Timing Readout Electronics for T-SDHCAL

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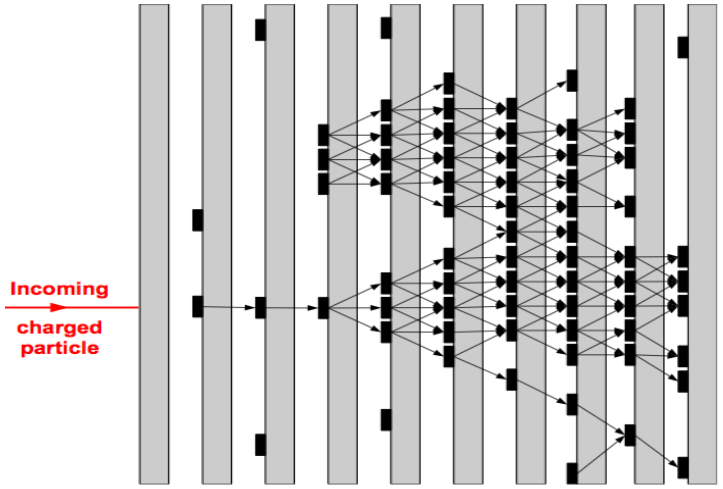
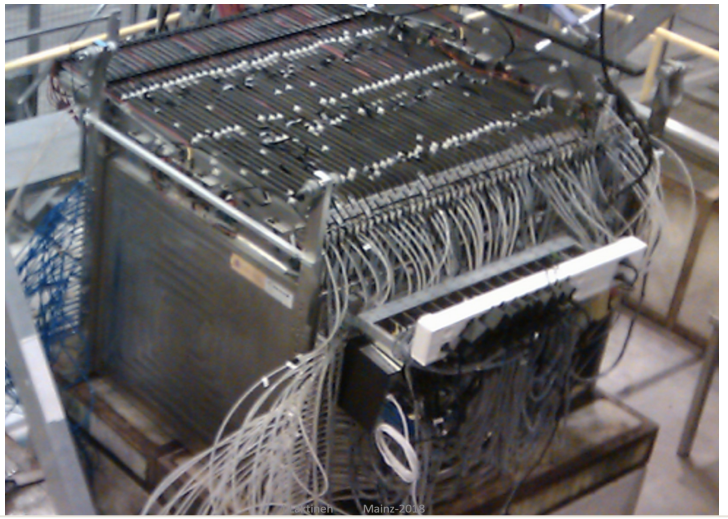
Outline

- Introduction
- Design of the front-end board (FEB) prototype
- Timing performance evaluation
- Double-FEB setup for mRPC cosmic ray test
- DAQ development
- Conclusion

Semi-Digital Hadronic CALorimeter

- SDHCAL is one of the high granularity PFA (Particle Flow Algorithm) calorimeters
  - Connect first hits and then their clusters using distance and orientation information
  - The energy information helps to optimize the connections of hits belongs to the same shower.
- A SDHCAL prototype built based on Glass RPC
  - 48 layers with GRPC as sensitive medium
- Semi-digital readout (HARDROC): hits associated to three different thresholds (2-bit)
  - 1st threshold = 110fC
  - 2nd threshold = 5pC
  - 3rd threshold = 15pC





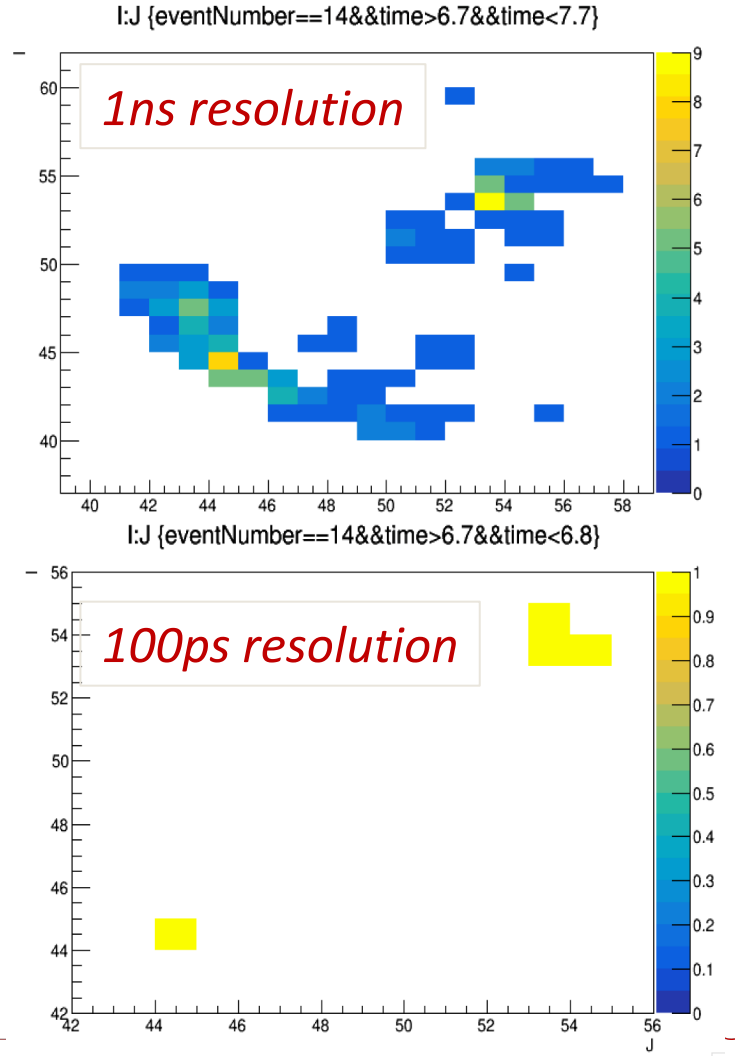
SDHCAL prototype at testbeam in 2015

Timing Electronics

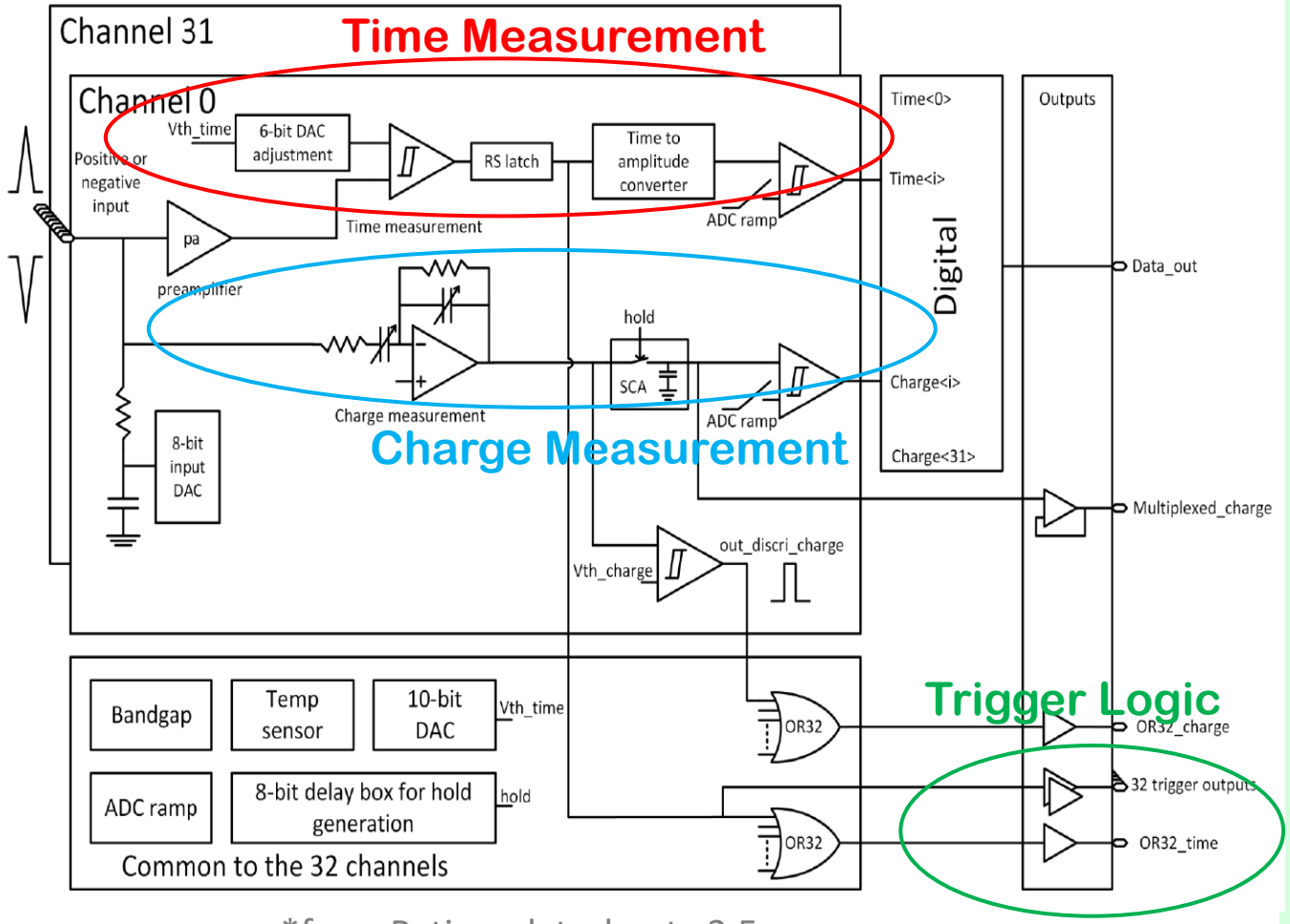
- Timing information can be very helpful to separate close-by showers and reduce the confusion for a better PFA application.
- Method: Adding some mRPC layers in the SDHCAL
- Front-End Electronics for mRPC readout
  - **High resolution timing measurement**

- Time measurement with 10 bits TDC interpolating 40MHz clock
- Timing resolution below 100 ps
- 32 input channels
- Power consumption: ~6mW/channel

Example: Pi-(20 GeV), K-(10 GeV) separated by 15 cm



Petiroc2B ASIC

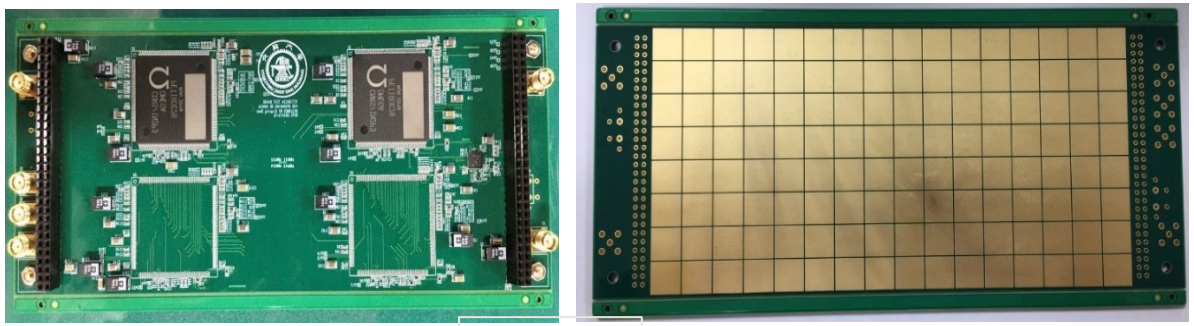


*from Petiroc datasheet v2.5a

- A 32-channel front-end ASIC designed for SiPMs readout (mRPCs as well).
- Charge and timing measurement
- 40 ps bin size of on-chip TDC
- Readout time: 12us
- Fast trigger line output
- Dynamic Range 0-480 pC i.e. 3000 photoelectrons @ 10^6 SiPM gain
- Fast fixed gain (40) inverting voltage preamplifier
- Slow shaper with adjustable shaping time from 25 to 100 ns
- Charge measurements by Track&Hold
- Power consumption 6mW/channel

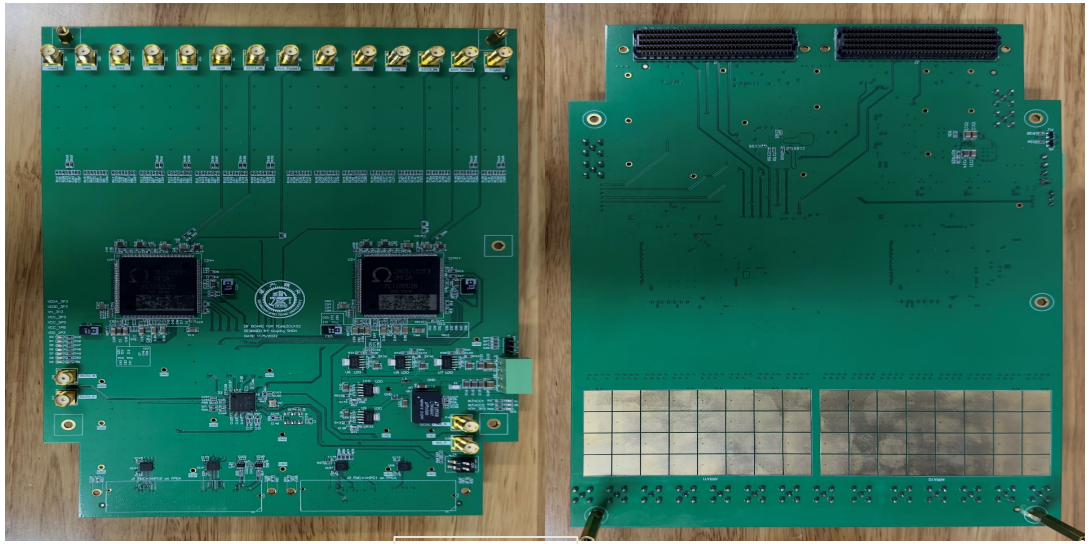
Front-end Board (FEB)

- A small FEB prototype
  - Timing performance validation
  - Readout scheme with mRPC detectors



FEB v1

- 2nd-version of FEB has been designed and fabricated
  - 2 Petirocs on-board
  - On-board power rails
  - 64-channel input pads
  - SMAs to inject signals
  - **Crosstalk issue in injection test has been fixed**

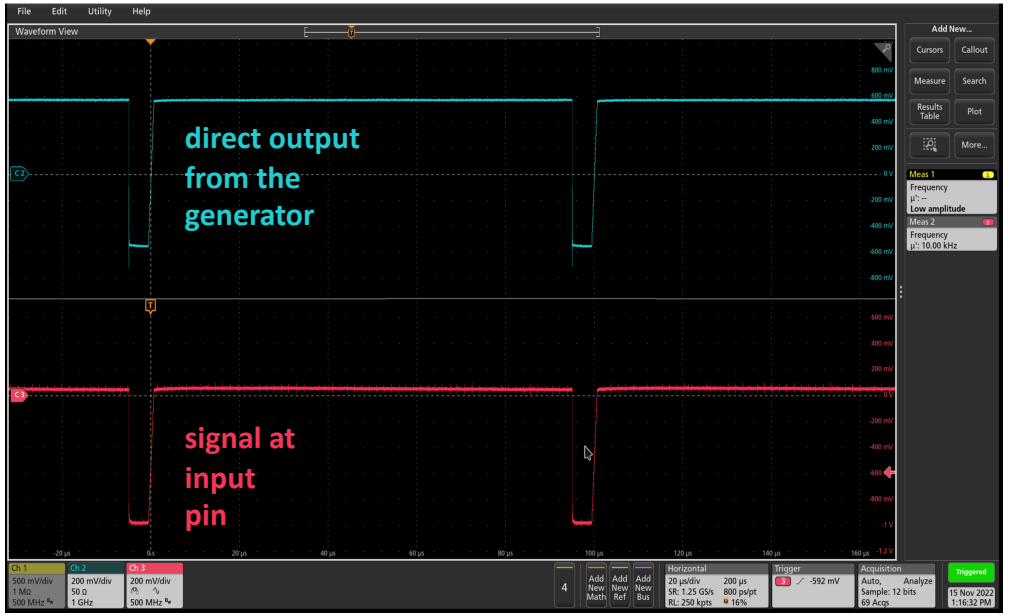


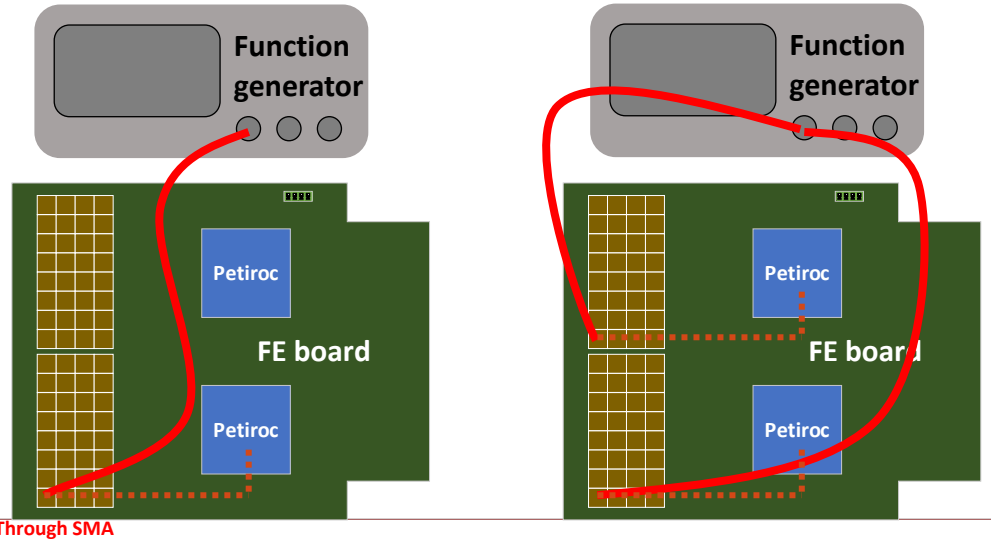
FEB v2

Injected Test

- Injection Test has been performed and verified.
- Timing performance has been evaluated based injection test

  - Setup 1: inject periodic signals to one channel, then measure the timing information between neighbor hits
  - Setup 2: inject signals to two channels, then measure the timing output of two chips



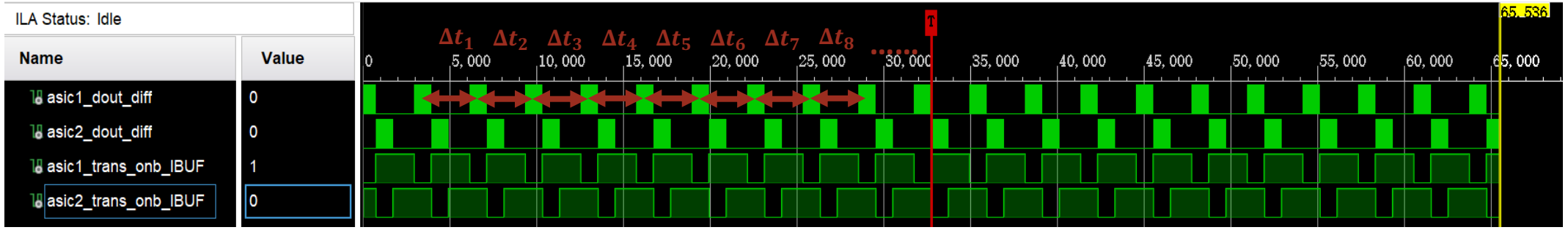


Signal profile:

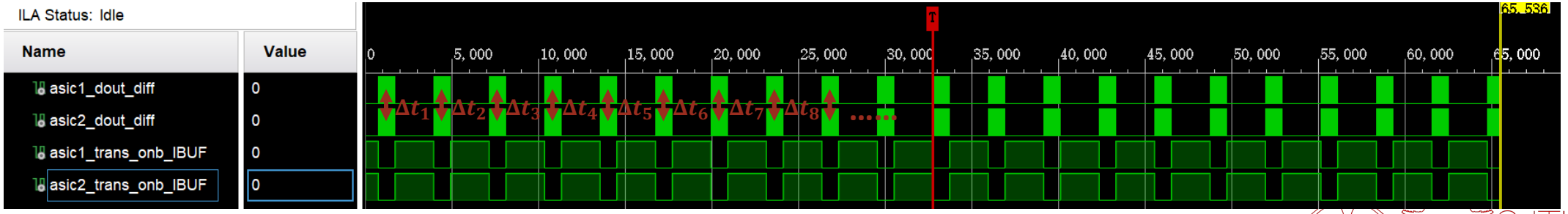
- Negative pulse
- *freq*: 10kHz (period of 100 μs) or 25kHz (period of 40μs)
- 20mV amplitude
- leading of 1us， trailing of 2ns

Timing Performance Tests

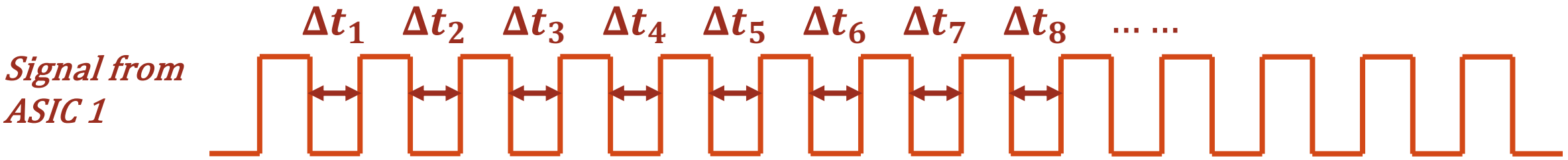
- Timing tests of a single input channel, with periodic injections
  - If Petiroc2B works properly, every two neighbor hits output should have the same time gap. Analyzing the time gaps can get us the timing performance.



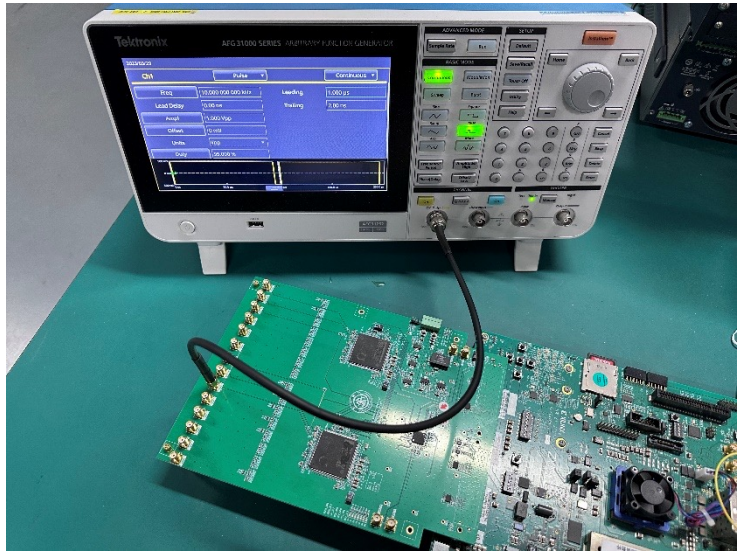
- Timing tests of two clock-synchronized chips
  - For the same single hit, the time gap between the two chips' output should be constant.



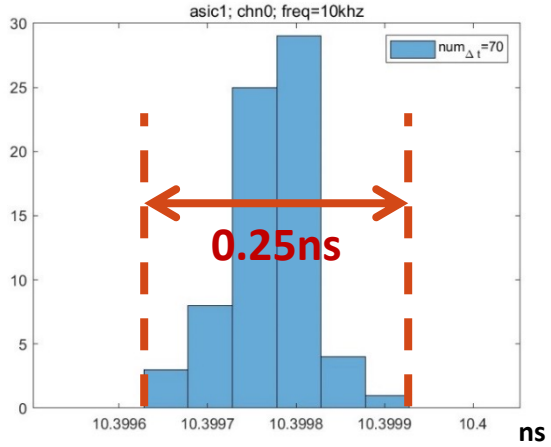
Timing between Neighbor Hits



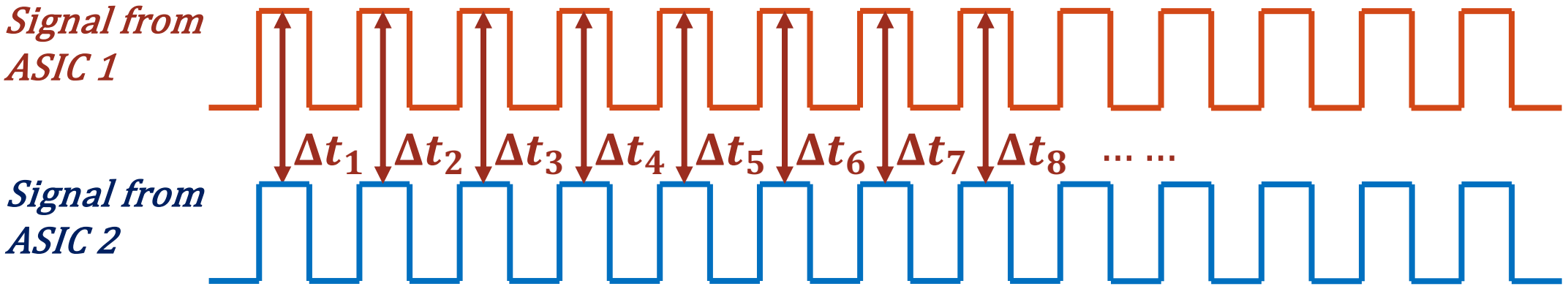
- Inject signal into one chip.
- Calculate the timing differences (**Δt**) between every two neighbor hits.
- Check if **Δt** is consistent.



Results:
- ✓ The std of **Δt** is 45.8ps
- ✓ **Δt** is consistent

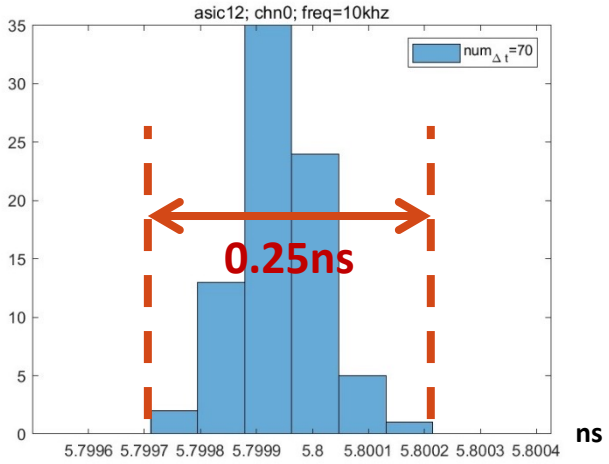


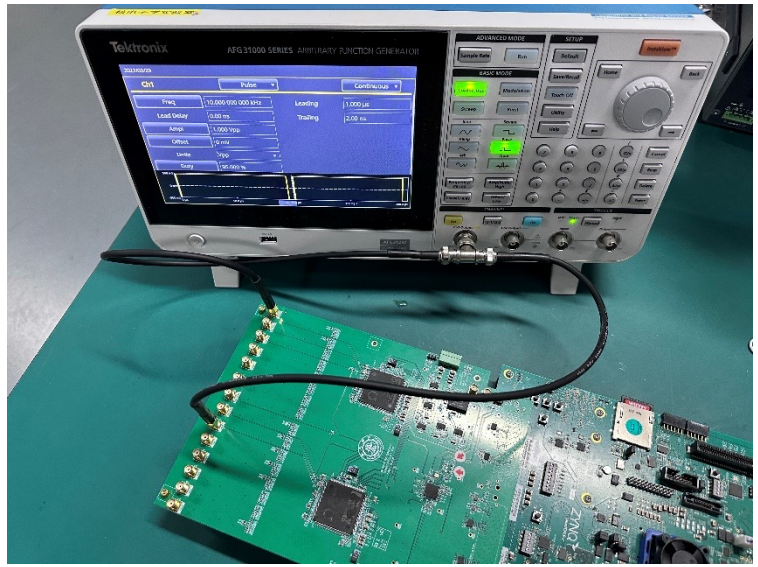
Timing between Two Chips



- Inject the same signal into two chips (with a double-pass).
- Calculate the **Δt** between two Petiroc2B chips of each hit.
- Check if **Δt** is consistent.

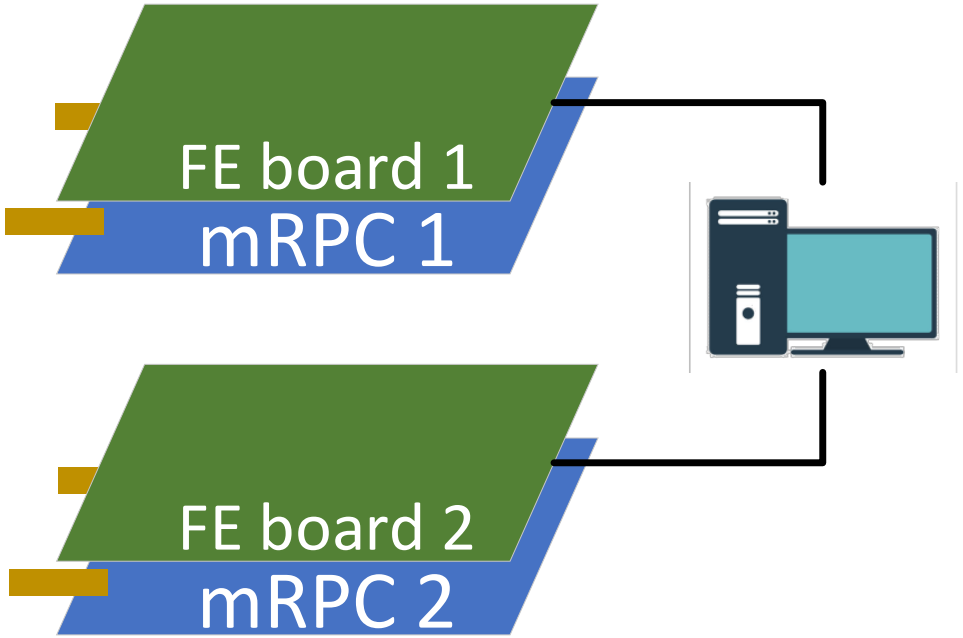
Results:
- ✓ The std of **Δt** is 53.6ps
- ✓ **Δt** is consistent



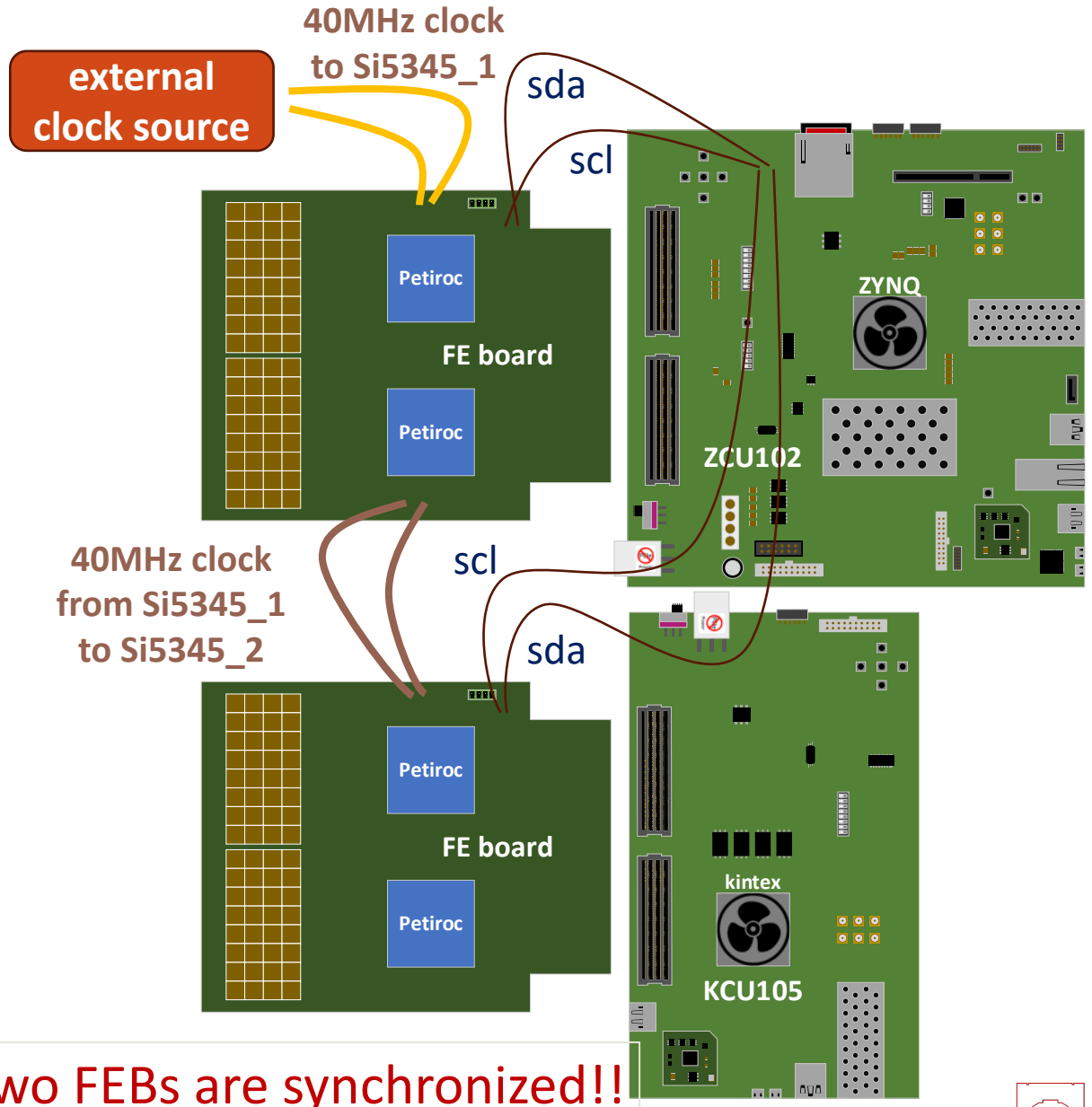


Setup for Cosmic Test

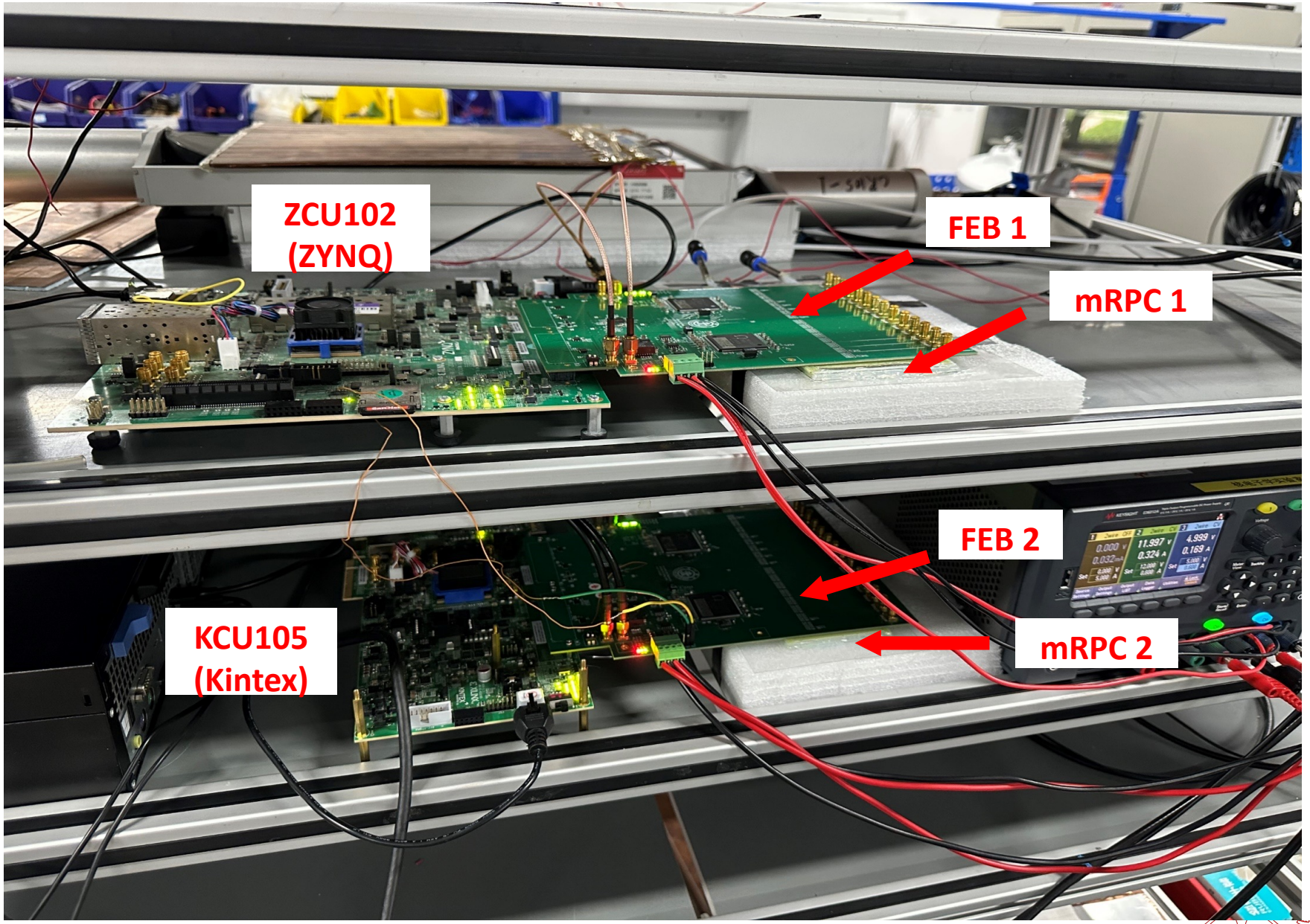
Detect cosmic ray signals by two FEBs that correspond to each other, including time and channel number (position information).



Setup of two FEBs with mRPCs

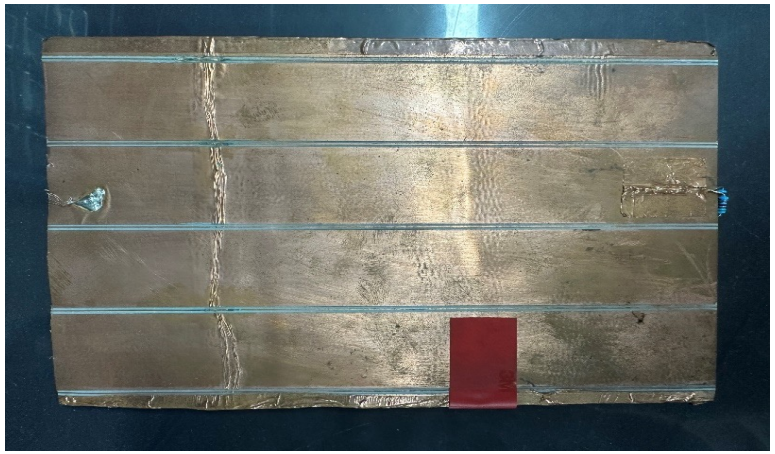


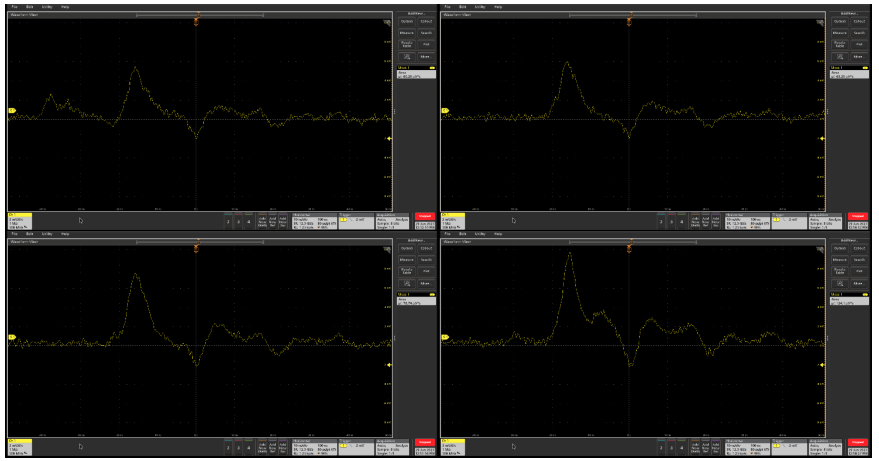
Two FEBs are synchronized!!


ZCU102
(ZYNQ)
FEB 1
mRPC 1
FEB 2
mRPC 2
KCU105
(Kintex)

mRPC Test

mRPC detector

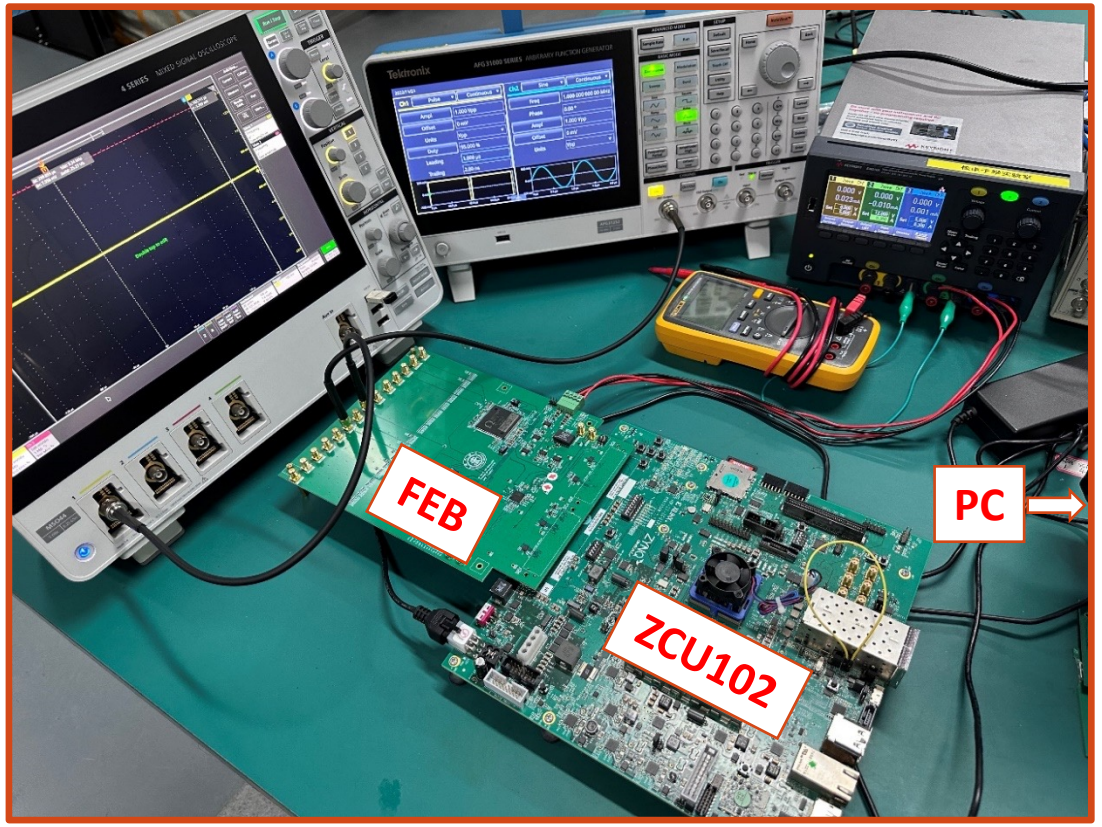


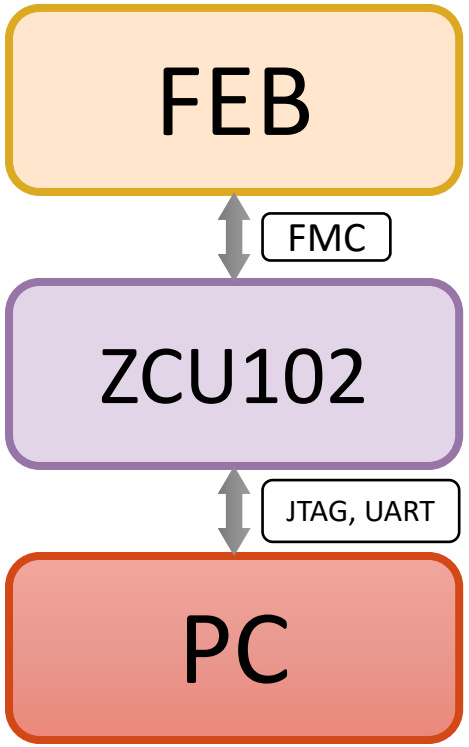


- The test conditions are:
  - voltage: 7500V
  - gas: 10% C4H10, 12% SF6, 18.9% F134a

- Preliminary Test
- Use a readout pad with copper strips, and observe the signal from an oscilloscope
- Can capture something, but probably noises only.
- Still working on the mRPC test, with our colleagues' help

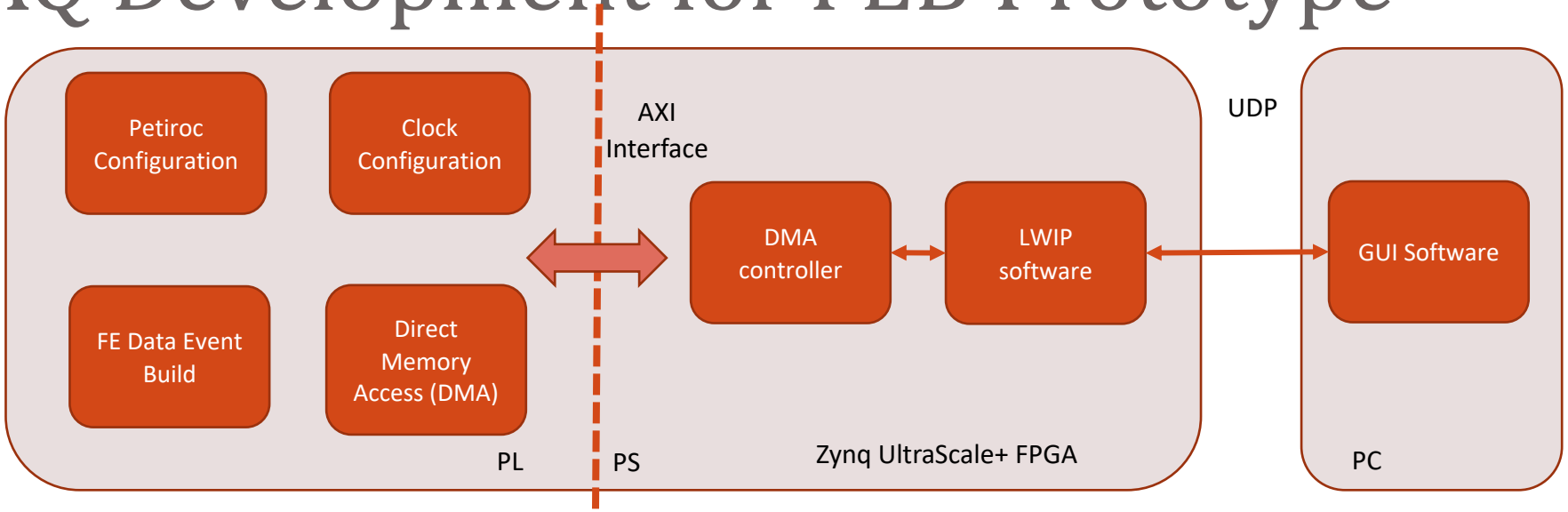
DAQ Development for FEB Prototype

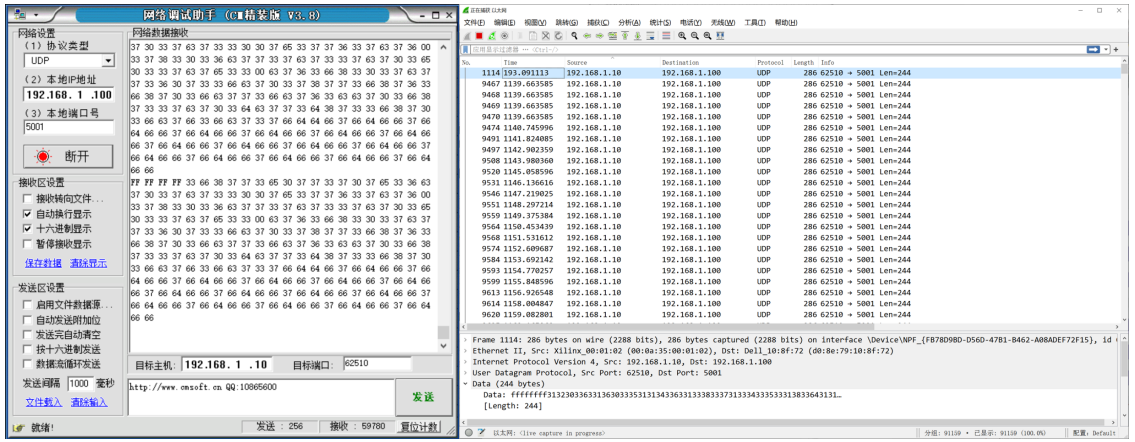




Xilinx ZCU102, with Zynq UltraScale+™ MPSoC

DAQ Development for FEB Prototype

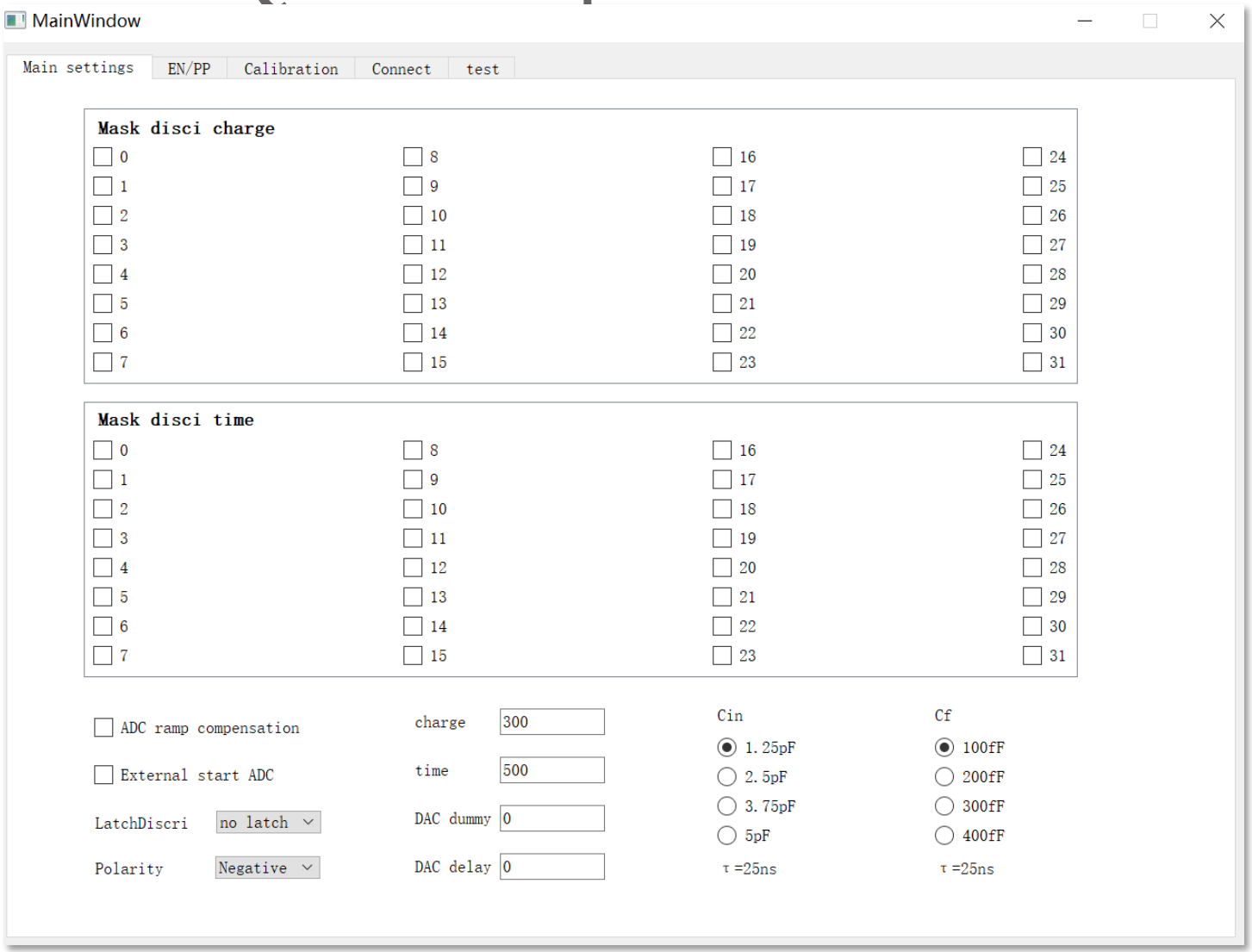




Ethernet data test - read from DMA

- The event data is sent to PS memory by a DMA in PL (FPGA)
- The ethernet transfer function is realized through PS (ARM core) of ZYNQ, using LWIP protocol
- Counter data has been tested and verified

DAQ Development for FEB Prototype



- The DAQ software is a Python GUI application.
- The GUI is designed via QT designer, which is set of cross-platform C++ libraries that implement high-level APIs.
- PyQt5 modules binding with QT v5.

Conclusion

- A FEB prototype based on Petiroc ASIC has been designed
- The timing performance of the FEB has been evaluated, which has a resolution better than $100ps$.
- The commissioning test of the FEB and mRPC detectors is ongoing.
- A DAQ system based on Zynq FPGA and PyQT5, is being developed steadily.

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CALICE
Calorimeter for ILC

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Thank you for your attention

Q&A

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