Chinese Academy of Sciences

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中国科学院

CHINESE ACADEMY OF SCIENCES

中国科学院高能物理研究所

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SRF Cavities for ADS Project in China

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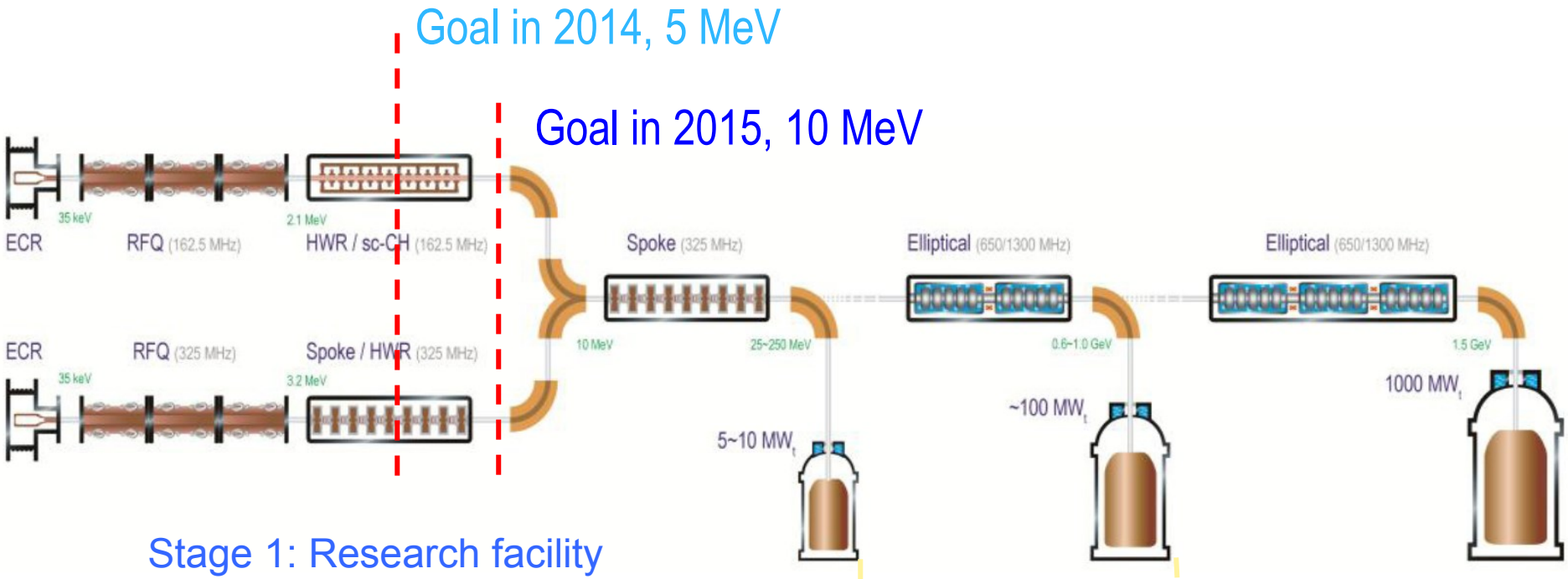
Institute of High Energy Physics (IHEP)

Contents

- **Introduction of ADS Project in China**
- Cavities for Injector I
- Cavities for Injector II
- Cavities for Main Linac
- Summary

Roadmap of ADS Project in China



Stage 1: Research facility

(~10 MWt, ~2023)

key technology R&D

Stage 2: Exp. facility

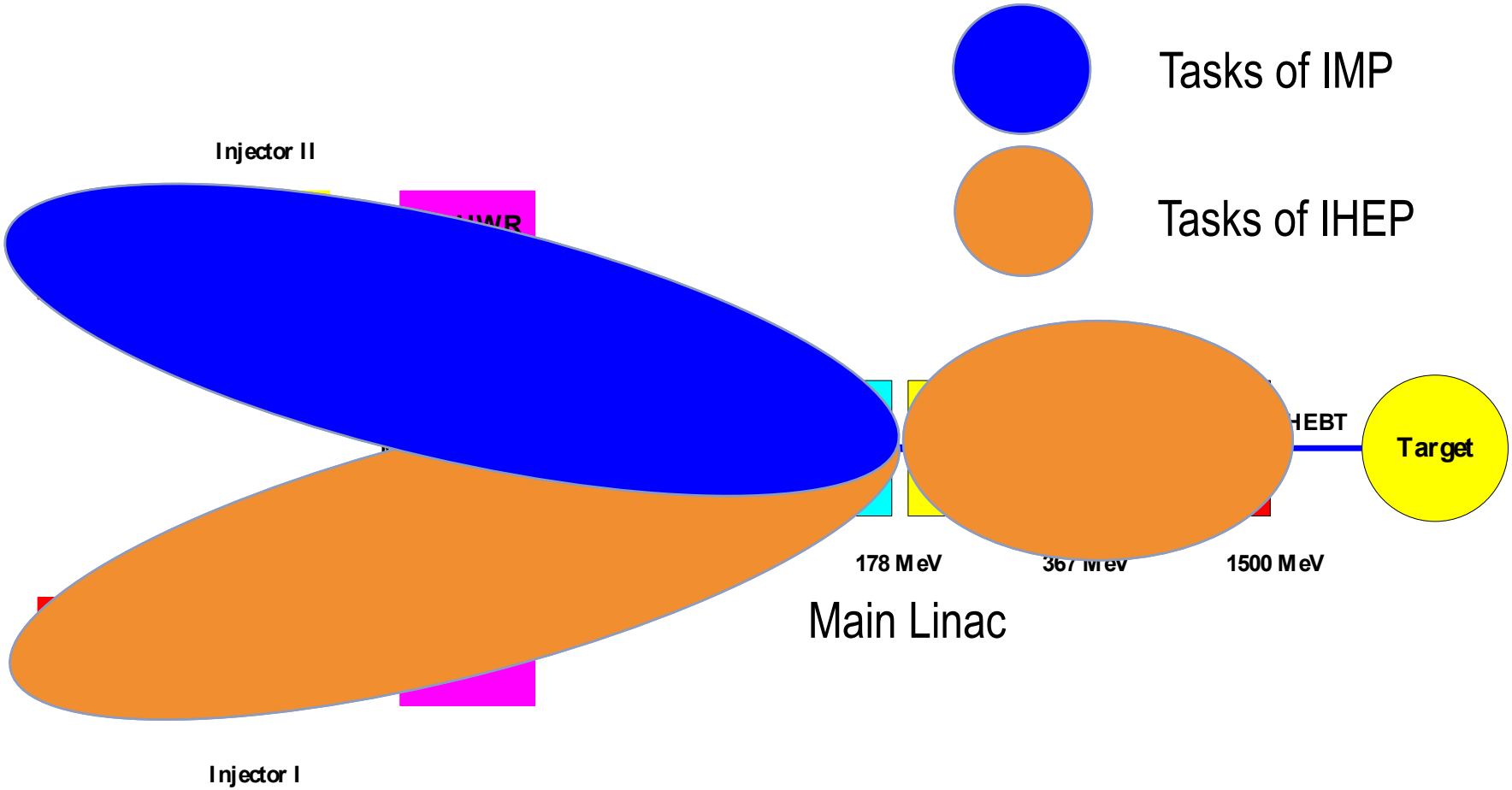
(~100 MW$_t$, ~2030)

Stage 3: Demo facility

(~1000 MW$_t$, ~2040)

"strategic Priority Research Program" of the Chinese Academy of Sciences

Layout of Accelerator for C-ADS



IHEP and IMP co-work on the accelerator. Final project has two identical injectors. Two designs of injector is due to technical uncertainty at very low energy segment.

General Specifications of the Cavities

	Spoke 012	HWR 010	HWR 015	Spoke 021	Spoke 040	Ellip 063	Ellip 082	Unit
Freq.	325	162.5	162.5	325	325	650	650	MHz
βg	0.12	0.09	0.14	0.21	0.40	0.63	0.82	-
Aperture	35	40	40	50	50	100	100	mm
Uacc	0.82	0.78	1.82	1.64	2.86	10.26	15.63	MV
Epeak	32.5	25	32	24/31	25/32	29/38	28/36	MV/m
Bpeak	46	50	40	50/65	50/65	50/65	50/65	mT
Temp.	4.5	4.5	4.5	4.5	2	2	2	K
Ploss	10 (70nΩ)	10 (70nΩ)	15.5 (70nΩ)	16.8 (70nΩ)	6.5	21	39	W
Number	12	6	6	28	72	28	85	-

Criteria: Bpeak = 50 mT for nornal operation, and 65 mT for compensation.

Operation temperature: 4.5 K is considerated for injectors or before 2015. 2 K may be the final decision, depends on the operation of demo injectors..

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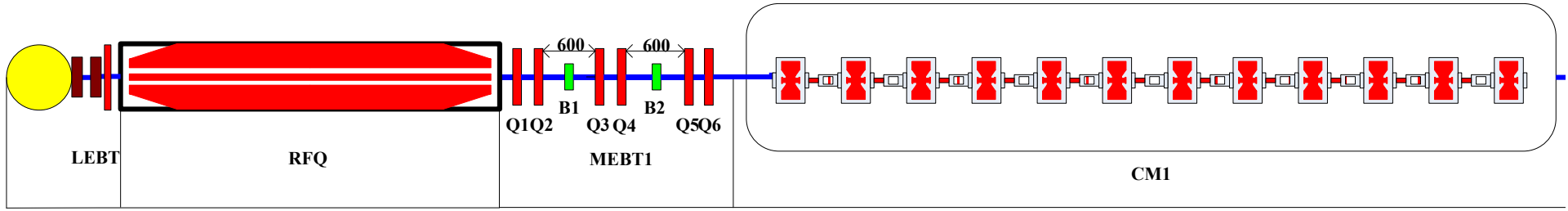
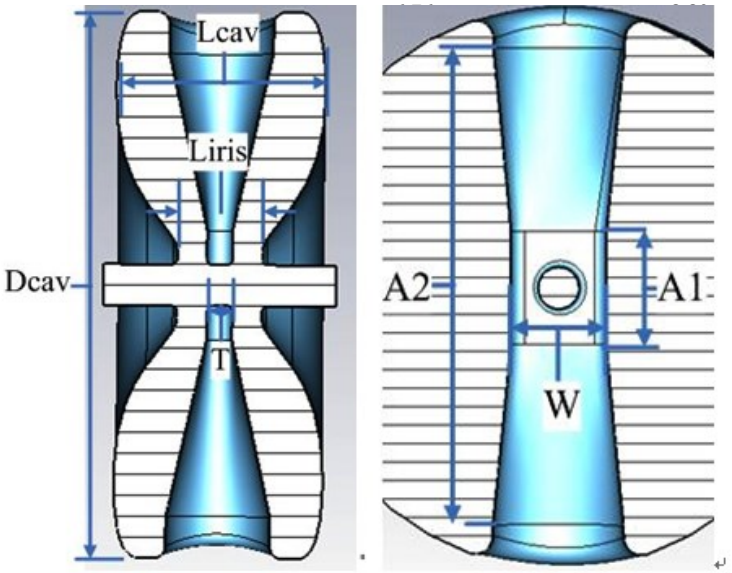
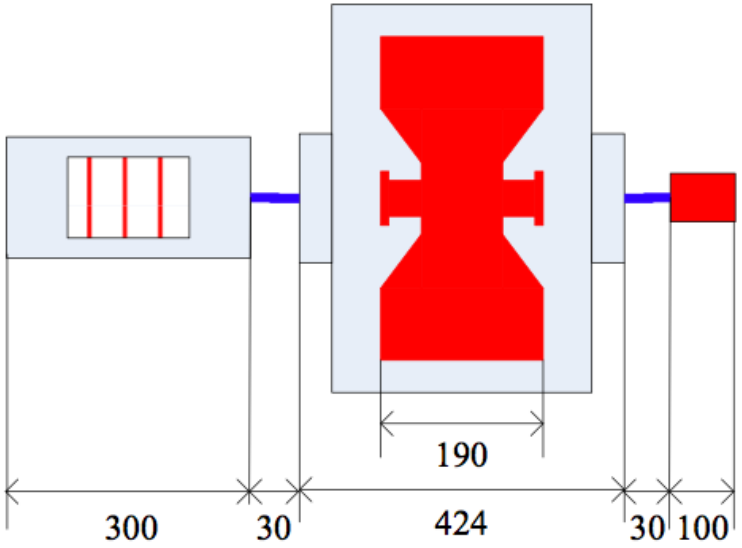
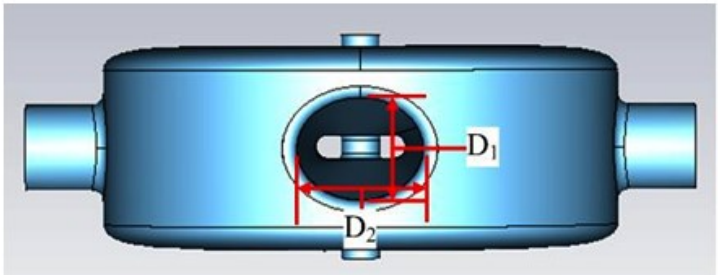
- HWR010 for Injector II
- Spoke021 and Ellip063 for Main Linac
- Plan for the furture

Spoke012 for Injector I





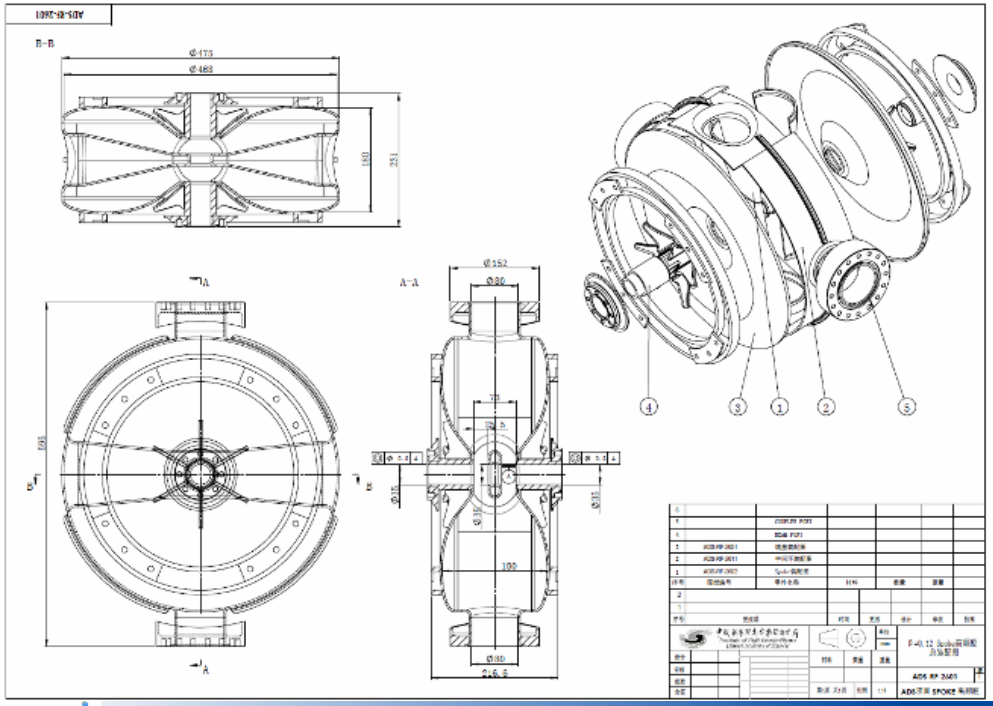




Jointly designed and fabricated by IHEP, PKU, and HIT

Design of Spoke012

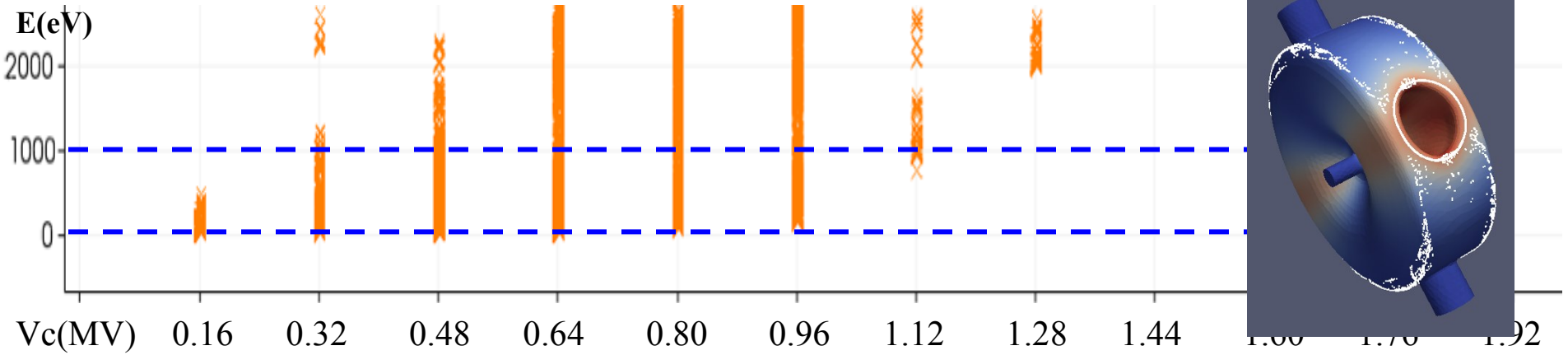
Parameter	Value
G	61 Ω
E_{peak}/E_{acc}	4.5



Geometry Parameters

Parameter	Value
W	82
Factor	1.25
R2in	199
R2out	164
Liris	73

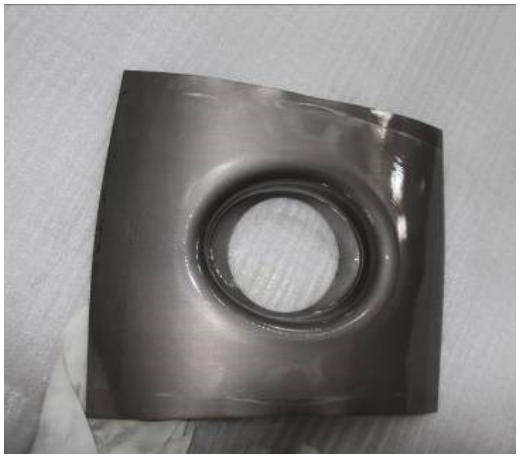
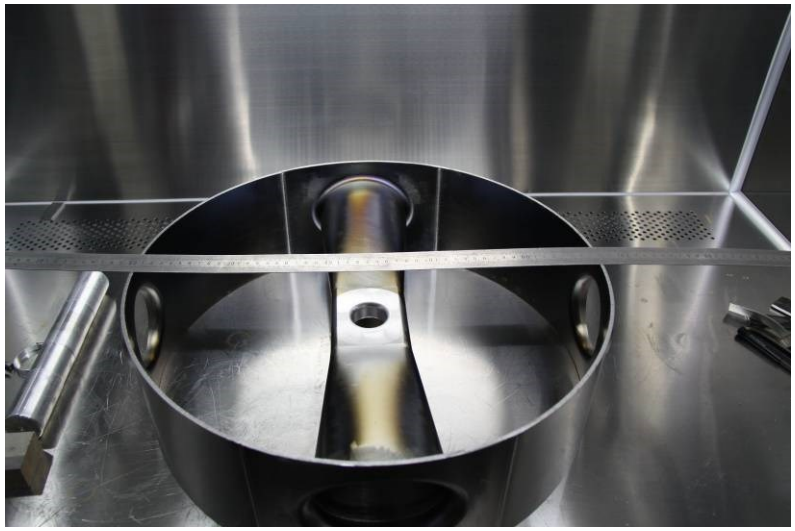
Simulation of Mutipacting and Detuning



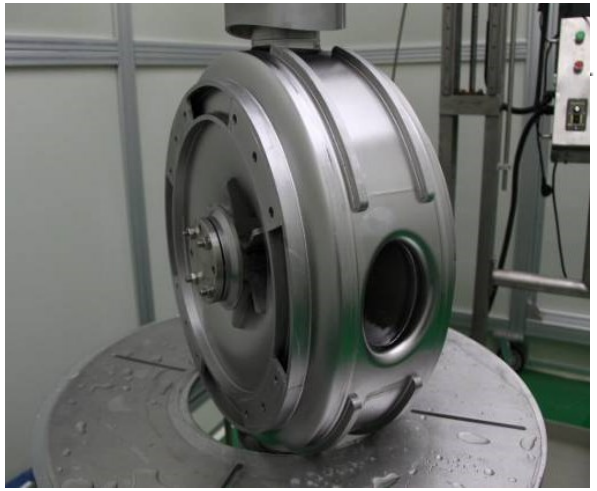
Ports free or locked	Stiff ribs	At 1 atm			df/dP (kHz/torr)
		Peak deform.(mm)	Peak stress (MPa)	Frequency shift (MHz)	
Free	No	3.256	157	-8.28	-10.9
Locked	No	0.218	389	-0.21	-0.278
Free	1st	0.11	<44.3	0.049	0.065
Locked	1st	0.065	<45.6	-0.044	-0.058
Free	2nd	0.848	89	-1.7	-2.24
Locked	2nd	0.11	118	0.014	0.018

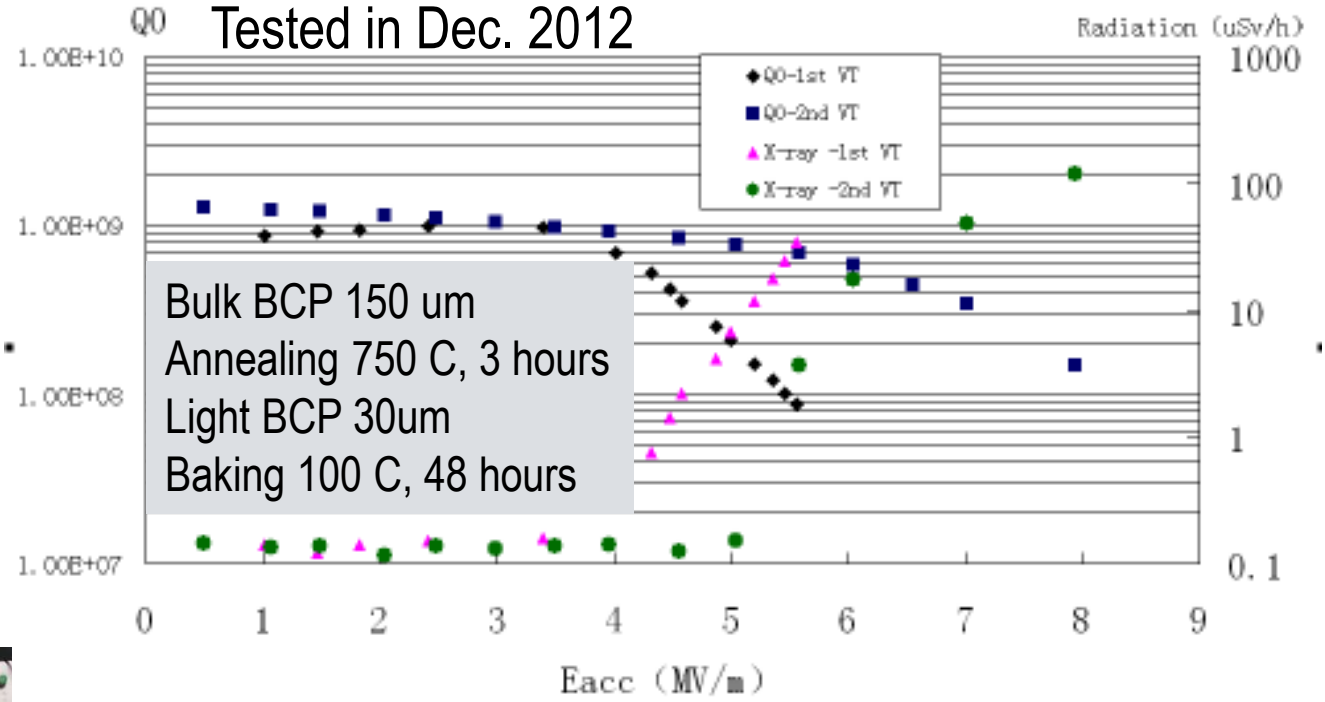
Fabrication of Spoke012



Vertical Testing of Spoke012-02

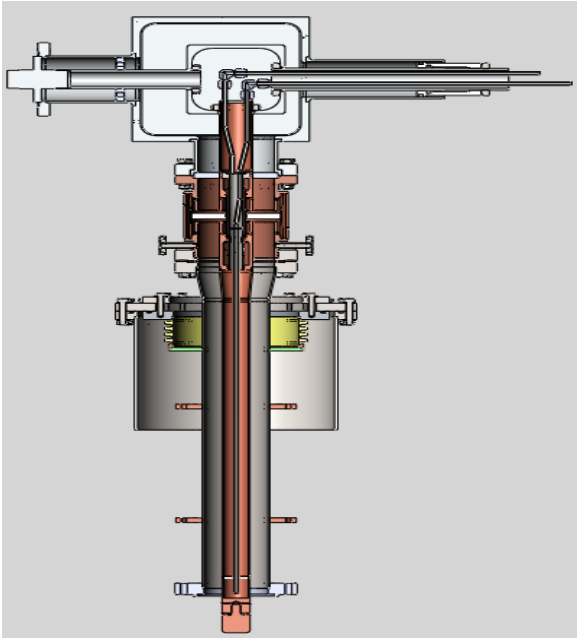


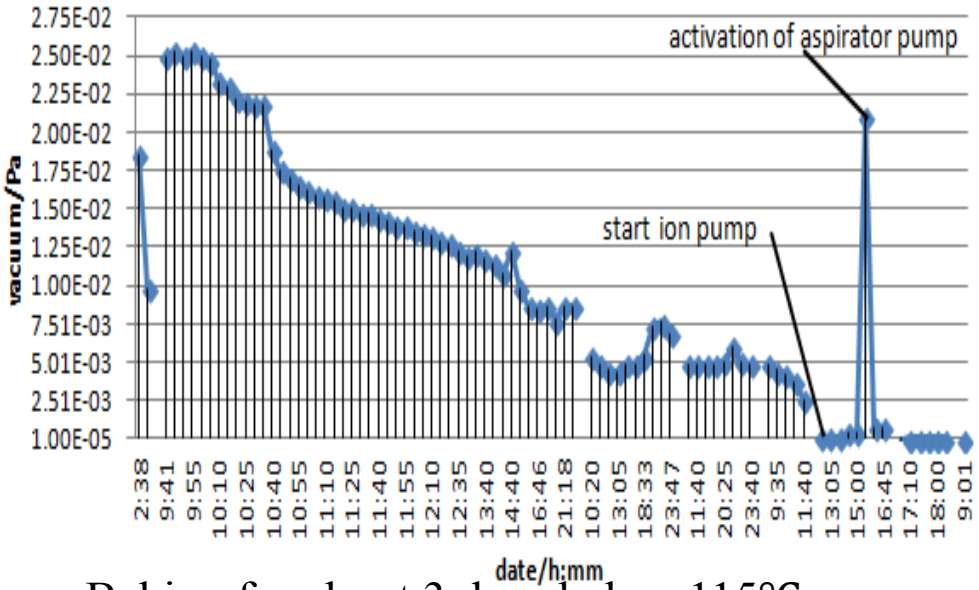


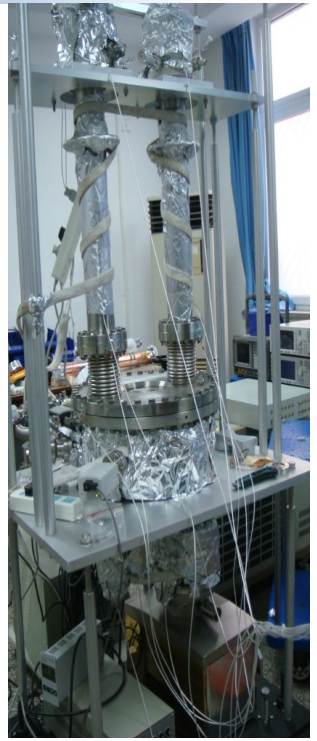
- ✓$Q0=5.8x10^8$ @6MV/m, 4K;
- ✓$Q0=3.4x10^8$ @7MV/m, 4K

No quench but heavy MP and FE.
Testing ended of FE.

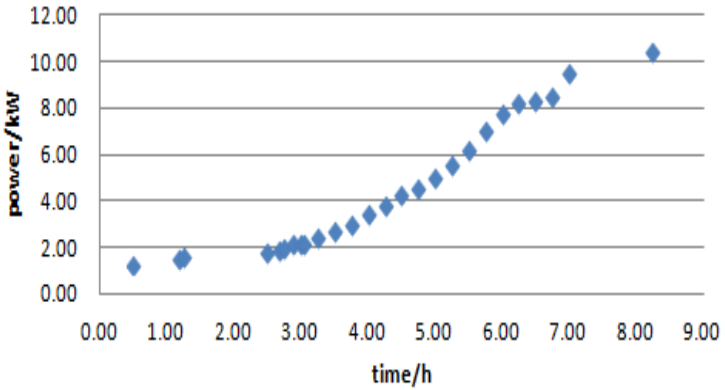
High Power Coupler for HT

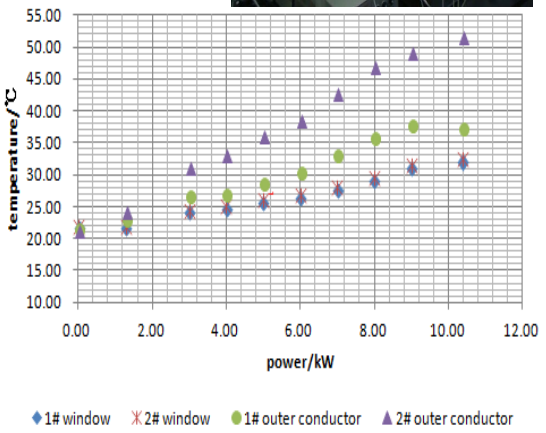






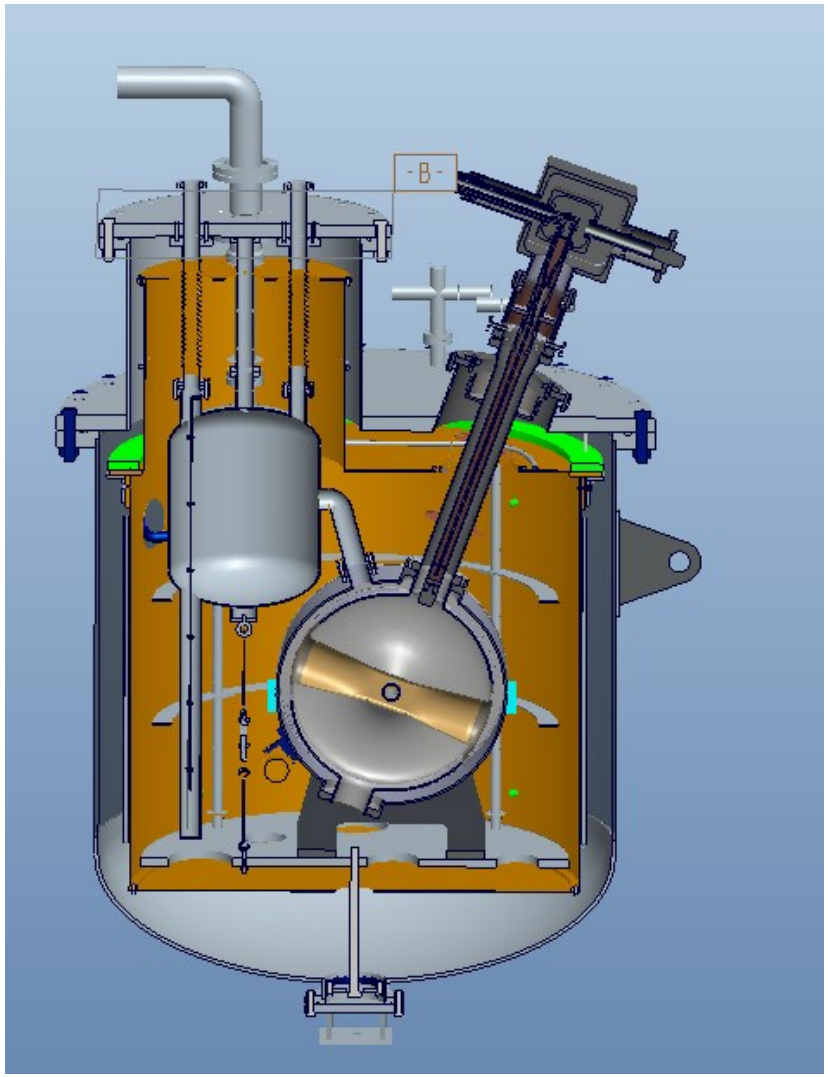
- Baking for about 3 days below 115℃
- Helium leak was better than 9.5E-10 mbarl/s

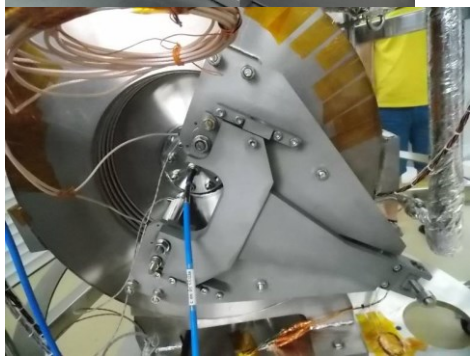




Commissioning with high power

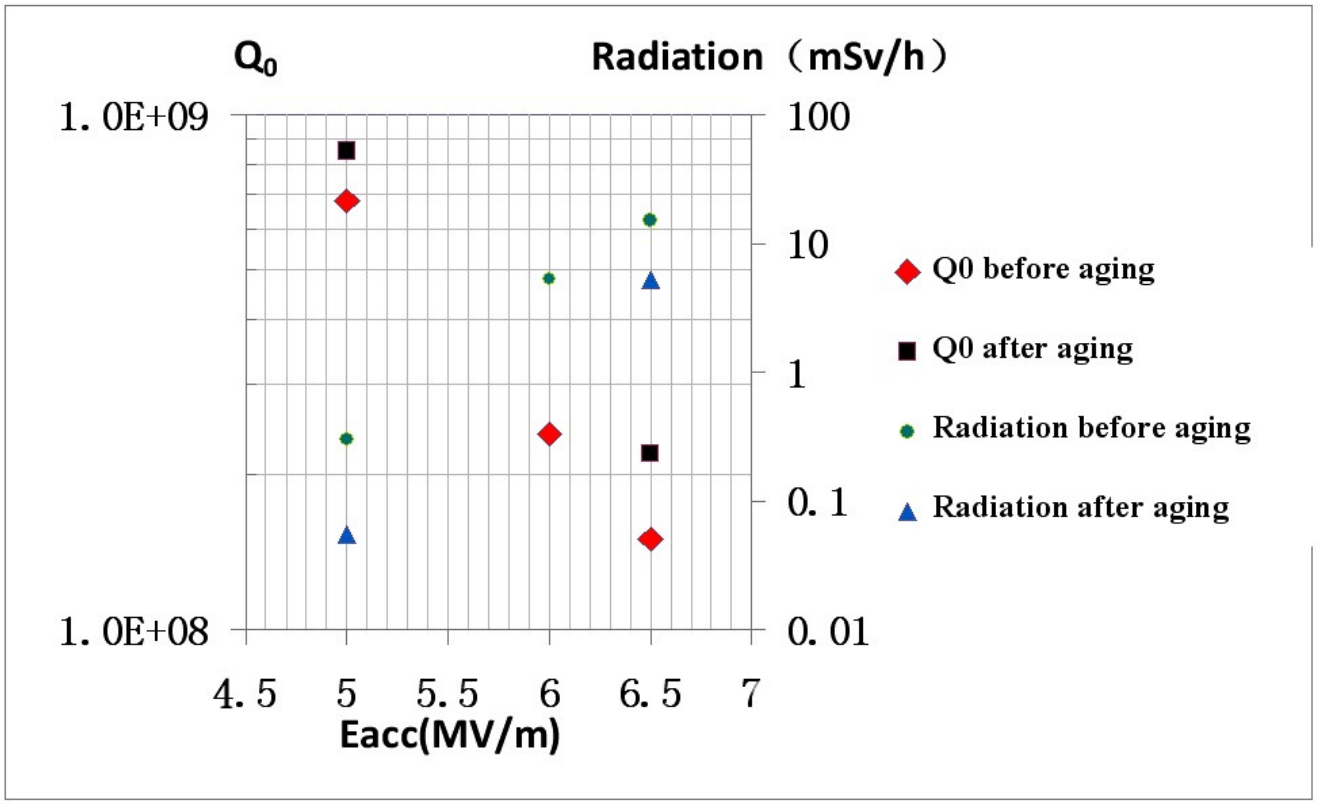
Horizontal Testing of Spoke012-2





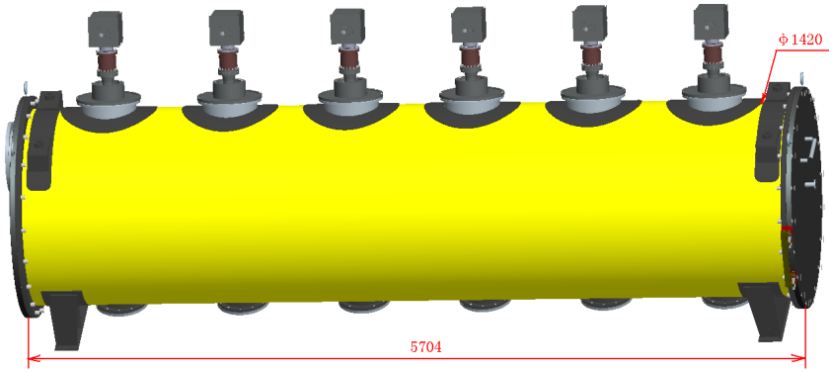
Piezo tuner was used for frequency loop and closed. The tuning range is +/- 1 kHz.
Level meter was used to measure the heat loading. The static loading is 15.1 W.

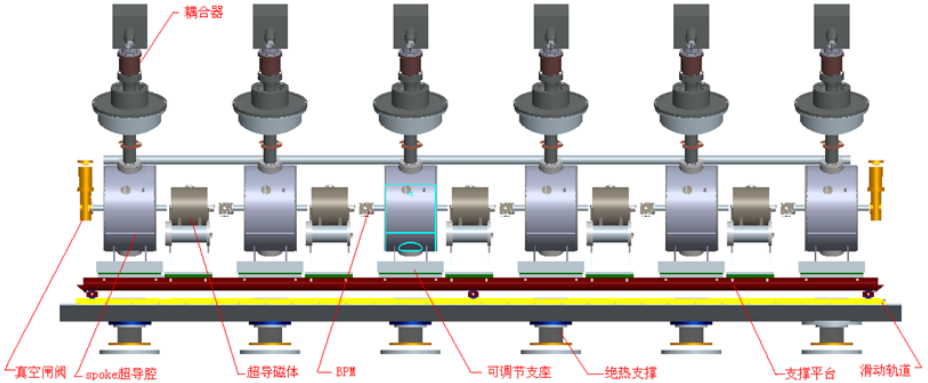
Results of horizontal testing

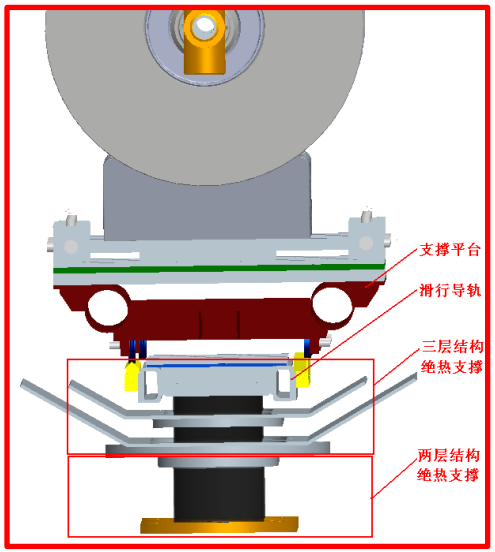


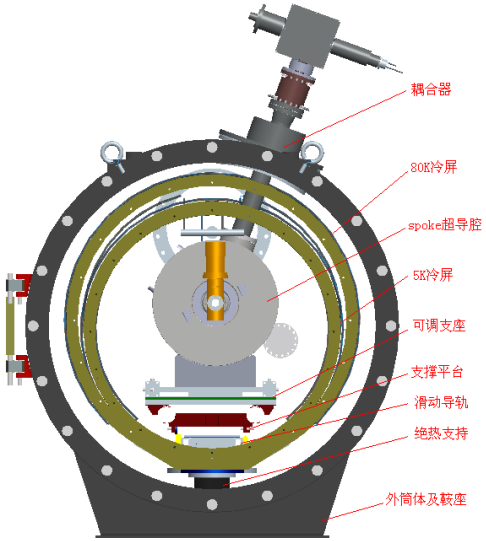
The testing lasted 5 days in Sept. 2013. The heavy multipactor ocured and was overcomed. Q0=2.2E8 was reached at Eacc = 6.5 MeV/m. It just 30% degraded from VT.

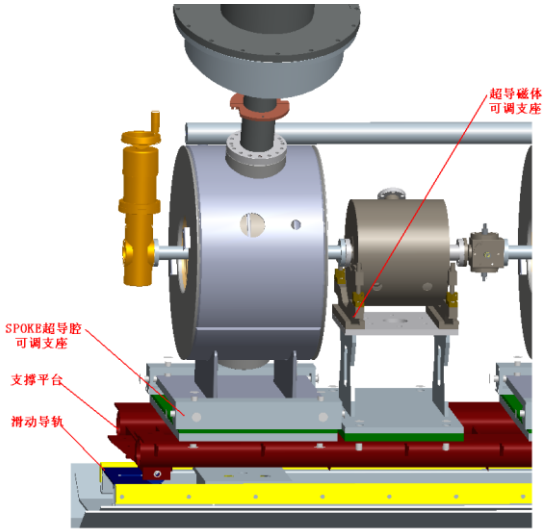
6-cavity Cryomodule for Injector I











5704 mm,6 spokes, 6 couplers, 5 solenoids, 5 BPMs, 2 valves inside

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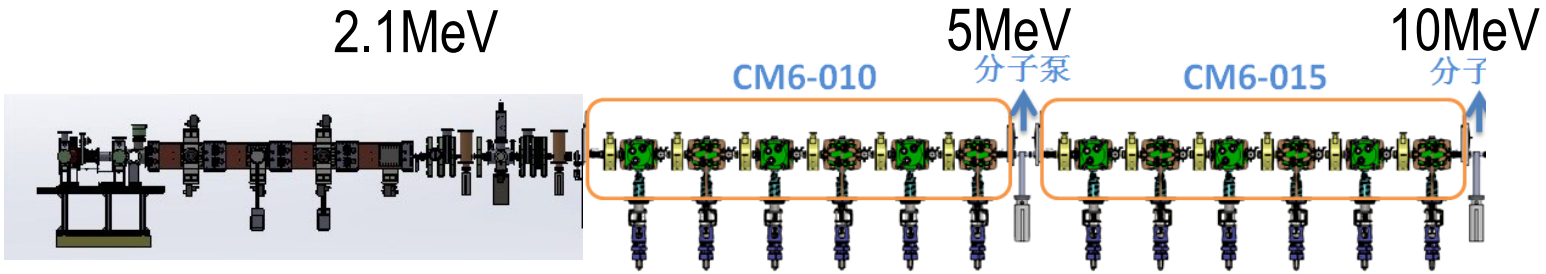
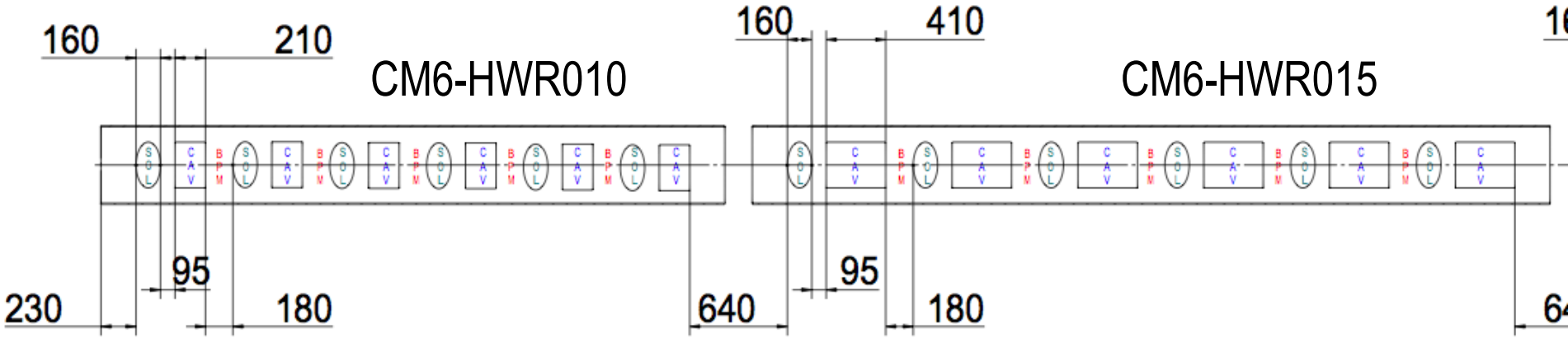
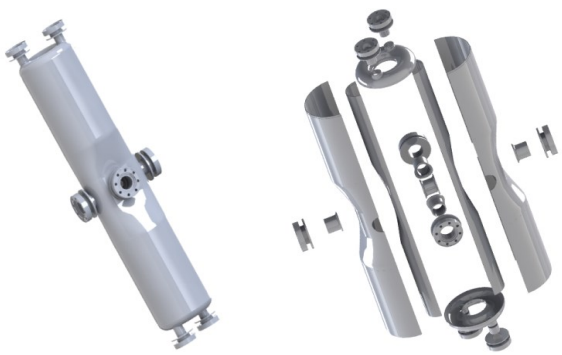
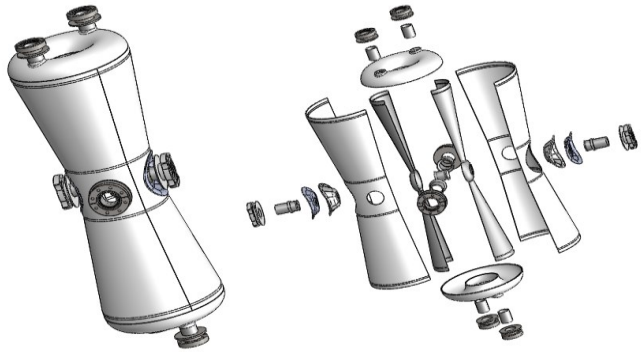
HWRs for Injector II





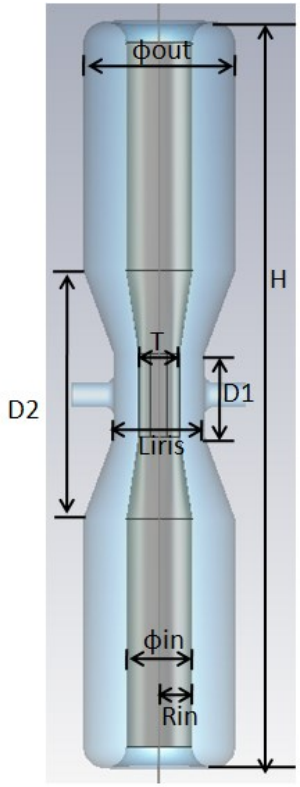


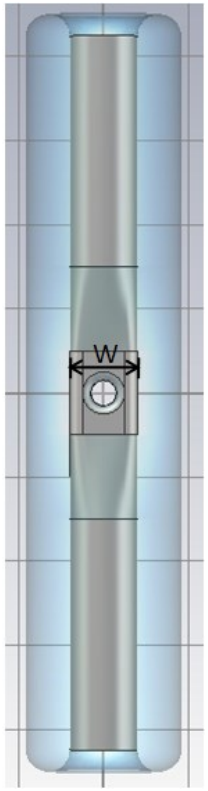
HWR010



HWR015

RF Design of HWR010





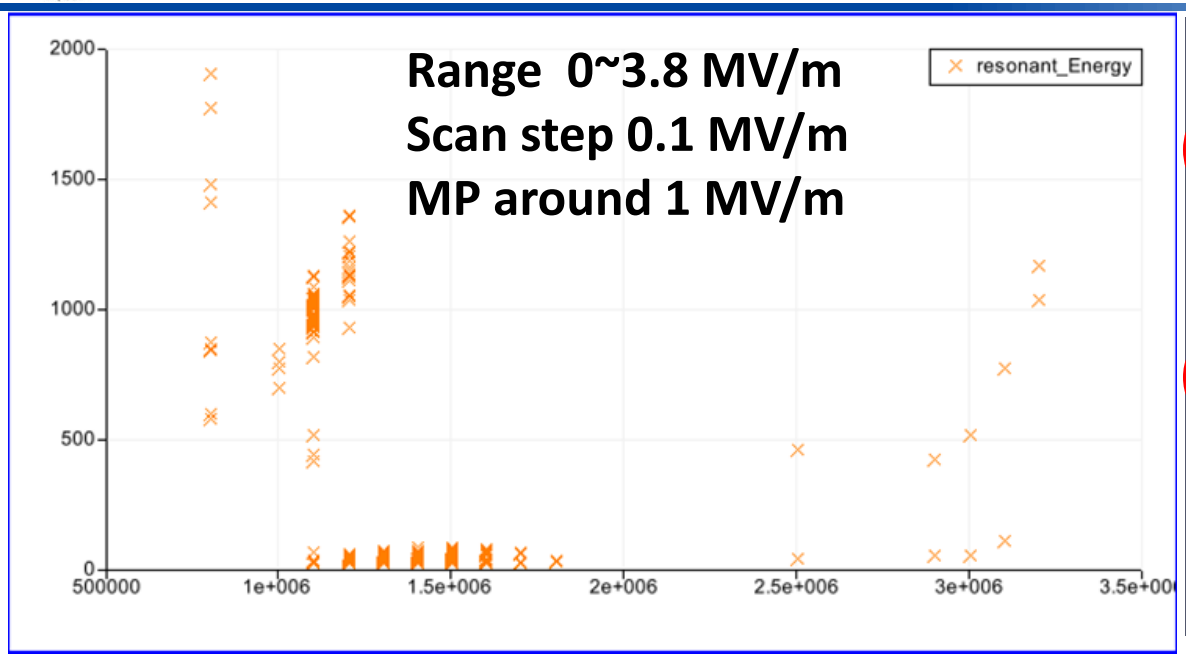
B_{pk}/E_{acc} ; E_{pk}/E_{acc}

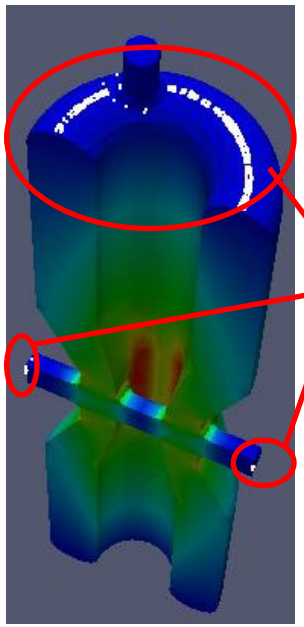
R/Q_0 ; G

Rin (mm)	40
Rout (mm)	92
Liris (mm)	110
T (mm)	45
W (mm)	90
D1	100
D2	300
Rblend2	15

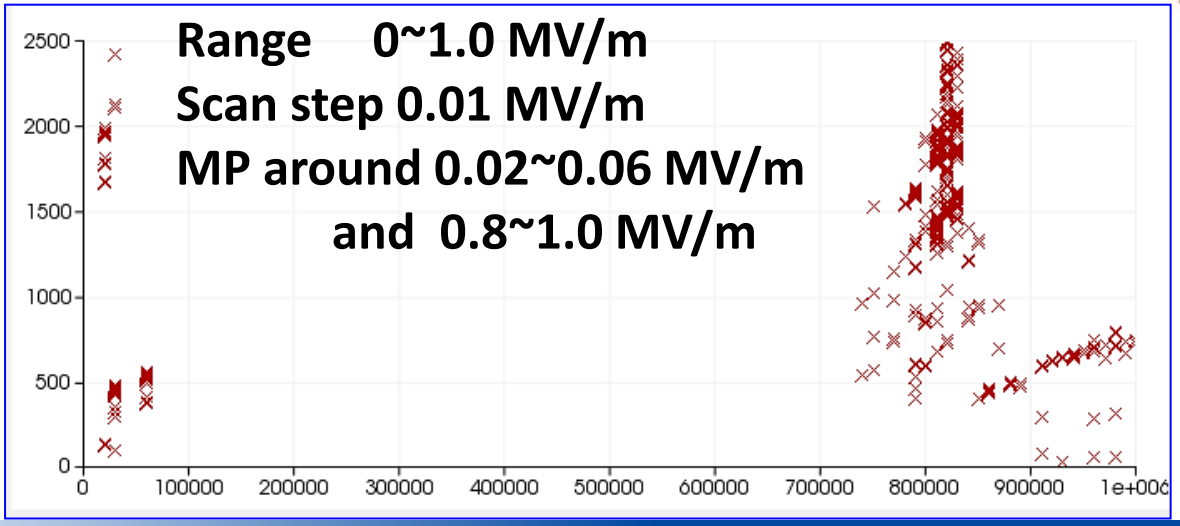
	HWR010 Squeezed
Freq(MHz)	162.5
βopt	0.101
Uacc(MV)	0.78
Eacc(MV/m)	4.5
Epeak(MV/m)	25
Bpeak(mT)	50
G=Rs*Q0(Ω)	28.5

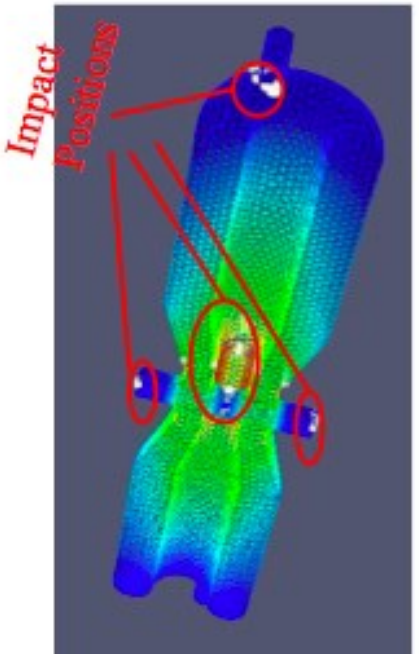
Simulation of Multipacting





Impact Positions





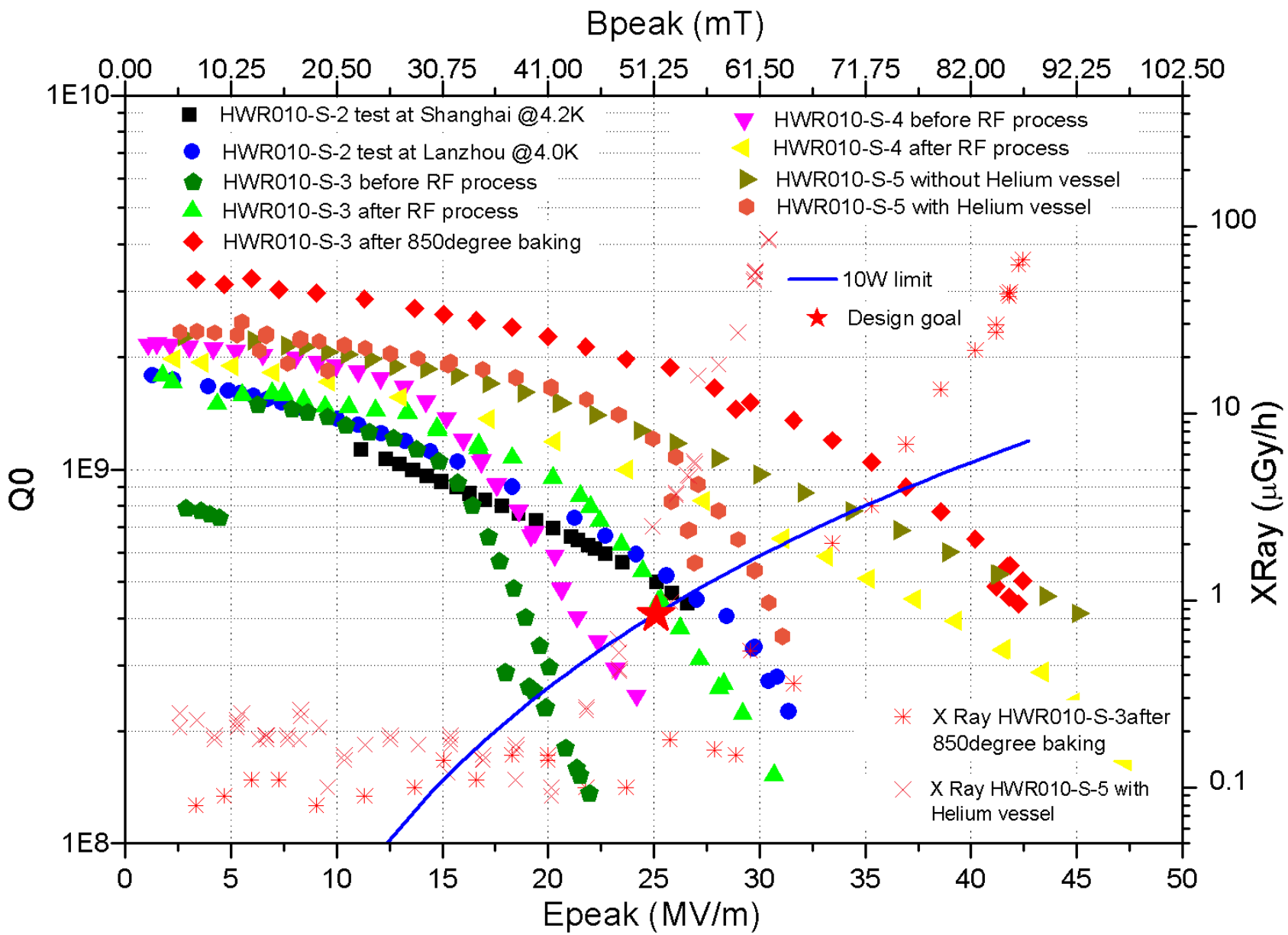
Fabrication of HWRs

- Material
  - OTIC，RRR>300，partly RRR>380
- Drawing, machining and BCP
  - Punching die，Al 7075
  - Surface survey before every step of fabrication
  - BCP (65%HNO_3:40%HF:85%H_3PO_4=1:1:2) 10um, resin by UPW, drying in cleanroom of class 100
  - Polishing every seam and BCP 10um before EBW
- E-beam welding
  - EWB by two different parameters:
    - #01, #02;
    - #03, #04, #05.

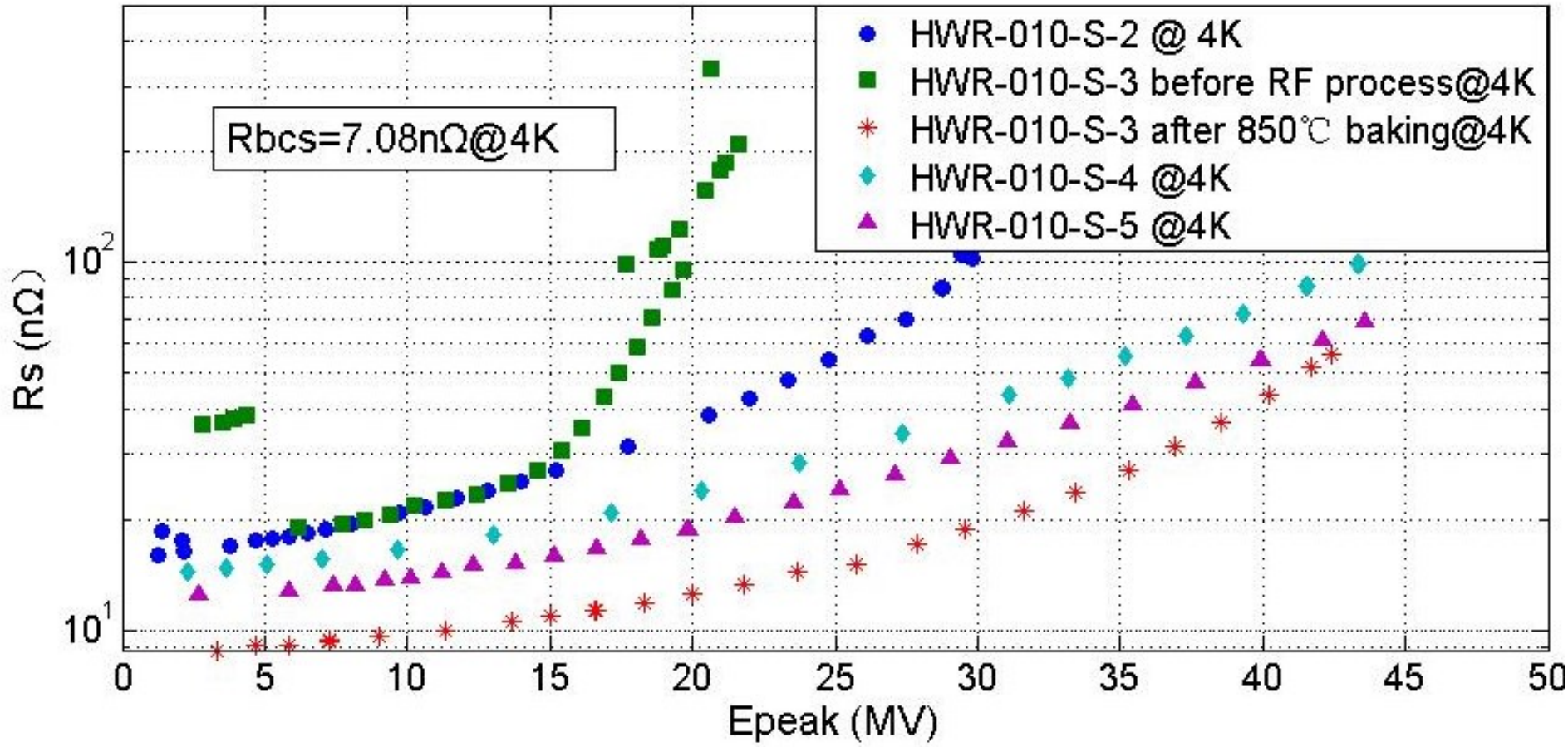
Surface Processing of HWRs

Cavity #	Test #	Bulk removal	Degassing	Light removal	Bake	Addition
2	12/01/12	120 um	680 C 3 hours	20 um	150~250C 48 hours	At SINAP w/o HPR
2	01/29/13	-	-	30 um	200 C 48 hours	At IMP
3	05/18/13	140 um	650 C 10 hours	30 um	120 C 48 hours	
3	07/16/13	-	850 C 3 hours	30 um	120 C 48 hours	
4	06/08/13	130 um	650 C 10 hours	30 um	120 C 48 hours	
5	03/23/13	160 um	650 C 10 hours	30 um	120 C 48 hours	Caps annealing
5	09/09/13	-	850 C	30 um	120 C 48 hours	He Vessel

VT results of HWR010-S-02~05



VT results of HWR010-S-02~05

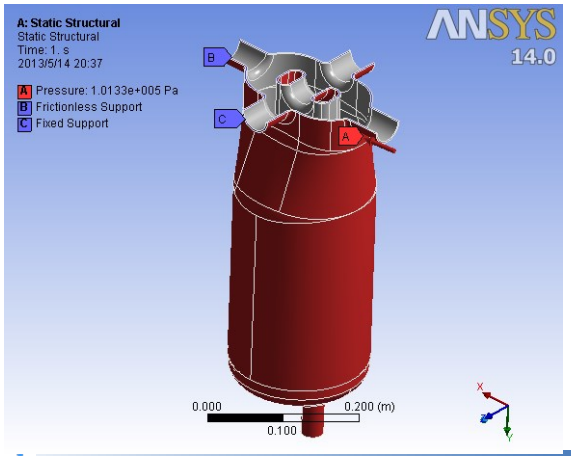


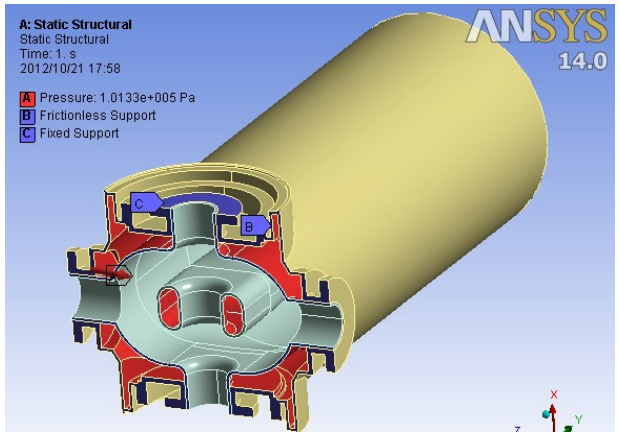
Cryoperm shielding,
< 20 mGs, at room temp.,
<7mT at 4 K, Rmag=0.8 nΩ

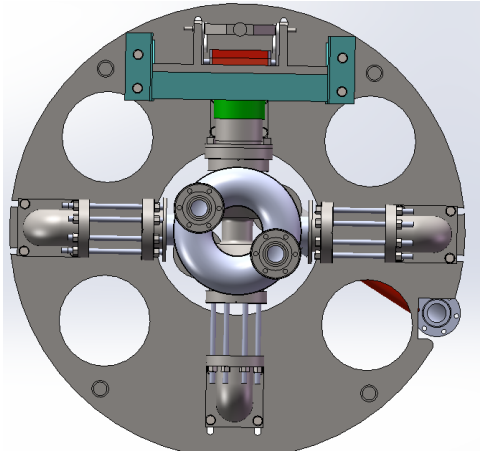
Rs of #5 is around10 nΩ. #3 after 850 C baking is around 2 nΩ.

Mechanical analysis

Cavity	Simulation result		Test result		
	Bared cavity	With He vessel	Bared cavity	With He vessel	
Bandwidth	235.5 Hz		--		
Pressure sensitivity	25.1	14.2	70	50	Hz/mbar
Helium fluctuation (+/-1.5mbar)	37.6	21.3	-	-	Hz
LFD coefficient	-4.66	--	-16.77	-	$Hz/(MV/m)^2$

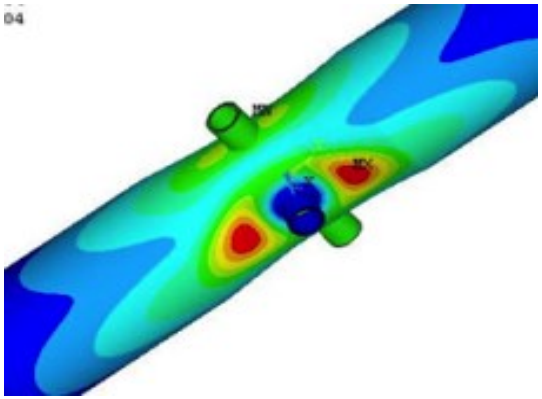






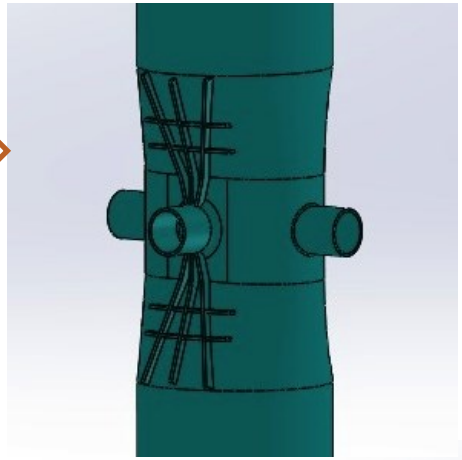
Ribs to reduce df/dp

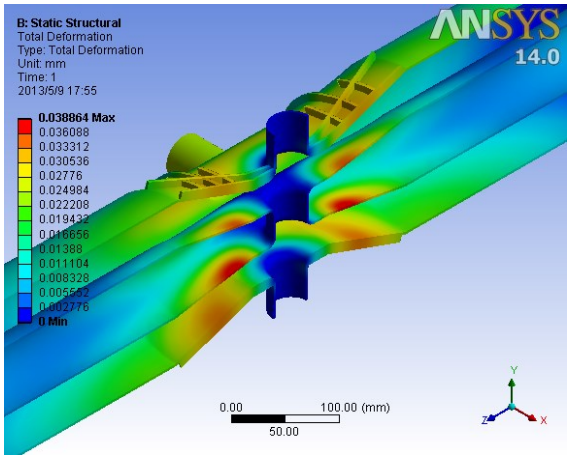
df/dp 70Hz/mbar → Goal → <5 Hz/mbar



<5Hz →

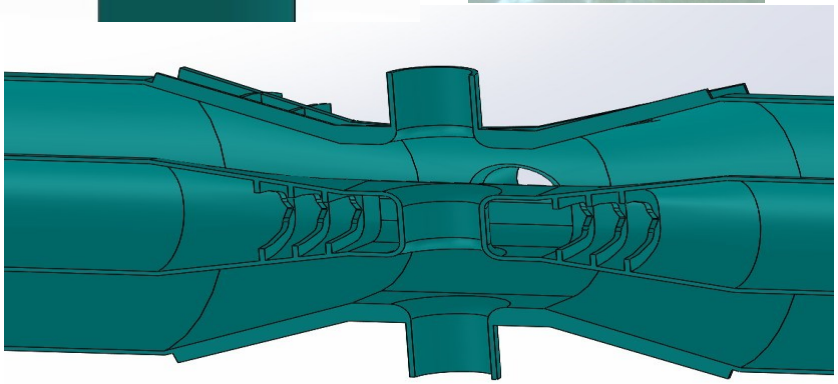
Ribs on one





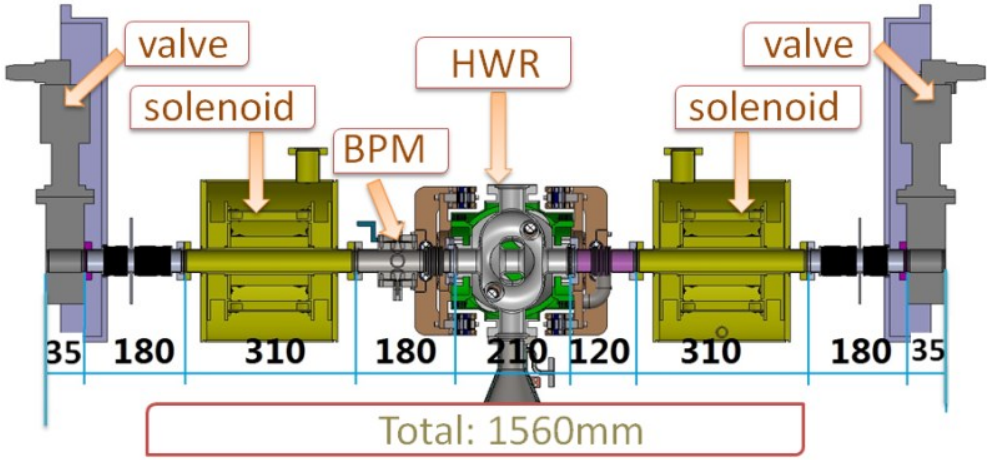
<1Hz →

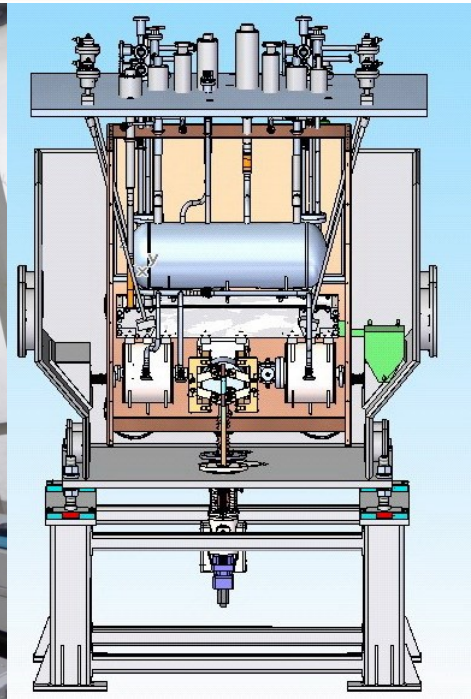
Ribs on both



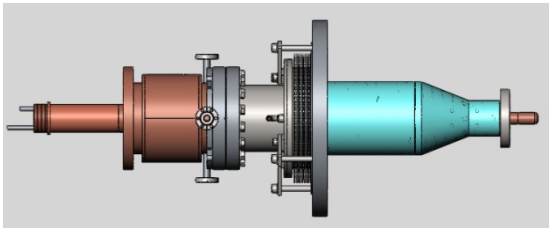
Horizontal Testing of HWR

Op. Temperature	4.4 K
Op. Pressure	1.25 bar
Cooling	bath
Pressure	±1.5 mbar
Dynamic load	10 W
Solenoid storage	27KJ

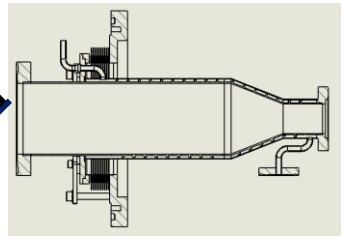




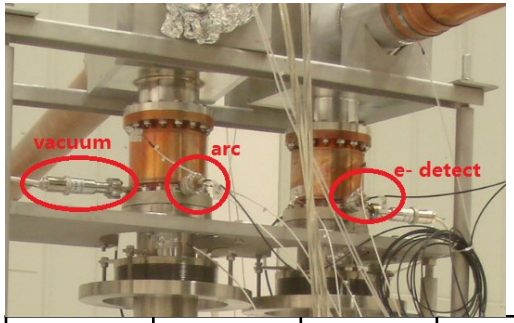
HWR Coupler and high power testing



details



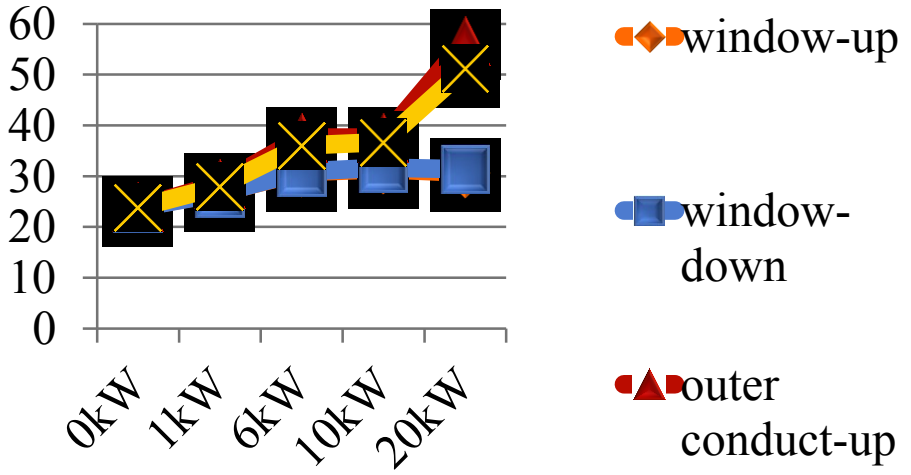
The outer conductor was designed to be cooled by helium gas through the spiral grooves around the outer surface while the inner conductor was cooled by water.



The coupler has passed a RF power of 20kW in continuous travelling wave mode limited by the RF source available.

Spiral grooves

Date	Start time	Stop time	Pf1 max	Elapsed time/hrs
2013-6-1	13:50	20:00	~212W	5.3 hrs
2013-6-2	9:25	16:30	~738W	7 hrs
2013-6-3	9:10	17:17	~Peak 1.3kW	6 hrs
2013-6-4	9:55	23:47	~2.90kW	12.3hrs
2013-6-5	9:10	22:32	~5kW	12 hrs
2013-6-6	9:13	21:56	~9.42kW	8 hrs
2013-6-7	9:07	20:50	~10.6kW	10hrs
2013-6-8	9:13	18:00	~20.0kW	8.6 hrs
Total conditioning time : 63~69 hrs				



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- Introduction of ADS Project in China
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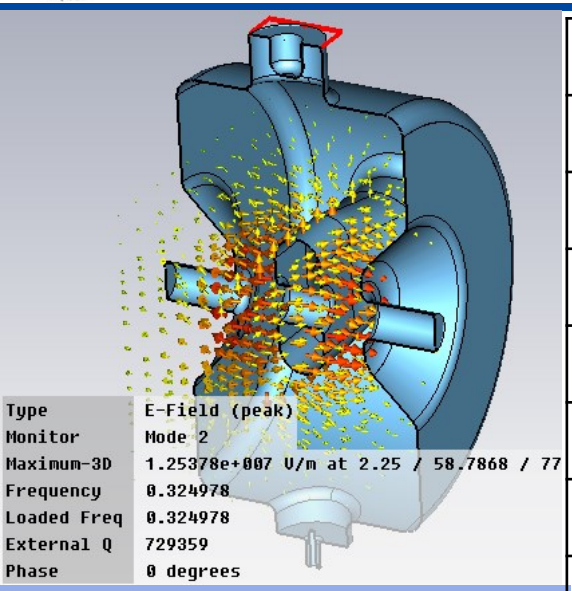
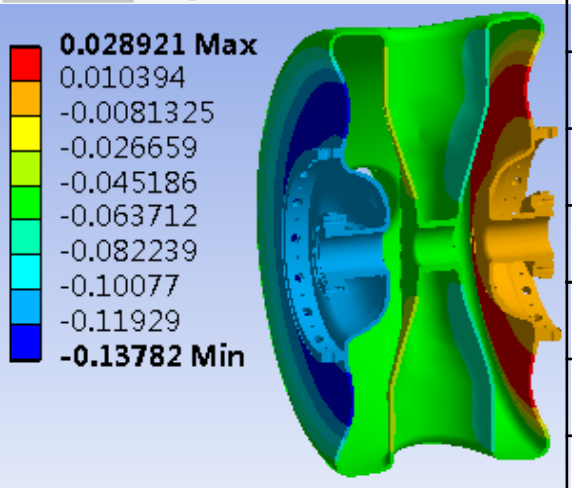
- **Cavities for Main Linac**
  - **Spoke021**
  - Ellip082
- Summary

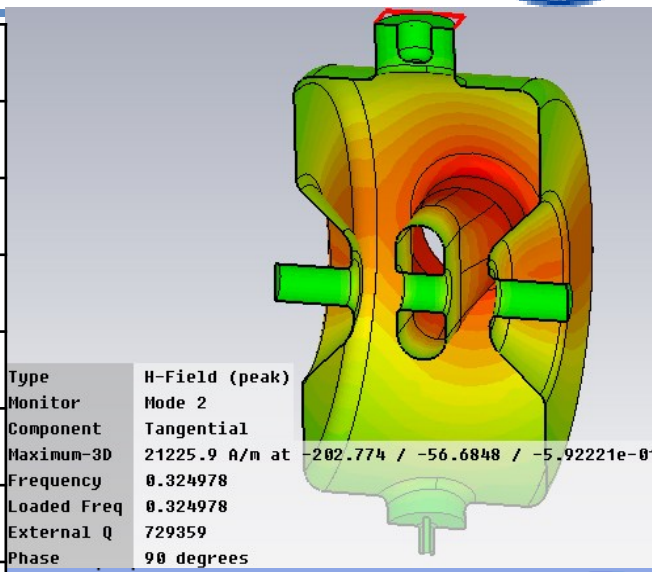
Specifications of Spoke021

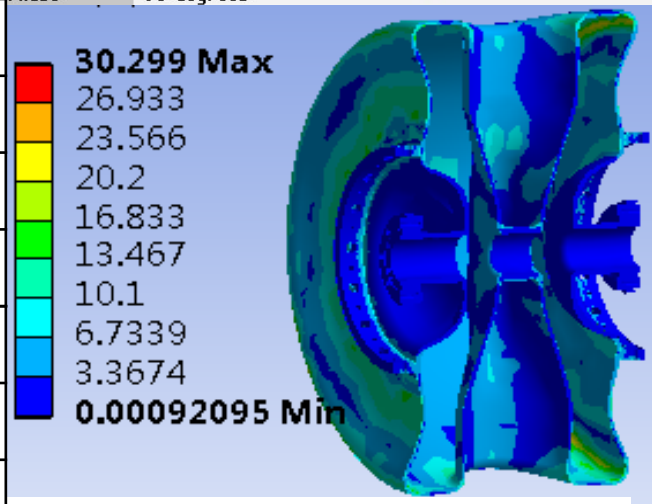


Para.	
E_p/E_{acc} /(void)	3.88
B_p/E_{acc} /mT/(MV/m)	8.13
β_{opt}	0.246
r/Q /Ω	206
G /Ω	87
Df/dL /kHz/mm	632
R_{BCS} /nΩ	0.68
Q0@Rres=5nΩ	1.38E10
$Q_{e,opt}$	7.28E5
Le @$Q_{e,opt}$ /mm	22.3
E_p /MV/m @1J	12.04
H_p /kA/m @1J	21.22
Vc @32.5MV/m /MV	1.75
Vc @65mT /MV /MV	1.58



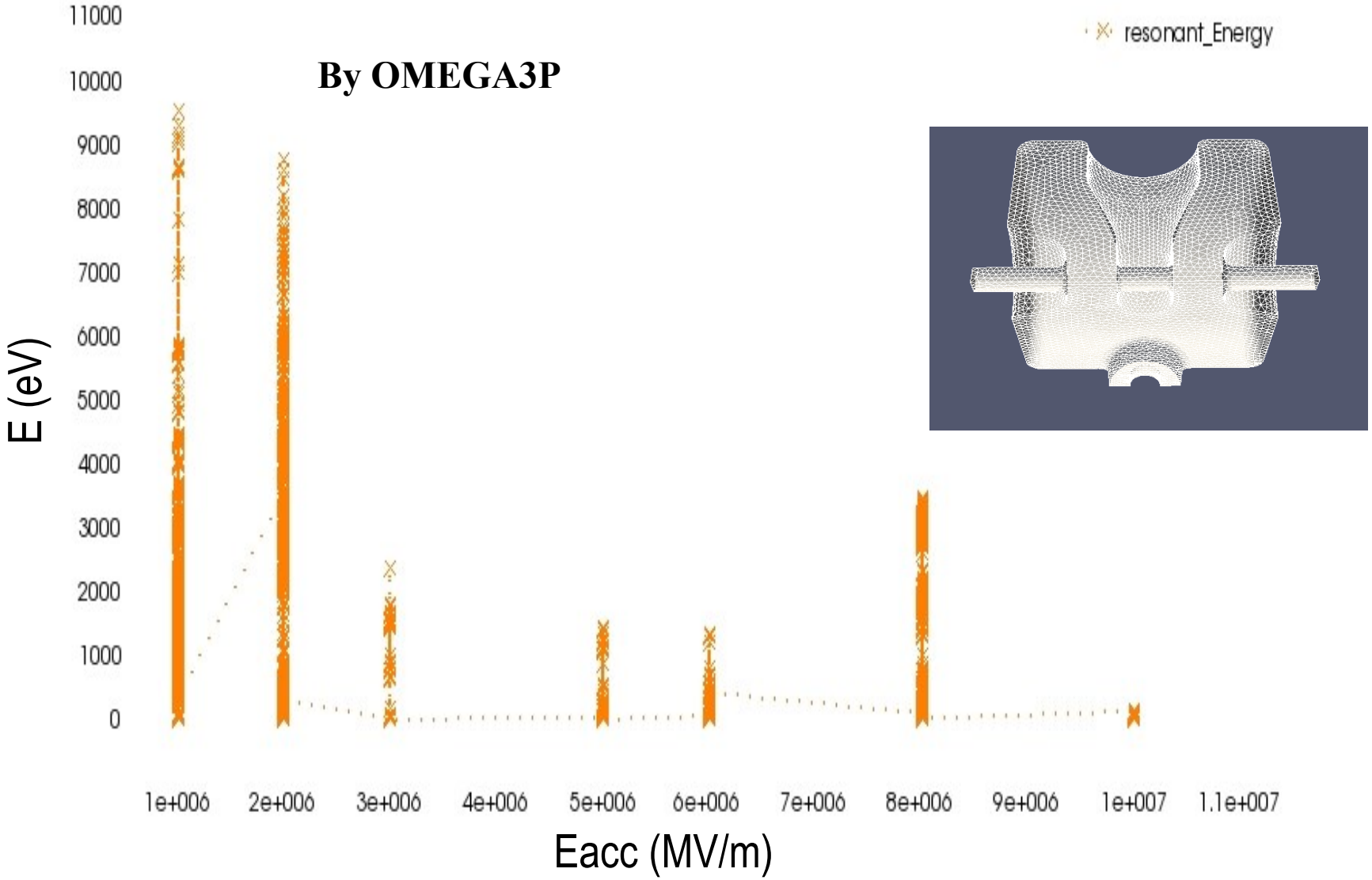
Directional Deformation
@1 atm & 800kg tuning force





Equivalent Stress
@1 atm & 800kg tuning force

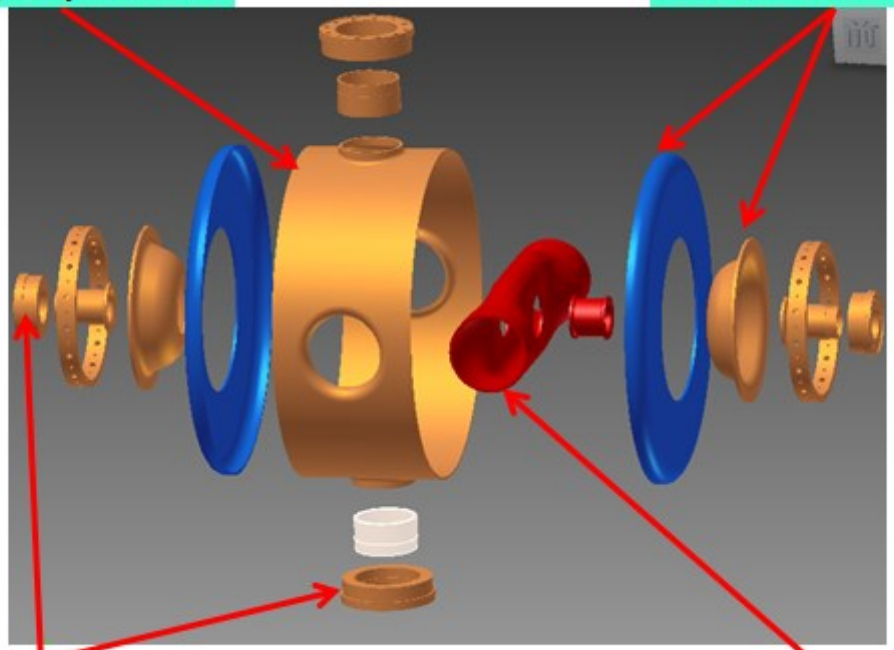
MP Simulation of Spoke021



Fabrication of Spoke021

Rolling the cylinder
Pulling the port blend

Forming the end plate
& nose-cone



Nb SST brazed joint

Squeezing the spoke pole

Ready for VT.

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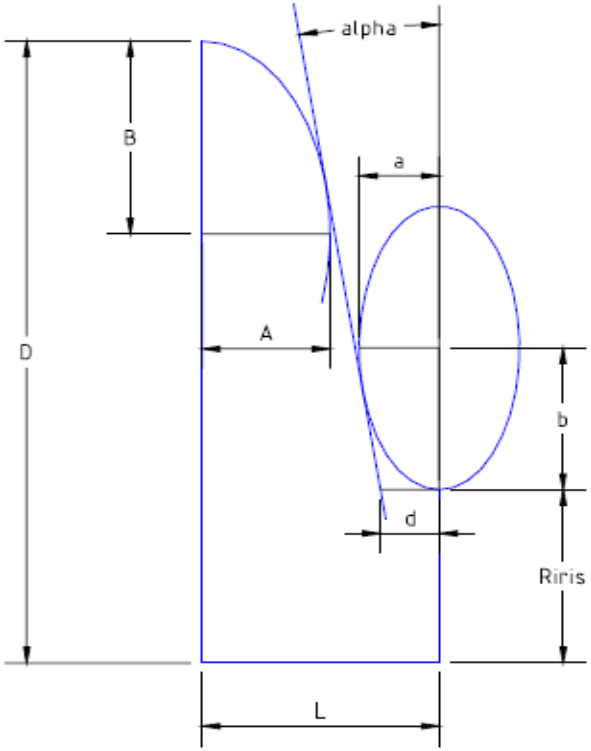
Design of Ellip082

Design Objective： 650MHz 5-cell SC Cavity， Eacc=15MV/m ， Q_0>3E9

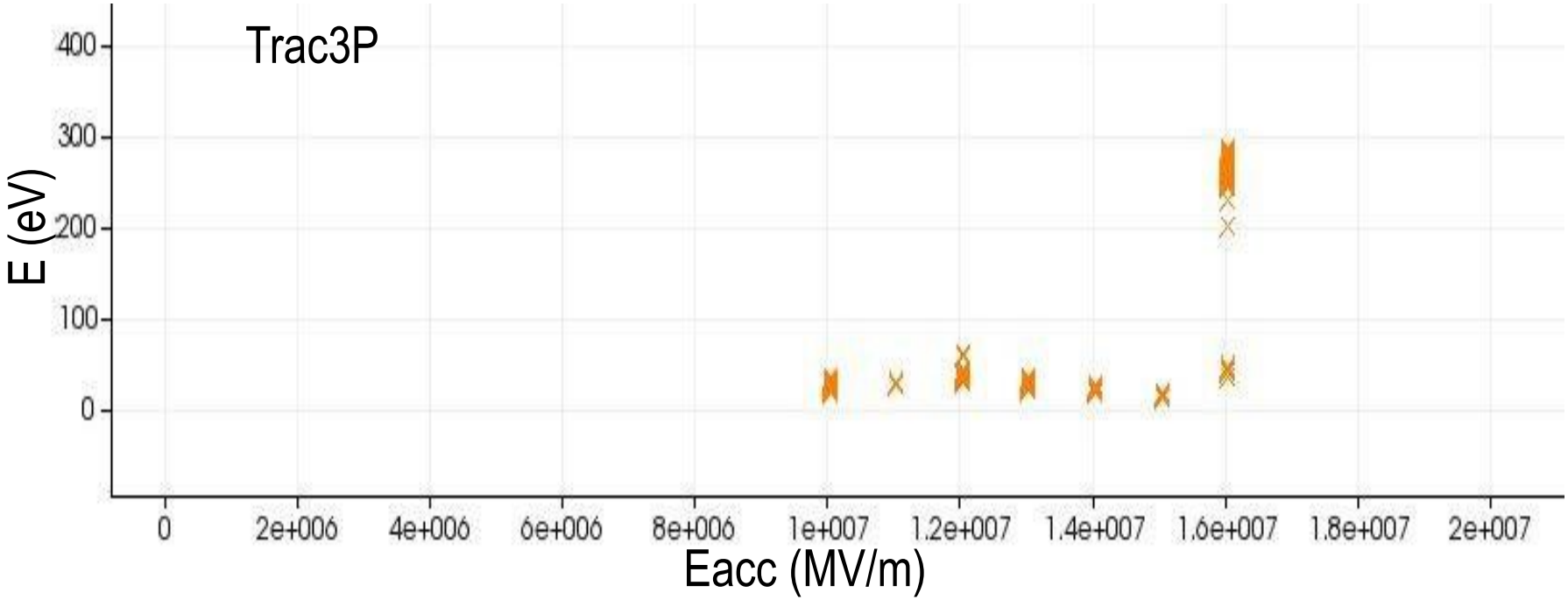
Design Principle：

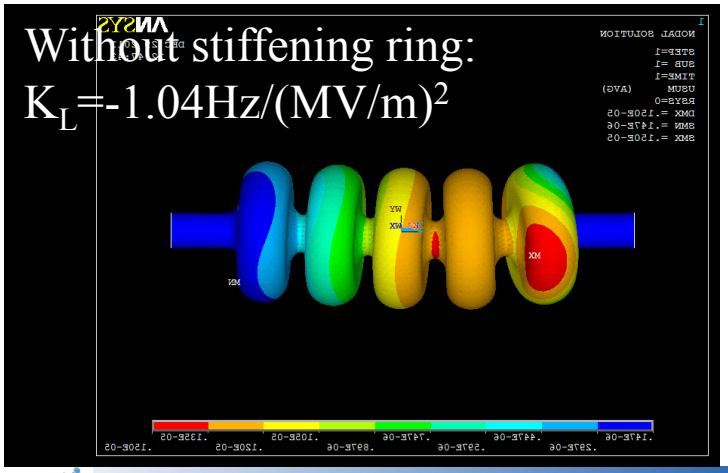
- ✓Large beam pipe and iris
- ✓low Epk/Eacc and Bpk/Eacc
- ✓No MP
- ✓Reasonable Lorentz factor

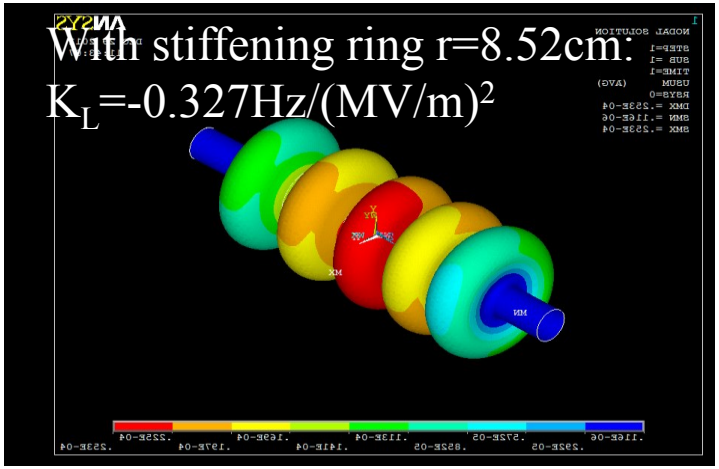


	Center cell	End cell
L (cm)	9.461	9.461
Riris (cm)	5	5
D(cm)	20.0207	20.0207
A(cm)	7.027	7.166
B(cm)	7.027	7.883
a(cm)	1.681	1.667
b(cm)	2.522	2.501
α (°)	7	6.678
E_p/E_{acc}	2.12	
B_p/E_{acc} mT/(MV/m)	4.05	
r/Q [Ω]	514.6	
G [Ω]	235.5	
k [%]	0.9%	
Field flatness [%]	>98	

MP and LF Simulation of Ellip082







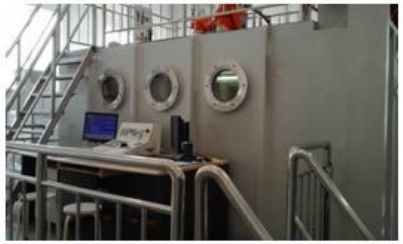
Fabrication of Ellip082

Ultrasonic clean

BCP

Dry in clean room

Encapsulation in clean room



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Summary

- In 2015, ADS project in China will has two 10 MeV, 10 mA and CW superconducting linac commission.
- The prototype of Spoke012 for injector I is qualified with VT and HT. Mass production now! A 6-cavity CM will be assembled and tested with beam by the end of 2014.
- The four cavities of HWR010 for injector II are qualified with VT. Mass production is on going. HT in TCM1 of will be done in early of 2014. And the first 6-cavity CM will be assembled and tested with beam in early of 2015.
- The SRF cavities for main linac are in fabrication and will be tested soon.

PLS read more details in the poster:

THP 021,	Z.Q. Li,	Design of Spoke021
THP 016,	W.M. Yue,	Development of HWR010
THP 081,	S.B. He,	Testing of Tuner for HWR010
THP 028,	P. Sha,	Research on Spoke040
THP 050,	X. Chen,	High Power Coupler for Spoke012
THP 098,	J. Zhang,	LLRF and Data Acq. for VT of Spoke012

Thanks!