OPTIMISATION OF THE AXIAL INJECTION SYSTEM FOR U400 CYCLOTRON (LINEAR BUNCHER)

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Abstract

The buncher with a linear ramp voltage at U-400 cyclotron axial injection system are investigated. The influence of a various parameters on bunching efficiency has been studied. Numerical and experimental results of the beam bunching are presented.

1 INTRODUCTION

The U-400 cyclotron axial injection system includes the two bunchers: first with linear ramp and second with sinusoidal voltage (Fig.1). In this report we present the results of analysis only for linear buncher.

Capture efficiency into acceleration (ratio intensity of the accelerated beam on R=60cm to injected one) without buncher is equal ≈8÷10% and with using only linear buncher - ≈25%. In the ideal case bunching efficiency of the linear buncher is near 80÷90%.

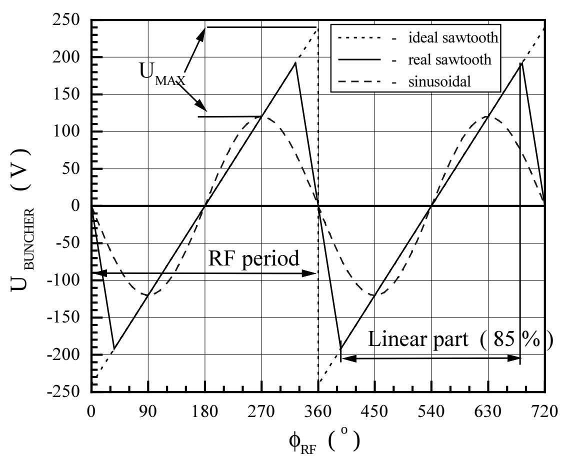

Figure 1: The time variation of the voltage on the buncher axis (saw tooth and sinusoidal).

2 NUMERICAL SIMULATION

The linear buncher is a single gridded gap system. The linear RF voltage is directly applied to the first electrode, the second one being grounded. Buncher parameters show in Table 1.

Table 1: Linear buncher parameters

Test ion	$_{40}Ar^{+4}$
A/Z	10
Uinj [kV]	13.75
Frf [MHz]	6.5
Gap between grids [mm]	10
Drift space L [m]	4.4
Bunch width $\Delta\phi$ [°]	30

For numerical simulation we used an $_{40}Ar^{+4}$ ion. Only phase motion without any focusing element was considered in our calculations.

Fig.2 shows the bunching efficiency as a function of the voltage on the buncher for various bunch width. The optimal voltage amplitude is ≈240÷260V (bunching efficiency ≈88%). For following calculation we used Ub=240 V.

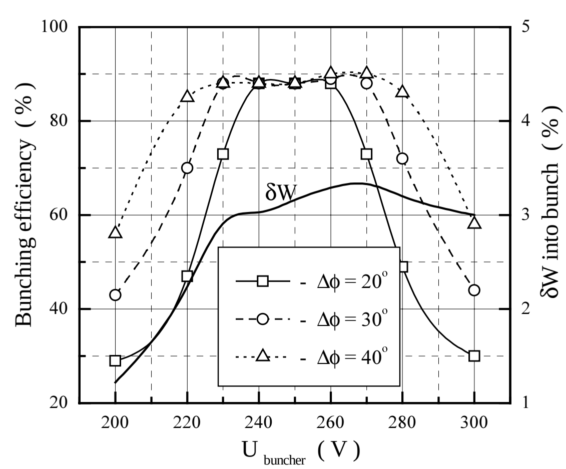

Figure 2: Bunching efficiency vs. voltage on the buncher Ub for bunch width Δφ=20°, 30° and 40° and energy spread into bunch δW for Δφ=30°.

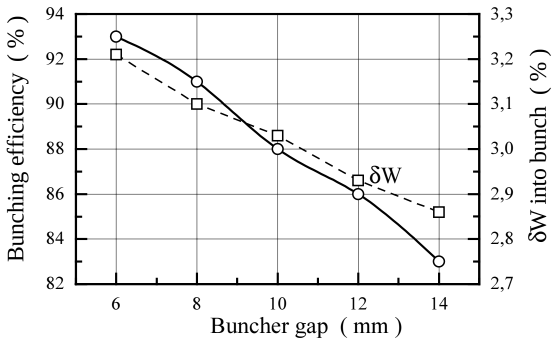

Figure 3: Bunching efficiency and energy spread into bunch vs. gap between the two gridded electrodes (Ub=240 V; Δϕ=30°).

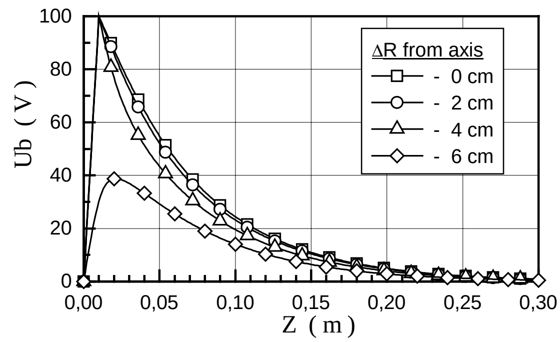

Figure 6: Potential distribution for the two gridded electrodes buncher on various distances from axis.

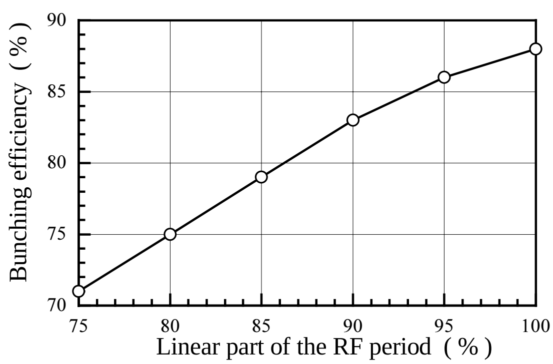

Figure 4: Bunching efficiency vs. linear part of the saw-tooth voltage (Ub=240 V; Δϕ=30°).

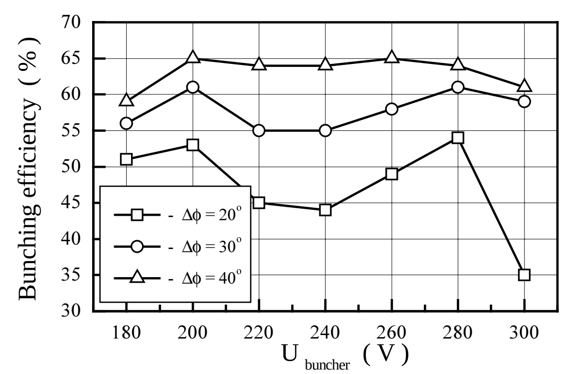

Figure 7: Bunching efficiency vs. voltage on the buncher Ub take into account stray field for the two gridded electrodes (Δϕ=20°, 30° and 40°).

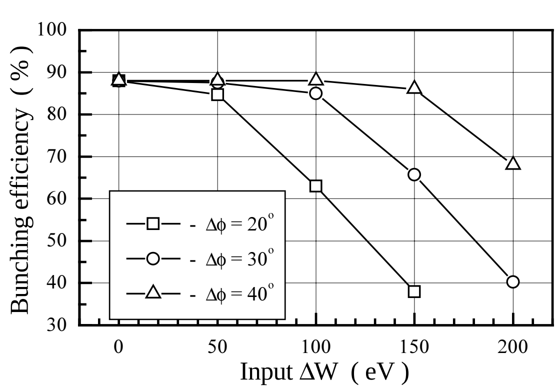

Figure 5: Bunching efficiency vs. energy spread on the buncher entrance (Ub=240 V; eZ = +4).

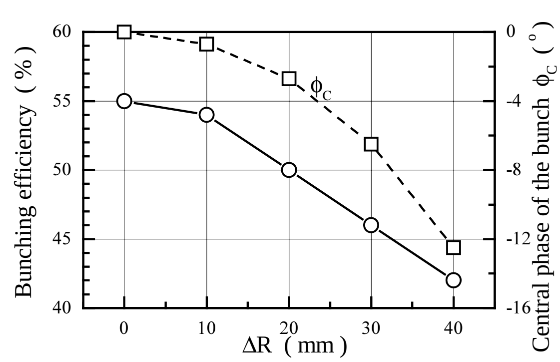

Figure 8: Bunching efficiency and central phase of the bunch ϕc vs. particles distance from axis for the two gridded electrodes (Ub = 240 V; Δϕ=30°).

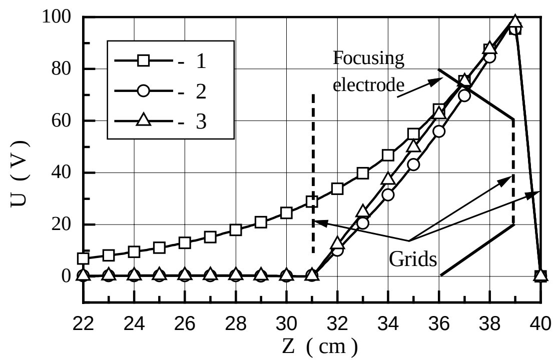

Figure 9: Potential distribution along axis : 1 – two grids; 2 – three grids; 3 – three grids and focusing electrode.

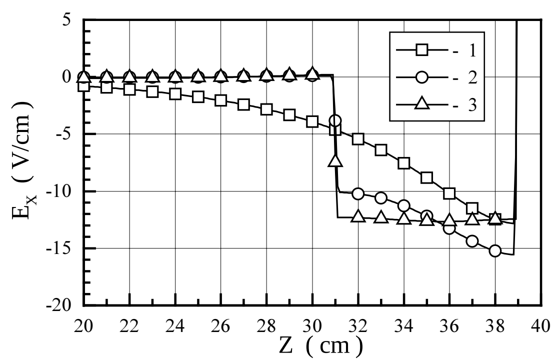

Figure 10: Electric field distribution along axis for variants as Fig.9.

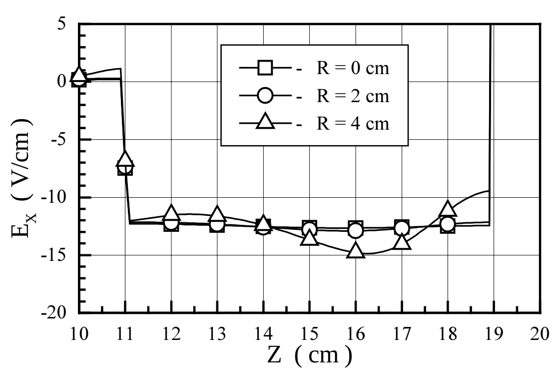

Figure 11: Electric field distribution for variant with three grids and focusing electrode on various distances from buncher axis.

Fig.3÷5 show the influence of the various parameters to the bunching efficiency. The energy spread in beam before gridded gap is a most important parameter. In previous calculation we take into account RF field only in gap between the two gridded electrodes. In reality we have unfortunately a negative stray RF field of low level but of large extent in front of first electrode [1]. Potential distribution is determined using the code RELAX (Fig.6). Fig.7 shows the bunching efficiency for calculation with using stray field (decreasing in comparison Fig.2).

Fig.8 shows the bunching efficiency for beam moving on various distances from buncher axis (for various potential distribution) and central phase of the bunch.

We used an additional third grounded grid in distance $\beta\lambda$=80 mm in front of the first electrode and additional focusing electrode on potential grid for more homogeneous potential distribution [1] for minimisation effects this stray RF field on the beam (Fig.9÷11).

3 CONCLUSION

Results of the numerical simulation were used in new construction of the linear buncher (third grounded grid and additional focusing electrode). Capture efficiency into acceleration (ratio intensity of the accelerated beam on R=60cm to injected one) with new linear buncher is equal ≈35%. The bunching efficiency increases but not yet enough.

Capture efficiency into acceleration with using two buncher (new linear buncher + sinusoidal buncher) is equal ≈60%.

At next step of simulation we needs to use the transversal emittances, focusing elements and spiral inflector. We also plan to take into account the space charge influence on the bunching efficiency.

4 REFERENCES

[1] A. Chabert et al. “The linear buncher of SPIRAL. Beam test of a prototype”, Nucl.Instr. and Meth. In Phys.Res. A423 (1999), pp.7-15.