

中国科学院高能物理研究所

SRF2013, 26th Sept., 2013, Paris

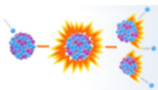
SRF Cavities for ADS Project in China

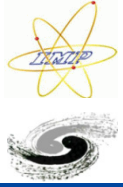
Y. He, W. Yue, S. Zhang, and Linac Group

Institute of Modern Physics (IMP)

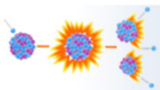
W. Pan, J. Dai, Z. Li, Z. Liu, and RF Group

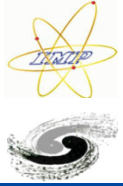
Institute of High Energy Physics (IHEP)





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

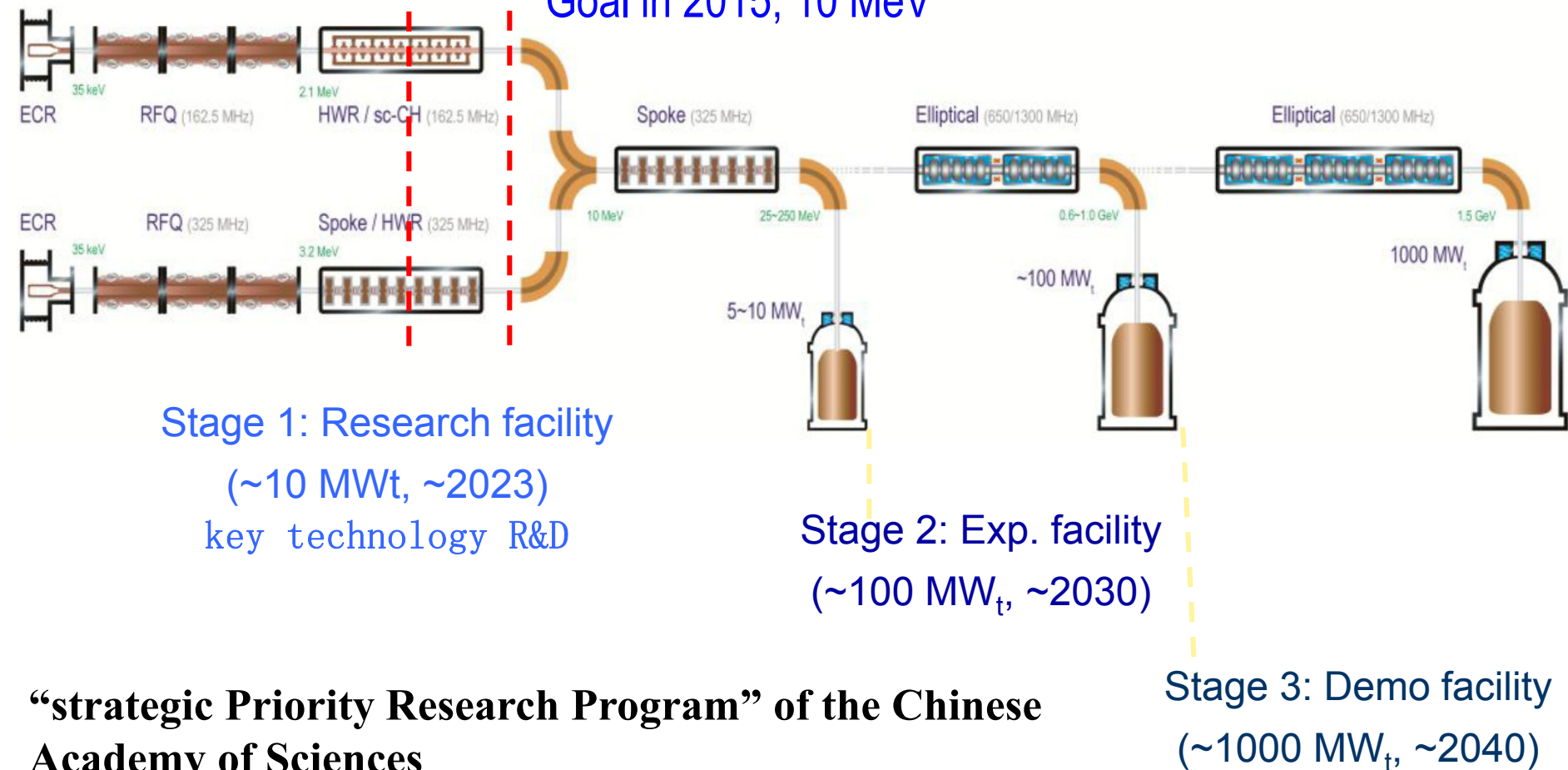




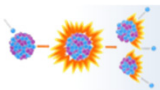
Roadmap of ADS Project in China

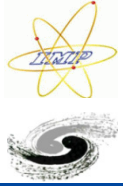
Goal in 2014, 5 MeV

Goal in 2015, 10 MeV

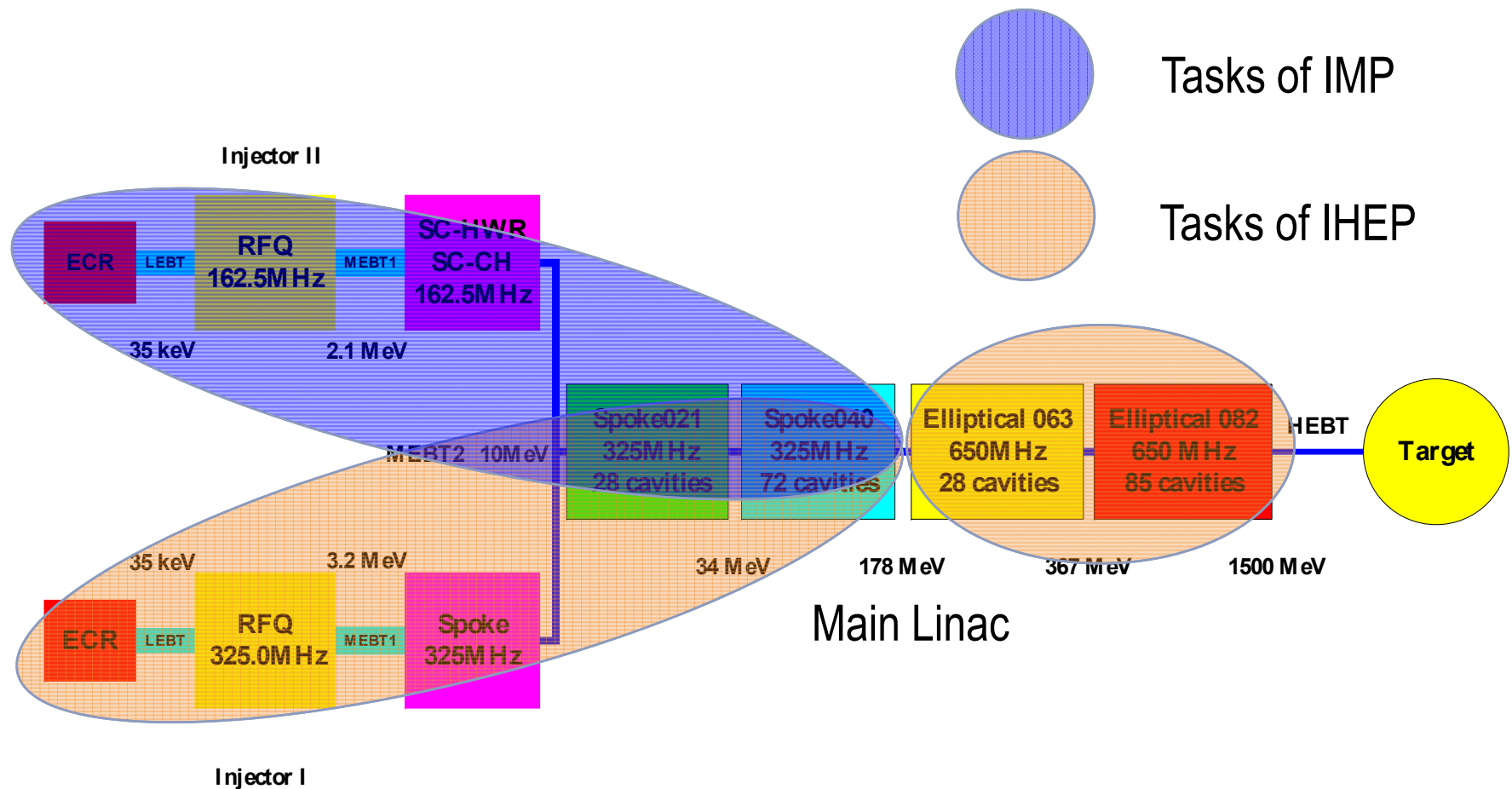


“strategic Priority Research Program” of the Chinese Academy of Sciences

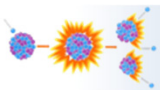


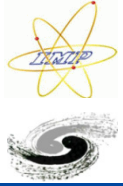


Layout of Accelerator for C-ADS



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.





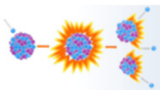
General Specifications of the Cavities

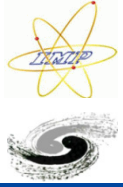


	Spoke 012	HWR 010	HWR 015	Spoke 021	Spoke 040	Ellip 063	Ellip 082	Unit
Freq.	325	162.5	162.5	325	325	650	650	MHz
βg	0.12	0.09	0.14	0.21	0.40	0.63	0.82	-
Aperture	35	40	40	50	50	100	100	mm
Uacc	0.82	0.78	1.82	1.64	2.86	10.26	15.63	MV
Epeak	32.5	25	32	24/31	25/32	29/38	28/36	MV/m
Bpeak	46	50	40	50/65	50/65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

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

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

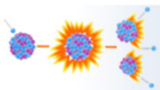


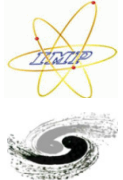


Contents

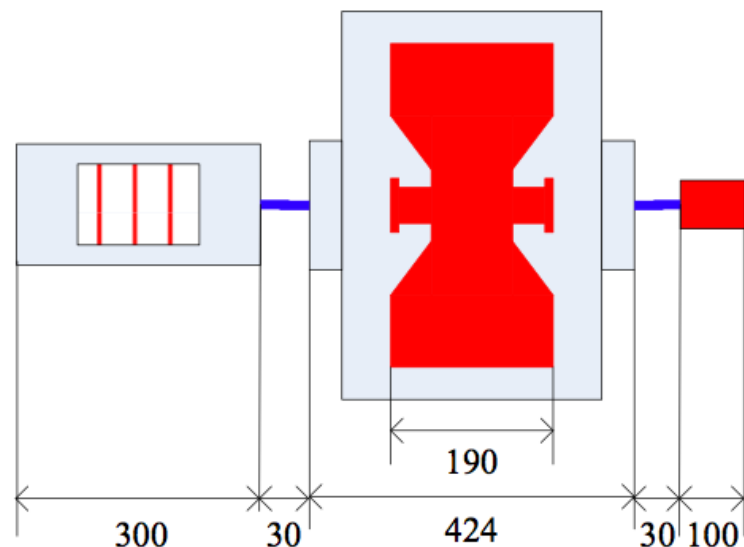
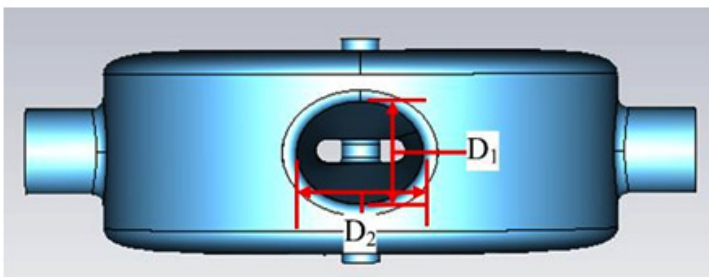
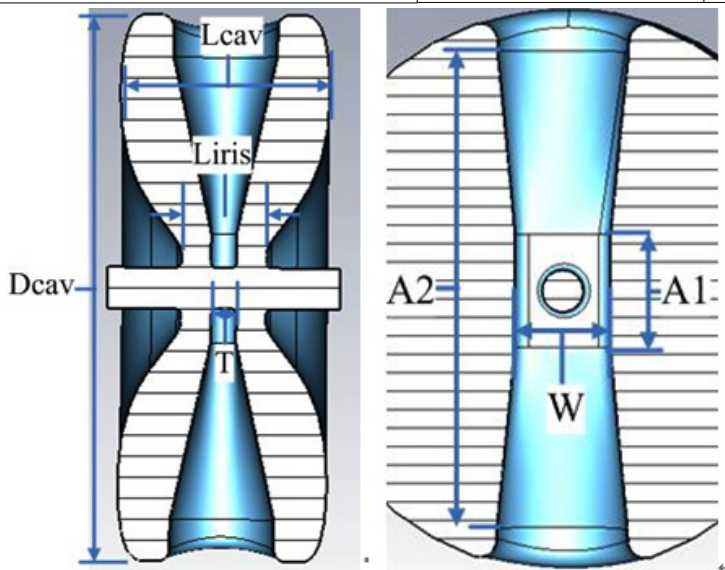
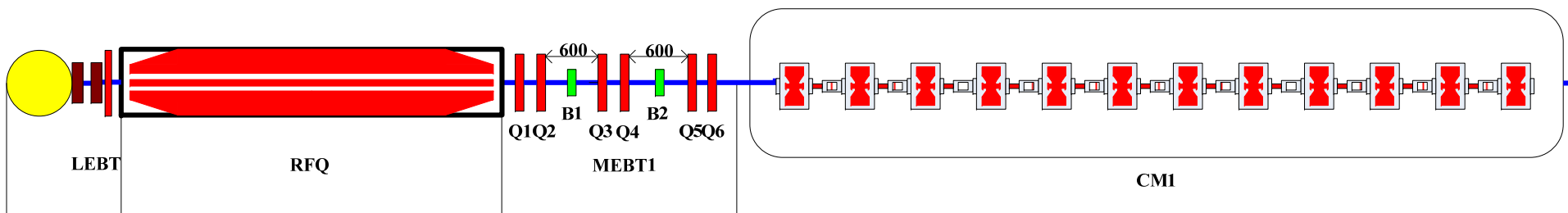


- Introduction of ADS Project in China
- **Spoke012 for Injector I**
- HWR010 for Injector II
- Spoke021 and Ellip063 for Main Linac
- Plan for the future

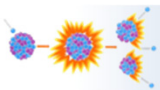


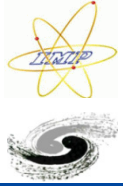


Spoke012 for Injector I



Jointly designed and fabricated by IHEP, PKU, and HIT



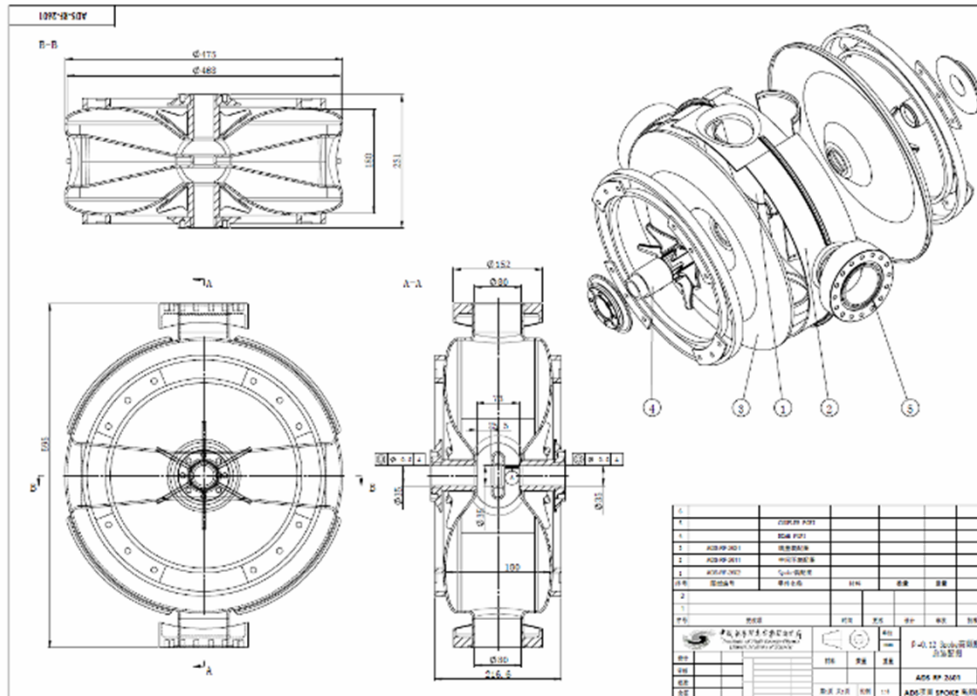


Design of Spoke012

Parameter

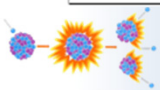
Value

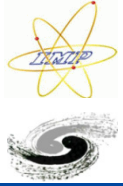
Frequency	325 MHz
G	61 Ω
R/Q ₀	142 Ω
E _{peak} /E _{acc}	4.5
B _{peak} /E _{acc}	6.4 mT/(MV/m)



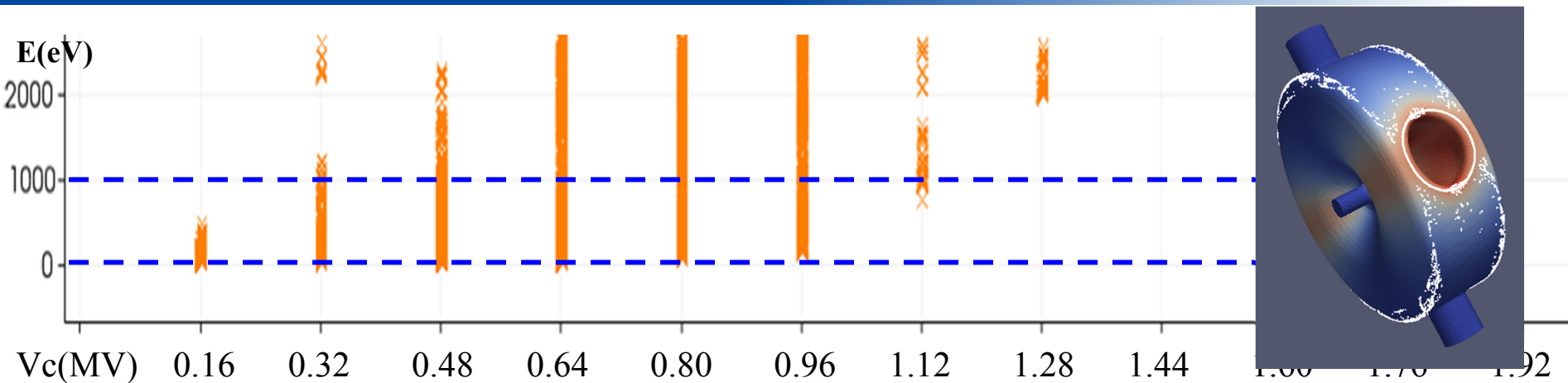
Geometry Parameters

Parameter	Value
T	22
W	82
D	90
Factor	1.25
R1in	47
R2in	199
R1out	35
R2out	164
Lcav	180
Liris	73
R	234

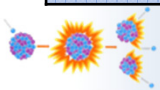


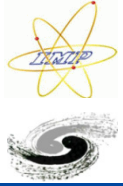


Simulation of Mutipacting and Detuning

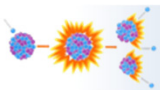
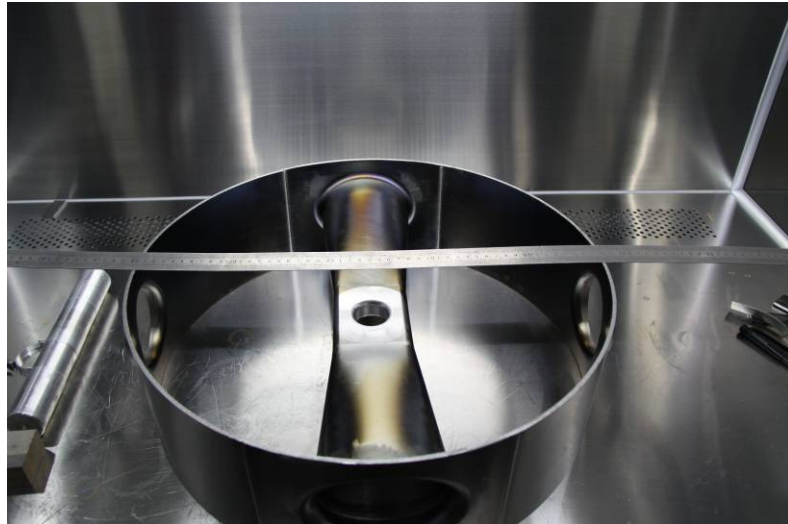
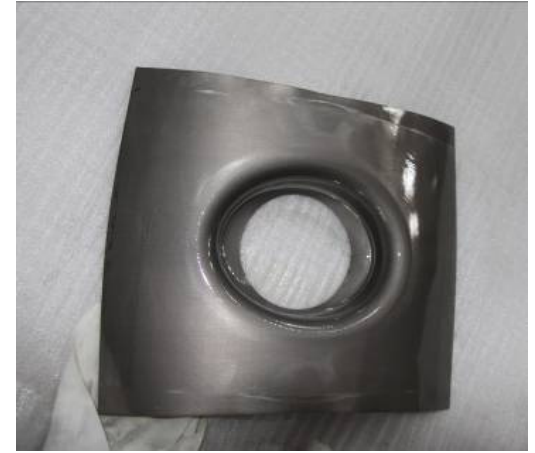
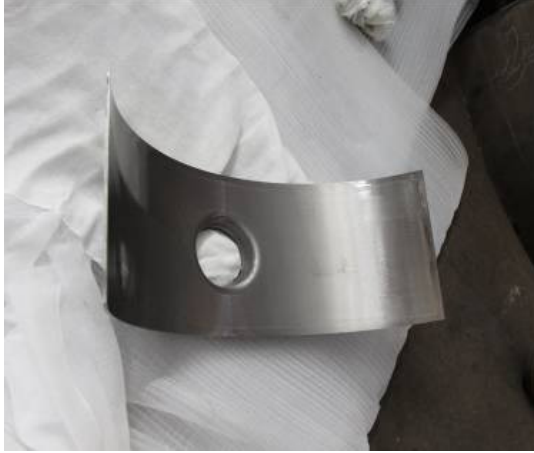


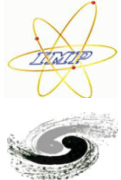
Ports free or locked	Stiff ribs	At 1 atm			df/dP (kHz/torr)
		Peak deform.(mm)	Peak stress (MPa)	Frequency shift (MHz)	
Free	No	3.256	157	-8.28	-10.9
Locked	No	0.218	389	-0.21	-0.278
Free	1 st	0.11	<44.3	0.049	0.065
Locked	1 st	0.065	<45.6	-0.044	-0.058
Free	2 nd	0.848	89	-1.7	-2.24
Locked	2 nd	0.11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



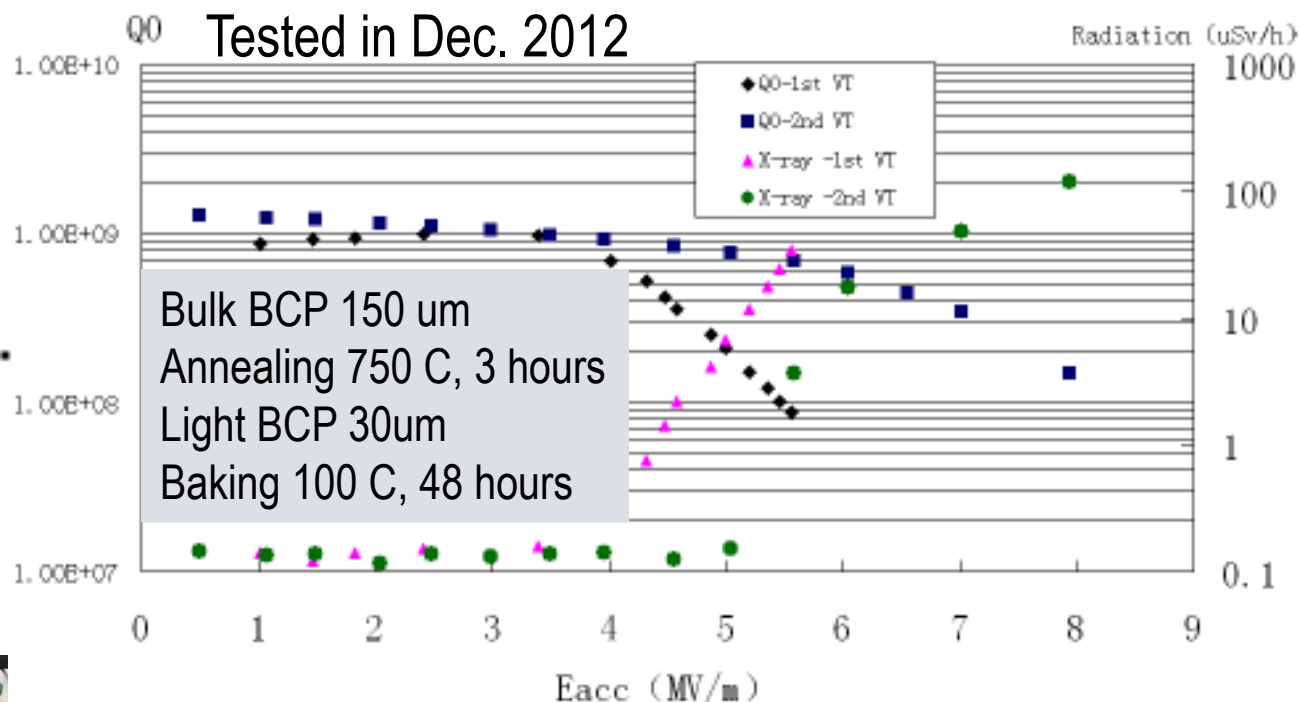


Fabrication of Spoke012





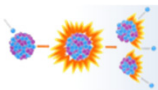
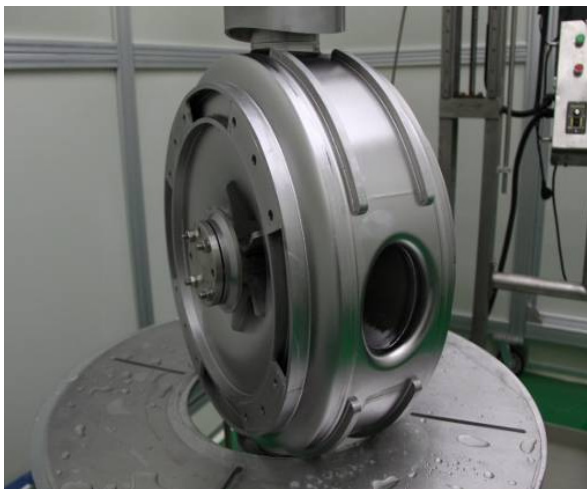
Vertical Testing of Spoke012-02

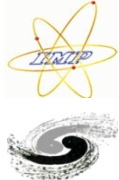


✓ $Q_0 = 5.8 \times 10^8$ @ 6 MV/m, 4K;

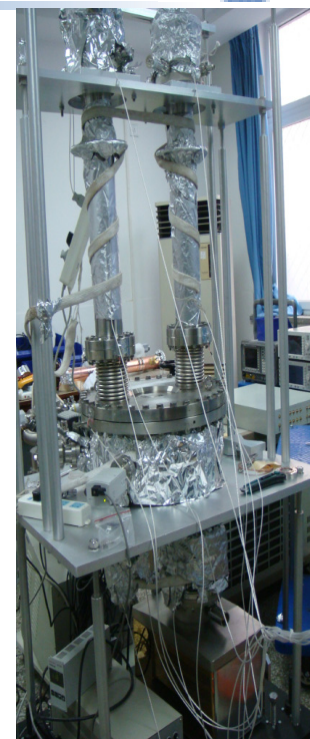
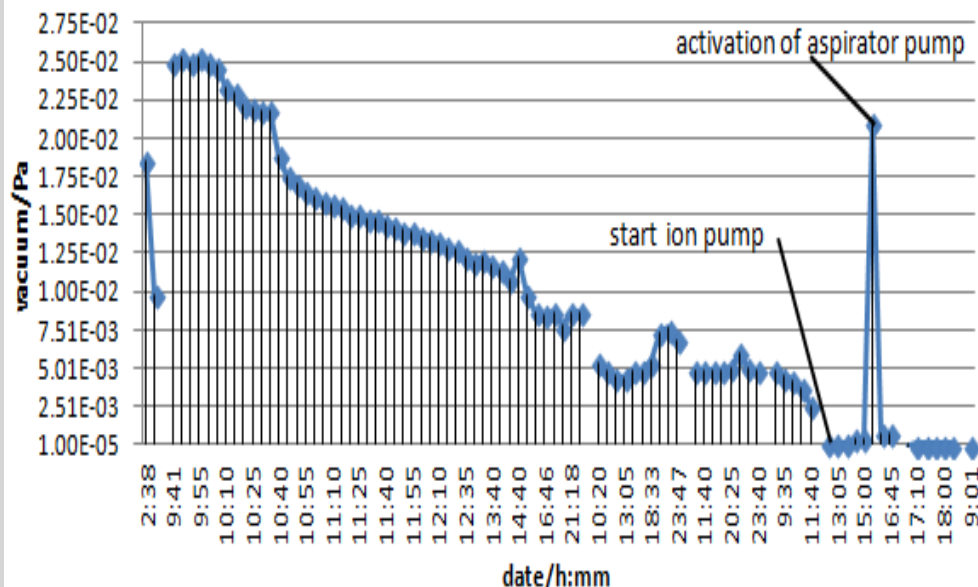
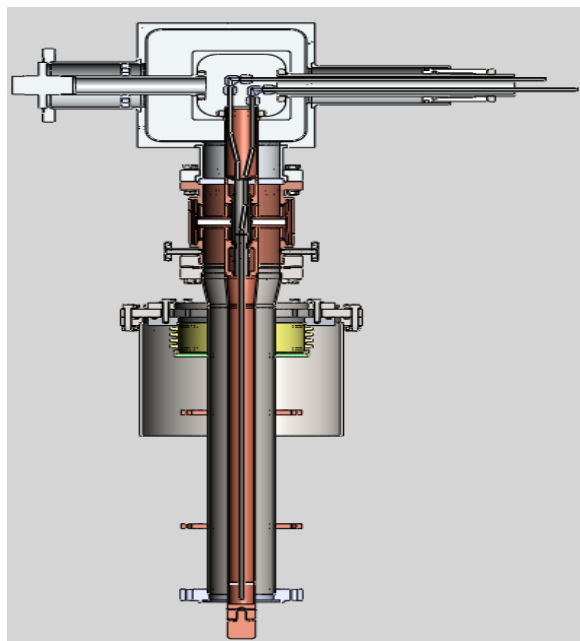
✓ $Q_0 = 3.4 \times 10^8$ @ 7 MV/m, 4K

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

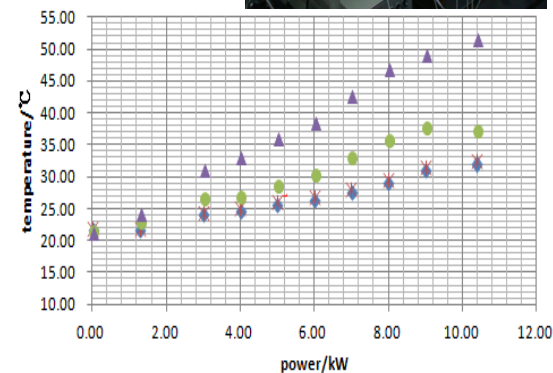
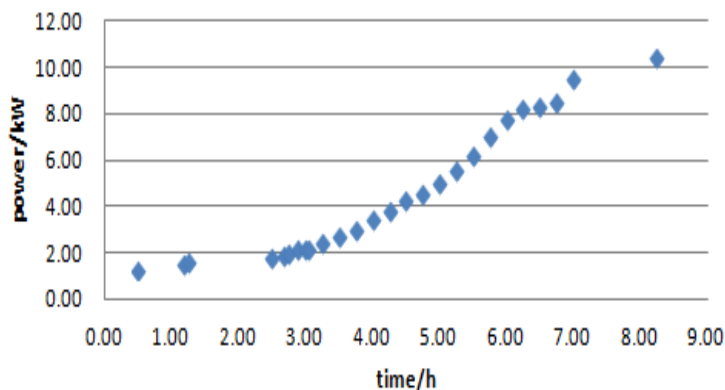




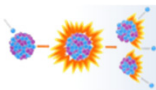
High Power Coupler for HT

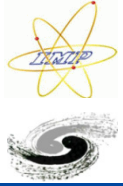


- Baking for about 3 days below 115°C
- Helium leak was better than 9.5E-10 mbarl/s

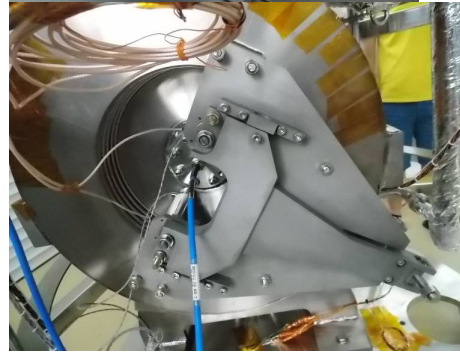
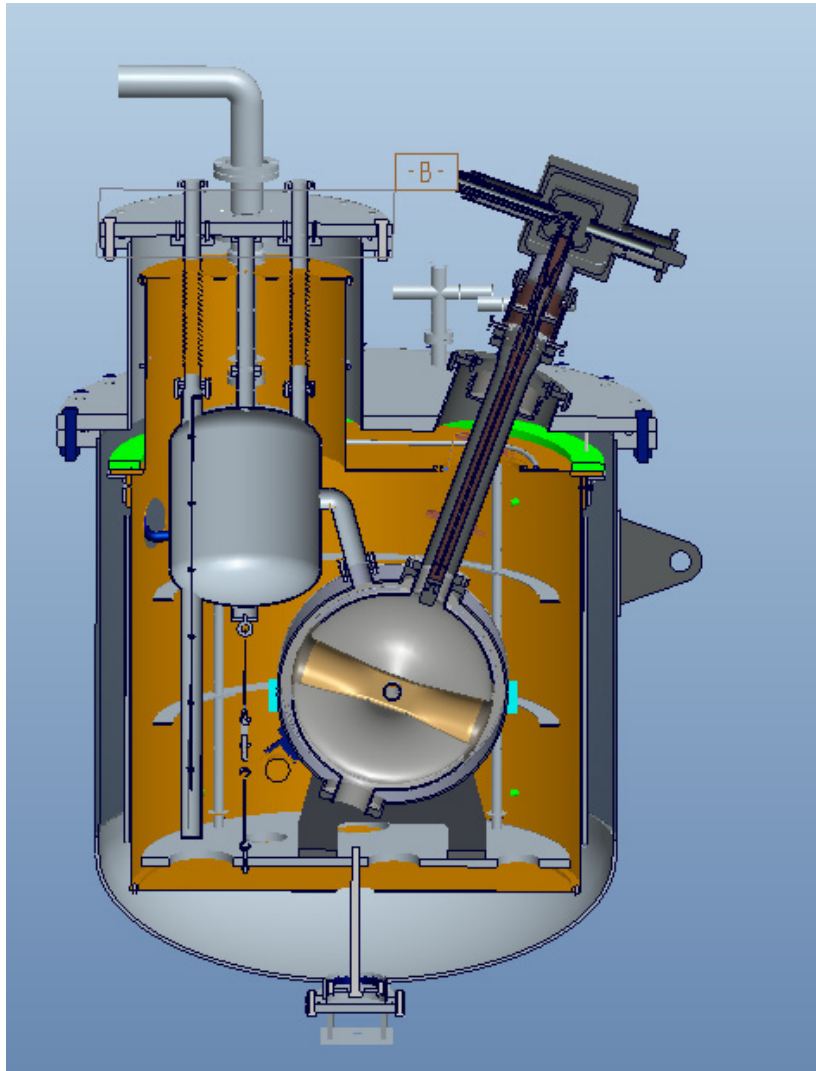


Commissioning with high power

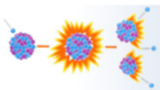


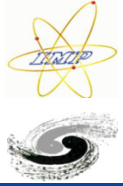


Horizontal Testing of Spoke012-2

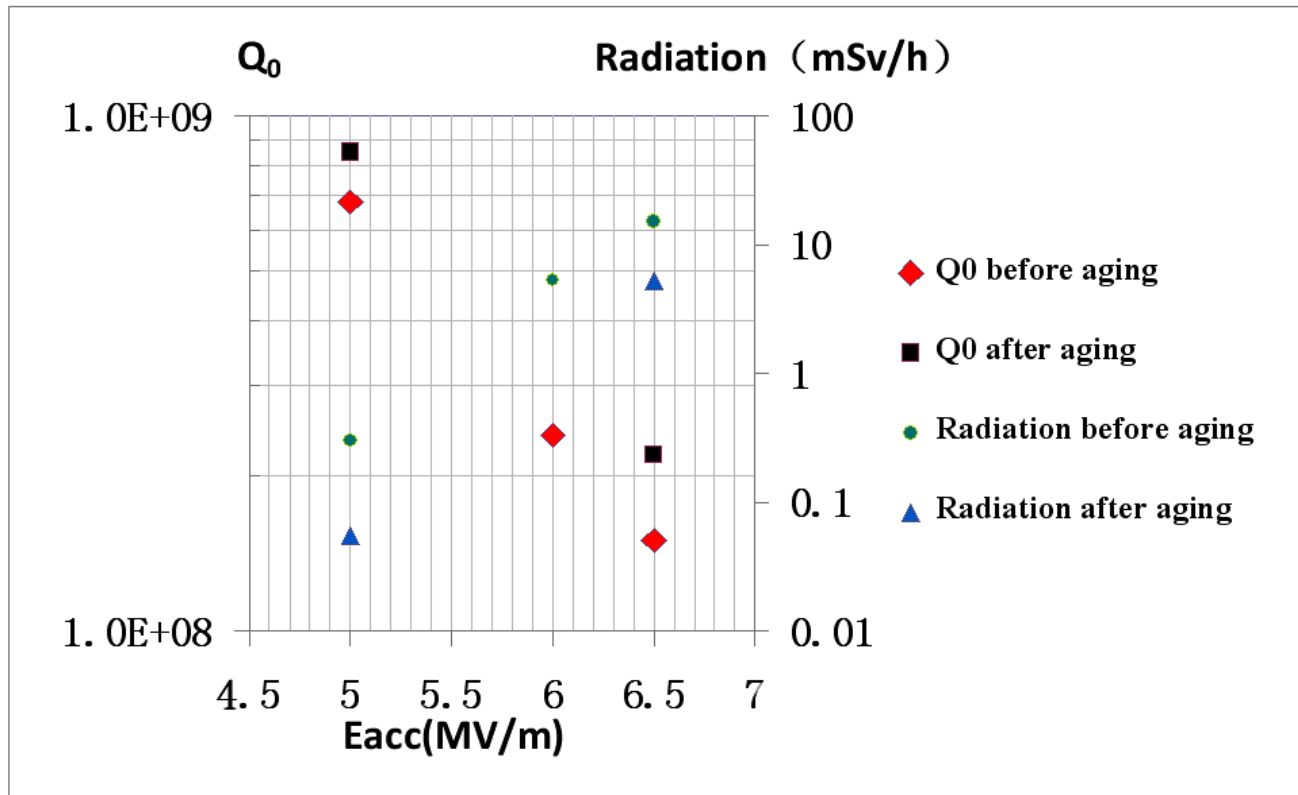


Piezo tuner was used for frequency loop and closed. The tuning range is ± 1 kHz.
Level meter was used to measure the heat loading. The static loading is 15.1 W.

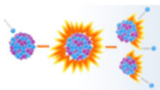


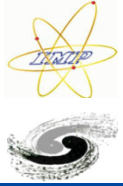


Results of horizontal testing

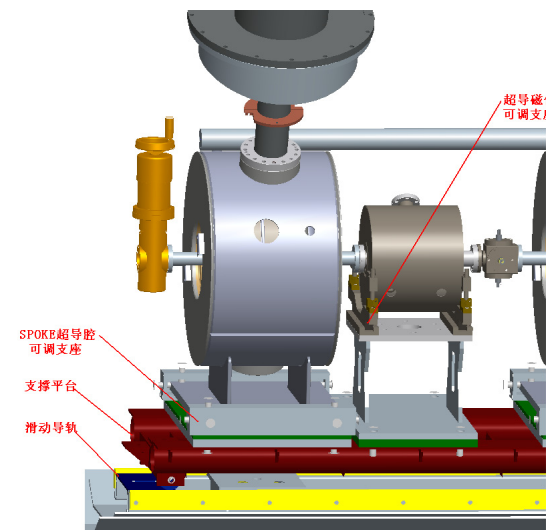
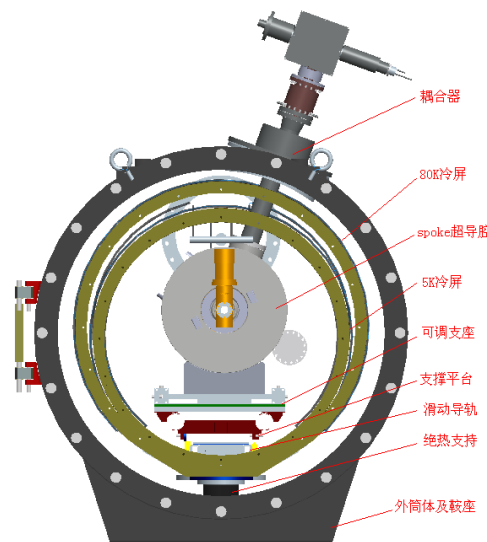
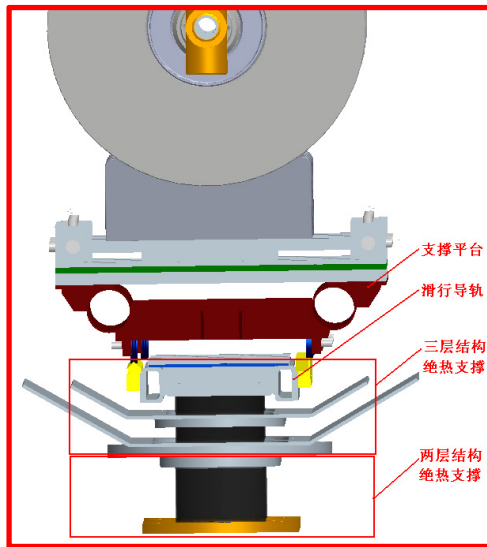
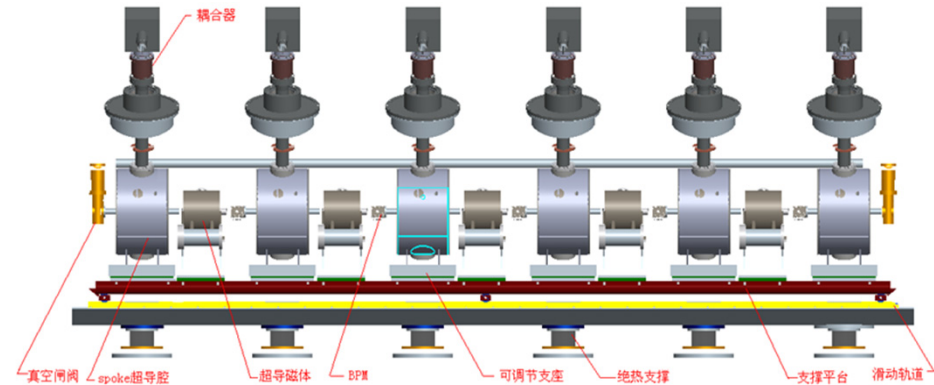
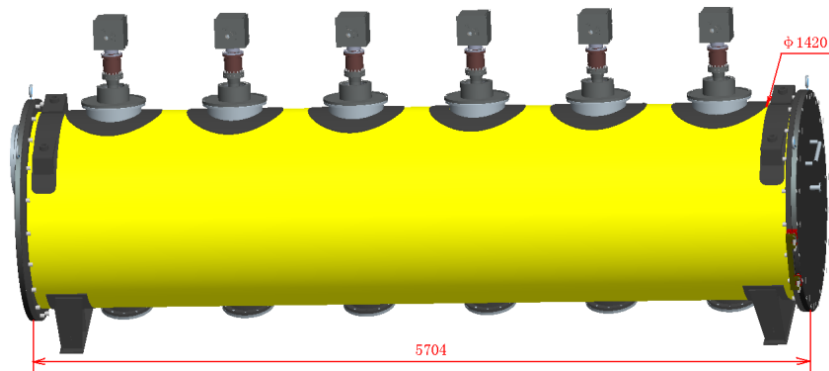


The testing lasted 5 days in Sept. 2013. The heavy multipactor occurred and was overcome. $Q_0=2.2E8$ was reached at $E_{acc} = 6.5$ MeV/m. It just 30% degraded from VT.

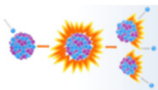


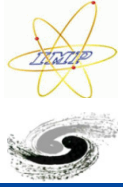


6-cavity Cryomodule for Injector I



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

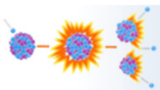


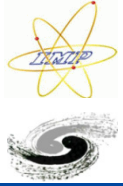


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HWRs for Injector II

2.1MeV

5MeV

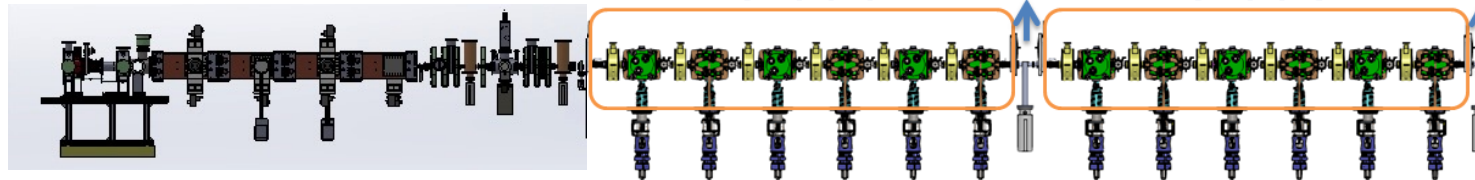
10MeV

CM6-010

分子泵

CM6-015

分子泵



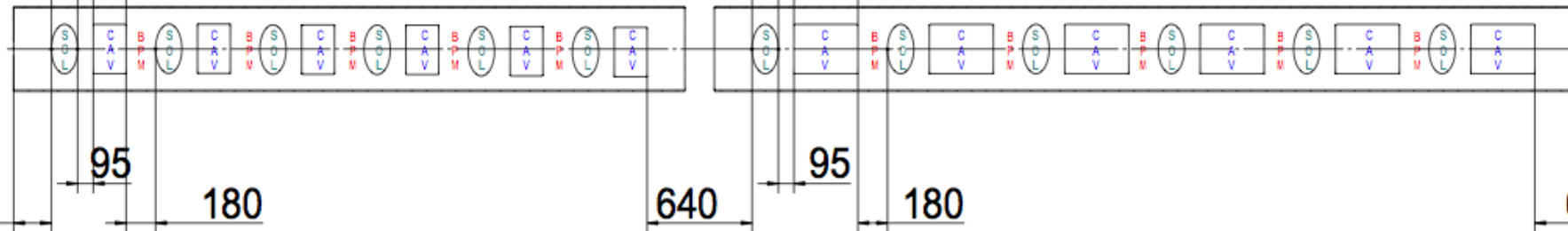
160 210

CM6-HWR010

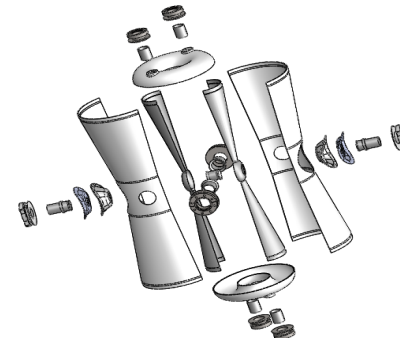
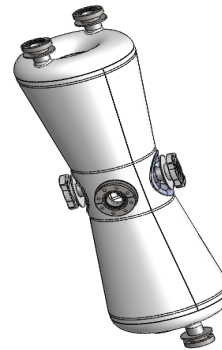
160 410

CM6-HWR015

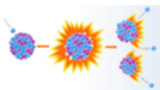
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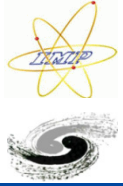


HWR010

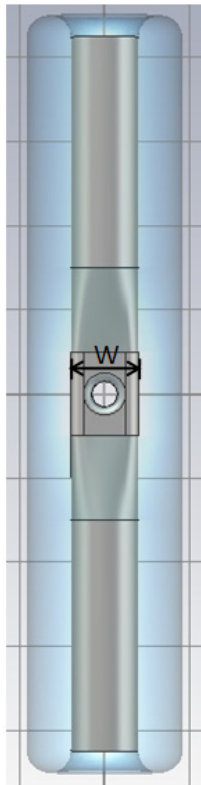
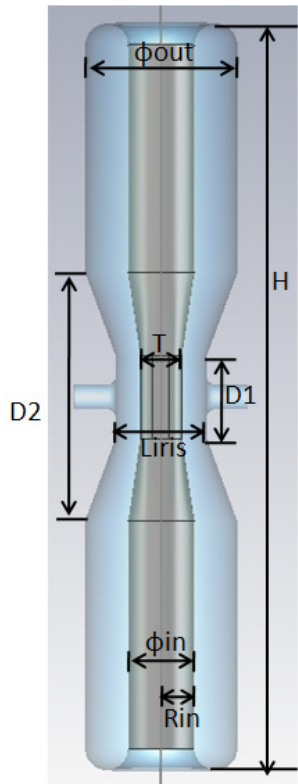


HWR015





RF Design of HWR010

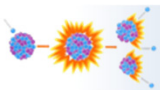


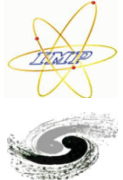
B_{pk}/E_{acc} ; E_{pk}/E_{acc}

R/Q_0 ; G

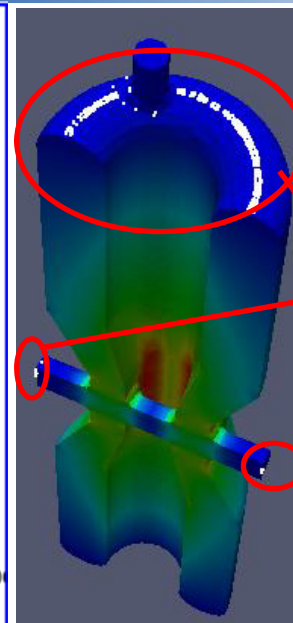
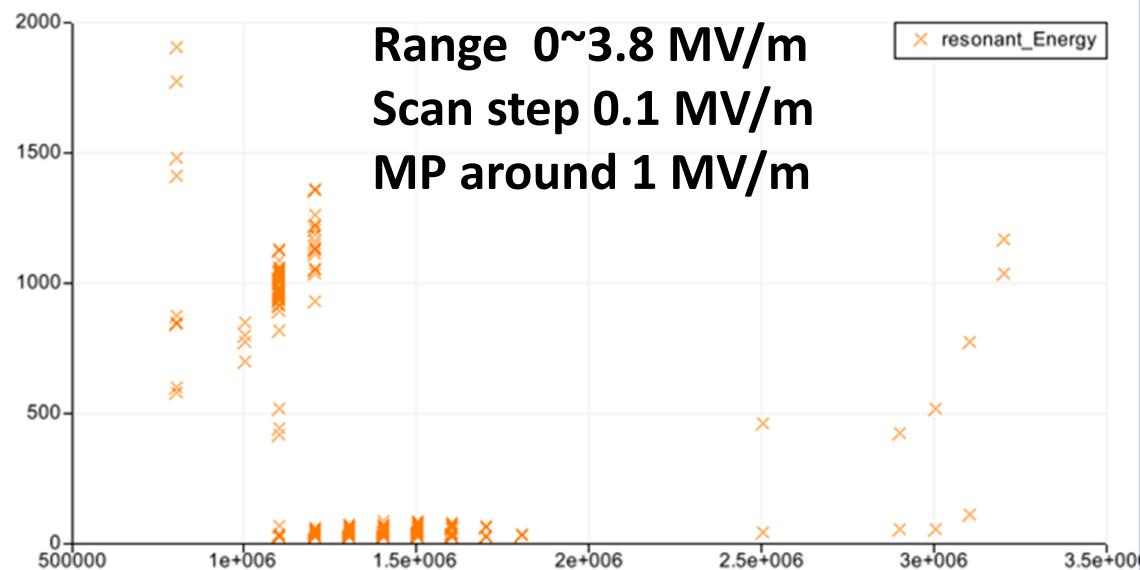
R_{in} (mm)	40
R_{out} (mm)	92
L_{iris} (mm)	110
T (mm)	45
W (mm)	90
D1	100
D2	300
Rblend2	15

HWR010 Squeezed	
Freq(MHz)	162.5
β_{opt}	0.101
U_{acc}(MV)	0.78
E_{acc}(MV/m)	4.5
E_{peak}(MV/m)	25
B_{peak}(mT)	50
G=R_s*Q₀(Ω)	28.5

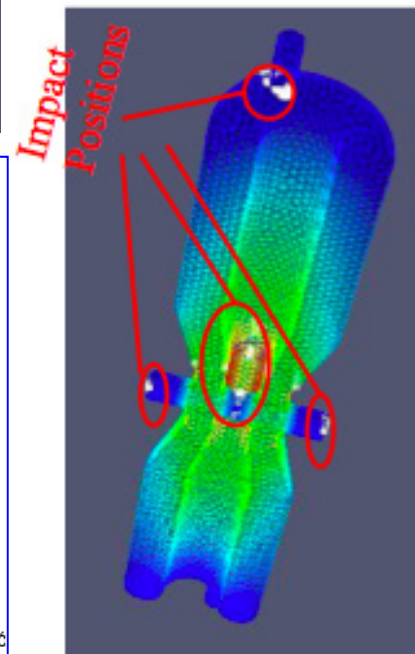
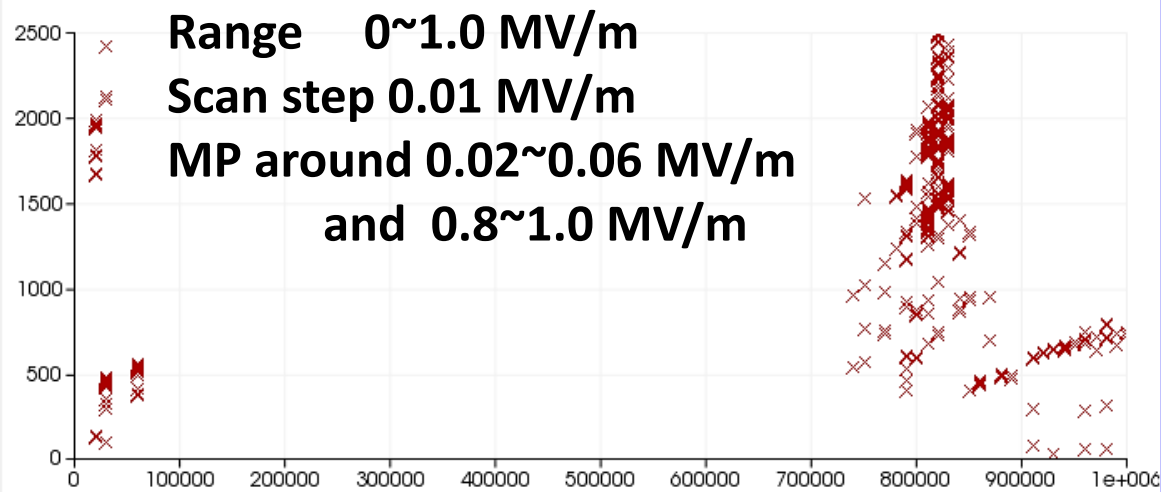




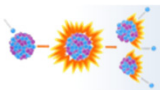
Simulation of Multipacting

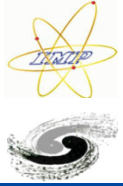


Impact Positions



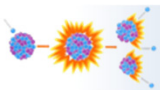
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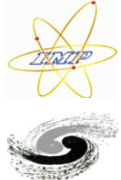




Fabrication of HWRs

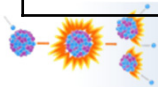
- ▶ Material
 - ▶ OTIC, $RRR > 300$, partly $RRR > 380$
- ▶ Drawing, machining and BCP
 - ▶ Punching die, Al 7075
 - ▶ Surface survey before every step of fabrication
 - ▶ BCP ($65\%HNO_3:40\%HF:85\%H_3PO_4=1:1:2$) 10um, resin by UPW, drying in cleanroom of class 100
 - ▶ Polishing every seam and BCP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

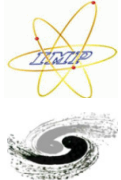




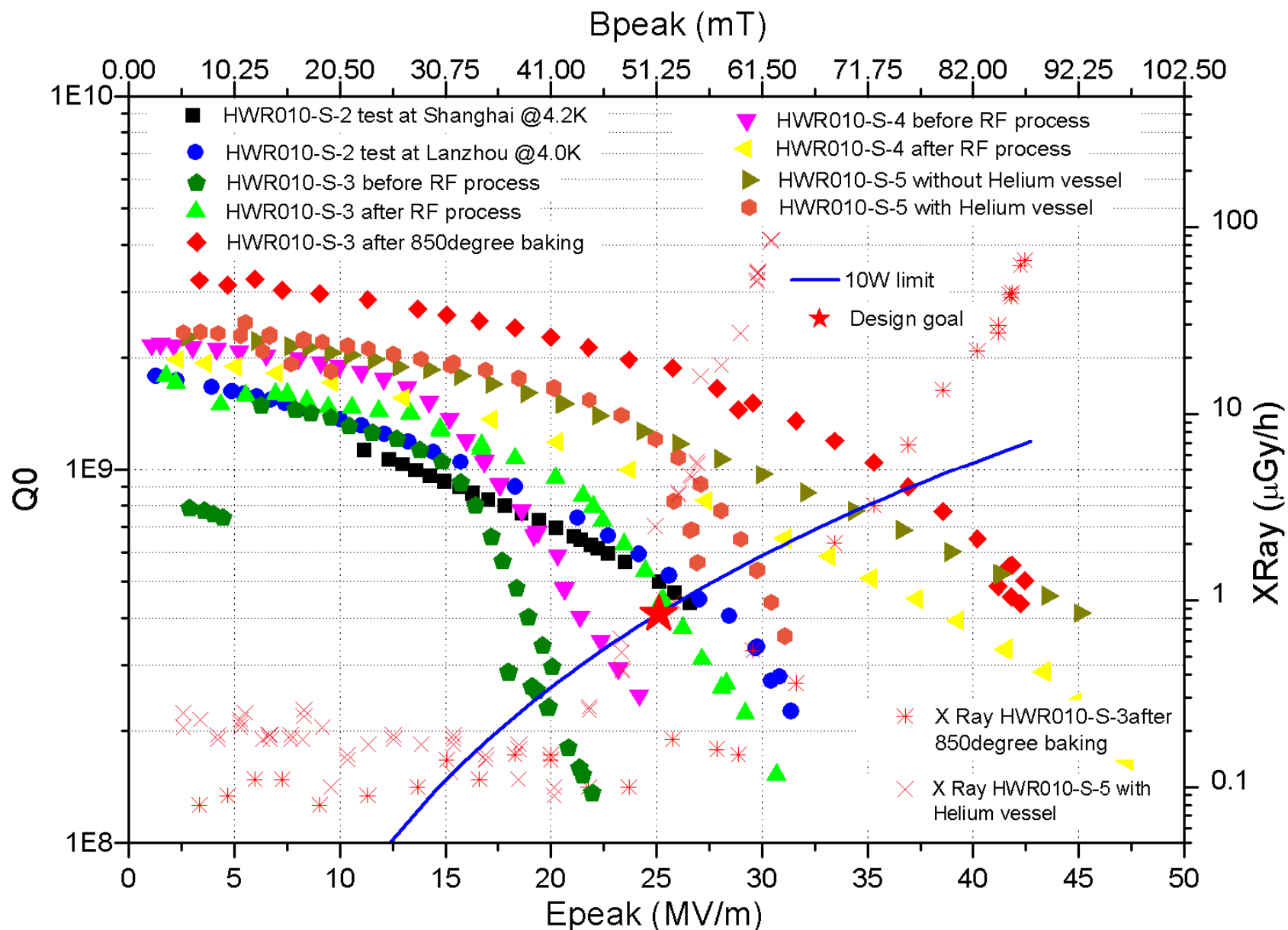
Surface Processing of HWRs

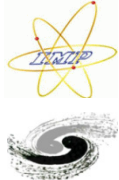
Cavity #	Test #	Bulk removal	Degassing	Light removal	Bake	Addition
2	12/01/12	120 um	680 C 3 hours	20 um	150~250C 48 hours	At SINAP w/o HPR
2	01/29/13	-	-	30 um	200 C 48 hours	At IMP
3	05/18/13	140 um	650 C 10 hours	30 um	120 C 48 hours	
3	07/16/13	-	850 C 3 hours	30 um	120 C 48 hours	
4	06/08/13	130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



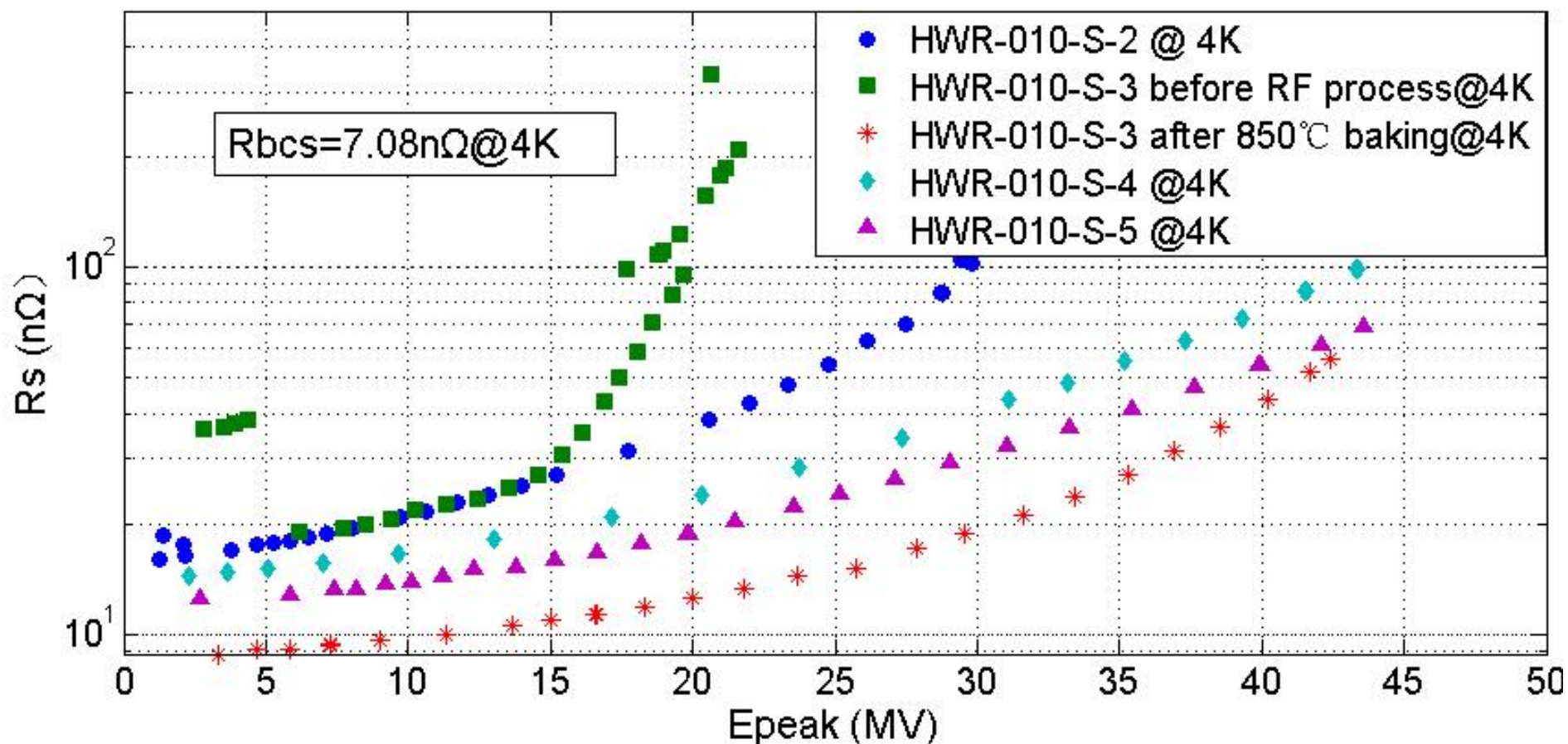


VT results of HWR010-S-02~05



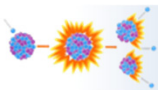


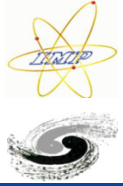
VT results of HWR010-S-02~05



Cryoperm shielding,
< 20 mGs, at room temp.,
< 7mT at 4 K, $R_{mag}=0.8 \text{ n}\Omega$

R_s of #5 is around 10 nΩ. #3 after 850 C baking is around 2 nΩ.

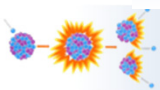
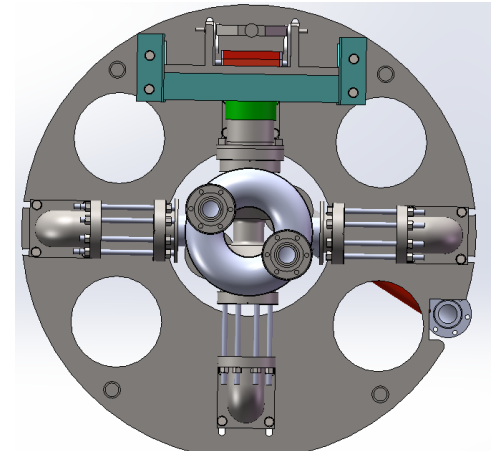
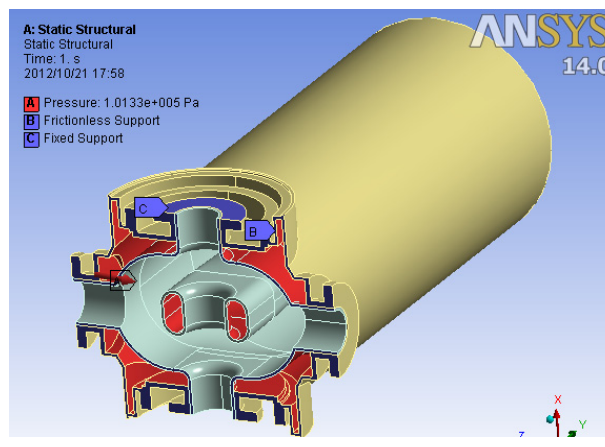
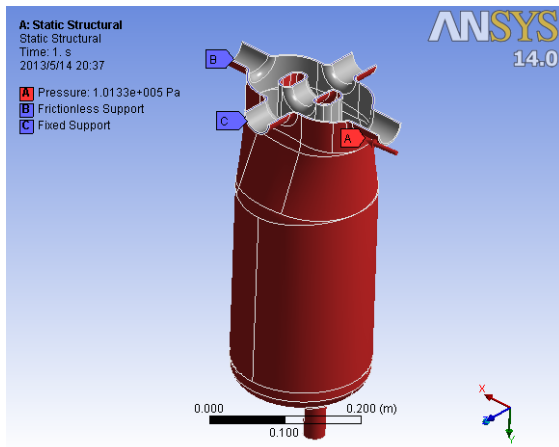


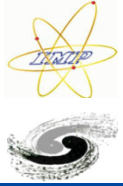


Mechanical analysis



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

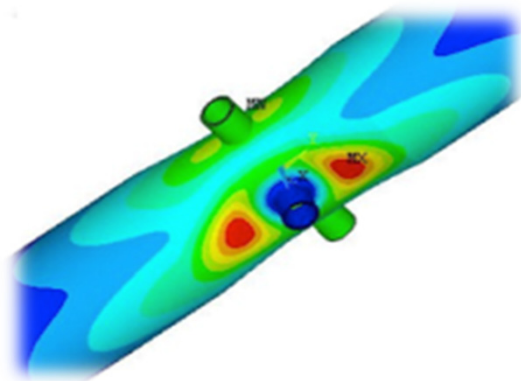
df/dp

70Hz/mbar

Goal



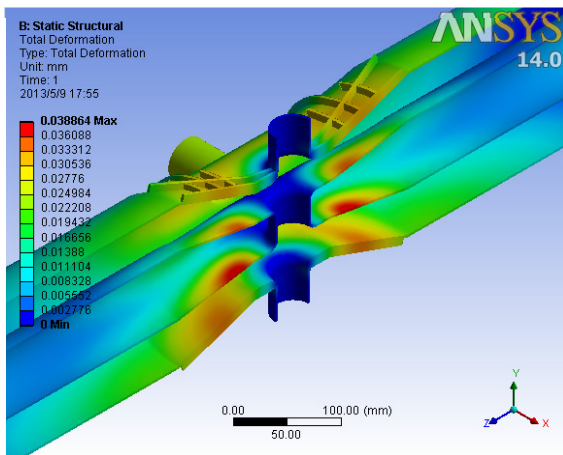
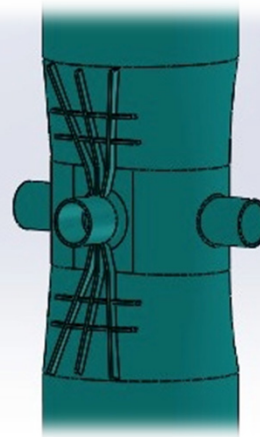
<5 Hz/mbar



<5Hz



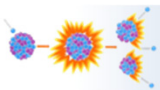
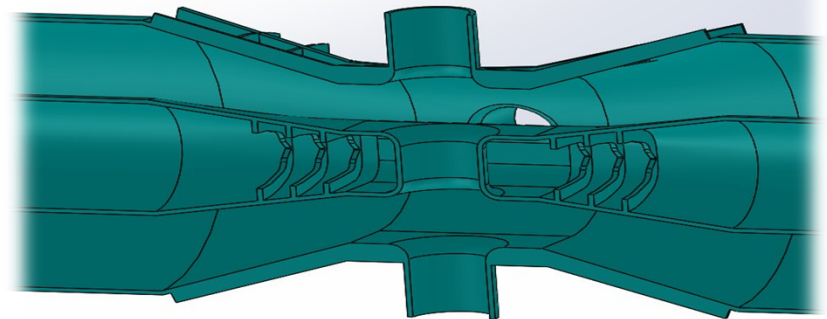
Ribs on one

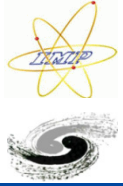


<1Hz



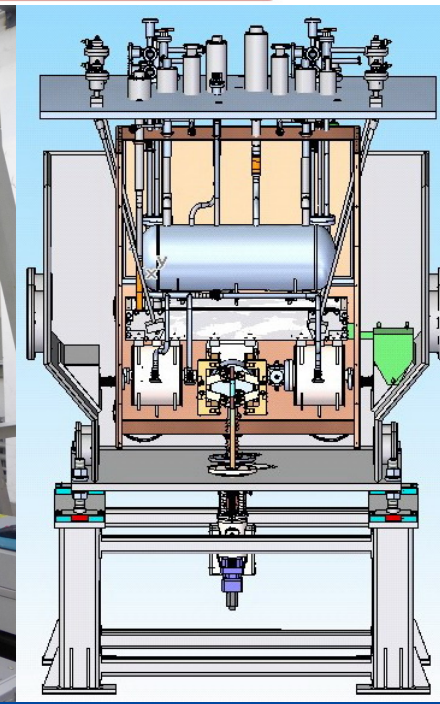
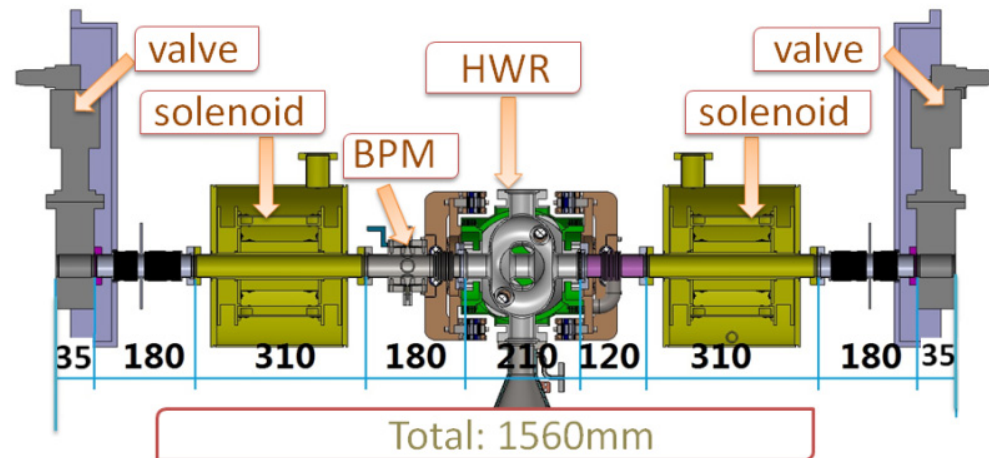
Ribs on both





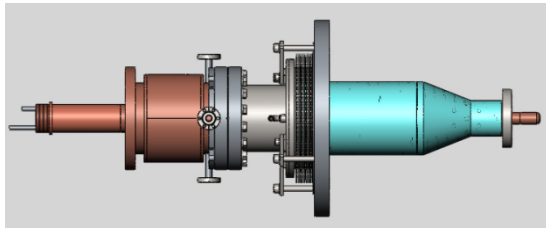
Horizontal Testing of HWR

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

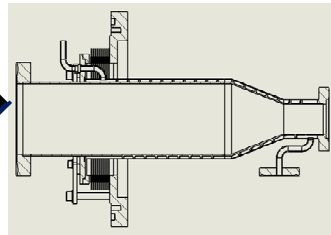




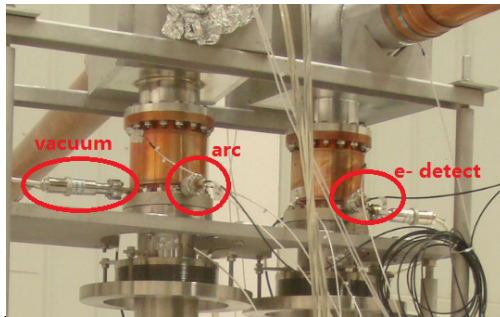
HWR Coupler and high power testing



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.

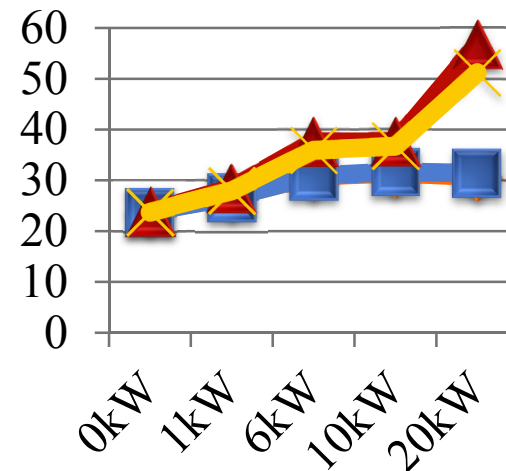


The coupler has passed a RF power of 20kW in continuous travelling wave mode limited by the RF source available.



Spiral grooves

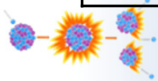
Date	Start time	Stop time	Pf1 max	Elapsed time/hrs
2013-6-1	13:50	20:00	~212W	5.3 hrs
2013-6-2	9:25	16:30	~738W	7 hrs
2013-6-3	9:10	17:17	~Peak 1.3kW	6 hrs
2013-6-4	9:55	23:47	~2.90kW	12.3hrs
2013-6-5	9:10	22:32	~5kW	12 hrs
2013-6-6	9:13	21:56	~9.42kW	8 hrs
2013-6-7	9:07	20:50	~10.6kW	10hrs
2013-6-8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

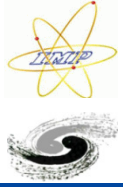


◆ window-up

■ window-down

▲ outer conduct-up

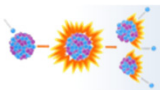


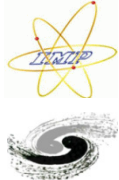


Contents

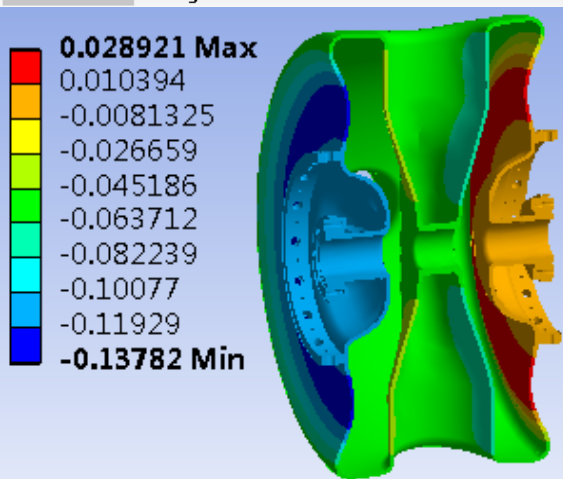
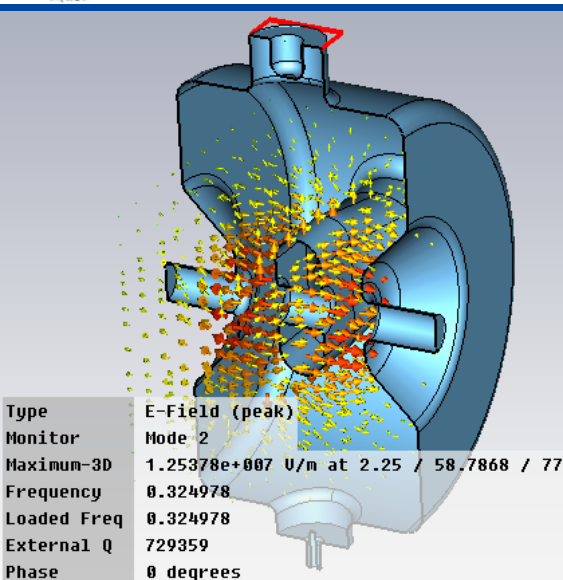


- Introduction of ADS Project in China
- Cavities for Injector I
- Cavities for Injector II
- **Cavities for Main Linac**
 - **Spoke021**
 - Ellip082
- Summary

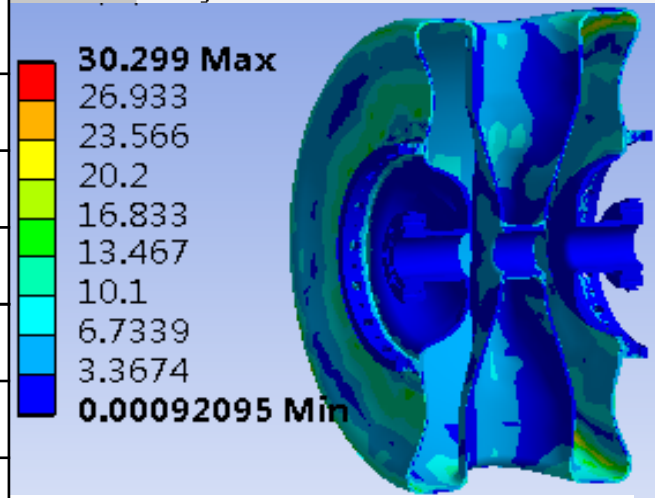
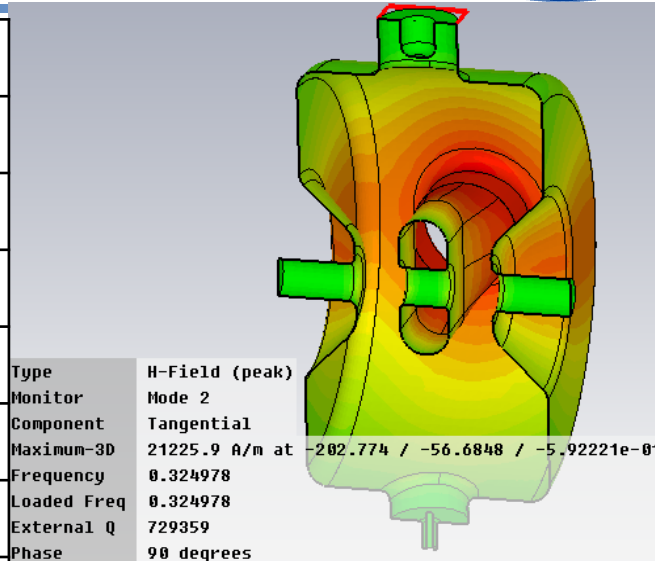




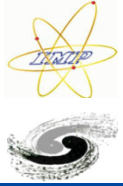
Specifications of Spoke021



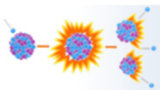
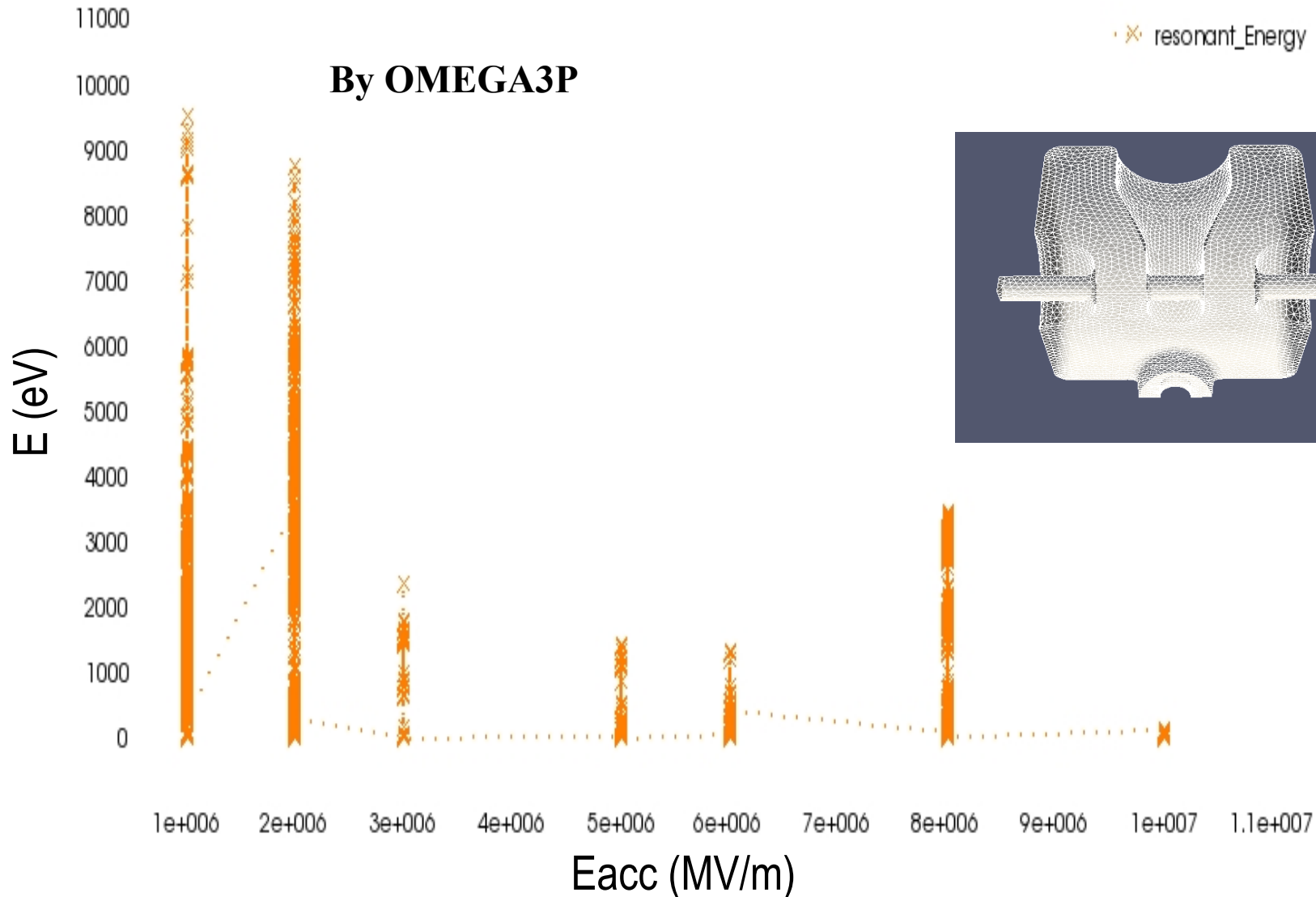
Para.	
E_p/E_{acc} /(void)	3.88
B_p/E_{acc} /mT/(MV/m)	8.13
β_{opt}	0.246
r/Q / Ω	206
G / Ω	87
Df/dL /kHz/mm	632
R_{BCS} /n Ω	0.68
$Q_0@R_{res}=5n\Omega$	1.38E10
$Q_{e,opt}$	7.28E5
$Le @Q_{e,opt}$ /mm	22.3
E_p /MV/m @1J	12.04
H_p /kA/m @1J	21.22
$V_c @32.5MV/m$ /MV	1.75
$V_c @65mT$ /MV /MV	1.58

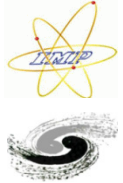


Equivalent Stress
@1 atm & 800kg tuning force



MP Simulation of Spoke021



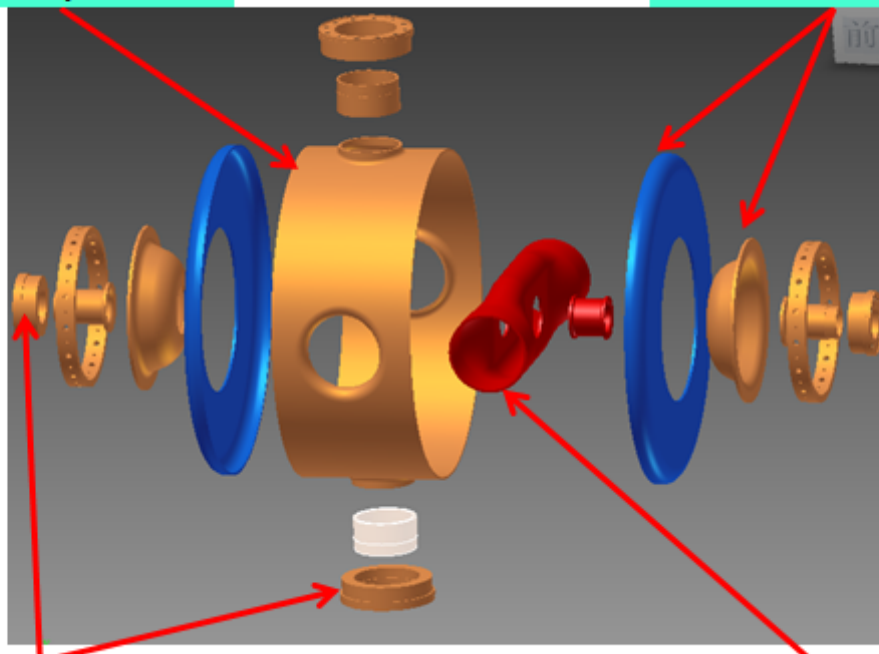


Fabrication of Spoke021



Rolling the cylinder
Pulling the port blend

Forming the end plate
& nose-cone

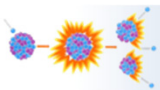


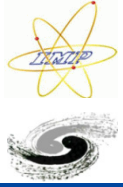
Nb SST brazed joint

Squeezing the spoke pole



Ready for VT.

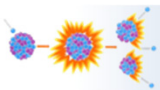


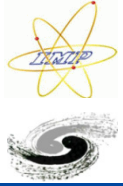


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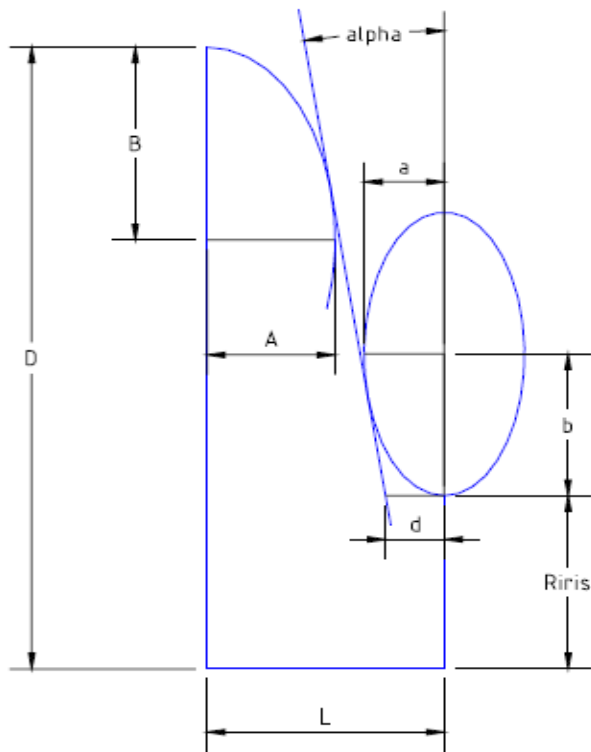


Design of Ellip082

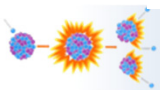
Design Objective: 650MHz 5-cell SC Cavity, $E_{acc}=15\text{MV/m}$, $Q_0>3E9$

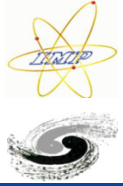
Design Principle:

- ✓ Large beam pipe and iris
- ✓ low E_p/E_{acc} and B_p/E_{acc}
- ✓ No MP
- ✓ Reasonable Lorentz factor

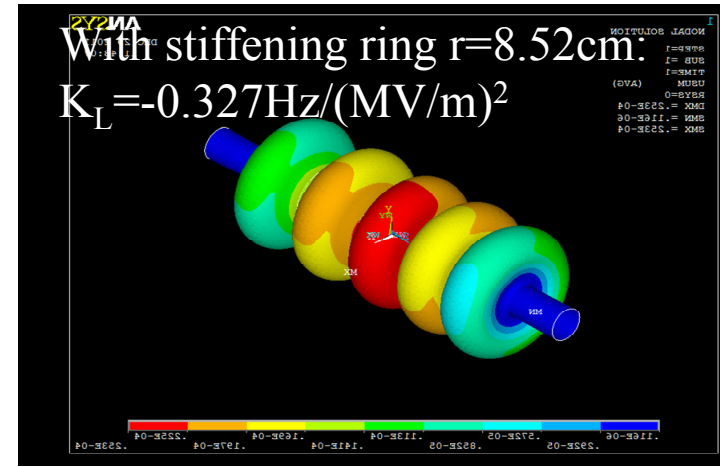
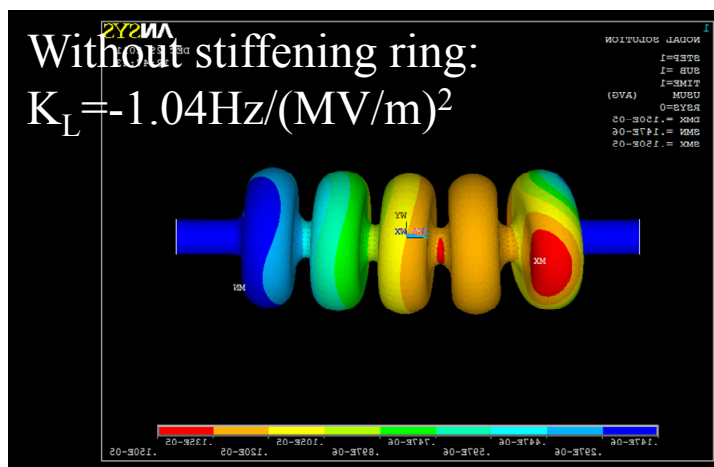
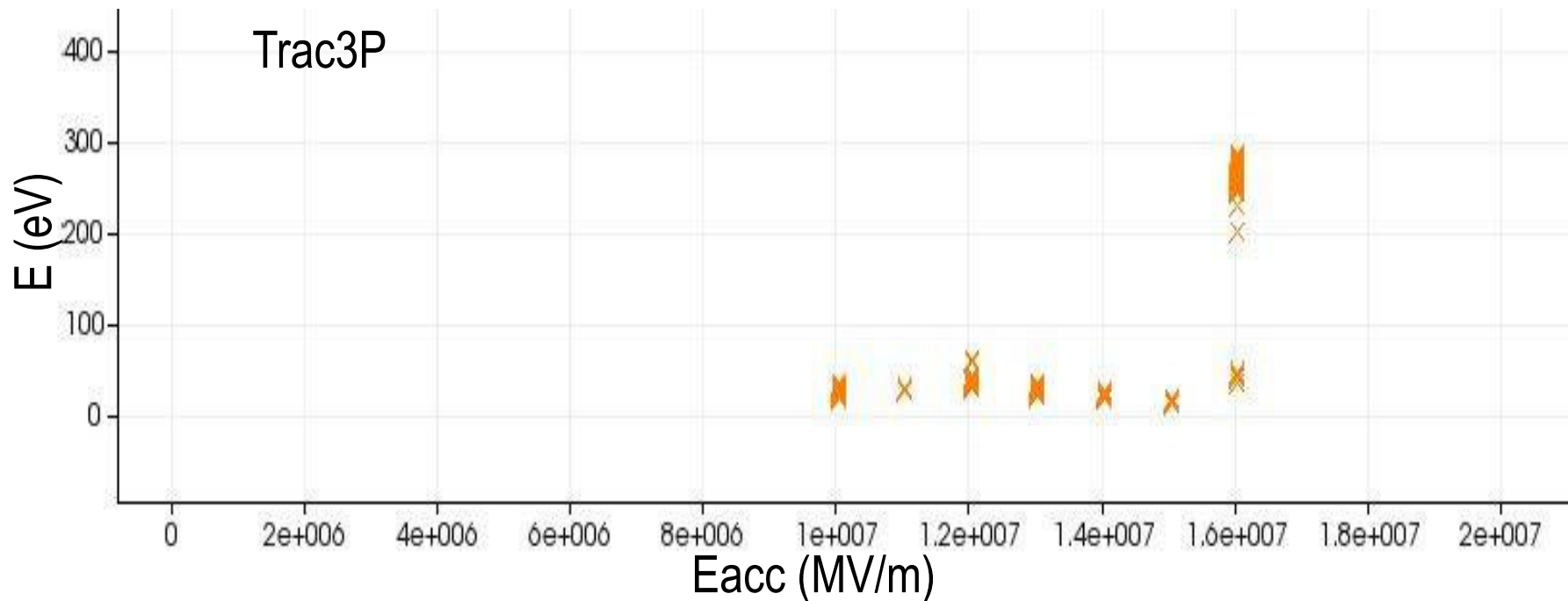


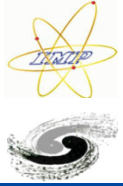
	Center cell	End cell
L (cm)	9.461	9.461
Riris (cm)	5	5
D(cm)	20.0207	20.0207
A(cm)	7.027	7.166
B(cm)	7.027	7.883
a(cm)	1.681	1.667
b(cm)	2.522	2.501
$\alpha (^{\circ})$	7	6.678
E_p/E_{acc}	2.12	
B_p/E_{acc} mT/(MV/m)	4.05	
r/Q [Ω]	514.6	
G [Ω]	235.5	
k [%]	0.9%	
Field flatness [%]	>98	





MP and LF Simulation of Ellip082





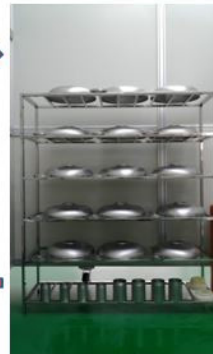
Fabrication of Ellip082



Ultrasonic clean



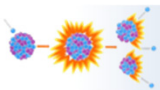
BCP

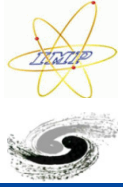


Dry in clean room



Encapsulation in clean room

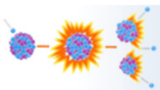


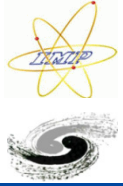


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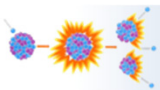


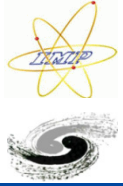


Summary



- ▶ In 2015, ADS project in China will have 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 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!

