Introduction for the Alignment of Wuwei Heavy Ion Medical Machine

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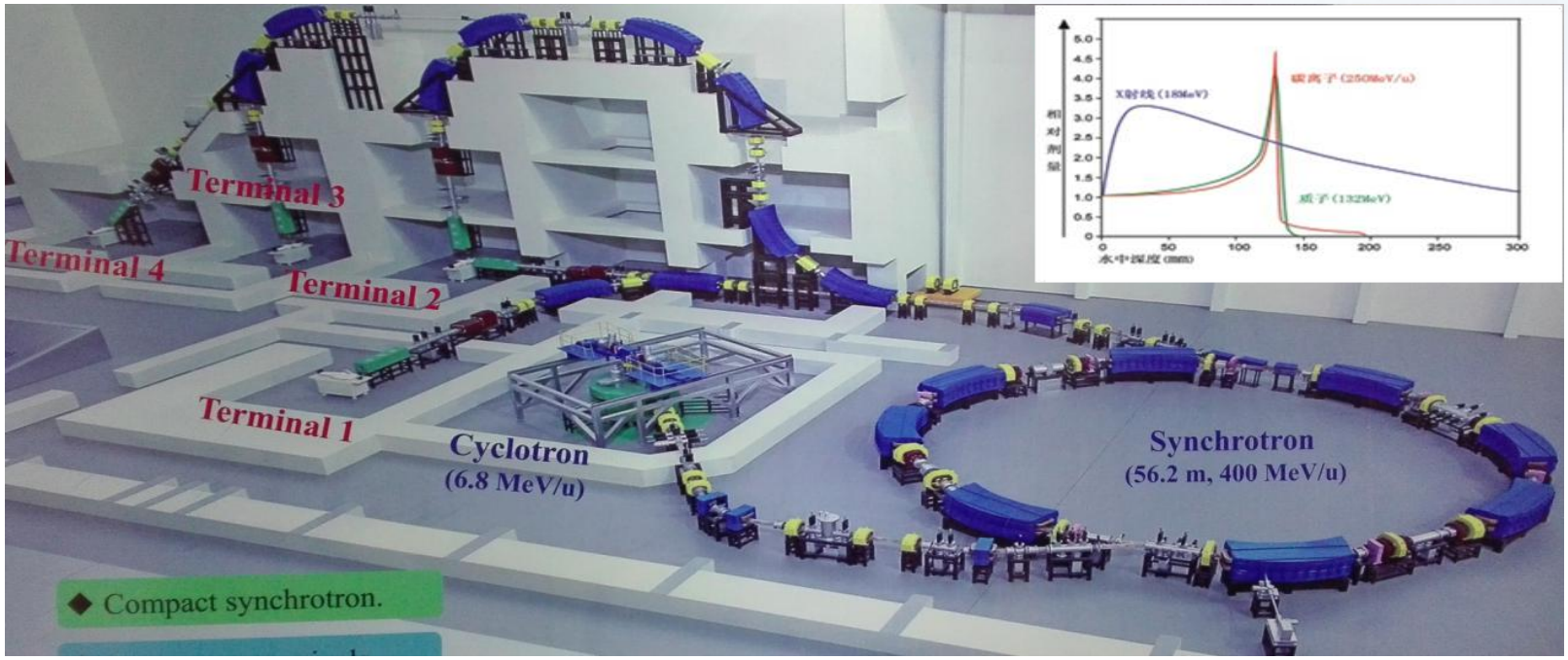
Content :

1 Introduction of Wuwei HIMM

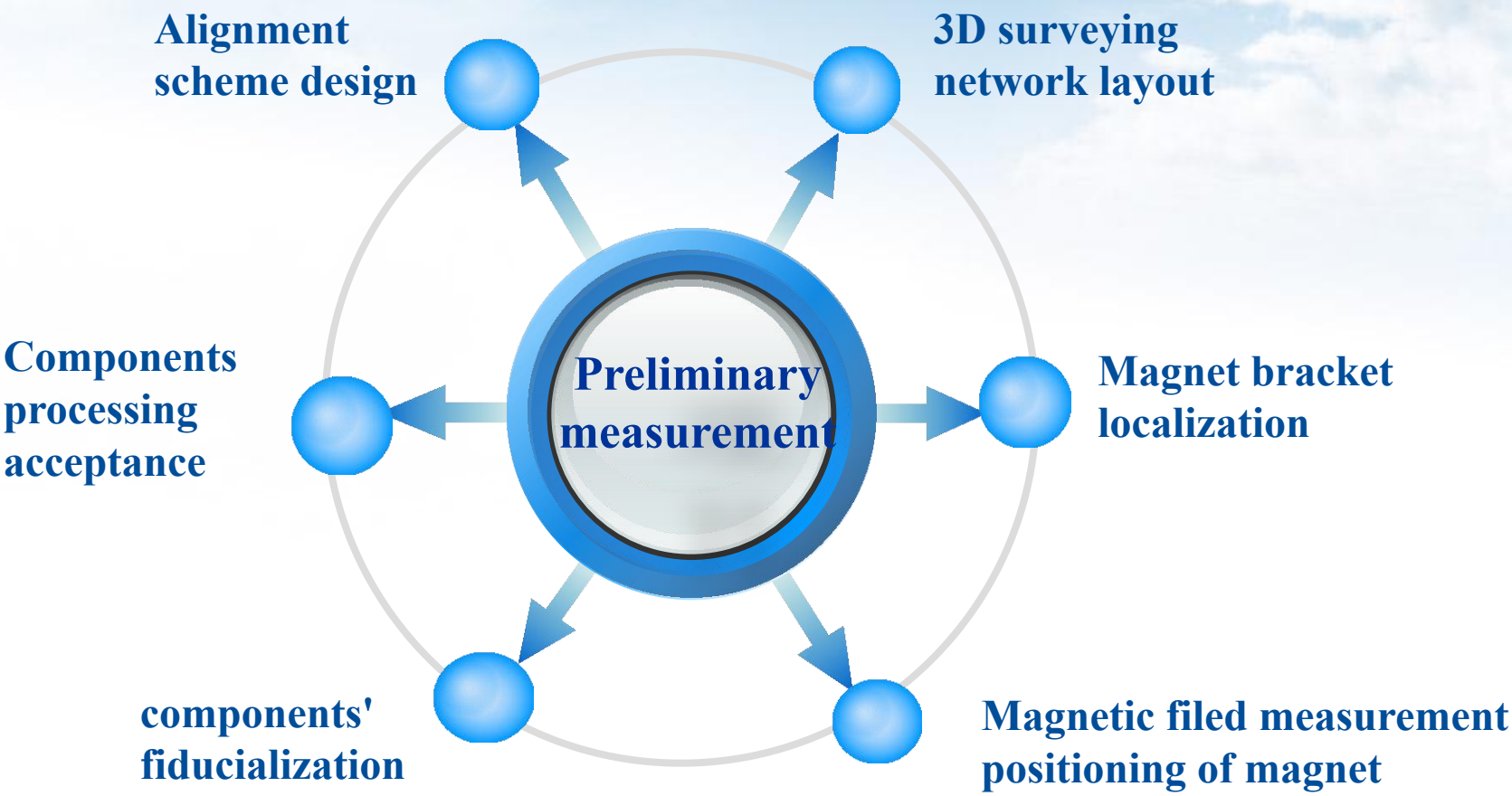
➢ The Wuwei HIMM is China's first domestic medical heavy ion accelerator independently developed and constructed by the Institute of Modern Physics of the Chinese Academy of Sciences. Which was started in 2013 and is located in Wuwei city. The total investment is 1.7 billion RMB, with a total construction areas of 213,000 square meters. It mainly includes heavy ion treatment centers and the supporting hospitals, as well as the Nursing Garden.

➢Consists : 2 ECR ion sources, a cyclotron injector, a medium energy transport system, a synchrotron, a high energy transport system, and 4 treatment terminals(A horizontal treatment terminal, 2 vertical treatment terminals and a 45 degree treatment terminal).

➢Parameters: The type of beam used for treatment is $^{12}C6+$. The beam energy provided by the treatment terminal is 120MeV/u～400MeV/u. The effective range of the beam in the human body is 270mm. The bragg peak of heavy ions can treat most cancers in the body with minimal damage to normal tissues.



2 Preliminary measurement of Wuwei HIMM

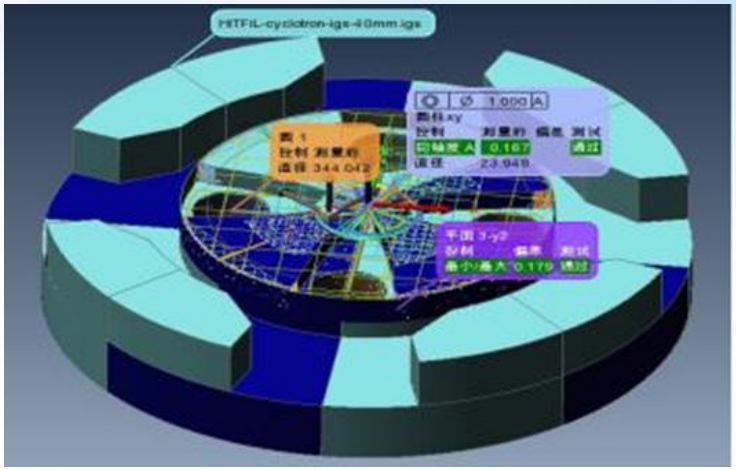


➢ Components accuracy requirements of the alignment for HIMM

Components / Error	Dipoles	Quadrupoles	multipoles	BPM	Treatment components
ΔX (mm)	0.10	0.10	0.10	0.20	0.50
ΔY (mm)	0.10	0.10	0.10	0.20	0.50
ΔZ (mm)	0.20	0.20	0.20	0.50	0.50
Δφ (mrad)	0.20	0.20	0.50	0.50	0.50
Δθ (mrad)	0.20	0.20	0.50	0.50	0.50
Δψ (mrad)	0.20	0.20	0.50	0.50	0.50

◻ Parameters for alignment : ΔX and ΔY are the transverse offset of the component installation, ΔZ is the longitudinal offset of the component mounting, Δφ is the pitching rotation around the X-axis , Δθ is yawing rotation around the Y-axis, Δψ is rolling rotation around the Z-axis .

➢ Acceptance measurement of HIMM processing components



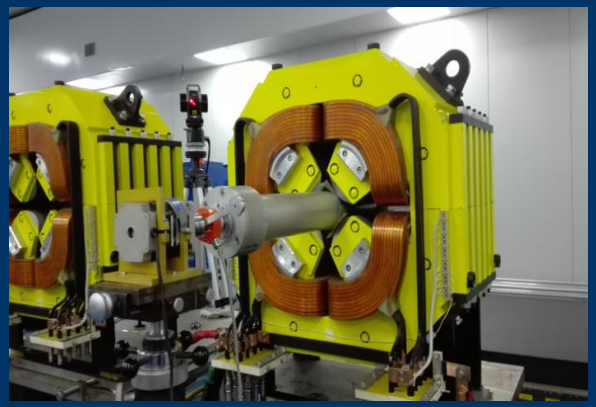
Measurement of machining acceptance of cyclotron

Assembly measurement of cyclotron

Alignment of an ion source

Acceptance measurement of vacuum chamber

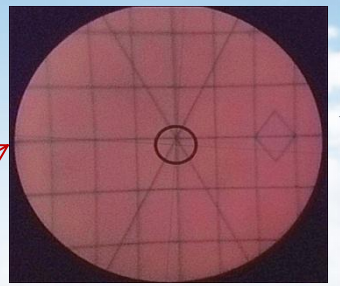
➢ Fiducialization of magnet



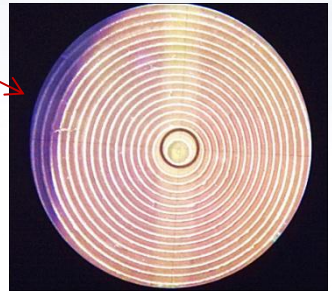
- Multi-pole fiducialization method : magnetic center. Multi-pole magnet is calibrated during the magnetic field measurement process, the laser tracker is used to position the harmonic magnetic field measurement coil at the magnet mechanical center, the magnetic center is acquired by the magnetic field measurement, and then the magnetic center is converted to the external reference base of the magnet.

- Fiducialization of the dipole is conventional mechanical calibration method. The geometric center of the component is constructed by reference reserved by the dipole, and finally the geometric center is converted to the reference benchmark of the magnet surface.

Calibration of beam diagnostic components



View screen



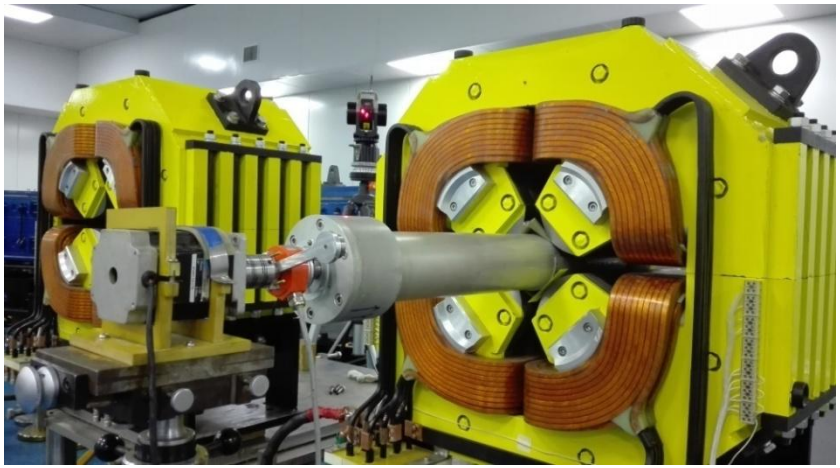
Faraday cup

- Calibration method: Alignment telescope and laser tracker combined calibration. Firstly, using an alignment telescope to aligned the center of all beam detectors to a centerline, then use a laser tracker to measure the flange reference of the alignment telescope and build a coordinate system, and the center line of the detectors are converted to external targets. Finally, the vacuum chamber is installed as a whole by using the laser tracker.

Positioning of magnetic field measurement

Dipole integral measurement orbit positioning

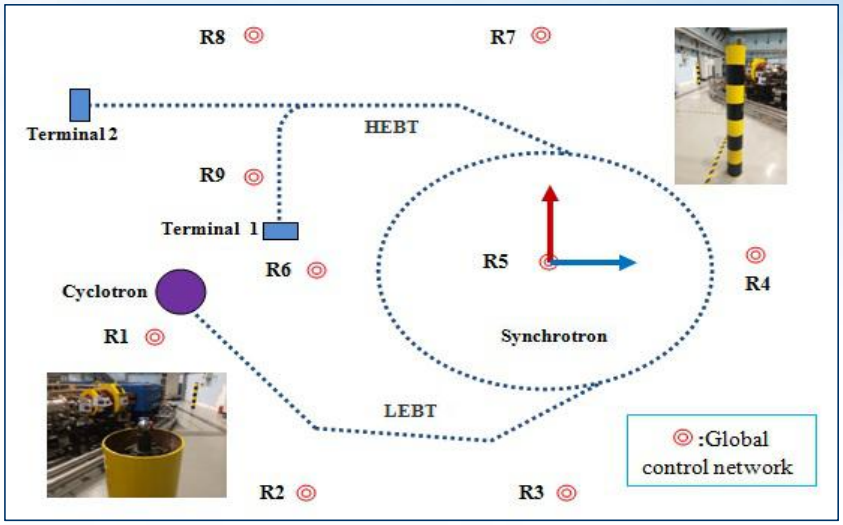
Dipole Hall probe mapping positioning

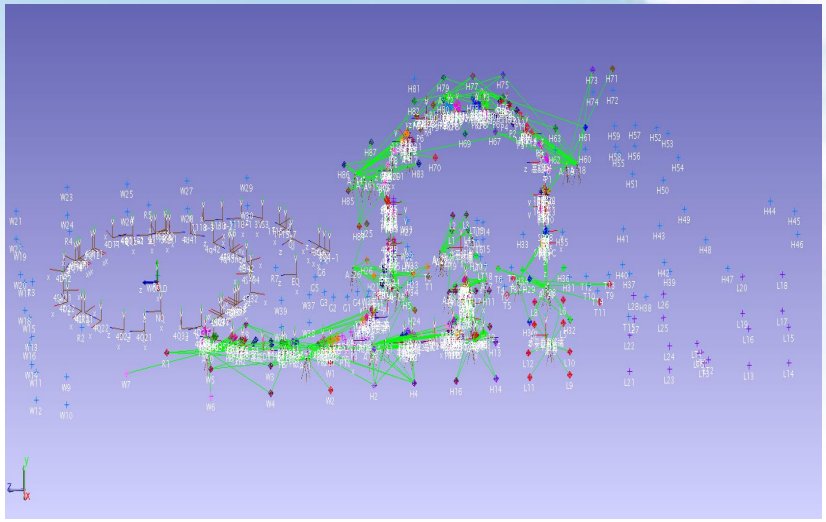


Quadrupoles harmonic measurement positioning

Alignment of cyclotron magnetic field measurement

➢ Layout and measurement of the 3D surveying network





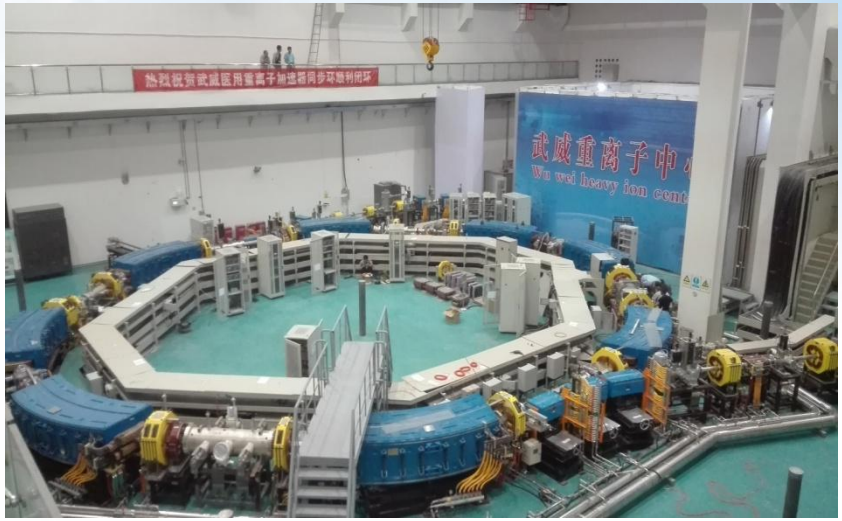
- The 3D surveying network of HIMM consists of two parts: the global surveying network and the local surveying network. The global surveying network set up first, the global surveying network consists of nine reference columns buried deep in the ground for more than 20 meters, three-dimensional adjustable target seats are installed on the top of the reference columns, and distributed near the beam line.
- Nearly 200 local surveying network spread on the nearby wall and ground according to the installation need. After measuring all network points, the USMN (Unified Spatial Metrology Network) using adjustment. Error of the overall surveying network after adjustment is 0.06mm.

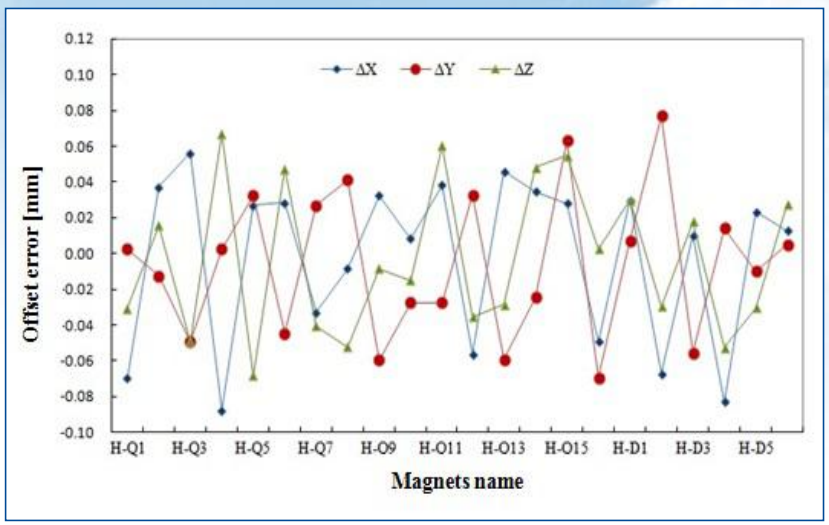
3 Installation and alignment of Wuwei HIMM

Installation and alignment of cyclotron and source beam line

- Because the cyclotron weighs over 80 tons and cannot be installed as a whole, we adopted the bottom-up hierarchical installation and alignment method in the installation process. The source beam is mounted on the top of the cyclotron and is more than 3m above the ground. In order to avoid occlusion and ensure the alignment accuracy of all components, we use the alignment method of erecting the laser tracker at high altitude.

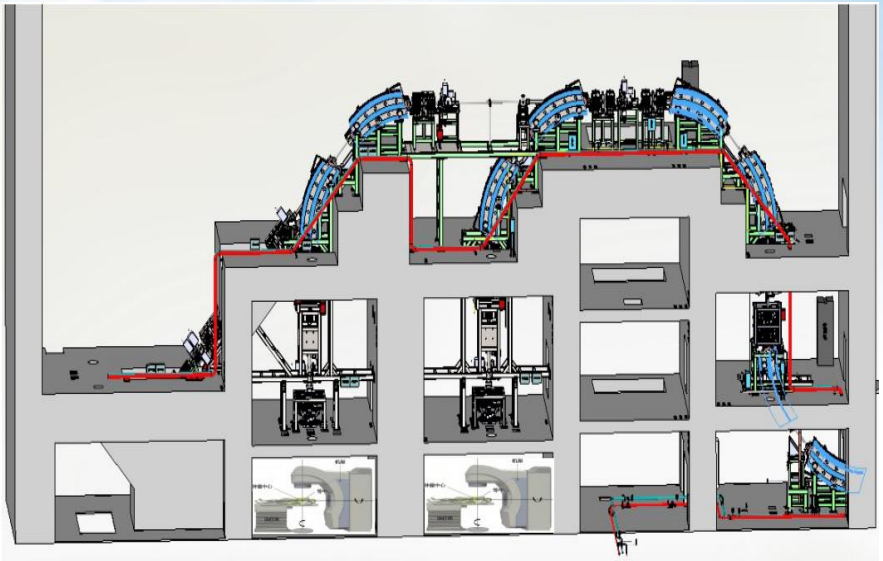
➢ Alignment of synchrotron

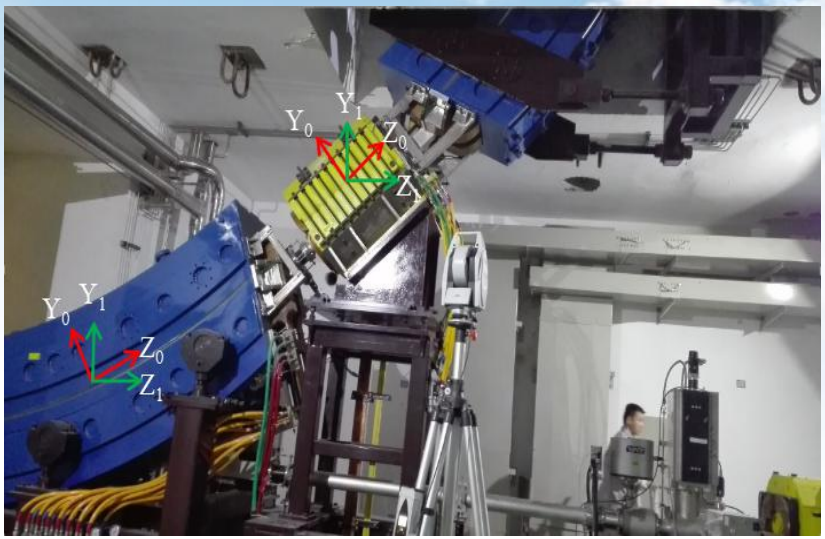




- The synchrotron has a perimeter of 56.1m, and no occlusion, good visibility conditions, We used one-station alignment adjustment in the track smoothing measurement, which can reduce the error of the transfer station, and ensure the relative positional accuracy between the magnets of the synchrotron.
- All quadrupoles, multipoles and dipole magnets alignment error of the synchrotron is no more than 0.1mm. The alignment accuracy of components such as beam diagnostic components, high frequency, and vacuum chamber is better than 0.5mm.

➢ Alignment of high energy transport system



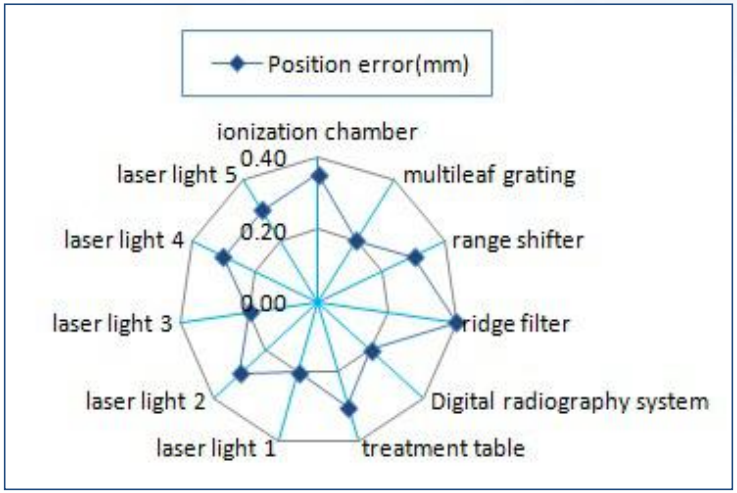


- Because of the height of the high energy transport system exceeds 18m and most components need vertical installation, the installation attitude of the components is different from that of the conventional accelerator. The design and research of surveying network extension, pre-alignment of various unit modules, conversion component reference, All problems in the alignment installation process of high-energy beam lines are solved. Which save much time for alignment, and finally all components of the high-energy transport system alignment accuracy are less than 0.1mm.

➢ Alignment of treatment components

- The treatment parts mainly include irregular ionization chamber, multileaf grating, range shifter, ridge filter and laser light and so on. The accuracy of the installation is lower than that of the magnet. All parts have no calibration data, according to the external dimensions of parts and processing drawings to find out the geometric center of the parts. With the help of the laser tracker and treatment room surveying network through the geometric center align all treatment components. All treatment components alignment position errors are less than 0.4mm .

Alignment of horizontal terminal component



Positioning errors of treatment components

4. Summary

- Wuwei HIMM all magnets alignment offset errors are less than 0.1mm, all treatment components alignment position errors are no more than 0.4mm, Which is better than the accuracy requirements. Wuwei HIMM successfully commissioned the beam at the end of 2015, and all beam parameters of the terminal, such as the beam energy, energy spread, current, transmission and emittance have reached the design goal.
- In 2016, testing was initiated by Beijing Medical Device Inspection Institute (such as electro magnetic compatibility, electrical safety, performance and software), and testing has been completed and clinical trials have begun. It is expected to be officially put into operation by early 2019.

Thank you for your attention!