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LOW INTENSITY ELECTRON BEAM MEASUREMENT AT SLRI BEAM TEST FACILITY*

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Abstract

The SLRI Beam Test Facility (SLRI-BTF), the latest extension of the existing accelerator complex, has recently been in operation at the Synchrotron Light Research Institute (SLRI). SLRI-BTF is capable of providing electron test beams with desired intensity and energy. By means of a wedge target downstream of the 40-MeV linac, the electron intensity of the test beam produced is variable between a few to millions of electrons per burst. The test beam energy is adjustable from 40 MeV to 1.2 GeV, depending on the acceleration time of the synchrotron booster. SLRI-BTF targets to service electron test beams to the development of the high-energy particle detectors and diagnostic instrumentations. In this paper, the measurement of the low intensity electron beam will be discussed.

INTRODUCTION

A new Beam Test Facility (BTF) has been constructed at the Synchrotron Light Research Institute (SLRI) to directly utilize the electron beam from the Siam Photo Source (SPS) injector [1, 2]. SLRI-BTF aims to provide electrons test beam with tunable energy ranging from 40 MeV to 1.2 GeV and variable intensity from a few electrons to millions of electron per burst to users in the community of high-energy particle detectors and instrumentations. The operation of SLRI-BTF benefits from the injection scheme of SPS where the injector operates twice daily and is available for SLRI-BTF more than 20 hours a day.

In order to service the electron test beam, it is necessary that the characteristics and parameters of the test beam, especially at low intensity, have to be determined. The beam profile measurement of the low-intensity electron test beam by a pixel-sensor type detector has been performed and the results are shown in this work.

SLRI BEAM TEST FACILITY

SLRI-BTF situates on the basement and shares an entrance with the SPS injector hall. Figure 1 depicts a layout of the SPS injector and a location of the SLRI-BTF experimental area. Electrons produced from a thermionic electron gun are accelerated by a coupled linac and a synchrotron booster to reach 40 MeV and 1.2 GeV, respectively. Then, the high-energy electron beam is extracted to the High-energy Beam Transport beamline (HBT) where a 4-degree bending magnet and two pairs of focusing and defocusing quadrupoles (QF, QD) transfer the electron beam toward the SLRI-BTF experimental station. Although SLRI-BTF is not running in the parasitic mode similar to other beam test facilities, the beam transport parameters up to the synchrotron booster should be kept the same as ones used during the regular injection. With this constraint, the electron beam intensity has to be reduced online. A wedge-shape tungsten target has been employed and installed in the target chamber, illustrated in Figure 2, to decrease high intensity electron beam at Low-energy Beam Transport beamline (LBT). It also provides flexibility in adjusting for constant electron beam intensity due to fluctuation of electron beam current. Since the electron intensity is attenuated before entering the synchrotron booster, the desired energy of the test beam can be acquired by controlling acceleration time of the synchrotron booster. With resolution of 10 µm, the target thickness can be adjusted up to 6 mm where the 40-MeV electron beam can be completely blocked. Slight tuning of quadrupoles and steerers may be necessary to obtain desired beam profile at the SLRI-BTF experimental station. While SLRI-BTF is in operation, all components starting from the first vertical bending magnet (BV), which deflects the electron beam to the storage ring, to the last component of HBT are turned off in order to avoid interference to the electron beam stored in the storage ring.

Electron beam parameters at HBT are listed in Table 1. Recently, the synchrotron booster has been upgraded and able to accelerate electrons up to 1.2 GeV. However, the repetition rate reduces to 1/3 Hz due to an increase of the ramping period of the bending magnet power supply.

Table 1: Electron Beam Parameters at High-Energy Beam Transport Beamline (HBT).

Particle	electron
Energy	1 GeV (1.2 GeV)
Energy spread	-0.05%
Current	10 mA
Pulse duration	8.5 ns
Bunch length	0.5 ns
Repetition rate	0.5 Hz (1/3 Hz)
# of electrons per burst	10^8

EXPERIMENTAL SETUP

In this measurement, the energy of the electron test beam is 1 GeV leading to 2-second repetition rate of the electron test beam. The electron intensity at the experimental station is adjusted to be less than five electrons per burst on average as requested by the users in the community of pixel sensor development. In order to reach such low intensity, the target

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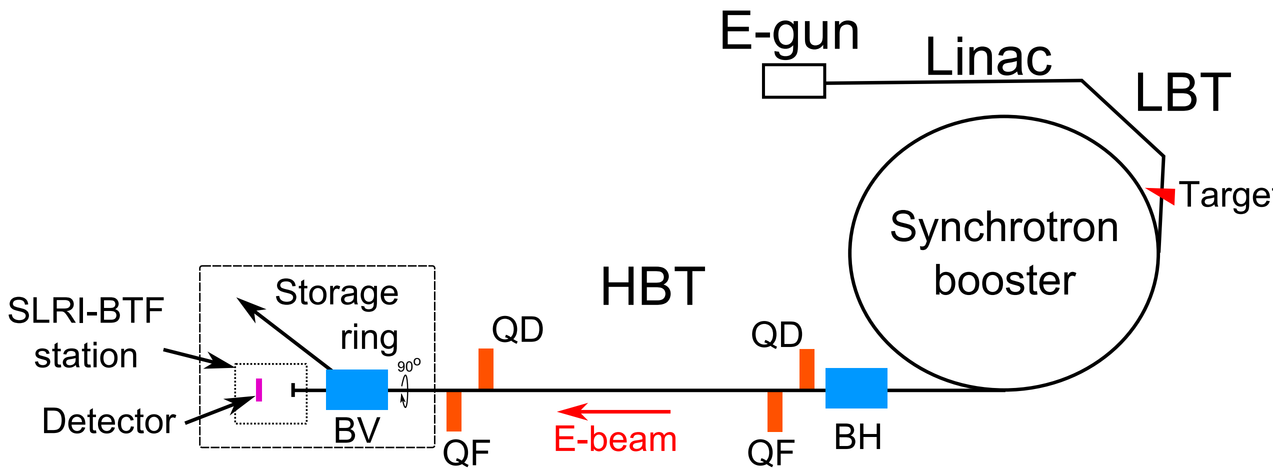

Figure 1: Layout of SLRI-BTF. Electrons from an electron gun are accelerated by a coupled linac and transferred along the Low-energy Beam Transport beamline (LBT) to the synchrotron booster. High energy electrons are then extracted to the High-energy Beam Transport beamline (HBT) where a horizontal bending magnet (BH) and two pairs of focusing and defocusing quadrupole (QF, QD) direct the test beam to the SLRI-BTF experimental station located next to the vertical bending magnet (BV).

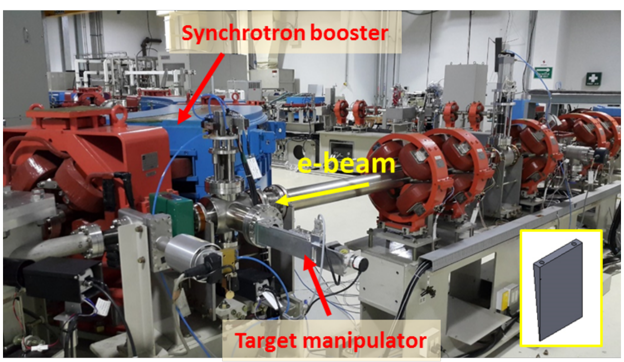

Figure 2: An LBT target chamber that contains a wedge-shape tungsten target (inset) for reducing electron beam intensity and locates at the entrance of the synchrotron booster.

was inserted with target thickness of 3.0±0.1 mm at the center of the beam line.

Figure 3: pALPIDE sensor (left) and DAQ board (right).

The pALPIDE pixel sensor [3] with 512 x 1024 pixels and 1.5 cm x 3 cm large has been used to measure the electron test beam profile. Figure 3 illustrates the pALPIDE sensor and the DAQ board. Collected data is recorded using the EUDAQ data acquisition framework [4] installed in a local computer and accessed remotely from the main control room. The external triggering signal of 100 ns wide is generated from the central timing unit and is sufficient for detecting all 11 small buckets of electrons extracted from the synchrotron booster. Since the detector is approximately 3 m away from the bending magnet, slight adjustment of steerers and quadrupoles was made in order to obtain a proper shape of the test beam on the sensor.

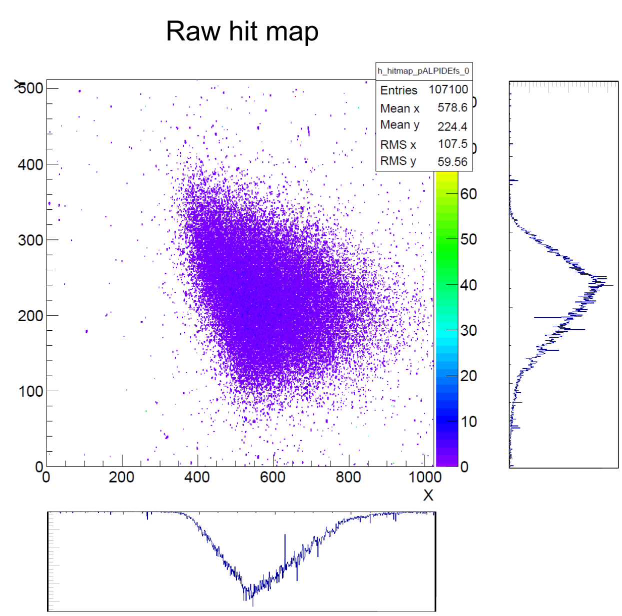

Figure 4: Raw hitmap and projections in x- and y-directions.

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RESULT

Figure 4 illustrates the beam profile of the electron test beam and its projections in horizontal and vertical directions. The result collected over 10 thousand raw hit entries and lasted around six hours. The raw hitmap depicts all pixels that are activated by particles. The horizontal and vertical beam sizes (1σ) of the electron test beam are 3.1 mm and 1.7 mm, respectively. Figure 5 shows distribution of the number of raw hits and clusters detected on the sensor. The average number of raw hits is 7.5 while the average number of clusters is 4.3. Approximately, 40 events were collected showing the number of clusters larger than 50 per repetition rate.

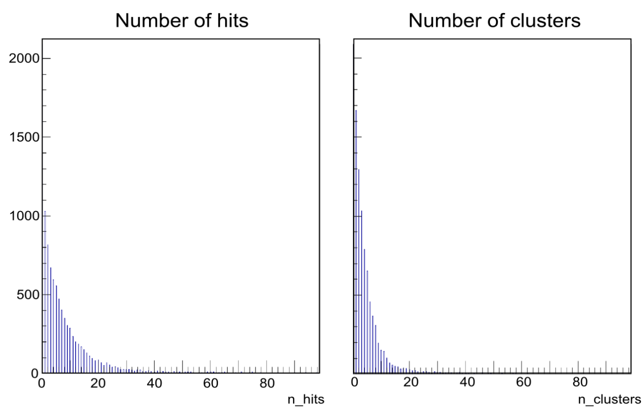

Figure 5: Histogram showing the number of raw hits and clusters on the detector.

Depending on the direction of the hitting electrons, more than one pixel may be activated and several hit pixels can be counted as one cluster. Figure 6 depicts the distribution of the cluster size where the cluster size of greater than unity indicates hitting of actual particles. Electrons with large transverse velocity tends to activate more pixels, leading to large cluster size, than that of low transverse velocity. With this consideration, the average number of clusters detected on the sensor is less than the average number of raw hits.

CONCLUSION

The beam profile of the electron test beam has been detected and the average number of raw hits and clusters have been measured using the pALPIDE pixel sensor detector. The result confirms SLRI-BTF is able to produce low intensity electron test beam (less than five electrons per burst on average) which is suitable for testing and calibration of high-energy particle detectors and instrumentations as well as investigation of their efficiency.

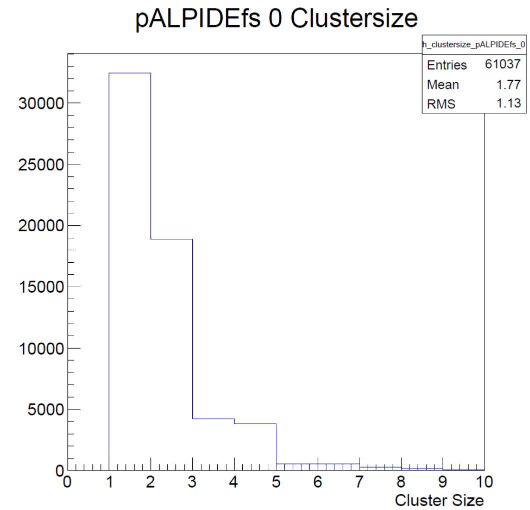

Figure 6: Histogram showing cluster sizes of detected electrons.

OUTLOOK

In parallel to the providing test beam to current users, some test beam parameters have to be measured such as beam emittance as well as the energy spread of low intensity test beam. Besides, the production of test beam at different energy ranges, i.e., 500 MeV or 1.2 GeV, will be performed to ensure the concept of using the synchrotron booster as an energy selector.

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