# Modified (Adjustable) DDC Filters within Libera Brilliance - Experience with Partial Fill Patterns and Pure T-b-T Measurements

White Paper

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# 1. Introduction

The intention of this document is to present in a clear and understandable practical issues of the functionality of the modified DDC filters for the Libera Brilliance and Libera Electron. The document emphasis is on the basic functionality of the Modified DDC filters, partial fill patterns and pure Turn-by-Turn measurements.

# 2. Usage of Modified DDC Filters

Libera Brilliance and Libera Electron features the so-called Turn-by-Turn - TbT data output, the data rate being exactly the revolution frequency of the accelerator. This data is essential for commissioning of the accelerator as well as for the machine physics studies. However, 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).

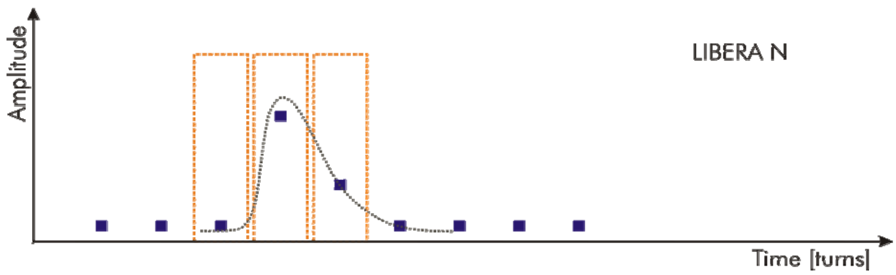


Figure 1: Smearing

The purpose of the modified DDC filter is to remove smearing between adjacent TbT samples, especially with partial fill pattern. IIR bandpass filters are designed much wider (approx three times the TbT sample rate, this was considered the best choice for 33% fill) to reduce ringing. At the same time, moving average filter processes only the data with signal (when partial fill), neglecting the part of the data without beam.

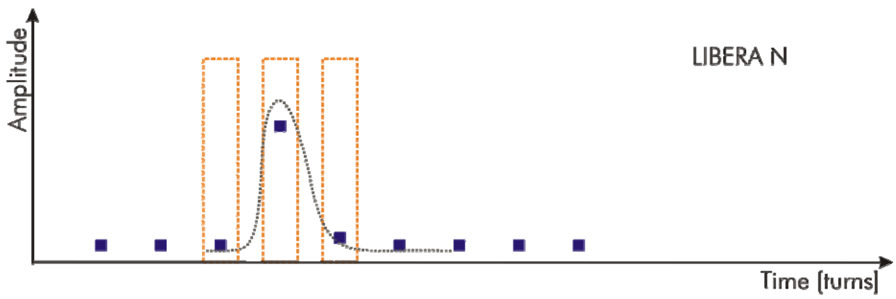


Figure 2: No Smearing

The usage of Modified DDC filters gives the best results for the studies using the Turn-by-Turn measurements, with the benefit of 'true & pure' Turn-by-Turn results (no smearing). There the electivity and usability of the modified DDC filters comes out in best way.

In other cases when these specific studies are not required, the usage of the DDC modified filters is insignificant.

# 3. Practical Measurements

## 3.1. SUM Data

The SUM = Σ = Va+Vb+Vc+Vd output data is very stable and it has also a high quality resolution but it looses its good stability when the DDC modified filter design is installed or when the Libera is "Tuned" (i.e. no Offset-tune in the configuration file and the MC clock is set exactly to the orbit revolution frequency). However, the good stability on the SUM can be reacquired exact frequency of the Offset-tune.

Note that it makes no difference for the SUM signal if the DSC is OFF or ON. For the X and Z position values the DSC does have its usual beneficial impact, but not for the SUM.

## 3.2. Storage Ring Filling Pattern

The measurements were performed on the ESRF storage ring where by default the 33 % fill is used for the Turn-by-Turn measurements. The following figure shows the ESRF ring filled with the 33 % fill at current of ~38 mA. This value is almost optimum for the Libera functionality since the ADC is well filled (counts are around +/- 20K) and the RF attenuators inside the Liberas are set to minimum. The width parameter is set to 101 (i.e. ~33%) and the delay parameter to 150 (i.e. middle of range of 304). The set-time-phase command in this case is set with a simple Matlab script, 30 times, every 5 seconds, with a value which increases from 1 to 301 in steps of 10. After setting that value, the same script waits a few second and then reads the SUM value and puts it away in an array. This measurement was performed on 8 units simultaneously with switching & DSC set to off.

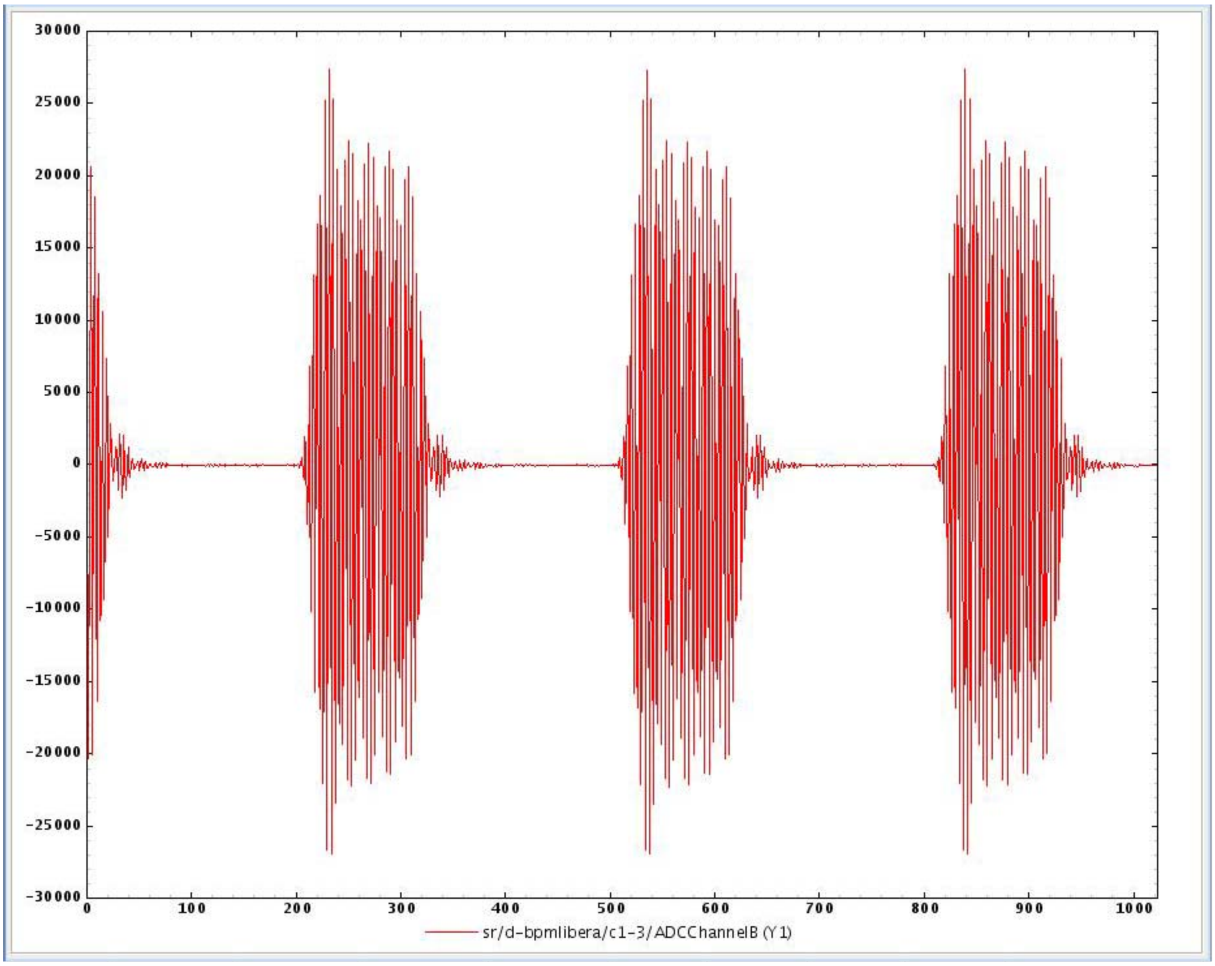

Figure 3: ADC read-out Through Tango Server @ 38mA 1/3 Filling

### 3.3. Scanning and Time Setting

Before the data acquisition is performed the timing value of each Libera acquisition window has to be set. The following picture shows the results of 4 units. The conclusion is that each Libera has to be set to the timing value that corresponds to the maximum of this time-scanning curve. The peak value of each scan indicates the optimum timing value.

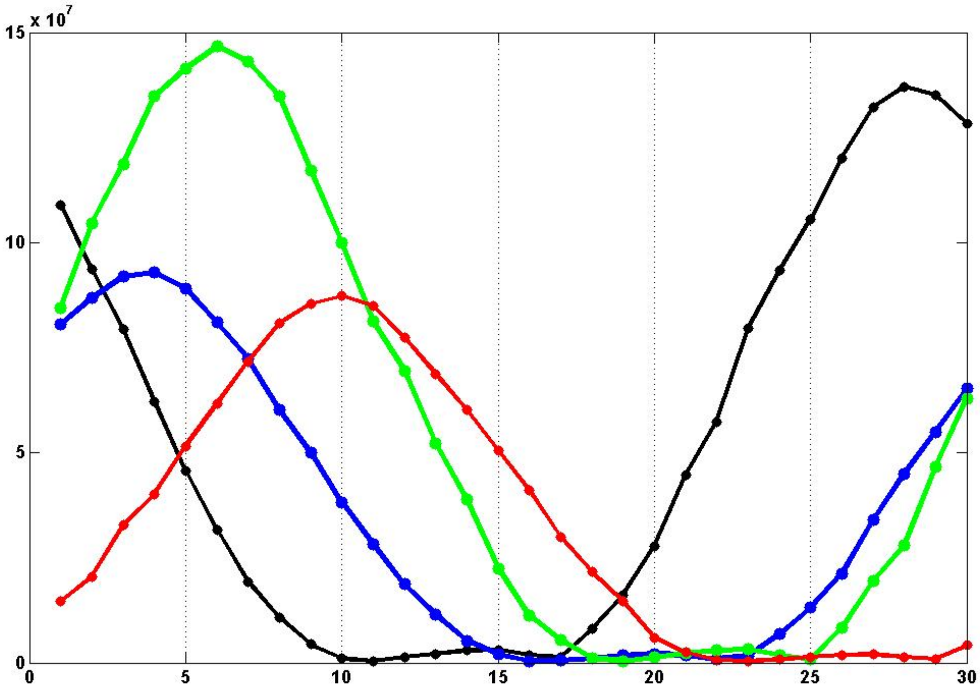


Figure 4: Scanning the 1/3 Summing Filter ('1us long') Through the Full 2.8 us Storage Ring Revolution Period in 30 Discrete Steps of ~93 ns.

### 3.4. Injection Measurements

Figure 5 shows an injection of a 1 us long stream of RF buckets (in fact ~300 buckets) from injector into the Ring. There were also arranged some steerers in a specific cell the Storage Ring so that after 1 single Turn of this injected stream the beam is 100 % dumped in the vacuum chamber roof. All 8 units see the 1us stream of beam signal only for 1 Turn. The injected current is 2 mA (Injector). Figure shows the SUM of the ADC readings at this injection of 2 mA (SY).

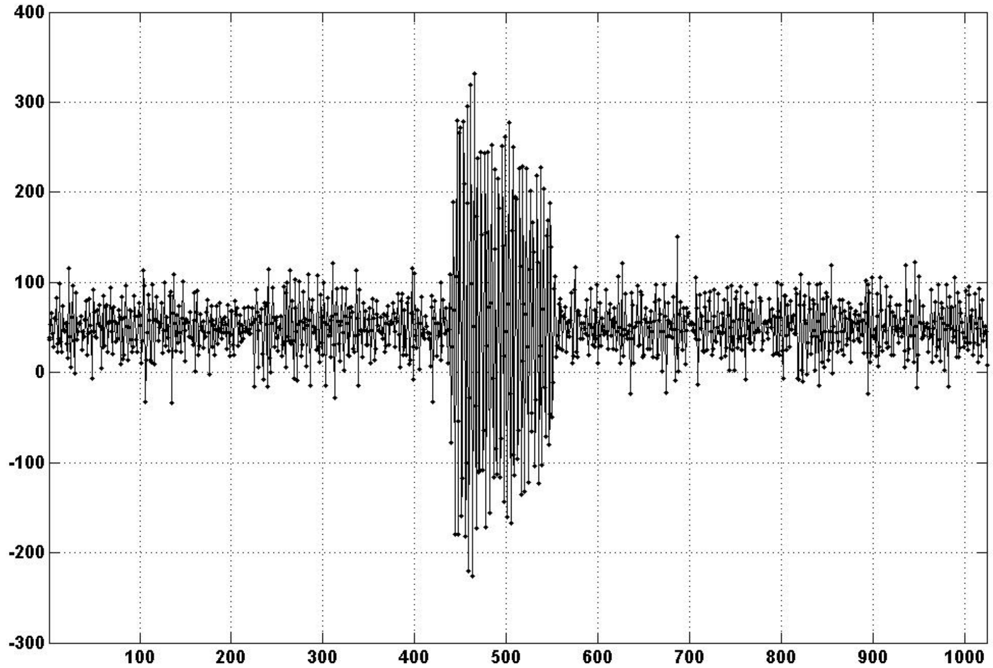


Figure 5: SUM of the ADC with 2 mA Injection from the Injector

### 3.5. Smearing Removed

The purpose of the modified DDC filter is to remove smearing between adjacent TbT samples, especially with partial filling pattern. The figure 6 shows exactly this in practice; the SUM output of one unit. Here the electivity of the modified DDC filters comes out. This is the desired result: one single spike and no noticeable smearing. It was verified that all units gave the same pure single-turn result.

However for single-turn acquisition, the trigger signal synchronization between Liberas is required. If this is not done, the signal of different units might not be displayed-acquired in the same turn. The main reason for this inconvenience is the difference in length and imprecision of trigger cables and consecutively different trigger signal delays. Because of this the triggering has to be harmonized on all Liberas. For this propose the trigger signal can be delayed with Libera trigger delay in range from 0 to 16384 ADC samples.

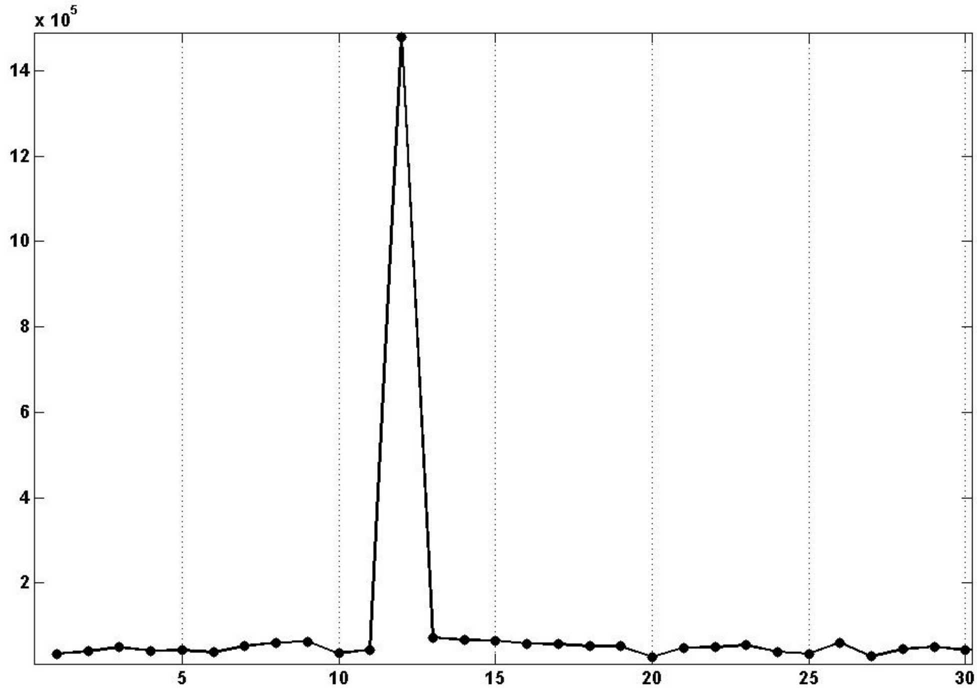


Figure 6: No Noticeable Smearing on a Single Spike

### 3.6. The Arrival and Survival of the Beam

Figure 7 shows the arrival of the beam, while on figure 8 the SUM output of 6 units of a similar injected beam is depicted. Now no longer with the steerers powered to dump the beam after 1 single turn and without RF power to the acceleration cavities: The beam survives for 60-70 turns in these conditions.

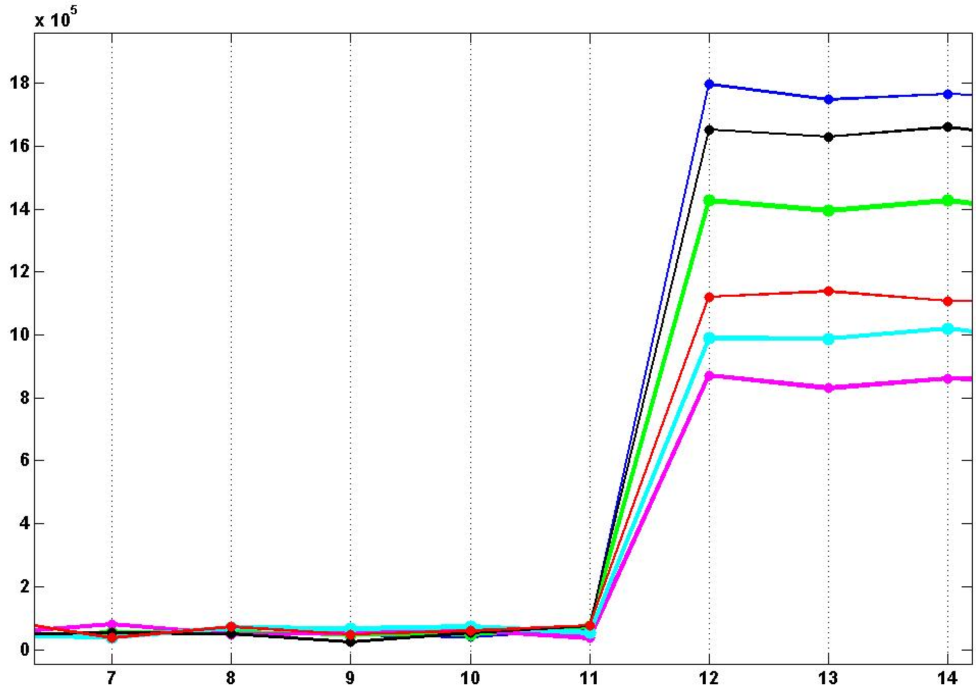


Figure 7: The Arrival of the Beam on Six Units

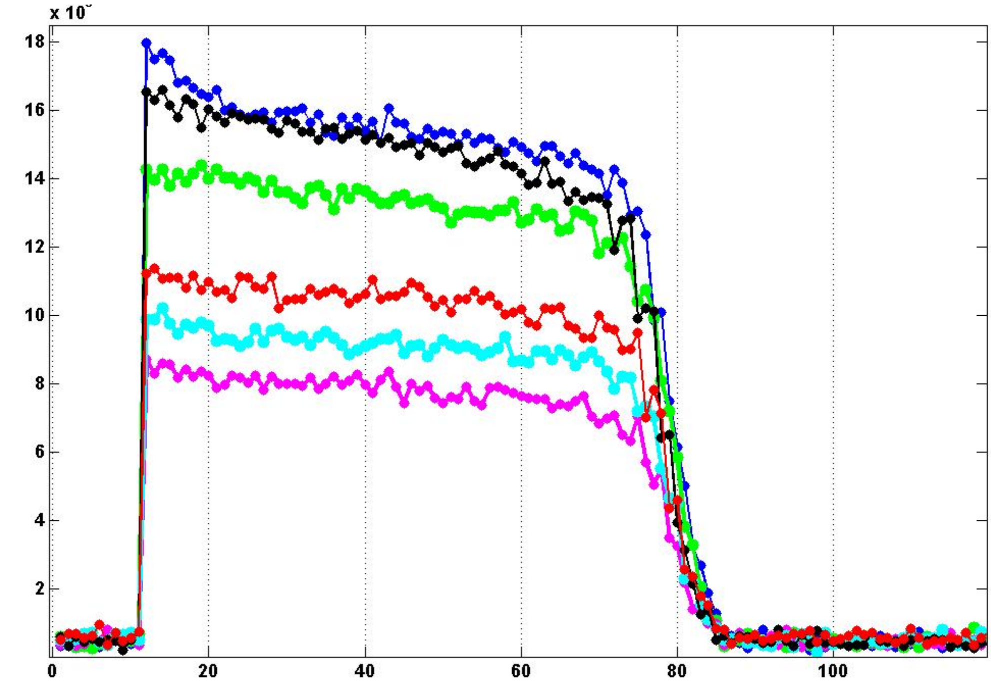


Figure 8: The SUM Signal on Six Units

## 3.7. Beam Kick

The figure below shows the results (of 1 single Libera unit) of 1000 Turns of horizontal beam position with the beam being kicked in one single passage by a 1us flat kicker. In BLACK oscillations reaches 1.5 mm, in RED a result of another measurement on the same beam but without the precedent beam kick.

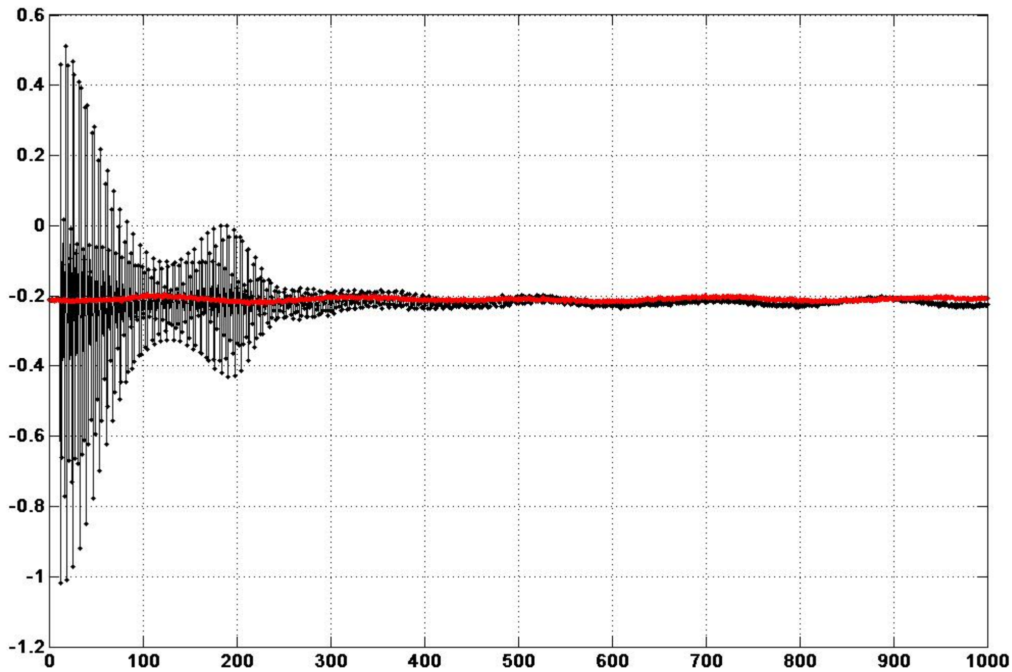


Figure 9: Beam Kick

The result from the precedent figure is zoomed and detailed on the next two figures. Figure 10 shows the same data but with a zoom at the first 20 Turns while Figure 11 shows the noise of the beam & Libera with a Non-Kicked beam: <2 um.

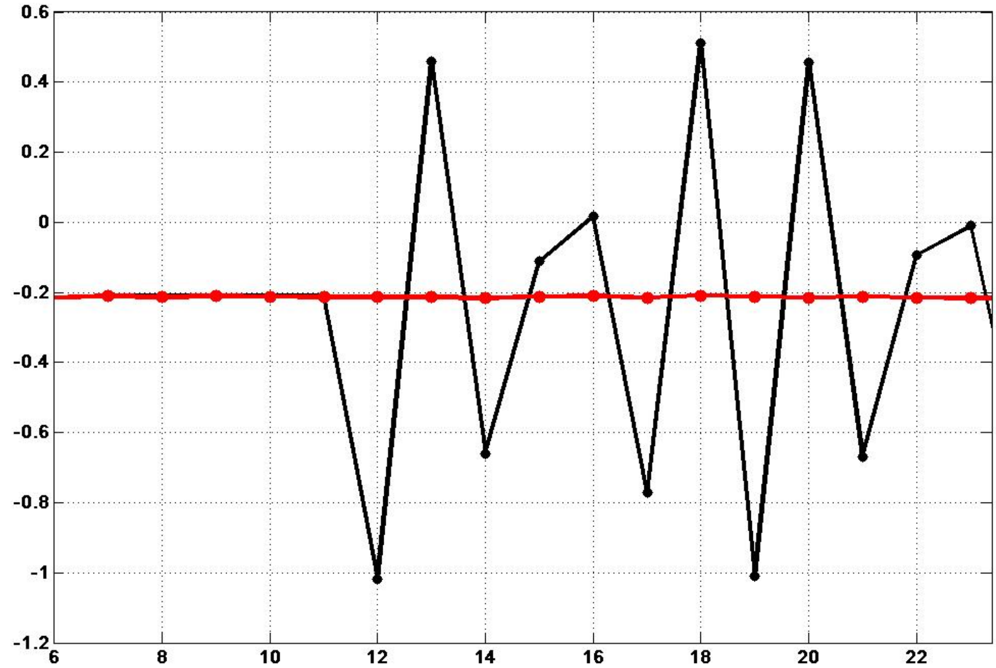


Figure 10: Beam Kick - First 20 Turns

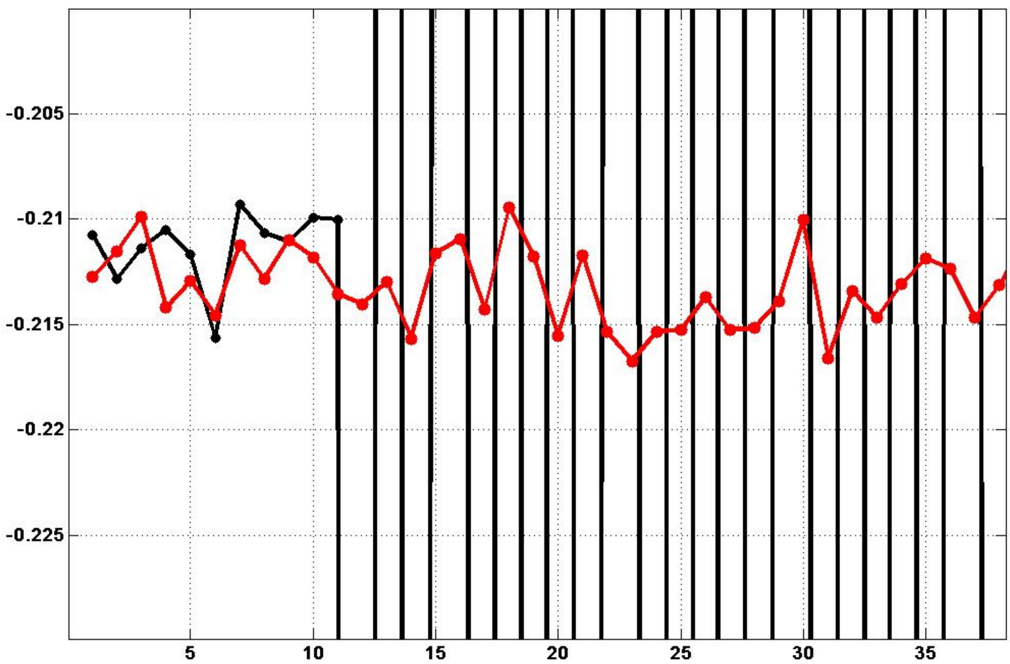


Figure 11: Non Kicked Beam Noise

### 3.8. Noise Value

The next figure shows a beam position measurement of 1000 turns on the Storage Ring filled with a current that corresponds to ~0.5 mA Injector current. The purpose here is to assess the noise values that can be expected when measuring in First-Turn mode when no beam is stored in the Ring and a small current is injected. The noise value is assessed at <1mm RMS for a current that is a factor 10 below nominal injector current.

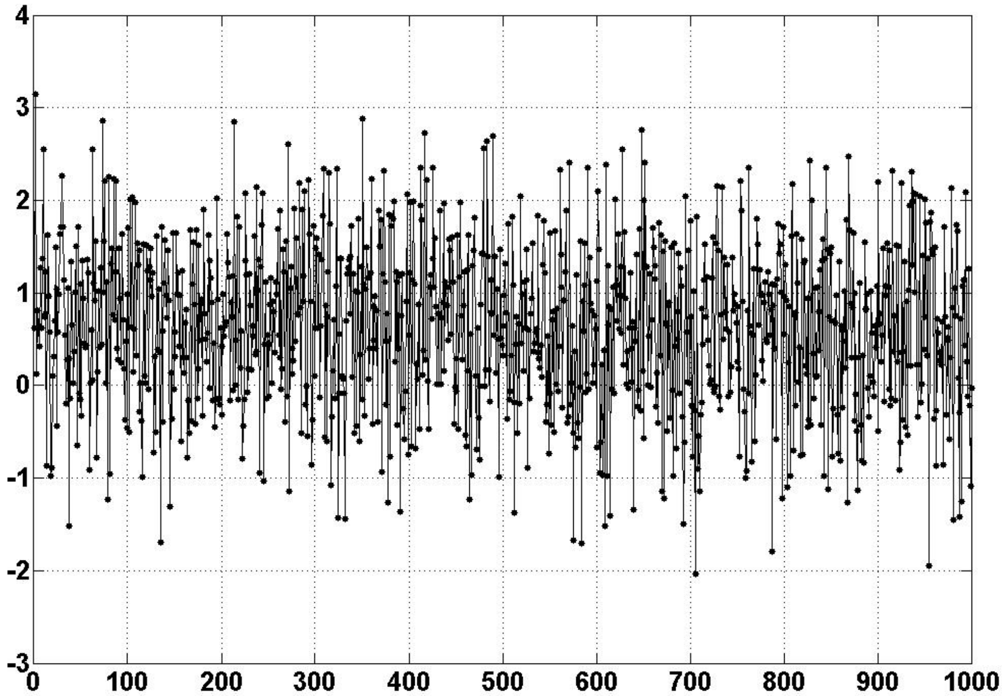


Figure 12: Position Measurement of 1000 Turns

# 4. References

Kees Scheidt: All included measurements and data