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BUNCHER FOR THE OPTIMIZATION OF THE INJECTION OF A 70 MeV CYCLOTRON

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Abstract

The design of an injection buncher for the 70 MeV cyclotron in use at Laboratori Nazionali di Legnaro (LNL) labs of INFN is under way. This buncher is to be installed between the ion source and the injection, to match the injected beam to the acceptance angle of the cyclotron's injection.

The planned design is a 3/2 beta-lambda double-gap driven with one or two harmonics of the 56 MHz cyclotron's frequency.

Remotely-driven variable capacitors will be used for easy tuning of the matching box from the control system.

The mechanical layout and simulations will be presented.

DESIGN OF THE BUNCHER

The injection buncher for the 70 MeV cyclotron at Laboratori Nazionali di Legnaro (LNL) of INFN is on design stage since a while, due to the commitment of the cyclotron's team to other activities. Nevertheless, slowly but constantly the design is being carried out by the team.

Relatively to older presentations [1, 2], the mechanical design is reconsidered and implemented in stability and accuracy. Beam dynamics simulations have been started, and the results are shown here. A chopper is also being considered.

GENERAL LAYOUT

The buncher will be installed along the injection line, between the multi-casp H^- ion source and the central region, in a dedicated vacuum box, placed between two focusing solenoids. The vacuum box can be isolated from the ion source and the cyclotron closing two gate valves, placed before and after the position of the buncher. The ion source provides up to 10 mA of DC current at 40 keV. The frequency of the buncher will of course be the same as the radiofrequency (RF) of the cyclotron, e.g. 56 MHz. The length of the buncher is calculated upon the $\frac{3}{2}\beta\lambda$, that is 73.995 mm, where $\beta\lambda$ is the distance covered by the ions accelerated by the source during one RF cycle.

Mechanical Layout

To improve the beam dynamics, the ground electrodes should be not too short. Two different configurations have been studied: a $\frac{3}{2}\beta\lambda$ buncher that has a longer drift tube, and a $\frac{1}{2}\beta\lambda$, that allows longer ground electrodes.

It is not possible to have long ground electrodes and long drift tube at the same time, due to the limited longitudinal dimensions: the two gate valves are placed at short distances before and after the position of the buncher.

The $\frac{3}{2}\beta\lambda$ and the $\frac{1}{2}\beta\lambda$ configurations have both been calculated and compared.

The $\frac{3}{2}\beta\lambda$ buncher This configuration allows the use of two separate electrodes for the injection of two different harmonics of the radiofrequency power.

Using the $\frac{3}{2}\beta\lambda$ configuration, and 5 mm between the RF electrode (the drift tube) and the ground (GND) electrodes, the length of the drift tube will be of 69 mm, and the total length of the whole buncher is 119 mm, with 20 mm of GND electrode's length.

To determine the inner diameter of the buncher we remind that it must be as small as possible, with respect to the diameter of the beam, to increase the transit time factor [3,4].

The dimensions of the $\frac{3}{2}\beta\lambda$ configuration are specified in Table 1.

Table 1: Dimensions of the $\frac{3}{2}\beta\lambda$ Buncher: Drift Tube and Ground (GND) Electrodes

Element	Length (mm)	Diameter (int/ext)
GND1	20	40/50
Gap1	5	-/-
Drift tube	69	40/50
Gap2	5	-/-
GND2	20	40/50

The rendering of the new design of the $\frac{3}{2}\beta\lambda$ can be seen in the following Fig. 1.

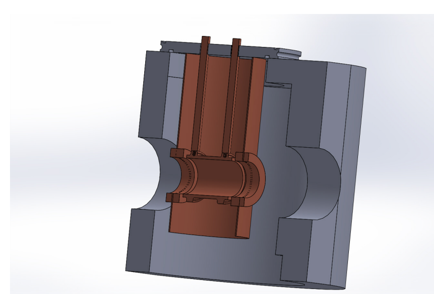

Figure 1: Rendering of the section of the buncher. The ground electrodes will be screwed with the external screen. Two electrodes are foreseen to feed the RF power to the buncher, at one ore two harmonics.

The Fig. 2 shows the calculation of the electric potential in the plane cutting the buncher along ts axis, where the Fig. 3 shows the detail of the potential along the axis of the drift tube.

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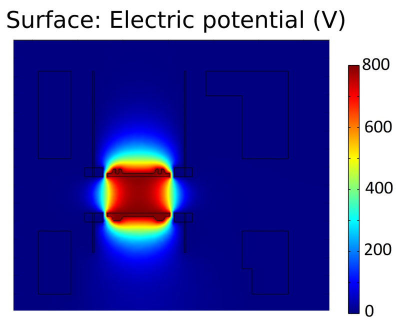

Figure 2: Simulation of the electric field for the $\frac{3}{2}\beta\lambda$ buncher. The beam travels horizontally.

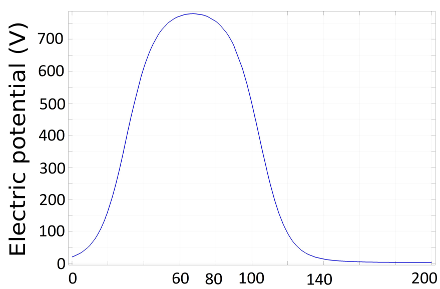

Figure 3: Simulation of the electric field along the axis for the $\frac{3}{2}\beta\lambda$ buncher.

With this configuration, the phase/energy plot can be seen in Fig. 4.

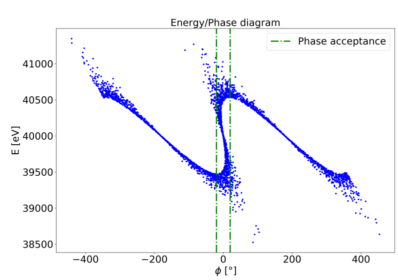

Figure 4: Phase/energy diagram for the $\frac{3}{2}\beta\lambda$ buncher.

The distribution of the particles inside the buncher is as in Fig. 5.

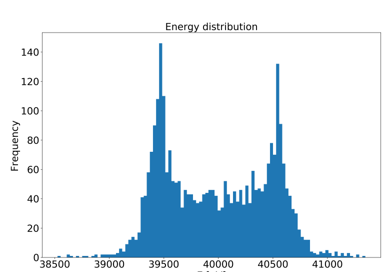

Figure 5: Distribution of the particles inside the bunches, for the $\frac{3}{2}\beta\lambda$ buncher.

The vertical (y) emittance was also calculated,and it is shown in Fig. 6.

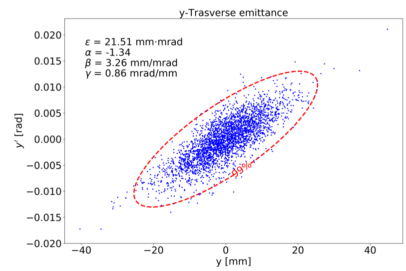

Figure 6: Vertical (y) emittance calculations the $\frac{3}{2}\beta\lambda$ buncher.

The horizontal (x) emittance was also calculated,and it is shown in Fig. 7.

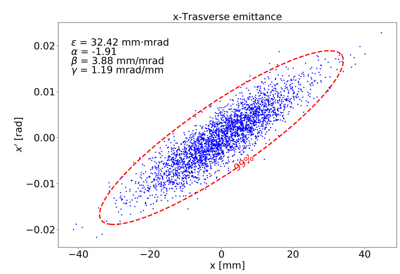

Figure 7: Horizontal (x) emittance calculations the $\frac{3}{2}\beta\lambda$ buncher.

The $\frac{1}{2}\beta\lambda$ buncher The rendering of the design of the $\frac{1}{2}\beta\lambda$ can be seen in the following Fig. 8.

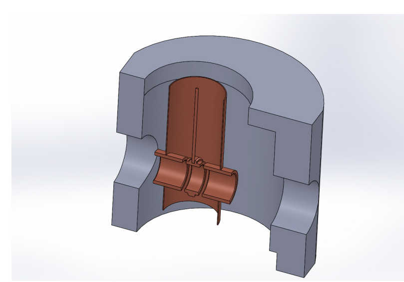

Figure 8: Rendering of the $\frac{1}{2}\beta\lambda$ buncher. The ground electrodes will be screwed with the external screen.

This second configuration has some advantages. The first one is that the ground electrodes can be longer, this improves the emittance of the injected beam. The second advantage is that the ground screen is at larger distance from the drift tube electrode: this decreases the capacitance of the buncher, allowing for a better matching impedance circuit between the RF amplifier and the buncher. Nevertheless, as can be seen in the electric potential simulations of Figs. 9 and 10, in the axis of the buncher the electric voltage is lower than in the border, paving the way for a worsening of the Transit Time Factor.

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The dimensions of the $\frac{1}{2}\beta\lambda$ configuration are specified in Table 2.

Table 2: Dimensions of the $\frac{1}{2}\beta\lambda$ Buncher: Drift Tube and Ground (GND) Electrodes

Element	Length (mm)	Diameter (int/ext)
GND1	40	40/50
Gap1	5	-/-
Drift tube	20	40/50
Gap2	5	-/-
GND2	40	40/50

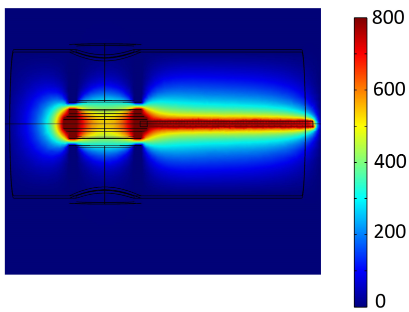

Figure 9: Simulation of the electric field for the $\frac{1}{2}\beta\lambda$ buncher. The beam travels vertically.

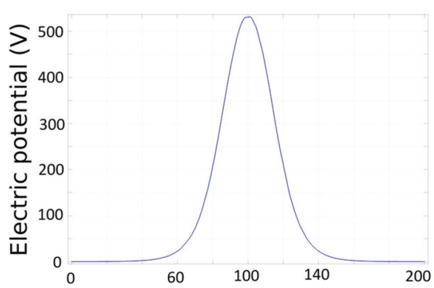

Figure 10: Simulation of the electric field on axis for the $\frac{1}{2}\beta\lambda$ buncher.

With this configuration, the phase/energy plot can be seen in Fig. 11.

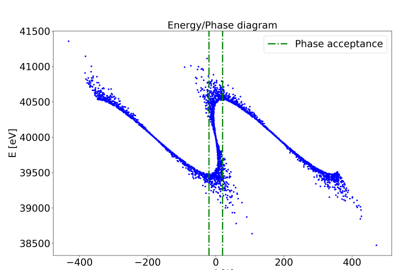

Figure 11: Phase/energy diagram for the $\frac{1}{2}\beta\lambda$ buncher.

The distribution of the particles inside the buncher is as in Fig. 12.

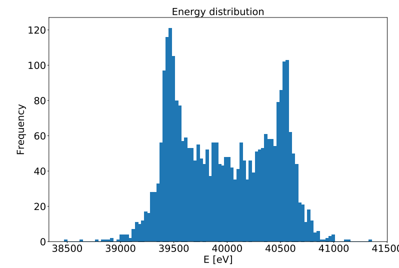

Figure 12: Distribution of the particles inside the bunches, for the $\frac{1}{2}\beta\lambda$ buncher.

The vertical (y) emittance was also calculated,and it is shown in Fig. 13.

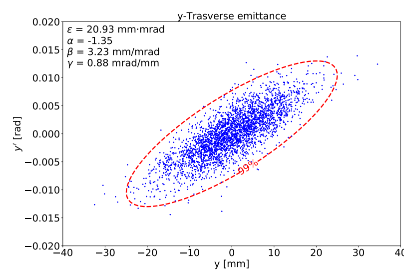

Figure 13: Vertical (y) emittance calculations the $\frac{1}{2}\beta\lambda$ buncher.

The horizontal (x) emittance was also calculated,and it is shown in Fig. 14.

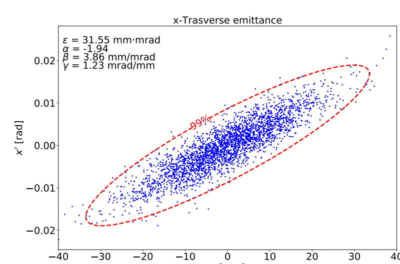

Figure 14: Horizontal (x) emittance calculations the $\frac{1}{2}\beta\lambda$ buncher.

COMPARISON OF THE TWO CONFIGURATIONS

The emittances of the two configurations are shown in the next Table 3. It can be seen that the two different drift tube lengths do not change much the emittance. For this reason the choice between the two configurations will be made based on mechanical stability or electronic circuitry.

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Table 3: Vertical (y) and Horizontal (x) Emittances (in mm·mrad) for the Two Different Configurations. It can be seen that there is no large difference.

Emittance	$\frac{3}{2}\beta\lambda$	$\frac{1}{2}\beta\lambda$
ϵ_y	21.5	20.9
ϵ_x	32.4	31.5

REFERENCES

[1] P. Antonini *et al.*, “Design of an injection buncher for the 70 MeV cyclotron”, *European Cyclotron Progress Meeting (ECPM) 2017*, Legnaro, Italy.

[2] P. Antonini *et al.*, “Design of an injection buncher for the SPES cyclotron”, *INFN-LNL Annual Report (2017)*, pp. 3-4.

[3] W. J. G. M. Kleeven, “Injection and extraction for cyclotrons”, *CAS - CERN Accelerator School and KVI: Specialised CAS course on small accelerators*, 2005, pp. 271-296. doi:10.5170/CERN-2006-012.271

[4] W. J. G. M. Kleeven, W. Gelbart, and J. Sura, “Optical properties of a two-gap buncher”, *Nucl. Instr. Methods Phys. Res., Sect. B*, vol. 64, pp. 367-370, Feb. 1992. doi:10.1016/0168-583X(92)95496-E