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The KEK PS Fast Beam Loss Monitor System

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Abstract

The higher beam intensities now being accelerated in the KEK proton synchrotron (PS) complex have increased the importance of observing the beam loss during acceleration. The beam loss should be continuously monitored to minimize radiation damage to the accelerator components. A fast loss monitor also is a good tool for observing where and when the beam is lost, by which we are able to get information on the beam dynamics. The development of a fast beam loss monitor system at KEK is described in this paper.

I. INTRODUCTION

The beam intensity in the KEK PS has gradually increased and the PS continuously is operated with an intensity of about $3x10^{12}$ppp. There are, however, some problems in maintaining this intensity in the accelerator and in the beam transport lines. The beam loss might come not only from a miss steering of the beam orbit but also from the short time scale dynamical behavior of the beam bunches. One property of a loss monitor which should be noted is the extremely high signal to noise ratio. In the usual beam monitor systems, the signal is proportional to all of the particles in the bunch. Any loss causing perturbation signal due to some short time behavior of the particles has to be extracted from the signal fluctuation. In a loss monitor, only the perturbed signal is seen.

We have adopted at KEK a secondary electron multiplier vacuum tube as a beam loss detector because of its good time response, compactness and ease of handling. The time response was tested in the TRISTAN electron-positron storage ring which has a bunch length of 300ps. The tube response was quite good, about 40 ns (Fig 1). This time response is good enough to enable turn by turn beam loss monitoring of an individual bunch in the proton synchrotron complex.

As an initial test, thirteen detectors were distributed around the accelerator complex. The PS complex consists of a 750 KeV Cockcroft-Walton, a 40 MeV linac, a 500 MeV Booster and the 12 GeV main ring. There is a transport line between the linac and booster and another line between the booster and main ring. One detector was placed near the 40 MeV transport line, eight detectors were placed around the booster, one detector near the 500 MeV transport line and two detectors in the main ring. The detected signals were digitized by fast CAMAC ADCs and acquired by a VME computer for analysis and display. The control and display software was written using X-windows under UNIX. This enabled simultaneous display of multiple detector signals and the ability to display the data on any X-terminal on the network.

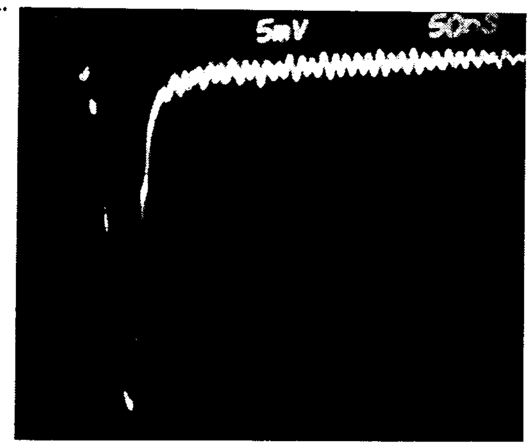

Figure 1. Time response of the detector.

II. HARDWARE CONFIGURATION

A. Detector

The detector is a secondary electron multiplier tube R595 made by Hamamatsu. The gain of the detector is around 10^5 - 10^7. Since the PS loss rate is very high, the tube gain is more than enough. The tube is installed into an aluminum case for light and noise shielding. Attached to the back of

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the case is a 20dB gain amplifier to avoid signal to noise ratio degradation from the detector to the electronics building located outside the tunnel (Fig. 2).

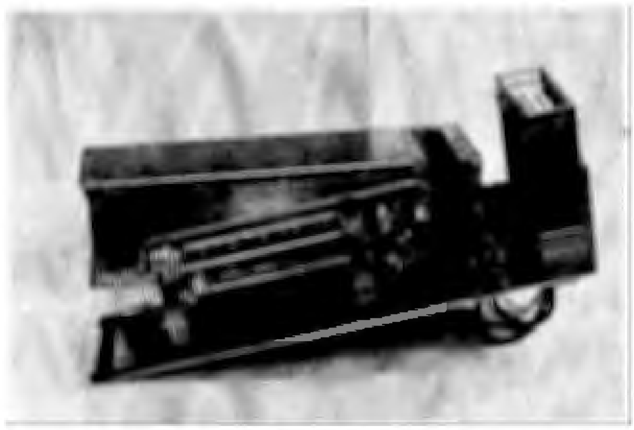

Figure 2 An overview of the detector.

The detector case is attached to the tunnel wall pointing to the beam pipe of interest. The front wall of the case is carefully adjusted so as to degrade the lower energy component of the background residual radiation. The gain calibration of each tube is still in progress. There is not enough data available yet to check performance degradation due to radiation damage of the tube.

B. CAMAC system

The detector signals are digitized by CAMAC ADCs located in a building outside of the accelerator tunnel. All timing signals and gating are controlled by CAMAC modules. For the beam transport lines a 100 MHz ADC is used. The booster accelerates one bunch in 25 msec. To acquire the turn by turn beam loss with sufficient resolution, a 100 MHz ADC with 2.5 MBytes of memory is used (Fig. 3).

Since the main ring accelerates nine bunches, a bunch selection system is used to select the bunch of interest. Also since the acceleration ramp is rather long, data along the whole ramp cannot be acquired. Instead only the loss

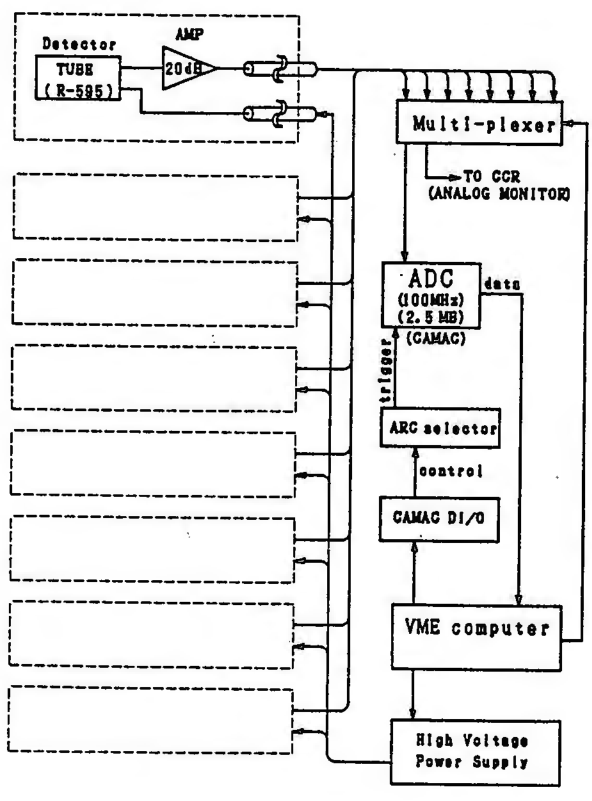

Figure 3 Booster loss system configuration.

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signal peak is digitized using a specially developed ADC and stored in memory. Figure 4 shows the nine bunch beam loss in the main ring. All ADCs have hardware memory so that the computer is not used during the actual acquiring of data (Fig. 5).

The ADC system described above enables us to observe time dependent beam loss for an individual bunch throughout the entire acceleration cycle. Beam loss due to betatron oscillation for instance, can be observed which will help in tuning the ring correctly.

The CAMAC crates are connected to a VME computer via the Branch Highway interface. The Branch Highway to VME interface card has hardware interrupt inputs which are used to signal the end of the acceleration cycle.

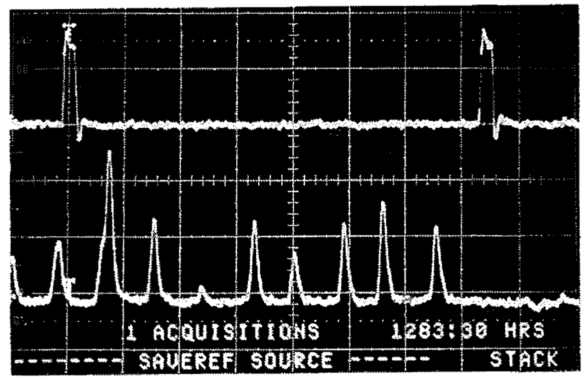

Figure 4 Nine bunch loss in the 12GeV main ring.

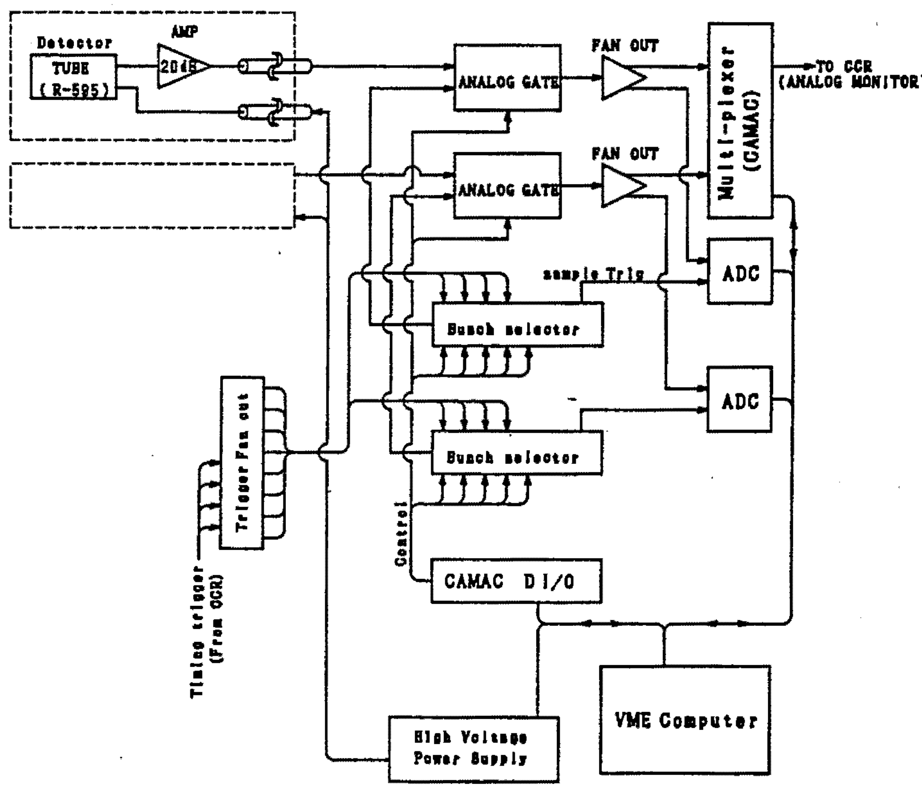

Figure 5 Main ring loss system configuration.

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III. Software

The data acquisition system software consists of a number of separate application programs written in C using X-windows and the OSF/Motif toolkit. The operating system is UNIX.

The CAMAC hardware information is stored in a database. Using a menu-driven program the user is able to easily update the location and module types, the command list, etc. of the CAMAC hardware in the system. The data acquisition program reads this database at start up as its only source of hardware information thus requiring no software changes when there is a hardware change.

The actual data acquisition is made up of several processes running simultaneously. There is a control process, a CAMAC process, and a separate graph process for each detector signal being acquired. Except for the signal data to be displayed all interprocess communication is handled by custom X events. The signal data to be graphed is passed via the UNIX message facility.

The control process oversees all aspects of the data acquisition system. This process maintains an additional database which lists which CAMAC commands start or stop the data acquisition for each detector, commands to read in the data, control of the detector voltage, and timing control. The user can create several software "detectors" for each hardware detector corresponding to different types of data desired.

The CAMAC process is the only means of communication with the hardware using a UNIX device driver developed especially for this purpose. This device driver has a command list mode in which the CAMAC instructions for all detectors are concatenated into a single list by the control process, passed to the CAMAC process and loaded into the device driver. At a hardware interrupt indicating the acceleration cycle has completed, this instruction list is executed and the data is passed back to the CAMAC process. The CAMAC process scales the data appropriately and sends the scaled data to the proper graph process by a UNIX message.

A separate graph process is running for each detector signal being acquired. The graph process sends to the CAMAC process graph scale and window size information so that the data can be scaled properly. The data is scaled in the CAMAC process to minimize the amount of data which has to be passed between processes; all redundant data are thrown away.

Although an object oriented language was not used for software development, the data structures and functions were constructed in an object oriented fashion. As a result there is good isolation between different types of data structures and functions which makes extension and debugging of the system easier. Also there are no hard-coded assumptions about the type and number of detectors so that this system could be used for other purposes.

IV. System performance

Figure 6 shows a typical display. Multiple detector windows as well as the control window are shown. The bunch tagging system is very effective in acquiring data from the same bunch throughout the accelerator complex. A comparison between the data displayed in several windows clearly shows where and when the contents of the bunch is lost. The beam loss shown in a single window varies from cycle to cycle showing the lack of beam stability. In the beam loss data for the booster loss has been observed outside of the rf bucket during acceleration. This type of loss cannot be observed very well with the usual type of beam monitors because this signal is buried in the signal from the particles in the rf bucket.

Although the system is working a number of improvements need to be made. Due to the large amount of data acquired (3 Mbytes), it takes two acceleration cycles (one cycle = 5 sec) for the graph windows to update. Considerable speed increases can be obtained by optimizing the data scaling routines. Also there are still problems in communication between the CAMAC device driver and the CAMAC process.

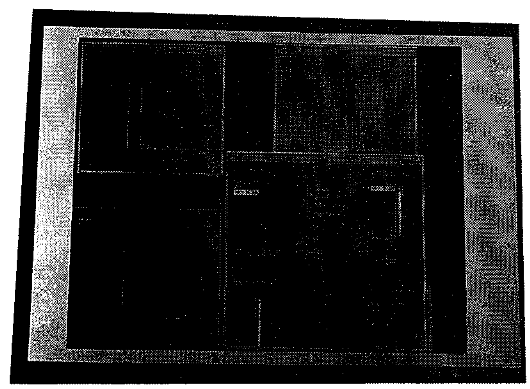

Figure 6 An example of the display picture.

V. Conclusion

A development of a fast beam loss system is now successfully going on at KEK. In spite of waiting for some improvements, the turn by turn beam loss observation in the accelerator has been certainly realized. Some examination on radiation damage of the detector and on the gain variation are waiting for soon.