Development of UV-sensitive MPPC for upgrade of liquid xenon detector in MEG experiment

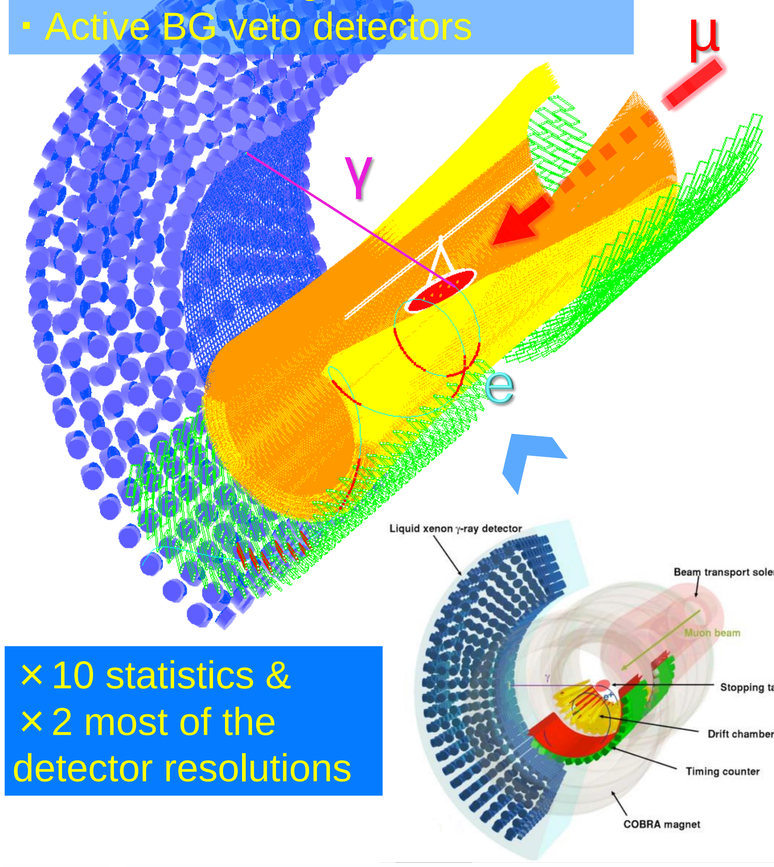
Daisuke Kaneko, on behalf of the MEG Collaboration

1 Introduction

MEG experiment, searching for $\mu^+ \rightarrow e^+ + \gamma$ decay has just finished the data taking in this August, and we are studying for a major upgrade of experiment.
The sensitivity goal of the upgrade is **~ 5×10^{-14}** which is one order of magnitude higher sensitivity than that of the present MEG.

Latest result : Phys. Rev. Lett. 110, 201801 (2013)
Upgrade proposal for PSI : arXiv:1301.7225

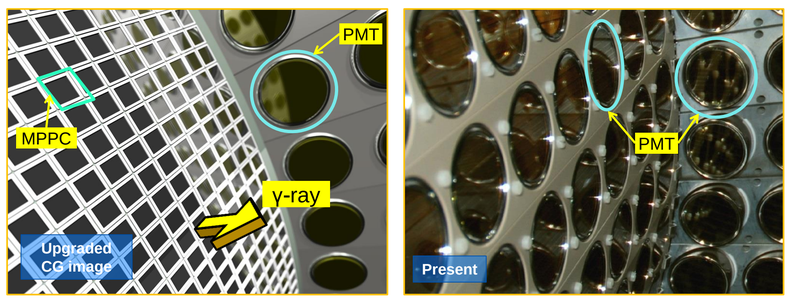
- Higher beam rate
- MPPC read out liquid Xe detector
- Unified volume drift chamber
- Pixelated timing counter
- Active BG veto detectors



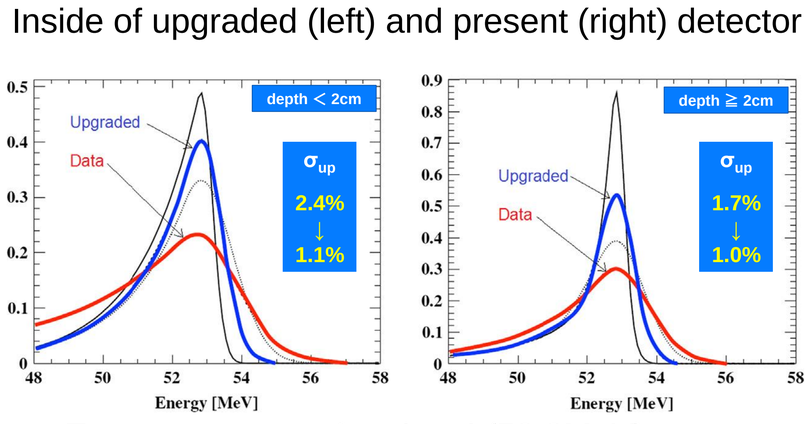
× 10 statistics &
× 2 most of the detector resolutions

2 Upgrade of Liquid Xenon Detector

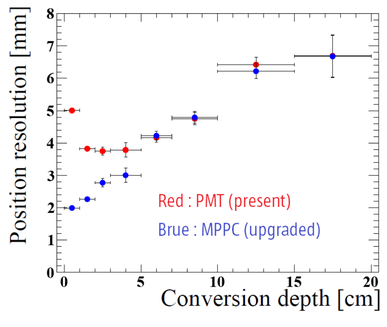
Liquid xenon *γ*-ray detector will be upgraded by replacing the current 2-inch PMTs on the γ incident face with smaller photosensor : MPPCs.
Because the performance of current detector was limited by the size of the PMT.



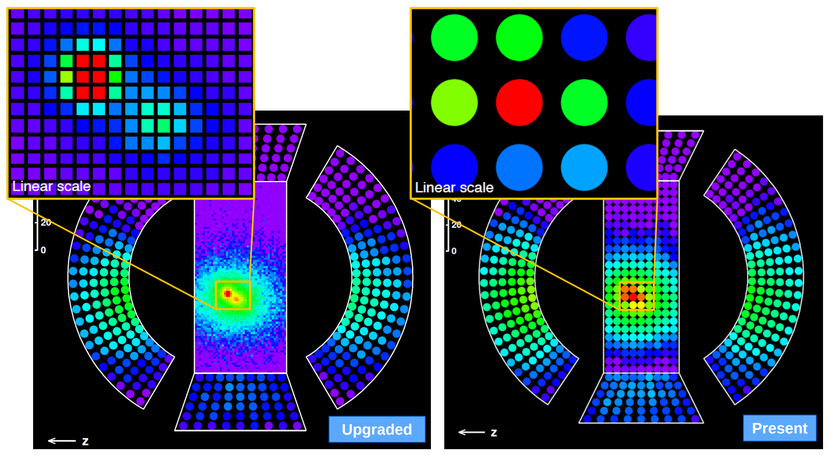
Inside of upgraded (left) and present (right) detector



Energy spectrum for signal (52.8MeV) γ-ray



The performance of the liquid xenon detector is expected to be drastically improved by this upgrade.



Scintillation light from the same two *γ* seen with upgraded and present detector. Capability to find accidental pile-up will also be improved.

3 MPPC for Liquid Xenon Detector

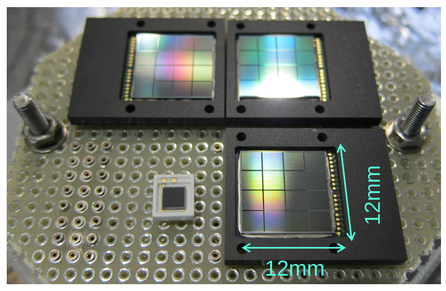
Large area UV-sensitive MPPC is under development in collaboration with Hamamatsu Photonics, since no such kind of MPPCs are commercially available yet.

Requirements

- **Sensitivity to liquid xenon scintillation (λ = 175 nm)**
- **Large active area (12×12 mm^2)**
- **Single photon counting capability**
- **Moderate trailing time constant ($\tau < 50$ ns)**

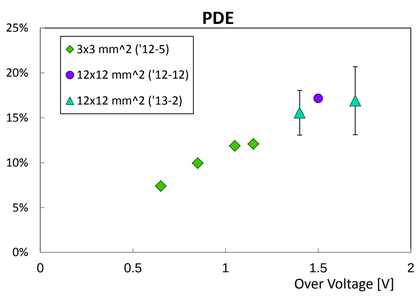
Features of developing UV-sensitive MPPC

- **No protection resin layer**
- **Anti-reflection coating**
- **Refractive index matched to LXe**

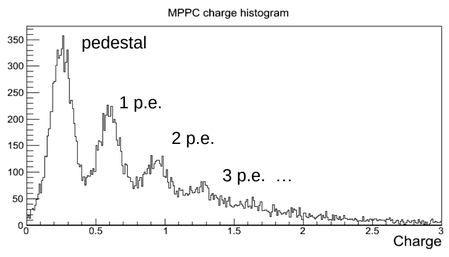


UV-sensitive large area prototypes, are tested in LXe together with calibration source etc.

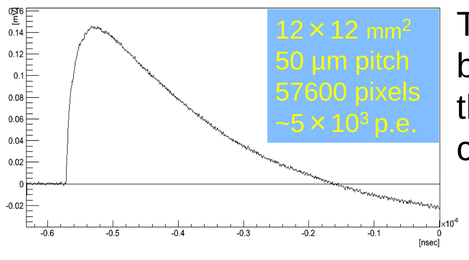
Achieved performance of UV-sensitive MPPC



PDE (photon detection efficiency) is higher than 15% after subtracting the effects of optical crosstalk and afterpulsing.



1 photo-electron can be resolved even with 12×12mm^2 area.



Trailing time constant become long due to the large sensor capacitance.

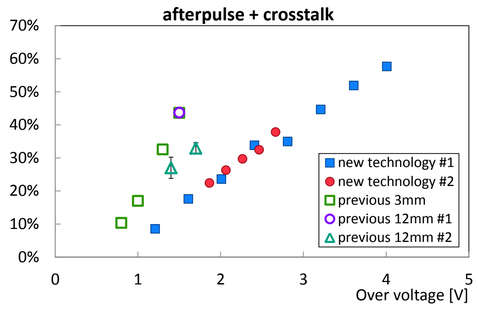
W. Ootani, et al., PoS (PhotoDet 2012) 035.
D. Kaneko, et al., 10.1016/j.nima.2013.06.054

4 Recent Developments

UV-sensitive MPPCs with new technology from Hamamatsu

cf. K. Sato, et. al., 10.1016/j.nima.2013.06.054

We tested 3×3mm^2, UV-sensitive and after pulse suppressed MPPCs in liquid xenon.

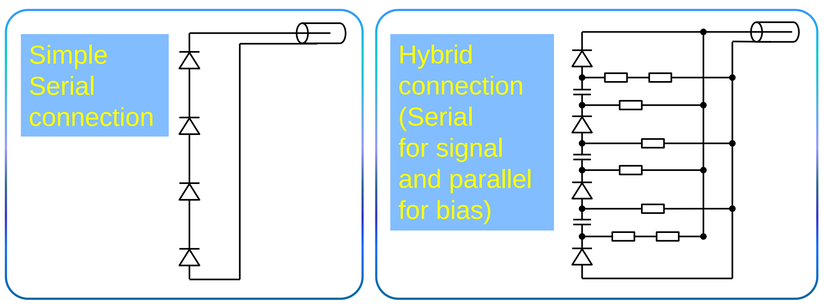


The probability of afterpulse is reduced compared to the previous UV-sensitive MPPCs.

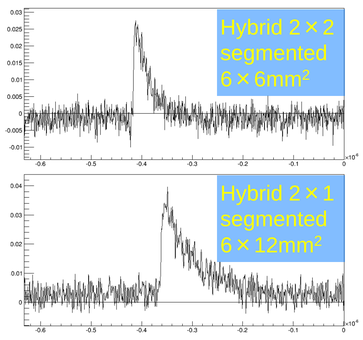
The PDE for LXe scintillation light of MPPC with new technology need optimization. That can be solved by improving process, and thus gain and PDE are expected to be improved thanks to extended operation voltage.

Serial connection of MPPCs to sharpen waveform

Long waveform tail of large area MPPC can be shortened by subdividing active area and connecting them in series. We tested serial connection of four 6×6mm^2 MPPCs (effective area = 12×12mm^2) in LXe.



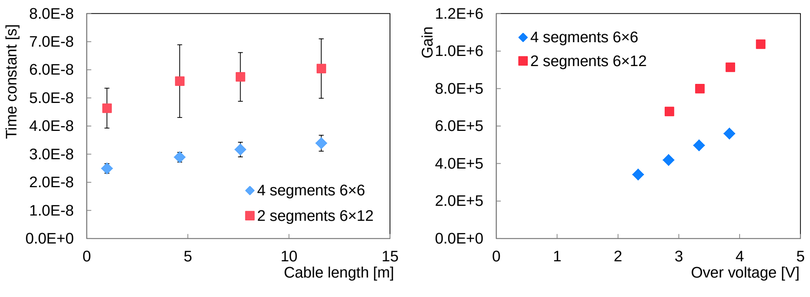
Total sensor capacitance is smaller with serial connection. It makes trailing time shorter, but makes gain smaller at the same time.



Example of single photoelectron event

Single photoelectron events can be resolved with serial connection.
Measured gain is $0.5 - 1.0 \times 10^6$.

Trailing time constant is 30 – 60 ns (~200 ns with all-parallel connection).



5 Summary

- The proposal of MEG experiment upgrade was approved by PSI, and we are now studying to realize the upgrade.
- Performance of LXe detector will be vastly improved.
- Basic requirements for MPPC application to LXe detector are satisfied. And further improvements are expected by new technologies of Hamamatsu.
- Engineering design for production is under way.
- Detector prototyping test is being planned.