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50 MeV ELECTRON LINAC WITH A RF GUN AND A THERMOIONIC CATHODE

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Abstract

The low energy part of our pre injectors is made up of a 90 kV DC thermoionic triode gun, followed by a 500 MHz sub harmonic pre buncher and a 3 GHz pre buncher. We propose a new design for a 50 MeV linac with a RF gun [1]. This study will compare the beam dynamics simulations for the new design and for our previous pre injectors.

RF CAVITY F – 3F

The RF gun F – 3F is integrated in a modulated cavity at sub harmonic frequencies 200 MHz and 600 MHz followed by a drift in order to bunch the beam.

The main difficulty is to adapt the cavity geometry in order to have exactly at harmonic 3: $F_3 = 3 \times F_0$.

Then, in order to be synchronised with the travelling wave section frequency we must obtain: $F_{3GHZ} = 15 \times F_0$.

The electrons emission is produced by a thermoionic cathode implemented inside the RF cavity

The feeding RF power is of 25 kW, the entry accelerating field, at the cathode position, is equal to 1.2 MV/m and the crest field is of 6.5 MV/m.

The grid is modulated at 200 MHz with a pulse length gate of 500 ps, i.e. a phase beam extension equal to 36 degrees. We can then choose the appropriate phase with respect to the RF cavity field.

GENERAL DESCRIPTION OF THE F/3F RF GUN 50 MeV LINAC

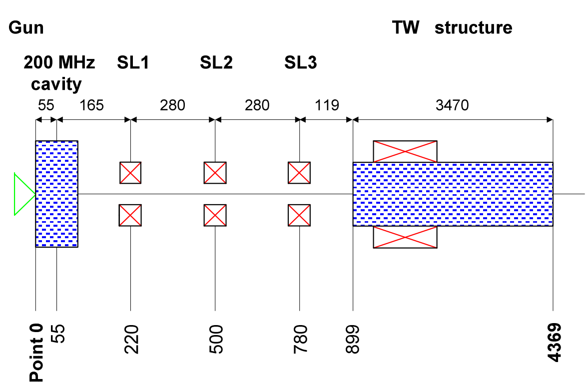

Figure 1: F/3F RF GUN 50 MeV linac (unit in mm).

Figure 1 shows a schematic layout of the F/3F RF gun 50 MeV linac. The subsystems are listed below:

- A RF gun with a thermoionic cathode.
- A 200 MHz/600 MHz cavity.
- Three focusing shielded lenses between the cavity and the accelerating structure.
- A travelling wave accelerating structure.
- A solenoid surrounding the beginning of the structure.

The total length is around 4.4 meters for 50 MeV beam energy. Our previous design for the BESSY II linac at the same energy had a total length of around 8 meters [2].

BEAM DYNAMICS SIMULATIONS

The Gun and the Cavity

The injection line from the gun to the accelerating structure includes the RF cavity with a 25 kW at 200 MHz and a 2.3 kW at 600 MHz.

The drift space between the cavity exit and the RF input of the section is around 900 mm long.

The radial focusing along the drift space is provided by 3 shielded lenses with respectively a magnetic field of 700, 400 and 450 Gauss.

At the cavity exit without space charge, the beam energy varies from 317 keV to 349 keV for a phase extension of 6 degrees at 200 MHz.

Figure 2 shows the phase-energy diagram at 200 MHz cavity exit. For a total charge of 240 pC, the energy varies from 274 keV to 354 keV, an energy spread of 80 keV, for a phase extension of 13 degrees at 200 MHz, i.e. 195 degrees at 3 GHz.

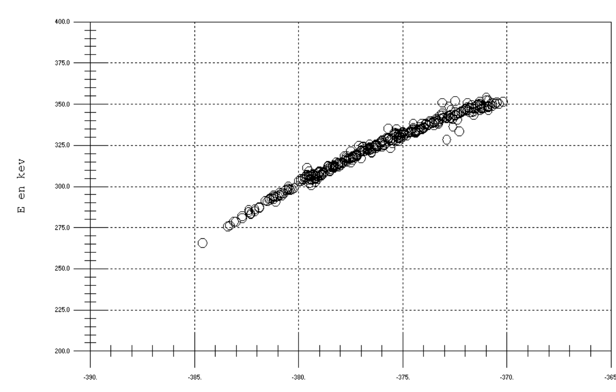

Figure 2: Phase-energy diagram at the cavity exit.

Figure 3 shows the phase-energy diagram at the accelerating structure entry after a drift space of 900 mm. For the phase extension, the same time scale was taken for figures 2 and 3.

After the drift, the phase extension was reduced from 195 degrees to 40 degrees for 91% of the gun charge.

The Accelerating Section

The main accelerating structure is identical to those made for the ALBA and BESSY II pre injectors [3].

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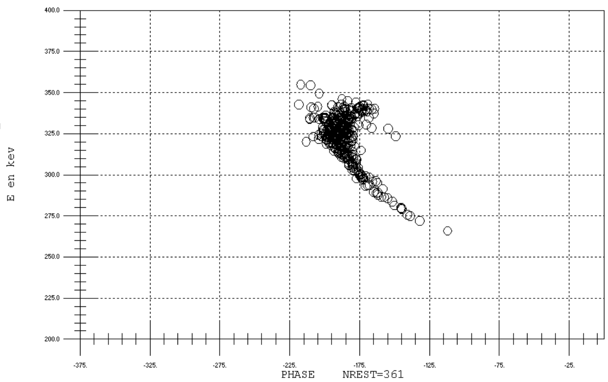

Figure 3: Phase-energy diagram at the structure entry.

It is a travelling wave 2π /3 mode section designed with a constant gradient. The iris diameter varies from 22.4 mm to 16 mm, giving a group velocity c/v_g from 51 to 149 over 96 cells including the couplers cavities ones.

The filling time is 0.88 µs and the power attenuation is equal to 5.6 dB.

A peak electric field of 23.4 MV/m on axis (36.1 MV/m on copper) provided with an 18 MW RF feed, allows an energy increase of 52 MeV.

Usually, this section is used without external focusing as the input beam energy is around 15 MeV in our previous design.

The phase adjustment between the RF cavity and the section insures the radial focusing. Nevertheless, a one meter solenoid is surrounding the beginning of the accelerating structure at 270 mm from the input flange. The magnetic field is equal to 1800 Gauss.

Radial focusing with and without external magnetic focusing will be given.

Figures 4 and 5 show respectively, at the linac exit, the energy and the energy histogram. Fig. 6 shows the phase histogram at the middle of the last linac cavity.

The transmission is equal to 99% of the gun current pulse (500 ps – 240 mA) i.e. 120 pC.

For 82% of the gun current, the energy spread at 50.3 MeV is inside 0.8 MeV, i.e. ± 0.8%. For 69% of the gun charge the energy spread is inside 0.5 MeV, i.e. ± 0.5%.

For 98% of the gun current, the phase extension is inside 14 degrees at 3 GHz, i.e. 13 ps. For 94% of the gun charge, the phase extension is reduced to 8 degrees at 3 GHz, i.e. 7.4 ps.

Figure 7 shows the beam cross-section at the linac exit.

For 94% of the gun current, the beam is inside a 4 mm diameter. For 75% of the gun charge, the beam radius is smaller than 0.42 mm.

Figure 8 shows the beam cross-section at the linac exit without an external magnetic focusing.

The focusing is insured by the radial RF field component. In fact, at the entry of each cavity the axial field variation focus the beam and the exit field variation defocus the beam.

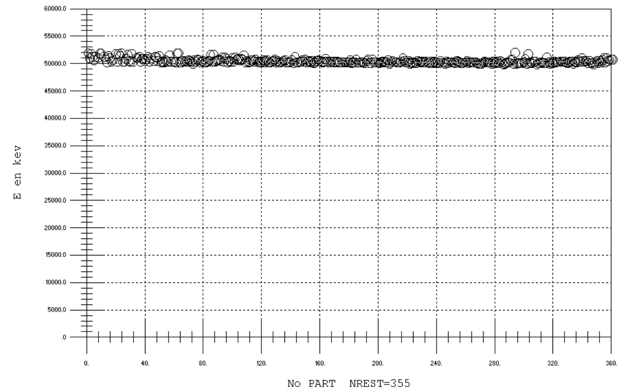

Figure 4: Energy at the linac exit.

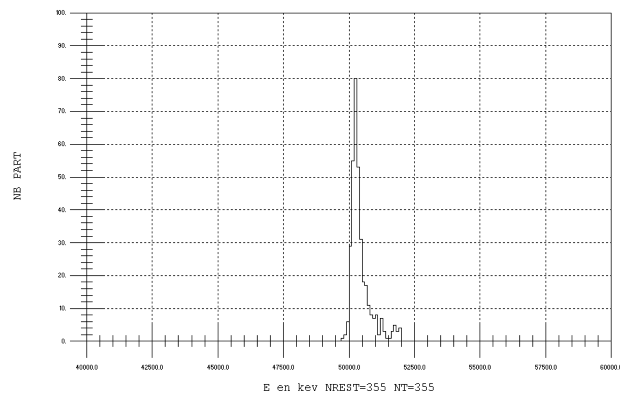

Figure 5: Energy histogram at the linac exit.

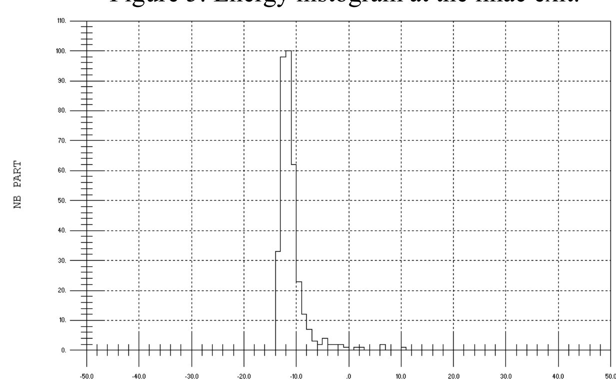

Figure 6: Phase histogram at the linac exit.

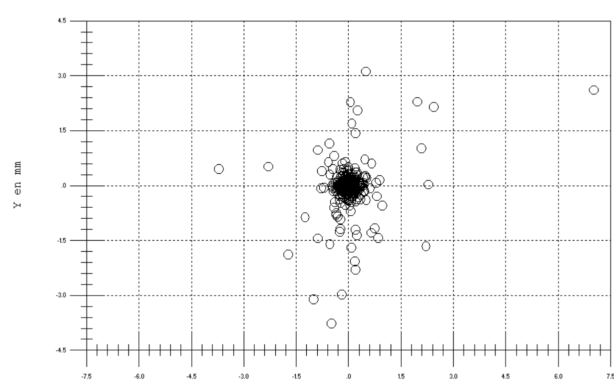

Figure 7: Beam cross-section at the linac exit.

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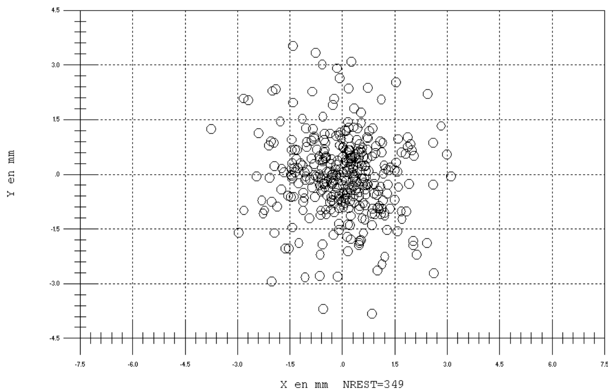

Figure 8: Beam cross-section without magnetic focusing.

The transmission is reduced from 99% of the gun current to 97% without the external magnetic field. The energy spread and the phase extension are unchanged. The beam is inside a 4 mm diameter for only 78% of the gun current. For 75% of the gun charge, the beam radius is now smaller than 1.8 mm.

For our previous design [2], we had at the gun level modulated with a 500 MHz a beam pulse of 1 ns–120 mA i.e. 120 pC charge. With the two pre-bunching cavities, 86% of the 1ns input pulse falls within a 64 degrees phase extension at the buncher entry and for 75% of the gun current the phase extension is reduced to 43 degrees.

Figures 9 and 10 show respectively, at the BESSY II linac exit, the energy histogram and phase histogram at the middle of the last linac cavity. Those figures are to be compared to figures 5 and 6 of the new design.

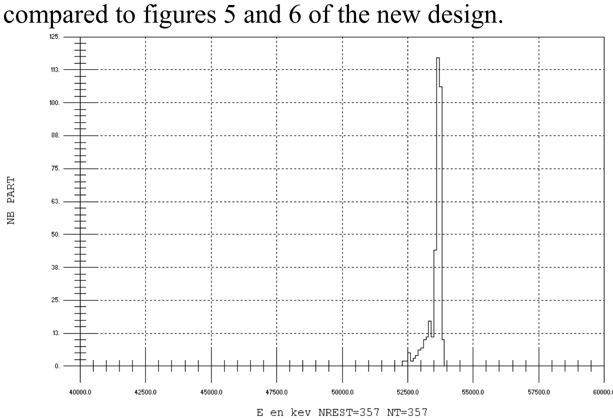

Figure 9: Energy histogram at the BESSY II linac exit.

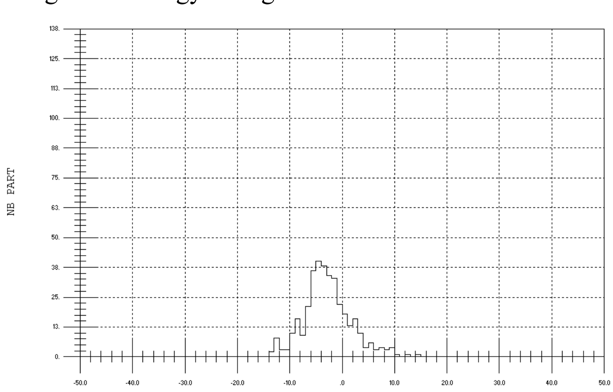

Figure 10: Phase histogram at the BESSY II linac exit.

Table 1 gives the beam properties at the linac exit for both layouts.

Table 1: Beam Properties at the Linac Exit

Gun Current	**BESSY LINAC**	**F/3F RF GUN LINAC**
Total transmission	79%	99%
Energy in MeV	53.5	50.3
$\Delta E = 0.8$ MeV	72%	82%
$\Delta E = 0.5$ MeV	66%	69%
$\Delta\varphi = 14$ degrees	70%	98%
$\Delta\varphi = 8$ degrees	54%	94%
Beam radius < 2 mm	66%	94%
Beam radius for 75%	3.5 mm	0.42 mm

CONCLUSION

With this F/3F RF gun, the performances are similar to a photocathode RF gun without the laser source reducing by this, the maintenance and time adjustment.

The RF gun F/3F associated with a travelling wave accelerating structure gives exit energy of 50.3 MeV with ±0.8% dispersion for 82% of the 120 pC gun charge. For 94% of this gun charge, the phase extension is inside 8 degrees at 3 GHz, i.e. 7.4 ps.

In all cases, the F/3F RF gun 50 MeV linac allows us to get rid of the 90 kV high voltage and gives us a compact 50 MeV linac in 4.4 meters long.

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