Status on the ADS SRF cavities

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On behalf of W. Pan, Y. He, and colleagues in ADS joint SRF group

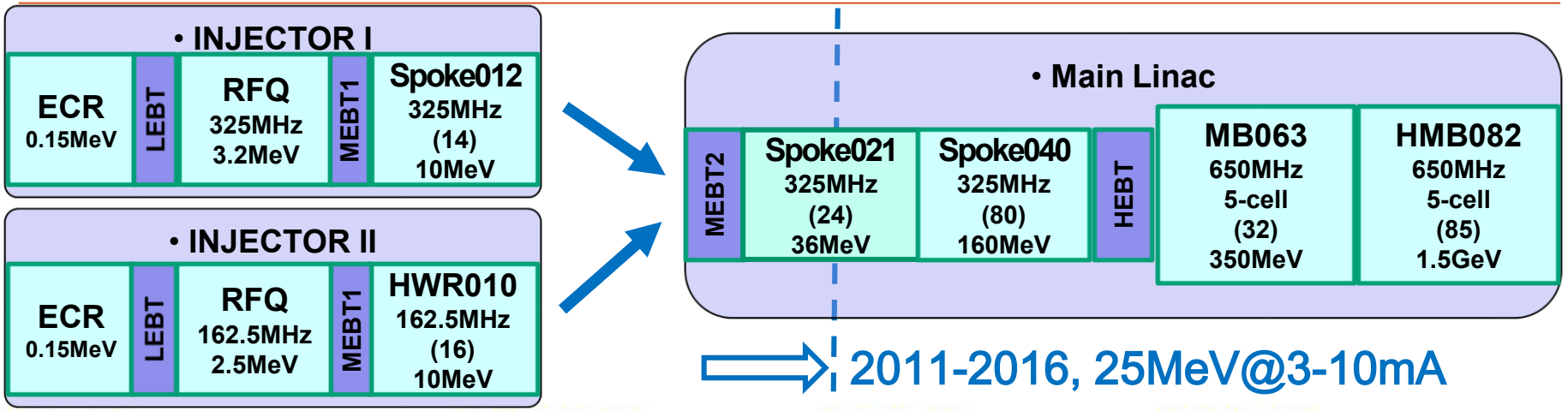
Institute of High Energy Physics (IHEP)

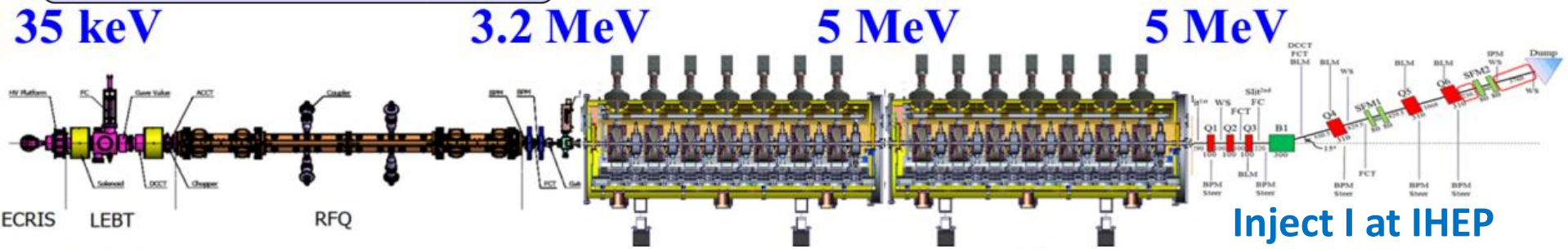
Institute of Modern Physics (IMP)

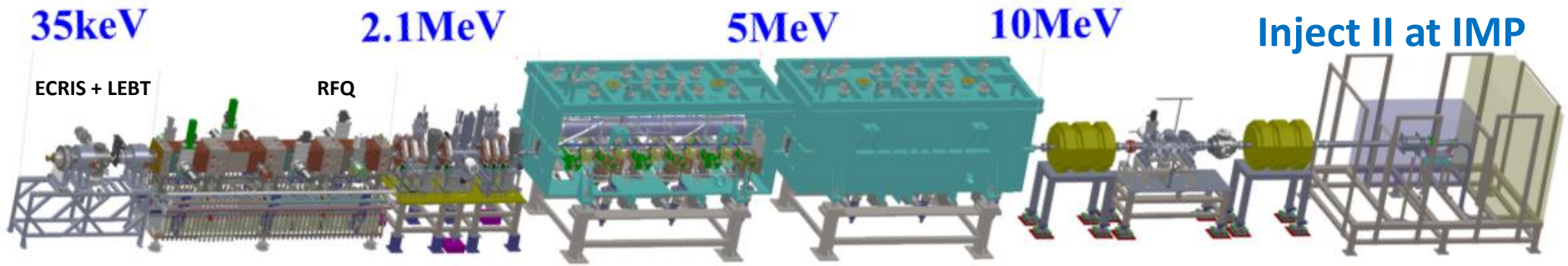
Outline

- Overview
- SRF Cavities for 325 MHz injector I at IHEP
- SRF Cavities for 162.5 MHz injector II at IMP
- SRF Cavities for 25MeV Demo-facility at IMP
- SRF Cavities for the future CIADS

Linac layout







SRF cavities overview

	Spoke 012	HWR 010	HWR 015	Spoke 021	Spoke 040	Ellip 063	Ellip 082	Spoke 024	HWR 325	CH 6cell
Freq. [MHz]	325	162.5	162.5	325	325	650	650	325	325	162.5
β_0	0.14	0.10	0.15	0.24	0.46	0.82*	0.86	0.24	0.14	0.067
Aperture [mm]	35	40	40	40	50	100	100	40	35	50
E_p/E_{acc}	5.0	5.9	4.9	4.4	3.9	2.6*	2.1*	4.0	4.6	12.1
B_p/E_{acc} [mT/(MV/m)]	6.9	11.8	6.1	9.4	9.2	4.7*	4.1*	6.4	4.8	9.1
G [Ω]	43	28.5	52	71	104	193	236	81	73	62
R/Q [Ω]	150	148	286	191	265	304*	515*	206	197	544

Note: Eacc normalized with $\beta_0\lambda$;

*: β_G is used instead of β_0

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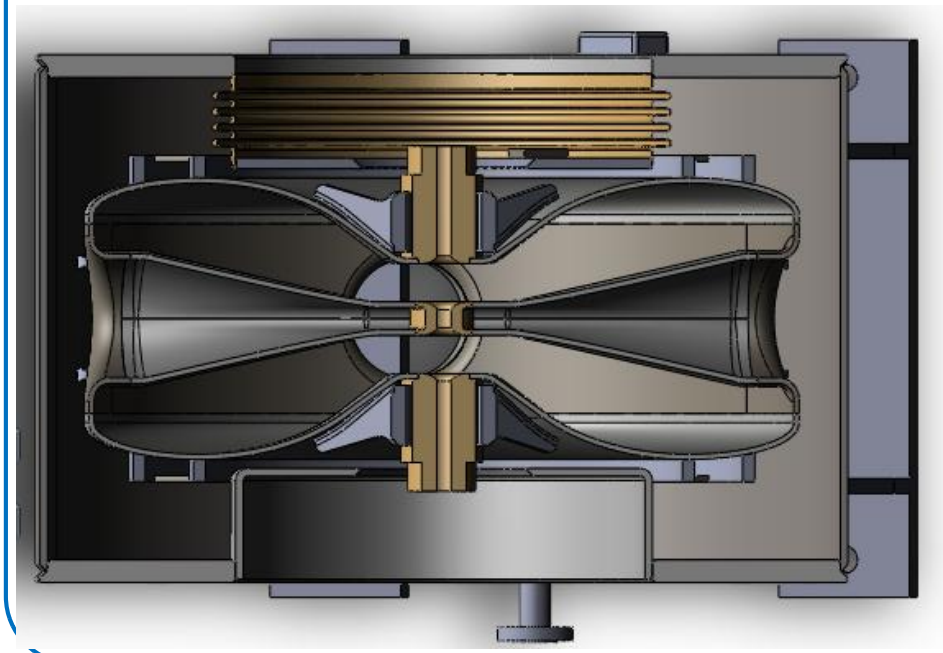
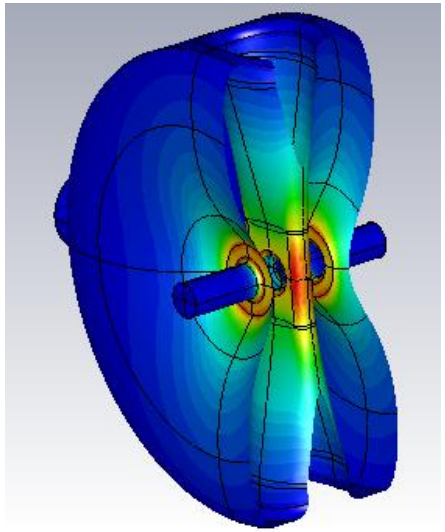
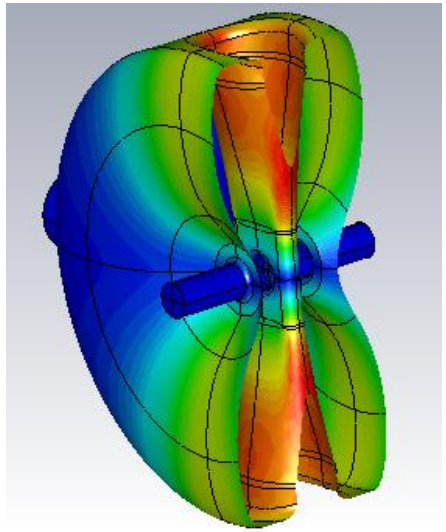
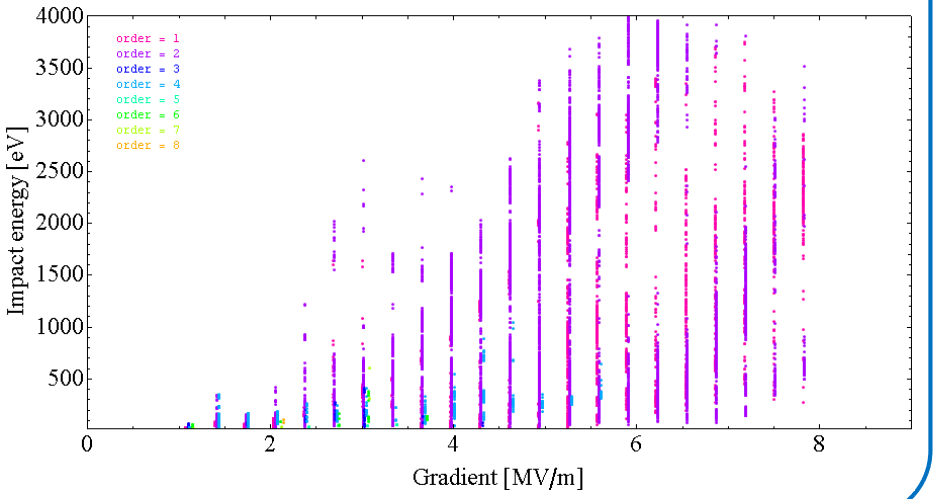
Design of the Spoke012 cavity

Designed $Vacc_0$	0.80 [MV]
Ep at $Eacc_0$	29.3 [MV/m]
Bp at $Eacc_0$	41.6 [mT]
Dynamic loss [W]	<11.6/1.2 (4K/2K);
df/dp (tuner attached)	-25 [Hz/mbar]



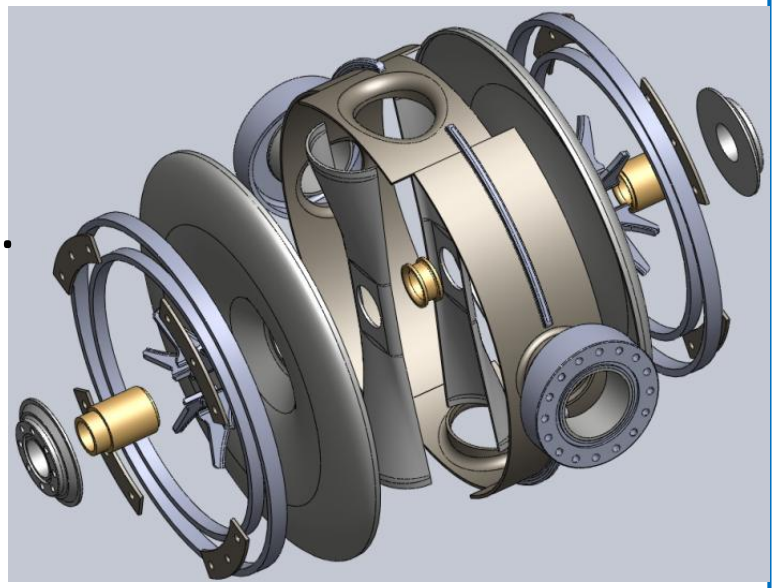


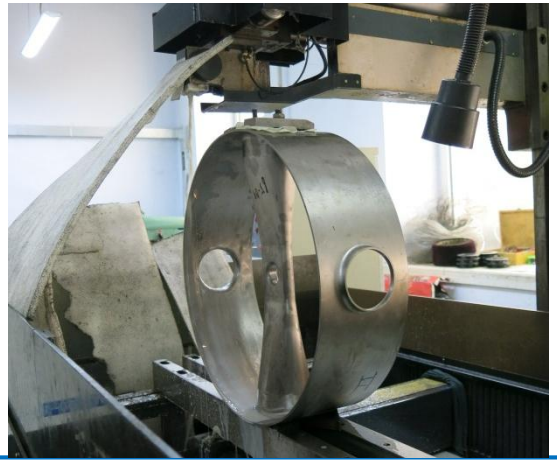




Fabrication of the Spoke012 cavities

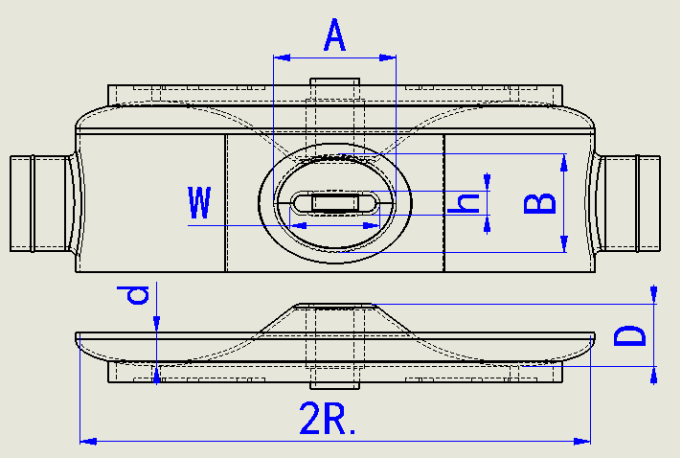
- Two qualified vendors provided 18 cavities; 6 more cavities from another two vendors were delayed.
- Fabrication process:
  - Deep drawing, annealing, machining, frequency control, grinding, EBW

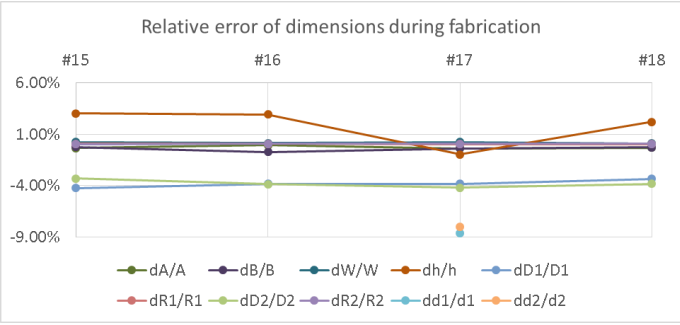


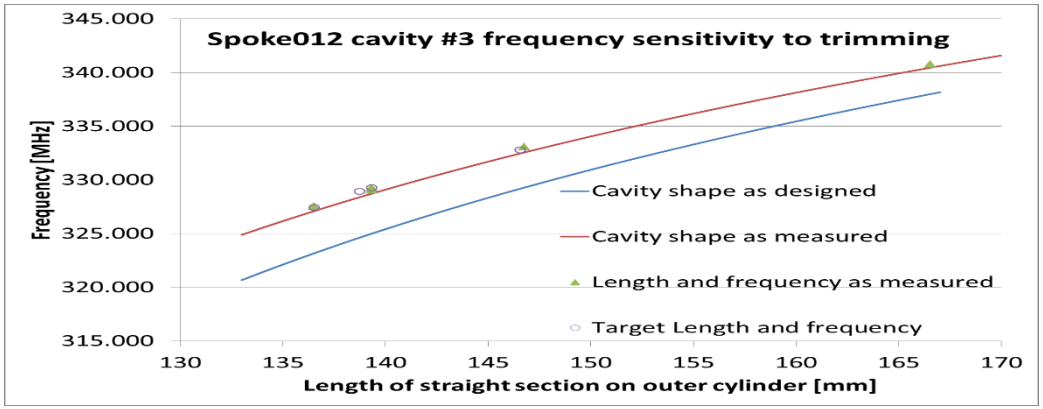


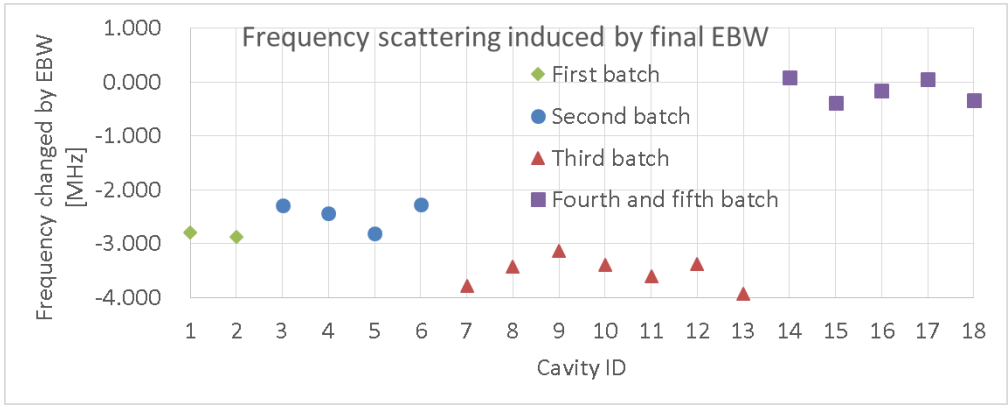
Quality control: frequency and surface

- Frequency sensitivity of trimming the central ring was calculated based on measured critical sizes.
- Defects were inspected and grinded before final EBW









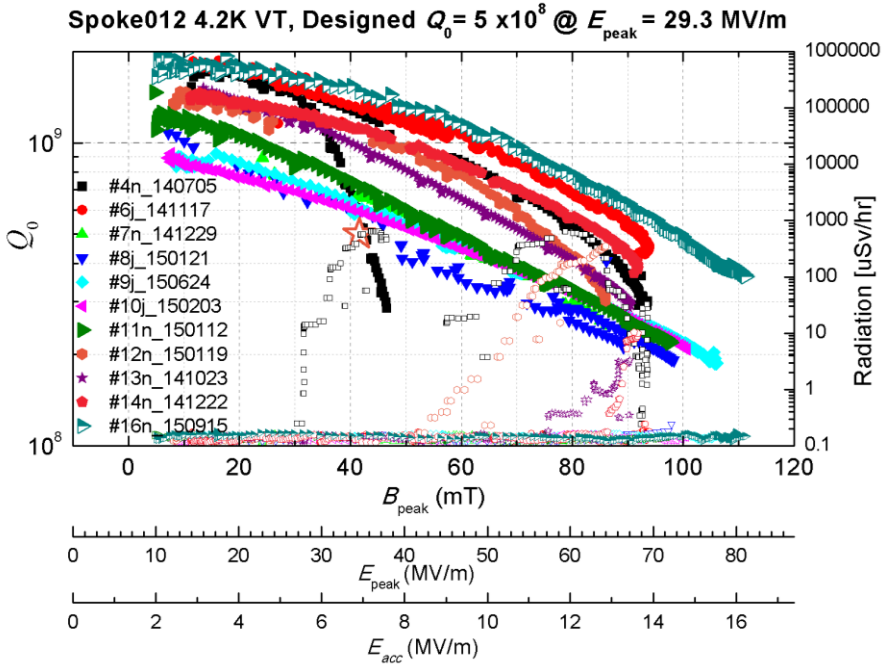
Post processing of Spoke012 cavities

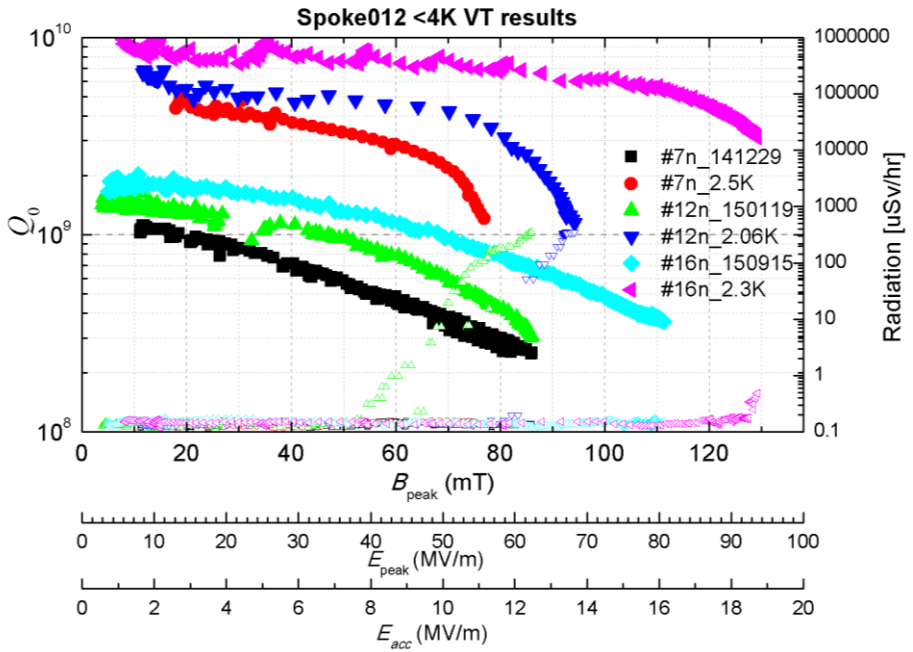
- BCP in Ningxia OTIC; re-HPR and clean assembly in house

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 applied to cavity string
- Will do more 2K tests when new dewar is ready





Spoke012 cavities in the cryomodules

- Feb – May 2015, two spoke cavities accelerated proton beam at 10 mA, 30~130 us, 1 Hz by 0.4 MeV
  - One tuner got stuck
  - Strong FE cracked ceramic window twice
  - Instability induced by piezo
- Improvements on CM1
  - New tuner design w/o piezo
  - Special gasket to protect window
  - **5.5 MV/m at 2K on beam line**
- Further improvement for CM2:
  - New coupler assemble in cleanroom
  - New cryomodule

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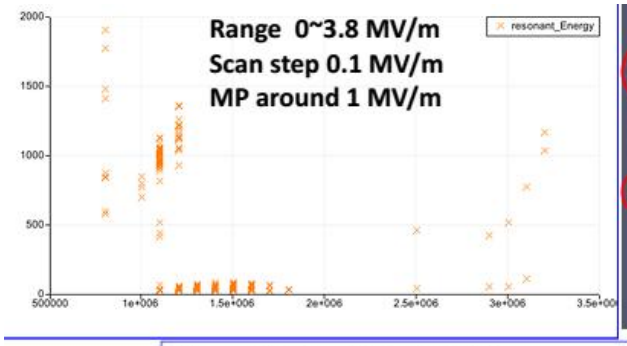
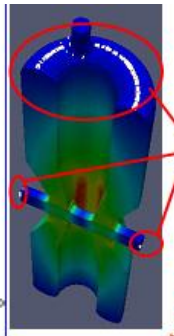
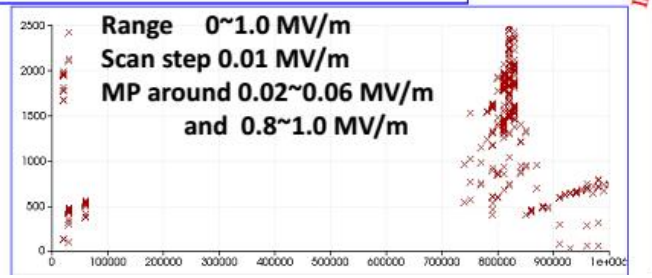
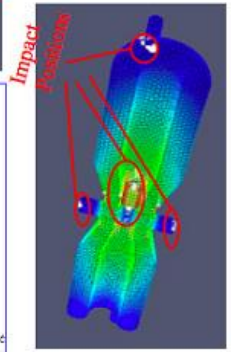
Design of HWR010 cavity

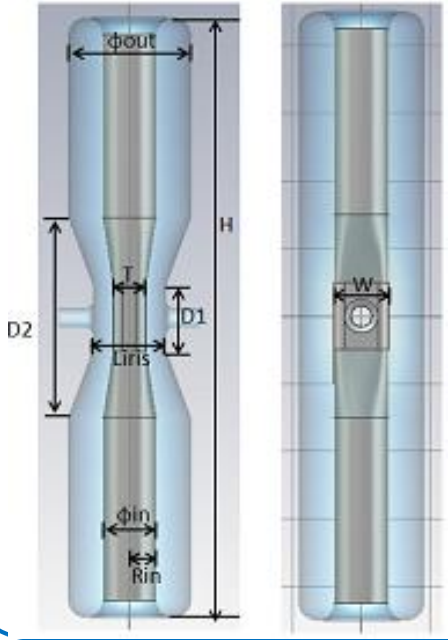
Designed $Vacc_0$	0.78 [MV]
Ep at $Eacc_0$	25 [MV/m]
Bp at $Eacc_0$	50 [mT]
Dynamic loss [W]	<10 (4K);
df/dp (design)	-5 [Hz/mbar]

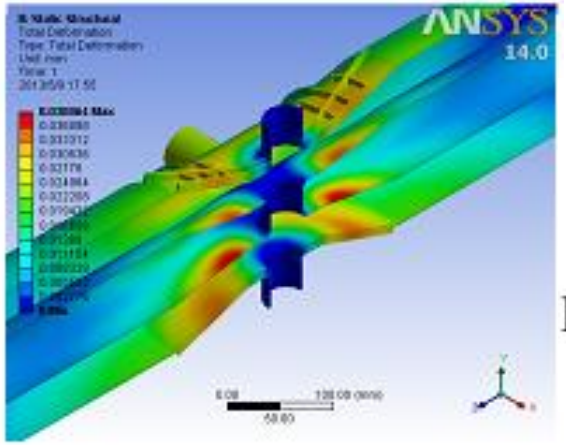


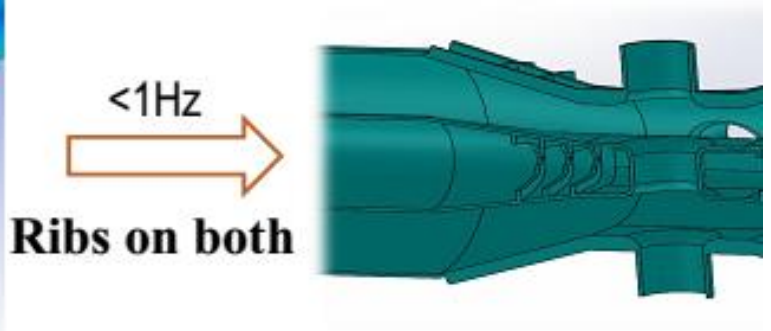






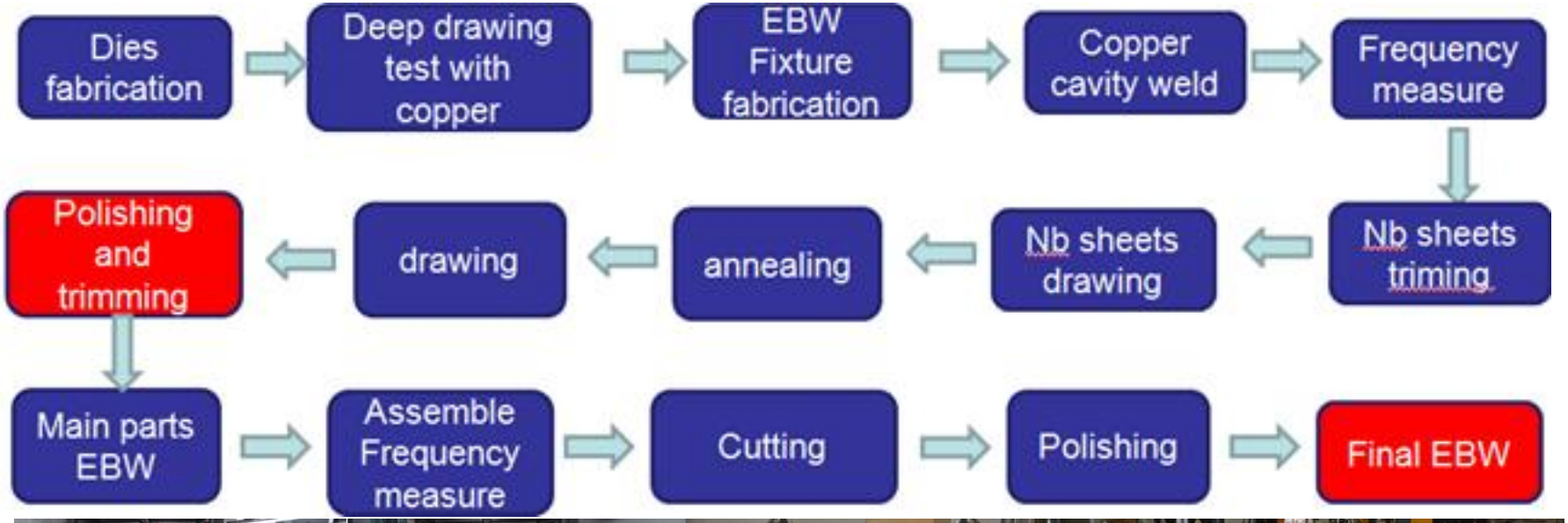






Fabrication of the HWR010 cavities

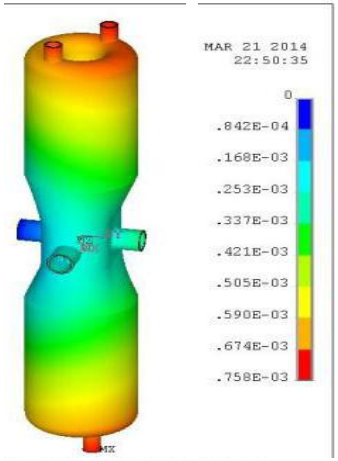
- Cavities for all cryomodules have been finished by a single vendor

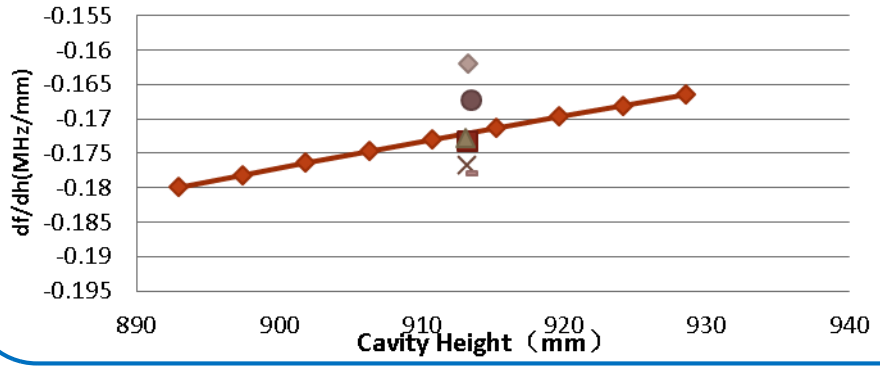


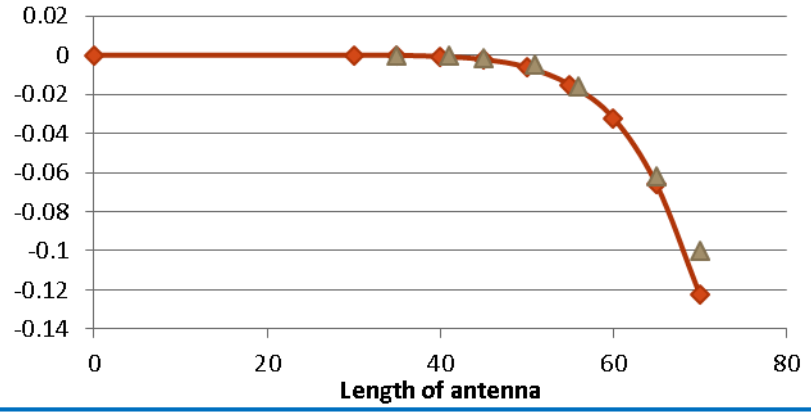
Frequency control of HWR010 cavities

- Major source of frequency error were simulated and agreed well measurements

	Simulation	Measured	Error
Trimming sensitivity（MHz/mm）	-0.168	-0.171	1%
BCP (MHz/150um)	0.039	0.044	10%
Antenna inserted (MHz)	-0.0052	-0.0056	7%
Pumping w/o stiffener（MHz/bar）	110	94	14%
Tuning（MHz/mm）	0.18	0.17	5.5%
Cooling down (MHz)	0.24	0.26	7.6%



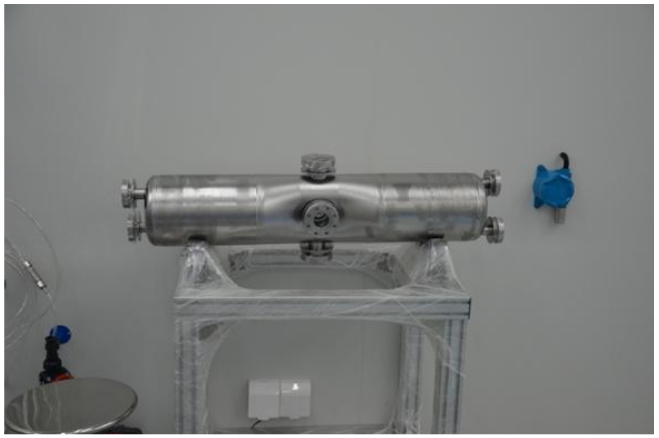


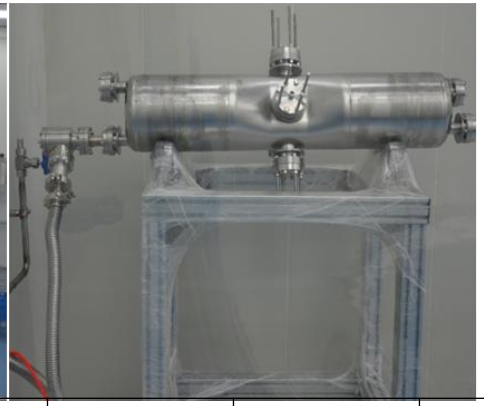


Post processing of HWR010 cavities

- Standard post-processing in house. EP facility is been built

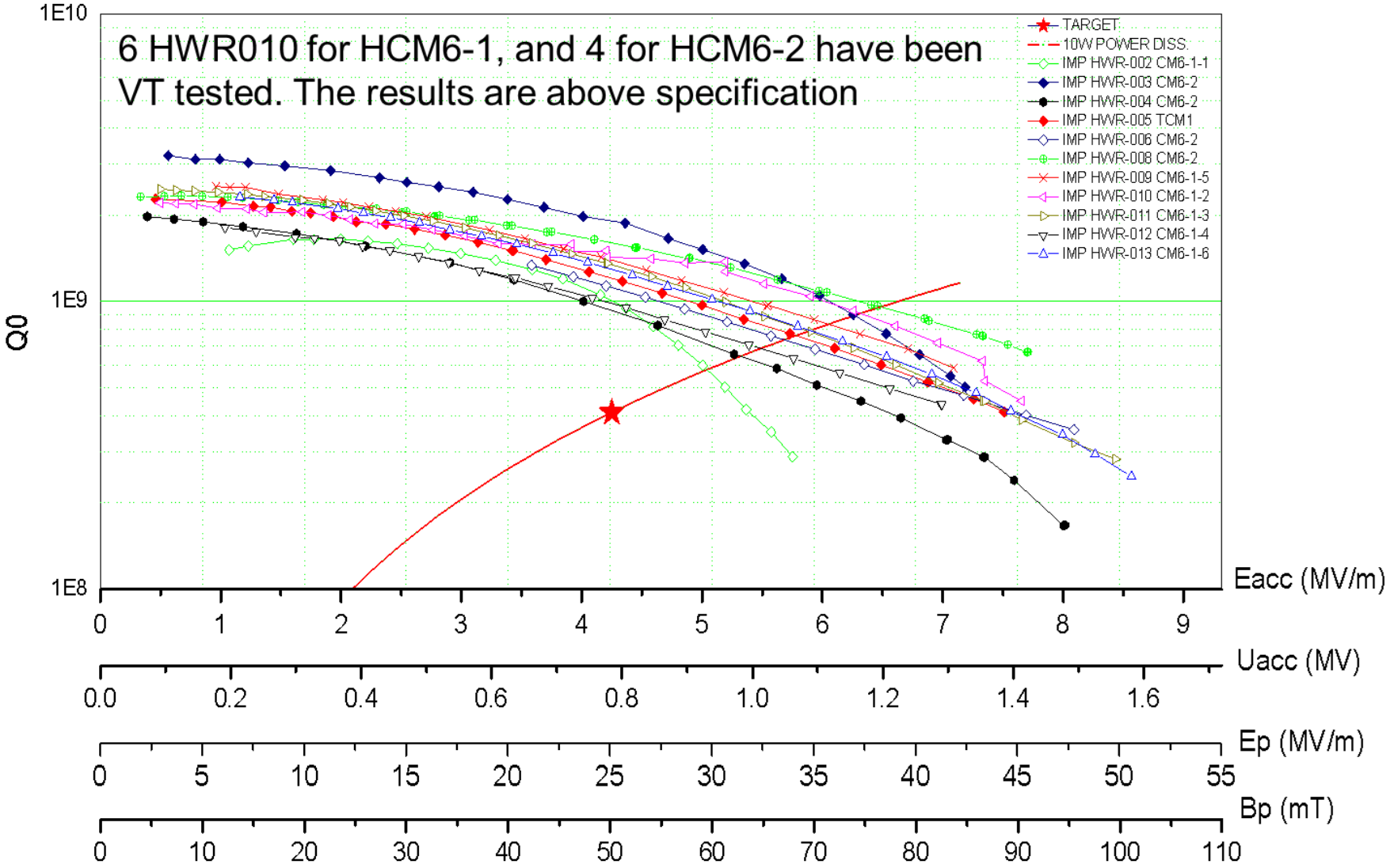




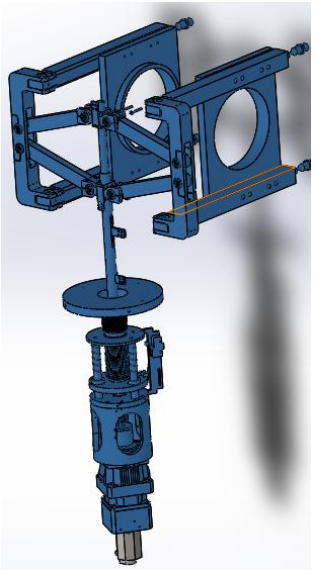
Degrease	Bulk BCP	High baking	Light BCP	Ultrasonic clean	HPR	Dry	Assembly	Leak check	Low baking

VT results of the HWR010 cavities



HWR010 cavities in the cryomodules

- 2014.9 – 2015.2, , one HWR010 cavity was operated in TCM with CW proton for 200 hours (max 10mA). Q0 was 8e8 at specified Ep=25MV/m (max 30MV/m)
- Since 2015.6, 6 HWR010 cavities in CM1 reached 25MV/m, and accelerated 2.7mA CW beam to 5.2 MeV. The gradient degraded after exposed to air by accident.
- The tuner and coupler works very well



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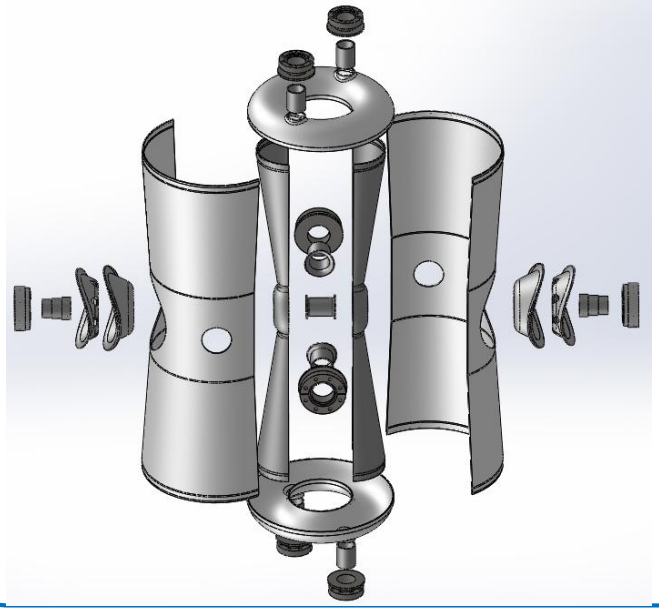
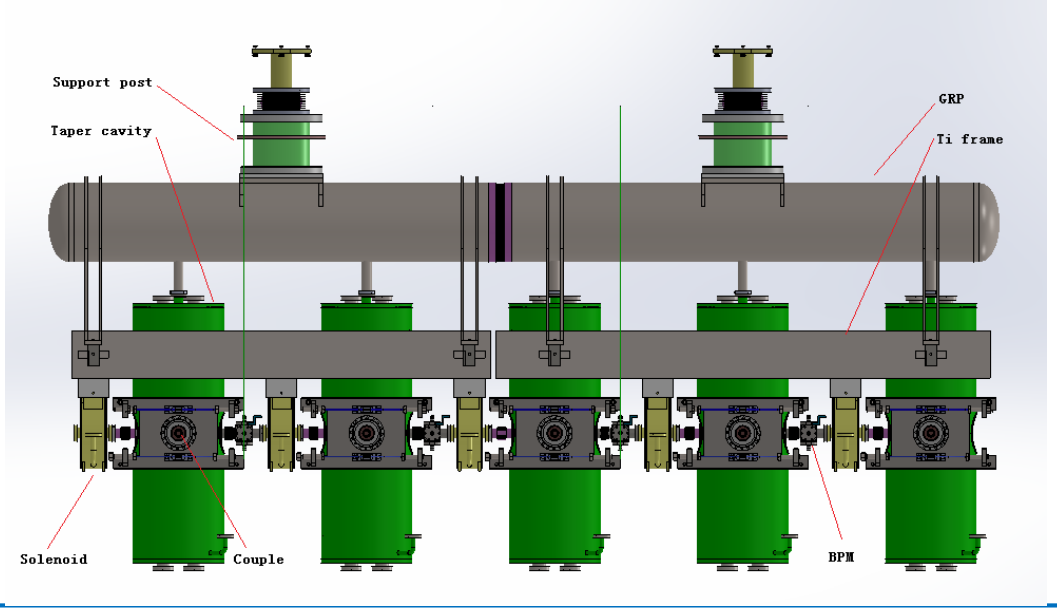
- SRF Cavities for 25MeV Demo-facility at IMP
  - HWR015 cavity by IMP
  - Spoke021 cavity by IHEP
- SRF Cavities for the future CIADS

HWR015 design

- For higher efficiency and shorter length, one CM with 6 spoke021 cavities was replaced by a CM containing 5 HWR015 cavities.
- The shaped is optimized for much higher Vacc than HWR010.

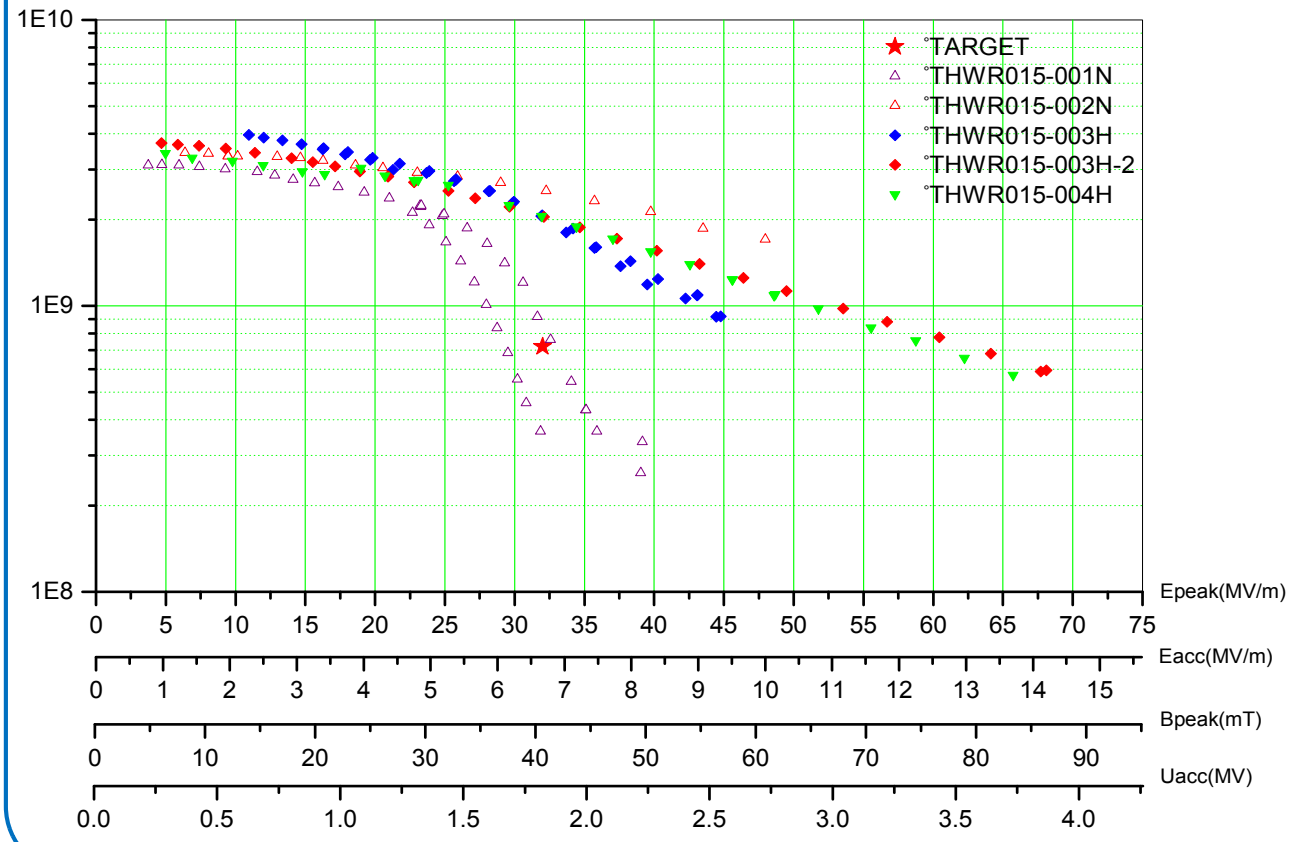
Designed $Vacc_0$[MV]	1.82
Ep at $Eacc_0$ [MV/m]	32
Bp at $Eacc_0$ [mT]	40
Dynamic loss [W]	<10 (4K);
df/dp [Hz/mbar]	-5





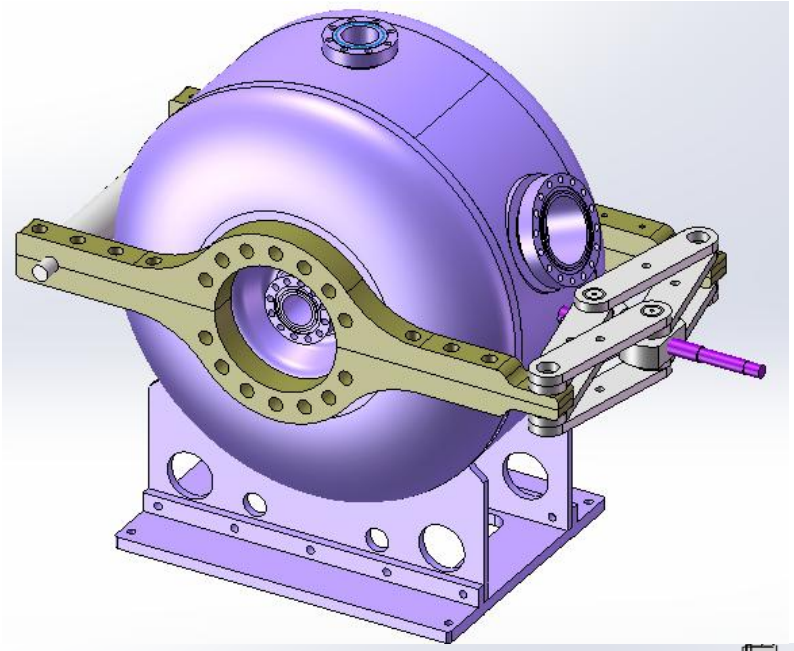
HWR015 fabrication and VT

- Four HWR015 cavities from two vendors were VT; three were qualified, while one needs re-test

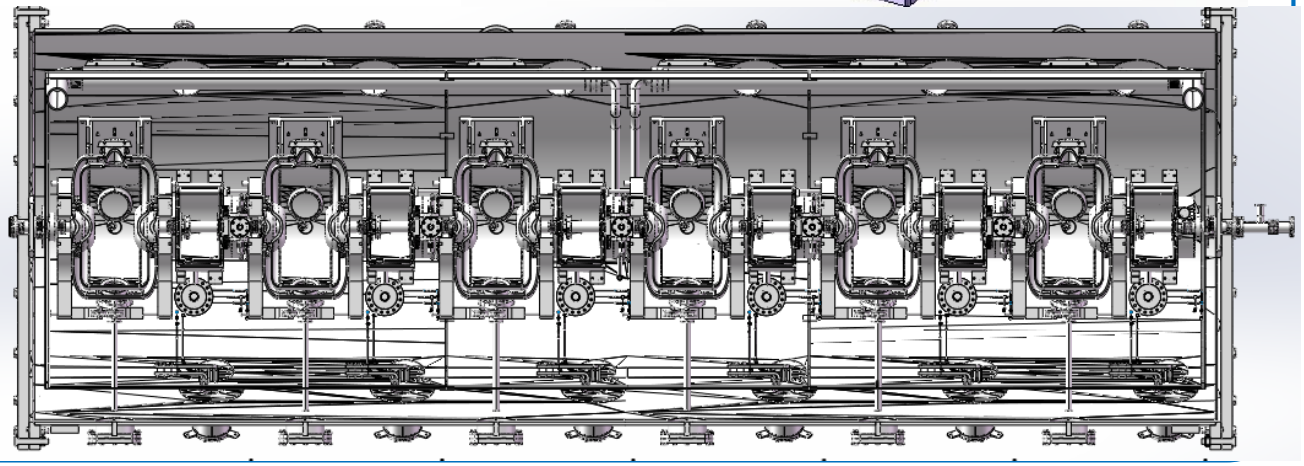


Spoke021 design

- The LHe vessel is without bellows, and it is optimized to compensate df induced by fluctuation of He pressure; the stiffness of the tuner also contribute to the results.

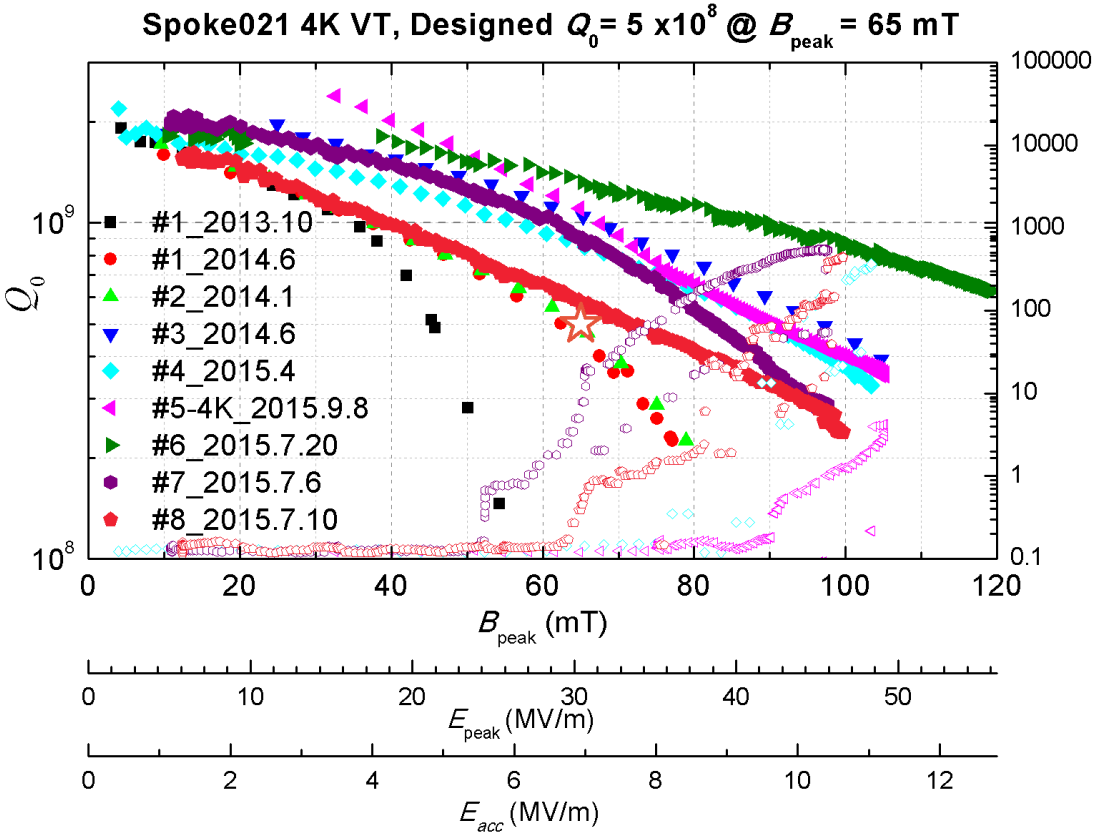


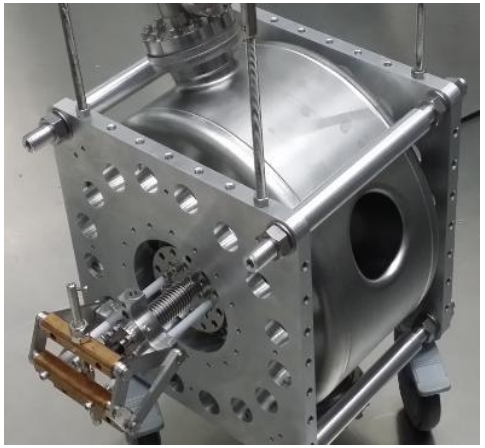
Designed $Vacc_0$[MV]	1.64
Ep at $Eacc_0$ [MV/m]	32.5
Bp at $Eacc_0$ [mT]	69
Dynamic loss [W]	<25 (4K)
df/dp [Hz/mbar]	+5
df/dL [kHz/kN]	47



Spoke021 testing results

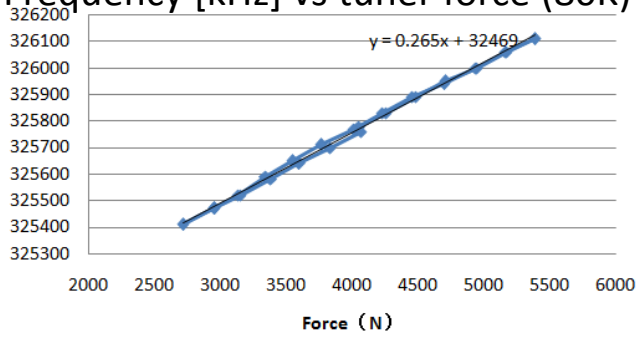
- Eight spoke021 cavities from two vendors have been fabricated and tested
- Tuner test on the 1st jacked cavity is promising





Radiation [uSv/hr]

Frequency [kHz] vs tuner force (80K)



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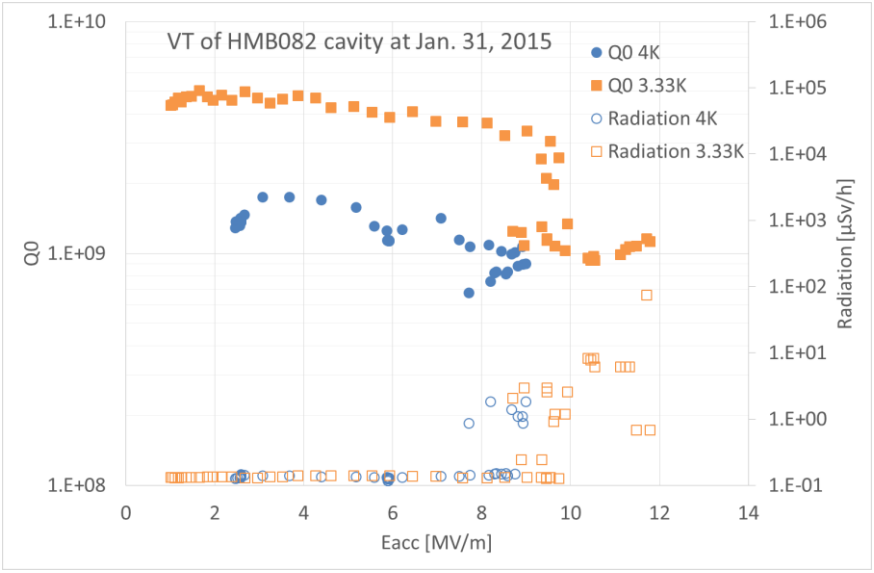
  - Cavities for higher energy
  - Alternatives to the current cavities

Spoke040 and Ellip082 cavity by IHEP

- In current design, there will be 72 Spoke 040 cavities and 28 Ellip 082 cavities in the ADS linac
- Two Spoke040 cavities, and two Ellip 082 5cell cavities have been built
- One Ellip 082 were tested in 4K and 3.3K

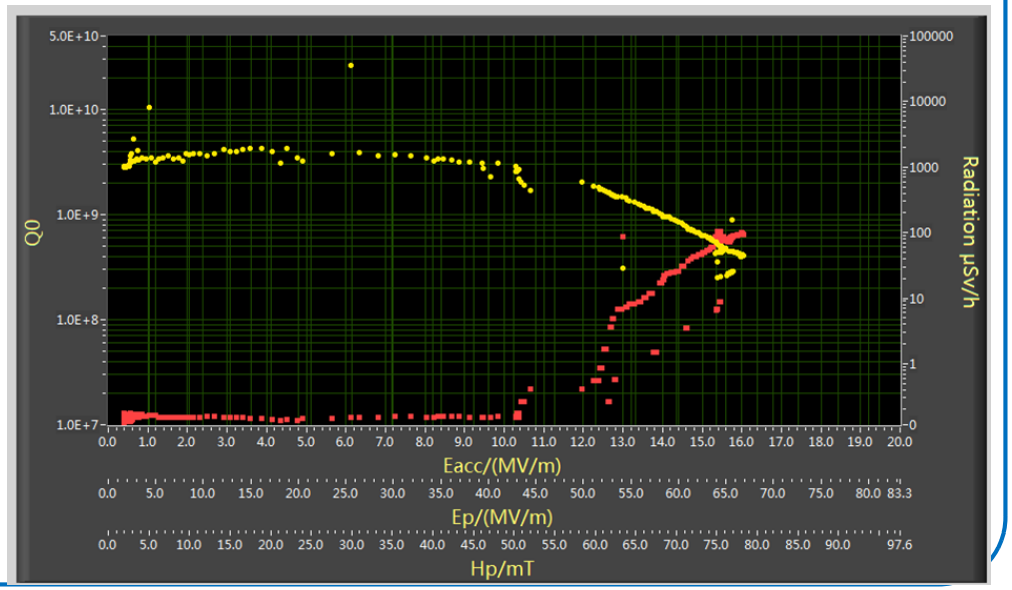
	Spoke 040	Ellip 082
Freq. [MHz]	325	650
β_0	0.14	0.86
Aperture [mm]	35	100
E_p/E_{acc}	5.0	2.1*
B_p/E_{acc} [mT/(MV/m)]	6.9	4.1*



HWR325 vs Spoke012 by IHEP

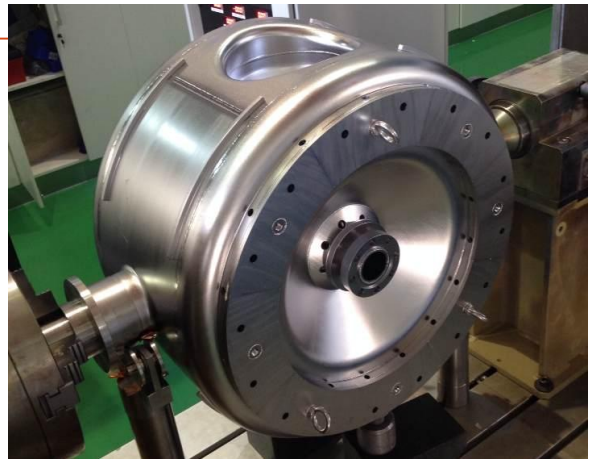
- Possible for Ep
- MP conditioning harder
- Similar Eacc achieved at 4K as Spoke012 cavity

	Spoke 012	Ellip 082
Freq. [MHz]	325	650
β_0	0.14	0.86
Aperture [mm]	35	100
E_p/E_{acc}	5.0	2.1*
B_p/E_{acc} [mT/(MV/m)]	6.9	4.1*
df/dp [Hz/mbar]	-25	236

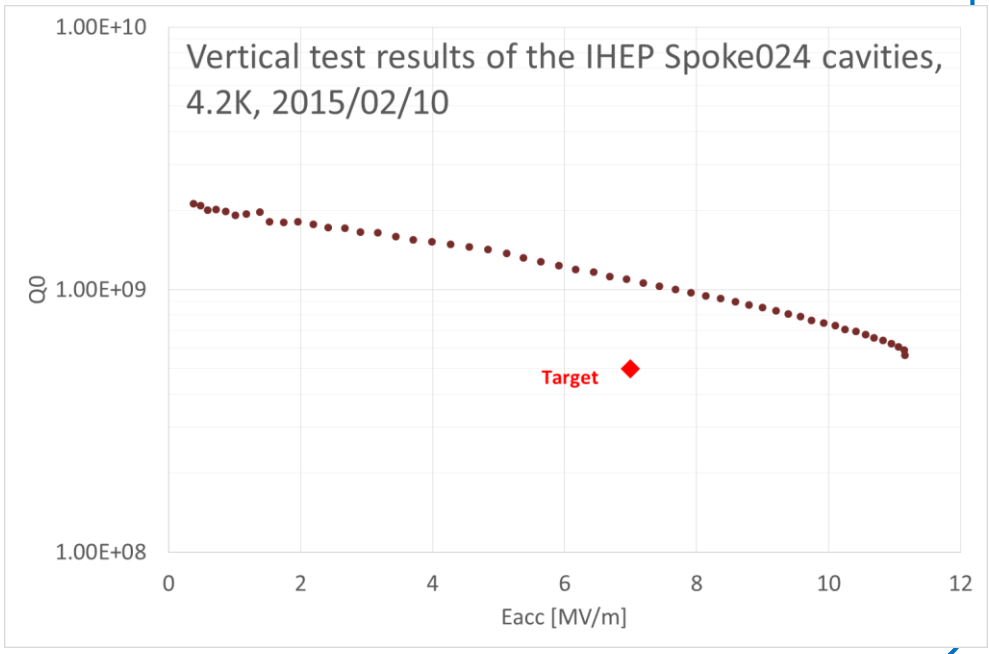


Spoke024 vs Spoke021 by IHEP

- Surface field minimized
- Similar Eacc achieved at 4K on the 1st VT as Spoke021 cavity
- Stopped due to tight project schedule



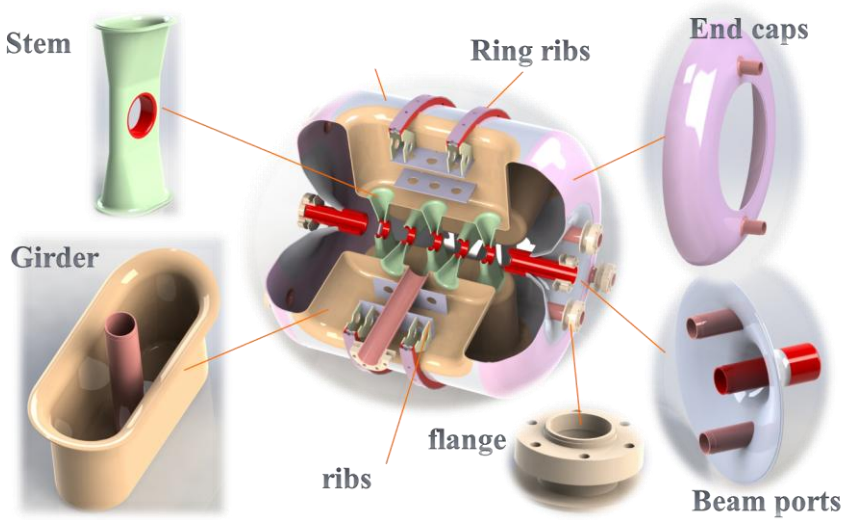
	Spoke 021	Spoke 024
Freq. [MHz]	325	325
β_0	0.24	0.24
Aperture [mm]	40	40
E_p/E_{acc}	4.4	4.0
B_p/E_{acc} [mT/(MV/m)]	9.4	6.4
G [Ω]	71	81
R/Q [Ω]	191	206

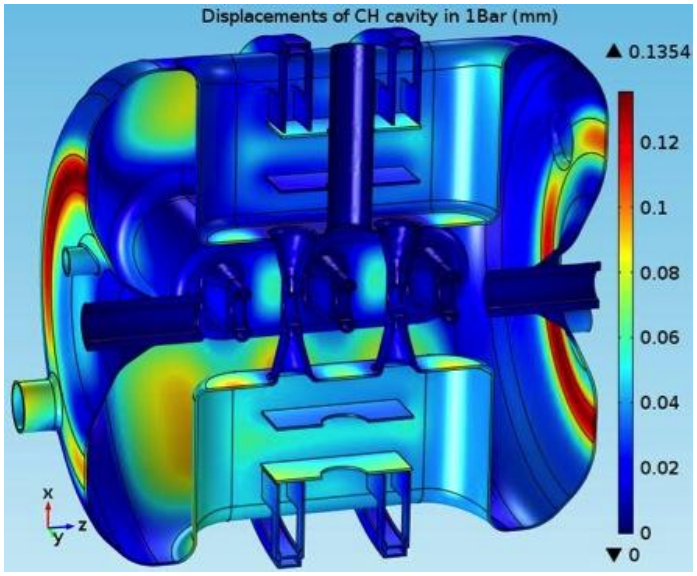


CH-6cell vs HWR010 by IMP

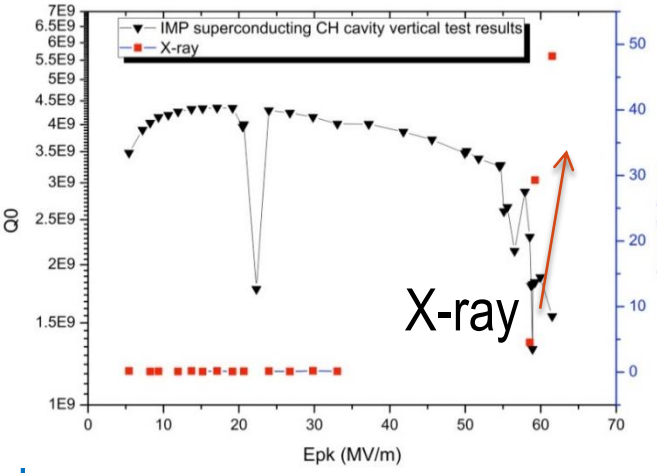
- To save space and elements like solenoid.

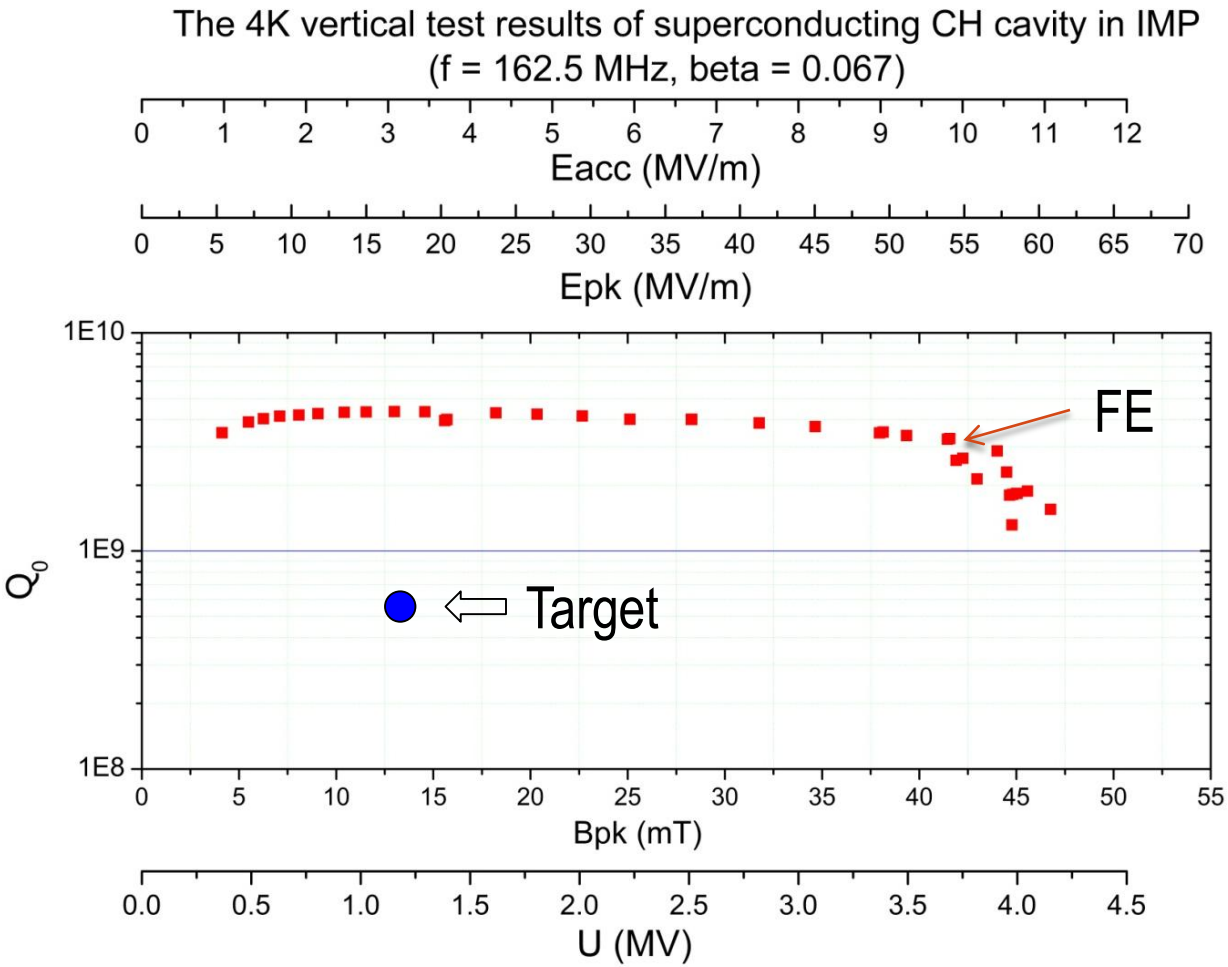
	HWR 010	CH 6cell
Freq. [MHz]	162.5	162.5
β_0	0.10	0.067
Aperture [mm]	40	50
E_p/E_{acc}	5.9	12.1
B_p/E_{acc} [mT/(MV/m)]	11.8	9.1
G [Ω]	28.5	62
R/Q [Ω]	148	544
Vacc[MV]	0.78	1.56
L (beam axis,mm)	200	700





CH-6cell vs HWR010 by IMP (2)





Thanks for your attention!