Tune and Chromaticity Splits in Bunch Trains

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Abstract

Changes in tunes and chromaticities are caused by the head-on and parasitic beam-beam collisions when LEP is operated with bunch trains. Two LEP configurations are considered, (i) L05P46 with bunch train collisions near pits 4 and 8 during the tests in November and December 1994, and (ii) M05P46 with collisions between four bunch trains in each beam foreseen for 1995. The chromaticities change by about a unit when the beam-beam effects at the even IPs are taken into account. These changes are believed to be caused by the β-beating due to the focusing action of the head-on beam-beam collisions. The tunes and chromaticities also differ for different bunches in the trains. The tune differences are as expected. The chromaticity differences depend on the configuration, and are of the order of unity, and larger than one might naively expect. Neither difference can be removed by static fields.

1 Introduction

During the bunch train tests in November 1994, tune and chromaticity splits between the bunches in a train were observed [1]. They must be caused by the head-on beam collisions in Pits 4 and 8, and the nearby parasitic beam-beam collision. Section 2 gives the results for tune and chromaticity splits in the LEP configuration L05P46 used in November and December 1994, while Section 3 gives the results for the LEP configuration M05P46 which will be used in 1995. Both are based on simulations with MAD. Section 4 contains my conclusions.

2 LEP Configuration L05P46 in 1994

For the bunch train tests in November and December 1994, bunch train bumps were only installed and bunch train collisions occurred only near Pits 4 and 8.

I define BEAMBEAM elements at all collision points, install them in groups, and execute TWISS commands. I use the term "collision points" when I do not distinguish between head-on and parasitic collisions, and the term "interaction point (IP)" for the head-on collision points. I label the collision points in the neighbourhood of the pits from A to G, where D coincides with the head-on collision point IP. Collision points A to C are to the left of the IP, while collision points E to G are to the right of the IP. I study the following cases:

- Single beam, i.e. no BEAMBEAM elements
- BEAMBEAM elements at IPs 4 and 8
- BEAMBEAM elements at all even IPs
- BEAMBEAM elements at collision points A to D in Pits 4 and 8
- BEAMBEAM elements at collision points B to E in Pits 4 and 8
- BEAMBEAM elements at collision points C to F in Pits 4 and 8
- BEAMBEAM elements at collision points D to G in Pits 4 and 8

In all calculations, I assume the following beam parameters: Energy $E = 45.6$ GeV, horizontal emittance $\epsilon_x = 30$ nm, vertical emittance $\epsilon_x = 1.2$ nm, bunch population $N = 2.78 \times 10^{11}$, corresponding to a bunch current $I = 0.5$ μA. In the last four cases, there are always four regularly spaced collision points, as seen by the four bunches in the train. The results of the simulation are shown in Tab. 2.

Table 2: Horizontal and vertical tunes, Q_x and Q_y, and horizontal and vertical chromaticities, Q'_x and Q'_y for various collision patterns during the 1994 tests

Collision pattern	Q_x	Q_y	Q'_x	Q'_y
Single beam	90.289232	76.194238	1.002426	0.996986
IPs 4 and 8	90.372094	76.257129	−1.406906	−1.368651
Even IPs	90.436430	76.306284	−2.404394	−2.835564
A-D in Pits 4 and 8	90.380113	76.234205	−0.985616	2.655608
B-E in Pits 4 and 8	90.386000	76.254552	−0.969160	0.115623
C-F in Pits 4 and 8	90.386000	76.254553	−0.969374	0.114423
D-G in Pits 4 and 8	90.380117	76.234218	−0.985686	2.648789

The row labelled "Single beam" simply shows that the configuration L05P46 has the desired tunes and chromaticities. With beam-beam collisions only in IPs 4 and 8, in the row labelled "IPs 4 and 8", both tunes increase by$\Delta Q \approx 2\xi$, and the chromaticities are lowered by a few units. When head-on beam-beam collisions at all even IPs are included, in the row labelled "Even IPs", the

- BEAMBEAM elements at collision points C to F in all pits
- BEAMBEAM elements at collision points D to G in all pits

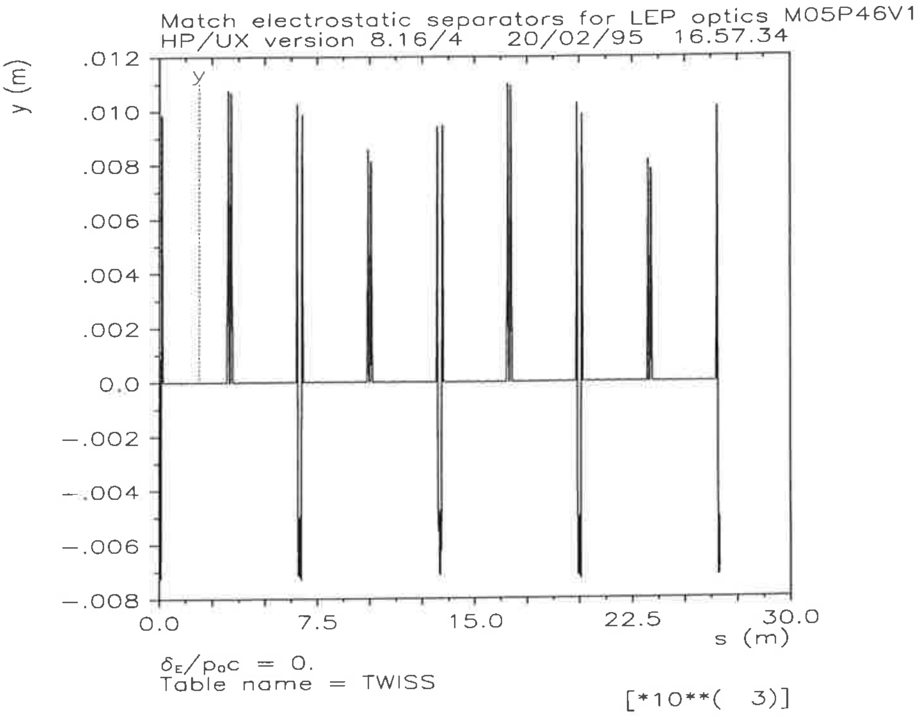

Figure 2: Vertical orbit bumps y for positrons in LEP for the electrostatic bumps in the M05P46 configuration at 45.6 GeV. Pit 1 is at the left.

Table 3: MAD files for the LEP Configuration M05P46 in 1995

Name	Contents
`feb20e.dat`	MAD input data
`feb20e.lis`	MAD output listing
`feb20e.ps`	MAD graphics file

The MAD data and results are in my directory **`LEP/LEP95/M05P46/20Feb95`** on the hp system. The files are shown in Tab. 3. The results of this calculation are summarized in Tab. 4. Including the beam-beam effects at IPs 4 and 8 in the M05P46 configuration changes the tunes as expected. The chromaticities change again by about half a unit. With beam-beam effects in all four even

[2] C. Bovet et al., CERN SL/94-95 (AP) (1994).

[3] E. Keil, SL-MD Note 46 (1992).

[4] A.Verdier and C. Zhang, private communication (February 1995).