Design of Beam Loss Monitor System for an 800 MeV Synchrotron Facility

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Abstract

The PIN photodiode with the coincidence technology for Beam Loss Monitor System (BLMs), was developed at DESY and has been used on HERA ring. It has been decided to install in the Beam Loss Monitor System for National Synchrotron Radiation Laboratory (NSRL) in Hefei, China. Such a system will help to tune machine and find the vacuum leakage. Detailed design of the BLMs is described in the paper.

It is the first time for some new technologies, such as FPGA, CAN bus, to be used for accelerator control in China. The design of the high-speed FPGA counter can be seen in this paper. The system also uses a PC for data acquisition and data analysis. It implements field control (here, CAN Bus) with a CAN Bus network adapter. Compression between this method and VME plus CAN IP is also described here.

Compared with the 920GeV-p and 30GeV-e in DESY HERA, there will be some new physics problem under the lower energy condition, when the detector is applied in NSRL. All of them are mentioned in this paper.

1. INTRODUCTION

NSRL in USTC has an 800Mev e-storage ring (HLS – Hefei Light Source). During the upgrading of accelerator in USTC, a BLM system will be installed to detect beam loss along the storage ring, tune the machine, and study the beam lifetime.

The beam loss detectors, originally developed by DESY, will be used to detect shower electrons induced by lost beam particles. Because of its special principle (figure 1), it is powerfully to be used in intense synchrotron radiation environment.

One detector has two PIN photodiodes, face to face. Electrons, with enough high energy, can go through these two diodes. Signals from two diodes generate output signal at the coincidence gate. As for the photons, it will be absorbed at one of the two diodes due to Compton effect, pair effect, and photoelectron effect. Charged particles generated from here can be stopped by the copper inlay between the two diodes. The copper inlay is thick enough to stop this kind of particles. Because of this reason, photons will not give out signal at the coincidence gate.

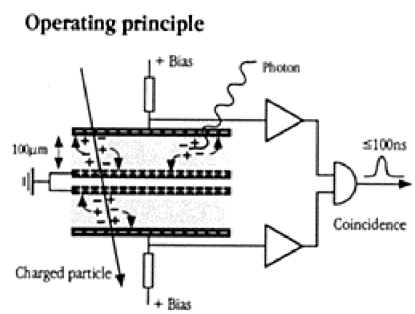

Figure 1. Principle of beam loss detector

24 detectors will be distributed at 12 places along the 65.88m HLS ring (figure 2). CAN BUS will be used to connect these detectors to a PC machine, which is the console of the system.

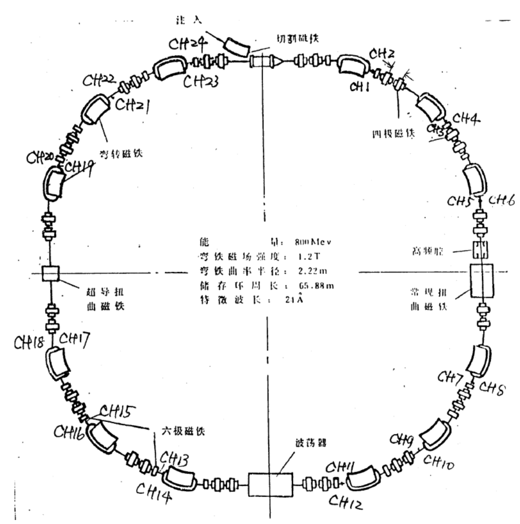

Figure 2. Distribution of Beam Loss Detectors along the HLS ring in NSRL

Because such detectors were originally developed for HERA ring in DESY, and there are many differences between HERA and HLS, there must be

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some physics problems in the installation and running of such a system, such as the position of installation, the detecting efficiency. It is worth studying and discussing these problems in such an 800Mev low energy condition.

2. STRUCTURE OF BEAM LOSS MONITORING SYSTEM

The whole beam loss monitor system uses CAN BUS to connect all the frontends and console, a PC machine (figure 3).

The console has a CAN BUS network adapter so that it can communicate with CAN BUS. We develop software for BLM system with LabVIEW. It can display and print count rates of all the channels, setup the parameters for the system, and calculate the beam lifetime. As for the performance, it is enough to use a PC as the console of the system. And also, it is cheap.

As for the frontend, MCUs are used as main controllers, one chip for one node. Every MCU controls two detectors. Count rates of the two detectors are collected by a high-speed counter, which is designed with FPGA. The count rates are also transmitted to PC through CAN BUS. All these operations are implemented by a MCU – MC68HC11A1.

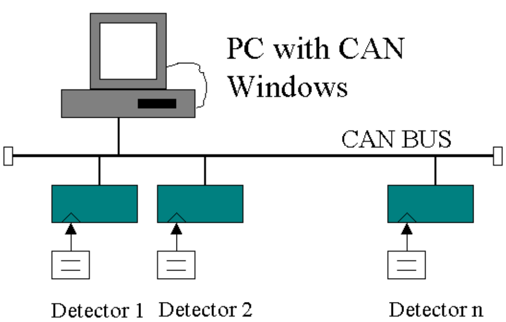

Figure 3. Structure of Beam Loss Monitor System

The counters have the following performance:

- Two channels, one channel for one detector;
- 16bits counter with 8bits buffer for each channel;
- Counting rate can reach 10MHz;
- Each channel can be enabled or disabled separately;
- Each channel can give interrupt signal;
- Interrupt can be enabled or disabled separately.

3. PHYSICS PROBLEM IN BLM SYSTEM

The PIN photodiodes beam loss detectors were originally developed for DESY HERA rings. There are many differences between HERA and HLS.

The first one is the energy. HERA has a 920GeV p-ring, and a 30GeV e-ring. They are all at very high energies. HLS is at only 800MeV. This will affect the distribution of shower electrons, induced by lost particles, on the surface of the vacuum chamber.

The second one is the circumference. HERA ring is 6.3km long, and HLS is only 66.13m long. The different length induces the different Lattice structure, the β functions, the η functions, and also the pathway of particles in vacuum chamber, which lose energy.

Because of these reasons, there must be many physics problems related to the installation and running of BLM system on HLS.

The First problem is the location of shower electrons. In another word, where the BLM detector should be located to detect the shower electrons induced by lost particles?

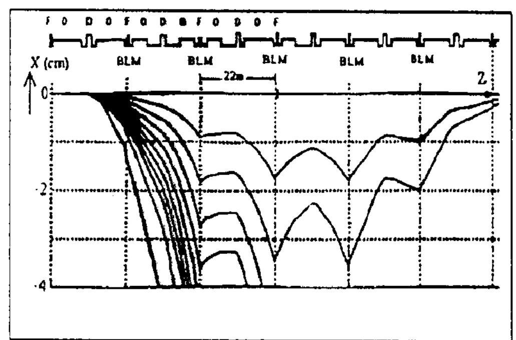

Figure 4. [HERA] Path of electrons with an energy loss of $\Delta E/E$ = -1% to –10% though a FODO structure. X is the horizontal displacement of the electrons. The pipe wall starts at x=± 4cm.

The deviation of the electron orbit (for those which lose energy due to some reasons, for example, inelastic scattering on the nuclei of the residual gas molecules.) from the normal orbit depends on the η function and the lost energy ΔE. The electrons may be lost at the next maximum of η function. In another word, the maximum of η function is most sensitive to those electrons. Figure 4 (Ref.1) is the path calculated for HERA e-ring. For that ring, the maximum is where the horizontal focusing quadrupoles stand in the arcs. In such a long ring, the defocusing ability of dipole is much weaker that that of quadrupoles. The most possible place of detecting shower electrons is just behind the horizontal quadrupoles.

For the ring of NSRL, it is very different. Figure 5 is the same calculation based on NSRL ring. This ring is much shorter than HERA e-ring. Trajectories of electrons will bend 30° at each dipole. The defocusing ability of dipoles here is much stronger than that in lager rings. It is better to detect shower electrons just behind the dipoles, not behind the horizontal quadrupoles.

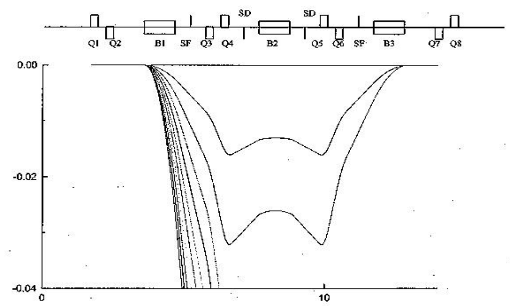

Figure 5. [NSRL] Path of electrons with an energy loss of $\Delta E / E$ = -1% to –10% though a FODO structure. X is the horizontal displacement of the electrons. The pipe wall starts at x=± 4 cm.

Another problem is the efficiency of detecting the beam loss. For a certain beam loss rate, how many count rate of shower electrons can be seen in BLM system?

To solve this problem, the distribution of shower electrons must be calculated once again for NSRL ring. It will be different from that of HERA e-ring due to the much different energy. This is an important factor in calculation of the distribution.

Another thing must be mentioned here is about the lifetime of beam.

For high energy machines like HERA e-ring, inelastic scattering with residual gas molecules is usually the dominant factor that determines beam lifetime. It is not the case for low energy rings like HLS, in which Touschek effect can not be neglected. Beam loss rate due to Touschek inner-bunch scattering may be at the same magnitude as that due to inelastic scattering. When inner-bunch scattering happens, if an electron loses a certain amount of longitudinal momentum, which implies energy loss in this case, there must be another electron that gains the same energy. If the former will hit inside wall of the vacuum chamber and be lost, the latter will reach the outside wal at almost the same azimuthal location. This is why we would like to place two detectors at each position, in the hope that the ratio of outside wall loss to inside wall loss can tell something about the proportion of Touschek beam loss. Machine physics studies with different bunch density and RF voltage will be interesting.

Mentioned above is some aspects of physics problems. During the installation and running of BLM system in NSRL, all these problems will be studied carefully. Some papers about this can be expected in the near future.

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