AXEL Experiment: Construction of a 1000L-size detector (2)

Shinichi Akiyama, Tohoku University

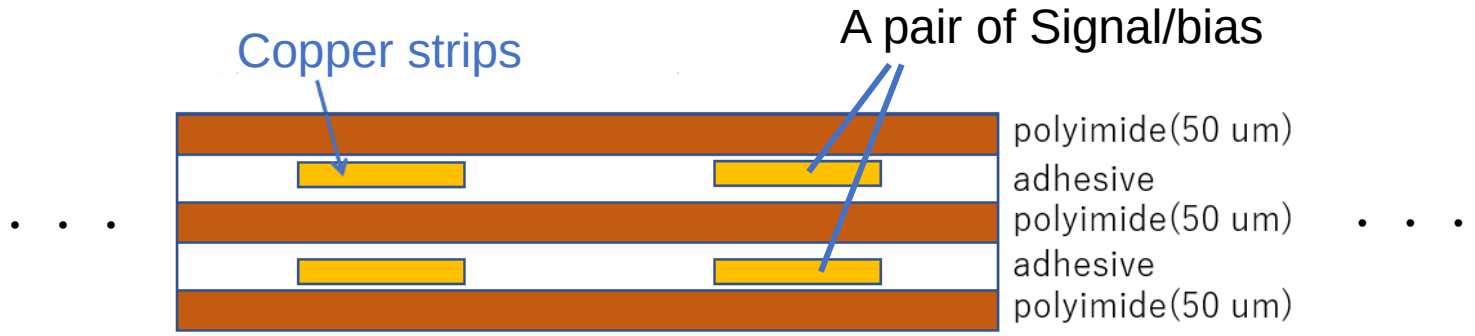
for the AXEL Collaboration

2 Nov 2022, Exploration of Particle Physics and Cosmology with Neutrino, Kyoto

Table of Contents

Readout system (FPC cable)

- ELCC and Frontend Board are redesigned from 56ch/unit → 64ch/unit for space saving of readout device
- New 64ch, one-body long FPC cable (~1m)



Cross-section of the FPC

・Thinner and wider strips make the FPC easier to be produced.

↓

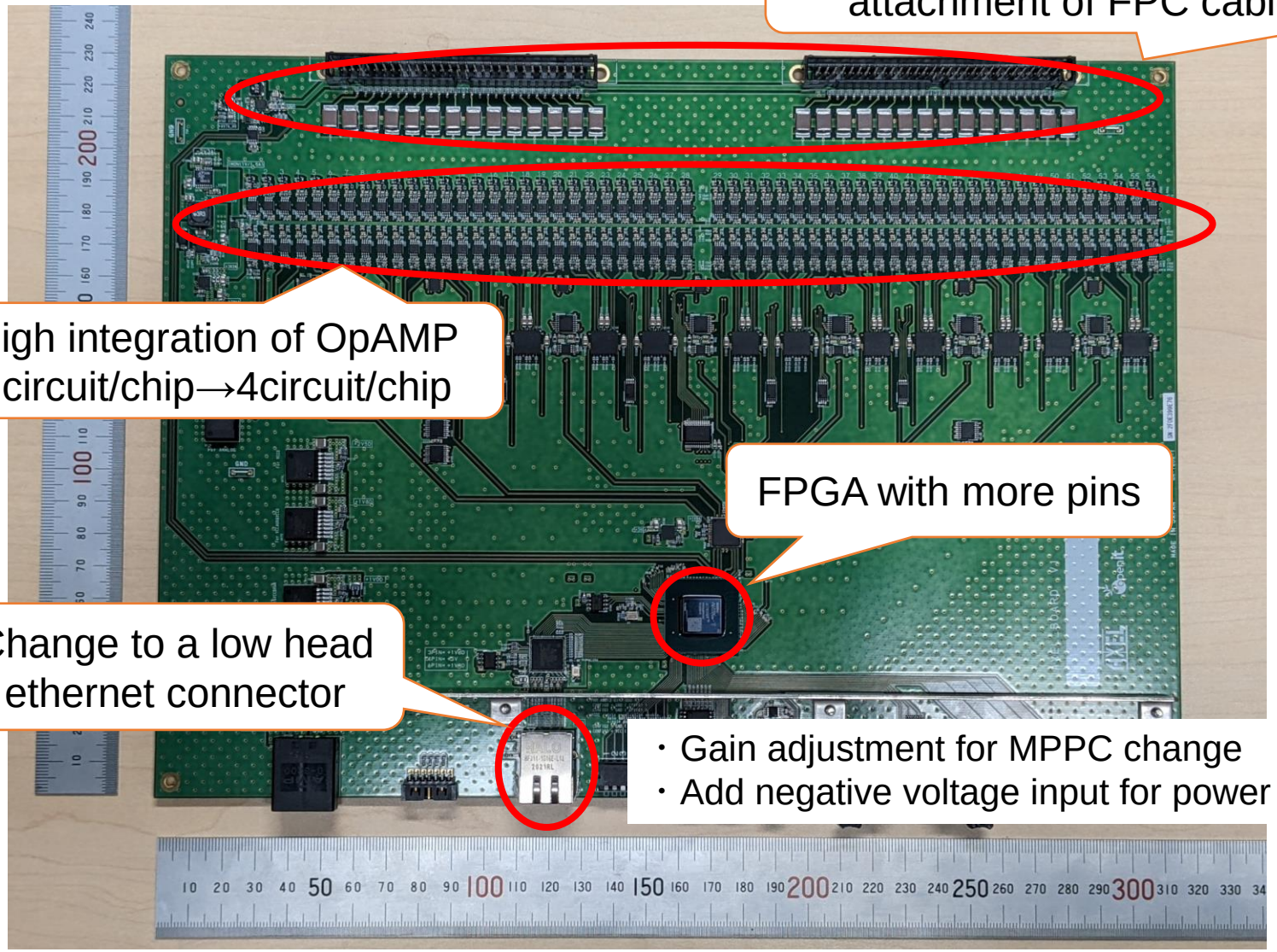
New structure needed, with the same impedance.

Strip width increases: 100 um (old one) → 200 um (new one)
Strip interval decreases: 400 um (old one) → 300 um (new one)
⇨Distance between pair strips increases for impedance matching. (65 → 90 um)

・Crosstalk between channels are measured with square wave (~0.1%)

Readout system (frontend board)

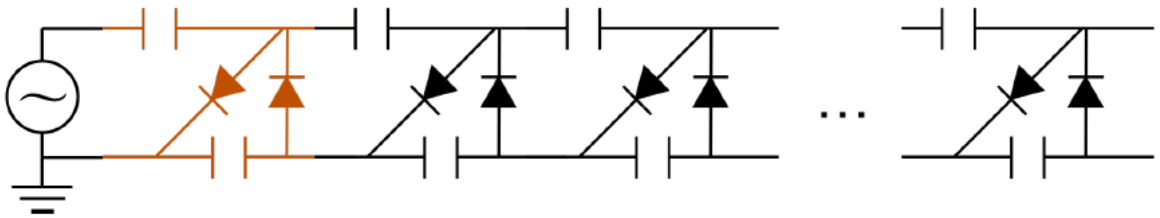
- Redesigning FEB for 64ch/board

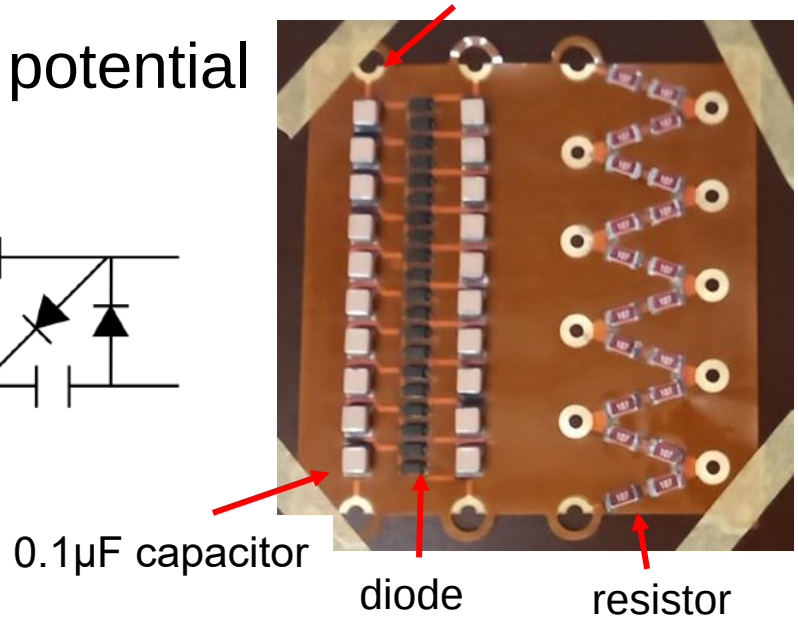


Cockcroft-Walton multiplier

- We need high voltage
  - Drift electric field 100V/cm/bar
  - EL process 3kV/cm/bar

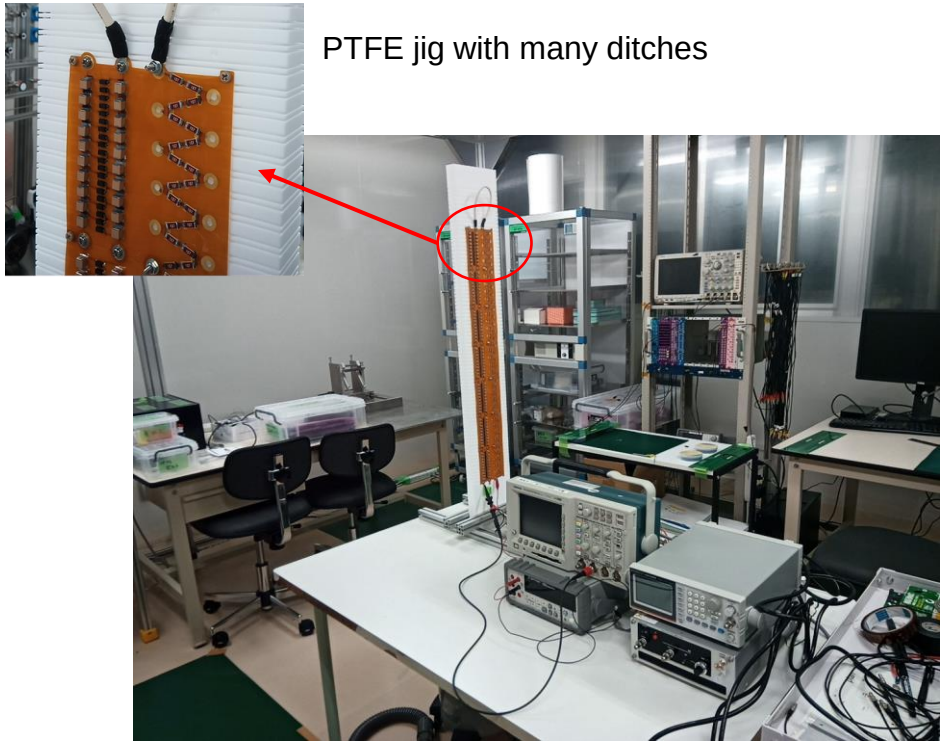
  → - 76.4kV for 1000L detector (with 80.5cm drift region)
- Make high voltage inside the chamber instead of using high voltage feedthrough to avoid surface discharge
- Cockcroft-Walton (CW) multiplier implemented on polyimide based FPC
- Resistor chain for equally divided potential



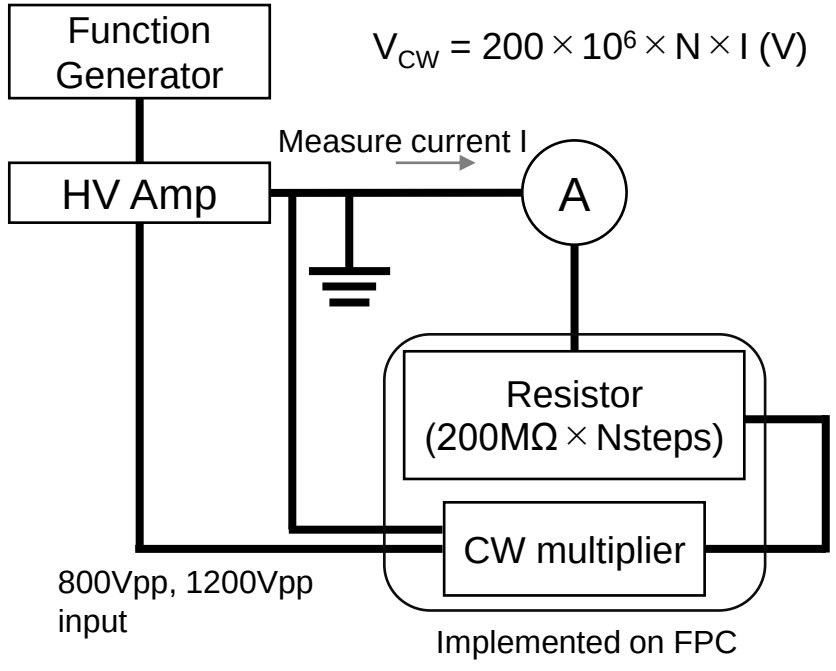


Step dependency of output voltage

- Ideal output of CW multiplier is 2NU (N: number of steps, U: amplitude of input voltage) but smaller values are observed in practice
  - Stray capacity of diode
  - Charge carry away by current on resistor
  - Reverse current on diode
- Measurement on 30～50 steps, 800Vpp,1200Vpp input voltage for understanding efficiency

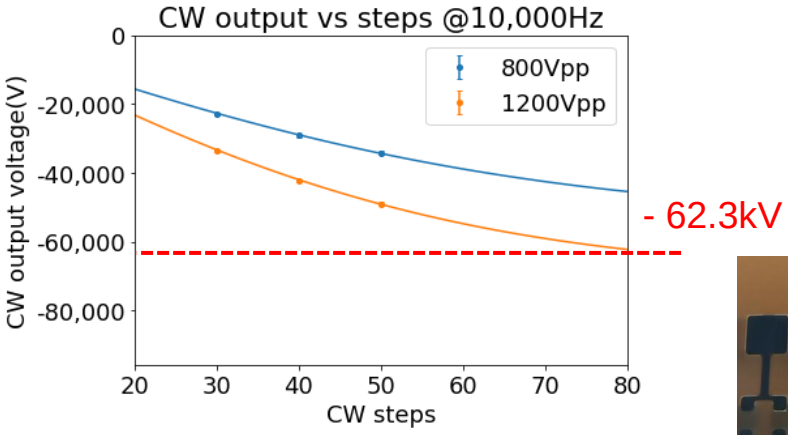


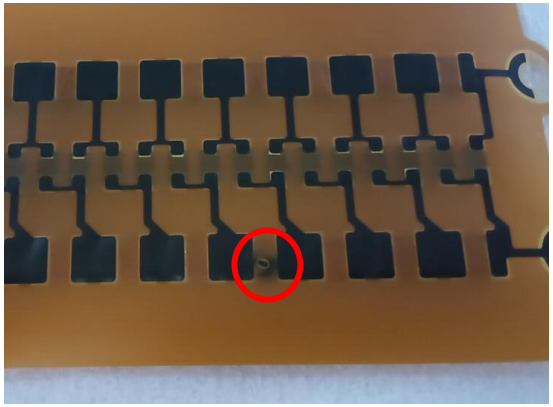
PTFE jig with many ditches

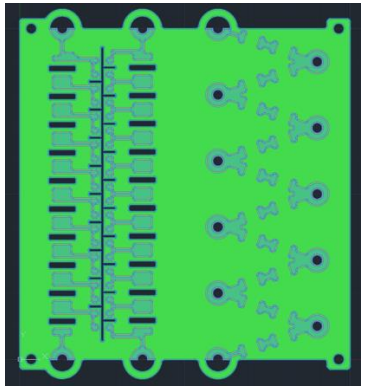


Estimation of output voltage for 1000L detector

- Estimated output volage at 80 steps (for 1000L) based on measurement results at 30 to 50 steps
- - 62.3kV at 1200Vpp, 10kHz input voltage → we need to increase input voltage while avoiding discharge to obtain - 76.4kV
- Countermeasure for electrical discharge
  - Using cap nut to avoid exposing screw threads
  - Redesigning the FPC (expand the interval of soldering pad, holes between pad to avoid surface discharge)

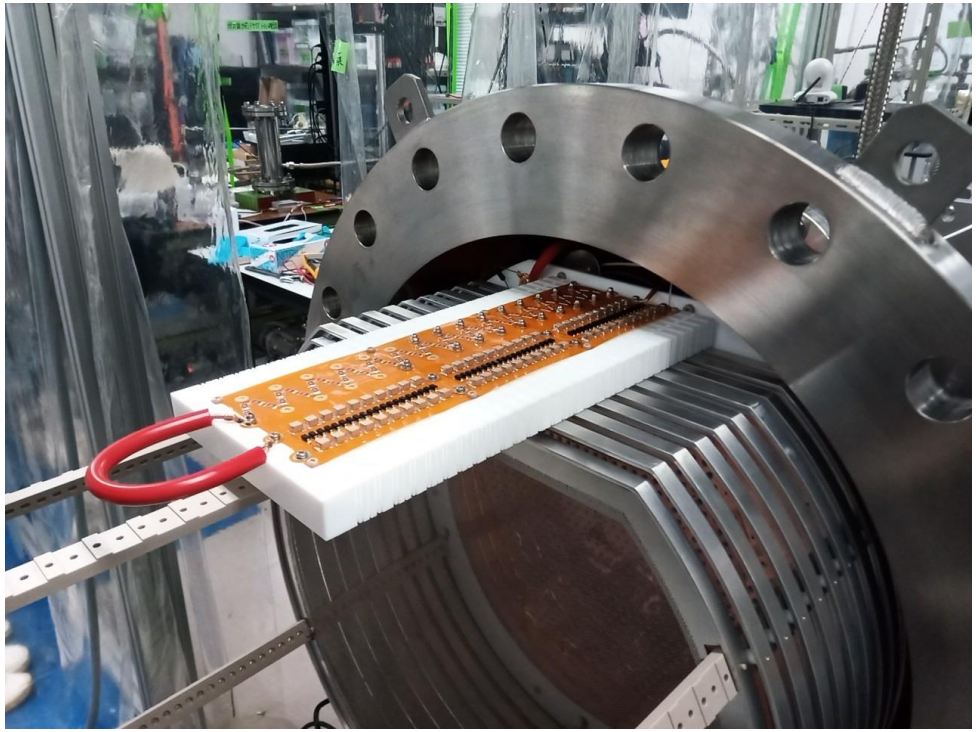


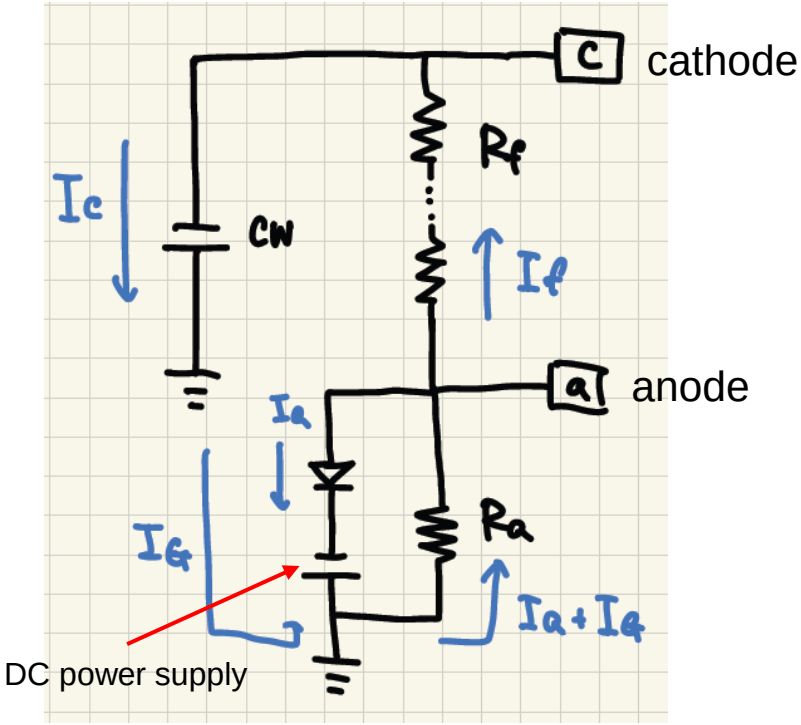




CW operation check in 180L detector

- CW installed in place of Cathode DC power supply in 180L detector
- Current on anode DC power supply is used to measure the output of CW multiplier

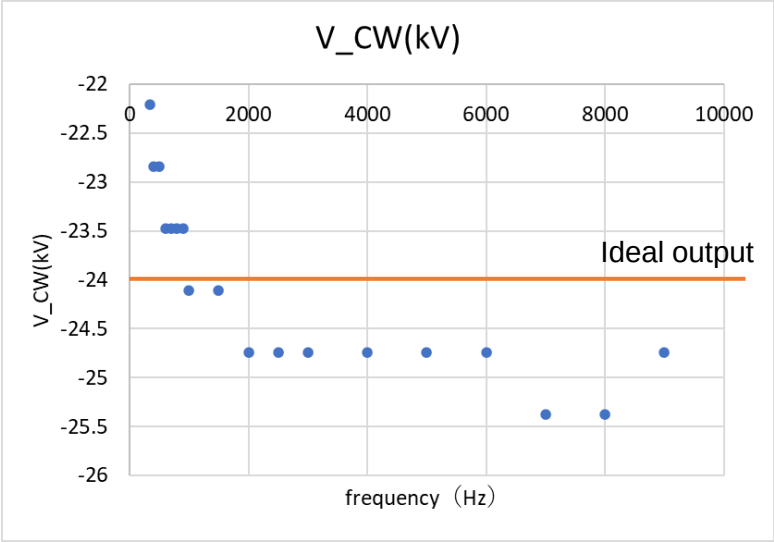




$$V_c = \left(\frac{R_f}{R_a} + 1\right) V_a - R_f I_a$$

CW operation check in 180L detector

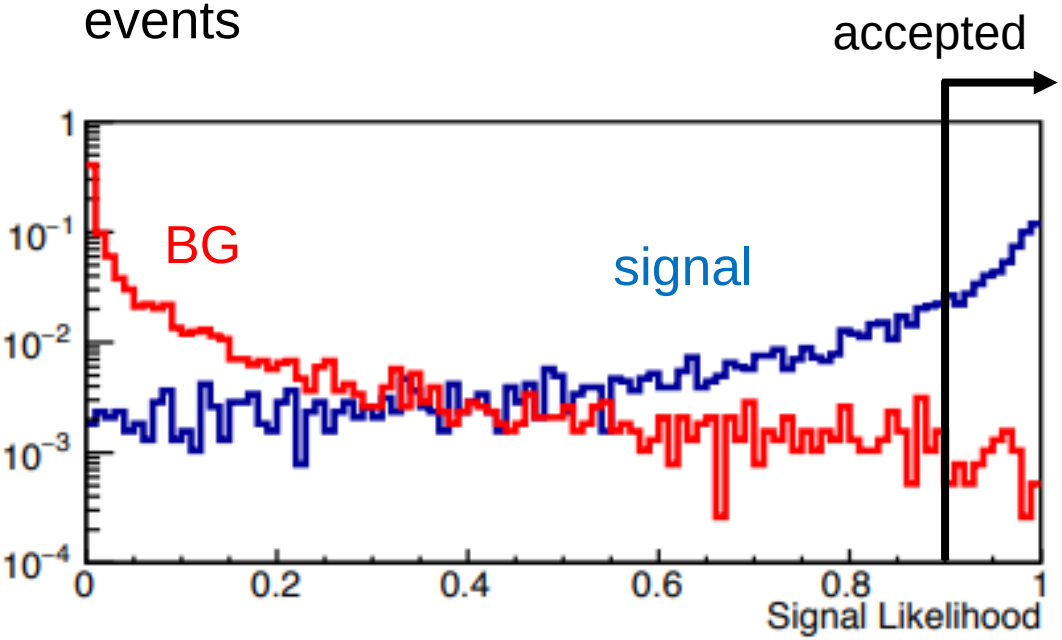
- Measured output voltage exceeds the ideal output in some input voltage, due to the miscaliblation or big systematic error (not yet evaluated).



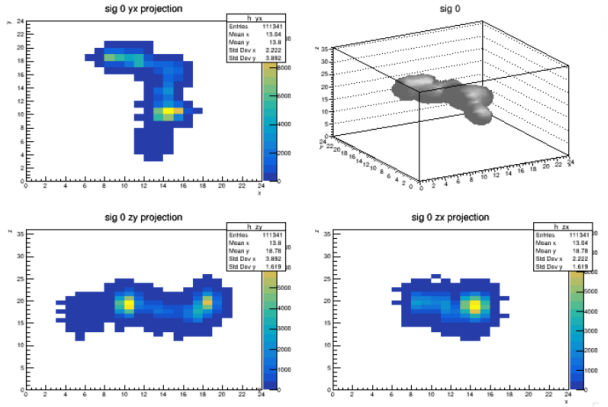
- Need to detect discharge for interlocking the input voltage
  - Detect light of discharge by usb camera (motion detection)
  - Monitor anode DC power supply, HV amp for CW input by data logger

Background rejection with topology using deep learning

- Classify 0νββ and BG using deep learning (3D-CNN, Densenet)
- Using simulated 0νββ and gamma-ray (^{214}Bi 2,448 keV) event topologies
- Achieved signal acceptance 27%, BG rejection: 99.9996% @ threshold 0.9008
- Will confirm using actual data of pair-creation



signal



BG

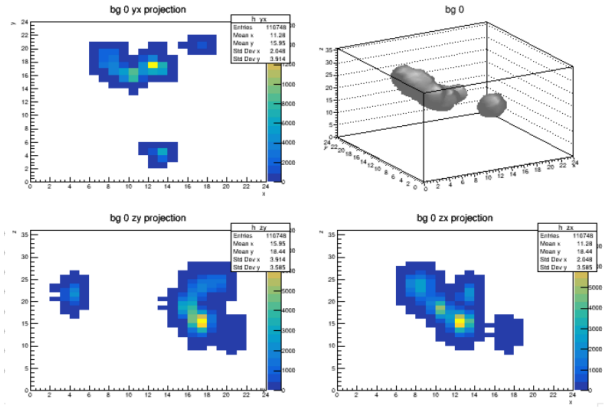
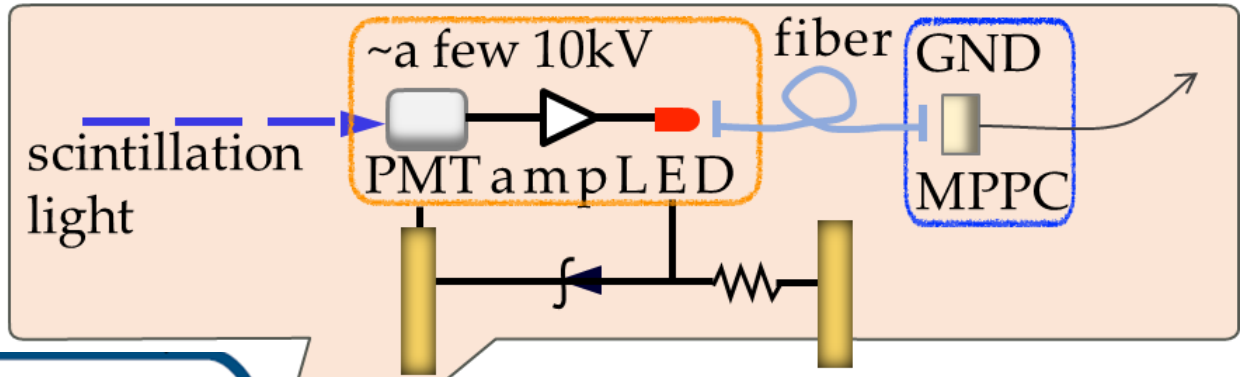
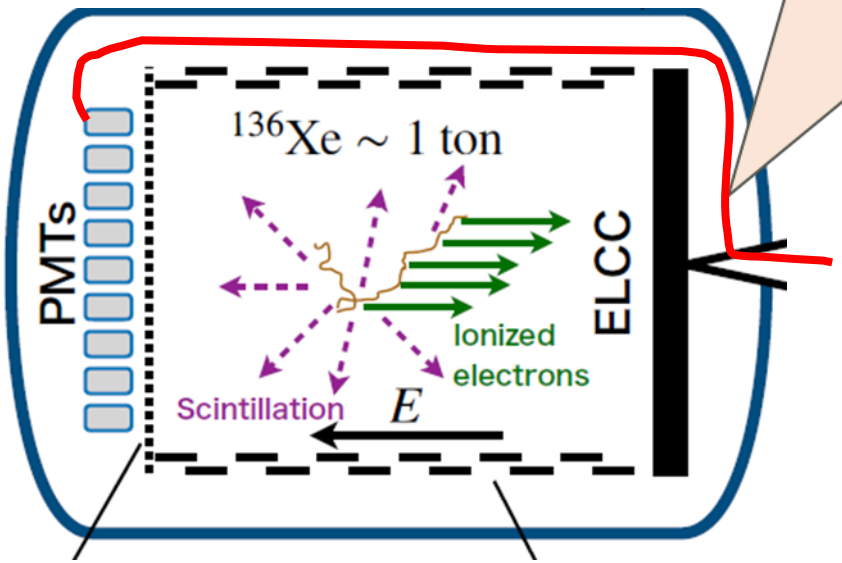
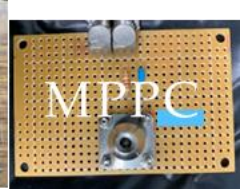


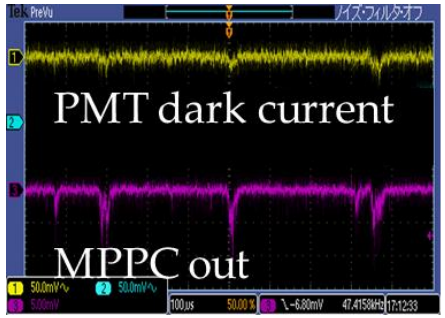
Photo isolation

- Operate PMTs at high electric potential
  - To put PMTs close to the cathode mesh
  - Drive LED with amplified PMT signal and readout with MPPC



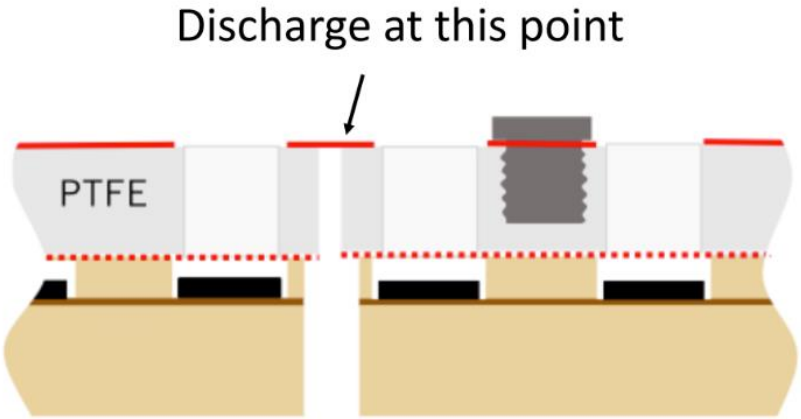


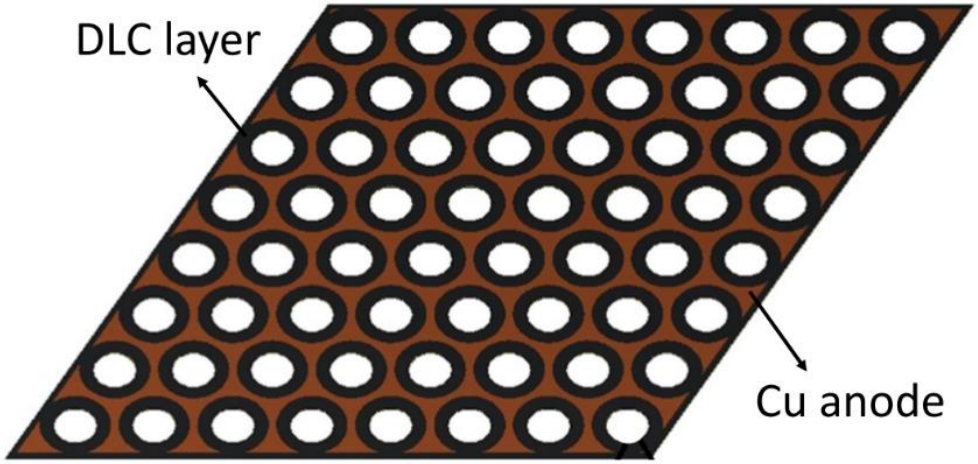




DLC ELCC

- Using diamond like carbon (DLC) to prevent electrical discharge on the edges of the anode
- Voltage drop in the DLC section when discharge occurs
- To confirm the DLC anode, we are now ordering Kapton-base FPC without coverlay





Summary

- Readout system upgrade for high integration of readout devices
  - New 64ch one-body FPC cable
    - Thinner and wider strips with same inpedance
    - Crosstalk between the channels are ~0.1%
  - Frontend board for 64ch/board is redesigning
    - Change connectors, OpAMP, FPGA
    - Gain adjustment
    - Add negative voltage input
- Cockcroft- Walton multiplier
  - Estimated output voltage for 1000L detector is -62.3kV → Need to increase input voltage, countermeasure for electrical discharge
  - CW operation check in 180L detector
    - Need to detect discharge for interlocking the input voltage by motion detection, data logger etc
- Background rejection with topology using deep learning
  - Achieved signal acceptance 27%, BG rejection: 99.9996% @ threshold 0.9008 using simulated 0vββ and gamma-ray (214Bi 2,448 keV) event topologies
- Photo isolation to put PMTs close to the cathode mesh
- DLC ELCC
  - Prevent electrical discharge on the edges of the anode by voltage drop in the DLC section.