# Production of the CADS spoke cavities and ancillaries, and lessons learned

Feisi He

On behalf of colleagues in IHEP SRF group

Institute of High Energy Physics (IHEP)
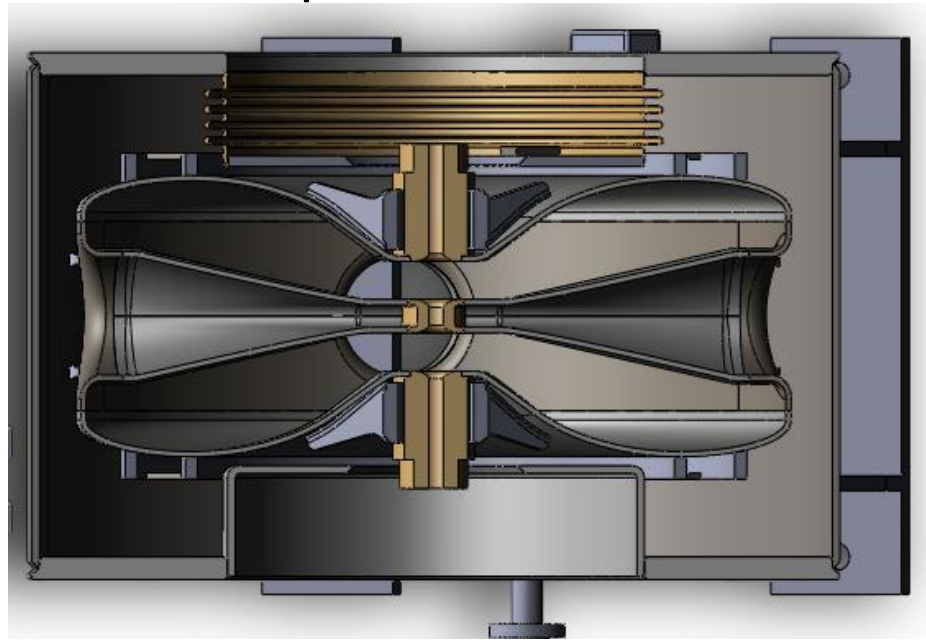
# Outline

- Background

- Fabrication and quality control

- Vertical test statistics

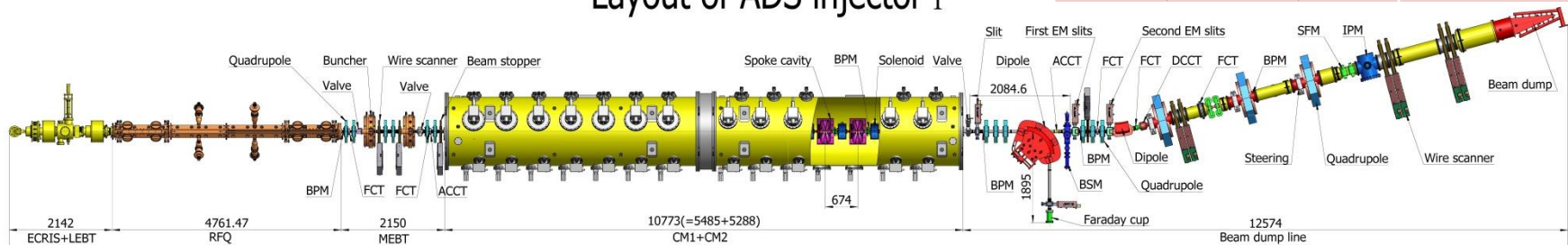- He vessel issues and solutions

- Tuner issues

# Spoke012 cavity

14 cavities in 2 CM. Beam commissioned
with 2mA CW proton from 3.2MeV to 10MeV
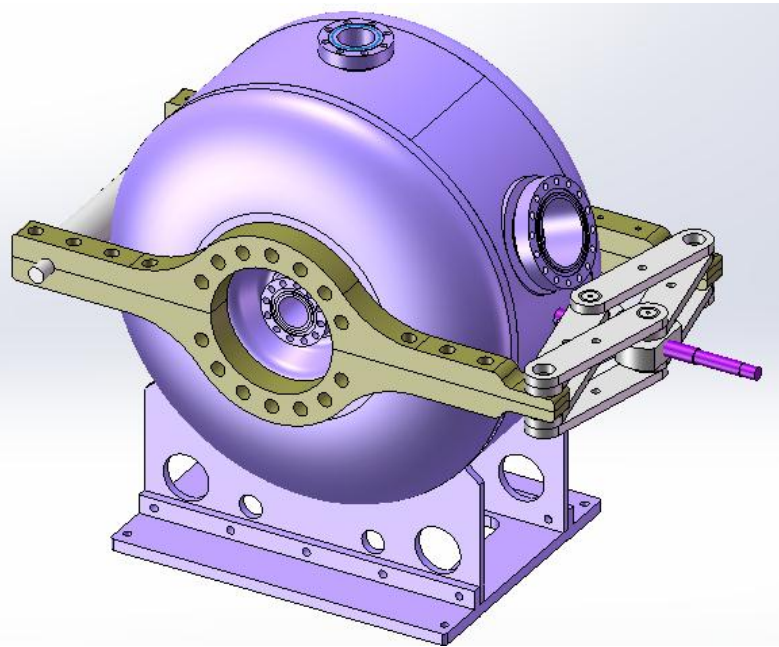


Layout of ADS injector I

| | Spoke 012 |
|---|---|
| $\beta_0$ | 0.14 |
| Aperture-mm | 35 |
| Ep/Eacc | 5.0 |
| Bp/Eacc-mT/(MV/m)$^2$ | 6.9 |
| G-$\Omega$ | 60 |
| R/Q-$\Omega$ | 150 |
| df/dp [Hz/mbar] | -40 |
| df/dp [Hz/mbar] (measured) | -130~-83 |
| LFD [Hz/(MV/m)2] | -13 |

# Spoke021 cavity

- 6 cavities in one CM. developed in IHEP, Assembled in IMP. Waiting for tunnel commissioning

|  | Spoke 021 |
|---|---|
| $\beta_0$ | 0.24 |
| Aperture-mm | 40 |
| Ep/Eacc | 4.4 |
| Bp/Eacc-mT/(MV/m)$^2$ | 9.4 |
| G-$\Omega$ | 71 |
| R/Q-$\Omega$ | 191 |
| df/dp [Hz/mbar] | -6 |
| df/dp [Hz/mbar] (measured) | <-10 |

# Outline

- Background

- **Fabrication and quality control**

- Vertical test statistics

- He vessel issues and solutions

- Tuner issues

# Spoke cavities fabrication

- Three qualified vendors provided 16 spoke012 cavities and 10 spoke021 cavities in the production phase. 19 prototype cavities of 6 types of cavities were from 6 vendors.
- 2012, 1st spoke cavity fabrication started
- 2012.12, 1st spoke012 cavity VT
- 2013.9, 1st spoke012 cavity HT with all ancillaries
- 2013.10, 1st spoke021 cavity VT
- 2014.3-9, 4 prototype spoke012 cavities VT, first vendor verified
- 2014.9-2015.3, 4 prototype spoke021 VT, second vendor verified
- 2015.4-9, spoke021 He-vessel tested and modified
- 2014.9-2015.11, 3 batches of 16 production spoke012 cavities from 3 vendors VT
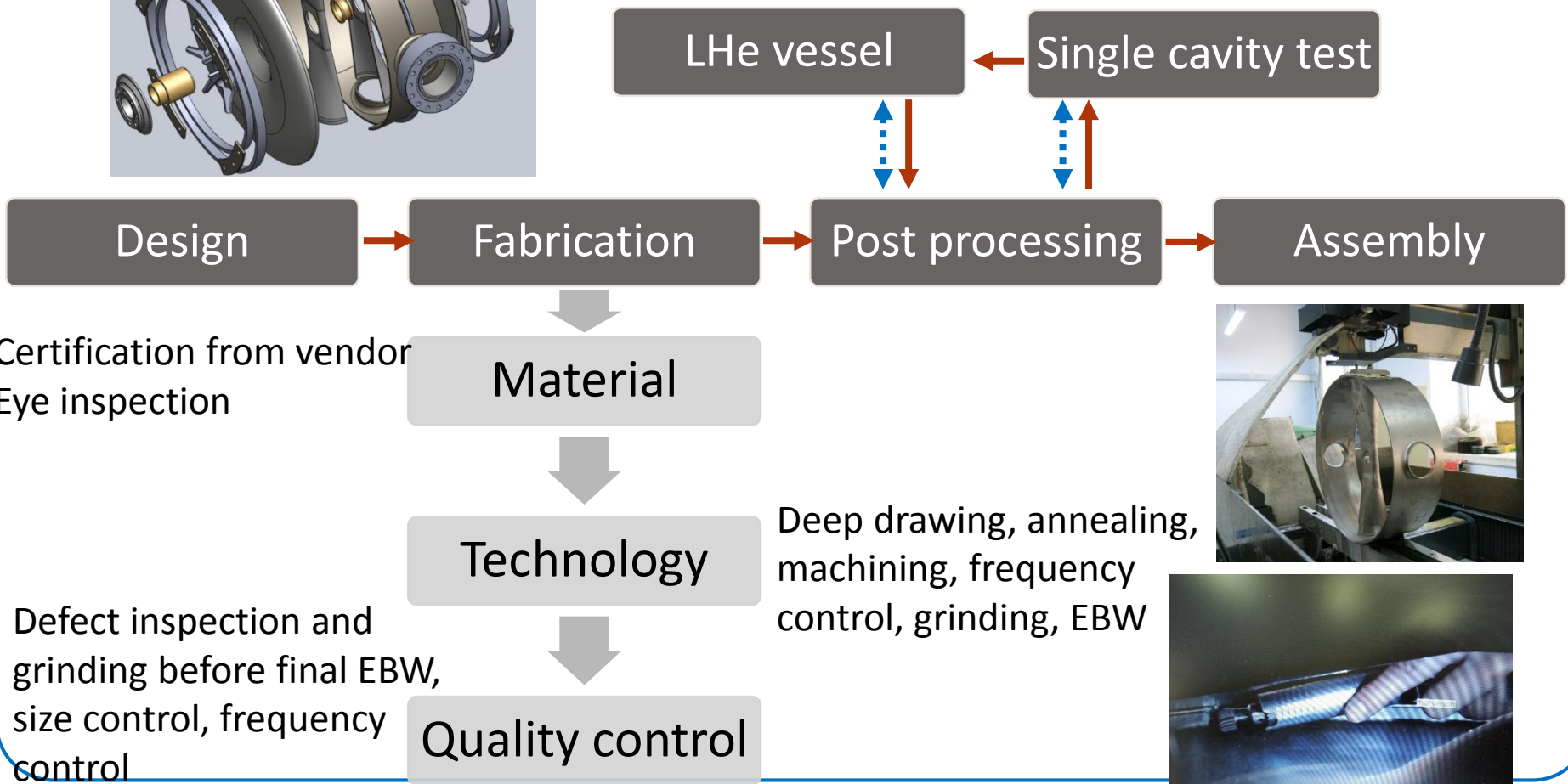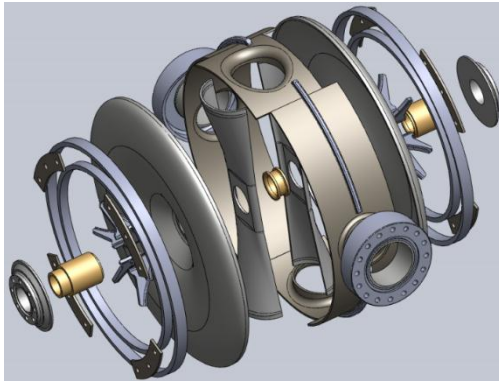- 2014.12-2016.2, 2 batches of 8 production spoke021 from 2 vendors VT

# Development of IHEP ADS SRF cavities



LHe vessel ← Single cavity test

Design → Fabrication → Post processing → Assembly

Certification from vendor
Eye inspection

Material

Technology

Deep drawing, annealing, machining, frequency control, grinding, EBW

Defect inspection and grinding before final EBW, size control, frequency control
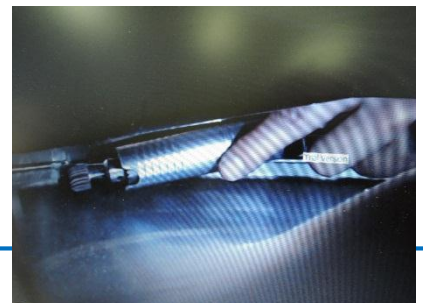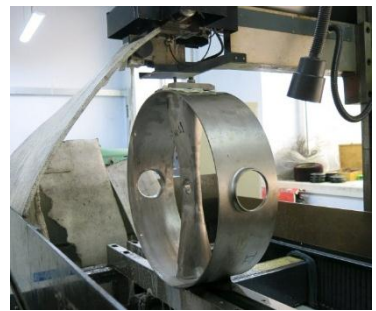
Quality control
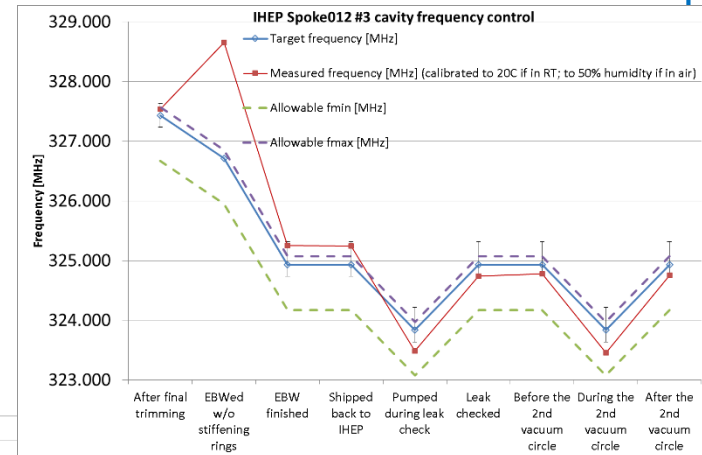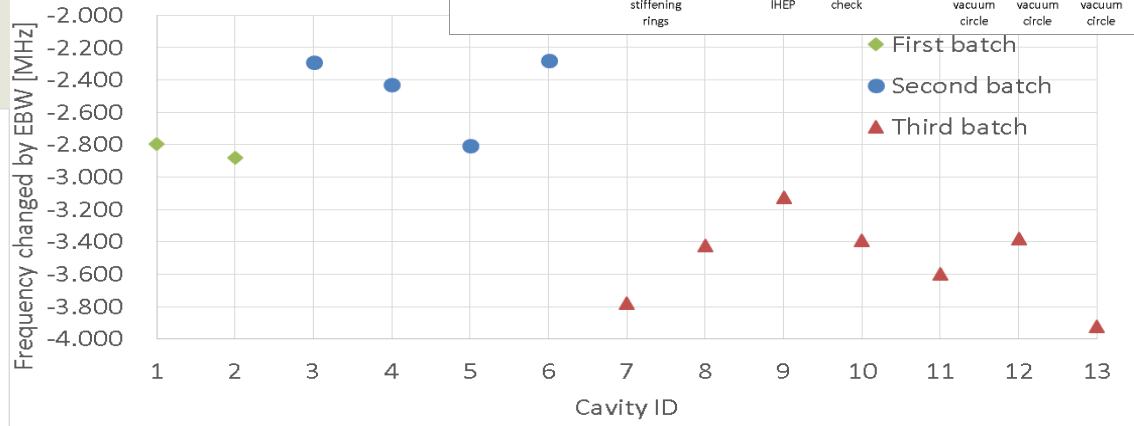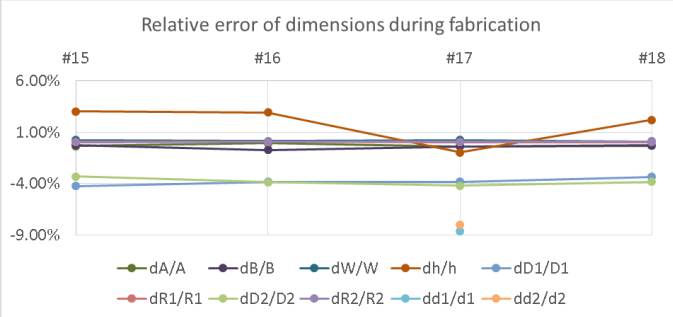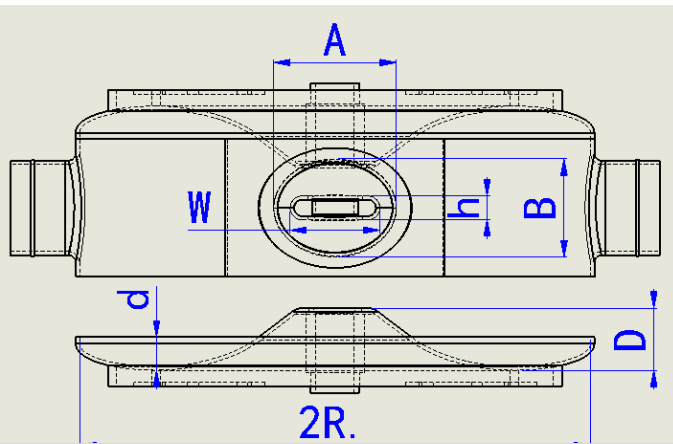
# Quality control: frequency control

- Frequency sensitivity of trimming the central ring was calculated based on measured critical sizes.
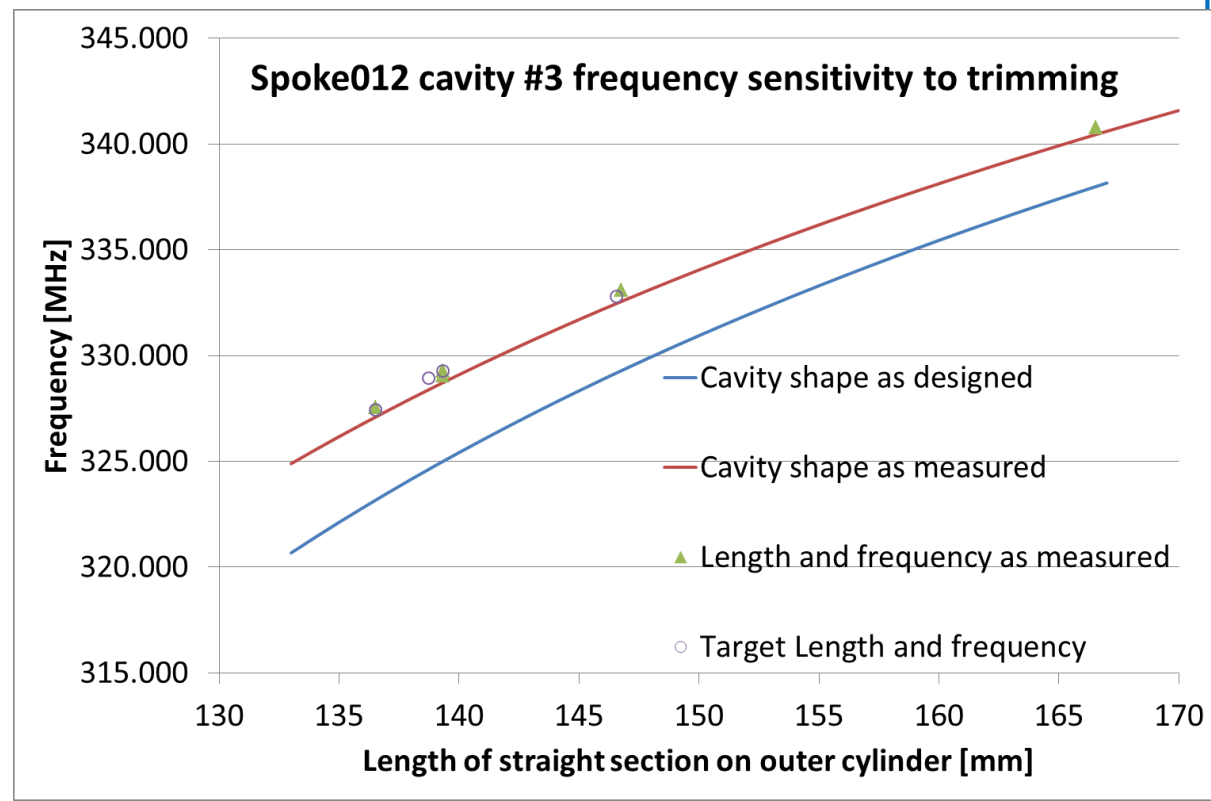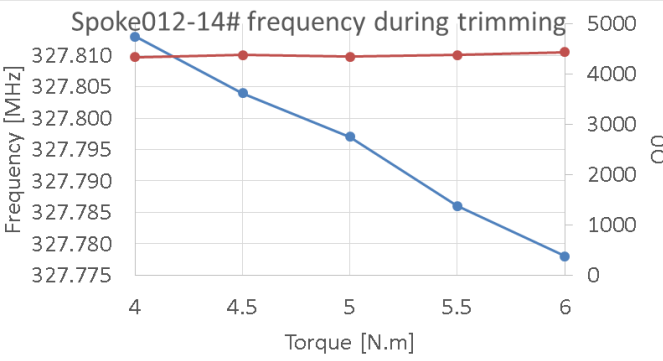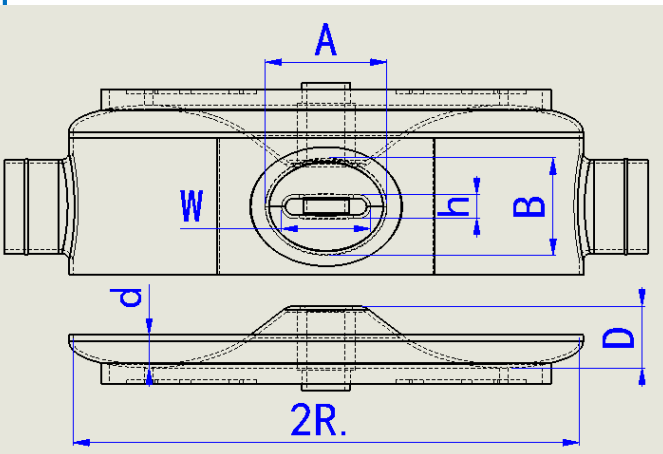
# Quality control: frequency control (2)

- F scattering induced by fabrication error is typically 2—4MHz(0.6-1.2%)

- Final EBW used to caused f scattering of 1.6MHz; it is 0.2MHz when stiffening ring were welded first.
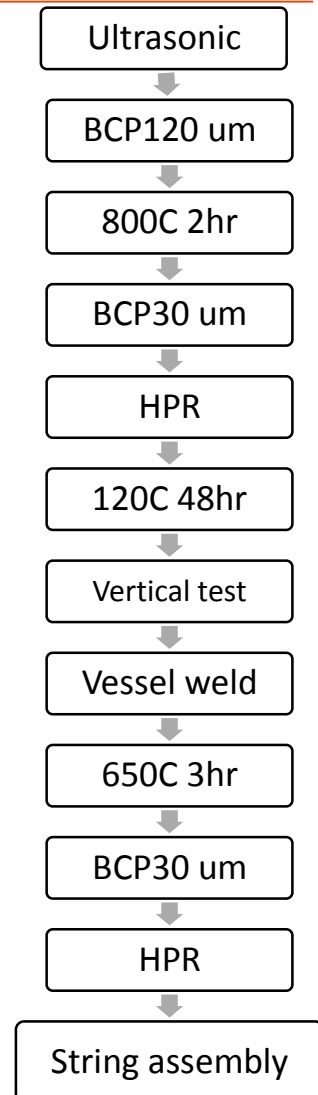
# Outline

- Background

- Fabrication and quality control

- Vertical test statistics

- He vessel issues and solutions

- Tuner issues

# Post processing of Spoke cavities

- BCP in Ningxia OTIC; re-HPR and clean assembly in IHEP



Ultrasonic → BCP120 um → 800C 2hr → BCP30 um → HPR → 120C 48hr → Vertical test → Vessel weld → 650C 3hr → BCP30 um → HPR → String assembly
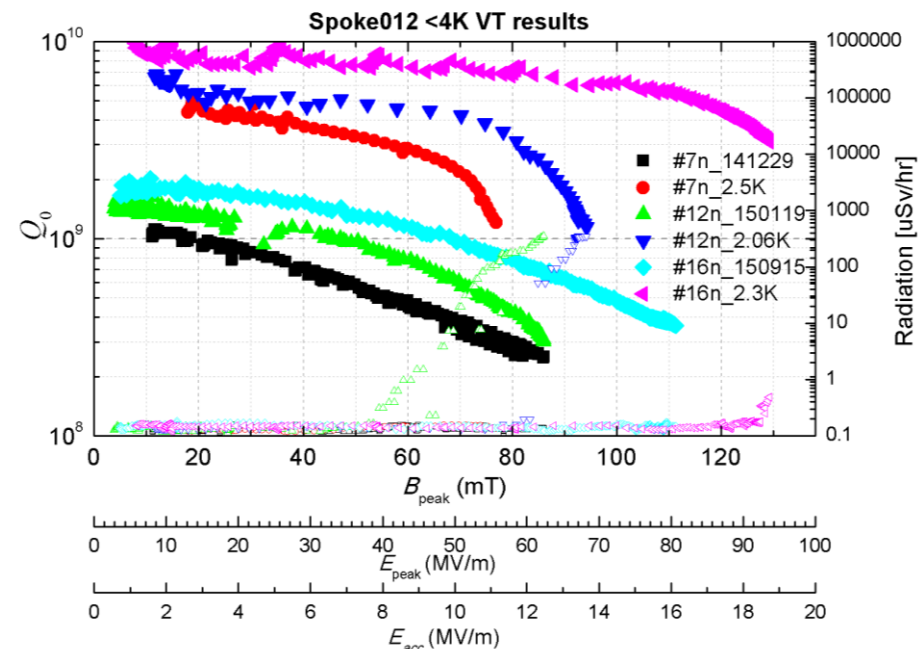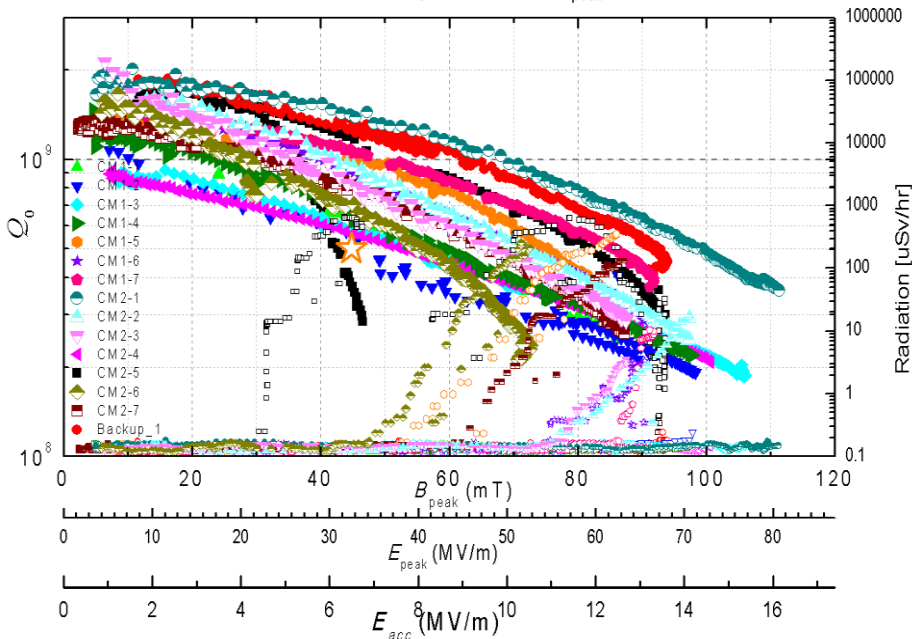
# VT results of the spoke012 cavities



- MP conditioned in 1 hour with variable coupler
- Eacc increased by 2 MV/m with better cooling
- 120C baking increases $Q_0$ by about 50-100%
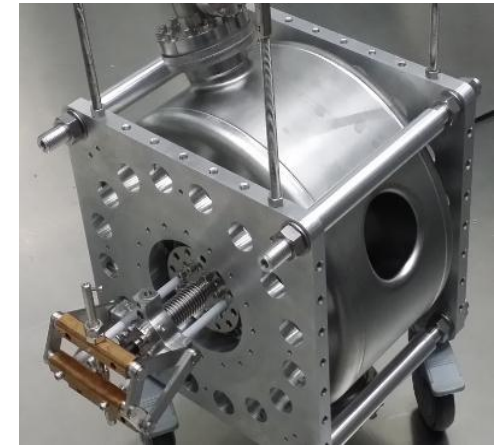- At 2K, Q0 is 6 times higher, Bp~125mT achieved.



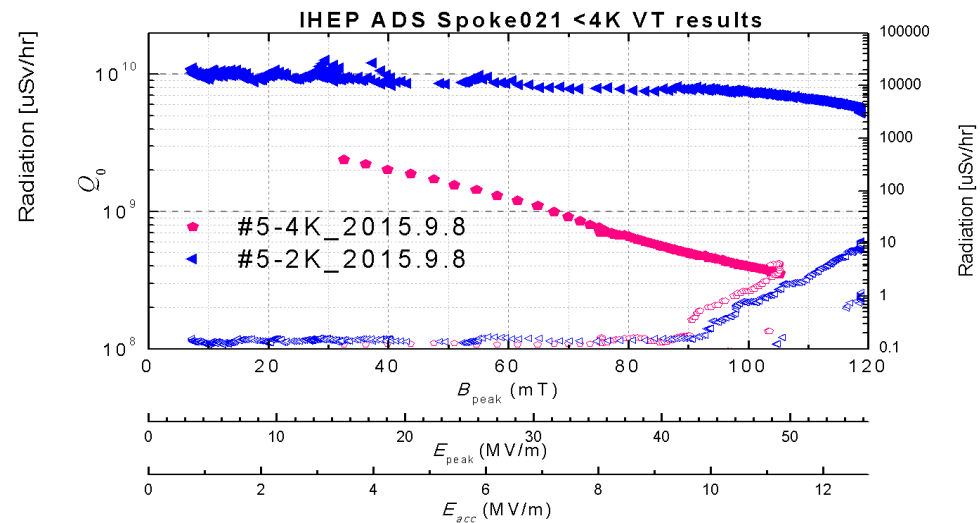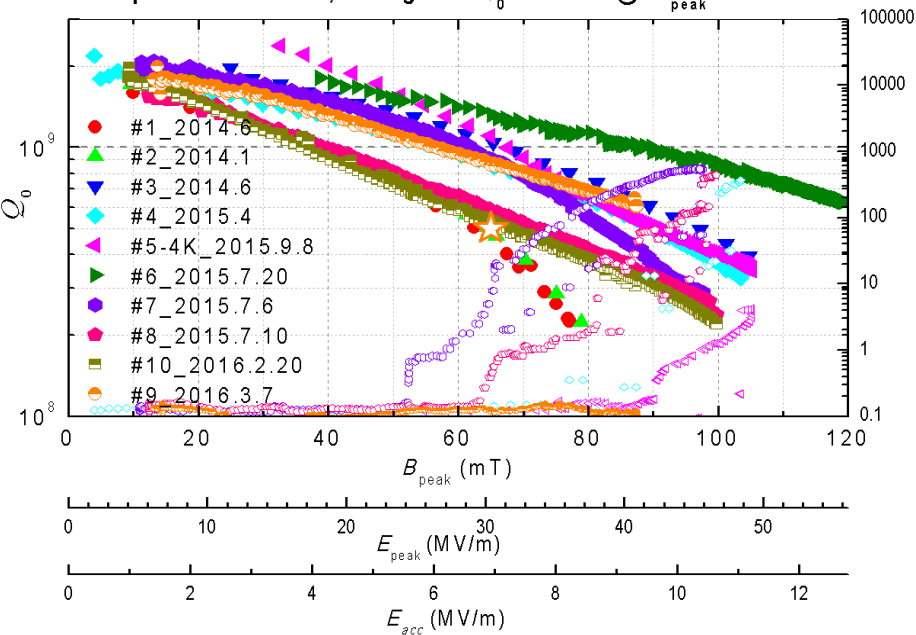Spoke012 4.2K VT, Designed $Q_0 = 5 \times 10^8$ @ $E_{peak} = 31.5$ MV/m

# Spoke021 testing results

- MP conditioned in 1 hour
- Design target consistently exceeded
- Bp of 120mT and Rres of 7nΩ achieved at 2K



Spoke021 4K VT, Designed $Q_0 = 5 \times 10^8$ @ $B_{peak} = 65$ mT



IHEP ADS Spoke021 <4K VT results

# Outline

- Background

- Fabrication and quality control

- Vertical test statistics

- He vessel issues and solutions

- Tuner issues

# Spoke012 He vessel

- Problem: way too huge df/dp (-130 than -40Hz/mbar)
- Mainly by deformation of beam pipe
- Solution: adding stiffeners to He vessel, and stronger TIG welding
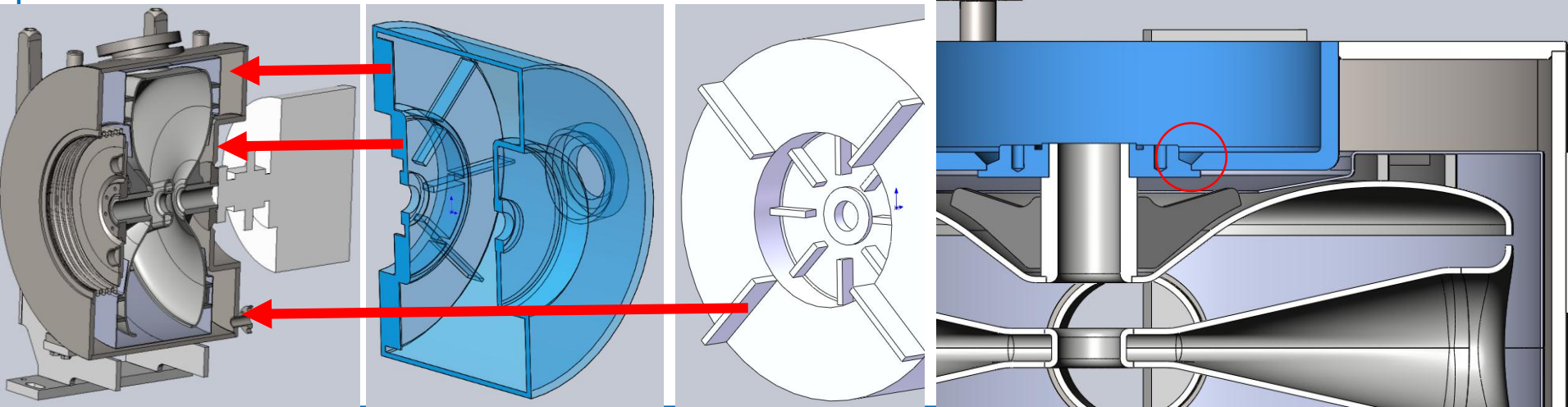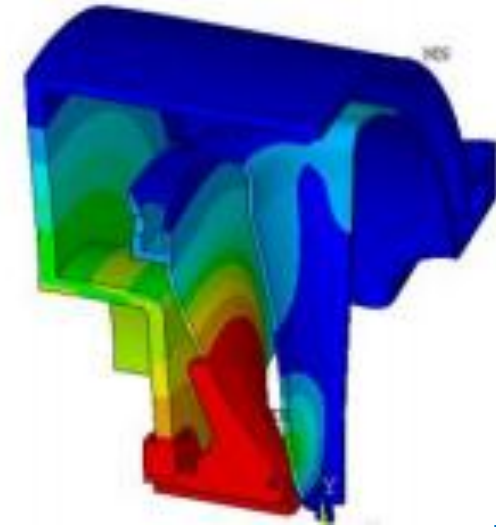
# Spoke021 He vessel

- Unexpected high df/dp
- df/dp is extremely sensitive to the depth of one weldment, which was switched from EBW to TIG
- Re-weld with EBW solved the problem

| df/dp [Hz/mbar] | Before | After |
|---|---|---|
| 021-5# | -60 | 0 |
| 021-6# | -40 | -13 |
| 021-7# | -58 | -12 |
| 021-8# | -82 | -9 |
| 021-9# | -67 | -15 |
| 021-10# | -65 | -11 |

| Weld depth[mm] (slide fit 0.2mm) | df/dp [Hz/mbar] |
|---|---|
| 5 | -1.0 |
| 4 | -6.5 |
| 3 | -16.2 |
| 2 | -32.7 |
| 1 | -64.4 |
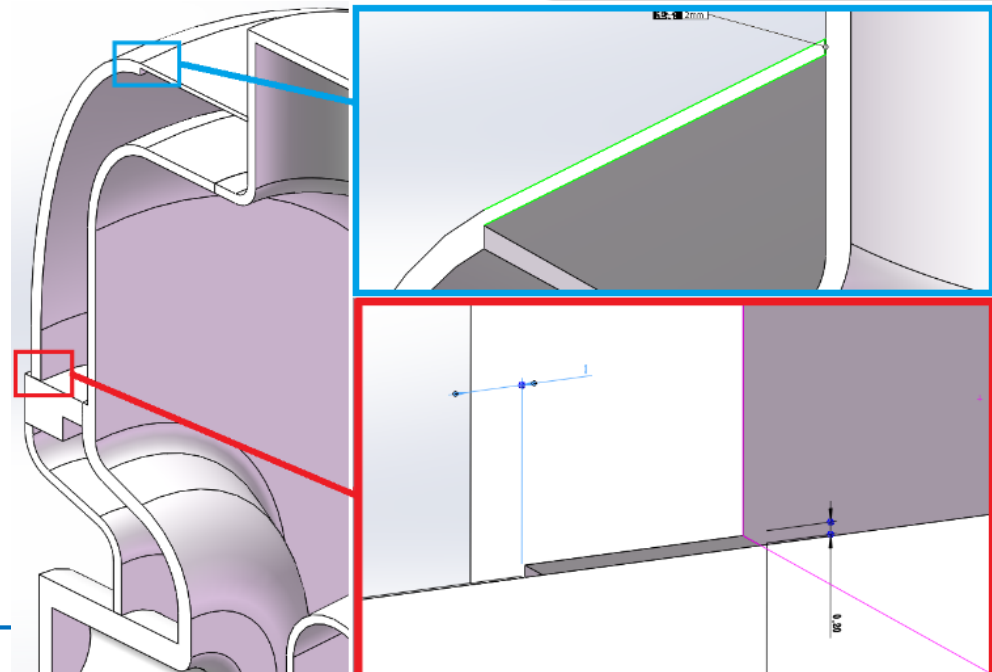
# Outline

- Background

- Fabrication and quality control

- Vertical test statistics

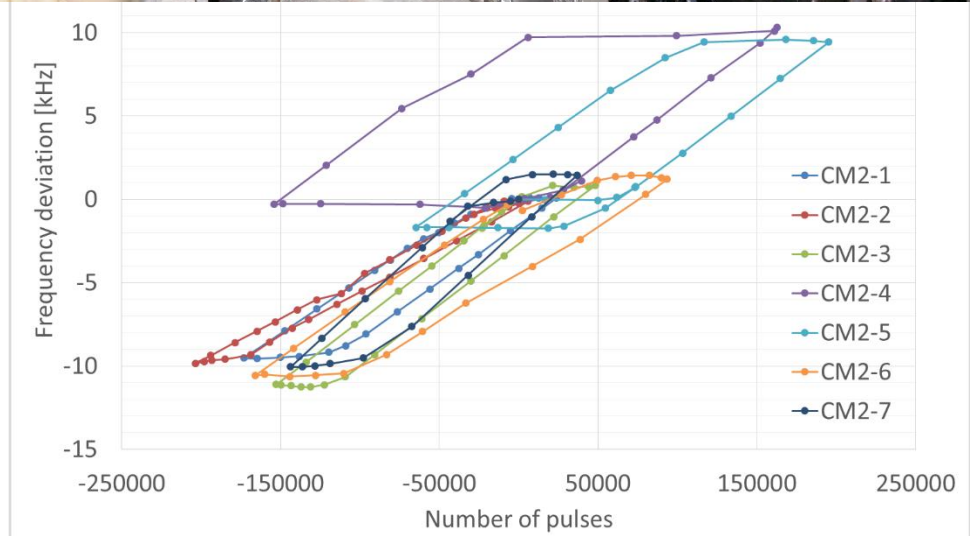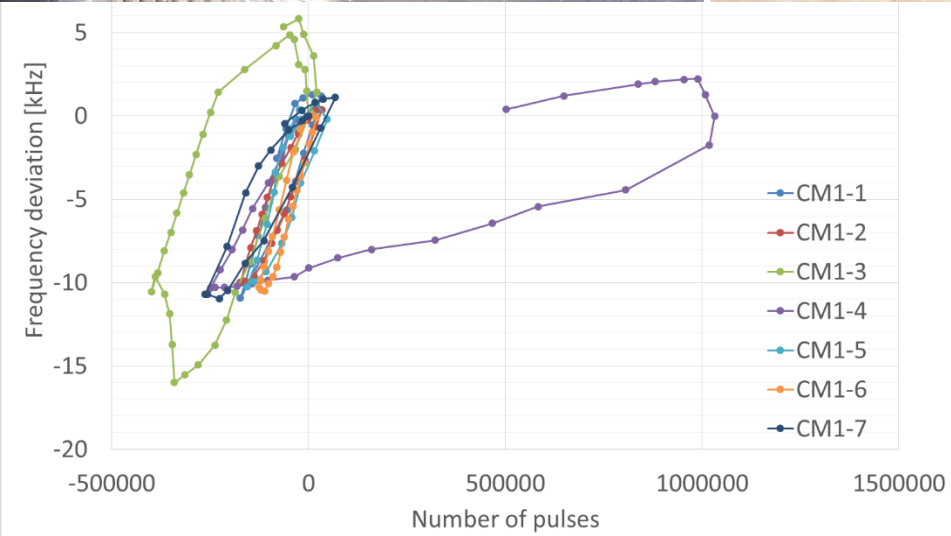- He vessel issues and solutions

- Tuner issues

# Tuner issue

- Switch from pushing to pulling help reduce df/dp
- Severe backlash and overshoot possibly caused by gears and joints
- They were replaced from service port, which helped more or less
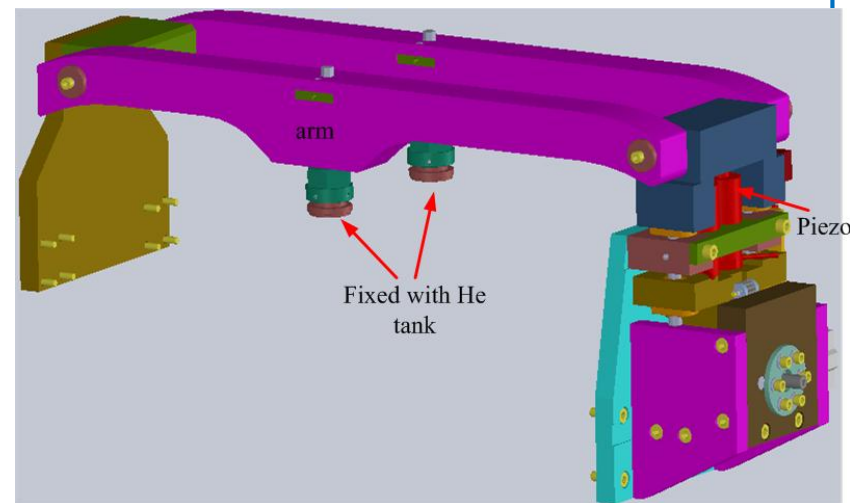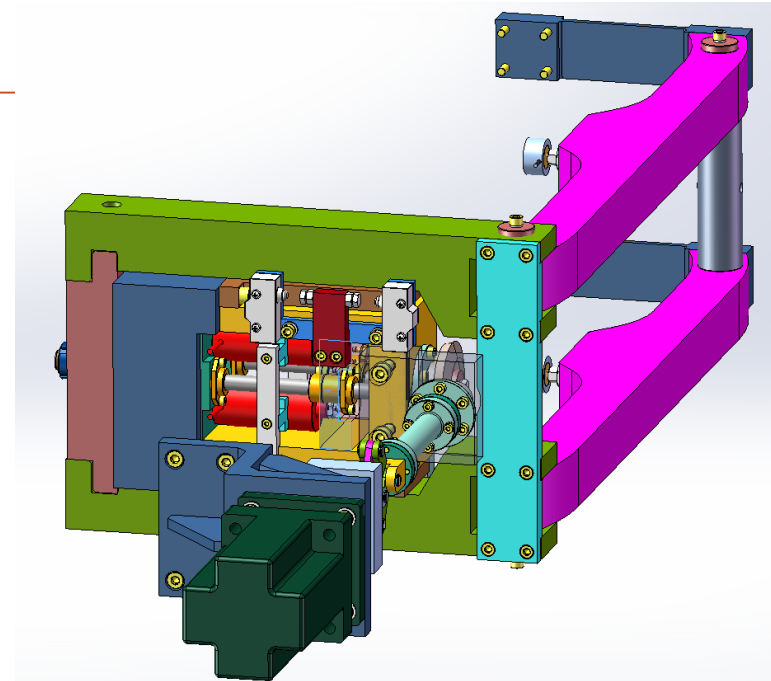
# Tuner issue (2)



| | CM1-1 | CM1-2 | CM1-3 | CM1-4 | CM1-5 | CM1-6 | CM1-7 | CM2-1 | CM2-2 | CM2-3 | CM2-4 | CM2-5 | CM2-6 | CM2-7 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Overshoot [Hz] | 55 | 105 | 5200/2995 | 1120/215 | 500 | 155 | 117.5 | 35 | 0 | 102 | 123 | 104.5 | 139 | 27.5 |

# Thanks for your attention!