Status of Liquid Argon TPC R&D (1)

2014/Dec./23, Neutrino frontier workshop 2014

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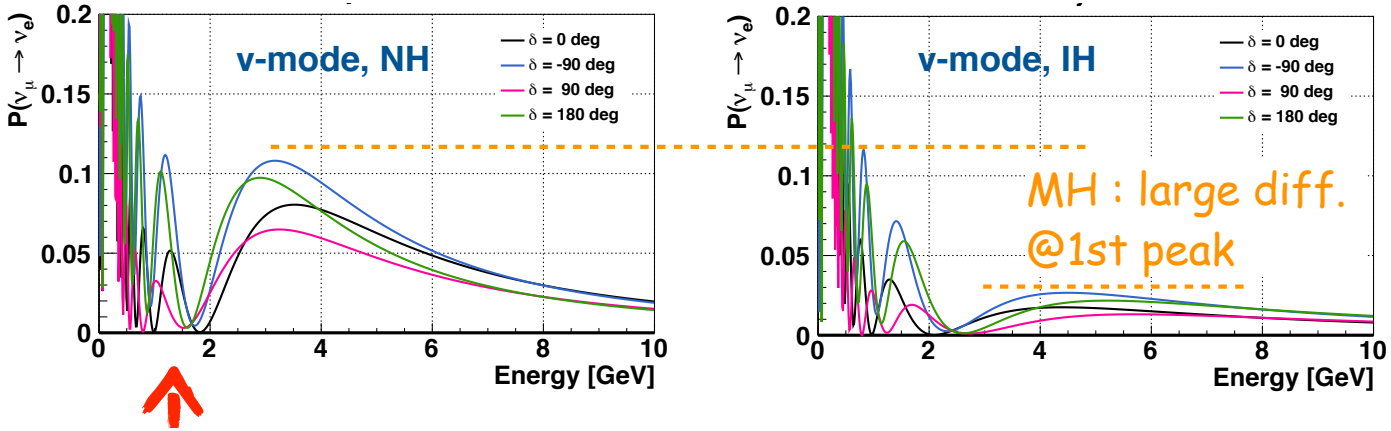
R&D collaboration with Iwate University, Yokohama National University
and Kure National College of Technology

1. Introduction
2. Development of 2D readout anode board
3. Development of charge readout electronics
4. Plan and summary

Introduction

- Liquid argon TPC (LArTPC)
  - a 3D imaging detector (TPC) with massive target (ρ=1.4g/cm^3)
  - has a capability of good particle identification and good energy resolution up to several GeV
- A large size LArTPC(>20kton) is a candidate of neutrino far detector in a future long-baseline neutrino oscillation experiment and a nucleon decay search experiment

Probability of $\nu_\mu \rightarrow \nu_e$ @2000km (with different CPV phases)

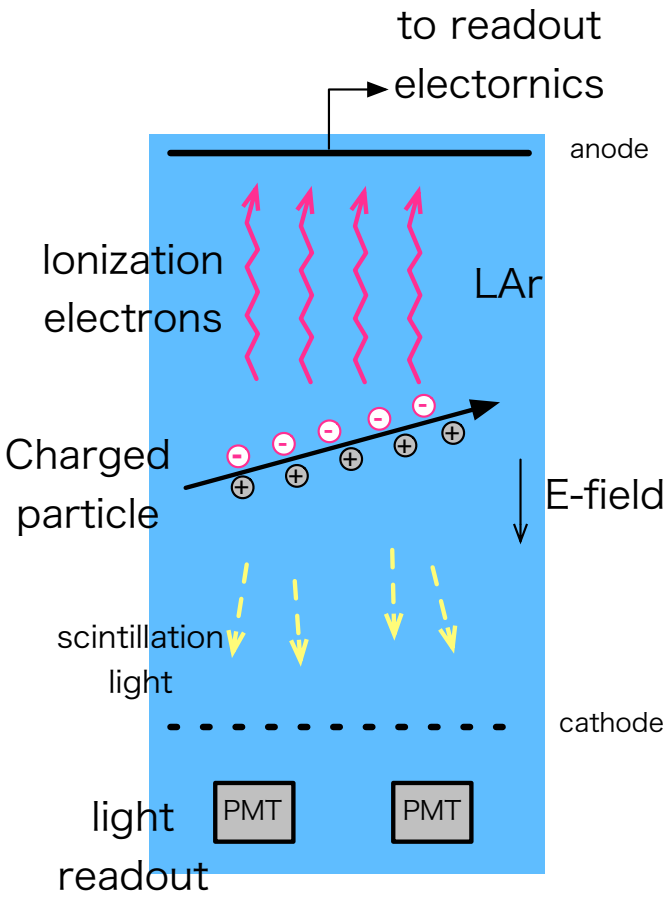


measurement of
$\nu_\mu \rightarrow \nu_e$ spectrum shape
including 1st,2nd osc. peak
→ exploring CPV, MH

Principle of LArTPC

Detecting ionization electrons

- 2D informations at readout plane (anode) with 3~4mm pitch + timing information (z-direction) → 3D track information
- # of ionization electron from minimum ionizing particle is **1fC/mm** (~6000e-/mm) after e-ion recombination(x2/3*)
- No amplification in liquid
- Attenuation during drift due to impurity (O_2,H_2O) : 1/e after 3msec drift (4.8m*) if 0.1ppb impurity → need a high purity LAr for long drift
- Drift velocity ~1.6mm/μsec depending on E-field (*)
- Diffusion is small (less than 1~2mm after 5m drift)



(* in the case of 500V/cm e-field)

Toward a large LArTPC detector

- Realization of a long drift length (>5m) is one of key subjects
  - Long drift → event containment, reduce # of readout channel

c.f. ICARUS(300ton) : ~27000ch
(1.5m drift, 2x4mx20m anodes)

WA105(300ton): ~7680ch
(6m drift, 6mx6m anode)

- It is important to establish basic technologies:
  - **High purity**

    stable long term operation with purity < 0.1ppb
  - **High voltage**

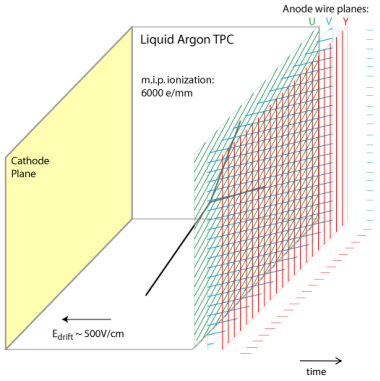
    reduce attenuation by increasing drift velocity
    → more than 250kV (500V/cm)
  - **Readout system**

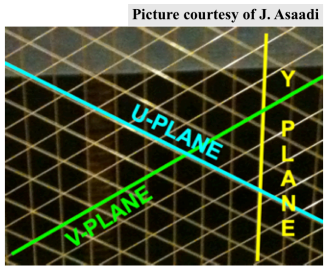
    low noise & high signal gain readout (signal-to-noise ratio > 10)

How to detect ionization electrons

single phase+wire readout

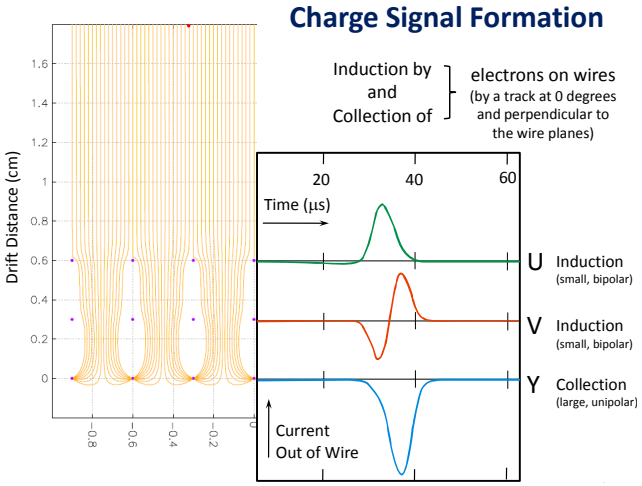
[ICARUS,US LArTPC]





8256 wires w/ pitch = 3mm

(μBooNE case)

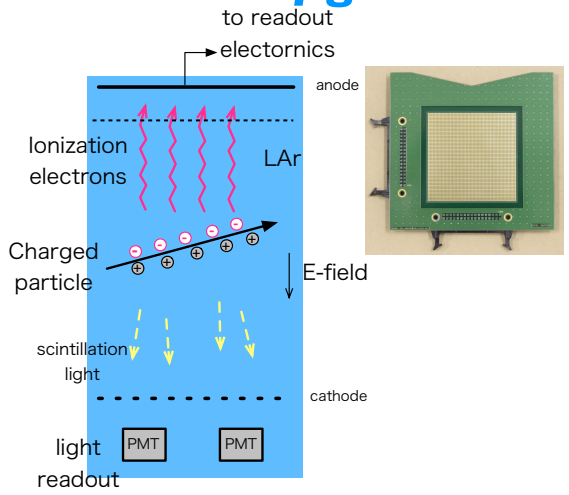


signal shape is different among different views

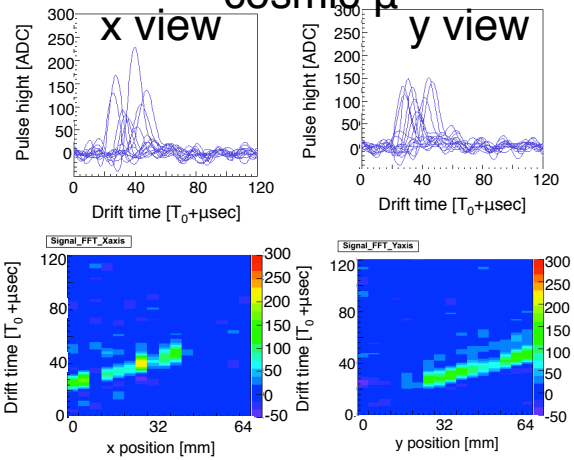
low capacitance
ICARUS size(4m x 20m) is established

single phase+pad readout

our configuration



cosmic μ

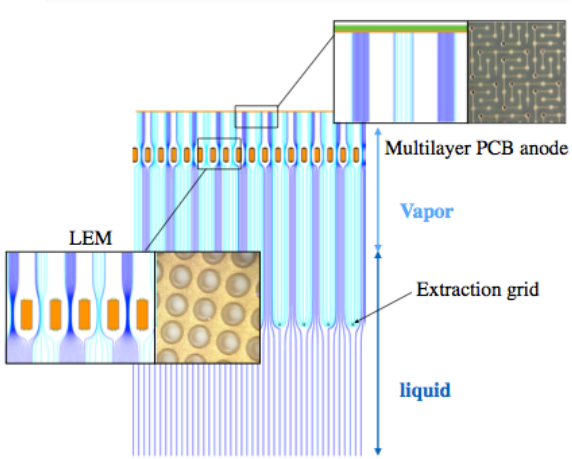


signal shape is identical between different views

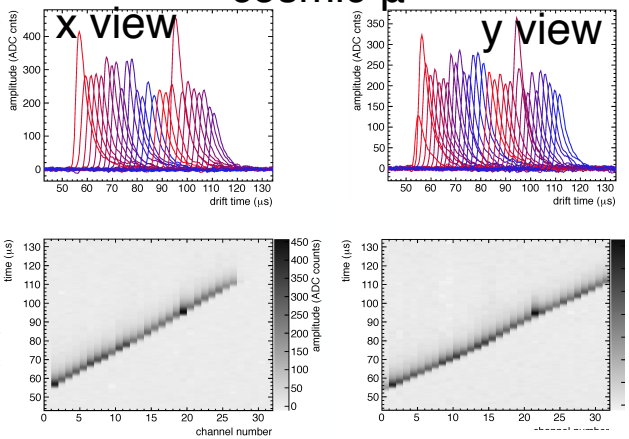
simple detector configuration

double phase+pad readout

[ETHZ]



cosmic μ

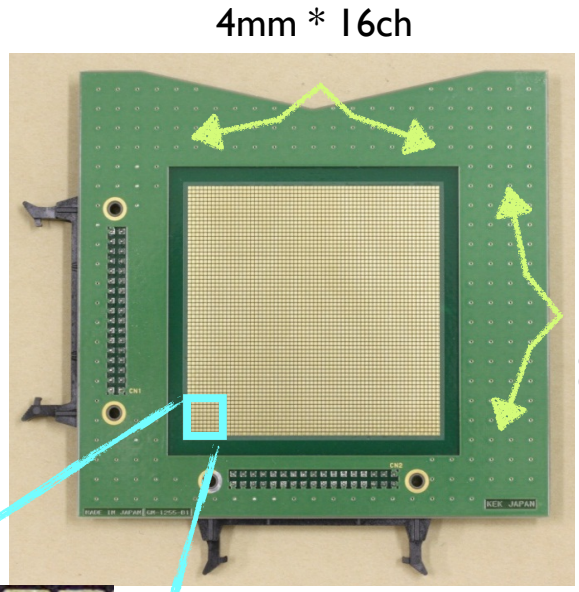


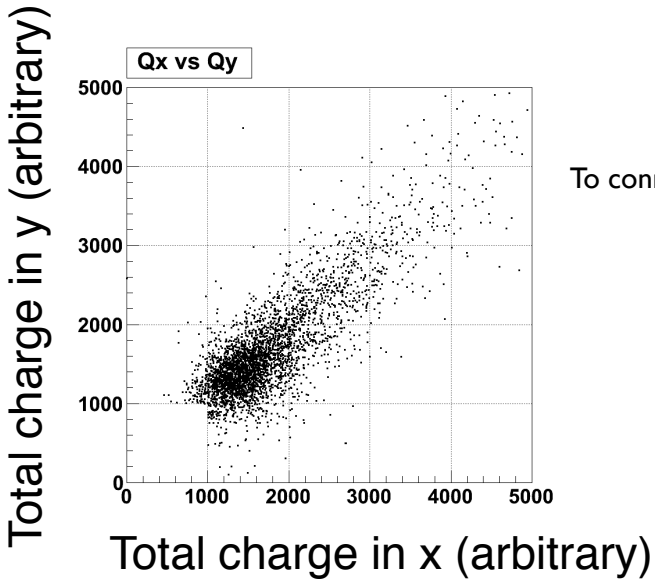
arXiv:1312.6487v1

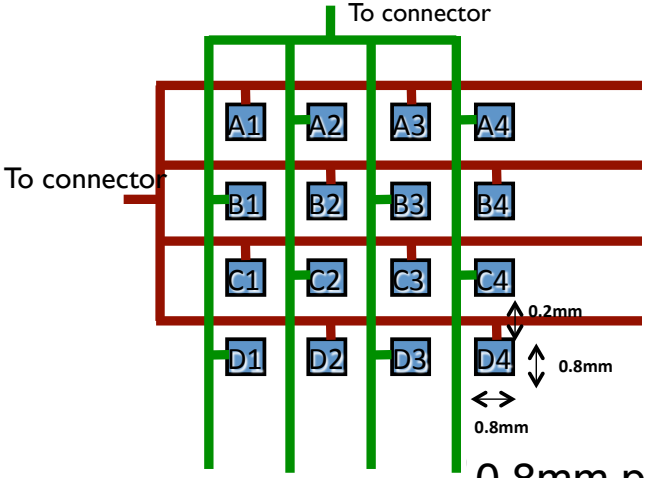
gain > 15 is obtained thanks to double phase amplification

R&D on 2D anode readout pad

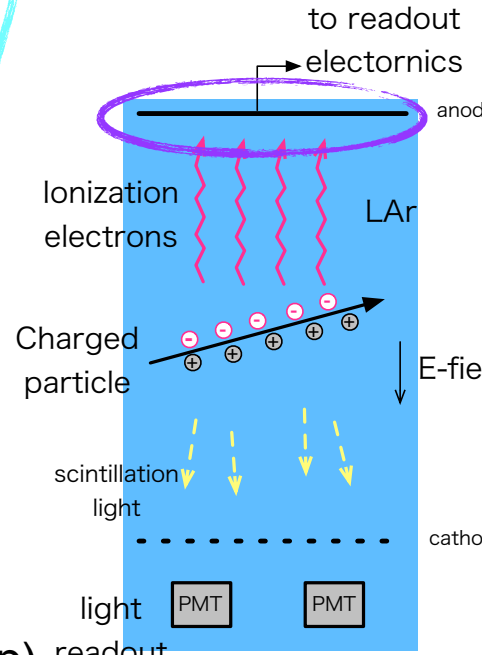
- We developed a 2D anode pad
  - based on PCB technologies (etching)
  - possible to make a large area board
  - 4mm pitch readout (small pads are connected along X or Y direction)
  - charge is shared in x and y channel (x1/2)
  - charge sharing is confirmed by cosmic data







0.8mm pad
0.2mm space



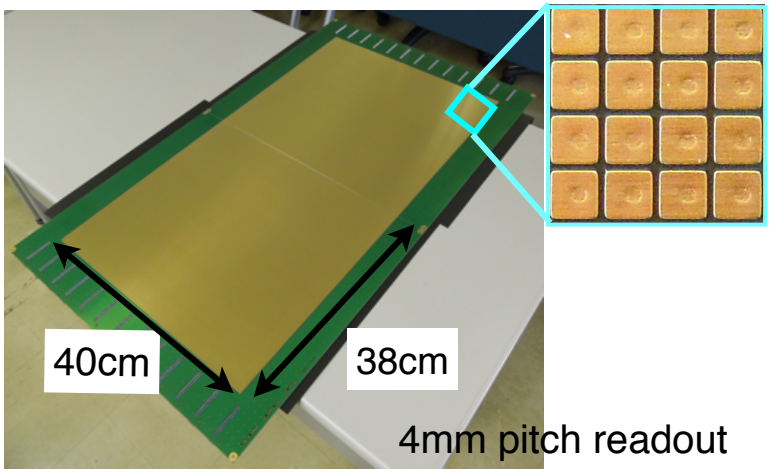
(developed with KEK e-sys group)

A large area 2D anode pad

A large area anode pad was also developed for KEK 250L LAr detector

based on 50cm x 50cm PCB (largest multilayer PCB in commercially available product)

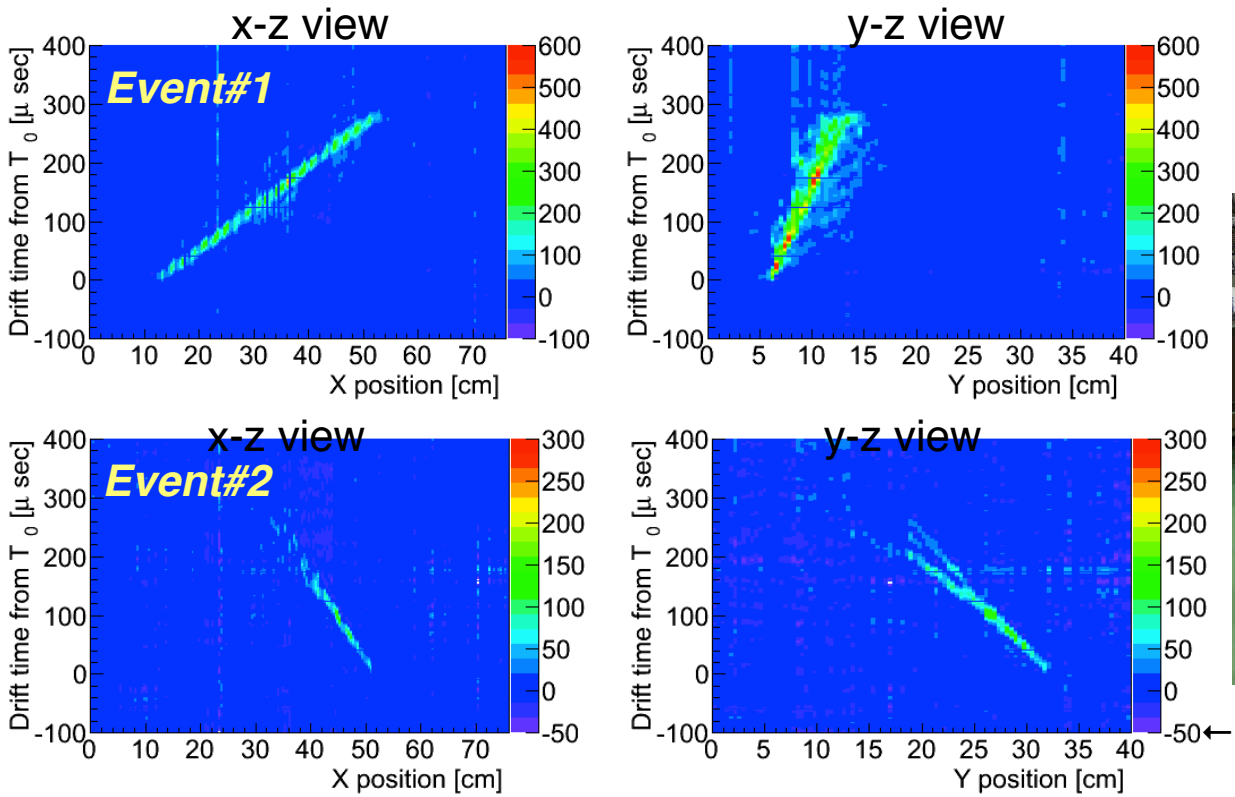
→ realize large area by connecting several boards

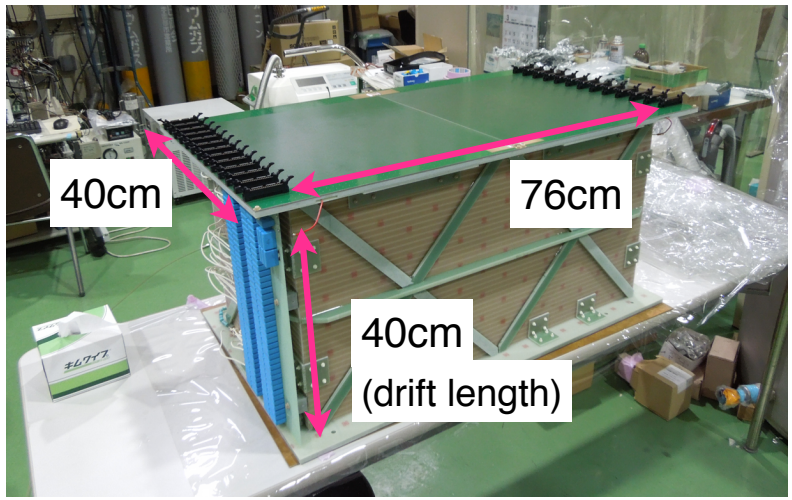


4mm pitch readout
380ch in total

76cm x 40cm readout test : cosmic ray events

[w/ CAEN TPC readout elec.]





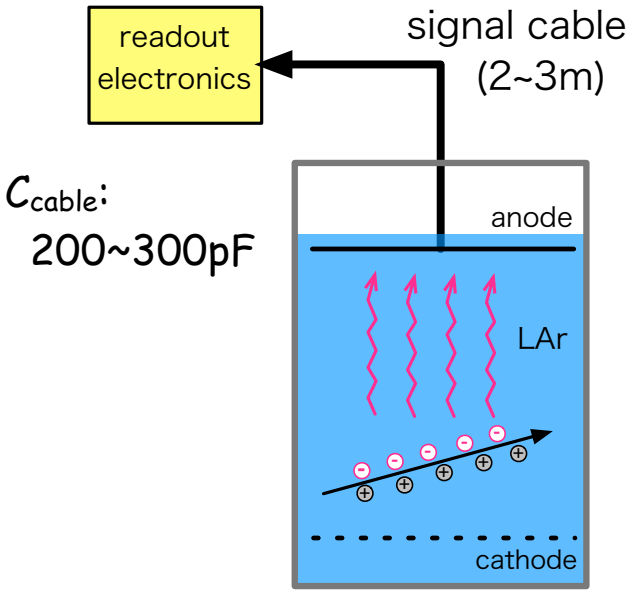
← two example events taken during Nov. ~ Dec '14 cosmic test (analysis is in progress)

R&D on readout electronics

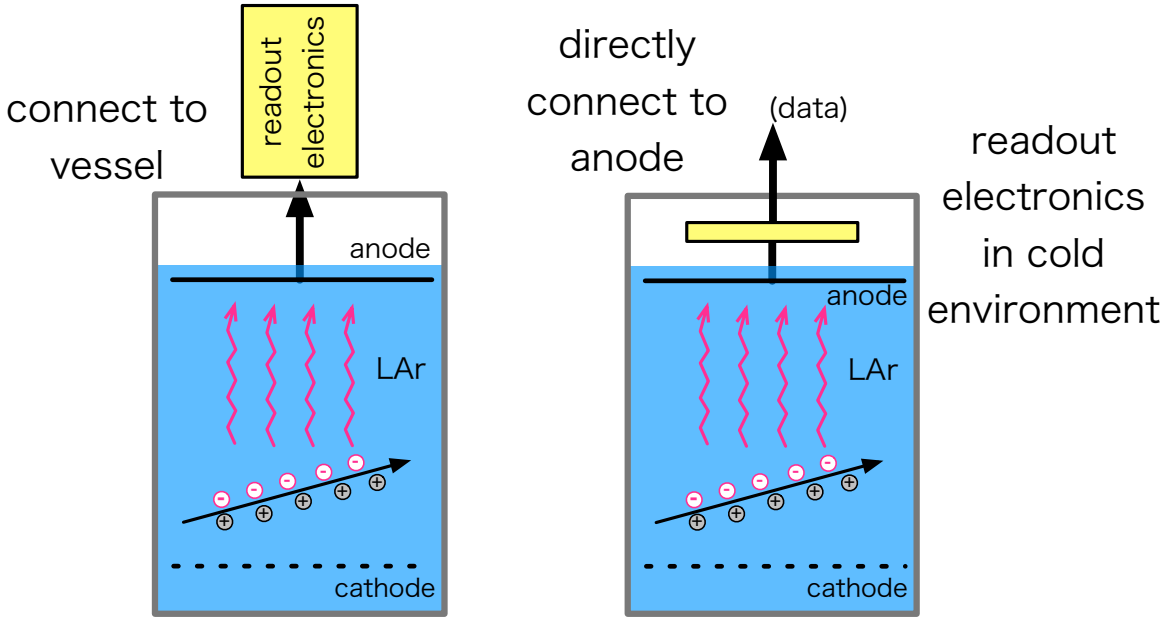
- ***Developing a low noise readout electronics***
- ***Placing the electronics as close as possible to the anode***

to reduce the detector capacitance → small noise

Present configuration



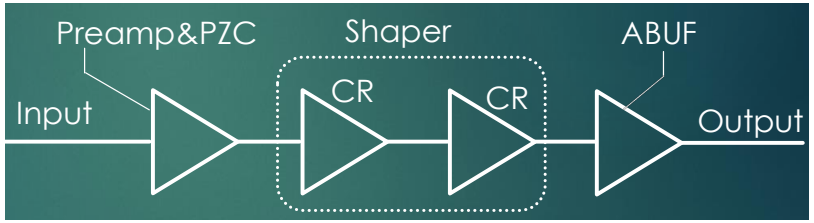
Possible improvements



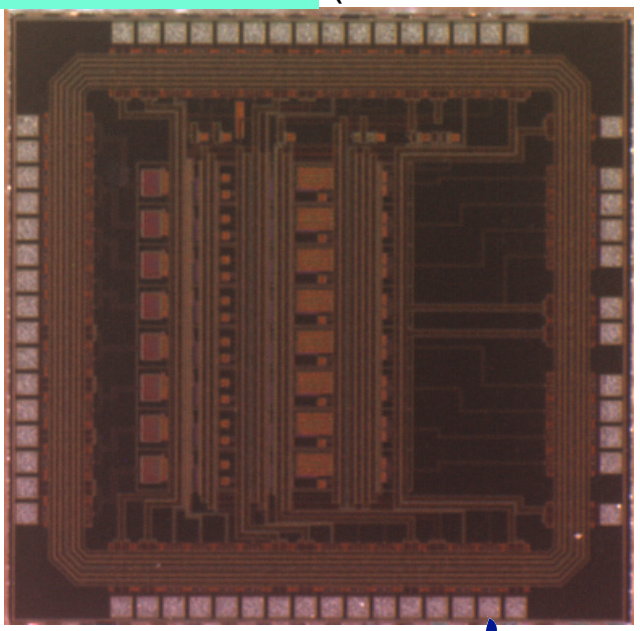
Development of low-noise and economical electronics

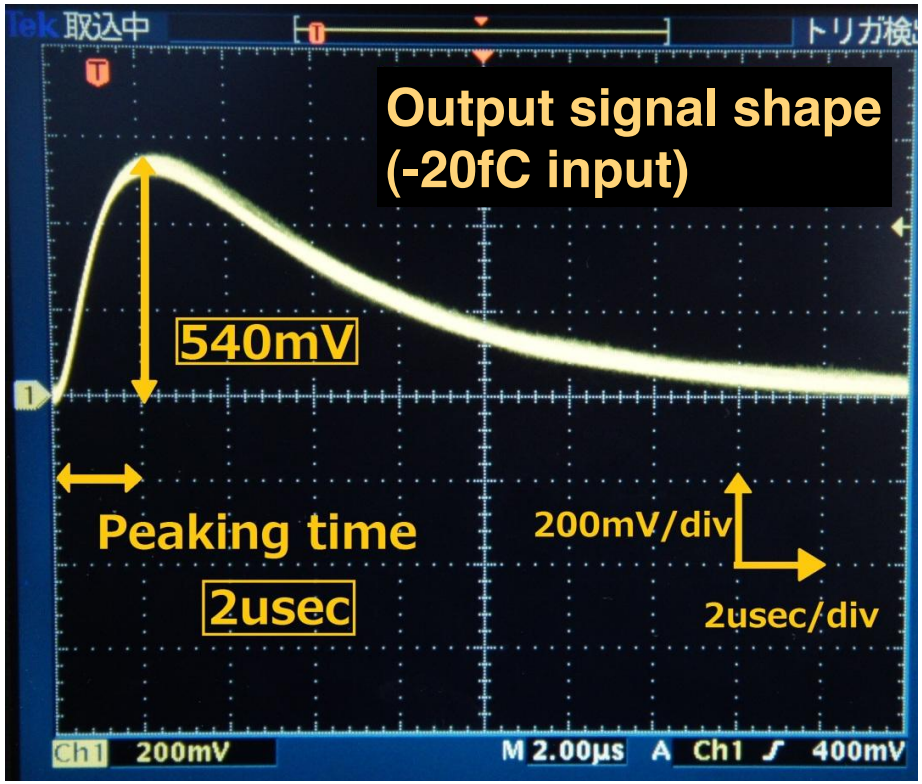
- a front-end (ASIC) chip for low noise analog pre-amplifier is developed
  - 8ch pre-amp&shapers in a chip
  - aiming to use in the low temperature environment (in first, testing in warm temp.)

block diagram



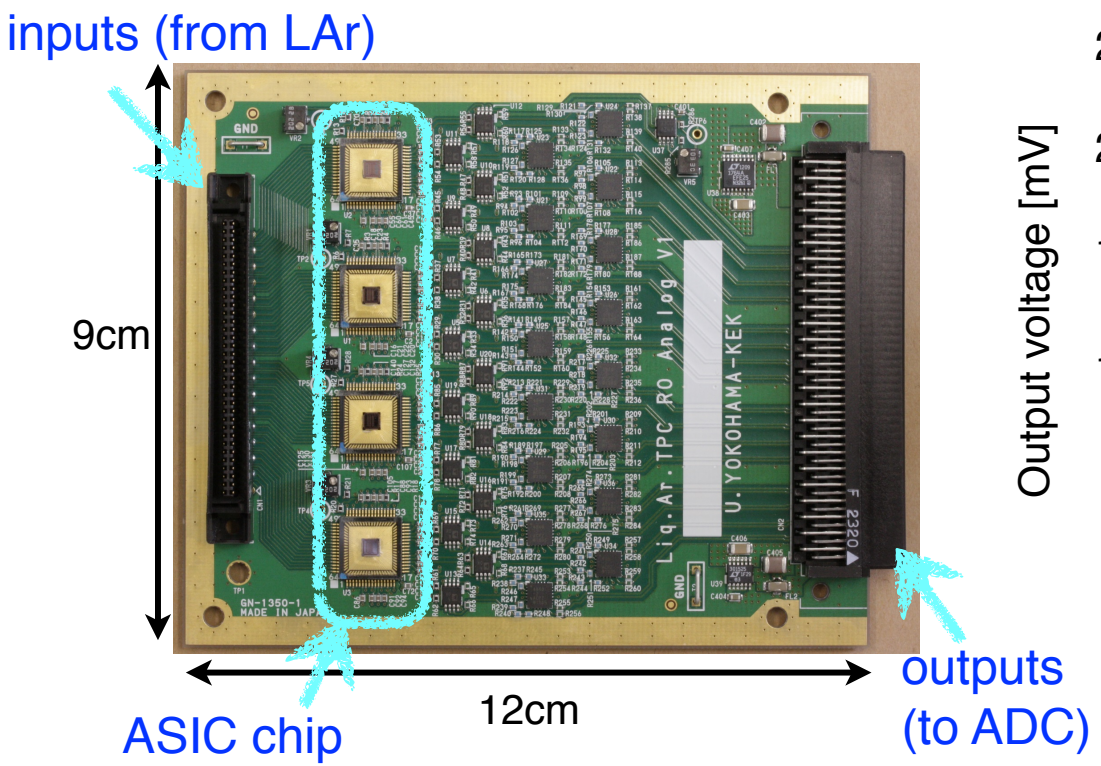
LTARS ASIC chip (2.8mm x 2.8mm)



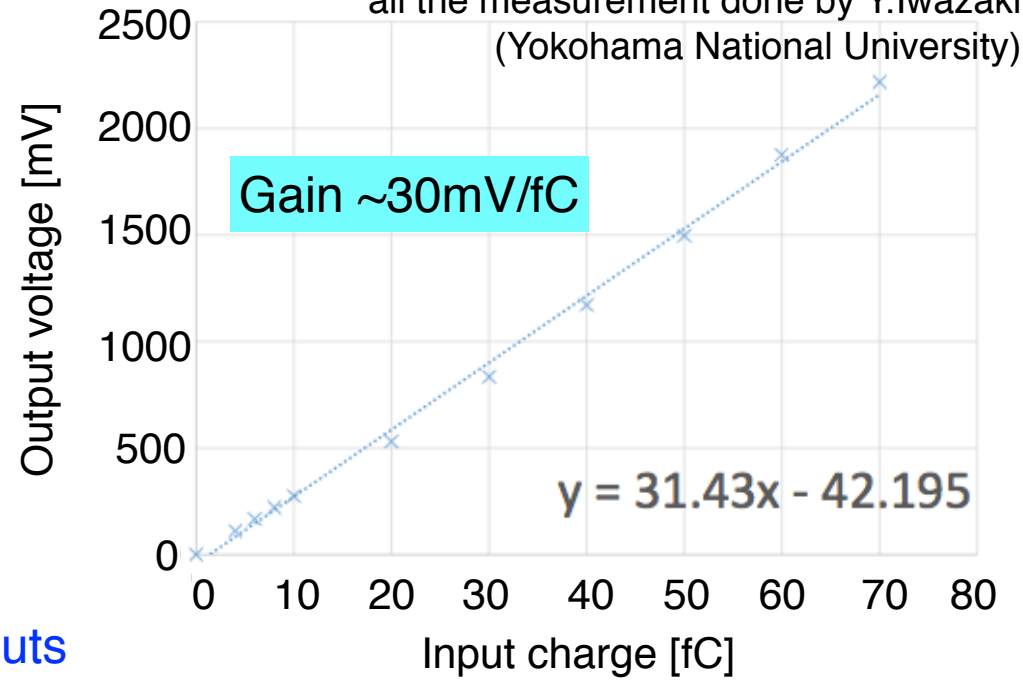


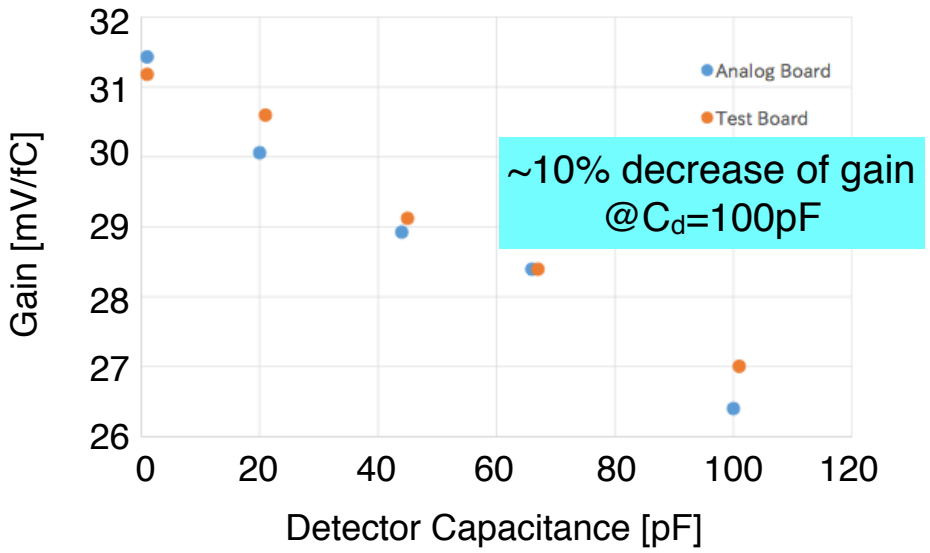
(developed with KEK e-sys group, one of Open-it projects http://openit.kek.jp)

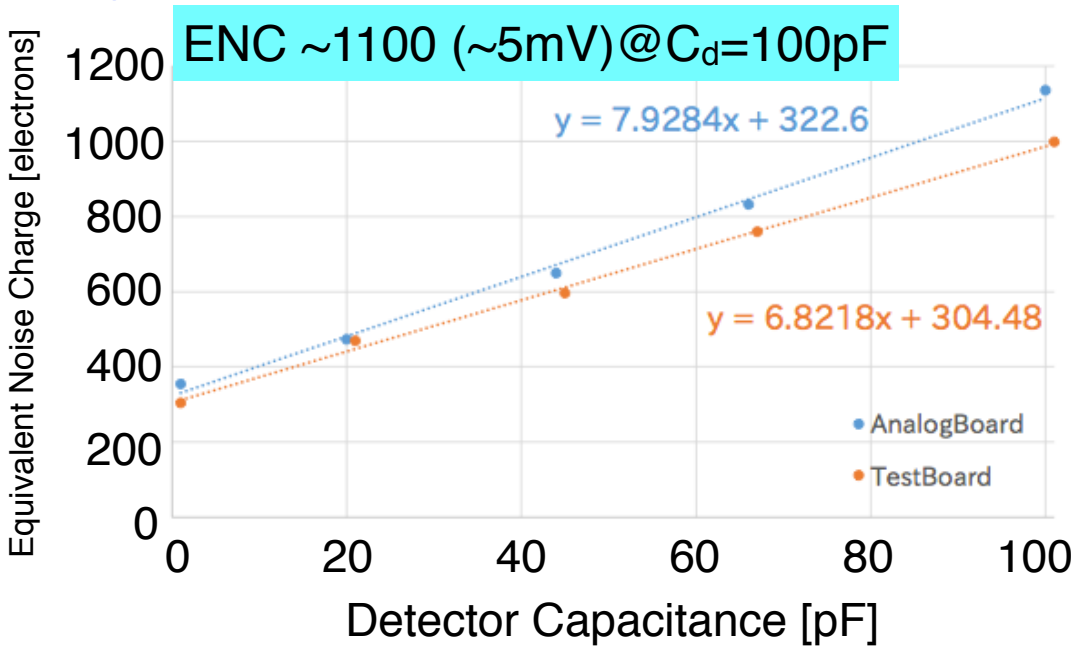
- 32ch analog readout board (w/ 4 ASIC chips) is also developed



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

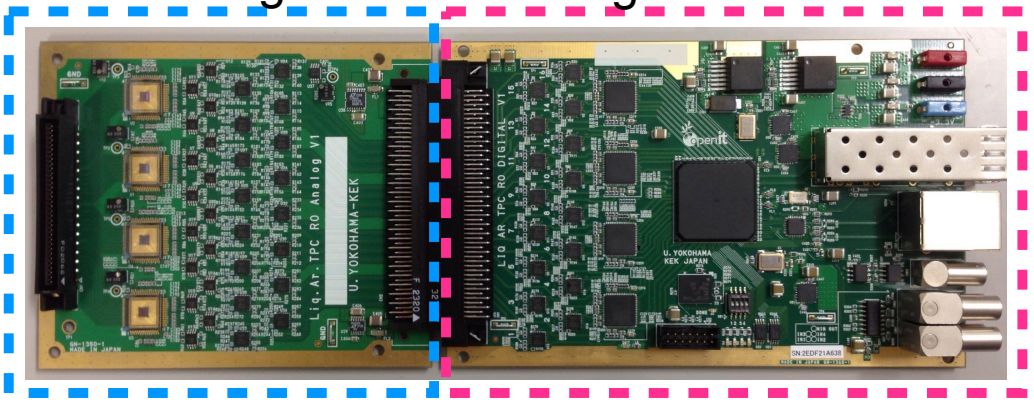






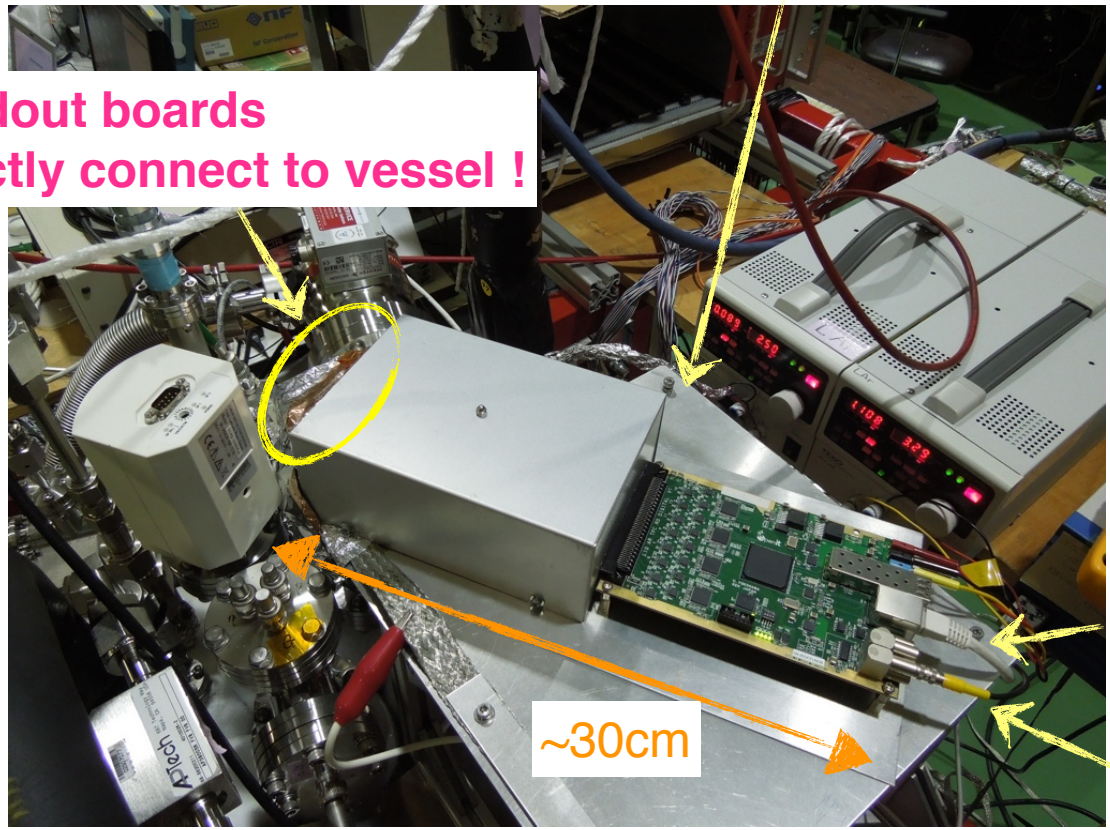
New readout system

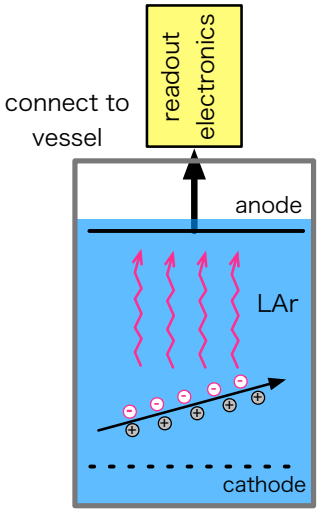
- A new digital board is developed
  - it enables to make a compact readout system



32ch differential inputs (2Vpp)
12bits FADC (10~40MSPS)
Airtix-7 FPGA
Ethernet (RJ45 or SFP)
NIM-in 4ch, NIM-out 1ch
size: 9cm x 14.5cm

openit
Open source consortium of Instrumentation

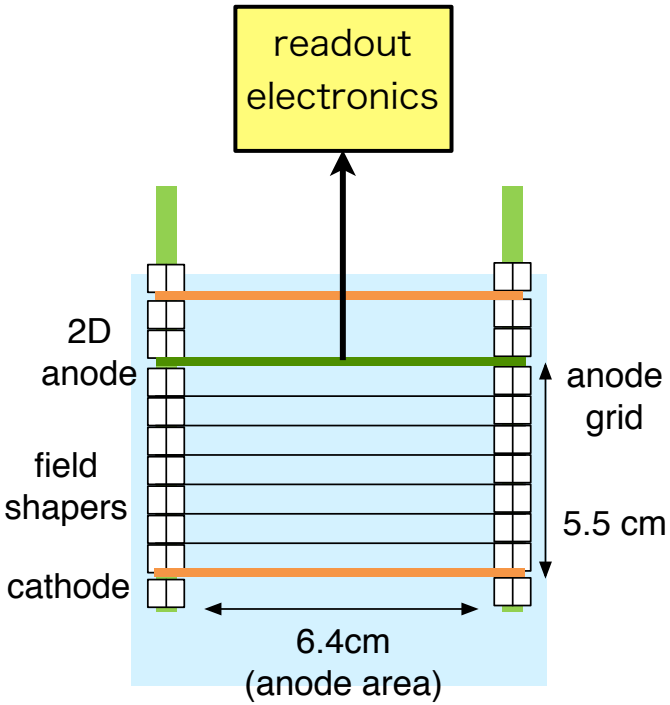


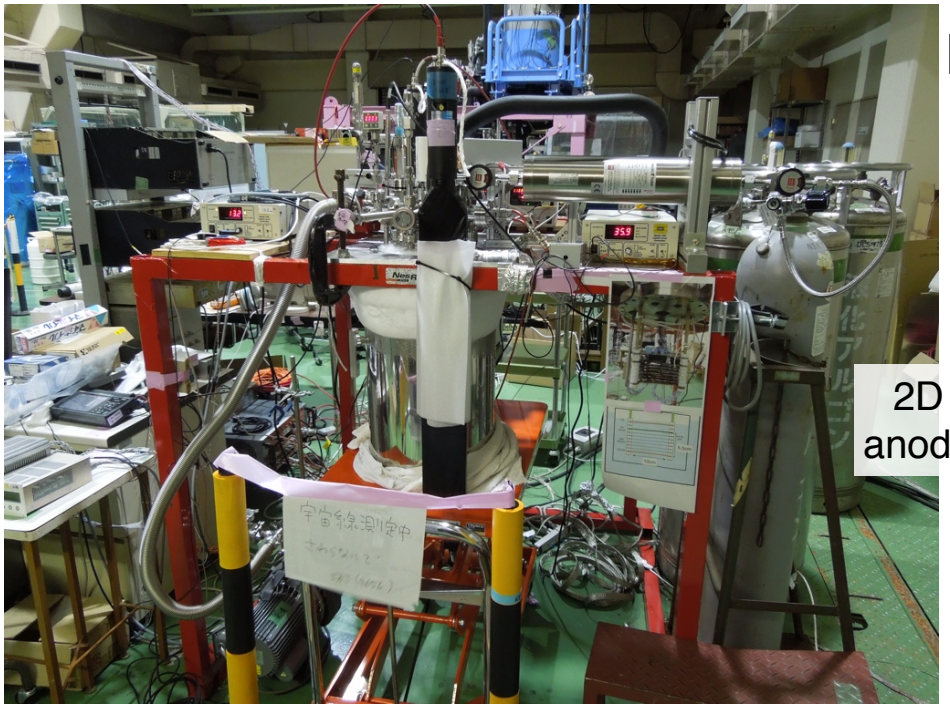


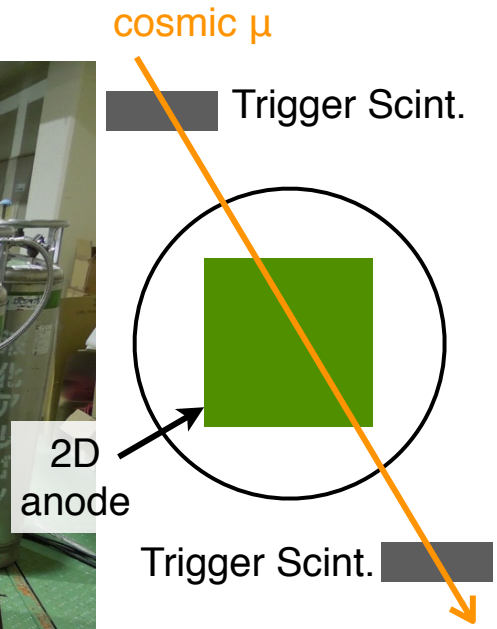
Cosmic test

- Performance of the new electronics has been evaluated based on cosmic muon signal of LAr

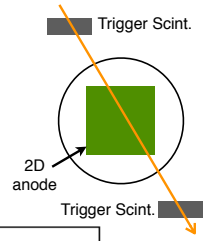
a small LAr detector (6.4cm x 6.4cm readout plane)

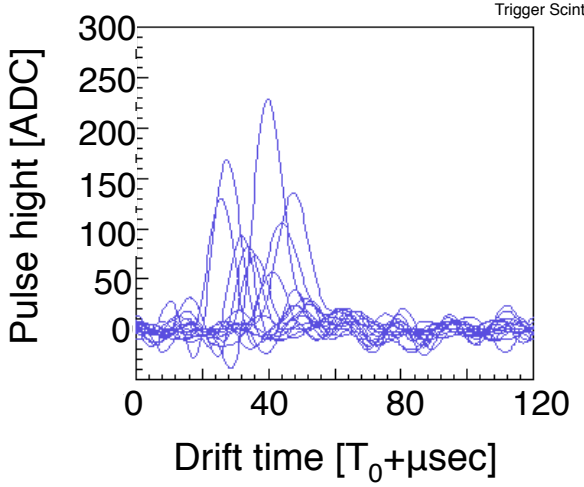


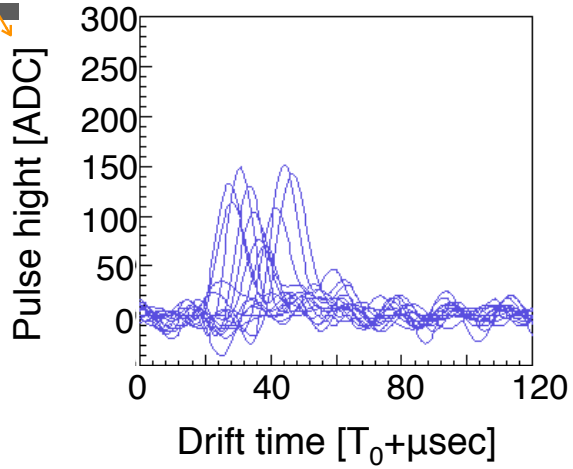




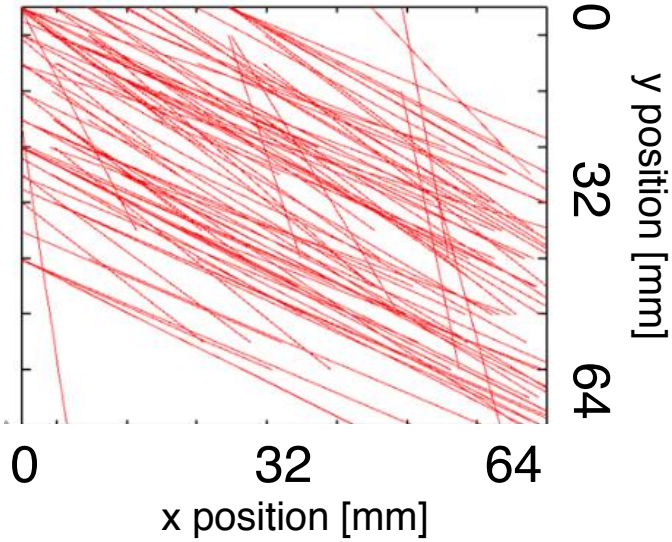
cosmic data

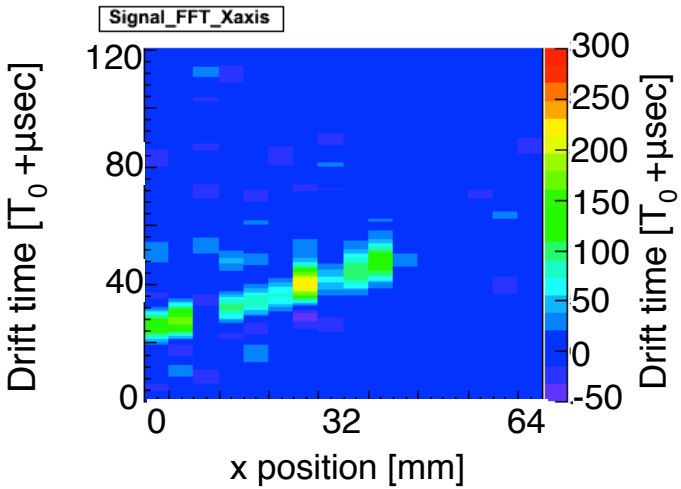


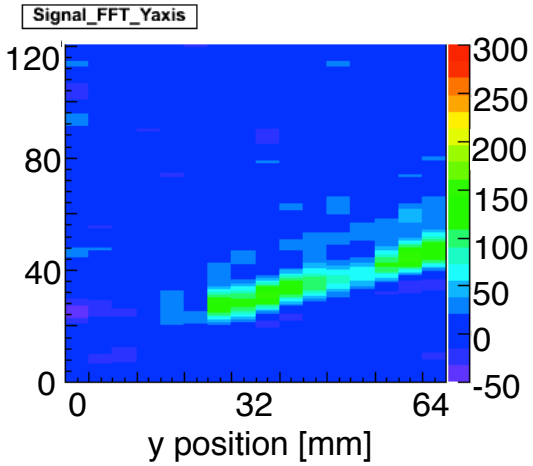


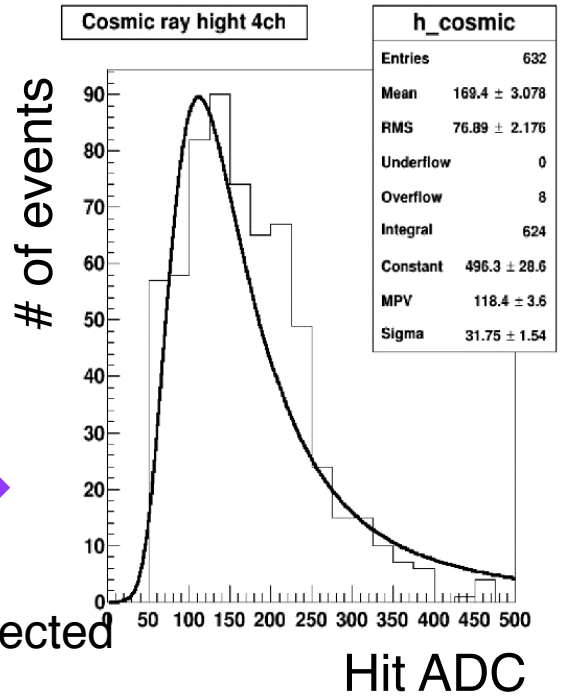


reconstructed tracks (~600 tracks)









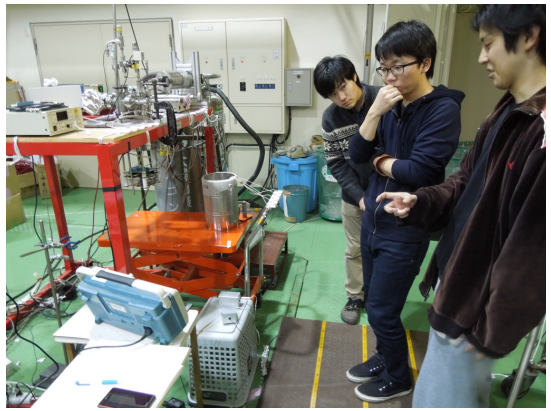
MIP signal ~120ADC in ch4 →
(noise ~11ADC in RMS)

signal size, noise size are as expected

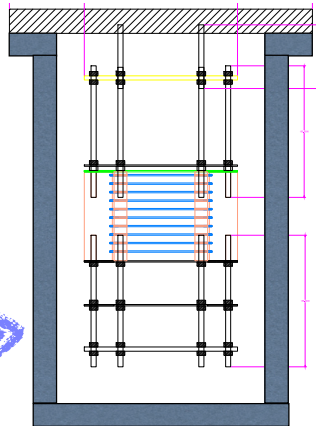
→S/N > 10 (single phase readout)

Plans toward a large detector

- At KEK, R&D on fundamental technologies toward realization of large scale detector
  - LAr purification(<0.1ppb), high voltage (500V/cm *long drift), readout system (S/N > 10)
  - Realizing long term operation of LArTPC with those technologies
  - R&D using a small detector



Cold test of detector component



new small detectors (e.g. l_{drift}=10cm, 100cm) are under construction/design

- Concurrently with the fundamental tech. R&D, plan to start R&D at WA105 experiment (6m x 6m x 6m detector) as world wide effort on large scale detector [neutrino platform at CERN]
  - demonstration both detector technologies and detector performance as a neutrino detector

Summary

- Toward realization of a large scale LArTPC ν detector, fundamental technologies R&D is in progress at KEK
- We developed a 2D anode readout pad and low noise readout electronics this year
  - developed 4mm pitch 2D readout pad for 76cm x 40cm area (detail performance check using cosmic rays is in progress)
  - improved S/N ratio using newly developed low noise electronics (ASIC)
- We plan to perform further R&D on the fundamental technologies using a small detector
- Recent R&D on high voltage system will be given by Sasaki-kun