Precise Measurement of 3D-position of SiPMs in the liquid xenon gamma-ray detector for the MEGII Experiment

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0. Abstract

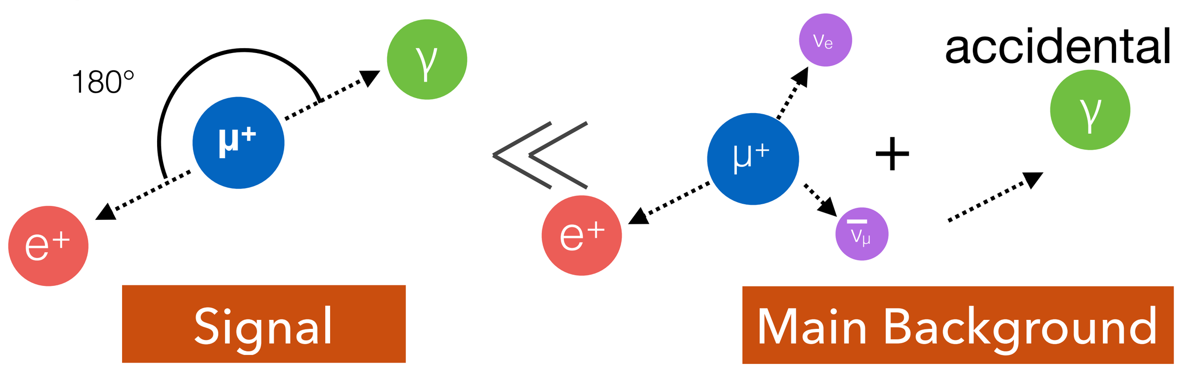
We developed two complementary ways to measure the position of SiPMs inside liquid xenon detector for MEG II experiment; one uses laser tools and the other uses X-ray beam.
We measured the position of all SiPMs to an accuracy of 320μm.

1. Introduction

MEG II Experiment

MEG II experiment searches for a charged lepton flavor violating(cLFV) decay, μ→eγ. If discovered, this is an clear evidence of **new physics beyond SM.**

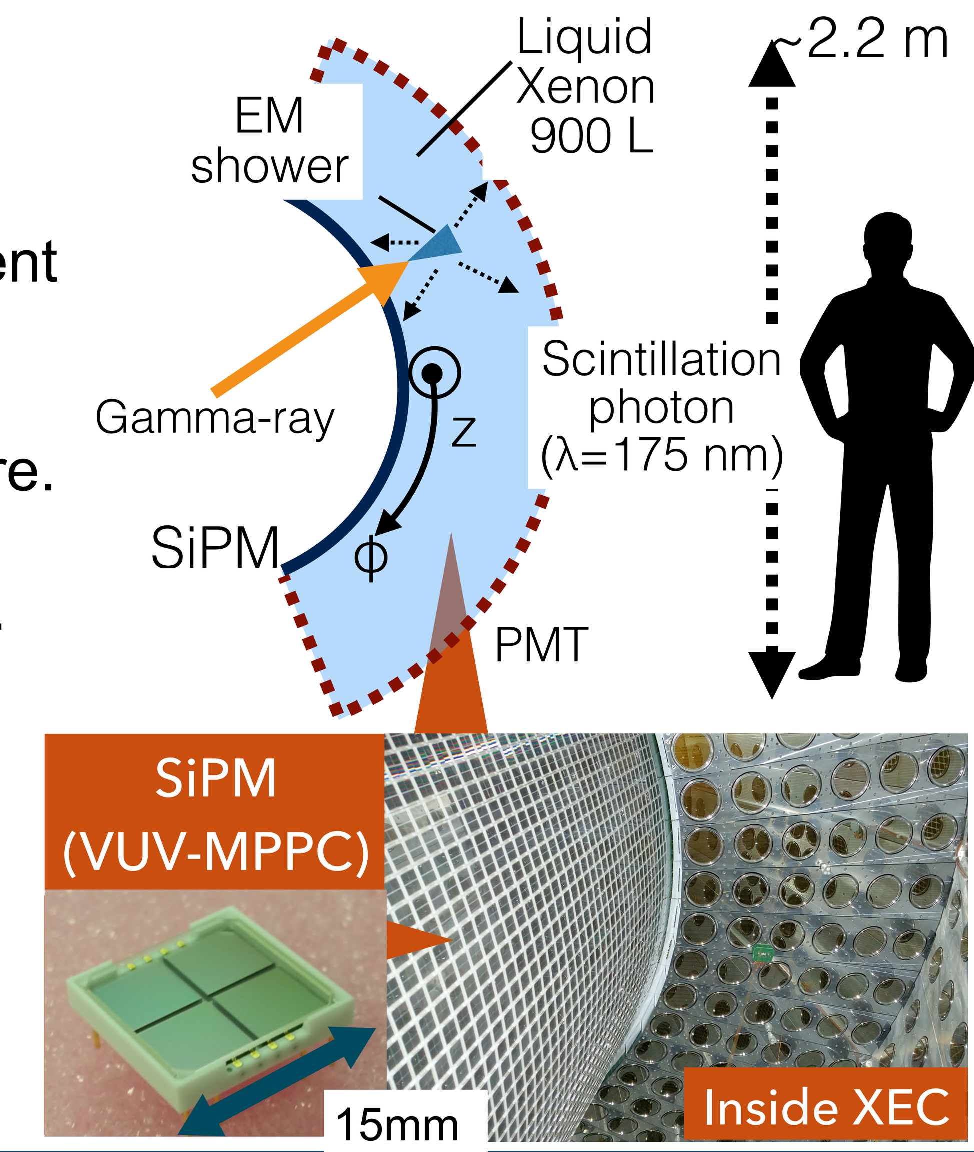
Back-to-back
Same time
$E_\gamma = E_{e^+} = 52.8$ MeV



Liquid Xenon Gamma-ray Detector(XEC)

XEC can achieve ~2mm position resolution of an incident gamma-ray with **4,092** SiPMs on its inner face.
The SiPMs are mounted on a precisely machined structure, but they shrink at the liquid xenon temperature.
The position of the SiPMs should be measured to an accuracy of **500 μm**, better than the position resolution.
To achieve this accuracy, we performed two complementary measurements.

Measurement	Laser	Xray
Temperature	△ room temp	✓ **LXe temp**(170K)
Coordinate	✓ **3D(x,y,z)**	△ 2D(z,ϕ)

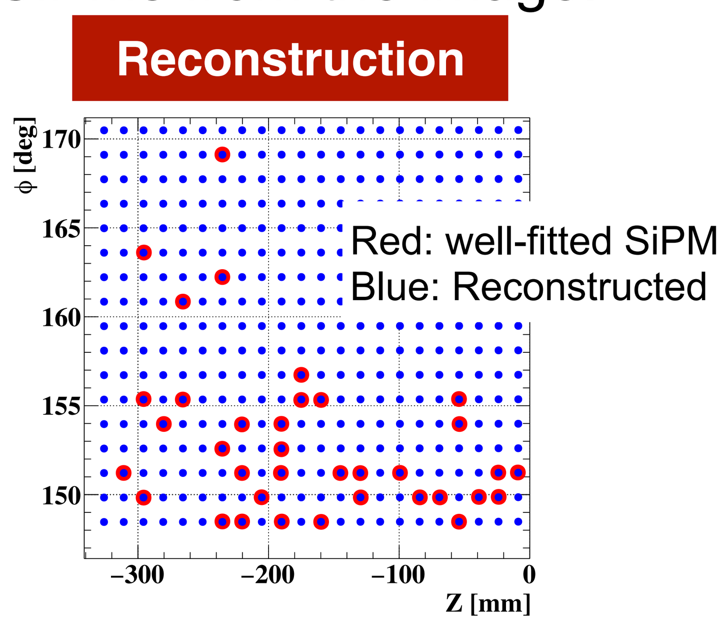


2. Laser Measurement @ room temp.

Method

Laser scanner can measure the position of an object by emitting laser and detecting reflected light (triangulation).
It measures the surface structure of the incident face.
We can reconstruct the position of SiPMs from the image.

Faro Edge ScanArm HD



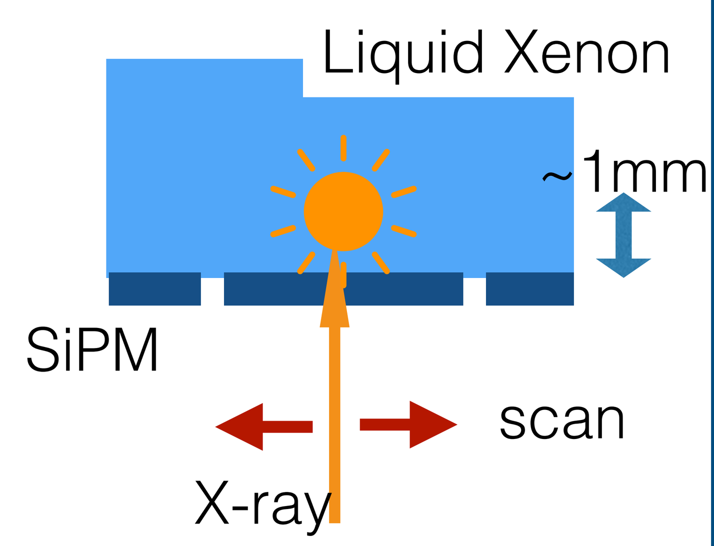
Result

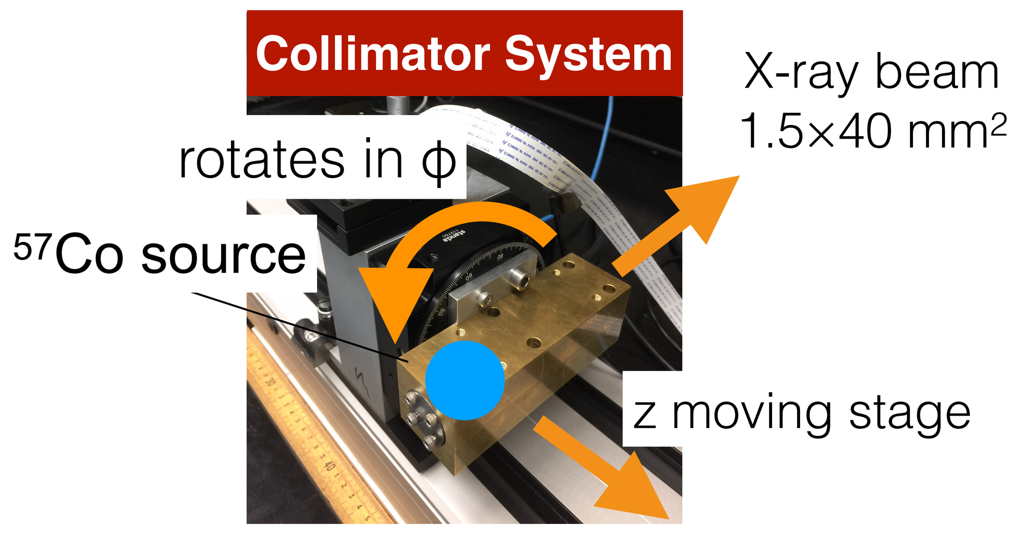
All SiPMs are scanned and the position of 10% of the SiPMs is obtained to an accuracy of ~120 μm.
Data quality is limited by the motion range of the scanner arm and scattering at the surface of the SiPMs.
The relative position of all SiPMs is reconstructed from the limited number of the SiPMs to an accuracy of 180 μm.

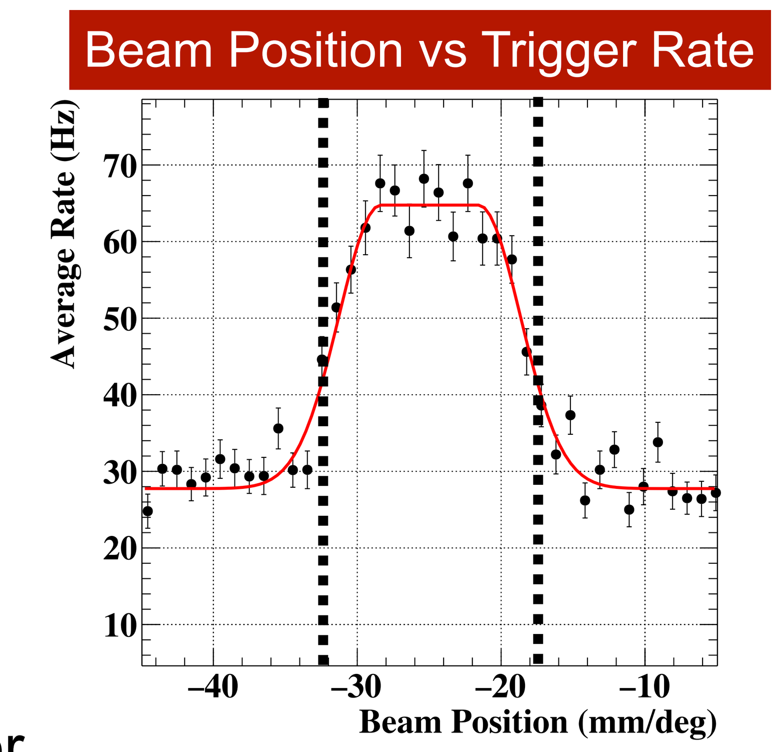
3. X-ray Measurement @ LXe temp.

Method

The nearest SiPM to X-ray's conversion is strongly illuminated.
By scanning the SiPM array in z and Φ direction with the beam and recording trigger rate of each SiPM, we can measure its position.







Result

We measured the position with a resolution of **250 μm**.
Collimator alignment by laser tracker makes systematic uncertainty, 30 μm in z direction and 80 μm in Φ direction.

4. Combination

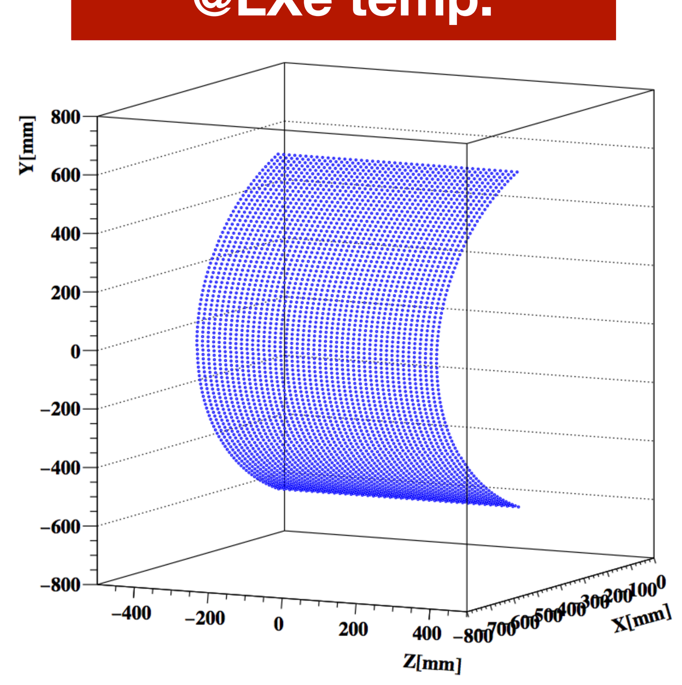
Transformed 3D position is fitted to X-ray's result.
After fitting, both results matched to an accuracy of 300 μm.
Furthermore, reasonable thermal contraction was observed.
Measured : a = 1.76±0.14 × 10^{-3}
Expected : a = 16±1 ppm•K^{-1}×110±10 K
= 1.8±0.2 × 10^{-3}
As a result, we obtained the position of all SiPMs to an accuracy of 320 μm.

3D-Position @ room temp. → transform & fit → 2D-Position @ LXe temp

Transformation

$$\vec{x}_{laser} \mapsto \underbrace{(1-a)}_{\text{scale}}\underbrace{R(\alpha,\beta,\gamma)}_{\text{rotation}}\vec{x}_{laser} + \underbrace{\vec{c}}_{\text{shift}}$$

3D SiPM position @LXe temp.



5. Summary

We used a laser scanner and an X-ray beam to measure the position of the SiPMs at room temperature and at LXe temperature, respectively.
In the end, by comparing the two results, **we reconstructed the position of all SiPMs to an accuracy of 320 μm**.
Furthermore, we observed reasonable thermal contraction of the SiPMs.

6. Acknowledgement

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7. Contact

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