The performance evaluation of the MPPC for the liquid xenon gamma-ray detector in MEG II experiment
(MEG II 実験での液体キセノンガンマ線検出器に用いるMPPCの性能評価)

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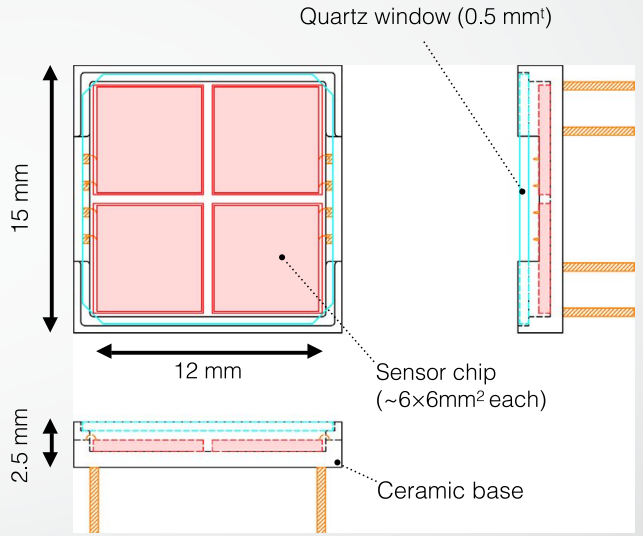
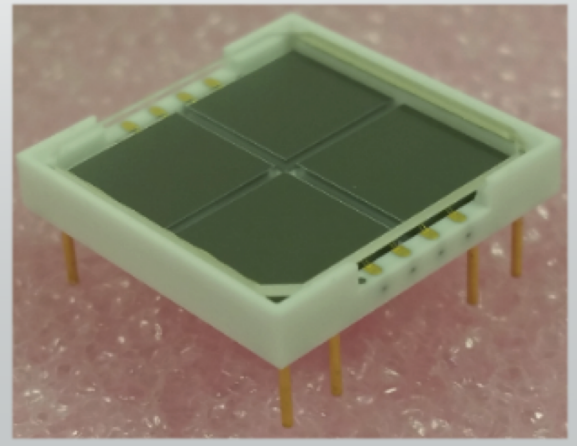
Large VUV-sensitive MPPC in MEG II

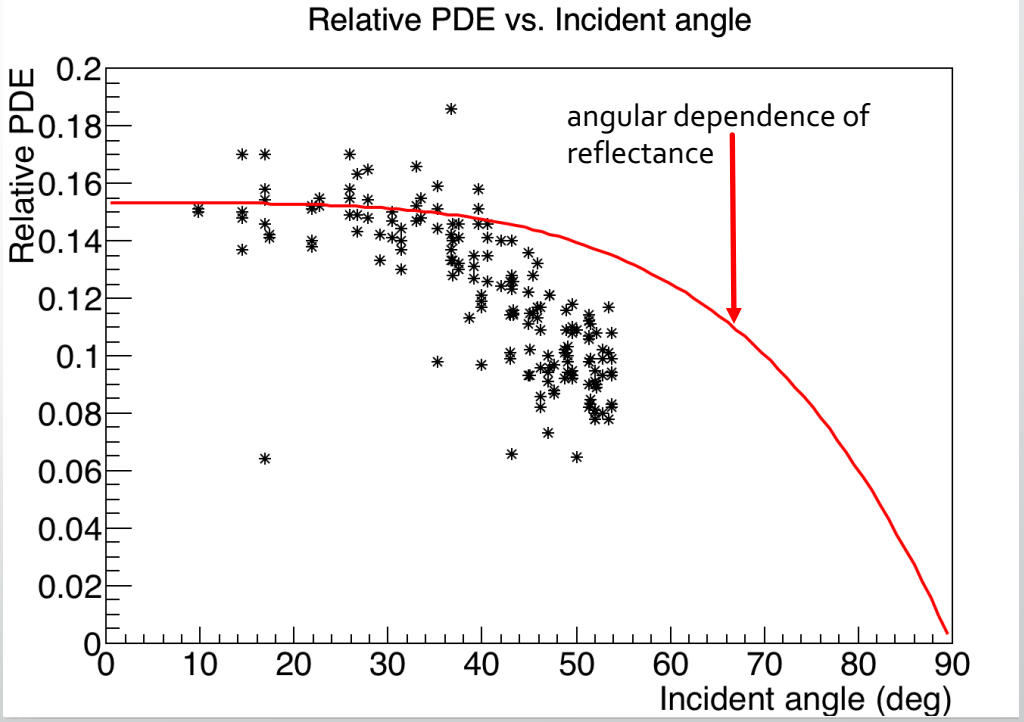
- In MEG II experiment, we have developed MPPCs with large sensitive area in collaboration with Hamamatsu Photonics
- Size: 12*12mm² with four 6*6mm² chips in the series connection
- Sensitive for Xe scintillated VUV photon (λ=175nm)
- Quartz window is placed to protect the sensor surface





The previous measurement of PDE angular dependence

- In the measurement of mass MPPCs, the PDE dependence against the incident angle of photons was shown
- The experiment is done in the liquid xenon, same as in MEG II experiment
- The result seems to be different from the expectation that only reflectance dependence exist

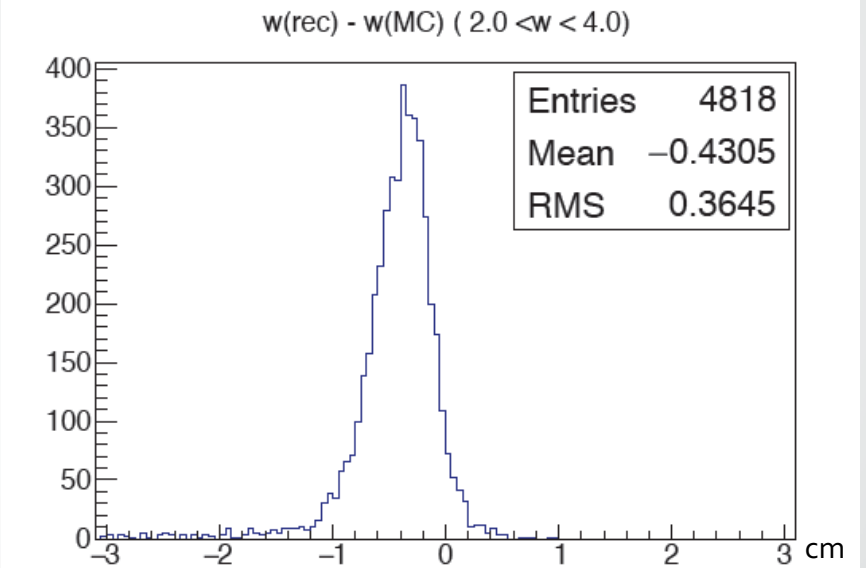


Ref: JPS2015秋季大会「MEG II実験液体キセノンガンマ線検出器に向けた再構成法の研究」,小川他

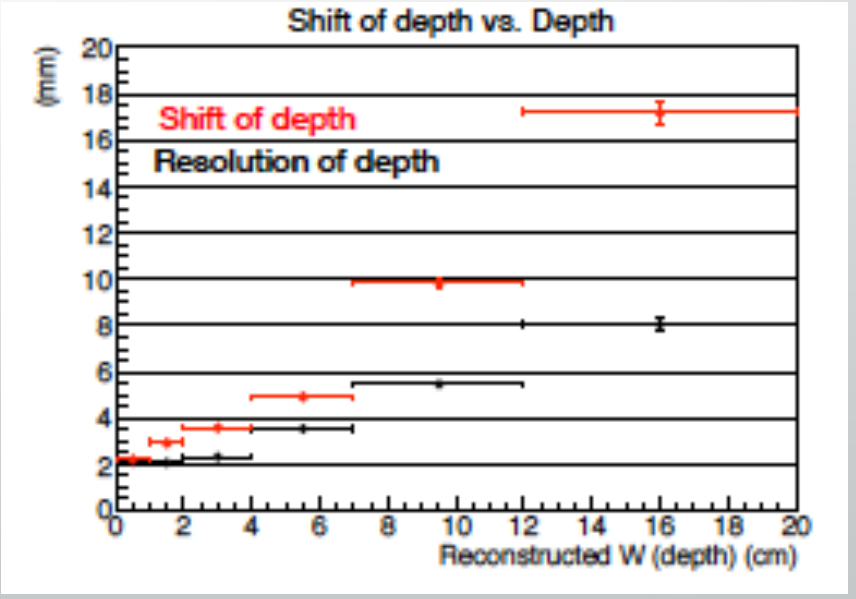
The problem with the unexpected angular dependence

- Reconstructed depth will change depending on the incident angle of photons
- The position reconstruction can be biased if a wrong angle dependence of the PDE is used.

→To understand the angular dependence of MPPC is needed



the difference between MC simulation and data



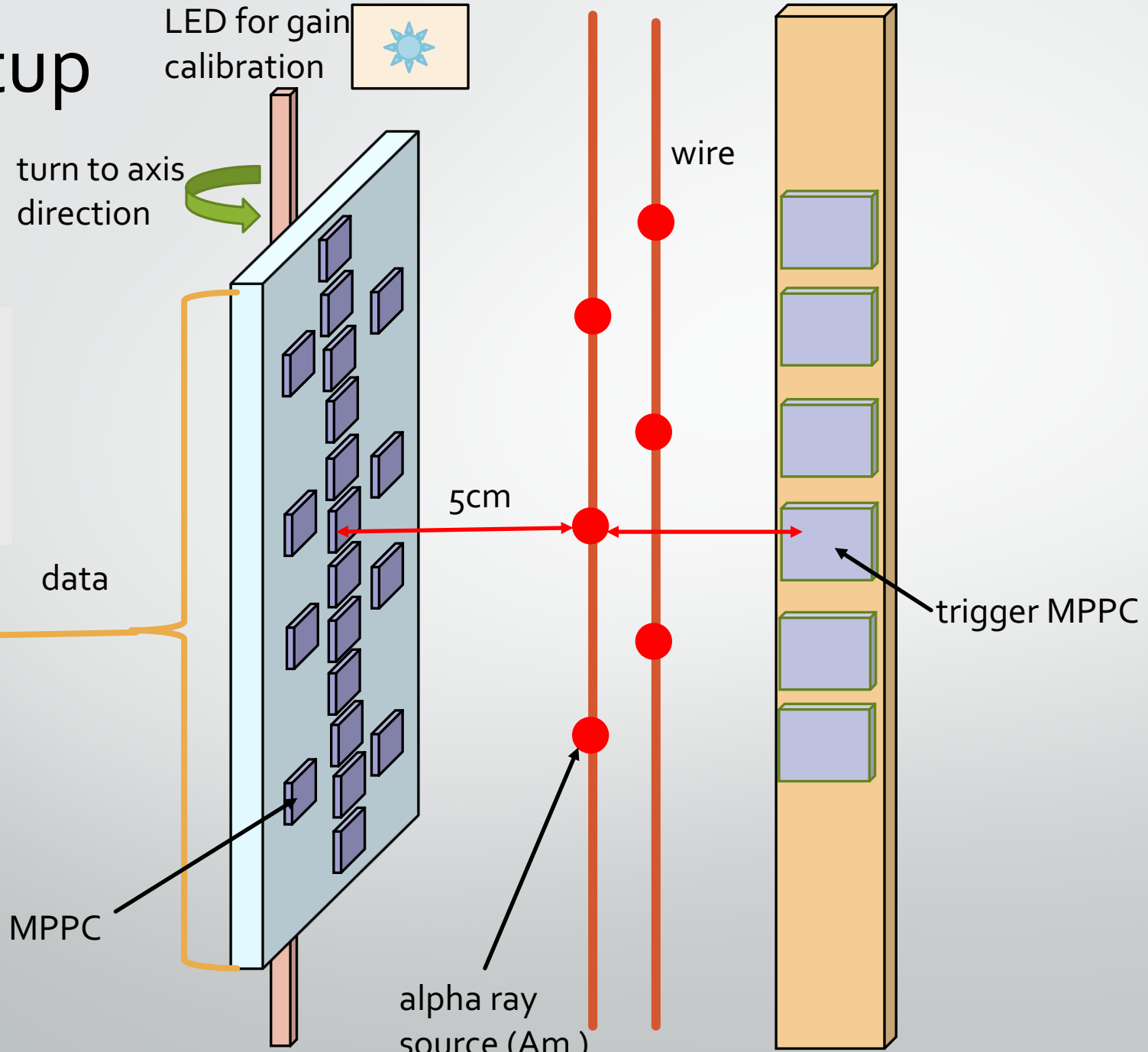
Xe

	gas Xe	liquid Xe
good	• easy to be treated with in the room temperature • no attenuation of photons	• refractive index: LXe~= quartz window, window is "transparent" • low temperature = MPPC dark noise is small
bad	• refractive index: gas Xe<quartz window • bigger dark noise • source cannot be treated as a point • alpha ray flying range is too long	• difficult to be treated, because to keep ~165K is needed • liquefaction takes much time

- The angular dependence of PDE for the final version of VUV-MPPC is measured in gas xenon
- Because of the convenience for using gas, gas xenon is used for this experiment
- The pressure of gas Xe is 2.6 bar, at room temperature
- To avoid the refraction in windows, windows on MPPCs are removed

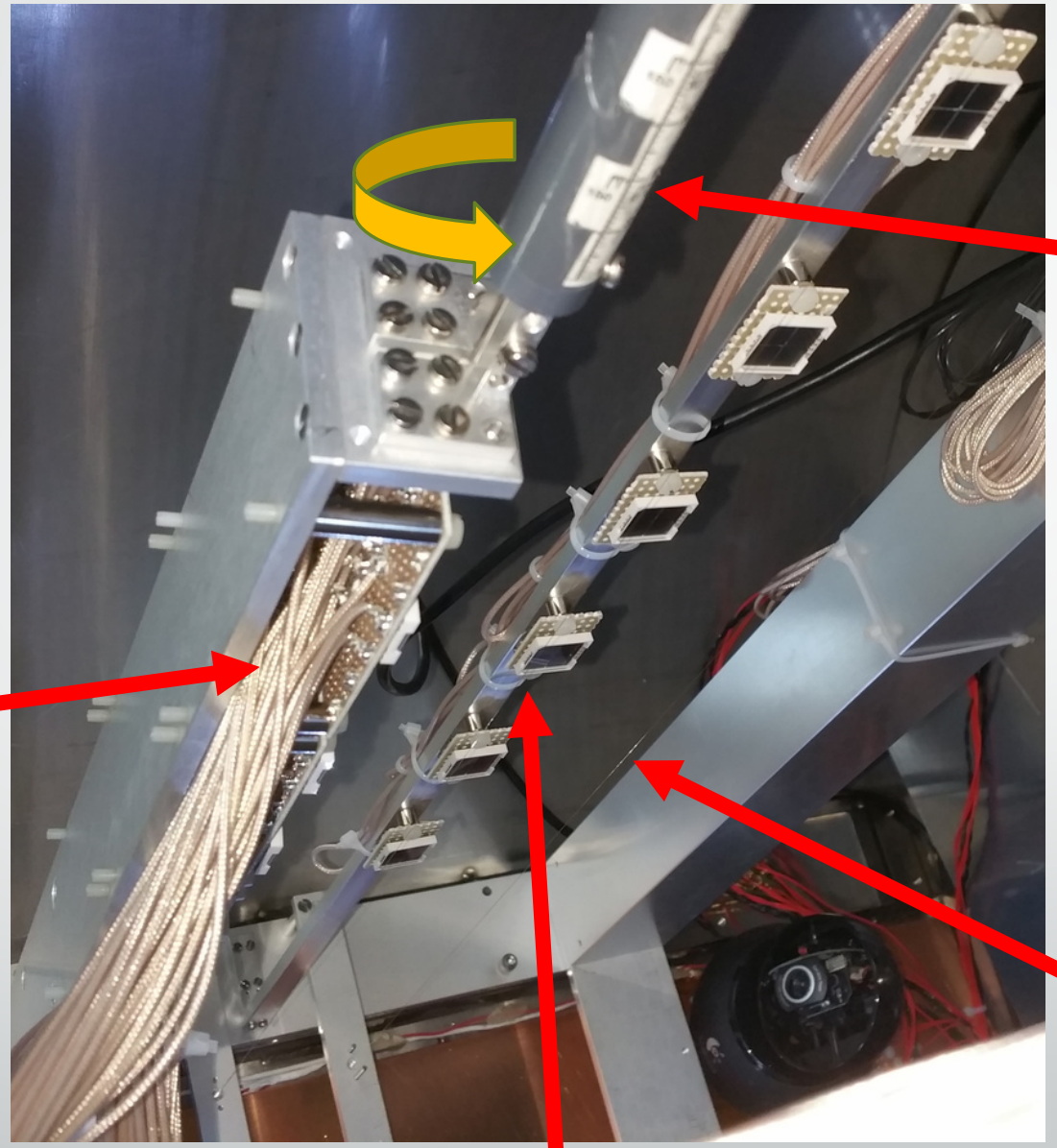
Setup

DRS (Domino Ring Sampling chips): the wave digitizer developed in PSI (Paul Scherrer Institut)

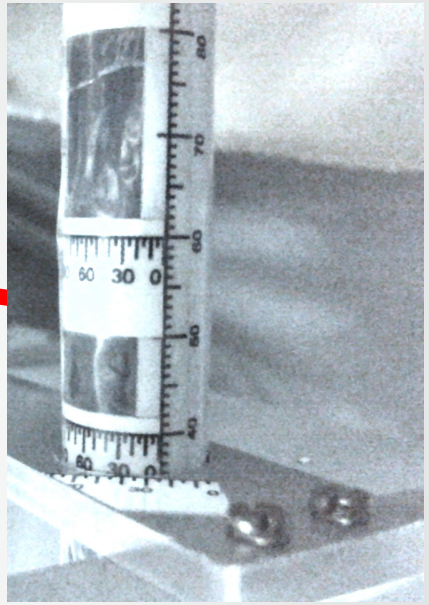


Setup

rod with MPPCs, signal is read by each chip



trigger channel

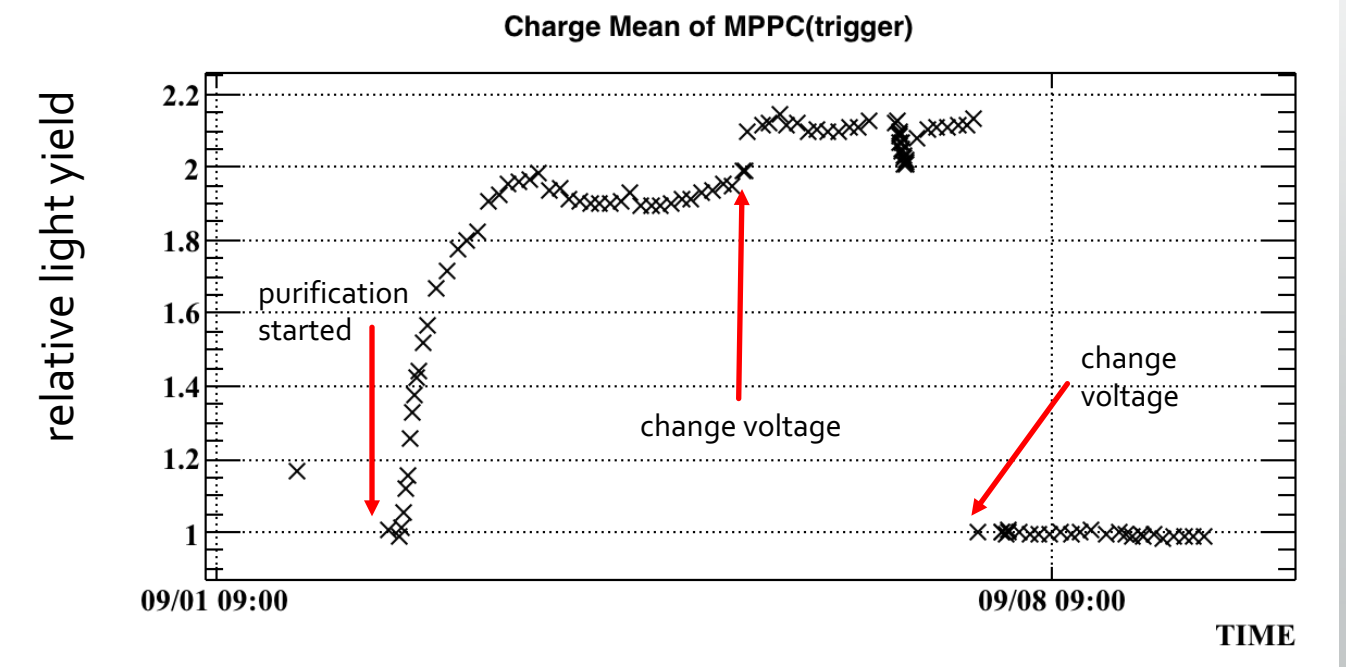


a pipe to check the angle (precision:~1°) and height of the rod, scale can be checked with a camera

wire with alpha ray source (Americium)

Purification

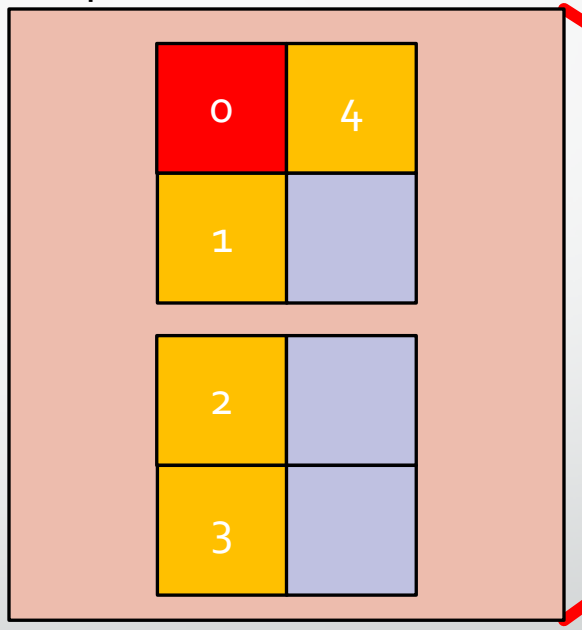
- The inside of the chamber must kept pure because with impurity the emission of light gets much worse
- Purification is done for several days with a getter pump
- X100 GXe volume is purified
- Because purification is not enough, but only relative PDE is discussed for measuring angular dependence



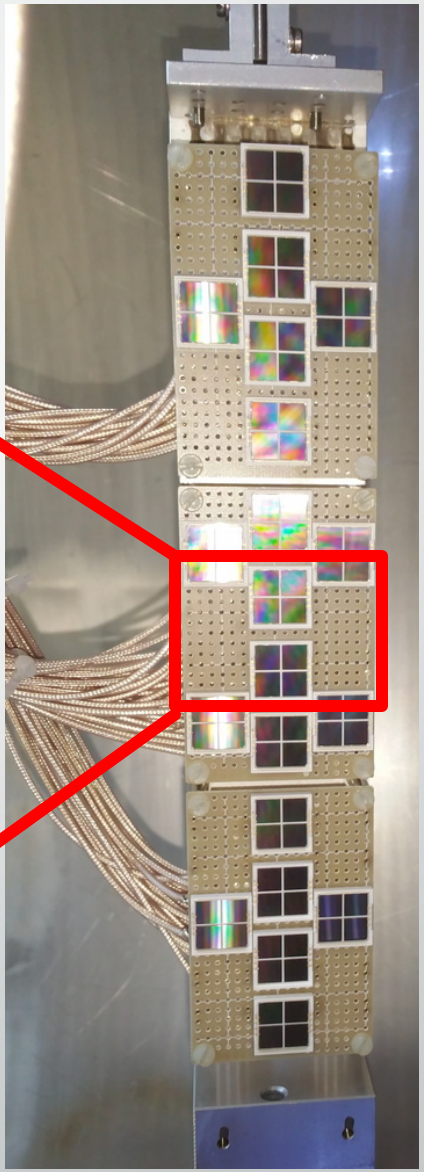
Data taking

- The MPPCs are rotated every 10 degrees, from 0 to 90
- Voltage is set as Hamamatsu recommended voltage (~Vbd+4.3V)
- Alpha ray source is set in front of trigger channel and ch 0
- Two kind data are taken; 1. LED run for calibration and 2. alpha ray run for getting number of photons

orange: used channels
red: used & in front of alpha source



the others are not used because there is no much time…



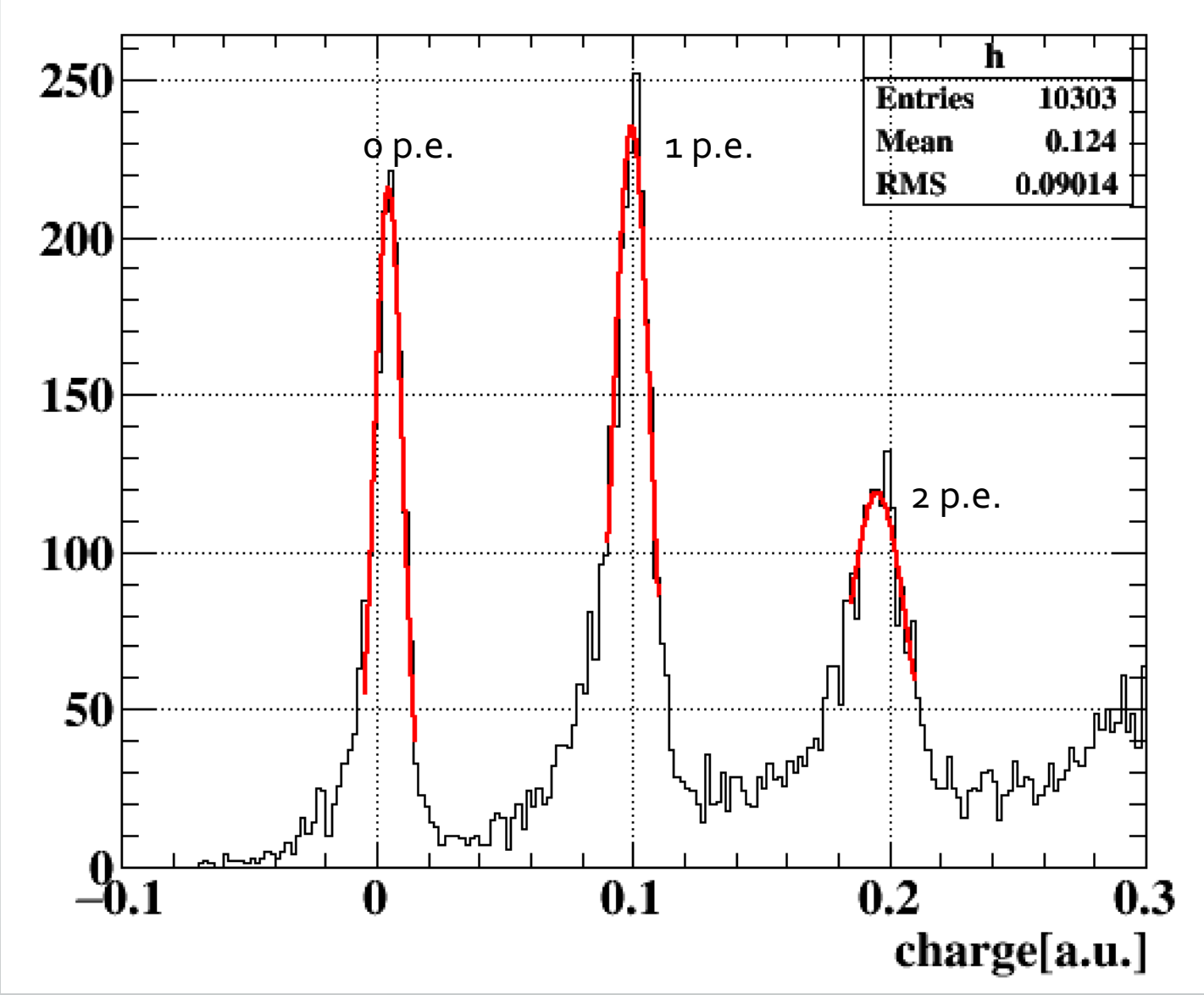
Analysis

1. Obtain a MPPC's gain
2. Transform charge to the number of photoelectrons
3. Count the number of photoelectrons from alpha ray on each angle
4. PDE is estimated by comparing the measured N_{pe} and the expected N_{pe}

expected value = (energy of alpha ray) / (w value) * (solid angle that is occupied by a MPPC)
w value: energy that is needed to create single photon, unique to each material

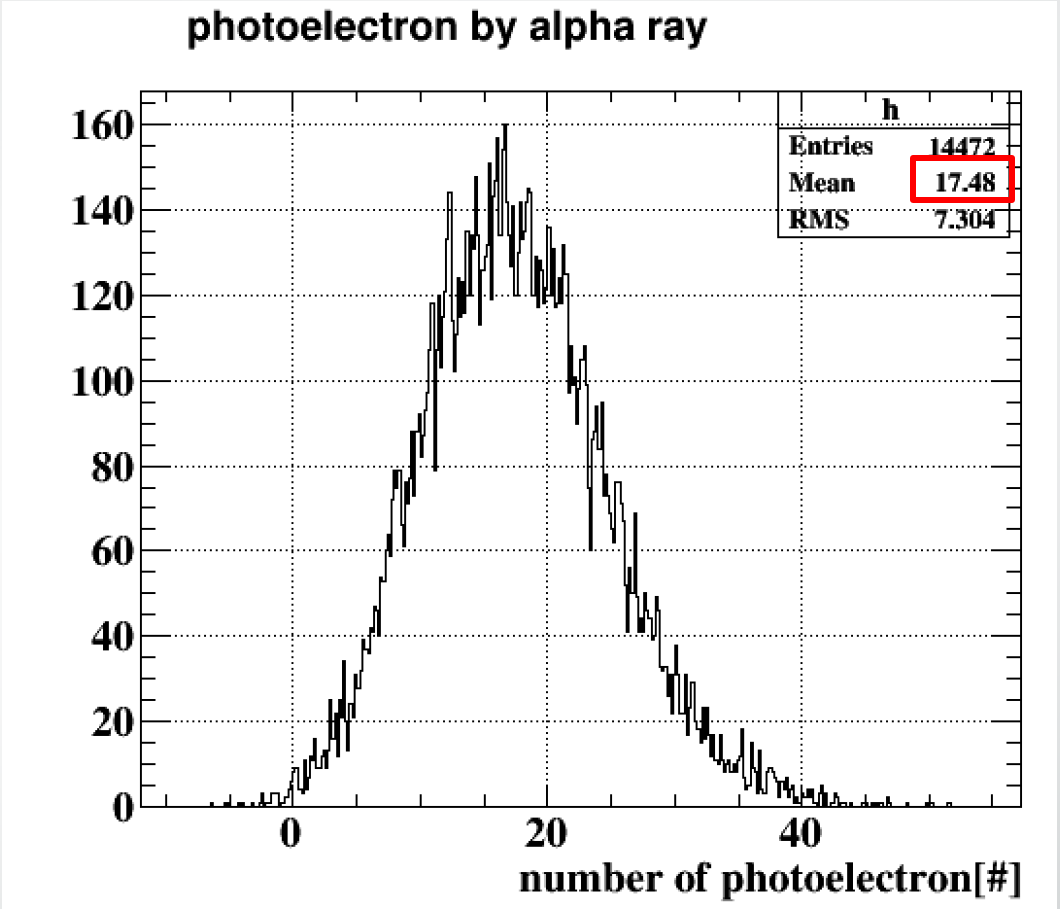
Gain

- MPPC gain is measured by the spectrum obtained for low level light from LED
- Gain is calculated by the distance of peaks

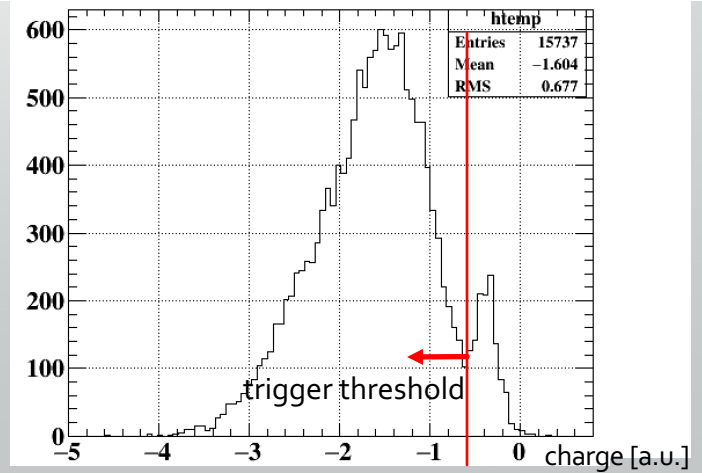


Alpha ray photon count

- The data are distinguished by trigger channel (with alpha ray) and pedestal signals are removed
- Mean is used for PDE estimation
- Cross talk, after pulse are not corrected for in the PDE estimation

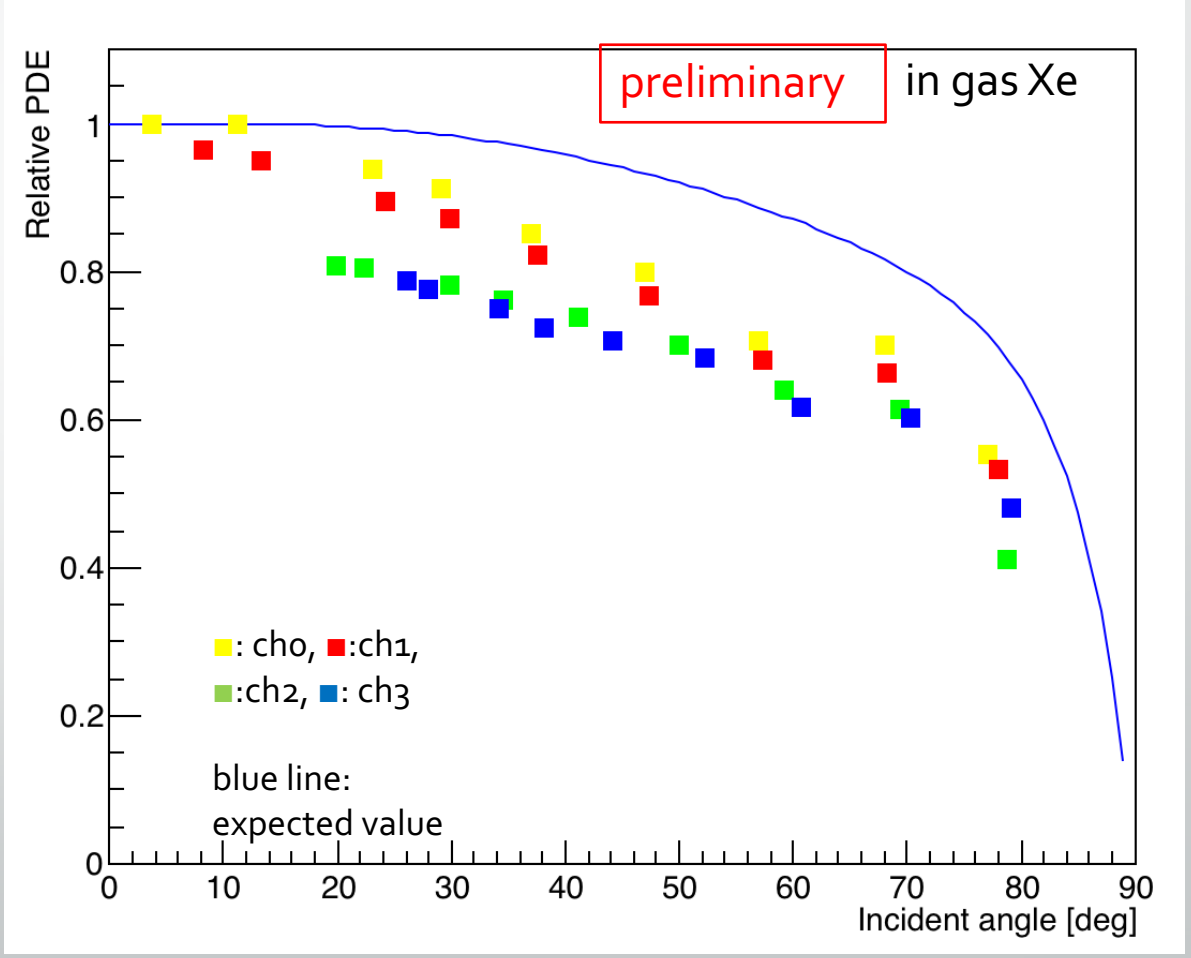


charge distribution of trigger channel



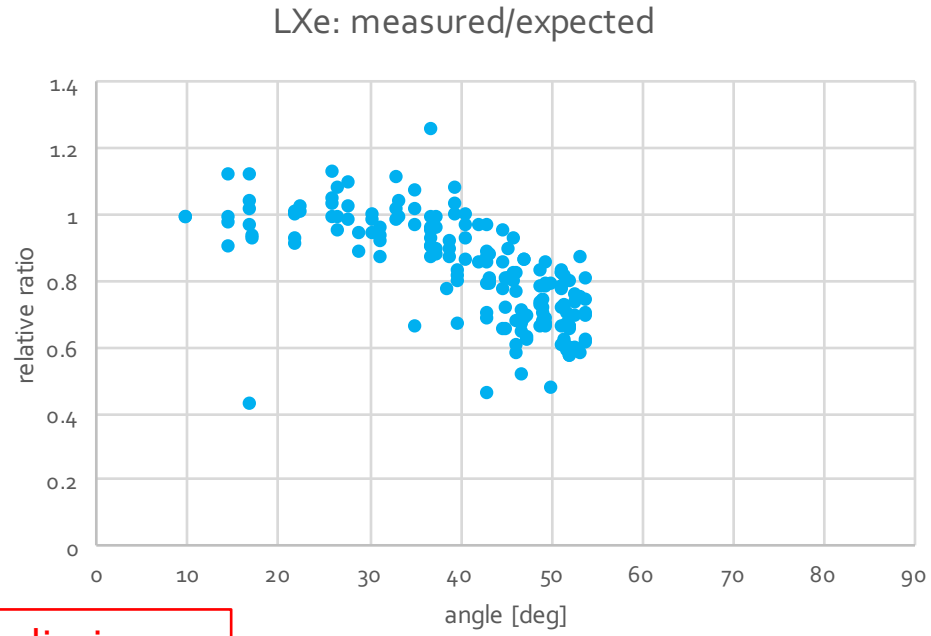
Result – the angular dependence of PDE in gas Xe

- Relative PDE = (measured photons)/(expected number of impinging photons)÷(PDE when $\theta = 0°$)
- Existence of angular dependence of PDE is confirmed

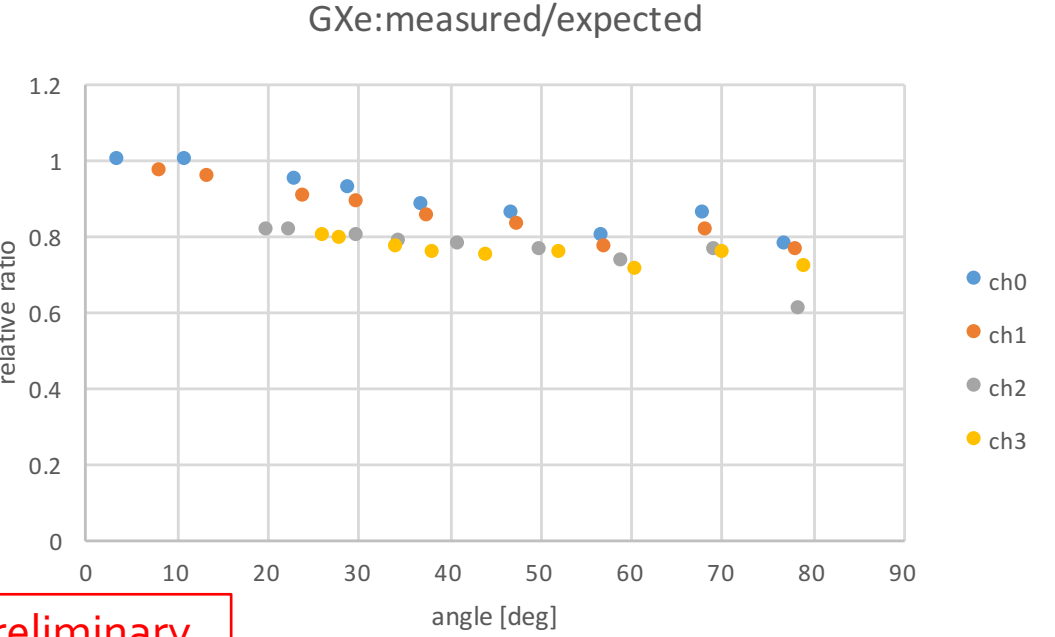


Comparison between in liquid and in gas

- Angular dependence of the ratio between measured data and expectation in liquid and in gas
- When $\theta = 0$, value is set as 1
- The ratio is not consistent
- The dependence of PDE is different in liquid and in gas
- The cause of this behavior is now under search



preliminary



preliminary

Next step

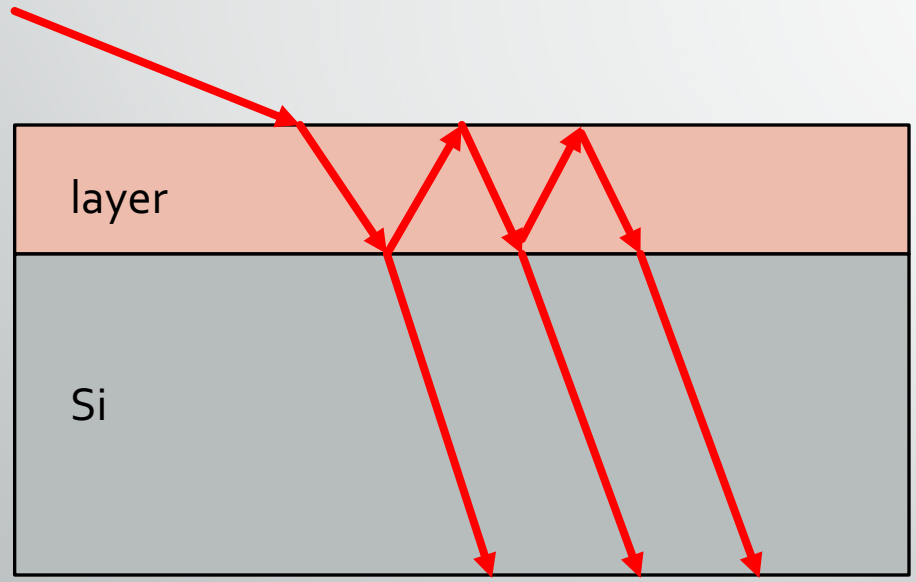
- Study the characters of MPPCs
  1. Study the difference between in the gas and the liquid
  2. Study sensor-by-sensor variation in MPPC properties
  3. Obtain an absolute PDE
     - Further purification of GXe
     - Correct cross talk and after pulse

Summary

- The experiment to check the angle dependence of PDE was done
- In the gas, angular dependence of PDE is not consistent with the expectation
- It seems that the tendency of PDE is different in the gas or in the liquid
- Angular dependence of PDE is needed to be understood for correct position reconstruction

backup

The model of expectation



- The refraction model shown in the figure is used
- Reflection rate and transmission rate are calculated from Fresnel equation

$$r_p = \frac{n_2^2 cos\theta - n_1\sqrt{n_2^2 - n_1^2 \sin^2\theta}}{n_2^2 cos\theta + n_1\sqrt{n_2^2 - n_1^2 \sin^2\theta}}$$

$$r_s = \frac{n_1 cos\theta - \sqrt{n_2^2 - n_1^2 \sin^2\theta}}{n_1 cos\theta + \sqrt{n_2^2 - n_1^2 \sin^2\theta}}$$

$$t = 1 - \frac{r_p + r_s}{2}$$

past experiment

- 6oo MPPCs are put into liquid xenon: on the top and the bottom
- LED calibration and alpha ray photons measuring is done