PROGRESS ON CONSTRUCTION OF *CYCIAE-100*, a 100 MEV H- CYCLOTRON AT CIAE

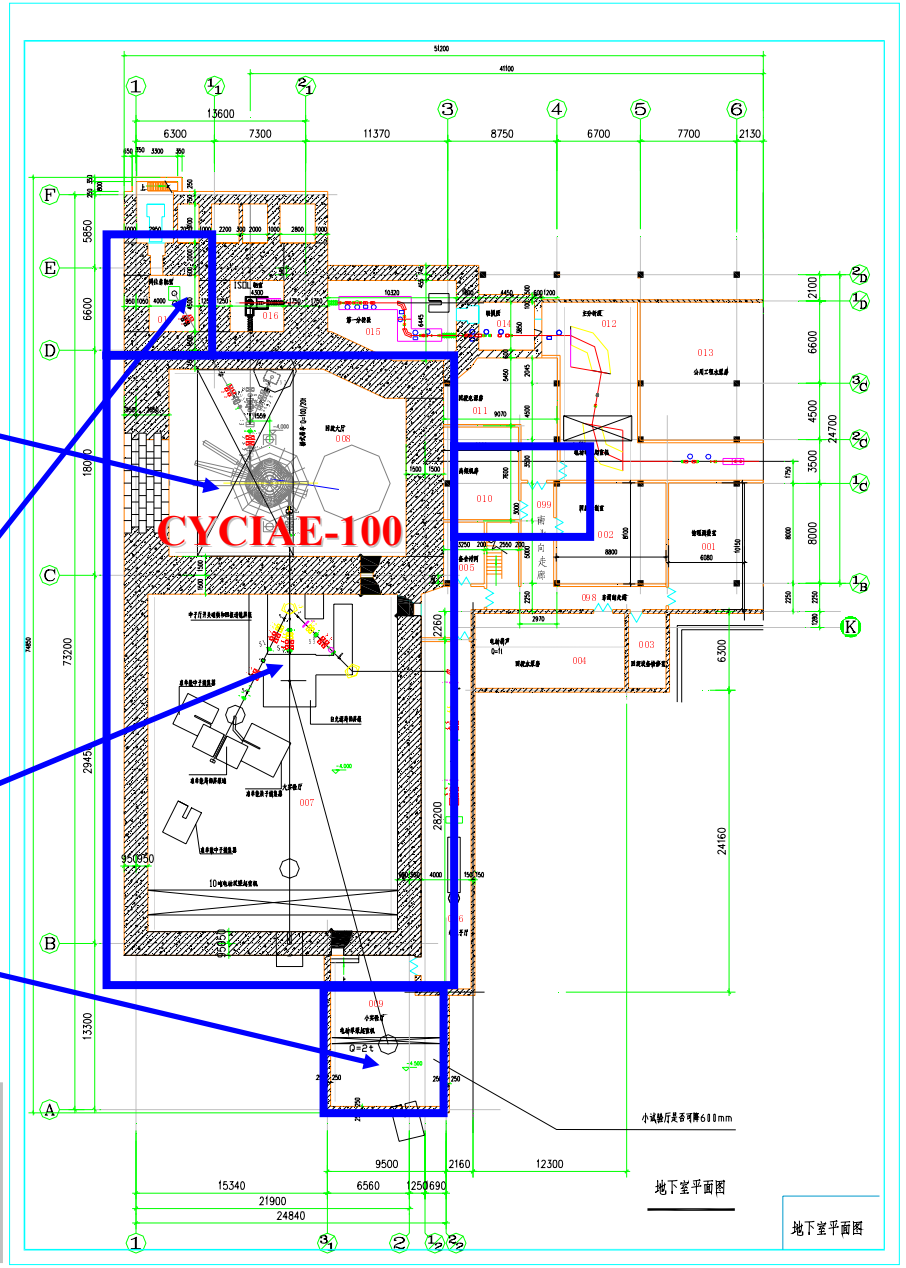
Tianjue Zhang, Zhengguo Li, YinLong Lu

China Institute of Atomic Energy

2010-9.7

Introduction about BRIF

- **Cyclotron:**
  100MeV /200uA
- **ISOL:**
  Resolution, 20000
- **SC Linac:**
  2MeV/u
- **Beam Lines**



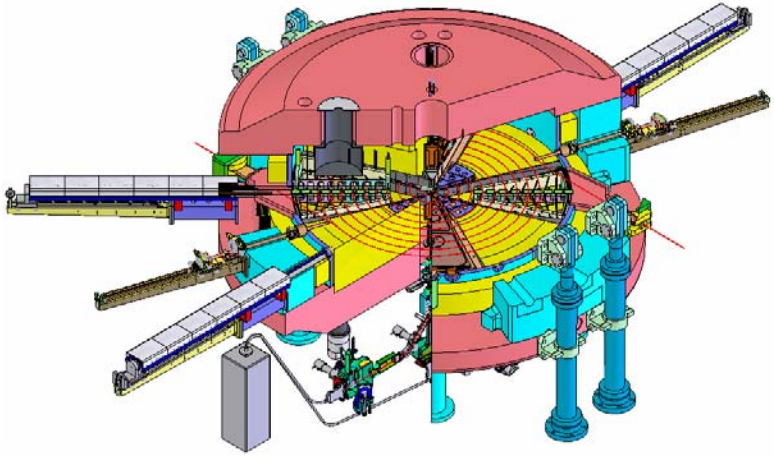
BRIF - The Beijing Radioactive Ion-beam Facility

团结 敬业 求实 创新

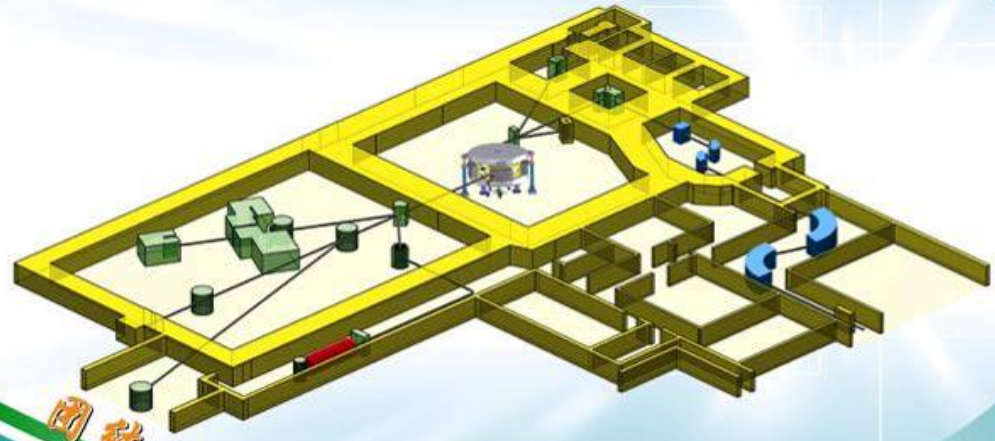
HI-13串列加速器

100MeV强流回旋加速器

100MeV强流回旋加速器是BRIF工程的主要组成部分。它能够提供能量75-100MeV连续可调，流强200μA的质子束。其特点是：紧凑型、高调变度的磁铁结构；加速电压随半径增加的双D盒谐振腔；强流外部负氢离子源与轴向注入；负氢剥离双向引出。建成后，能独立用于核物理、核医学的基础研究和国防核科技的应用基础研究，同时也能用于产生放射性核束，与串列加速器和超导增能器联机运行。

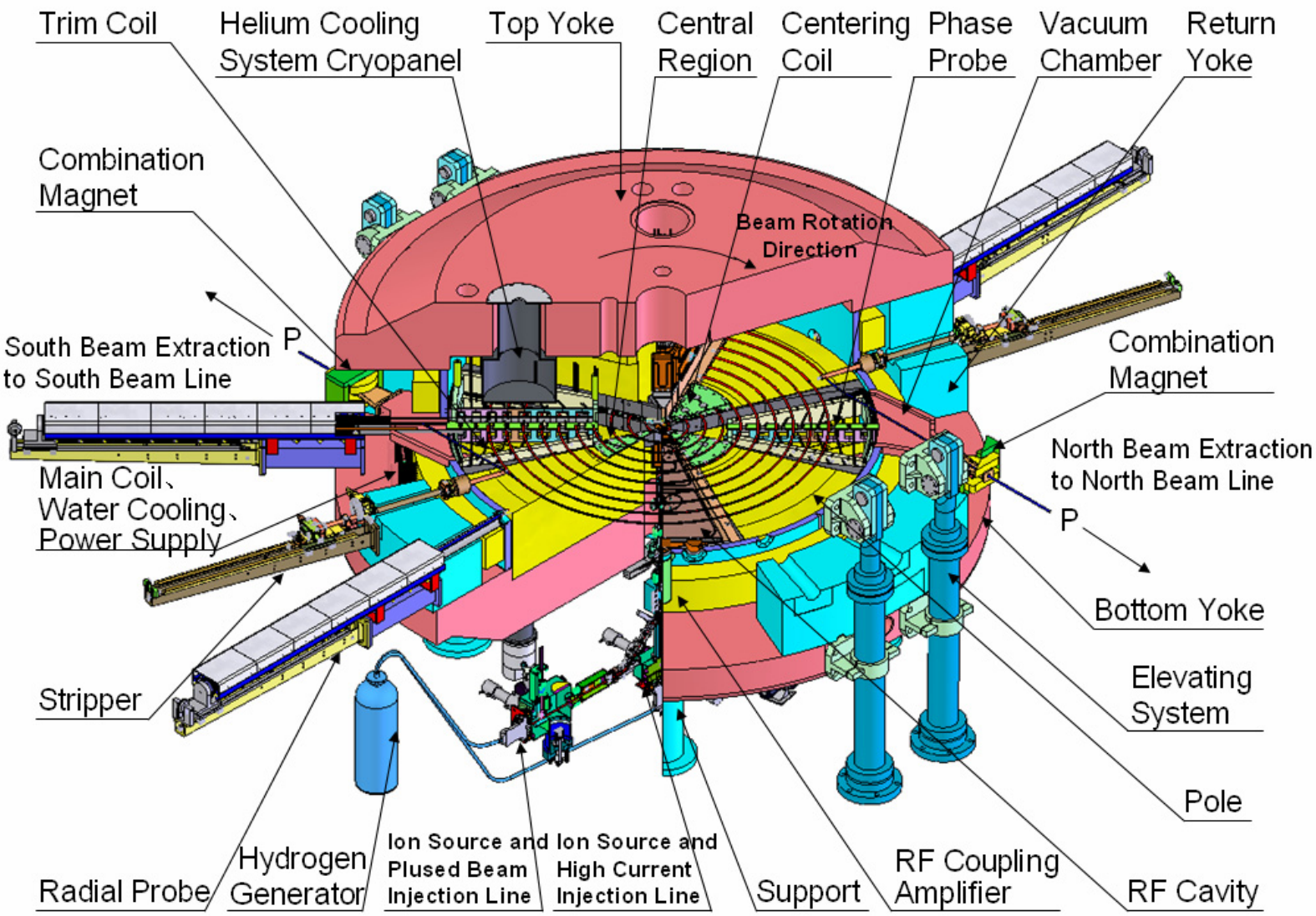


串列加速器升级工程



团结 敬业 求实 创新

General View of CYCIAE-100



Plan of Talk

A: Brief Introduction

B: CONSTRUCTION PROGRESS of CYCIAE-100

- Magnet
- RF
- Main Coils
- Elevating system
- Magnetic field measurement System
- Source, Injection & Extraction
- Others

C: THE KEY CERTIFICATION TESTS

- Central Region Model
- 1:1 RF Cavity Test
- Vacuum Cryo-panel test

D: New schedule of the Project

A. Brief Introduction

- CYCIAE-100, a fixed field, four sectors compact cyclotron, will provide a 75MeV - 100MeV, 200 μA - 500 μA proton beam.
- 2006, the preliminary designs
- 2007~2009，the detailed design & construction

Up to now

- ✓ The main magnet in the final assembly stage.
- ✓ Two main magnet coils are ready.
- ✓ Two 100kW RF power supplies have been tested.
- ✓ The vacuum chamber and elevating system will be completed soon.

A. Brief Introduction

- **Central Region Model Test Stand (CRM):**
  Received satisfactory results and passed the formal certification.
- **Full scale RF cavity test:**
  The measured *f* and Q values coincide well with the design.
- **The vacuum cryo-panel test:**
  Test results provide valuable information to cryo-panel final design.

Plan of Talk

A: Brief Introduction

B: CONSTRUCTION PROGRESS of CYCIAE-100

- Magnet
- RF
- Main Coils
- Elevating system
- Magnetic field measurement System
- Source, Injection & Extraction
- Others

C: THE KEY CERTIFICATION TESTS

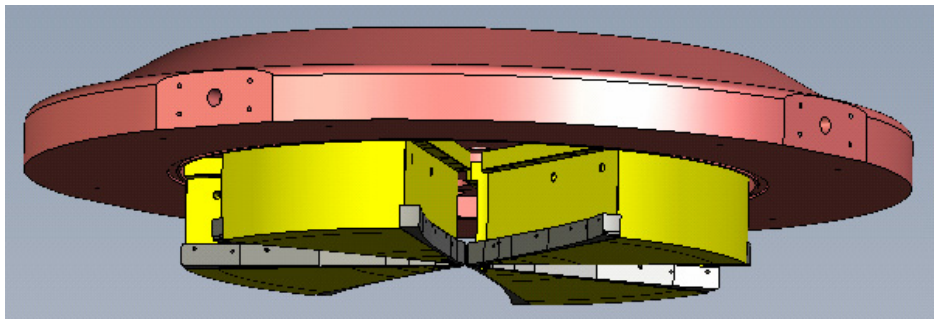
- Central Region Model
- 1:1 RF Cavity Test
- Vacuum Cryo-panel test

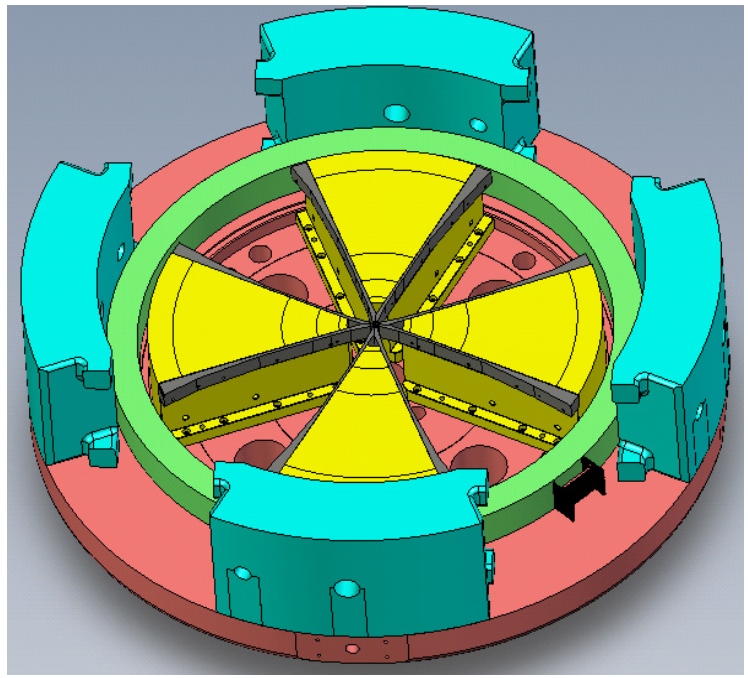
D: New schedule of the Project

B: Main progress of CYCIAE-100

– Magnet

The final Structure design:





Dia.: 6160 mm

Pole Dia.: 4000mm

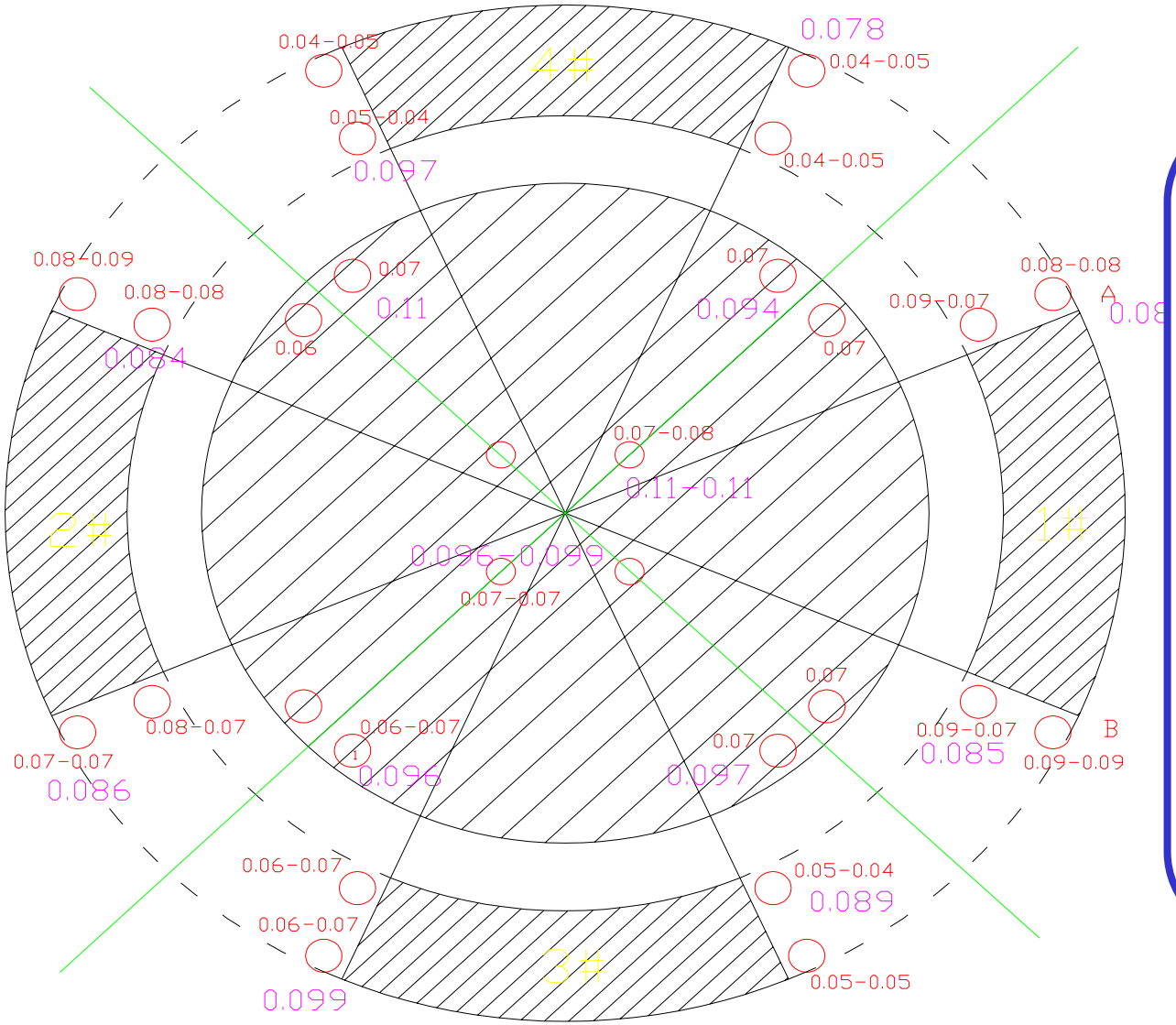
Height: 2820 mm

Weight: 435 t

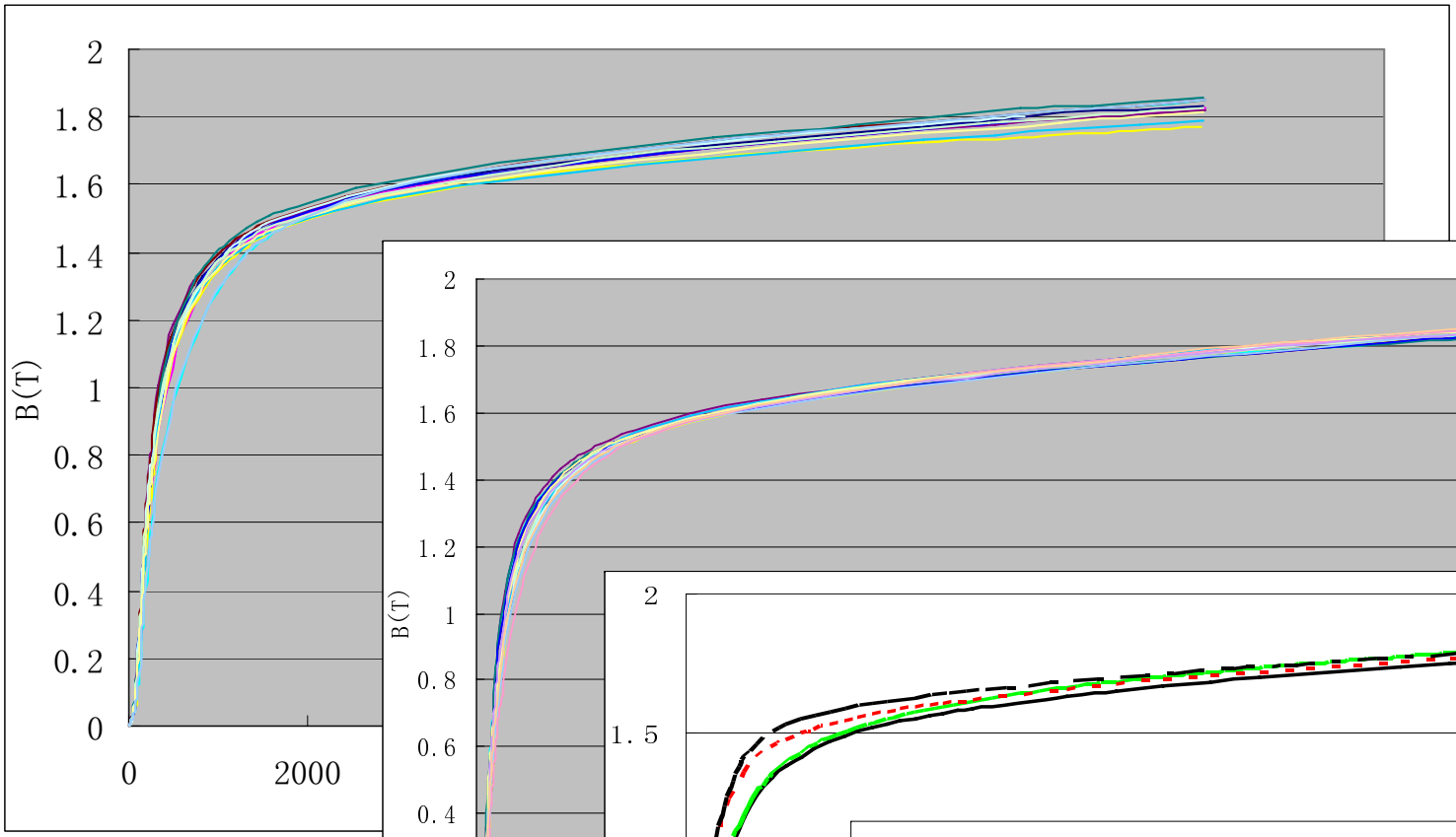
The rough magnet sectors were transported to CIAE from France in April of 2008.

Cast steel for the top/bottom yokes and return yoke were accomplished in 2008.

The yokes are formed from 5 pots molten steel pouring together.

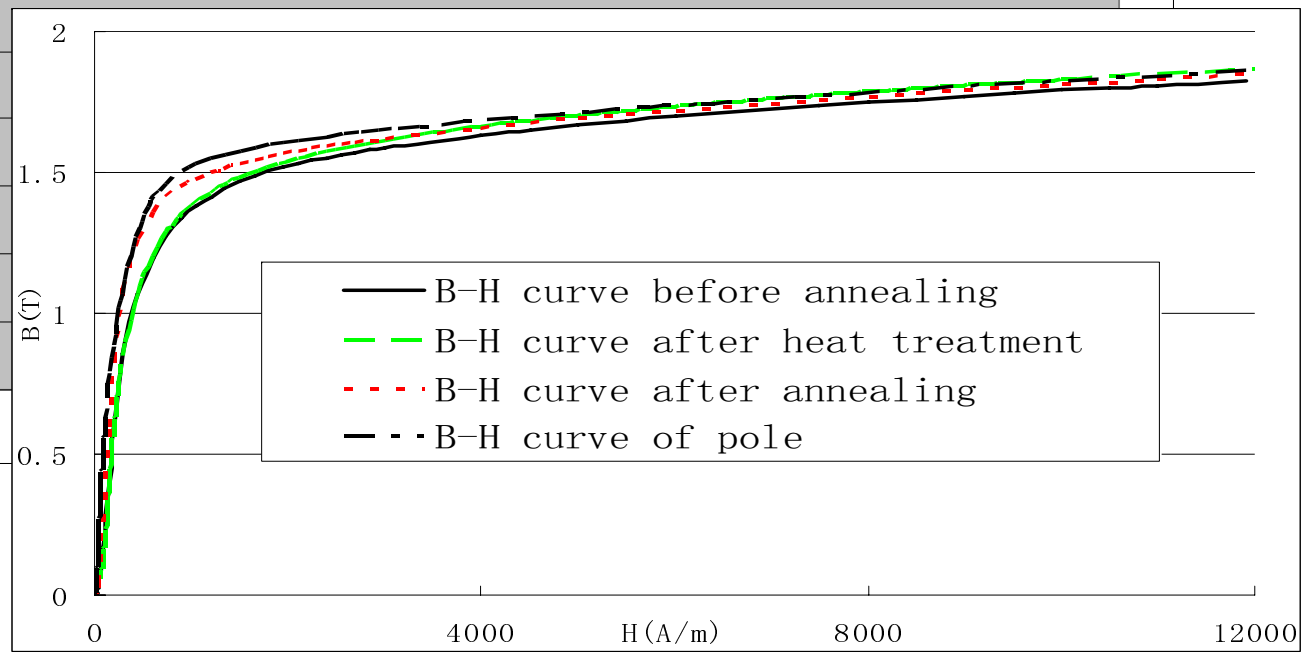


return yokes & top/bottom yokes: the chemical composition meets the designed specifications

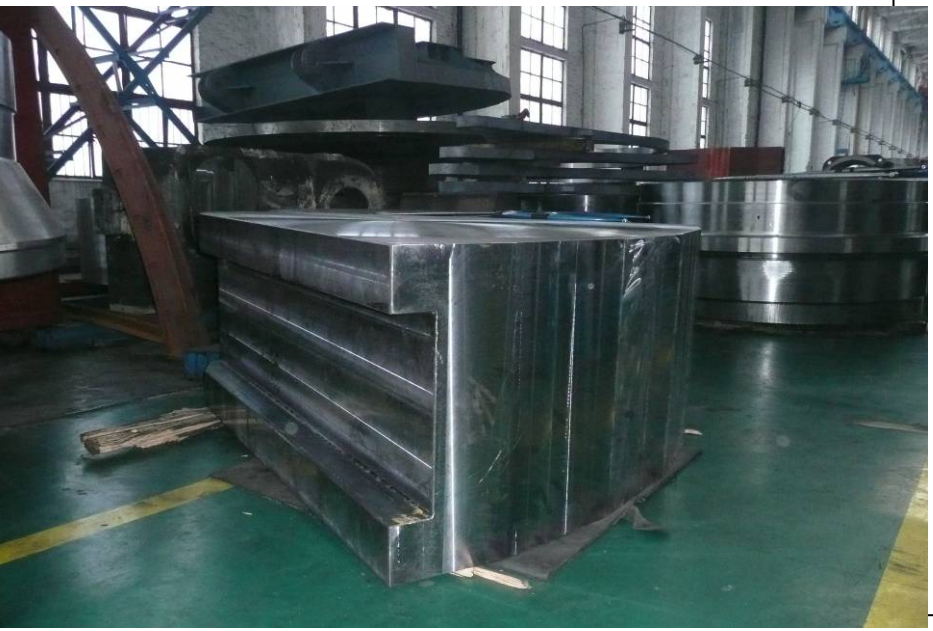


BH curves of the top/bottom yoke

BH curves of the yoke



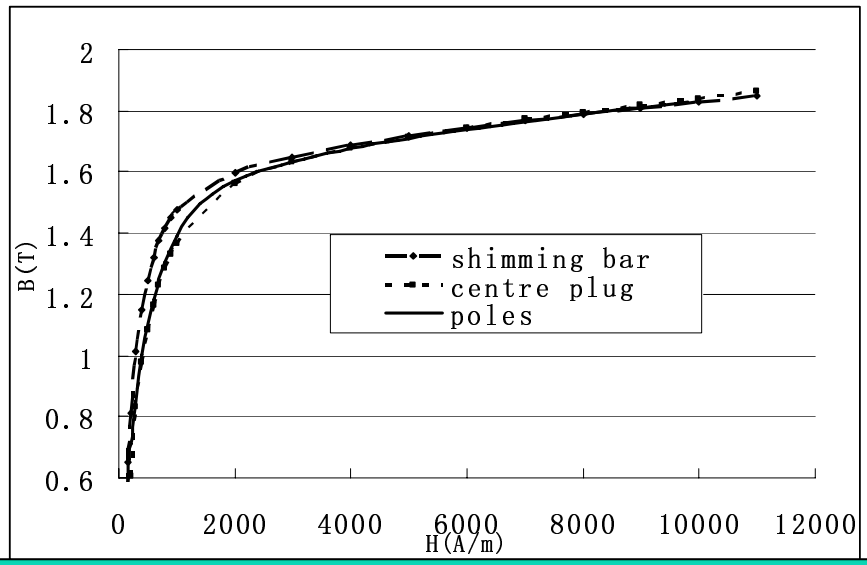
All components (pole sectors, top/bottom yokes, return yokes, shimming bars, central plug) have been fabricated.



A top/bottom yoke weighs 129 tons ← molten steel of 280 tons.

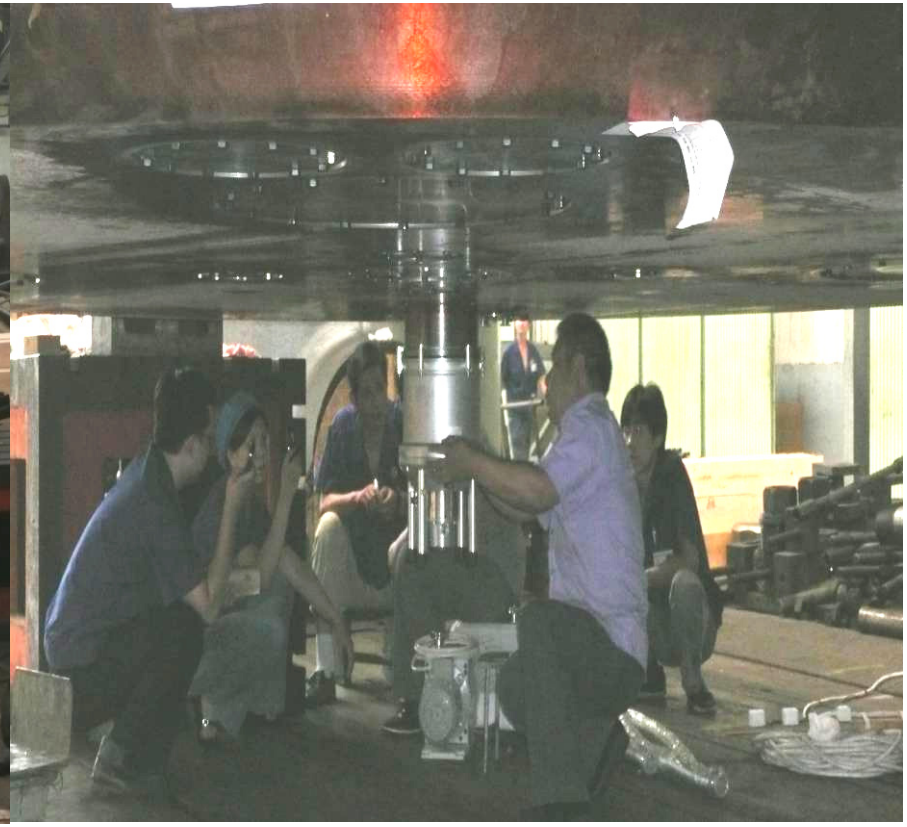
Each return yoke weighs 15 tons ← molten steel of 42 tons

Shimming bars center plug



	C	Si	Mn	P	S
Shimming bars	0.004	0.025	0.14	0.01	0.004
Center plug	0.003	0.135	0.14	0.009	0.001
Compensation	0.003	0.02	0.14	0.006	0.004

Turn-over of main magnet top/bottom Yokes: tools for installation of CYCIAE-100



Vacuum checking for top/bottom yokes is under going now.

Plan of Talk

A: Brief Introduction

B: CONSTRUCTION PROGRESS of CYCIAE-100

- Magnet
- RF
- Main Coils
- Elevating system
- Magnetic field measurement System
- Source, Injection & Extraction
- Others

C: THE KEY CERTIFICATION TESTS

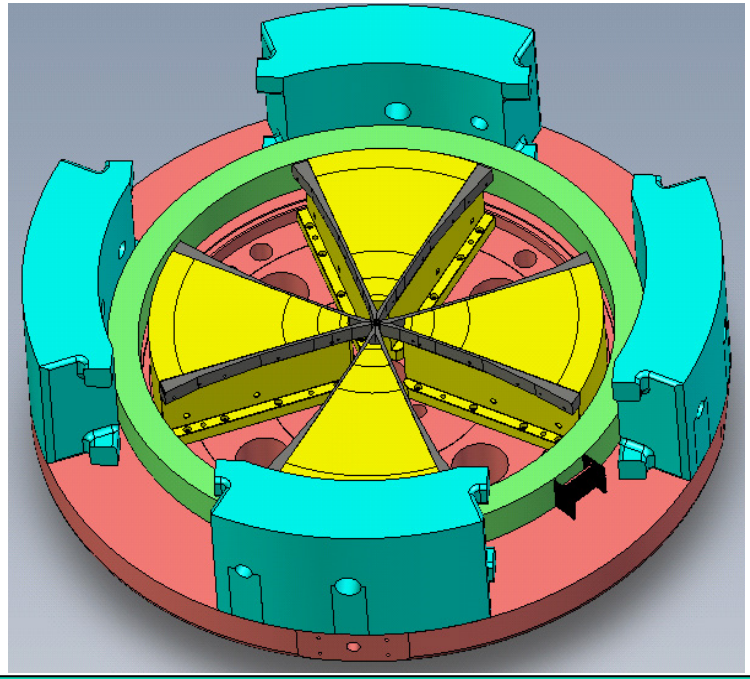
- Central Region Model
- 1:1 RF Cavity Test
- Vacuum Cryo-panel test

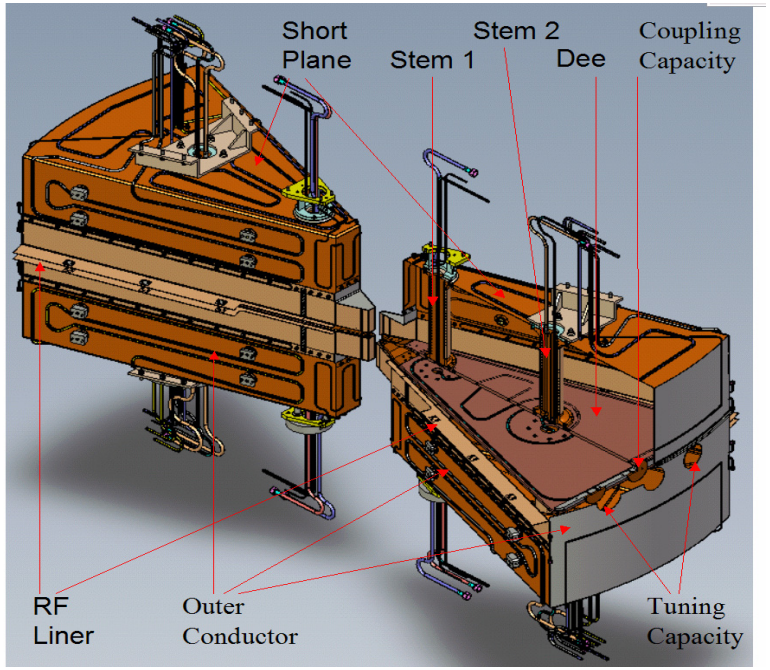
D: New schedule of the Project

B: Main progress of CYCIAE-100

– RF System

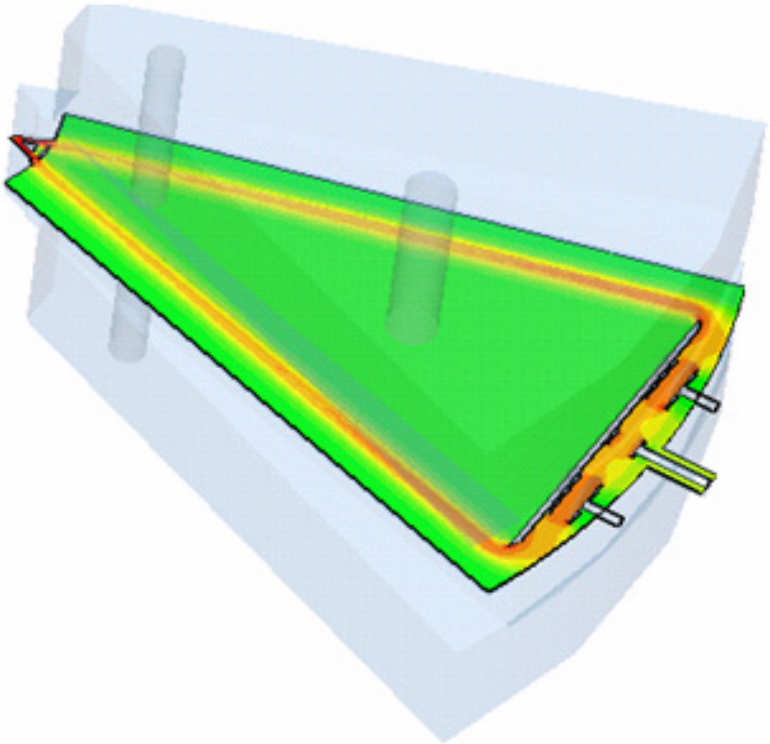
- There are two RF cavities installed in two valleys.

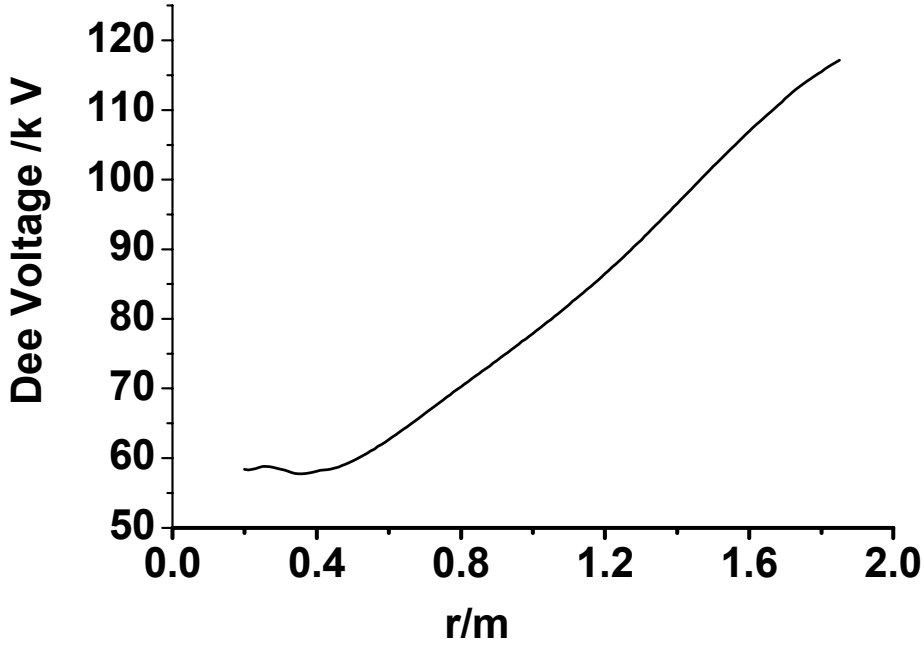




B: Main progress of CYCIAE-100

– RF System





2 stems structure,

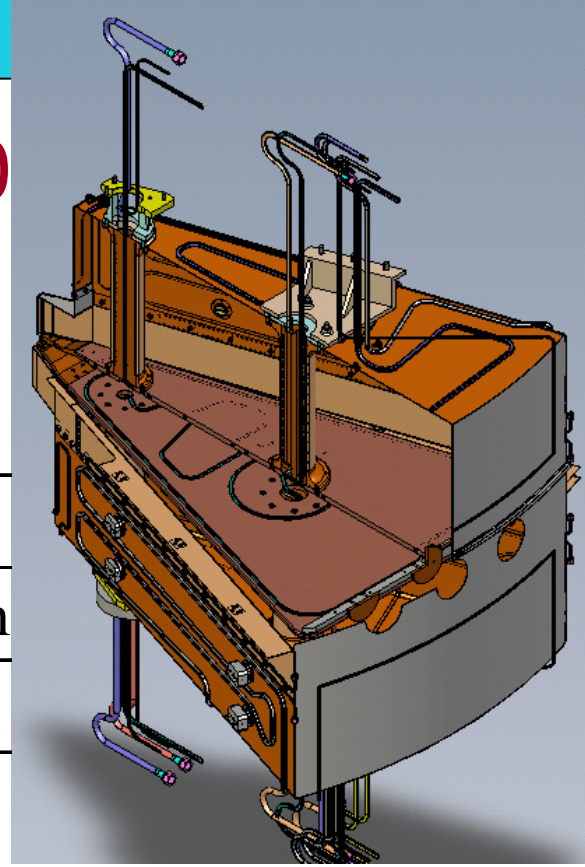
60kV at central region and 120kV at outer radius.

B: Main progress of CYCIAE-100

RF System

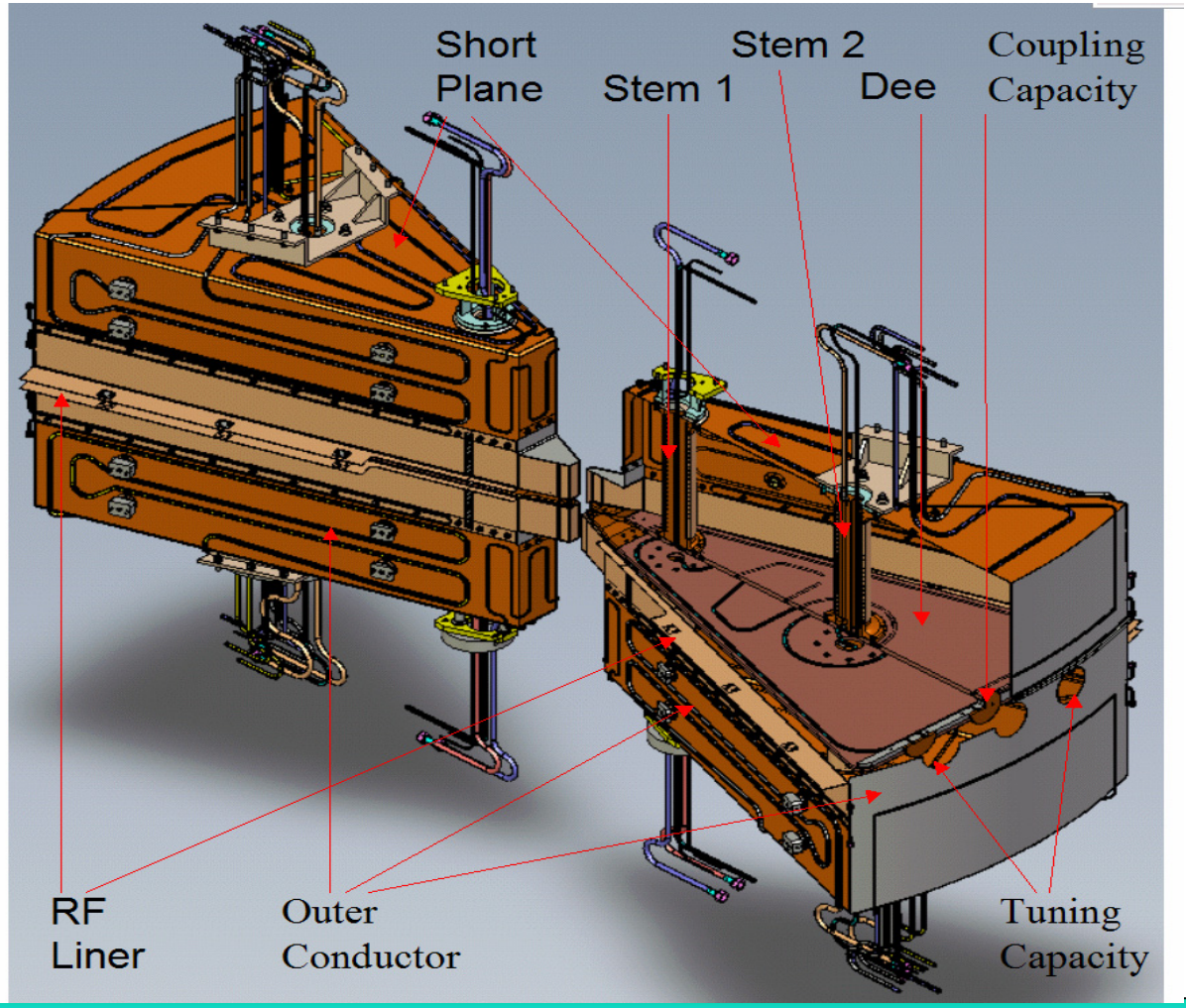
RF Cavity Dimensions

Outer conductor		Inner conductor	
Height of the Cavity	1.26m	Radius of Stem 1	6.4cm
		Radius of Stem 2	7cm
Outer Radius	1.98m	Length of Dee along its symmetric axis	1.86 m
Angle	36.6Deg.	Dee Angle	34.4Deg.



B: Main progress of CYCIAE-100

RF System

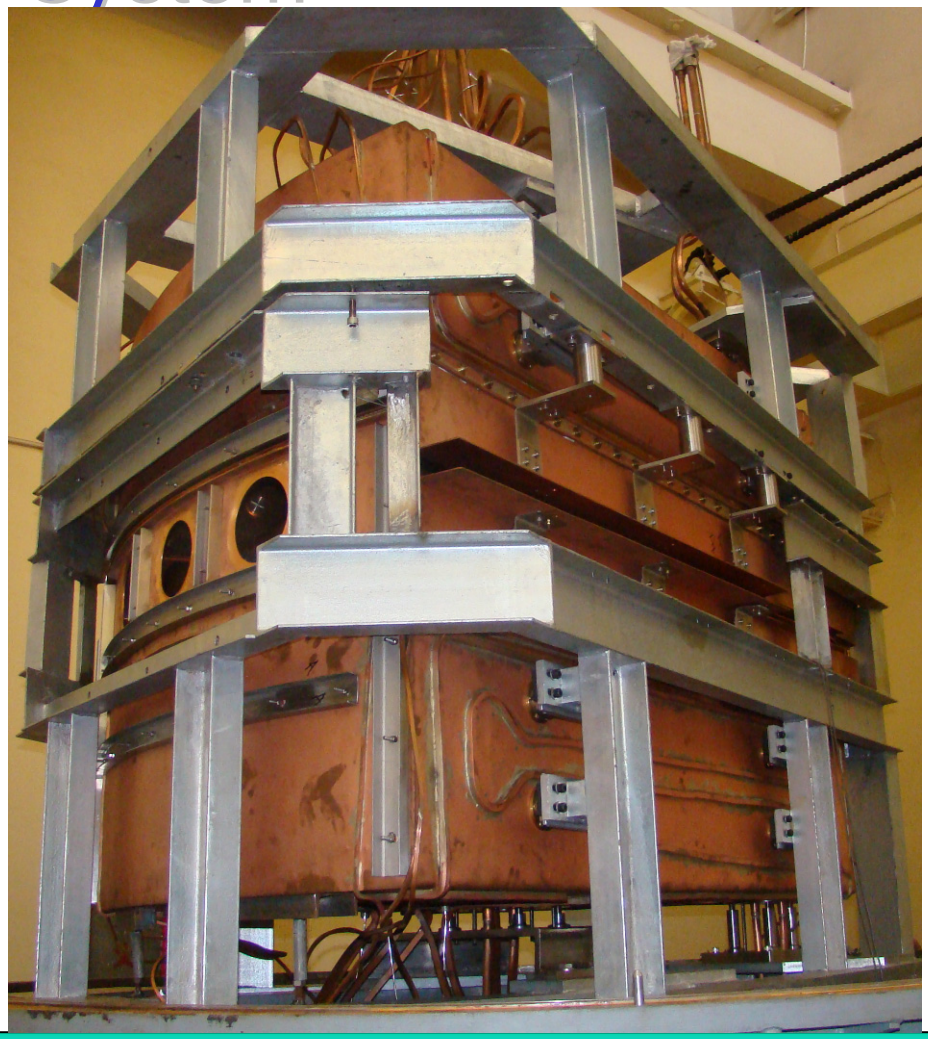


Calculated frequency: **44.32 MHz**, Q value: **10300**, dissipated power on the two cavities: **57kW**.

B: Main progress of CYCIAE-100

RF System

installed test RF cavity →1:1scale



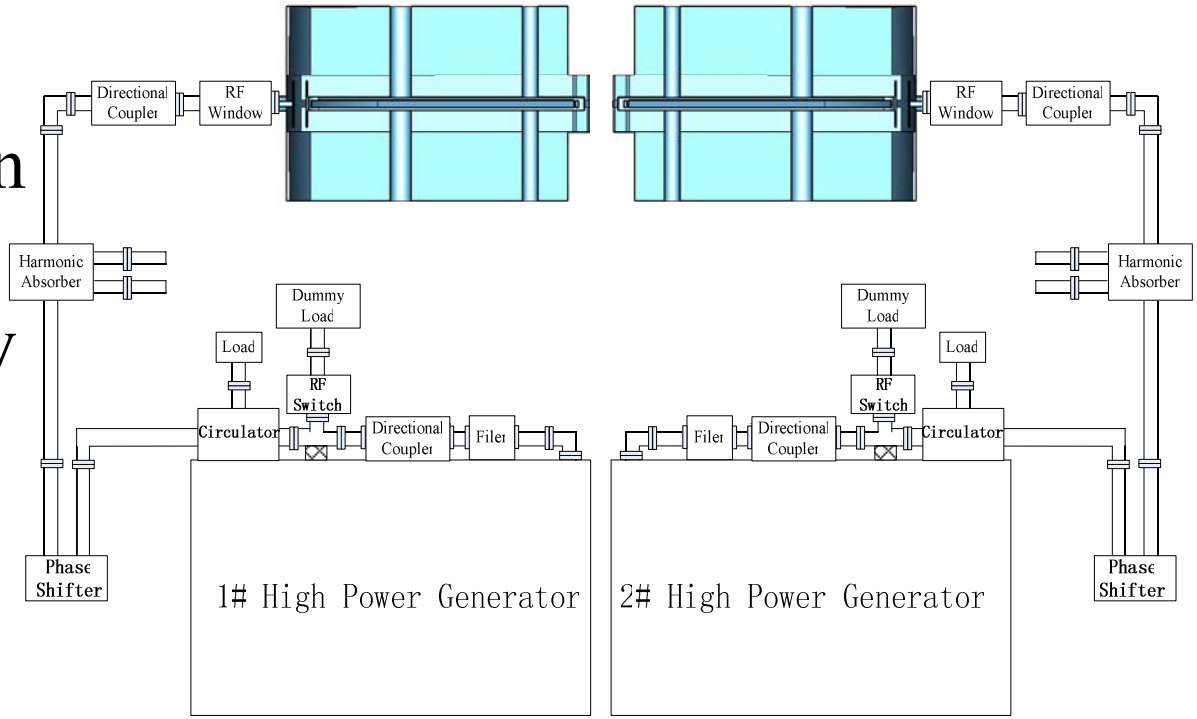
cold measurement frequency:
45.8 MHz,

Q value:
9300 .

B: Main progress of CYCIAE-100

RF System

Two cavities are driven by two 100kW RF generators separately with phase synchronization.



LLRF Control

The digital LLRF control system has been built and tested, results are: phase stability is better than +/-0.1° , the amplitude stability is better than 5×10^{-4}.

B: Main progress of CYCIAE-100

– RF System **RF power generators**

The 6kW driving power amplifier and monitoring devices

B: Main progress of CYCIAE-100

– RF System: **RF power generators**

The check and acceptance on construction site :

2×100kW RF power generators and transmission lines have been completed and meet the design requirements.

The power generator and transmission line installed with test cavity.

Plan of Talk

A: Brief Introduction

B: CONSTRUCTION PROGRESS of CYCIAE-100

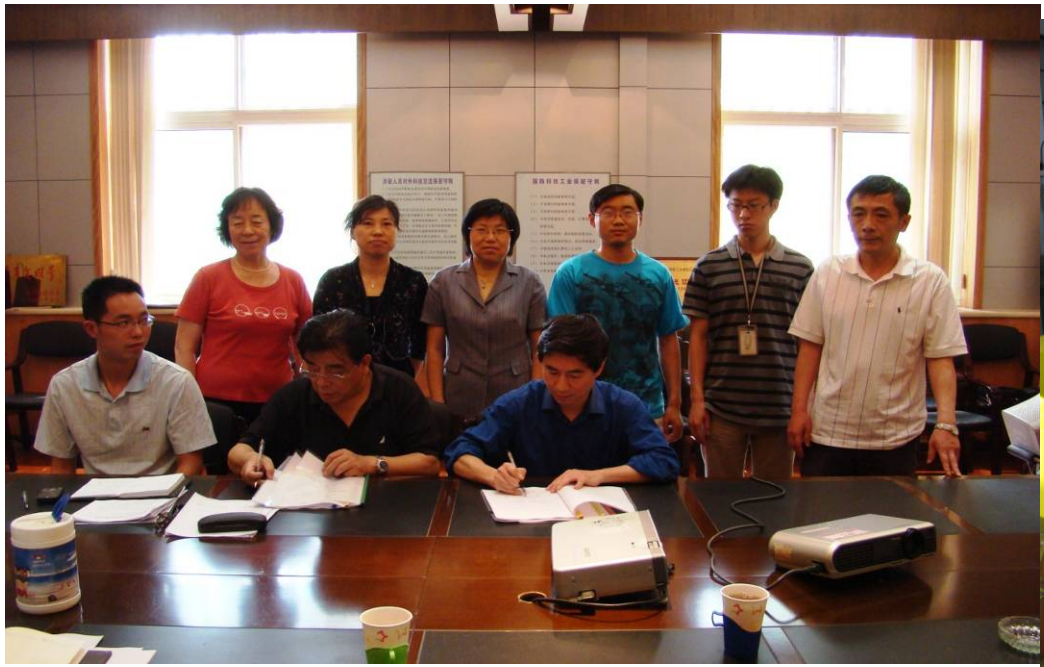
- Magnet
- RF
- Main Coils
- Elevating system
- Magnetic field measurement System
- Source, Injection & Extraction
- Others

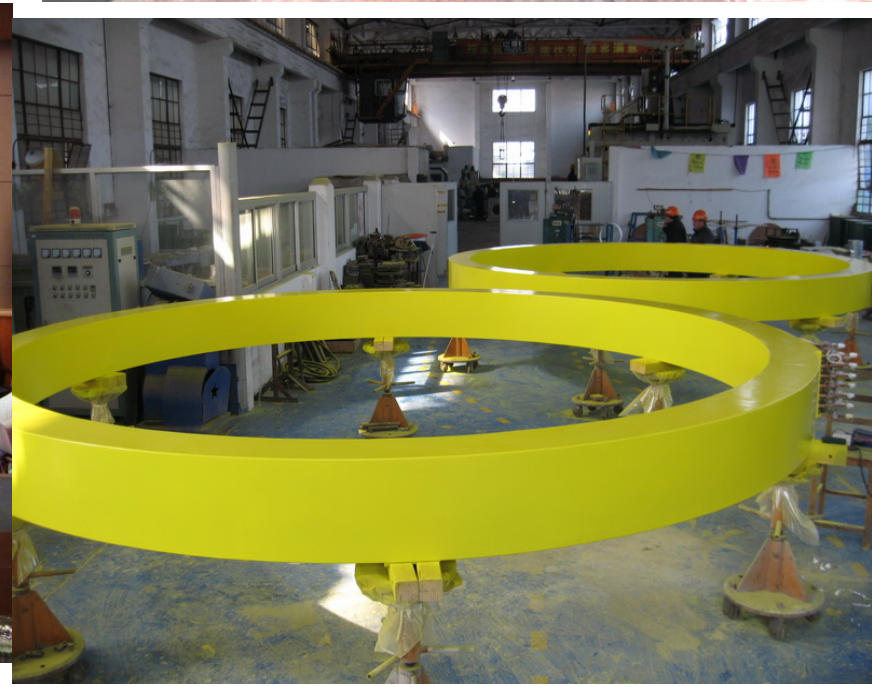
C: THE KEY CERTIFICATION TESTS

- Central Region Model
- 1:1 RF Cavity Test
- Vacuum Cryo-panel test

D: New schedule of the Project

-2008, purchase of copper tubes,
-2009, coil construction,
-2010, transported to the magnet fabricating factory.





Coil with the designed manipulating tools and transportation on road

Plan of Talk

A: Brief Introduction

B: CONSTRUCTION PROGRESS of CYCIAE-100

- Magnet
- RF
- Main Coils
- Elevating system
- Magnetic field measurement System
- Source, Injection & Extraction
- Others

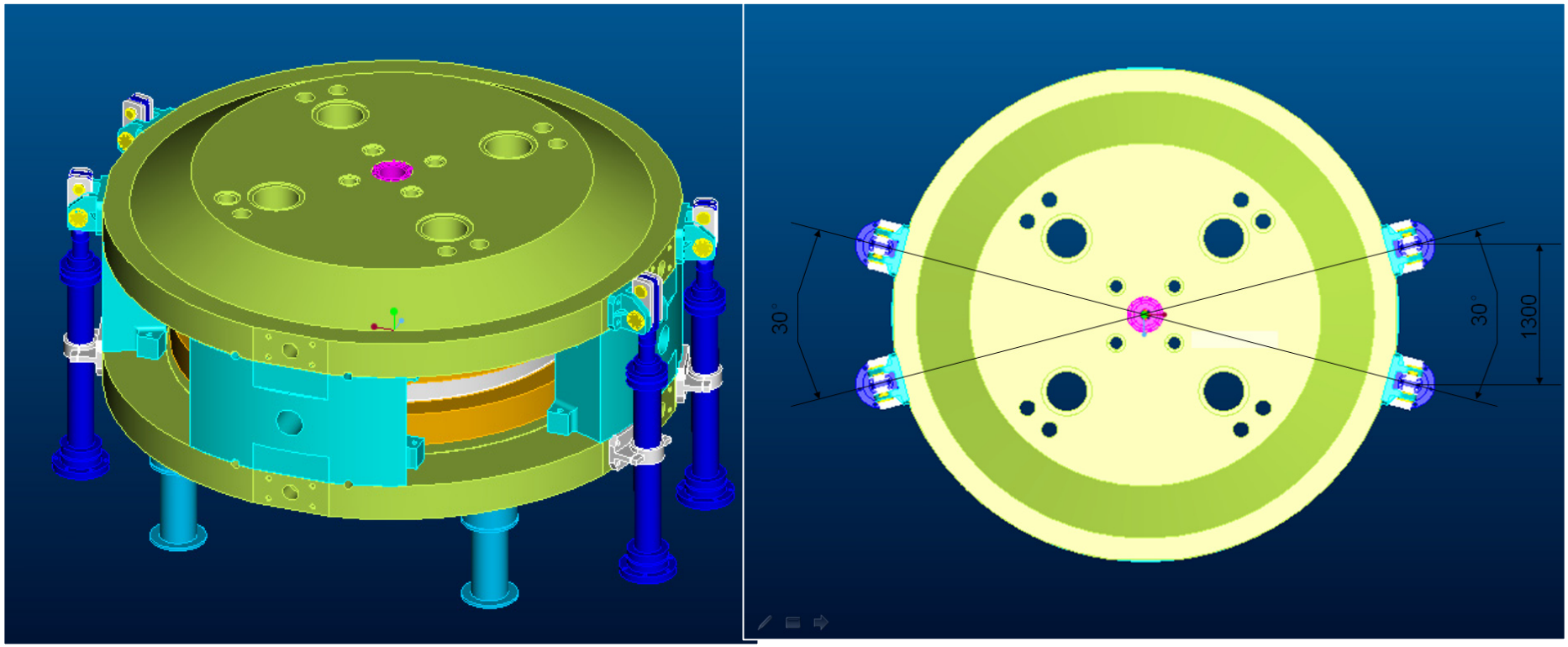
C: THE KEY CERTIFICATION TESTS

- Central Region Model
- 1:1 RF Cavity Test
- Vacuum Cryo-panel test

D: New schedule of the Project

B: Main progress of CYCIAE-100

Elevating system



The elevating system: 4-point hydraulic system, raise a weight of 180 tons and a height of 1500mm with the synchronous precision of 0.20mm.

The elevating system will be transported to magnet manufacture factory at end of 2010.

Plan of Talk

A: Brief Introduction

B: CONSTRUCTION PROGRESS of CYCIAE-100

- Magnet
- RF
- Main Coils
- Elevating system
- Magnetic field measurement System
- Source, Injection & Extraction
- Others

C: THE KEY CERTIFICATION TESTS

- Central Region Model
- 1:1 RF Cavity Test
- Vacuum Cryo-panel test

D: New schedule of the Project

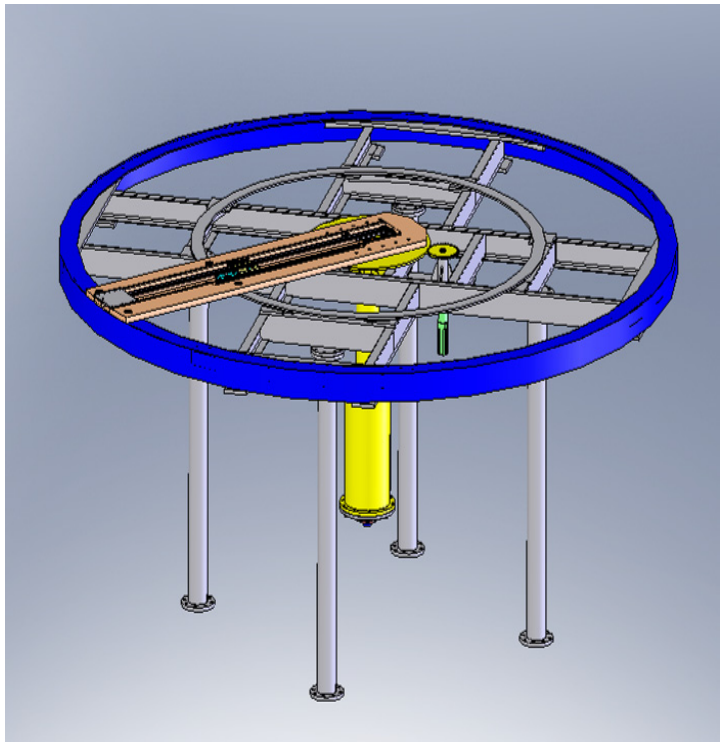
B: Main progress of CYCIAE-100

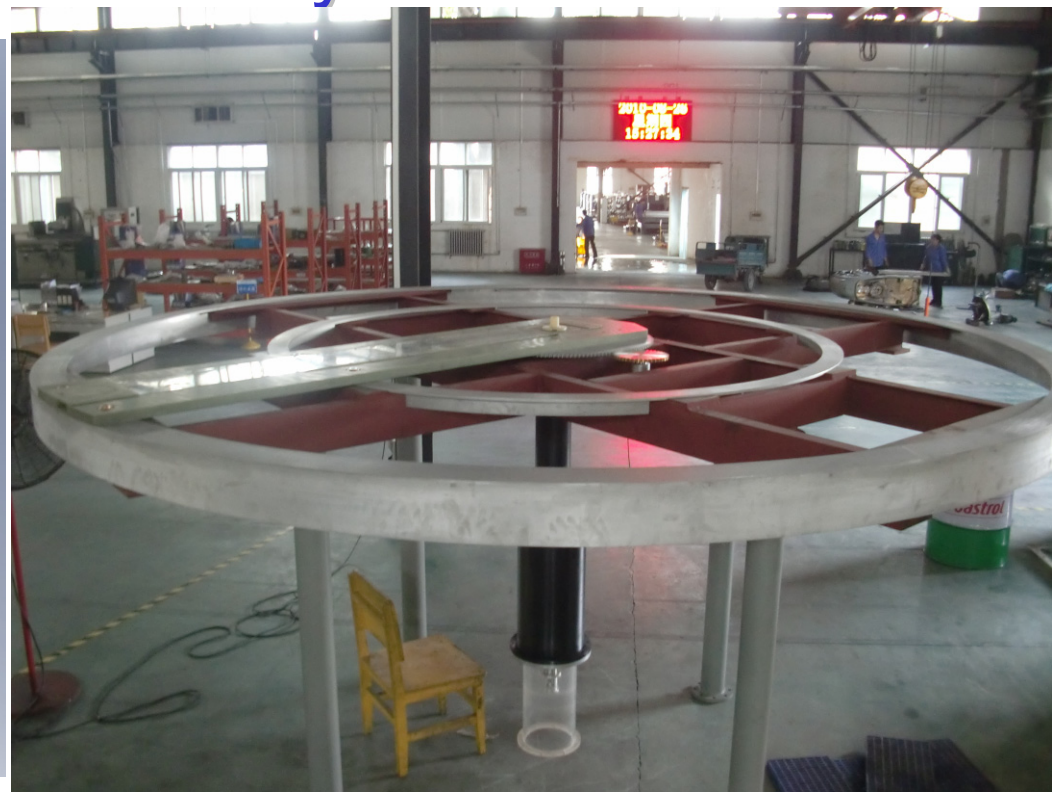
Magnetic field measurement System

A high resolution three dimension locating platform: for dipole, quadrupole, solenoid lens, ion source and switching magnet.

B: Main progress of CYCIAE-100

Magnetic field measurement System





The measurement of main magnet field: 3 hall probes will be rotated simultaneously with beam: The position accuracy < 0.1mm in radius and < 13 seconds in azimuth.

Plan of Talk

A: Brief Introduction

B: CONSTRUCTION PROGRESS of CYCIAE-100

- Magnet
- RF
- Main Coils
- Elevating system
- Magnetic field measurement System
- Source, Injection & Extraction
- Others

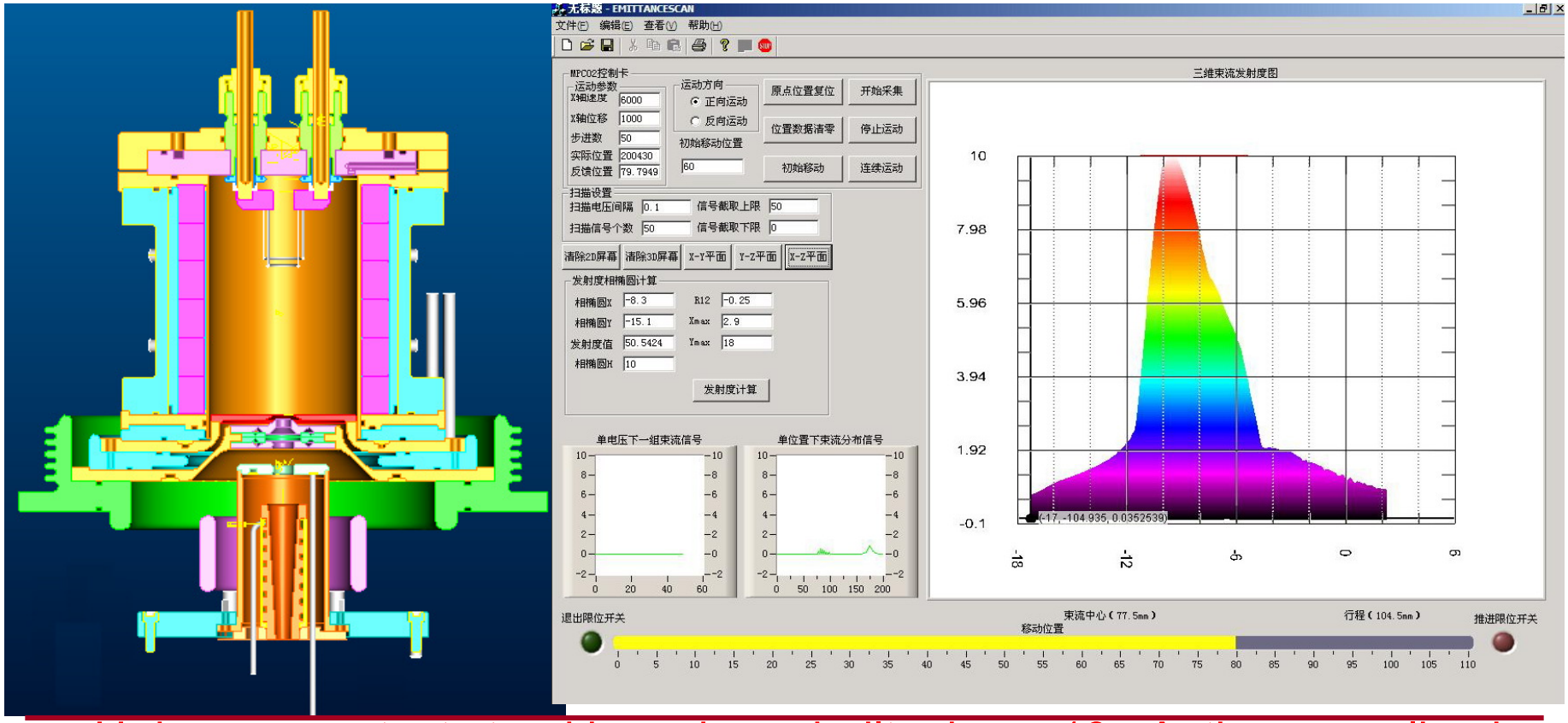
C: THE KEY CERTIFICATION TESTS

- Central Region Model
- 1:1 RF Cavity Test
- Vacuum Cryo-panel test

D: New schedule of the Project

B: Main progress of CYCIAE-100

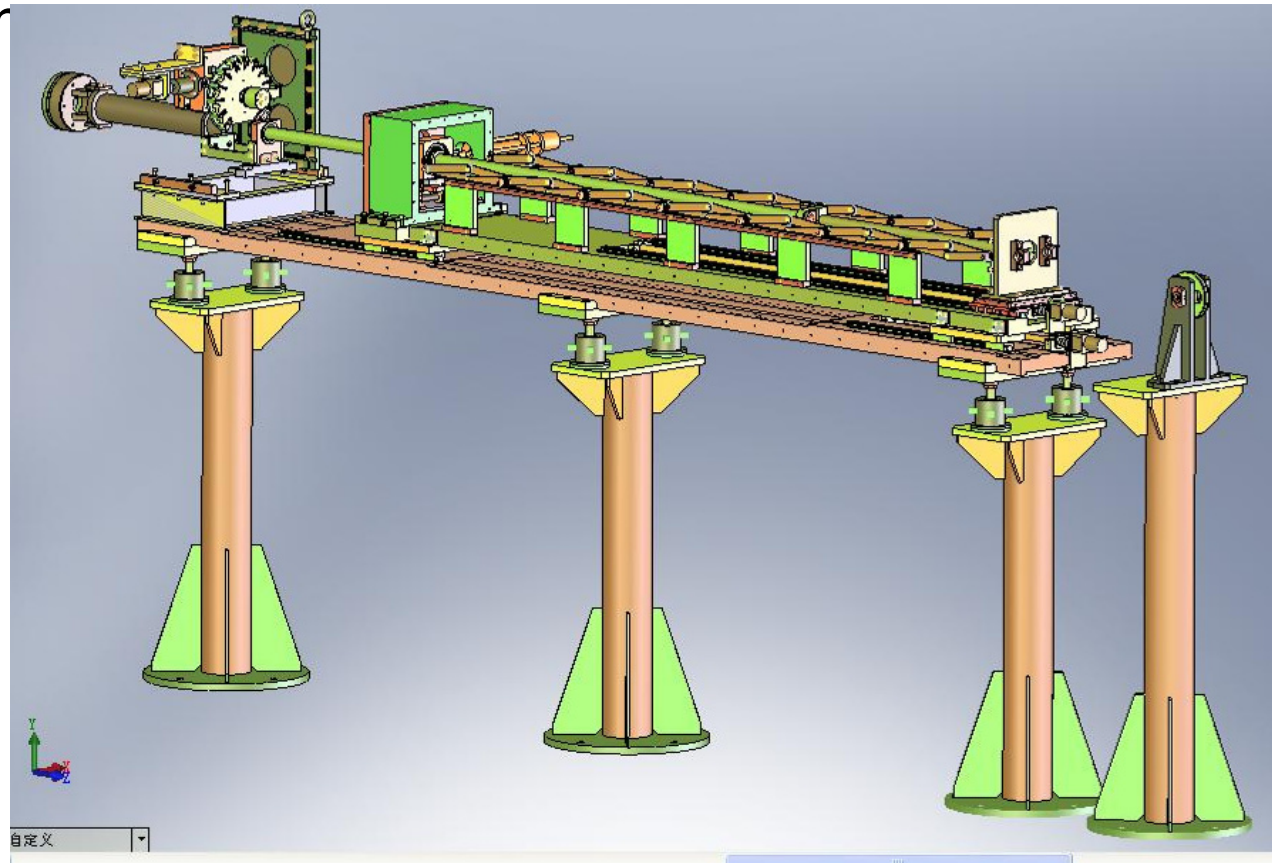
– Source, Injection and Extraction



H- ion source test stand have been built: above 10mA, the normalized emittance of 80% of the beam reach 0.45 mm-mrad.

B: Main progress of CYCIAE-100

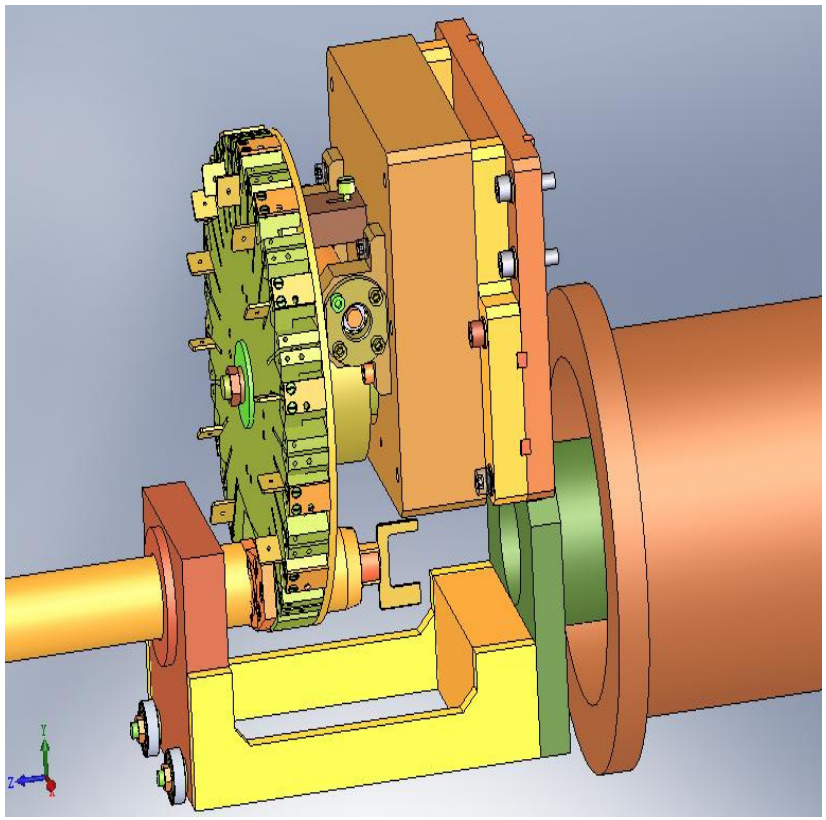
- **Extraction**
- Two proton beams extracted in dual opposite directions.
- Stripping system

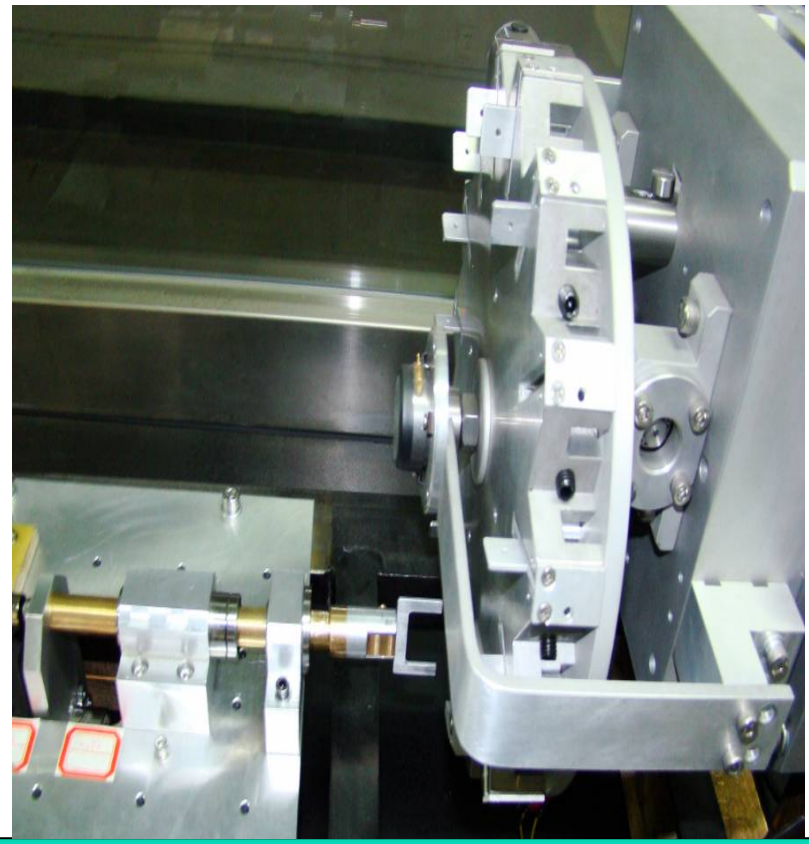


B: Main progress of CYCIAE-100

– Extraction

- The stripper foil changing in the vacuum.
- Foil exchanger with 12 foils was built and tested





Plan of Talk

A: Brief Introduction

B: CONSTRUCTION PROGRESS of CYCIAE-100

- Magnet
- RF
- Main Coils
- Elevating system
- Magnetic field measurement System
- Source, Injection & Extraction
- Others

C: THE KEY CERTIFICATION TESTS

- Central Region Model
- 1:1 RF Cavity Test
- Vacuum Cryo-panel test

D: New schedule of the Project

B: Main progress of CYCIAE-100

– Vacuum system

- The main vacuum should be better than 5×10^{-6} Pa, the total pumping speed needed should be more than 140,000L/s.
- The main vacuum chamber: Aluminum cylinder with 1.27m high and 4.08m in inner diameter.
- It is machining and will be sent to the magnet building factory.

B: Main progress of CYCIAE-100

– Main magnet power supply

The main magnet power is built and tested:

110A/286V, $\pm 1 \times 10^{-5}$/8h in stability.

B: Main progress of CYCIAE-100

– Beam Diagnostics System

- The experimental study on signal acquisition, data transmission, system control, etc. has been performed.

– Dose Monitoring and Safety Interlock System

- The layout design of the devices for radiation monitoring, safety interlock and the installation location have been completed.

– Computer Control System

- EPICS system is chosen for YCIAE-100 cyclotron, which contains about 1,100 DI/DO and 300 AI/AO signals. For the power supply systems, a digital RS-232/485 control interface had been selected to perform various control tasks.

Plan of Talk

A: Brief Introduction

B: CONSTRUCTION PROGRESS of CYCIAE-100

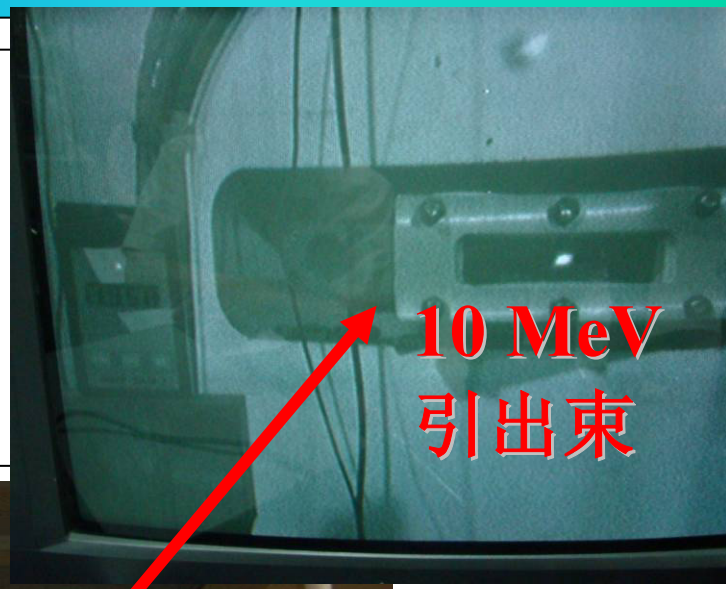
- Magnet
- RF
- Main Coils
- Elevating system
- Magnetic field measurement System
- Source, Injection & Extraction
- Others

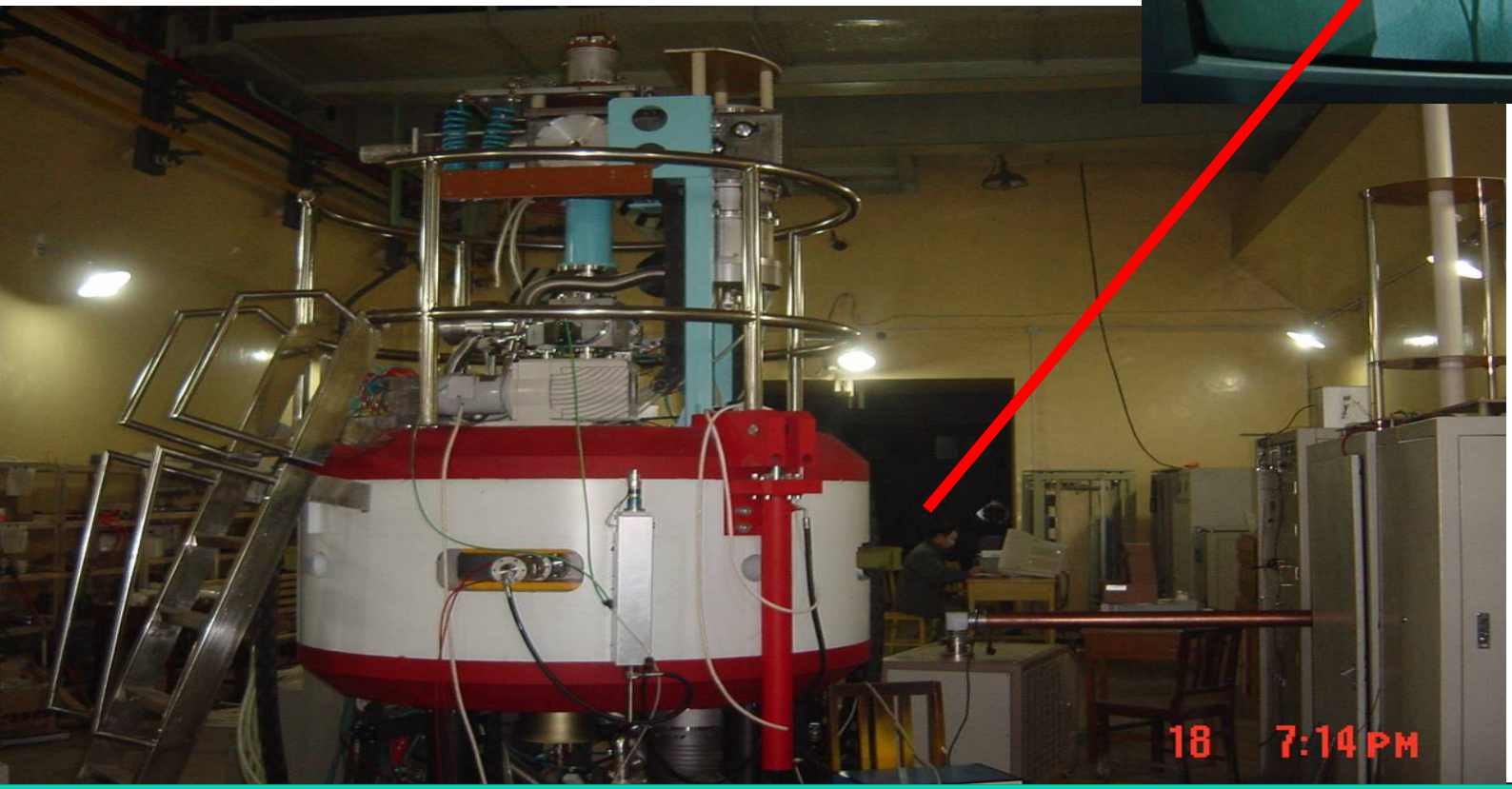
C: THE KEY CERTIFICATION TESTS

- Central Region Model
- 1:1 RF Cavity Test
- Vacuum Cryo-panel test

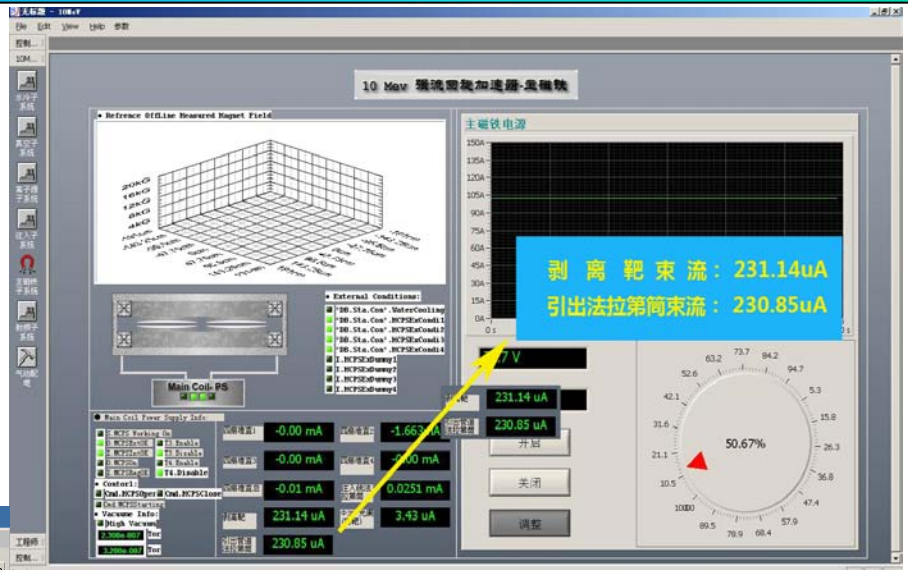
D: New schedule of the Project

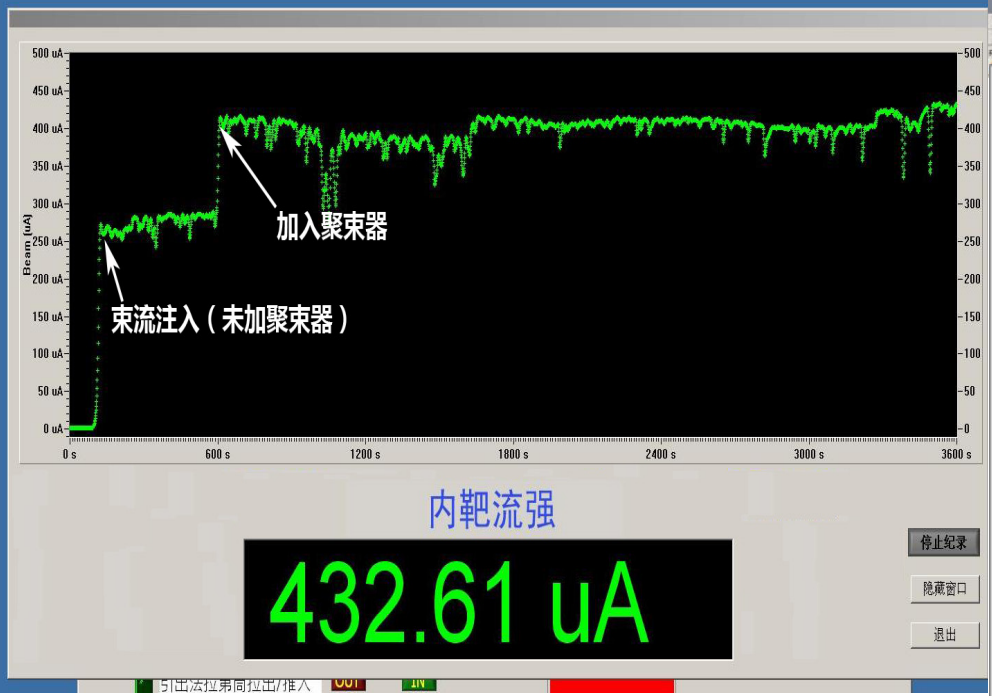
CRM has successfully built and tested: The internal beam is up to 432 μ A and extraction beam reaches 230 μ A under the condition of 64% RF duty ratio.

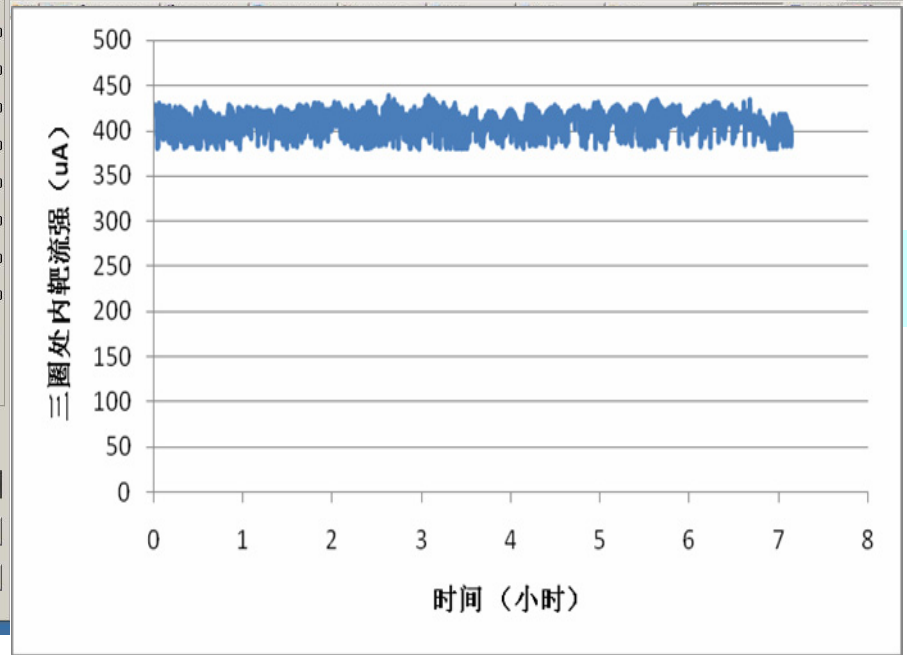




Beam tuning and measurement results in 2009 for CRM







C. THE KEY CERTIFICATION TESTS

–CRM (Central region model)

Some typical beam test dada

year	Ccurrent of ion source	RF duty	Inter-current (buncher off)	Inter-current (buncher on)	Current extracted
2008	2.1mA	25%	28uA	48uA	5.8uA
	2.1mA	70%		130uA	
2009	2.43mA	100%		432.6uA	
	2.43mA	64%			230uA

The beam injection efficiency is 17.7%, the beam acceleration efficiency is 94.5%, the beam extraction efficiency is near 100%.

C. THE KEY CERTIFICATION TESTS

– Full Scale RF Cavity Test

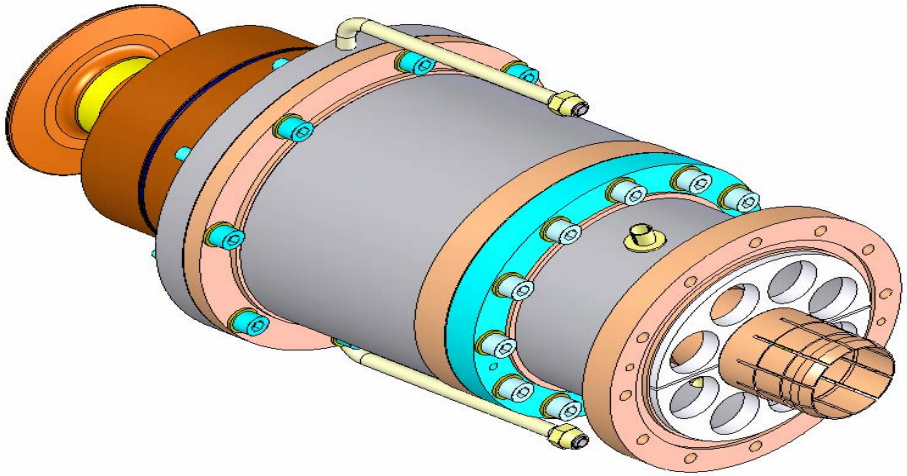
→Two technological difficulties are solved: soldering and form calibration for large scale cavity.

→Q value is improved to 9300 by polishing the cavity surface and other measures, and coincides well with the designed value of 10300.

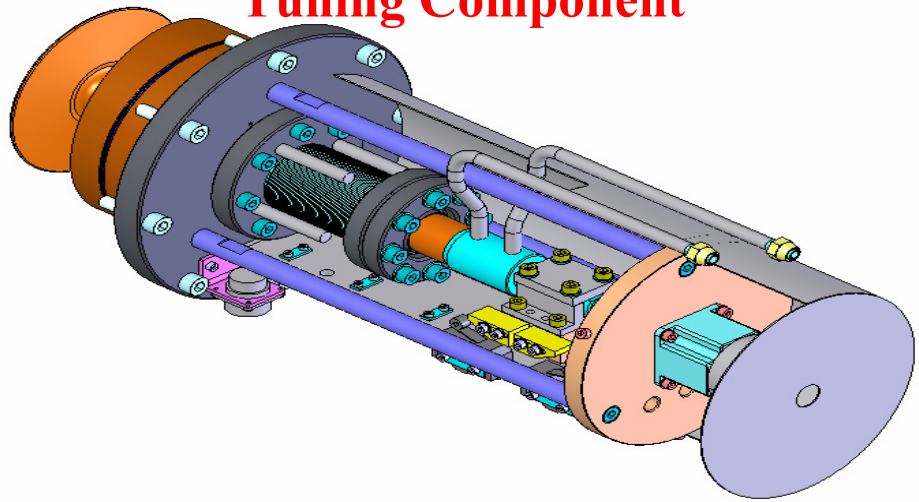
→The test cavity with power is being carried out.

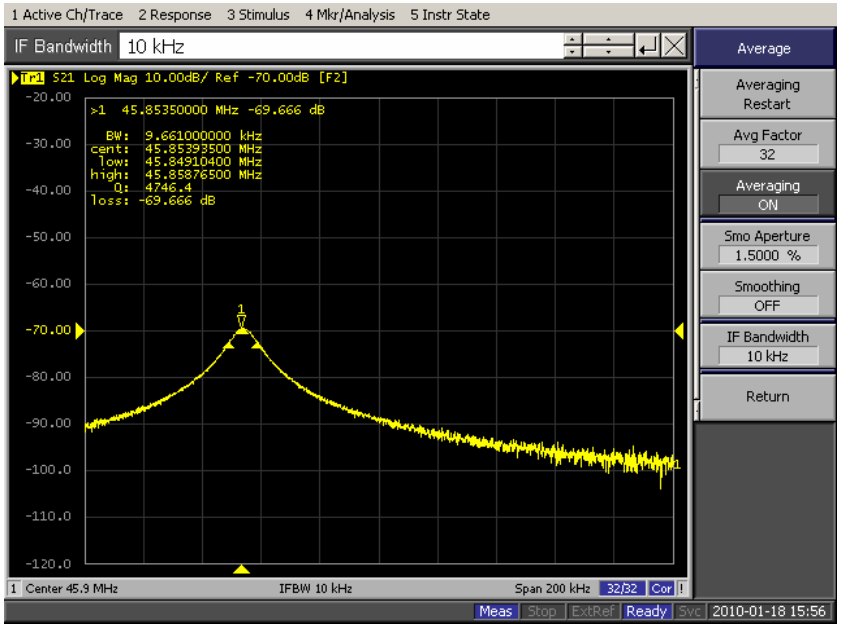
CYCIAE-100, a 100 MeV H- Cyclotron for RIB Production

Power feed-in Component

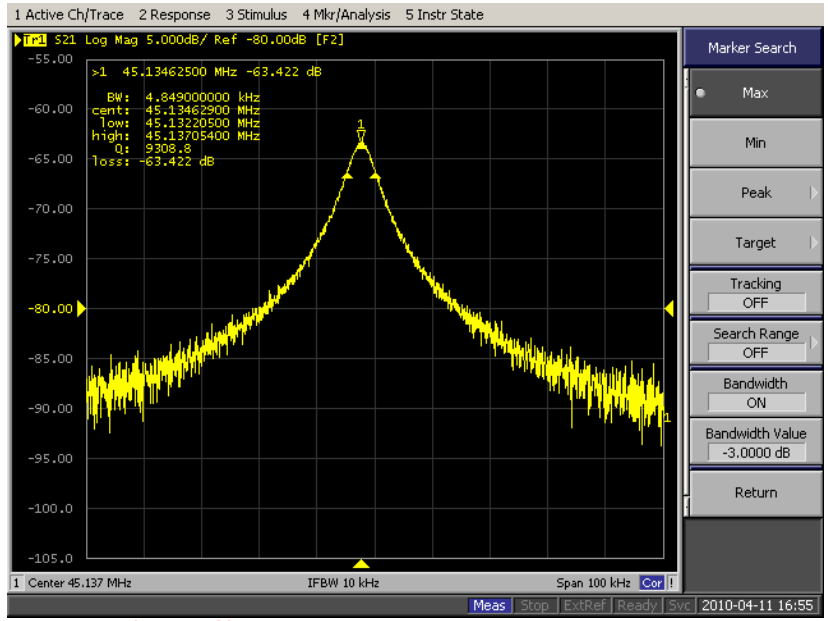


Tuning Component





Without finger contact



With finger contact

C. THE KEY CERTIFICATION TESTS

– High Power RF Cavity Test

The test cavity with power is being carried out.

C. THE KEY CERTIFICATION TESTS

– Vacuum Cryo-panel test

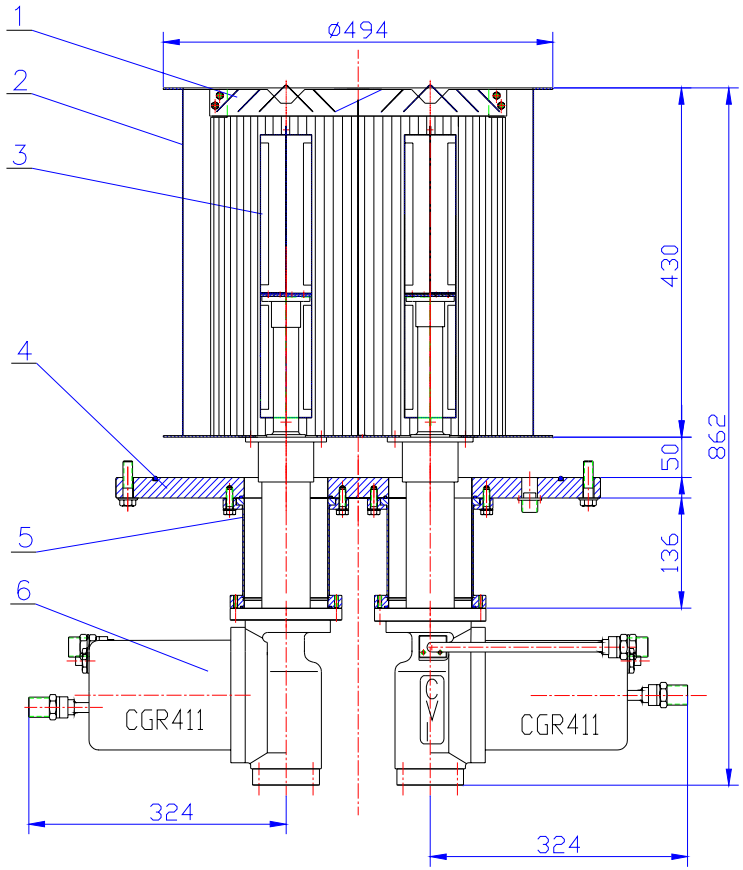
→A pressure of 5×10^{-6} Pa is required in the CYCIAE-100 cyclotron, more than 140000 L/s of total pumping speed is needed.

→A test stand with plug-in cryopump was built.

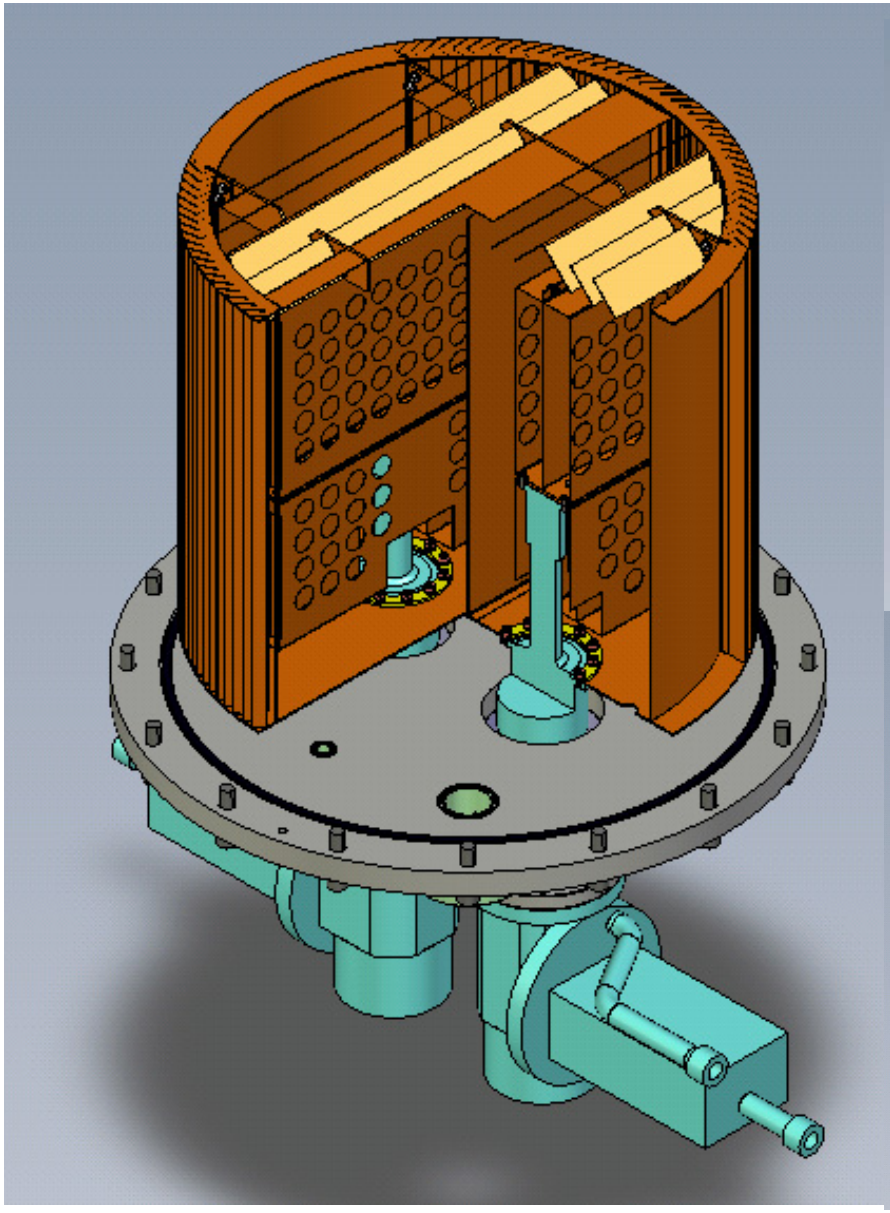
→ A pressure of 5.8×10^{-6} Pa was got with the designed plug-in cryopump of 15000 L/s under the condition of 67.7K on shield top, 19K on the cold head. The test results and design parameters are coincided well.

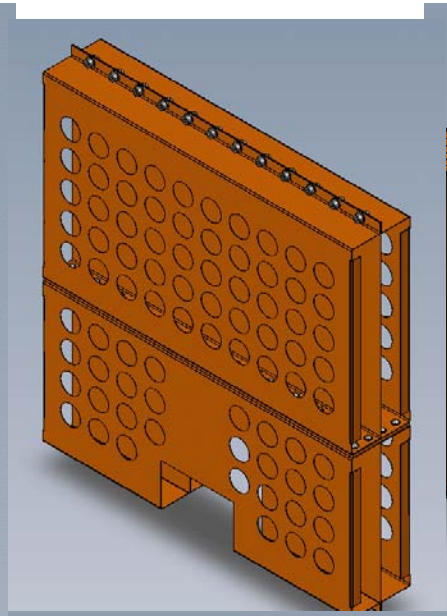
C. THE KEY CERTIFICATION TESTS

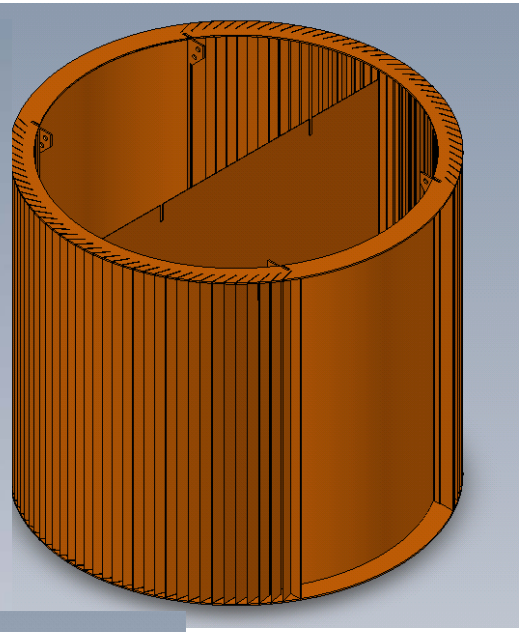
– Vacuum Cryo-panel test

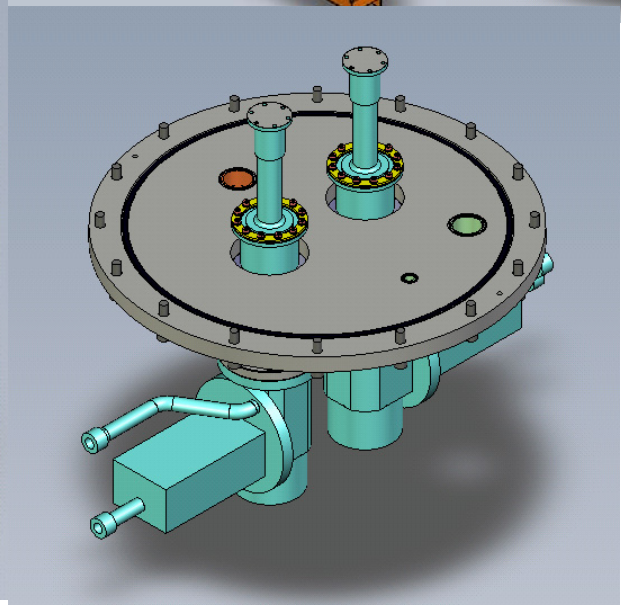


Structure and appearance of Test Cryopanel



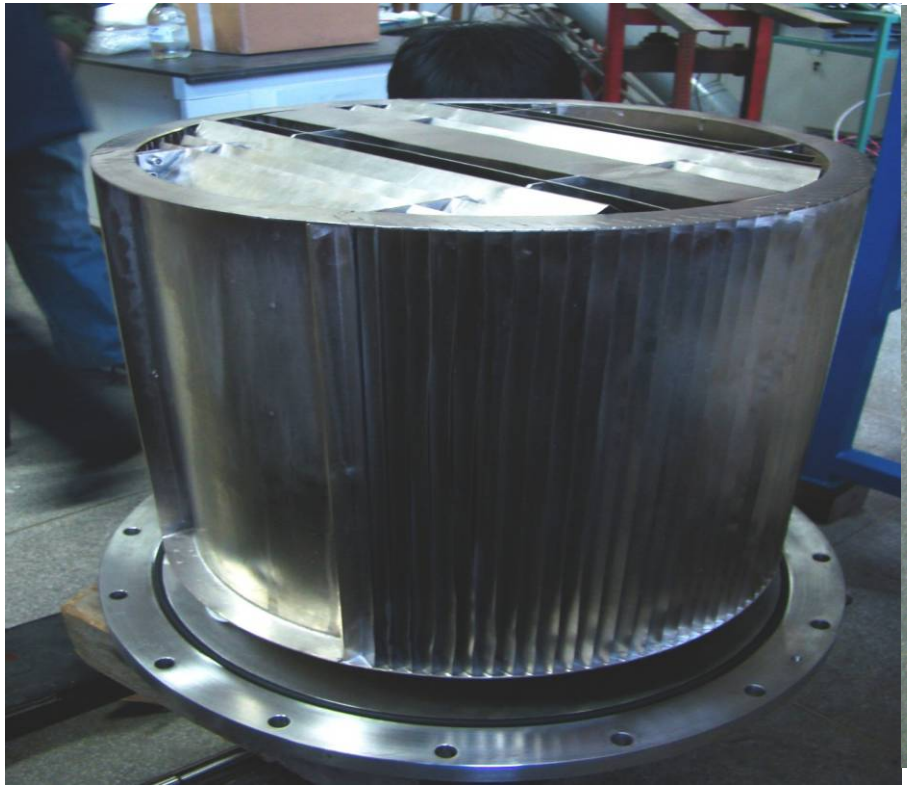


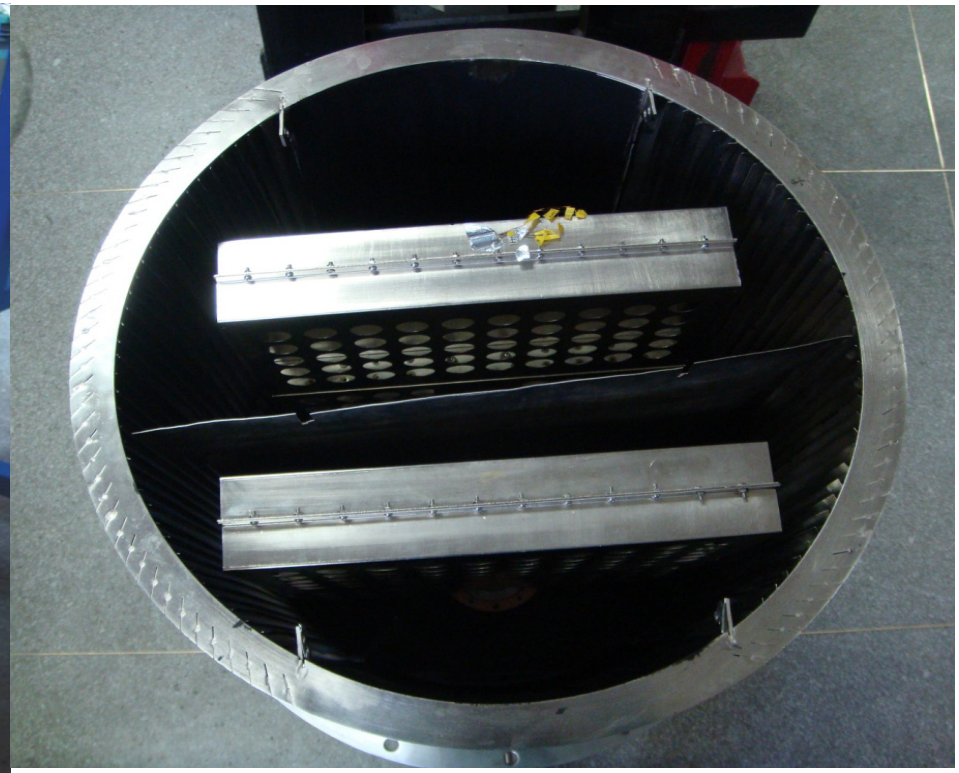




Designed Test Cryopanel

C. THE KEY CERTIFICATION TESTS





The vacuum cryo-panel test has provided a valuable information to the final cryo-panel structure design of CYCIAE-100.

CONCLUSION AND NEW SCHEDULE

- A remarkable progress has been achieved in the past few years in the design, construction and experimental verification of CYCIAE-100.
- The most of key equipments of CYCIAE-100 have been fabricated or will be finished by the end of this year.
- The schedule of BRIF as a whole project has to be postponed for some budget reasons.
- According to the new schedule, CYCIAE-100 will get the first beam at the end of 2013.

Acknowledgement

For the designs and constructions of CYCIAE-100, many institutes such as **TRIUMF, PSI, LNS**, etc. give us big support. The team of Technology Division of BRIF at CIAE would like to give the grateful acknowledge to these institutes for their help.

Welcome to visit CIAE

Tjzhang@ciae.ac.cn