Technology of High Power RF Couplers for Superconducting Resonators

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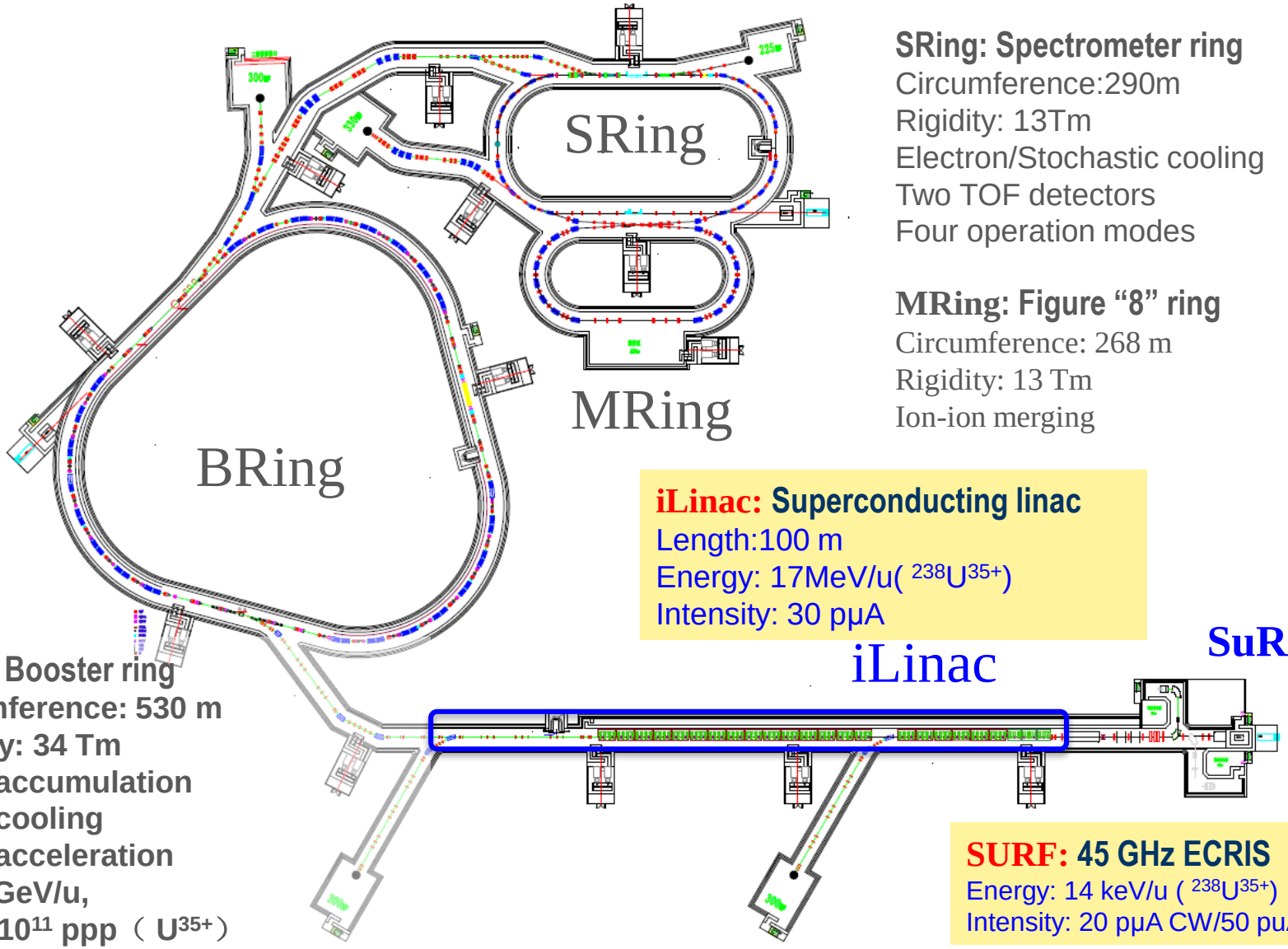
31/07/2017

Outline

- Motivation
- Coupler Design
- Operation Feedback
- Summary

Project HIAF (2017-2024)



SRing: Spectrometer ring
Circumference:290m
Rigidity: 13Tm
Electron/Stochastic cooling
Two TOF detectors
Four operation modes

MRing: Figure "8" ring
Circumference: 268 m
Rigidity: 13 Tm
Ion-ion merging

iLinac: Superconducting linac
Length:100 m
Energy: 17MeV/u($^{238}U^{35+}$)
Intensity: 30 pμA

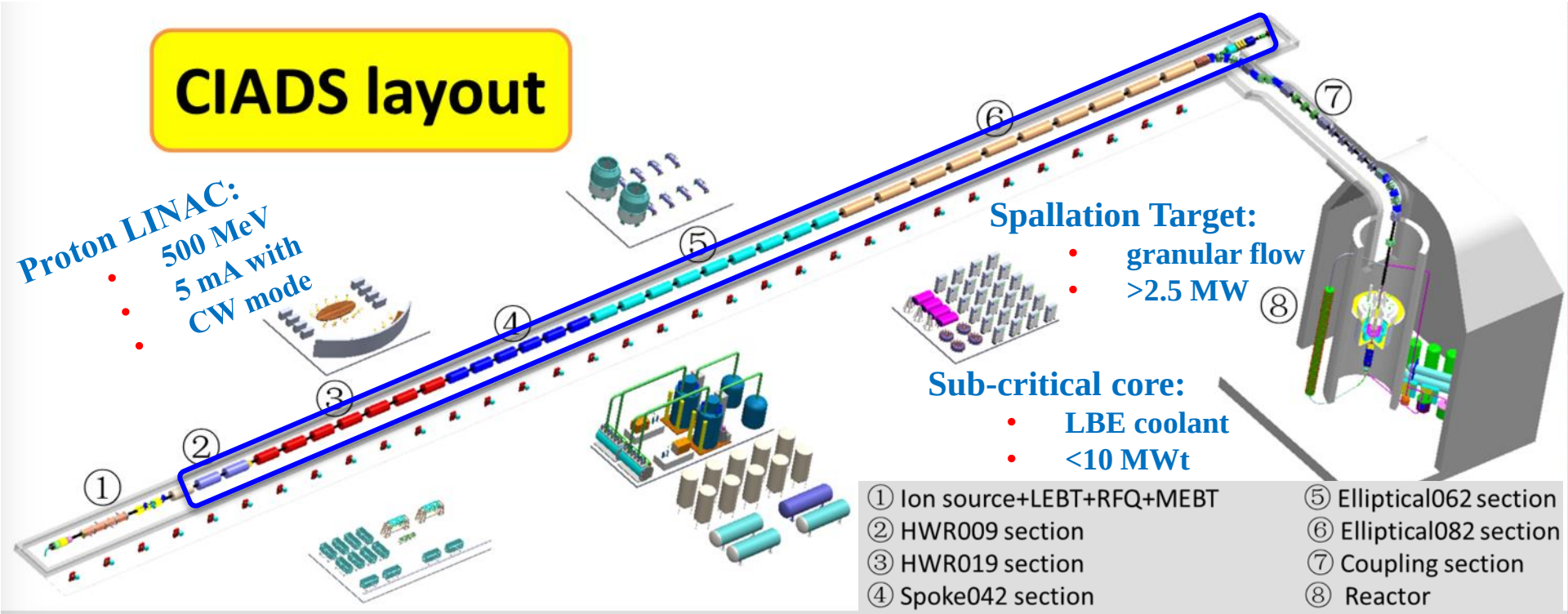
BRing: Booster ring
Circumference: 530 m
Rigidity: 34 Tm
Beam accumulation
Beam cooling
Beam acceleration
E=0.8 GeV/u,
I= 1.5x10^{11} ppp（ U^{35+}）

SURF: 45 GHz ECRIS
Energy: 14 keV/u ($^{238}U^{35+}$)
Intensity: 20 pμA CW/50 puA pulsed

For details, please Prof. Hongwei Zhao`s talk in this conference

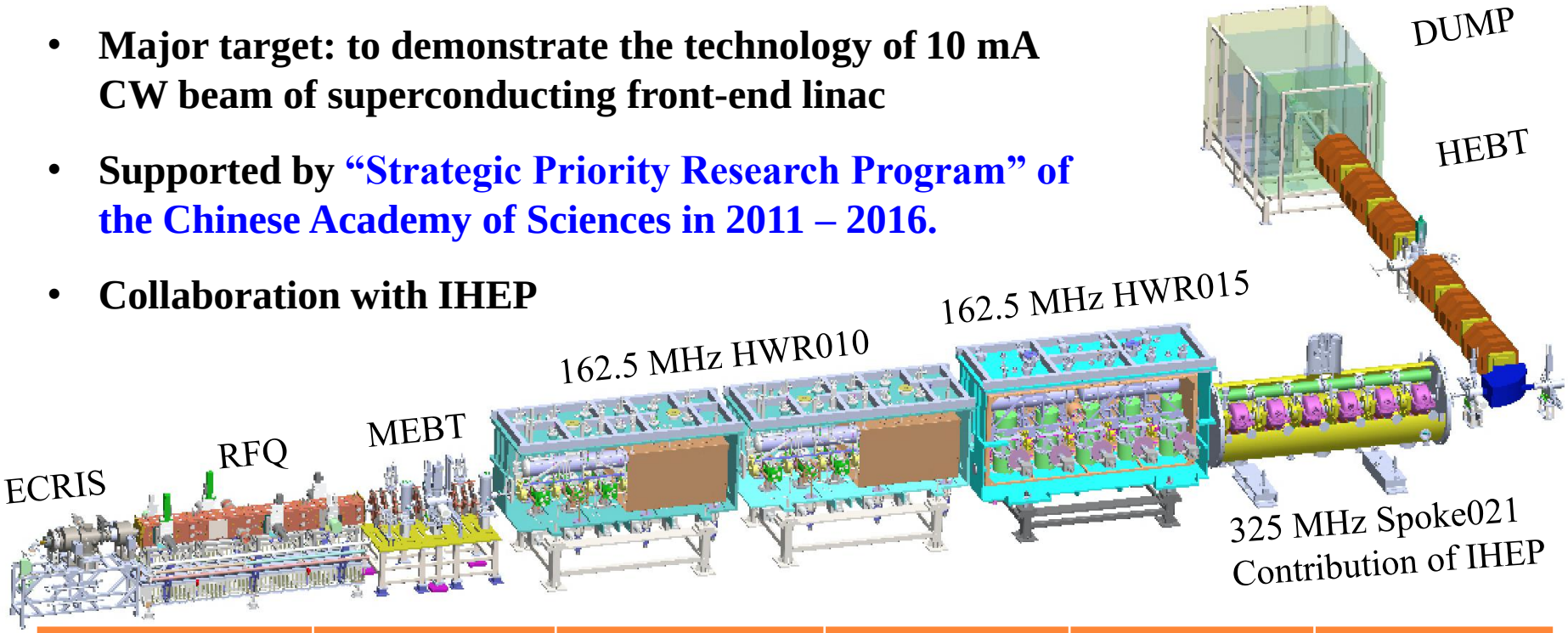
Project CIADS (2018-2024)

China Initiative Accelerator Driven System (CIADS)



Chinese ADS Front-end Demo Linac

- **Major target: to demonstrate the technology of 10 mA CW beam of superconducting front-end linac**
- **Supported by "Strategic Priority Research Program" of the Chinese Academy of Sciences in 2011 – 2016.**
- **Collaboration with IHEP**



	RFQ/IMP	CM1/IMP	CM2/IMP	CM3/IMP	CM4/IHEP
frequency	162.5 MHz	162.5 MHz	162.5 MHz	162.5 MHz	325 MHz
output energy	2.1 MeV	5 MeV	9 MeV	17 MeV	25 MeV
cavity type	4-vane	HWR010	HWR010	HWR015	Spoke021
cavity number	1	6	6	5	6

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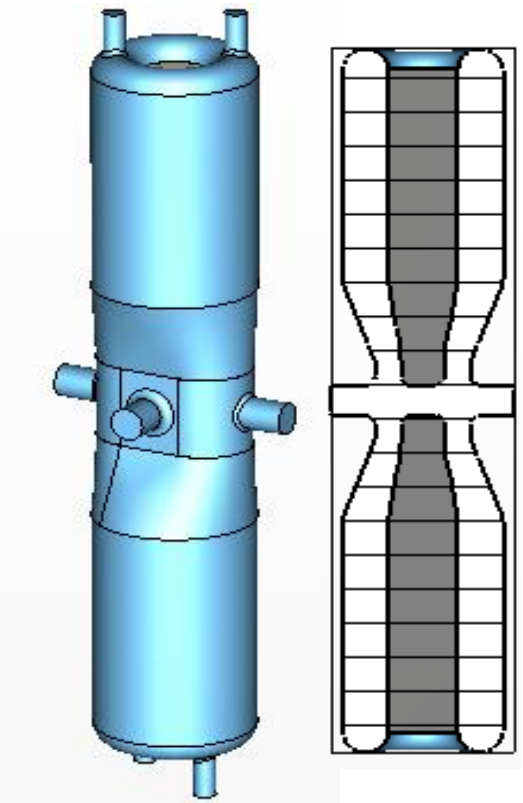
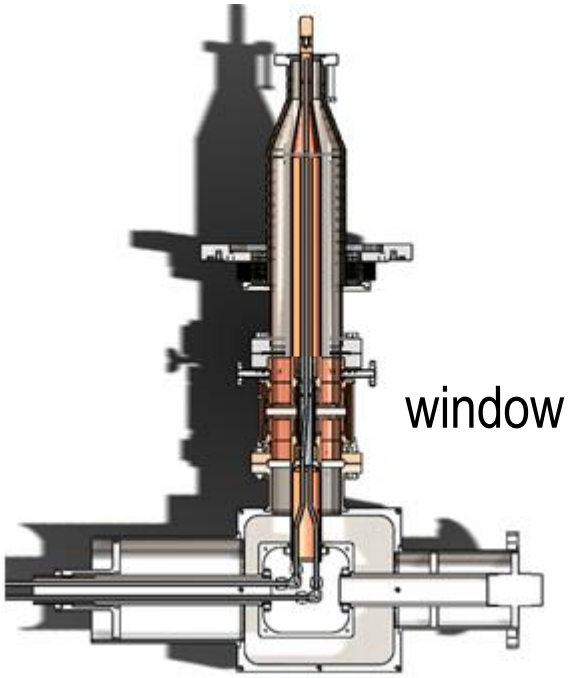
Coupler for SC HWR010



10mA CW H^+ beam



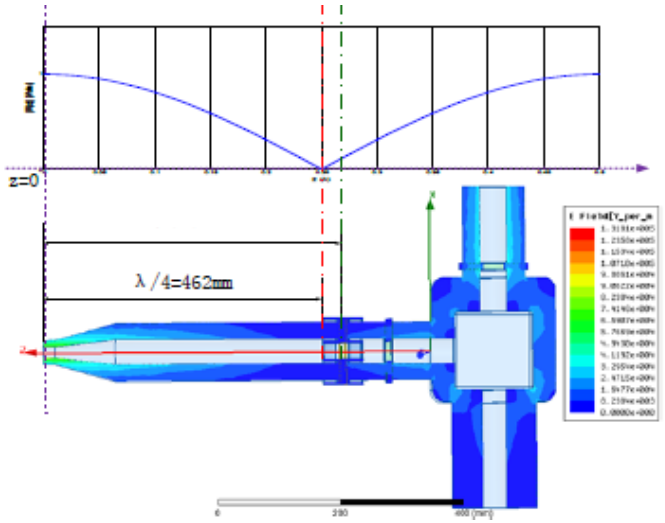
window

Design & Built by IHEP

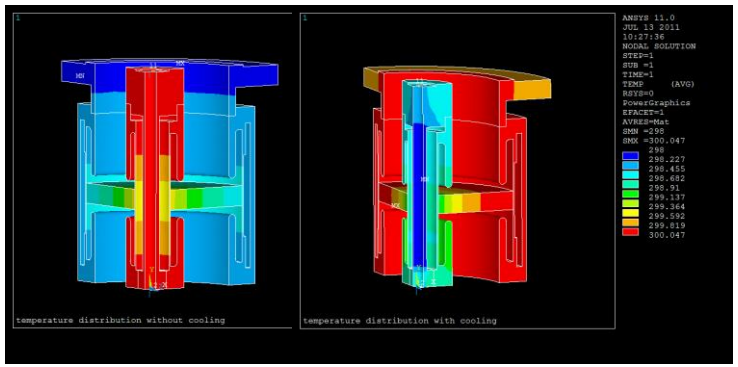
f (MHz)	162.5
β_{opt}	0.101
Vacc (MV)	0.78
Epeak (MV/m)	25
Bpeak (mT)	50
Pdiss(W) (4.5K)	10

f (MHz)	162.5
Pf (kW)	10
Pref (kW)	8
Qe	5E5
Pdiss(W) (4.5K) 15kW	0.18
Pdiss(W) (80 K) 15kW	14.2

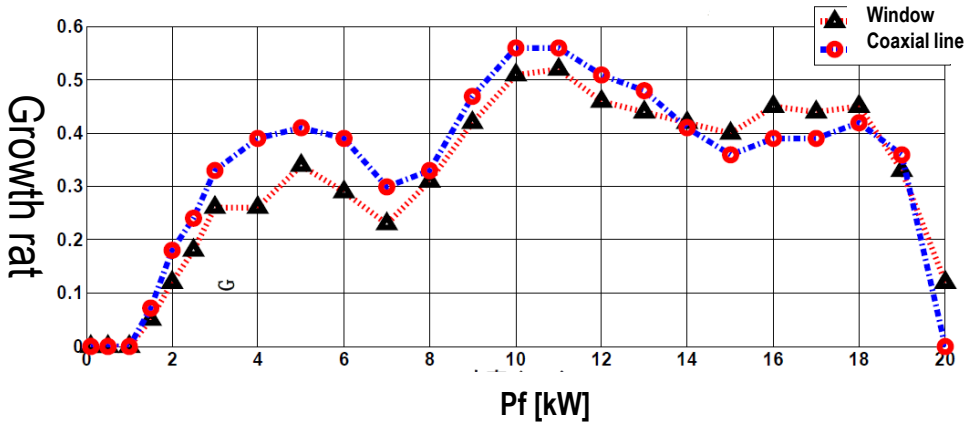
HWR010 Coupler Main Concerns



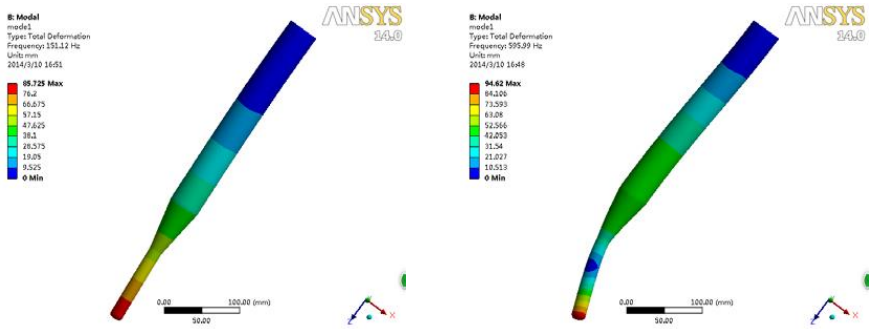
Windows position calculation



Inner conductor cooling w/o water



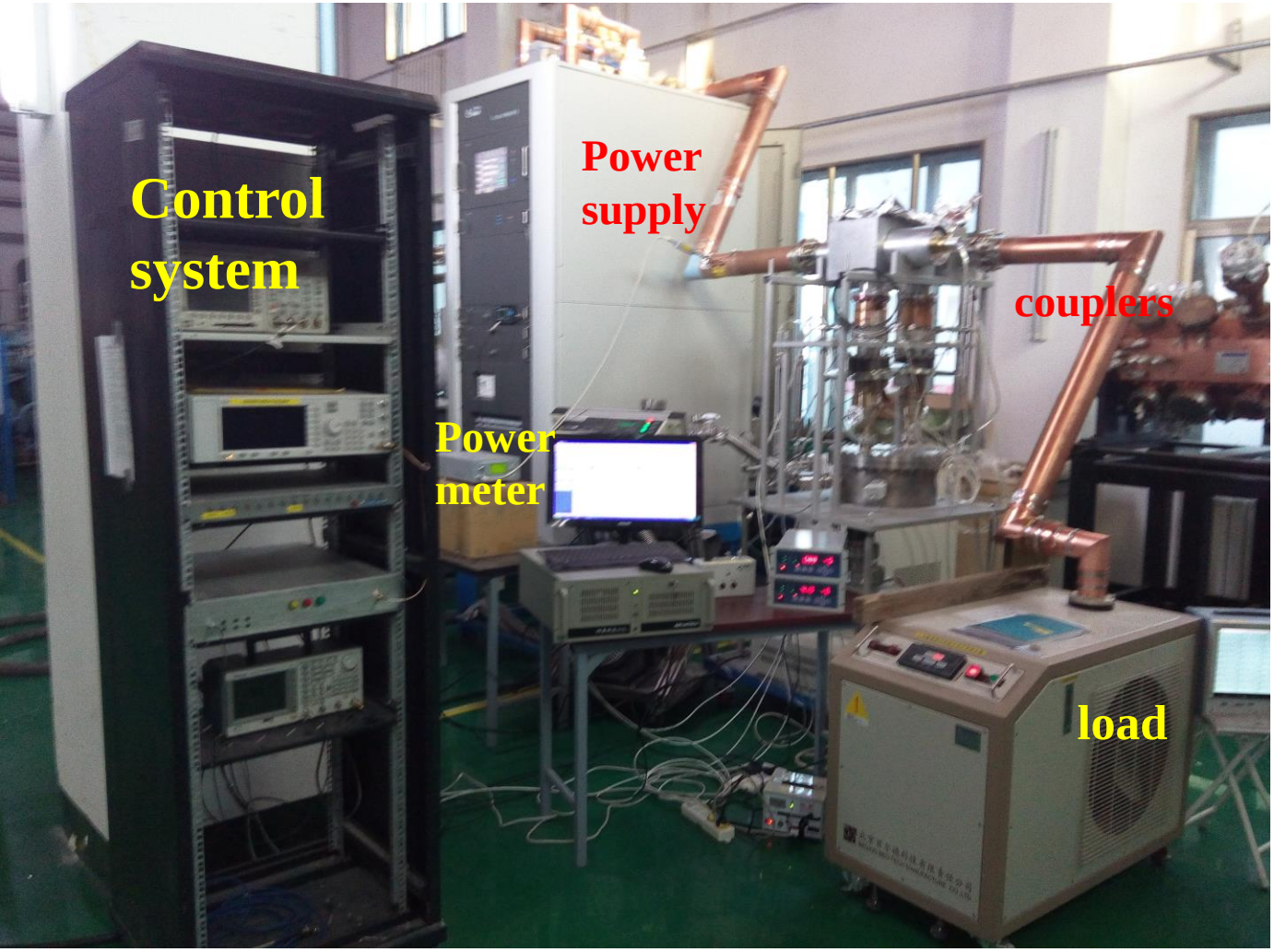
MP simulation for the coupler



Vibration mode	1	2	3	4
Frequency [Hz]	151	596	1475	1758

From, PH.D thesis of Fanbo Meng

Coupler RF test Stand



Test procedure

1.ARC: AFT

2.Vacuum interlock: 5E-5Pa

3. T rise: < 10°

4. MP voltage: <1V

1. Travelling Wave

Duty Factor: 1%, 10%, 50%, 75%, CW

Freq: 100Hz,

2. Standing Wave

Duty factor: 10%, 50%, CW

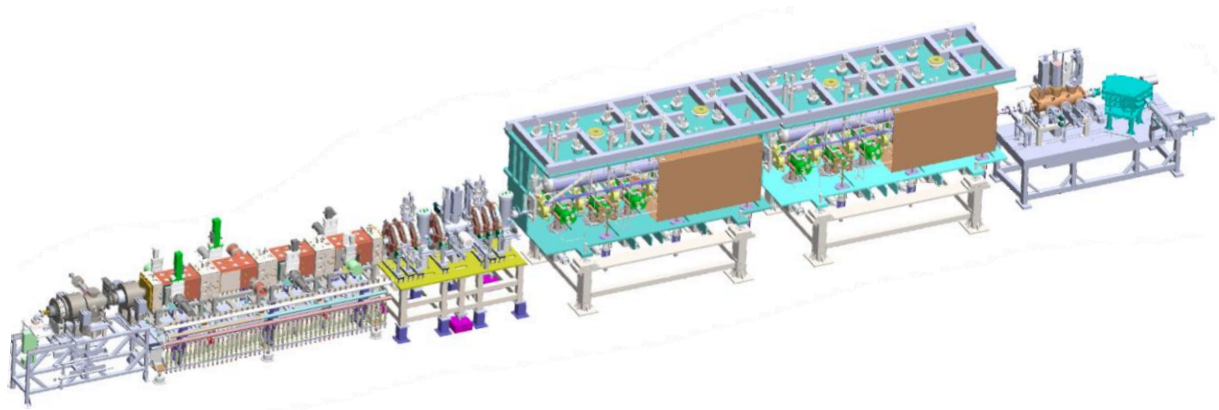
Freq. 100Hz

Phase shift: 10° /time

total shift: 90°

Travelling Wave: 20KW， Standing Wave: 8KW (phase shifter)

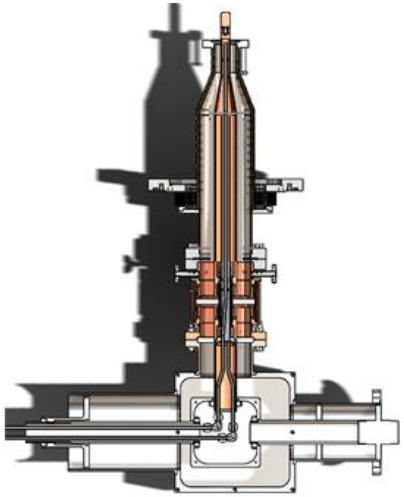
10 MeV Coupler Operation

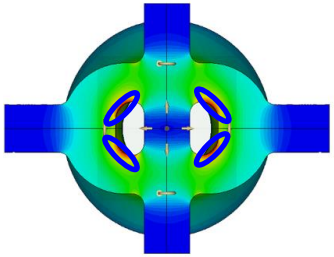


10 MeV operation for 2 months, ceramic windows of 2 couplers were leaking each CM.

Crack of ceramic window

New Coupler Design for HWR010

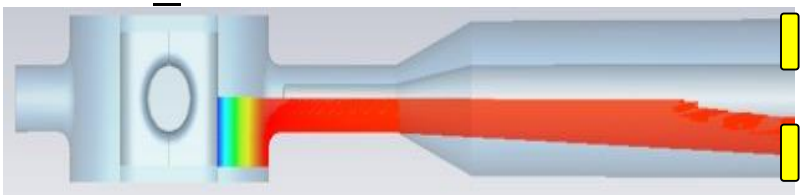


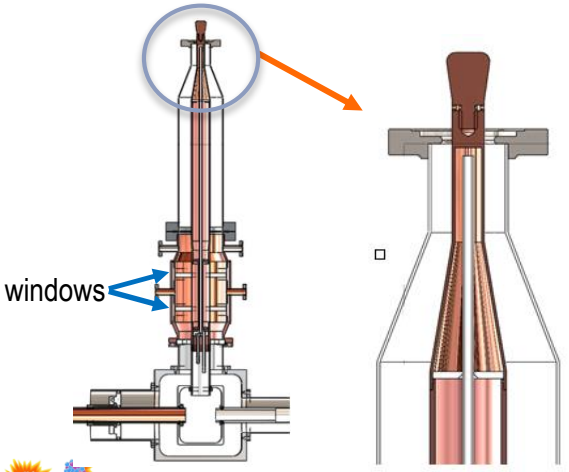


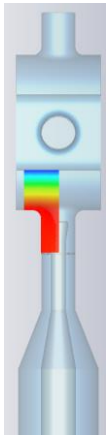
E_ field

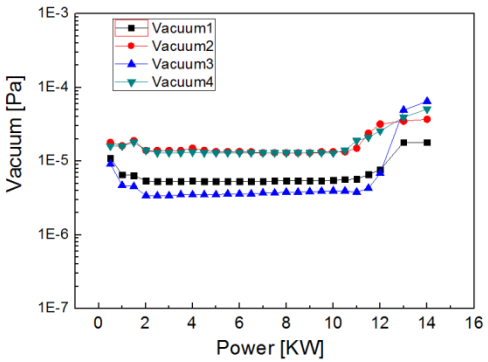
Field emission e from the cavity hitting on the ceramic window.

Ceramic window



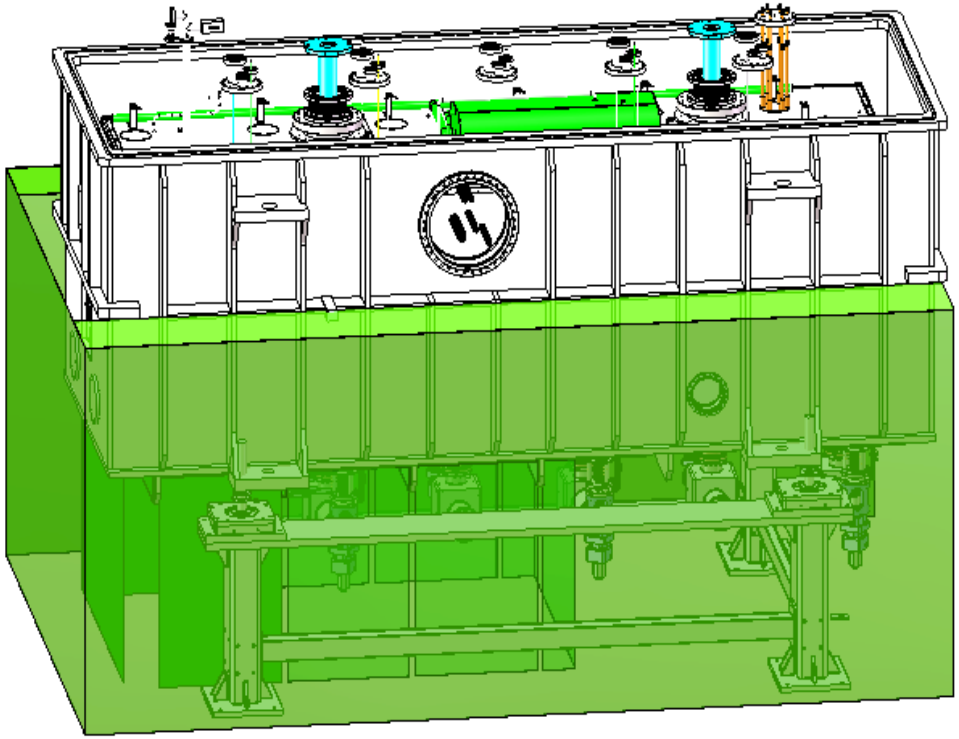






Couplers passed the power test

HWR010 Coupler Replacement online

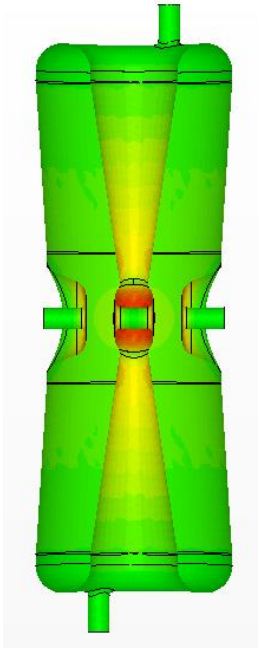


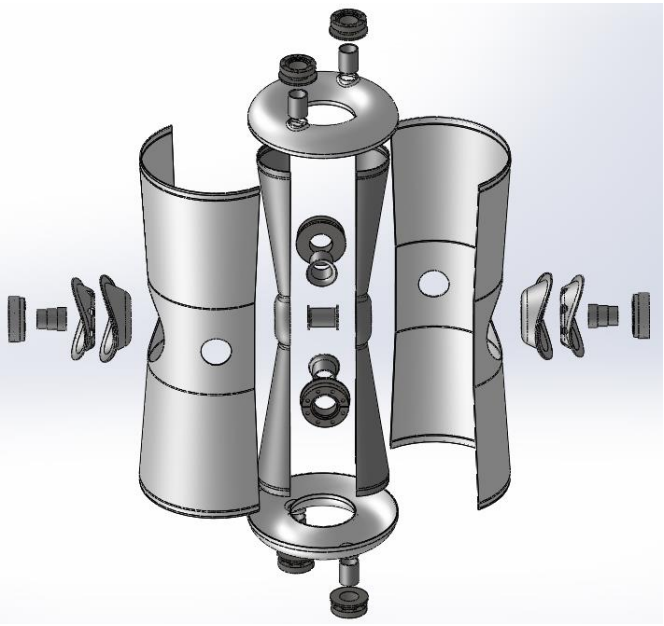
Temporary Clean room for coupler replacement

coupler replacement

New couplers has worked for more than 1 year, no leaks were found, and the new couplers work very well.

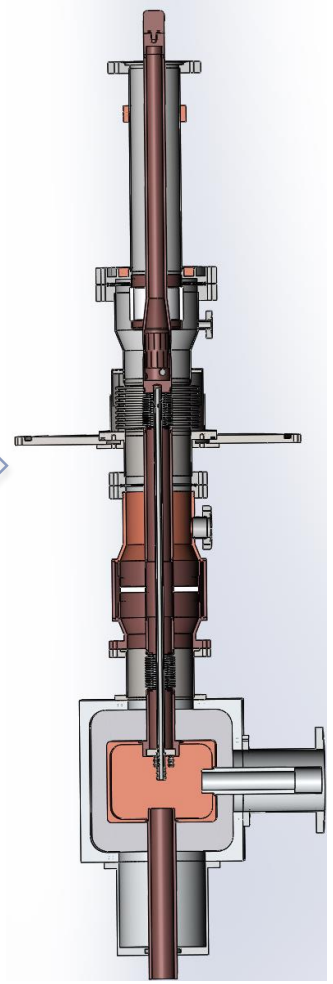
Coupler for SC HWR015





10mA H^+

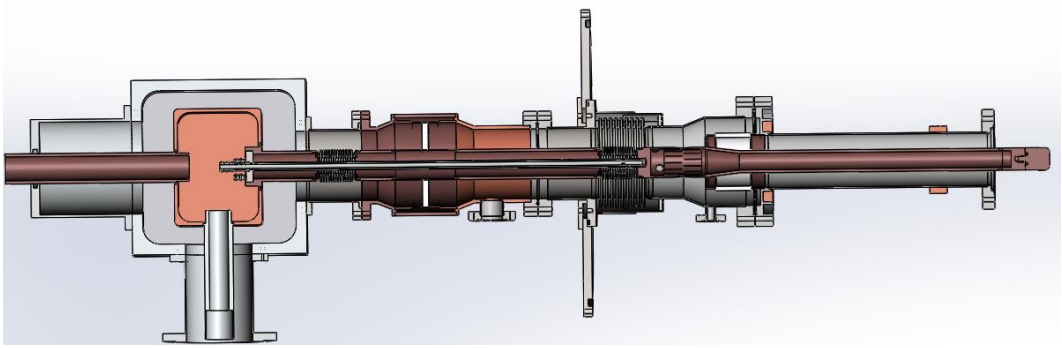
Pf>20KW



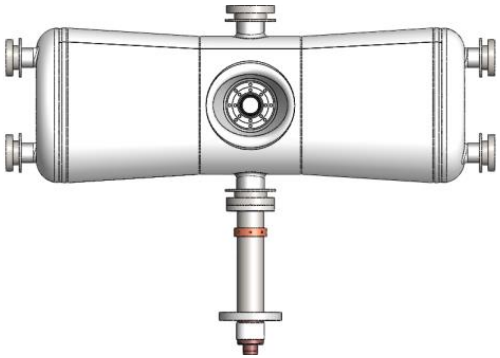
TTFIII like coupler

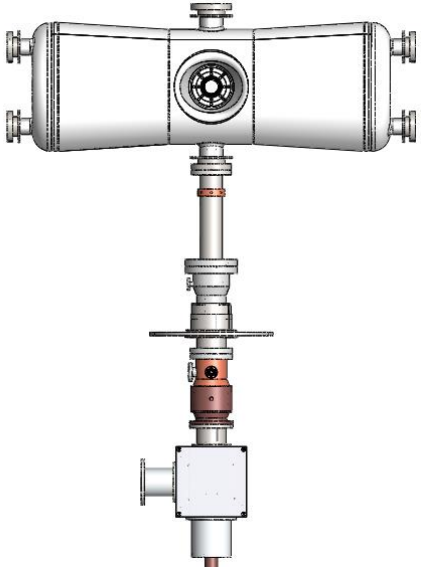
F[MHz]	βopt	Vacc [MV]	Emax [MV/m]	Bmax [mT]
162.41	0.15	1.8	32	40

20 KW Coupler Design for HWR015



Goal:
1. 20 KW T/S wave test
2. S11< -20dBm
3. Leaking rate <10E-10 mbar*L/s
4. Temp. rise<10 ˚

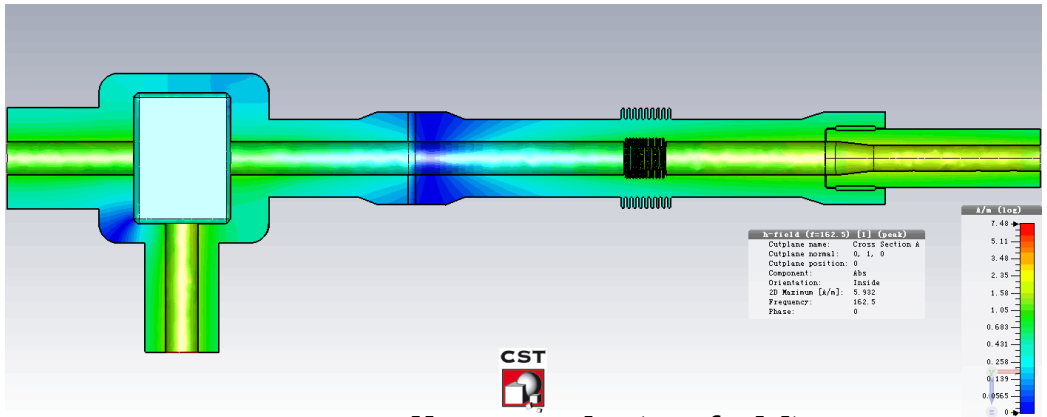




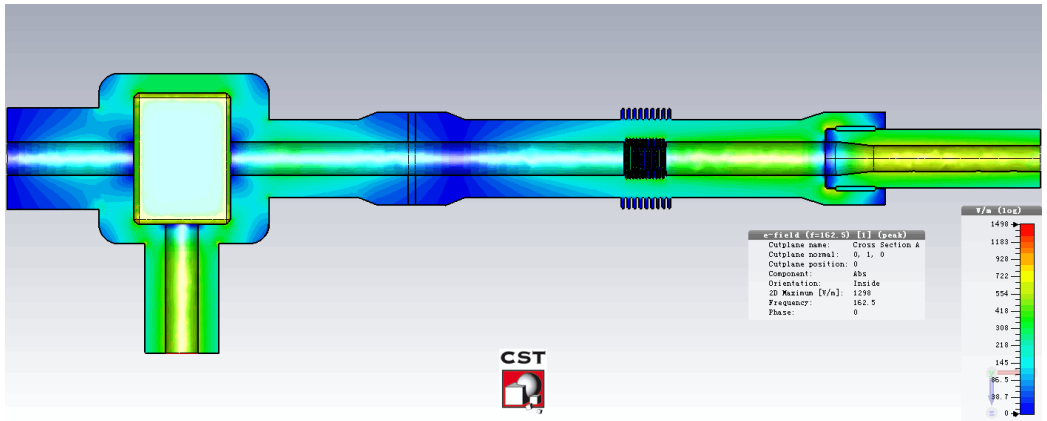
advantage:

1. Dual-windows more reliable
2. Easy for assembling
3. Reduce the size of the crymodule

New coupler RF design

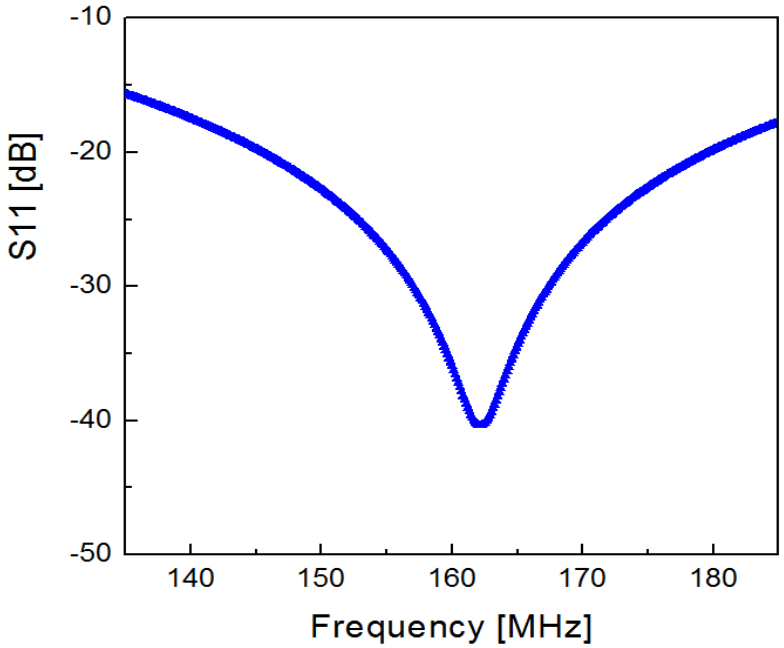


Travelling mode (H_field)



Travelling mode (E_field)

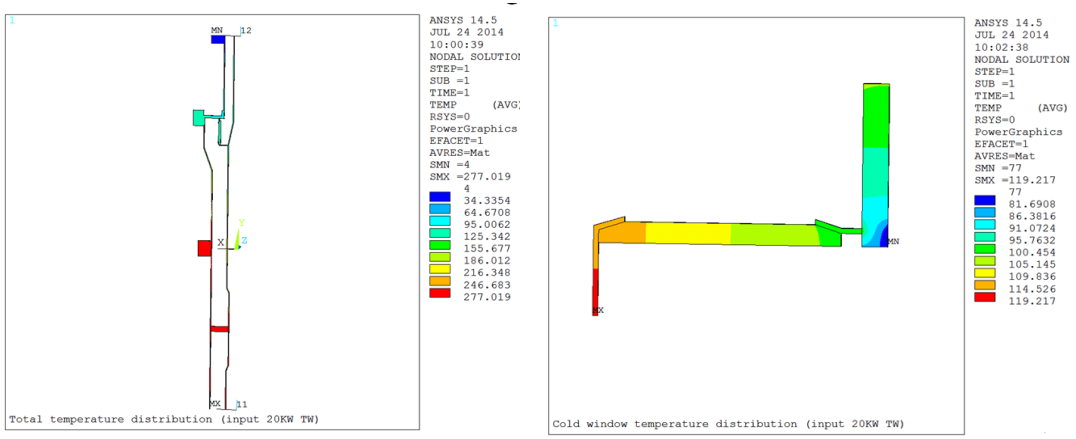
Power transmission



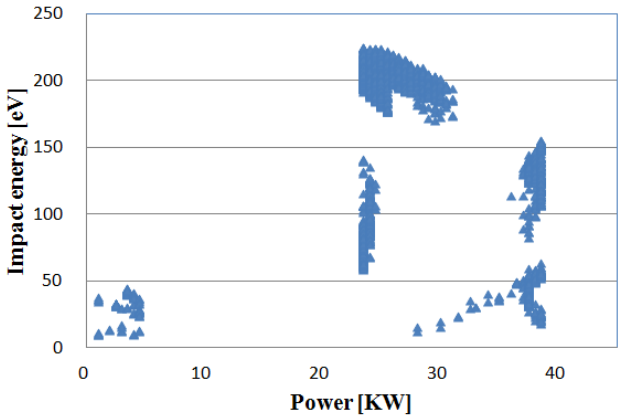
S11<-35dB@162.5MHz

Thermal &MP simulation

Thermal simulation



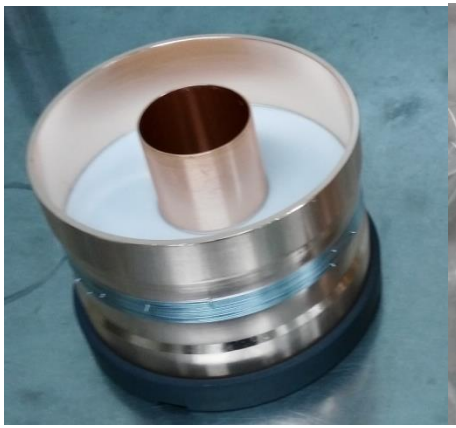
MP simulation

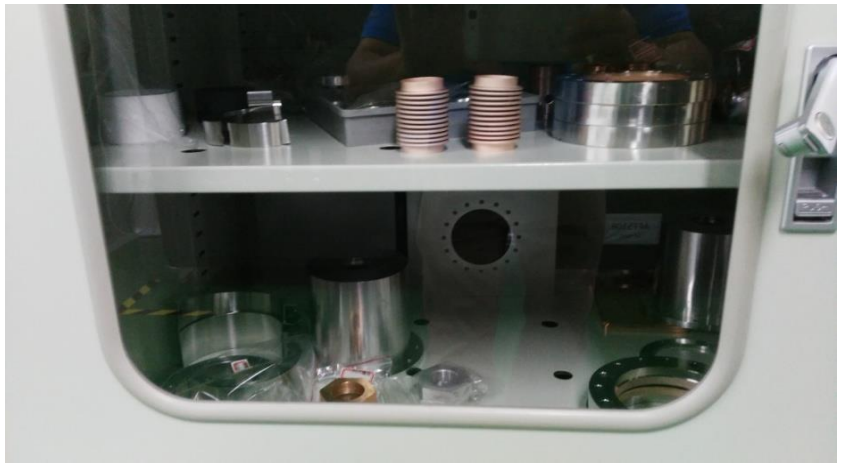


	4K (W)	80K (W)
static	0.1	10
20 KW (travelling)	0.8	35

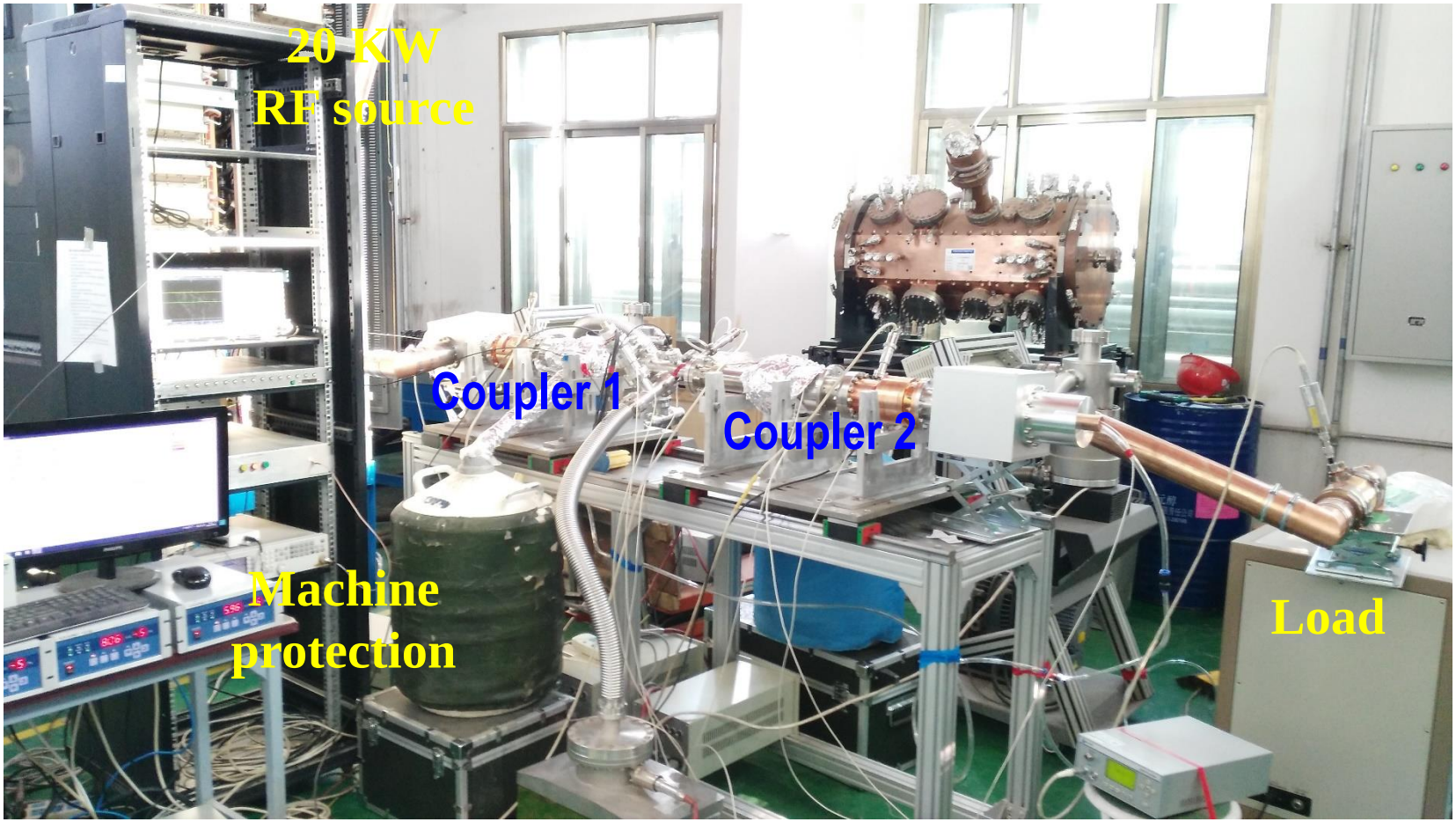
No hard MP below 20 kW travelling wave

Coupler Fabrication

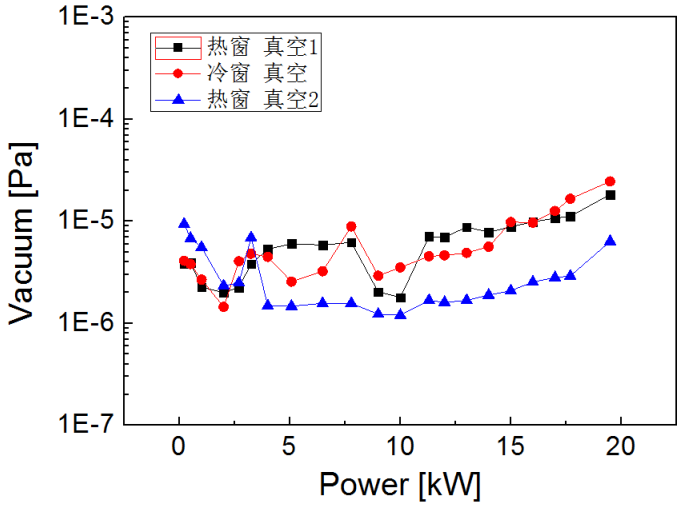




Coupler RF Test



Coupler RF Test



CW 20 kW for both travelling and reflecting modes

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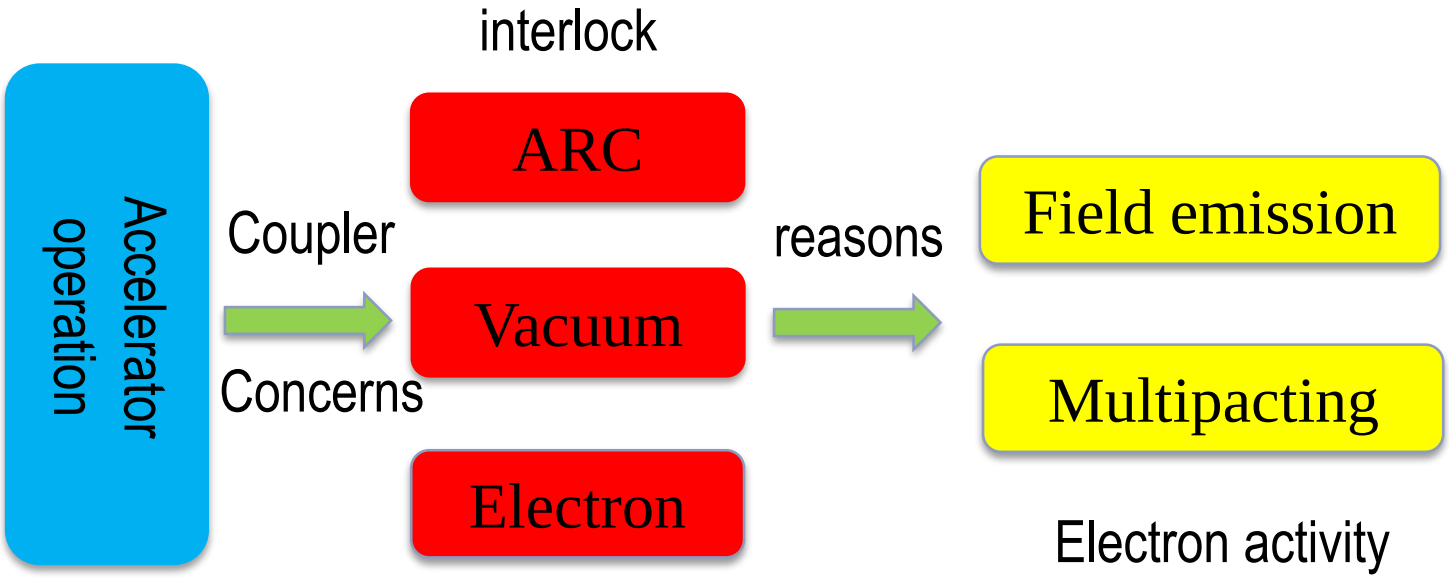
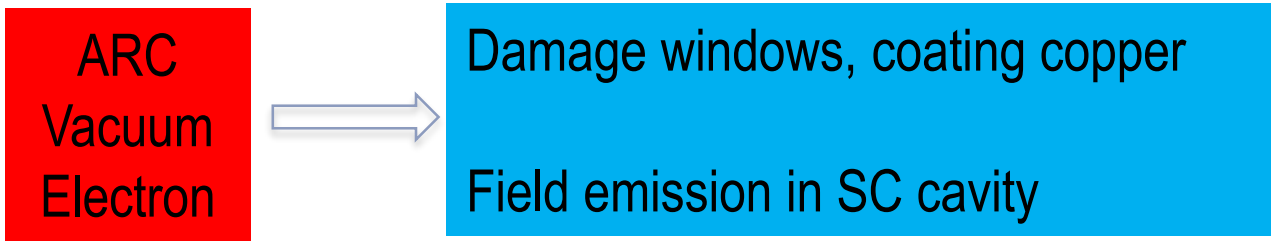
Coupler Operation Feedback

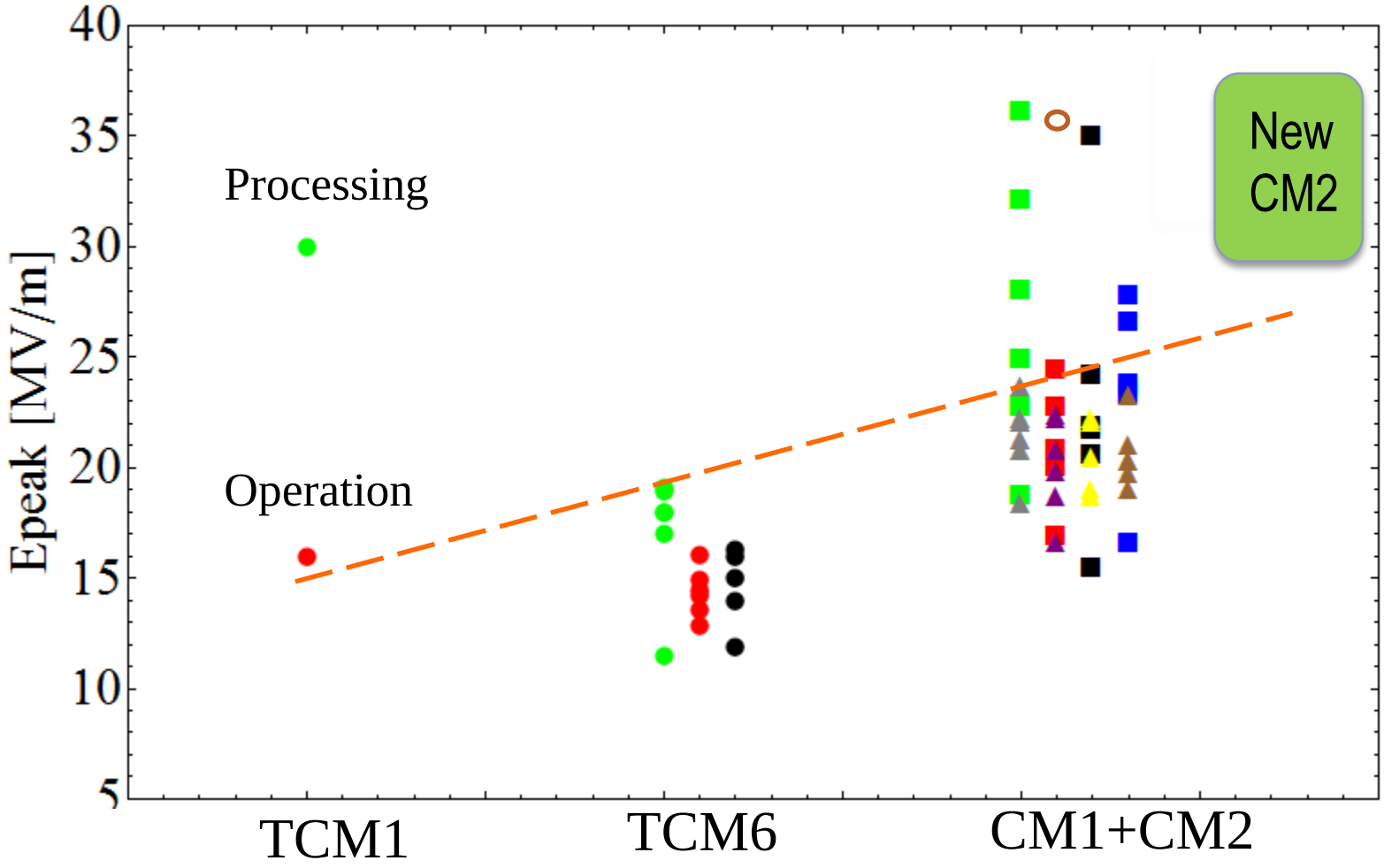
The main concerns for the couplers during SC accelerator operation are the ARC, vacuum and electron probe interlock.





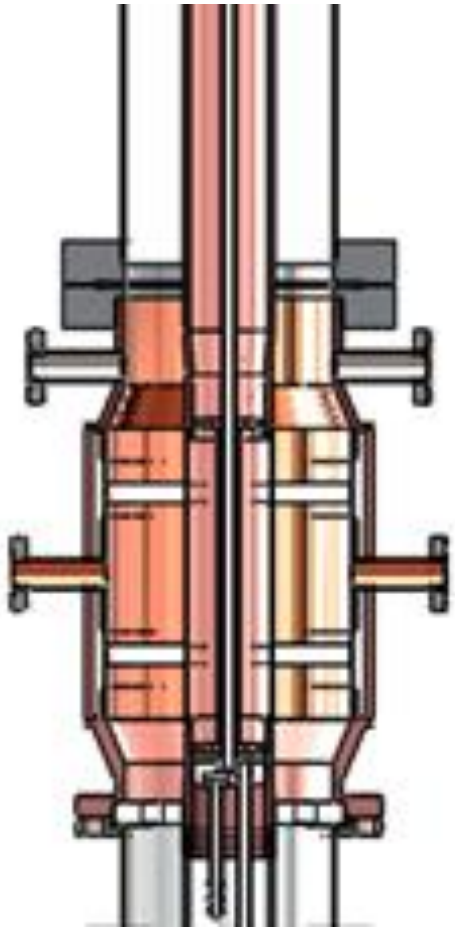
P.V. Tyagi *et al*, 2016, R. Ballantini *et al*, 1999

Summary of Cavity Gradient



Achivable gradient grow up with new cryomodules. Cavity Gradient will degrade with long time operation (leaking, Gas burst out from coupler).

Coupler Brze



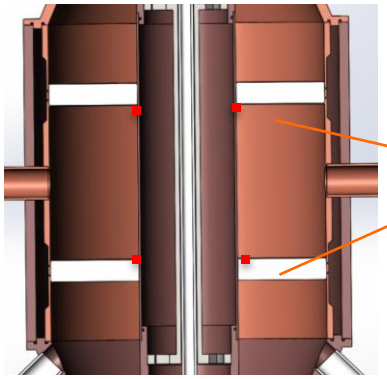
Braze for the windows

AgCuPd Braze ozzed

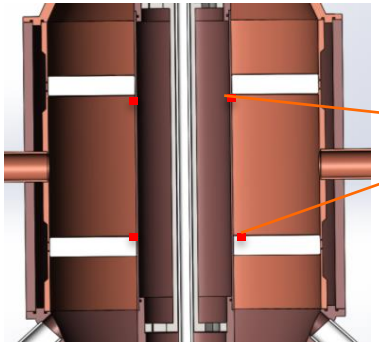
Arcing during the condition of the coupler.

Solve

1. groove

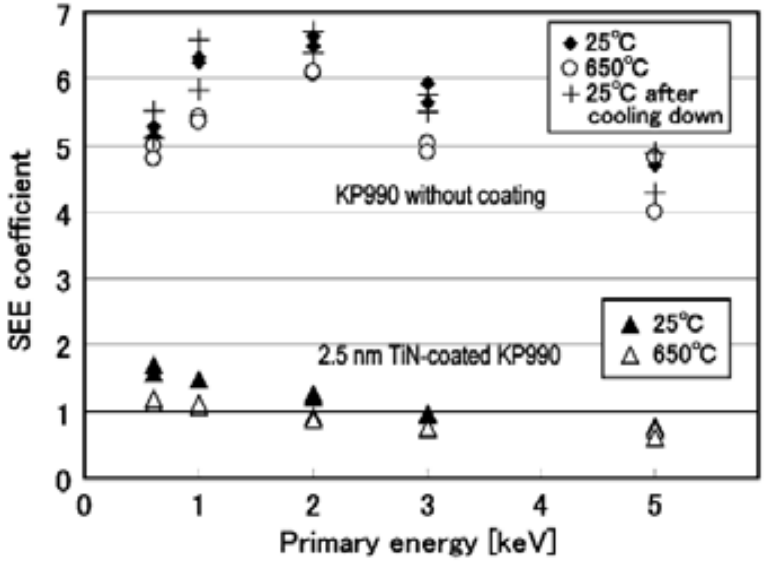


2. AuCu Braze

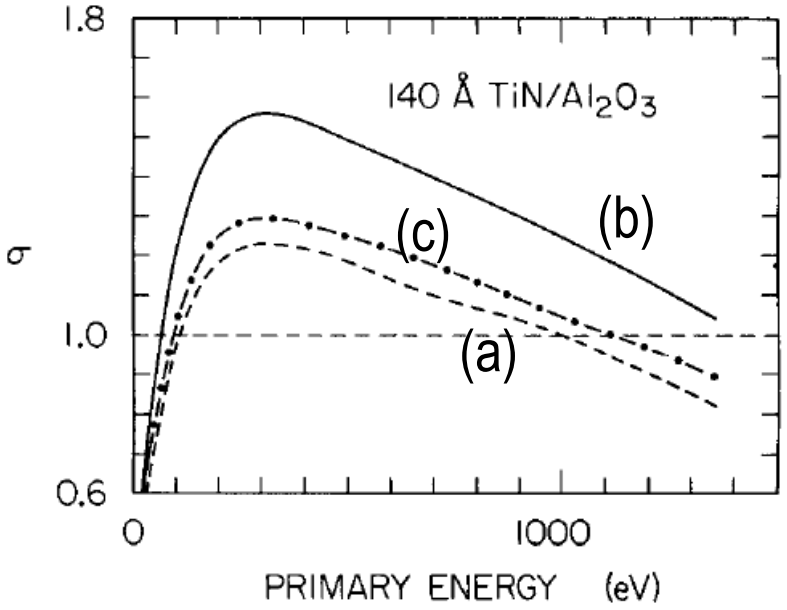


Both of the two ways solve the problem.

Coating thin film for Windows



SEE W/O TiN coating for Ceramic



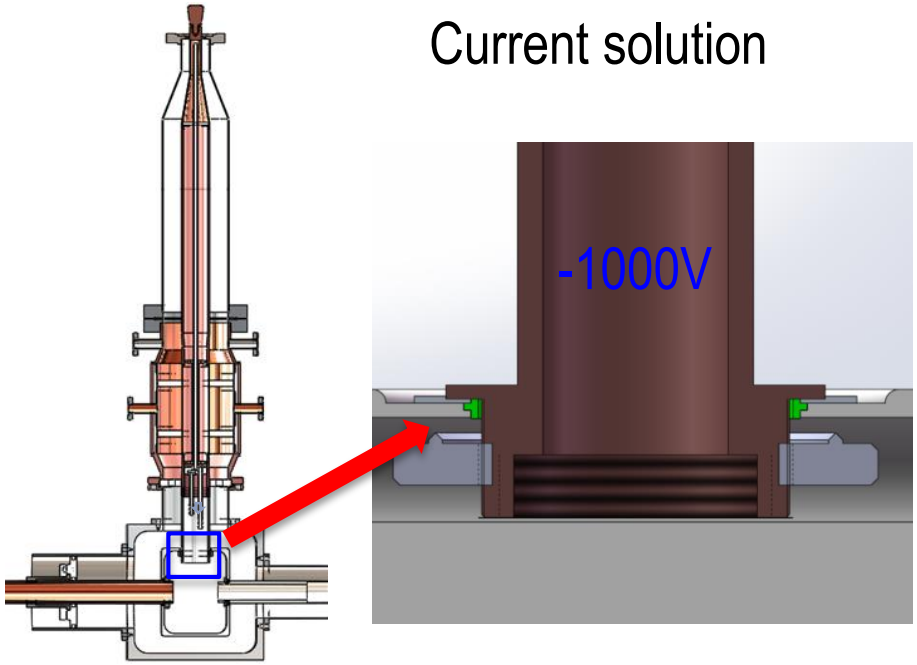
We try to coat TiN on the windows. But during the condition, the couplers still burst out of gas, especially after the assembling of the the new crymodule.

(a) after deposition, air exposure, and bake at 550 ·*in vaccum* for 10 h;, (b) exposed to room air 1h, (c) electron bombarded, total dose=3 E17cm^{-2}.

Extreme layer thinness resulted in a significant drop in the SEE yield

Nyaiesh *et al* : Properties of thin antimultipactor coatings

Solve for the MP caused by Windows

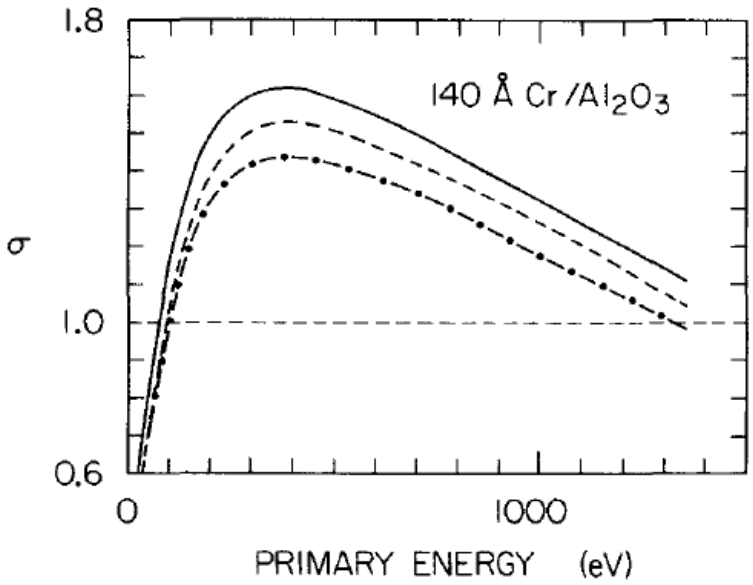


Current solution

Bias for the inner conductor

We biased the inner conductor and no burst out of gas unless the bias unworked.

Next step



same conditions as previous side.

Cr2O3 layer produced a stable SEE yield, not as low as TiN. But it is sufficient to prevent electron multipactor.

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Summary

- Two types of dual-windows couplers have been developed at IMP, which proved reliable than signal window couplers. They all achieved their design goal 12 kW and 20 kwW.
- Electron activities are the main reasons for the coupler and SC cavity degradation.

For low beta cavity, couplers design should be considered the field emission in the SC cavity.

MP suppresion in couplers need more work to do especially for SC cavites.

Thank you!