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Accelerating cell design for 200 MeV separated drift tube linac in KOMAC

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1. Introduction

For several applications such as space radiation effect test and radiography, proton beam with energy level of GeV is utilized. [1,2] In the acceleration process up to GeV energy, separated drift tube linac (SDTL) structure can be used in medium energy region up to ~200 MeV. It has simple geometry as quadrupole magnet is situated outside of the drift tube, thus, having advantage in optimizing drift tube design for efficient acceleration. [3] In this study, employing SDTL, efficient accelerating cell structure for 200 MeV proton accelerator is designed from 2D electromagnetic analysis utilizing SUPERFISH code [4] by maximizing effective shunt impedance (ZTT) maintaining low Kilpatrick number under 1.3.

2. Methods and Results

In this section, trend of ZTT and Kilpatrick number following several geometrical parameters of the cell is investigated. Optimization of geometrical parameters is conducted under the proton beam energy of 100 MeV and resonance frequency of 350 MHz which is tuned by adjusting gap distance between drift tubes.

2.1 Trend of ZTT and Kilpatrick number following tank diameter, face angle, and drift tube diameter

Overall shape of the cell is determined from the tank diameter, face angle, and drift tube diameter. Therefore, it is necessary to find optimal value of these parameters to maximize ZTT. Figure 1 shows ZTT and Kilpatrick number when tank diameter is varied with other parameters fixed. It is seen that there exists optimal tank diameter for maximum ZTT whereas Kilpatrick number monotonically decreases. Such trend can be roughly discussed in terms of equivalent circuit of the cell. [5] Under the same normalization of electric field, electric field between drift tubes increases when tank diameter is increased as relative area of drift tube is more centrally located where electric field is maximum. As it leads to capacitance increase, gap distance between the drift tubes significantly increases to decrease the capacitance so that maintain resonance frequency. As a result, by the competition between cell length and transit time factor (increase when gap distance decreases) which affects ZTT, there exist optimal tank diameter for maximum ZTT while Kilpatrick number decreases as gap distance increases.

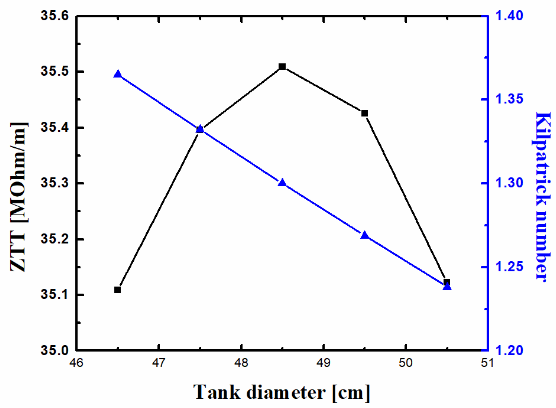

Fig. 1. Trend of ZTT and Kilpatrick number along with tank diameter.

Figure 2 shows ZTT and Kilpatrick number when face angle is varied with other parameters fixed. It is seen that ZTT and Kilpatrick number increases as face angle increases. As capacitance between drift tubes decreases when face angle increases, gap distance between drift tubes should decrease to tune resonance frequency and increased transit time factor leads increase in ZTT. As a result, ZTT can be maximized increasing face angle under the constraints of Kilpatrick number and required space of upper flat part for stem. (5 cm)

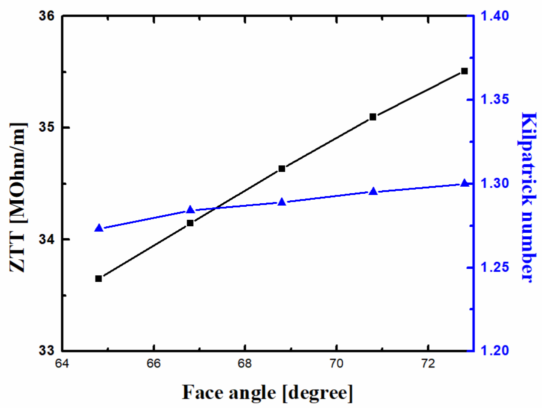

Fig. 2. Trend of ZTT and Kilpatrick number along with face angle.

Figure 3 shows ZTT and Kilpatrick number when drift tube diameter is varied with other parameters fixed. It is seen that ZTT and Kilpatrick number increases as drift tube diameter increases. As drift tube diameter increases, inductance of drift tube decreases. Therefore, gap distance between drift tubes decreases increasing capacitance to tune resonance frequency. Then, increased transit time factor leads increase in ZTT. Under constant face angle, maximum drift tube diameter is decided to reserve the space for stem. As a result, optimal combination of drift tube diameter and face angle can be found maximizing ZTT satisfying constraint of Kilpatrick number.

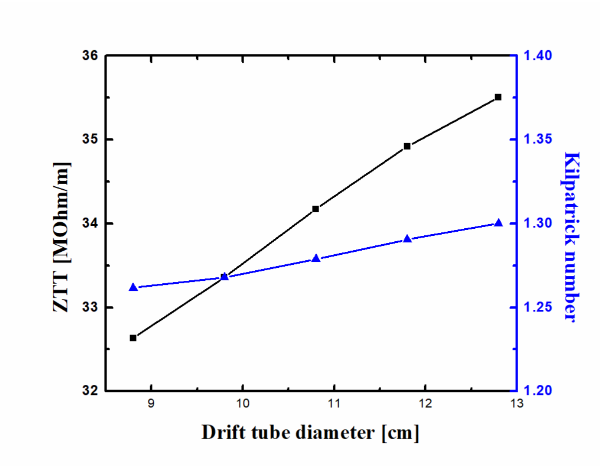

Fig. 3. Trend of ZTT and Kilpatrick number along with drift tube diameter.

2.2 Trend of ZTT and Kilpatrick number following inner, outer nose radius and flat length

Geometrical parameters in the nose part of drift tube consists of inner, outer nose radius and flat length. As maximum electric field point situates in the nose part, appropriate parameters are needed to minimize Kilpatrick number. Figure 4 shows ZTT and Kilpatrick number when inner nose radius is varied under the condition of constant sum of inner and outer nose radius. As electric field at the axis decreases with increase in inner radius, ZTT decreases. However, Kilpatrick number shows minimum value along the inner radius as maximum electric field point transits from the point where inner nose radius situates to the point where outer nose radius situates. As a result, optimal point can be picked maintaining highest ZTT under constraints of Kilpatrick number.

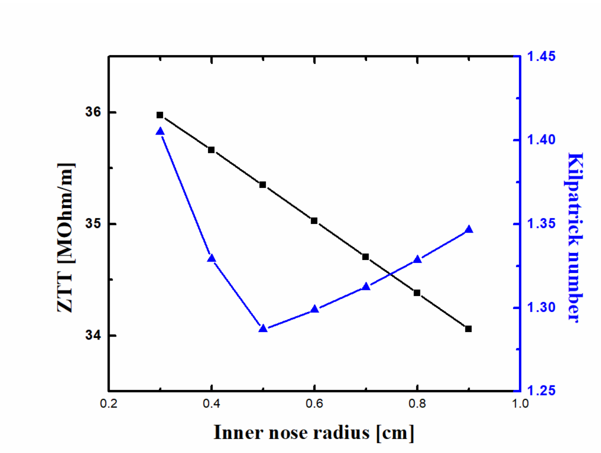

Fig. 4. Trend of ZTT and Kilpatrick number along with inner radius under constraint of constant sum of inner and outer radius.

2.3 Optimal design parameter and comparison of ZTT value with other facility

After several sweeps of geometrical parameters considering the trend described in the previous chapters, optimal design parameters of the cell are found as shown in the Fig. 5 and detailed parameter described in Table 1. In terms of ZTT, current cell design shows higher value than that of KOMAC and J-PARC facility as can be seen in the Fig. 6.

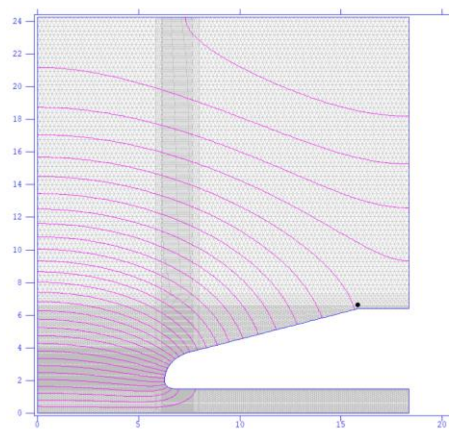

Fig. 5. View of SDTL cell and electric field from SUPERFISH code.

Table I: Design parameter of cell

Tank diameter [cm]	48.5
Drift tube diameter [cm]	12.8
Face angle [◦]	72.8
Outer nose radius [cm]	1.78
Inner nose radius [cm]	0.45
Flat length [cm]	0.1
Bore radius [cm]	1.5
Stem diameter [cm]	4

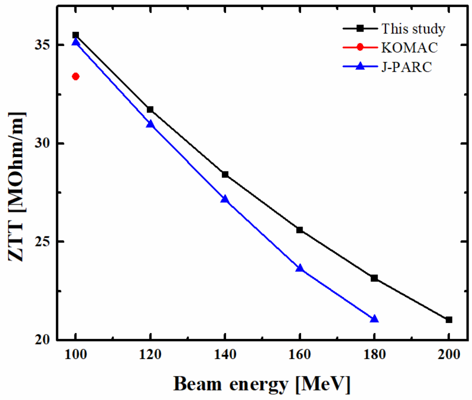

Fig. 6. Comparison of ZTT value with KOMAC and J-PARC facility.

3. Conclusions

Optimal SDTL cell geometrical parameters for 200 MeV proton accelerator are investigated observing trend of effective shunt impedance and Kilpatrick number along with parameter sweep. Choosing optimal tank diameter, drift tube diameter, and face angle, effective shunt impedance is maximized. Simultaneously, geometrical parameters of nose part are optimized for low Kilpatrick number. As a result, design parameters for the cell with high acceleration efficiency and robustness for arcing can be deduced.

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