LONGITUDIAL BEAM DYNAMICS AT RF-COMRESSOR*

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Abstract

Researches at the field of electron diffractoscopy require ultra-short beam bunches. For the production bunches with length about hundreds fs reasonable to apply longitudinal bunch compression. Usually such compression is carried by two kind of devices, first one is system of magnetic elements so called chicane, and the second one is combination of RF-cavities so called RF-compressor. Limitations on application of these devices belong to beam parameters. Mains beam incoming parameters are beam duration, charge, energy, energy deviation- longitudinal distribution.

The paper describes longitudinal dynamic of beam passing through RF-compressor to minimize beam length. We study a low energy (4MeV) bunch compressor design to produce a short (<150 fs) bunch length.

INTRODUCTION

Transverse Lorentz force in relativistic beam proportional to:

$$F_r(\mathrm{r}) \sim Q\frac{1}{\gamma^2} \tag{1}$$

Under some meaning of charge, we come to regime when space charge force will be sufficient.

Our scheme based on an S-band RF-compressor, utilizing the bunching properties of standing waves. It has been recently proposed as an alternative to magnetic compressors in order to avoid beam quality degradation due to Coherent Synchrotron Radiation effects [1,2]. We present here a numerical study of the beam dynamics in an S-band compressor.

Layout

The layout of our model consist from RF-gun, drift space, RF-compressor and one more drift space (see Fig. 1).

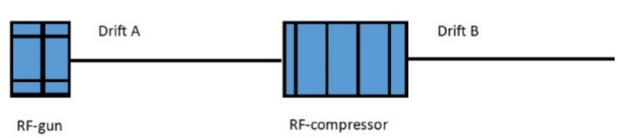

Figure 1: Layout of model.

RF-gun consist of 1.5 accelerator cavities on 2856MHz which work at π-mode

First drift space is caused by technical tools and should be minimum about 0.5m. It is required for beam diagnostic and focusing system.

Compressor includes 4 RF-cavities with length of each 50.1mm, and equal to $\frac{\lambda}{2}$ and have frequency equal to 2855.183MHz.

Drift B is the distance to longitudinal focus

Incoming Beam

Beam parameters after RF-gun are following: duration is about 2ps energy 3-5 MeV. Charge of beams in our simulations was equal to 1, 10 and 100pC

Beam distribution at phase of RF-gun equal to 3deg presents in Fig. 2.

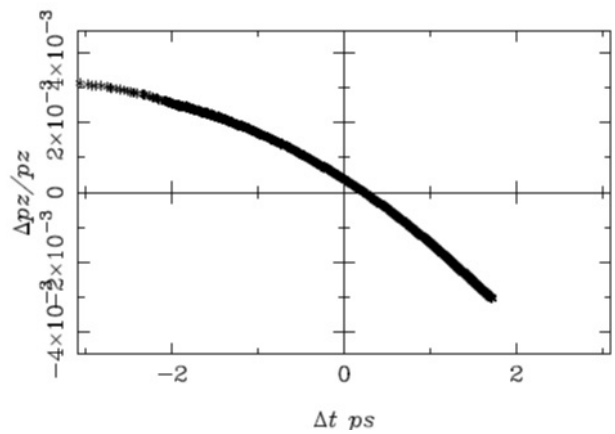

Figure 2: Longitudinal phase space of beam at the entrance to RF-compressor.

The distribution configuration is determined by RF-gun cavity phase φ_0 and have cosine form.

$$E_z = E_0\cos(\omega\,\mathrm{t}+\varphi_0)\,, \tag{2}$$

LONGITUDINAL DYNAMICS

RF-Compressor

Longitudinal distribution of electric field at compressor (see Fig. 3) was obtained by CST Studio simulation of structure Maximal magnitude of electrical field at RF-compressor equal to 30MV/m, total power consumption is about 1.7MW.

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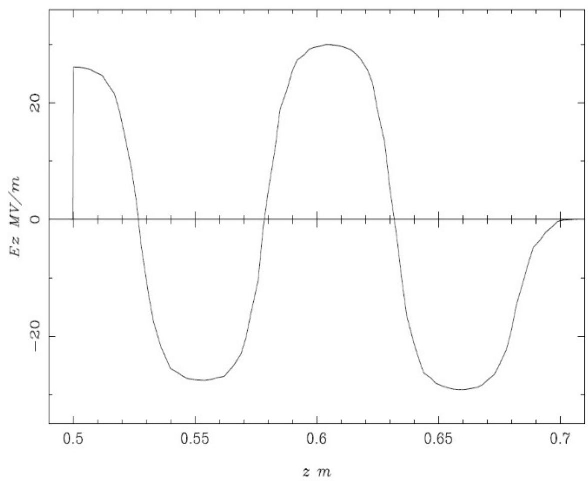

Figure 3: RF-compressor electrical field longitudinal distribution.

A beam with energy about 4MeV is injected into an RF-compressor structure in the phase without acceleration. After this beam undergoing interaction with electromagnetic field of compressor. As a result of such interaction beam tail gets addition acceleration while head undergoes deceleration (see Fig. 4) [3,4].

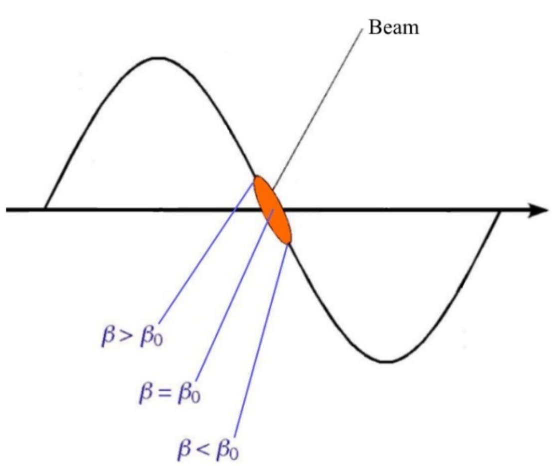

Figure 4: Interaction beam with RF-field zero accelerating phase.

SIMULATIONS

We simulate bunch dynamics for different charge. In order to take into account space charge forces ASTRA was used. Test charges are equal to 1pC, 10pC and 100pC.

In order to minimize bunch length we vary the phase of RF-compressor. Phase scan results are shown in Fig. 5.

Changing length of bunch along the installation is illustrated in Fig. 6.

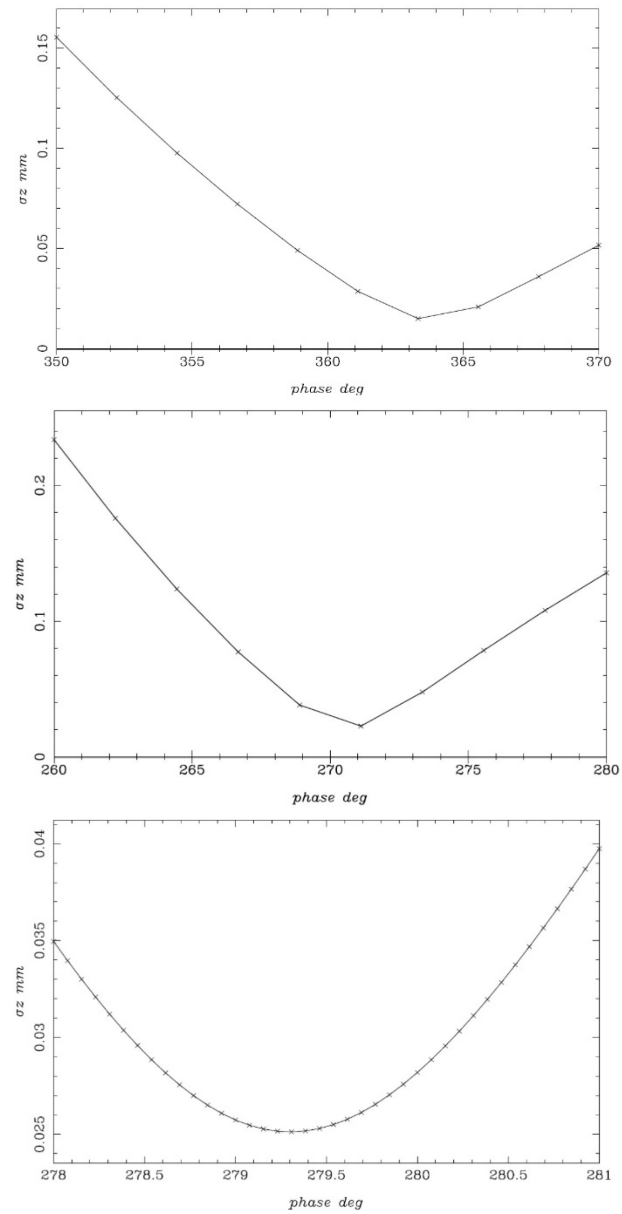

Figure 5: Phase scan for the different beam charges: upper 1pC, middle 10pC, lower 100pC.

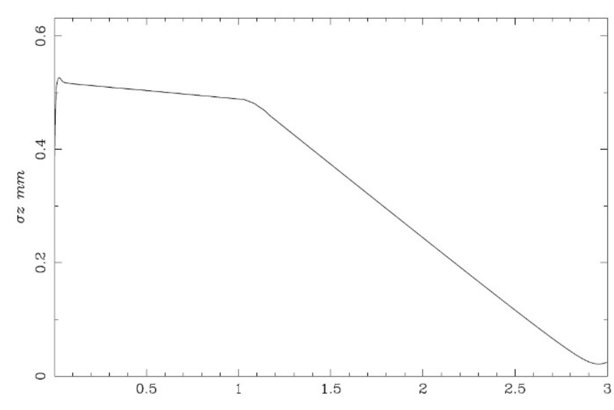

Figure 6: Typical envelope for bunch length. It is similar for different beam charges

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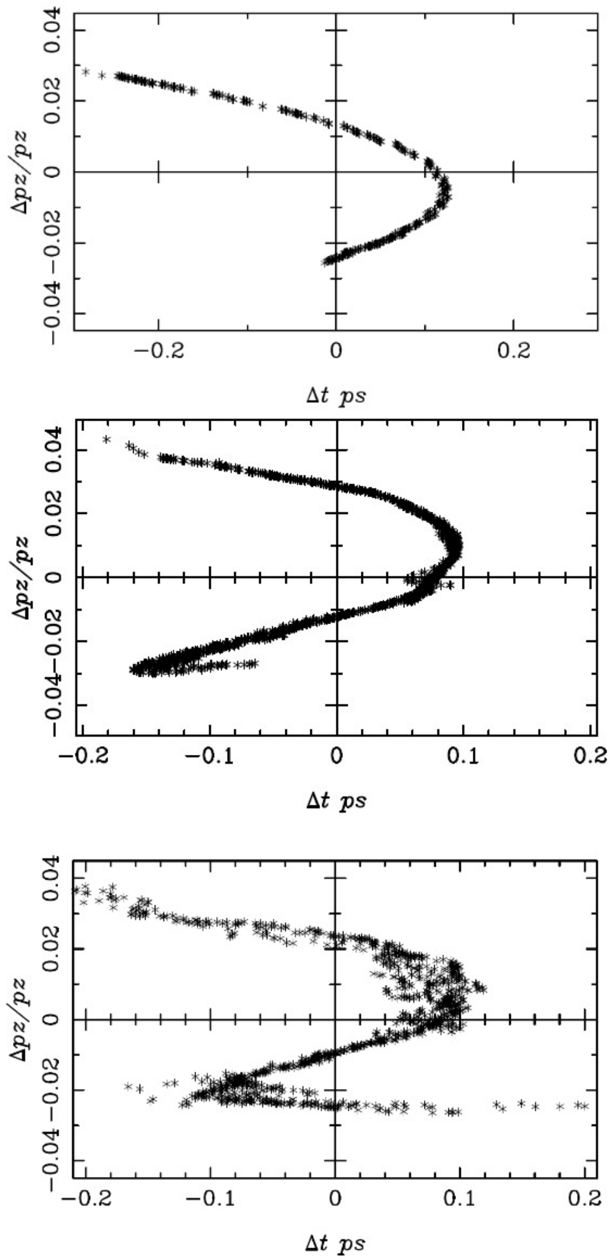

Figure 7: Longitudinal phase space at longitudinal focus for the different beam charges: upper 1pC, middle 10pC, lower 100pC.

SUMMARY

We obtain the estimation of installation size. Beam characteristics was obtained for different charges of bunch. Required beam length in few hundreds picoseconds was obtained (see Figs. 7,8).

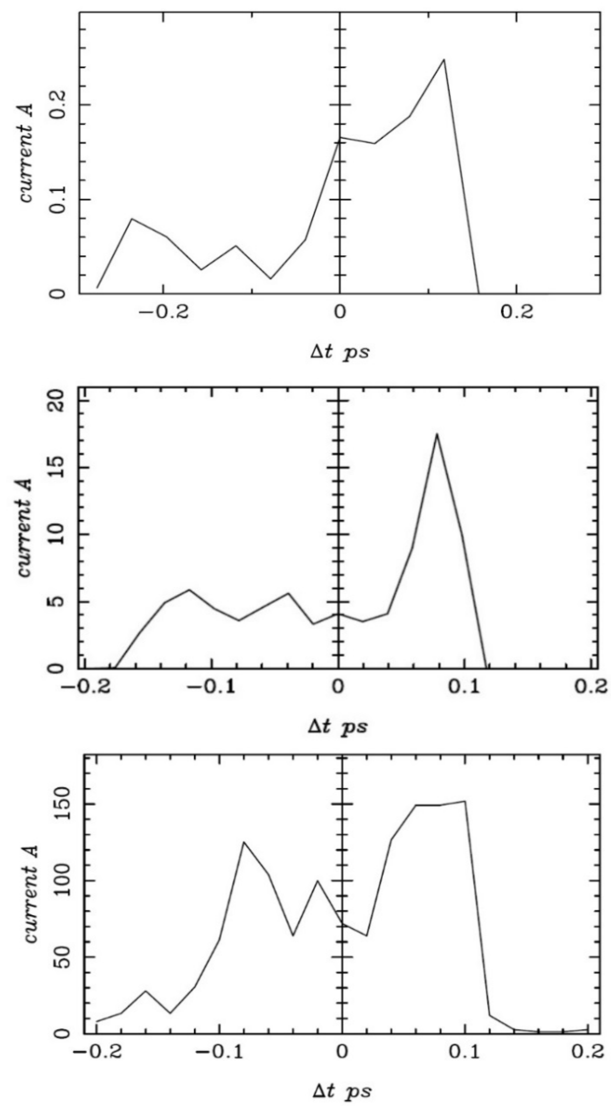

Figure 8: Longitudinal density distribution at longitudinal focus for the different beam charges: upper 1pC, middle 10pC, lower 100pC.

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