Updates of Timing electronics for T-SDHCAL

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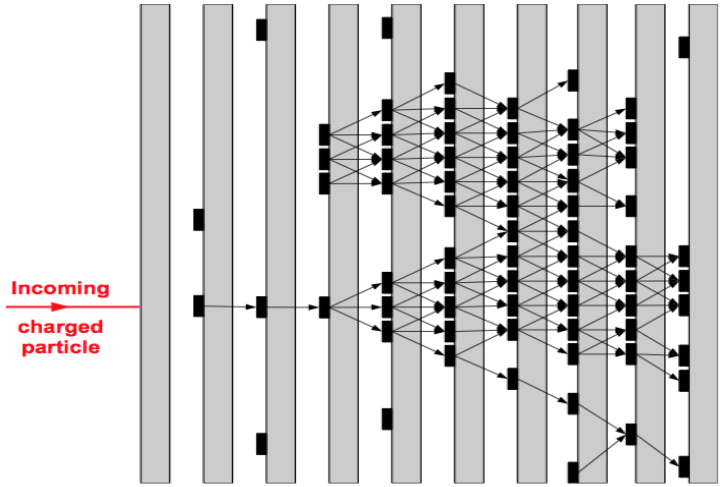
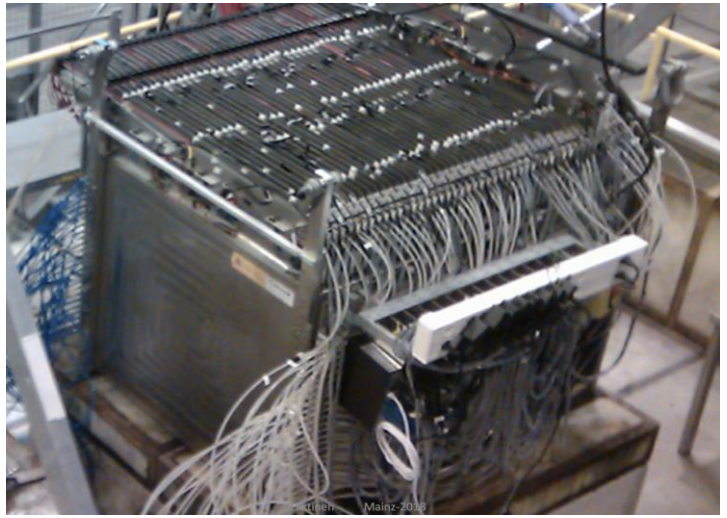
Outline

- Introduction
- 2nd version of FEB prototype
- Timing performance evaluation
- Double-FEB setup for cosmic ray test
- DAQ development
- Conclusion & plans

Semi-Digital Hadronic CALorimeter

- SDHCAL is one of high granularity PFA (Particle Flow Algorithm) calorimeter
  - 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
- Semi-digital readout: hits associated to three different thresholds
  - 1st threshold = 110fC
  - 2nd threshold = 5pC
  - 3rd threshold = 15pC
- 48 layers with GRPC as sensitive medium
- Dimensions: 1m×1m×1.3m





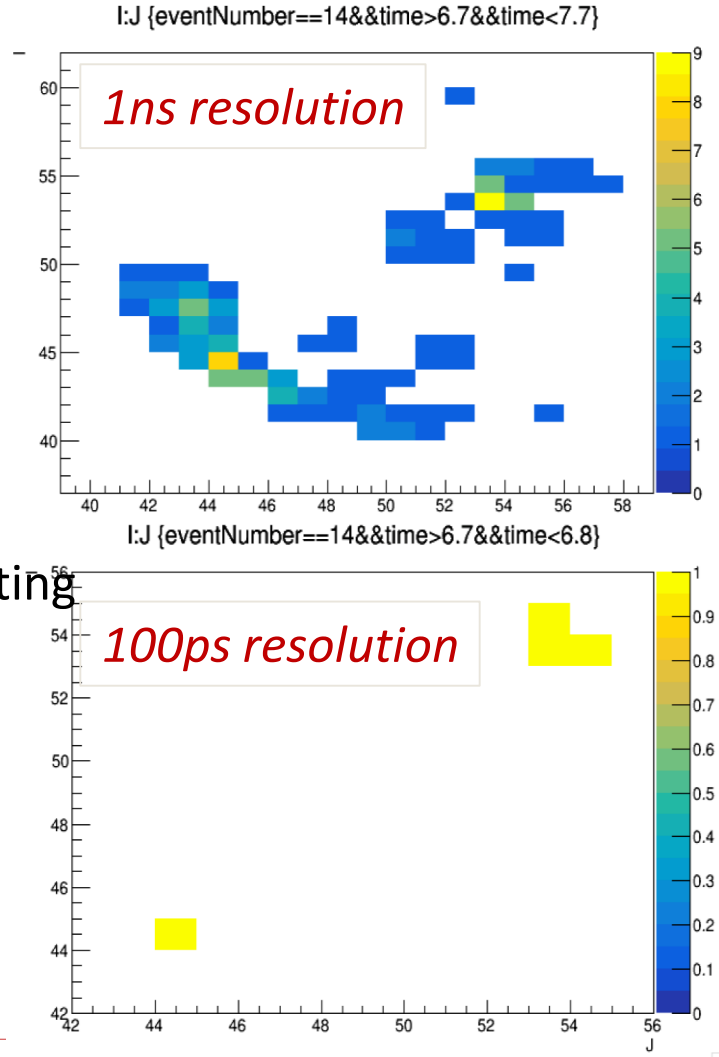
SDHCAL prototype at testbeam in 2015

Introduction of Timing Electronics

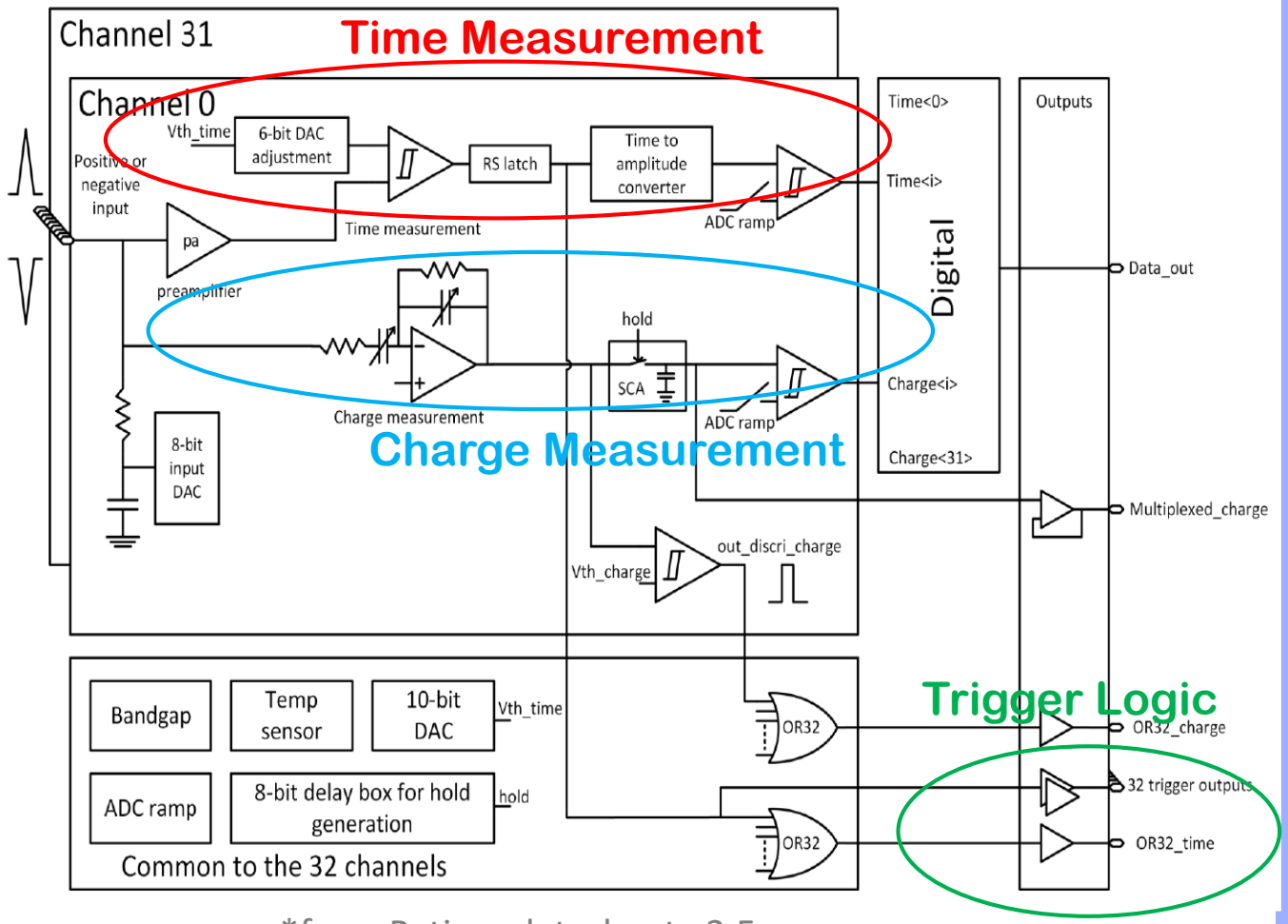
- Timing information can be very helpful to separate close-by showers and reduce the confusion for a better PFA application.
- Method: Adding some mRPC layers in the SDHCAL
- Front-End Electronics for mRPC readout
  - **High resolution timing measurement**

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

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



Petiroc2B ASIC

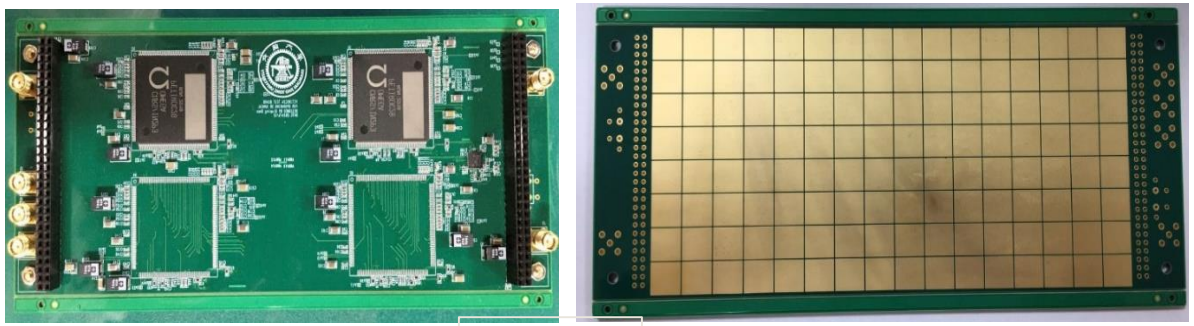


*from Petiroc datasheet v2.5a

- 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
- 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

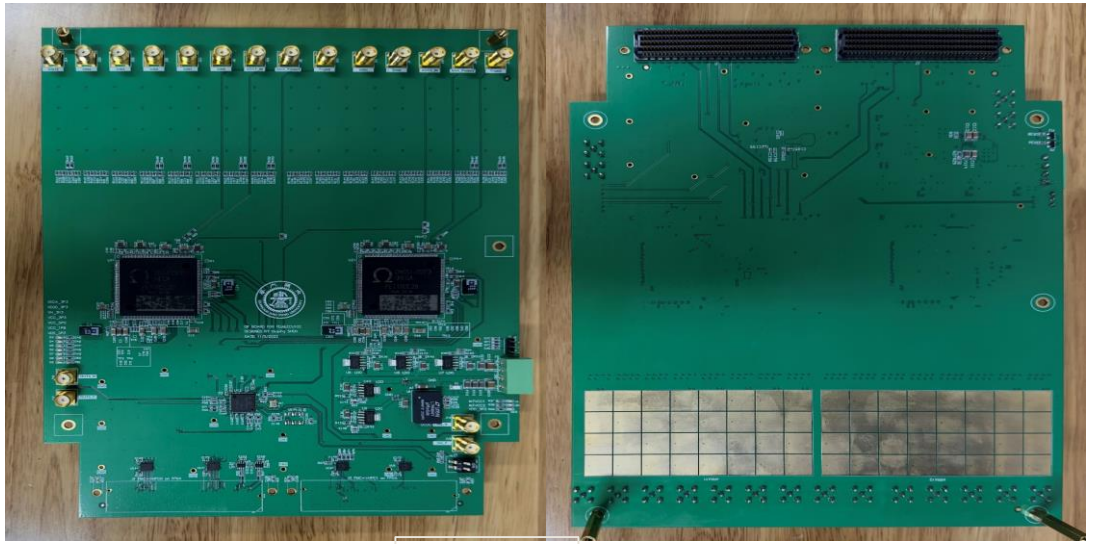
Overview

- 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**

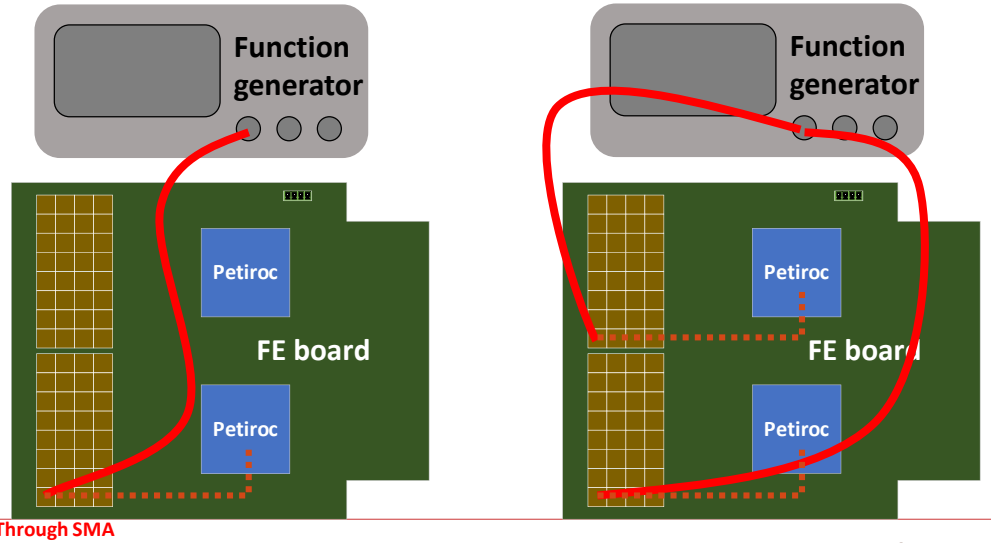


FEB v2

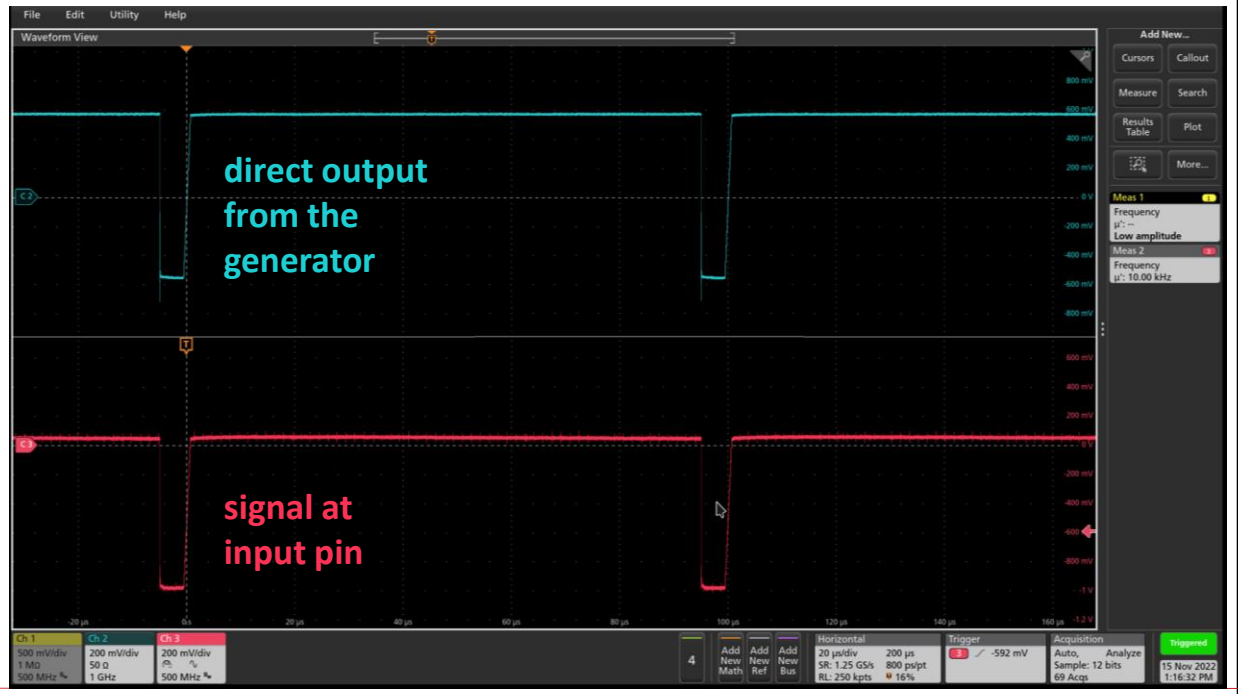
Injected Test

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

Setup:
- Setup 1: inject signal to one channel of one chip. For timing between neighbor hits
- Setup 2: inject signal to two channels from two chips. For timing between two chips

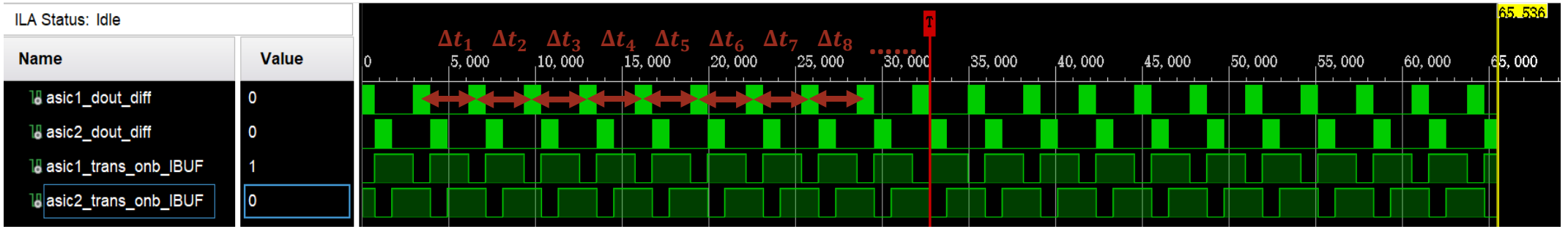


Signal profile:
- Negative pulse
- *freq*: 10kHz (period of 100 μs) or 25kHz (period of 40μs)
- 95% duty
- 1Vpp amplitude
- leading of 1us
- trailing of 2ns

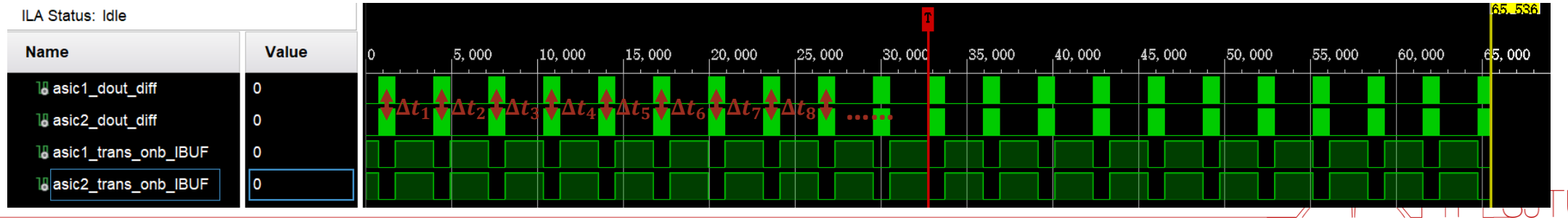


Timing performance tests

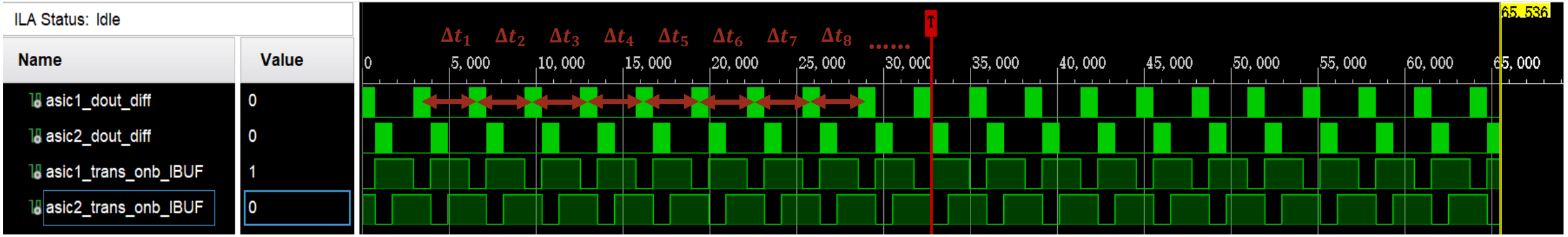
- To test the timing performance, two experiments are implemented:
  - timing tests for single chip, between neighbor hits
    - If Petiroc2B is working properly, every two neighbor hits should have the same time gap (when inject signal is uniform). So analyzing the time gaps can get us the timing performance.



  - timing tests for single hit, between two chips
    - Because two chips share one clock source, the phase difference should be fixed, which means that for the same single hit, the time gap between two chips should be fixed.



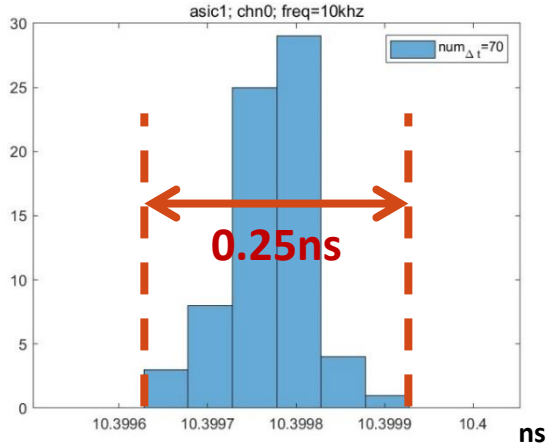
Timing between neighbor hits

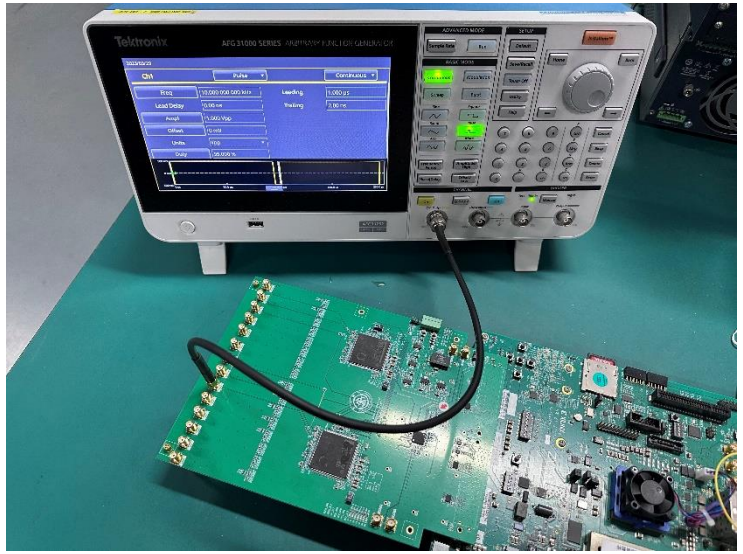


- Inject signal into one chip.
- Calculate the timing differences (**Δt**) between every two neighbor hits.
- Check if **Δt** is consistent.

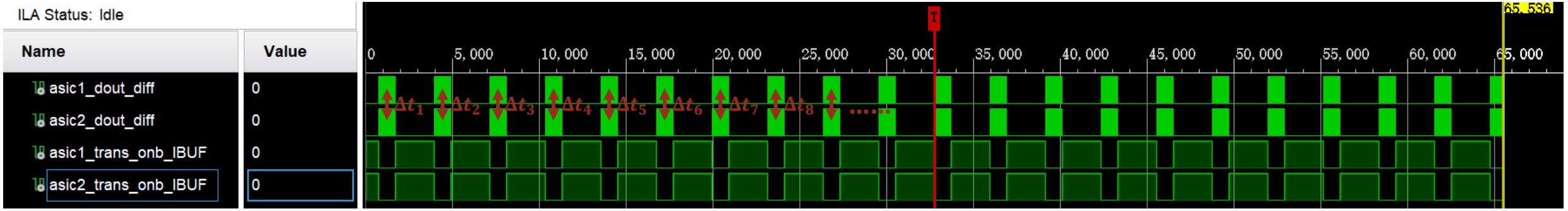
Results:

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





Timing between two chips

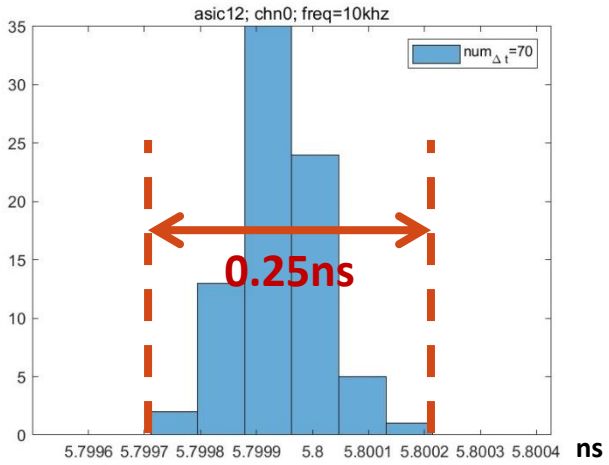


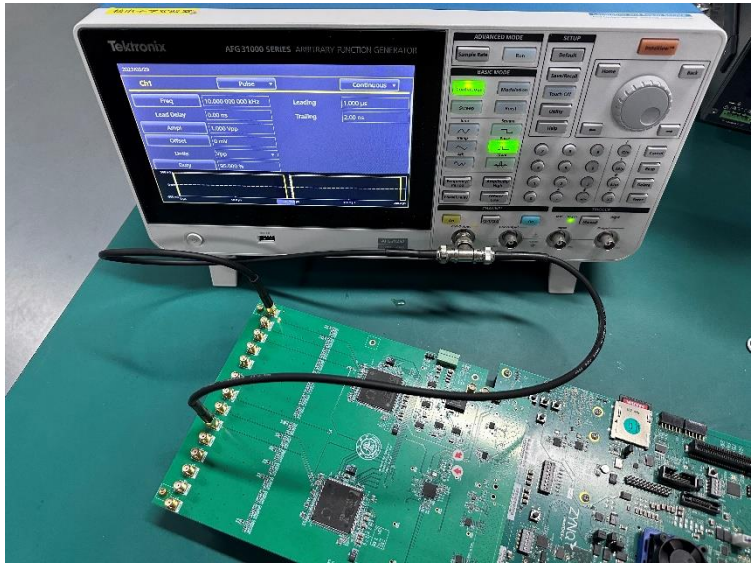
- Inject the same signal into two chips (with a double-pass).
- Calculate the **Δt** between two Petiroc2B chips of each hit.
- Check if **Δt** is consistent.

Results:

✓ The std of **Δt** is 53.6ps

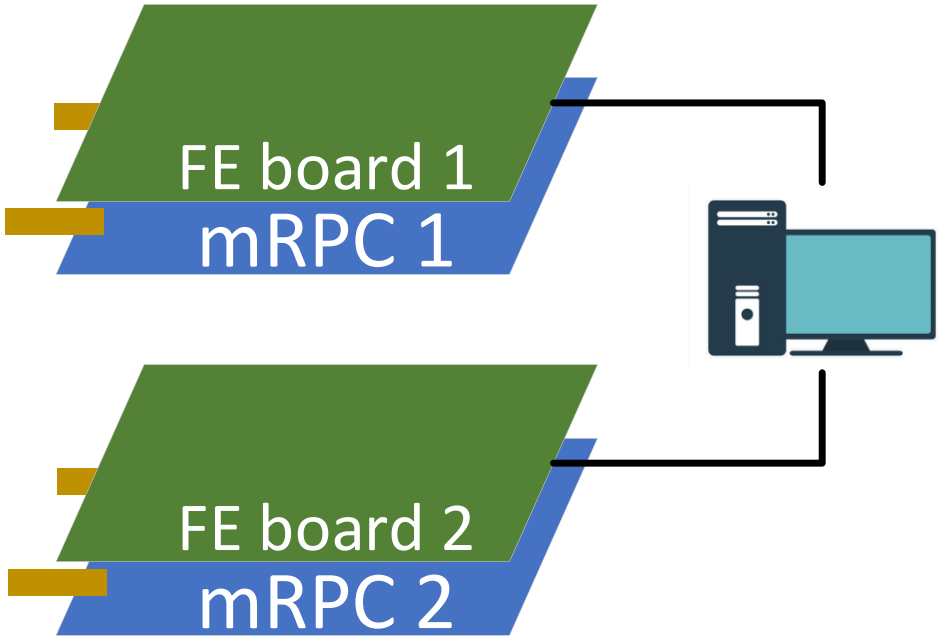
✓ **Δt** is consistent



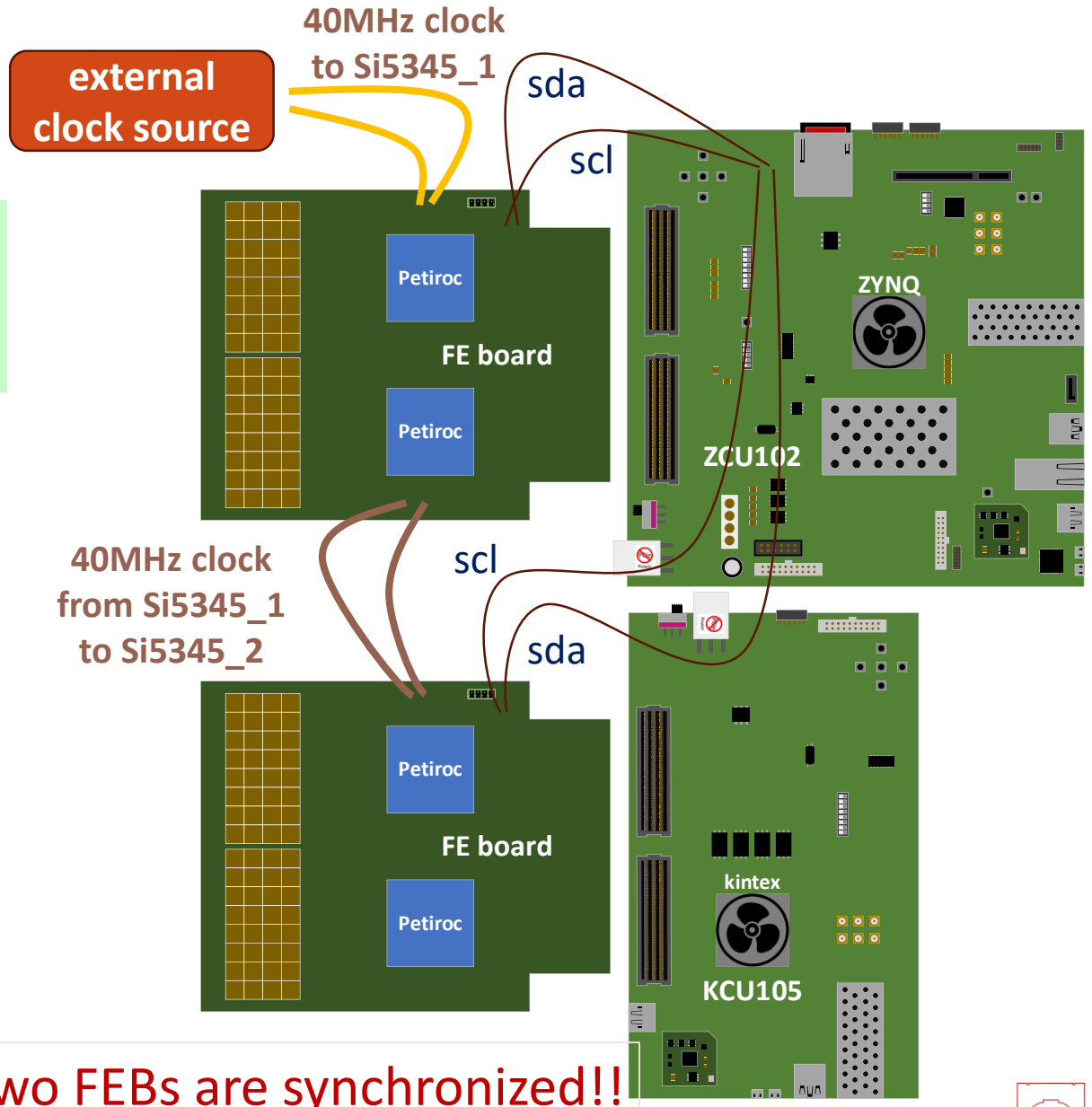


Setup for Cosmic Test

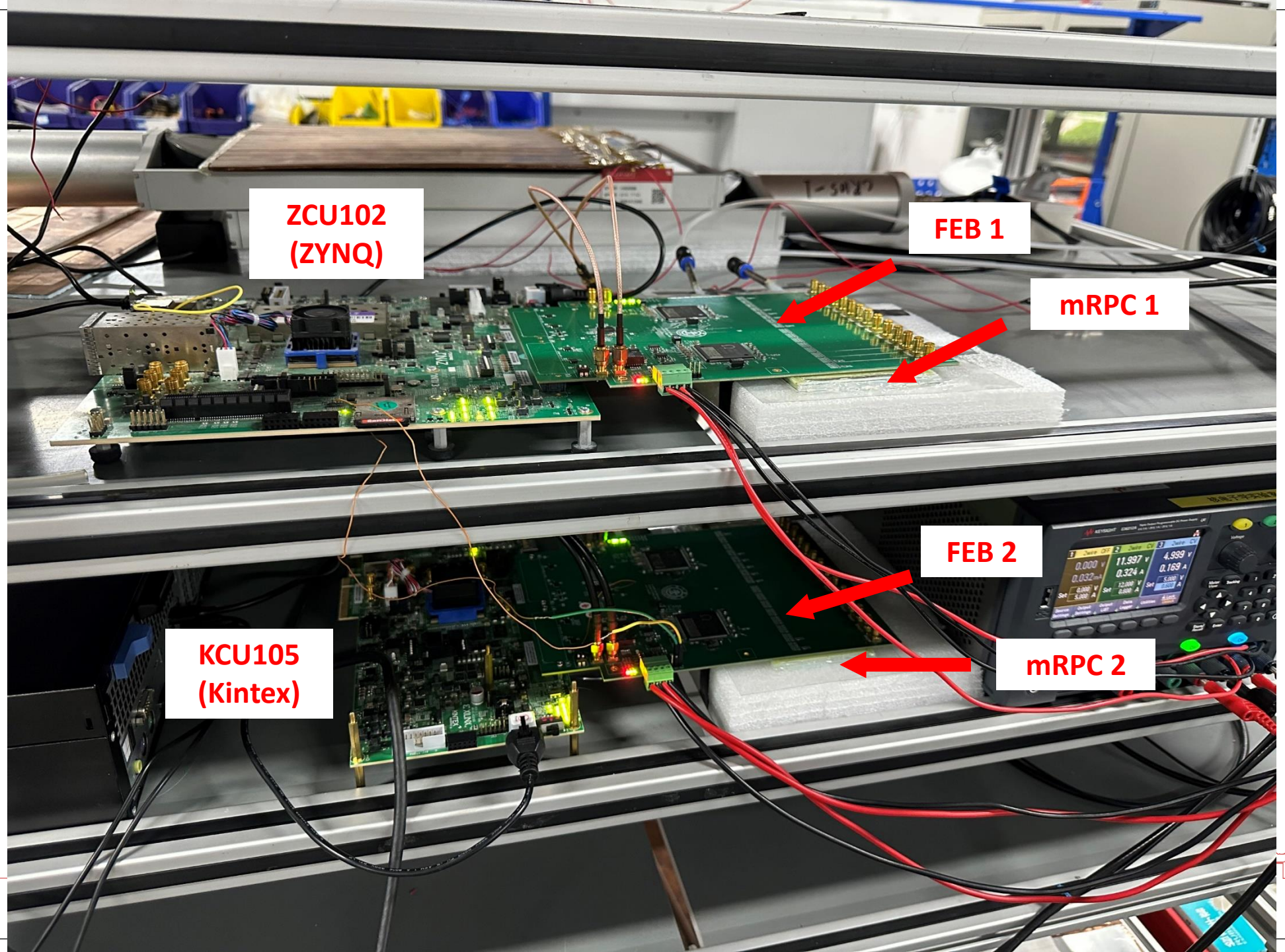
The objective is to detect cosmic ray signals by both FEBs that corresponds to each other, including time and channel number (location information).



Setup of two FEBs with mRPCs

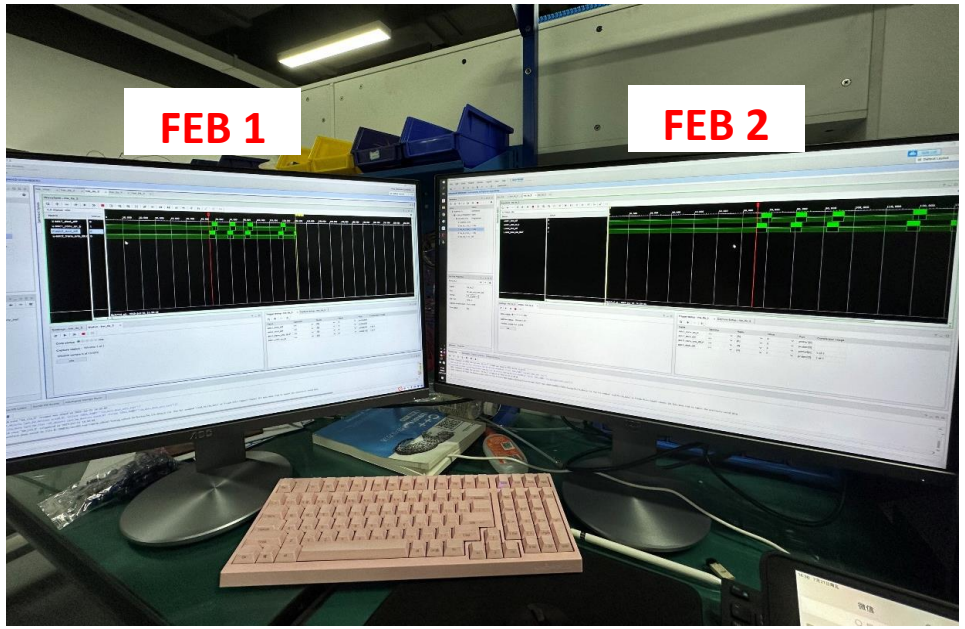


Two FEBs are synchronized!!


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

Injection tests for double-FEB system

- the signal is injected from the same channel of the function generator, with a bi-pass, and the cables are of equal length so that the signals can reach two boards simultaneously
- calculate **Δt** of each instance between two FEB
- repeat the test one hour later, to see if the **Δt** are consistent

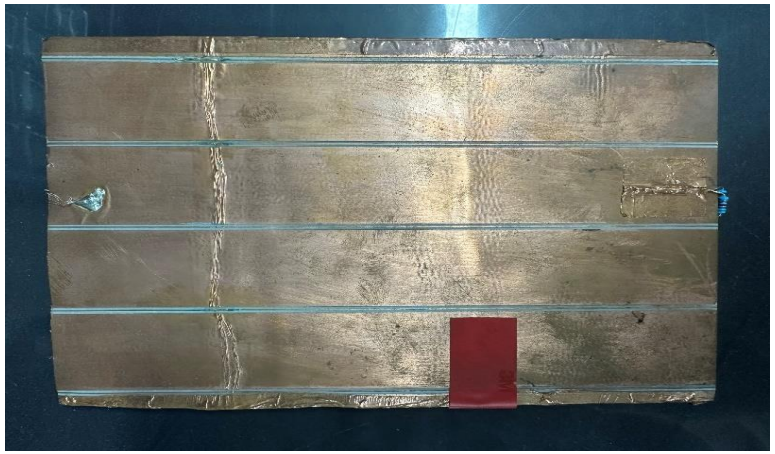


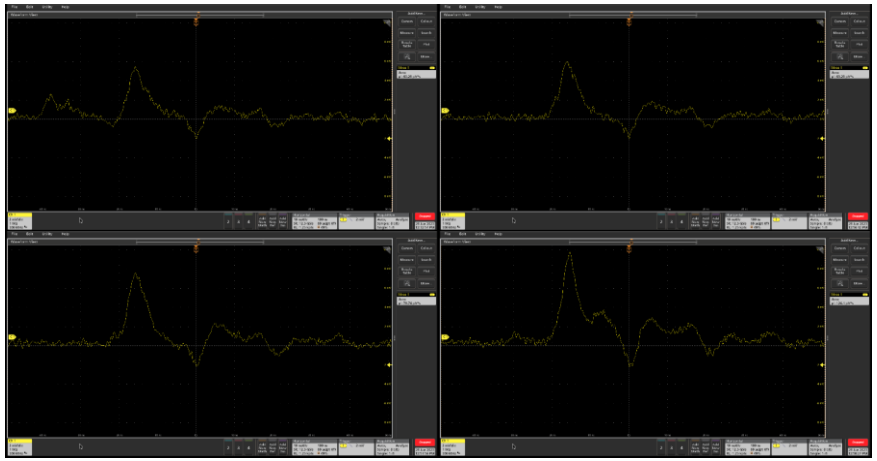
Results:
- ✓ The std of **Δt** is 54.6ps
- ✓ **Δt** is consistent

两板事例时间差平均值为2.3294us (mean)
两板事例时间差方差为2981.3778ps^2 (variance)
两板事例时间差标准差为54.602ps (std)

mRPC Test

mRPC detector

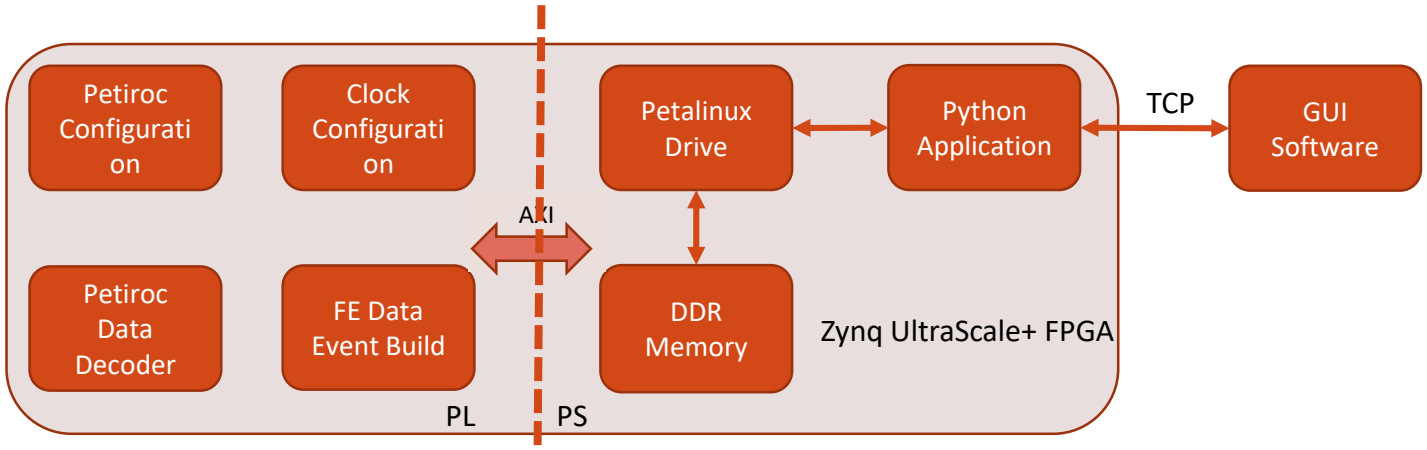


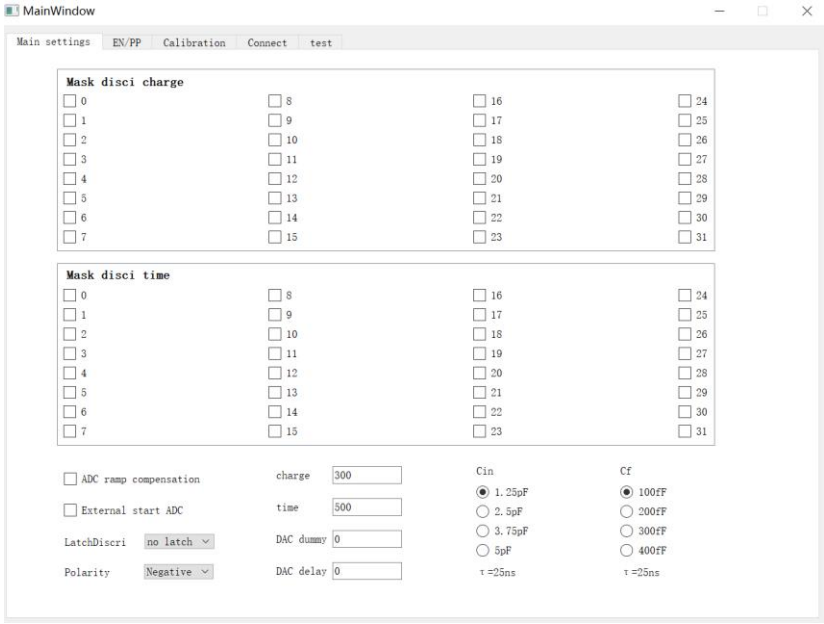


- The test conditions are:
  - voltage: 7500V
  - gas: 10% C4H10, 12% SF6, 18.9% F134a

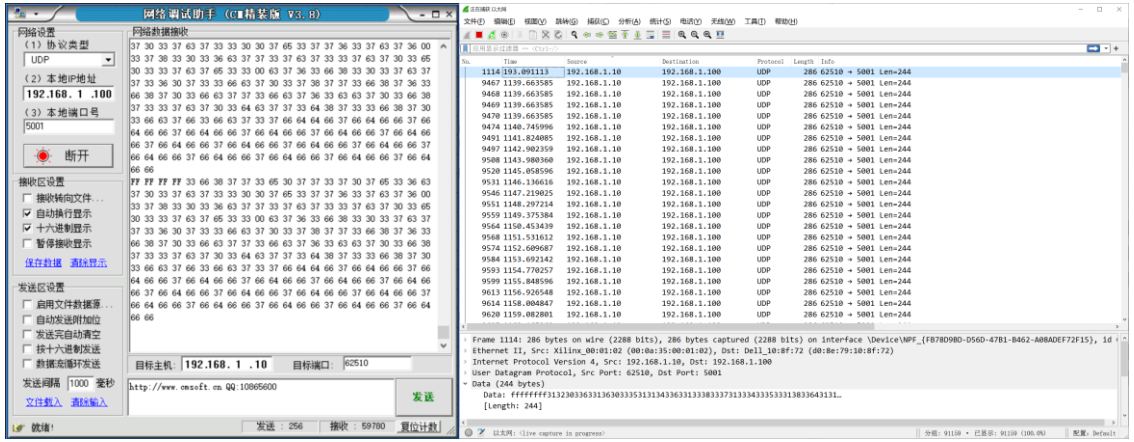
- Preliminary Test
- Use a readout pad with copper strips, and observe the signal from an oscilloscope
- Can capture something, but probably noises only.
- Still working on the mRPC test, with our colleagues' help

DAQ 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.



Ethernet data test - read from DMA

- The data is read from a DMA configured 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

Conclusion

- The timing performance of a small FEB prototype has been validated, with a resolution under $100ps$.
- Double-FEB system has been validated through injection tests.
- DAQ through ethernet has been preliminarily validated.

Further plans

- Build a customized test platform to operate mRPCs properly
- Validate the FEBs with mRPCs, by observing signals from cosmic rays
- Complete DAQ system development
- Build large-sized modules

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CALICE
Calorimeter for ILC

SJTU

Thank you for your attention

Q&A

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