MEG II 実験液体キセノンガンマ線検出器における イベント再構成法の改善

Improvement of the event reconstruction method for the MEG II liquid xenon detector

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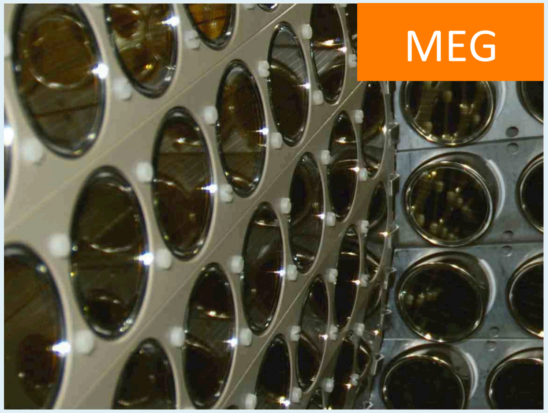
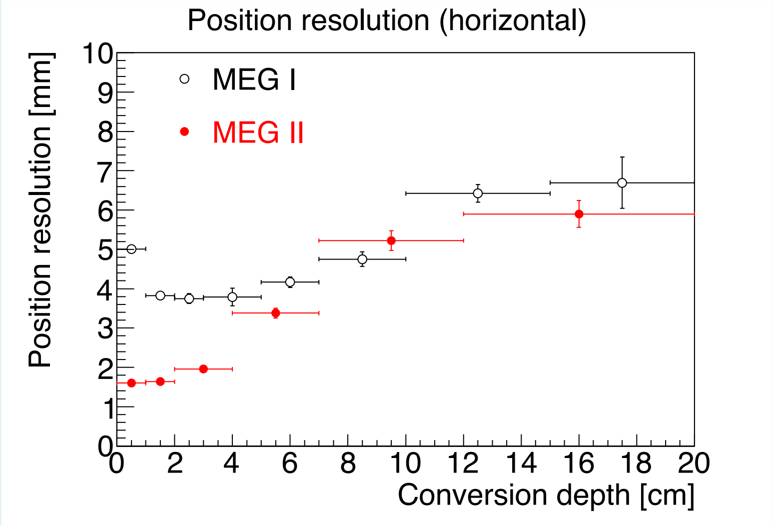
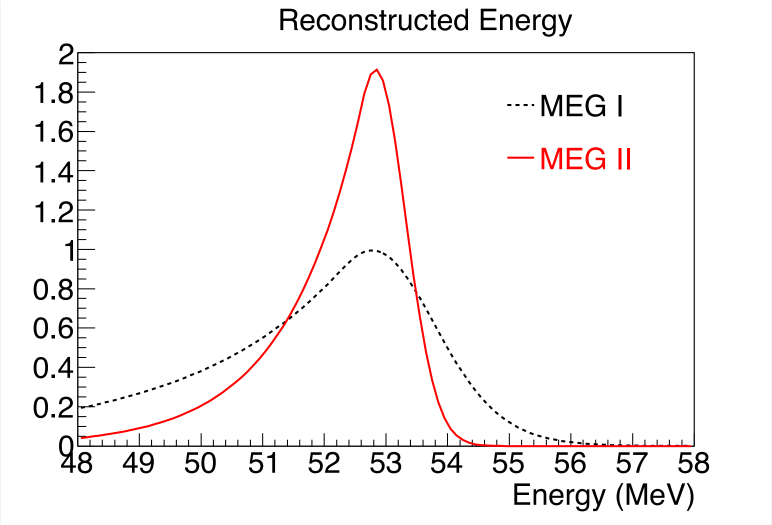
Upgrade of LXe detector for MEG II

- Replace 216 2-inch PMT of γ entrance face to 4092 12×12mm^2 MPPC.
  - Granularity and uniformity of scintillation readout will improve.



- Position and energy resolution will significantly improve.





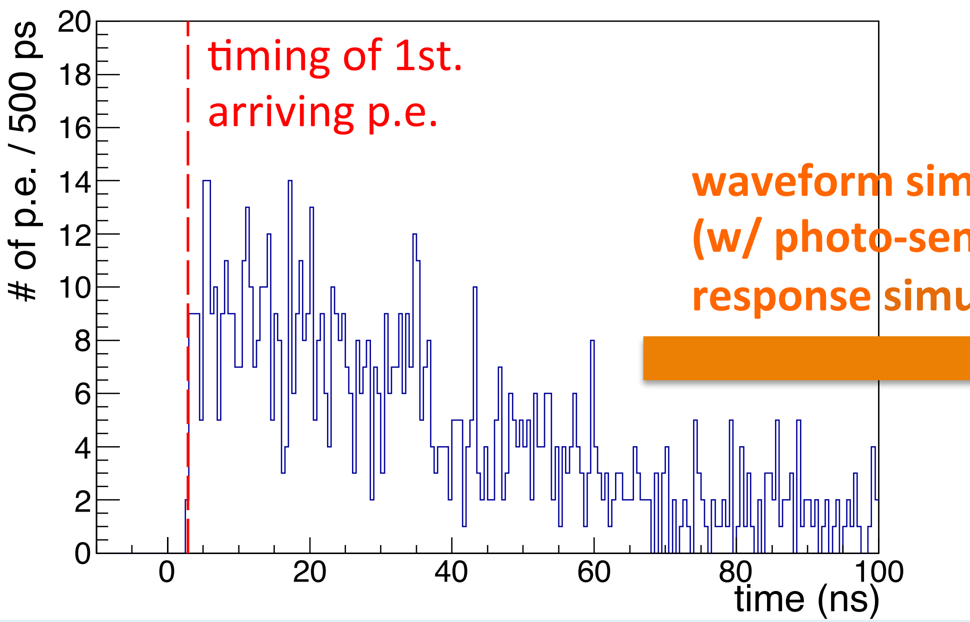
Timing resolution -previous study-

Detector timing resolution	
Intrinsic (from MC truth)	~ 30 ps
Practical (from WF analysis)	~ 60 ps

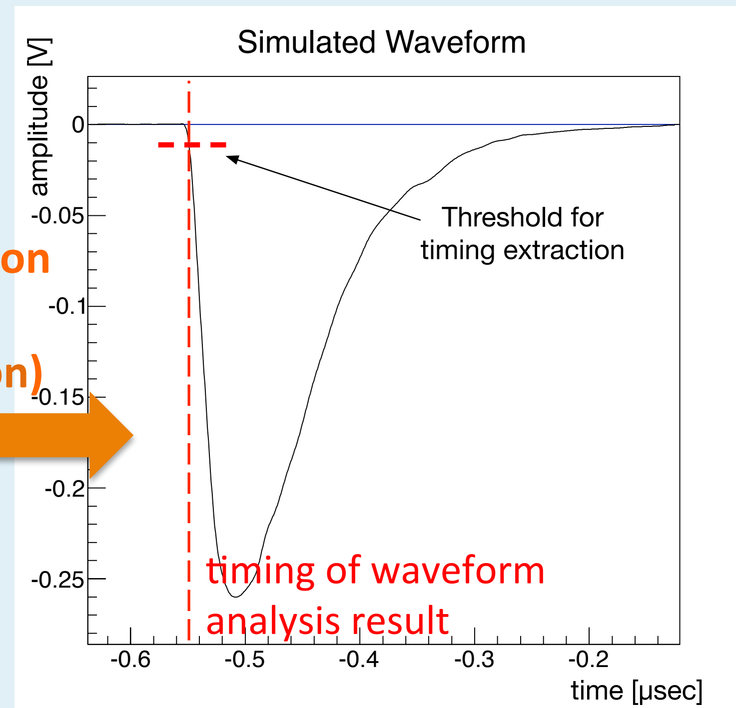
large difference

- Here we focus on **timing resolution**.
- We observed **the difference between practical and intrinsic resolution.**
  - **Intrinsic resolution**: estimated from **MC truth timing** of 1st. arriving p.e.
  - **Practical resolution**: estimated from **timing of waveform analysis result**.
- We foucused on this difference and tried to **improve the practical resolution.**

Timing distribution of arriving p.e. (for a sensor)

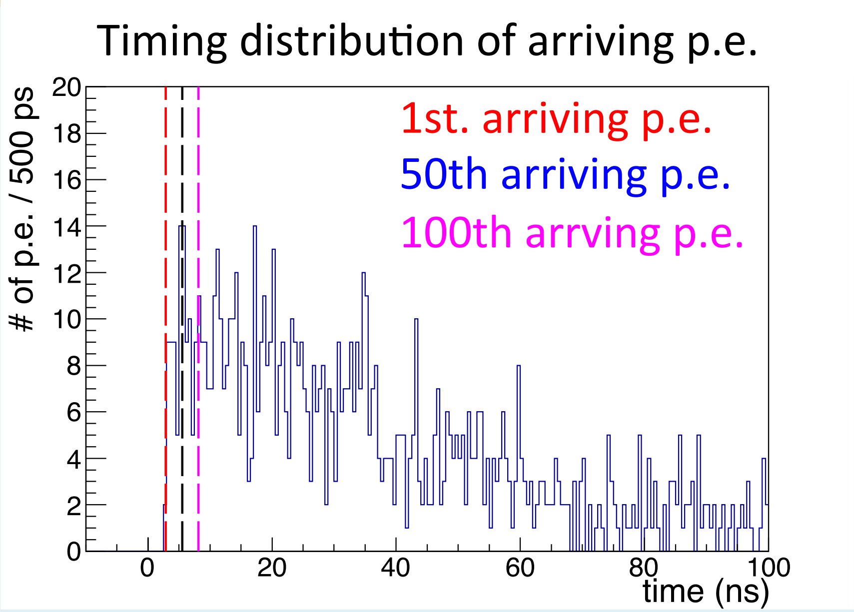


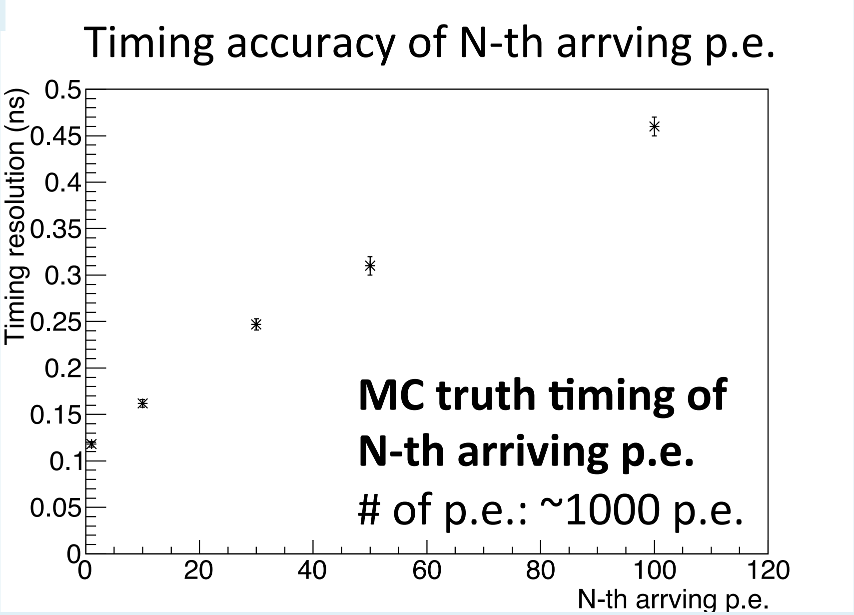
waveform simulation (w/ photo-sensor response simulation)



Effect of threshold -MC truth-

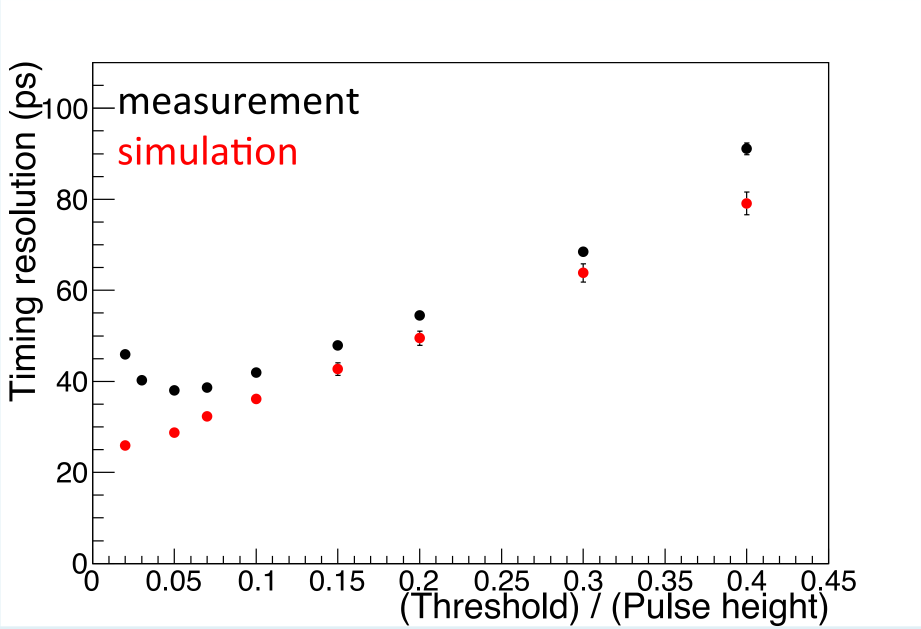
- We found that **photoelectron which arrives earlier have more accurate timing information.**
  - **This can cause the difference b/w intrinsic and practical resolution.**
    - MC truth timing:
      timing of 1st. arriving p.e.
    - Waveform analysis result:
      timing of the p.e. which cross the threshold
  - This suggests that lower threshold leads to better timing resolution

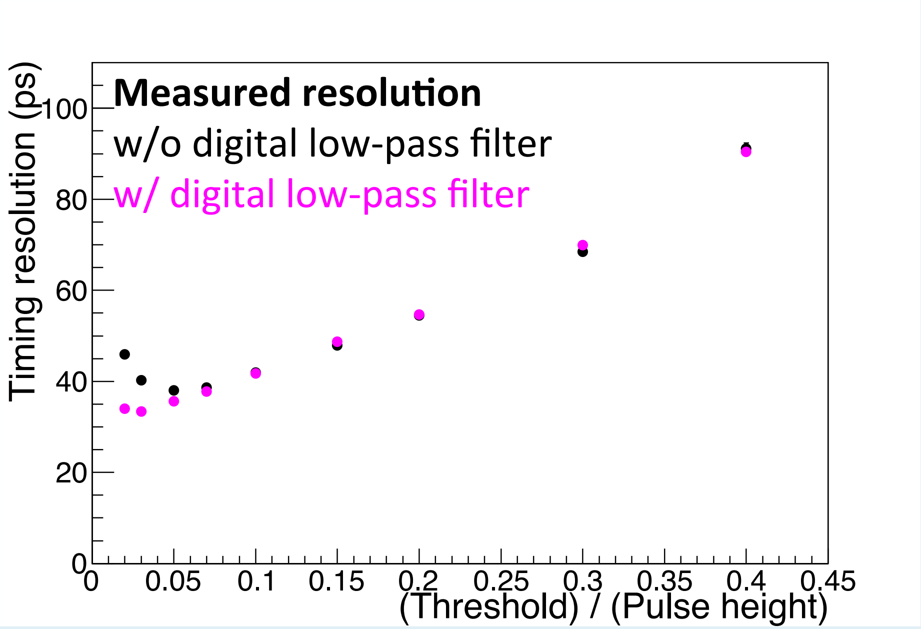




Effect of threshold -data-

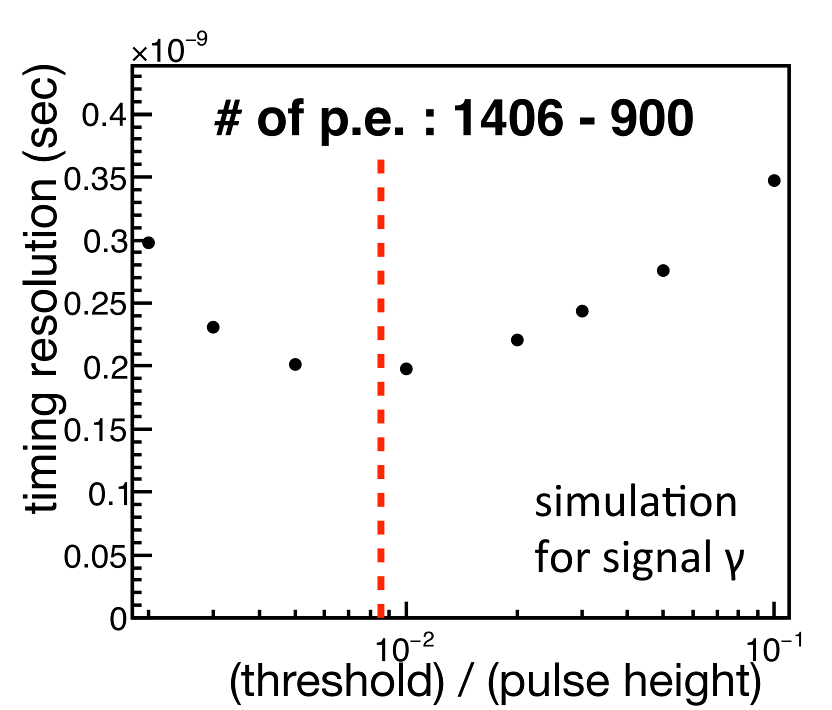
- We checked the resolution in the data with several threshold.
  - Xenon scintillation light from alpha source ~2500 p.e.
- **Smaller threshold leads to better resolution** when threshold is sufficiently high.
  - Measured resolution is roughly consistent with simulation.
- **Degradation of resolution is observed when threshold is low.**
  - It can be suppressed by using digital low-pass filter.
  - Seems to be **coming from the high frequency noise**.

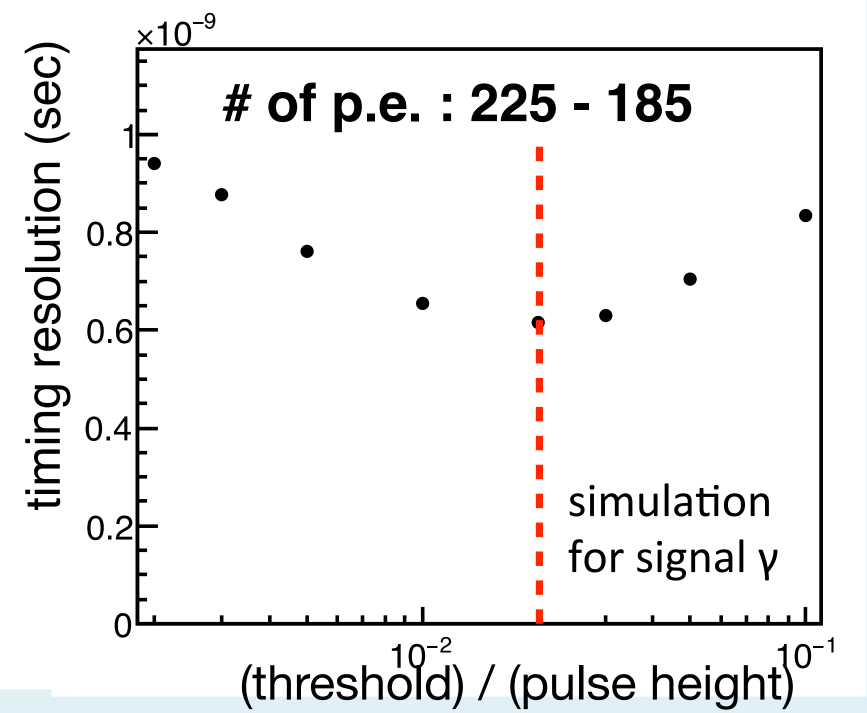




Timing resolution of signal γ-ray

- **We tried to improve the timing resolution of signal γ-ray by optimizing threshold**.
- There is the threshold which gives the best resolution.
  - noise observed in MEG is included in the simulation.
- In the timing extraction from waveform, this **best threshold is used in all sensors.**
  - Best threshold depends on # of p.e. as S/N ratio depends on # of p.e.
  - Timewalk effect becomes larger than constant fractionmethod , but it can be corrected.

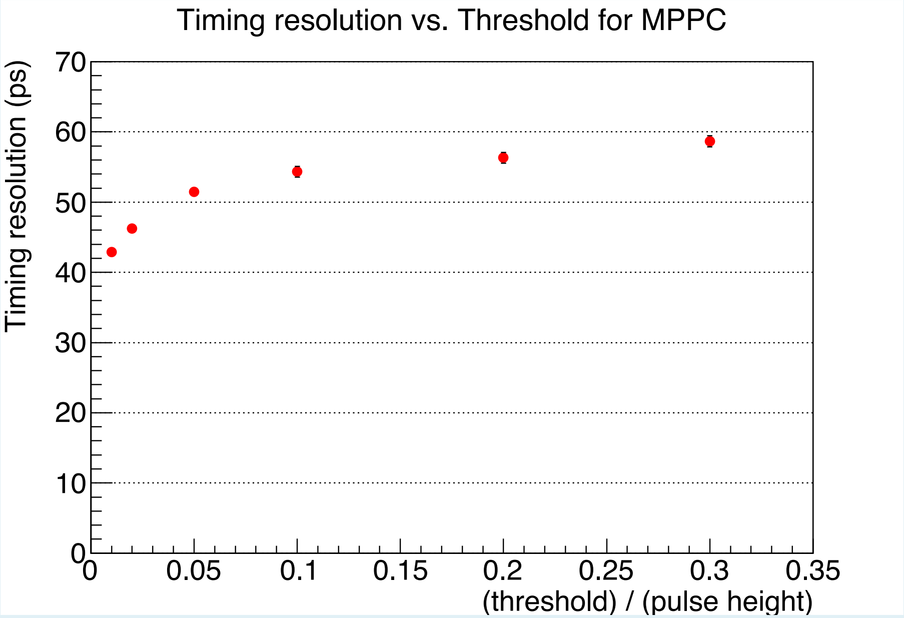


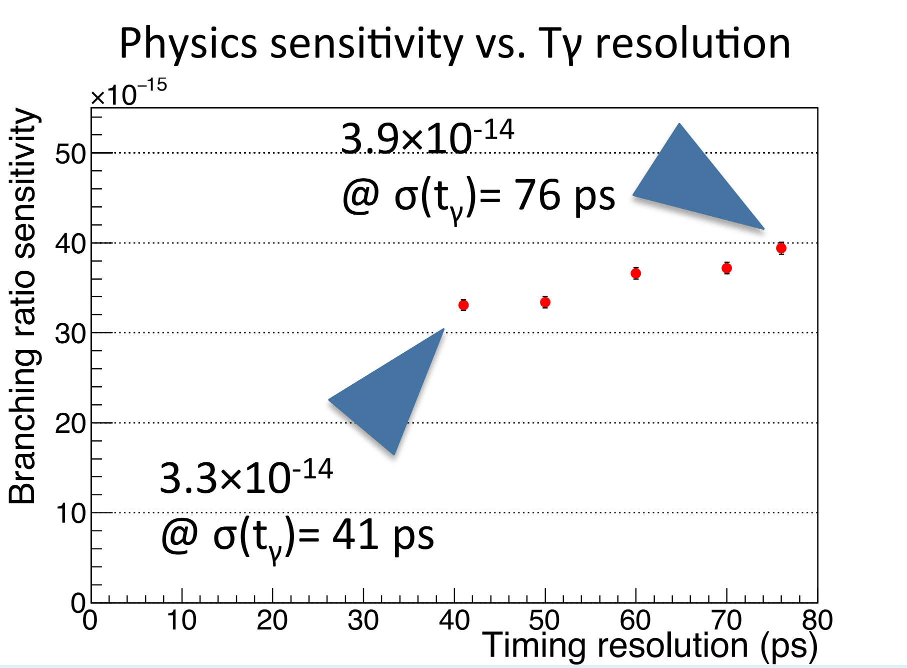


Timing resolution of signal γ-ray

- We can achieve ~40 ps detector timing resolution by threshold optimization.
- There is still some possibility that we cannot achieve this good resolution.
  - Depending on noise condition (level, frequency, etc…).
  - In any case, we can increase the threshold to avoid them.
    - **40 - 60 ps resolution seems achievable.**
- Detector timing resolution for have **~10% effect to physics sensitivity**.

Detector timing resolution	
Intrinsic (from MC truth)	~ 30 ps
Practical (from WF analysis)	~ ~~60~~ **40** ps

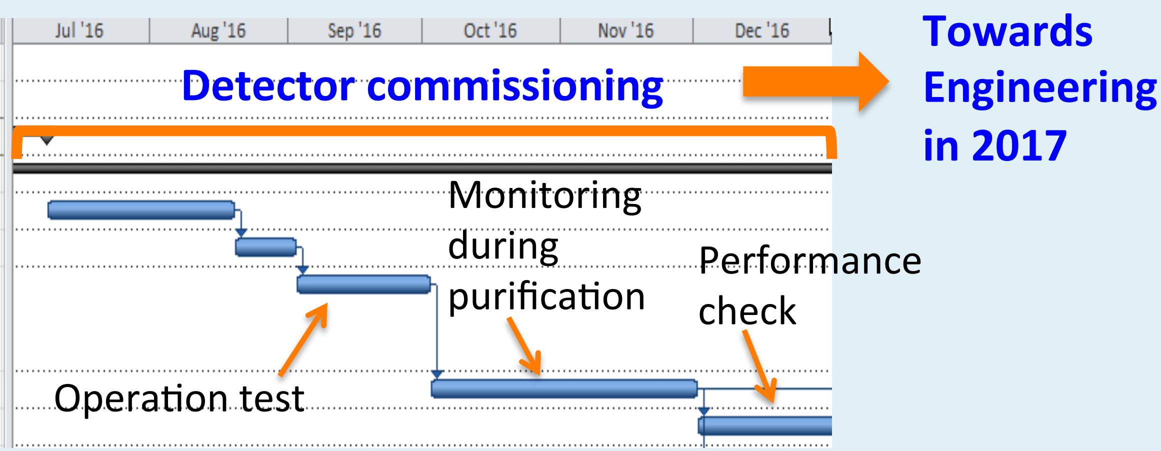




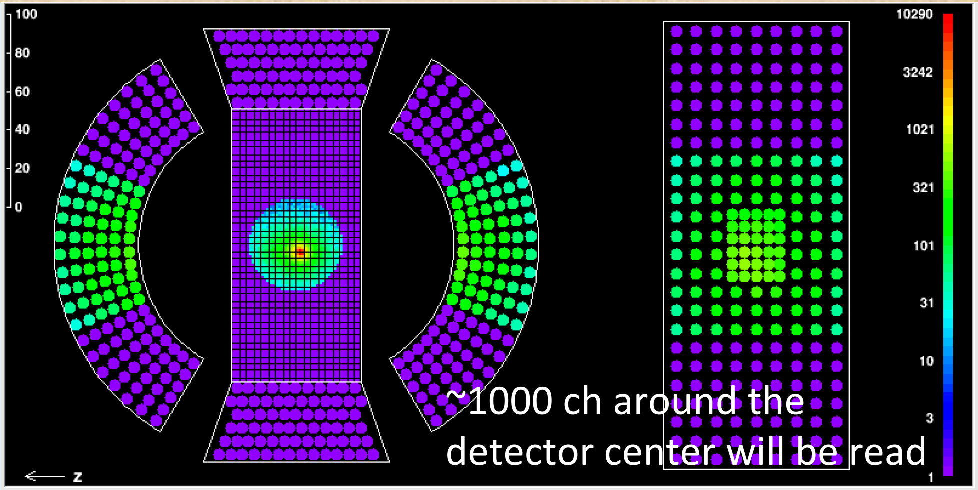
Plan for 2016

- After the detector construction, **commissioning of LXe detector** is planned.
  - Xe liquefaction, operation test, purification w/ monitoring, performance check
- The goal of this year is to check the detector performance.
  - **17.6 MeV γ-ray** from Li (p,γ) B will be used to check the performance.
    - This is the temporal solution. Final resolution measurement and detector calibration will be done 2017 with 55MeV γ-ray .
  - **The number of electronics is limited.** We can read ~1000 out of 4760ch.
    - Mass production of the full electronics will be done after confirming their performance this year.

⊞ Development of UV-MPPC	753 days	Tue 01.01.13	Fri 23.01.15
⊞ Prototype	865 days	Tue 01.01.13	Fri 15.05.15
⊞ Detector construction	598 days	Wed 19.11.14	Fri 08.07.16
⊟ Commissioning	364 days	Wed 01.06.16	Tue 30.05.17
Installation	42 days	Sat 09.07.16	Fri 19.08.16
Operation tests(liquefaction)	14 days	Sat 20.08.16	Fri 02.09.16
Operation tests(DAQ with limited ch., LED, alpha, Cosmics, AmBe, Neutron Generator)	30 days	Sat 03.09.16	Sun 02.10.16
Purification	60 days	Mon 03.10.16	Thu 01.12.16
Calibration with CW	60 days	Fri 02.12.16	Mon 30.01.17



Performance check -position & timing-



- Lower γ-ray energy
  - Lower p.e. statistics have little effect to position and timing
- Limited number of electronics
  - Use γ-ray which hits the center of detector.
    - Area to be read will be limited.
  - Little effect even with limitted number of readout ch.
    - Only the MPPC whose # of p.e. is large needs to be read for position and timing reconstruction.
- **Expected resolution is sufficient to check the improvement from MEG.**

MEG II (Simulation)	17.6 MeV γ readout: 1024 ch	17.6 MeV γ readout: all ch	52.8 MeV signal γ readout: all ch
Position	2.1 mm	2.1 mm	1.9 mm
Timing	53 ps	52 ps	41 ps

Performance check -energy-

- Lower γ-ray energy
  - Lower p.e. statistics have little effect
  - If electronics for all channel are available, resolution better than 1% is expected.

- Limited number of electronics
  - Wider area needs to be read for energy reconstruction
    to avoid event-by-event fluctuation of shower.
  - Number of readout electronics will limit the performance.
- **Expected resolution is 1-1.6%. Still good to check the improvement from MEG**
  - Energy resolution in MEG: 2.8 % for 17.6 MeV γ.
  - **This will be useful as we could not reproduce the measured energy resolution by simulation in MEG.**

MEG II (Simulation)	17.6 MeV γ readout: 1024 ch	17.6 MeV γ readout: all ch	52.8 MeV signal γ readout: all ch
Energy (w<2cm)	1.6%	0.9%	0.7%
Energy (w>2cm)	1.2%	0.7%	0.6%

Summary

- LXe detector will be upgraded aiming to significantly improve the performance.

- We found that we might be able to improve the timing by optimizing the threshold used for timing extraction.
  This has a ~10% effect to physics sensitivity.

- The startup and performance check of the detector is planned in this year.
  We found it possible to check the detector improvement from MEG, even though the energy of γ-ray is lower and the number of electronics is limited.