SLAC-PUB-4909
March 1989
(A)

BEAM-LOSS MONITORS IN THE SLC FINAL FOCUS*

R. G. JACOBSEN AND T. MATTISON
Stanford Linear Accelerator Center, Stanford University, Stanford, California 94309

ABSTRACT

Beam-loss monitors in the SLC Final Focus System are used for protection of accelerator and detector components, optimizing adjustment of beam halo collimators, and as diagnostics of beam size and halo. Construction of a variety of monitors based on discrete ion chambers, proportional tubes, continuous ion chambers, and signals from the Mark II detector is reported. The interfaces to the SLC control system, the Mark II detector data acquisition system, and the SLC machine protection system are discussed. Experience with the system during SLC commissioning and operation is presented.

1. OVERVIEW

The e^+ and e^- beams of the Stanford Linear Collider (SLC) must be precisely controlled so as to produce luminosity without creating unacceptable backgrounds in the Mark II detector. To assist in this process, the Final Focus System (FFS) and Interaction Region (IR) of the SLC have been instrumented with several types of radiation monitors. These provide information to the machine operators in a variety of forms optimized for specific uses. Three basic problems are addressed:

1. Protection of the accelerator and detector from beam-related damage.[1]
2. Identification of the sources of unacceptable detector backgrounds.[2]
3. Optimization of machine tuning and collimation to reduce background to acceptable levels.[2,3]

The FFS was originally equipped with loss monitors only for protection against accelerator component damage. The monitors were later upgraded and augmented for use in background monitoring and minimization. Other monitors were created for protecting the Mark II detector against radiation damage. Ultimately, real time data from the Mark II has been utilized for background minimization.

When beams were first being brought into the SLC FFS in early 1987, radiation levels were high. On several occasions dose rates of tens of thousands of rads per hour were recorded in the tunnel, with rates above a thousand rads per hour common. (All dose rates in this paper are quoted for 10 pps beams). This was sufficient to endanger accelerator control electronics, which have since been relocated to the surface. Improvements in beam quality, steering and alignment quickly brought the radiation level down. During Fall of 1988, dose rates in the FFS were routinely below 100 rads/hr, with rates near many collimators often below the resolution of the monitors. These rates, combined with recently increased shielding, are believed to be compatible with Mark II requirements.

Since the Mark II detector was installed in early 1988, the accumulated dose near it is within expectations. In the IR, about 30-50 rads have accumulated. This rises to 100 rads near the beamline inside the detector endcaps, with a cumulative dose of about 500 rads on the beampipe at the smallest angle detector element.

2. DEDICATED MONITORS

The SLAC machine protection system has been described elsewhere.[4,5,6] In addition to toroid comparators, the FFS tunnel is instrumented with 60 Protection Ion Chambers (PICs)[6] to detect beam loss at the 1% level. These were placed near each

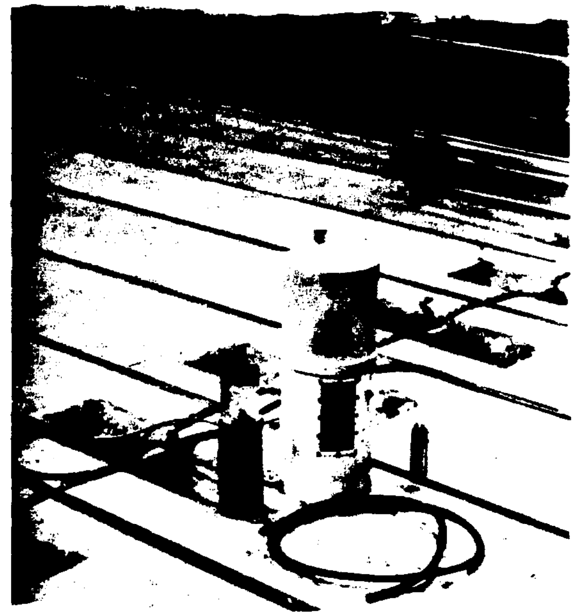


Fig. 1. The four types of dedicated monitors. The large white cylinder in the center is a BSOIC, with a PIC to the left and a PT to the right. In front is a short length of PLIC cable.

of the fixed and movable collimators provided to absorb misdirected beams. These collect ionization charge from a 1.3 liter active volume using a 300 V applied potential. The signal is then routed to an electronics chassis in a surface support building, where it is filtered and compared to machine protection limits. As originally installed, the PICs provided useful data down to about 20 rad/hr. Changing their active gas from helium to argon and improving the signal processing by providing software pedestal subtraction improved this to about 1 rad/hr. Some of the channels also received improved electronics, which allows them to be used down to about 10 mrad/hr.

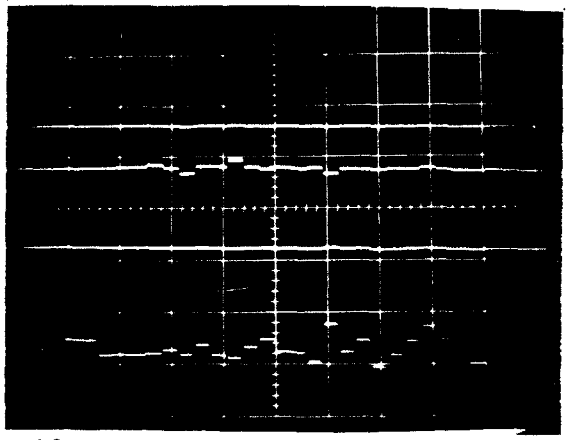
The chambers were read through the SLC computer control system, which provided a table of radiation levels. This allowed operators to check the levels occasionally and to plot[7] the radiation versus other quantities, such as adjustable collimator positions. It was not suitable for efficient tuning, however, as even a dedicated button pusher could only get a display update about every five seconds. A system using a SHAM module[8] and oscilloscope readout (with video transmission to the SLC console) provides a visual analog readout on every beam pulse. The sensitivity of this display method is reduced to about 5 rad/hr by noise, which is adequate for fast tuning. The PICs were also read by the Mark II data acquisition system on a pulse-by-pulse basis.

To ensure complete coverage, a Panofsky Long Ion Chamber[9] (PLIC) was installed in both the North and South FFS. A PLIC is a gas-filled length of coaxial cable used as an ion chamber, where the signal's time of arrival is used to indicate the position of the source. Both ends of each cable can be read out by remote oscilloscope. The signal at the upstream

* Work supported by the Department of Energy, contract DE-AC03-76SF00515.

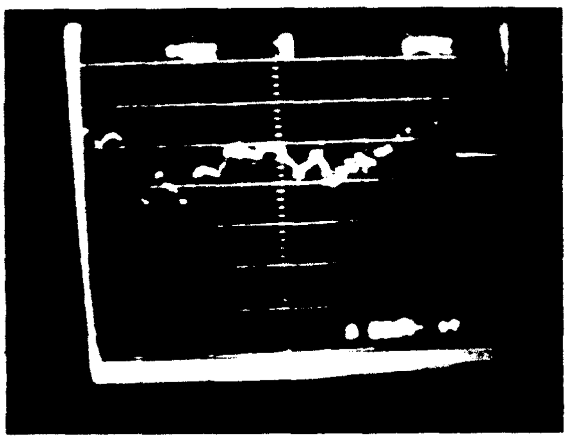
Presented at the IEEE Particle Accelerator Conference, Chicago, IL, March 20-23, 1989

end has about a 5-foot resolution in position with a sensitivity of about 20 rad/hr. The sensitivity in primarily limited by pickup of noise from the kicker magnet, which is used to direct the outgoing particles to their dump. The downstream end of the cable has a sensitivity an order of magnitude better, but can only resolve position to 50 feet.



3-89 6299A5

Fig. 2. Fast PIC display. Each trace shows radiation vertically and PIC number horizontally. The top two traces display data from the South FFS, while the lower two show the North FFS. Each trace of a pair shows the same data, but the scale of the lower trace is a factor of 5 less sensitive.



3-89 6299A4

Fig. 3. Upstream PLIC signal from the North FFS. The scale is approximately 100 feet per horizontal division and 50 rad/hr per vertical division.

The Beam Shut-Off Ion Chamber (BSOIC) is the most sensitive and accurate monitor. It is self-contained except for AC power and provides a logarithmic output for doses between tens of μrad/hr and about 5 rad/hr. An internal source provides a calibration reference and relay contacts are available for protection use. Unfortunately, BSOICs are large, expensive and scarce. This limited their use to a pair in the IR, where they can provide Mark II radiation protection and cross calibrate other devices.

The most compact monitor is the Proportional Tube (PT). These proportional counters have an active volume 80 mm long and 20 mm in radius. They are run at 2000–2400 V with HRS gas. At the highest voltage they are sensitive to a single minimum ionizing particle. Their radiation response at lower voltages has been calibrated against the BSOICs using SLC backgrounds, and separately with a pulsed x-ray source.

Four of these PTs are installed inside the endcaps of the Mark II detector, one near each of the four small-angle detectors. These tubes are connected to "defender" electronics which inhibit the beams if radiation levels exceed a preset threshold. The threshold was originally set to 1 rad/hr for all four tubes, but was later raised to 4 rad/hr for the two nearest the beam line to reduce the amount of time lost to beam trips during tuning.

Other tubes are distributed in varying positions around the outside of the Mark II, near the synchrotron radiation masks in the IR and near the last several collimators in the FFS tunnel. They were often moved as the sources of background were better determined, and were connected to integrators and amplifiers in the Mark II electronics house, from which signals are sent to the Mark II data acquisition system and the SLC control system in a manner completely analagous to the PICs.

Many locations in the FFS and IR, especially on the Mark II detector itself, had thermo-luminescent dosimeters attached. Although these were only removed and read occasionally, they served as valuable confirmation of other readings.

3. MARK II INTERFACES

Once commissioning had advanced far enough that the Mark II detector could be rolled onto the beamline, it immediately indicated that backgrounds were present in undesirable amounts. The signals in the detector subsystems were analyzed to distinguish types and sources of backgrounds. The quantities that proved most immediately useful were the fractional occupancy in the main drift chamber, the number of muons seen in the detector endcaps, and the amount of electromagnetic debris in each endcap.

Once software was available for calculating the background amounts, code was added to the Mark II online system to form useful displays. These were available in the Mark II control room directly and could be viewed remotely from the SLC consoles. Software was also added to allow control of the detector displays remotely so the SLC operators did not need Mark II personnel present. The most useful display is shown in Fig. 4,where changing bars indicate the level of backgrounds and give an immediate visual cue for tuning. Figure 5 shows a display versus time, which is useful for detecting slower trends.

In theory, these displays should be ideal — they show backgrounds important to the detector, as the detector sees them, and with good precision. Unfortunately, the Mark II data acquisition was not optimized for this type of data. The normal physics trigger selects the noisiest beam pulses. When the beam was noisy and backgrounds were high, each trigger required a

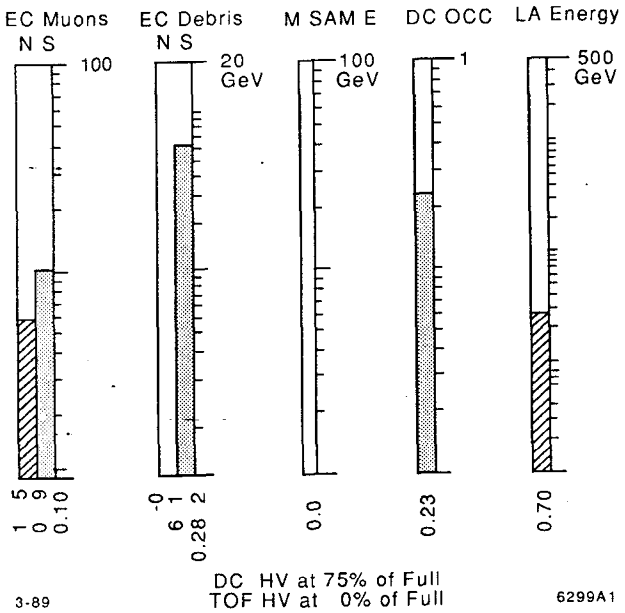


Fig. 4. Bargraph display available in the Mark II and SLC control rooms. Each bar represents a particular background measurement. The status of certain detector systems are displayed at the bottom. Not shown are various error and status messages that are available on the same page.

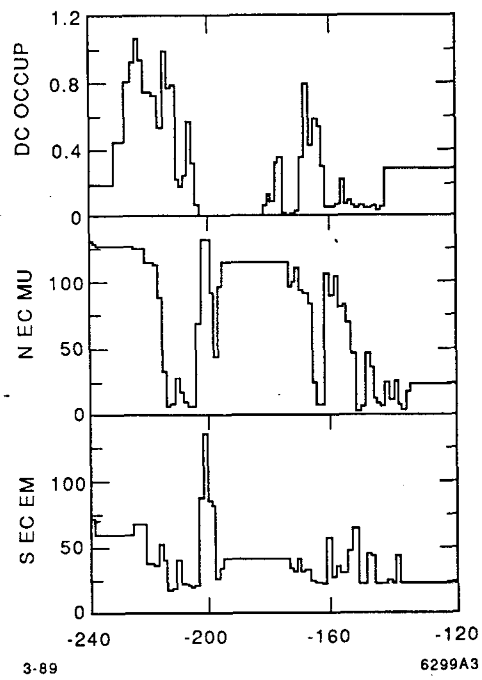


Fig. 5. Background history display. Each plot shows a different measurement versus time. The time scale is selectable, as is the amount of averaging done. About 40 different quantities are available for plotting.

significant amount of time to read out and process. This resulted in the displays lagging behind the tuning of the machine by up to 30 seconds, which greatly reduced the efficiency of tuning. To improve this, the trigger was enhanced with several new modes for background data-taking. A rate limit was added to prevent events from filling software queues and increasing latency, and an improved random trigger was added. Additionally, it proved possible to take the most important background measurements and implement them in hardware. This allowed the drift chamber occupancy, endcap muons and endcap debris signals to be routed to analog meters visible from SLC control via a video signal. It proved much faster to tune on the meters, as they provide immediate feedback to the operators.

ACKNOWLEDGMENTS

Many people have given effort to the system described here. Special thanks should be given to Dave Coupal, Chris Hearty, Walt Innes, Rudy Larsen, John Matthews, Marc Ross, Rudi Thun, Puru Voruganti, Andrew Weir, and Dave Wilkinson.

Thanks are also extended to SLAC Editorial Services and Technical Illustrations who kindly helped prepare this document.

REFERENCES

1. *Momentum Slits, Collimators and Masks in the SLC,* D. R. Walz, A. McFarlane, E. Lewandowski; this conference.
2. *Beam Collimation and Detector Backgrounds at e^+/e^- Linear Colliders,* D. L. Burke *et al.*, this conference.
3. *Operational Experience in Commissioning the Final Focus of the SLC,* W. Kozanecki *et al.*, for the Final Focus Group; this conference.
4. *The Stanford 2-Mile Accelerator,* ed. R. B. Neal, SLAC 1968.
5. *The 1-msec and 50-microsec Networks of the Machine Protection System: Functional Description, Layout and Interlocks,* K. E. Breymayer (SLAC), SLAC–TN–67–004, Jan. 1967.
6. *The Final Focus MPS,* R. Erickson, SLAC Memorandum, March 1987.
7. *Instrumentation, Computer Control and Electronic Systems for the SLAC Beam Switchyard,* ed. D. A. G. Neet, SLAC–68.
8. *CORRELATION PLOT: An Online Facility for Data Acquisition and Analysis,* M. Flores, J. Kupiec, N. Phinney; this conference.
9. *Drift Chamber and Pulse Height Readout Systems using Analog Multiplexing,* E. Cisneros, H. K. Kang, J. Hall, R. S. Larsen, IEEE Trans. Nuc. Sci. NS–24 (1977) 413.
10. *Long Ion Chamber Systems for the SLC,* J. Rolfe *et al.*, this conference.