CEPC Vacuum System

Yongsheng Ma
Institute of High Energy Physics. CAS
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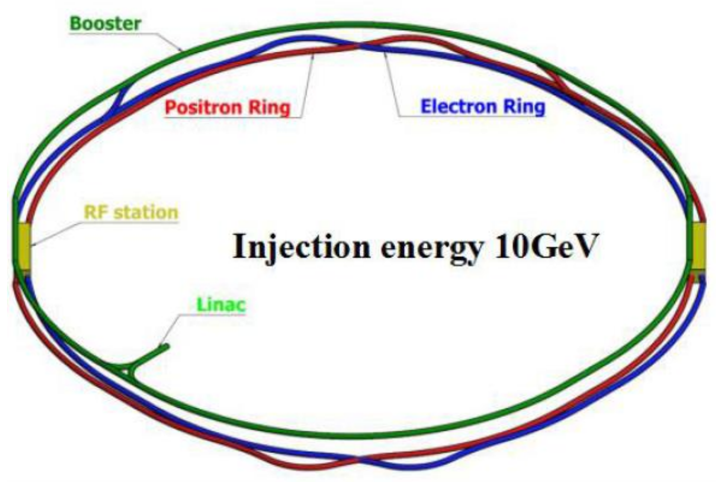
Outline

- ◆ **Introduction**
- ◆ **Vacuum Requirement Vs Calculation of Collider**
- ◆ **Progress R&D**
  - ➢ Vacuum chambers
  - ➢ NEG coating inside of vacuum chambers
  - ➢ RF shielding bellows
  - ➢ MDI vacuum
- ◆ **Summary**

Preview of CEPC vacuum system



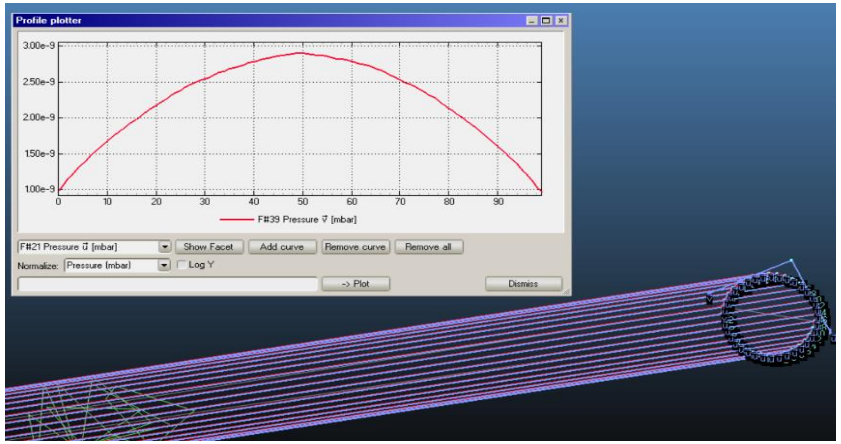
CDR Vacuum requirements and configuration Vs TDR

	Material	Cross Section
Booster	Extruded aluminum 6061	φ56
Electron Ring	Extruded copper, NEG film	56×75 to **φ56**
Positron Ring	Extruded copper, NEG film	56×75 to **φ56**
MDI	Copper/tungsten alloy, NEG film	φ20

Machine and Vacuum Parameters

	E	I	ρ	Vacuum	
	Gev	A	m	Torr	
Higgs	120	0.0167	10700	2×10^{-9}	CDR
W	**80**	**0.084**	**10700**	$\mathbf{1.5 \times 10^{-9}}$	**TDR**
Z	**45.5**	**0.803**	**10700**	$\mathbf{8 \times 10^{-10}}$	**TDR**
tt	**180**	**0.0033**	**10700**	$\mathbf{1 \times 10^{-8}}$	**TDR**

Vacuum pressure profile of pipe



Vacuum Requirement Vs Calculation of Collider

✓ PSD （photon-stimulated desorption）as a Function of Critical Energy of SR

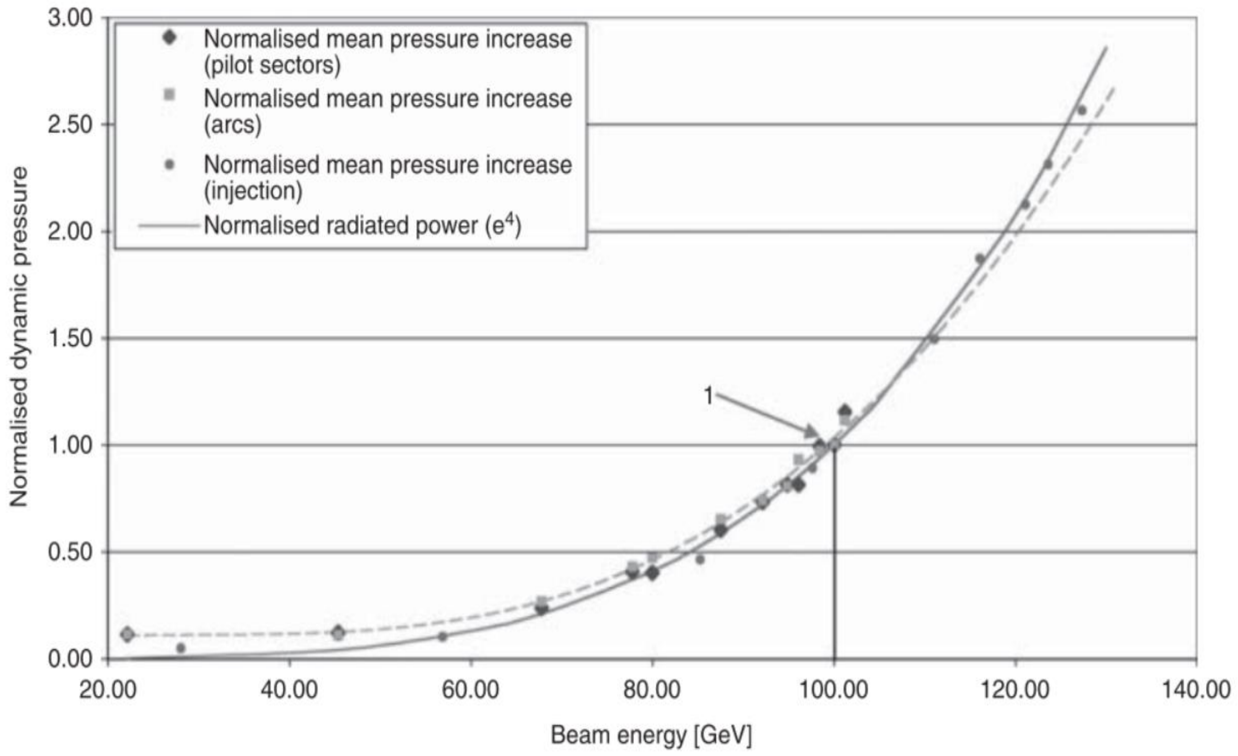


Figure 4.38 Normalised pressure increase in LEP as a function of beam energy. Source: Reprinted with permission from Billy et al. [114], Fig. 4. Copyright 2001, Elsevier.

	E	PSD
	Gev	molecules/photon
Higgs	120	**2.00E-05**
W	80	**1.00E-05**
Z	45.5	**4.00E-06**
tt	180	**1.35E-03**

[4] MALYSHEV O B. Vacuum in Particle Accelerators [J]. 2020,

Vacuum Requirement Vs Calculation of Collider

- PSD （photon-stimulated desorption） & TD （thermal desorption）
- Pav-Ar, CH_4-partial pressure， calculated as 1% gas load

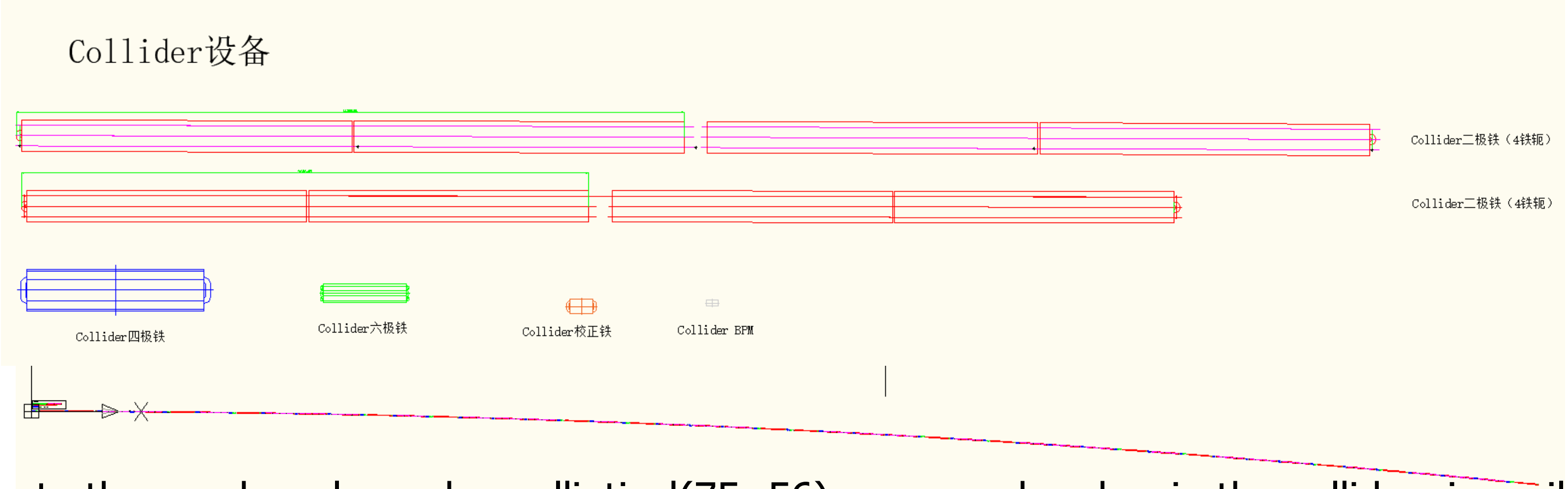
CEPC 30MW								
	PSD	q_{td}	q_{lsr}	q	P_s	SIP Distance	Pav	Vacuum requirement
	molecules/photon	Torr·L/s·cm²	Torr·L/s·cm²	Torr·L/s·cm²	L/s	m	Torr	Torr
Higgs	2.00E-05	1E-12	8.21E-12	9.21E-12	10	22	1.1E-9	2×10^{-9}
W	1.00E-05	1E-12	2.75E-11	1.48E-11	10	22	1.5E-9	1.5×10^{-9}
Z	4.00E-06	1E-12	1.50E-10	3.09E-11	10	11	1.0E-09	8×10^{-10}
tt	1.35E-03	1E-12	2.43E-12	1.65E-10	10	11	4.1E-09	1×10^{-8}
CEPC 50MW								
Higgs	2.00E-05	1E-12	1.43E-11	1.53E-11	10	22	1.7E-9	2×10^{-9}
W	1.00E-05	1E-12	4.82E-11	2.51E-11	10	22	2.1E-09	1.5×10^{-9}
Z	4.00E-06	1E-12	2.59E-10	5.28E-11	10	11	1. 8E-09	8×10^{-10}
tt	1.35E-03	1E-12	3.98E-12	2.70E-10	10	11	6.5E-09	1×10^{-8}

- In Z & tt mode, the number of sputtering ion pumps (SIP) needs to be doubled
- Due to the high flow intensity of Z mode, the vacuum is lower than the design value, which needs to be further evaluated

[4] MALYSHEV O B. Vacuum in Particle Accelerators [J]. 2020,

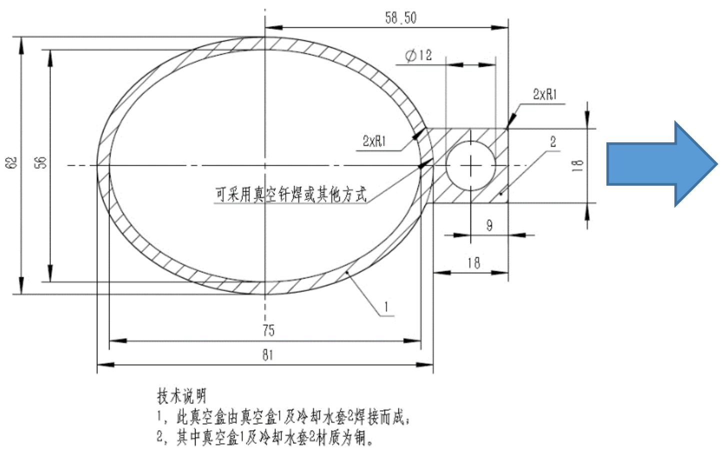
Progress R&D: Vacuum chamber

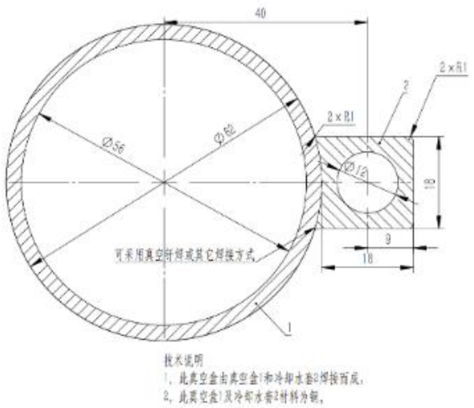
- Due to the length of the magnet, the maximum length of the vacuum chamber is obout 11.3 meters, and the shortest length is about 3.8 meters.



Wang YW
LI MX

- To eliminate the quadrupolar wakes, elliptical(75×56) vacuum chamber in the collider ring will be replaced by circular chambers with dimeter of 56 mm

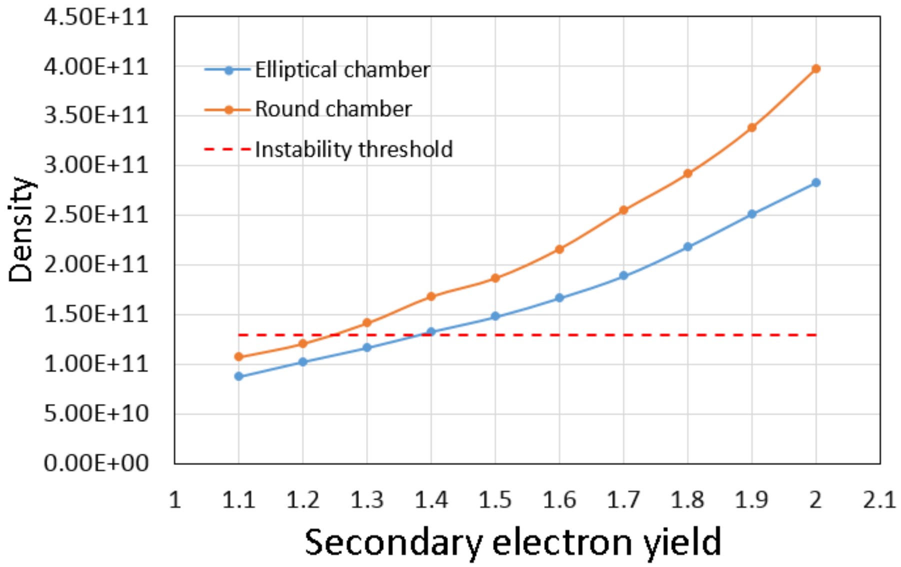




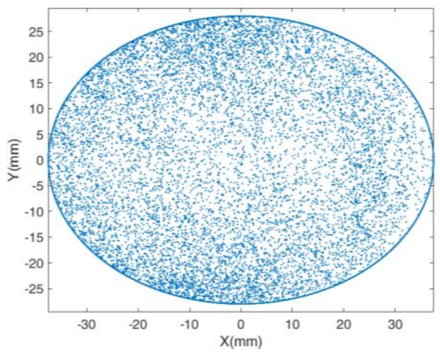
Challenge and Response : Electron Cloud & *impedance*

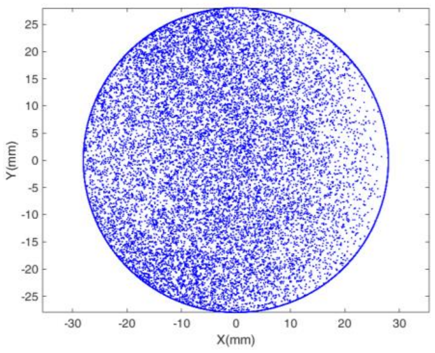
Liu Yu Dong

Electron Cloud of positron ring



Elliptical chamber: SEY<1.3
Round chamber: SEY<1.2
NEG coating : effective method on control





Resistive wall impedance

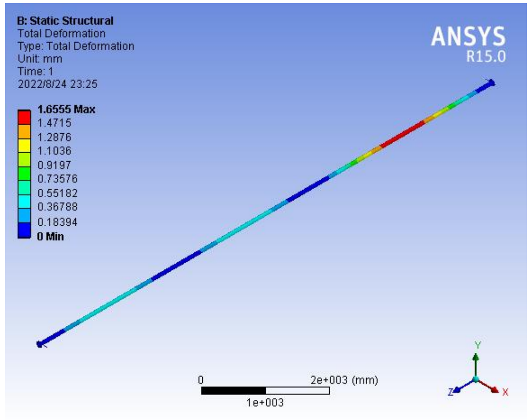
Round pipe of Copper (2mm) with NEG coating (200nm)

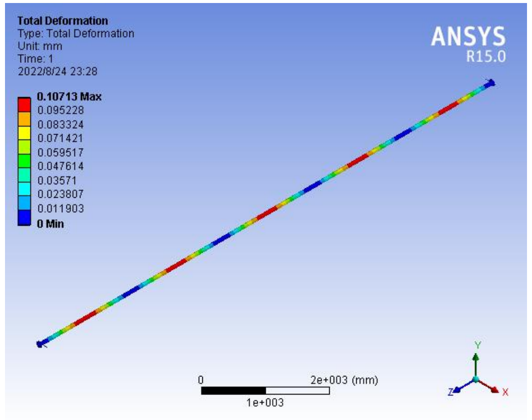
Strictly control on the coating thickness for impedance source to restrain the instability!

Liu Yu Dong .Modification suggestion of vacuum chamber for the collider ring. 2021/3/25

Strength calculation of 10 m vacuum chamber

- Good support is an important guarantee to ensure that the 10-meter vacuum chamber does not deform

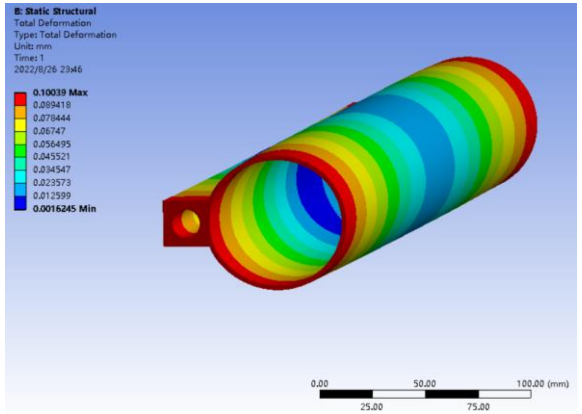


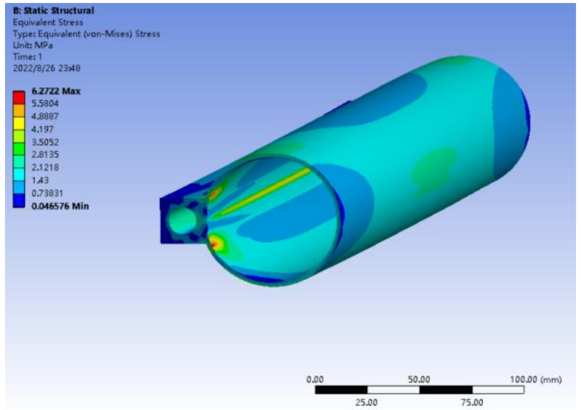


Every 3m is supported, with a maximum deformation of 1.66mm;

Every 2m is supported, with a maximum deformation of 0.1mm

- The RF bellows need enough compression length

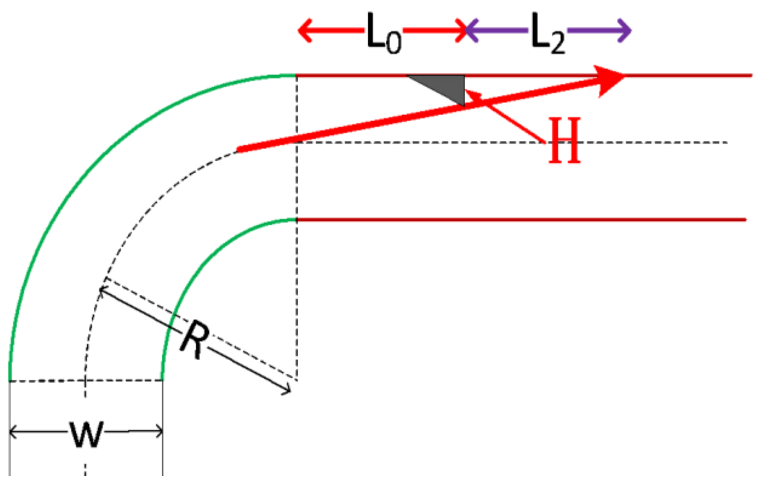


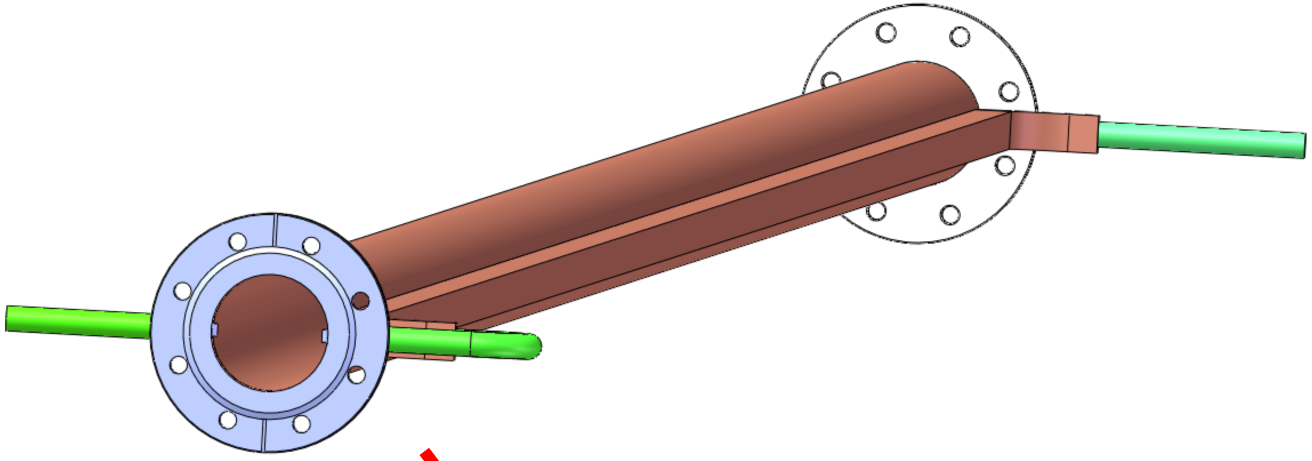


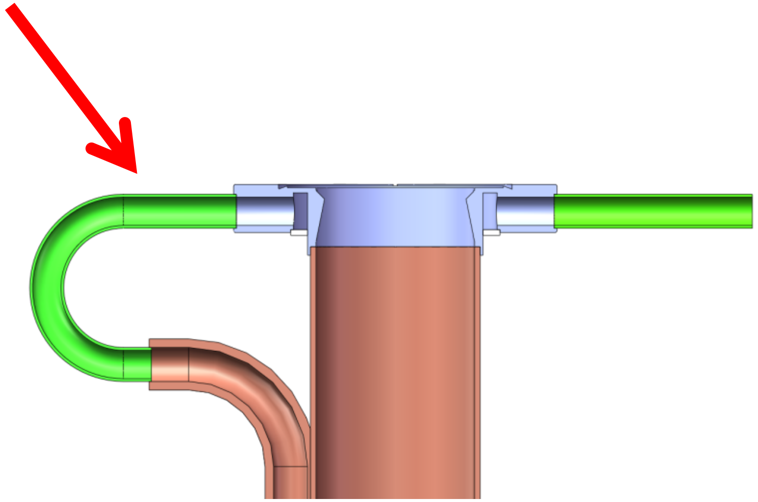
The block and water cooling design

◆ **Block is used to protect the bellows and BPM from the synchrotron radiation etc.**

W(m)	R(m)	H(m)	L0(m)	R+0.5W-H	Cos	Thita	L2(m)
0.056	10700	0.001	0	10700.027	0.9999975	0.00225	0.445
0.056	10700	0.0005	0	10700.028	0.9999974	0.00227	0.221



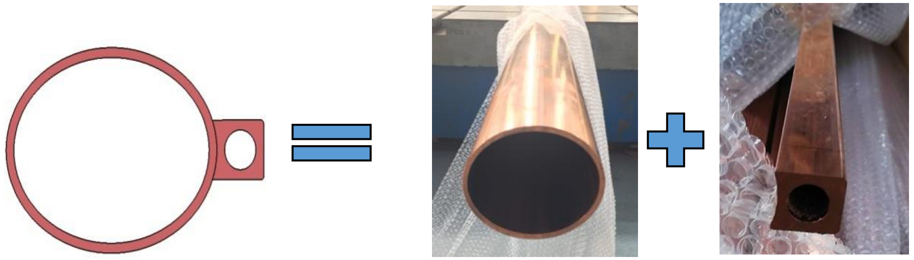




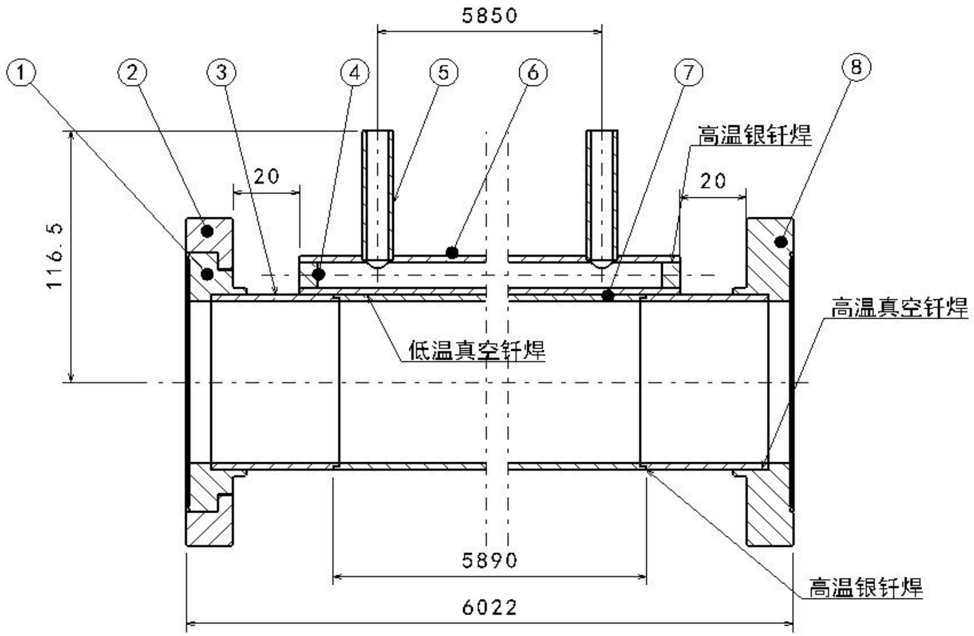
- ➢ Due to the large bending radius, a 1mm block at the dipole iron outlet can block the synchronous light irradiation in the downstream 0.44m area, theoretically.
- ➢ The installation accuracy needs to be very high.

Technique process Cu vacuum chamber

- Cu beam pipe and water cooling channel are extruded respectively, and brazed together.
- Stainless steel material is used for flanges, and there is a rotatable flange at an end of vacuum chamber.
- The flanges and beam pipe are welded by high temperature brazing solder, and low temperature brazing solder are used between the beam pipe and water cooling channel.



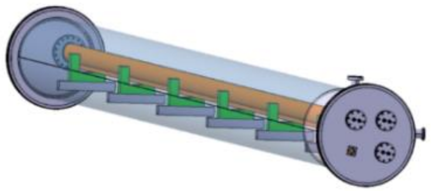
Vacuum chamber　　Beam pipe + Cooling channel



Cu and Al vacuum chamber prototypes

- A 6 m long simple vacuum furnace is fabricated, which is used to weld the water cooling channels of Cu chambers through low temperature brazing solder.
- The welding seams are checked by wire-electrode cutting. The welding joints are smooth and have good contacting.
- The prototypes of copper & aluminum vacuum chambers with a length of 6 m have been fabricated and tested, which meet the engineering requirements.





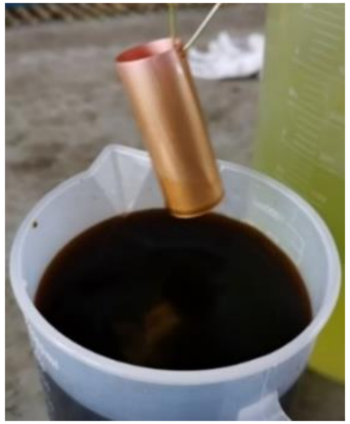
Round chamber is easier to be fabricated.

Preparation of Cu substrate for NEG coating

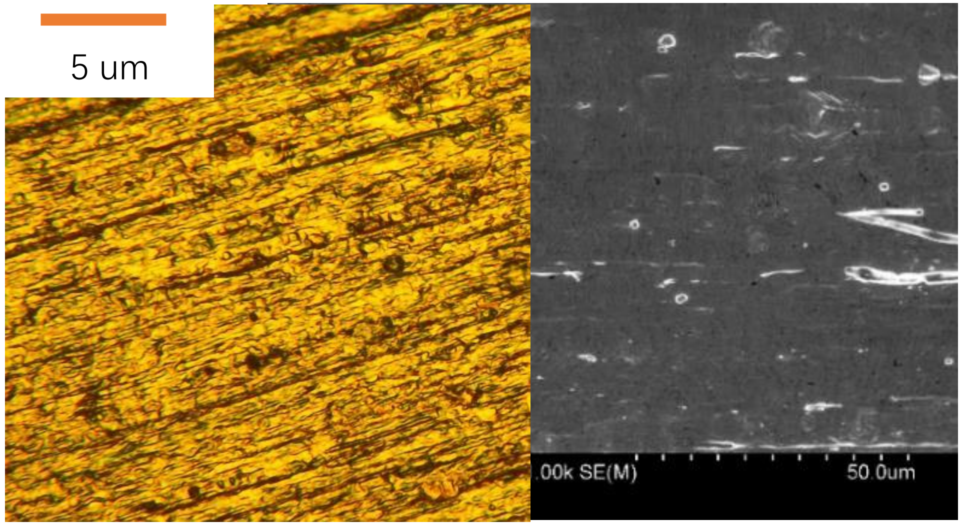
■ **Vacuum pipes fabricated for NEG coating**

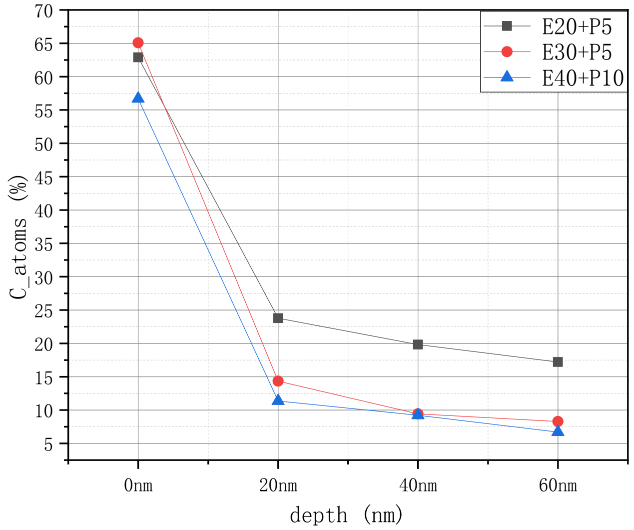
Vacuum pipes will be degreasing

etching



passivation

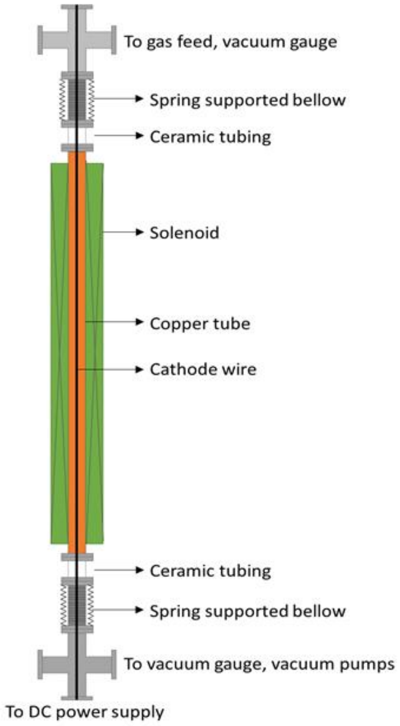


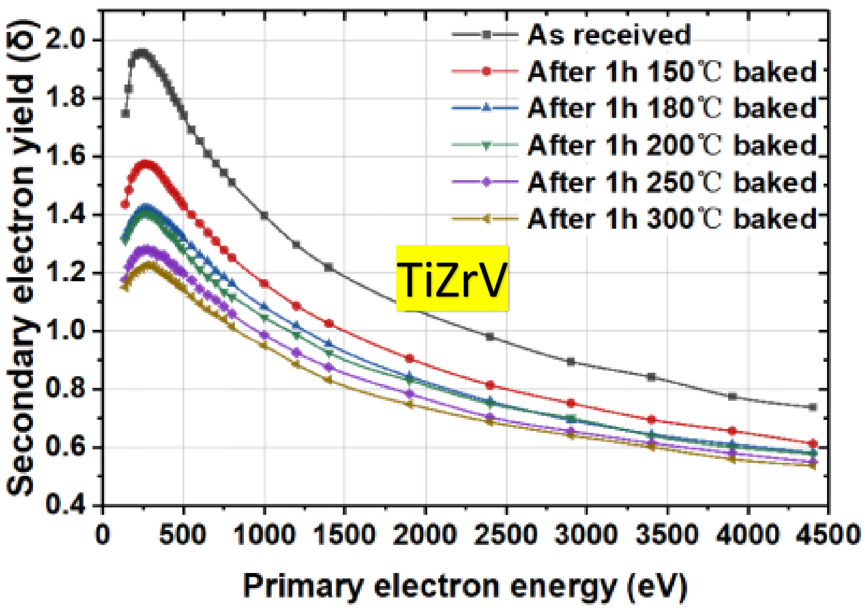


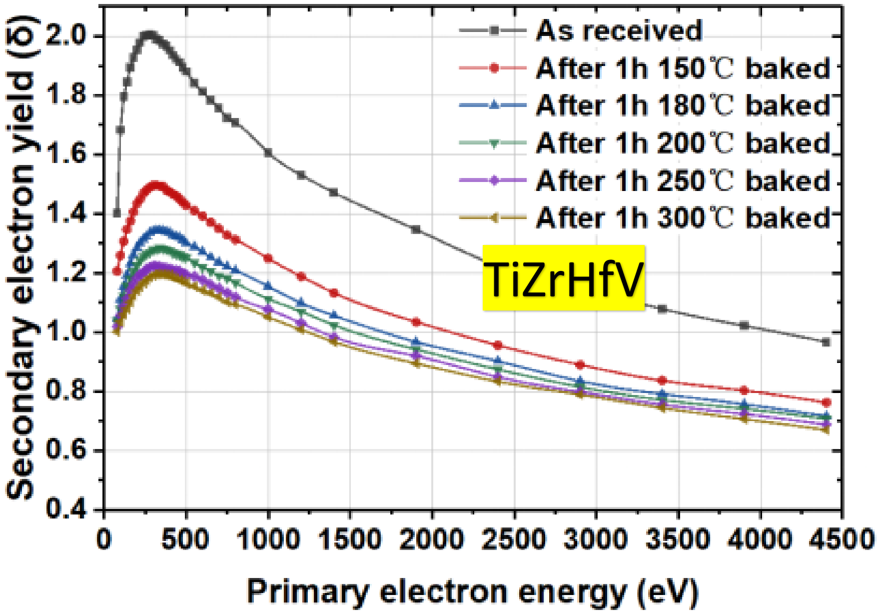
The content of oxygen decreases as depth of Cu surface

NEG coating of vacuum chamber

- NEG coating suppresses electron multipacting (SEY < 1.2) and beam-induced pressure rises, as well as provides extra linear pumping.
- The NEG coating is a titanium, zirconium, vanadium alloy, deposited on the inner surface of the chamber through sputtering.
- The coating thickness should lower than 200nm to control impedance source to restrain the beam instability!



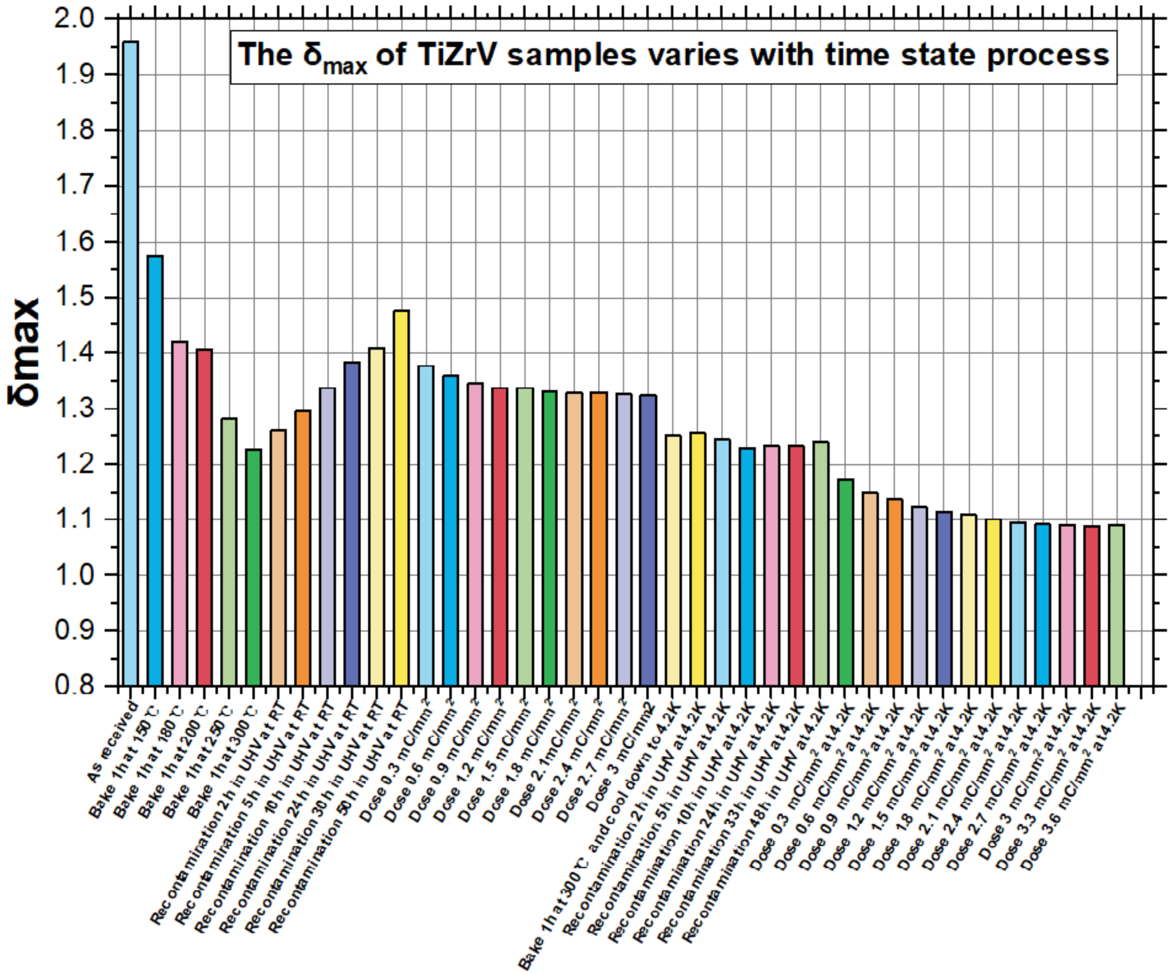


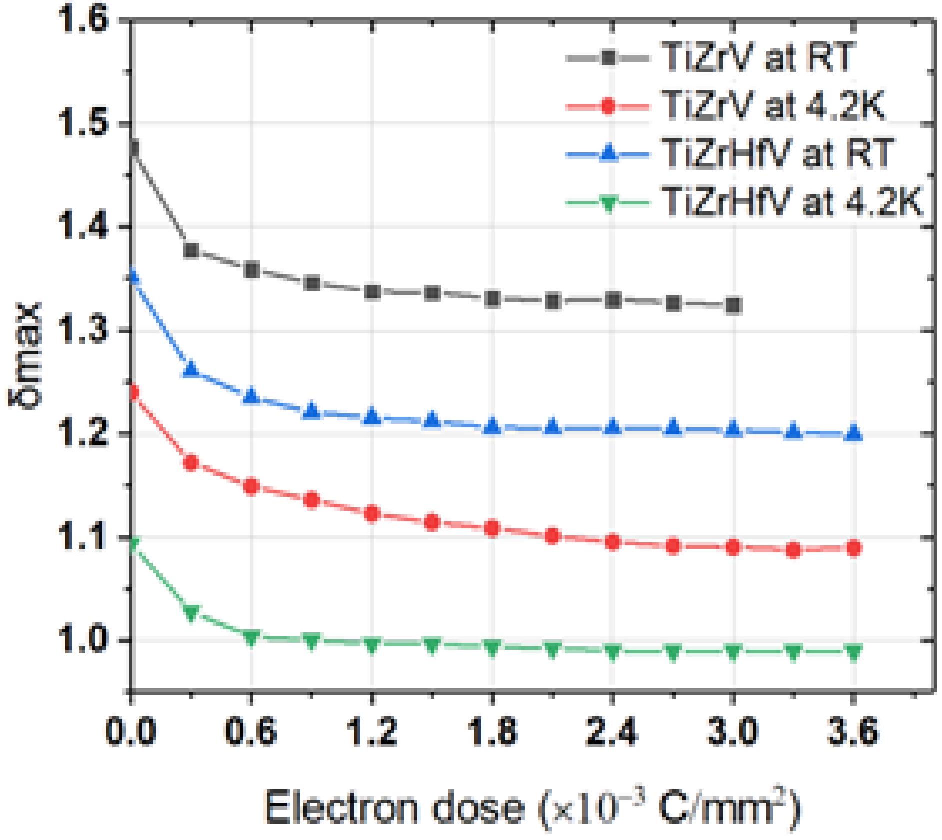


[1] LIU S, LIU Y, WANG P, et al. Experimental study on secondary electron emission characteristics of Cu [J]. Rev Sci Instrum, 2018, 89(2): 023303.

◆ SEY of NEG coating

SEY will decrease to 1.1 after synchrotron radiation

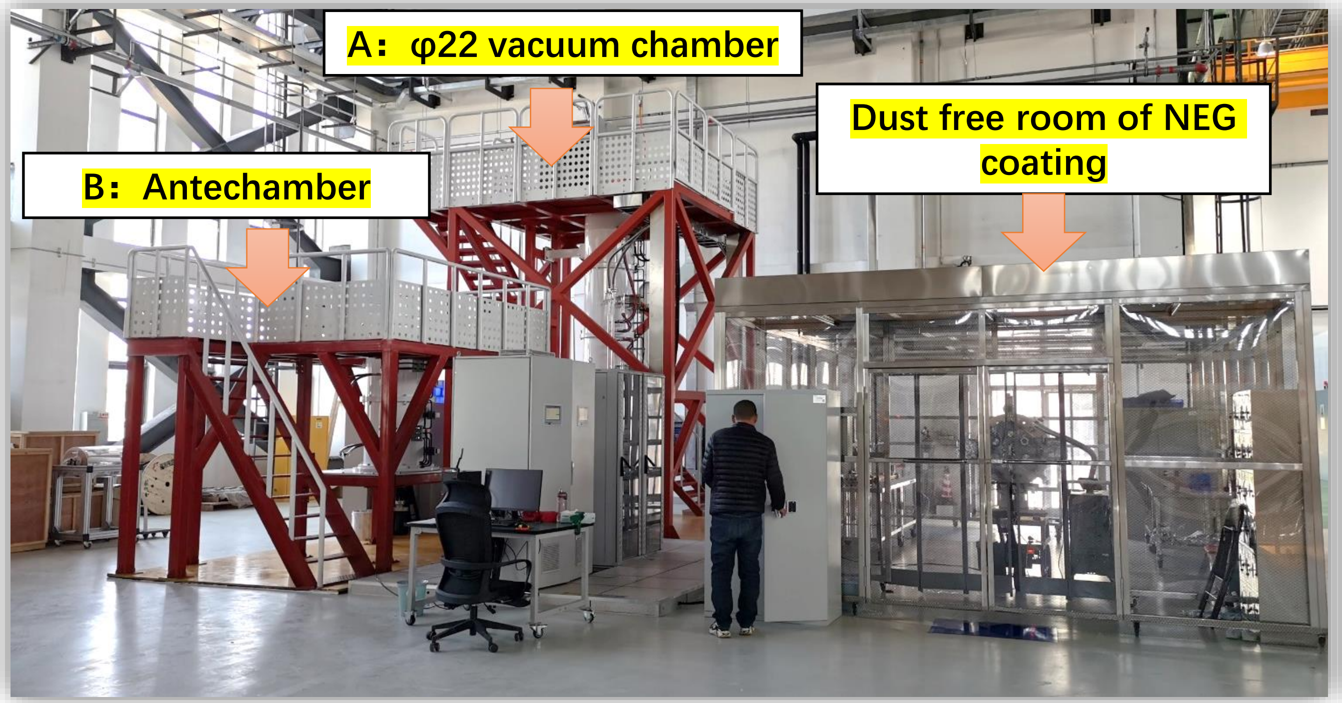




NEG coating facility synergy of HEPS

□ NEG coating of vacuum pipe

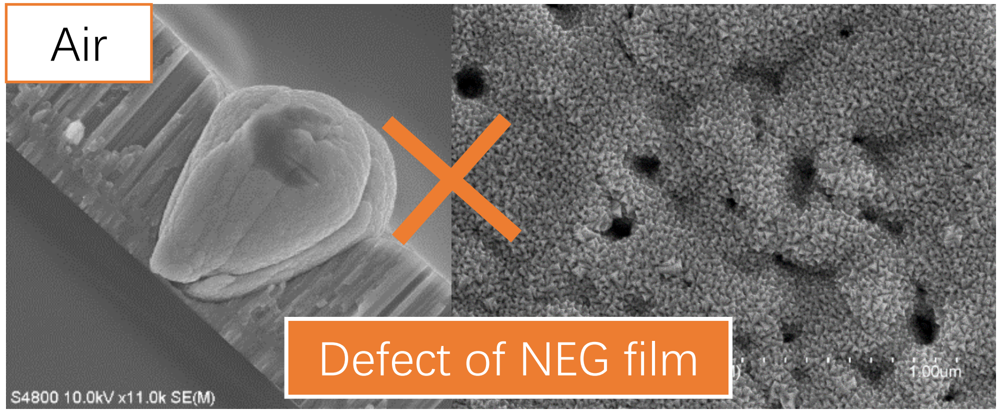
A setup of NEG coating which has ability to coat 4 meters long pipe has been built for vacuum pipes of HEPS at location of PAPS. And several test vacuum pipes of 4 meters long, φ22 mm of inner diameter have been coated, which shows that NEG film has good adhesion and thickness distribution. Theoretically, It is easier to be coated of CEPC vacuum pipe, because of the ratio of diameter to length is 56/6000 which is bigger then 22/4000.

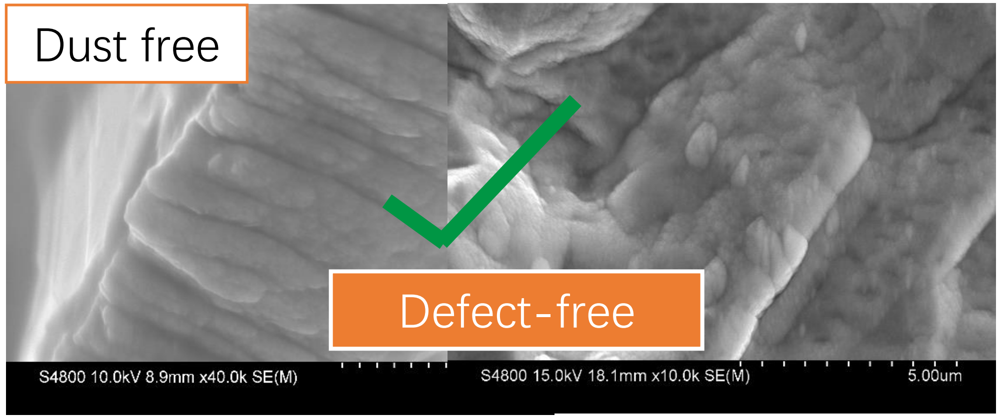


NEG coating facility synergy of HEPS

◆ **Quantity Production Control of NEG coating**

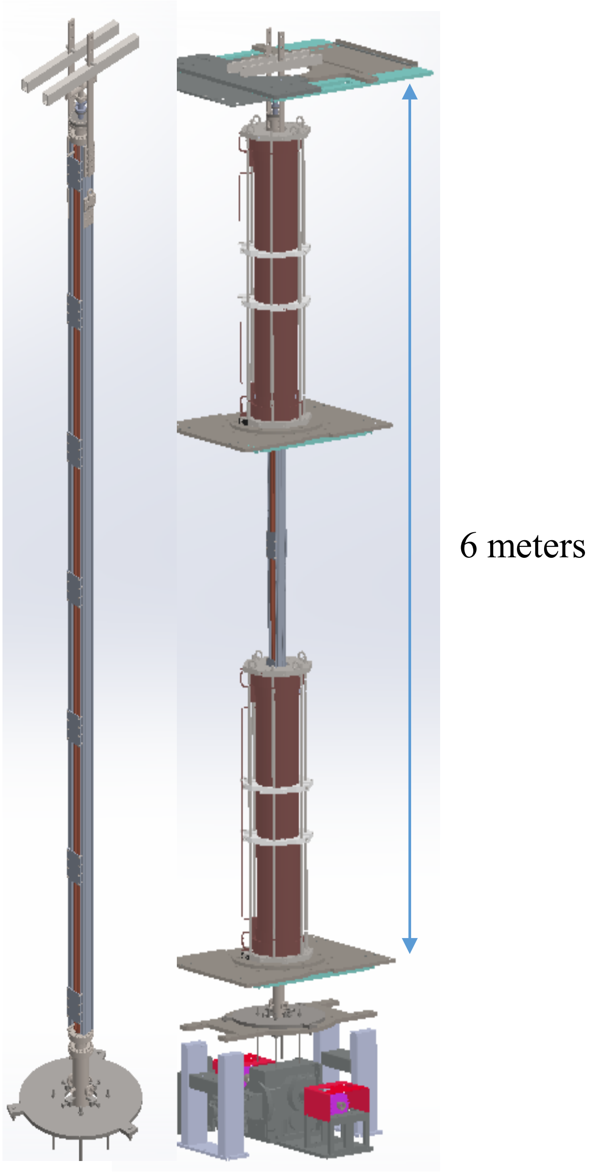
✓ Develop strict and standardized vacuum chamber assembly process to reduce pollutants and particles entering into NEG film during installation





NEG coating facility @ Dongguan

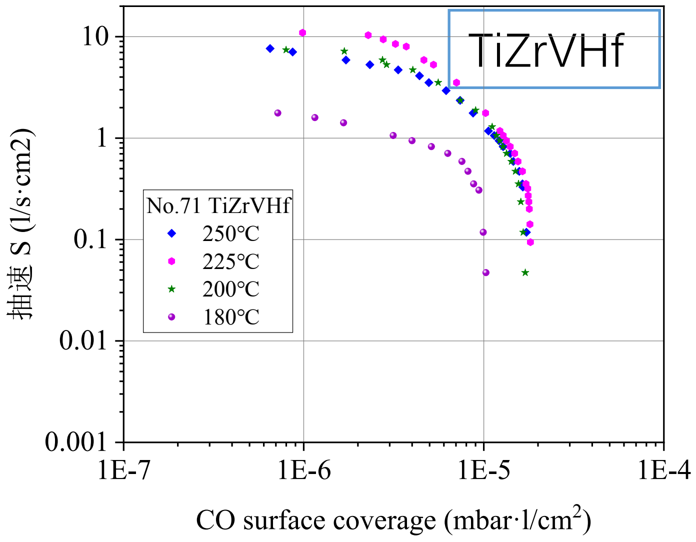
- A setup of NEG coating which has ability to coat 6 meters long pipe by moves solenoid is being built for vacuum pipes at location of Dongguan of Guangdong province.

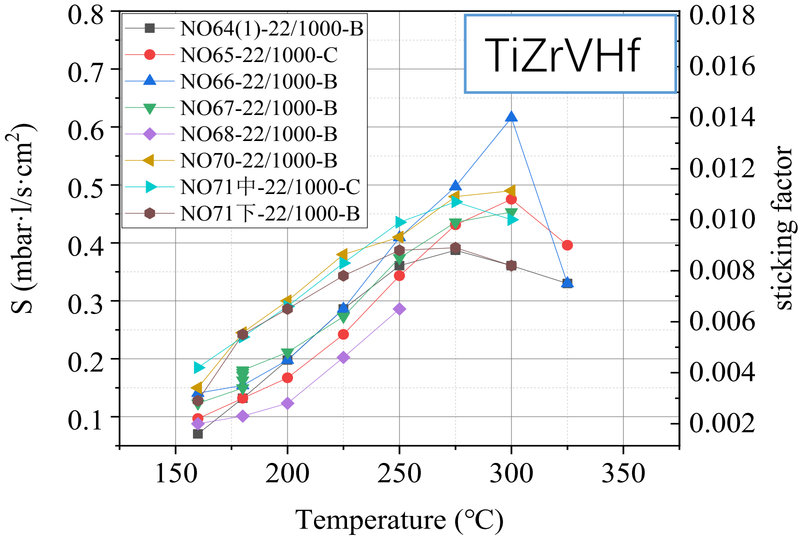


Progress R&D: NEG coating

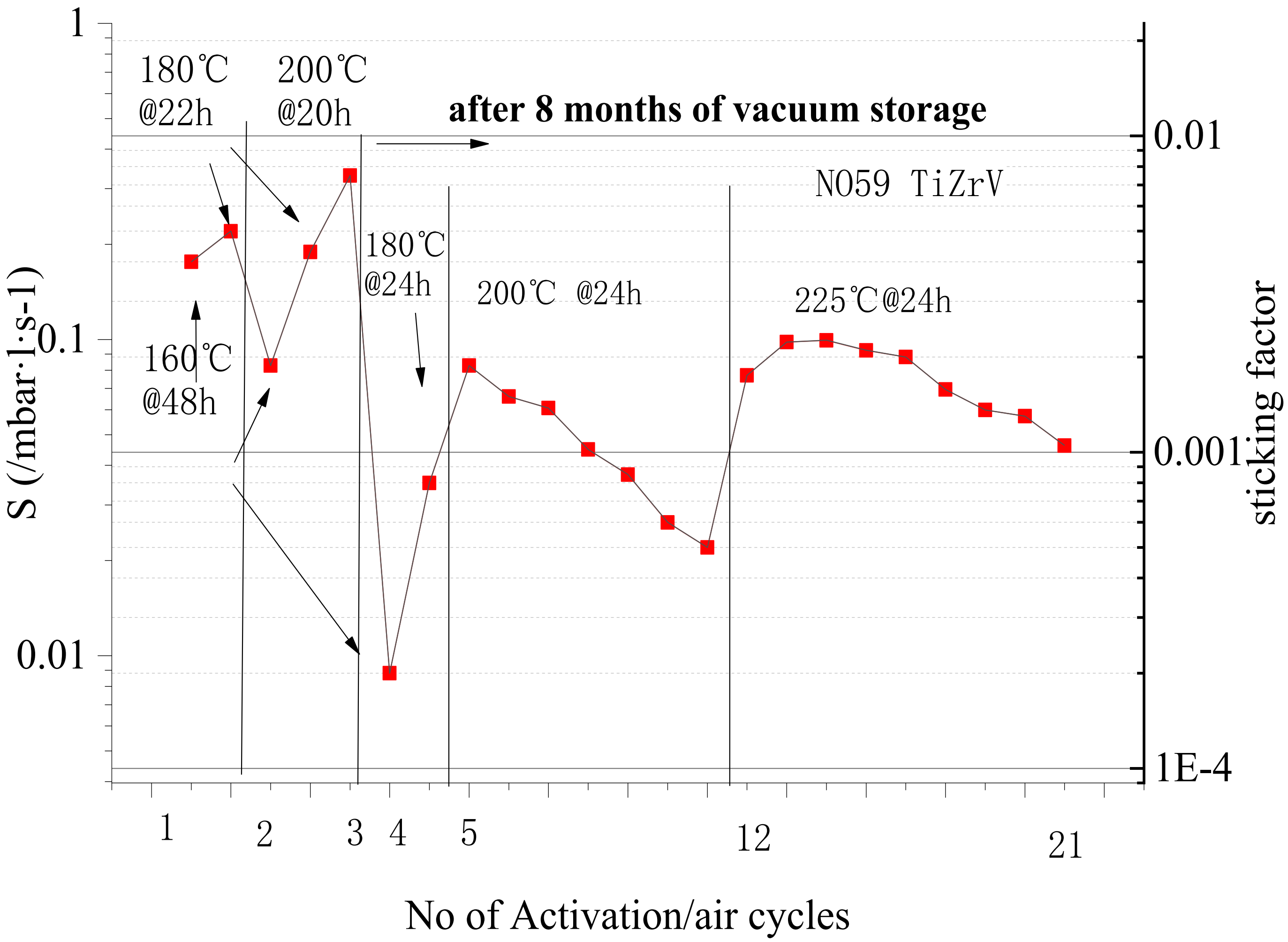
◆ Capacity and Pumping Speed of NEG

•Capacity is an important parameter to characterize the life times of NEG film
•Pumping speed will determine the pressure of vacuum



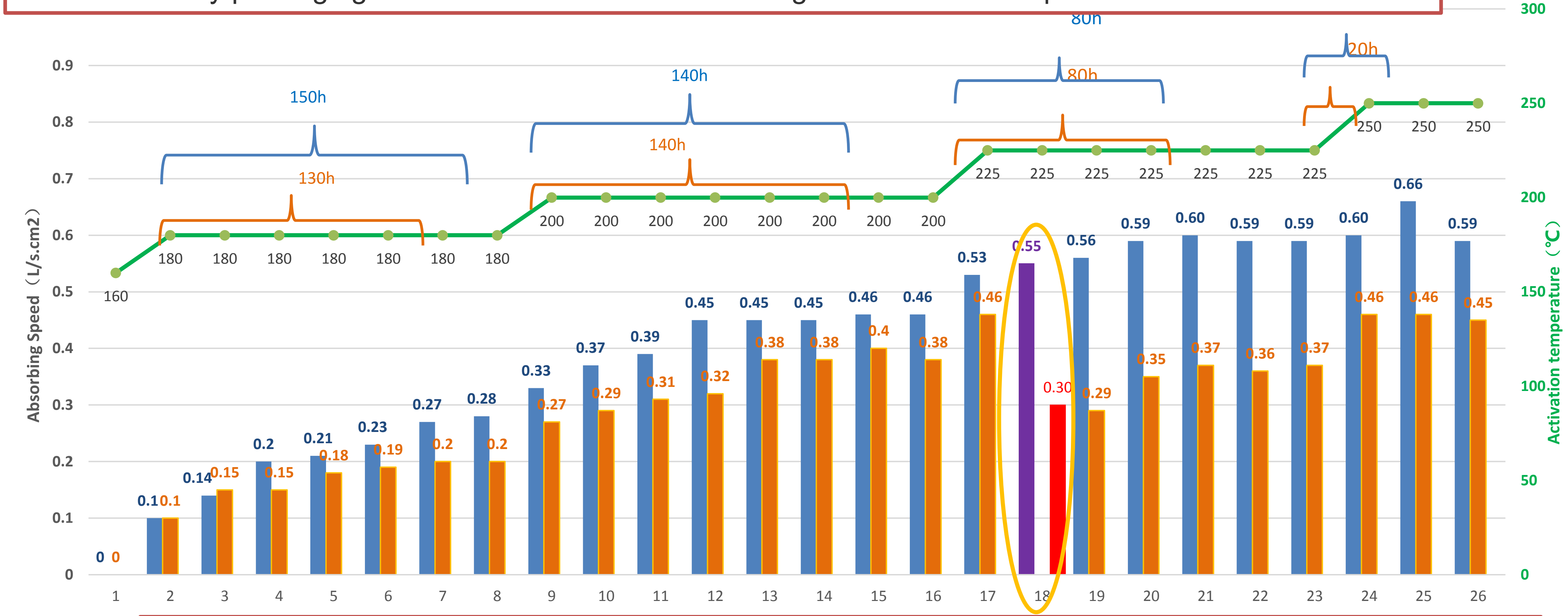


◆ Pumping Speed as Activation/air Cycles



☐ Absorbing speed of NEG coating at different activation temperature vs time

The pumping speed of NEG decreases with the increase of times of use, but the pumping speed of NEG can be increased by prolonging the activation time and increasing the activation temperature

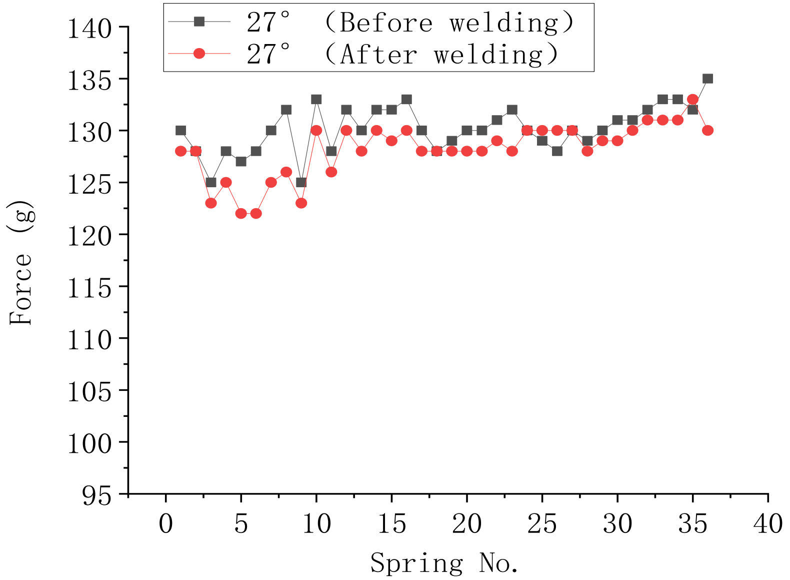


N063 is the number of NEG coating, (2),(3) represent the two different NEG coating pipes at the same coating process

- No63 (2) After 11 months N2 storage
- No63 (3) After 7 months Ne storage
- No63 (2) -18, Measure pumping speed immediately after cooling , the pressure is about 5E-9 Torr. While the others measurement
- No63 (2) -18, The background of vacuum pressure is high during this NEG coating activation, due to only turbo molecular pump(TMP) worked at this occasion, while others activation both TMP and ion pump worked together . Which shows that the bad background vacuum of activation has an negative effect on the NEG pumping speed.

R&D of RF shielding bellows

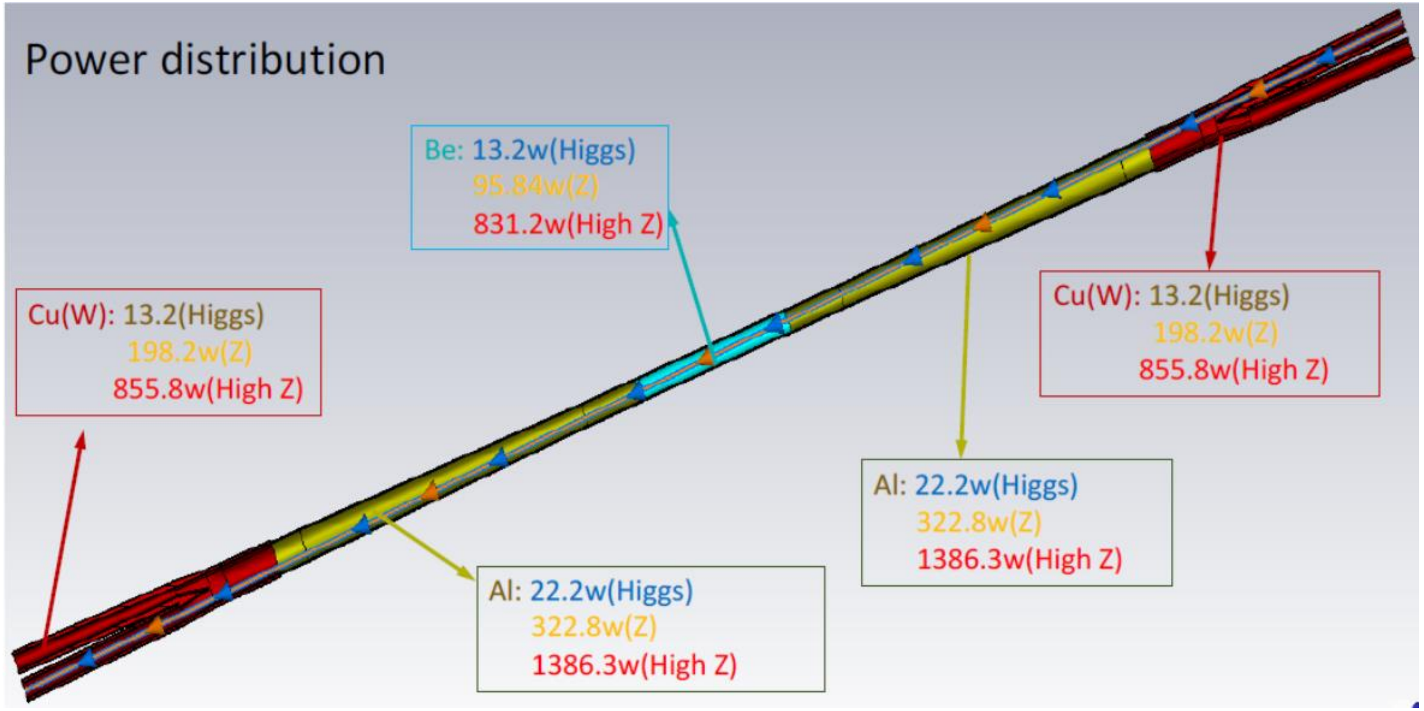
- Vacuum bellow modules are needed to compensate the mechanical misalignments of the vacuum chambers during installation and to absorb their thermal expansion during the bake-out. In order to reduce the beam impedance during operation with beams these modules are equipped with RF bridges to carry the image current.[1]
- The key components experiments such as spring fingers and contact fingers have been carried out. Contact force is uniformly from different fingers and meets the target of 125±25g. The prototypes of RF shielding bellows have been fabricated in local company.



MDI vacuum

◆Conception design

- OFE copper or Tungsten alloy will be used to made the fork vacuum chamber of MDI
- NEG coating is suggested to the fork vacuum chambers
- Water cooling pipe is designed due to the high thermal load of impedance at high light Z model.



Summary

- Elliptical vacuum chambers in the collider ring are replaced by circular chambers with dimeter of 56 mm.
- The prototypes of copper & aluminum vacuum chambers with a length of 6 m have been fabricated and tested, which meet the engineering requirements.
- Similar to positron ring, NEG coating is proposed to vacuum chamber of electron storage ring to absorb extra gas load.
- The prototypes of RF shielding bellows have been fabricated. Contact force is uniformly from different fingers and meets the target of 125±25g.
- Tungsten alloy will be used to made the fork vacuum chamber of MDI

Thank you !