THE BEAM LOSS MONITORING SYSTEM AT ELSA

D. Proft[*], A. Balling, F. Frommberger and W. Hillert, ELSA, Bonn, Germany

Abstract

A new diagnostic tool to monitor beam loss in the storage ring at the Electron Stretcher Facility ELSA has been set up. It enables the investigation of causes for electron loss in real time, providing an essential tool needed to achieve the planned beam current upgrade from 30 mA to 200 mA. The monitoring system consists of 32 pin-diode based radiation detectors spread around the storage ring. Therefore, individual electron loss can be localized after each quadrupole. The readout system was designed to allow an integration of single loss events within 70 μs in order to be able to correlate these events to machine state changes. The used monitoring hardware and readout system will be detailed. Furthermore first measurements of the beam loss during injection, the fast energy ramp during acceleration and the extraction phase will be presented.

INTRODUCTION

Occurring beam loss is a clear indication for limited accelerator performance. Its detection requires a dedicated monitor system because of the very low rates which are not detectable with common hardware like beam current monitors. For common issues, like the identification of installation errors, minimization of material activation and the avoidance of radiation background at the experiments, a spatially distributed system is sufficient.

Additionally, at ELSA, time resolved beam loss information is also required to correlate beam loss events to machine state changes in the different phases of the acceleration cycle. A collaboration between ELSA and Cosylab was initiated and resulted in the development of a complete solution for beam loss detection at the storage ring [1].

REQUIREMENTS FOR BEAM LOSS DETECTION AT ELSA

The design goal of the whole beam loss monitoring system was to detect any kind of electron loss in the main stretcher ring during the so called *booster-mode*, which is the default operation mode of the Electron Stretcher Facility ELSA [2]. The acceleration cycle in this mode consists of the following steps: During the injection phase, electrons are produced by the 50 kV source for polarized electrons [3] and pre-accelerated to 1.2 GeV using a linear accelerator and the following booster synchrotron with a repetition rate of 50 Hz (Figure 1). Several of these injections are accumulated in the main storage ring (up to an internal beam intensity of 30 mA) and then the final acceleration to the desired extraction energy of typically 2.4 GeV takes place. After that, the beam is slowly extracted to the experimental area using resonance extraction. Thus, a continuous beam of polarized electrons with a few 100 pA for typically 5 seconds is provided to one of the both hadron physics experiments *crystal barrel (CB)* and *BGO-OD* with an overall duty cycle of typically more than 70%.

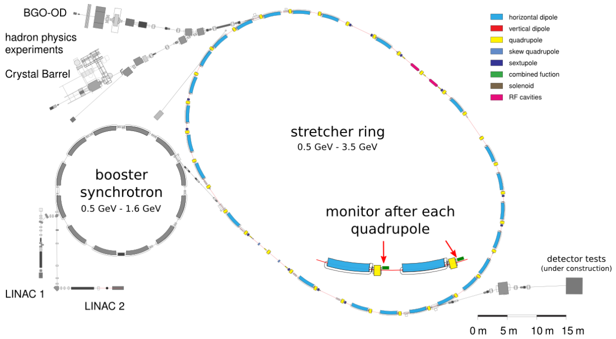

Figure 1: The ELSA accelerator facility.

To fulfill the future requirements of the experiments, a higher external beam intensity is required. Additionally the extraction time should be increased to offer a higher duty cycle. This can only be accomplished by increasing the internally stored beam intensity from 30 mA up to 200 mA. Essential for this procedure is the reduction of beam loss during the whole accelerator cycle.

The need of polarized electrons for double polarization experiments requires an electron source based on photoemission cathodes. Because these are limited to much smaller beam currents than thermionic guns, an optimization of the transfer efficiency at injection to the stretcher ring should be the first step to increase the overall stored beam intensity.

During the fast energy ramp several depolarizing resonances are crossed. To preserve the polarization of the electron spin, betatron tune jumps are applied to compensate intrinsic resonances. Additionally harmonic orbit corrections are applied to compensate imperfection resonances [4]. Both require fast manipulations of the closed orbit and betatron tune on a time scale of less than 20 ms. For optimization of the machine state and beam loss during these corrections, spatial as well as time resolved loss informations on a 1 ms scale are required.

HARD- AND SOFTWARE

The beam loss detection is set up by using semiconductor radiation detectors manufactured by *Bergoz Instrumentation*. The contained reverse biased pin diodes generate signals upon minimum ionizing particles crossing through

---

[*] proft@physik.uni-bonn.de

the depletion zone. The maximum count rate of the included amplifier and comparator exceeds 10 MHz. To reduce noise and events caused by synchrotron radiation photons, two diodes are set up in a coincide circuit and mounted face to face inside each monitor. The small design (3 × 7 cm) allows us to supply the main stretcher ring with 32 detectors. To improve the detection rates the monitors are installed behind each quadrupole in which the beam profile shows a maximum in either horizontal or vertical plane.

The generated TTL-logic compatible pulses are processed by *Cosylab*s FPGA based *BSC*s [5] which can be supplied with two BLMs each. The amount of pulses is summed up within a configurable time slot from 70 μs up to 10 seconds, and is stored in an internal buffer memory with a depth of 3700 records for each monitor. On the one hand this allows real time capture of loss events with high accuracy during injection and ramp phase of the accelerator. On the other hand the amount of data can be reduced by choosing a higher granularity during extraction phase in which the accelerator parameters are not changed rapidly.

The 16 installed BSCs are grouped in 6 segments and connected to a personal computer with a serial bus (RS485) (see Figure 2). After completing a capture cycle, the internal buffers are read out by a multi-threaded in house developed software allowing parallel communication with the BSCs in each segment. The processed beam loss data is sent to the accelerators control system for real time visualization. On demand, the data can also be stored to hard disk for later analysis. In this way any improvements made to the machine parameter sets can be compared to recent sets to proof any optimization.

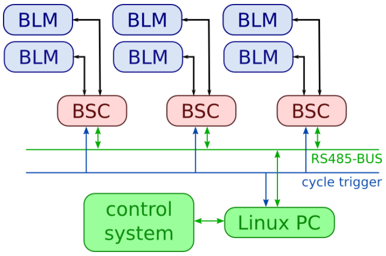

Figure 2: Schematic overview of one segment of the beam loss monitoring system.

Changes to the beam loss systems configurations are easily available through predefined presets. The user can choose to observe only parts of the accelerator cycle (i.e. injection, injection and ramp or a whole cycle) and set the desired temporal resolution. Additionally a complete free configuration is also possible: Here, the capture length and capture offset with respect to the cycle begin can be set freely. For other modes of operation (especially the storage mode, in which up to 100 mA beam current are accumulated and stored in the ring without extraction) the hardware trigger is not available and is therefore replaced by a software based trigger.

MEASUREMENTS

The whole system consisting of 32 BLMs, 16 readout electronics (BSCs) and the personal computer has been set up completely and allows first measurements of the beam loss during the booster mode.

As a first step to optimize the accelerators performance, in order to store up to 200 mA internal current, the beam loss during the injection phase should be analyzed. Therefore the loss events during 17 consecutive cycles have been recorded and averaged, thus reducing the effects of varying injection shot charge from the booster synchrotron.

The beam loss rates at every monitor have been integrated during the length of each injection shot (20 ms), giving the total loss after each quadrupole. Figure 3 shows the corresponding event counts versus the sector number in which the BLM is mounted.

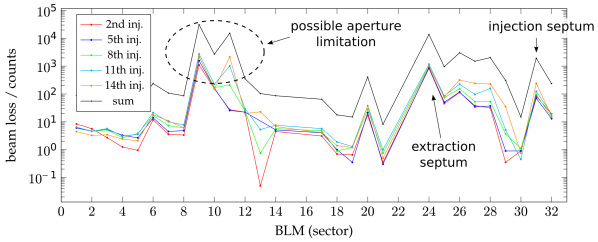

Figure 3: Beam loss during injection phase in booster mode.

Areas with injection and extraction septa show up in the beam loss distribution with significantly high rates. The loss in these sectors is unavoidable due to the design of the septum magnets. Nevertheless procedures to reduce the loss, like adjusting the beam position and injection bump, can now take place. Beside that, the loss rate increases slightly while the internally stored beam intensity grows during the injection. This disagrees with the need of a high accumulated beam intensity within an adequate injection time.

The measurement also reveals a possible aperture limitation in sector 8. The loss rate is as high as in the sector where the extraction septum is positioned (24). This occurrence can now be further analyzed by using bumps in the appropriate sectors. If the loss rate reduces significantly, one can check up for obstacles inside the vacuum chamber.

Time Resolved Measurement

First measurements with a high temporal resolution have also been made. To confirm the capabilities of the monitoring system, the electron loss produced by a single injection shot is shown in figure 4. The data was taken with a resolution of 200 μs using a monitor right behind the extraction septum.

On a larger time scale the beam loss during the first part of the acceleration cycle can be observed. The resolution was slightly increased to 260 μs to allow a capture length of barely one second. The loss events are resolved high

ISBN 978-3-95450-115-1

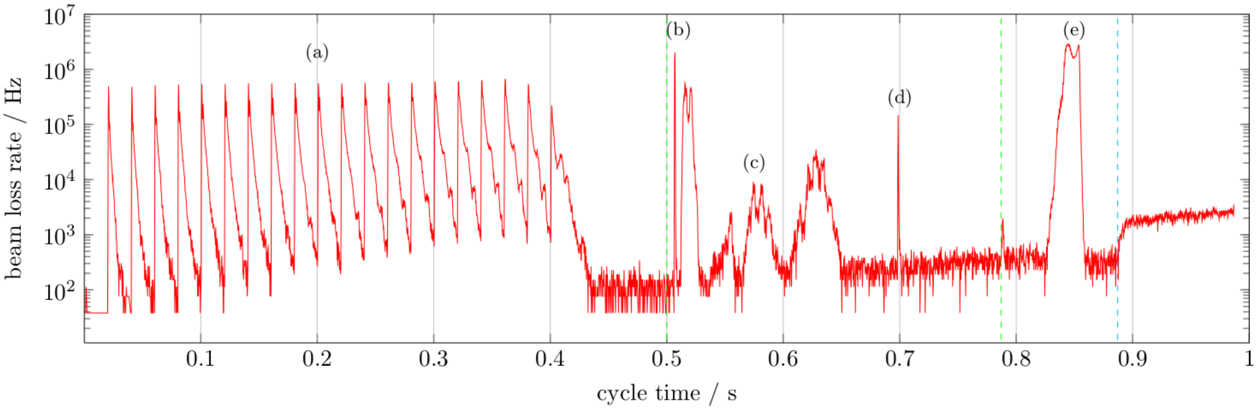

Figure 5: Beam loss rates behind the extraction septum during injection and ramp phase, correlated to machine state changes: a) injection shots from booster synchrotron, b) start of energy ramp, c) harmonic orbit correction for spin preservation at imperfection resonances, d) fast betatron tune jump for fast intrinsic resonance crossing, e) setup of horizontal tune to prepare the resonance extraction.

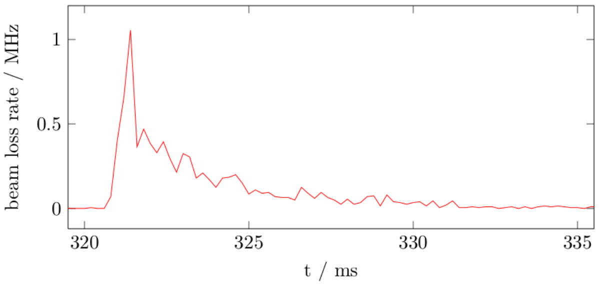

Figure 4: Loss rates by a single injection shot behind the extraction septum.

enough to match them to machine state changes (see Figure 5).

CONCLUSION

The beam loss detection system at ELSA is a new powerful tool to improve the accelerator health. The precise spatial measurement of beam loss rates during standard operations allow an investigation of several problems related to aperture limitations and malfunctions of components. Especially the high beam loss rates in one sector are of high interest and are now investigated, to hopefully avoid them in the future. Beside that the high temporal resolution is sufficient to disclose steering and synchronization errors during the critical fast energy ramp. Here some discrepancies during the beginning of the ramp show up in almost all sectors yielding to a possible synchronization error between the magnet and/or RF ramp. Additionally further optimization tasks can now take place to improve the overall accelerator performance. This includes the optimization of the transfer line from the booster synchrotron to the stretcher ring beside improvement of the extraction efficiency.

REFERENCES

[1] A. Balling, “Machine-Mode Aware Beam Loss Monitoring”, PCaPAC08 Conf. Proc., TUP007

[2] W. Hillert, “The Bonn Electron Stretcher Accelerator ELSA: Past & Future”, EPJ A s01 (2006) 139.

[3] W. Hillert, et al., “The 50 kV inverted source of polarized electrons at ELSA”, AIP Conf. Proc. 570 (2001) 961.

[4] M. Hoffmann, et al., “The polarized electron beam at ELSA”, AIP Conf. Proc. 570 (2001) 756.

[5] BLM Signal Conditioner, Cosylab, `http://www.microioc.com/blm.htm`.