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SPX Cavity Field Analysis

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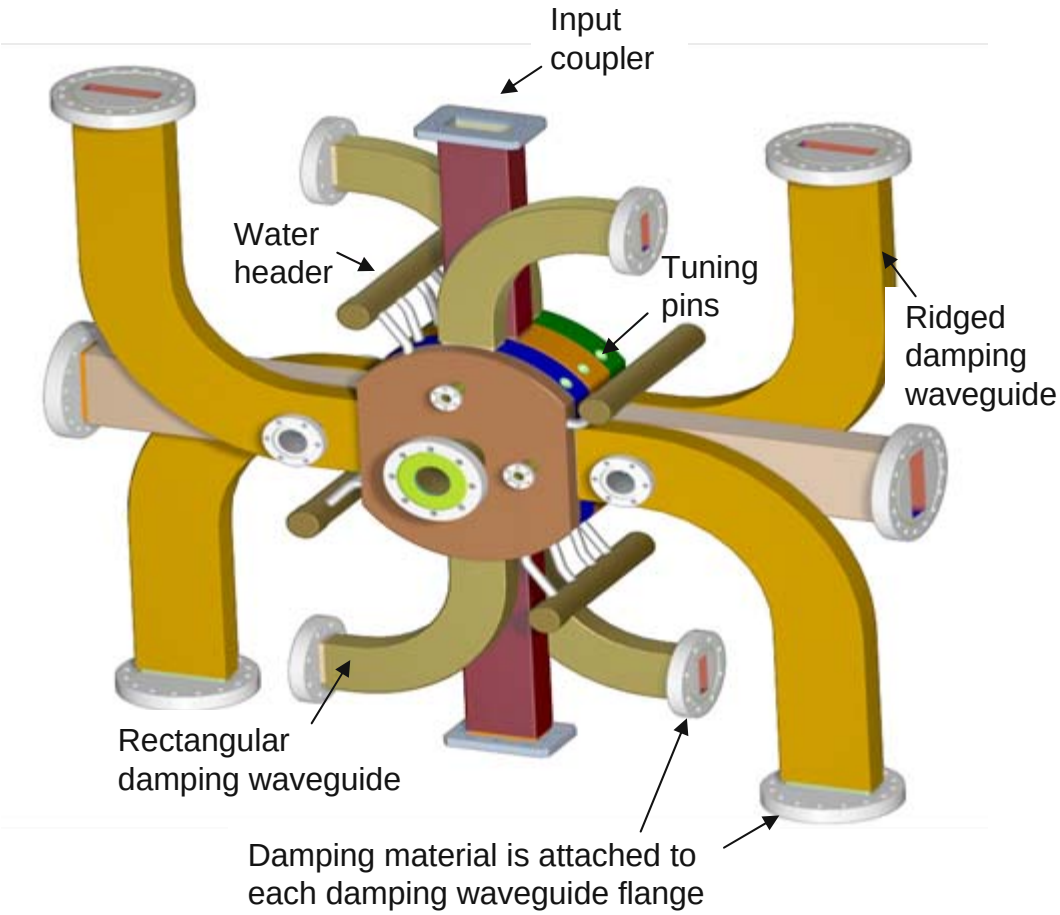
2.8GHz Deflecting Cavity Design for the APS Storage Ring

- Heavy damping is required for many of the non-operating modes in the deflecting cavity.
- The damping stability threshold for the APS is very stringent and is much lower at higher frequencies.
- The deflecting mode is not the lowest-order, or fundamental, mode in the cavity.
  - Can not exclusively use the natural cutoff frequencies of waveguide to exclude the operating mode and damp other modes
  - The monopole mode is the lowest order mode and is especially difficult to damp sufficiently because it couples very strongly to the beam.
- Superconducting cavities are more difficult to damp because of limits on the peak surface magnetic fields.

Normal-Conducting Deflecting Cavity Design

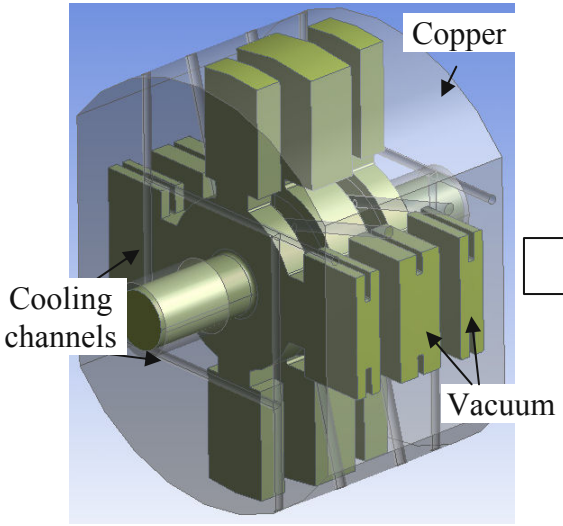
Frequency	2.815 GHz
Deflecting Voltage	2 MV
Peak Power	2.8 MW
Working mode Q_o	12000
R_t / Q	117
Iris radius	22 mm
Phase advance	π
Structure length w/o beam pipes	11.17 cm
Duty Factor	0.147%
Pulse Rate	1.0 kHz
Kick / (Power) $^{1/2}$	1.19 MV/MW$^{1/2}$
Beam Current	100 mA



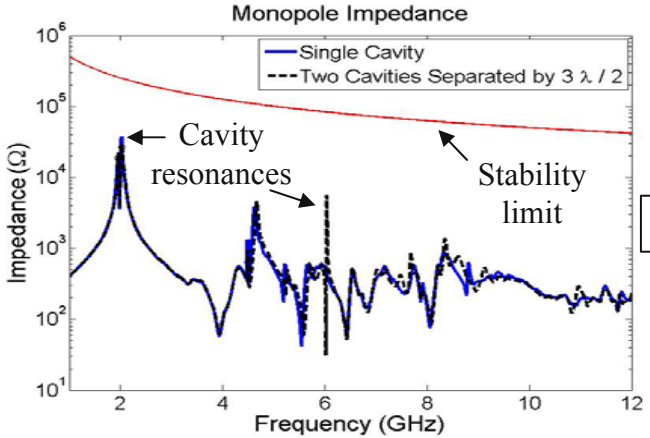
Normal Conducting Cavity Design Flow

- Iterative process evaluated rf / physics / mechanical design and structural analysis
- Parallel analysis optimized the cavity performance
- Final analysis performed on the cavity rf parameters due to the overall effect of cumulative structural changes due to thermal loading.

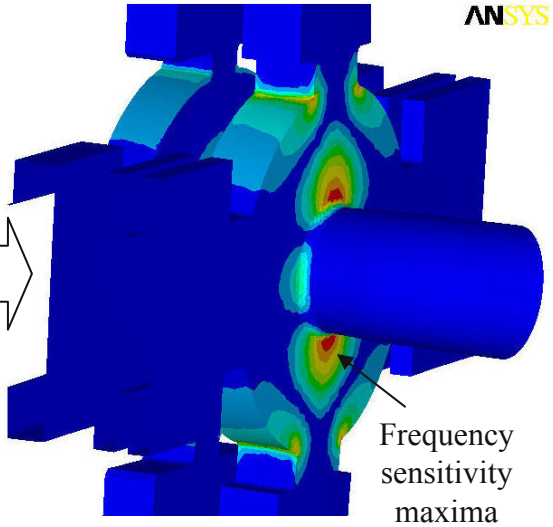
Mechanical Design



Physics Parameters

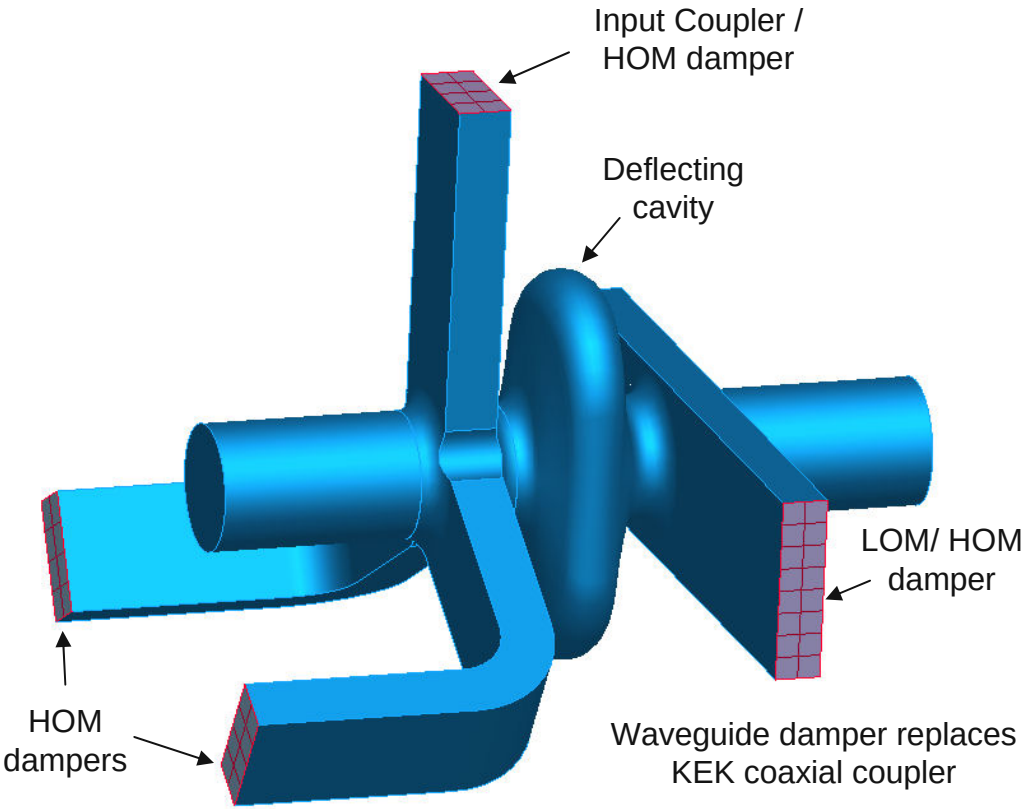


RF Parameters after Structural Analysis



APS 2.8 GHz Superconducting Single-Cell Deflecting Cavity

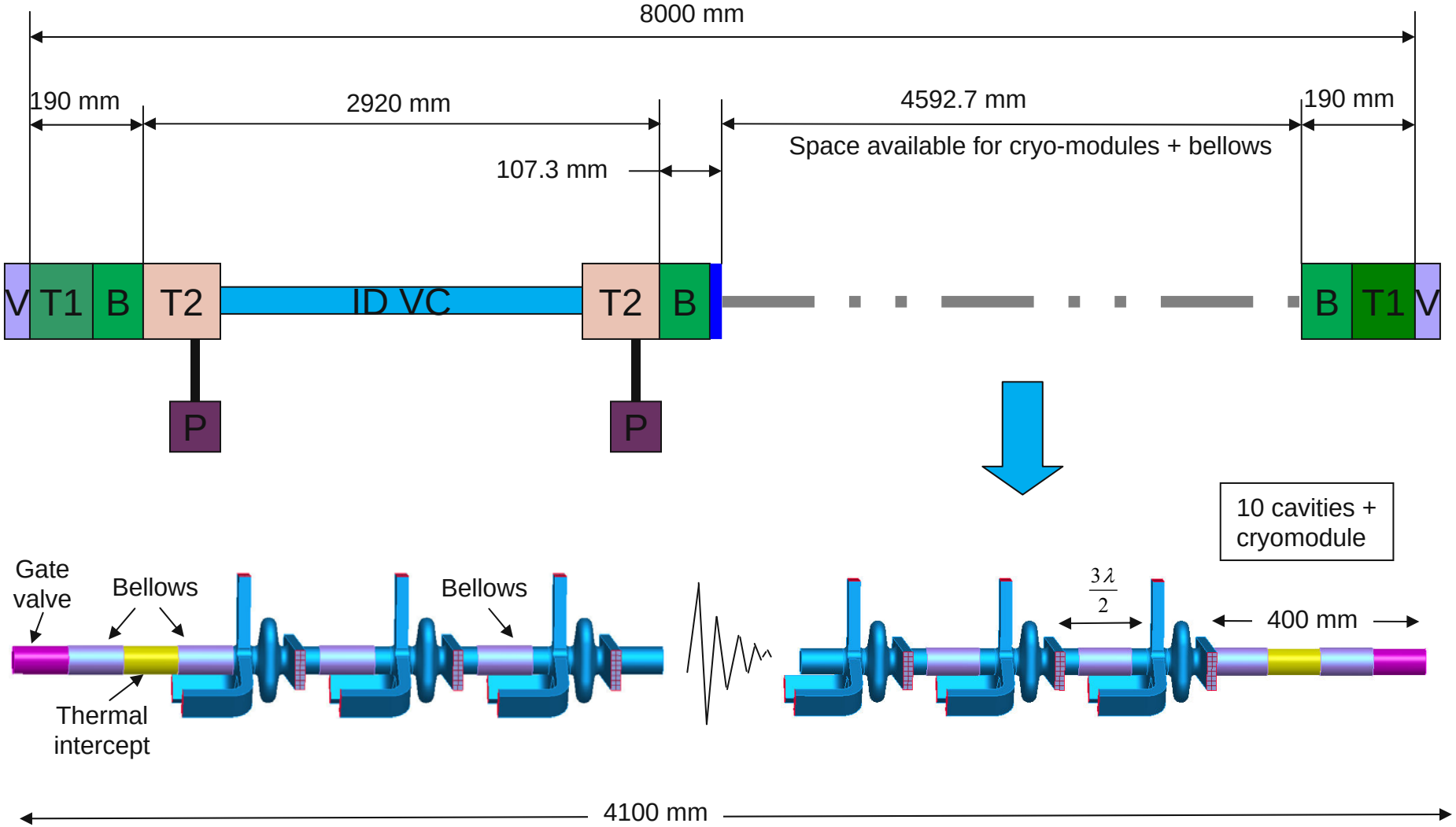
Frequency (GHz)	2.815
Deflecting Voltage	4 MV * 2
Qo (2K)	$3.8 * 10^9$
G	235
R_T / Q (Ω/m)	37.2
Beam radius	2.5 cm
No. Cavities	12 * 2
Operation	CW
Beam Current (mA)	100
E_{sp}/V_{defl} (1/m)	83.5
B_{sp}/V_{defl} (mT/MV)	244.1



Compact single-cell cavity / damper assembly

Since superconducting cavities are more difficult to damp, more dampers are required (and achieve less damping as compared to the NC design).

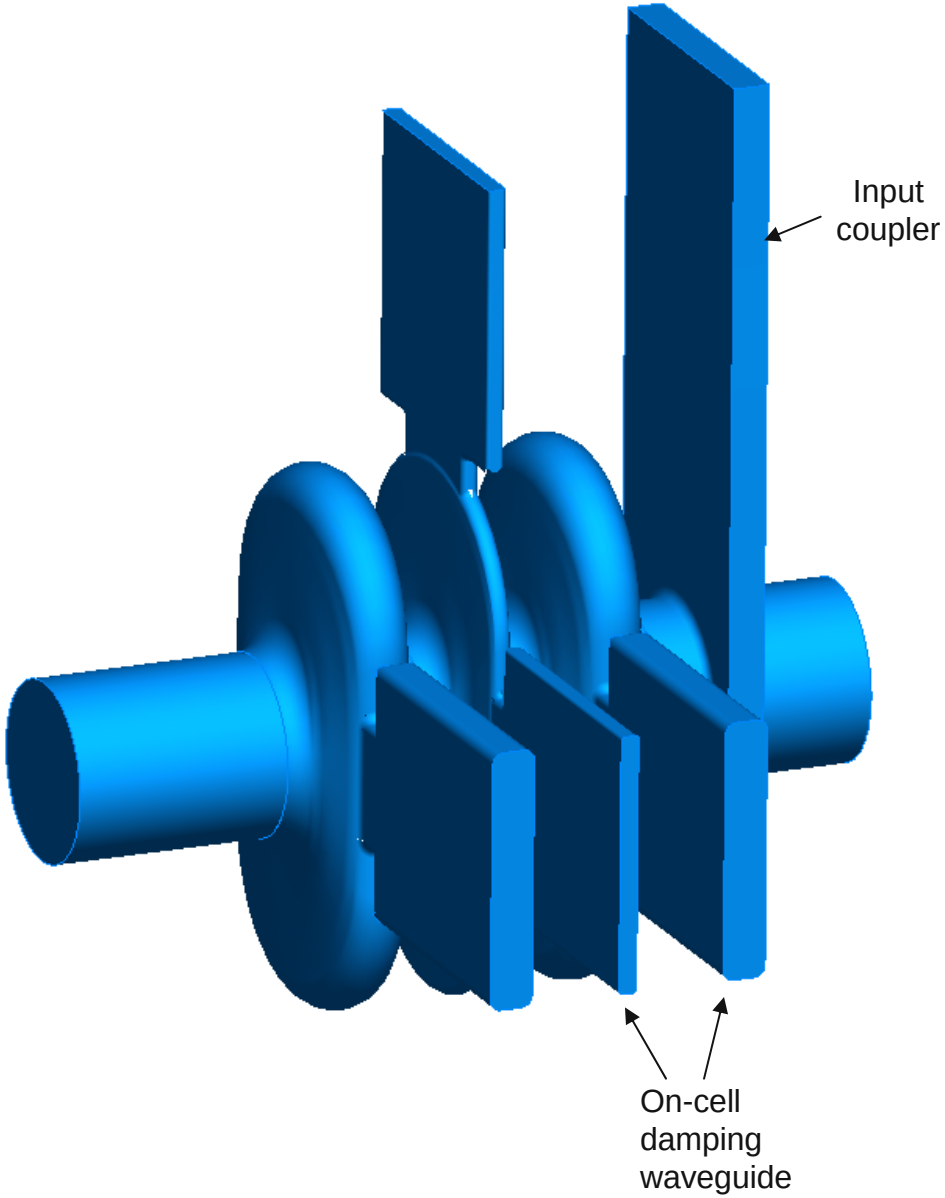
Deflecting Cavity Layout - Schematic



Single-cell cavities require substantial beamline space.

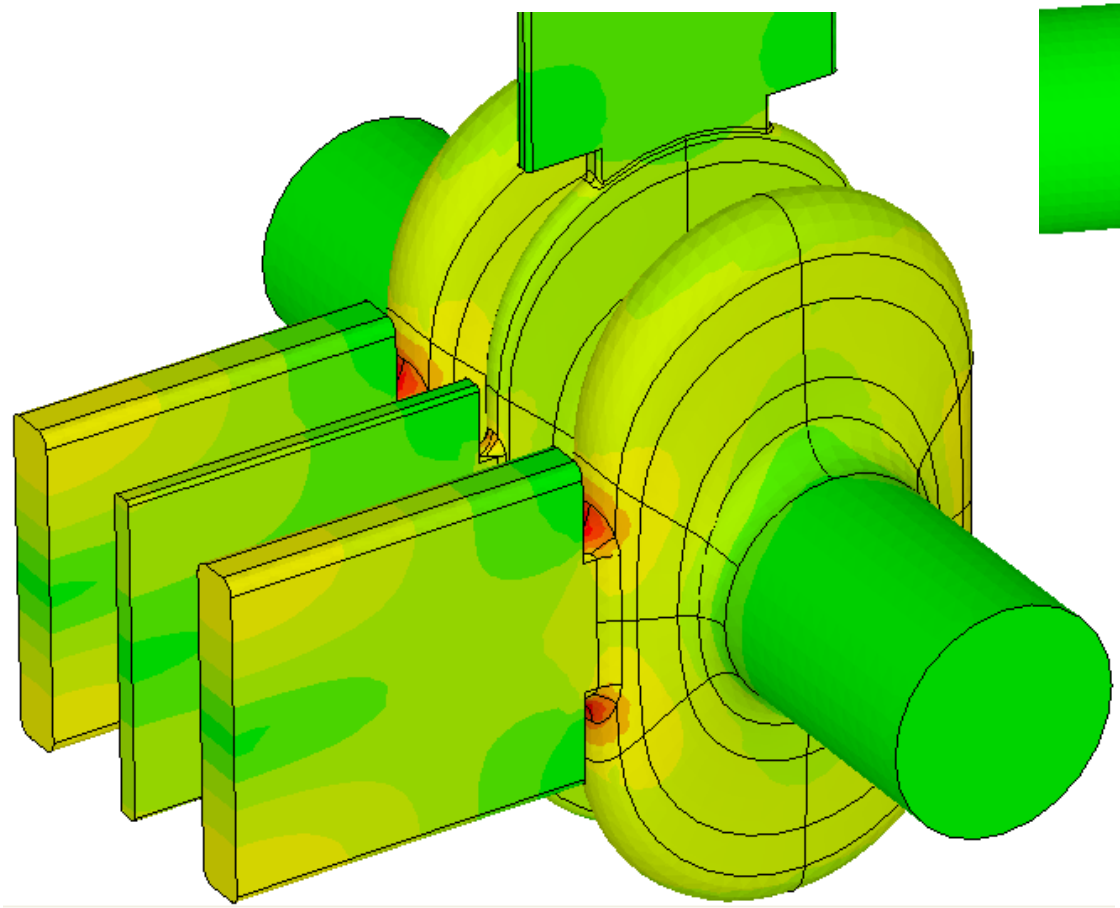
3-Cell Cavity Design

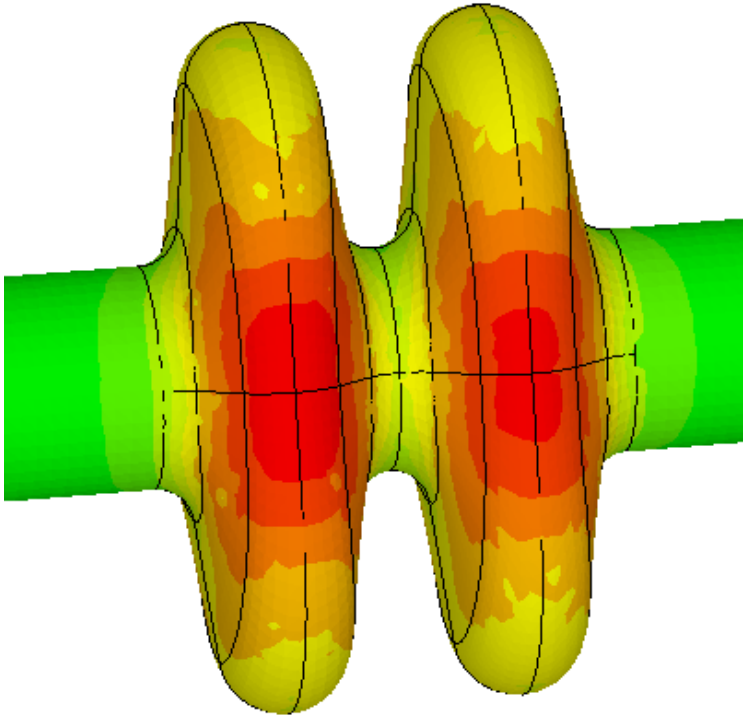
- Single-cell superconducting cavities are a strong possibility for SPX, but their disadvantages are important.
- Multi-cell cavities have a better fill-factor so fewer and / or shorter cryomodules are required.
- Fewer rf systems are required if a vector modulator can not be used or is prohibitive. This will potentially have significant savings on the power supply, rf amplifier and low-level controls, etc.
- 3-cell cavity reduces the number of cavities by 35% at its present state.
- Novel features of the 3-cell cavity must be validated including on-cell damping and shortened center-cell.



On-Cell Dampers: Surface B-Fields for Monopole Modes

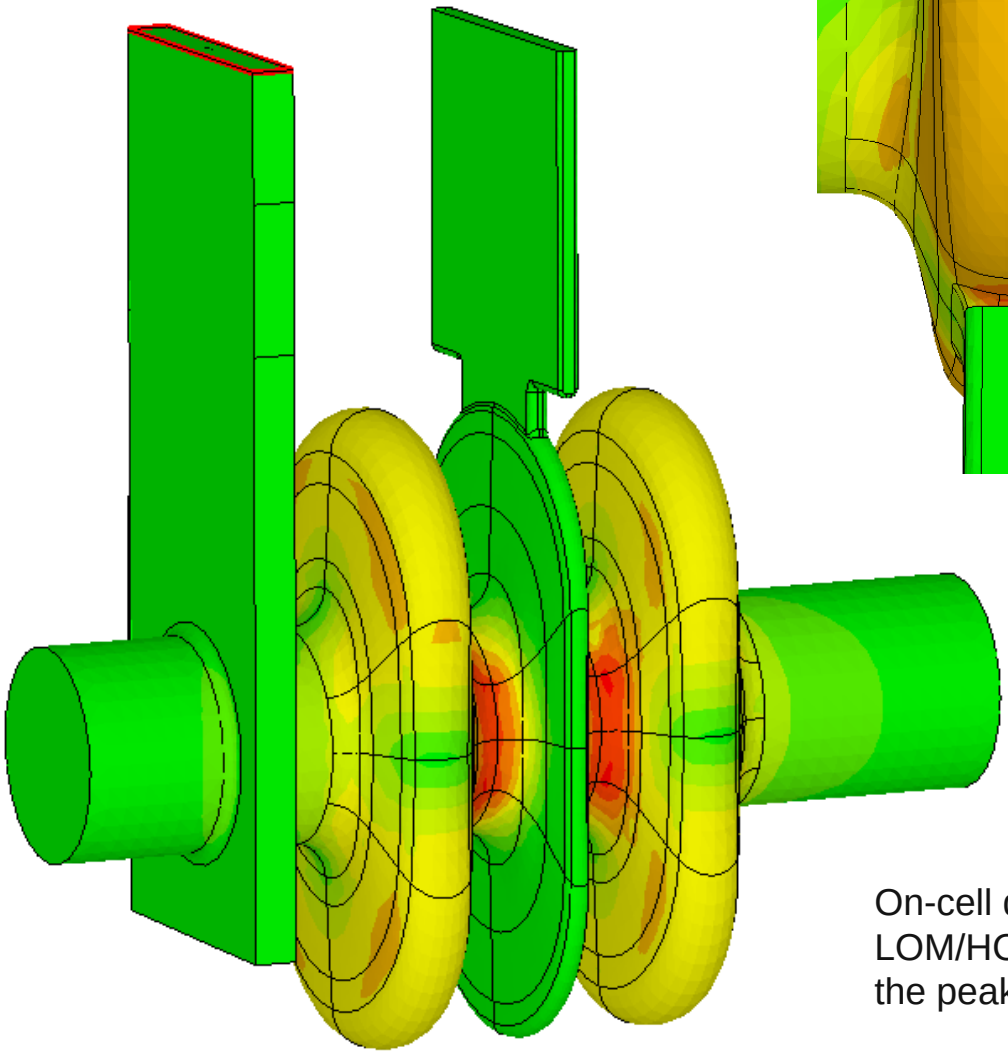
Surface magnetic fields limit
the peak operation of a cavity

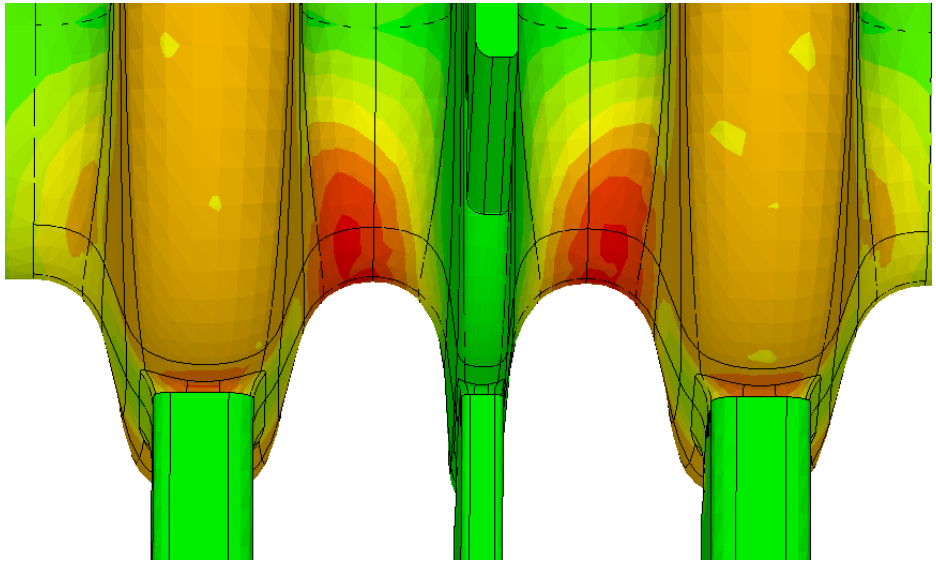




On-cell dampers can NOT be used on cavities driving a monopole mode since they accentuate the magnetic field

On-Cell Dampers: Surface B-Fields for Dipole Modes





Peak magnetic field is located on the cavity iris and not near the on-cell damper.

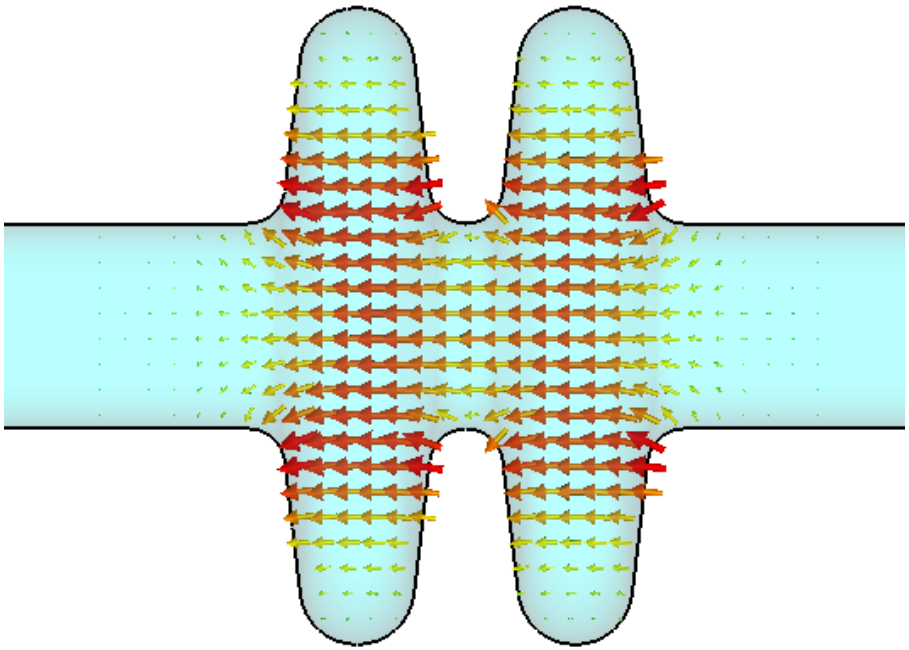
On-cell damper is adjusted for maximum LOM/HOM damping without enhancing the peak surface magnetic field.

Cavity Damping

- We will describe cavity mode types referred to as monopole and dipole modes.
- We will describe cavity mode phase advances between cells of a multi-cell cavity for a given cavity mode type.
- The mechanism used for damping the lower-order-mode (LOM) and higher-order-mode (HOM) monopole modes will be discussed.
- Issues and approaches for selectively damping dipole modes with different phase advances to the operating mode (but close in frequency) will be discussed.

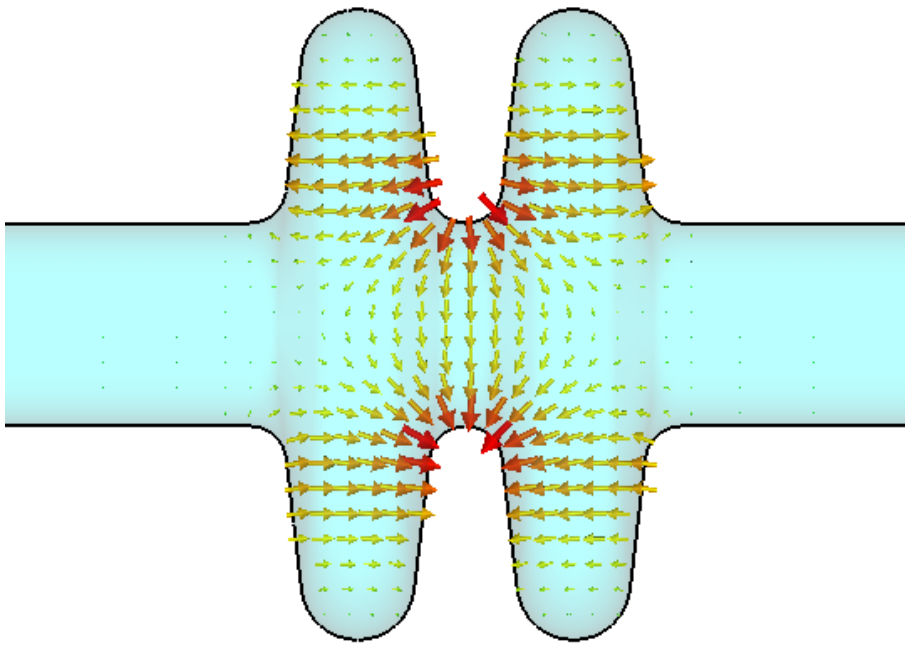
Multi-cell Cavity: Monopole / Dipole Mode Electric Fields

0 - mode has no phase shift between cells



0 - mode monopole mode electric field

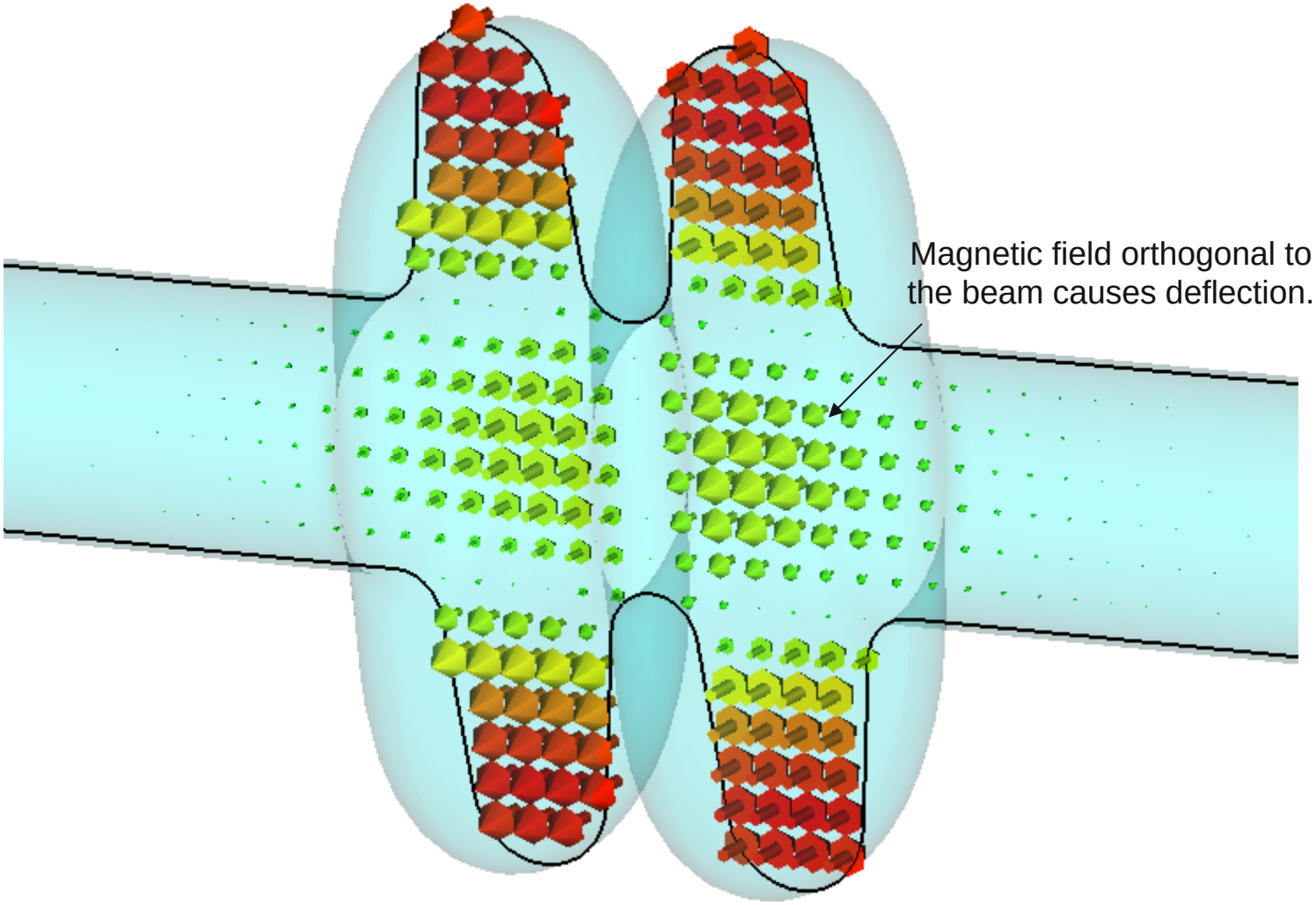
π - mode has a 180° phase shift between cells



π- mode dipole mode electric field

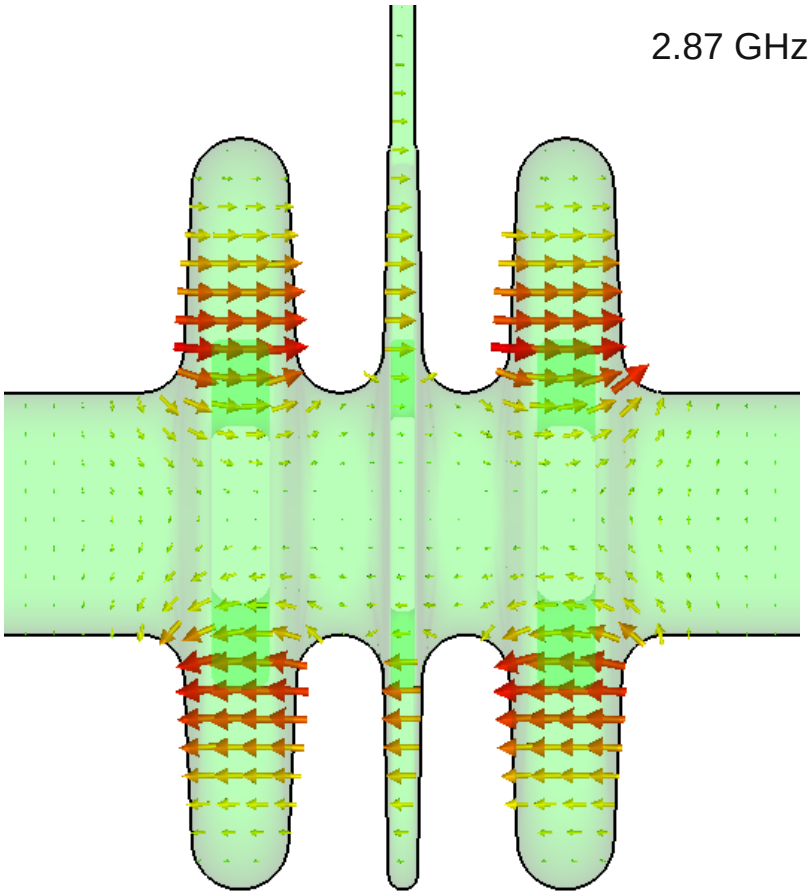
A 2-cell cavity supports 2 different phase advances between cells for each type of mode (TM_{010}, TM_{110}, etc), i.e., the 0 - and π - mode

Multi-cell Cavity: Dipole Mode Magnetic Field

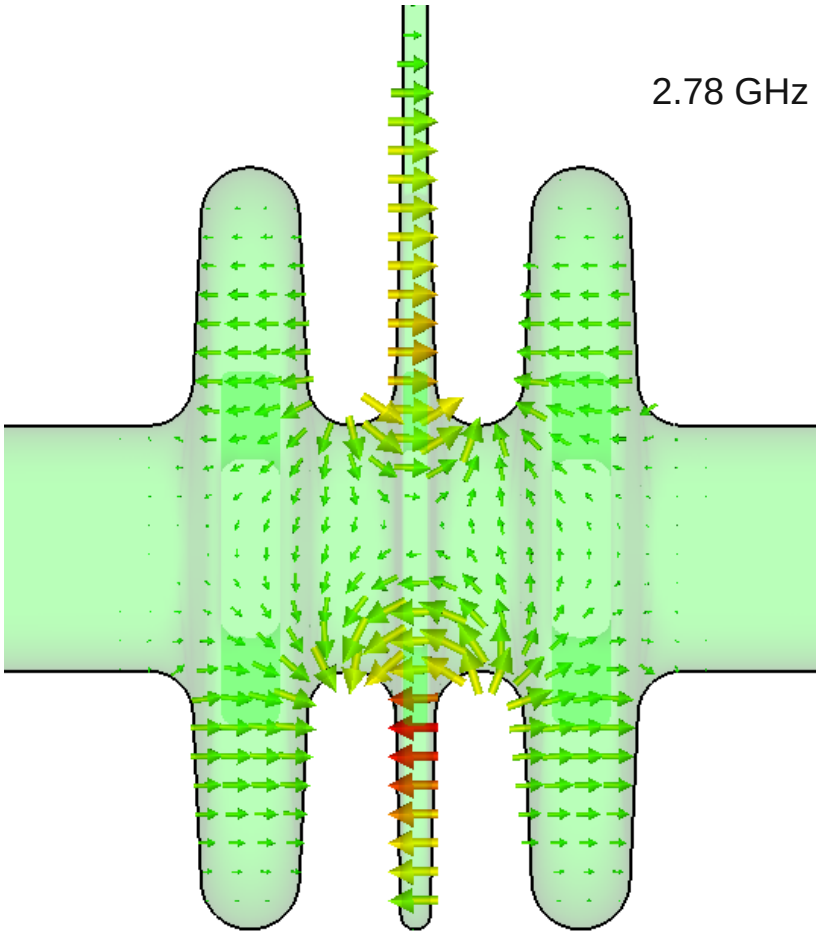


π - mode dipole mode

3-Cell Cavity: Deflecting Mode 0 and π Phase Advance

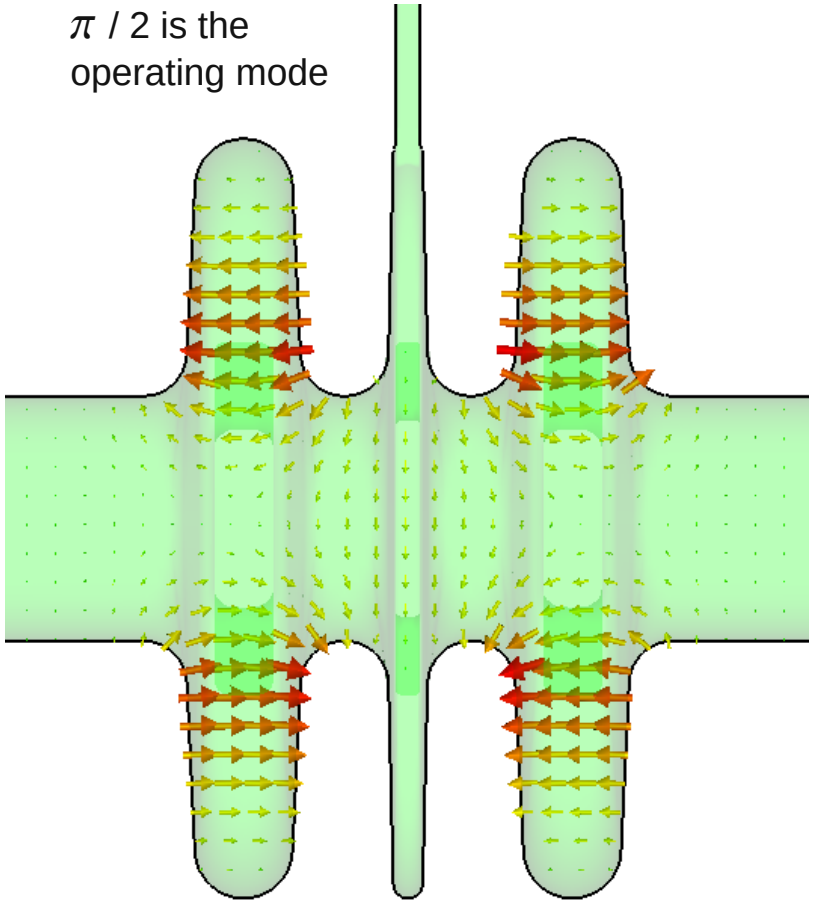


0 - mode Dipole Mode

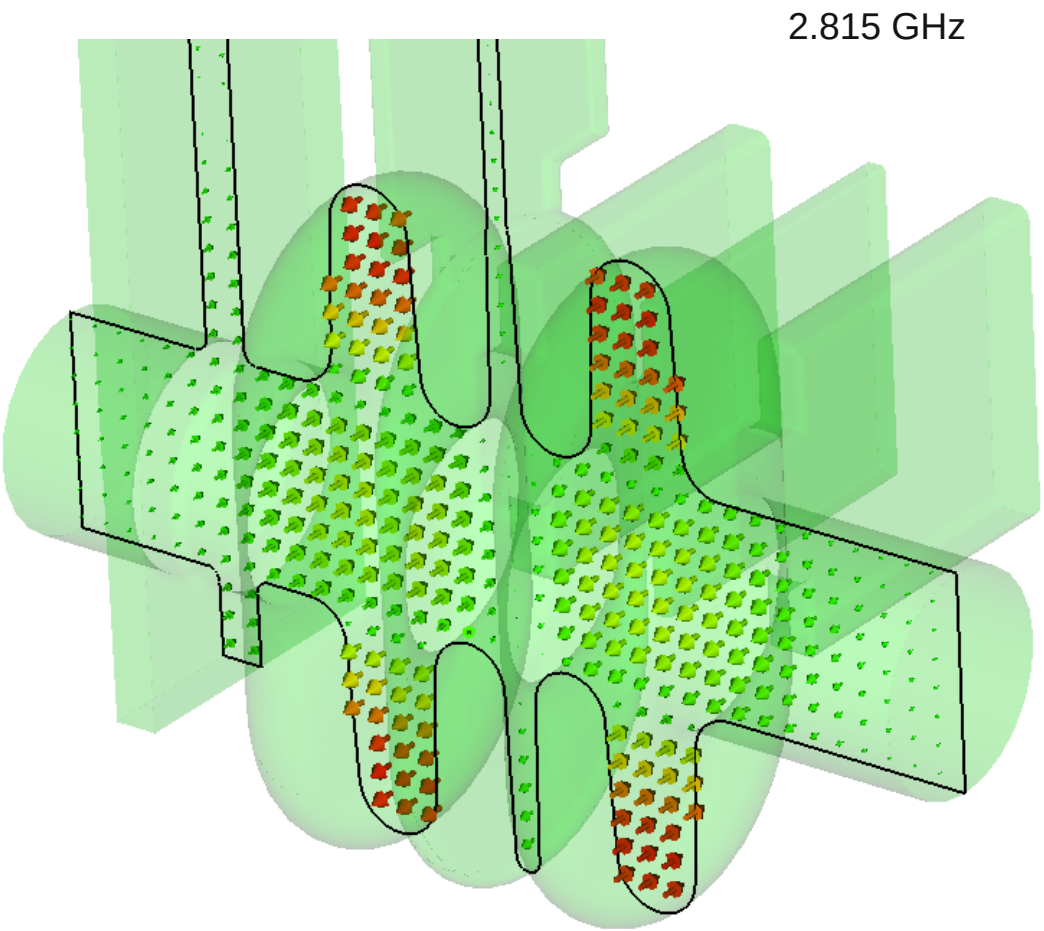


π - mode Dipole Mode

3-Cell Cavity: Deflecting Mode π / 2 Phase Advance



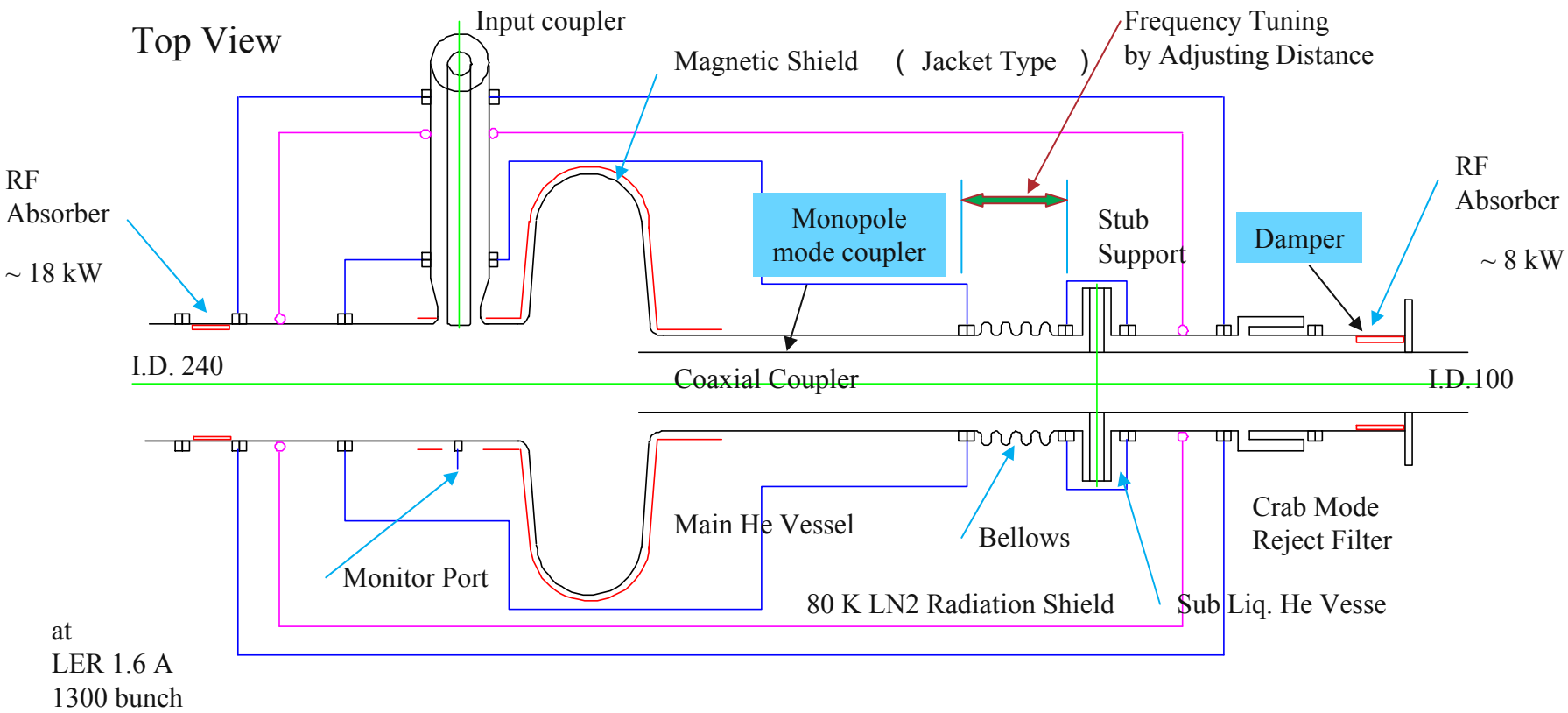
Electric field



Magnetic field

π / 2 - mode Dipole Mode

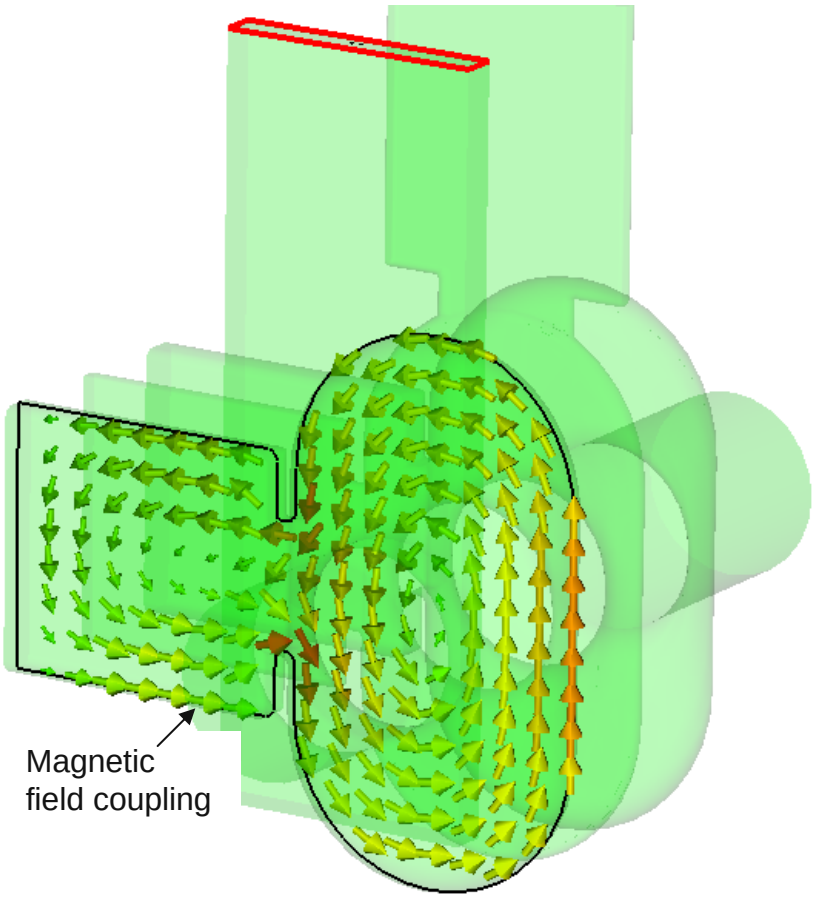
KEK Design for a Monopole Mode Damper*



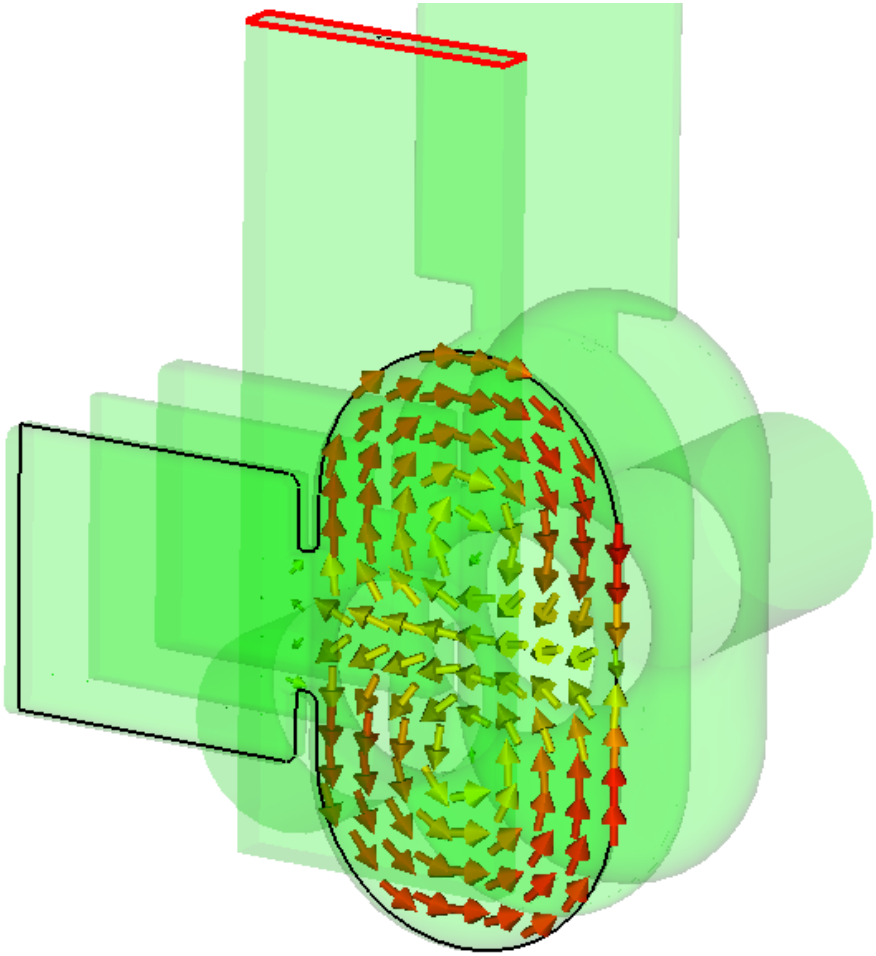
Length of structure is ~ 3 meters

*Courtesy K. Hosoyama (KEK)

3-Cell Cavity: Compact Damping of Monopole Modes



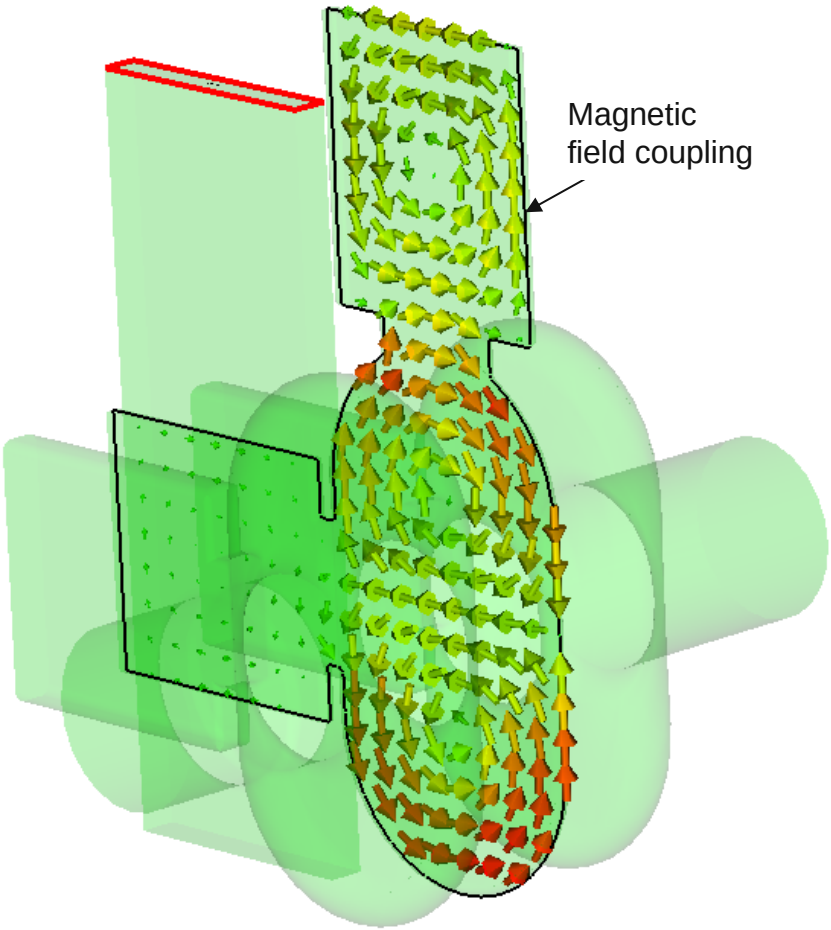
Magnetic field in the end-cell
for a monopole mode.



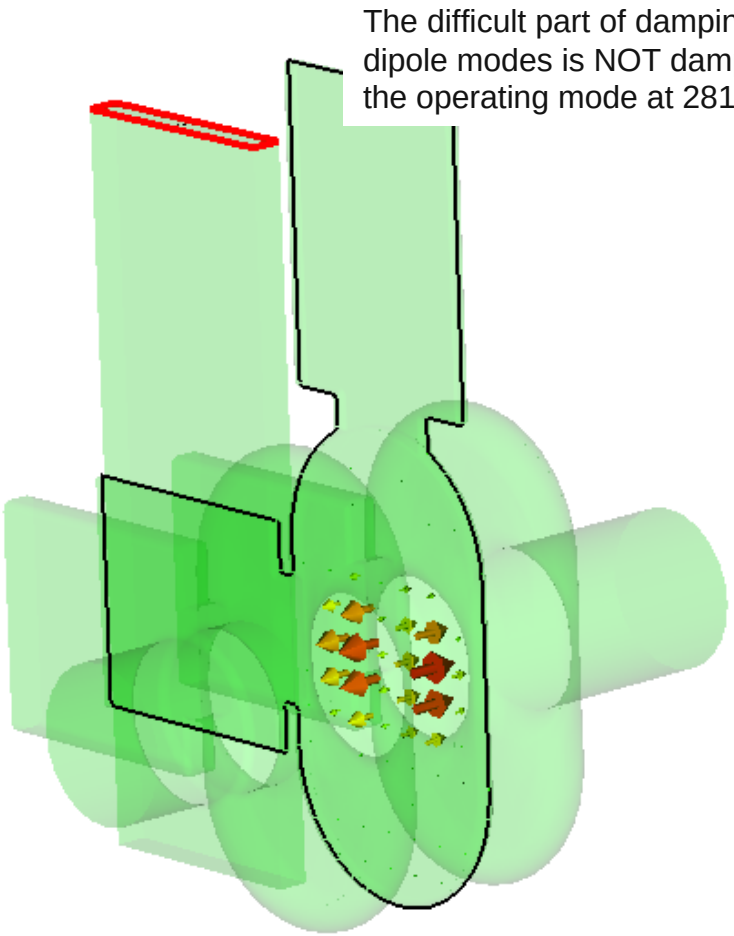
Magnetic field in the end-cell
for a dipole mode.

Monopole mode is magnetically coupled to the damping waveguide via the TE_{10} mode, while the dipole mode is rejected by the dampers in the end-cells.

3-Cell Cavity: Selective damping of Dipole Modes



Magnetic field in the center cell
for the π-mode



Magnetic field in the center cell
for the $\pi/2$-mode

Dipole modes are selectively damped in the vertical damping waveguide in the center cell except for the operating π / 2 – mode which has minimal coupling into the center cell.