

STUDY OF A RF GUN WITH A THERMOIONIC CATHODE

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Abstract

The low energy part of our pre injectors [1] is made up of a 90 kV DC thermoionic triode gun, followed by a 500 MHz sub harmonic prebuncher and a 3 GHz prebuncher. These two cavities are respectively fed with 500 W, a modulation of ± 25 kV, and 90 W corresponding to a ± 10 kV. The gun grid is modulated within a 500 MHz signal. The initial 1 ns phase extension at the gun level is reduced, at the buncher entry, to 40 ps for 75% of the gun current. This study proposes to replace the gun and the two cavities by a RF gun integrated in a modulated cavity at 200 MHz followed by a drift in order to bunch the beam. This study will compare the beam dynamics simulations for these two cases.

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.

Figure 1 represents the cavity geometry together with the electric field lines for both frequencies: 200 MHz and 600 MHz.

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 buncher frequency we must obtain: $F_{3\text{GHz}} = 15 \times F_0$.

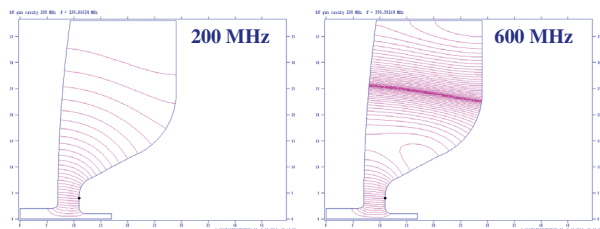


Figure 1: Geometry and field lines of the RF cavity.

The electrons emission is produced by a thermoionic cathode implemented inside the RF cavity. Fig. 2 represents the electric field inside the cavity at 200 MHz.

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.

To induce a constant acceleration over the whole beam and reduce like this the energy spread; the cavity is fed by 2 frequencies F and 3F i.e. 200 MHz and 600 MHz.

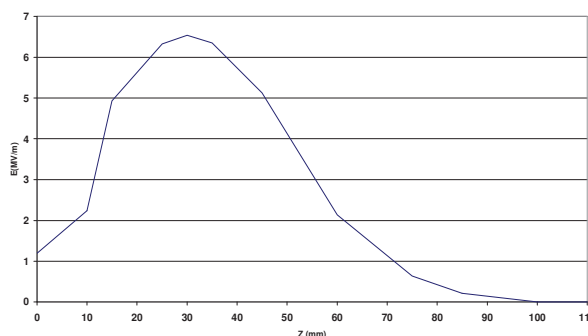


Figure 2: Electric field at 200 MHz.

BEAM DYNAMICS SIMULATIONS

Previous Injection Layout

Figure 3 represents the previous injection layout of our linacs.

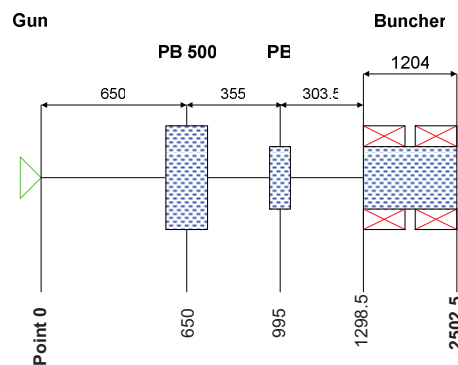


Figure 3: ALBA and BESSY injection.

The injection line from the gun to the buncher includes two pre-bunching cavities at 499.654 MHz and at 2997.924 MHz for our linacs, except for SOLEIL with a booster not in the sub harmonic range [2]. The drift between the pre-buncher and the buncher is 650 mm long. The beam modulation is about ± 25 kV with a 500 W RF feed.

The pre-bunching cavity allows for only one pulse at 3 GHz, instead of three, from the one nanosecond pulse. This enables a halving of the energy spread in Single Bunch mode [3].

The beam modulation of the 3 GHz pre-bunching cavity is about ± 10 kV with a 90 W RF feed. The drift between the pre-buncher and the buncher is 300 mm long.

The radial focusing along the drift space is provided by 4 shielded lenses not represented in the layout.

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Driven by a 5 MW RF power, the buncher increases the beam energy up to 15 MeV using an average electric field on axis of 18 MV/m. Surrounding the buncher, shielded solenoids help guide the beam onwards through the structure.

New Injection Layout

Figure 4 represents the new injection layout of the RF cavity F-3F.

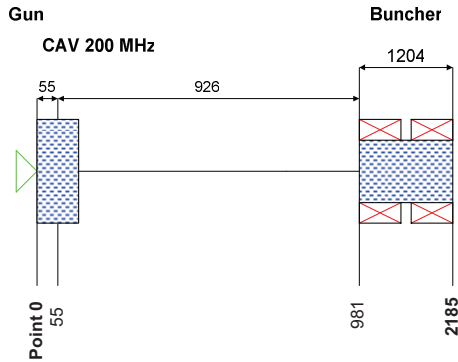


Figure 4: RF cavity injection.

The injection line from the gun to the buncher 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 and the buncher is around 900 mm long.

The radial focusing along the drift space is provided by 3 shielded lenses not represented in the layout.

Longitudinal Simulations without Space Charge

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, i.e. 85 ps.

After a drift space of 900 mm, at the buncher entry the beam phase extension is reduced to 0.4 degrees at 200 MHz i.e. around 6 ps.

At the buncher exit and for 15 MeV, the energy spread is inside 90 keV for the total input beam.

Table 1 gives the beam properties at the buncher exit for both layout and without space charge.

Table 1: Beam Properties at the Buncher Exit

	ALBA	BESSY	RF CAVITY
Buncher entry (ps)	40.0		6.0
Energy (MeV)	15.7		15.4
ΔE (keV)	120		90
Δt (ps)	5.5		6.0

Complete Beam Simulations at 240 mA

Figure 5 and 6 show respectively, at the buncher exit and for the previous ALBA and BESSY injection, the energy and the energy histogram. Figure 7 shows the phase histogram at the middle of the last buncher cavity.

The transmission is equal to 91% of the gun current pulse (500 ps – 240 mA).

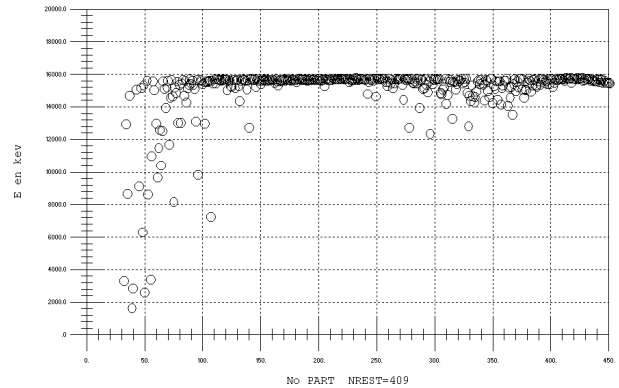


Figure 5: Energy at the buncher exit.

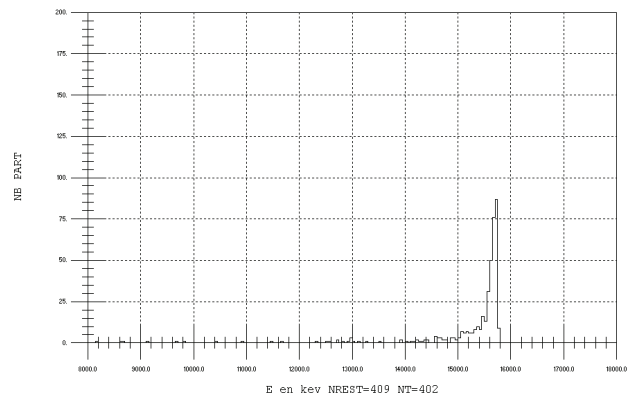


Figure 6: Energy histogram at the buncher exit.

For 76% of the gun current, the energy spread at 15.7 MeV is inside 0.8 MeV, i.e. $\pm 2.55\%$.

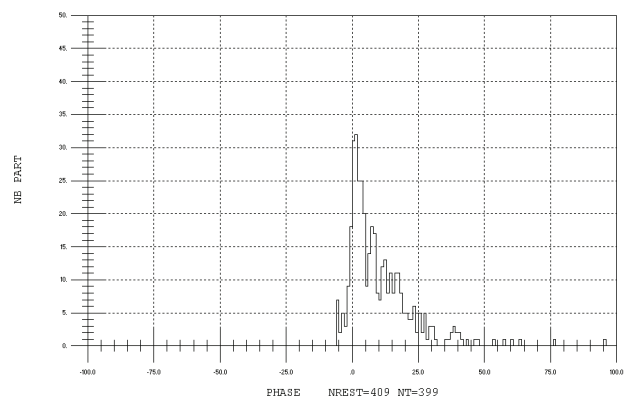


Figure 7: Phase histogram at the buncher exit.

For 68% of the gun current, the phase extension is inside 20 degrees at 3 GHz, i.e. 18.5 ps.

Figure 8 shows, at the buncher entry and for the new RF cavity injection, the phase histogram for 240 mA. The energy varies from 274 keV to 354 keV, an energy spread of 80 keV with a 33 ps phase extension for 89% of the gun current. To compare with the 32 keV and 6 ps without space charge.

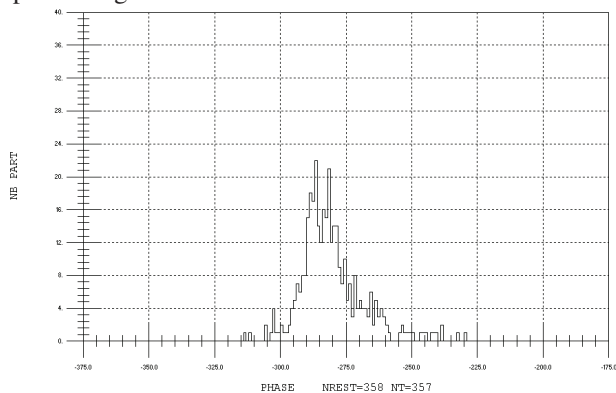


Figure 8: Phase histogram at the buncher entry.

Figures 9 and 10 show respectively, at the buncher exit, the energy and the energy histogram. Fig. 11 shows the phase histogram at the middle of the last buncher cavity.

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

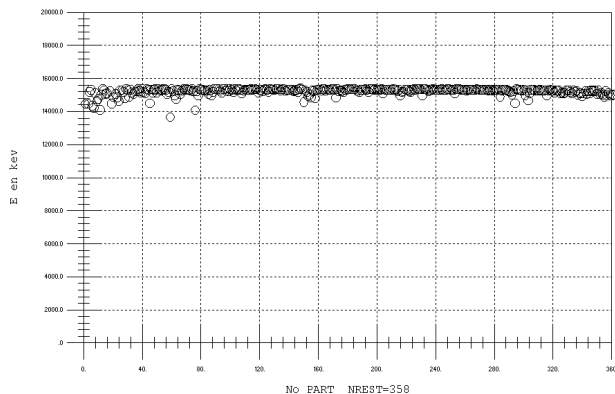


Figure 9: Energy at the buncher exit.

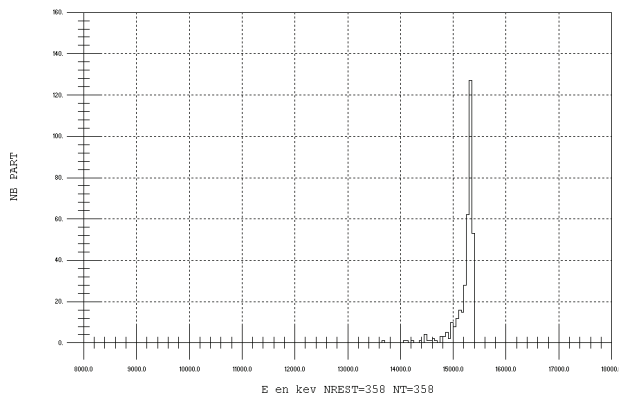


Figure 10: Energy histogram at the buncher exit.

For 96% of the gun current, the energy spread at 15.4 MeV is inside 0.8 MeV, i.e. $\pm 2.55\%$.

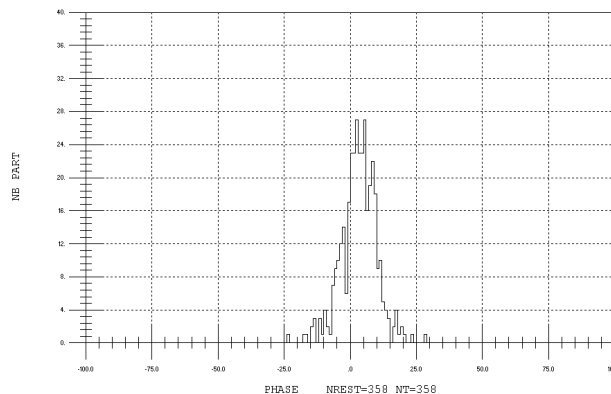


Figure 11: Phase histogram at the buncher exit.

For 89% of the gun current, the phase extension is inside 20 degrees at 3 GHz, i.e. 18.5 ps.

Table 2 gives the beam properties at the buncher exit for both layout and for a gun current of 240 mA.

Table 2: Beam Properties at the Buncher Exit for 240 mA

Gun Current	ALBA BESSY	RF CAVITY
Transmission in:		
$\Delta E = 0.8 \text{ MeV}$	76%	96%
$\Delta E = 0.4 \text{ MeV}$	64%	89%
$\Delta\phi = 20 \text{ degrees}$	68%	89%
$\Delta\phi = 8 \text{ degrees}$	38%	50%

CONCLUSION

With this RF gun, the performances are similar to a photocathode RF gun without the laser source.

The RF gun F – 3F associated with a buncher gives an exit energy of 15.4 MeV with a $\pm 1.3\%$ dispersion for 90% of the 240 mA gun current. For a 100 mA current, 97% of the gun current is inside $\pm 1.3\%$ dispersion.

In all cases, the RF gun allows us to get rid of the 90 kV high voltage.

REFERENCES

- [1] A. Setty et al, "Design and Construction of Turnkey Linacs as Injectors for Light Sources", Proceedings IPAC 2012, USA, Louisiana, May 2012.
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- [3] A. Setty et al, "Commissioning of the 100 MeV preinjector for the ALBA synchrotron", PAC09, Vancouver, BC, Canada, May 2009.