UPDATE ON SSR2 CAVITY EM DESIGN FOR PIP-II*

THPLR032

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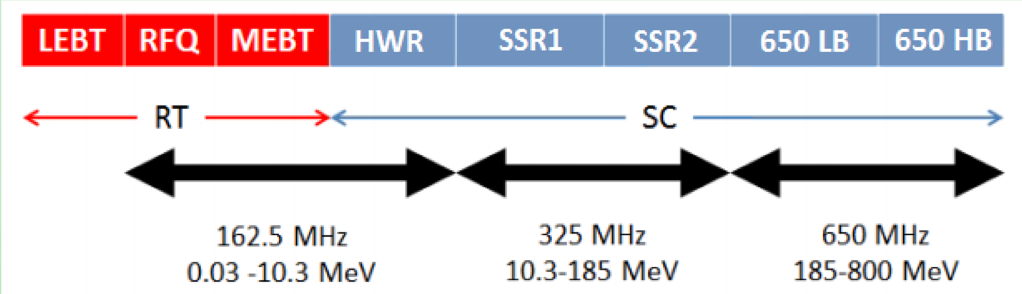
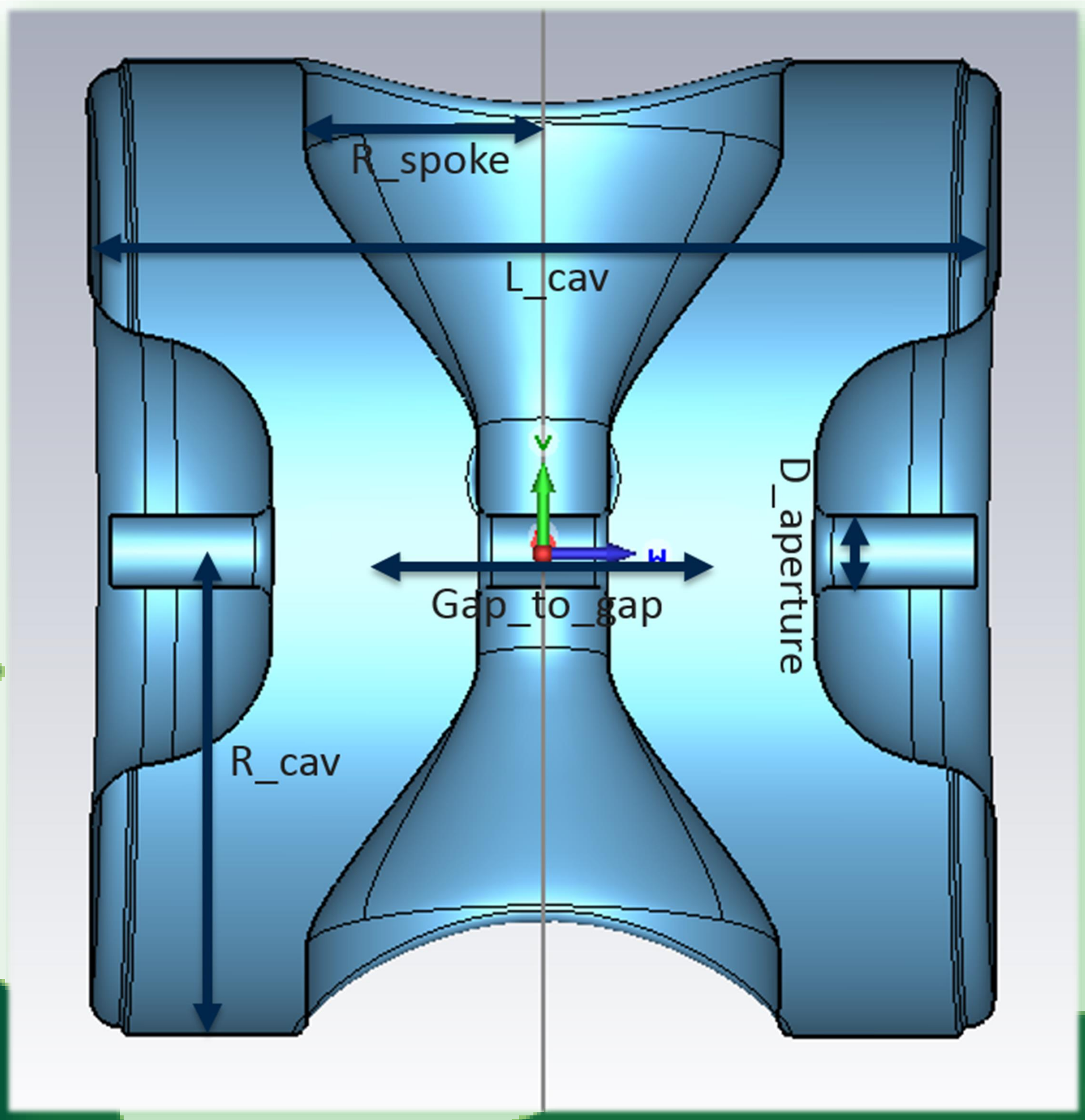
Introduction

- Proton Improvement Plan-II (PIP-II) is Fermilab plan for future improvements to the accelerator complex aimed at providing LBNE (Long Base Neutrino Experiment) operations with a beam power of at least 1MW on target.



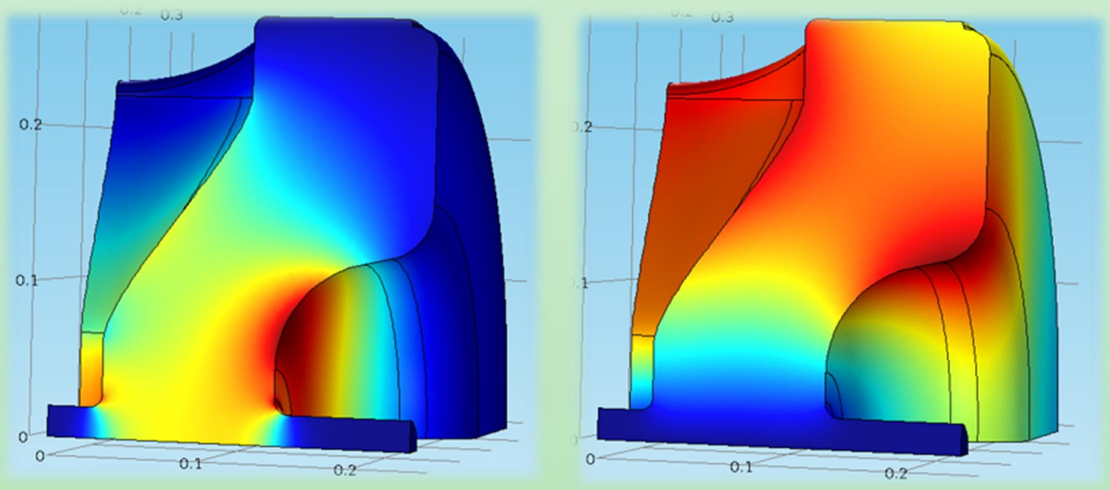
- The central element of the PIP-II is a new superconducting linac: one 162.5 MHz half wave resonator (HWR), two single spoke resonator sections at 325 MHz (SSR1 and SSR2), two families of 650 MHz elliptical cavities low beta (LB) and high beta (HB).
- SSR2 design has been updated mainly to mitigate multipacting, trying to preserve the cavity performance.
- A summary of the RF design studies is presented: EM parameters, quadrupole field asymmetry and multipacting simulations.



Parameter	[mm]
L_cav	500
R_cav	271.6
R_spoke	130.7
D_aperture	40
Gap_to_gap	185.9

Geometry and RF parameters

- SSR2 is a single spoke resonator operating at 325 MHz, for particle acceleration from 35 MeV to 185 MeV.
- The cavity Y-Z section is shown in the figure at the top center of the poster.



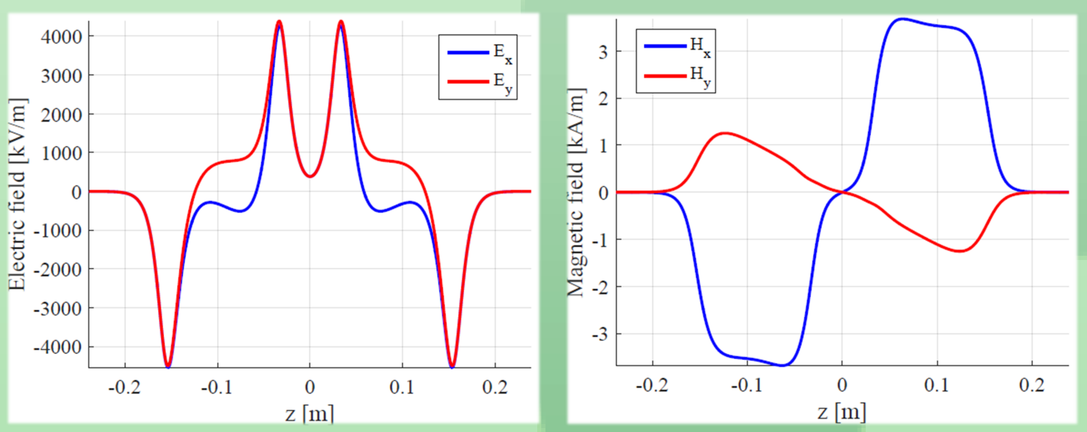
- SSR2 electric (left) and magnetic (right) field have been simulated with Comsol Multiphysics.
- β_{opt} has been picked after optimization of the linac section, it has not changed going from SSR2 v1.0 to v2.6 (new design).
- $L_{eff} = \beta_{opt}*\lambda$ is the definition used for effective length.
- Overall cavity performance satisfy PIP-II project needs.

Parameter	SSR2 v1.0	SSR2 v2.6
Frequency [MHz]	325	325
Optimal beta β_{opt}	0.471	0.475
Effective length $L_{eff}[m]$	0.435	0.438
E_{peak}/E_{acc}	3.45	3.38
B_{peak}/E_{acc} mT/(MV/m)	6.11	5.93
G [Ohm]	113	115
R/Q [Ohm]	290	297
Max en. gain[1] [MeV]	4.98	5.17

[1] calculated at 40 MV/m and 70 mT max peak fields.

Transverse field asymmetry

- Spoke resonators have a central electrode that lies on one of the axes perpendicular to the particles motion, breaking the axial symmetry of the cavity.
- The lack of azimuthal symmetry affects transverse electric and magnetic fields: a particle will be subject to non-uniform radial kick.



- Electric (left) and magnetic (right) transverse fields at r=10 mm in SSR2 v2.6.
- The two transverse momentum gain components can be calculated integrating the fields over z axis, according to the Lorentz force equations.

$$\Delta p_x(r,\alpha)c = \int_{z_i}^{z_f} \left(\frac{E_x(r,\alpha)}{\beta} - Z_0 i H_y(r,\alpha) \right) e^{i\frac{kz}{\beta}}\, dz$$

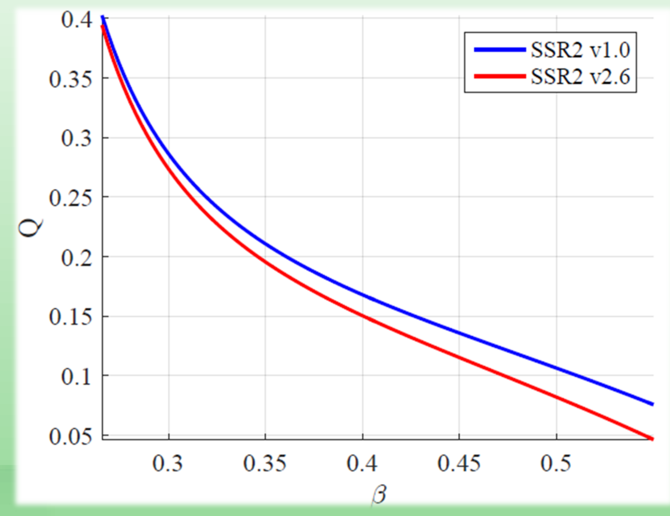
$$\Delta p_y(r,\alpha)c = \int_{z_i}^{z_f} \left(\frac{E_y(r,\alpha)}{\beta} + Z_0 i H_x(r,\alpha) \right) e^{i\frac{kz}{\beta}}\, dz$$

Assymetry parameter Q

- Since the transverse field asymmetry will induce a quadrupole kick, one can define the parameter Q, which is directly proportional to the quadrupole strength.

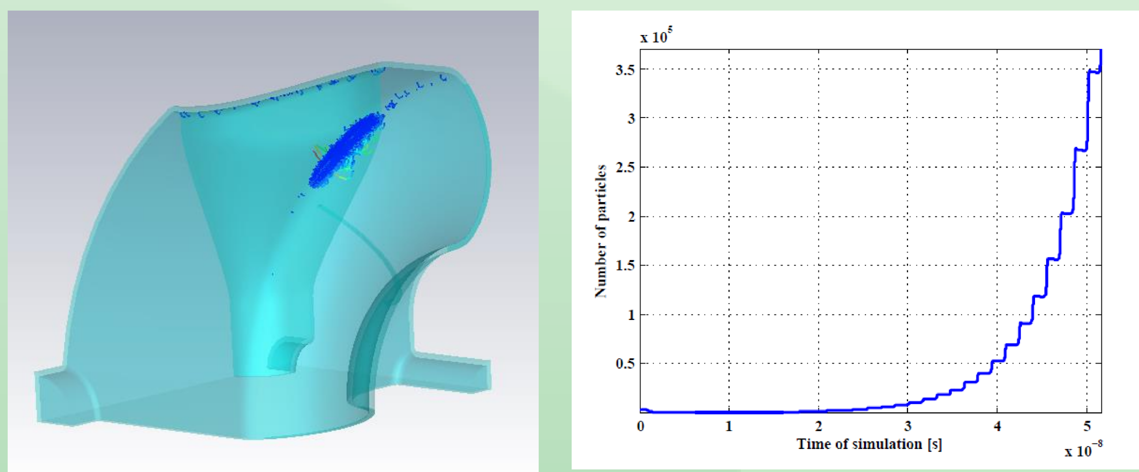
$$Q = \frac{\Delta p_x(r,0)c - \Delta p_y(r,\pi/2)c}{\left(\Delta p_x(r,0)c + \Delta p_y(r,\pi/2)c\right)/2}$$

- Q parameter comparison for SSR2 v1.0 and V2.6, both cavities show asymmetry in the whole beta range, the quadrupole amplitude will be manageable by the corrector in the solenoids.

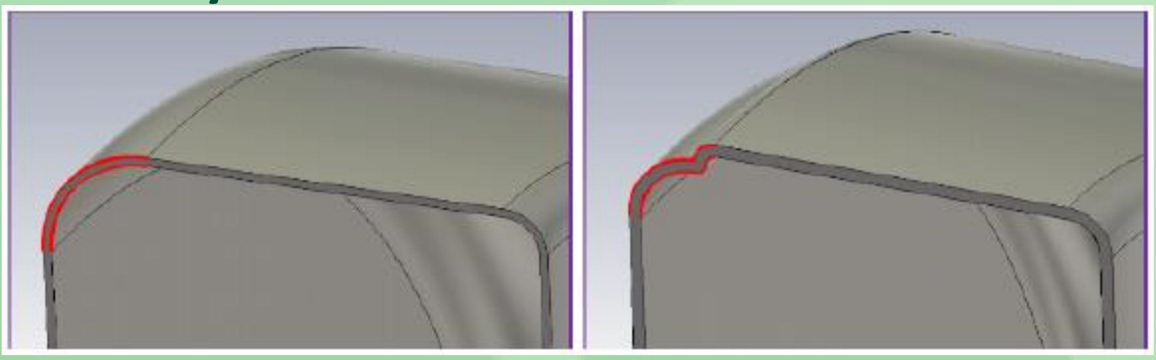


Multipacting mitigation

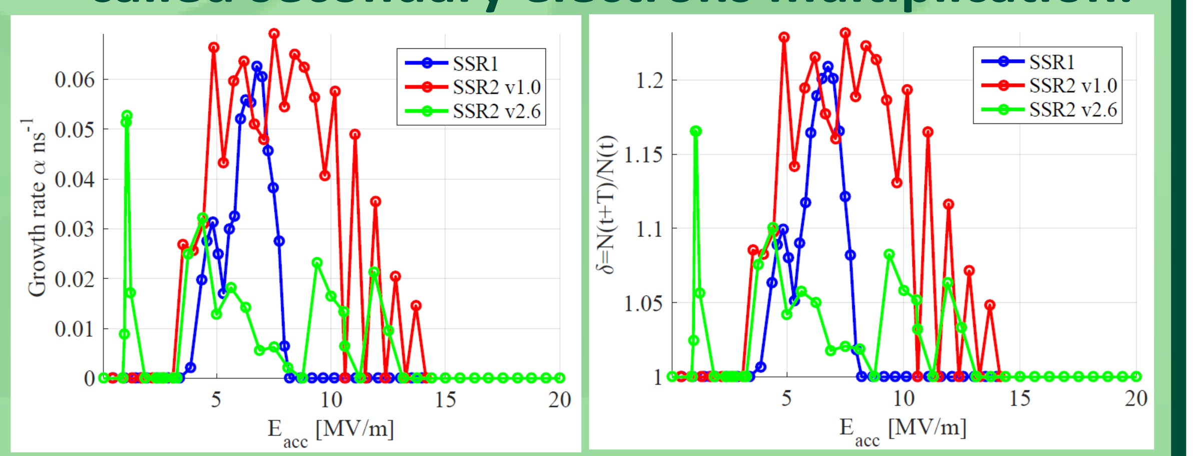
- SSR2 design has been modified since studying multipacting for the previous cavity design predicted strong and wide MP barriers.



- Most intense multipacting in v1.0 occurs at the blend between cylindrical shell and cavity wall.



- SSR2 v1.0 on the left and v2.6 on the right: the new design shows a double curvature step.
- If MP occurs, the number of particles grows exponentially with time, $N(t)=N_0e^{\alpha t}$, where α [1/ns] is the growth rate.
- δ=N(t+T)/N(t) is the increment of electrons within one RF period T, δ can be called secondary electrons multiplication.



- MP growth rate and δ, comparison: SSR2 v2.6 not only shows lower intensity than v1.0 but also lower than SSR1, which has been built and tested at FNAL.

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