



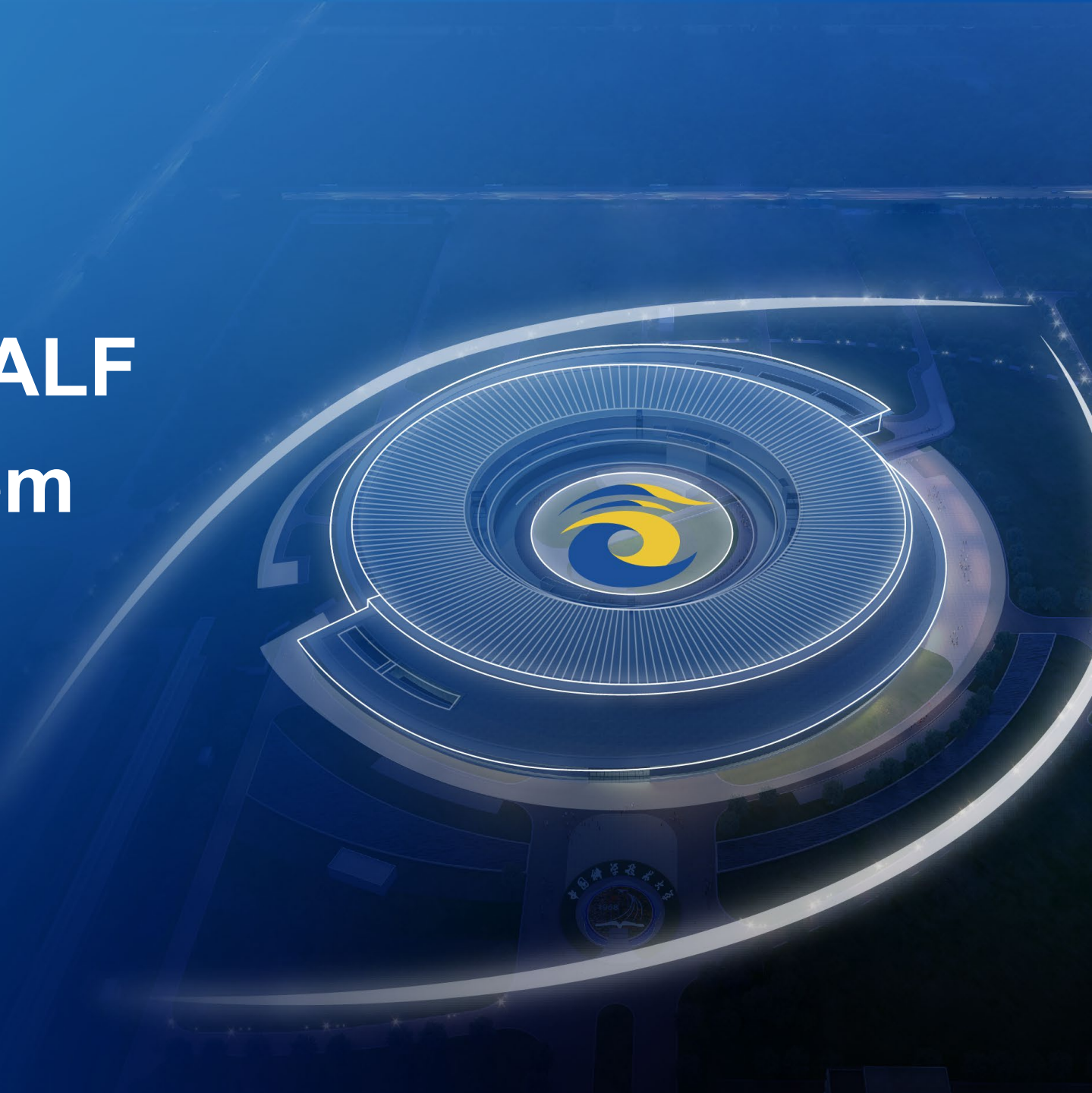
University of Science and Technology of China
National Synchrotron Radiation Laboratory

Progress of the HALF Alignment System

Xiaoye He

Oct 6th, 2026

IWAA2026, Oct 5th - 9th, 2026 | Tsukuba, Japan



OUTLINE

01 Introduction

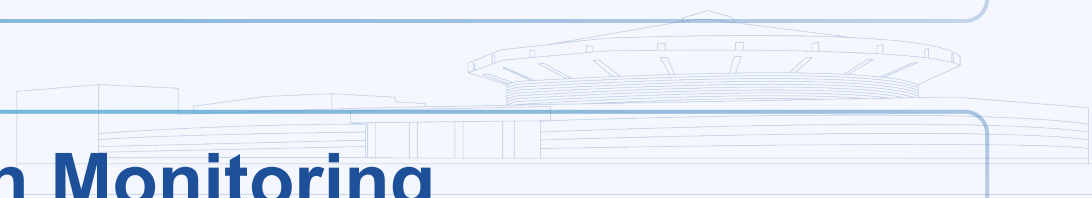
02 Control Network Construction

03 Components Fiducialization

04 Pre-alignment of Components

05 On-site Installation and Smooth

06 Deformation Monitoring





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01

Introduction



**Transport
Line 138 m**



**Storage Ring
480 m**

**Injector
192 m**

**Hefei Advanced Light Facility is a Fourth-generation
Diffraction-Limited Synchrotron Light Facility.**



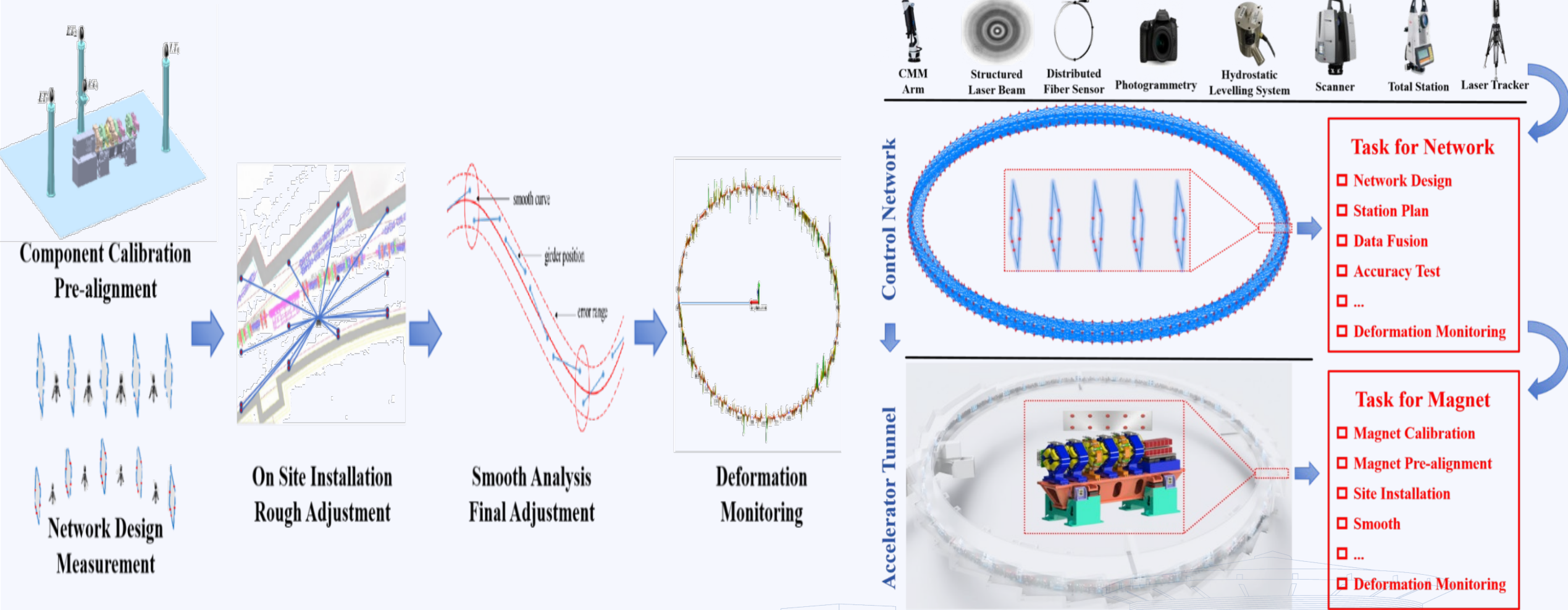
**Construction Site: Hefei Future Science City
Gangji Town, Changfeng County**

Parameter	Design Index	Acceptance Index
Energy [GeV]	2.2	2.2
Perimeter [m]	479.86	---
Beam Intensity [mA]	350	175
Beam Natural Emittance [pm·rad]	85.8	≤100 (10mA Beam Intensity)
Horizontal Balance Emittance [pm·rad]		≤200 (175mA Beam Intensity)
Beam Orbit Stability	<10% Transverse Beam Spot Size	<20% Transverse Beam Spot Size
Straight Sections	5.3 m×20 +2.2 m×20	---
Operating Mode	top-off Constant current operation	---
Brightness [phs/s/mm ² /mrad ² /0.1%bw]	1.15×10^{21}	5×10^{20}

Achieve design indexes after acceptance

Requirements of accelerator physical design for storage ring alignment								Challenges Higher Precision Large Workload Shortage of Staff Complex Interfaces
	Machine	Position accuracy (mm)			Attitude accuracy (mrad)			
		ΔX	ΔY	ΔZ	$\Delta \theta_x$	$\Delta \theta_y$	$\Delta \theta_z$	
Inside Girder	Quadrupole Sextupole Octupole	± 0.03	± 0.03	± 0.15	± 0.10	± 0.10	± 0.10	
	Corrector dipole	± 0.30	± 0.30	± 0.20	± 0.20	± 0.20	± 0.20	
	Bending dipole	± 0.20	± 0.20	± 0.15	± 0.10	± 0.20	± 0.20	
Between Adjacent Girders	Magnet alignment girder	± 0.05	± 0.05	± 0.20	± 0.10	± 0.10	± 0.10	
	Other machine	± 0.20	± 0.20	± 0.30	± 0.20	± 0.20	± 0.20	

Requirements for alignment accuracy are at the highest level at home and abroad



The HALF Alignment is a complicated work consists of **5 steps** as above.



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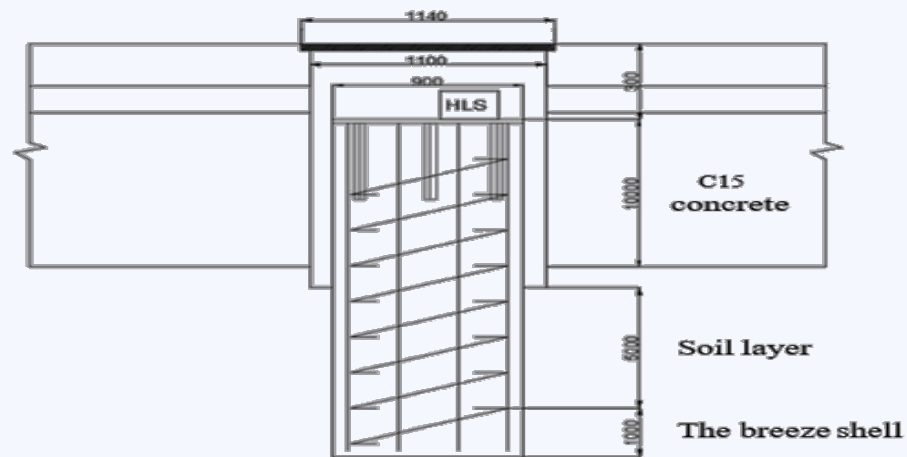
02

Control Network Construction

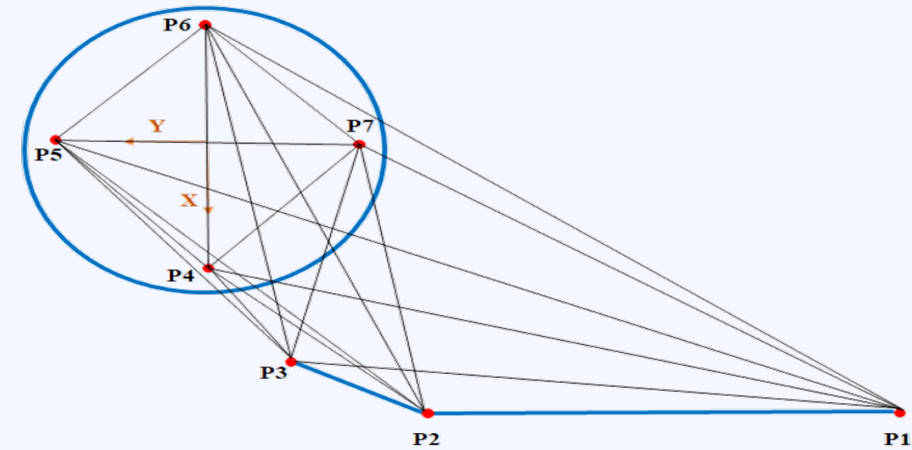
2.1 First Class Control Network-Preliminary Design



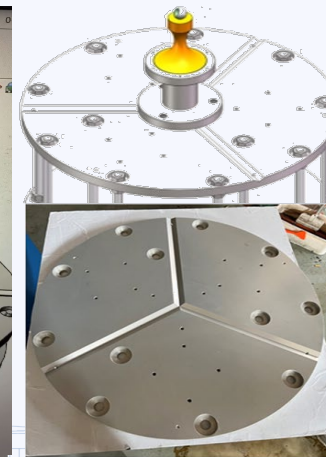
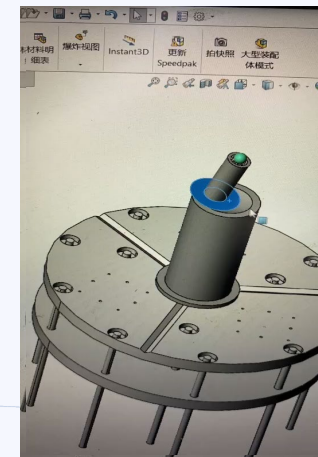
Layout



Structure Diagram



Measurement Roadmap

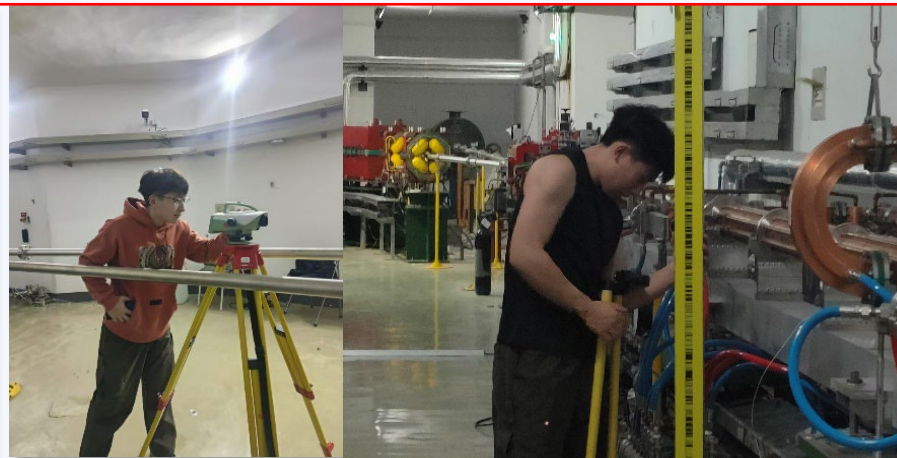


Top Structure

2.1 First Class Control Network-Software and Hardware Preparation



GNSS-GS



Level-LS15



Total Station-TS60



Vertical Shaft Guide-Wild NL

Software
PRC-COSA



PRC-NASEW



USA-STARNET



EU-SA

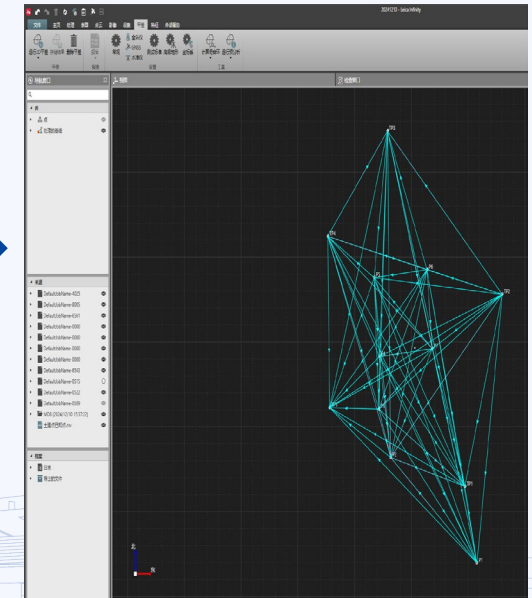
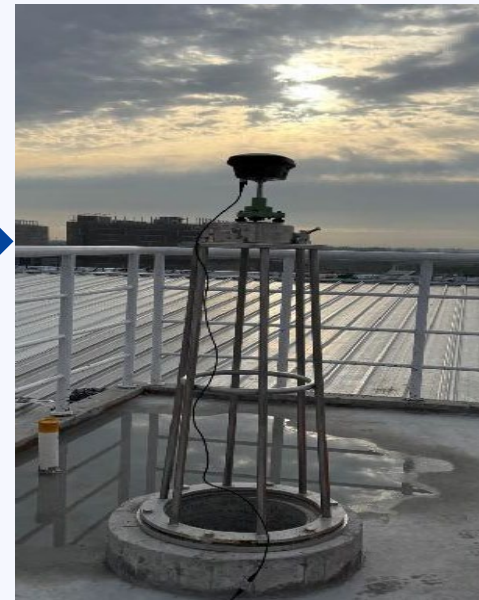
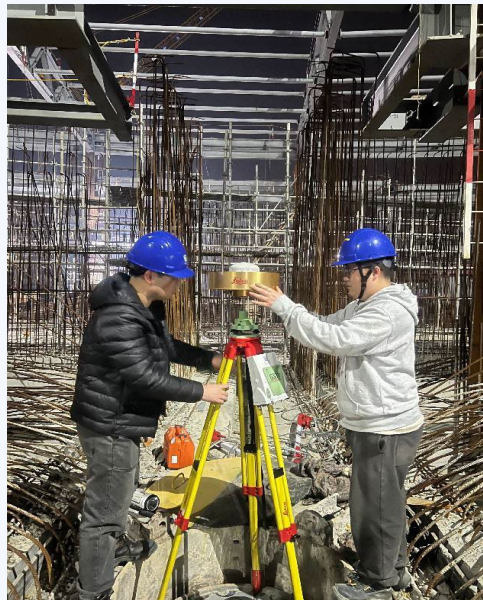


EU-INFINITY



2.1 First Class Control Network GNSS:

- (1)**Field Work:** Begin with plumb transfer→ Setting up GNSS at network points→ Measure the antenna height→ Static surveying.
- (2)**Data Process:** Baseline processing and adjustment with Leica Infinity→ Coordinate comparison with Cosa.
- (3)**Measurement count:** Six static GNSS measurements have been performed.
- (4)**Measurement Instrumentation:** Leica GS10, GS16, and GS18 receivers.



Field Work (December 2024)

Data Process

2.1 First Class Control Network-202603

GNSS(Comparison of GNSS measurement results of three epochs):

Point ID	202511		202601		202603		202603-202301		202603-202511	
	X[m]	Y[m]	X[m]	Y[m]	X[m]	Y[m]	X[mm]	Y[mm]	X[mm]	Y[mm]
P1	-145.5162	352.5656	-145.5209	352.5639	-145.5181	352.5668	2.8	2.9	-1.9	1.2
P2	-145.5066	156.1364	-145.51	156.1338	-145.5079	156.136	2.1	2.2	-1.3	-0.4
P3	-114.4536	103.924	-114.455	103.9225	-114.4551	103.9248	-0.1	2.3	-1.5	0.8
P4	-65.7786	65.7887	-65.7793	65.7893	-65.7796	65.7902	-0.3	0.9	-1	1.5
P5	0	0	0	0	0	0	0	0	0	0
P6	65.7936	65.7849	65.7919	65.7852	65.7926	65.7848	0.7	-0.4	-1	-0.1
P7	0	131.6111	0	131.6095	0	131.6096	0	0.1	0	-1.5

Comparisons among the three epochs of data are all within **3 mm**, which falls within the accuracy range of GS16 and GS18 receivers.

2.1 First Class Control Network-202603 GNSS:

Point ID	Two sessions		Three sessions		X difference[mm]	Y difference[mm]
	X [m]	Y [m]	X [m]	Y [m]		
P1	-145.5196	352.5661	-145.5181	352.5668	-1.5	-0.7
P2	-145.5078	156.1358	-145.5079	156.136	0.1	-0.2
P3	-114.4553	103.9242	-114.4551	103.9248	-0.2	-0.6
P4	-65.7798	65.7895	-65.7796	65.7902	-0.2	-0.7
P5	0	0	0	0	0	0
P6	65.7924	65.7852	65.7926	65.7848	-0.2	0.4
P7	0	131.6112	0	131.6096	0	1.6

The coordinate differences of collimation points from two-session and three-session combined solutions are all less than **2 mm**, consistent with the GS nominal accuracy.

2.1 First Class Control Network

Total Station:

- (1)Field Work: Begin with plumb transfer→ Setting up TS60 at network points→ Measure the antenna height→ Surveying.
- (2)Data Process: Processing and adjustment with Cosa→ Coordinate comparison with STARNET.
- (3) Measurement count: Five Total Station measurements have been performed.



Field Work (December 2024)

观测日期: 2024.12.06			天气: 晴朗		成绩:		温度: 7.7℃			气压: 1024.0hPa			湿度: 0.5%	
测站名: Z1			仪器高: 1.3622m		开始时间: 16:54:08		结束时间: 17:02:59			仪器: 890547				
测回	目标点	量位	水平盘读数 (° ′ ″)	2C	度盘方位角 (° ′ ″)	归零方位角 (° ′ ″)	竖盘读数 (° ′ ″)	i (″)	天顶角 (° ′ ″)	斜距 m	平距 m	高差 m	棱镜高 m	
1	P1	I	72.00311	1.10	72.00309	0° 0′ 0.00″	88.52301	8.00	88.522211	247.0039	246.9561	4.9928	1.2230	
		II	252.00300				271.07459			247.0038	246.9556	5.0120		
	P2	I	124.37226	1.13	124.372204	52° 36′ 51.45″	88.17128	8.59	88.170425	158.8174	158.7463	4.6187	1.4930	
		II	304.37215				271.43043			158.8175	158.7460	4.6320		
	P7	I	189.35330	2.34	189.353180	117° 35′ 1.21″	89.32254	6.77	89.321864	34.2503	34.2492	0.3230	1.3140	
		II	9.35306				270.27481			34.2501	34.2489	0.3253		
	P6	I	240.27305	1.22	240.272991	68° 26′ 59.32″	89.45219	8.43	89.451352	110.8139	110.8128	0.3608	1.4740	
		II	60.27293				270.14549			110.8140	110.8129	0.3698		
	P1	I	72.00305	0.38	72.003035	59° 59′ 59.76″	88.52314	9.40	88.522203	247.0038	246.9560	4.9912	1.2230	
		II	252.00302				271.07474			247.0039	246.9557	5.0138		
2	P1	I	72.00301	0.14	72.003007	0° 0′ 0.00″	88.52323	9.49	88.522280	247.0039	246.9561	4.9902	1.2230	
		II	252.00300				271.07467			247.0040	246.9558	5.0129		
	P2	I	124.37240	2.99	124.372251	52° 36′ 52.44″	88.17128	8.45	88.170431	158.8169	158.7458	4.6188	1.4930	
		II	304.37210				271.43041			158.8172	158.7457	4.6318		
	P7	I	189.35324	3.20	189.353129	117° 35′ 1.22″	89.32254	7.02	89.321841	34.2503	34.2492	0.3230	1.3140	
		II	9.35302				270.27486			34.2503	34.2492	0.3254		
	P6	I	240.27306	1.24	240.273001	68° 26′ 59.94″	89.45216	8.48	89.451315	110.8142	110.8132	0.3609	1.4740	
		II	60.27294				270.14553			110.8142	110.8131	0.3700		
	P1	I	72.00306	0.70	72.003028	0° 0′ 0.21″	88.52315	8.63	88.522284	247.0038	246.9560	4.9912	1.2230	
	II	252.00299	271.07458				247.0038			246.9556	5.0119			
统计:														
②测回统计结果			Z1站外业观测手簿											
序号	目标点	归零方位角 (° ′ ″)	天顶角均值 (° ′ ″)	斜距 m	平距 m	高差 m	备注: 限差控制							
1	P1	359.595997	88.522309	247.00379	246.95583	5.00123	2C互差9.00″							
2	P2	52.365233	88.170445	158.81718	158.74689	4.62519	半测回归零差5.00″							
3	P7	117.350072	89.321850	34.25012	34.24900	0.32417	水平角测回互差9.00″							
4	P6	168.265958	89.451335	110.81414	110.81311	0.36538	垂直角指标差互差15.00″							
							垂直角测回互差15.00″							
							斜距测回互差5mm							

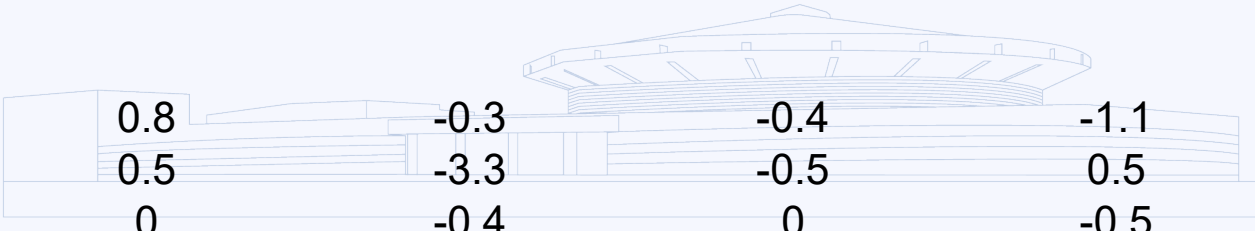
Data Process

2.1 First Class Control Network-202603

Total Station(fix point P5 as the origin and the azimuth of the P5–P7 line is fixed):

Point ID	First		Second		Third		Forth		Fifth (202603)	
	X[m]	Y[m]	X[m]	Y[m]	X[m]	Y[m]	X[m]	Y[m]	X[m]	Y[m]
P5	0	0	0	0	0	0	0	0	0	0
P1	-145.4915	352.57	-145.5143	352.564	-145.5146	352.564			-145.5154	352.566
P2	-145.4998	156.153	-145.5048	156.135	-145.5066	156.135			-145.506	156.135
P3	-114.4489	103.931	-114.4517	103.923	-114.453	103.924			-114.4523	103.923
P4	-65.7805	65.795	-65.7779	65.7873	-65.7774	65.7871	-65.778	65.7874	-65.7778	65.7885
P6	65.795	65.7811	65.7941	65.7873	65.7935	65.7834	65.793	65.7867	65.7935	65.7862
P7	0	131.607	0	131.608	0	131.609	0	131.609	0	131.61

1st-2nd		2nd-3rd		3rd-4th		4th-5th	
(X) [mm]	(Y) [mm]	(X) [mm]	(Y) [mm]	(X) [mm]	(Y) [mm]	(X) [mm]	(Y) [mm]
0	0	0	0	0	0	0	0
22.8	6.5	0.3	-0.3				
5	18.1	1.8	-0.6				
2.8	8.1	1.3	-1				
-2.6	7.7	-0.5	0.2	0.8	-0.3	-0.4	-1.1
0.9	-6.2	0.6	3.9	0.5	-3.3	-0.5	0.5
0	-1.1	0	-1.1	0	-0.4	0	-0.5



2.1 First Class Control Network-202603

Total Station VS GNSS:

GNSS Calculation Data VS Total Station Point Coordinates

Point ID	Two-session comparison with total station		Three-session comparison with total station	
	X[mm]	Y[mm]	X[mm]	Y[mm]
P1	-2.5	0.4	-2.7	0.7
P2	-2	1	-1.9	1.1
P3	-2.7	2.1	-2.8	1.9
P4	-1.7	2.6	-1.8	1.7
P5	0	0	0	0
P6	-0.9	-1.3	-0.9	-1.4
P7	0	-0.1	0	-0.1

- Comparisons between GNSS two/three session solutions and total station measurements reveal **small overall deviations**, all point deviations being within **3 mm**. The results satisfy the requirements in view of point coordinates and instrument accuracy specifications.

2.1 First Class Control Network-First Measurement-202412

Level:

(1)Measurement Point: 5 civil construction points and 7 alignment points.

(2)Measurement Instrumentation: Leica LS15

(3)Measurement Requirements:

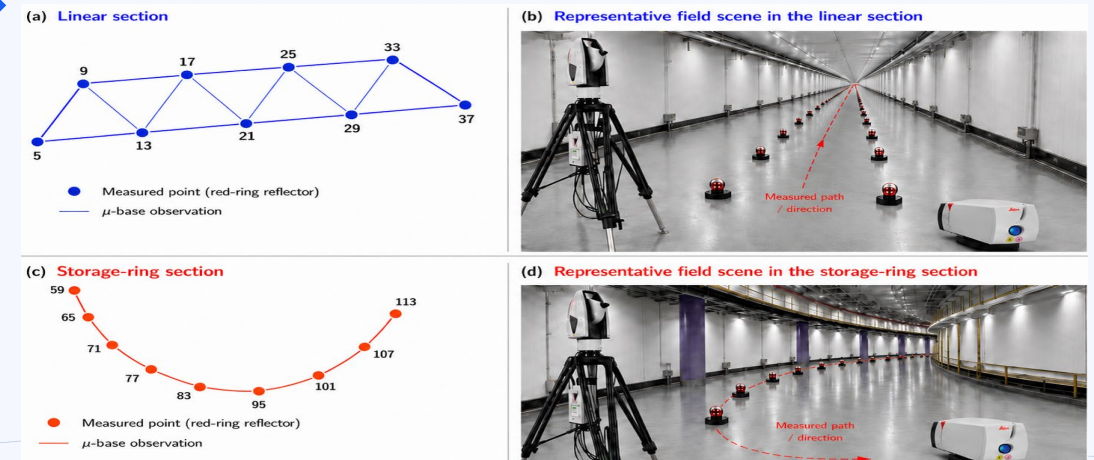
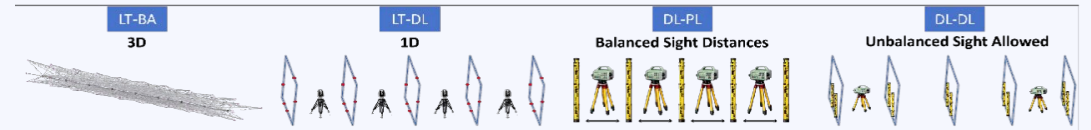
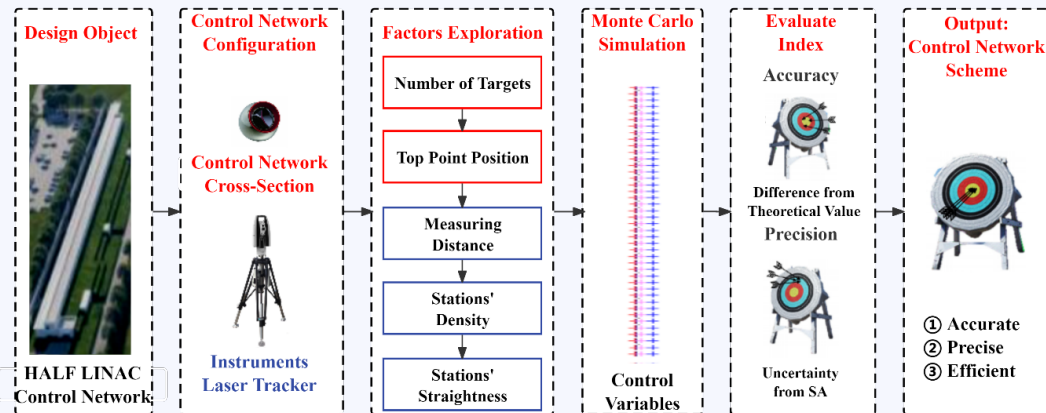
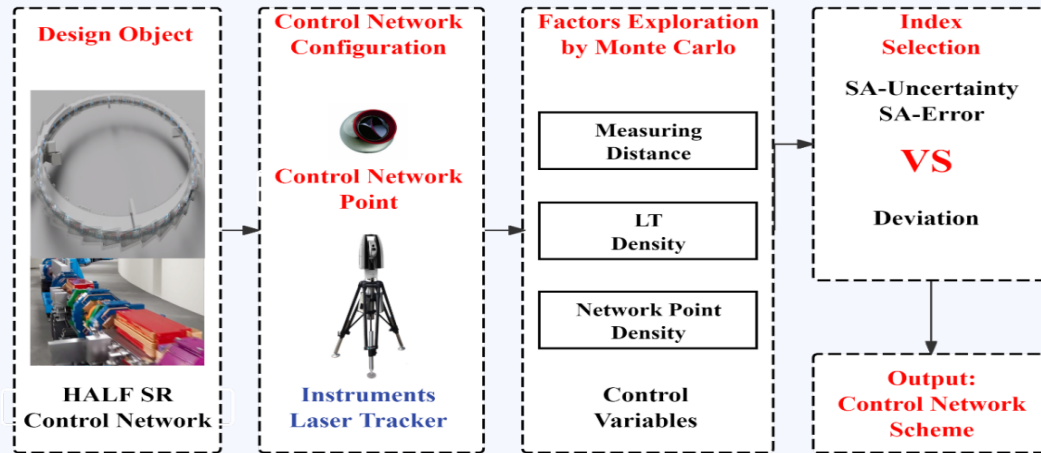
100% satisfied Sight Length 3-50 m, $\Delta SL < 1.5$ m,
 $\Sigma \Delta SL < 6$ m.

80% satisfied Sight Length 4-30 m, $\Delta SL < 1$ m,
 $\Sigma \Delta SL < 3$ m.

(4)Measurement Detail: A total of 13 leveling lines were measured in both forward and reverse directions, resulting in 26 runs and 98 instrument setups.

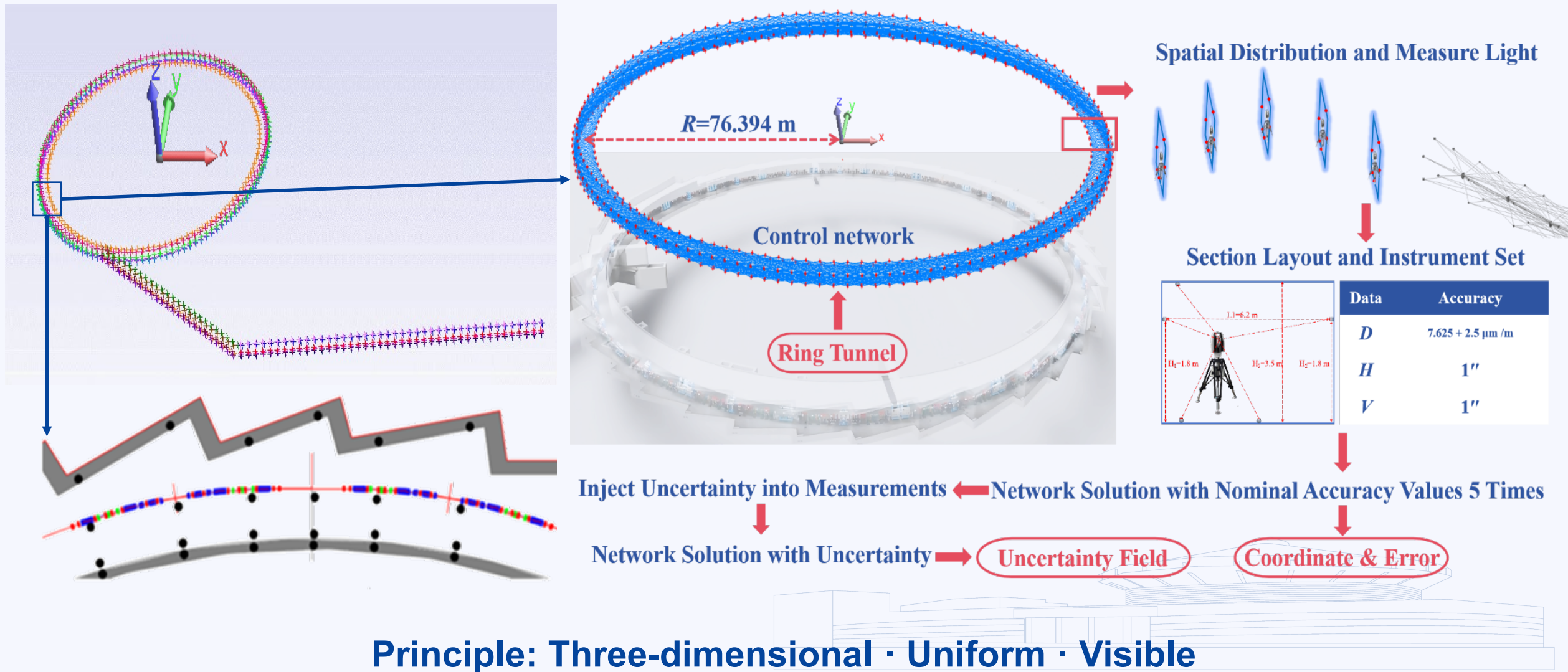


2.2 Second Class Control Network-From LT-based Simulation to Multi-Source Fusion



Simulation → Fusion / Validation → Engineering Application

2.2 Second Class Control Network-Simulation



2.2 Second Class Control Network-Network Design

Every other section

Tracker station interval

6 + 6 sections

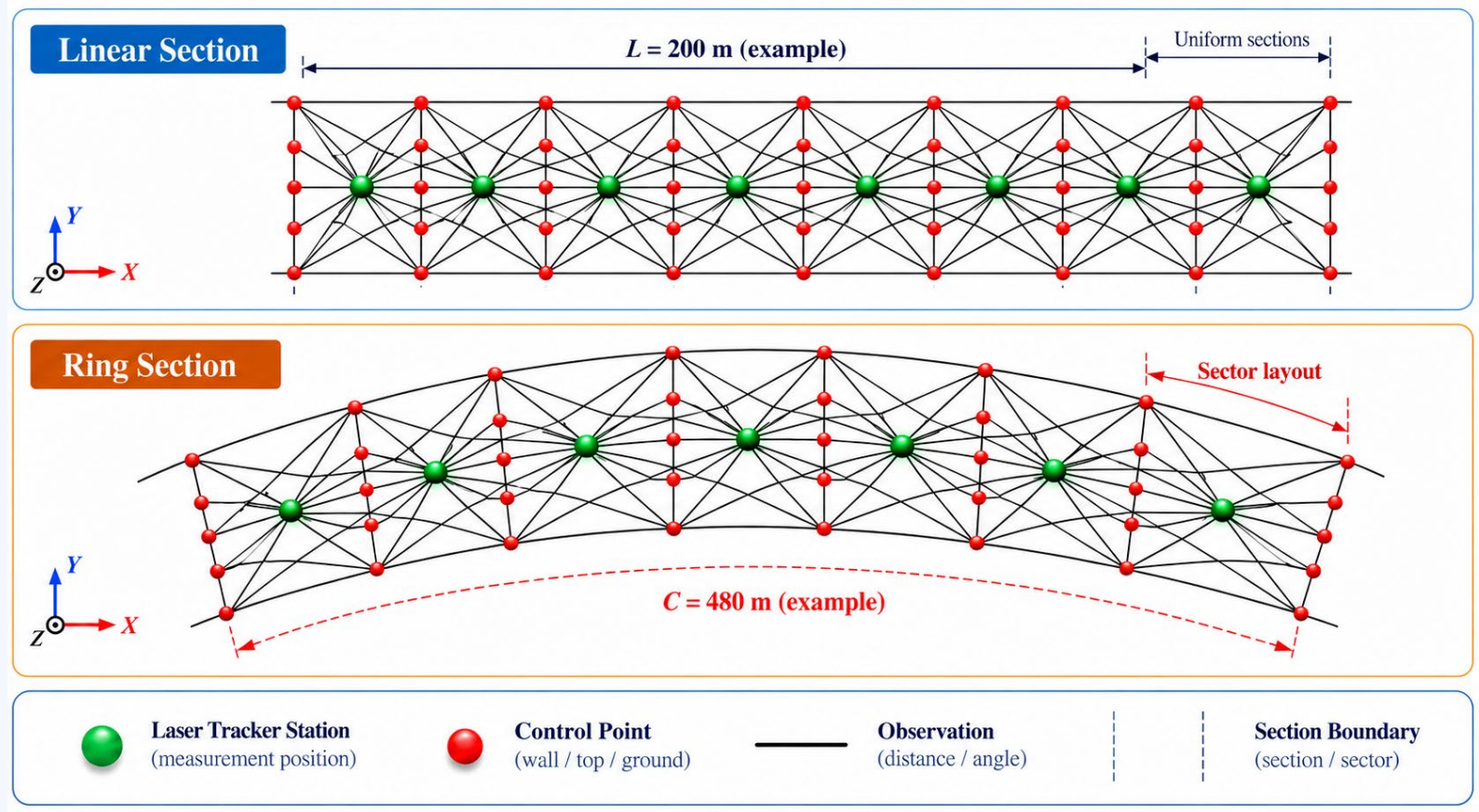
Forward / backward coverage

~60 points

Observed per station

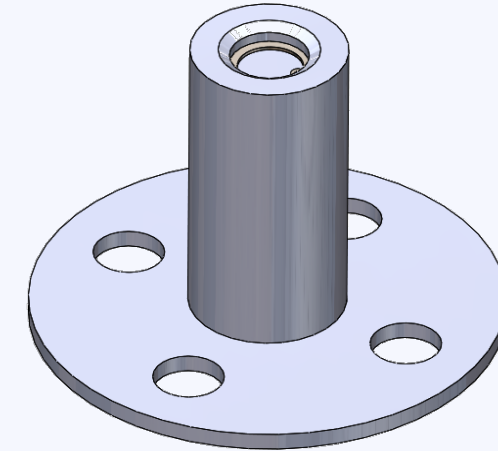
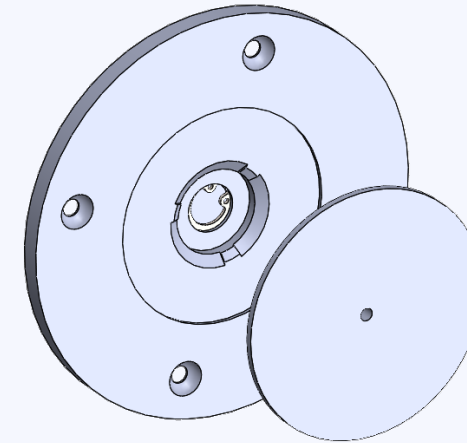
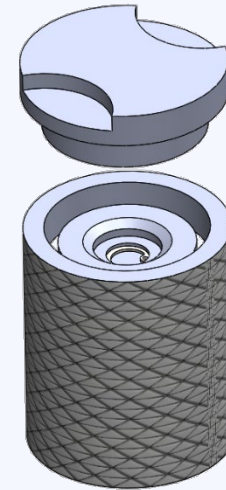
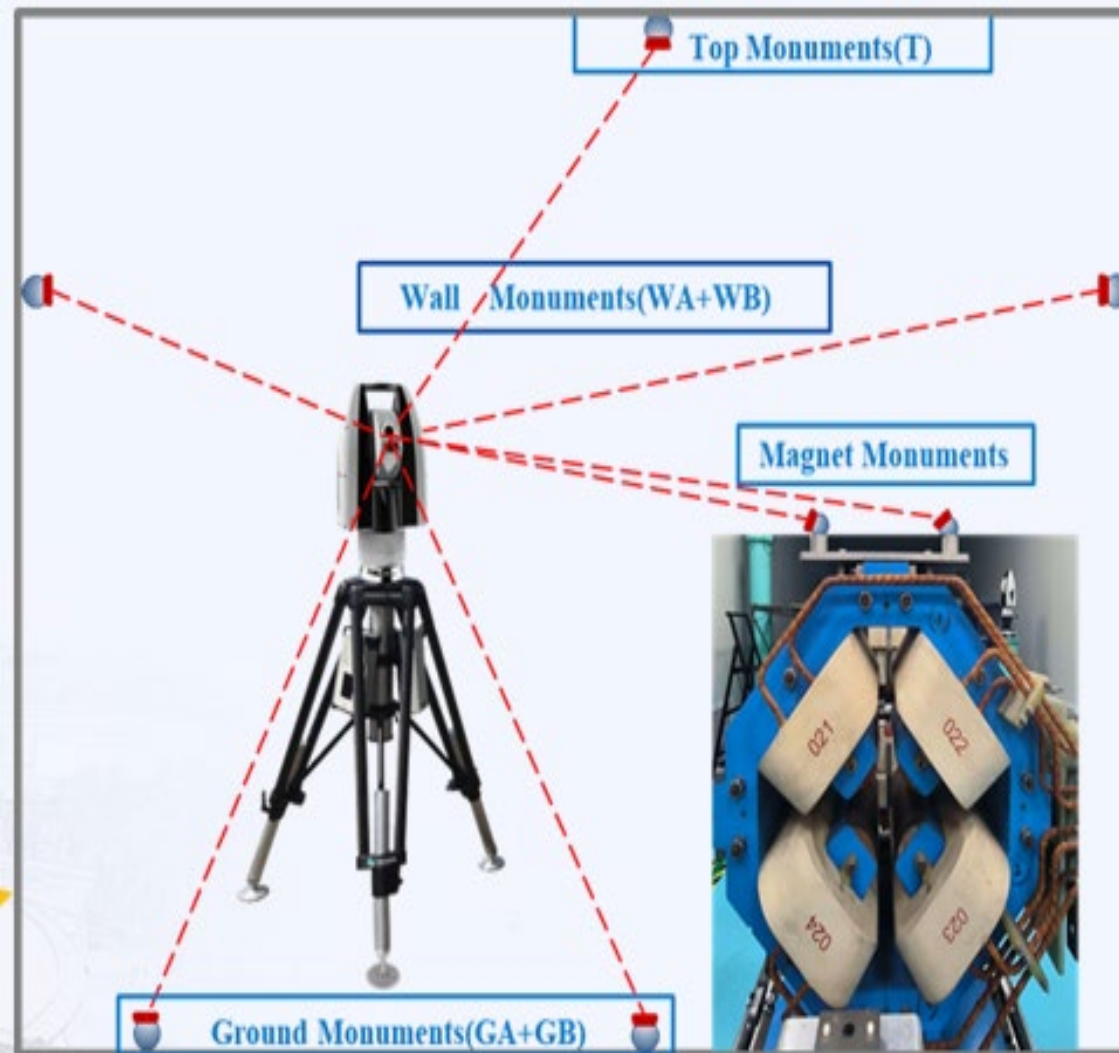
~50 common points

Between adjacent stations



High redundancy is designed into the observation geometry before adjustment.

2.2 Second Class Control Network-Control Point Structural Design

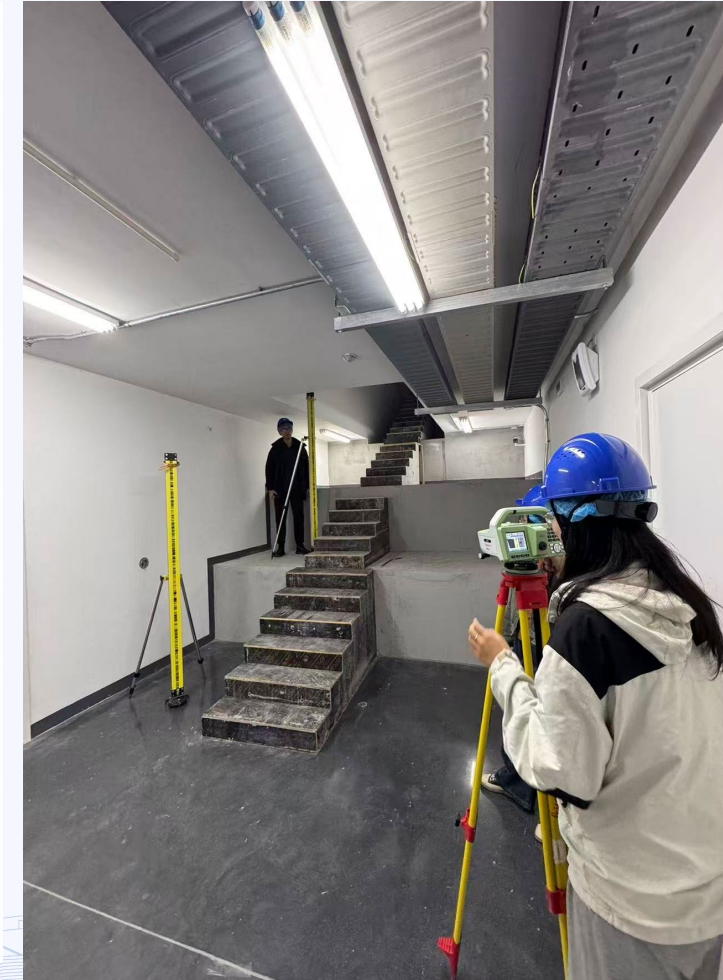
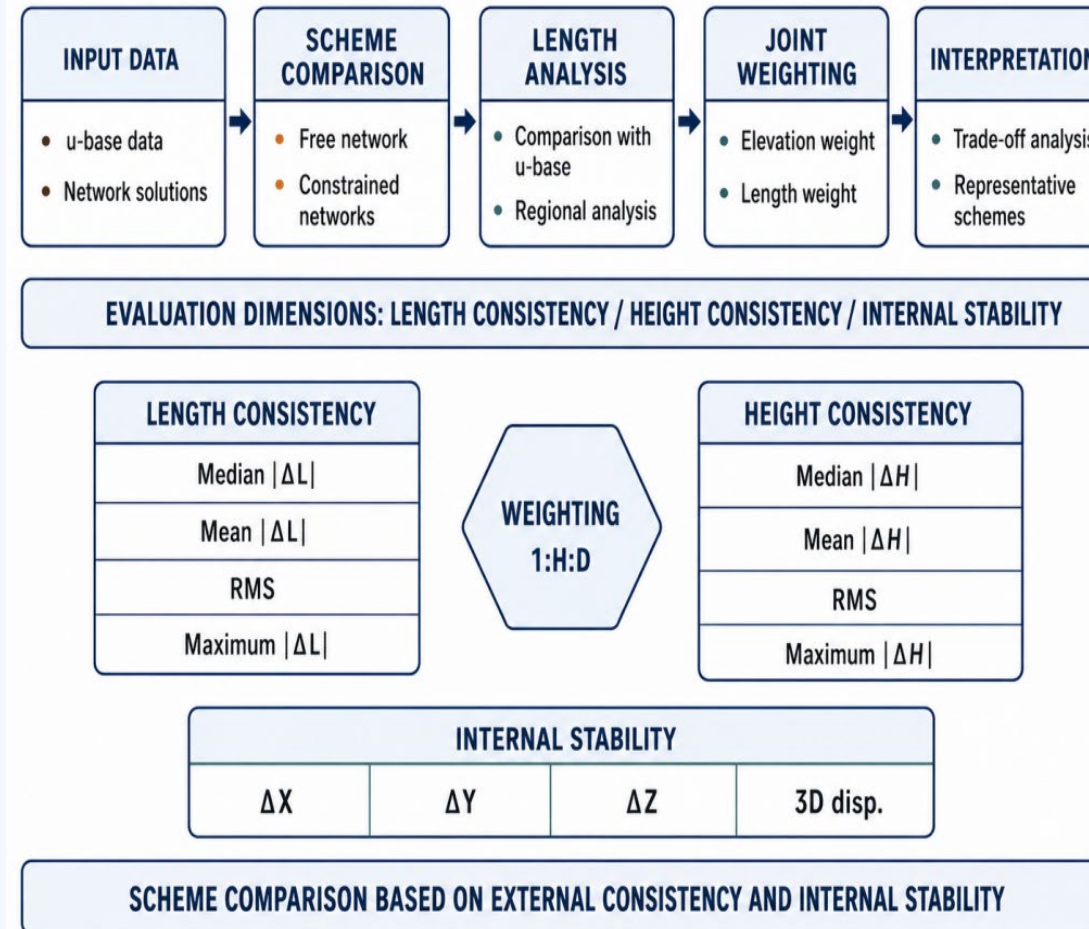


Ground

Wall

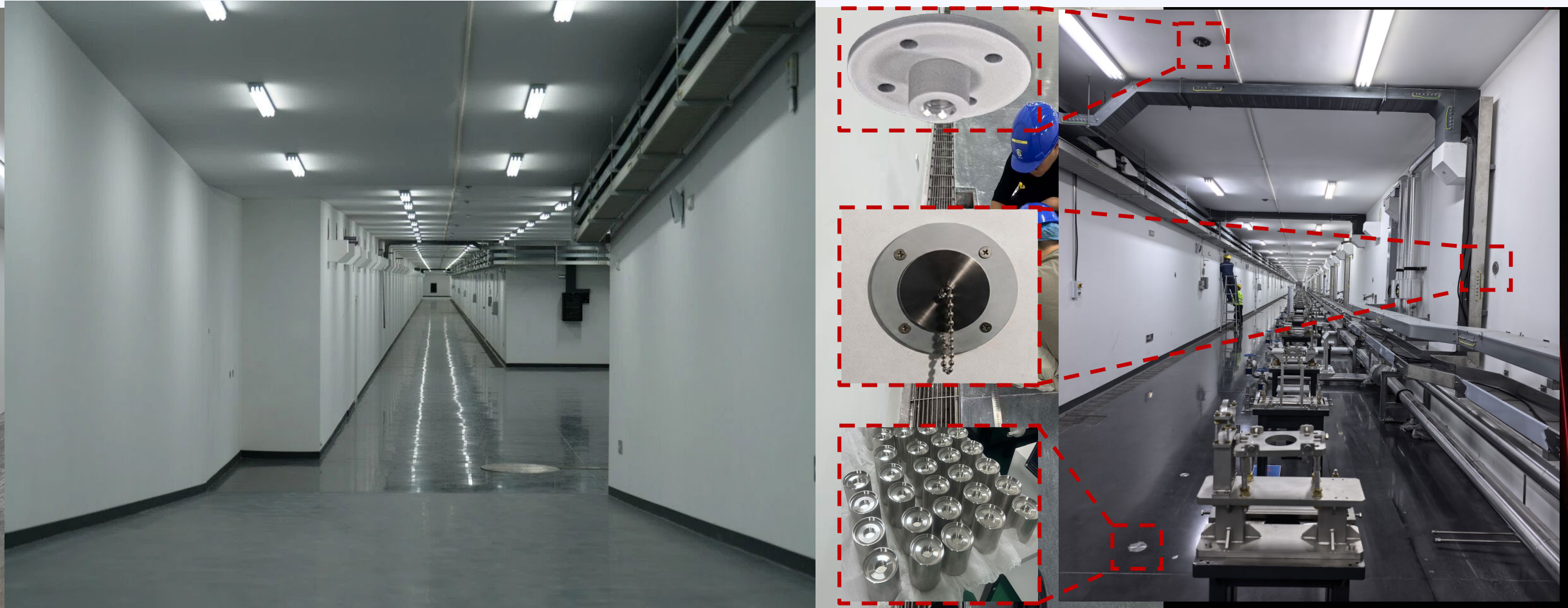
Top

2.2 Second Class Control Network-Fusion / Validation



Principle: Multi-Source – Cross-Validation – Unified Adjustment

2.2 Second Class Control Network-Engineering Application



Injector: Full Survey and Installation Completed | Storage Ring: Installation Underway

From design into real engineering practice

2.3 Injector Control Network – Four-Epoch Monitoring

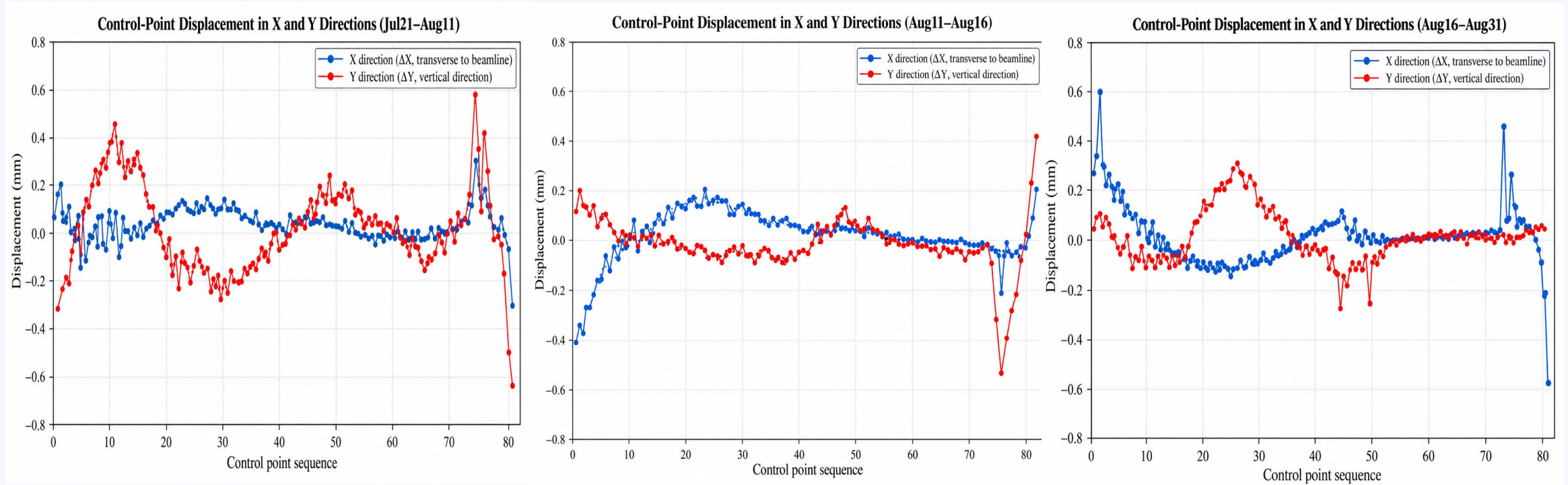
Jul 21

Aug 11

Aug 16

Aug 31

4 survey epochs | 5 pairwise comparisons | direct presentation of ΔX and ΔY curves



Adjacent epochs: mostly small differences

Longer intervals: clearer cumulative behavior

Largest deviations: injector terminal region

2.4 Conclusion

01

DESIGN

A high-redundancy 3D control-network scheme was established with uniform geometry, visibility and robust observation coverage.

02

VALIDATION

Laser tracker solutions were strengthened by independent elevation and distance information through multi-source cross-validation.

03

MONITORING

Four-epoch injector measurements show small short-term variations and clearer long-term cumulative displacement near the terminal region.

04

APPLICATION

The injector workflow has been fully applied, while the storage ring has entered initial installation and monitoring.

Next: Periodic Remeasurement → Stable-point Identification → Disturbance Diagnosis → Protection and Alignment Decisions

Design → Validate → Monitor → Maintain



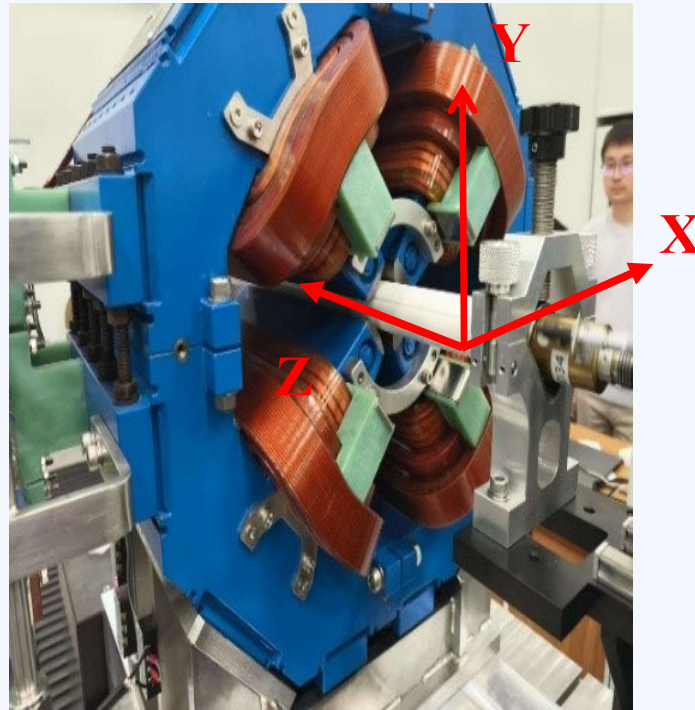
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03

Components Fiducialization

3.1 Define the Survey Specifications

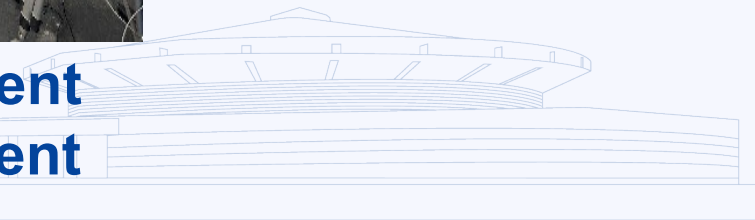
The geometric center of magnets is measured by coordinate measuring machine (CMM) in factories. During magnetic measurement, we verify data and correct deviations based on the magnetic center, following established calibration procedures.



**Injector Quadrupole
Magnet Alignment**



**Point Measurement
Platform Alignment**

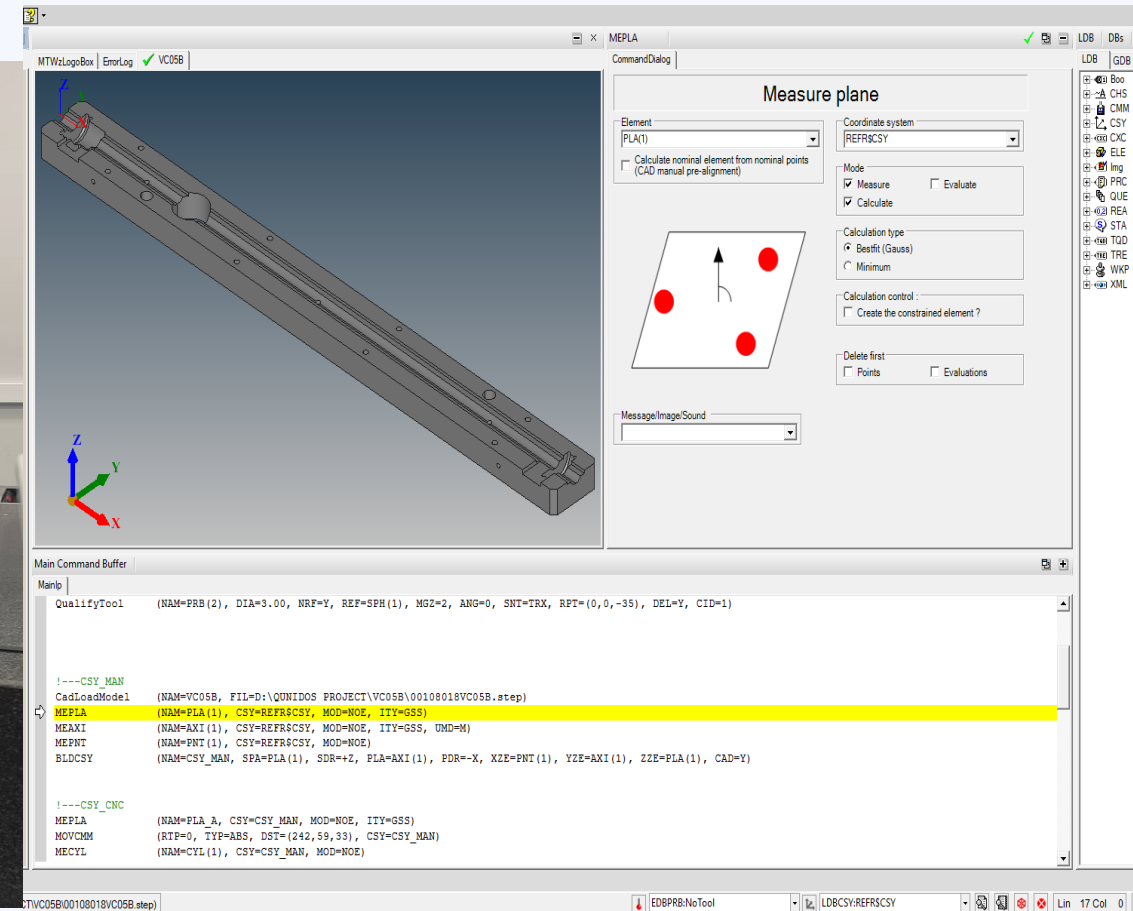
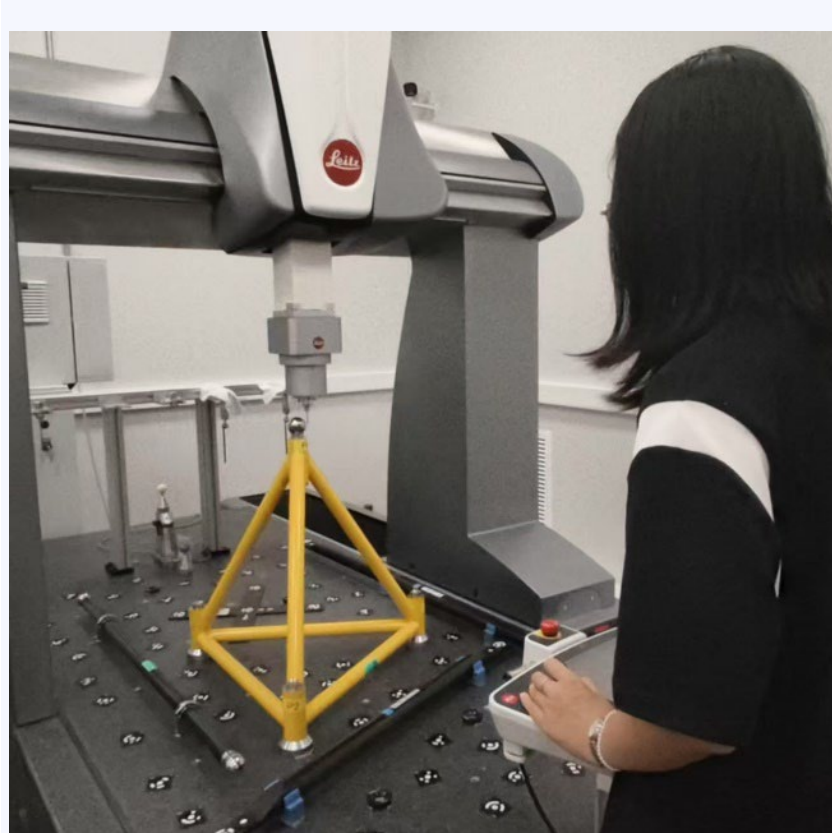


3.2 Measurement Site



3.3 The Use of CMM

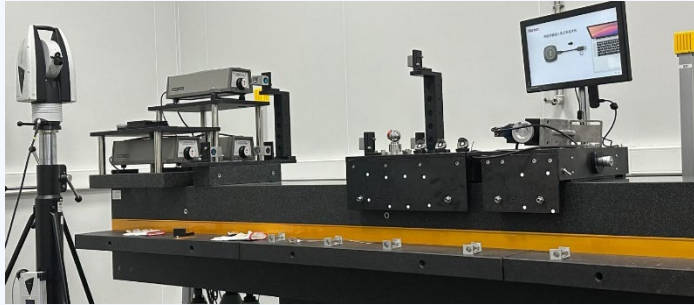
The alignment system also uses CMM to measure equipment such as copper vacuum tube press molds.



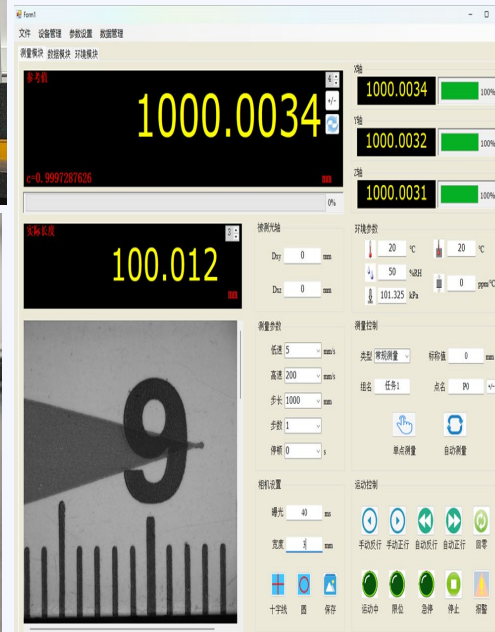
Use-Hardware

Use-Software

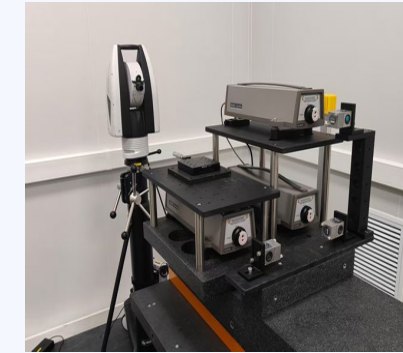
3.4 The Use of Laser Interferometer



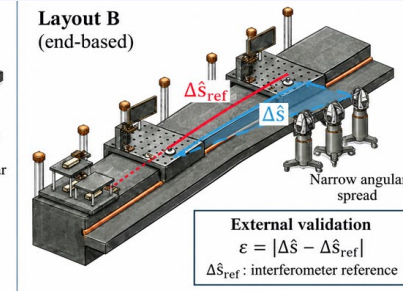
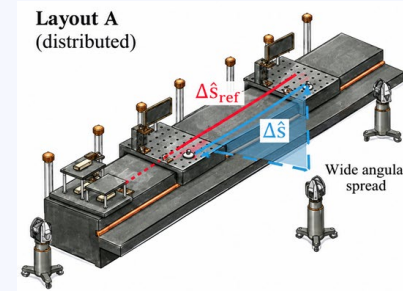
Layout



Software



On-site Calibration of Laser Tracker



Layout Verification and Error Analysis
Using Distance as Reference

External validation
 $\epsilon = |\Delta\hat{s} - \Delta\hat{s}_{ref}|$
 $\Delta\hat{s}_{ref}$: interferometer reference



Use

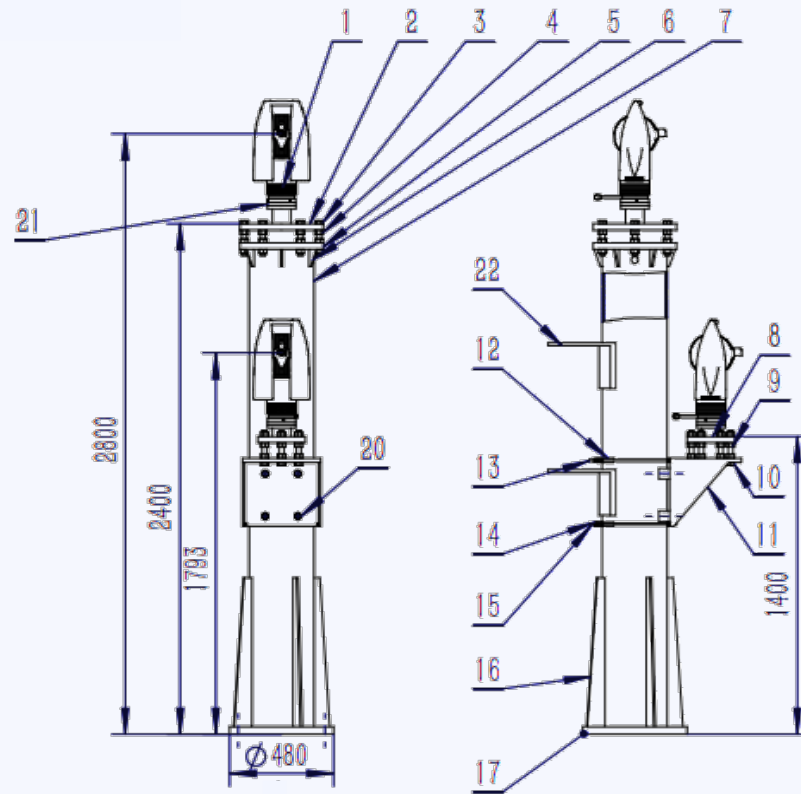


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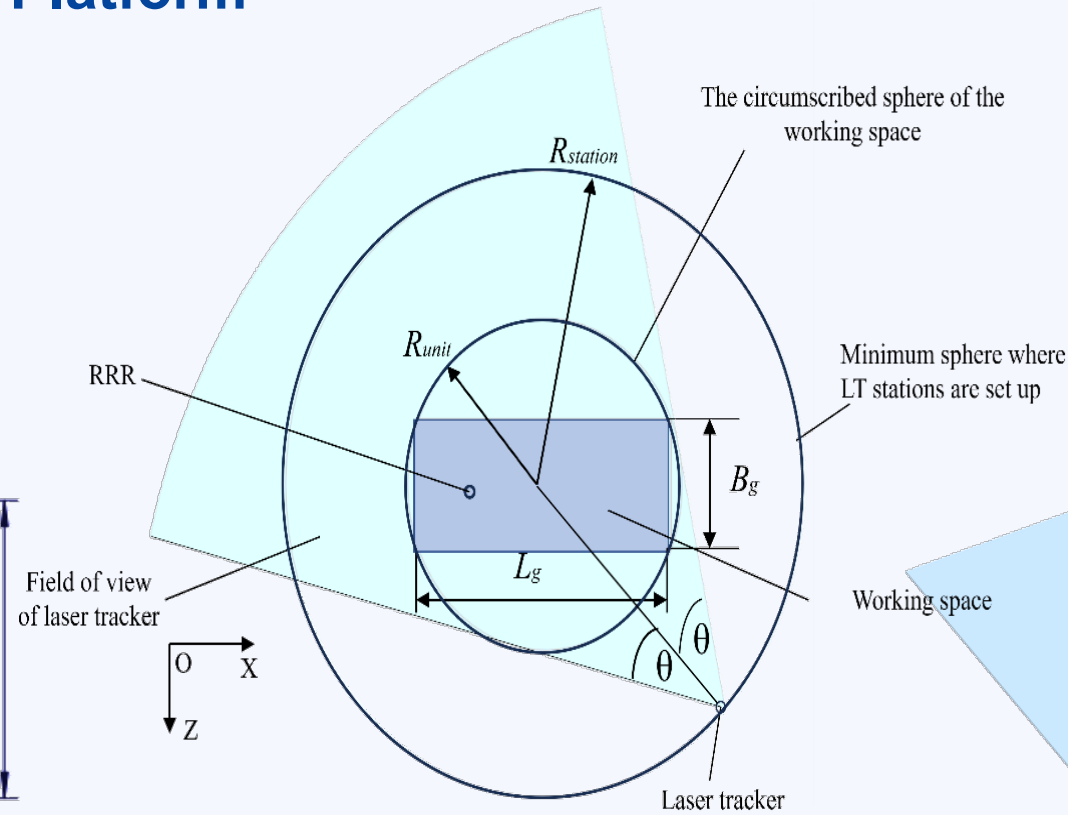
04

Pre-alignment of Components

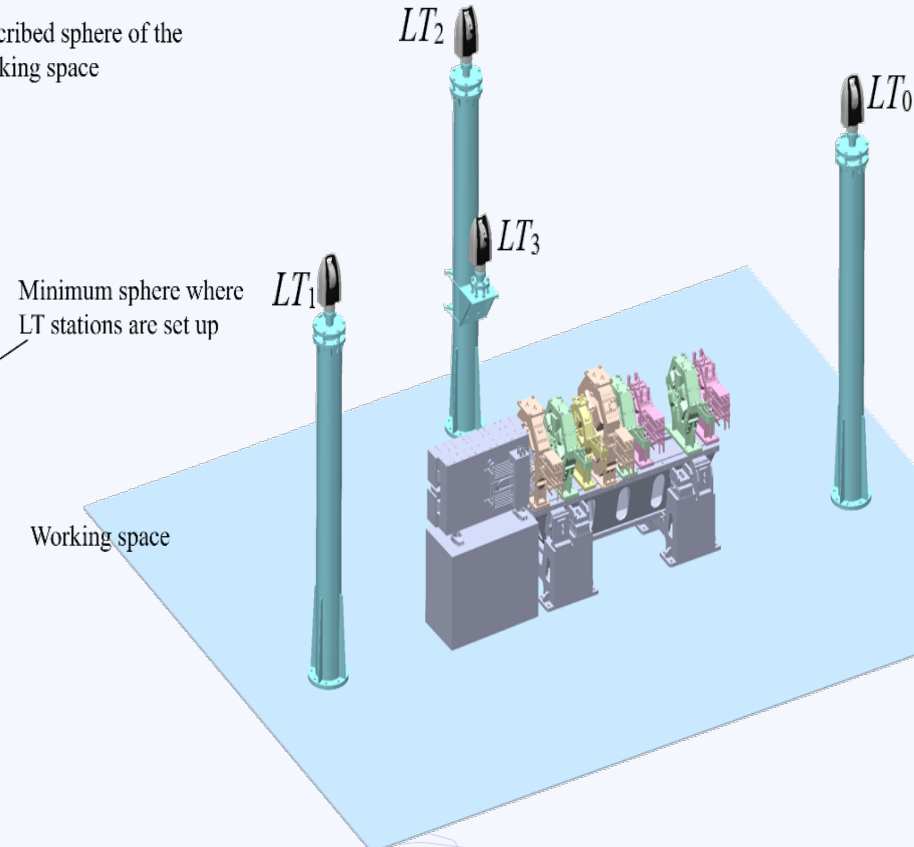
4.1 Design of Pre-alignment Platform



Pillar Design Drawing

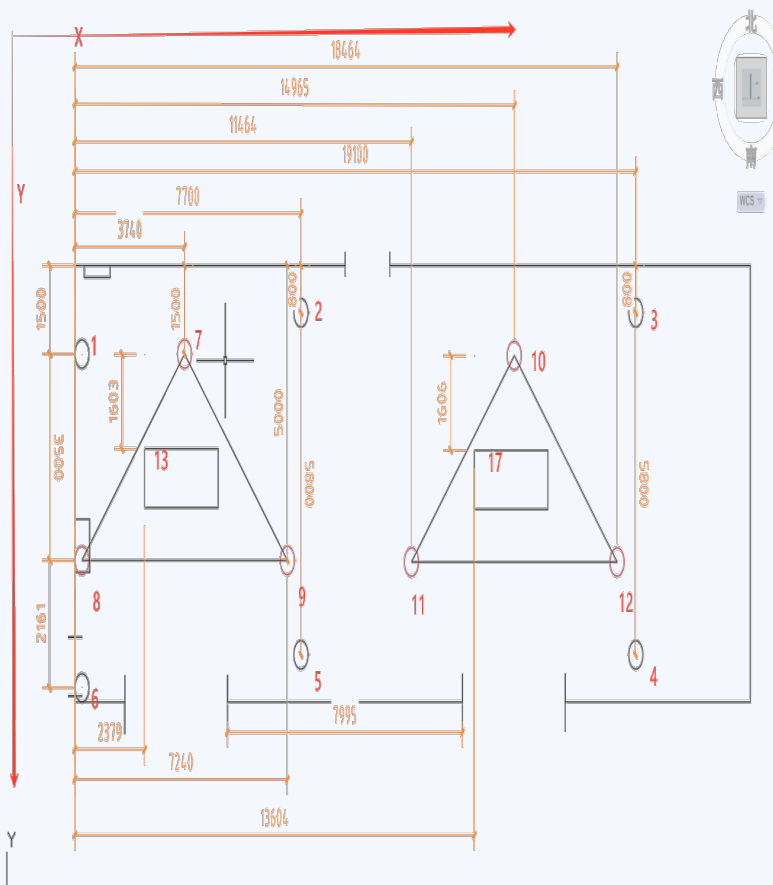


Model Conceptual Diagram



Design and optimize the measurement model for the four-laser system, considering constraints of **the target sphere's incidence angle and the geometric layout.**

4.2 Platform Construction

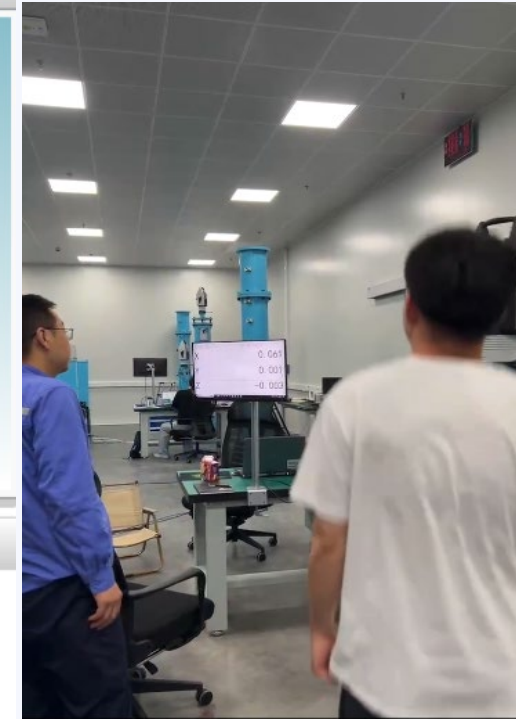
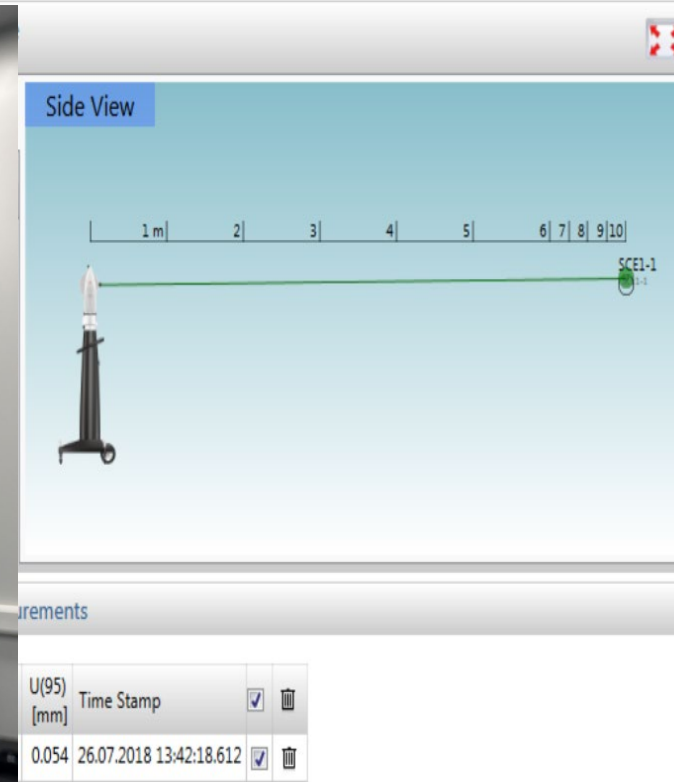
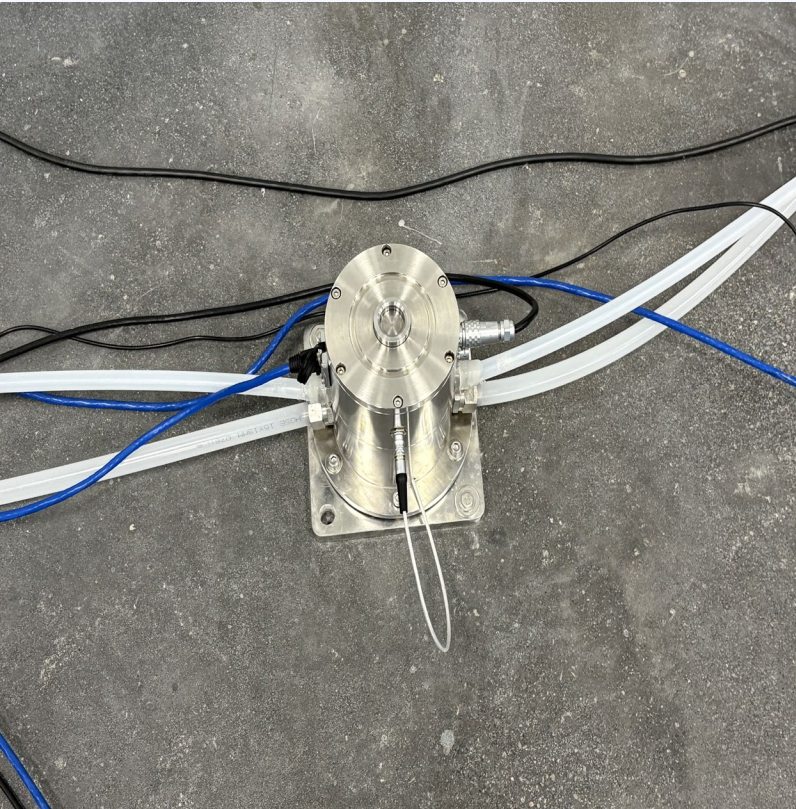


Construction



During the construction of the pre-alignment platform, the sight was checked, and sand filling was used to reduce column vibration.

4.3 Stability Test



Foundation Stability Test

Super Cat Eye Test

Vibration Test

Stability and vibration issues in foundations, worktables, and marble guides were monitored using hydrostatic leveling systems, laser interferometers, and laser trackers. Localized foundation instability and power-frequency vibrations were identified.

4.4 Put Into Service



Engineering site



Visiting

Currently, the pre alignment platform has been put into use.

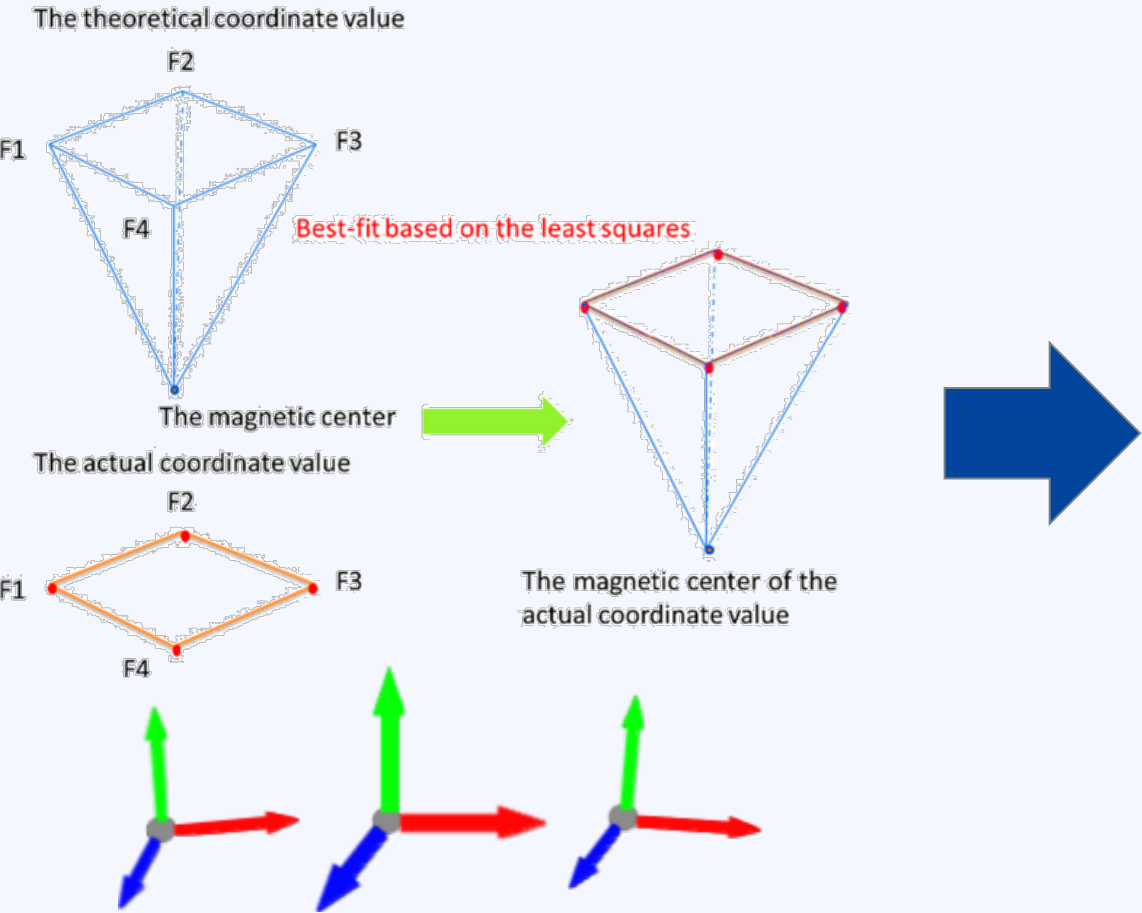


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05

On-site Installation and Smooth

5.1 Software Development



标定组 机械组 匹配-生成

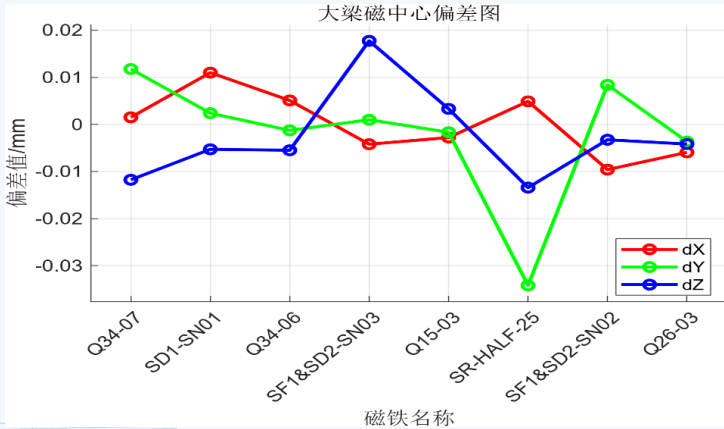
导入 E:\1.HALF资料及相关的数据处理\样段\样段各大梁的预准直数据\20251010-第

Datum Select Q78-SN07

磁铁名称	DX/mm	DY/mm	DZ/mm	RX/°	RY/°	RZ/°
DL	-27.3103	-440	1.1445e+03	0	-2.1411	0
CR5	-59.3463	0	1.7337e+03	0	-2.1411	0
RB1-SN02	-40.5647	0	1.4142e+03	0	-2.5077	0
Q78-SN04	-23.3207	0	934.5209	0	-2.8743	0
LGB3-2	0.0016	0	189.9298	0	-1.4372	0
Q78-SN07	0	0	0	0	0	0
FCR3	9.0118e-05	0	-165.0000	0	0	0
RB2-SN02	3.2179	0	-359.9932	0	-0.1245	0

Q15-02#

靶标球坐标值	X(mm)	Y(mm)	Z(mm)
Tar_1:	178.102	431.292	-62.997
Tar_2:	0.202	431.329	-63.237
Tar_3:	-177.899	431.276	-62.993
Tar_4:	-177.882	431.303	62.988
Tar_5:	0.044	431.295	62.880
Tar_6:	178.208	431.305	63.001
上顶平面滚动角:	-0.021	rad	
磁中心:	-0.006	-0.004	0.000



Through self-developed software, we can obtain the magnetic center and the offset.

5.2 Injector Installation and Alignment Scope



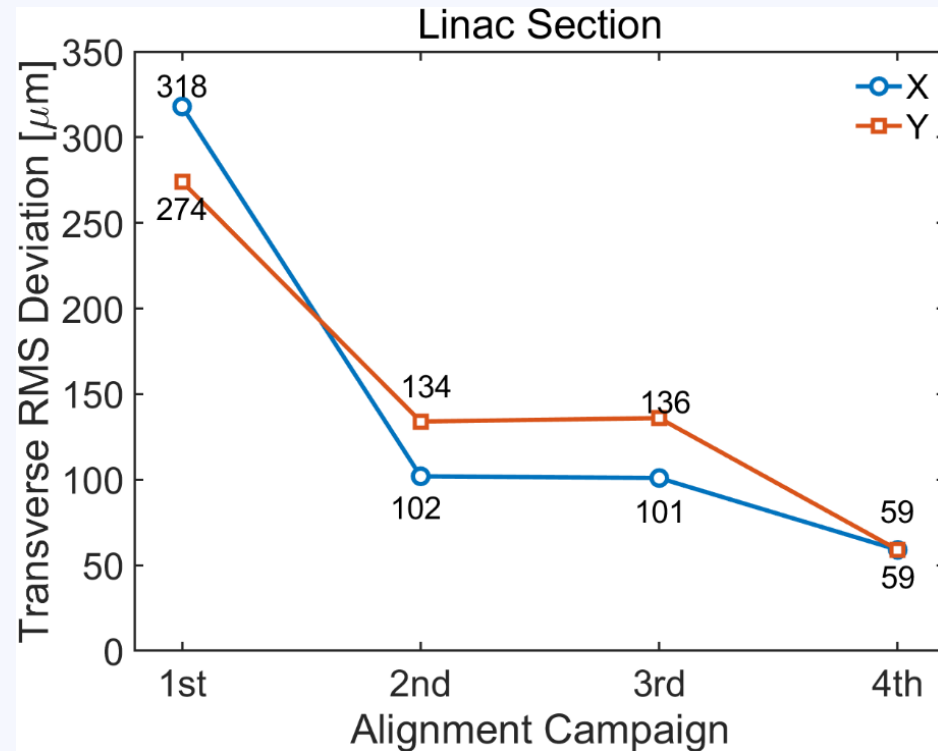
Component-specific Alignment Tolerances

Component	X [μm]	Y [μm]	Z [μm]	Attitude [mrad]
Short magnetic lens	± 50	± 50	± 200	—
Medium solenoid	± 50	± 50	± 200	—
Long solenoid	± 50	± 50	± 200	—
Short quadrupole magnet	± 150	± 150	± 1000	± 0.2
Long quadrupole magnet	± 150	± 150	± 1000	± 0.2
Accelerating structure	± 100	± 100	± 200	± 0.4
Beam position monitor (BPM)	± 100	± 100	± 500	± 0.4
Beam profile monitor (PRF)	± 150	± 150	± 500	± 0.4

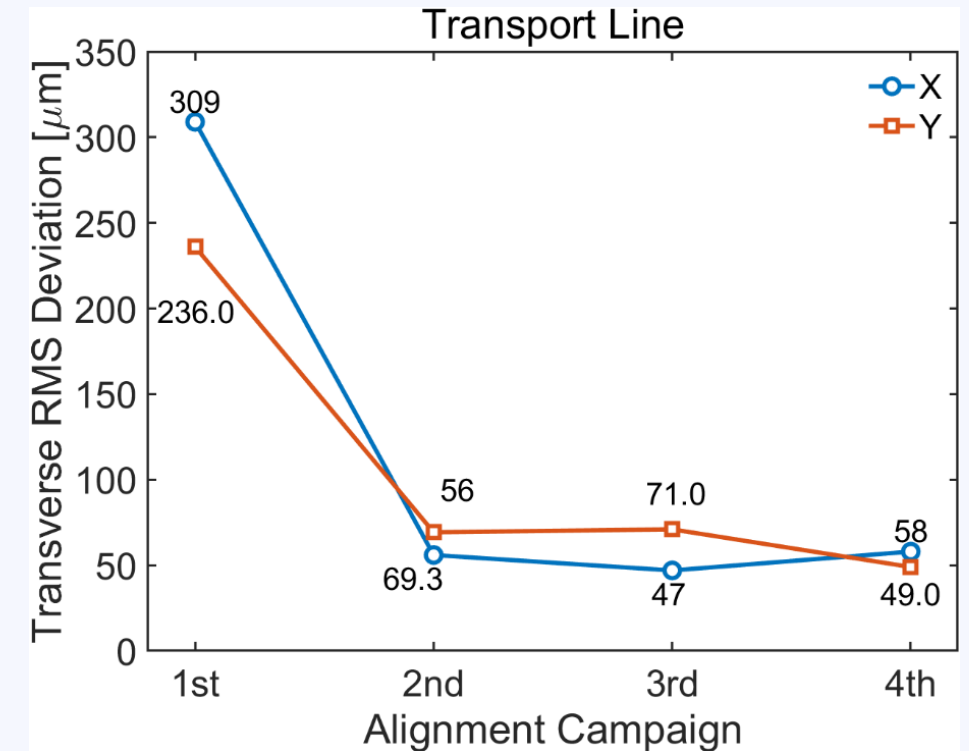
**All injector components have been installed,
Four rounds of measurement and alignment adjustment have been completed.**

5.3 Injector Alignment through Four Survey and Adjustment Campaigns

Four successive post-installation survey and adjustment campaigns refined injector alignment.



Final transverse RMS
Linac
X / Y = 59 / 59 μm
Transport Line
X / Y = 58 / 49 μm



1st Survey → Adjustment → 2nd Survey → Adjustment → 3rd Survey → Final Adjustment → 4th Survey

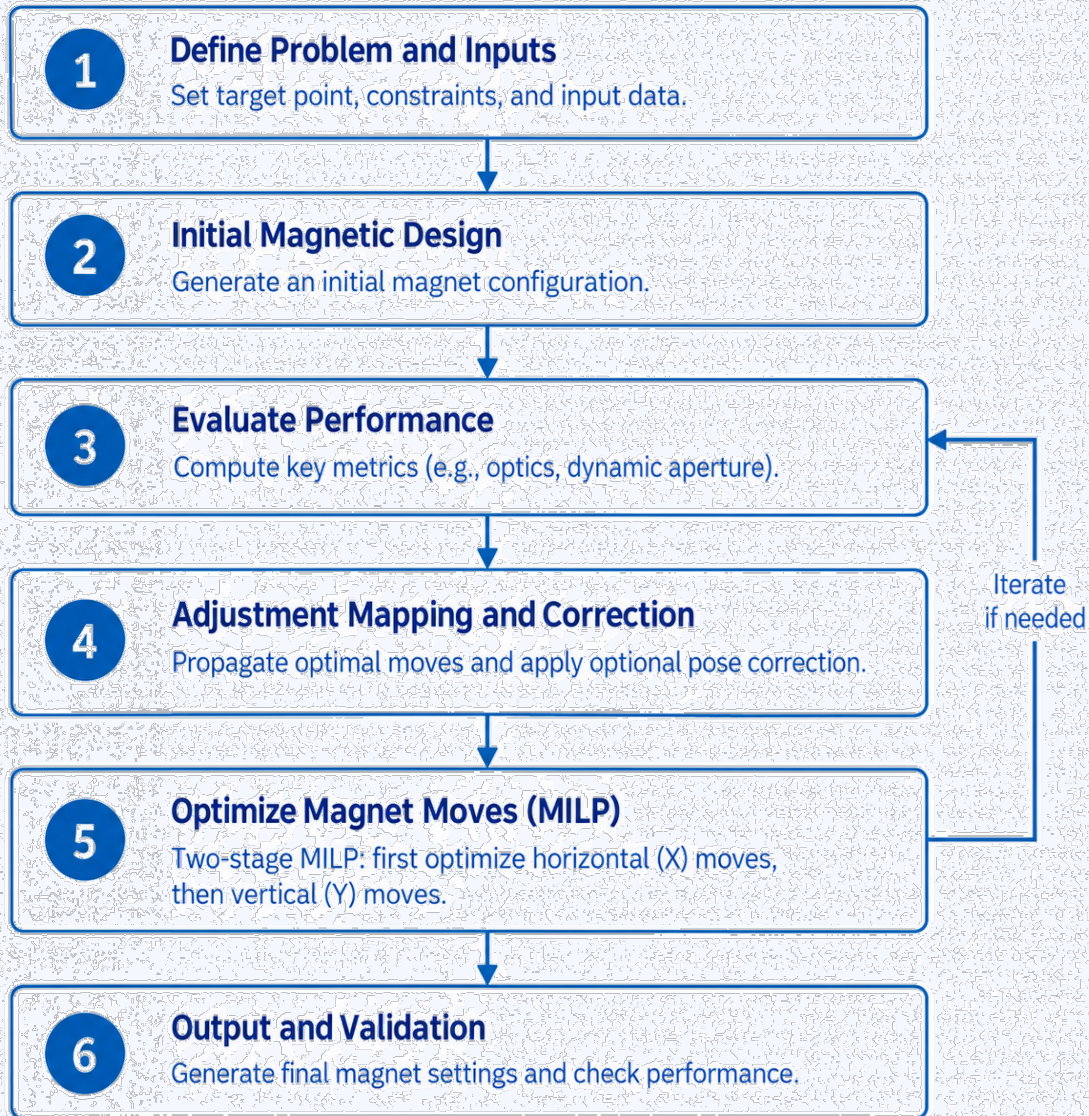
The injector alignment converged from the ~300 μm level after initial installation to ~50–60 μm RMS.

5.4 Injector Final Alignment Results and Compliance

The fourth-round best-fit position deviations were evaluated against the component-specific X, Y and Z alignment tolerances.

Component Type	No. of Components	X / Y Tolerance [μm]	Z Tolerance [μm]	X / Y Compliance	Z Compliance	Overall Status
Magnetic lenses / solenoids	5	±50	±200	5 / 5 (100%)	5 / 5 (100%)	Within tolerance
Accelerating structures	40	±100	±200	40 / 40 (100%)	39 / 40 (97.5%)	One Z-direction deviation
Quadrupole magnets	66	±150	±1000	66 / 66 (100%)	65 / 66 (98.5%)	One Z-direction deviation
Beam profile monitors (PRFs)	3	±150	±500	3 / 3 (100%)	1 / 3 (33.3%)	Two Z-direction deviations
Buncher	1	±100	±200	1 / 1 (100%)	1 / 1 (100%)	Within tolerance
Energy spectrometer	1	±150	±500	1 / 1 (100%)	1 / 1 (100%)	Within tolerance
Orbit correctors*	2	±150	±1000	2 / 2 (100%)	2 / 2 (100%)	Within tolerance
Dipole magnets*	7	±150	±200	7 / 7 (100%)	7 / 7 (100%)	Within tolerance

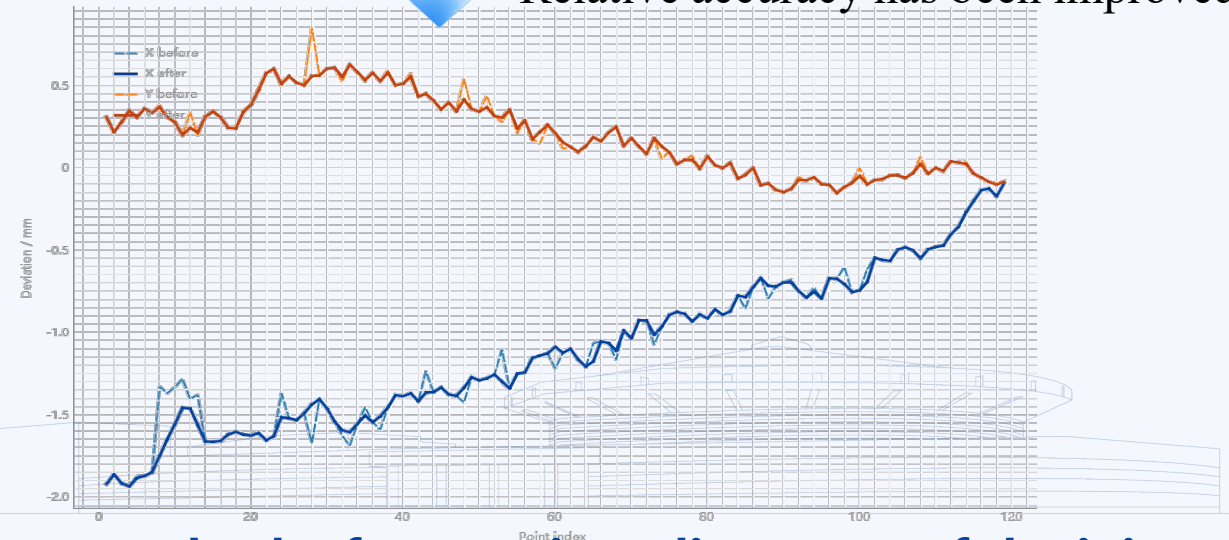
Transverse alignment: All 125 evaluated components satisfied the specified X and Y tolerances.
Longitudinal alignment: 121 of 125 components satisfied the Z tolerance; the four remaining deviations were all in the longitudinal direction.
Overall: The fourth-round alignment achieved **100% transverse compliance** and **96.8% full XYZ positional compliance**.



Global Sparse Optimization



Relative accuracy has been improved

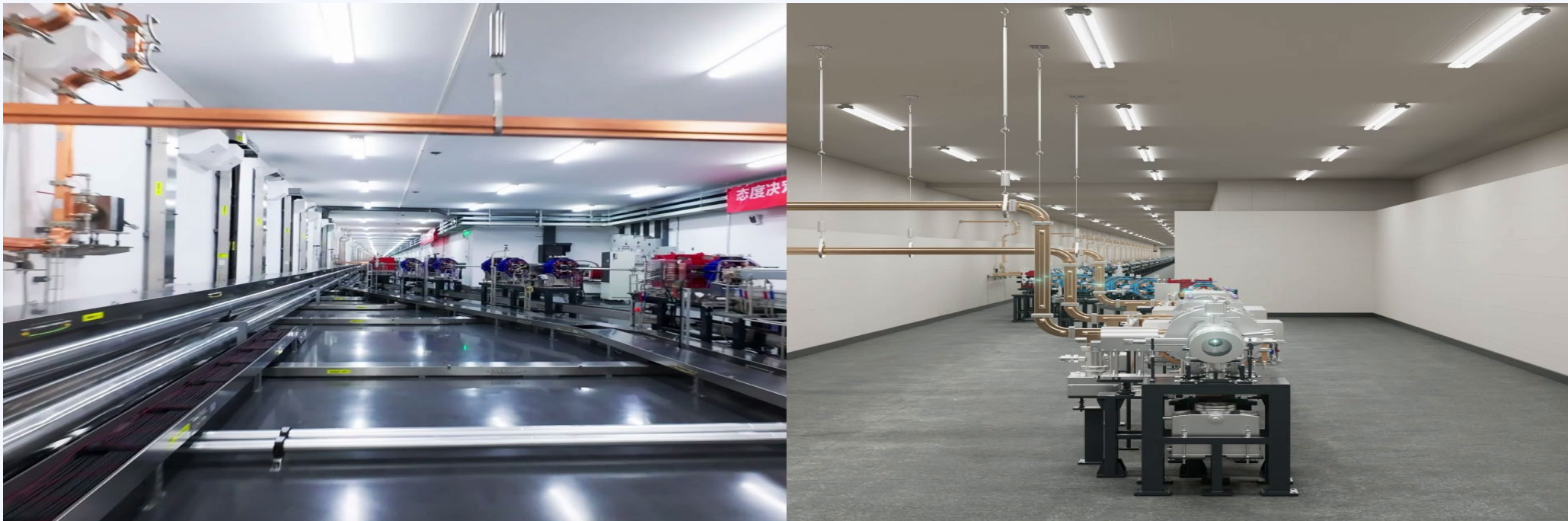


Relative accuracy check after precise adjustment of the injector

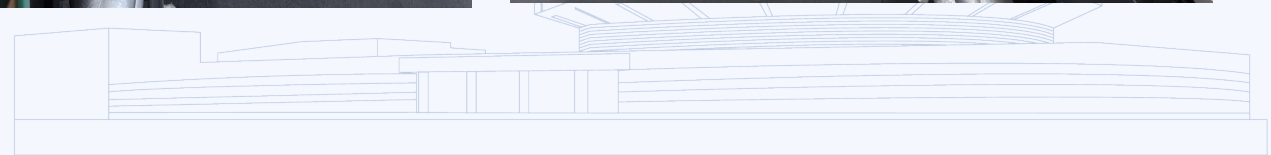
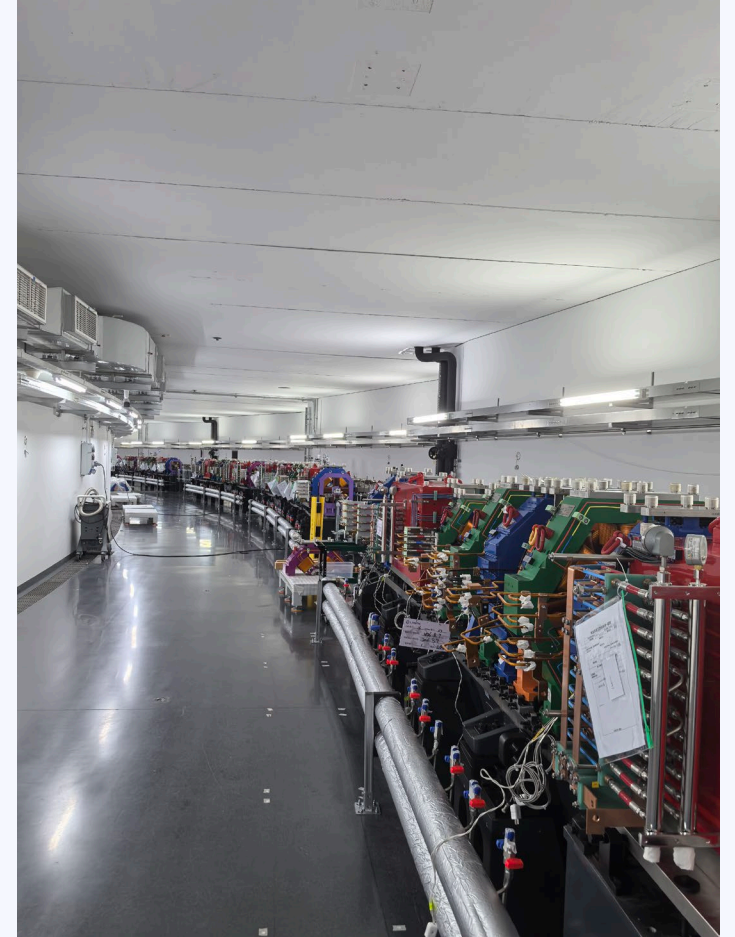
5.5 Installation

On September 20, 2026, coinciding with the 68th anniversary of the University of Science and Technology of China, the HALF injector successfully commenced beam commissioning and achieved stable beam output. The HALF injector is designed for full-energy injection at 2.2 GeV. By September 20, the beam energy reached 2.28 GeV, exceeding the design specification. The measured energy spread was 0.04%, and the charge at the end of the linac was 0.39 nC, indicating that the key beam parameters have met or surpassed the design requirements.

On-site Installation vs. BIM Model: Perfect Alignment



Most online devices in the storage ring have been aligned and installed, with full completion expected by the end of December 2026. Three rounds of measurement and fine alignment are scheduled for early March 2027, after which beam commissioning will commence.



Neighbor-to-neighbor variation
(periodic difference)

$$D_{i,i} = -\frac{1}{h_i}, D_{i,i+1} = \frac{1}{h_i}$$



Geometric roughness operator

$$K = D^T W D$$



Generalized eigenvalue problem

$$K \phi_k = \lambda_k M \phi_k$$

M accounts for nonuniform magnet spacing



$$a_k = \phi_k^T M d$$

- weighted projection onto the geometric basis
- M accounts for nonuniform magnet spacing

Reconstruct:

$$d = \sum_{k=1}^N a_k \phi_k$$



Total orbit

$$\Delta x = \sum_k b_{x,k} = J_{xx} d$$

Alignment response matrix

$$J_{xx} = \frac{\partial x_{BPM}}{\partial x_{magnet}}$$

Bridge from geometry to beam



Geometric variation is represented in a modal basis and then related to orbit response through the alignment response matrix



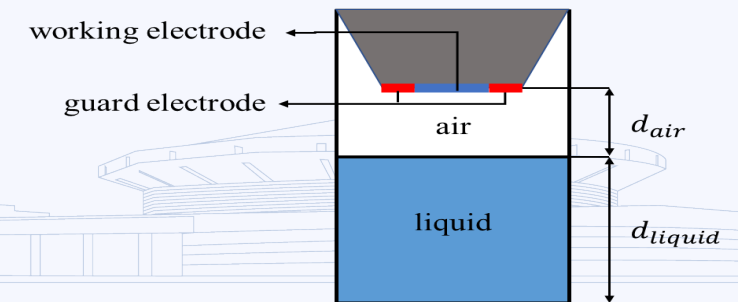
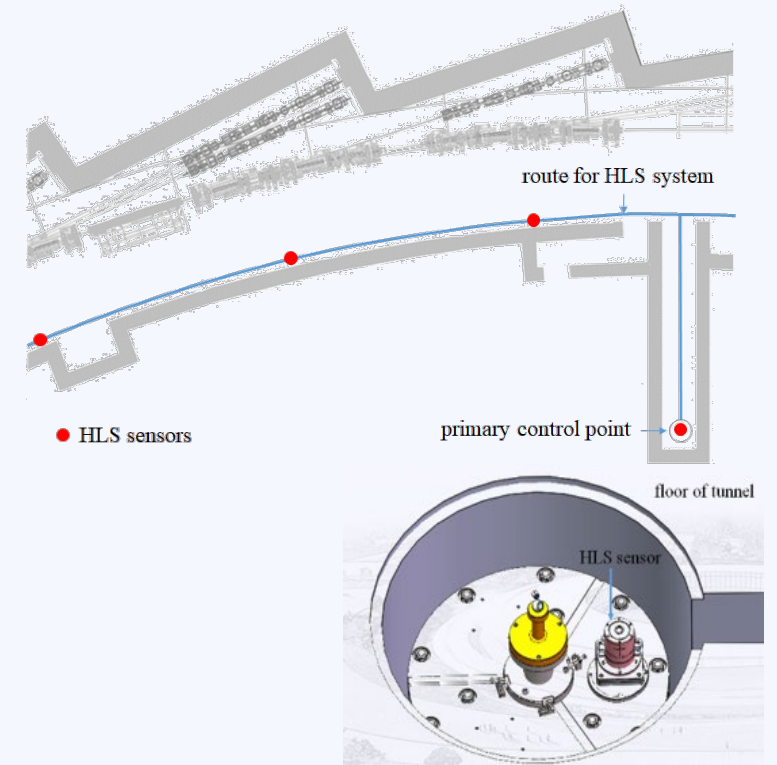


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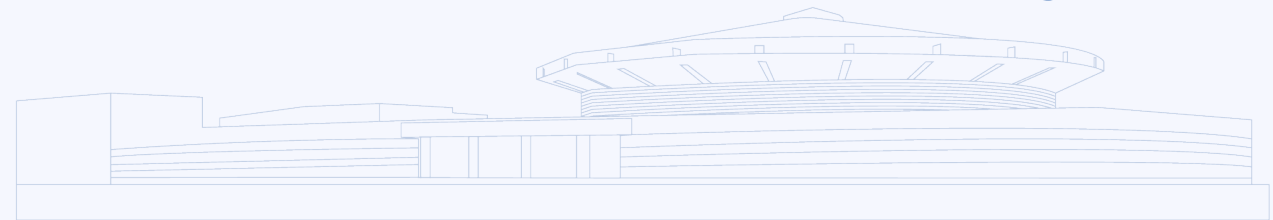
06

Deformation Monitoring

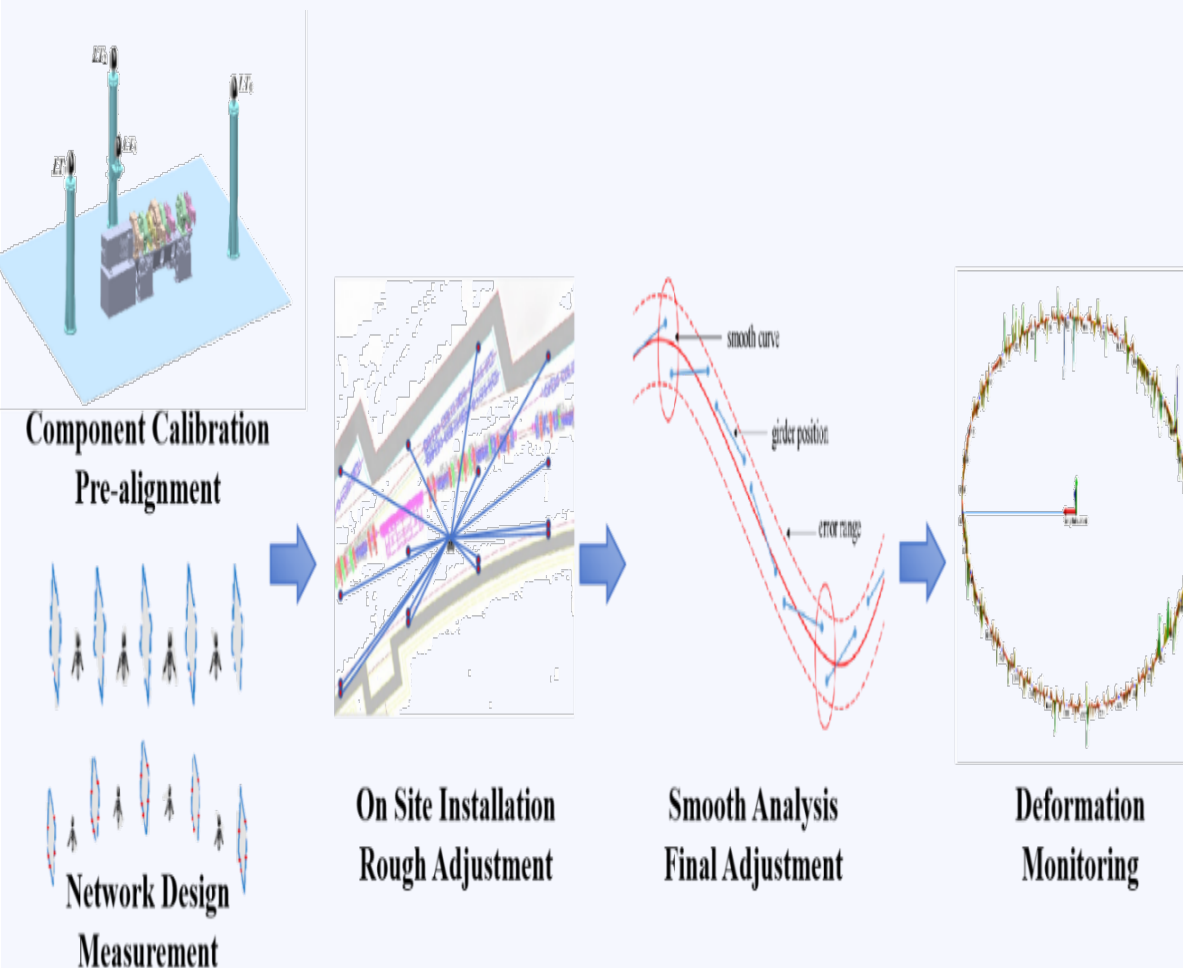
Deformation Monitoring



- (1) The HALF project is progressing in an orderly manner, and the alignment system has been completing the corresponding work according to the project requirements and CPM table, from civil engineering, installation of machine internals to deformation monitoring systems.**
- (2) Theoretical and technical research has been conducted on the special requirements for alignment accuracy of the fourth generation particle accelerator, Scientific research work to improve accuracy and efficiency in each sub-stage of the alignment phase.**
- (3) In the process of completing various tasks of the project, we will combine research results and strive to push the alignment of particle accelerators to new heights in theory and technology.**



Research Achievements towards HALF Alignment (2023.09-2025.12)



- 2026-NIMA-Magnetic center measurement and fiducialization with single stretched wire and precision surface plate
- 2026-Measurmnt-Weight-based network analysis for constructing cost-effective and adaptive node networks
- 2026-NIMA-Research on the methods of coordinate transfer of dual-laser-tracker system in the confined space of particle accelerator
- 2025-JINST-Significance analysis of scale factor in coordinate transformation under multi-condition simulation
- 2025-MST-Accuracy index selection during optimization of particle accelerator ring tunnel network design based on Monte Carlo method
- 2025-RSI-Design and experiment of a four-station laser tracker multilateration measurement system and evaluation of uncertainties
- 2025-JINST-Research on accuracy testing of close-range photogrammetry for geometric feature measurement in particle accelerator
- 2025-TIM-Techniques for Uncertainty Modeling and Data Fusion for High-Precision Installation of Large Insertion Device in the Particle Accelerators
- 2025-TIM-Research and Design of Linac Tunnel Control Network Configuration by Simulations
- 2024-NIMA-Research on the optimization methods of common points layout for survey and alignment of particle accelerators
- 2024-中国激光-Layout Optimization of Four-Channel Laser Pre-Alignment System for Hefei Advanced Light Facility
- 2024-JINST-Research on methods to suppress the error accumulation in the elevation direction for accelerator tunnel control network
- 2024-JINST-Research on datum transformation model in particle accelerator component installation
- 2024-NIMA-Research on particle accelerator control network deformation prediction algorithm with machine learning
- 2024-JINST-Research on fusion and deformation analysis of decade' HLS-II control network surveying data
- 2024-PS-Robust 3D coordinate transformation based on genetic algorithm intelligent weighting
- 2024-NIMA-A common points selection method based on the uniformity of FLTMMs for pre-alignment of particle accelerators
- 2024-中国激光-Self-Adaptive Weighted Rank-Defect 3D Bundle Adjustment of Laser Tracker

Alignment Team



University of Science and Technology of China
National Synchrotron Radiation Laboratory



Cooperative Partner



University of Science and Technology of China
National Synchrotron Radiation Laboratory



国家同步辐射实验室
National Synchrotron Radiation Laboratory

欧洲核子中心
European Organization for Nuclear Research

中国科学院高能物理研究所
The Institute of High Energy Physics of the Chinese Academy of Sciences

海克斯康
Hexagon

北京长城计量测试技术研究所
AVIC Changcheng Institute of Metrology & Measurement

武汉大学
Wuhan University

合肥工业大学
Hefei University of Technology

中国人民解放军网络空间部队信息工程大学
Information Engineering University

安徽瑞西尔德新材料科技有限公司
RayShield

安徽创谱仪器科技有限公司
Anhui Specreation Instrument Technology co., LTD

合肥聚能电物理高技术开发有限公司
Hefei Juneng Electro Physics High-tech Development Co., Ltd



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THANKS!

Xiaoye He

Dec 6th, 2026

