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CEPC vacuum R&D

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- NEG coating inside of vacuum chambers
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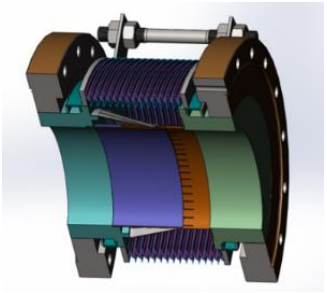
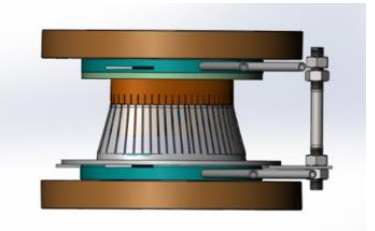
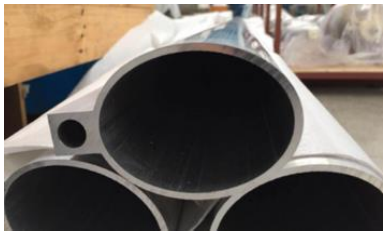
Introduction

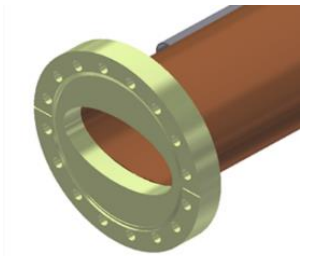
- Vacuum bellow modules are needed to compensate the mechanical misalignments of the vacuum chambers during installation and to absorb their thermal expansion during the bake-out. In order to reduce the beam impedance during operation with beams these modules are equipped with RF bridges to carry the image current.[1]



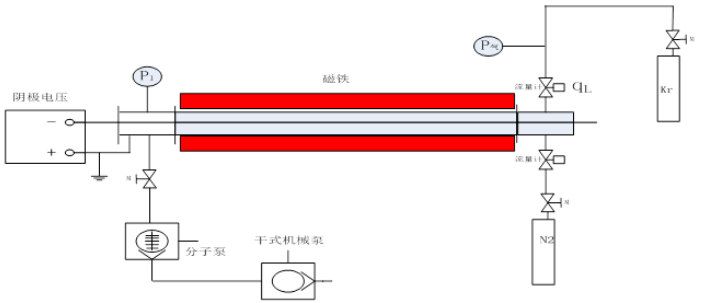


- Aluminum chamber for electron ring, copper chamber for positron ring. Some technical challenges such as extrusion, machining and welding have been solved.



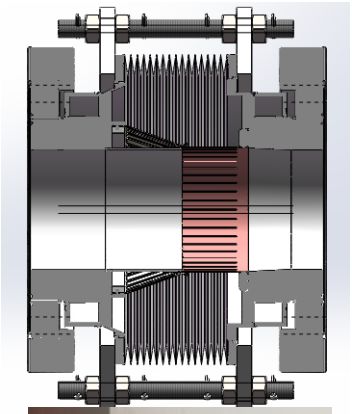


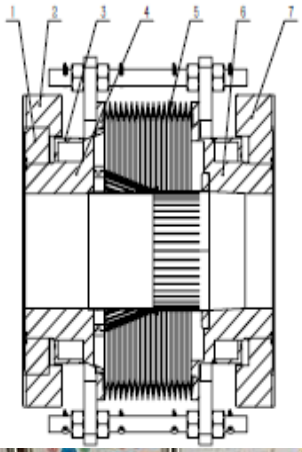
- NEG coating coated inside of copper vacuum chamber is employed to suppress SEY. Setups have been built for a long vacuum chamber, and coating methods and parameters are being studied. The structure, composition, SEY and pumping speed of NEG film samples are measured.



[1]IPAC2015-WEPHA005

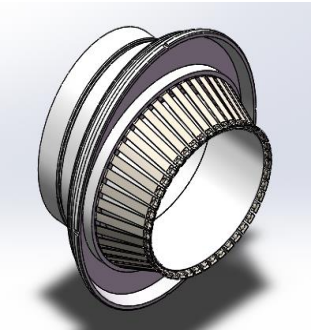
Progress of R&D of RF shielding bellows





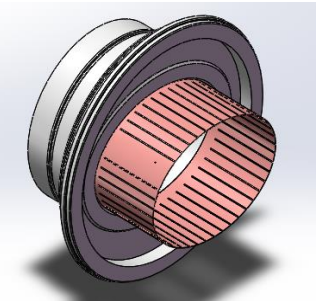
Bellows module

Spring fingers module



- Total length: 140 mm
- Inner and exterior diameter of bellows: 125mm/140mm
- Expansion/contraction: 5mm/12mm
- Offset: 2 mm
- Bending: 50 mrad

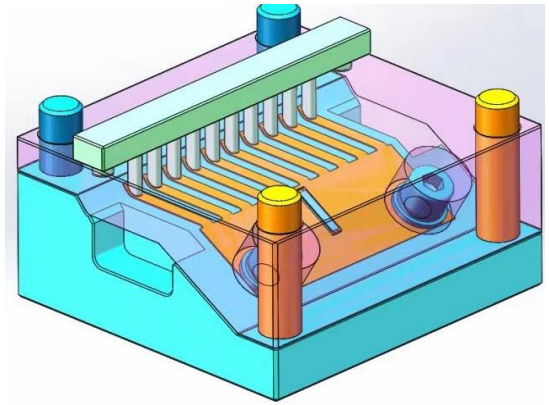
Above technical specifications have been reached.

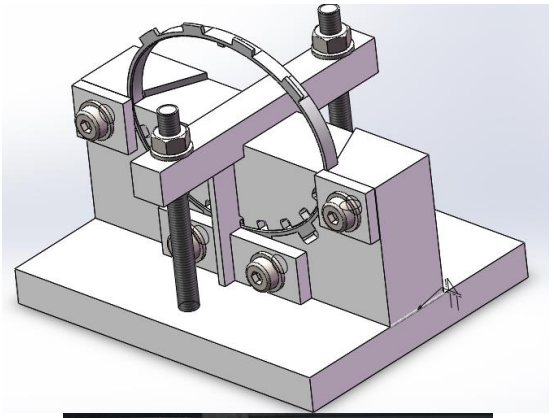


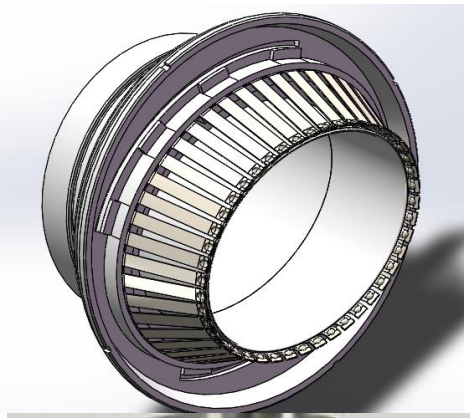
Contact fingers module

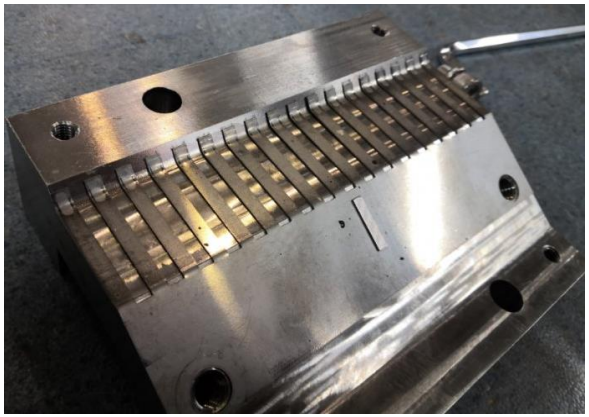
◆ optimization of spring fingers

Contact force between the spring fingers and the contact fingers is a key parameter. The beforehand angle of contact fingers are being adjusted to achieve it.

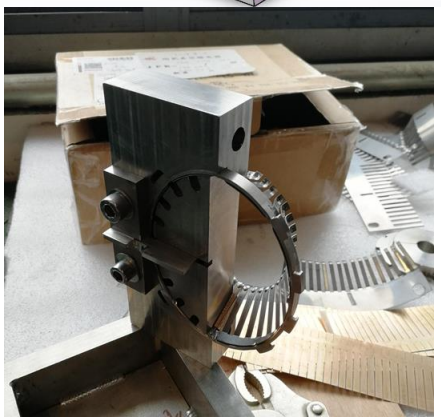








Mould of contact fingers adjustment



Mould of compression ring

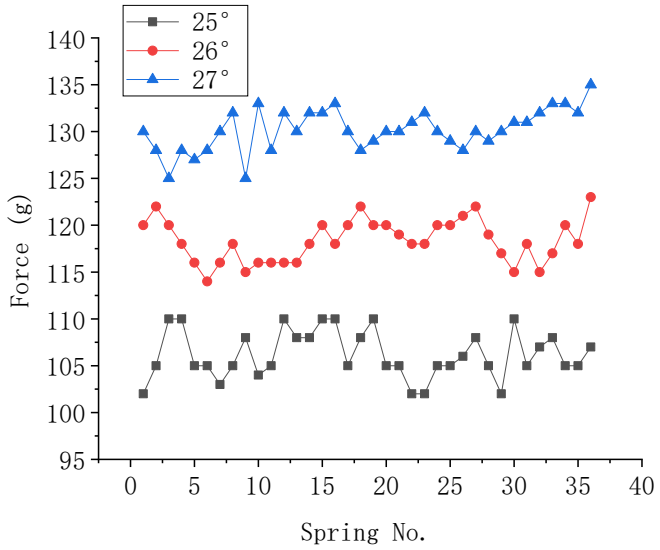
Assembled of contact and spring fingers

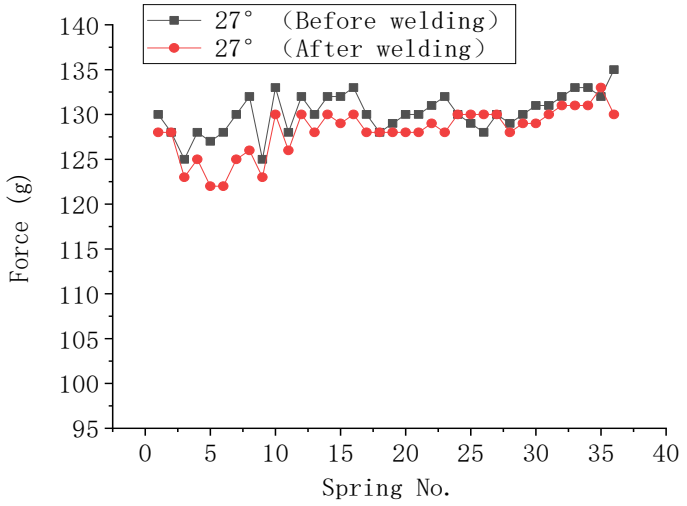
◆ optimization of spring fingers

- Contact force is determined by pre-bending angle of the contact fingers. Different pre-bending angles of 25° ,26° ,27° ,31° have been tested which shows that 27° is best.
- 27° is chosen and which forces between the spring fingers and the contact fingers is uniformly from different fingers and is about 125±5g, which meets 125±30g.

Before weld

After weld

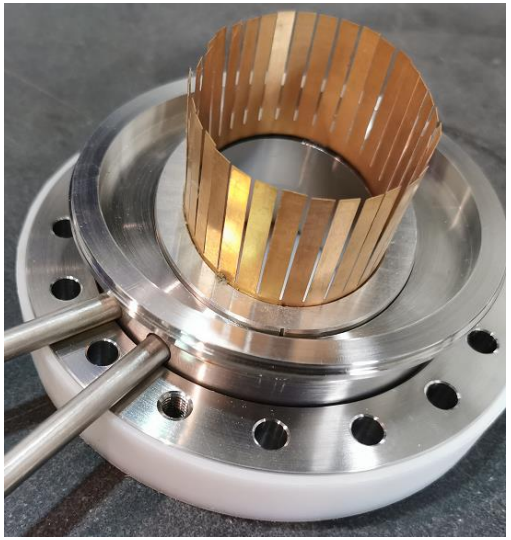




Prototype of RF shielding bellows

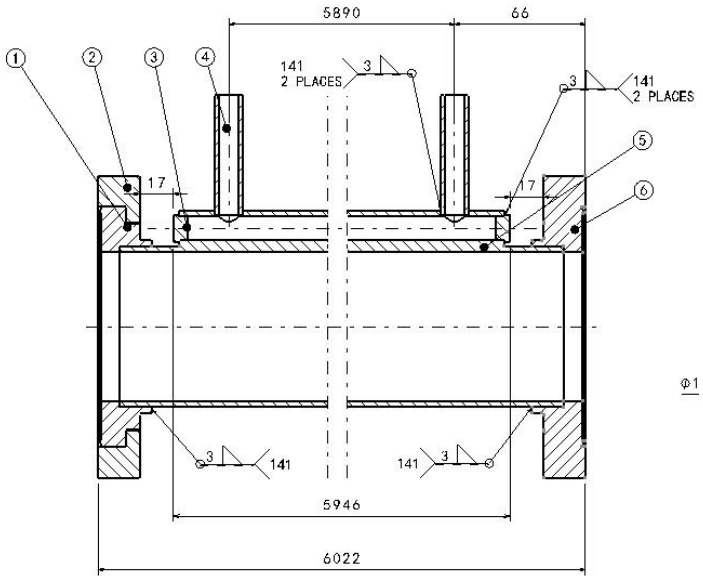
Prototype Ⅰ:

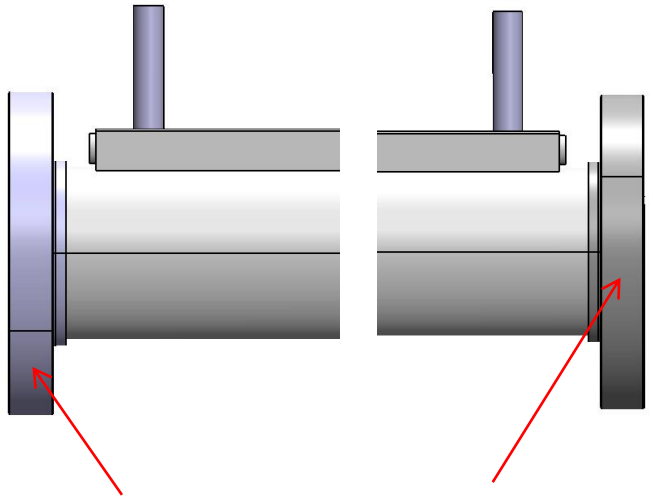
Prototype Ⅱ:



Progress of R&D of Al vacuum chamber

Structure of Al vacuum chamber





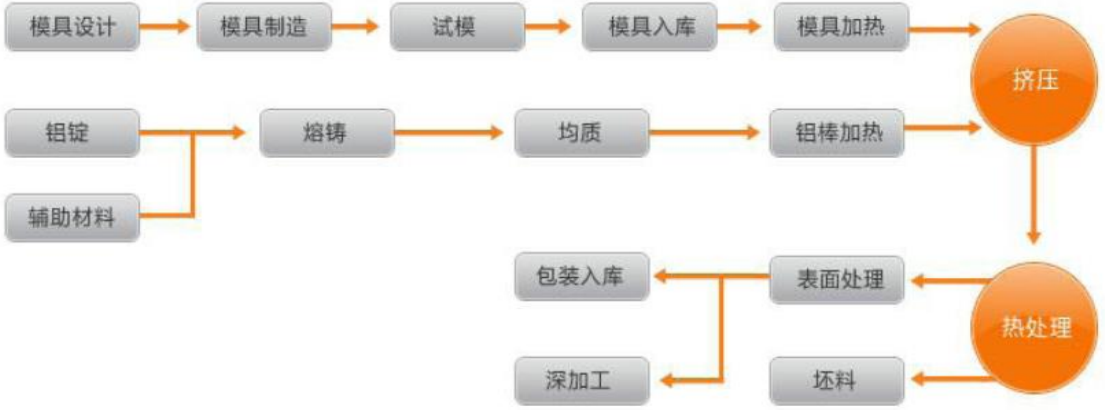
CF100 rotatable flange

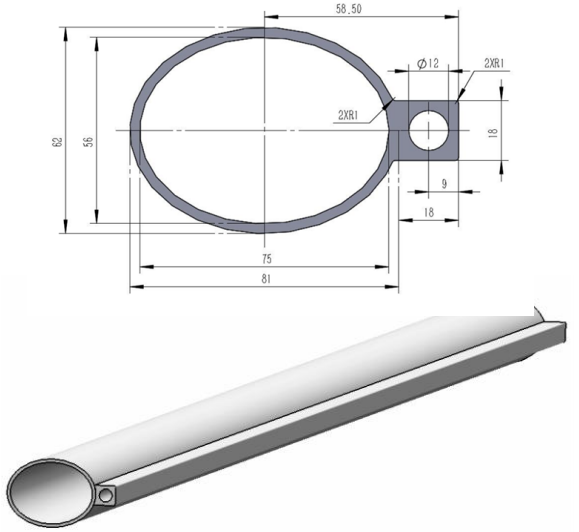
CF100 no-rotatable flange

Al-6061 is chosen as the material of Al vacuum tube, and flanges are fabricated from explosion bonding S.S.-Al transition plate. Flanges and tube are welded by manual AC TIG. The fittings for water cooling channels are also Al-6061 and are welded by TIG.

Fabrication process of Al vacuum tube

Aluminum vacuum tube is thermally extruded. Extrusion follows these steps as follows:

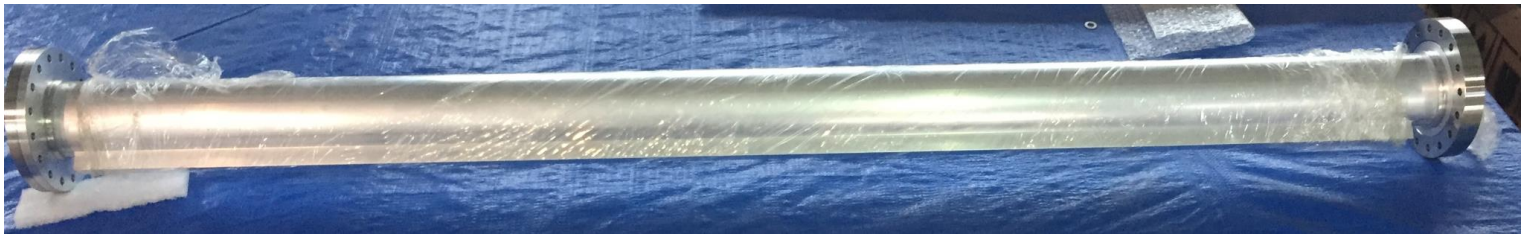


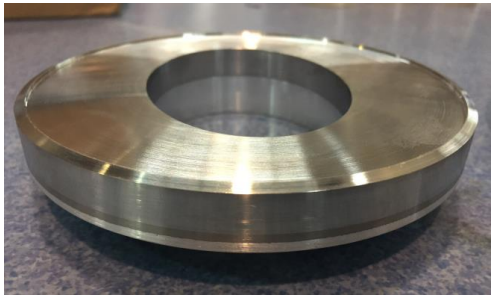


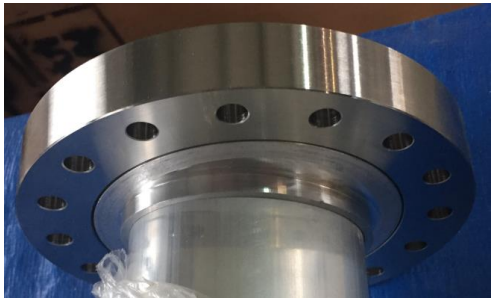
Aluminum vacuum chamber
(elliptic 75×56, thickness 3, length 6000)

The connection ports of cooling water channels are machined by numerical control machine tool.

Conflate flanges of S.S.-Al transition material



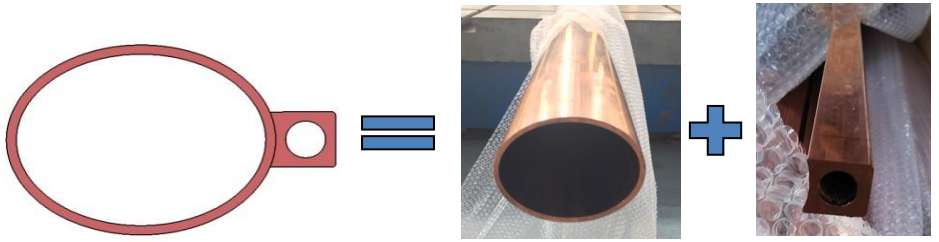




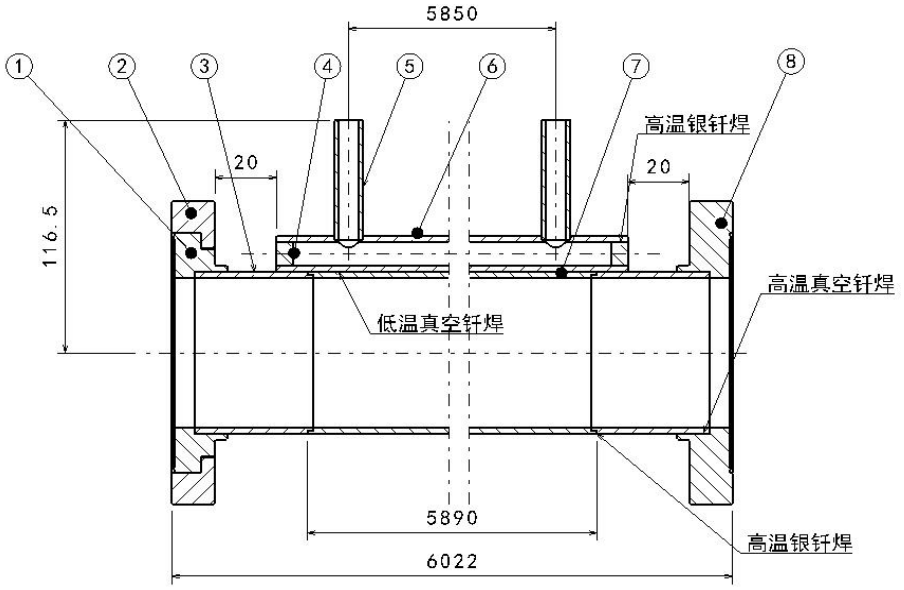
- **S.S.-Al transition plate are fabricated through explosion bonding in a domestic company.**
- **Ultrasonic flaw detection is used before the flange will be machined.**
- **Leak detection is carried out after the flanges has been machined.**

Progress R&D of Cu vacuum chamber

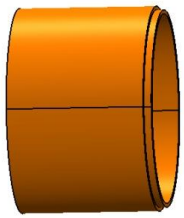
- **Cu beam pipe and water cooling channel are extruded respectively, and brazed together.**
- **Stainless steel material is used for flanges, and there is a rotatable flange at an end of vacuum chamber.**
- **The flanges and beam pipe are welded by high temperature brazing solder, and low temperature brazing solder are used between the beam pipe and water cooling channel as a 6 m long high temperature vacuum furnace is difficult to be found.**



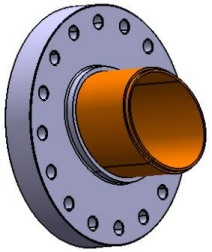
Vacuum chamber Beam pipe + Cooling channel



Technique process of Cu vacuum chamber

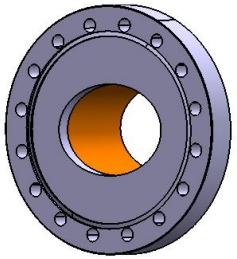


Transition tube machining

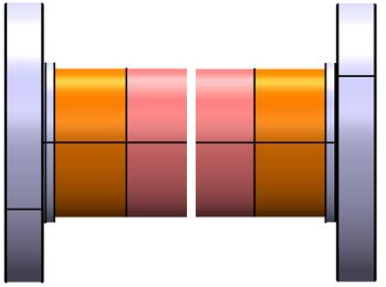


Brazing

Leak detection

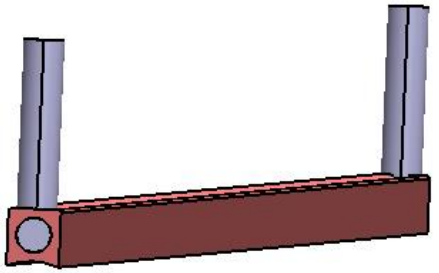


Knife edge machining of flange



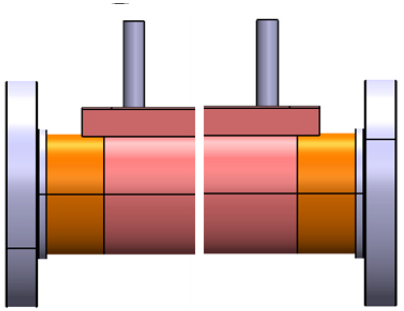
Silver brazing or EBW

Leak detection



Welding of fittings for cooling channel

Leak tests for hydraulic pressure and vacuum



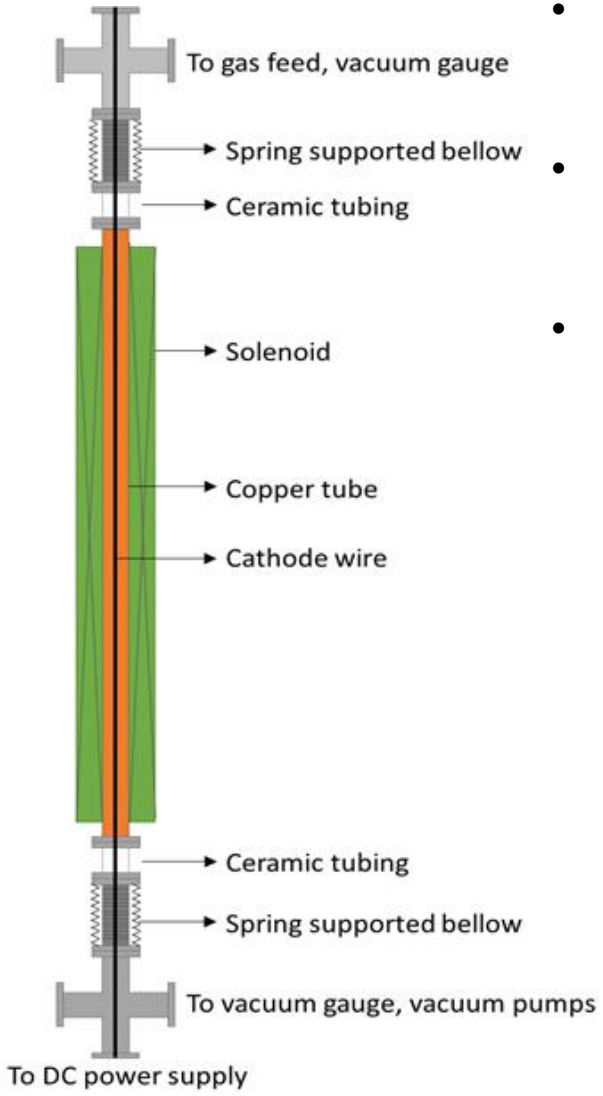
Welding between beam pipe and cooling channel with a low temperature brazing solder

Cleaning, leak detection, baking and pumping down

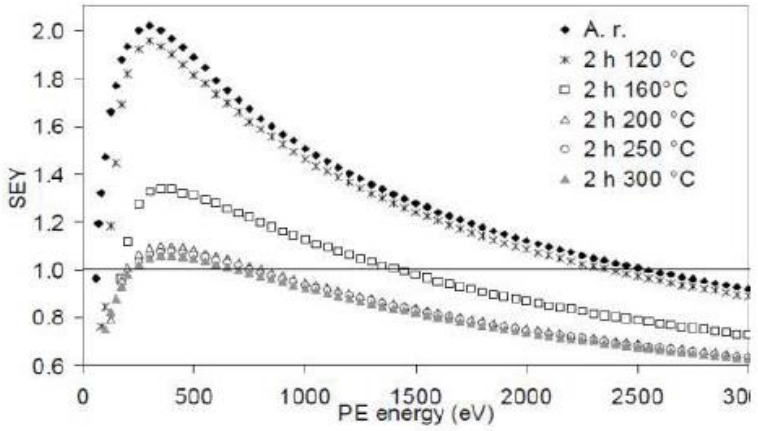
Cu and Al vacuum chamber prototypes

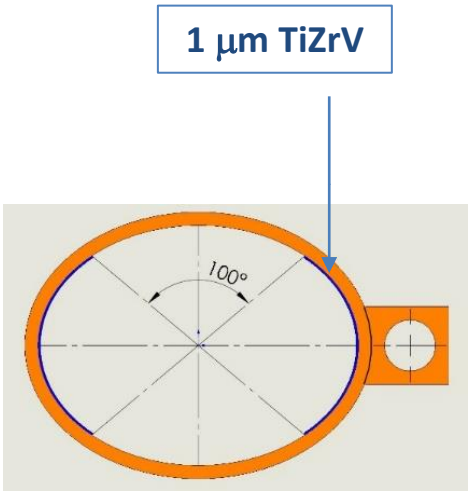
Project	Targets of the midterm	Present status	Remarks
The Leak rate of the vacuum chambers	3×10^{-10}Torr.L/s	3×10^{-10}Torr·L/s	Achieved
The ultimate pressure of the vacuum chambers	3×10^{-10} Torr		Will be achieved

NEG coating of the inside 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.**
- **In order to decrease the resistive wall impedance, the top and bottom of the vacuum chambers will be uncoated NEG films, while the other part of inner surface will be coated with NEG films in thickness of 1 μm , which may supply enough pumping speeds and absorbed gas capacities, and acceptable impedance budgets.**

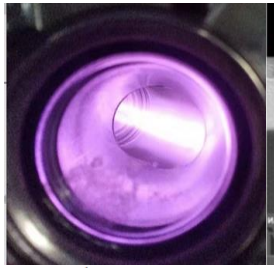


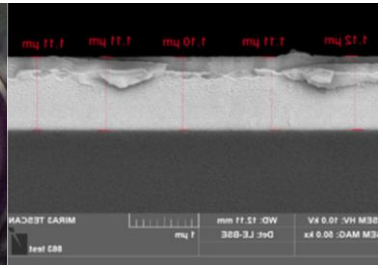


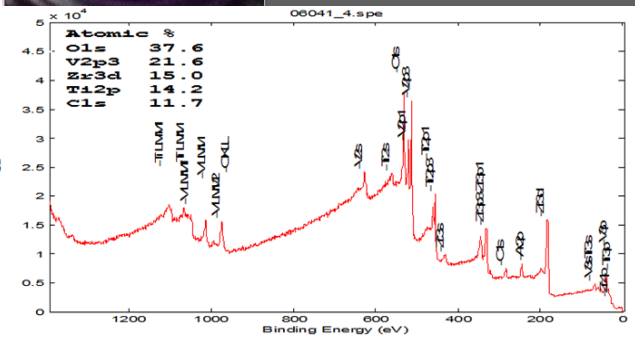
B. Henrist, N. Hilleret, App. Surf. Sci.172(2001)95

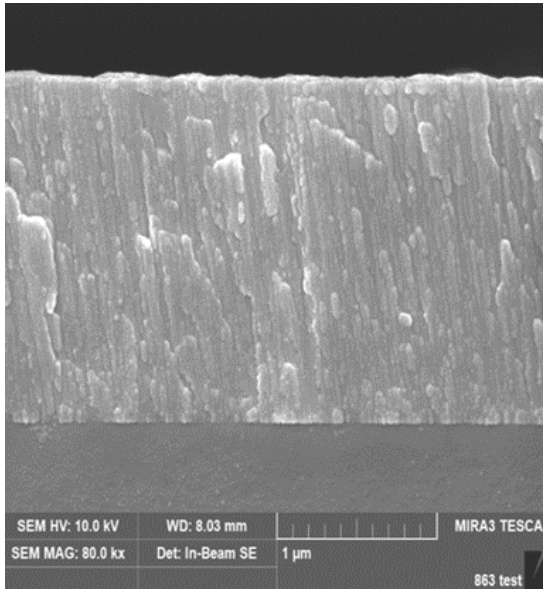
NEG coating setup

- The setup of NEG coating has been built, and some experiments have been done.
- Thickness of film: ~1.1 μm; Proportion: Ti：Zr：V=0.28 : 0.3 : 0.42 (after Ar^+ surface etching of 10 nm) ; Columnar film for high pumping speed.
- All related parameters (plasma gas pressure, substrate temperature, plasma current, and magnetic field value) are recorded and suitably adjusted to ensure the stability of the deposition process.
- A horizontal coating equipment is easy to be installed, and long vacuum chambers can be coated by moving the solenoid.



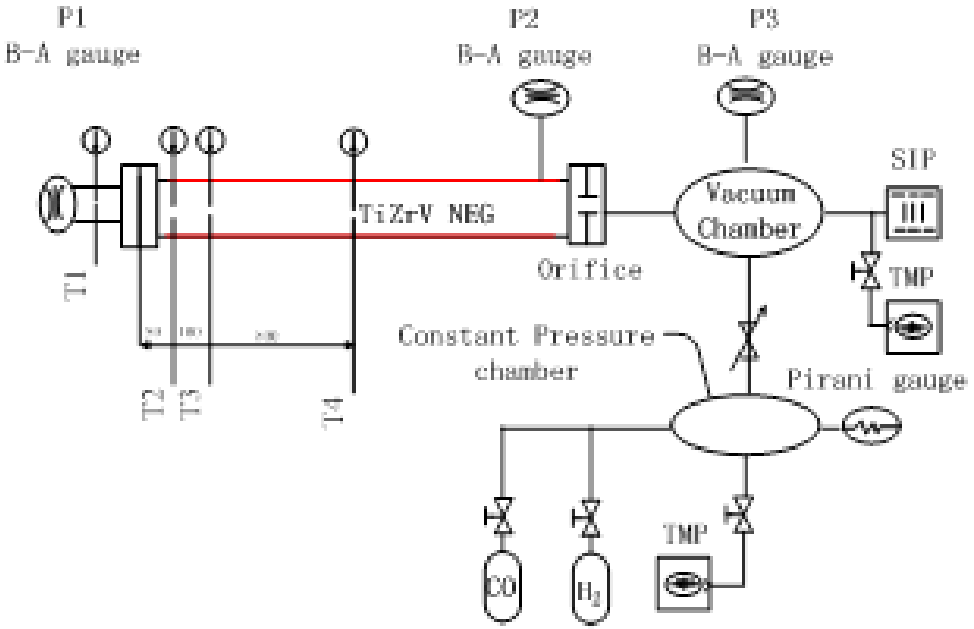






NEG coating setup

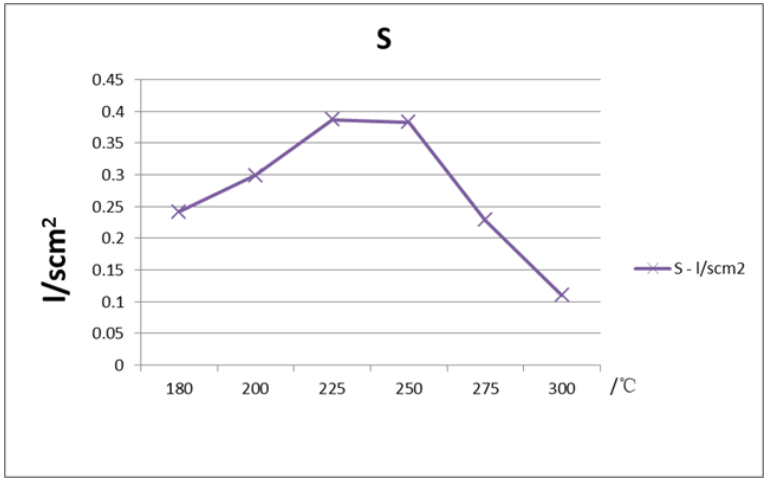
Pumping speed measurements for NEG films



A high pure hydrogen（99.999%）is introduced by the injection valve, the gas passes through the coated pipe and is absorbed by the NEG film. The P2/P1 ratio is measured by the pressure gauges, which is related to the average sticking probability and pumping speed of the pipe walls.

Results of pumping speed for NEG film

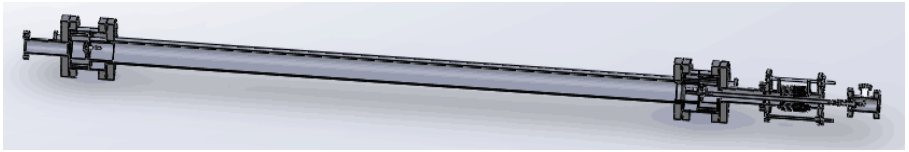
NO	P2/P1	Sticking probability	S [L/(s·cm²)]	Note
CEPC4-B2-180-24 for H2	8.5	0.0055	0.242	Stainless steel pipe Length * diameter： 750*35
CEPC4-B2-200-20 for H2	11.6	0.0068	0.2992	
CEPC4-B2-225-20 for H2	17.5	0.0088	0.3872	
CEPC4-B2-250-20 for H2	17	0.0087	0.3828	
CEPC4-B2-275-20 for H2	8	0.0052	0.2288	
CEPC4-B2-300-20 for H2	3.5	0.0025	0.11	

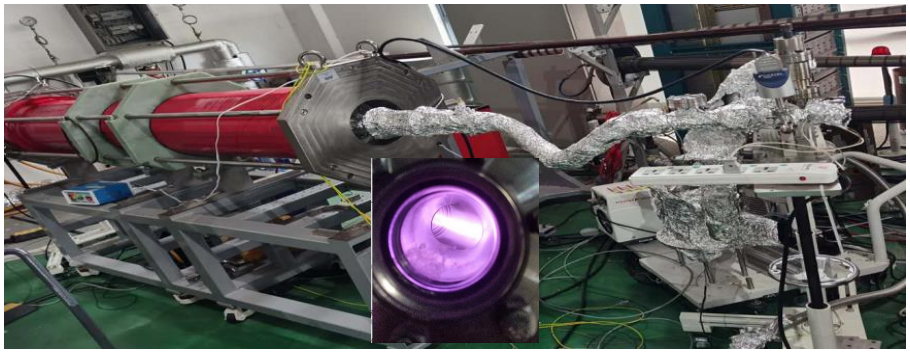


NEG coating NO.CF100-600-0006

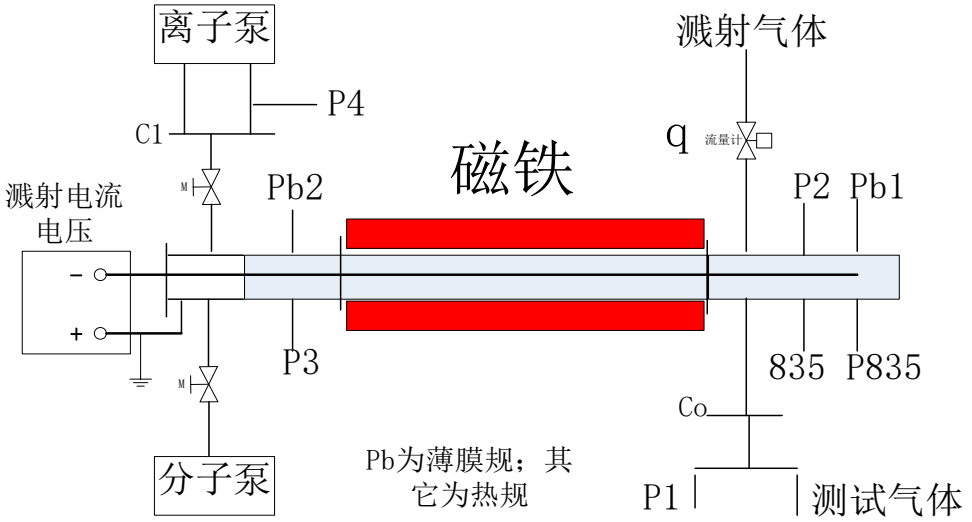
- **1.5m long vacuum pipe have been coated to explore the coating parameter at geometrical shape of 56×75.**

NEG No. CF100-1500-0001



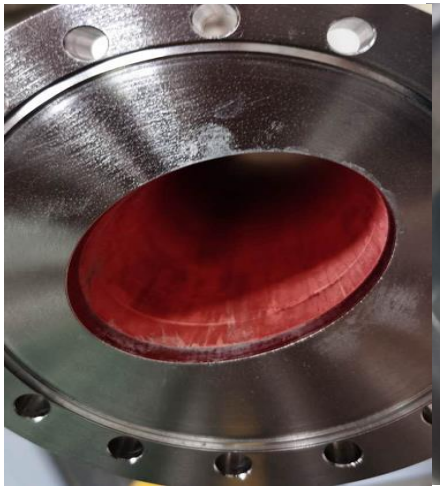


Coating parameter	value
Magnetic(G)	300
Substrate Temperature （℃）	120
Vacuum of coating （Pa）	1
Discharge current（A）	0.4
Discharge voltage（V）	300
Deposition time（h）	10
Geometric diameter（mm）	56×75×1500



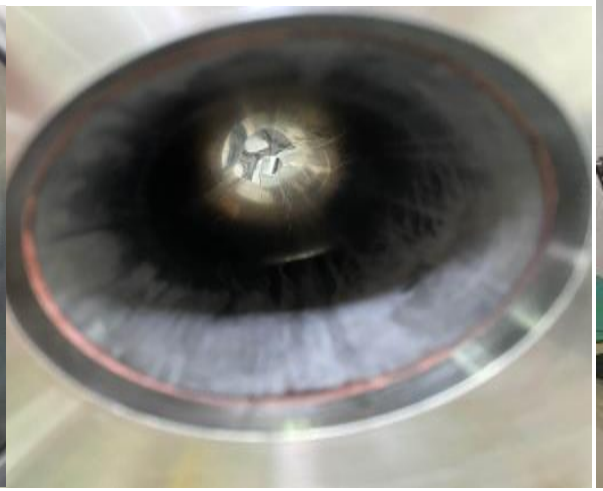
Ultimate vacuum test of NEG coating pipe

- **56×75×1500 NEG coating pipe:**
  - ✓ 180℃/24h activation 5.9-10mbar
  - ✓ 200℃/24h activation 3.3-10mbar



Before coating

2 targets



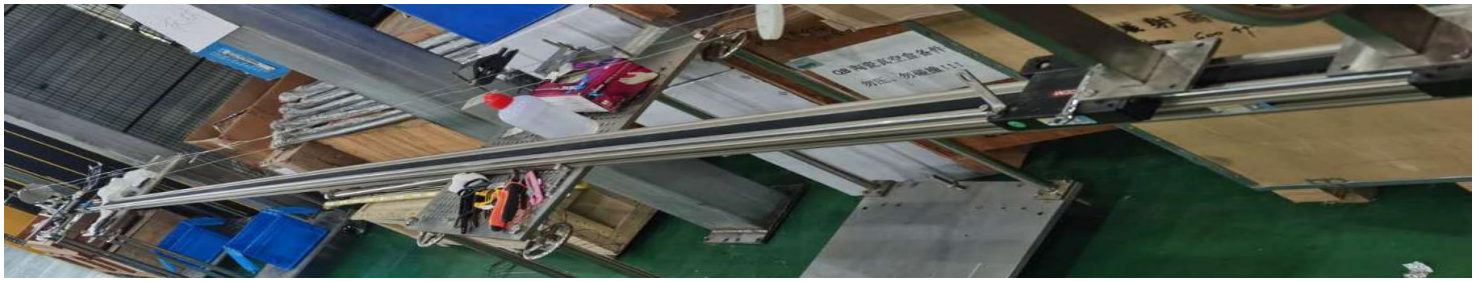
After coating

Ultimate vacuum testing

Preparation for NEG coating of 6 m pipe

■ Cathodes and vacuum pipes fabricated for NEG coating

✓ It is very difficult to made a 6 m long cathode. Cathodes were fabricated by 3 Diameter of 1mm Ti, Zr ,V



✓ Vacuum pipes will be degreasing, etching, passivation

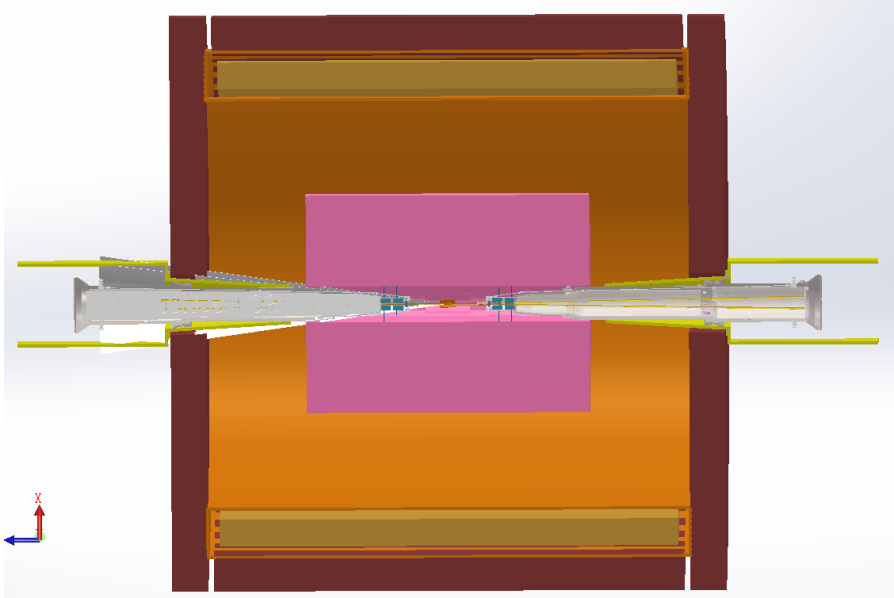
NEG coating NO.CF100-600-0006

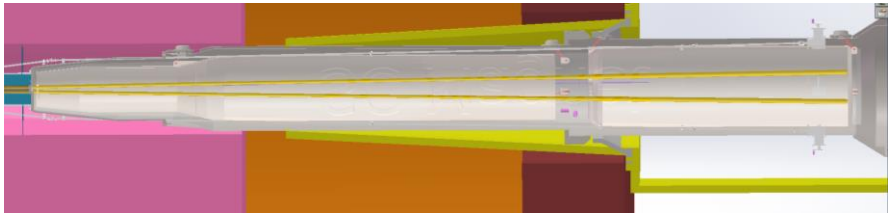
- A horizontal coating equipment is easy to be installed, and 6m long vacuum chambers can be coated by moving the solenoid.
- 6m long vacuum pipe will be coated after those parameters are optimized.

CEPC MDI vacuum design

◆ 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

- The prototypes of copper & aluminum vacuum chambers with a length of 6 m have been fabricated and tested, which meet the engineering requirements. Surface treatment of copper will be taken into account.
- 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.
- 1.5m long vacuum pipe have been coated to explore the coating parameter at geometrical shape of 56×75. 6m long vacuum chambers will be coated by moving the solenoid by a horizontal coating equipment .

Thank you !