（別紙様式５）

変革を駆動する先端物理・数学プログラム（FoPM）

国外連携機関長期研修　報告書

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Overview of this training course

I stayed at Paul Scherrer Institute (PSI) and participated in the MEG II experiment. In the MEG II experiment, it is important to measure the energy, position, and timing of a gamma ray and a positron from a muon decay with high resolution. Liquid xenon gamma-ray detector (LXe) measures the energy, position, and timing of the gamma-ray. In this training course, a dedicated run to evaluate the performance of LXe has been completed and the data analysis is ongoing.

MEG II experiment

The MEG II experiment is searching the rear muon decay ($\mu \rightarrow e\gamma$) with the highest sensitivity using the world's most intense direct current muon beam produced at PSI. $\mu \rightarrow e\gamma$ decay is forbidden in the standard model but is expected to be observable in the new physics. Therefore, if this decay can be observed, it is evidence of the new physics. The physics data-taking started in 2021, and the data acquisition was also conducted in 2023 from June to November.

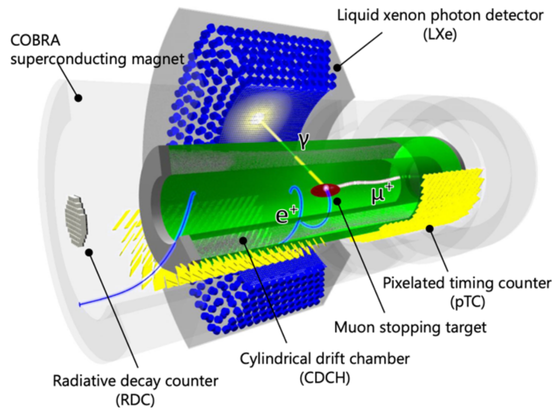

Fig. 1 The detector of MEG II experiment.

Liquid xenon gamma-ray detector (LXe) (Fig. 1)

LXe consists of 900 L of liquid xenon, 4092 Multi-Pixel Photon Counters (MPPC), and 668 photomultiplier tubes (PMT). These photon sensors read out the scintillation light from the gamma-ray incident on liquid xenon. The gamma-ray energy, position, and timing are reconstructed from the light intensity and distribution. It is necessary to reconstruct the gamma-ray events with high resolution to perform the rear muon decay search with high sensitivity.

Dedicated run to evaluate the performance of LXe

A dedicated run to measure the resolution of LXe is performed once a year. In 2023, physics data was acquired until October, and time for this dedicated run was allocated in November.

The detector setup is changed from that used for the physics run in this run (Fig. 2). A pion beam and liquid hydrogen target are used, and the gamma-ray pairs from charge exchange reactions are used for the data acquisition. A timing counter is installed on the opposite side of LXe across the liquid hydrogen target. A gamma-ray pair emitted at an angle of 180 degrees can be selected by detecting gamma rays at LXe and the timing counter. These gamma rays have energies of 55 MeV and 83 MeV, which is

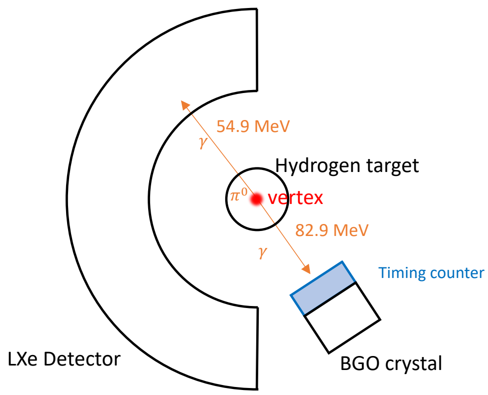

Fig. 2 The setup of the LXe performance evaluation run. The timing counter is installed on the opposite side of LXe.

close to the gamma-ray energy of 52.8 MeV in the signal event, making them useful for calibration and performance evaluation.

The timing counters used for the dedicated performance evaluation run were prepared in October. The timing counters used in 2022 were broken and they had to be repaired. The timing counter consists of a plastic scintillator plate, MPPCs, and PCB boards (Fig. 3). The scintillation light is read out from both ends of the plate. The two plates are stacked crosswise, and a lead converter is installed in front of the counter. The adhesion between MPPCs and the scintillator plate had been detached and was repaired. The damaged cable was also repaired.

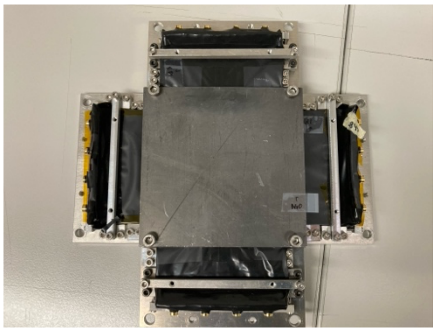

Fig. 3 The picture of the timing counter. It consists of two plastic scintillator plates and a lead converter.

The operation of the timing counters was checked at the lab before the installation to the actual detector. It was confirmed that there was no problem with the counter adhesion and that the counters had sufficient timing resolution.

The timing counter was installed in early November (Fig.4). It was confirmed that all channels were working after the installation and the data acquisition was started. As a result of cooperation with the target, beam, and trigger group, sufficient statistics were obtained for the entire LXe area. We were also able to perform additional tests that were not originally planned.

Fig. 4 The picture of the timing counter installation work. There is a readout electronics on the right side. The cables from the timing counter are connected to the electronics.

The data analysis is currently ongoing. First, the photon sensors in LXe should be calibrated. The photon sensors are calibrated using the calibration data taken every day, and the performance evaluation run is also used for the calibration. After the calibration, the timing resolution will be evaluated.

The gamma-ray hit timing on the timing counter is used as a reference in the timing resolution evaluation. The timing resolution of the timing counter can be estimated by the time distribution of the time difference between the two plates that constitute the timing counter. From the gamma-ray hit time distribution at LXe and the timing counter, the timing resolution of LXe can be evaluated. However, it should be noted that this is affected by the spread of the position of the gamma-ray emission position in the target. This is measured in advance by installing the timing counter also in front of LXe. It can be measured from the time difference between the two counters and the timing resolution of each timing counter. As a preliminary result, it was confirmed that the timing resolution of LXe is almost the same as that in 2022 but the detailed calibration and the performance evaluation are ongoing.

I am grateful for the opportunity to spend four months in an out-of-country laboratory collaborating with researchers from around the world. In particular, this work would not have been possible without the cooperation of the target, beam, and trigger groups in the MEG II experiment.