

Beam loss monitors at the ESRF

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Abstract

The European Synchrotron radiation facility is a third generation x-ray source providing x-rays on a continuous basis. As a facility available to external users, the monitoring of radiation caused by the loss of high-energy stored beam is of great concern. A network of beam loss monitors has been installed inside the storage ring tunnel so as to detect and localize the slow loss of electrons during a beam decay. This diagnostic tool allows optimization of beam parameters and physical aperture limits as well as giving useful information on the machine to allow the lifetime to be optimized and defects localized.

1 INTRODUCTION

Modern synchrotron light sources are being pushed by users to provide higher photon brilliance. This is achieved both by a reduction of the stored beam emittance and by the increase of magnetic fields with short period undulators. The latter requires the close proximity to the beam of the insertion device magnetic poles. At the European Synchrotron Radiation Facility (ESRF), vacuum chambers of internal dimensions as low as 8mm are used with lengths up to 5m. Large amplitude betatron oscillations excited by Touschek, elastic and inelastic collisions in the vertical plane give rise to a loss of particles on the small aperture insertion device vacuum vessels. The push to low emittance increases significantly the contribution to these losses from Touschek collisions. It is important in order to control these losses that they are continuously monitored. Beam loss detectors have been developed at the ESRF which detect the radiation shower produced by the passage of high energy electrons through the vacuum chamber walls. Two types of detector have been developed:

- i) Short fast losses during injection pulses and sudden beam losses.
- ii) Prolonged beam loss during the decay period of a stored beam.

The former type are required to be very sensitive, whereas the second type should be designed so as to measure linearly very large bursts of radiation.

A good review of the different beam loss detector types is given in [1] and is summarised in table 1.

In all cases care should be taken in the case of a synchrotron light source that the signal detected is not significantly perturbed by the contribution from the background high-energy synchrotron radiation. This may be achieved as in [2] by the coincidence detection on two photodiodes. At the ESRF the higher energy radiation due to the Bremstrahlung of electrons escaping the vacuum chamber is discriminated from the synchrotron radiation by shielding the detector with 10mm thickness of lead and placing the detector on the inside of the storage ring. For the case of the fast detectors, synchrotron radiation is not a problem as they are only sensitive to large bursts from beam losses. A simple detector system is employed using a perspex rod as a scintillator coupled to a high gain photo-multiplier. This method was chosen to allow a large number of detectors to be installed. The average anode current is monitored rather than the count rate of scintillation events. Although in principle scintillation counting should give better linearity over a greater dynamic range, in practice the particle revolution rate and the filling pattern limit the maximum achievable count rate. This maximum rate is different for different filling patterns (eg single bunch and multi-bunch) thus affecting the performance in different filling modes, similarly the maximum count rate during injection is limited to 10Hz by the injection rate. The photo-diode solution although providing a simple solution gave too low a count rate at the locations at which the detectors were to be located. A fast beam loss detector using a 1mm Perspex fibre coupled to a silicon photodiode is also used. Each of the 32 cells of the ESRF storage ring is equipped with one slow beam loss detector and 3 fast beam loss detectors.

Type of Beam loss detector	Advantages	Disadvantages
Long ionisation chamber [7]	Can give position sensitivity	Expensive and complex electronics
Short ionisation chamber [3]	Linear over many decades	Measurement of very low currents is very expensive
Scintillator + Photomultiplier (PM) [6]	Simple and cheap	Long term degradation of scintillator and drift of PM
Pin Photo-diode [5]	Simple and cheap	Limited count rate.

Table 1: Different beam loss detector types.

In practice the slow beam loss detectors have also been useful in detecting injection losses by reducing dramatically the injected current from the linac so as not to saturate the detectors. This latter mode of injection optimisation is particularly important as this operation normally involves injection over very long periods of time and significant accumulated doses around the accelerator structure if the full injection beam current is used.

2 DETECTOR CONSTRUCTION

The construction of the slow detector is shown in figure 1 and the fast beam loss detector in figure 2.

In each case a scintillating Perspex light guide channels part of the scintillations produced by the passage of high energy particles in the medium to a photodetector.

2.1 Slow detector.

A 60cm long, 25mm diameter rod of perspex is used as the scintillator. A high sensitivity visible light sensitive photomultiplier is used to collect the light (Electron tubes device P30CW12 with bi-alkali photocathode and integrated high voltage supply.). The device is shielded from synchrotron radiation with a 10mm wall thickness lead tube. The anode current from the photomultiplier is amplified in an electronic card outside the tunnel with a gain of 5×10^7 V/A. The sensitivity of the device can be adjusted over several decades and set to a calibrated level by introducing a small known light intensity into the top of the device and changing the control voltage to the photomultiplier high voltage supply.

SLOW BEAM LOSS DETECTOR
(New version)

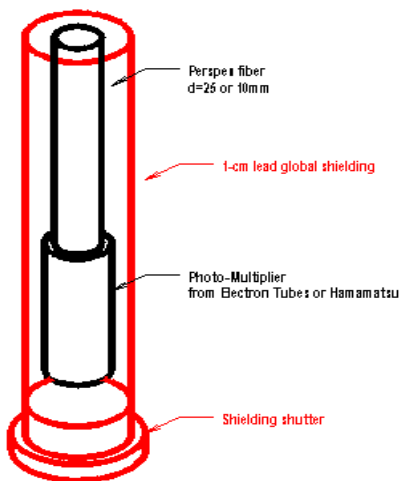


Figure 1: Slow beam loss detector

2.2 Fast Detector

A 1mm diameter Perspex fibre 60cm long is coupled to a photodiode. The fibre is shielded in a 2mm-wall thickness lead tube. The photodiode signal is directly amplified with a gain of 10^8 V/A. This amplifier is connected using a single co-axial cable to the outside of the tunnel. An electronic card outside of the tunnel is used to provide a supply voltage bias to the connecting cable and receive the incoming pulse. This electronic card gives a further gain of about 20 with a rise time of about 50ms and a fall time of about 2 seconds.

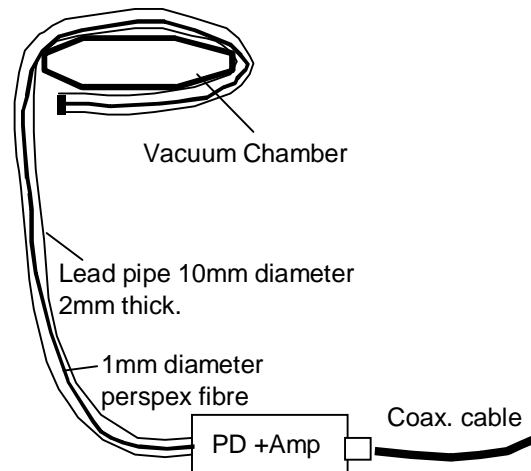


Figure 2: Fast beam loss detector

The signals from the two detector types are available as slowly varying analogue signals, which are read by an analogue to digital converter and processed for display and storage on the control system terminals in the control room. The system is summarised in figure 3.

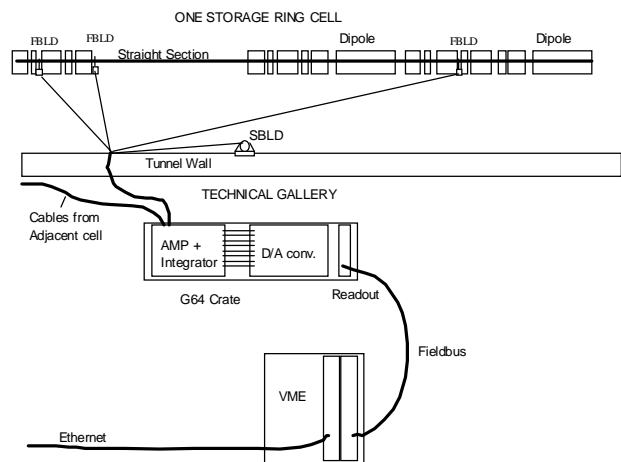


Figure 3: Acquisition system

The signals from all the detectors are summarised in a graphical application, which shows the time variation of all the detectors (figure 4).

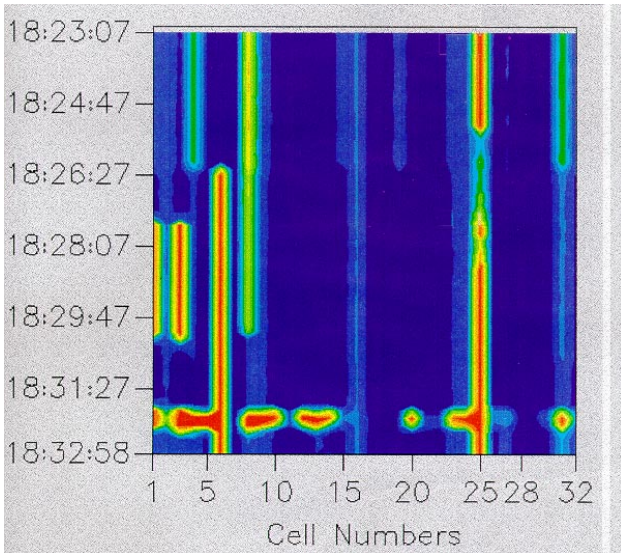


Figure 4: Graphical display of a class of detectors

3 USE OF BEAM LOSS DETECTION AT THE ESRF

Some of the current applications of the beam loss detectors are given below.

3.1 Detection of defective components.

The lifetime may be suddenly reduced by a local reduction in physical aperture due for example to the deformation of an RF finger. This will become immediately apparent on the slow detectors in the following cells or on the fast detectors when trying to re-inject.

3.2 Detection of poor vacuum

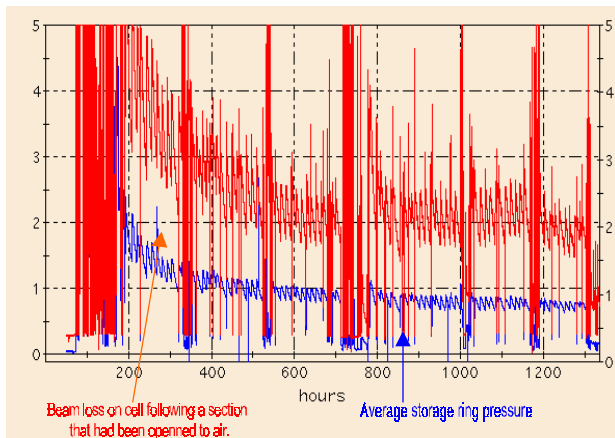


Figure 5: Vacuum conditioning after a shutdown

Following interventions on vacuum on the storage ring, the vacuum improves from a relatively poor value, due to conditioning, over several weeks. This is evident from the lifetime and beam losses on straight section vacuum vessels (figure 5). A growing leak in a cell may be detected by increases in the losses on the insertion device vessel in the following cell (figure 6).

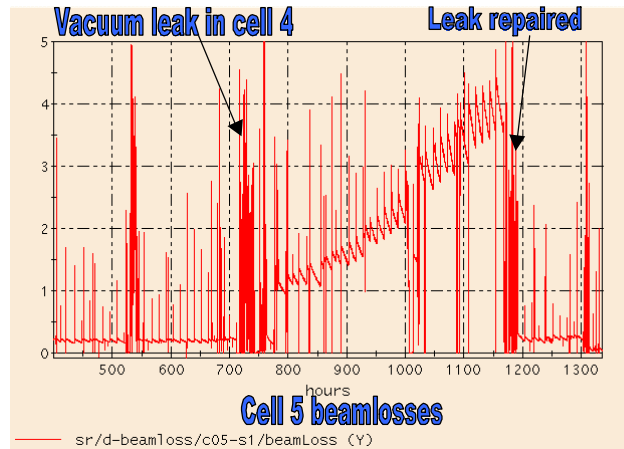


Figure 6: Indication of vacuum problems

3.3 Optimisation of scraper settings

The losses on the small vacuum vessels are a problem due to increased Bremsstrahlung on the beam line and due to activation of the vacuum chamber. The losses can be dramatically reduced and concentrated at the position of the scraper by optimising its position (figure 7).

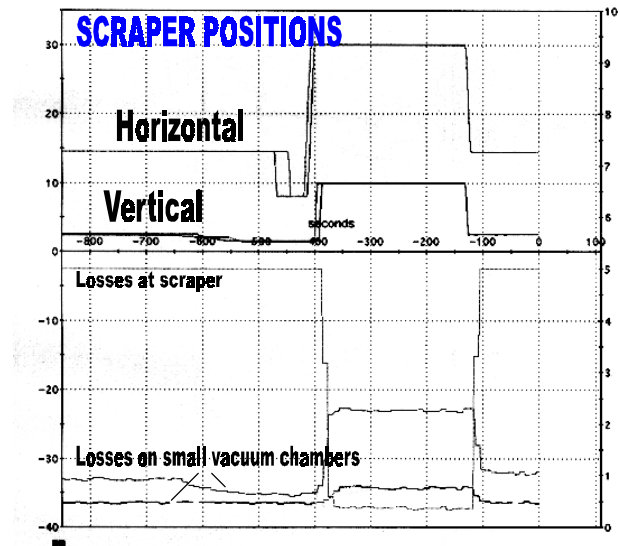


Figure 7: Scraper optimisation

3.4 Detection of tuning problems.

Increased loss of particles may occur due to poorly corrected resonances which may become apparent due to

insertion device gap dependent tune changes. This affects the lifetime but is also very visible as increased losses at the small gap vacuum chambers. The fast response of the signal allows rapid optimisation (figure 8).

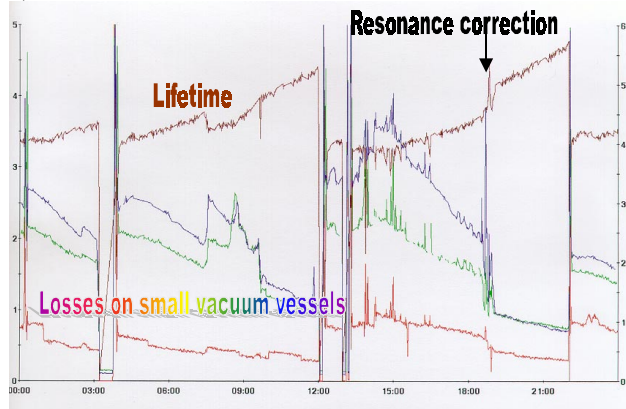


Figure 8: Detection of tuning problems.

3.5 Injection optimisation.

The requirement of minimising the total number of lost electrons in order to satisfy radiation safety limits implies that injection optimisation should be done with very low injected currents. The use of current transformers to measure the efficiency becomes very noisy, whereas the sensitive signals from the slow beam loss detectors around the storage ring allow the losses to be quickly and easily minimised.

4 SUMMARY

Fast and slow beam loss detectors are installed all around the ESRF storage ring. The slow beam loss detectors are very useful as a diagnostic in monitoring various machine defects including losses during injection.

5 ACKNOWLEDGEMENTS

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REFERENCES

- [1] "Beam loss detection" K.Wittenburg Proc 1st DIPAC 93 CERN PS/93-35 (DB) pp11-20
- [2] W.Bialowans, F.Ridoutt, K.Wittenburg DESY "Electron beam loss monitors for HERA" EPAC 1994
- [3] M.Plum, D.Brown, A.Browman, R.Macek "Ion-chamber beam loss monitor system for the Los Alamos Meson Physics facility PAC 1995

- [4] O.Kaul, B.Sarau, K.Wittenburg DESY "Fast measurement of lifetime changes and beam losses in DORIS by the use of Bremstrahlung from a collimator"
- [5] "Monitoring Beam losses at the Synchrotron Radiation Elettra facility" ST/M-TN-94/4
- [6] J.R.Parker et al "A beam spill monitor for LAMPF" IEEE Trans. On Nucl. Science Vol 20 3 (1973) p 596-598
- [7] J.Rolfe et al "Long ionisation chamber system for the SLC" SLAC-PUB-4925, (1989)