

Study on Time Offset Effect for Scintillation Detectors with Series-Connected SiPM Readout

Kosuke Yanai¹, G. Boca^{2,3}, P. W. Cattaneo³, M. De Gerone^{4,5}, F. Gatti^{4,5}, M. Nakao¹, M. Nishimura¹, W. Otani¹, M. Rossella², Y. Uchiyama¹, M. Usami¹



1. The University of Tokyo, Tokyo, Japan
 2. INFN Pavia, Pavia, Italy 3. The University of Pavia, Pavia, Italy
 4. INFN Genova, Genova, Italy 5. The University of Genova, Genova, Italy

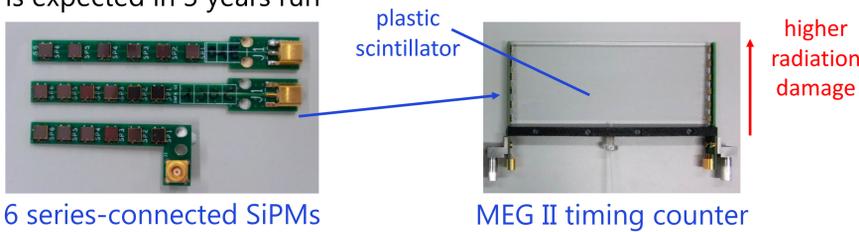
Core-to-Core Program



Abstract Time response of scintillation detectors with **series-connected SiPM** readout was studied. We discovered that the signal line of series-connected SiPMs can produce **non-negligible time offsets** depending on the hit position of the particle. Moreover, we studied the effect of radiation damage, and found that **non-uniform radiation damage** to the series-connected SiPMs can potentially **enhance this time offset**. In the end, we present a possible way to **correct this time offset** in the case of MEG II pixelated Timing Counter (pTC) in which 6 series-connected SiPMs are used for readout.

Introduction

- Series connection of SiPMs
 - SiPMs are widely used for readout of scintillation detectors
 - Series connection** of SiPMs lowers the capacitance and sharpens the signal waveform, leading to **better timing resolution**
- MEG II pixelated Timing Counter (pTC)
 - Consists of a plastic scintillator with **6 series-connected SiPM** readout on both sides
 - Achieves **~36 ps** resolution with multiple hit scheme
 - Non-uniform radiation damage** to SiPMs of order $\sim 10^9 n_1 \text{ MeV/cm}^2$ is expected in 3 years run



Aim & Motivation

- Understand the time response of scintillation counters with series-connected SiPM readout
 - Investigate **vertical position dependence** of time response
 - Investigate the **effect of radiation damage to SiPMs** on time response

Measurement Setup

- Definition
 - (Time center) = (time_{ch1} - time_{ch2})
 - Constant fraction method** (20%) is used
- Timing measurement was repeated for
 - Each hit position
 - Differently damaged SiPM chain
 - Reversed order of SiPMs

Legend for SiPM types:

- non-damaged SiPM (light blue)
- neutron-irradiated SiPM ($8.7 \times 10^8 n_1 \text{ MeV/cm}^2$) (dark grey)
- electron-irradiated SiPM ($3 \times 10^9 n_1 \text{ MeV/cm}^2$) (yellow)
- neutron-irradiated SiPM ($5.5 \times 10^9 n_1 \text{ MeV/cm}^2$) (black)

Patterns shown: Non-damaged, Pattern A, Pattern B, Pattern C, and their reversed versions.

Application

- Effect on MEG II pTC
 - Signal propagation time between two SiPMs was found to be **~80 ps**
 - By setting this offset between SiPMs in MC simulation **pTC resolution was found to degrade** from **36.5 ps** to **41.4 ps**, and further degradation is expected from radiation damage to SiPMs
 - We plan **pTC operation at 10°C**, which might reduce the overvoltage deviation among SiPMs
- Offline correction
 - Position dependence of the time offset can be checked** in pTC using positron tracking information
 - Correcting this offset in the offline analysis in the case of no radiation damage **suppresses the pTC resolution degradation** to **39.2 ps**
 - Importance of offline correction increases with accumulated level of radiation damage to SiPMs

Result

- Position dependence of pulse height
 - Pulse height is larger for hit points closer to less-damaged SiPMs
- Position dependence of time center
 - Intrinsic time offset** of counter was measured to be **~100 ps** using non-damaged SiPM chain
 - Damaged SiPM chains show significantly different values, suggesting **additional effect from radiation damage** to SiPMs

Discussion

- Pulse height behavior
 - Common current flow** to all SiPMs in series connection
 - Difference in I-V characteristics causes **overvoltage difference** (i.e. gain difference) according to the damage level of SiPMs
- Time center behavior
 - Signal line of series-connected SiPMs causes some time offset
 - Time response of SiPM (**charge collection speed**) changes with the overvoltage
 - Time response of **SiPMs closest to readout is dominant**
 - Time offset enhances in "normal order" as SiPMs closest to readout are more damaged

Summary & Conclusion

- Using **series connection of SiPMs** in scintillation timing detectors can produce **non-negligible time offsets** depending on the hit position
- Non-uniform radiation damage** to series-connected SiPMs causes **overvoltage deviation** among SiPMs
- Time response of SiPMs change with overvoltage, and **radiation damage to SiPMs** can possibly **enhance the position dependent time offset**
- In MEG II pTC, this position dependence can be monitored from positron tracking information, and **offline correction can suppress pTC resolution degradation** due to this time offset to some extent
- Monitoring & correction** of this position dependence is important for such timing detectors in high rate experiments

References

[1] A. M. Baldini, et al., "The design of the MEG II experiment", Eur. Phys. J. C (2018) 78: 380, arXiv:1801.04688
 [2] Y. Uchiyama, et al., "30-ps Time Resolution with Segmented Scintillation Counter for MEG II", Nucl. Instrum. Methods A, 845:507-510, 2017