Carbon Ion Therapy at Lanzhou

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Outline of this talk

01 History Review and key technology development

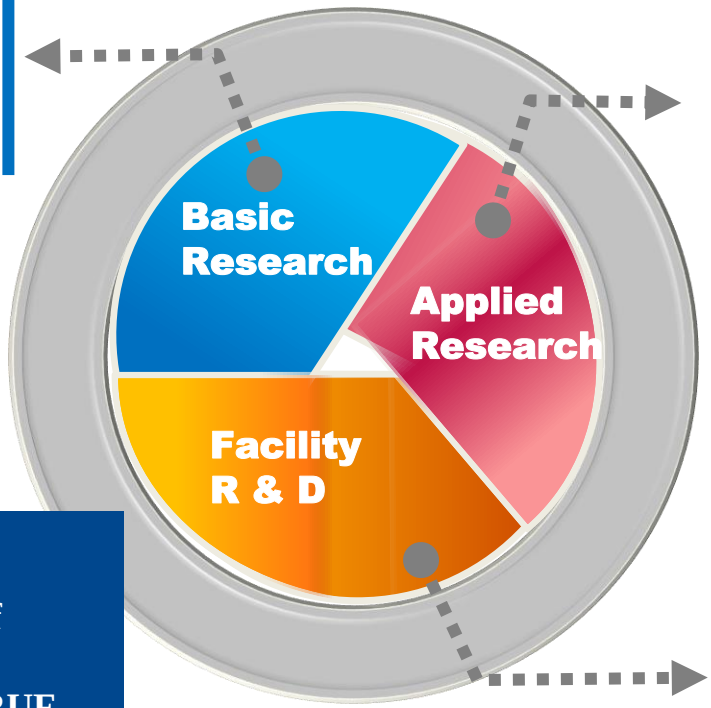
02 Carbon ion therapy demon-facility developed by IMP

03 Challenge and future plan

IMP and research fields

IMP is the biggest nuclear physics research center in China for heavy ion basic-science and nuclear technology application

- Nuclear physics
- Atomic physics
- Nuclear chemistry
- Radiation chemistry
- Material science
- Hadron physics
- High Energy Density physics
- Accelerator physics



- Radiation biology
- Radiation medical science
- Radiation material
- Advanced nuclear energy
- Nuclear-detector technology

- Ion Accelerator
- Large scale experiment facilities
- Special experiment facilities

High Priorities at IMP

- Precision mass measurement of exotic and stable nuclides
- CIADS, HIAF , ADANES, ADRUF
- Tumor therapy & mutation breeding
- Material sciences

- 850 staff+325 students
- 600-700 M CNY/per year

IMP Existing Facility: HIRFL

Heavy Ion Research Facility in Lanzhou (HIRFL)

- 85% users from domestic institutions
- 15% users from abroad

SSC (K=450)
100 AMeV (H.I.), 110 MeV (p)

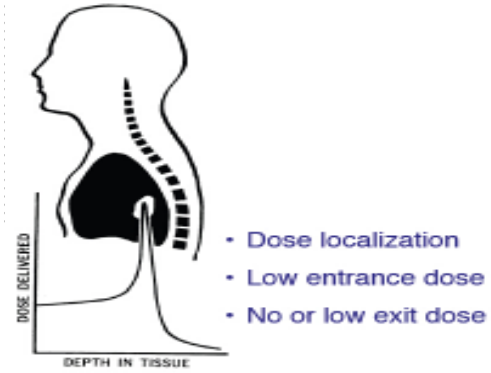
SFC (K=69)
10 AMeV (H.I.), 17~35 MeV (p)

- HIRFL operation time > 7200 hours/y
- Beams from H_2^+ to ^{238}U at different energy

History of heavy ion cancer therapy

HISTORY

1946 — First Proposal
Robert Wilson proposed the use of Bragg Peak for radiation therapy.



1977 — First Patient
The first patient was treated with carbon ion in Phase I trials at Lawrence Berkeley National Laboratory (LBNL).

1994 — First Dedicated Facility
NIRS in Japan built the first heavy ion accelerator for medical use in the world (HIMAC).

1997 — Active Scanning
GSI developed an active ion beam delivery system called raster scanning. A target volume can be painted in three dimensions with a tightly focused pencil beam.

2006 — Ion Therapy in CHINA
From November 2006 to July 2013, 213 patients were treated with carbon ions at Heavy Ion Research Facility in Lanzhou (HIRFL),China.

Up to now — Fast Development
At present, more than 8 facilities in operation for carbon-ion radiotherapy in the world.

- Inverted depth-dose distribution
- High relative biological effect (RBE)
- …

Heavy Ion Therapy Development at IMP

With carbon ion beam from HIRFL

Basic research with cells and animals.

1993-

Clinical trial of superficial tumor: 103

2006-2009

Development of treatment technology

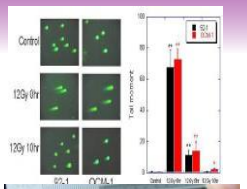
Clinical trial of deep-seated tumor: 110

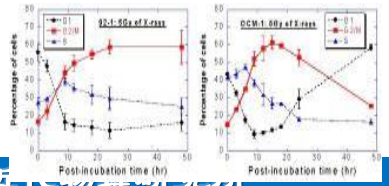
2009-2013

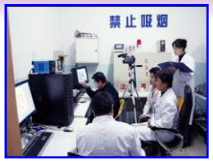
Construction of demo facilities.

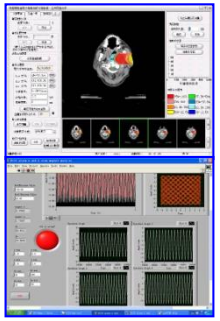
2012-2016

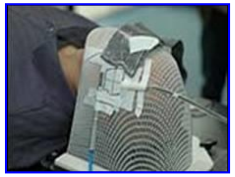
Industrialization

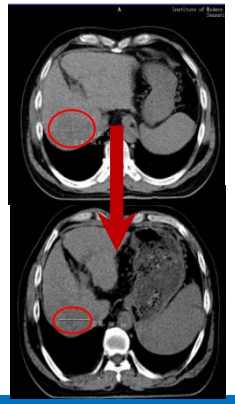


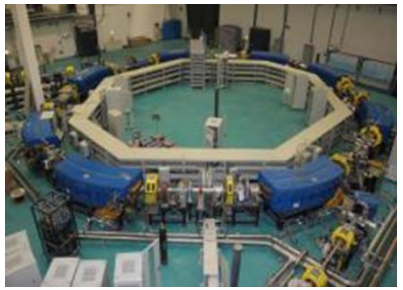




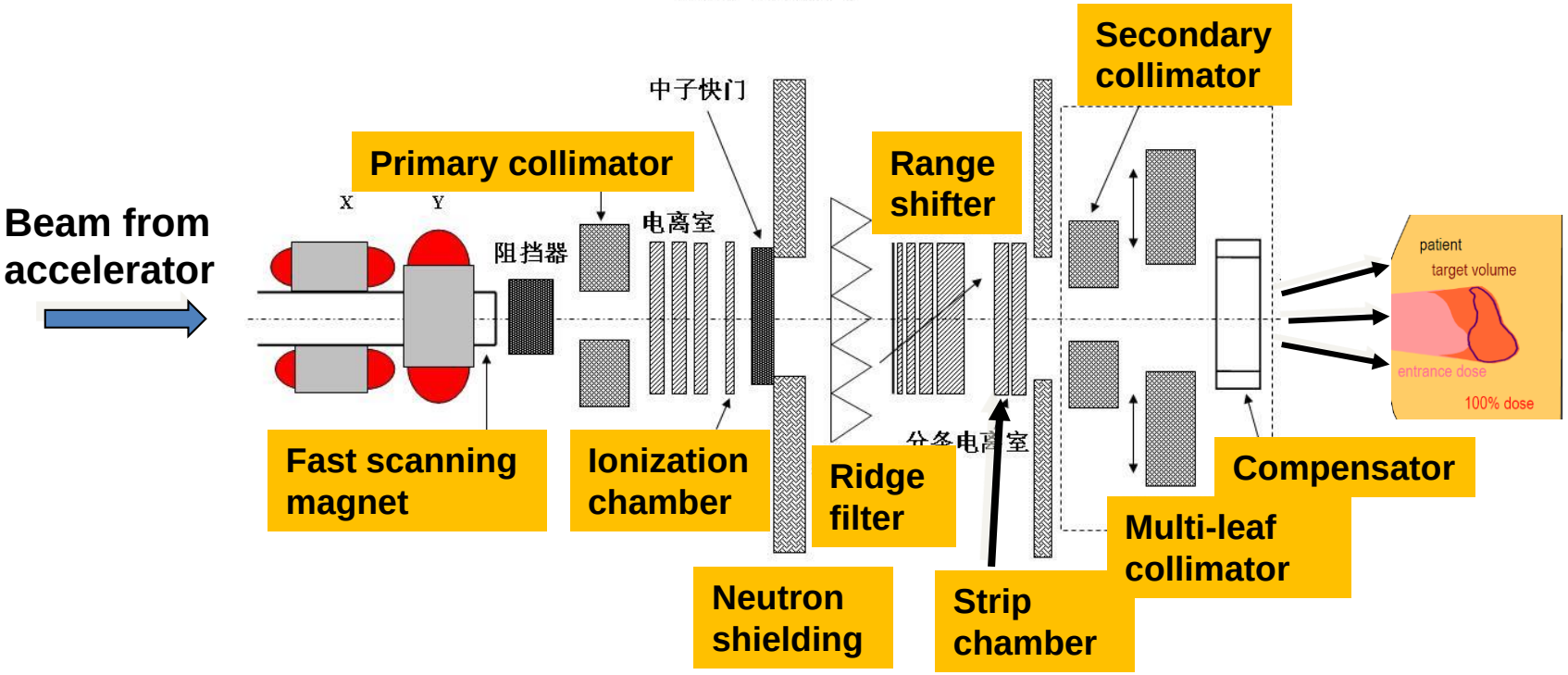






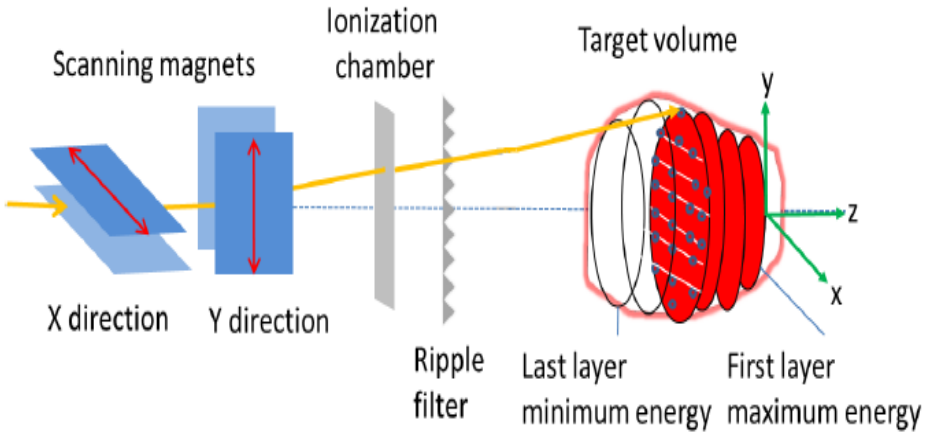


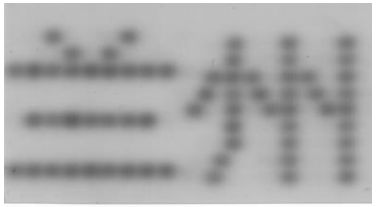
Nozzle Layout of beam delivery

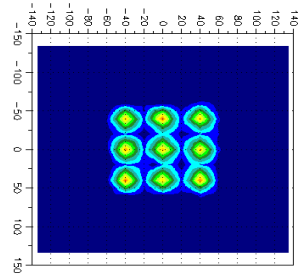


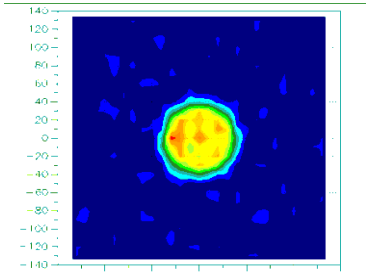
2D conformal, 2D layer-stacking conformal and 3D spot-scanning irradiations

Spot Scanning Beam Delivery

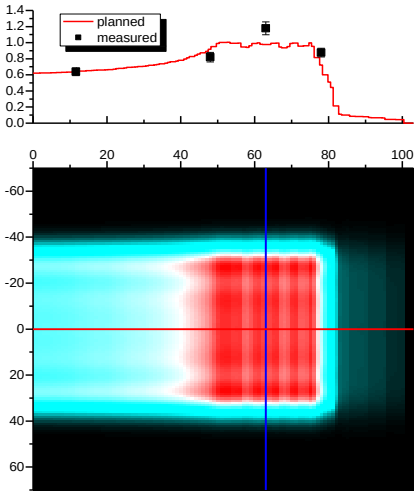


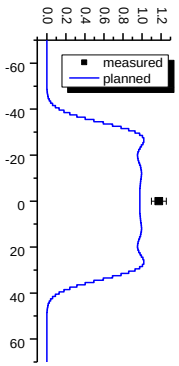


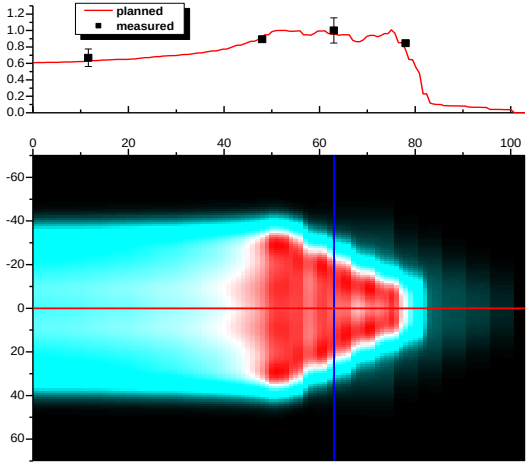


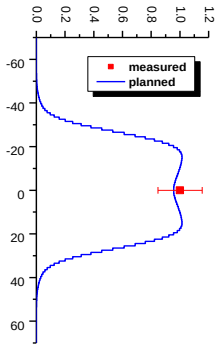


arbitrary shapes delivered by spot scanning





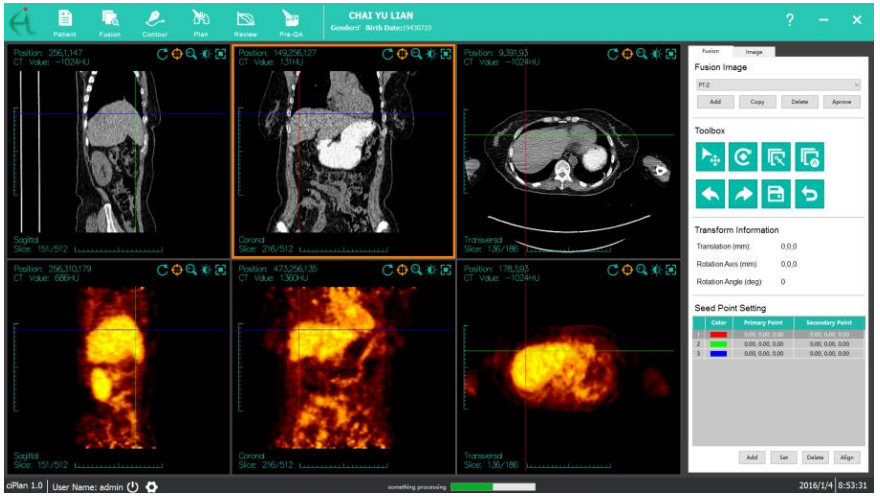




spot scanning beam delivery to different targets (cylinder and truncated cone)

compliance of measured and planned doses within an error of 5%

Carbon Ion Treatment Plan (ciPlan) developed by IMP



- Image preprocessing
- Organ delineation
- 3D reconstruction
- Field set-up
- Dose calculation
- Plan evaluation
- QA data preparation
- Virtual simulation
- Plan comparison
- Auxiliary positioning
- …

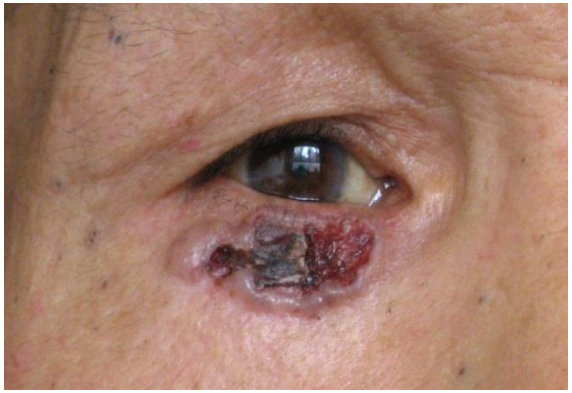
Clinical trial treatment of 213 patients at HIRFL

Treatment time	Treatment depth	Number of cases
November 06-16, 2006	1.6 cm	4
January 07-15, 2007	2.1 cm	9
March 13-20, 2007	2.1 cm	14
August 11-16, 2007	2.1 cm	9
December 15-21, 2007	2.1 cm	15
March 20-25, 2008	2.1 cm	15
September 11-17, 2008	2.1 cm	16
March 02 - 07, 2009	2.1cm	21
Total (2006-2009)		103

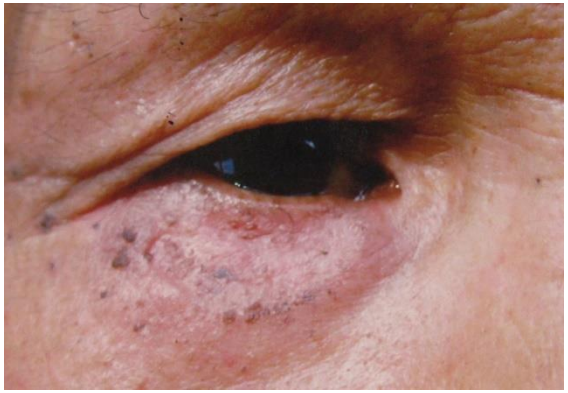
Tumor type	Number
Liver cancer	16
Lung cancer	22
Adenocarcinoma (adenosquamous carcinoma, pancreatic cancer)	3
Brain tumor (brain glioma, malignant meningioma, etc.)	18
Head and neck tumors (eyes, nose, throat, salivary gland, thyroid, etc.)	16
Bone and soft tissue sarcoma	13
Pelvic malignant tumors (rectal cancer, prostate cancer, chordoma, ovarian cancer, etc.)	9
Others	6
Total (2009-2013)	110

Examples of follow-up treatment effects

Postoperative recurrence of basal cell carcinoma



Before

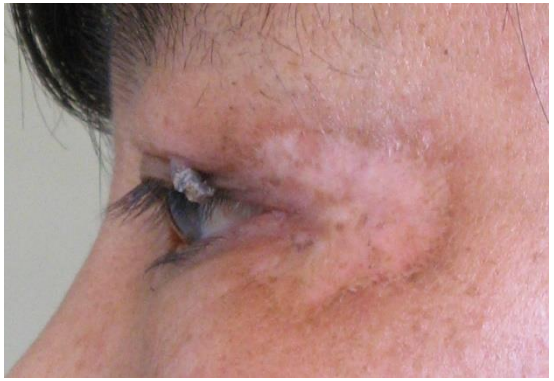


3 years later

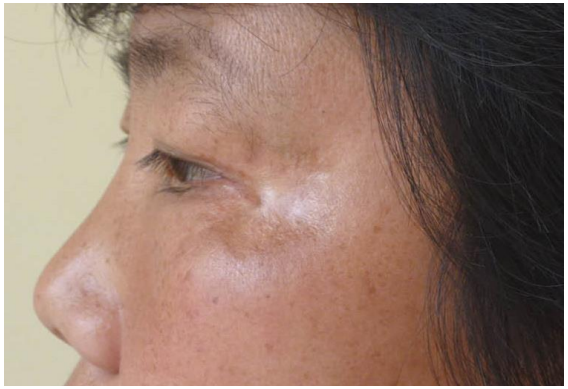
7 years later

Left outer canthus basal cell carcinoma

Before

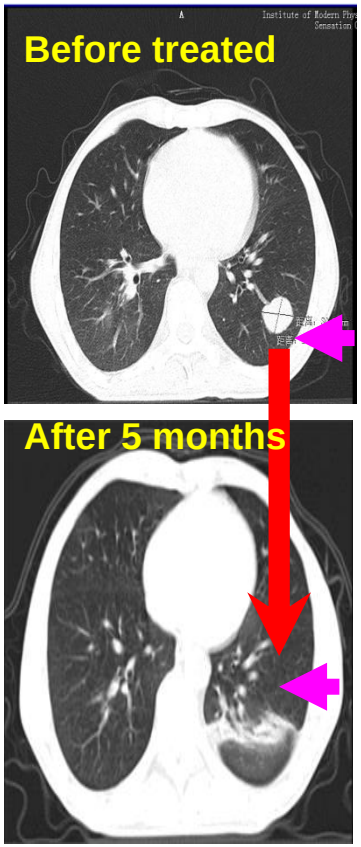


4 months later



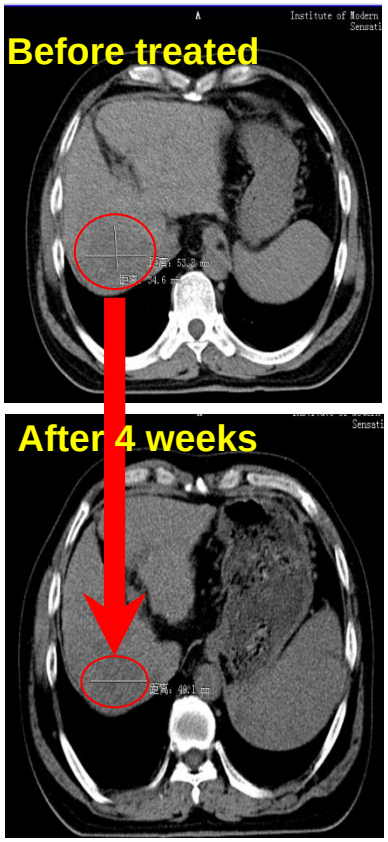
5 years later

Examples of follow-up treatment effects



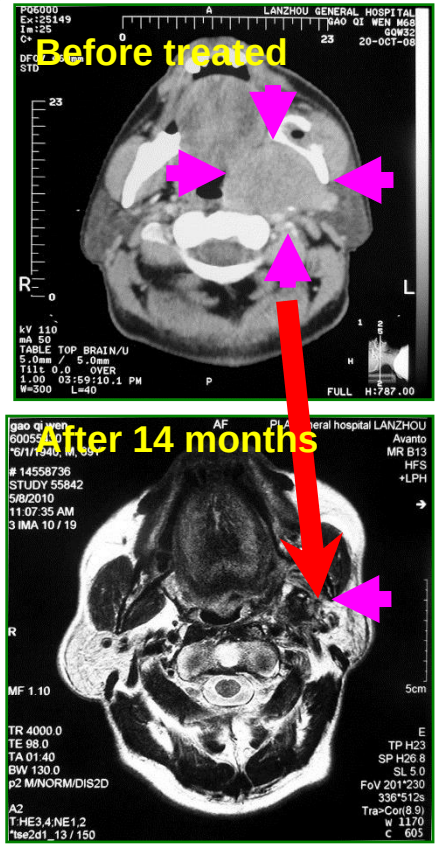
metastatic carcinoma of lung

disappears



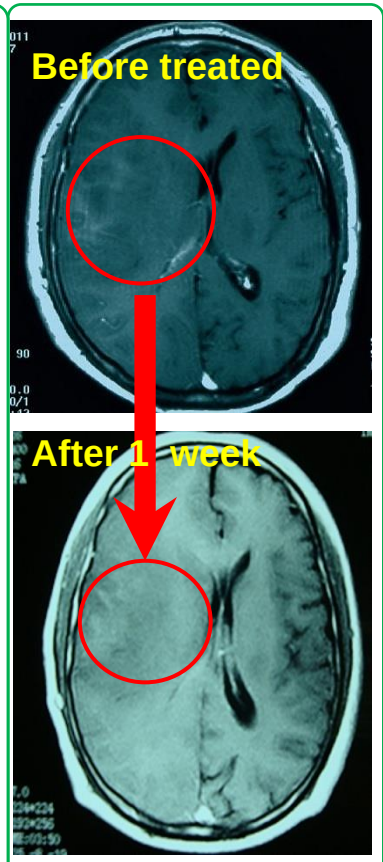
primary carcinoma of liver

reduces 30%



cell carcinoma of salivary gland

disappears



Brain glioma

reduces 10%

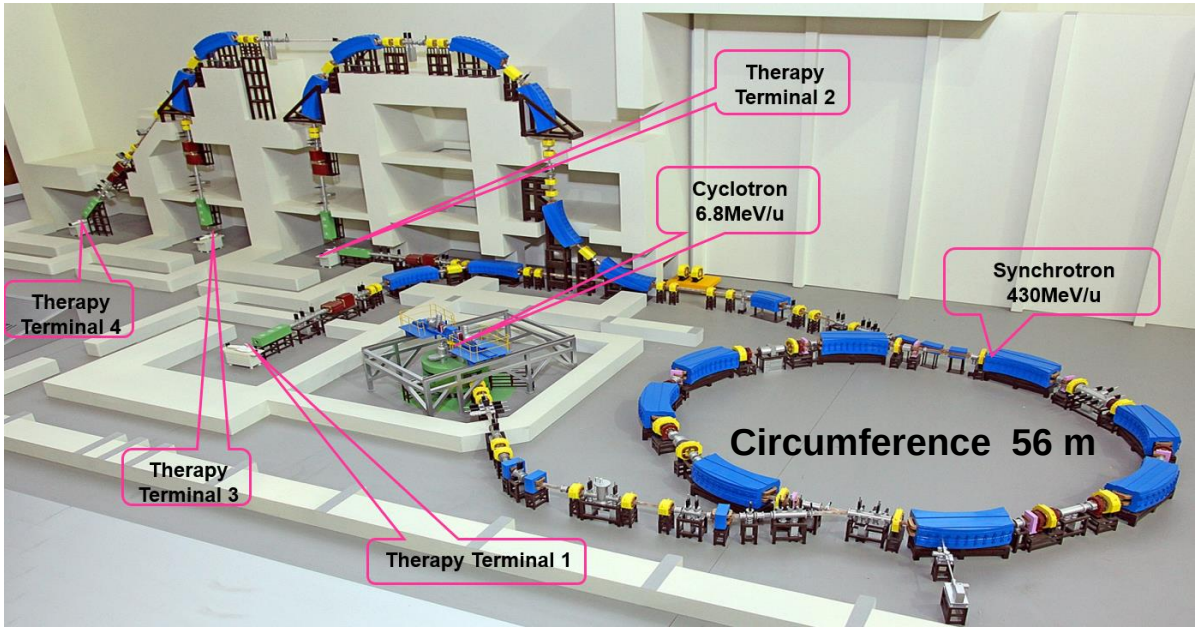
prostatic carcinoma

reduces 30%

Progress of Carbon Ion Therapy Demon- Facility Developed by IMP

Wuwei Demo-Facility for Carbon Ion Therapy

Combination of cyclotron injector + striping injection+ synchrotron



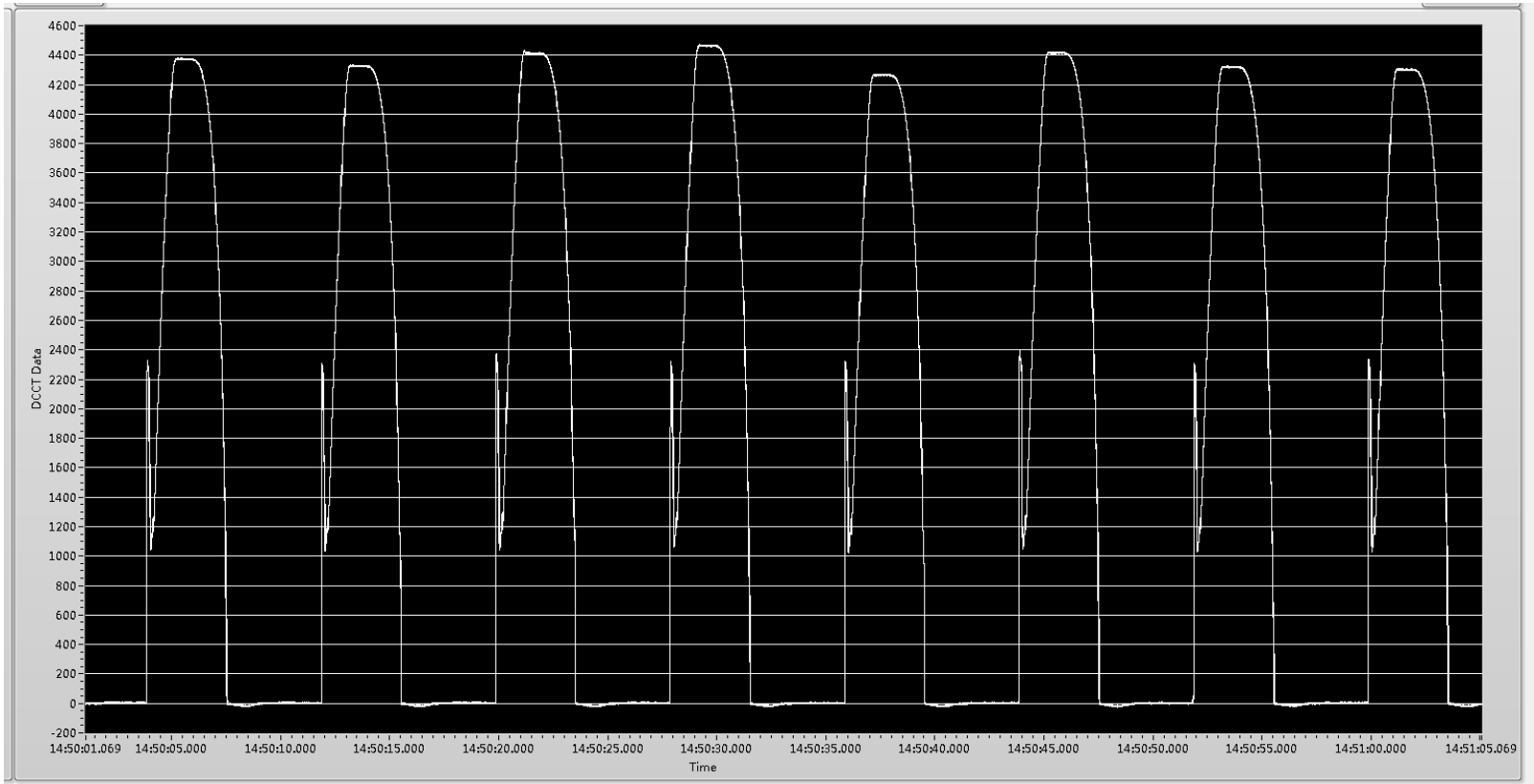
- $^{12}C^{6+}$ beam
- E: 100-430 MeV/A
- I: 0.5-1.0 $\times 10^9$ ppp
- Beam commissioning completed.
- Specifications reached
- Safety validation and detection completed.
- Clinical treatment with patients will start soon.

Milestones of Wuwei Facility

- First beam : Dec. 2015
- Registration detections of national and international standards GB9706, GB4793, GB4943, YY0505, IEC60602-2-64 and so on have been finished (2016-2018).
- Clinical trial treatment of 47 patients will be started by the end of June, 2018 to validate treatment effect and performance of the facility.
- It is expected to be in commercila operation in 2018.

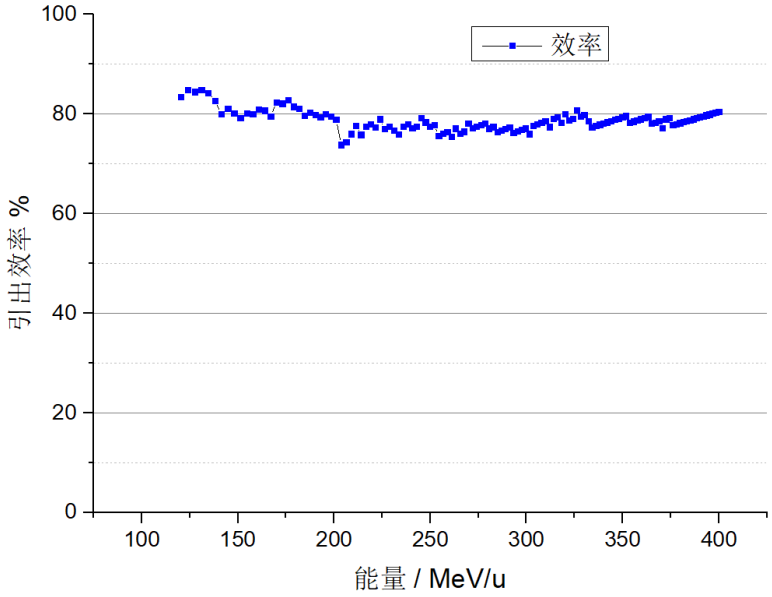
Central Control Room in Wuwei

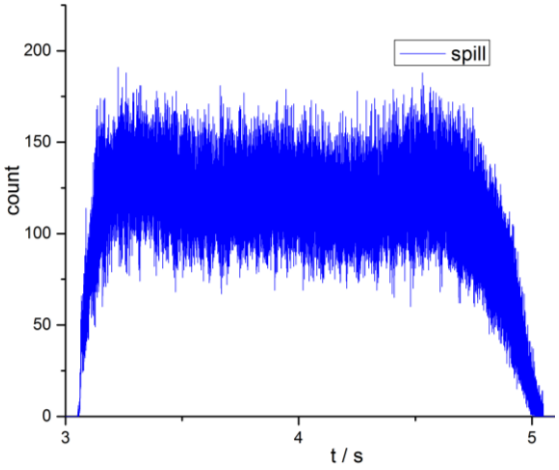
The injection beam intensity can reach 4×10^9 ppp, and the injection gain factor is 400

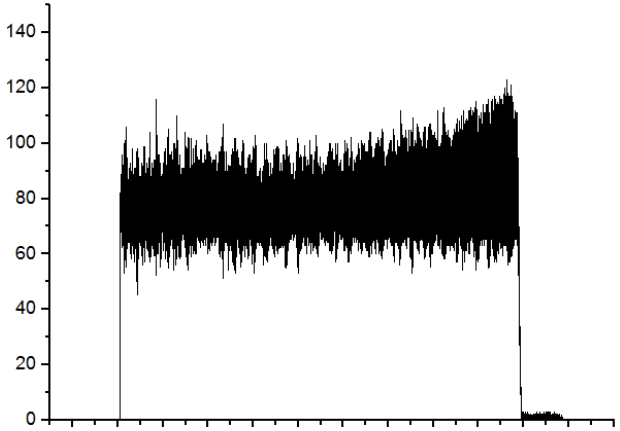


Beam current from DCCT in synchrotron during injection，acceleration and slow extraction

Slow extraction efficiency higher than 80% and the beam structure was improved through feedback system





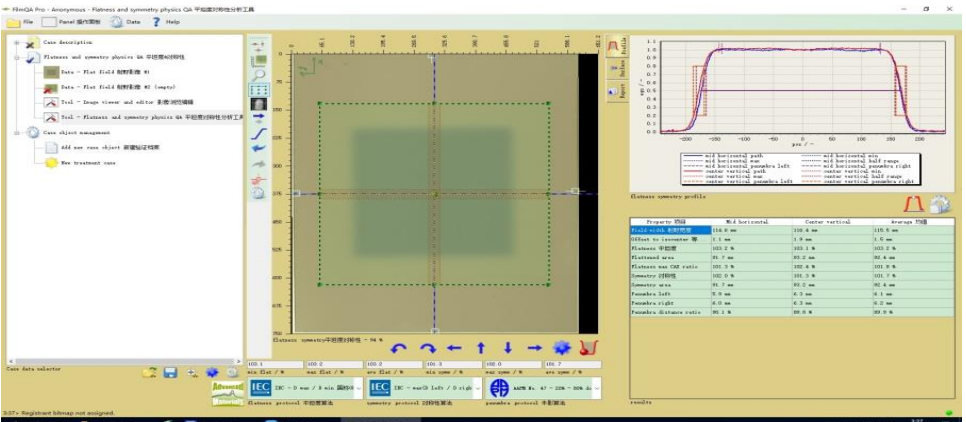


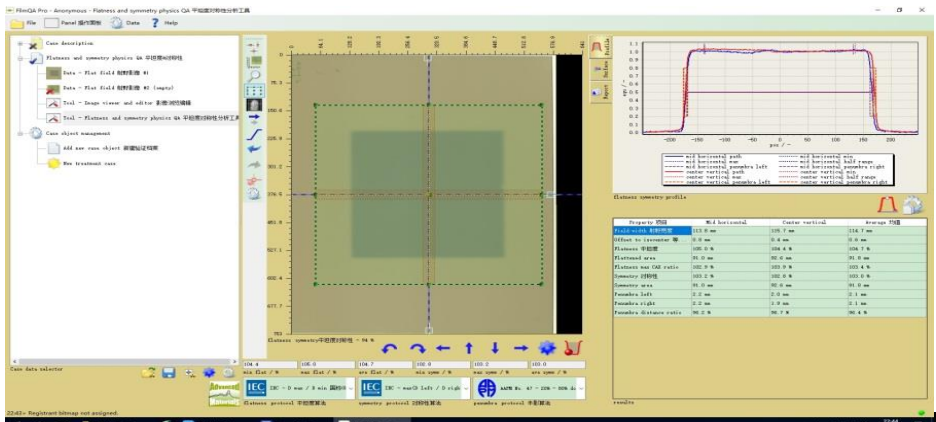
Beam Flatteness of 2# treatment terminal

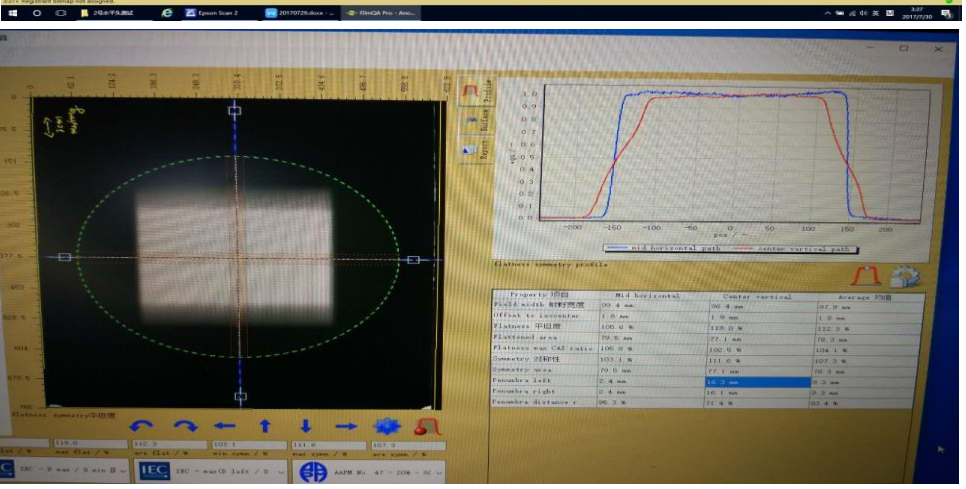
120MeV/u 103.2%

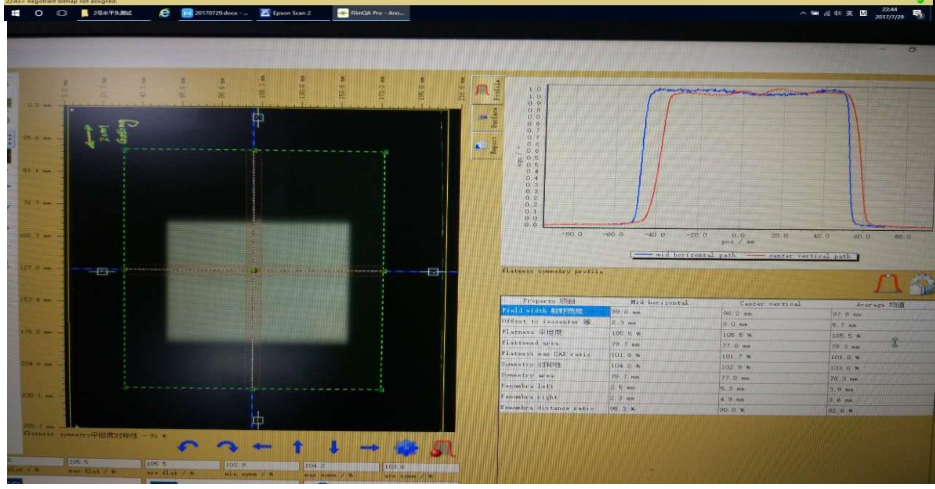
400MeV/u 105%

Typical requirement 100-106%



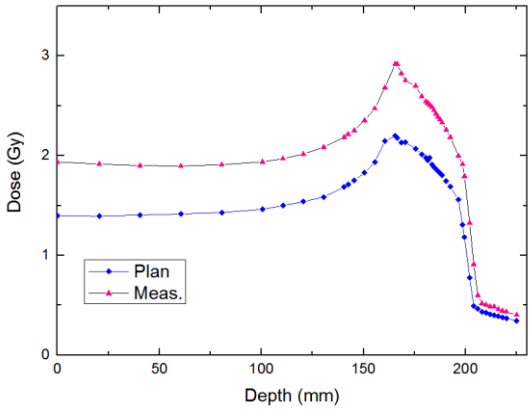


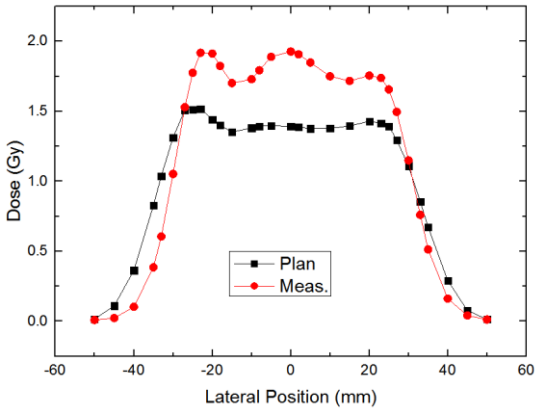


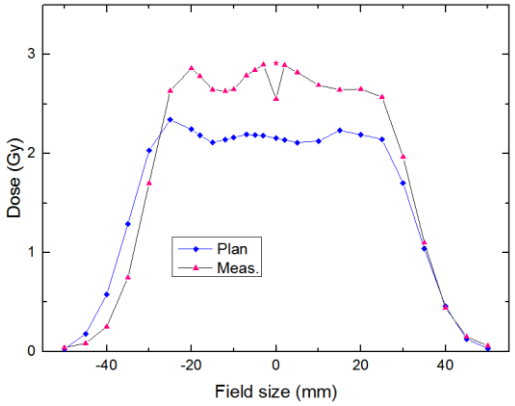


3D Spot Scanning Dose Distribution

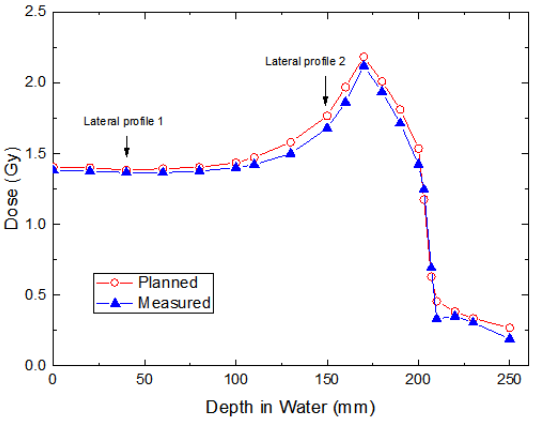
Before optimization

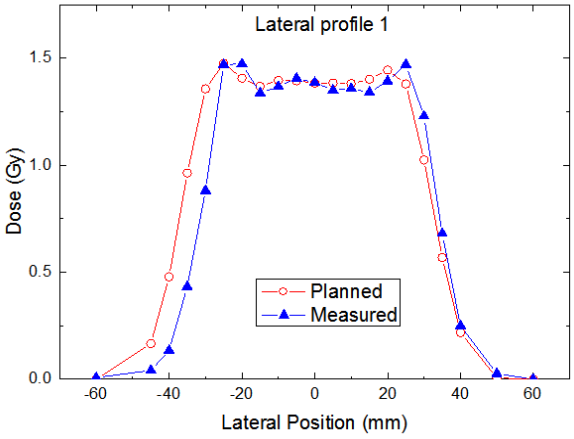


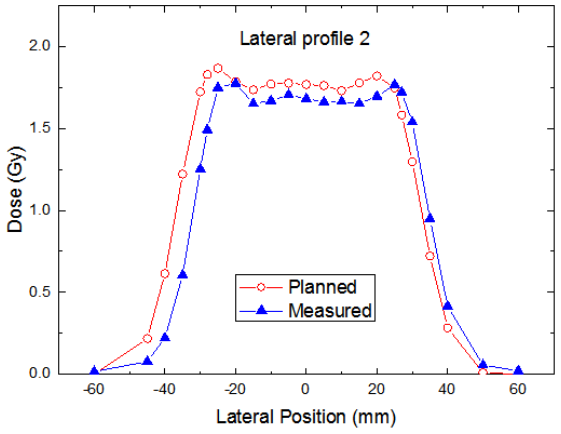




After optimization







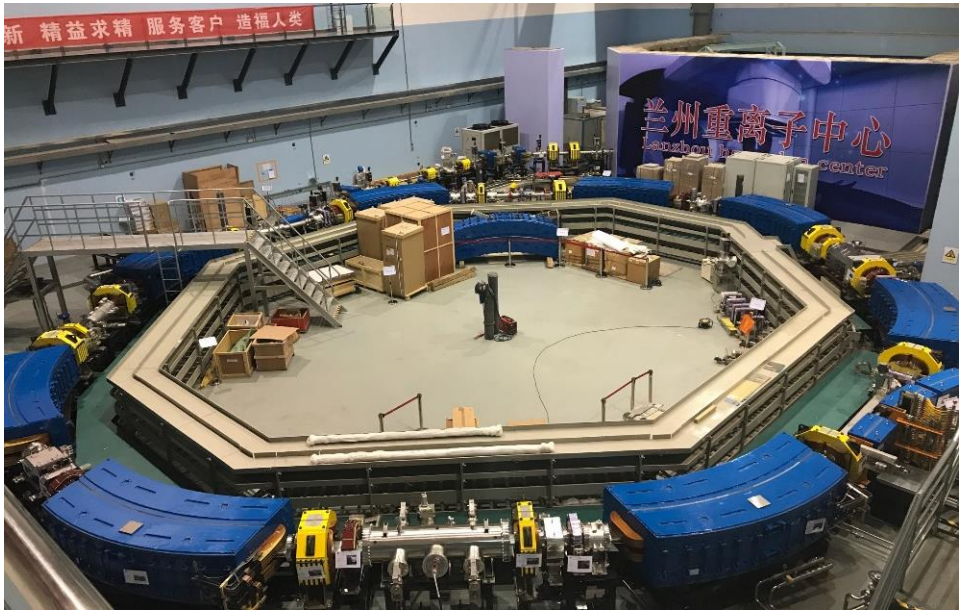
Depth distribution

Transverse distribution

SOBP

Lanzhou Heavy-Ion Tumor Therapy Center

- Relying on Gansu Provincial Tumor Hospital.
- Installation completed.
- The facility will be commissioned by September of 2018.



Challenge and future plan

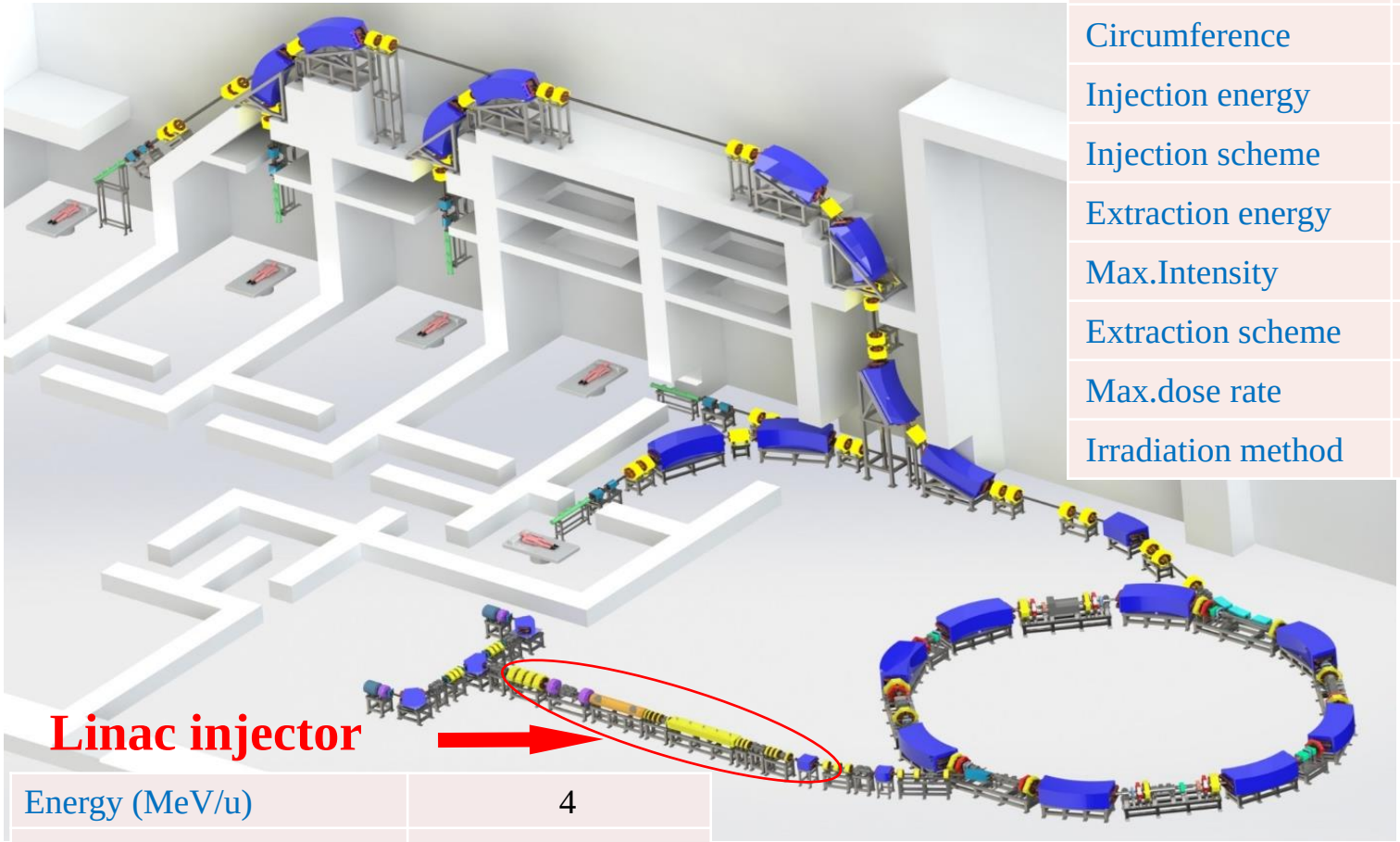
1. Patient treatment numbers for each dedicated therapy facility: 1500-2000 patients/year, challenging !

2. Superconducting magnet technology may increase the magnetic field, minimize size of the magnets and rotating gantry and decrease the cost.

3. Linac injector can be used to enhance the beam intensity with new injection mode.

4. Next generation ion therapy machine
   - Laser ion source +RFQ and DTL in one cavity+SC technology
   - More compact and new beam-delivery system

Linac +Synchrotron for carbon beam



Linac injector

Energy (MeV/u)	4
Current (euA)	250 (C^{4+})
Momentum spread(δP/P)	$\leq \pm 2\times10^{-3}$
Emittance(π mm.mrad)	≤ 10 (5σ)

Synchrotron

Ion	C^{6+}
Circumference	58m
Injection energy	4 MeV/u
Injection scheme	Stripping injection
Extraction energy	80-430MeV/u
Max.Intensity	1.5×10^{9} pps
Extraction scheme	RF-Knockout
Max.dose rate	5 GyE/min/l
Irradiation method	Gating/Layer stacking

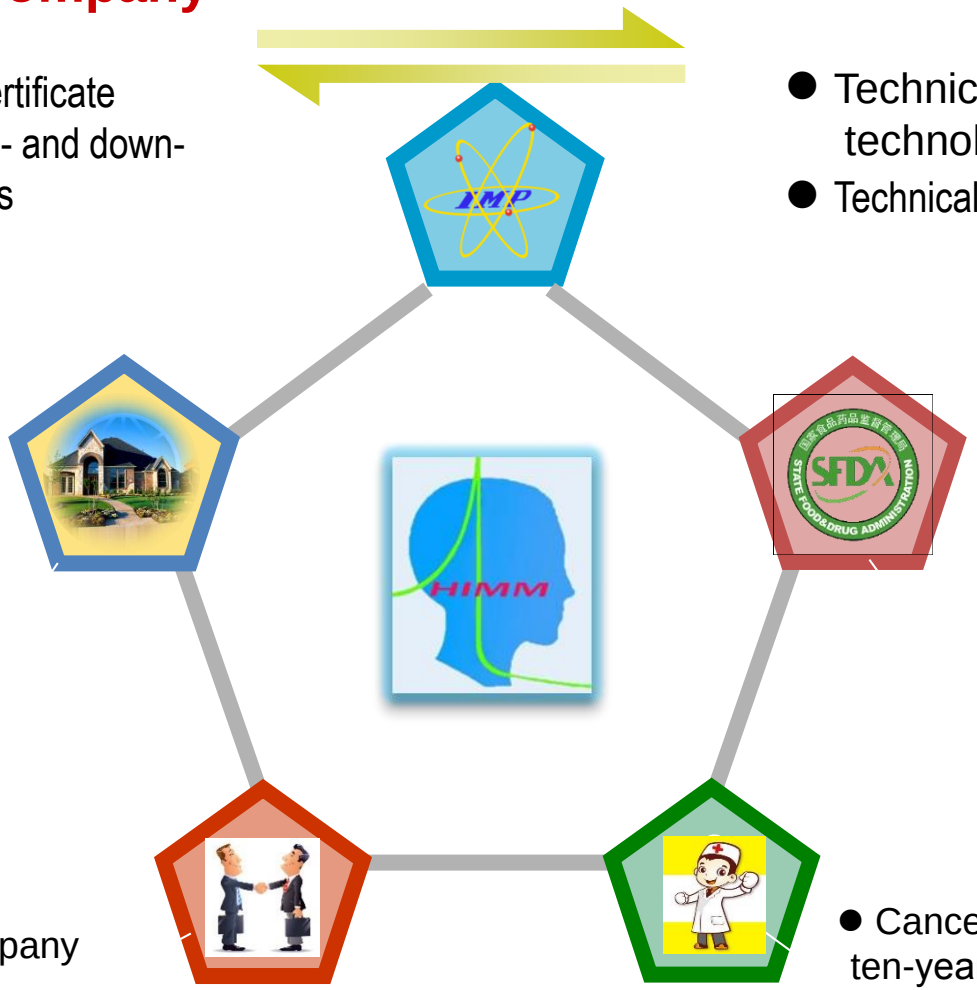
Cooperation mode of ion therapy Project

Kejin Taiji Company

- Product standard
- Manufacturing Certificate
- More than 400 up- and down-stream enterprises

IMP

- Technical design and key technology
- Technical support during operation



Government

- Policy support
- Coordination
- Land and planning

CFDA

- Registration detection
- Clinical trial
- Examining
- Registration certificate

Investors

- Investment Company

Hospitals

- Cancer hospital with more than ten-year's radiation qualification

Summary

- Heavy-ion beam has some favorable characteristics for therapy.
- IMP has demonstrated carbon ion therapy technology with 213-patients clinical trial treatment by the beam from HIRFL.
- IMP built two dedicated compact demon-facilities for carbon ion therapy in Wuwei and Lanzhou.
- IMP is developing new technologies for the next generation ion therapy machine to reduce the facility size and cost.
- You are welcome to join us for collaboration.

Thank you for your attention!