Development of heavy ion radiotherapy facilities in China

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Contents

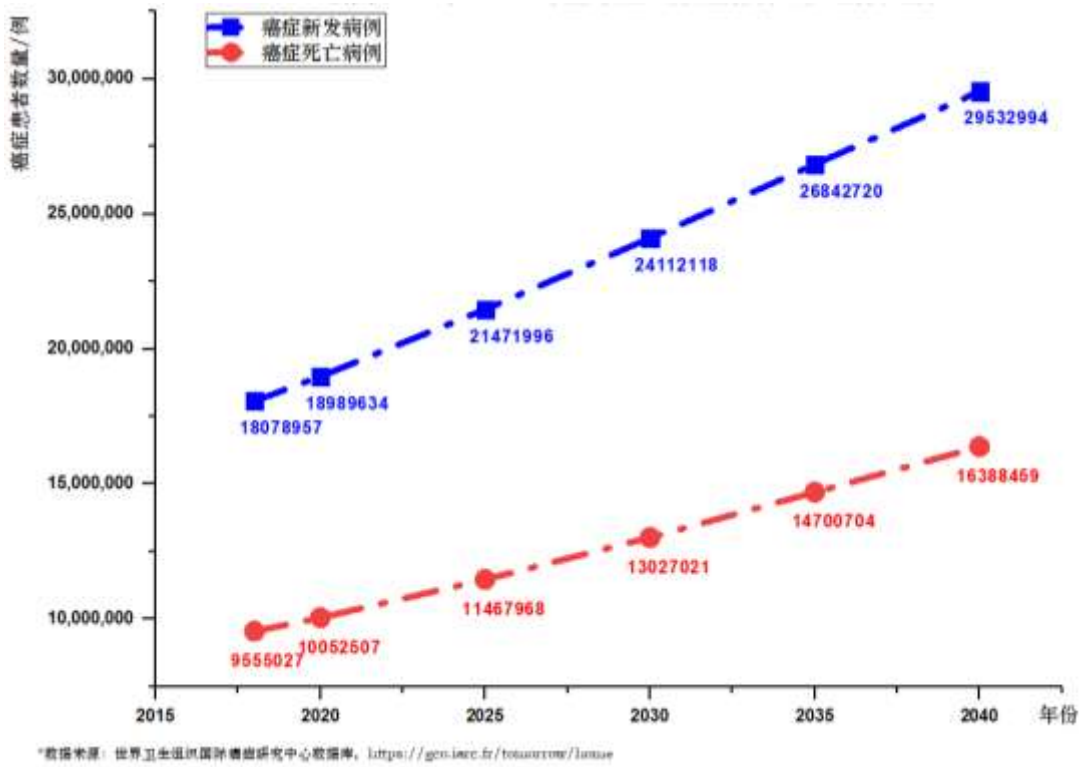
lanzhou ion therapy co., LTD.

*HIMM： Heavy Ion Medical Machine. It is the product produced by Lanith company, and Lanith is affiliated to IMPCAS.

01 Background

Current status of cancer in global and China

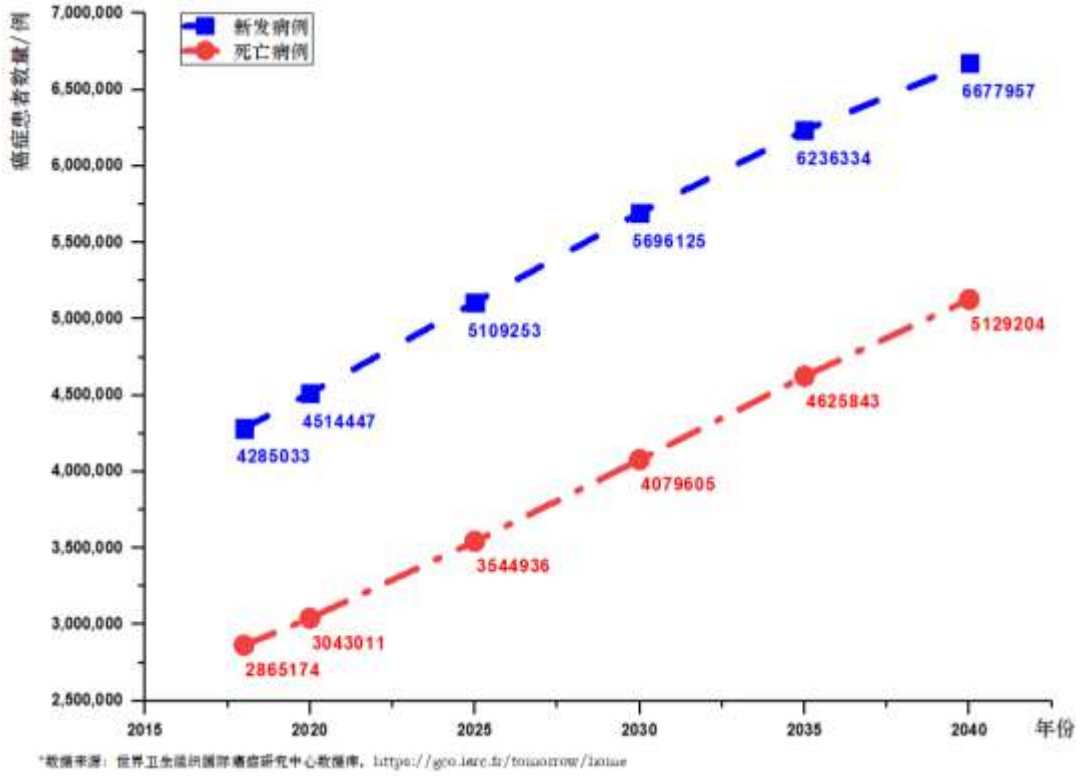
The global cancer cases predicted by IARC form 2018-2040



19 million →29.5 million 2.4%/year

10 million →16.4 million 2.6%/year

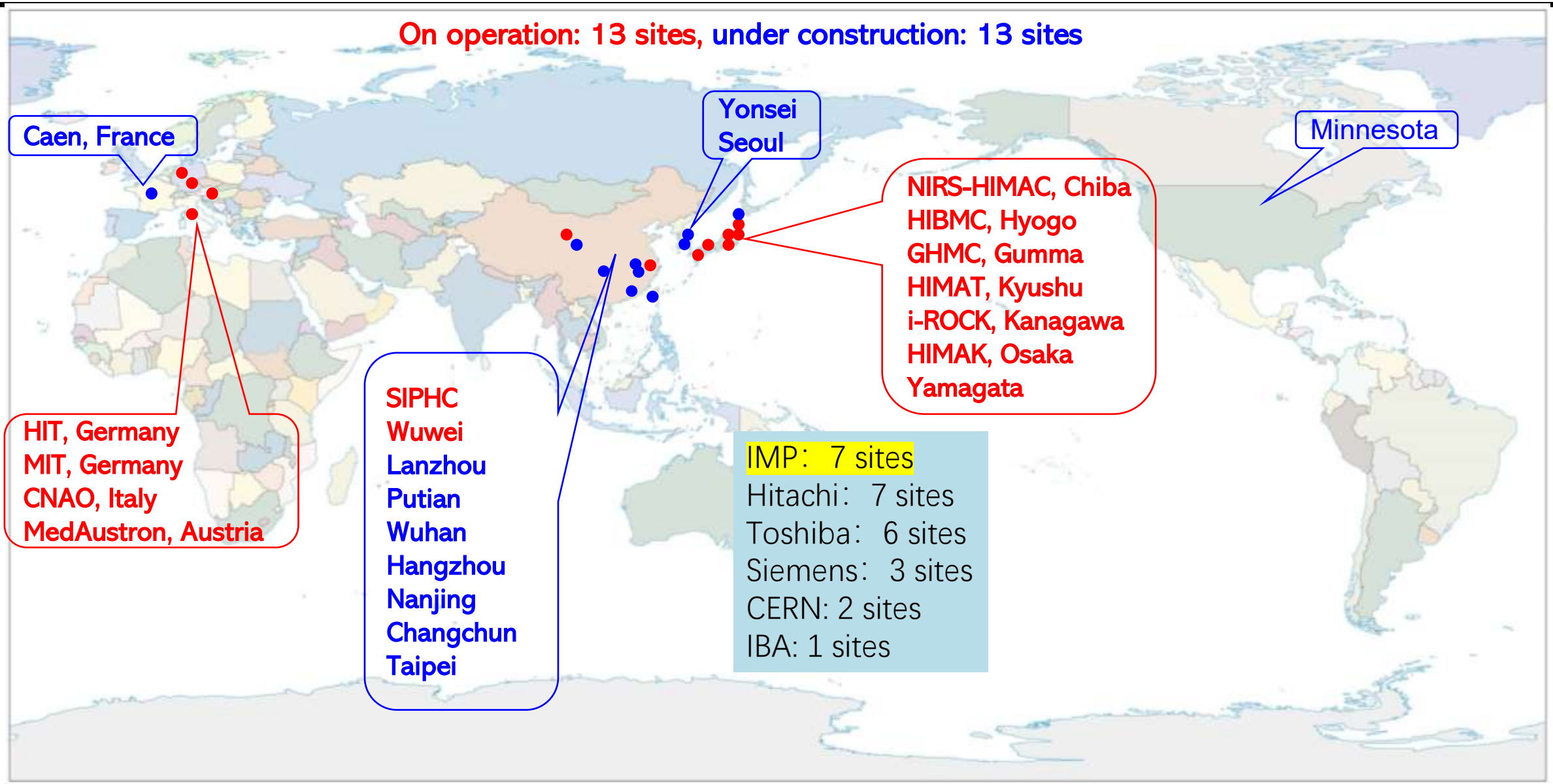
The cancer cases in China predicted by IARC form 2018-2040



4.5 million → 6.6 million 2.2%/year

3 million → 5.1 million 2.9%/year

Heavy ion radiotherapy facilities in the world



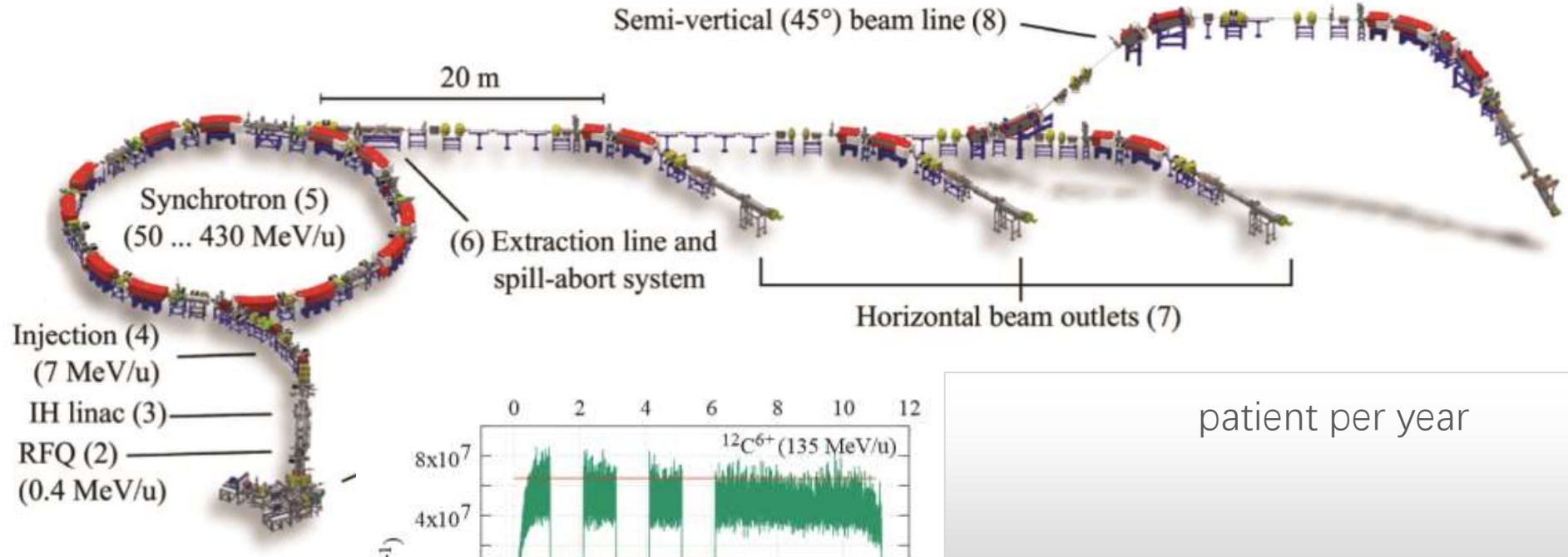
02 Heavy ion radiotherapy facilities in China

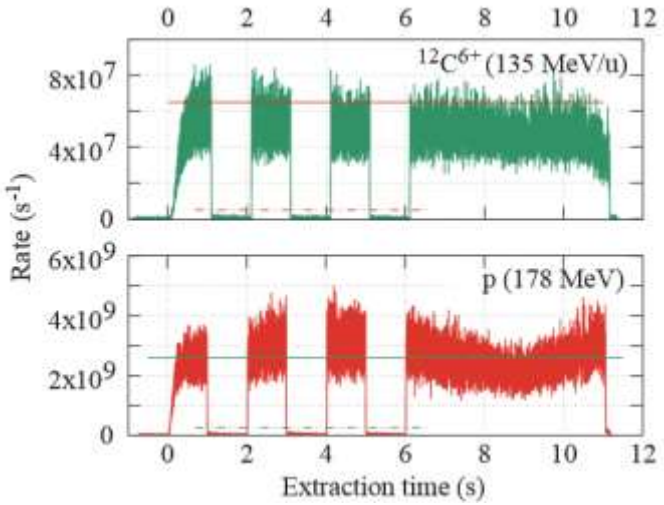
Heavy ion facilities in China

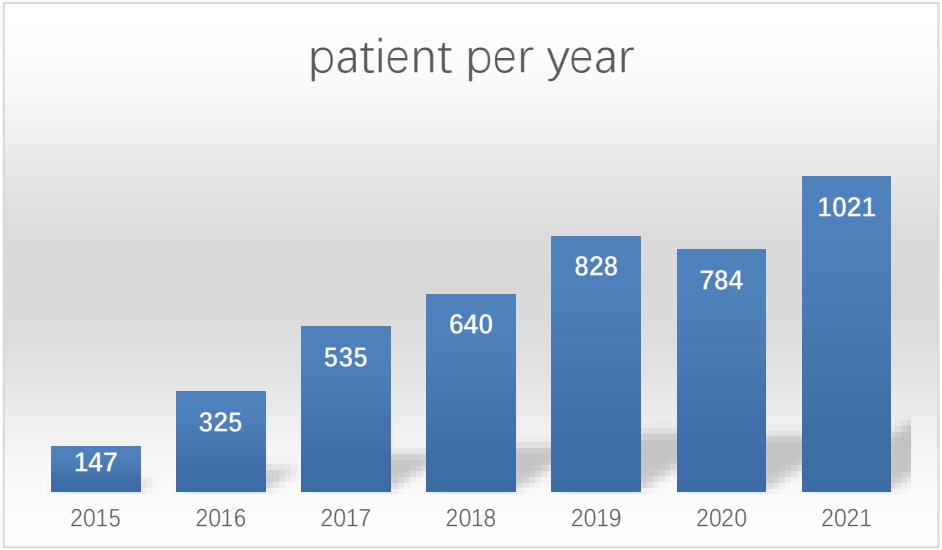
- **In operation**
  1. Shanghai proton and heavy ion center (Siemens)
  2. Wuwei Heavy ion therapy center (IMP)
- **Under construction: 9 sites**
  1. Lanzhou Heavy ion therapy hospital (IMP)
  2. Xuzhou heavy ion center (Hitachi)
  3. Mazu Health center (IMP)
  4. Renmin hospital of wuhan university (IMP)
  5. Zhejiang cancer hospital (IMP)
  6. Jiangsu cancer hospital (IMP)
  7. The First Bethune Hospital of Jilin University (IMP)
  8. Heyou international hospital (Hitachi)

IMP/ALL: 7/10

SPHIC: Shanghai proton and heavy ion center







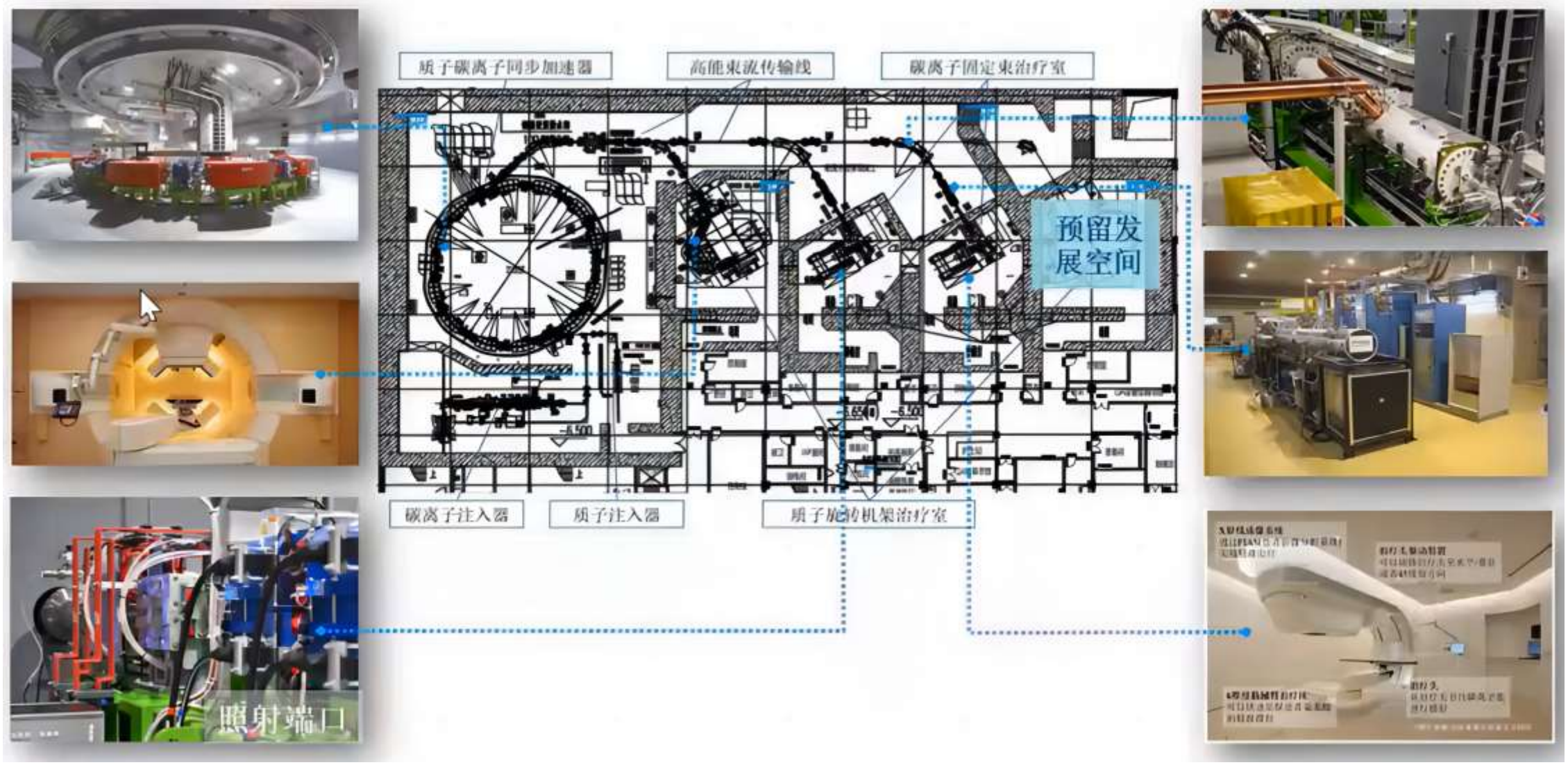
Vender: SIEMENS

Treatment rooms：4

Proton: max. $2*10^{10}$ /spill

Carbon: max. $1.0*10^{9}$ /spill

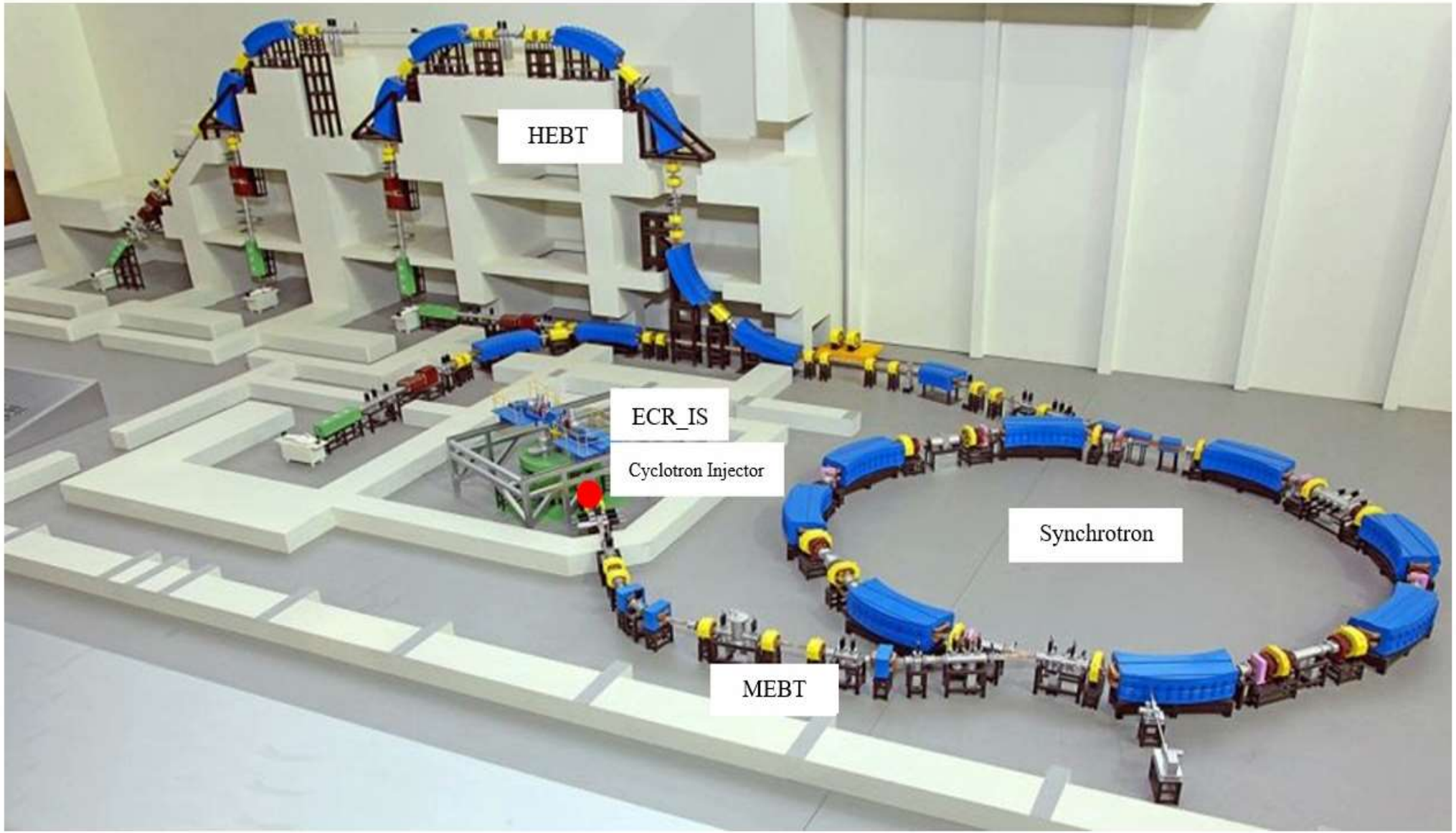
Xuzhou and Heyou heavy ion center*



*Slide from Professor Lu Jiade

HIMM facilities in China

Princeple of HIMM accelerator

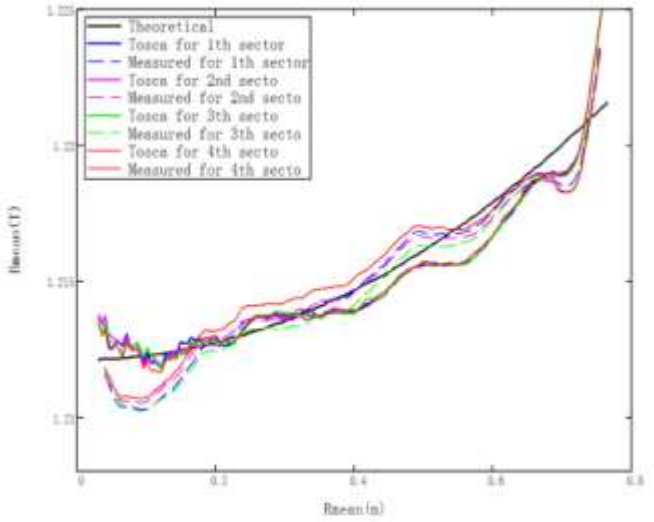


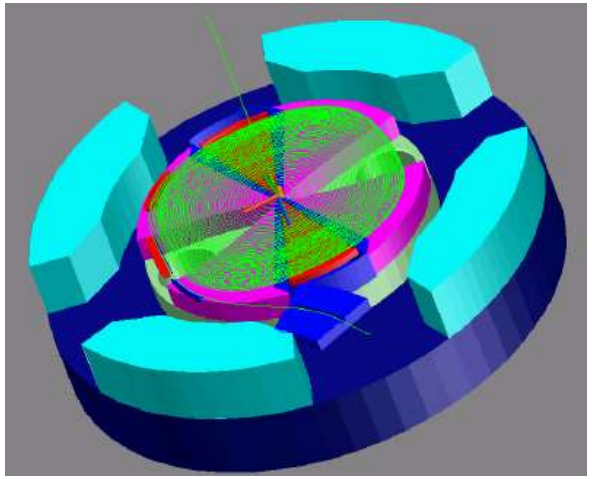
Note: can't provide beams for multiple rooms simultaneous

Design of the cyclotron injector

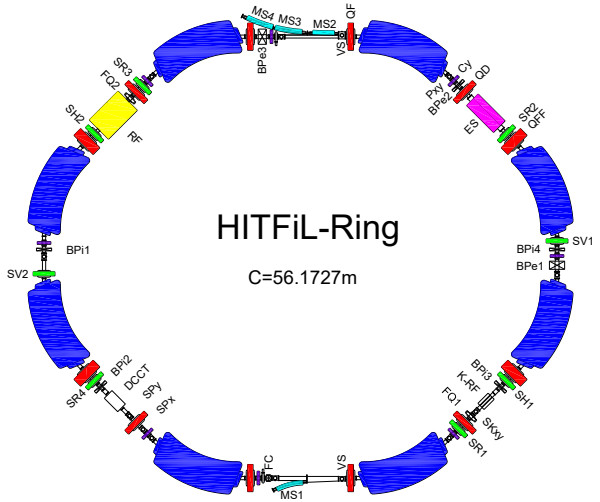
Beam	
Particle	$^{12}C^{5+}$
E_k （MeV/u）	~6.3
I (euA)	>10uA
Dp/p	≤±5e-3
E (pi`mm`mrad)	25(5sigma)
Acclerator	
R_inj (cm)	75
R_ext (cm)	2.7
F_r (MHz)	7.755
Harmonic	4

Magnet	
Diameter (m)	2.92
Height (m)	1.52
Number of sectors	4
Angle of the sector °	56
Radius of the sector (mm)	840
B_{IC} (T)	1.212T
B_{max} (T)	1.8T

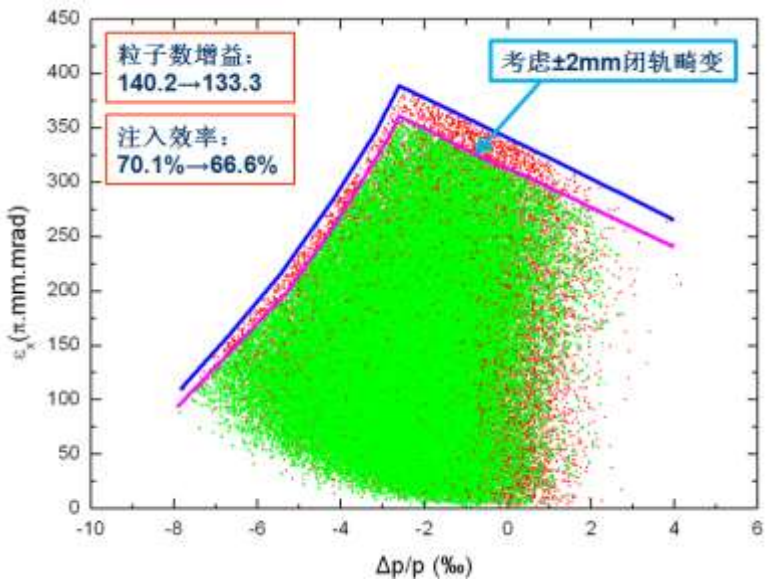


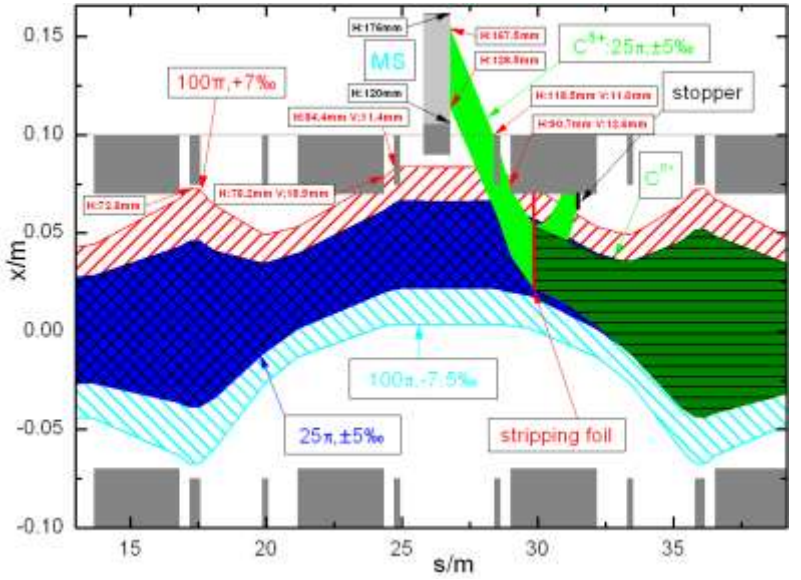


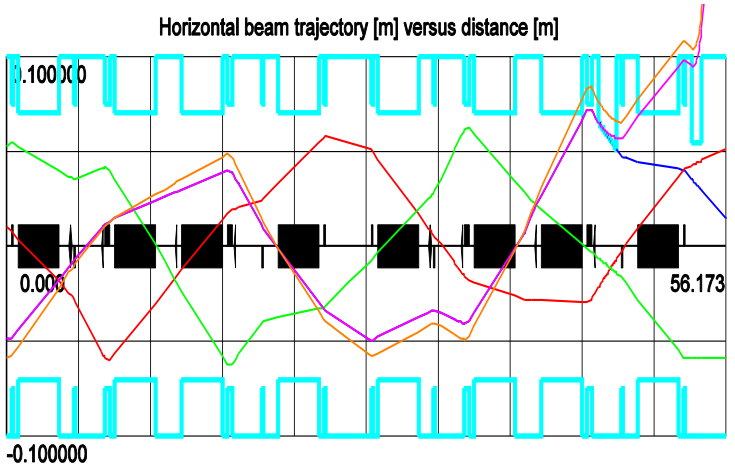
Design of the synchrotron

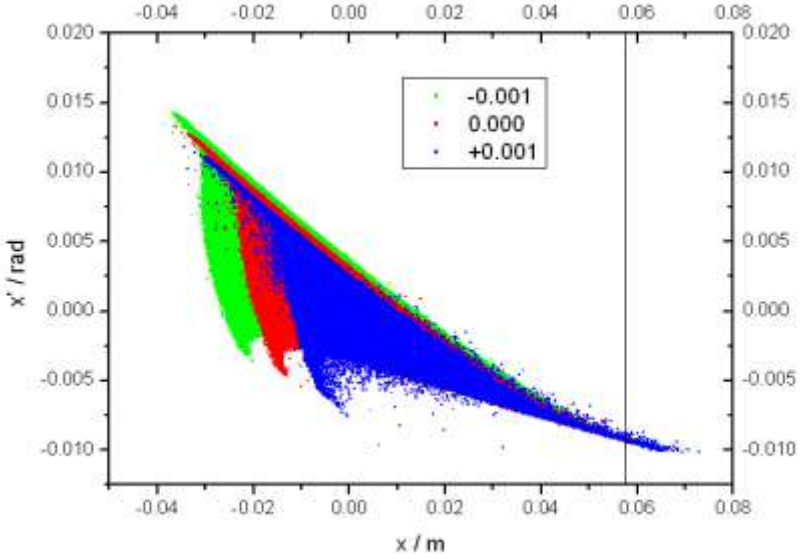


Beam	
Particle	12C6+
Ek （MeV/u）	120-400
part. number	4e8
Acclerator	
circumference	56.2
Q_x / Q_y	1.68/1.23
H	1 or 2







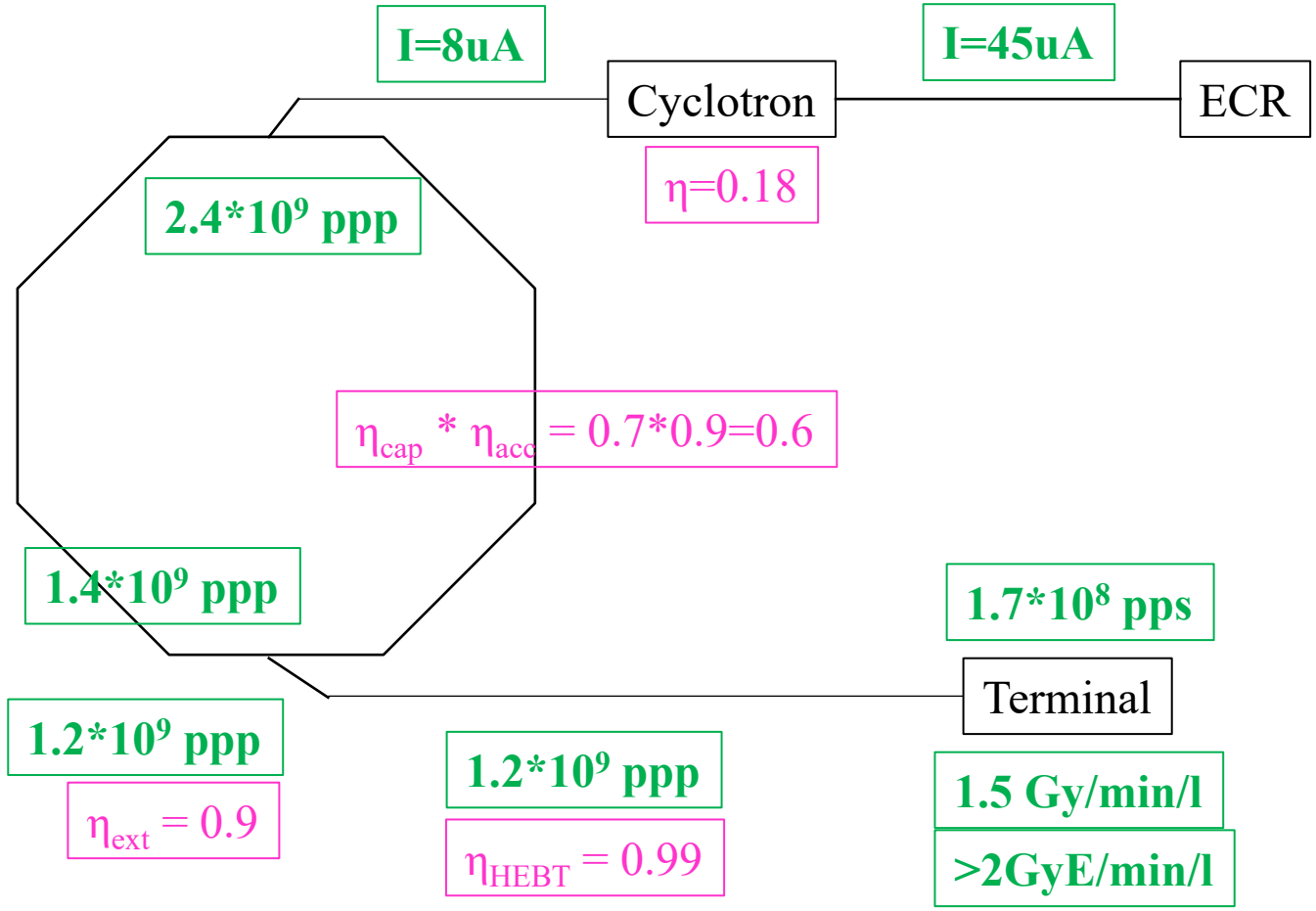


Photograph of the HIMM facility

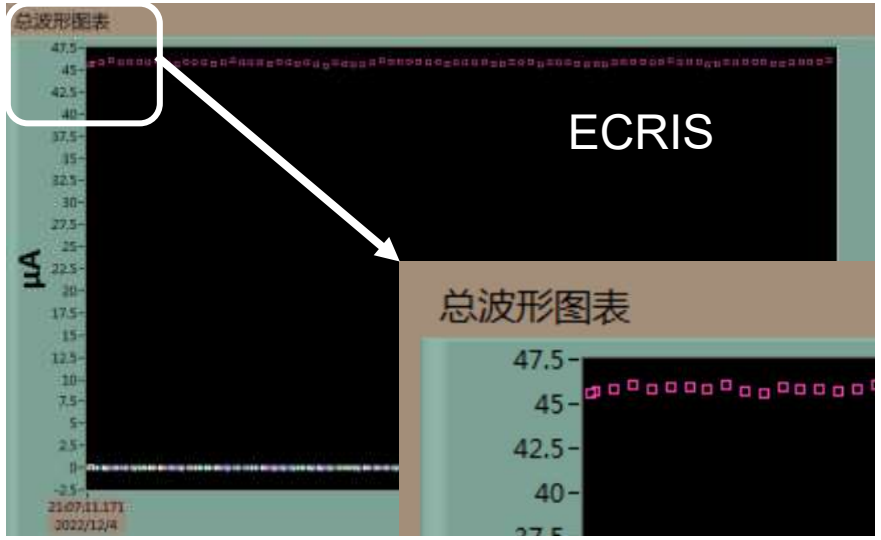
① ② ③ ④

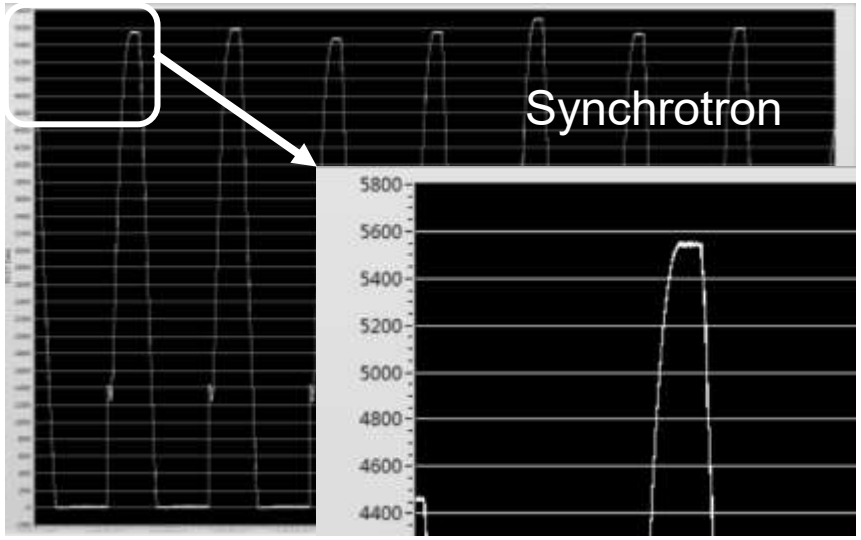
① Synchrotron ② Cyclotron ③ HEBT ④ Data center

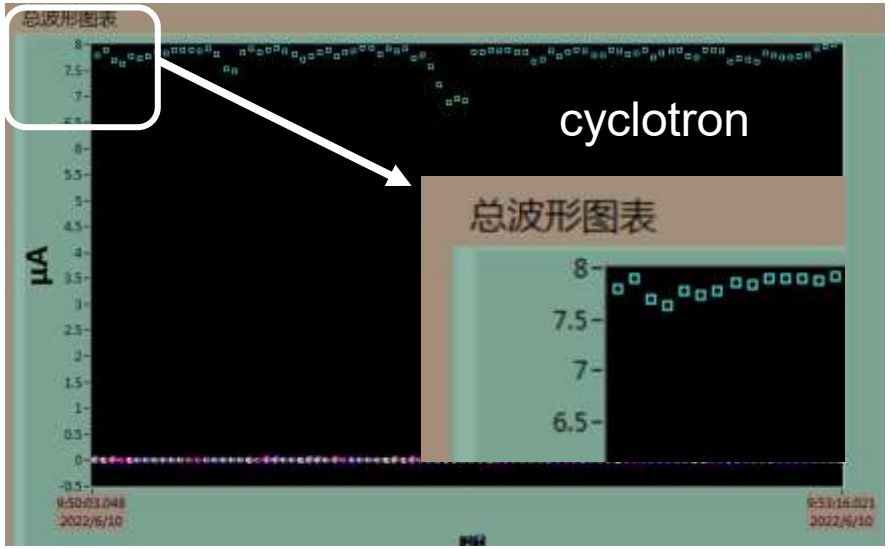
Beam intensity----generalization

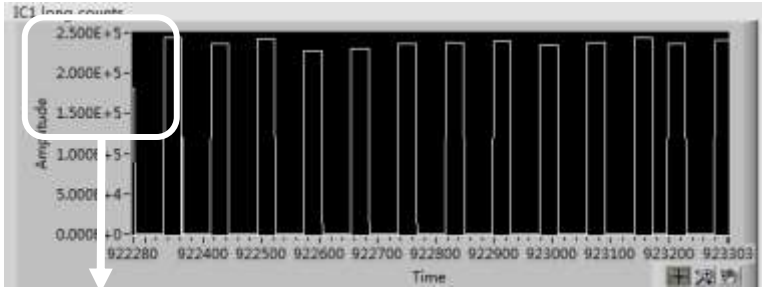


Beam commissioning

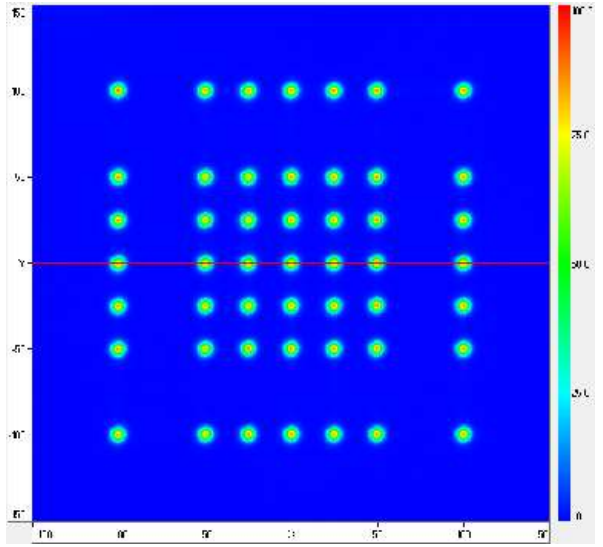






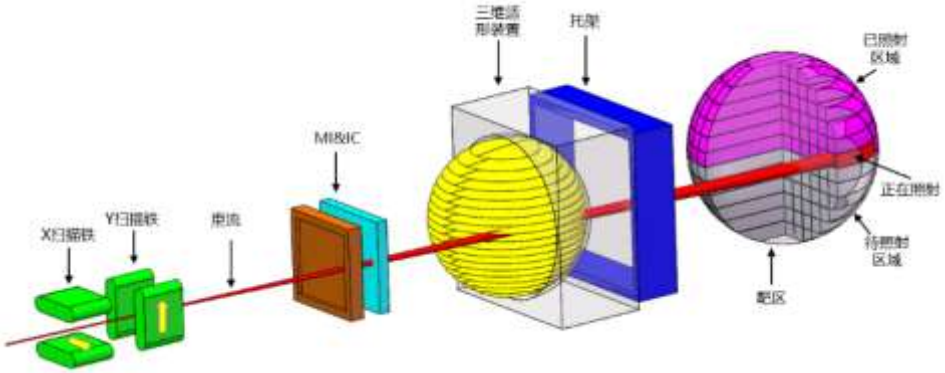


Particle number:
IC count × coefficient
=2.45e5*5000=**1.22e9** ppp

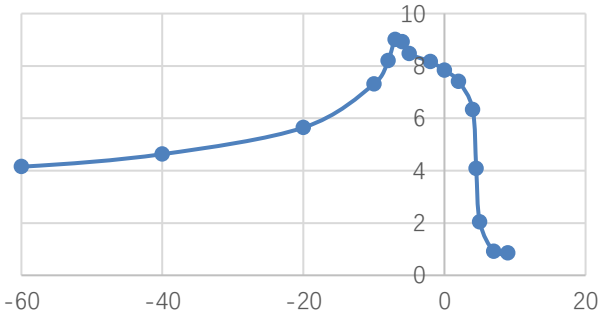


Carbon ion Flash Cell irradiation experiment

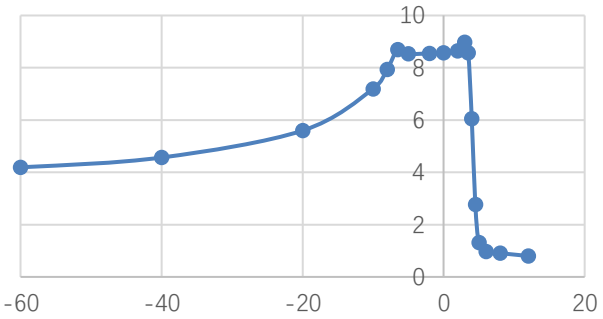
- Dose rate：40Gy/s、60Gy/s，80Gy/s，120Gy/s
- Dose per fraction：1Gy、2Gy、4Gy、8Gy、12Gy
- Target size：20mm*20mm*10mm，and 20mm*20mm*4mm

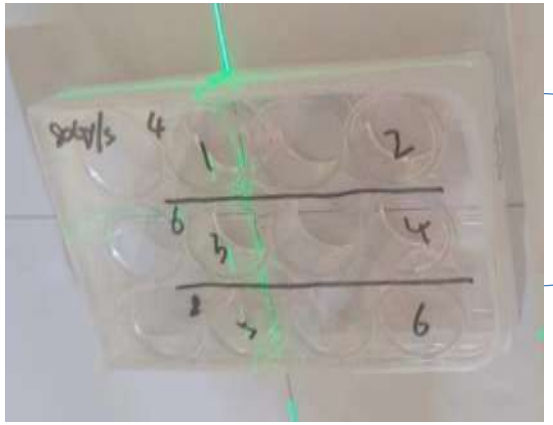


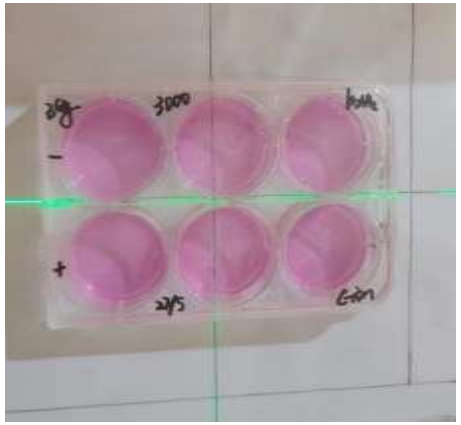
RF10-uniform distribution of RBE dose (assumption)



RF10-uniform distribution of physics dose

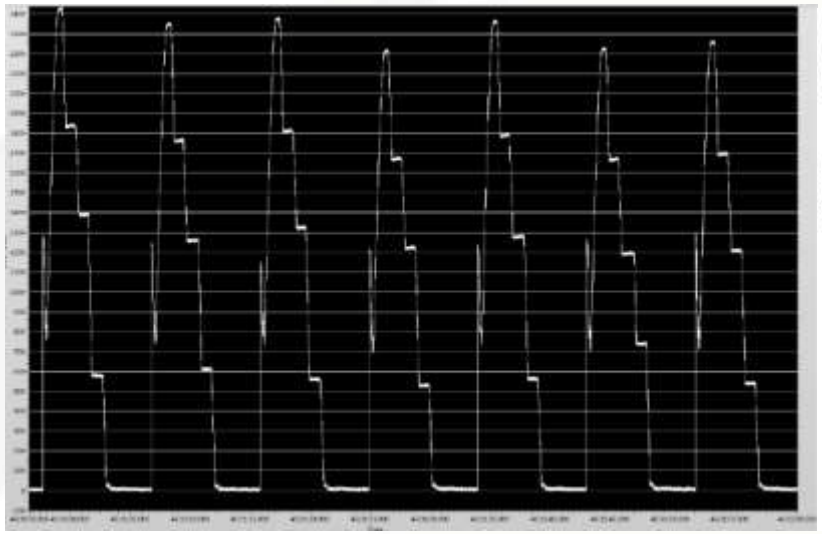


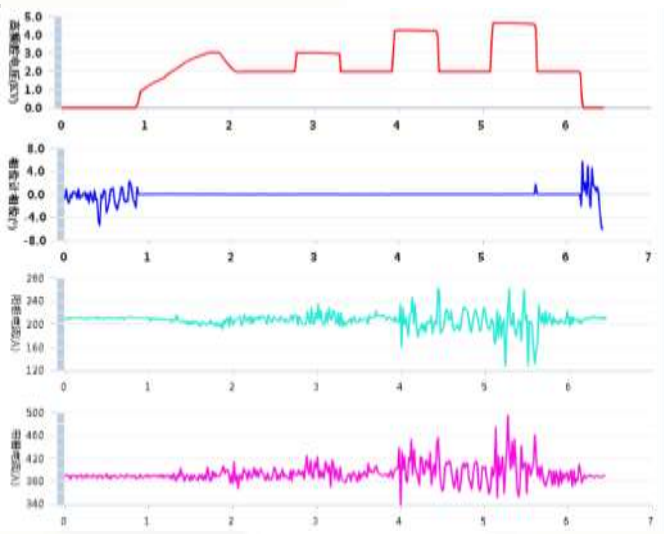


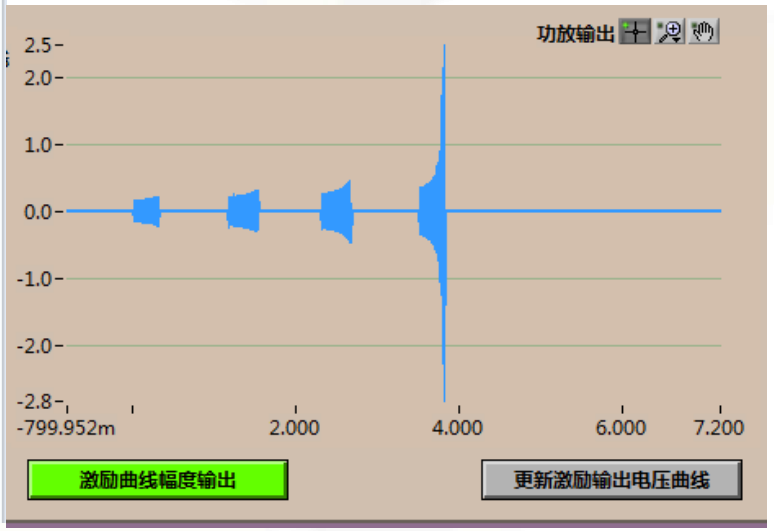


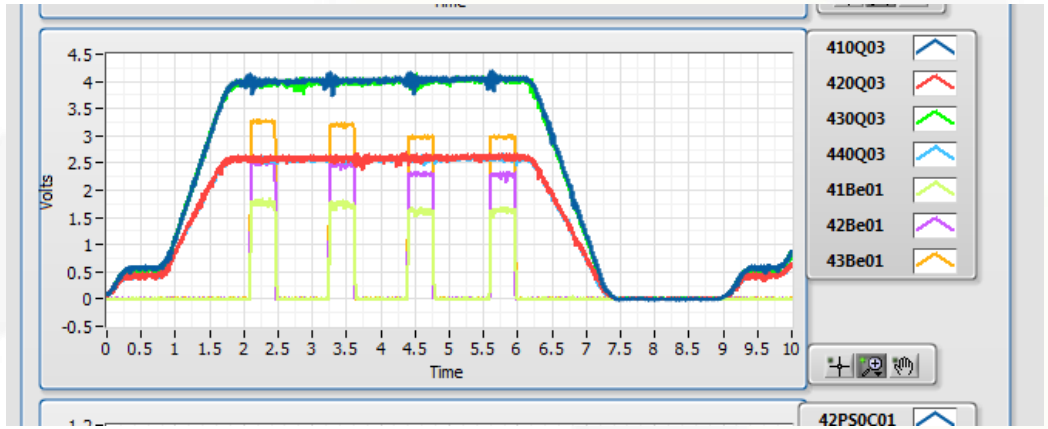
Multi-Energy operation

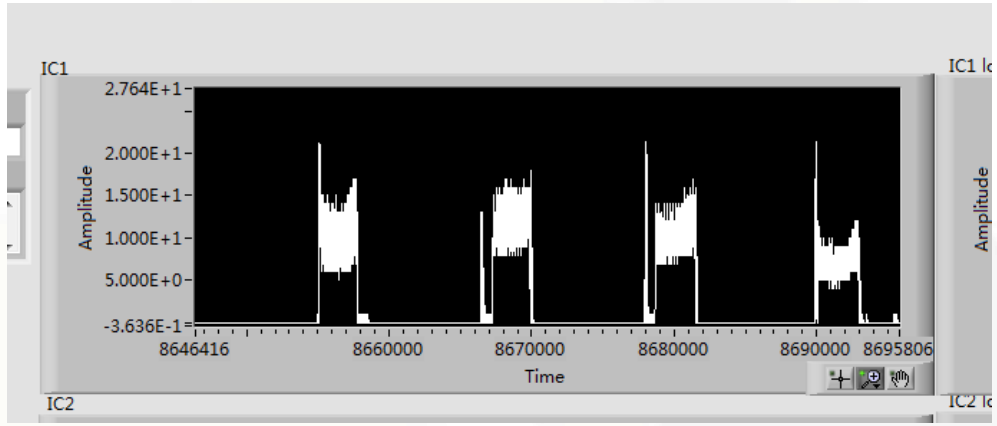
- Test in HIMM-2, the beam energies are 261.03/263.23/265.43/267.62MeV/u， the interval of the bragg peak is 2mm.
- The screenshots of the DCCT， RF， TRF， PS， IC, the time interval between different energy is 0.5s.



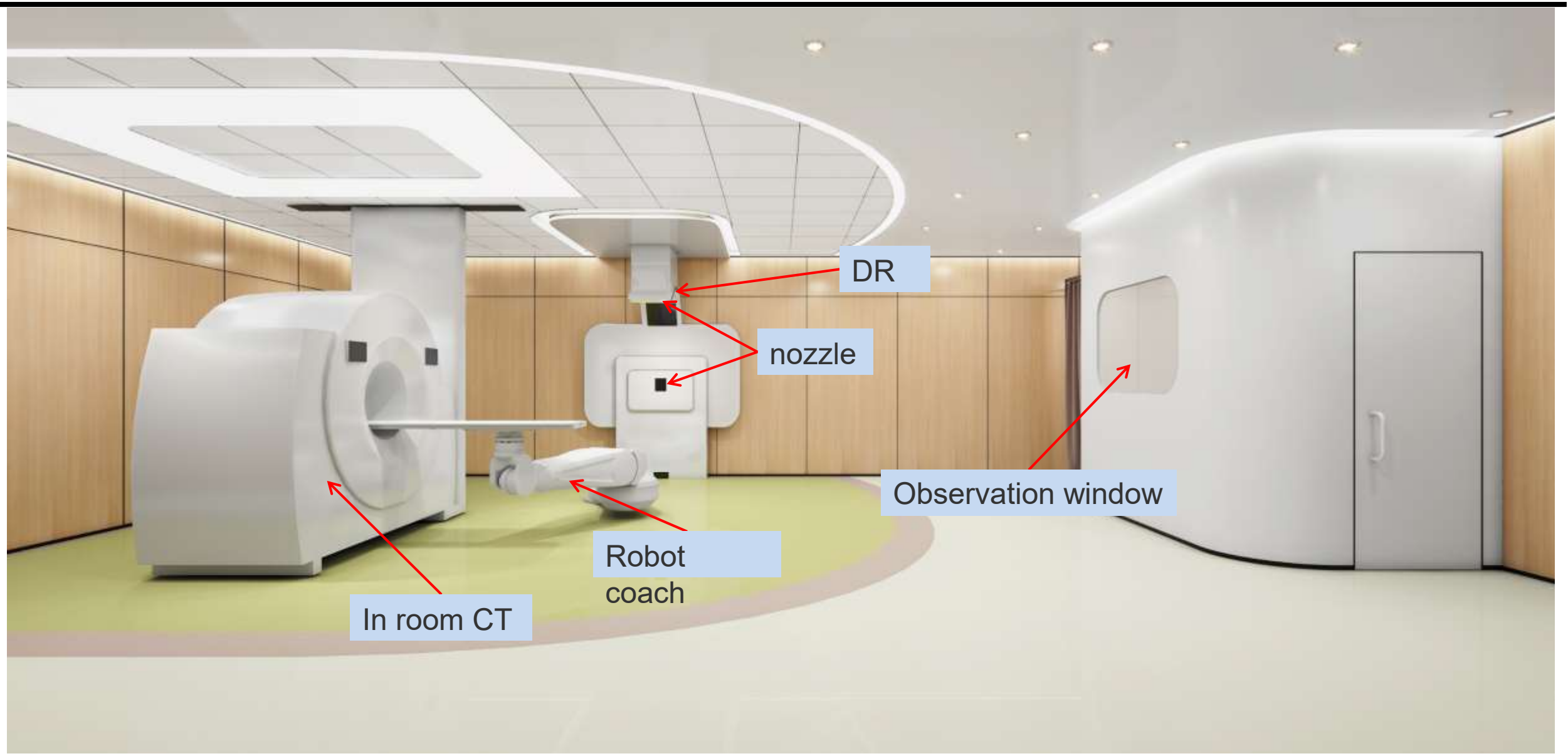








Equipment configuration in the treatment room



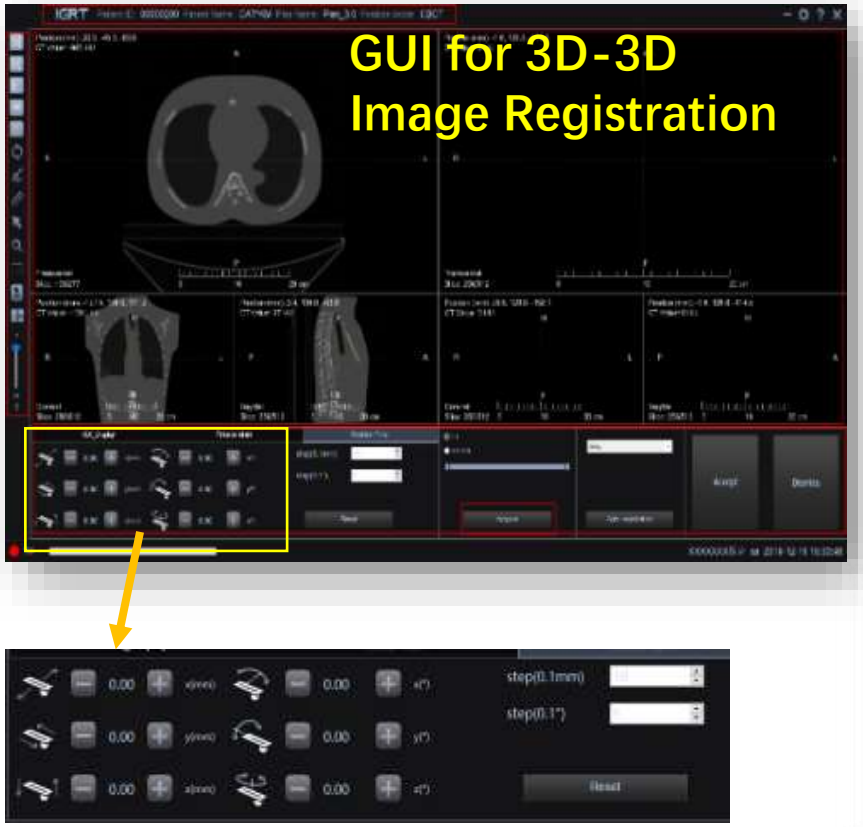
TCS: terminal control system

Imaging Guide Positioning System(IGRT)

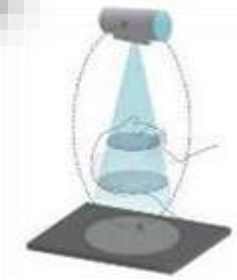
- DR: CT / 2D:3D registration;
- CBCT: CT / 3D:3D registration ;
- CT: CT / 3D:3D registration ;

Matching Accuracy : < 1mm
Time needed to match (3σ) : bone match < 15s; gray match < 20s

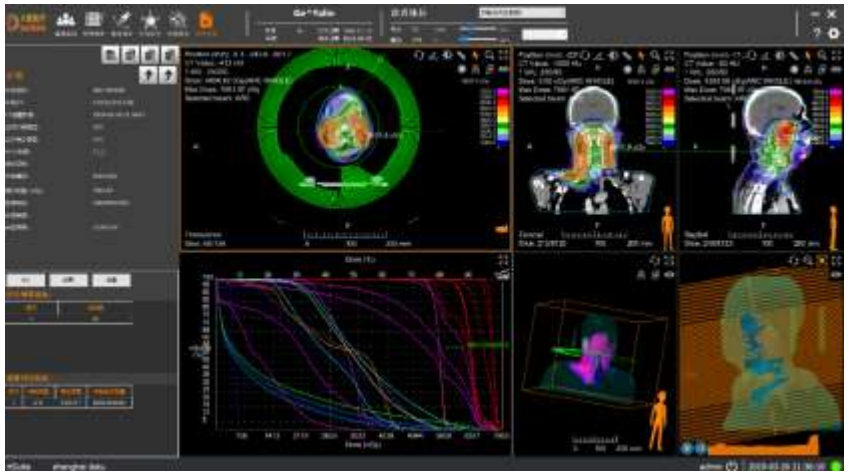
CT/DR

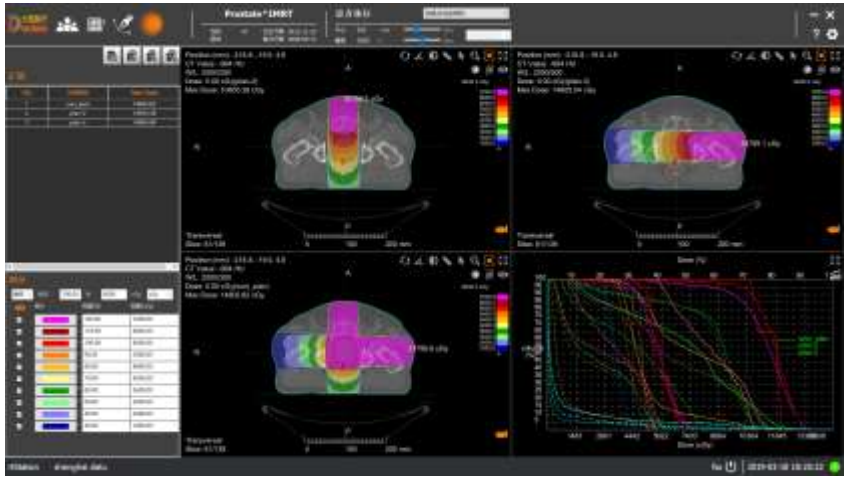


CT/CBCT



TPS: Treatment Planning System





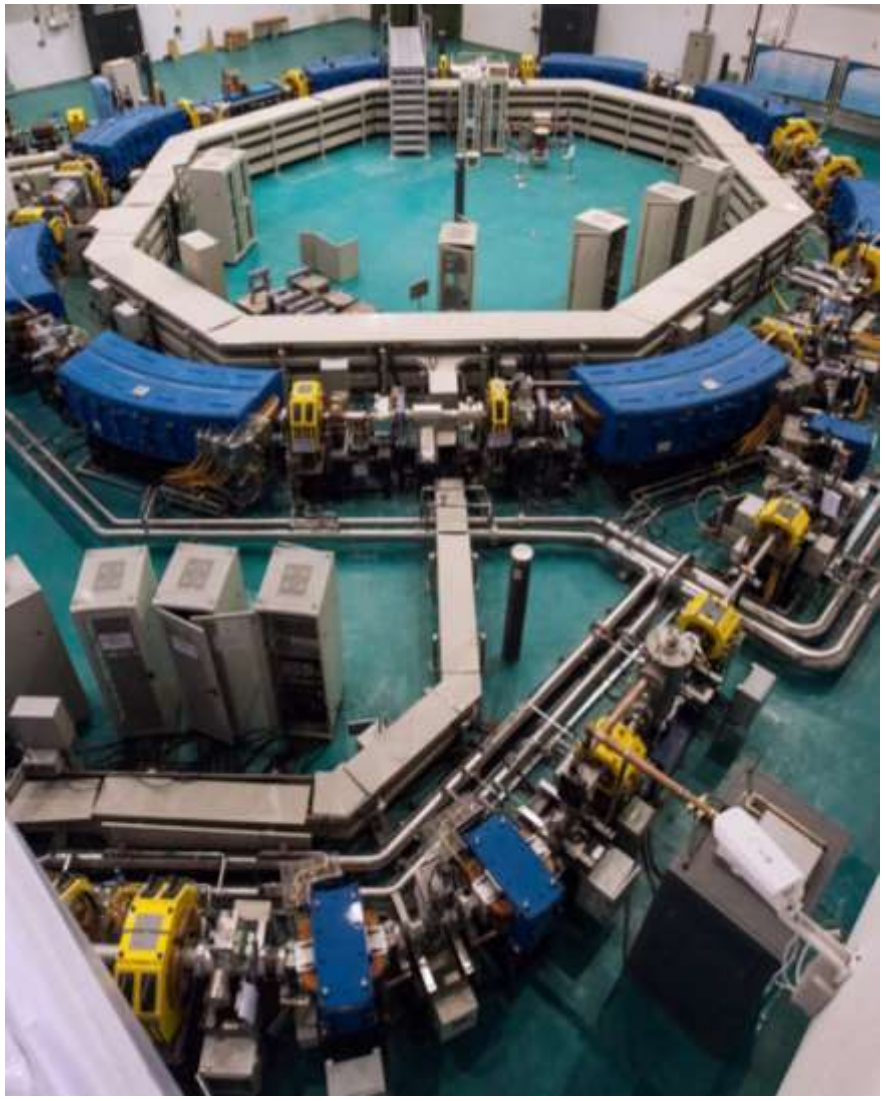
- GPU based optimization engine
- Monte Carlo algorithm is adopted
- multi biological models and multi particle types
- Dose comparison of multiple therapeutic devices (X ray, proton, helium, carbon ion, etc.)
- Multimodal image fusion and registration
- Multi plan dose superposition and dose deformation superposition
- ……

Note: the customer can also choose RayStation

03 Status of HIMM facilities

HIMM-1 milestones

1. Apr. 2014, started the installation
2. Dec. 2015, beam commissioning finished
3. May 2018, get the test reports from CFDA
4. Nov. 2018 –May. 2019, clinical trials (46 cases)
5. Sep. 2019, get the certificate from CFDA(NMPA)
6. Mar. 2020, hospital started operation

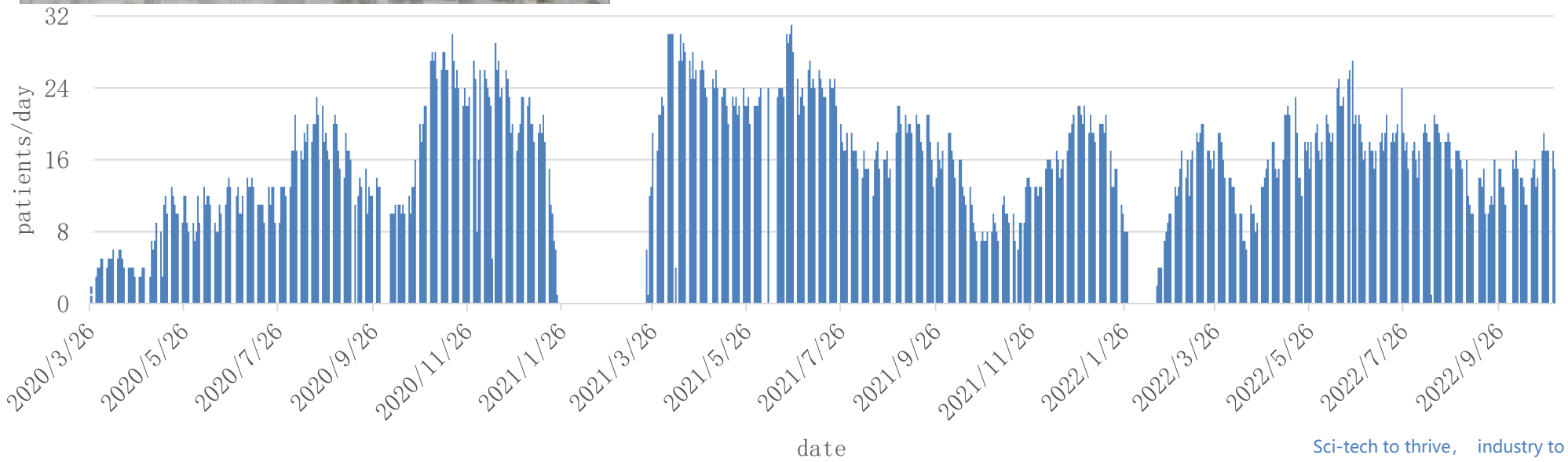


Status of HIMM-1

- March 26, 2020 started the operation

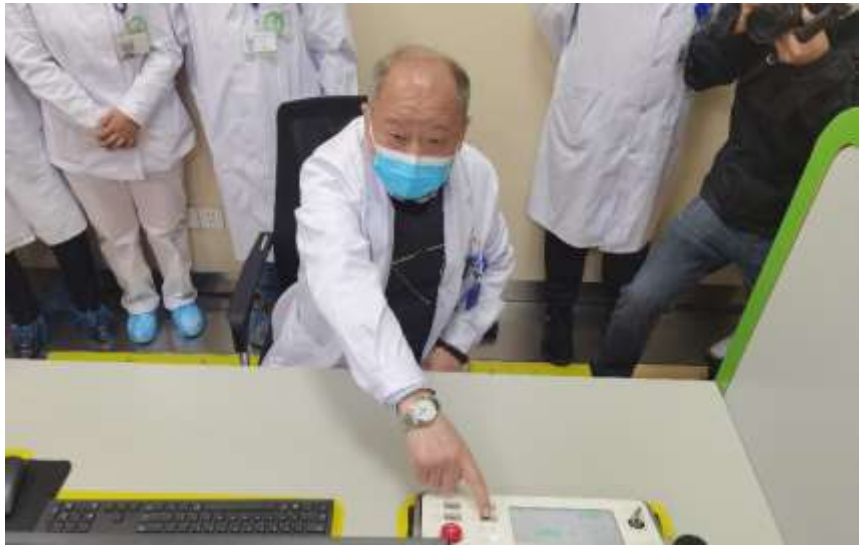
Number of patients

year	2020	2021	notes
patients	206	256	<10 months, 1 treatment room
Operating ratio	97.4%	97.1%	<10 months, 1 treatment room



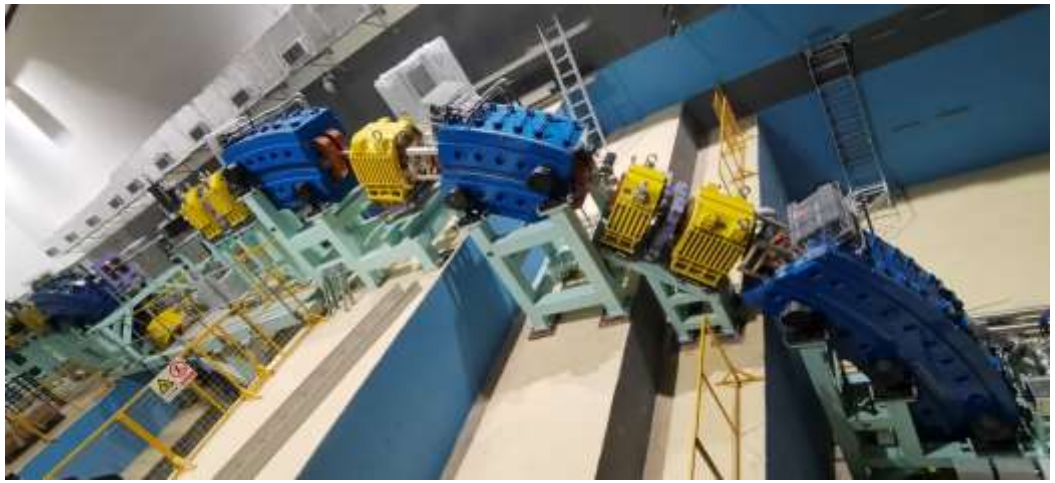
HIMM-2

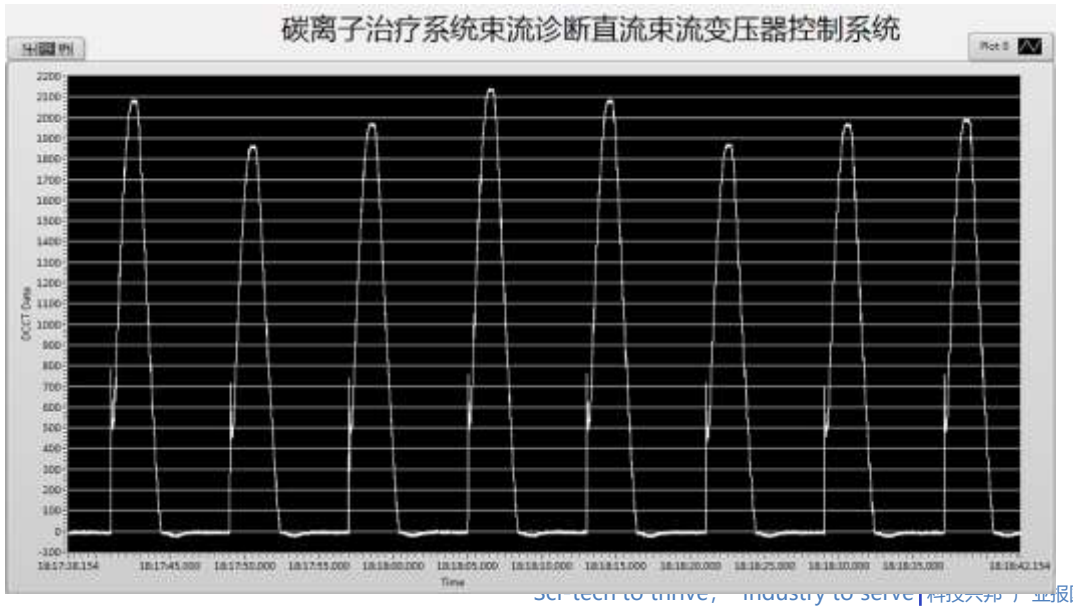
- Oct. 2022.10， The clinical trial started
- Will start operation at the beginning of 2023



HIMM-3

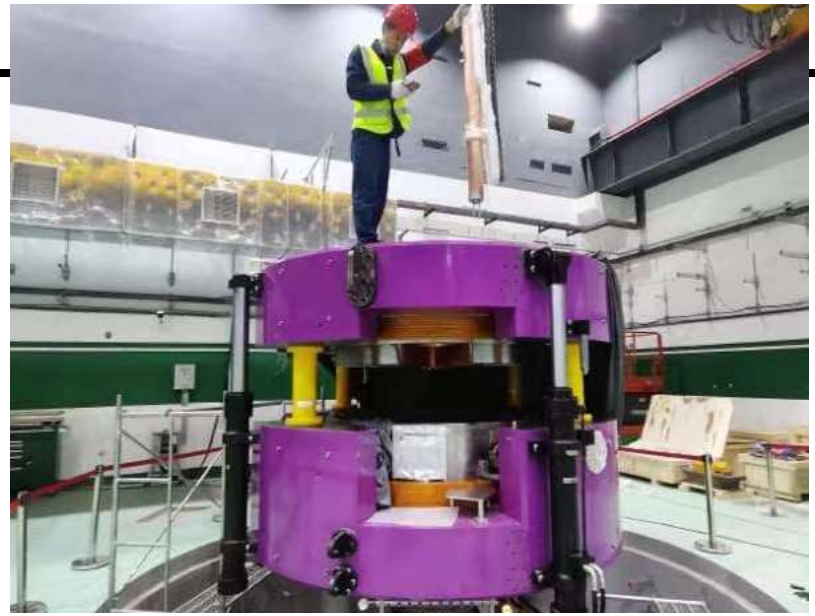
- Contract was signed in Nov. 2019
- Installation started in May 2022
- beam commissioning finished in Dec. 2022
- Expected to be put into clinical use in May 2023





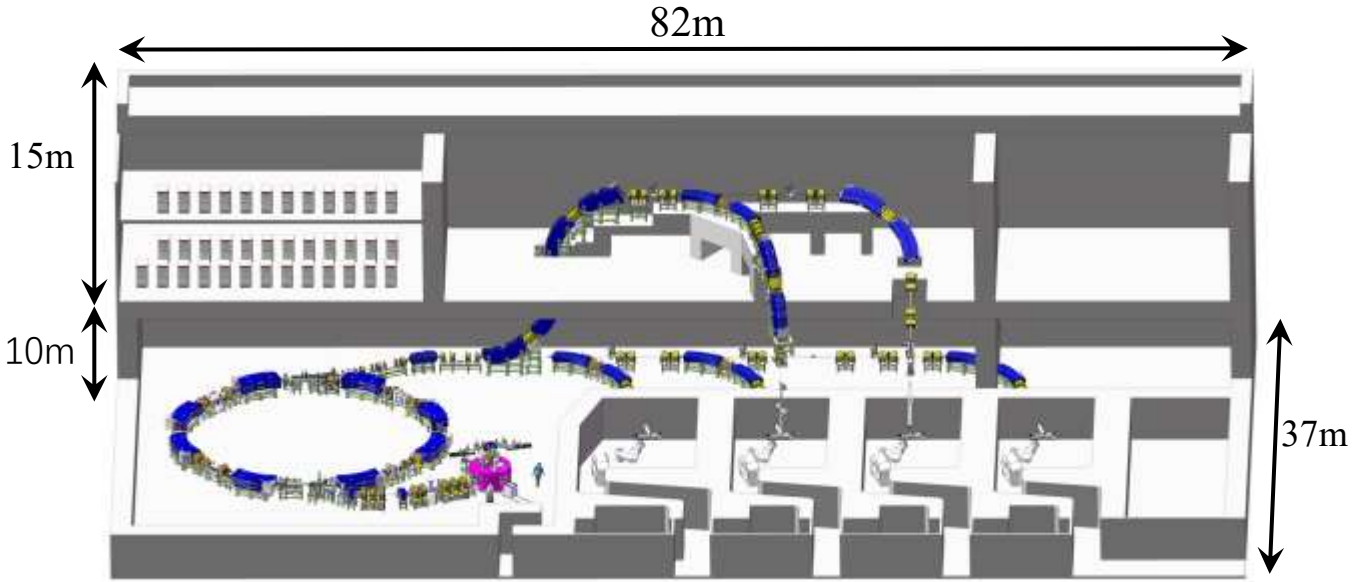
HIMM-4

- Nov. 2022，Installation started
- Expected to be put into clinical use in May 2023



HIMM-5

- Contract was signed in Nov. 2020
- Expected to be installed in Feb. 2023

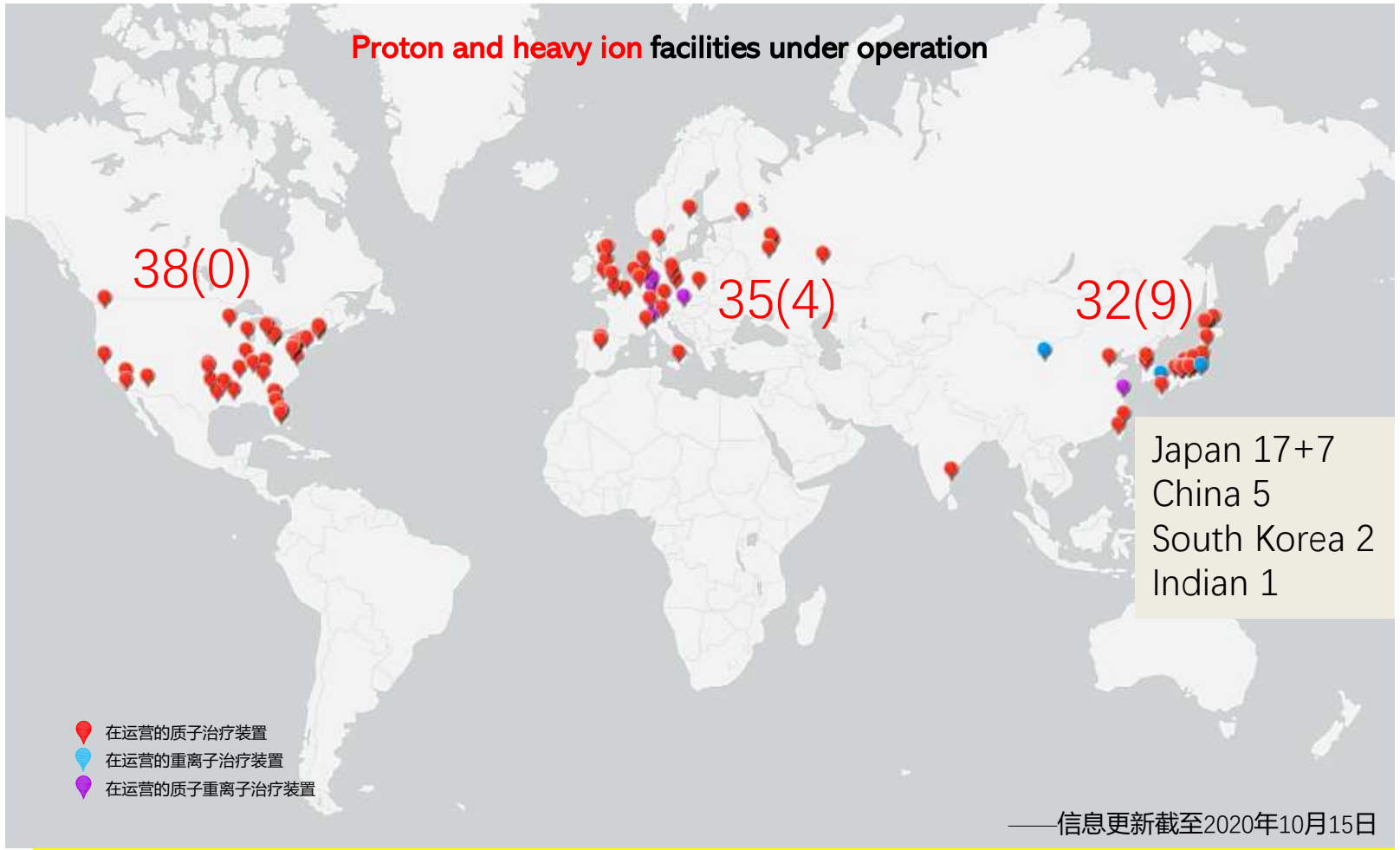


HIMM-6/7

- Contract are signed in 2021 and 2022
- The civil design has been completed and the building construction is in progress

04 Prospect

Particle therapy facility in operation world wide



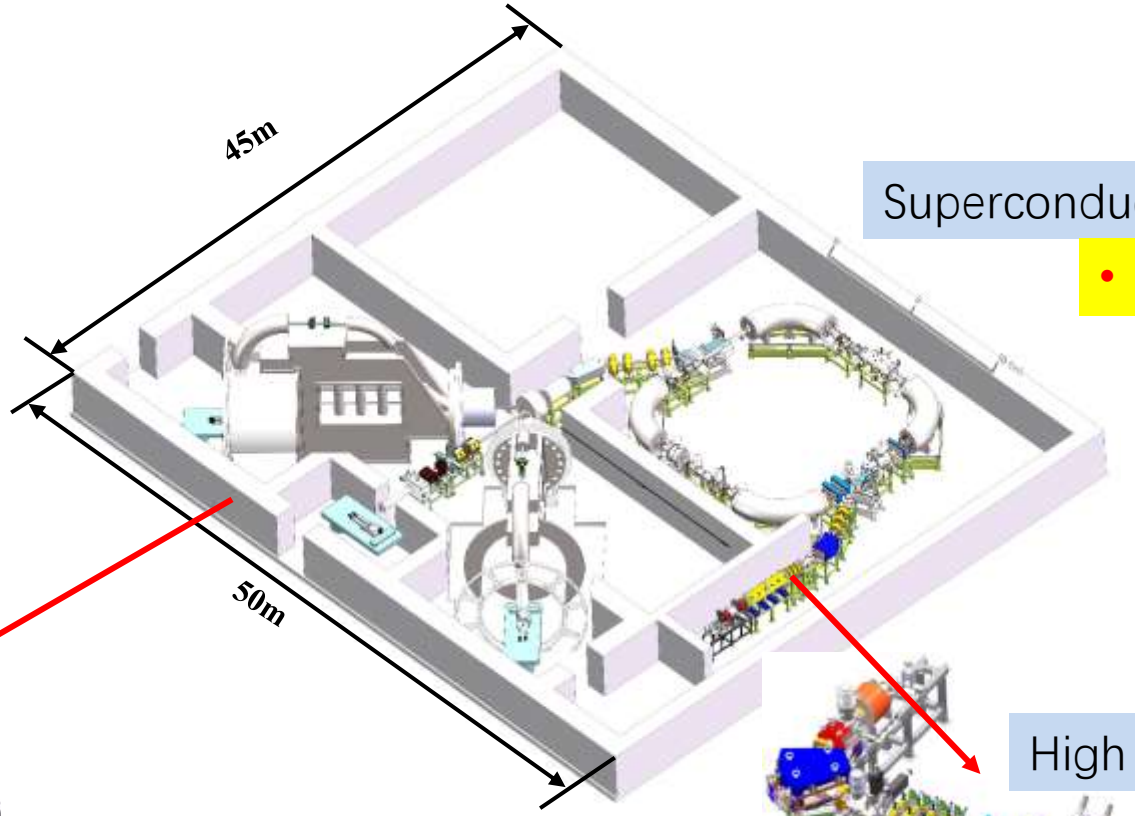
There are over 14,000 linear accelerators in global, over 3,300 after_loading units in global, but only 104 particle therapy facilities in global!
It has huge development space for particle therapy in the future!

The proton and heavy ion radiotherapy facilities are mainly located at the countries in America, Europe and Asia. The total number of facilities is 105, which are distributes as follows:

- America has 38 operating proton therapy facilities
- The 35 facilities in Europe are mainly located at Germany, France, Italy, Spain, Netherlands, Russia etc.
- The 32 facilities in Asian are mainly located at Japan, China, South Korea and India.

Reduce the size of the facility

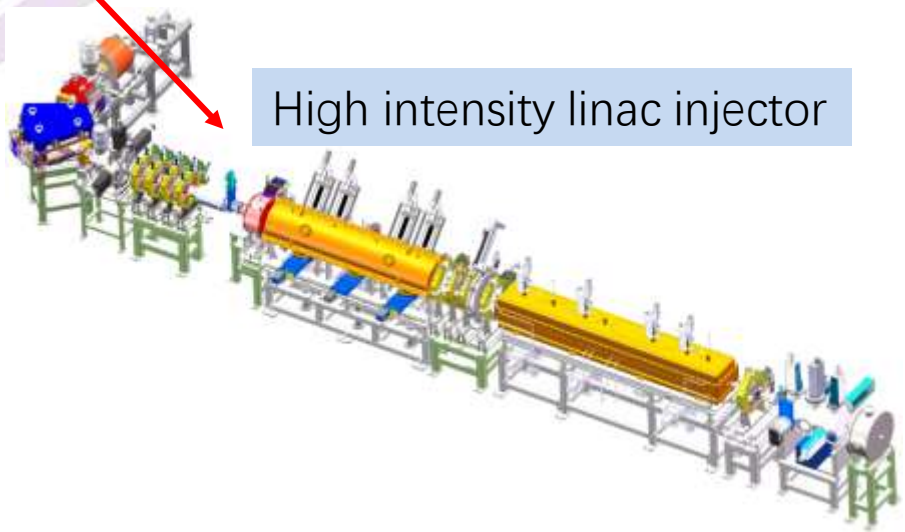
- the total number of particle therapy facility in operation is 104, but only 13 of them are heavy ion facility. Why?
- Size of the conventional heavy ion facility (4 treatment rooms): **70m×45m**



Superconducting heavy ion facility

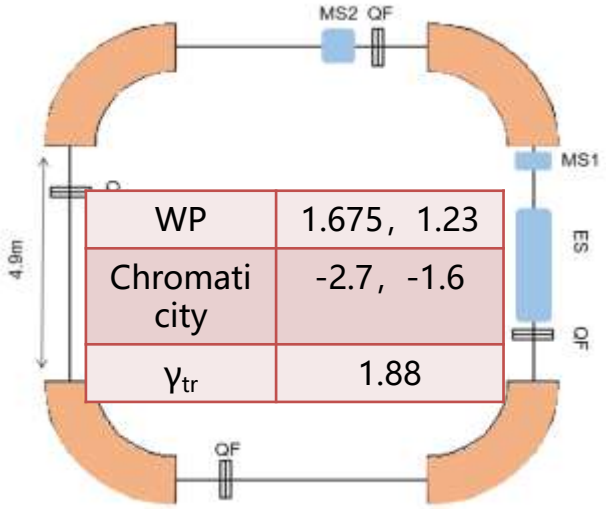
- **Footprint:50m×45m**

Superconducting gantry

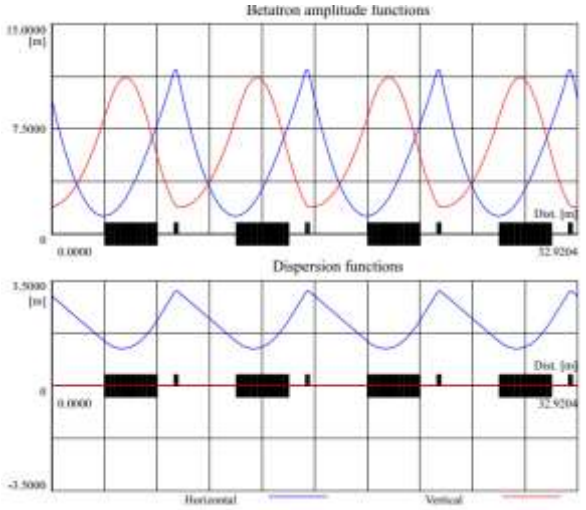


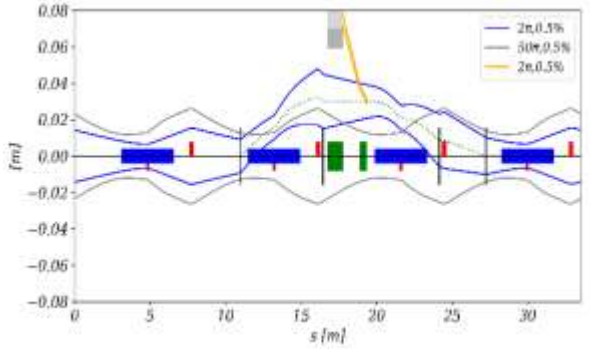
High intensity linac injector

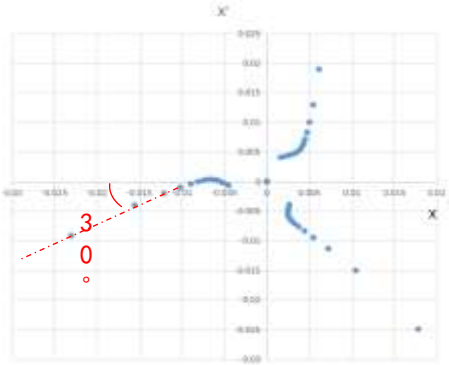
Synchrotron with superconducting magnets



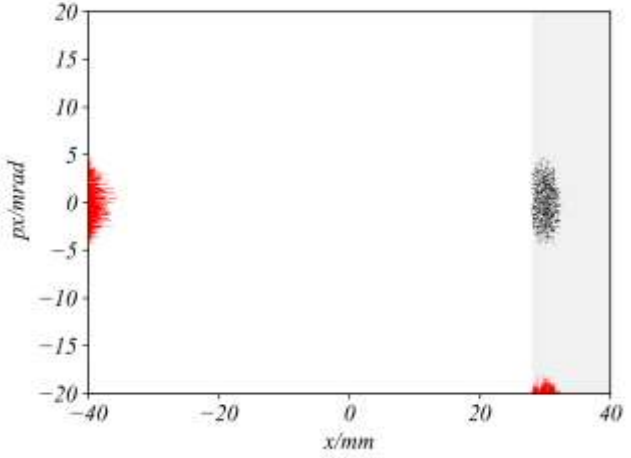
WP	1.675，1.23
Chromaticity	-2.7，-1.6
γ_{tr}	1.88

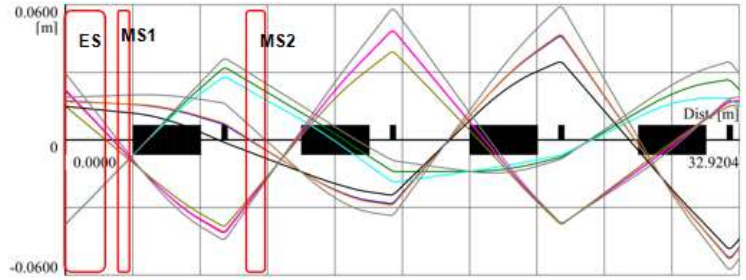




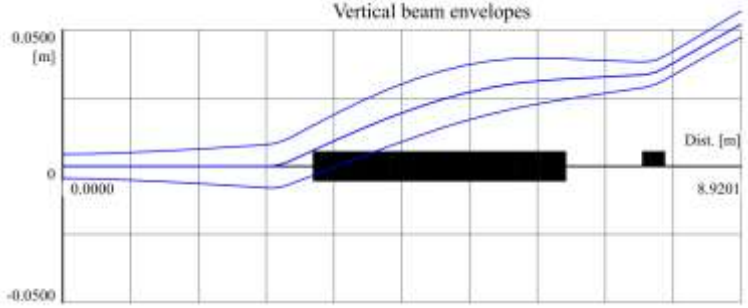


phase space (turn=1)





Vertical beam envelopes

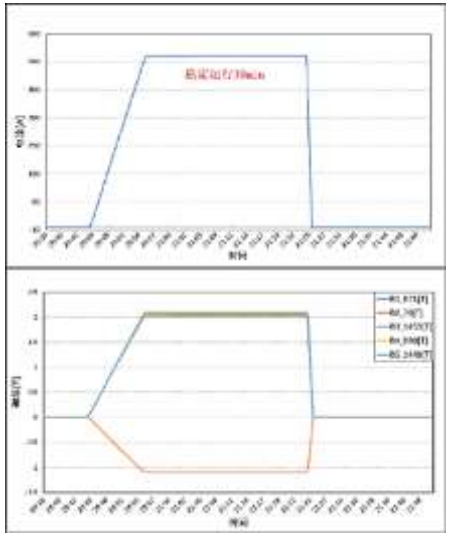


Testing of the superconducting magnet

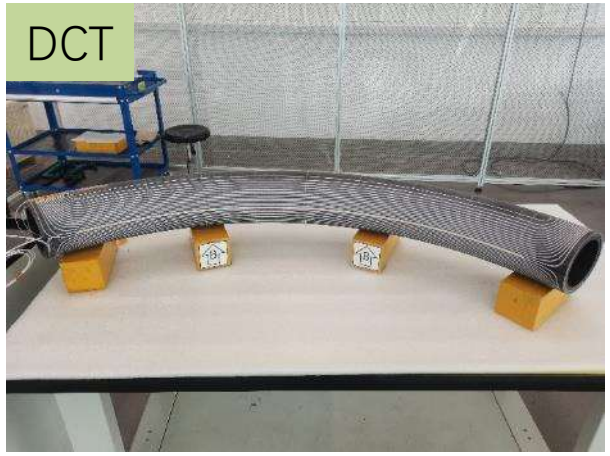
First generation: straight dipole

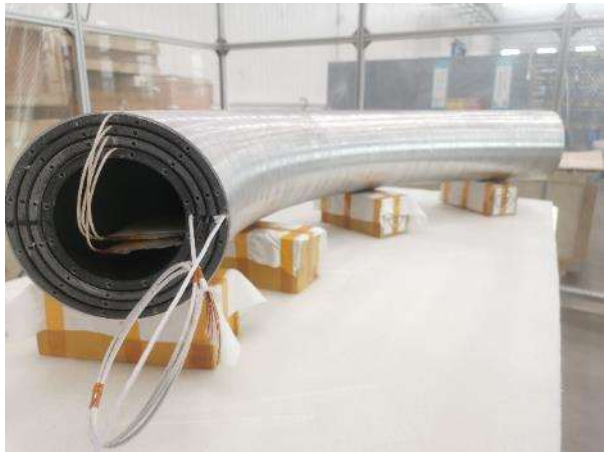
Second generation: Arc-shaped dipole

CCT



DCT





Prospect

- Currently, there are totally 8 HIMM facilities in operation or under construction in China. This number will be expanded to 15 in the next 5 years as our prediction.
- In the next 10 years, we hope that we can assembly more than 30 HIMM facilities worldwide (including 25 in China).
- The small size of the synchrotron with superconducting magnets will replace the old version (conventional magnet) in next 5 years.

Thank you for your attention!