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

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for the AXEL group

No Introduction

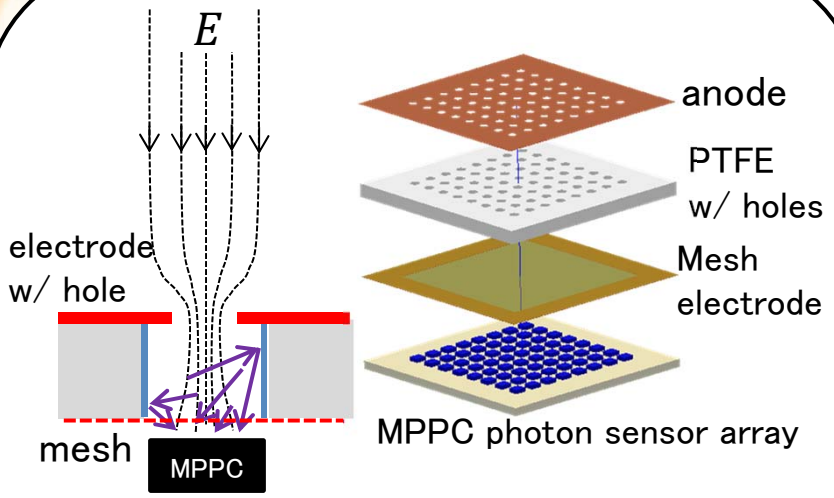
Pioneering work by NEXT has demonstrated the superiority of high pressure Xenon gas TPC as the neutrinoless double-beta decay search detector.

Contents of my talk:

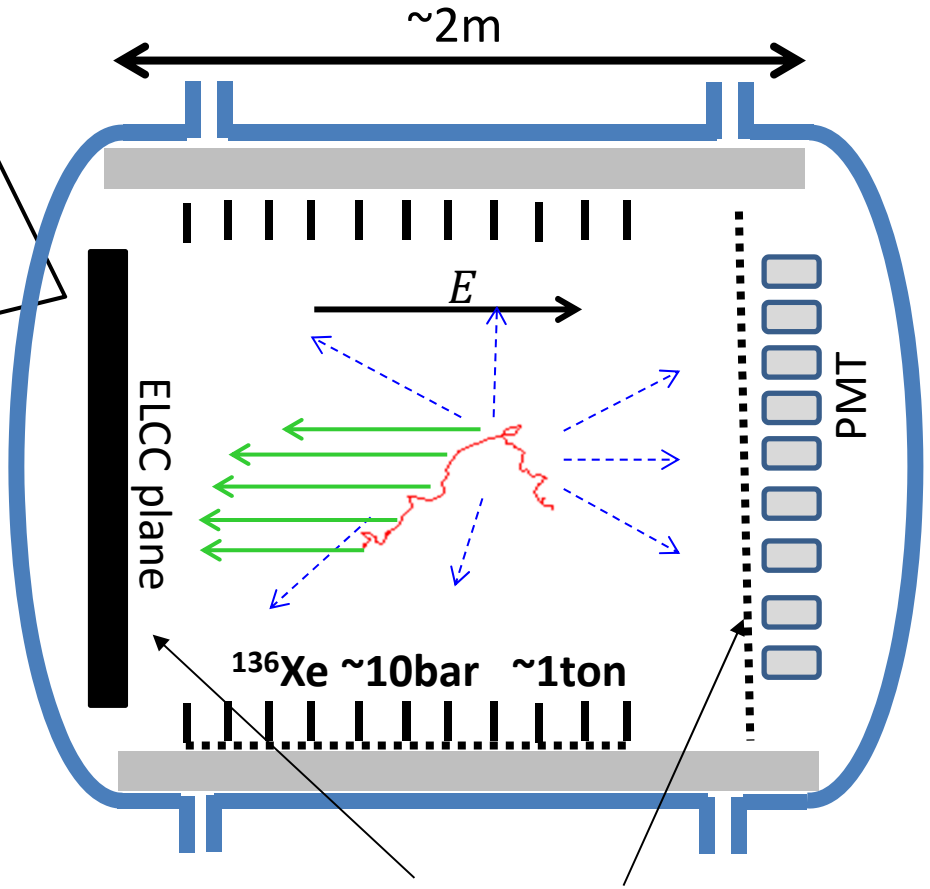
- Project overview
- ELCC(Electroluminescence Light Collection Cell)
- Demonstration by prototype
- Next prototype plan
- Sensitivity

What we propose in the AXEL project

Electro luminescence light collection cell (ELCC)

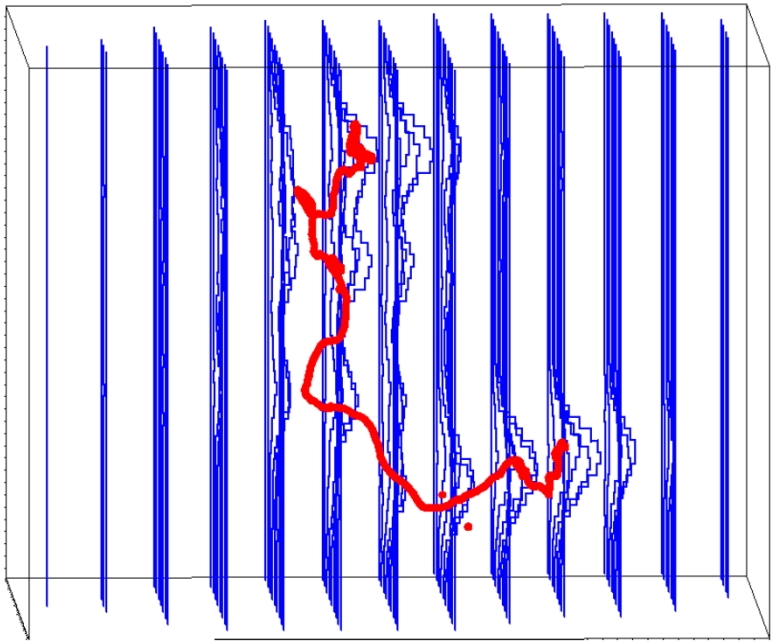


High Pressure Xe gas TPC



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

Background rejection by event topology



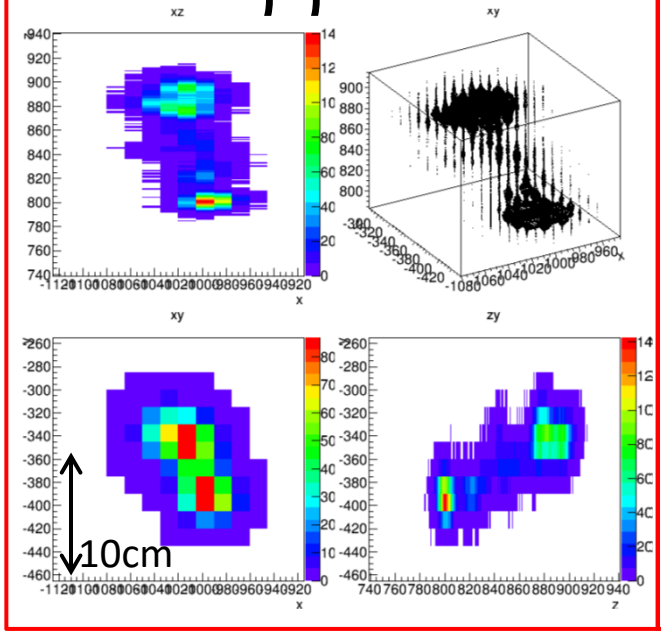
AXEL

-Expected event topologies-

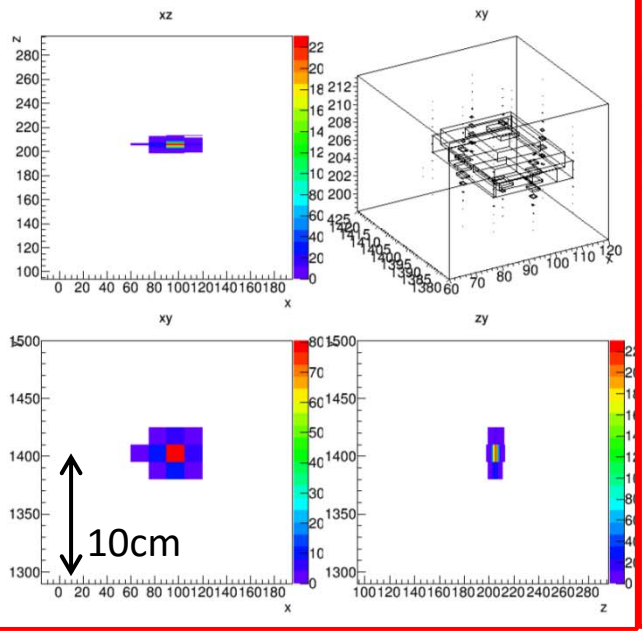
simulation

10atm, 15mm pitch, 1μs sampling (~1mm)

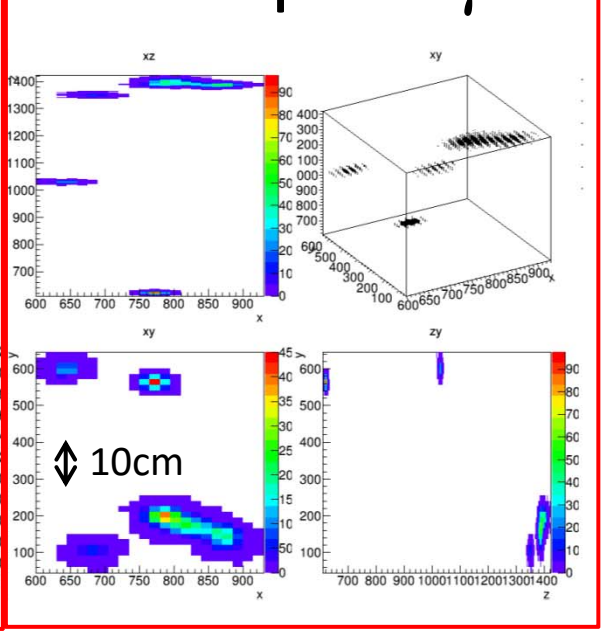
0νββ



α

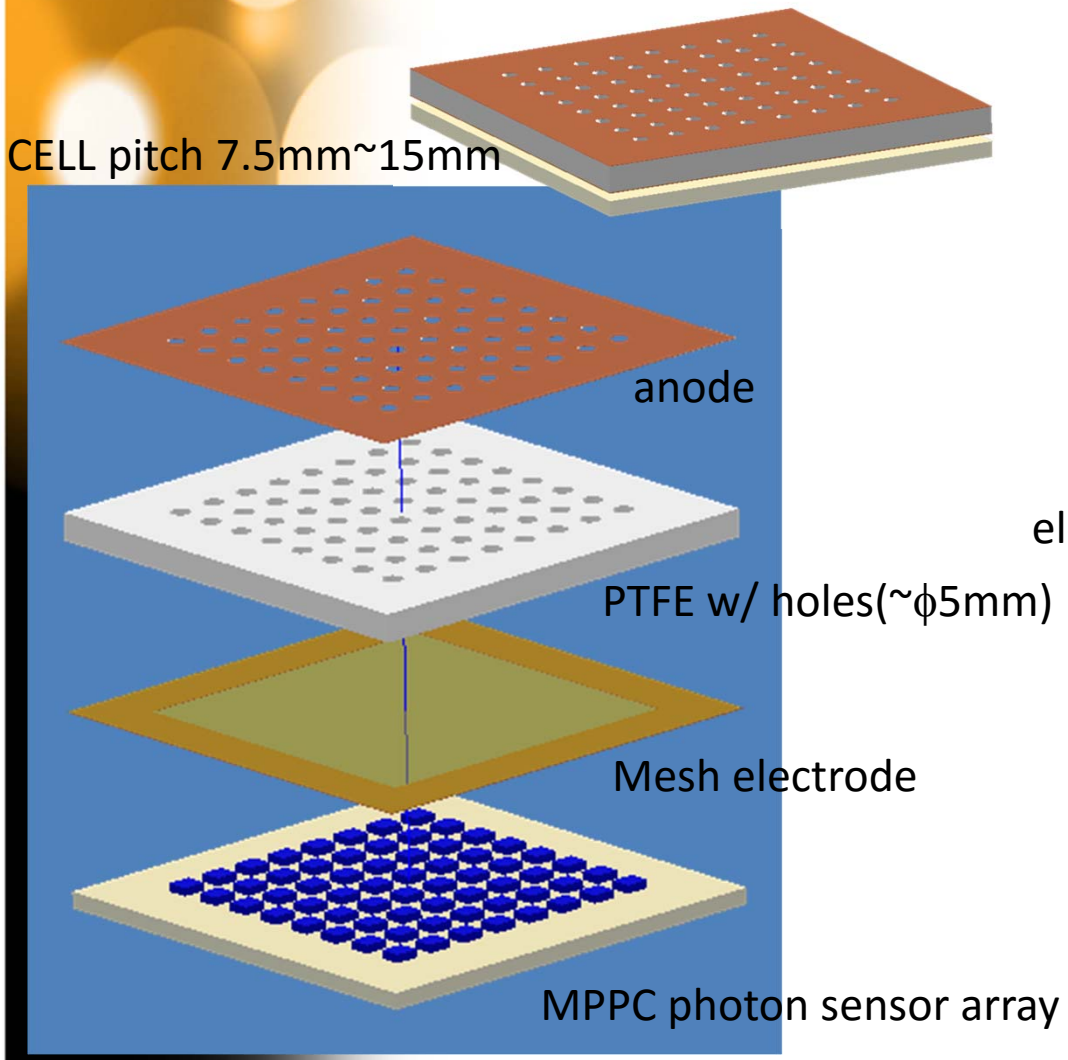


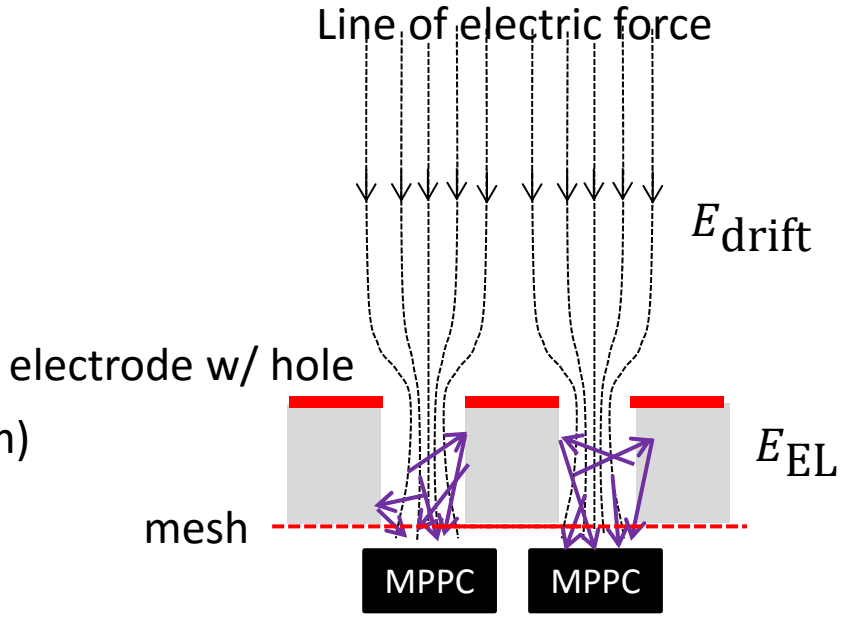
Compton γ



ELCC

-ElectroLuminescence Light Collection Cell -





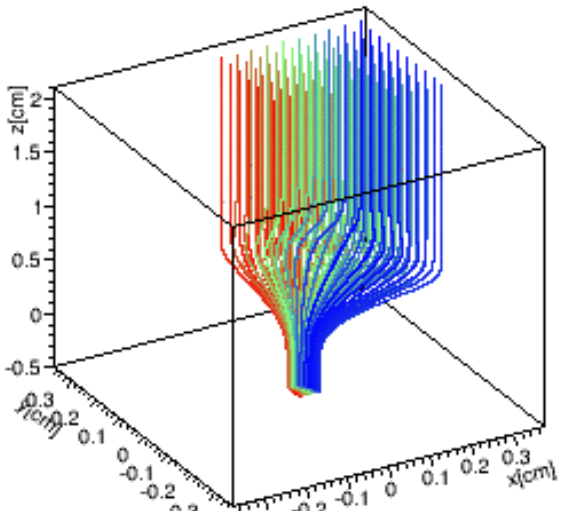
If $E_{\mathrm{EL}} \gg E_{\mathrm{drift}}$, lines of electric force are collected into holes

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

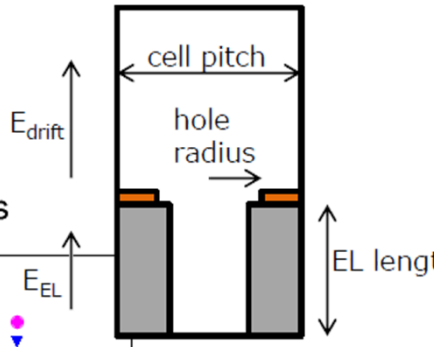
→ Kiseki Nakamura's poster for more details

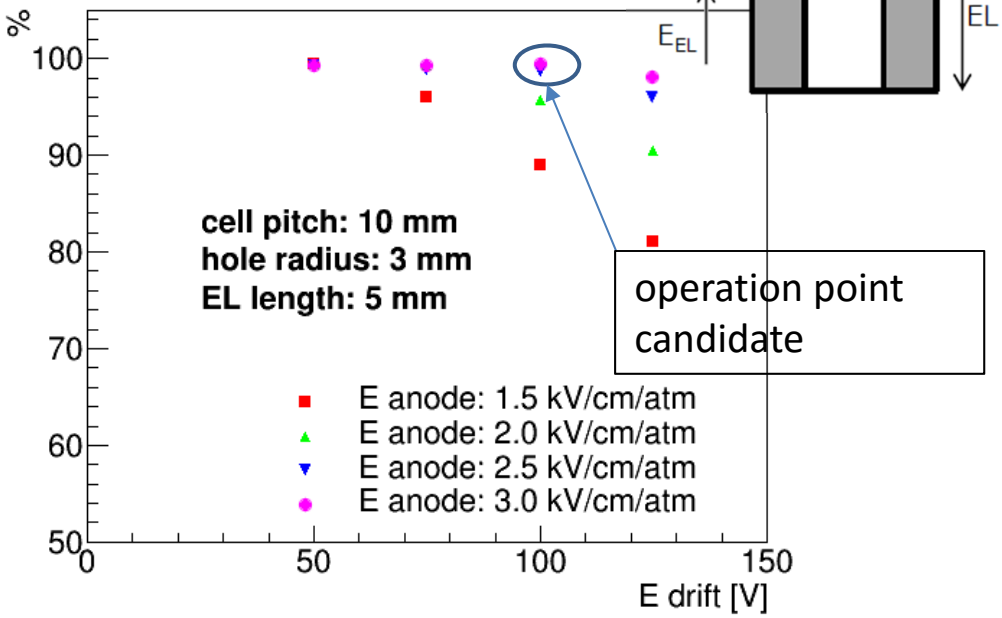
ELCC -Electric field calculation-

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



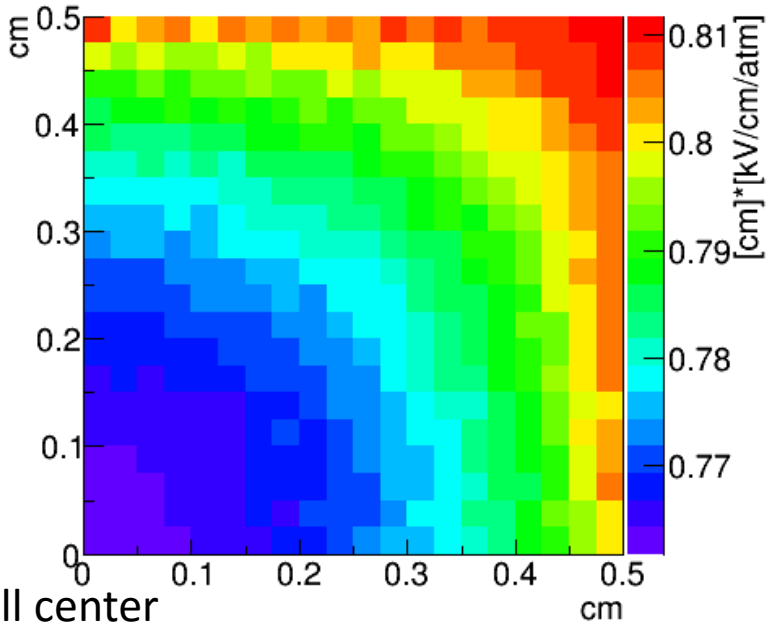
pass ratio of electric field lines





operation point candidate

Integral of field over EL threshold



cell center

→ Kiseki Nakamura's poster for more details

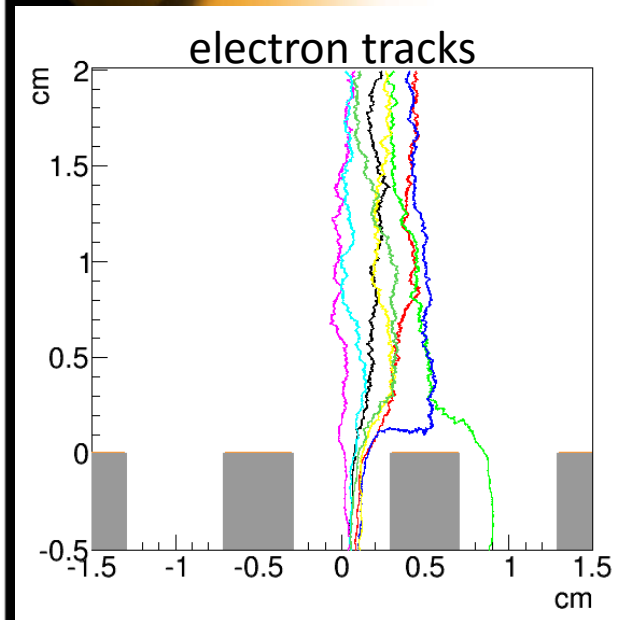
ELCC - electron track simulation-

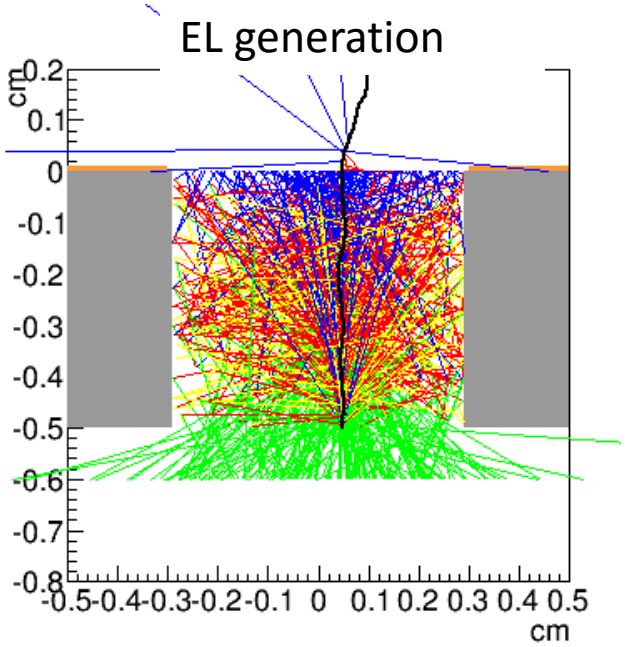
- by Garfield++

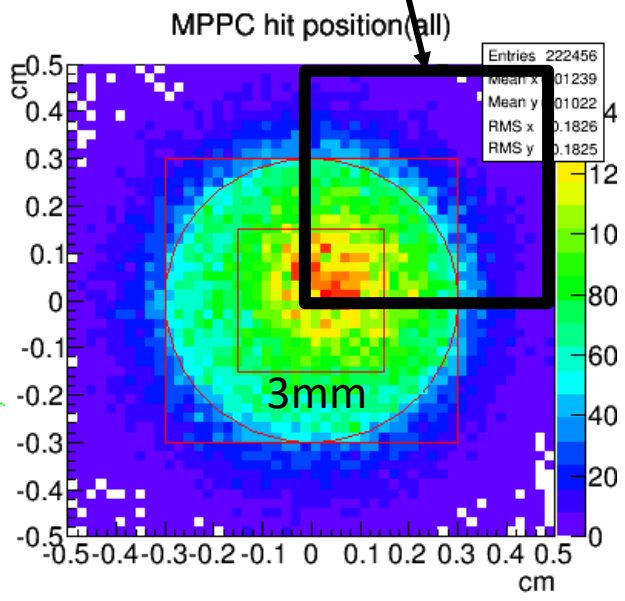
  w/ hand-made EL generation code
- ~15% of tracks go next cells, still collection efficiency is ~100%
- 60photons x PDE/1e- w/ 3mm□ MPPC)

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

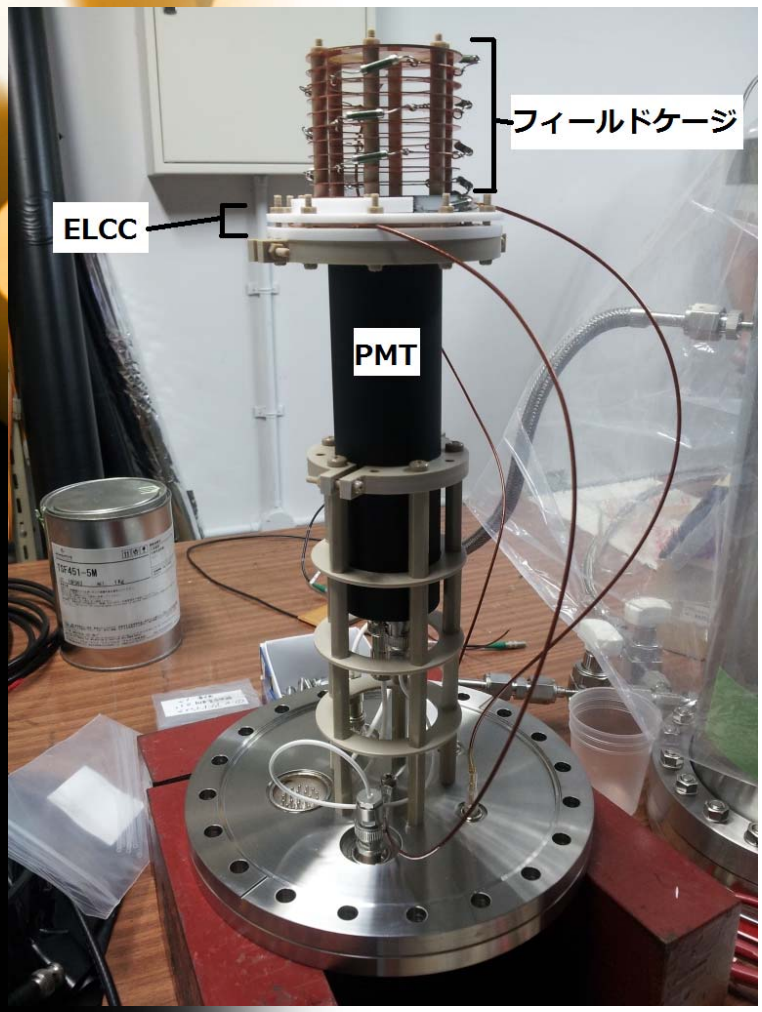
initial electron generation region





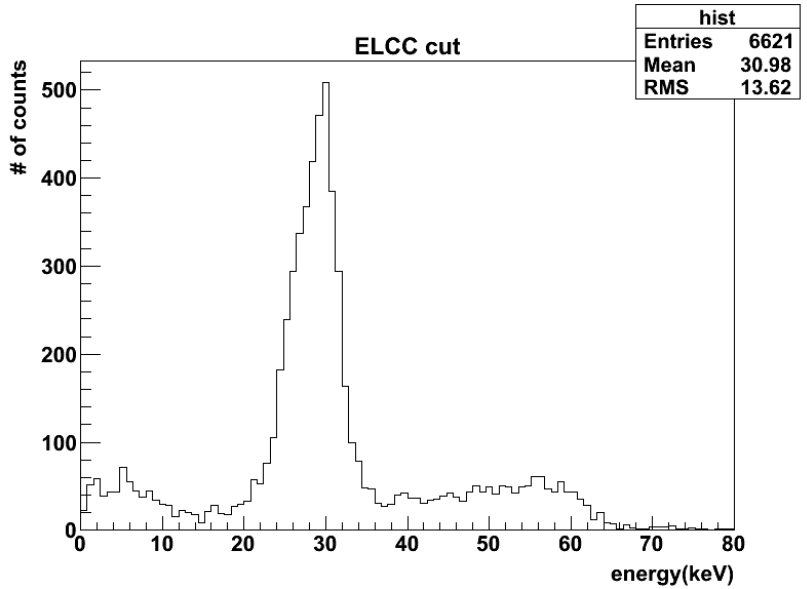


1st prototype in 2012



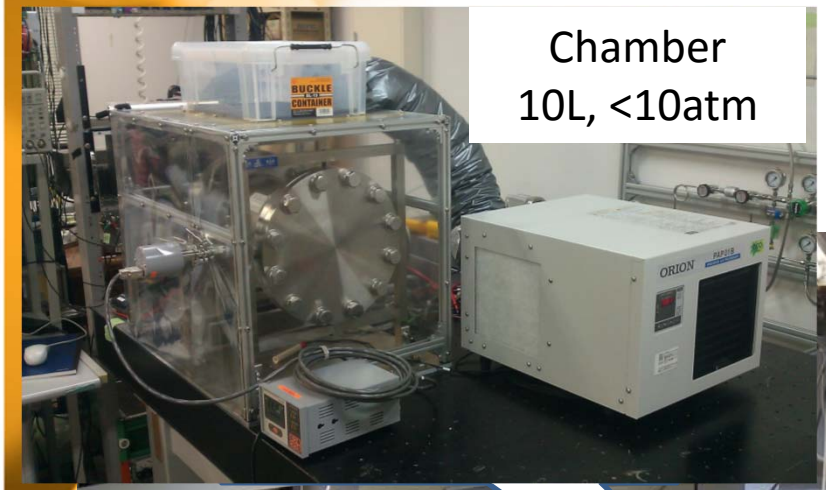
1 bar, w/ PMT

14%(FWHM)@30keV escape peak



30keV Escape peak

Project space in Kyoto University



gas system

2.5m

2.5m

electronics

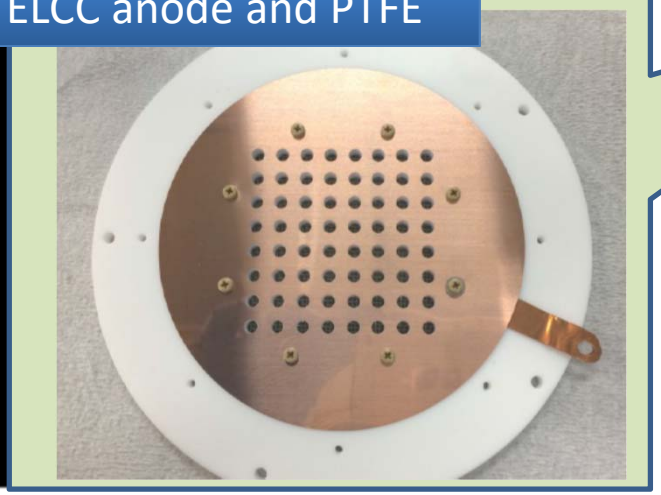
5m

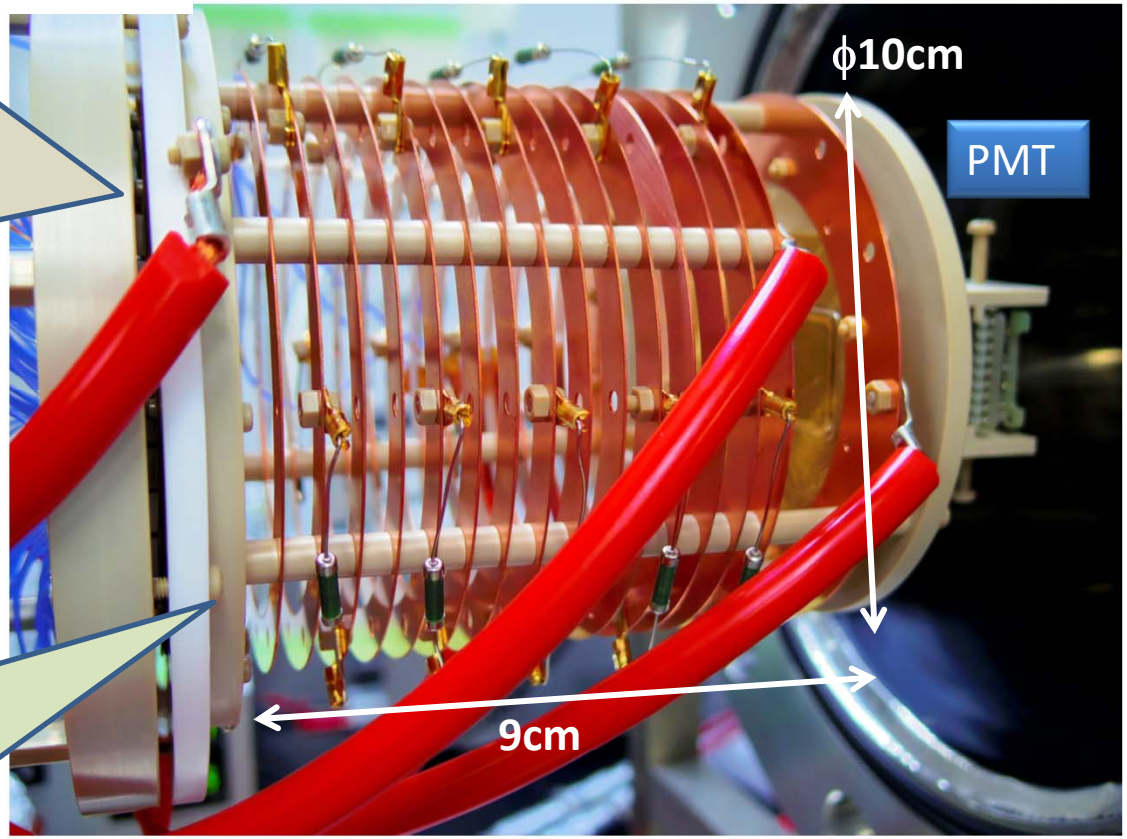
Prototype detector for ELCC demonstration

8x8 sensors
sensitive to VUV(175nm) photons

MPPC

ELCC anode and PTFE





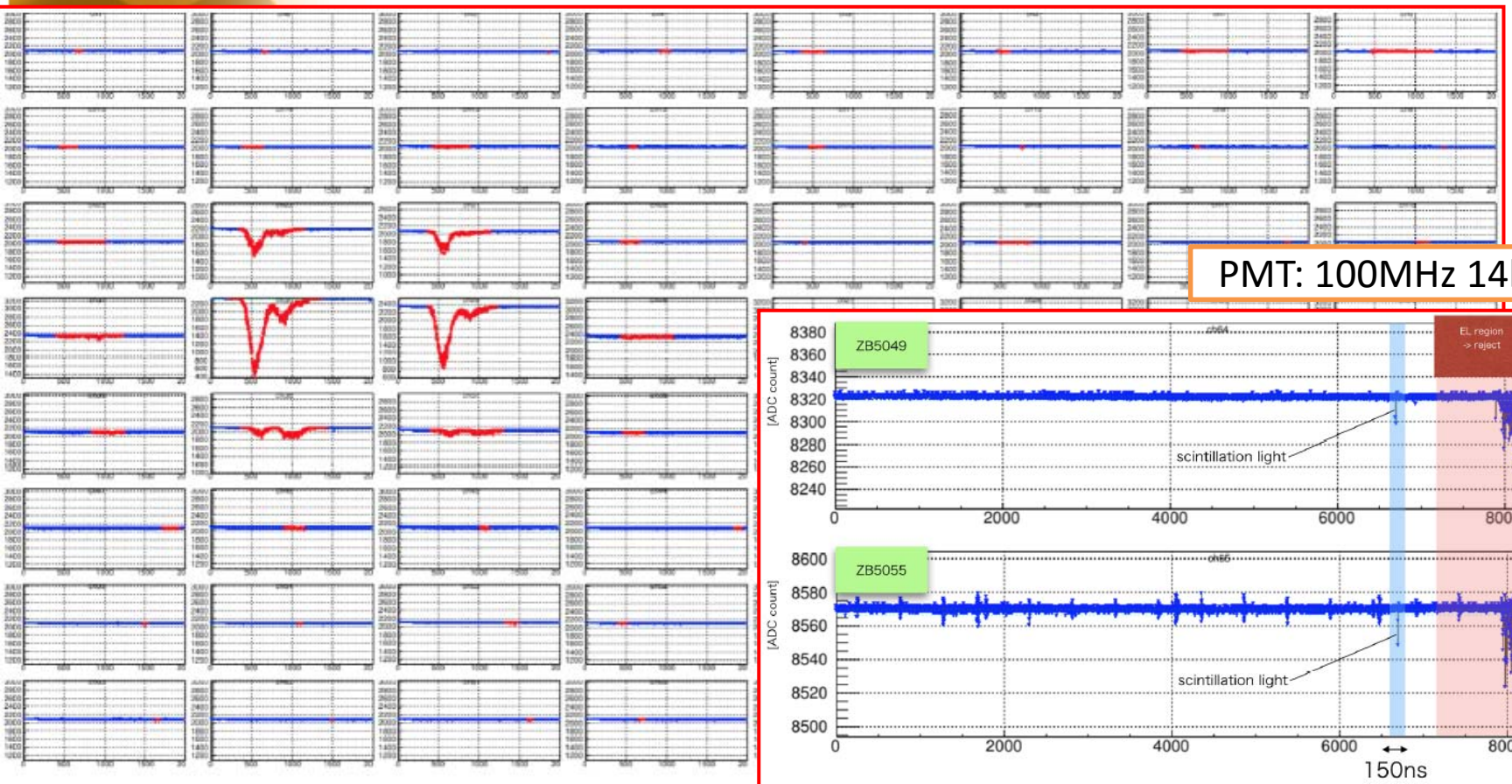
Purpose: demonstrate high energy resolution at 511 keV, 10bar.
However, only 122 keV, 4 bar result today…

Event sample

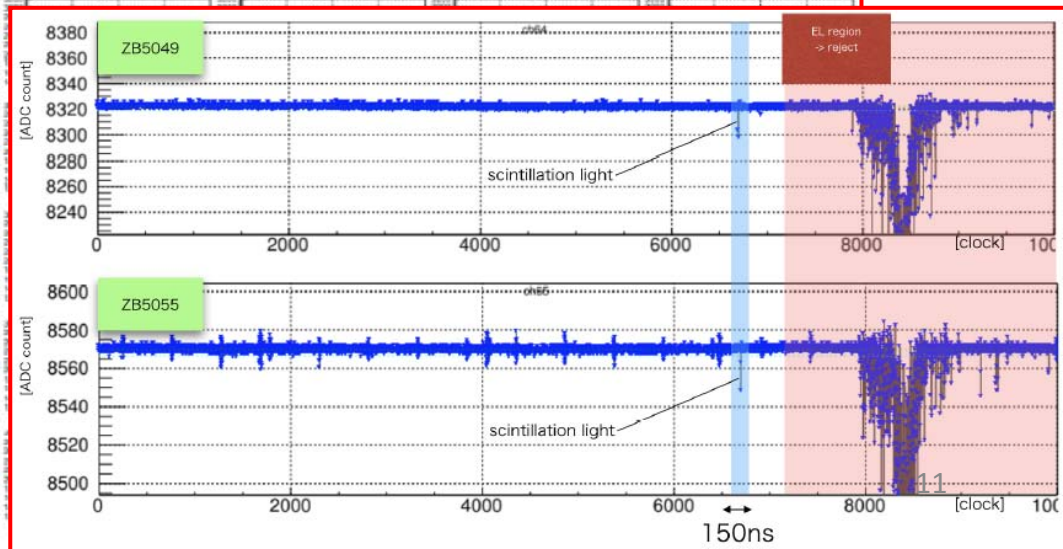
waveforms of MPPC and PMT

– EL light & scintillation light are observed

MPPC: 65MHz 12bit 2Vpp



PMT: 100MHz 14bit 2Vpp

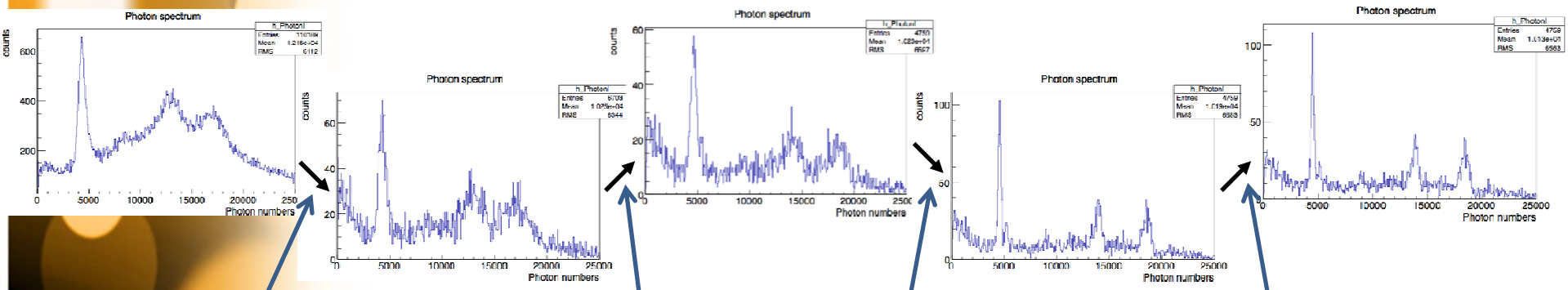


→ S.Ban's poster for more details

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

Photon spectrum at various stage of correction/cut

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

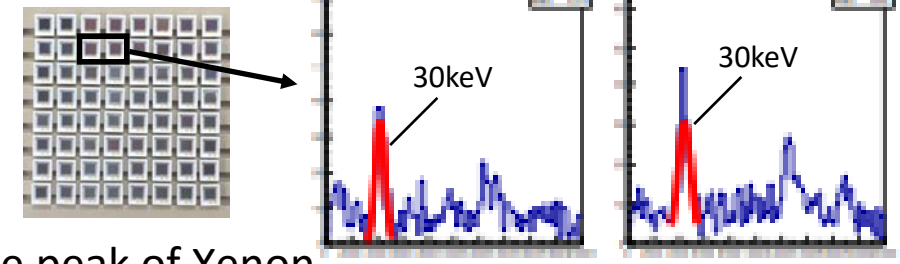


fiducial&saturation cut

time variation correction & another fiducial cut

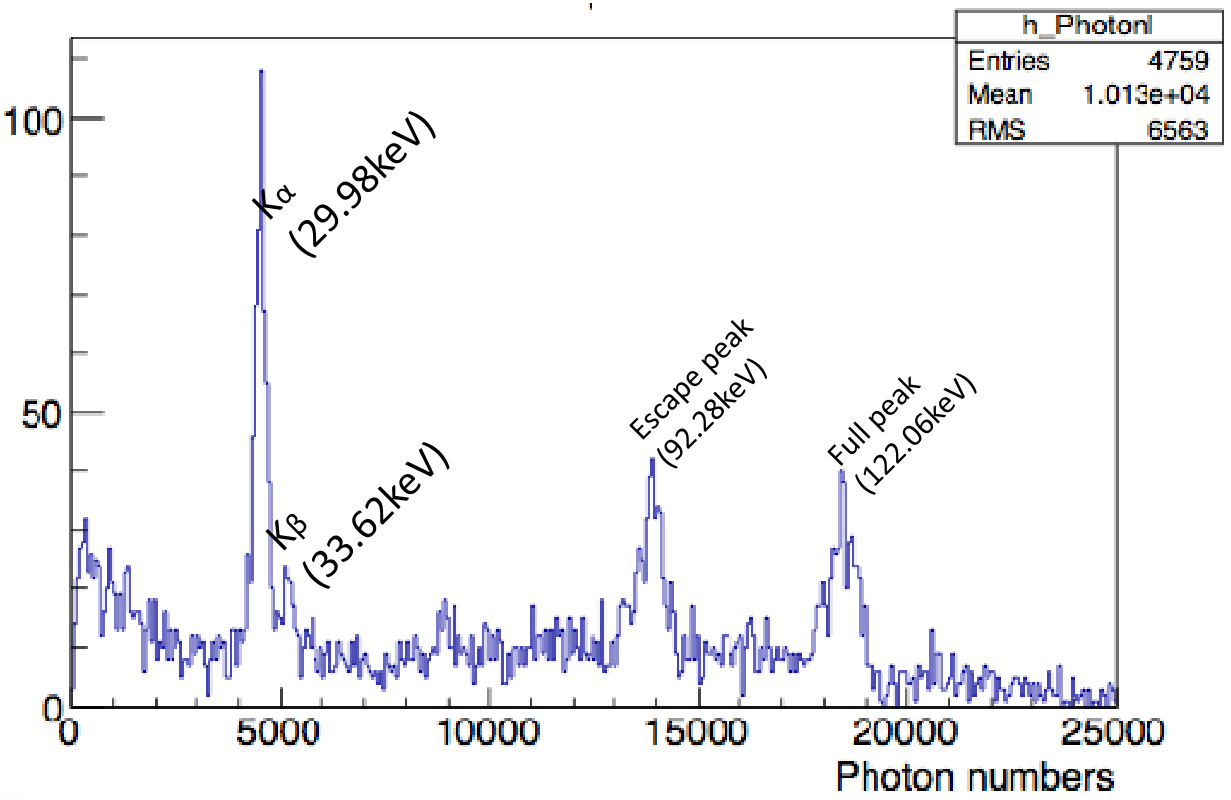
Cell-by-cell EL gain correction

Dark current subtraction

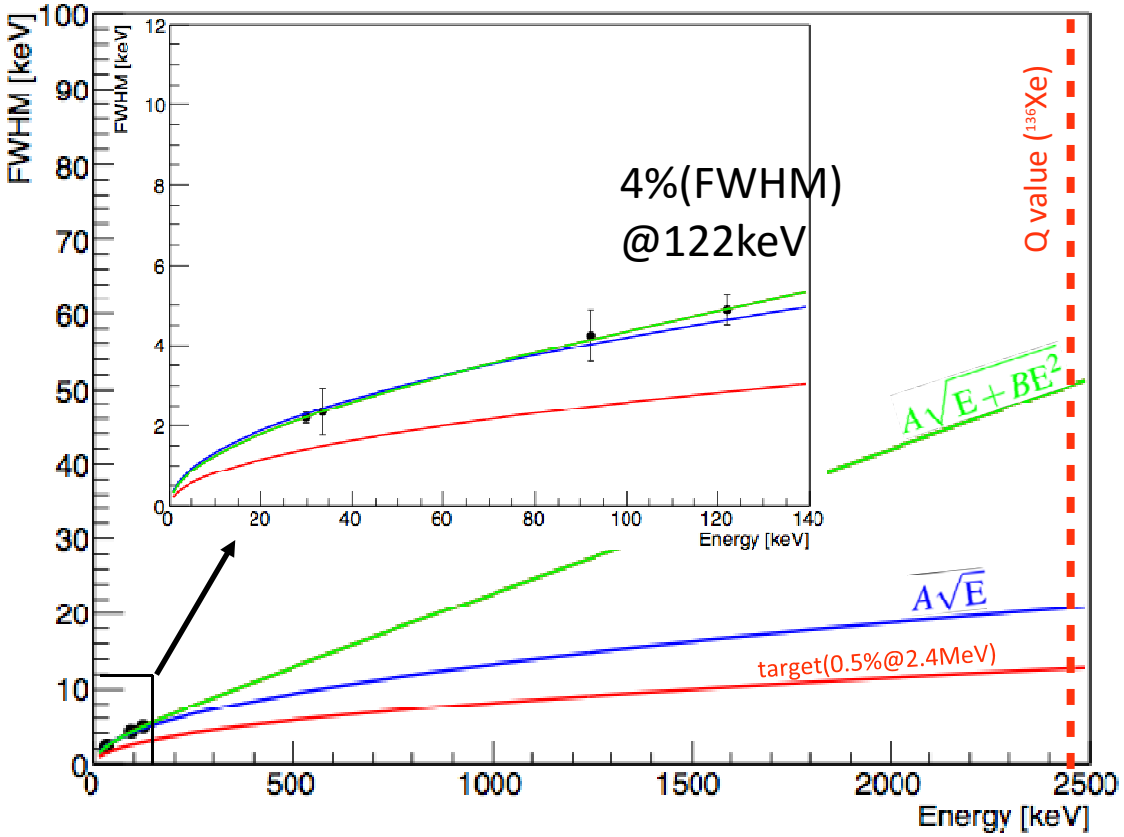


30keV escape peak of Xenon

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



Energy resolution at 4 bar

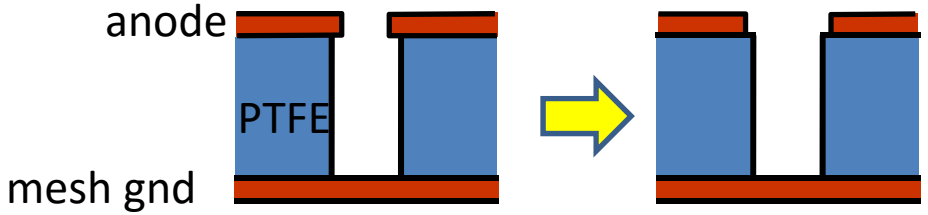


Extrapolated FWHM energy resolution at Q value(2458keV)

- ✓ **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, measurement at higher energy desired

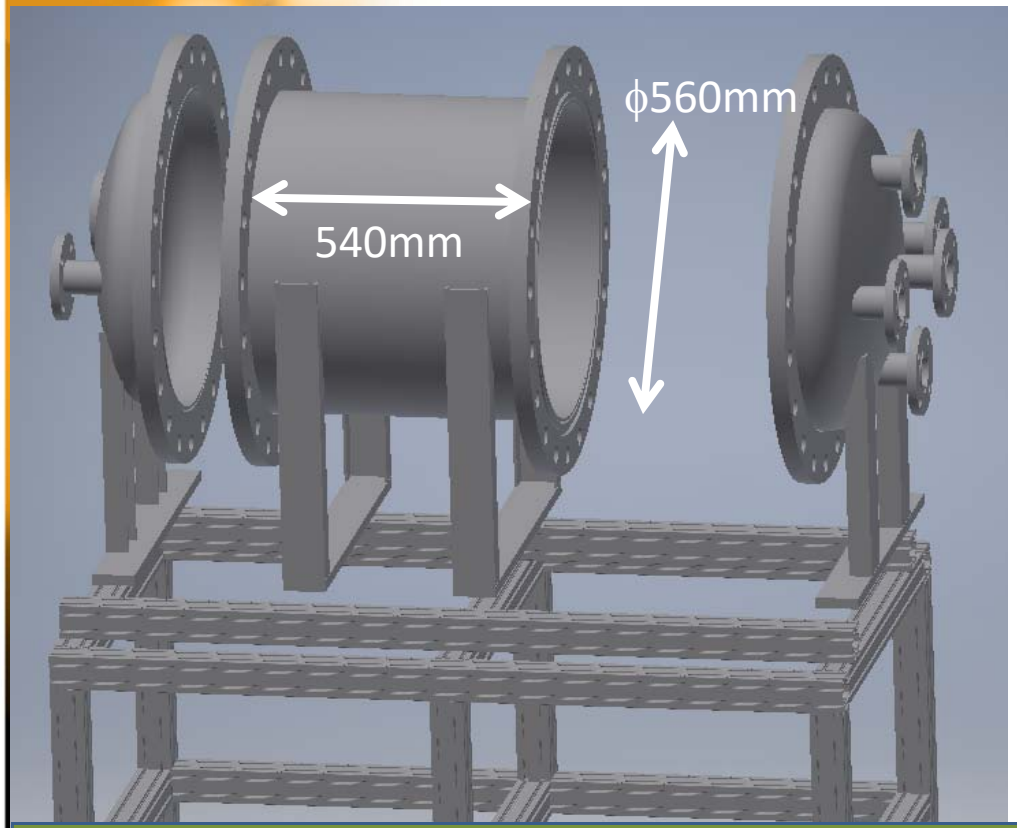
On-going development

- 511keV@10bar measurement w/ current prototype
  - ✓ prevention of discharge
    - ✓ more control on holes in anode and PTFE of ELCC

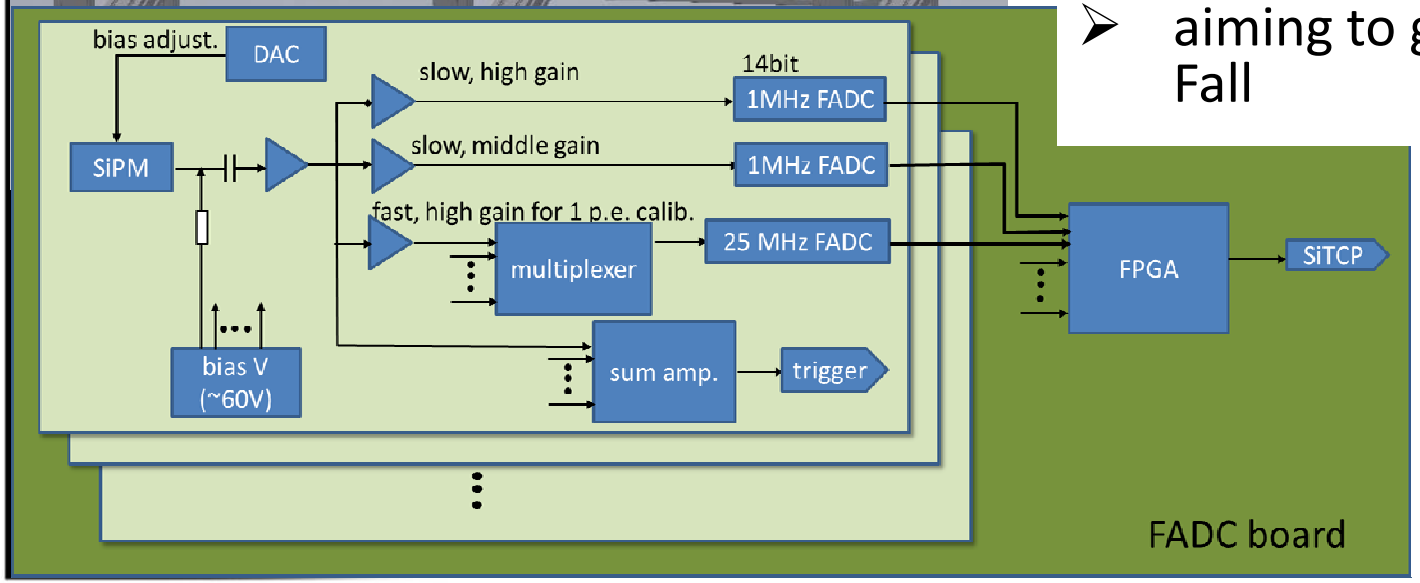


  - ✓ Gas circulation with getter

Next prototype



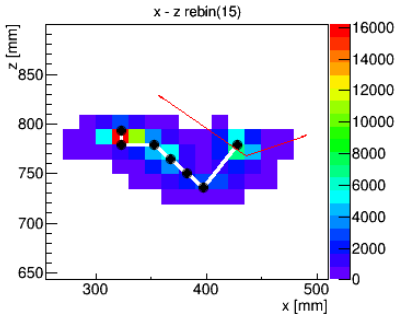
- demonstrate energy resolution at around Q-value
- ~1,000 channel
  - ✓ Hamamatsu photonics VUV-4 MPPC
  - ✓ developing custom ADC board
- ✓ Cathode voltage ~70kV
  - ✓ developing Cockcroft-Walton power supply
- aiming to get result by 2017 Fall

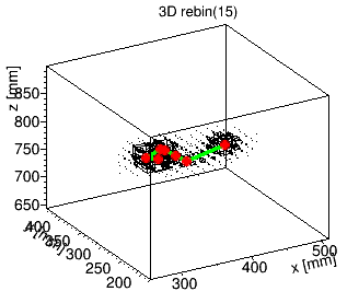


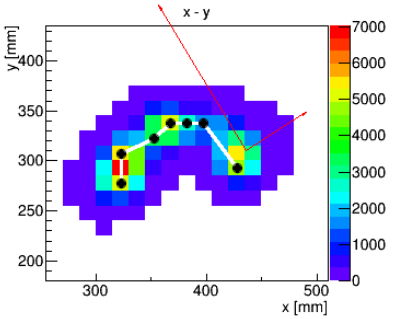
→ Kiseki Nakamura's poster for more details

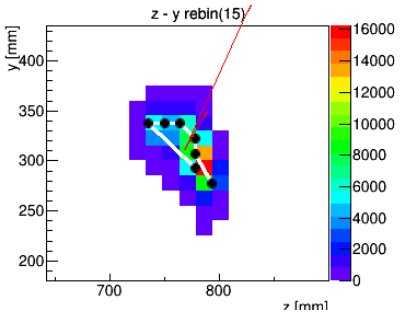
Finally, (very) rough sensitivity estimation

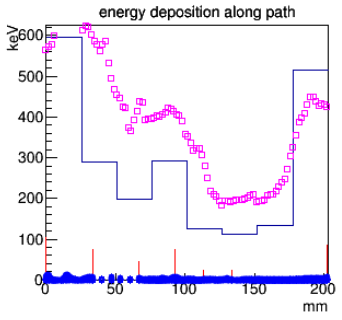
- 10bar 1ton enriched ^{136}Xe
- Signal
  - ✓ a few events/year @ $m_{\beta\beta}$=20meV
    - 79% contained in fiducial volume
    - 49% after clustering
    - 22% after blob-recognition
- Background
  - ✓ Only ^{214}Bi considered now. (cannot be separated by *E*)
  - ✓ 10 ton low background(3ppb) material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





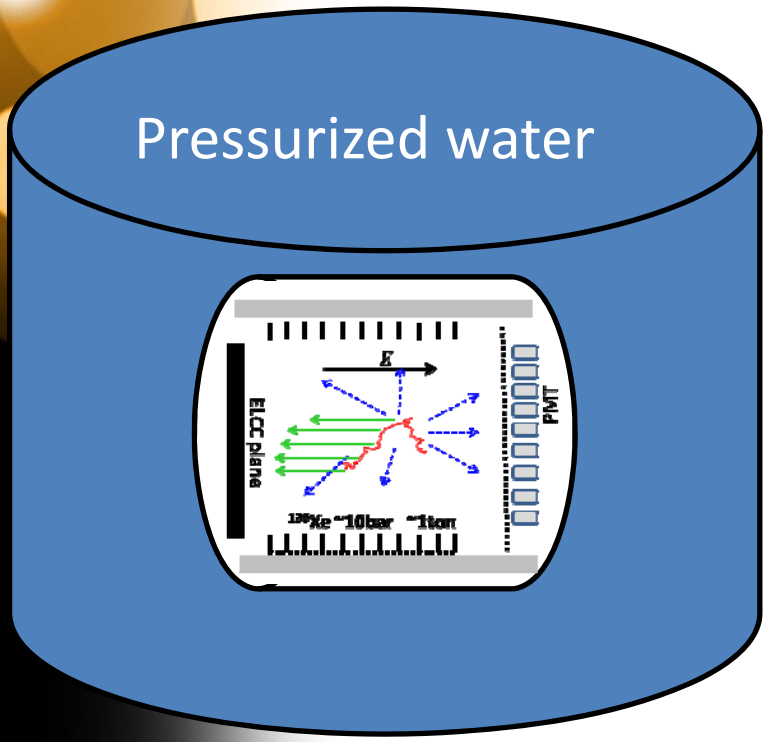






Recognition of track with a blob at both ends.
(algorithm optimization still in progress)

Finally,
(very) rough sensitivity estimation



- Thin vessel in low-bkg. pressurized water
  - bkg 7evts/yr → 0.1 evts/yr

→ sensitivity to ~20 meV

Summary

- AXEL is a high pressure Xe-gas TPC to search for $0\nu\beta\beta$
  - A Xenon ElectroLuminescence detector

    → Advanced Xenon ElectroLuminescence detector once 0.5%(FWHM) resolution is deonstrated
- We have developed a new electroluminescensce 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 at ~2 MeV in the next year