THE U-70 MACHINE CONTINUOUS BEAM LOSS MONITORING

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Abstract

A new beam monitor system for continuous measuring radiation levels around the U-70 accelerator is being developed. The system consists of 120 monitors mounted close to the median plane and providing complete coverage of the U-70 ring. Each monitor is a small Ionization Chamber (IC). Chamber's currents are digitized by a current-to- frequency converters (CFC) with individual 16 bit counters. The data acqusition part is done in the framework of the U-70 control system under construction. This presentation gives description of all the main components of the monitoring system.

1 INTRODUCTION

The IHEP U-70 proton synchrotron has the circumference of 1483 m and comprises 120 bending magnets. The beam circulation time is about 7 s (2 s injection, 3 s acceleration and 2 s flattop). At present, the beam intensity is typically $2 \bullet 10^{13}$ protons per cycle, but there is a strong effort to increase it for the upcoming physical experiments. A number of factors cause beam losses over the cycle, accompanying all processes above: mistakes of the injection and extraction, closed orbit distortion, betatrone resonanses, instabilites, equipment malfunctions, local leakages in the vacuum chambers, etc. It is anticipated that monitoring at each cycle time and position distribution of the losses would be a very useful diagnostic tool for setting-up and final tuning the machine. The obsolete Photomultiplier-based beam loss monitoring system, put in operation twenty years ago, is not able to meet these requirements because of the very poor processing electronics /1/. The signal from only preselected monitor can be measured over single time gate at each cycle. In addition, Photomultiplier tubes as radiation detectors are not good tools for large accelerators. The main drawbacks are:

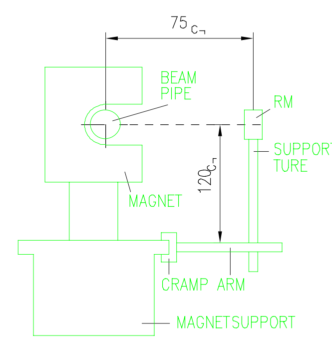
- narrow dynamic range because of saturation;
- strong dependence of the gain on supplied voltage, as a consequence of that an indivdual power supply is necessary;
- aging;
- low radiation immunity.

That is why we are developing a new loss monitor system for the U-70 that is free from these drawbacks. The monitors are small (0.16 L) home-made IC's , filled with air at local barometric pressure. They are mounted close to each of the magnets. The IC signals are processed simultaneously and continously over the cycle by digital integrators with time resolution not less 10 ms; thus, required time and position resolution are provided as well as full levels of losses over the cycle. The last property gives an opportunity to minimize the residual activation caused by beam losses. This report presents monitor design, their mounting and processing equipment.

2 MONITOR MOUNTING AND DESIGN

For the sake of homogeneity all monitors are placed at a distance of 75 cm from the median plane as shown in Fig.1.

Fig.1. Beam Loss Monitor Mounting



Such a mounting ensures maximum monitor sensitivity to beam losses and uniform geometry with respect to the closed orbit; also, it does not block access to the magnet and the beam pipe. Magnetic materials are not used in the detector, so the magnetic fild force does not act on the detector body. The monitor is attached to the support duralumin tube. The lower part of this tube is clamped in a horizontal steel arm, and the last one is attached to the magnet support by a cramp.

The IS is shown in Fig.2.

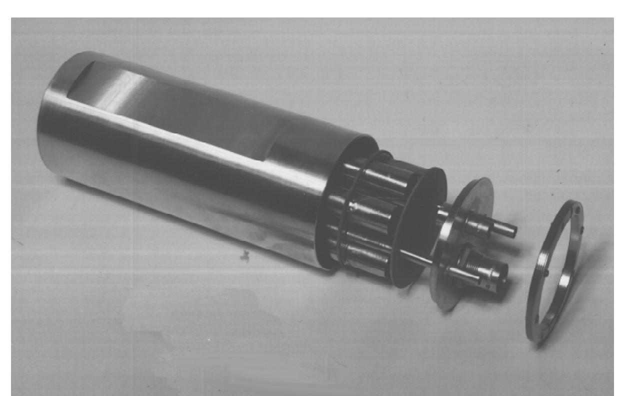


Fig.2. Photo of the RM

The sensitive volume is composed of seven thin-wall tubes of stainless steel. The tube length is 125 mm, the inner diameter is 16 mm; thus, the active volume is about 0.16 L. Through the tube a 0.1 mm diameter Wo wire is stretched as in proportional counters. All inner wires are electrically connected to a coax connector, all tubes are done to the second one. Mechanical clamping the tubes and wires is done by means of a circle duralumin plate and four plates of metallized glass plastics. Both coax connectors are fixed on the duralumin plate. The whole electrode assembly is inserted into a duralumin cylinder with welded face, of inner diameter 74 mm and length 178 mm and fixed by a thread ring above the plates with the connectors.

Chamber performance allows one to use it in the proportional mode when the volume is filled with Ar and high voltage is applied. To do this two fill tubes are placed onto the connector face. This possibility extends the range of applications of the chamber toward to higher sensitivity and time resolution; in our case, however, the ionization mode is sufficient.

According to data reported in /2/ we have chosen negative voltage -700 V to be applied to the wires, so that the signal is picked up from the tubes.

3 PROCESSING ELECTRONICS

We do not use the front end electronics. The monitor signals are fed via long (up to 1 km) coax cables to the back end electronics placed in the Main Control Room. A block diagram of the electronics is shown in Fig.3.

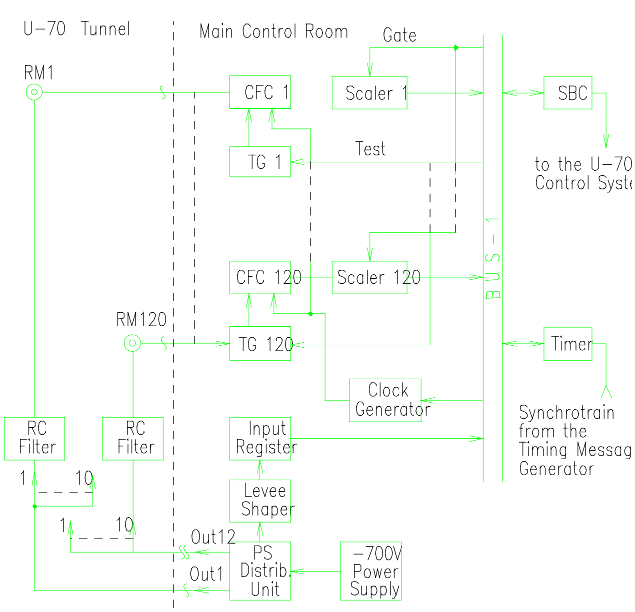


Fig. 3. A simplified block diagram of the Beam Loss Monitoring System

Processing a loss monitor signals is challenging task as ones vary over a wide range and have no single correlation with the beam intensity. We have chosen digital integration based on using a CFC followed by a Counter. The advantages are:

- the monitor signal has current nature, so a current- to -voltage converter is unnecessary, which allows to achieve a higher dinamic range;
- the counter's reading is proportional to the charge collected at theIC;
- integration time is restrained only by the digital memory capacity and not by component parameters; thus, integrating over the cycle becomes possible.

All electronic modules except for the Power Supply are packaged into Eurocard style.

3.1 CFC AND COUNTER

The tests for beam loss levels of practical interest have shown that the IC currents are in a range from 50 pA to 5 μA. Commercial single monolithic integrated circuits as a CFC's are not suitable because their input bias currents are too high; we therefore had to perform the CFC of discrete components. The domestic high speed J-FET Op Amp is used as an input integrator. The CFC is based on the charge balance technique with an external clock. The same clock for all channels allows one to get a small spread (no more than 1%) of conversion ratios for all channels as the transfer function is proportional to the clock frequency. The clock is provided by a crystal generator. For setting full-scale the frequency can be chosen at will from a number 200-400- 800 kHz. The input signals are fed to the integrator after RC-stretching with a time constant of 2-3 ms to avoid a saturation caused by short pulses. The CFC's are in active state at all time, but gating is done in the all 16 bit counters simultaneously, so the maximum time window is order of 100 ms for the 800 kHz clock. The minimum gate width is 10 ms. The numbers of time windows and their width are chosen at will, but as a rule, the full cycle beam time has to be covered. The time gap between adjacent gates necessary for reading is order of 10 mcs and can be neglected. Testing CFC's and counters is done by individual Test Generator (TG) during beam pauses.

The module with serial number ED00070 houses 8 measuring channels.

3.2 TIMER

Timing system is performed by the the IHEP Timing System synchrotrain with 1-ms time resolution /3/. Also, it contains the beam intesity data, the main cycle events, astronomical time, etc. The embedded Timer consists of two modules: timing message receiver and multimode timer /3/. The first one decodes and processes the synchrotrain, the second one produces all the time intervals and markers necessary for the system operation.

A Single Board Computer (SBC) ME 186 is used.

3.3 POWER SUPPLY

The negative voltage -700 V is distributed to 12 outputs by means of resistors. Each output derives the 10 adjacent monitors for high reliability and economy. These outputs are monitored with an input registers after level changing. Power Supply RC-filters with time constant about 40 ms are inserted for each monitor to suppress 50-Hz ripples.

4 CONCLUSION

The monitors with mounting accessories as well as the electronics have been produced and tested. After the software has been created, the beam loss monitor system will be released for use.

5 ACKNOWLEDGEMENT

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