SIMULATION OF MULTIPACTING WITH SPACE CHARGE EFFECT IN PIP-II 650 MHZ CAVITIES

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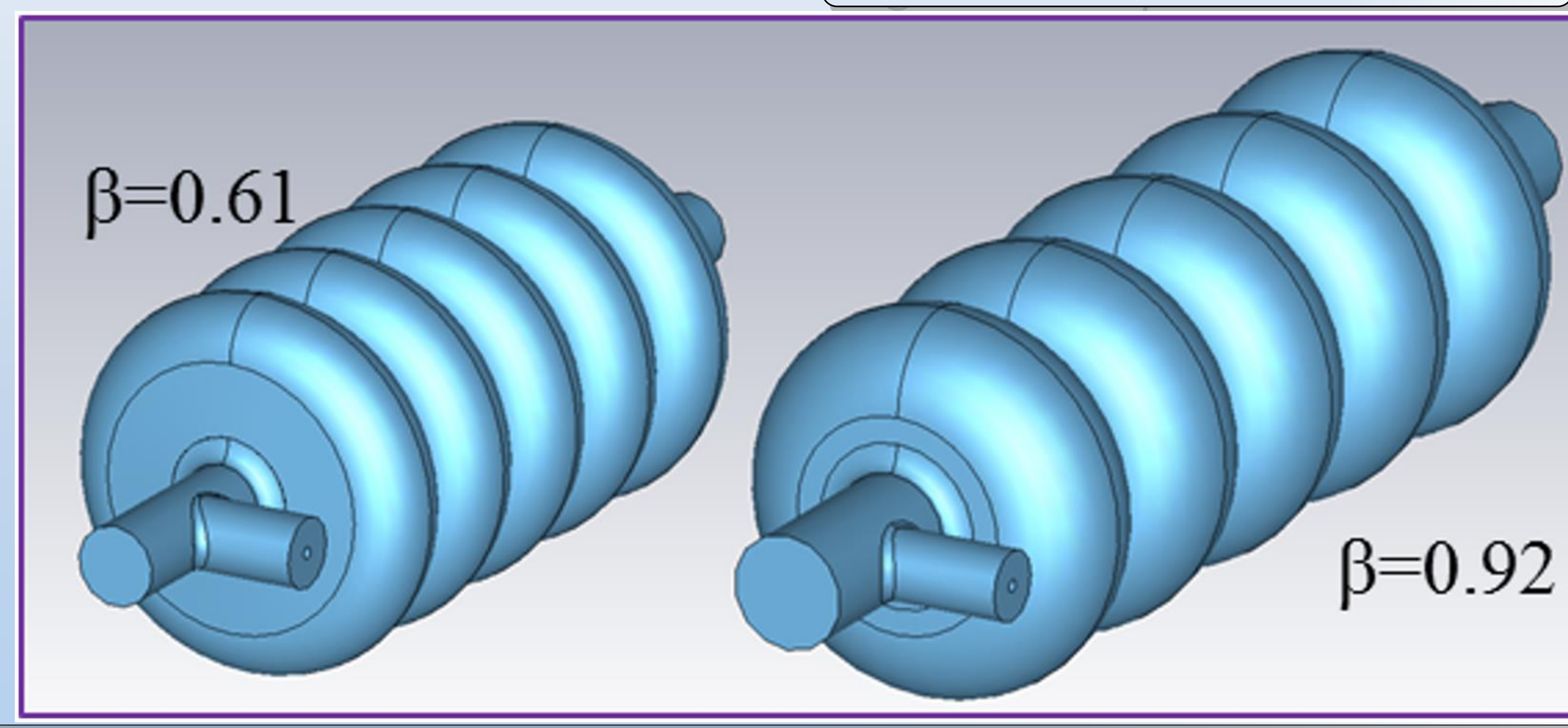
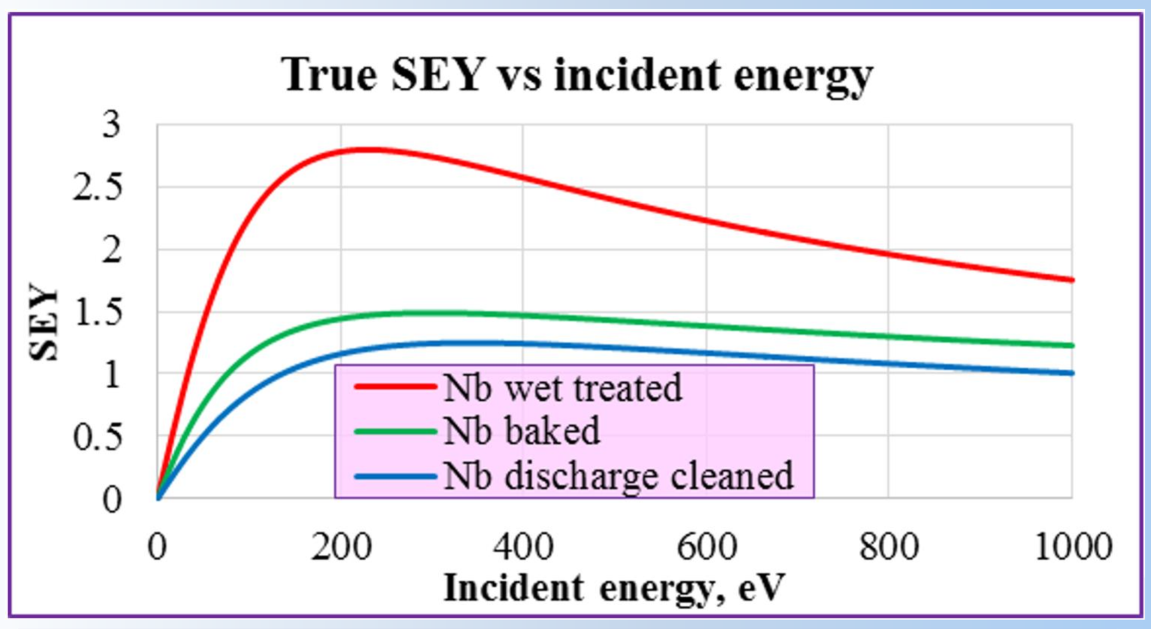
Abstract

The central element of the Proton Improvement Plan -II at Fermilab is a new 800 MeV superconducting linac, injecting into the existing Booster. Multipacting affects superconducting RF cavities in the entire range from high energy elliptical cavities to coaxial resonators for low-beta part of the linac. The extensive simulations of multipacting in the cavities with updated material properties and comparison of the results with experimental data are routinely performed during electromagnetic design at Fermilab. This work is focused on multipacting study in the low-beta and high-beta 650 MHz elliptical cavities. The new advanced computing capabilities made it possible to take the space charge effect into account in this study. The results of the simulations and new features of multipacting due to the space charge effect are discussed.

High and low β 650 MHz cavities.

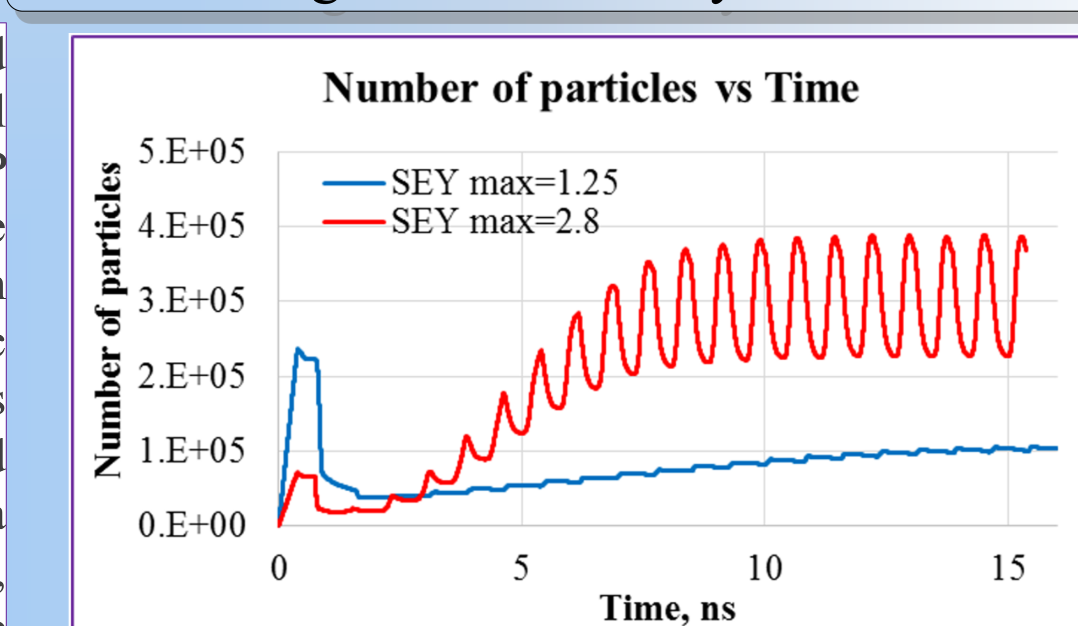




Different SEY data were used to evaluate impact of surface finish.

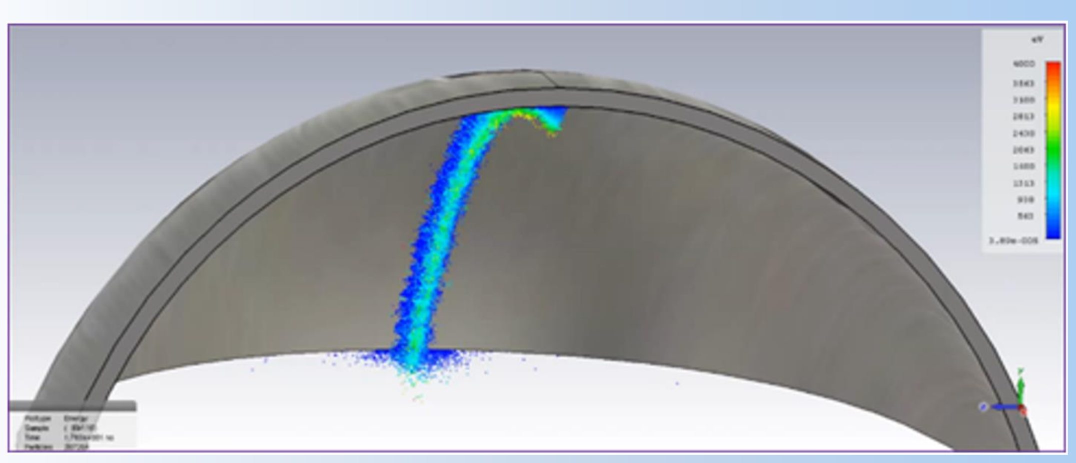
Developed multipacting is essentially a space charge limited process. During developed multipacting there are one or several bunches of electrons in RF device volume (number depends on MP order), which are well formed by phase focusing mechanism. Space charge of an electron bunch pushes peripheral particles out from phase stability interval (and possibly from area where dynamic conditions for multipacting exist). Therefore, a number of electrons constantly go out of the game. This loss of electrons is compensated by secondary electrons re-emitted at each RF cycle. Finally a dynamic equilibrium is established between losses and re-emission, and the process comes to the steady state regime, in which discharge current density stops at certain level.

Discharge current density saturation



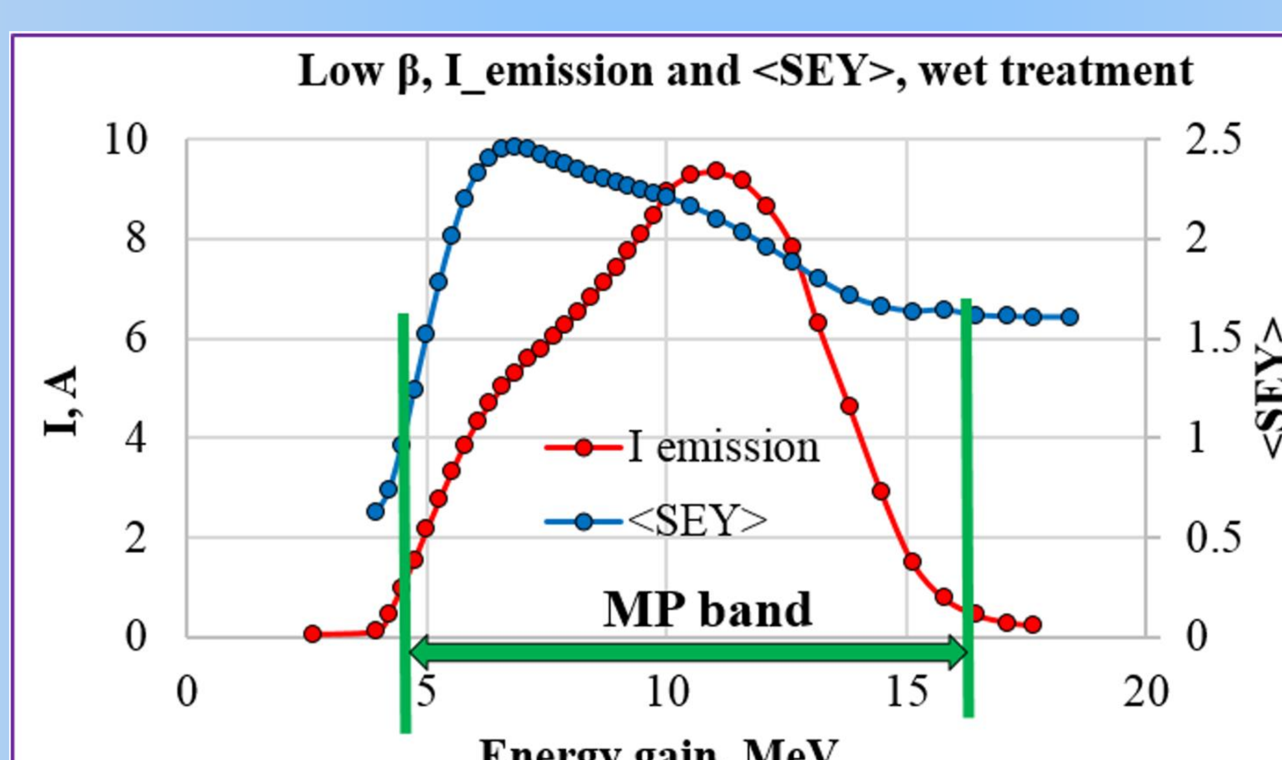
Saturation level depends on SEY of material.

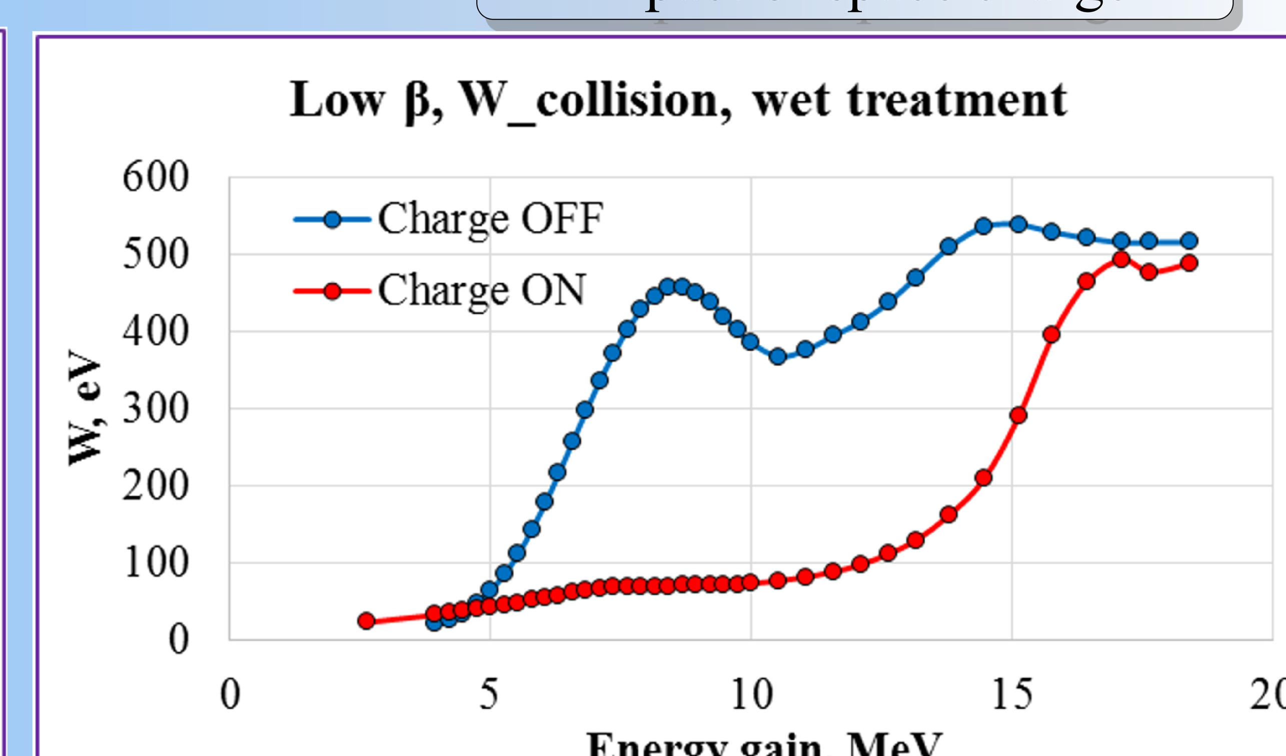
Impact of space charge



Snap shot of steady state multipacting with space charge effect. Particle colours indicate their energy.

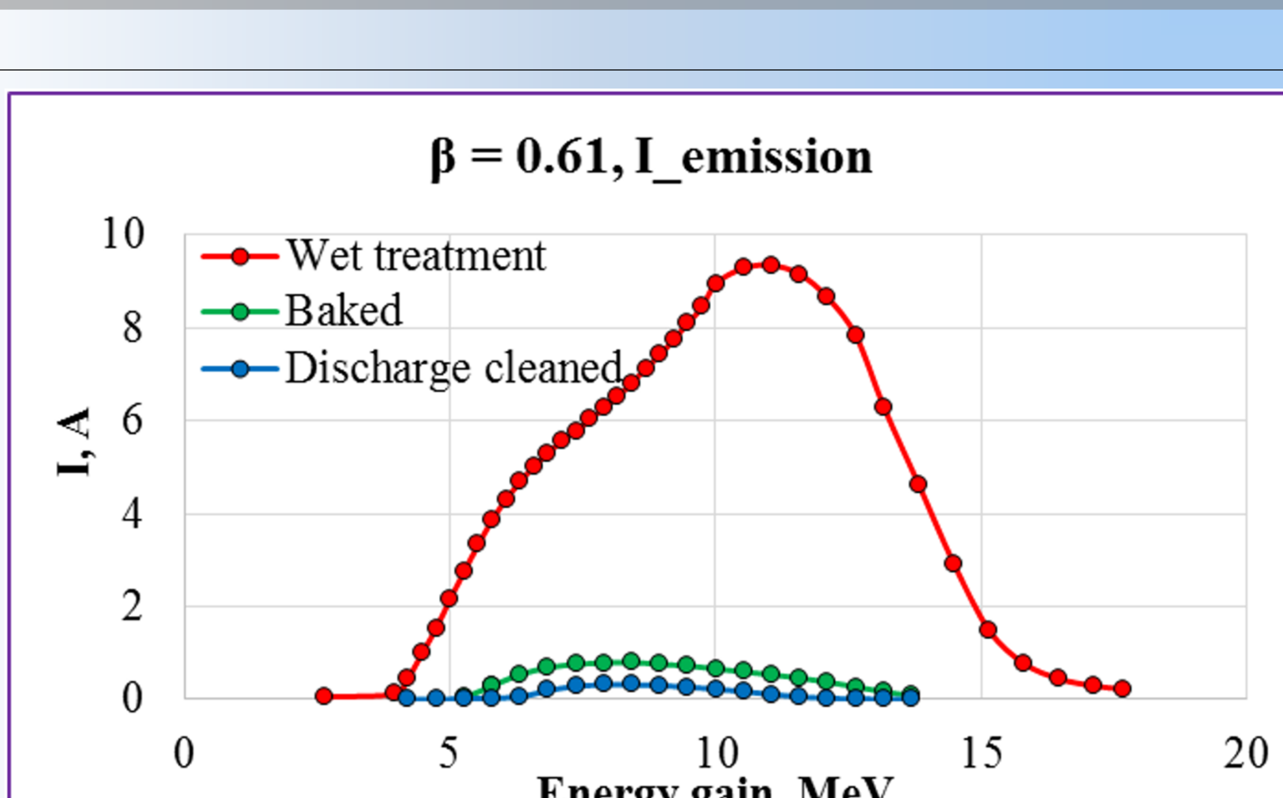
Direct comparison of multipacting intensity with and without space charge effect is not possible. For saturated regime a growth rate is zero, and an effective secondary emission yield is not a convenient indicator either, since it always equals 1 during multipacting regardless intensity of discharge. Instead a total steady state re-emission current was used as MP characteristic in case of active space charge effect.

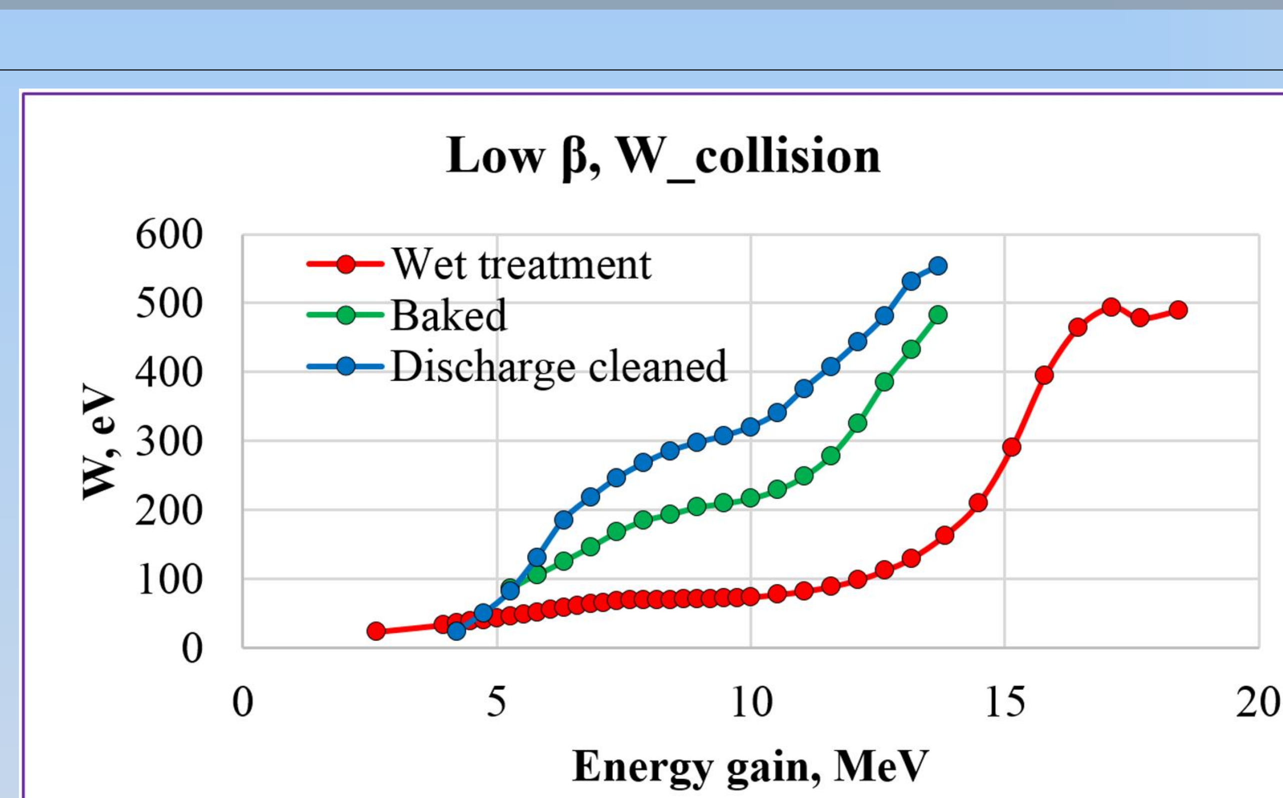


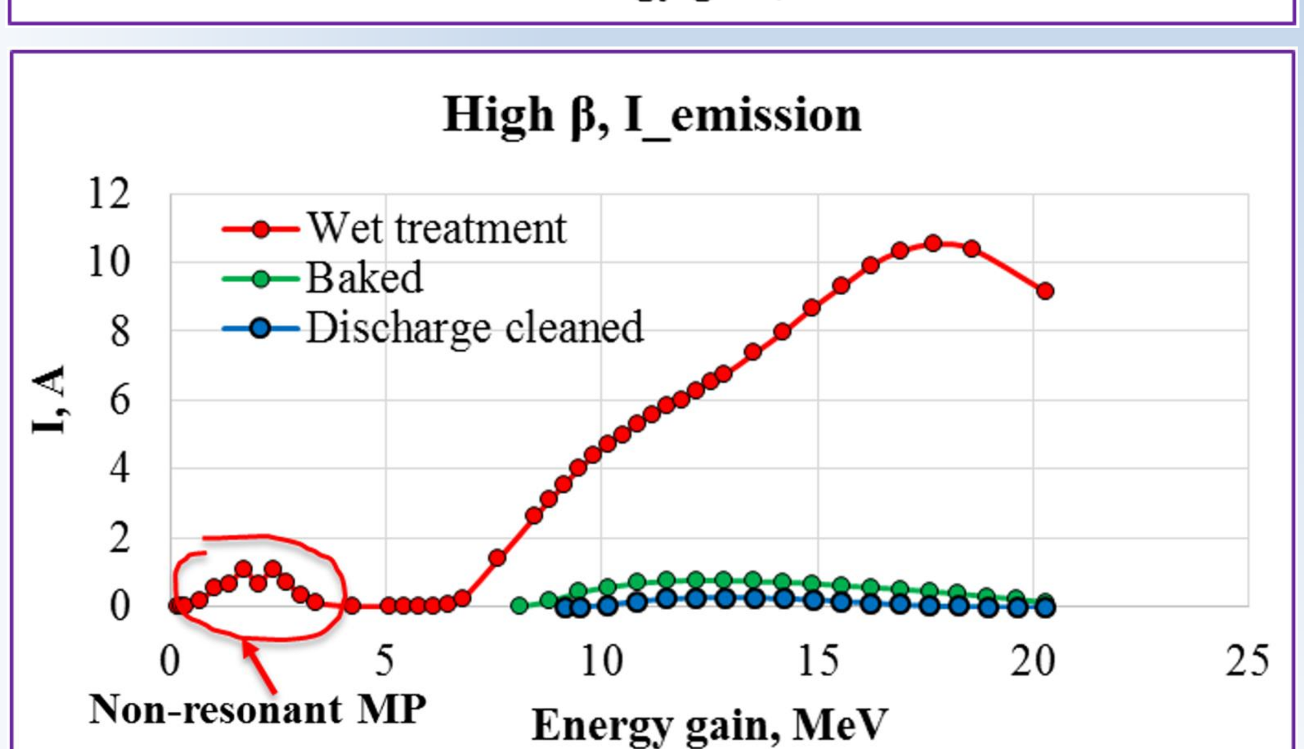


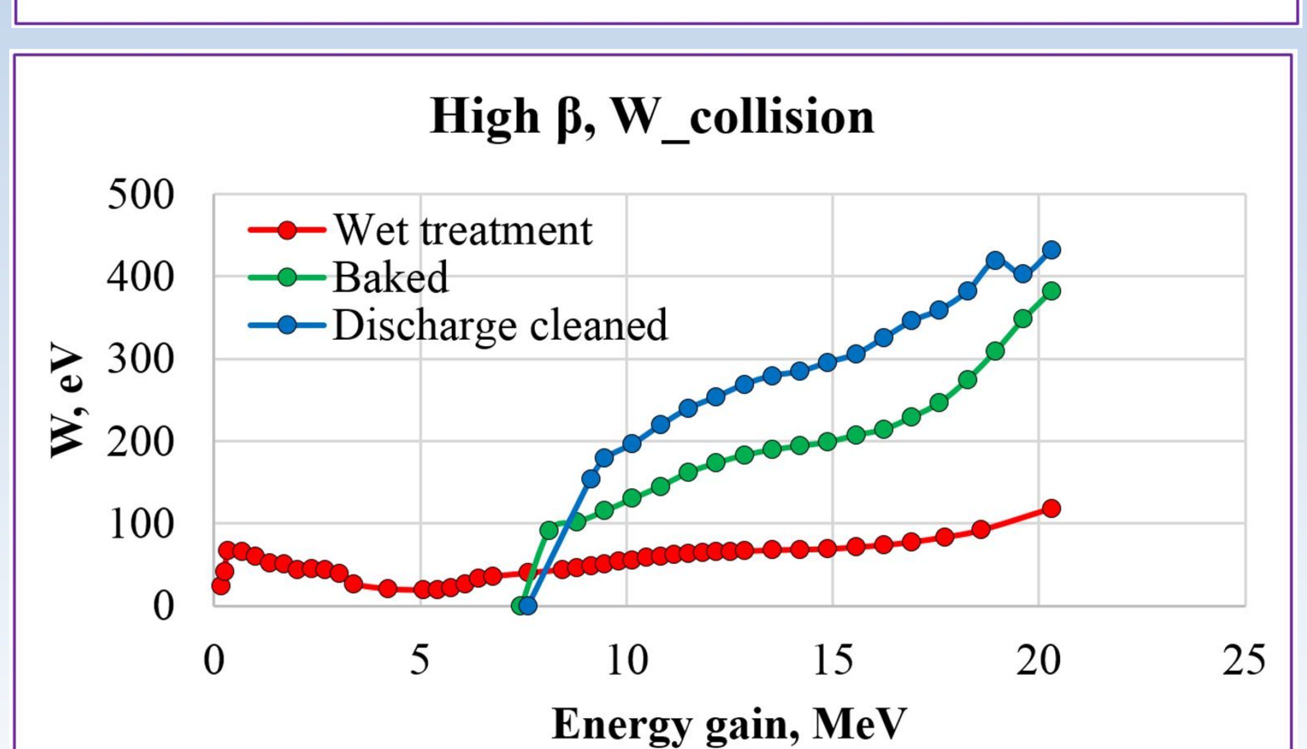
Total steady state re-emission current of multipacting with space charge effect was compared with effective secondary emission yield <SEY> obtained in simulation without space charge. The result of comparison is consistent with theoretical and experimental results. Namely, a maximum of MP band moves toward higher fields when space charge is ON; the MP band itself is narrower and energy of collision is lower compare to the simulations with zero space charge. But it is important to notice that the lower boundary of MP is predicted very accurately by the simulations based on the elementary theory without space charge effect.

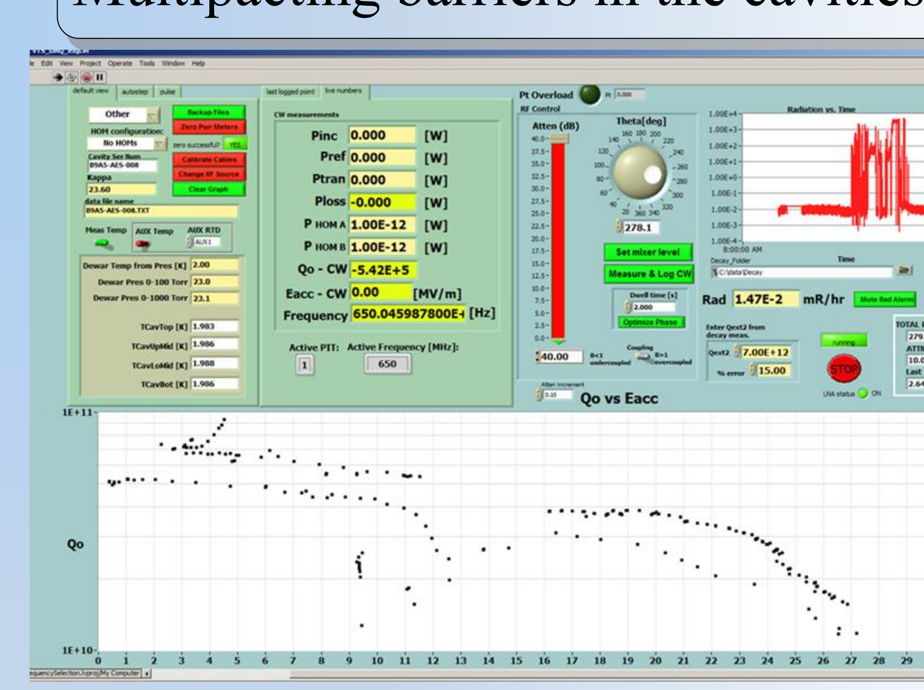
Multipacting barriers in the cavities











In the power tests of 5 cell high beta cavity at Fermilab the MP barrier was observed in the energy gain interval of 10.6÷17 MeV.

Conclusion

The inclusion of space charge effects in MP simulations does not result in significant changes of MP barriers. On the other hand the energy of collision and the power deposition in the simulations with active space charge effect are apparently very different compare to classic theory. That is interesting phenomena, which requires further study.