LArTPC R&D status

2015/Aug./5, Workshop for Neutrino Programs with facilities in Japan

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R&D collaboration with Iwate University, Yokohama National University and Kure National College of Technology

1. Introduction
2. Status of LArTPC R&D at KEK
3. Outlook & Summary

Introduction

- Liquid argon TPC (LArTPC) has a capability of good particle identification and good energy resolution up to several GeV
- A large size LArTPC(>10kton) is a candidate of neutrino detector for long-baseline neutrino oscillation physics studies (CPV,MH), nucleon decay search, SN neutrino observation, atmospheric neutrino measurements etc.
- Largest LArTPC up to now is ICARUS T600 (300ton x 2)

c.f. DUNE 10kton detector = 58m x 14m x 12m (plan)

Establishing key technologies to realize a large LArTPC detector with affordable cost is an urgent subject

R&D activity at KEK

We aim for realization of a long drift toward a large scale LAr detector

- event containment
- reduce # of readout channel (cost down)

We focus necessary fundamental technologies R&D toward a realization of the long drift using small scale LArTPC detectors

(10L, 250L detectors)

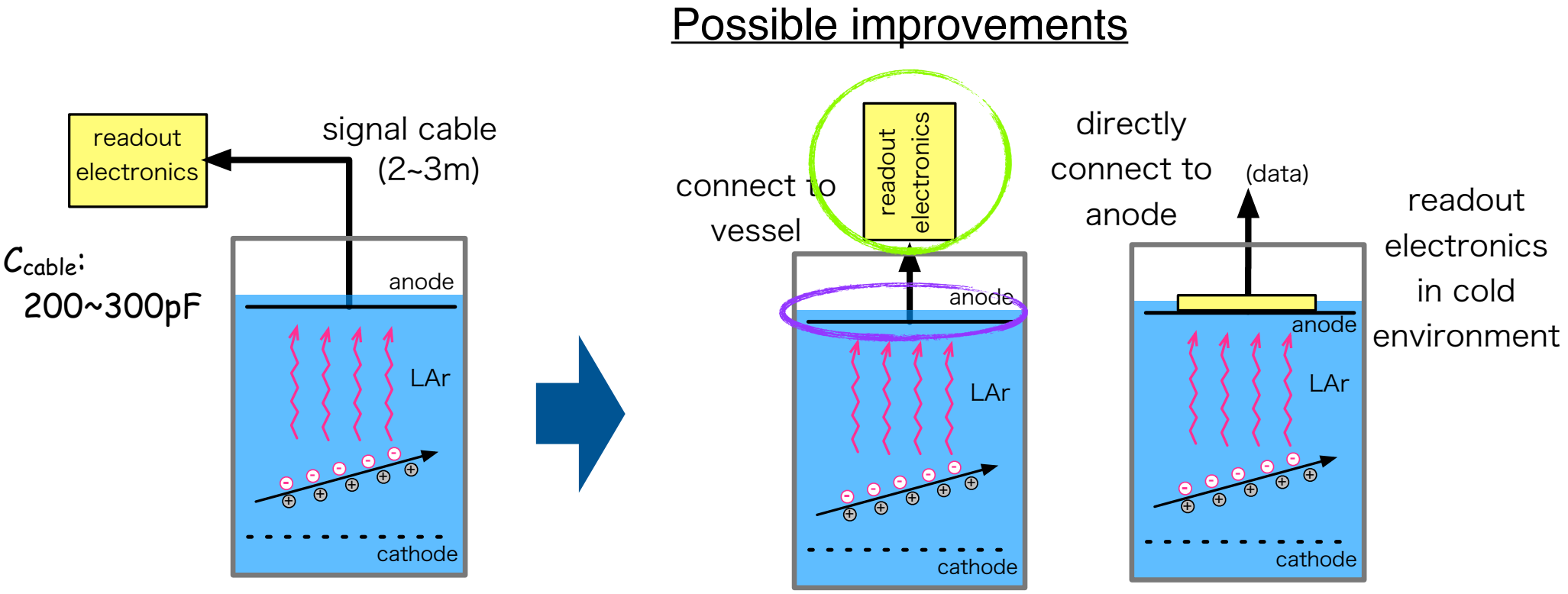
- **High purity** stable long term operation with purity < 0.1ppb
- **High voltage** small attenuation by increasing drift velocity (> 500V/cm)
- **Readout system** low noise & high signal gain readout (S/N ratio > 10)

Today's talk : *- R&D on readout system*
- A new small scale LArTPC detector

R&D on readout system

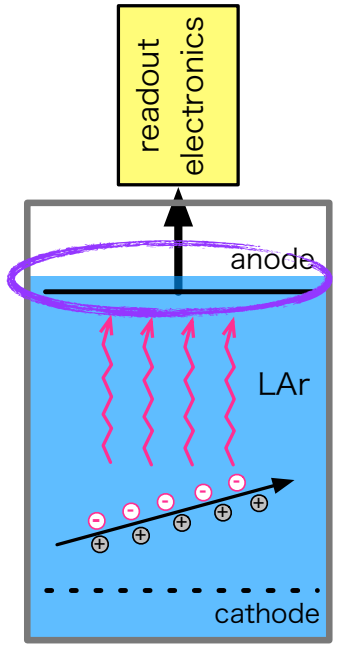
- ***Developing an economical and low noise readout electronics***
- ***Placing the electronics as close as possible to the anode***

to reduce the detector capacitance → small noise

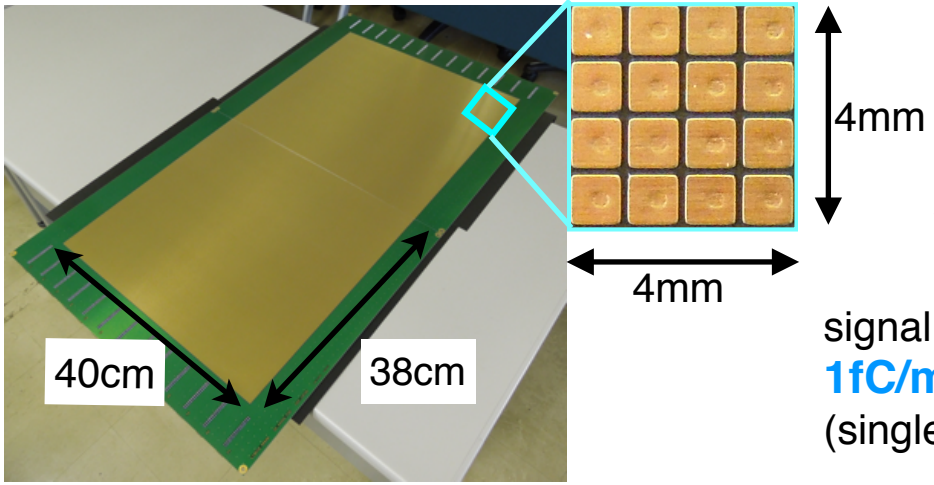


R&D on 2D anode readout board (strip readout)

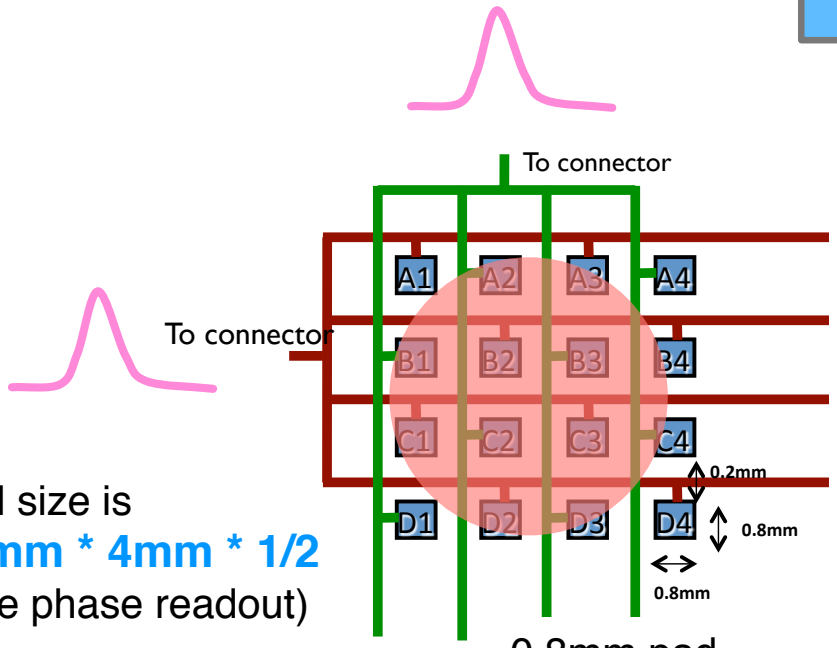
- Based on multilayer PCB technologies
- Making up 4mm pitch strip readout with connecting 0.8mm^2 pad
  - signal shape is identical for both x and y channel
  - charge is shared in x and y channel half-and-half
- Commercially available largest product is 50cm x 50cm
  - realize a large area with connecting several boards



<u>76cm x 40cm anode</u>



4mm pitch readout. 380ch in total



signal size is
1fC/mm * 4mm * 1/2
(single phase readout)

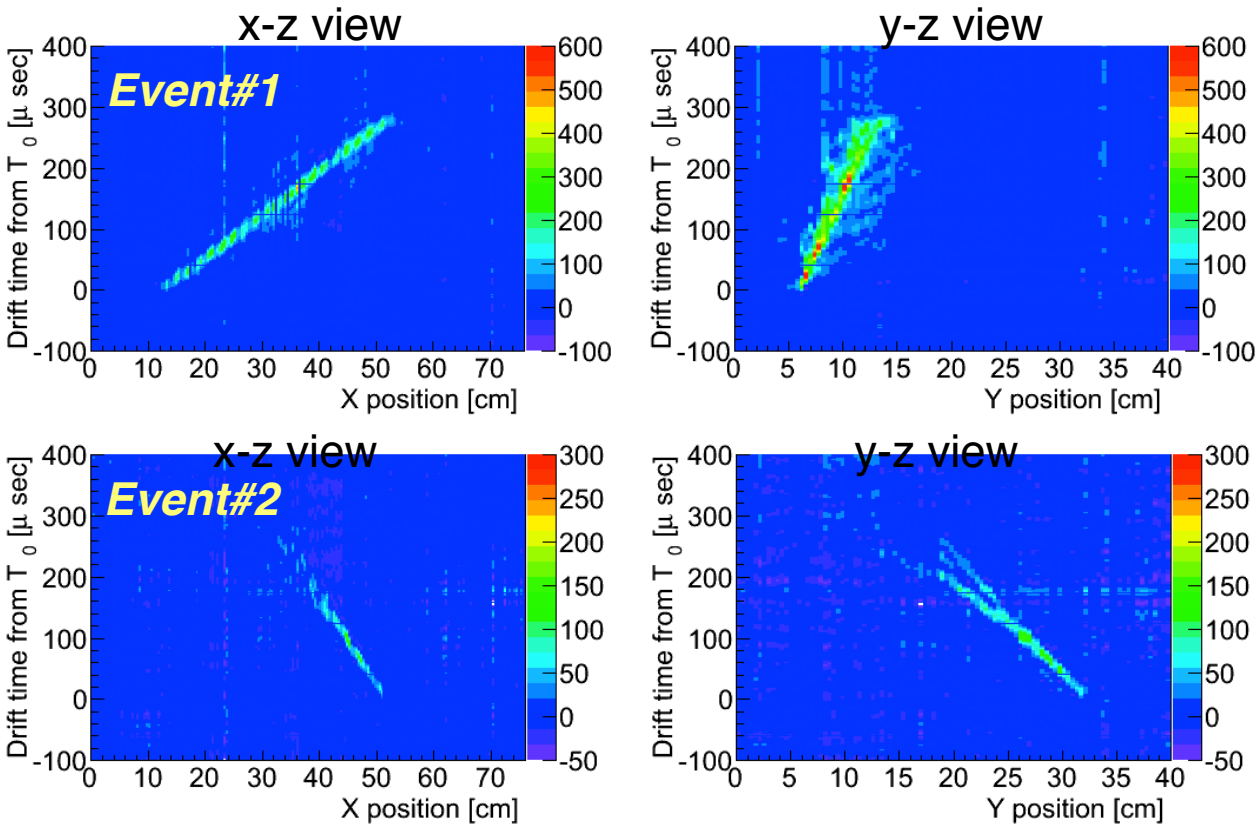
0.8mm pad
0.2mm space

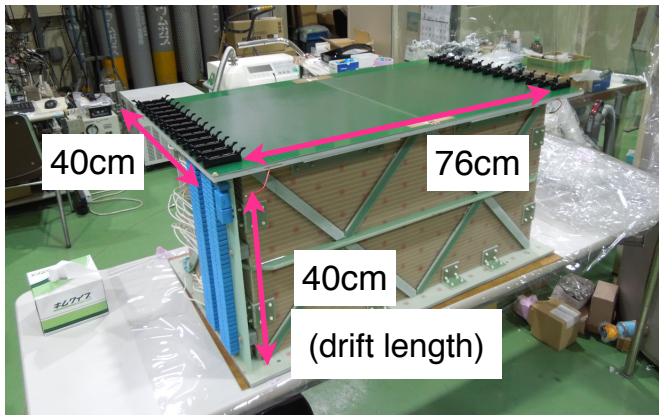
(developed with KEK e-sys group

Cosmic ray events w/ a large area anode board

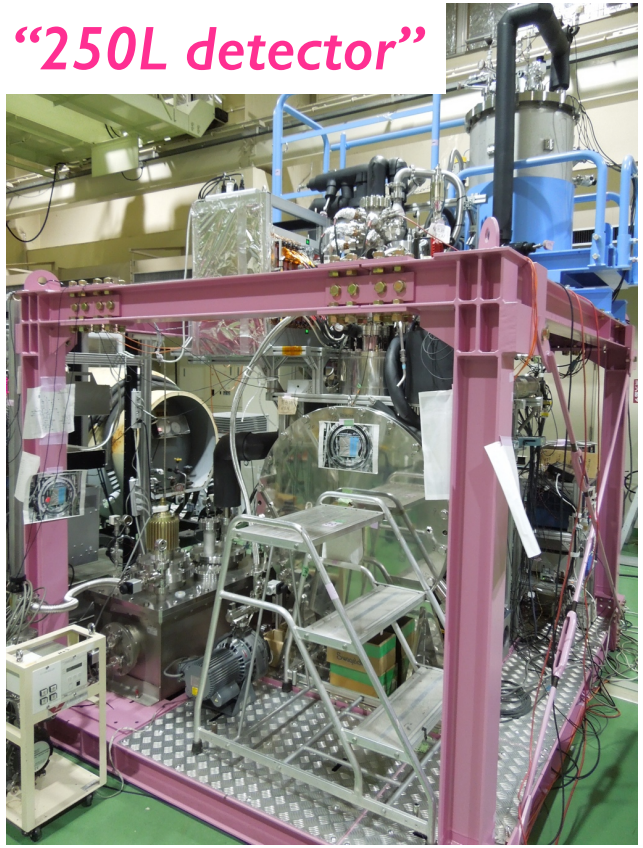
76cm x 40cm readout test : cosmic ray events

[w/ CAEN TPC readout elec.]





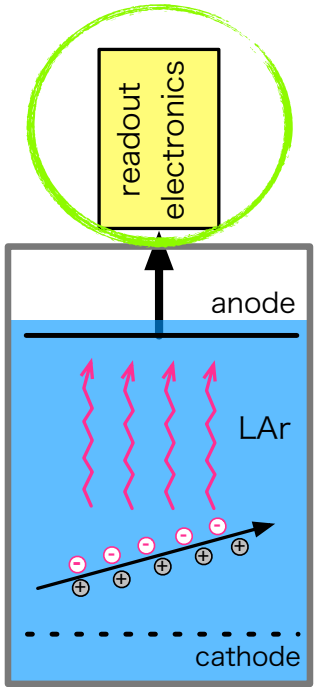
"250L detector"



Toward larger area readout, we aim to reduce the capacitance of the anode board

Development of economical and low-noise electronics

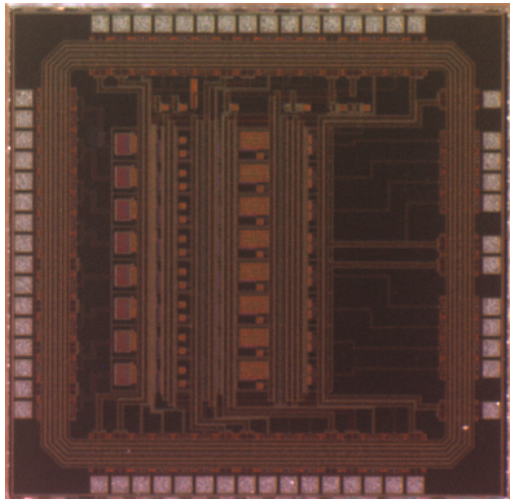
We're developing a front-end chip (ASIC) for
a low noise analogue pre-amplifier

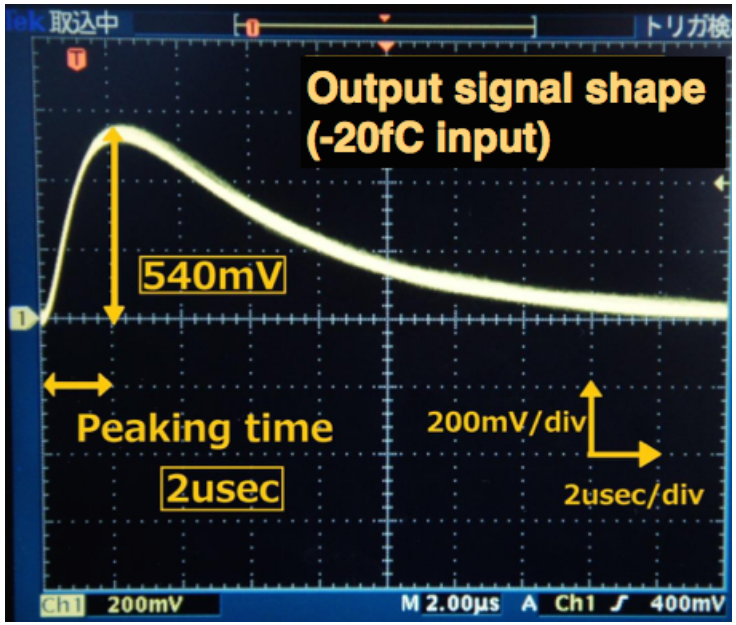


LTARS ASIC (1st version)

- 8ch pre-amp. & shapers in a chip (2.8mm x 2.8mm)
- acceptable det. capacitance ~100pF
- operation voltage ±2.5V
- aiming to use in the low temperature environment
  (in first, testing in warm temp.)

LTARS ASIC chip

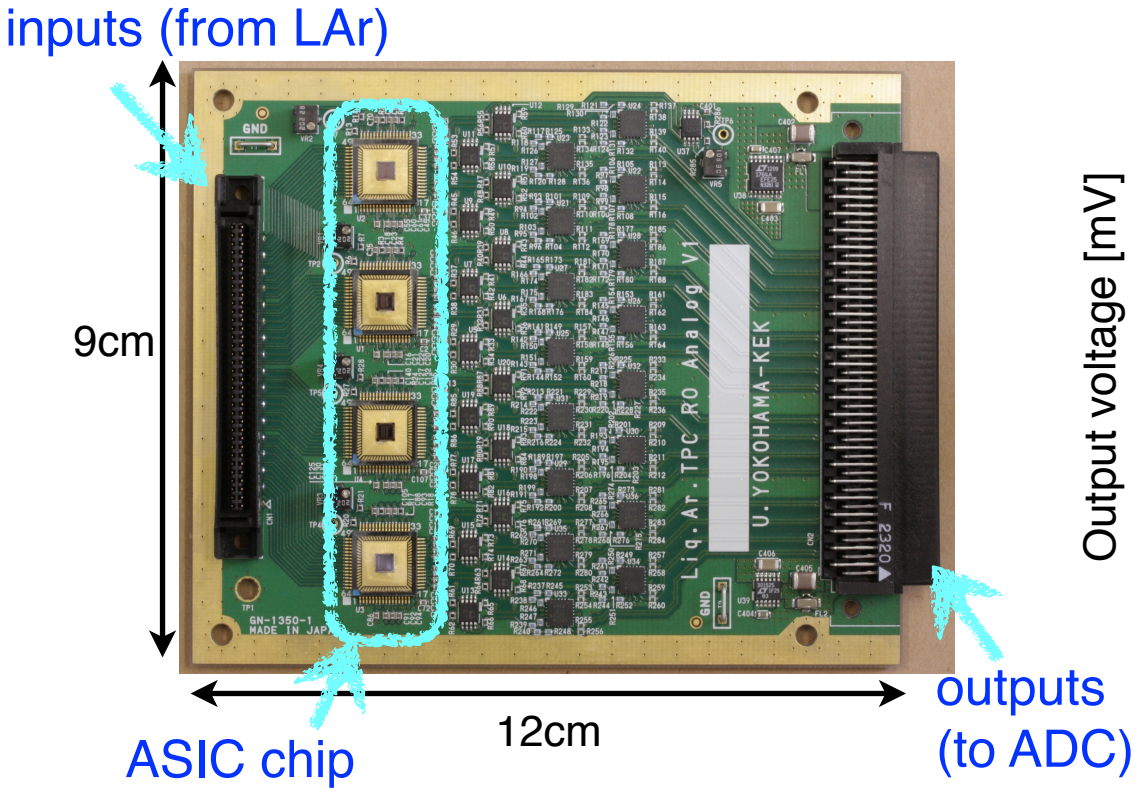


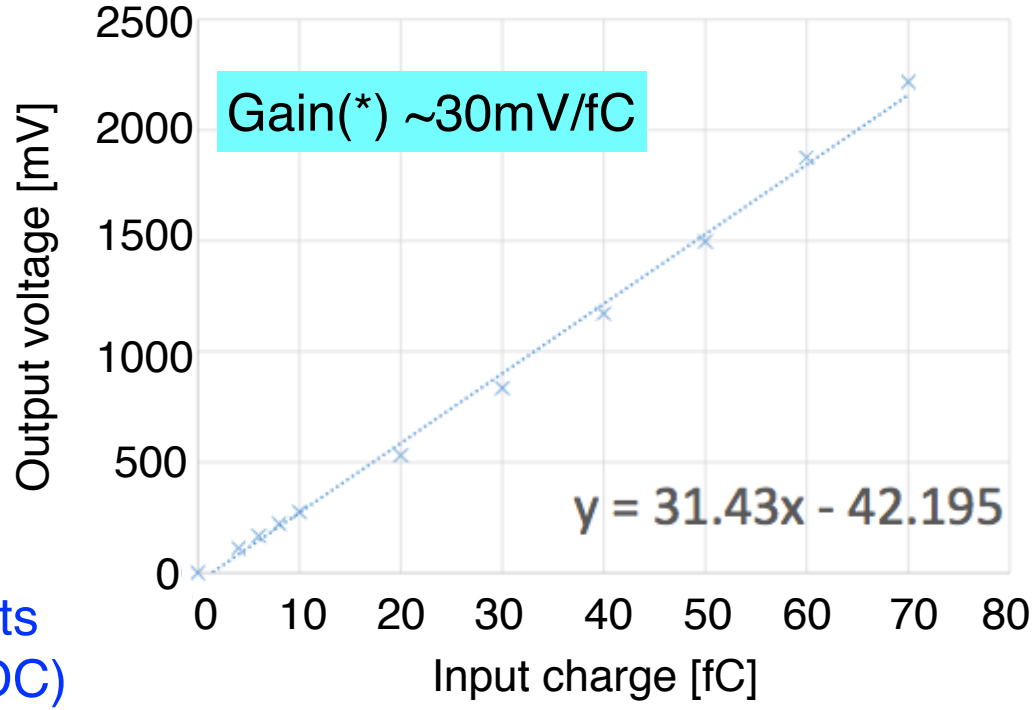


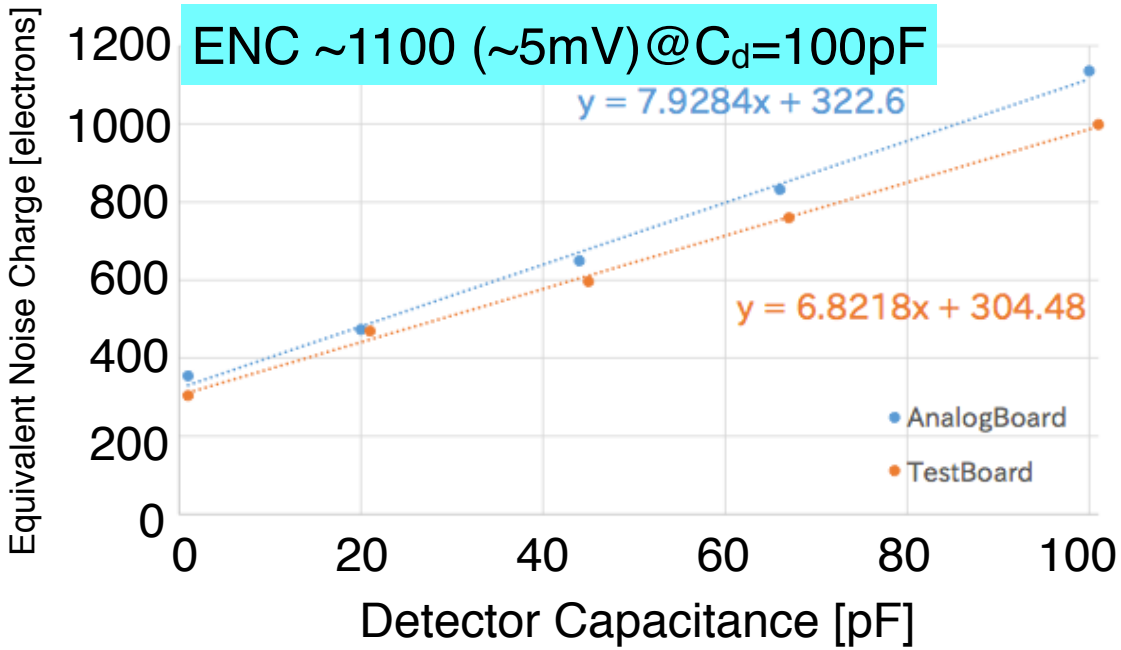
ref: Yuya Iwazaki's Master thesis, Yokohama National U. (2014)

developed with KEK e-sys group, one of Open-it projects http://openit.kek.jp/project/LTARS/public/pll

● Performance evaluation





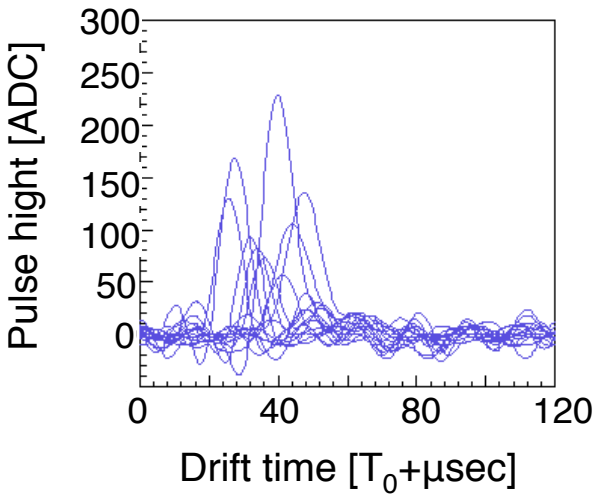


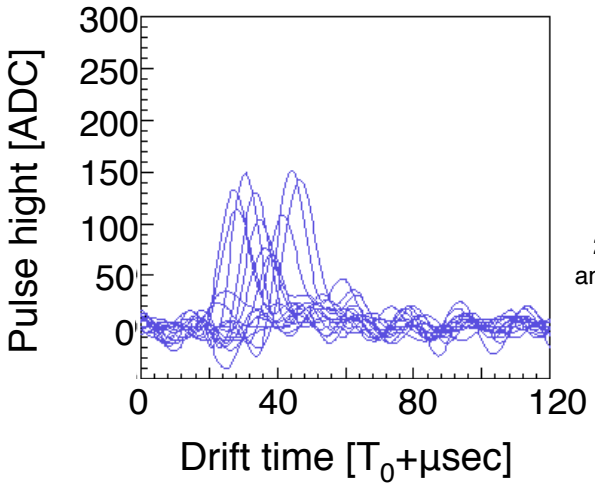
(*) ~10% decrease of gain@C_d=100pF

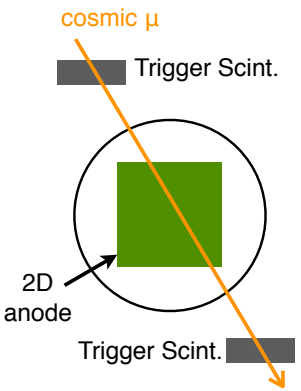
Performance is consistent with the ASIC design (expectation from simulation studies)

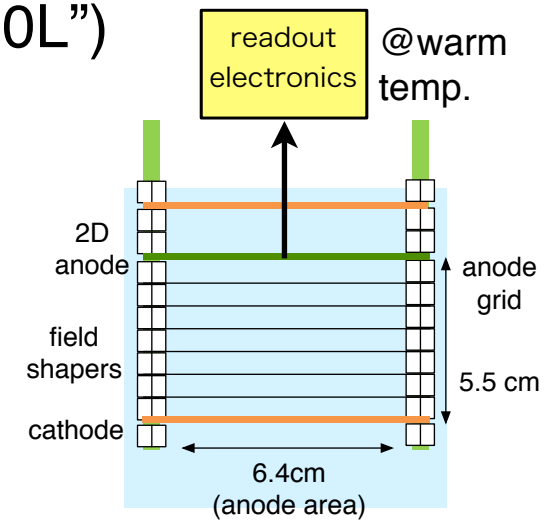
all the measurement done by Y.Iwazaki (Yokohama National University)

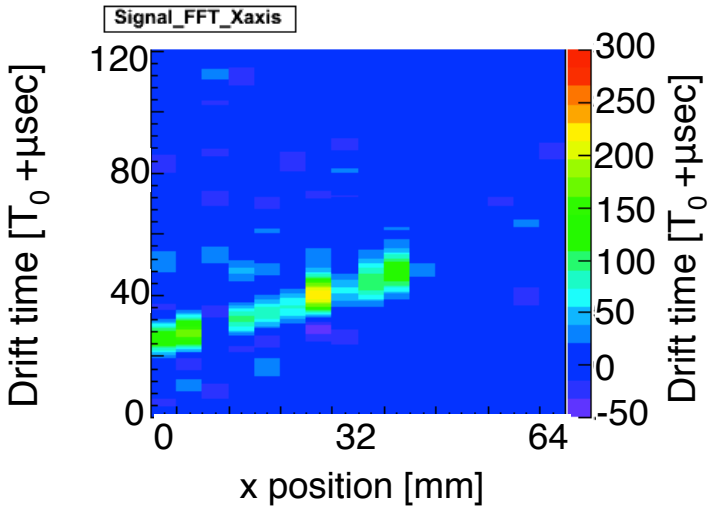
Performance check w/ cosmic events using a small det. (“10L”)

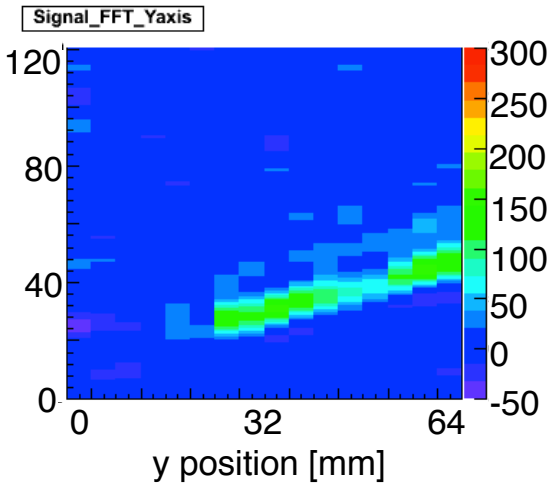




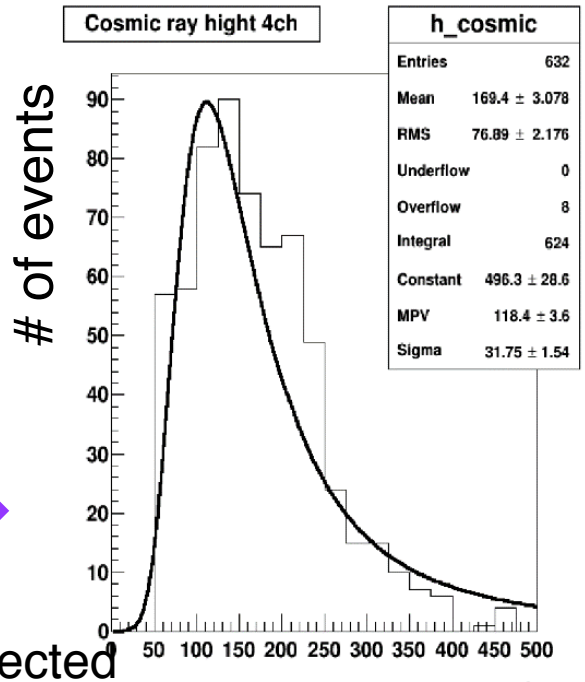








Signal size was evaluated from ~600 cosmic muon tracks



MIP signal ~120ADC in ch4 → (noise ~11ADC in RMS)

signal size, noise size are as expected

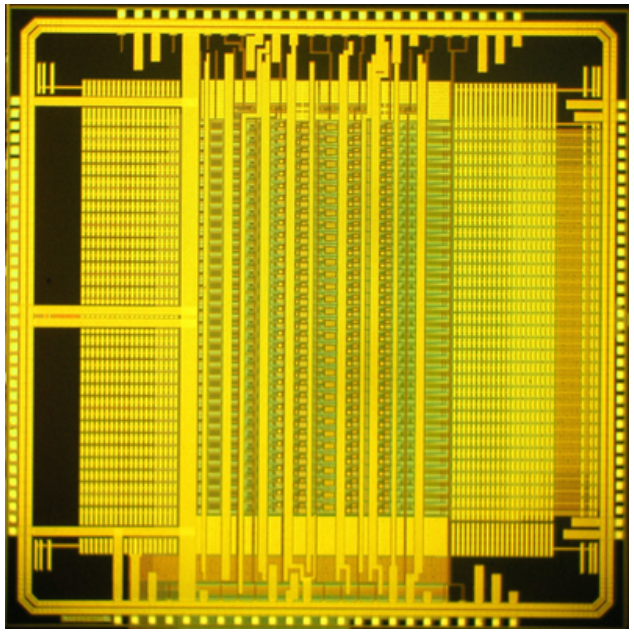
→S/N > 10 (single phase readout)

Development of next version ASIC

Toward a large size detector readout, we develop a next version of ASIC

LTARS2014 ASIC

LTARS2014 ASIC chip (5mm x 5mm)



specification change from the previous version

- 32ch in chip (# of ch. per chip is increased)
- acceptable det. capacitance ~300pF
- operation voltage ±0.9V
- low power consumption (< 50mW/32ch)
- expected noise is ~2000 e- @300pF
- conv. gain ~9mV/fC

Performance of the ASIC is under evaluation

study by Y.Kuromori (Iwate University)
L.Zambelli (KEK)
developed with KEK e-sys group,

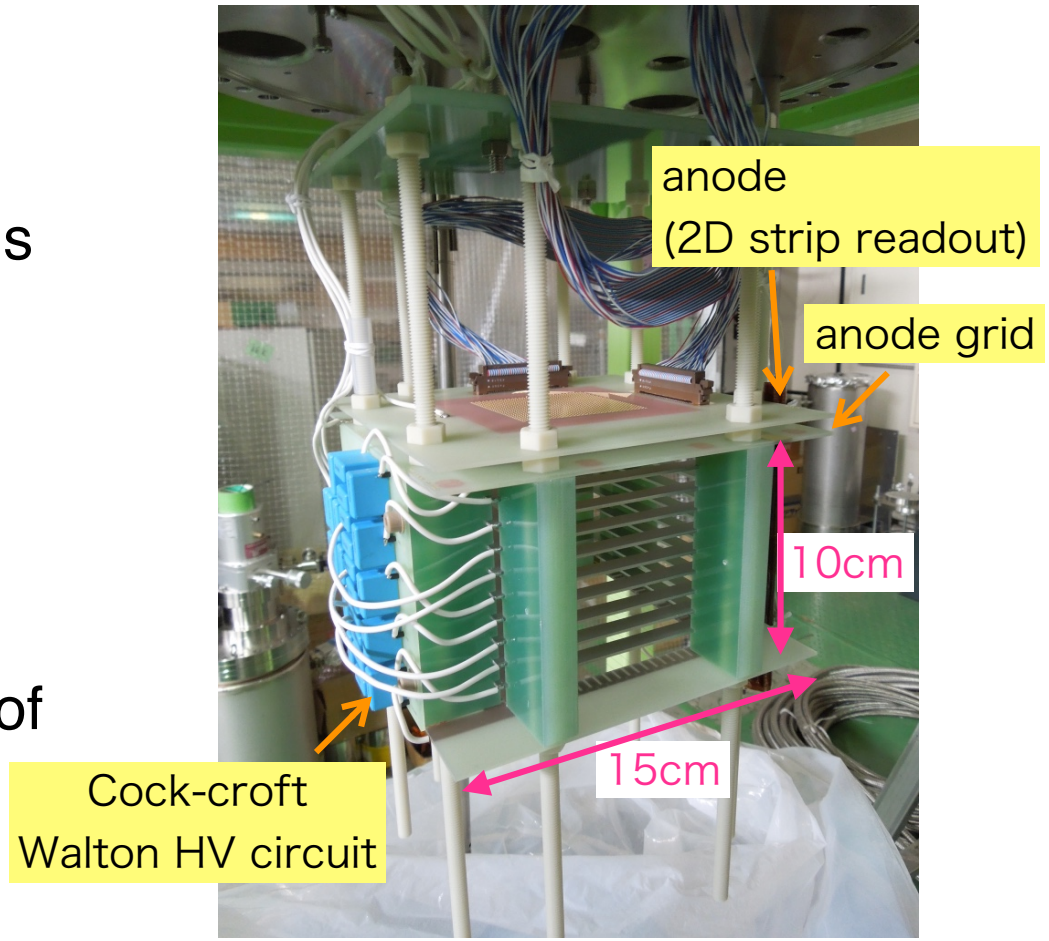
one of Open-it projects http://openit.kek.jp/project/LTARS2014/LTARS2014

Open source consortium of Instrumentation

A new small detector

Preparing a new small detector which is used for fundamental tech. R&D

- Design based on the knowledge accumulated so far
- Improving some issues in the previous small detector
  - e.g. non-uniform electric field
- Electric field simulation study was performed
- Commissioning is planed by the end of this month

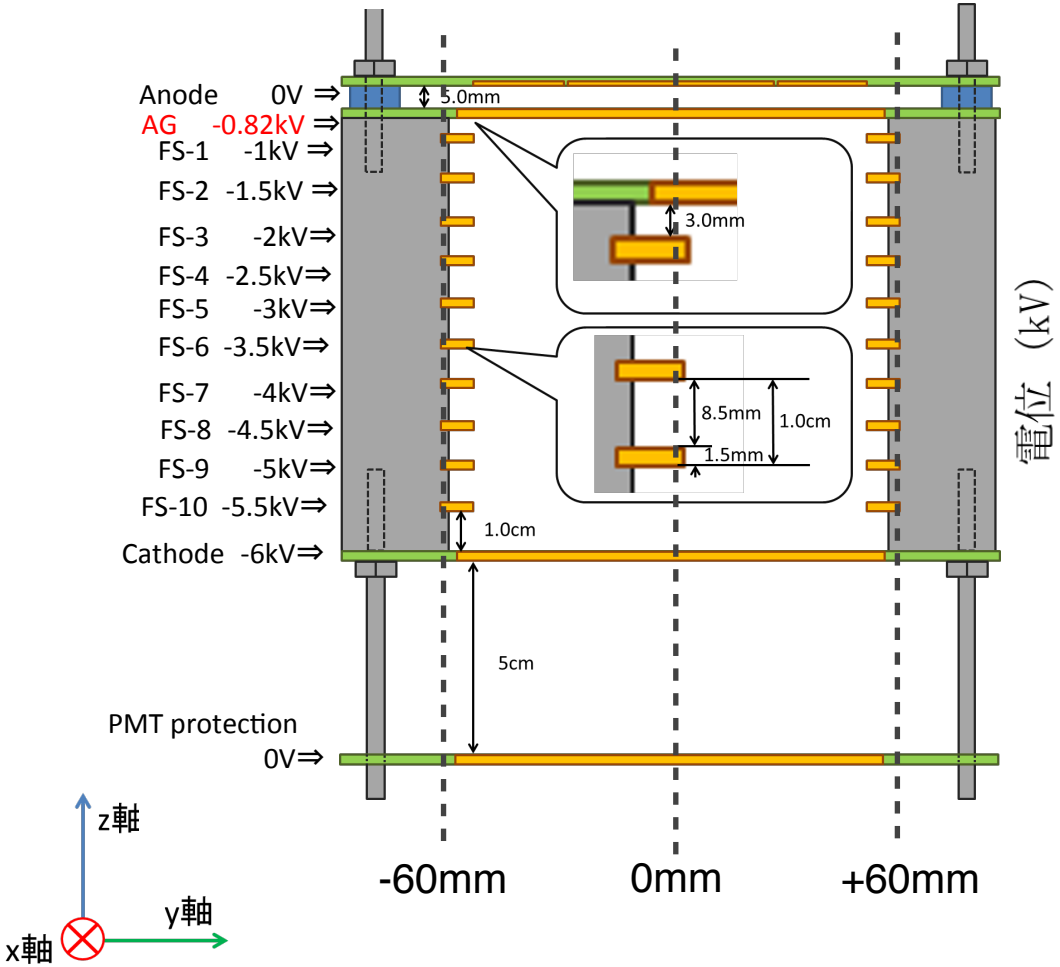


“30L detector”

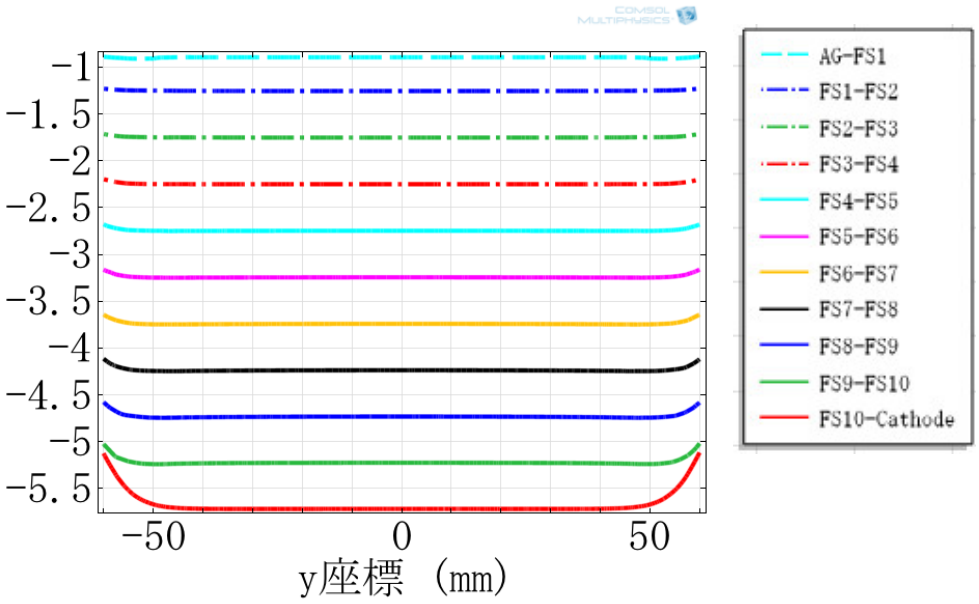
Electric field study using a FEM tool

We studied the electric field in the TPC field shaper using a FEM tool (COMSOL4.4)

Configuration:



AG-Cathode electric potential (at x=0, each z position)



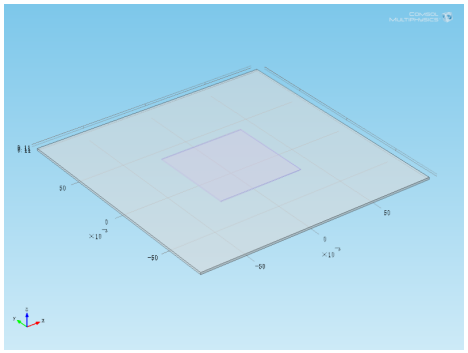
Uniform electric field (500V/cm) is formed in the fiducial volute (|x|,|y| < 32mm)

study by Y.Kuromori (Iwate University)

Improvement of non-uniform electric field

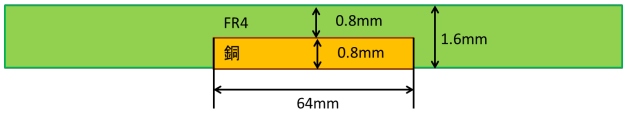
Configuration:

old anode board:

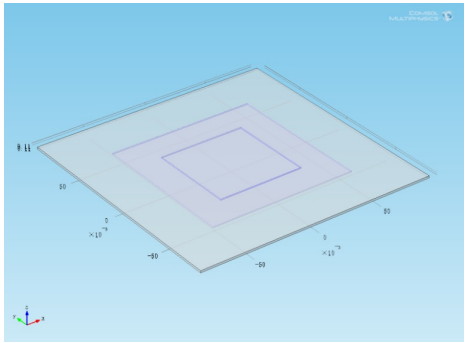


（縦）×（横）×（高さ）

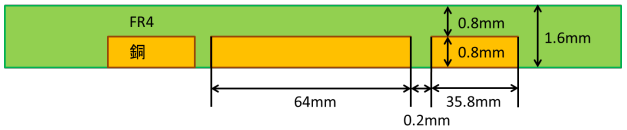
・構成
Anode全体　180mm×180mm×1.6mm
読み出し部　64mm×64mm×0.8mm
・材料
読み出し部　⇒　銅
その他　⇒　FR4



new anode board:

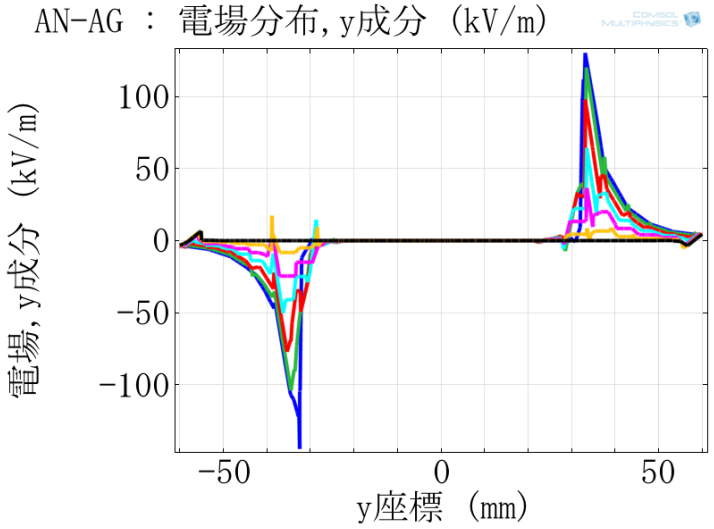


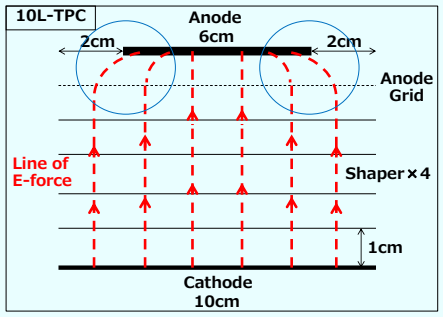
・構成
Anode全体　180mm×180mm×1.6mm
銅枠　外枠　100mm×100mm×0.8mm
内枠　64.2mm×64.2mm×0.8mm
読み出し部　64mm×64mm×0.8mm
・材料
読み出し部、銅枠　⇒　銅
その他　⇒　FR4



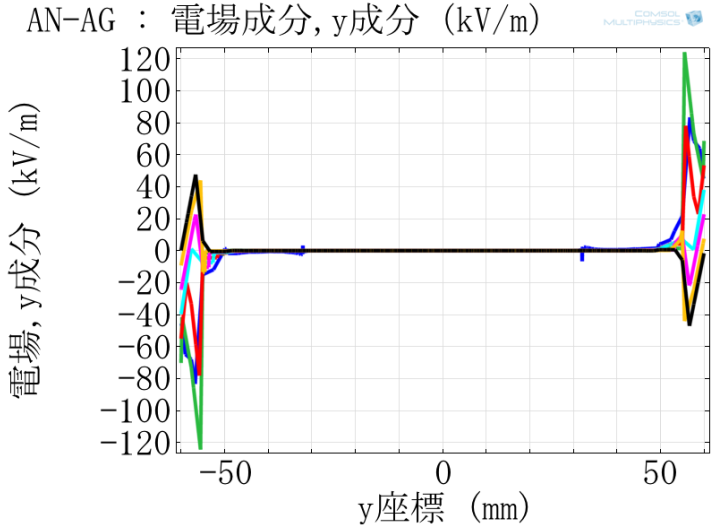
In the old configuration, anode readout area is 64mm x 64mm while the inner surface of TPC field shaper is 100mm x 100mm. This difference causes non-uniform E-field around the edge of anode.
This non-uniformity is improved by adding an electrode around the readout area.

old anode board:





new anode board:



Outlook & Summary

- We focus fundamental tech. R&D using small scale detectors at KEK
- We're developing pre-amplifier ASIC as an economical & low-noise readout electronics
- A new small scale detector is prepared
  - we will perform fundamental tech. R&D, such as 2D strip anode board, readout electronics, high voltage generation, LAr purification etc. using this detector (→ experimental proof will be performed using a larger detector such as the 250L detector)
- We're also studying at CERN neutrino platform (WA105 experiment) for R&D on a large scale prototype detector