# MODULATION OF THE LEPTON PRODUCTION FOR THE CERN LEP PRE-INJECTOR

G.P. Benincasa, P. Burla, L. Casalegno, A. Daneels, J.P. Delahaye
B. Frammery, F. Giudici, I. Kamber, J. Lewis, P. Schenkels, C.-H. Sicard, Ch. Serre
PS Division, CERN, CH-1211 Geneva 23, Switzerland

Abstract: Unique features of the LEP Pre-injector (LPI) machine, first stage of the CERN complex dealing with $e^+/e^-$, lead to specific modulation techniques for the alternate lepton production schemes. The LPI consists of both a Linac pulsing up to 100 Hz and an Accumulator adapted to the slower cycling of the CPS machine, next stage of the lepton production.

In addition to a well-known Pulse-to-Pulse-Modulation (PPM) of the CPS, a multi-level sequencing device is needed to drive the LPI. Extra constraints come from ins-precise timing requirements for the Linac and lack of dead time in the accumulator stacking process.

After a description of the operating principles, comes an analysis of the methods used to deal with simultaneous slow and fast modulations; according to the CPS master requirements, a two-stage local sequencer drives alternate cycling of both the Accumulator and the Linac production settings. Finally, one standard scheme is presented to illustrate the current possibilities of these modulations.

## Introduction

The LPI consists of a 500 MeV Linac pulsing at 100 Hz (LIL) and an Accumulator (EPA) producing electrons or positrons for the CPS-SPS-LEP machine complex (Fig.1). The basic requirements for this production are the following: within a repetitive frame of a number of 1.2 sec periods, the LPI should provide a few bunches of $e^-$ or $e^+$ of a required intensity. The 1.2 sec period is called BASIC PERIOD (BP) and the frame, a SUPERCYCLE. In between those, a CYCLE consists of a number of BPs separating two consecutive ejections. The 10 msec Linac repetition rate is referred to as LIL period [1].

In the Linac, for $e^+$ production, a high intensity $e^-$ beam, produced by an $e^-$ Gun is accelerated to 200 MeV, hits a Converter target which produces secondary low energy positrons accelerated to 500 MeV. The energies on the Converter and at the end of the Linac are controlled through the HF phases in the six klystrons and through timings driving the saving and

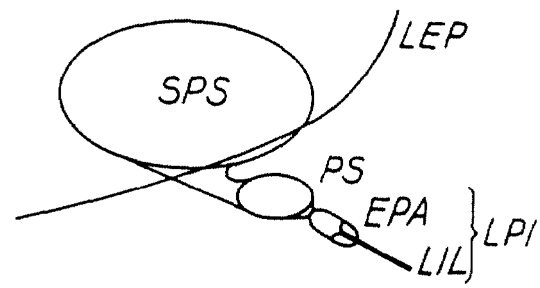


*FIG. 1: THE LPI ACCELERATORS IN THE LEP COMPLEX*

restoring of HF power in the LIPS cavities. For the $e^-$, the Converter is removed and a low intensity $e^-$ beam is produced by the Gun and accelerated through a defined set of accelerating sections to get to the same final energy as the $e^+$. Despite a constant 100 Hz pulsing of all the LIL power equipments for thermal stability, timing handling allows for an effective beam production rate ranging from 1 to 100 Hz.

On every cycle, the Linac bunches are injected into the Accumulator on a bunch-to-bucket mode. Accumulation to the required intensity is performed into one to eight bunches. An HF 19 MHz cavity compensates for energy losses due to Synchrotron Radia tion. The beam is stored for complete damping and ejected to the CPS on CPS request, also on a bunch-to-bucket mode. In the following Cycle, accumulation may resume after a few millisecond dead time with the other particle type.

As the same Gun, Linac and Accumulator are used for both type of particles and various production schemes, the Pulse-to-Pulse Modulation (PPM) must deal with the Gun settings, the Converter position, the Linac accelerating system HF phases and timings, the steering and focusing elements along the Linac and the injection lines, the Accumulator HF cavity phase and injection/ejection devices (bumpers, kickers, septa) (Fig.2). All the Linac timings as well as the fast injection and ejection ones are to be of a one-nanosecond absolute precision.

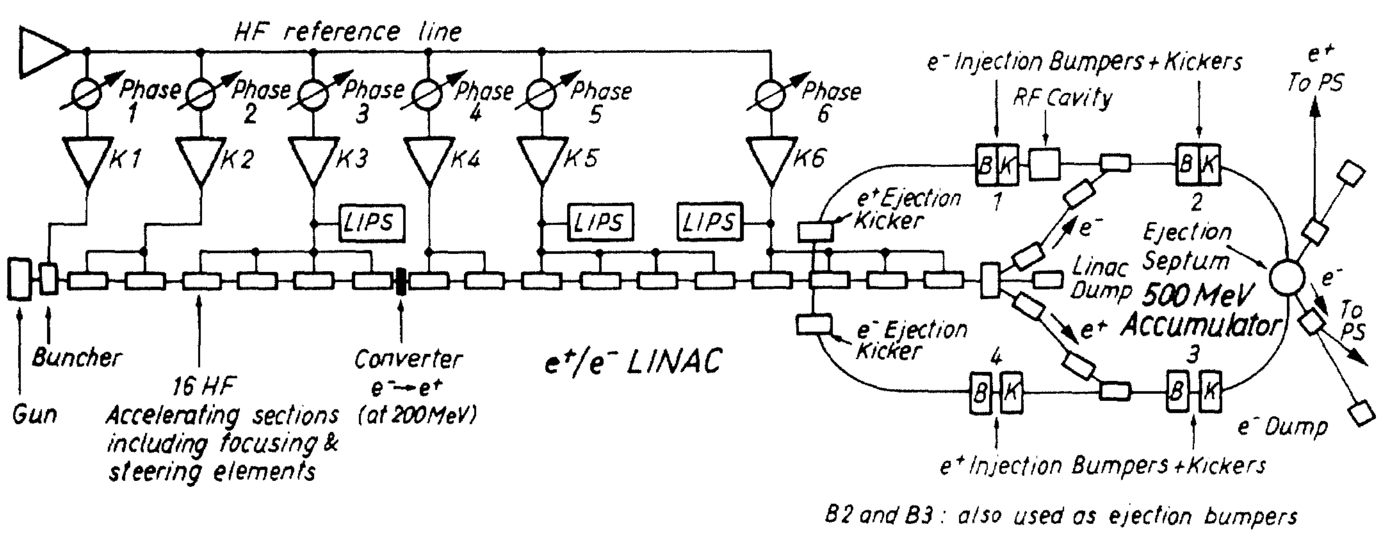


*FIG. 2: THE LPI (LIL+EPA) LAYOUT WITH THE MAIN ELEMENTS*

## PPM Realization

### Standard PPM

As long as modulation occurs at the cycle rate, it is essentially an adaptation of the well known CERN CPS standard PPM [2] in use since 1980. A few changes were required by the LPI specific constraints and by the local processors technological evolution [3].

The CPS PPM is driven through the so-called PLS telegram [4]. This telegram also drives the LPI central timing and sequencing, for synchronization purpose through a local facility called Telegram Slave Unit (TSU) [5]. Depending on the CPS telegram, the TSU emits a serial telegram similar to the CPS one, containing information about the PRESENT and NEXT cycles.

Although the standard PPM is effective on a cycle to cycle basis, it is worked out every Basic Period (1.2 s) to allow for the updating of control and acquisition on very long cycles (as on the operational 10 BP $e^+$ accumulation cycle).

This telegram drives the LPI modulation through: (see Fig. 3).

Software in the local processors. Real-time tasks are executed in a number of local Camac microprocessors [6] called SMACCs. The PPM software modules in these SMACCs are divided into two groups of two real-time tasks:

- A first interrupt triggers a subroutine that reads the LPI TSU telegram, stores the indication about the PRESENT and the NEXT Cycles and sets the table pointers accordingly. The end of this subroutine starts a preparation task that builds up the control and acquisition tables.
- A second interrupt starts the Camac access subroutine, which uses the two previous tables. This task is kept very short to be executed as fast as possible. Eventually, it starts the "arrangement task" which transfers to the local data base column the acquired data for the PRESENT cycle.

Timing decoders. Decoders built in the LPI Central Timing modules enable or inhibit the output pulses according to one selected information of the TSU telegram.

## The Fast Timing Sequencer (FTS)

Handling the LIL and EPA injection 100 Hz repetition rates to achieve various production schemes and intensities requires a 10 ms-based modulation of those processes. This time scale is not suitable for software PPM but should be controlled by a faster specific hardware which is called Fast Timing Sequencer (FTS) [7].

The FTS uses the same hardware environment as the other SMACCs. It can drive via 64 sets of 4 parallell lines, the different timing modules used for the $e^-$ Gun, the LIL klystrons and the EPA injection and ejection kickers.

Each timing module consists of two identical chains - 19 Mhz Camac counter (coarse), plus a ns cable-delay (fine) - delivering pulses every 10 ms. The two output pulses enter a device that selects one of the two channels, may add a 1 or 5 ms delay or inhibit the output pulse. The 4 FTS lines that control each module consist of:

- $e^+$ and $e^-$ lines to select one of the two channels,
- an Inhibit line to disable the output,
- a Production/Dummy line which selects immediate or delayed output.

This last facility is provided to keep a 100 Hz pulsing frequency regardless of the effective beam production rate.

The FTS also fulfills the following tasks:

- it performs beam intensity control in EPA, via a feedback loop or a manual control, with a resolution of one LIL bunch,
- it delivers the EPA bucket numbering and emits accordingly bursts of 19 MHz pulses used as a clock for the LIL, injection and ejection timing modules,
- it drives the converter target movements.

The FTS processor is table-driven: each TSU telegram determines a pair of tables that will be used for the next Basic Period. Both of them consists of 120 time slots; each slot describes the status of the LPI elements for one LIL Period (Fig.4). Two real-time events allow for a fast switchover between those two tables, one of which is programmed for Accumulation (Production) and the other for Storage (Dummy). The same kind of process is also used to control the EPA beam intensity.

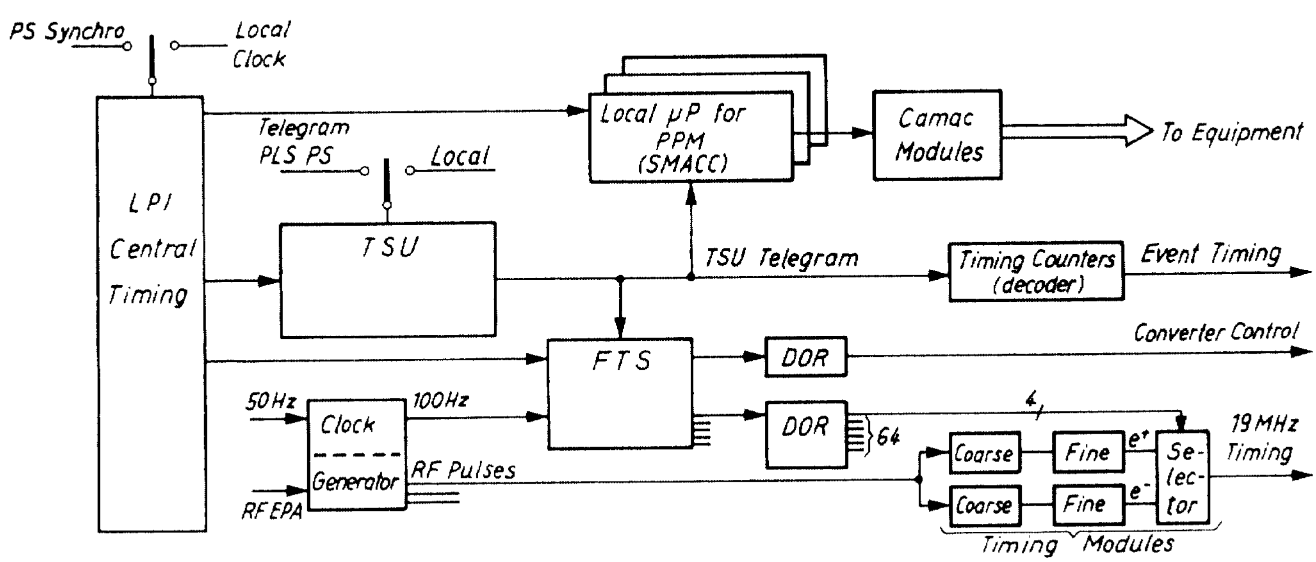


FIG. 3: GENERAL STRUCTURE LAYOUT OF THE LPI PPM OPERATION

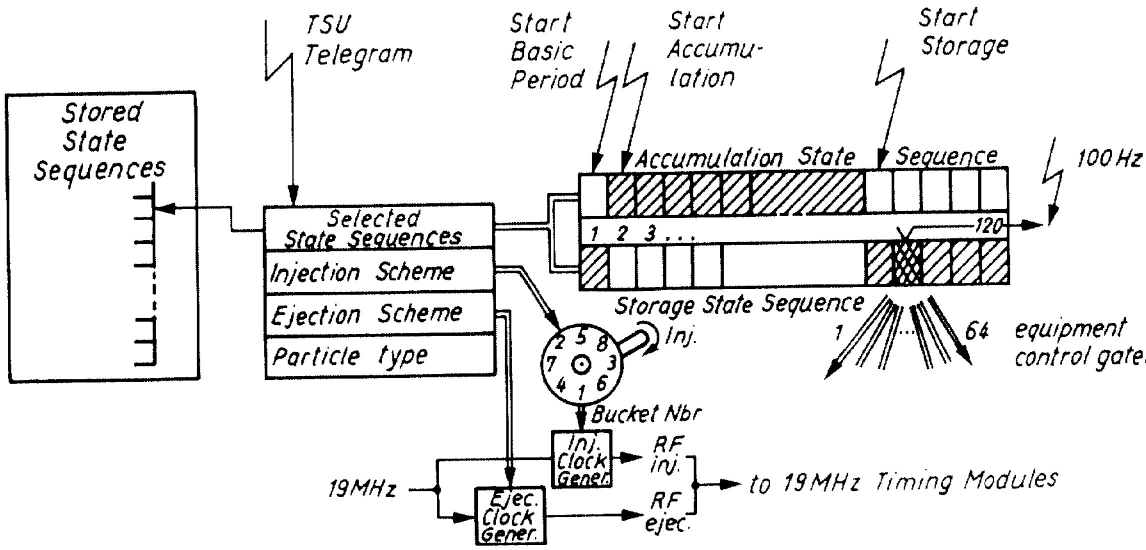


FIG. 4: SCHEMATIC BLOC DIAGRAM OF THE FAST TIMING SEQUENCER (FTS)

## Typical Supercycle

A typical supercycle consists of three cycles which are used to produce beams for the Machine Developments of the CPS and SPS. Each of the cycles is defined by editing its TSU telegram. The supercycle is built as a sequence of these telegrams. For both types of particles an intensity level is then fixed. This standard supercycle could be described by the following table:

| CYCLE | $e^+$ Accumul. | $e^+$ Storage | $e^-$ Accumul. |
|---|---|---|---|
| Cycle length | 10 BP | 1 BP | 1 BP |
| Inj. Freq. | 100 Hz | No Inj. | 50 Hz |
| No. bunches | 8 bunches | - | 4 bunches |
| Ej. scheme | 1-3-5-7 | 2-4-6-8 | 1-3-5-7 |
| Synchro ej. | CPS | CPS | CPS |
| Intensity | $1.2.10^{11}$ $e^+$ | ($6.10^{10}$ $e^+$) | $2.10^{11}$ $e^-$ |

On the first cycle, as soon as the required intensity is reached, the LIL Gun goes to a Dummy state (trigger delayed by 1 ms). This state remains unchanged on the second cycle until 140 ms before ejection. Then, the Converter is removed, the Klystron K4 is set to Dummy (timing delayed by 5 ms), the LIL phases and steerings are set to $e^-$ values and the Gun current is decreased by a factor of 10. The EPA injection elements are then switched to their $e^-$ settings. At the beginning of the third cycle, the EPA RF cavity phase and ejection elements settings are modified. The $e^-$ gun pulses now alternately on Production and on Dummy timings to obtain a 50 Hz beam production rate. When the $e^-$ $2x.10^{11}$ particle number is achieved, the e storage mode is established and the PPM LIL parameters are switched back to their $e^+$ values.

## References


[1] The LPI Beam Commissioning Team, First Experience with the LEP Pre-injector (LPI), Proceedings of the IEEE Particle Accelerator Conference Washington, 1987, Vol.1 p. 298.300.

[2] G.P. Benincasa, F. Giudici, P. Skarek, Fast Synchronous Beam Property Modulation using a large distributed Microprocessor System, presented at the Particle Accelerator Conference, Washington, 1981.

[3] L. Casalegno, J. Cuperus, A. Daneels et al., Distributed Application Software Architecture applied to the LEP Preinjector Controls, presented at the 7th IFAC Workshop on Distributed Control Systems, Bad-Neuenahr, West-Germany, 1986.

[4] P. Heymans, B. Kuiper, Current Control of Interacting Accelerators with Particle Beams of Varying Format and Kind, presented at the Conference of Computing in Accelerator Design and Operation, Berlin, 1983.

[5] J. Lewis and P. Heymans, The Program Line Sequencer, a new Approach., Proceedings of the IEEE Particle Accelerator Conference, Washington, 1987, Vol.1 p. 640-642

[6] W. Heinze et al., SMACC, CERN/PS 85-24 (CO) report presented at the 1985 Part. Accel. Conf., Vancouver, Canada, May 1985.

[7] P. Schenkels, LPI Fast Timing Sequencer (FTS) and Data Table Editors, CERN Int. PS/CO/Note 86-9, 26 03.86.