# 500-MHZ BUNCHER FOR THE 72-MEV INJECTION LINE

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*A further increase of the 590-MeV cyclotron beam current needs an upgrade of the existing RF systems. One of the options is to install a rebuncher at the third or tenth harmonic of the fundamental frequency in the 72-MeV injection line. The consideration of the required RF power and of the manufacturing costs lead to the design of a 500-MHz double-gap single-stem drift-tube cavity The detail engineering of the cavity, including coupler and tuning system, is finalized and the production will start at the beginning of 2005.*

## INTRODUCTION

An upgrade of the PSI cyclotron facility from the actual 1.8 mA beam current to 3 mA brings new challenges: towards higher accelerating voltages for the four 50 MHz RF cavities of the 590 MeV main ring cyclotron to reduce space charge effects require amplifiers able to handle large RF power swings.

Moreover, the proton bunches length at the exit of Injector 2 is typically about 2 cm (FWHM) and increases up to about 8 cm at the end of the 58-m injection line due to the energy dispersion and space charge repulsion [1]. A rebuncher installed in the transfer line would help to better match the beam to the ring cyclotron and may eventually lead to the decommissioning of the 150-MHz flat-top cavity.

Several types of buncher at 150 MHz and 500 MHZ have been investigated [2]. At 150 MHz, normal-conducting coaxial half-wave resonators were considered. However, the required RF power would be as high as 130 kW for a beam aperture diameter of 50 mm to provide a 718 kV RF voltage per gap. At 500 MHz, the best numerical performances were obtained for normal-conducting two-gap drift-tube cavities operating in the 2 π-mode. For an RF voltage per gap of 218 kV, the needed RF power for such a type of cavity where the drift tube is maintained by two stems is about 7 kW (50 mm aperture diameter). The quoted RF voltages per gap were determined with the tracking code MAD9P [3]. To ease the manufacturing procedure and the assembly, a 500 MHZ double-gap drift-tube cavity with a single stem has been designed (Fig. 1).

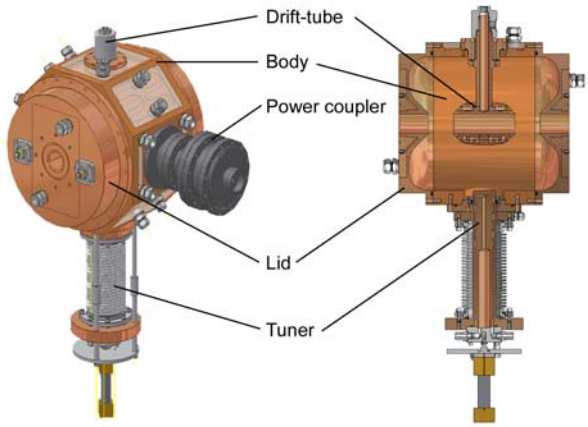


**Fig. 1:** 3D view (left) and cross-section (right) of the buncher including coupler and tuning system.

## GEOMETRICAL AND RF CHARACTERISTICS

The drift-tube cavity has an inner diameter of 346 mm and an inner length of 385 mm which makes it very compact. The stem which maintains the drift tube has a diameter of 41 mm. The plunger for frequency tuning is located opposite to the stem. The power coupler is located in a plane orthogonal to the stem and the plunger (Fig. 1). The length of the two gaps is 65.8 mm. The profile of the electric field along the beam axis is shown in Fig. 2. Note that the geometrical center-to-center gap distance is slightly different from the electrical one. The electric and magnetic field contour lines of this resonator for a given plunger position are shown in Fig. 3 and Fig. 4.

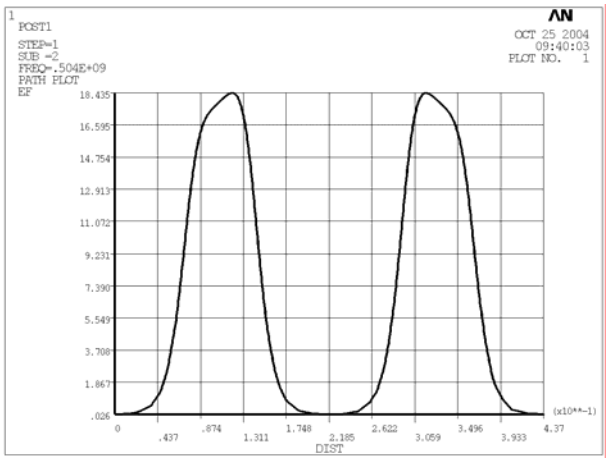


**Fig. 2:** Amplitude of the electric field along the beam propagation axis of the drift-tube cavity (a.u.).

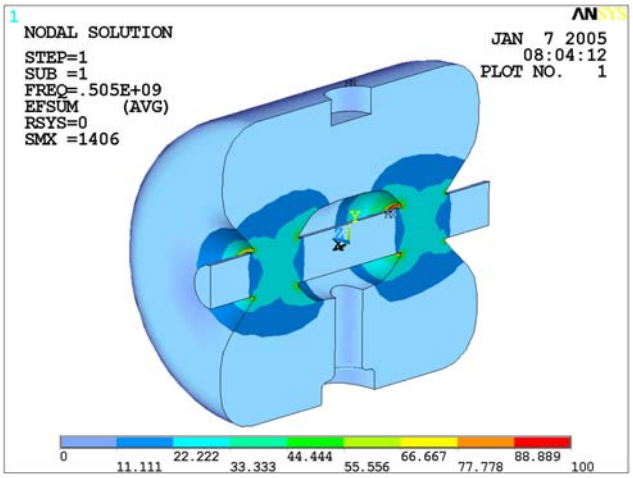


**Fig. 3:** Electric field contour lines of the drift-tube cavity for a given tuner position (a.u.).

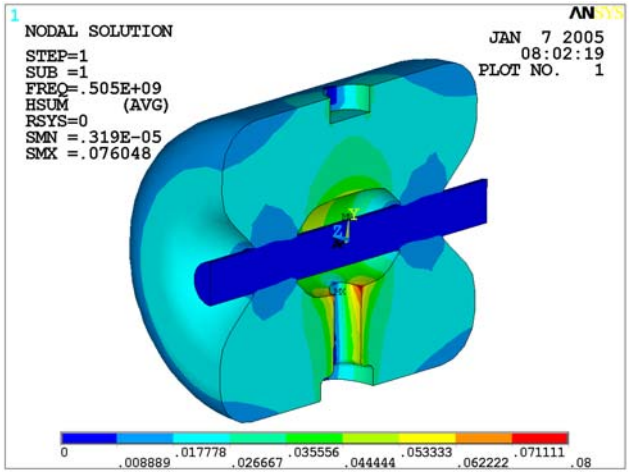


**Fig. 4:** Magnetic field contour lines of the drift-tube cavity for a given tuner position (a.u.).

## MECHANICAL DESIGN

The buncher is made from oxygen free high conductivity copper (OFE-grade). The main parts are the buncher body itself, the two lids and the removable drift tube. The buncher body and the two lids will be completely machined out of a forged copper tube. Cooling channels directly machined into the buncher body provide the necessary cooling. The plunger for frequency tuning will be hydraulically driven. For the inductive input power coupler, we chose the Elettra type [4], the same type which has been used for the 500-MHz SLS cavities.

The main parameters of the buncher are given below:

| | |
|---|---|
| Resonance frequency: | 506.328 MHz |
| Gap voltage: | 218 kV |
| Quality factor: | 34'000 |
| Dissipated power, operating case: | 10 kW |
| Dissipated power, max. case: | 30 kW |
| Hydraulic tuning system range: | 2.34 MHz |
| Cavity body: | Cu-OFHC |
| Vacuum pressure: | 1e-6 mbar |
| Total leak rate: | 1e-6 mbar l/s |

## SIMULATION

An ANSYS coupled field analysis RF-Thermal-Structural-RF was used to predict the behaviour of the buncher. The applied simulation technique is similar to the one described in [5]. The thermal simulation results show a maximum temperature of about 90°C within the stem of the drift tube (Fig. 5). This relatively high temperature is a result of a conservative assumption of the boundary conditions such as 30 kW dissipated RF power, about three times more than required for the normal operating condition, and relatively low convection values in the cooling channels. Due to the fact that the foreseen amplifier is able to provide 30 kW of RF power this was selected as the maximum case. But even in this worst case, it would be possible to operate the buncher. The tuning range is sufficient for this maximum case. The relatively large tuning range was chosen in order to have the possibility to tune the cavity at any operating conditions and to allow to compensate for some manufacturing tolerances. Table 1 gives an overview of the simulation results.

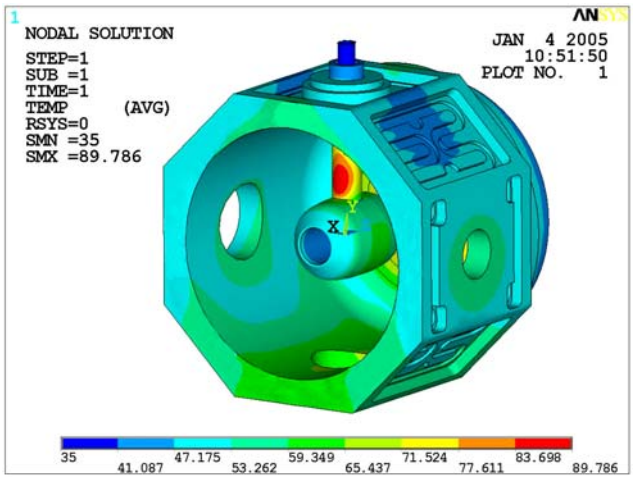


**Fig. 5:** Temperature distribution on the walls of the drift-tube cavity for a dissipated RF power of 30 kW.

| | |
|---|---|
| Operating frequency | 506.328 MHz |
| Thermal drift @ 30kW RF-Power | -270 kHz |
| Tuning range:<br>Plunger @ 30mm (min. position)<br>Plunger @ 80mm (max. position) | 2.34 MHz<br>505.32 MHz<br>507.66 MHz |

**Table 1:** Simulation results

## CONCLUSIONS AND OUTLOOK

A 500-MHz buncher for the 72-MeV injection line of the ring cyclotron consisting of a one stem drift-tube cavity has been designed based on earlier preliminary numerical calculations [2, 3]. The manufacturing will start in 2005. Cold tests involving the measurement of the amplitude of the electric field along the beam axis will be performed and compared with the numerical simulations. Hot tests with bunch length measurements will follow to assess the efficiency of this new type of buncher.

## REFERENCES

[1] R. Dölling, *New Time-Structure Probes Between Injector and Ring Cyclotron*, this report.

[2] J.-Y. Raguin et al., *Comparative Design Studies of a Super Buncher for the 72 MeV Injection Line of the PSI Main Cyclotron*, Proc. EPAC 2004, Lucerne, Switzerland, pp. 1162-1164.

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[4] C. Pasotti et al., *Numerical Investigation on the Elettra 500 MHz Power Coupler*, Proc. EPAC 2004, Lucerne, Switzerland, pp. 1006-1008.

[5] M. Bopp et al., *Coupled Field Analysis of the New Ring Cyclotron Cavity*, PSI Scientific and Technical Report 2001, Vol. VI, pp. 9-10.