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PROGRESS IN THE DESIGN OF A NEW 150-MHz FLAT TOP CAVITY FOR THE PSI RING CYCLOTRON

WEPO018

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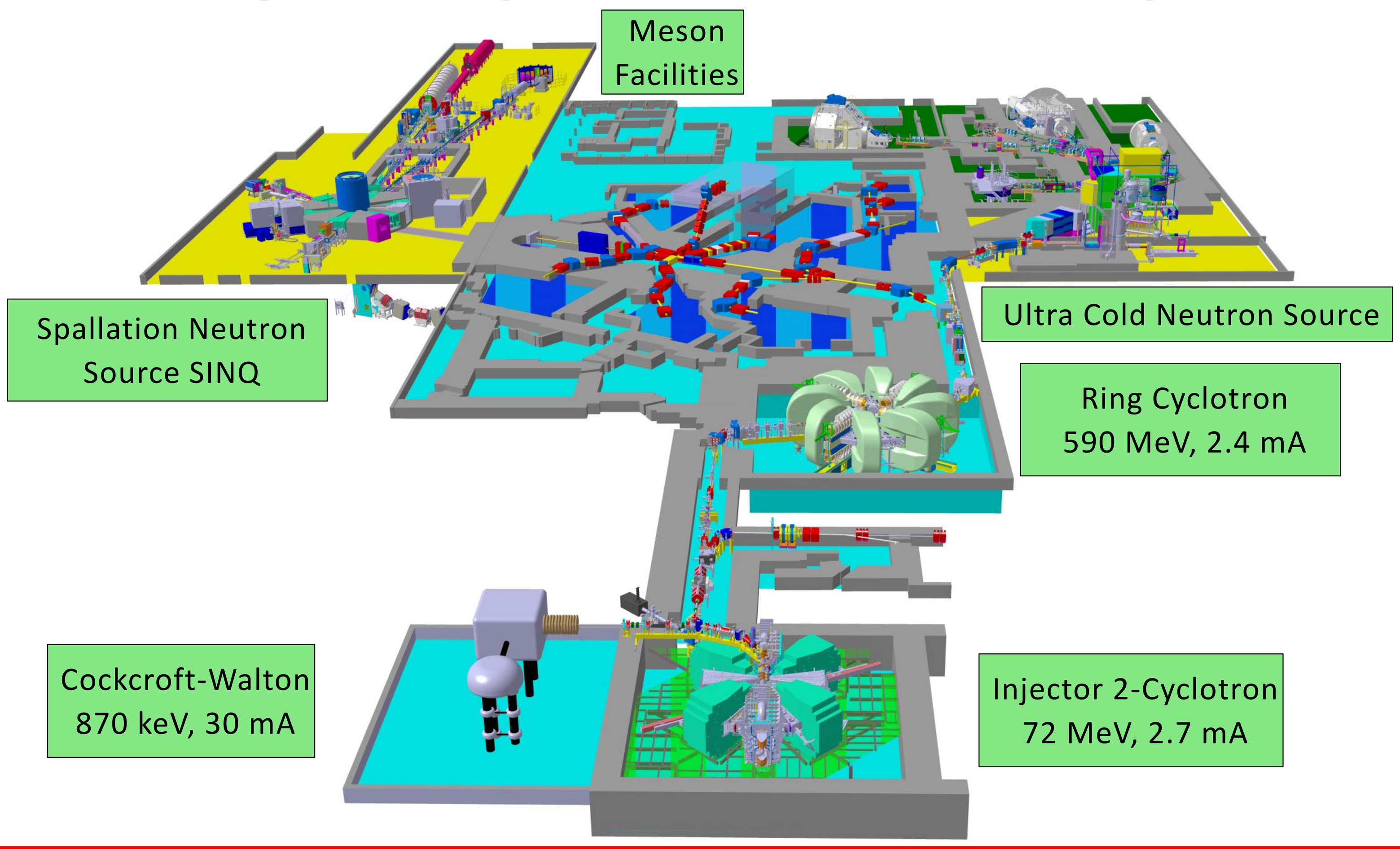
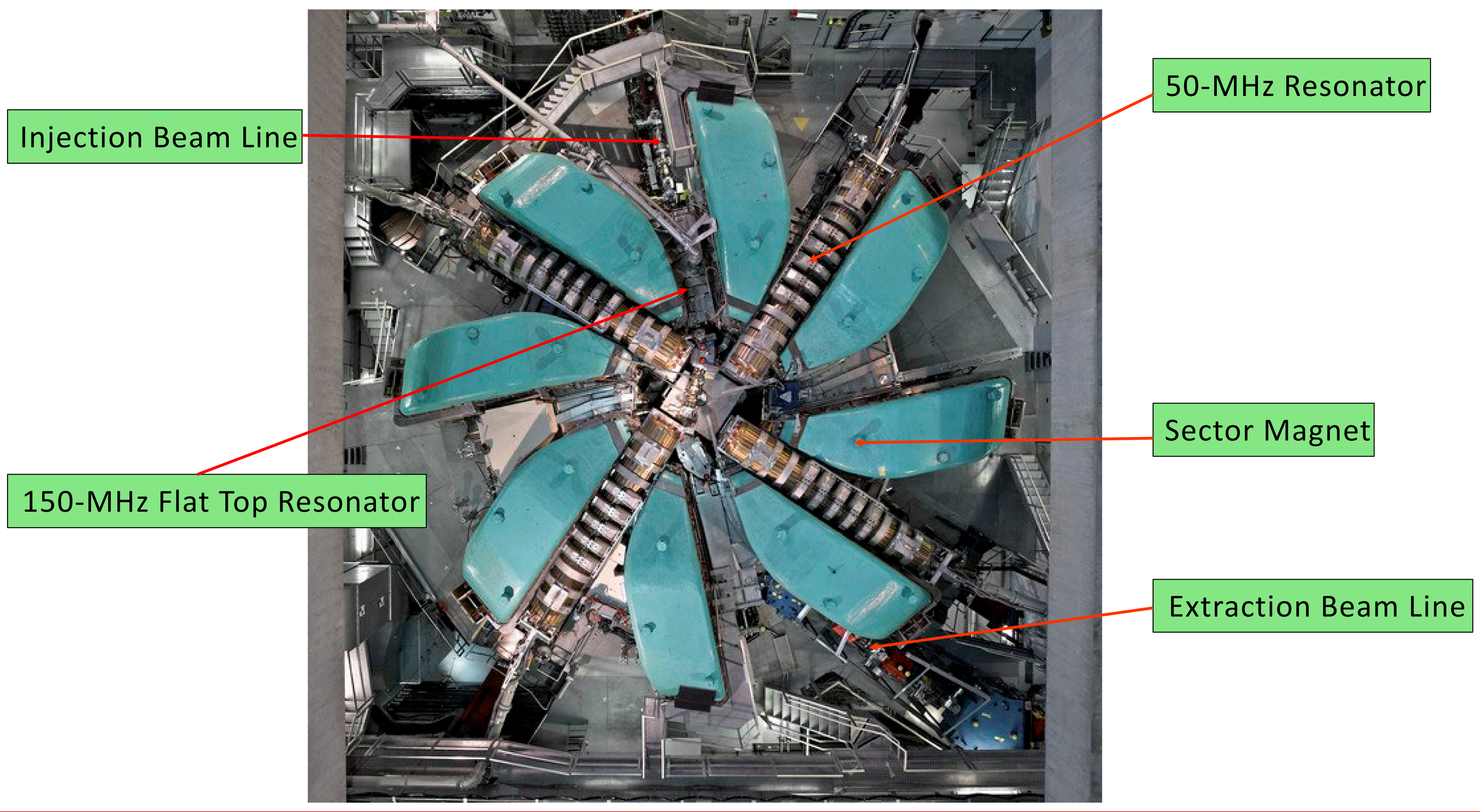
Abstract

Increasing PSI's 590-MeV main cyclotron beam current to 3 mA requires the replacement of the existing power-limited 150-MHz flat top cavity with a new cavity. This new cavity has been designed to withstand a 700-kV peak voltage and a 140-kW dissipated average power. Although very similar in its geometry to the original flat top cavity currently in operation, in the new design, special attention has been paid to the shaping of the four electrodes for maximizing the shunt impedance. Furthermore, the topology of the cooling water channels has been optimized to increase the power handling capabilities of the cavity. Finally, in order to mitigate multipacting observed in the current design, variations on the new cavity baseline geometry have started to be explored.

High Intensity Proton Accelerator Facility



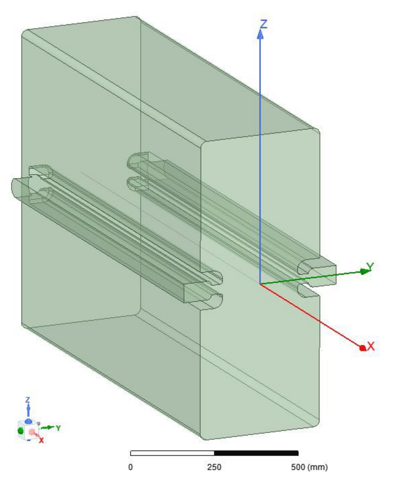
Ring Cyclotron



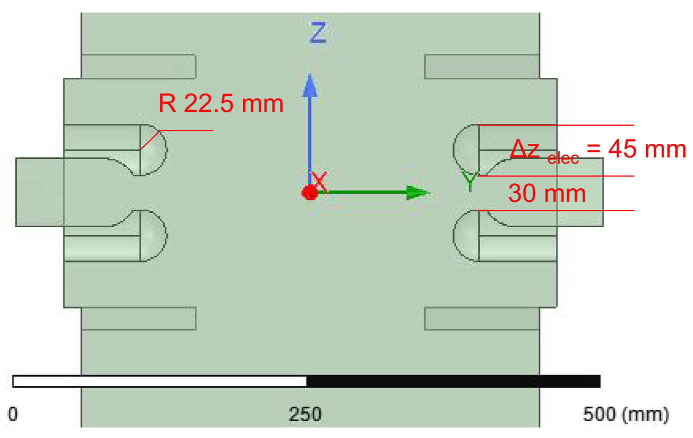
RF Design Studies

New cavity frequency and inner dimensions

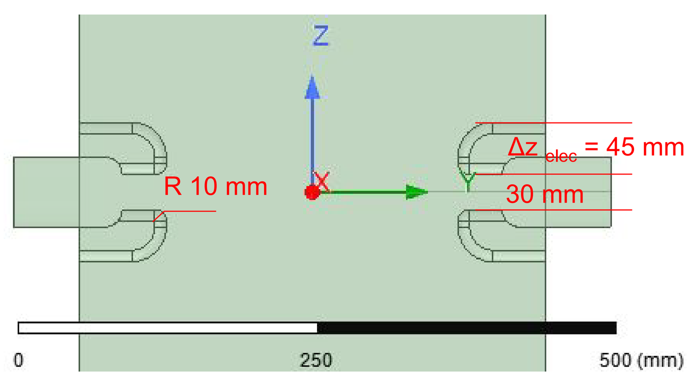
Design frequency	151.8984 MHz
Inner length	2,700 mm
Inner width	200 mm
Inner height	~ 954.5 mm
Electrodes length	2,585 mm



New cavity vacuum volume – One-half

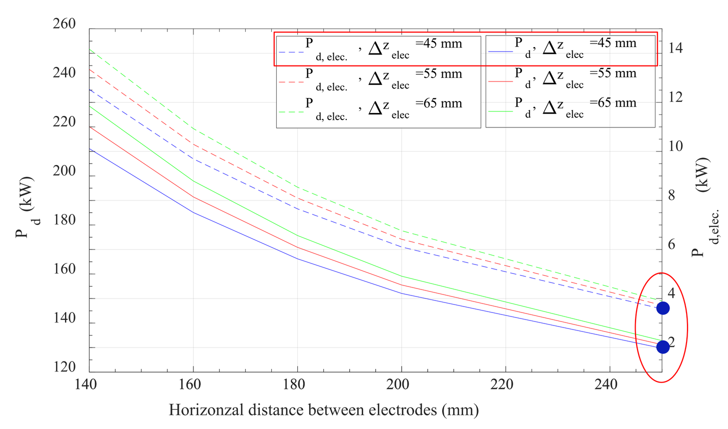


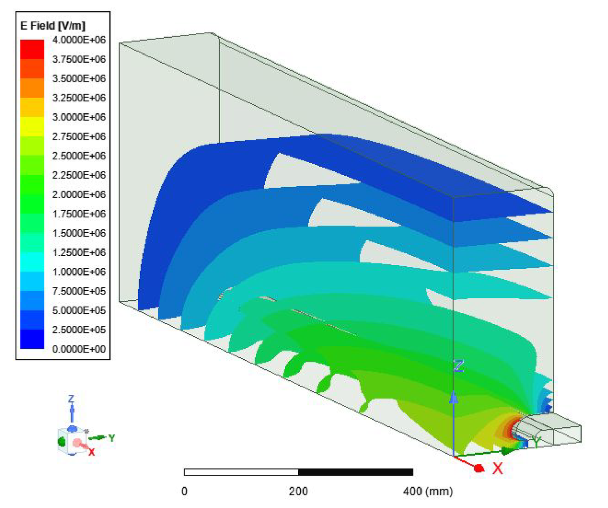
Actual cavity electrodes' topology



New cavity electrodes' topology

- For a 3-mA beam current, each 50-MHz main cavity of the Ring cyclotron requires a peak accelerating voltage of 910 kV.
- The required peak voltage of the 150-MHz flat top cavity is then about 640 kV. Adding some reserve, the new cavity is being designed for a maximum peak voltage of 700 kV.
- Due to mechanical constraints, the new aluminum cavity RF studies, performed with the 3D electromagnetic code ANSYS HFSS, mainly focused on optimizing the electrodes.
- With new electrodes' topology and for an aluminum conductivity of 34 MS/m, parametric studies done by varying the horizontal gap between electrodes and the electrodes' thickness show that the total average dissipated power is minimized for a 250-mm gap (the maximum distance to reduce field leakage) and electrodes' thickness of 45 mm and is about 130 kW.
- Adding some more margin, the mechanical design is based on a total average dissipated power of 140 kW.

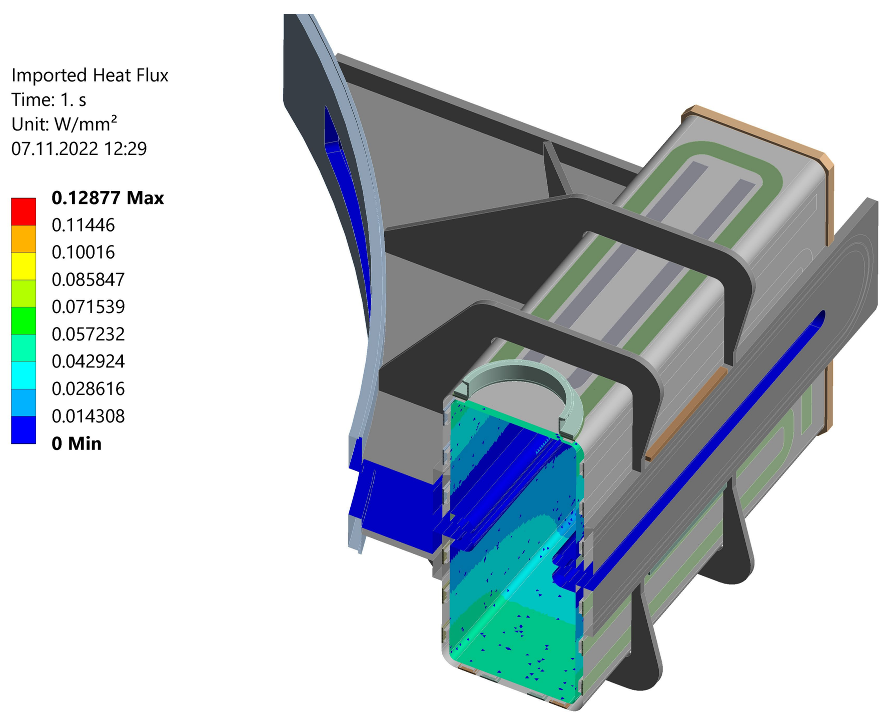




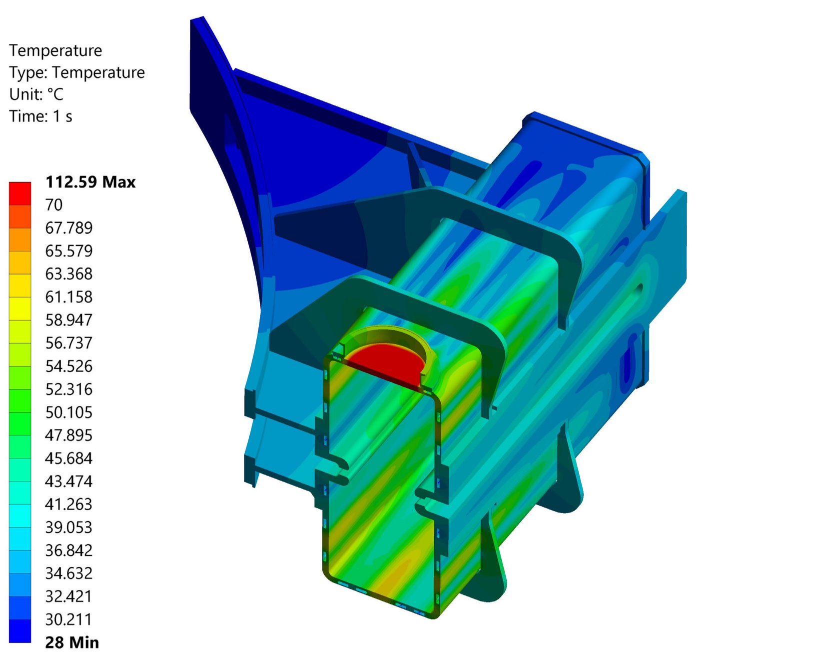
3D electric field for a 700-kV cavity voltage

Mechanical Design and One-Way Simulations with ANSYS

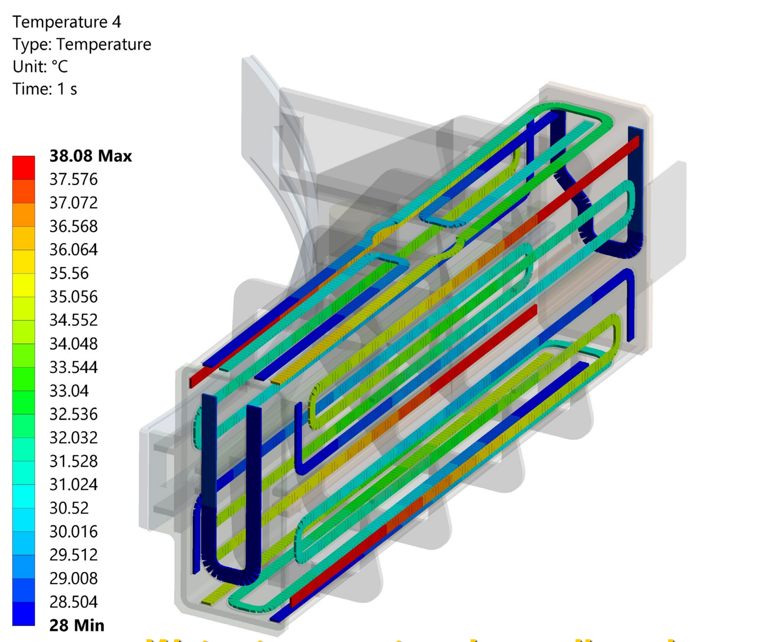
- Within ANSYS HFSS the total dissipated power on the outer surface of the vacuum cavity volume of 140 kW is retrieved. The results are imported as heat flux in the ANSYS Steady State Thermal module.
- With the following input data: cooling channel size 10 mm × 40 mm, forced flow water convection coefficient 4986 W/(m²K), water velocity 1.2 m/s, ambient temperature 26° C, air convection coefficient 10 W/(m²K), simulations give a maximum body temperature of 70° C and water temperature difference of 11° C.
- The cavity temperature distribution obtained at the previous step is imported in the ANSYS Static Structural module with applied loads corresponding to a pumping out of air inside the cavity (1 bar external pressure) and an external pressure of 1.7 bar on the cavity flat side where an inflatable gasket is installed. Simulations give a maximum deformation of 1.29 mm.



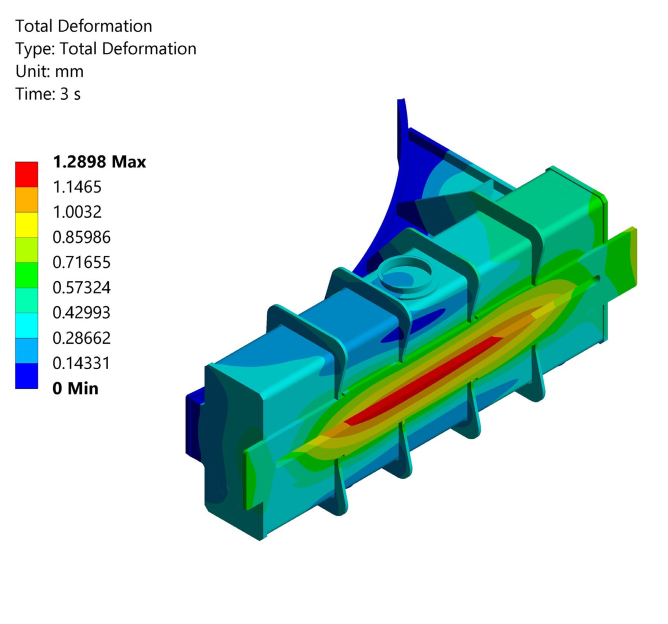
New cavity body heat flux map for a 140-kW dissipated power



New cavity body temperature map



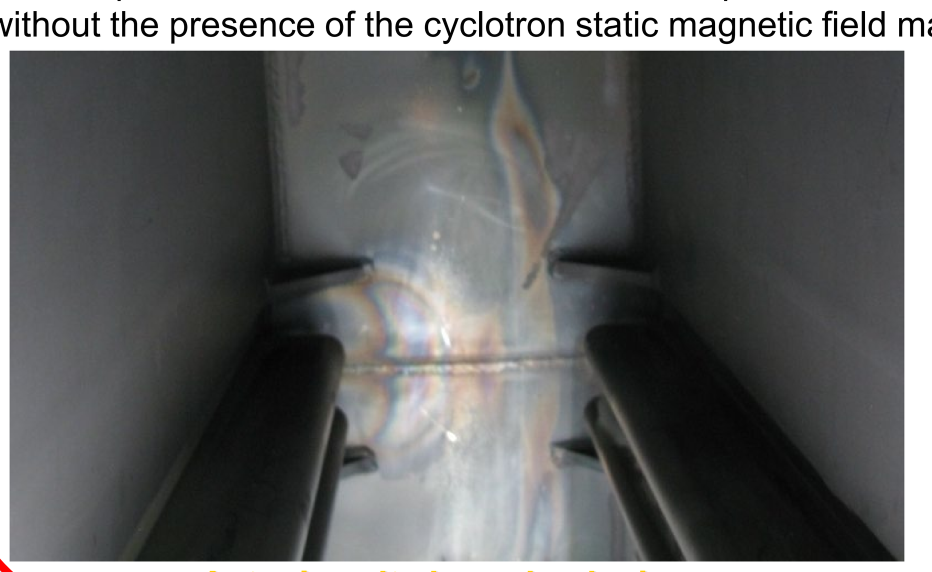
Water temperature in cooling channels



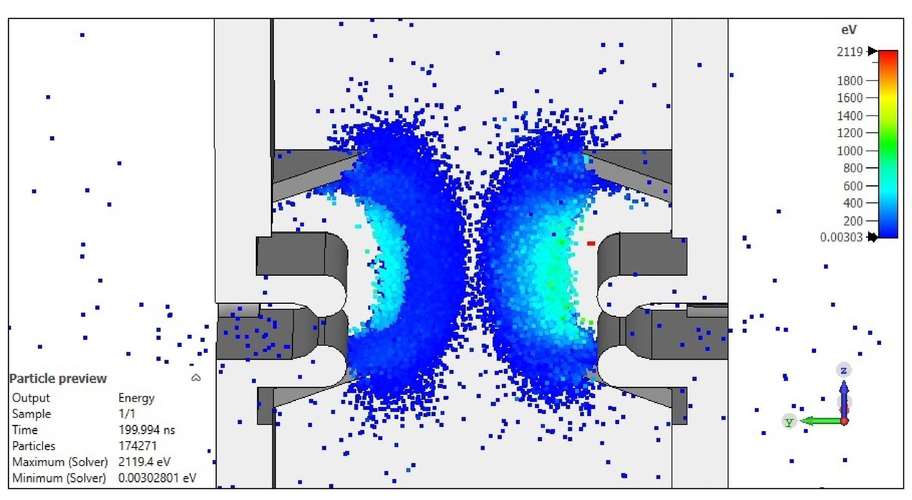
New cavity deformation

Multipacting Studies

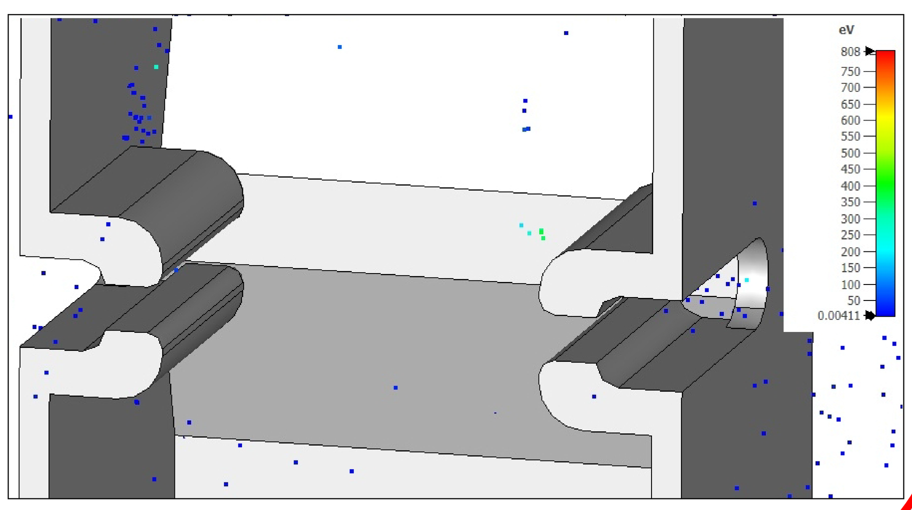
- A visual inspection of the inside current flat top cavity revealed that multipacting occurs on the cavity back wall.
- Using the Particle-in-Cell (PIC) solver from CST Studio's Suite, multipacting simulations which involve coupling of the electromagnetic field maps generated by CST's eigenmode solver to the PIC solver were performed.
- An homogeneous electron distribution was assumed throughout a volume closed to the cavity back wall and comprising the electrodes' ends.
- It was possible to obtain similar crescent-shaped electron distributions for simulations without the presence of the cyclotron static magnetic field maps.
- These crescent-shaped electron distributions are inherent to the cavity design even as the new cavity does not have the original cavity triangular-shaped reinforcements.
- Geometric changes of the back wall in the vicinity of the electrodes' ends and of horizontal middle cavity plane are being explored in order to remove the potential well which traps the particles between the four electrodes and the back wall.
- In a cavity geometry with a recession within the back wall it is possible to mitigate the multipacting but assuming copper material.



Actual cavity inner back plane



Actual cavity and e- distributions



New cavity and recession within back wall

Conclusions

Designed to withstand a peak voltage of 700 kV and an average power of 140 kW, the RF design studies of the new 150-MHz flat top cavity show that adopting a horizontal distance between the electrodes of 250 mm and a maximum electrode thickness of 45 mm minimizes the required cavity dissipated power. Moreover, the modest dissipated power per electrode indicates that dedicated electrode cooling channels are not required. This new cooling channel system designed and simulated with ANSYS is such that the maximum cavity body does not exceed 70° C. A one-way ANSYS Static Structural analysis of the cavity shows that the maximum structural deformation is less than 1.5 mm and self-consistent simulations are in progress. PIC CST Studio Suite multipacting studies have also been initiated by modifying the cavity back wall closed to the electrodes' end.