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COMPARISON OF THREE BUNCHER STRUCTURE DESIGNS FOR THE 3 MeV SPL CHOPPING LINE

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The preliminary design of the Superconducting Proton Linac [1] chopping line is given in Ref. [2]. Seven bunching cavities at the bunch frequency of 352.2 MHz provide the longitudinal focusing inside the line. The present study is a first attempt to define the type of RF structure and the geometrical and RF parameters for the bunchers, in order to allow refining the beam dynamics design of the line.

The main parameters for these cavities are imposed by the beam dynamics, i.e. by bunch spacing, transverse beam size, longitudinal emittance and beam energy:

Aperture radius:	20. mm
Operating frequency:	352.2 MHz
Nominal effective voltage:	100.0 kV
Duty factor:	14 %
Particle velocity:	0.08 c (3 MeV energy)

The required maximum duty factor of 14% corresponds to the full SPL.

We have investigated three possible geometries in order to choose the most suitable one for the buncher. They are:

a) a single cell cavity (pill-box, TM01 mode) with nose cones, similar to the design of the SNS bunchers [3],
b) a single cell cavity with half drift tubes containing quadrupoles, similar to the design of the Linac2 bunchers [4],
c) a 2-gap quarter-wave structure, similar to the Linac3 buncher [5].

The cross-sections of the three structures are shown in Figures 1, 2 and 3. The simulations were performed using Urmel and Superfish for 2D and MicroWave Studio for 3D. The table below reports for comparison the main parameters of these structures (referred all to 3D MicroWave Studio calculations with similar mesh).

	Cell with nose cones	Cell with half drift tubes	Quarter-wave
Inner cavity radius (mm)	260.0	182.0	n.a. (height 153. mm)
Inner longitudinal dimension (mm)	120.	120.	100.
Outer longitudinal dimension (mm, flange to flange)	200.	(40.)*	140.
Cavity gap (mm)	14.0	20.0	7.0 (2 gaps)
Computed Q value	21264	14257	5783
Shunt impedance (kΩ, linac def.)	750.0	188.	708.4
R/Q (Ω, linac def.)	30.6	13.2	122.4
Transit time factor	0.43	0.40	0.53
Average gradient on axis (MV/m at 100 kV)	2.03	2.08	2.76
Peak surface E field (MV/m at 100 kV)	21.2	17.2	18.8
Peak power (kW at 100 kV)	13.3	53.2	14.1
Average power (kW at 100 kV)	2.3	7.5	1.98
Maximum effective voltage (kV, for 1.8 Kilpatrick)	156.	192.	176.

* : Minimum distance between quadrupoles faces

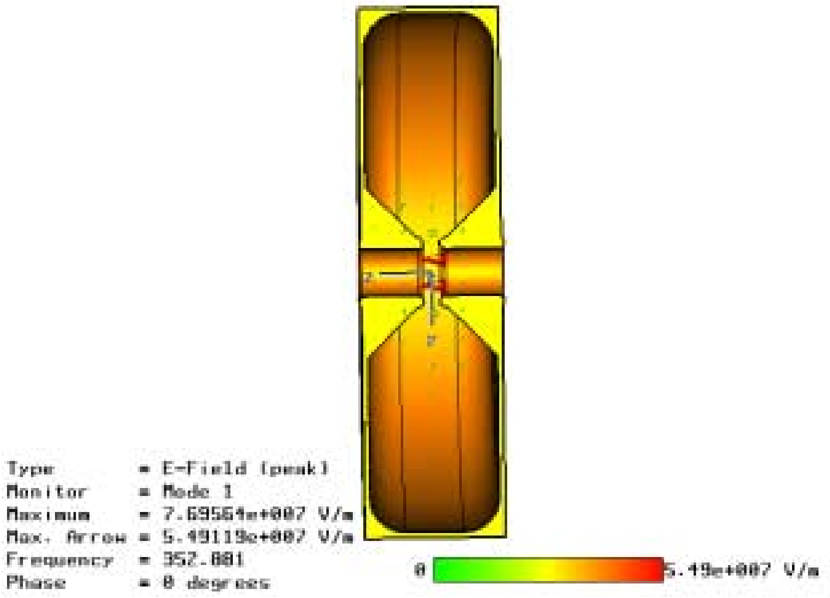

Figure 1: Single Cavity with Nose Cones.

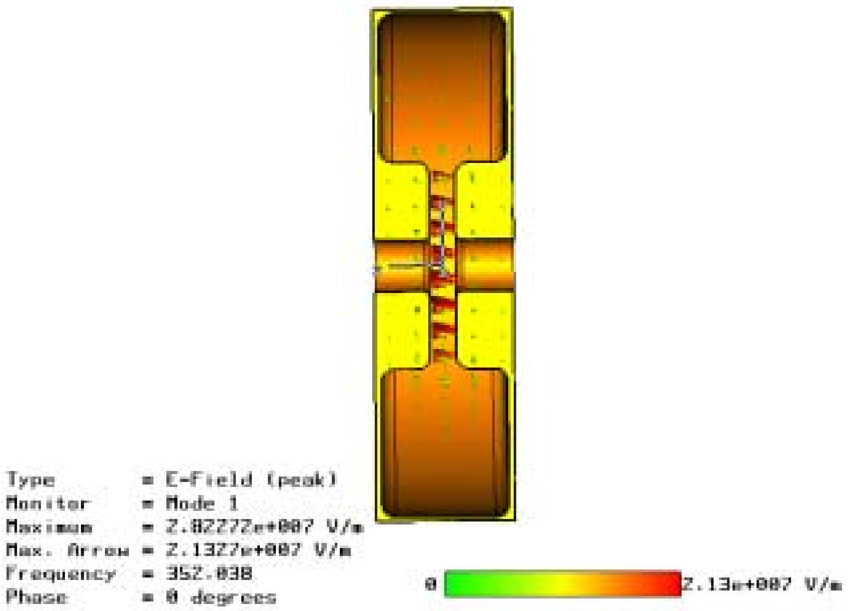

Figure 2: Single Cavity with Quadrupoles.

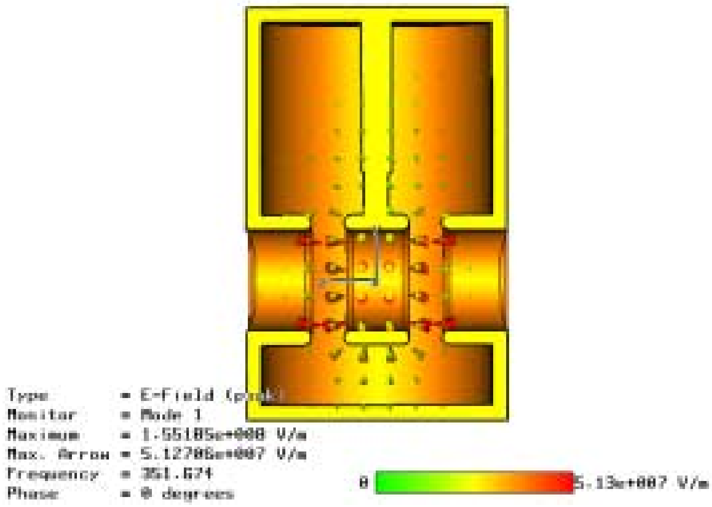

Figure 3: Quarter-Wave Cavity

Comparison of designs

The important parameters are: a) the effective longitudinal dimension, which has to be small to shorten the chopper line and b) the shunt impedance, which determines the peak power needed and finally the cost of the RF amplifier.

The single cell with nose cones and the single cell with quadrupoles are based on the same RF mode. The nose cones increase the shunt impedance and the rounding of the wall edges increases the quality factor of the first design. In order to reduce the distance between the focusing elements we can include them in half drift tubes in the cavity body, which gives the second design. The quadrupoles are not shown in the figure but they occupy the large areas surrounding the beam chamber. For this cavity, the drift tube capacitance reduces drastically the shunt impedance increasing the peak RF power by a factor 4. The decrease in distance between the quadrupoles, from 200 mm to about 40 mm, is not such as to justify the large difference in the cost of the RF amplifier, considering as well that in the case of the SPL chopping line with 30 mA beam current space charge effects are still tolerable.

The quarter-wave cavity has the shortest length and the highest shunt impedance. However, the welding and brazing processes involved in the fabrication will probably reduce its shunt impedance with respect to the ideal values of the simulations more drastically than for the other designs, bringing it in the same range as the nose cone cavity. Moreover, this type of cavities is well known to be particularly prone to multipactoring, as indicate the experience with the Linac3 cavity (101 MHz) and the Decelerating RFQ bunchers (202 MHz). Another reduction in size to adapt the design to 352 MHz will probably go more into the dangerous multipactoring region.

In conclusion, the shunt impedance and the length of the quarter-wave resonator are not so drastically better as to justify the risks of multipactoring. In the same way, the shorter quadrupole distance of the drift tube cavity does not compensate for its much lower shunt impedance. Our preference then goes to the single cell with nose cones. Contacts have been already established with the company in charge of the construction of the SNS bunchers (JP Accelerator Works), in order to exchange useful information and to explore the cost of a fabrication in the USA.

References

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