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Ramping High Currents

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Abstract

Despite recent improvements the LEP ramp is still a delicate flower. Bunch length constraints have been a major hassle in 1998 and a long time was spent setting up a good ramp for high intensities. Possibilities to relax on the bunch length constraints in the future as well as their impact of the ramp will be evaluated. At the level of orbit control, the limitations of the recently introduced orbit feed-forward will be presented. The situation of orbit control in the ramp will be reviewed. Finally possibilities to shorten the turnaround time will be discussed.

1 RAMPS IN 1998

Throughout the 1998 run the ramps have been plagued by the limitations imposed on the power flowing through the RF signal cables. To keep the bunch lengths above 9 to 10 mm the synchrotron tune Q_s had to be lowered for energies above 30 GeV and the wigglers had to be kept on up to very high energies (80 GeV for the emittance wigglers). Those constraints generated a cascade of problems and a solid ramp was only available in September. Fortunately the Qloop worked extremely well.

When a ramp with very good average transmission (97%) was finally established in September a single beam of over 920 μA was ramped without losses to 92 GeV. The tune evolution for this record ramp is shown in Figure 1. This ramp is quite robust and works for a large range of bunch currents with minor tune adjustments at injection.

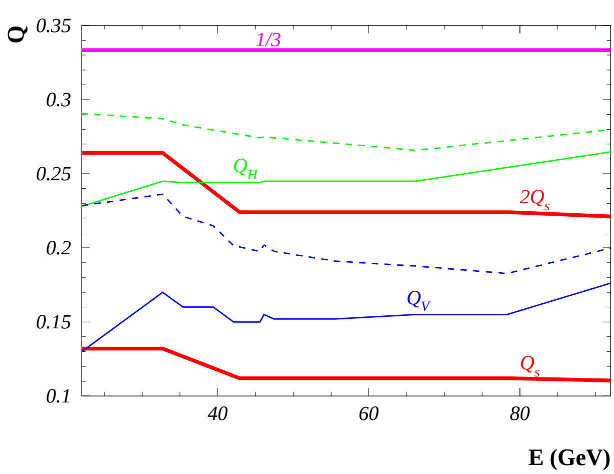

Figure 1: Tune evolution in the standard 1998 operational ramp for a single beam of 920 μA. The coherent tunes are represented by a full, the incoherent tunes by a dashed line. The only SBR that is crossed is $Q_x = 2Q_s$.

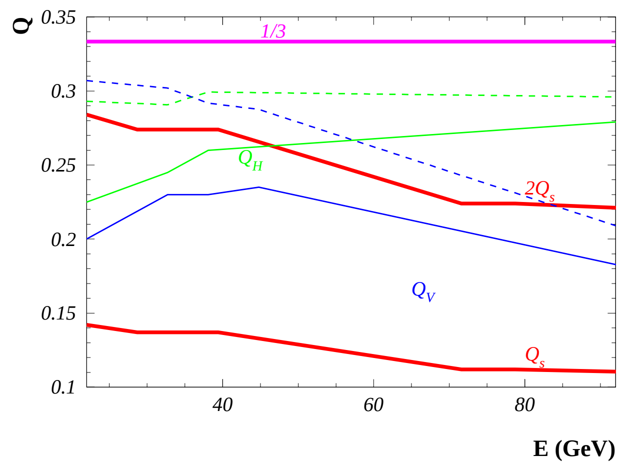

Figure 2: Possible ramp scenario with the a new working point and bunch currents of 1 mA.

2 RAMPS IN 1999

In 1999 all RF cables will have been replaced and limitations related to the power flowing through those cables will have been lifted. In principle this would allow to ramp with any bunch length, but a minimum length of 7 to 8 mm is still recommended to protect HOM couplers and avoid fast transient loads on the cryogenics system.

Nevertheless the Q_s function will have fewer constrains and the wigglers can be ramped down again at more reasonable energies (around 50-60 GeV) to avoid problems for the vacuum system.

Being able to choose “freely” the evolution of Q_s would be very helpful to ramp bunch currents of 1 mA with the new WP [1]. Figure 2 shows a scenario for a ramp based on this new WP with 1 mA bunch currents. The main difficulties arise because the horizontal tunes (coherent and incoherent) sit between the vertical tunes at the start of the ramp and because the coherent coupling resonance must be avoided. Two SBRs must be crossed during the ramp.

A tool to generate, store, recall and display various ramps for the Qloop would be useful to test out various ramp scenarios.

3 ORBIT

An orbit correction feed-forward was developed and used in 1998 [2]. This tool is useful to iron the orbit in the ramp during setup and to follow slow drifts. But it does not work in unstable conditions when the QS0 quadrupoles move around erratically.

A key point for the orbit is the β_y^* squeeze. At 45 GeV the squeeze triggers vertical orbit problems in the middle of the ramp. An analysis of some critical ramps shows however that the problem is less severe if the orbit is properly corrected at injection. When the squeeze was moved to high energy the orbit problems were concentrated over a few vectors and were mastered with an appropriate correction and trim incorporation strategy.

Problems with the orbit in the ramp essentially vanished after September 1998 when the squeeze was moved to high energy, when the orbit was systematically corrected at injection and when orbit drifts in the ramp were corrected once per week with the feed-forward.

The recommendations for the future are therefore :

- β_y^* should be squeezed at high energy.
- The orbit in the ramp should be corrected with the feed-forward.
- The vertical orbit should always be corrected at injection and before the squeeze using the correctors next to the QS0 quadrupoles.
- One should be extremely careful with orbit corrections during stops in the ramp to avoid producing corrector functions with spikes.
- It may be useful to nominate a sheriff to follow the orbit in the ramp.

If those rules are applied we should be on the best track to control the orbit in the ramp.

4 TURNAROUND

Figure 3 shows the distribution of the turnaround time for all fills that were brought into physics. The typical value is 75 minutes and the average 90 minutes. In Figure 4 the contributions of the setup, filling, ramp and adjust periods are shown in more detail. The typical and average delays are given in Table 1.

Table 1: Typical and average time spend in various LEP modes in 1988.

Mode	Typical Time (min)	Average Time (min)
Setup	9/12	15
Filling	20	26
Acceleration	17	20
Adjust	15	19

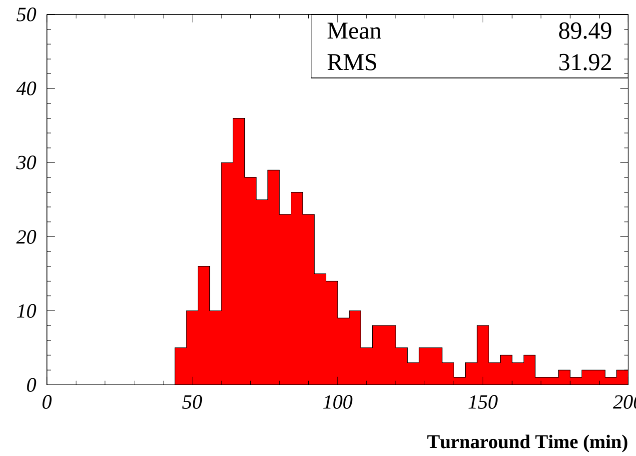

Figure 3: Distribution of the turnaround time for fills that were brought into physics in 1998.

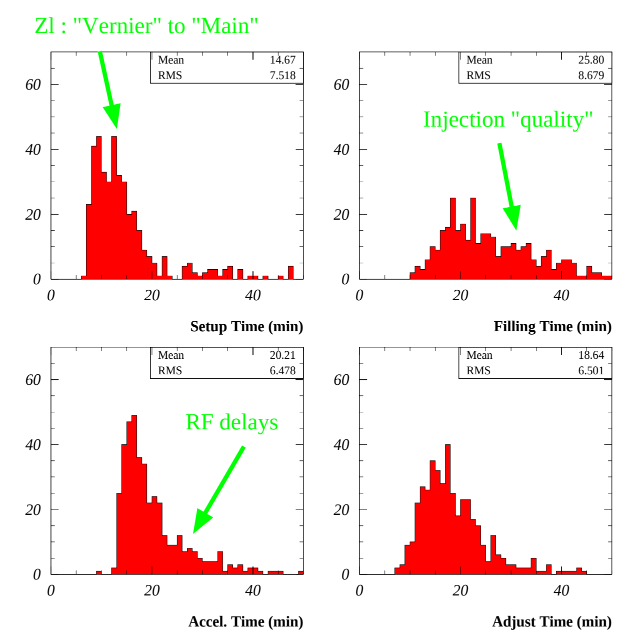

Figure 4: Distribution of setup, fill, ramp and adjust durations for fills that were brought into physics in 1998.

In the future some improvements may reduce the time for turnaround by 5 to 10 minutes and, even more important, reduce the spread in turnaround times.

The shortest time for setup is given by the 5 to 6 minutes required to cycle the main dipoles and to the ramp down the superconducting quadrupoles. The initialisation and the switch from vernier to main generators of the ZLs takes about 3 minutes. It is visible as a second peak in Figure 4. The ZL tasks can be run in the shadow of the dipole cycling.

The distribution of the time required for filling clearly shows that this is the place where one can hope for the largest gains. Reproducible injection conditions in the form of good lepton intensities and high injection efficiencies would be of great help. A regular injection maintenance, for example during or after the RF maintenance period, may be very valuable in that respect.

The minimum ramp time cannot really be improved, since we are limited in ramp speed. The tail in the ramp time distribution visible in Figure 4 is dominated by problems related to the RF system (switch on, oscillations,...).

Loading and correcting the orbit is the “heaviest” task during physics preparation. Time can be gained with a more flexible reload (variable step numbers and sizes, implementation planed for 1999), by incorporating the Golden orbit into the ramp (to reload significantly fewer correctors) and by avoiding lengthy and fancy orbit correction before the beams are colliding.

5 OUTLOOK

For the 1999 LEP run the boundary conditions for the ramp, in the form of tight bunch length constraints, will be relaxed. Bunch lengths will be able to go down to 7 to 8 mm. With the orbit under control nothing prevents us from ramping bunch currents of 1 mA.

The minimum turnaround time can probably be shortened by 5 to 10 minutes. Significant gains of the average turnaround time can be achieved mainly with a more reproducible injection.

6 REFERENCES

[1] K. Cornelis, M. Lamont, M. Meddahi, “New Working Point at 22 GeV”, SL-Note-98-067 (MD).

[2] J. Wenninger, “Orbit in the Ramp”, Proc. of the 8th LEP Performance Workshop, CERN-SL-98-006 (DI).