Periodic Seasonal Variation of Magnets Level of the STB ring

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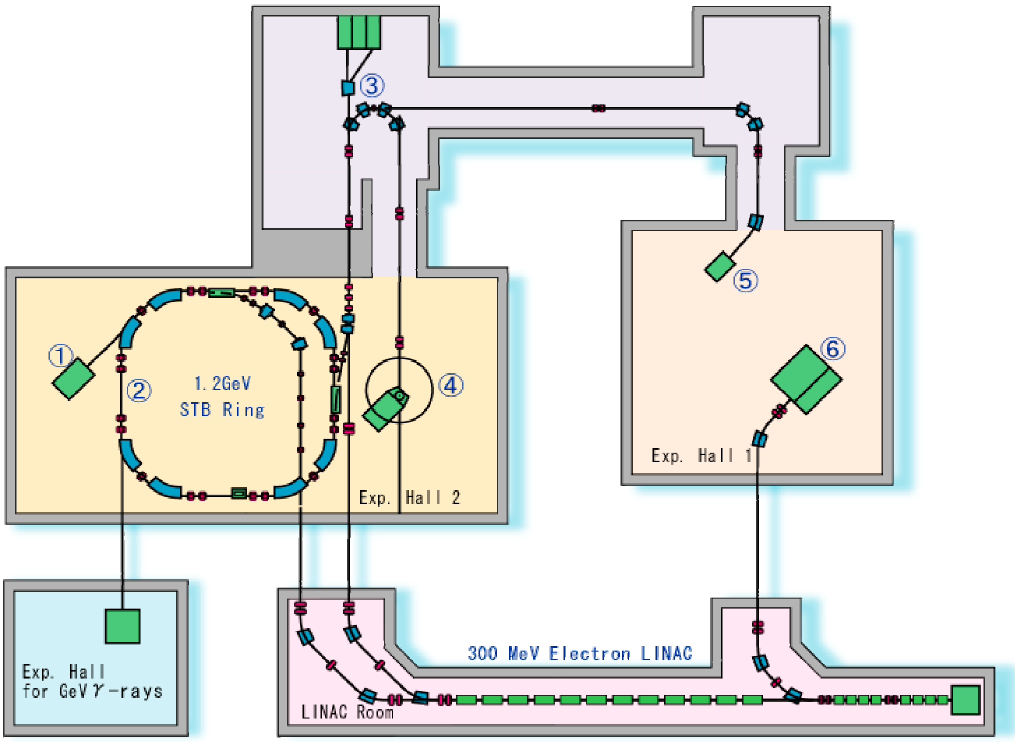
1. Introduction

The STretcher-Booster (STB) ring, a 1.2 GeV electron synchrotron, was completed in December, 1997 at the Laboratory of Nuclear Science (LNS), Tohoku University.Since then, heavy objects such as concrete blocks for radiation shielding and a spectrometer magnet for nuclear physics experiments were placed near by the ring. A total weight of these objects is more than 400 tons. Re-surveying of magnets alignment was started after three years passed since the STB ring was commissioned. This has been done a few times a year. The purpose of the alignment inspection is to investigate whether the installation of the heavy apparatus near the ring dislocates the position of the magnets. In addition, very recently a new building of an experimental hall for use of high energy γ-rays from the electron beam in the STB ring was constructed close to the building of the STB ring. Accordingly we wondered that the magnets position might be dislocated. In this article, the magnets level after the construction of the new building as well as an expected change of the closed orbit distortion (COD) in the STB ring are reported, and future subjects are also discussed. Figure 1 shows the machine layout of the LNS facility.The STB ring is in the experimental hall No.2.



Experimental Area — Main Equipment

① 1.2 GeV γ-ray Experiment : SCISSORS system. TAGX system
② 1.2 GeV Electron Experiment : Internal target system (planned)
③ 300 MeV Pulsed Beam Experiment : Coherent radiation measurement system
④ 300 MeV Continuous Beam Experiment : Large Dipole Magnetic Spectrometer
⑤ 300 MeV γ-ray Experiment : Photon Tagging system
⑥ 60 MeV Pulsed Beam Experiment : High-intensity electron beam radiation system

Fig.1 Accelerator layout of the Laboratory of Nuclear Science, Tohoku University.

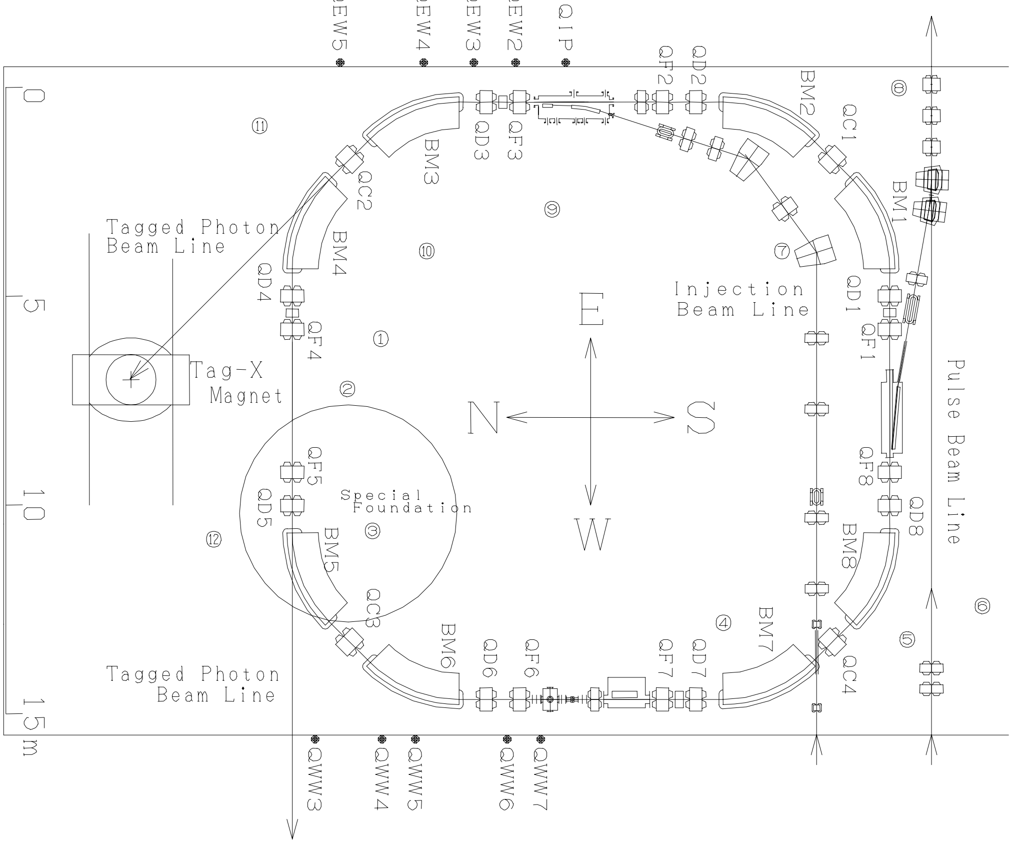
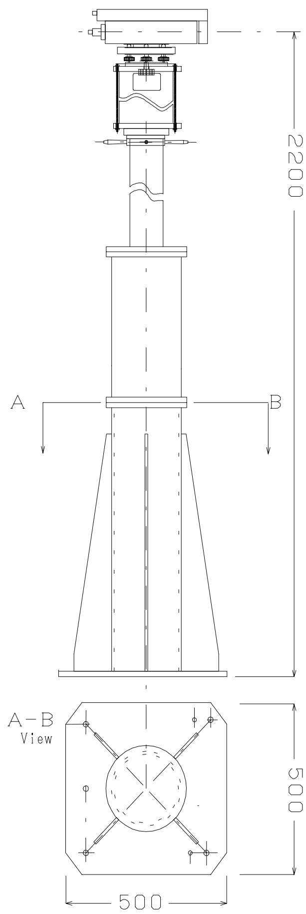


Fig2 The STB ring in the experimental hall No.2. A circular mark on the BM5 shows a part of the base which was separated from the floor of the hall. Small circular marks with numbers show setting points of surveying poles. QIP, QEW and QWW on the east and the west walls are marking points on the walls.



There are three modes of operation of the STB ring: i)the stretcher mode, in which a pulsed-beam from the electron LINAC is converted to a quasi cw-beam for nuclear experiments, ii)the booster-storage mode, in which the beam energy is ramped up to 1.2GeV and then the electron beam is used for high-γ experiments and internal-target experiments, and iii)the booster mode is going to be used as an injector for a planned storage ring of synchrotron radiation.

In advance of the commissioning of the STB ring, a final accurate alignment was carried out for 8 bending magnets and 20 quadrupole magnets in the beginning of October, 1996. A tolerance of the magnets positioning of 0.1 mm was settled by an theoretical estimation of allowable beam orbit distortion.

Fig.3 A pole for level survey.
It is made of iron-steel of about 100 kg, the height of 2.2 m can take aim at the targets.

2. The surveying apparatus and method

Fig.4. The scenery of the surveying at the east side straight section of the ring. The height of the standard target for the aiming is set to be 2.2 m because of the 2.0 m-tall radiation shields inside of the ring.

The surveying instrument is WILD－NA 2 with GPM3 parallel plate micrometer of Leica and its specifications are,

shortest focusing distance	1.6m
magnification of the telescope	40 x
Setting accuracy	±0.3"
device for levelling up	self adjustable with the compensator within working range of ～30'

The sphere target of Taylor Hobson loaded onto the pedestal is taken aim at. The machining accuracy of these parts are within 10 μ m. The pole for surveying was originally made in KEK but an additional iron pipe of 0.4 m-tall is put on the top in order to get the sufficient height of 2.2 m for aiming. The reason why we use such taller standard target position is as follows. To protect various electronic devices inside the STB ring against the strong radiation particularly in the stretcher-mode operation, the height of concrete shield block is required to be about 2 m. It may be well recognized by Fig. 4. Consequently the standard level height of 2.2 m at the top of the B-magnet is being employed as the standard level height for the surveying.

Since the top face of the Q-magnet yoke is 166 mm lower than that of the B-magnets, an iron bar with inscribed target line is put onto the standard level surface of the Q-magnets for height compensation so that the surveying can be done at the same time with the B-magnets.

Numbers of standard surface plates for alignment on the top face of the magnet yoke are 3 for the B-magnets and 2 for the Q-magnets, respectively, along the design beam orbit. Each plate contains a hole with a diameter of 40 mm, and the pedestal of the surveying target can be plugged in. Each surveying point of one magnet is here numbered from the upstream of the beam trajectory. For example, BM5-1 means the 1-st surveying point of the bending magnet No.5.

Deviation of the magnetic center from the central beam orbit is deduced from the measured level data with the compensation heights of the pedestal and the target bar.

At the beginning we were troubled to find locations for surveying whole ring because of very tight spacing of devices. However the locations of level surveying has been fixed to be about 10 places and there is no dead angle. The temperature of cooling water for the magnets is controlled to be 20±2℃ for 24 hours, and the room temperature is normally kept at 25 ± 1℃. The air temperature outside of the building is roughly - 2～7℃ in February, 22～28℃ in June, and 30～35℃ in August .

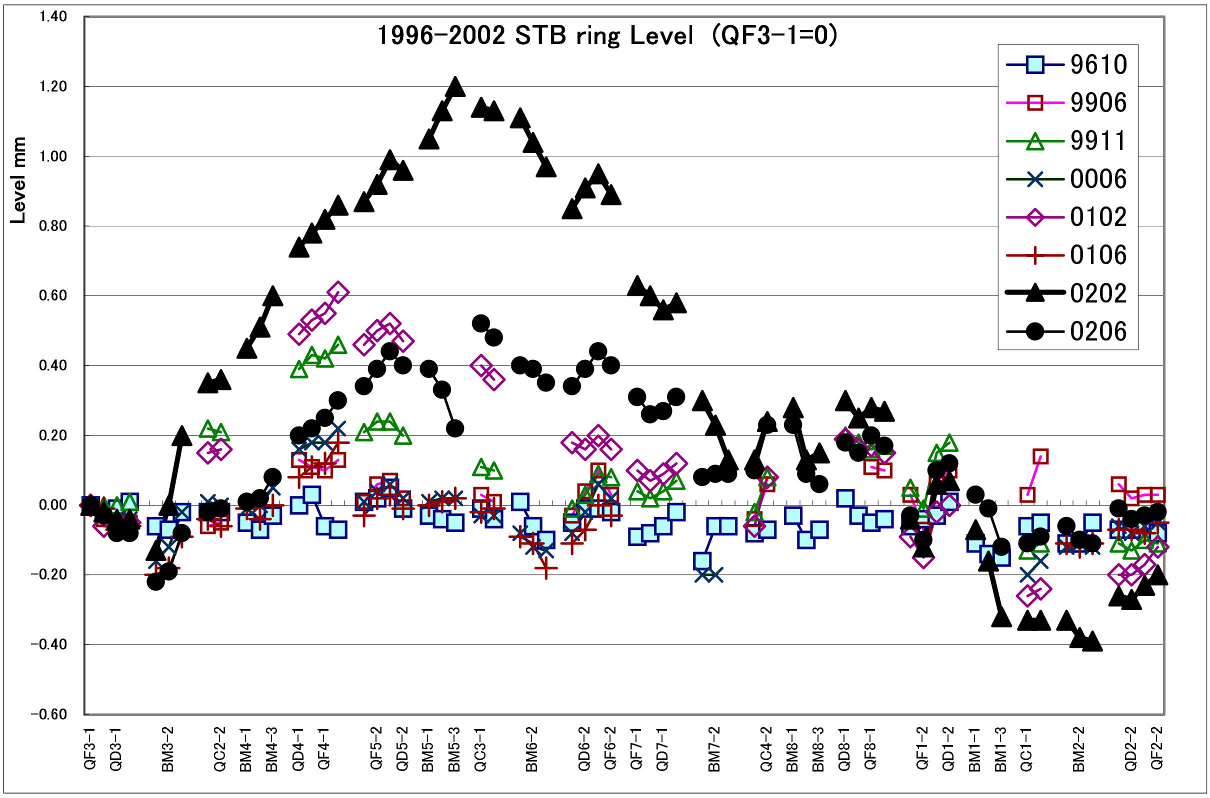


Fig.5 Measured magnet level plotted by setting the level of QF3-1 to be zero. An indication 0202, for example, means measured in February, 2002.

3. Measured variation of the magnet level

Surveying data of the magnet level measured so far are shown in the Fig.5. In the figure, the data is plotted by setting the point of QF3-1 to be zero, which is located downstream the beam injection point. The vertical displacement in June, 1999 was in the range of ± 0.1mm, which was fairly small in spite of that 3 years had passed since the final alignment. However, the range of the displacement expanded to about 0.6 mm in November, 1999 that was only 5 months later. If we omit the data in 2002, this change of the magnet level show the same pattern every year. In other words, deviation of the magnet vertical positions becomes smaller within 0.5 mm in the summer season, and it is getting bigger than 0.8 mm in the winter season conversely. Particularly displacement at the arcs from BM3 to BM5 including the north straight section is conspicuous. Taking a look at the data in 2002, the deviation was expanded up to 1.6 mm, which was probably due to construction of the new building. However, after finishing the construction that was found to be recovered again in June, 2002 (the latest data measured in September, 2002 is shown in Fig.7).

Back to Fig.5, one can see that relative vertical displacements of QF5, QD5, and BM5 are not much changed each other. It turned out that the floor base of these magnets is independent from other places of the ring. Because the very old experimental hall No.2 had been a target room of nuclear physics experiments, not constructed for accelerators, a large spectrometer used to be placed on this area. We noticed that these 3 magnets are put on a column base of the spectrometer with a radius of 2.6 m, and confirmed by old documents that the surveying target of QD5-2 is located around the center of the base. This independent base which is already shown in Fig.2 is completely separated from the floor structure of the experimental hall No.2, and its maximum load is 100 tons/m^2.

Because the seasonal variation of the magnet level is considered to result from the distortion of the building itself, the QD5 magnet is expected to be not affected by the distortion, so that it had better to consider the surveying points of QD5-2 as the reference point to discuss the measured data.

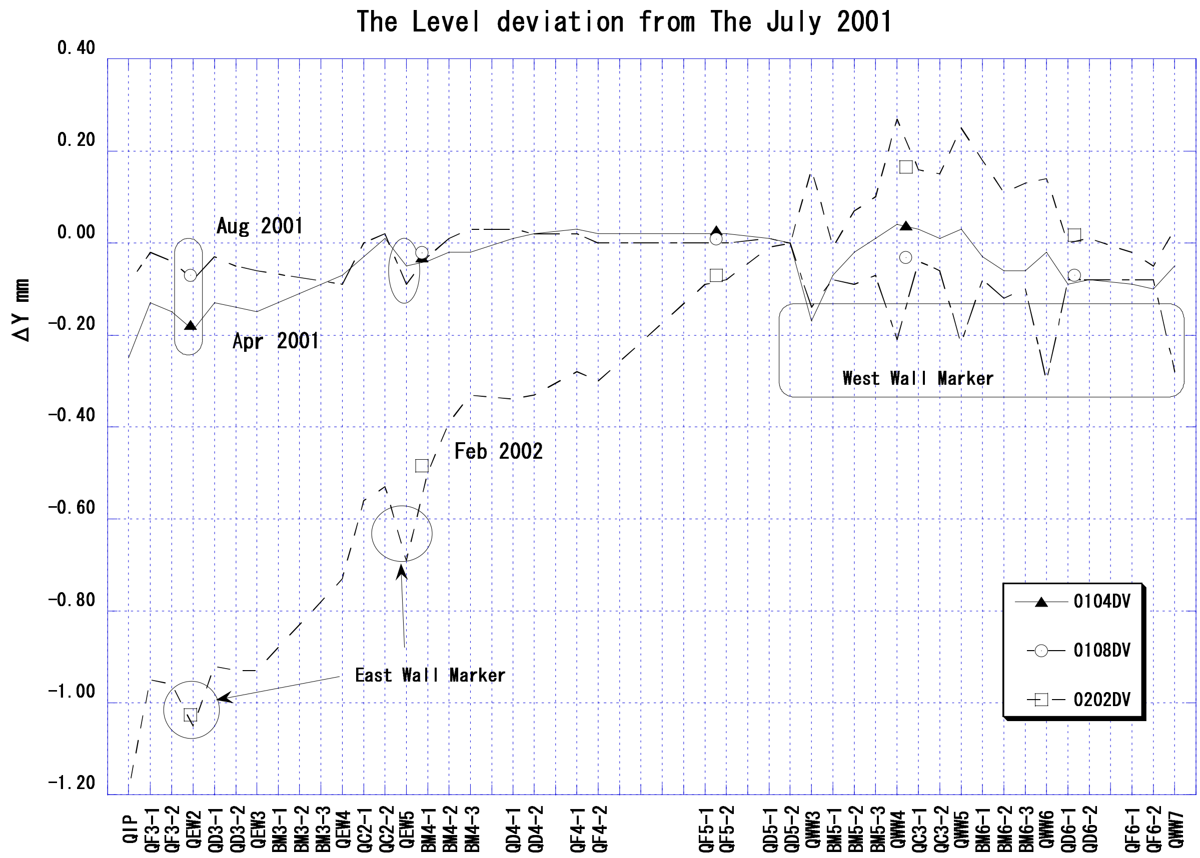


Fig.6 The deviation of each surveying term relative to the data on June, 2001 is shown for the north straight section.
There is no big change in level data in a warm term from April in 2001 till August. Because of influence of the digging construction in February, 2002, the inclination of the east wall becomes the past maximum, and the inclination of the magnet around that east wall slopes becomes to be the same again.

Figure 6 shows measured magnet levels including reference markers of the east and west walls of the hall, which were taken from April, 2001 until February, 2002. To investigate the seasonal distortion of the building, the data of the reference markers on the walls are plotted next to that of the magnets near by. There is no big change can be seen in a term from April until August in this figure. When the summer comes, the wall markers of the west side begin to tilt a little (oval symbols in the figure). We found the floor level is stable after the climate gets warm and it continues from April till early October. When the winter comes, the east side of the ring begins to go down and the west side goes down together. Except for the data of February, 2002 (new building had been under construction), the floor level of the experimental hall No.2 is seasonally varied and the wall as well. A critical temperature of which this change begins seems to be around 15℃.

One-year observation of the variation taken from June, 2001 until June, 2002 is shown in Fig.7. In a term of February, 2002, the deviation of the magnet level reached 1.6 mm which was almost double of the usual winter level. The east straight part from QC1 to BM3 went down to the lowest position ever measured. A part indicated by a circle shows the magnet levels of BM5 for before and after re-alignment. The reason of this change is explained in the following chapter.

Note error bars are not put on the surveying data of February, 2001. Because there was some imperfection for setting the surveying pole and then the systematic error was a bit large, it might be hard to see the plots if the error bar is left. Though there are a few data, it seems to be almost flat in June, 2001.

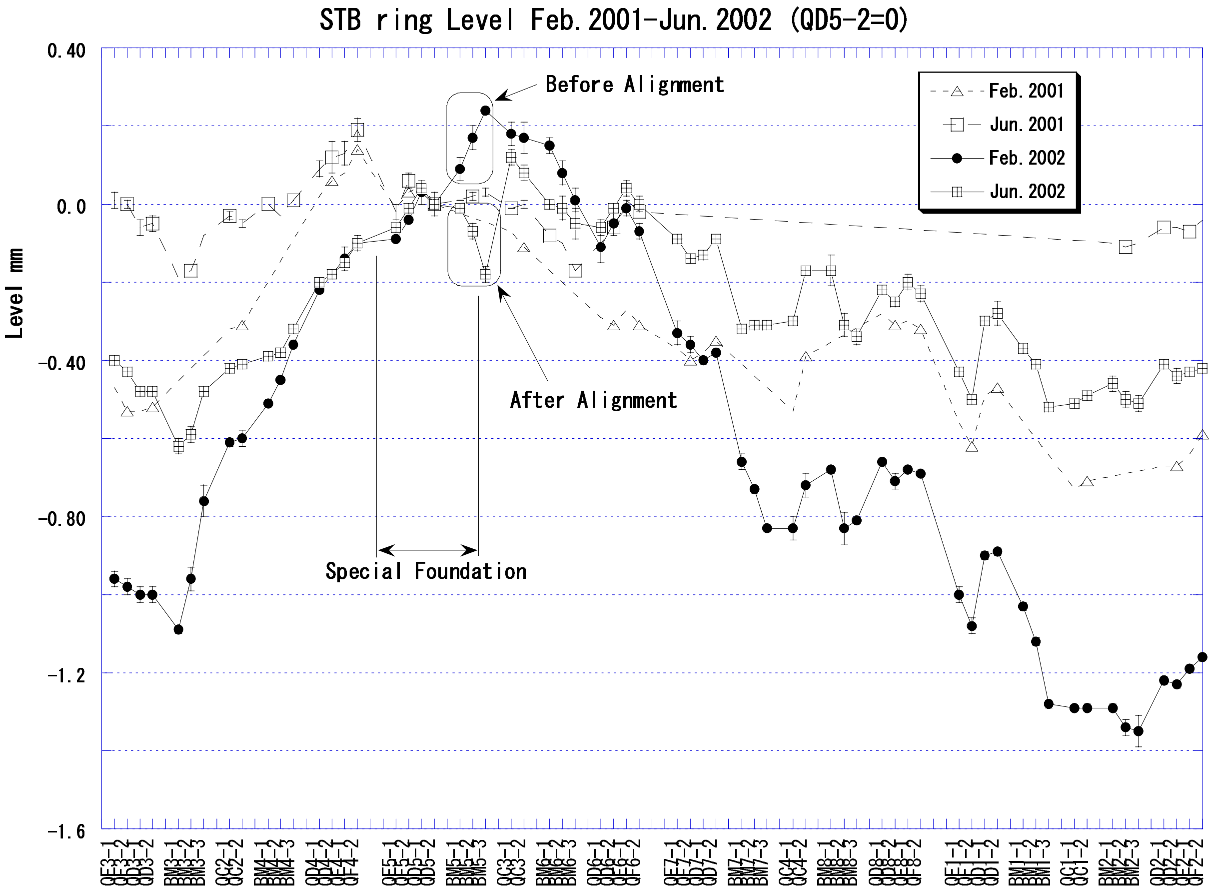


Fig.7 Level data from February, 2001 till June, 2002 plotted relative to QD5-2.
The Data of 2002 are shown by solid line.
The circular marks in the figure denote before and after the BM5 re-alignment.

4. Influence of the construction of a new building

Since the accelerator complex are underground, digging construction to built the new experimental hall began in January, 2002. It was filled up again with the soil in late May, and construction was completed in July. The new experimental hall will be used as a target room of Bremsstrahlung γ-rays produced from an internal target wire inserted into the STB ring. The energy of the γ-rays should be tagged by detecting the electrons inside the bending magnet, so that the apparatus around BM5 was also restructured. In addition to putting a new vacuum chamber, a new movable girder for BM5 was installed, which will be used to make a sufficient space between the magnet return-yoke and the vacuum chamber when they prepare the tagging detector.

After installing the girder, three-dimensional positioning measurement by the theodolites and level measurement were done for BM5. Before the re-installing of the girder, BM5 was a bit tilted. That is BM5-3 was lower than BM5-1 by 300 μ m because of the winter season. We intentionally tilted it by 150 μ m at the re-installing in May. However after the construction of the new building was completed, BM5 was found to be conversely tilted by 200 μ m. In Fig.8, the variation of the magnet level observed before and after the construction of the new building is shown.

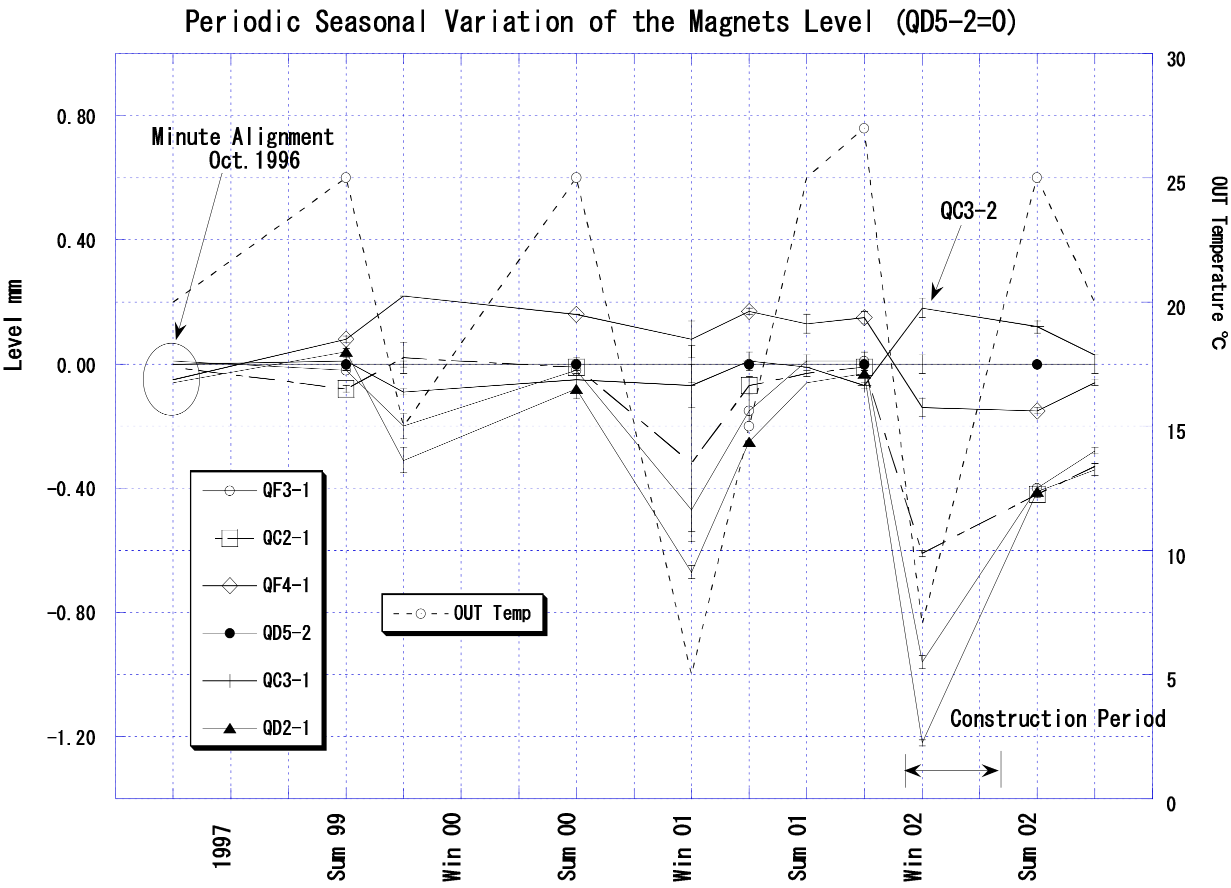


Fig.8 Periodic seasonal variations of the magnets level in the ring until now. QC3-2 (in the side of the west wall) is raised, and other magnets go down greatly in February, 2002 term because of the influence of the new experimental hall construction.

It is clear that the movement of BM5, QC3, BM6, QD6 and QF6 which are located near the west side wall was much affected by the building construction. Although the tilt of BM5 has been gradually going back to the usual level, the west side seems to be still sinking which was found a measurement in September. This behavior has never observed so far, so that we have to watch it.

The building of the experimental hall No.2 was built on a stable ground of planed rock, and the base of the floor was designed to prop 10 tons/m^2 except small area for the spectrometer where QD5 is now sitting. Most part of the hall is underground and only the roof is above the ground, so that the air temperature may not much affect inside the hall.

Allowable total load on the floor is estimated to be 500 tons, while the actual load amount to be 700 tons. Nevertheless the variation of the floor level is considered to be caused by influence of the air temperature, because the vertical position of the each magnet comes back to near own original position in June every year. For complete interpretation of the dynamics of the floor distortion, investigations from view of the geology and the building engineering will be necessary.

5. Influence for closed orbit distortion (COD)

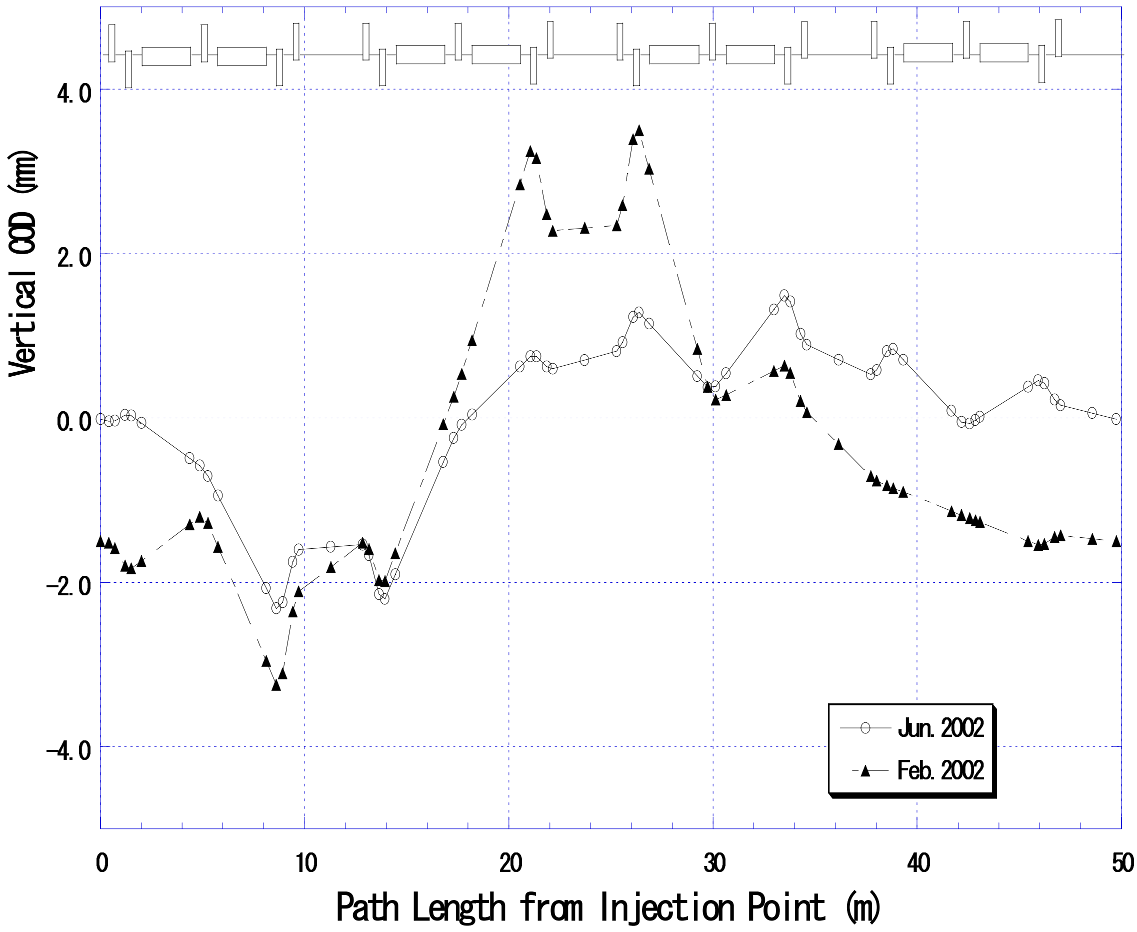


Fig.9 Expected vertical COD in the STB ring at February in 2002 and June.

Expected vertical beam orbits in the STB ring calculated with the measured level data of February and June, 2002 are shown in the Fig.9. As one can see, difference of the orbit distortion reaches more than 5 mm. In the actual operation of the STB ring, the correction of COD has been done at each boot-up of the ring for every machine time. The operating point of the betatron tune has been not standardised because the machine tuning is still under way. Therefore the COD is not able to be directly compared with the calculated one. However we have noticed that the beam orbit is seasonally varied. In the booster mode operation, the COD correction can be done for the injection energy (usually 200 MeV), while at the flat-top energy the COD is being not corrected because of no sufficient strength of steering magnet.

The most serious influence of the variation of the magnet level may be a change of the beam orbit of extracted beam in the stretcher operation. It is very difficult to make an identical orbit by the COD correction in the ring all the time, so that tuning of the transport of the extracted beam suffer a complicate procedure. In addition to the magnet level variation, we have problems on stability of the magnet power supplies. Correlation between the COD and the seasonally varied magnet positions is not clear at the moment. However the machine operation and the beam diagnostics are getting much better recently, continuous surveying of the magnet level will be a useful data for a feedforward correction of the beam orbit.

The basic parameter of the STB ring and present Beam performance are shown in the following.

The basic parameter

Lattice Type	Chasman-Green (Double-Bend Achromat)
Superperiodicity	4
Circumference	49.75 m
Betatron Tune	horizontal 3.30 vertical 1.20
Momentum Compaction Factor	0.0378
RF Frequency	500.14 MHz
RF Voltage	150 kV
Harmonic Number	83
Maximum Energy	1.2 GeV
Injection Energy	0.2 GeV or 0.15 GeV

The beam performance of the ring

Booster Mode (October, 2002)

Maximum Energy	1.2 GeV
Maximum Beam Current	50 mA
Beam Lifetime at 1.2 GeV	1.5 min (50mA) 10 min (10mA)

Stretcher Mode

Energy	150 ~ 200 MeV
Extraction	Third order resonance
Maximum Average Current	~ 1.3 μ A (at 200 MeV, 300 Hz repetition)
Extraction Efficiency	approximately 60 %

6. Future subjects and prospects

There are some problems in the surveying. In case of that the surveying point is closer than the shortest distance of the level apparatus of 1.6 m, the aiming cannot be performed and some data are missing. The measured data seems to be dependent on specific surveying person.

To improve the precision of these data, a device which allow us to survey rapidly without personal individual deference is required. At present, level measurement by using water pipes is examined. Those characteristics are mentioned in the following.

A level surveying by using the telescope contains only data inside the focusing range of 5 ~ 7 m, so that the measurement for the whole ring cannot be done at the same time. Consequently the surveying has to be done many times so as to connect the data altogether. This procedure does not take only a long time but also has a possibility of including large error. However if we use the water pipe device together, an absolute difference between places separated by a longer distance can be directly measured and then the error by disconnection of the data along the ring circumference will be reduced drastically. Furthermore the water pipe level meter is not expensive and easy handling for surveying. Of course the atmospheric pressure has to be taken into account during we watch the seasonal variation of the magnet positioning.

The author deeply appreciate prof. Hama for his cooperation and advice.

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