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THE 500 MeV INTENSE POSITRON SOURCE OF THE SACLAY LINAC

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Abstract

Positron acceleration at the Saclay high duty cycle linac is made between 20 and 130 MeV at the Low Energy Station and between 150 and 500 MeV in the High Energy Room. Average intensities in the whole energy domain are the highest available among the various laboratories. Energy widths (FWHM) as low as 1 MeV are obtained for low energy beam ($\lesssim$ 100 MeV) by special use of the first two sections (S7, S8) which rotates the phase space (ΔE, $\Delta\phi$). Beams can be switched between Low Energy and High Energy Stations with a period of 1 second. Various factors of the e^-/e^+ conversion rate are including the magnetic and RF phase adjustments ; they are illustrated by analyzing the energy spectrum obtained with acceleration in the first section S7 only. Beam monitoring includes high sensitivity ferrite monitors, RF cavities, wire chambers and scintillation detectors. A removable converter assembly will be used for an easy maintenance in a highly activated field.

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The Saclay high duty cycle 600 MeV electron linac is now a place unique in the world for accelerating average intensities above 50 nA of positrons from 20 to 500 MeV producing by annihilation in flight intense monochromatic photon beams used for the study of photonuclear reactions.

Reliable operation during long runs is obtained by limiting systematically the level of the electron beam power. Operation with a high power rotating target is excluded ; the target is unmoved : a piece of gold, with a thickness of one radiation length. This strongly water cooled target is probably able to withstand more than 100 μA average intensity of 90 MeV electrons on a spot of 1 mm in diameter ; it has been tested at a level of 80 μA for continuous operation and in most of the experiments, the average beam intensities effectively used are limited to 50 to 60 μA. That limitation is also important for reducing the effect of the electromagnetic shower on the first accelerating section (S7). This specially designed standing-wave accelerating section has been described previously[1]. Particular emphasis is put on the stability of the various elements ; general improvements of power generators, transmitters and RF pilot system are contributing to this goal.

Typical adjustments

Two kinds of typical operation are in use.

For most of the experiments done in the *Low Energy Room*, a maximum energy of 110 MeV is sufficient and emphasis is put on the intensity of the beam in a energy width of $\Delta E/E$ = 1.5 %. The solution adopted takes advantage of the separate adjustment of the RF phase at the entrance of first (S7) and second (S8) accelerating sections. Figs.1A and 1B give some results of a calculation made for an electron bunch of energy E and phase ϕ. One reads on Fig.1A the phase space at the entrance of S8 for different values of the S7 RF phase adjustment Φ_7; the lower part of the figure is relative to the value $\Phi_7 < 90°$; the positrons are first slowed down ; the upper part is the normal adjustment with $\Phi_7 > 90°$; the effect of selecting the initial energy

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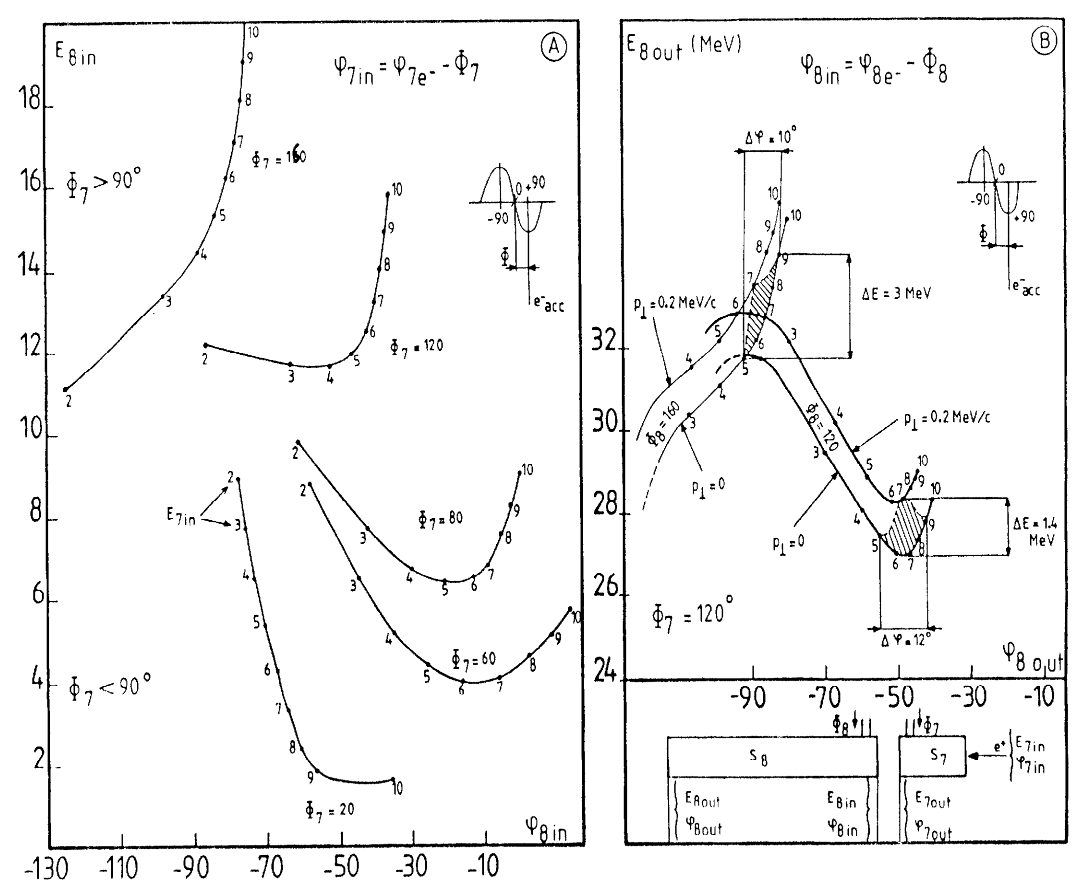

Fig. 1 - Phase space at the entrance (A) and at the end (B) of section S8.

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of the positrons at the entrance of S7 (E_{7in}) by various adjustment of the magnetic lens field at the converter (for example from 1.8 to 1 Tesla) is to change the beam phase Φ_{8in} at the end of S7.

Experiments made with feeding only S7 with RF (the other sections S8...S12 being not activated) and analyzing the energy spectra in the Low Energy Room, have demonstrated that various families of energy are selected according to the adjustments of the magnetic elements (lens and solenoids) for a given value Φ_7. Among the peaks observed, two of them are relative to the $3\pi/2$ and the $\pi/2$ Larmor angle between the converter target and the entrance of S7, but evidence has been found for a family with an initial energy E_7 of about 20 MeV.

The final adjustment is illustrated on Fig. 1B. By changing the S8 RF phase Φ_8 one rotates the phase space at the end of S8 (E_{8out}, Φ_{8out}) and one obtains for example with $\Phi_8 = \Phi_7 = 120°$ a narrow energy spectrum ; such an adjustment gives a gain of roughly a factor of two for the analyzed beam intensity in the Low Energy Station.

For operation at the maximum energy of 130 MeV in the Low Energy Room and the acceleration to the *High Energy Room*, the best results are obtained with a narrow phase bunch and the strongest initial acceleration ; the initial energy spread is bearable with reference to the $\Delta E/E = 1$ % monochromatizing slit used at energy of 300 or 400 MeV. For improving the energy spectrum for such a "High Energy" adjustment, it is generally worthwhile to lower the value of the magnetic field at the converter target, selecting lower values of E_7 and obtaining a narrower phase bunch.

Conversion rates and energy spectra

The conversion rates, expressed as the positron beam intensity obtained after acceleration for a given 90 MeV electron beam intensity impinging on the converter target are given on the Figs. 2 and 3. Curves A are relative to the intensity at the entrance of the monochromatizing slit and curves B are relative to the beam analyzed in $\Delta E/E = 1.5$ % for the Low Energy Room and in $\Delta E/E = 1$ % for the High Energy Room. The quoted rates are not the best obtained values but mean values in numerous runs with some differences in the adjustments and in the status of the elements. Typical emittance values as measured in the Low Energy and High Energy Rooms are respectively 1.8×10^3 MeV mm.mrd and 1.5×10^3 MeV mm. mrd.

Table 1 gives typical values of the widths of the energy spectra as measured with (A) or without (B) the special (Φ_7, Φ_8) phase adjustment.

Table 1

Energy of accelerated positrons (MeV)	35	90	130	180	340	440
Widths of energy spectrum (FWHM) (MeV)	1.35	2.50	3	1.9	3.2	4.1
	(A) with			(B) without		
	phase space rotation					

Beam diagnostics

A large number of monitors are used to meet the two requirements of the accurate location of the high average intensity of electrons at the entrance of the quadrupole triplet focussing the beam on the converter target and of the quick and easy detection of very low peak intensity of the positron beam at the beginning of the adjustment.

After the last section (S6) accelerating the electrons, there is a ferrite position monitor with a sensitivity of 0.2 mm for a 10 mA peak intensity and a secondary electron diaphragm monitor checking also permanently the centring of the beam . In complement there are gamma-ray detectors looking to any beam losses. A television camera gives permanently in the control room the direct observation of the surface of the target or, at any times it is needed, of a remotely controlled luminescent screen introduced in the plane of the target (the repetition rate of the beam pulses is then reduced from 1000 to 6 Hz).

The positron monitors in the linac are high sensitivity ferrite toroidal intensity monitors and RF cavities. The first have a very low background of 0.2 μA peak current. The second have a sensitivity of 0.5 μA. (We used also remotely controlled diaphragms coupled to gamma-ray detectors). For the beam handling lines, intensities are measured with the ferrite monitors and profiles are given by wire chambers or revolving scintillator systems.

The high sensitivity of the toroidal monitors for positron beam is obtained by using a high value for the loading resistance (6 to 10 kΩ) associated with a small number of whorls (30), instead of the values used for the electron beam monitors (1 kΩ - 120 whorls).

Maintenance

The main difficulty is the high residual activity in the converter assembly. Changing the target itself is relatively easy. But the big problem is changing, if it is needed, the coils, the vacuum box and the cooled collimator. A newly designed assembly will offer the possibility to disconnect easily the whole converter assembly by the use of a quickly opened flange joint.

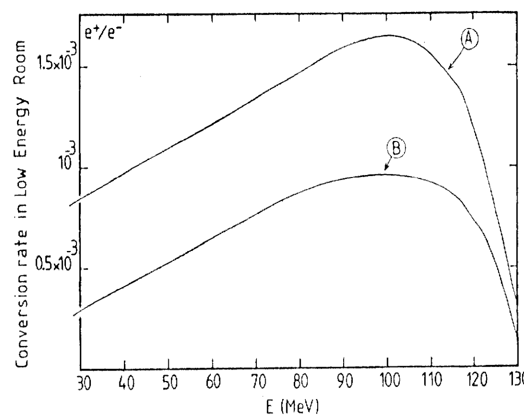

Fig. 2

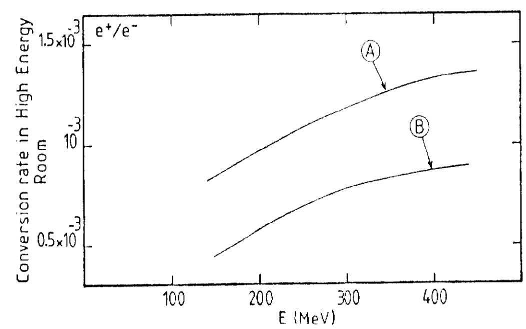

Fig. 3

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[1] B. Aune, M. Juillard, F. Netter and A. Pacchioni, Intense beams of 100 to 500 MeV positrons. IXth Int. Conf. High Energy Accelerators, 295, May 1974.