Presentation 18

Injection Rate

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The injection rate was analysed in an experiment reported in reference [1]. The aim of this experiment was to investigate to what extent the saturation current was limited by the injection process itself.

18.1 The injection process

When an injected bunch arrives at the septum position (see Figure 18.1), the circulating beam is pushed towards the septum by means of three fast kicker magnets (this is referred to as the 'fast injection bump') so that the distance between the injected beam and the circulating beam is adequate.
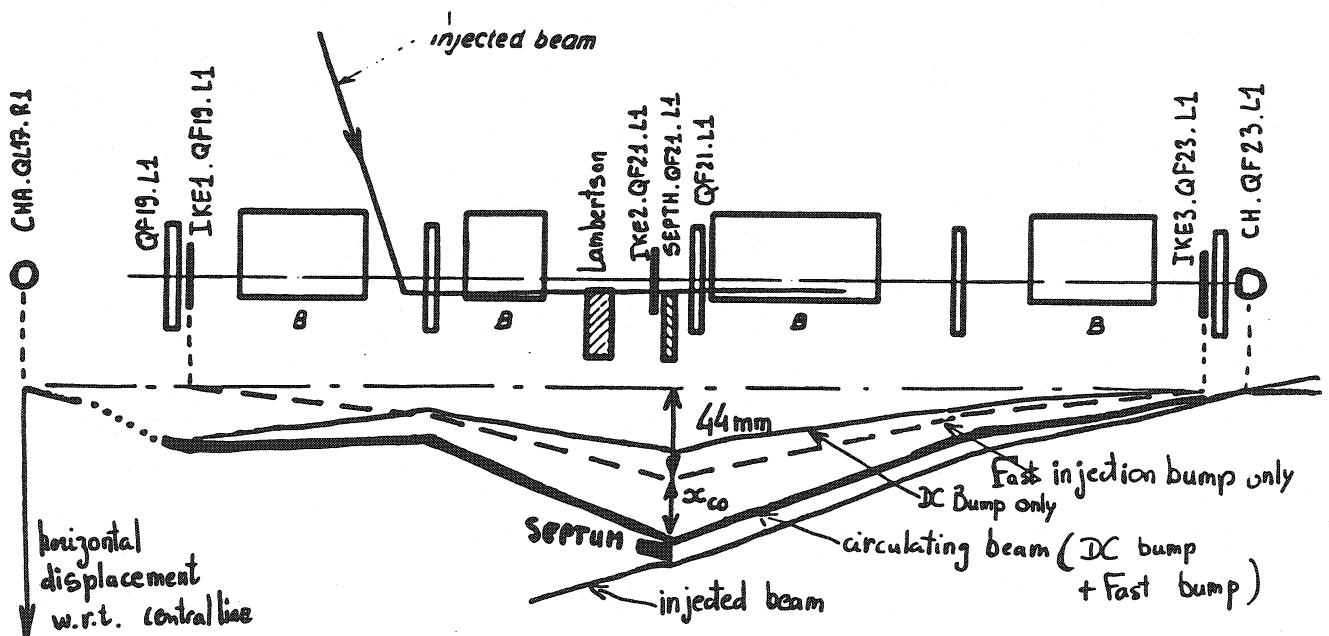

Figure 18.1: LEP injection scheme

If this distance is made too small, the circulating beam may be scraped against the septum, which results in a low stored intensity. If it is made too large the injected beam can be outside the dynamic aperture, which results in a zero injection efficiency. The experiment reported below [1]

was done to quantify this.

18.2   Experiment on injection rate

The distance between the injected beam and the circulating beam at the injection time was varied by means of a local closed orbit distortion which had been calibrated previously. The position of the circulating beam at the septum was also measured with the two adjacent beam position monitors (the sum of their measurement provides the position at the septum [2]) to cross-check the previous calibration.

The stacking rate was measured from the increase of the stored current with time [1]. The injection efficiency was obtained from the additional knowledge of the injected current.

The stacking rate, efficiency and stored current at saturation are shown on Figure 18.2. For all these measurements the machine status is identical, i.e. the incoherent tunes do not change (Q_h=71.38, Q_v=77.26).

18.3   Interpretation of the experiment

For an amplitude of the DC bump smaller than -9mm (see figure 18.1), the fast increase of the saturation current with the bump amplitude can be interpreted in terms of an equilibrium between injected and scraped current. This is confirmed by the measurement of the life time of the circulating beam when the fast kickers are turned on and no beam is injected. For these cases, we assume that the horizontal beam size is given by :

$$\sigma_h = \sqrt{E_h.\beta_h + (bD_h\sigma_e)^2} \tag{18.1}$$

where b is a bunch lengthening factor. We use the measurement corresponding to a position of the DC bump of -12mm (see Figure 18.2), for which the circulating current is very low i.e. b is equal to one, to determine the position of the septum. For the other points, this position is used to compute the number of transverse standard deviations at which the beam is scraped, which makes it possible to obtain b from equation 18.1. The value of b so obtained, multiplied by 5mm, is plotted versus bunch current on Figure 18.3. As the transverse beam size can be obtained also from the beam life time with injection off and kickers on, the values of b obtained this way are also shown. All this is explained in detail in [1].

This interpretation of the saturation current is consistent up to a value of the DC bump at the septum of about -8mm (current per bunch of about 300μA). For values above it, it is not. This suggests the another phenomenon takes over to limit the current per bunch.

18.4   Dynamic aperture at injection

We see on Figure 18.2 that the injection efficiency is zero for an amplitude of the DC bump of about 0mm. This corresponds to a distance between injected particles and circulating beam of about 17mm (with parallel trajectories). Thus for a distance larger than this, the injected particles are lost, i.e. we reached the dynamic aperture of the machine. As this distance is much smaller than what can be expected from tracking [1], an additional experiment was done in order to measure the horizontal dynamic aperture of LEP by kicking a circulating beam [3]. This experiment confirmed the above value.

References

[1]   K. Hübner, A. Verdier, E. Weisse, LEP Commissioning note 20.
[2]   J. P. Koutchouk, LEP Commissioning note 15.
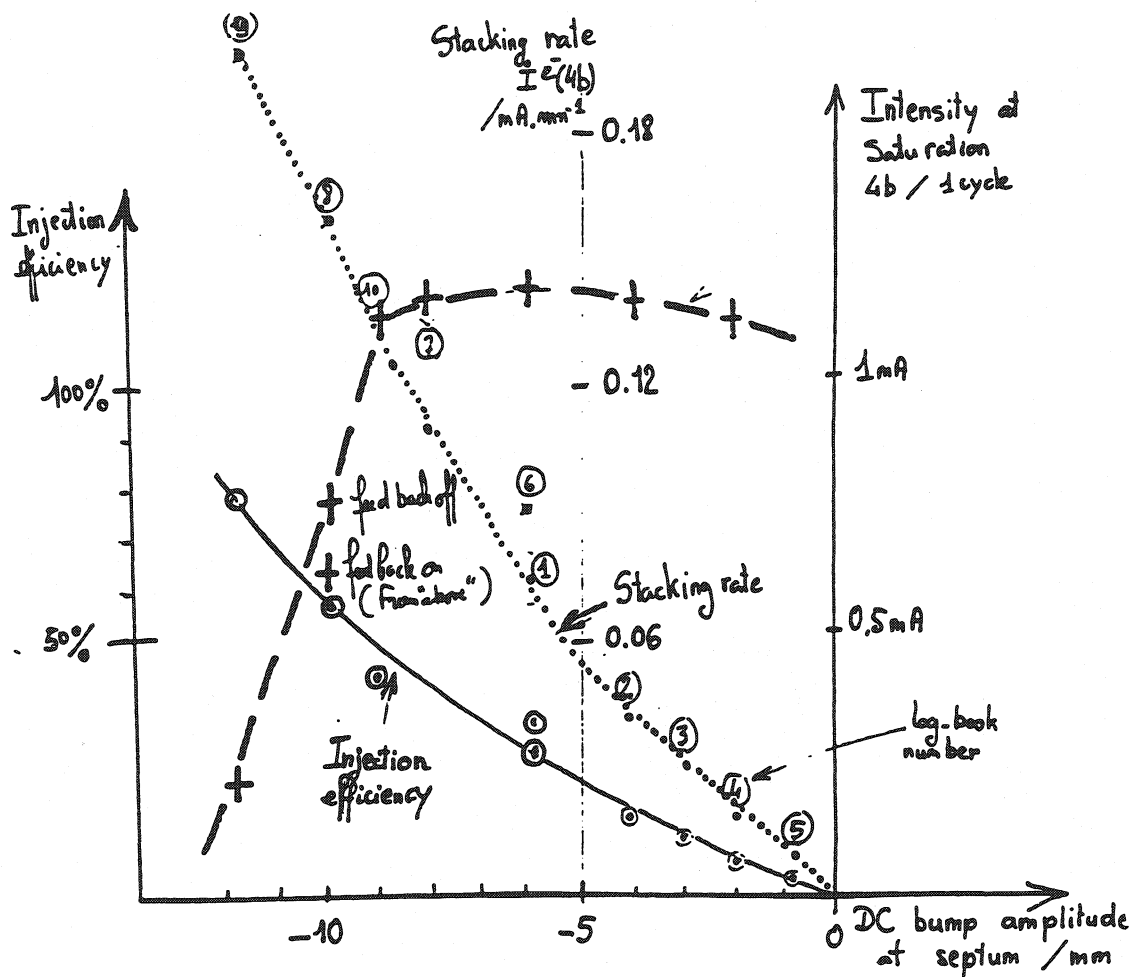[3]   J. Miles, G. Schröder, A. Verdier, E. Weisse, LEP Performance note 30.
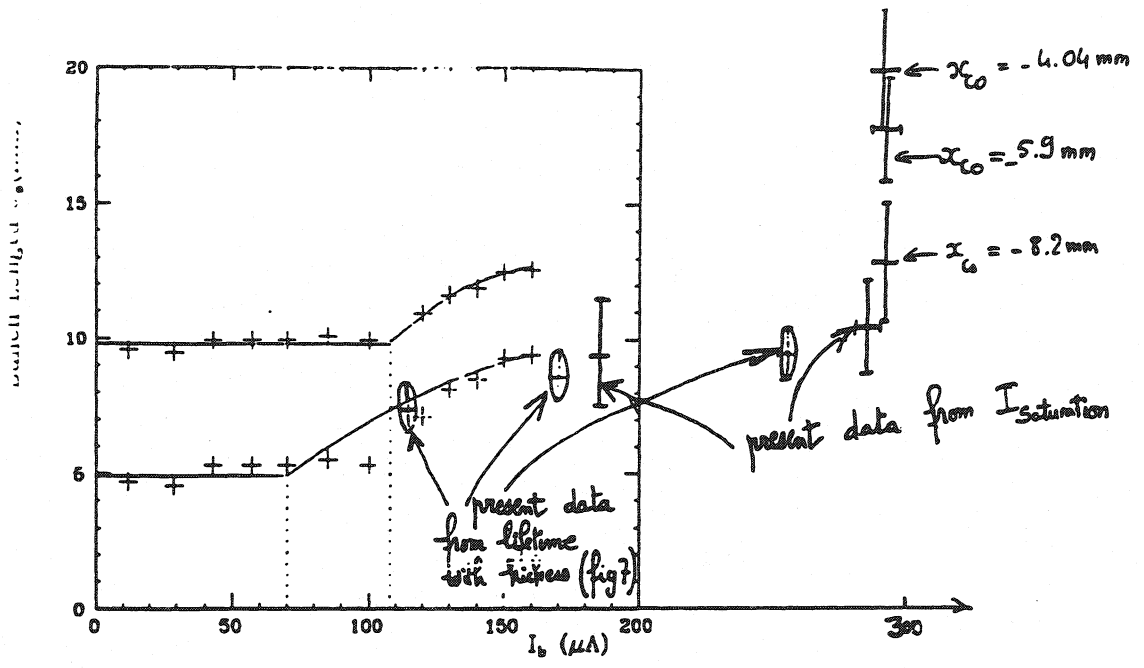
Figure 18.2: Injection as a function of injection bump amplitude

Figure 18.3: Bunch length as a function of bunch current