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KEKB Beam Loss Monitors

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Abstract

To monitor beam losses during injection and storage of the KEKB accelerator, we have installed 23 air ionization chambers in the Beam Transport (BT) Line and 109 chambers around the tunnel containing the electron and positron storage rings. These monitors also form part of the beam abort interlock system for machine protection. An additional 16 chambers dedicated to background studies were installed in the vicinity of the BELLE physics detector. We report on the design of the hardware and data-acquisition system for the beam loss monitors.

1 Detector hardware

The basis of the detector system is the free-air ionization chamber developed originally for the use at the Proton Synchrotron[1]. The ion chamber is the Fujikura FC-20D, a coaxial design consisting of an inner conductor of outer diameter 9 mm, an outer, corrugated conductor of outer diameter 25 mm, and a grounded shield layer of diameter 29.2 mm. (See Figure 1.) The inner and outer conductors are separated by an air gap. Electrons freed by ionizing radiation are pulled toward the outer conductor, which is held at a positive potential of 200 V relative to the shield layer; the inner conductor collects positive ions, with a typical drift time of 1 ms. The resulting current is fed into an integrator/amplifier module, described in the next section. A spiral polyethylene spacer wraps around the inner conducter, permitting air to flow through the chamber to minimize the effects of oxidation on the chemical composition of the gas.

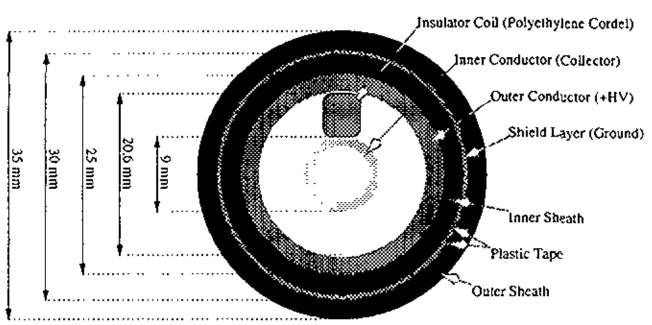

Fig. 1 Cross-section of ion chamber.

The conductors are made of copper. The effective threshold for ionizing radiation to penetrate into the chamber is about 1 MeV for electrons, and about 50 keV for γ rays. Since at 200V there is no charge multiplication effect, the response of the chamber is determined from the volume of air enclosed between outer conductor and collector. For the FC-20D, this corresponds to 8.54×10^{-8} C/R, or 9.74×10^{-8} C/rad, per meter length of chamber. The 109 chambers around the KEKB ring tunnel consist of 5-meter long segments, with 16 1-meter segments for background studies placed around the beam pipe near Belle, and 23 chambers of lengths ranging from 5 meters to 8 meters plus some doubled 5-meter-long segments in the BT line.

2 Ring chambers

The purpose of the ring chambers is to monitor beam losses during injection, and to provide machine protection in the event of sudden beam instability or loss.

2.1 Electronics

Figure 2 shows a block diagram of the loss monitor front-end electronics for a chamber in the KEKB ring. The 5-meter long chambers in the ring are mounted on the outer wall of the tunnel near the beam pipe, and are distributed roughly evenly around the ring with an average spacing of 28 meters per chamber. Each chamber is connected to an electronics rack in one of four sub-control rooms located around the ring. A low-pass filter is attached to the supply voltage input near the chamber to block pick-up noise and provide a current-limiting resistance in the event of break-down.

The front-end module comprises three stages: integrator, amplifier, comparator/latch. Each module handles eight channels, with four modules per quadrant. In the first stage a 47 nF integrating capacitor gives 10.2 mV/mrad for the 5 meter chambers in the ring. The RC time constant is selectable at 4 settings of 10, 100, 300, or 1000 ms. The 10 ms setting is used for injection monitoring, being half the width of the injection cycle at the maximum injection rate of 50 Hz. The latter three settings are used in normal operation mode, for stored current loss monitoring.

At the second stage, amplifier gains of 1, 10 and 100 are selected via front-panel switches. One gain is selectable per 8-channel module.

The comparator is used to issue a hardware beam abort signal via the latch if the loss level exceeds a threshold which is settable for each channel by front-panel potentiometer. The latches for all 8 channels in the module are OR'ed together to form the abort interlock signal. In order to know which channel in the module actually tripped the abort, the state of each latch is brought to a front-panel connector on the module, and is read by a VME-mounted digital I/O unit (Profort PVME-501), which is then read out by computer. The digital I/O unit is also used to send a reset signal to the front-end module.

In parallel with the comparator stage, the loss signal

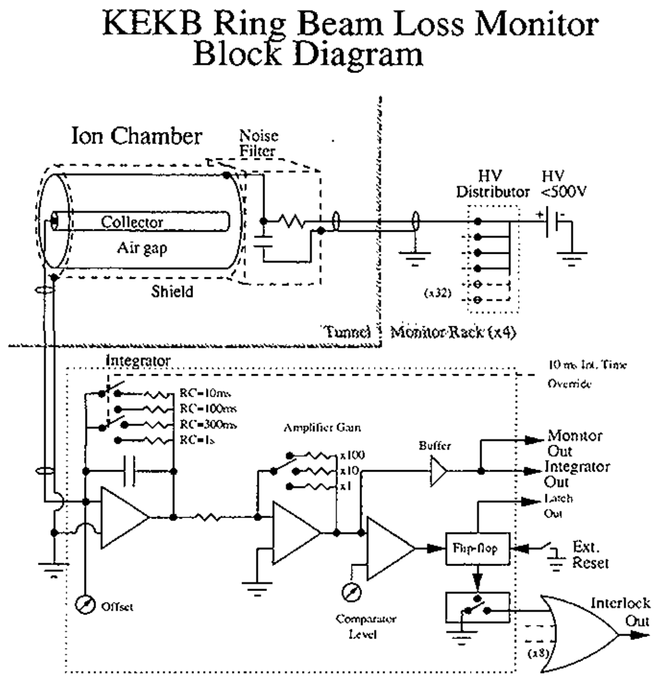

Fig. 2 Block diagram of the systems for the KEKB ring tunnel.

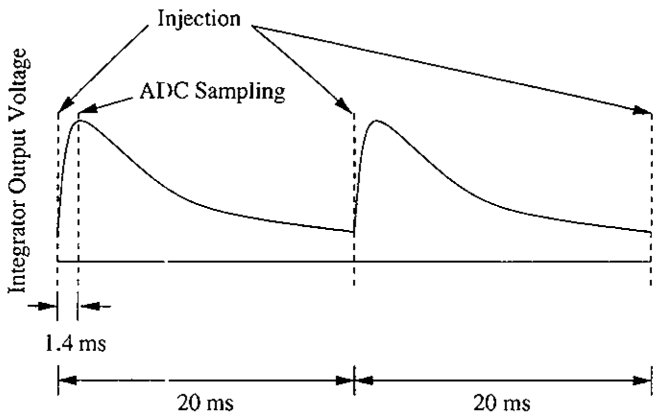

Fig. 3 Loss monitor pulse shape during use in injection mode. The rise time of the pulse is largely determined by the drift time of the chamber ($\sim$ 1 ms), the fall time by the integrator time constant of 10 ms.

is buffered and send to a 16-bit ADC (Profort PVME-332). In normal operation mode, the ADC is sampled at intervals using an internal timer inside the VME controller. The integrator time constant used in this mode is typically set to 1000 ms with a 1000 ms ADC sampling period. When injection monitoring mode is selected, a signal line from the digital I/O unit is pulled low to force the integrating time constant to 10 ms. In this mode the ADC sampling trigger is synchronized to the injection trigger, delayed 1.4 ms to match the peak of the loss signal after injection due to drift time in the chamber.

The shape of the loss monitor signal during injection mode is shown in Figure 3.

2.2 Data acquisition and control systems

The data acquisition and control system for the loss monitors is based on the EPICS IOC system in use at KEKB. The ADCs and digital I/O units are mounted in VME crates, one in each sub-control room, from which readings are relayed once per second to a loss monitor display panel running in the control room. A typical example of the display is shown in Figure 4. Each channel is displayed as a bar-graph with logarithmic scale, with each bar located near its physical location on the ring diagram. The logarithmic scale covers three decades, indicated by the color of the bar: green, yellow or red. The background color of the bar changes to indicated that a channel has exceeded its threshold and tripped the beam abort interlock. The numerical readings of the monitors are also logged separately and can be displayed and correlated with the readings from other monitors.

2.3 Interaction Region Monitors.

Early on during stored beam operation, high radiation backgrounds were found near the interaction region (IR) during HER stored current operation. In order to better understand the source of the high backgrounds, an additional set of 16 ion chambers were installed very close to the beam pipe. These chambers are 1-meter long, and are mounted on movable frames. They are represented in Figure 4 in the central part of the display. These chambers are not connected to the beam abort interlock system.

One hypothesis for a source of high backgrounds in the Belle detector was the presence of a hard target (aperture restriction) in the upstream straight section from the detector. The presence of such a hard target has been ruled out by the absence of visible loss in the upstream IR loss monitors. The high loss rates in the downstream IR loss monitors (which are largely insensitive to synchrotron radiation) have magnitude proportional to the HER beam current, and modulations correlated with the direction of the beam through the IR, which appear to be the result of spent/scattered particles which have been swept out of the beam downstream of the interaction point (IP) by strong bending fields there. The design of the beamline uses no strong bending in the straight section leading up to the IP, so spent particle losses are expected to be higher downstream. A similar, less intense, loss pattern from the LER beam is seen on the LER's downstream side of the IP as well.

3 Beam Transport Line

An earlier version of the ring loss-monitor system was installed in the Beam Transport (BT) line which connects the end of the linac with the KEKB rings. The electronics used there are more closely based on the Proton Synchrotron design, with an adjustable integration time determined by opening and closing the switch in

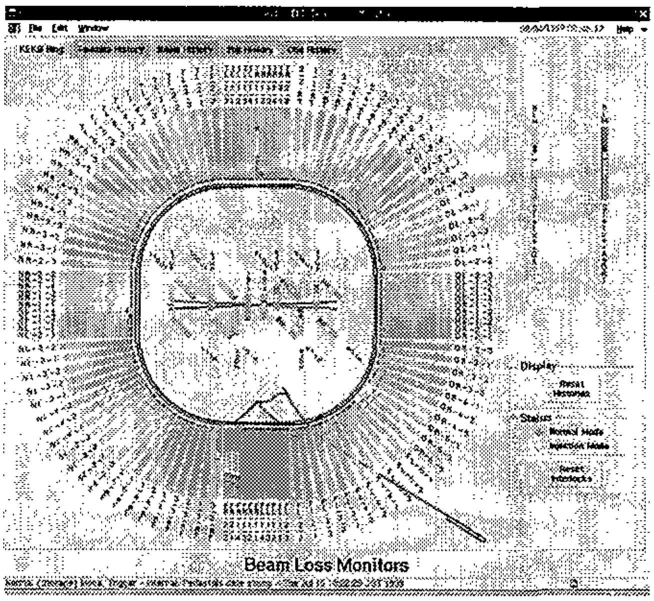

Fig. 4 Example of loss monitor display during HER injection. Regions of high beam loss are seen near the injection point at the bottom, near one of the scraper masks at lower left, and downstream of the Belle detector at the top. The extra monitors at the center give a more detailed display of the losses around the Belle interaction region.

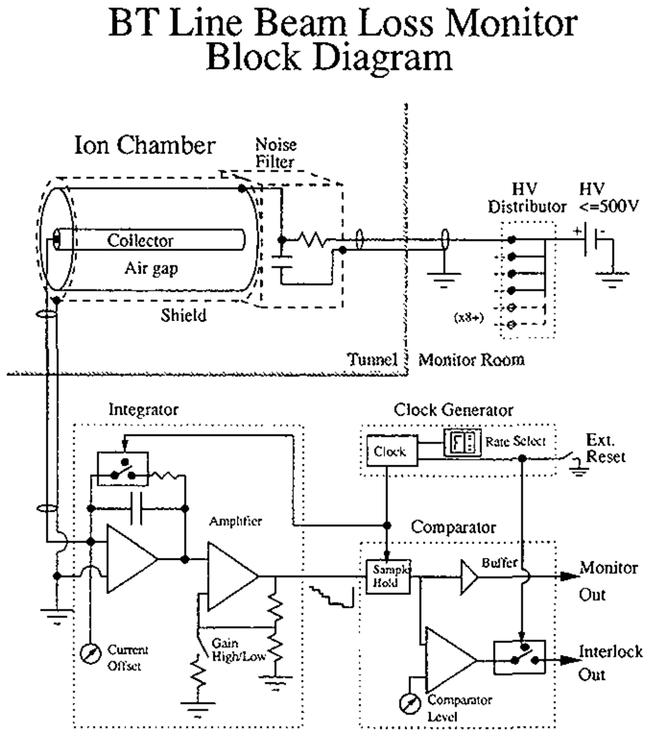

Fig. 5 Block diagram of the systems for the Beam Transport Line.

the first stage of the front-end electronics. (See Figure 5.) The integration period is adjustable by front-panel control of the clock generator in the separate control module, ranging from 0.2 to 3.2 seconds in units of 0.2 seconds. The value at the end of the integration period is held in the sample-hold buffer of the comparator module, and is read out via CAMAC-based ADC. The comparator can be used to open an interlock line for the radiation safety system. 8 of the 23 channels in the BT line are connected to the radiation safety interlock system.

4 Performance

The ring loss monitors have proven effective at aborting the beam when instabilities set in. When the monitors are run at highest gain, which is most useful for injection tuning, the gains in some channels near the mask have had to be lowered, to avoid tripping the beam unnecessarily. The gains of individual channels closest to the beam dumps have also had to be lowered, to avoid aborting one ring when the other has been intentionally dumped. Since gains on the modules as designed are controlled at the module (8-channel) level, the individual channel gains have been changed by changing resistors on the amplifier stage of the affected channels, which is inconvenient. A modification to allow remote gain changes to individual channels is planned.

The BT line modules have worked well from the beginning. The original mechanical switches have been replaced by solid state ones in order to avoid mechanical failure during continuous operation, as the mechanical ones neared the end of their expected lifetimes.

5 Conclusion

Beam loss monitors have been installed in the KEKB ring tunnels, beam transport line tunnels, and near the interaction region to provide injection tuning, machine protection, and radiation safety protection against bad injection conditions. They have worked very well, providing an early diagnostic during injection, and have also proven useful in background studies near the interaction region. Further upgrades are planned, consisting mostly of increased capability for remote control of gains.

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References

[1] H. Nakagawa, S. Shibata, S. Hiramatsu, K. Uchino and T. Takashima, NIM 174 (1980) 401-409.