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ENERGY BEAM POSITION MONITOR BUTTON ARRAY ELECTRONICS FOR THE EUROPEAN XFEL

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Abstract

The European XFEL (X-Ray Free Electron Laser) at DESY (Deutsches Elektronen-Synchrotron) in Hamburg/Schenefeld started commissioning in early 2017. Before the pulsed electron beam is accelerated to its final energy of 14 GeV, the energy of the bunch can be compressed in three bunch compression chicanes at 130 MeV, 700 MeV and 2400 MeV. The vacuum chamber in these sections is tapered from 40 mm round beam pipe to a 40 cm rectangular shaped vacuum section. A custom made button array type of BPM(Beam position Monitor) is installed in this section with 26 button electrode feed-throughs. The analog and digital readout electronics for this monitor and the first experience with the calibration and operational aspects of this system are presented in this poster.

INTRODUCTION

The European XFEL (X-Ray Free Electron Laser) at DESY (Deutsches Elektronen-Synchrotron) in Hamburg, Germany has been constructed in the past 8 years and has been commissioned in spring 2017 [1]. It can provide X-rays in the range from 0.25 to 25keV for three independent undulator beamline-lines. The electron beam is generated by a UV (ultra violet) light pulsed laser and a normal condcuting RF gun in which the electrons are released from a cathode. It can be accelerated at a high repetition rate of up to 222 ns. This is done during an RF (radio frequency) pulse of 10 Hz with superconducting accelerating modules [2] and up to a maximum energy of 14 GeV. A sketch from the entire facility can be seen in Fig. 1.

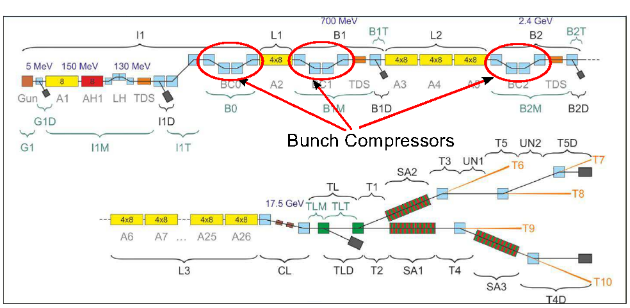

Figure 1: European XFEL Section Overview with bunch compressors.

Bunch compressors are installed in the locations BC0, BC1 and BC2 at the three ascending energies 130 MeV, 700 MeV and 2.4 GeV. All three bunch compressors allow for a very flexible compression scenarios of the electron bunch.

This is achieved by tapering the standard vacuum pipe diameter of 40 mm to a diameter of 400 mm. A principle sketch from the chicane layout can be seen in Fig. 2.

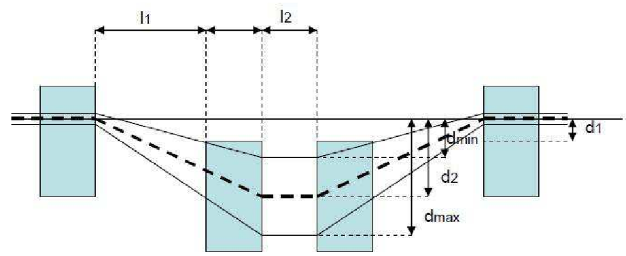

Figure 2: Sketch of XFEL BC chicane layout.

With an increasing energy from 130 MeV to 700 MeV and to 2.4 GeV the bending angle reduces and the length l1 from the chicane therefore increases significantly. More details about the conceptaul design and bending angles can be found in [3]. A picture from the compression chicane at 2.4 GeV is shown in Fig. 3.

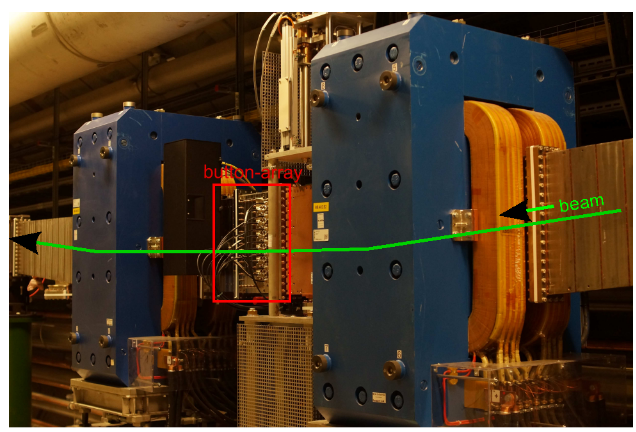

Figure 3: Bunch compressor chicane B2 at 2.4 GeV. The inner two magnets of the bunch compressor chicane are shown.

BUTTON ARRAY MONITOR

In order to determine the energy or the compression respectively in the dispersive part from the chicane a novel type of button electrode array has been designed [4]. It is composed of the same type of electrode button feed-throughs that have been used in the standard button type type installation all along the machine [5]. The difference in the button array vacuum component lies in the geometry. Along the vertical dimension an array of 13 button feed-throughs is arranged to cover the whole height of 400 mm in the vertical

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dimension. This is also done for the opposite side. In total 26 RF (radio frequency) channels have to be read out. A picture from the vacuum part for one side from the array is shown in Fig. 4.

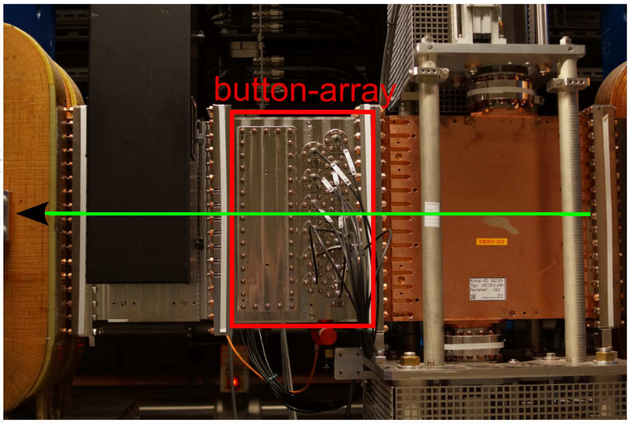

Figure 4: Electrode button array with 13 feed-throughs from one side of monitor. Not shown here: Each button electrode has its counterpart on the other side of the chamber which also enables to measure the horizontal beam position.

One of the key features of this system is a high position resolution of better than 50μm rms for the whole aperture for a charge range from 20 pC up to 1 nC [6].

ELECTRONICS SYSTEM

The RF signals from the pickups in the vacuum chamber are connected to a electronic read out system which is situated less than 10 m away. The electronics are realized in μtca system [7]. The RF front-end is composed of 4 RF channels and the digitizer is a commercial available board [8]. The μtca system, RF front-end and digitizer have been described before in [9, 10]. A crate has been equipped with 6 RF front-ends and digitizers to read out a total of 24 channels from the button pick-up array.

Firmware and Server

The digitization is done with a machine synchronous clock signal of 108 MHz with 16 Bits and the firmware based post-processing is triggered with the machine trigger at 10 Hz. The firmware calculates the intensity from each button electrode and sends this data to the Device server which is also running in the crate. Here the beam position in the vacuum chamber is calculated. The front-end server for the B0 chicane is shown in Fig. 5. The raw signals from the ADC can be investigated here for each RF front-end/digitizer pair individually. A seventh instance shown in the right corner indicates under which button the beam is located in vertical direction. The exact calculation of the vertical position takes place after the calibration.

CALIBRATION

The calibration of the monitor is done beam based. With the help of a sophisticated beam energy server [12] the beam

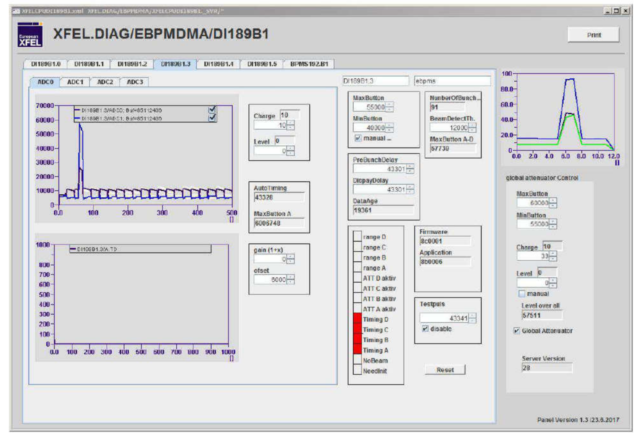

Figure 5: Front-end server B1 chicane.

is steered in the vertical direction. A beam optics based automated calculation delivers information about the expected beam position in the chicane. While the steered bunch crosses the electrodes it gives a characteristic raw ADC amplitude readout pattern shown in Fig. 6.

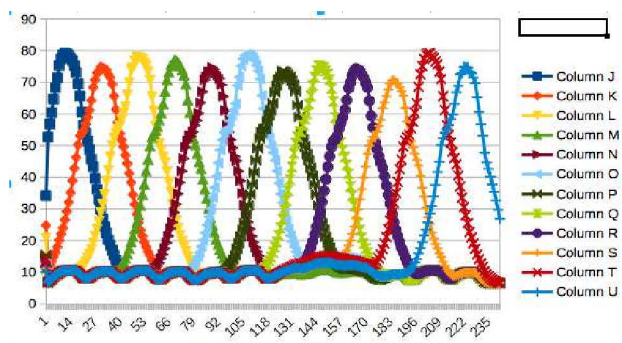

Figure 6: The raw amplitudes for an amplitude sweep in the vertical direction. The amplitude of each button is shown in a different color.

The calibration constant is calculated with the delta over sum algorithm in this multi-button array configuration as it is done for other types of BPM with four pick-ups. A decision is made between which adjacent buttons the delta over sum algorithm is applied. This depends on the maximum detected signal amplitude. The characteristic calibration curve is shown in Fig. 7

After applying the corrected amplitude values including the chamber geometrical offsets to the sensitivity between neighboured button electrodes a position sweep has been done. The result is shown in Fig. 8.

SUMMARY AND OUTLOOK

The energy BPM electronics show that it is in principle working without losing continuity of the calibration constant. During machine operation it has shown to be working and to be of importance for future energy feedbacks or energy calibration. Further investigations and system improvements are under way.

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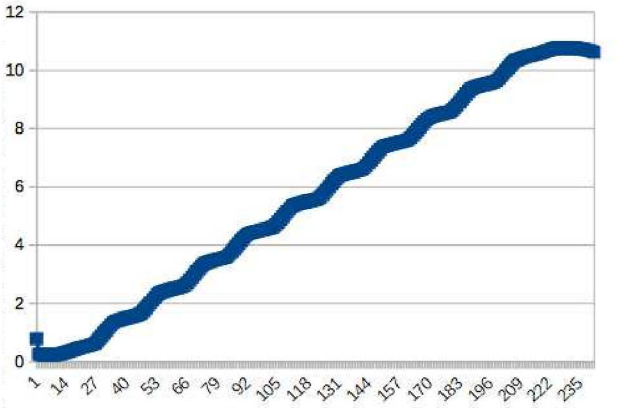

Figure 7: The calculated sensitivity in the chamber in vertical direction.

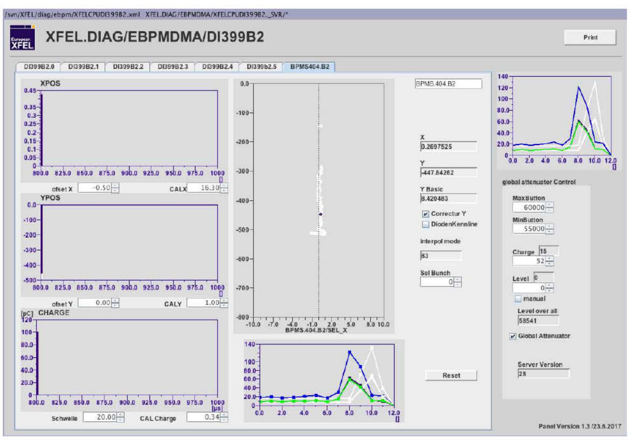

Figure 8: Position sweep in vertical direction after applying the slope correction.

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