MEG II実験
液体キセノンガンマ線検出器における光センサーの較正

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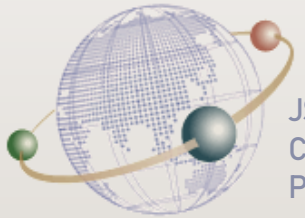
家城佳, 他MEG IIコラボレーション

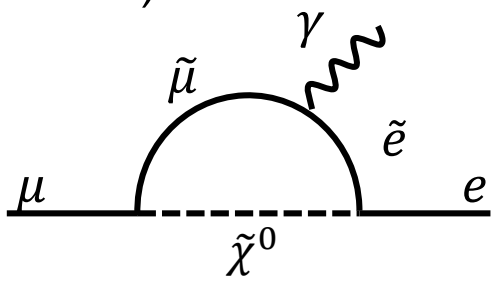


JSPS
Core-to-Core
Program

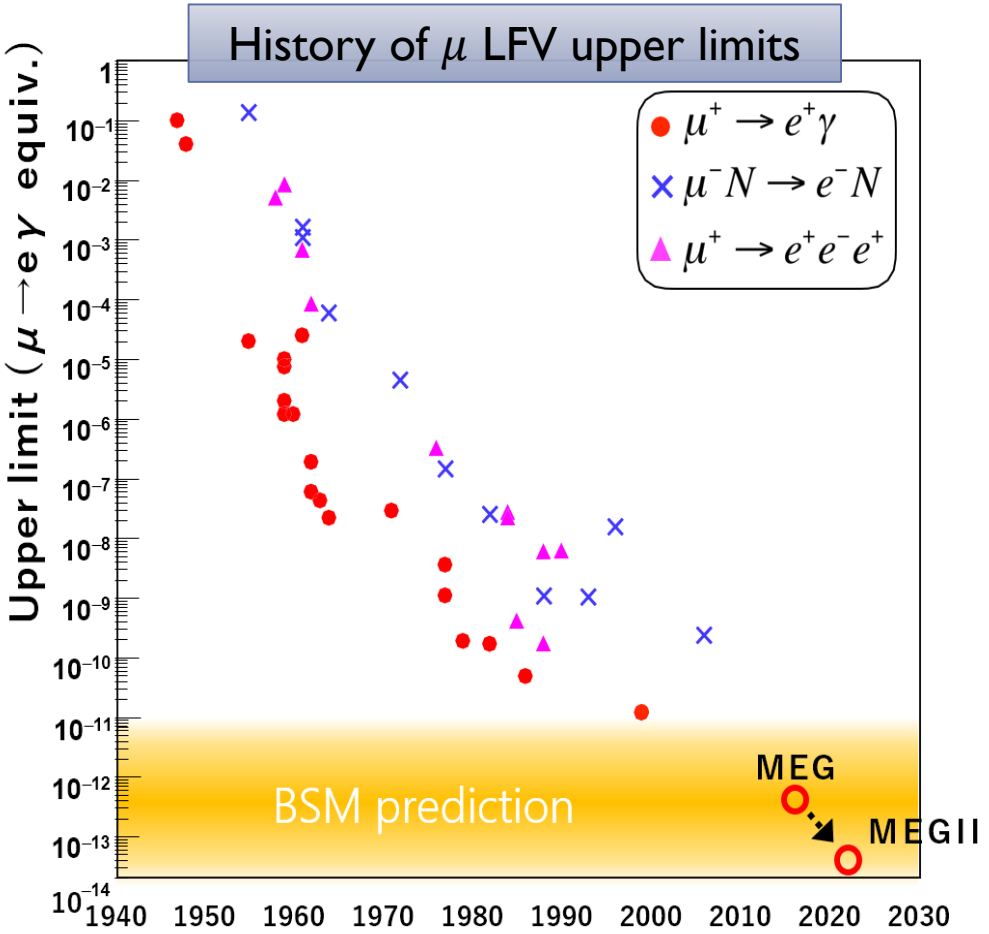
$\mu \to e\gamma$ decay

MEG II experiment searches for cLFV decay, $\mu \to e\gamma$.

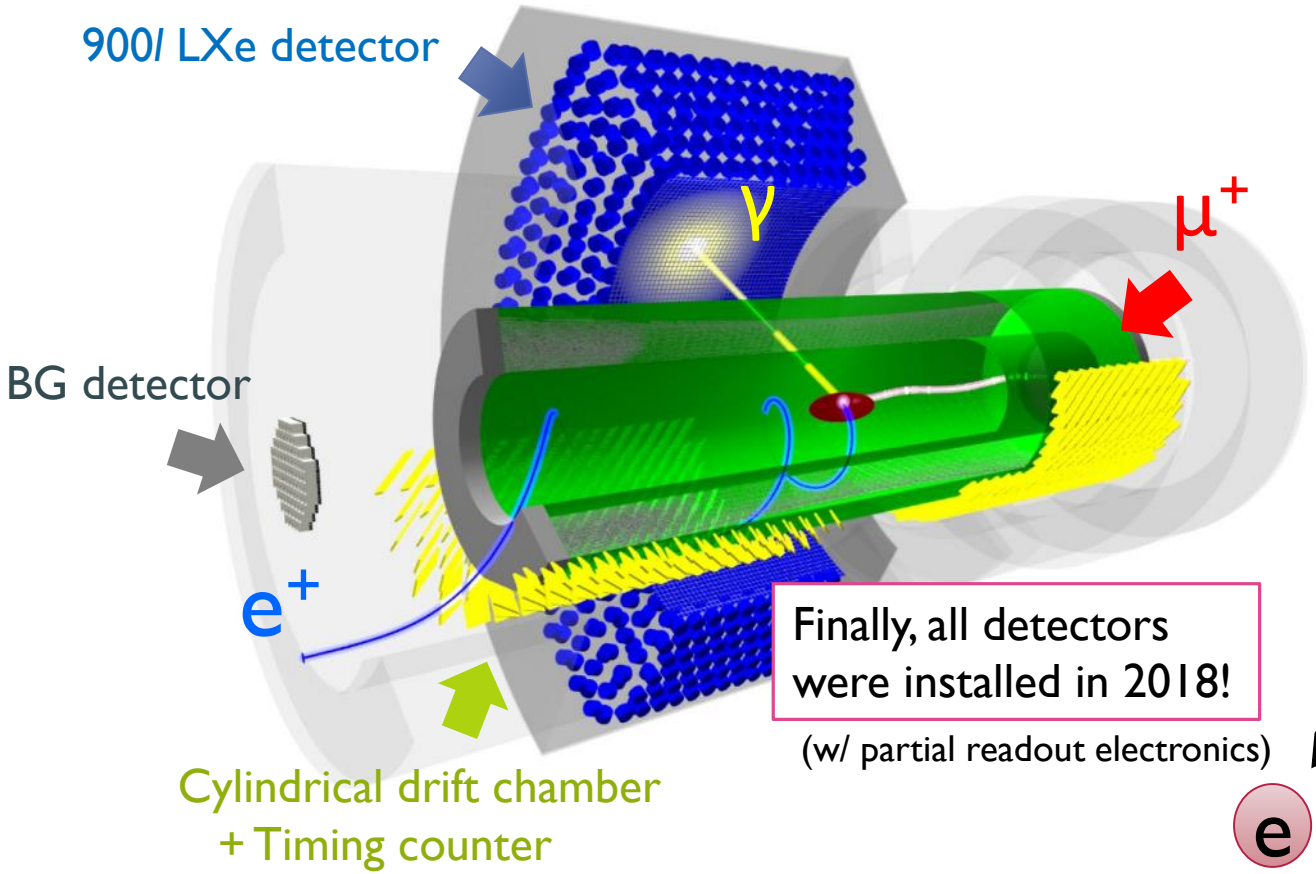
- Sensitivity goal: 6×10^{-14}
  (10 times better than MEG)
- BSM prediction : $O(10^{-14})$
  (e.g. SUSY-seesaw)



If $\mu \to e\gamma$ is found → Discovery new physics!



MEG II experiment

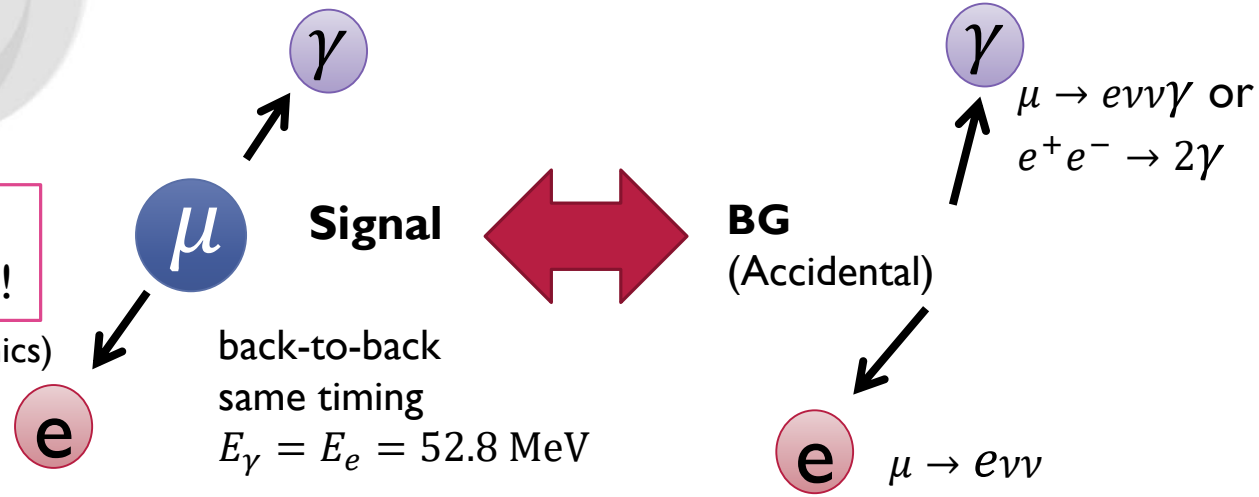


Finally, all detectors were installed in 2018!

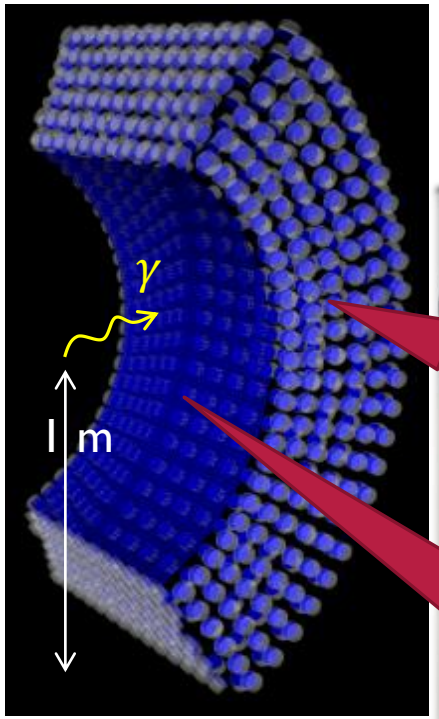
(w/ partial readout electronics)

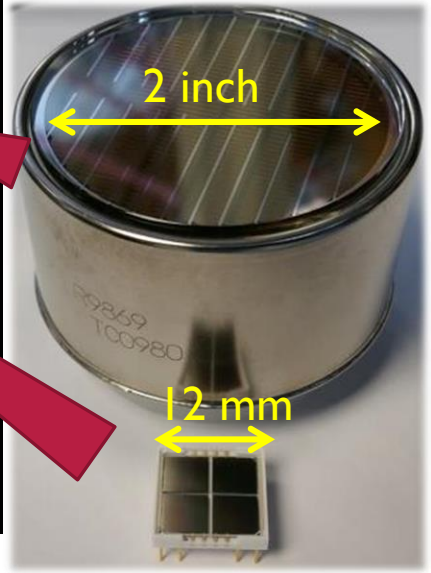
Key concepts:

- **High rate** continuous μ^+ beam at PSI ($7 \times 10^7 \mu/\mathrm{sec}$)
- **High resolution** detectors to distinguish $\mu \to e\gamma$ from accidental BG



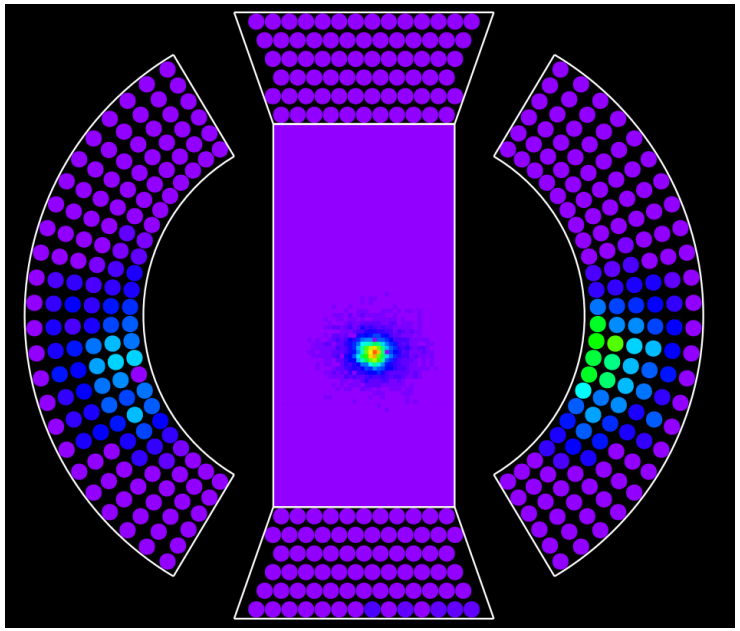
LXe γ detector





900L liquid Xe (LXe) scintillator
to detect energy, position and timing of γ

In MEG II, γ entrance face is replaced from
- 216 PMTs (2 inches)
- to 4092 MPPCs (12x12 mm^2)

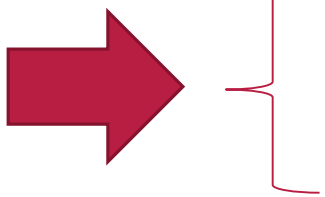


Light collection uniformity and granularity improved!
→ x2 energy and position resolution improvement expected

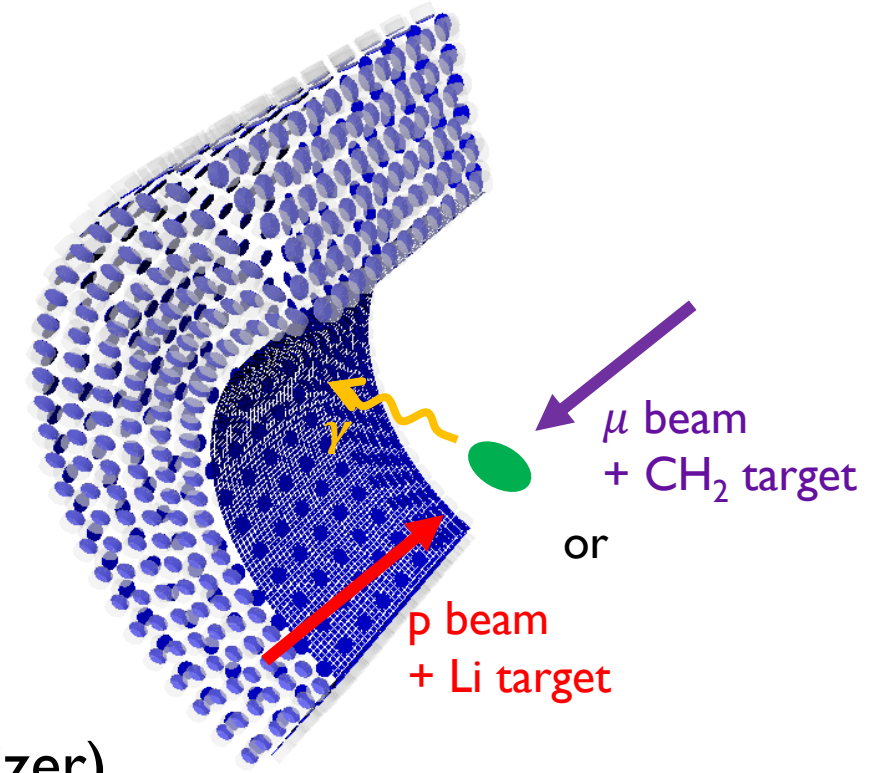
Pre-engineering run 2018

γ data taking in Nov.-Dec. 2018

- 17.6 MeV γ from radiative capture of p on Li target with CW proton beam (first time in MEG II)
- 40~55 MeV γ from $\mu \to e\nu\nu\gamma$ & $e^+e^- \to 2\gamma$ with μ beam



- Measure detector resolution
- Measure BG



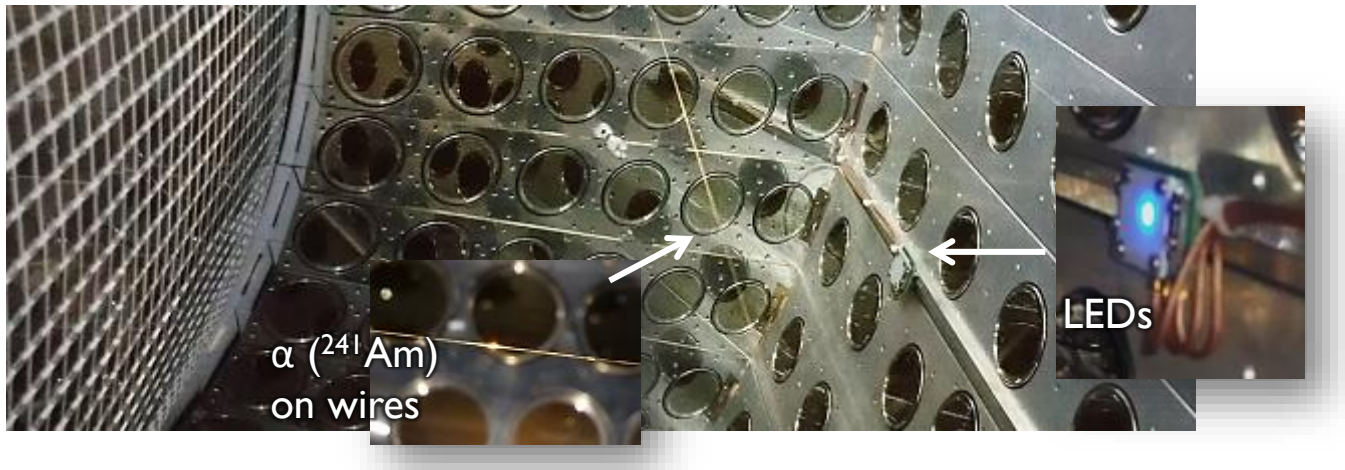
Only ¼ of readout electronics (1.2 GHz waveform digitizer) was available.

Calibration of MPPC and PMT

To achieve good resolution, characteristics of sensors must be understood well.

$$N_{photons} = \frac{charge}{Gain*EQF*PDE}$$

Gain: charge of 1 p.e.
EQF: Excess charge factor
= crosstalk + afterpulse of MPPC
PDE: Photon Detection Efficiency

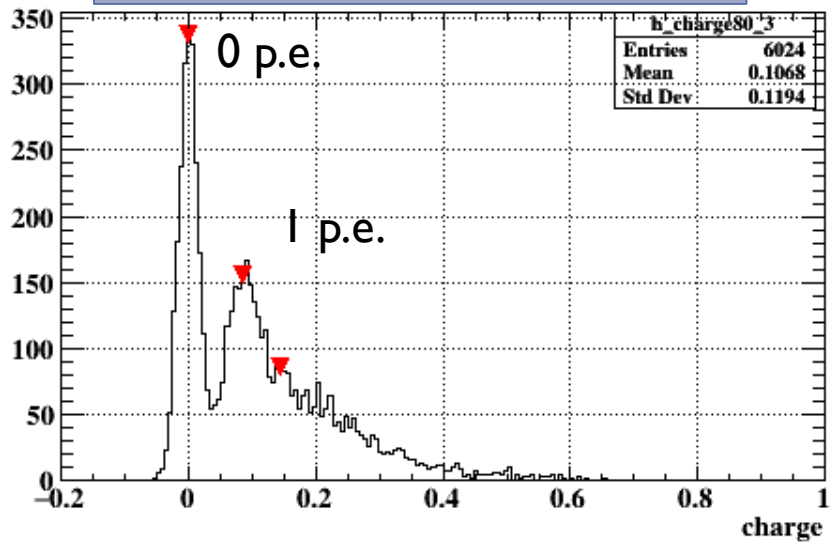


Calibration sources:
LEDs → Gain, EQF
α sources → PDE

Gain and EQF (MPPC)

Gain and EQF are measured in weak LED data.

Example of charge distribution



Gain = (1p.e. charge) – (0p.e. charge)

EQF (= crosstalk + afterpulse)

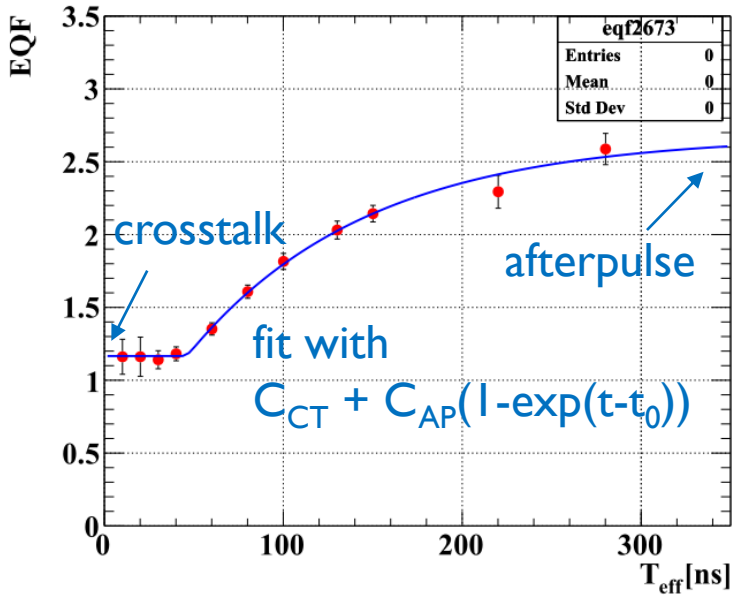
$$= \frac{\text{charge mean (observed)}}{\text{charge mean (expected)}}$$

Estimated from fraction of 0p.e. events assuming Poisson statistics.
P(0p.e.) = exp(-charge_mean)

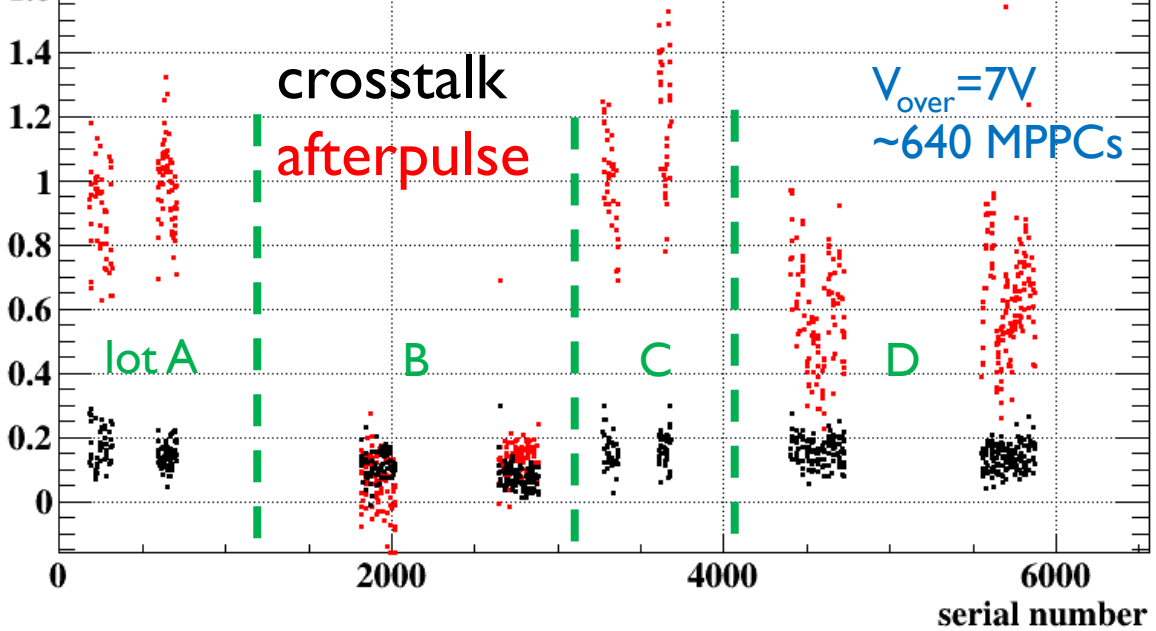
EQF and production lot

Effect of crosstalk and afterpulse can be measured separately by changing charge integration time.

example of EQF vs. integration time



crosstalk, afterpulse vs. serial number



Afterpulse was measured to differ largely depending on production lot, but it is not a problem as far as we measure it.

Test of all MPPCs

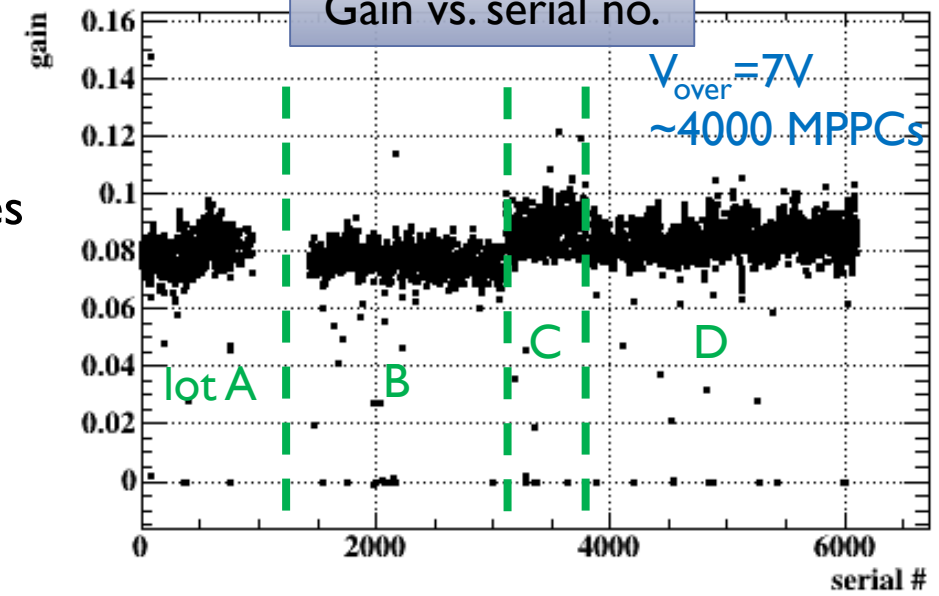
Gain, EQF of all MPPCs were measured with LED after pre-eng. run.

Outliers in gain distribution are mainly due to bad readout electronics channels, but some of them are not due to electronics:

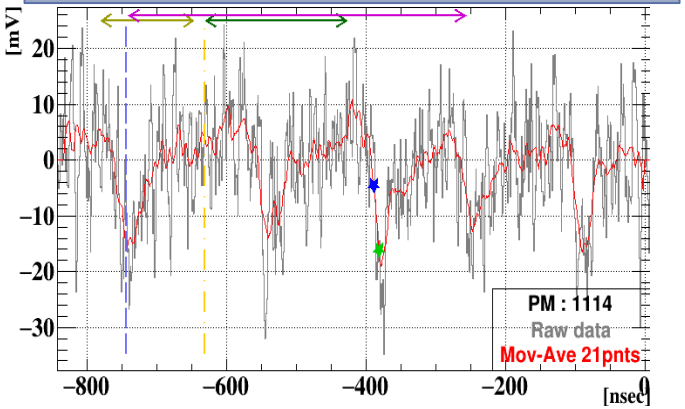
Dead channel:
- 9 channels (0.2% of total)
- Most likely due to bad cables

High dark current channel:
- 19 channels
- Reason is unknown

Gain vs. serial no.



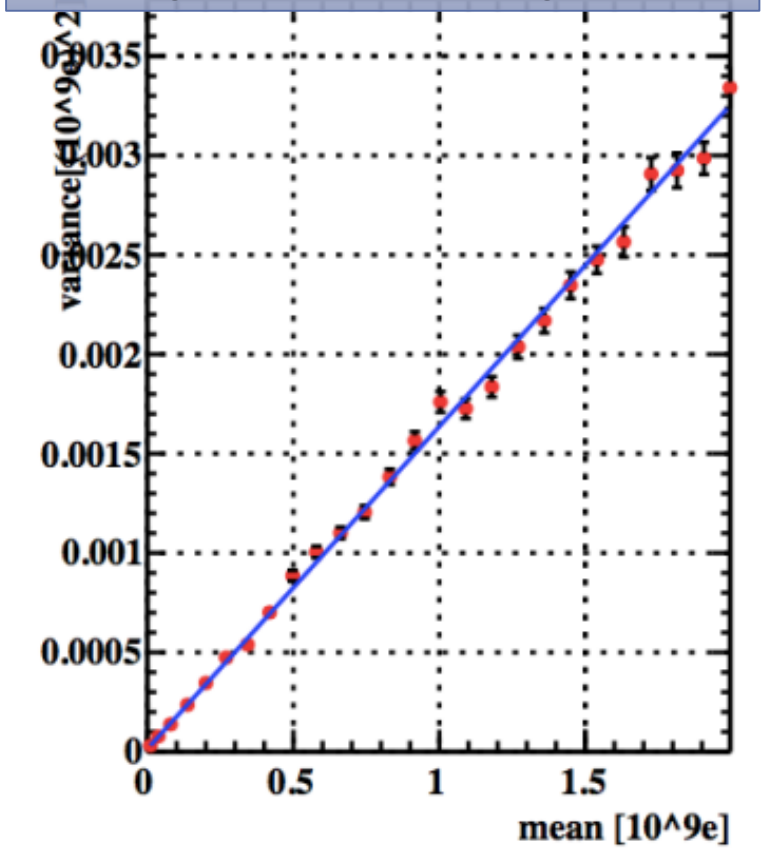
Waveform of high dark rate ch.



In principle, these bad channels does not make a big effect on detector performance.

Gain (PMT)

Charge variance vs. charge mean



For PMTs, gain is derived from variance and mean of LED data.

Mean = gain * $N_{p.e.}$ * e

Variance = $gain^2 * \sigma_{p.e.}^2 * e^2 + \sigma_0^2$

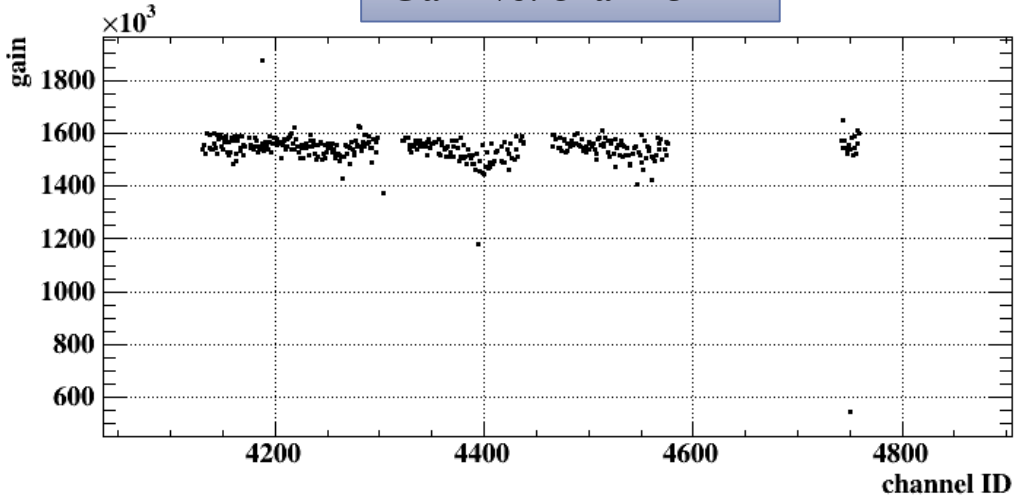
$N_{p.e.}$

noise, LED variation

gain
= slope of variance vs. mean

Bias voltage is adjusted to equalize the gain.

Gain vs. channel ID

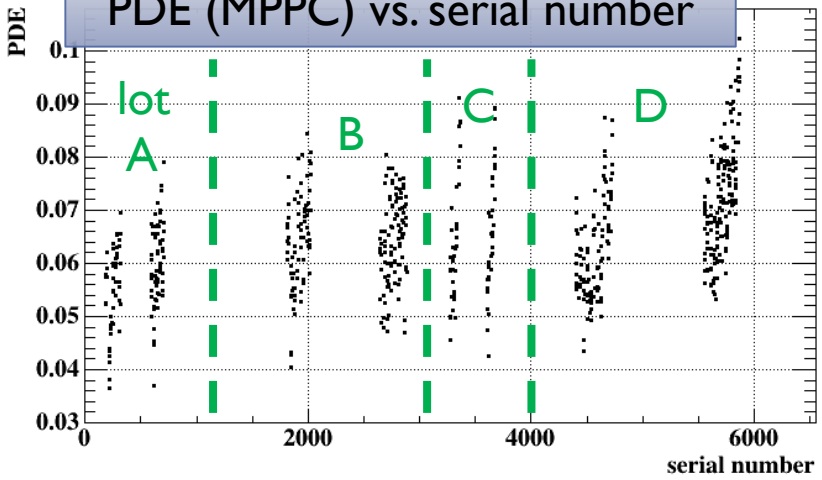


PDE (MPPC), QE (PMT)

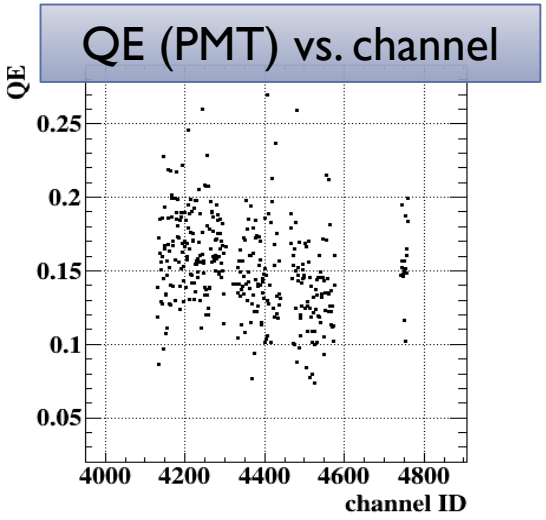
PDE, QE was measured with ^{241}Am α source inside LXe detector.

PDE = Np.e.(measured) / Np.e.(expected in MC)

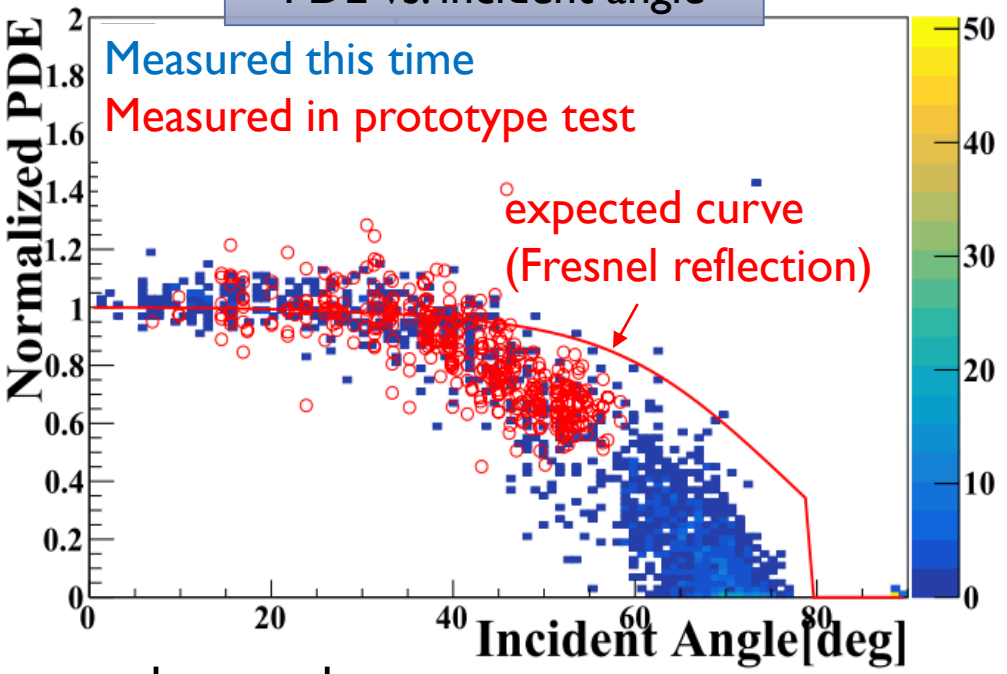
PDE (MPPC) vs. serial number



QE (PMT) vs. channel



PDE vs. incident angle



MPPC PDE was measured to be small (~7%), for the reason not understood yet.
It is measured to be small at large incident angle, as we observed in prototype test.
Effect on performance is expected to be small at least for energy and timing resolution.

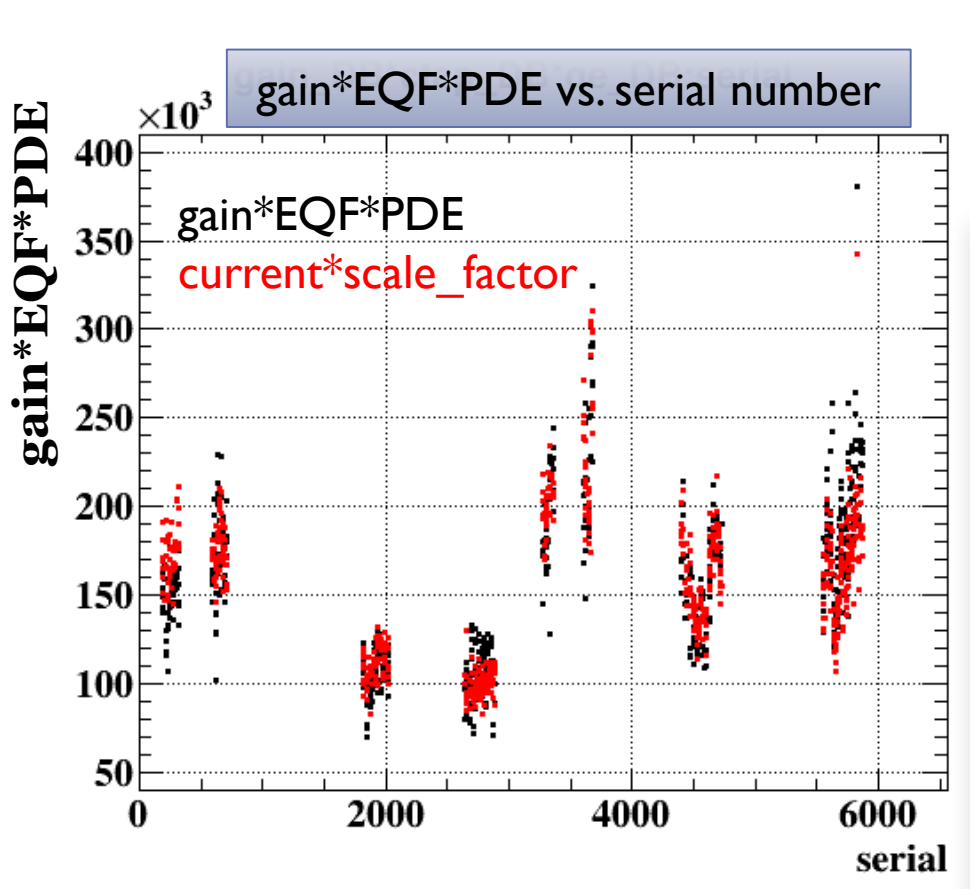
Summary

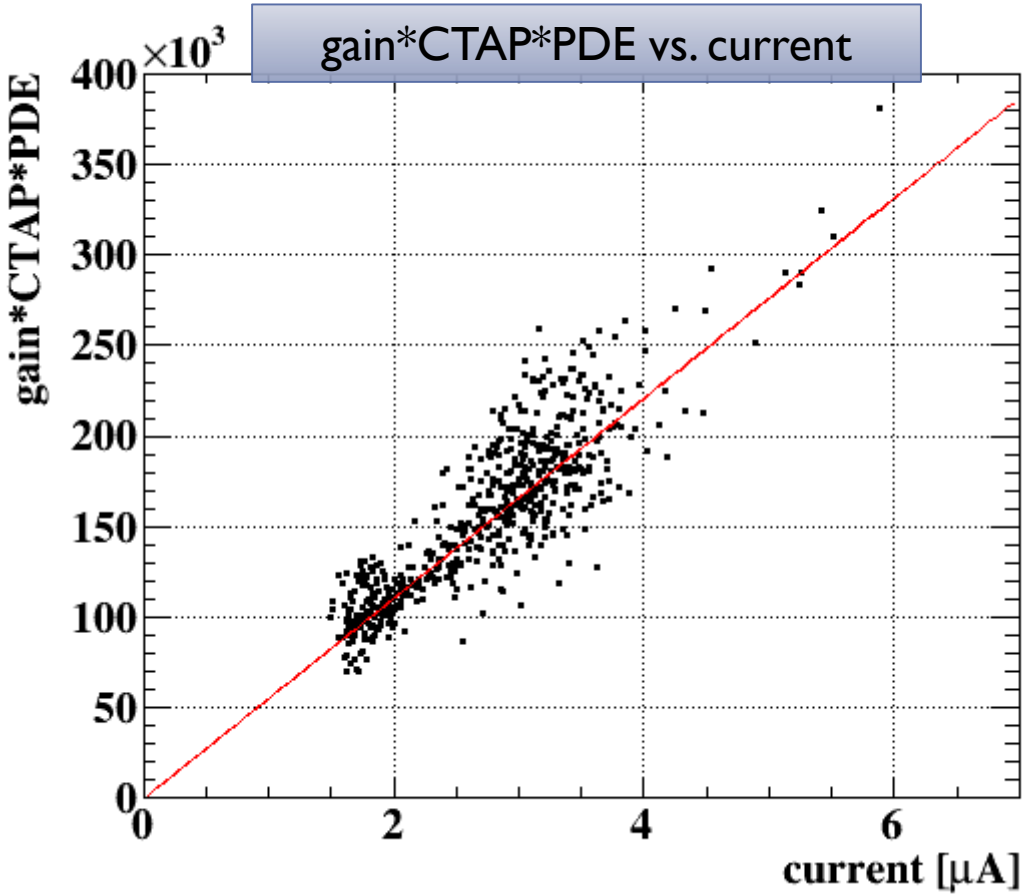
- Calibration constants of MPPCs and PMTs are measured successfully.
  - Afterpulse of MPPC was found to differ largely in different production lot.
  - For MPPCs, dead channels (x9) and high dark rate channels (x19) were found.

  Effect on resolution is expected to be minor.

  - PDE was measured to be small (~7%), compared to the values measured before construction (~20%). Effect on energy and timing resolution is expected to be small, and effect on position resolution is being evaluated.
- Variation of calibration constants over time is an other important topic → next talk

Crosscheck with current





BACKUP SLIDES

Gain monitoring