Performance Evaluation of Readout Circuit for 2.6m-wire Drift Chambers for Kaonic Nucleus Experiments at J-PARC

Yuto Kimura (RARiS, D1 / RIKEN-Nishina, Meson RIKEN ECL Research Team, JRA) for the J-PARC E80 collaboration,
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E-Mail: y_kimura@raris.tohoku.ac.jp

Abstruct: We are planning the J-PARC E80 Experiment to investigate the $\bar{K}NNN$ system and the J-PARC E89 Experiment to determine the spin-parity of the $\bar{K}NN$ state. In addition, experimental studies of kaonic nuclei with heavier systems and multiple kaons are also being considered. For these future experiments, we have constructed a new detector system with a large solid-angle coverage and sufficient neutron detection efficiency. In this poster, we report on performance tests of a candidate preamplifier board (SONY-CXA3653Q) intended for the Cylindrical Drift Chamber (CDC), which is one of the main detectors in the new system. The evaluation was carried out using a test chamber with the same wire length and cell structure as the CDC.

Next kaonic nucleus exp. at J-PARC

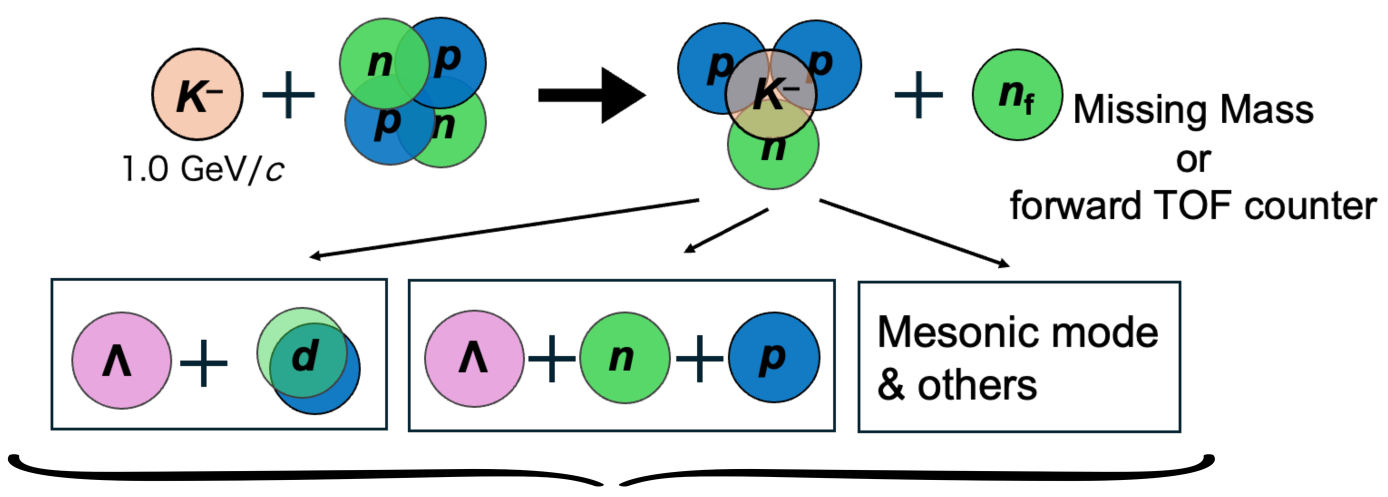
In J-PARC E15, "K^-pp" was succesfully observed[1]. What's the next?

"Existence" → "Properties"

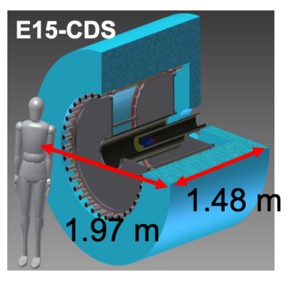
- J-PARC E89: Further investigation of "$\bar{K}NN$" (S. Ohtaka [P-01])
- **J-PARC E80**: "$\bar{K}NNN$" serch as a first step to heavier systems
  - How will binding energy, width, branching ratio etc... change?
  - Really compact?[2]

J-PARC E80 and Cylindrical Detector System (CDS)

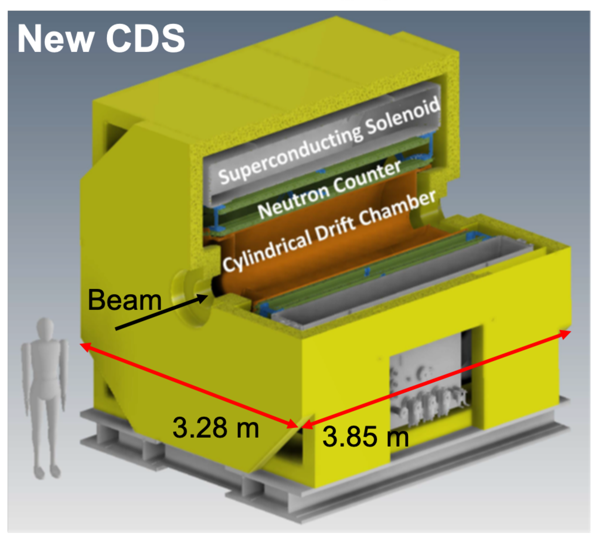
What we will detect



All the decay particles from K-nucleus must be detected as in the E15 experiment.



Upgrade!

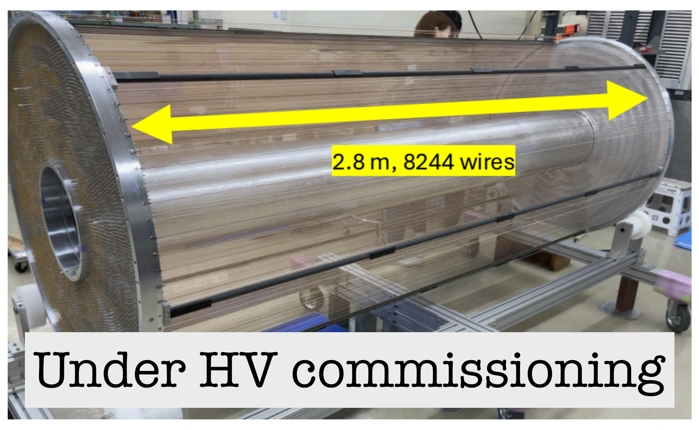


Compared with the case of E15 ("K^-pp")

- The neutrons to be detected are produced.
  → Neutron detection eff.: x4 (3% → 12%)
- The number of decay particles from K-nucleus increases.
  → Solid angle: x1.6 (59% → 93%)

Cylindrical Drift Chamber (CDC)

Structure



Wire length is **2580 mm**
(3 times longer than E15-CDC's 883.8 mm)

- Consists of two aluminum end plates and a CFRP cylinder as the inner wall.
- 8,244 wires(The wire tension was applied so that the wire sag was less than 200 um.)
- 15 layers of hexagonal cells with a typical drift length of 9 mm

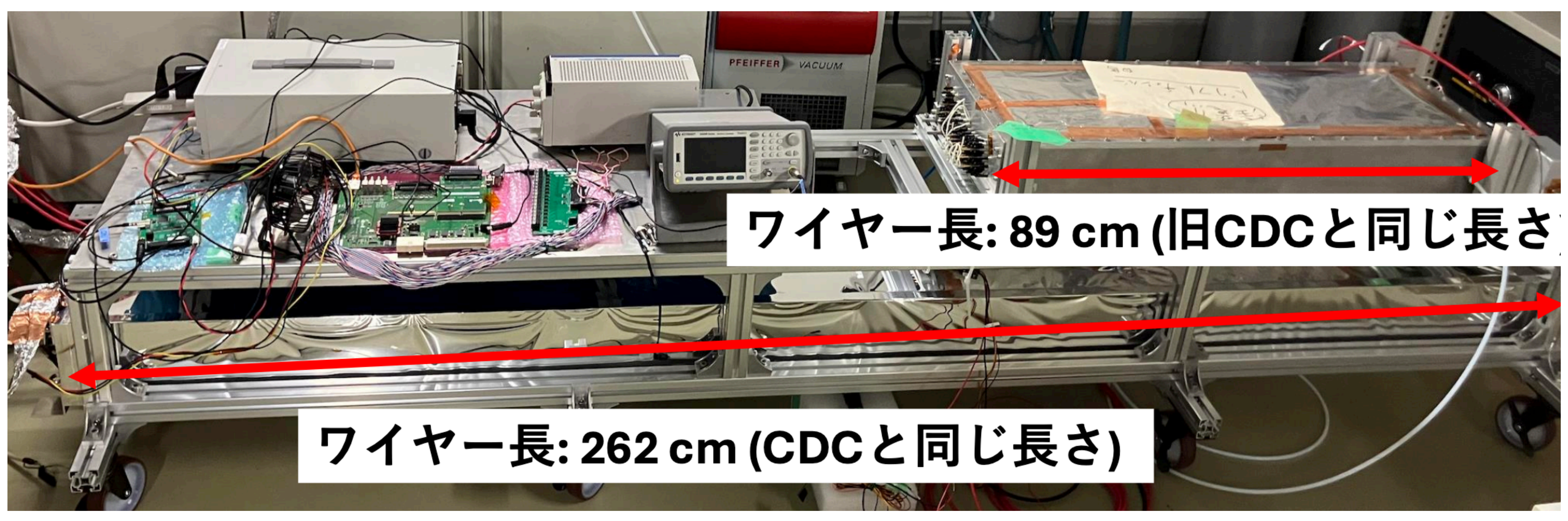
Readout candidate 1: "SONY-ASD (CXA3653Q chip)"[3]

- Consist of "Pre-amp" and "main-amp"
- Time constant τ = 16 ns (fixed)
- V-threshold is shared by all channels.
- **We used this board as a readout for the E15-CDC.**

Can this be used for a 2.6-m-long wire chamber?

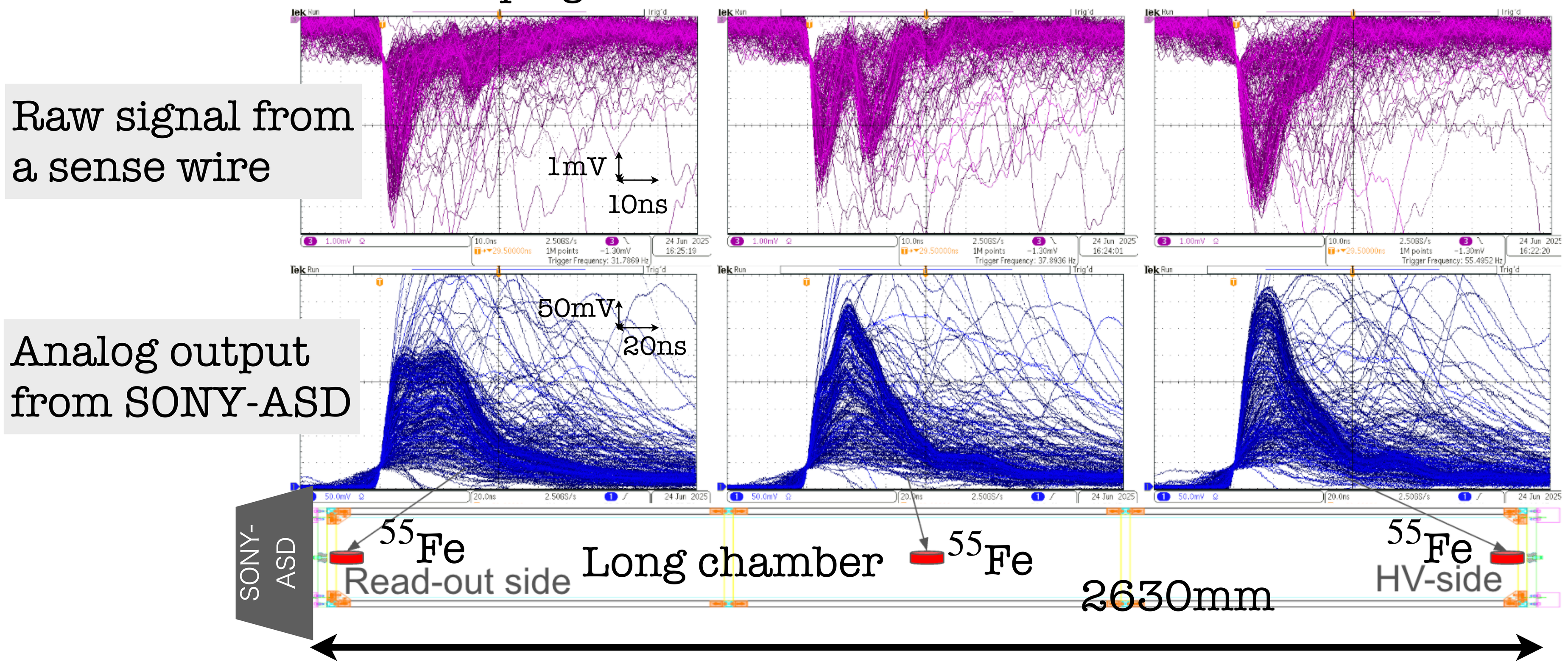
Performance Evaluation with Test Chambers

A feasibility study of the SONY-ASD was carried out using a test chamber with the same wire length and cell structure as the E80-CDC, together with a reference test chamber having the same wire length as the E15-CDC. These chambers is denoted as "long chamber" and "short chamber".

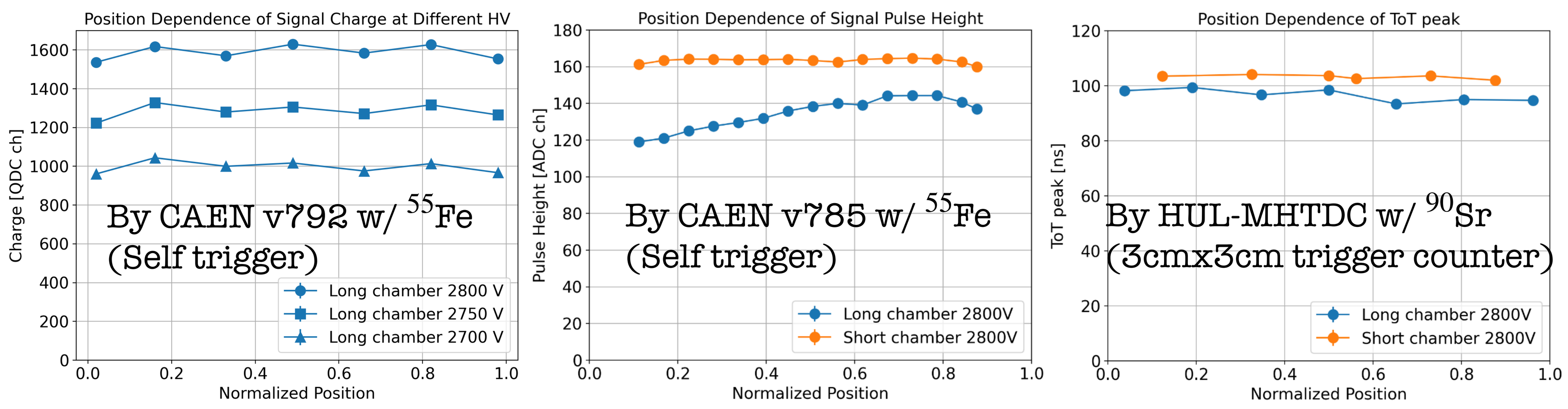


1. Raw signal and analog output from SONY-ASD

Due to the long wires, the direct and reflected signals can be separated depending on the avalanche position. The reflected signal distorts the amplified waveform in the SONY-ASD with a shaping time of 16 ns.



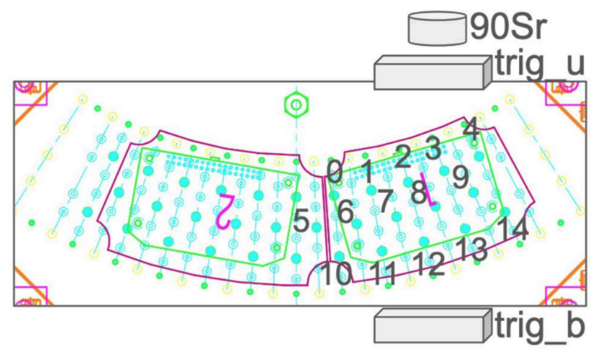
2. Position dependence of signal charge, pulse height and ToT



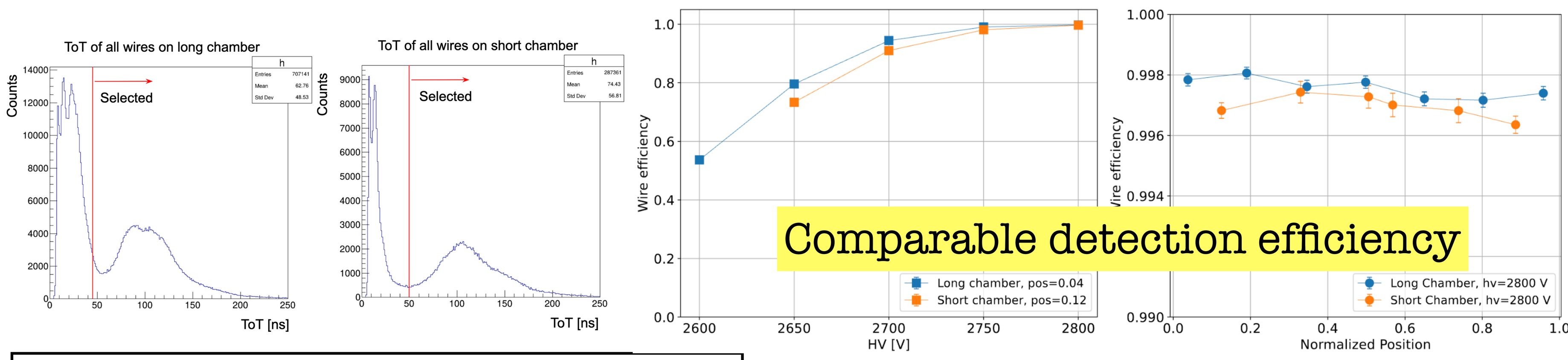
- Signal charge is conserved.
- Pulse height decreases toward the readout end (long chamber only).
- Peak of ToT has no clear position dependence.

3. Single wire detection efficiency

For the efficiency calculation in the following subsection, only hits with ToT values exceeding the thresholds shown in figures were used.



Detection efficiency is defined as the fraction of events in which the expected wire in Layer 2 fires when Layer 1 and Layer 3 give a coincidence.



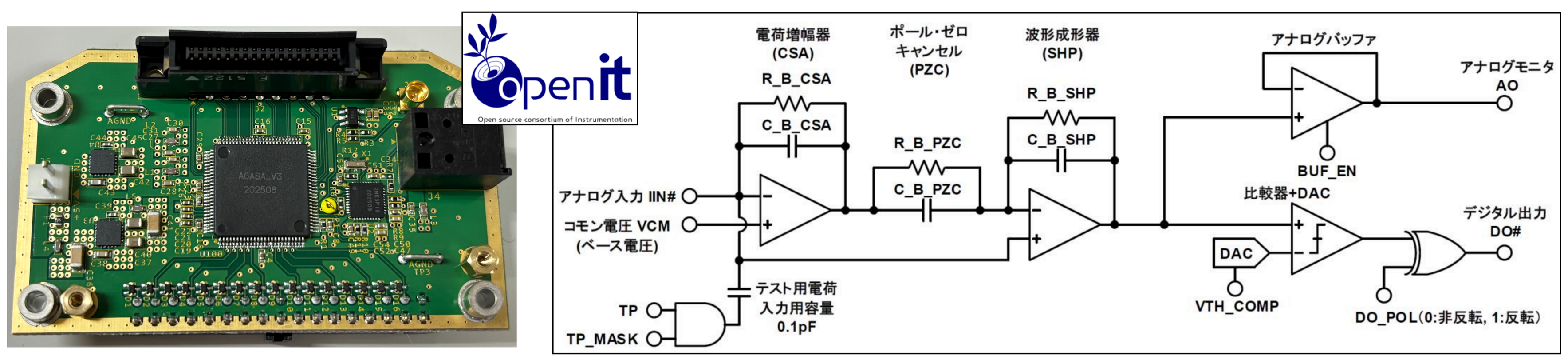
Summary and Prospect

Waveform distortion due to signal reflections was observed in the long chamber. Nevertheless, a sufficiently high detection efficiency, comparable to that of the short chamber, was achieved (~100% at 2800 V for Ar-C2H6(50:50)).

While the SONY-ASD showed sufficient performance, we are evaluating the other preamplifier board, which offers further optimization potential.

Readout candidate 2: "ASAGI 16ch version"

ASAGI[4], originally a 32-channel readout board developed by SPADI-A, was downsized to a 16-channel version for our chamber.



- Consist of Charge Sensitive Amp, Pole Zero Cancel and SHaping Amp.
- The total resistance and capacitance values can be adjusted by changing the number of connected elements through on-chip register settings.
  → **Time constant is flexible!** (τ = 8ns - 1us)
- V-threshold can be set to each channels individually.

After basic characterization, a beam test at J-PARC K1.8BR Beamline is planned next month to study the parameter dependence of detection efficiency and position resolution in order to determine the optimal settings for ASAGI.

[1] T. Yamaga et al., Phys. Rev., C102. (2020) 044002
[2] T. Sekihara et al., Phys. Rev. C (2012) 065205
[3] ATLAS TGC Collaboration, Amplifier-Shaper-Discriminator ICs and ASD Boards, Technical Report, ATLAS Internal Note MUON - NO - 1,1999.
[4] Y. Yamamoto, U Osaka Master Thesis (2023)