first measurements with Libera Spark

Motivation : replacement of the 25years old ESRF's Booster BPM system (electronics)

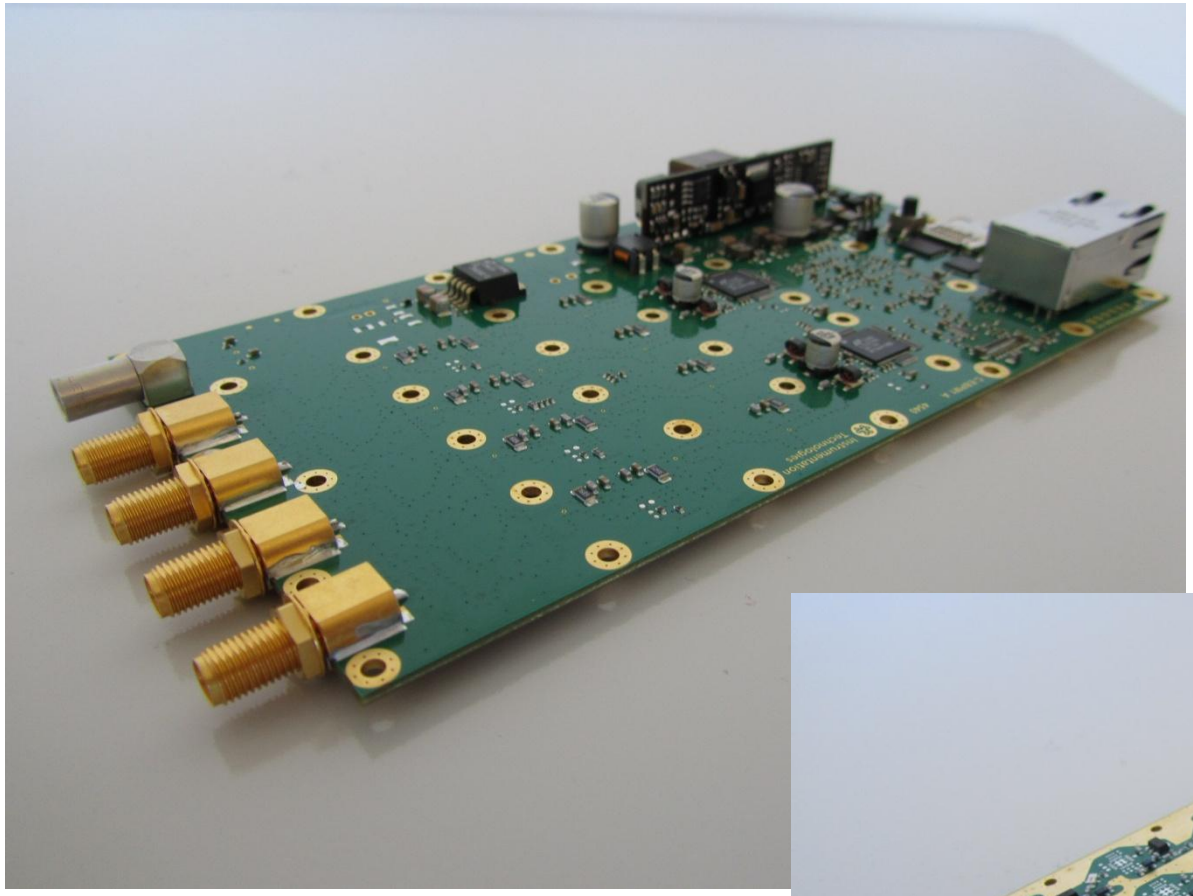
Goals & Aims : modern system with maximum sensitivity & lowest noise capable of Turn-by-Turn measurements

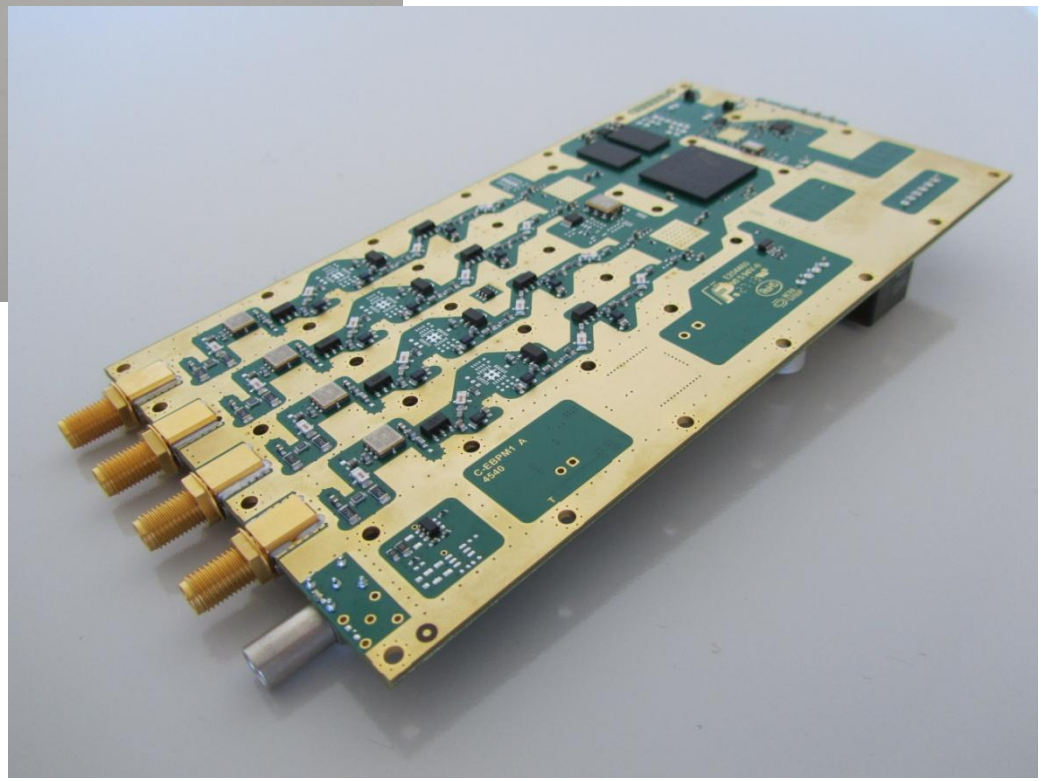
Other considerations :
- simplicity
- low costs
- self-contained system

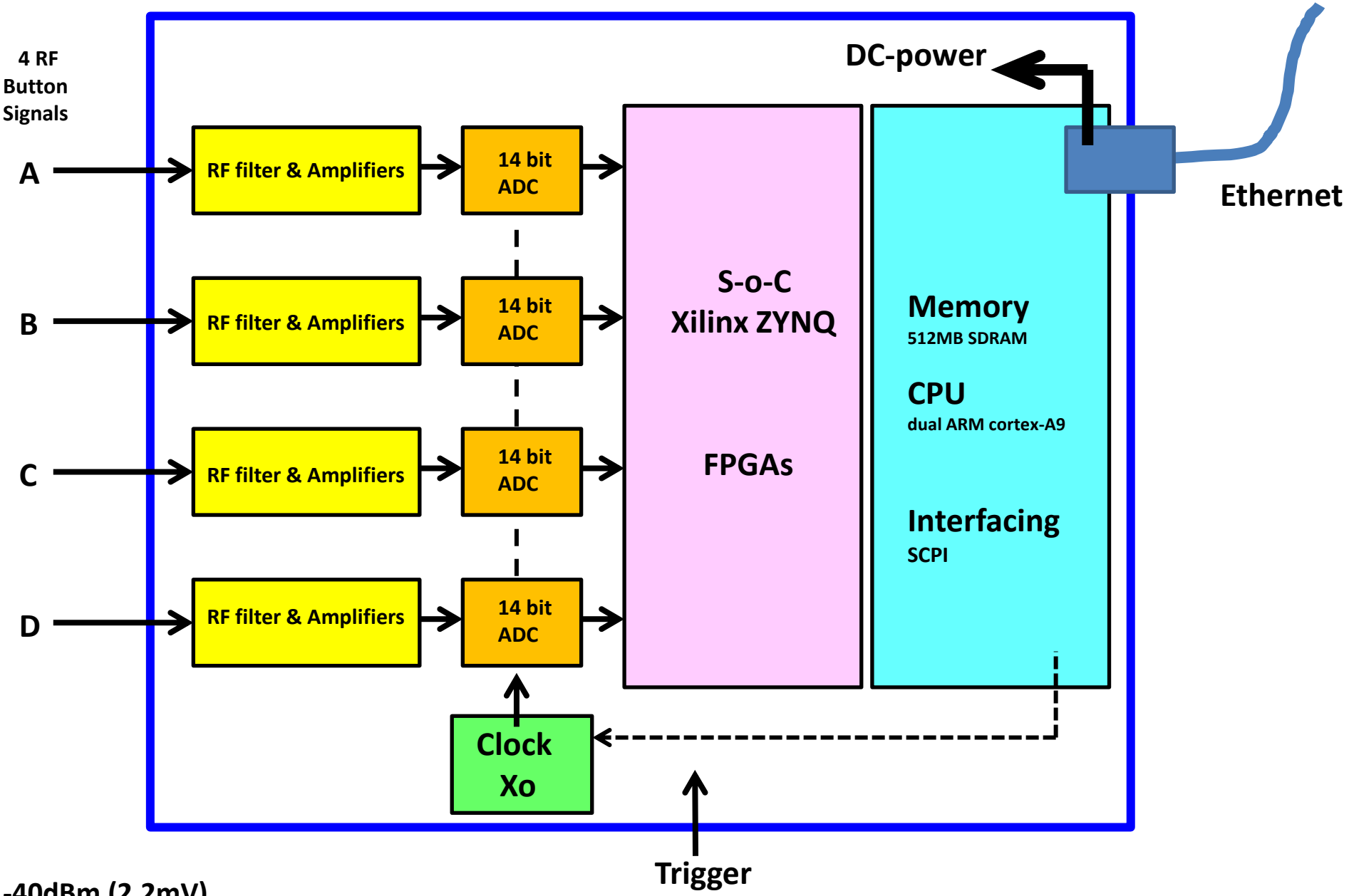
The Spark, product definition :
- 4 channel digitizer for weak RF signals
- adequate signal processing for data-rate reduction
- efficient interface for control & read-out via Ethernet
- suitable chassis & housing, with Power-over-Ethernet

Libera-Spark

Libera-Spark




C-EBPM1 A
6540



-40dBm (2.2mV) for ADC full-scale

RF = 352MHz
Xo = 108MHz

Note : - No PLL
- No variable Gain

ESRF-Booster

Circumference=300m

Orbit time = 1us

Harmonic No. 352

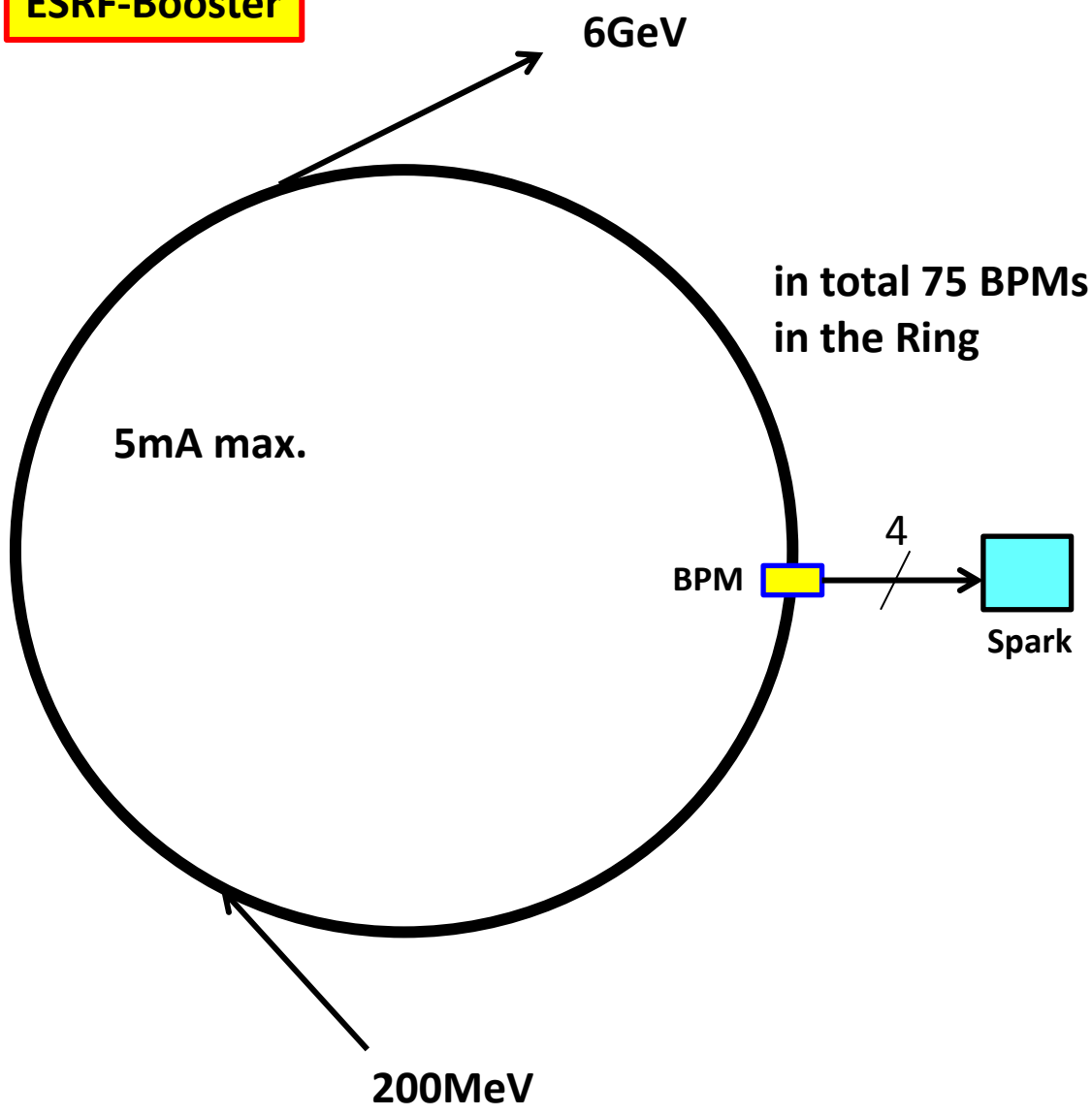
RF-freq. =352.202 MHz

Acceleration cycle = 50ms

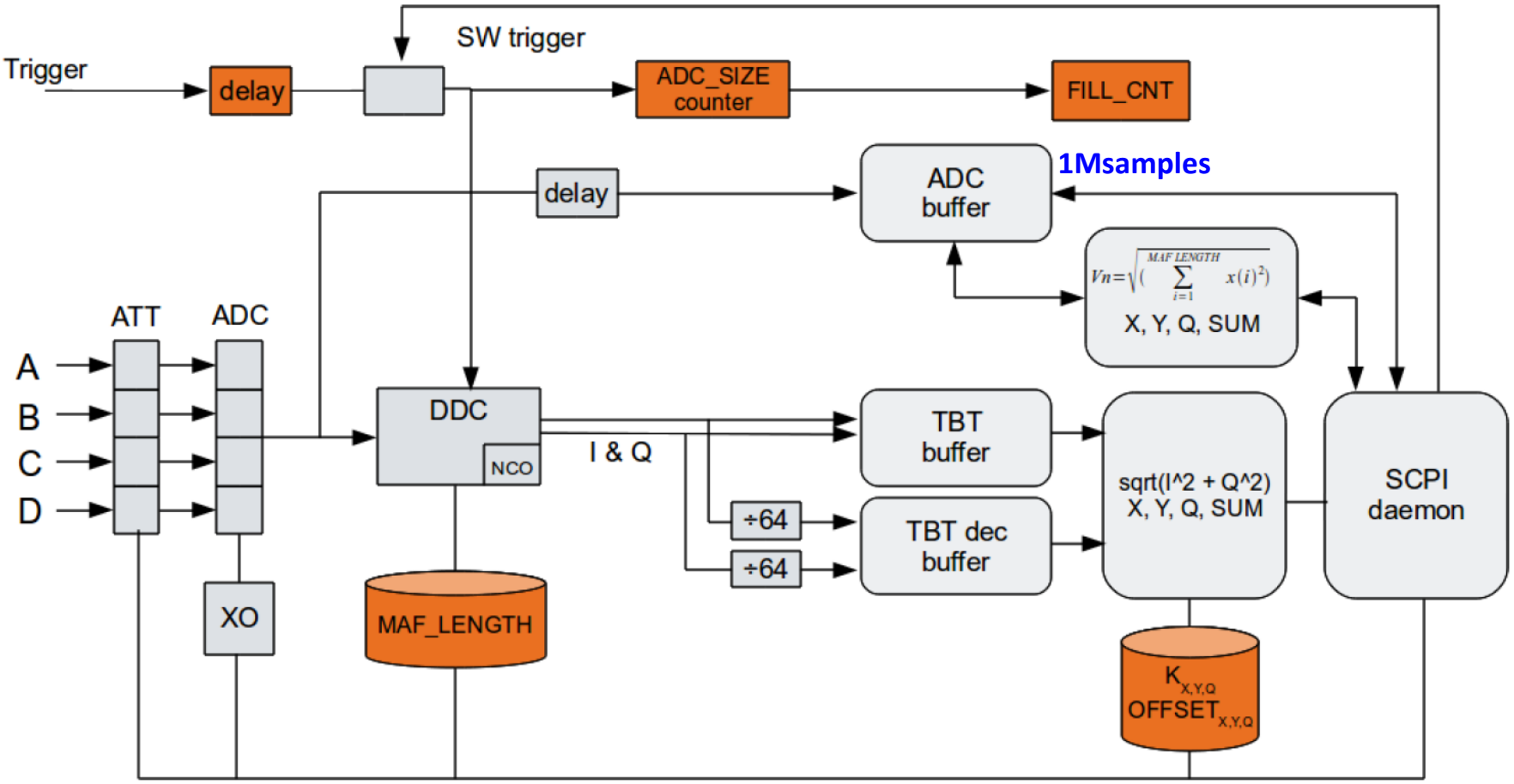
after Injection, the beam
makes about 50 000 Turns

BPM requirement : measure
at <u>Turn-by-Turn rate</u>

The Spark takes
108 samples/Turn
i.e. 108MHz



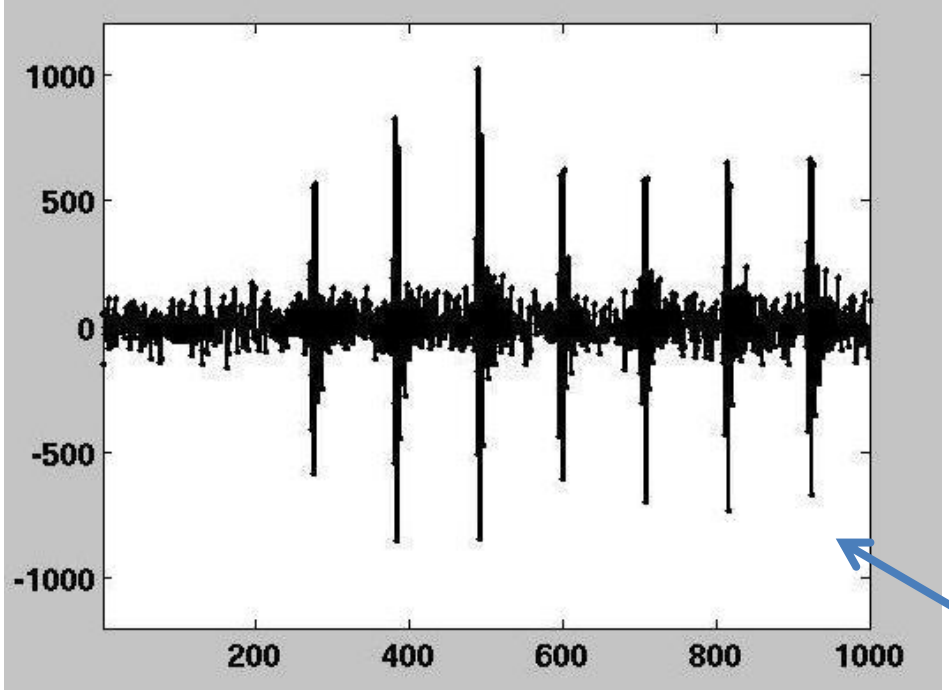
Complete processing scheme is shown in Figure 8. Orange color stands for a parameter.

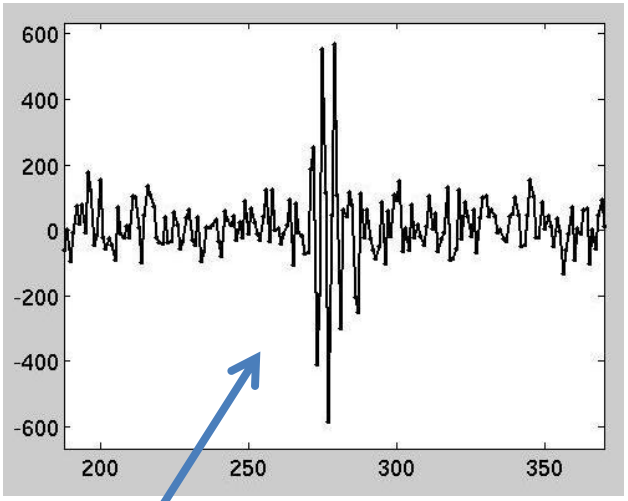


- **The DDC does quadrature demodulation : I & Q outputs are available**

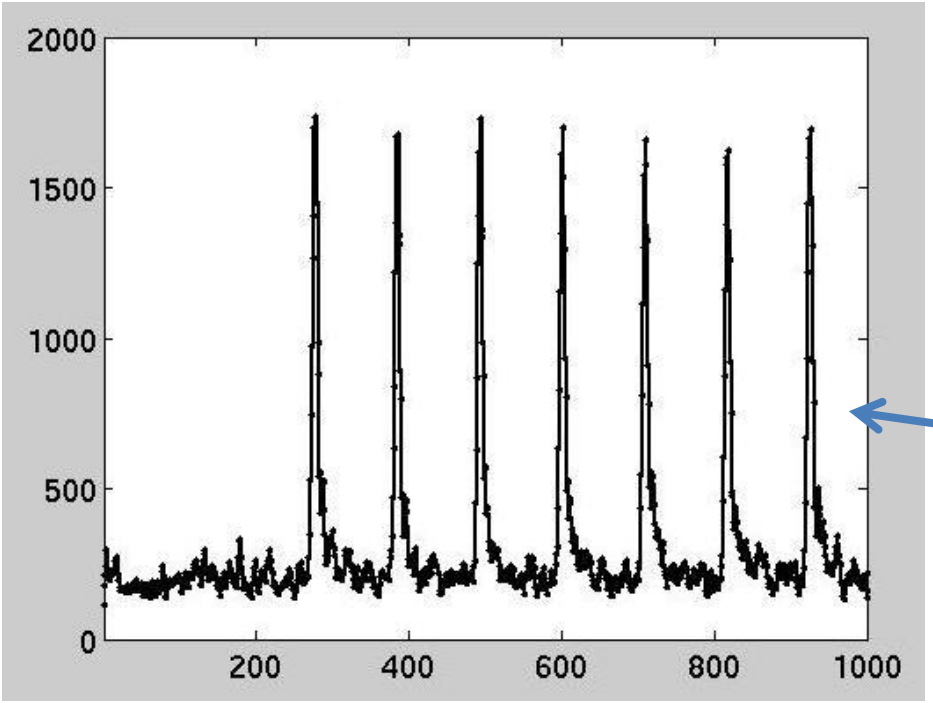
- **The DDC also allows a (MAF) filtering on the ADC**
  (however, does not work well with I & Q demodulator)

- **So a time-domain processing was also added (but now limited to 1Ms ADC buffer = 9mS)**





Raw ADC signals with only a single bunch in the Ring



Summed & Filtered ADC signals with only a single bunch in the Ring

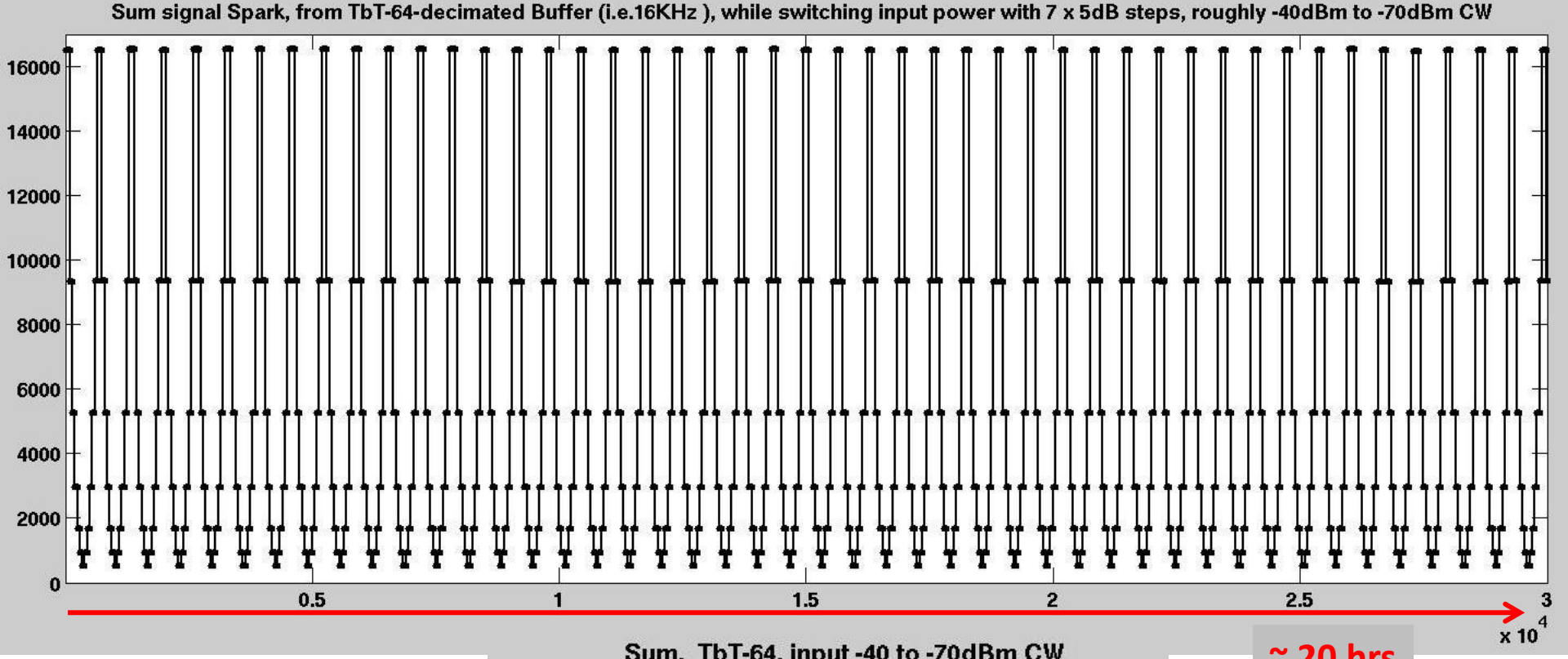
Short report of (many) tests done :

- **Resolution (noise),**
- **Beam_Current_Dependence ,**
- **Long-Term stability**

} **of the Beam Position (Kx & Kz = 10,000)**

- Absolute value and the stability of the XOs (i.e. of 75 different units)

- Resolution of Turn-by-Turn measurements (with single bunch fill & Time-Domain processing)



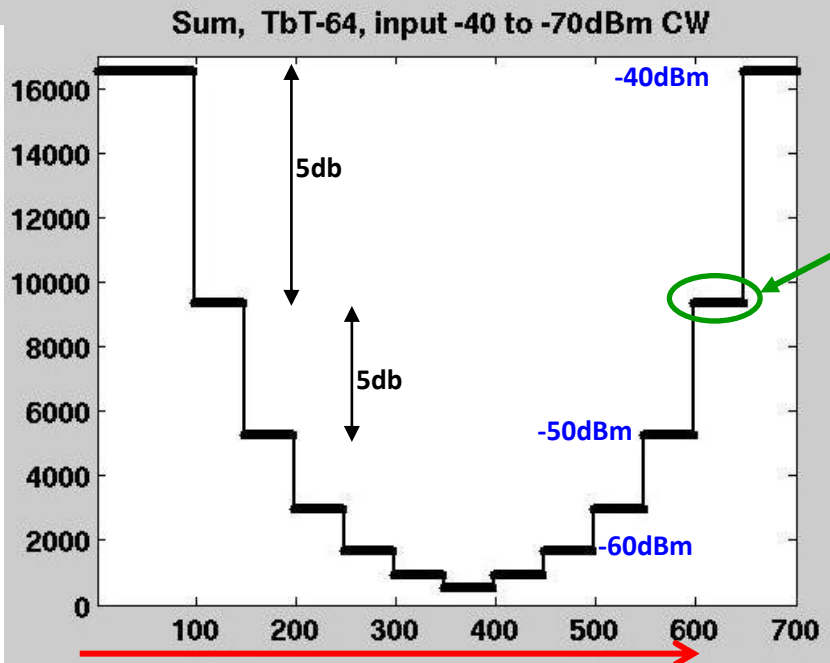
~ 20 hrs

TbT-dec64 buffer (16KHz)
of 1600 samples (=0.1 sec)

was read every 2 secs

<u>average</u> & <u>rms</u> values on
X and Z calculated

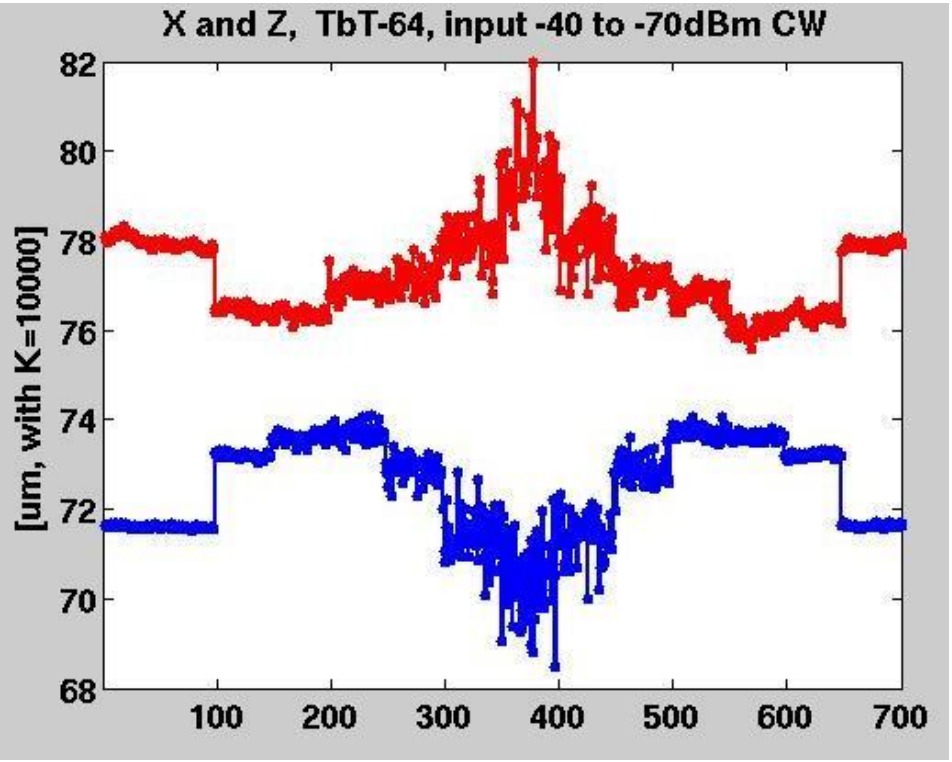
every 100 sec the RF input level
was changed by 5dB
7 steps from -40 to -70dBm

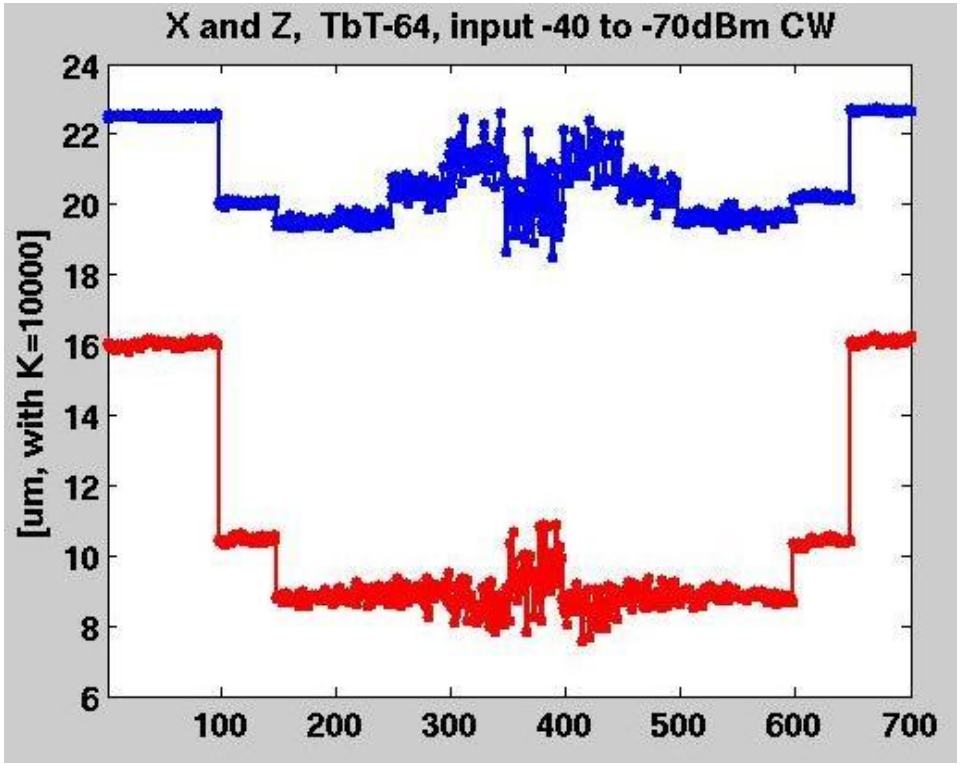


50 points

~ 20 min

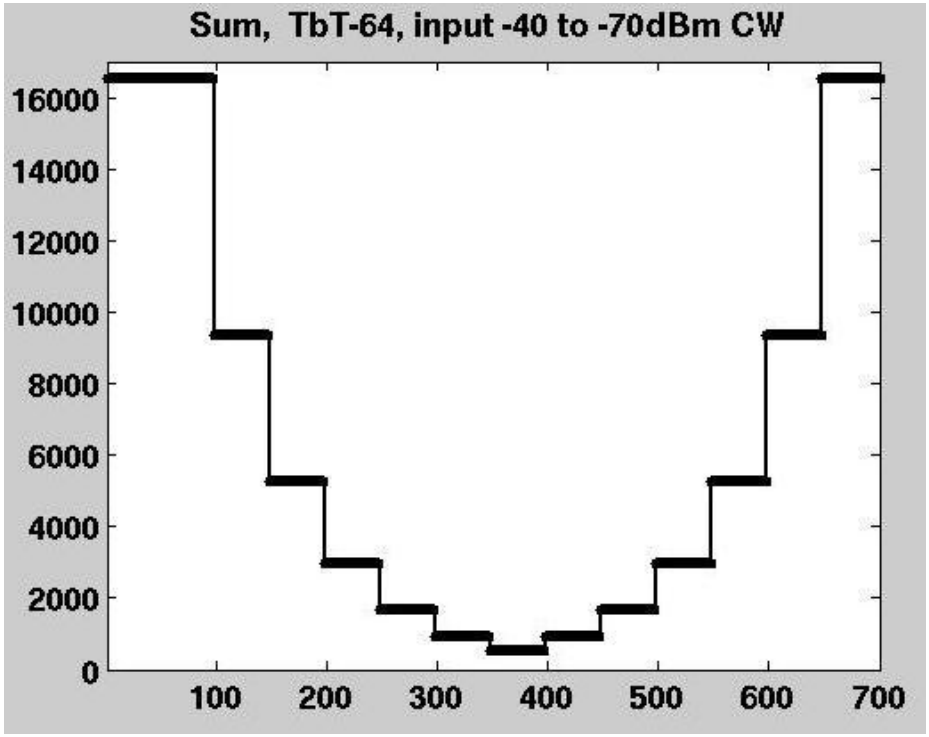
measured on 2 Sparks , X & Z

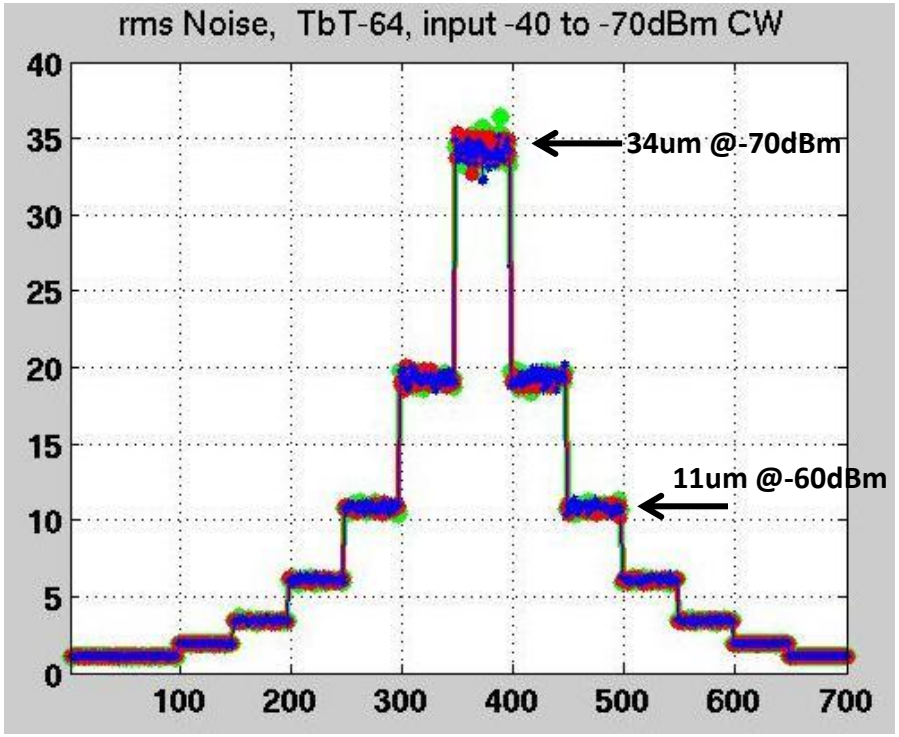




Beam_Current_Dependence : 3 , 3 , 3 , 8 [um] between -40 / -70dBm

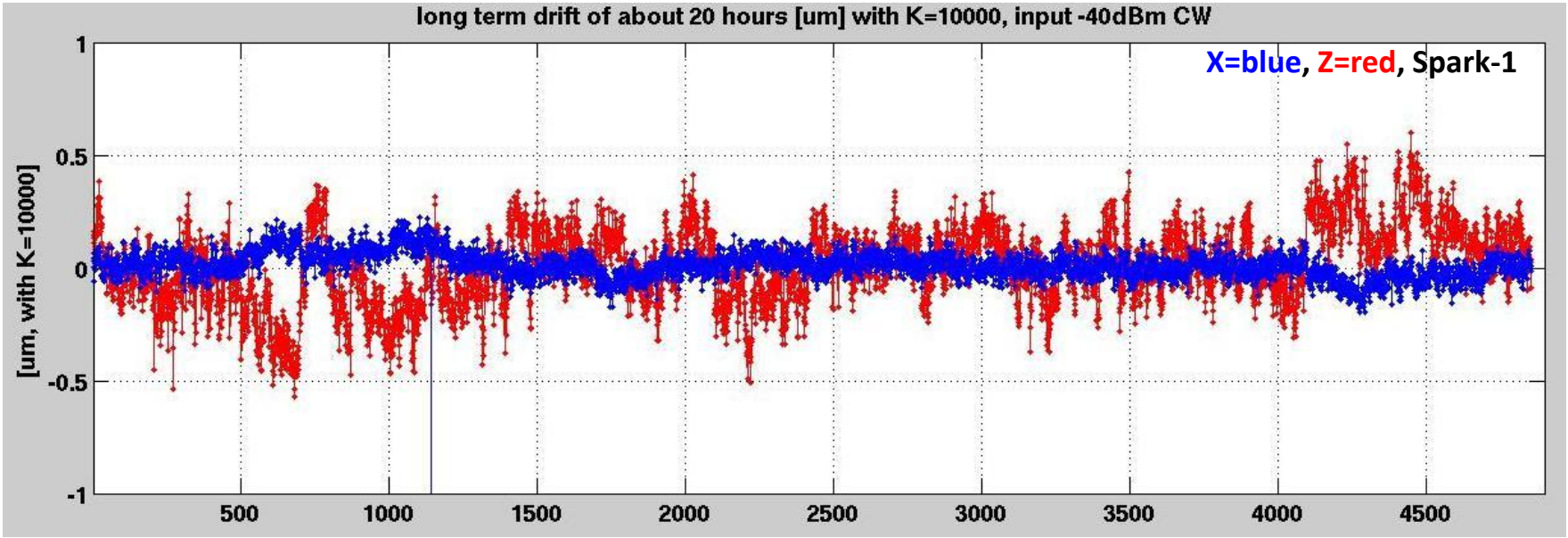
measured on 2 Sparks , X & Z

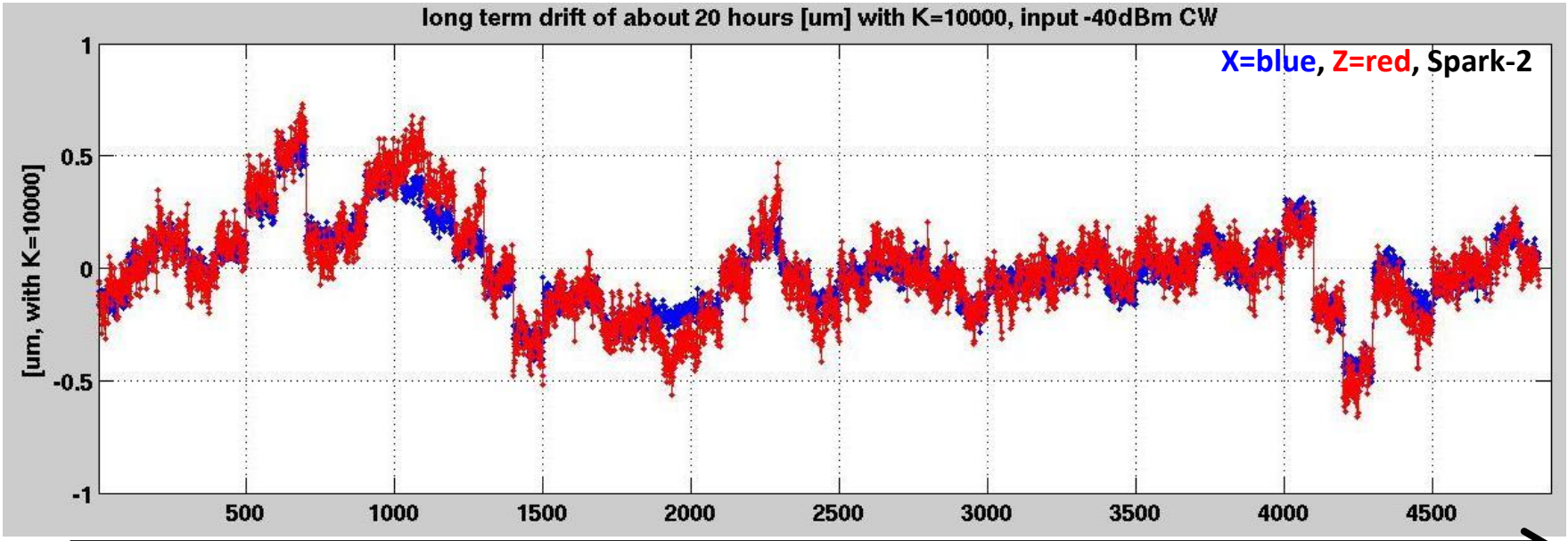




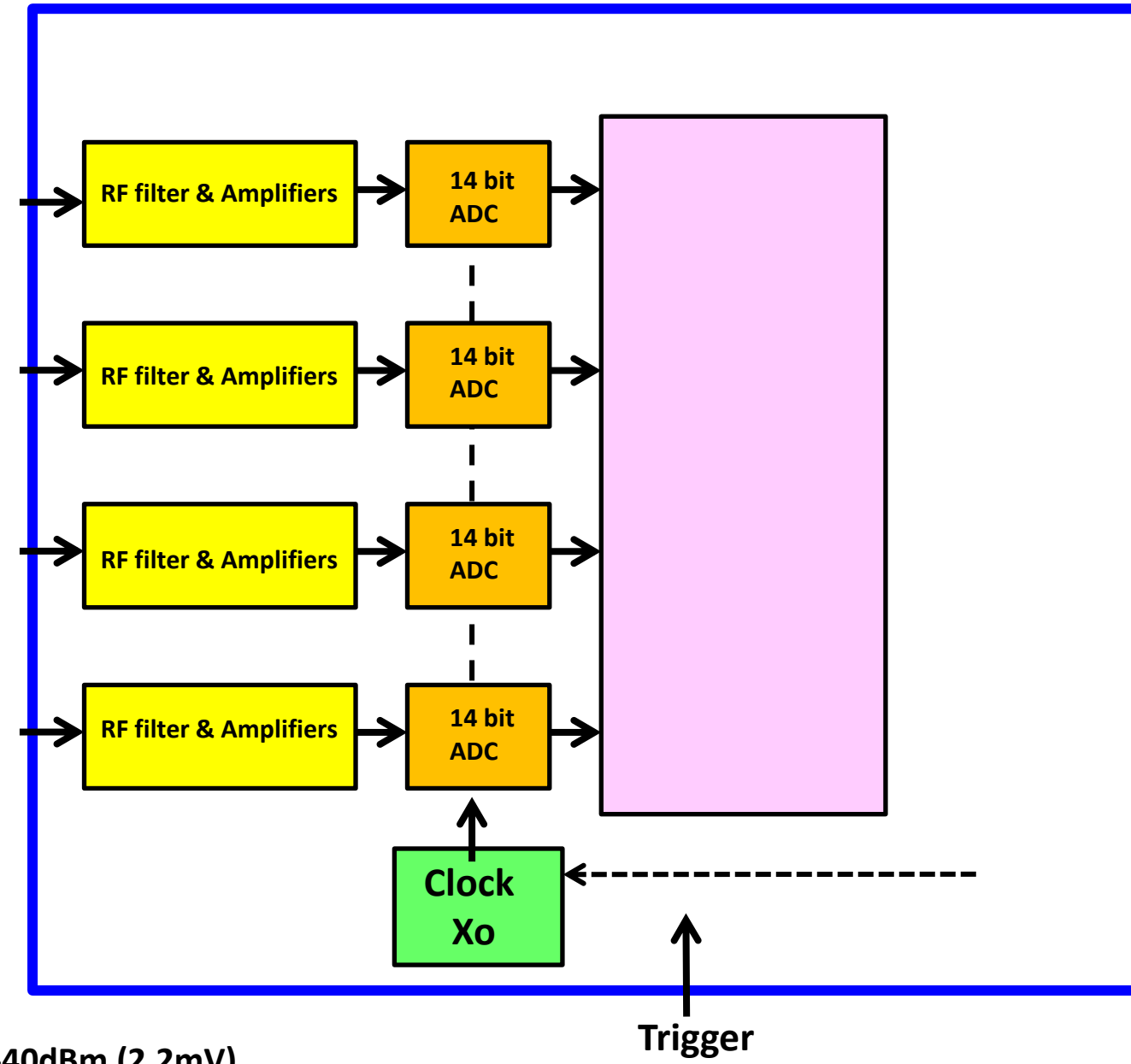
	-40	-50	-60	-70	Input Level[dBm]
Noise (resolution) :	1.1	3.4	11	34	at 16KHz rate [um]

long term drifts < 1um





but up to 4dB difference in relative Gain between the 4 chs



-40dBm (2.2mV)
for ADC full-scale

Absolute value and the stability of the XOs (considering 75 different units)

Note : the Spark has no PLL ,
however the TbT buffers are started by the Trigger

This implies :

TbT data is synchronized between all BPMs by that single Trigger
(of course adjusting individual trigger delays to compensate for diff. cable lengths etc.)
at the Start,
but may drift in the measurement window (due to real XO freq. is not the set value)

Remedy :
This difference (set-real) can be easily measured, on each Spark, by an FFT on the ADC buffers,
The re-program all the XOs so that now the real XO freqs are very close,

and then hope that it stays like this, so that you do no have to do this every day or week.
(* reprogramming the XO implies a reboot . . .)

No results shown here but XO stability is OK on the 2 prototypes

ESRF-Booster

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Harmonic No. 352

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BPM requirement : measure at <u>Turn-by-Turn rate</u>

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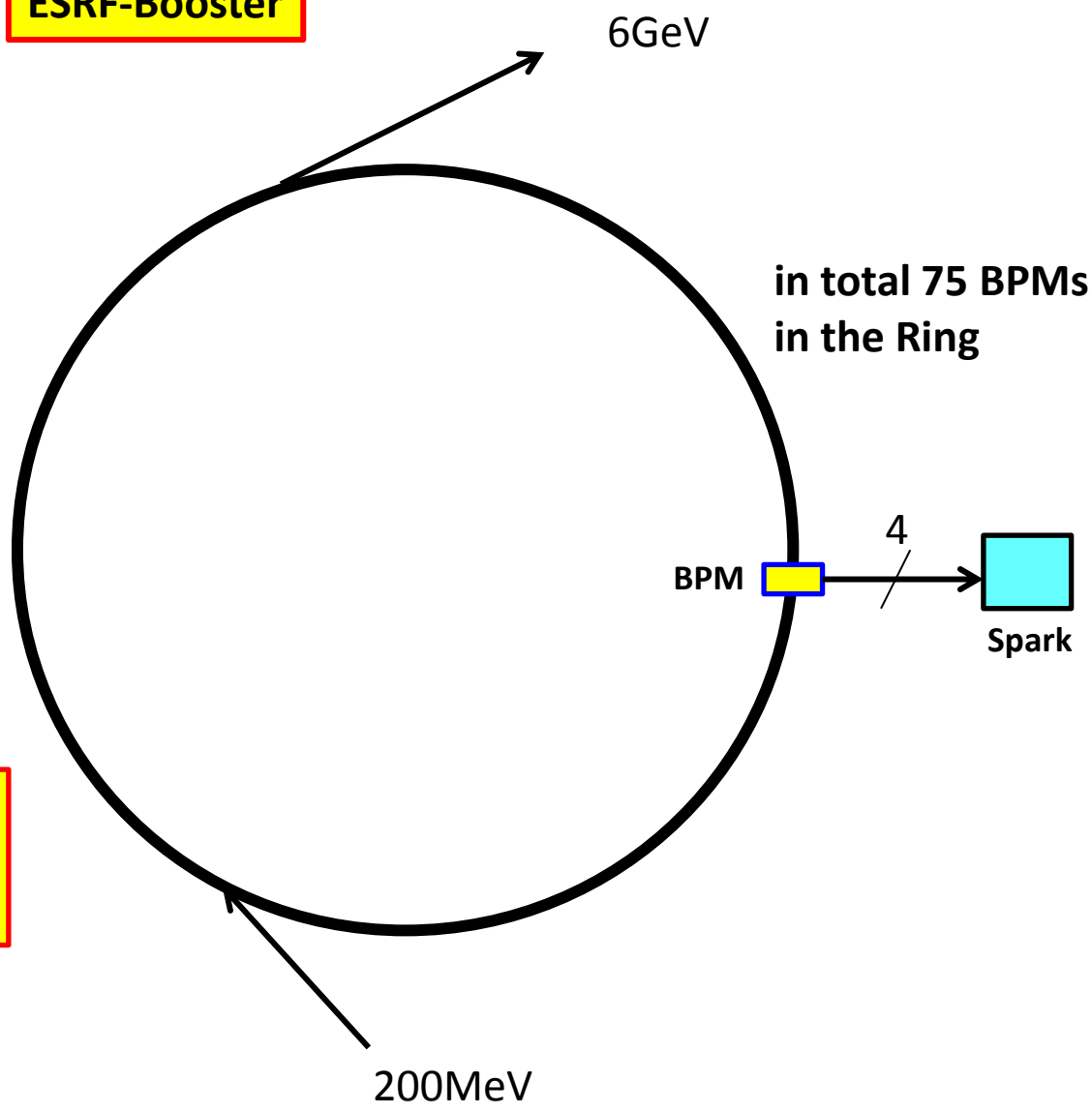
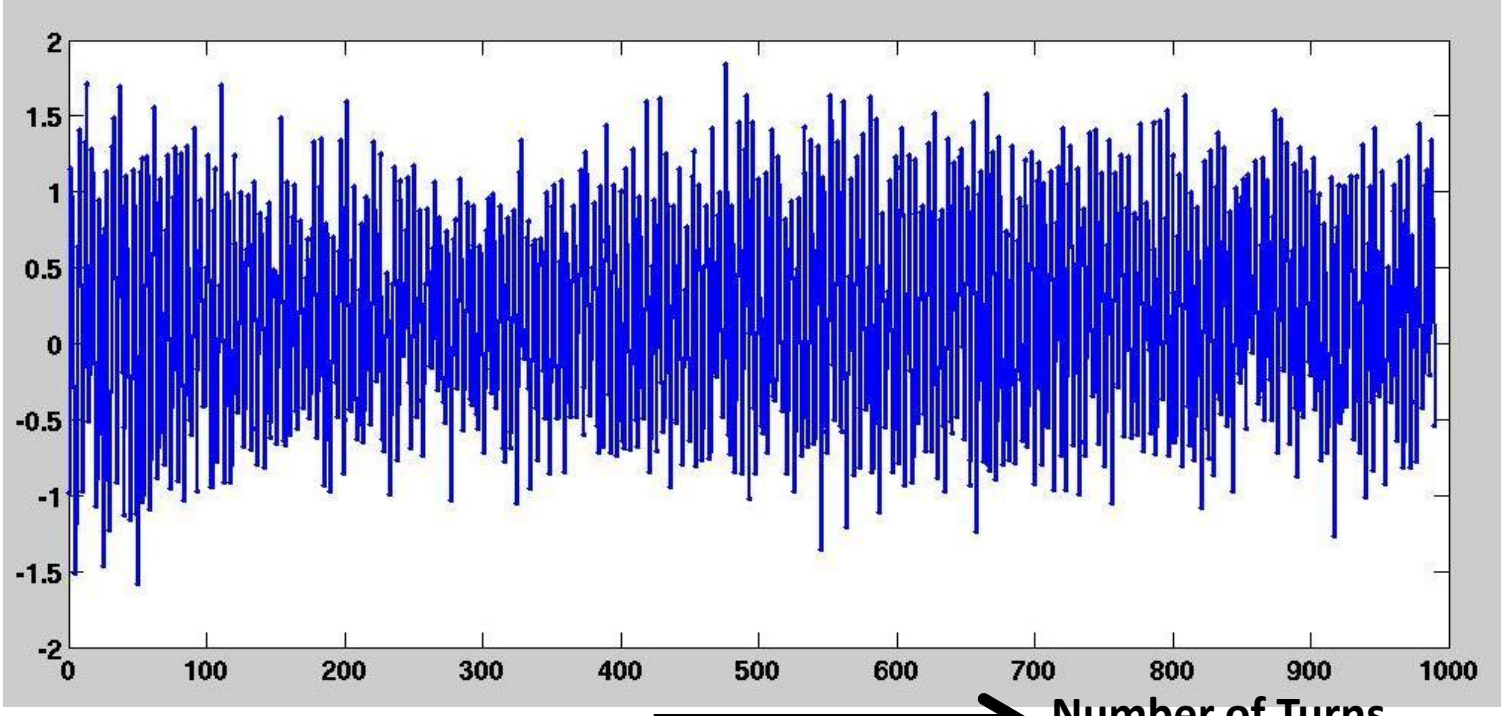
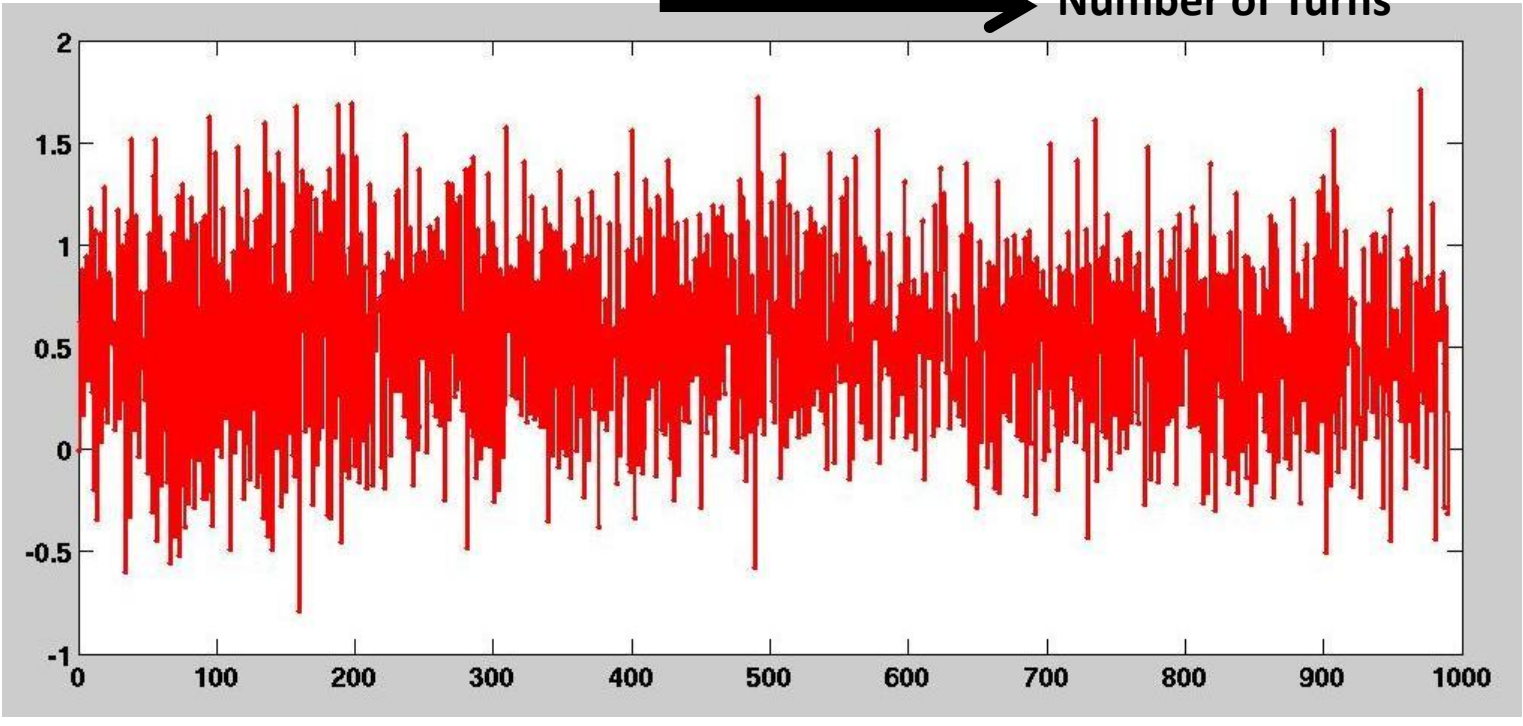


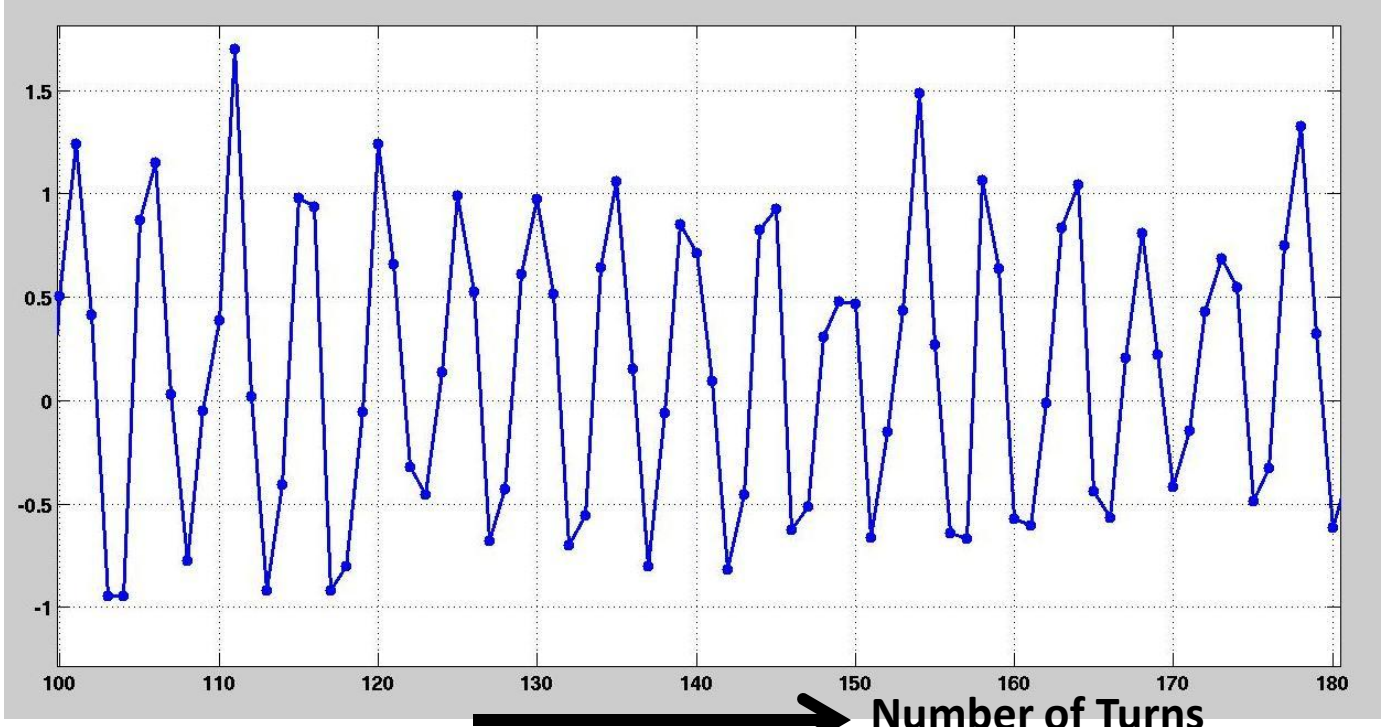


Hor. Position

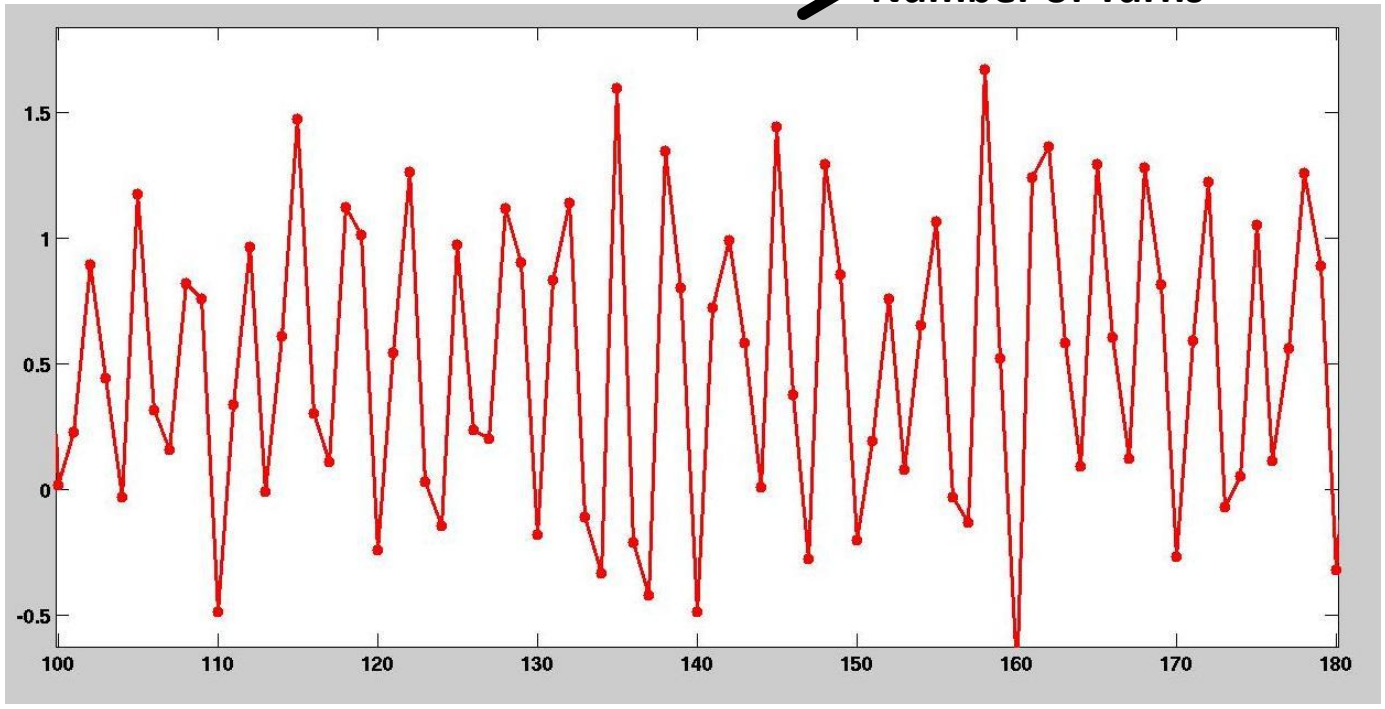
Number of Turns



Vert. Position



Number of Turns



Hor. Position

17 oscillations

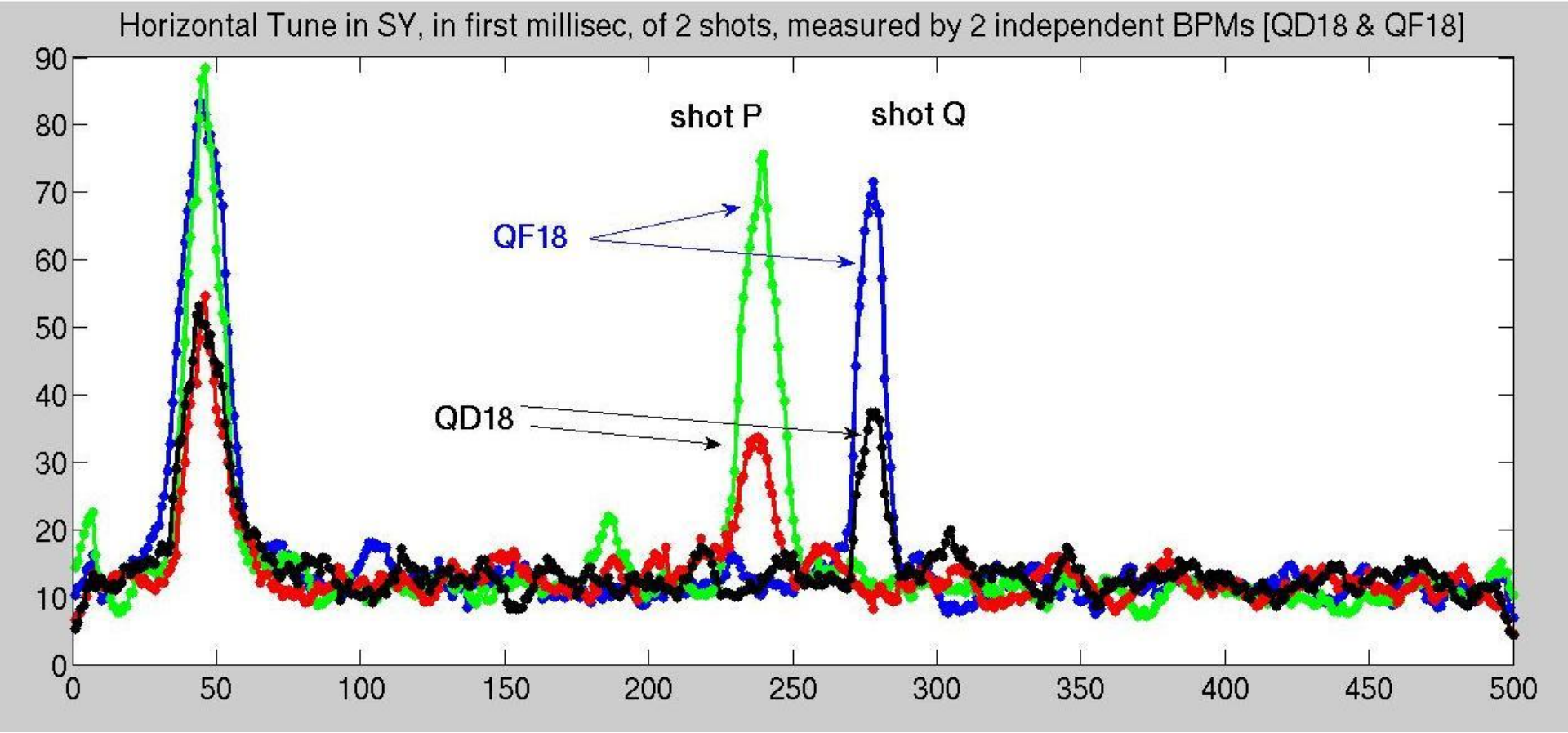
Time-Domain Processing on the ADCs

Vert. Position

24 oscillations

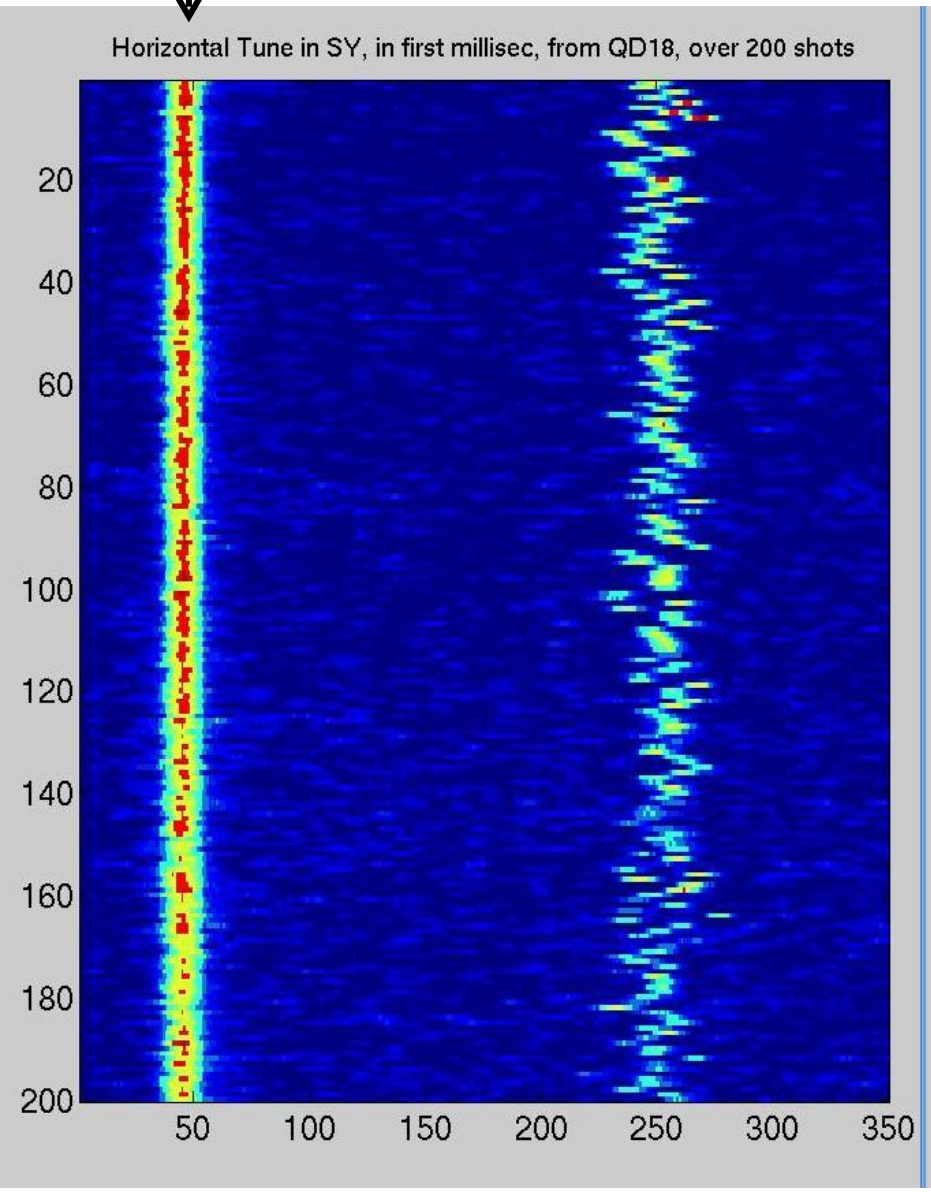
Hor. Beam oscillation
at 46KHz

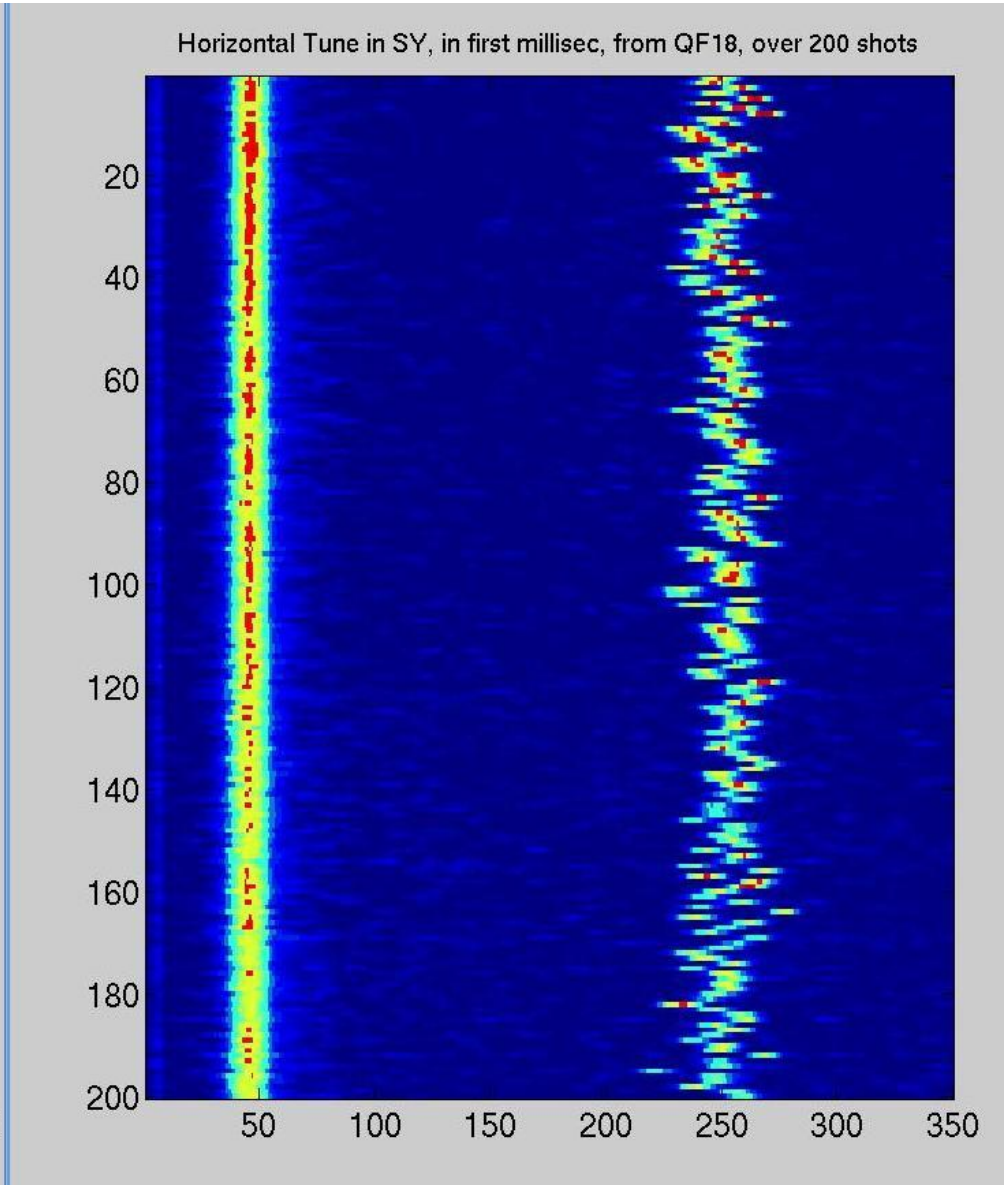
2 shots of Hor. Booster Tune



Hor. Beam oscillation at 46KHz

200 shots of Hor. Booster Tune, showing strong fluctuations

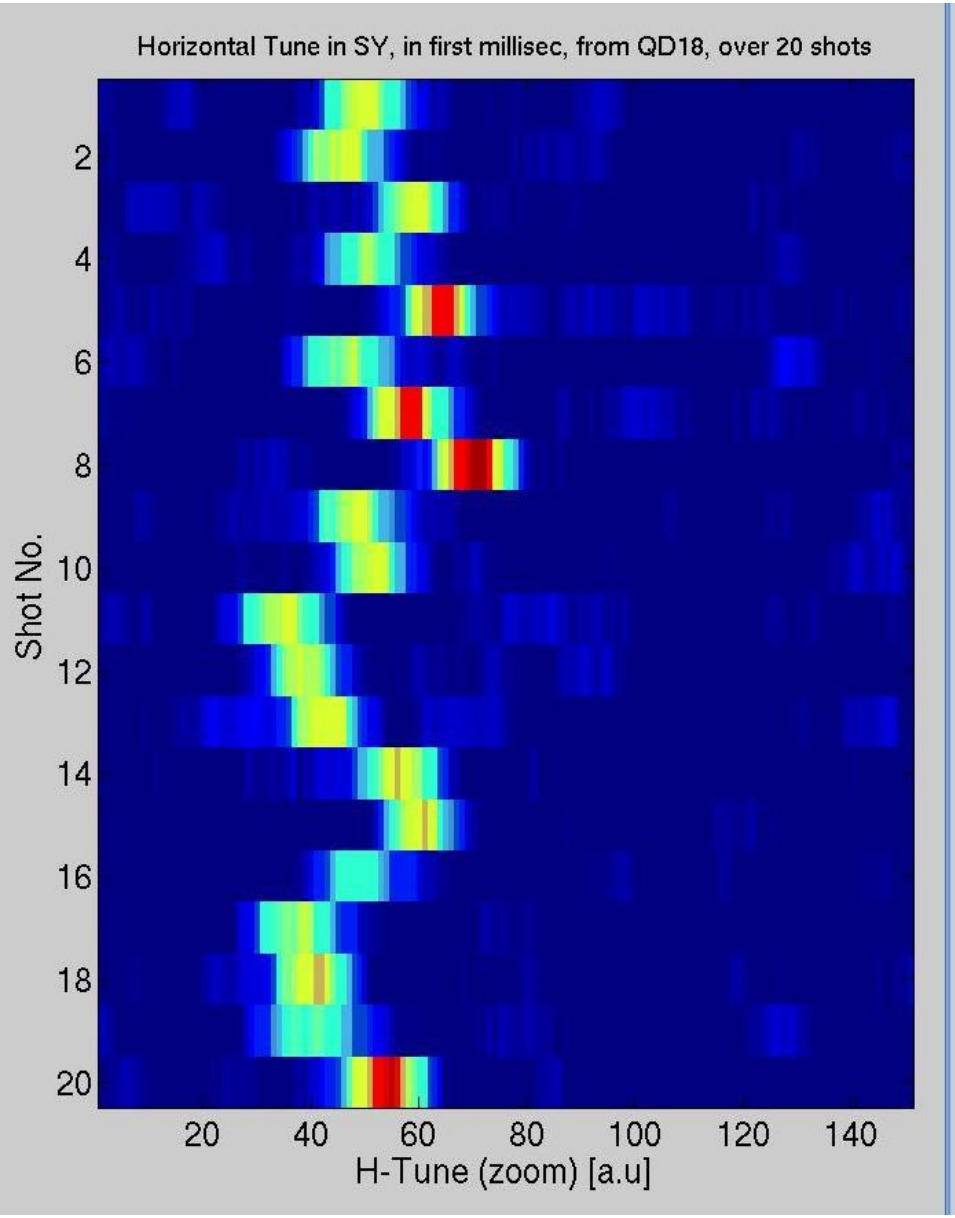


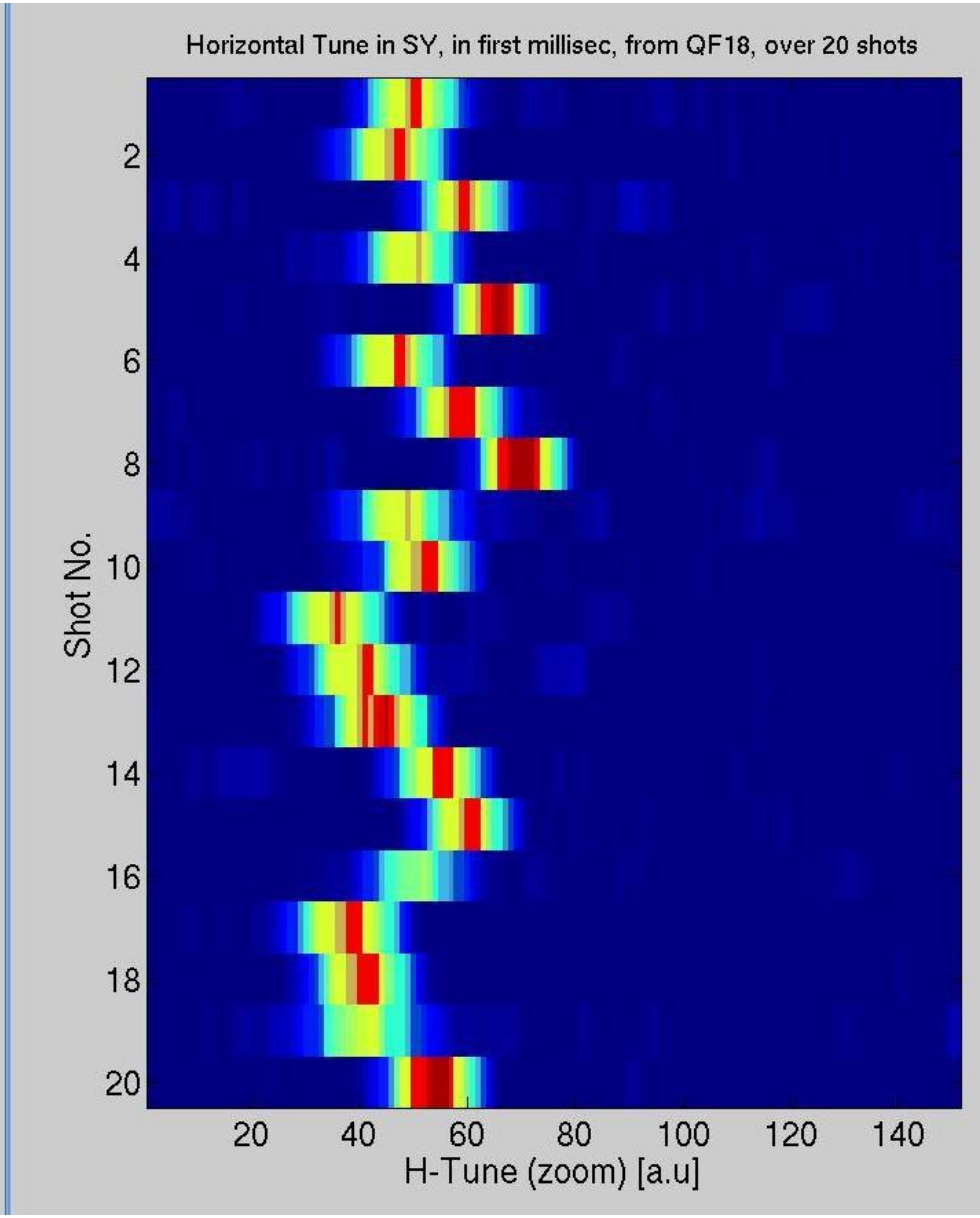


Left picture : from BPM QD18

Right picture : from BPM QF18

20 shots of Hor. Booster Tune, showing strong fluctuations

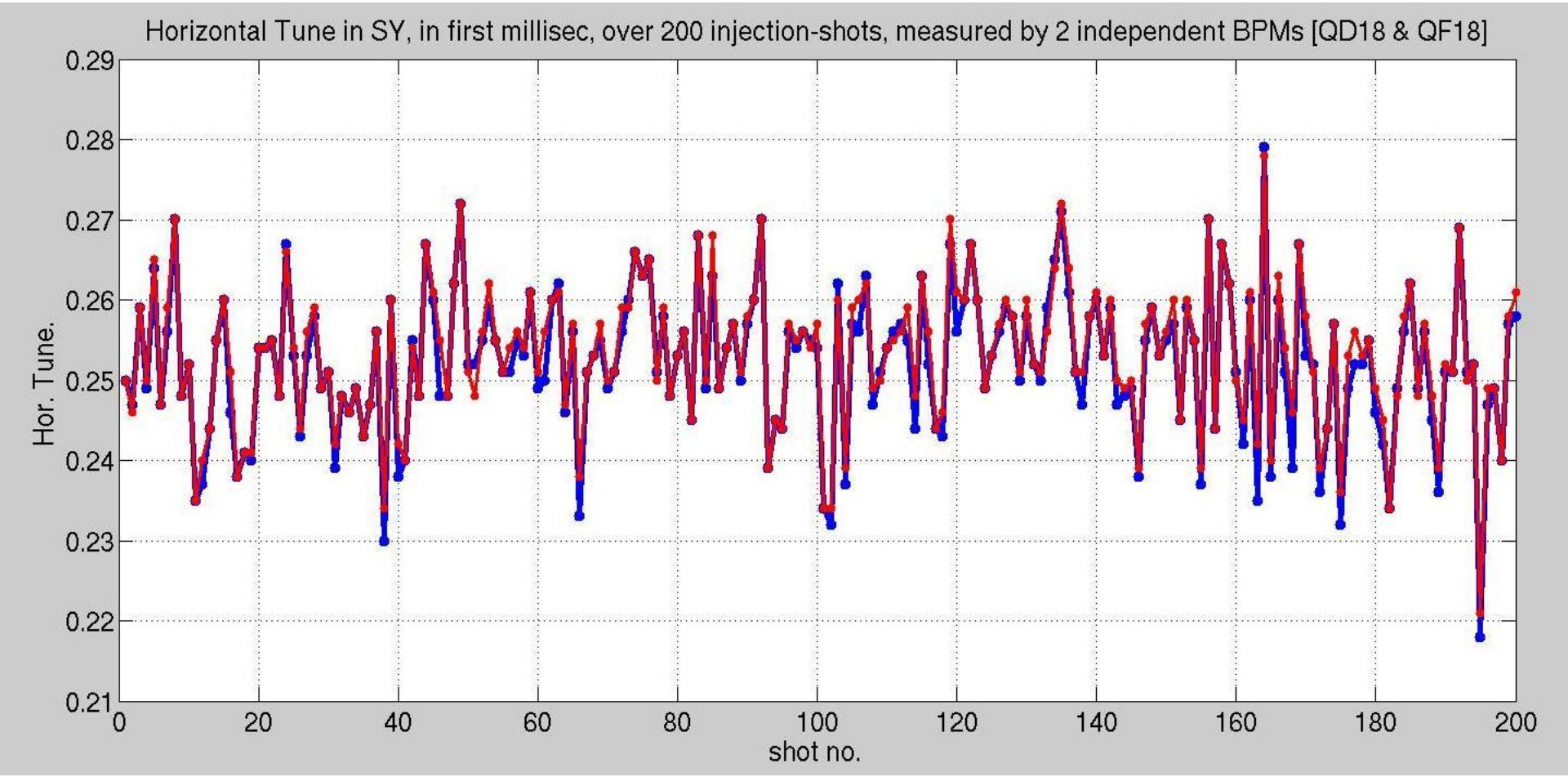




Left picture : from BPM QD18

Right picture : from BPM QF18

200 shots of Hor. Booster Tune, Red & Blue curves from 2 independent BPMs



how did the Spark development & its agreement on price came about ?

alternatifs (in-House development, buying system from PSI, Boris Keil)
were fully assessed (price, suitability, delays, risks etc.)

then I-Tech was asked if they could provide 80 units for 3800 Euros/unit
including all development costs

then 2 separate contracts were signed in 2013 :

- April , 45 Keuros , for design study -> reports & manuals
- August , 45 Keuros , for delivery of 2 prototypes

important : an early (but informal) agreement was reached that
if both contracts gave satisfaction then, for the series (78),
the price would be such that this (global) value of 3800 Euros per unit is meet

Commercial Price of Spark now : approx. 4800 Euros (for small quantities)
(promo-version approx. 4500 Euros)

what next with Libera Spark :

- 81 units purchased now, delivered early November

- where to put them ? :
  - inside Tunnel, close to BPM (2m), no shielding at all
  - inside Tunnel, in groups (5) inside shielding castes (5cm Pb)
  - in accessible cabinets, with long RF cables (upto 60m) from BPM

- What about Spark + :
  - with a PLL and variable RF Gain (space foreseen on PCB)
  - and 10Hz SA output

Spark + can satisfy (demanding) BPM requirements in a Storage Ring,
although not for Fast Feedback, no Interlocks, no Post-Mortem,
and more tedious offset management when changing RF attenuators
but with 1um long-term stability / reproducibility