ELECTRONS BEAM DYNAMICS OF THE 100 MEV PREINJECTOR HELIOS FOR THE SOLEIL SYNCHROTRON

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Abstract

A 100 MeV electron linac is under construction, in order to inject into the booster synchrotron of SOLEIL[1]. The linac is designed to work according to two operation modes : a short pulse mode (2 ns – 0,5 nC) and a long pulse mode (300 ns – 8 nC). Calculation of the beam dynamics, using our self-made code PRODYN, has been carried out from the gun to the end of the linac. Special care has been taken on the gun design to avoid an overfocusing outcoming beam in order to obtain a final low emittance. Calculations results are given.

INTRODUCTION

The electron dynamics are complicated. Their energies varies from zero to more than one MeV in a length comparable to the prebucket dimension. Velocities are different at the same abscissa. On-axis oscillations occur. Space-charge effect can locally be large. RF field phase and amplitude laws must be shaped precisely. Such non-linear bunching and acceleration process requires a step-by-step simulation made in time domain. All efforts have been made to implement it as an highly interactive fully three-dimensional tool for design purposes.

PRODYN [2] includes backward as well as forward movements and relativistic space-charge effects. The provided elements are : RF accelerating cell, drift, magnetic lens, quadripole, dipole and bending magnet. The accelerating cell may include a magnetic lens and a dipole. Subharmonic frequencies can be used.

GENERAL DESCRIPTION OF THE LINAC

Fig. 1 shows a schematic layout of the 100 MeV linac. The subsystems are listed below :

- A 90 kV triode gun which derives from a Pierce gun diode geometry.
- Four short focusing shielded lenses between the gun and the buncher.
- An electrostatic chopper.
- A prebunching cavity.
- A standing wave buncher.
- Two travelling wave accelerating structures.
- A Glazer lens between the buncher and the first section.
- A triplet between the two accelerating structures.

The main specifications of the linac are presented in table 1.

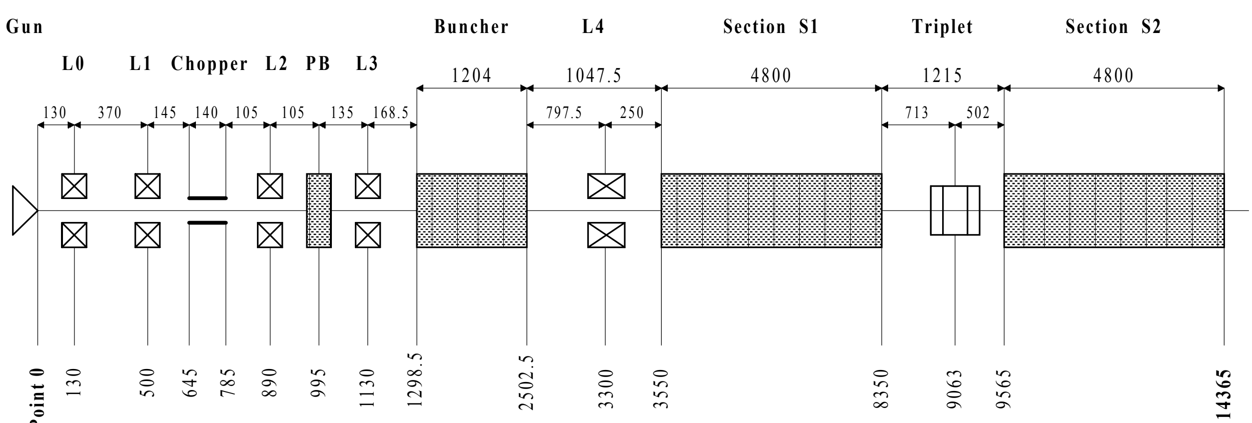

Figure 1 : Schematic layout of the 100 MeV linac (unit in mm)

Table 1: Linac Specifications.

RF frequency	2998,3 MHz
Energy	≥ 100 MeV
Energy spread	< ± 1,5 %
Repetition rate	Adjustable from single shot up to 10 Hz
Normalised emittance $4\pi\beta\gamma\sigma\sigma'$	≤ 200π mm. mrad
Short Pulse Mode	1 to 4 pulses
Gun pulse width	2 ns
Time between pulses	50 to 300 ns
Output charge per pulse	0,5 nC
Long pulse mode	
Gun pulse duration	300 ns chopped at 352,202 MHz
Nominal charge per pulse	5 nC
Maximum charge per pulse	8 nC

According to the two different running modes, two current levels are needed at the gun output : 120 mA for the long pulse mode and 450 mA for the short pulse mode.

SIMULATION RESULTS

The Gun and the Prebuncher

The EGUN [3] code was used for the optimisation of the gun geometry. For 120 mA, the outcoming beam is slightly focused and for 450 mA the beam is divergent.

The cathode will be an EIMAC Y-845 with a 0.5 cm^2 emissive area. For both operation modes, the outcoming beam is practically parallel in order to limit the space charge effects and therefore to reduce the final emittance. The four short shielded lenses between the gun and the buncher ensure the beam focusing at low energy.

The chopper is made of an electrostatic deflector followed by a drift and ending with a collimator. A voltage of approximately 1 kV applied on the 15 cm long metallic plates ensures the beam a 1cm deflection at the end of the 18 cm drift. The chopper will be used, only in the short pulse mode, to avoid filling the adjacent booster buckets between pulses.

The geometry of the prebunching cavity, with noses and rounded shapes without opposing plane surfaces, together with the magnetic shield minimise the multipactor risks.

The beam modulation is about ± 10 keV with a 90 W RF feed. The drift between the prebuncher and the buncher is 30 cm long. In the 120 mA mode, the prebunching compresses 60% of the gun current inside a 50 degrees phase extension, while in the 450 mA mode, 55% of the gun current lies inside a 50 degrees phase extension at the buncher input.

The Buncher

The buncher is a 1.1 meter long standing wave structure at the π/2 mode.

The beam aperture diameter is ø 27 mm. The first two of the 22 cells have a reduced beta for the bunching process (ß = 0,78 and 0,90).

A 5 MW RF input power increases the energy up to 15.7 MeV with an average electric field on axis of 18.7 MV/m (peak field of 27 MV/m). The beam focusing is ensured by two shielded solenoids surrounding the buncher structure and providing a maximum magnetic field of 0.2 Tesla.

The choice of this high energy buncher avoids the use of solenoids on the first accelerating structure. For both modes, we find at buncher exit around 80 % of the gun current.

Without the prebunching cavity the electron capture is reduced to 25 %. Calculation for the 120 mA (respectively 450 mA) mode give 64 % (respectively 56 %) of the gun current inside a 13 degrees phase extension at buncher exit.

For the 120 mA mode, 64% of the electrons lies inside ± 0.64% energy spread and for 59% the energy band width is reduced to ± 0.48%.

For the 450 mA mode, we find 58% of the gun current inside ± 0.64% energy spread and 53% inside ± 0.38% energy spread.

Fig. 2 shows the energy histogram at the buncher exit for the 120 mA mode.

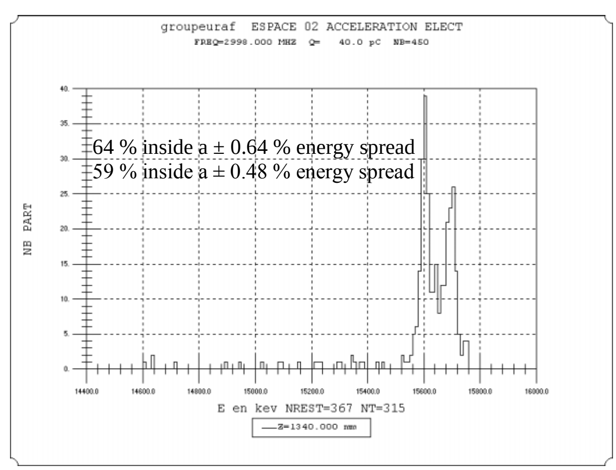

Figure 2 : Energy histogram at the buncher exit for the 120 mA mode.

The Accelerating Sections

The main accelerating structures are the LIL standard travelling wave 2π /3 mode sections from the CERN, designed with a constant gradient. The iris diameter varies from 25 mm to 18 mm, giving a group velocity c/v_g from 51 to 149 over 135 cells.

The filling time is 1.35 µs and the power attenuation is 7,4 dB.

A peak electric field of 14.8 MV/m provided with a 9 MW RF feed, allows an energy increase of 45 MeV per section and a final energy of 106 MeV at the end of the linac.

The sections are used without external focusing, except for a triplet between them and a Glazer lens between the buncher and the first section. The linac phase adjustments insures radial focusing in the first unit. Energy spectrum broadening is corrected with particle of lowest energy put at the “wave crest” of the second unit with some radial defocusing.

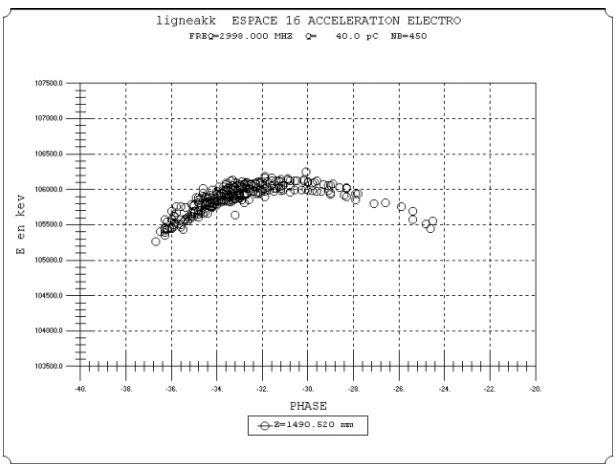

Figure 3 : Phase-energy diagram at the linac exit for the 120 mA mode.

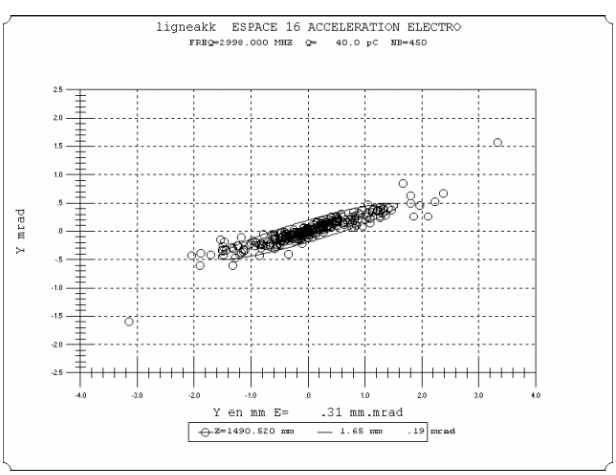

Figure 4 : Emittance at the linac end for the 120 mA mode.

Figures 3 and 4 show the phase-energy diagram and the Y-Y’ plane emittance at the linac end for the 120 mA mode.

Table 2 gives the beam properties for both main operation modes at 120 mA and 450 mA.

Table 2: Beam Properties.

Injection mode	300ns–120mA	2ns–450mA
Final average energy	106 MeV	106 MeV
Total current transmission	61 %	56 %
Current transmission in:		
$\Delta\phi$ = 16 degrees		56%(252mA)
$\Delta\phi$ = 12 degrees	61%(73mA)	54%(243mA)
Δ E/E = ±0,85 %		56%(252mA)
Δ E/E = ±0,44 %		54%(243mA)
Δ E/E = ±0,33 %	61%(73mA)	
Δ E/E = ±0,2 %	54%(65mA)	
$4\beta\gamma\sigma\sigma'=99\pi 10^{-6}$m.rad average value	61%(73mA)	
$4\beta\gamma\sigma\sigma'=154\pi 10^{-6}$m.rad average value		56%(252mA)

CONCLUSION

Beam dynamics for the two operation modes showed actual possibility of reaching the emittance goal for the total current transmission without any energy filter.

Emittance growth is kept moderate by the adjustment of the magnetic field at the injection level, specially on the fourth short shielded lens between the prebunching cavity and the buncher.

The expected low energy spread is achievable, thanks to the small phase extension at the buncher exit and the use of two accelerating units which allow for fine adjustment of the beam to RF wave positions.

REFERENCES

[1] M. A. Tordeux and C. Bourat, Theoretical study of the 100 MeV linac, injector of the ring SOLEIL, EPAC 98, Stockholm.

[2] D. Tronc and A. Setty, Electrons RF auto-focusing and capture in bunchers, Linear Accelerator Conference 1988, Virginia.

[3] W. B. Herrmannsfeldt, EGUN An electron optics and gun design program, SLAC report 331, 1988.