

物理ラン開始へ向けた
MEG II実験検出器のアライメント

**MEG II Detector Alignment
Towards Physics Run**

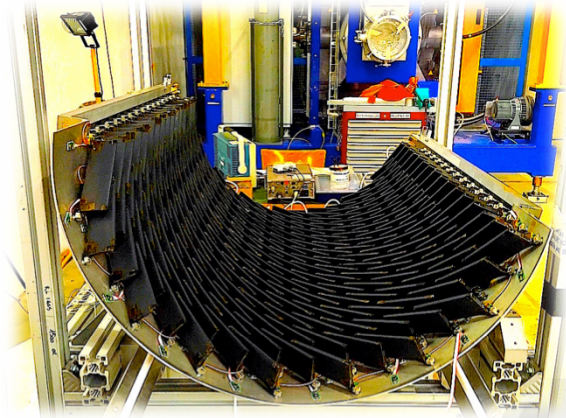
Mitsutaka Nakao

(The University of Tokyo)

On behalf of MEG II Collaboration

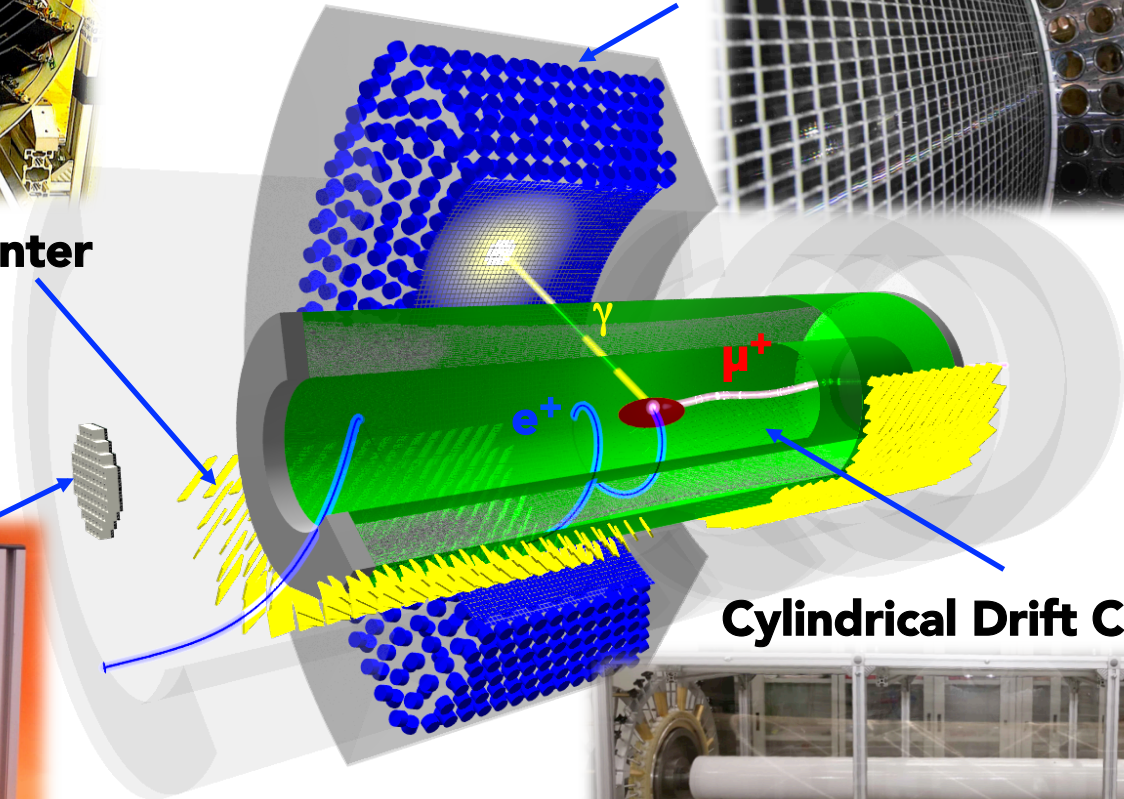
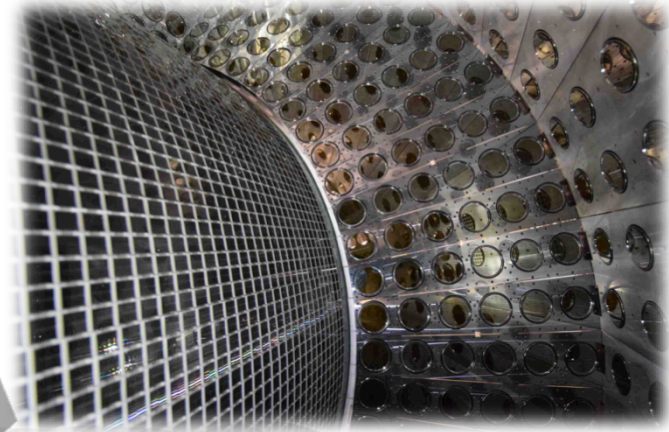


MEG II Detector

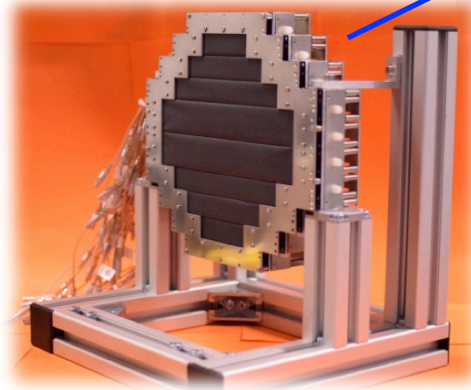


Positron Timing Counter

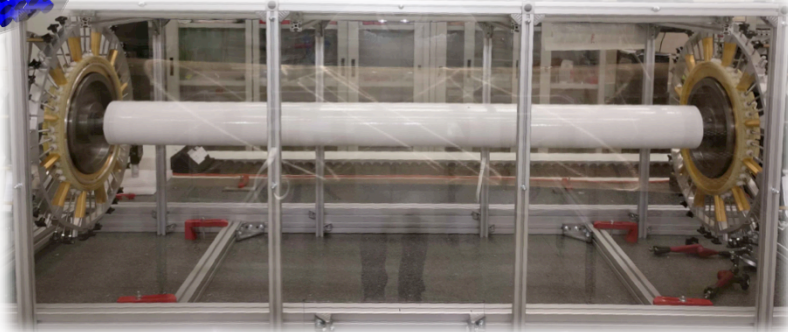
**Liquid Xenon
Gamma-ray
Detector**



Cylindrical Drift Chamber

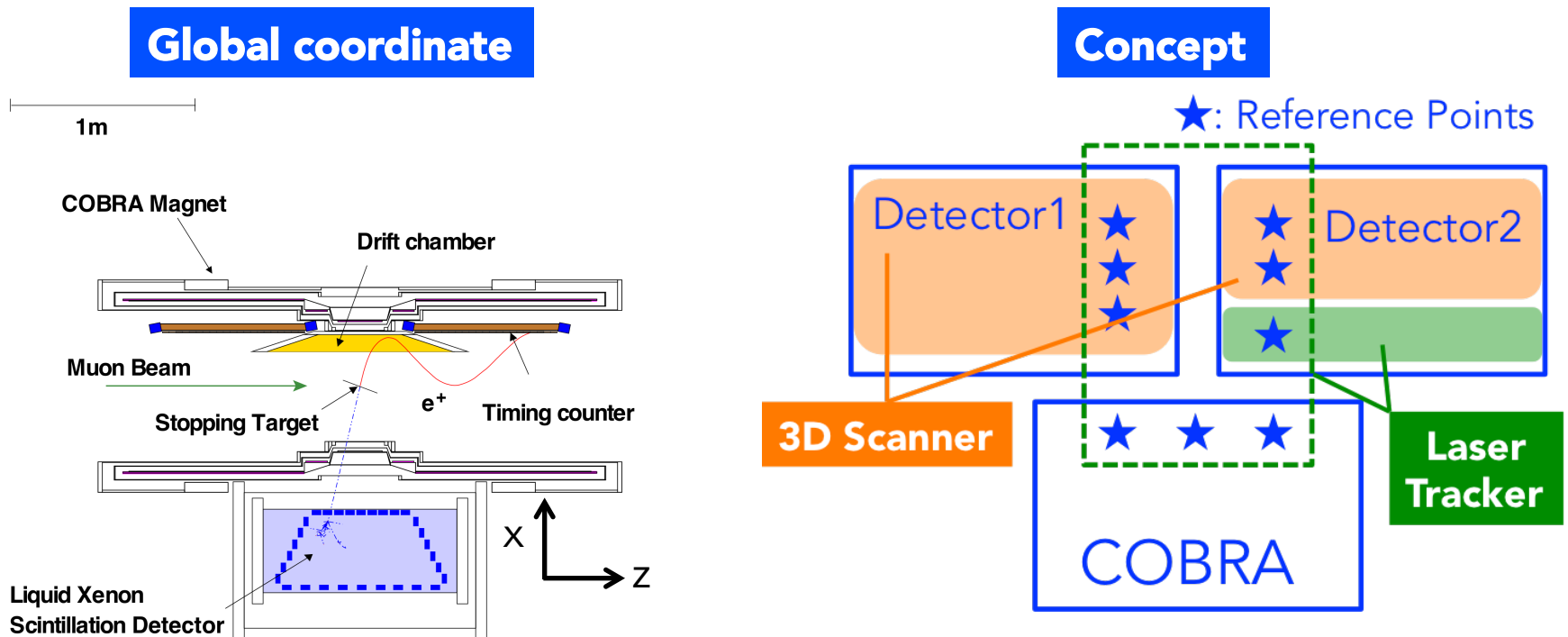


Radiative Decay Counter



Detector Alignment in MEG II

- The goal is to know the position of detectors in global coordinate with a high accuracy.
- 3D Scanner will be used for measurements within a detector(local position).
- Laser Tracker will be used for making connections among detectors(global position).
- Reference points are measured by both methods.

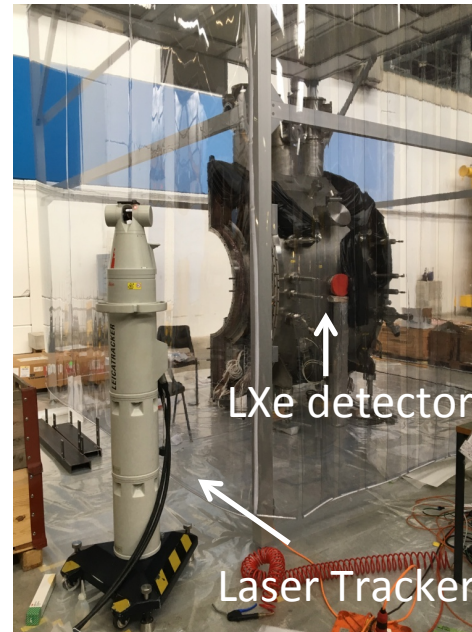


3D Survey

3D Scanner (FARO)



Laser Tracker (Leica)



- Composed of laser head and corner cube.
- Laser emitted from laser head is reflected at corner cube.

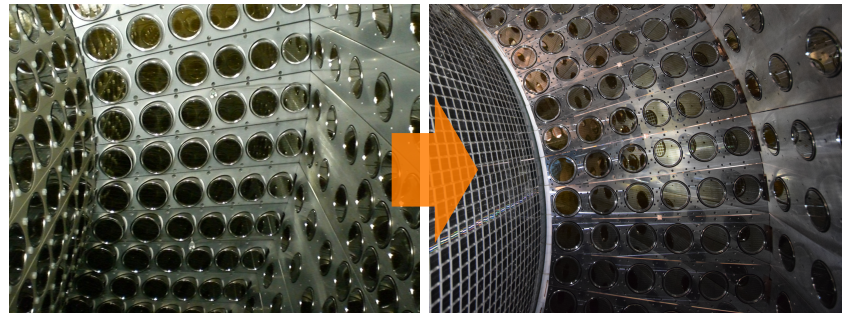
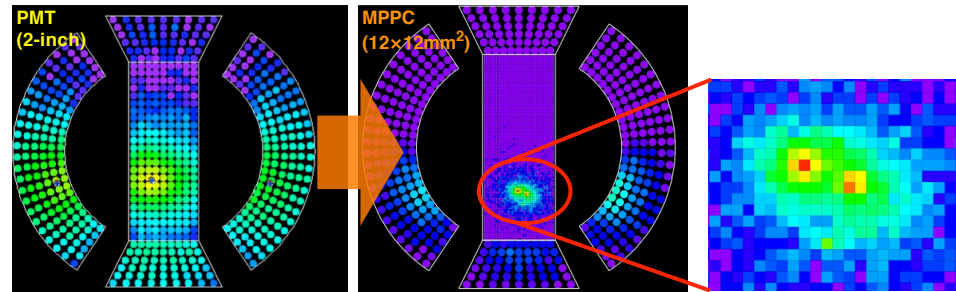


※cited from FARO website, but we do not use FARO's one!

MEG II LXe Detector

LXe Upgrade Better resolution for γ

- Replace PMTs on inner face with MPPCs.
- Modified PMT layout at lateral face.
- Wider inner face.
- Better uniformity of photon collection (better ΔE).
- Higher granularity of scintillation readout (better Δx).



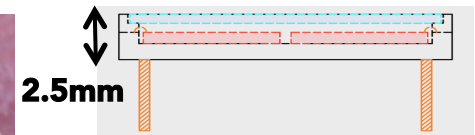
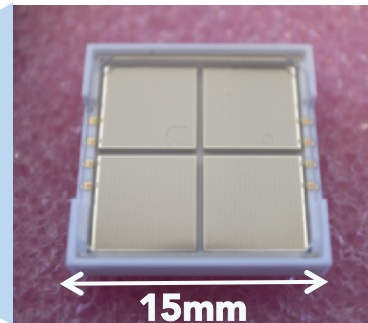
MPPC for LXe



- 22 MPPCs on 1 PCB
- 2 PCB in 1 row (22*2 MPPCs)
- 93 row (22*2*93 MPPCs)

Hamamatsu S10943-4372

side view



- 50 μm pitch pixel
- 6 x 6 mm² x 4 chips
- crosstalk and afterpulse suppression
- quartz window for protection
- ceramic package

LXe Detector Alignment

Requirement

- More precise alignment is required for LXe since resolutions will be significantly improved.
- Target precision: $\sim 500 \mu\text{m}$

Our Plan

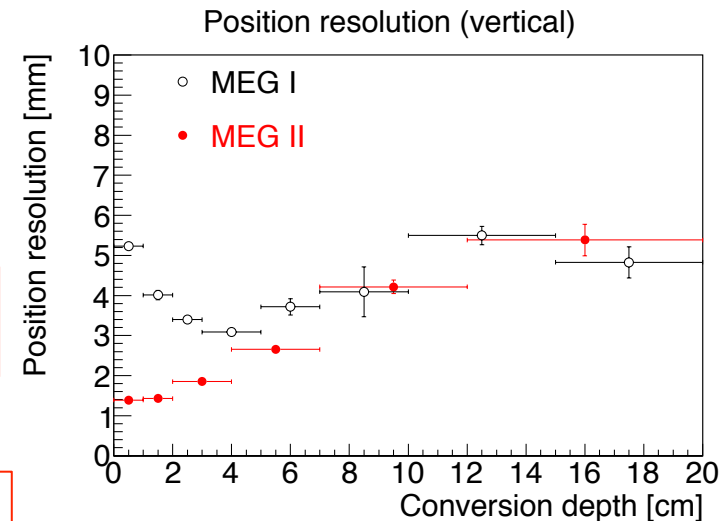
- **Global position** of LXe in experimental area(πE5).
 - global coordinate.
 - laser tracker + corner cube.
- **Local position** of photo-sensor in LXe.
 - 3D scanner for MPPCs
 - Laser tracker for PMTs
- **Possible displacement/deformation**.
 - x-ray survey
 - potentiometer
 - cosmic ray

during sensor installation
@ room temperature

after installation
@ LXe temperature(165 K)

Detector performance for signal γ -ray

	MEG (measured)	MEG II (simulated)
Efficiency	65%	70%
Position	$\sim 5 \text{ mm}$	$\sim 2.5 \text{ mm}$
Energy	$\sim 2\%$	0.7 - 1.5%
Timing	67 ps	40 - 60 ps



Measurements

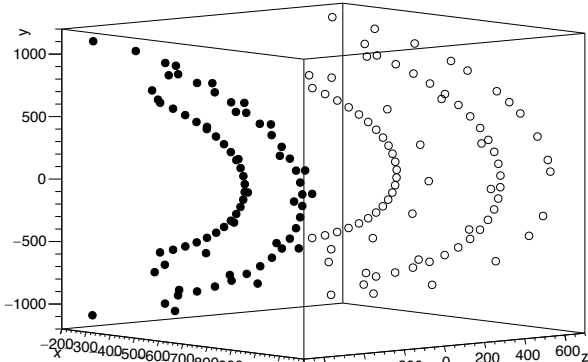
PMT (Laser Tracker)



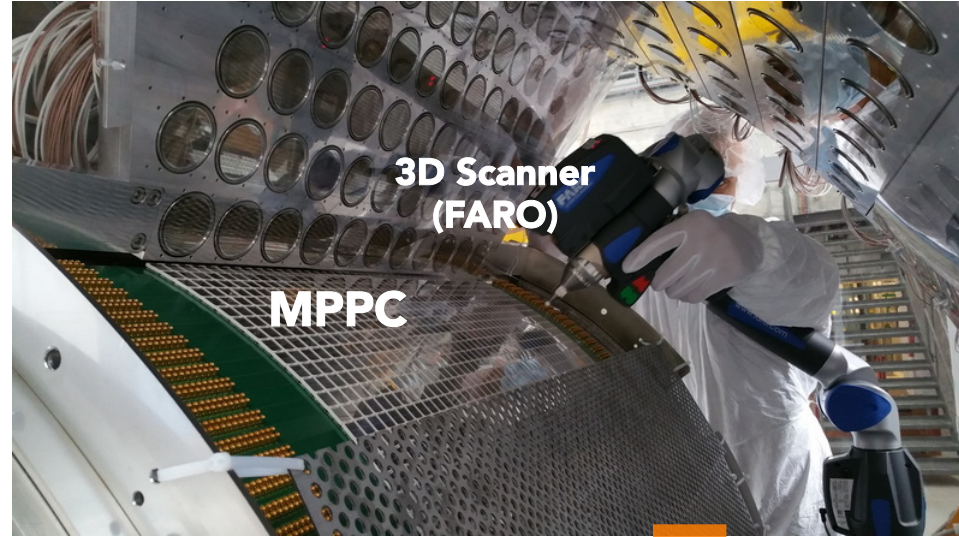
corner cube



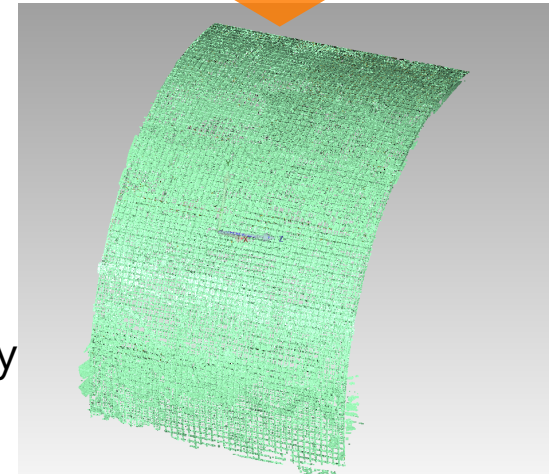
y:x:z



MPPC (3D Scanner)



- We performed 3D measurements using laser tracker and 3D scanner.
- PMT holders were measured by laser tracker.
- All MPPCs were measured by 3D scanner.



Analysis of FARO data

- Each MPPC position and direction can be described by **6 Parameters**.

- position: x, y, z
- rotation: α, β, γ

- Fitting model (\rightarrow)

- 4 cuboids.

- Data used for fitting:

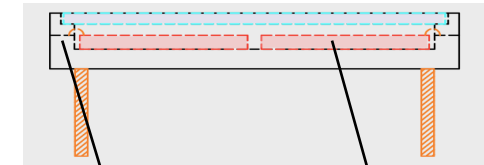
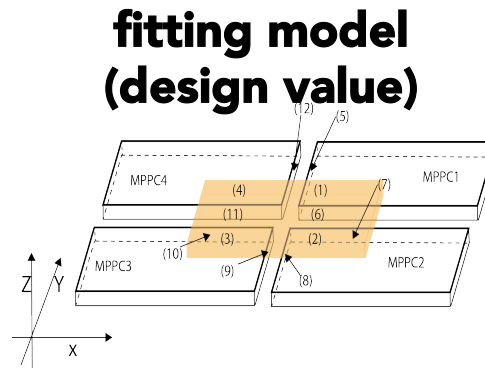
- cross at center.
- side and top part of 4 chips.

- Calculate **distance** b/w data points and mode

- Find the 6 parameters to **minimize** sum of $(\text{Distance}/\sigma)^2$.

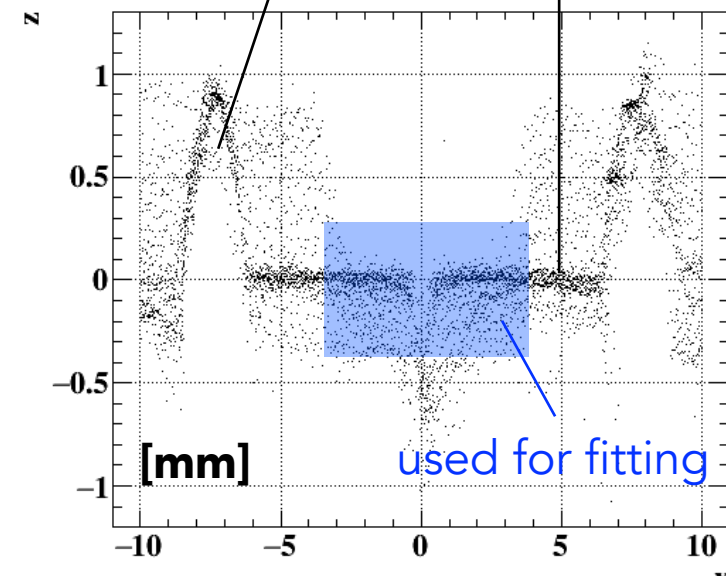
- **Iteration** until fitting is converged.

- Apply this process to all 4092 MPPCs



ceramic package

MPPC surface

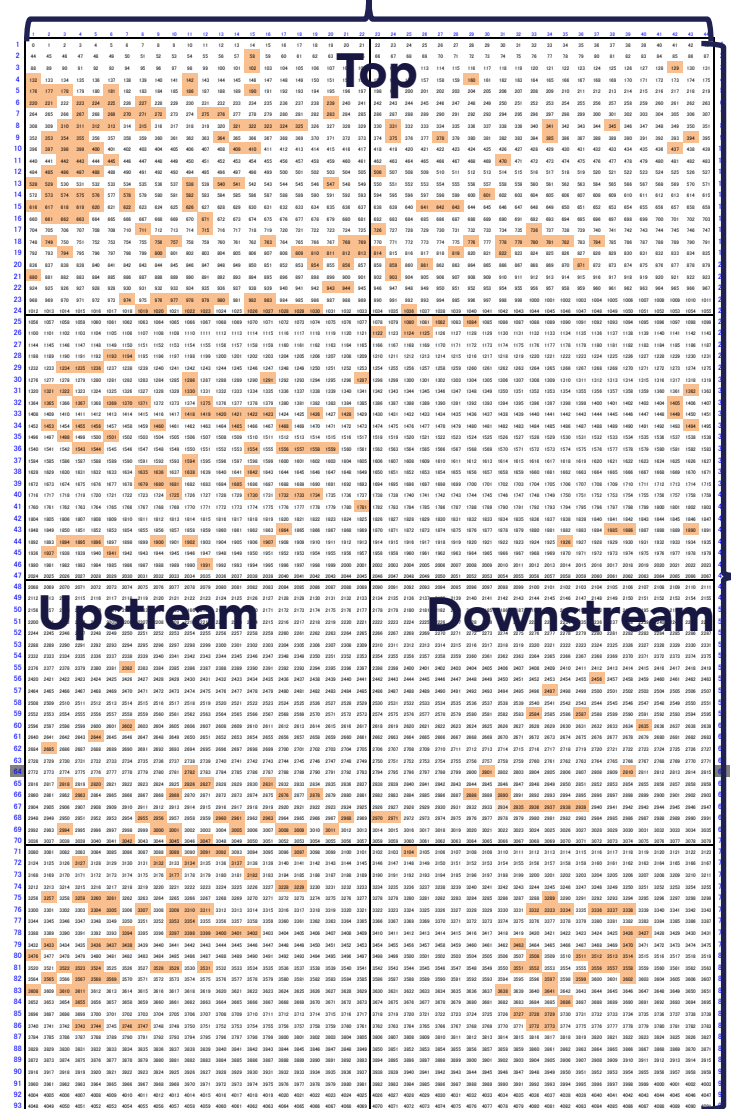


side view of scanned data

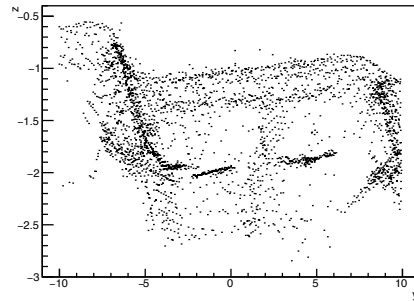
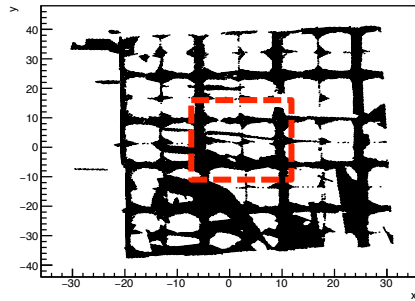
Results & Discussion (1)

- Only 356 MPPCs out of 4092 are well fitted and find the position and direction.
- This is due to bad quality of data.
- Data quality depends on reflection and is restricted by accessibility of FARO arm.

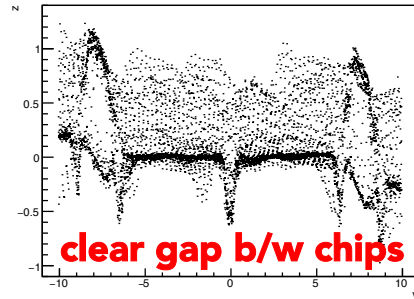
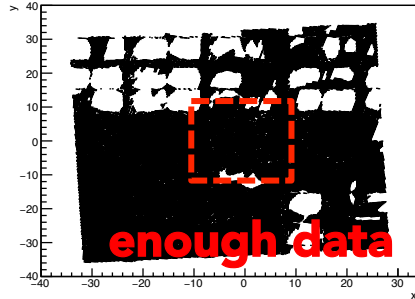
... well fitted 44



y:x **Bad quality** z:y (<x>-10&&x<10&&y>-10&&y<10)



y:x **Good quality** z:y (<x>-10&&x<10&&y>-10&&y<10)



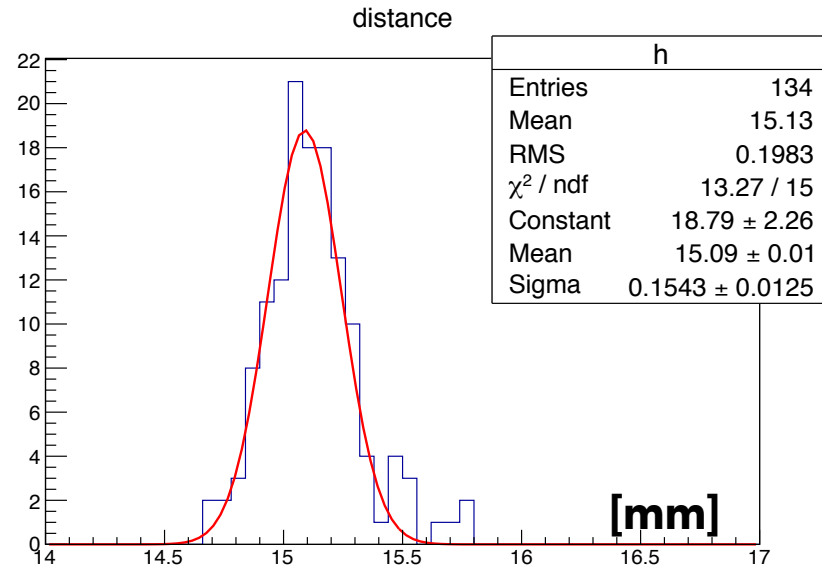
Bottom

Results & Discussion (2)

Check

- Calculate distance b/w adjacent MPPCs to evaluate fitting accuracy.
- The distance should be 15.1 mm as a design value.
- Mean: 15.09 ± 0.01 mm
- Sigma: 0.15 mm
< 0.5 mm: requirement

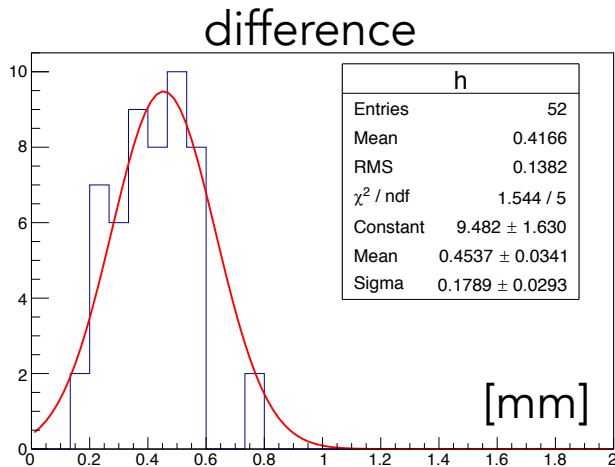
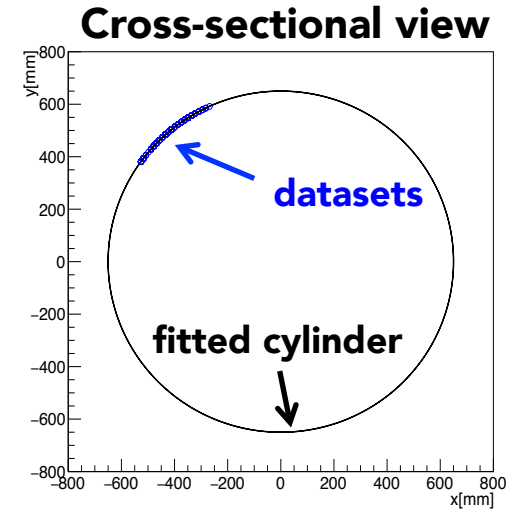
Distance b/w adjacent MPPCs calculated only for fitted MPPCs



- **Good**: the accuracy for fitted MPPCs is enough.
- **Bad**: the number of fitted MPPCs is small.

Solution

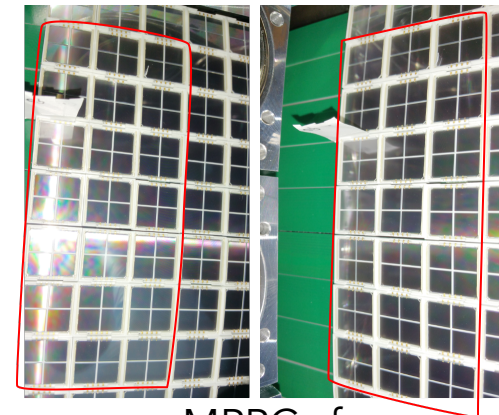
- To reconstruct all MPPCs, we tried **cylindrical extrapolation**.
 1. divide data points (from FARO fit) into 2 groups
 - one is used for cylindrical fitting(**1st datasets**).
 - the other is used for checking(**2nd datasets**).
 2. fit with cylinder using **1st datasets** and find radius and direction of axis.
 3. calculate positions of **2nd datasets** assuming the fitted cylinder.
 4. compare calculated position and results from FARO fit.
- Mean of the difference: **0.45 mm (< 0.5 mm: requirement)**
→ **cylindrical extrapolation seems working well.**



Yet another solution:

Picture reconstruction

- 3D reconstruction using pictures from different angles.
- checked consistency and got enough accuracy within ± 2 rows.



same MPPCs from different angles

Prospects

Room
temperature

LXe
temperature

Detector
Installation

2017

2018

- **MPPC reconstruction**

- Improvement of FARO fitting (by using more MPPCs or better models).
- Cylindrical extrapolation.
- Picture reconstruction.

- **Potentiometer**

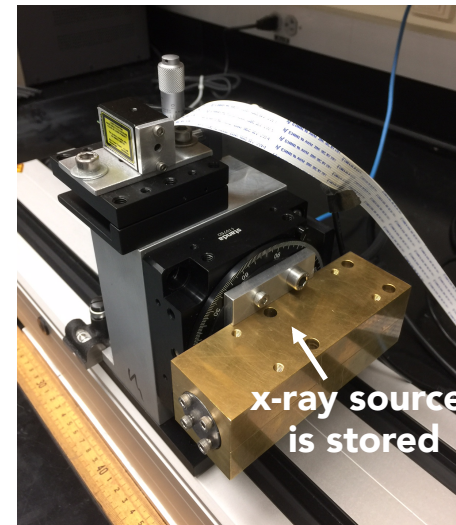
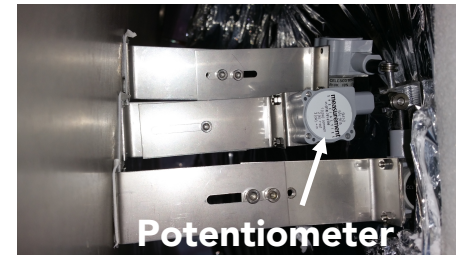
- Measure and monitor possible displacement/deformation of inner vessel.

- **X-ray survey**

- Produce collimated X-ray beam of known position and orientation.
- 124/132 keV from ^{57}Co
- Spot size at LXe: $1.2 \times 40 \text{ mm}^2$

- **Cosmic ray**

- In MEG I, cosmic ray were used to measure the position of the DCH frame relative to the LXe detector.
- An accuracy of 1 mm in horizontal and vertical directions were achieved.



Summary

- **MEG II detector and its alignment**

- 3D scanner and laser tracker are used for measurements of every detector.
- Detectors are aligned to global coordinate.

- **LXe detector alignment**

- Target accuracy: ~0.5 mm
- In room temperature, MPPCs are measured by 3D scanner and PMT holders are measured by laser tracker.
- In LXe temperature after installation of detector, possible deformation will be measured by x-ray and potentiometer.

- **MPPC reconstruction using 3D scanned data**

- Some MPPCs are successfully reconstructed with an accuracy of 0.15 mm.
- Others are failed due to bad quality of data.
- However, they can be compensated by using cylindrical extrapolation with an accuracy of 0.45 mm.

- **Prospects**

- Potentiometer installation and x-ray survey follows towards physics run.