BEPCII Pre-alignment and Hold Level Adjustment

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Introduction of BEPCII pre-alignment

- BEPCII is built in the existing tunnel of BEPC and upgrade the storage ring from single ring to two independent rings. BEPC’s Bend magnates are used in the outer storage ring, the inner storage ring is complete a new one. Pre-alignment project need to fiducialize magnets, install each cell’s components on it’s girder and align them. Because in the tunnel, working space is very narrow and a lot of work need to be carried out at the same time, pre-alignment was done out of the tunnel. This can greatly relief the burden of tunnel work and improve working efficiency.
- There are 84 cells need to do pre-alignment installation ,and it was started on August 2005 and finished on August 2006.

Pre-alignment member and instruments

- We arranged two groups to do pre-alignment. Each group includes two alignment technicians and two workers. Beside these, a lift worker worked for these two groups.
- Measurement instruments are laser tracker, leica NA2 level and electronic gradienter.

BEPCII pre-alignment proposal

- According to the sequence of pre-alignment, it includes fiducialization of magnets, calculate the nominal position of components, install components on the girder, precisely adjust the components on girder, fix them, lifting and transport the cell to tunnel.

- Generally it takes 5 days to finish a pre-alignment cell.

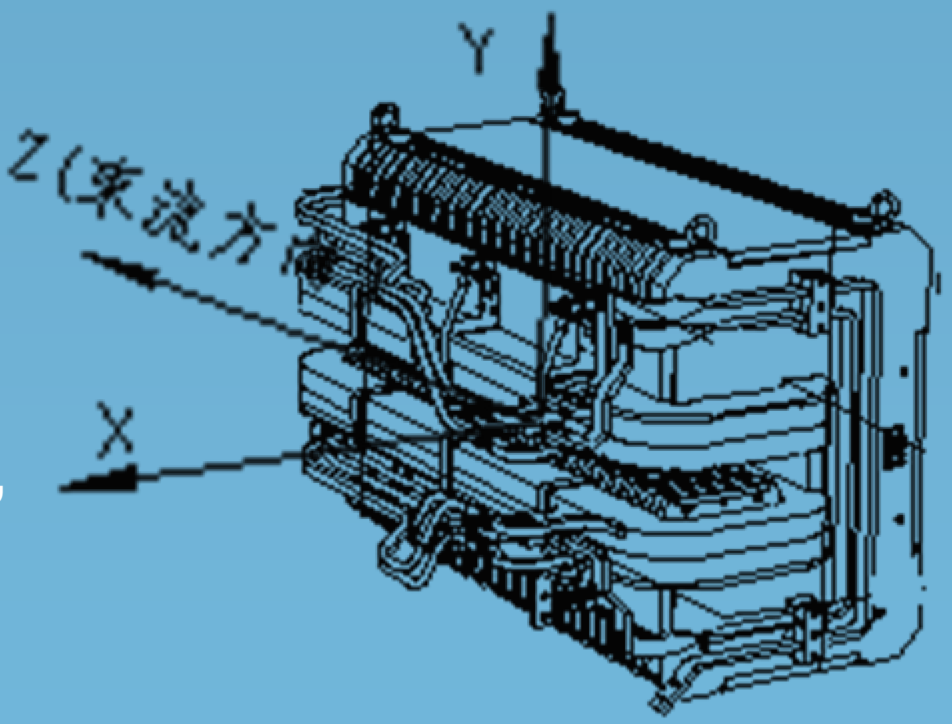
pre-alignment cell

Fiducialization of magnets

- Fiducialization is to provide a mechanical reference to the effective centerline of the magnets.
- Fiducialization instruments are laser tracker, leica NA2 level and electronic gradienter.
- We use pre-alignment cell’s girder as magnet fiducialization workbench, it is supported by jacks.
- In order to make the ground stable, each time before fiducialization, we put the magnets on girder for more than 12 hours.

Fiducialization of magnets

- Each magnet will have its own fiducial coordinate system. The rules to establish fiducial coordinate system is : The origin is in the center of magnetic poles, the z-direction is same as beam, y-direction is vertically upward, Cartesian right-handed system.



Dipole’s fiducial coordinate system

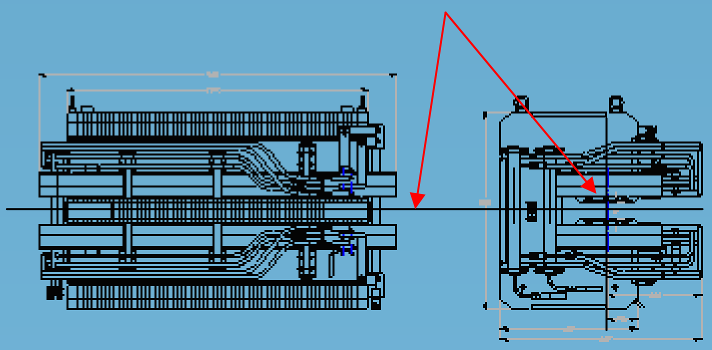
Fiducialization of magnets

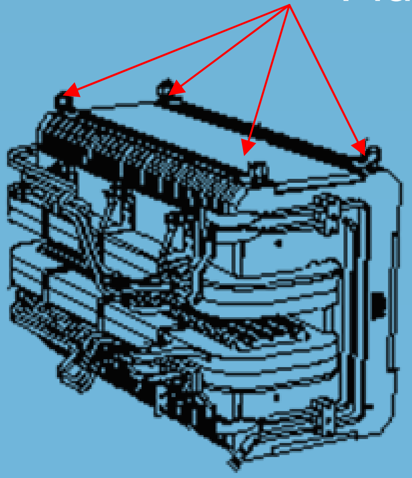
- Every magnate needs having two valid measurements. Valid measurements means the errors of corresponding fiducial points get from these two measurements should within the tolerances in the list.

magnates	X(mm)	Y(mm)	Z(mm)
Dipole	0.10	0.10	0.15
Quadrupole	0.04	0.04	0.1
Sextupole	0.05	0.05	0.1
corrector magnet	0.15	0.15	0.15

Fiducialization of a Dipole Magnet

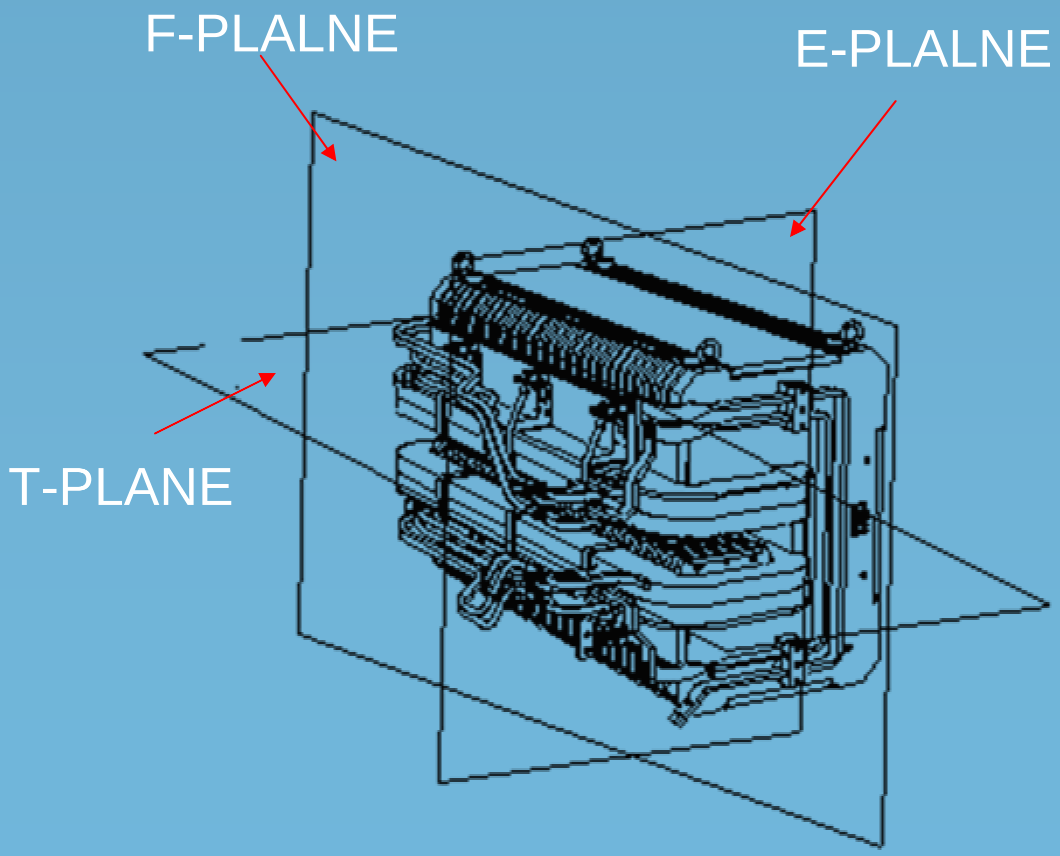
- Fiducialization is to determine the coordinates of fiducial points relative to the centerline.





Fiducialization of a Dipole Magnet

- Use laser tracker scan lower magnetic pole get T-PLANE; scan the front surface of magnet get F-PLANE; scan the side surface of magnet get E-PLANE.



Fiducialization of a Dipole Magnet

- The intersecting line of T-PLANE and F-PLANE is parallel with centerline. Use these three planes to establish a fiducial coordinate system. In this coordinate system measure fiducial points get Dipole Magnet’s fiducial coordinates.
- T-PLANE is a fiducial plane to establish fiducial coordinate system, the measurement result of T-PLANE is important to fiducialization. But the surface of lower magnetic pole is very narrow, laser tracker scan it is easy to get large errors. In order to solve this problem we use leica NA2 to check the measurement result of laser tracker.

Fiducialization of a Dipole Magnet

- We use a fiducial plane to help measuring the surface of lower magnetic pole. At the each end of the fiducial plane can put a 1.5" metal sphere target.
- Before laser tracker measurement, we use NA2 level the surface of lower magnetic pole to remove roll and pitch.
- Then use laser tracker to establish a level coordinate system, in this coordinate system measure the surface of lower magnetic pole. If some points is higher or lower than other points too much we need to re-measure it.

Adjust the lower pole to level

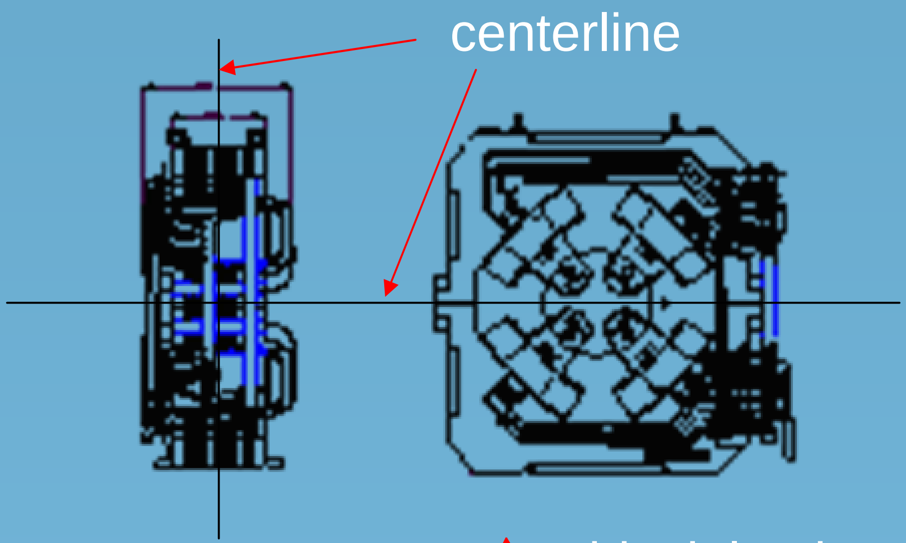
Fiducialization of a Dipole Magnet

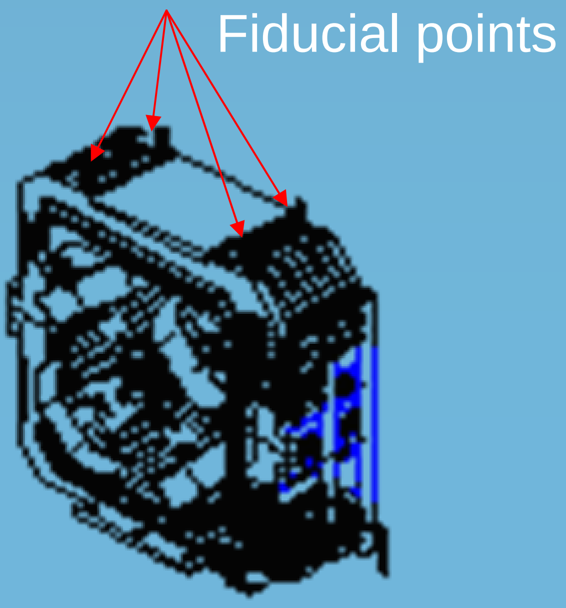
- Accelerator physics requires dipole's Roll tolerance should be 0.1mrad, it's can not be realized only with laser tracker. We use leica NA2 and electronic gradienter to do the Roll fiducialization.
  - Firstly, use NA2 level the lower magnetic pole, then use electronic gradienter measure the fiducial plane.

Measure dipole's Roll

Fiducialization of Quadrupoles

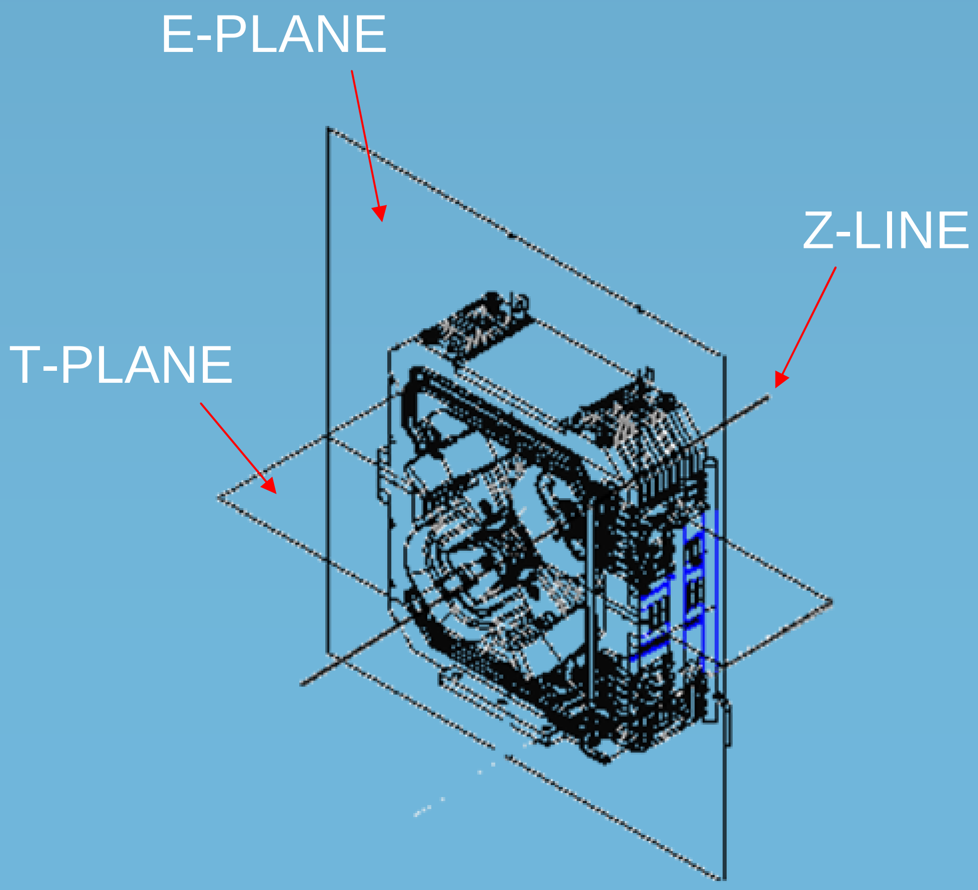
- The centerline and fiducial points of Quadrupoles are shown in the picture.
- We use a mandrel and tiles to determine the centerline of Quadrupoles .





Fiducialization of Quadrupoles

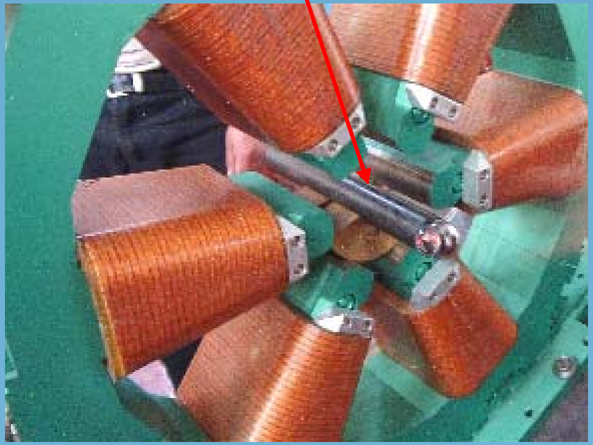
- The mandrel and tiles will be placed in contact with two lower poles. Use laser tracker measure the ends of mandrel get Z-LINE.
- Put a fiducial plane into the poles, make it contact with two lower poles. Use laser tracker measure its surface get T-PLANE.
- Scan one side surface of the magnet get E-PLANE.



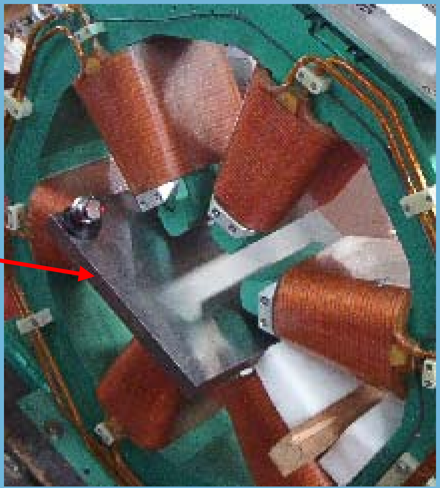
Fiducialization of Quadrupoles

- Use these planes and Z-LINE to establish fiducial coordinate system. In this coordinate system measure fiducial points get Quadrupole’s fiducial coordinates.
- Sextupole and corrector magnet’s fiducialization is similar with Quadrupole.

mandrel and tiles



fiducial plane



Magnets' nominal coordinates

- In order to align the components of each cell we need to establish a cell coordinate system. The origin is in the center of dipole, z points to the beam direction, y vertically points upward, right hand coordinate system.
- According to the parameters given by accelerator physics we can convert magnets' fiducial coordinates to the nominal coordinates in the cell coordinate system.
- We found temperature change can markedly influence the precision of the magnets' position. It's necessary to do some correction to the nominal coordinates.
- Through longtime experiment, we got an appropriate correctional coefficient(1.144E-05/℃). We use this coefficient multiply the z-direction coordinates of every magnet to do the correction.

Magnates, Vacuum Chamber installation and adjustment proposal

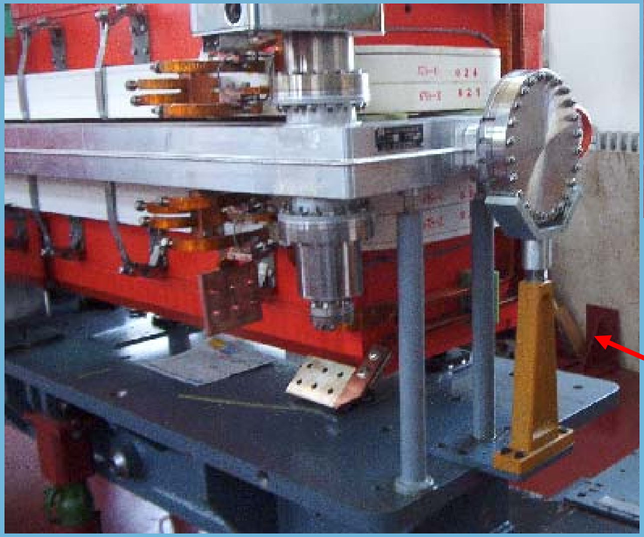
- The components need to install in a cell generally are dipole, quadrupole, sextupole, corrector magnet, vacuum system, girder and so on.
- Dipole's position is decided by the girder's mechanical structure. It is supported by pedestals and steel balls, its position can not be adjusted.

Steel ball

Magnates, Vacuum Chamber installation and adjustment proposal

- Corrector magnate has its own adjustable pedestal.
- Vacuum chamber is supported by struts.

pedestal



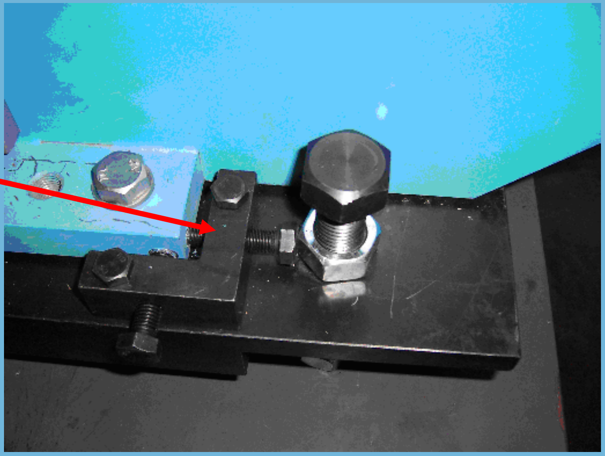
struts

Magnates, Vacuum Chamber installation and adjustment proposal

- In order to install vacuum chamber, we need to low down quadrupole and sextupole and then restore them. So we put them on one plate.
- The position of quadrupole and sextupole can be adjusted by screws on the plate.

plate

screw



Magnates, Vacuum Chamber installation and adjustment proposal

- To do cell pre-alignment, we input the nominal coordinates of components into laser tracker and measure the fiducial points of dipole to do best-fit, then survey and adjust the components to the required installation precision.
- Errors of components should within the tolerances in the list.

Components	X(mm)	Y(mm)	Z(mm)
Quadrupole	0.05	0.05	0.08
Sextupole	0.05	0.05	0.08
corrector magnet	0.15	0.15	0.15
Vacuum chamber	0.3	0.2	0.3

Magnates, Vacuum Chamber installation and adjustment proposal

Hold Level Adjustment

- Use laser tracker to survey tunnel control network have a problem is that in the first station we establish a level coordinate system to do measurement then move station continue the survey, we can find the errors in elevation direction will become more and more larger. This shows the adjustment of laser tracker is not appropriate to do three-dimensional move station survey.
- Through compare the elevation result of laser tracker's measurement and level's measurement. we find, in each single station, the precision in elevation direction of laser tracker is similar with level(comparation error of elevation is 0.07mm). This shows the coordinates laser tracker measured in each single station is reliable, the factor that affects the result of move station measurement is laser tracker's adjustment method.

Hold Level Adjustment

- We want to find a new adjustment method. This adjustment should be able to reserve the precision of coordinates which laser tracker got in each single station. Then using this adjustment method to process laser tracker move station measurement result will avoid large errors in elevation direction.
- In order to realize this method, our primary ideal is that in each single station, laser tracker should establish a level coordinate system. When use the result of these single station measurement to do adjustment we should make the coordinate of these single station hold the level direction.
- This is a study we want to do next, now we are just in the beginning.

Thanks for your attentions !