FIRST TESTS OF SuperKEKB LUMINOSITY MONITORS DURING 2016 SINGLE BEAM COMMISSIONING

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Abstract

The SuperKEKB e^+e^- collider aims to reach a very high luminosity of 8 10^{35} $cm^{-2}s^{-1}$, using highly focused ultra-low emittance bunches colliding every 4ns. Fast luminosity monitoring is required for luminosity feedback and optimisation in presence of dynamic imperfections. The aimed relative precision is about 10^{-3} in 1ms, which can be in principle achieved thanks to the very large cross-section of the radiative Bhabha process at zero degree scattering angle. Diamond, Cherenkov and scintillator sensors are to be placed just outside the beam pipe, downstream of the interaction point in both rings, at locations with event rates consistent with the aimed precision and small enough backgrounds from single-beam particle losses. The initial configuration installed for the 2016 "phase 1" single beam commissioning will be described, including the sensors, mechanical set-up, readout electronics and first stage DAQ. Preliminary measurements and analysis of beam gas Bremsstrahlung loss data collected with the luminosity monitors will be reported and compared with a detailed simulation, for several experimental conditions during the SuperKEKB commissioning.

INTRODUCTION

We aim at fast luminosity monitoring during phases "2" (at luminosity=10^{34} $cm^{-2}s^{-1}$) and "3" (at luminosity=8x10^{35} $cm^{-2}s^{-1}$), to give a feedback on the train luminosity and bunch by bunch luminosity in the range of 1 to 10 ms. The "phase1" single beam commissioning of SuperKEKB [1] started on February and will last until the end of June 2016. During this phase, single crystal diamond sensors (sCVD from cividec [2], 4x4 mm^2, 500 μm) were installed and to serve as beam loss monitors and are placed in both rings downstream from the IP, outside the beam pipe, at 11 meters in the middle of a 2 meters drift after a quadrupole in the positron ring (LER) and at 27 meters in a drift after a sextupole in the electron ring (HER). The chosen positions are the good candidates for the fast luminosity monitoring, with enough event rates from the radiative Bhabha process to achieve the aimed precision. However, the goals of the background measurements are to test our luminosity monitors, confirm that the luminosity signals are not contaminated by single beam losses and to compare the collected data with a detailed simulation performed by SAD [3] and GEANT4. In parallel, the ZDLM [4] (Zero Degree Luminosity Monitoring) Cherenkov and scintillator sensors (50x15x15 mm^3) are placed at the same given positions in both rings just next to the sCVDs and have similar goals. The advantage of having different sensors is to perform a cross check on the acquired data, provide improved mitigation of systematic effects and backgrounds and to cover a large range of luminosities.

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EXPERIMENTAL SETUP AND DAQ

Our mechanical setup was installed in December 2015, it consists of pillars in each ring(l.h.s of Fig. 1 for LER) . Each pillar supports a movable plate with two sCVDs connected to a cividec charge amplifier each (r.h.s of Fig. 1) and a fixed plate with the ZDLM monitors. The movable plate is associated with a remotely controlled motor to scan in the vertical plane over a range of 2.5 cm. The signals are sent to the electronic rack in the E-Hut of the Belle II experiment, by rigid half inch heliax cables connected at different stages with special connectors. The electronic rack of "phase 1" is equipped by an RF SYNCHRO which synchronizes the DAQ sampling clock to the RF clock, a 10 bits Keysight oscilloscope (2.5 GHz BandWidth and up to 20 GSPS), a Linux gateway, a windows server on which analysis using MATLAB is performed, high voltage power supply for the diamond sensors (400 V) and low voltage power supply for the charge amplifiers (12 V).

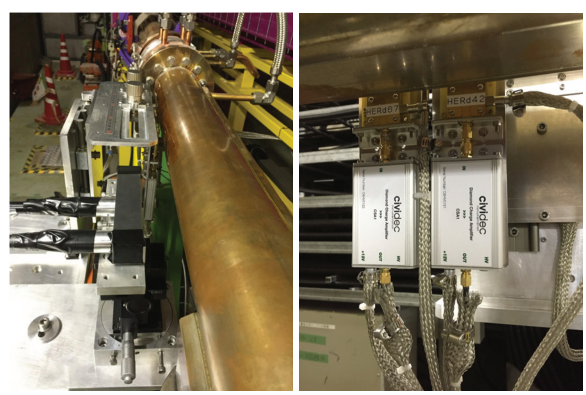

Figure 1: The top of the pillar holding the sCVDs and the ZDLM monitors downstream from the IP in the LER on l.h.s and the sCVDs connected to the charge amplifiers in the HER on r.h.s.

SINGLE BEAM BACKGROUNDS

Processes

Single beam backgrounds are mainly due to three processes:

• *Beam gas Bremsstrahlung*: is the emission of electromagnetic radiation due to the deceleration of the particles of the beam after being deflected by the electric field of the remaining gas nuclei in the vacuum chamber. The loss rates due to Bremsstrahlung are essentially proportional to the vacuum level and the beam current. The deflected particles lose energy and exit the 6 mm Copper beam pipe creating a signal in our sCVDs due to charged secondaries.

• *Touschek*: is the elastic Coulomb scattering between particles of the same bunch, resulting in energy transfer from the transverse plane to the longitudinal plane due to relativistic effects, which can thus cause particle loss. The loss rates due to Touschek are inversely proportional to the beam size.

• *Coulomb*: is the elastic Coulomb scattering of the bunch particles on the nuclei of the gas atoms. The loss rates due to Coulomb depend mainly on the pressure level and the beam current.

Simulations

To estimate the loss rates in our sCVDs from the above mentioned processes, a compact SAD simulation code is used. The dedicated code generates the three processes all over the ring taking into account the cross sections, the beam parameters and the experimental conditions. Scattered particles are then tracked to the positions of the diamond sensor and lost particles are treated in GEANT4 to study the signal in the sCVD. Detailed simulations are performed for Bremsstrahlung loss process in the LER since results show that it has the dominant loss rate in the sensors compared Coulomb and Touschek, by a factor 10. In the drift at 11 meters downstream from the IP we collect Bremsstrahlung particles scattered at locations up to 25 meters upstream from the IP, of energies ranging from zero to 4 GeV (beam energy) (l.h.s of Fig. 2) and with an average exiting angle of 7 mrad (r.h.s of Fig. 2). The low energy Bremsstrahlung positrons exit the beampipe on the low energy side, resulting in a shower of secondaries mainly concentrated at +x where we place the sCVDs (l.h.s of Fig. 3). An average of 14 charged secondaries per incident exiting particle are produced but only an average of 2 charged secondaries per incident particle give a signal in the diamond sensor (r.h.s of Fig. 3)

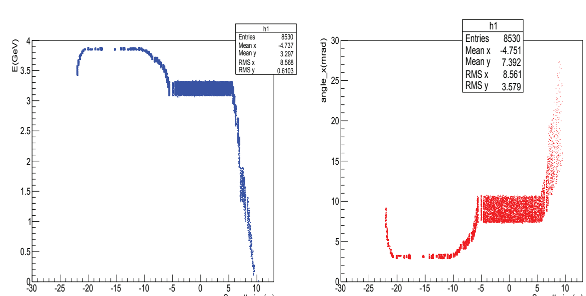

Figure 2: The energies of the lost particles in the drift at 11 meters in the LER as a function of scattering positions on l.h.s and their horizontal exiting angle on r.h.s.

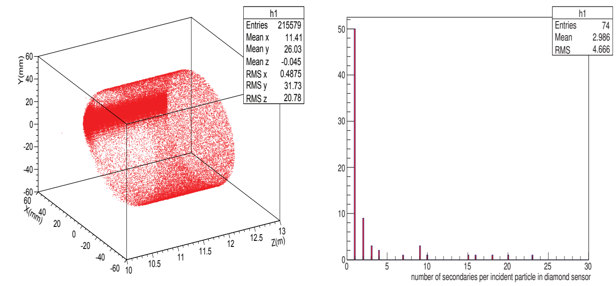

Figure 3: 3D distribution of secondaries from the Bremsstrahlung particles exiting the 6 mm Cu on the low energy side (+x) (l.h.s) and the histogram of the number of secondaries per incident particle giving a signal in the diamond sensor on r.h.s.

Measurements

Data acquisition started in the beginning of March in the LER and the HER, scripts with MATLAB are running for a realtime measurement and data are preprocessed before being saved in log files. Archives of EPICS data from the machine parameters are saved and then associated to the data during analysis. As for preliminary analysis, loss rates are calculated at different beam currents and vacuum pressures. 1 MIP (Minimum Ionising Particle) corresponds to 2.9 fC generated charge in the diamond sensor. The signal is then amplified by the charge amplifier (Gain = 4mV/fC) to 11.6 mV. The energy deposited in the diamond sensor is a Landau distribution, and this was simulated by GEANT4 (l.h.s of Fig. 4) and confirmed by data (r.h.s of Fig. 4)

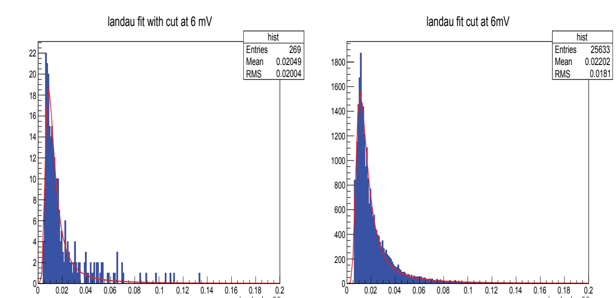

Figure 4: Landau distribution of deposited charge of incident particles in GEANT4 on l.h.s and from data on r.h.s.

Data from sCVDs in the LER

Data taken during the storage of the beam with an average value of 410 mA and an average pressure of 3.4 nTorr produces a loss rate of 4668 PPS (Particle Per Second). Figure 5 shows the variation of the vacuum pressure as a function of the beam current in the LER. The variation of the loss rate in the sCVD per 10 ms is given as a function of beam current on (l.h.s of Fig. 6) and as function of the vacuum pressure on (r.h.s of Fig. 6).

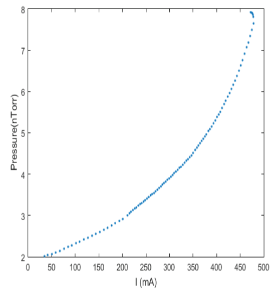

Figure 5: Vacuum pressure as a function of beam current in the LER.

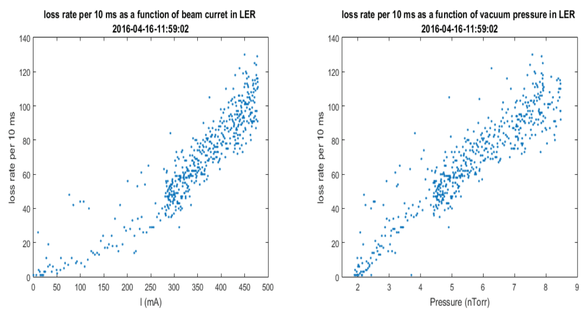

Figure 6: The loss rate per 10 ms in the sCVD as a function of beam current of the LER (l.h.s) and as a function of vacuum pressure (r.h.s).

Data from Cherenkov Detector in LER

To compare the data from the sCVDs to that from the ZDLM monitors, we acquired data from Cherenkov sensor using our Keysight oscilloscope. The distribution of the peak values of the collected events is presented on (l.h.s of Fig. 7) and the loss rate in the Cherenkov as well as in the sCVD are presented on (r.h.s of Fig. 7). The analysis gives a total loss rate in Cherenkov of 5285 PPS for a stored beam with an average current of 134 mA and average vacuum pressure of 1.2 nTorr, which is 10 times larger compared to data from the sCVD at the same conditions. This factor is smaller than the ratio of the active areas of the sensors, but must also depend on the distances of the sensors from the beam pipe

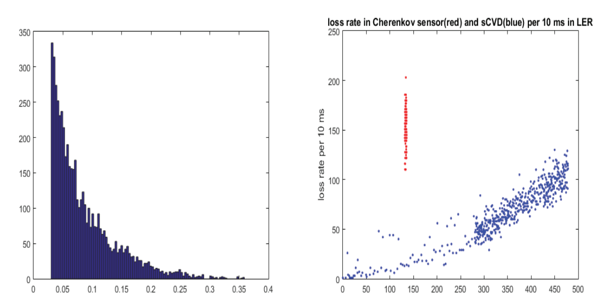

Figure 7: The distribution of the peak values of the signals collected by the Cherenkov sensor on l.h.s and the loss rates in the Cherenkov(red) and in the sCVD as a function of current on r.h.s.

and the efficiency of the chosen cut to define signals. This analysis is still preliminary.

CONCLUSIONS AND NEXT PLANS

The luminosity monitors of SuperKEKB are successfully installed in both rings and are taking data as beam loss monitors during the single beam commissioning of phase1. Detailed simulations of losses from Bremsstrahlung are performed and are compared to acquired data at different beam currents and pressures. Data from ZDLM Cherenkov sensor are analysed and compared to losses in the sCVD as a preliminary step. On the other hand data taking will continue until the end of "phase 1", and simulations of Touschek and Coulomb will be performed to be compared to the data. For "phase2", a window at 45° will be installed in the drift at 11 meters in the LER to increase the level of signal in the our sensors and thus to achieve the aimed precision on the luminosity monitoring. The DAQ system will be replaced by an ADC, FPGA to perform calculations on the train and bunch luminosity and an DAC.

ACKNOWLEDGEMENTS

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