Development of the FoCal-E PAD detector and its electronics for the LHC-ALICE experiment

Motoi Inaba, Tatsuya Chujo†, Masahiro Hirano† for the ALICE FoCal collaboration

Tsukuba University of Technology, Amakubo 4-3-15, Tsukuba, Japan. †University of Tsukuba, Tennodai 1-1-1, Tsukuba, Japan.

Purpose

In order to study the initial state of the high-energy heavy-ion collision, it is proposed to install a forward calorimeter (FoCal) in the LHC-ALICE experiment.

FoCal is going to have an electro-magnetic calorimeter (FoCal-E) to measure the direct photons and a hadron calorimeter (FoCal-H) to observe the jets, and the FoCal-E consists of low-granularity silicon-pad (PAD) modules and high-granularity silicon-pixel (MAPS) modules.

The first beam test of the FoCal-E, namely a combination of PAD and MAPS modules, was carried out at CERN PS and SPS beam lines in 2014.

We developed a trigger signal converting circuit, a trigger signal processor, a temperature monitor using precision digital thermo-sensors, independent regulated power circuits and isolated high-voltage generators for PAD modules.

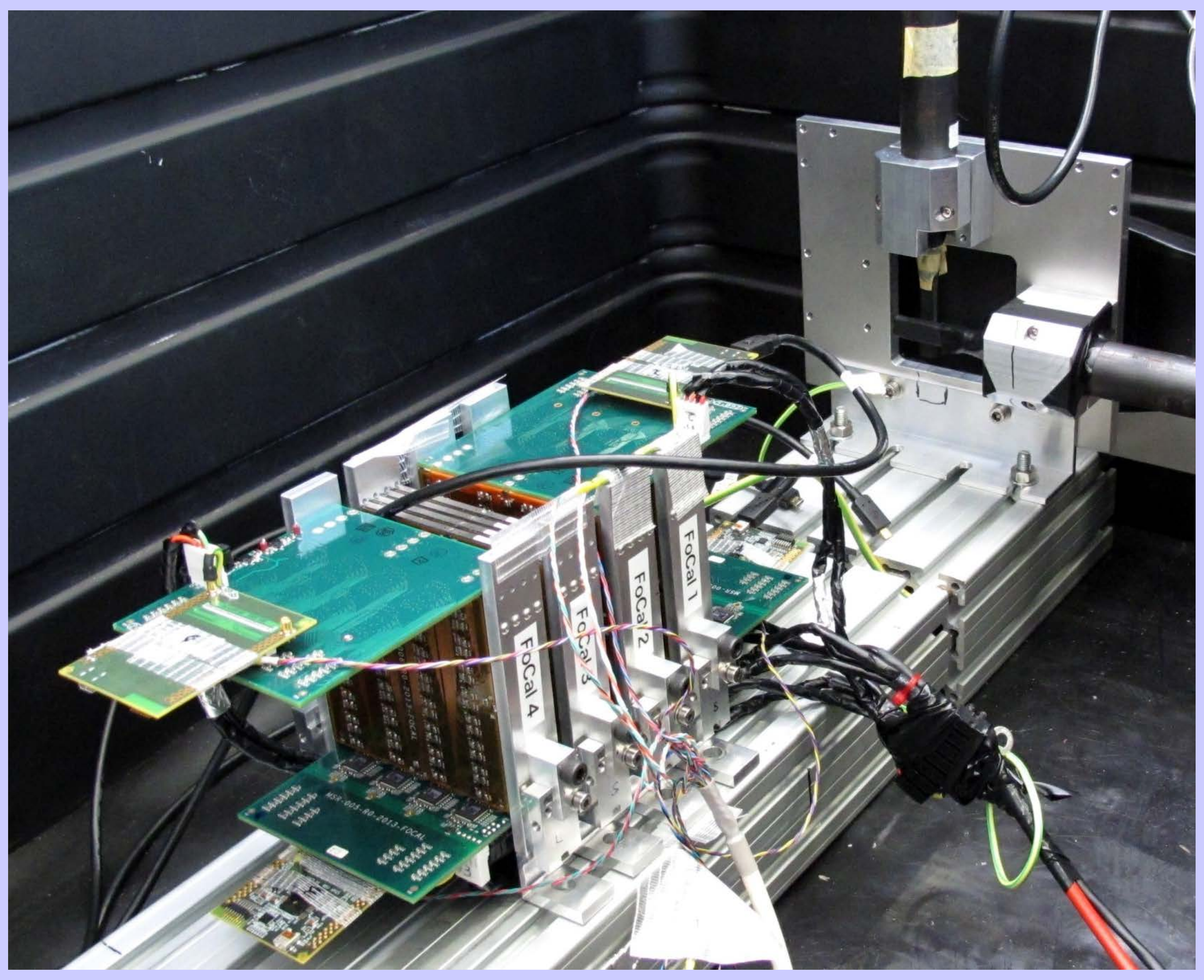

Fig. 1 FoCal-E PAD modules at CERN PS beam line.

The FoCal-E PAD module

Each FoCal-E PAD module has 4 pairs of a tungsten tile and the 8 x 8 silicon photodiode array as shown in Fig. 1. The sizes of a tungsten tile and a photodiode cell are 94.3 x 94.3 mm^2 and 11.3 x 11.3 mm^2, respectively.

The output signal is derived as the current sum of 4 photodiode cells in the same position by a summing board. The summing board makes low-gain and high-gain output signals. Prototypes of the PAD module and the summing board were designed and fabricated at ORNL.

We used frontend hybrid boards with the APV25 analog pipeline ASIC, the CERN RD51 SRS-ADC-C-Card and SRS-FEC-Card to read out signals of the FoCal-E PAD module at the first beam test in 2014 as shown in Fig.2. We are going to have new frontend hybrid boards with the VMM2 mixed-signal ASIC and SRS-D-Card.

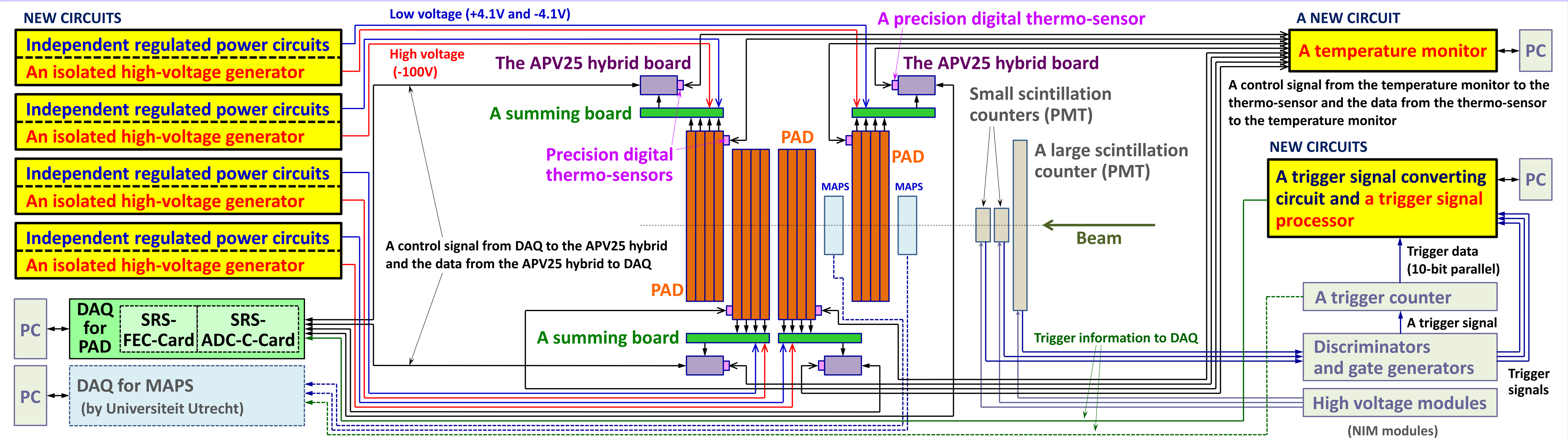

Fig. 2 The beam test setup and developed circuits.

A new temperature monitor

Fig. 3 shows a temperature monitor with high-precision digital thermo-sensors to manage the temperature-sensitive photodiodes. The thermo-sensors are controlled through the 1-wired serial interface, and it is easy to increase the number of sensors up to 160. In the remote control mode, it sends the temperature data to a personal computer through the USB interface. Figs. 4 and 5 show the exterior of the temperature monitor and thermo-sensors, respectively.

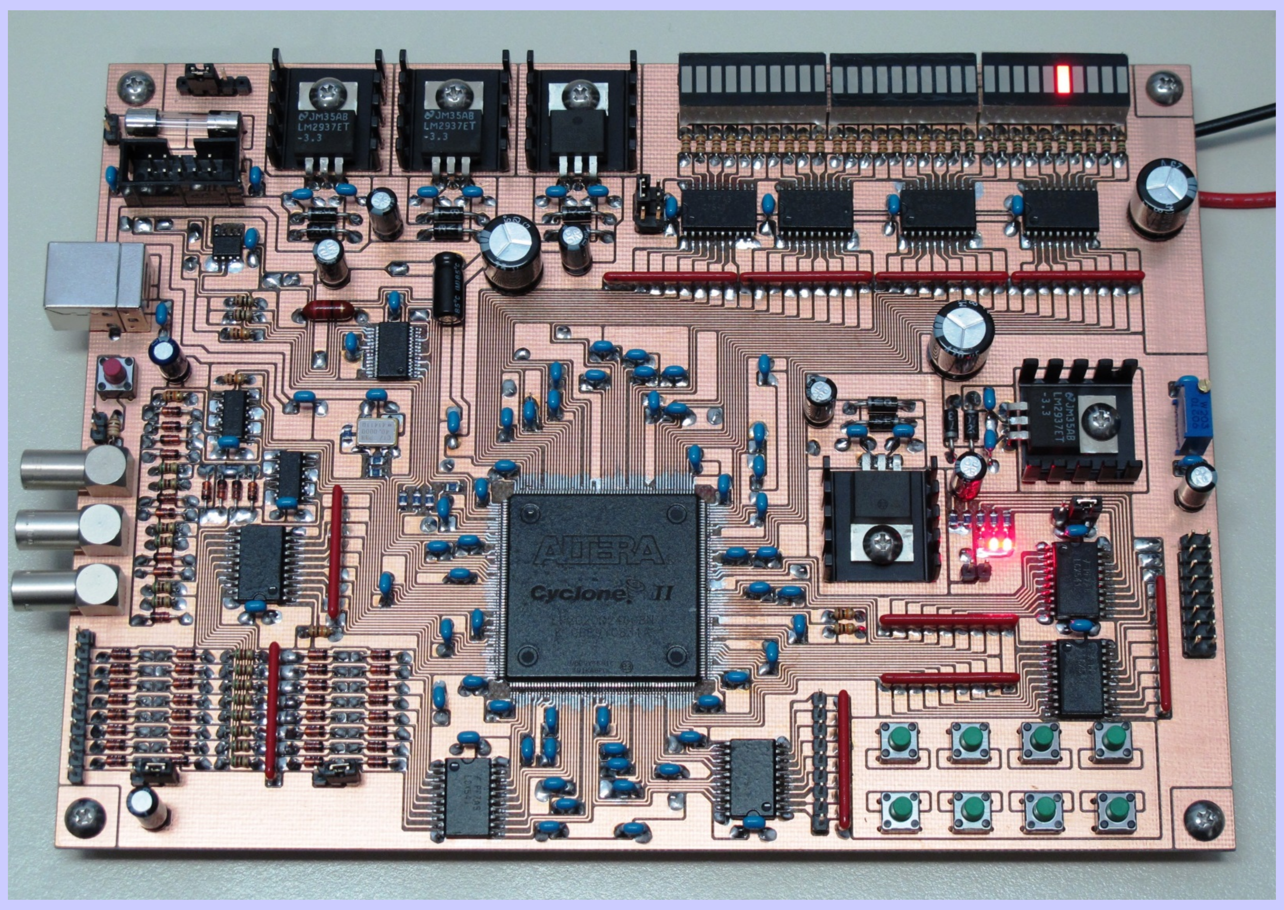

Fig. 3 A new temperature monitor.

Fig. 4 The exterior of the temperature monitor.

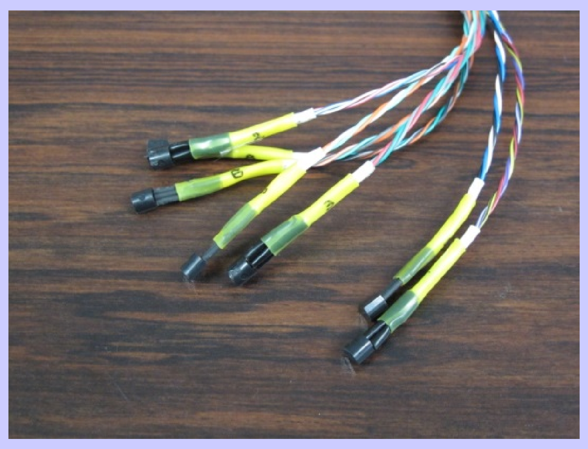

Fig. 5 High-precision digital thermo-sensors.

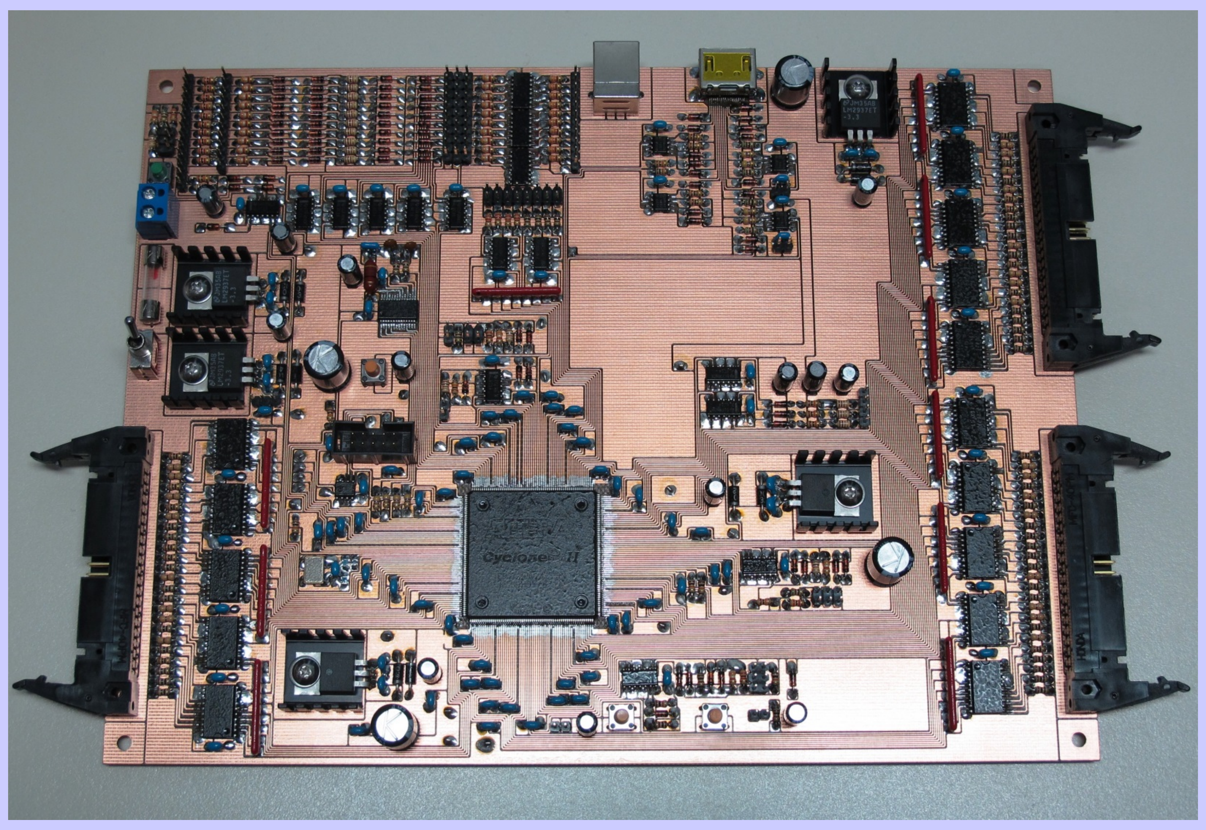

Fig. 6 A new trigger signal processor.

A new trigger signal processor

First, we developed a trigger signal converting circuit with the CPLD to merge the PAD data with the MAPS data because they were working on different DAQs as shown in Fig. 2. The circuit receives the 10-bit parallel trigger data from a trigger counter through optocouplers and sends a serial trigger data with the timing and channel information to DAQ for PAD. The circuit and DAQ for PAD can be connected with each other through an ordinary HDMI cable.

And then, we developed a new trigger signal processor with the FPGA as shown in Fig. 6. The new circuit can read out the discriminated signals of three scintillation counters directly and make a higher-precision serial trigger data for PAD. It is easy to modify the trigger configuration through the USB interface. The circuit also has three output ports for 8-digit 7-segment LEDs.

The new trigger signal processor is going to be used at the next beam test.

New exclusive low voltage and high voltage supplies

Since the APV25 hybrid board and a summing board were very sensitive to the electrical noise on the power lines, we made the independent regulated power circuits and isolated high-voltage generators. It could bring the good results to improve S/N on the frontend electronics for PAD.

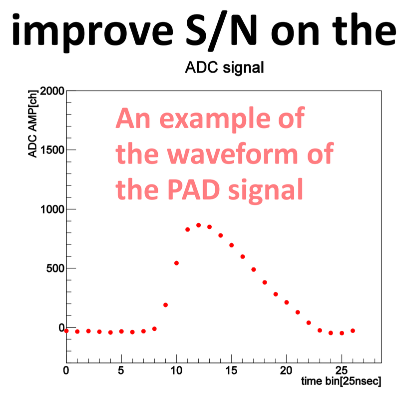

Fig. 7 The PAD signal

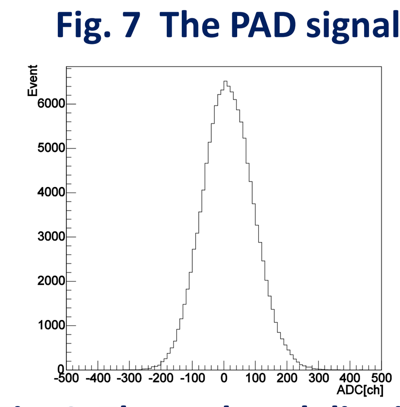

Fig. 8 The pedestal distribution

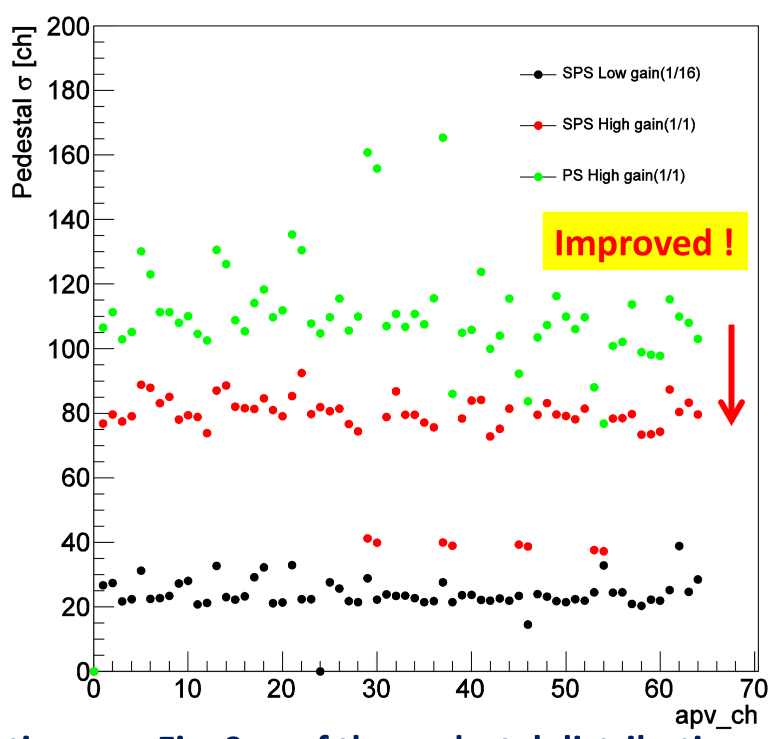

Fig. 9 σ of the pedestal distribution

Summary

We have developed the trigger signal converting circuit, the new trigger signal processor, the new temperature monitor using precision digital thermo-sensors, the new independent regulated power circuits and isolated high-voltage generators for PAD modules.

The new temperature monitor has got the important data to manage the temperature-sensitive photodiodes, and the new regulated power circuits and high-voltage generators have cut off the electric noise on the power lines successfully.

We are planning to do the next beam test to study the energy resolution and the dynamic range of the FoCal-E PAD modules using the new trigger signal processor at CERN PS and SPS beam lines in October, 2015.