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Effect of Teflon Wrapping on the Interaction Position Reconstruction Resolution in Long, Thin Plastic Scintillator Pillars

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Introduction

- Development is underway of a compact, high efficiency, single volume scatter camera (SVSC).
- One design consists of long, thin, optically-isolated organic scintillator pillars that are arranged in a square array.
- Optical isolation confines the transport of scintillation light to the pillar where a neutron interaction occurs, after which it is collected on a photodetector (PD) at each pillar end.
- The fired pillar centroid marks the interaction (x, y)-coordinates, while the z-coordinate along the pillar long dimension is reconstructed using the ratio of the signals' amplitudes $\ln(A_1/A_2)$ and their arrival time difference $(t_1 - t_2)$.
- Teflon wrapping is being considered for optical isolation due to its availability and ease of use.
- The diffuse reflector forces scintillation photons into longer paths before reaching the pillars' ends, especially in the case of the high aspect-ratio pillars (1:1:40) of the optically segmented SVSC (OS-SVSC).
- This work investigates the effect of this behavior on the z-location reconstruction resolution.

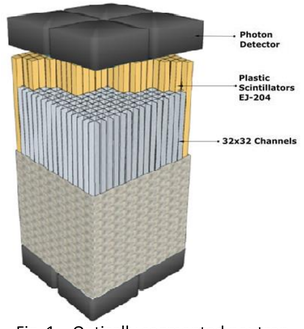

Fig. 1 – Optically segmented neutron scatter camera design

Experiment description

- A $5\ mm \times 5\ mm \times 200\ mm$ EJ-204 pillar is mounted with a silicon photomultiplier (SiPM) at each end.
- A single pillar scan is performed using collimated gamma rays from ^{22}Na to control the scintillation position along the pillar length.
- The relative amplitudes and arrival-time differences of events in the 511-keV Compton edge region are used to fit a line to $\ln(A_1/A_2)$ and $(t_1 - t_2)$ versus position.
- The lines' slopes m_A & m_t and intercepts b_A & b_t are used to reconstruct two interaction positions for each event:

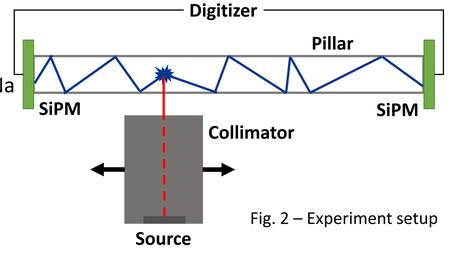

Fig. 2 – Experiment setup

$$z^A_{recon} = \frac{\ln(A_1/A_2) - b_A}{m_A} \qquad z^t_{recon} = \frac{(t_1 - t_2) - b_t}{m_t}$$

- The variances σ_A^2 and σ_t^2 in the reconstructed position dictate reconstruction resolution.
- A best linear unbiased estimator (BLUE) is used to combine the two resolutions into a single estimate:

$$\sigma^2 = \frac{\sigma_A^2\sigma_t^2(1-\rho^2)}{\sigma_A^2 - 2\rho\sigma_A\sigma_t + \sigma_t^2}$$ where ρ is the correlation coefficient

- The experiment is repeated after wrapping the pillar in Teflon.

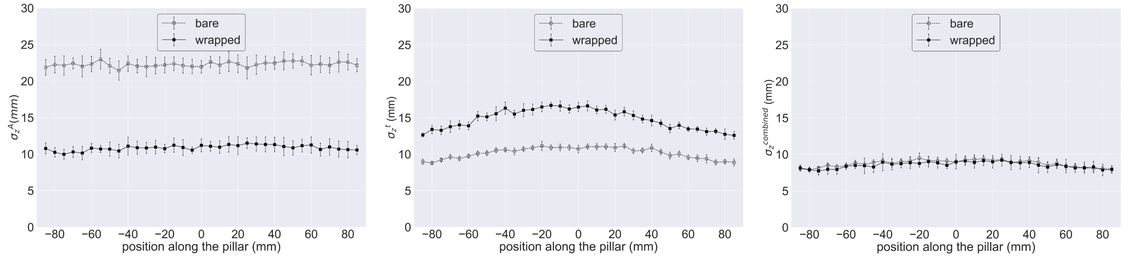

Fig. 3 – The amplitude-based (left), timing-based (middle) and combined position resolutions (right).

Results

- For bare pillars, the reconstruction based on the signals' charge is less precise than the one based on their arrival times: $\sigma_z^A \approx 23\ mm$ compared to $\sigma_z^t \approx 12\ mm$.
- This behavior is reversed after wrapping in Teflon: $\sigma_z^A \approx 9\ mm$ & $\sigma_z^t \approx 17\ mm$.
- Teflon causes the scintillation photons to undergo more reflections, which
  a) increases the chance for photons to escape the wrapping or get absorbed in the pillar bulk material, leading to an increased ratio between photons collected at both ends and better amplitude-based reconstruction resolution; and
  b) increases the variance in the pulses arrival times, leading to poorer timing-based reconstruction resolution.
- The two opposite effects lead to a combined reconstruction resolution that exhibits little improvement at most scintillation positions and overall does not improve with wrapping the pillar.

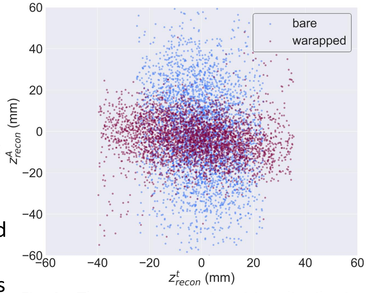

Fig. 4 – The reconstructed position distributions for the true interaction location of 0 mm.

Conclusions

- The effect of Teflon wrapping on reconstructing radiation interaction locations in long, thin pillars of the OS-SVSC design has been investigated.
- While wrapping the pillars improves the amplitude-based reconstruction, it deteriorates the timing-based position resolution such that the combined reconstruction resolution shows little to no improvement.
- Other means of optically isolating the OS-SVSC pillars that eliminate the effort of wrapping each individual pillar may be considered.
- Interaction time and energy resolutions are another considerations in the SVSC design that were not the focus of this study.

Acknowledgment

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