Survey and Alignment of J-PARC

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J-PARC

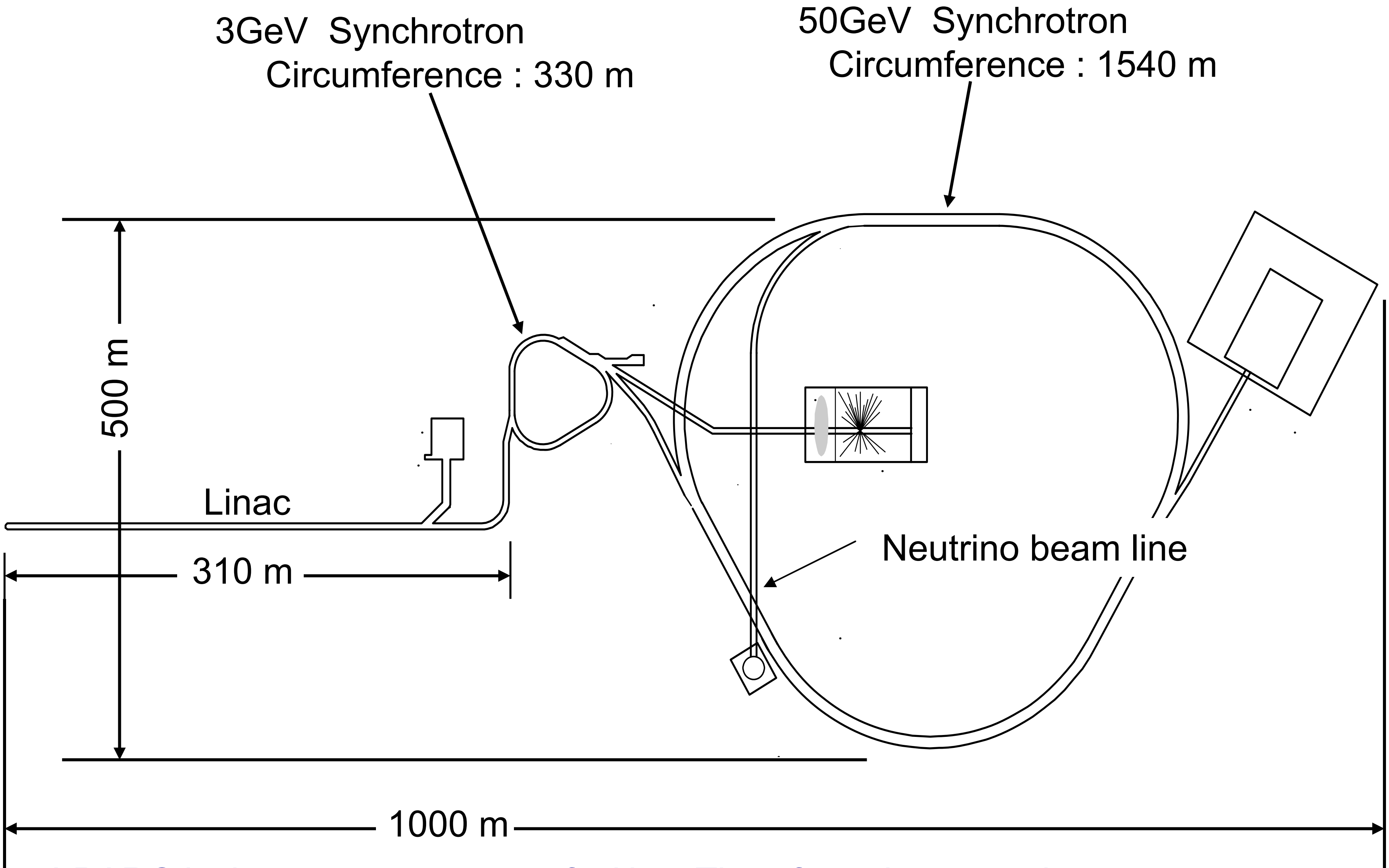
High Intensity Proton Accelerator Facility

Geodetic Survey of J-PARC from 2002 to 2003 has already been reported with IWAA2004 at CERN.

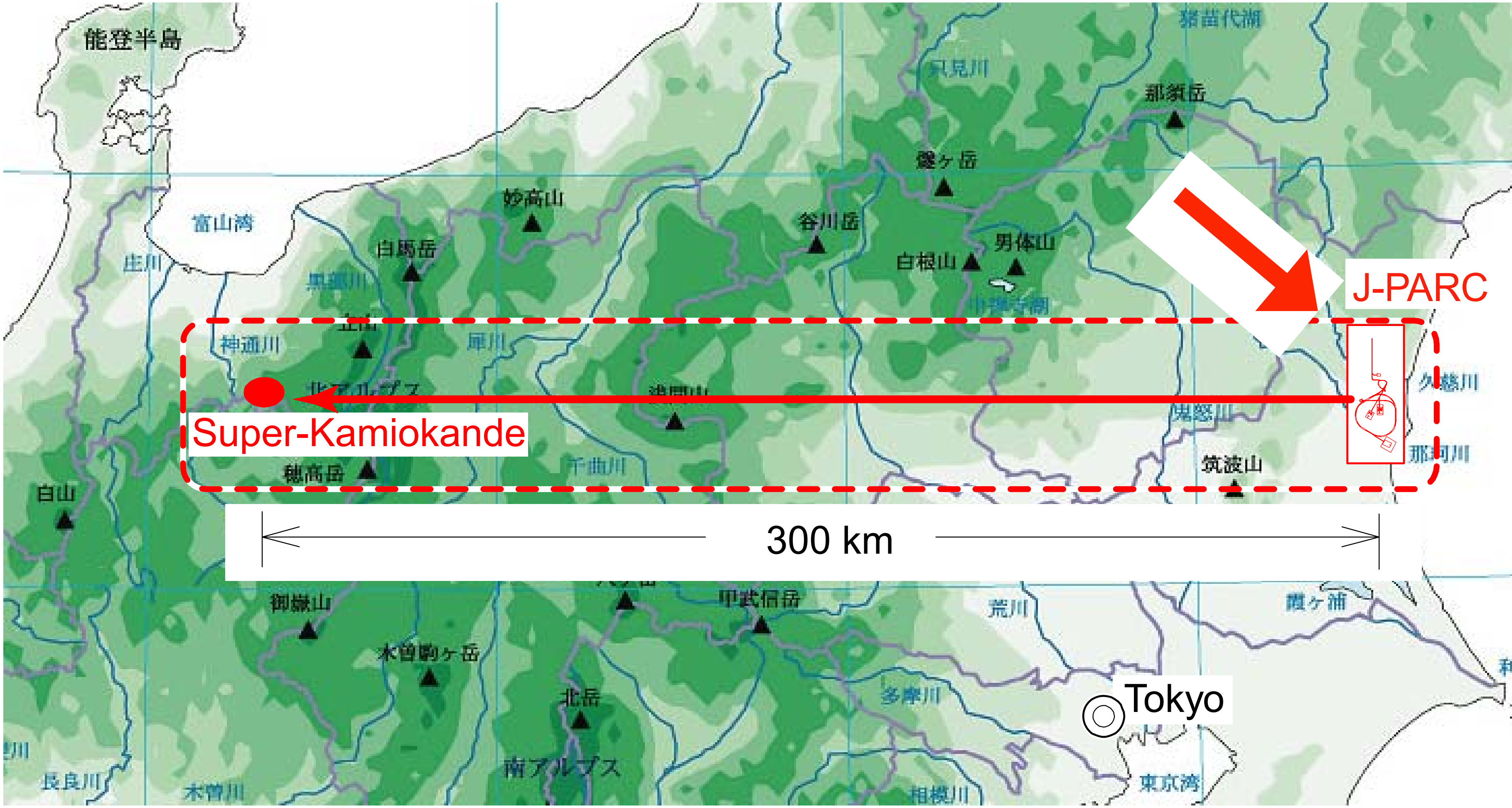
This report is the continuation, and the report from 2004 to the last week.

J-PARC is constructed along seaside, and constructed at sandy area.

It’s difficult to countermeasure against uneven settlement.

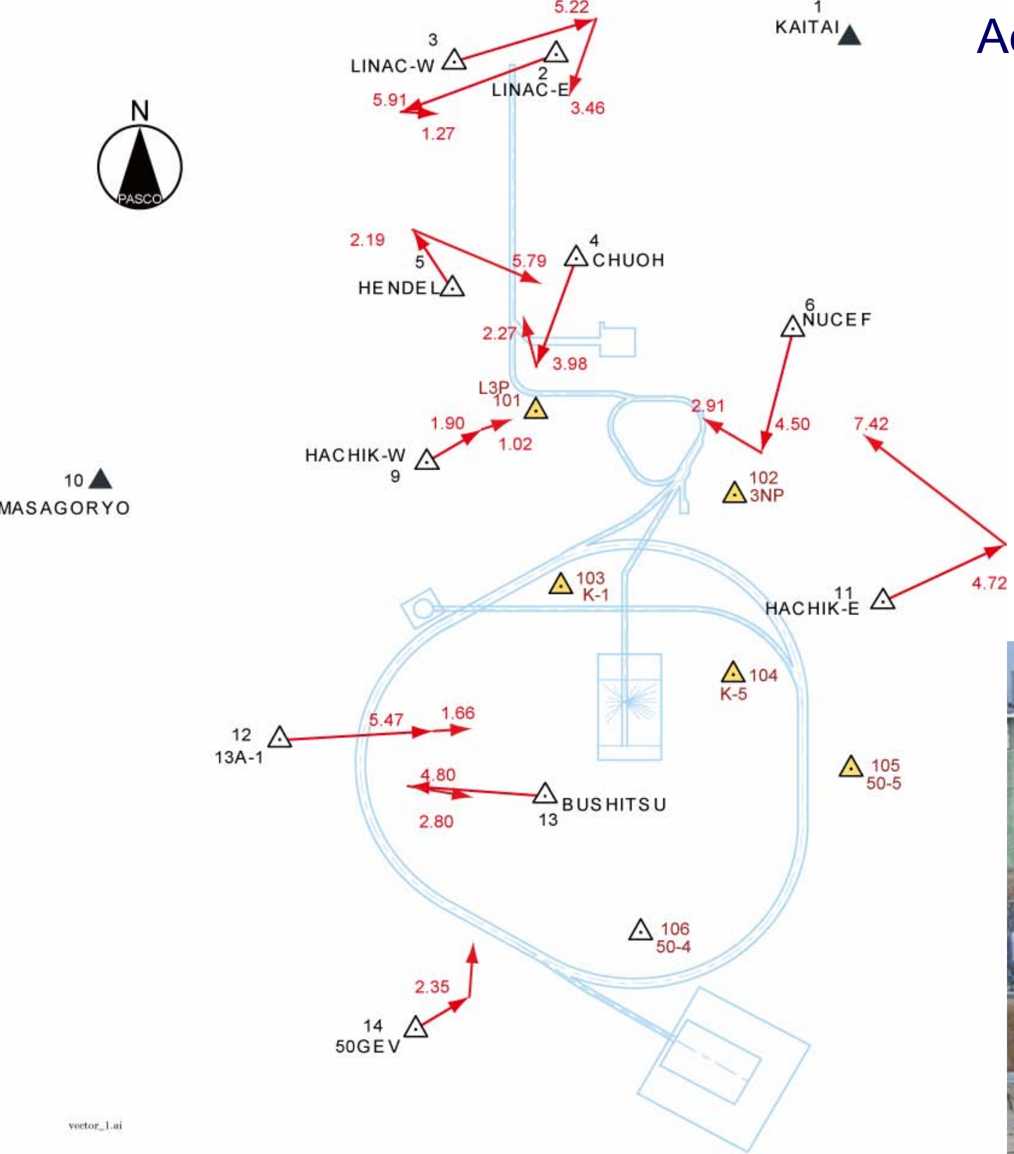


J-PARC is the large accelerator facility. Therefore, the surveying in the TOKAI campus is considered the curvature of the earth.



Long Baseline Neutrino Oscillation Experiment from J-PARC to Kamioka

Accelerator Tunnels are Constructed by Open Cut Method

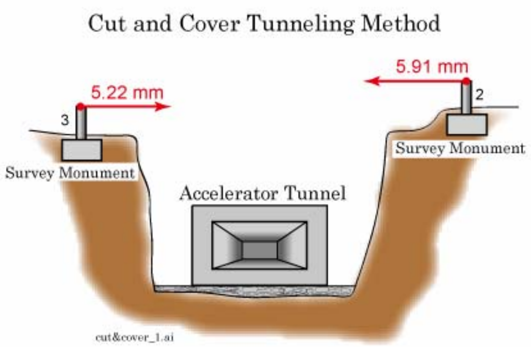


: SURVEY MONUMENTS Linking with KAMIOKANDE by GPS

: SURVEY MONUMENTS by

Horizontal displacements of surv

from February, 2003 to February, 2005



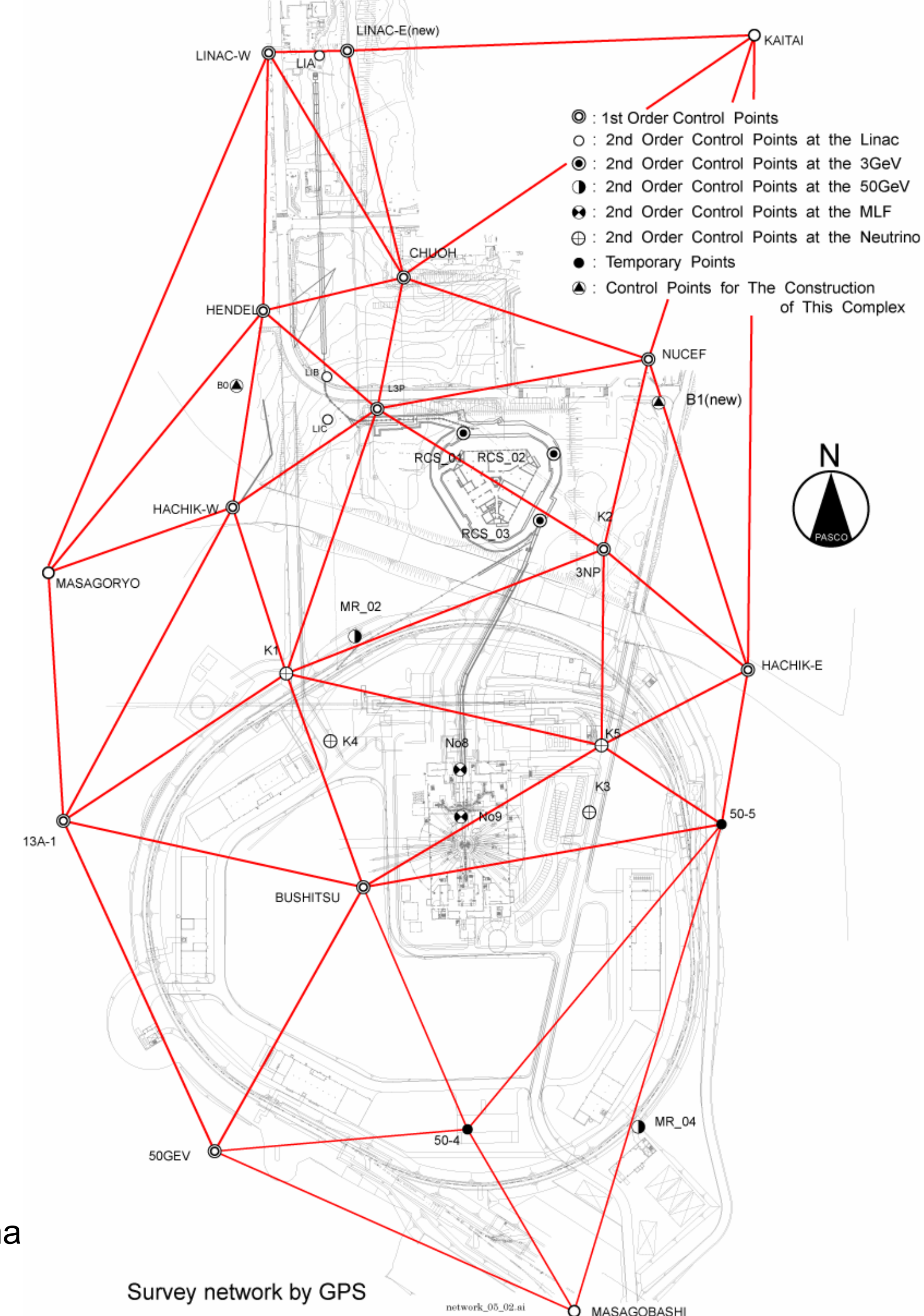
Both Monument toward into the Trench

The Foundation was moved because of change in the load of soil and pile working under constructing.

Surface Network by GPS

Trilatelation by GPS

Sights between monuments could not be surveyed each other by woods because of under construction.

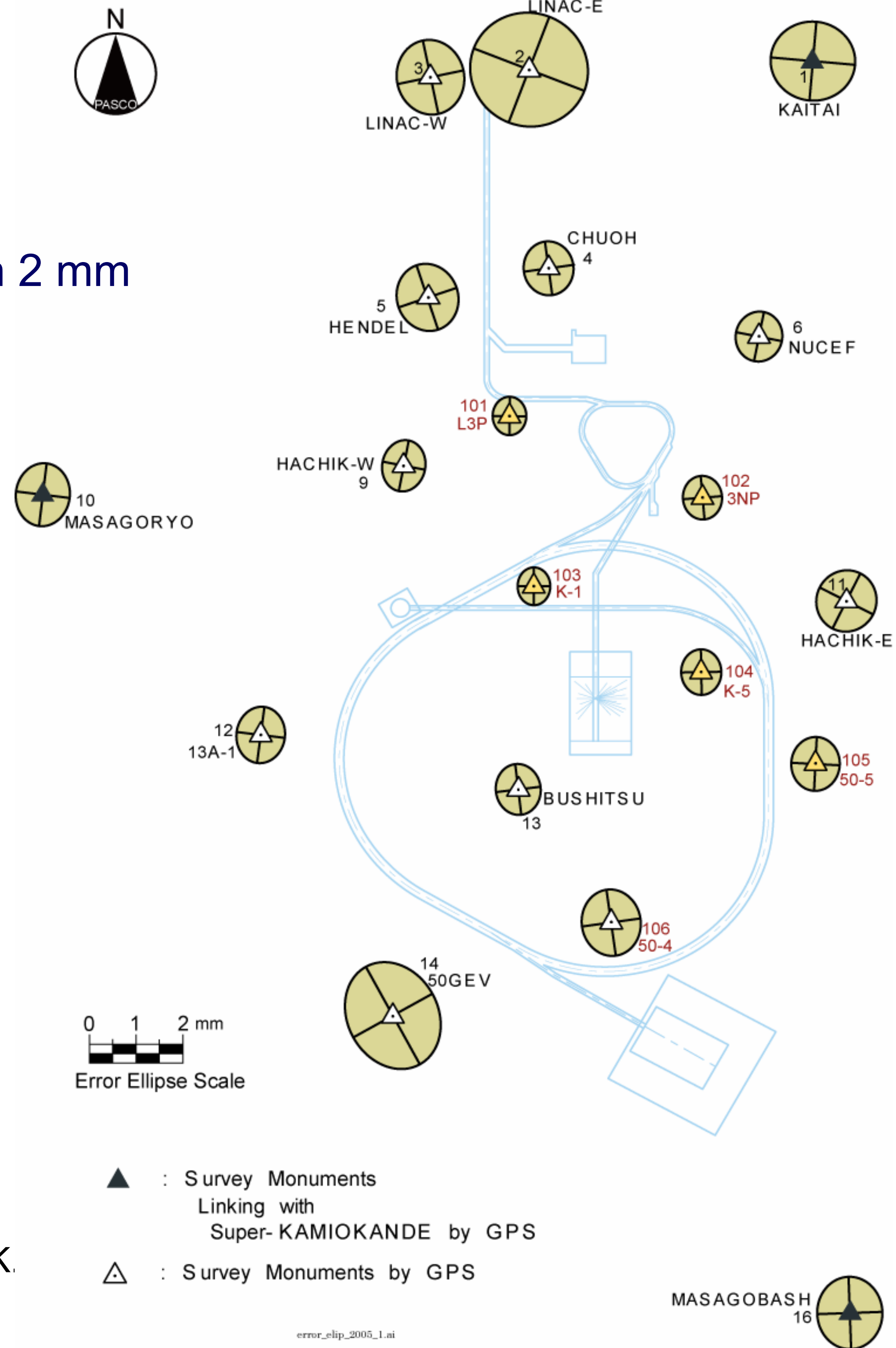


K. Mishima

Survey network by GPS

Error Ellipse

Most Error Ellipses are within 2 mm



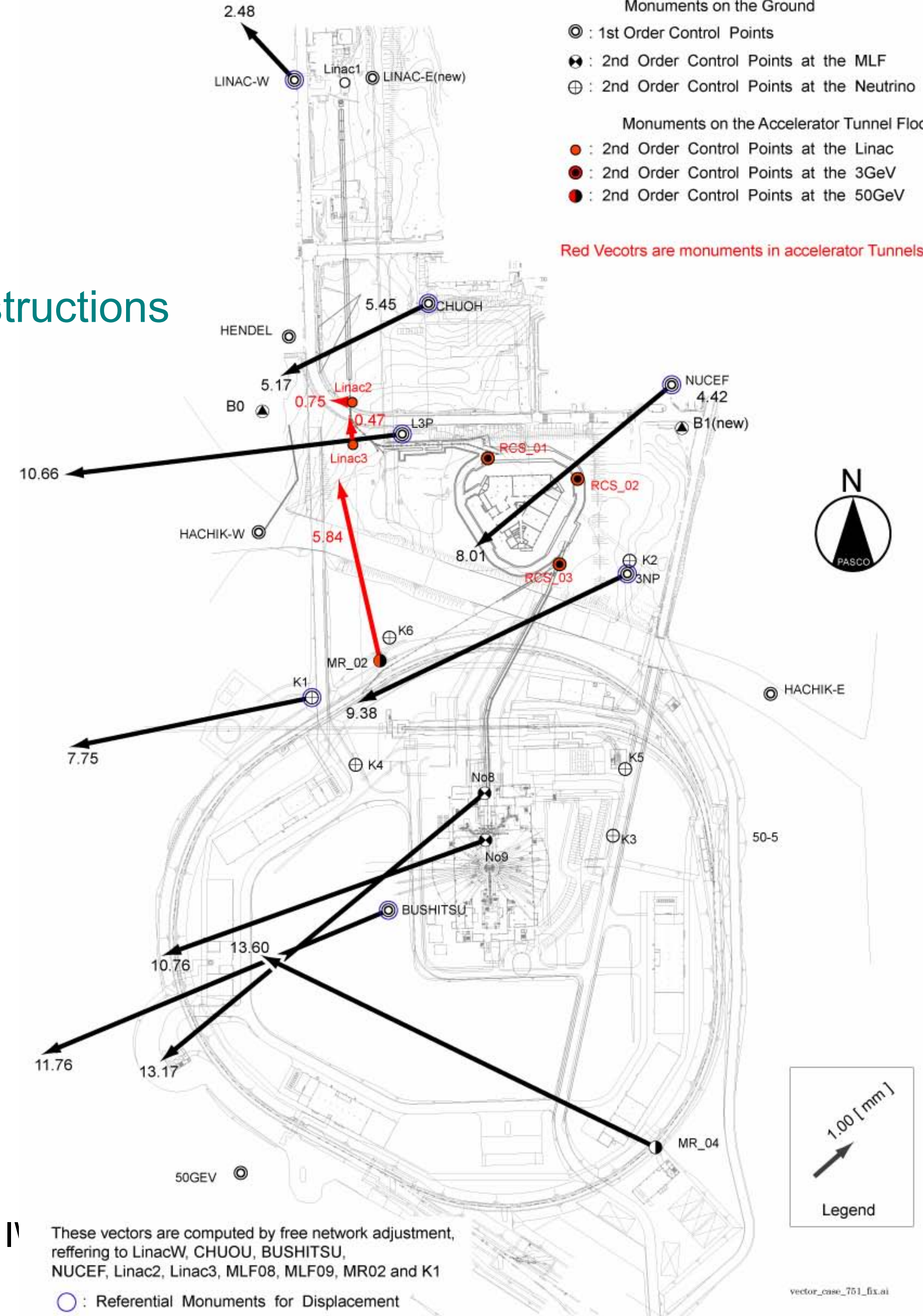
K.

Displacement Vectors

of Monuments from 2005 to 2006

(1) Tunneling works and building constructions were closed to the last stage. Therefore, the foundation was under huge load changing.

(2) The survey method has changed from GPS to total station.



K. Mishima, I'

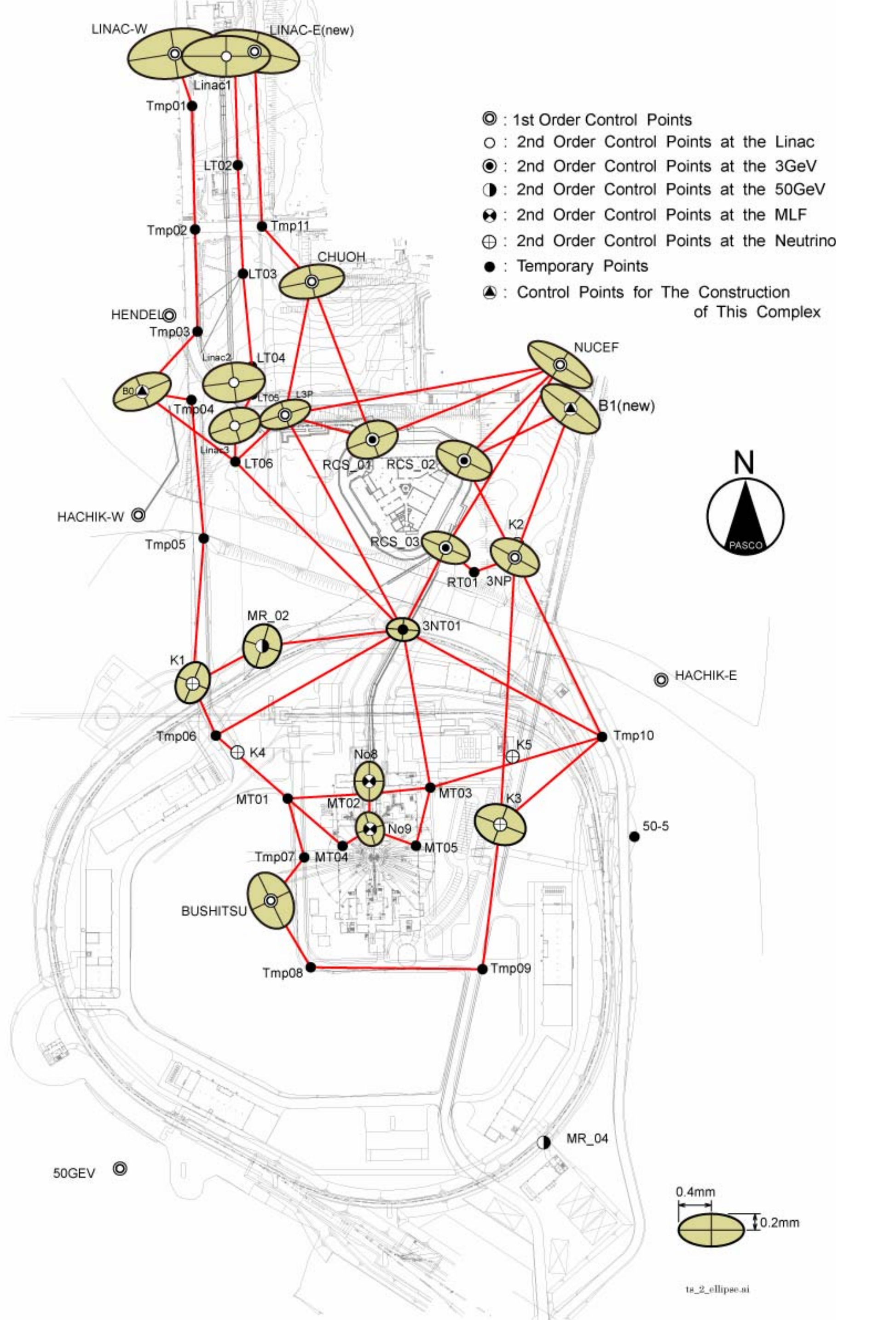
Surface Network & Error Ellipse

Most Error Ellipses are

within 0.2 mm

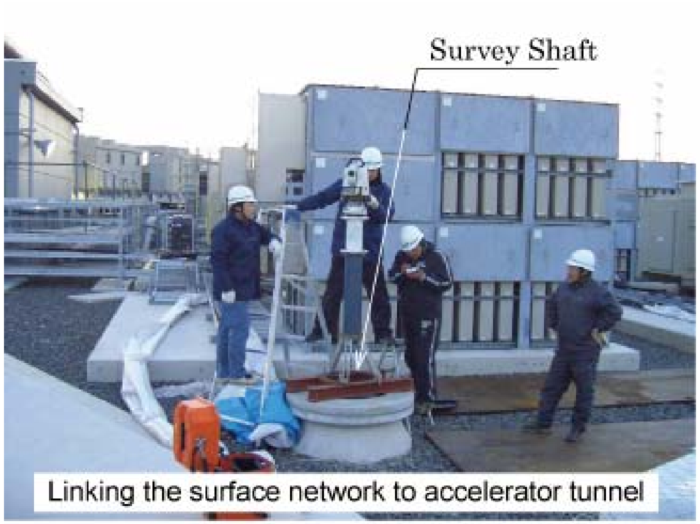
The visibility for the surveying
has extended.
Then the survey method
was changed from GPS to TS.

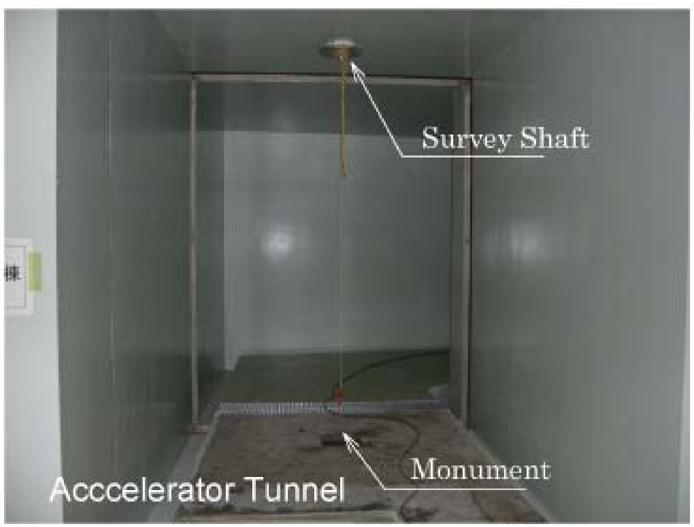
These monuments will be stabilized
to become the end of
tunneling and building construction.

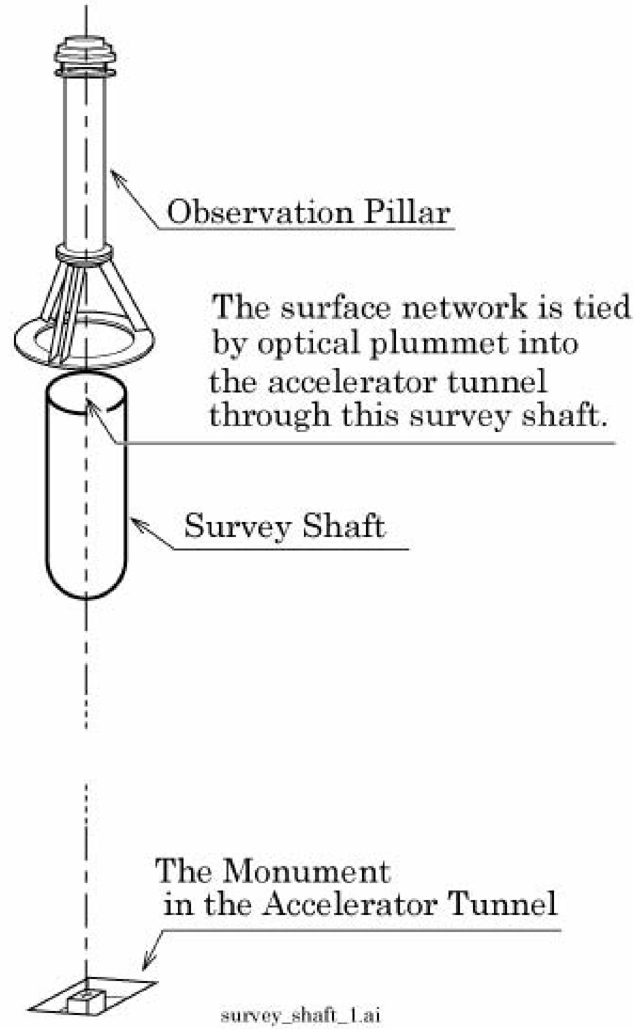


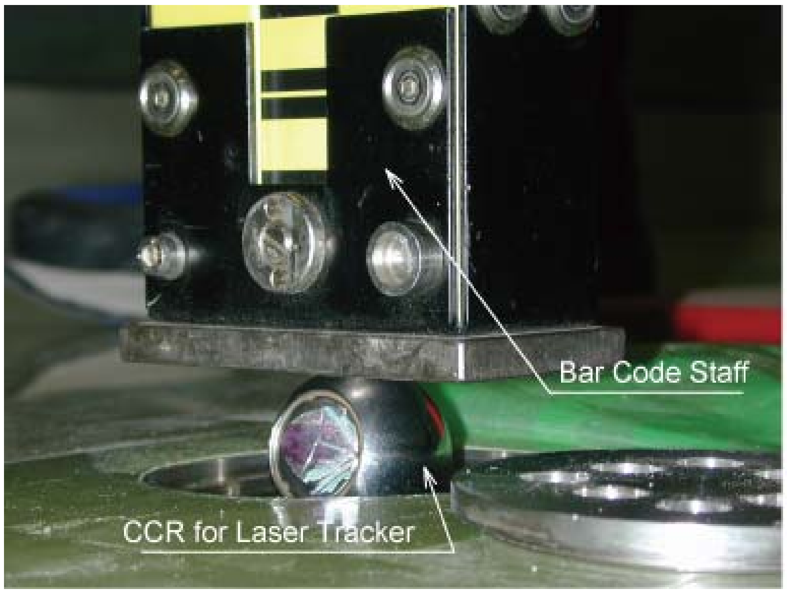
K. Mishin

Surface Network had been tied to some accelerator tunnels through survey shafts

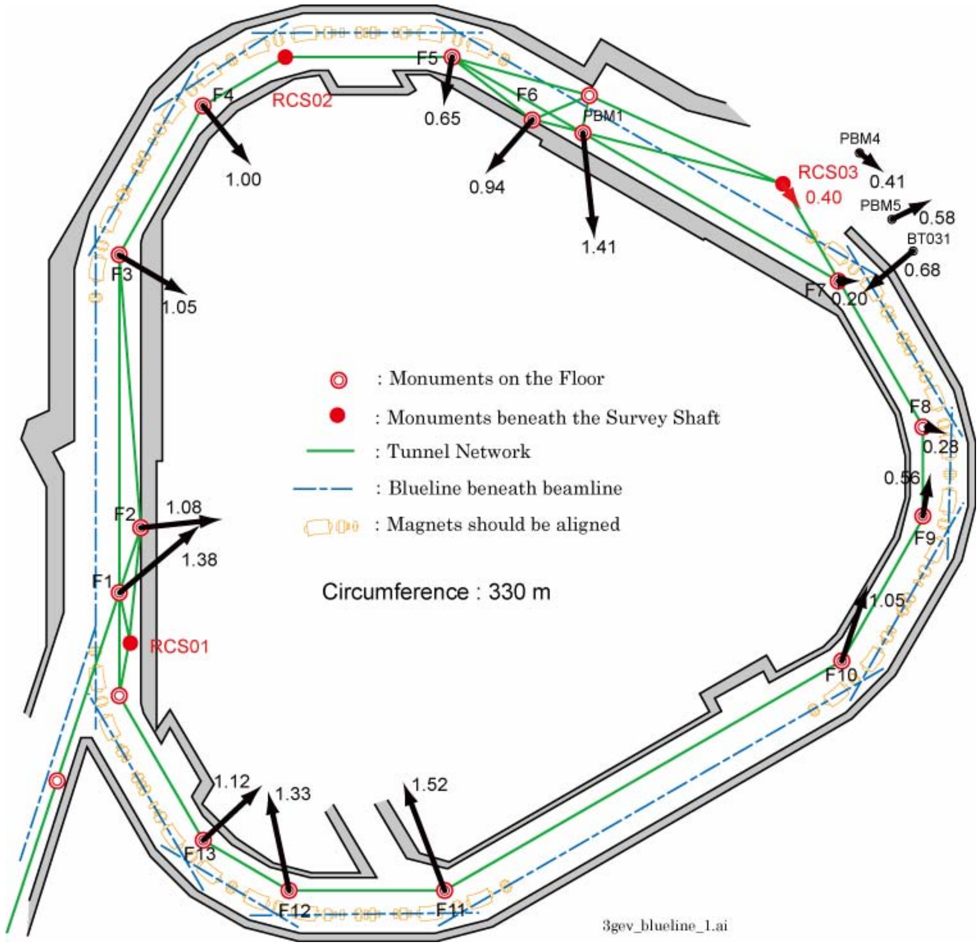






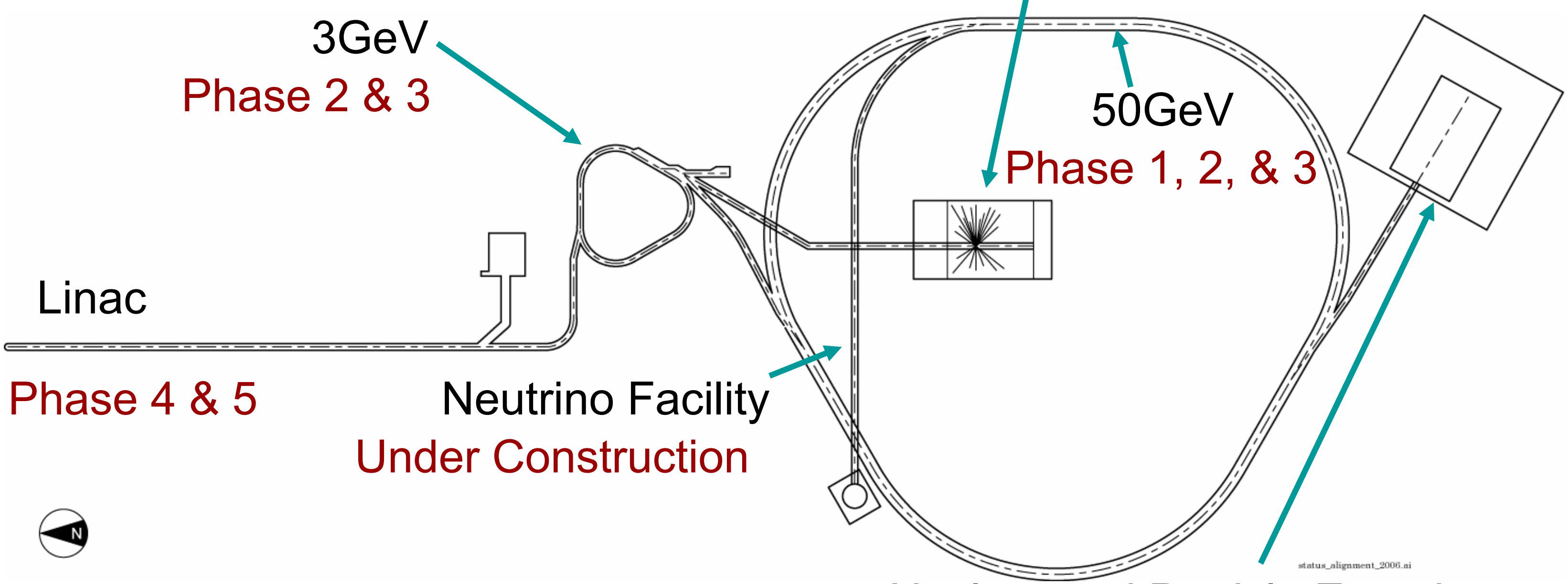

Bar Code Staff
CCR for Laser Tracker


One kind of monument in the accelerator tunnel
CCR for Laser Tracker


F5
F4
RCS02
F6
PBM1
0.65
1.00
0.94
1.41
PBM4
RCS03
0.41
0.40
PBM5
0.58
BT031
0.68
F3
1.05
F7
0.20
: Monuments on the Floor
: Monuments beneath the Survey Shaft
: Tunnel Network
: Blueline beneath beamline
: Magnets should be aligned
F8
0.28
0.56
F9
F2
1.08
1.38
F1
Circumference : 330 m
1.05
RCS01
F10
1.12
1.33
1.52
F13
F12
F11
3gev_blueline_1.ai

Status of Alignment in J-PARC

Phase 1 : Blue line Survey on accelerator Floor
Phase 2 : Installing of Components in Accelerator Tunnels
Phase 3 : Pre-alignment of Components
Phase 4 : Fine alignment of Components
Phase 5 : Smoothing



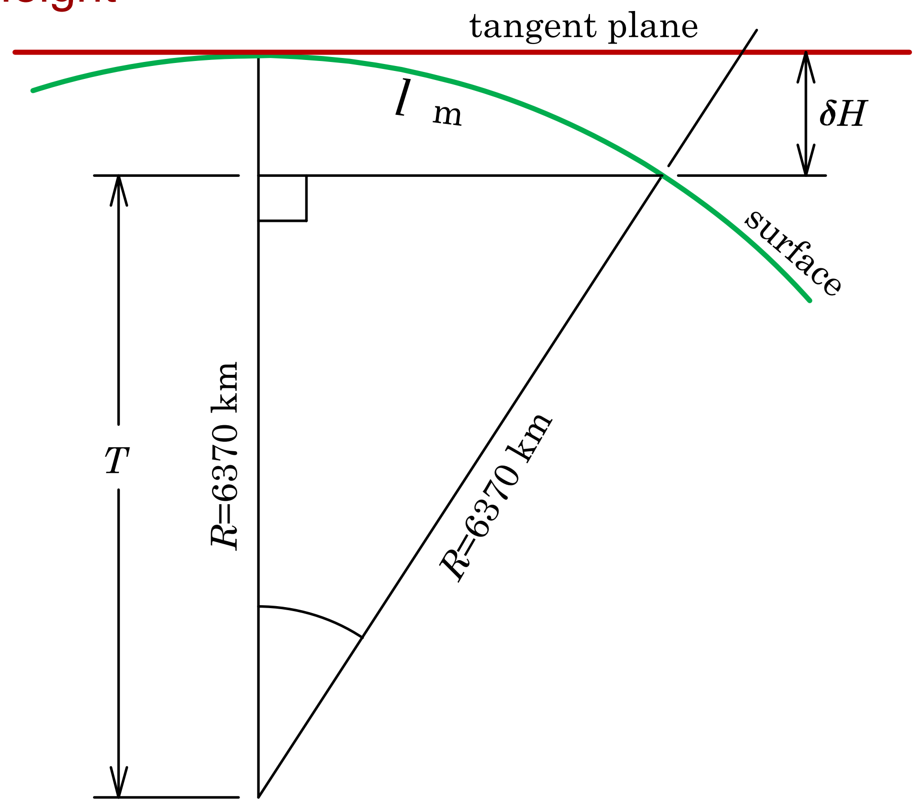
The Effect of Curvature of the Earth for the Beam Height

- It is general that height of these components of accelerator is aligned along a horizontal plane.
- However, this straight line is parallel straight line to curvature of the earth.
- This line is not straight line for the beam.

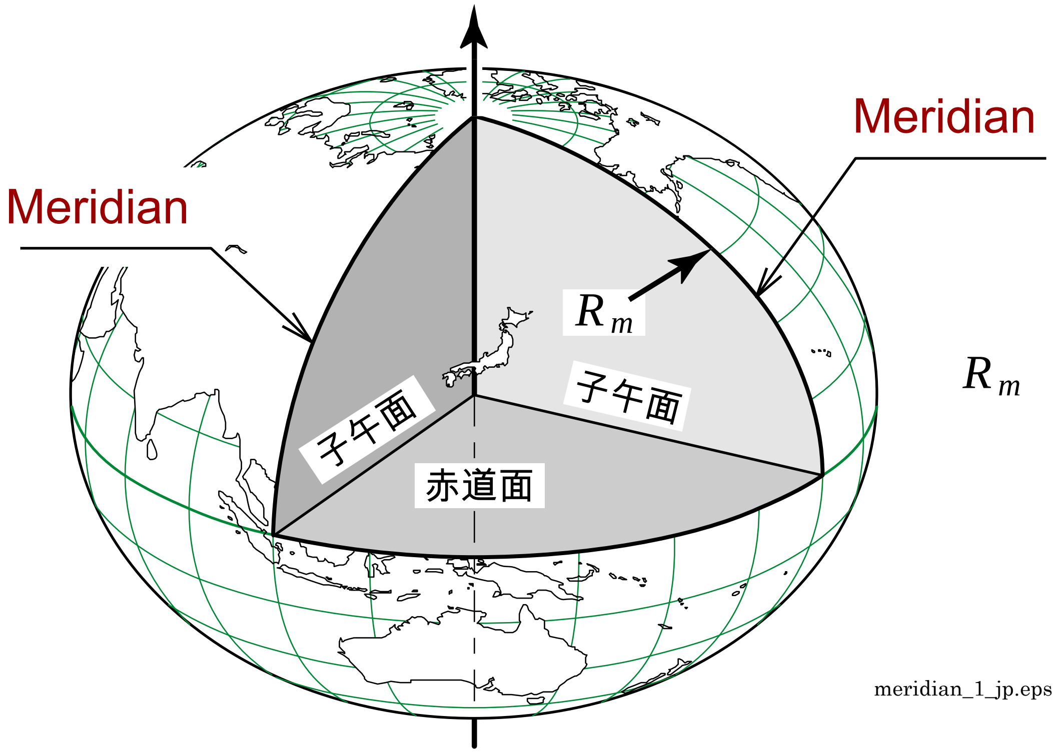
The Effects of curvature for Height

Effects of curvature for height

l [m]	δH [mm]



The curvature of the earth affects for the Beam height.
Therefore, the curvature of the earth must be considered when components of the accelerator are aligned.

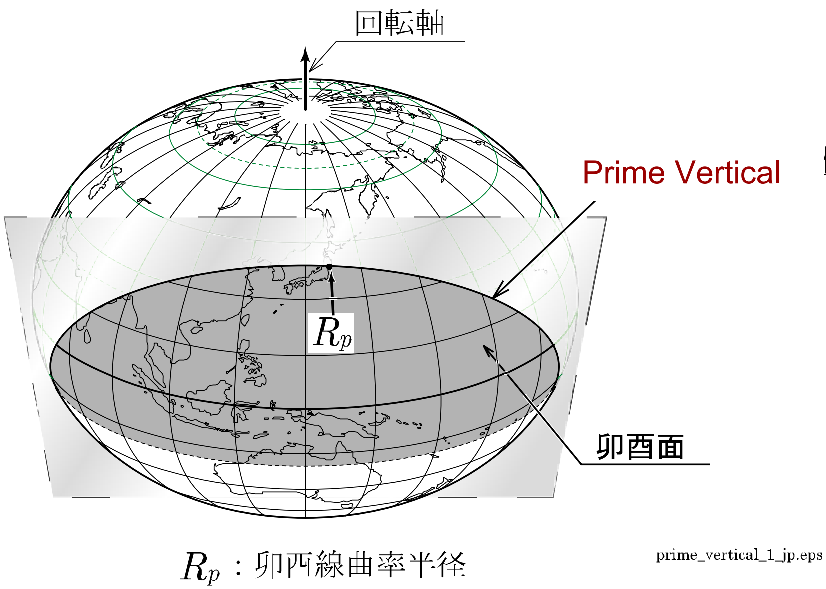


R_m ：子午線曲率半径

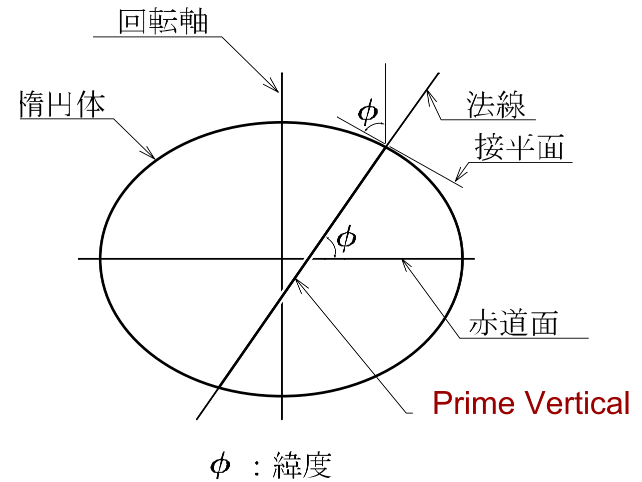
Radius of Curvature in Meridian

The radius of curvatures are Three types.

1. Radius of Curvature in Meridian
2. Radius of Curvature in Prime Vertical
3. Radius of Curvature in Vertical Cut



(a) 卯酉面と曲率半径

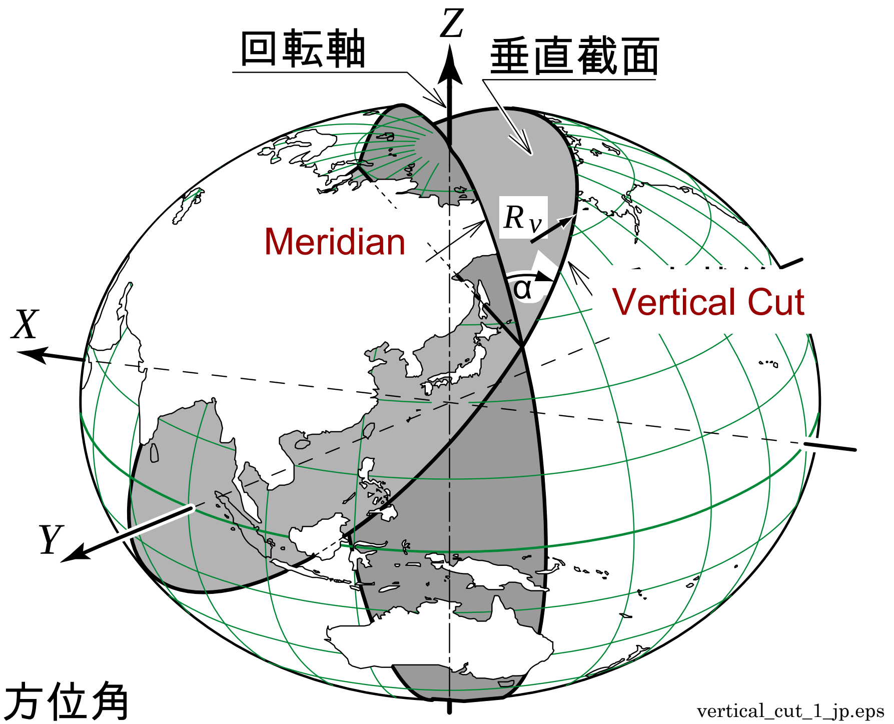


(b) 卯酉面を横から見る

Radius of Curvature in Prime Vertical

The radius of curvatures are Three types.

1. Radius of Curvature in Meridian
2. Radius of Curvature in Prime Vertical
3. Radius of Curvature in Vertical Cut



α ：方位角

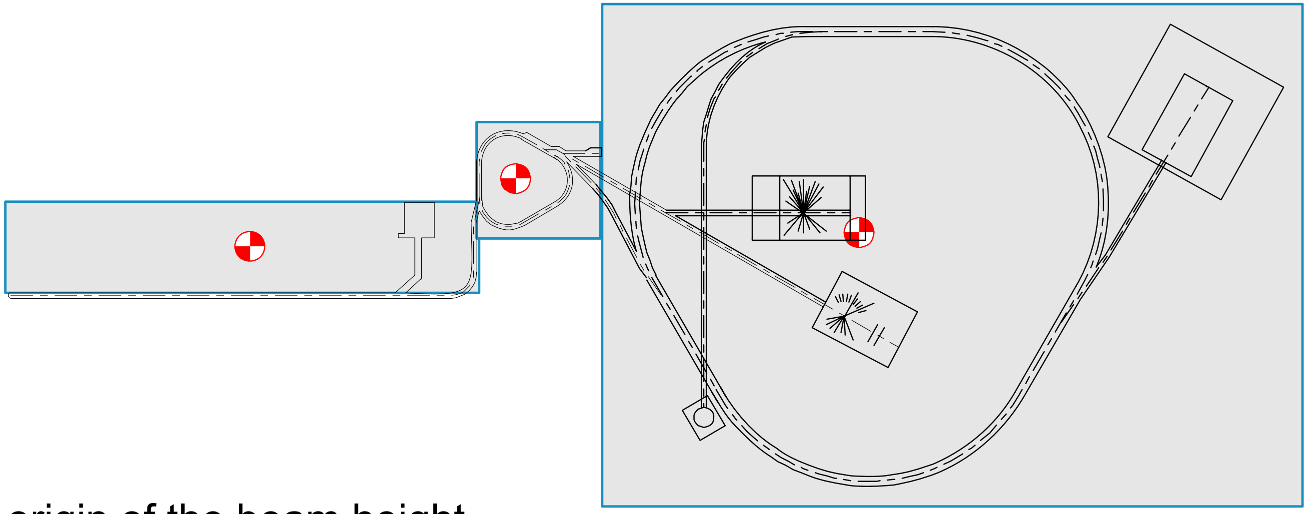
R_v ： Radius of Curvature in Vertical Cut

The radius of curvatures are Three types.

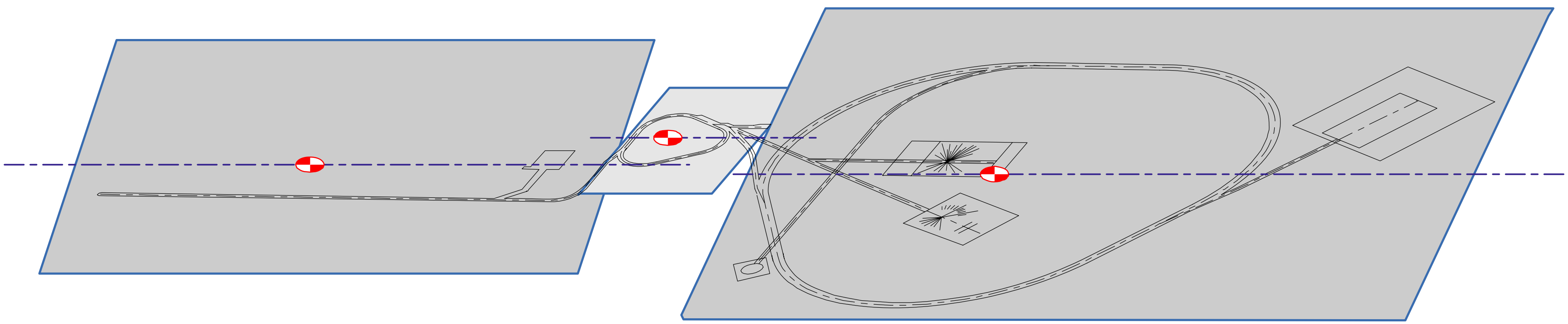
1. Radius of Curvature in Meridian
2. Radius of Curvature in Prime Vertical
3. Radius of Curvature in Vertical Cut

- These Radius of Curvatures are different according to latitude and longitude.

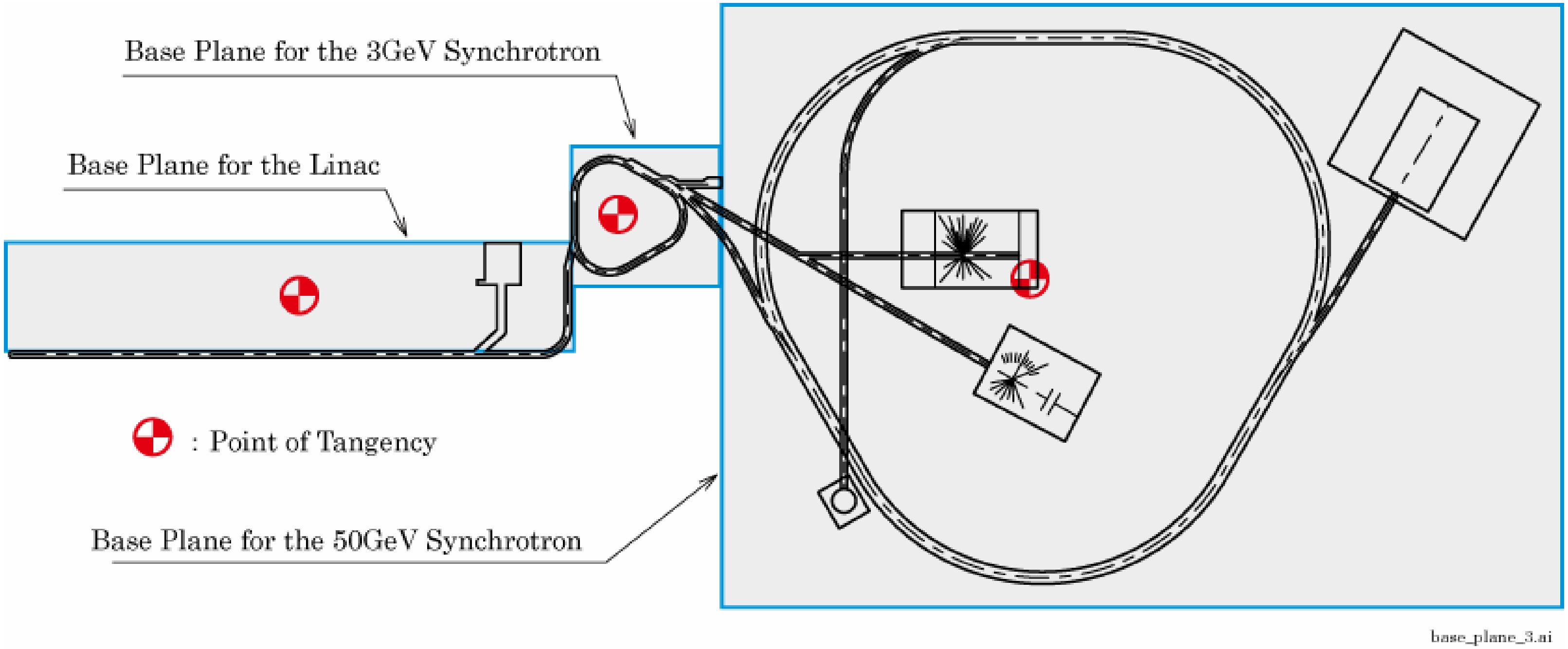
Therefore, it is necessary to set the tangential plane by the latitude and the longitude.



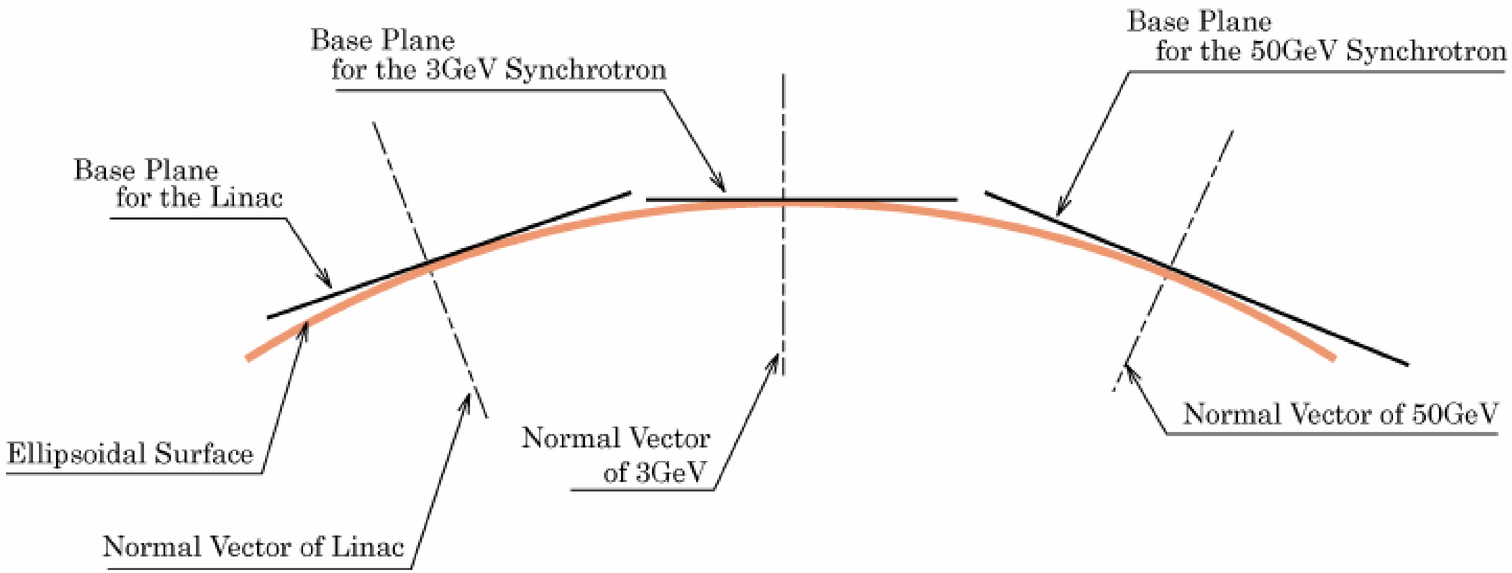
: origin of the beam height



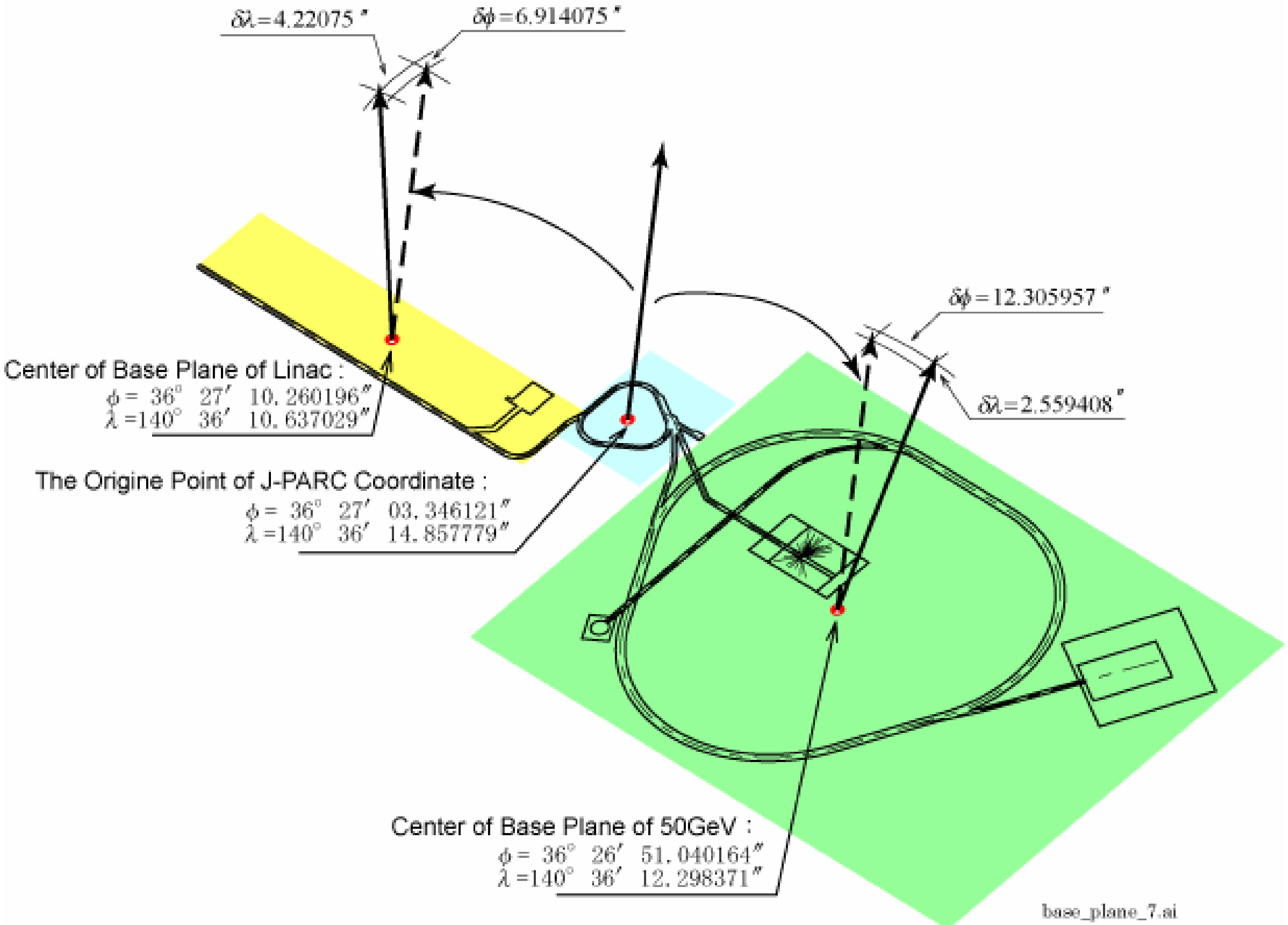
Base plane are set to 3 major accelerators



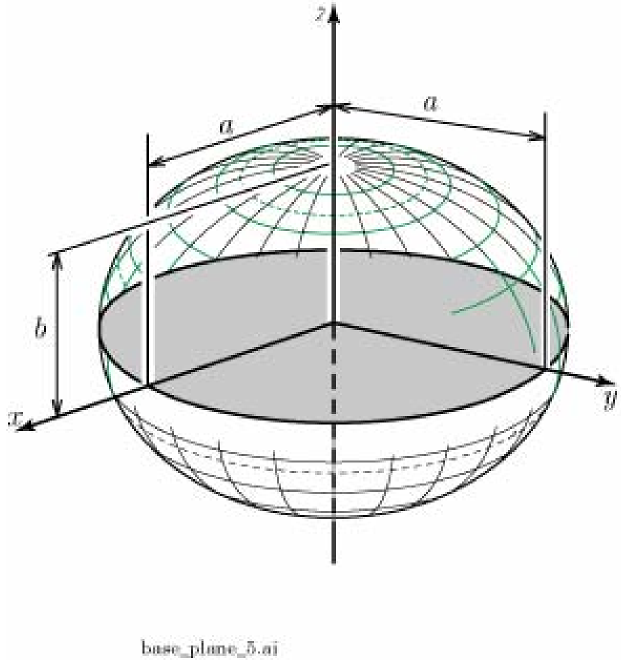
Base Plane for the 3GeV Synchrotron
Base Plane for the Linac
: Point of Tangency
Base Plane for the 50GeV Synchrotron
base_plane_3.ai

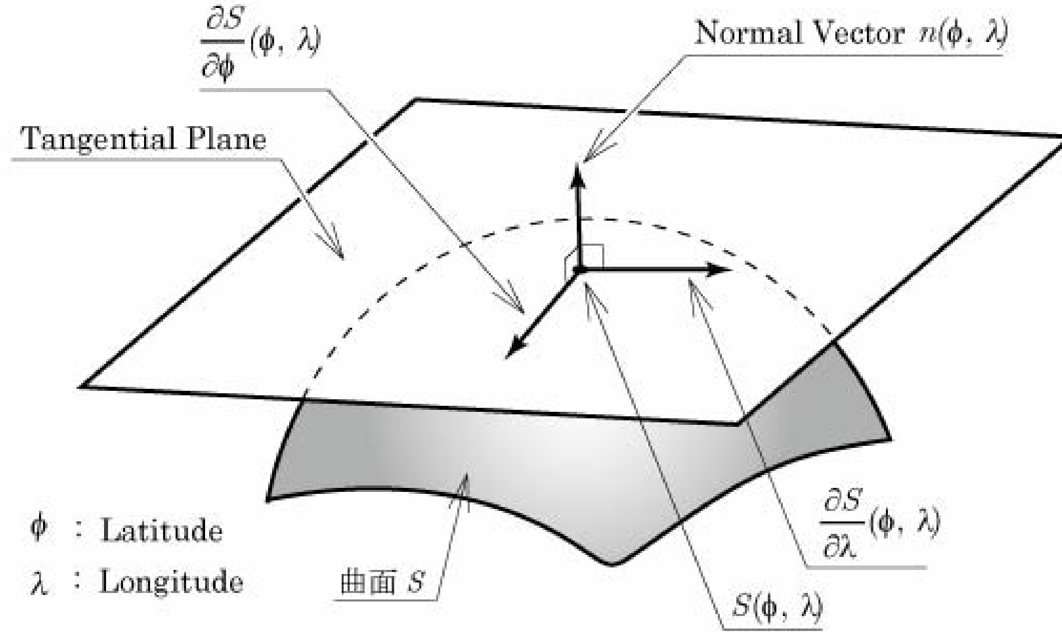


Base Plane
for the 3GeV Synchrotron
Base Plane
for the 50GeV Synchrotron
Base Plane
for the Linac
Ellipsoidal Surface
Normal Vector
of 3GeV
Normal Vector of 50GeV
Normal Vector of Linac



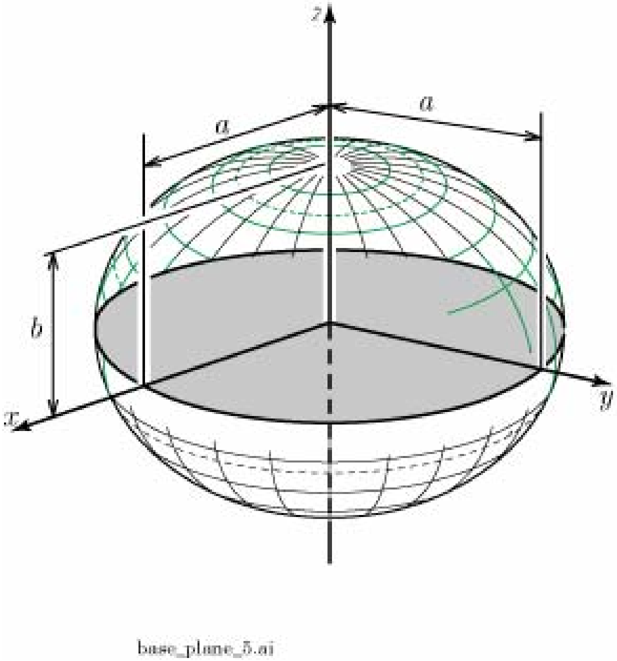
Relation of Each Base Plane

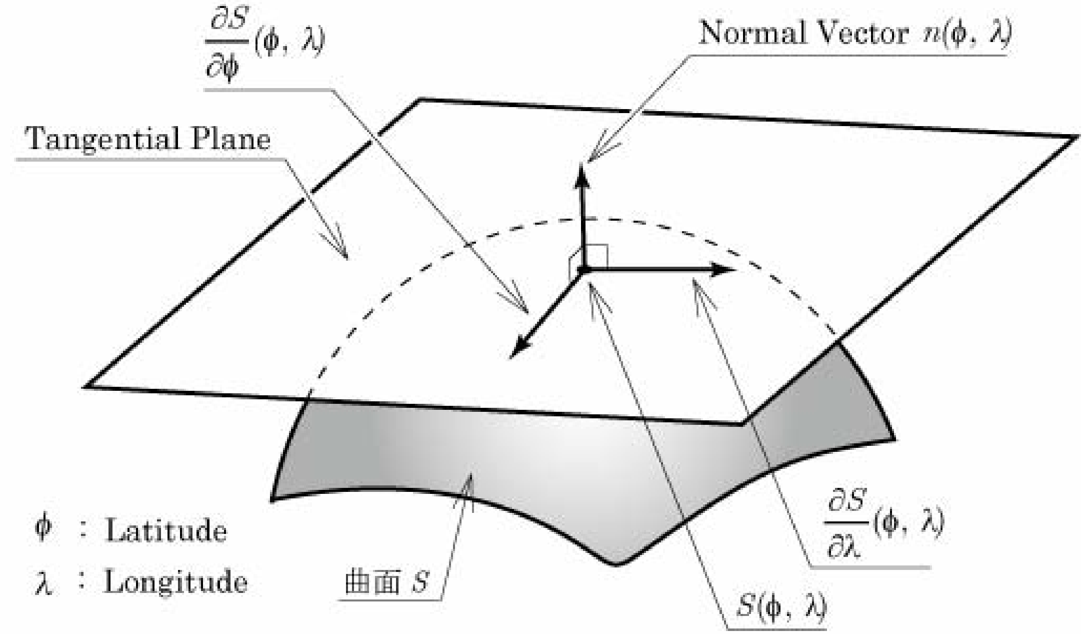




$$S(\phi, \lambda) \quad : \quad \begin{cases} x = Q \cos\phi \cos\lambda \\ y = Q \cos\phi \sin\lambda \\ z = \dfrac{b^2}{a^2} Q \sin\phi \end{cases}$$

The position on the earth can be described as this equation in geocentric 3D coordinate by latitude ϕ , longitude λ and radius of curvature in prime vertical Q on the ellipsoid GRS80.

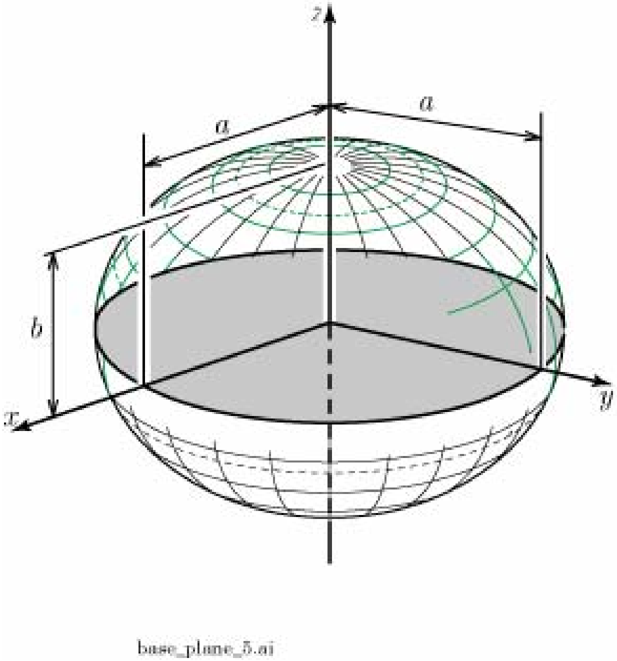


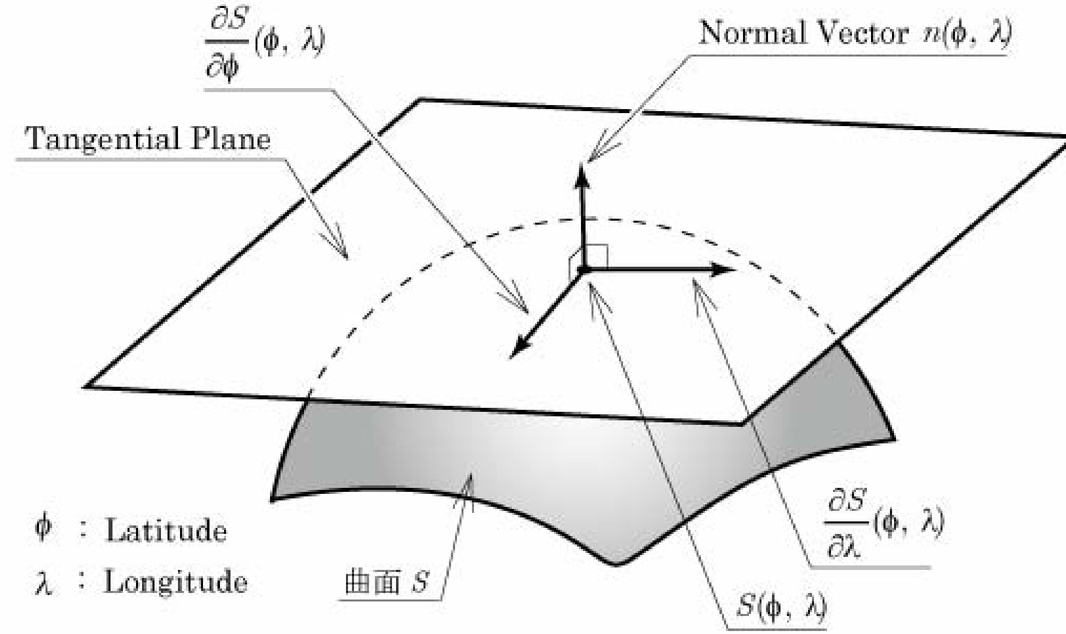


The derivative of the previous equation with latitude ϕ and longitude λ gives their tangent line.

$$\frac{\partial S}{\partial \phi} = \left(\frac{\partial x}{\partial \phi}, \frac{\partial y}{\partial \phi}, \frac{\partial z}{\partial \phi} \right) = \left(-Q \sin\phi \cos\lambda \,,\, -Q \sin\phi \sin\lambda \,,\, \frac{b^2}{a^2} Q \cos\phi \right)$$

$$\frac{\partial S}{\partial \lambda} = \left(\frac{\partial x}{\partial \lambda}, \frac{\partial y}{\partial \lambda}, \frac{\partial z}{\partial \lambda} \right) = \left(-Q \cos\phi \sin\lambda \,,\quad Q \cos\phi \cos\lambda \,,\qquad 0 \qquad \right)$$





Then the normal vector is described as following equation

$$n(\phi,\lambda) = \frac{\dfrac{\partial S}{\partial \lambda} \times \dfrac{\partial S}{\partial \phi}}{\left\| \dfrac{\partial S}{\partial \lambda} \times \dfrac{\partial S}{\partial \phi} \right\|} = \frac{\left(\dfrac{b^2}{a^2}\cos\phi\cos\lambda \quad , \quad \dfrac{b^2}{a^2}\cos\phi\sin\lambda \quad , \quad \sin\phi \right)}{\sqrt{\left(\dfrac{b^2}{a^2}\right)^2 \cos^2\phi + \sin^2\phi}}$$

The normal vector is substituted with $n_0(\phi, \lambda) = (\alpha_0, \beta_0, \gamma_0)$

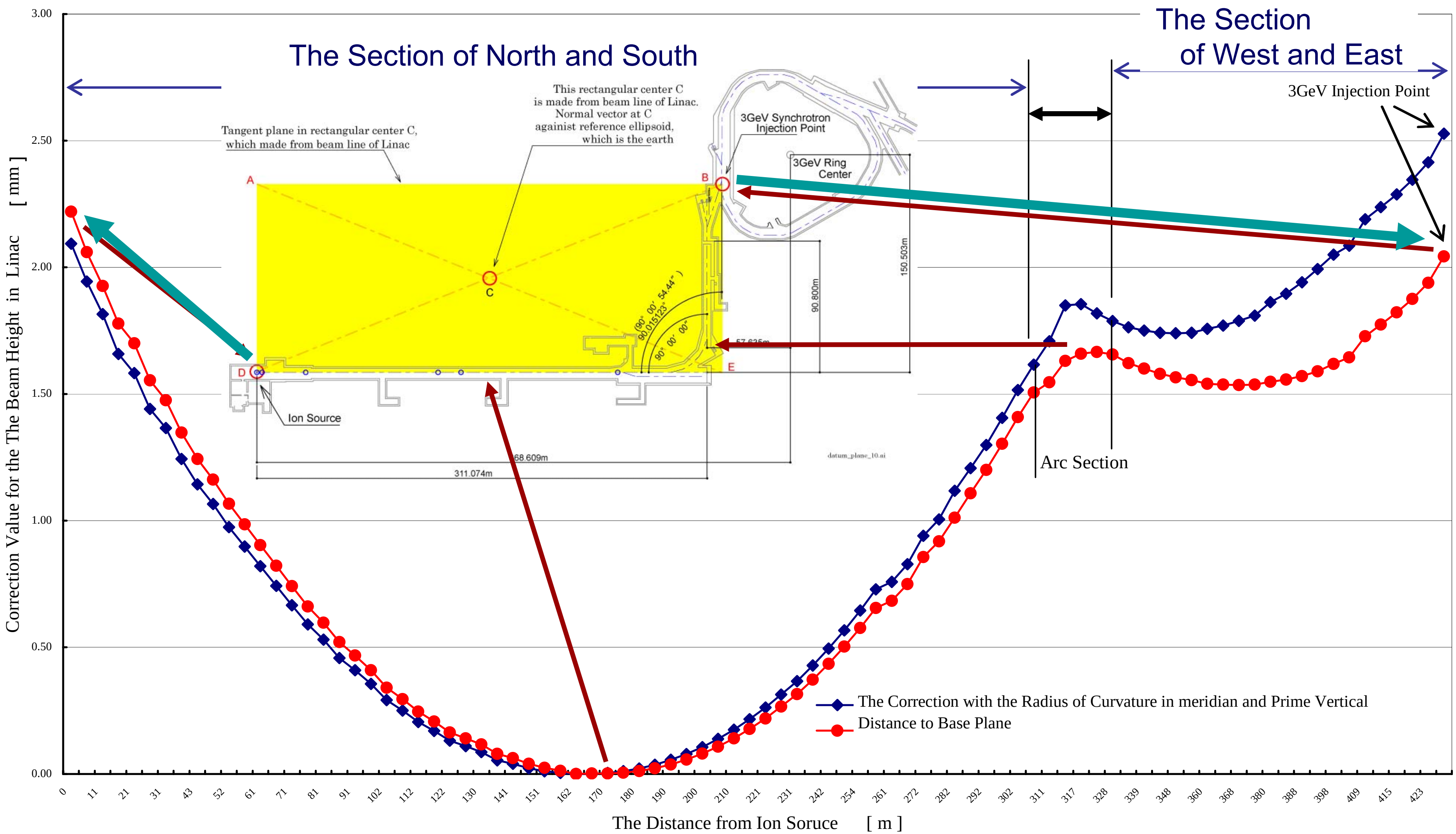
The equation of the base plane which contains the point on the surface of the earth $P_0(x_0, y_0, z_0)$ is

$$\alpha_0(x - x_0) + \beta_0(y - y_0) + \gamma_0(z - z_0) = 0 \quad .$$

Coordinates of fiducial points on components are calculated by its latitude and its longitude.

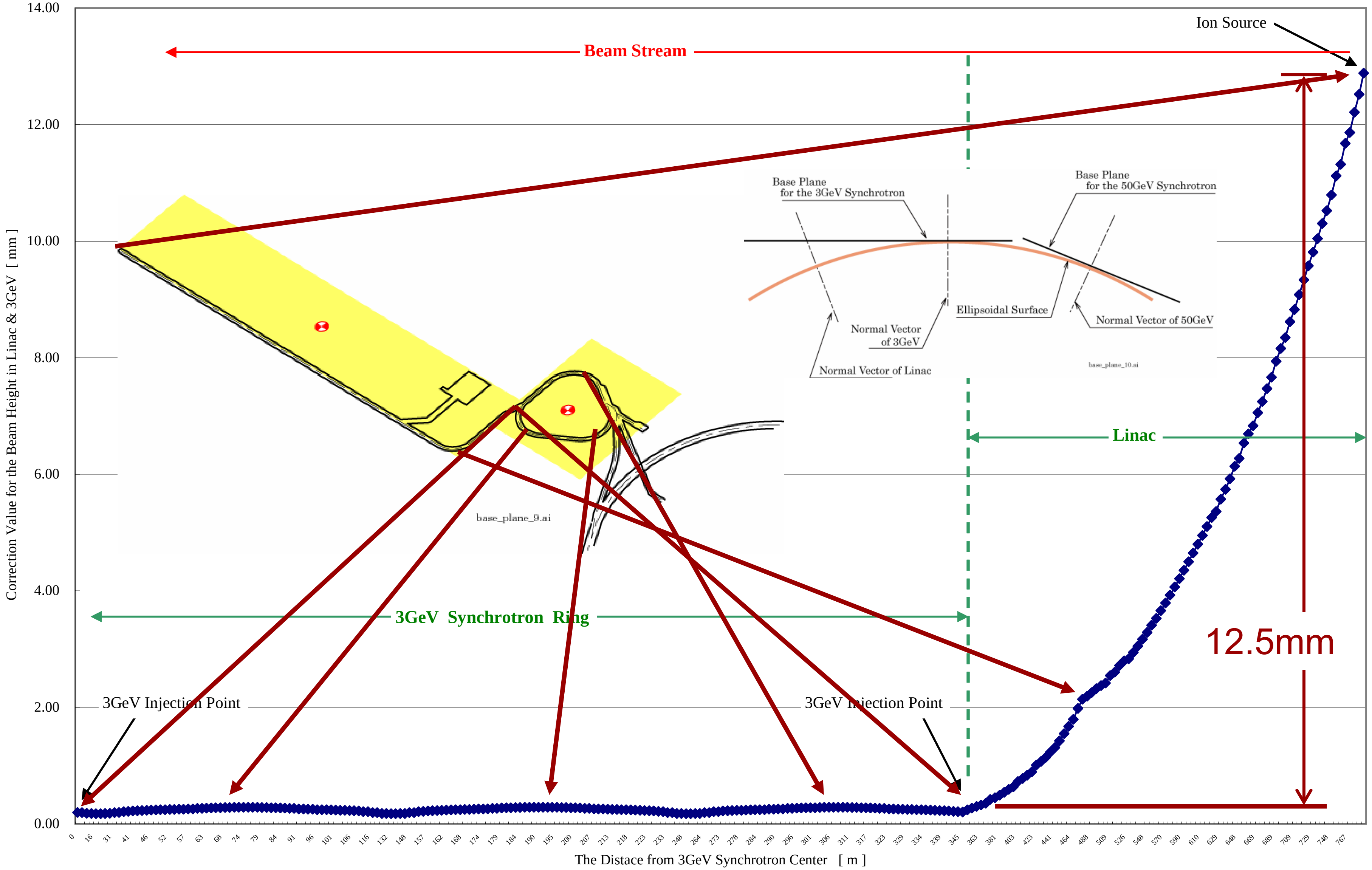
The correction value for the beam height is the distance from these coordinates to this base plane.

The Ion Source and Injection Point at 3GeV Ring Should be equal Distances



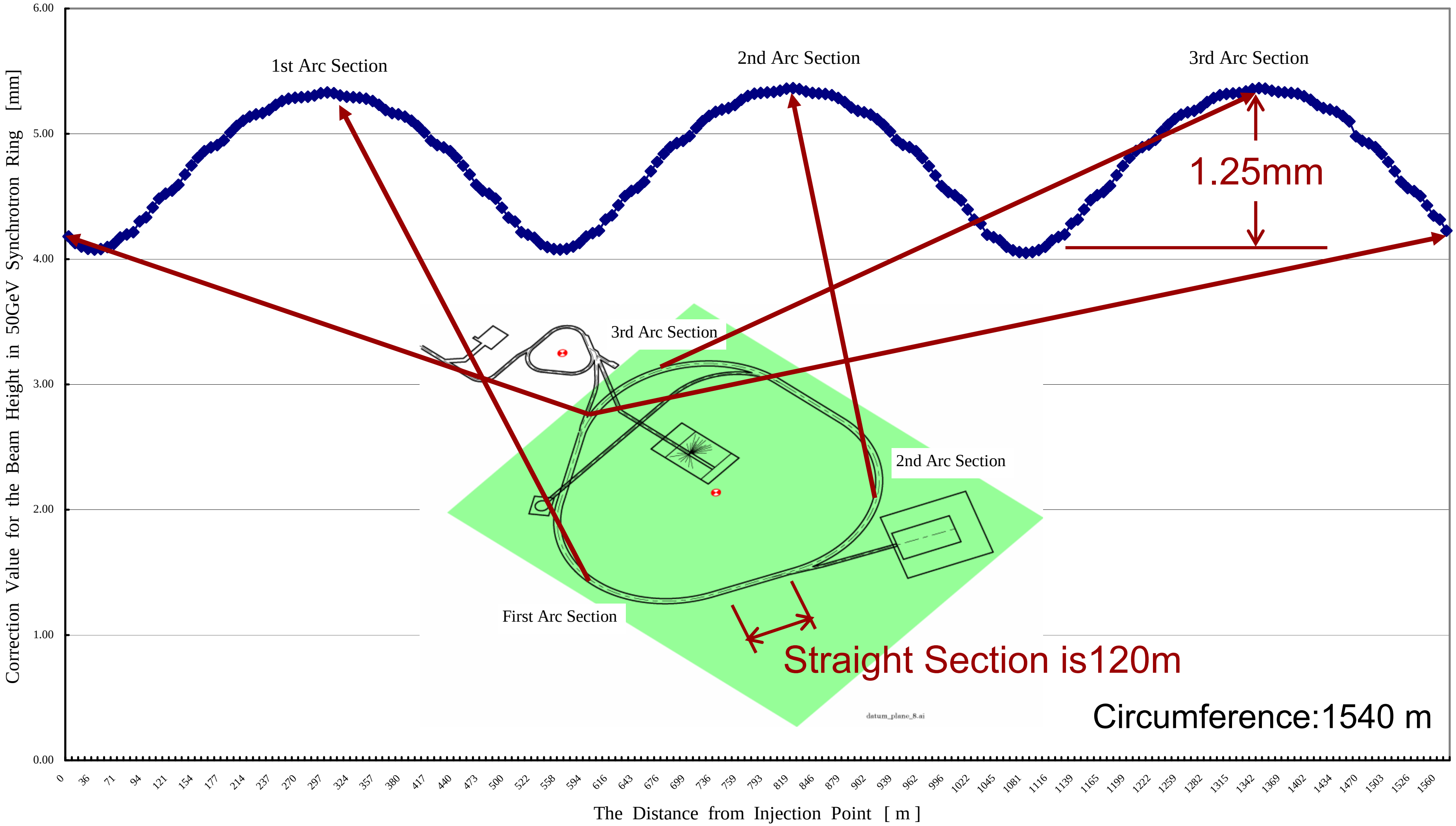
It is right to correct by distances from components to base plane

Distances from Linac & 3GeV Components to Base Plane at 3GeV Ring



It is Right to Have Set 3 Base Planes.

Distance from 50GeV Components to Base Plane of 50GeV Ring



Difference between Min. and Max. of These Distances is 1.25 mm,
Though Circumference is 1540 m

Thus, the method of correcting curvature of the earth to the beam height has been checked out.

But, uneven settlement is bigger than correction value.

Therefore, the way to correct is under discussion.

It will be used to refer for smoothing.

Start to Beam Commissioning :

Linac ; The end of This Year

3GeV ; The year of 2007

50GeV ; The year of 2008

To Be Continued to next IWAA

Thank you