Proceedings of the Linear Accelerator Conference 1990, Albuquerque, New Mexico, USA

THE LEP INJECTOR LINAC

R. Bossart, J.P. Delahaye, J.C. Godot, J.H.B. Madsen, P. Pearce, A. Riche, L. Rinolfi
CERN, CH-1211 Geneva 23

ABSTRACT

The LEP Injector Linac (LIL) has been working for two years of routine operation as the LEP injector. Performance limitations are discussed and typical beam measurements are presented. Measures to improve the reliability are explained and a scheme for possible improvements of the positron production is described.

INTRODUCTION

Operating since 1988 as the LEP source, three main objectives have been addressed:

- Measure and optimize the peak performances
- Improve the reliability
- Study an improved positron production scheme

Although the overall peak performance is above the nominal value, a consolidation programme has been set up to improve the long term reliability. In particular, a new gun modulator, a new bunching system, a change of accelerating section front-plates, a fixed target and an upgrading of the klystron modulators. In the light of future projects, the bottleneck of LIL would be the positron production and a study has been made to improve this parameter.

LIL PERFORMANCE

A detailed description of LIL is given in reference[1]. The design was optimized around its positron performance which is determined mainly by the characteristics of the electron beam on the target, the matching of the e^+ flux into the accelerating section, and further acceleration and transport downstream. Table 1 shows the beam performance of the linac providing the primary e^- beam:

Table 1
Peak Performance of Primary Beam at the Target

No-load energy:	225 MeV
Charge:	48 nC
Pulse length:	20 ns (at FWHH)
$\frac{\Delta p}{p} = \pm 8\%$	(full width at the base)
Horizontal beam size:	1 mm (FWHH)
Vertical beam size:	2.5 mm (FWHH)

The e^+ production is not very sensitive to spot size and position within one mm. Matching the e+ flux into the accelerating section is obtained with a pulsed solenoid (1.5 T) put right after the target.

With the bunching system optimized and LIL optics matched, several measurement sessions of the peak performance have been made. Results (for both beams) are reported in reference [2]. Table 2 gives a summary for e^+ production. Figure 1 presents a comparison of the peak performance reached and the design values.

Table 2
Positron Production Characteristics

Gun current:	5 A
Transmiss. efficiency in the buncher	80%
for primary beam:	80%
N^o of e^- on the target:	$2.9\ 10^{11}$
N^o of e^+ at the end of LIL total:	$17.4\ 10^8$
within $\frac{\Delta p}{p} = \pm 1\%$:	$12.9\ 10^8$
Unresolved conversion efficiency:	$6\ 10^{-3}$
Resolved conversion efficiency:	$4.4\ 10^{-3}$
Final energy:	500 MeV

RELIABILITY IMPROVEMENTS

A new gun modulator has been designed to improve the maintainability. The control of all parameters is made through fibre optic links. The platform reaches a maximum of 100 kV, and the working value is 80 kV. The amplitude of the pulse, applied to the grid of the gun, is adjusted according to the beam intensity for e^- and e^+ cycles. A facility which allows the pulse length to be varied is also implemented. A beam test line has been designed and installed to measure the performance in the laboratory.[3].

The present buncher was designed for a maximum beam current of 20 A and an input energy of 100 keV. It provides a no-load energy gain of 28 MeV with a bunching efficiency of 60 % within $\Delta\phi = 16^o$ (80% of particles). However, after several RF break-downs occurred in the buncher, a series of machine studies were made [4], and the results obtained helped clarify the behavior of the bunching system. Presently, a project is going on to replace the buncher by another one seven times shorter. The output energy will be reduced to 4 MeV. Calculations have shown that the bunching efficiency could be kept similar to the present one in the range of a beam intensity of 10 A [5]. The mechanical assembly will be simplified, reduced in size, and the construction of a spare will be possible at a relatively low cost. The free space will be used to install a matching section between the buncher and the first accelerating sections and to add instrumentation. The new gun modulator and the new bunching system will be installed on LIL, at the end of 1990.

During the construction of LIL, the envelope end plates of the accelerating sections were corroded. With time, several vacuum leaks appeared. All sections were removed from the tunnel and the corroded welds redone [6].

The SLED type cavities, called LEP Injector Power Savers (LIPS) [7], used to increase the RF peak power, have their end flanges made of mild steel. This was a weak point for the vacuum in the LIPS tank. An improvement has been made with the construction of a new tank built completely in stainless steel with larger pumping holes and new types of gasket. In August 1990, a new set of cavities were successfully tested with an RF peak power of 32MW.

During 1989 two designs of target systems without any mechanical movement were investigated:

i) The required e^- intensity is made to pass through a 0.25 mm diameter hole on the axis of the target. The energy spread in the e^- beam is larger than before.

ii) Deflecting the electron beam (cycle e^-) through a 2.5 mm diameter hole beside the 5 mm diameter target [8]. Figure 2 gives a sketch of the layout. Behind the target, focusing is given by solenoids. The extended version of TRANSPORT [9] was used to calculate the new e^- trajectory. Both solutions were used in operation during LEP runs and the stability was good. In the first solution, the small central hole, reduces the e+ production by roughly 10% and the continuous high beam intensity gives a large activation in the target area. Hence the second method is currently being used [10].

Over the last two years the reliability of the klystron modulators has been increased [11]. Despite more than 5000 hours of beam requested yearly, the downtime, due to modulator faults has been reduced. As with the SLAC experience a regular adjustment of each thyratron reservoir voltage has been found necessary to minimize the faulty shot rate, and obtain long lifetimes. The present useful lifetime of these tubes looks to be in excess of 17000 hours at the 100 Hz rate with 35 kV, 3400 A and a voltage pulse width of 6.5 μs. The individual klystron power outputs have been adjusted to give between 13.5 and 24 MW with a 4.5 μs RF pulse width, depending on their position in the linear accelerator. The present indications are that the average lifetime of these devices does not exceed 15000 heater hours.

New PIN-switches have been installed in spring 1990, in order to work with a higher RF-power (up to 400 W) at the input of the klystrons. The reliability of the phasing system for the klystrons has been improved by a modular construction of the RF-phase detectors and a new design of the signal processing for phase correction by a new microprocessor system.

STUDY FOR IMPROVED POSITRON PRODUCTION

The positron production rate would have to be improved for two possible future CERN projects namely the LEP luminosity improvement programme[12] and a possible Beauty Factory (BFI)[13]. The positron rate including the capture and acceleration by LIL as well as the accumulation is given by: $\frac{dN^+}{dt} = \eta_a \eta_p N^- E^- f$; where η_a is the accumulation efficiency, η_p is the e^- to e^+ conversion efficiency, N^- is the number of particles in the primary beam, E^- is the energy of the primary beam, f is the linac repetition frequency. In principle all these different parameters can be improved. Schemes[12] based on the increase of the primary beam power are summarized in Table 3.

Moving the converter target downstream in the linac (Fig 3) and powering two adjacent accelerating sections with one modulator equipped with LIPS, allows to increase the mean acceleration from a conservative value of 12 MeV/m to 18 MeV/m. The primary beam energy is then enhanced from 220 MeV to 700 MeV. The remaining RF sections of LIL are then sufficient to accelerate the beam to the operational energy or up to 700 MeV, which would reduce the accumulator damping time by a factor 2.7 and therefore permit a LIL repetition frequency of 150 Hz which is possible with some improvement of the klystron modulators[11]. The primary beam intensity is presently limited by the momentum spread introduced by the beam loading in the accelerating sections. A higher field in the RF sections would allow the higher charge to be accelerated within the same momentum spread. Finally η_p would also be improved with a flux concentrator inspired by the SLC system and η_a could be raised by using a magnetic energy compressor at the end of LIL. As a preparation, high gradient tests will be performed with the spare LIL section.

CONCLUSIONS

The typical performance of the LEP Pre-Injector is now a factor 3 for e+, and a factor 5 for e-, above the nominal requirements assumed during the LEP design. The reliability of LIL is such that beam availability for the LEP machine is close to 96 % of the scheduled time. The scheme and the necessary LIL modifications will be implemented if and when an improved positron performance will be required.

Table 3

Parameters	Unit	Design performance	Present max. performance	Required for LEP 200	Required for BFI
e^+ accumulation rate	10^{10} e^+/s	1.8	6.5	20	45
Primary beam power	W	576	1056	3065	7380
Number of particles	10^{11}	1.8	3.0	4.3	4.6
Primary beam energy	MeV	200	220	440	660
Repetition frequency	Hz	100	100	100	150

ACKNOWLEDGEMENTS

We acknowledge the contributions made by all of the staff of the Lepton Group in the PS division and the Operation Team.

REFERENCES

[1] J.H.B. Madsen, CERN Divisional Report PS 89-56 (LP)

[2] J.P. Potier, L. Rinolfi, CERN Internal Note PS/LP 90-12

[3] A. Pisent, L. Rinolfi, CERN Internal Note PS/LP 90-14

[4] R. Bossart, J.P. Delahaye, L. Rinolfi, CERN Internal Note PS/LP 89-36

[5] A. Pisent, L. Rinolfi, CERN Division Report 90-.58 (LP)

[6] J.C. Godot, CERN Internal Note PS/LP 89-17

[7] A. Fiebig, C. Schieblich, EPAC, Nice (1990) and CERN Divisional Report PS 90-13 (RF)

[8] A. Riche, CERN Internal Note PS/LP 89-23

[9] A. Riche, EPAC, Nice (1990) and CERN Divisional Report PS 90-22 (LP)

[10] R. Bertolotto, J.H.B. Madsen, A. Riche, L. Rinolfi, Internal Notes PS/LP 89-24 and 89-27

[11] P. Pearce, S. Hutchins, 19th Power Modulator Symposium, San Diego (1990) and CERN Divisional Report PS 90-27 (LP)

[12] J.P. Delahaye, K. Hübner, CERN Internal Note PS/LP 89 - 32

[13] B. Autin et al., EPAC, Nice (1990) and CERN Divisional Report PS 90-25 (LP)

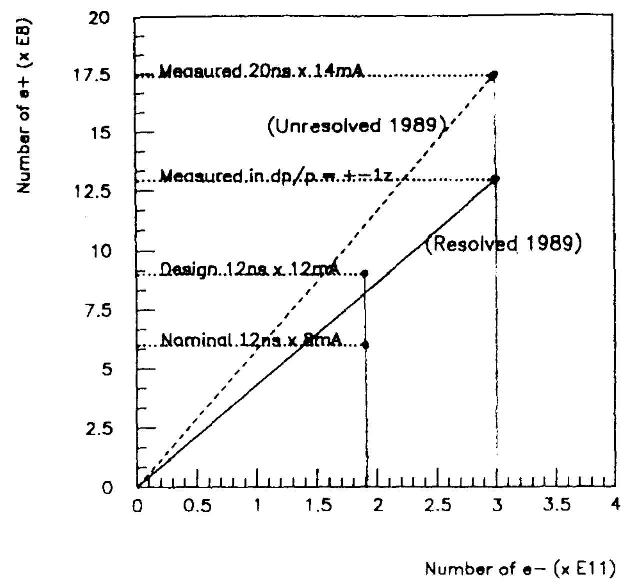

Figure 1: Comparison of peak performance to design performance

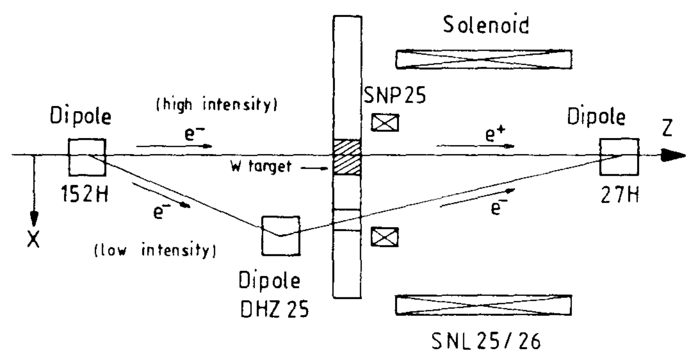

Figure 2: Layout with a fixed target for the e⁻ and e⁺ production

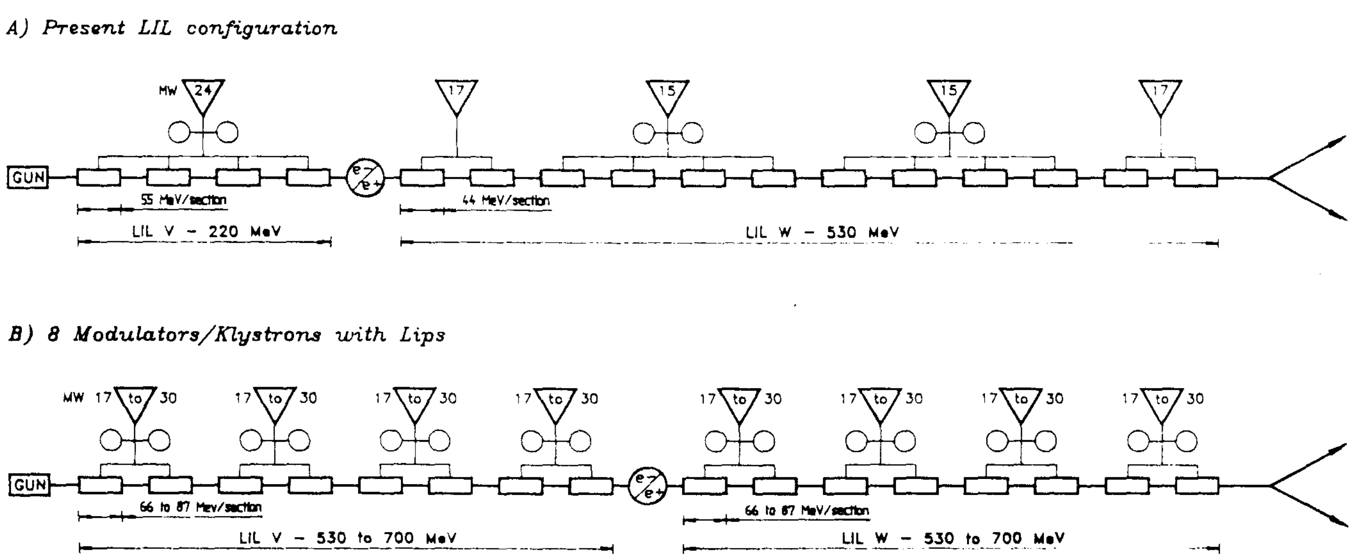

Figure 3: Proposed LIL configuration for an improved e⁺ production