EXPERIENCE WITH THE ELECTRON AND PROTON BEAM LOSS MONITOR (BLM) SYSTEMS AT HERA

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Abstract

Since the beginning of the proton acceleration in HERA, the BLMp(roton) system has to prevent the superconducting magnets from beam loss induced quenches. A statistic of this functionality is presented and the different reasons of beam aborts caused by the BLMp-system and the few beam loss induced quenches are discussed. The equivalent BLMe(lectron) system is used mainly for diagnostics. Especially during the studies of the electron lifetime problem in HERA, the BLMe system localized exactly the position of trapped "dust" particles in the ring. The localization mechanism and the performance of the BLMe system are presented.

1 INTRODUCTION

The PIN-Diode-BLMs[1] used at HERA are designed to measure minimum ionizing particles created by beam losses in an environment of intense synchrotron radiation emitted by the high energy electron beam. The coincidence counting technique is responsible for the good background reduction from high energy photons. The HERAp system consits of 262 BLMs while the HERAe system uses 214 similar BLMs.

2 THE HERA BLMp-SYSTEM

The aim of the BLMp system at the HERA proton ring is to reduce (hope: cancel) beam loss induced quenches of the superconducting magnets. Therefore PIN-Diode-BLMs are positioned on top of each quadrupole and connected to individual counters. If the adjustable count threshold is reached within 5.2 ms, the counter sends an alarm to the HERA alarm loop which fires the beam dump within one turn in case of more than 4 BLM-alarms. The count threshold of the BLMs depends on the maximum tolerable proton loss rate inside a superconducting magnet whitch is a function of the magnet current and the beam energy respectively. The threshold and the tollerable number of alarms are adjustable by software. More details are given in [2].

2.1 Statistics

Table 1 shows statistics of operation of the BLM System in HERAp in last two years. Note that the average proton current increased from 40 mA in 1994 (during 27 weeks) to more than 60 mA (during 30 weeks) in 1995.

[1] The PIN-Diode-BLMs are descript in detail in [1]

The reasons for a beam abort triggerd by the BLM system includes beam steering errors, RF & PS trips, shorten magnet coils, etc. The number of error-aborts triggered by the BLMs in 1994 were due to a failure in the Alarm system. No error aborts were observed in 1995.

However, the number of quenches in 1995 was too high. About 90% of the quenches occurred during the ramp from 40 to 820 GeV/c. The counter thresholds were not changed since the beginning of 1994. For 1996 we have decreased the threshold for all BLMs during the ramp by a factor 4.

Two quenches occurred in 1994 and in 1995 due to a poor injection of the machine in which the injected beam was lost in the first superconducting magnet within the first turn. There is no chance for a BLM system to avoid this!

Six errors in 1995 were the result of a wrong recabeling of 8 successive alarm channels resulting in negative alarms. Before notice, each of the negative alarms had to be compensated by ‘real’ alarms (plus 4) to abort the beam. The quenches happened due to local losses in this area.

A typical time constants for losses due to RF or magnet problems is 50 - 100 ms or longer. During this time the loss rate increase from normal operation (≤ 1 Hz) to the threshold rate (≥ 20 kHz) (Fig. 1a). In 1995 we observed 31 events with a time constant of about 5.2 ms (Fig. 1b). Three of these events resulted in quenches but in most cases, the BLM system acted fast enough to prevent from a quench. The driving mechanism of this fast beam loss is not yet understood.

1994 (27 weeks)	total	errors	5 ms events
beam aborts by BLMs	75	10	1
quenches	20	0	1
1995 (30 weeks)			
beam aborts by BLMs	114	0	28
quenches	34	6	3

Table 1: Operation statistics of the BLMp system

The post mortem analyses of the BLM count rates (see [2]) is very helpful for diagnosis the reason for beam aborts. More than 90% of the beam aborts were caused by real beam losses (and beam loss induced quenches) detected by the BLMs, indicating a failure in at least one machine component (including the operator). The main position for losses are the aperture limits at the collimators and at the normal conducting parts of HERAp. Nevertheless, there are events where the main losses occurred in superconducting parts of HERA although the collimators were closed.

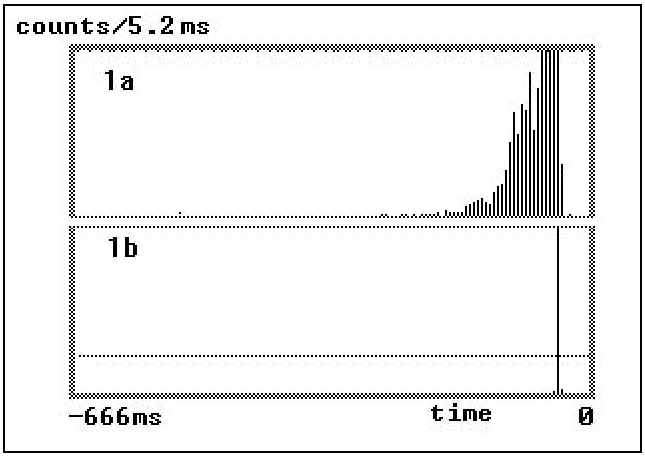

Figure 1: The last 666 ms before beam abort versus loss rate (arb. units) of a BLM in HERAp. One line represents the count rate integrated over 5.2 ms. The threshold is represented by a horizontal line. 1a: normal increase of the loss rate due to RF drop. 1b: very fast beam loss. The time of the beam dump is indicated by the fast decrease of the rate near t=0.

3 THE HERA BLMe-SYSTEM

The aim of the HERAe BLM system is to observe the position of beam losses around the ring. An integration time between 0.1 - 100 s can be chosen by the operator. The BLMs are mounted on the inside of the vacuum chamber of the electron ring just behind each focusing quadrupole. This specific position is responsible for the localization of targets in the vacuum (e.g. residual gas, micro particles, dust) within one, the previous, FODO cell (see 3.1). This is very useful to study lifetime phenomena in HERAe, especially the trapping of micro particles [3,4].

3.1 The loss localization mechanism

The lifetime of an electron beam in a storage ring is determined typically by Bremsstrahlung on residual gas molecules in the vacuum. The Bremsstrahlung spectrum covers the whole energy spectrum up to the maximum energy E of the beam. The path of an electron after a Bremsstrahlung interaction depends on the amount of lost energy and on the position of the target in the ring. Here we will concentrate on positions in normal FODO cells, located in the arcs. More details can be found in [5].

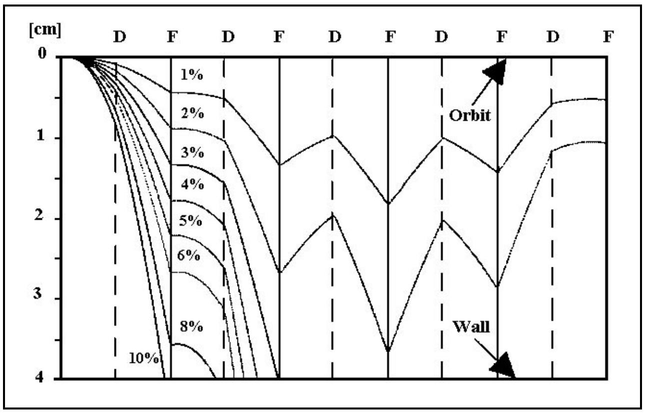

Figure 2: Path of electrons after energy losses. The deviation from the nominal energy is given in %. The vacuum wall starts at 4 cm in HERAe.

Fig. 2 shows the path of electrons in a FODO magnet structure with different amounts of lost energy at. Electrons with a large energy loss hit the vacuum pipe within the same FODO cell where they undergo Bremsstrahlung. A small loss of energy leads to an electron loss within one of the next FODO cells or at the next dispersion maximum. Electrons survive if their energy loss is smaller than the momentum acceptance $E_{min} \approx E - E/100$ of the machine. Fig. 3 illustrates, that the energy range $[e_{min}, e_{max}]$ of electrons which reach the BLM depends on the position of the target and on the sensitive length L of the BLM. This length is determined from Monte Carlo calculations by the length of the shower distribution outside the vacuum chamber near the BLM (L = 22 cm). The monitor is crossed by n (= 0.16) charged shower particles per electron lost in this area[2]. The cross section σ_r for an electron loss within l can be calculated from the Bremsstrahlungs cross section σ

$$\sigma_r = \int_{e_{min}}^{e_{max}} \left(\frac{d\sigma}{dk}\right) \cdot dk \Big/ \int_{E_{min}}^{E_0} \left(\frac{d\sigma}{dk}\right) \cdot dk$$

Fig. 4 shows the cross section versus the position of the target in a FODO cell in front of the adjacent BLM. σ_r is zero outside this region. Therefore the BLM observes losses from targets inside the previous FODO cell only. This behavior was observed during the HERA electron runs in 1994 [3,4], 1995 [6] and in the beginning of 1996.

The expected BLM count rate for a single local target is given by

$$N = N_{tot} \cdot \sigma_r \cdot n \cdot \varepsilon_{blm}$$

where N_{tot} is the total electron loss rate (derived from the measured lifetime) and ε_{blm} (=0.348) is the measured

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[2] All numbers from [5]

efficiency of the BLM. The calculated rate compares with the measured rates within a factor 4 [5].

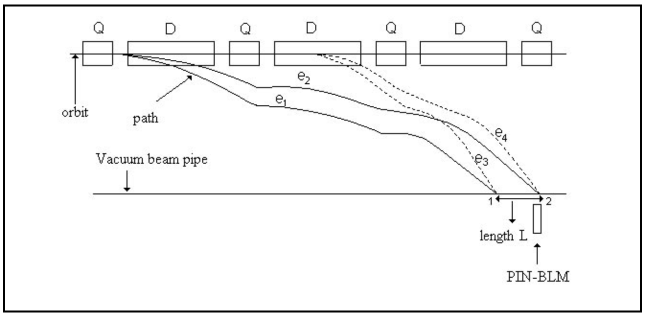

Figure 3: Path of electrons with by L defined energy losses after Bremsstrahlung at different locations (not in scale). $e_{1,3}$ and $e_{2,4}$ represents $e_{min}$and e_{max}.

Note that only electrons from the previous FODO cell can reach the sensitive area of the BLM behind the focusing quadrupole. If the BLM is positioned in front of the quadrupole, it is able to observe electrons created from targets in some previous FODO cells. The same situation occures if the shower distribution length L is longer than the distance between the quadrupole and the following BLM. In this case an exact localization of the target could be difficult. This is true for PETRA [7], where L is about 1 m because of the aluminum vacuum pipe and the BLMs are mounted about 30 cm behind the quadrupole.

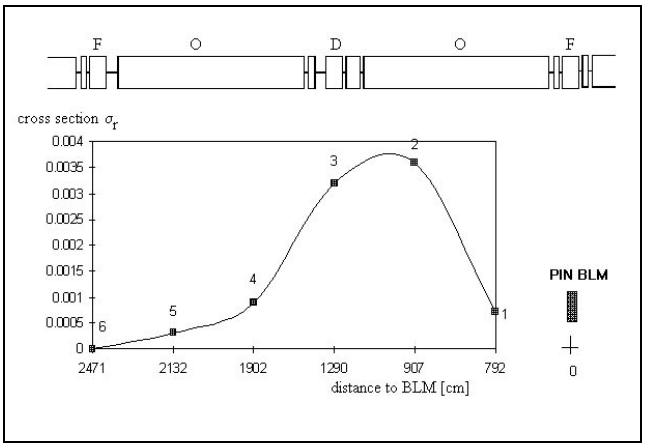

Figure 4: Cross section σ_r along a FODO cell in the arc.

4 Summary

The BLM system at HERAp is working very reliable. The threshold of the count rate during the acceleration of the protons will be more sensitive in 1996 to reduce the probability of beam loss induced quenches. The time interval of 5.2 ms is short enough to prevent beam induced magnet quenches in nearly all cases of losses. We will install additional BLMs at the collimators with a readout time of 100 µs to observe the loss behaviour within a faster scale.

The BLMe system is very helpful in observing lifetime phenomena in HERAe. The localisation of targets in the vacuum is very useful to studie the phenomena of trapped targets. Flights of targets around the machine were observed as well as stable ones over a long periode [4]. A statistics of the positions of local losses is used to find problematic sections in the machine.

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