



# Development of the Readout System for CEPC AHCAL Prototype

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## Introduction

As a vital component of the calorimetry of the Circular Electron Positron Collider (CEPC), the analog hadron calorimeter (AHCAL) uses scintillator, silicon photomultiplier (SiPM) and steel as medium to detect the hadrons. Its 70 mm × 70 mm × 40 -layer prototype is under construction. The readout system of AHCAL is designed to achieve high accuracy of the energy measurement, providing large channel number and dynamic range. An applied special integrated circuit (ASIC) named SPIROC is applied in the readout system for high integrity and low power consumption. Moreover, the readout system is easily scalable for different sizes of sensitive area.

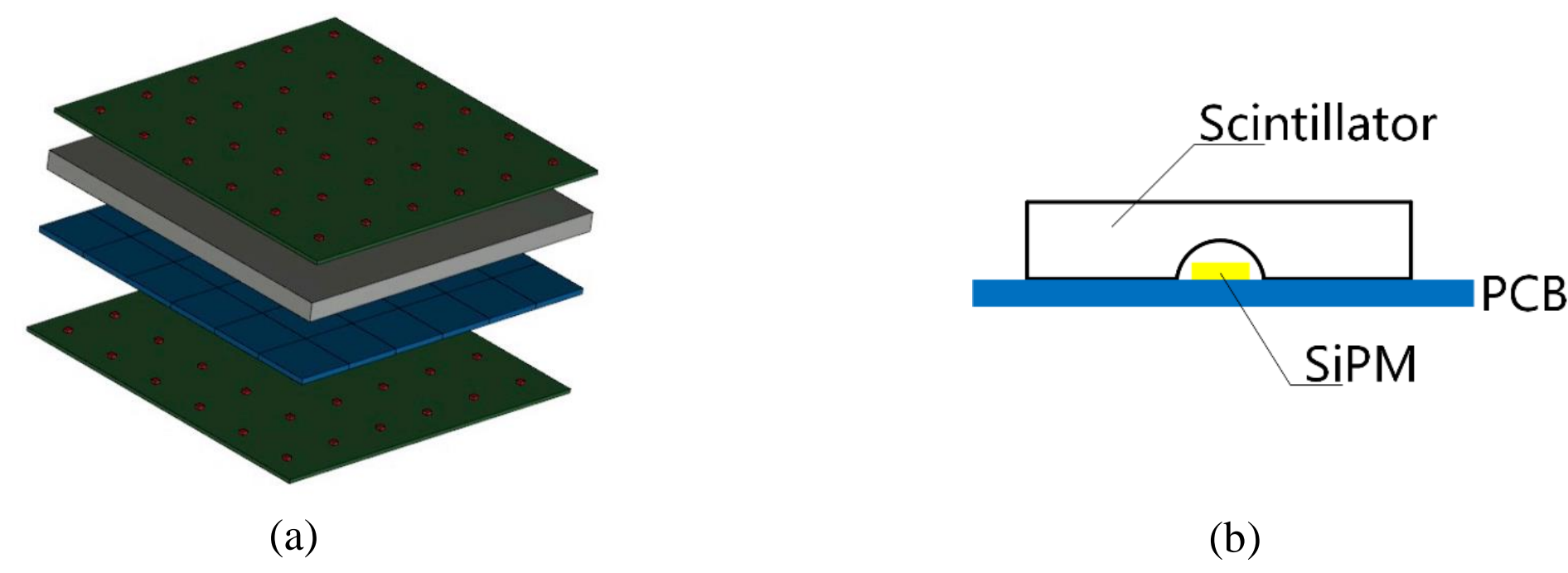


Fig.1 Structure of AHCAL prototype (a) and the coupling method of scintillator and SiPM (b).

## SPIROC

The readout system for AHCAL prototype adopts SPIROC, which offers 36 SiPM readout channels per chip. SPIROC can be conducted to collect, amplify, and digitize the SiPM signals. It is expected to have the advantages of large dynamic range, low power consumption and high integrity. There is a channel-by-channel embedded DAC for SiPM bias voltage adjustments. It is quite useful when the SiPMs have different operating voltages or when temperature compensation is necessary. SPIROC also supports the daisy-chain structure, which is very convenient for expansion in the number of readout channels. Figure 2 shows a photograph of SPIROC.

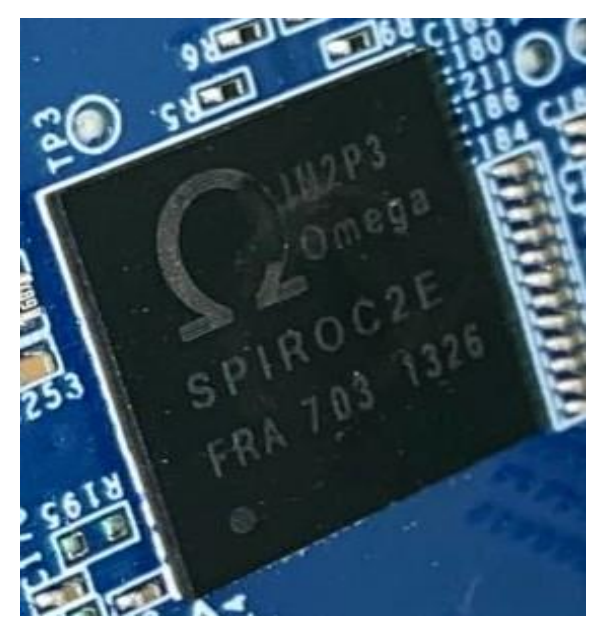


Fig.2 Top view of SPIROC

## Quality Control

The gain difference between different channels of AHCAL prototype can lead to worse linearity and resolution of the energy reconstruction, which are difficult to be revised. The main sources of the difference are scintillator light yield, SiPM gain and SPIROC electronic gain. For a good energy reconstruction of the incident particles in AHCAL, the gain difference should be controlled strictly. Test platforms designed for scintillators and SiPMs are respectively implemented to screen out the qualified scintillators and SiPMs, while SPIROC electronic gain difference can be adjusted by chip configuration.

A soft contact method is adopted by a SiPM fixer (figure 4(a)) to make the SiPM test more convenient and the screened SiPMs easy for welding in the prototype. The SiPM test platform (figure 4(b)) is able to measure I-V curve, dark count rate and gain of the tested SiPM. Figure 4(c) gives out the platform response to several photons and the photons can be clearly distinguished.

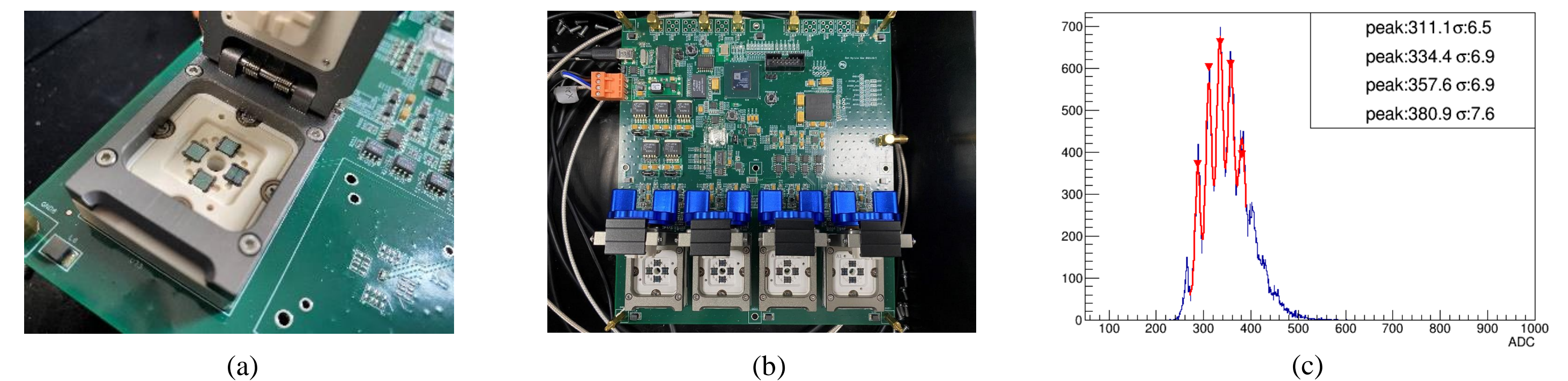


Fig.4 Photographs of SiPM fixer (a) and SiPM test platform (b) and the results of LED calibration (c).

The scintillator test platform (figure 5(b)) with 144 channels aims at measuring the light yield of massive scintillators quickly. As shown in figure 5(a), <sup>90</sup>Sr source is moved by a step motor to generate events. A clear energy spectrum is shown in figure 5(c).

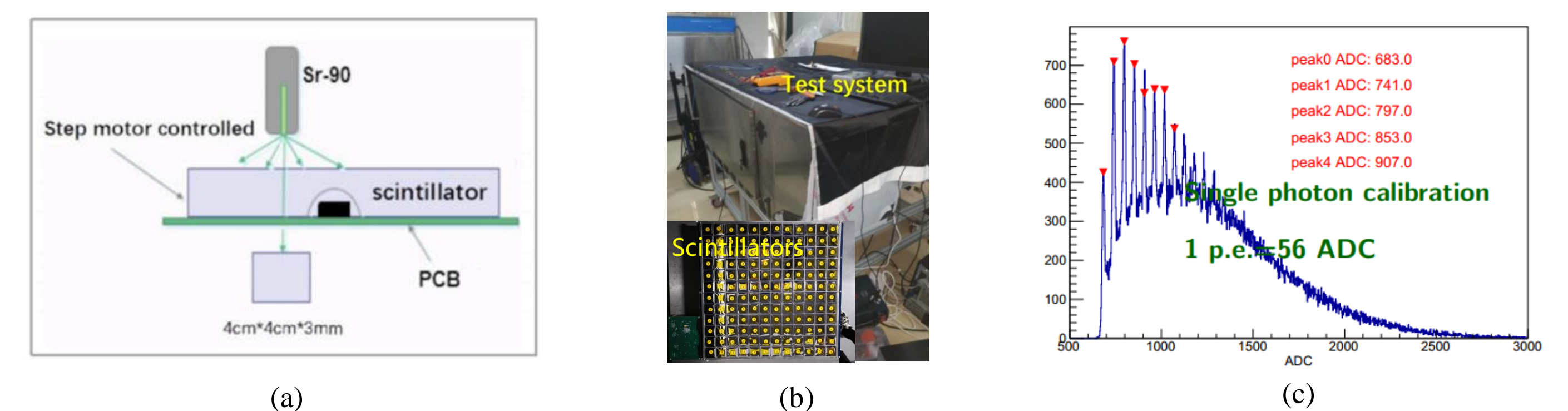


Fig.5 Scheme of scintillator test (a) and photograph of scintillator test platform (b) and the measured energy spectrum of <sup>90</sup>Sr source (c).

## Readout System

The whole readout system is mainly composed of the HCAL Base unit (HBU) boards, data interface (DIF) boards, Gigabit transceiver (GBT) board, server and PC. SiPMs are amounted on the HBU board, with scintillators on the top of them. SiPM signals are amplified, sampled and digitized by SPIROC on HBU board. In particular, the HBU board adopts a scalable design, making it possible to change the sensitive area when necessary. DIF board controls the working status of SPIROC, as well as receives the data of events. GBT board is a data tube between the server and DIF boards to realize the data and command transmission. PC is used to interact with the GBT board to acquire the real-time information of system power consumption. Data of events are finally stored in server for analysis. Figure 3 shows the schematic view and photograph of the readout system respectively.

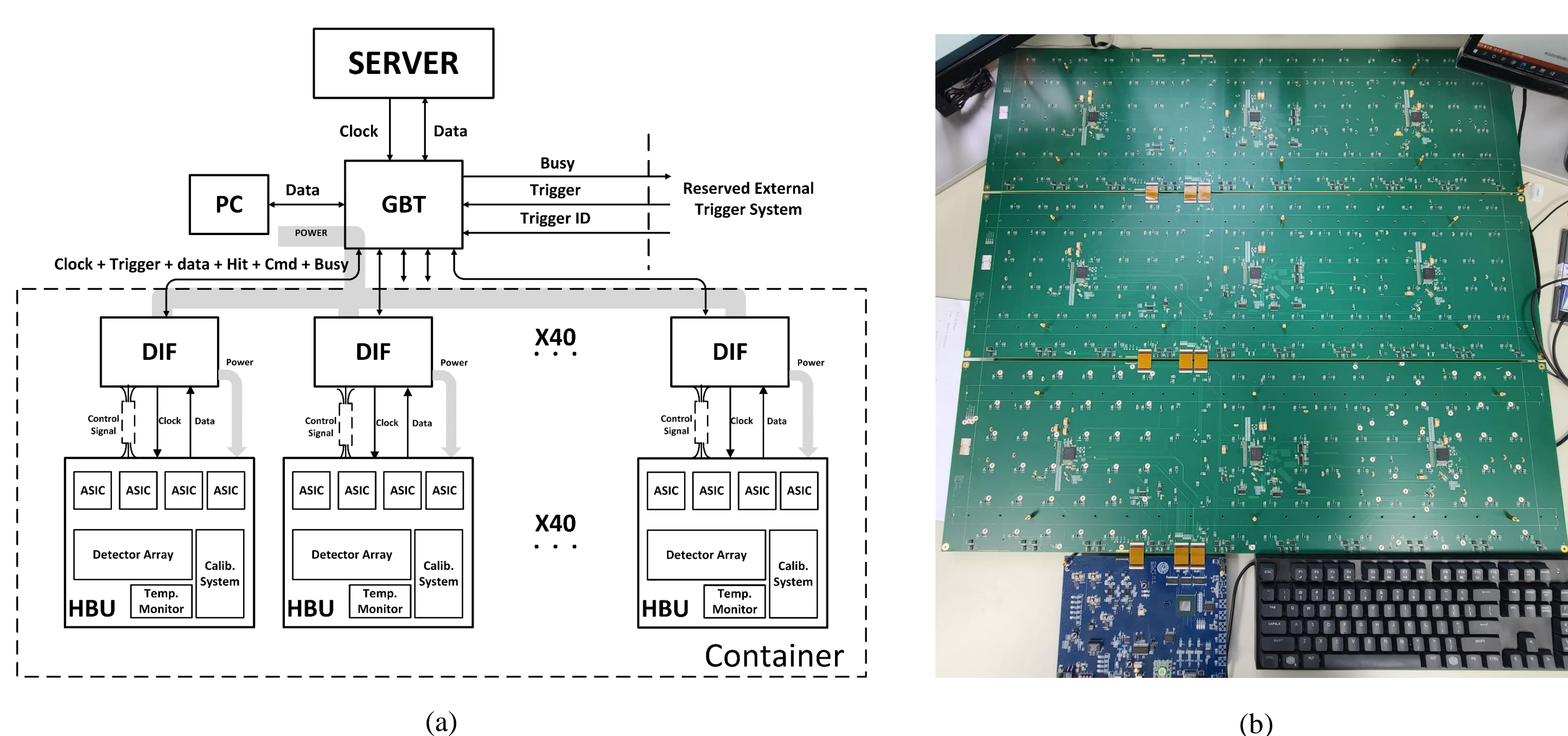


Fig.3 The schematic view (a) and photograph (b) of the readout system for CEPC AHCAL prototype

## Temperature Compensation

SiPM gain is strongly dependent on temperature. To maintain the gain, the operating voltage should be adjusted corresponding to the temperature change. Temperature monitoring is established based on temperature sensors located evenly in all SiPM cells. According to the real-time information from the temperature monitors, the field of temperature can be reconstructed and then the bias voltage of SiPM can be tuned to minimize the temperature-caused gain drift by the internal 5-volt DAC of SPIROC.

## Conclusion

The readout system based on SPIROC has been developed for CEPC AHCAL prototype. For better linearity and resolution of the prototype, the quality control of scintillator and SiPM is carried out successfully. Temperature compensation of SiPM is also considered. Besides, a series of basic measurements are conducted to prove that the readout system of AHCAL prototype works properly.

## Acknowledgements

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