The operation conditions of BEPCII Storage Ring vacuum system

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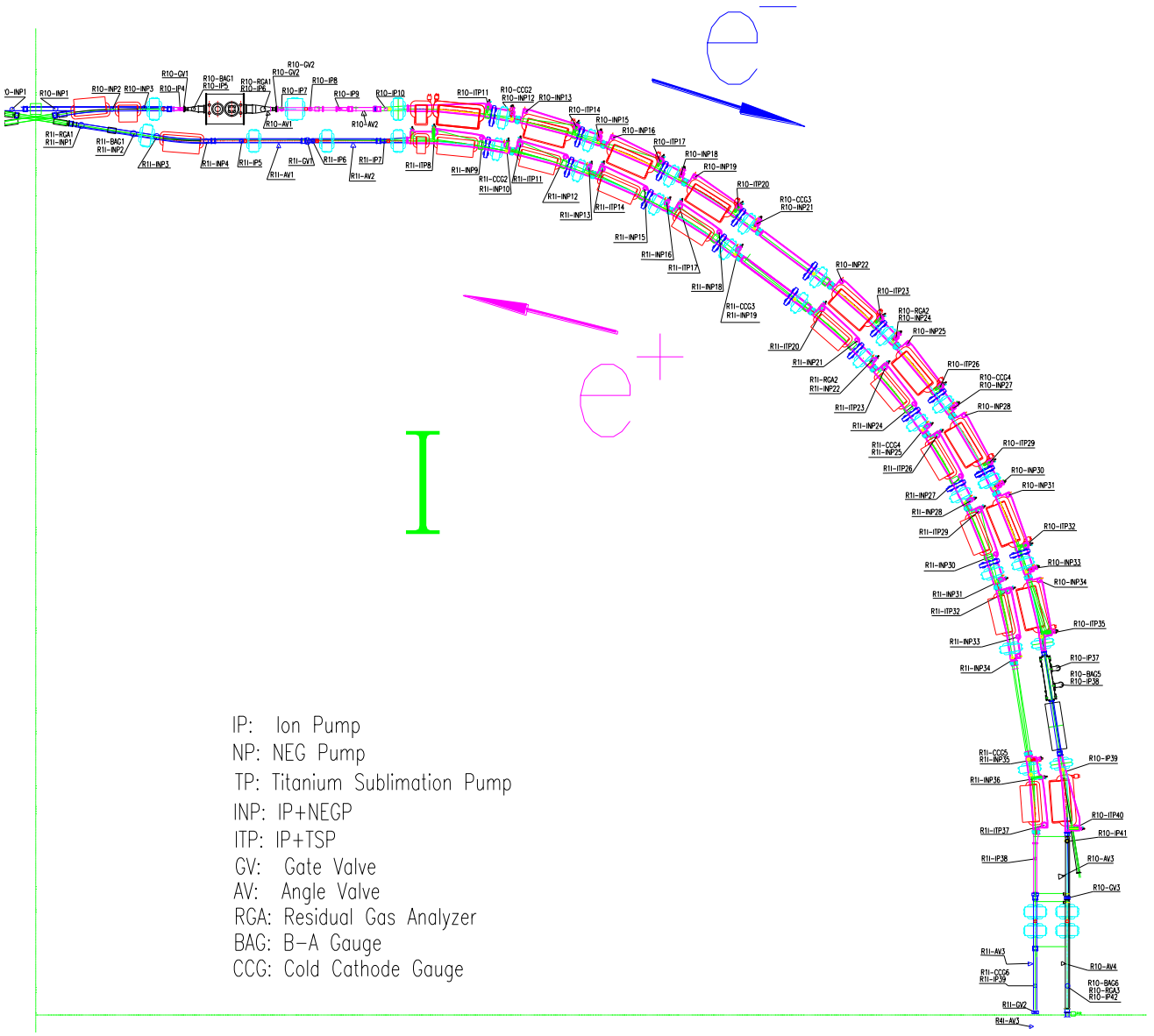
The Layout of BEPCII

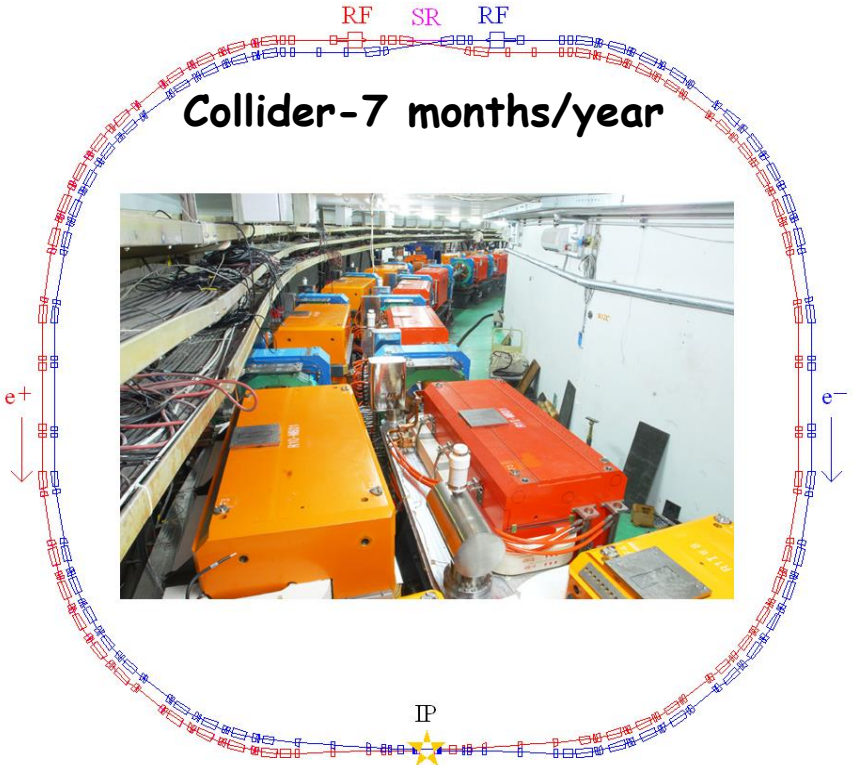
- BEPCII is a double-ring collider within the existing BEPC tunnel.
- **The designed luminosity of BEPCII is $1.0 \times 10^{33} cm^{-2} s^{-1}$ at the beam energy of 1.89GeV,** which is about two orders of magnitudes higher than the one of BEPC.
- Each ring can be filled with up to 93 bunches with the maximum beam current of 0.9A per ring.

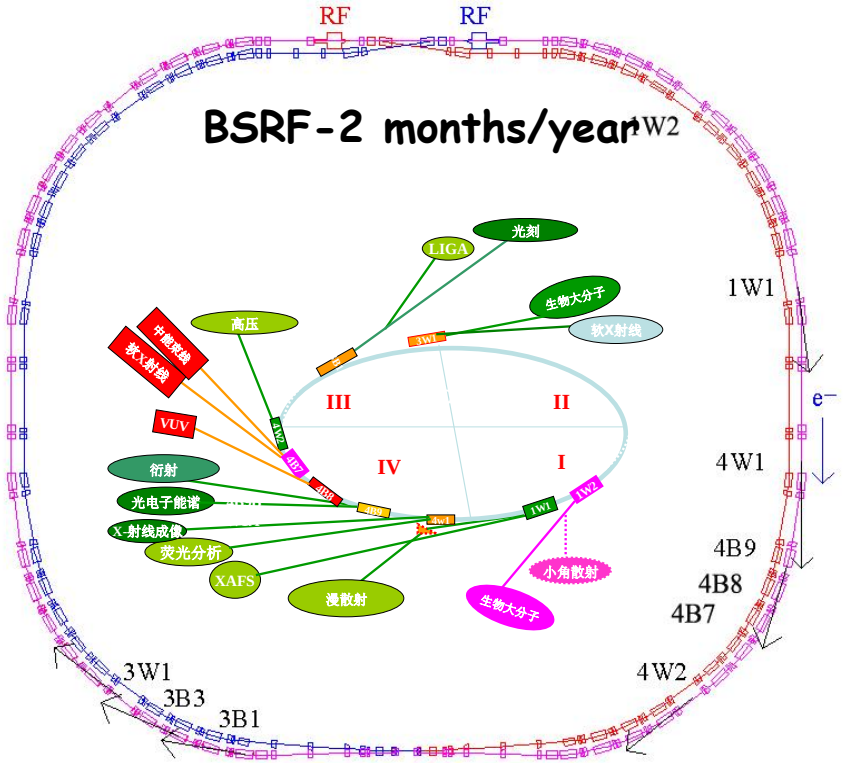


Distribution of the vacuum devices in a quadrant

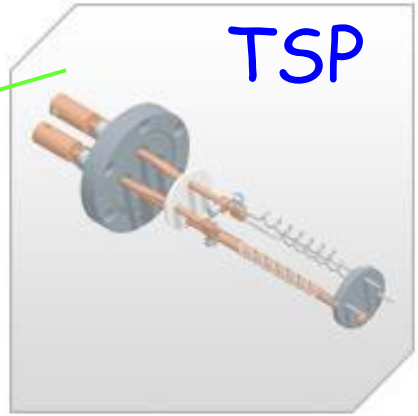
Introduction to BEPCII

- BEPC II is a two-ring e+e- collider running in the tau-charm energy region (Ecm = 2.0-4.2 GeV)
- The collider consists of two 237.5 m long storage rings, one for electrons and one for positrons. They collide at the interaction point with a horizontal crossing angle of 11*2 mrad
- The machine also provides a high flux of synchrotron radiation at a beam energy of 2.5 GeV, known as Beijing Synchrotron Radiation Facility.





Ring Vacuum System

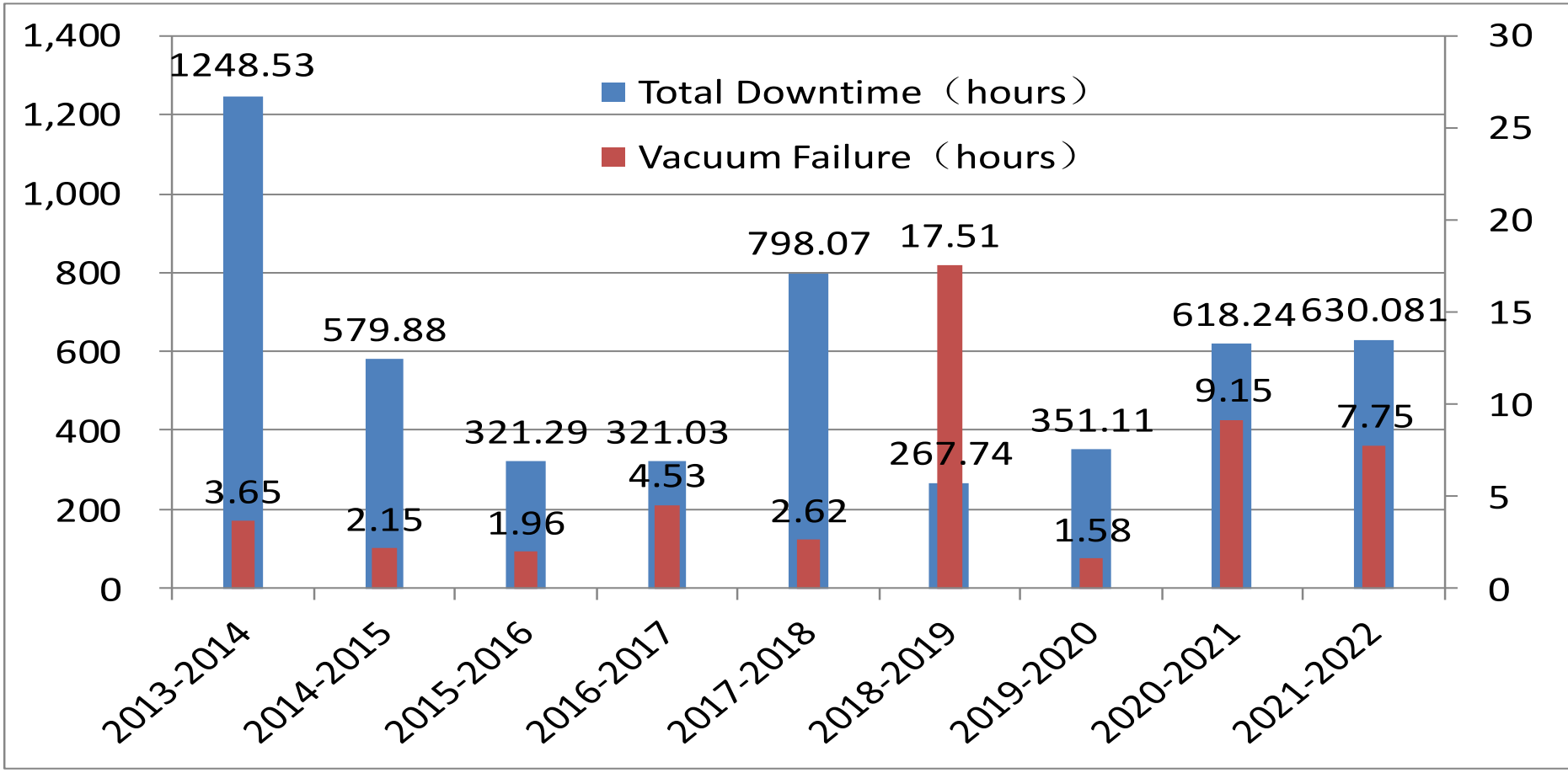


Ion Pump

Photon Absorber

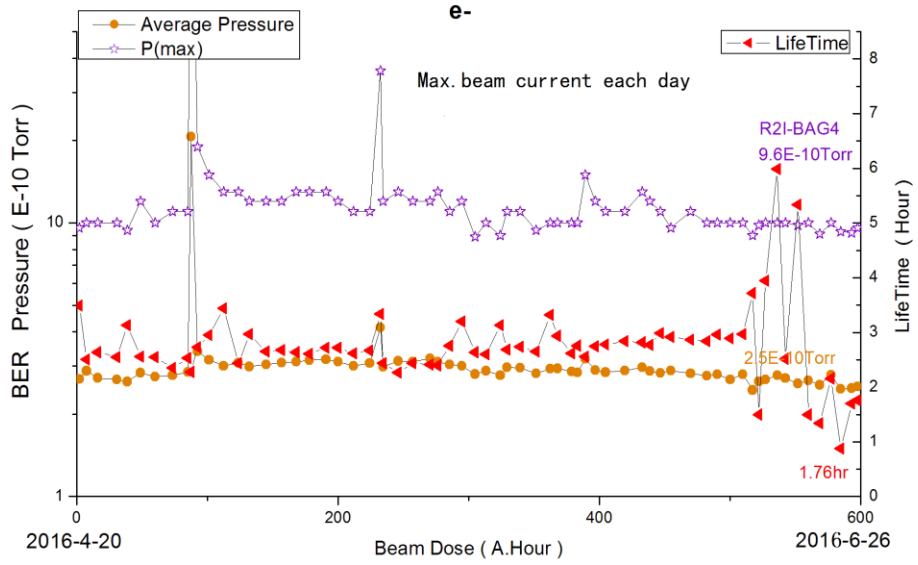
RF Bellows

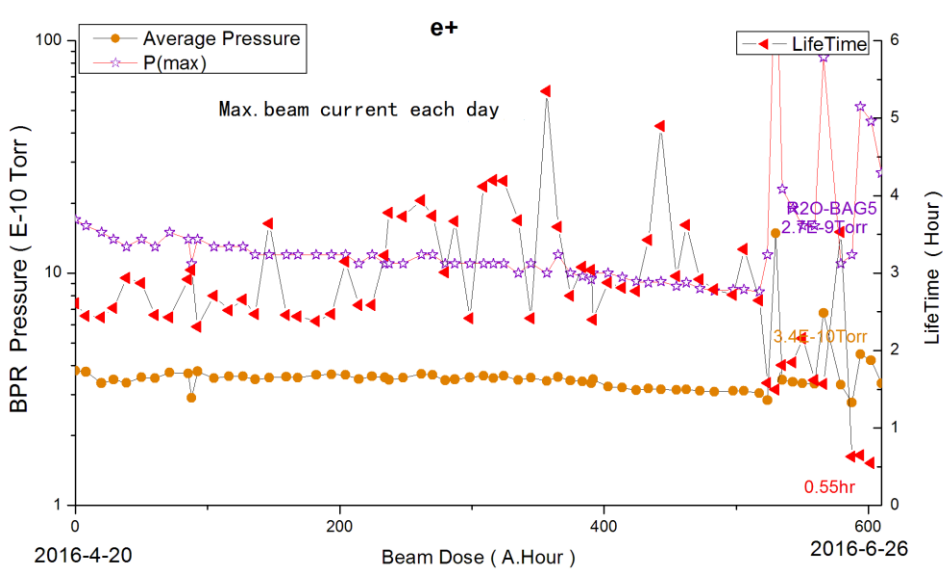
Total downtime and vacuum failure time in recent years

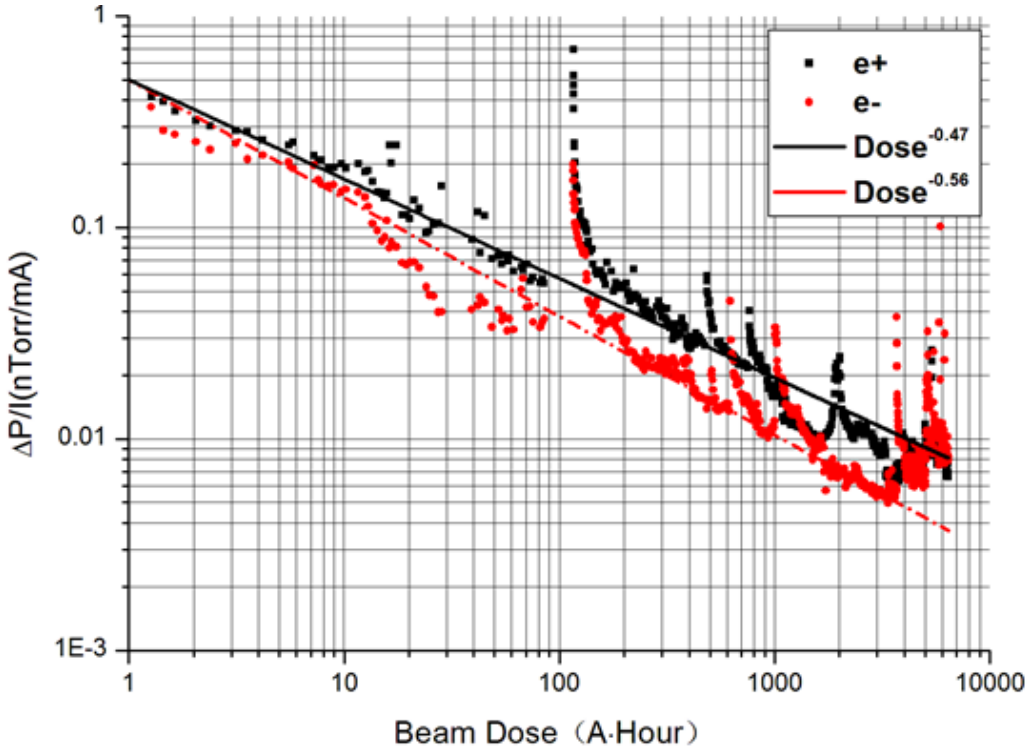


- Since 2013, only a few downtime due to vacuum failure every year, and it is on the decline.
- Several vacuum systems exposed to the atmosphere are due to RF(coupler ceramic), magnet(kicker), beam measurement(DCCT) system failures.

Dynamic pressure operating state of the storage ring



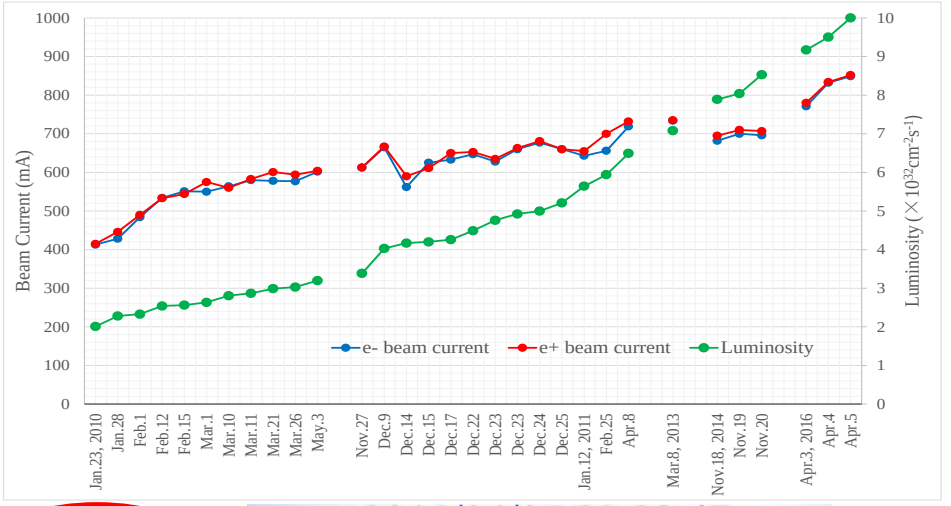


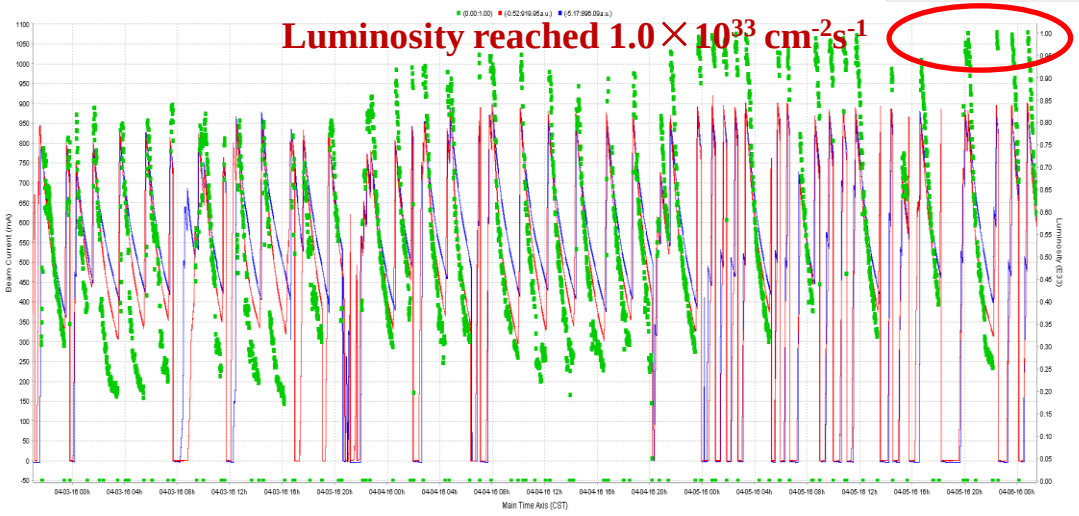


- Pav<6x10^{-10}Torr (1.89GeV)
- The average pressure after each exposed atmosphere is higher, but it can recover quickly.
- The double-ring ΔP/I vs Beam Dose curve showed an exponential decrease (e - (-0.56)/e + (-0.47)).
- Colliding luminosity reached the design target $1.0 \times 10^{33}\ cm^{-2}s^{-1}$。

Luminosity reached 1.0×10^{33} $cm^{-2}s^{-1}$ @1.89GeV 850mA Apr.5.2016 22:29

- April 5, 2016, Colliding luminosity of $1 \times 10^{33}cm^{-2}s^{-1}$,successfully reached the design index. This means the performance of the collider reaches 100 times before the transformation.





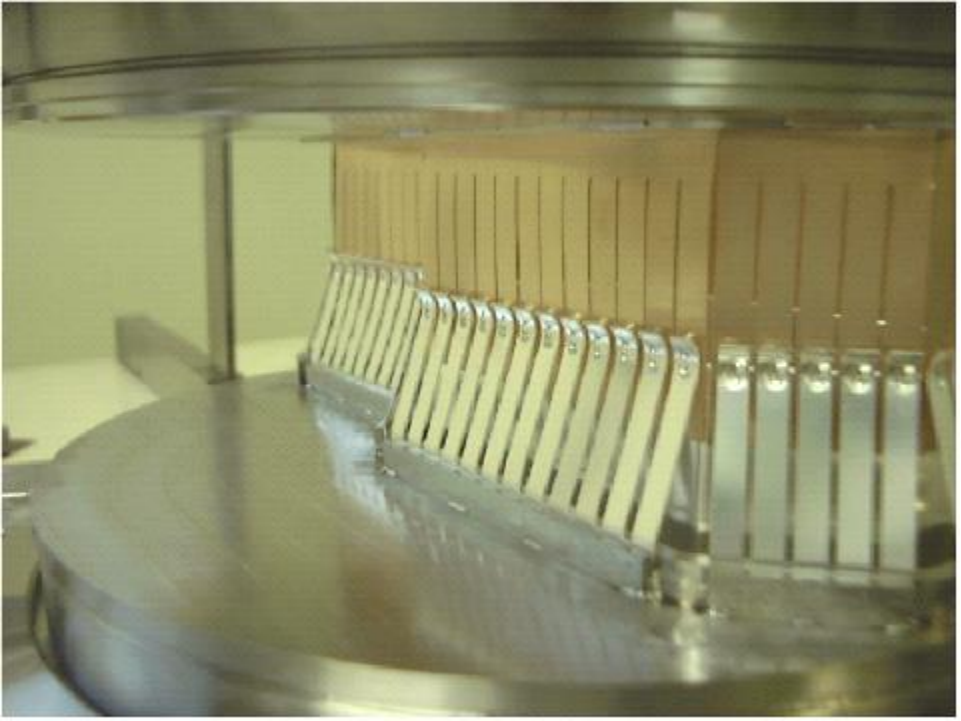
2016/04/05 22:29:47

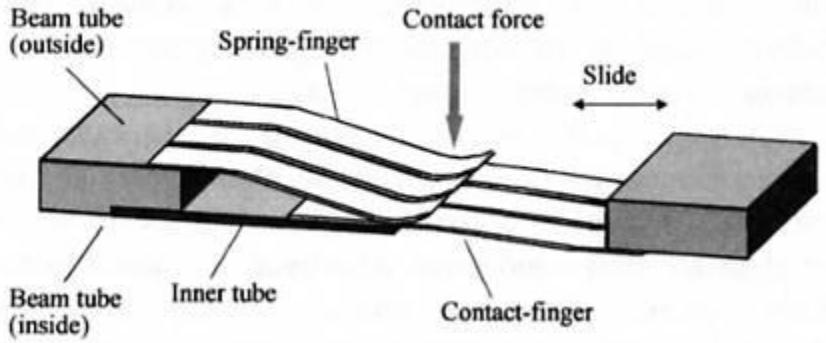
Luminosity	10.00	E32/cm^2/s
	e+	e−
Energy [GeV]	1.8831	1.8831
Current [mA]	849.18	852.31
Lifetime [hr]	1.53	2.30
Inj.Rate [mA/min]	0.00	0.00

Examples of typical hardware failures

Double-Fingers RF Bellows

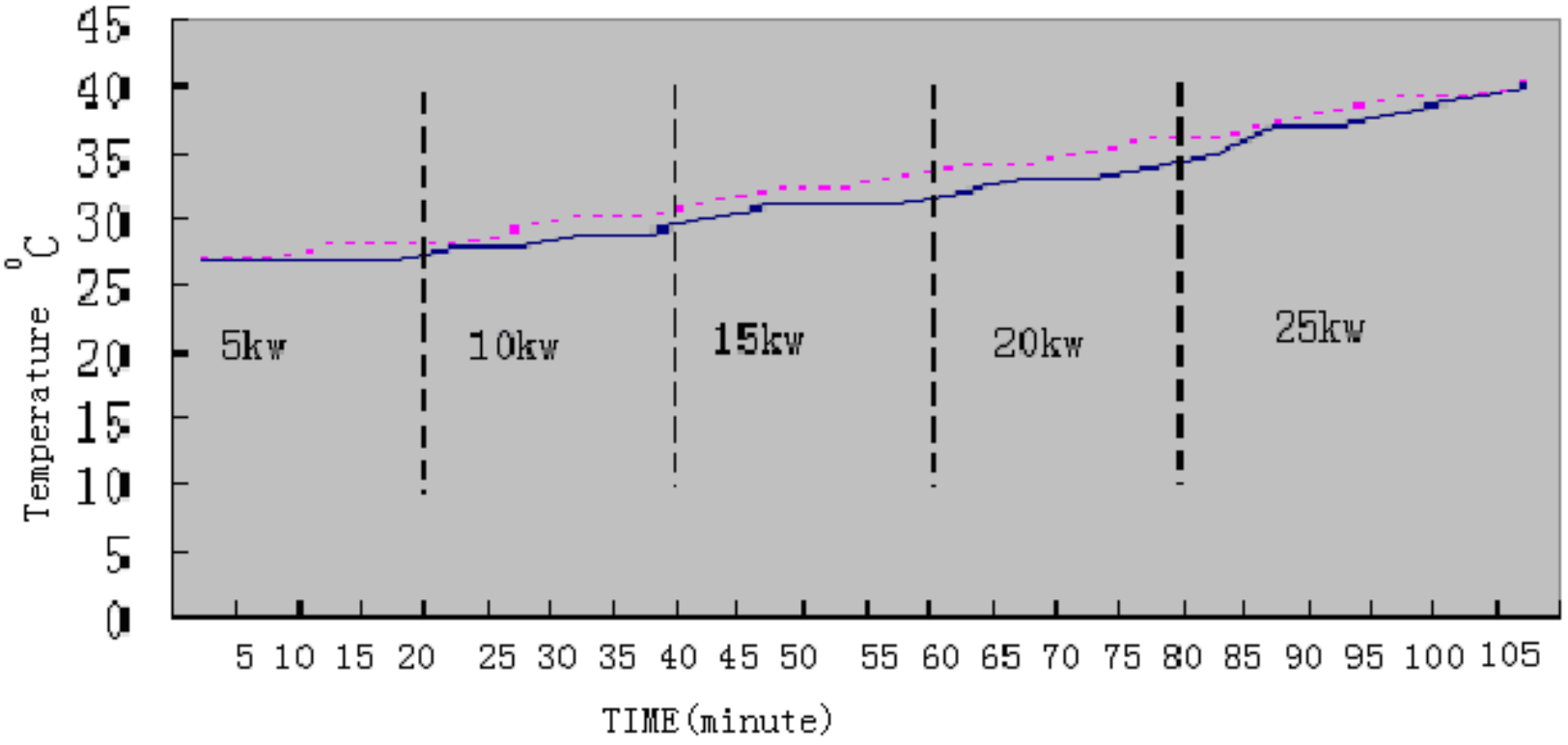
(VALQUA LTD.)





- Fingers: Shield-Finger + Spring-Finger
- Spring-Finger : Inconel alloy
- Contact-Finger: CuBe (C1720)
- Max. Contraction : 18 mm
- Max. Expansion : 6mm
- Offset : ±2 mm
- Bend: ±50 mrad
- Tilt: 0

Temperature rise of contact fingers as a function of input powers for two kinds of RF shielding Bellows



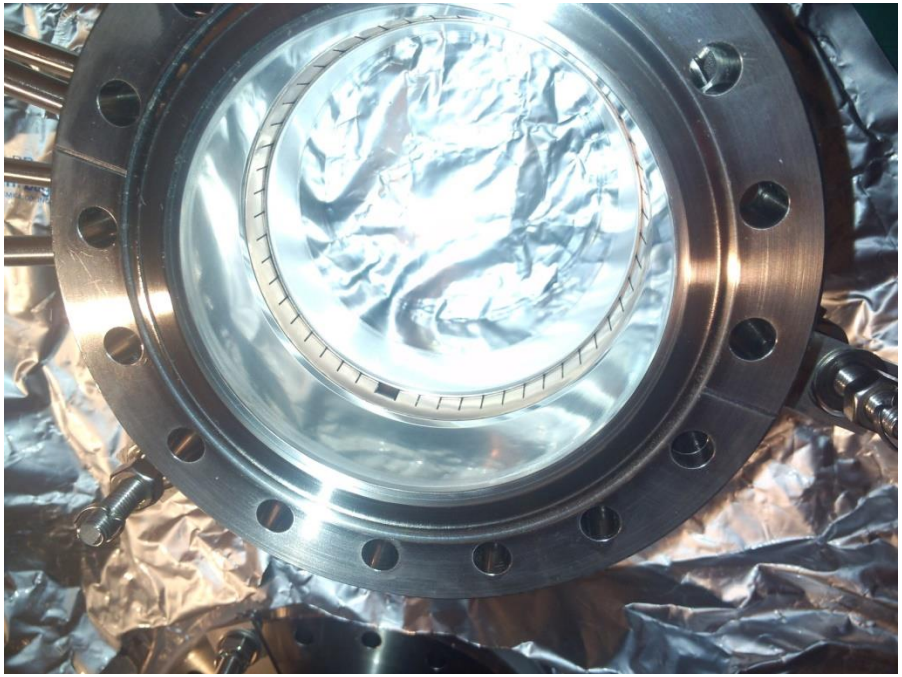
BEPCII

Two-finger bellows ..... single-finger bellows

Peak wall current	RMS wall current	Peak wall current density	RMS wall current density	Peak electric field at wall
58.1 A	6.1 A	355.8 A/m	37.4 A/m	1.34×10^{5} V/m

Damage finger of RF bellow:

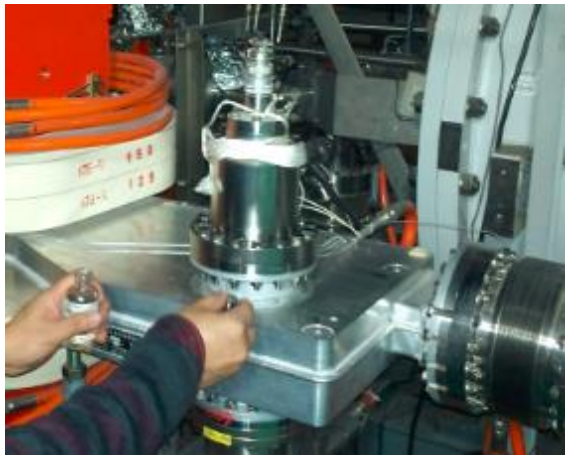
Burnt contact finger

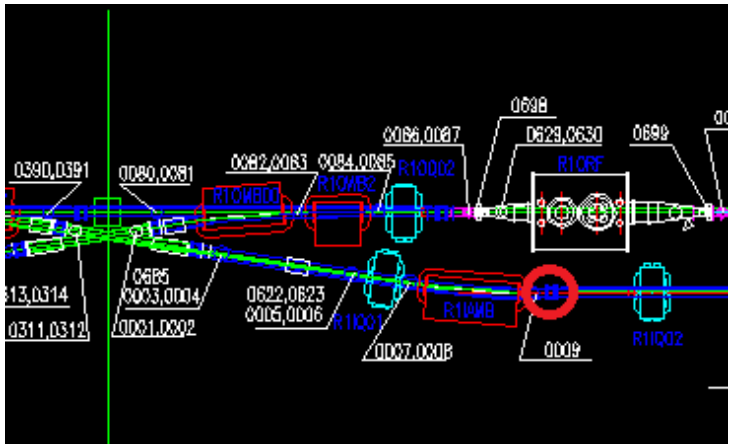


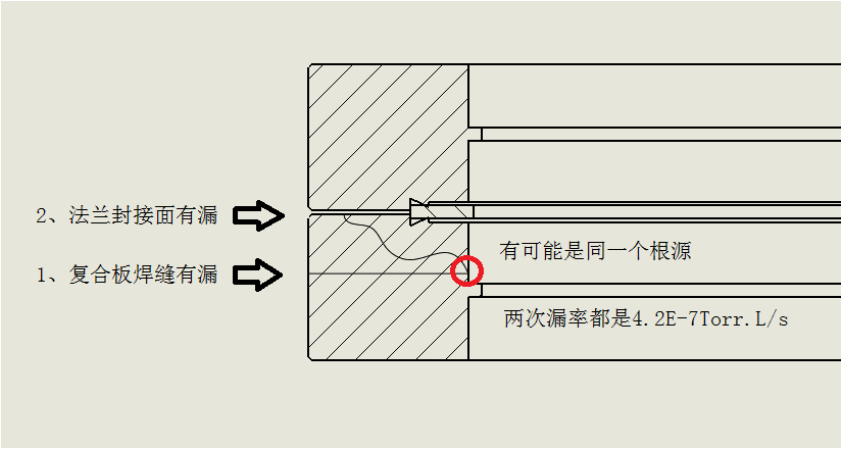
Compressed contact finger

Leak on Al-SST composite plate flange :

- The nearby vacuum was worse from 2×10^{-10}Torr to 1.5×10^{-9}Torr, ion current increased to 8uA.
- The leak was located on weld of Al-SST composite plate flange.





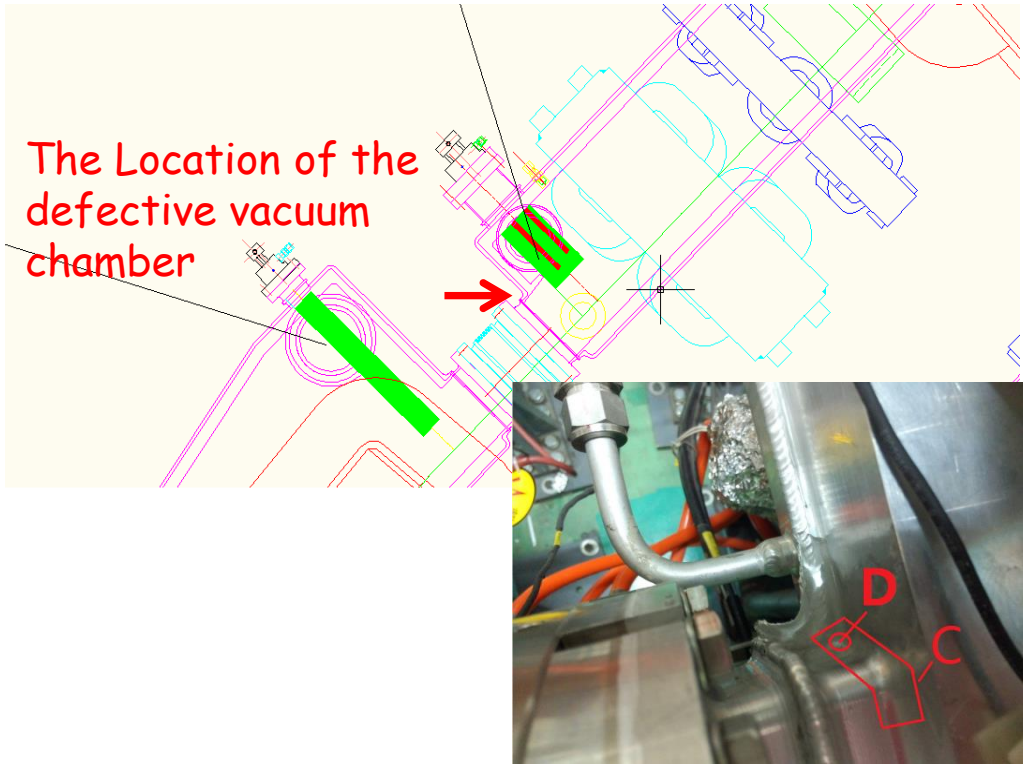


Actually

- We used vacuum glue on weld and flange sealing surface respectively in different time.
- Same leak rate ~ 4.2×10^{-7}Torr .L/s.

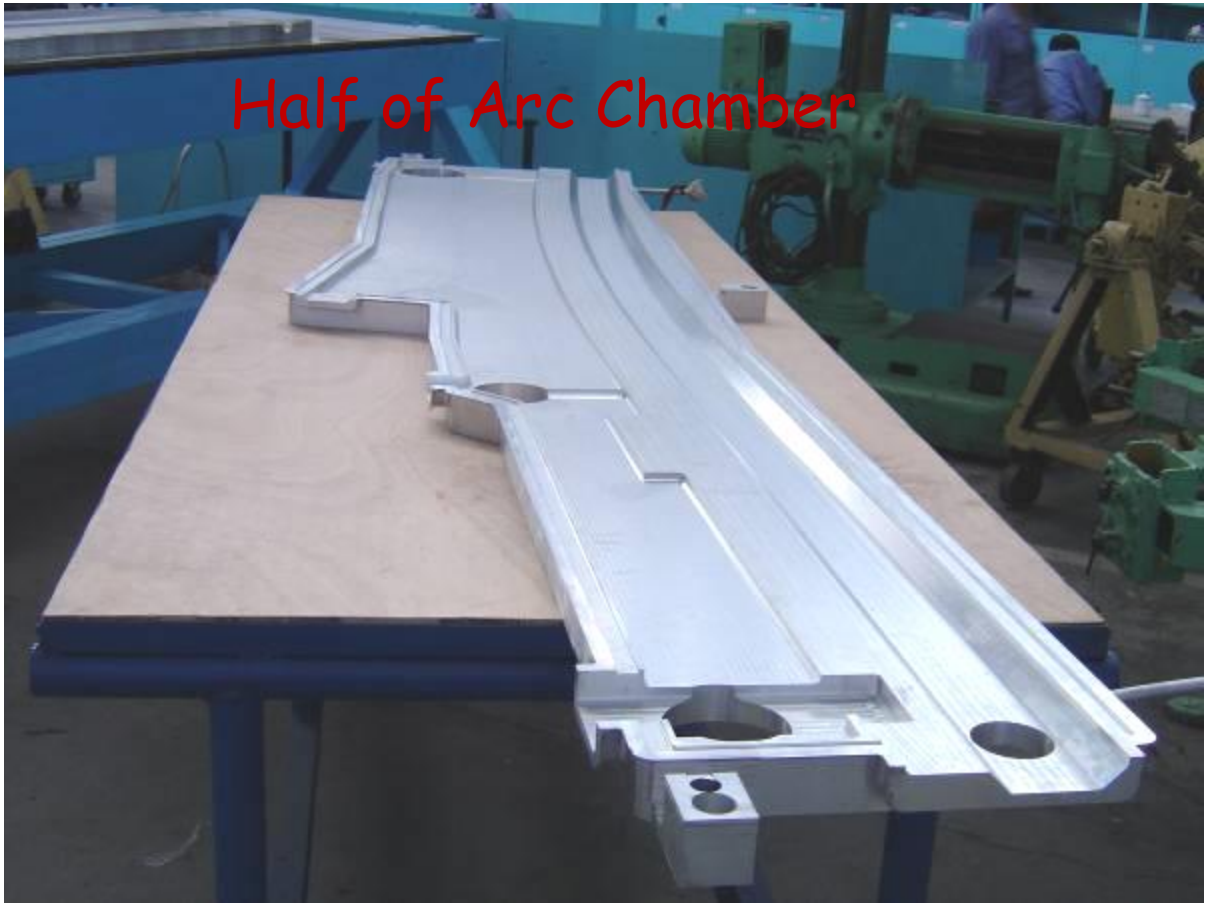
Leak on Al-Vacuum chamber material:

- The nearby pressure(R2O-CCG4) was worse to 2×10^{-8}Torr.
- Used Helium at a small flow rate and alcohol ,RGA quickly responded, the leakage was accurately located on D as shown in the picture below .



Review: The leak location was similar to the first leak for material defect on Aug.20 2013.

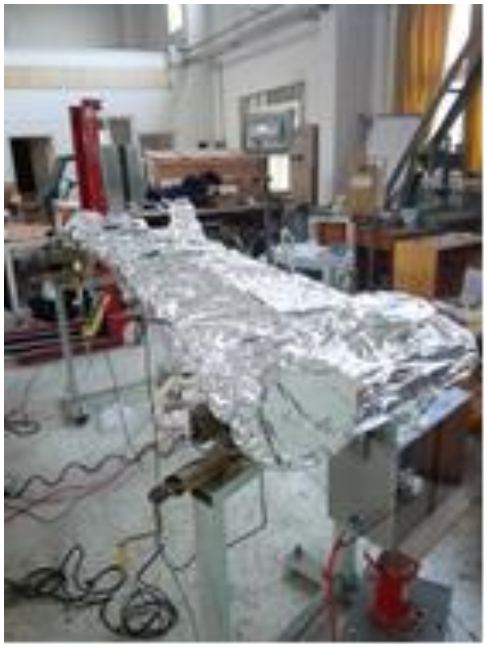
Arc chamber replacement part



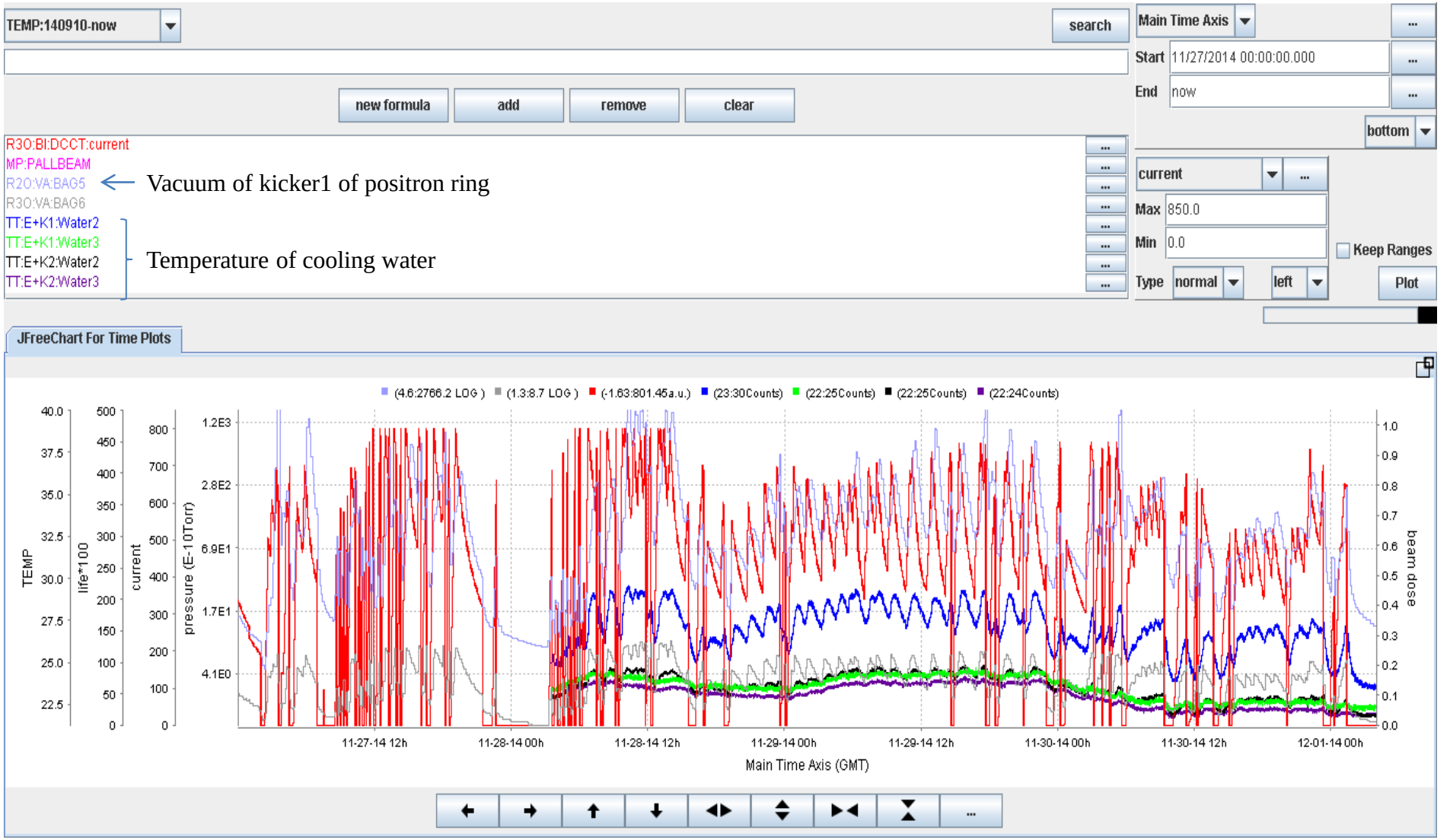
- Aluminum alloy 5083-H321 is chosen as the arc vacuum chamber material.
- The vacuum chamber consists of the upper and lower pieces. The two pieces made by an oil-less machining process to improve the contour precision and reduce the outgassing rate, are welded together.

Ultimate vacuum test

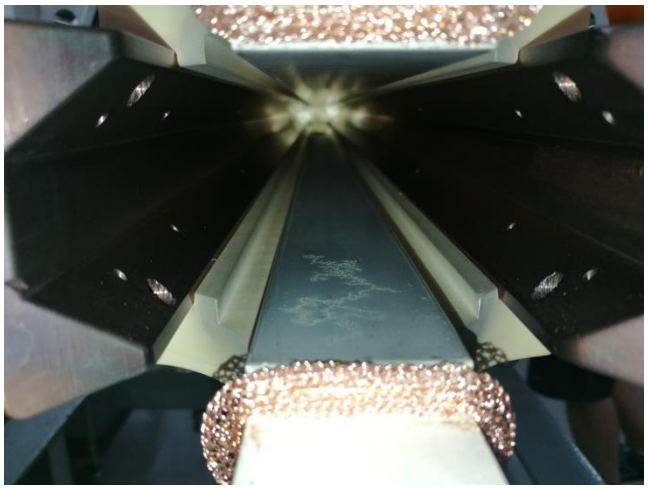
- 100L/s ion pump × 2
- 150L/s ion pump × 1
- 400L/s(H_2) NEG pump × 1
- Bakeout Temperature: 120℃
- Bakeout time: 72h
- Ultimate vacuum:<2.9 ×10^{-8}Pa

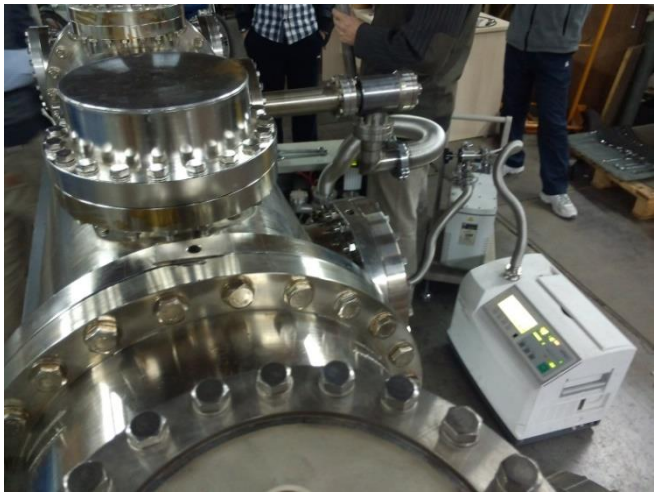


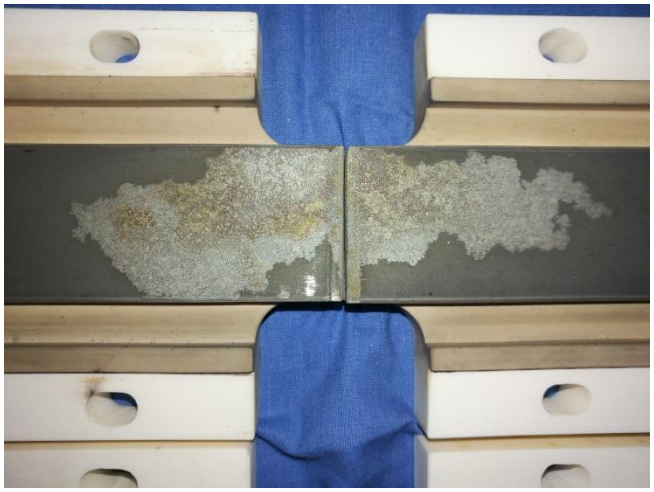
- Nov.27.2014~Dec.5.2014,Vacuum of the kicker 1 of positron ring was worse significantly than before with the increase of beam current .



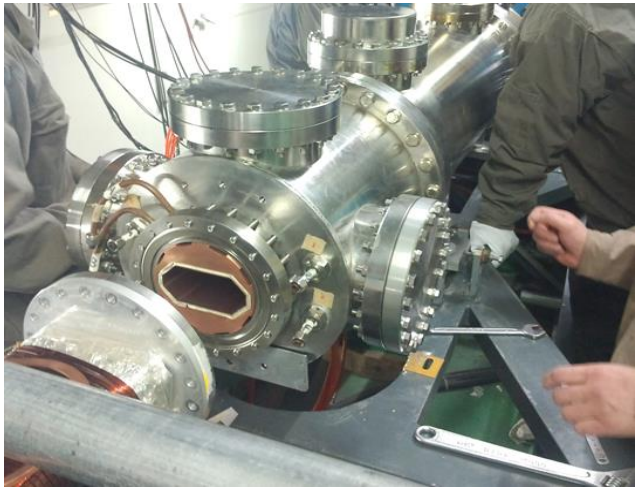
- The faulty kicker was replaced.
- Beam wakefield lead to the failure of coating.







Broken Coating



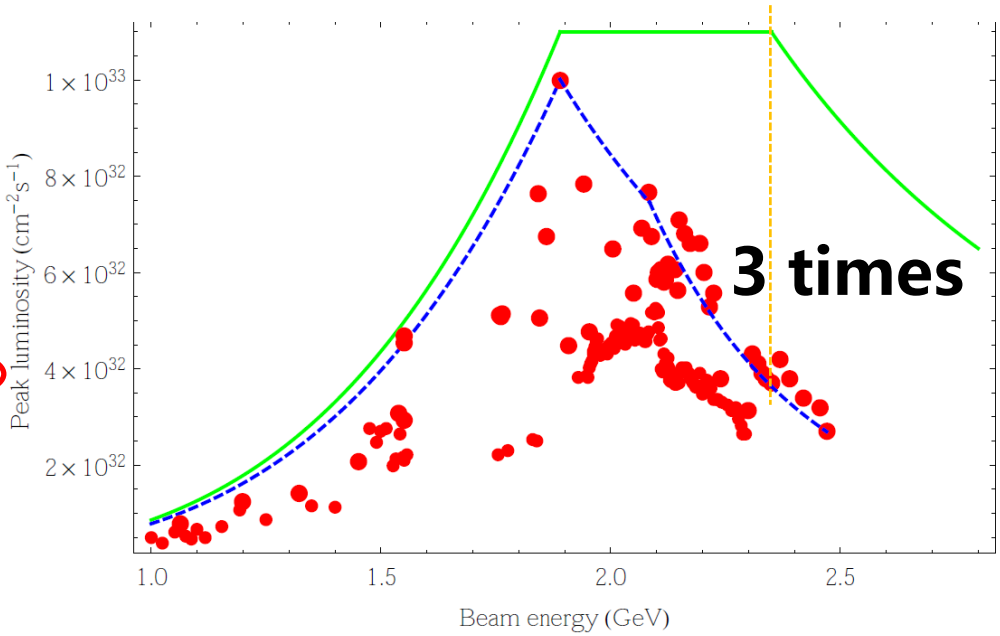
New Kicker

Design parameters before/after upgrade

Beam Energy：2.35GeV

	BEPCII	BEPCII-U
Lum [$10^{32}cm^{-2}s^{-1}$]	**3.5**	**11**
β_y^* [cm]	**1.5**	**1.3**
Bunch Current [mA]	7.1	7.5
Bunch Num	56	120
SR Power [kW]	**110**	**250**
$\xi_{y,\mathrm{lum}}$	**0.029**	**0.036**
Emittance [nmrad]	147	152
Coupling [%]	**0.53**	**0.35**
Bucket Height	0.0069	0.011
$\sigma_{z,0}$ [cm]	1.54	1.04
σ_z [cm]	**1.69**	**1.3**
RF Voltage	**1.6 MV**	**3.3 MV**

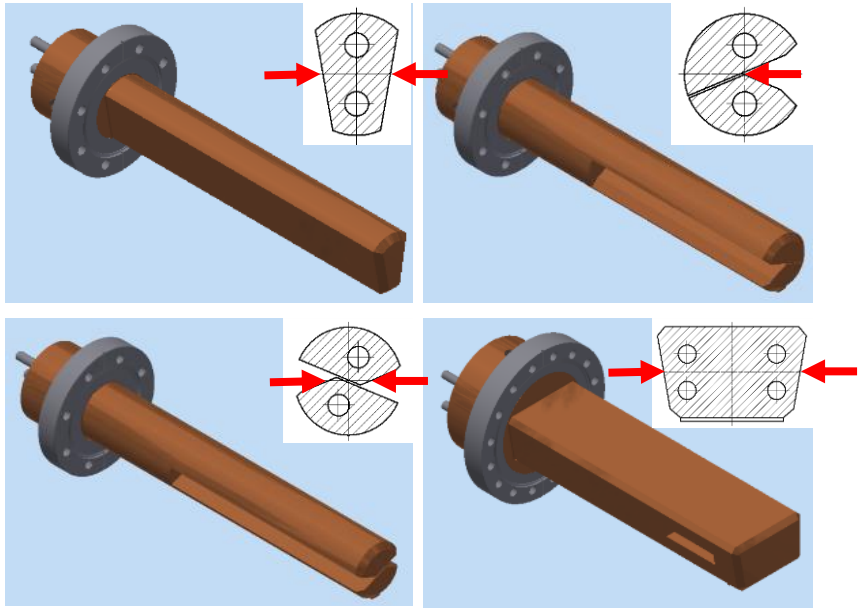
BEPCII-U vs BEPCII



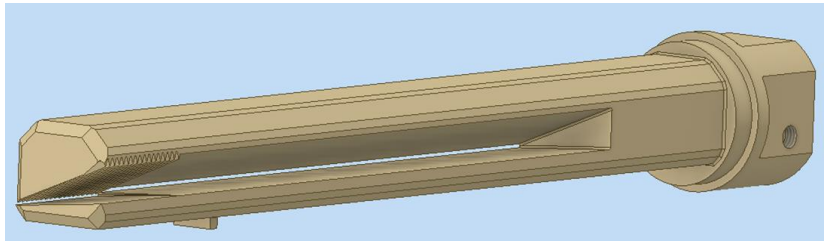
- **Luminosity is increased by a factor of 3 @2.35GeV**
- **Maximum beam energy is increased from 2.1GeV to 2.8GeV.**

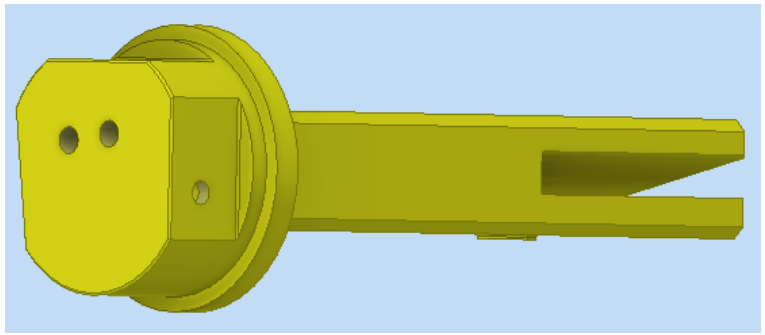
Hardware upgrade ----photon absorber

Typical model of BEPCII



Typical model of BEPCII-U

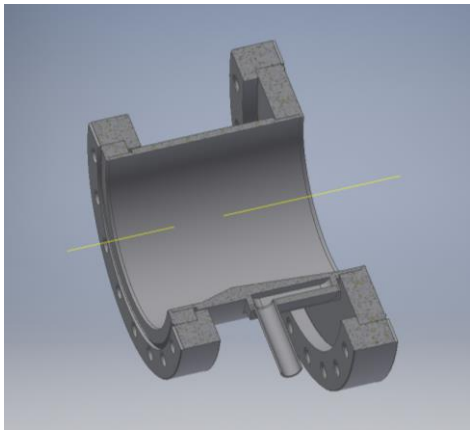


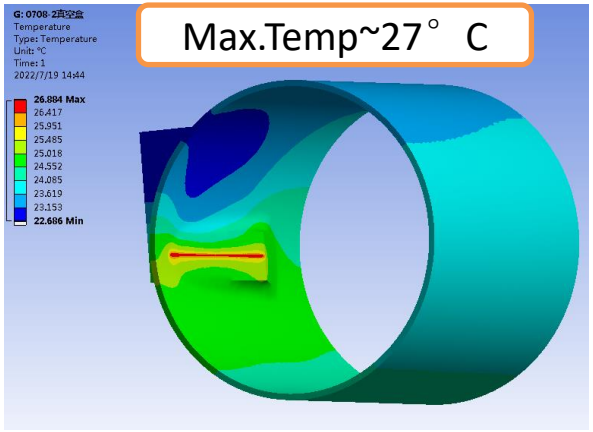


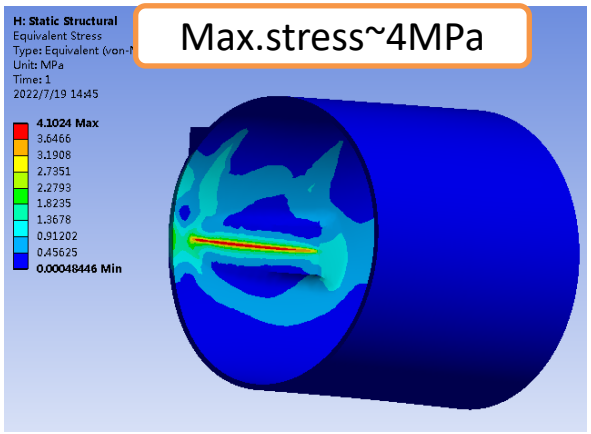
Photon absorbers bear ~85% of the synchrotron radiation power:

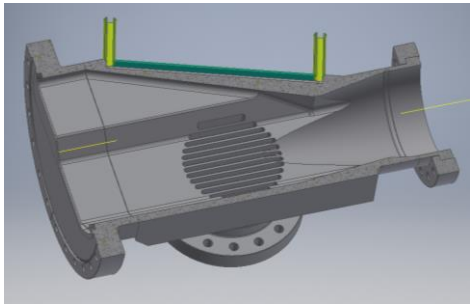
- The SR power increases from 110kW to 250kW after upgrade
- To reduce the power density, the incident angle is decreased and sawtooth structure is added
- Eliminate double sides absorber design

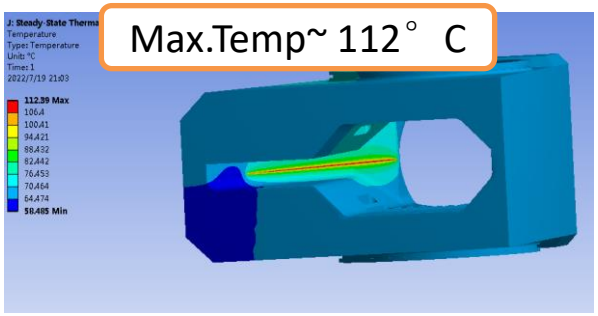
Hardware upgrade ----Vacuum chamber

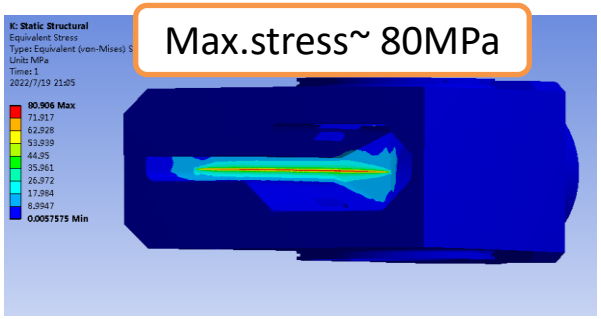












- Part of the vacuum chambers are changed to OFC(oxygen free copper) material.
- The inner-absorber is added.
- Increase the light receiving area.

Summary

- The performance of the vacuum system of the storage ring has been good.
- The vacuum system failure time is less each year
- Hardware equipment aging need to attract attention(e.g. material defect , weld of bellows).
- Equipment with high outgassing is scheduled to be removed(Wiggler).

THANKS FOR YOUR ATTENTION