

A newly observed effect affects the LEP beam energy

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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 daytime, whereas the reference show almost no time dependence. This characteristic calm period occurs every night.

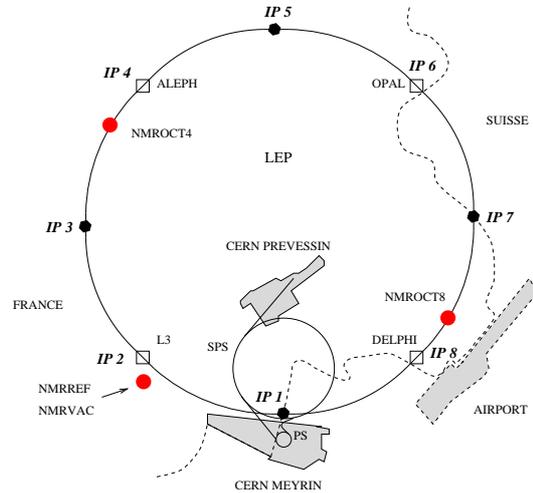


Figure 1: LEP ring with its experiments and the positions of the 4 NMR probes. Two probes, NMRREF and NMRVAC, are installed in the reference magnet in a surface building close to IP2 (L3) while NMROCT4 and NMROCT8 are mounted underground in two LEP bending magnets near IP4 and IP8.

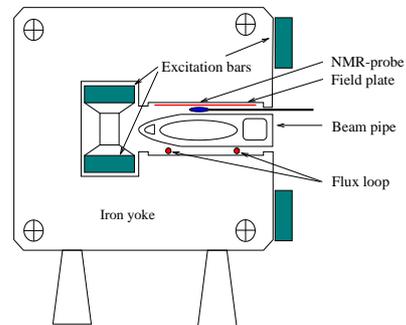


Figure 2: LEP tunnel bending magnet with the NMR probe off centre in the slit between field plate and the vacuum chamber wall. The two flux loop wires are situated underneath the vacuum chamber.

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.

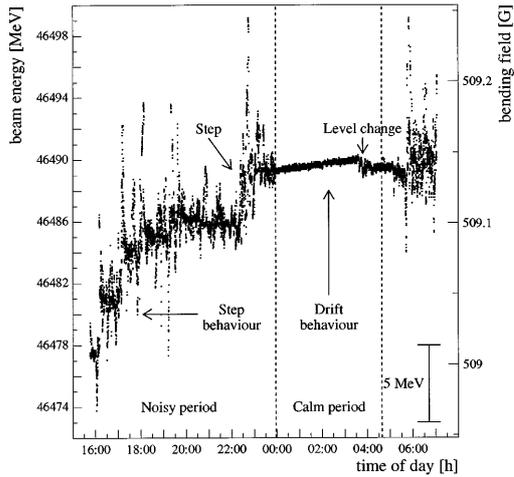


Figure 3: Magnetic field in one tunnel magnet close to IP8 as function of the time in the fill. The B field is expressed in corresponding units of the beam energy.

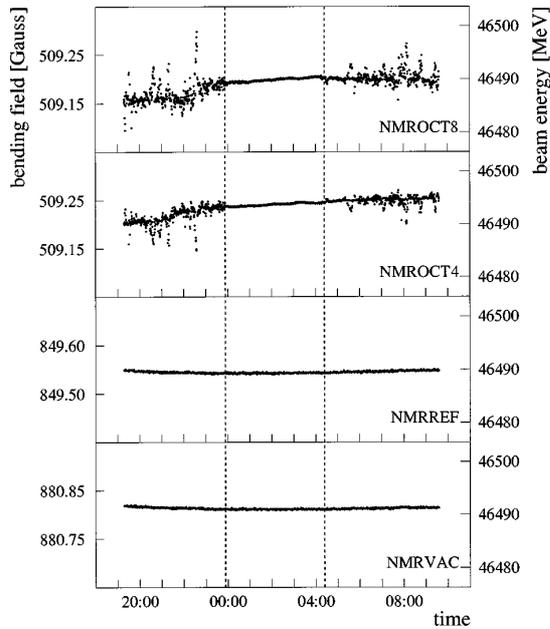


Figure 4: Bending field in Gauss of all NMR probes during one fill. The dotted lines denote the start and the end of the calm period between midnight and four o'clock.

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 observations 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

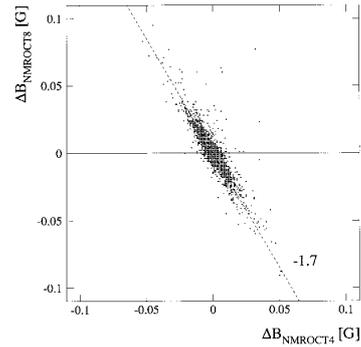


Figure 5: Anti-correlation of NMROCT4 and NMROCT8. The differences of subsequent magnetic field measurements ΔB of NMROCT4 and NMROCT8 are correlated with a coefficient of -1.7.

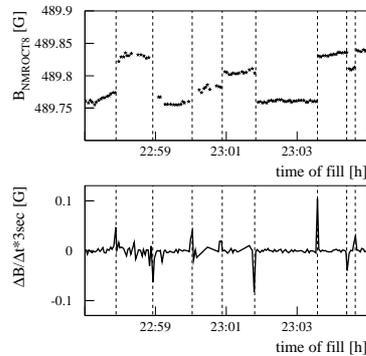


Figure 6: Flux loop readings in octant 8 (bottom) compared to NMROCT8 measurements.

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 correlation denotes a current flow in the same direction of the ring, an anti-correlation an opposite flow. The correlation is changing close to IP1 and IP6. At IP1 the inversion of the correlation occurs around the electron and positron injection

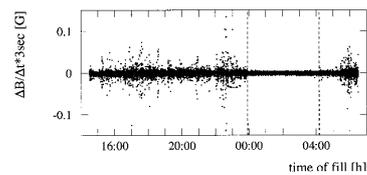


Figure 7: The flux loop readings in octant 8 note the calm period between midnight and four o'clock as well as the NMR probes.

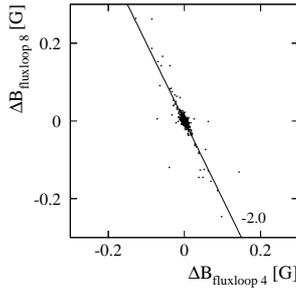


Figure 8: Anti-correlation of the flux loop readings. The difference of consecutive flux loop measurements in octant 4 and 8 displayed one against the other.

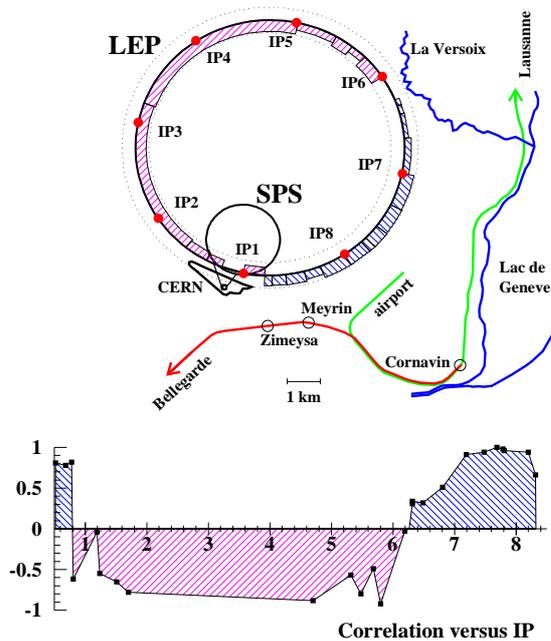


Figure 9: Correlation of earth cable currents within LEP. Bottom: The correlation factor of two simultaneous earth current measurements near at position of NMROCT8 and the position marked on the horizontal axis is shown. Top: Map of the Geneva area with LEP, the river La Versoix, the Geneva lake and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

line (fig. 9 at abscissa value 0.8 and 1.2). Between IP6 and IP7 a more gradual decrease of the correlation is recorded.

The flux loop measurements and the earth cable current measurements pointing to a current which is flowing between two electrical poles in the Geneva area. Therefore the time dependence of the potential differences measured between rails and ground, between the LEP vacuum chamber and a reference ground as well as the B field was recorded (fig. 10). The voltage between the rails and ground has been 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

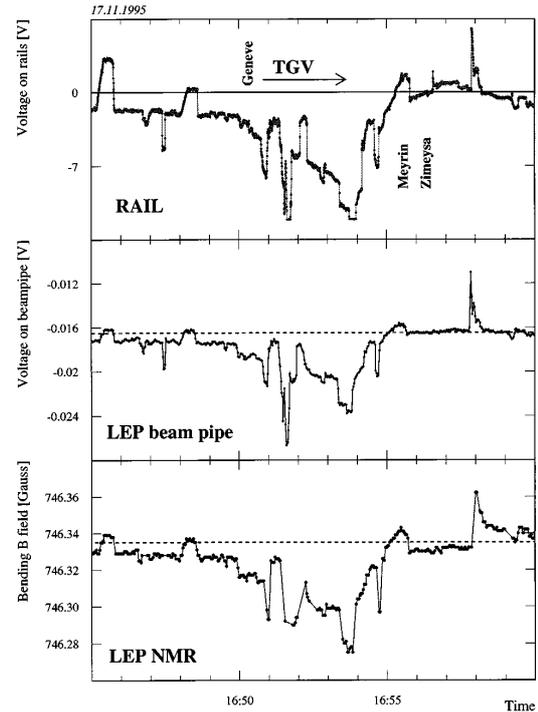


Figure 10: Time dependence of three signals recorded at different locations. Top: Voltage between the rails and a reference ground at the Zimeysa railway station. Middle: Voltage between the LEP vacuum chamber and a reference ground near IP8. Bottom: The magnetic field changes measured by NMROCT8.

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

- [1] R. Assmann *et al*, (The working group on the LEP energy) "The energy calibration of LEP in the 1993 scan", *Zeitschrift für Physik C* 66, 567-582 (1995).
- [2] M. Geitz, "Investigation of the Environmental Effects on the LEP Beam Energy", diploma thesis, RWTH Aachen, PI-THA Nr.96/14, also to be published, CERN SL/96-xx (BI).
- [3] "The Train Effect", CERN, to be published.