AXEL—a high pressure xenon gas TPC for 0νββ search

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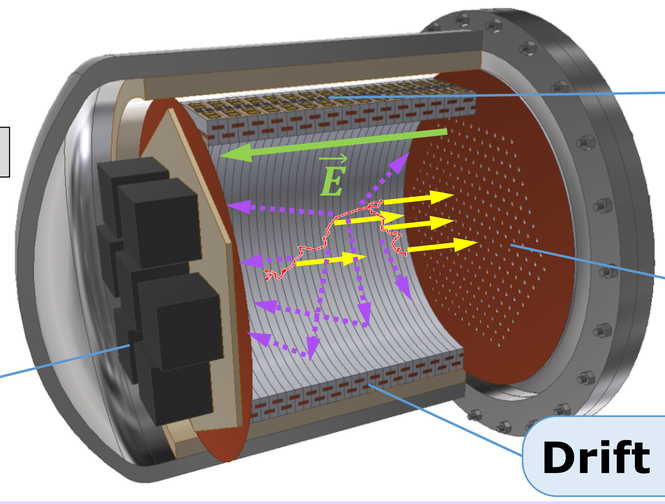
AXEL

- **A** **X**enon **E**lectro**L**uminescence detector (**AXEL**) is a high pressure xenon gas TPC to search for 0νββ of ^{136}Xe.
- The project is now in R&D phase.
  - ➢ 10-L prototype: Demonstration of our original detection method, ELCC
  - ➢ 180-L prototype: Evaluation of energy resolution near Q-value (2.458 MeV)

Feature

- ✓ **Large mass**
  —high pressure up to 10 bar
  —good scalability with solid structure
- ✓ **High energy resolution**
  —targeting 0.5% FWHM @Q-value
- ✓ **Background rejection** by tracking

Concept Drawing



Cockcroft-Walton Voltage multiplier
for HV generation

ELCC
energy measurement & tracking

PMTs
for time-zero signal of TPC

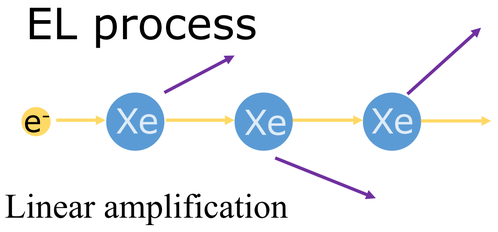
Drift field cage

: Drifting electrons
: Scintillation photons

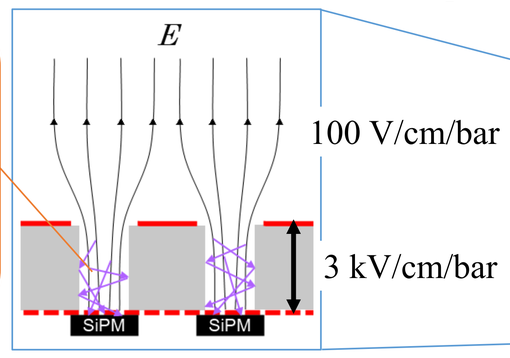
ELCC

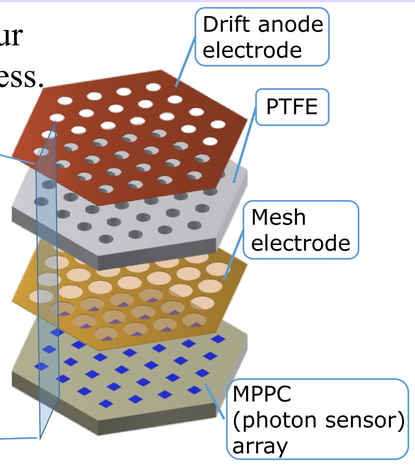
Electroluminescence **L**ight **C**ollection **C**ell (**ELCC**) is our original device to detect ionization electrons via EL process.

EL process



Linear amplification
⟶ Less fluctuation



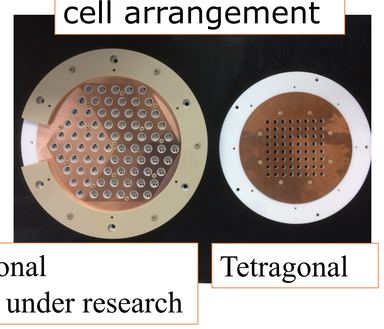


The usefulness of EL process in 0νββ search is demonstrated in the pioneering work by the NEXT collaboration.
In addition, ELCC has following features.

- EL amplification in a cell
  ⟶ EL gain does not depend on initial position of an electron.
- Rigid structure
  ⟶ No distortion like mesh.

High energy resolution is achievable even in large detector.

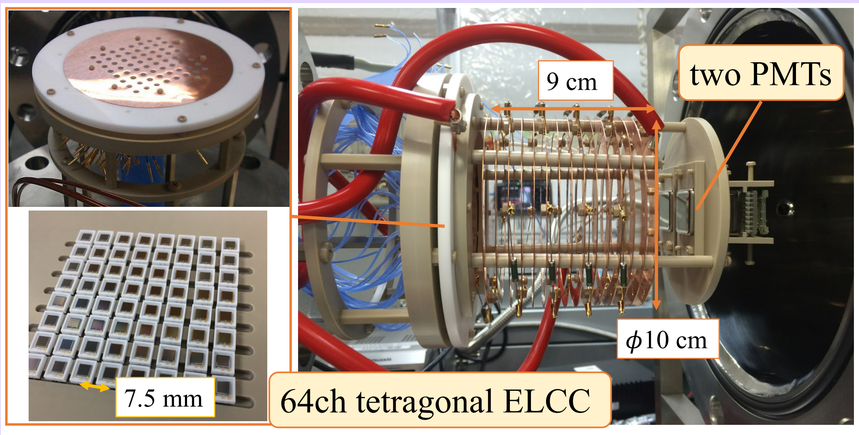
Two options for cell arrangement



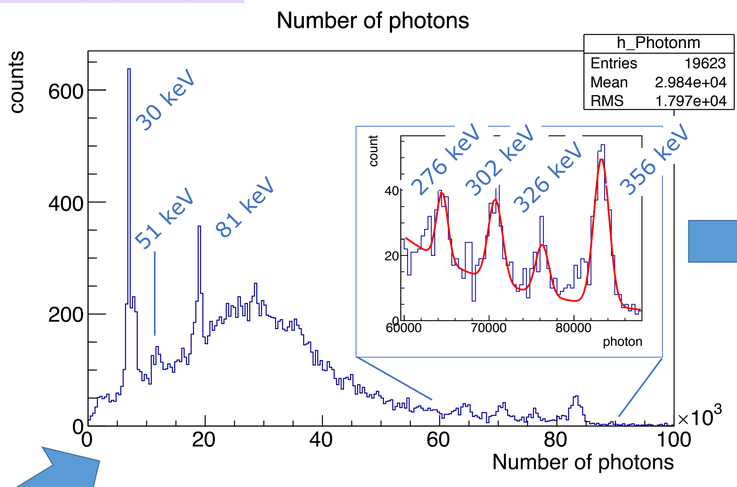
Hexagonal
—now under research

Tetragonal

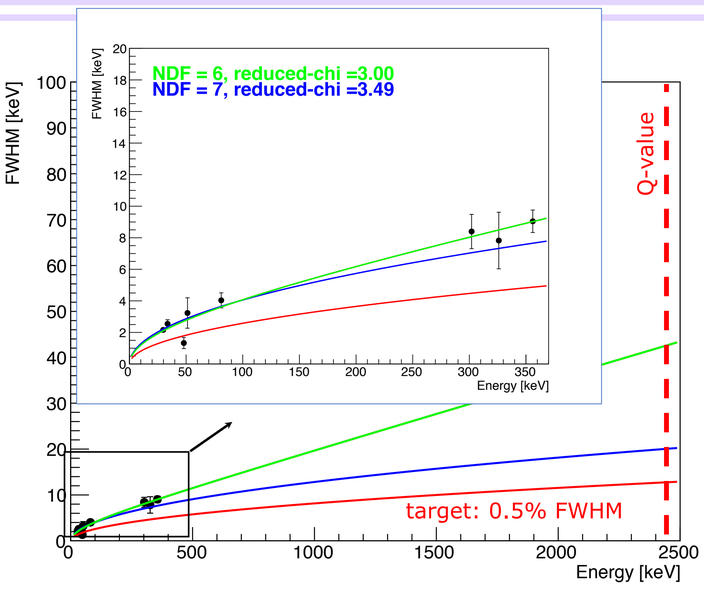
Energy resolution (10-L prototype)



Conditions	
Gas	Xe 8 bar
E_{EL}	2.375 kV/cm/bar
E_{drift}	83 V/cm/bar
Source	^{133}Ba



After several cuts
(fiducial cut, FADC saturation cut, …)
and corrections
(cell by cell gain correction, MPPC saturation correction, …)



Extrapolating the energy resolution to Q-value(2.458 MeV)
by $A\sqrt{E}$ (only statistics) : **0.82% FWHM**
by $A\sqrt{E+BE^2}$ (with any other causes) : **1.74% FWHM**

It is required to evaluate the energy resolution near Q-value.
⟶ 180-L prototype!!

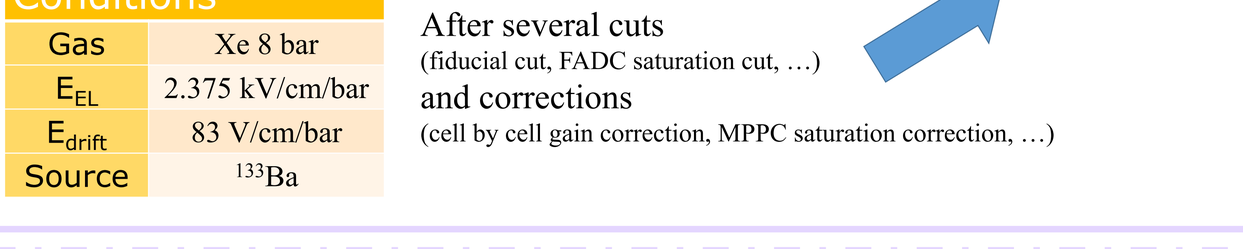
For 180-L prototype & a future larger detector

Cockcroft-Walton voltage multiplier

The voltage of the drift top electrode will be **65 kV** for 180-L prototype,
and **few hundred kV** for future detector.

!! **Electric discharge on the feedthrough** will become a severe problem !!

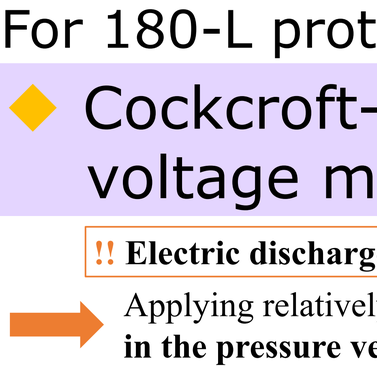
Applying relatively low AC voltage (few kV) and convert it to DC high voltage **in the pressure vessel** with Cockcroft-Walton (CW) voltage multiplier.



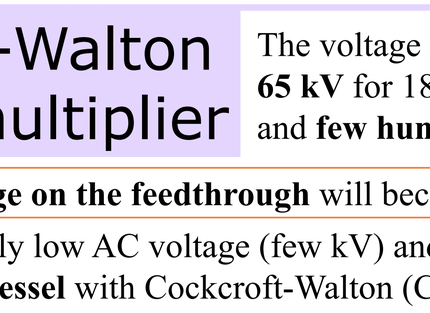
CW multiplier on a FPC

For use in xenon gas,
only low-outgassing materials are allowed.

- Polyimide-based Flexible Print Circuit (FPC)
- Electrically conductive epoxy



10-stage CW multiplier
- 100-nF capacitors
- 100-MΩ resistors; two for each stage



We achieved output of **10.3 kV** with input amplitude of 540 V.

The output voltage was stable for at least 12 hours.

Higher voltage is expected to be generated with higher input or more stages.

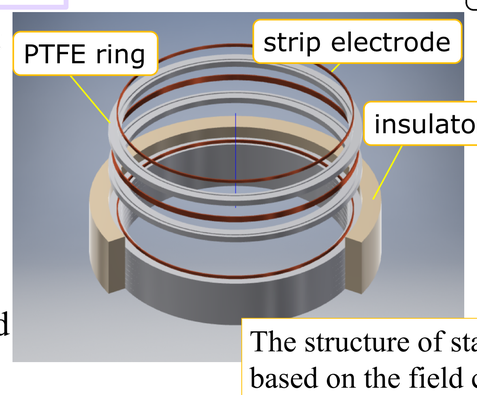
! The effect of electrical noise caused by charging capacitors is under investigation. !

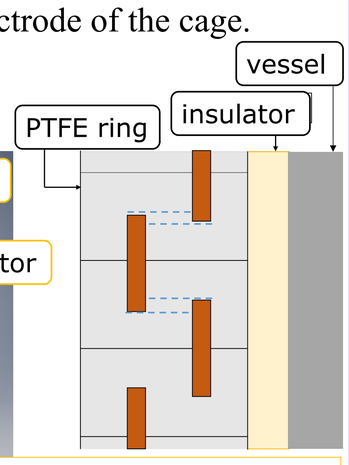
Drift field cage

The drift field cage for a larger detector must
- form a strong and uniform field(**100 V/cm/bar ±5%**) over a large volume.
- **prevent an electric discharge** between the vessel and an electrode of the cage.
- **reflect scintillation photons** (VUV; λ~175 nm) on PMTs.

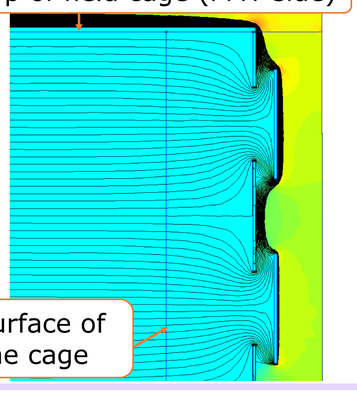
Double strip structure

Strip electrodes of two different radius with a little overlaps.
⟶ The potential of vessel (0 V) do not affect the fiducial volume.
⟶ Good uniformity of electric field even on the surface of the cage

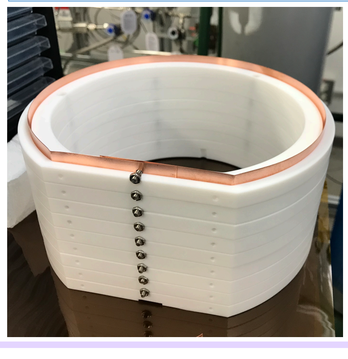


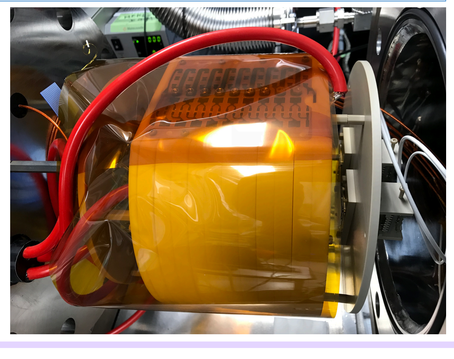


The structure of stacking PTFE rings is based on the field cage of LZ experiment.



A test of this structure in 10-L prototype is ongoing!!





Other developments

- Front end board
- Calibration system for more than 1,000 MPPCs
- Background rejection by tracking with deep learning technique
- Positive ion detection for less diffusional tracking