# REAL TIME MANAGEMENT OF THE AD SCHOTTKY/BTF BEAM MEASUREMENT SYSTEM

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### *Abstract*

The AD Schottky and BTF system relies on rapid acquisition and analysis of beam quantisation noise during the AD cycle which is based on an embedded receiver and digital signal processing board hosted in a VME system. The software running in the VME sets up the embedded system and amplifiers, interfaces to the RF and control system, manages the execution speed and sequence constraints with respect to the various operating modes, schedules measurements during the AD cycle and performs post processing taking into account the beam conditions in an autonomous way. The operating modes of the instrument dynamically depend on a detailed configuration, the beam parameters during the AD cycle and optional user interaction. Various subsets of the processed data are available on line and in quasi real time for beam intensity, momentum spread and several spectrum types, which form an important part of AD operation today.


## INTRODUCTION AND OVERVIEW

### *Functional Overview*

Beam diagnostics based on measurement of beam quantisation noise are principally nondestructive and therefore have always played an important role for antiproton machines at CERN. The Antiproton Decelerator's (AD) beam consists of a few $10^7$ particles which have to be measured with sufficient precision at all frequencies on the flat tops and the ramps during an AD cycle (Fig. 1), with either bunched or randomly coasting beam.

The system hardware consists of longitudinal pick ups (measurement of beam intensity N and momentum spread dp/p), controllable signal amplifiers, an ADC and eight digital receivers controlled by a digital signal processing stage (DSP) hosted in a dedicated VME board (DRX) [1] and synchronised real-time software (RTT) running in the DSC (see [2] for in-depth description). For optional beam transfer function measurements (BTF) (measurement of transversal tune) which can be scheduled independently anywhere during an AD cycle a transversal Pick up and a controllable coloured noise generator for beam stimulation [3] are used. The RTT continuously schedules measurements, sets up the system hardware, post-processes the data and communicates up-stream. The system is expected to always run, auto-adapt itself to the beam parameters and conditions, be highly configurable for machine development sessions and permanently produce on-line results which must be available for at least three AD cycles.

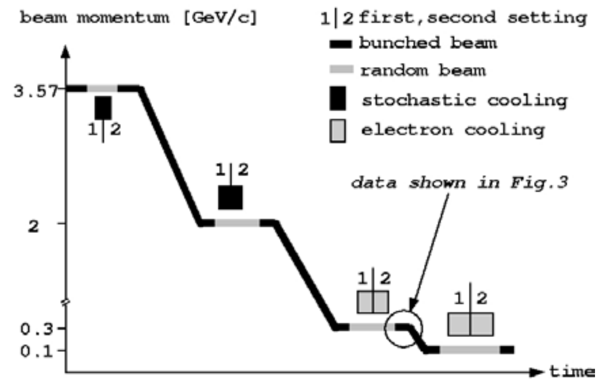


Fig.1: the beam momentum (black/grey trace) during an AD cycle, where the beam is bunched (black) or de-bunched (grey). Stochastic (black square) and electron cooling (grey square) on the flat tops all require different instrument settings. BTF measurements can be made on any ramp or flat top.

### *Structural Overview*

The main logical components of the system with respect to the front-end software are shown in Fig. 2 together with directed and synchronised information flows. Analogue signals generated by three pick ups in each beam-plane enter the amplifier and signal mapping hardware. This hardware receives configuration for gain, filter, input and mapping of pick ups to amplifier channels organised in a table of settings which is stepped through depending on the revolution frequency (f tables, Fig. 2). It receives this configuration at times which are determined by the conditional clock and beam logic unit (CBL) as indicated by a many dimensional data flow arrow. The CBL is an eight-dimensional looping counter which steps down each 20ms clock tick ($T_x$, interrupts received from an external source) and is realized as software structure. It maps to the eight receivers and inhibits (according counter > 0) or releases (according counter = 0) the many dimensional data flows. The CBL selects one process parameter set (PPA) for the DRX and one eight-dimensional counter setting for itself out of many configurations, and one setup for the amplifiers from the frequency table. This selection depends on the CBL counter values and on four external informations: $T_x$, $f_{rev}$, the beam bunched or de-bunched condition and the status of the stochastic and electron cooling systems (on or off).

The data from the set of receivers which participate in a particular measurement is read out, post-processed (see [2]) and the next measurement involving these receivers is started when the according data flows are released by the CBL. When the processing for any of the results is finished the timestamped values for N, dp/p, $f_{rev}$, schottky spectra and in the case of BTF measurements also correlation and noise stimulation data are released into the (circular) history buffer where they persist for at least three AD cycles. Control system standard communication software provides access to the history buffer for a graphical instrument interface in the control room offering views on selected data subsets and editing of instrument configurations.

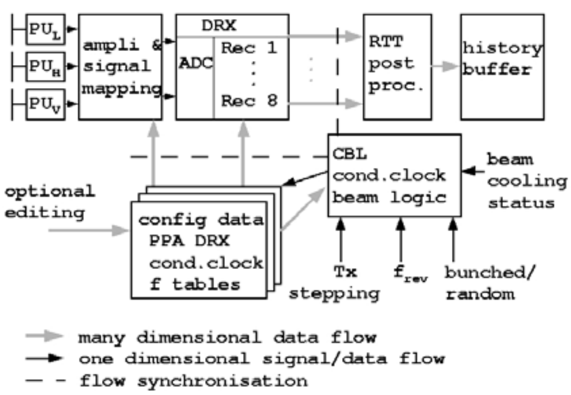


Fig. 2: system information flow overview showing the logical components in the front end software.

## REQUIREMENTS, CONSTRAINTS AND CONTROLS

### *Repetition Rate*

In order to study and survey the AD deceleration efficiency the repetition rate of the measurements has to be as high as possible. The time each single de-bunched beam measurement needs is determined by the settings of bandwidth, number of averages needed on an observation harmonic (where the pick ups and electronics have maximum performance for the given beam conditions) and the type of processing performed in the DRX, as shown in Table 1. For bunched beams the overall execution time is kept below 20ms[1] by optimizing the ADC samping clock for each measurement individually. Each row of Table 1 corresponds to a PPA for the beam condition and to a CBL setting, which determines the execution time for the receivers concerned by this measurement.

Table 1: settings used for different beam conditions, frequency spans wide sp1 (and additionally narrow for de-bunched beam sp2), observation harmonic n, number of averages (avg) for instrument setting 1 and 2 and their total execution time.

| beam [GeV/c], condition | sp1 (sp2) [Hz], n [1] | avg [1] | execution time [ms] |
|---|---|---|---|
| 3.57, bunched | 14k, ~1 | 1 | 20 |
| 3.57, debunched | 5000 (2000), 5 | 50 | 2200 |
| 2, bunched | 14k, ~1 | 1 | 40 |
| 2, debunched | 7000 (3500),10 | 53 | 1460 |
| 0.3, bunched | 14k, ~3 | 1 | 40 |
| 0.3, debunched | 3600 (2500), 4 | 36 | 1920 |
| 0.1, bunched | 14k, ~1 | 1 | 40 |
| 0.1, debunched | 1500 (1000), 9 | 10 | 1400 |

### *Autonomous instrument*

Taking into account the beam conditions which are likely to be encoutered during an AD cycle sets of optimized settings can be found beforehand. Since the $f_{rev}$ which is acquired from the RF system is not available during the flat tops it must be inferred from a look-up table. Furthermore the ADC sampling frequency must be kept proportional to $f_{rev}$ and close as possible but below the maximum rate of 40MHz for each measurement on bunched beam, or kept fixed at 40MHz for de-bunched beam.

In the middle of any ramp the instrument configuration is switched from the previous flat top's bunched setting to the next flat-top's bunched settings with respect to the revolution frequency, with a relatively wide span. During the beam cooling on any flat top the initial wide span (sp1) is narrowed down (to sp2) when a certain percentage of the cooling time has passed (1st and 2nd settings in Fig.1).

### *Configurable instrument*

The configuration data sets shown in Fig. 2 are activated following the inputs of the CBL and are subject to complex real-time constraints,

[1] we often schedule with 40ms to decrease the amount of data

nevertheless they can be edited in order to adapt to changing requirements and to schedule single-shot BTF measurements at any time during the cycle. Any changes are read by the RTT once every few seconds and are activated in the system components when the according data flow gets released by the CBL, therefore the ongoing measurement and processing are not disrupted.

## RESULTS

The data generated by the system for one AD cycle can reach many MBytes depending on the configuration but the control system should not have to sustain such a data rate for on-line visualisation, also the machine physicist is interested only in the subset of data related to the phenomen under study. Therefore the non-synchronised standard communication software must rely on built-in knowledge about the measurement types and timestamps in order to select data subsets on request from the history buffer.

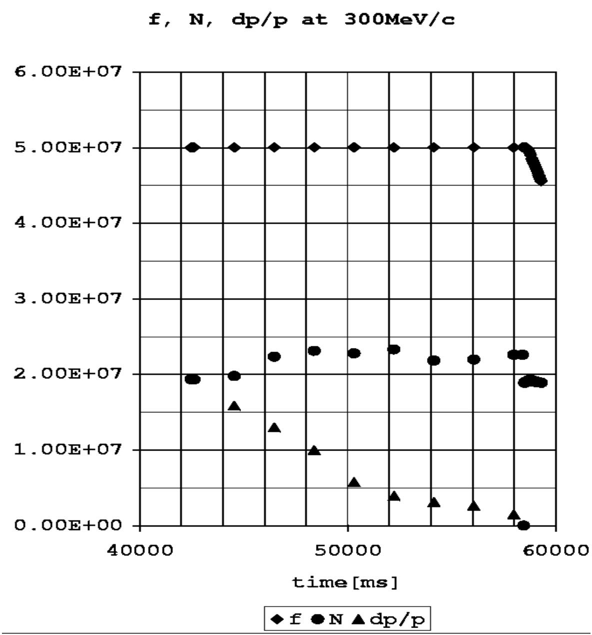


Fig.3a: data taken on 24 Sept 2002 at the end of flat top 300MeV/c: diamonds: $f_{rev}$ [1/100 Hz]; circles: N [1]; triangles: dp/p [1e-10], injection t=0. The beam is bunched again at 58460ms.

The Fig. 3a shows the $f_{rev}$, N and dp/p at the end of the 300MeV/c flat top as indicated in Fig.1, with a measurement repetition rate of 1920ms (Table 1) for de-bunched beam and a high repetition rate of 40ms the beginning of the ramp. The dp/p, which is available only for de-bunched beam measurements, decreases during beam electron cooling on the flat top. Variations observed for N reflect uncertainties of 20% for de-bunched beam, the first measurement on bunched beam is rejected (set to 0.0) due to strongly deformed bunches. The zoomed view on the same data (Fig. 3b) shows again a stable beam intensity around 1.9e7 with better that 5% uncertainty for decreasing $f_{rev}$ offering high temporal resolution.

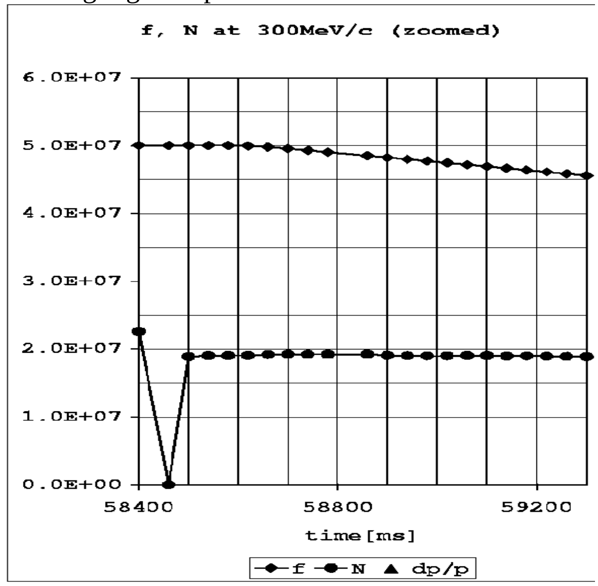


Fig. 3b: zoomed view on the data of Fig.3a (bunched beam) which shows the high temporal resolution for bunched beam measurements.

## CONCLUSION

The dependency of the system settings on the beam conditions was translated, in the case of the AD, to a dependency on revolution frequency (and therefore time) and a few external conditions which drive a conditional beam logic unit. Both requirements of beeing highly configurable and completely autonoumous are met, and a high temporal resolution is realized.

## REFERENCES

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[2] M. E. Angoletta, L. Bojtar, V. Chohan, A. Findlay, M. Ludwig, O. Marqversen, F. Pedersen, "Antiproton Beam Parameters Measurement by a new Digital-Receiver-Based System," CERN PS 2001/16, Geneva, Switzerland, 4. April 2002.

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