Tune Scans in LEP

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Abstract

Luminosity optimization in LEP required systematic studies of the dependence of some beam parameters on the values of the betatron tunes. For this purpose a measurement sequencer was conceived in the environment of the LEP control system which : a) changed the betatron tunes at a speed of about 0.5 Hz and b) acquired data from various beam instruments, such as transverse emittances, beam lifetimes and tunes, at a rate of about 2 Hz.

This paper summarizes the experimental procedure and the subsequent data treatment. Results on the beam sizes as a function of the betatron tunes are shown.

I. Measurement Procedure

During a tune scan the betatron tunes of LEP are changed by triming the main quadrupole strings. The available trim range is $\Delta q_h = \Delta q_v = \pm$ 0.15 with a resolution of 0.001. The maximum number of trim steps is 400 and the time interval between tune changes is 2 seconds., hence a complete scan takes about 12 minutes measurement time. Synchronous to the tune variations several beam parameters are recorded. The tunes themselves are tracked by the LEP q-meter in PLL mode [1]. The transverse beam dimensions are recorded from the UV-monitors and beam lifetimes from the bunch current transformers.

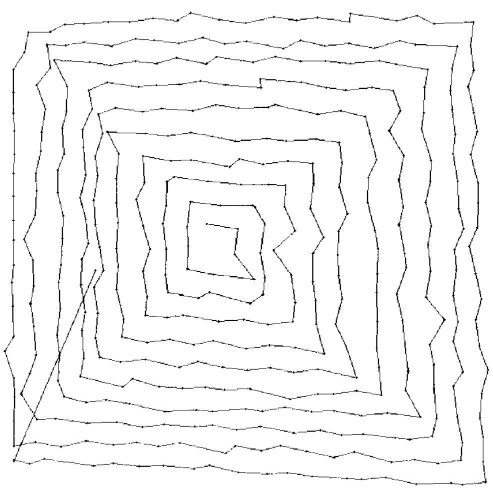

Figure. 1. Trace of measured tunes during a tune scan; horizontal axis: measured q_h; vertical axis: measured q_v

Fig. 1 shows the measured tunes during a tune scan. Consecutive points of the scan are connected with a line. Optionally the scan pattern could be rotated by 45^0 in order to cross specific beam resonances faster.

More details on the measurement procedure can be found in [2] and references therein.

II. Data Processing

As first procedure the data from the different instruments are merged together using timestamps. The synchronism of the clocks of all computers involved allows a synchronisation to a precision of 100 msec. This is adequate for the tune scan application.

After this procedure the data is available for visual inspection.

Before the data of several scans can be joined together another processing step has to be done: Usually one is not able to measure all requested data within the same fill. Beam losses occur when crossing specific resonances and below a certain intensity the data can not be compared to the previous data sets. But as soon as the machine is cycled and refilled, the nominal machine settings are the same, but the machine does not reproduce exactly the same beam parameters for the same tunes. This is easily understood, as the orbit correction is not the same, magnet erros are randomly distributed and the temperature has might have changed.

Hence these variations are taken into account by a readjustment of the data sets to fit to each other. For this purpose a slice along a straight line in the q_h,q_v plane is programmed for each measured beam parameter and the data is displayed with a different symbol for each scan. Fig. 2 shows an example of such a slice. One data set has been left deliberately too low in order to demonstrate the effect.

If the data for a scan does not fit to the global average, the data is adjusted. If the correction has to exceed 10%, the data set is rejected. This entire process is very time consuming, as many slices have to be done and inspected.

III. Available data sets

During the LEP running period 1994 systematic studies of the working diagram were performed. The following machine conditions were of interest: The untuned lattice at injection energy (beam energy 20 GeV, $\beta_v^\star$ = 21 cm) and the tuned lattice at collision energy (beam energy 45.6 GeV, $\beta_v^\star$ = 5 cm).

As LEP was operated in 1994 with horizontal pretzel orbits comparative measurements were done by performing tune scans with the pretzel orbits on or off. None of the available data sets contains beams in collision. Even at moderate bunch currents colliding beams suffer from many more strong resonances and no consistent data set could be recorded over a wide tune range for colliding beams. As an example, the figure on the last page of this paper shows the inverse of vertical and horizontal beam sizes as a function of the measured tunes. In the top picture one can clearly see the main coupling resonance $q_h = q_v$ and its synchrotron sidebands ($q_s = 0.065$). Furthermore the synchro-betatron resonance $q_v = 2 \cdot q_s$ is strongly seen and we see an indication of the third order resonances $q_v = 2 \cdot q_h$ and $q_h = 2 \cdot q_v$ respectively.

IV. Conclusions

A measurement sequencer that records beam parameters as a function of the betatron tunes is a very valuable tool for beam diagnostics and the understanding of the machine lattice. Data of the beam sizes as a function of the betatron tunes have been recorded for many different machine conditions.

It is very difficult to interpret the data for luminosity optimization. The available data is only from seperated beams, hence the effects of the beam-beam force which finally determine the luminosity performance are not included in the scan results. In this case the data from tune scans provide starting information in order to select potential candidates for the working point. On each individual candidate the beams have to be brought into collision and the machine performance has to be studied in detail.

References

[1] K. Lohmann, M. Placidi and H. Schmickler Q-Monitoring in LEP, LEP-BI Note 88-45.

[2] H. Schmickler,"Tune Scans", Proc. of the Third Workshop on LEP Performance, Chamonix 1993.

Figure. 2. Slice through the data for the vertical beam size (top) and horizontal beam size (bottom). The data from each tune scans is indicated with a different symbol.