The Time of flight Measurement Electronics for Back-n at CSNS

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I. Introduction

Back-n is a white neutron beam line at China Spallation Neutron Source (CSNS). The time structure of the primary proton beam makes it fully applicable to use time-of-flight (TOF) method for neutron energy measurement. We implement the TOF measurement on the general-purpose readout electronics system which is designed to adapt all of the seven detectors in Back-n. Fig.1 shows the electronics system. Fig.2 shows the photograph of FDM and TCM.
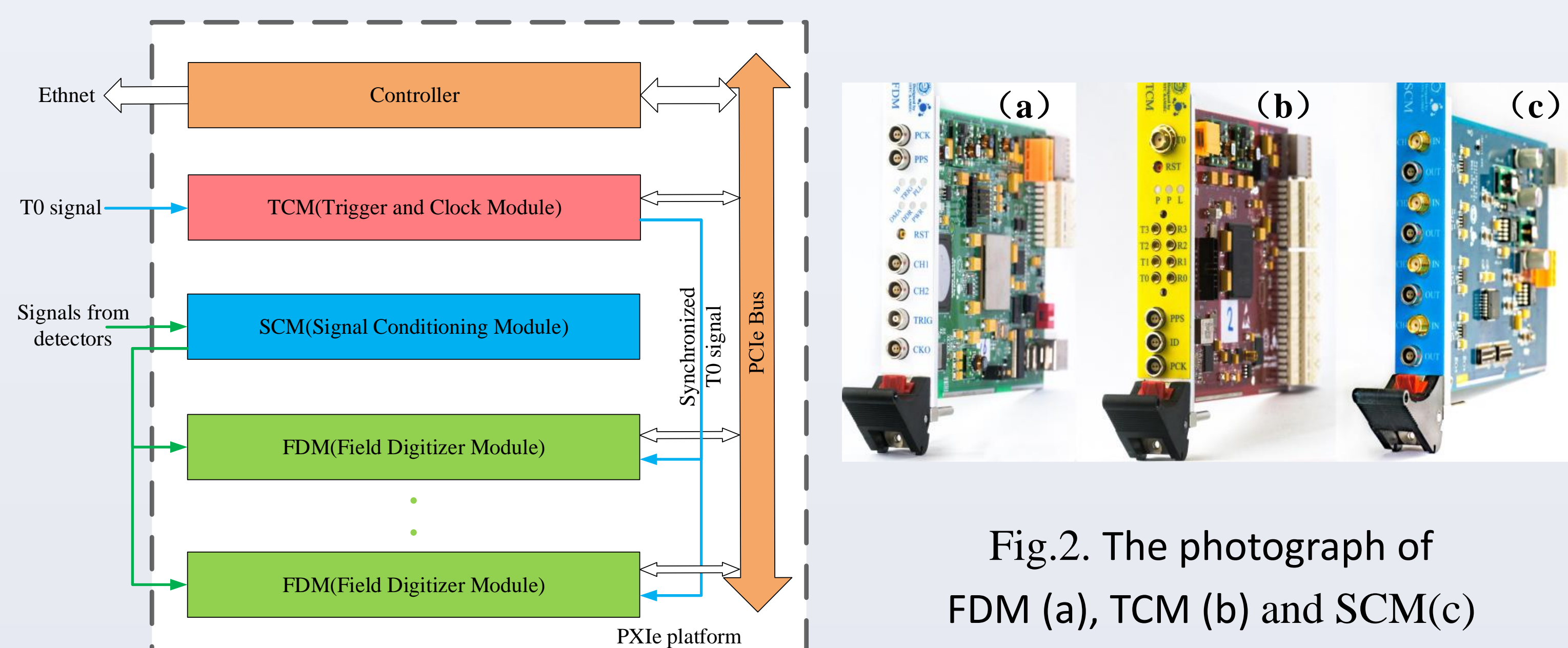

Fig.1. General-purpose Readout Electronics System

Fig.2. The photograph of FDM (a), TCM (b) and SCM(c)

T0 signal is transmitted to the general-purpose readout electronics which represents the neutron emission from the target. Signals from detector systems can be seen as the time of capturing neutrons. TOF is the interval between T0 signal and signals from detector systems, shown in Fig.3.
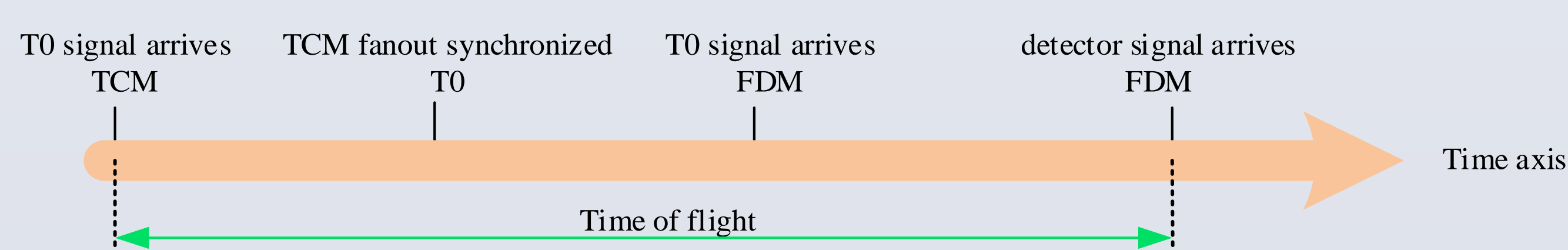

Fig.3. Time of flight schematic

II. Implement of The TOF Measurement

T0 signal is an asynchronous signal to TCM. The interval between T0 signal and FPGA Clock is measured by a FPGA-based TDC recorded as t1, this interval will then uploaded to the chassis controller in DMA method via PCIe. After a dedicated time recorded as t2, the synchronized T0 signal will be distributed to FDMs by differential star buses on the PXIe back-plane. t1 and t2 are showed in Fig.4.
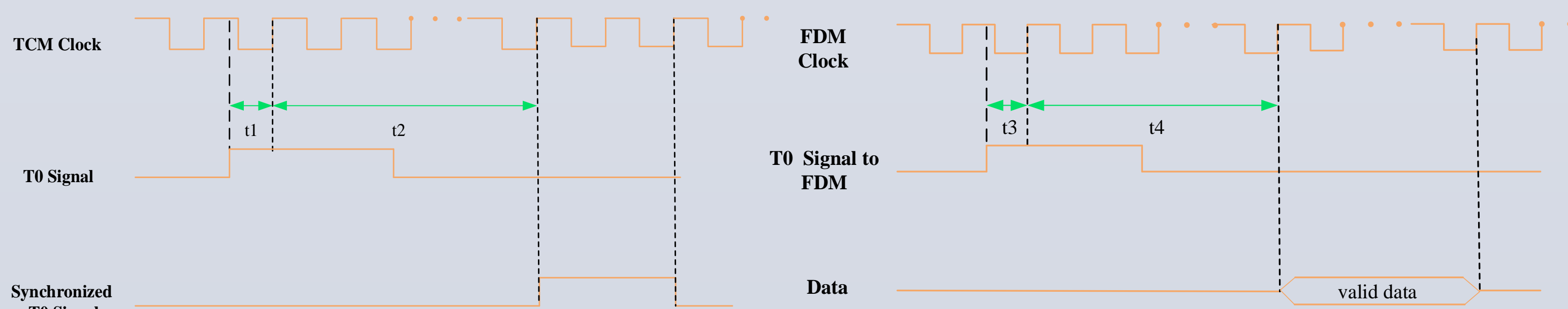

Fig.4. The schematic of t1 and d1   Fig.5. The schematic of t2 and t3

Though the clock of TCM and FDM is homologous, the phase is not deterministic every time the platform powers on. A FPGA-based TDC is used to measure the interval between T0 signal and FDM clock, which is recorded t3. Signals from detectors are conditioned by SCM and then transmitted to FDM, The ADC on FDM digitize the signals at 1G/s sampling rate. The interval between T0 signal and the first sampling data is recorded as t4. t3 and t4 are showed in Fig.5.

The results and sampled data will then also be uploaded to the chassis controller. FDM results will be aligned with TCM results by T0 ID.

We use CFD (Constant Fraction Timing) method to get the interval between the first data point and the threshold point after acquiring the data, this interval is recorded as t5.

Fig.6 shows the schematic of t5. There are some dedicated intervals we don't elaborate, including the transmission delay of the TCM, FDM and the back-plane buses, because they can be calibrated. Finally, we get the following formula, in which d represents the sum of all the dedicated delays.

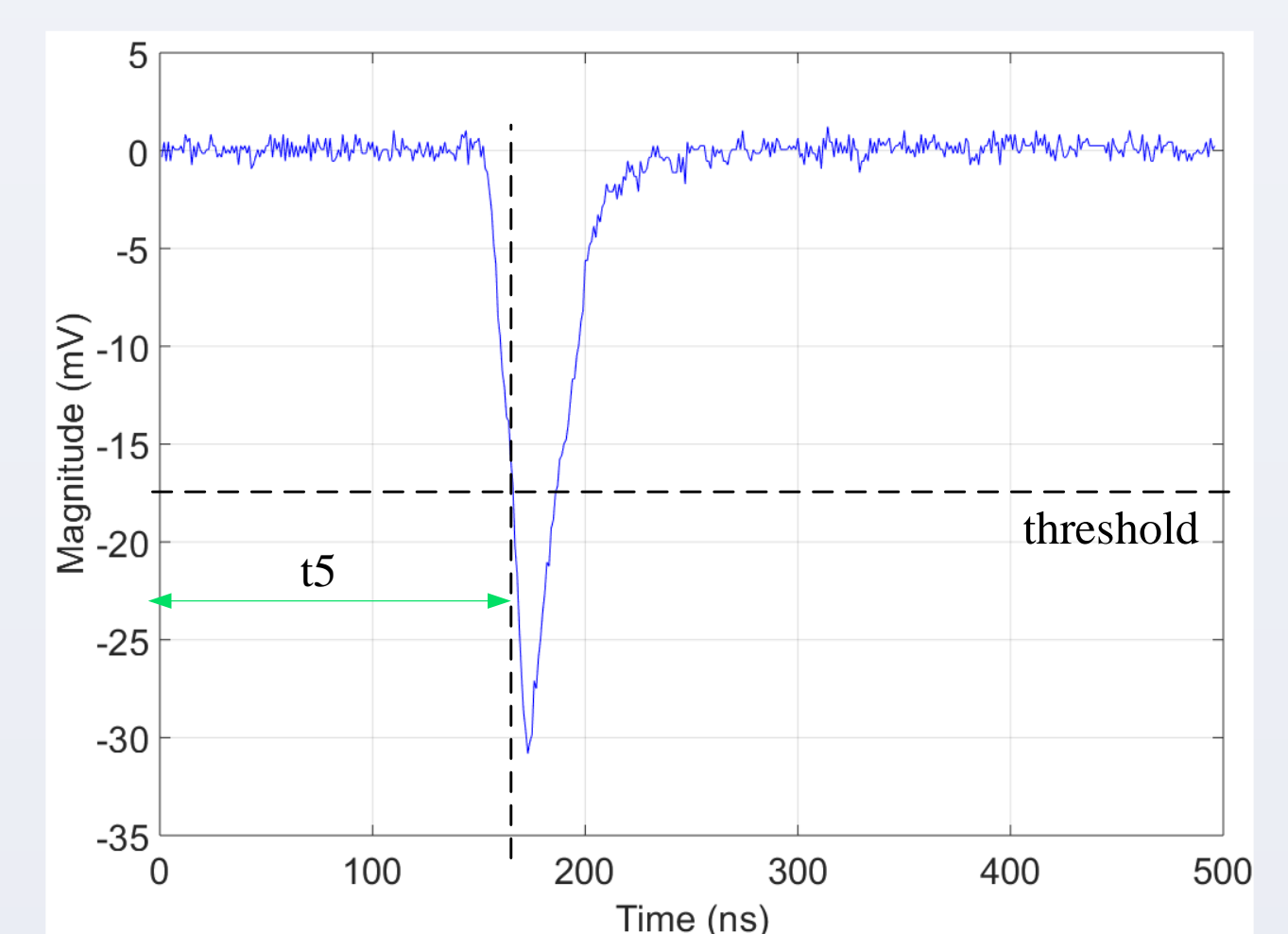$$TOF = t1 + t2 + t3 + t4 + t5$$

Fig. 6. The schematic of t5

III. Test and Results

To evaluate the accuracy of the TOF measurement system, we simulate the T0 signal and detector signals, use CFD method to find the capturing neutrons time offline, combine the results of TCM data, and then get TOF.
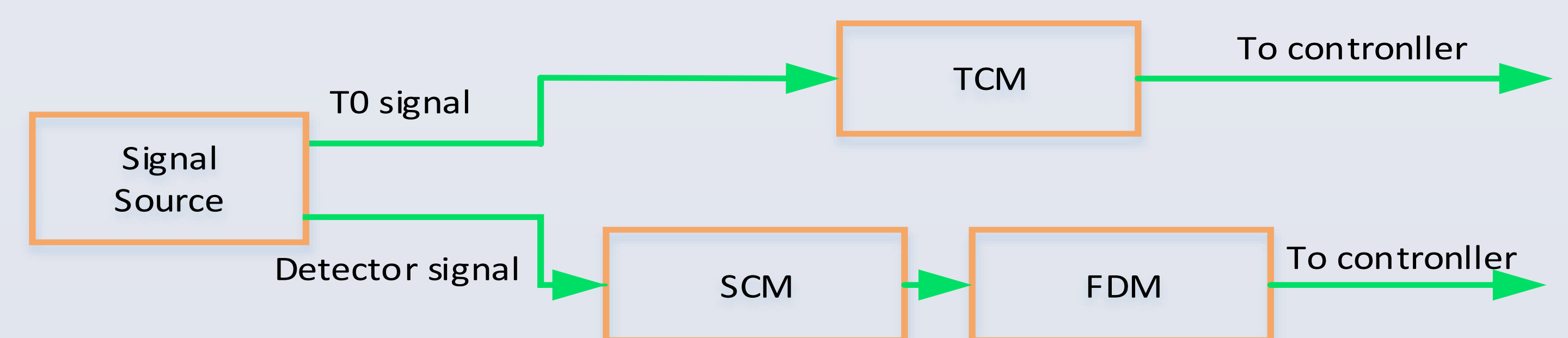

Fig.7. Diagram of TOF accuracy evaluation

Fig.7 shows the test diagram of TOF. Fig.8 shows the scene of TOF accuracy evaluation and Fig.9 is the result.
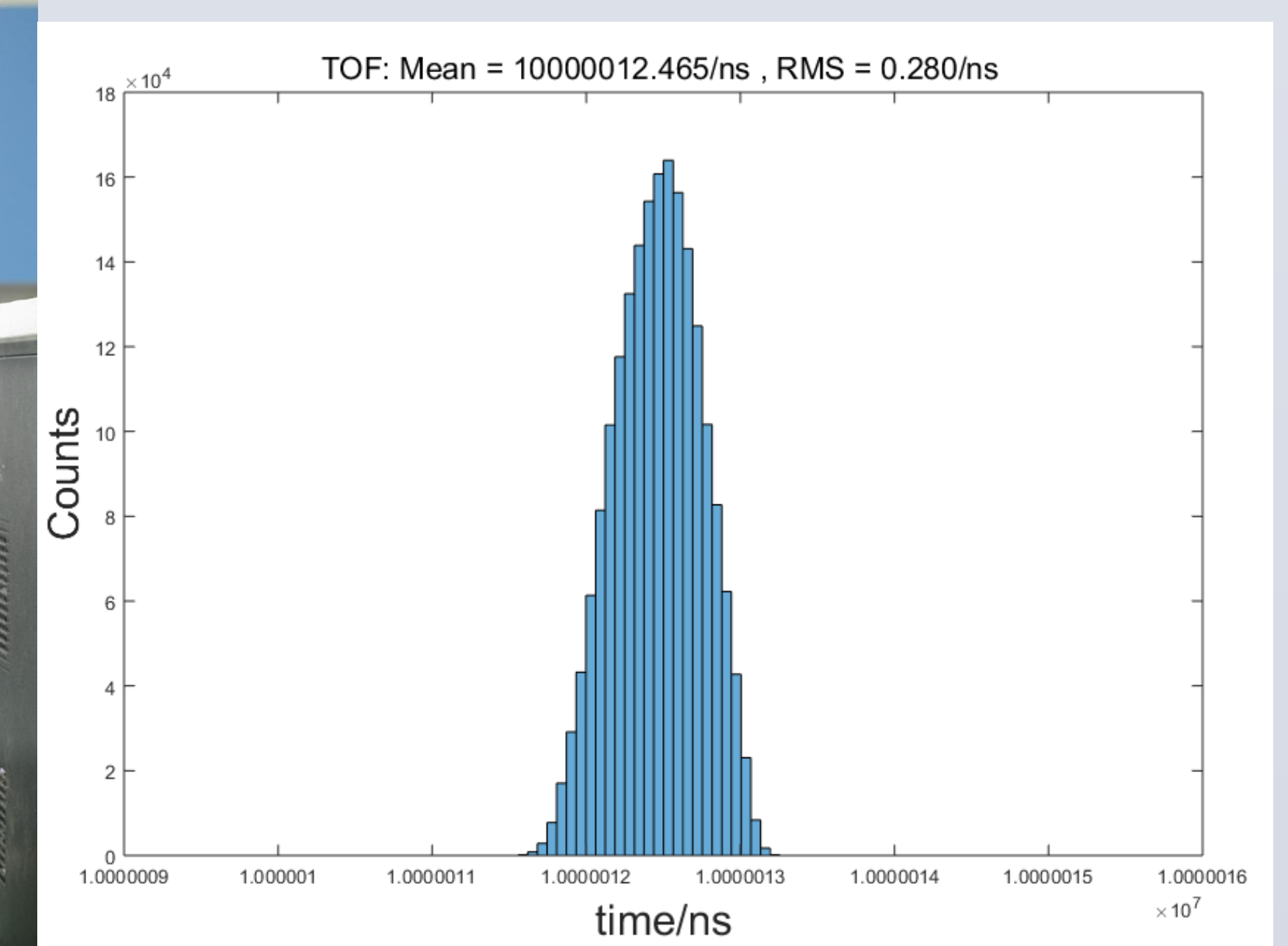

Fig.8. Scene of TOF accuracy evaluation

Fig.9. Result of TOF accuracy evaluation

IV. Conclusion

On the general-purpose readout electronics system of back-n, we have implemented a TOF measurement system to measure the neutron energy. The accuracy of the system is sub-nanosecond in large dynamic range and applicable for Back-n. We will calibrate it in actually use.

Acknowledgement