
# The Primary Design of Spoke014 cavity

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# The requirements and parameters

- β=0.14
- The beam power per cavity: 5 kW.
- The diameter of beam tube: 50 mm.
- Antenna coupler is preferred. The position is perpendicular to the spoke, just as SSR1.
- The input coupler is a 50-ohm coaxial structure. Inner conductor diameter: 33.4 mm; Outer: 76.8 mm (78.4 mm in SSR1).
- $Q_e$~5.6e5
- $E_{acc}$ (operating): 6~7 MV/m

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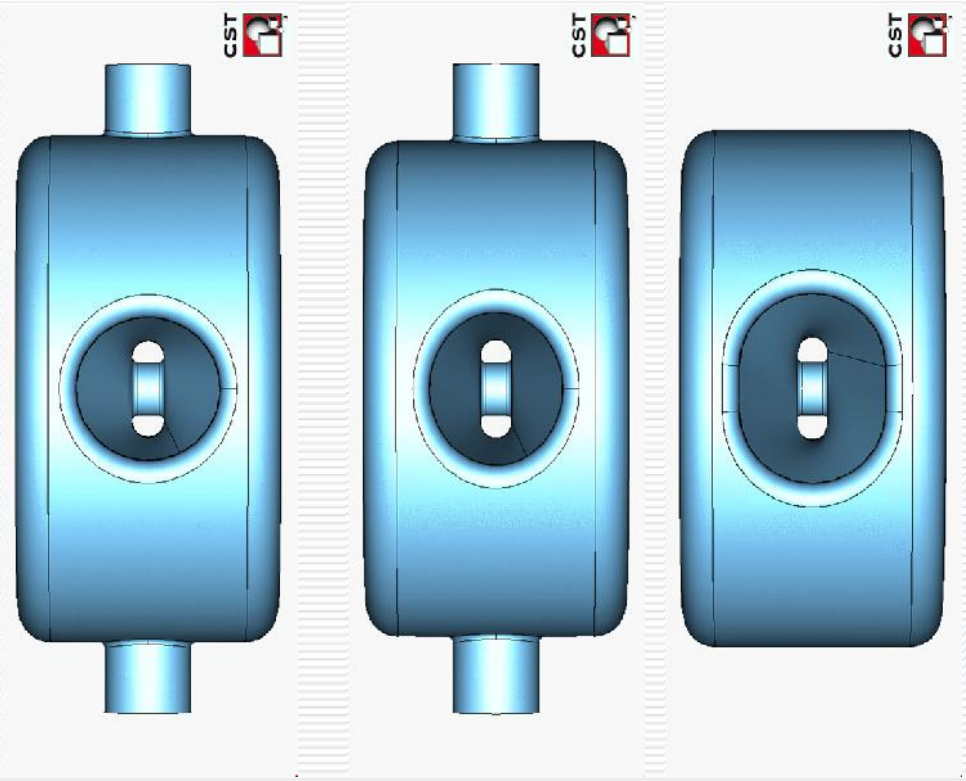
# The cross section of spoke



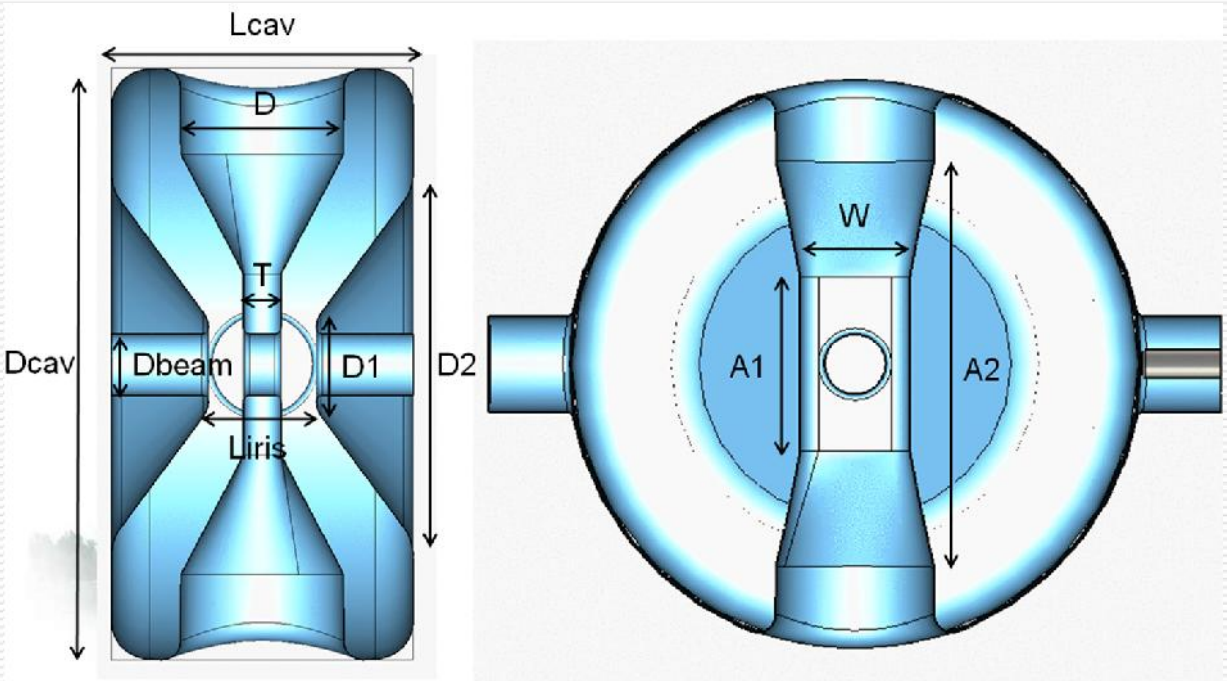
3 types of cross section:

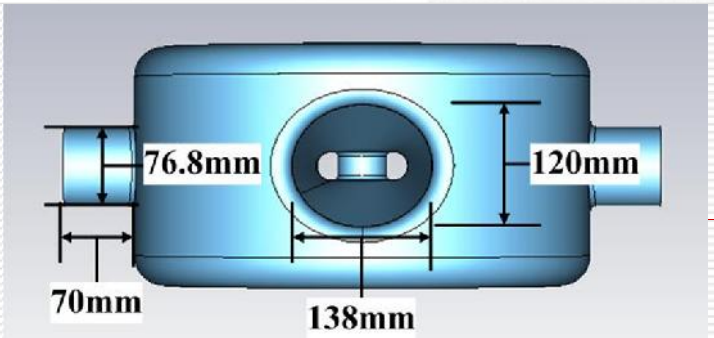
- The left shape is round.
- The middle shape is ellipse.
- The right shape is racetrack.

The results of MWS show that: the $B_{peak}/E_{acc}$, $E_{peak}/E_{acc}$, $R/Q_0$ and G of the middle type perform best. So the middle type has been adopted.

| | Left | Middle | right |
|---|---|---|---|
| G (Ω) | 69 | 74 | 72 |
| $R/Q_0$ (Ω) | 117 | 124 | 118 |
| $E_{peak}/E_{acc}$ | 3.90 | 3.48 | 3.39 |
| $B_{peak}/E_{acc}$ (mT/(MV/m)) | 4.41 | 3.94 | 4.23 |

# Geometry parameters



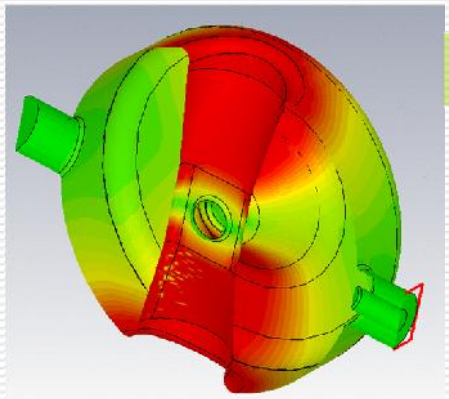




Main parameters:

- $L_{cav}$: 240 mm, cavity
- $L_{iris}$: 2βλ/3=86 mm, iris to iris length
- W: 109 mm, spoke width
- T: 29 mm, spoke thickness
- $D_{beam}$: 50 mm, beam tube diameter

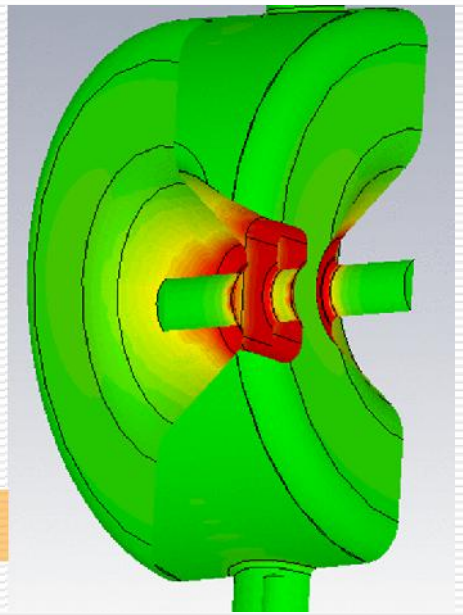
# The RF parameters

- RF simulation settings: 100 lines/wavelength, 3.96 million mesh cells.
- $E_{acc}$ is calculated with $L_{iris}$ ($2\beta\lambda/3$).
- $R/Q_0=V^2_{acc}/\omega U$



Magnetic field

Electric field



| Frequency (MHz) | G (Ω) | $R/Q_0$ (Ω) | $E_{peak}/E_{acc}$ | $B_{peak}/E_{acc}$ (mT/(MV/m)) | $Q_e$ |
|---|---|---|---|---|---|
| 325.0 | 73 | 117 | 3.34 | 4.18 | 5.6e5 |

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# Mechanical design consideration

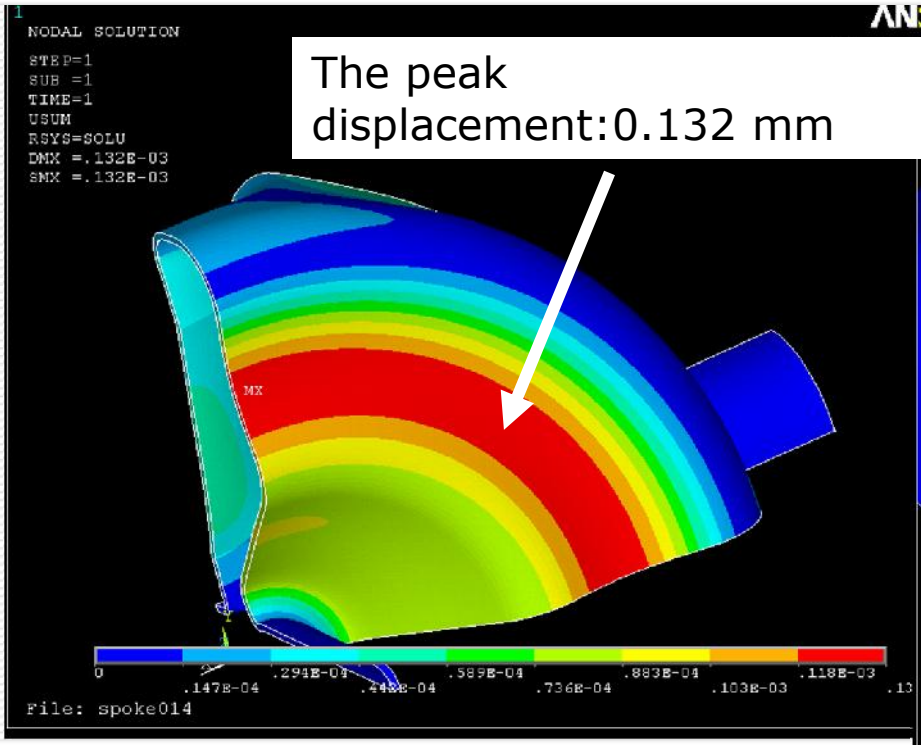
- We have little experience about the mechanical design of spoke cavity before.
- Solidworks and ANSYS are used to do the simulations.
- The material properties of niobium we used: Density=8560 kg/m$^3$, Young's modulus=107 GPa, Poisson ratio=0.359, shell thickness=3.5 mm.
- There're two steps:
  - First, we use the cavity model without stiff ribs.
  - Second, we calculate it with stiff ribs (in progress).

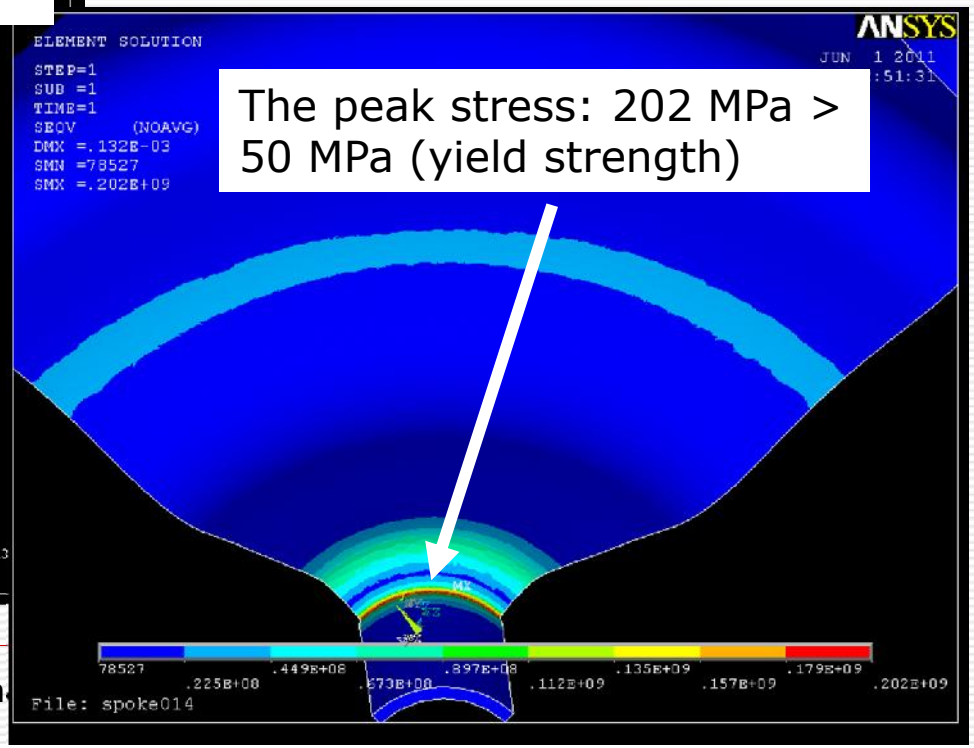
# The spoke cavity without stiff ribs

- Simulation settings: 1/8 cavity, tetrahedral mesh cells, 270912 air cells, 68487 shell cells.
- Beam tube ports, coupler port and vacuum port are all fixed.
- The simulation includes:
  - External load
  - Tuning sensitivity (Beam tube ports free)
  - Lorentz force detuning (static)

# External load

The external load: 1.18 atm (900 torr) → Frequency shift: -86.9 kHz

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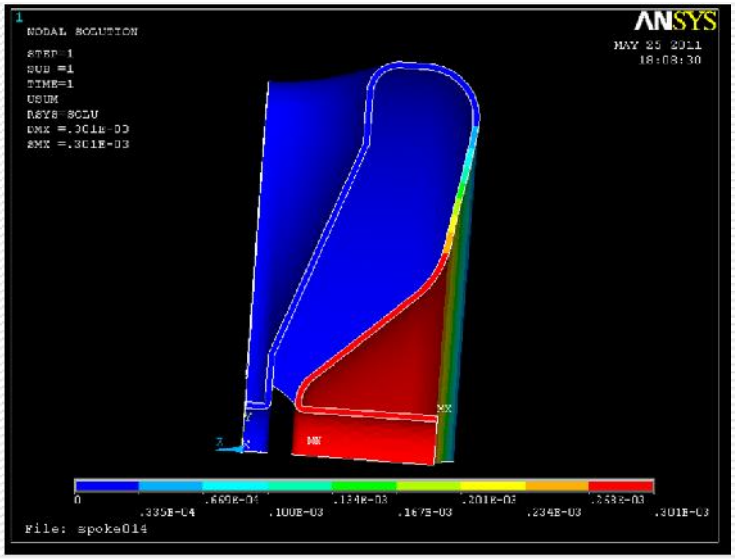
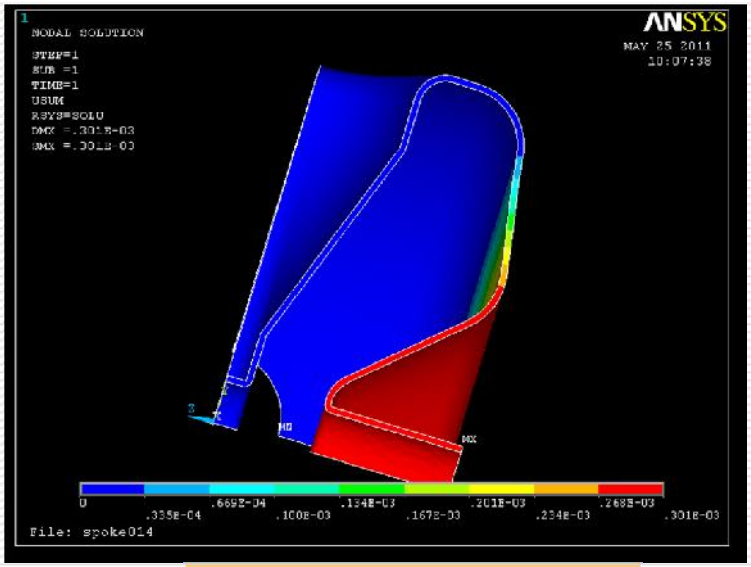
# Tuning sensitivity

Pulling: 980 N ⟶ cavity length:+0.6 mm ⟶ +617 kHz shift

Cavity length (beam tube flange): +1028 kHz / mm



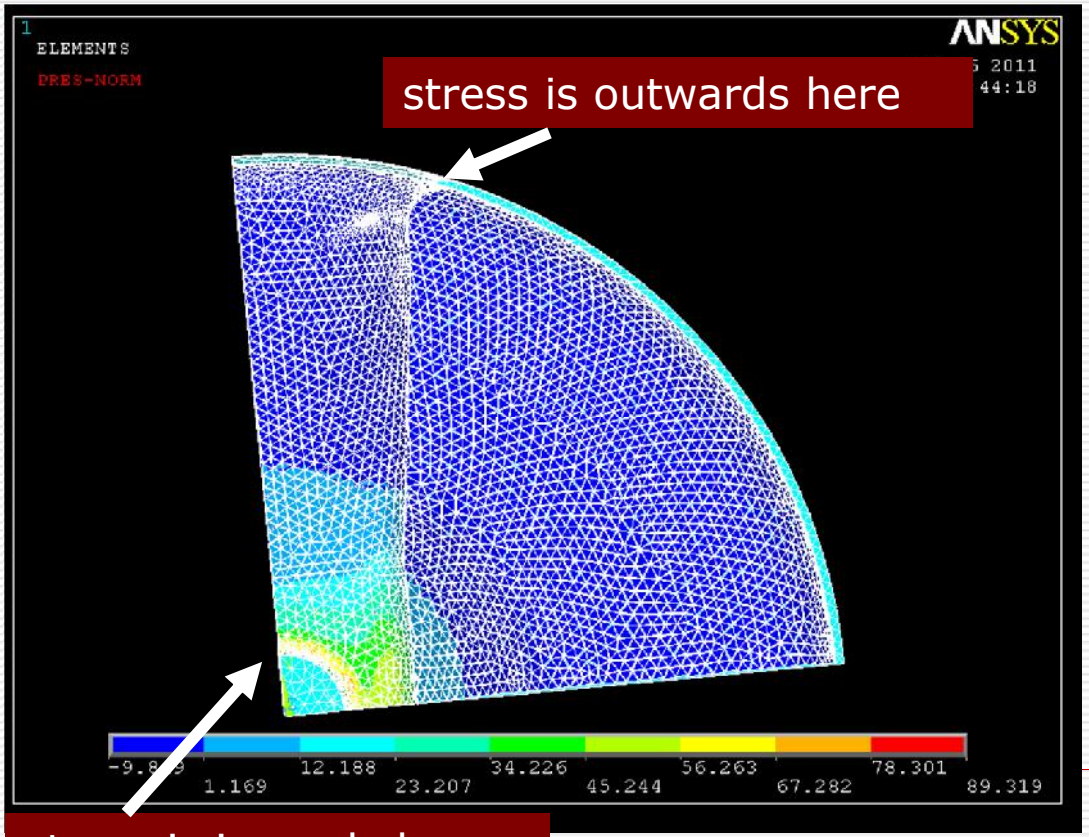

Displacement of Pushing



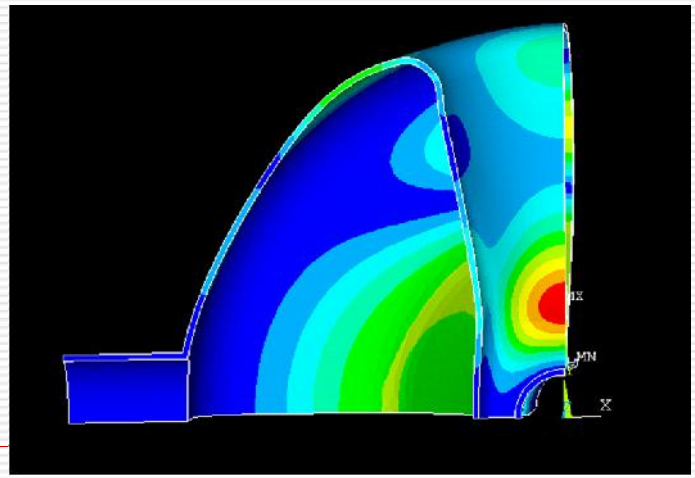

Displacement of Pulling

# Lorentz force detuning (static)

The Lorentz detuning coefficient: -6.33 Hz/(MV/m)$^2$

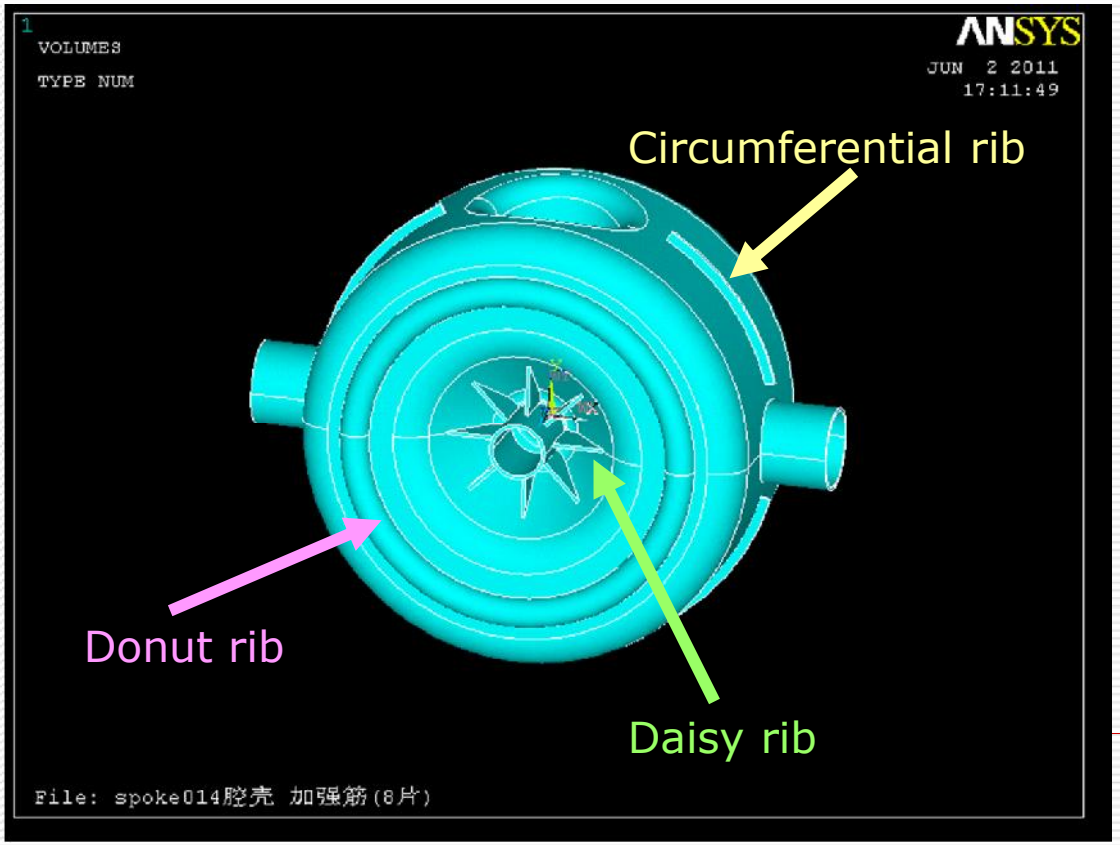



Displacement



# The spoke cavity with stiff ribs

- Simulation settings: 1/8 cavity, tetrahedral mesh cells, 270912 air cells, 83258 shell cells.
- The simulation process is the same as without stiff ribs.




3 types of ribs are used.

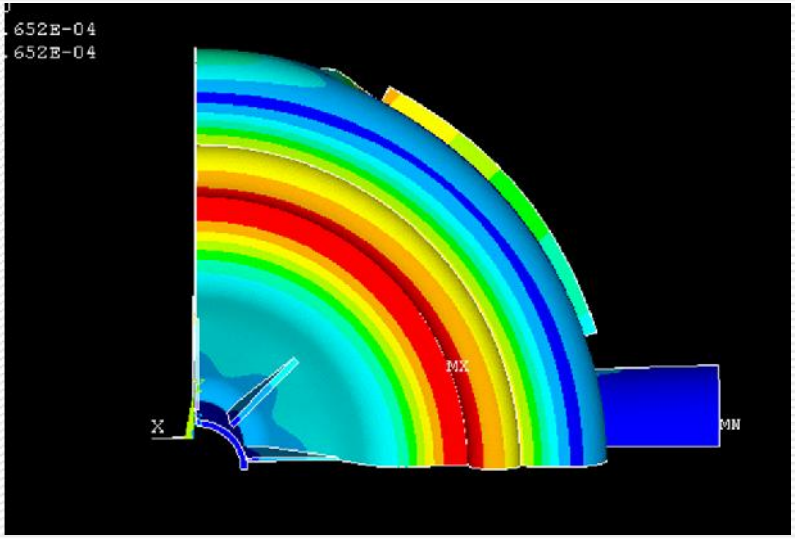
The thickness of ribs is 3.5 mm.

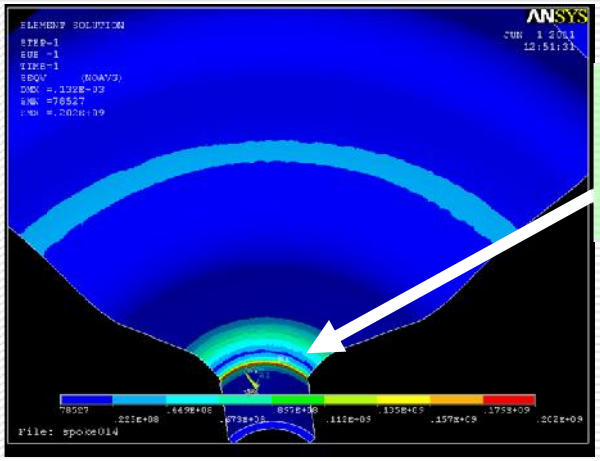
- two donut ribs
- Four circumferential ribs
- Eight daisy ribs

# External load with ribs

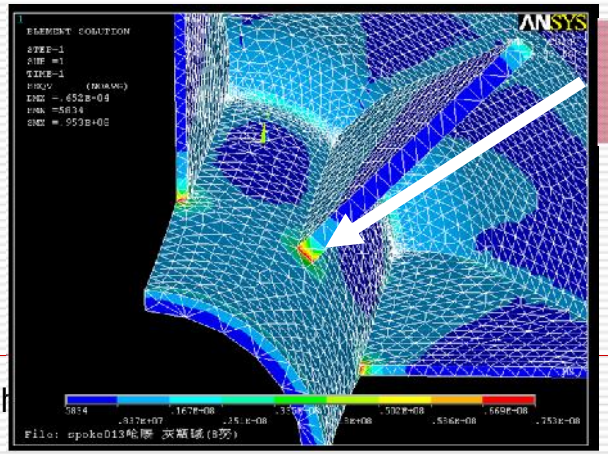
The external load: 1.18 atm (900 torr) ⟶ Frequency shift: -12.6 kHz

Peak displacement: 0.0652 mm, while 0.132 mm without ribs.




The peak stress: 202 MPa (without ribs)

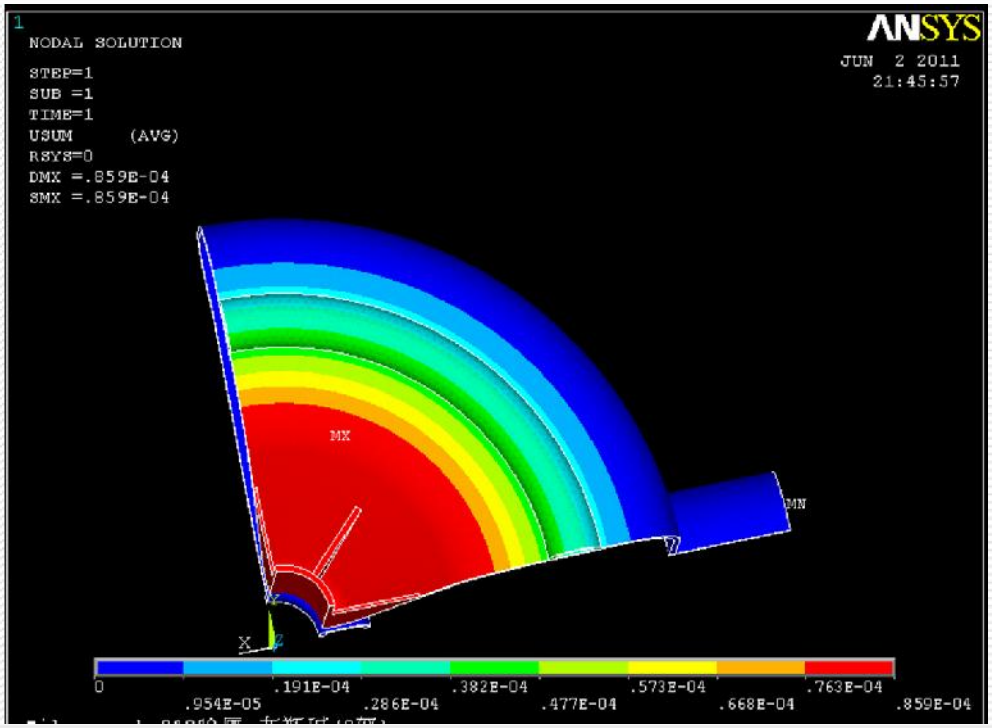



The peak stress: 75 MPa (with ribs)

# Tuning sensitivity with ribs

Pulling: 980 N ⟶ cavity length:+0.172 mm ⟶ +178 kHz shift

Cavity length (beam tube flange): +1040 kHz / mm




The peak stress: 9.9 MPa

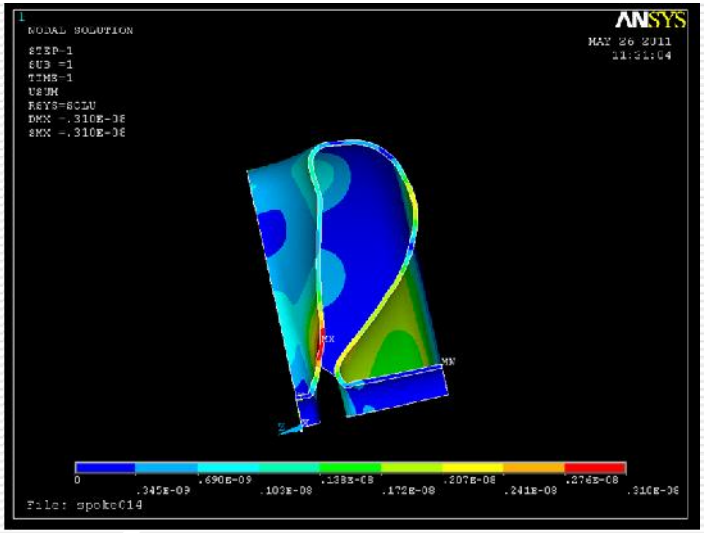
Yield strength: 50 MPa

Tuning range: ±800 kHz

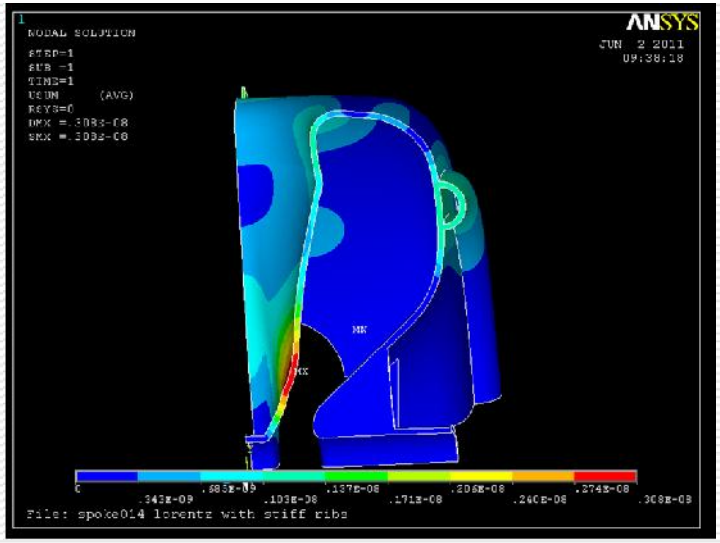
# Lorentz force detuning with ribs (static)

The Lorentz detuning coefficient: -3.79 Hz/(MV/m)$^2$, compared to -6.33 Hz/(MV/m)$^2$ without ribs.

Displacement without ribs

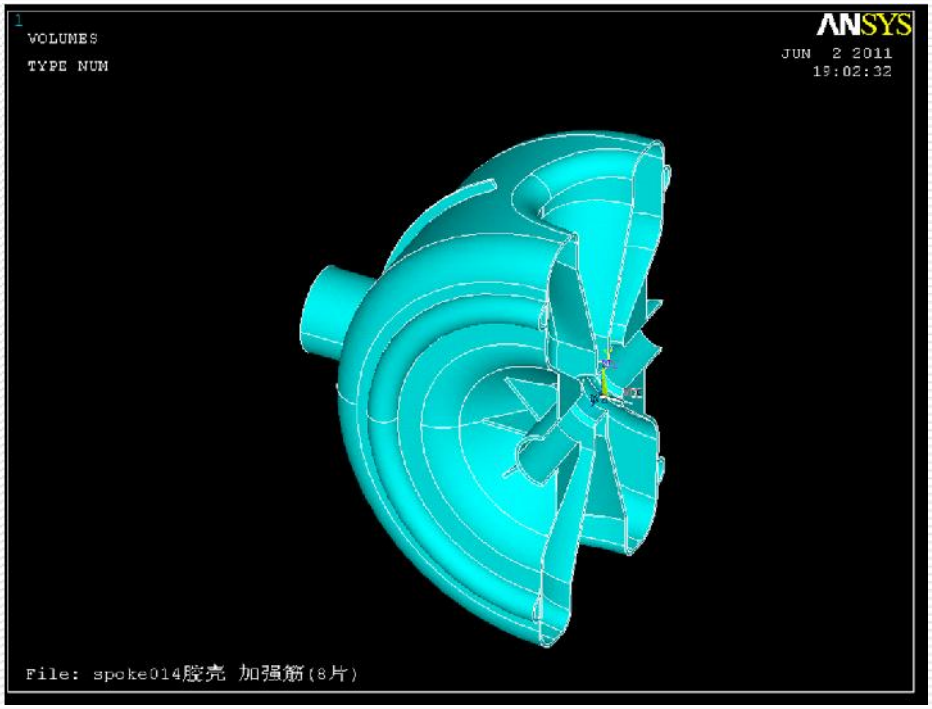



Displacement with ribs



# Microphonics

- The beam tube ports are fixed.
- ½ cavity, the first 5 mechanical oscillation modes calculated.




| mode | f(Hz) |
|---|---|
| 1 | 97 |
| 2 | 175.43 |
| 3 | 265.85 |
| 4 | 369.51 |
| 5 | 445.4 |

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# Summary and outlook

- The RF design of β=0.14 spoke cavity has been finished.
- The mechanical design (with stiff ribs) is in progress now.
- Research of the cavity unit with tuner, coupler, helium vessel, etc, are the main work in future.
- Next, we will focus on β=0.12 spoke cavity, whose beam aperture changes from 50 mm to 40 mm .

# Thanks you!