

CYC2022

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Cyclotrons and their Applications

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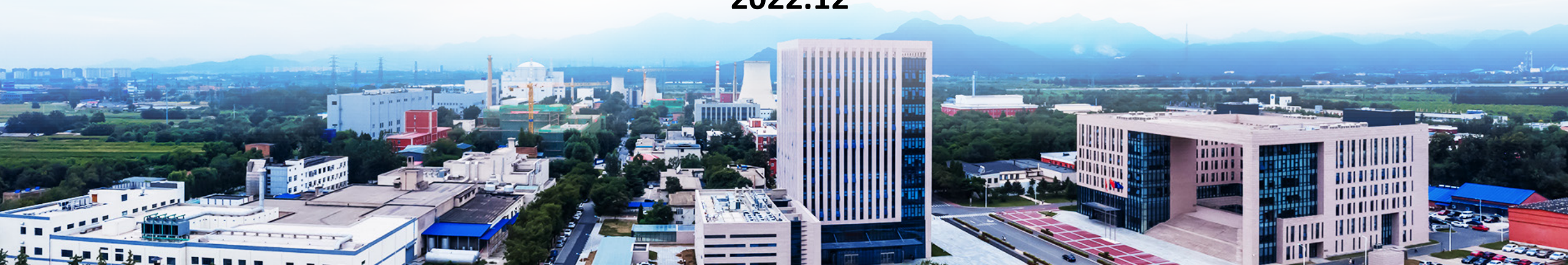
China Institute of Atomic Energy & Huazhong University of Science and Technology



The commissioning of Superconducting Cyclotron CYCIAE-230 at CIAE

Dr. Chuan Wang on behalf of the Cyclotron team at CIAE

2022.12



Outline



1 Introduction to CYCIAE-230

2 Commissioning of subsystems

3 Commissioning of CYCIAE-230

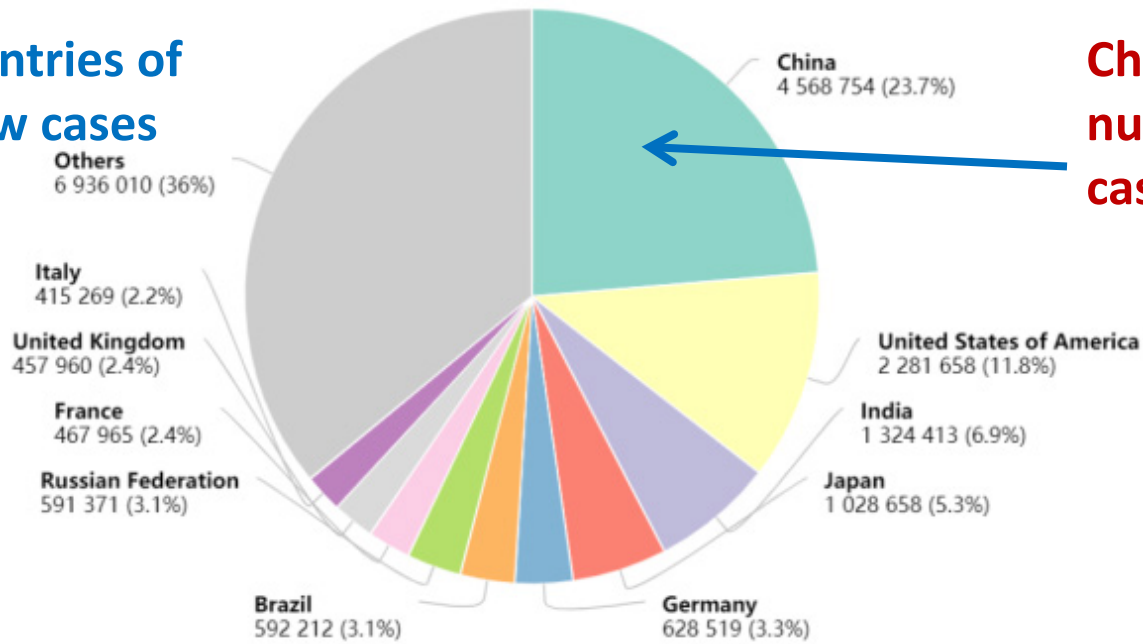
4 Summary and the Future Plan

Introduction to CYCIAE-230

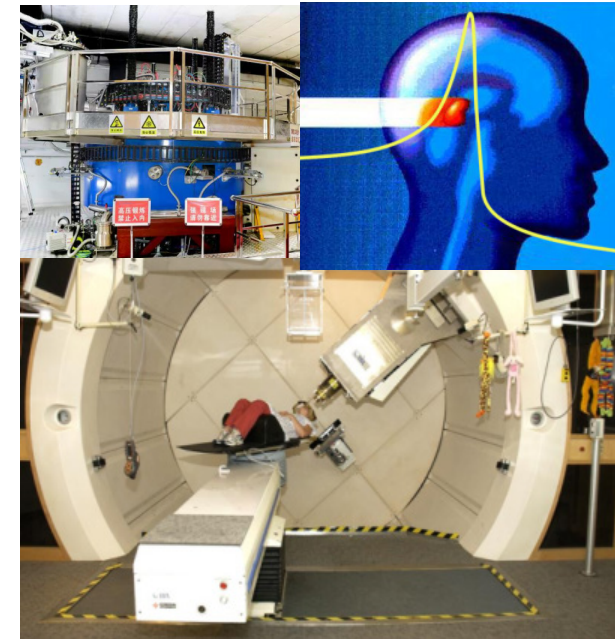
Cancer is the 2nd largest cause for death in the world, and the 1st cause for death in China.

According to the latest global cancer data in 2020 released by the International Agency for Research on Cancer (IARC) of the World Health Organization (WHO), there are 4.57 million new cancer cases in China, including 2.48 million men and 2.09 million women, accounting for 23.7% of the world's total. **And according to PTCOG, ~60% PT system is based on cyclotron.**

Top 10 countries of yearly new cases



China is leading the number of new cases and death.

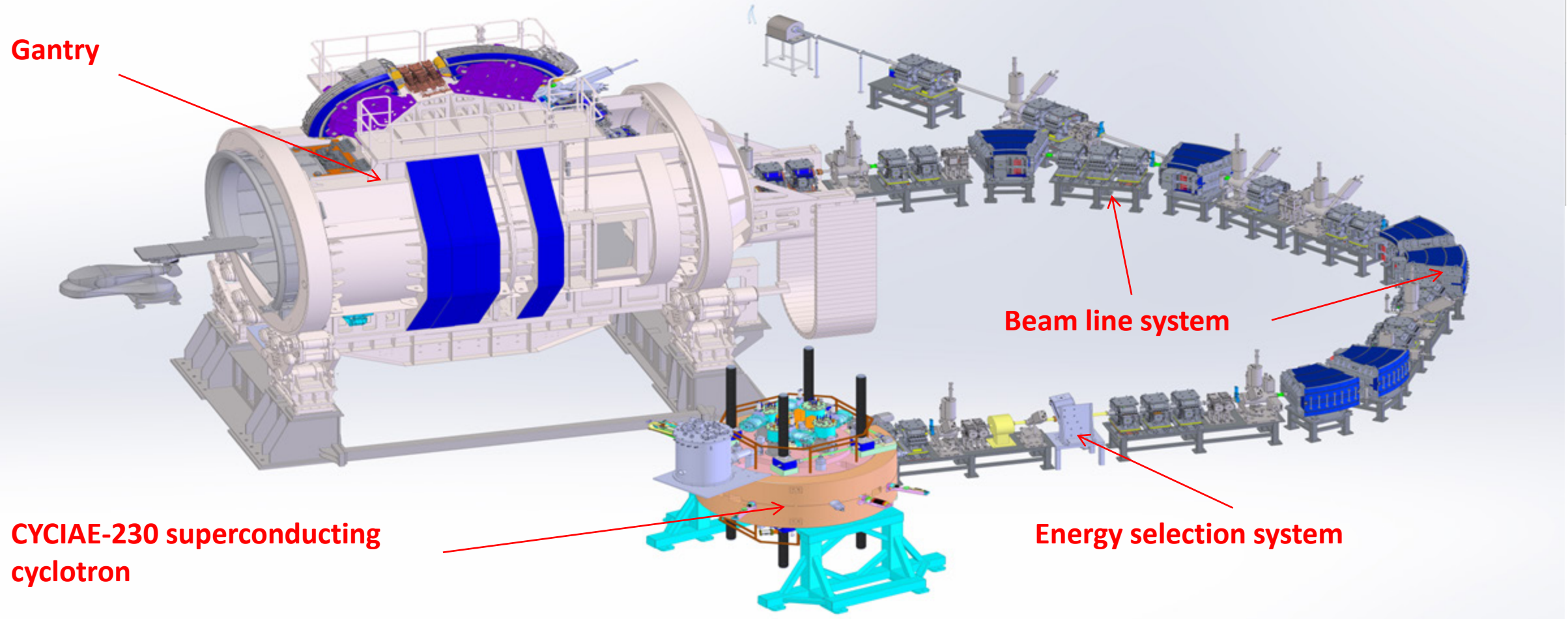


Estimated by WHO, the yearly new cases will increase 60% in 20 years.



Introduction to CYCIAE-230

Granted by CNNC, the cyclotron project was launched in 2016. **The rest of the proton therapy system was granted by Ministry of Industry and Information Technology in 2017.**



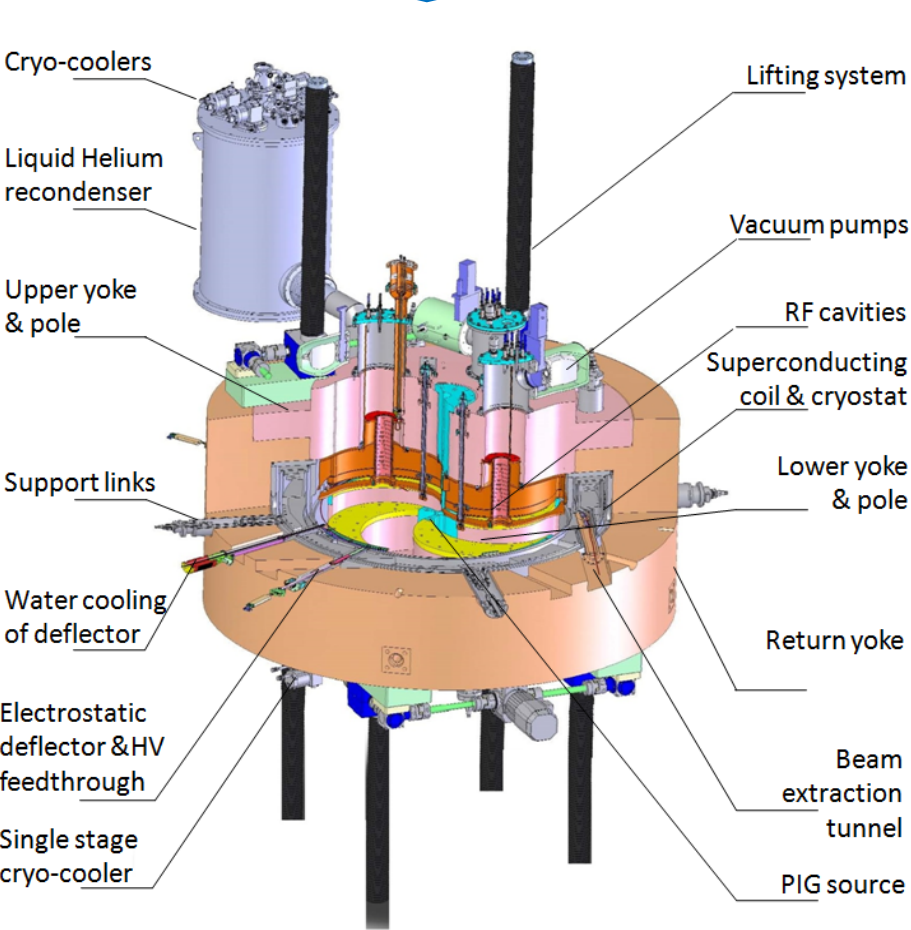
Proton beam in the energy range of 200 MeV – 250 MeV has various applications, like proton therapy, SEE test and radiation hardening of microchips, etc.

Design highlights

Isochronous cyclotron with LTS coil.

Design Parameters of CYCIAE-230 superconducting cyclotron

Beam	
Beam current from ion source	10 mA
Extracted beam energy	240 MeV
Extracted beam current	A few hundreds of nA
Magnet	
Pole structure	Spiral
Pole radius	85.0 cm
Weight	~80 tons
Hill gap	5.0 cm
Central field	2.3 T
Coils	
Coil type	NbTi low temperature superconducting wire
Current density	≤50A/mm2
Ampere-Turn Number	~600000 A.T×2



RF Cavity	
Number of cavity	4
RF frequency	~71 MHz
Harmonic Mode	2
Cavity Voltage	80~110kV
RF Amp. output Power	200 kW
Extraction	
Method	Resonance crossing & precessional motion
Elements for extraction	2 E deflectors and 6 magnetic channels
Deflector voltage	< 100 kV/cm
Deflector gap	5 – 7 mm
Ion source	
Type	Cold cathode Penning ion source

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Commissioning of subsystems

Milestone

The commissioning site was ready in Dec. 2019.

In 2019.12, the sc magnet was transferred from the field mapping site to the commissioning site



Commissioning site



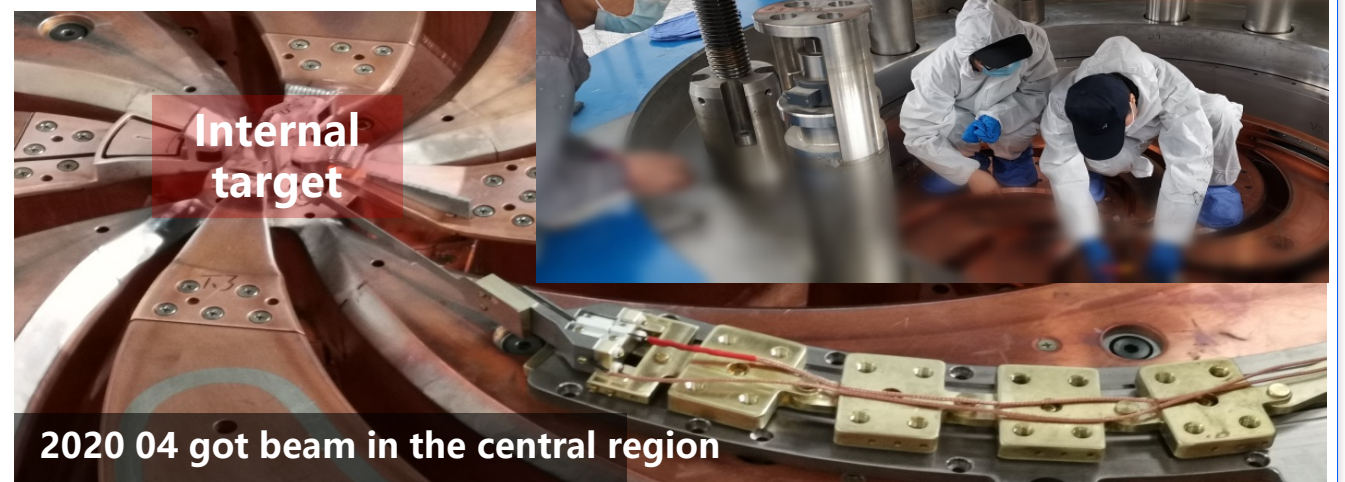
2019 12 mapping site

Then finish the installation of subsystem of the cyclotron, such as RF, ion source, central region etc.



RF amplifier

Coaxial line



Internal target

2020 04 got beam in the central region

Outline



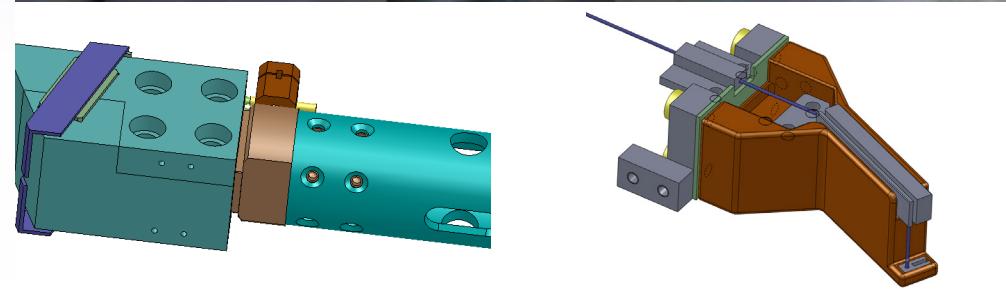
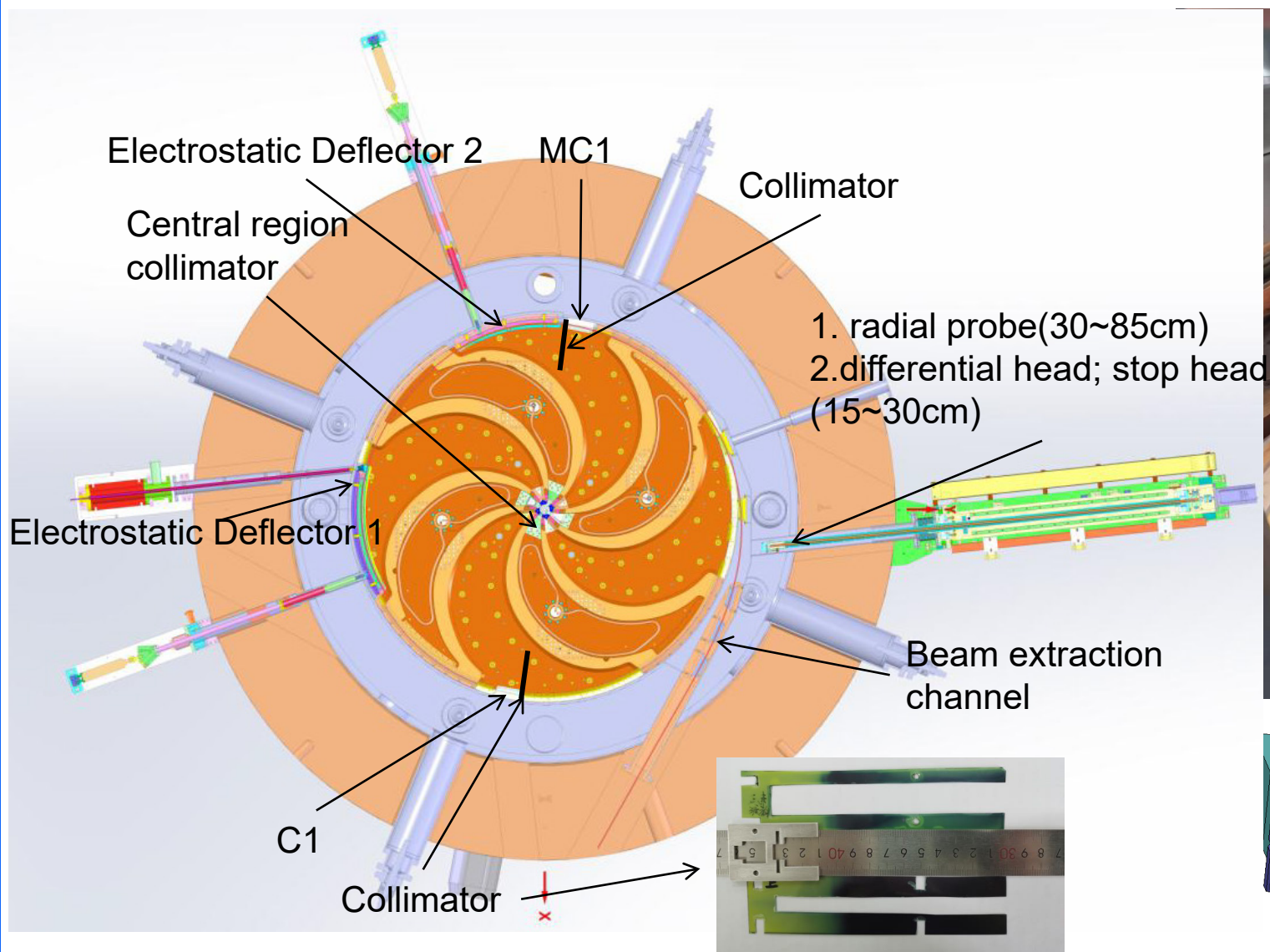
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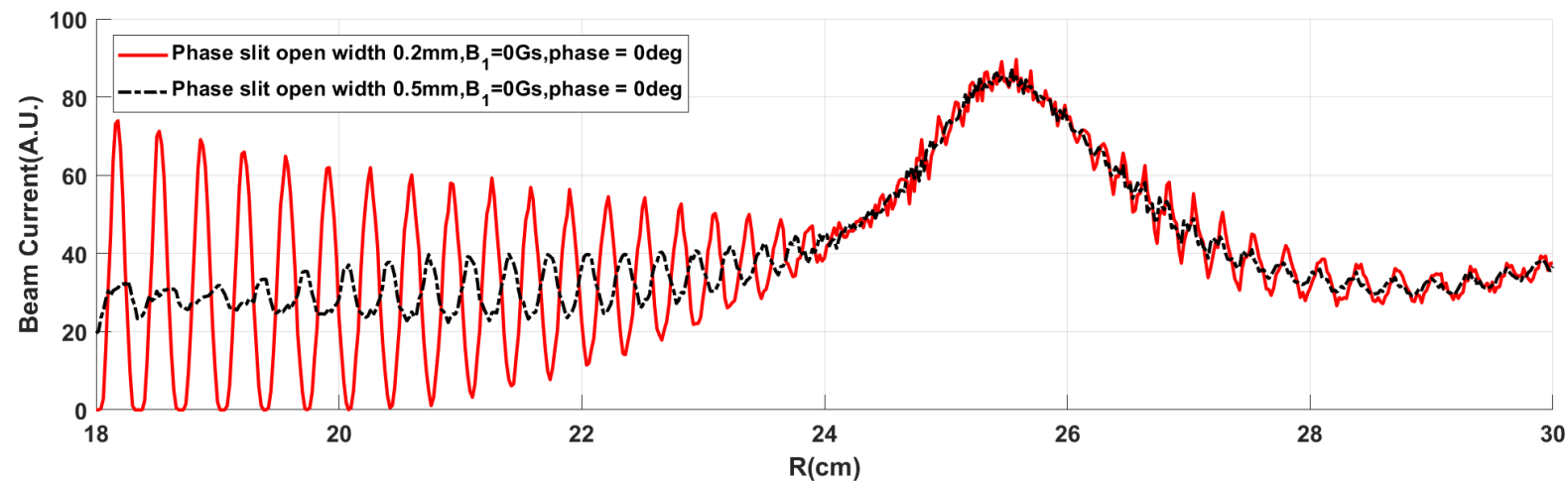
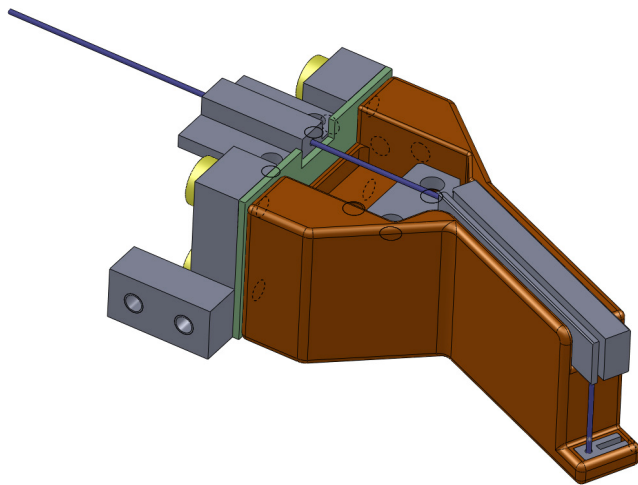
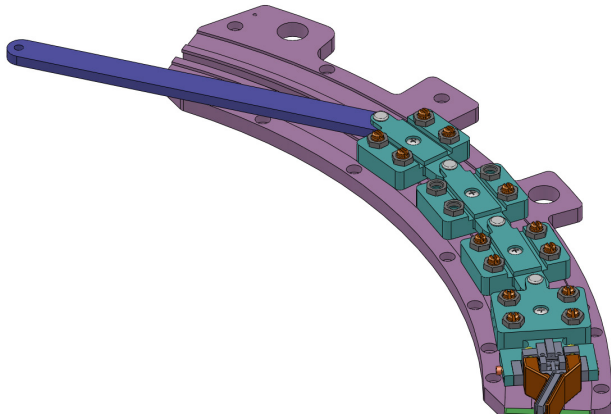
Commissioning of CYCIAE-230-Layout and diagnostics



Reliable diagnostics is the key issue for the commissioning of CYCIAE-230 type SC

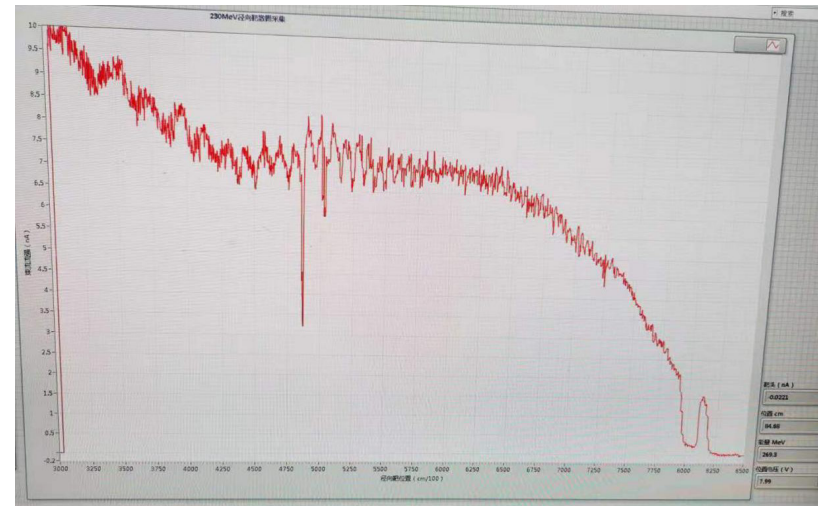
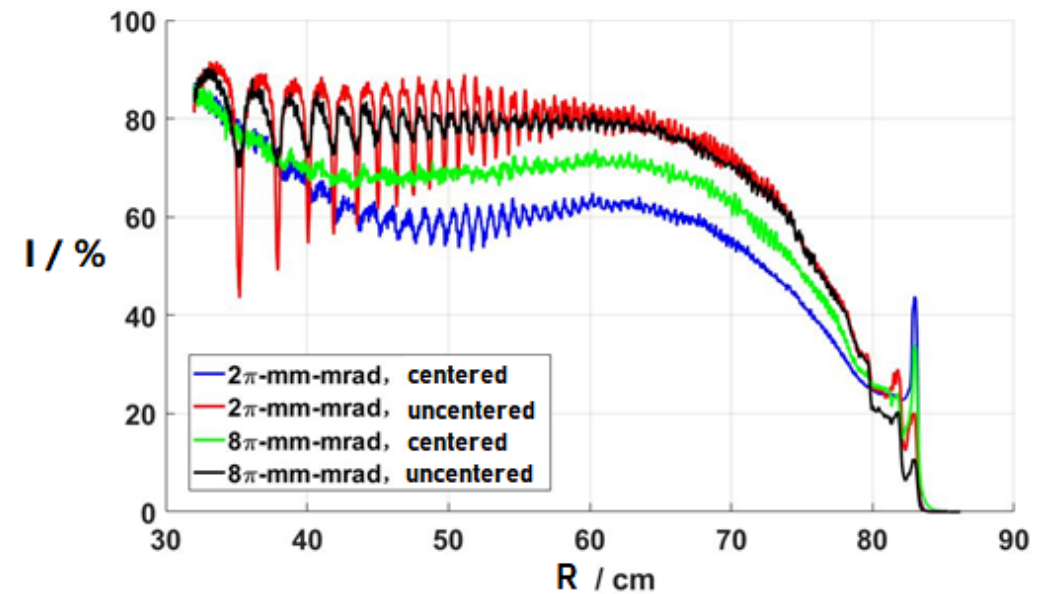
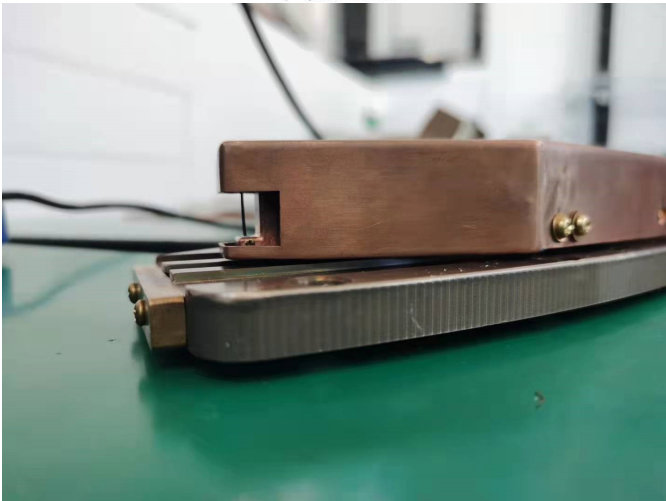
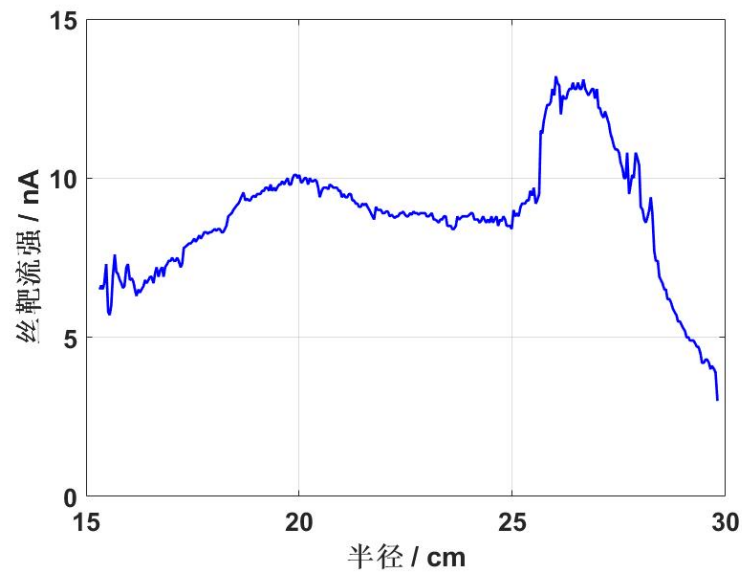
Commissioning of CYCIAE-230-an example of failure

Radial Centering using differential probe



Simulated turn pattern using 0.2mm phase slit.

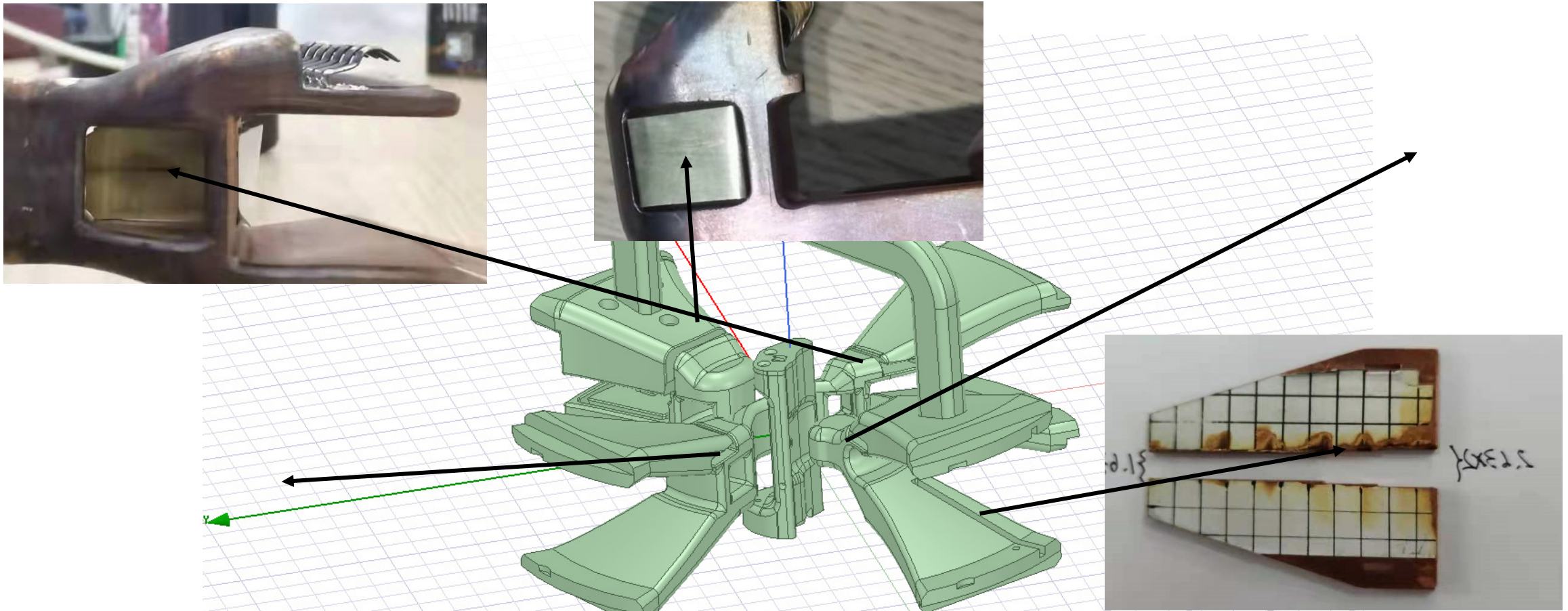
Commissioning of CYCIAE-230-an example of failure



Up to now, the radial alignment is achieved by radial probe.

Commissioning of CYCIAE-230-vertical alignment in central region

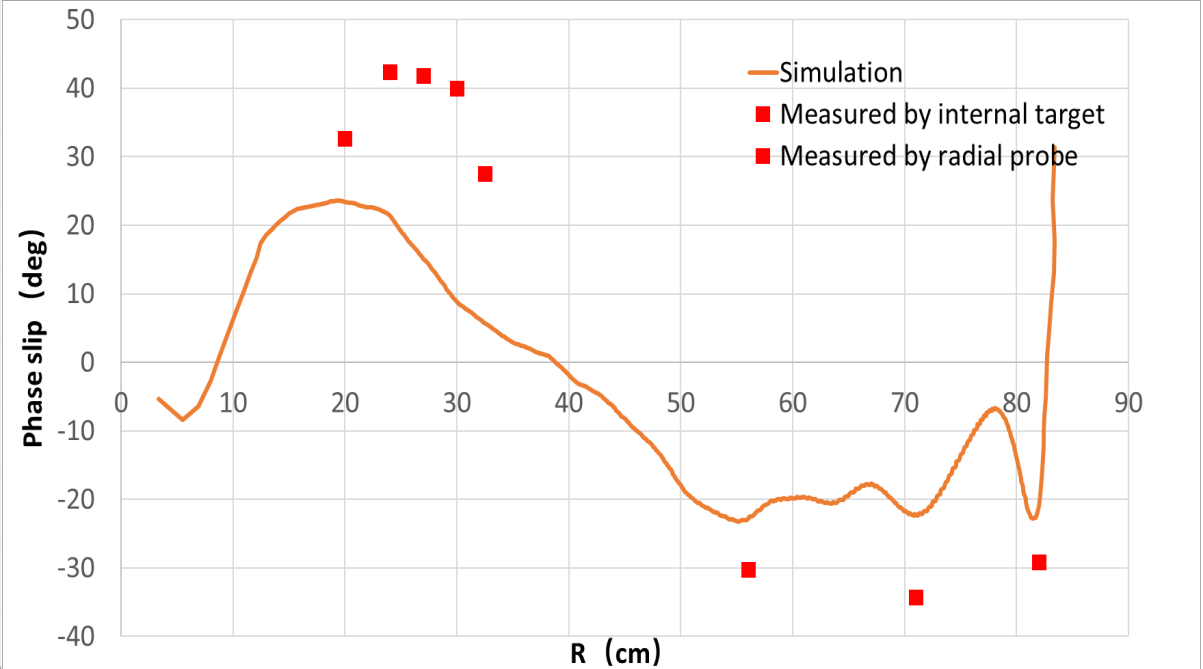
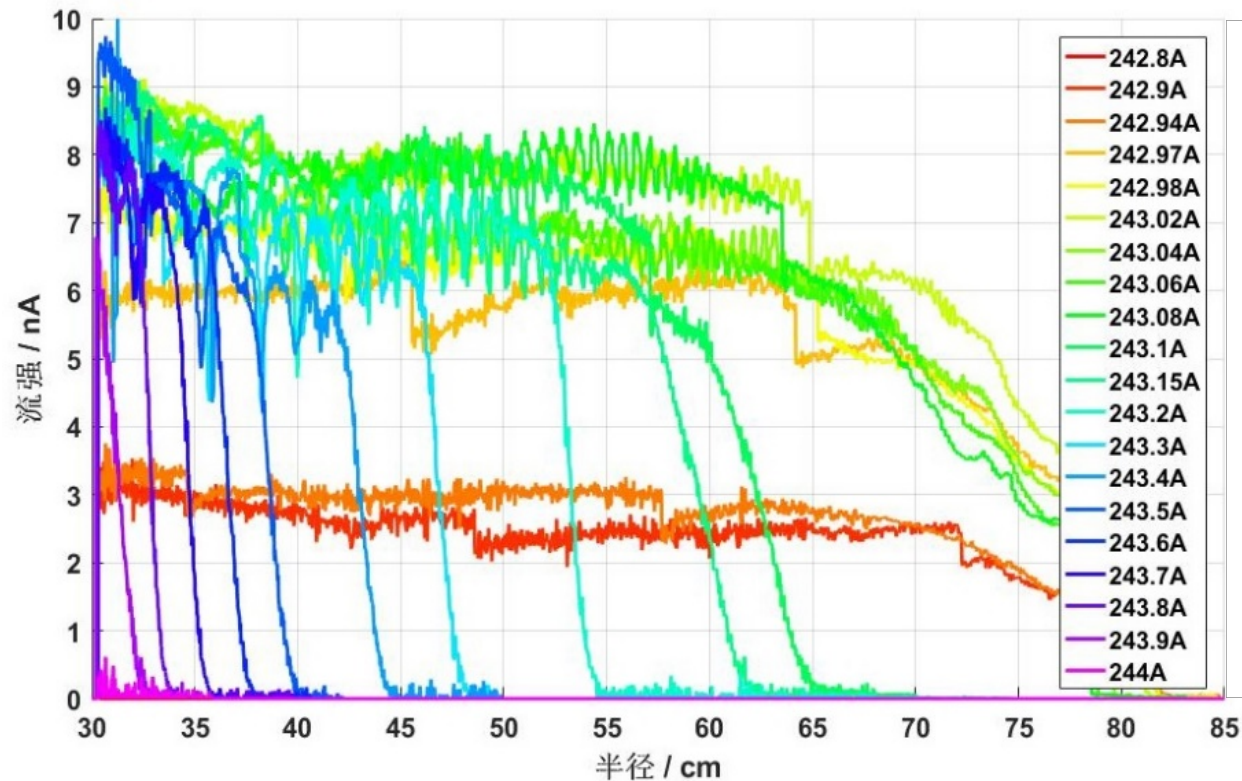
Traditional way to diagnostic beam position in central region



The axial alignment of the beam in the central region is achieved by adjusting the position of ion source and central electrode.

Commissioning of CYCIAE-230-Isochronous measurements

$$\sin \varphi(R) = 2 \frac{\bar{I} - I_0}{\Delta I} \quad \bar{I} = \frac{1}{2} (I^- + I^+) \quad \Delta I = I^- - I^+$$

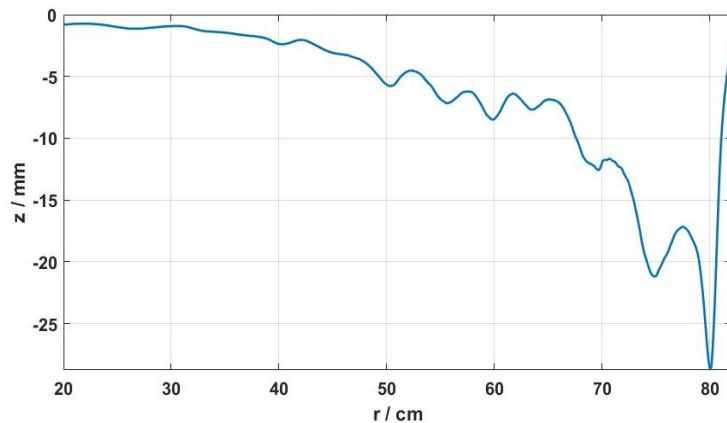


Isochronous measurements using the internal target and the radial probe

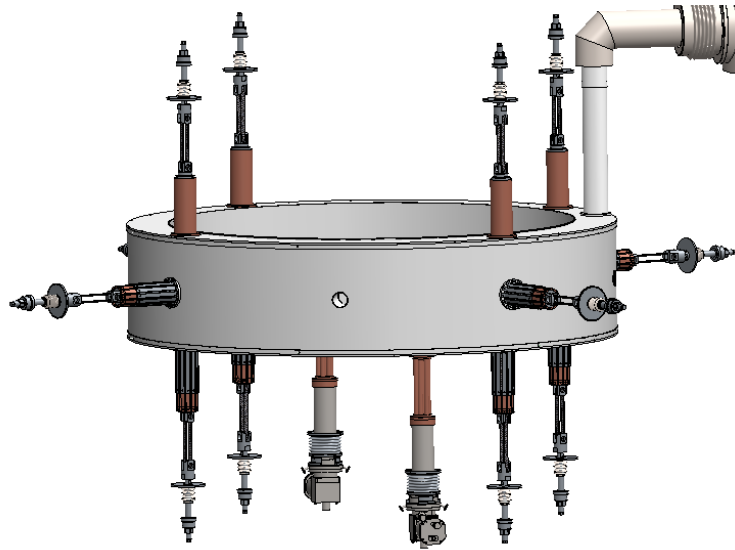
Commissioning of CYCIAE-230-coil position alignments

The position sensitive region near $R=80\text{cm}$, become a good indicator for coil positioning

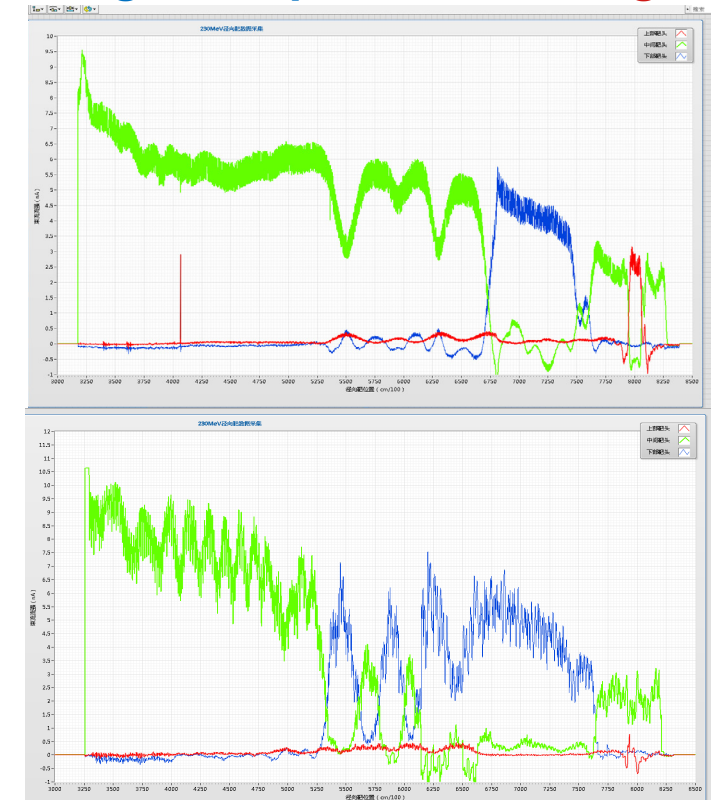
According to our calculation
1mm coil shift in vertical
direction equals to $\sim 30\text{ mm}$
beam shift



12 support links, could achieve
positioning precision in 0.02mm



Using radial probe with 3 fingers

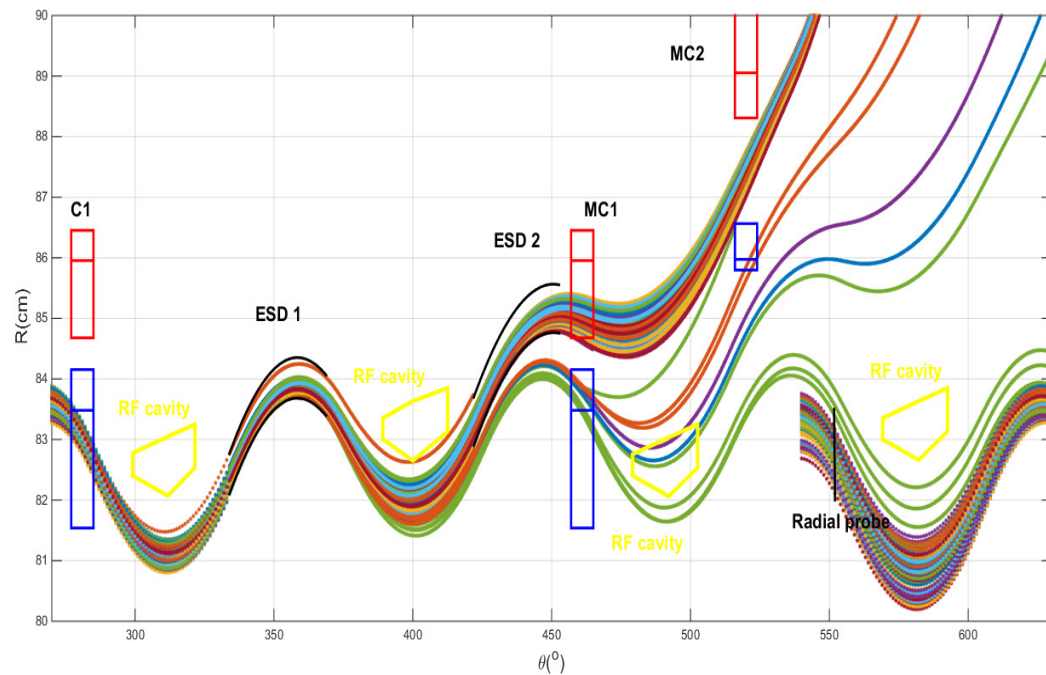


Good vertical alignment is achieved.

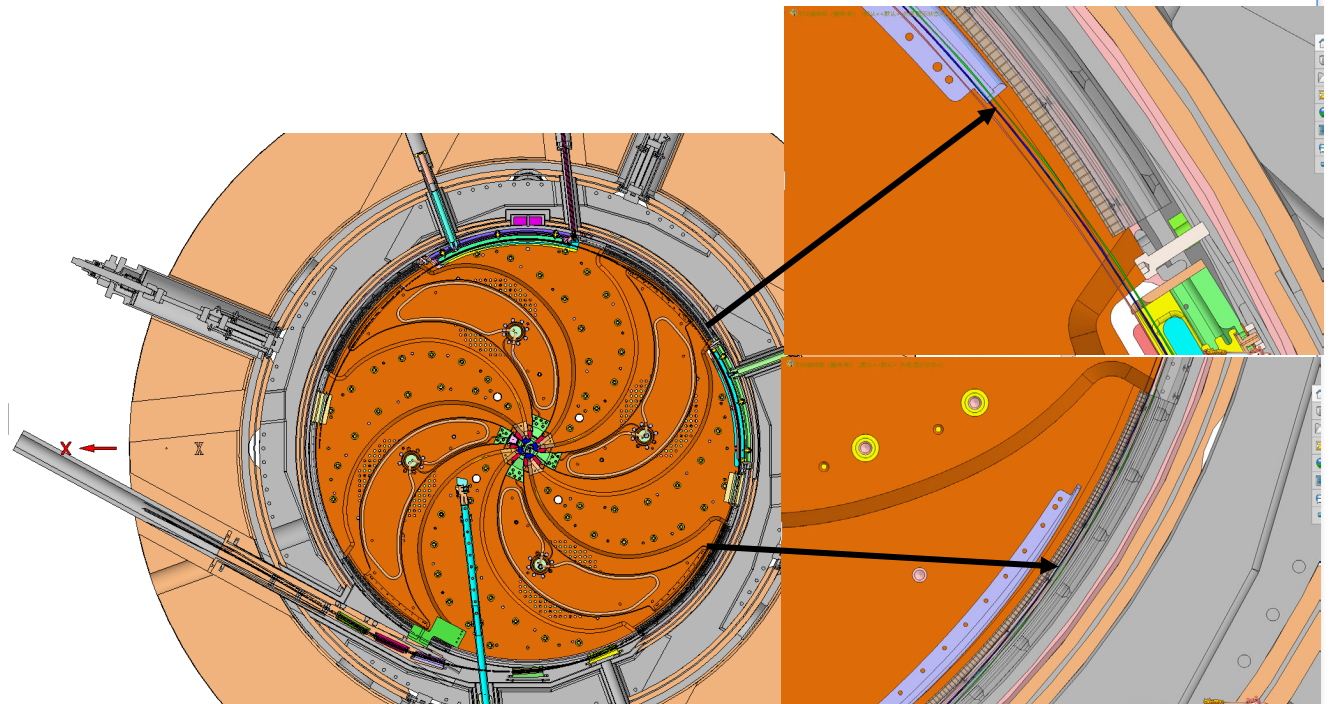
Commissioning of CYCIAE-230-extraction elements alignments

Trajectory design in extraction region

After **~700 turns**, the extracted beam must pass the ESDs, MCs and the tailboard of the RF cavities with the tolerance of **~2mm**.



The trajectory of the last turn is inside the tailboard before ESD2, and outside the tailboard after ESD2.

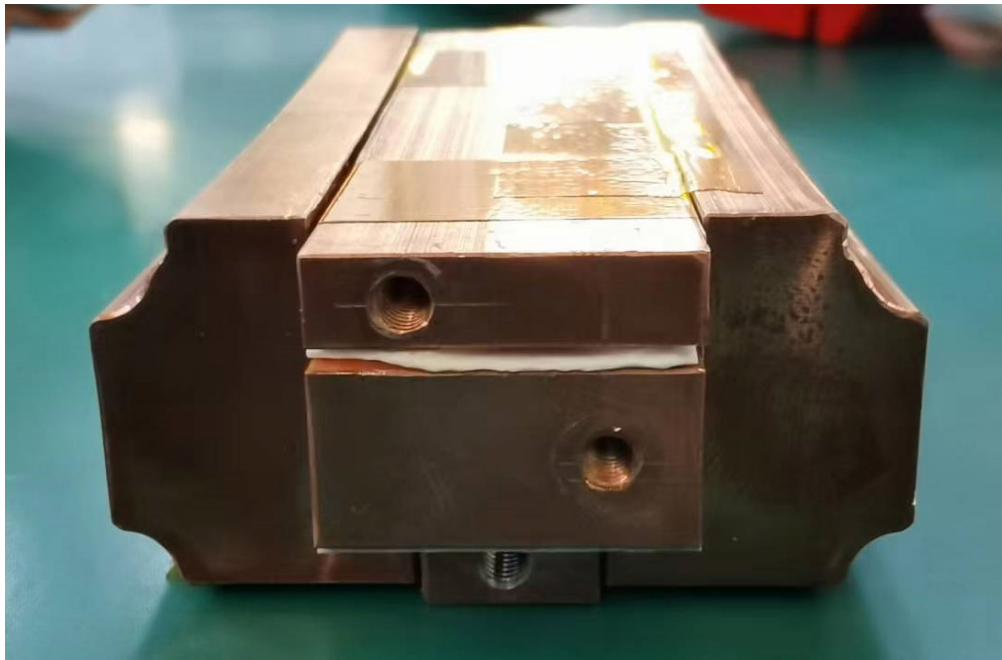


The positioning of the extraction elements is important.

Commissioning of CYCIAE-230-extraction elements alignments

Newly developed diagnostics for extraction elements alignments

Probe with radial fingers used for the commissioning of ESDs.

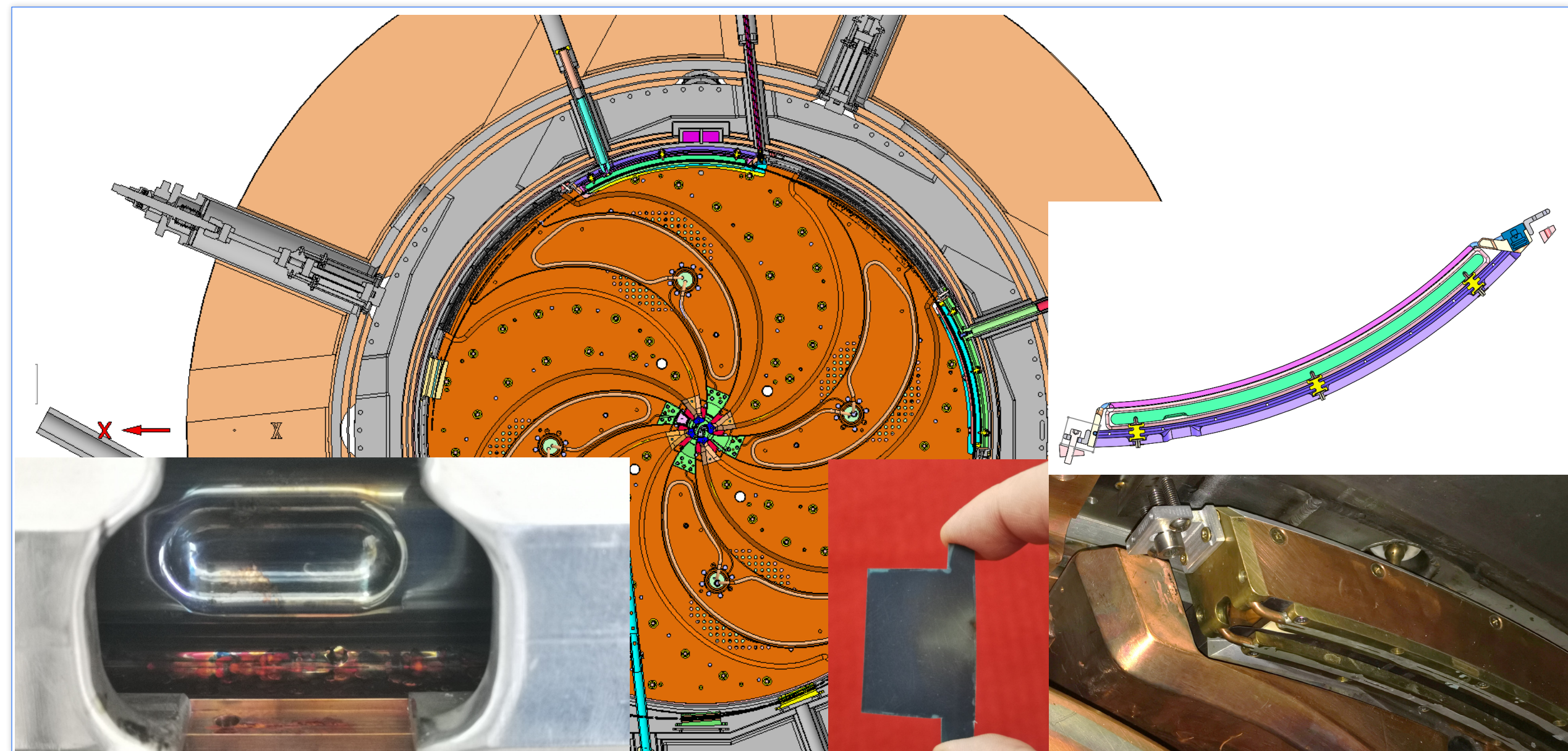


Self shielded probe for the commissioning of MCs.



The positioning of the extraction elements is important.

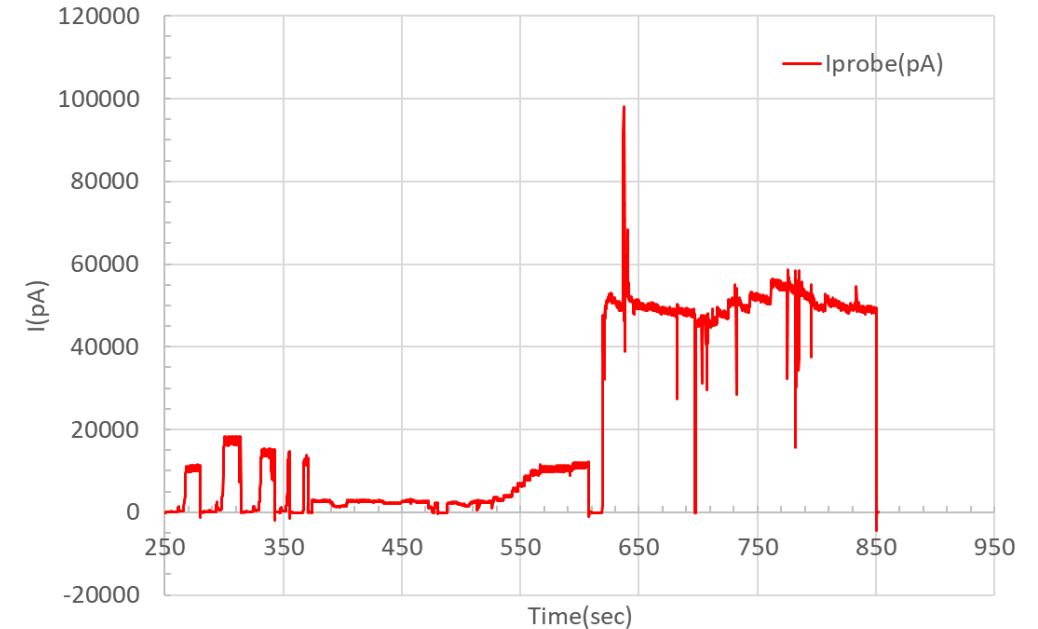
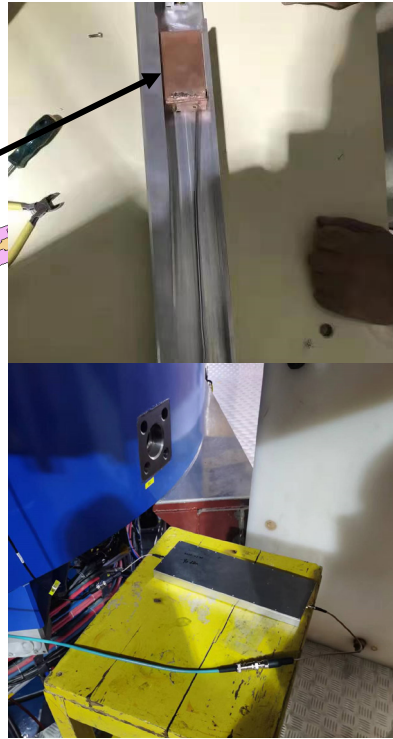
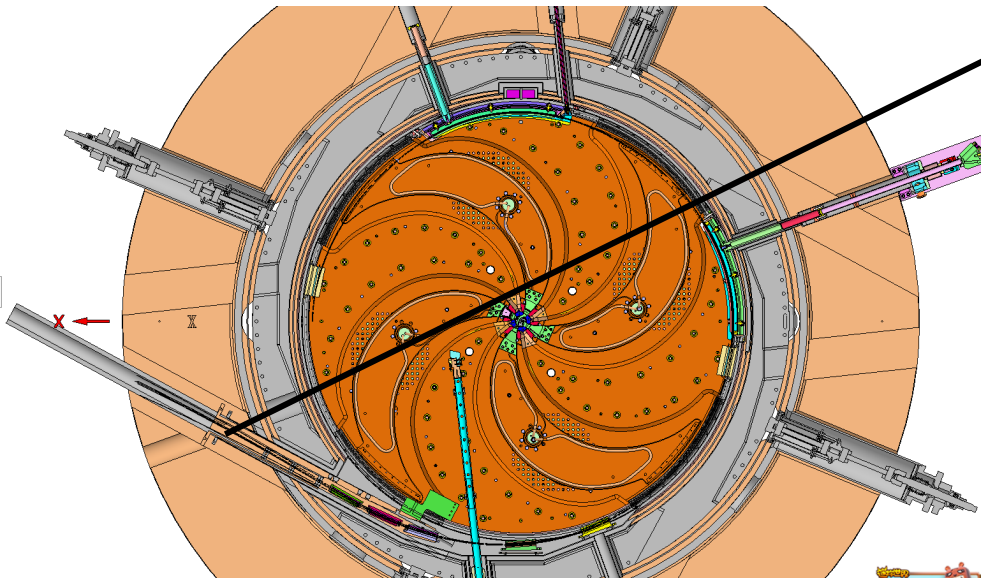
Commissioning of CYCIAE-230-extraction elements alignments



Commissioning of CYCIAE-230-Beam commissioning

Beam extraction test

After ~700 turns, the extracted beam has been measured at the end of the extraction port with a LIBERA current meter.



The beam on the copper target is over 50 nA @ energy of 241.6MeV~242.7MeV (estimated by extraction simulation).

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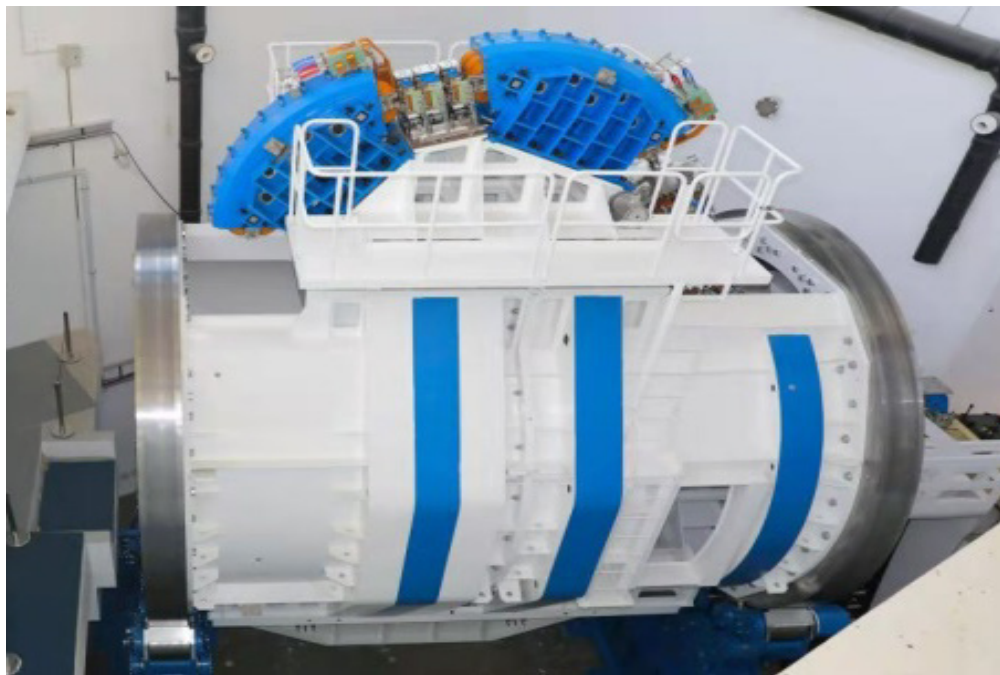
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Commissioning of ESS, Beam line and Gantry is on going...



The 160-ton gantry has been tested and the isocenter positioning precision of 0.3mm is achieved during 360-degree rotation test. The commissioning of other parts will be fully performed after obtaining the approval from Beijing Environmental Protection Bureau.

