BEAM LOSS MONITORS FOR THE HERA PROTON RING

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Abstract: Described are proposed beam loss monitors for the HERA Proton Ring. They are designed to measure beam losses in the presence of strong synchrotron radiation background from the HERA Electron Ring. These monitors warn of beam losses in the superconduction magnets. They can also be used as a diagnostic tool to determine the distribution of losses around the ring.
The detector consists of two PIN - photodiodes operating as a semiconductor detector in a coincidence mode. Therefore the synchrotron radiation coming from the HERA Electron Ring will be suppressed. In the case of a beam loss in a superconducting magnet, the detector counts charged showerparticles which leave the magnet and cross the two diodes. The rate of these particles is proportional to the rate of the beam loss. The efficiency of the detector in measuring beam losses is calculated by Monte-Carlo calculations and additional measurements.

Introduction

The HERA Proton Ring is mainly equipped with superconducting magnets. If beam losses occur in a superconducting magnet, the deposited energy of the shower particles will heat up the superconducting coil. The coil can tolerate only a certain amount of heat before a quench. [1] gives $R_{quench} \approx 2 \times 10^8$ protons as a critical number for losses inside a magnet at 820 GeV/c. The temperature time constant of a superconducting magnet is about 16 ms [2], so that the losses can be distributed over this time intervall. To shield the magnets against beam loss induced quenches, it is forseen to have a beam loss monitor system which is able to warn in case of an excessive locallized loss rate. Because of the strong synchrotron-radiation background coming from the HERA Electron Ring, typical loss monitors like ionisation-chambers are unserviceable in the face of a massive lead-shield [3]. Two fast PIN - photodiodes working as semiconductor detectors in a coincidence mode will effectively suppress the background. In this paper the principle work of such a new beam loss monitor is discussed.

Beam Loss Detection

In the superconducting parts of an accelerator like HERA, positions with a large β-function are mainly affected by beam losses. This is the case inside the superconducting quadrupoles. The Monte-Carlo program Gheisha 8 [4] is used to calculate the particle shower after a loss of a proton in the longitudinal middle of a quadrupole. The calculation shows that the shower is widely spread over the second half of the quadrupole and the adjacent superconducting correction coil. The shower particles are leave the vacuum tank of the magnets within a few meters. So the loss monitors need to be located near the downstream end of each quadrupole. They detect a fraction of the charged shower particles leaving the magnet. The particles that cross both diodes give a coincident signal and will be counted. The expected rate of minimum ionizing particles (mips) crossing an area of 1 cm^2 at such a position is calculated by the Monte-Carlo program. The result is shown in Fig. 1. Because of the wide spread of the shower in all directions the result is independent of the exact location of the beam loss.

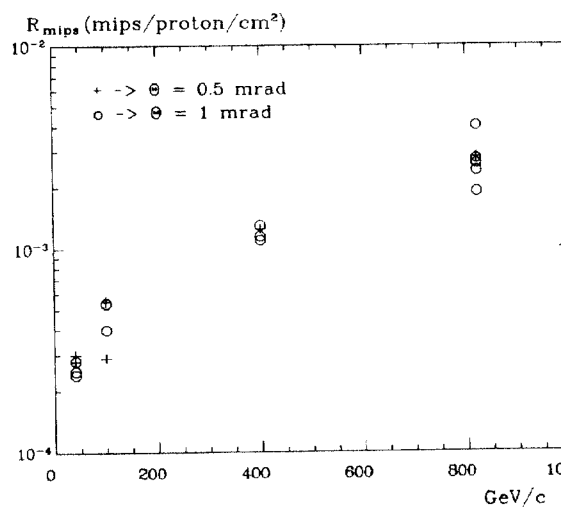

Figure 1: Rate of minimum ionizing shower particles crossing an aera of 1 cm^2 at the downstream end of the quadrupole. θ is the angle of the incident proton.

A beam loss monitor is naturally residing in a strong field of radiation which results in radiation damage of the monitor components. The influence of this damage is measured by [5] and [6]. A small reduction in the gain of the amplifier with increasing integrated dose was established. This gain reduction can be compensated by readjusting the threshold of the coincidence. In all probability such a detector should be usable for several years at positions without strong beam losses. To shield the detector against the synchroton radiation, it is covered with a 3 cm lead shield except for the side facing the magnet.

The Detector

The detector consists of two PIN - photodiodes BPW 34, one on top of the other. The effective area of each diode is $F = 0.075\ cm^2$. They are normally biased with 15 V, so that the thickness of the depletion zone is about $100\mu m$. The signal produced by a diode from the crossing of a minimum ionizing particle is about 10^4 electrons. The accompanying amplifier processes the signal in a time interval less than 100 ns. This interval corresponds to the bunch spacing in HERA[1]. The two amplifiers are connected to a coincidence unit. The electronics is housed with the diodes in the same small box ($5 \times 5 \times 5cm^3$). In case of coincident events, a counter located in the HERA tunnel, is incremented. If a preset rate is reached, the counter sends a signal to the alarm loop of HERA. First measurements with a prototype of such detector gave an efficiency of about $\varepsilon = 4\%$. Increasing the bias up to 90 V gave an efficiency of $\varepsilon = 45\%$. This characteristic gives a method to set the efficiency to accommodate various positions of the detectors in the accelerator.

Signals

[1] gives the expected critical loss rate R_{quench} as follows:

$$R_{quench}(820\ GeV/c) \approx 2 \times 10^8\ Protons/16ms;$$

$$R_{quench}(40\ GeV/c) \approx 10^{11}\ Protons/16ms$$

The resulting signal rate S from the detector is

$$S = F \times R_{quench} \times R_{mips} \times \varepsilon$$

This gives

$$S(820\ GeV/c) = 5 \times 10^4\ counts/16ms;$$

$$S(40\ GeV/c) = 2.1 \times 10^4\ counts/16ms$$

Because of the counting technique, the maximum detectable rate is 1 $count/bunch = 1.7 \times 10^5\ counts/16ms$. The minimum rate is limited by the background. Due to the coincidence readout, the background is expected to be smaller than $10^2\ counts/16ms$. Therefore three orders of magnitude are available for the diagnosis of beam losses.

[1]Therefore it is possible to measure the losses of an individual bunch

Conclusions

The described beam loss monitors are based on a coincident readout of two PIN - photodiodes. They are well suited for the measurement of beam losses in the presence of synchrotron radiation. To protect the superconducting magnets against beam loss induced quenches, one monitor for each quadrupole is forseen. In addition, monitors will be placed at those positions which are often affected by losses. This could also be in the warm parts of the ring. This system will provide an exellent protection against beam induced quenchs and will be a good tool for beam loss diagnostics around the ring. The monitors can be used in every kind of high energy accelerator, especially where strong synchrotron radiation affects the beam loss measurements. They are relatively radiation resistant, easy to handle, cheap, and therefore simple to install or replace at any desired position.

Acknowledgements

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