Diagnostics for non linear beam dynamic studies at ESRF

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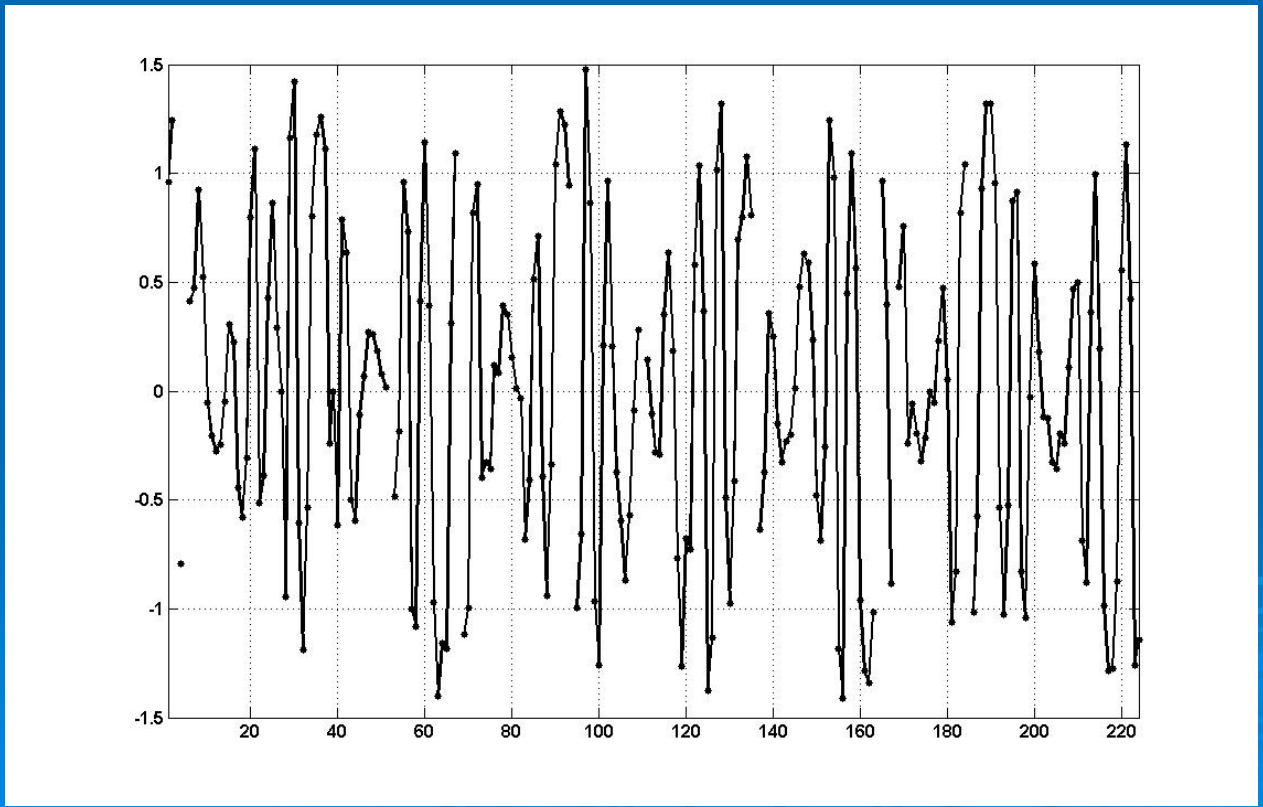
Beam parameters affected by non linearities of the optics

- Orbit, phase space trajectory
- Tune
- Lifetime/losses

orbit

- Turn by turn measurement on every BPMs
- Correction of the non linearity of the pickup response



Turn by turn measurement

From 2000 until the *Libera* implementation:

The “1000 tours” system:

- Not a true turn by turn
- 4 measurements needed to measure an orbit
- Averaging needed to achieve a good resolution

In the future: Libera BPMs…

Libera RF front end

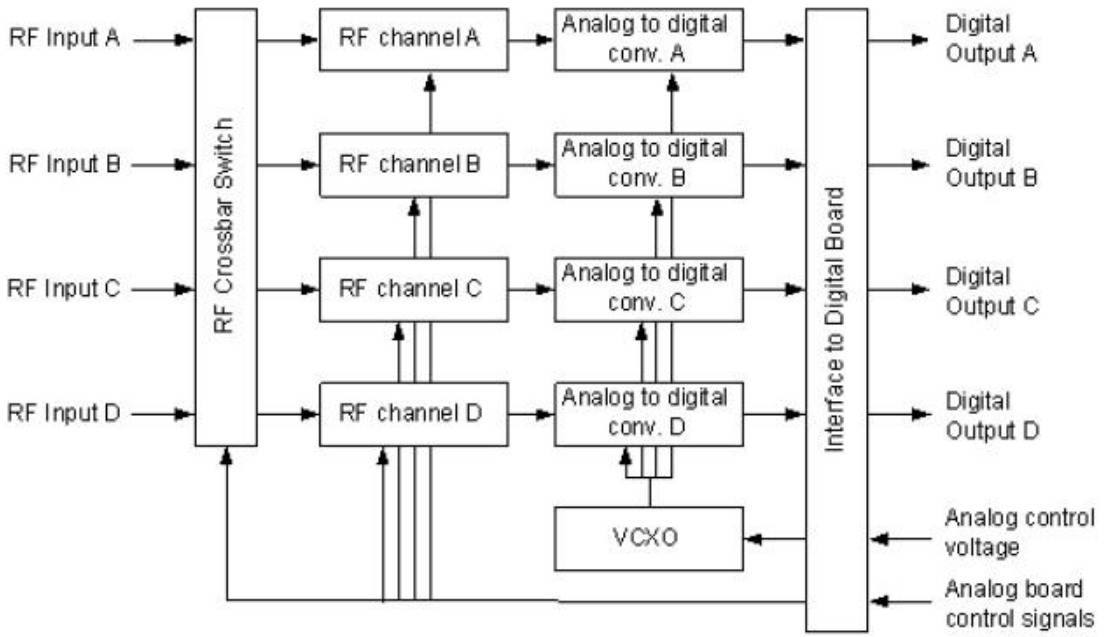


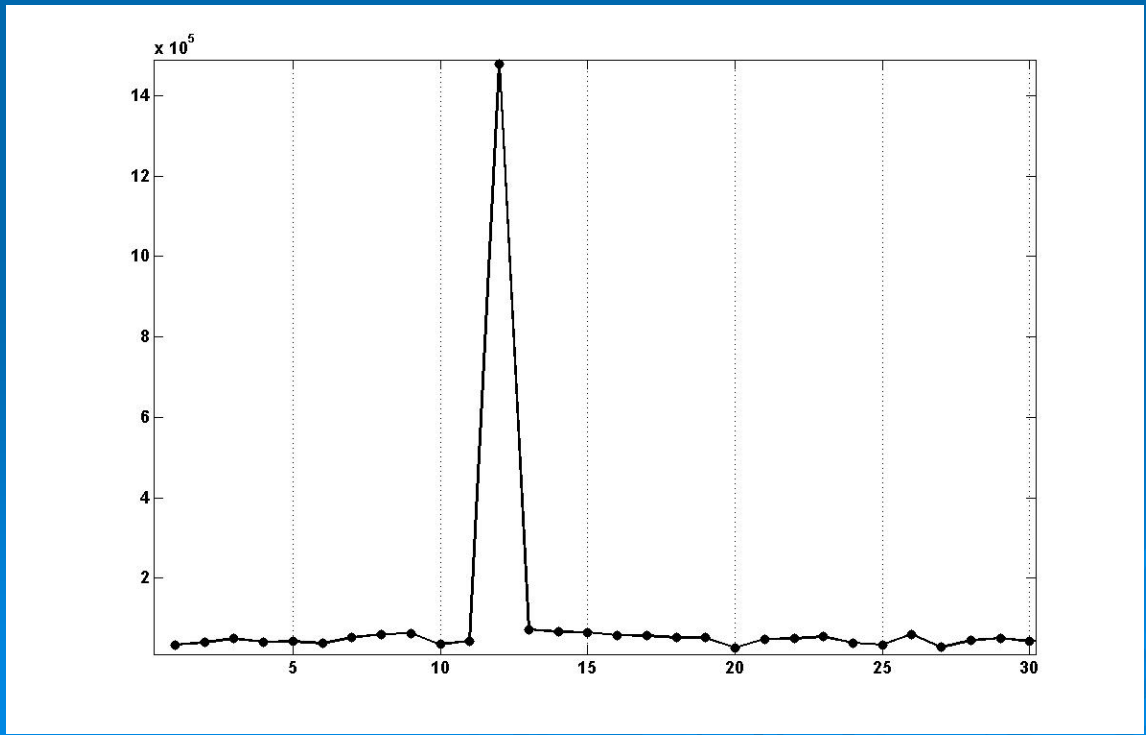
FIGURE 2. Analog board block diagram

- 4 X 10 MHz bandwidth channels
- Cross channels multiplexing
- 16 bits 125 Msps ADC

Libera customisation: true single turn filter

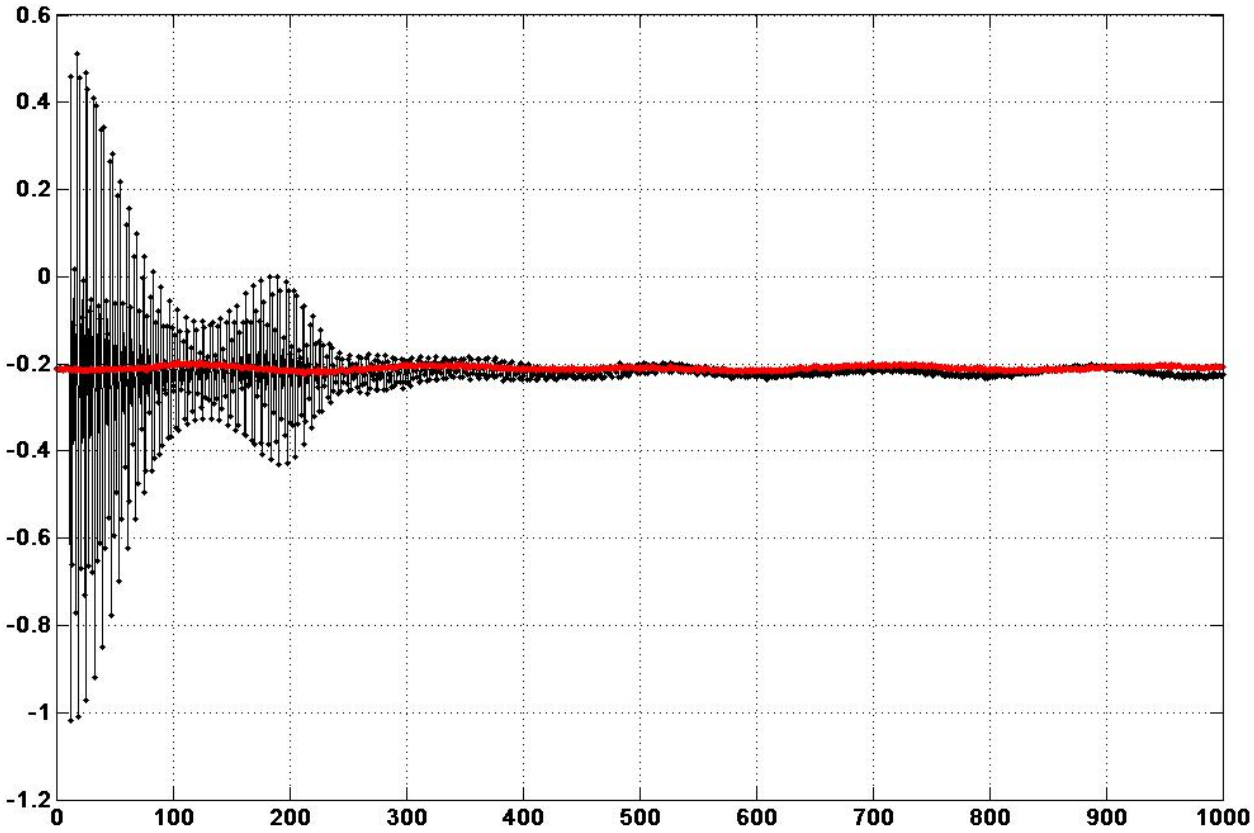
Once optimum timing adjusted inject 1/3 fill in SR and kick it out after 1 single Turn :

One single Turn should be seen on the SUM signal, without smearing



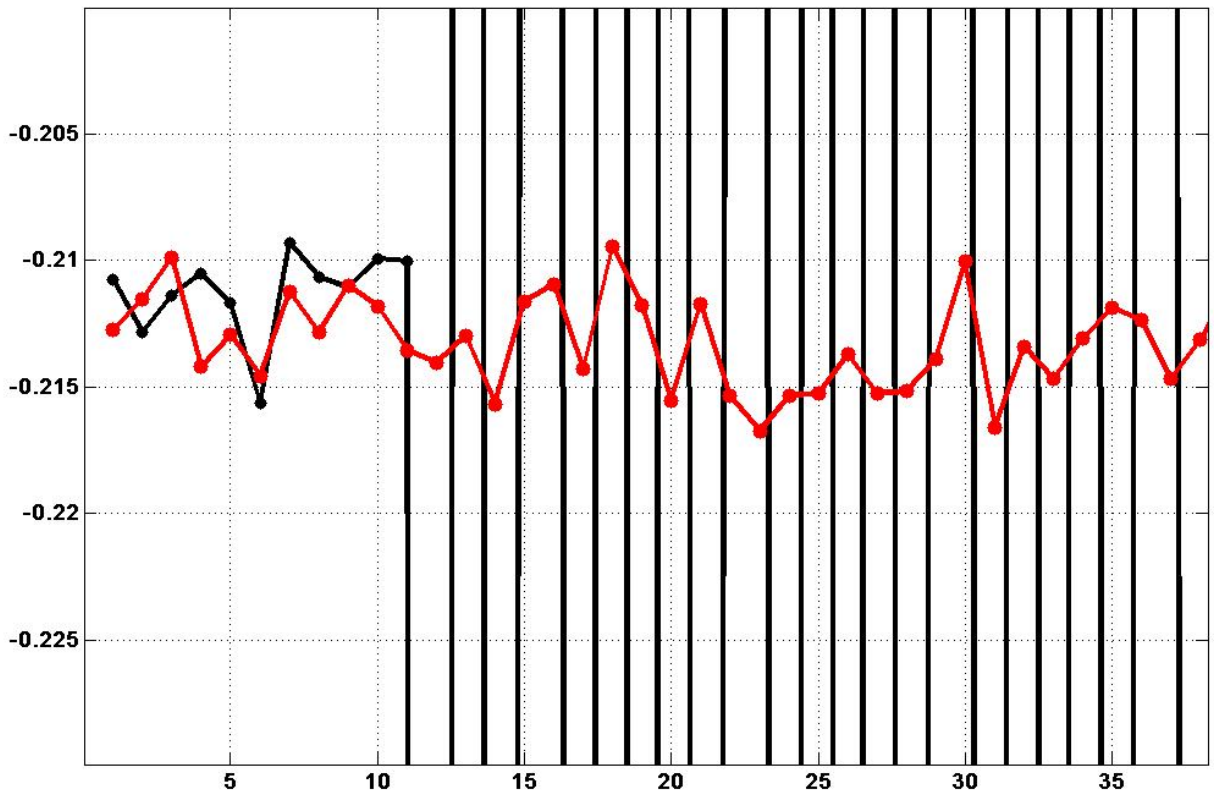
1.5mm pk-pk amplitude with 150Amp kick from Inj. Kicker-1

1.5 mm



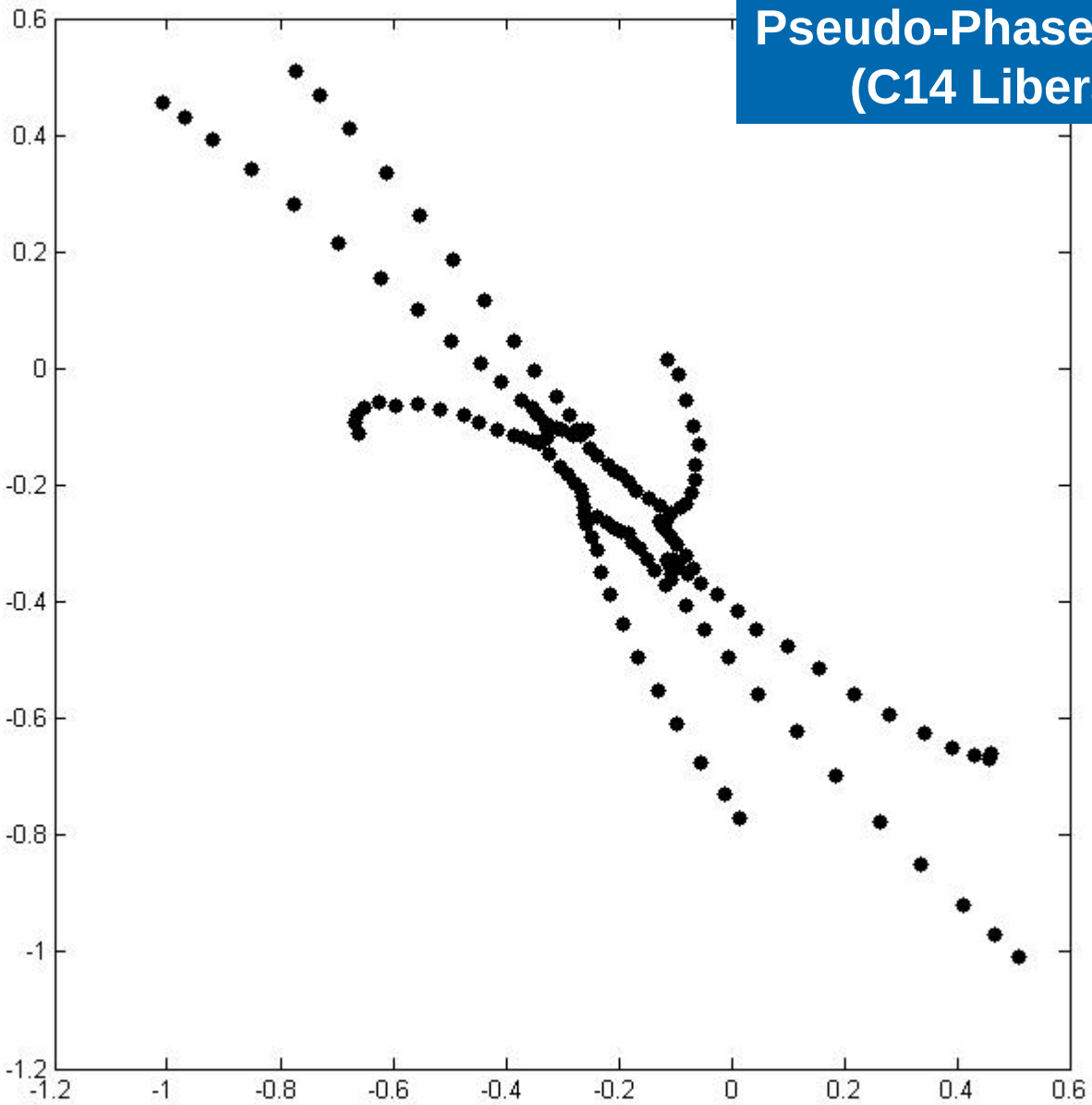
1000 Turns

5 um



Noise assessed at **~1.8um rms** in Turn-by-Turn position measurement
@ 38mA 1/3 fill, Libera-C14 max. gain.

Pseudo-Phase-Space Plot (C14 Libera)



Production of non linears phenomenons

- Single turn kickers magnets:
- Horizontal:

injection kickers

1us rise time and fall time, 1us flat kick

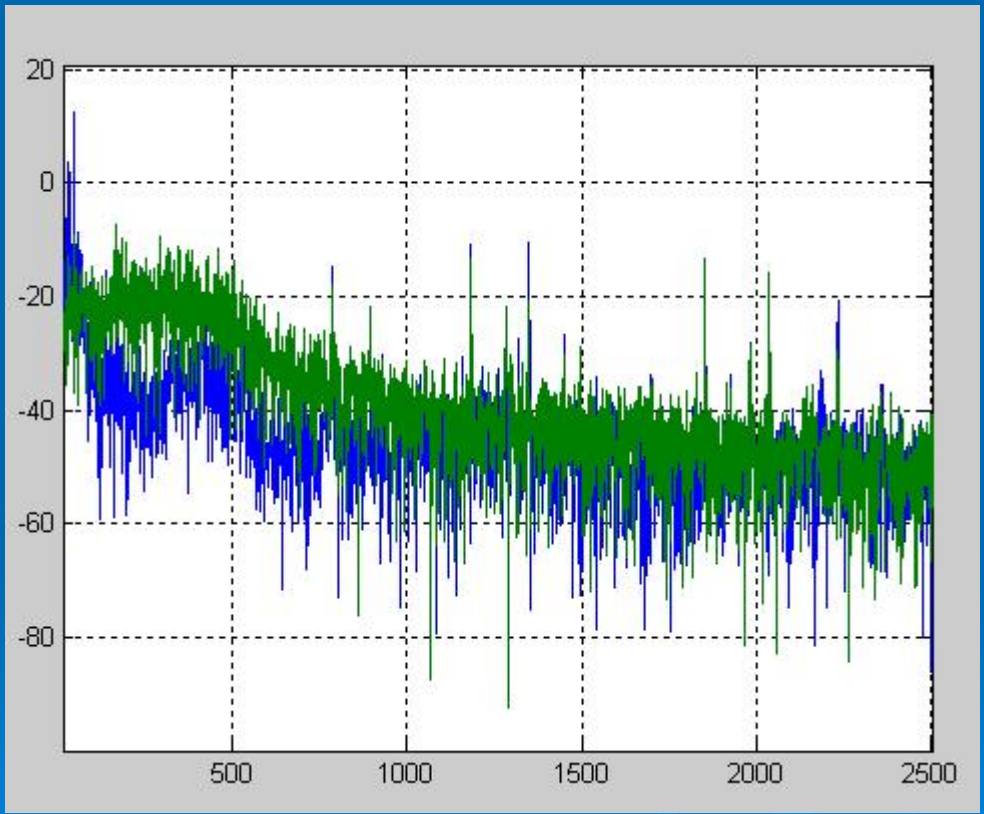
- Vertical:

Dedicated kicker with similar pulse shape

- Amplitude of the kicks:
- Horizontal: 2 mrad at with β=5m
- Vertical: more than enough…(limited by the +/-4mm ID chambers physical aperture)

Used to kick a 1us pulse bunches train (1/3 filling patern)

Libera resolution

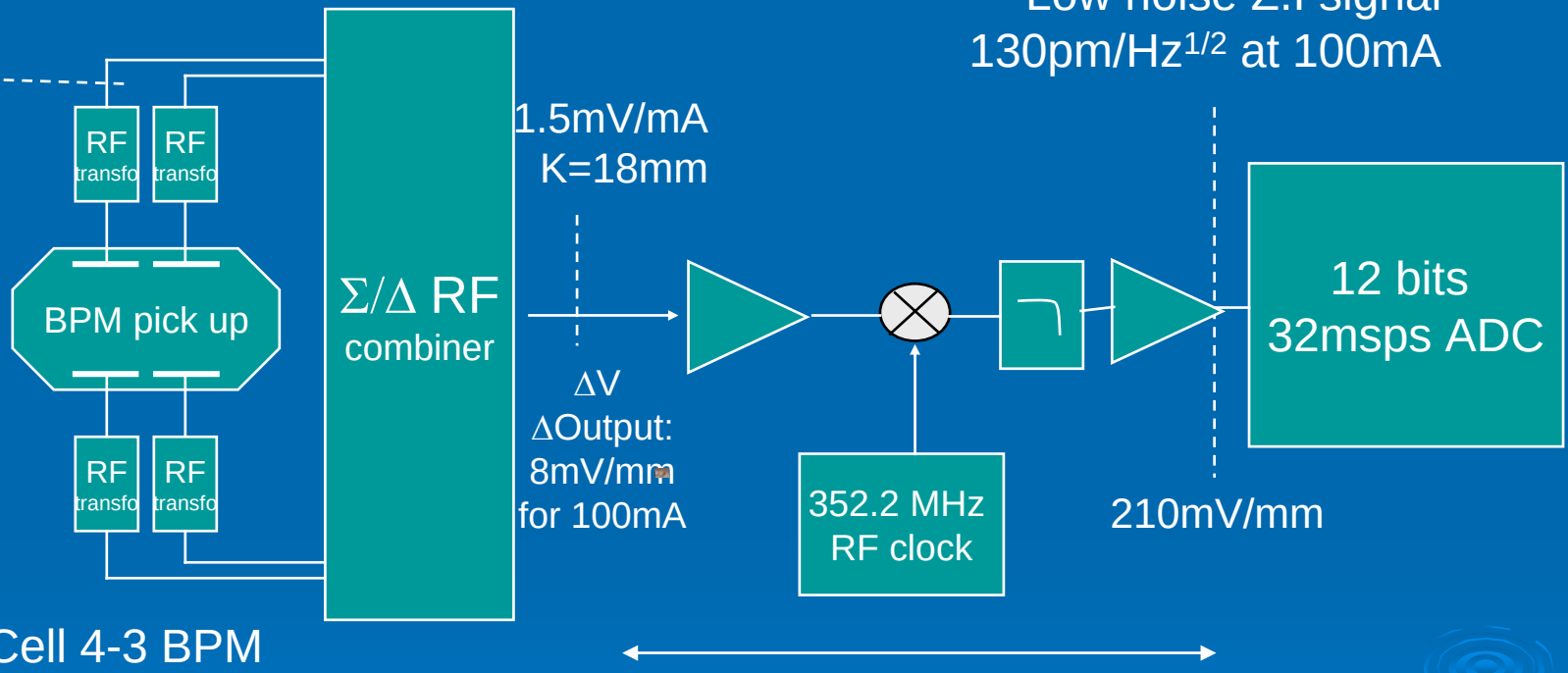


Blue : feedback OFF
Green: feedback ON
Cut off: 300Hz

Scale:
Vertical:dBμm/$Hz^{1/2}$
Horizontal:1Hz/div

=> Noise floor: 3nm/$Hz^{1/2}$

RF recombination scheme: frequency mapping set up used in 2004

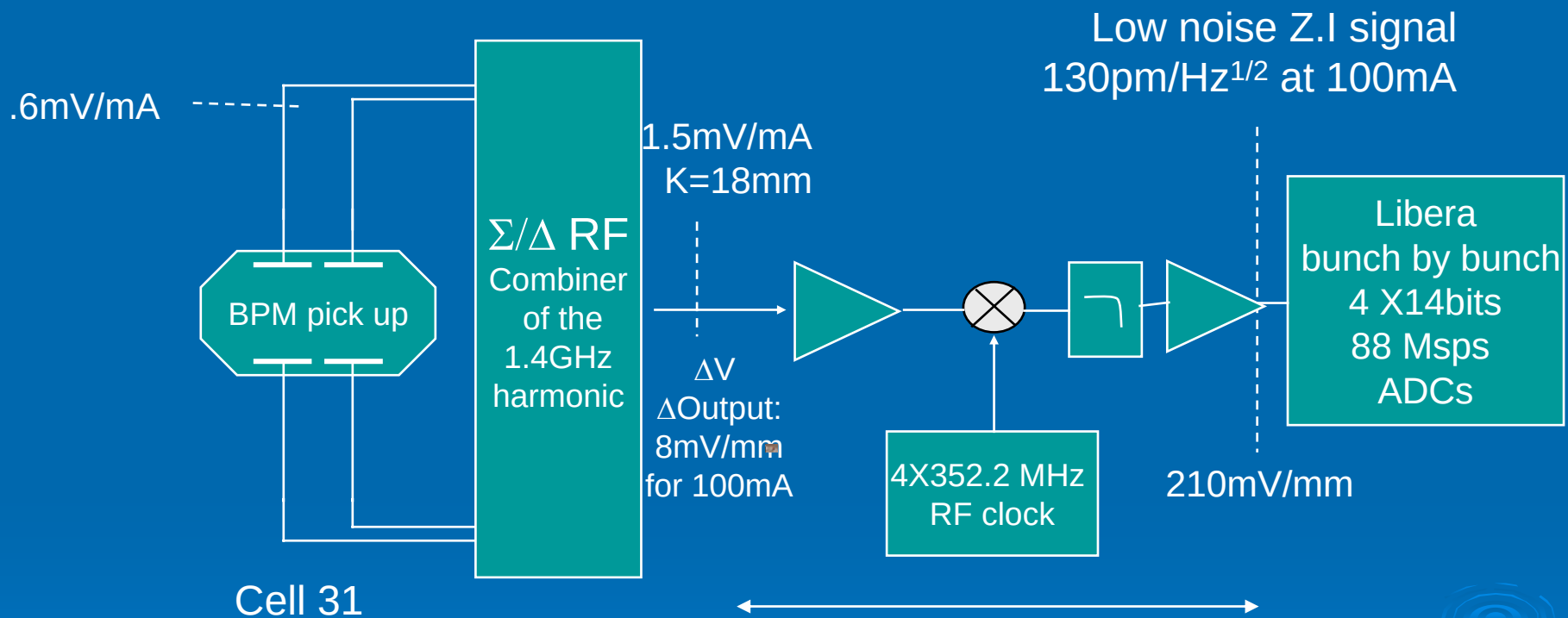


G= 28dB, N=6dB, KT=-174dBm/Hz$^{1/2}$

=> noise at the analyzer input = -140dBm/Hz$^{1/2}$ =30nV/ Hz$^{1/2}$

BPM sensiotivity: 8mm/V at 100mA =>**resolution= 130pm/Hz$^{1/2}$**

RF recombination scheme: multibunch feedback electronics



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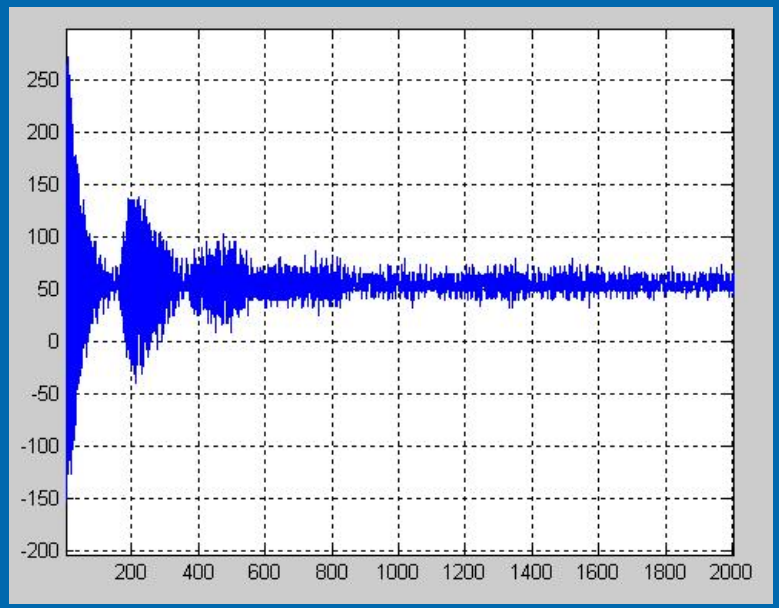
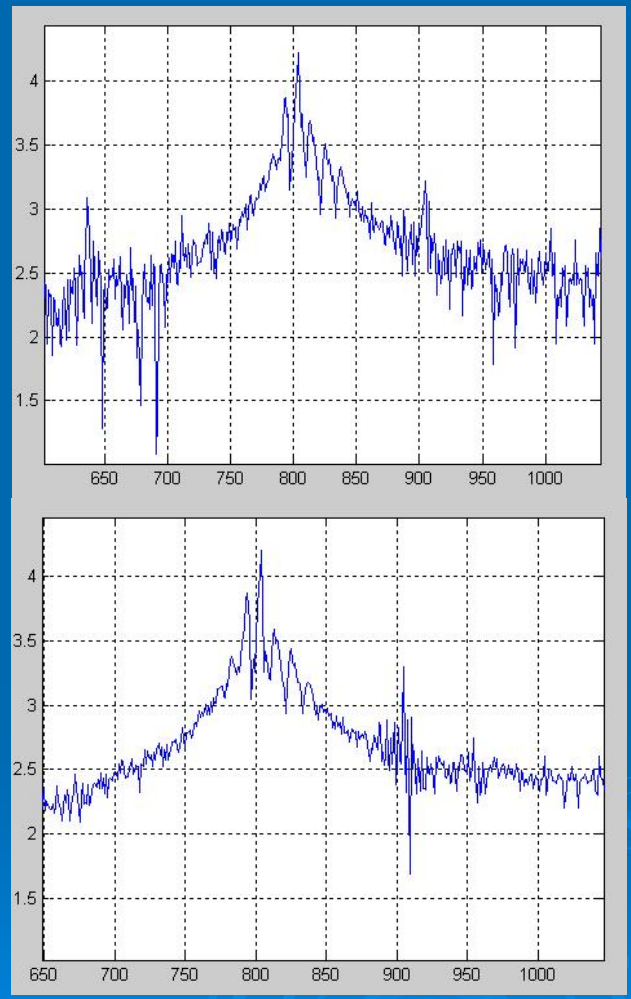
Bunch by bunch signal acquisition

FFT analysis





50 μm initial amplitude
Signal from one single bunch

Bunch by bunch or mode by mode tune measurement available

- 40KHz zoom on the FFT of the previous signal.
- Upper plot : single bunch data.
- Lower plot: averaging over 300 bunches
- Vertical scale : 6dB/div

Lifetime measurement

- Our normal diagnostic is parametric current transformer.
- the lifetime is derived from the I(t) signal
- Lifetime measured: 60 hours with 1 hour resolution after 60s
- 60 hours= 1.5 10^5s =>
- I resolution = 2 10^{-7} over 60s or 1.2 10^{-6}over 1s
- Resolution versus integration time is limited by : the noise in the magnetic material and the current source stability

I(t) resolution

2 issues:

- White noise:

Narrow bandwidth amplifier noise, ADC resolution , thermal noise …

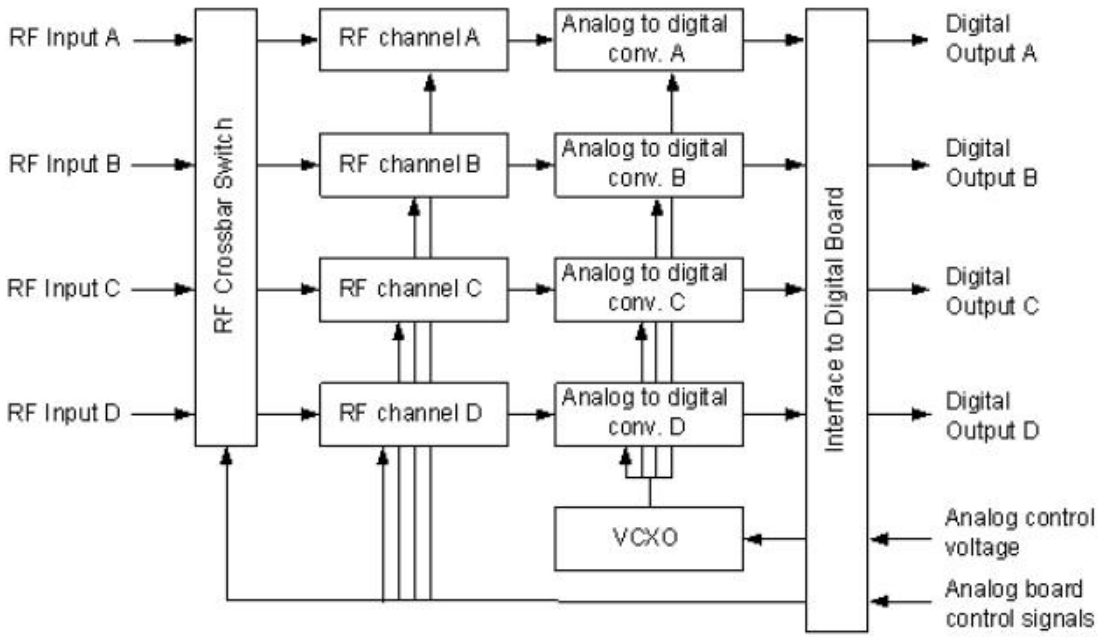
- 1/f noise:

Amplifier noise at very low frequency, voltage or current reference drift …

Is the PCT the best current monitor?

- Modern RF digital RF receiver (*Libera* type for instance):
- 13 true bits resolution per channel at 125 msps (62.5MHz BW) ; 4 channels
- The beam signal will be a narrow bandwidth RF signal coming from a set of BPM pickup electrodes for instance….

Libera RF front end



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RF receiver resolution:

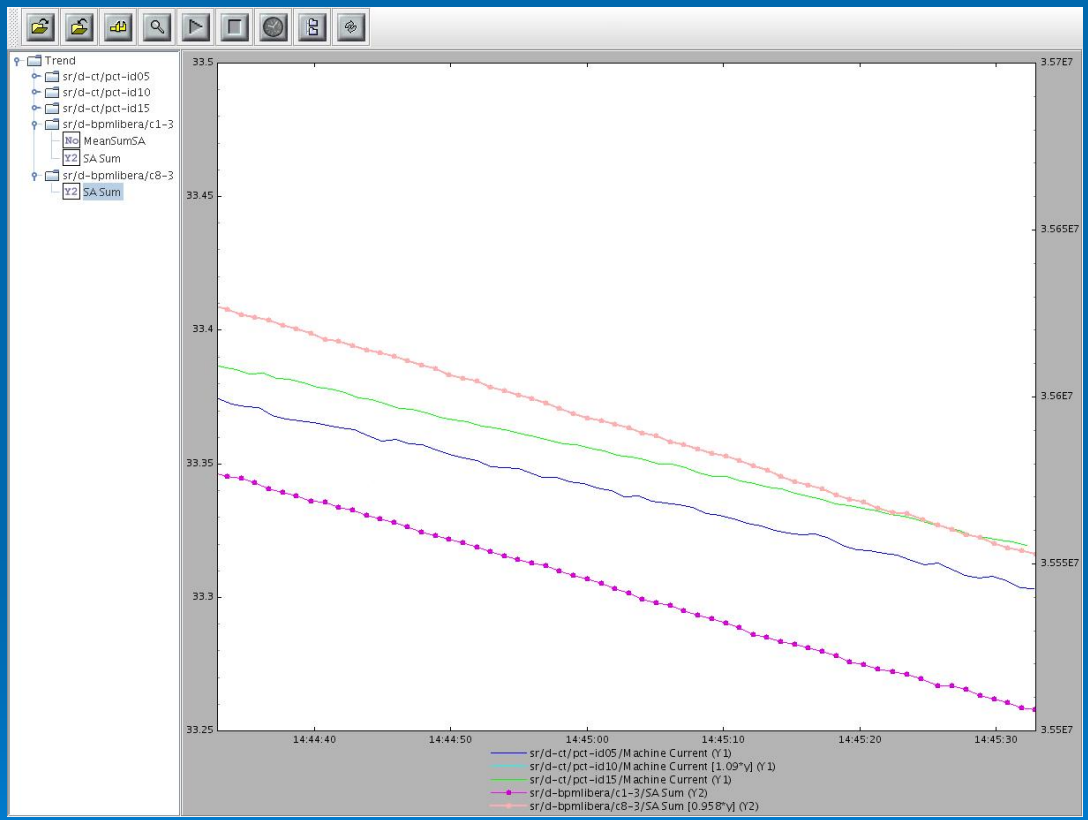
- $1.25\ 10^{-4}$ in 62.5 MHz => $1.5\ 10^{-8}$ in 1Hz.
- 250 hours = $(1.5\ 10^{-6})^{-1}$ so it seems to indicate that 250 hours lifetimes are measurable with a 1% resolution at a 2Hz rate !
- Is it true?

Maybe not completely:

At low current the noise of preamplifier will not be negligible compared to the ADC resolution

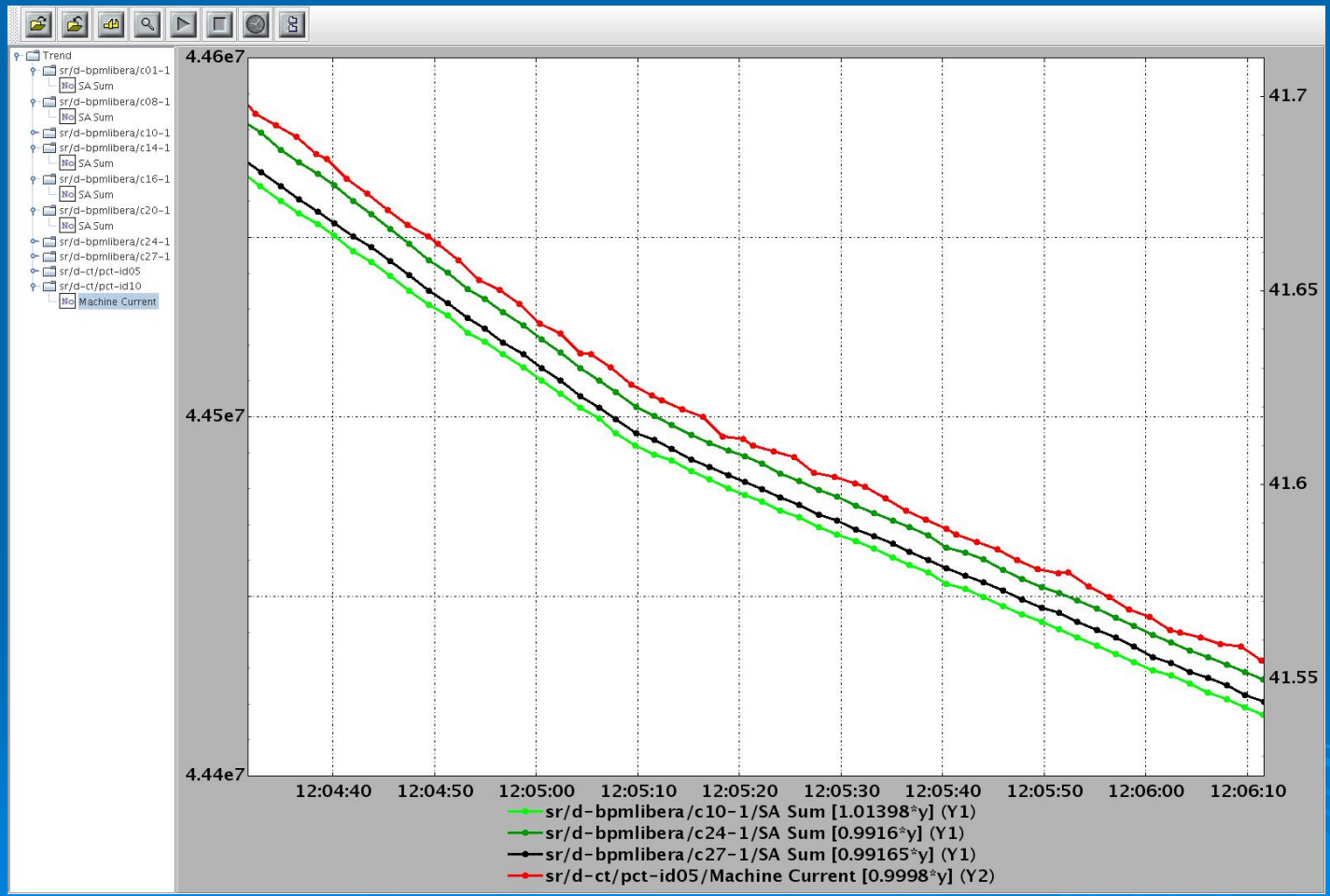
The drifts of the ADC reference and RF front end gain (1/f noise) should be considered…

PCT/ Libera comparison



- The RF receiver looks at least as good as a PCT, but nothing dramatic….

PCT/ Libera comparison



RF receiver resolution

- Actually the resolution is limited by slow fluctuations of:
- ADC voltage reference
- RF components gain or attenuation
- So over minutes the intensity and lifetime measurements get spoiled
- But we usually have 100 to 200 BPMs electronics so we could average…

Conclusion

- A set of 100 to 200 digital BPMs can be turned into a very fast lifetime monitor fo machine study sessions for data acquisition over short time periods.