Development of the Beam-diagnostic Target Protection Interlock for MW Operation in the J-PARC Neutrino Beamline

#47

Ayana Asai[A] (asai@s.okayama-u.ac.jp), Ken Sakashita[B], Yota Hino[B], Yusuke Koshio[A] (Okayama univ.[A], KEK[B])

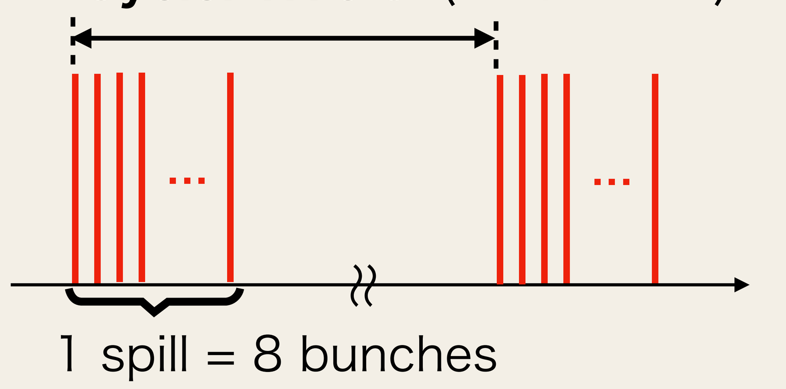
OKAYAMA UNIVERSITY
NEUTRINO '26 International Conference on Neutrino Physics and Astrophysics June 22nd - 26th, 2026
UCI Department of Physics & Astronomy

1. Introduction

Beam Power Upgrade

- The **J-PARC neutrino beamline** is being upgraded to enable high-statistics neutrino measurements
  - precision oscillation studies, rare-event searches
- The beam power is planned to reach **1.3 MW** in 2028

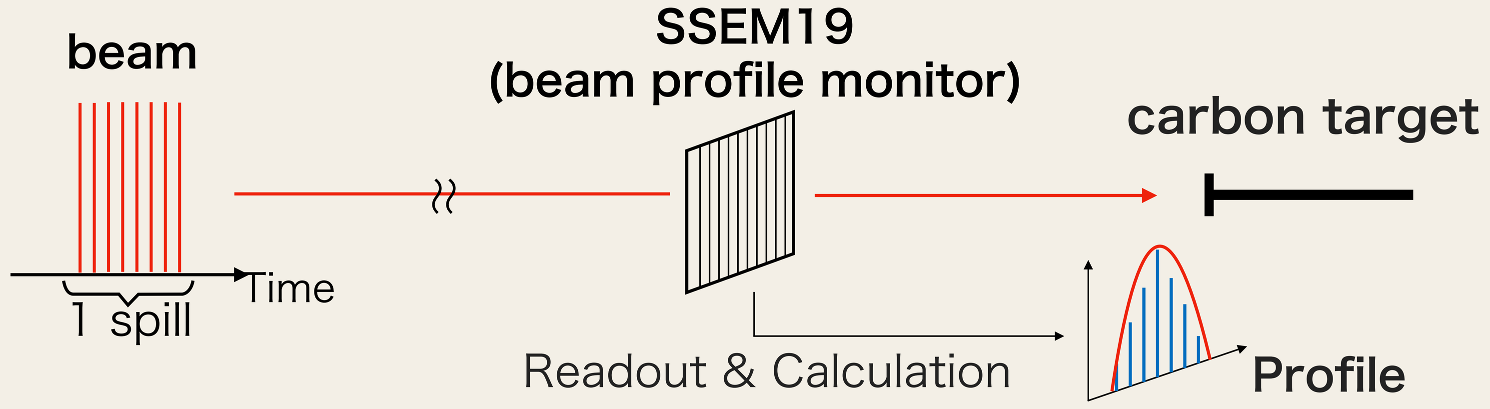
$$\text{Beam power [W]} = \underset{30\ \text{GeV}}{\text{Proton energy [eV]}} \times \text{Current [A]}, \quad \text{Current [A]} = \frac{\text{Number of protons} \times e}{\text{Repetition cycle [s]}}$$

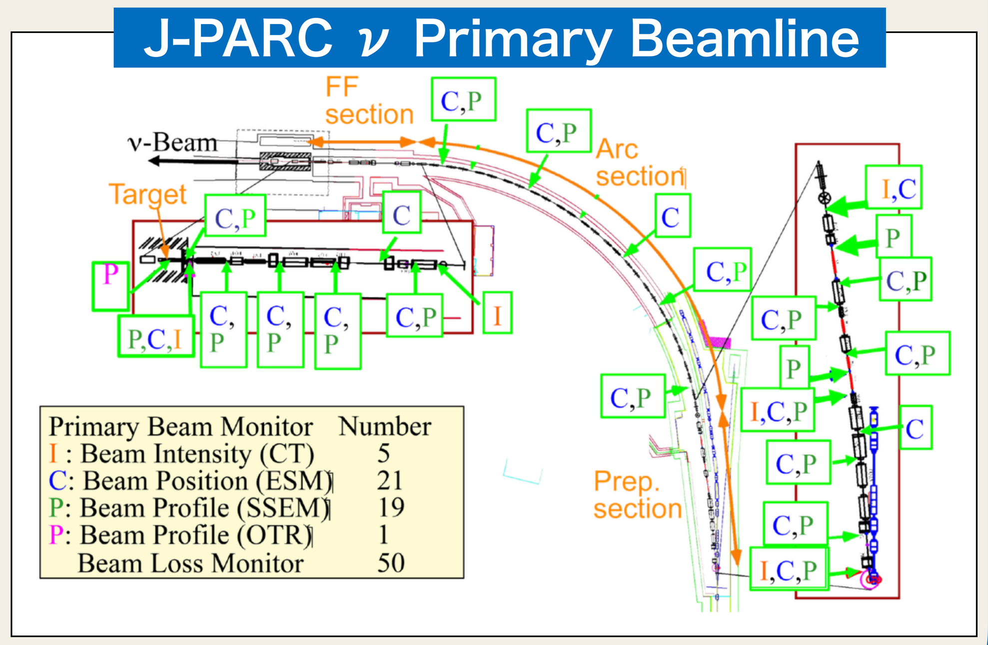


Target Protection System

- Misaligned or high-density beams can thermally damage the target
- Interlock thresholds: **Beam-center offset** $|\Delta x| > 1.5$ mm,
  Beam density $> 2.0 \times 10^{13}$ protons/mm^2
  (narrow beam -> high density)

-> If an abnormal beam is detected, stop the next beam extraction





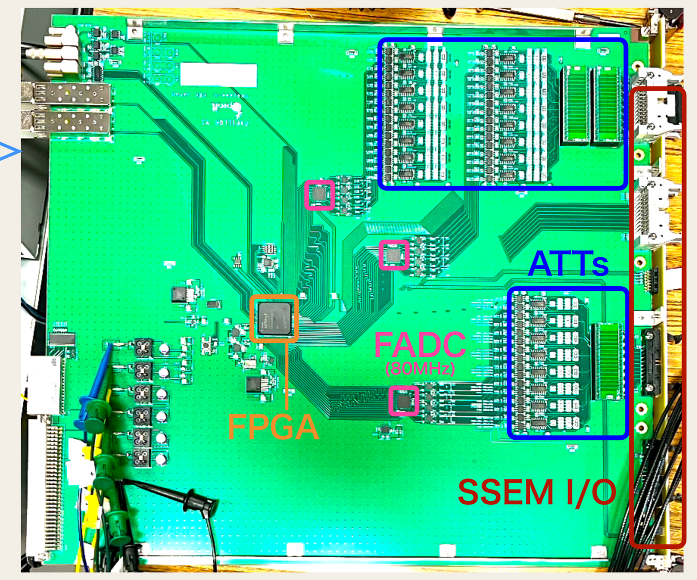
2. FPGA-based Calculation Module

Current: Calculation on semi-online computer

- Bunch-by-bunch Gaussian fitting analysis
- Processing takes ~1 s
  -> **insufficient for the future 1.16 s cycle operation**

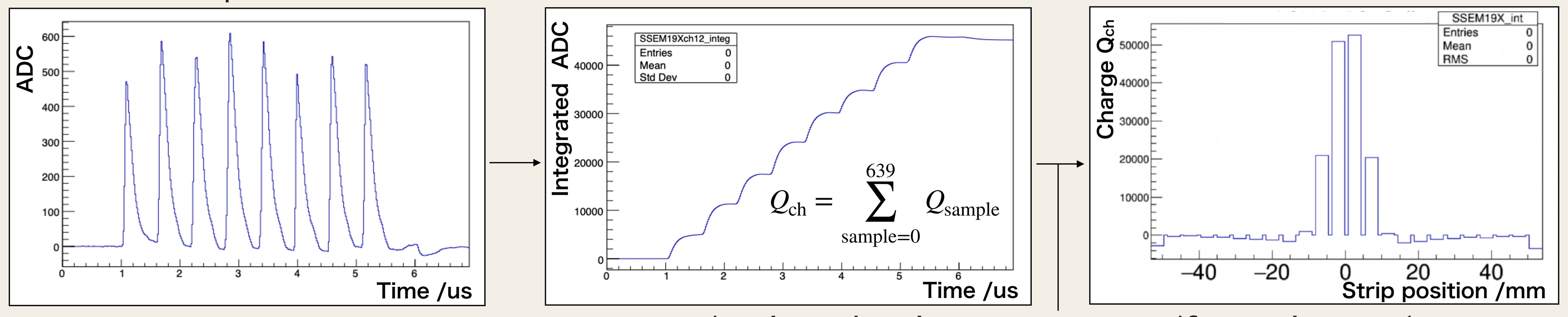
-> Develop a new FPGA-based online calculation module

PAPILLON
beam **P**osition **A**nd **P**rof**IL**e inter**L**ock m**O**dule for **N**eutrino experiment



PAPILLON Calculation on FPGA

1. ADC waveforms for each strip
2. Integrate the waveforms (summation)
3. Calculate the Q-weighted beam profile



position $X = \dfrac{\sum_{ch=0}^{23*} Q_{ch} \times x_{ch}}{\sum_{ch=0}^{23} Q_{ch}}$,

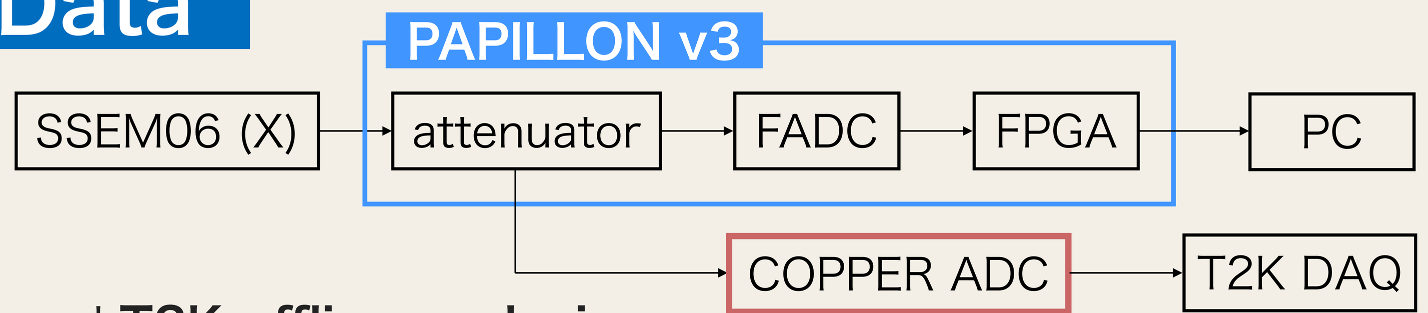
width $\sigma_x = \sqrt{\dfrac{\sum_{ch=0}^{23*} Q_{ch}(x_{ch} - X)^2}{\sum_{ch=0}^{23} Q_{ch}}}$

*strip selection: $Q_{ch} > 1{,}200$ (for noise cut)

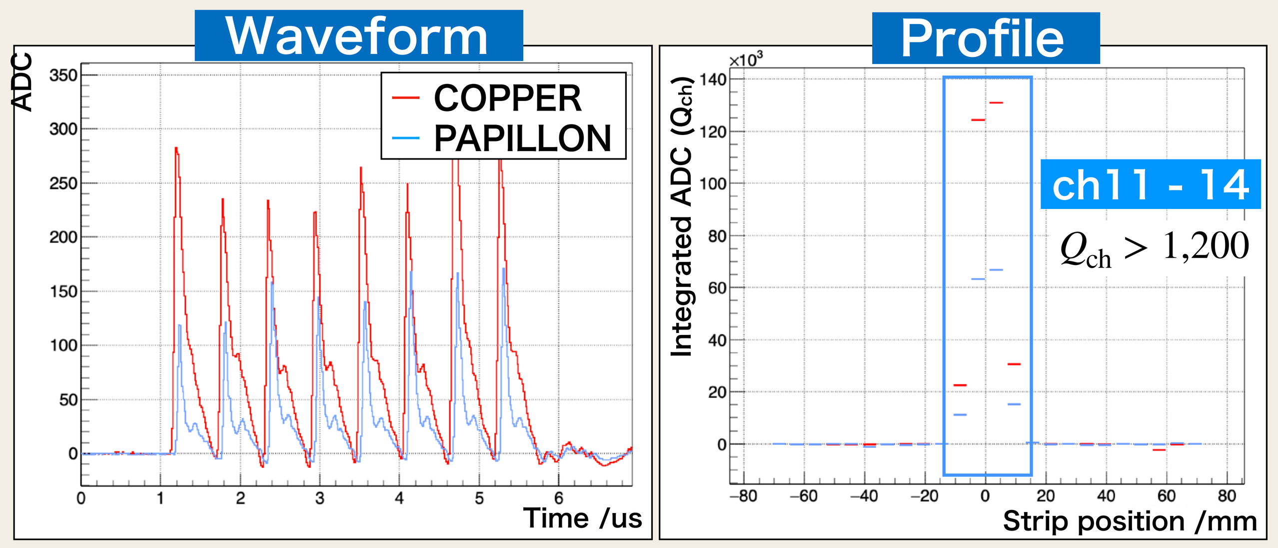
3. Validation with Beam Data

First test of PAPILLON v3

- Confirm data acquisition with SSEM06 (X)
- Validate the FPGA calculation
- Compare with the existing board (COPPER) and **T2K offline analysis**



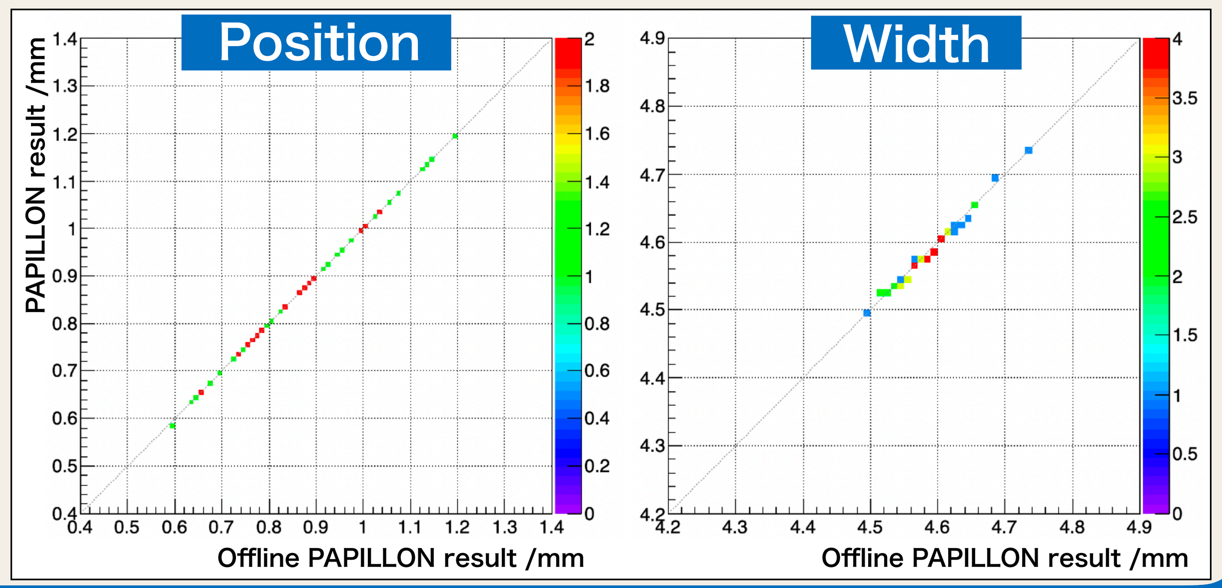
Waveform and Beam Profile



- The waveform difference is likely due to the ADC frequency response
- A charge threshold was applied to reject noise-only (no signal) strips
  -> The **PAPILLON** calculation mainly uses the center 4 strips

FPGA calculation validation

- The FPGA calculation was reproduced offline using the save waveform data
- The FPGA and offline results **agree well**
  -> The implemented calculation works as expected



4. On-board vs. Offline Analysis

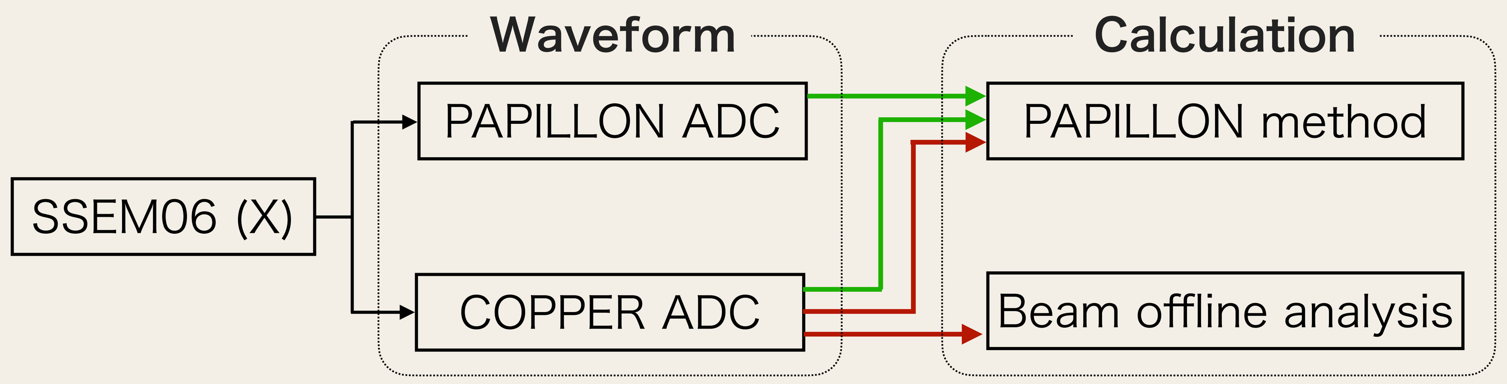
Beamtest Result

- Compared PAPILLON FPGA results with beam offline analysis
  - **Position**: systematic offset of about -0.1 mm (PAPILLON)
  - **Width**: larger, especially for narrow beams (PAPILLON)

Origin of Differences

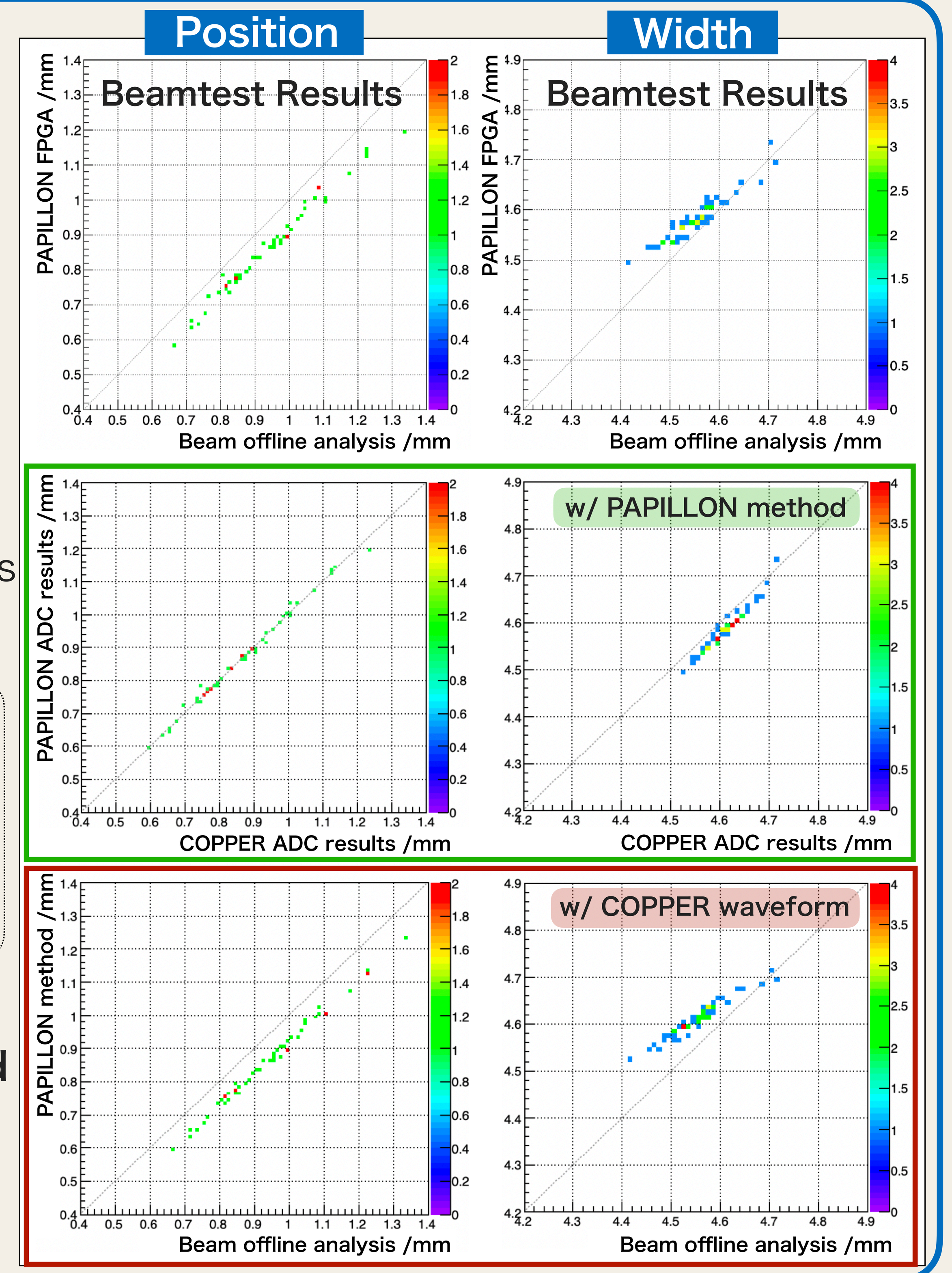
- Waveform effect: PAPILLON ADC vs. COPPER ADC
  (due to ADC frequency response differences)
- Calculation effect: PAPILLON method vs. beam offline analysis

-> The two effects were evaluated separately



- Waveform effect is small
- Beam-test trends mainly come from the **calculation-method effect**; the correlation is approximately linear

-> If the linearity is confirmed,
FPGA interlock thresholds can be set from this correlation



5. Summary

- Toward MW beam operation, an FPGA-based target protection system, PAPILLON, has been developed
- PAPILLON calculations show an approximately linear correlation with beam offline analysis; further studies are ongoing

This poster is supported by JSPS KAKENHI Grant Number 25H00396