DAΦNE LINAC OPERATIONAL PERFORMANCE

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Abstract

DAΦNE, the Frascati Φ-Factory presently under commissioning, is an e^+/e^- collider whose injection system is composed by a ≈ 60 m Linac and by a ≈ 33 m long damping ring connected to each other and to the DAΦNE main rings by ≈ 180 m of transfer line. Both the positron and the electron beams are alternately produced and accelerated by the Linac up to the operation energy of 510 MeV. Because of the high peak and integrated luminosity requested to DAΦNE, the requirements concerning some of the relevant Linac features, in particular the value of the positron macrobunch peak current are very demanding. During the Linac operation all the design values have been achieved and in most cases surpassed. A description of the relevant operational performances of the DAΦNE Linac is presented.

1 INTRODUCTION

The first part of the Frascati Φ-Factory [1] injector is an S band (2856 MHz) Linac that alternately produces and accelerates the electron and positron beams up to the collider operation energy of 510 MeV. Before injection into the Main Rings the beams are stored into the Accumulator ring [2] for phase space damping. The Linac has been designed built and installed by the USA firm TITAN BETA [3], the system check-out has been done by TITAN and LNF personnel jointly, while the commissioning of both beams has been entirely performed by the LNF staff. The commissioning phase started on April 1996 and was concluded on February 1997. Since then the Linac has been operating on a base of 15 days per month.

Table 1: DAΦNE Linac beam parameters.

	Electron Mode		Positron Mode	
	Design	Achieved	Design	Achieved
Operation Energy (MeV)	510 800 max	510 740 max	510 550 max	510 540 max
rms Energy Spread (%)	0.5	0.56	1.0	0.95
Macrobunch Current (mA)	150	300	36	70
Macrobunch Length (ns)	10 FWHM	10 FWHM	10 FWHM	10 FWHM
Emittance @ 510 MeV (mm mrad)	1.0	< 10	10.0	< 10
Repetition Rate (pps)	50	50	50	50

Table 1 lists the Linac beam relevant parameters. The values on the table must be analyzed keeping in mind that the operation energy of the collider is fixed at 510 MeV and that the acceptance of the downstream transfer line and Accumulator ring is 1.5 % for the rms energy spread and 10 mm mrad for the emittance at 510 MeV. The high positron current obtained allows to significantly reduce the main rings injection time, with beneficial effects on the integrated luminosity in DAΦNE.

2 SYSTEM DESCRIPTION

In what follows a general description is presented, detailed information can be found in reference [4]. Figure 1 shows the RF Linac layout. In the positron mode about 5.5 A of electrons are accelerated up to ~ 200 MeV at the positron converter (PC) target for positron production and capture. An e^+/e^- separator kills the secondary electron beam produced during the conversion and allows the use of the downstream diagnostics for monitoring the positron beam only. In the electron mode the PC metallic target is extracted and the separator is turned off so that the electron beam can go directly to the Linac end.

The injector system includes a 150 keV max thermionic gun, a pre-buncher and a buncher both at 2856 MHz. All the 15 accelerating sections are the well known 2856 MHz 3 m long 2/3 π TW CG sections designed for the first time by SLAC. The necessary RF power is produced by 4 RF stations, each consisting of a 45 MW 4.5 μsec klystron (Thomson TH2128C) and of a SLED pulse compressor. The accelerating gradient is about 17 MeV/m in all the sections and 24 MeV/m in the capture section (CS) where twice the RF power is applied. The energy gain due to the SLED is about 1.6. The positron converter scheme is based on the SLAC design: a removable tungsten-rhenium target is used for the pair production, while a flux concentrator jointly with DC solenoid magnets generate the 5 T peak magnetic field necessary for the positron capture. The focusing of the beam is obtained by a FODO arrangement of quadrupoles with pitch changing according to the beam energy. Solenoidal field magnets are used in the gun and PC areas. Beam Diagnostics include 14 beam position monitors, one at the end of each of the accelerating sections, 4 fluorescent screens placed at the end of E5 section, on the PC target, at the separator output and at the Linac end. Finally, 4 wall current monitors of the resistive type placed at the gun output, at the PC, at the separator output and at the Linac end, allow to measure the beam current along the Linac.

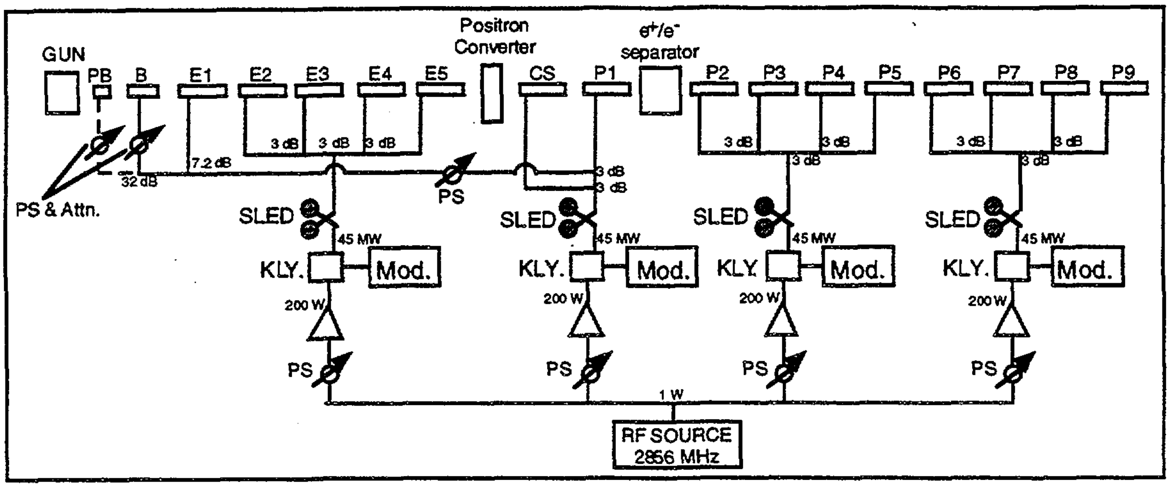


Figure 1: DAΦNE LINAC RF layout.

A CAMAC-Macintosh control system, with software in LabView, allows full remote control of the Linac. A separate GPIB controlled system based on two scopes and a wide band multiplexer is used for the system and beam diagnostics signals.

3 POSITRON MODE RESULTS

Figure 2 shows the signals from the 4 current monitors during a typical run in the positron operation mode. From left to right, the signals show 7.4 A (e$^-$), 5.7 A (e$^-$), 81 mA (e$^+$) and 67 mA (e$^+$) currents at the gun output, at the PC, at the separator output and at the Linac end respectively. The positron production efficiency, defined as the ratio between the positron current at the Linac output and the electron current at the positron converter, is 1.18 %.

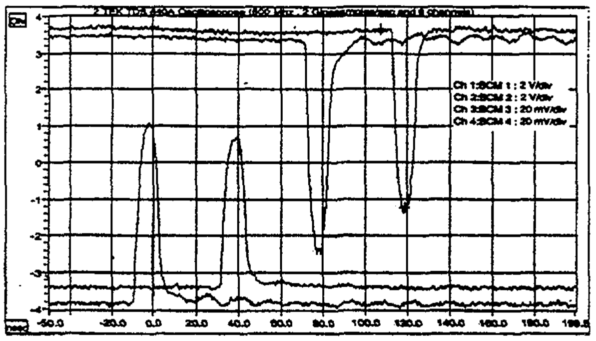
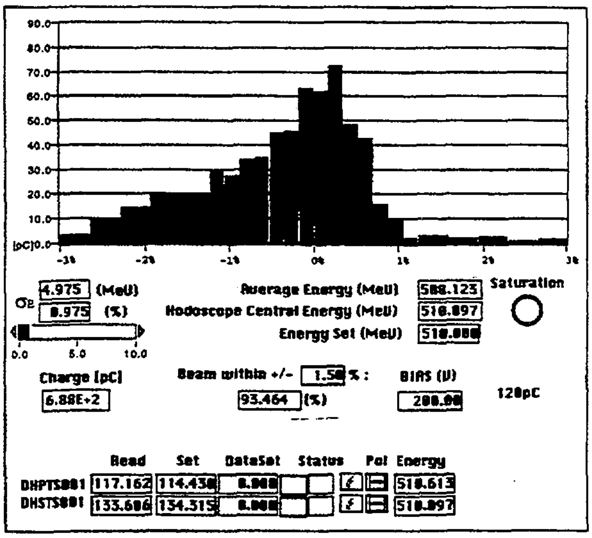


Figure 2: Current monitor signals in positron mode.

An estimate of the electron beam energy at the PC has been performed by using the corrector coil at the end of section E5 jointly with the profile monitor placed before the PC. The value obtained is ~ 190 MeV. The spot size at the PC target, measured by observing the thin fluorescent screen assembled in direct contact with the PC target surface, has a rms radius < 1 mm.

In Figure 3 the energy analyzer [5] control window shows a positron beam energy distribution at 510 MeV with rms spread of 0.98 %. It is worth to point out (see figure 3) that 93% of the beam is within the energy acceptance of ± 1.5 % of the downstream transfer line and Accumulator ring.

Emittance measurements, not yet performed, are foreseen in the near future by using the 3 gradients method [6]. Anyway, simulations have shown that the overall acceptance of the Linac downstream the PC is < 10 mm mrad, so that this value can be assumed as a upper limit for the beam emittance value.



σE 4.975 (MeV)
0.975 (%)

Average Energy (MeV) 508.123
Hodoscope Central Energy (MeV) 510.897
Energy Set (MeV) 510.000

Charge [pC] 6.88E+2

Beam within +/- 1.50 % : 93.464 (%)

BIAS (V) 200.00

120pC

	Read	Set	DataSet	Status		Pol		Energy
DHPTS001	117.162	114.430	0.000	☐	☐	⚡	⊟	510.613
DHSTS001	133.606	134.315	0.000	☐	☐	⚡	⊟	510.897

Figure 3: Energy distribution of the positron beam.

The RF Linac scheme allows to operate in the positron mode with the CS RF phase in 2 different configurations: accelerating and decelerating field. It has been evidenced [7] that in the decelerating mode a significant gain in the positron capture should be obtained at the cost of a small loss in energy.

Figure 4 shows some preliminary measurements of this effects performed on the DAΦNE Linac. Currently, the CS is used in the accelerating mode.

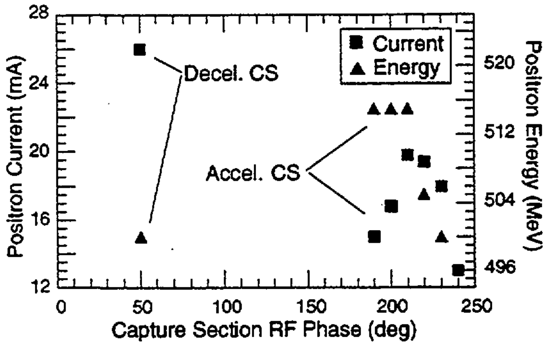


Figure 4: e$^+$ current & energy vs CS RF phase.

4 ELECTRON MODE RESULTS

In the electron mode of operation the PC target is extracted, the flux concentrator and the separator are turned off, the electron gun output current is drastically reduced and the output power coming out from the klystrons is diminished.

Figure 5 shows the electron beam current along the Linac during a typical run. From left to right 565 mA are present at the gun output, 350 mA at the PC, 325 mA after the separator and 297 at the Linac end.

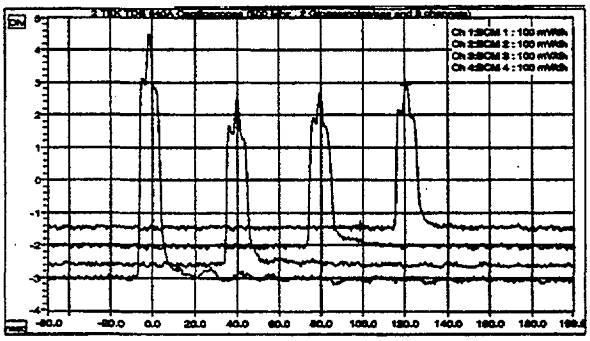
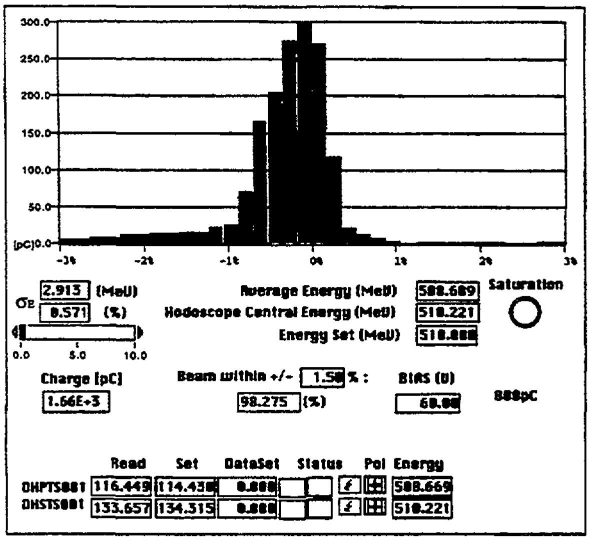


Figure 5: Current monitor signals in electron mode.



σE 2.913 (MeV)
0.571 (%)

Average Energy (MeV) 508.689
Hodoscope Central Energy (MeV) 510.221
Energy Set (MeV) 510.000

Charge (pC) 1.66E+3

Beam within +/- 1.50 % : 98.275 (%)

BIAS (V) 60.00

	Read	Set	DataSet	Status	Pol	Energy
DHPTS001	116.449	114.430	0.000			508.669
DHSTS001	133.657	134.315	0.000			510.221

Figure 6: Energy distribution of the electron beam.

The electron beam energy distribution is shown in Figure 6. It can be seen that the rms spread is 0.57 % and that practically all the beam is within the acceptance of the downstream transfer line and Accumulator ring.

It must be said that macrobunch currents of up to 1 A at the Linac end have been obtained with the electron beam. Anyway such a current values cannot be used because the beam loading inside the accelerating sections generates an increase of the energy spread (3 % rms with 1 A) beyond the transfer line and Accumulator acceptance.

5 CONCLUDING REMARKS

As part of the DAΦNE injector, the major requirements to the Linac come from the positron mode of operation. As already said, the good results obtained with the positron beam permit to reduce the DAΦNE injection time with beneficial effects on the integrated luminosity.

After a total of about 300 days of 24 hours/day operation shifts, all the Linac subsystems are completely debugged and the reliability level achieved is quite satisfactory. The fault statistics indicate in the gun pulser and in the modulator PFN capacitors the principal sources of faults. The reasons of these faults have been understood and actions for fixing them are being adopted.

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REFERENCES

[1] C. Biscari, " Performance of DAΦNE", this Conference.

[2] M.E. Biagini et al., "Performance and operation of the DAΦNE Accumulator", this Conference.

[3] K. Whitham et al., "Design of the e$^+$/e$^-$ Frascati Linear Accelerator for DAΦNE", PAC 93, Washington, May 1993.

[4] F. Sannibale, M. Vescovi, R. Boni, F. Marcellini, G. Vignola, "DAΦNE Linac commissioning results", DAΦNE Technical Note BM-2, April 1997.

[5] F. Sannibale, M. Vescovi, "Linac to Accumulator area transfer line & DAΦNE Linac spectrometer", DAΦNE Technical Note LC-3, February 1992.

[6] F. Sannibale, "DAΦNE Linac beams emittance measurement design", DAΦNE Technical Note LC-5, September 1992.

[7] B. Aune, R.H. Miller, "New method for positron production at SLAC", SLAC-PUB-2393, September 1979.