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FIRST TESTS OF SUPERKEKB FAST LUMINOSITY MONITORS DURING 2018 PHASE-2 COMMISSIONING*

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Abstract

The SuperKEKB e^+e^- collider aims to reach a very high luminosity of 8×10^{35} $cm^{-2}s^{-1}$, by using highly focused ultra-low emittance bunches colliding every 4 ns, it is essential to have an orbit feedback system at the Interaction Point (IP) to maintain the optimum overlap between two colliding beams. Luminosity monitoring systems including LumiBelle2 and ZDLM as input to dithering feedback system used to stabilize the horizontal orbit at the IP were developed and will be described, including the detectors, mechanical set-up, DAQ. Preliminary measurements and analysis of background and first stage luminosity monitoring data collected will be reported and compared with simulation.

INTRODUCTION

SuperKEKB, with so called "nano-beam scheme", beams with ultra-low emittance colliding every 4 ns, can reach a very high luminosity of $8\times10^{35}cm^{-2}s^{-1}$ [1]. With those small beam-beam parameters, luminosity is very sensitive to the beam-beam offset, which is caused by ground motion or other external source. In order to maintain the optimum beam collision condition, it's quite essential to have an orbit feedback system at IP [2]. For the vertical offset at IP, beam-beam deflection method is used for orbit feedback like the case of KEKB. For the horizontal plane, a dithering system similar to that operated in the past at PEP-2 [2, 3] was adopted, which is also called luminosity feedback system. The luminosity monitoring system including LumiBelle2 (Luminosity Monitoring for Belle-2) and ZDLM (Zero Degree Luminosity Monitoring) used for orbit dithering feedback in the horizontal plane were developed, and also tested during SuperKEKB Phase-2 commissioning. The systems and first results will be described below.

LUMIBELLE2 AND ZDLM

LumiBelle2 and ZDLM are two groups from LAL, CNRS and IPNS, KEK, respectively, with different way to measure the luminosity based on monitoring the Bhabha scattering at vanishing angles on both side of the IP.

LumiBelle2

For LumiBelle2, single crystal diamond detectors (sCVD from CIVIDEC [4], 4×4 mm^2, 140μm+C2, 500μ+C6) were installed outside of the beam pipe, 10 meters downstream of IP in Low Energy Ring (LER) and 30 meters in High Energy Ring (HER), the chosen positions have been carefully studied for fast luminosity monitoring with enough events rates from radiative Bhabha process to achieve aimed relative precision in previous study [5].

ZDLM

For ZDLM [6], which is based on the one used for KEKB in the past, Cherenkov and scintillator sensors (50× 15 × 15 cm^3) are used and placed at the same given positions in both rings just next to the sCVD detectors. It detects and integrates photons from radiative Bhabha events which are proportional to the luminosity in a certain luminosity range.

The advantage of having different detectors is to perform a cross check on the acquired data, provide some improve mitigation of systematic effects and to cover a large luminosity range.

EXPERIMENT SET-UP

Our new experiment set-up was installed in January 2018. A custom made window on the beam pipe inclined at 45 degrees coupled with a Tungsten radiator to maximize the electromagnitic shower [7] in LER was also implemented. For LumiBelle2, due to the lower detect efficiency for diamond detectors because of its small dimension, and different particles to be monitored in HER and LER, two diamond detectors with thickness of 140μm, coupled with current amplifiers (C2) and one with 500μm coupled with charge amplifier (C6) were installed in the LER, while two with 500 μm coupled with C6 and one with 140μm coupled with C2 were installed in the HER.

Mechanical Set-Up

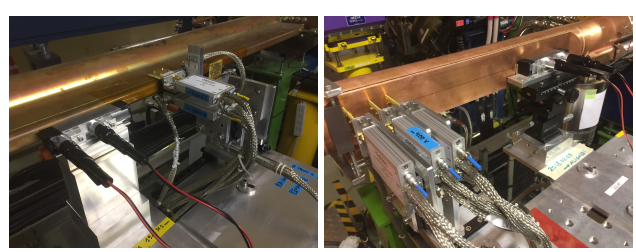

Figure 1: Mechanical set-up in both ring(lhs for LER and rhs for HER).

The mechanical set-up for luminosity monitoring system consists of pillars in each rings, as shown in Figure 1 (lhs for

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LER and rhs for HER). Each pillar supports two fixed plates for LumiBelle2 and ZDLM, respectively. Three diamond detectors for LumiBelle2 were installed with support on the plate, the first one is associated with a remotely controlled motor to scan in the horizontal plane over a range of 2.5 cm. Cherencov and scintillator detectors for ZDLM were installed on the other plate with carefully alignment nearby.

Date Acquisition System

Data acquisition system for both LumiBelle2 and ZDLM are located in Belle-2 Electronics Hut and are connected to detectors with long (100 m) half inch HELIAX cables, with which we can investigate the raw signal data without big attenuation.

LumiBelle2 DAQ functional diagram is shown in Figure 2. Four signals among six incoming are selected and fed to a GSPS 10-bit AC-coupled ADS board (FMC126, 4 DSP), requiring a clock at 1GHz (2×RF). The four ADC digital outputs are fed to a VIRTEX-7 FPGA board (VC707, Xilinx): calculating the Train Integrated Luminosity (TIL), Bunch-by-Bunch Integrated Luminosity (BIL), COUNT (event rate) and RAW SUM (direct summing all of samples) in real time, up to 1kHz, for the four incoming CVD inputs, simultaneously. The DAQ also contains a 16-bit DAC, providing 8 analog outputs with 1 kHz bandwidth, that can be configured independently to convert to any TIL, BIL, COUNT and RAW SUM values, from any channels.

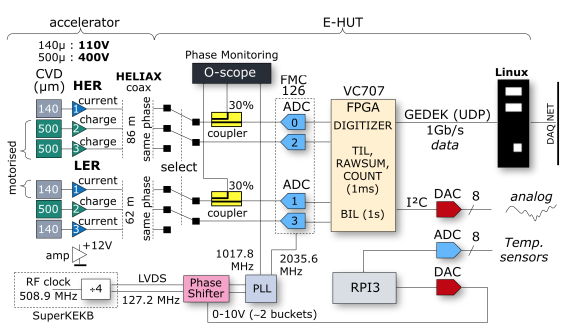

Figure 2: LumiBelle2 DAQ function diagram.

The DAQ has been initially designed to handle a maximum rate of one bunch each 2ns (all buckets filled). It makes use of two principles : (1) the luminosity is proportional to the CVD pulse peaks and rate and (2) there is a phase unicity between CVD pulses and RF clock, allowing to position the samples on the peak positions. As the ADC is AC-coupled, the mean value of the pulse train is always centered to 0V, which requires measuring also the pedestal of each pulse. This explains that we sample at twice the RF. As illustrated in Figure 3, for PHASE-2, the amplifiers are not fast enough and accept only 4ns-rate (Quasi-two bucket filled pattern). Here, the same rule applies: one sample (1) is positioned on the peak (The Phase Shifter on Figure 2 is used to find the optimum phase). Therefore, the pedestal is not obtained from the following sample (+1ns), but on the 3d sample (+3). The luminosity process integrates over 1ms the sum of all differences Diff(n) above a defined threshold to provide the TIL value. For the BIL, the same process provides 5120 sums each 1 second, corresponding to the unitary sums of each bucket. The COUNT value gives the number of pulses during 1 ms, therefore TIL/COUNT gives the mean pulse amplitude. The RAW SUM value calculates the sum of all samples above a defined threshold and is intended for channels using Charge Amplifiers with 10-ns FWHM, that cannot be handled easily by TIL/BIL formulae. All the real-time data are uploaded to a Linux machine through GEDEK protocol (ALISE) over UDP link at 1 GB/s.

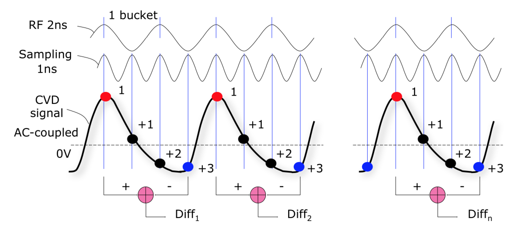

Figure 3: Quasi-2 bucket spacing for LumiBelle2 DAQ.

ZDLM DAQ is built based on NIM plug-in, including CF discriminator, gate and analog integrator with time constant of 1 ms, scheme is shown in Figure 4. Similar to LumiBelle2, ZDLM provide counts (event rate) and integrated signal at 1 kHz with analog way for TIL and BIL.

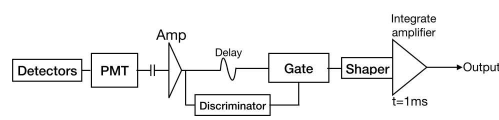

Figure 4: ZDLM DAQ scheme.

FIRST RESULTS IN PHASE-2

Phase-2 commissioning of SuperKEKB started with single beam commissioning from March, 2018, and now beam collision is ongoing. All the data for luminosity monitoring are saved and then analysis was performed associated with the archived EPICS data from the machine parameters.

Background

During the single beam commissioning, signals for LumiBelle2 and ZDLM come from single beam loss, mainly on Bremsstrahlung and Touschek [8]. Figure 5 shows an example of single beam loss signals, as well as the beam current and pressure as function of time. It shows a good correlation between signals and key machine parameters. A full simulation includes single beam loss generation, tracking with SAD and signal estimation in detector based on Geant4 was also done, vacuum profile after the final focus system insertion was also considered to weight the simulated results based on previous simulated vacuum profile [9]. Comparison between simulation and LumiBelle2 measurements in different condition are shown in Figure 6. Linear relationship between TIL and rates with the product of current and pressure prove that the main background signals come from Bremsstrahlung and Touschek processes. Simulated results

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are about 10% higher than measurements for LER and about 25% higher for HER [10], this can be explained by the fact that the simulated vacuum profile may be different from the reality at IP, where most of the detected beams are scattered. Also the threshold for experiment and simulation was not calibrated. The rate for LER is about 1000 times higher than HER because there is a custom made window coupled with a Tungsten radiator in LER, the ratio factor about 1000 is consistent with simulation.

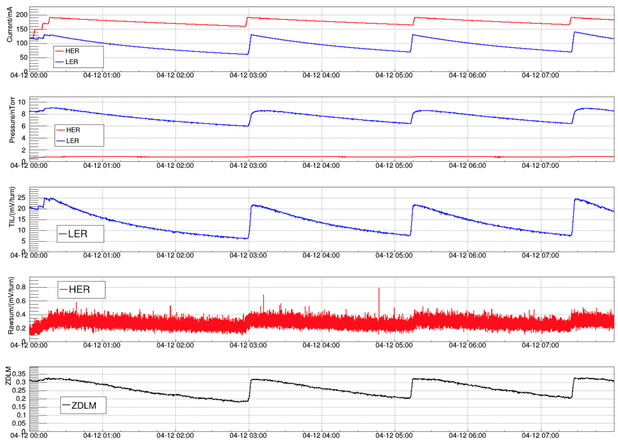

Figure 5: Signal from single beam loss.

For ZDLM, the counting rate in LER is about 2.76×10^5 PPS for a stored beam with an average current of 113 mA and average vacuum pressure in the sensitive region of 2.06 nTorr, which is about 12 times larger compared to LumiBelle2 in LER in the same situation. The difference can be explained by the different efficiency due to different type, size and position of the detectors.

First Collision

First collision of SuperKEKB was achieved on 25th, April 2018. Preliminary results of LumiBelle2 and ZDLM are shown in Figure 7. Since Bhabha events are the same in both side, when the correlated signals are observed in both side, and there is no other specific change which may cause this coincidence, it means the beams are colliding at IP. After the first horizontal beam-beam deflection observed in the early morning of 25, April, beam scanning in vertical plan was performed. First observable collision happened at 18:03 during beam scanning. While the statistics is poor in HER, it still correlates clearly with LER, it agrees well with our simulation.

CONCLUSION AND NEXT PLANS

The luminosity monitors of SuperKEKB are successfully installed in both rings and are taking data as beam loss monitors during single beam operation and as luminosity monitors during beam collision. Based on the past 1.5 months operational experience, both luminosity monitors: LumiBelle2 and ZDLM work well. First beam collisions were observed by both LumiBelle2 and ZDLM in both rings, this gives us good confidence that they can serve as input to the dithering feedback system to stabilize the horizontal beam orbit in the future in real time.

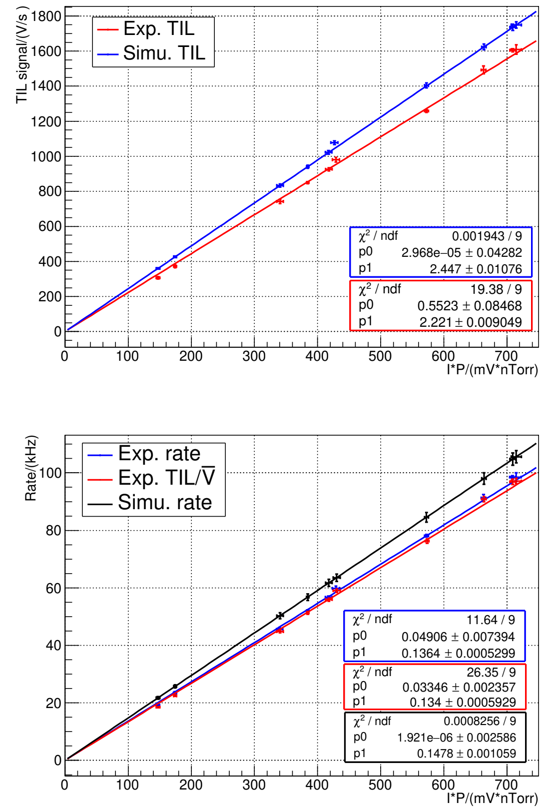

Figure 6: Comparison between simulated TIL and rates with mesurements.

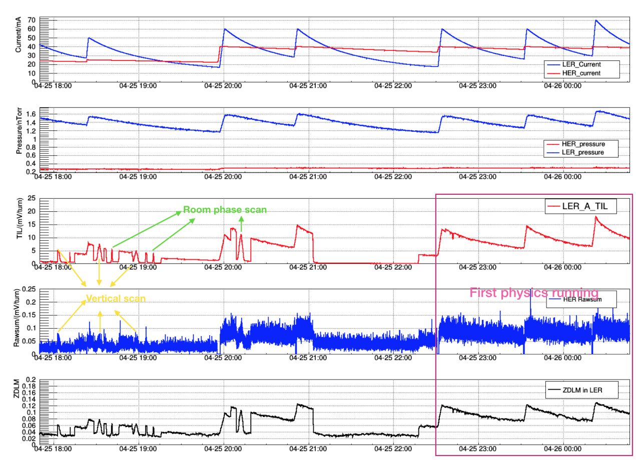

Figure 7: beam collision observed during phase and vertical scanning.

The comparison of simulation and experiment both on background and luminosity monitoring allows us to give some reasonable predictions of signals we will have to deal with for the future luminosity monitoring in Phase-3.

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REFERENCES

[1] Y. Ohnishi *et al.*, “Accelerator design at SuperKEKB”, Prog. Theor. Exp. Phys. 2013, 03A011 (2013).

[2] Y. Funakoshi *et al.*, “Interaction point orbit feedback system at SuperKEKB”, Proc. of IPAC’15, Richmond, VA, May 2015, paper MOPHA054.

[3] A. S. Fisher *et al.*, SLAC-PUB-12608, July 2007.

[4] CIVIDEC, https://cividec.at/

[5] D. El Khechen *et al.*, “First tests of SuperKEKB luminosity monitor during 2016 since beam commissioning”, Proc. of IPAC’15, Busan, Korea, May 2015, paper MOPMDB006.

[6] T. Hirai, S. Uehara and Y. Watanabe, “Real-time luminosity monitor for a B-factory experiment”, Nuclear Instruments and Methods in Physics Research, Section A, pp. 670-676, 11 Feb. 2001.

[7] C. G. Pang *et al.*, “Preparation of CVD diamond detector for fast luminosity monitoring of SuperKEKB”, Proc. of IPAC’17, Copenhagen, Denmark, May 2017, paper MOPAB027.

[8] D. El Khechen, PhD thesis “Fast luminosity monitoring using diamond sensors for SuperKEKB”, Université Paris-Sud, 2016.

[9] *M. Ady*, “Monte-Carlo simulation of ultra high vacuum and synchrotron radiation for particle accelerators”, PhD thesis, école polytechnique férérale de Lausanne (EPFL), July 2016.

[10] S. Di Carlo *et al.*, “Early phase-2 results of LumiBelle-2 for the SuperKEKB electron ring”, Proc. of IPAC’18, Vancouver, Canada, April 2018, paper THYGBE4, this conference.