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MULTIPACTING OPTIMIZATION OF A 750 MHz RF DIPOLE*

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Abstract

Crab crossing schemes have been proposed to re-instate luminosity degradation due to crossing angles at the interaction points in next generation colliders to avoid the use of sharp bending magnets and their resulting large synchrotron radiation generation, highly undesirable in the detector region. The rf dipole has been considered for a different set of applications in several machines, both rings and linear colliders. We present in this paper a study of the effects on the multipacting levels and location depending on geometrical variations on the design for a crabbing/deflecting application in a high current (3/0.5 A), high repetition (750 MHz) electron/proton collider, as a matter to provide a comparisson point for similar applications of rf dipoles.

INTRODUCTION

Multipacting conditioning and processing is one of the principal limitations of the performance of rf structures. It consists of the emission of large amounts of secondary electrons by the rf cavity walls due to incident primary electrons. This can lead to localized and resonant trajectories sustained by the primary electrons, reaching impact energies correspondent to a secondary emission yield (SEY) greater than the unit, causing a cascade effect that can incur severe problems, such as low achievable gradients in the structure, bunch instabilities, and quenches by thermal breakdown in the case of superconducting structures [1]. Due to its complexity and random nature, this non-relativistic phenomenon has been for a long time an important case of study that needs to be assessed in order to further improve the operation and performance of current and future particle accelerators.

The SEY changes for different material and is surface condition dependent [2], therefore the impact energy bandwith ($E_{II} - E_I$) to have multipacting condition (i. e. $\delta > 1$) varies from case to case, see Fig. 1. In the case of pure and clean Nb, the range of impact energies for the multipacting condition is $E_I > 150$ eV, and $E_{II} < 2000$ eV. The multipacting barriers are known to be either soft and easily processed and cleaned or hard multipacting barriers that cannot be removed by processing and may need redesigning the cavity geometry in order to properly operate.
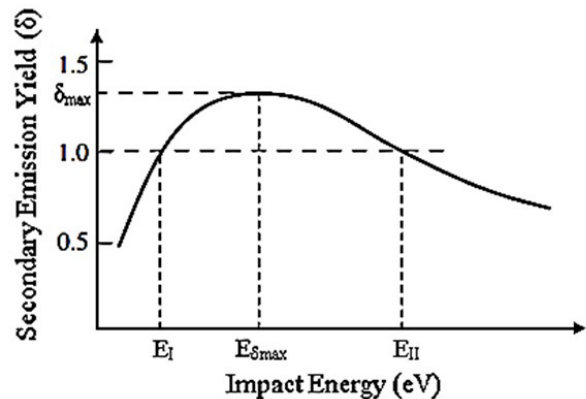
Figure 1: Secondary emission yield as a function of the particles' impact energy.

750 MHz RF DIPOLE DESIGN

The 750 MHz rf dipole was designed as a compact superconducting crab cavity for a luminosity correction scheme at the interaction points (IPs) of Jefferson Lab's Medium Electron-Ion Collider (MEIC) with crabbing voltages from $V_T = 1.3$MV to 1.8 MV for the case of electrons. However, multiple applications of such device in linear colliders such as beam spreader or high polarization corrector are under study and development [3,4]. The rf dipole operates as a deflector/crabber in its lowest mode (TE-like) and the electric and magnetic oscillating fields for this mode are shown in Fig. 2, and its parameters are enlisted in Table 1.
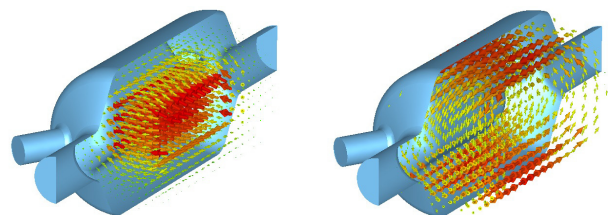
Figure 2: 750 MHz rf dipole longitudinal cross section with the electric (left), and magnetic (right) fields for the fundamental mode.

METHODOLOGY

We used the extrusion length of the endcaps (see Fig. 3) as a varying parameter to study the optimization of the multipacting conditions for the 750 MHz rf dipole, keeping all the other geometrical parameters fixed with exception of the cavity radius that was used to correct the resonant fre-

Table 1: Parameters of 750 MHz Crab Cavity RF Dipole Prototype

Parameter	750 MHz	Units
$\lambda/2$ of π mode	200.0	mm
Cavity length	341.2	mm
Cavity radius	93.7	mm
Bars width	63.0	mm
Bars length	200.0	mm
Bars angle	45	deg
Aperture diameter -d	60.0	mm
Endcaps' extrusion -l	60.0	mm

(a)

(b)

(c)

Figure 4: Comparison of the multipacting impact energy and resonant locations for increasing values of the extrusion length of the endcaps, from 20 mm -*right most in* (a)- to 50 mm -*left most in* (c)-.

quency of the fundamental mode. This results in the change of the total cavity length but keeping the parallel bars length constant to the effective length of $\lambda/2 = 0.2$ m.
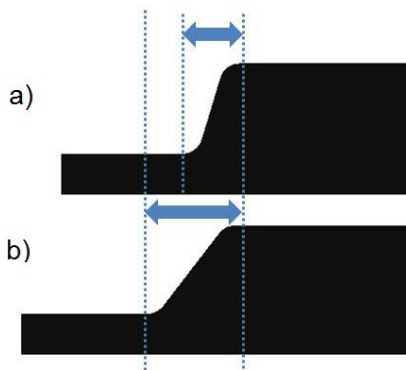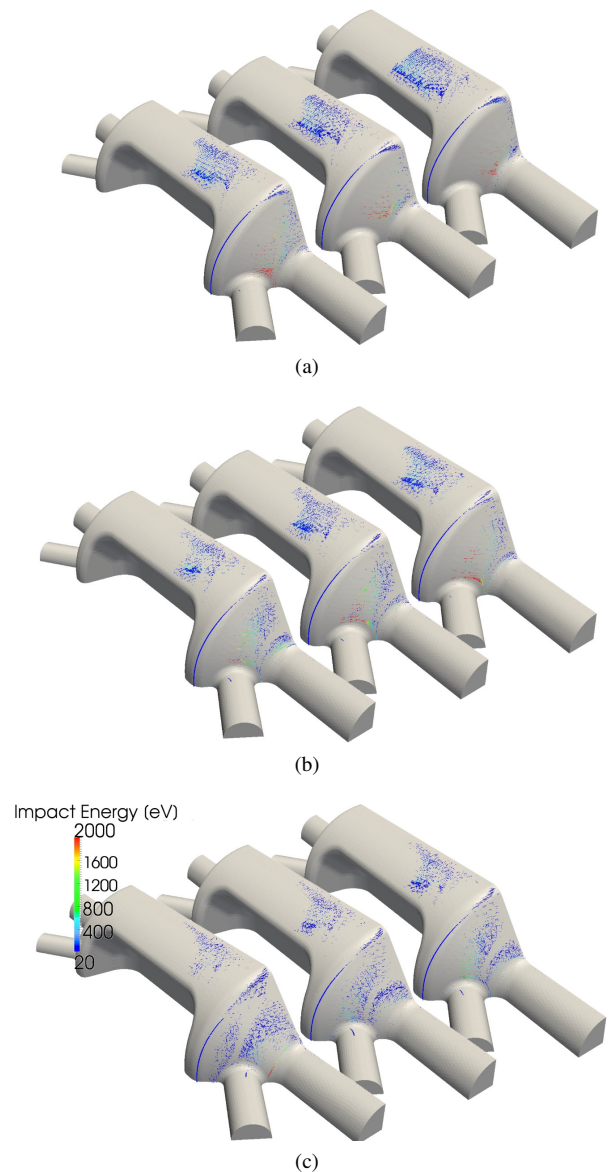

Figure 3: Variation of the extrusion length of the endcaps to study the multipacting condition and its optimization feasibility for the 750 MHz rf dipole.

MULTIPACTING ANALYSIS

Once a set of models with different extrusion lengths from $l_{min} = 20$ mm to $l_{max} = 50$ mm were generated, we used the Omega3P and the Track3P codes from the ACE3P Suite developed by SLAC to obtain the eigenmodes and the multipacting conditions respectively. The resulting 3D locations and impact energies (in color code) of the multipacting conditions for 9 of the studied models are presented in Fig. 4, where the value of the extrusion length is increasing (from right to left and top to bottom respectively in Fig. 4). The particles' resonant locations considerably clear out from the top of the external conductor to populate slightly more the endcaps, where both the electric and magnetic fields are lower, this places them closer to the auxiliar ports, making it easier for the vacuum systems to help in the processing of multipacting.

We used the two extremal values of our optimization parameter l_{min} = 20 mm, and l_{max} = 50 mm to compare the multipacting levels obtained by the simulatons as seen in Fig. 5. It can be observed that the multipacting barri-

ers do not appear to have great differences between each other, despite the fact that for the model with smaller endcap's extrusion (l_{min} = 20 mm, Fig. 5(a) right most) higher impact energies are reached, which is not necesarily an important feature since particles with impact energies > 2000 eV do not contribute to multipacting in Nb. However, both multipacting barriers are well defined at the lower voltage levels, keeping the operating levels virtually multipacting free. What is hard to appreciate from the graphs is that the barriers for the model with smaller extrusion legth are heavily denser than those for the model with longer extrusion length.
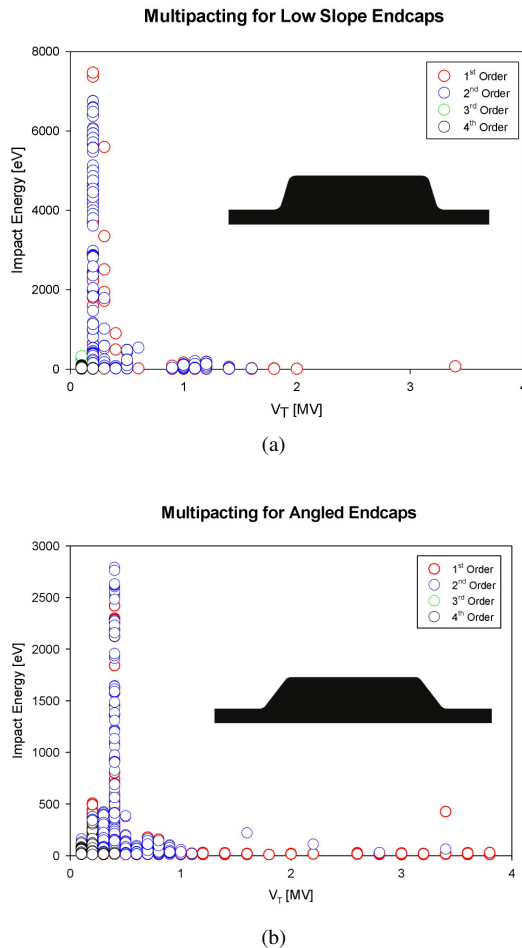
(a)

(b)

Figure 5: Multipacting levels as a function of the transverse voltage for the 2 extremal values of extrusion length of the encaps: 20 mm (a), and 50 mm (b).

TESTING THE SIMULATIONS

The 750 MHz rf dipole prototype has been fabricated and tested in several occasions, both in Niowave, Inc. and Jefferson Lab's vertical testing areas (VTA). Two multipacting barriers at low transverse voltage levels ($V_T < 1$ MV) were observed at both 4 K and 2 K cryotests, and easily processed and eliminated at 2 K. A comparison between the Q_0 data with multipacting events taken during the cryotest at Jefferson Lab's [5] and the multipacting levels obtained from the simulations, showing very good agreement, is presented in Fig. 6.

CONCLUSIONS

In the present work we studied the effects on the resonant locations, and incident energies for multipacting condition on the 750 MHz rf dipole due to variations of the geometrical parameter *extrusion length* of the cavity endcaps (l), for a range between 20 mm to 50 mm. We presented a subset of the studied models to illustrate the variations in the location and density of resonant particles in the cavity structure using
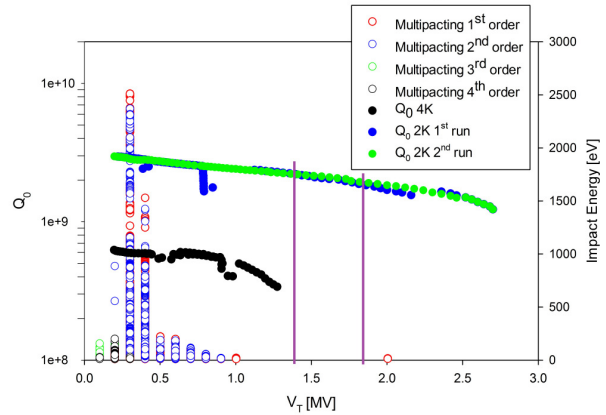

Figure 6: Q_0 curves at 4 K (solid black) and 2 K before processing (solid blue) and after processing (solid green) of multipacting compared to the multipacting levels obtained from the TRACK3P-ACE3P simulations. The purple lines enclose the design crabbing kick range needed per cavity.

the parameter l as tweaking knob. Even when the multipacting barriers appear at roughly the same field levels in all our simulations, the density of the resonant particles and their impact energy decrease, and also the resonant positions relocate to potentially less problematic areas of the structure as the parameter l increases. We compared the simulation results with the experimental observation of multipacting events for the 750 MHz rf dipole prototype with considerably good agreement. We conclude that by modifying the extrusion length, the multipacting can be tweaked for the case of the rf dipole. It is necesary to carry out further studies to determine if a different parameter can also be used to further optimize the mutipacting in the rf dipole geometry to lower the multipacting levels, such as the blending radius of the endcaps, which consistently showed to be one of the most susceptible to multipacting locations. However, the experimental data has proven that multipacting is easily processed and is not a limiting factor in the rf dipole performance, not just for the 750 MHz prototype, but for the 400 MHz and the 499 MHz prototypes as well [6].

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