The Current Cyclotron Development Activities at CIAE

Shizhong An, Tianjue Zhang

China Institute of Atomic Energy (CIAE)
Beijing

2010-11.22

Greatful acknowledged is very fruitful and long lasting collaboration with PSI & Triumf, LNLS.

Content

- Introduction
- Operating 0.5mA CYCIAE-10
  - ➔ CYCIAE-10: Beam current upgrade
- The Progress of Being Constructed Projects
  - ➔ CYCIAE-100
  - ➔ CYCIAE-14
- The Future Plan
  - ➔ D-/H-: CYCIAE-70
  - ➔ 5mA: CYCIAE-800
- Conclusion

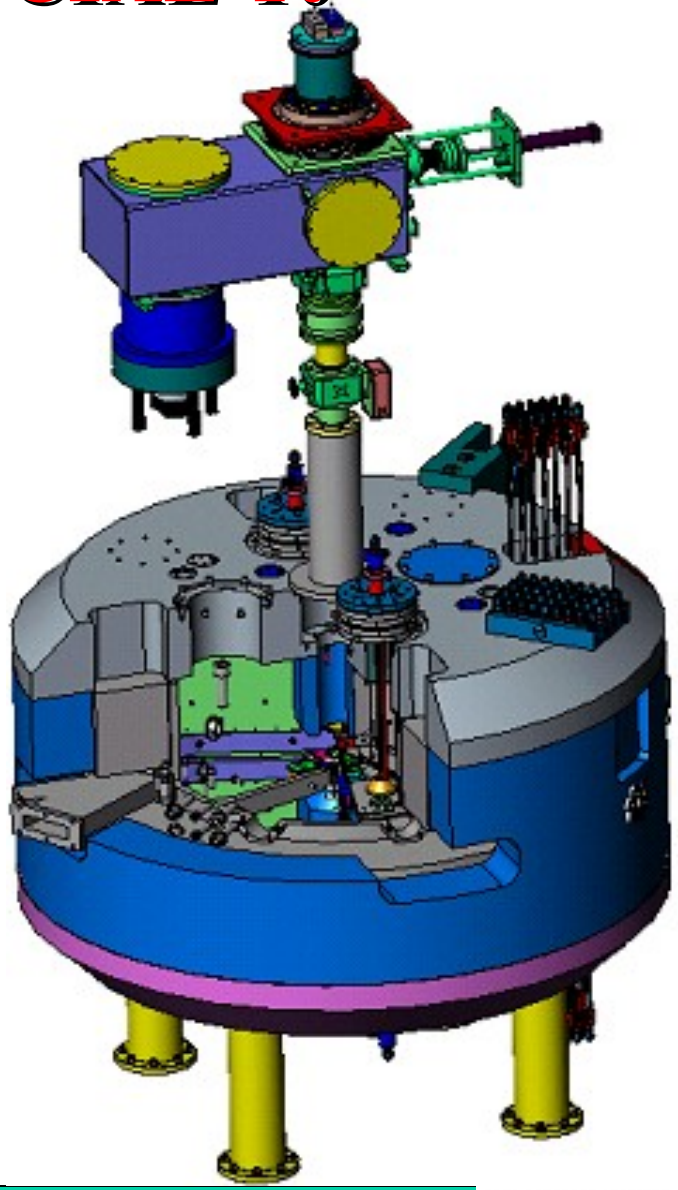
Introduction

- A 10 MeV Central Region Model cyclotron, CYCIAE-10, was successfully built and the internal beam current was up to 430μA. The upgrading on CYCIAE-10 is being made to increase the beam current to mA level for the possible application research related to BNCT.

- Two cyclotrons are being built at CIAE: CYCIAE-100 and CYCIAE-14. As the driving accelerator for the Beijing Radioactive Ion-Beam Facility (BRIF), CYCIAE-100 is a main part of upgrade project of Beijing Tandem Laboratory and it has a great construction progress this year.

- Some future developing plans are being conducted at CIAE: Based on the applications for ADS systems and proton radiography, 800 MeV high power proton cyclotron, CYCIAE-800; 70 MeV compact high intensity H- cyclotron, CYCIAE-70 for multi uses including radioactive ion-beam (RIB) production.

Beam Upgrade of CYCIAE-10

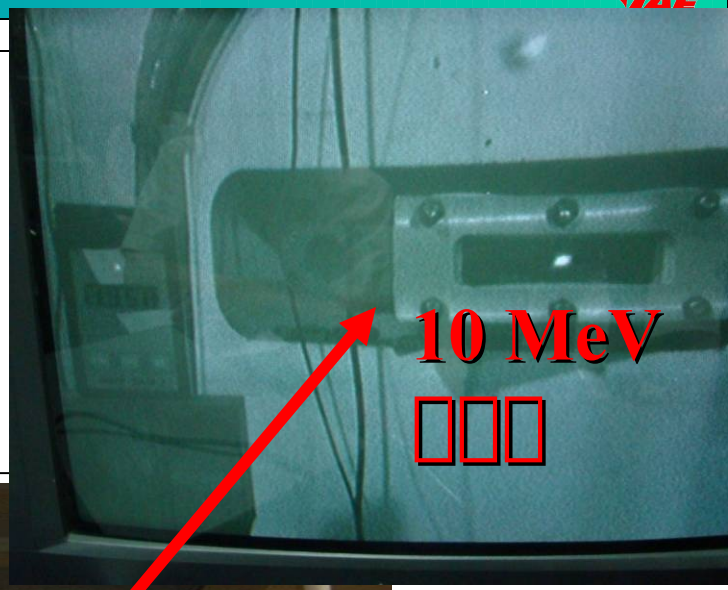


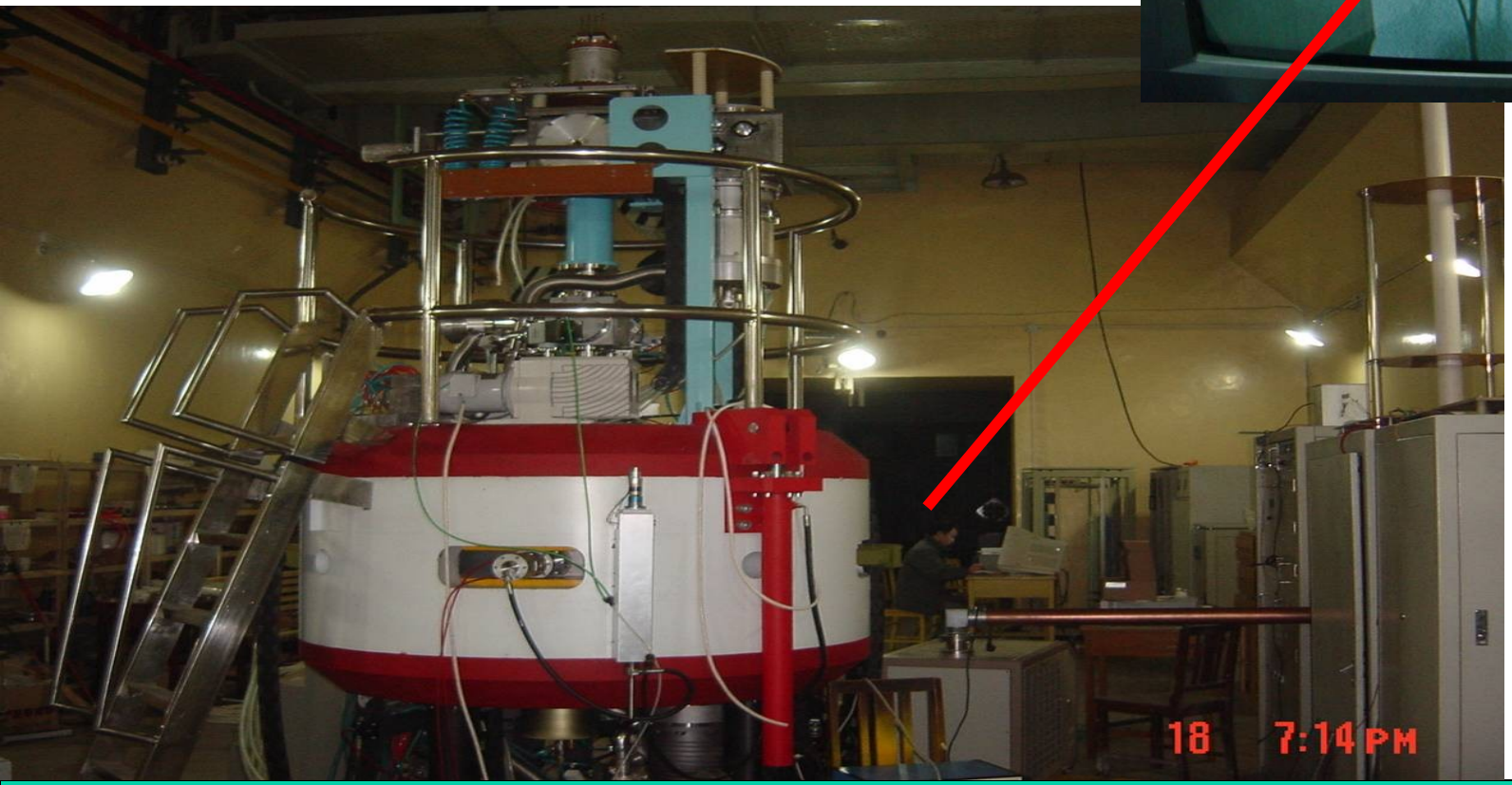
A central region model (CRM) is specially designed to confirm the design results and test various aspects of techniques, which will be used for CYCIAE-100.

Beam Upgrade of CYCIAE-10

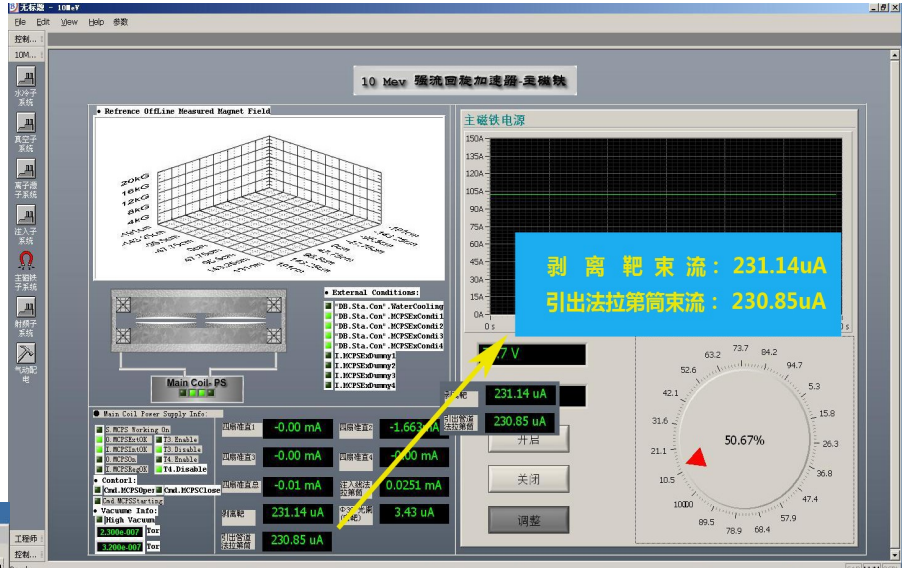
Beam				Ion Source	
Accelerated Ions		H^-	10 MeV	Type	H^- multicusp
Beam intensity	internal target	H^-	430 μA	Arc power	2.5 kW
	Extracted	proton	230 μA		
Magnet structure				RF system	
# of sectors		4		RF power	13.5 kW
Sector angle		50° □ 54°		#, angle of Dee	2, 30°
Peak field		1.75 T		Frequency	70.5 MHz
Coil power		6 kW		D voltage	40 kV
Beam extraction: stripping extraction				Control: PLC	

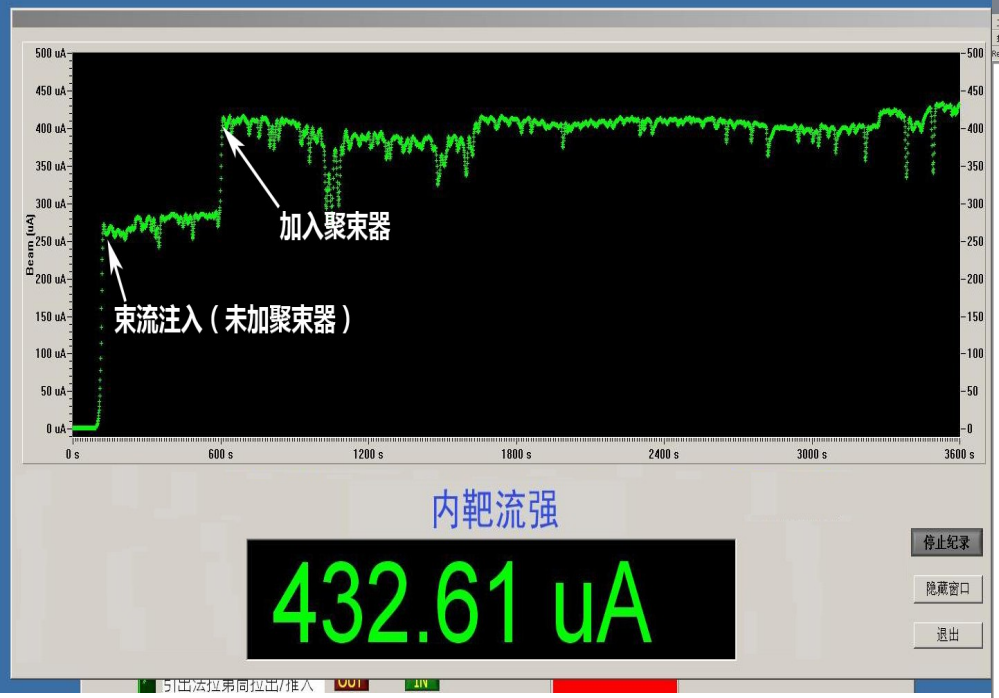
CYCIAE-10 has successfully built and tested: The internal beam is up to 432μA and extraction beam reaches 230μA under the condition of 64% RF duty ratio.

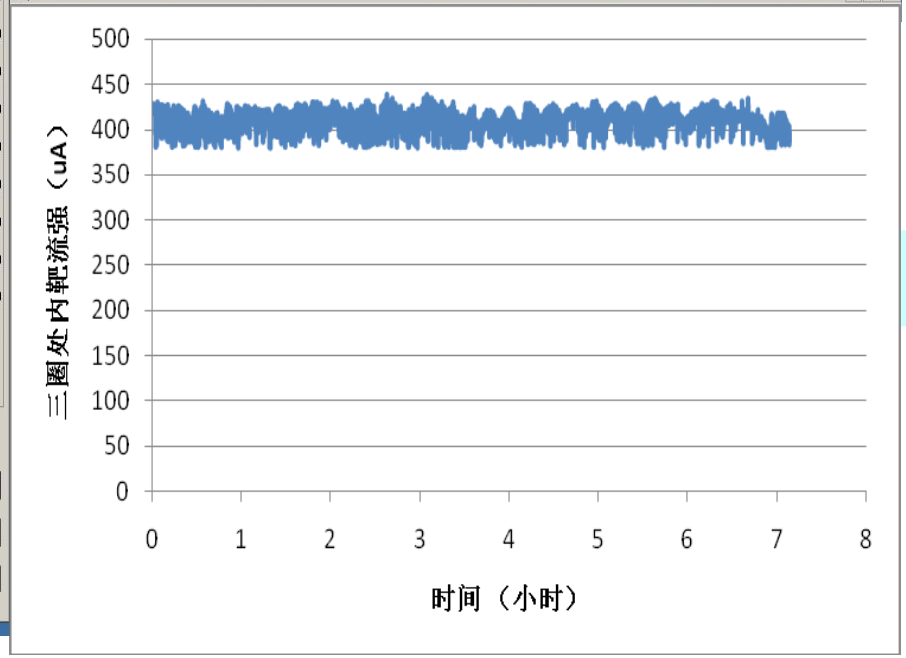




The beam injection efficiency is 17.7%, the beam acceleration efficiency is 94.5%, the beam extraction efficiency is near 100%.







Beam upgrade of CYCIAE-10

- The beam upgrade is going on ➔ 1mA
- Some high intensity cyclotron studies:

  including strong focusing straight edge sector magnet, high stability RF accelerating system, high efficiency injection, extraction, beam dynamics, etc
- It has laid a solid foundation for the construction of PET cyclotrons.
- For the possible application research related to Boron neutron capture therapy (BNCT).

Main progress of CYCIAE-100

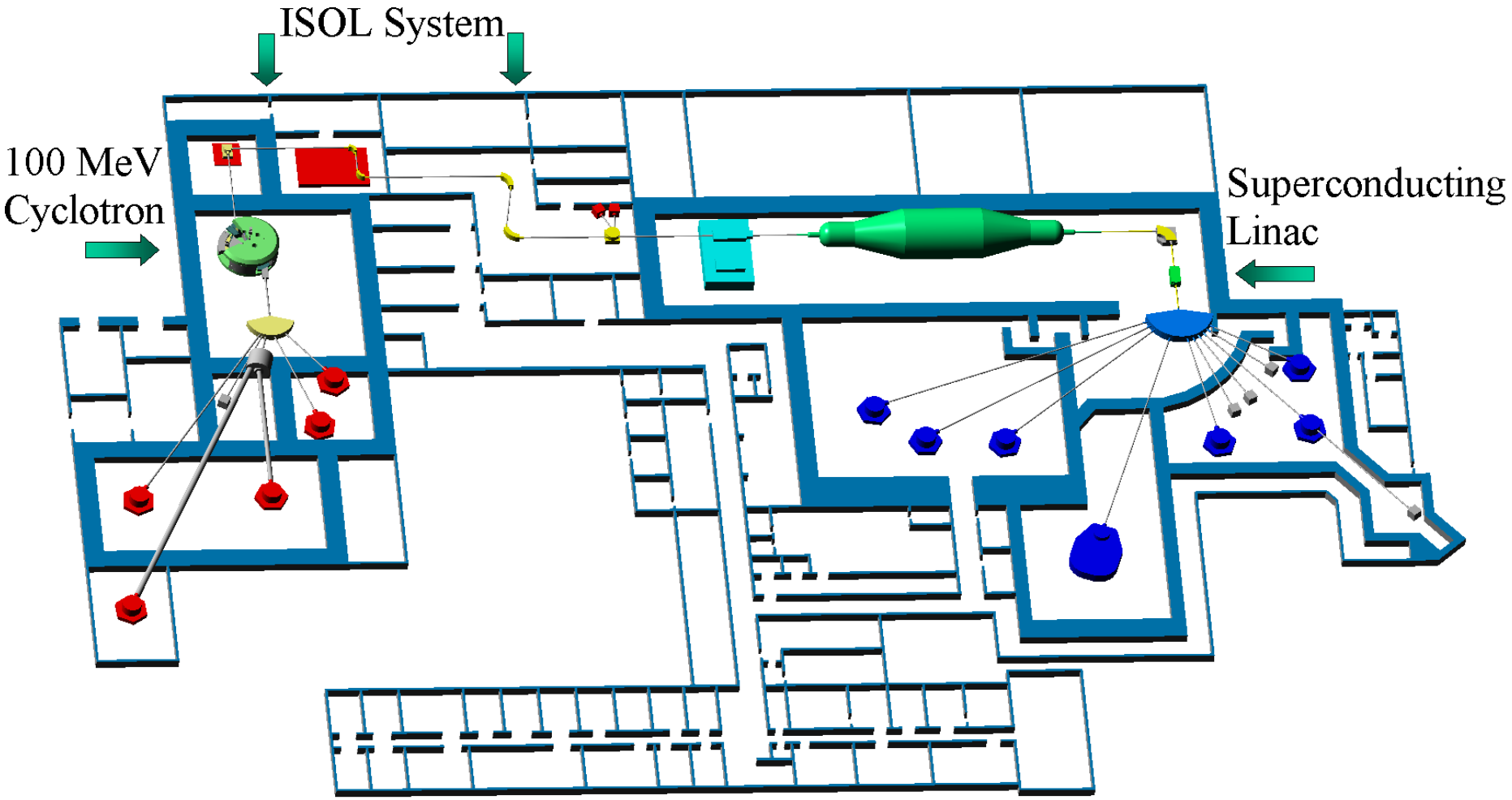
CYCIAE-100 → A New Project of Cyclotron Based Radioactive Ion Beam Facility:

→75 MeV ~ 100 MeV, 200 μA ~ 500 μA: 50kW

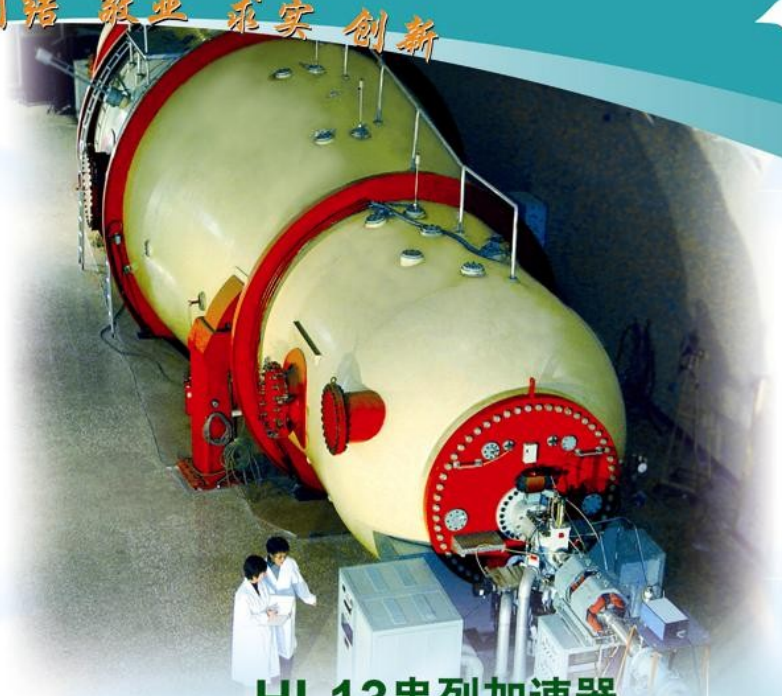
→CYCIAE-100 will get the first beam at the end of 2013!

As one of the main projects at CIAE, the Beijing Radioactive Ion-beam Facility (BRIF) will be used in fundamental and applied research such as **neutron physics**, **nuclear structure**, **material and life sciences, medical isotope production**.

Beijing Radioactive Ion-beam Facility (BRIF)



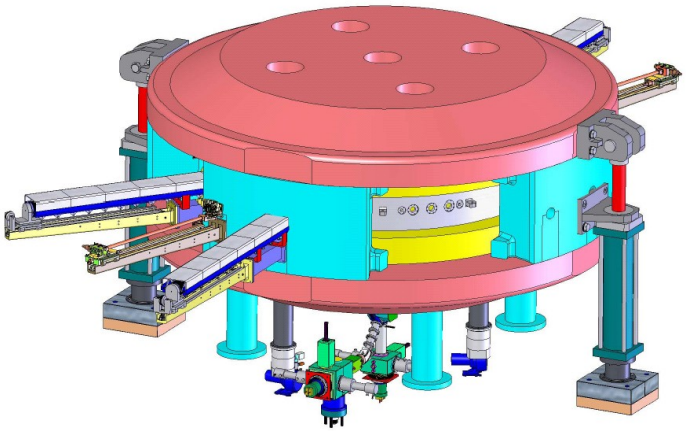
团结 敬业 求实 创新



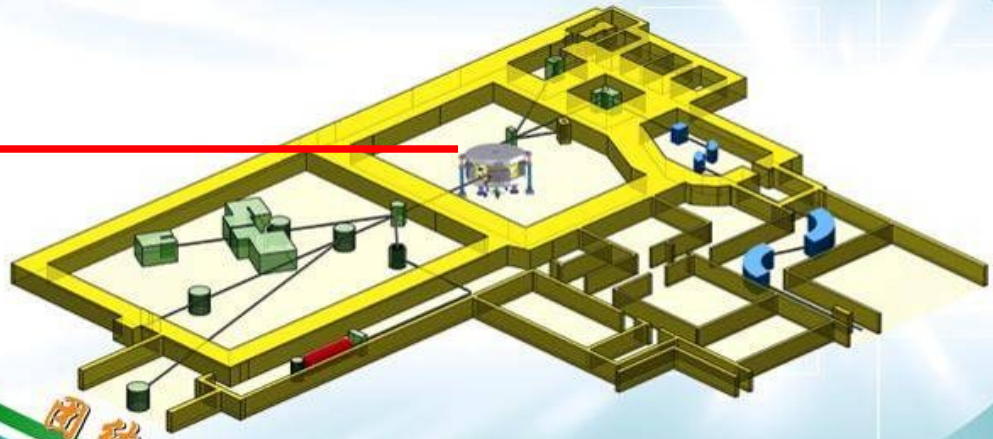
HI-13串列加速器

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

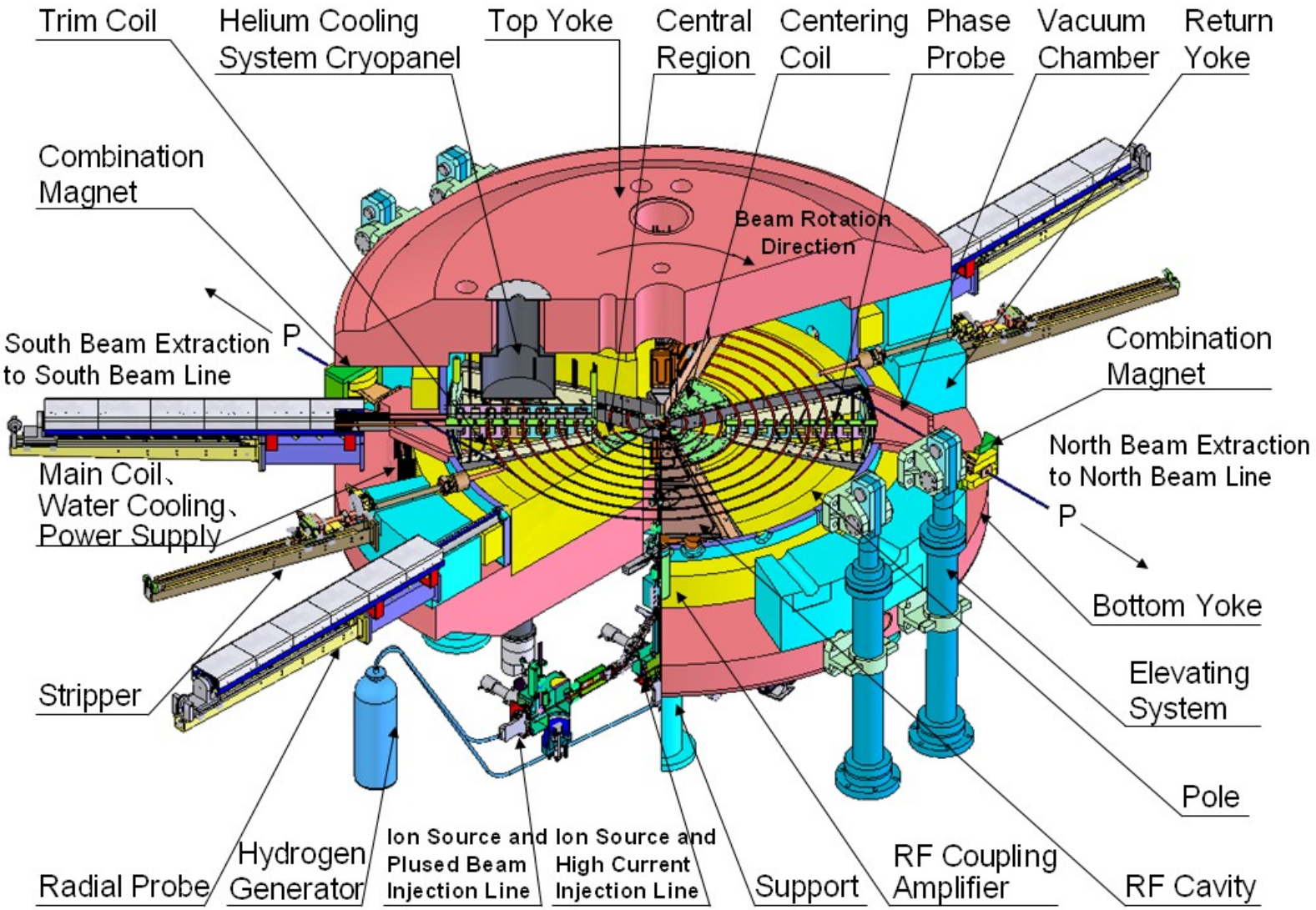


团结 敬业 求实 创新

General Description of CYCIAE-100

- Based on the basic design requirement of the energy and current for this machine, we decided to use a compact magnet and acceleration with stripping extraction for CYCIAE-100.
- It is a fixed field, four sectors cyclotron.
- Tow cavities installed into the valleys of the magnet will accelerate beam 4 times per turn.
- The beam will be injected axially into the central region from two injection lines, for high average current and for pulse beam respectively.

General View of CYCIAE-100



Main Parameters of CYCIAE-100

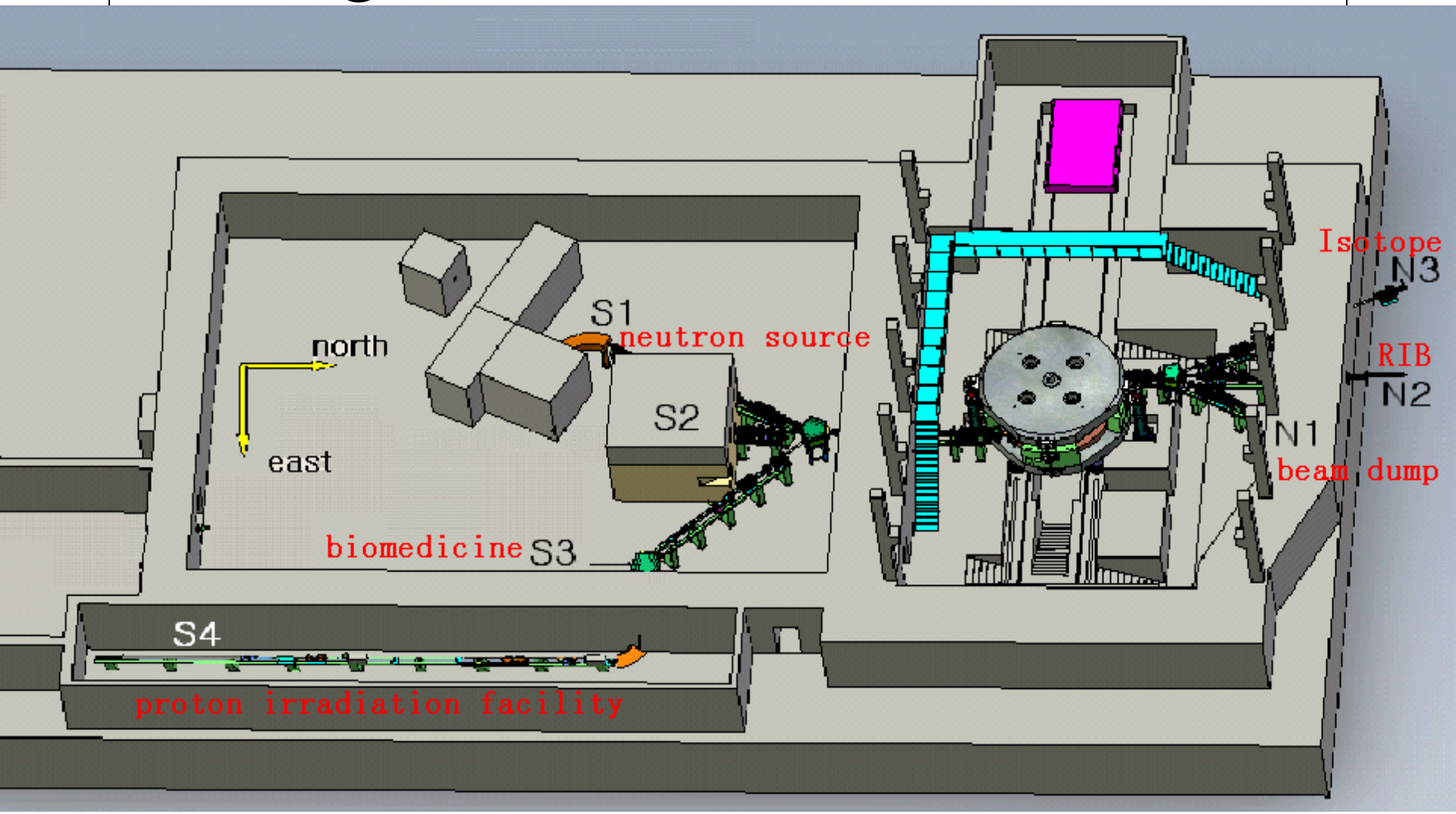
- Magnet

Number of Ssctors	4
Sector Angle	~47°
Field in Hill	1.35 T
Radius of the Pole	2000 mm
Inner Radius of the Yoke	2410 mm
Outer Radius of the Yoke	3080 mm
Gap between the valley	1200 mm
Gap between the Hills	40~50 mm
Total Weight of Iron	~433 t

- RF System

Number of Dees	2	Dee Voltage	60~120kV
Dee Angle	38°	Harmonic Mode	4
Frequency		44.3722 MHz	

7 Target Stations for CYCIAE-100



Main progress of CYCIAE-100

- 2006, the preliminary designs
- 2007~2009 □ the detailed design & construction
- 2010:

✓ The main magnet in the final assembly stage.

✓ Main magnet coils are ready.

✓ Two 100kW RF power supplies have been tested and the measured *f* and Q values coincide well with the design for the RF cavity.

✓ The vacuum chamber and elevating system will be completed soon.

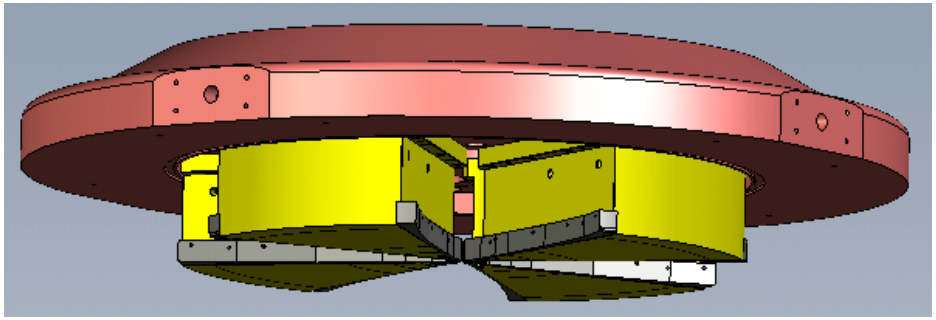
✓ Received satisfactory results and passed the formal certification.

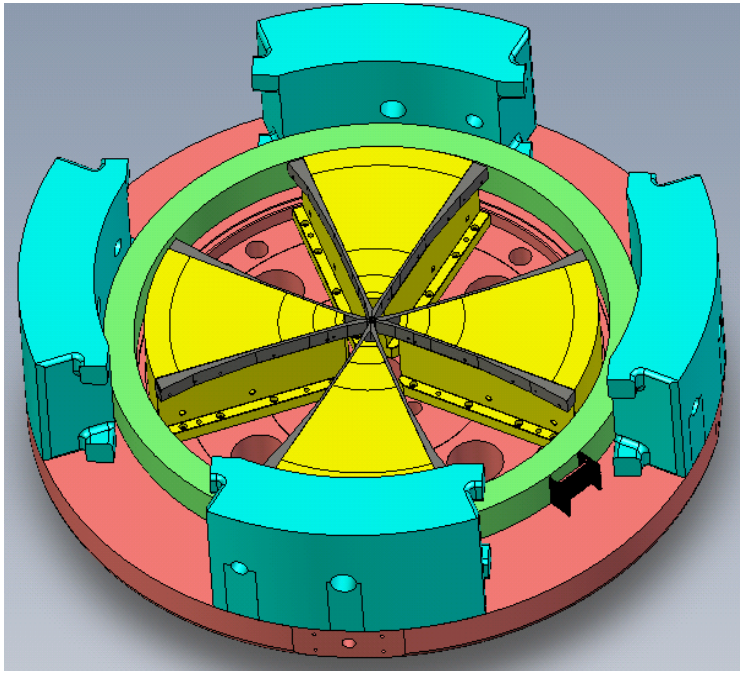
Main progress of CYCIAE-100

- Magnet

4 straight sections and the maximal filed: 1.35T

Extraction radius of 2m





Dia. □ 6160 mm

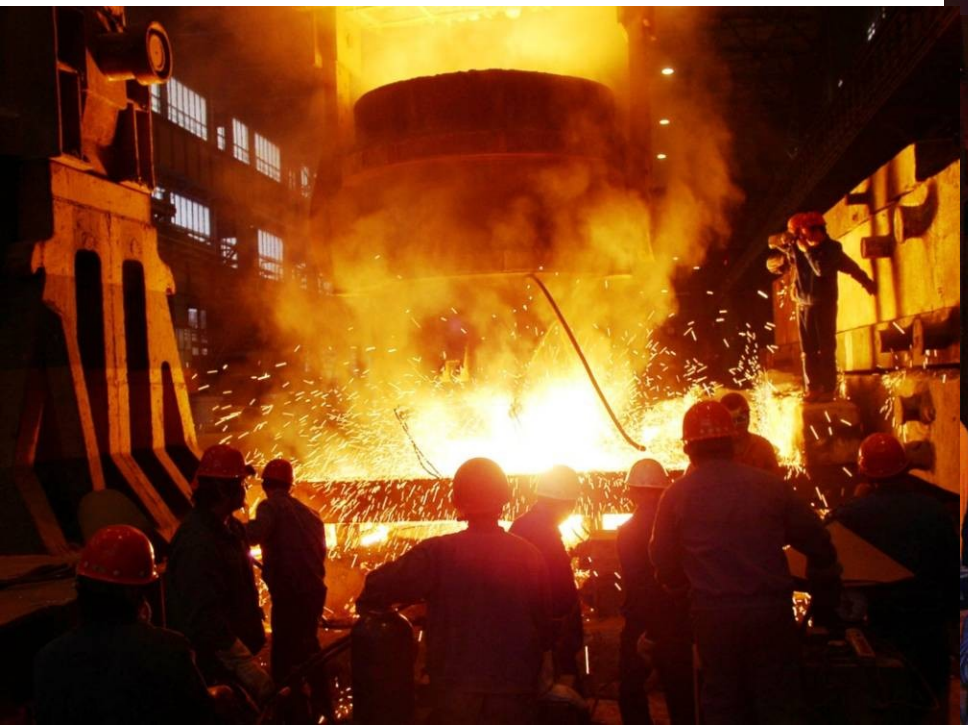
Pole Dia.: 4000mm

Height □ 2820 mm

Weight □ 435 t

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

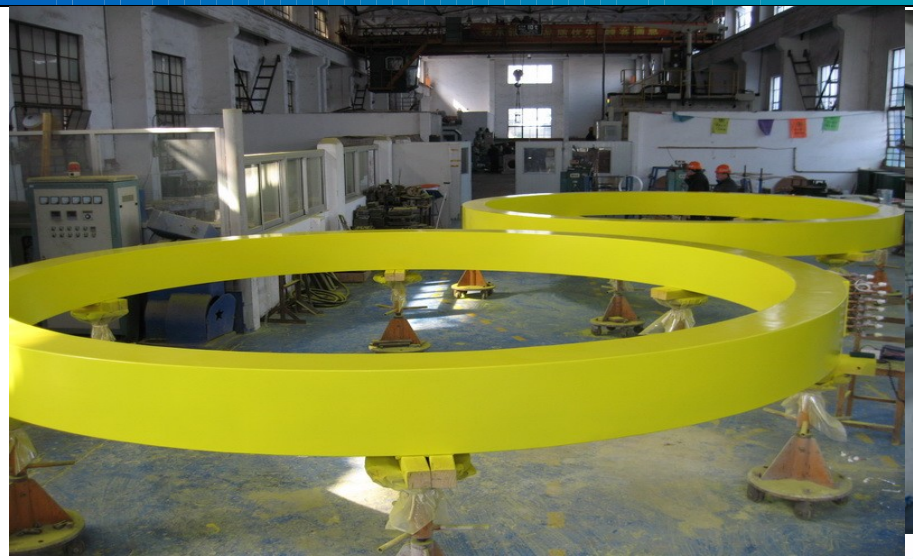
The yokes are formed from 5 pots molten steel pouring together.



Yokes, Poles, Shimming bars, center plug

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

Vacuum checking for top/bottom yokes is under going now. The magnet is expected to be finished by end of 2010.

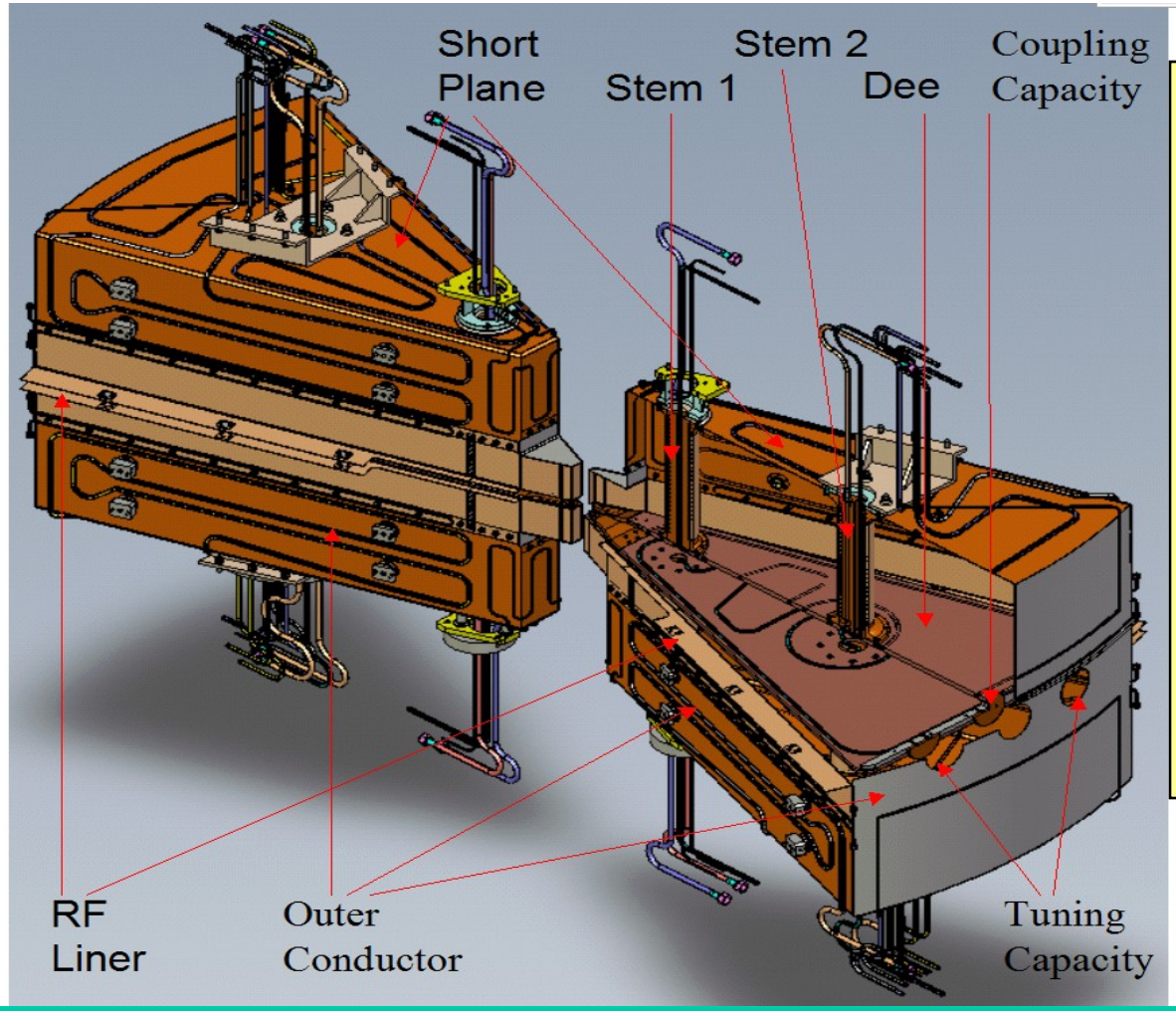



2010/03/18 11:20


HOWO
2010/03/19 11:24

Main progress of CYCIAE-100

RF System: 2 cavities in the valleys, 2 opposite extraction system



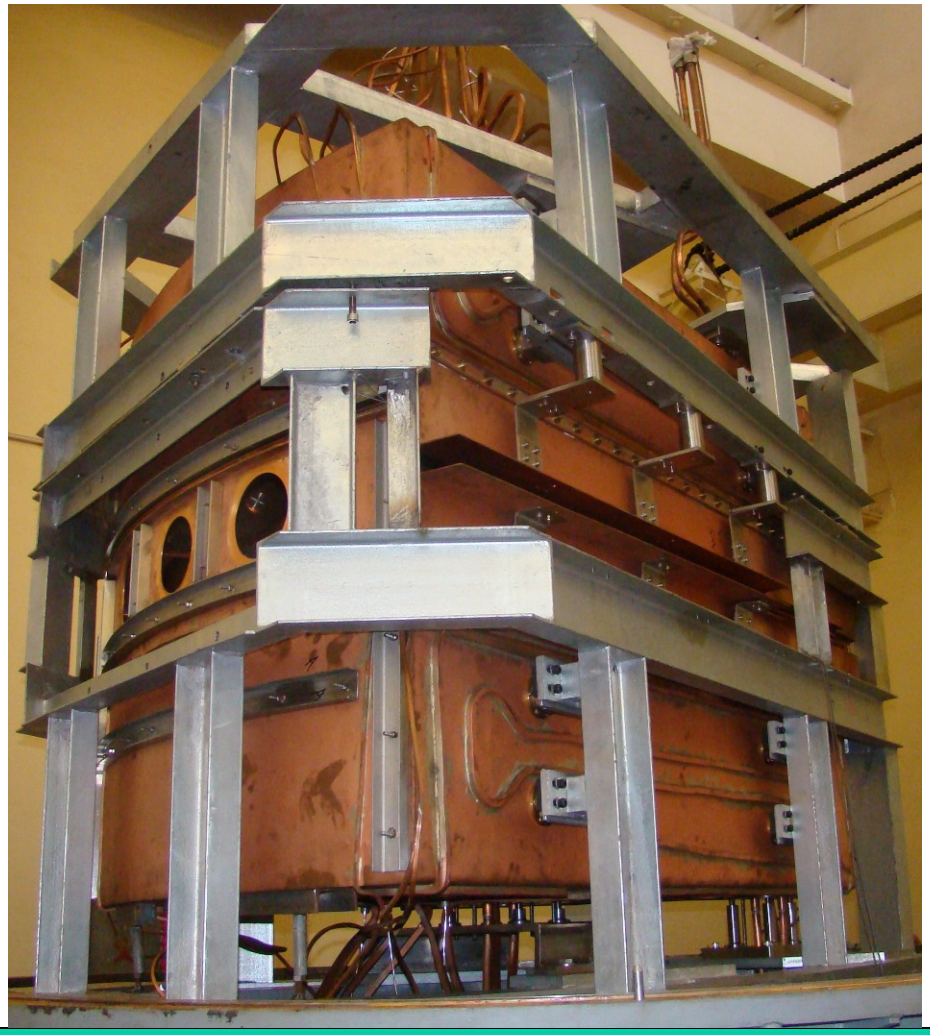
frequency:
44.32 MHz

Q value: **10300**
dissipated power on

the two cavities:
57kW. The voltage:
60kV-120kV

Main progress of CYCIAE-100

Installed test RF cavity



cold measurement frequency:
45.8 MHz,

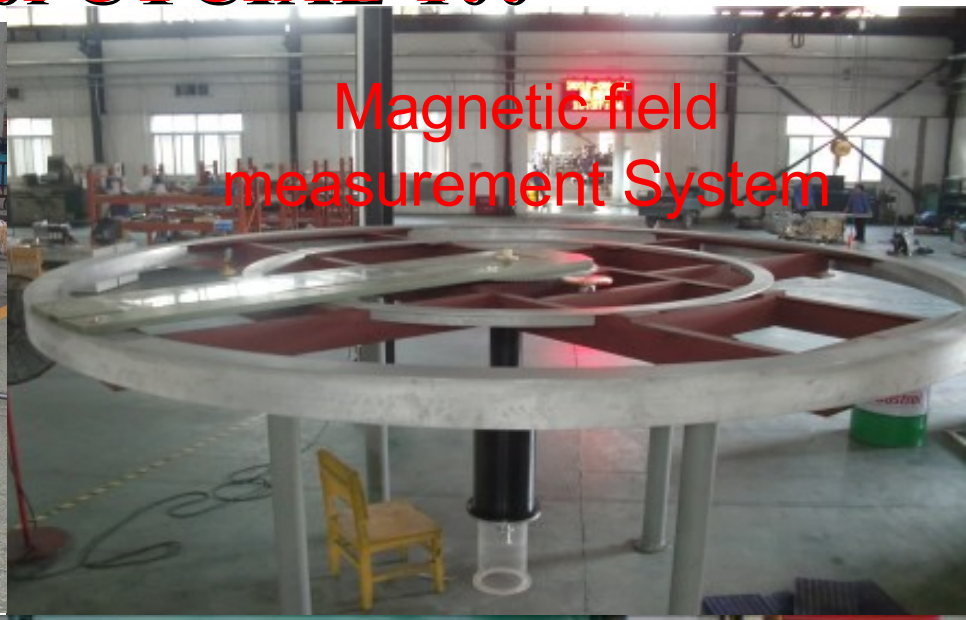
Q value:
9300 .

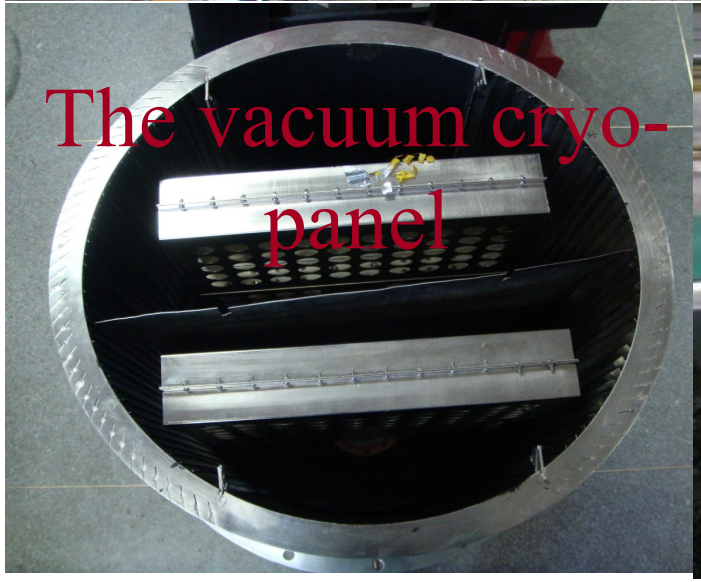
Main progress of CYCIAE-100

– RF System: 2×100kW RF power generators

The test cavity is inside the vacuum tank with power.

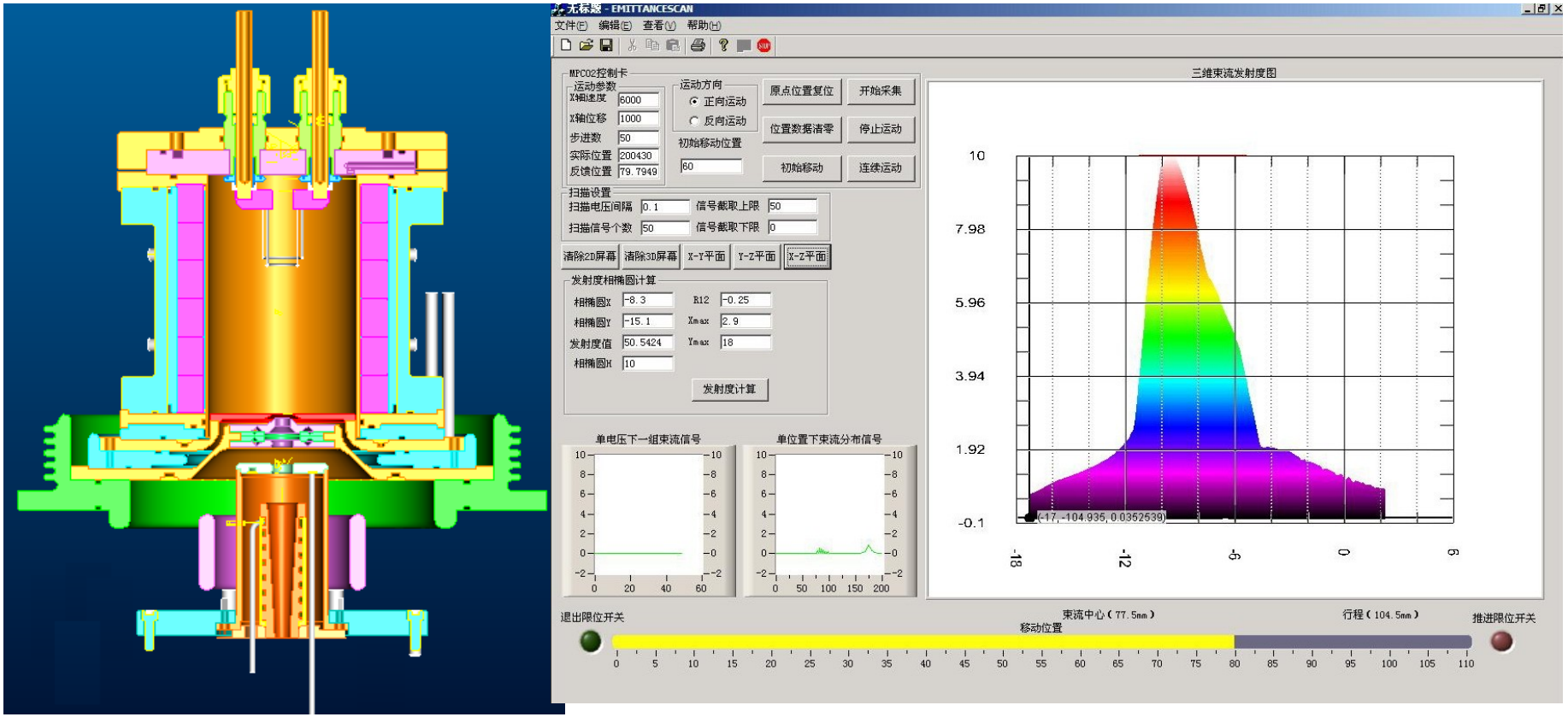
Main progress of CYCIAE-100





Main progress of CYCIAE-100

– H- Source



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

Construction of CYCIAE-14

CYCIAE-14 → Similar to the operating CYCIAE-10

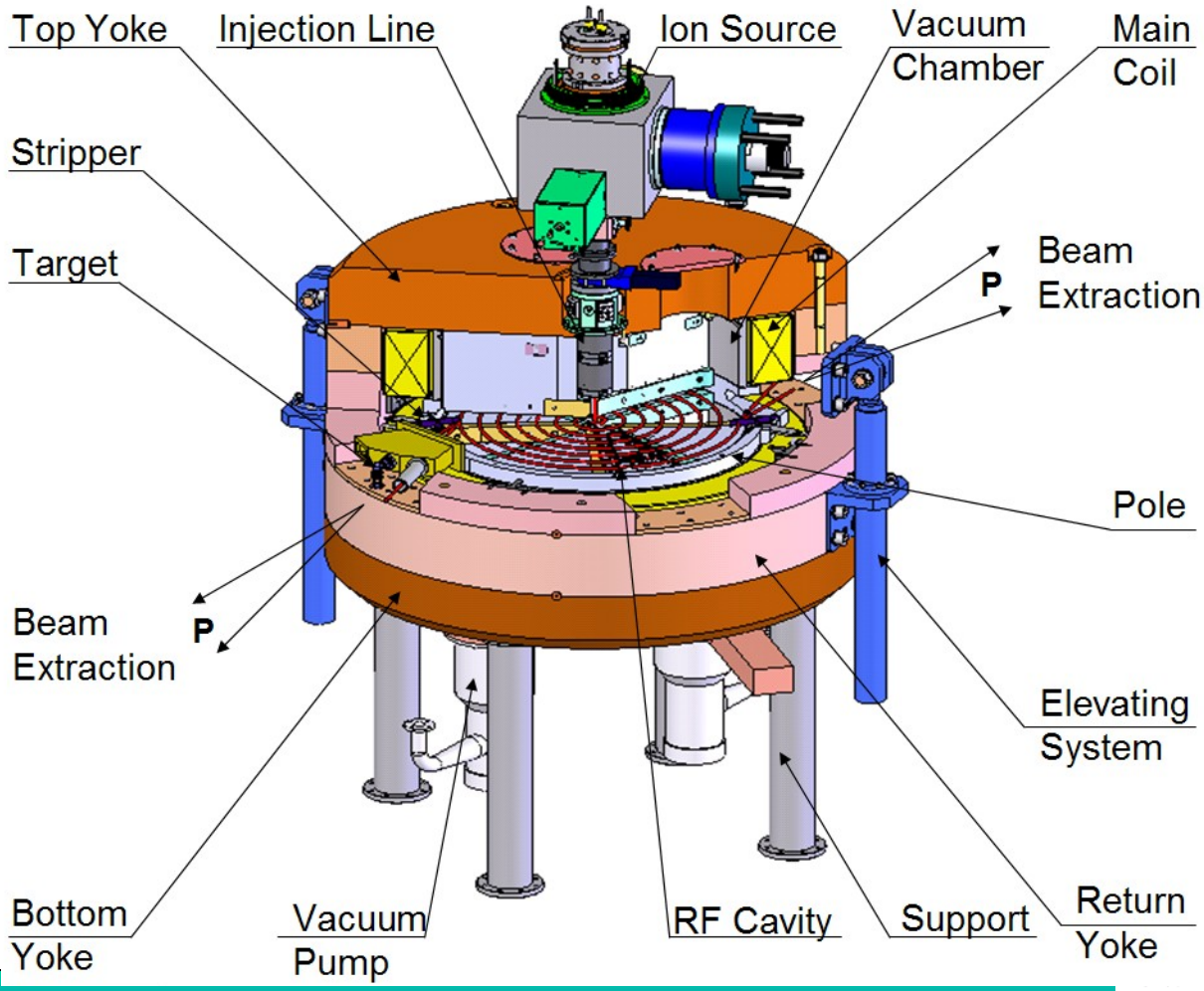
Design Goal:

→ PET cyclotrons:

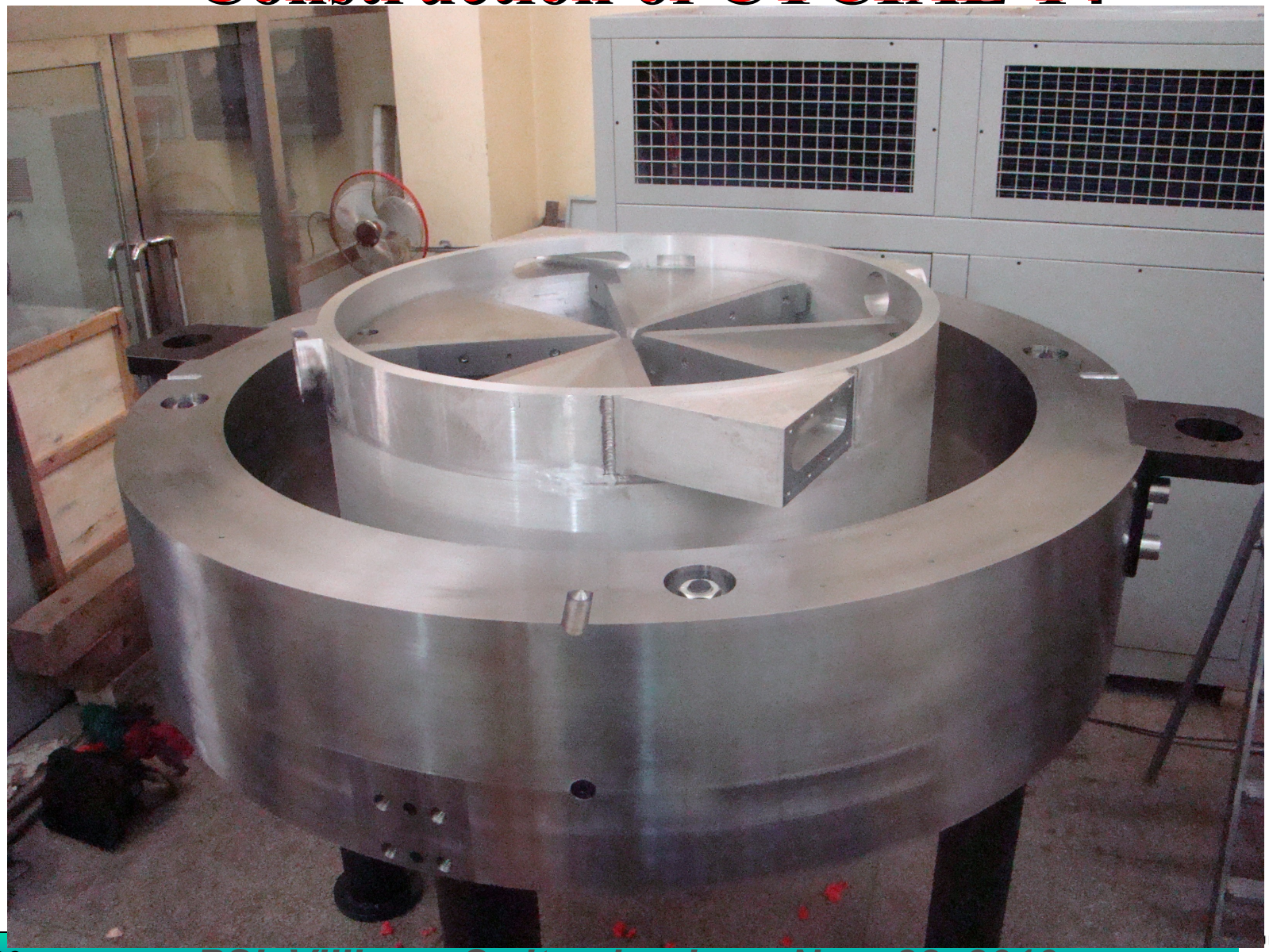
400μA ,

14.6 MeV

First beam will be got **next year**!



Construction of CYCIAE-14

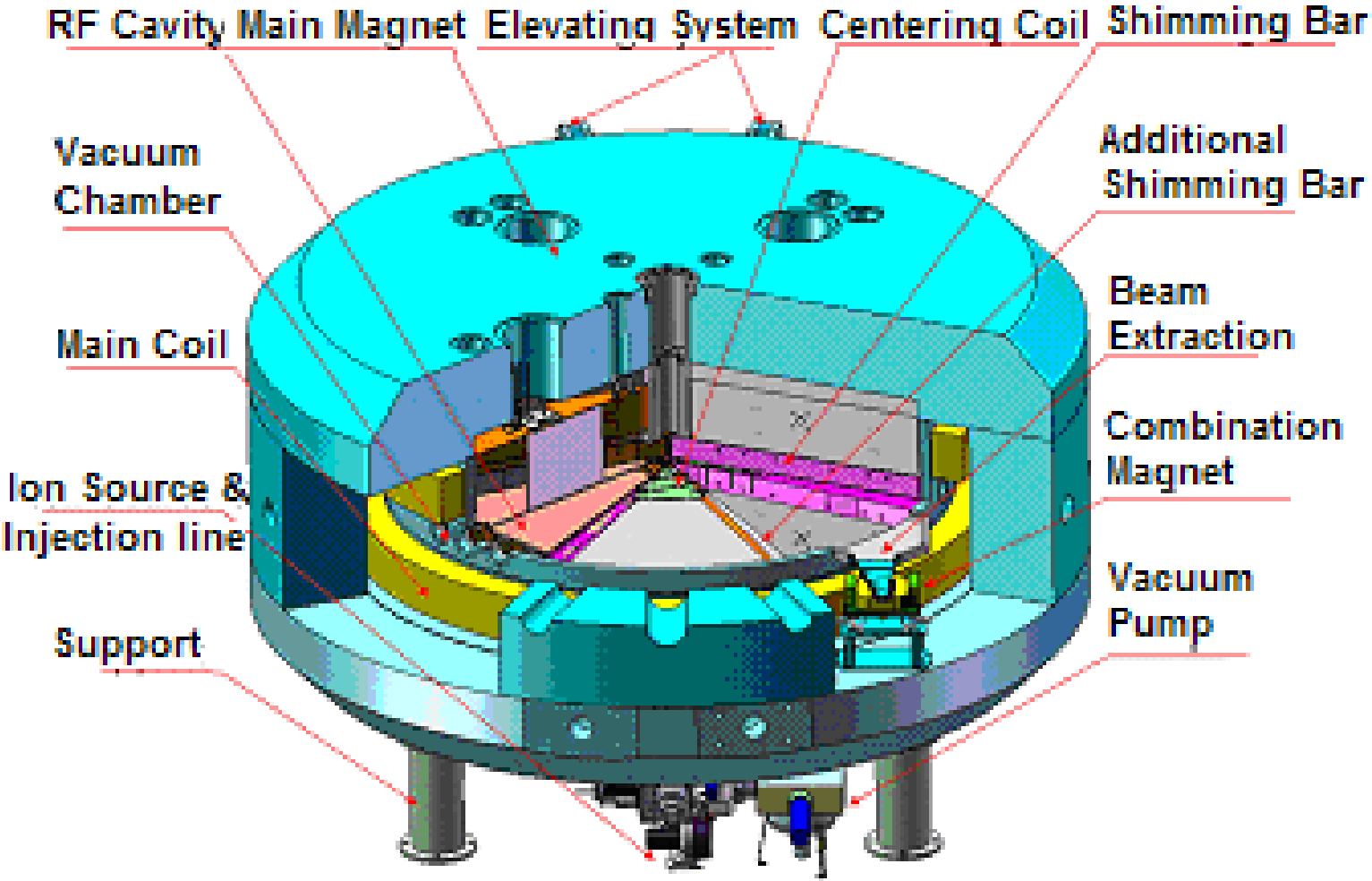


The D-/H- CYCIAE-70

40μA/ 18~33 MeV D+, 700μA/35~70 MeV H+

RIB production and the field of nuclear medicine.

Based on the design of CYCIAE-100



Concept Design of 5 mA CYCIAE-800

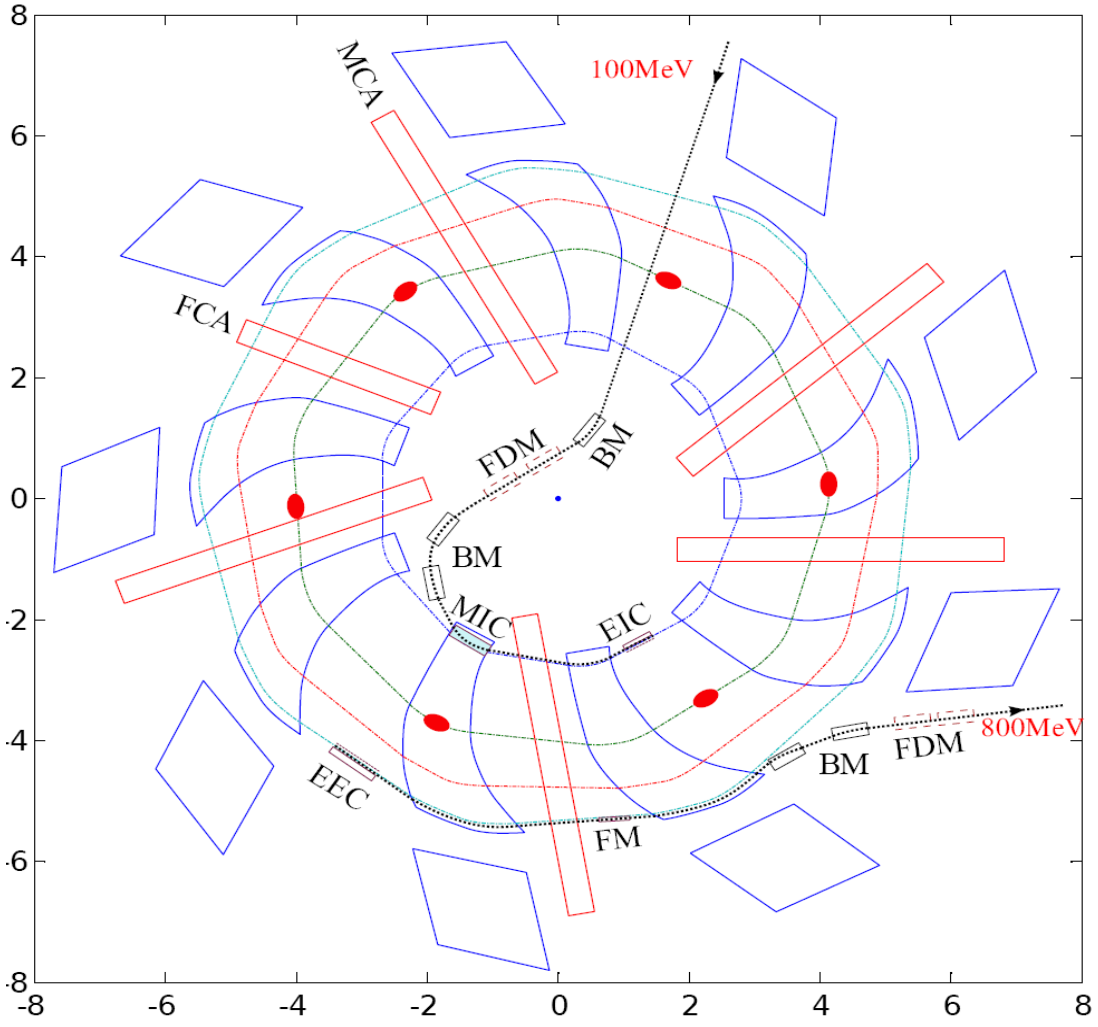
5mA, 100MeV → 800 MeV.

Lots of work are done together with **Werner Joho, Andreas Adelmann, Peter Sigg, etc.** from PSI: Layout of CYCIAE-800 is based on the **PSI Ring**.

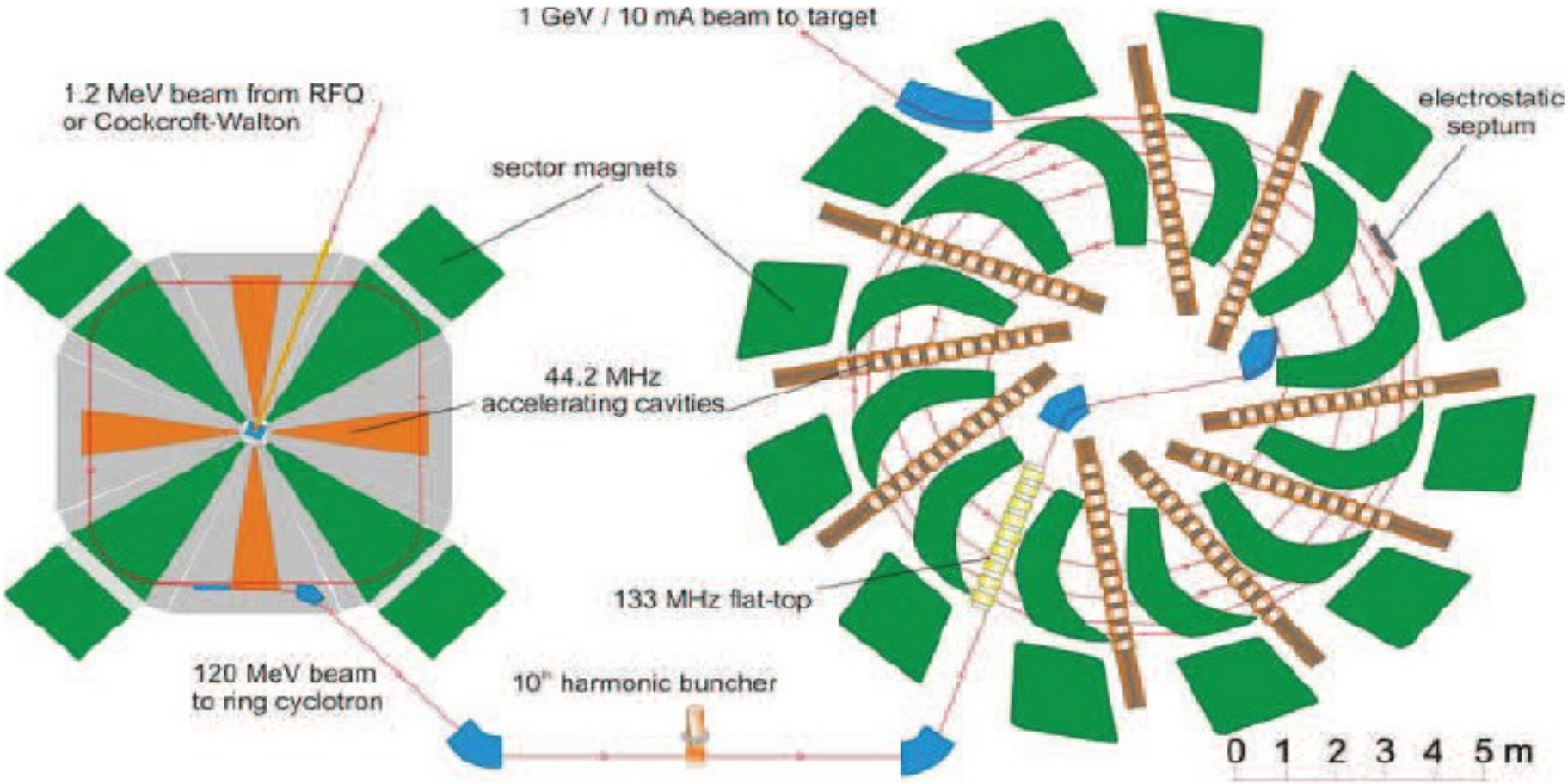
First step: 0.5mA CYCIAE-100 as injector

Second step: New 5mA 100MeV cyclotron.→ **4MW** beam power.

Main purpose for $150MW_{th}$ **ADS demonstrator.**



10mA, 1GeV PSI 'Dream Facility'



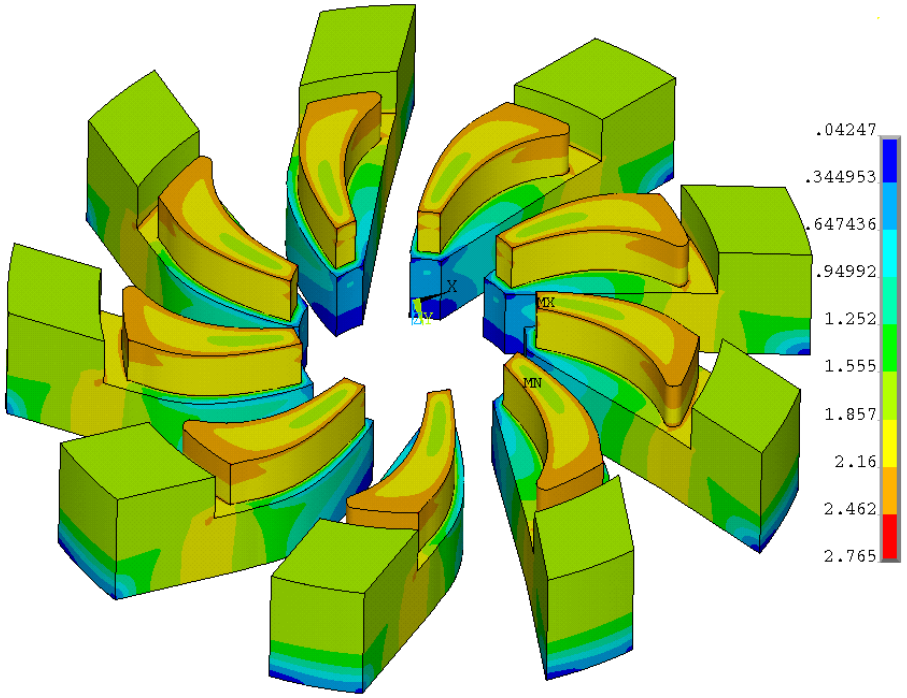
10MW beam power for 375MW$_{th}$ ADS burner:

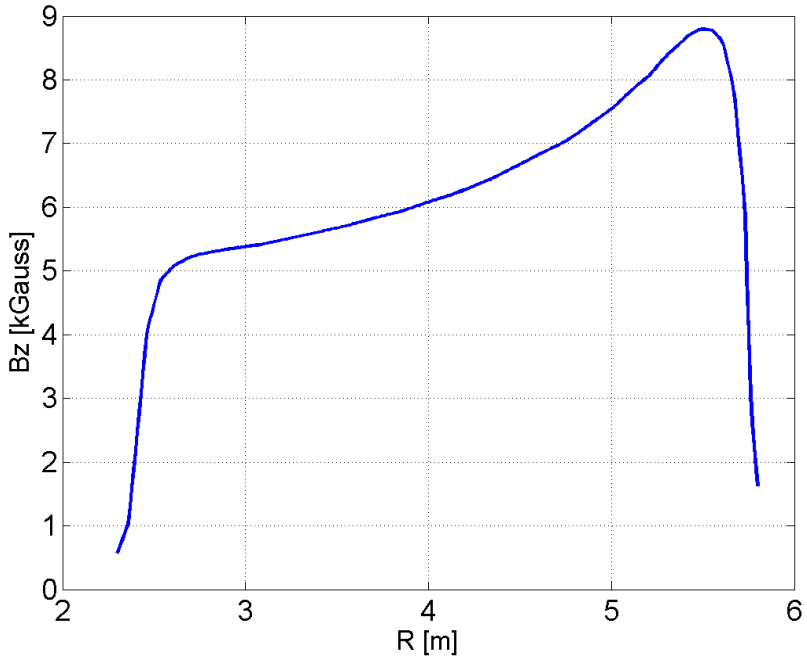
J.Grillenberger, M. Seidel, PSI, Beam Dynamics Newsletter, No. 49, p61. Aug. 2009.

Concept Design of 5 mA CYCIAE-800

Item	Value
Sector number	9
Kinetic energy (MeV)	100→800
Max Magnetic Field(T)	1.5 – 2.00
Average orbit radius (m)	2.76-5.42
RF frequency(MHz)	44.37
Peak RF voltage (MV)	1.0
Harmonic number	6
Main cavity number	5
Flat-top cavity number	1 or 2
Qr/Qz at extraction	1.55/1.40
dR/dn at extraction (mm)	7 (centering injection)

Concept Design of 5 mA CYCIAE-800



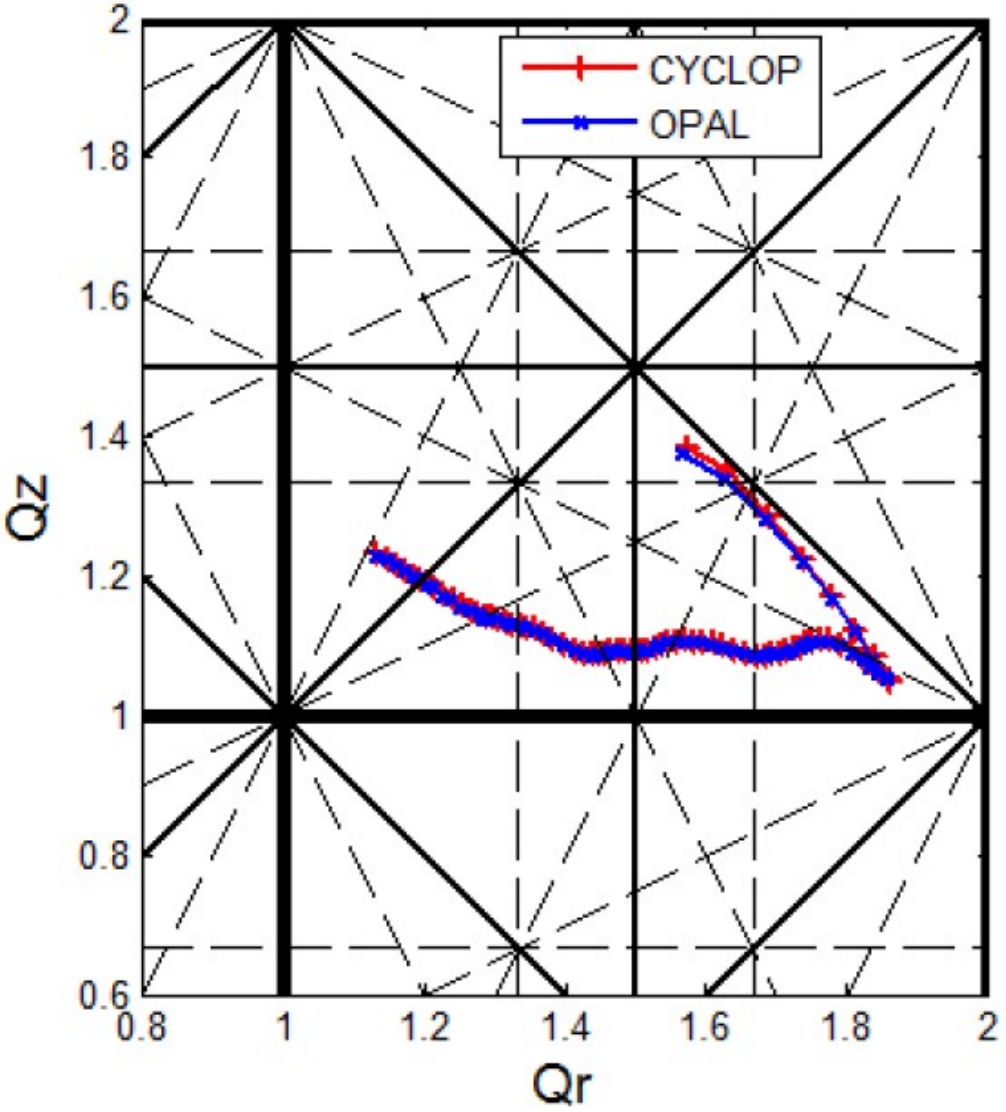


The inner/outer radius of pole (mm)	2460/ 5700
The inner/ outer radius of Yoke (mm)	6200/ 8000
The width of magnet angle (˚)	13.6 – 17.8
The spiral angle (˚)	0 – 46

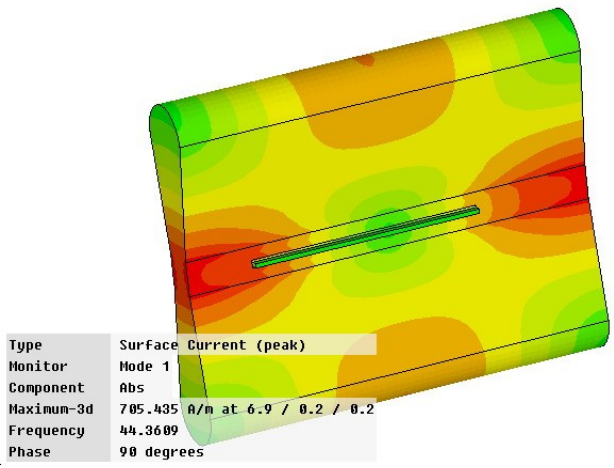
Concept Design of 5 mA CYCIAE-800

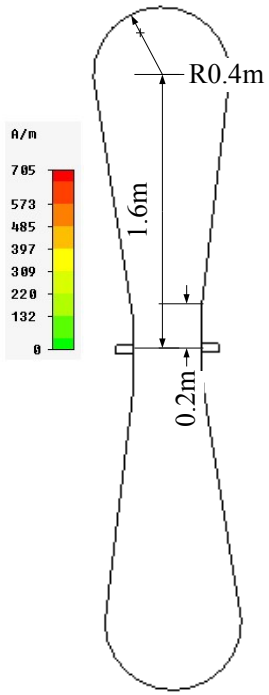
Tune diagram:

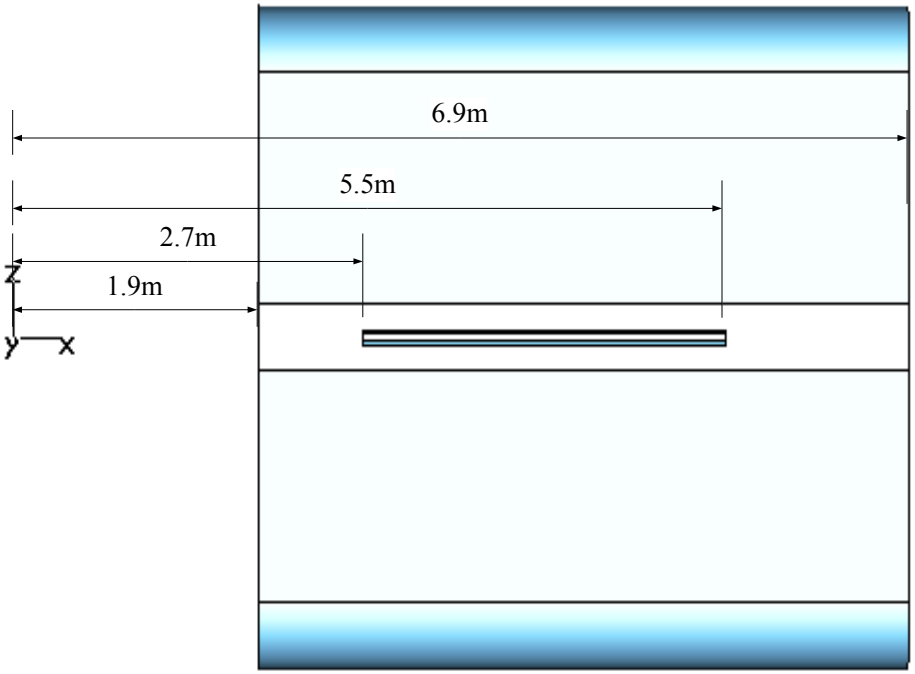
No Space charge



Concept Design of 5 mA CYCIAE-800







Cavity parameters are scaled from the existing 50.6MHz PSI cavity

Peak Voltage (MV)	**1.0**
Frequency (MHz)	**44.37**
Power (MW)	**1.5**

SUMMARY

- A remarkable progress has been achieved in the past few years in operating CYCIAE-10 and in the design, construction and testing components 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 first beam will be got at the end of 2013.
- The design of a D-/H- CYCIAE-70 is done.
- Preliminary design study of 5mA CYCIAE-800 is existing.

Welcome to visit CIAE, Beijing