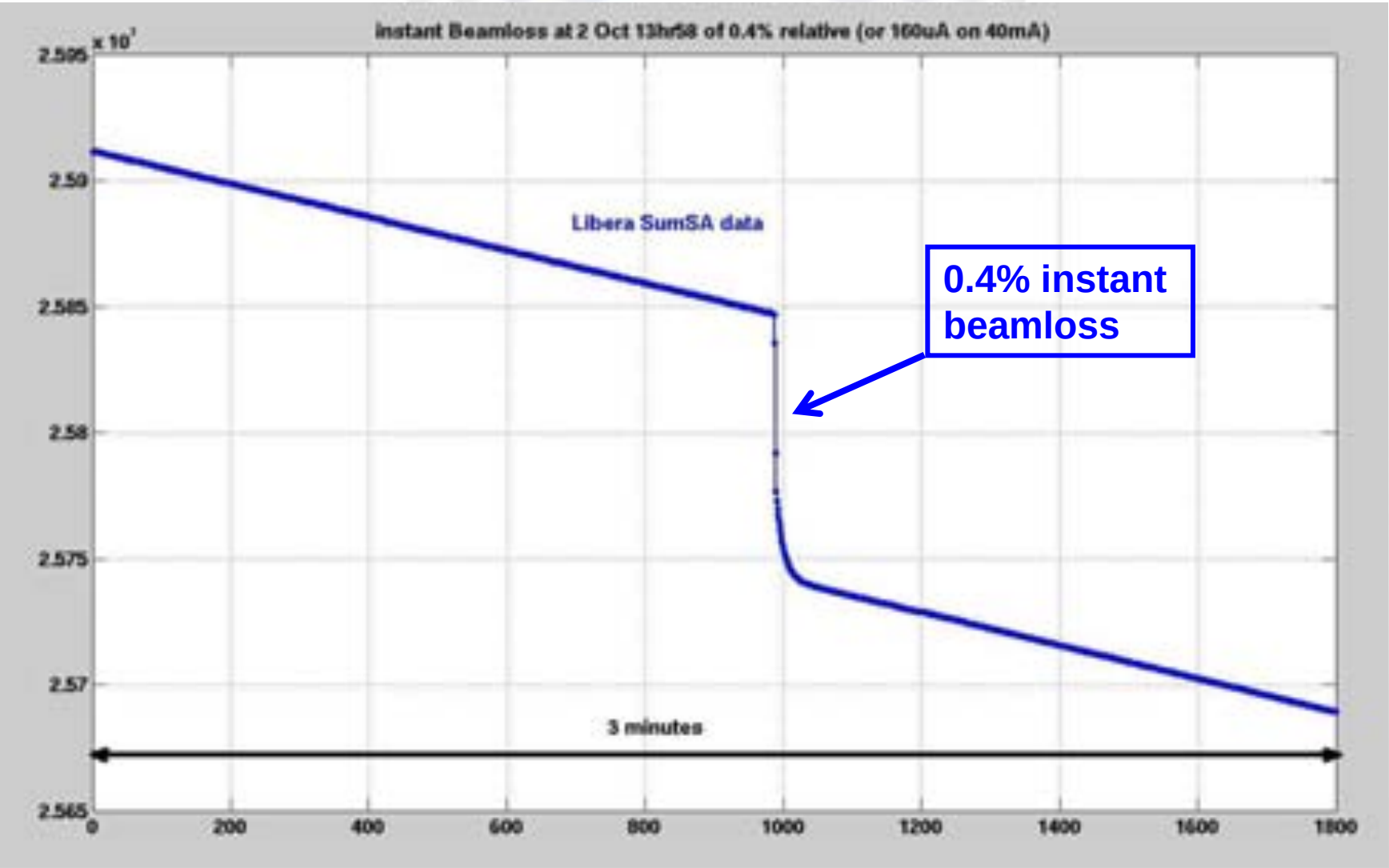

Lifetime [hrs]
black curve = Libera-BPMs
red curve = 3 PCTs
65
60
55
50
45
40
35
30
25
20
15
0
5
10
15
20
25
ID operations ?
LT-accidents
refills
Time [hrs]
30sec measurement time

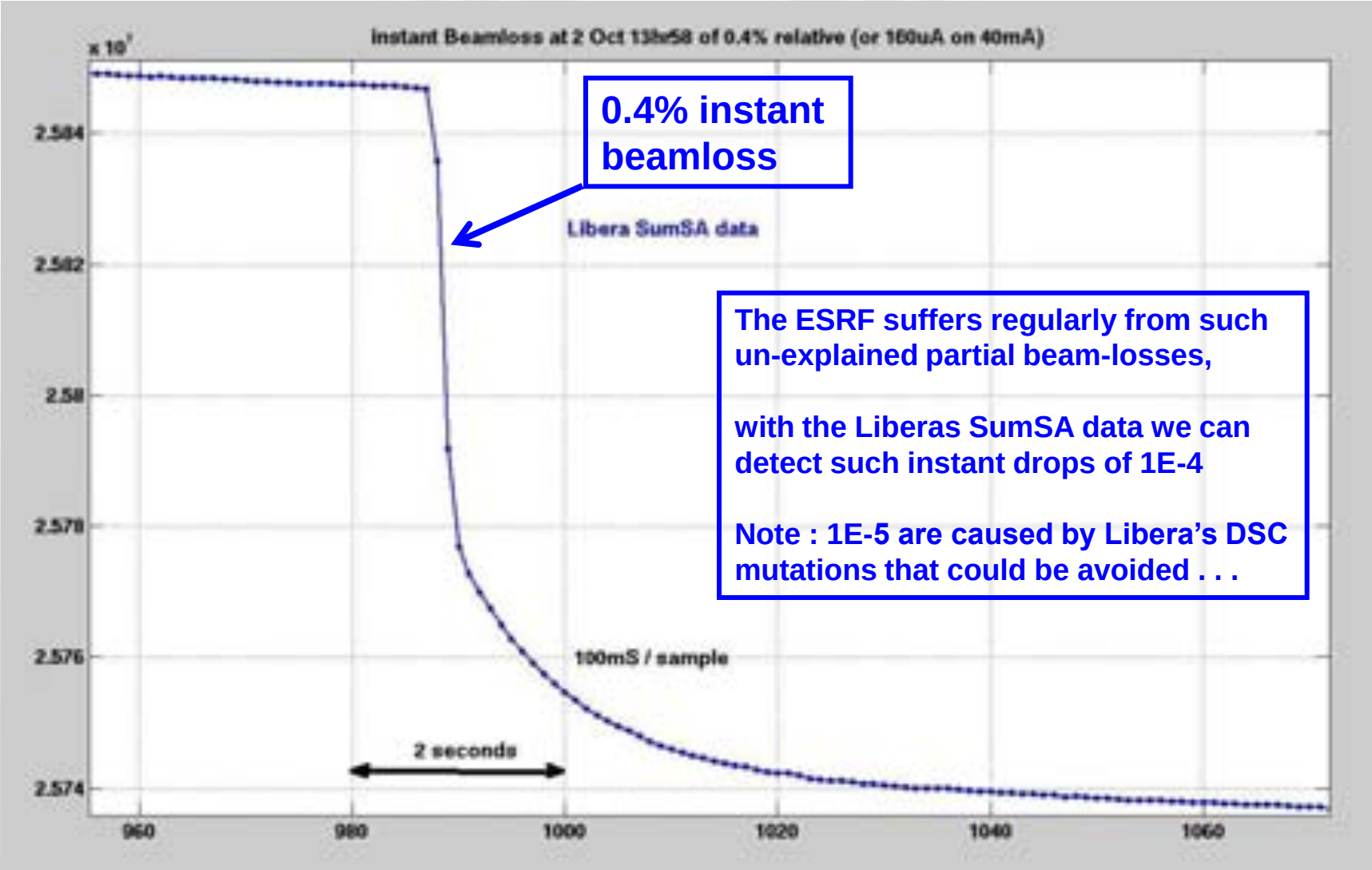


Conclusion : Liberas are faster

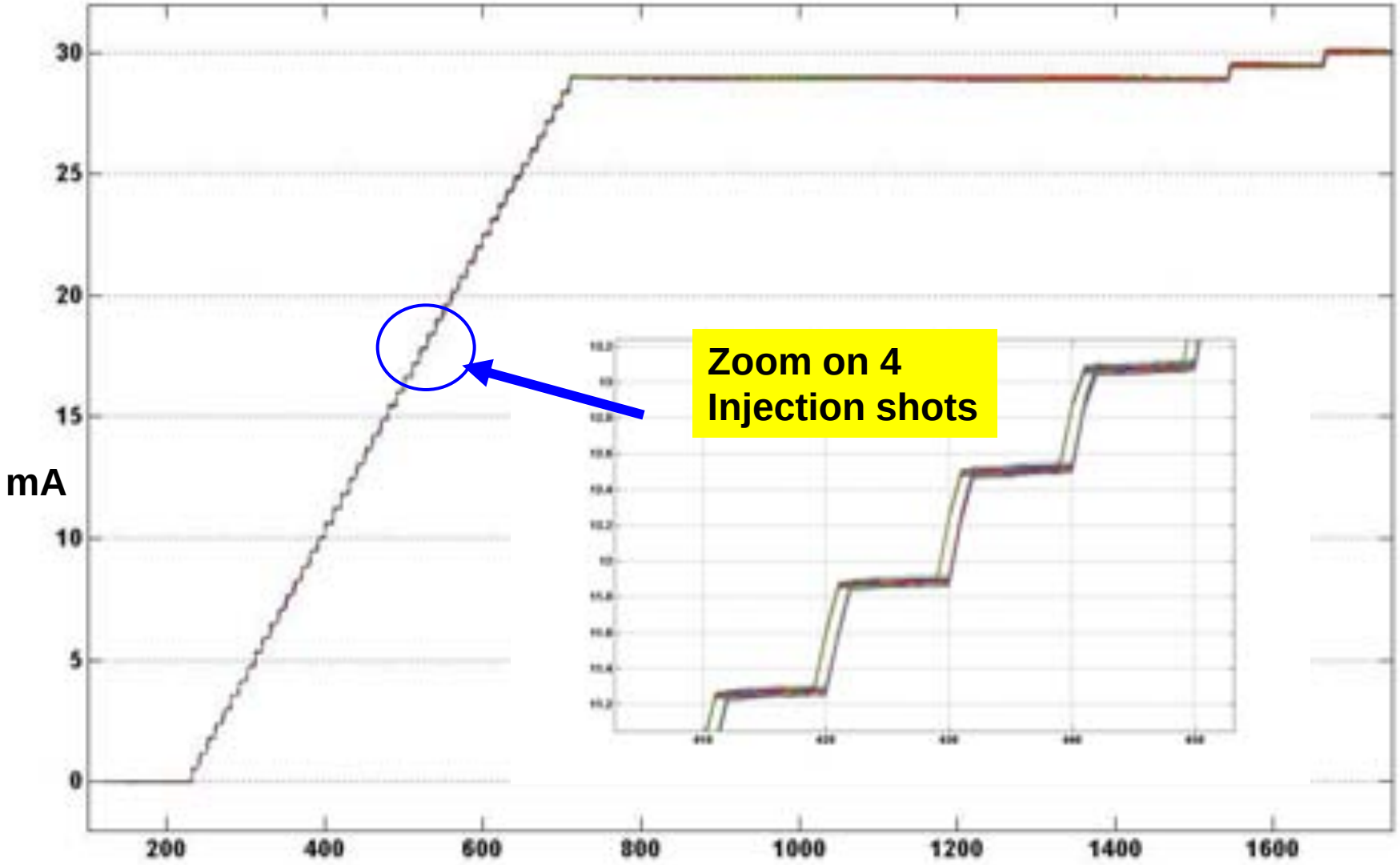
Lifetime measurements : response times of 3 PCTs and the Liberas




instant Beamloss at 2 Oct 13hr58 of 0.4% relative (or 160uA on 40mA)
x 10^1
2.595
2.59
2.585
2.58
2.575
2.57
2.565
0
200
400
600
800
1000
1200
1400
1600
1800
Libera SumSA data
0.4% instant beamloss
3 minutes


Instant Beamloss at 2 Oct 13h58 of 0.4% relative (or 160uA on 40mA)
x 10^7
2.584
2.582
2.58
2.578
2.576
2.574
960
980
1000
1020
1040
1060
0.4% instant beamloss
Libera SumSA data
100mS / sample
2 seconds
The ESRF suffers regularly from such un-explained partial beam-losses,
with the Liberas SumSA data we can detect such instant drops of 1E-4
Note : 1E-5 are caused by Libera's DSC mutations that could be avoided . . .

Added Current [mA] , derived from Sum of 4 buttons



final issues :

- we are using all added functionalities in 2.10 firmware (lifetime, DSC_survey, statistics etc.)
- we may have some few more new ideas ….
- and we still see improvements possible to DSC & health deamons

- we are concerned with Libera's break-down statistics . . .

- we are still investigating the FA network and mystery when using the 4 rocket-I/O ports

Towards full use of the Libera BPMs in the ESRF Storage Ring

many thanks !

for your hospitality

and your attention