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## Introduction

- Project X is a proposed proton accelerator complex at Fermilab
- The CW low current operation of the Project X requires superconducting cavities to operate at a high loaded Q
- Therefore it requires mechanical design optimization of cavities to minimize the sensitivity to microphonics
- We present our experience in using COMSOL Multiphysics for evaluation of sensitivity of operating frequency shift due to both fluctuations in the helium pressure ( $df/dP$ ) and mechanical resonances

## Microphonics: Spoke Cavity

- Frequency shifts due helium pressure fluctuations is a major issue in superconducting RF cavities
- Here is an example for how  $df/dP$  is calculated using COMSOL for a spoke cavity

Electromagnetic Waves	Solid Mechanics	Moving Mesh
<ul style="list-style-type: none"> <li>Solving only for the RF domain</li> <li>Applying the proper boundary conditions</li> </ul>	<ul style="list-style-type: none"> <li>Solving only for the Cavity Vessel</li> <li>Applying the proper fixed constraints, symmetries, displacements, and boundary load</li> </ul>	<ul style="list-style-type: none"> <li>Solving for all domains</li> <li>Applying the proper prescribed and free mesh deformation/displacement</li> </ul>

Stainless Steel Vessel

Niobium Shell RF Domain

PEC

PMC

Fixed Constraint

Pressure Boundary Load

Symmet Boundar

Prescribed Displacement  $u, v, w$

Three Multiphysics Modules

Two Simulation Studies

Study<sub>1</sub>

- Eigen-frequency (to find  $f_0$ )

Study<sub>2</sub>

- Stationary (solving only for solid mechanics and moving mesh)
- Eigen-frequency (to find  $f_p$ )

EM

- Eigen frequency simulation to find the resonant frequency ( $f_0$ )

Solid Mech

- Find the deformation under given pressure load ( $P_L$ )

Moving Mesh

- Update the mesh after deformation

EM

- Eigen frequency simulation to find the resonant frequency after deformation ( $f_p$ )

$df/dP$  [Hz/Torr]

	Comsol	Ansys
Fixed	24.7	26.6
215 $\mu$ m	-282.6	-281
Free	-637.4	-632

## Modal Analysis: Elliptical Cavity

- Mechanical resonances are another concern for SRF cavities
- Here is an example for how we used COMSOL to resolve this issue for an elliptical cavity

- EM

  - Eigen frequency simulation to find the resonant frequency ( $f_0$ )

- Solid Mech

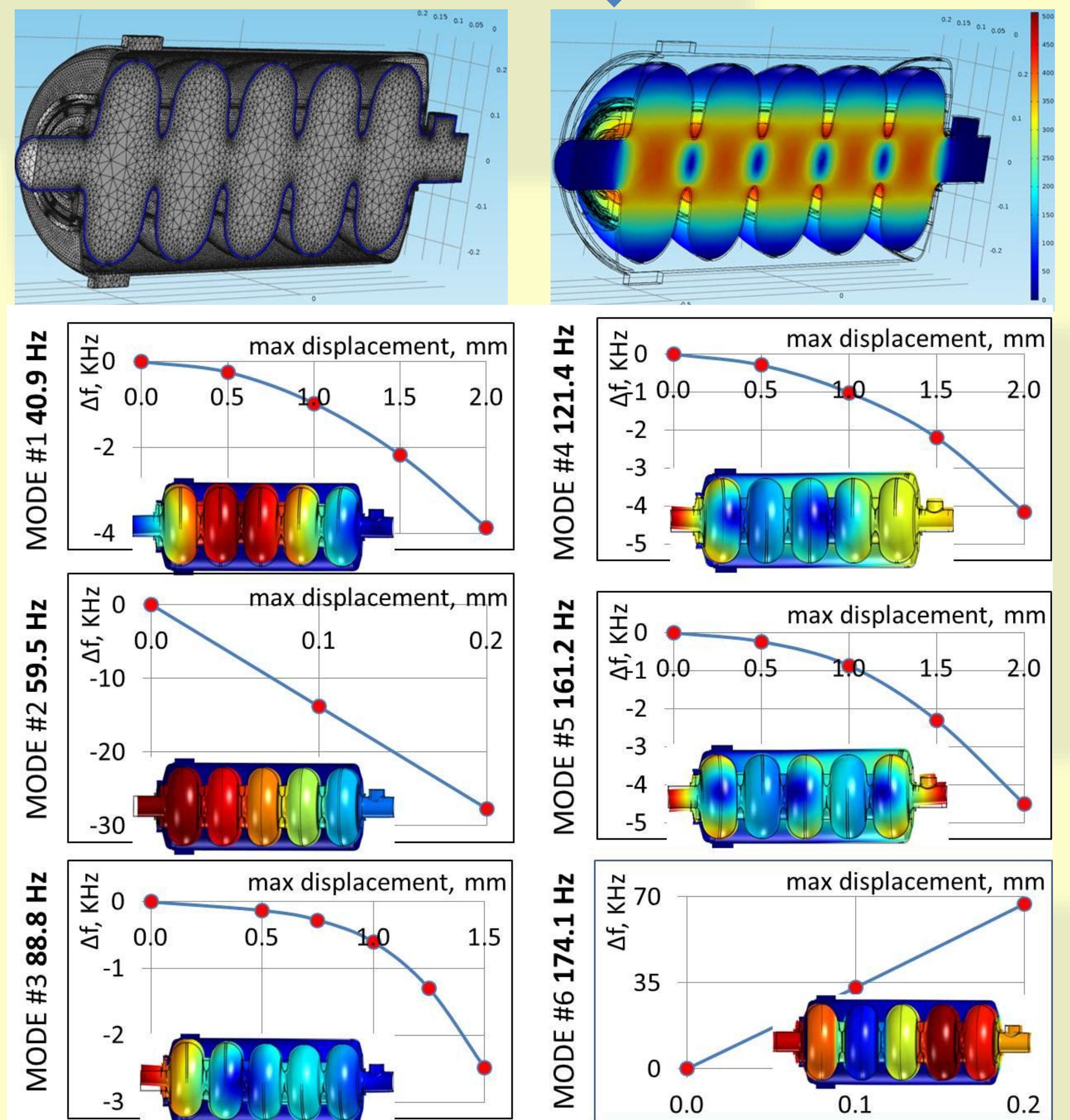
  - Solid Model analysis in "mechanical" domain

- Moving Mesh

  - Update the mesh after deformation

- EM

  - Eigen frequency simulation to find the resonant frequency after deformation ( $f_p$ )



## Conclusion and References

- Multiphysics analysis is essentially needed to model components for particle accelerators
- Frequency shifts due to pressure fluctuation needs to be carefully modeled in SRF cavities
- COMSOL as a multiphysics tool helped us a lot in that perspective

### References:

- S. D. Holmes, "Project X functional requirements specification", IPAC'12, New Orleans, THPPP090