

SAPT:

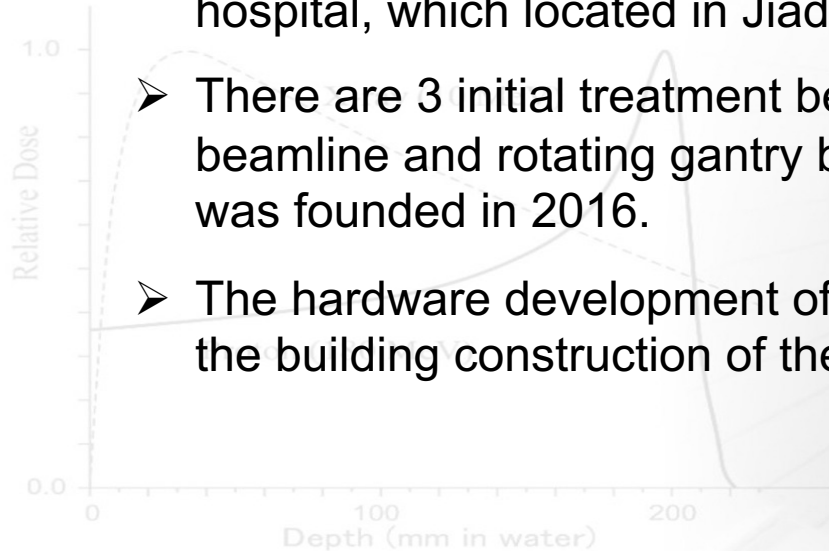
A synchrotron based Proton Therapy

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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, Jilading

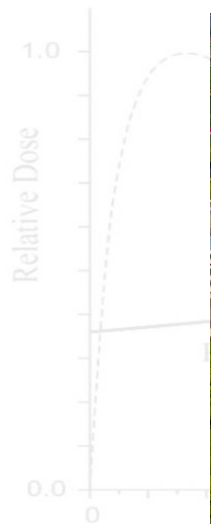


SXFEL
Soft XFEL User Facility
1.5GeV e⁻ / ~1keV x-ray

SSRF
3.5GeV Synchrotron Light Source

SARI, Zhangjiang

**SSRF (including the development team)
merged to Shanghai Advanced Research
Institute, CAS (2018.10)**



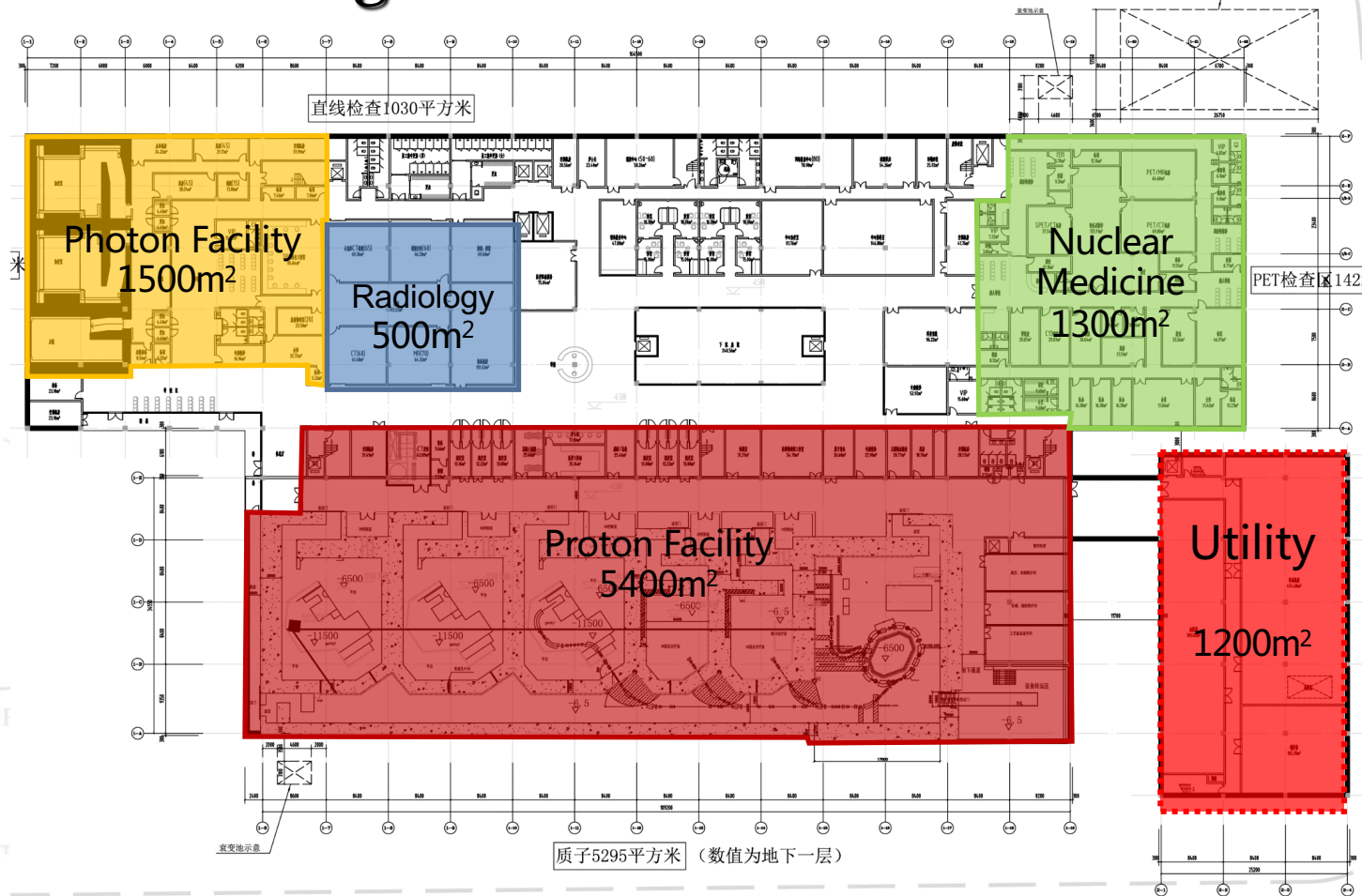
Building for Ruijin Hospital Proton Therapy Facility

Area of Building: 26075 m², underground (13000 m²) and above ground (13000 m²)

Construction Period: 2014/12–2016/11



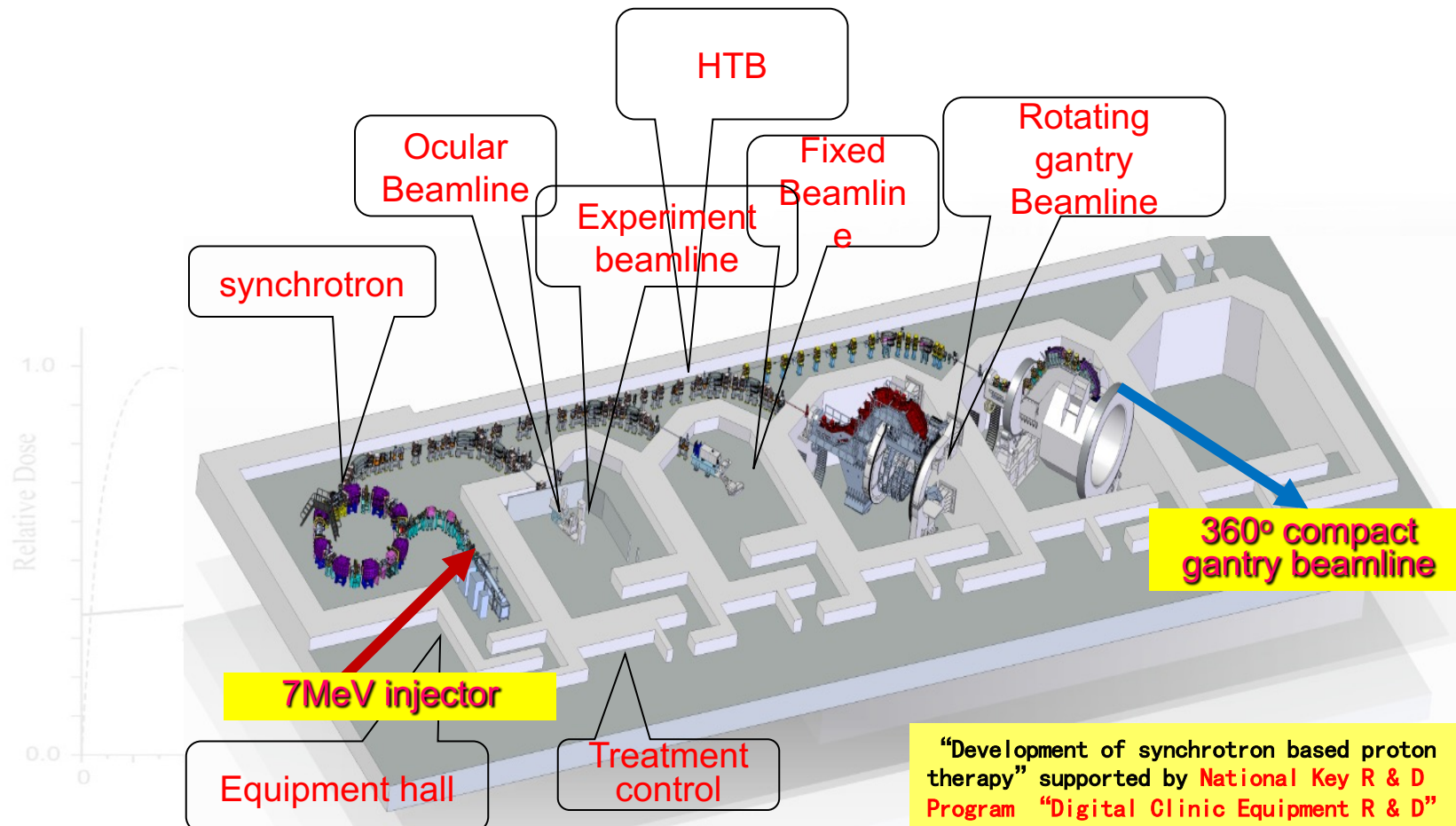
Underground floor – Treatment area



Milestones

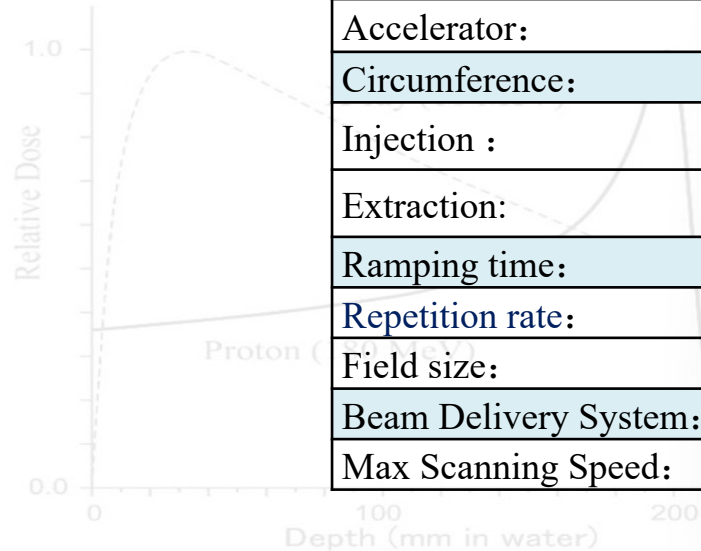


Proton Facility Layout



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:	$4\sim 8 \times 10^{10}$
Accelerator:	FODO, 8 bends
Circumference:	24.6 m
Injection :	Multi turn painting
Extraction:	3 rd 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

S

P

Spot scanning

Well shaped target
No compensators and collimators
intensity modulated

G

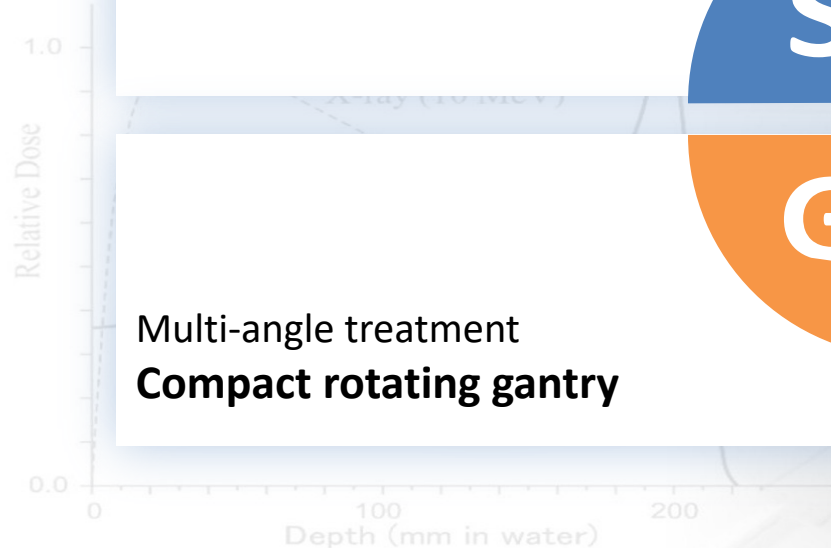
I

6 degrees of freedom couch
auto registration and positioning

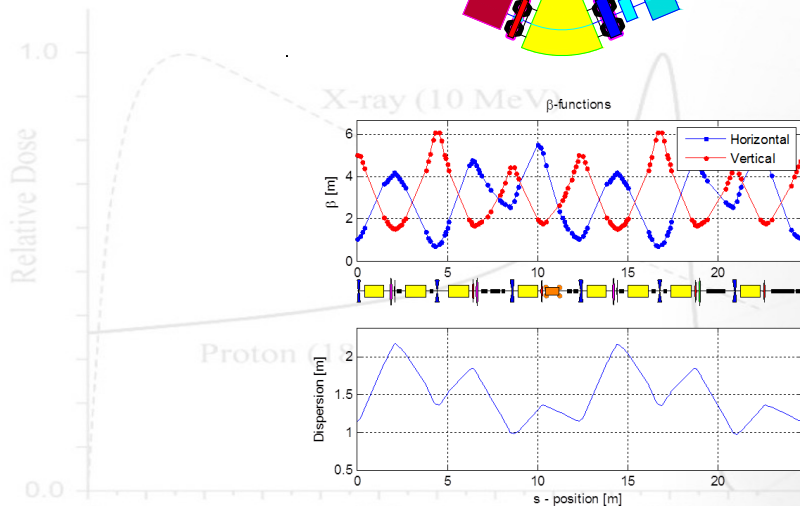
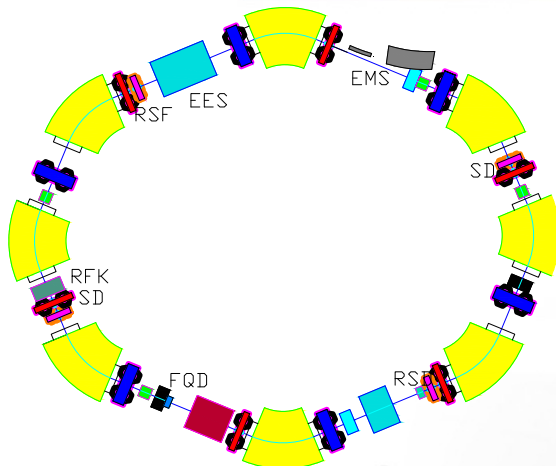
Multi-angle treatment

Compact rotating gantry

Image Guiding



Synchrotron Performance

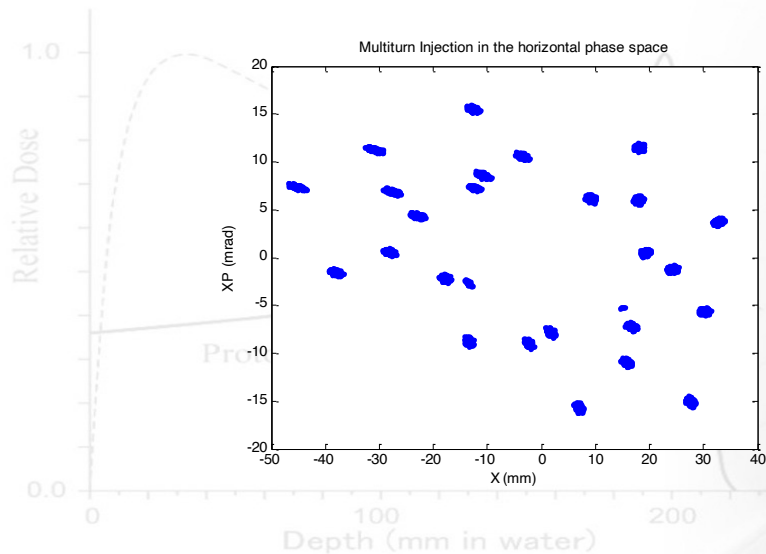


Focus on increasing acceptance

Energy at Injection	MeV	7
Energy at Extraction	MeV	70-235
Extraction beam number per spill		$4-8 \times 10^{10}$
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 dipole) β_X/β_Y	m	5.5/6.27 (4.37)
Max dispersion η_x	m	2.17
Momentum compact factor, α_p		0.4028
Transition gamma γ_t		1.576
Max RF voltage V_{rf}	kV	2

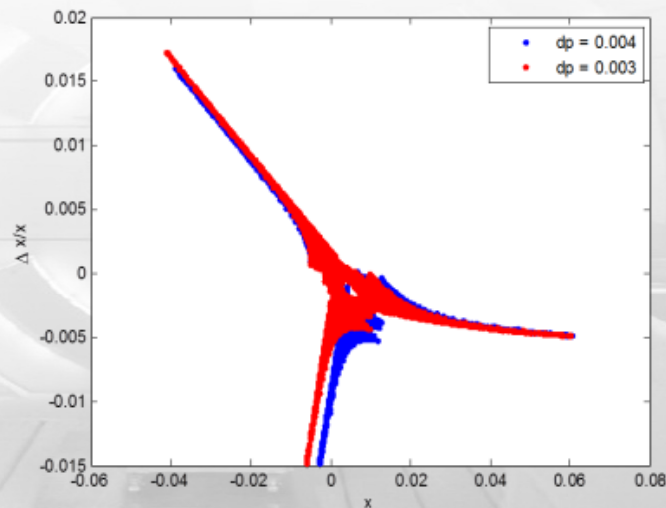
Multi-turn Injection

- ❑ 30 Multi-turn injection, painting by bump decreasing at horizontal and mismatch at vertical
- ❑ 2 kicker bump, ES+MS
- ❑ Injection efficiency 30%
- ❑ Max beam intensity 1.6×10^{11}

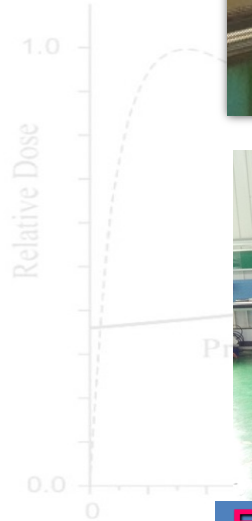
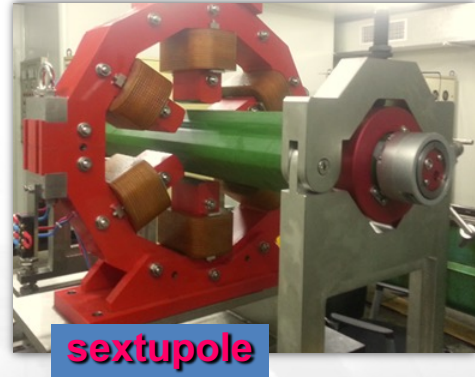
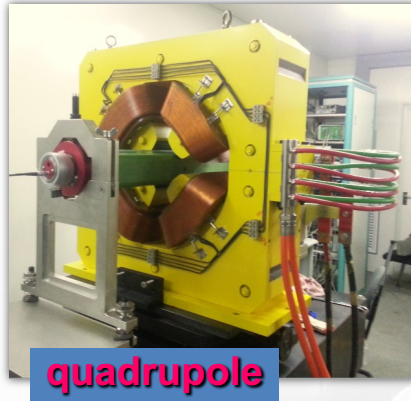
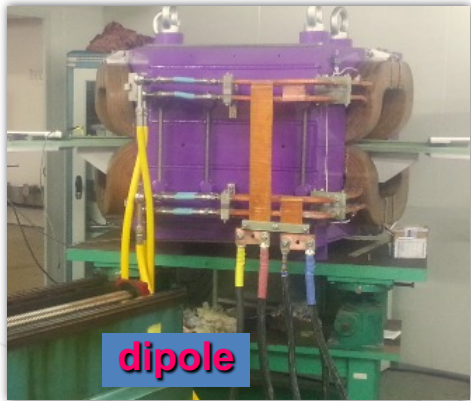


3rd order Extraction

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

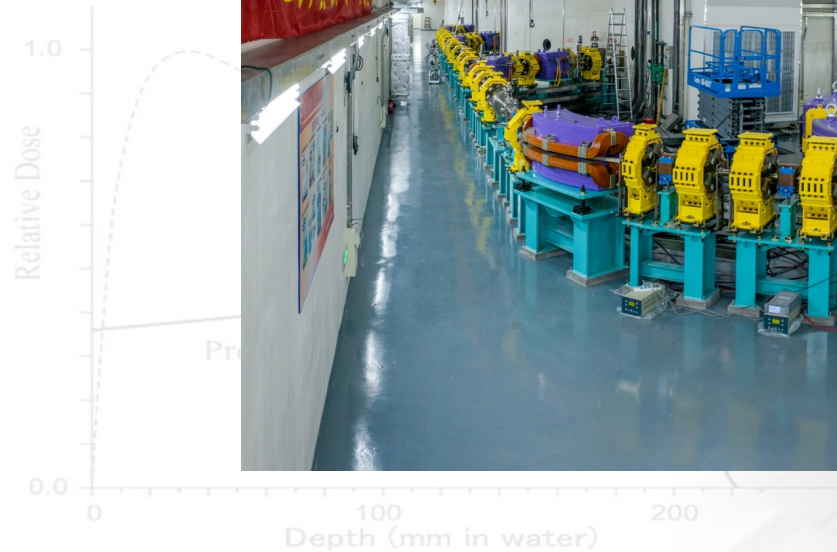


Key components of accelerator



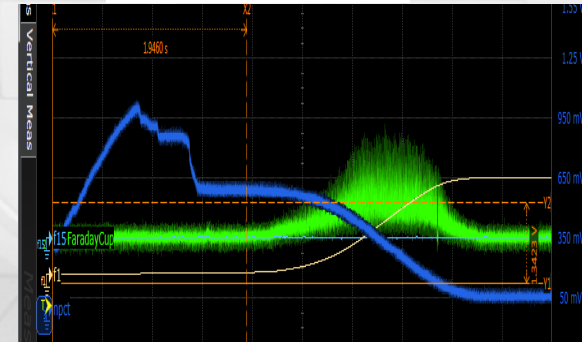
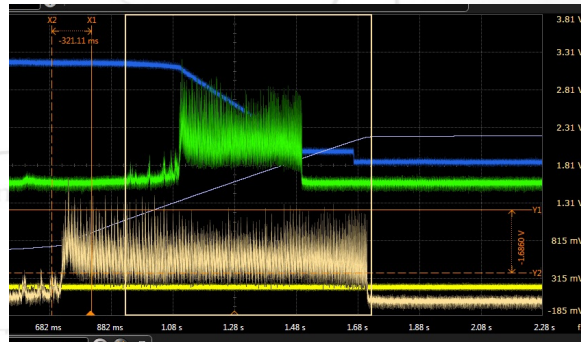
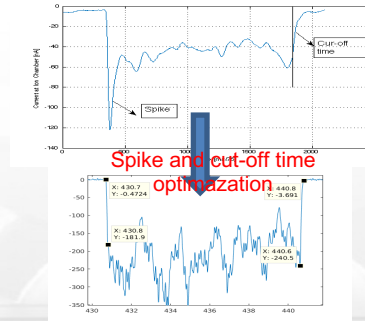
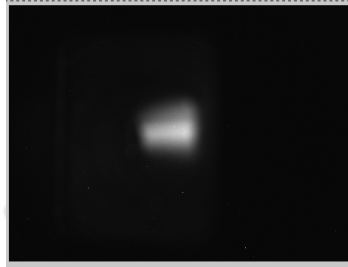
Proton Accelerator and Beam Transfer Beam Line

Good Reliability: up time > 98% in clinical trials



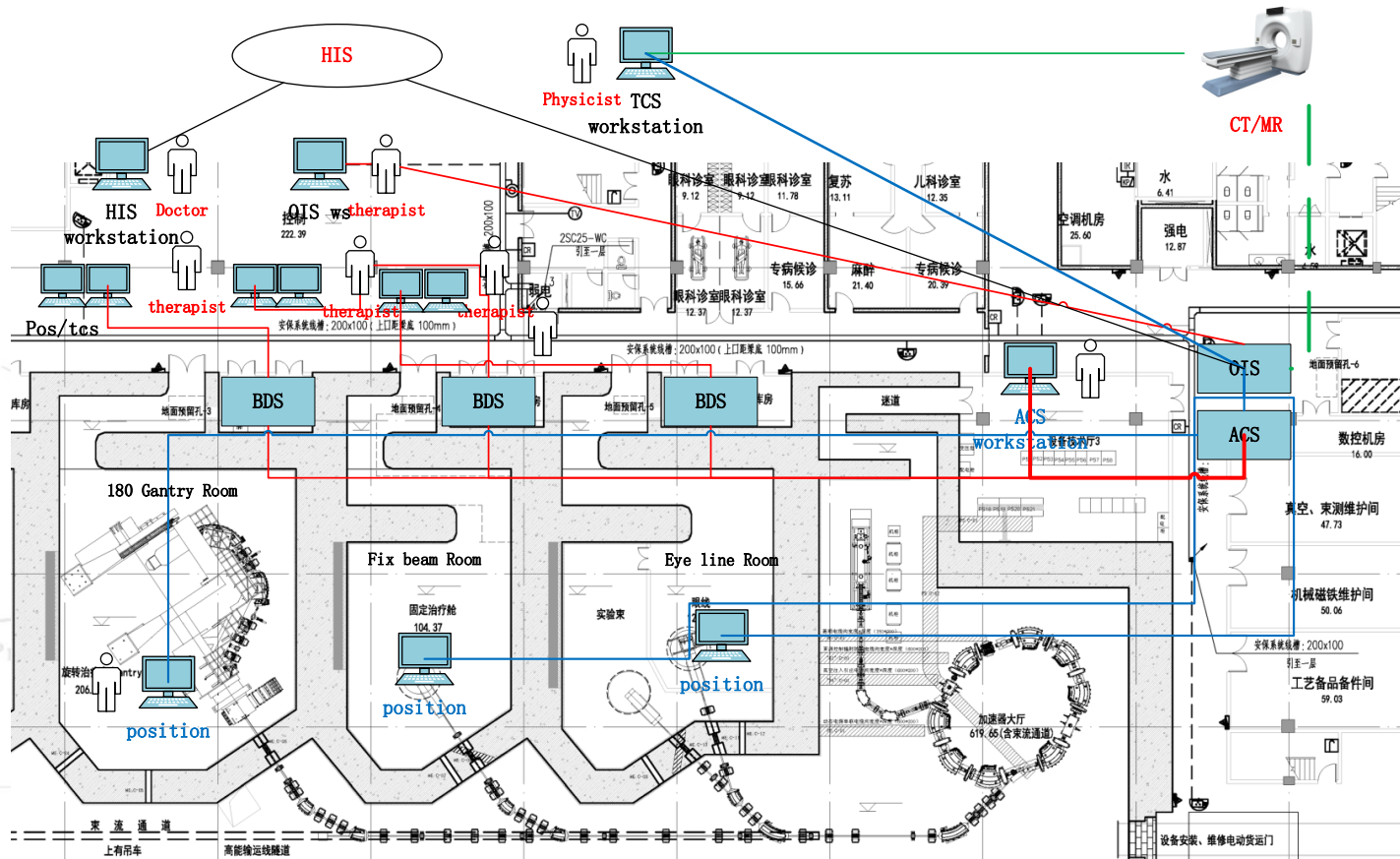
Accelerator Commissioning

- 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 ;



Beam profile and current at HTB

Multi-energy extraction experiment



Treatment room

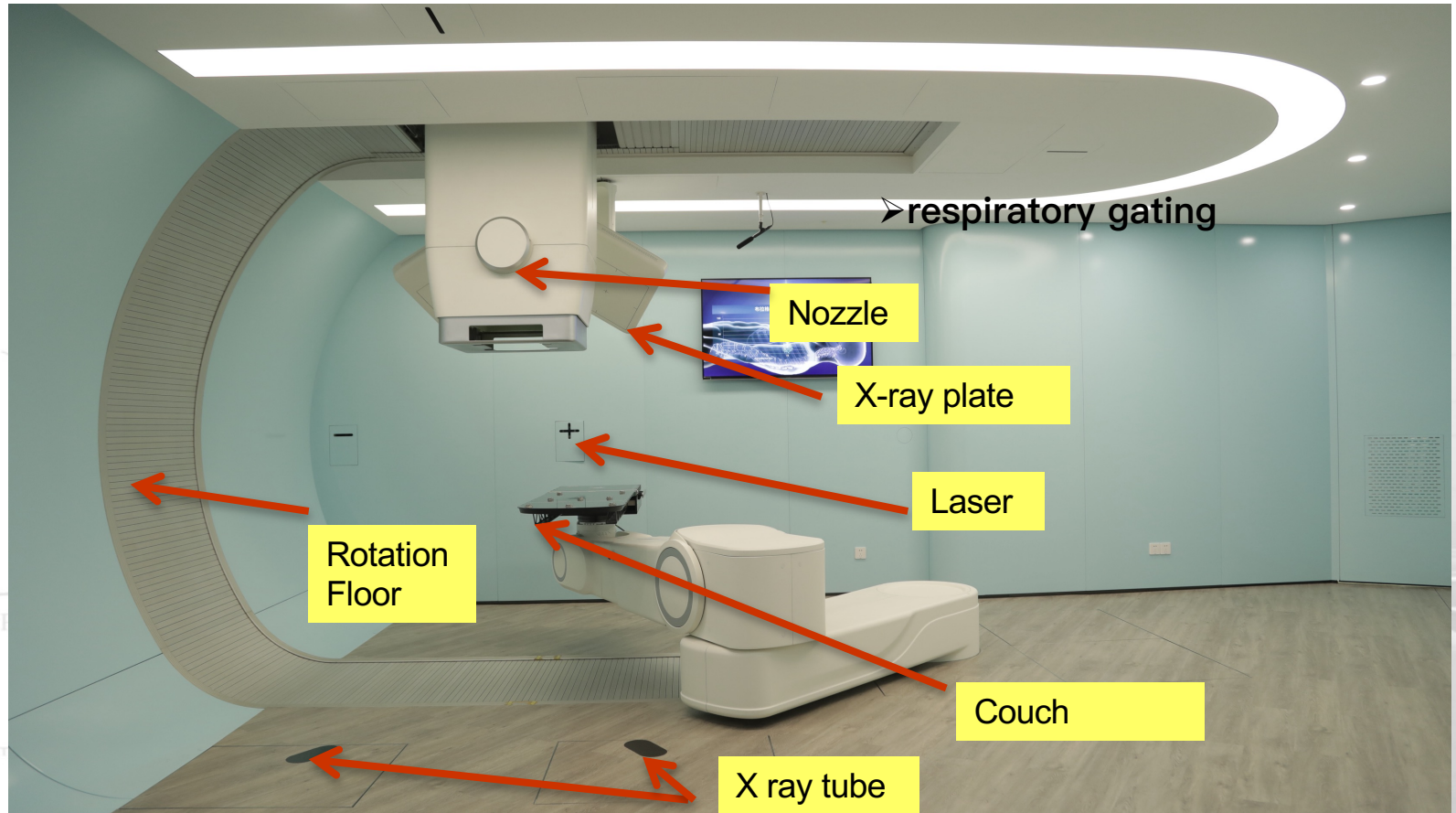
Fixed beam Room



Eye treatment room

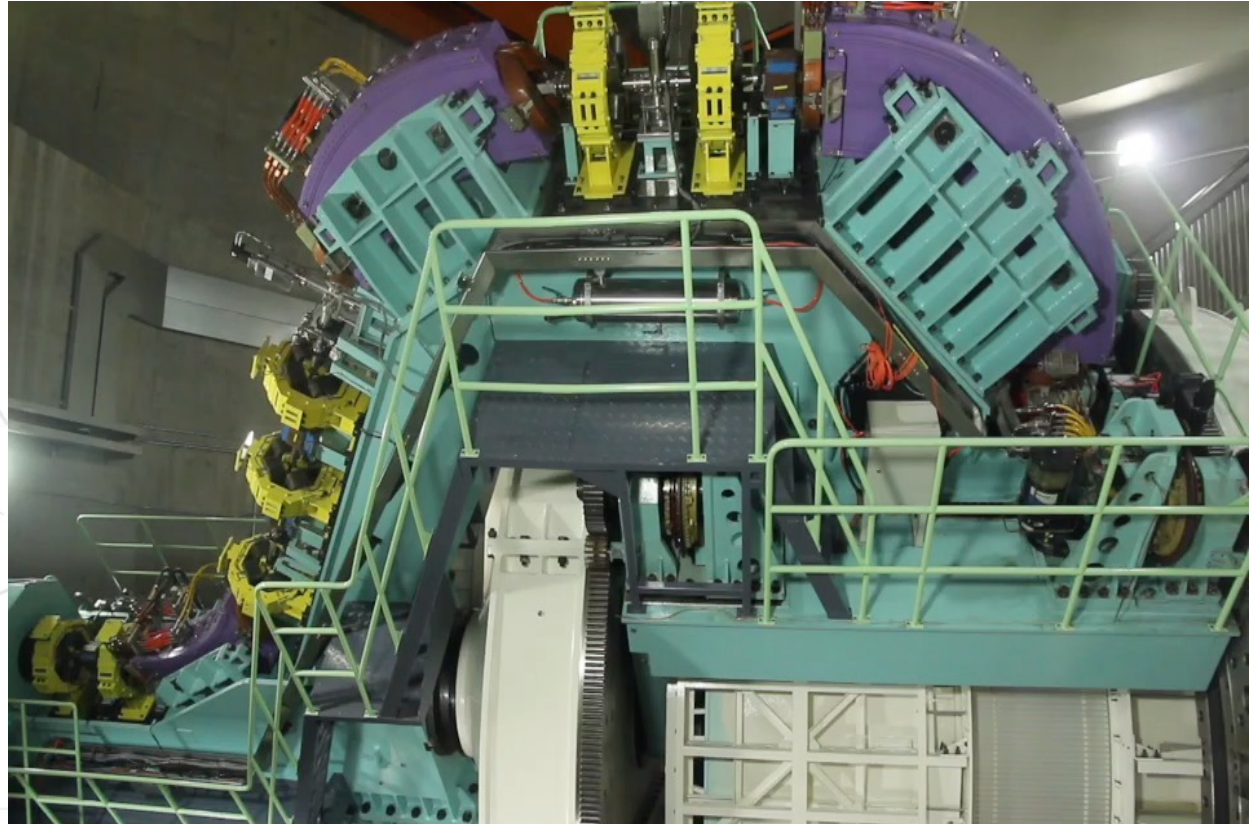
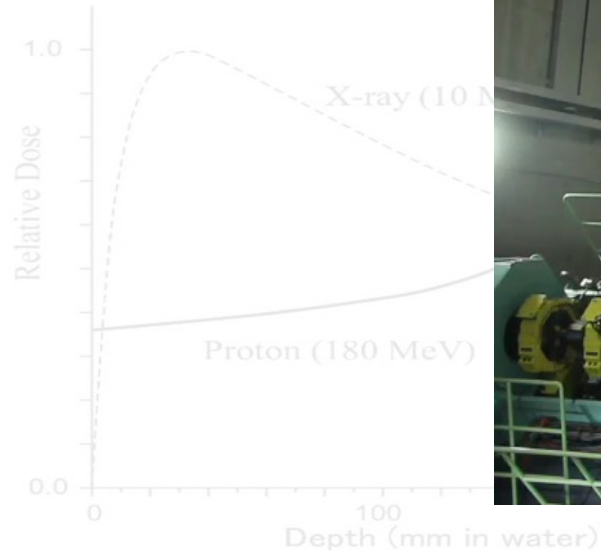


180 Gantry Room



180 gantry

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

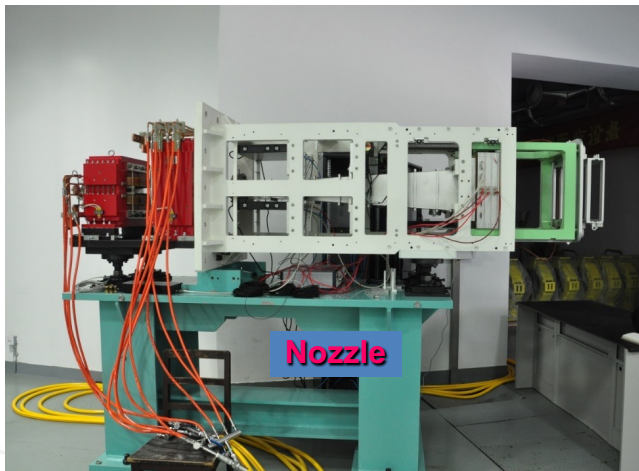


Compact 360 gantry room



Smaller and more accurate
CBCT/In room CT

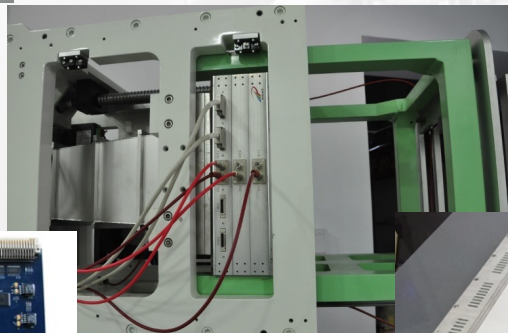
Beam Deliver System



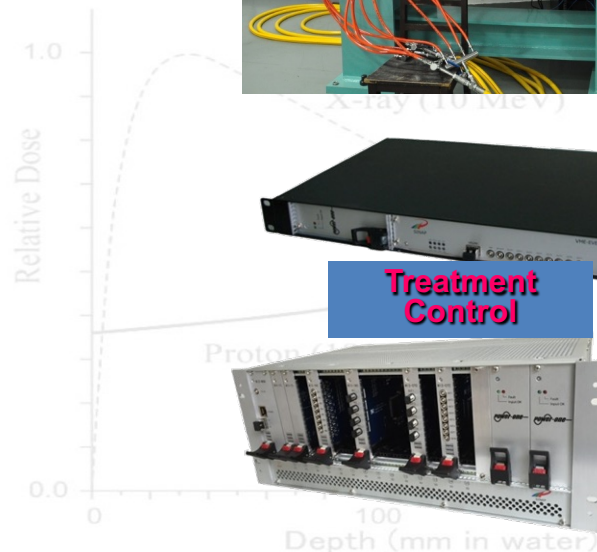
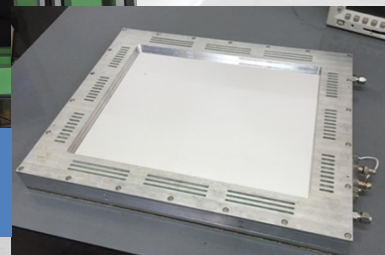
Depth	34 g/cm ²
SOBP	30 g/cm ²
Field Size	40 cm (ScanU) 30 cm (ScanV)
SAD	2.65m
Speed	2cm/ms (ScanU) 0.5cm/ms (ScanV)



**Treatment
Control**

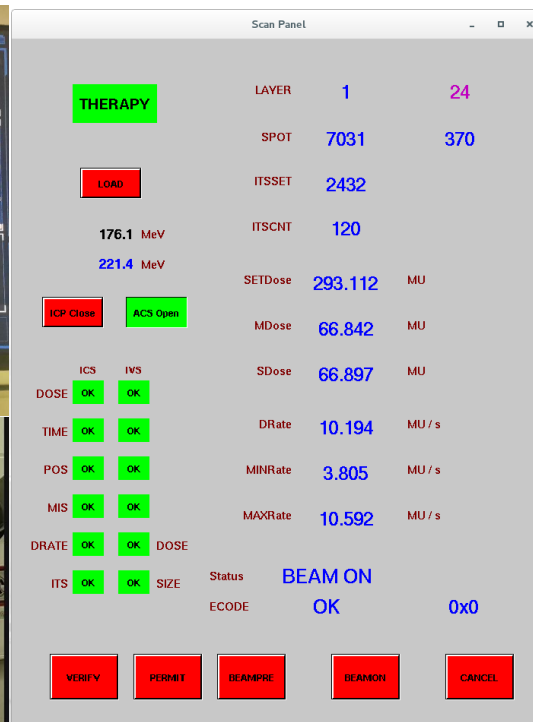
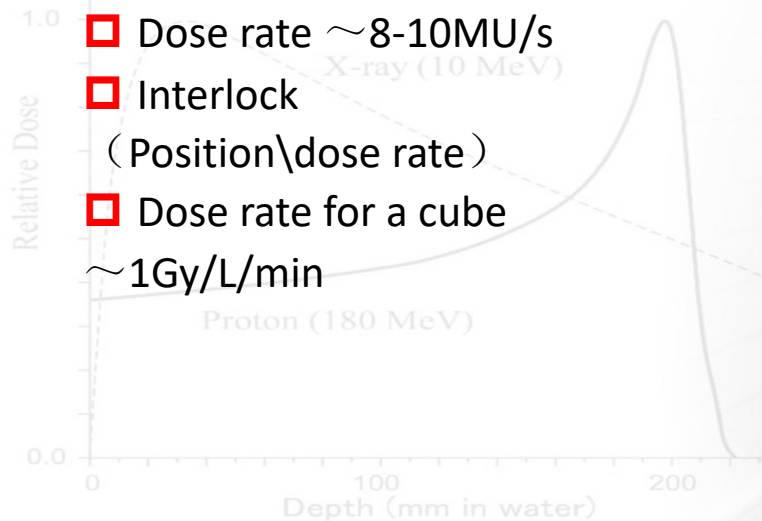


**Ion
chamber**



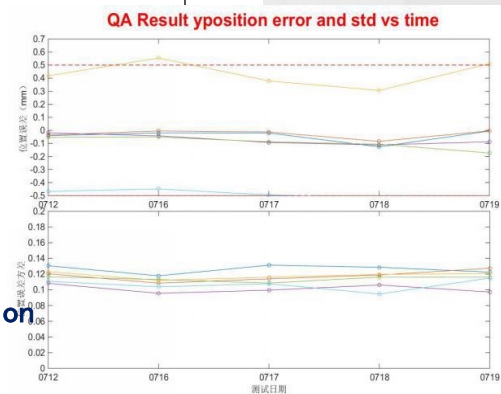
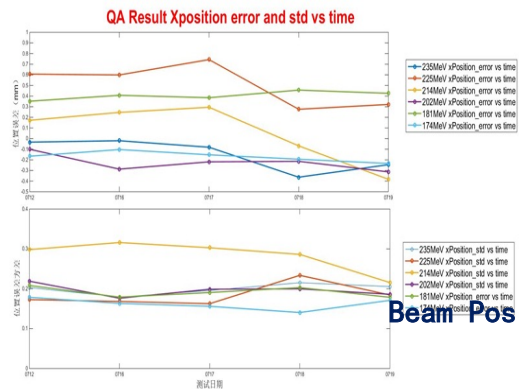
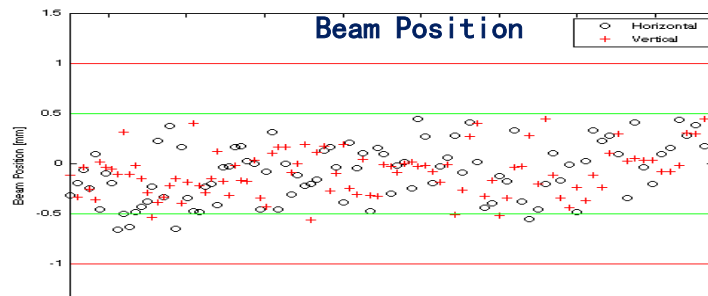
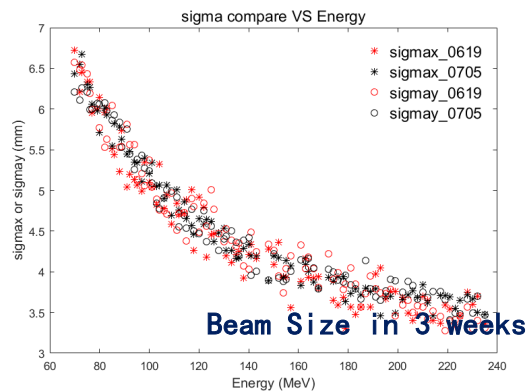
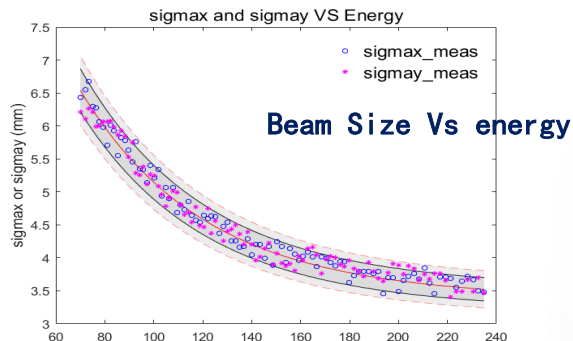
Performance of BDS

- ❑ Dose Linearity (3%)
- ❑ Dose Repeatability (2%)
- ❑ Dose stability (Day、Week 2%)
- ❑ 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

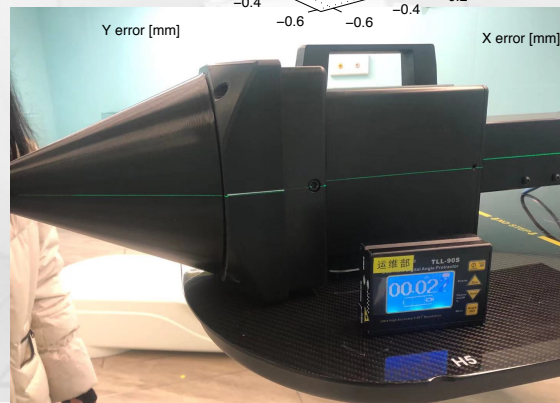
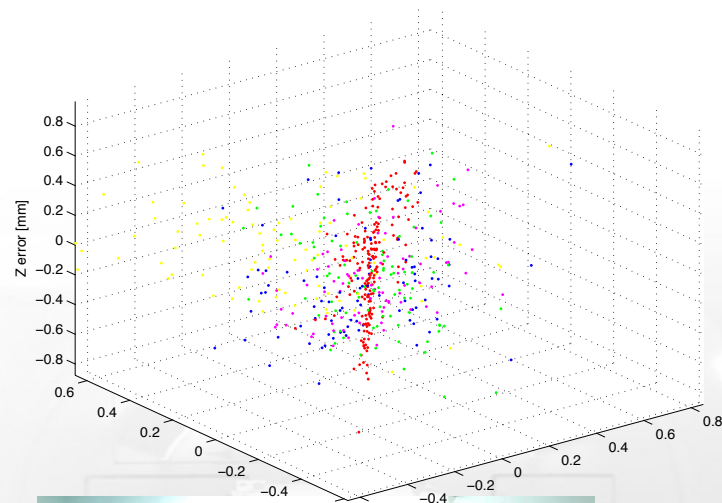
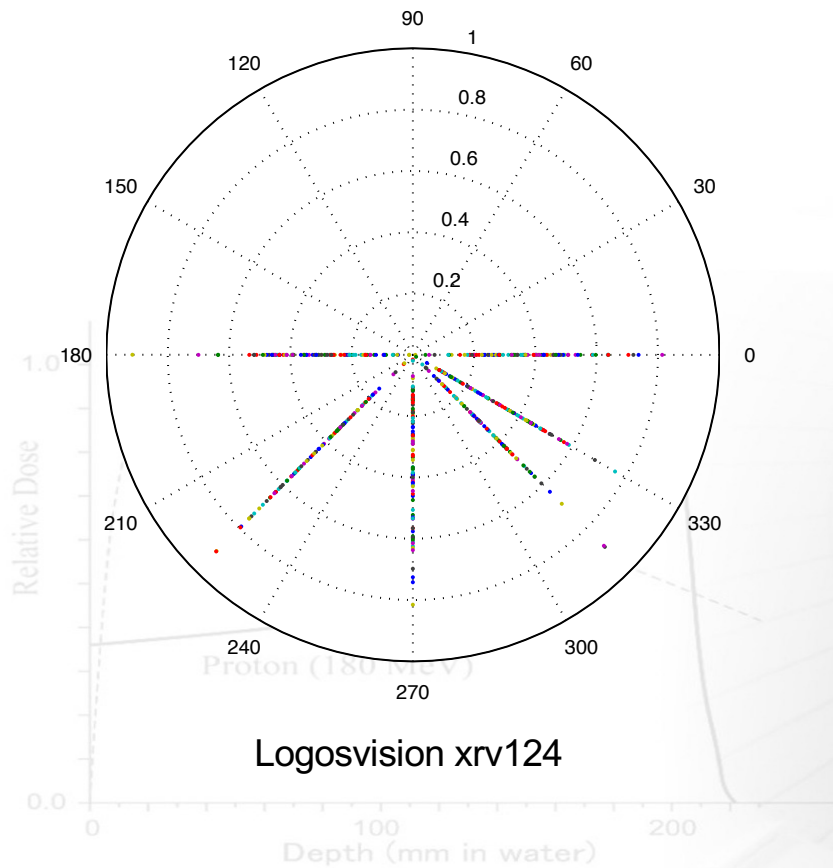


Beam Size and position

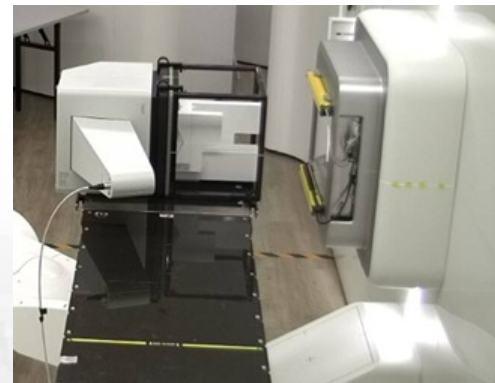
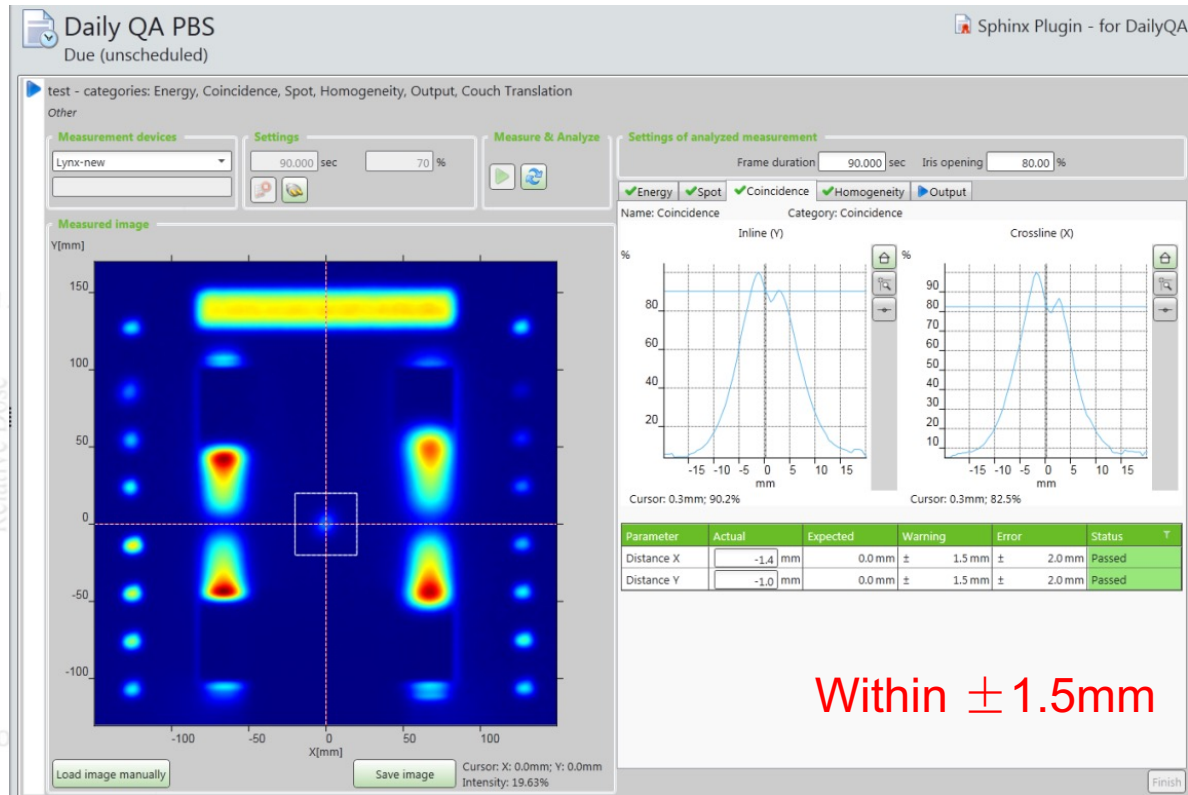
- Beam size $< \pm 15\%$;
- Position $< \pm 1\text{mm}$



Beam Position at ISO Center



Daily QA --dosimetry



IBA Lynx + Sphinx

测量部分		与基准值差在±1mm内	通过 不通过
17	能量检查 (109MeV)	与基准值差在±1mm内	通过 不通过
	能量检查 (142MeV)	与基准值差在±1mm内	通过 不通过
	能量检查 (172MeV)	与基准值差在±1mm内	通过 不通过
	能量检查 (221MeV)	与基准值差在±1mm内	通过 不通过
18	束斑位置、大小检查 (109MeV)	位置偏差在±1.5mm内 大小偏差在±10%	通过 不通过
	束斑位置、大小检查 (142MeV)	位置偏差在±1.5mm内 大小偏差在±10%	通过 不通过
	束斑位置、大小检查 (172MeV)	位置偏差在±1.5mm内 大小偏差在±10%	通过 不通过
	束斑位置、大小检查 (221MeV)	位置偏差在±1.5mm内 大小偏差在±10%	通过 不通过
19	影像中心和束流中心一致性	偏移≤1.5mm	通过 不通过
20	MU均匀性检查	与基准值差在±3%内	通过 不通过
21	MU输出重复性检查	与基准值差在±3%内	通过 不通过

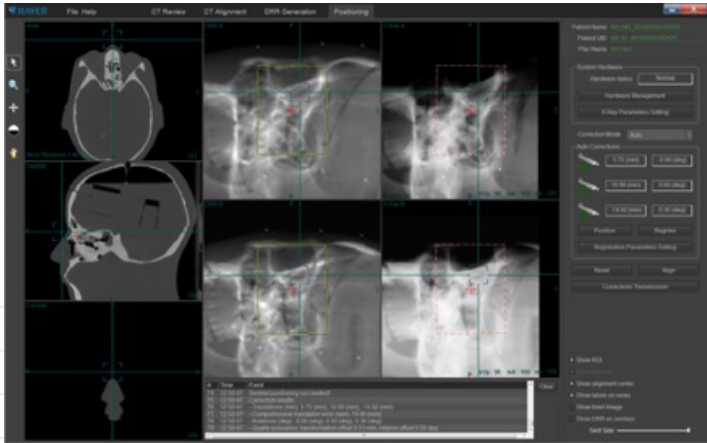
Within $\pm 1.5\text{mm}$

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



Daily QA
protocol

Patient Positioning and Verification System



➤ couple KV-X-ray imaging and high-precision patient positioning systems for automatic six degrees of freedom setup correction $< \pm 1\text{mm}$

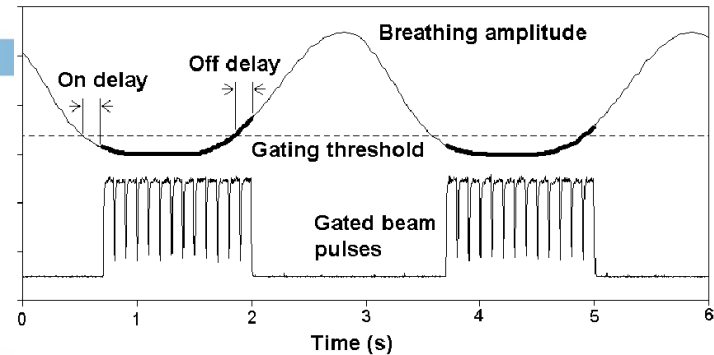
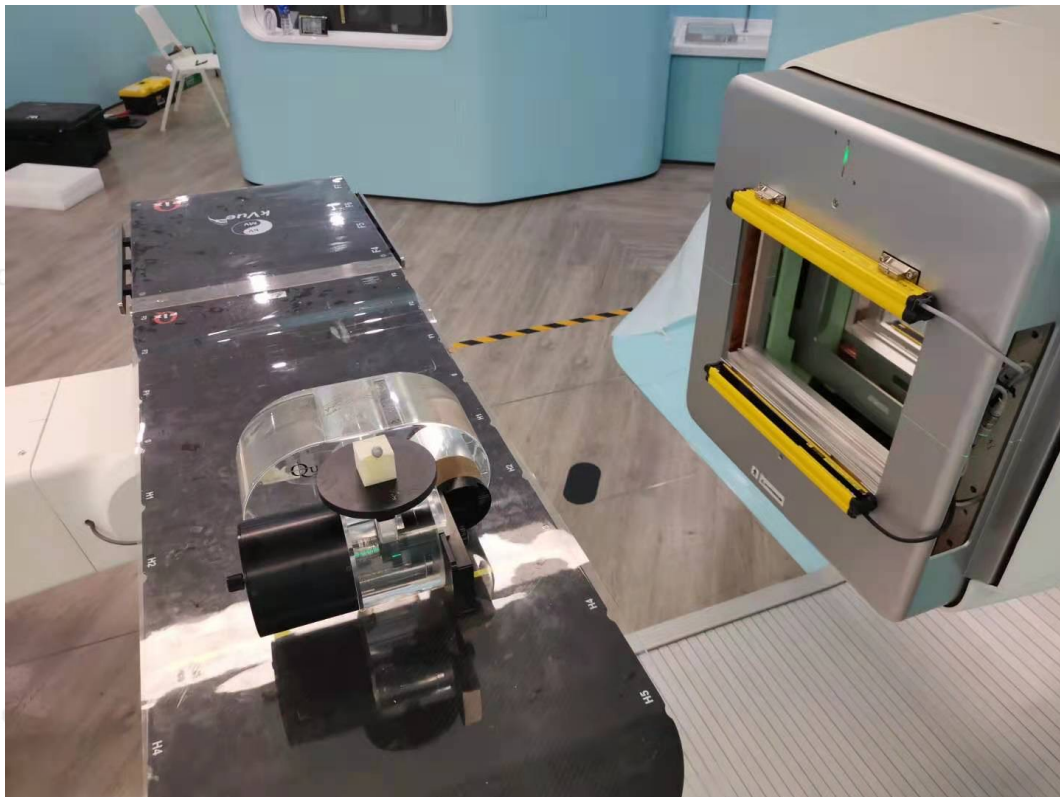
➤ GPU-based fast 2D/3D image registration (a few seconds)

6 degrees of freedom couch

Move: $\pm 1\text{mm}$

Rotation: $\pm 0.2^\circ$

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

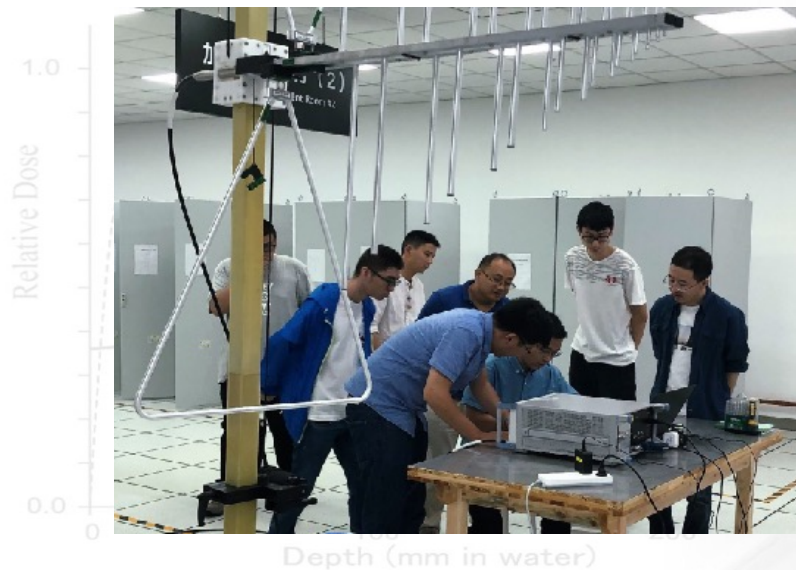
EMC YY 0505 and so on

47 patients

Head and neck, Thorax, abdomen,
pelvis, spine,

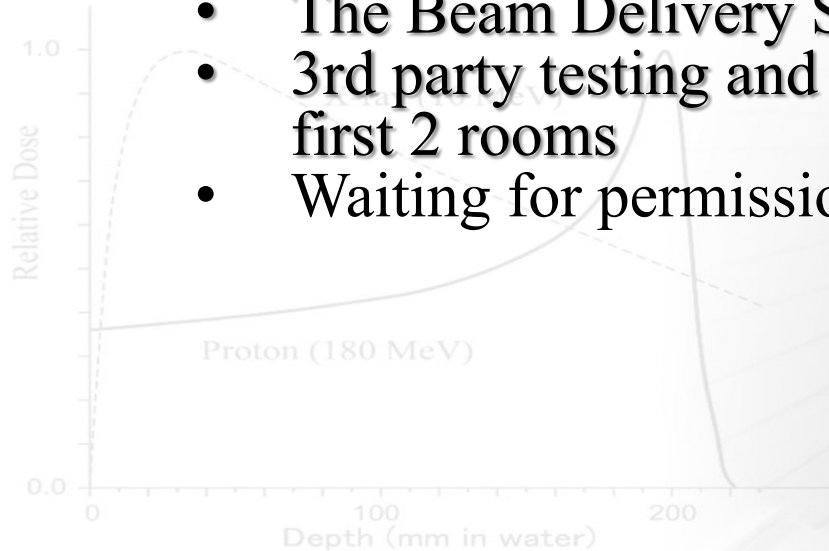
Fractions: Least 5 , Most 8

Most 24 Patients one day



Summary

- SAPT is a synchrotron base proton therapy, have fixed room and gantry rooms
- The synchrotron employs multi-turn injection and 3rd order extraction
- The Beam Delivery System using spot scanning
- 3rd party testing and Clinical trials are finished for the first 2 rooms
- Waiting for permission to open!



Thank you for your attention

