SLRI BEAM TEST FACILITY DEVELOPMENT PROJECT[*]

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Abstract

The SLRI Beam Test Facility (SLRI BTF) is a part of the future upgrades of the SLRI accelerator complex. Upon completion, SLRI BTF will be able to produce electron test beams with the number of electrons ranging from a few to several thousand electrons per bunch. The project is divided into three stages based on the complexity of the electron reduction setups. The simple setup for the initial stage has been implemented without any modifications to the current High-energy Beam Transport line (HBT) while additional elements together with an existing 4-degree dipole are required for the short-term setup in the second stage. For the last stage, a new dedicated transfer line equipped with a high-resolution energy selector will be constructed to direct the electron beam from the HBT beam line to an experimental station. This project aims to provide a defined number of electrons with maximum energy of 1 GeV for calibration and testing of high energy detectors as well as other beam diagnostic instrumentations.

INTRODUCTION

The Synchrotron Light Research Institute (SLRI) is a facility that provides synchrotron light generated from 1.2 GeV electron beam to users for various studies [1]. The SLRI accelerator complex includes a 40 MeV linac, a synchrotron booster that accelerates electron beams to electron beam energy of 1 GeV, and a storage ring where the electron beam energy is finally ramped up to 1.2 GeV. Electrons are injected into the storage ring twice daily in order to ensure sufficient intensity of synchrotron light produced. Due to the availability of the injector, SLRI has initiated the project that utilizes the high-energy electron beam by setting up a dedicated Beam Test Facility (BTF). SLRI BTF targets to provide a defined number of electrons, from a few to million electrons per bunch, in tunable electron energy range up to 1 GeV mainly for calibration and testing of high energy detectors and diagnostic instrumentations.

PLAN FOR SLRI BTF DEVELOPMENT

The construction plan of SLRI BTF is divided into three stages corresponding to the experimental setups:

First Stage

In the first stage, the experiments with a simple setup were performed without any modifications of an existing transport line. The purposes of this stage are to confirm the detection of high-energy electron beam outside a vacuum chamber and the reduction of electron beam intensity using a metal target. Figure 1a) illustrates main components for test beam production including an electron gun (E-gun), a Low-energy Beam Transport line (LBT), HBT, and two accelerators. The location of the SLRI-BTF experimental station is next to the vertical bending magnet (BV) where the electron beam is transported to the storage ring (SR). This bending magnet is turned off when SLRI BTF is in operation. The electron beam extracted from the synchrotron booster with properties shown in Table 1 is deflected by a 4-degree horizontal magnet (BH) and adjusted by two sets of focusing (QD) and defocusing (QF) quadrupoles.

Table 1: Electron Beam Parameters at High-energy Beam Transport Line (HBT).

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

To perform the electron beam reduction, a lead target is located next to a beam outlet and between two collimators (see Figure 2). A Timepix detector [2] is placed at the end to measure electrons that survive from the target and pass through two collimators. The Timepix software installed on the local computer is used for data acquisition and remotely controlled by the computer in the main control room. The area of the SLRI BTF experimental station is approximately 17 m^2. This area was originally reserved for a Faraday cup to measure current of the electron beam that is extracted from the booster.

Electron beam intensities measured by the Timepix detector without and with different targets are shown in Figure 3. Data were collected with an acquisition time of 5 s, when the target was unused, and 10 s for others. Without a reduction target, the electron intensity is in the same order of magnitude as the design parameter (see Table 1) while those measured with targets show an expected trend where the thicker target allows lower intensity of secondary electron beam. The lowest intensity of 10^4 electrons per burst was measured with the target thickness of 13.5 mm. However, the intensities detected with lead targets are larger than the predicted values. This results from unwanted secondary par-

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[*] Work supported by National Science and Technology Development Agency (NSTDA) under contract FDA-C0-2558-855-TH

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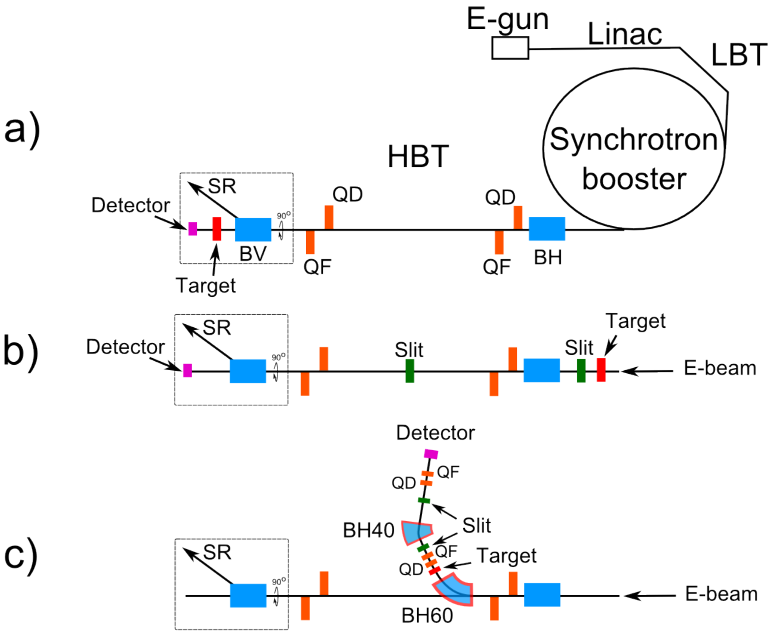

Figure 1: Conceptual diagrams of SLRI BTF with three different experimental setups; simple (a), temporary (b), and permanent (c).

ticles that are generated when the target is bombarded by high-energy electron beam.

Second Stage

The second stage of SLRI BTF, motivated by the DAFNE BTF, INFN Italy [3], was introduced for beamline modification. The existing bending magnet is used as an energy selector in order to suppress the effect of secondary particles.

Figure 1b) depicts a layout of SLRI BTF in the second stage where HBT is modified by implementation of a target and two slit chambers. The target and the upstream slit chambers locate in front of the magnet while the downstream slit chamber is next to the first pair of quadrupoles. The tungsten target is used, due to its short radiation length, to reduce the electron intensity by increasing electrons' transverse velocity. The target thickness of 1.7, 2.0, and 2.3X_0 where X_0 is the radiation length are chosen to allow flexibility in obtaining electrons at intermediate and high energy ranges. Since the power generated by electrons at the target is low, water cooling on the target is unnecessary. Both pairs of slits also made of tungsten are used together with the magnet to select electrons with desired energy and to increase energy resolution. The slit gaps are designed to be as small as 0.01 mm wide. Assuming the electron beam size traversing the

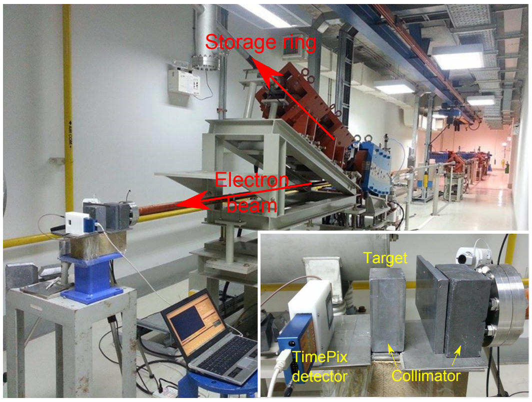

Figure 2: Experimental station temporarily setup with a lead target, two lead collimators, and a Timepix detector.

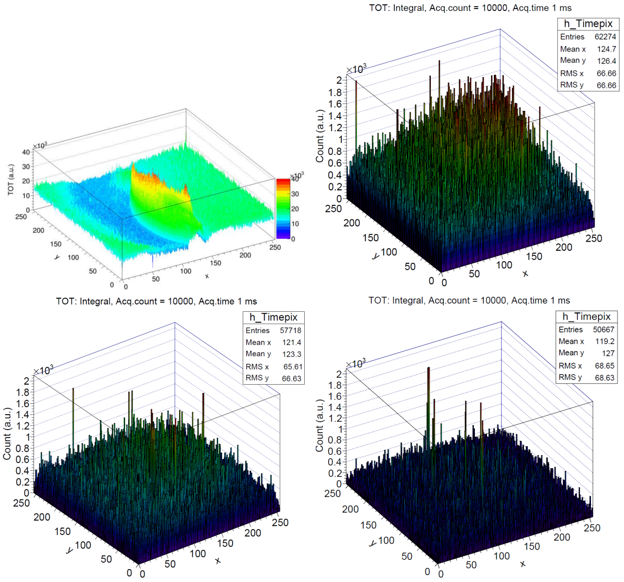

Figure 3: Electron beam intensities detected by a Timepix detector without (top-left), with 5 mm (top-right), 9 mm (bottom-left) and 13.5 mm (bottom-right) thick lead targets.

target is 5 mm with a slit gap of 1 mm, the energy resolution provided by the magnet of 7.2 m bending radius is up to 2%.

The Monte Carlo N-Particle code (MCNP) [4] was employed to study the energy distribution of electrons that traverse the target of three different thickness. The simulated results with an initial electron-beam energy of 1 GeV are shown in Figure 4. The effect of the target thickness starts to appear when the energy of the secondary electron beam is higher than 400 MeV. The dispersion of data at high energy is caused by insufficient statistic recorded.

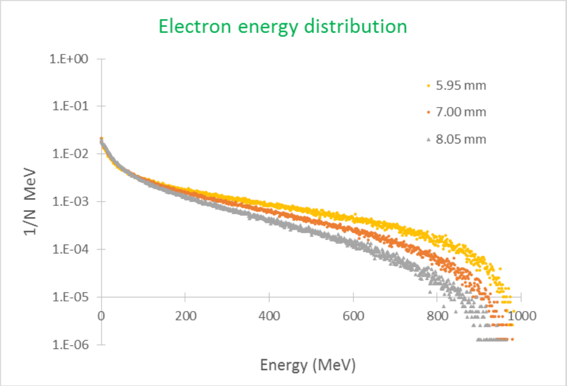

Figure 4: Target simulation by the Monte Carlo N-Particle (MCNP) code with 1.7, 2.0, and 2.3X_0 where X_0 is the radiation length and the initial electron beam energy of 1.0 GeV.

Last Stage

In the long-term operation of SLRI BTF, all of the elements added in the second stage will be relocated to a new beamline dedicated for the SLRI-BTF station. The large experimental area will increase flexibility in setting up tested detectors and instrumentations.

The layout of the long-term SLRI BTF is shown in Figure 1c). Following the first couple of quadrupoles, a 60-degree dipole will be installed to deflect the 1 GeV electron beam from the synchrotron booster to the SLRI BTF experimental station. The reduction target, a pair of focusing and defocusing quadrupoles, and the upstream slit are installed next to such dipole. In order to improve resolution, an additional 40-degree bending magnet following by the downstream slit and another pair of quadrupoles will be used as an energy selector and will direct the electrons with required energy to the experimental station.

Concerning the conceptual design of this stage, the dynamics of the electron beam that transports from the synchrotron booster to the end station of SLRI BTF has been studied by MADX simulation code and results are illustrated in Figure 5. The electron beam sizes in x and y coordinated were calculated with two possible cases and are listed in table 2.

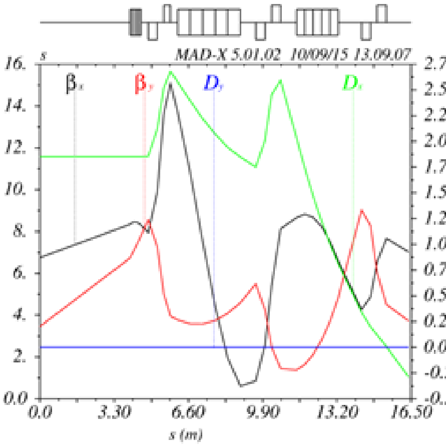

Figure 5: MADX simulation of electrons transported from the synchrotron booster to the SLRI-BTF experimental station.

Table 2: Two possible electron beam sizes calculated with the 1 GeV electron beam at the locations of the reduction target and the detector.

Location	Case 1	Case 2
Target	$\sigma_x = 0.9112$	$\sigma_x = 0.6302$
	$\sigma_y = 0.1316$	$\sigma_y = 0.03075$
Detector	$\sigma_x = 1.3399$	$\sigma_x = 1.5429$
	$\sigma_y = 0.2281$	$\sigma_y = 0.1984$

CONCLUSION

The first stage of SLRI BTF has been achieved and the electron intensity is strongly reduced from 10^8 to 10^4 electrons per burst using a lead target. The ongoing second stage aims to significantly decrease background and reduce electron intensity down to 1-100 electrons per burst. In the long-term operation, SLRI BTF with a separate beamline will provide much flexibility in conducting experiments. Different diagnostic systems will be considered and used to improve the beam quality [5].

ACKNOWLEDGMENT

I would like to thank S. Sangaroon for discussion on MCNP simulation code. I would also like to acknowledge P. Valente and the DAFNE BTF team for technical suggestion in the development of BTF. This work is supported by National Science and Technology Development Agency (NSTDA) under contract FDA-C0-2558-855-TH.

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