EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

CERN - SL Division

SL/Note 94-96 (BT)

MODIFIED LEP SEPARATOR CONFIGURATIONS FOR OPERATION WITH BUNCH TRAINS

B.Goddard, W.Kalbreier, M.Lamont, V.Mertens

Abstract

It is planned that LEP will be operated with Bunch Trains from 1995 onwards, in order to meet the luminosity requirements at LEP2 energies. Additional separators are necessary to provide the required separation around the even experimental Interaction Points (IPs), and modifications to the existing installations are also necessary in the odd IPs. In addition to the changes required to the controls software at various levels, the opportunity will also being taken to migrate the process controllers from XENIX and OS-9 to LynxOS, which particularly affects expert software. In this note details are given of several important modifications which have been made to the original proposal. The newly proposed configurations in 1995 and 1996 will provide additional flexibility for the Bunch Train scheme, and allow a streamlining of the controls of the various separator types (ZL, ZL2, ZX, ZY). Under this new proposal a return to Pretzel operation could be possible at any time during 1995 with a minimum of machine intervention.

Geneva, Switzerland
28 November, 1994

(SL/Notes. '94)

CONTENTS

1. INTRODUCTION.

A detailed breakdown of the implications of the Bunch Train scheme for the LEP separator systems has already been made in [1]. This note describes the main features and advantages of a recent new proposal [2] which offers significant advantages over the previous plan.

1.1. LEP2 requirements

The peak LEP luminosity in 1994 was $\approx 2\times10^{31}$ cm^{-2}s^{-1}, which gave an integrated luminosity of ≈ 60 pb^{-1}. The target for LEP2 in three years of operation is 500 pb^{-1}, requiring a peak luminosity of around 7×10^{31} cm^{-2}s^{-1}. To achieve this high luminosity at least eight bunches per beam, with around 1 mA per bunch, will be required. However, the Pretzel scheme has been limited to bunch currents of around 400 μA by the horizontal beam-beam encounters in mid-arc, although recent results have shown that more current can be accumulated under special conditions [3].

The proposed Bunch Train scheme [4] should not suffer from this fundamental limitation, since vertical separation bumps are created in the long straight sections where the momentum dispersion is very small. It is therefore hoped that the same bunch currents can be achieved as for normal four bunch operation.

The minimum inter-bunch spacing of 87 λ_{rf} (74.2 m or 247.5 ns) is imposed by the distance from the IP to the first separator, and the maximum number of bunches in a train is limited to four by the capabilities of the LEP experiments. At Z° energies LEP will be able to operate with four trains of positrons against four trains of electrons, with a total of up to 16 bunches per beam. At W-pair energies, the available RF power will limit the current to a maximum of around 8 mA per beam. The maximum luminosity would then be obtained with eight bunches per beam and 1 mA per bunch. This would correspond e.g. to four trains of positrons and four trains of electrons, each with two bunches.

2. A NEW SEPARATOR CONFIGURATION FOR BUNCH TRAINS

2.1. Proposal

The newly proposed separation scheme for Bunch Trains in 1995 is shown for the even IPs 2,4,6 and 8 in figure 1. Newly constructed ZL2 separators will be placed between the quadrupoles QS6 and QS7 to provide the separation bump. The first four ZL2 vertical separators have already been installed in IPs 4 and 8 for the initial tests of the scheme.

In the odd straight sections half of the existing separators must be moved to positions further away from the IP, figure 2. The existing Pretzel separators ZX will stay in the machine until the 1995/96 shutdown, to allow a final choice of scheme for LEP2 to be deferred until sufficient operational experience has been gained with Bunch Trains. The ZX units will then be transformed into vertical separators ZY, and redeployed near the existing separators ZL.QS2 in the even IPs, giving the final LEP2 configuration shown in figure 3.

This new scheme differs significantly from the original proposal detailed in [1] in the following ways:

- All ZX and ZX trim separators now remain in LEP until the end of 1995, instead of removal in the 1994/95 shutdown. A return to Pretzel operation would therefore be possible without significant machine intervention.

- The QS7 separators for Bunch Trains will now be of type ZL2, rather than ZY (modified ZX). This means that the four units already installed in IPs 4 and 8 will remain in the present positions. All these units will be powered by the high voltage (HV) generators of the present Pretzel separators, with one electrode at HV and one at ground.

- The extra separators to be installed in the 1995/96 shutdown near the existing ZL.QS2 units for LEP2 purposes will be of type ZY.

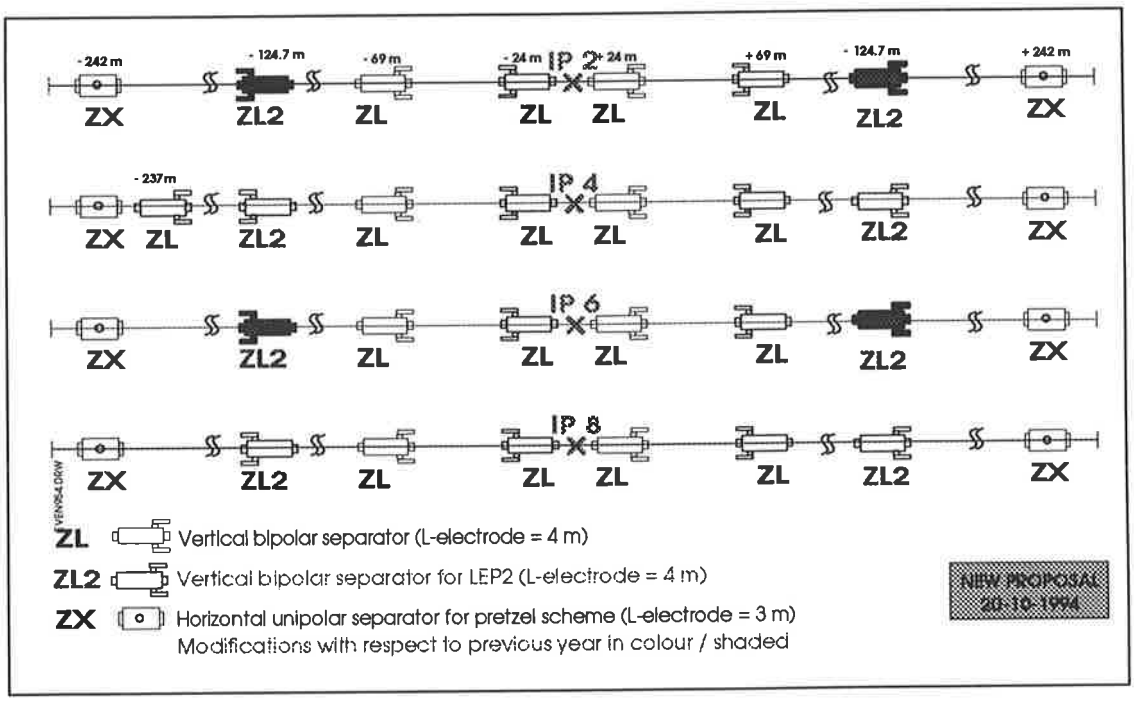

Figure 1: 1995 Bunch Train separator layout in even IPs 2, 4 6 and 8.

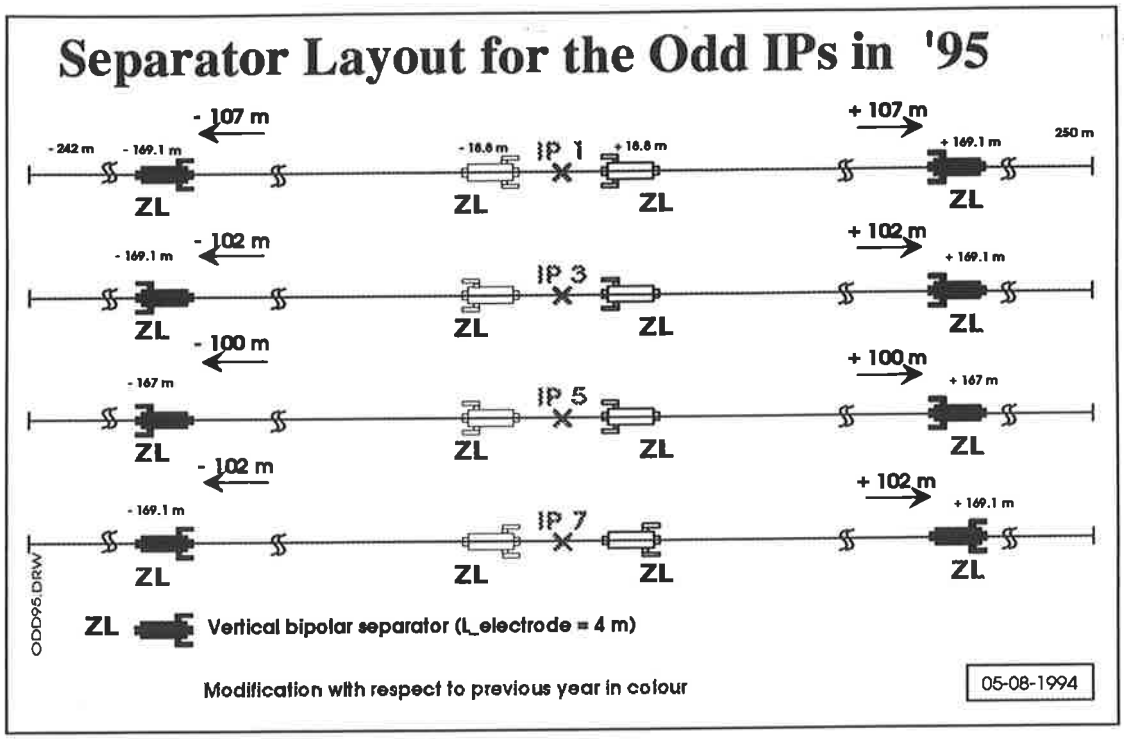

Figure 2: 1995 Bunch Train separator layouts in odd IPs 1, 3, 5 and 7.

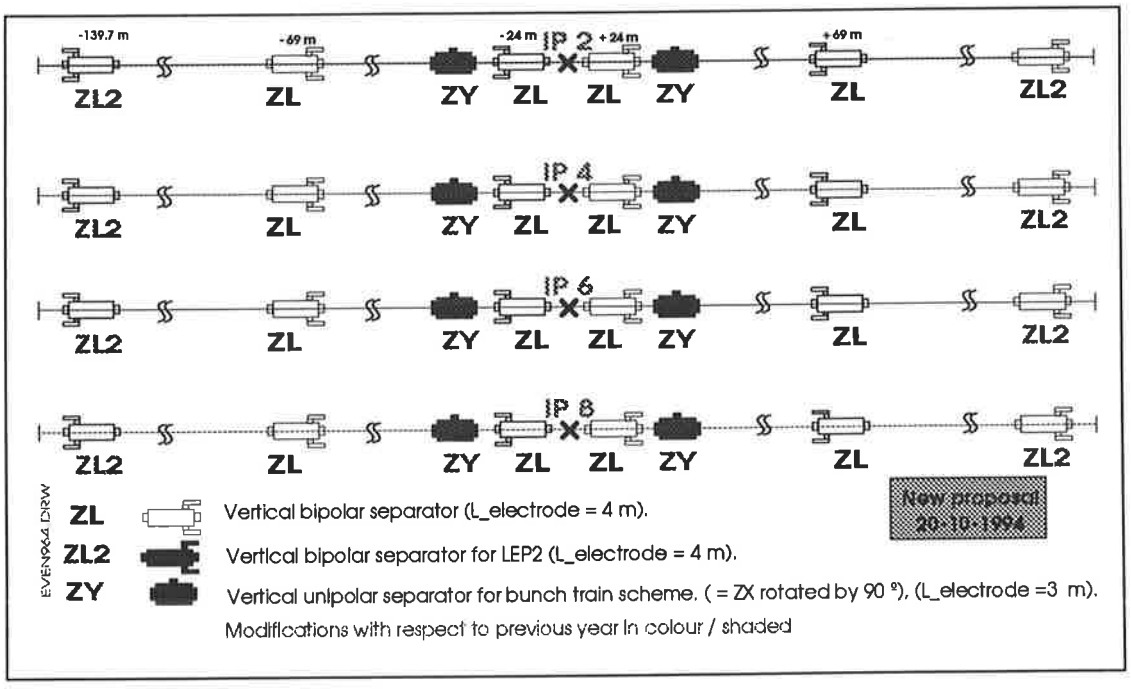

Figure 3: 1996 Bunch Train separator layouts in even IPs 2,4,6 and 8.

2.2. Features and advantages

The modified scheme has the following features and advantages:

- The Bunch Train separators next to QS7 are at situated at a distance from the IP corresponding to a phase advance of about $3\pi/4$. The separation at the even IPs is limited by the integrated field of these separators, which in turn could limit the maximum bunch current at injection. More separation will be available with the new scheme; i) because the electrodes of the ZL2 units are 4 m long compared to 3 m in the ZY units, the available integrated field $E\times L_{new} = 8.9$ MV, compared to $E\times L_{old} = 7.5$ MV; and ii) because the ZL2 units are bipolar, as opposed to the monopolar ZY units, the possibility exists to connect both electrodes to high voltage generators of opposite polarity and thus increase the available integrated field to $E\times L_{new} = 12.4$ MV. The potential gain is therefore a factor of about 1.7.
- The separators next to QS4 need not to be modified since they are used at only 36% of their maximum E×L.
- The separators next to QS2 will be used at about 93% of their maximum E×L=12.4 MV. In the earlier proposal it was planned to add extra ZL2 units which would increase the maximum E×L by about a factor two. However, a more modest upgrade will now be made by adding the ZY units at this location, with E×L = 4.7 MV. This will give a total E×L = 17.1 MV, an increase of 38% which should be an ample safety margin. This upgrade is only necessary for LEP2, and can wait for the long 1995/96 shutdown.
- For the existing Pretzel sextupoles the proposal is now to leave half in LEP and modify the other half for Bunch Trains, involving a rotation about the horizontal axis by 30°. Preliminary measurements of the electron/positron tune split with Bunch Trains indicate that this should be sufficient.

3. SEPARATOR POLARITY AND CLOSED ORBIT BUMPS

3.1. Initial tests in 1994

For the initial tests in 1994 it was realised that the polarities of the closed orbit (c.o.) bumps in IPs 4 and 8 should be opposed, in order that the residual vertical dispersion be reduced to acceptable levels. With the convention that a positive (+) bump is defined by an upwards deflection of positrons in the first separator, the bump in IP4 was installed as positive, and that in IP8 negative. In both IPs this installation involved the polarity reversal in two ZL separators, and in IP8 the polarity of the new ZL2 separator was also inverted.

3.2. Operation in 1995 and beyond

With all four Bunch Train bumps in the even IPs, 'MAD' simulations [4] have shown that two of the bumps should be positive and two negative. This combination minimizes both the offsets in the collision of the bunches of a given train, and the residual vertical dispersion. The simulations require that the bumps in the odd IPs are all of the same sign, and the constraints from the LEP beam dumping system in IP 5 fixes this to be positive. For practical reasons concerning the number of polarity reversals and conditionings required the variant shown in table 1 was chosen.

LEP IP	1	2	3	4	5	6	7	8
bump polarity	+	-	+	+	+	-	+	+

Table 1: Chosen combination of separator Bunch Train c.o. bumps.

4. MODIFICATIONS TO CONTROLS SOFTWARE AND HARDWARE

4.1. Initial tests in 1994

For the initial tests in 1994, the existing hardware of the Pretzel separators has been used to power the newly-installed ZL2 separators. Shortly before the start of the extended Bunch Train test period the high voltage cables from the Pretzel tanks were swapped to the ZL2 tanks, together with the required control cables.

The setting of the voltage levels for the existing ZL separators has been done using the present PCR level software ('Sloppysoft'). New procedures for the ramp, squeeze, collide and vernier adjustment have been defined and incorporated into the 'LEPexec' control sequencer. For the new ZL2 separators the existing Pretzel separator expert software has been used, which has proved adequate to date (the voltage on these separators ideally remains constant, and in practice is changed infrequently).

4.1. Operation in 1995 and beyond

For operation in 1995 and beyond the two ZL2 separator tanks in each IP will be powered by the existing Pretzel HV power supply, controlled by the existing SPS type hardware. Several important changes will be made to the existing controls software and hardware, in order to render the overall control and surveillance of the separators more homogeneous.

- A significant effort will be made to replace the existing XENIX PCAs with LynxOS PCs. XENIX is becoming increasingly obsolete, and an effort is currently being made by SL/CO to phase out all XENIX machines. This changeover requires a complete rewrite of the expert programs 'console' and 'acond', both of which make heavy use of the CGI graphics package which is not available on LynxOS. 'Console' is extensively used for diagnostic purposes by the separator specialists in the eight different LEP HV zones, and is also used in the PCR for non-standard controls, e.g. during MD, and for commissioning of new operational procedures; 'acond' is used primarily during the long shutdown for automatic HV conditioning of the separators, saving time for the equipment specialists.

- The high-level control of the new ZL2 separators for operation will be moved to the 'Sloppysoft' interface, involving the commissioning of various 'black boxes' for the equipment control and surveillance. Some modification of the 'Sloppysoft' interface will be necessary to properly incorporate the use of tables for bringing the beams into collision, switching between LEP hyper-runs, ensuring updated settings for vernier adjustment, allowing synchronous variation of bump amplitudes, etc. At this occasion the equipment access, including the ZL separators, will be changed to use the new 'EQUIP' mechanism via a message handler [5], which will also entail modification of 'Sloppysoft' to use 'MEQUIP'.

- The reception and redistribution of the timing signals for the ZL separators will be moved away from the present G-64 based hardware to controller cards in the LynxOS PCs. This approach offers more direct access and monitoring facilities.

- The expert software used for in-depth control and analysis of the existing Pretzel separator systems will also be incorporated into the new 'console' program, thus providing a centralised and more homogeneous diagnostic interface. The old expert software 'prinst' will be ported to LynxOS, so that it will remain available for a possible resumption of Pretzel operation.

- The current alarms and diagnostic software will be updated to take account of the changes, and upgraded to incorporate the new requirements of the SL/BT and SL/OP users.

- The logging of separator data is at present accomplished using flat files stored on a SL/BT machine and viewable by 'EXCEL'. Part or all of this will be moved into the existing LEP measurement and logging database (DB) framework, at least for the most essential parameters such as separator voltages and spark events. This will enable rapid correlation with currently logged parameters, the benefits of a centrally maintained DB, and the possibility of producing fixed PCR displays for improved operational feedback.

REFERENCES

[1] B.Balhan, J.-P.Deluen, J.H.Dieperink, N.Garrel, B.Goddard, R.Guinand, W.Kalbreier, M.Laffin, V.Mertens, *Separator systems for the LEP Bunch Train project*, SL/Note 94-64 (BT), 1994.

[2] W.Kalbreier, in Summary notes of the forty-second meeting of the Bunch Train study group, 1994.

[3] L.Arnaudon, P.Collier, K.Cornelis, M.Jonker, J.Jowett, R.Olsen, E.Peschardt, *Removal of the Pretzel intensity limit*, SL MD Note 150, 1994.

[4] Bunch Train study group, *Preliminary report of the 1994 Bunch Train study group*, CERN SL/94-72 (AP), 1994.

[5] P.Charrue, *Accessing equipment in the SPS-LEP controls infrastructure: the "SL-EQUIP Package"*, CERN SL/93-86 (CO), 1993.

DISTRIBUTION

ARNAUD, C.	MT/ESI
BAILEY, R.	SL/OP
BALHAN, B.	SL/BT
BARISY, A.	SL/BT
BILLY, J.C.	AT/VA
BOBBIO, P.	SL/BT
BOHL, T.	SL/OP
BONVIN, R.	SL/BT
BORER, J.	SL/BI
BOVET, C.	SL/BI
BOUSSARD, D.	SL/RF
BRUNNER, O.	SL/RF
BURKHARDT, H.	SL/OP
CAMPORESI, T.	PPE/DED
CARLIER, E.	SL/BT
CASTELLI, G.	SL/BT
CHARRRUE, P.	SL/CO
COLLIER, P.	SL/OP
CORNELIS, K.	SL/OP
DEDIEU, B.	SL/BT
DEHNING, B.	SL/BI
DELUEN, J.-P.	SL/BT
DE RIJK, G.	SL/OP
DIEPERINK, J.	SL/BT
DUCRET, R.	SL/BT
EVANS, L.	DG/DI
FAUGIER, A.	SL/OP
FERNQVIST, G.	SL/PC
FISCHER, C.	SL/BI
FOFFANO, G.	MT/ESI
FOA, L.	DG/DI
GAREYTE, J.	SL/AP
GARLENC, V.	SL/BT
GARREL, N.	SL/BT
GELARD, D.	ENT/BT
GESCHONKE, G.	SL/RF
GODDARD, B.	SL/BT
GRAFSTRÖM, P.	SL/EA
GRÖBNER, O	AT/VA
GUINAND, R.	SL/BT
GYR, M.	SL/BT
HAEBEL, E.	SL/RF
HERR, W.	SL/AP
HILAIRE, A.	SL/BT
HILLERET, N.	AT/VA
HOHBACH, R.	PS/RF
HÜBNER, K	DG/DI
VON HOLTEY, G.	SL/EA
JONKER, M.	SL/OP
JOWETT, J.	SL/AP
JUNG, R.	SL/BI
KALBREIER, W.	SL/BT
KEIL, E.	SL/AP
KEIZER, R.	SL/BT
KINDERMANN, H.	SL/RF
KISSLER, K.H.	SL/DI
KLEM, J	SL/AP
LAFFIN, M.	SL/BT
LAMONT, M.	SL/OP
LAUCKNER, R.	SL/CO
LAURENT, M.	MT/ESM
MARCHAND, A.	SL/BT
MEDDAHI, M.	SL/AP
MERLE, F.	SL/BT
MERTENS, V.	SL/BT
MUTTONI, Y.	MT/ESI
MYERS, S.	SL/DI
PERAIRE, S.	SL/BT
PESCHARDT, E.	SL/RF
PINGET, B	ENT/BT
PLACIDI, M.	SL/BI
PONCET, A.	MT/ESH
POOLE, J.	SL/DI
RIZZO, A.	SL/BT
ROLANDI, L.	PPE/ALE
ROSS, M..	SL/BT
ROY, G.	SL/OP
SCHMICKLER, H.	SL/OP
SCHRODER, G.	SL/BT
SOUBEYRAN, J.	SL/BT
TAYLOR, T.	AT/MA
VERDIER, A..	SL/AP
VERHAGEN, H.	SL/BT
VERSOLATTO, B	AT/VA
VOSSENBERG, E.	SL/BT
WENNINGER, J.	SL/OP
WEISSE, E.	SL/BT
WYSS, C.	AC/DI
ZOTTER, B.	SL/AP