

AXEL
High pressure Xenon gas TPC
for neutrinoless double beta decay search

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for the AXEL group

No Introduction

Pioneering work by NEXT has demonstrated the superiority of high pressure Xenon gas TPC as the neutrinoless double-beta decay search detector.

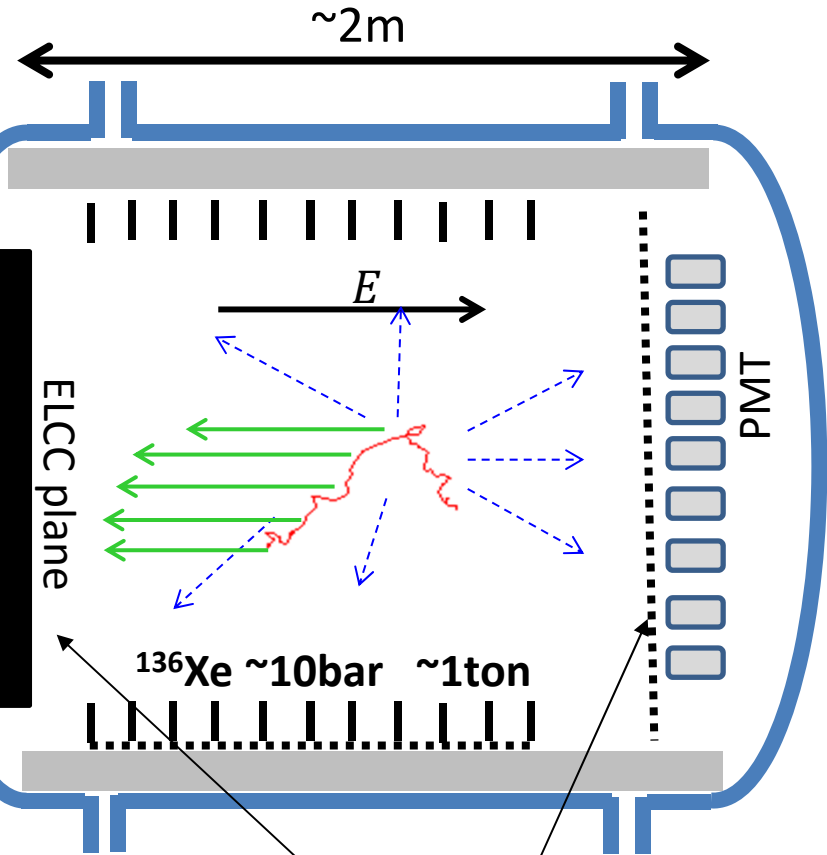
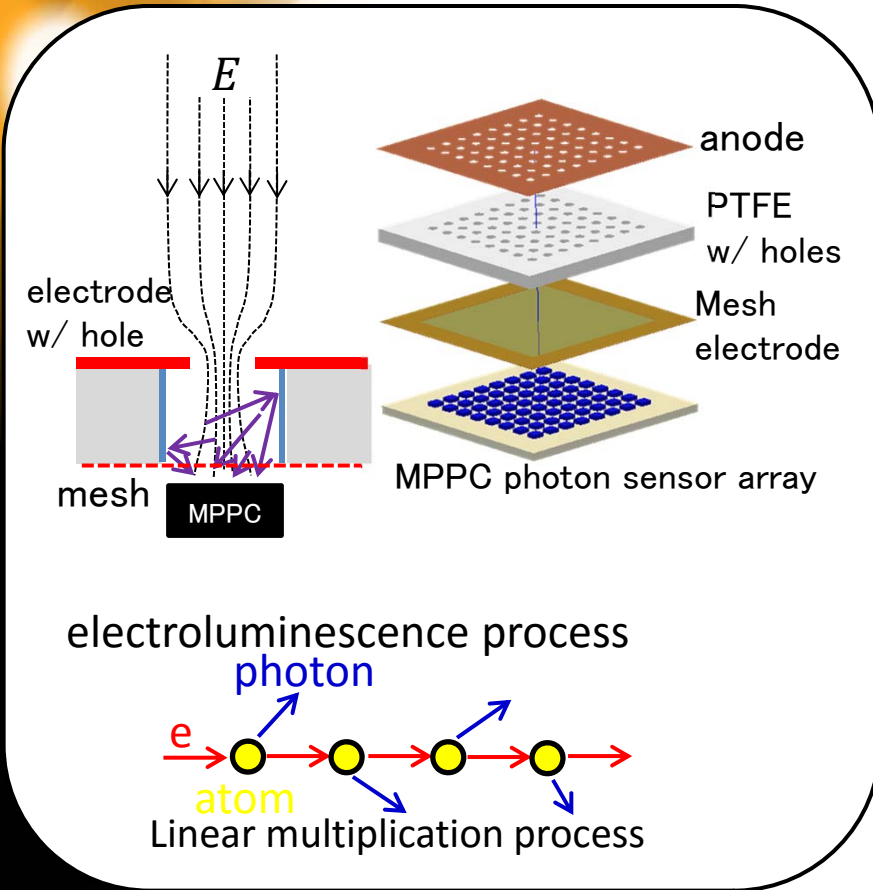
Contents of my talk:

- Project overview
- ELCC(Electroluminescence Light Collection Cell)
- Demonstration by prototype
- Next prototype plan
- Sensitivity

What we propose in the AXEL project

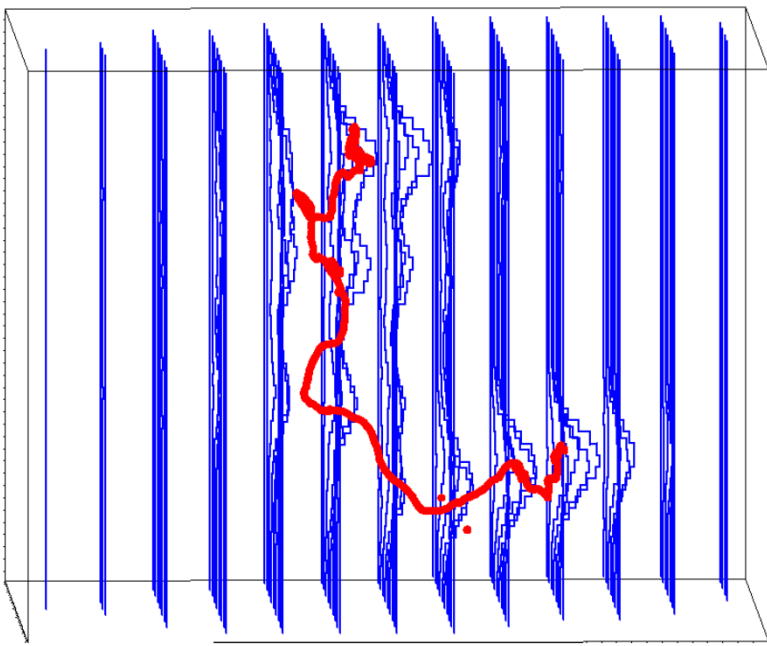
Electro luminescence light collection cell (ELCC)

High Pressure Xe gas TPC



High energy resolution
(goal: $<0.5\%$ (FWHM))

Background rejection by event topology



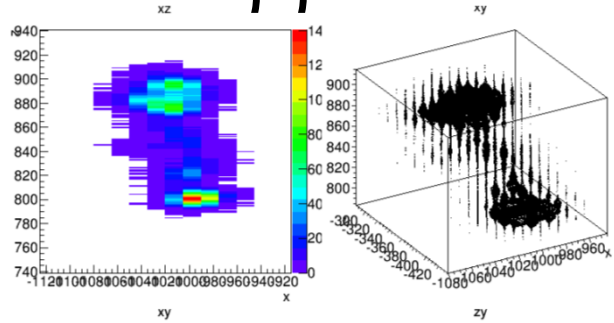
AXEL

-Expected event topologies-

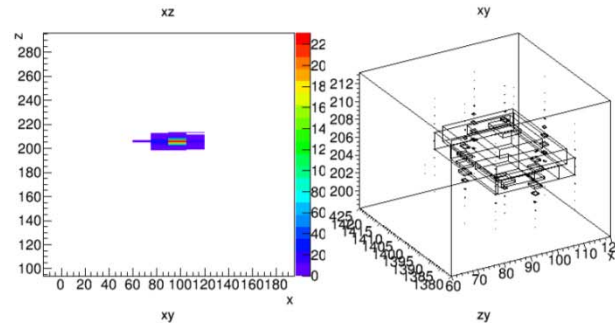
simulation

10atm, 15mm pitch, 1 μ s sampling (\sim 1mm)

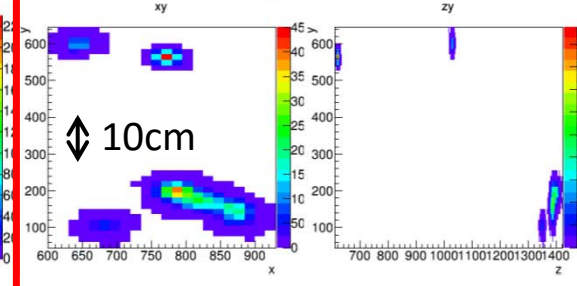
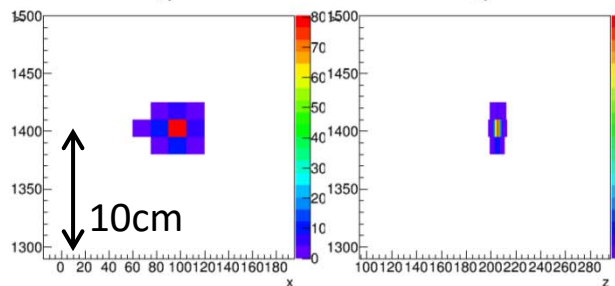
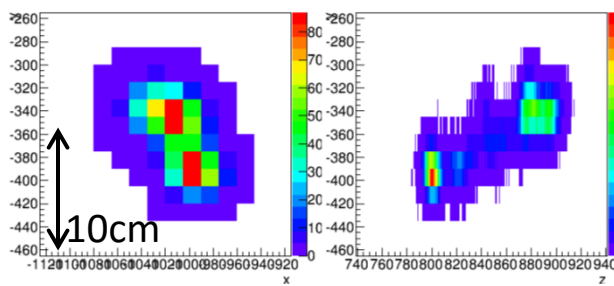
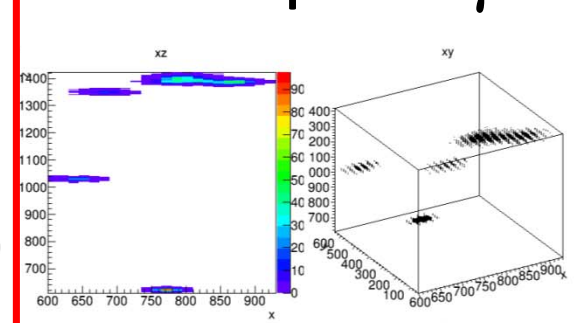
$0\nu\beta\beta$



α

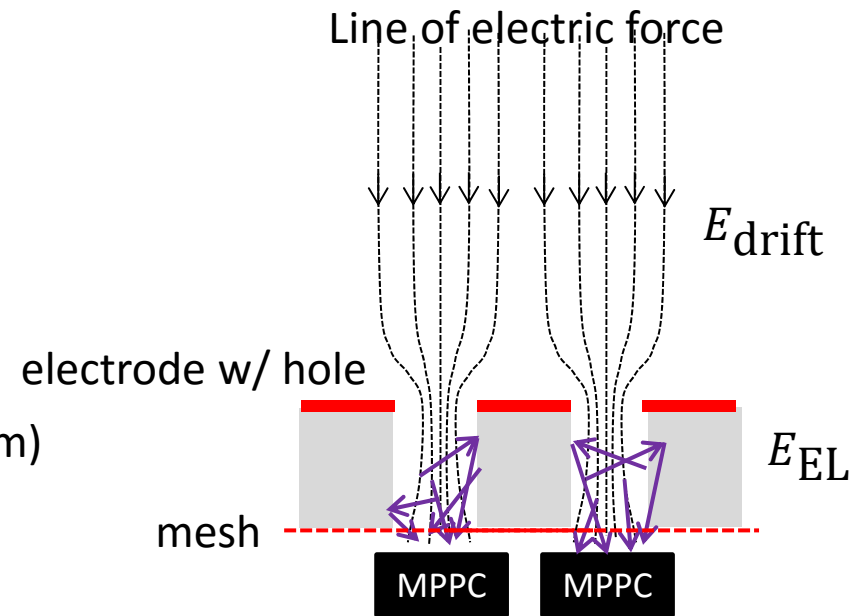
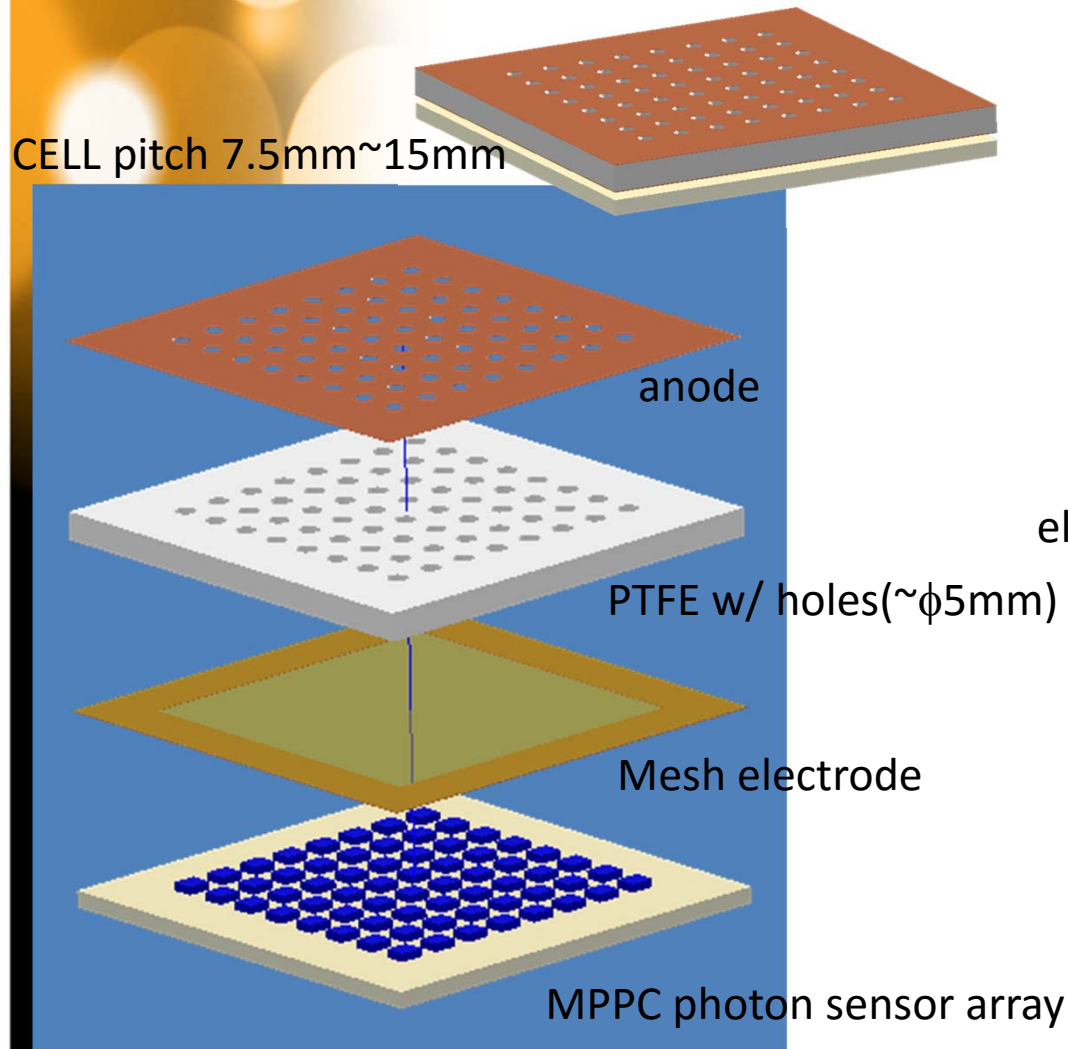


Compton γ



ELCC

-ElectroLuminescence Light Collection Cell -

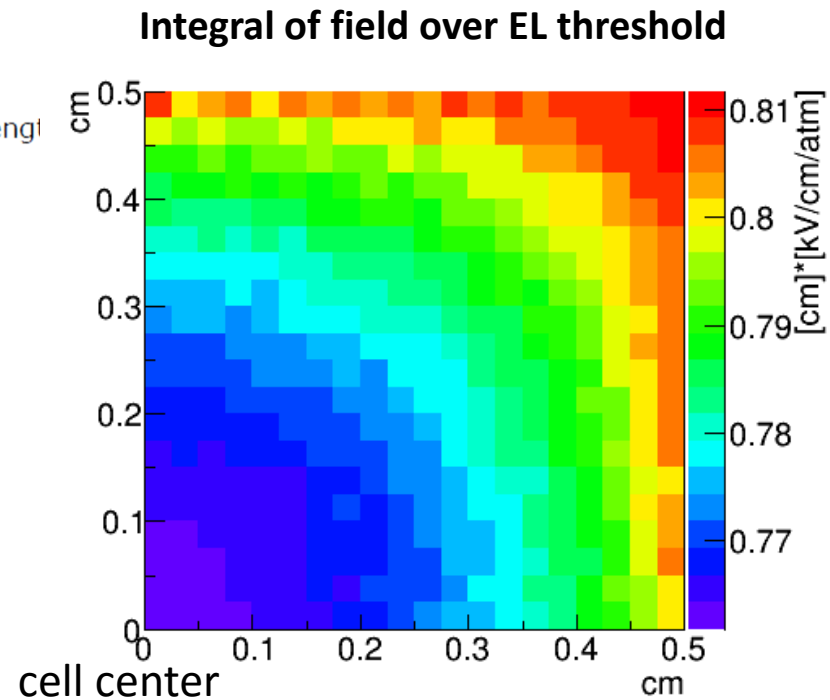
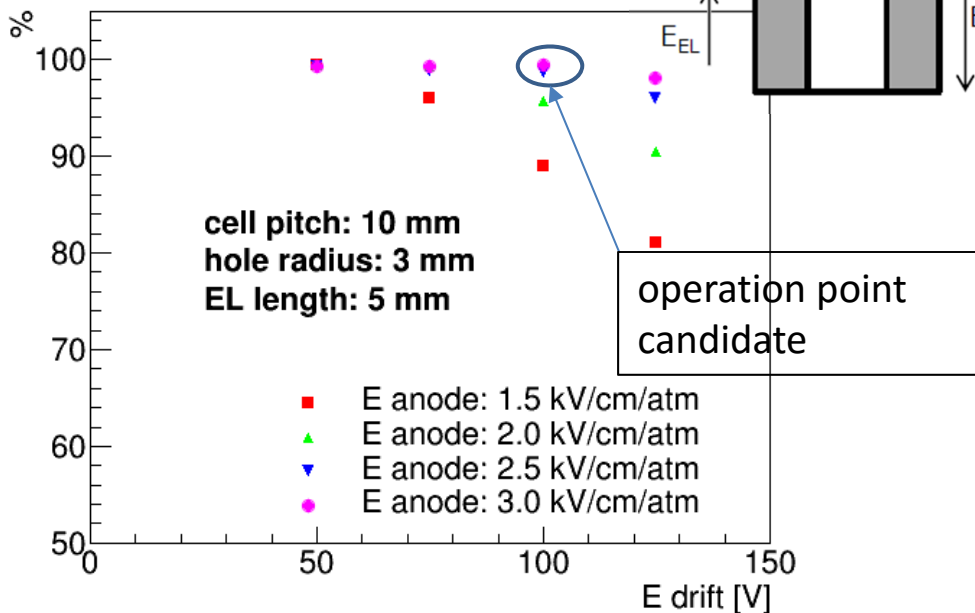
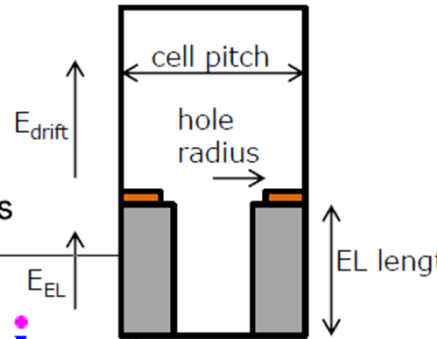
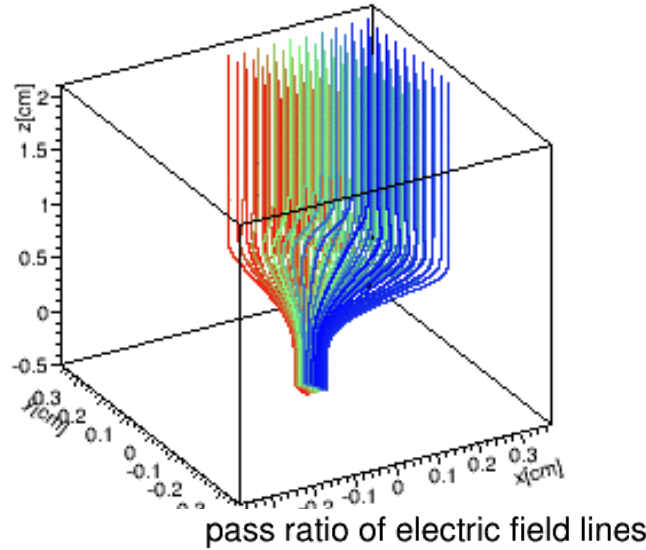


If $E_{\text{EL}} \gg E_{\text{drift}}$, lines of electric force are collected into holes

- Uniform response in wide area
- extendable to large size with the rigid structure

ELCC -Electric field calculation-

- ✓ by Finite Element Method(Elmer)
- ✓ Electric field lines are collected into cell when E_{EL}/E_{drift} and hole size is sufficiently large.
- ✓ Non-uniformity of field inside cell : < 1.7%

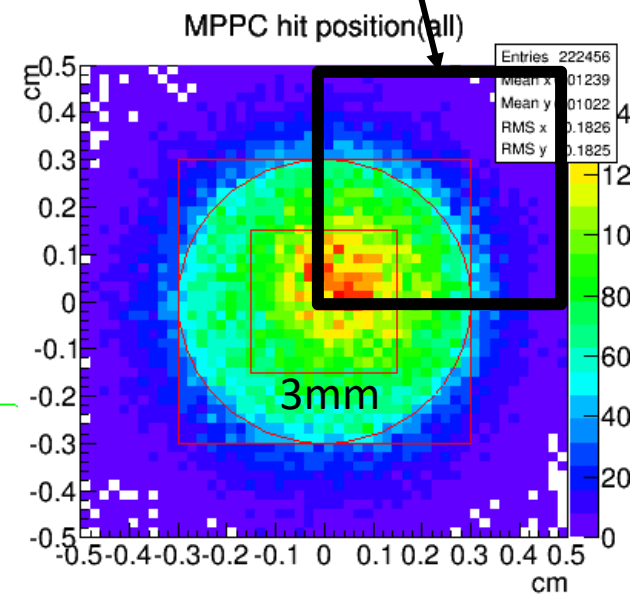
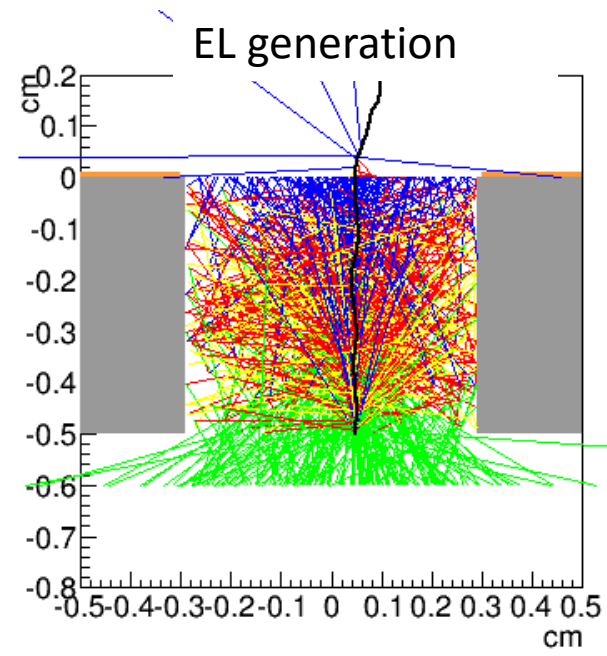
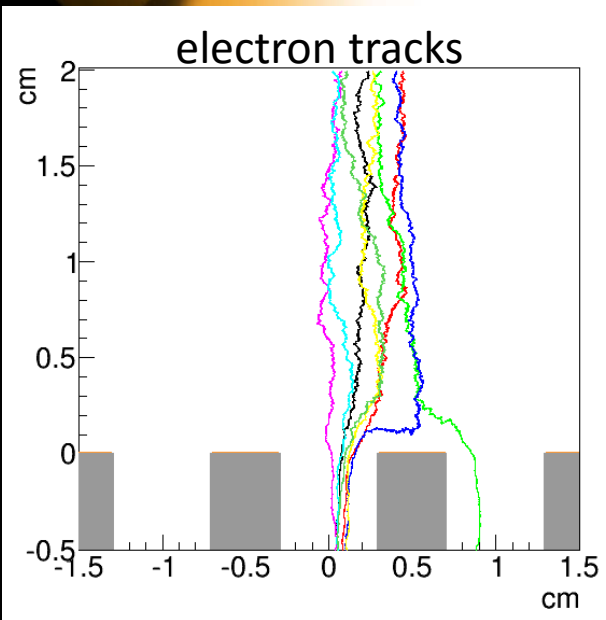


ELCC - electron track simulation-

- by Garfield++
w/ hand-made EL generation code
- ~15% of tracks go next cells, still collection efficiency is ~100%
- 60photons x PDE/1e- w/ 3mm \square MPPC)

$E_{drift}=100V/cm/atm$
 $E_{EL}=3kV/cm/atm$

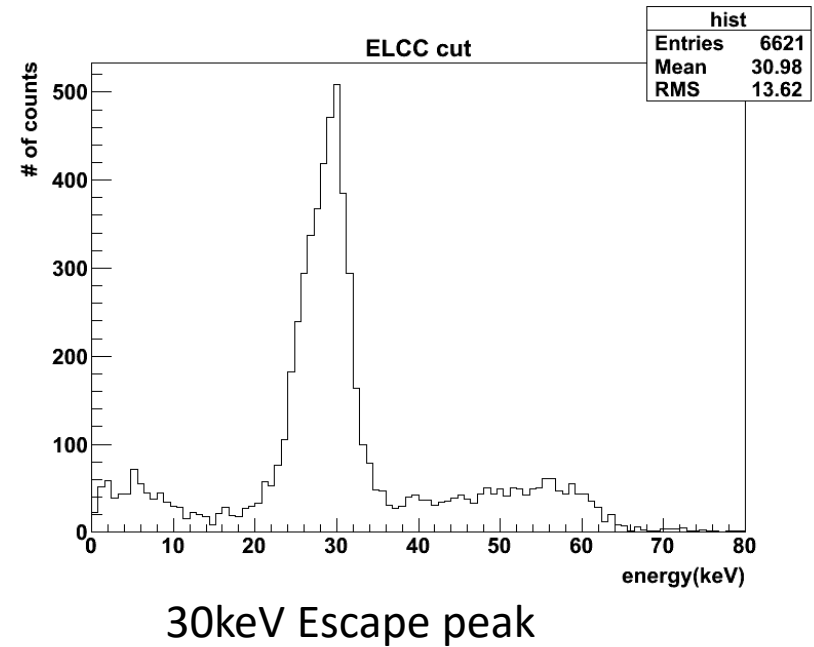
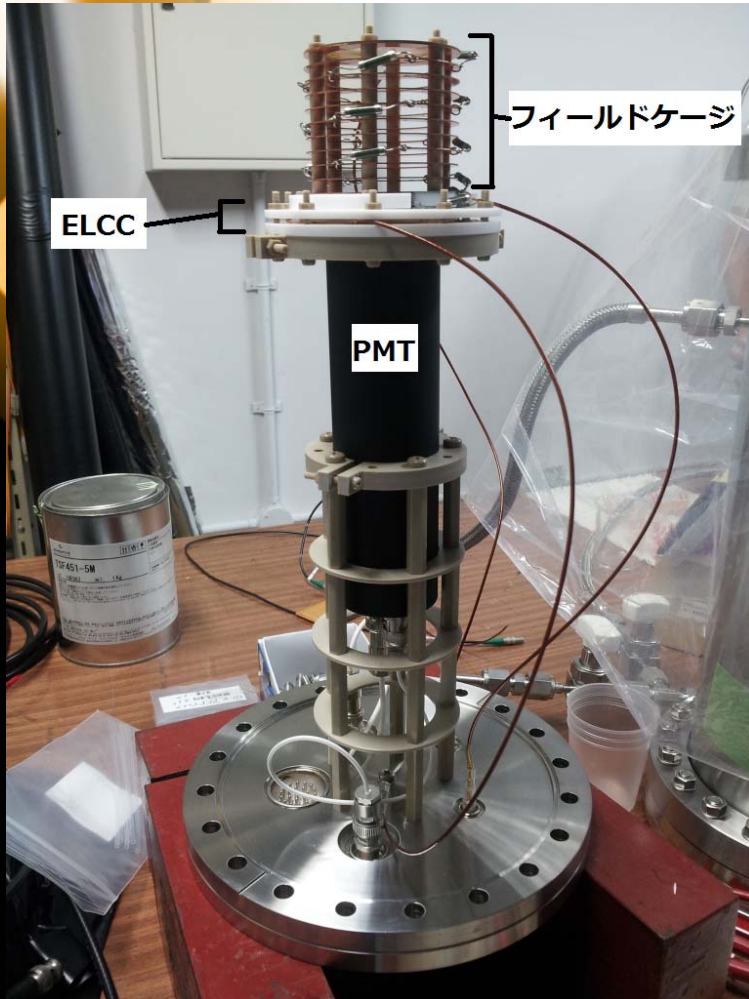
initial electron generation region



prototypes in 2012

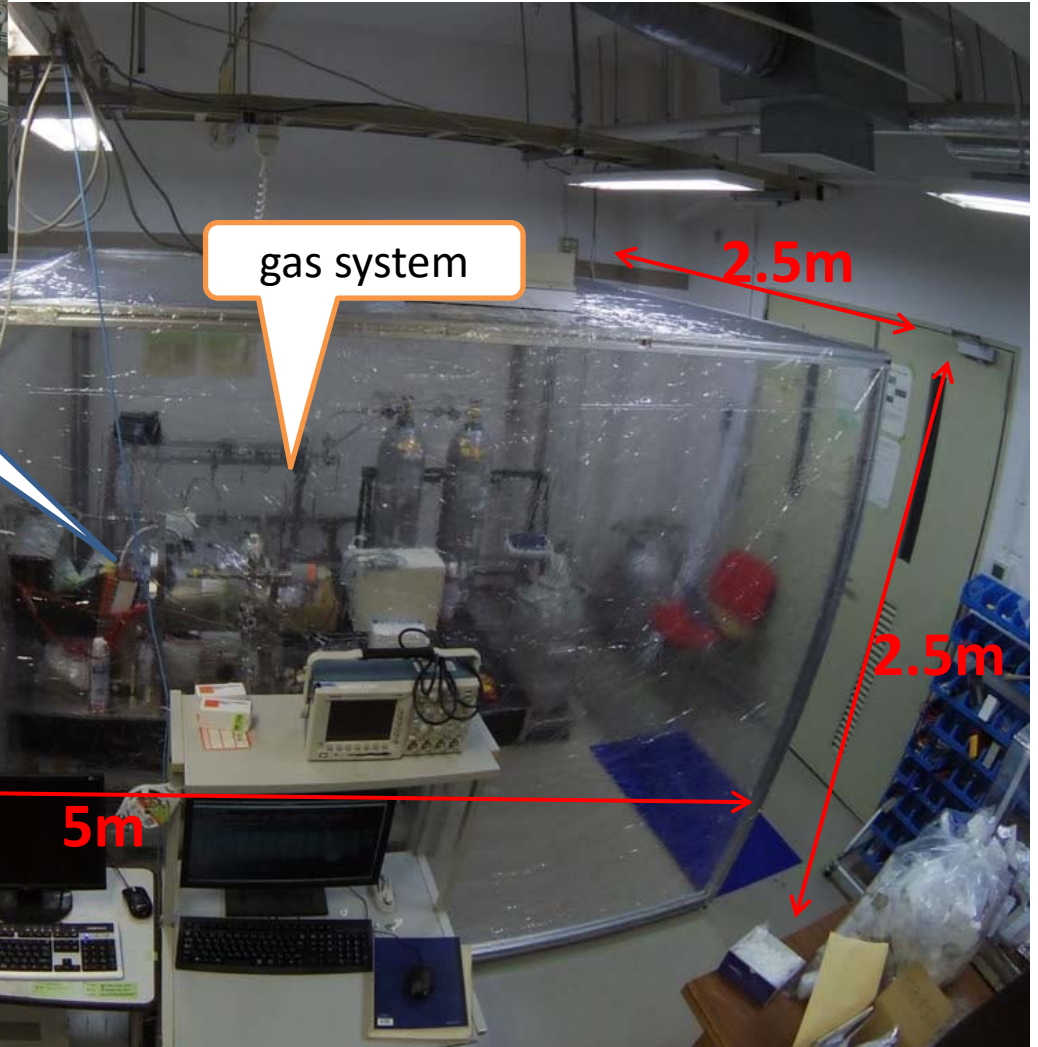
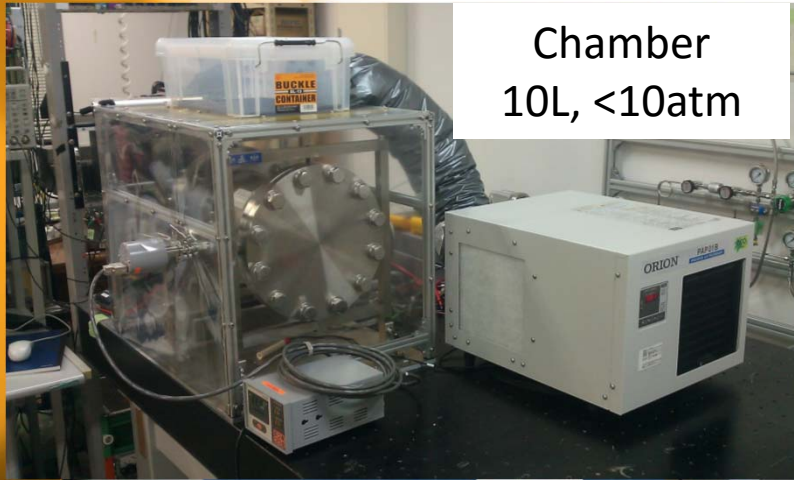
1 bar, w/ PMT

14%(FWHM)@30keV escape peak



Project space in Kyoto University

Chamber
10L, <10atm



gas system

2.5m

electronics

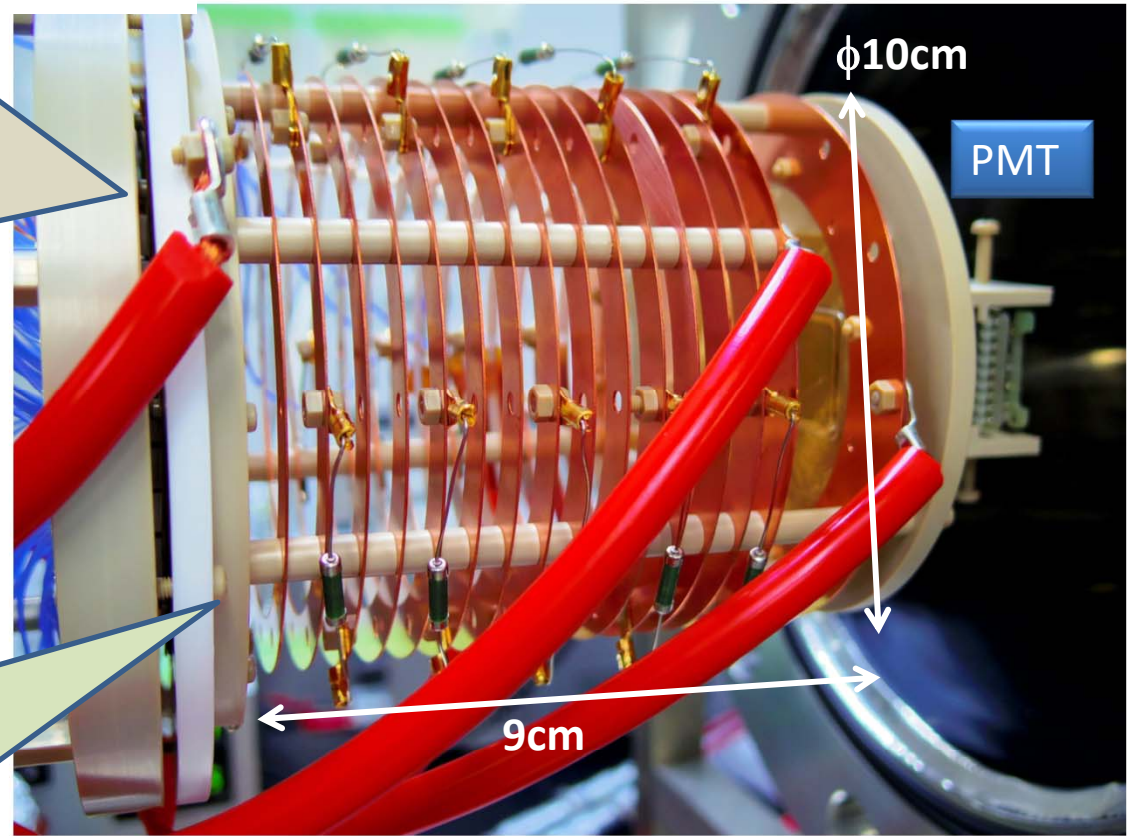
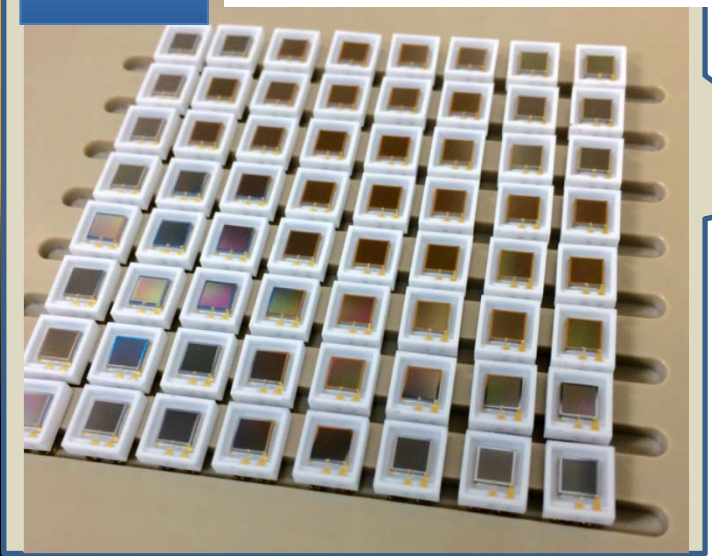
5m

2.5m

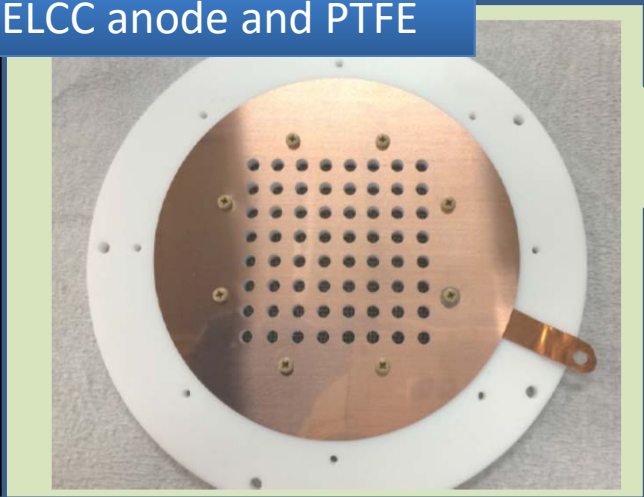
Prototype detector for ELCC demonstration

8x8 sensors
sensitive to VUV(175nm) photons

MPPC



ELCC anode and PTFE



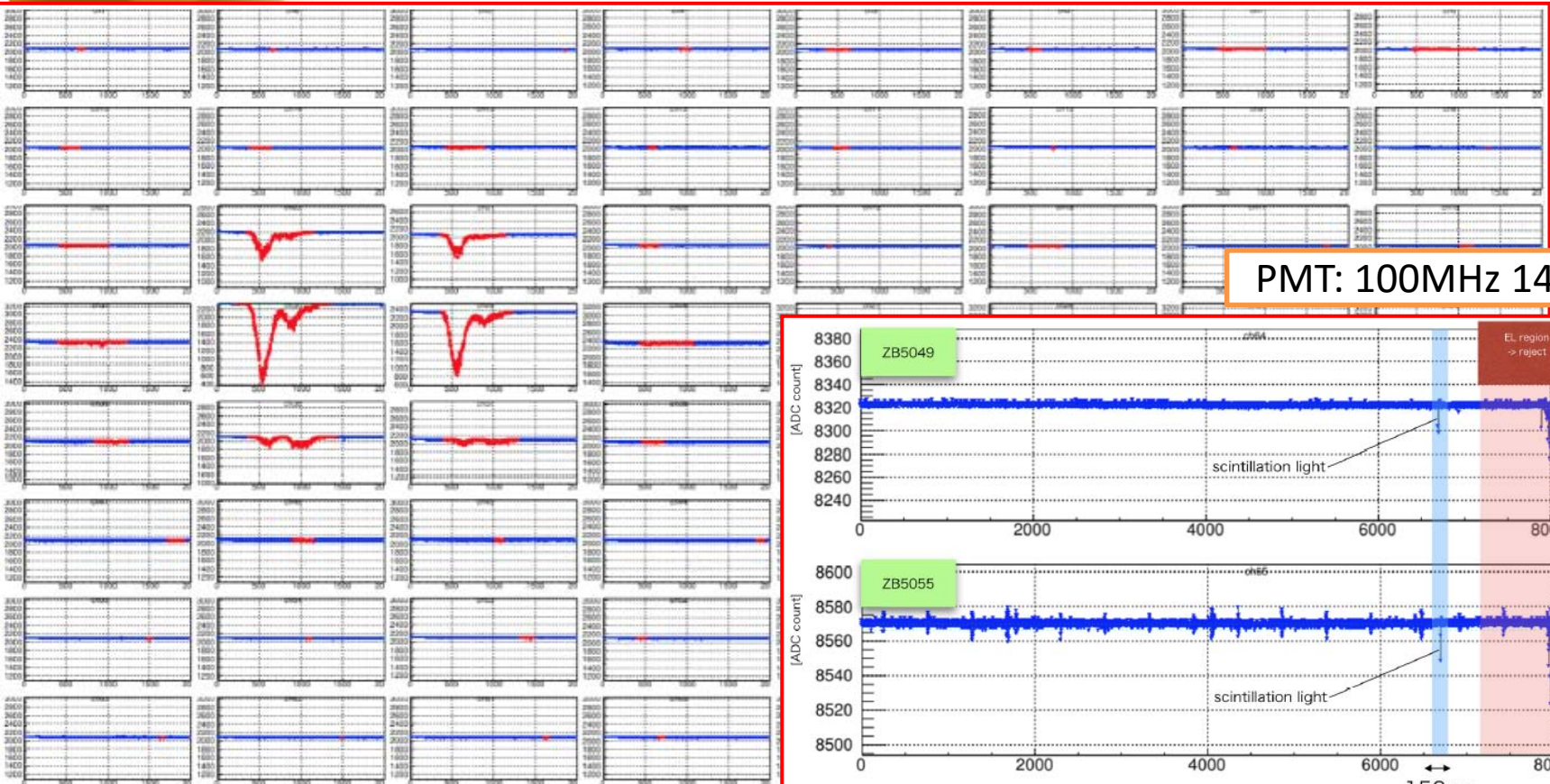
Purpose: demonstrate high energy resolution at 511 keV, 10bar.
However, only 122 keV, 4 bar result today...

Event sample

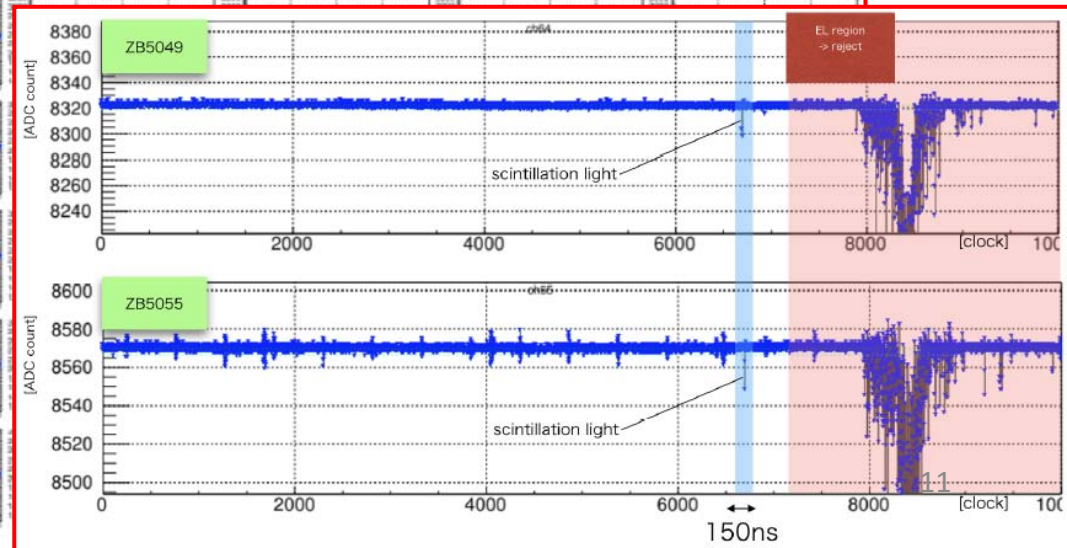
waveforms of MPPC and PMT

– EL light & scintillation light are observed

MPPC: 65MHz 12bit 2Vpp



PMT: 100MHz 14bit 2Vpp

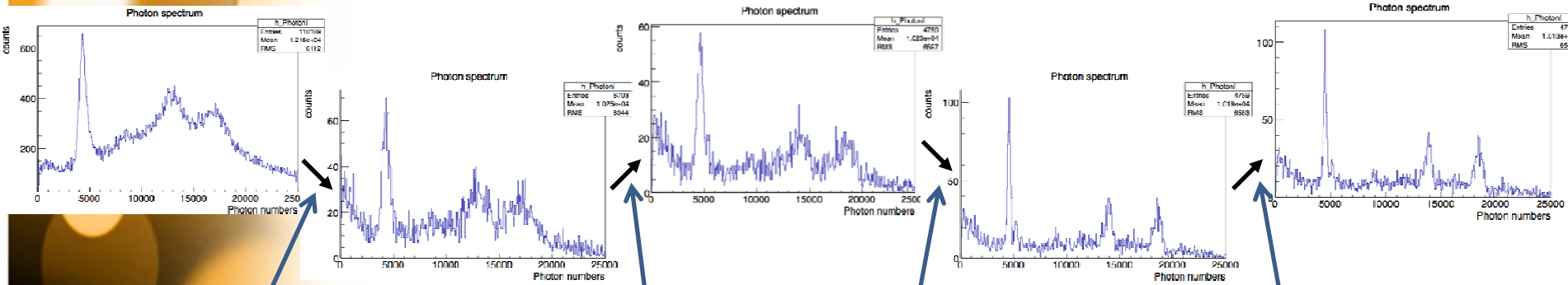


→ S.Ban's poster for more details

Data at 4bar w/ ^{57}Co (122keV)

Photon spectrum at various stage of correction/cut

$E_{EL}=2.7\text{kV/cm/atm}$
 $E_{drift}=100\text{V/cm/atm}$

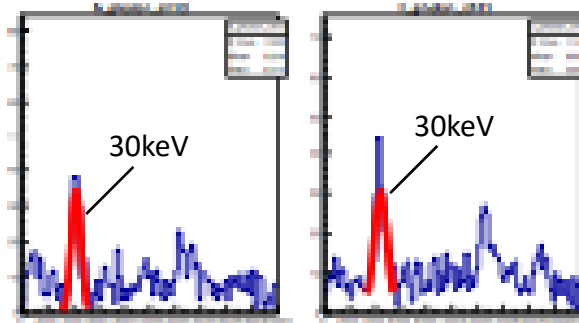
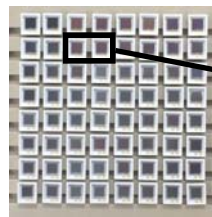


time variation correction
& another fiducial cut

Dark current
subtraction

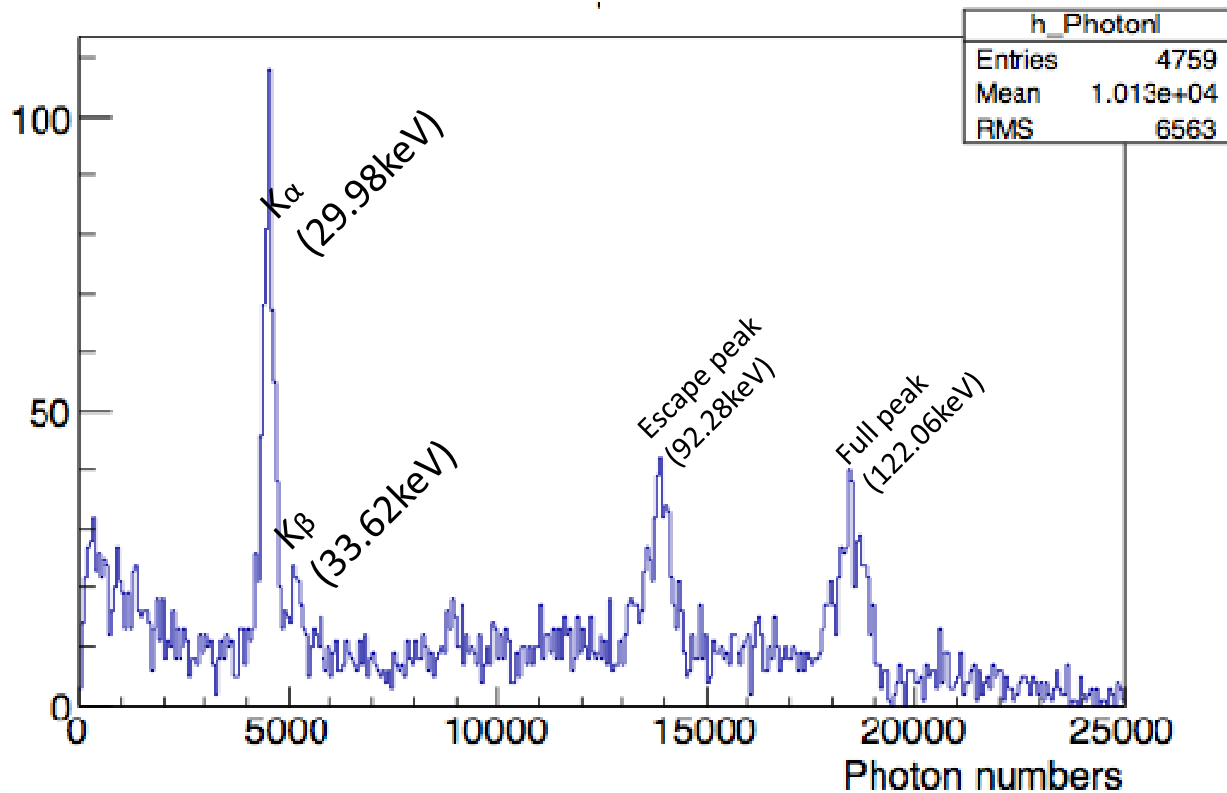
fiducial&saturation
cut

Cell-by-cell
EL gain correction

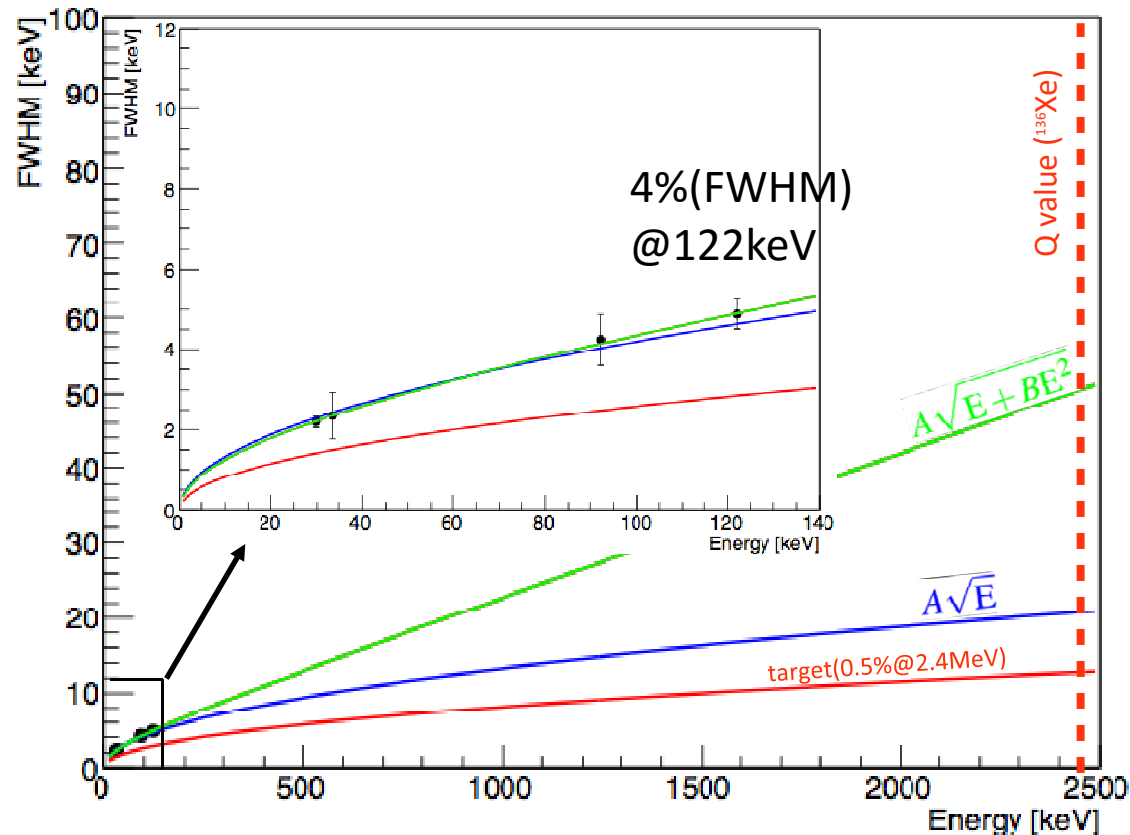


30keV escape peak of Xenon

Spectrum at 4bar w/ ^{57}Co (122keV)



Energy resolution at 4 bar



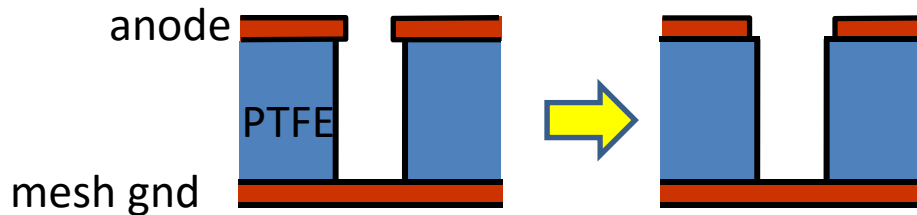
Extrapolated FWHM energy resolution at Q value(2458keV)

- ✓ **0.85%** when extrapolated by $A\sqrt{E}$ → could be improved by higher electric field
- ✓ **2.03%** when extrapolated by $A\sqrt{E} + BE^2$ → need investigation, but measurement at higher energy desired

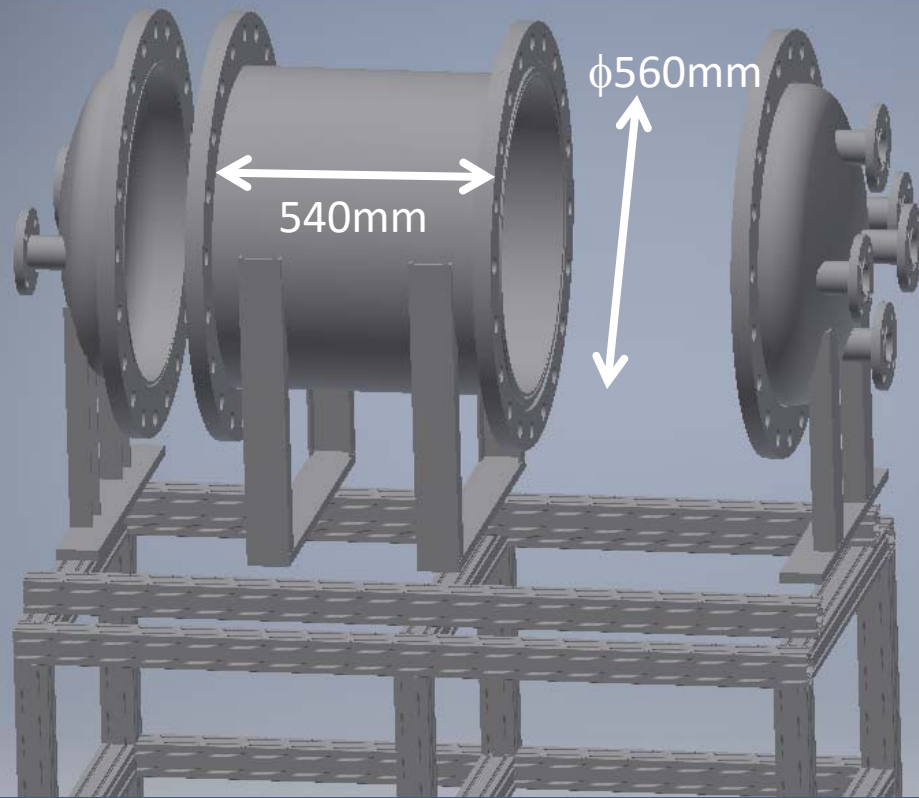
On-going development

➤ 511keV@10bar measurement w/
current prototype

- ✓ prevention of discharge
- ✓ more control on holes in anode and PTFE of ELCC

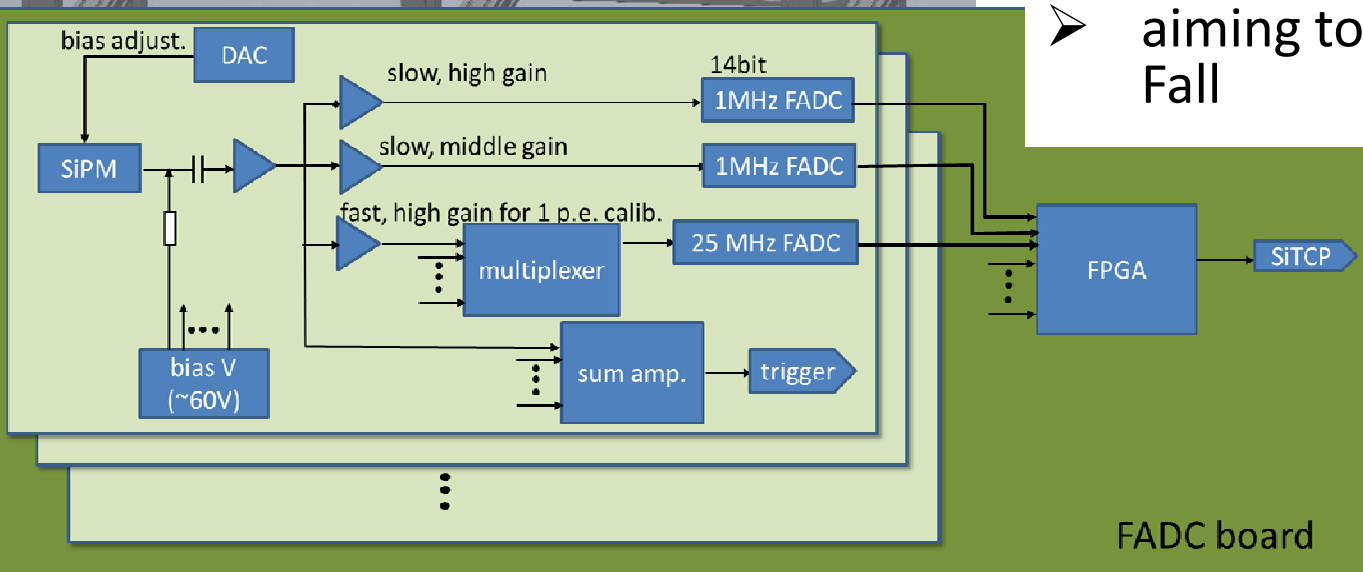


- ✓ Gas circulation with getter



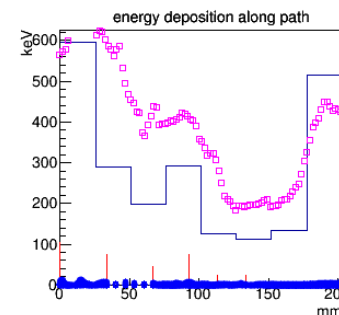
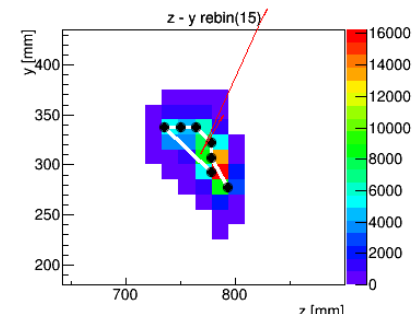
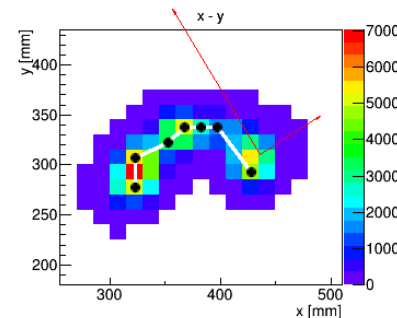
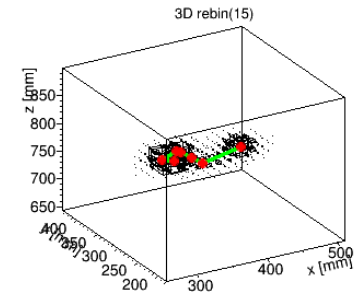
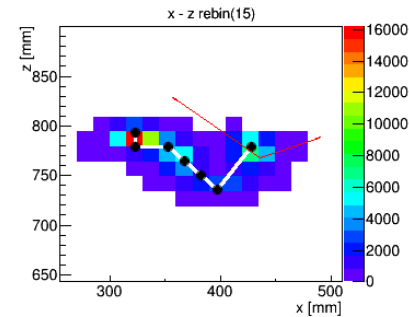
Next prototype

- demonstrate energy resolution at around Q-value
- ~1,000 channel
 - ✓ Hamamatsu photonics VUV-4 MPPC
 - ✓ developing custom ADC board
- ✓ Cathode voltage ~70kV
 - ✓ developing Cockcroft-Walton power supply
- aiming to get result by 2017 Fall



Finally, (very) rough sensitivity estimation

- ❑ 10bar 1ton enriched ^{136}Xe
- ❑ Signal
 - ✓ a few events/year @ $m_{\beta\beta}=20\text{meV}$
 - 79% contained in fiducial volume
 - 49% after clustering
 - 22% after blob-recognition
- ❑ Background
 - ✓ Only ^{214}Bi considered now. (cannot be separated by E)
 - ✓ 10 ton low background(3ppb) material
 - 12k evts/yr in fiducial
 - 75 evts/yr after clustering
 - 7 evts/yr w/ blob-recognition

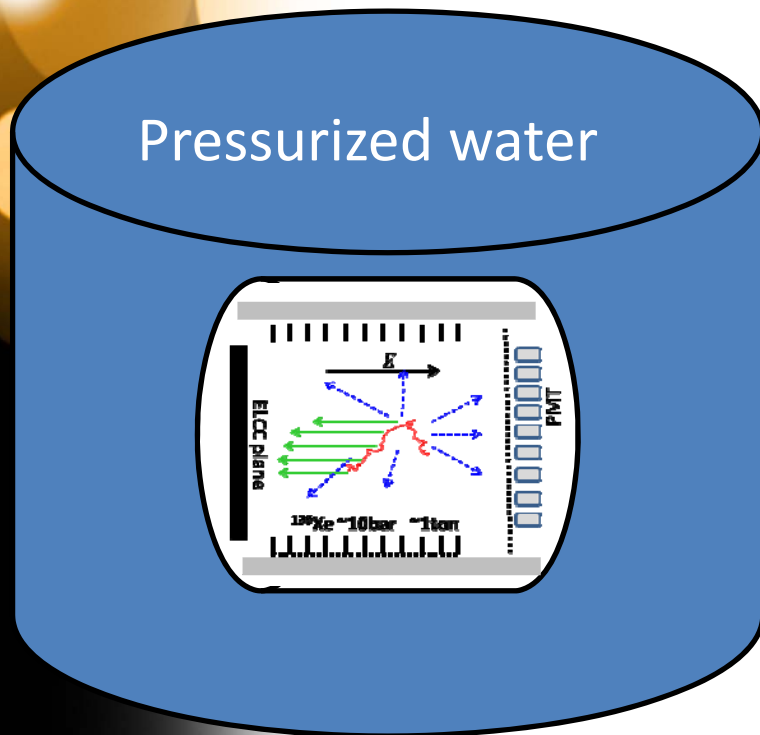


Recognition of track with a blob at both ends.

(algorithm optimization still in progress)

Finally, (very) rough sensitivity estimation

- Thin vessel in low-bkg. pressurized water
bkg 7evts/yr \rightarrow 0.1 evts/yr
 \rightarrow sensitivity to ~ 20 meV



Summary

- AXEL is a high pressure Xe-gas TPC to search for $0\nu\beta\beta$
- We have developed a new electroluminescence read out method, ELCC.
 - ❑ high energy resolution
 - ❑ extendable to large size
- Performance demonstrated at 122 keV, and to be demonstrated at 511 keV in this year and 2 MeV in the next year