6th Korea-Japan PHENIX/sPHENIX/RHICf/EIC Collaboration Meeting

INTT Bus Extender Performance

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on behalf of the sPHENIX-INTT group

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Bus Extender

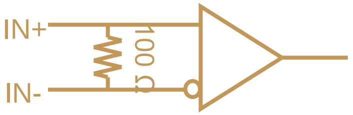
Bus Extender

- Requirements of advanced technique
  - Data Transfer : 12 Gbps
  - Length : more 1.2 m
  - Flexibility : freely handled in a narrow space

There is no commercial cable available.

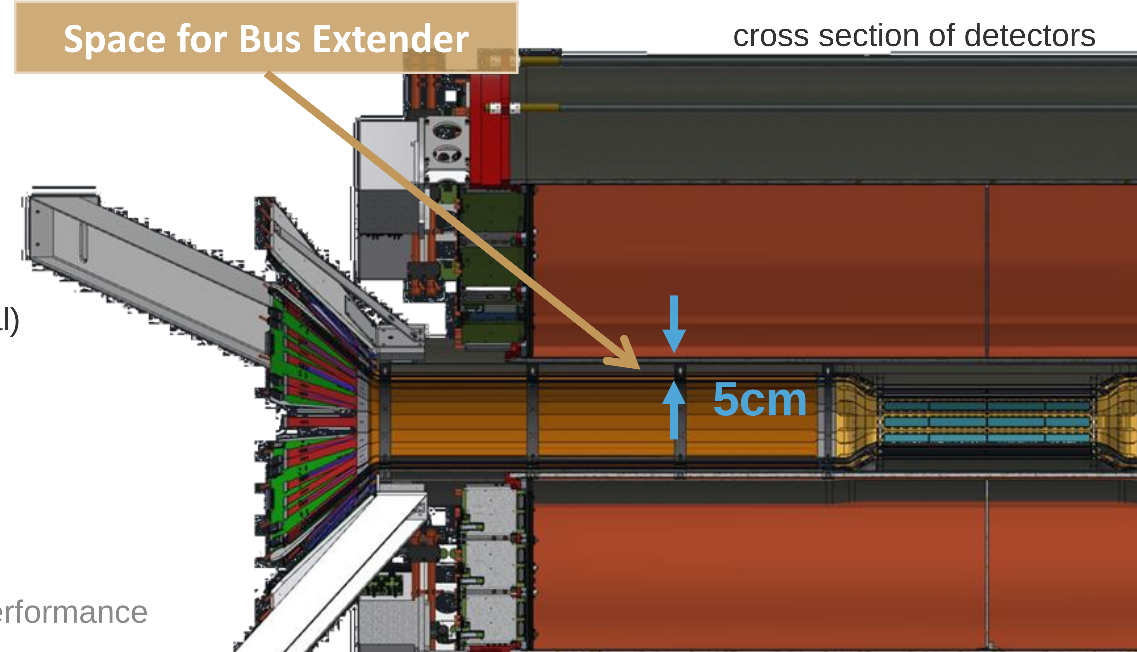
- To develop a high-signal-density cable using flexible printed cable technology

density : 130 µm × 62 LVDS pairs
speed : 200 Mbps / pair



LVDS(Law Voltage Differential Signal)

cross section of detectors



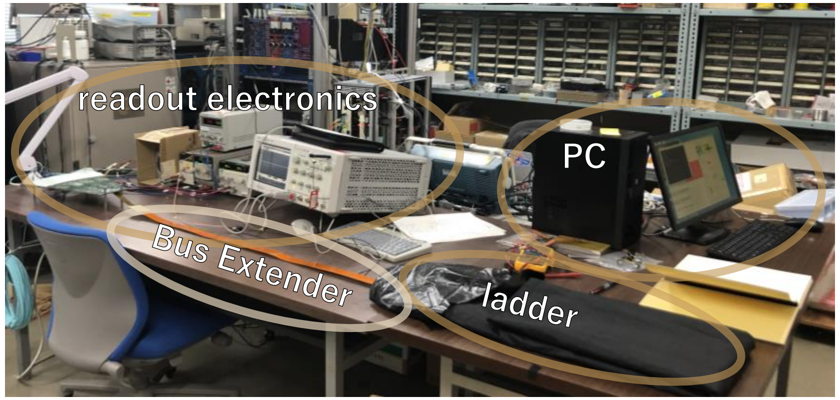
- Introduce New Technology
  - Using a liquid crystal polymer(LCP) as substrate

Measurements

Electrical Property

To see the performance of the signal transmission with the actual INTT setup,

- Compare the test pulse results w/ and w/o the Bus Extender
  1. Data quality itself
  2. Pulse shape
     of the signal transmission



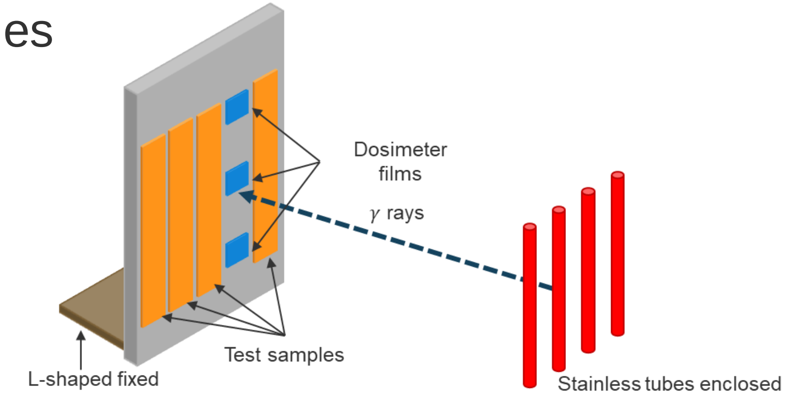
Testbench @NWU

Measurement of output signal using oscilloscope

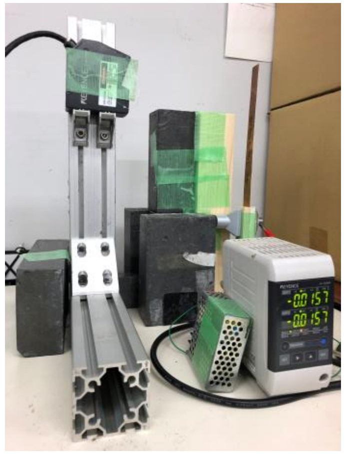
Mechanical Property

To assess the long-term stability and radiation hardness

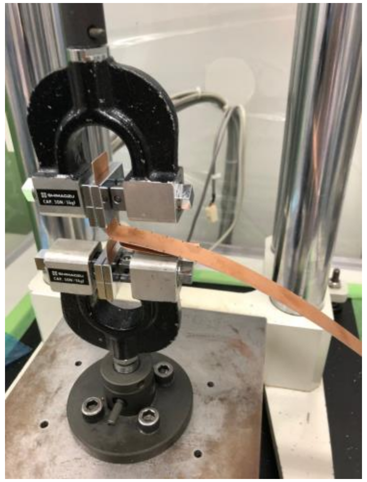
- Irradiation test using several test samples
  1. Young's modulus
  2. Peeling strength



Irradiation setup



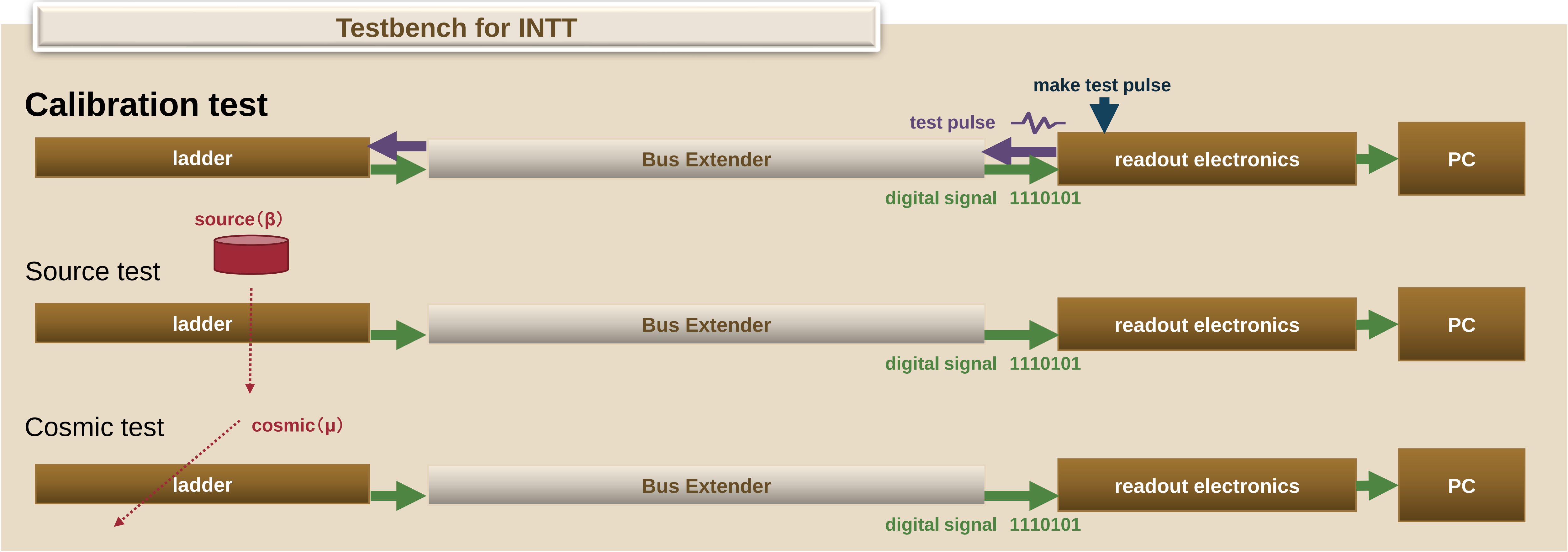
Measurement of natural frequency



Peeling test by universal tester

Data acquisition

- In Nara Women’s University, we have built a test bench and evaluated performance of INTT ladders
  - Three kinds of measurements（using **test pulse**, source, or cosmic）



Data acquisition using test pulse

Purpose

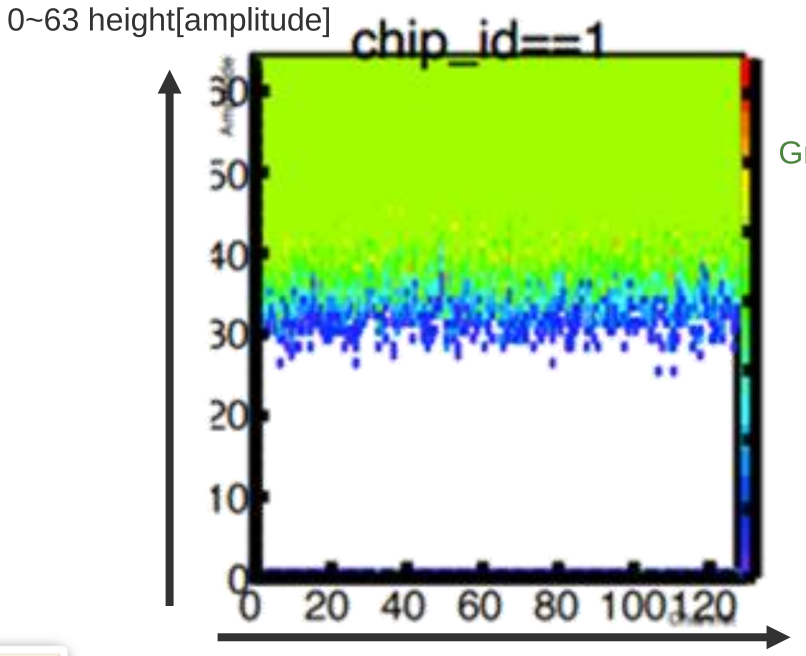
Evaluate whether signals are sent and received normally

How to

- Test pulse with 64 different heights are sent to each channel (3328 channels) 10 times
- Set a threshold, convert from 64 to 8 levels of pulse height

Procedure

1. Generate test pulse by readout electronics
2. Convert from analog to digital signals by readout chips in ladder
3. Send digital signal from ladder to PC

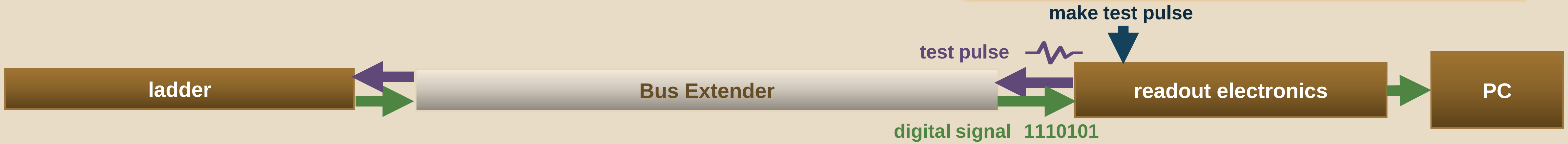


Green means 10 pulses

× 26

Testbench for INTT

Compare measurement 'w/ Bus Extender' with 'w/o Bus Extender'



Data Analysis

- Evaluate the threshold using the test pulse data
- Compare the threshold value w/ and w/o Bus Extender

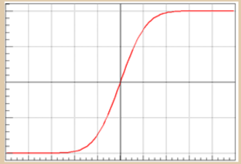
Calculate parameter from Fit function

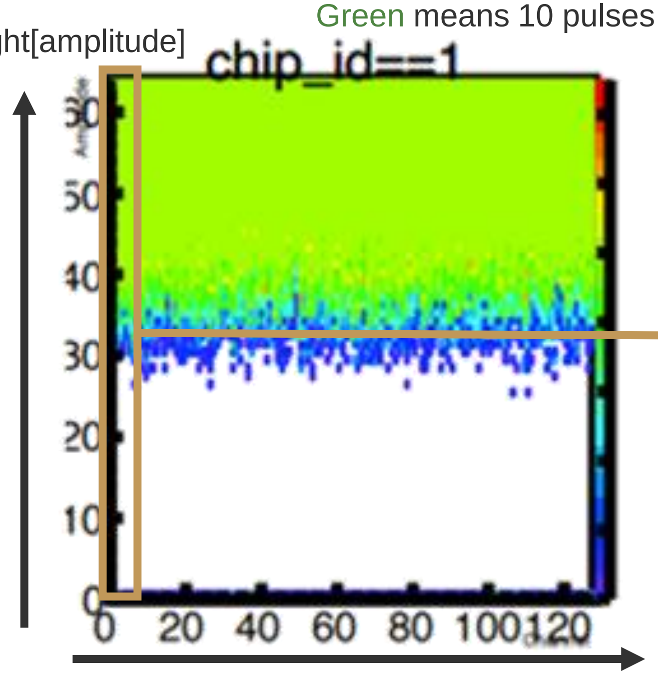
Fit func : f(x) = [p0] × erf((x - [p1]) / [p2]) + 5

※[p0], [p1] and [p2] are parameters

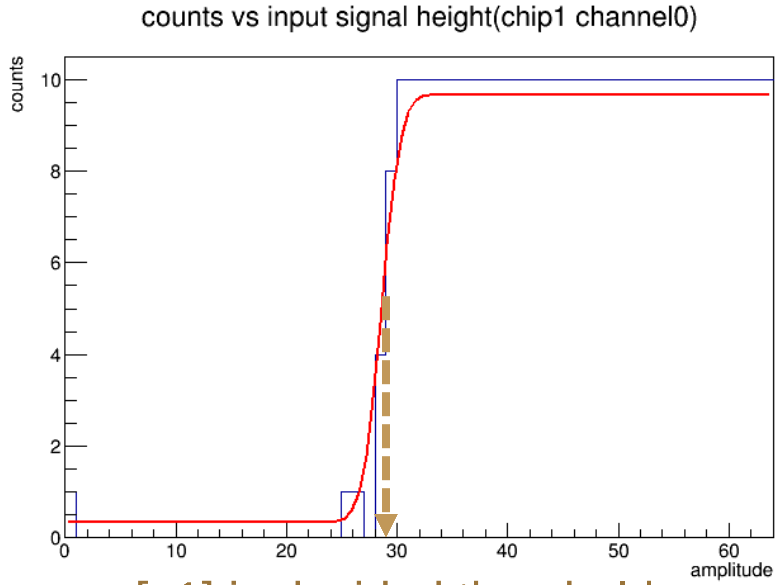
Error func : erf(x)

$$\mathrm{erf}(x) = \frac{2}{\sqrt{\pi}} \int_0^x e^{-t^2}\, dt$$





Pick up 1 channel

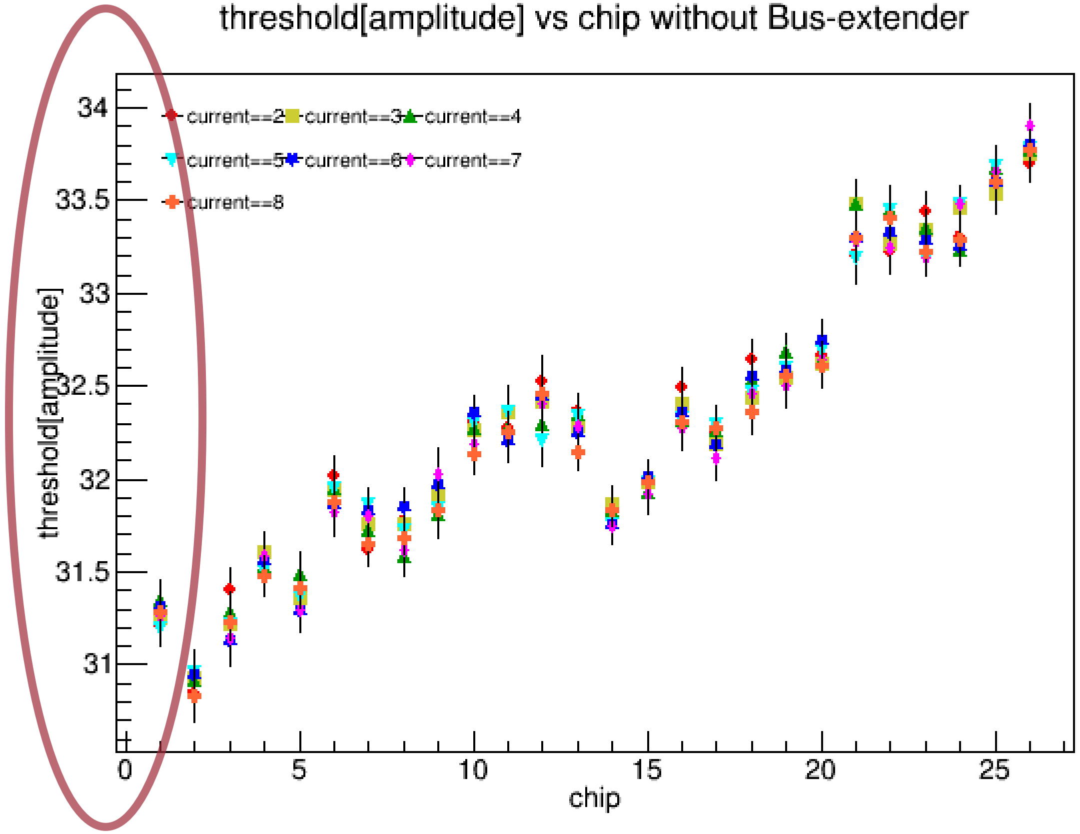


[p1] is decided threshold

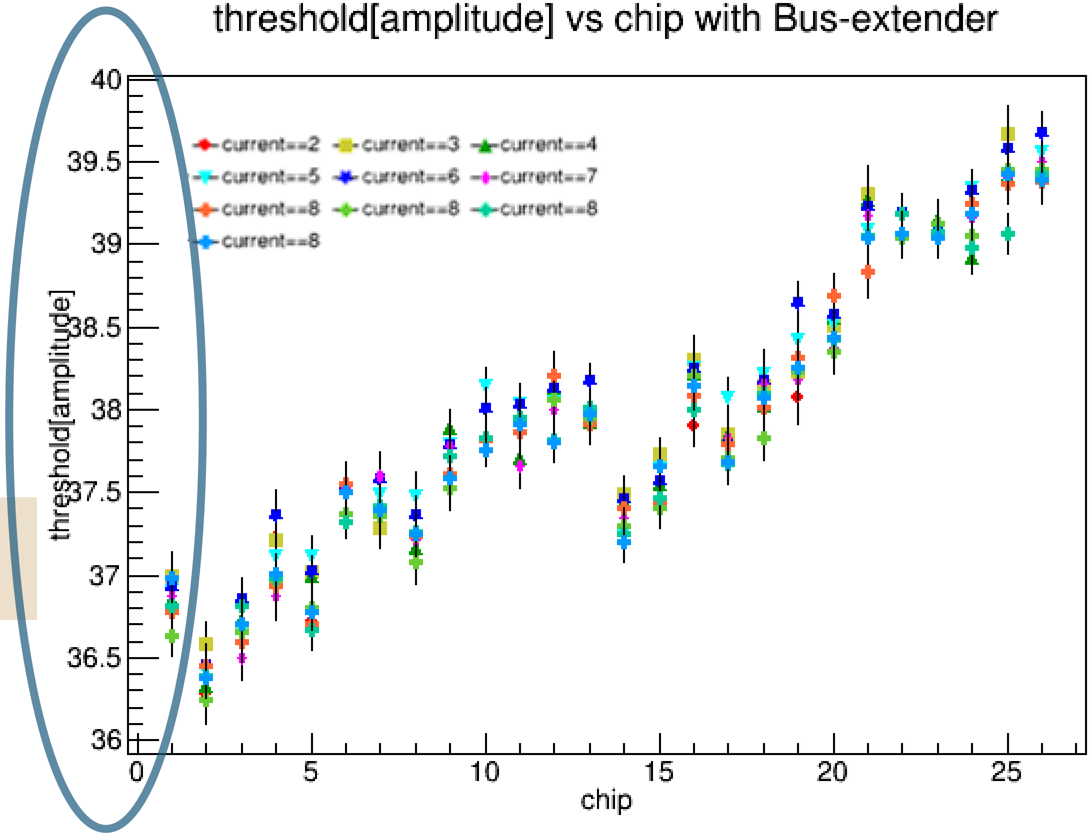
Threshold of input signal

30.5 ~ 34.0 [amplitude]

36.0 ~ 40.0 [amplitude]

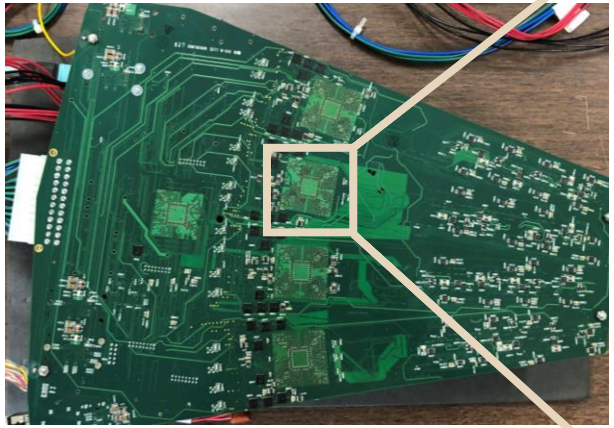


Using Bus Extender

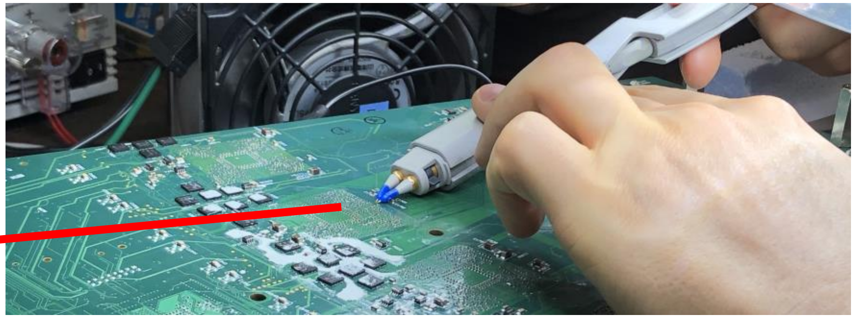


The result shows the higher threshold w/ Bus Extender. This indicates the test pulse is attenuated by the Bus Extender. I confirm the acquisition rate of test pulses over the threshold.

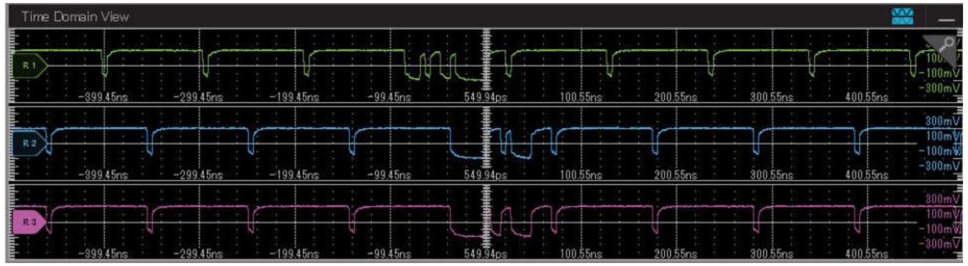
observe digital output signal by oscilloscope



Back of one of readout electronics

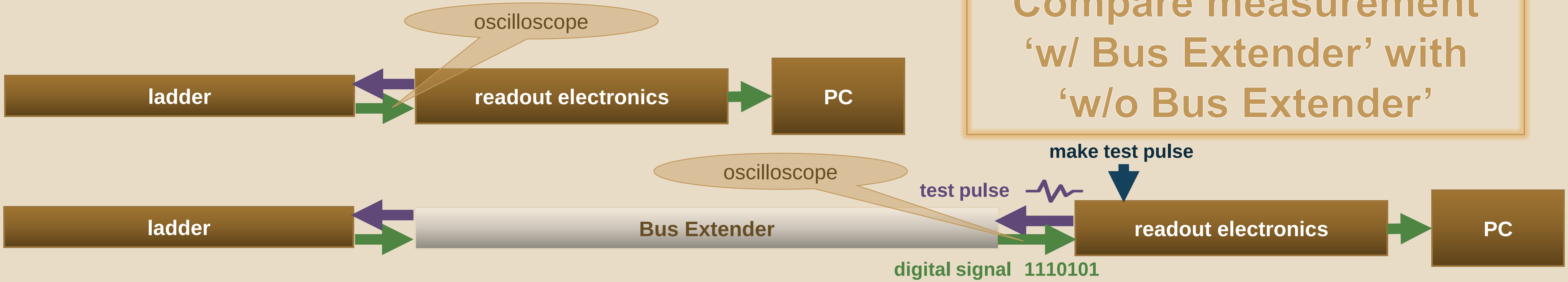


To observe output digital signal with differential probe



Output waveform measured with oscilloscope

Testbench for INTT

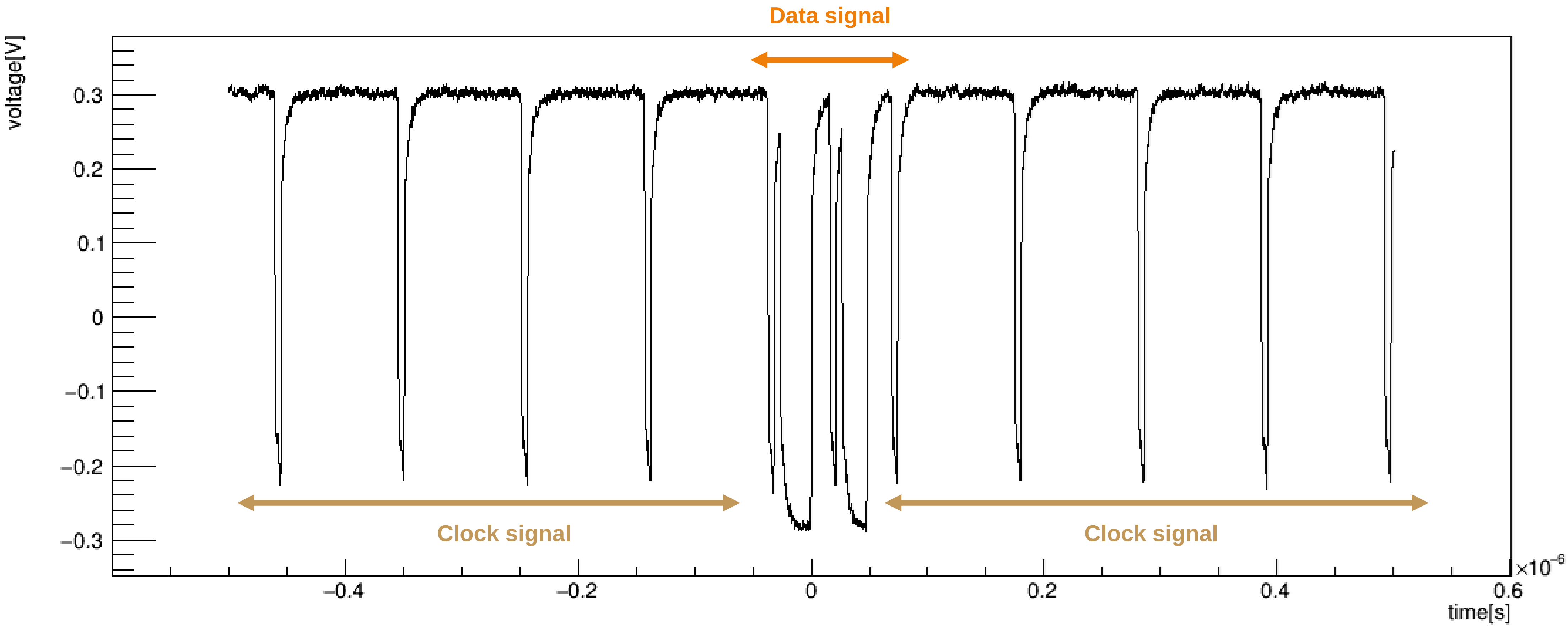


Compare measurement ‘w/ Bus Extender’ with ‘w/o Bus Extender’

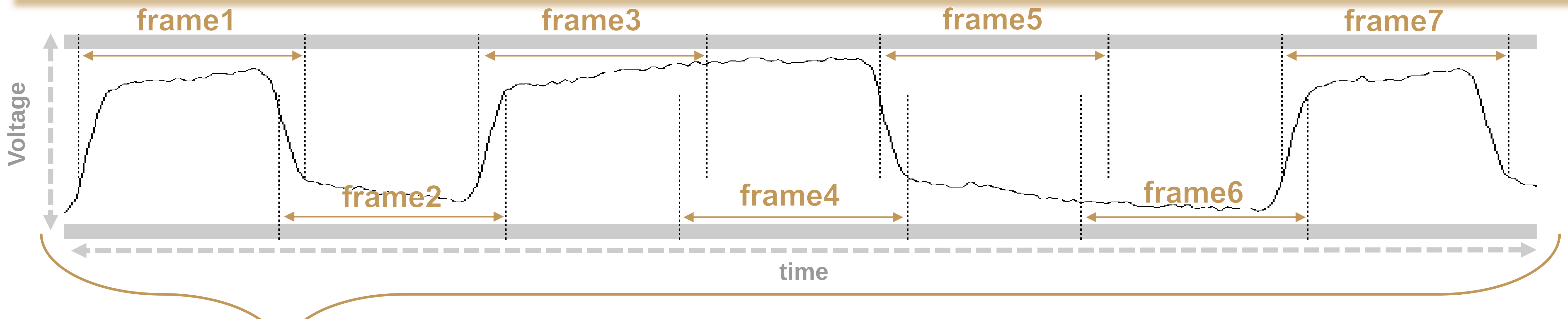
Output signal waveform

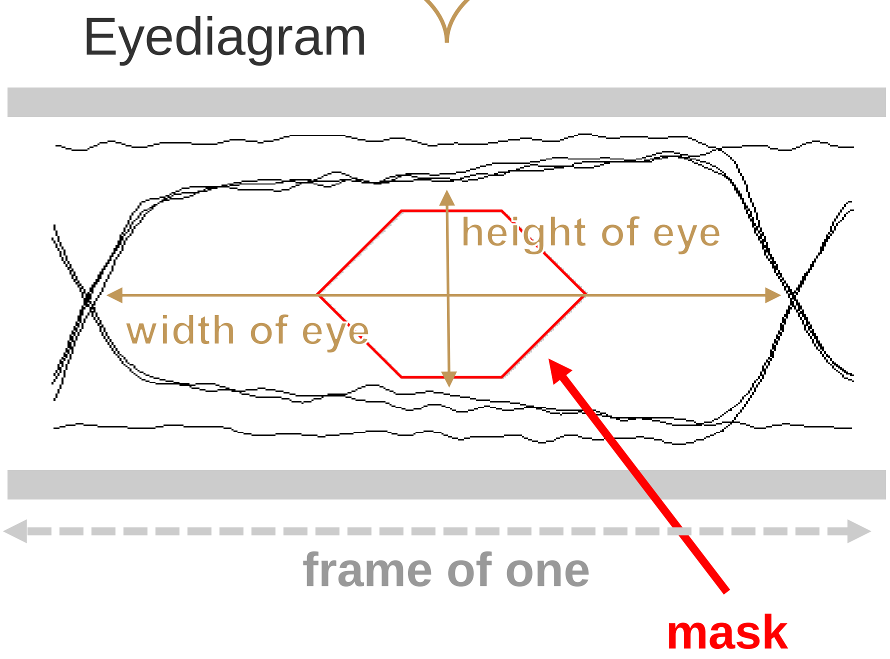
Observe digital output signal using the oscilloscope

- This graph is output signal waveform w/o Bus Extender
- make eyediagram from this graph and analyze



Eyediagram



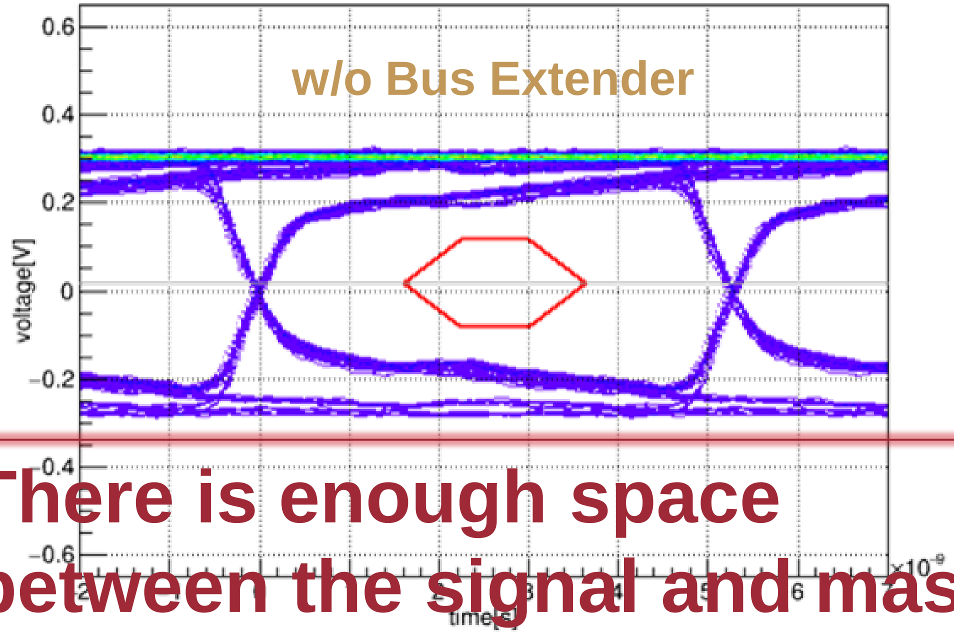


Eyediagram

- **To visualize distortion of a waveform when a signal is sent**
- The eye diagram is made by slicing the data into single pulses and overlaying them
  - It looks like an eye ー>「Eye」diagram
- We can evaluate voltage and margin of timing from eye height and width
- Mask indicates minimum height and width to need to judge correct data
  - We confirm whether signal observed touch mask
  - Mask is defined that error rate is lower than 10^{-12}

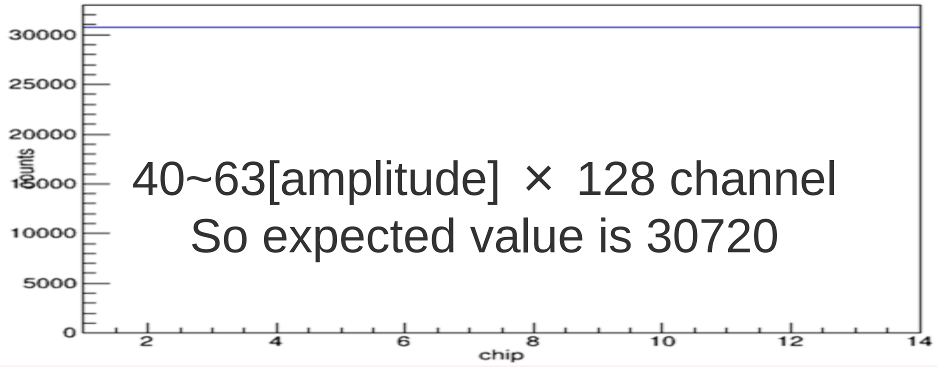
Compare eyediagram with received entries

3mA



There is enough space between the signal and mask

Using Bus Extender

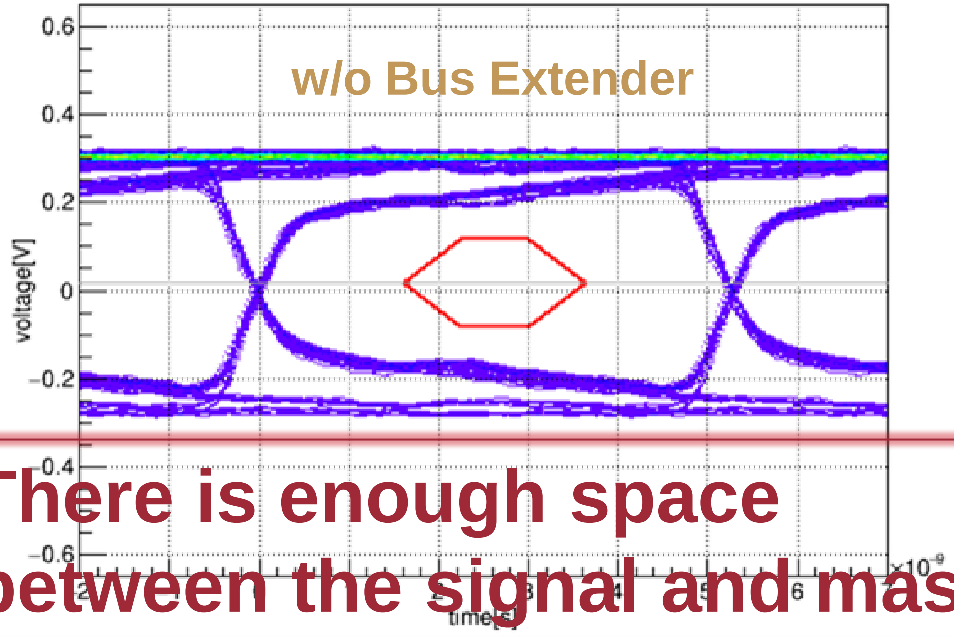


40~63[amplitude] × 128 channel
So expected value is 30720

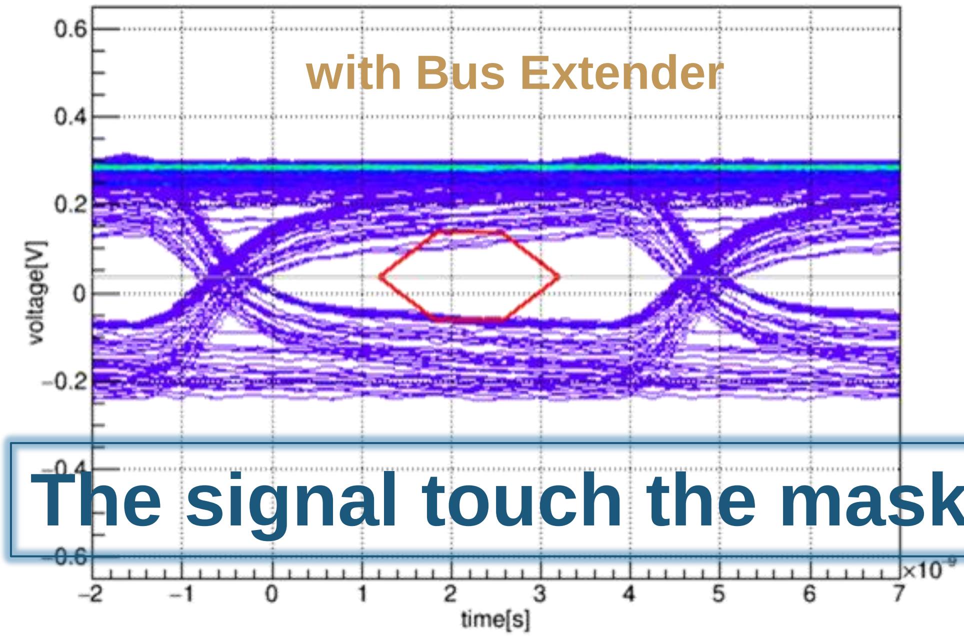
100% Successfully received

Compare eyediagram with received entries

3mA

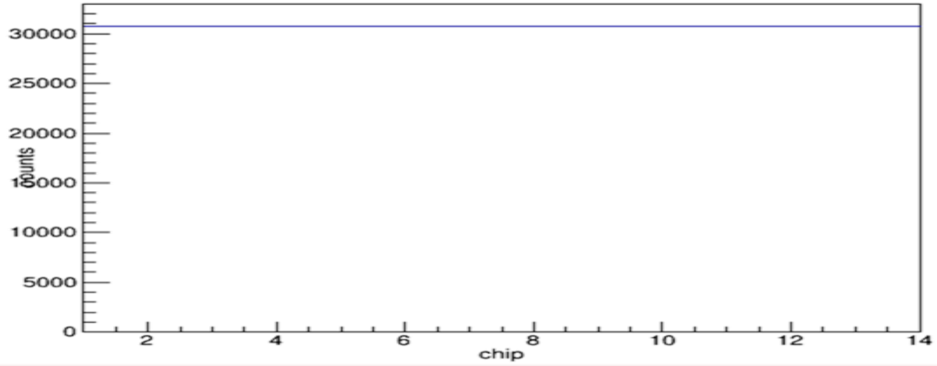


There is enough space between the signal and mask

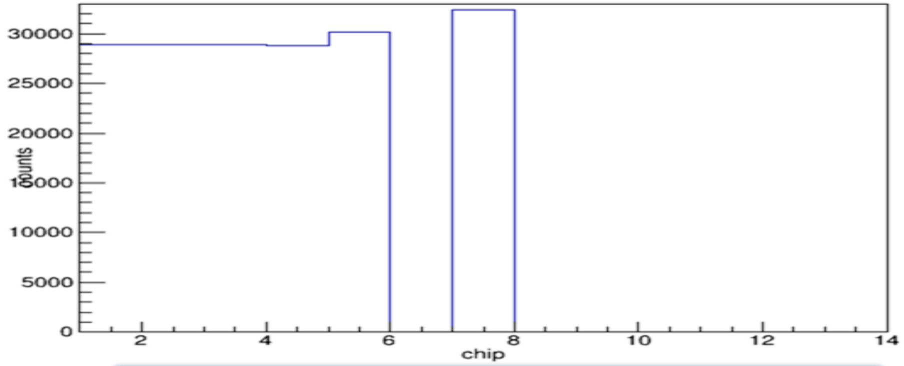


The signal touch the mask

Using Bus Extender



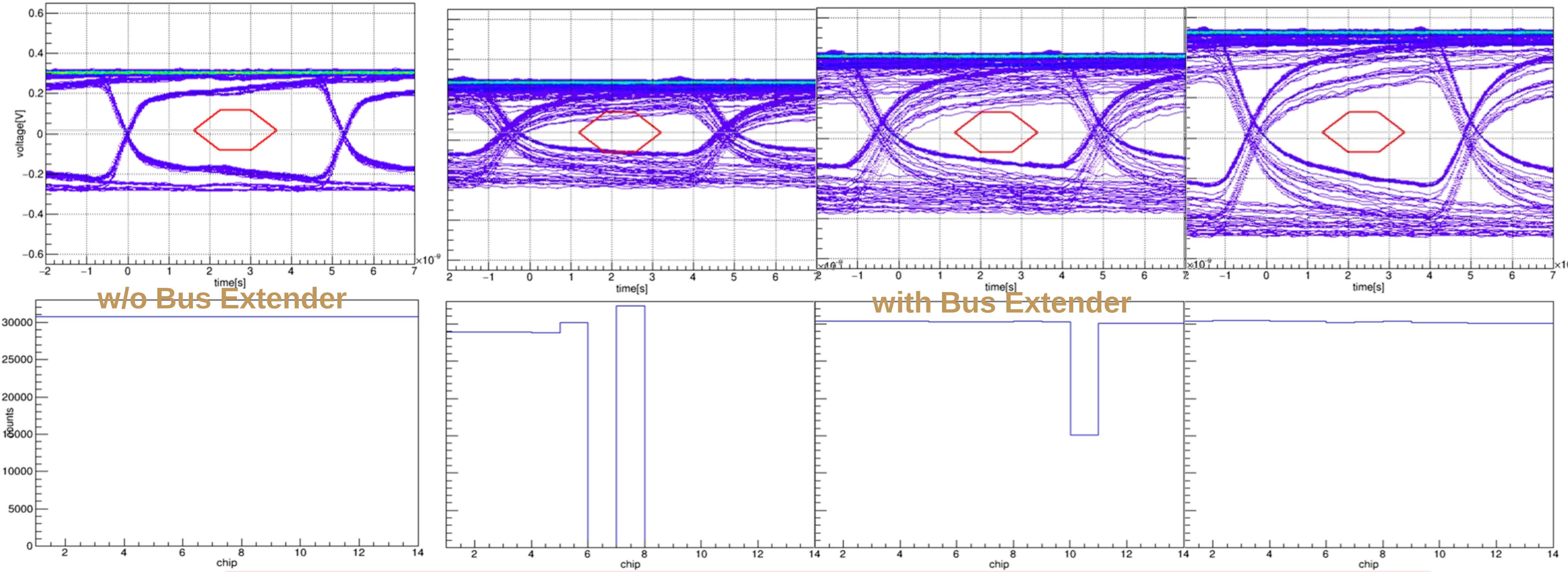
100% Successfully received



Transmission failed

Higher current drawing of LVDS

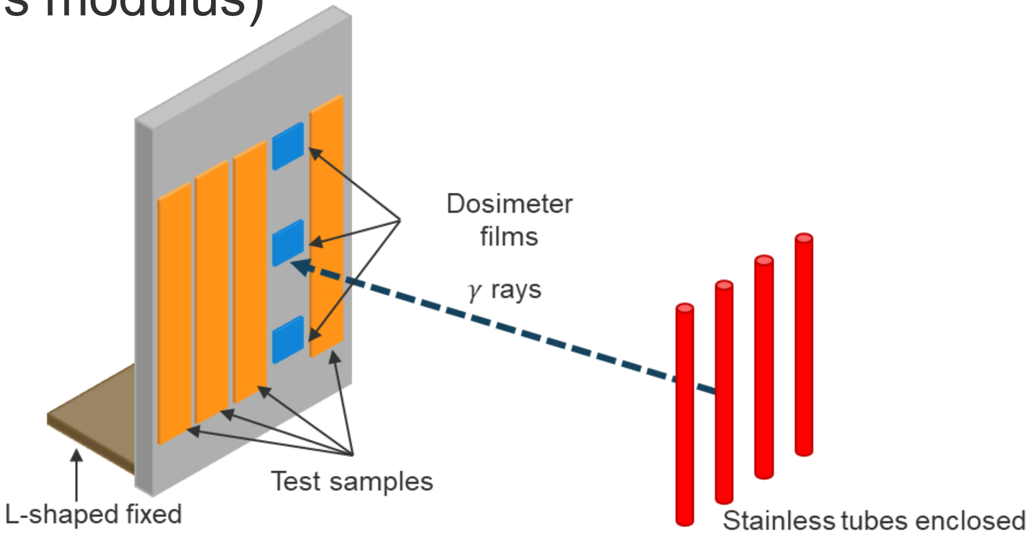
3mA | 3mA | 5mA | 8mA



We found that increasing the amount of current creates a margin in the waveform and reduces erroneous judgments.

Radiation hardness

- Long term stability under a radiation environment is important for INTT
  - Keep healthy for at least three years of operation
  - Bus Extender is produced with advanced materials, LCP and adhesive sheet. Good to know the radiation hardness
- FPC samples are exposed by strong Gamma source(^{60}Co)@QST Japan
  - Radiation dose: 5 kGy, 500 kGy, 1000 kGy
- Evaluate radiation hardness with two mechanical quantities
  - Stiffness (Young's modulus)
  - Peeling Strength



Radiation resistance test
@Takasaki Advanced Radiation Research Institute

Preparation room

Dosimeter films
Range : 1 – 150kGy
Accuracy : 7% 5 – 150kGy

Evaluation methods

- Young's modulus
  - Vibrate the sample and measure the natural freq. by the LASER system

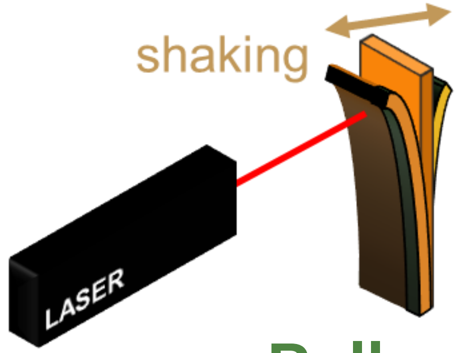
The relational expression between natural frequency and Young's modulus

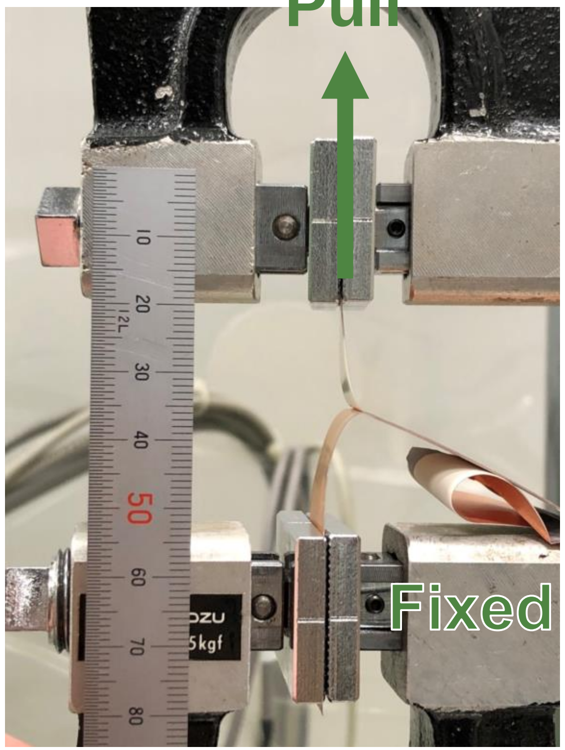
$$f_n = a\sqrt{bE}$$

f_n : Natural frequency
E : Young's modulus
a : Coefficient 1
b : Coefficient 2

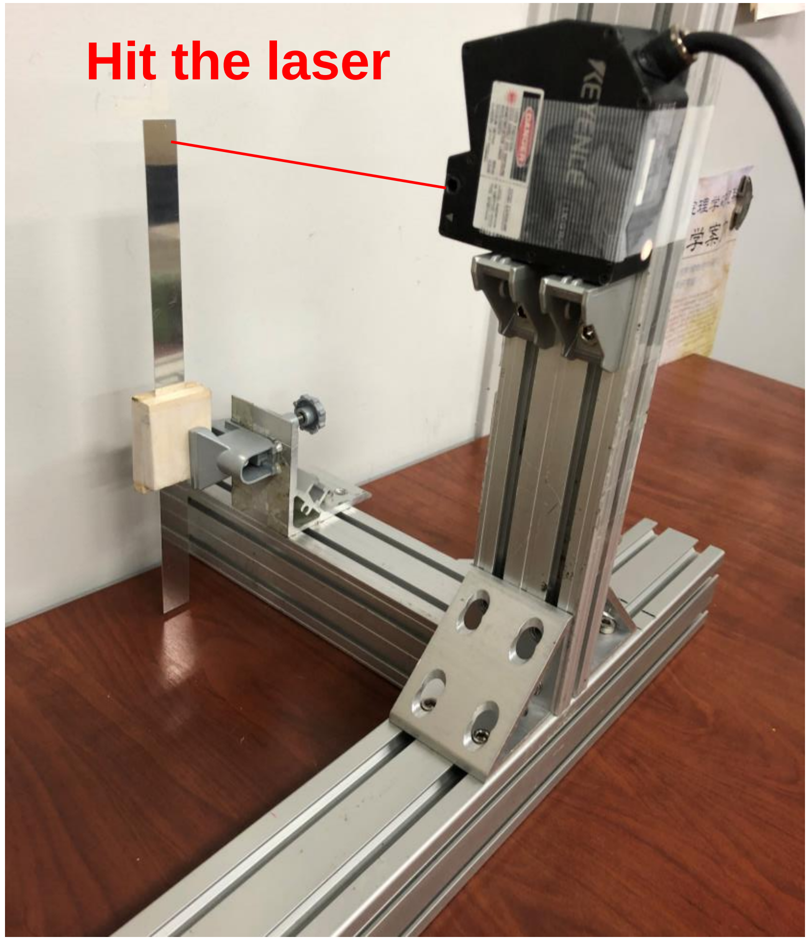
- Peel strength
  - Sample peeled off at 180 degrees and measure its strength by a tensile tester

Measurement of natural frequenc @Rikkyo Univ.



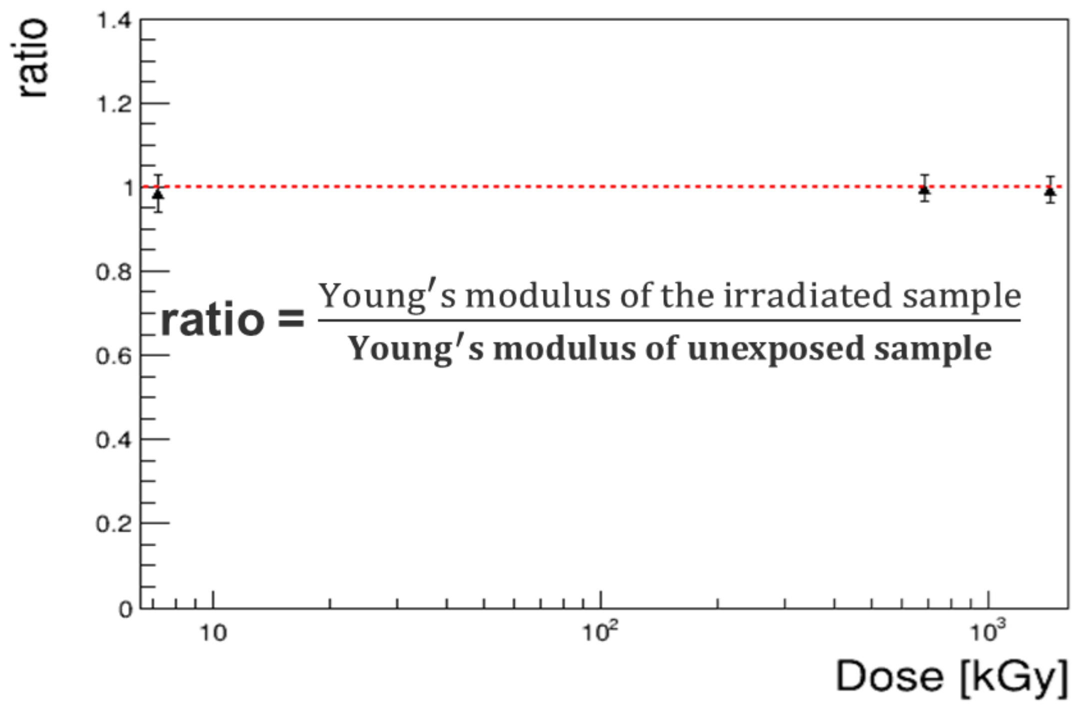


Peeling test using a tensile tester

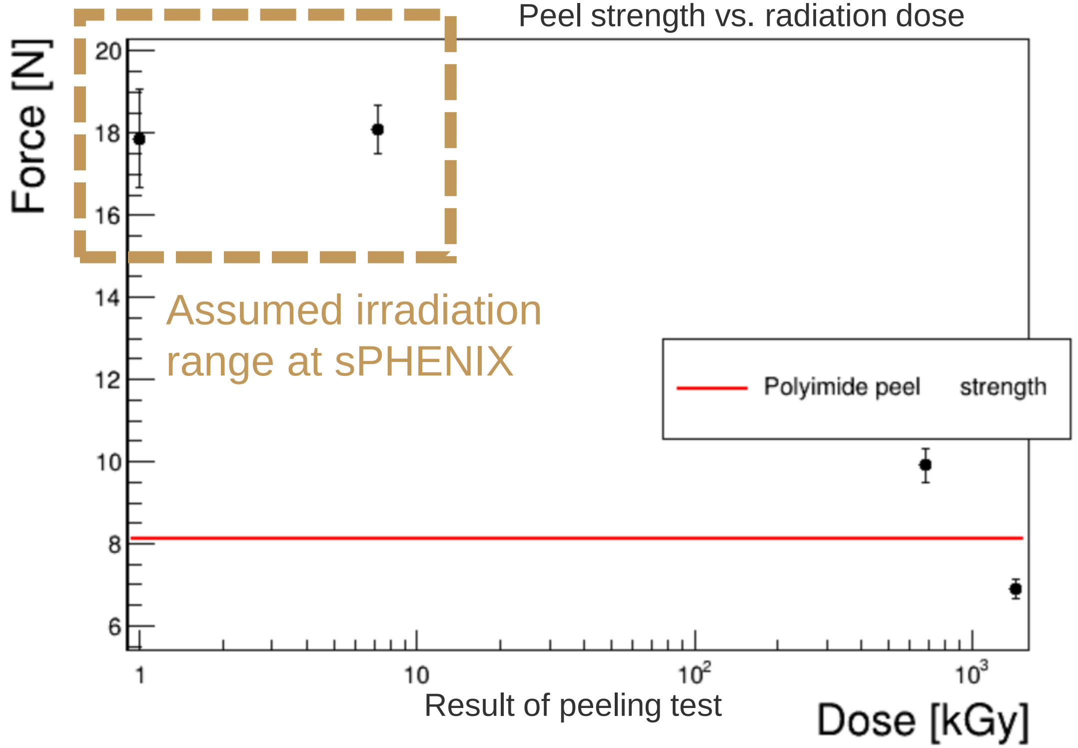


Results of mechanical quantities

Young's modulus ratio vs. radiation dose



Peel strength vs. radiation dose



Result of peeling test

- Young's modulus : No change within 7% uncertainties by radiation exposure
- Peel strength : No change for sPHENIX data taking and get smaller clearly for the higher exposure

Radiation hardness of Bus Extender is good enough for sPHENIX

Summary

Electrical properties and Radiation hardness were studied

Electrical Properties

- Calibration test is useful with Bus Extender
  - The threshold becomes high because of the attenuation of the test pulse.
- The pulse shape of the signal transmission is distorted.
- Increasing the amount of current creates a margin in the waveform and reduces erroneous judgments.

Radiation hardness

- Evaluate using Young's modulus and peel strength
- No change of Young's modulus within the error of 7%
- No change of the peel strength for irradiation range at sPHENIX

Bus Extender is ready for mass production
Mass production of the Bus Extender will start in 2021

Back Up