Development of pre-shower counter for time calibration of MEG II liquid xenon detector

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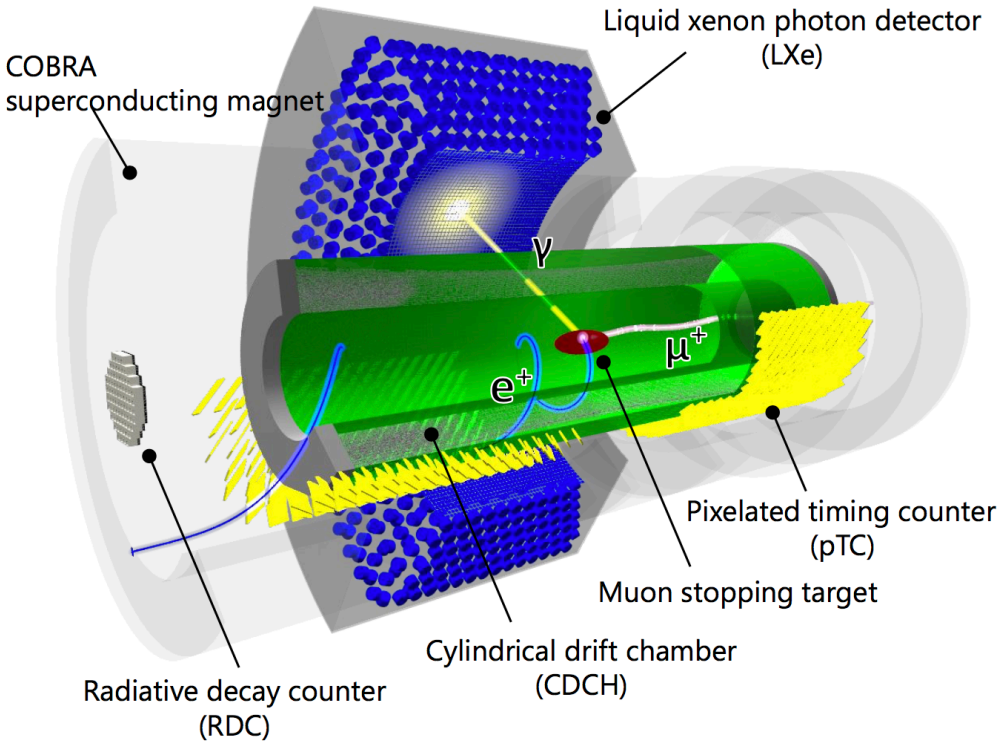
On behalf of MEG II collaboration

The University of Tokyo

MEG II Experiment



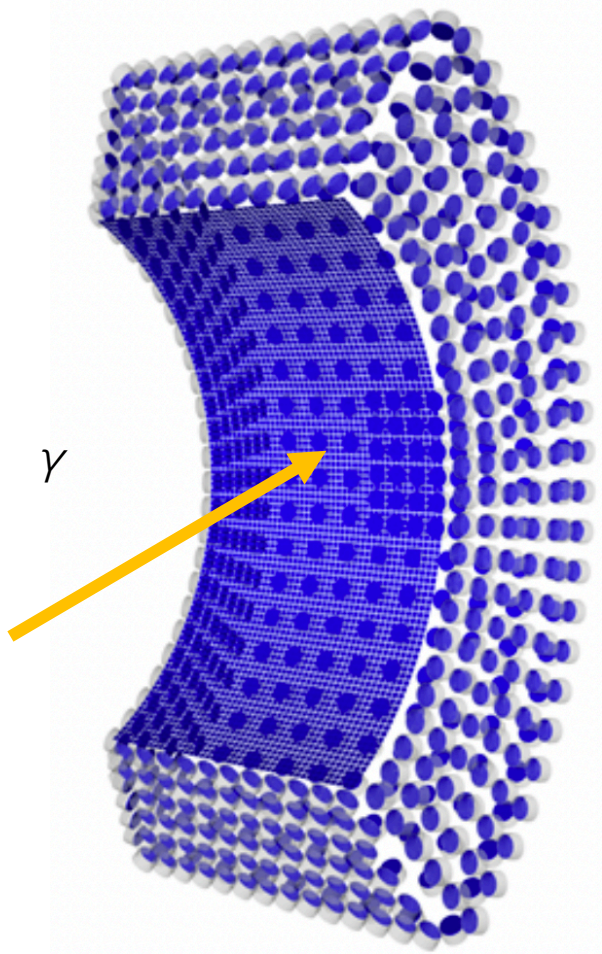
Upgraded from MEG

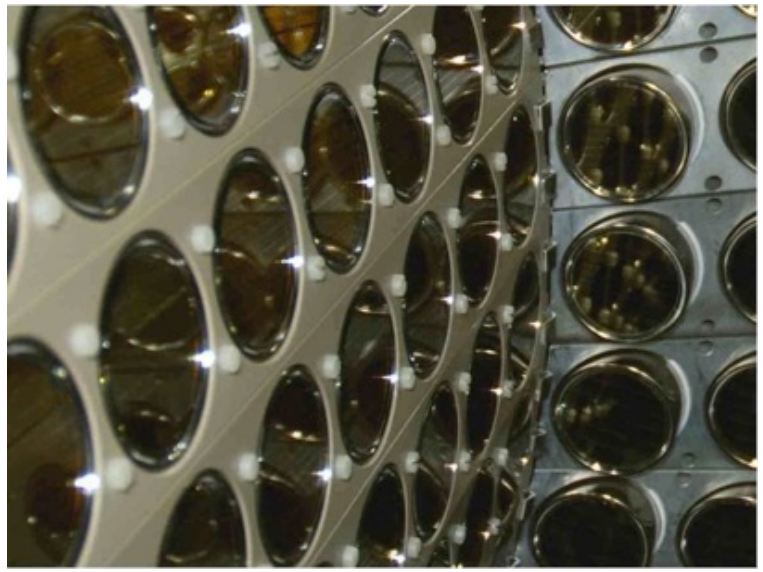
- μ^+ beam stopping rate
  3×10^7 /s → 7×10^7 /s
- Improved efficiency and resolution of each detector

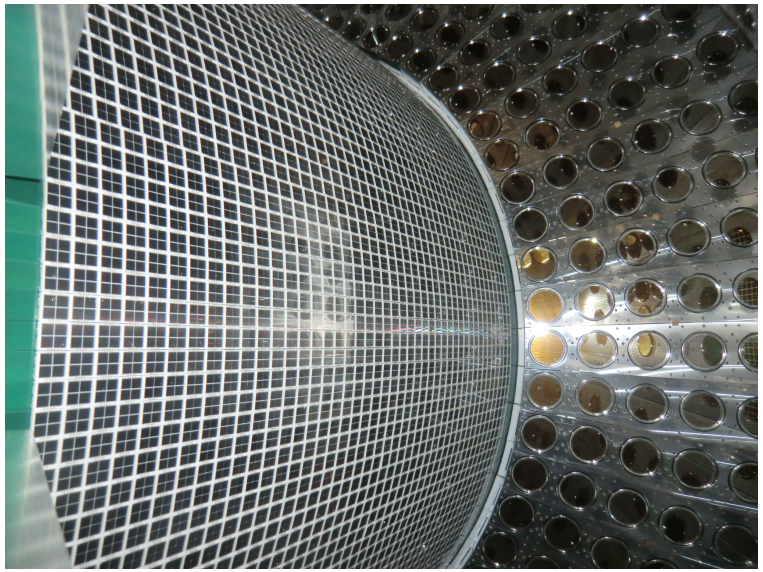
Expected sensitivity

$4.2 \times 10^{-13} \rightarrow 4 \times 10^{-14}$

Liquid Xenon Detector (XEC)

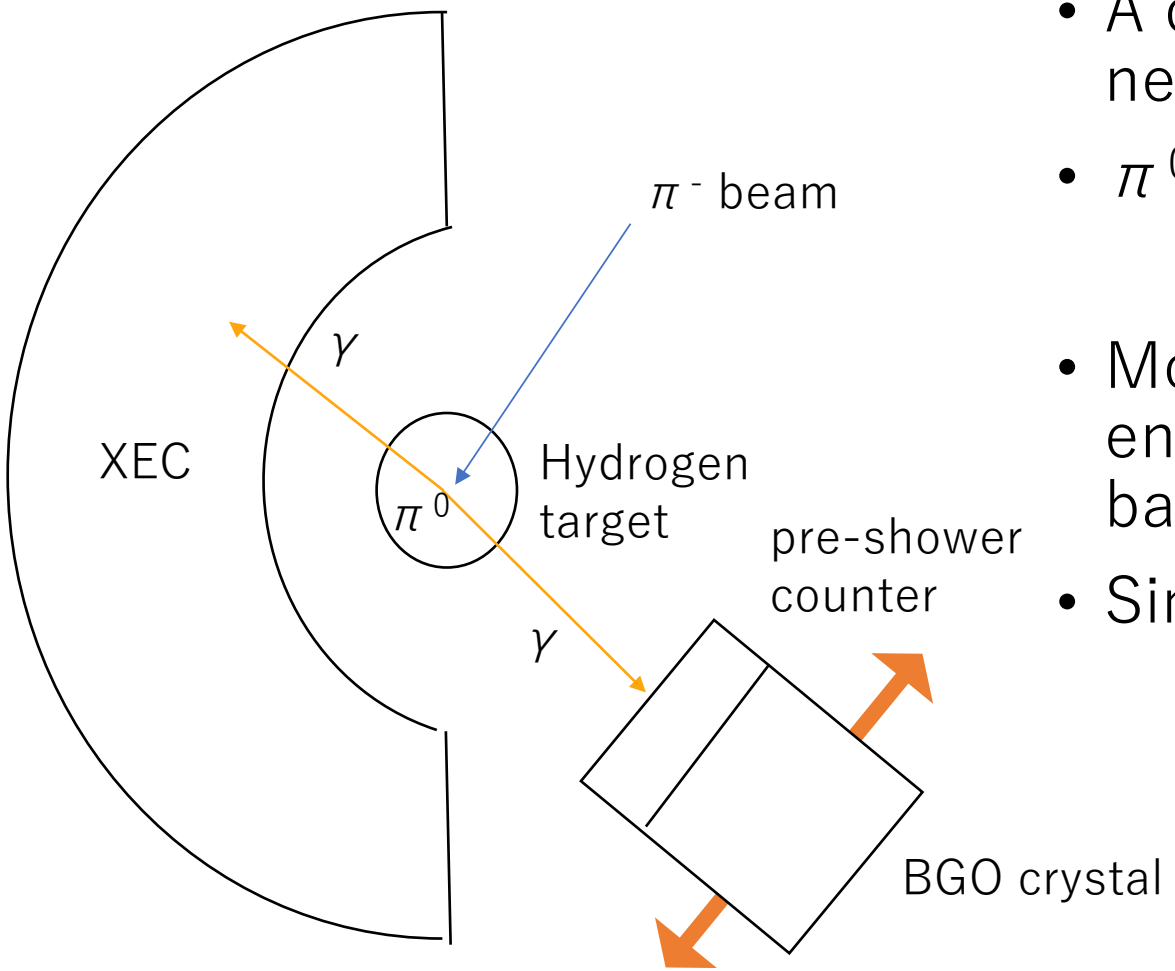






Replaced 216 PMTs with 4092 MPPCs
→ Smaller unit : time resolution 67 ps → 50~70 ps

Calibration using Charge EXchange

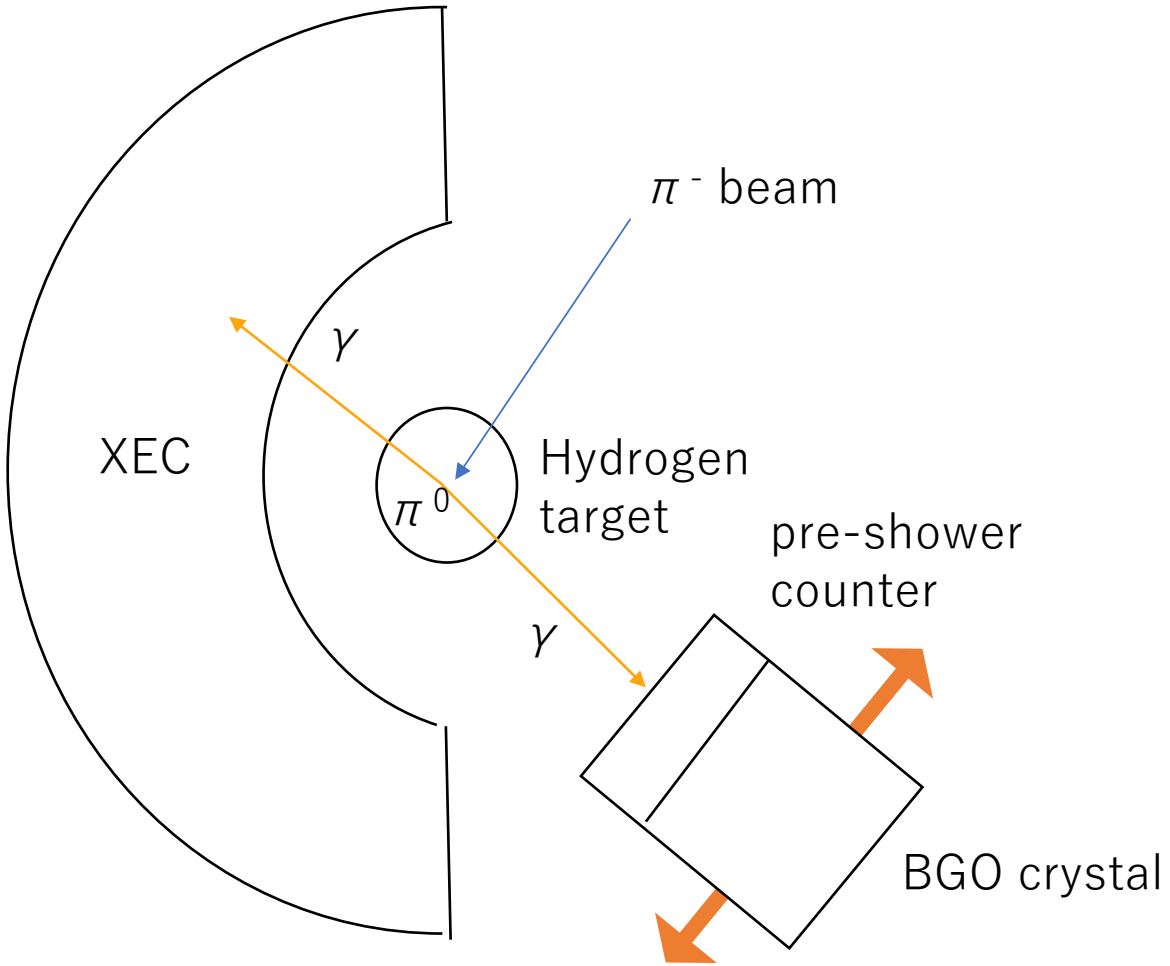


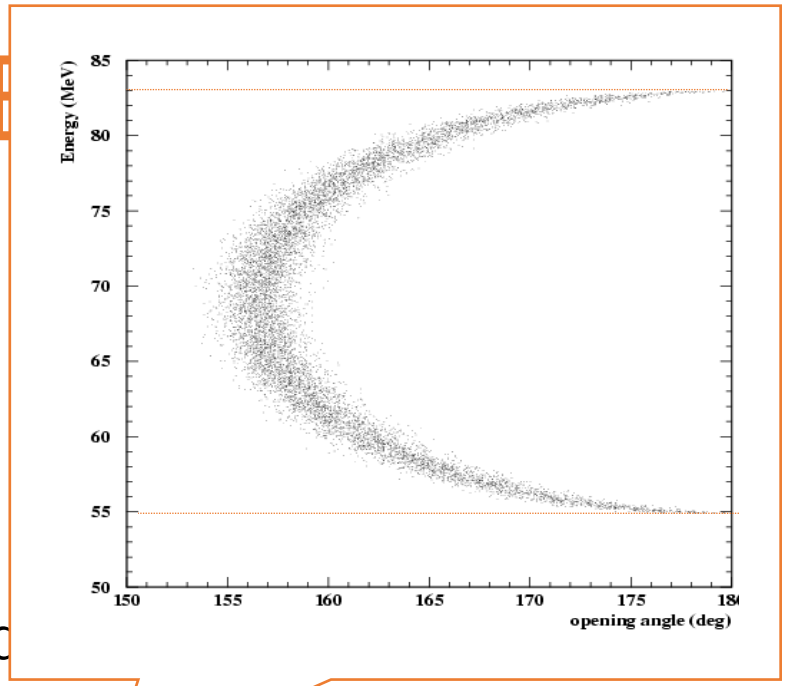
- A calibration run for XEC planned next year
- π^0 is produced in

$$\pi^- p \rightarrow \pi^0 n$$

- Monochromatic 54.9 or 84.9 MeV energy γ-ray selecting back-to-back event from $\pi^0 \rightarrow \gamma\ \gamma$
- Similar energy with signal γ

Calibration using Charge E





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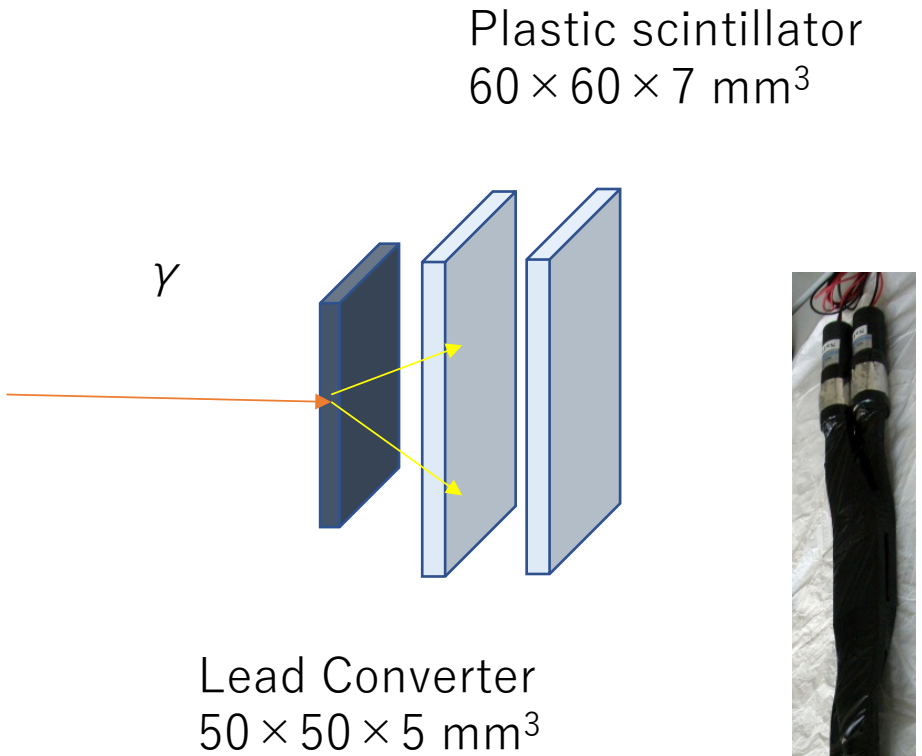
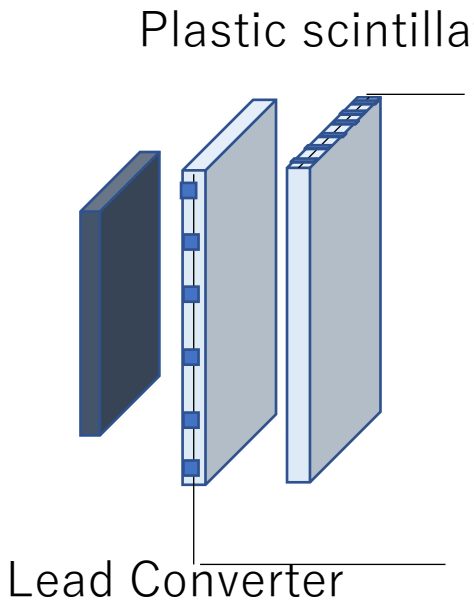


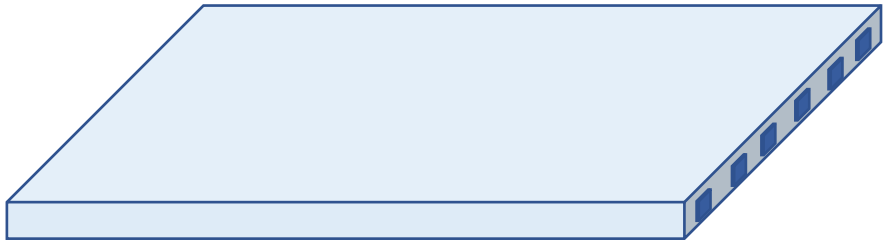
- Pre-shower counter for a timing measurement
- BGO crystal for energy and position measurements

Pre-shower counter @MEG

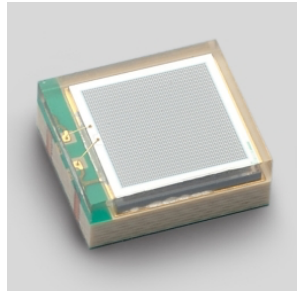
- Make a charged-particle shower with a lead converter
- 2 plastic scintillators read-out with fine mesh PMTs
- Reached 90 [ps] with a single scintillator
- Final time resolution 72 [ps] is worse than that of LXe (50~70 [ps])

Pre-shower Counter @MEG II





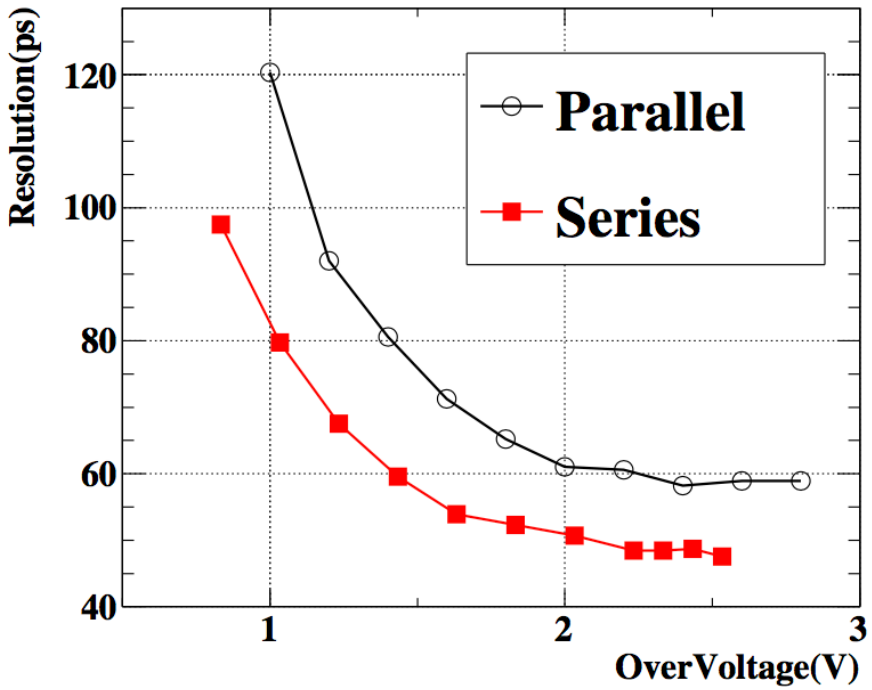
Plastic scintillator
- 92 × 92 × 5 [mm^3]
- BC420, Saint-Gobain



MPPC
- S13360-3050PE, Hamamatsu Photonics
- 3 × 3 [mm^2] photosensitive area
- Vop ~ 54 [V]

Good timing resolution can be achieved like MEG II Timing Counter

Previous Research about MEG II TC



To achieve better resolution
- High light yield
  → more MPPCs
- Fast rise time
  → series > parallel

Reached 50 [ps] resolution
- $90 \times 40 \times 5$ [mm^3], BC422 scintillator
- 6 series SiPMs (ASD-NUV3S-P-50)

M. Nishimura et al., Pixelated positron timing counter with SiPM- readout scintillator for MEG II experiment. In *Proceedings 4th Int. Conf. on New Photo-Detectors*, PoS(PhotoDet 2015)011, Mo- scow, Russia, (2016)

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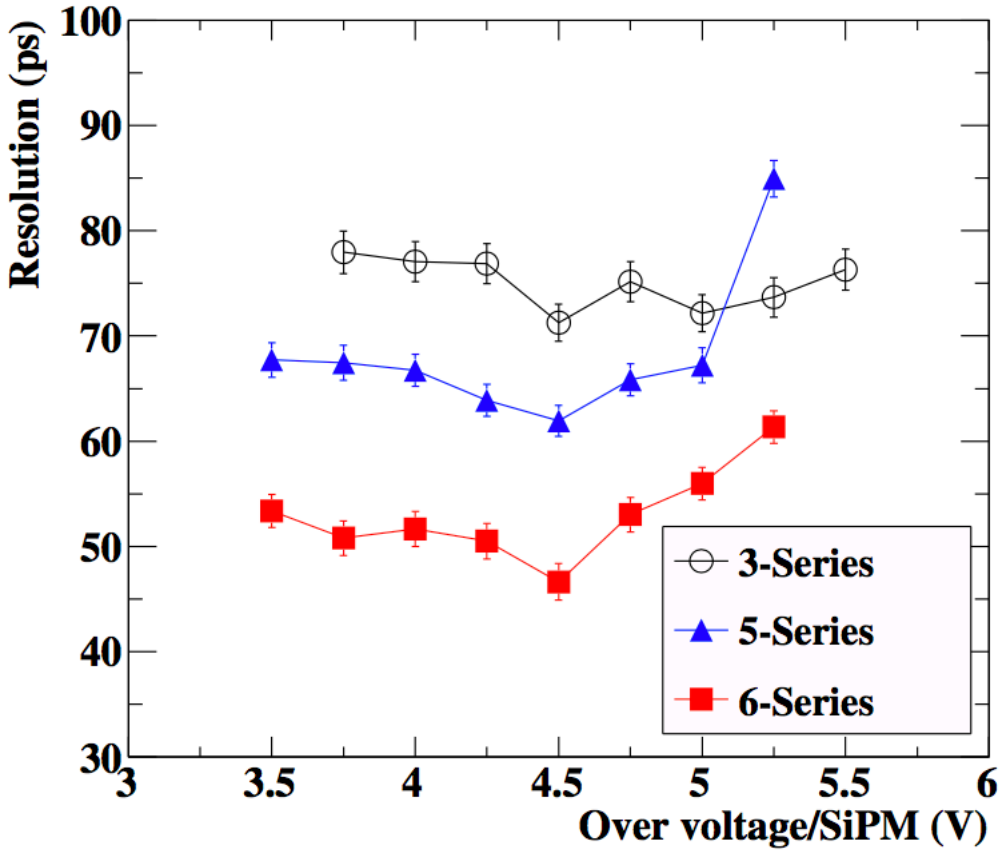

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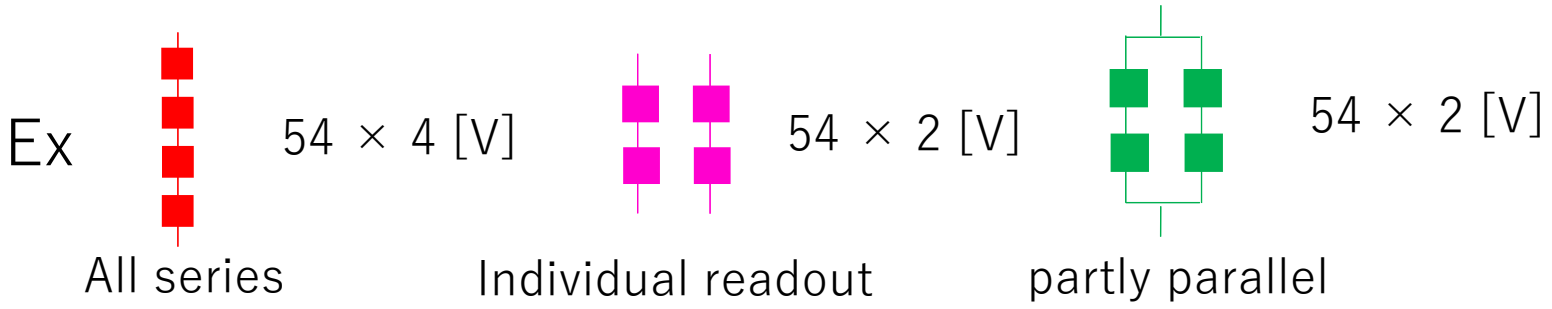
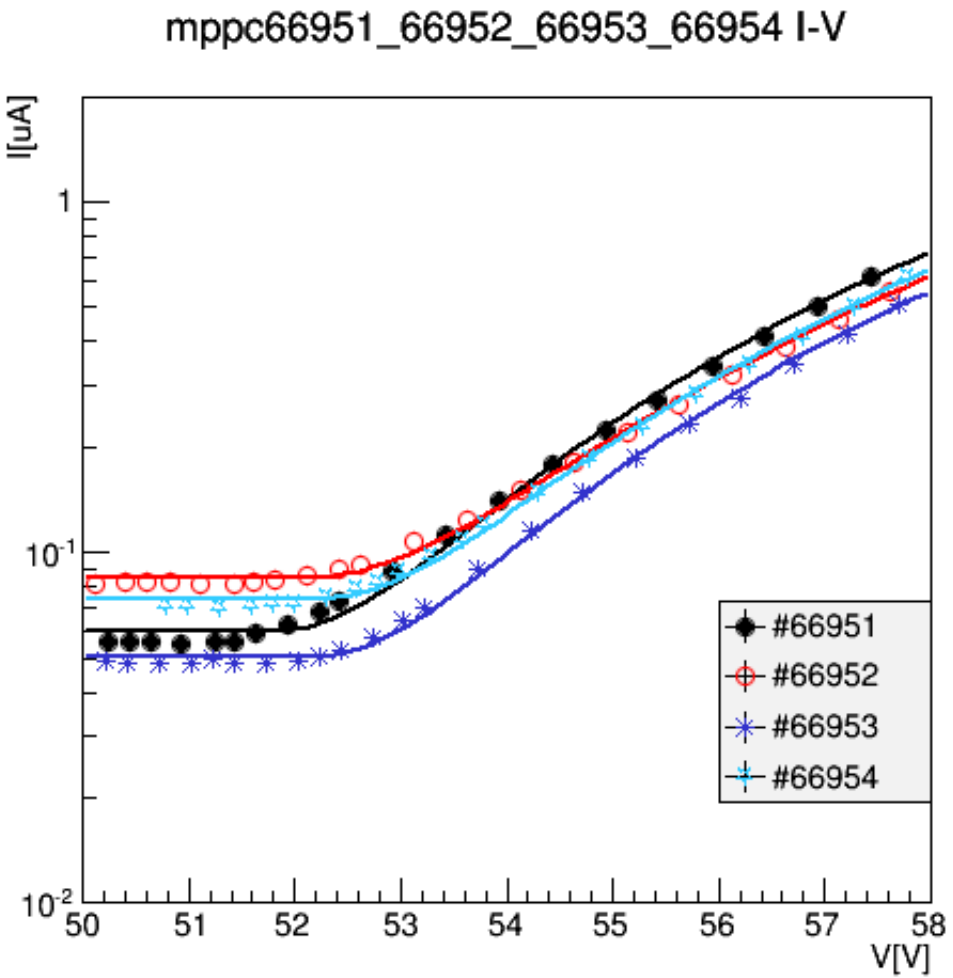
This Research

- Better time resolution is desirable than that of LXe detector 50~70 [ps]
- More MPPCs in series gives better resolution though HV limits (240 [V]) the number
- Compare connections which include parallel connection and read out individually.



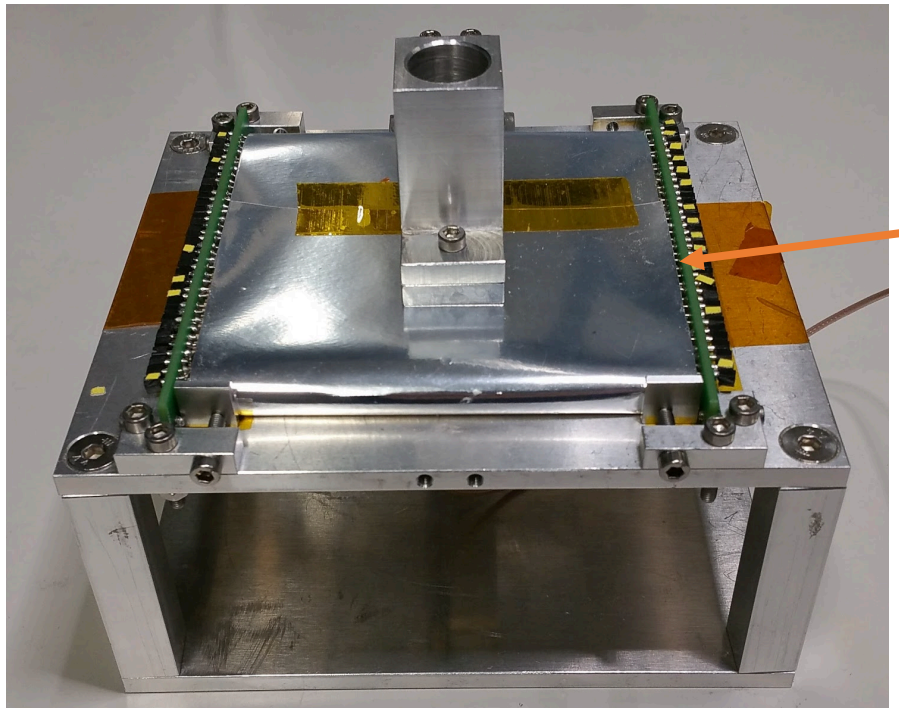
MPPC Selection



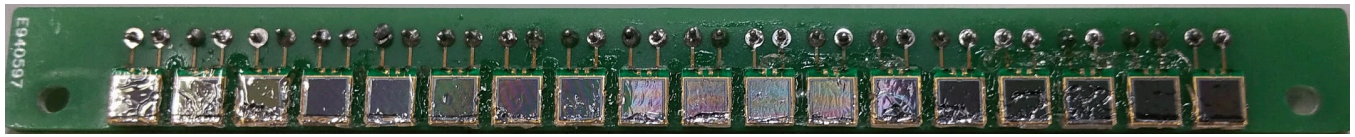
MPPCs connected in series or parallel must have similar characteristics.

- I-V measurement for 100 MPPCs
- Choose 36 MPPCs which have similar I-V curves

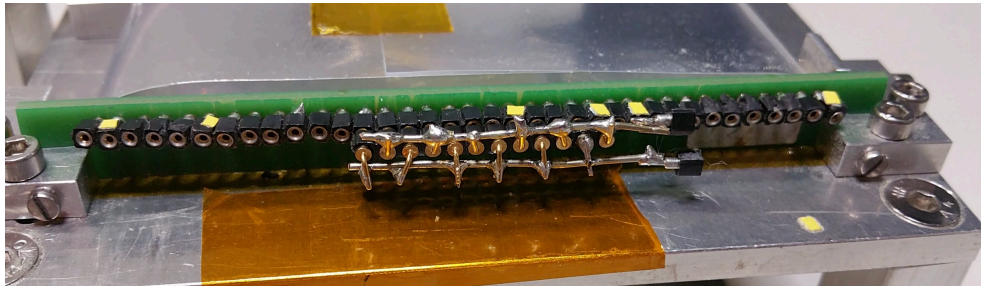
Test Setup



Reflector : ESR2 (Polyester)
Optical grease : 6262A, OHYO KOKEN KOGYO CO.

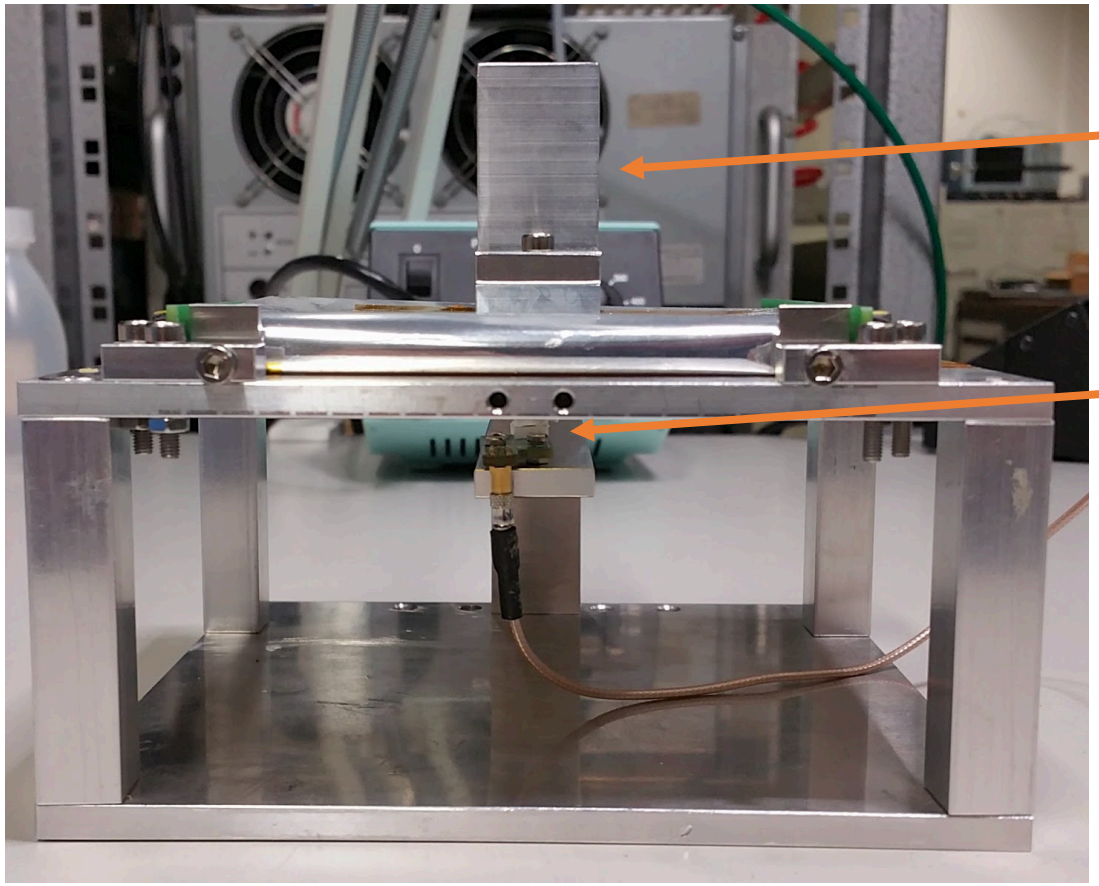


18 MPPCs on the one side

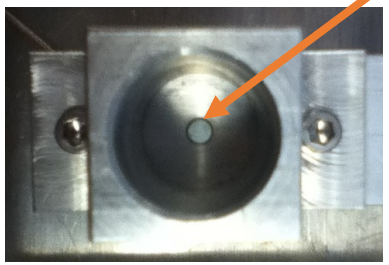


Change the number of MPPCs used or connection

Test Setup



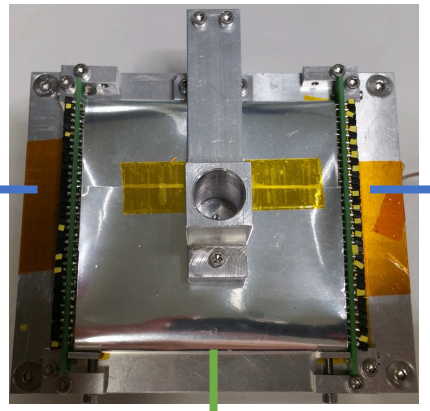
collimator



Sr 90
- 3.7 [MBq]

Trigger counter
- Plastic scintillator
  $5 \times 5 \times 5 mm^3$
  BC422
- MPPC
  S10362-22-050C

Test Setup

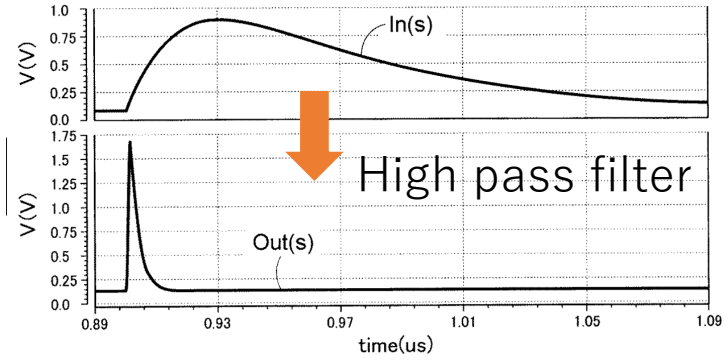


Ch2

Ch1

trigger

Pole zero cancellation : R~1kΩ



Amp

Amp

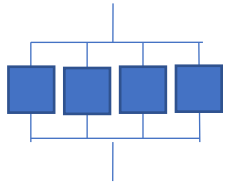
Amp

×1/8

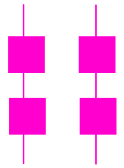
DRS
(Waveform digitizer)

Measured Connection

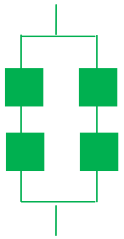
All series



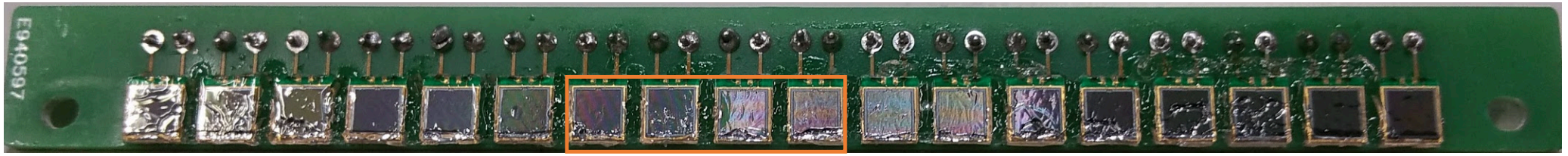
All parallel



Individual readout

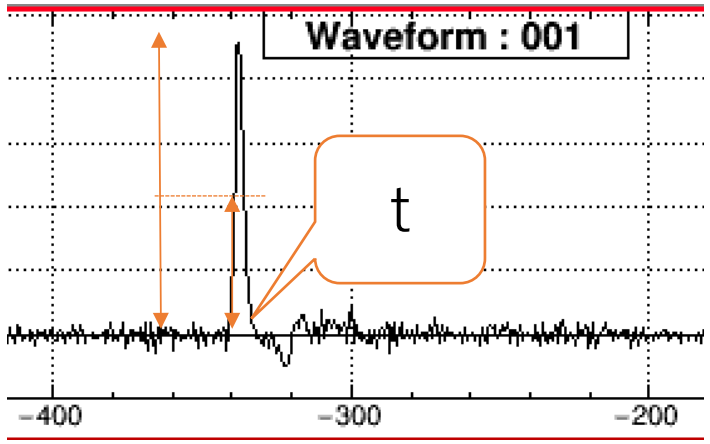


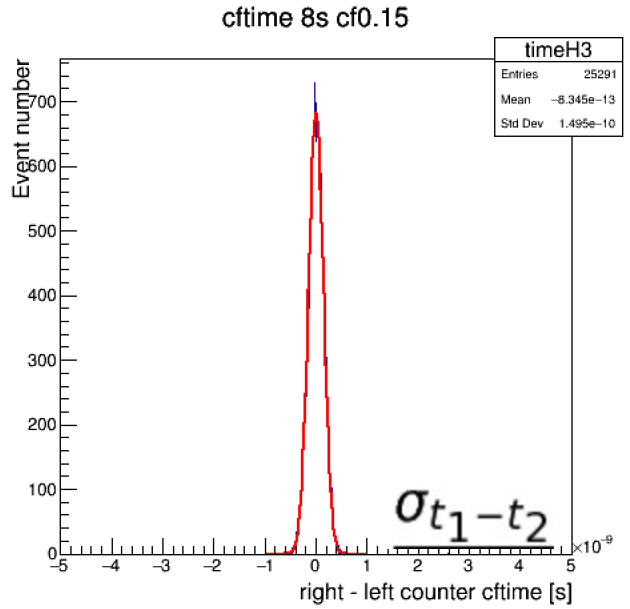
partly parallel



Tested with different number of MPPCs.
MPPCs were selected from the middle.

Calculation of Timing Resolution





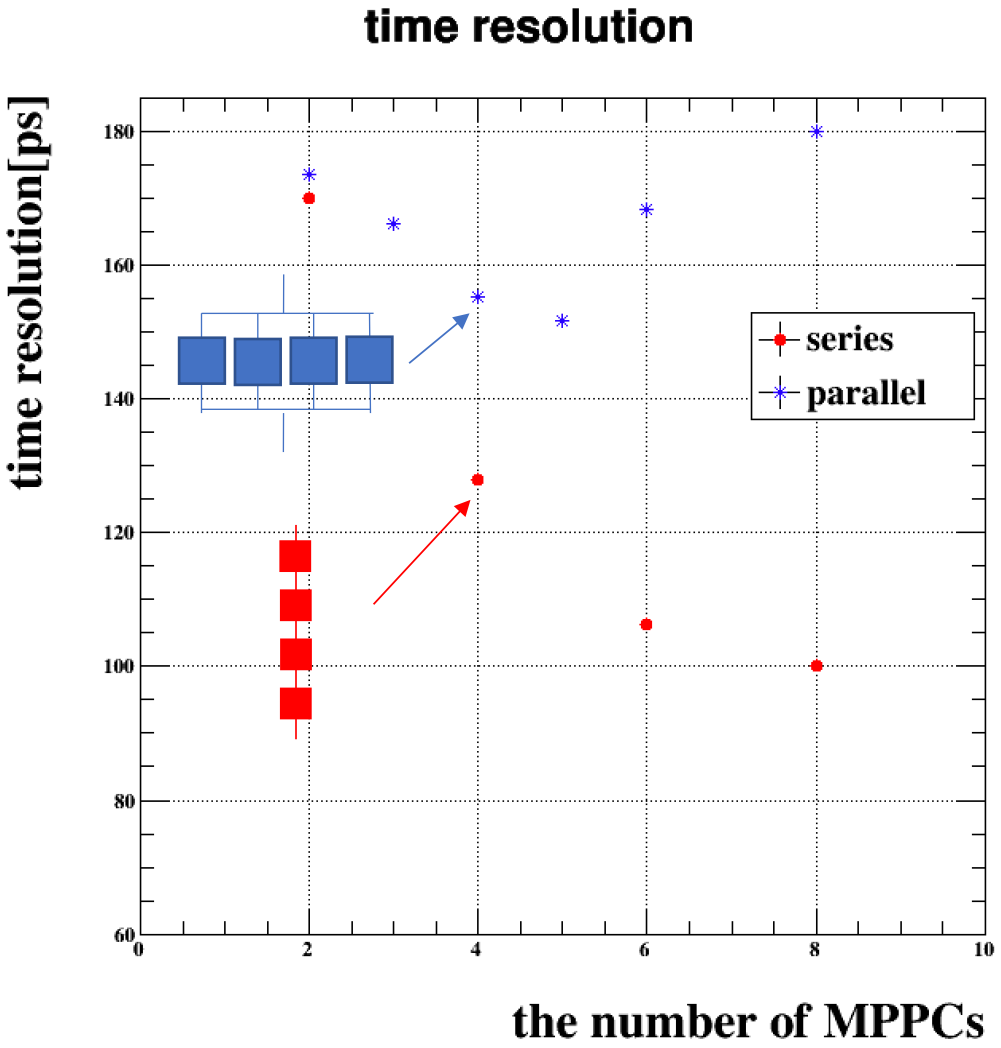
How to derive timing : constant fraction method

- Choose the time which gives a certain fraction of the signal height
  → narrow variation depending on the pulse size

Then, subtract the time of one side from the other side

$$\sigma_{counter} = \frac{\sigma_{t_1-t_2}}{2}$$

Series and Parallel Connection



Checked difference between series and parallel connections.
Resolution of series connection is superior to that of parallel.

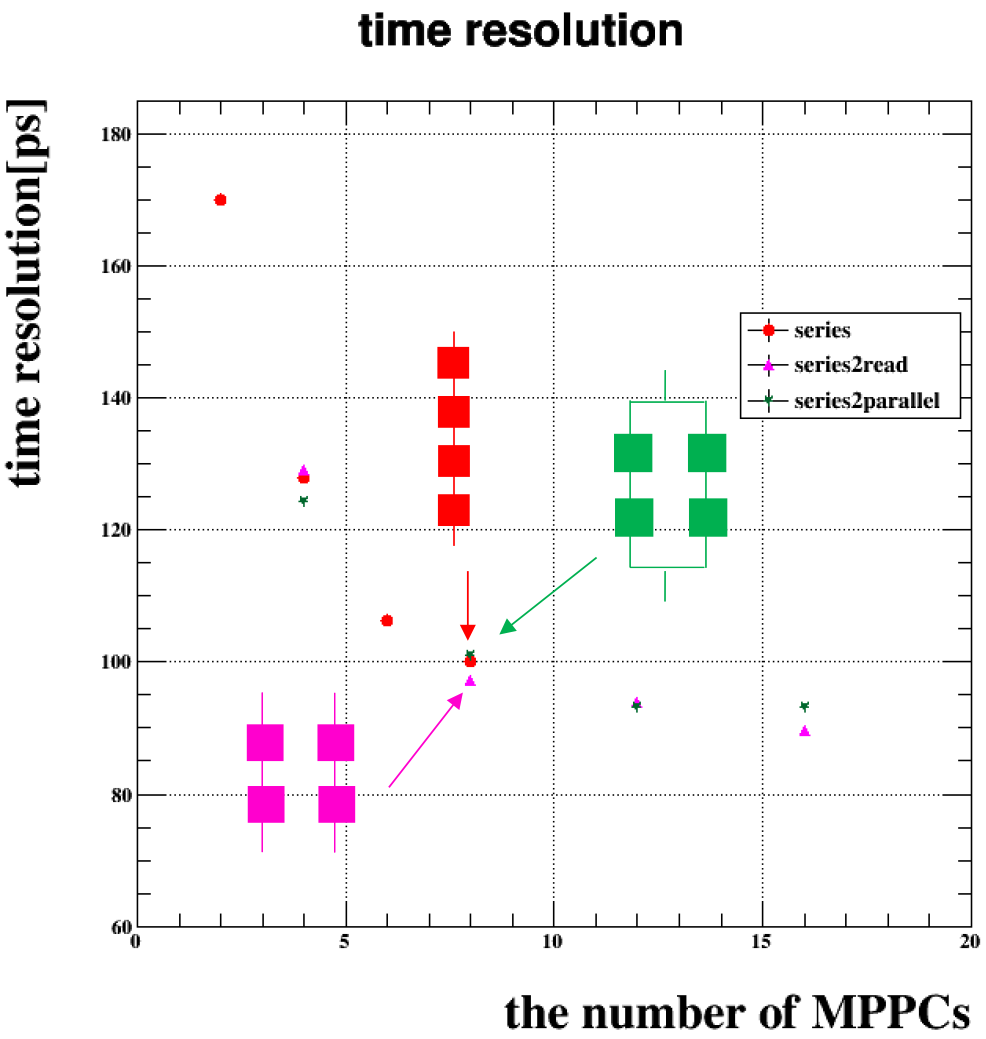
Series

- Resolution improves as more MPPCs are connected

Parallel

- Resolution doesn't improve with many MPPCs due to large capacitance

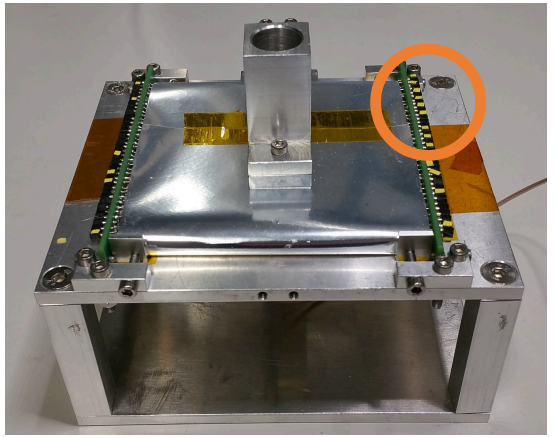
To Connect More MPPCs

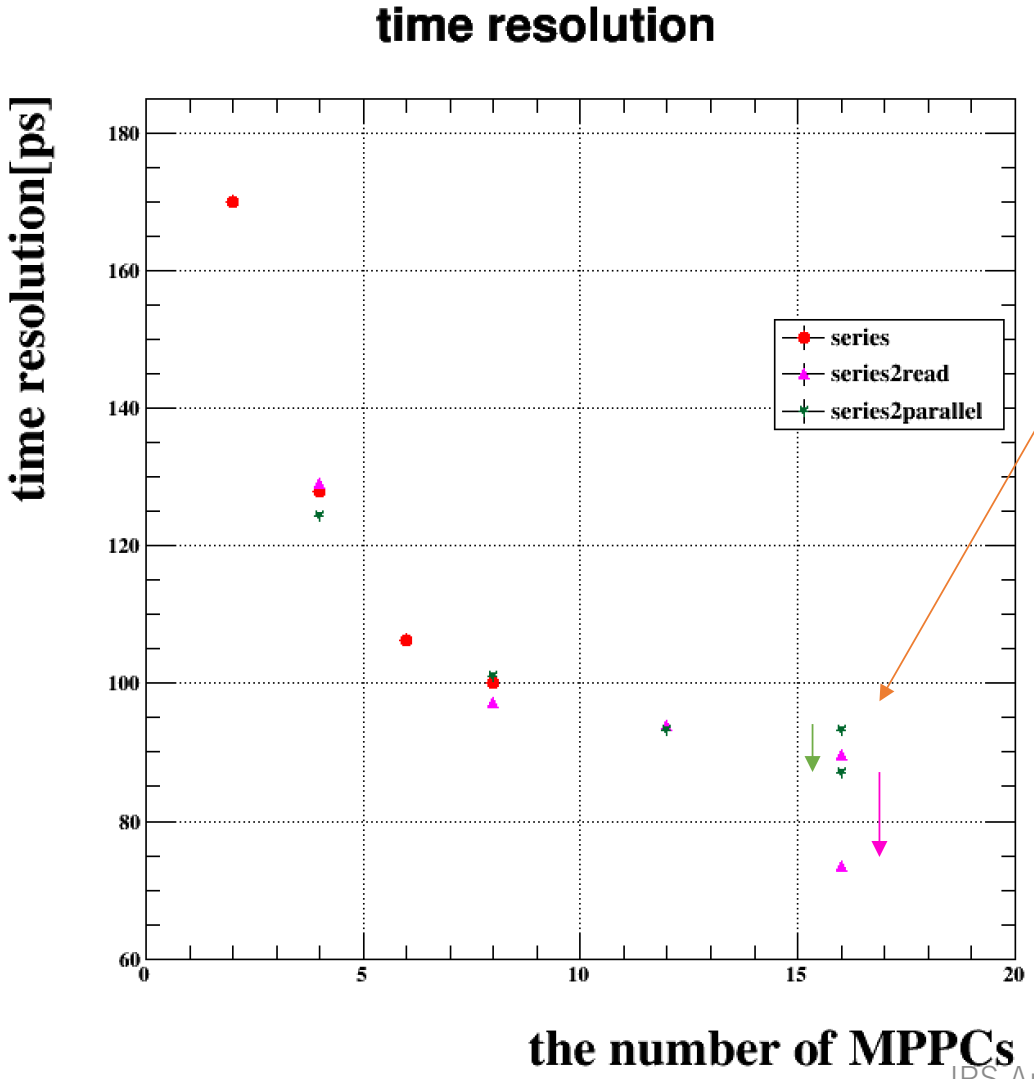


HV limits the number of MPPCs connected in series
→ more channel readout or parallel connection

- Resolution gets better as more MPPCs are connected
- Difference is not large among the three
- Rise time and S/N were not so different.
- Measurement uncertainty was probably large because the noise was unstable.

Modified Result



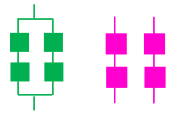


About 90 [ps] resolution is much worse than 50 [ps], the previous research

We found a problem of optical attachment between MPPCs and a scintillator
→ smaller light yields

After fixing the attachment,
8series2read: 89.5 [ps] -> 73.3 [ps]
8series2parallel: 93.2 [ps] -> 87.1 [ps]

Summary

- The pre-shower counter for LXe detector timing calibration will be upgraded based on MEG II Timing Counter study.
- A proto-type counter was made and resolutions were compared with various different connections.
- Confirmed that series connection gives better resolution than parallel connection.
- We tested several other connections ()
  → smaller bias voltage, small number of read out channels
  → resolution was not so different (noise was unstable)

Prospect

- Reached 73 [ps] by improving optical connection.
- Redo the measurement with improved optical connection and better noise situation.
- Other practical connections should be tested