The Design and Performance of a High Sensitivity Loss Monitor System for use in the Fermilab Antiproton Rings

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ABSTRACT

As part of a general laboratory cleanup of hazardous materials from the accelerator enclosures we have replaced the liquid scintillator based paint can type beam loss monitors with improved loss monitors based on plastic scintillator. This paper describes the design of these counters and their performance in the PBAR source.

I. HARDWARE DESIGN

New loss monitors for the antiproton source at Fermilab have been constructed and installed. These are based on NE102 plastic scintillator, and have been designed to be sensitive to single lost particles and short lived nuclear decay products. Figure 1 shows the design of the scintillator and light guides.

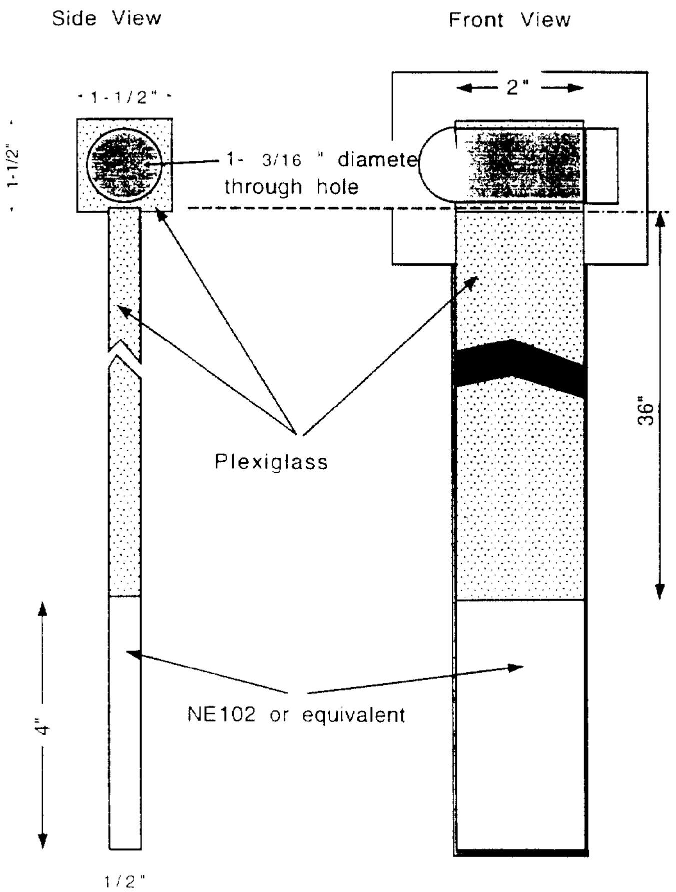

Figure 1. Loss monitor light guides and scintillator.

† Operated by the Universities Research Association, Inc under contract with the U.S. Department of Energy.

The 4" x 2" x 1/2" pieces of scintillator are glued to 36" long lucite light guides. The light guides are used to keep the phototubes away from the stray fields and particles near the beam pipe. A small lucite coupling attachment is glued to the top of the light guide to hold the side view RCA 4552 photomultiplier tubes. The RCA 4552 photomultiplier tubes, which are recycled from the paint can detectors, are an excellent tube for this application because the solid photocathode is a much more rugged than a head on phototube. Figure 2 shows a photograph of the light guide with a phototube inserted into the coupling attachment.

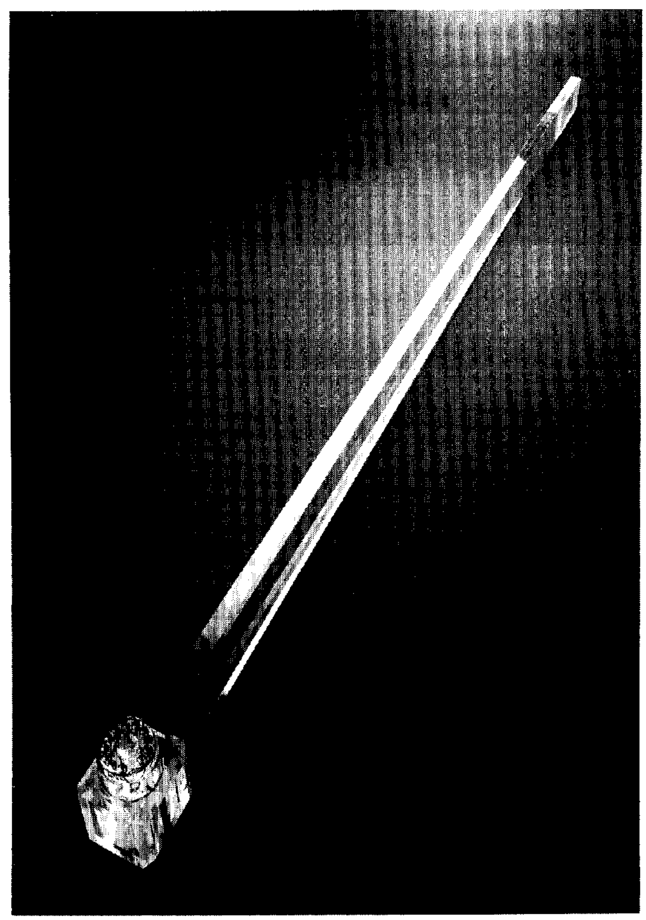

Figure 2. Photograph of loss monitor light guides. A phototube is shown inserted in the coupling attachment.

The base of the phototube was modified to have a smaller standing current than the original paint can loss monitors. We use a 100 μa resistive voltage divider, which should protect the phototube from being damaged by large losses.

The entire assembly shown in Figures 1 and 2 is housed in a gray PVC schedule 80 pipe, as is shown in Figures 3 and 4. This inexpensive housing has proven to be very durable.

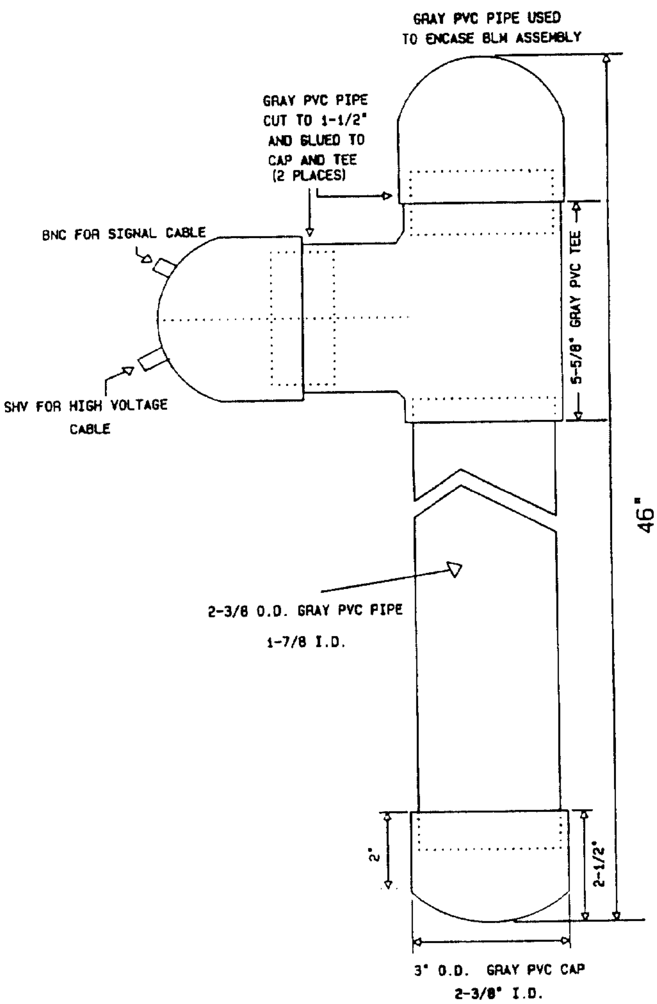

Figure 3. Drawing of PVC loss monitor housing.

II. READOUT

The loss monitors are read out using obsolete equipment from the HEP equipment pool. We use LeCroy 612A photomultiplier amplifiers with 20 db gain to amplify the signals from the phototubes. These signals are then fed into discriminators and readout with CAMAC scalars. Figure 5 shows a block diagram of the readout system. We have a large number of different types of discriminators, most have a 100 mv threshold. We most often left the CAMAC scalars counting continuously, and cleared them at a 1 HZ or 15HZ rate.

III. PREDICTED AND MEASURED SIGNAL SIZE

Paint can type loss monitors are much more sensitive to beam loss than ion chambers. We have measured signal sizes about 7000 times larger from "paint can" loss monitors with respect to ion chambers. This is due to the large gain of the photomultiplier tube. In the PBAR source we often have very small beam currents, so the sensitivity to very small losses is desired.

We estimate the signal size for minimum ionizing particles as follows. The dE/dx energy loss in the scintillator is about 1.9 MeV/cm. The light yield of plastic scintillator is about 1 photon per 100 eV. We estimate that about 10% of the light from the scintillator is captured by the light pipe, and about 20% of this captured light shines on the photocathode. The quantum efficiency of the photocathode is about 10%, and the phototube gain is about 5×10^5. Combining all these factors gives a signal size of about 10^8 electrons in about a 20 ns pulse, or about a 40 mv pulse into 50 ohms. This is too small for our discriminators to detect without amplification, but with amplification these signals are easily seen.

Figure 4. Photograph of PVC loss monitor housing.

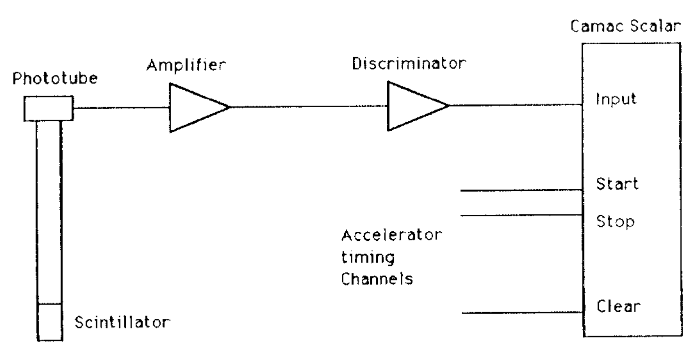

Figure 5. Loss monitor readout block diagram.

The actual counters give about 20 mv signals before amplification from 1.2 MeV gammas from a Co^{60} source. This demonstrated level of sensitivity allows the loss monitors to be sensitive to both minimum ionizing tracks and short lived radioactive states produced by interacting beam.

IV. PERFORMANCE IN THE BEAM

During a recent studies period we tested the usefulness of the loss monitors for determining the location of aperture restrictions. To demonstrate that the loss monitors could locate obstructions in the beam we measured the loss monitor counting rates in both the accumulator and debuncher storage rings as a scraper was slowly inserted into the beam. Figure 6 is a reproduction of our loss monitor display program taken during one of these tests. The figure shows a three piece linear representation of the debuncher storage ring, with the lattice beta functions and the beam pipe size shown for reference. The counting rates in the loss monitors are displayed on top. There are large losses just downstream of the scraper, while the other loss monitors in the ring show no signals. This test and others showed that the loss monitors could determine the location of aperture restrictions.

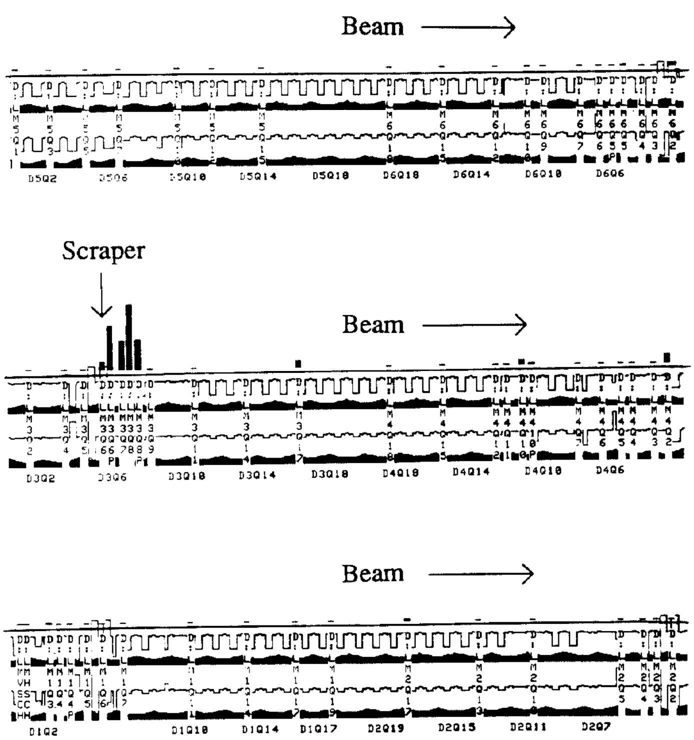

Figure 6. Debuncher loss monitor rates while scraper at the location shown is slowly inserted.

In real practice the locations of aperture restrictions in the accelerators were found by injecting 8 GeV/c protons, then heating the beam slowly by applying white noise through the transverse damper system. The location of aperture restrictions was observed where the loss monitors counted the highest. The improved loss monitors proved to be a useful tool during the last studies period for improving the aperture of the two storage rings in the PBAR source.

V. ACKNOWLEDGMENTS

We would like to thank Doris Dick, Judy Sabo and Marvin Olson for their parts in the fabrication and installation of the loss monitors.