DETECTION OF ELECTRON LOSSES DURING INJECTION INTO THE ESRF STORAGE RING

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Abstract

The storage ring of the European Synchrotron Radiation Facility is equipped with a network of beam loss detectors to detect the slow losses during the decay of the stored beam. These detectors use highly sensitive photo multipliers and have been adapted in order to resolve in time, turn by turn, the rate of electron loss following the injection process. The time resolved study of the losses following injection allows the study of the mechanism of different loss processes. An understanding of the significance of the different loss processes is important in order to improve the overall efficiency and to control the radiation dose produced.

The electrons lost during the injection process are detected via the shower of secondary particles created due to their passage through the vacuum chamber, the magnet blocks and the detector shielding. With this diagnostic we distinguish for the first time, losses from the end of the transfer line, losses due to transverse phase space acceptance and then due to the longitudinal capture process. Intense losses are seen during the first tens of turns due to the large horizontal betatron oscillation of the beam followed by distributed losses over several hundred turns due to the longitudinal dynamics of the injected beam. By looking just at the losses when exiting the TL2 transfer line, we see that they account for a 1% loss of the beam and the vertical size of the beam was determined to be 1mm FWHM. The losses during the longitudinal capturing of the injected beam account for around half of the injection losses.

1 FEATURES

- Detects turn by turn the losses during the injection process
- Distinguishes losses due to the horizontal capture process and longitudinal capture
- Allows optimisation of beam steering, injected phase and injected energy
- Distinguishes electrons lost in the horizontal and vertical planes
- Gives a tune measurement of the lost electrons
- Very sensitive - allowing measurements with only a few hundred femto-coulombs of injected beam

2 DETECTOR DESIGN

A Perspex rod 25mm in diameter and 600mm long is used to convert the high-energy radiation shower into visible scintillations. The Perspex rod then guides this light to the sensitive face of a photo multiplier tube. The anode current gives an analogue signal of the beam loss magnitude (in contrast to the pulse counting method used by some beam loss monitors [1]).

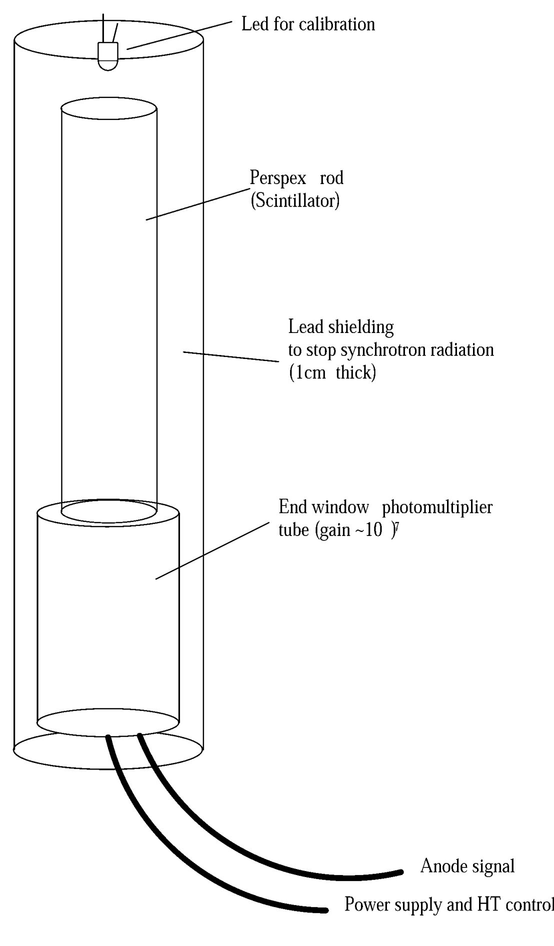

Fig. 1 Beam loss detector design

The anode current is recovered, integrated and amplified to give a sensitive readout of the slowly varying losses during the beam decay, while the direct signal can be sent

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via a low loss 50ohm cable to the control room for analysis on an oscilloscope so as to resolve in time the loss amplitudes. These turn by turn loss amplitudes would not be measurable using a pulse counting system. The use of very sensitive photo multipliers also means that measurements can be taken with good signal to noise ratio even with very weak injected beams (~300 fC).

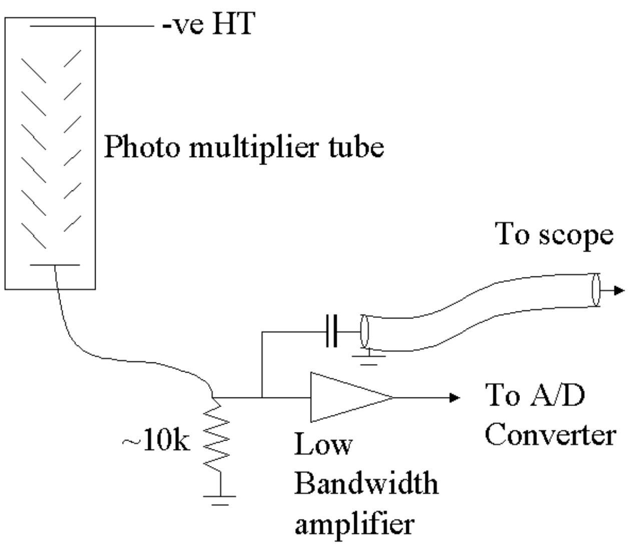

Fig. 2 Signal detection circuit

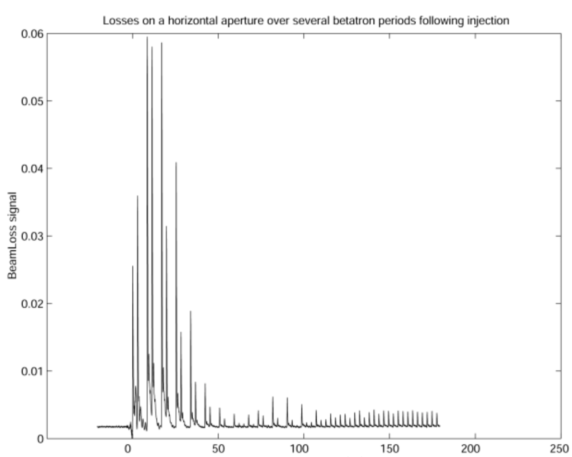

Fig. 3 Losses in the horizontal plane due to transverse motion

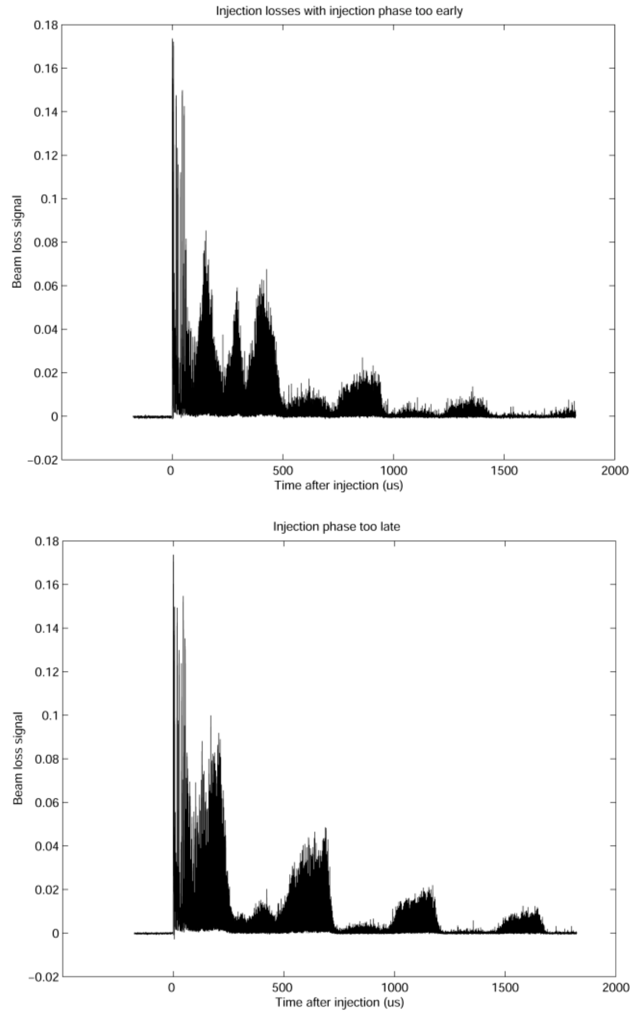

Fig 4 Asymmetry seen in loss bursts when injecting early (upper) and late (lower trace)

3 MEASUREMENTS

3.1 Monitoring injection capture processes

Scrapers can be used to localise the losses in the vertical or horizontal planes (that would otherwise be lost on small gap chambers or the injection septum). The losses seen on the horizontal scraper are due to high amplitude horizontal betatron oscillations during the first few turns. Losses on the vertical scraper appear to be mainly due to losses during the longitudinal capture process, perhaps due to off energy electrons with shifted tunes passing through a vertical resonance.

3.2 Monitoring injection phase

Incorrect timing of the injected pulse can be seen in the pattern of the successive bursts of losses separated by half a synchrotron period. Particles offset in phase (time) at injection become offset in energy a quarter synchrotron period later. If there is an offset in injected phase, then bursts will be alternately strong and weak as shown in fig 4. Energy offsets can also be indicated by changes in the separation of successive bursts during the synchrotron period. Pairs of bursts will be produced separated by a period of just over half a synchrotron period. This could be understood as being due to an offset in the injected phase ellipse in energy and a loss process only for energy offsets on one side (This could be due to particles lost on a vertical resonance due to energy offset to higher energies causing a tune shift towards a resonance.)

3.3 Tune Measurements

Within the bursts of losses due to longitudinal motion of the injected beam there are faster variations due to transverse motion of the beam. By taking an FFT of the turn by turn variation of these losses, peaks in the frequency spectrum can be seen which could be consistent with an effective tune of the lost particles. We see that the frequency is very close to 1/3rd and the losses occur mainly on a vertical aperture. These losses could therefore be explained by large vertical transverse betatron oscillations excited on a third order resonance.

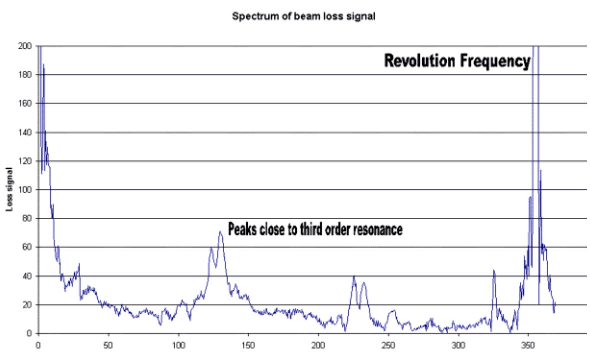

Fig 5 Vertical spectrum measurement of lost particles

3.4 Losses from the transfer line.

By measuring only the losses synchronised with the injection (prior to making a turn of the storage ring), the losses due to the passage in the transfer line can be separated from subsequent losses. A plot of the variation in losses was made as the beam is scanned vertically against the chamber wall. This measurement gives the profile of the beam at that location which was determined to be 1mm FWHM.

4 CONCLUSIONS

Measuring time dependent losses following an injection pulse gives useful information about the mechanisms of the beam loss. This is important in optimising the efficiency of the injection process.

5 REFERENCES

[1] W.Bialowons, F.Ridoutt, K.Wittenburg, "Electron Beam Loss Monitors for HERA"DESY

[2] B.Joly, U.Weinrich, G.A.Naylor, "Beam loss monitors at the ESRF" DIPAC99, Daresbury Laboratory UK.