Readout Electronics for the Belle II Imaging Time-Of-Propagation Detector

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Abstract— **A front-end electronic readout system for a novel 8192-channel Belle II imaging Time-Of-Propagation detector [1] was designed, built, and integrated. The purpose of the detector is to identify charged hadrons with high precision. Sampling of the analog waveforms is done by switched-capacitor array application-specific integrated circuits, while data acquisition is controlled by Xilinx Zynq-7000 system on a chip devices.**

T HE BELLE II experiment at the SuperKEKB electron-positron collider is opening a new era in beauty physics. One of the main objectives of the Belle II program is to search for rare processes predicted by theories beyond the Standard Model of physics. Belle II, compared to its predecessor Belle, has improved particle identification capabilities, which are in part realized by the barrel 16-module imaging Time-Of-Propagation (iTOP) detector. Passage of hadrons through the iTOP module quartz components generates Cherenkov photons, which, after multiple reflections, get collected by Hamamatsu R10754-07-M16(N) 4 x 4 microchannel plate photomultiplier tubes (MCP-PMTs) (Fig. 1).

Fig. 1. Hamamatsu R10754-07-M16(N) 16-pixel MCP-PMT.

Every photomultiplier anode wire is inserted in an individual socket of a special Front board, which is parallel to the MCP-PMT back surface. The signals are routed to the pads mounted on the back plane of the Front board. Four MCP-PMTs are served by one Front board; thus a 4 x 2 MCP-PMT array, with two connected Front boards (Fig. 2), collect signals from 128 iTOP channels.
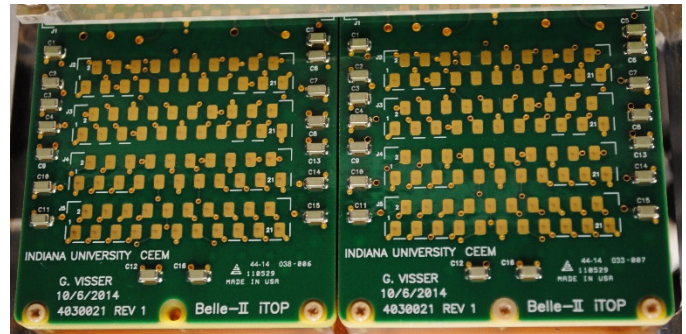

Fig. 2. Two Front boards.

At the heart of the iTOP readout system there is a custom designed application-specific integrated circuit (ASIC), which primary function is to sample the amplified waveform, collected from the photomultiplier tube anodes. Deep sampling is done by switched-capacitor arrays that perform Wilkinson 12-bit analog-to-digital conversion, with one ASIC bit corresponding to about 0.4 mV. Every ASIC digitizes 8 channels.

Four ASICs are hosted by an ASIC carrier board (Fig. 3 and Fig. 4); a pair of ASICs is mounted on each side of the board. Thus one ASIC carrier board reads out signals from 32 MCP-PMT channels. Physically, the ASIC carrier board is oriented orthogonally to the Front board. Two pogo pin assemblies are installed at one of the edges of the ASIC carrier board. The pogo pins (one for each MCP-PMT anode) are pressed against the pads on the Front board for the anode signal pick-up. Then the MCP-PMT waveforms are amplified and later digitized.

The digitization in four ASICs is controlled by Xilinx Zynq-7000 Z-7030 system on a chip (SoC) mounted on a top surface of the ASIC carrier board. Four ASIC carrier boards are interconnected by mezzanine connectors. One of the ASIC carrier boards, in its turn, is connected to a Standard Control Read-Out Data (SCROD) board (Fig. 5 and Fig. 6). Through the mezzanine connectors, the digital data from each of 128

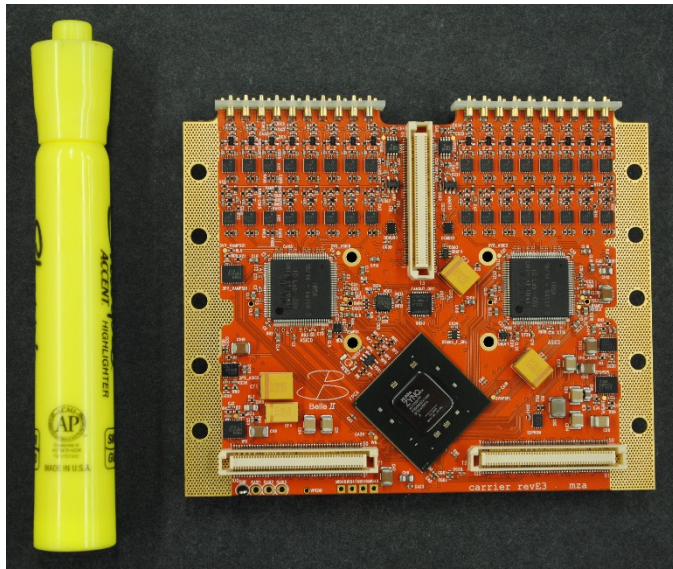channels of four ASIC carrier boards get collected by the SCROD board.

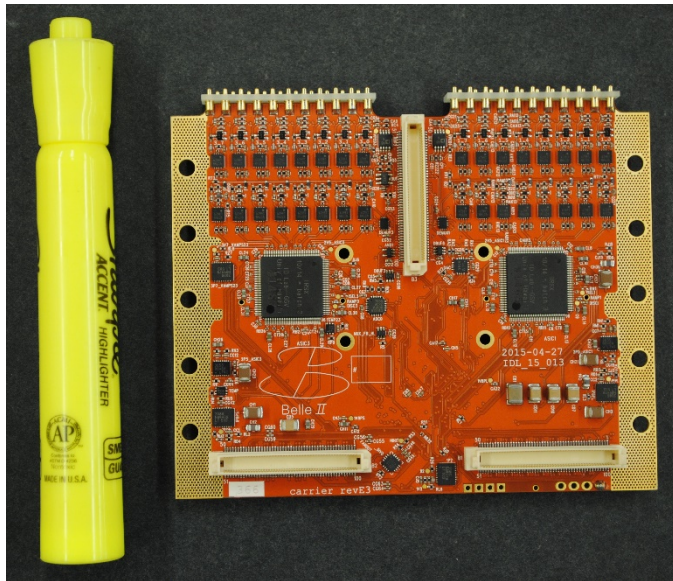Fig. 3. Top view of the ASIC carrier board.

Fig. 4. Bottom view of the ASIC carrier board.

The main electronic component of the SCROD board is Xilinx Zynq-7000 Z-7045 SoC that controls triggering and clock distribution, as well as the data collection and transfer to the Belle II back-end data acquisition system. The SCROD board is equipped with two Avago AFBR-57D7APZ fiber optic transceivers, one for data output, and the other for triggering. The interconnected four ASIC carrier boards and one SCROD board form a board stack, which serves as one 128-channel Subdetector Readout Module (SRM) (Fig. 7). Cherenkov photons in one iTOP module are read out by 32 MCP-PMTs. Four SRMs are installed in each iTOP module to

read out signals from 512 MCP-PMT anodes. In total, 64 SRMs are needed to read out all of the 8192 iTOP channels.
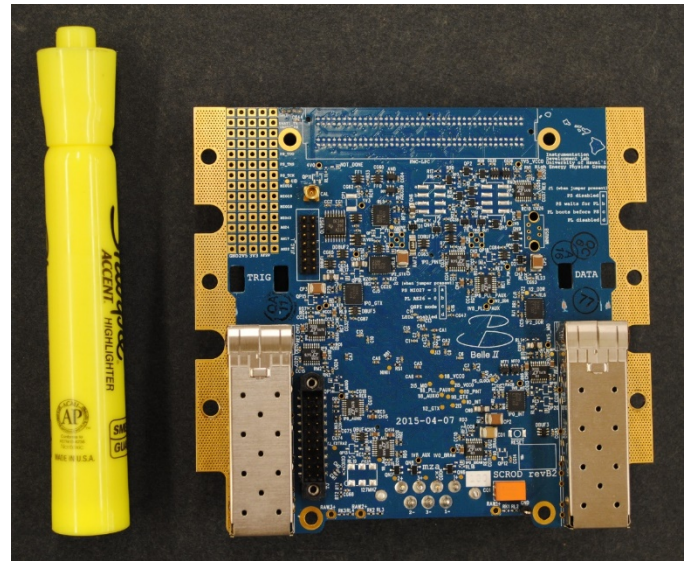

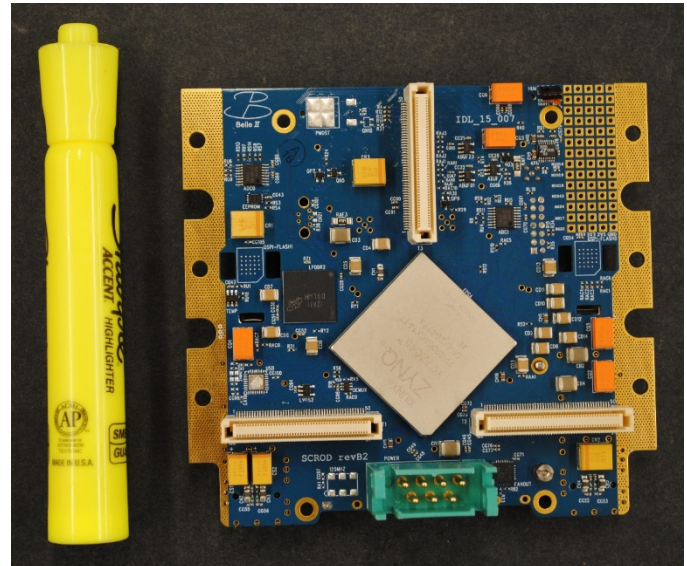Fig. 5. Top view of the SCROD board.

Fig. 6. Bottom view of the SCROD board.

The high voltage for the MCP-PMTs is provided by resistive divider boards, which are mechanically attached to each SRM. In the SRM, the ASIC carrier and SCROD boards are attached to aluminum plates for heat removal; in addition, copper disks are coupled to the SoCs.

Performance of the individual ASIC carriers and of the SRMs was evaluated by a variety of measurements. Particularly, the time resolution of the ASIC channels from measuring a 20 ns time difference between leading edges of two 1.5 V analog 7 ns pulses was found to be from 20 ps to 30 ps. Consequently, the time resolution of the ASIC channels coupled with the MCP-PMT channels was found to be from

60 ps to 90 ps from measuring a time difference between leading edges of analog 1.5 V and 7 ns pulse and the MCP-PMT pulse from a detected single photon laser signal (the MCP-PMT transit time spread is equal to about 30 ps). All of the 16 iTOP modules, together with one spare module, are fully integrated with the SRMs.
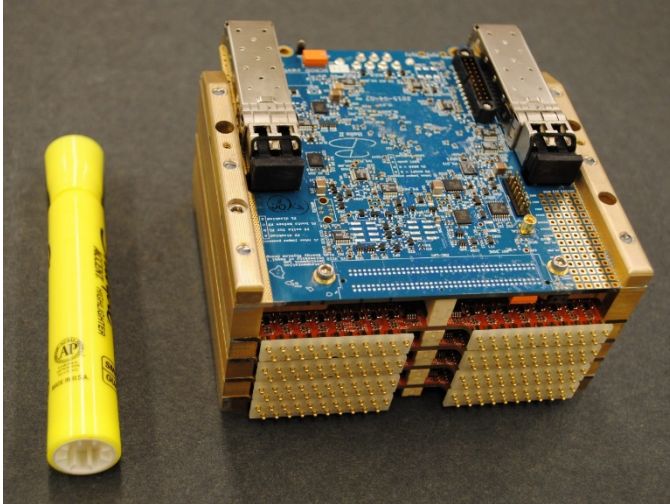

Fig. 7. 128-channel Subdetector Readout Module.

A specialized Common Pipelined Platform for Electronic Readout (COPPER) board version III (COPPER-III) was developed for the Belle II experiment as a main component of the back-end data acquisition system [2]. Every COPPER-III board collects data from four SRMs. Thus 16 COPPER-III boards collect the data from all of 64 iTOP SRMs.
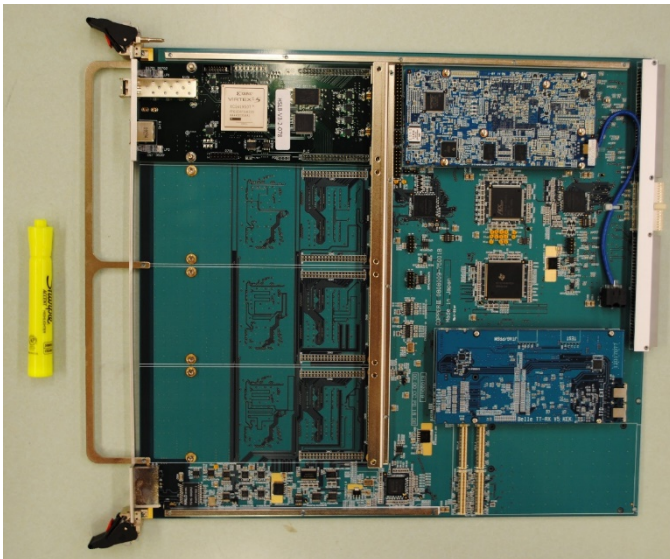

Fig. 8. COPPER-III board.

REFERENCES

[1] T. Abe, et al., Belle II Technical Design Report, KEK-Report-2010-1, 2010.
[2] M. Nakao, et al., Data acquisition system for Belle II, JINST 5, C12004, Dec. 2010.