AXEL

High pressure Xe gas TPC for neutrinoless double-beta decay search

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What's AXEL?

We are developing a high pressure Xe gas TPC to search for 0νββ from ^{136}Xe (Q=2.48MeV).

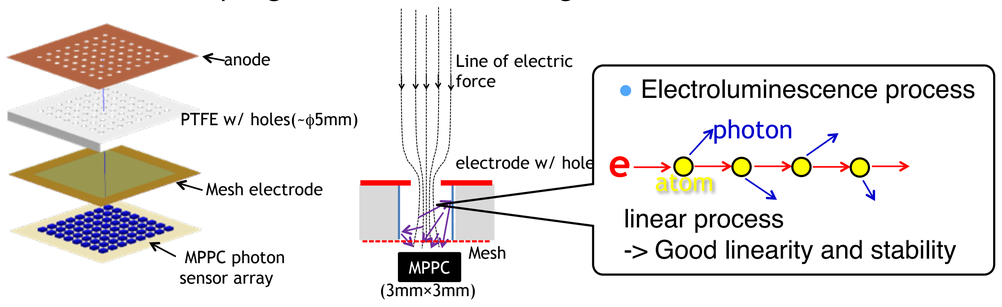
Feature

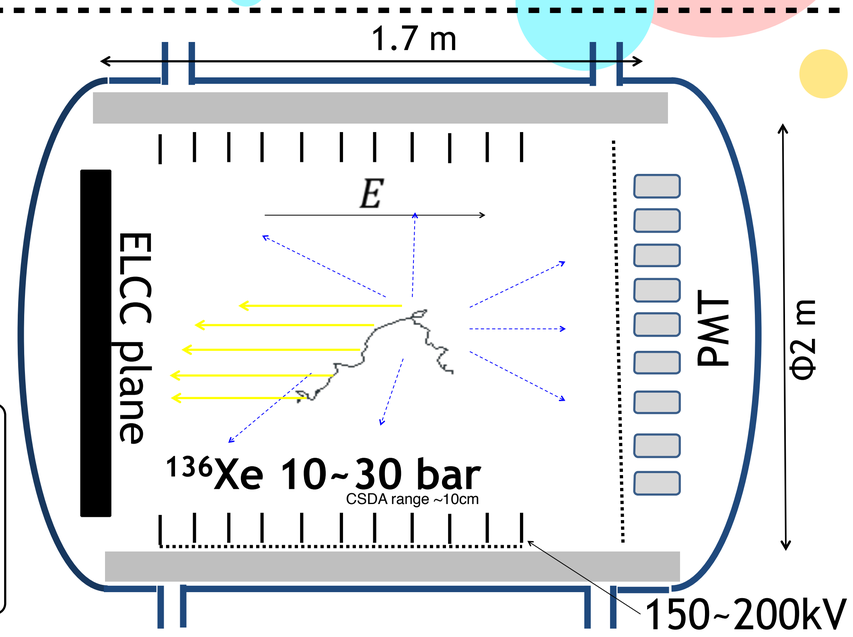
- Good energy resolution : 0.5% (FWHM@2.48MeV)
  -> Using proportional scintillation mode
- Large mass (1ton)
- Background rejection with tracking
  -> Reject alpha (very short track)
  -> Reject compton gamma (multi-site event)
  -> Reject gamma (single blob at end point)

ELCC (Electroluminescence Light Collection Cell)

- Ionization electrons are collected into a cell and produce EL
- Less dependence on event position
- Easy to extend to large area due to solid structure

We are developing ELCC with our original idea!

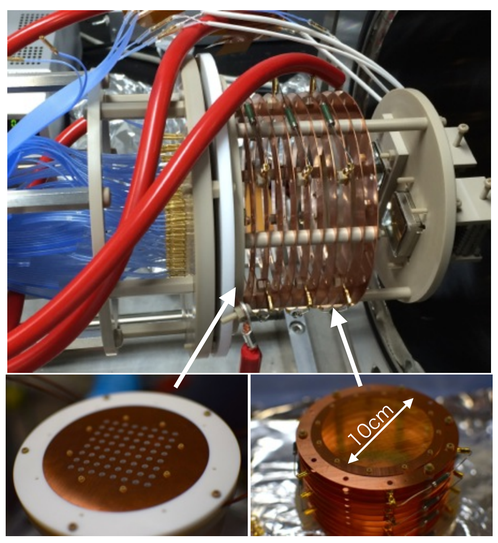




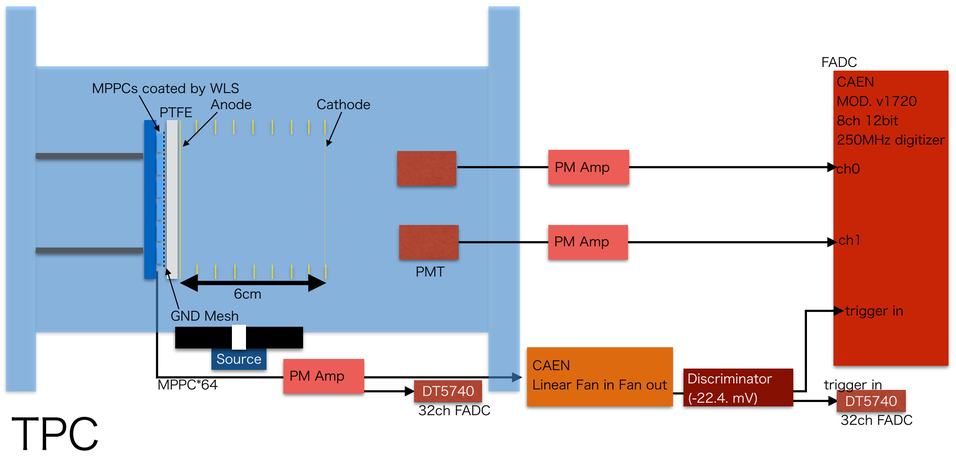
R&D Status

Prototype Chamber

Prototype chamber with 64ch MPPCs, two PMTs and up to 10 bar Xe gas.

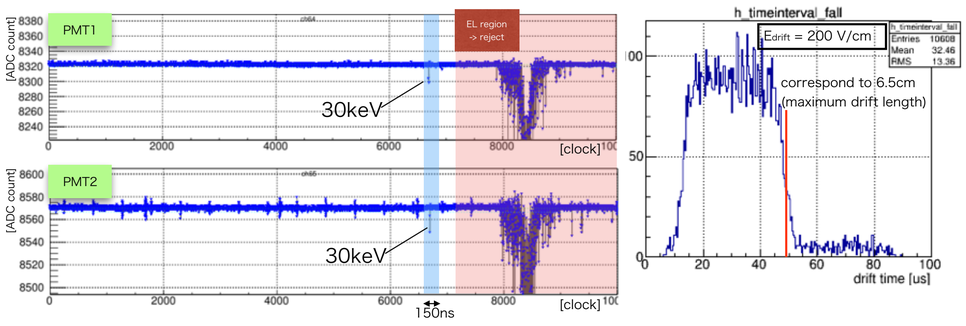


Sensitive volume : 6cm-long and 10cm diameter.
MPPC sensitive only to visible light. An acrylic plate coated with WLS(TPB) is placed in front. Will be replaced with VUV-sensitive MPPCs in November.



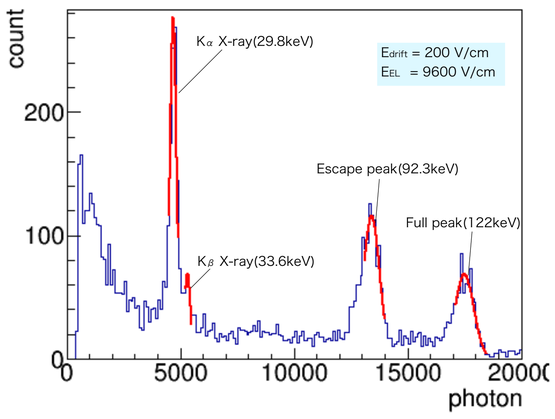
Demonstration as a TPC

In order to determine t_0 signal, coincidence of two PMT signals within 150ns is required.
-> Succeed to detect scintillation light signal and reconstruct z position.
-> Drift velocity was measured.



Energy Resolution

Energy measurement using ^{57}Co gamma source and 4 bar Xe gas.



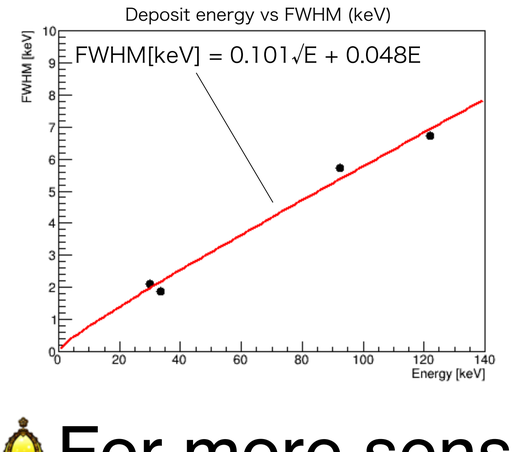
- Evaluate EL gain using 29.98keV peak

initial electrons : 29980eV / 22.1eV(W-value) = 1347.5
detected photons : 4692.2 photons
-> over all gain = 4692.2 / 1347.5 = 3.482

consistent with reference : $dN_{photon}/dz = 70(E/p - 1.0)p$
noble gas detector (ISBN : 978-3-527-40597-6)

- The energy resolution was evaluated by fitting these peaks with Gaussian.

Energy [keV]	29.78	33.62	92.28	122.06
# of photon	4692.2	5323.6	13418.2	17501.9
FWHM	7.1%	5.6%	6.2%	5.5%



We evaluated FWHM at Q-value by fitting the plot of deposit energy vs energy (FWHM) with the function : $\mathrm{FWHM} = A\sqrt{E} + BE$
(E : energy[keV], A,B : Fitting parameter)

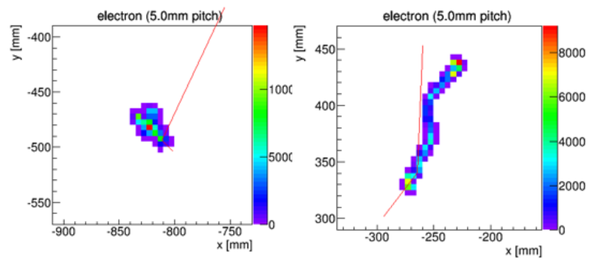
Extrapolate to 2.48MeV
-> FWHM(@2.48MeV) : 4.96%

Cross talk by the WLS plate may be an issue.
-> Replace with VUV-sensitive MPPCs soon.

For more sensitivity

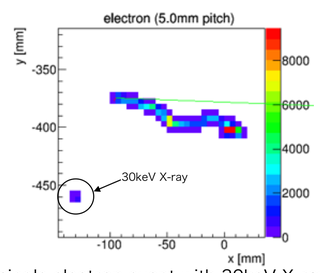
Add He gas into Xe to make it easy to search the two end points of 0vbb decay

Simulated event display



double beta decay event
(30 bar, 100% Xe)

double beta decay event
(30 bar, 25% Xe & 75% He)



single electron event with 30keV X-ray
(30bar, 25% Xe & 75% He)

- Can reject single-end-blob event.
- Can use X-ray emitted from Xe to reject single electron event
  -> cannot use in pure Xe gas because of too short m.f.p.

Now evaluating signal efficiency and back ground rejection ability by simulation.

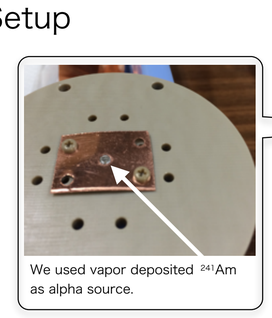
Basic properties of MPPC

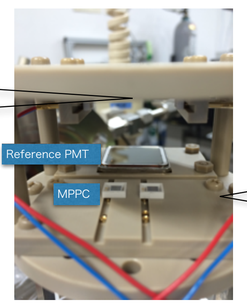
PDE measurement

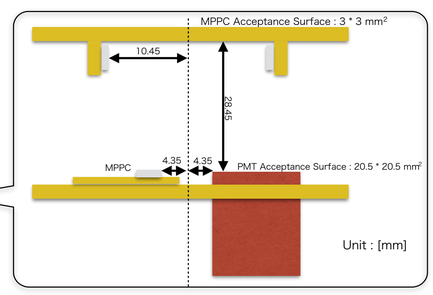
・Motivation
- Want to measure PDE for VUV light(170nm) from high pressure Xe gas.

・Experiment
- Mini chamber filled with 8bar Xe gas.
- Scintillation light from α (UV-PMT as a reference).

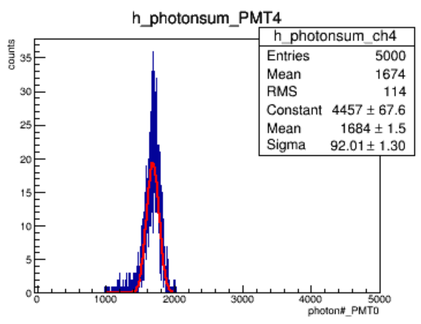
・Setup



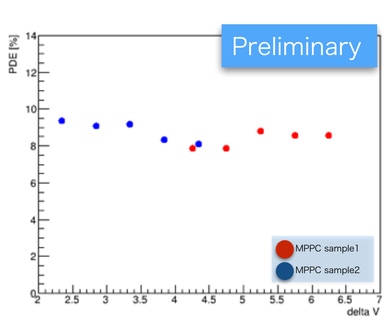




・Results



Photon spectrum of alpha source detected by PMT
-> alpha ray has mono-energy.



PDE vs over voltage

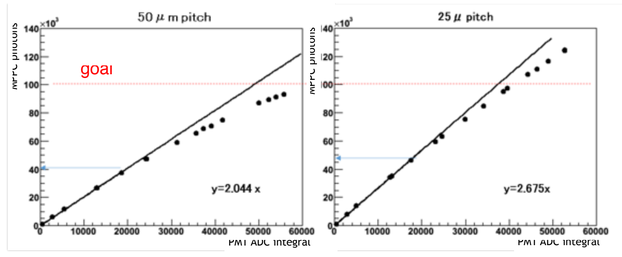
Effect of crosstalk and afterpulse is corrected.
But still under check. PDE can be better (PDE:11~12%)

Linearity of MPPC

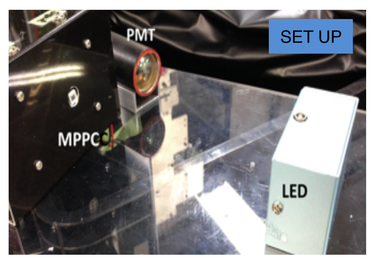
・Motivation
- Linearity is very important to obtain high energy resolution.
- Many photons (~10^5) may come in long time (~5usec).

・Studied by using LED light and comparing PMT.

・Result
- Good linearity up to ~4*10^4 photons/5us (50um-pitch pixel, crosstalk suppression),
  ~5*10^4 photons/5us (25um-pitch pixel, non crosstalk suppression).
-> We can apply correction with little errors.
-> Correction fluctuation due to non-linear effect : 0.0033%(@10^5 photons)
- Recovery time τ is evaluated by fitted by the function : $y = \frac{1}{1/ax + \frac{\tau}{\mathrm{Npixels} \times 5\mu s}}$
-> Result : 49.5ns(50um), 89.3ns(25um), consistent with spec sheet.



Plot of photons detected by PMT vs photons detected by MPPC



Future plan

Upsizing our detector.