The Alignment of BEPCII LINAC

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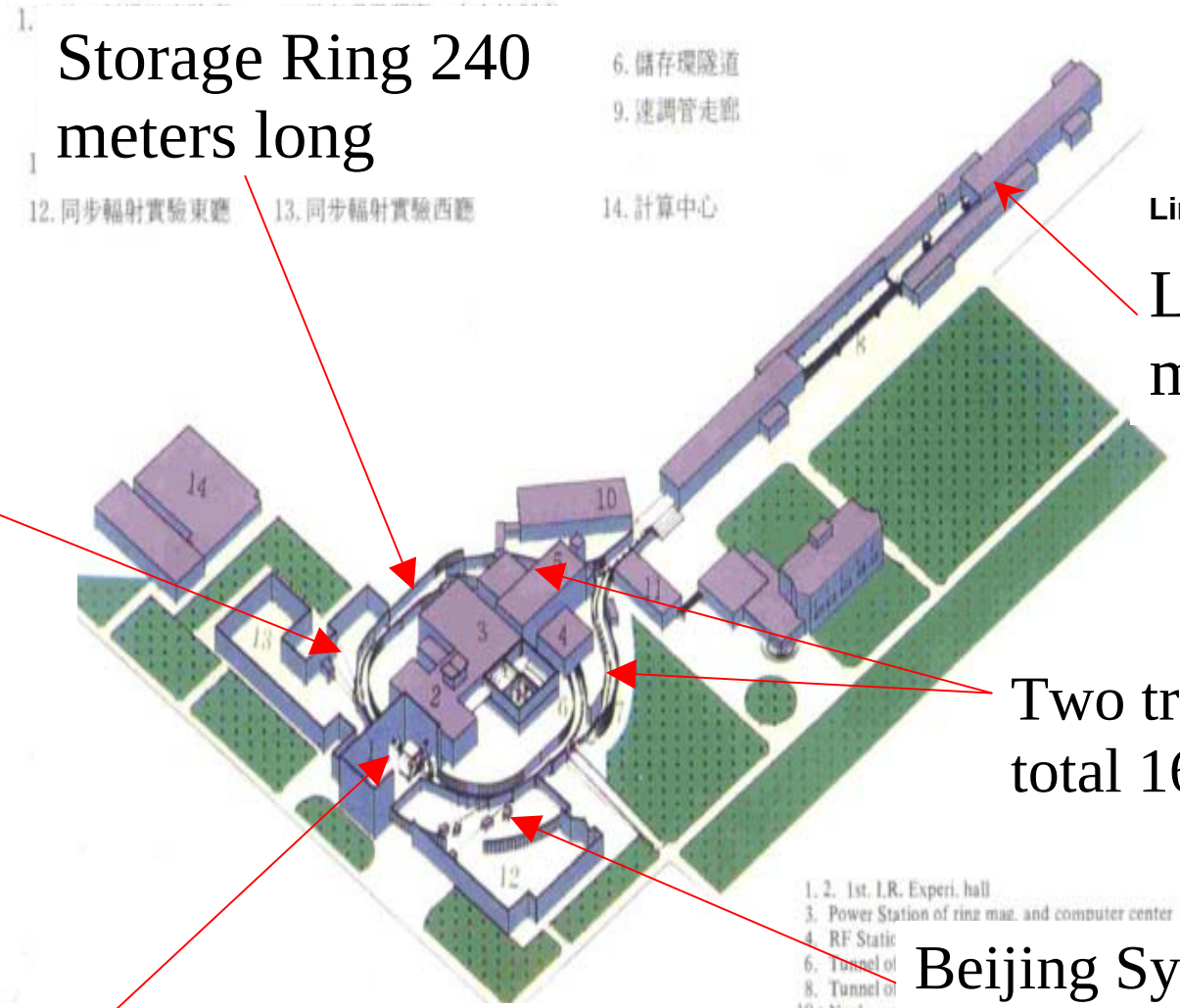
A.Brief Introduction of BEPC

The Beijing Electron Positron Collider (BEPC) consists of the linear injector, storage ring, transport line, Beijing Spectrometer(BES), and Beijing Synchrotron Radiation Facility (BSRF)

Aerial View of BEPC


Storage Ring 240 meters long
Linear Injector
LINAC, 202 meters long
Beijing Synchrotron Radiation Facility
Two transport lines, total 160 meters long
Beijing Spectrometer
Beijing Synchrotron Radiation Facility

BEPC LINAC

BEPC Transport Line

Beijing Spectrometer

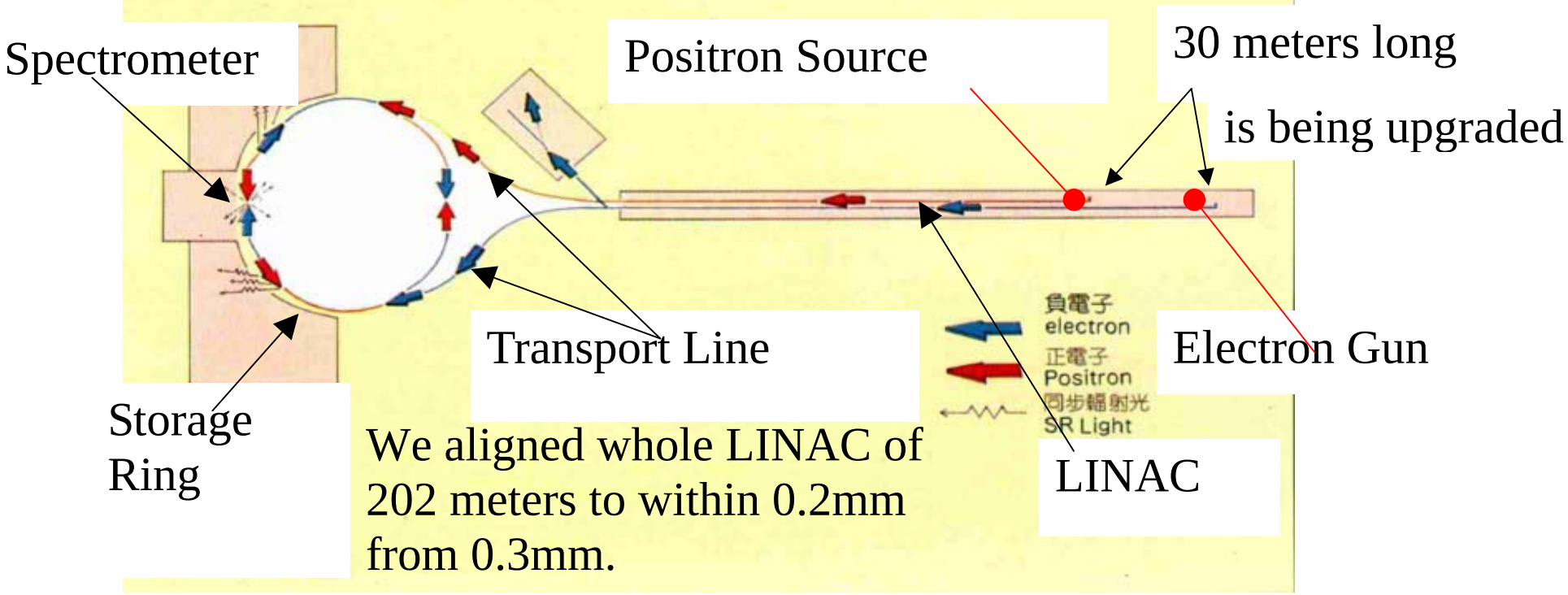
BEPC Storage Ring

Beijing Synchrotron Radiation Facility

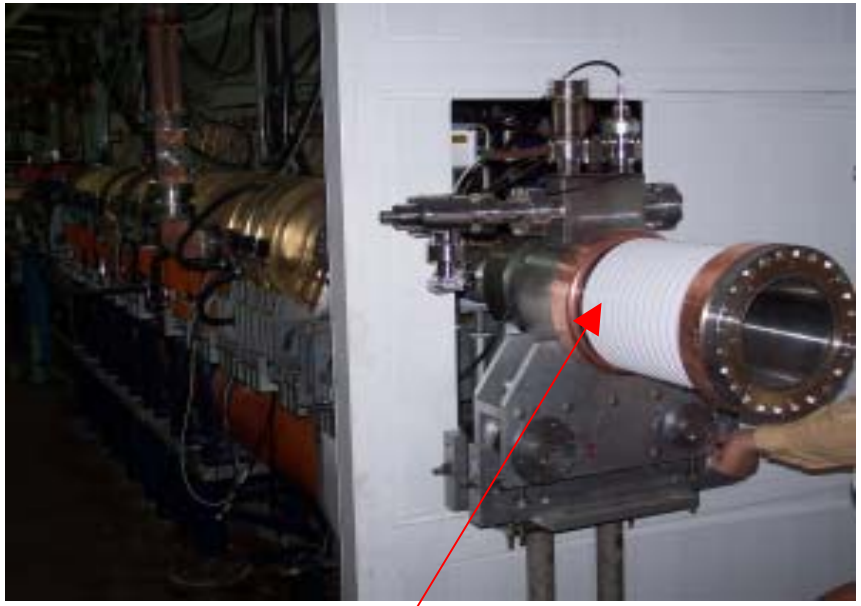
B.Brief Introduction of BEPCII

BEPCII is a major Upgrade of BEPC, It will be constructed within the existing BEPC tunnel.

1.For BEPC LINAC, the upper 30 meters of BEPC LINAC from electron gun to positron source will be upgraded.



BEPC Electron Gun



BEPCII Electron Gun being installed

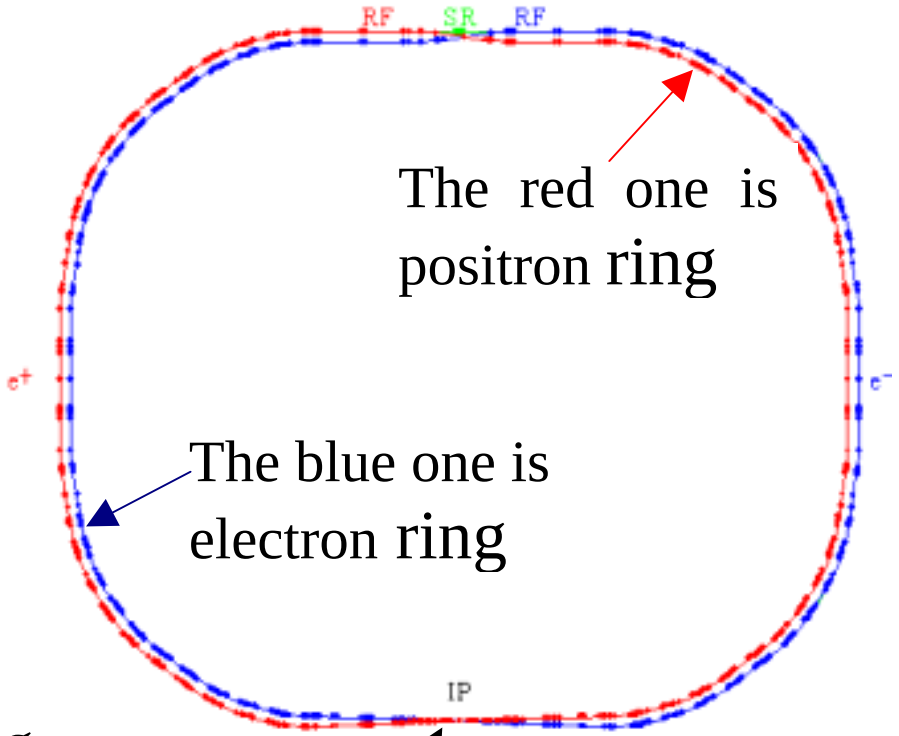
BEPC Positron Source

BEPCII Positron Source

2.For BEPC storage ring, the old single ring will be upgraded to double-ring in next year.

BEPC single ring

BEPCII double ring
The next year, we will install a new ring(model).

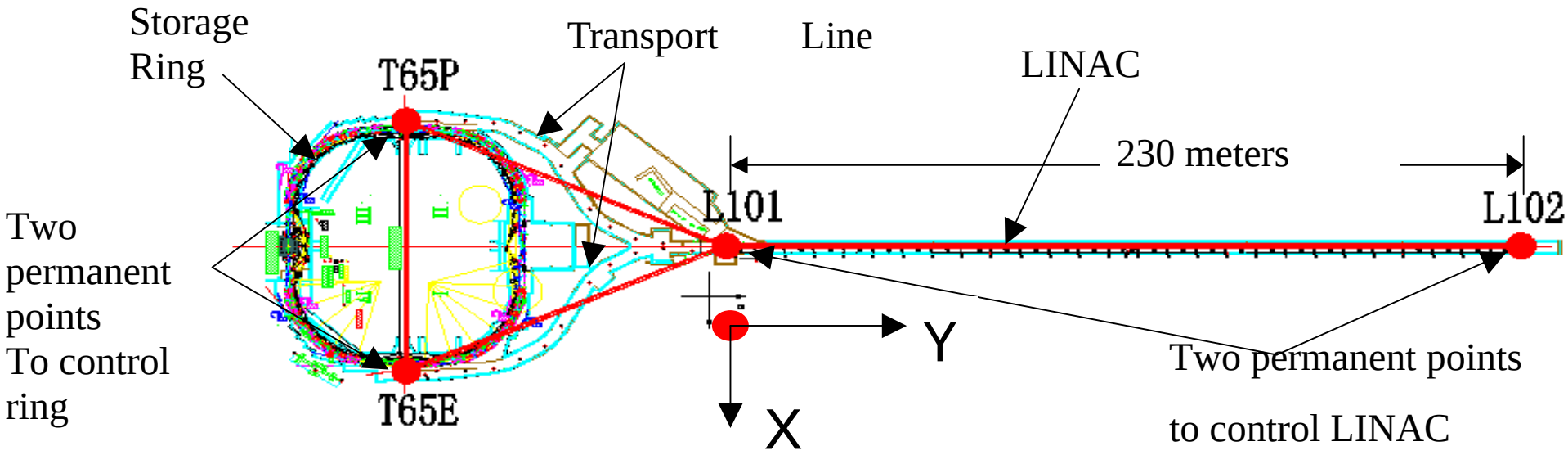


At the interaction region, the beams collide with horizontal crossing angle of ±11 mrad

C. The Surface Network Survey of BEPCII

1. The Surface Network of BEPCII and its measurement

The BEPCII Surface Network is also BEPC Surface Network that consists of the 4 permanent monuments named T65P, T65E, L101 and L102. We use T65P and T65E to control the storage ring position, use the L101 and L102 to control the LINAC position. In the next year, we will use the total station TDA5005 to measure the surface network.



D.The Survey and Alignment of BEPCII LINAC

1.The Alignment Tolerance of the LINAC

●The alignment global tolerance

Horizontal and vertical absolute position tolerance of various LINAC components (rms) is 0.2mm.

Also absolute straightness of the LINAC should be less than 0.2mm in horizontal and vertical direction.

●The relative alignment tolerance

Adjacent component-to-component relative alignment tolerances is 0.1mm in horizontal and vertical direction.

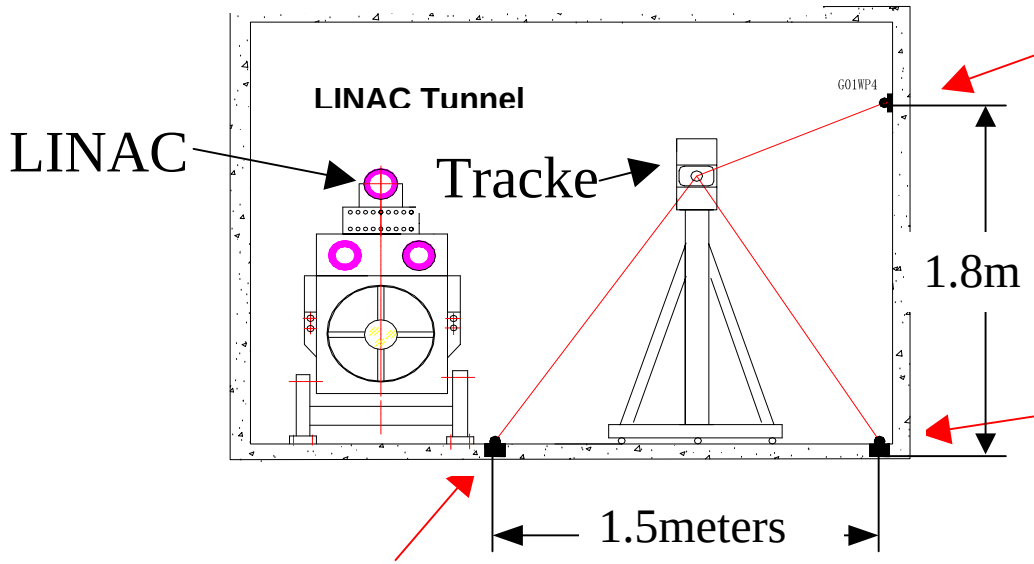
2.The Main Method of the Survey and Alignment

We layout a 3 dimensional control network in LINAC tunnel, measure its horizontal coordinate with total station and laser tracker, and measure its vertical coordinate with level, and then we measure and adjust the LINAC position with laser tracker relative to the 3 dimension network.

3.The Layout of the network

The floor and wall of LINAC tunnel was populated with 3 dimensional monuments.

The Cut View of



The monument LH2.

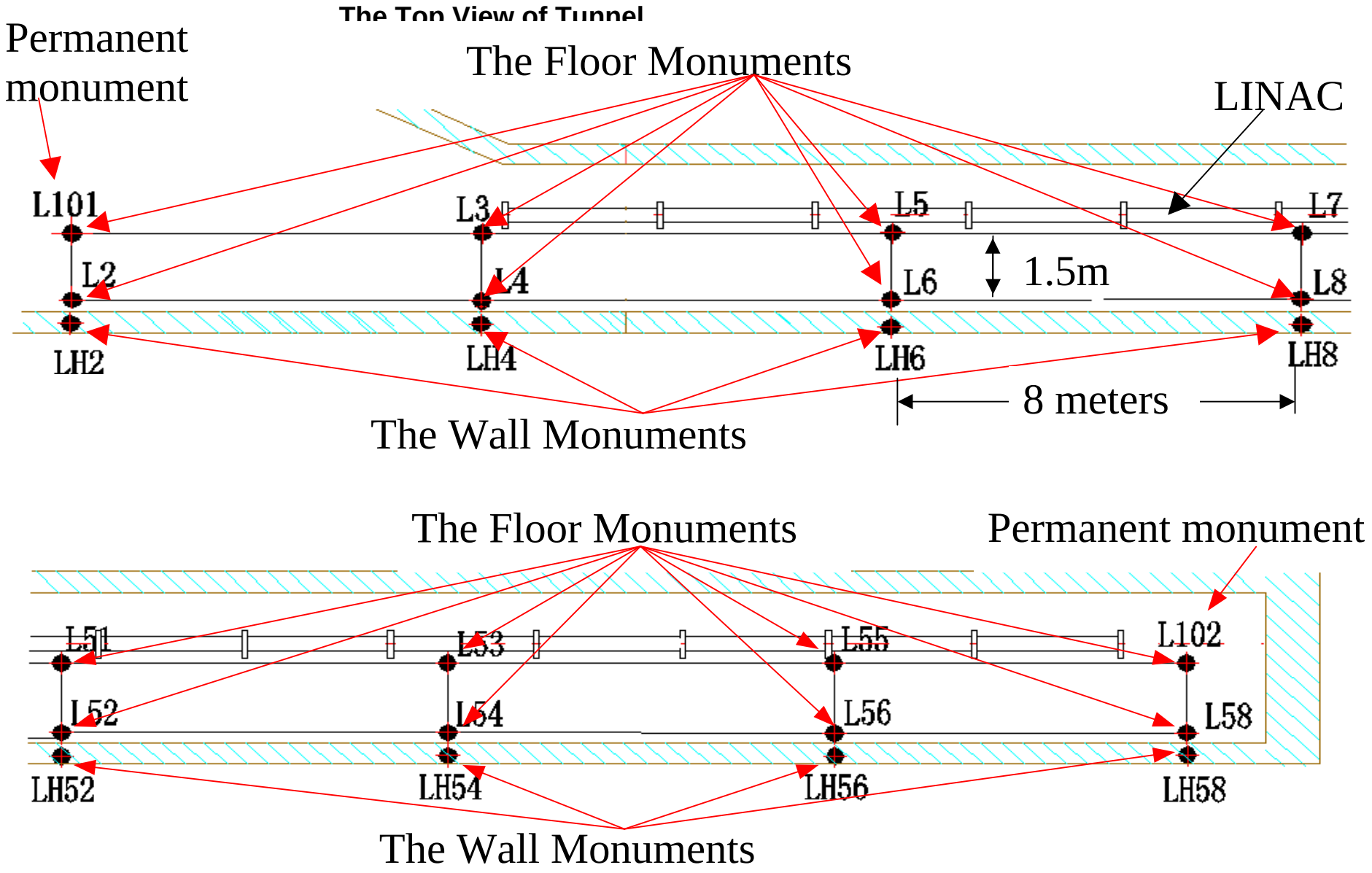
We fix 24 monuments on the wall from LH2 to LH58 at a height of 1.8 meters above

Monument L2

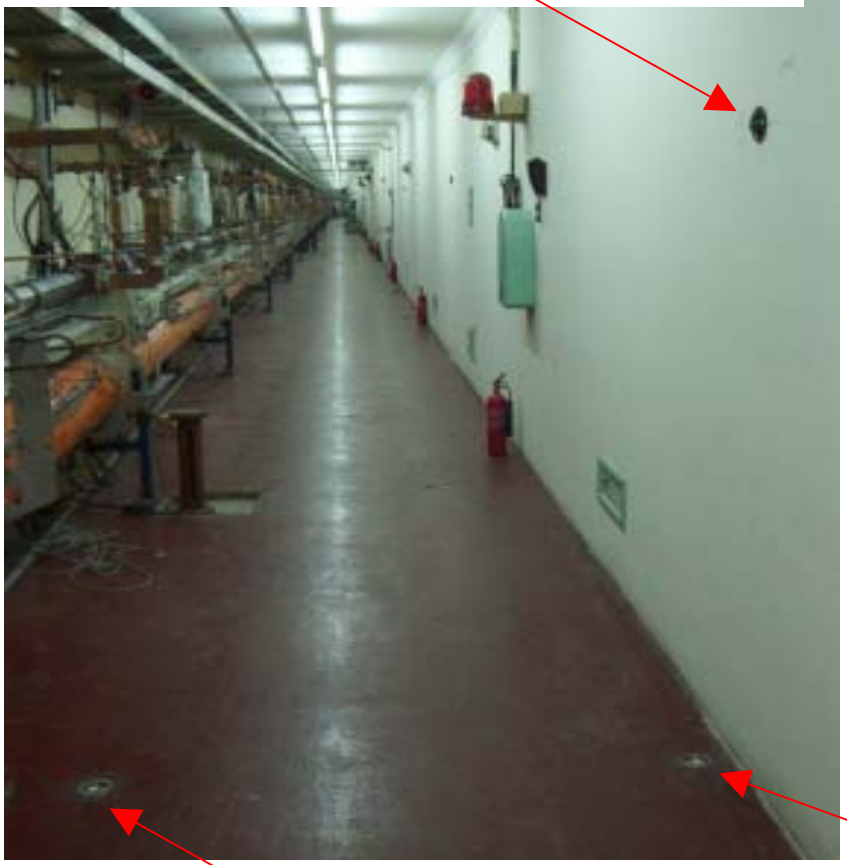
We fix 24 monuments on floor along the foot of the wall from L2 to L58 at intervals of 8 meters.

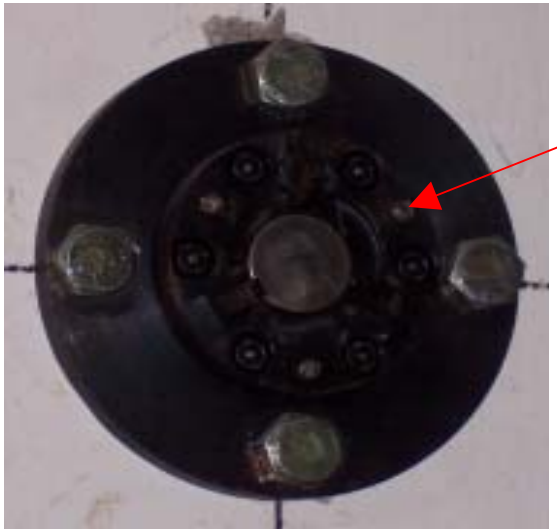
This is permanent monument L101 on floor.

We fix 22 monuments on floor along the LINAC girder between L101 and L102 spaced at intervals of 8 meters over 230 meters.

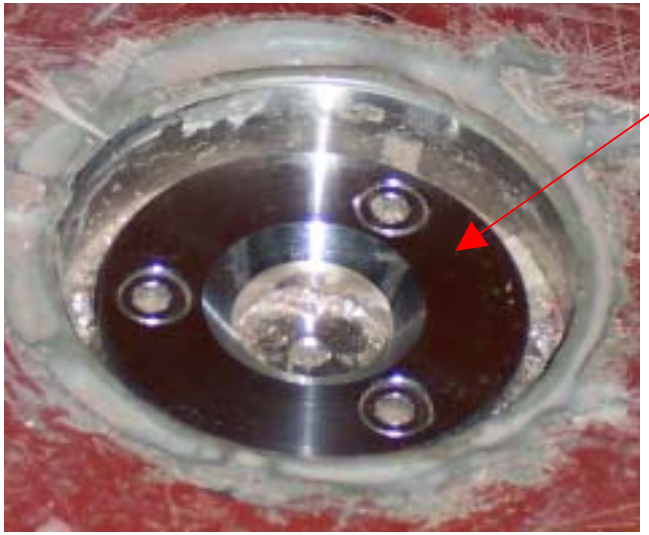

The Top View of Tunnel
Permanent monument
The Floor Monuments
LINAC
L101
L3
L5
L7
L2
L4
L6
L8
1.5m
LH2
LH4
LH6
LH8
8 meters
The Wall Monuments
The Floor Monuments
Permanent monument
L51
L53
L55
L102
L52
L54
L56
L58
LH52
LH54
LH56
LH58
The Wall Monuments

The monuments on the wall at a height of 1.8 meters above the floor





Wall Monument



Floor Monument

The monuments on floor along the LINAC girder

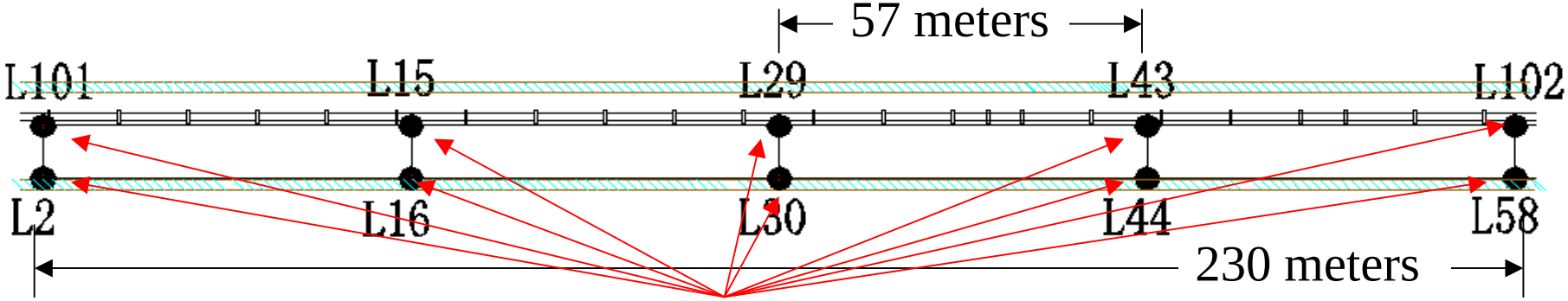
The monuments on floor along the foot of the wall.

4.The Measurement of the control network

●Measurement of horizontal coordinates of network

●We use the total station of Leica TDM5005 to survey the supporting framework of control network in horizontal in forced centering mode.

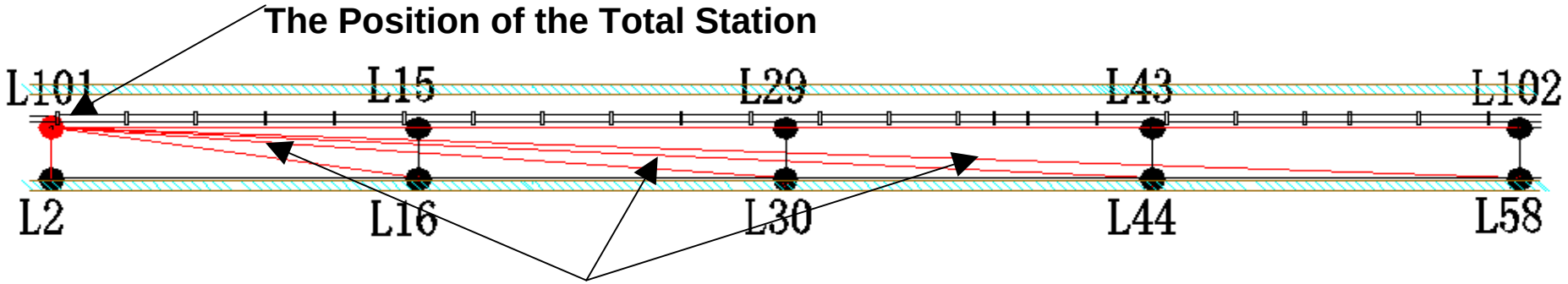
The supporting framework of network consists of the following 10 floor monuments.



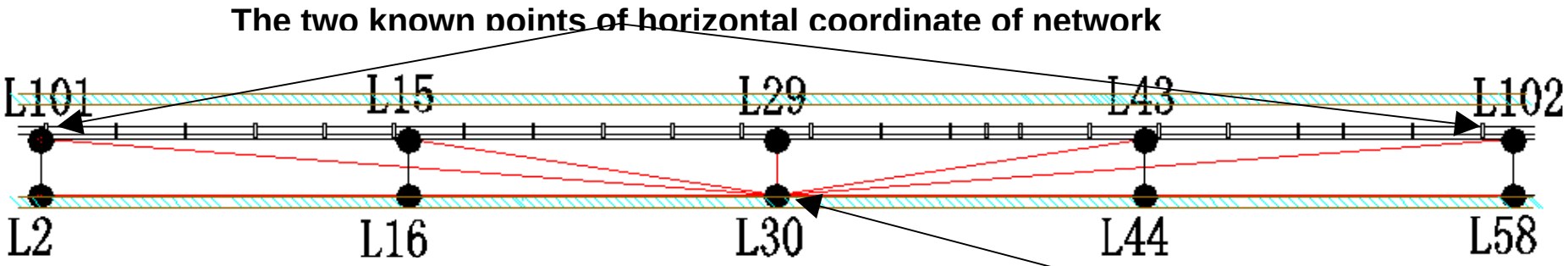
The 10 monuments constitute the framework

The total station was centered on each of the 10 monuments to measure 9 directions and distances of other monuments.

This figure shows that the total station was centered on permanent monument L101 and measure the 9 directions and distances.

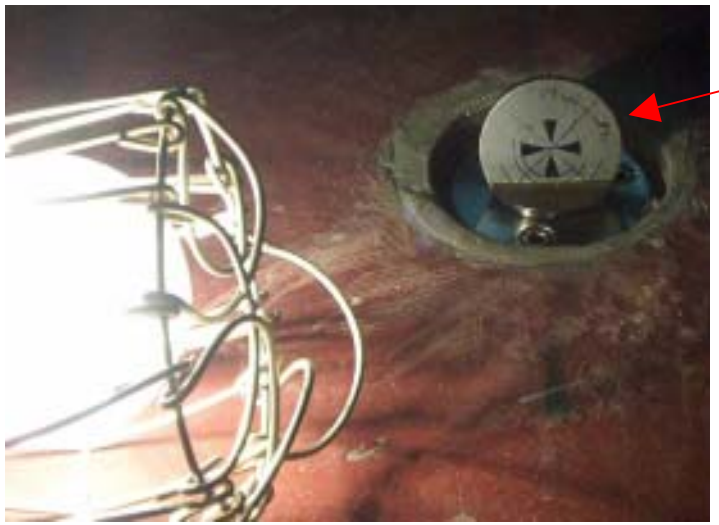


The red lines show the 9 directions and distances measured by the total station on L101.



The observing directions and distances when the total station is on L30

The surveyor was observing monuments with total station.

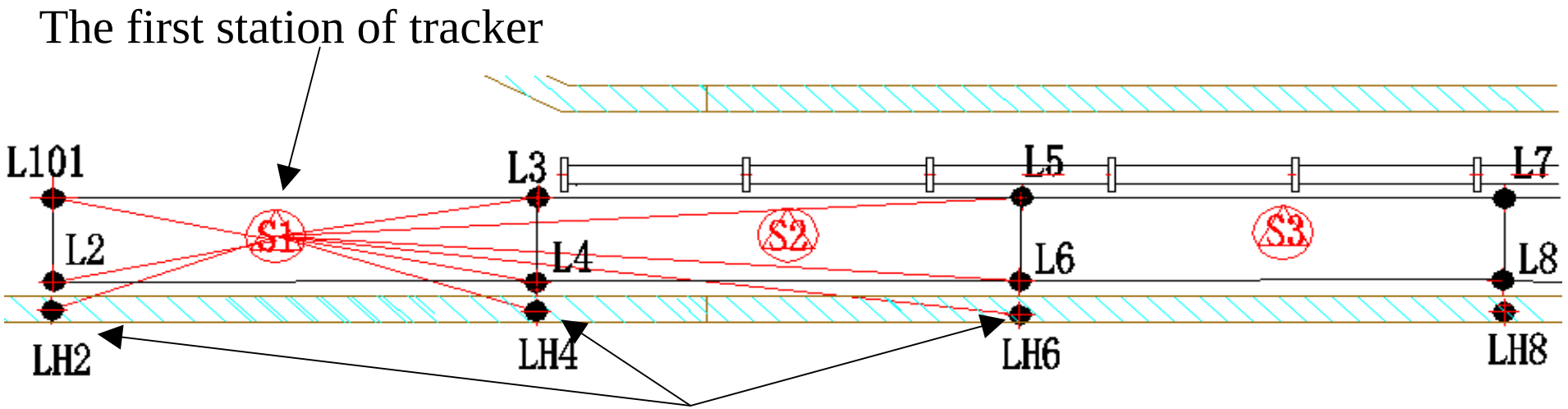


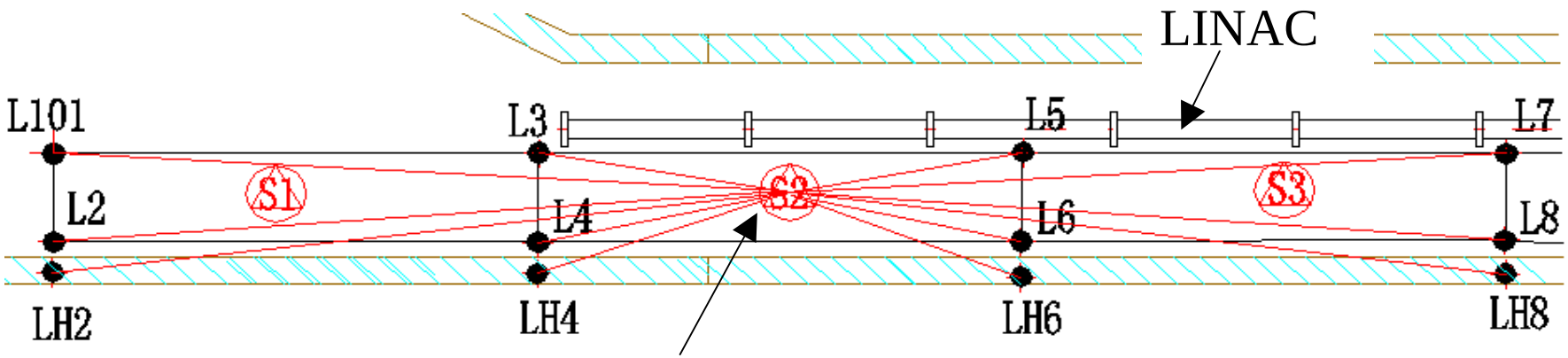
The triangulation measurement accuracy of the total station is 2.2 seconds.

The distance measurement accuracy of the total station 0.17mm.

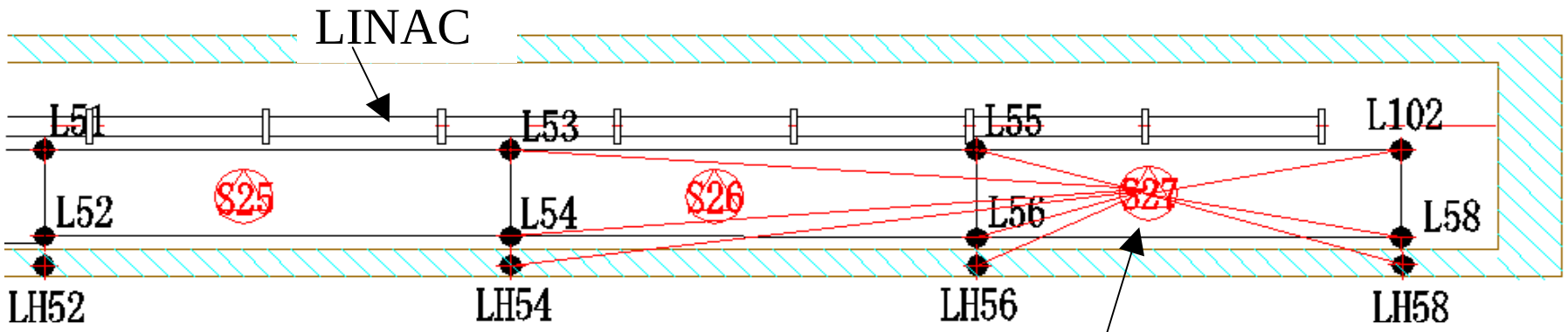
●We use the laser tracker FARO SI to measure all monuments of the network in horizontal in free station.

The Laser tracker was setup along LINAC at intervals of 8 meters over the network of 230 meters long.





The second station of tracker and its observed 12 monuments



The last station of the tracker is here

The Wall monument

Tracker

The tracker was measuring wall monument

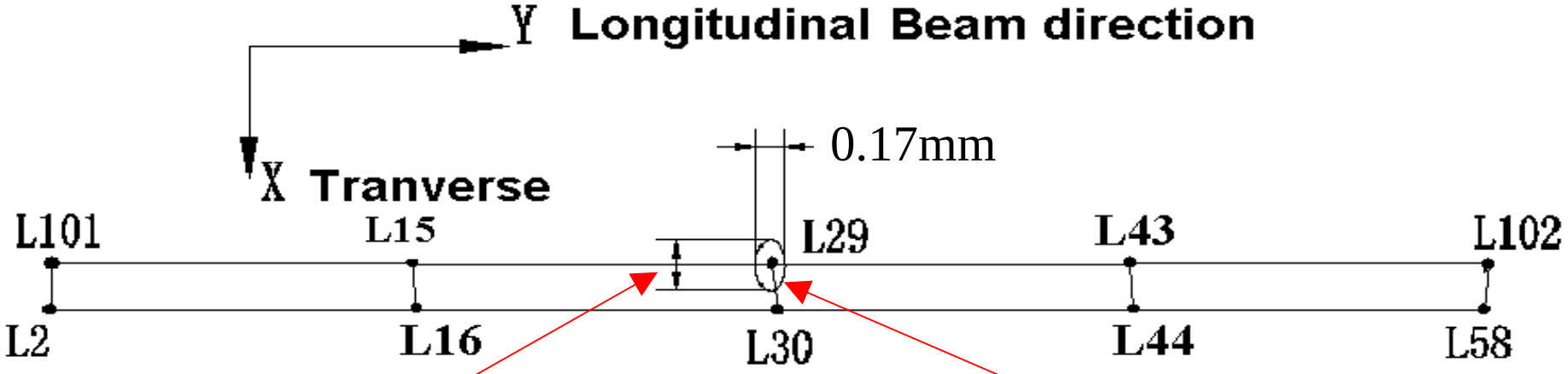
Floor monument

Tracke

The tracker was measuring floor

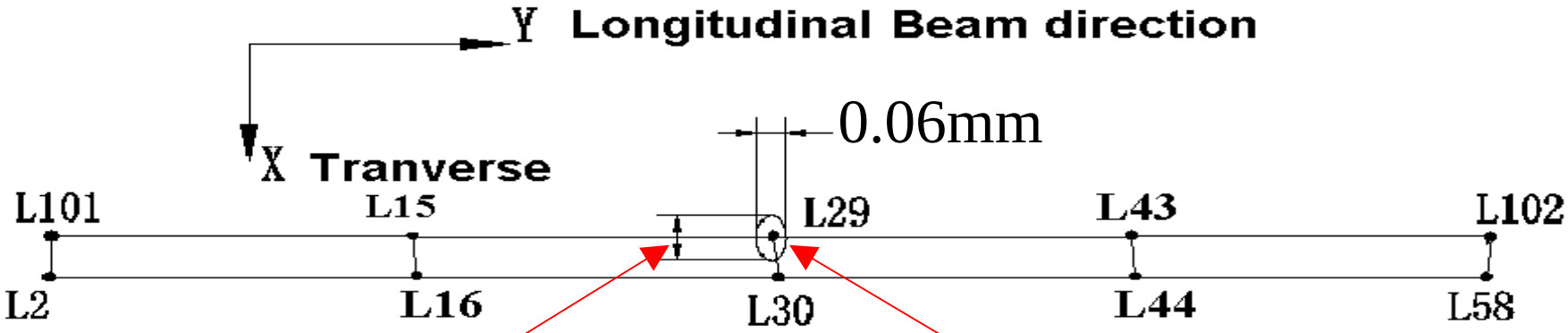
●The measurement accuracy of horizontal coordinate of the network.

If we only use the tracker to measure the network, the maximum absolute transverse coordinate (X direction, perpendicular to LINAC in horizontal) error of control point should come up to 0.4mm, It can not meet the alignment tolerance of 0.2mm.



If we first do a control survey to the supporting framework of the network with total station, then use tracker to measure the network wholly, and adjust the two sets of observations from total station and tracker together, in that case the maximum absolute transverse coordinate error of control point can be reduced from 0.4mm to 0.14mm. It can meet the alignment tolerance of 0.2mm.

The maximum relative transverse coordinate error of adjacent control point is 0.05mm.



The maximum absolute transverse coordinate error can be reduced to 0.14mm

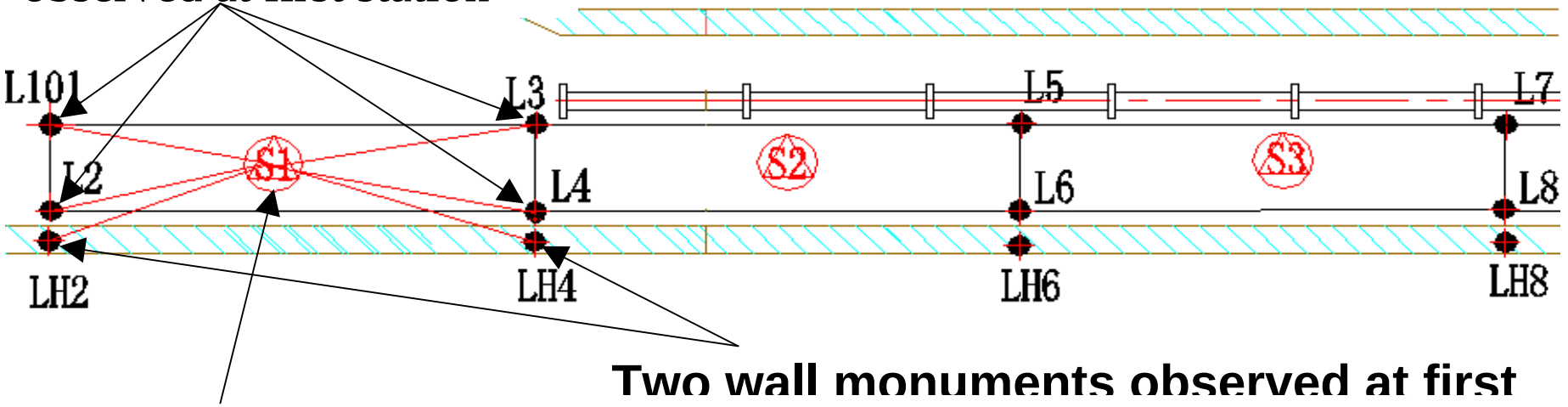
Maximum absolute error ellipse, If using total station and tracker to measure network together.

●The measurement of vertical coordinate of network

●We use the Level of Leica NA2 to measure the vertical coordinate of network.

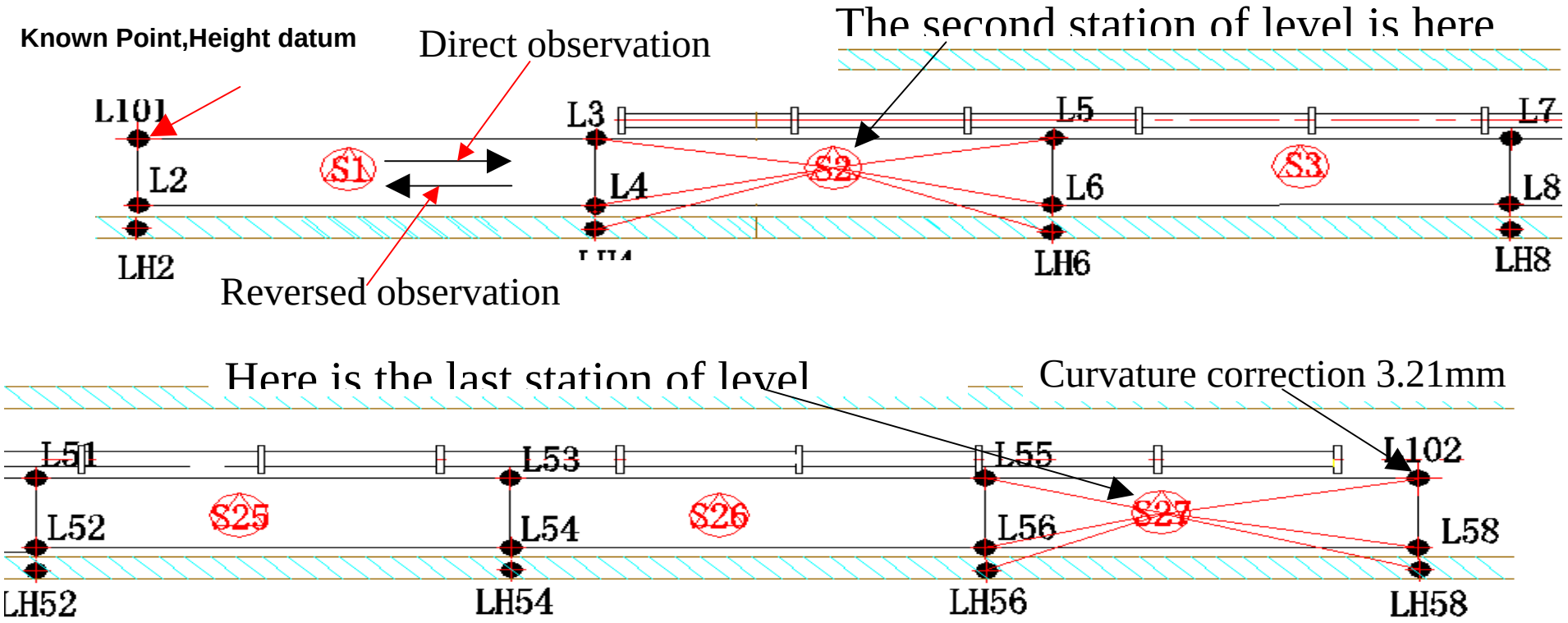
The level was setup along LINAC at intervals of 8 meters over the network of 230 meters to measure the height of every monument in direct and reversed observation mode.

The 4 floor monuments observed at first station



Two wall monuments observed at first

The first station of level is here.



●The closing error of height in direct and reversed observation is 0.15mm.

The maximum absolute vertical coordinate (Z direction) error of control point is 0.12mm(rms)

The maximum relative vertical coordinate error between adjacent control points is 0.04.

Optical tooling scale for measuring height of wall monument

The leveling staff for measuring the height of floor

Leica NA2 Level

Leveler

The leveler was measuring the height of monument

Leveling staff

1.5 inches tooling

Floor monument

Wall monument

1.5 inches tooling

Optical tooling scale fixed on the tooling ball

●The construction of 3 dimensional normal coordinate of the network

The three dimensional coordinate of network consists of horizontal and vertical coordinate.

The horizontal coordinate stems from a measurement to network in horizontal with total station and tracker.

The vertical coordinate stems from a measurement to network in vertical with level.

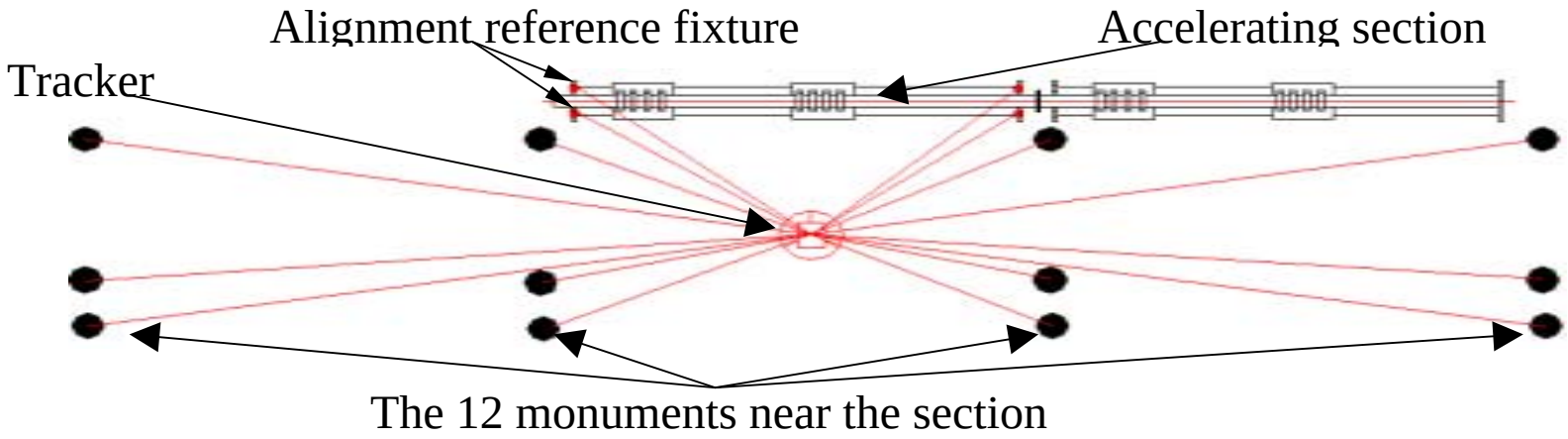
5.The alignment and adjustment of LINAC

The survey and alignment of BEPCII LINAC is to align all components along its ideal straight line. The rms deviations of components in transverse and vertical from the straight line do not exceed 0.2mm.

We measured the component position in 3 dimensions only by laser tracker with respect to the 3 dimensional

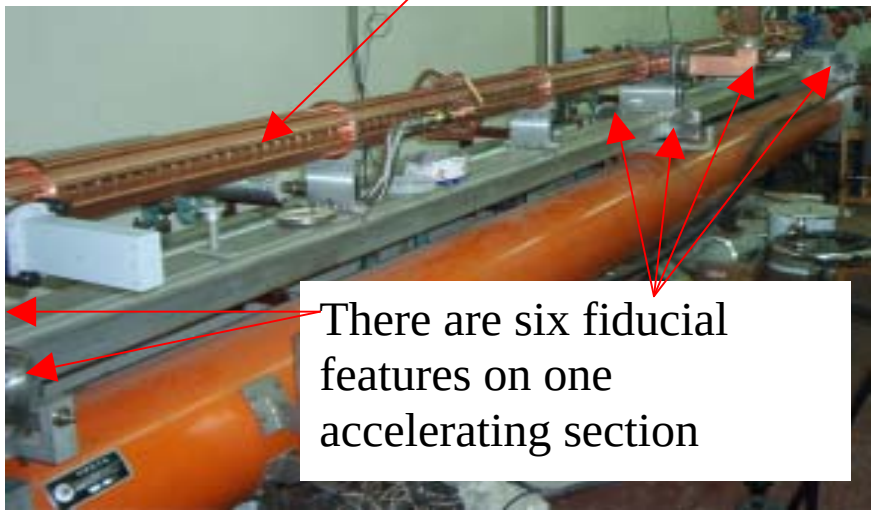
network and adjusted position offsets to within 0.05mm in transverse and vertical directions.

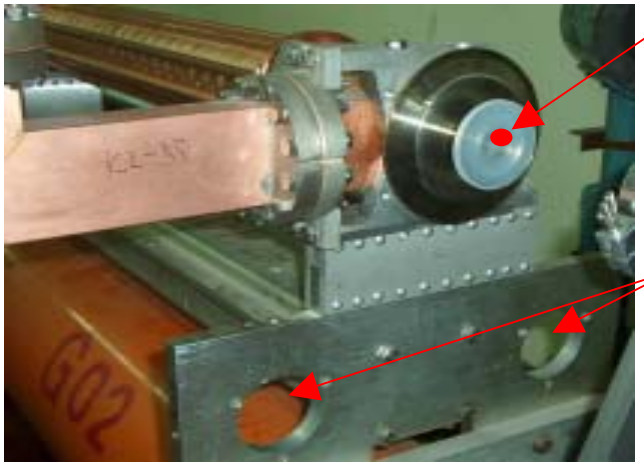
Before measuring the position of a component, we first used the tracker to measure 12 monuments populated in 3 dimension close to the component, and best-fit the actual coordinates of the 12 monuments to their normal coordinates of the network, the standard deviation of the best-fit should be less than 0.07mm. After the best-fit of coordinates, the component position can be measured with tracker.

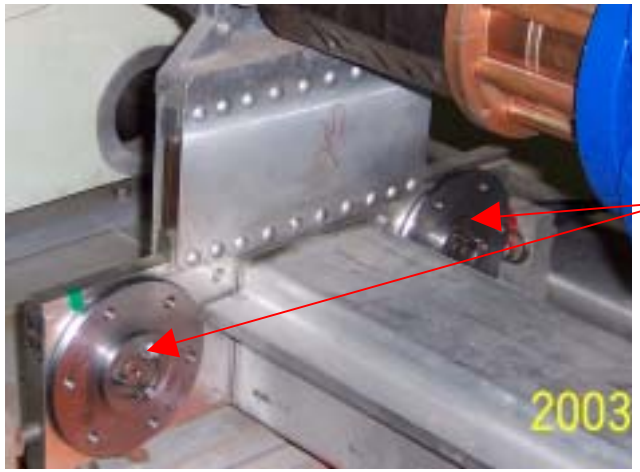


●The fiducial feature and alignment reference fixture of main LINAC component — accelerating section

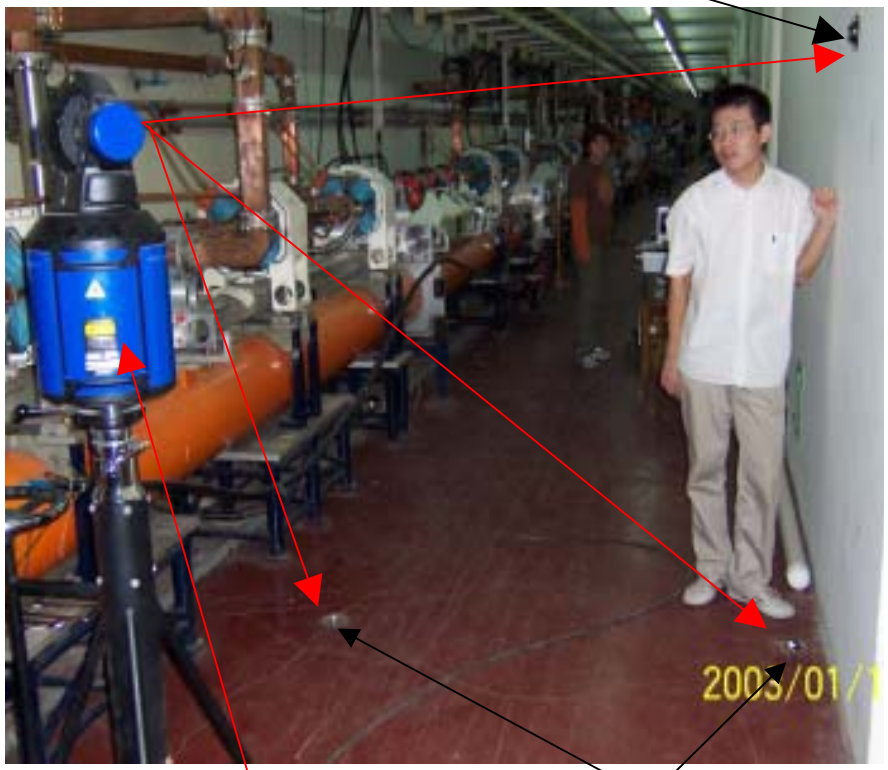
This is accelerating







Wall monument



Two floor monuments

The tracker measures monuments actually first and and best-fit to normal network.

Reference fixture and reflector

After the best-fitting of coordinate, use tracker to measure the position of accelerating section and adjust the offsets to within 0.05mm .

6. The overall alignment error of LINAC

● Overall absolute transverse error(rms) of accelerating section=

[The maximum absolute transverse coordinate error of control point 0.14^2

+Tracker measurement error 0.035^2

+Alignment reference fixture manufacture error 0.01^2

+Fitting error between fixture and fiducial hole 0.03^2

+Fiducialization error of fiducial hole relative to beam line 0.025^2

+The position adjustment offset $0.05^2]^{0.5}$

=0.16mm

<less then 0.2mm(Required LINAC straightness)

●Overall relative transverse error(rms) of accelerating section=

[The maximum relative transverse coordinate error of control point 0.05^2

+Tracker measurement error 0.035^2

+Alignment reference fixture manufacture error 0.01^2

+Fitting error between fixture and fiducial hole 0.03^2

+Fiducialization error of fiducial hole relative to beam line 0.025^2

+The position adjustment offset 0.05^2]$^{0.5}$

=0.09mm

<0.1mm(Required relative alignment tolerance between adjacent components)

●Overall absolute vertical error(rms) of accelerating section=

[The maximum absolute vertical coordinate error of control point 0.12^2

+Tracker measurement error 0.035^2

+Alignment reference fixture manufacture error 0.01^2

+Fitting error between fixture and fiducial hole 0.03^2

+Fiducialization error of fiducial hole relative to beam line 0.025^2

+The position adjustment offset 0.05^2]$^{0.5}$

=0.14mm

<less then 0.2mm(Required LINAC straightness)

●Overall relative vertical error(rms) of accelerating section=

[The maximum relative vertical coordinate error of control point 0.04^2

+Tracker measurement error 0.035^2

+Alignment reference fixture manufacture error 0.01^2

+Fitting error between fixture and fiducial hole 0.03^2

+Fiducialization error of fiducial hole relative to beam line 0.025^2

+The position adjustment offset $0.05^2]^{0.5}$

=0.09mm

<0.1mm(Required relative alignment tolerance)

The end, Thank you

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