A newly observed effect affects the LEP beam energy

G. Brun, B. Dehning, P. Galbraith, K. Henrichsen, M. Koratzinos, M. Placidi, P. Puzo
CERN, Geneva, Switzerland
A. Drees, BUGH, Wuppertal, Germany, M. Geitz, RWTH, Aachen, Germany

Abstract

The LEP magnetic bending field and therefore the beam energy is changed by a current flow over the vacuum chamber. The current is created by trains travelling between the Geneva main station and destinations in France. Some of the rail current leaks into earth and returns to the power station via the LEP tunnel where the vacuum chamber is one of the conductors. Train leakage currents penetrate LEP at the injection lines from the SPS close to IP1 and between IP5 and IP7, thereby interacting with the magnetic dipole field. The observed changes in B field cause beam energy increases of several MeV.

1 INTRODUCTION

The LEP energy was determined with high precision in 1995 to improve the errors on the Z mass and width and to confirm the results of the 1993 measurements [1]. For the first time since LEP was commissioned the bending field has been monitored with probes installed inside the tunnel dipole magnets.

2 MAGNETIC FIELD MEASUREMENTS

The magnetic field was measured simultaneously with 4 NMR probes in almost all fills. Figure 1 gives an overview about the position of all probes with respect to LEP. Two NMR probes are located in the reference magnet and the two other NMR probes in the tunnel dipole magnets close to IP4 (NMROCT4) and to IP8 (NMROCT8).

The probes in the tunnel magnets are installed in a slit between the pole faces of the magnet and the vacuum chamber wall (fig. 2). At this off centre position the field homogeneity is ensured by an additional field plate. Induction wires are installed in the field gap of the bending magnets to measure magnetic flux changes. The induction wires form a one turn loop (flux loop). The total LEP ring is divided into eight parts such that one flux loop is extending over an octant.

The magnetic field for a long LEP fill (fig. 3) shows from midnight to around 4:00 only a slow drift. The two other periods show fast field variations. The field increase during the 14 hour measurement corresponds to a beam energy rise of 12 MeV. The steps occur each time after a strong fluctuations of the B field. The B field shows a tendency of saturation at the end. The difference of the tunnel and reference NMR readings is displayed in figure 4. The tunnel NMR probes expose strong field variation during day-time, whereas the reference show almost no time dependence. This characteristic calm period occurs every night.

The short term variations ($\Delta t \leq 5$ min) of the tunnel NMR probes are strongly anti-correlated. If NMROCT8 measures a magnetic field increase, NMROCT4 measures a decrease and vice versa. Anti-correlation is presented in figure 5.
The flux loop and the NMR readings are correlated. Since flux loops measure the time derivative of the magnetic field, changes of the field level should be accompanied by peaks of the flux loop signal. Figure 6 shows the time dependence of both signals.

The characteristic calm period is also recorded by the flux loop (fig. 7, octant 8). The flux loops in the two ring octants which have NMRs record a short term anti-correlation (fig. 8). The measured correlation coefficient is -2.0. The adjacent flux loops show almost the same characteristic signals. These obervations and the fact that flux variations inside the gap of the magnet are likely to be caused by currents on the vacuum chamber point to global current flow.

The path of the currents can be determined by measurements at different locations. For technical reasons a current is measured on a earth cable which is connected in parallel to the vacuum chamber every 40 m. Current clamps were used to measure the parasitic flow. Figure 9 shows the correlation factor of two simultaneous measurements taken at different places along the LEP tunnel. The lower part shows the correlation factor as a function of the position in the storage ring. The upper part of figure 9 shows the correlation plot projected on the LEP ring. One device acts as a reference and stays at the magnet which is equipped with the NMROCT8 probe, whereas the other is displaced. A cor-
Figure 8: Anti-correlation of the flux loop readings. The difference of consecutive flux loop measurements in octant 4 and 8 displayed one against the other.

Figure 9: Correlation of earth cable currents within LEP. Bottom: The correlation factor of two simultaneous earth current measurements near at position of NMROCT8 and the position marked on the horizontal axis is shown. Top: Map of the Geneva area with LEP, the river La Versoix, the Geneva lake and the railways to Lausanne, Bellegarde (Lyon, Paris) and the airport.

Figure 10: Time dependence of three signals recorded at different locations. Top: Voltage between the rails and a reference ground at the Zimeysa railway station. Middle: Voltage between the LEP vacuum chamber and a reference ground near IP8. Bottom: The magnetic field changes measured by NMROCT8.

measured at the Zimeysa train station (fig. 9) several kilometres away from the voltage and B field measurements near IP8. The measured potential difference between the rails and ground is proportional to the current leaking into ground and penetrating LEP. The shape of the three signals is almost identical and caused by a train leaving the main station of Geneva as indicated in figure 9.

3 CONCLUSION

The trains operating between the Geneva main station Cornavin and destinations in France (e.g. TGV, Paris - Geneva) cause a current flow on the LEP vacuum chamber. The currents enter and leave the LEP tunnel near IP1 and IP6. The measured B field variations cause beam energy increases of up to 12 MeV [2, 3].

4 REFERENCES

