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Modified Filters, Current Monitoring

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Libera WORKSHOP 2008

14. October 2008

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- **Introduction**
- **Modified digital filtering on Libera Brilliance, why & how**
- **Libera Brilliance as a beam current monitor**

Introduction

- **Described ideas actually originated at ESRF (by Kees Scheidt) during their tests of Libera Brilliance units.**
- **Needed modifications to the standard filters were done by Vladimir Poučki.**
- **These are examples of how the system can grow with collaboration.**

Modified DDC Filtering, Why

• **The Turn by Turn data is essential for commissioning of the accelerator as well as for various machine physics studies.**

• **Due to the "natural" properties of correctly structured filters (respecting the Nyquist theorem), the smearing between adjacent TbT samples is not negligible.**

•**The smearing of the TbT output data is a real problem for the precise measurement of certain accelerator characteristics (called lattice parameters, like the local Beta-Values and the phase-advance).**

Smearing
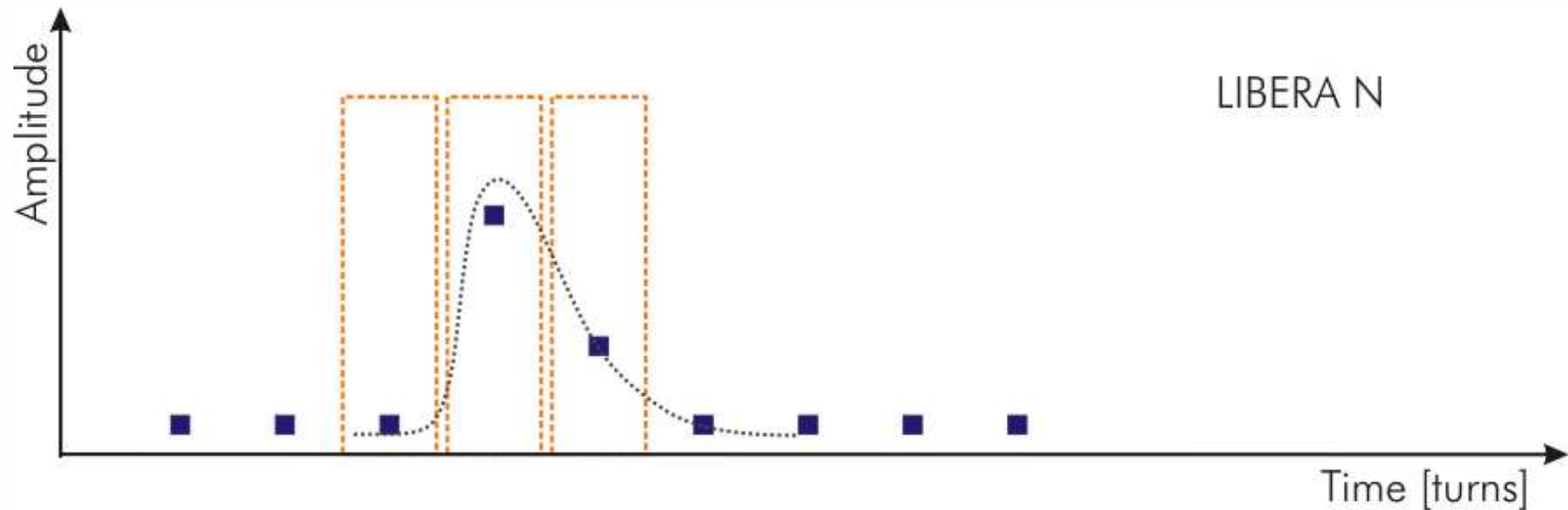
- **Main reasons:**
  - **Narrow filtering (Nyquist) – longer tail**
  - **Acquisition window covers complete TbT period**

Reduced Smearing
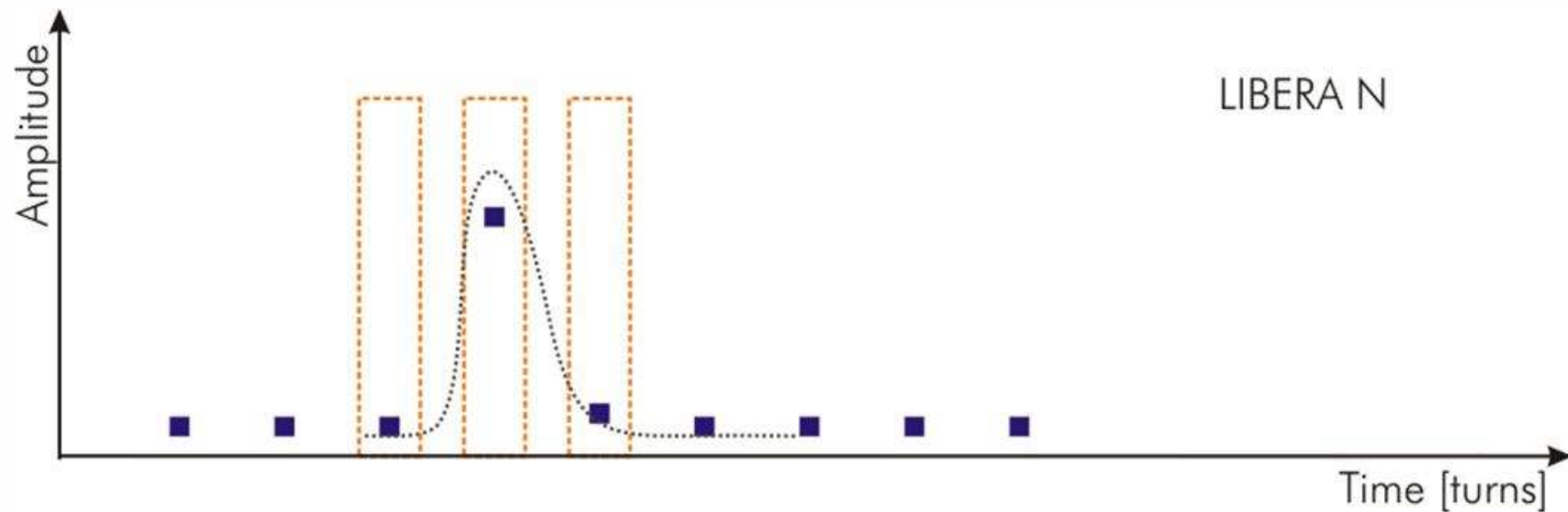
- **Wider filters – shorter tail**
- **Acquisition window covers adjustable part of TbT period**

Wider TbT Filters

- Analog bandwidth of the data is approx 12MHz.

- To prevent unwanted aliasing, the default 3dB bandwidth of the TbT filters is always well below half of the output sampling rate.

- ESRF case:

  - Revolution frequency 355kHz

  - Default TbT filter 3dB point at below 150kHz.

- The modified TbT filters have been widened to approximately 3 times the TbT data rate.

TbT Acquisition Window

- **The acquisition window of the standard moving average filters covers the whole TbT period.**
- **ESRF case: 304 ADC samples or 2.81 *µs***
- **When the accelerator is filled with certain partial fills, the real signal will be distributed only on a certain sector of the TbT period**:
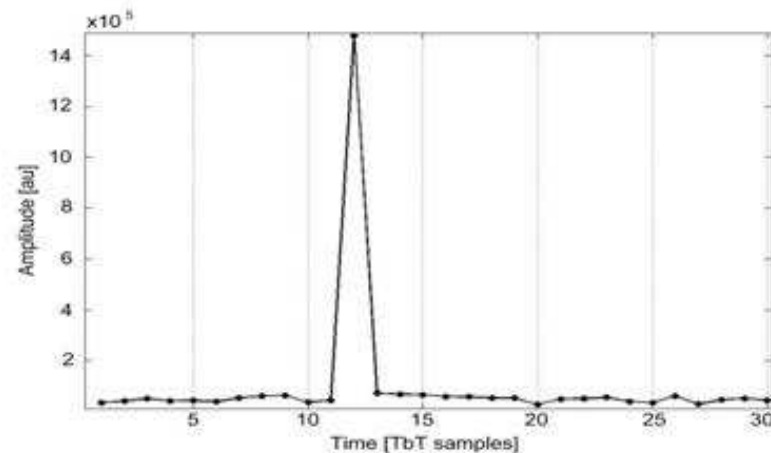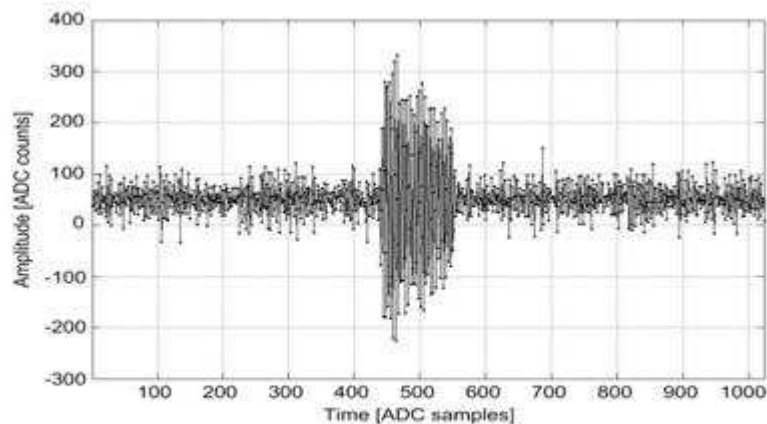
1/3 filling at ESRF, ADC data readings from Libera

**Courtesy of Kees Scheidt, all figures with measurements on beam**

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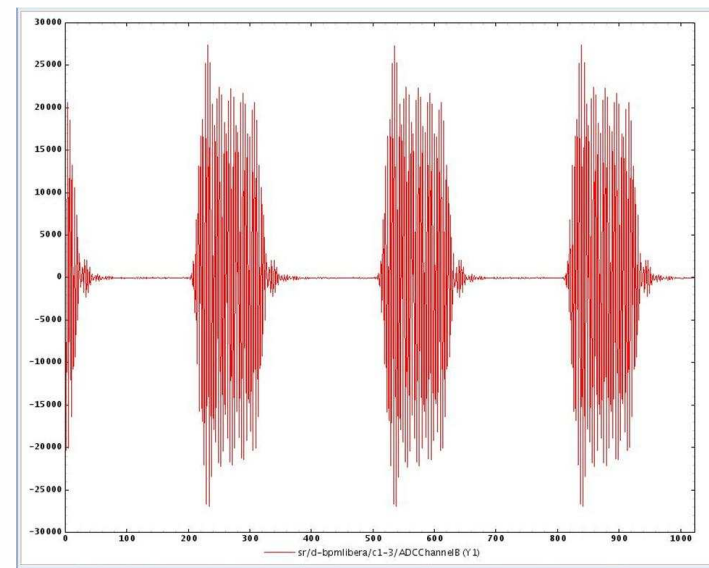
Measurements on Real Beam, Single Turn

- **1μs long beam, single turn**

- **Libera reading in ADC samples (~9ns per sample), left**

- **Libera reading in TbT samples (2.81μs per sample), right**
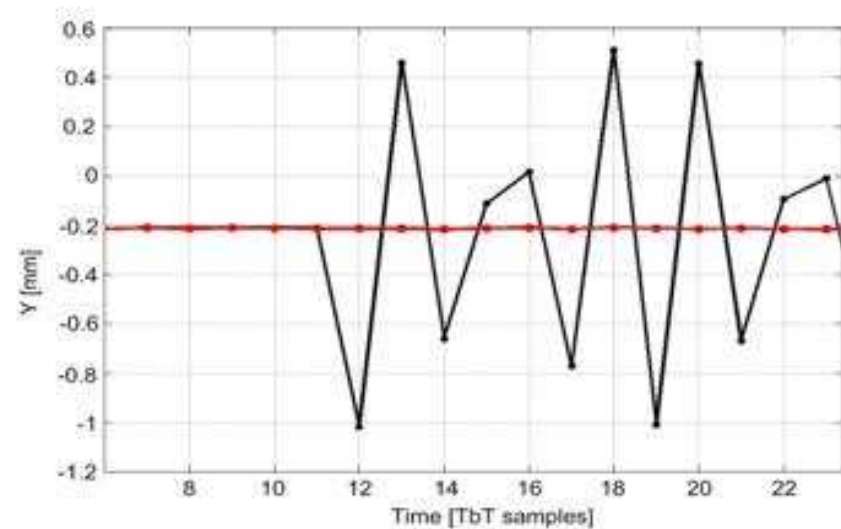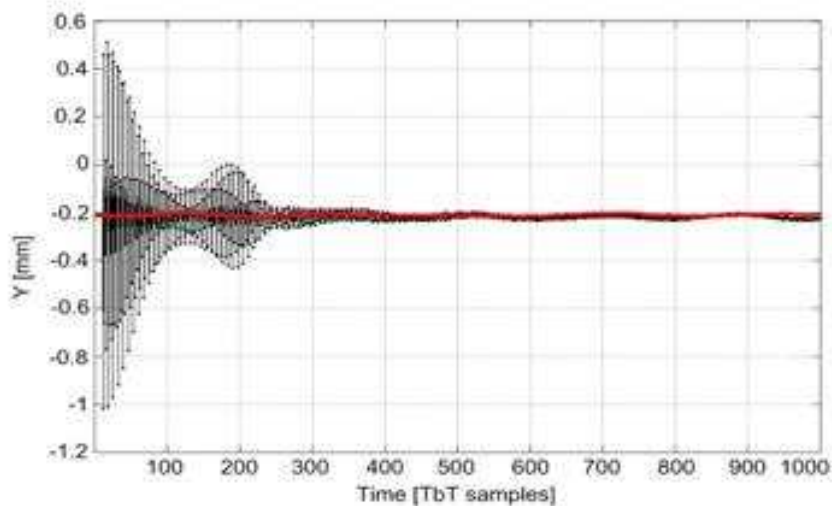
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Measurements on Real Beam, Beam Arrival

- **Beam was not dumped after first turn**

- **Independent measurement for each TbT sample can be observed**
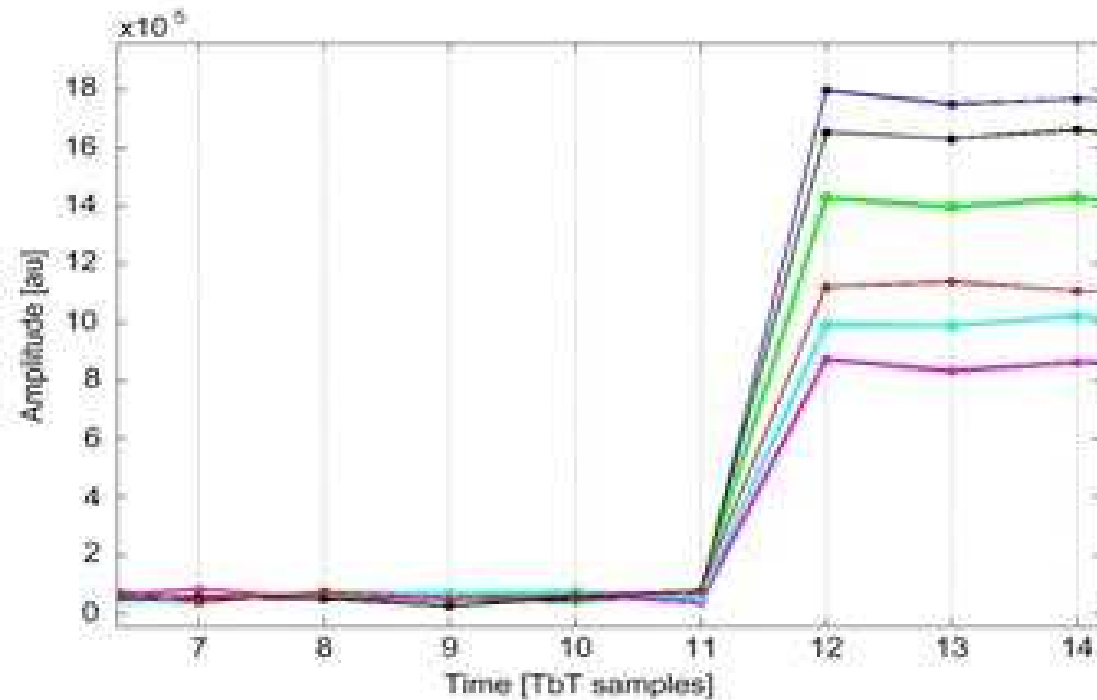
Measurements on Real Beam, Beam Kick

- Single turn flat kick, 38mA at 33% fill

- Horizontal position, left

- Horizontal position, zoomed, right

Summary of Modified Filters

- It is an example of how the digital system can be successfully tailored to a special task just by a change in software.
- The test results gave very clean and expected results.
- We would like to emphasize successful collaboration between users (ESRF) and manufacturers of the instrument (Instrumentation Technologies).

Beam Current Monitoring with Libera Brilliance

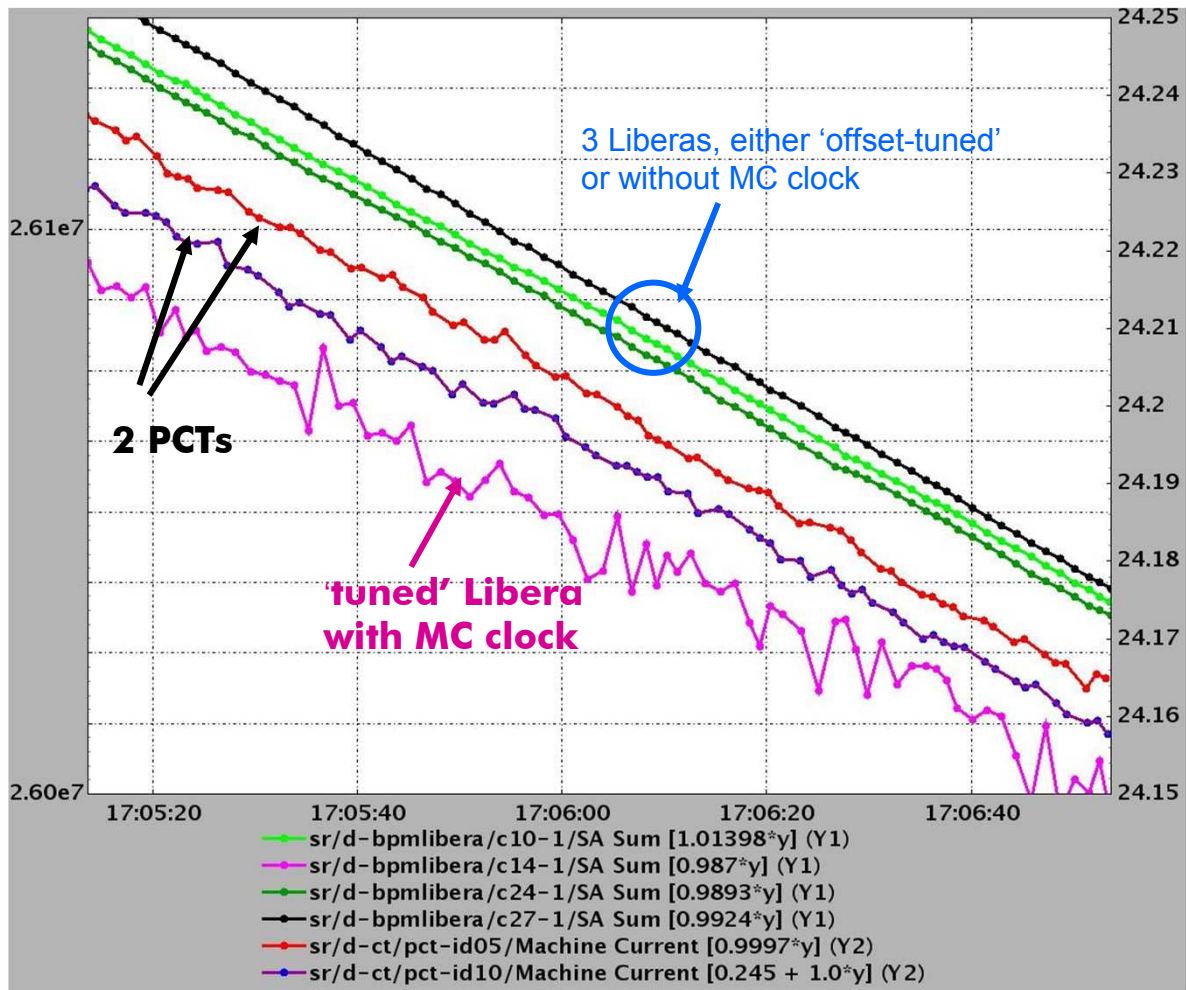- Libera was initially not developed as the beam charge monitor. However, the sum signal (sum of all four electrodes) is standardly available within all data streams.
- The document presents the quality of the Libera SUM signal and the potential for current or beam-charge measurements in both the Storage Ring and the Injector (Booster and Transfer Line).

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Measurements on ESRF

- All these measurements were on ESRF, done and reported by Kees Scheidt, who also made all the graphs.

- No changes in Libera sw or hw are needed, it is just about how the instrument is exploited.

The Decay of the Beam

- **4 bunches filling pattern**
- **Done at SA data rate**
- **Competitive with other current monitor devices**
- **Even lower RMS possible by averaging the data from more Liberas**

3 Liberas, either 'offset-tuned' or without MC clock

2 PCTs

'tuned' Libera with MC clock

sr/d-bpmlibera/c10-1/SA Sum [1.01398*y] (Y1)
sr/d-bpmlibera/c14-1/SA Sum [0.987*y] (Y1)
sr/d-bpmlibera/c24-1/SA Sum [0.9893*y] (Y1)
sr/d-bpmlibera/c27-1/SA Sum [0.9924*y] (Y1)
sr/d-ct/pct-id05/Machine Current [0.9997*y] (Y2)
sr/d-ct/pct-id10/Machine Current [0.245 + 1.0*y] (Y2)

Tuned vs Offset-Tuned Performance

- **Decimated TbT data (at 5kHz rate)**
- **Offset-tuned (left) vs Tuned (right)**
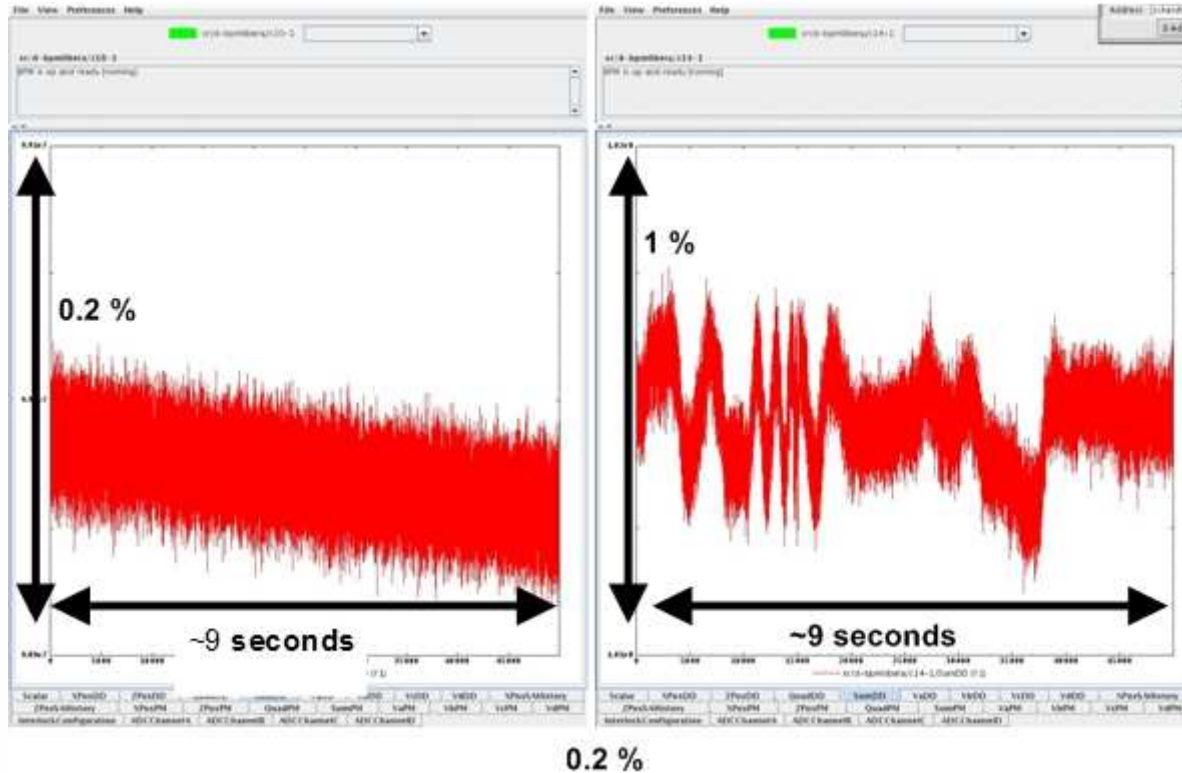
The Injection Studies, 1

- **Injection in the storage ring at 10Hz**
- **Done at decimated TbT data rate, 5kSps**
- **Sum signal of Libera is displayed**
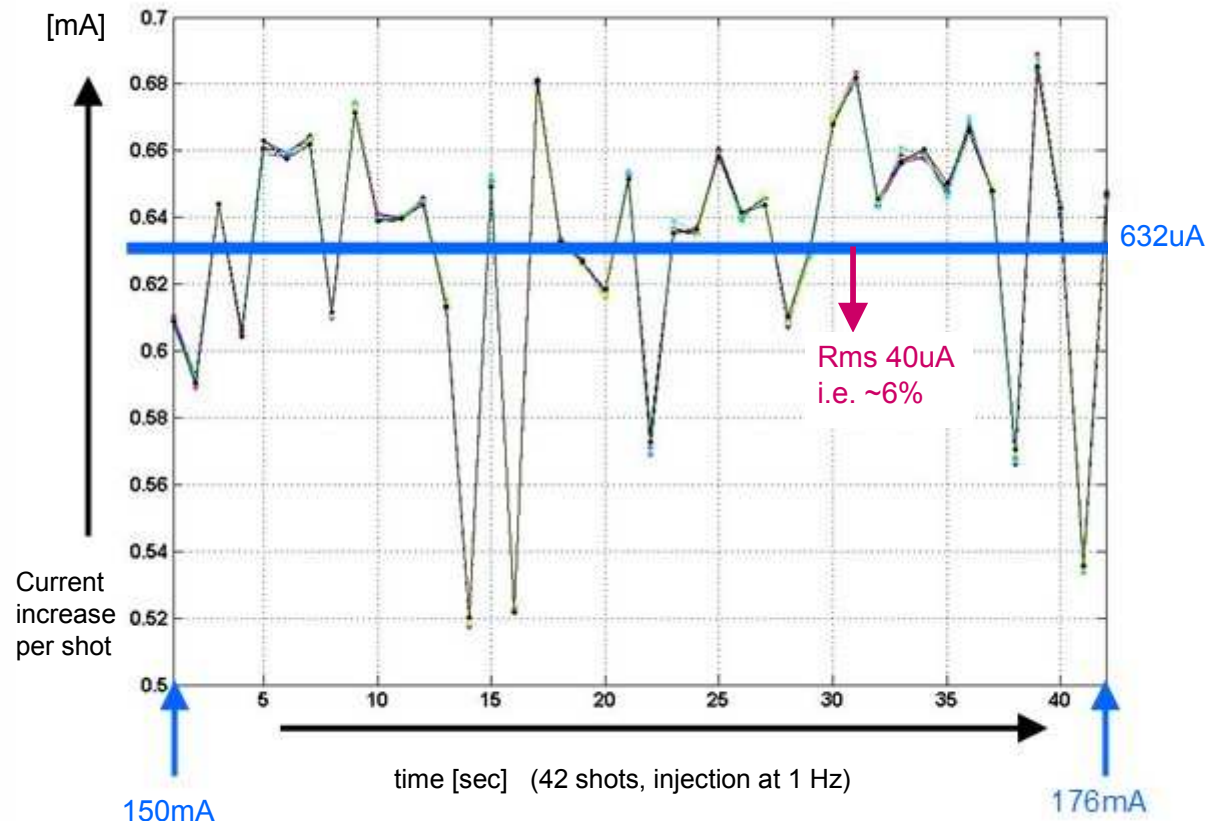- **Useful for injection loss studies**

Injection of 4 x 10mA over 50Ksamples ~9 seconds

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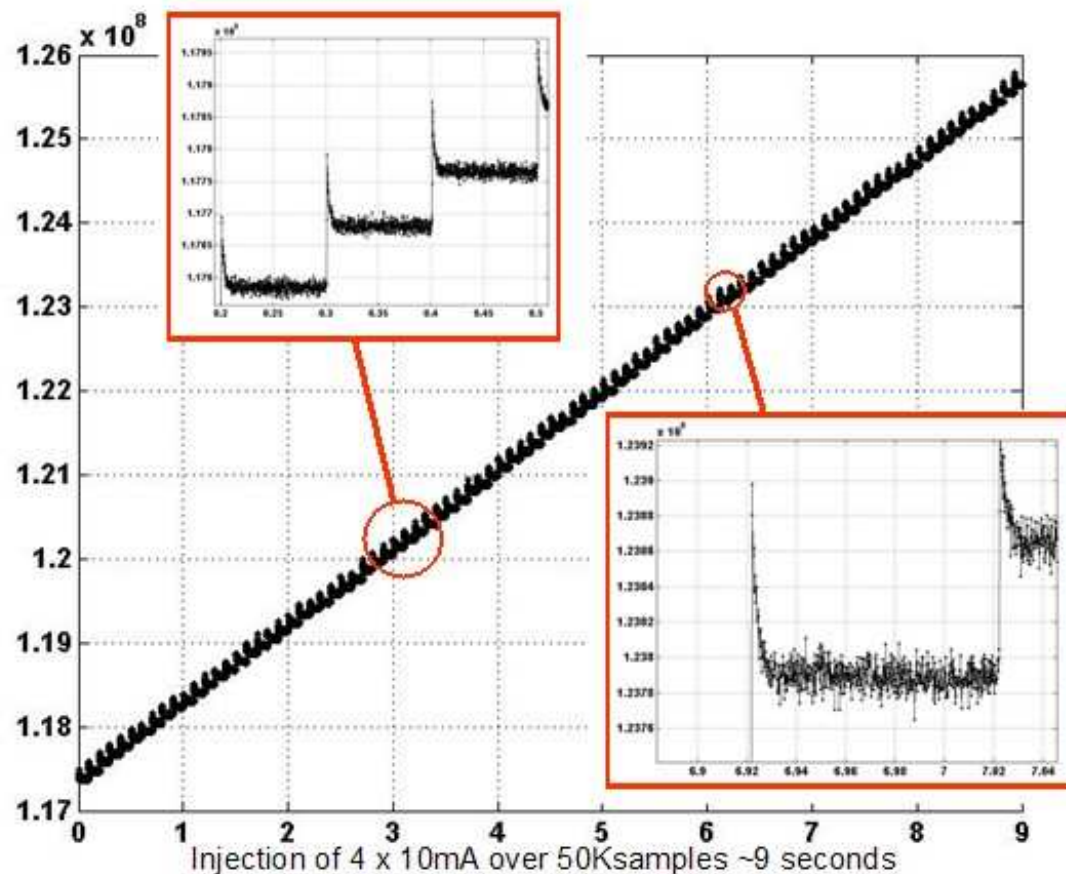
The Injection Studies, 2

- **Same data as on previous slide, filtered and normalized**
- **Useful for detailed injection loss studies**
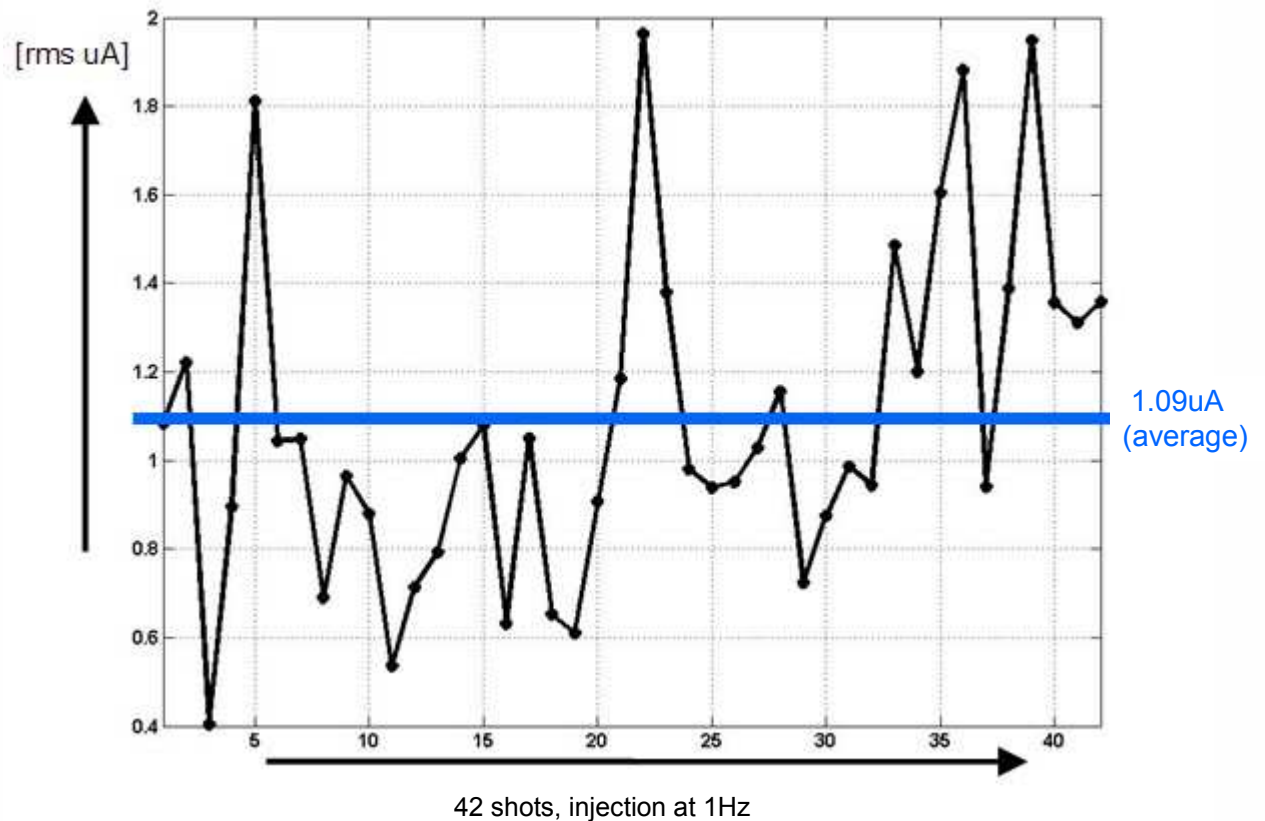
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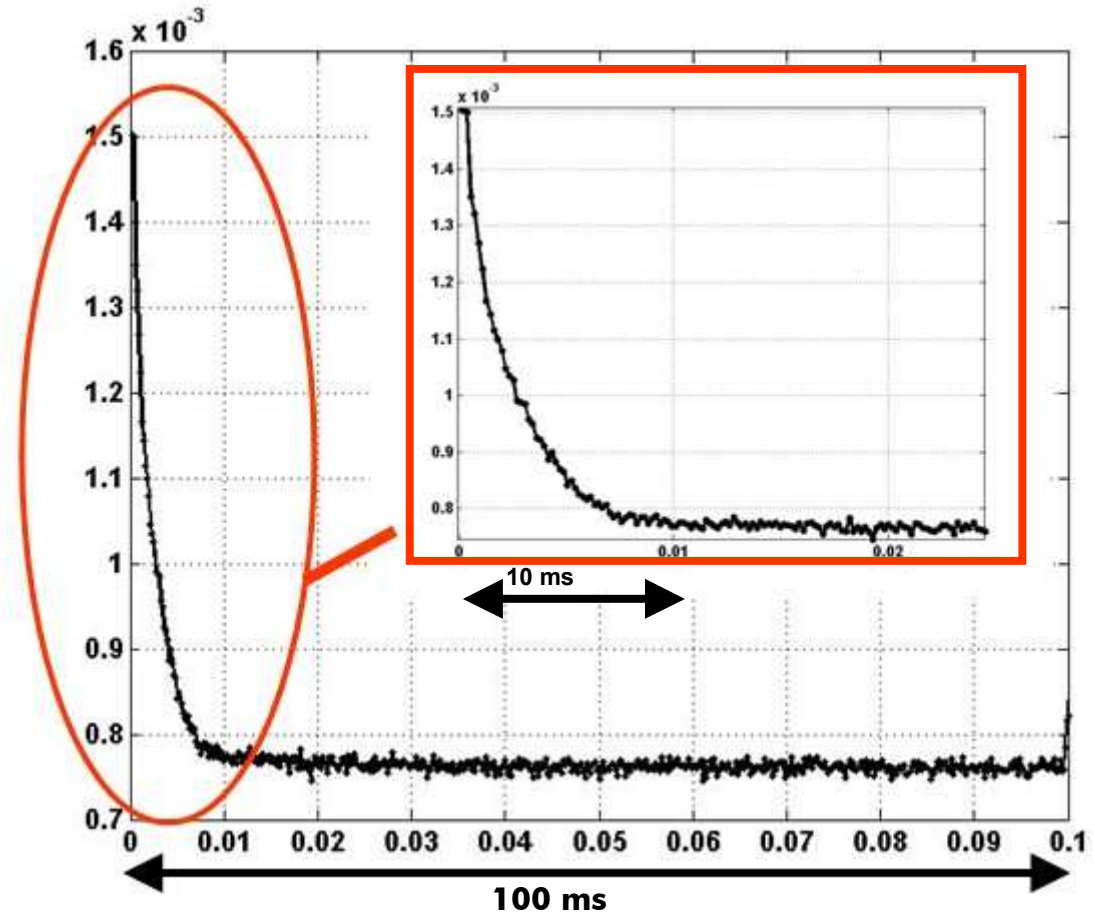
Accumulated Current Measurement, Big Picture

- **Parallel measurement on 8 Liberas**
- **42 injections in the storage ring, at 1Hz, SR current from 150 to 176mA.**
- **Big fluctuations of accumulated current per shot**
- **8 Liberas are plotting almost identical graphs.**

[mA]

632uA

Rms 40uA
i.e. ~6%

Current increase per shot

time [sec]   (42 shots, injection at 1 Hz)

150mA

176mA

Accumulated Current Measurement, Resolution

- **Resolution of 8 Liberas on each of 42 injecions was calculated.**
- **The average RMS is calculated to be 1.09μA.**

[rms uA]

1.09uA (average)

42 shots, injection at 1Hz

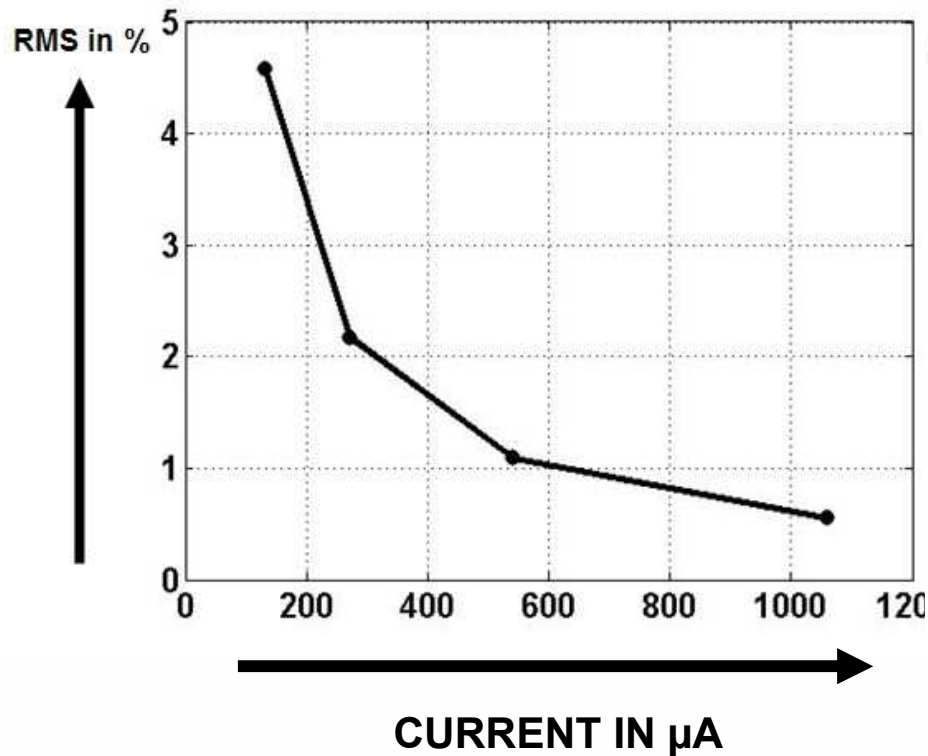Instrumentation Technologies

Libera as Injection Efficiency Monitor

- The sensors should be installed on booster and transfer line to monitor efficiency.

- This situation was simulated on storage ring, with "injector" signals (1us long, down to 130μA of current)

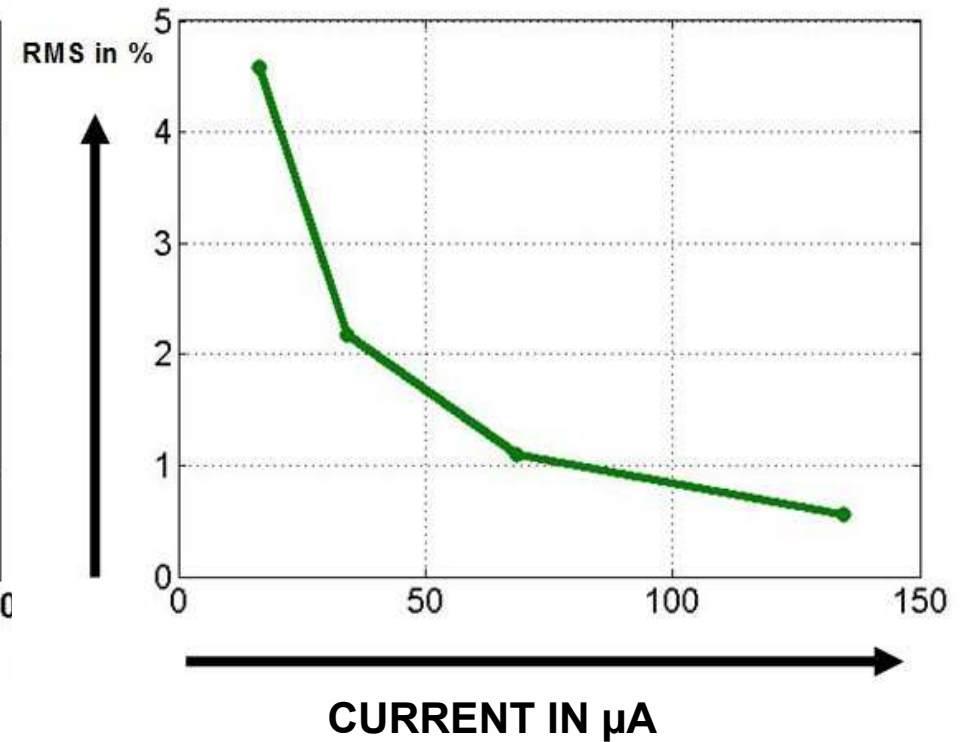**TbT sum signal (400 turns) at four different low currents.**

400 samples at Turn-by-Turn rate (i.e. 355 KHz)   1/3 filling

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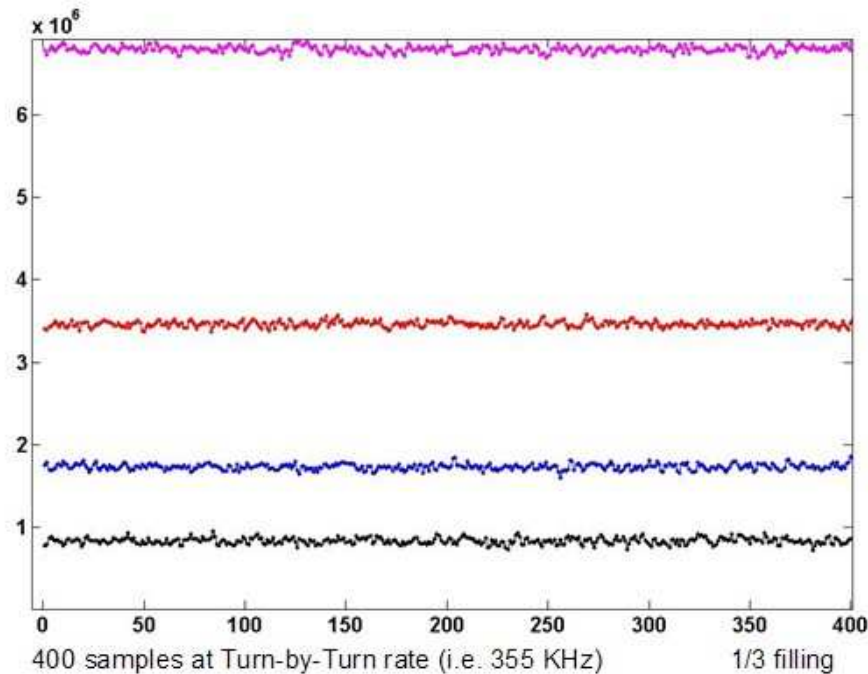
Resolution of current measurement

Buttons

Recalculated to striplines

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Summary on Beam Current Measurements

- **The quality of the Liberas SUM signal and the potential for current or beam-charge measurements in both the Storage Ring and the Injector (Booster and Transfer Line) were confirmed.**
- **The device performs in excellent way for fast (e.g injection losses) and slow measurements (beam decay, beam top-up dynamics).**
- **The quality is degraded if the Modified DDC filter or by not using the Offset-tune feature.**

Conclusion

- This presentation's message was about the thing that we like most when dealing with accelerator community, the spirit of collaboration.
- It shows that the instrument is alive and it can be improved or used in a new way if the ideas are right.
- Such improvements and new usages are of mutual interest.
- Thanks again to Kees for his work.

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