LINAC INJECTOR FOR SOLEIL

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Abstract

To ensure the beam of the Synchrotron Light Source SOLEIL against ion and dust particle trapping [1], we are studying alternative options for the linac injector : a 100 MeV, 3 nC electron linac (ELIOS) which will be commissioned first; and secondly, a 350 MeV, 0.3 nC positron linac which will be driven by a 340 MeV, 40 nC high intensity e^- linac. Both options have to be compatible with regard to construction, and because of the positron option we are obliged to use RF linacs. No use of RF gun, FEL, or SASE is foreseen, keeping in mind the economical aspect and reliability of the injector.

1 . INTRODUCTION

The SOLEIL project is a 2.15 GeV storage ring with a circumference of 336 m [2]. It is filled at the operating energy using a synchrotron booster and an RF linac. Since 1991 at the beginning of the study we considered injecting positrons into the storage ring ; however following the successfull commissioning of several new electron synchrotron light sources, we expect to get, after some R&D on the ring vacuum chamber, good electron beam stability and lifetimes greater than 24 hours. The arrangement of linacs presented here is done with the aim of injecting electrons and possibly later positrons.

2 . INJECTION PARAMETERS

2.1 Storage Ring and Booster

The storage ring may be filled in two modes : (1) multibunch mode (MB) that consists of 500 mA in 560 bunches, 2 ns apart ; (2) single bunch mode (SB) with 80 mA in 8 bunches. The 108 m circumference booster (Tr = 360 ns) achieves injection and ejection in 300 ns in a single turn mode at the frequency of 10 Hz. Its longitudinal acceptance is 10 ns, and its injection energy acceptance is ±1.5 %.

2.2 Linacs

For both injection modes the macropulse current is chopped in order to decrease the beam-loading along the linac and to increase the injection efficiency into the booster. The storage ring injection rate at 10 Hz and linac macropulse charge are shown in the following table . The filling time takes values from 18 seconds [e^- SB mode] to 9 minutes [e^+ MB mode].

- SB mode : 3 pulses of 5 ns, 120 ns apart
- MB mode : 30 pulses of 5 ns at 100 MHz (300 ns)

	SB mode		MB mode	
Option	inj. rate (mA/min)	Q_{linac} (nC)	inj. rate (mA/min)	Q_{linac} (nC)
e^-	270	1	900	3.3
e^+	20	0.075	60	0.28

3 . COMPATIBILITY BETWEEN e^- AND e^+ OPTIONS

There are three building stages (see Fig. 1). The first machine to be built is ELIOS (Electron Linac Injector of Soleil), a 100 MeV electron linac (cf. section 5) of 10 m length close to the booster. A second possible stage is a 24 m long 340 MeV electron linac for positron production (cf. section 4), which will be built upstream. It will be followed by an e^-/e^+ converter and only the first accelerating section of the positron linac. By constructing a provisional test line, one would be able to optimize the positron yield at 100 MeV. Owing to a removable shielding wall between them, both electron injection into the booster and positron tests could be run at the same time.

After the tests, the positron linac will be connected by puting two accelerating sections in place of the gun and buncher of ELIOS. This new linac called EPLUS (Electron Positron Linac Ulterior version of Soleil) will be 53 meter long.

4. e^+ OPTION

4.1 Requirements.

With *4.6* 10^9 $e^+ . s^{-1}$ in SB mode (resp. *1.8* 10^{10} in MB mode) at 10Hz, the required *positron flux* for Soleil is far below that of collider projects, and is in the order of magnitude of the existing high luminosity storage rings. An upgrade of the existing devices of positron production then means essentially an improvement of the economical and operational aspects.

The next main parameter is the *acceptance* of the positron Linac : it has to be defined regarding the local emittance used in booster study, at its injection energy, i.e. 1 10^{-5} π m.rad. We choose a final e^+ energy of 350 MeV and an acceptance of *0.3*π MeV/c.cm, keeping in mind a possible increase of the latter.

Finally, we have to take into account the small aperture accelerating section already in place, which will be the last positron one, and which will affect the transverse global acceptance.

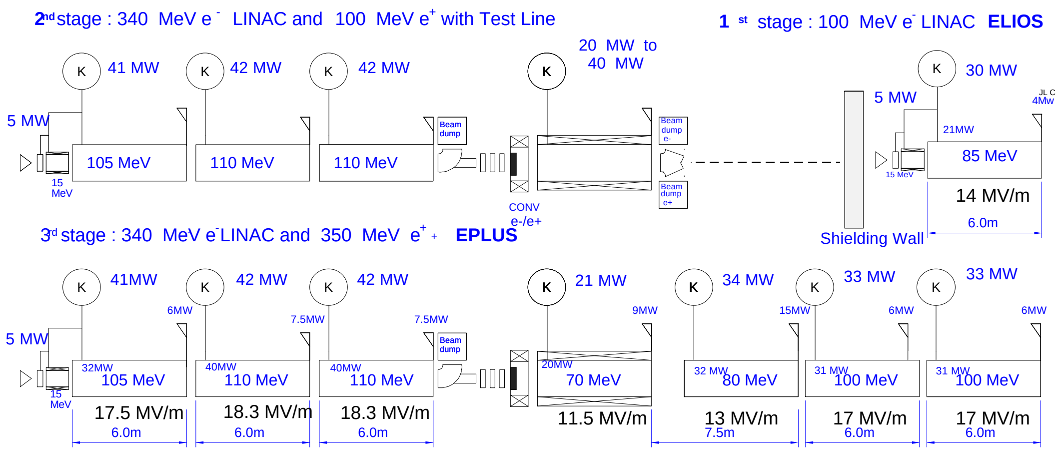

Figure 1 : Layout of the three building stages 1) ELIOS, 2) e+ Test line, 3) EPLUS

4.2 Converter and Matching device

The well-known concept of positron production, i.e. e^+/e^- pair production in a high Z target, leads to particles with a wide spread in angle and energy. Only a very small fraction of them will be guided by a magnetic matching system. The main issues of the latter are the following : to maximize the acceptance phase space volume, and then, to match it to that of the positron linac.
The Flux Concentrator (FC) as used at SLC and DaΦne, uses a high (> 5T) and slightly decreasing field, compared to the Quarter Wave Transformer (< 2T). A much higher positron energy band is then captured ; but for real efficiency, only the relative energy spread at the booster entrance needs to be considered, and so low final positron energy is not compatible with FC. However advantages could be taken from FC in relaxing some operational constraints : e^- beam size on target, e^- bunch length or phase control of e^+ accelerating sections. But, as we see in section 4.4, optimization of our e^- linac provides restricted parameters and allows us to use the QWT.
However, 'know-how' matters as well, and following a CERN collaboration we could build a short, 'in vacuum' solenoid (5 cm, Imax = 6 kA, 1.8 T) [3].

No use will be made of an e^+/e^- separator because optimized tuning of RF and magnetic fields will have been made in the previous stage of construction (e^+ 100 MeV test line). Particularly, a search of the decelerating phase will be performed, wich provides the highest bunching of the low energy positrons [4].

Finally, the QWT will transform a 1.5 mm, 250 mrad, 8 ± 0.7 MeV and 20 ps four dimensions phase space into the phase space of the linac, and a 2% e^+/e^- GeV^{-1} positron yield is expected. Accurate calculations will be run with the dedicated Runge-Kutta integration based COMPOST code [5].

4.3 e^+ Linac : 350 MeV, 0.3 nC

Studies of the transport of a reference ellipse emerging from the converter have been made in an analytic manner. It already leads to attractive results, comparing the two main focusing devices. Fine numerical fitting will be done later with dedicated codes such as modified TRANSPORT [6] and BETA [7] for pseudo-periodic parameters and correctors calculations respectively.
(i) Solenoidal focusing is described by two linear differential equations [8]. One can derive the complex transfer matrices of an accelerating section with slowly varying solenoidal fields as well as fringe fields. Then, we consider the short high field solenoid as a lens focusing at infinity for the positrons from the reference ellipse ; and the following low field solenoids have to make an image of the converter in the plane of the last iris of the accelerator. We find that all four sections have to be focused.

Although the resulting acceptance could be high, one has to take care about misalignments and systematic field errors, which cause detrimental deflections to the large positron beam. Taking the first accelerating section as an example, we find that a 2‰ systematic transverse field component induces 5% beam losses.
(ii) A thick lens formulation gives the optimized parameters for a F0D0 channel without acceleration [9] : beat factor, filling factor (ratio of the length of the quadrupoles to the total length of the channel), and the uniform quadrupole strength. The acceleration is taken into account by increasing the distance between the quadrupoles, according to a thin lens approximation formula :

$$\mathbf{L_n} = \frac{\mathbf{P_0}}{\gamma} \exp\left(\mathbf{n}\frac{\gamma \Lambda_0}{\mathbf{P}_0}\right) \left[\exp\left(\frac{\gamma \Lambda_0}{\mathbf{P}_0}\right) - 1 \right]$$

where $\mathbf{L_n}$ is the n-th drift space, $\mathbf{P_0}$ (Λ_0) the momentum (equivalent length) of the first drift space, and γ the local accelerating gradient.

However, our quite high filling factor makes the matching unsuccessfull : actually, the quadrupole thickness has to be considered. Such a treatement has been done [10], considering again the linear differential equations of motion and deriving the transfer matrix of an accelerating section with a quadrupole. A numerical process then shows a slight decay of the Q-strength (10 % overall) as the energy increases, if one wants to ensure the pseudo-periodicity of the channel.

In practice, a choice has to be made for a restrained number of current families. Figure 2 shows first results injected in the TRANSPORT standard version code. Note that large irises have been prefered at critical low energies.

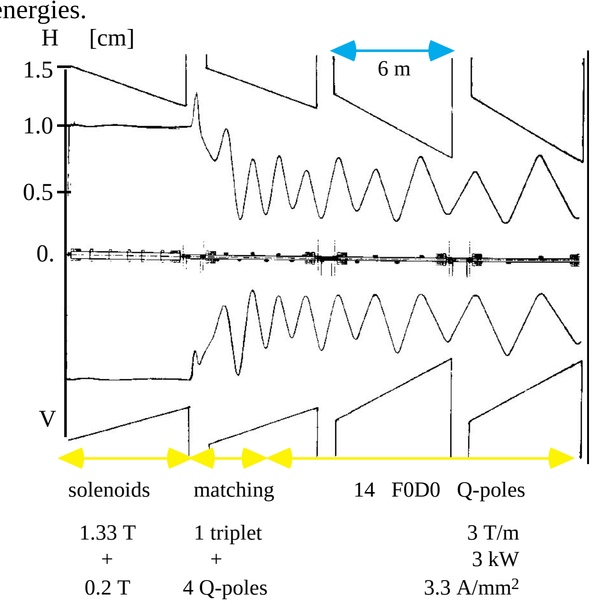

Figure 2 : Beam envelopes in Positron Linac

4.4 e^- Linac : 340 MeV, 40 nC

Both positron flux and e^+/e^- conversion efficiency lead to various solutions in energy/charge for the electron beam. But tightened requirements on the converter (2σ-1mm spot size and ±4 % energy spread) fix the energy and charge to 340 MeV and 40 nC.

Three 6 meter long, 40 MW - 2 µs TW standard sections provide an accelerating gradient of 18 MV/m. The waveguides are under vacuum. A 90 kV - 2 A triode gun is followed by a prebuncher cavity and a S-band SW 15 MeV buncher. These studies are in progress.

5. e^- OPTION

ELIOS is a small RF linac (S-band at 3 GHz) of 100 MeV, yielding 3 nC/macropulse at 10 Hz. A klystron working at 30 MW, 3.2 µs FWHM (1 kW average power) feeds a 6 meter standard TW accelerating section of 85 MeV (21 MW), a 1.1 meter SW buncher of 15 MeV (5 MW) and a single prebuncher cavity of 20 kV (10 kW). No use of solenoids on the section is desirable, in order to limit the probability of RF multipactor in the cells. A higher buncher energy is then prefered, and the choice of a 15 MeV buncher fixes the ultra-relativistic e^- bunch phase extension.

The cavity, buncher and accelerating structure are standard products from General Electric Medical System France. The klystron modulator of 80 MW (2.5 kW average power) could be the same that used for the ESRF. The waveguides towards the buncher are pressurised (N_2 or SF_6) and the one towards the accelerating structure is under vacuum.

The 90 keV triode gun driven by a comb generator produces short pulses of 5 ns, 250 mA at 100 MHz in synchronism with the booster RF. This gun could be the same as the CLIO one [11]. The accelerated charge being small, the beam is focused by shielded lenses between the gun and buncher. Figure 3 shows a sketch of ELIOS.

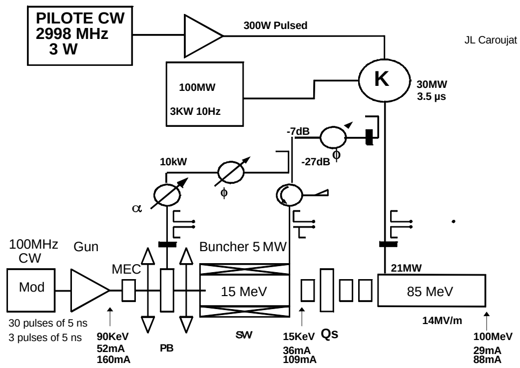

Figure 3 : Sketch of the Electron Linac ELIOS

7 . ACKNOWLEDGEMENTS

We would like to thank our colleagues from the LURE Linac group for their constant participation in this work, especially D. Betaille, P. Brunet, P. Lebasque, J. Lesrel , L. Melard, Ch. Prevost, and J.L. Caroujat, M. Moulin, and D. Fraticelli for the preparation of figures.

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