TUNNEL LEVEL VARIATION IN THE SuperKEKB INTERACTION REGION

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Abstract

SuperKEKB is an electron-positron collider, which aims to achieve a peak luminosity 40 times higher than that of KEKB. The vertical beam sizes of both rings are reduced to 50 - 60 nm at the interaction point, which accounts for a factor of 20 in the luminosity increase, and the beam currents are doubled from those of KEKB. Tunnel motion can be a critical problem in realizing the collisions of such small beams. A hydrostatic leveling system, comprising 18 sensors, was installed on both sides of the interaction point to monitor tunnel level variations continuously. The effects of heavy rain, and the installation of radiation shields, on the tunnel floor level were clearly seen. The HLS data obtained during SuperKEKB construction and commissioning are reported.

INTRODUCTION

Tunnel level variation can be critical for realizing stable collisions of small beams at SuperKEKB [1,2,3]. In order to monitor tunnel floor level variation, we installed 18 capacitive Hydrostatic Levelling System (HLS) units manufactured by BINP [4] in the local chromaticity correction (LCC) sections, which extend to ~100 m from the interaction point (IP) on either side, as shown in Fig. 1. The floor level has been continuously monitored since the installation of the HLS units in August 2015. The effects of outside air temperature, rainfall, tides and the construction are shown in the following sections.

FLOOR VARIATION DUE TO WEATHER

Figure 2 shows the floor level change over approximately an 8-month period, where levels relative to the reference sensor located at the left end in Fig. 1 are plotted. The sensor label "TL094" indicates that the sensor is located ~94 m to the left of the IP, for example. The floor near the IP started sinking with respect to the reference point (or the left end and right end of the LCC section started floating with respect to the IP) and reached the lowest level in winter. It started floating up again, as spring came. The average temperature outside and precipitation are shown in Fig. 3 for comparison. The floor level variation appears to follow seasonal changes of the outside air temperature. It should be noted, however, that the tunnel is located at ~11 m below the ground surface, and that the temperature variation is much smaller there than that of the outside air. The mechanism of the seasonal tunnel motion is not well understood at this point.

The IP floor started sinking rapidly in early September, which seems to have some correlation with the precipitation. We had a localized torrential downpour in this area at that time and this likely changed the underground water level and the tunnel level. A few weeks of relatively dry weather followed, which seemed to push up the IP floor. It took about a few months for the tunnel (or the underground water) to settle down. The seasonal change of the floor level is observed to be more than 1.2 mm over the approximately 8-months period. Heavy rainfall can change the floor level as much as 0.5 mm as indicated in Fig. 4.

Tidal effects are also seen. Figure 5 shows the floor level change over two days monitored by two HLS units. Tidal data from the nearby port are plotted for comparison. A clear diurnal effect is seen in the floor motion and the peak-to-peak was measured to be approximately 25 μm during this period.

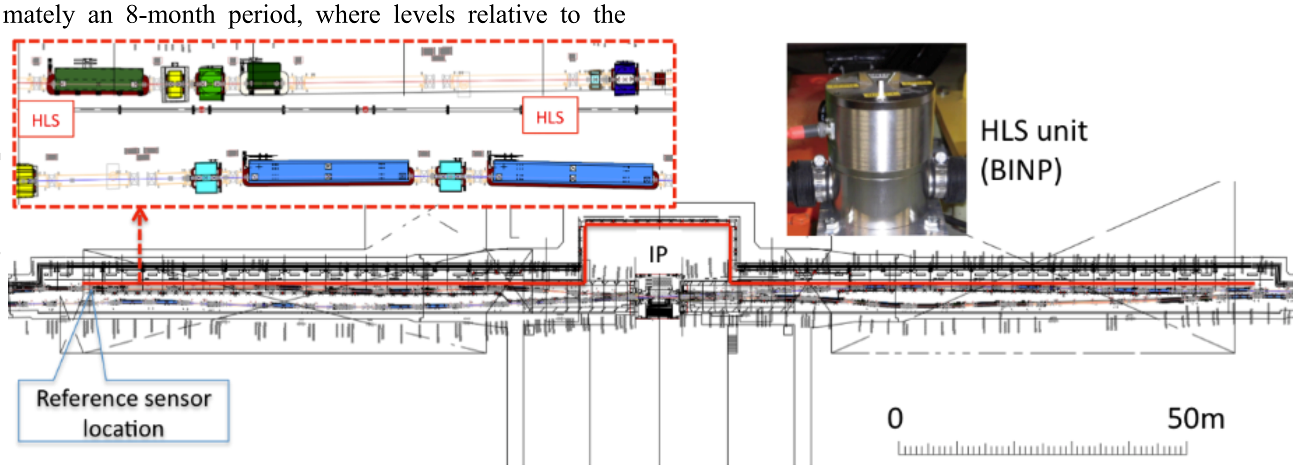

Figure 1: 18 HLS units are installed along the red line.

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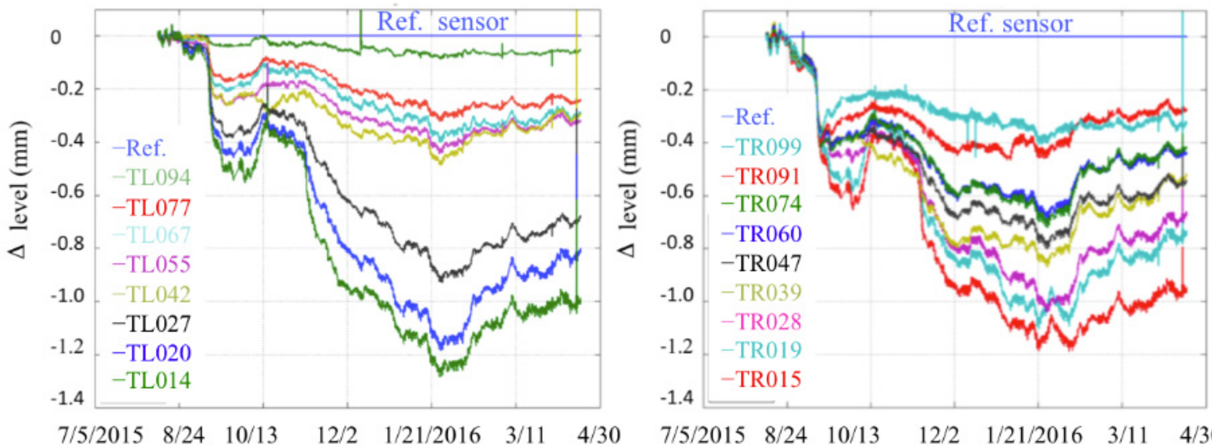

Figure 2: Floor level change at the left side of the IP (left) and the right side of the IP (right) are shown. Floor level with respect to the reference HLS unit has been plotted, beginning from August 2015.

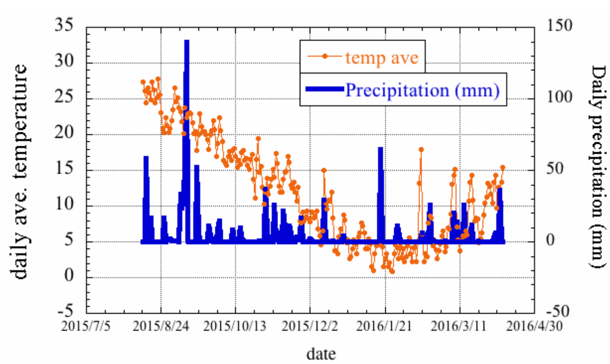

Figure 3: Precipitation and outside air temperature.

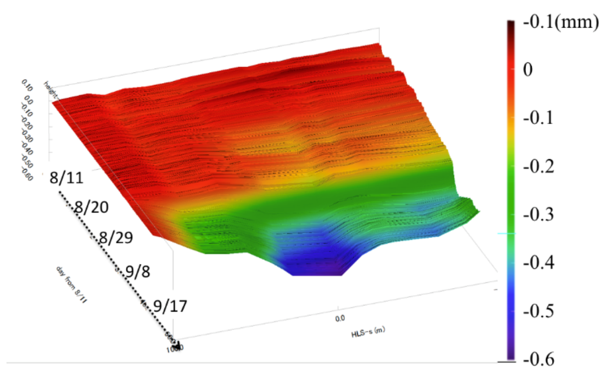

Figure 4: Effects of precipitation in early September.

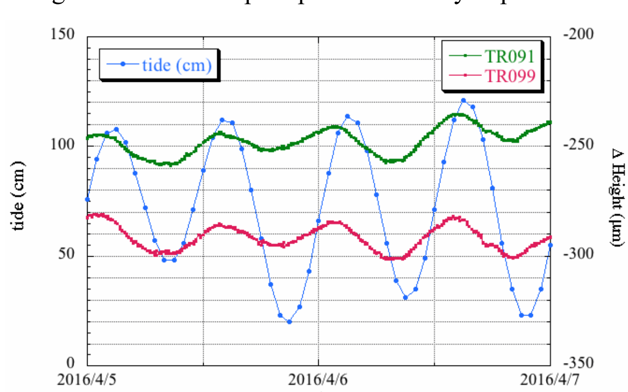

Figure 5: Tidal data compared with the tunnel motion.

EFFECTS OF THE CONCRETE SHIELD

The IP and the sections ~30 m from the IP on either side are covered by radiation shields. They are made of reinforced U-shaped concrete units as is shown in Fig. 6. Each section weighs about 60 tonnes. The shields were installed after the installation and final alignment of the magnets was carried out. Floor sinking can ruin the precision alignment of the magnets near the IP. The floor levels during the radiation shield installation are shown in Fig.7. Two sections were installed per day, and three days were needed to complete the installation on each side of the IP. The sensors near the IP presented the largest variation of approximately 200 μm. This caused a misalignment of the magnets near the IP. We did not realign the magnets this time for the Phase I operation where no collision takes place. We will consider this for the Phase II luminosity run, where alignment of the IR magnets becomes more critical.

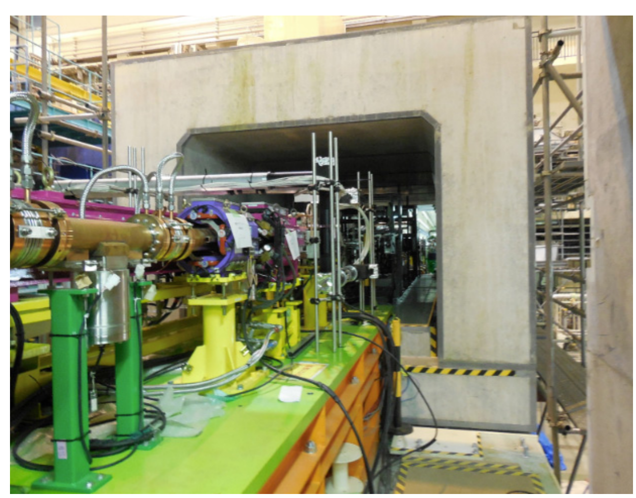

Figure 6: Radiation shield covering the beam line is shown.

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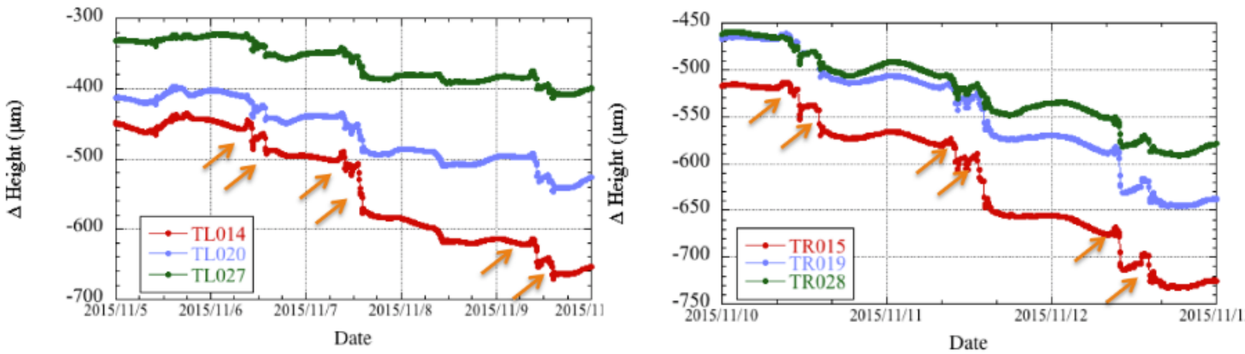

Figure 7: Level change due to the radiation shield installation.

EARTHQUAKE OBSERVED BY HLS

The 2016 Kumamoto earthquake hit the southern part of Japan in mid-April. The HLS units recorded the main shock (magnitude 7.3), which occurred at 1:25, April 16 (JST), as seen in Fig.8.

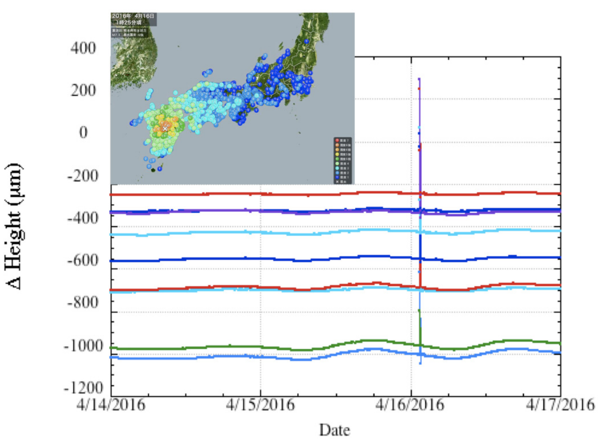

Figure 8: Floor level jump caused by the earthquake.

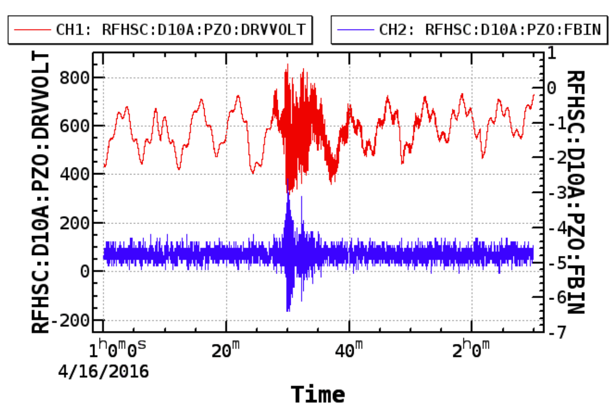

Figure 9: Variation of the tuner voltage (red) position (blue).

It was sensed by the other accelerator components, such as the RF tuner (Fig.9) and the displacement sensor, which measures the distance between a quadrupole magnet and its adjacent sextupole magnet (Fig. 10). It took about 4 minutes for the seismic wave to arrive at the SuperKEKB ring. Although the tunnel floor vibrated and disturbed the accelerator components, the abort system for the circulating beams was not triggered. This is likely because we were running the machine with relaxed beta-functions at the IP for vacuum scrubbing, and two beams were not colliding at that time.

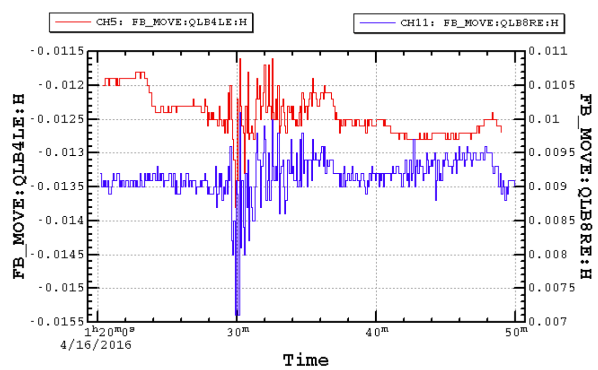

Figure 10: The variation seen in the displacements between two adjacent magnets.

CONCLUSION

We installed 18 HLS units in the LCC sections at the either side of the IP. Tunnel level variation has been monitored since August 2016 by this system. The tunnel level seems to vary with the weather, such as outside air temperature and precipitation (or/and ground water level). Tidal motion was also observed and the amplitude was approximately 25 μm. The effects of construction work around the IP were clearly seen. Since some of the construction work took place after the magnet alignment, re-alignment of some of the magnets is likely needed before the Phase II luminosity run. The 2016 Kumamoto earthquake caused a sudden change of the SuperKEKB floor level but did not result in a beam abort. The relatively slow variations of the tunnel level can be corrected by the orbit correction. A feedback of the HLS data to the optics correction and beam orbit feedback will be helpful for future SuperKEKB operation.

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