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Electromagnetic Design of the Tuning System for the Re-bunching Cavities of the ESS MEBT

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1 Introduction and Motivation

The preliminary electromagnetic design of the re-bunching RF cavities for the ESS Medium Energy Beam Transport (MEBT) has just been presented in [1]. Therefore, it is strongly recommended to read that report before tackling this new one.

In the present report, a study on the tuning system required for the re-bunching cavity in order to correct the frequency shift due to both the thermal expansion and the manufacturing tolerances is presented. It is expected that the insertion in the cavity of a plunger tuner in a region of high magnetic field increases the resonant frequency of the TM_{010} accelerating mode. Specifically, the insertion of one ore two slug tuners in the cavity and their effects on both the resonant frequency and the axis electric field are carefully studied here.

2 Optimized re-bunching cavity including one tuner

In this section, a hollow cylinder is inserted into the optimized re-bunching cavity *A30W126T45_v1* studied in [1] (see tables 3 and 4 for a complete characterization of the cavity). The resulting topology of the re-bunching cavity and the tuner is depicted in figure 1. The slug diameter is set to $D_{tuner} = 44.5$ mm. A maximum penetration of $L_{pronf} = 60$ mm is allowed inside the cavity. The resonant frequency of the TM_{010} mode as a function of L_{pronf} is shown in figure 2. As expected, the resonant frequency increases as the cylinder penetrates into the cavity. A tuning range of 1 MHz is obtained. Moreover, as it can be seen in figure 3, the inclusion of the tuner up to 60 mm does not significantly affect the E_z field along the axis of the cavity which is crucial from a beam dynamics point of view.

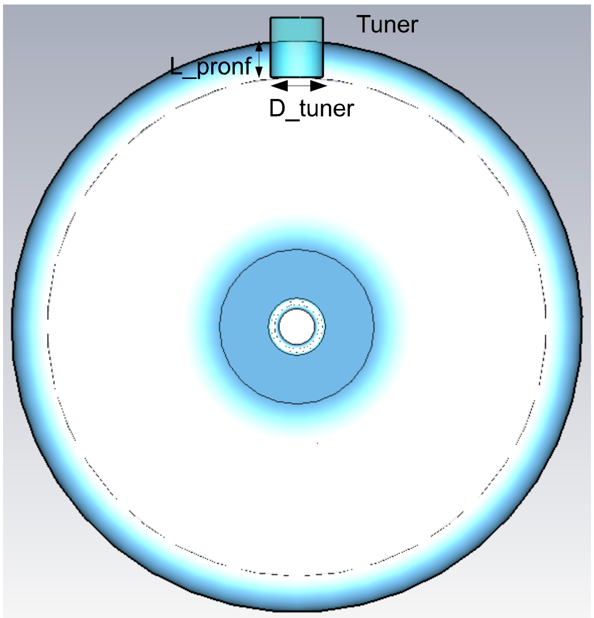

Figure 1: Optimized re-bunching cavity *A30W126T45_v1* including one tuner.

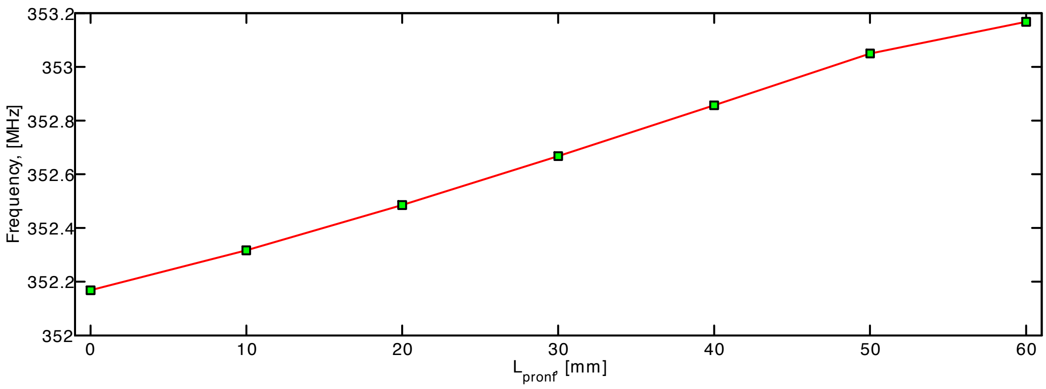

Figure 2: Resonant frequency of the TM_{010} mode as a function of L_{pronf} for the *A30W126T45_v1* re-bunching cavity of figure 1 including one tuner.

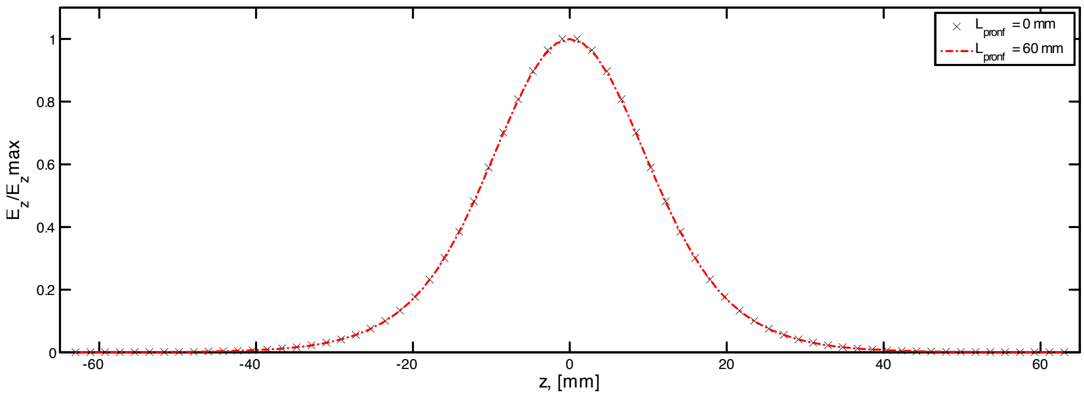

Figure 3: Normalized E_z field along the axis of the cavity *A30W126T45v1* of figure 1 calculated with Comsol for $L_{pronf} = 0$ mm and $L_{pronf} = 60$ mm.

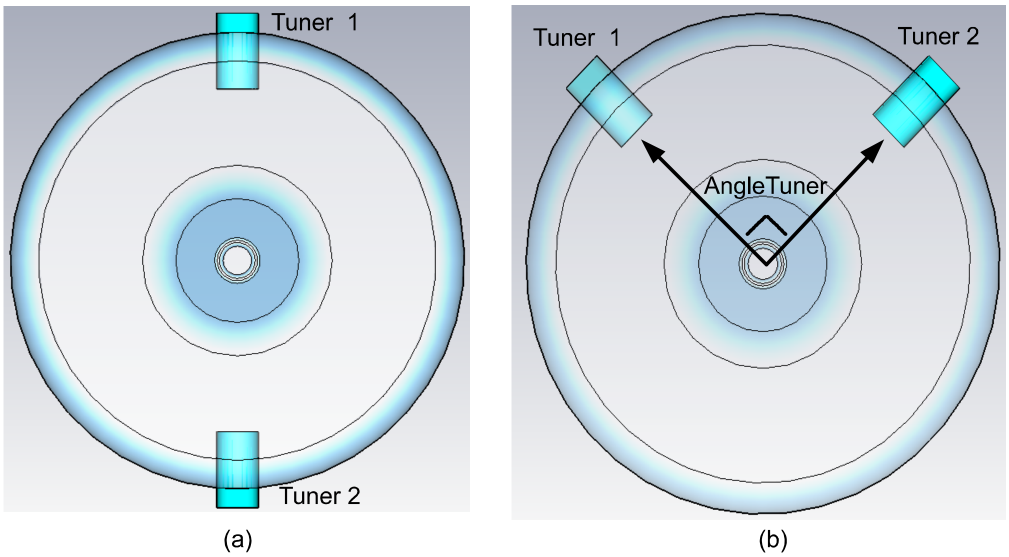

Figure 4: Optimized re-bunching cavity *A30W126T45_v1* including two tuners located (a) one opposite to the other and (b) with a specified angle ($AngleTuner$) between them.

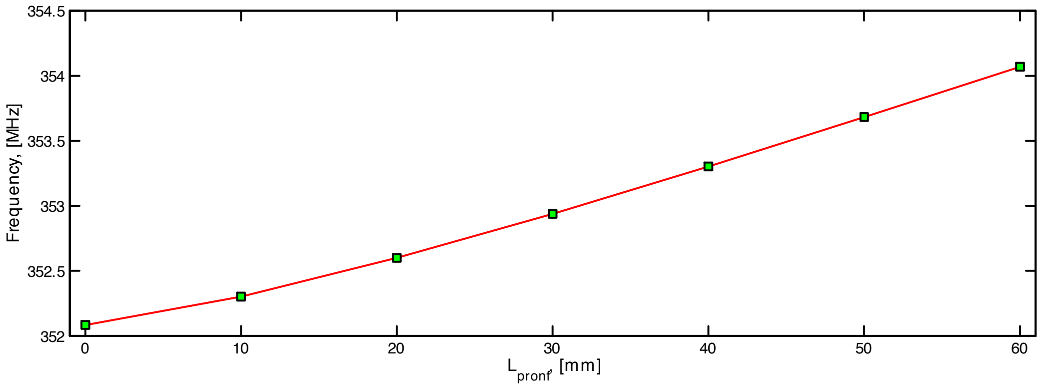

Figure 5: Resonant frequency of the TM_{010} mode as a function of L_{pronf} for the *A30W126T45_v1* re-bunching cavity of figure 4-a.

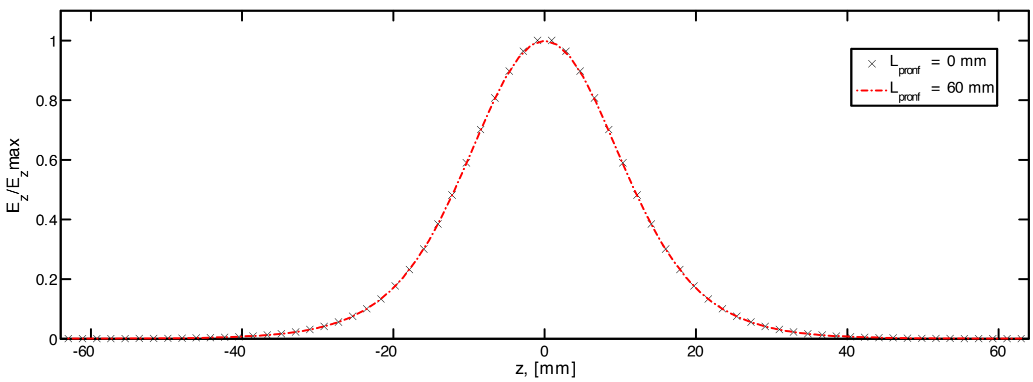

Figure 6: Normalized E_z field along the axis of the cavity *A30W126T45v1* of figure 4-a calculated with Comsol for $L_{pronf} = 0$ mm and $L_{pronf} = 60$ mm.

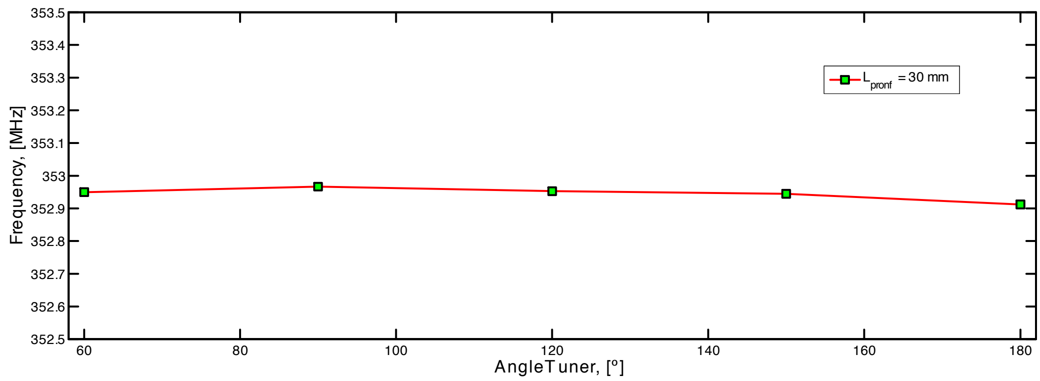

Figure 7: Resonant frequency of the TM_{010} mode as a function of the relative position of the tuners *AngleTuner* for the *A30W126T45_v1* re-bunching cavity of figure 4-b. *L_pronf* is fixed to 30 mm.

3 Optimized re-bunching cavity including two tuners

In this case, two hollow cylinders are inserted into the cavity. First, as shown in figure 4-a both cylinders are located in opposite positions. Both the slug diameter D_{tuner} and the maximum penetration L_{pronf} remain fixed. The new tuning range with this new configuration is plotted in figure 5. As it can be seen, a tuning range of almost 2 MHz is now obtained, thus doubling the range obtained with only one tuner. In addition, the E_z field along the axis of the cavity is again not affected by the presence of the tuners, as shown in figure 6. Finally, the position of the tuners inside the cavity is also studied. To this end, figure 7 shows the resonant frequency of the cavity as a function of the relative angle *AngleTuner* between tuners for a fixed $L_{pronf} = 30$ mm. As it can be seen, the resonant frequency of the cavity is barely affected.

4 Conclusions and Future Work

A tuning system for the ESS re-bunching cavity has been presented here. The main conclusions of our work are:

1. The tuning range available with 2 tuners (2 MHz) is almost double than the one obtained with 1 tuner (1 Mhz)

2. The insertion of the tuners does not seem to affect the E_z axis electric field on the cavity.

3. Moreover, for the 2-tuner topology, the position of the cylinders in the cavity does not affect the resonant frequency of the accelerating mode.

Besides these conclusions, some remarks must be pointed out:

1. Taking into account the manufacturing considerations presented in [1], the optimum position for the tuners when designing the cavity should be half the dynamic range of the designed tuning system ($L_{pronf} = 30$ mm in this report). This should allow us to successfully tune the cavity due to its thermal expansion and to the fabrication tolerances.

2. Once the themal analysis of the cavity is performed and the thermal expansion of the cavity found, a decision can be made about the dynamic range of the tuning system as well as how many tuners are needed and how many of them are movable.

References

[1] O. González, J. L. Muñoz and I. Bustinduy, "Preliminary electromagnetic design of the re-bunching RF cavities for the ESS MEBT," Internal ESS Bilbao Communication, December 2011