HERA Electron-Beam Lifetime Disruption Machine Studies and Observations

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Abstract

Extensive machine studies of the electron beam lifetime problem in HERA were performed in Dec 1995 at energies ranging from 12 GeV to 27.5 GeV and at currents up to 40 mA. Transient and persistent rate increases observed in 214 electron beam loss monitors around the machine and in background and electron detectors at the ZEUS, HERMES and H1 experiments coincided with transient and persistent electron beam lifetime disruptions. The observations were consistent with the passage through the electron beam of dozens of disrupting targets (dust particles) per minute, whereby many permanent lifetime disruptions and local electron loss rate increases (stationary target trappings in quadrupoles) could be observed per hour at high current and energy. Detectors indicated frequent longitudinal motion of transient disrupting targets at speed $\approx$ 60 m s^{-1} at 12 GeV along arc regions, the targets apparently being frequently lost in straight sections. The time evolution of electron loss monitor rates around the ring illustrates clearly the passage of targets through the beam, the trapping of targets in particular quadrupoles, and the successful removal of many disrupting targets by strong repeated beam kicking and high-frequency beam kicking.

The integrated ion pump system was again implicated as the disruption culprit. Regions most prone to disruption were identified and integrated ion pumps there were replaced with trial Non-Evaporative-Getter (NEG) pumps. Preliminary results from NEG pump trial machine studies from 24/05/96 to 08/06/96 are presented.

1 INTRODUCTION

HERA loss monitor counts are triggered by both deflected beam electrons and synchrotron radiation [1]. At the injection energy 12 GeV electron counts dominate, whereas at the luminosity operation energy 27.5 GeV electron losses due to trapped targets account for typically less than 3% of counts, rendering identification of local disruption events difficult. Observations were thus performed over a range of energies from 12 GeV to 27.5 GeV at currents ranging from ≈ 20 mA to 40 mA.

At operating currents in the range 5 mA to 40 mA and at energy 12 GeV total counts at a given monitor range from zero to tens of events over an integration period of 12 s, whereas at energy 27.5 GeV tens of thousands of counts are registered over 12 s due to the contribution of synchrotron radiation. Counts were integrated for each loss monitor over a 12 s integration period at 12 GeV and during the ramp to 27.5 GeV , and thereafter an integration period 1 min was used. In addition to these, non-archived counts integrated over ≈ 1 s could be observed on a PC application.

The following normalisation is used in this paper to remove monitor-to-monitor count variations due to geometry and dispersion:

$$N_{i,j} = \frac{R_{i,j}/I_i}{R_{i-1,j}/I_{i-1}} \quad i = 0, 1, 2, \ldots, \quad j = 1 \ldots 214 \ , \tag{1}$$

where $R_{i,j}$ denotes the integrated count (‘rate’) of monitor j over time interval t_{i-1} to t_i and I_i is the beam current. Thus *changes* in the relative reaction of each monitor are reflected by departure from $N_{i,j} = 1$, which value then represents predominantly the synchrotron radiation background and beam electron losses due to deflection from residual gas molecules in the vacuum chamber.

2 EXAMPLE RUNS

In Fig. 1 we see examples of the reaction of individual monitors at 12 GeV and 27.5 GeV . Lifetime reductions seems to correlate with local rate increases in certain monitors. There are also many transient reactions to be seen in the monitors, some of which correlate with changes in the lifetime curve. At 12 GeV the reaction due to scattered electrons dominates over synchrotron radiation, permitting easy recognition of events, whereas at 27.5 GeV transient reactions can be identified but are difficult to resolve against the now dominant synchrotron radiation background.

More global insight is obtained when the time development of the normalised rates $N_{i,j}$ of all monitors is displayed simultaneously in one diagram. In Fig. 2 the normalised rate is associated with shade for a run at 12 GeV the longitudinal flight of targets can be easily discerned. The reaction of monitor NL191 shown individually in Fig. 1 can be identified. Normalised rates up to 9 times the residual gas and synchrotron radiation contributions are displayed. Trappings can also be detected in this way at 27.5 GeV , although the flight of particles can't be resolved.

3 STATISTICAL ANALYSIS OF LIFETIME DISRUPTIONS

One can use the linear correlation coefficient between $R_{j,i}/I_i$ and $1/\tau_i$ to investigate correlations between local loss monitor rate changes and the global beam lifetime τ.

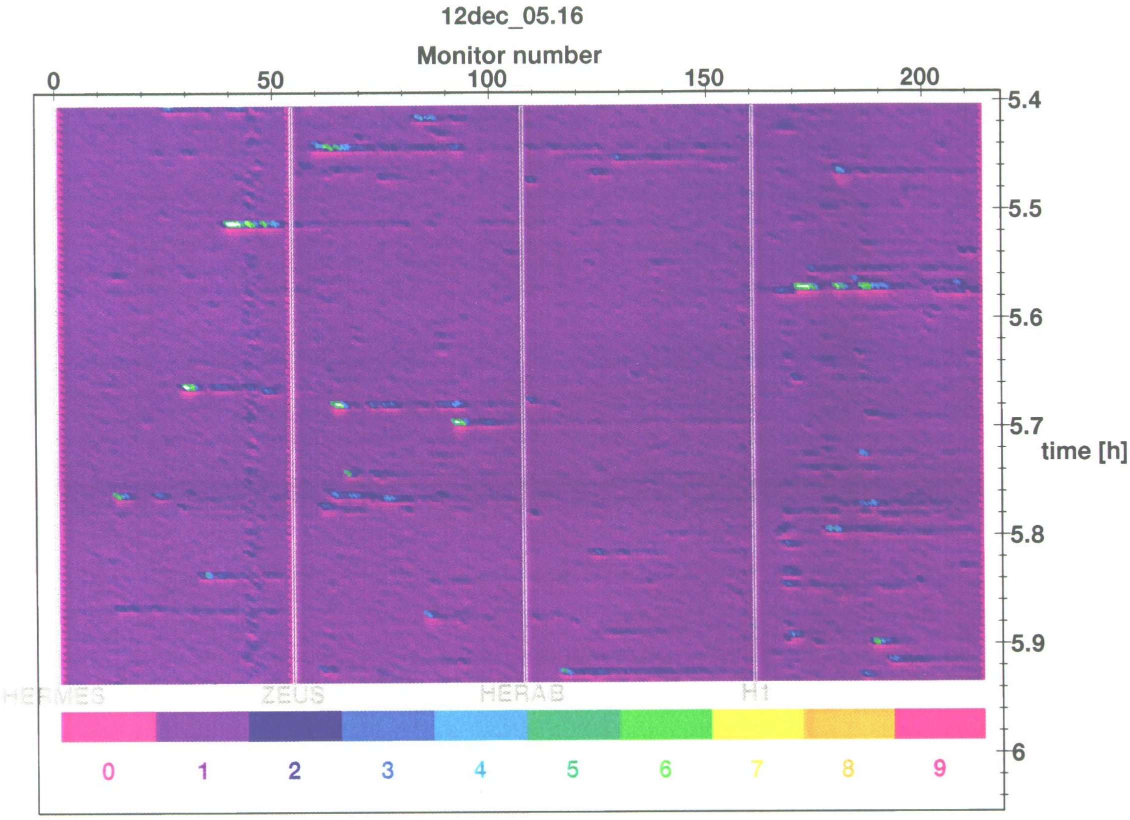

Figure 2: Example of electron loss monitor reaction time development for the entire HERA electron storage ring at 12 GeV. The normalised rate $N_{i,j}$ is associated with hue over the range $0 \ldots 9$. Activity in the octant NR (North-right) is high. The 'flight' of individual targets along portions of the machine can be identified.

The result of such correlations is shown in Fig. 3 for typical 12 GeV and 27.5 GeV runs. One sees clear correlation between local loss monitor rate changes and the lifetime. Both figures indicate high activity in the North-Right octant. One must exercise caution in the interpretation of correlations with rates in monitors near the experiments; electrons deflected elsewhere can apparently enter monitors at these high dispersion locations.

4 EXPERIMENT DETECTOR OBSERVATIONS

Various detectors at the experiments ZEUS, H1 and HERMES indicate the transient passage of disrupting particles through the beam (not only in the experiment region themselves) and show permament rate increases when disrupting particles are trapped by the beam. In Fig. 4 we see a myriad of events in the ZEUS electron-gated background detector over a 5 minute period.

5 NEG PUMP TRIALS

During 1995/1996 winter shutdown the integrated ion pumps of the North-Right octant region NR 205 - NR 392 were replaced with trial NEG pumps. From 24/05/96 to 08/06/96 beam loss monitor observations revealed a significant reduction of disrupting particle activity in that region, as illustrated in Fig. 5 by the r.m.s. of the loss monitor count rates for a typical electron run at 12 GeV . No persistent disruptions were identified during the machine studies period in the NEG pump region at 12 GeV or 27.5 GeV .

6 CONCLUSION

Statistics of lifetime disruption events in the HERA electron beam have been collated with the assistance of the HERA electron beam loss monitors during the machine studies periods 06/12/95 to 17/12/95. Analysis of the data confirms that the susceptibility of the beam to lifetime disruptions has a regional dependence.

The loss monitor observations and observations in various experiment detectors again confirmed the suspicion that the HERA electron beam lifetime disruption is caused by discrete scattering targets, hundreds or thousands of which constantly pass through the beam per hour, and tens of which are trapped at high energy for many hours.

Machine studies from 24/05/96 to 08/06/96 revealed a reduction of loss rate events in those regions where integrated ion pumps were replaced with non-evaporative getter pumps.

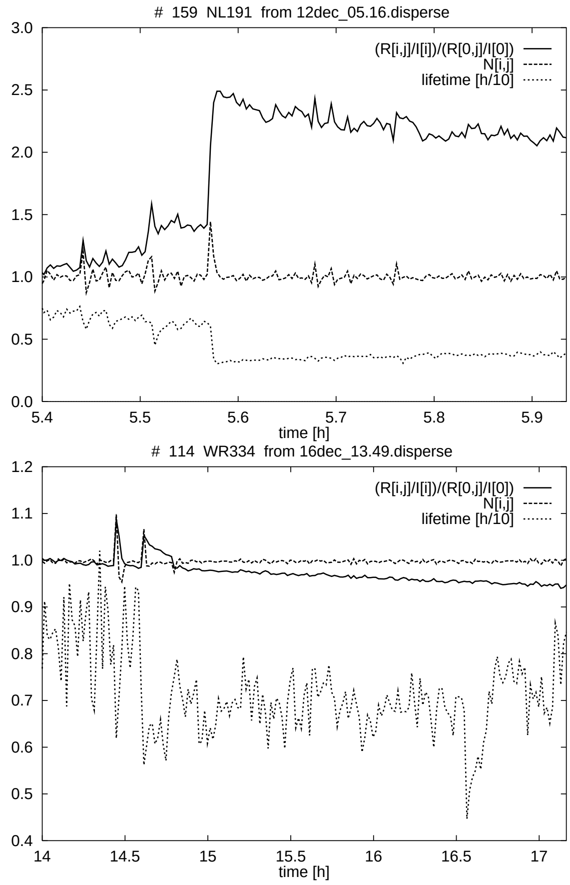

Figure 1: Examples of the reaction of loss monitors at energy 12 GeV (upper) and 27.5 GeV (lower). The count-per-current scaled by the initial count-per-current, the normalised rate $N_{i,j}$ (see Eq. (1)) and the scaled lifetime $\tau/10$ are shown. Reductions in the lifetime coincide with local loss rate increases.

7 REFERENCES

[1] Bialowons, W., Ridoutt, F., and Wittenburg, K. (1994), Electron beam loss monitors for HERA, in *Fourth European Particle Accelerator Conference (EPAC94)*, Vol. 2, p. 1628, World Scientific

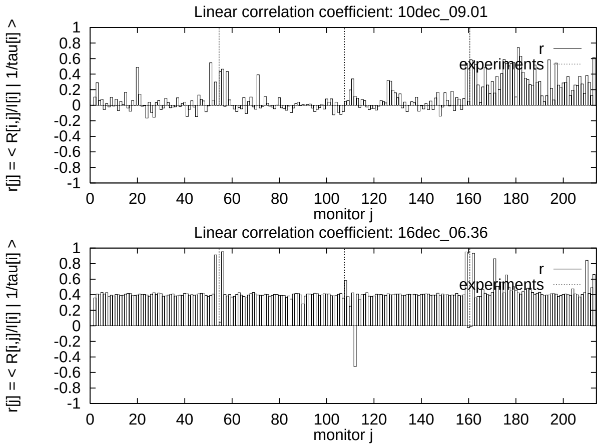

Figure 3: Linear correlation coefficient r_j for each loss monitor j between $R_{i,j}/I_i$ and $1/\tau_i$ for typical 12 GeV (upper) and 27.5 GeV (lower) run periods.

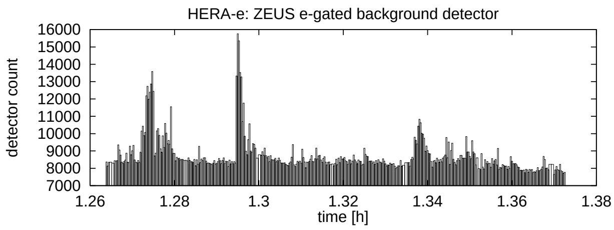

Figure 4: ZEUS e-gated background detector rates during a typical HERA electron run showing response to the passage of disrupting particles through the beam.

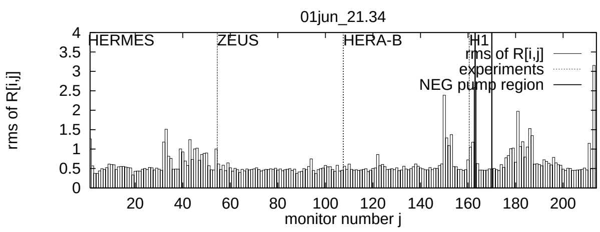

Figure 5: R.m.s. of the HERA loss monitor counts with trial NEG pump region for a typical 12 GeV run.