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.
2. Identification of the sources of unacceptable detector backgrounds.
3. Optimization of machine tuning and collimation to reduce background to acceptable levels.

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 comparable to 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. In addition to toroid comparators, the FFS tunnel is instrumented with 60 Protection Ion Chambers (PICs) to detect beam loss at the 1% level. These were placed near each...

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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 30 feet.

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, BSOIC's are large, expensive and scarce. This limited their use to a pair in the IR, where they can protect 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 50 mm long and 20 mm in radius. They are run at 2000-3000 V with HBr 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 mask 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 analogous to the PTs.

Many locations in the FFS and IR, especially on the Mark II detector itself, had thermoluminescent 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
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.

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