SURVEY AND ALIGNMENT OF THE MEDICAL ACCELERATOR PATRO AT HIBMC

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1. INTRODUCTION

The HIBMC (Hyogo Ion Beam Medical Center) is the complex of the ion beam radiotherapy where is next to the Spring-8 (Fig.1, Fig.2). This paper presents a review of the survey procedures of these 1st and 2nd order control points in the whole of this complex and alignment method at these facilities of the PATRO (Particle Accelerator for Therapy, Radiology and Oncology).

Fig.1 HIBMC and Spring-8 in Harima Science City

Fig.2 Hyogo Ion Beam Medical Center (HIBMC)

The PATRO consists of four major parts of the injector system, the main accelerator, the high energy beam transport system and the treatment room (Fig.3). The 2 different types of beams are used for treatments at this center, proton (70-230MeV/u) and carbon ion beams (70-320MeV/u).

The injector consists of two 10GHz ECR ion sources, 1MeV/u RFQ linac, 5MeV/u Alvarez linac and a debuncher. Operation frequency of the linac is 200MHz.

The synchrotron ring is a separated function type with a strong FODO focusing structure and its super periodicity of 6. The circumference of this ring is 93m. Beam is slowly extracted by the third order resonance scheme.

There are 5 treatment rooms. One with horizontal and vertical beam lines, one with a 45 degree oblique beam line, one with another horizontal line and 2 isocentric proton gantry lines.

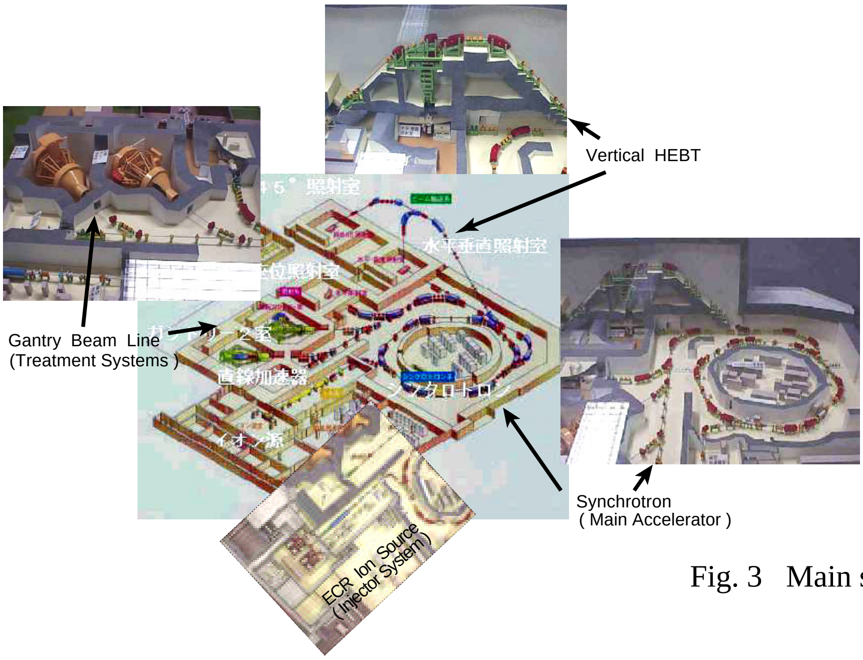

Fig. 3 Main systems of PATRO

2. THE SURVEY FOR THE WHOLE OF PATRO AREA

2.1 The kind of monuments

The kind of survey monuments are as the next.

2.1.1 First order monuments

1st order monuments were installed in uniformed precision at the whole of PATRO area. Because of the precision of these monuments were not biased.

2.1.2 Second order monuments

The purpose of 2nd order monuments was the alignment for these machine components. These 2nd order monuments settings were based on more than two 1st order monuments.

2.1.3 Level marks

The purpose of level marks was referred for the height to machine components. These level marks settings based on a floor level monument.

2.2 The layout of these monuments

These 1st, 2nd order monuments and level marks were allocated to the PATRO area as shown in Fig.4.

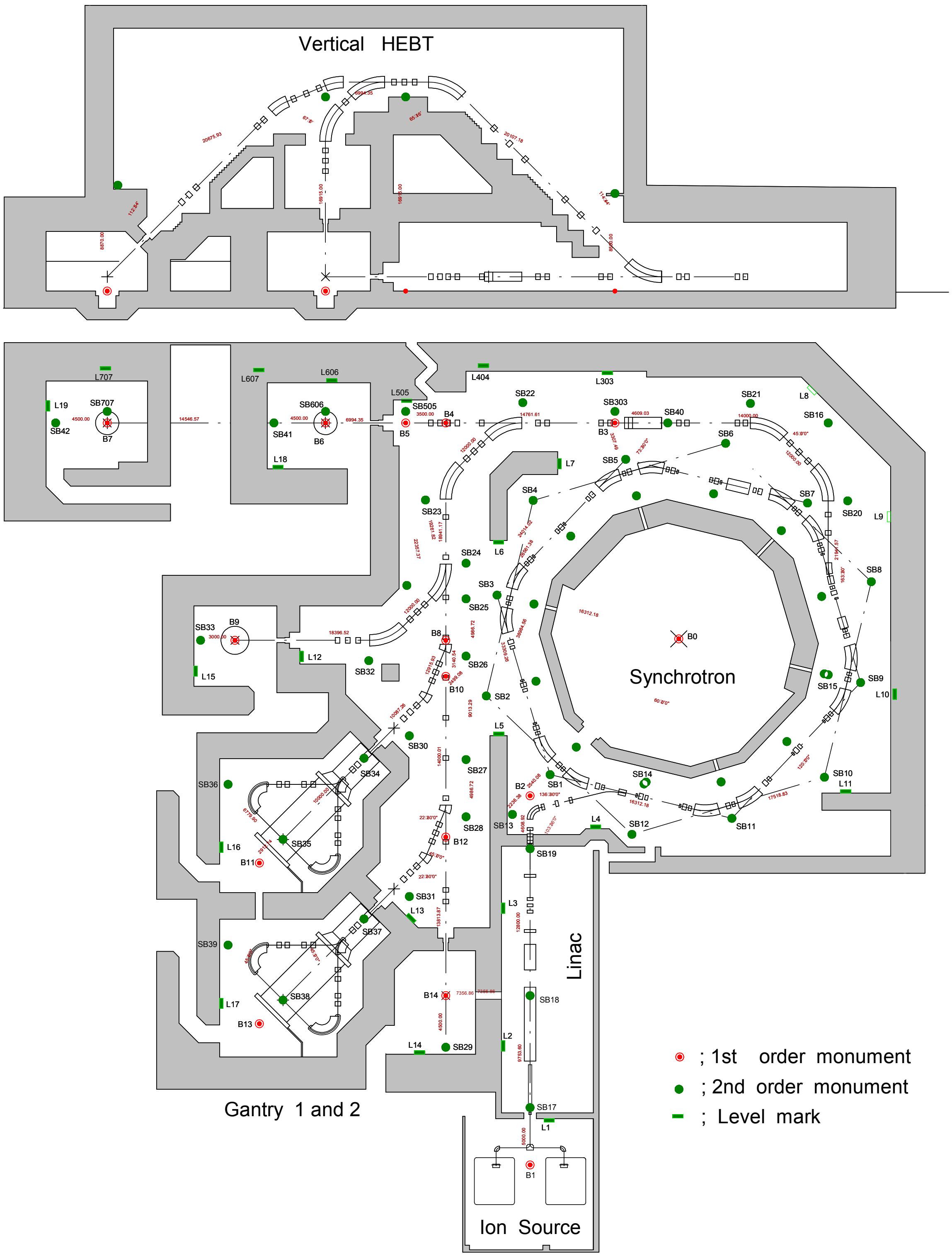

Fig. 4 The allocation of 1st, 2nd order monuments and level marks

2.3 The survey of the 1st order monuments

2.3.1 The survey network for the 1st order monuments

The survey network for the 1st order monuments is shown in Fig.5.

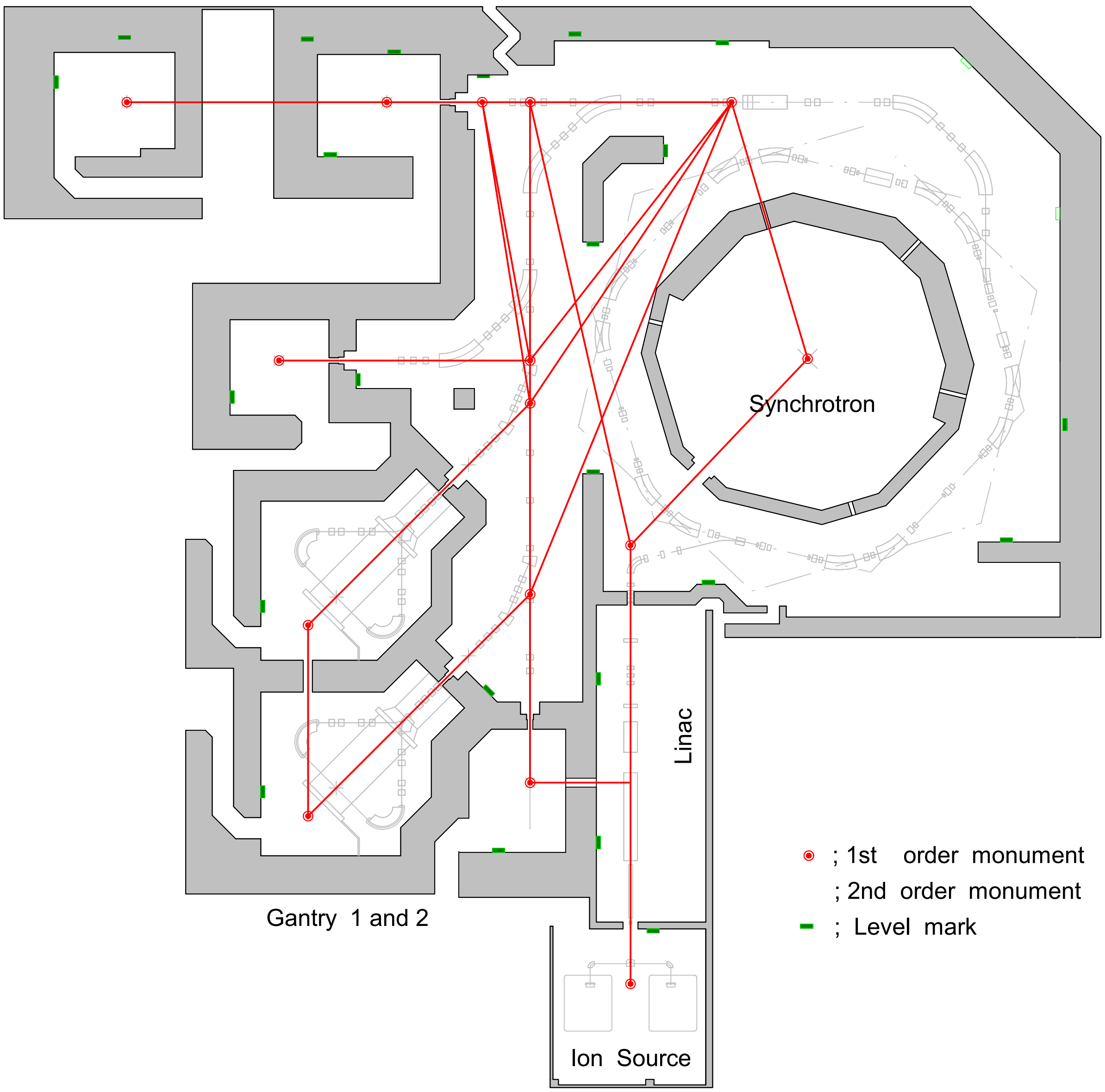

Fig.5 The survey network for the 1st order monuments

2.3.2 The method and instruments of the survey for the 1st order monuments

2.3.2.1 The method of determination on the final coordinate of the 1st order monuments

These 1st order monuments were surveyed twice. Firstly, we surveyed to the crossing mark on the 1st order monuments. These monuments were movable and adjustable (Fig. 6). These monuments had adjusted to the difference between the results of first surveying from the designed coordinates. Secondary, we surveyed again to the same network and confirmed these coordinates.

Fig. 6 The structure of monument

2.3.2.2 The observing instruments

These 1st order monuments were surveyed by The MEKOMETER ME5000 (Fig. 7) for the distance measurements and by the T-3000 for the angle measurements.

Fig. 7 MEKOMETER ME5000

Fig. 8 Centering by optical plummet on the auxiliary pillar

2.3.2.3 The observed data processing (the network adjustment)

Any measurement always has errors. Therefore, to minimize these errors, it must be measured with the high accurate survey instrument. These errors what cannot eliminate with some precise survey instruments computes by the survey network adjustment to the optimal error processing. In this survey work at HIBMC, the survey data were calculated by the survey network adjustment program PAG-U. The method of network procedure was free network adjustment.

2.3.3 The results of the survey for the 1st order monuments

The results of the survey for the 1st order monuments are shown in Fig.9.

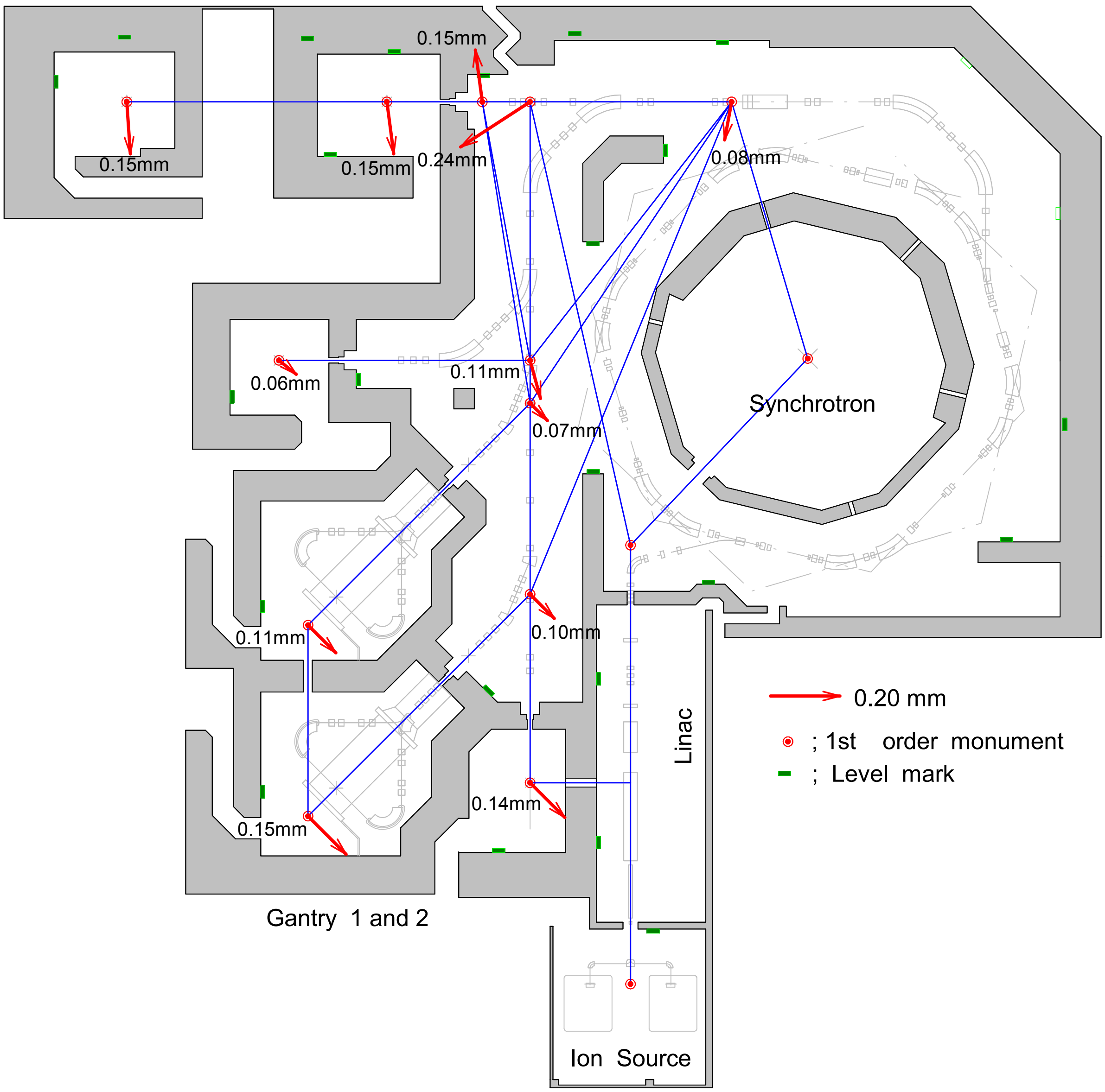

Fig. 9 The results of the survey for the 1st order monuments

2.4 The survey of the 2nd order monuments

2.4.1 The survey network for the 2nd order monuments

The survey network for the 2nd order monuments is shown in Fig.10.

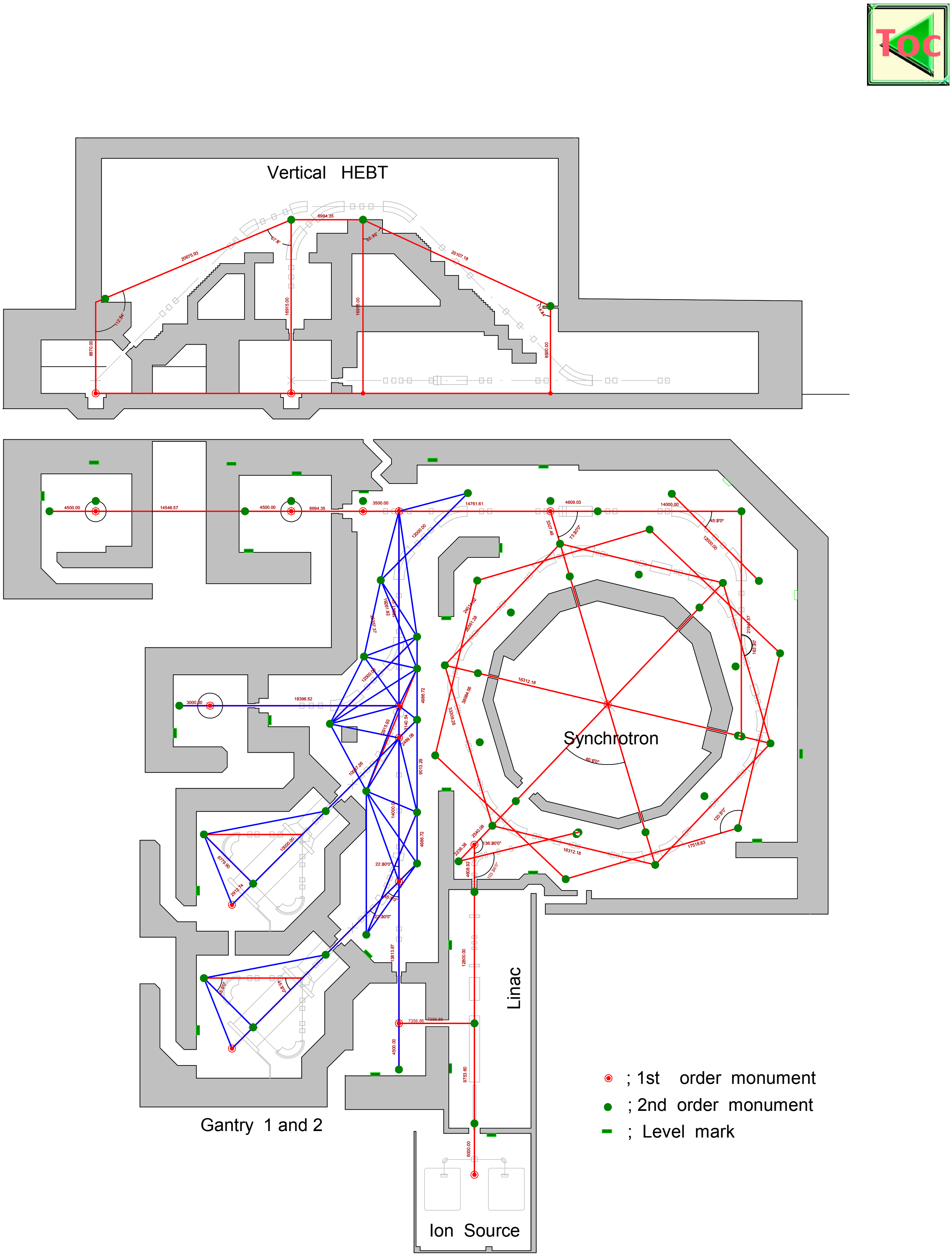

Fig. 10 The survey network for the 2nd order monuments

2.4.2 The method and instruments of the survey for the 2nd order monuments

The 2nd order monuments were surveyed as same way as 1st order monuments and by same instruments as 1st order monuments.

These survey data of 2nd order monuments were not calculated by the free network adjustment but by the fixed network adjustment. The fixed monuments were the 1st order monuments.

2.4.3 The results of the survey for the 2nd order monuments

The results of the survey for the 2nd order monuments are shown in Fig.11.

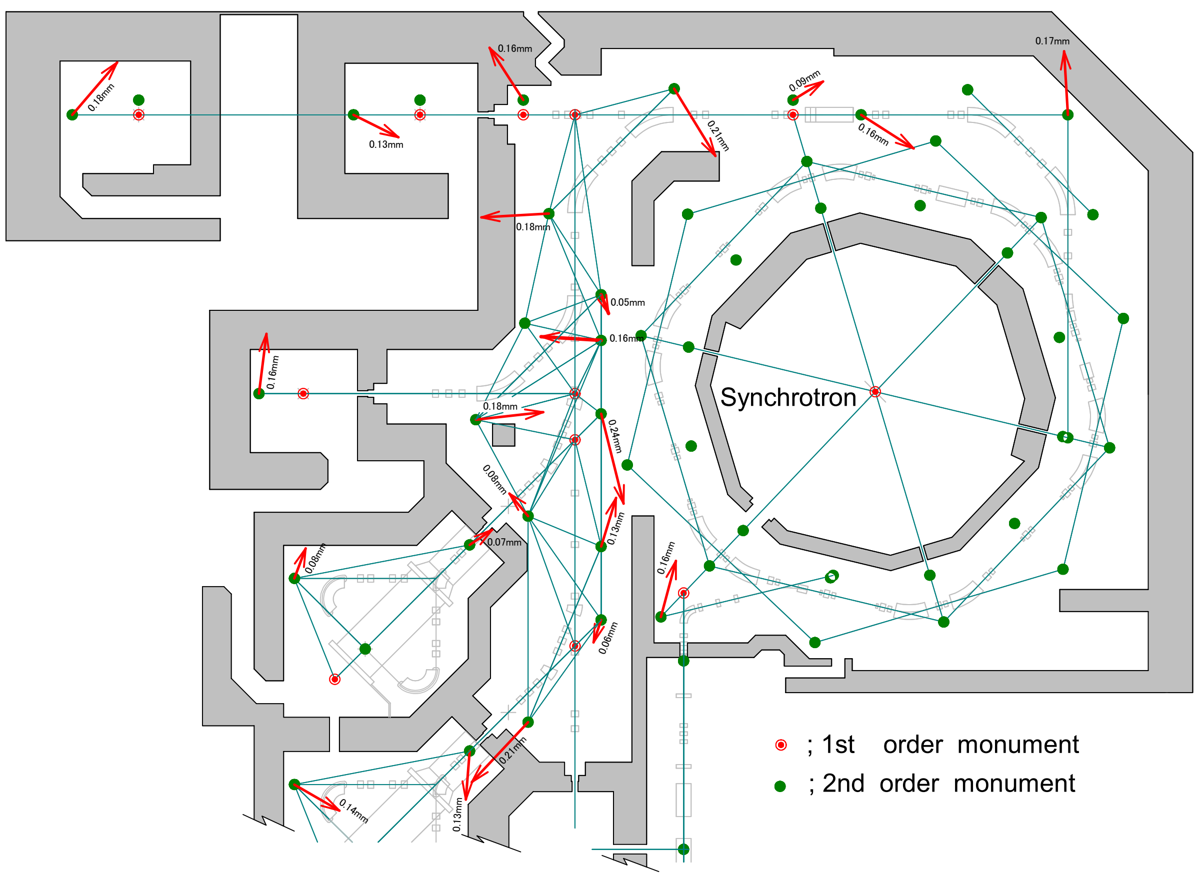

Fig. 11 The results of the survey for the 2nd order monuments

2.5 The survey of the synchrotron monuments

2.5.1 The survey network for the synchrotron monuments

The survey network for the synchrotron monuments is shown in Fig.12.

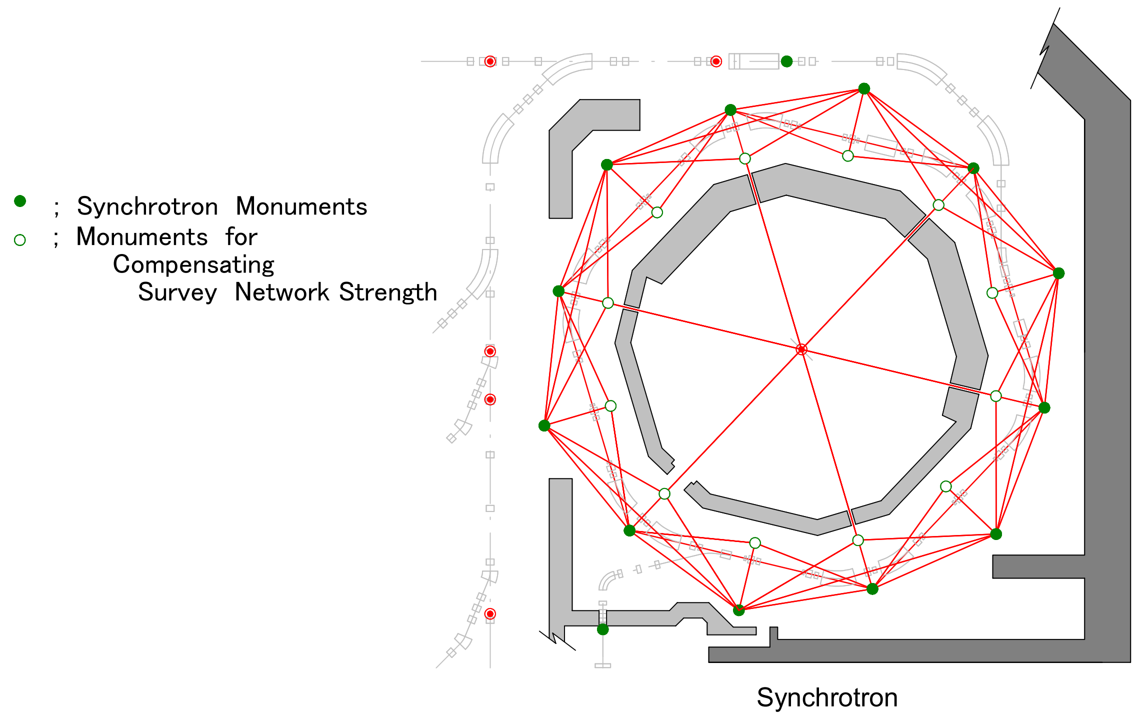

Fig. 12 The survey network for the synchrotron monuments

2.5.2 The method and instruments of the survey for the synchrotron monuments

The synchrotron monuments were surveyed as same way as 1st and 2nd order monuments and by same instruments as 1st 2nd order monuments.

The survey data of the synchrotron monuments were calculated by the free network adjustments. These monuments were referenced by the 1st order monuments.

2.5.3 The results of the survey of for the synchrotron monuments

Fig.13 shows the error ellipses of the synchrotron monuments. The results of the survey for the synchrotron monuments are shown in Fig.14.

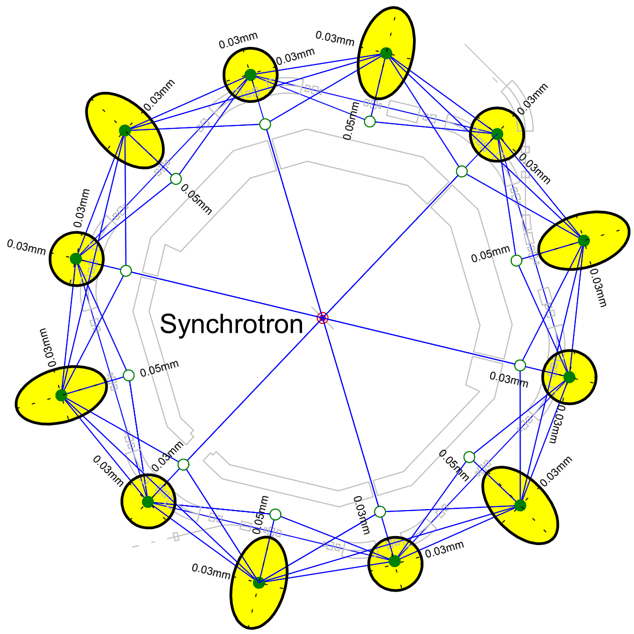

Fig.13 The error ellipses
of the synchrotron monuments

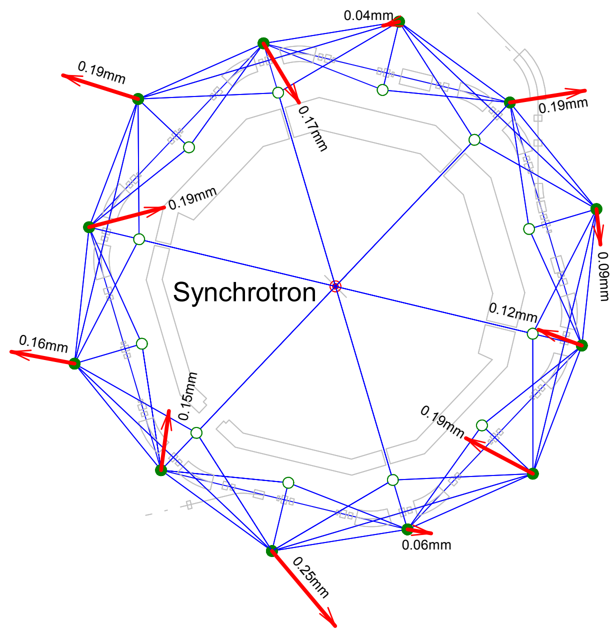

Fig.14 The results of the synchrotron monuments

3. THE ALIGNMENT FOR THE SYNCHROTRON RIG

3.1 Prealignment

The prealignment is a first phase of the alignment. Each machine component will be aligned individually from the geodetic survey coordinate. In HIBMC, these coordinates are the 1st order, 2nd and synchrotron monuments.

3.2 Parameters for alignment

The next phase of the alignment is the precise alignment and the final smoothing. Therefore, it is necessary to transform into the coordinate system of each component from the geodetic survey coordinate system.

Fig.15 shows parameters for alignment with each component. The alignment for *S*, *X* and yawing had been measured with the laser tracker.

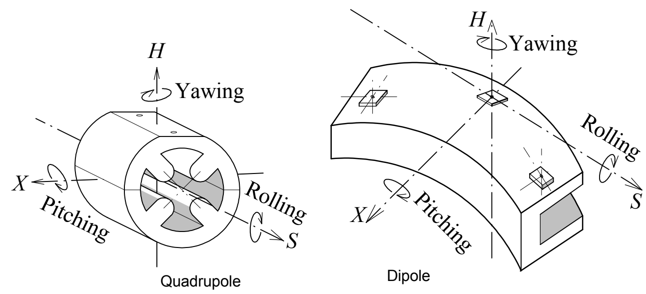

Fig.15 parameters for alignment

The alignment for rolling and pitching had been measured with digital inclimeter. And the alignment for *H* has been measured with the tilting level N-3.

With this coordinate transformation, the alignment becomes possible to close in the area where is surrounded with 1st order, 2nd order and synchrotron monuments

3.3 The tolerance of alignment for each component

Table 1 shows the tolerance of the alignment for each component.

Table 1 Tolerance of the alignment of alignment

Components	Reference components or monuments	Required precisions (mm)		Tilt (Pitching, Rolling, Yawing) (mm/m)
		X and *Y*	Beam stream	
Dipoles	Dipoles Monuments, Level marks	±0.1	±0.5	±0.1
Multipoles	Dipoles (mainly) (monuments level marks)	±0.1	±0.5	±0.5
Steering magnets	Quadrupoles	±0.5	±0.5	±0.5
Beam position monitors	Quadrupoles (mainly) (monuments level marks)	±0.5	±0.5	±0.5

3.4 The method of the alignment

The alignment process of each component, dipoles, multipoles, and the other components was following as Fig.16.

First of all, these machine components were adjusted the height to the beam height and they were adjusted the tilting to the horizontal plane at the same time. They were adjusted alternately to the beam height and the horizontal plane. And the machine components have converged to the ideal beam height and the horizontal plane.

Then they have been adjusted these components by the laser tracker to the direction of the beam stream and on the beam line. It adjusts to be longitudinal at the component on the real horizontal plane.

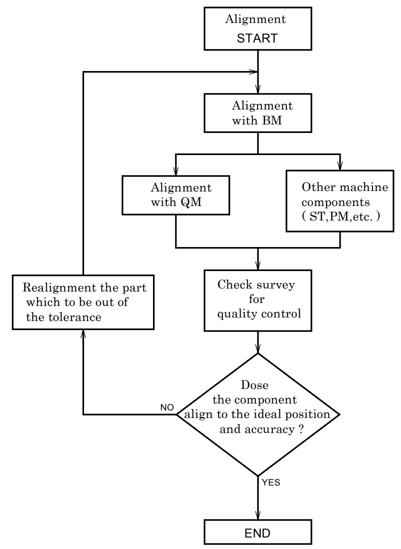

Fig.16 The flowchart of the alignment

3.5 The alignment for the dipoles

First, it has been adjusted these dipoles. This is the reason why the alignment at the straight section in the synchrotron ring is based on these dipoles.

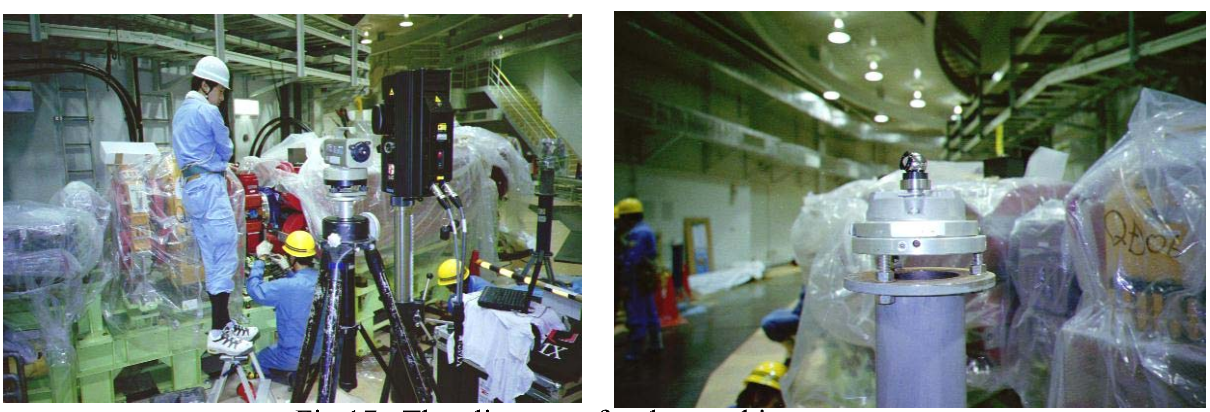

Fig.17 The alignment for the machine components

3.6 results of the alignment for the dipoles

Fig.18 shows results of alignment for 12 dipoles. It shows these differences from final aligned positions to designed positions.

These results of alignment are satisfying the tolerance for these dipoles (Table 1), with maximum displacement of -0.12 (mm/m) in the pitching.

3.7 The alignment for the quadrupoles

Next it adjusted quadrupoles which were based on dipoles. These quadrupoles have data of the difference between magnetic center and magnet yoke center. It is very convenient for the laser tracker to determine component's position with such a difference.

3.8 results of the alignment for the quadrupoles

Fig.19 shows results of alignment for 24 quadrupoles. It shows these differences from final aligned positions to designed positions.

These results of alignment are satisfying the tolerance for these quadrupoles (table 1), with maximum displacement of -0.12 (mm/m) in the rolling.

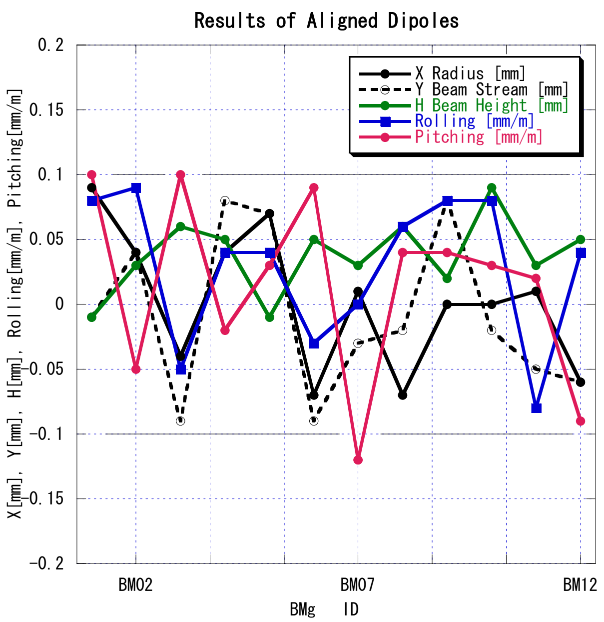

Fig.18 Results of the alignment for Dipoles

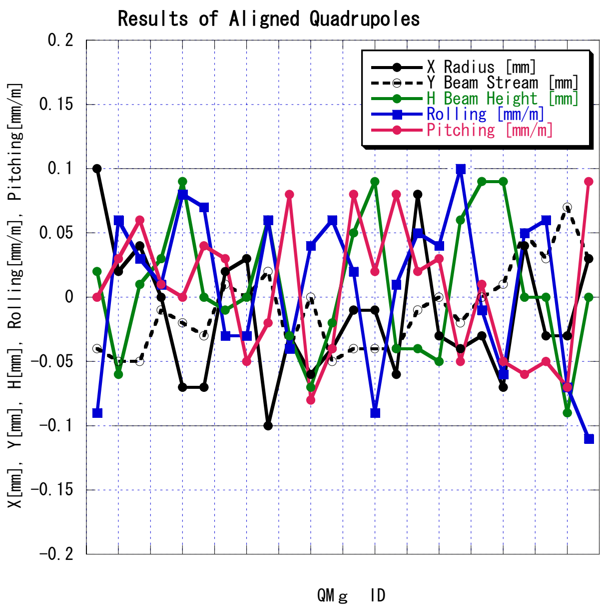

Fig.19 Results of the alignment for quadrupoles

4. REFERENCES

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[3] K.Mishima, T. Ishii, *Survey And Alignment of the Siam Photon Project,* Asian Particle Accelerator Conference 2001 (APAC'01)