Ion Therapy in China:
Status of Shanghai Proton Therapy Therapy Facility

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Outline

• Introduction
• Shanghai Proton Therapy Facility
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• Summary
Introduction

➢ China now has big population of cancers, its annual increment of diagnosed cancer patients in 2017 is about 4 million, more than 10,000 a day.

➢ Great demand to hadron therapy has been appeared in recent years, and about ~80 hadron therapy centers or facilities were proposed to be built all over the country.

➢ Now there are only two facilities in medical treatment in China. One proton machine in Shandong is from IBA, and one proton and carbon machine in Shanghai is from SIEMENS.

➢ IMP in Lanzhou has developed a carbon therapy system based on its heavy ion research facility and completed a clinical trial of more than 200 patients from 2006 to 2013.
Introduction

➢ Currently, there are six teams engaging in development of hadron therapy facility in China, including IMP, SINAP, CIAE, HUST, Hefei ion medical center and Wuxi New RT.

➢ IMP, SINAP and Wuxi New RT are developing synchrotron based carbon or proton therapy facilities, the rest three are working on superconducting cyclotron based proton therapy facilities.

➢ The first carbon therapy facility developed by IMP just started the clinical test this month, and the first proton one by SINAP is under installation and commissioning now.

➢ In addition, there is a R&D on laser acceleration based low energy proton therapy under going in Peking University.
R&D on a laser proton acceleration cancer therapy is being performed at PKU. A proton beam with 1% energy spread/30pC/10MeV@100TW is in routine operation.

Efforts to accelerate proton to 100MeV for a low energy PT is under way now.
SINAP: Shanghai Institute of Applied Physics

➢ SINAP: a research organization on nuclear science and technology, mainly working on large-scale accelerator light sources and thorium melten salt reactor nuclear energy system;

➢ One of the 106 research institutes under Chinese Academy of Sciences, founded in 1959, now has ~1200 staff and 500 graduate students;

➢ Design, construct and operate synchrotron light source – SSRF, X-ray free electron lasers – SXFEL and SHINE

➢ Conduct frontier research in nuclear physics, physical biology, inter-surface physics, nano-science, photon science, accelerator physics and technology

➢ Transfer nuclear technology: such as design and construct the first synchrotron based proton therapy demo facility in China
Shanghai Synchrotron Radiation Facility

First seven beamlines

Storage Ring

Booster

Linac
High Gain FELs developed by SINAP

**SDUV-FEL:**
65m, 180MeV, 250-350nm

**DCLS:**
150m, 300MeV, 50-150nm

**SXFEL Facility:**
300m, 840MeV, 9-40nm
530m, 1.6GeV, 2-10nm
A National Big Scientific Infrastructure: a high rep-rate hard X-ray FEL based on CW SCRF linac is funded with a strong support from Shanghai local government (about 80% of the budget ~1.5B US$).

- e-beam: 8 GeV
- Photon energy: 0.4-25 keV
- Pulse duration: 1-100fs
- Repetition: 1MHz
- Total length: 3.1km
  ca.38m underground
Shanghai Proton Therapy Facility

➢ Funded by local government in 2013, as a part of the whole proton therapy development program, including setting up a proton therapy center.

➢ This proton therapy facility is being developed by SINAP and installed in the proton therapy center of Shanghai Ruijin hospital, which located in Jiading, Shanghai.

➢ There are 3 initial treatment beamlines, a fixed beamline, an ocular beamline and rotating gantry beamline, and one more gantry beamline was founded in 2016.

➢ The hardware development of the therapy facility started in early 2014, the building construction of the proton therapy center started in Dec. 2014.
➢ SINAP, Aptron Particle Equipment Co. and Ruijin Hospital jointly develop the therapy facility, aiming to complete the first clinical commissioning by the end of 2018.
Architectural design of Ruijin Proton Therapy Center
Ruijin Hospital Proton Therapy Center

- **Area of Building**: 26075 m²,
  underground (13000 m²) and above ground (13000 m²)
- **Construction Period**: 12/2014/-11/2016
Underground floor – Treatment area

- Proton Facility: 5400 m²
- Nuclear Medicine: 1300 m²
- Photon Facility: 1500 m²
- Radiology: 500 m²
- Utility: 1200 m²

Additional note: Proton Facility 5295 m² (value for the lower floor)
Proton Facility Layout

- HTB
- Rotating gantry Beamline
- Fixed Beamline
- Experiment Beamline
- Ocular Beamline
- synchrotron
- 7MeV injector
- Equipment hall
- Treatment control

“Development of synchrotron based proton therapy” supported by National Key R & D Program “Digital Clinic Equipment R & D”
# Main Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
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<tbody>
<tr>
<td>Energy Range</td>
<td>70~235 MeV</td>
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<tr>
<td>Energy Levels</td>
<td>94</td>
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<tr>
<td>Range in Water</td>
<td>0~30.0 g/cm²</td>
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<tr>
<td>SOBP:</td>
<td>1~14 cm</td>
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<tr>
<td>Dose rate:</td>
<td>&gt;2 Gy/min/Liter</td>
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<tr>
<td>Extraction intensity per spill:</td>
<td>$4 \times 10^{10}$</td>
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<tr>
<td>Accelerator:</td>
<td>FODO, 8 bends</td>
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<tr>
<td>Circumference:</td>
<td>24.6 m</td>
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<tr>
<td>Injection:</td>
<td>Multi turn painting</td>
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<tr>
<td>Extraction:</td>
<td>3rd resonance slow extraction with RF-KO</td>
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<tr>
<td>Ramping time:</td>
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<tr>
<td>Repetition rate:</td>
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<tr>
<td>Field size:</td>
<td>30 cm × 40 cm</td>
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<tr>
<td>Beam Delivery System:</td>
<td>Spot Scanning</td>
</tr>
<tr>
<td>Max Scanning Speed:</td>
<td>2 cm/ms</td>
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Development of Proton Therapy Facility

➢ Design started in 2010 and key hardware manufacture started in 2014;

➢ The components manufacture of treatment system was mainly performed in 2017, including the scanning nozzle, robot couch, treatment control system, equipment of ocular beam line;

➢ Development of software of treatment system was mainly performed from 2016 and 2018, including OIS and TCS; RayStation was bought in 2016;

➢ The accelerator installation was performed from December 2016 to April 2017, then its commissioning was carried out from May to Sep. 2017;

➢ The installation and technical commissioning of nozzle in the fixed beam line were conducted from June 2017 to June 2018;

➢ The gantry installation and commissioning were made in parallel from Nov. 2017 to June 2018.
Key components of accelerator

- Dipole
- Quadrupole
- Sextupole
- Extraction septum
- RF cavity
- Power supply
Proton Accelerator and Beam Transfer Beam Line
Proton Accelerator System

Accsys Injector

Synchrotron
Commissioning

- April 27, 2017: First beam of injector;
- May-June, 2017: 70-235 MeV ramping;
- June 14, 2017: First extraction beam at the profile at HTB;
- Since October, 2017: 94 energies are tuned, and rotating beam optimization is under going;

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<td>1</td>
<td>70.0</td>
<td>12*10^{10}</td>
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<td>80.9</td>
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<td>91.2</td>
<td>10*10^{10}</td>
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<tr>
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<td>100.2</td>
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<td>61%</td>
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<td>111</td>
<td>10*10^{10}</td>
<td>62%</td>
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<tr>
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<td>62%</td>
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<tr>
<td>7</td>
<td>130.1</td>
<td>10*10^{10}</td>
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<td>65%</td>
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<tr>
<td>15</td>
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</tr>
<tr>
<td>16</td>
<td>221.4</td>
<td>7*10^{10}</td>
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</tr>
<tr>
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<tr>
<td>94</td>
<td>235.0</td>
<td>8*10^{10}</td>
<td>67%</td>
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Beam at exit of fixed transfer line

Position change in a Spill +/- 0.4mm

235MeV HWFM 8/8mm

Beam position and beam size stability
Overall layout of treatment system
Fixed beam treatment room

Design Sketch

now
## Nozzle system

<table>
<thead>
<tr>
<th>Specification</th>
<th>Value</th>
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<tbody>
<tr>
<td>Maximum range</td>
<td>34 g/cm²</td>
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<tr>
<td>SOBP length</td>
<td>30 g/cm²</td>
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<tr>
<td>Field size (ScanU)</td>
<td>40 cm</td>
</tr>
<tr>
<td>Field size (ScanV)</td>
<td>30 cm</td>
</tr>
<tr>
<td>SAD</td>
<td>2.65 m</td>
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<tr>
<td>Scanning speed (ScanU)</td>
<td>2 cm/ ms</td>
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<tr>
<td>Scanning speed (ScanV)</td>
<td>0.5 cm/ ms</td>
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<tr>
<td>Spot size (sigma)</td>
<td>2.5 – 4.5 mm</td>
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<tr>
<td>Dose rate</td>
<td>2 Gy/liter/minute</td>
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</table>
Nozzle commissioning with beam

235MeV, 11*11 spots, 26mm pitch, 6000 counts per spot

235MeV, four 30*30mm fields, 1600 counts per spot
Nozzle commissioning with beam

- 235MeV, three 60*80mm fields, 2000 counts per spot
- patched in three machine cycles
Robot Couch

SMEC Couch
- Absolute accuracy: ±1mm
- Repeat accuracy: ±0.3mm
- Rotation accuracy: ±0.2°
- Max load: 135kg

Shenyang GR Couch
- Absolute accuracy: ±0.20mm
- Repeat accuracy: ±0.08mm
- Rotation accuracy: ±0.014°
- Max load: 150kg
RAYER: Patient Positioning and Verification System

RayStation V7.0.0.19: Treatment Planning System

- IGRT couple X-ray imaging and high-precision patient positioning systems for automatic six degrees of freedom setup correction
- GPU-based fast 2D/3D image registration (a few seconds)
- Optimized treatment workflow
- Using RayStation with MOSAIQ
Rotating Gantry installation and commissioning

- The rotating treatment system, included rotating gantry and robot couch, is under installation and will start commissioning with beam in Sept. 2018.
- Rotating weight: 90 tons; Measured ISO center accuracy: ±0.26mm
- Rotating accuracy of the shaft system is less than 0.1mm; Accuracy of the gear ring attains DIN3, and its circles run-out less than 0.1mm.
- The rotating floor can keep synchronously revolute with the gantry.
Proton Beamline for Ocular Treatment

- The design and construction is performed under the collaboration with PSI, similar to the OPTIS2.
- Components of the beam line (nozzle assembly), eye treatment chair, x-ray image and laser positioning system were manufactured by SCHAER in Switzerland and shipped to Shanghai.
- Nozzle control system, treatment control system is under development.
- The installation and commissioning of this ocular beamline will start in Sept. 2018.
Plan of Next Phase

➢ 2017 -- 2018

- Perform and complete the installation and commission of fixed, rotating and ocular treatment room beam;
- Optimizing the function and performance to meet the requirements of clinical trials;
- Perform the third-party checking and testing;

➢ 2019 -- 2020

- Perform and complete the clinical trials of fixed beam, 180 degree rotation beam and eye treatment room;
- Develop and complete a 360 degree compact rotating gantry beamline and treatment room;
- Complete the whole system test and the clinical trial evaluation;
Summary

➢ Development of the Shanghai proton therapy facility is in good shape;
➢ Installation of the accelerator started in Nov. 2016 and completed in Apr. 2017; beam commissioning started in May. 2017, commissioning of fixed beam system started in Oct. 2017 and will be completed by end of 2018;
➢ Work focus in 2018 is the treat room commissioning of fixed beamline, gantry and ocular beamlines;
➢ Checking and testing, cFDA certification are being carried out simultaneously, expecting to complete in 2020;
➢ Future development: compact synchrotron and gantry.
Thank you for your attention!

谢谢！