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 \(10^9 \text{ n}_{\text{MeV/cm}^2}\) is expected in 3 years run

**Measurement Setup**

- **Definition**
  - \((\text{Time center}) = (\text{time}_{\text{ch1}} - \text{time}_{\text{ch2}})\)
  - Constant fraction method (20%) is used
- **Timing measurement** was repeated for
  - Each hit position
  - Differently damaged SiPM chain
  - Reversed order of 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 \(\sim 100 \text{ ps}\) 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
  - 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 SiPMs (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

**Application**

- **Effect on MEG II pTC**
  - Signal propagation time between two SiPMs was found to be \(-80 \text{ ps}\)
  - 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 \(10^\circ\text{C}\), which might reduce the overvoltage deviation among SiPMs

- **Offline correction**
  - Position dependence of the time offset can be checked in pTC using position 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

**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 variation** 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 position 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**