

Survey and Alignment of SSRF

An aerial photograph of a large, modern stadium with a distinctive white, curved roof and a green field inside. The stadium is surrounded by various campus buildings, including multi-story academic or administrative structures. The background shows a cityscape under a blue sky with scattered clouds.

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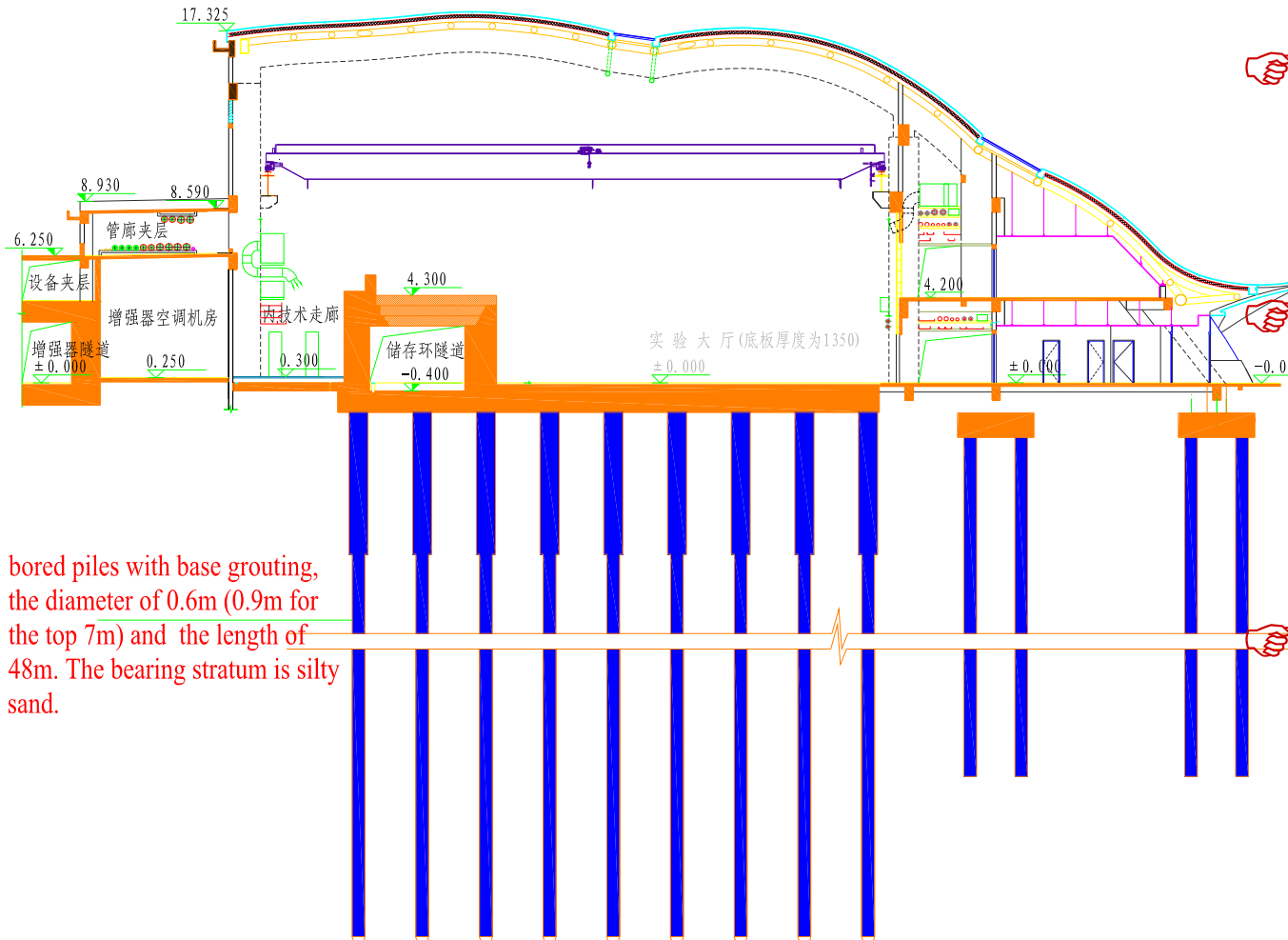
Part 1 Introduction



Introduction

- ☞ Shanghai Synchrotron Radiation Facility, 3.5GeV
- ☞ Zhangjiang high-tech Park.
- ☞ 25th December 2004 with the first piling, 24th December 2007 got the first light.
- ☞ 20-cell DBA of 432m circumference
- ☞ Phase I 7 Front-ends installed

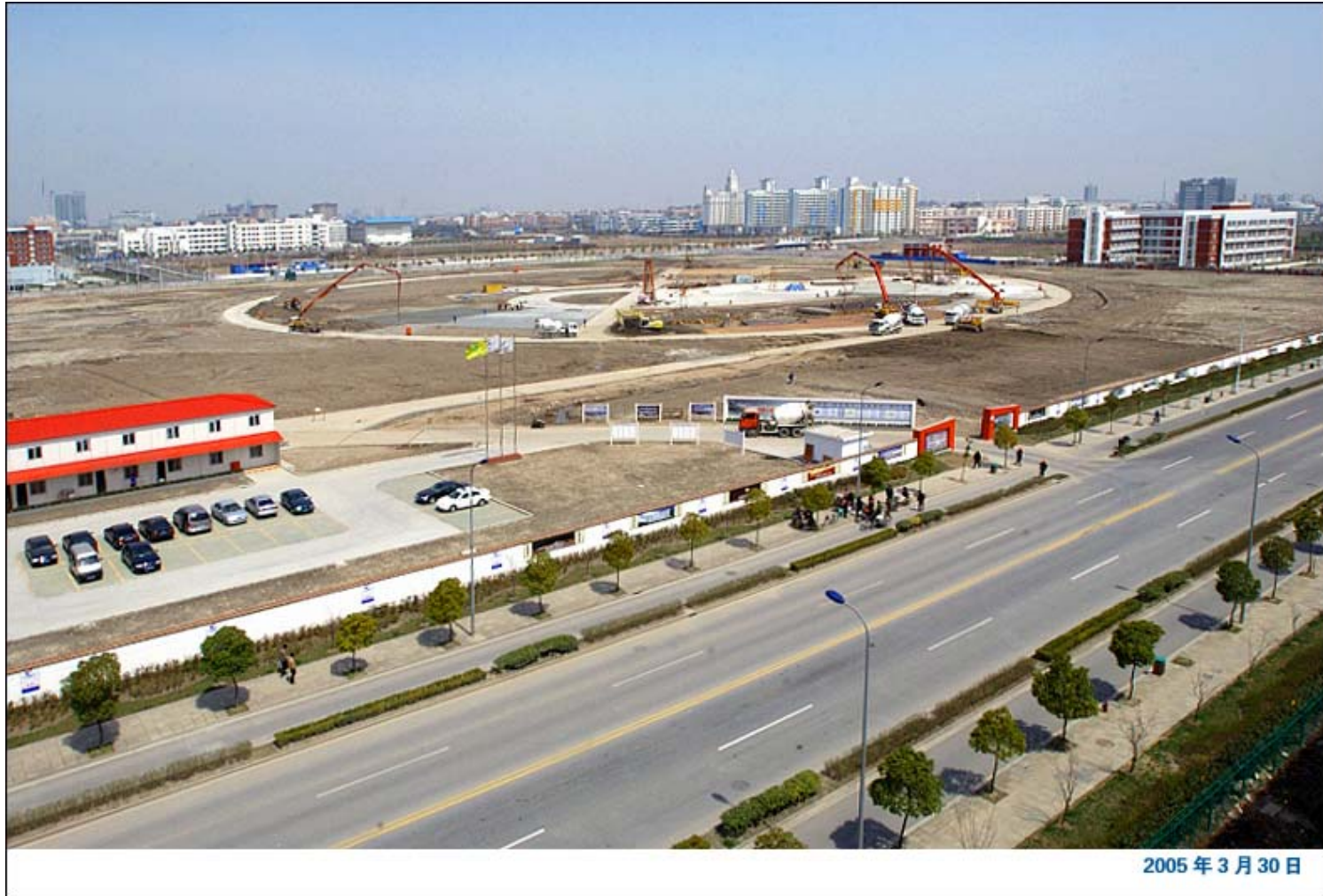
The Section of the whole foundation structure



bored piles with base grouting, the diameter of 0.6m (0.9m for the top 7m) and the length of 48m. The bearing stratum is silty sand.

1800 piles
For SR,
960 piles
Piles:
diameter
0.6m,
length 48m.
Bearing
layer is
silted fine
sand.

The status of building (3/30/2005)



The status of building (2/19/2006)



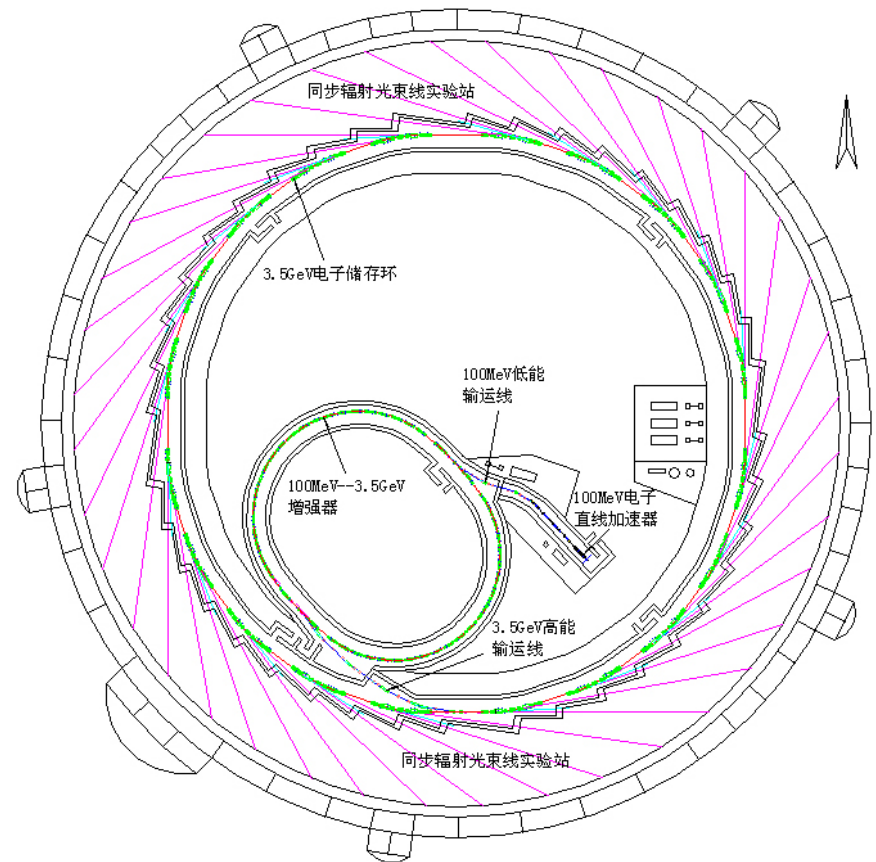
The status of building (4/19/2007)



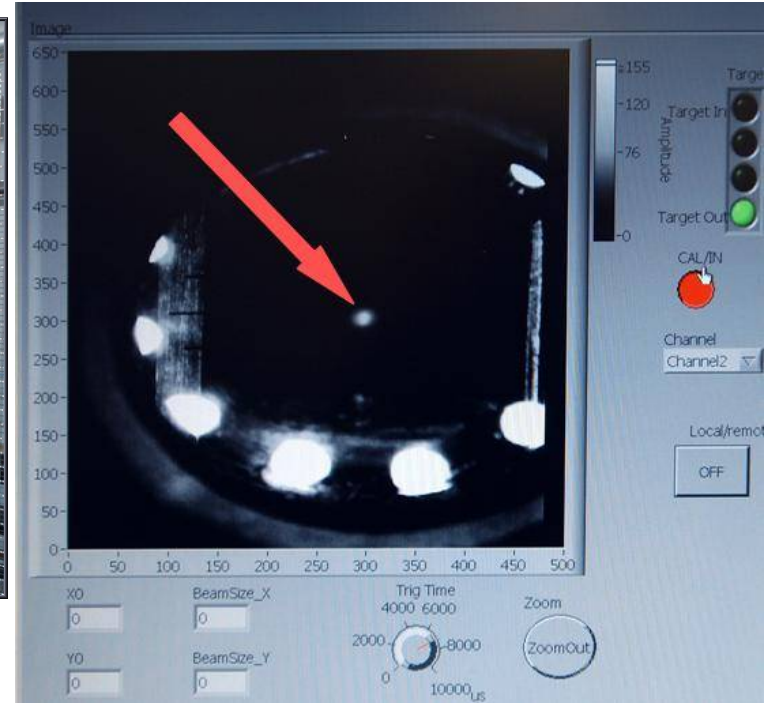
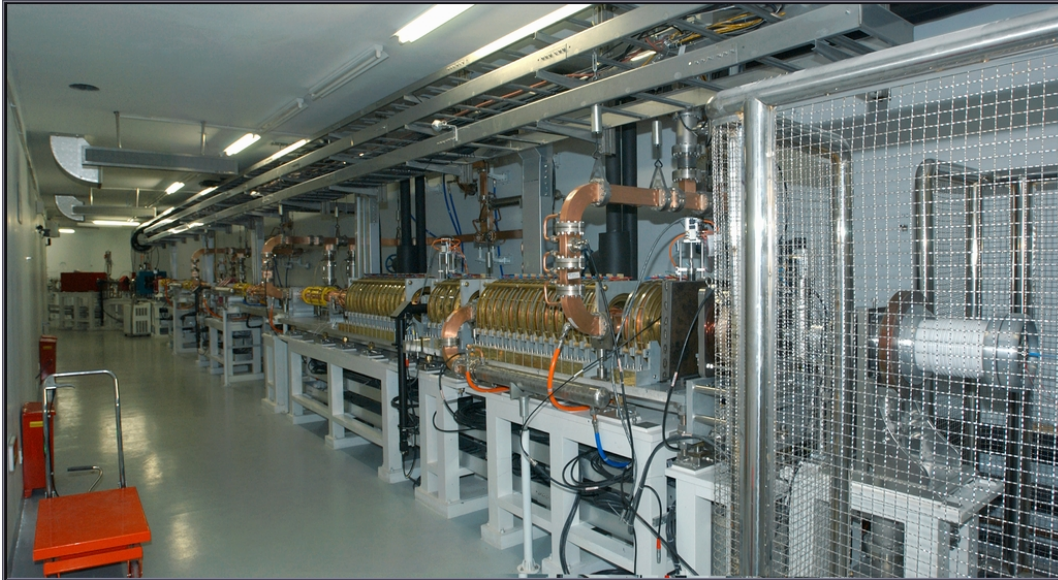
2007年4月19日

Layout of SSRF

- 👉 100MeV Electron Linac (All Parameters are OK)
- 👉 3.5GeV Booster (Most Parameters are OK)
- 👉 3.5GeV Storage Ring (3GeV, 100mA)
- 👉 7 Beam lines



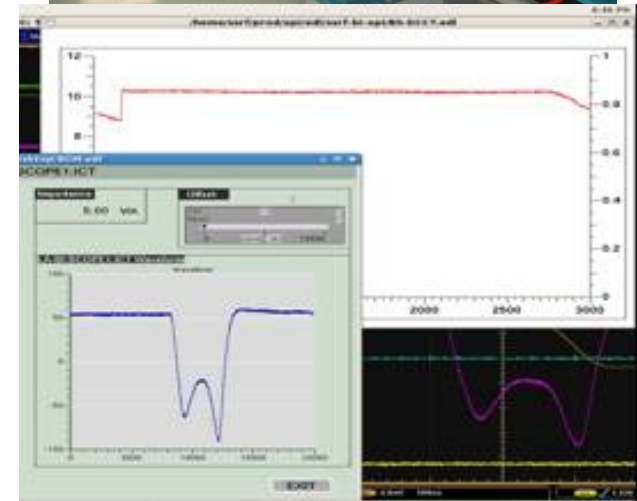
Progress overview-Linac



- 👉 Installation and realignment completed on 6th May 2007.
- 👉 Commissioning started on 13th May.
- 👉 First beam at the end profile of linac on 14th May.
- 👉 All of the design parameters were achieved in August.

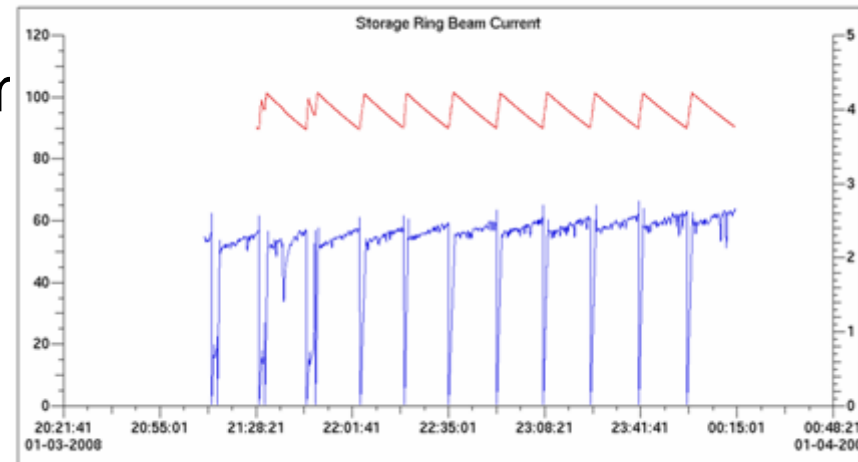
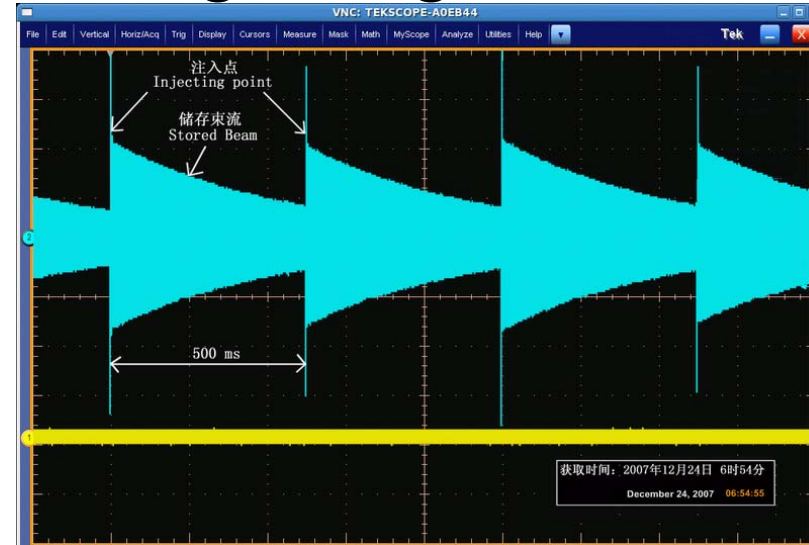
Progress overview-Booster

- 👉 Installation and re-measurement completed on 22nd September 2007.
- 👉 Commissioning started on 30th September. The beam was successfully circulated several times without correctors in the night, 1st October.
- 👉 On 5th October, ramping to 3.5GeV
- 👉 On 30th October, a 5mA multi-bunch 3.5GeV beam was achieved at high energy transfer line.



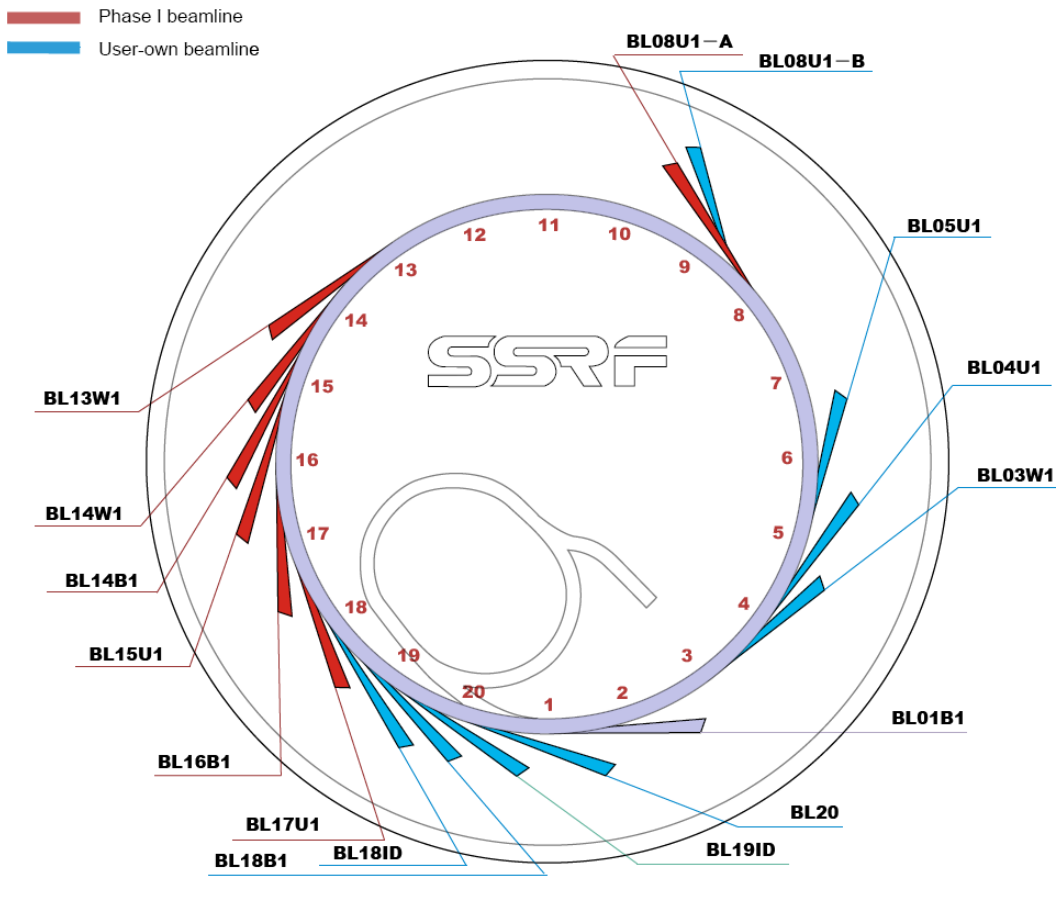
Progress overview-Storage ring

- 👉 Installation and re-measurement completed on 13th December 2007.
- 👉 Commissioning started at 18:20 21st December. First turn beam was gotten at 21:08, and many turns at 21:18.
- 👉 On 24th December, beam was stored at 3GeV and first synchrotron radiation light was seen at the light diagnostic beam line and 16B's front-end.
- 👉 At 20:19, 3rd Jan, 2008, 100mA beam current
- 👉 Room temperature RF cavity (courtesy to KEK)



Progress overview-Front-end

7 Front-ends



Part 2 Control network

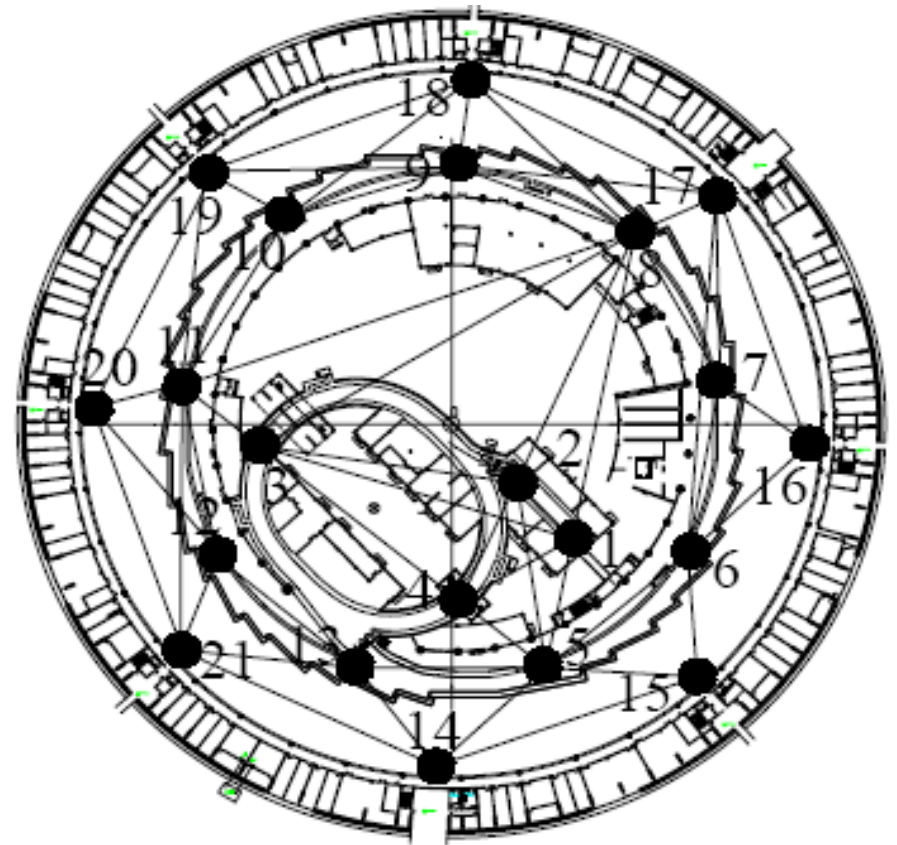


Global horizontal control network

Surveyed 4 times:

- 👉 September 2006(big error)
- 👉 November 2006(formal data,0.5mm point error)
- 👉 January 2007(check measurement,0.3mm point error, constriction factor 9.2×10^{-5} .)
- 👉 November 2007(confirm circumference)

Instruments: total station+ plummet



Global network observation



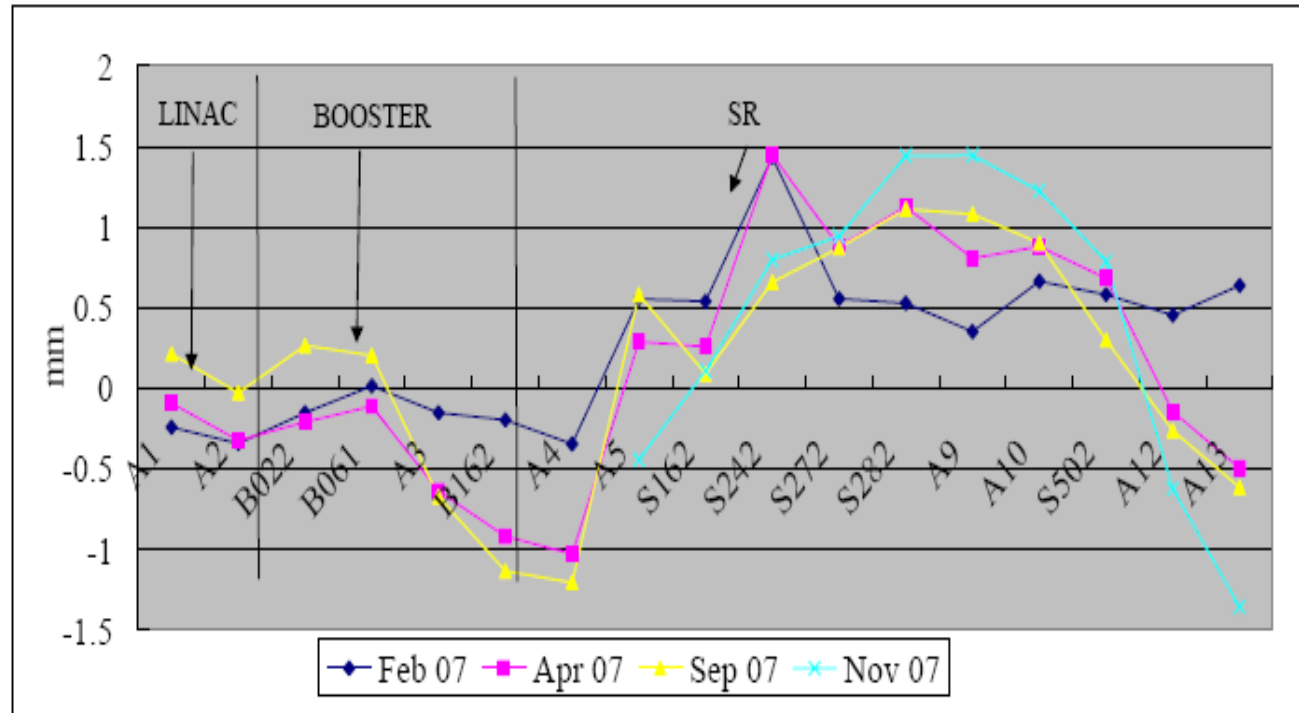
Leveling

Surveyed 5
times

NA2

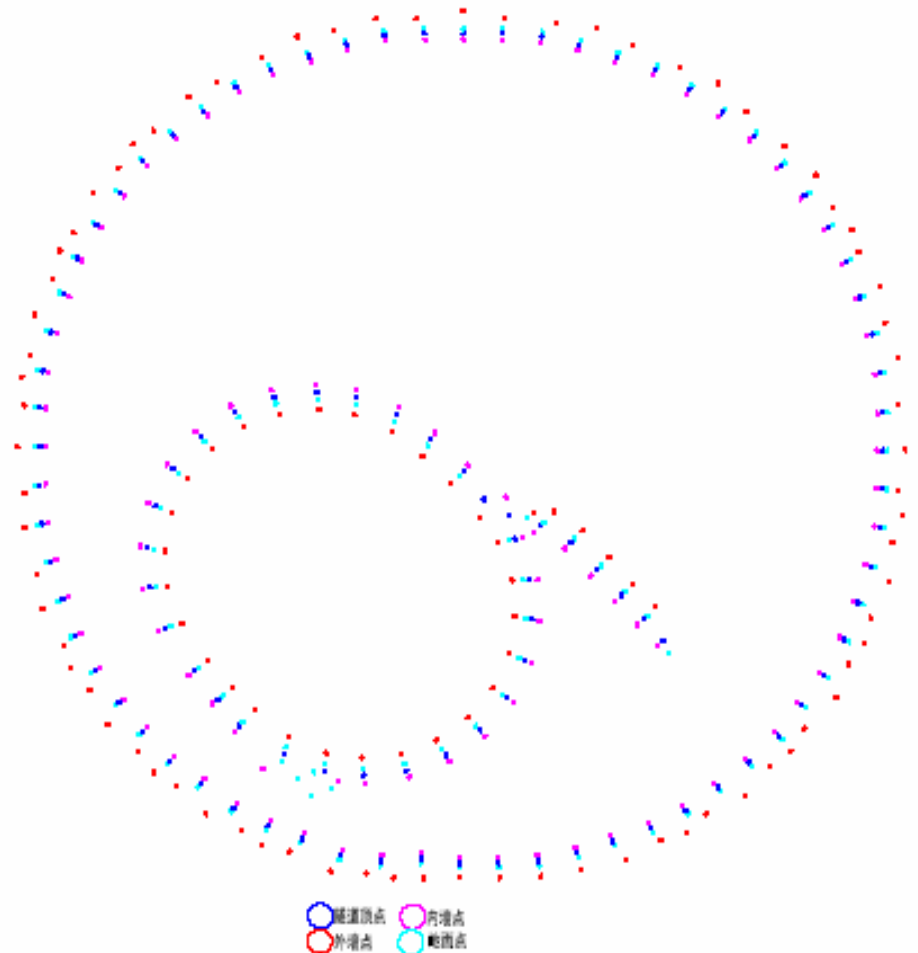
NA3003

DNA03

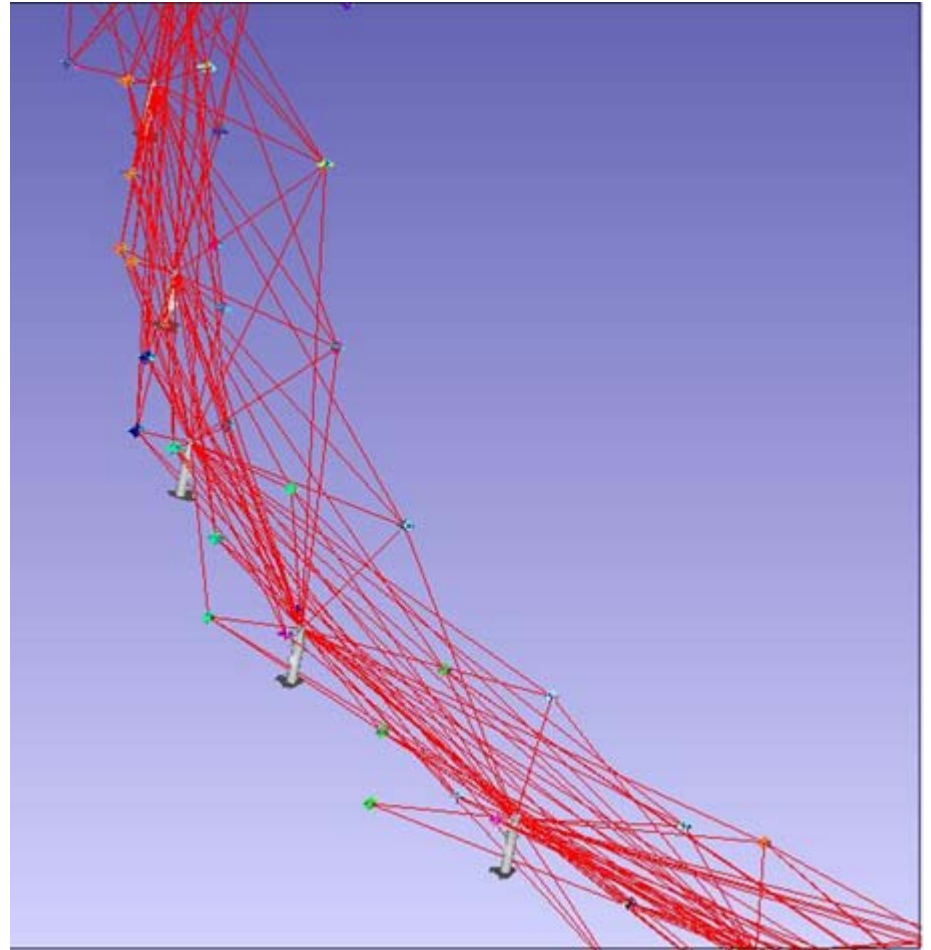
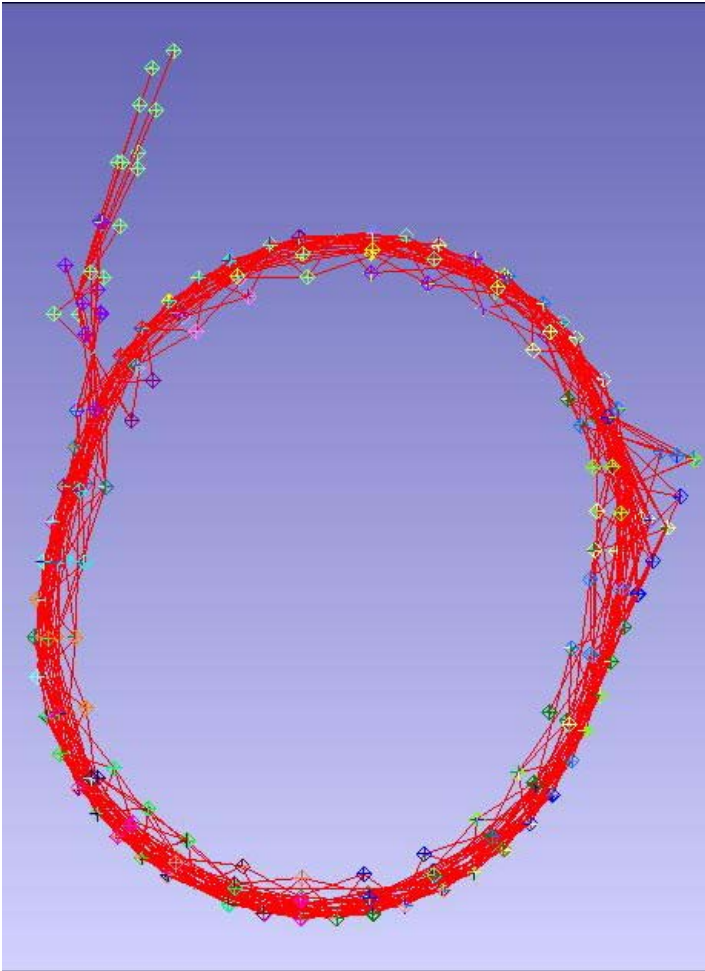


Local control network

- 👉 Linac
- 👉 Booster
- 👉 Storage ring



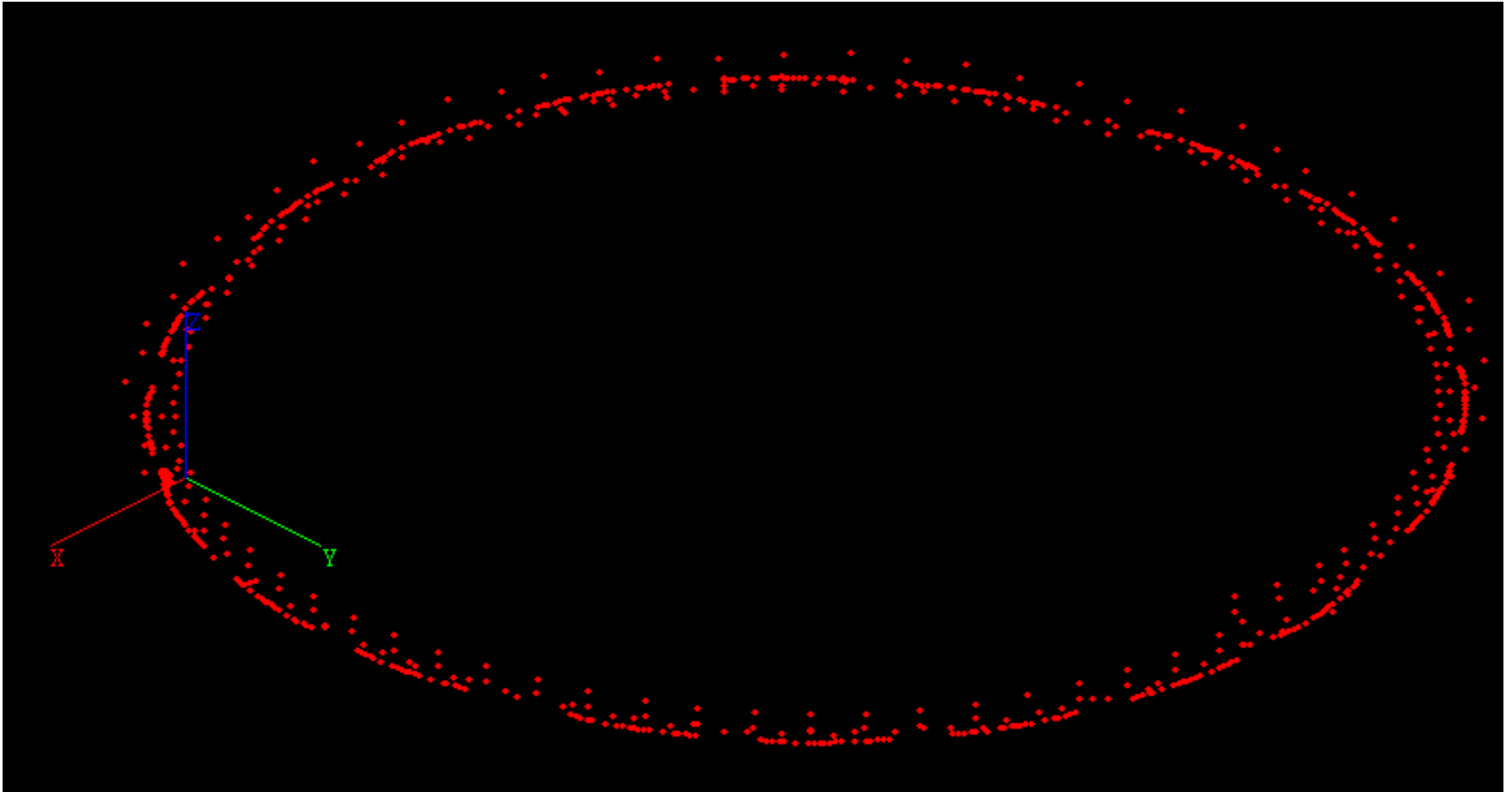
Booster network



Storage ring control network(1st)

- 👉 Surveyed four times for the moment
- 👉 The first time survey took place in December 2006
- 👉 Storage ring wall and slab hadn't been cast fully with the cell 8 area providing access to the central courtyard.
- 👉 Huge construction.

Storage ring control network shape



Storage ring control network(2nd)

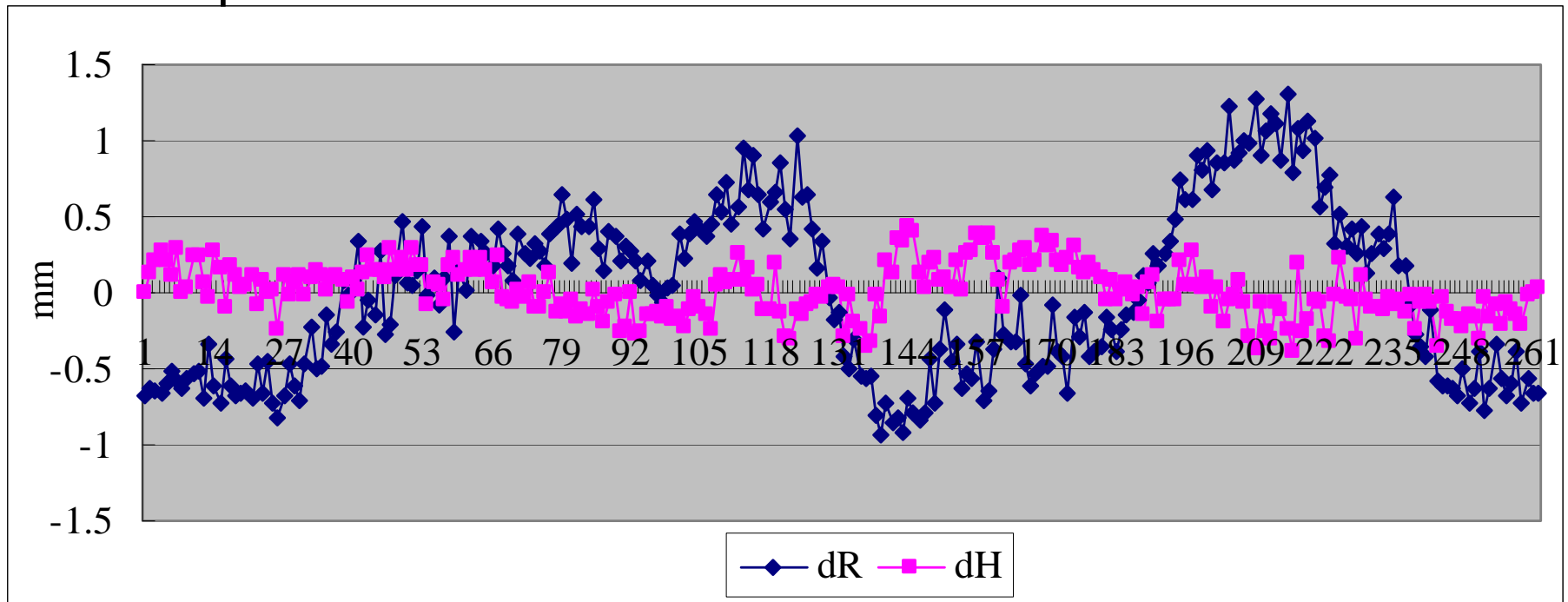
- 👉 In June 2007, just before first girder having been pre-alignment would be craned to storage ring tunnel.
- 👉 The instrument was Faro Xi 4500 with software Insight, 73 stations. Data was separated as horizontal and vertical parts.
- 👉 For horizontal part, software “Survey” to get optimized 2D coordinates smaller than 0.5mm and average adjacent point errors 0.1mm.
- 👉 Vertical part, software “NASEW95”.
- 👉 Hz+V=3D

Storage ring control network(3rd)

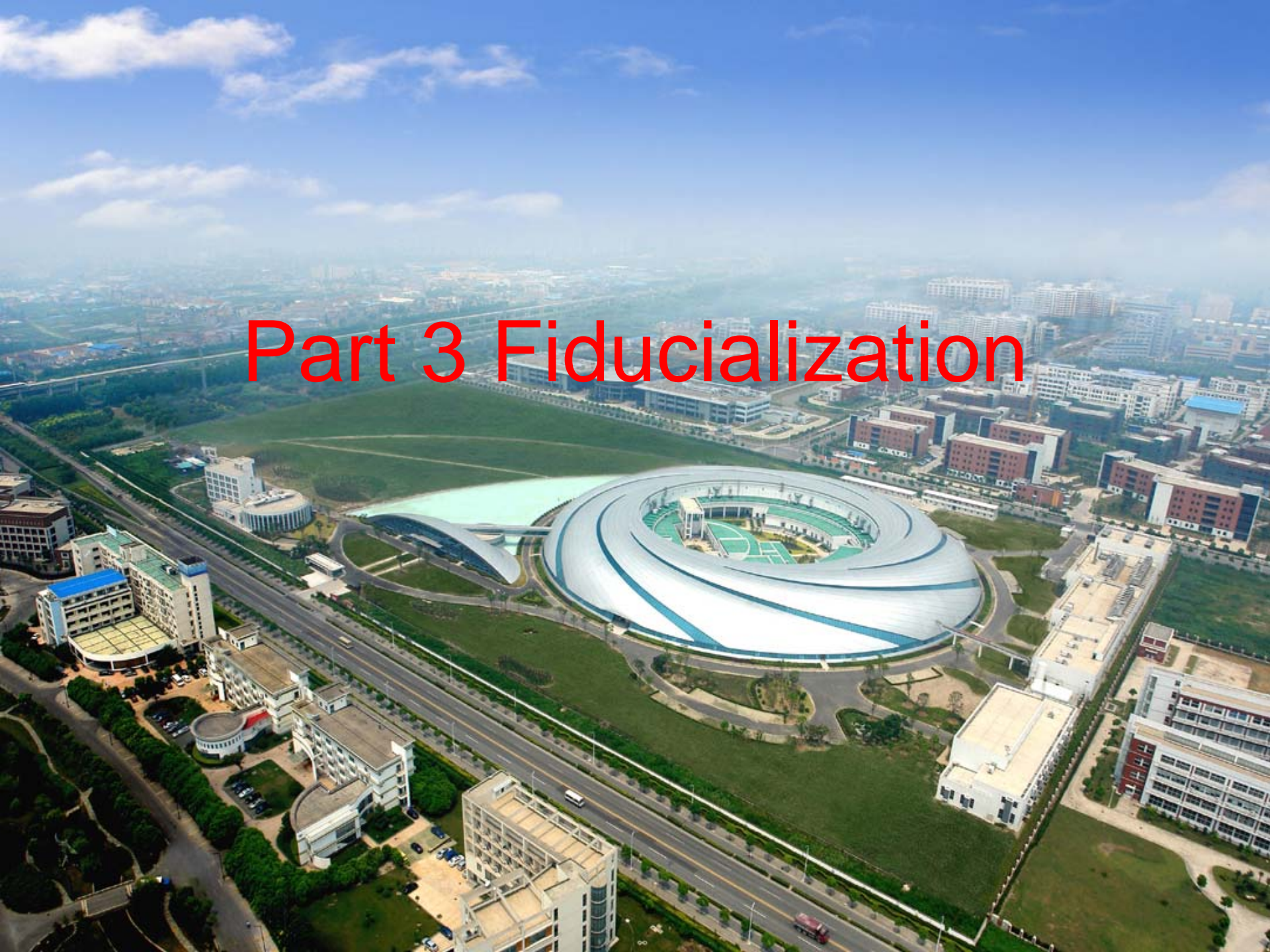
👉 The third time survey serves as a recheck for the formal data and was carried out in July 2007 by IHEP survey and alignment group.

Storage ring control network(4th)

☞ Before commissioning, most of the nests on the wall and monuments in floor and nests of all the quadruples and dipoles are served as observation points and do a complicated measurement.



Part 3 Fiducialization



Overview

- 👉 Not similar as other accelerator facility, SSRF takes almost 95% of the components' fiducialization which has cost about 1/4 time and resource of us.
- 👉 The main instruments for fiducialization are laser tracker and articulated arm.

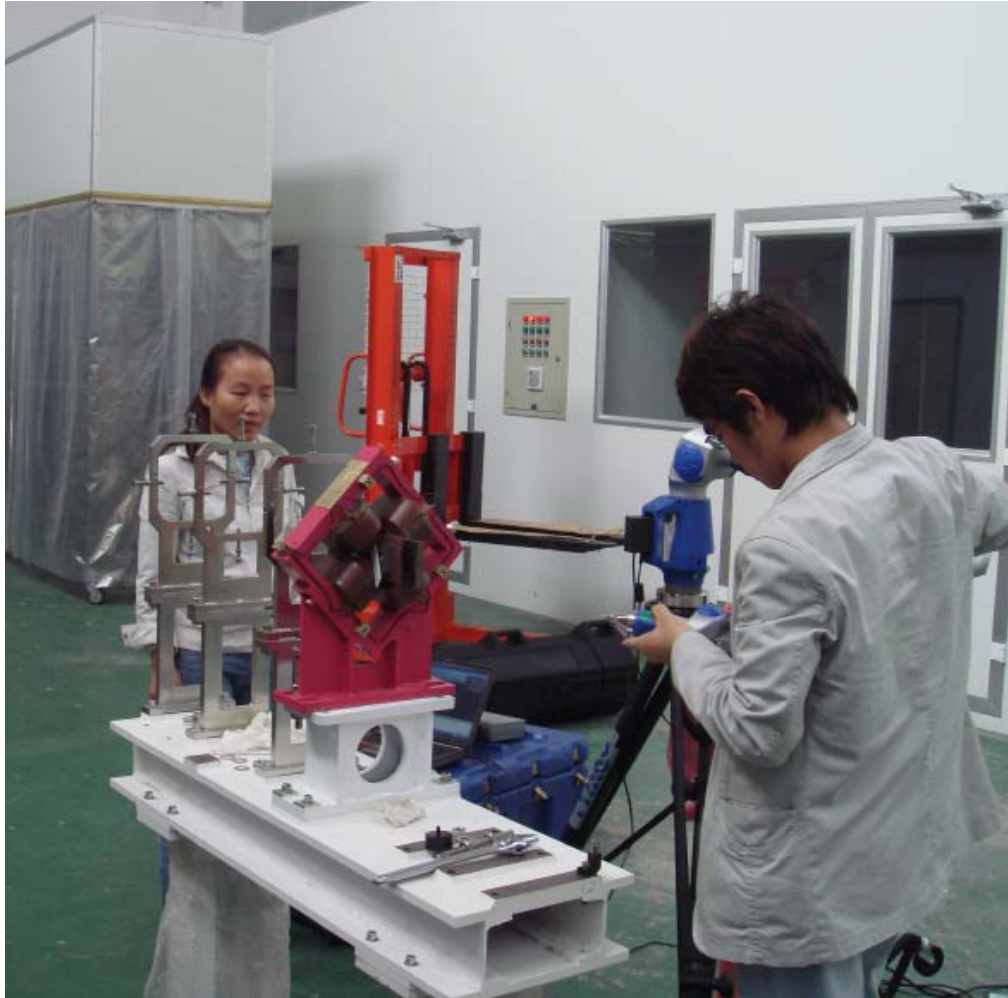
Articulated arm

- ☞ Takes 80% fiducialization tasks: coil and all magnets of linac, and quadruples, sextuples, dipoles and correctors of booster and sextuples, all correctors, vacuum chambers and light absorber of storage ring.
- ☞ Software “CAM2” provides a platform for automatic program including measure indication, calculation and analysis is very convenient and can avoid blunder and enhance efficiency.

Laser tracker

- 👉 Quadruples and dipoles of storage ring are fiducialized by laser tracker. IHEP survey and alignment group take the responsibility to fiducialize these two types of magnets.
- 👉 For quadruples of storage ring, it designed to trace the origin to magnet centre through magnet field measurement coil, but some mistakes caused this some difficulty and as a result mechanical centre substituted the field centre.

Linac



Booster



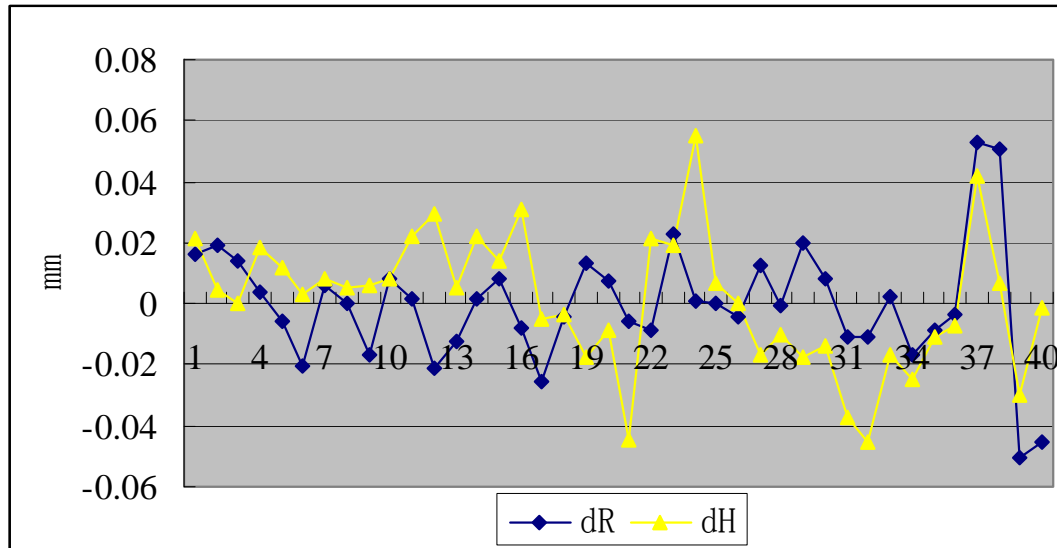
Storage ring

 Q、S、C



Contrast of Quadruples fiducialization


☞ Quadruples were fiducialized again as an accept test initially, but about $10\sim 20^\circ\text{C}$ temperature difference between IHEP site and SSRF pre-alignment site challenged our tolerance. Although after scale compensation, the reference values of magnets' fiducials were small. All the quadruples were fiducialized again.



Part 4 Pre-alignment



What we have done

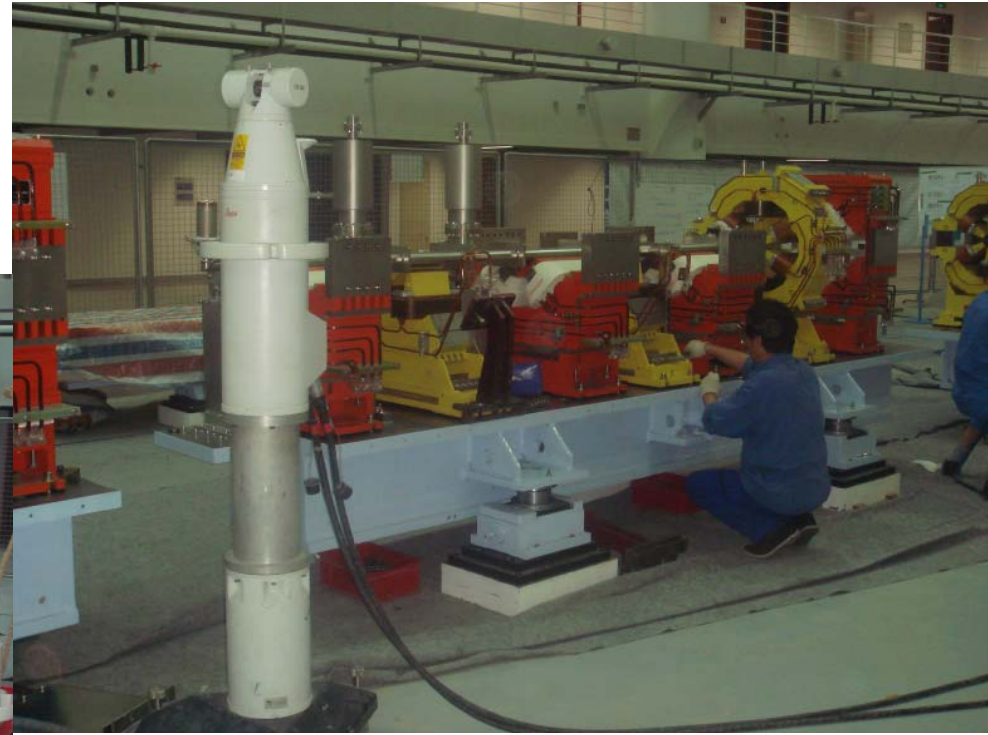
 The number of girders to be pre-alignment for booster and storage ring was 56 and 60, separately.

Booster



Storage ring (1)

Pre-alignment



Storage ring (2)

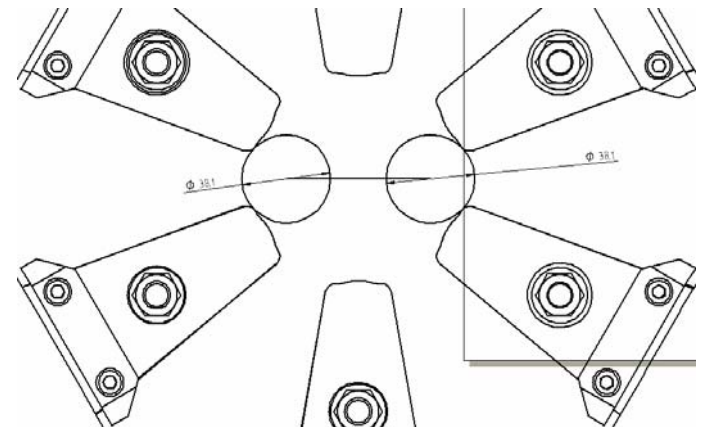
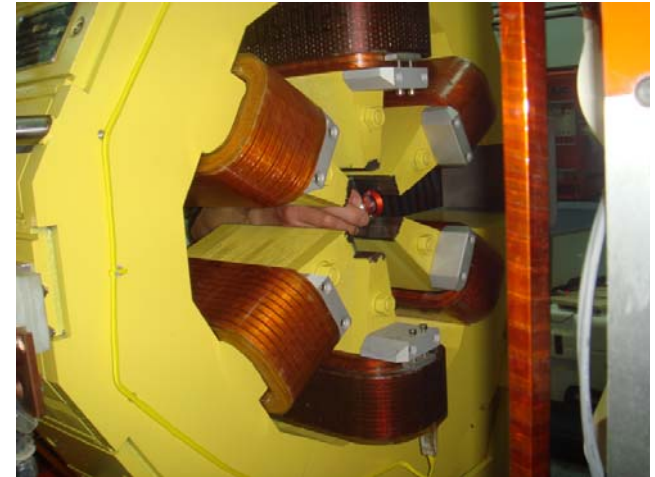


Front-end



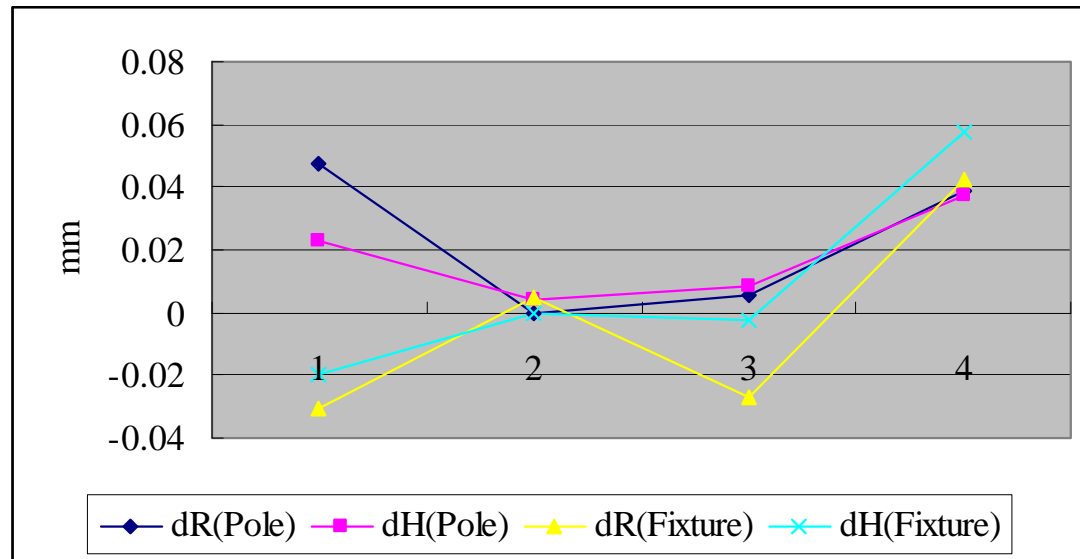
Poles' check (1)

- ☞ The initial purpose was to confirm fiducialization and pre-alignment quality by alignment telescope and fixture through direct poles' measurement.
- ☞ For operator's convenience, the instrument was substituted by laser tracker and a 1.5" corner cube reflector.
- ☞ The poles of magnets are served as main check method.



Poles' check (2)

☞ Most of the poles' check was coincided with the alignment result exactly, two or three girders of total 60 showed a bit bigger deviation which may be caused by unqualified fiducialization or pre-alignment and corrected correspondingly.



A3 girder's pole check result of Cell 02

Part 5 Installation on site



The work being done

- ☞ Centre marking on flooring
- ☞ Pouring the support
- ☞ Girders including pre-aligned and non-standard, injection components and most components of the two beam transport line etc.
- ☞ For storage ring, dipoles, most vacuum chambers and ID-BPM.

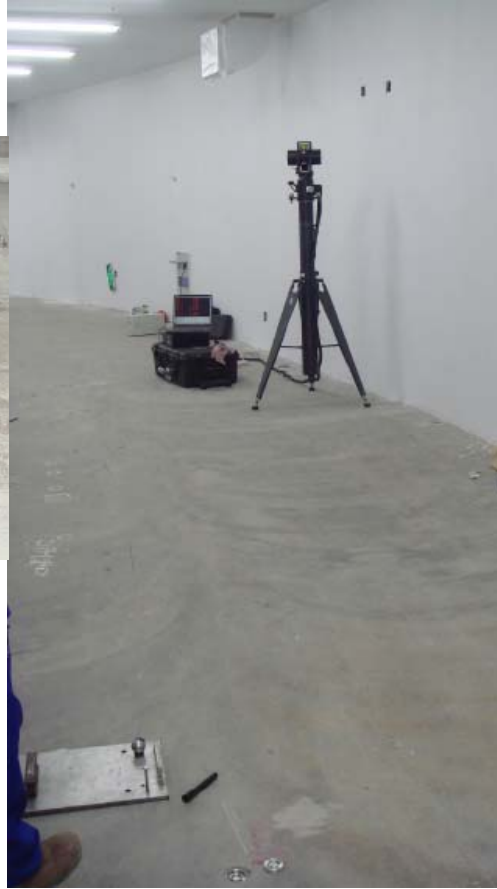
Method

- 👉 Laser tracker under the control of local network. Through more than 10 adjacent nests' measurement, a best fit can be done and the instruments' local frame could be transformed to global frame and the alignment could be started.
- 👉 In order to reduce the affect of longitudinal direction to radial direction, local frame with two coordinate axes were coincide with beam longitudinal and vertical direction respectively was widely adopted.

Linac



Booster(1)



Booster(2)



Booster(3)



Storage ring(1)



Storage ring(2)



Roll deviation check

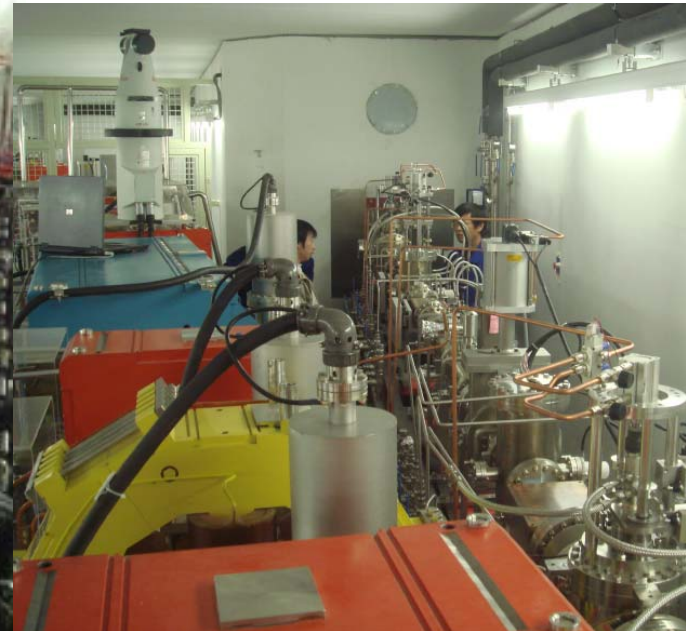
- 👉 Electronical inclinometer, nivel20.
- 👉 After a girder has been aligned and re-checked by laser tracker, the nivel20 would be put on the top of quadruples via an precisely-machined marble.
- 👉 For all of the quadruples, the roll readings were no bigger than 0.2mrad.



3 room-temperature RF cavities from KEK



Front-end

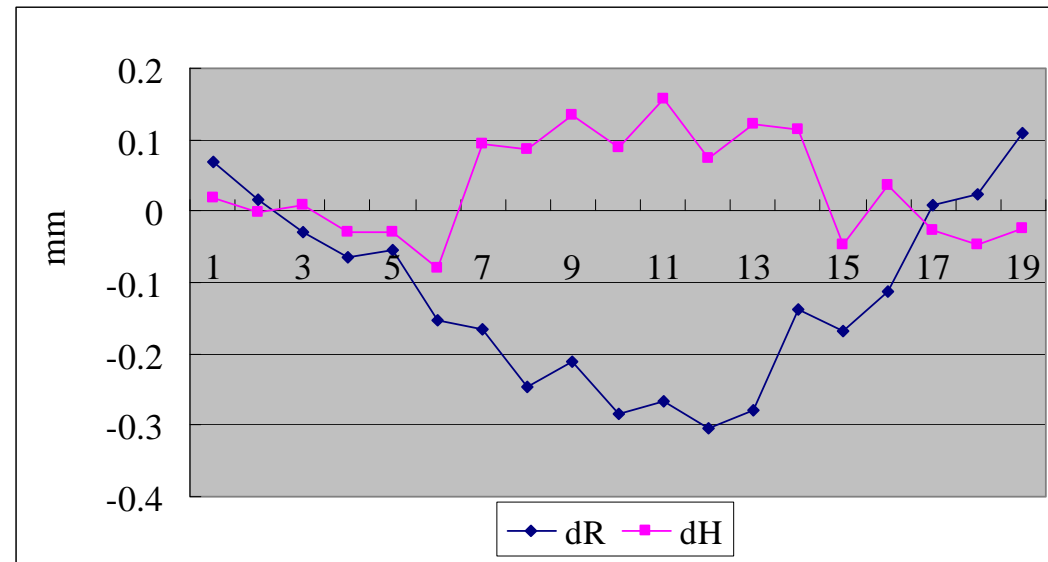


Part 6 Smoothing



Overview

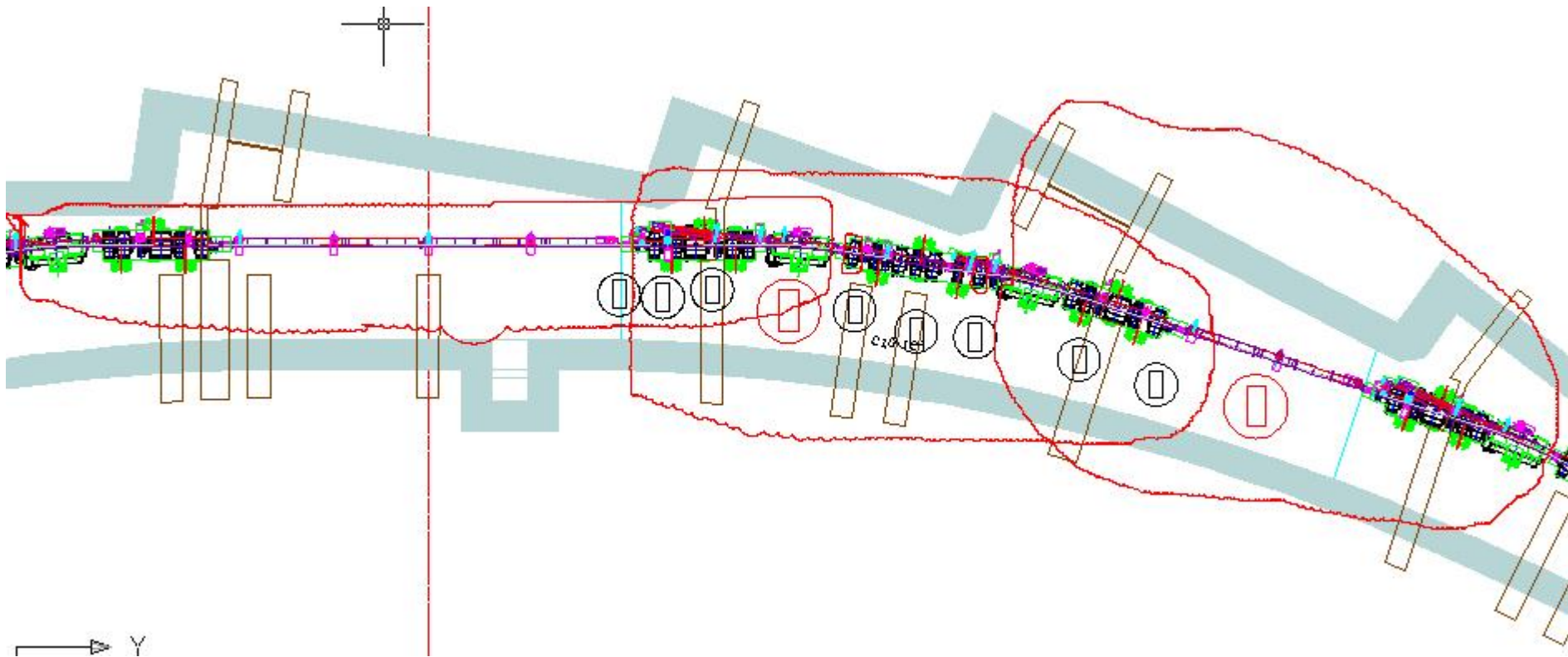
- 👉 Final survey including control network and magnets' fiducials.
- 👉 For linac, a final adjustment was performed.
- 👉 For booster and storage ring, we provided a list to be adjusted according to the smoothing result, but the physicist thought that the result was rather good and left the alignment unchanged.



The biggest deviation of storage ring

SR smoothing method

Best fit actual to reference coordinates to calculate the smoothing of orbit.

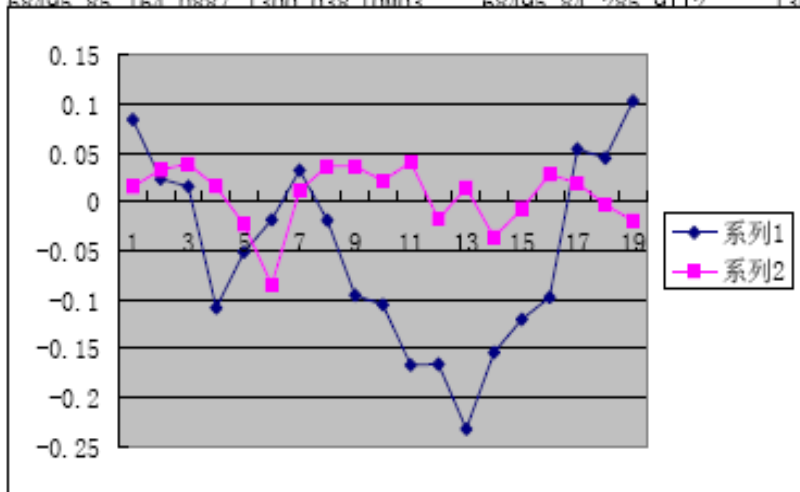


Inter-cell

BM, QM, SM

Group 19

10M01	68464.15	163.1477	1300.015	10M01	68464.07	286.8521	1300	0.0837	0.0151	359.9998	
10M02	68478.88	163.6539	1300.033	10M02	68478.86	286.346	1300	0.0231	0.0325	359.9999	
10M03	68495.85	164.0887	1300.038	10M03	68495.84	285.9112	1300	0.0154	0.0384	359.9999	
10M04								0	-0.1087	0.0153	359.9999
10M05								0	-0.0517	-0.0234	360
10M06								0	-0.0187	-0.0853	359.9998
10M07								0	0.032	0.0113	359.9996
10M08								0	-0.0191	0.0363	359.9996
10M09								0	-0.0958	0.0362	359.9998
10M10								0	-0.1056	0.0212	359.9998
10M11								0	-0.167	0.0402	359.9999
10M12								0	-0.1663	-0.0179	360.0001
10M13								0	-0.2326	0.0141	360.0001
10M14								0	-0.1543	-0.0365	360.0001
10M15								0	-0.1205	-0.0077	360
10M16								0	-0.0978	0.0279	360.0001
10M17								0	0.0537	0.0188	360
10M18	67962.17	174.2873	1299.997	10M18	67962.13	275.7127	1300	0.0445	-0.0032	360	
10M19	67904.68	174.7953	1299.98	10M19	67904.58	275.2048	1300	0.1028	-0.0197	360.0001	

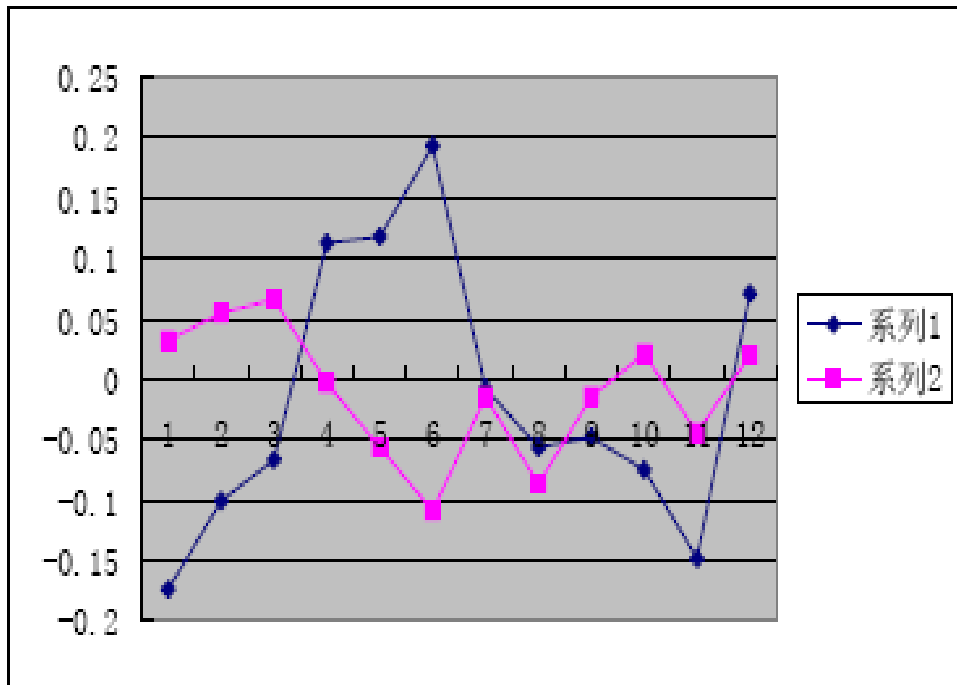


RMS 0.106944 0.031688

Intra-cell

 BM, QM, SM

Group 20
10M14
10M15
10M16
10M17
10M18
10M19
11M01
11M02
11M03
11M04
11M05
11M06

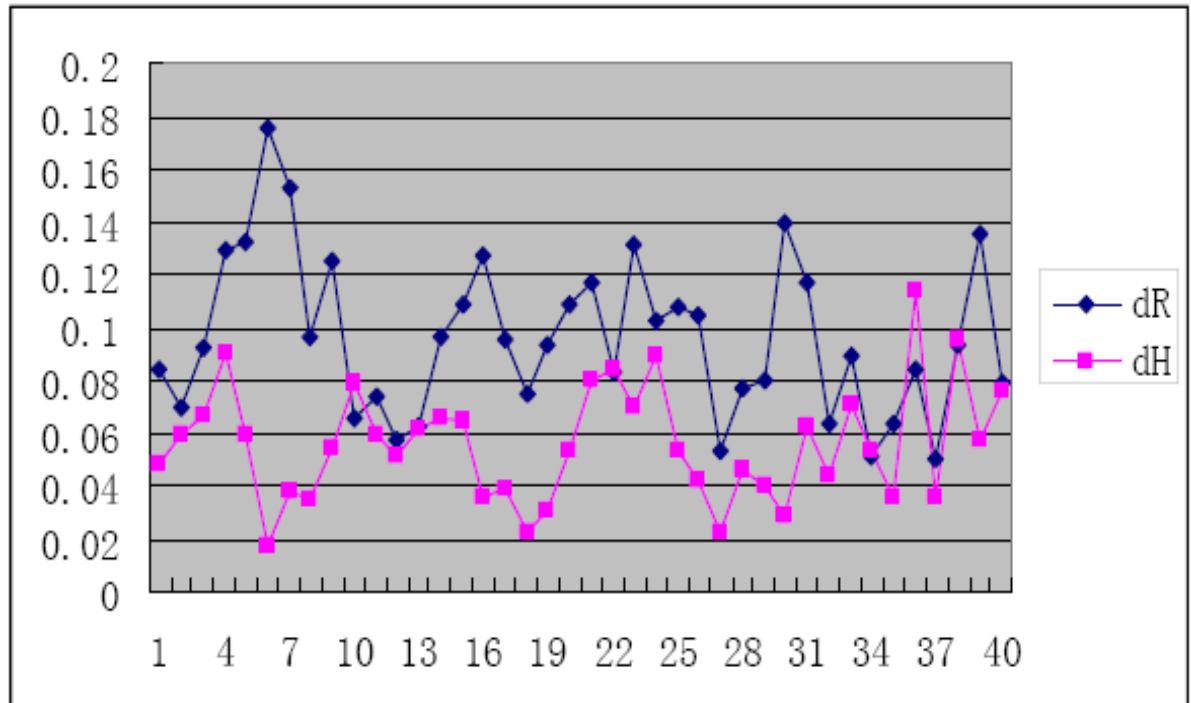


00	-0.1733	0.0324	360
00	-0.1003	0.0549	359.9999
00	-0.0664	0.0661	360
00	0.1129	-0.0029	360
00	0.118	-0.0559	360
00	0.1931	-0.1084	360
00	-0.0074	-0.0144	-1E-04
00	-0.0559	-0.0862	0
00	-0.0477	-0.0142	0
00	-0.0745	0.0212	1E-04
00	-0.1479	-0.0438	1E-04
00	0.0711	0.0201	-0.0001

RMS 0.110452 0.053173

Statistic RMS

- 👉 40 best fit
- 👉 0.10mm in radical direction
- 👉 0.06mm in height direction



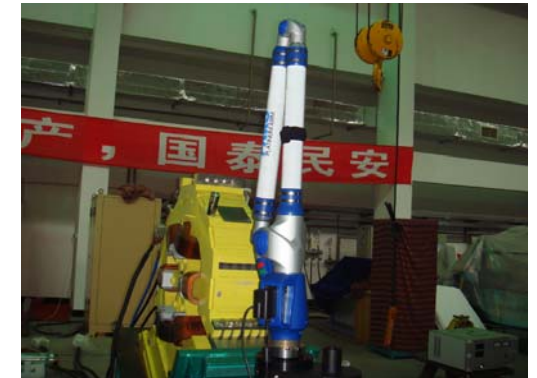
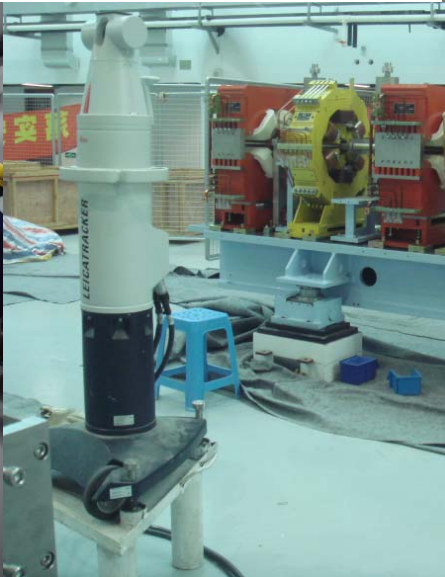
Part 7 Conclusion



Instrumentation

- 👉 Total station (TDM5005)+plummet (NL)
- 👉 Level (NA2, NA3003, substituted by DNA03)
- 👉 Laser tracker (LTD500, LTD600, 2 LTD640,Faro Xi, API)
- 👉 Articulated arm (FARO platinum 2.4m,1.2m)
- 👉 Inclinomometer (Nivel20)

Instrumentation and Software



- 👉 MeasurePro
- 👉 CAM2 V4.5
- 👉 Insight V5.0
- 👉 Axyz V1.4.3
- 👉 Metrology V5.0, V6.0, V7.0
- 👉 Spatial Analyzer

Manpower




 3 engineers of SSRF

 3 engineers from Shanghai Equipment Installation Company

Conclusion

- 👉 The global and local control network can be surveyed periodically and accurately.
- 👉 Laser tracker is main tool for alignment.
- 👉 Articulated arm make fiducialization can be performed accurately and rapidly.
- 👉 Too many software do cause difficulty at the beginning, but each has its merits which can be very useful in special occasions.

Acknowledgement

-  Thanks everyone in the accelerator alignment community who has helped us.
-  People of Shanghai Equipment Installation Company did their best for survey and alignment of SSRF.
-  The work IHEP survey and alignment group have done gave us confidence to keep on.

Thank you for your attention

谢谢！

