European Organization for Nuclear Research

CERN – PS Division

CERN/PS 98-016 (LP)

The LEP Pre-Injector as a Multipurpose Facility

J.P. Potier, L. Rinolfi

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The LEP Pre-Injector (LPI) provides electron and positron beams at 500 MeV. In 1988, it was used for the first time to produce single electrons at 180 MeV in order to calibrate the L3 detector. Since this first experiment a dedicated irradiation area has been built downstream of the linac. This facility uses electron beams with an energy range adjustable from 180 MeV to 700 MeV with intensity, pulse duration and repetition rate, which can be varied within wide limits. Some LEP detectors, and almost all future LHC (Large Hadron Collider) detectors, have already used this facility intensively. When the LPI accumulator works at 308 MeV, the critical energy of the synchrotron light radiated in the bending magnets is 45 eV. It corresponds to the synchrotron radiation which will be produced by 7 TeV protons in the LHC. To study the crucial issue of desorption in the LHC vacuum chamber a first synchrotron light line, at room temperature, has been installed followed by a second one for cryogenic temperatures. This paper reviews the experiments that have been done, the beam characteristics for these facilities and the possible evolutions in the near future.

Presented at the 6th European Particle Accelerator Conference (EPAC98),
June 22 - 26, 1998, Stockholm,

Geneva, Switzerland
24 June 1998

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1 INTRODUCTION

The LPI is the lepton source for CERN's Large Electron Positron collider (LEP). This source includes the LEP Injector Linac (LIL) and the Electron Positron Accumulator ring (EPA). For stability and fast availability reasons, the LPI is kept running between the LEP fillings. Then it is free for other activities at no additional costs. Furthermore, as the accumulation time of the LPI for LEP is shorter than the cycling of the LEP injector chain, time is available to produce particle beams in parallel with LEP fillings. To benefit from these possibilities, a dedicated irradiation area LEA (LIL Experimental Area) was opened in 1992. In EPA, the first Synchrotron Light Facility (SLF 92) was open in 1991 and the second one (SLF 42) in March 1998.

2 TEN YEARS OF EXPERIMENTS

Figure 1 is the layout of the different LPI facilities. Number 1 shows the extraction line where the first experiments were performed in 1988, to calibrate the vertex of L3 detector with a fine momentum resolution using 180 MeV single electrons [1]. It was followed, in 1991, by irradiation with a beam at 500 MeV to measure the radiation damage on samples of the LAA calorimeter. The doses were in the range of 1 to 30 MRad. This line, difficult to operate in parallel with LEP fillings, has been dismantled.

Number 2 shows the general purpose irradiation area LEA. It allows irradiation in parallel with LEP activities. In this area, the L3P collaboration has tested the time response and light output of several BGO crystals foreseen for a high-precision crystal electromagnetic calorimeter for the LHC. Lead/Scintillating fibers calorimetry studies continued in 1993/1994 [2,3,4]. In 1993 and 1995, OPAL used the facility to study the radiation induced leakage currents on the guard rings of the silicon micro-strip detector [5]. In 1994, ATLAS performed radiation tests on Switched Capacitor Array chips. Since then an intensive use of LEA is pursued by ALICE, LHC-B and CMS [6],[7].

Number 3 shows the first Synchrotron Light Facility. SLF 92 was installed to study the gas desorption [8] at room temperature and then upgraded to study the photoelectron yield and photon reflectivity at grazing incidence (11 mrad) from different LHC vacuum chamber materials [9]. Then SLF 92 became the line to study gas desorption at cryogenic temperatures [10]. Now it is upgraded to simulate as closely as possible the LHC vacuum chamber. These measurements provide realistic input toward a better understanding of the electron cloud phenomena and vacuum behaviour expected in the LHC.

Number 4 shows the new synchrotron light facility SLF 42. The program initiated at room temperature on the first line, will continue with this second line.

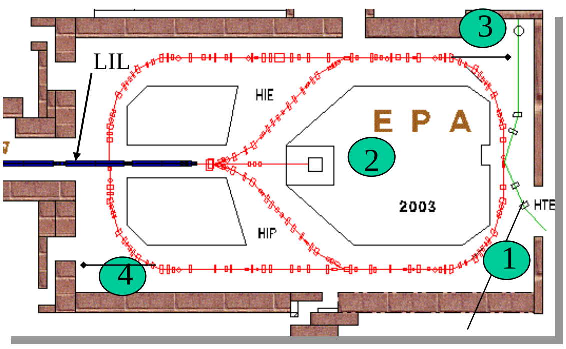

Figure 1: Layout for LPI facilities
1 - Single electron line;
2 - LIL Experimental Area (LEA)
3 - Synchrotron Light Facility 92 (SLF92)
4 - Synchrotron Light Facility 42 (SLF42).

3 THE LIL EXPERIMENTAL AREA

Due to the high positron performance achieved by the LPI as LEP injector, it is possible to accumulate efficiently the lepton beams in a time shorter than the cycling of the LEP injector chain (14.4s), leaving 3.6 s or more available for LEA beams. Since 1992 pulsed power supplies have been progressively implemented to allow fast switching of the lepton beams between EPA injection and LEA area as well as the change of LIL focusing quadrupole to de-couple as much as possible LEP and LEA beams. The repetition rate of the linac can be tuned also independently between LEP and LEA.

The samples to be irradiated are placed, in the air, on a motorised table, whose horizontal position is computer controlled. An exit window of 0.1 mm (Al) between the LIL vacuum and the air towards LEA is situated 2 m upstream of the table. Its contribution to the diffusion is 3.2 mm (rms) in both planes at the table. At the experiment position, the beam can scan an area of up to 10 cm by 10 cm. The scanning program controls horizontal and vertical dipoles. The integrated charge is measured from a beam position monitor upstream of the exit vacuum window. Table 1 gives the range of the beam characteristics for LEA users.

Table 1: LEA Beam Characteristics

Parameters	Units	Range	Nominal
Energy	MeV	180 to 700	500
Charge per pulse	e^-	5×10^8 to 2×10^{10}	4×10^9
Frequency	Hz	1 to 100	100
Beam sizes (rms values) at LEA experiment (in air)	mm	3.3 to 6	$\sigma_x = 3.6$ $\sigma_y = 5.6$
Scan area	cm^2	10 x 10	-

The nominal values correspond to those used for LEP operation or if LEA users request no change.

Figure 2 shows the beam profile taken from a scintillator screen in the LEA beam line placed 3 m upstream of the window. It corresponds to a particular LEA parameters setting.

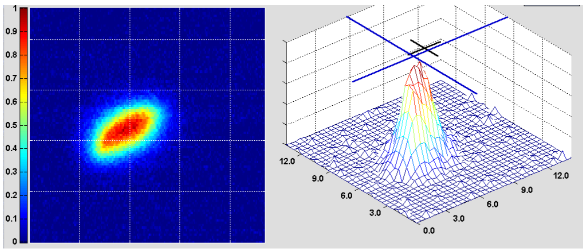

Figure 2: Beam profile for LEA experiment.

The measured beam sizes are 3.3 mm and 2.5 mm (FWHM). For the nominal conditions, the measured rms normalised emittances are ~ 60 π mm mrad.

4 THE SYNCHROTRON LIGHT FACILITIES

The EPA critical energy E_c (eV) is given by:

$$E_c = 1551 \times E^3$$

where E (GeV) is the electron beam energy in EPA.

The photon flux F (photon/s) without collimation is given by:

$$F = 8.08 \times 10^{17} \times E \times I$$

where E is the same as above and I (mA) is the beam current.

At 500 MeV the rms geometrical EPA equilibrium beam emittances are:

$\varepsilon_x = 0.1\ \pi\ 10^{-6}$ rad m, $\varepsilon_y = 0.03\ \pi\ 10^{-6}$ rad m.

In the middle of the dipoles, $\beta_x = 6.3$ m and $\beta_y = 13.3$ m. The dispersion being negligible (0.001 m), the light source has a size of $\sigma_x = 0.8$ mm while $\sigma_y = 0.6$ mm.

Figure 3 shows the synchrotron light critical energies versus EPA momentum as well as the different operating points used in EPA during the runs for the LHC vacuum chamber development. For 308 MeV, E_C = 45 eV simulating the critical energy of the synchrotron radiation produced by the LHC at its design energy of 7 TeV. For 500 MeV, E_C = 194 eV which is the nominal momentum of EPA for LEP running and for 565 MeV, E_C = 280 eV simulating the critical energy of the defunct American project SSC (Superconducting Super Collider).

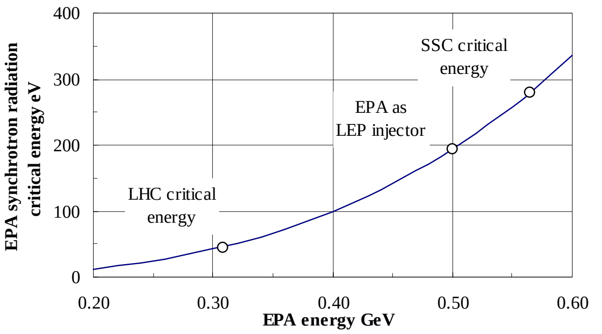

Figure 3: Critical photon energies versus EPA beam energies.

Since the beam has to be stored in EPA to use the SLF lines, the experiments can only be done in dedicated time i.e. between LEP fills or outside LEP running periods. As the EPA is run well below its normal operating energy

(400 to 650 MeV), great care has to be taken to reproduce the magnetic properties of the ring in order to achieve reasonable injection and accumulation efficiencies. Furthermore, the closed orbit position and its slope in both planes, has to be strictly controlled in the bending magnet where the light source is situated. This is obtained with 2 pairs of dipoles without disturbing the accumulation rate too much. Under these conditions, the maximum accumulated charge is 4.5×10^{11} e^- in about 20 s. Table 2 summarises the EPA parameters for the possible range of the parameters and for the current LHC studies.

Table 2: EPA parameters for SLF

Parameters	Units	Range	LHC
Energy	MeV	200 to 600	308
Critical energy	eV	12 to 335	45
Charge	e^-	up to 4.5×10^{11}	3×10^{11}
Intensity	A	up to 0.172	0.115
Nb buckets	N	1 to 8	8
Tune	Q_x, Q_y	4.537, 4.298	idem
Vacuum	Torr	10^{-9}	idem

Between the light source in the middle of the bending magnet and the SLF lines, the vertical source collimation angle is 7.8 mrad and the horizontal one is 5.3 mrad. Figure 4 shows the photon flux as used by SLF users.

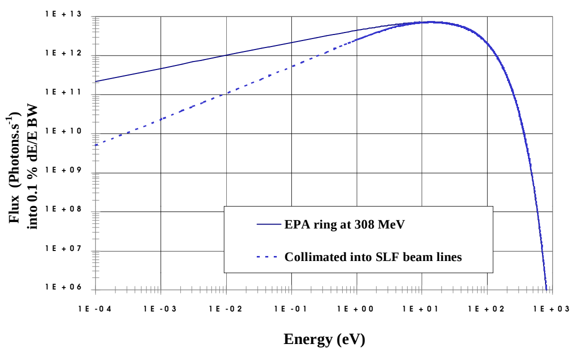

Figure 4: Photon flux in SLF lines (308 MeV, 115 mA).

5 FUTURE OF LPI FACILITIES

Due to the increasing number of requests for these facilities and with the possible interference with the LEP program, the SPS/PS physics coordinator has made the co-ordination since the end of 1997.

Both SLF lines will continue an intensive programme for the LHC vacuum chamber development until 2000, for the reflectivity and photon yield studies at room and cryogenic temperatures. The study of the multipacting effects with the electron cloud will be investigated. Other tests, with COLDEX installed in the EPA ring, are under discussion.

In 1998, CMS and LHC-B will get beam time to continue studies on electromagnetic calorimeter prototypes. The LAL (Orsay) has requested beam time to study radiation damage in tungsten crystal in view of e^+ production for future Linear Colliders.

All LPI facilities are expected to run up to the end of 2000, as does the LEP program does, when the financing will end.

6 ACKNOWLEDGEMENTS

The authors would like to thank B. Dupuy who developed the LEA scan program, E. Chevallay and S. Del Burgo who developed LEA image analysing and V. Baglin who provided the data for the EPA synchrotron light as well as the LPI operation team for their enthusiasm in the running of this facility.

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