SAPT:

A synchrotron based Proton Therapy

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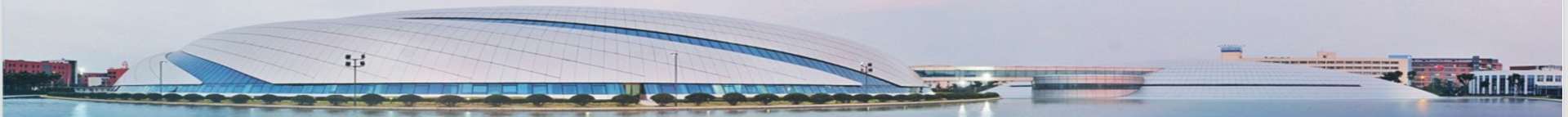
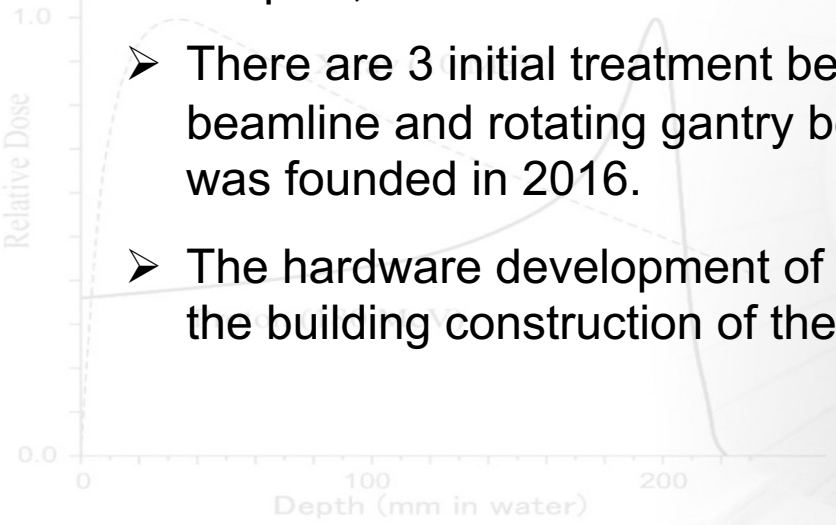


Shanghai Proton Therapy Facility

- Funded by Shanghai local government and , Ministry of Science and Technology，a dedicated proton therapy.
- This proton therapy facility is being developed by SINAP/SARI, A spinoff of the SSRF 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.



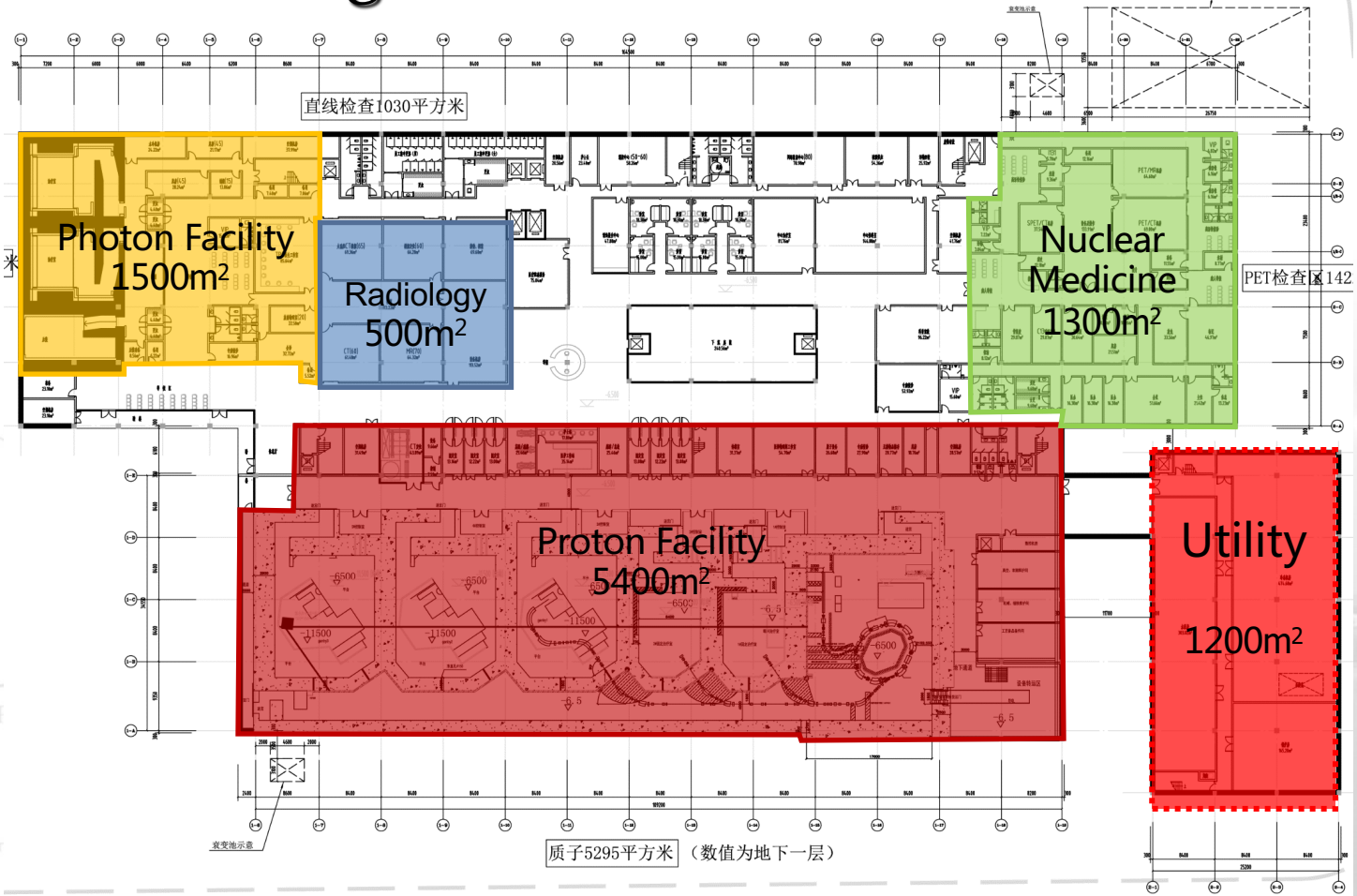

SINAP, Jlading
SXFEL
Soft XFEL User Facility
1.5GeV e- / ~1keV x-ray
SSRF
3.5GeV Synchrotron Light Source
SARI, Zhangjiang
•SSRF (including the development team) merged to Shanghai Advanced Research Institute, CAS (2018.10)

Building for Ruijin Hospital Proton Therapy Facility

Area of Building：26075 m^2,underground (13000 m^2) and above ground (13000 m^2)

Construction Period：2014/12-2016/11

Underground floor – Treatment area



Milestones

Key hardware manufacture

Commissioning Treatment system Installation

3rd party testing start

Testing Finish 2021.6

Clinical trial Finished 2022.6

2012.02 Start

2013-2015 Accelerator Installation

2016

2017

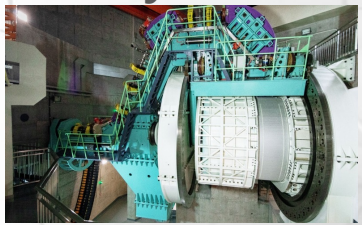
2018 Accelerator ready

2019

2020 ALL Fixed special approval channel for innovative medical devices

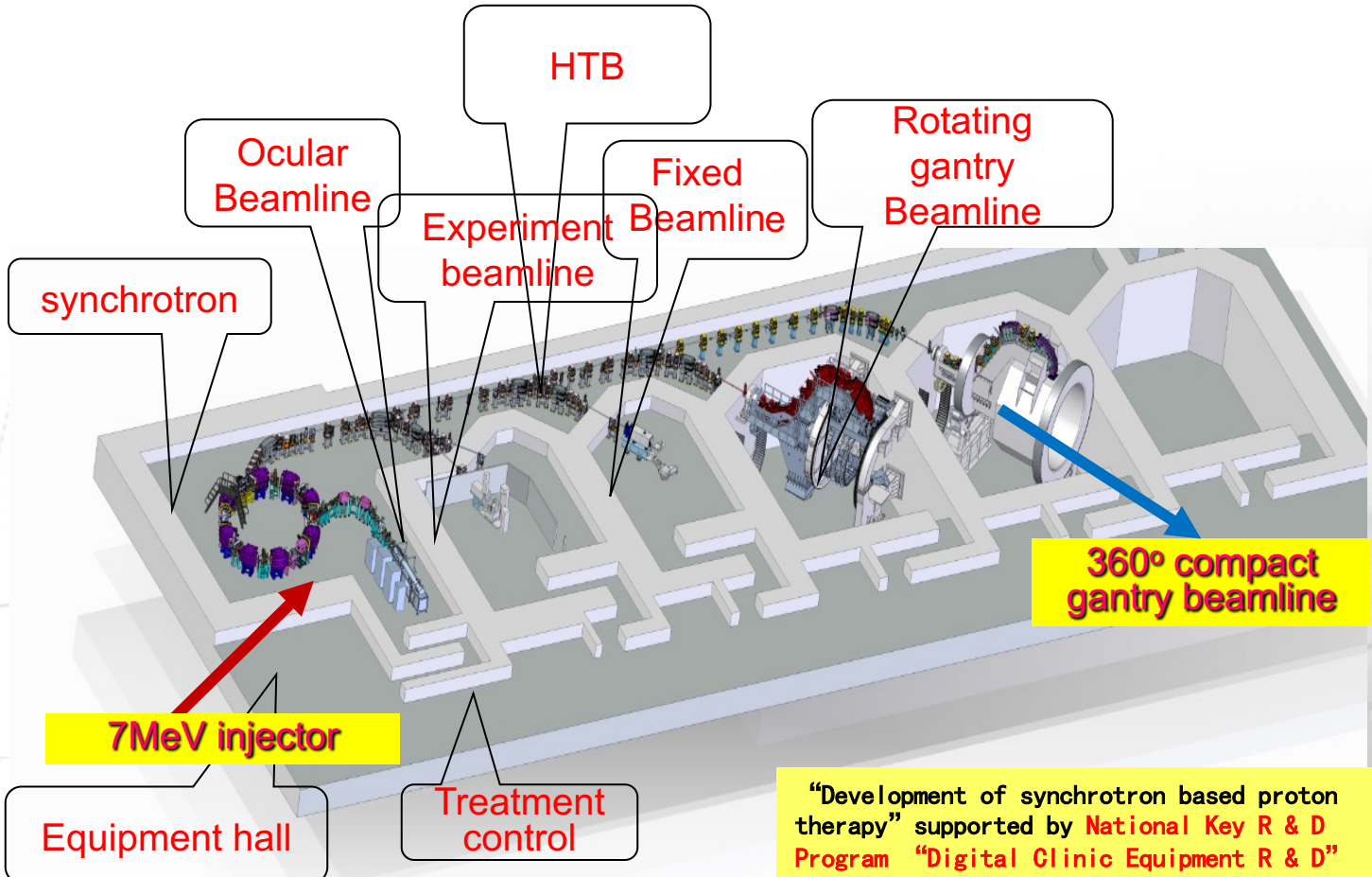
2021.11 Clinical trial Start

2022.9 Registration Certificate



Waiting for permission to open!

Proton Facility Layout



"Development of synchrotron based proton therapy" supported by National Key R & D Program "Digital Clinic Equipment R & D"

Main Parameters

Energy Range	70~235 MeV
Energy Levels	94
Range in Water:	0~30.0 g/cm^2
SOBP:	1~14 cm
Dose rate:	1~2 Gy/min/Liter
Extraction intensity per spill:	4~8×10^{10}
Accelerator:	FODO, 8 bends
Circumference:	24.6 m
Injection :	Multi turn painting
Extraction:	3rd resonance slow extraction with RF-KO
Ramping time:	0.7s
Repetition rate:	0.5~0.1 Hz(variable)
Field size:	30 cm ×40 cm
Beam Delivery System:	Spot Scanning
Max Scanning Speed:	2 cm/ms

Advantages and characteristics

Accelerator-Synchrotron
Dynamic energy change, high beam utilization, low radiation

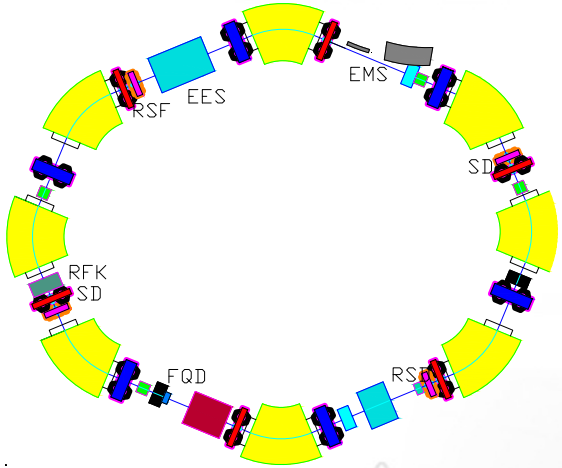
Spot scanning
Well shaped target
No compensators and collimators
intensity modulated

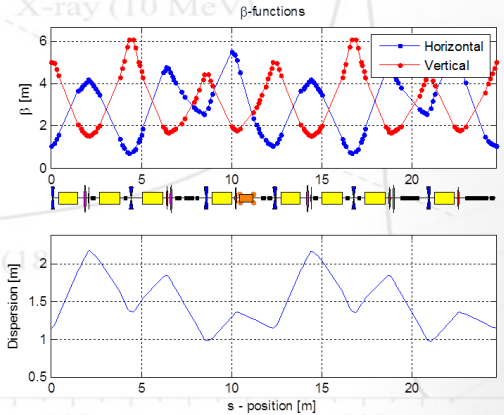
Multi-angle treatment
Compact rotating gantry

6 degrees of freedom couch
auto registration and positioning

Image Guiding

Synchrotron Performance



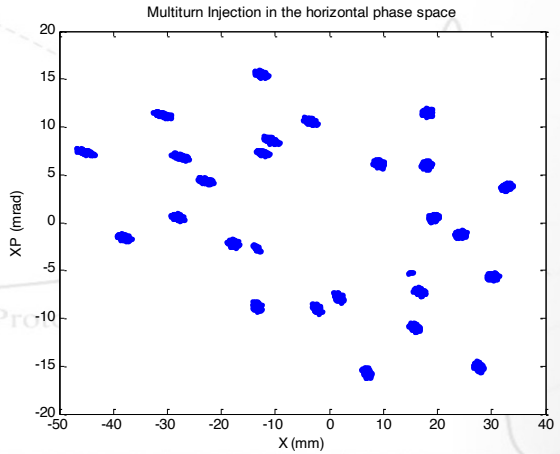


Focus on increasing acceptance

Energy at Injection		MeV	7
Energy at Extraction		MeV	70-235
Extraction beam number per spill			$4\text{-}8\times10^{10}$
repetition frequency		Hz	0.1-0.667Hz
Circumference		m	24.6
magnetic rigidity			0.3830-2.4321
Ramping curve			trapezoidal wave
Tune,ν_X/ν_Y	Injection		1.7/1.45
	extraction		1.67/1.46
Natural chromaticity, ξ_X/ξ_Y			-1.50/-1.26
Max β（in diploe） β_X/β_Y		m	5.5/6.27（4.37）
Max dispersionη_x		m	2.17
Momentum compact factor, α_P			0.4028
Transition gamma γ_t			1.576
Max RF voltage V_{rf}		kV	2

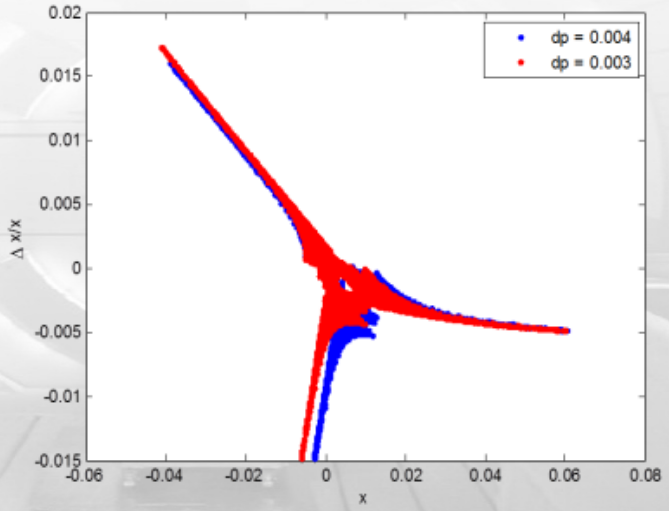
Multi-turn Injection

- 30 Multi-turn injection, painting by bump decreasing at horizontal and mis-match at vertical
- 2 kicker bump, ES+MS
- Injection efficiency 30%
- Max beam intensity 1.6e11

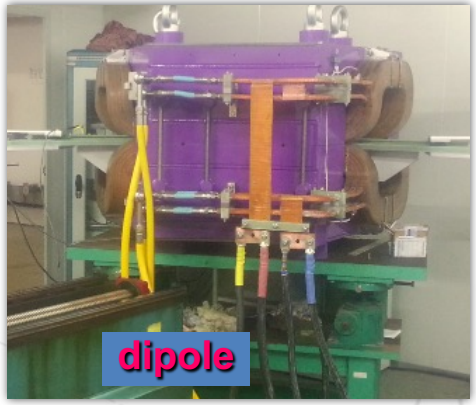


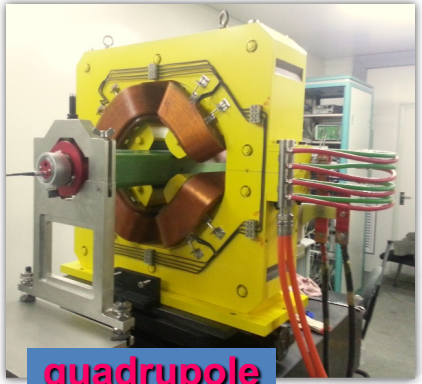
3rd order Extraction

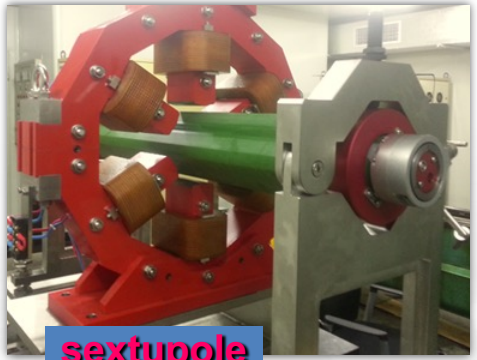
- RF-KO
- 2 Resonance Sextupole(SR) + 2 Chromaticity Sextupole(SC)
- EES+2 EMS

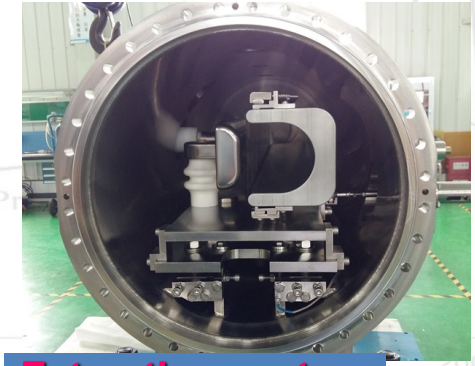


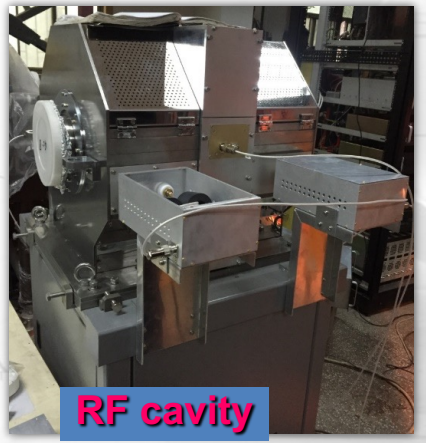
Key components of accelerator


dipole


quadrupole


sextupole


Extraction septum


RF cavity

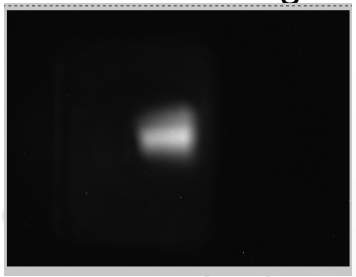

Power supply

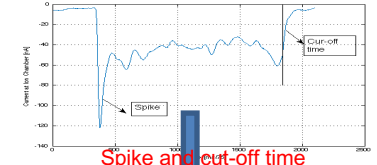
Proton Accelerator and Beam Transfer Beam Line

Good Reliability： up time > 98% in clinical trials

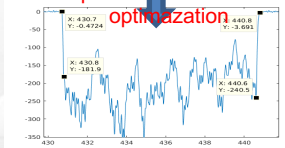
Accelerator Commissioning

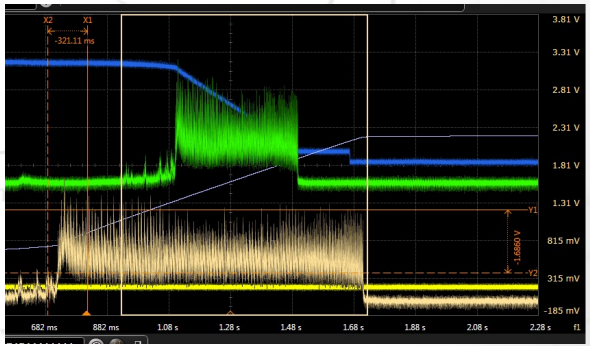
- April 27, 2017: First beam of injector;
- May- June, 2017: 70-235 MeV ramping;
- June 14, 2017: First extraction beam at the profile at HTB;
- Since October, 2017: 94 energies are tuned. and rotating beam optimization is under going ;

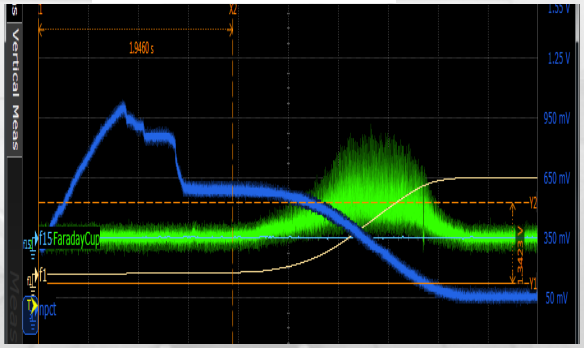




Spike and cut-off time optimization



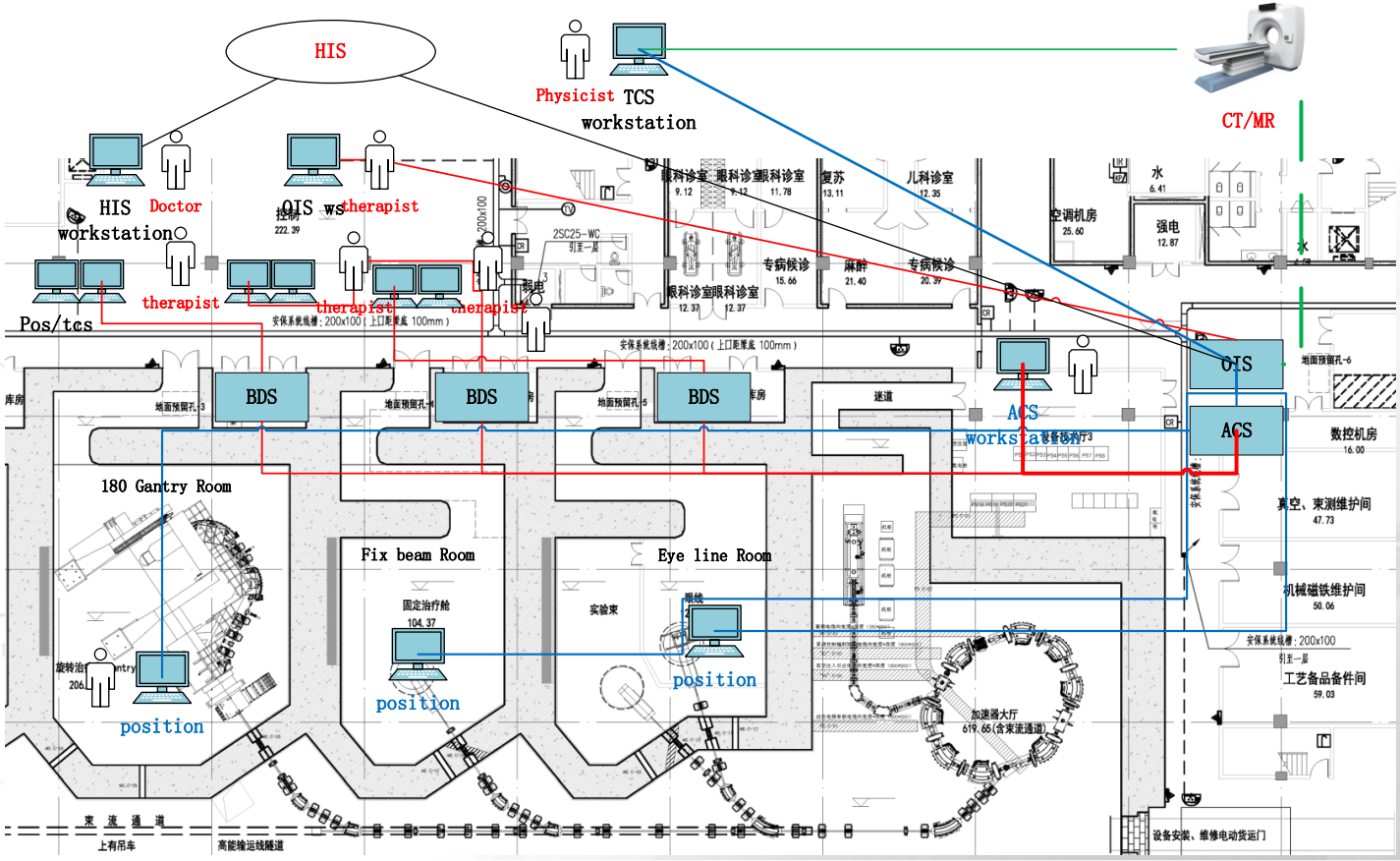




Beam profile and current at HTB

Multi-energy extraction experiment

Overall layout of treatment system

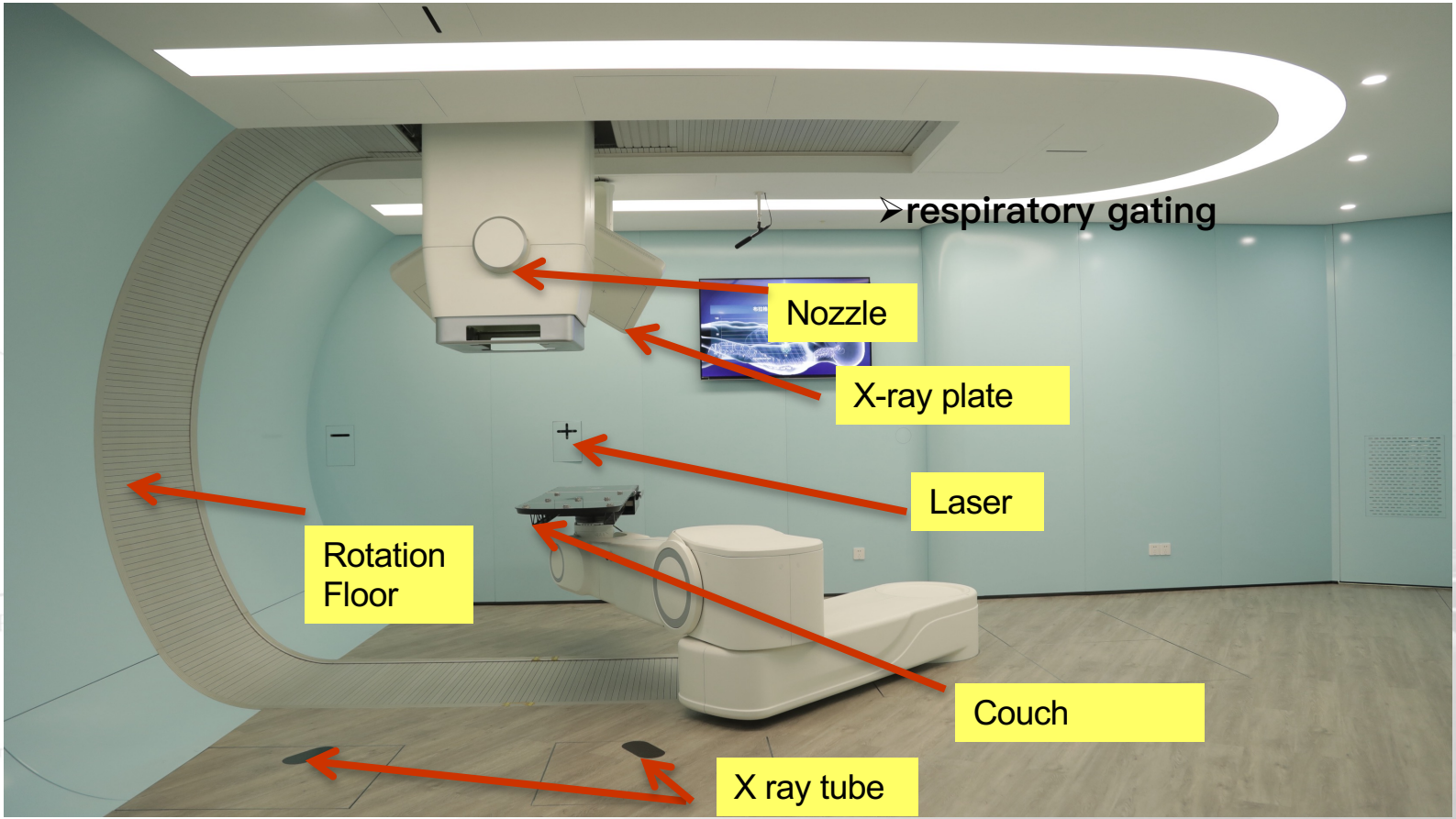


Treatment room

Fixed beam Room

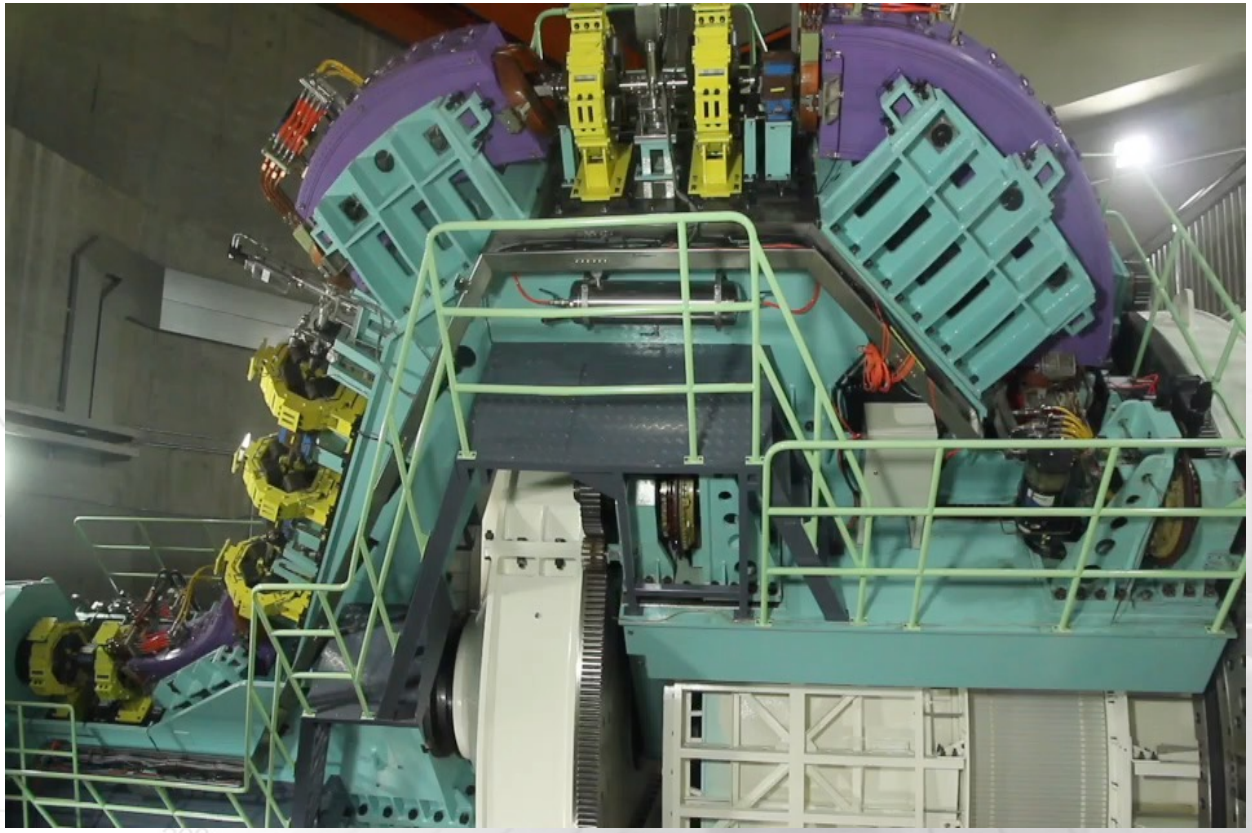
Eye treatment room

180 Gantry Room



180 gantry

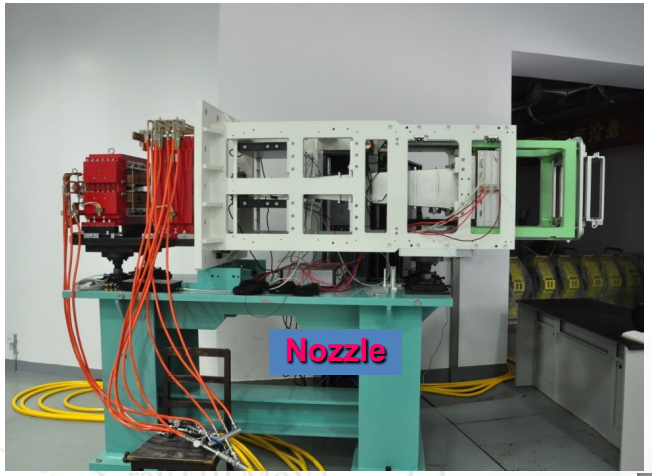
13meters long
5.5 meters radius
93/170 tons
1mm ISO center



Compact 360 gantry room

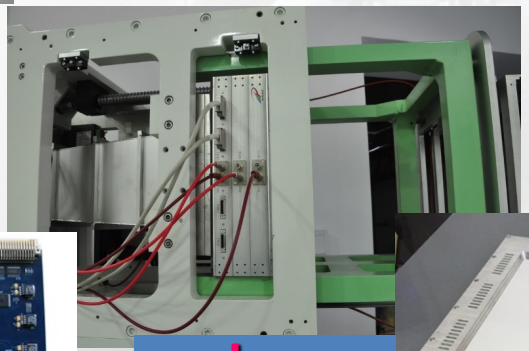
Smaller and more accurate
CBCT/In room CT

Beam Deliver System

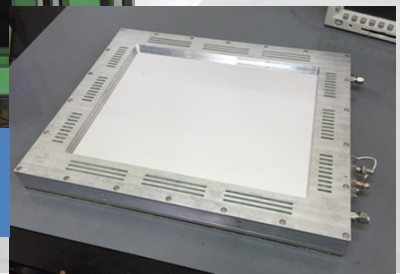


Depth	34 g/cm^2
SOBP	30 g/cm^2
Field Size	40 cm (ScanU) 30 cm (ScanV)
SAD	2.65m
Speed	2cm/ms (ScanU) 0.5cm/ms (ScanV)

Treatment Control

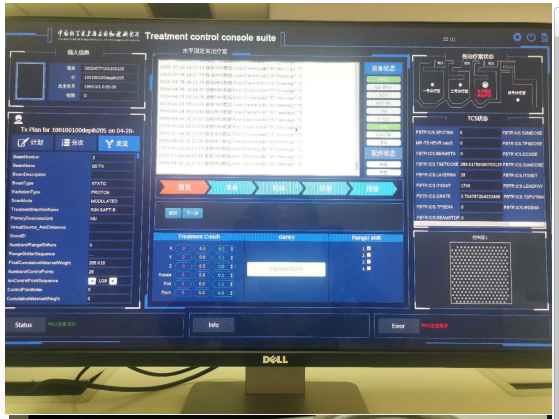


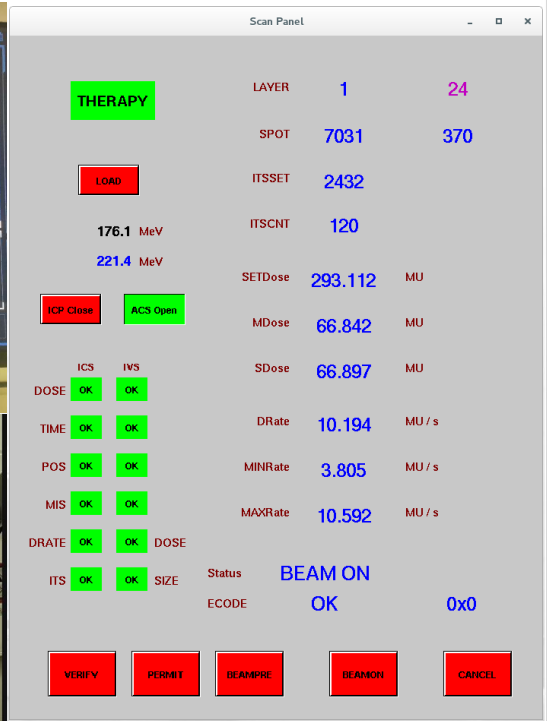
Ion chamber

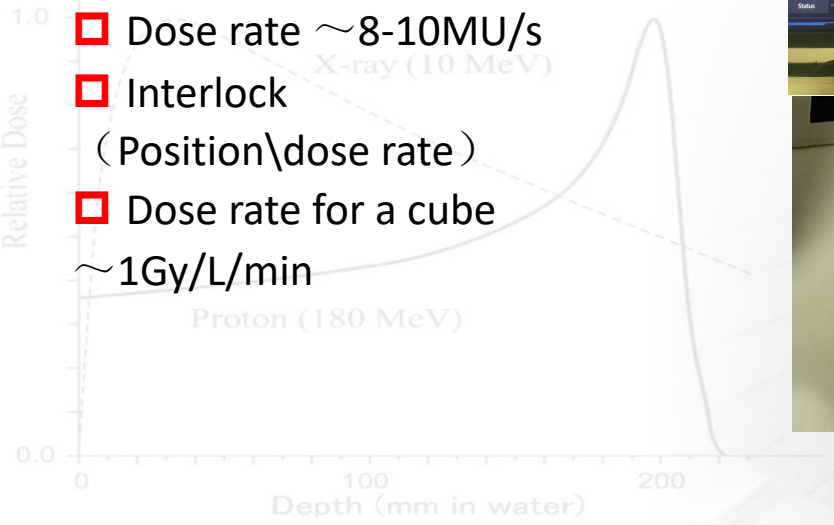


Performance of BDS

- Dose Linearity（3%）
- Dose Repeatability（2%）
- Dose stability（Day、Week2%）
- Range Stability（0.3mm）
- Spot Dose accuracy 200～30counts
- Dose rate ～8-10MU/s
- Interlock
  （Position\dose rate）
- Dose rate for a cube
  ～1Gy/L/min

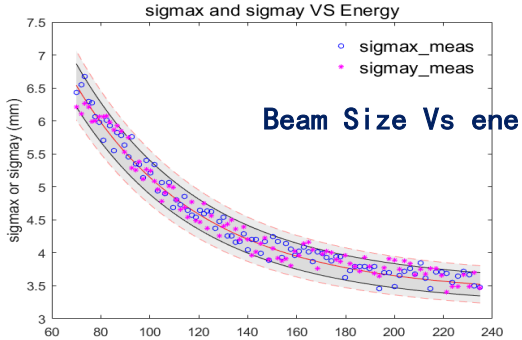


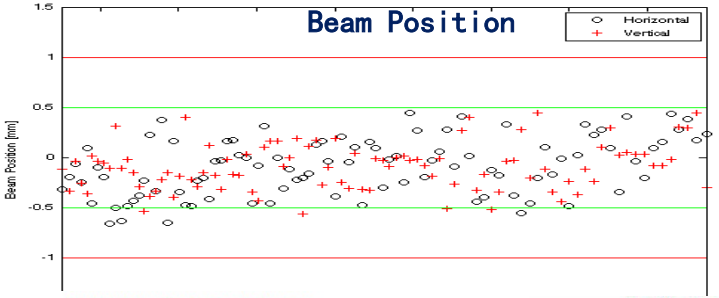


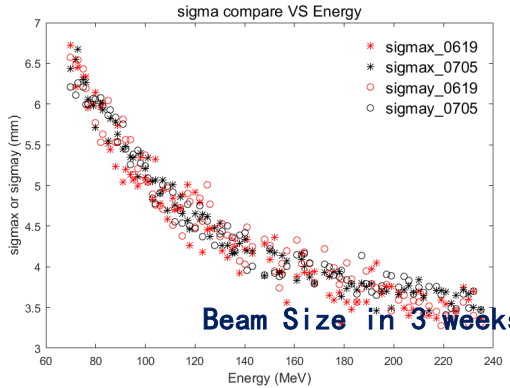


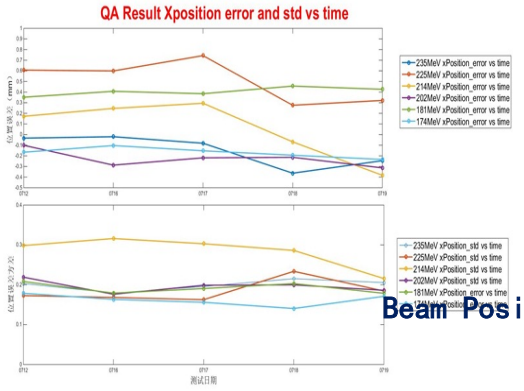
Beam Size and position

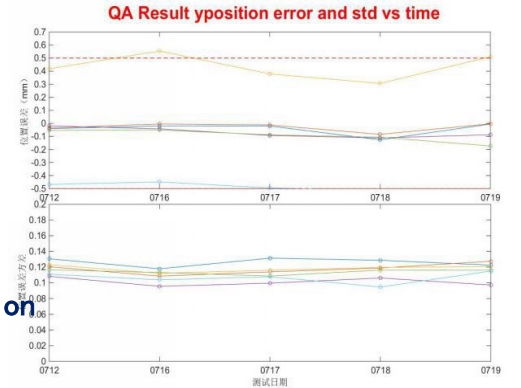
- Beam size < ± 15%;
- Position < ± 1mm



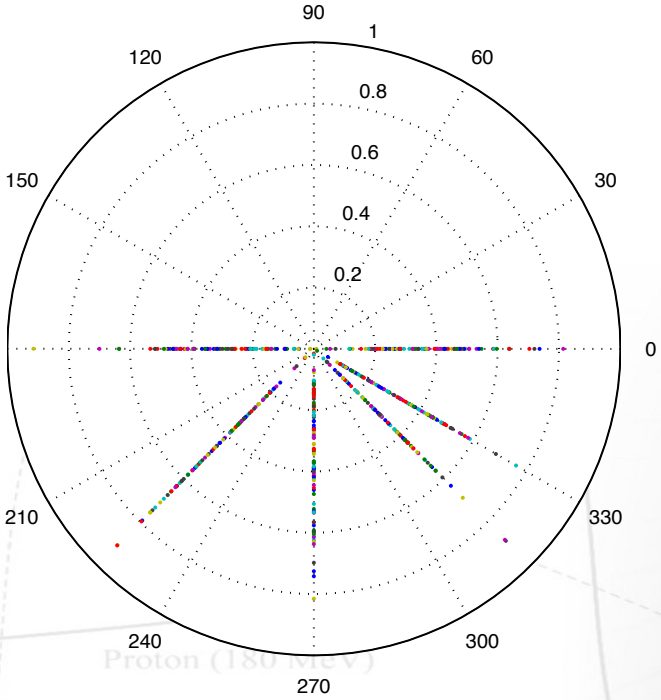




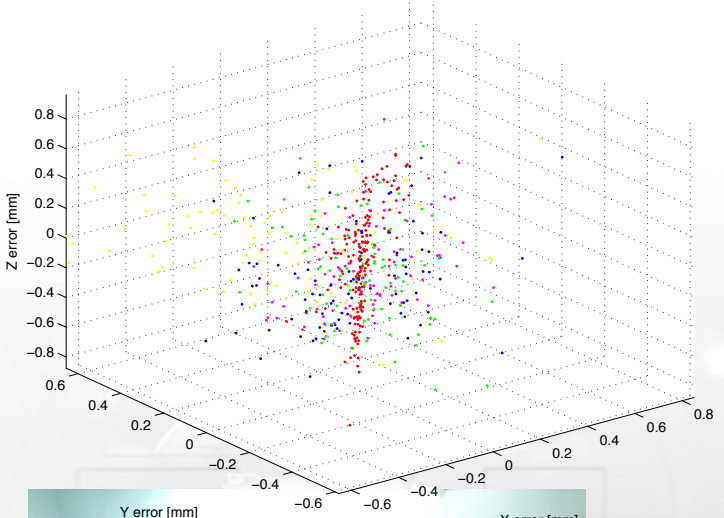


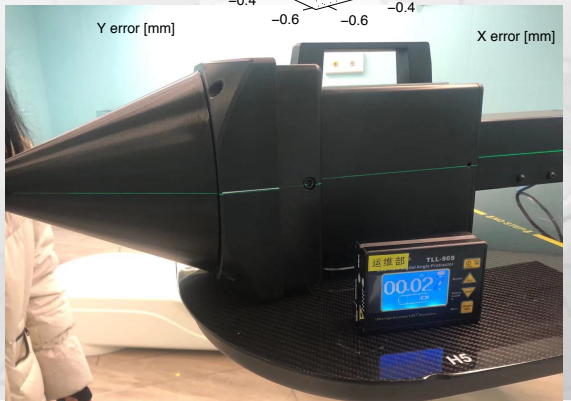


Beam Position at ISO Center

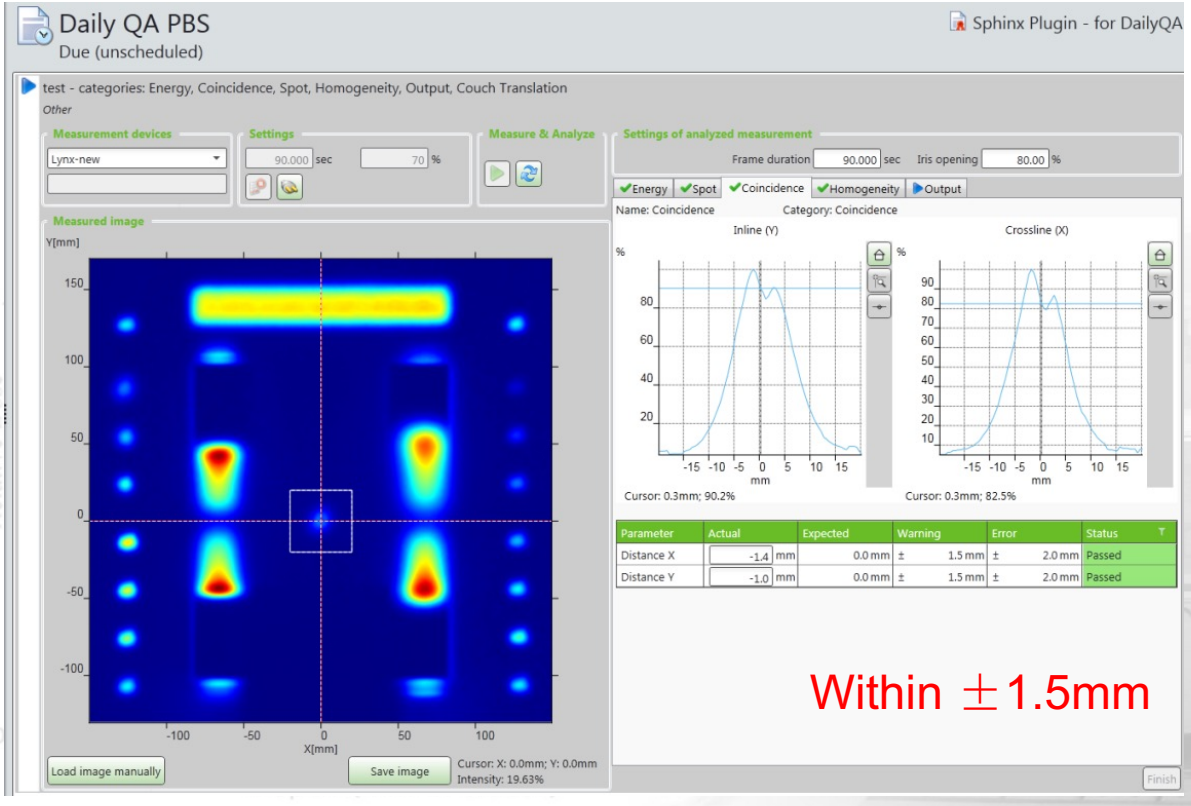


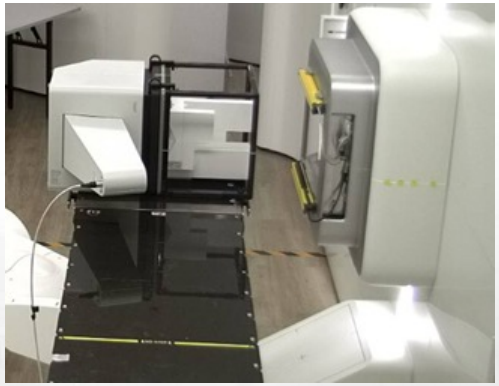
Logosvision xrv124





Daily QA --dosimetry





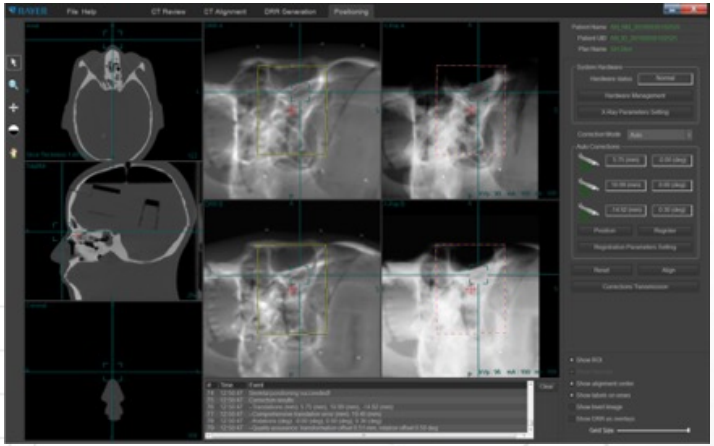
IBA Lynx + Sphinx

Daily QA protocol

- ✓Energy stability
- ✓Spot size
- ✓Homogeneity
- ✓Coincidence
- ✓MU repeatability

Within ±1.5mm

Patient Positioning and Verification System



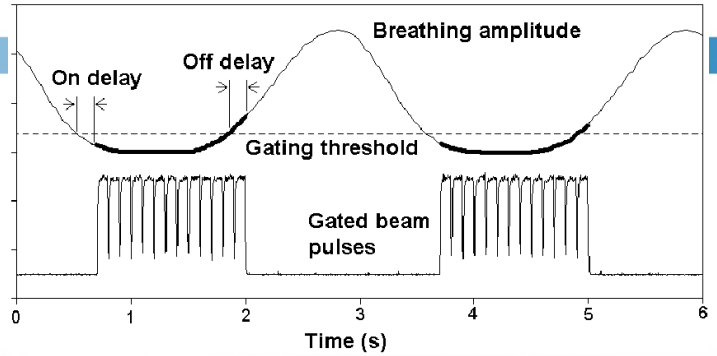
- couple KV-X-ray imaging and high-precision patient positioning systems for automatic six degrees of freedom setup correction **< ±1mm**
- GPU-based fast 2D/3D image registration (a few seconds)

6 degrees of freedom couch

Move：±1mm

Rotation：±0.2°

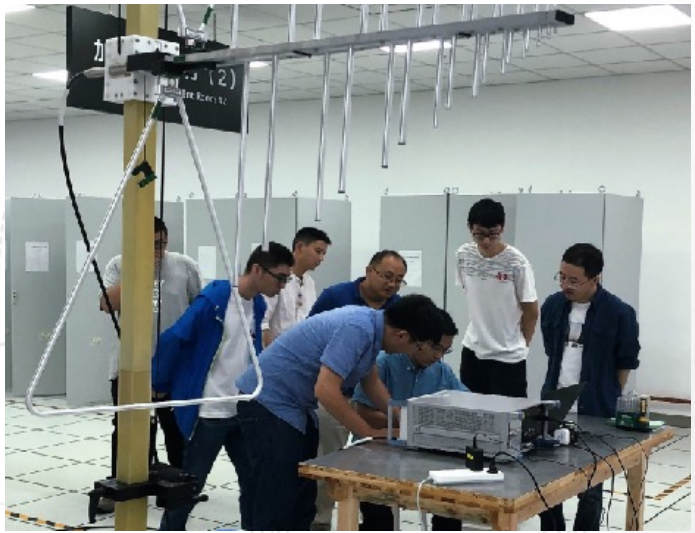
respiratory gating



3rd party testing and Clinical trials

Guidelines for technical review of proton/carbon ion therapy systems

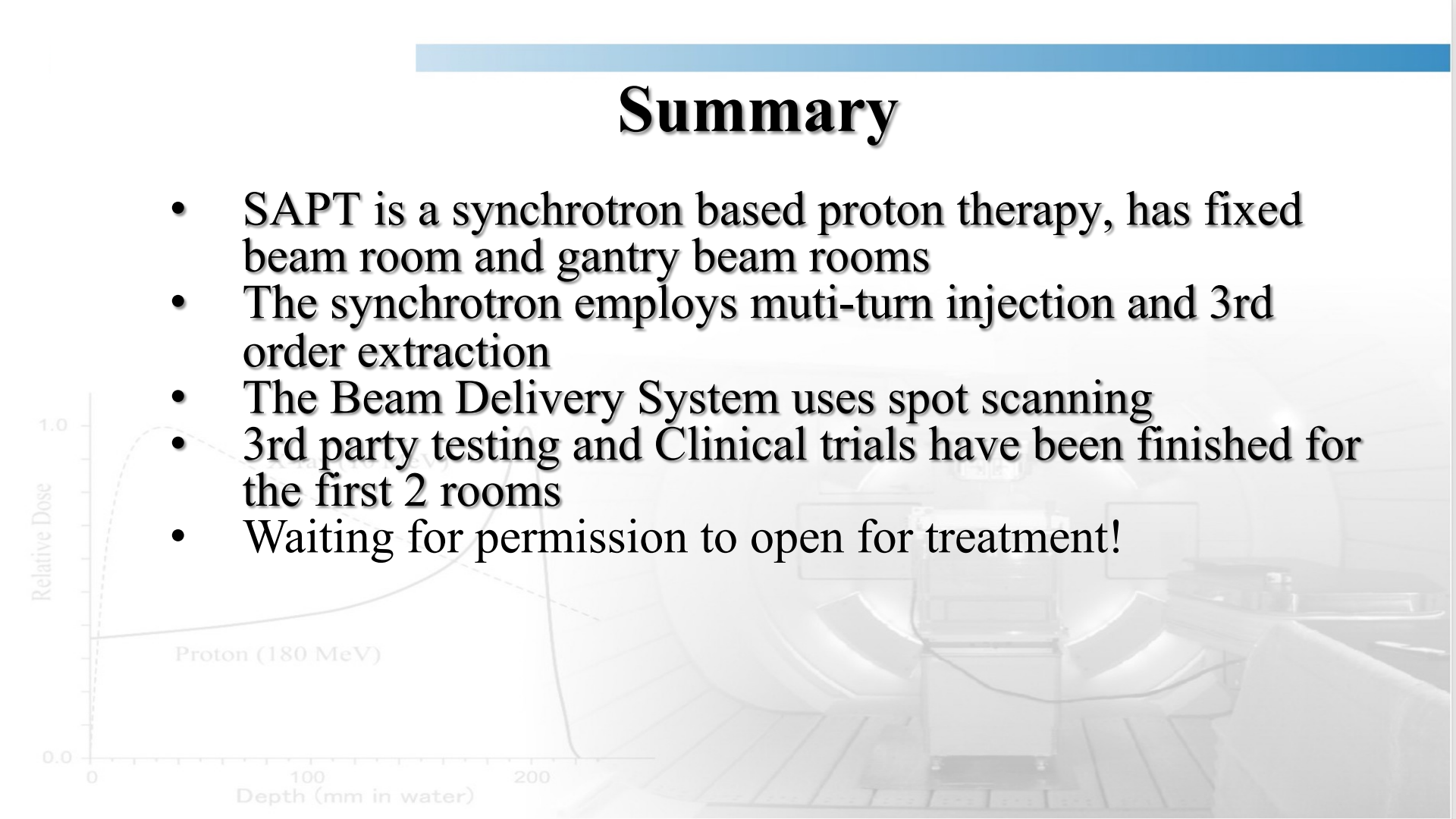
Performance –IEC62667
Safety IEC 62601-2-64 and so on
EMC YY 0505 and so on



47 patients
Head and neck, Thorax, abdomen, pelvis, spine,
Fractions： Least 5 ， Most 8
Most 24 Patients one day

Summary

- SAPT is a synchrotron based proton therapy, has fixed beam room and gantry beam rooms
- The synchrotron employs muti-turn injection and 3rd order extraction
- The Beam Delivery System uses spot scanning
- 3rd party testing and Clinical trials have been finished for the first 2 rooms
- Waiting for permission to open for treatment!



Thank you for your attention