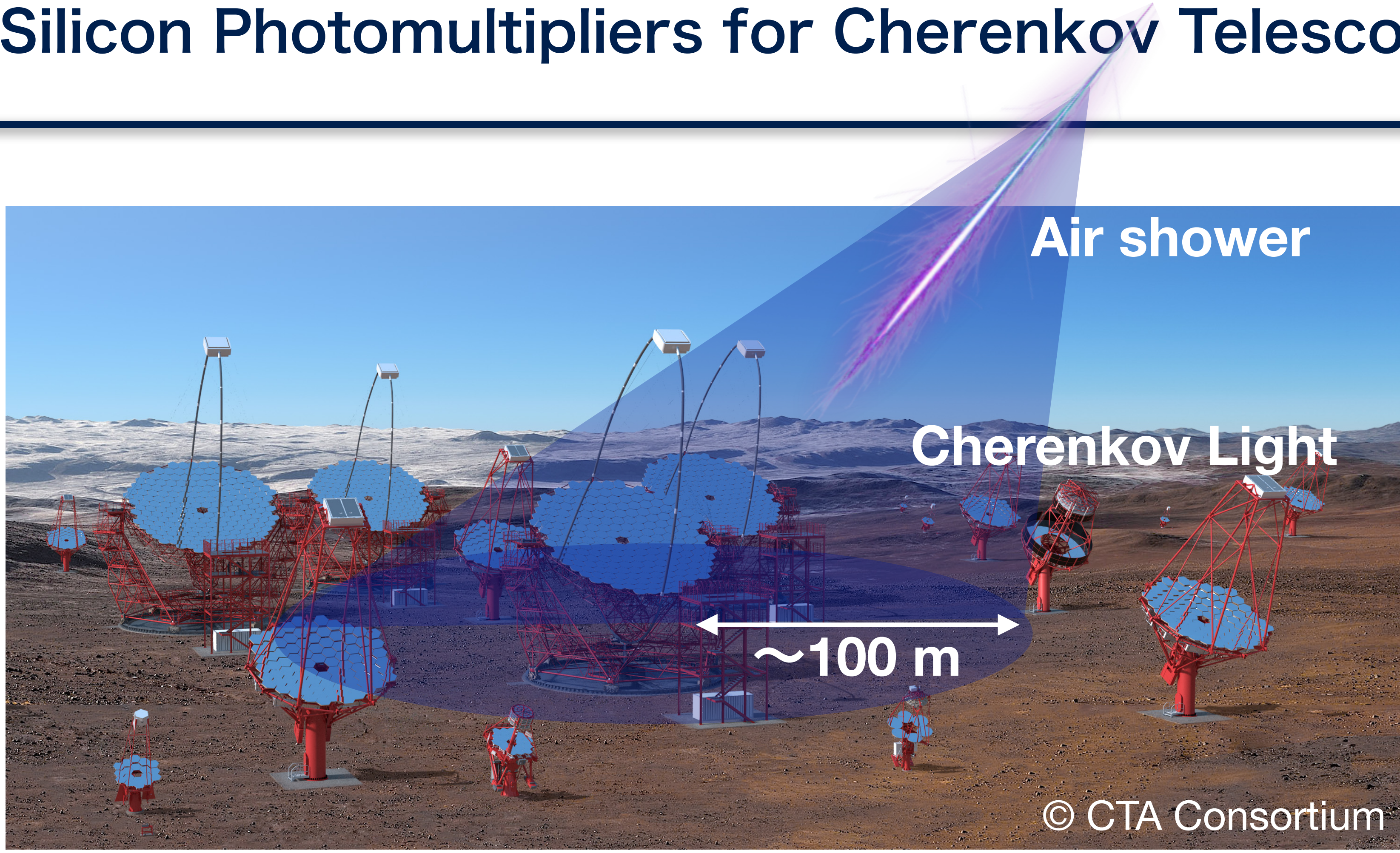
Characterization of SiPM Optical Crosstalk and its Resin Thickness Dependence

Yuki Nakamura, Akira Okumura, Hiroyasu Tajima, Anatolii Zenin

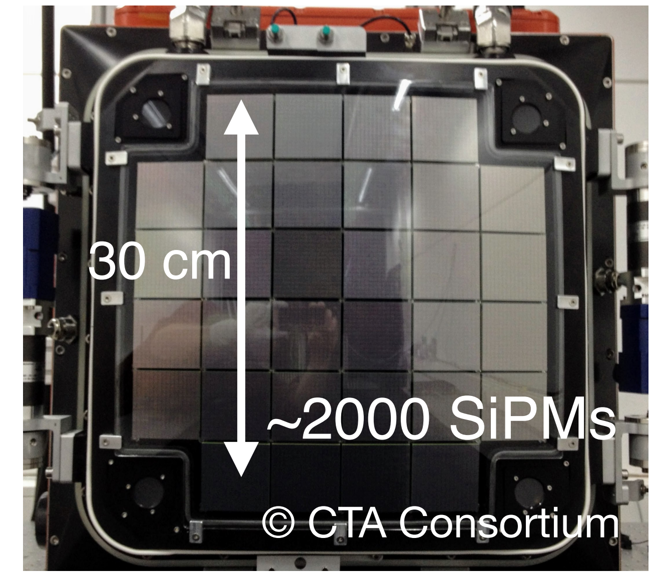
Institute for Space-Earth Environmental Research, Nagoya University

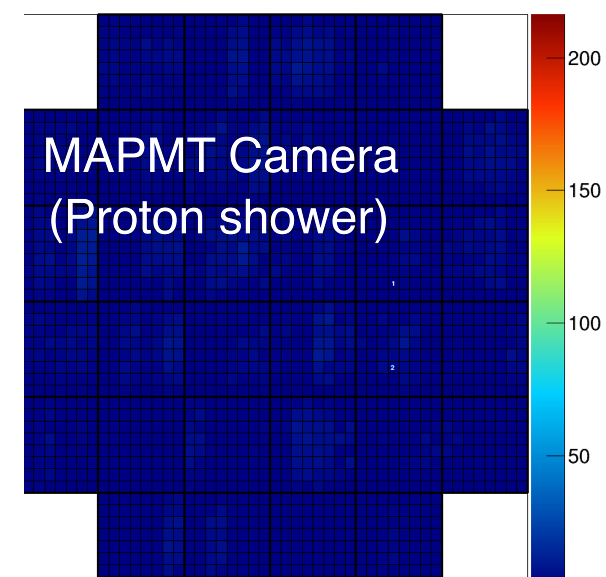
PD18, University of Tokyo

Silicon Photomultipliers for Cherenkov Telescopes



SiPM Camera





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- Cherenkov telescopes typically use PMT
- Silicon Photomultipliers (SiPMs) are chosen for small-sized telescopes in the Cherenkov Telescope Array (CTA)
  - High photo detection efficiency
  - Low cost per channel (~2000 SiPMs / camera)
  - Tolerance against high rate environment (**can use under moon light**)
  - **Optical crosstalk**
  - Temperature dependence of gain

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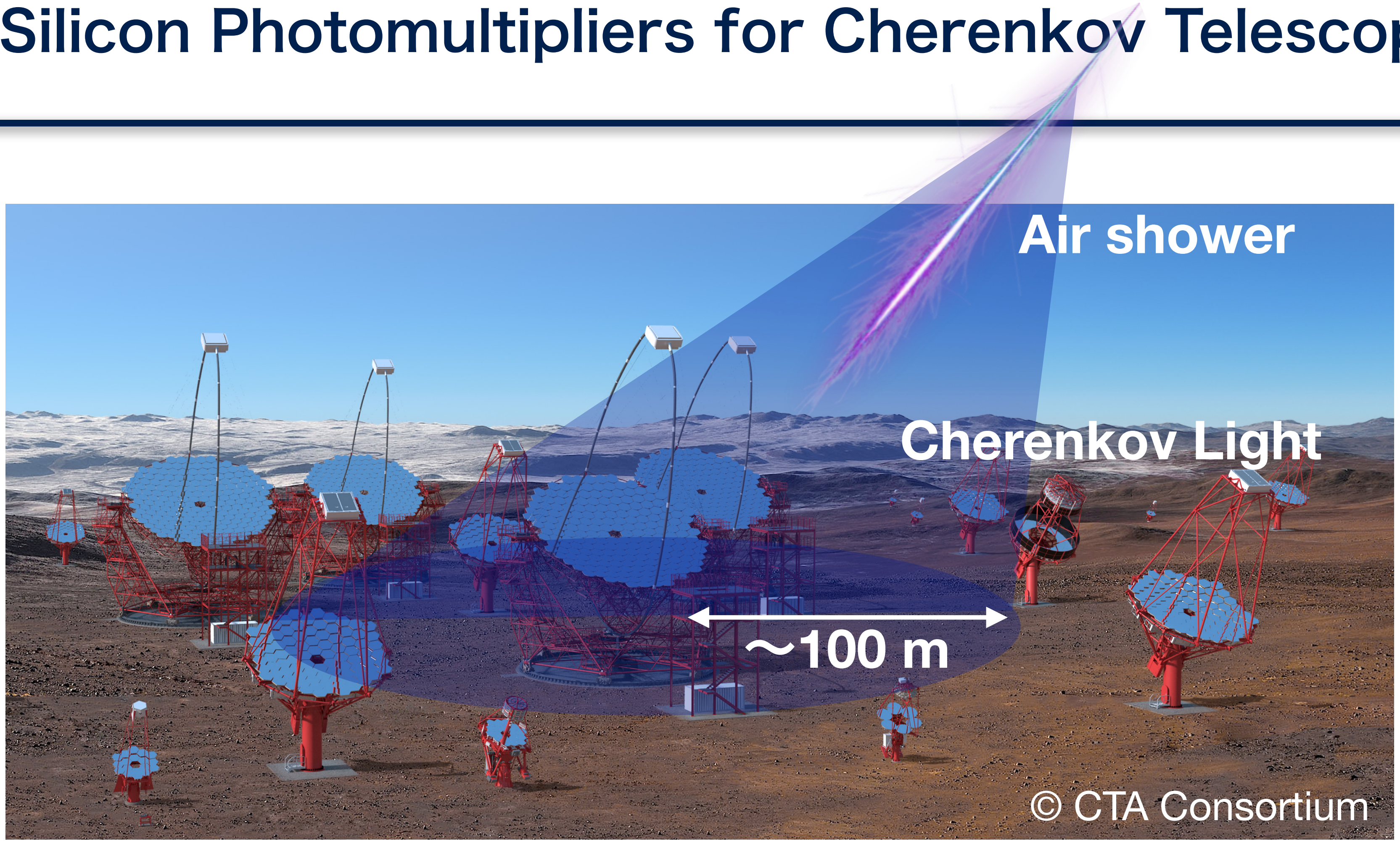

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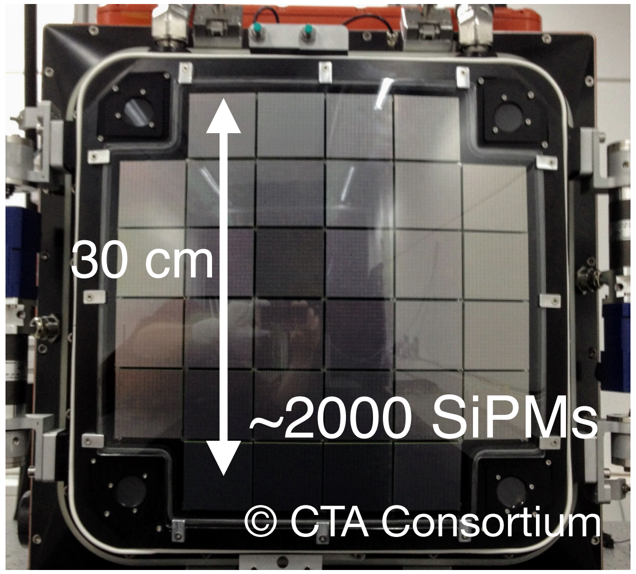

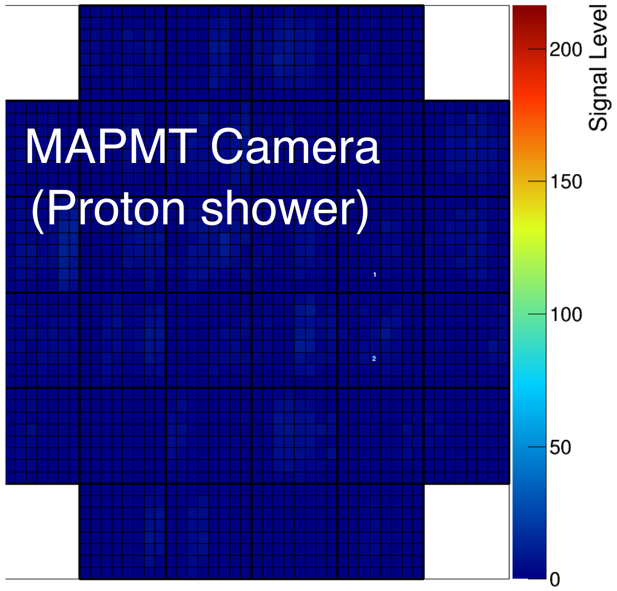

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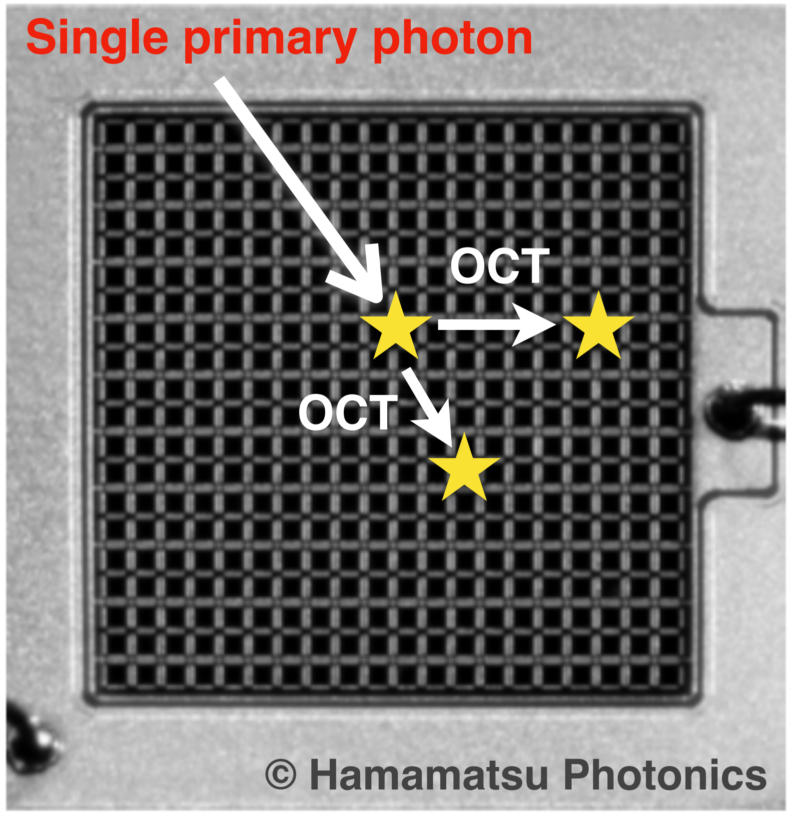
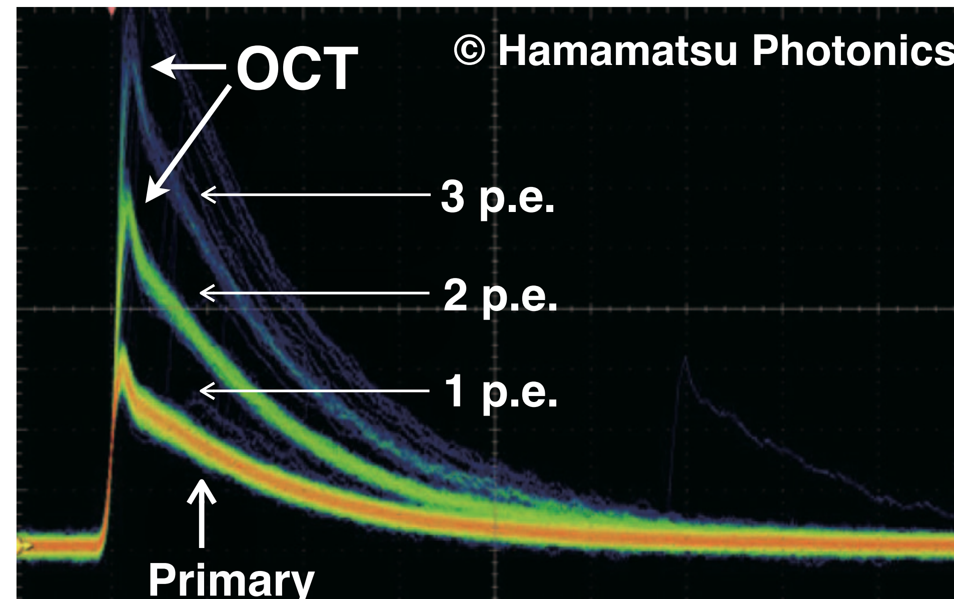
Optical Crosstalk (OCT)

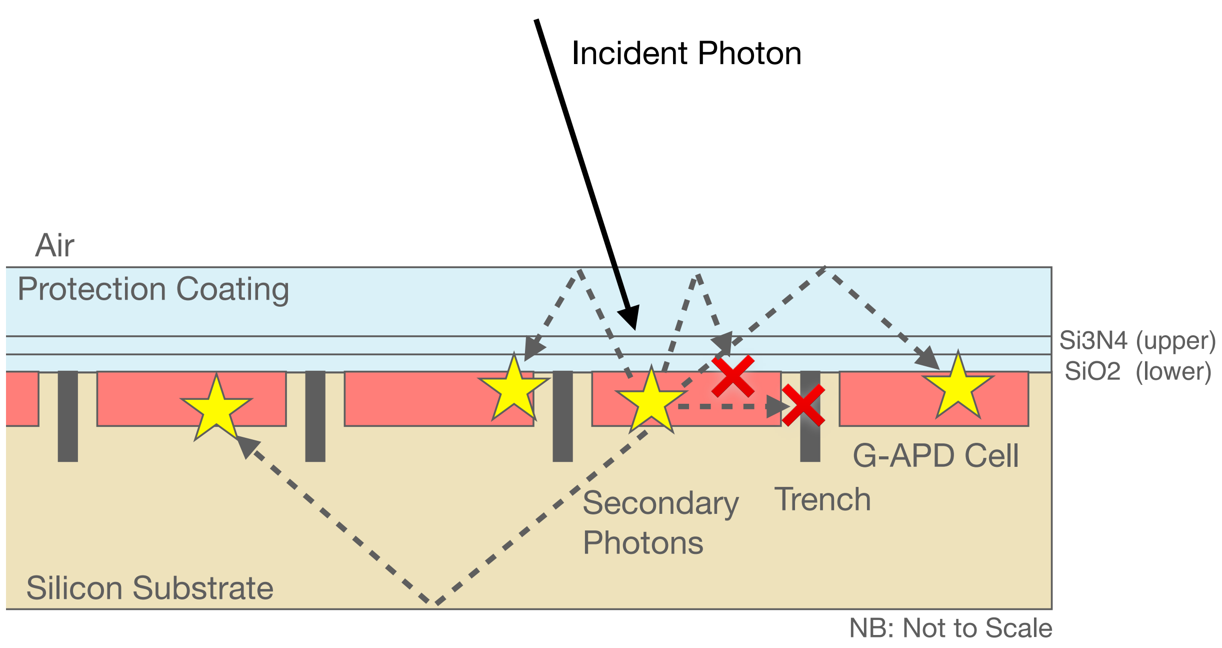




- Crosstalk caused by optical photons (not electrical crosstalk)
  - Secondary photons are emitted from the fired cell during avalanche
  - Neighboring cells detect these photons
- Can not distinguish primary and OCT signals from waveforms
  - Mistake the number of detected photoelectrons
  - Makes charge resolution worse
  - False trigger will be made by OCT
  - **Low OCT rate is important to suppress such effects**

Coating Thickness Dependence of OCT rate (single-pixel SiPM)

- Propagation paths of OCT photons depend on coating thickness
  - Escape to outside of the SiPM: thicker coating
  - Return to the original cell : very thin coating
- OCT rate of single-pixel SiPM have the expected dependence
- With coating is preferred for easy handling



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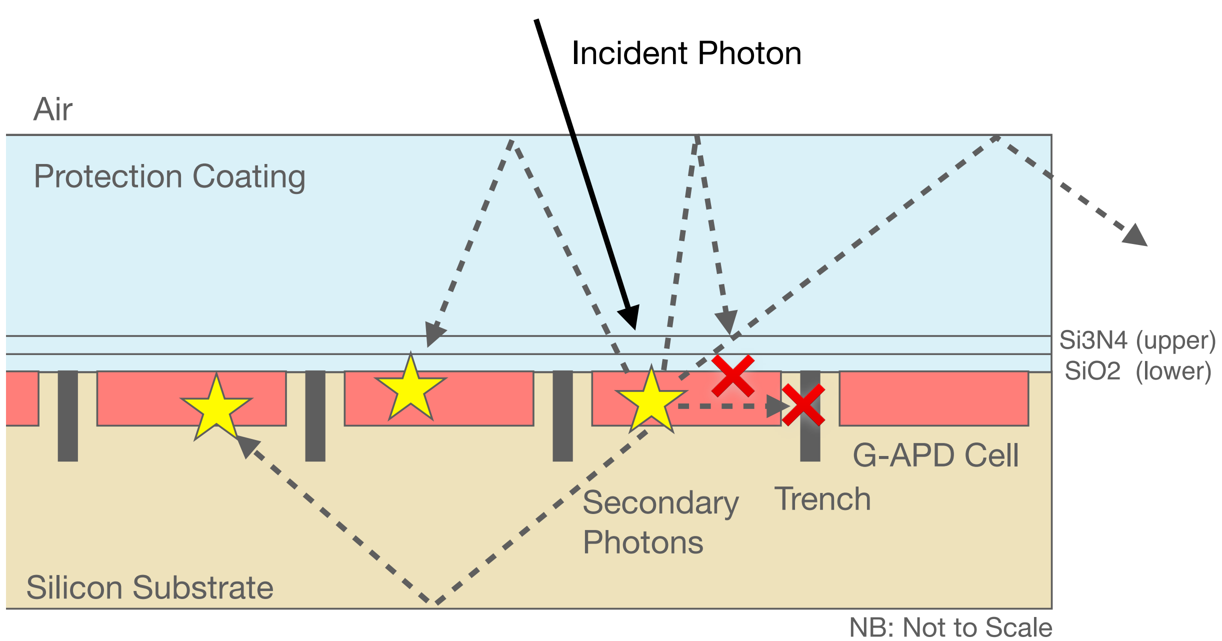
Thicker Coating



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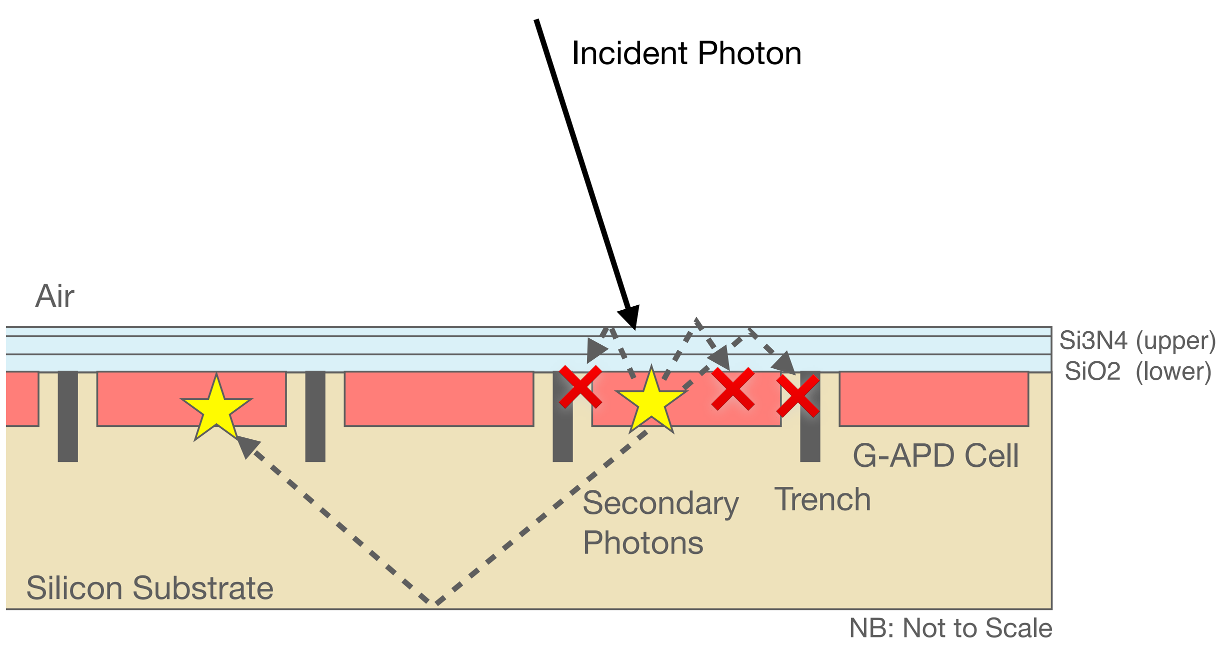
Very Thin Coating



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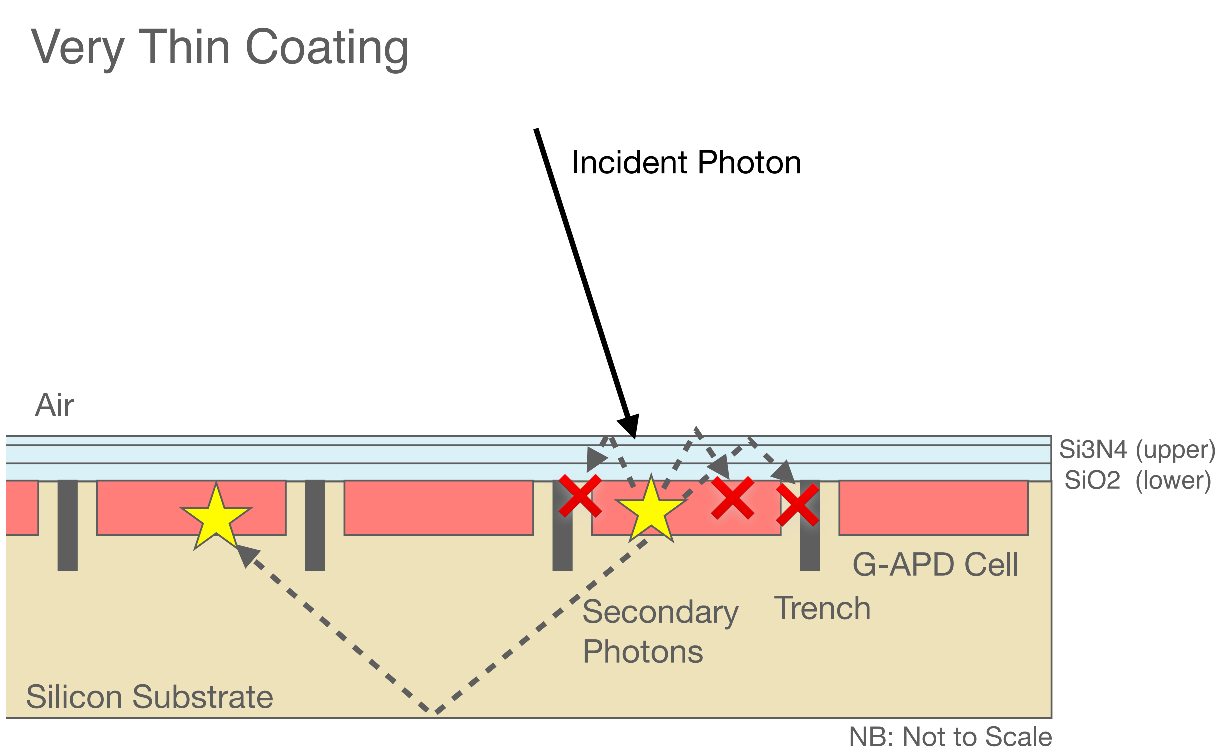

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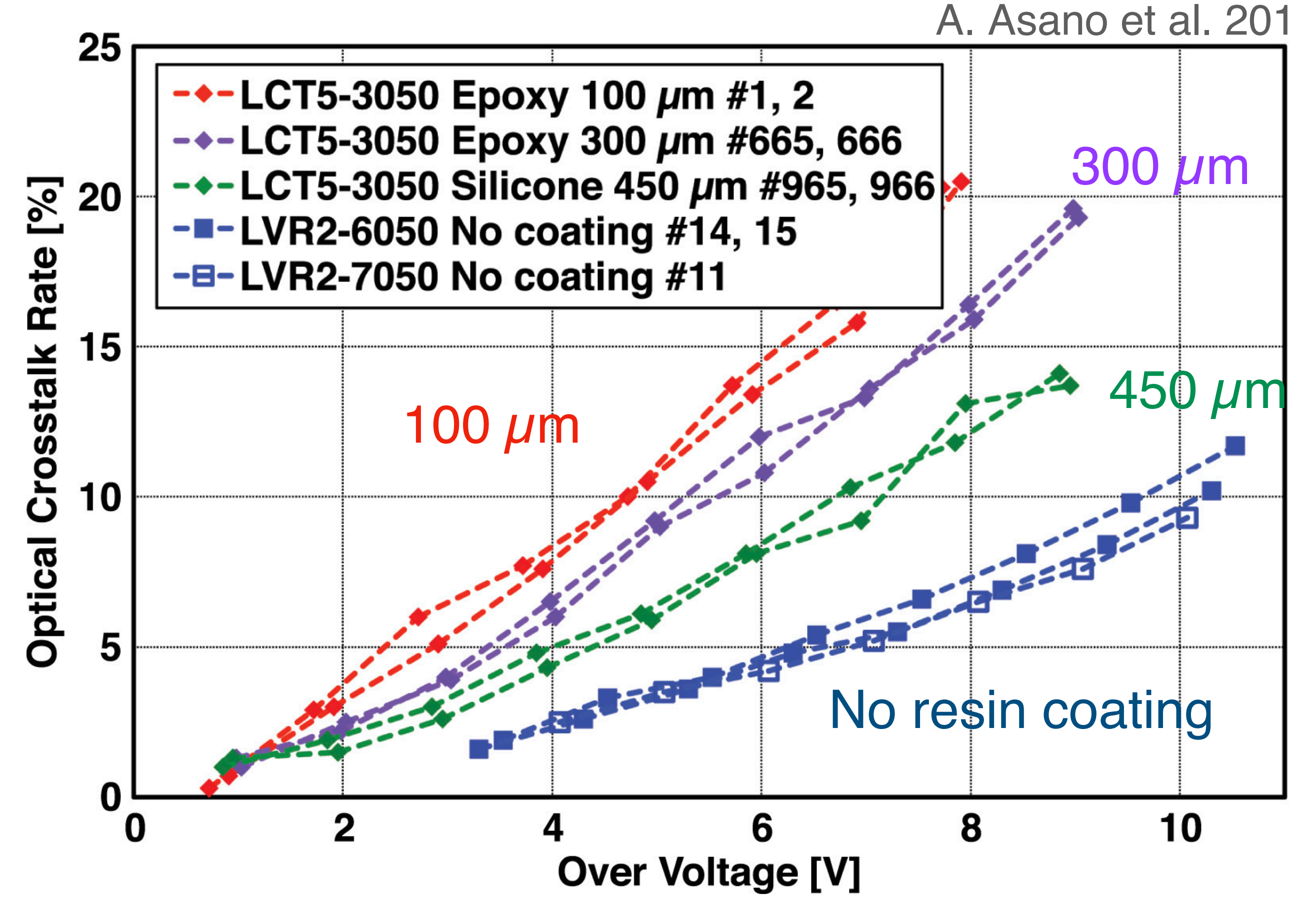
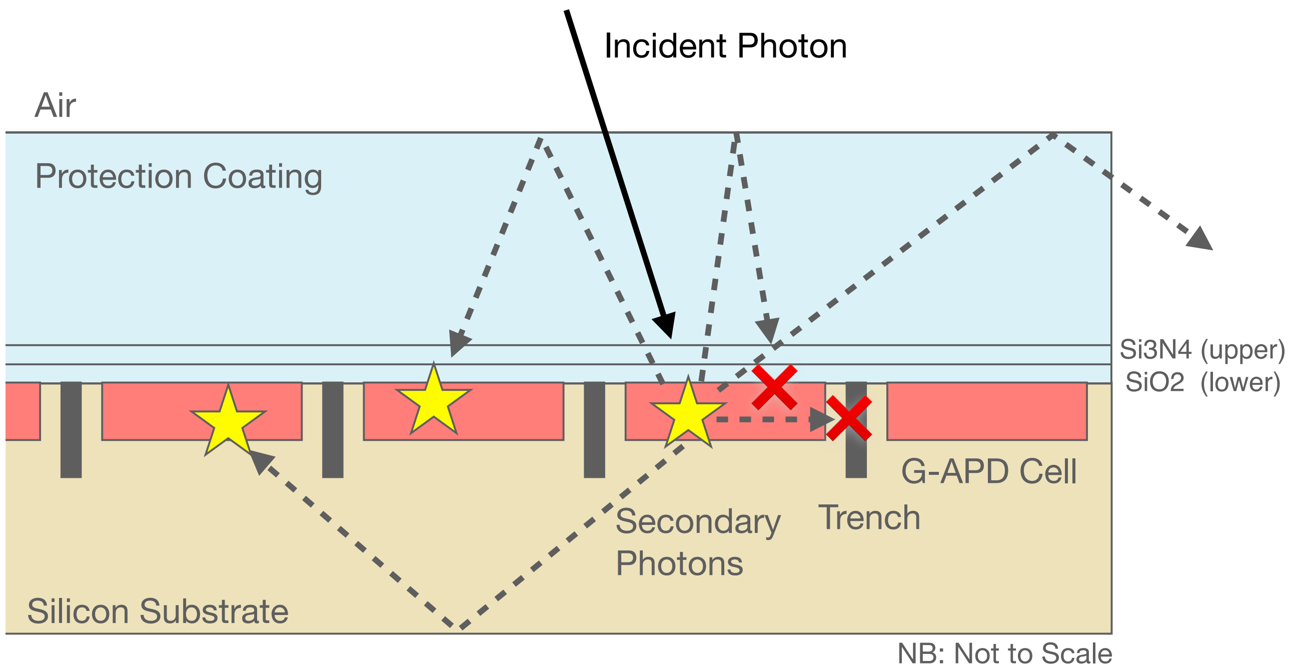
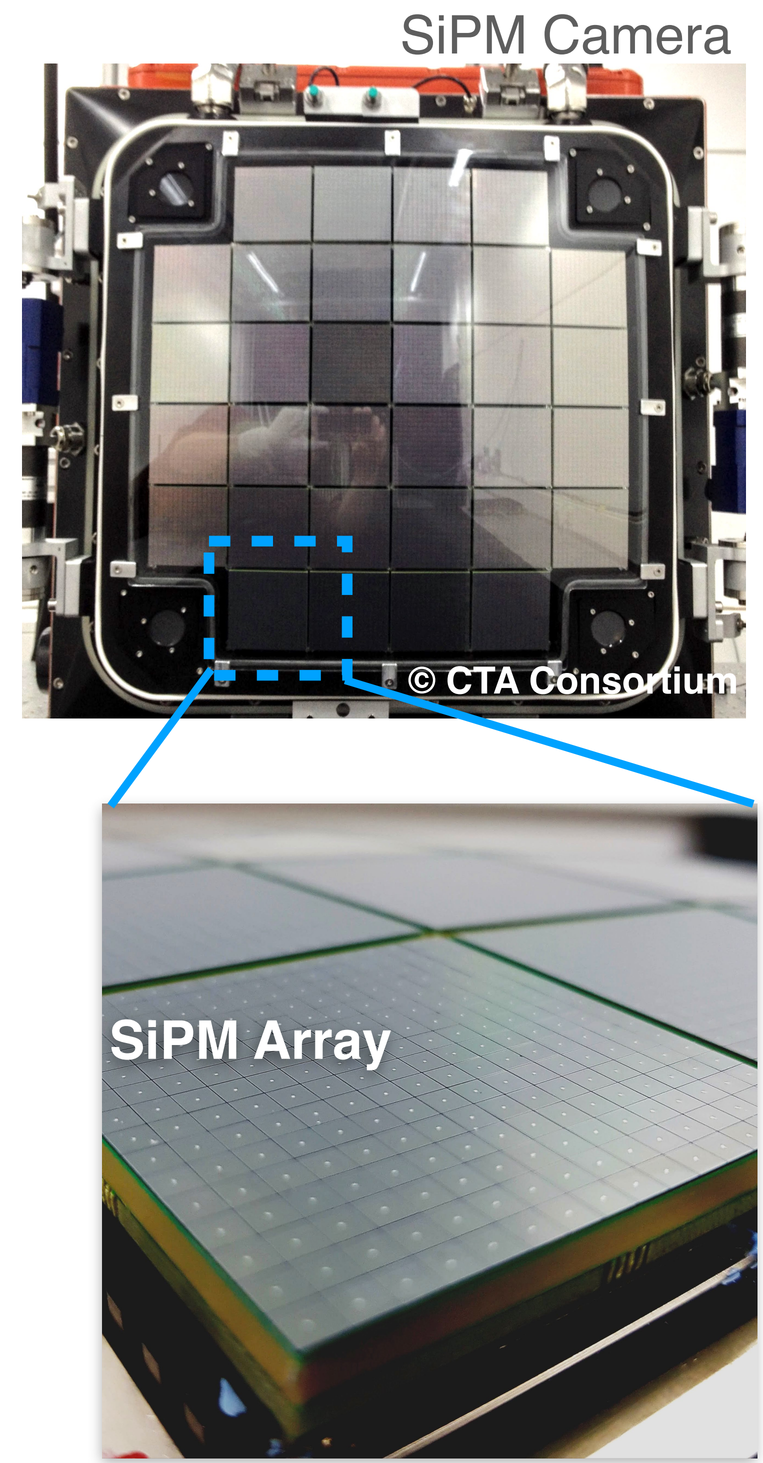


Propagation of OCT photons in SiPM arrays





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- SiPM array is used to the camera
- **Photons can propagate to neighboring SiPMs**
  - Amount of such OCT have never been evaluated
  - Makes Cherenkov image fuzzy
  - Can we choose “thicker coating” for Cherenkov telescopes?
- We used glass plate to change the coating thickness
  - We can use same SiPMs
  - Easy to control the coating thickness

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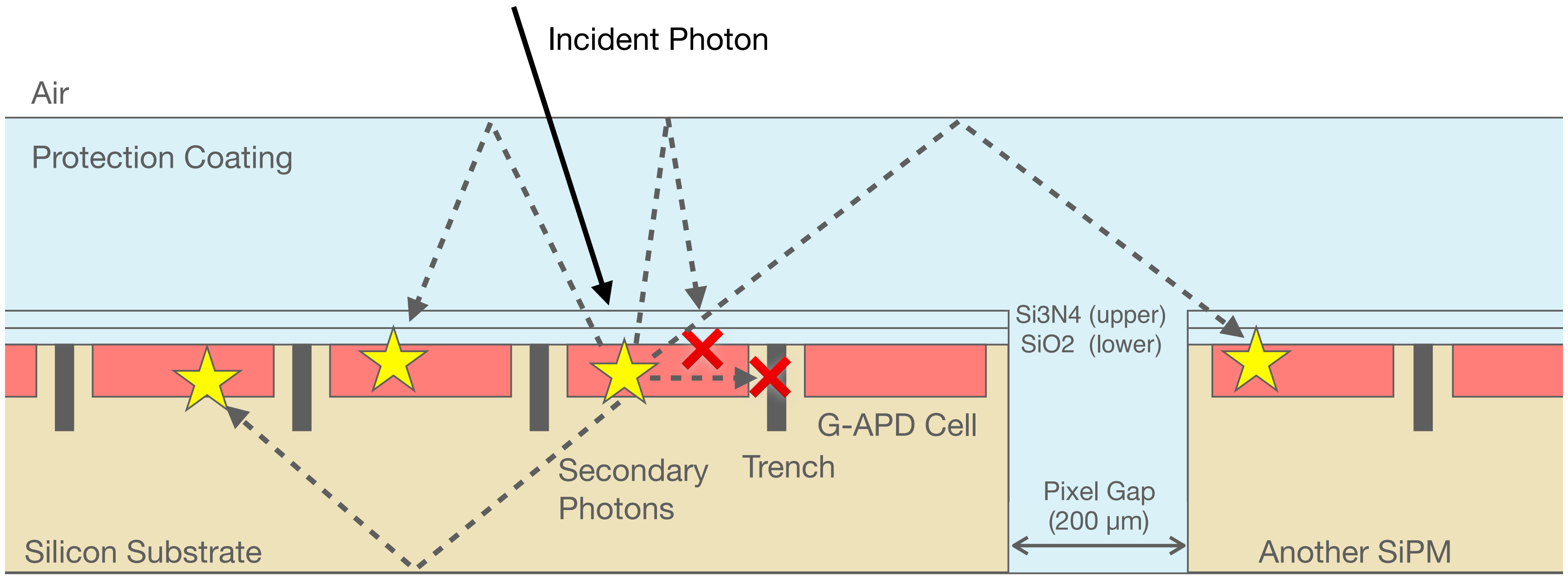

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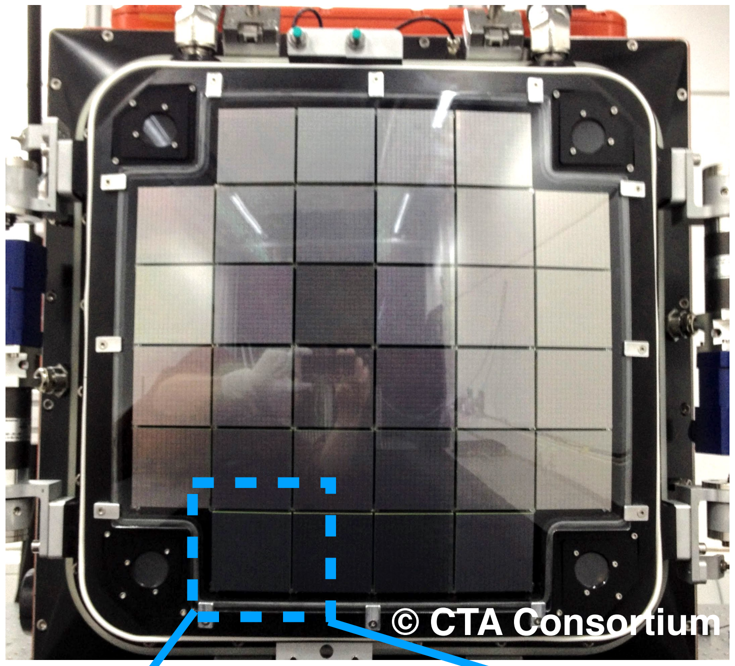

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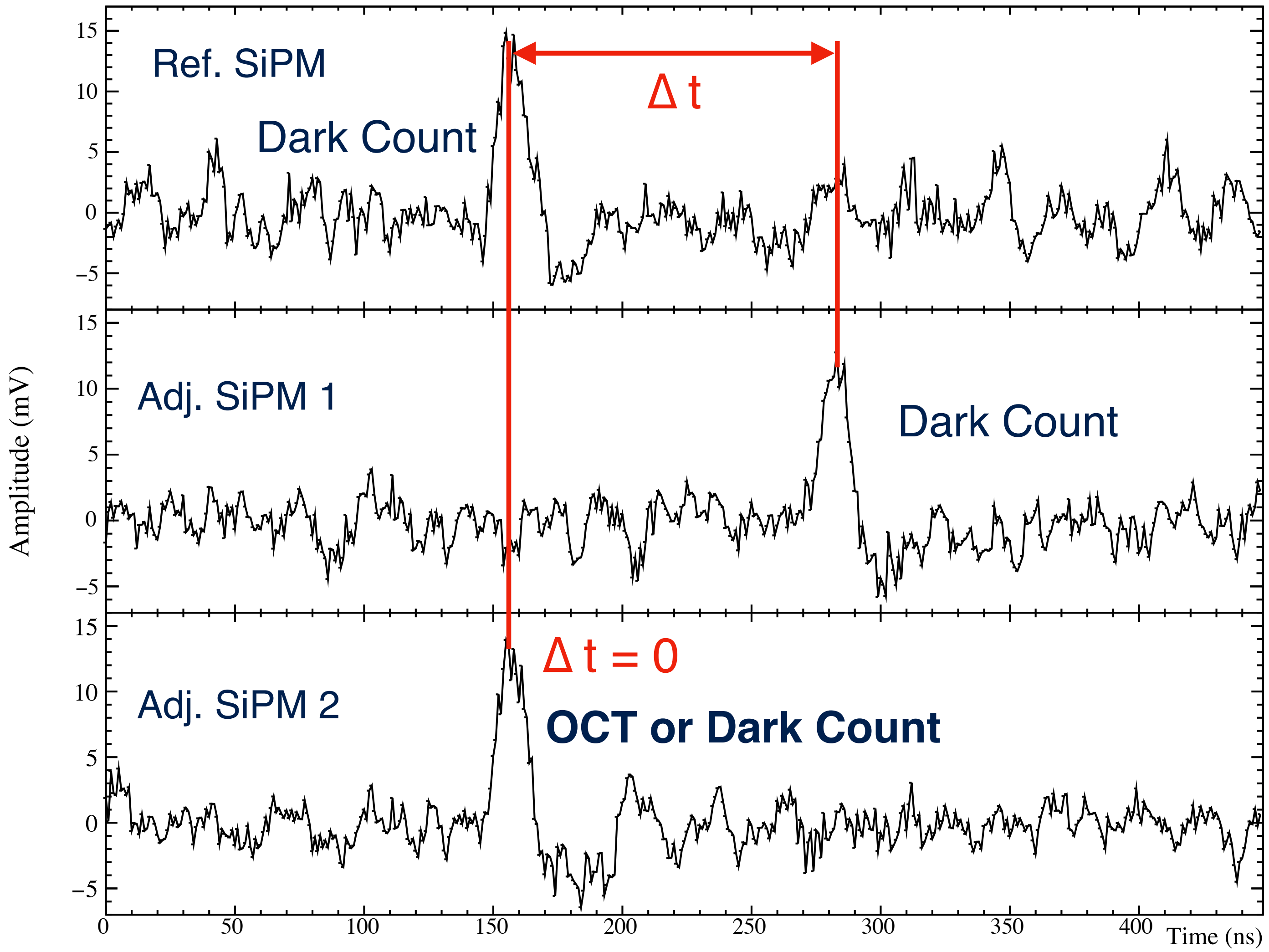
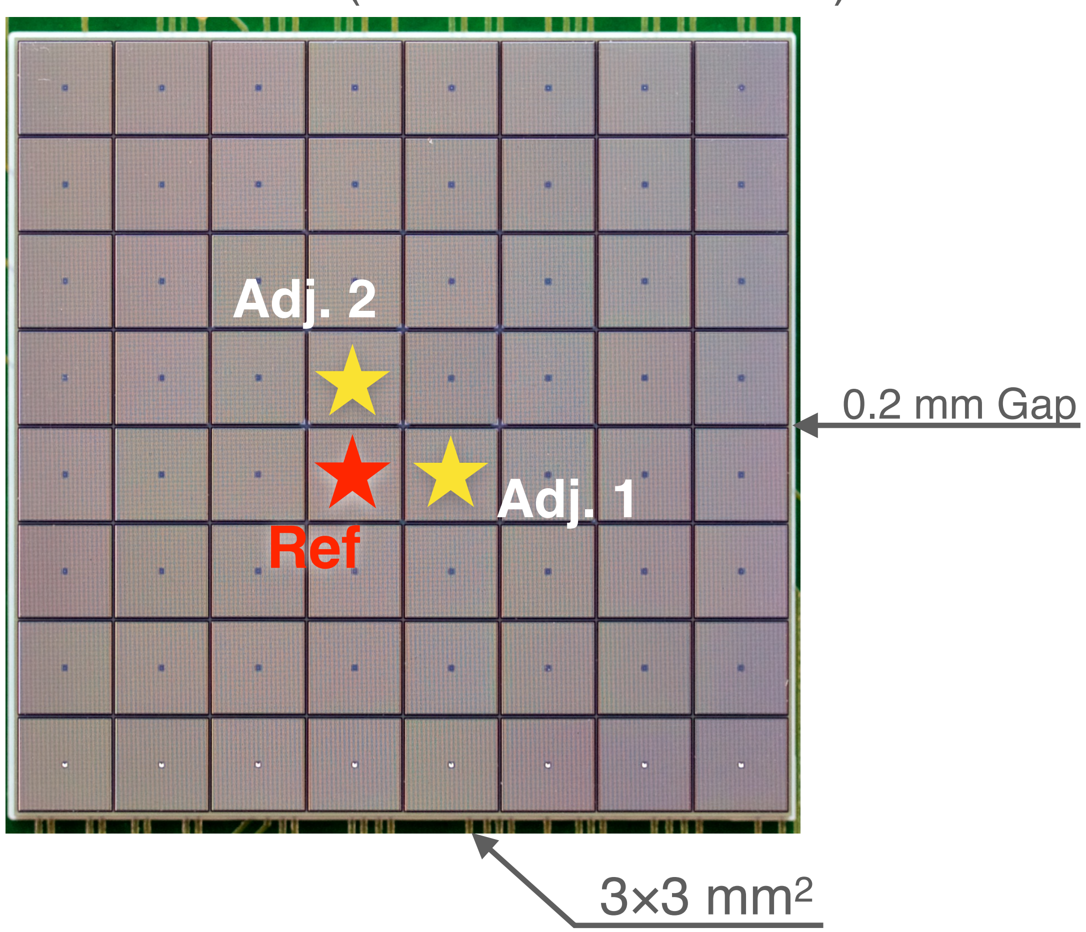


64-ch SiPM (S13361-3050NS-08)



- » Recorded waveforms of 64-ch SiPM by dedicated ASICs
- » Used **only dark count (no LED illumination)**
- » Counted the number of coincidence events with the reference SiPM
  - » Neighboring-SiPM OCT
  - » Accidental dark count

Can not be distinguished from the waveforms

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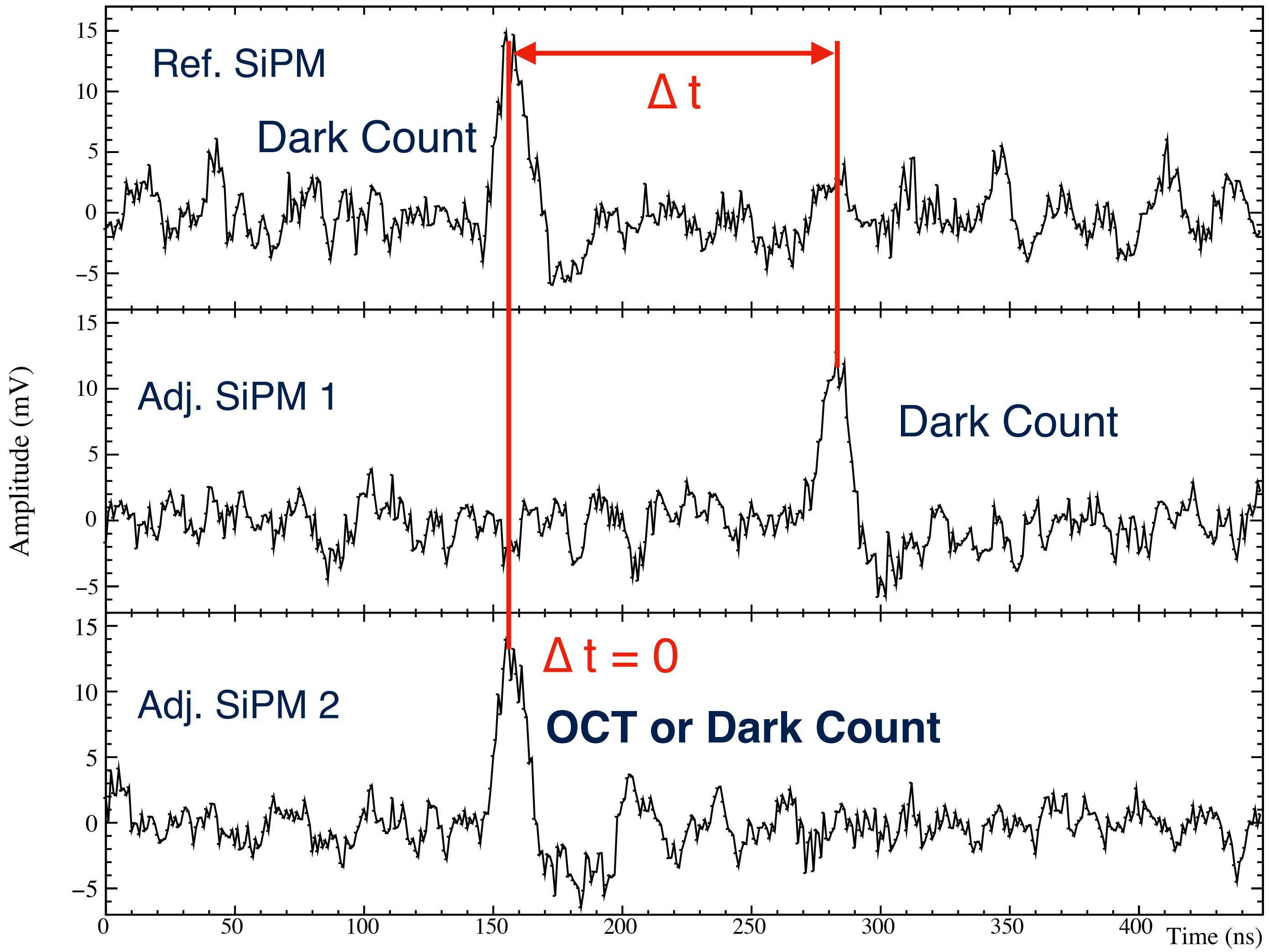

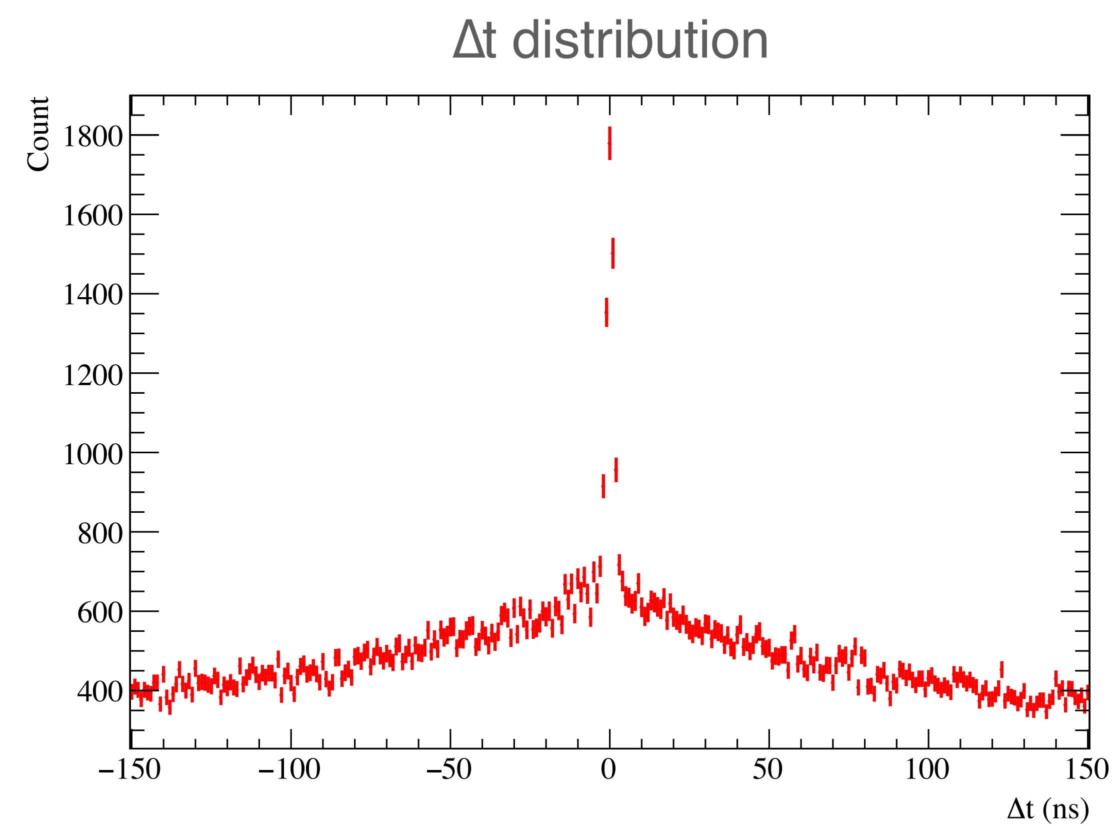

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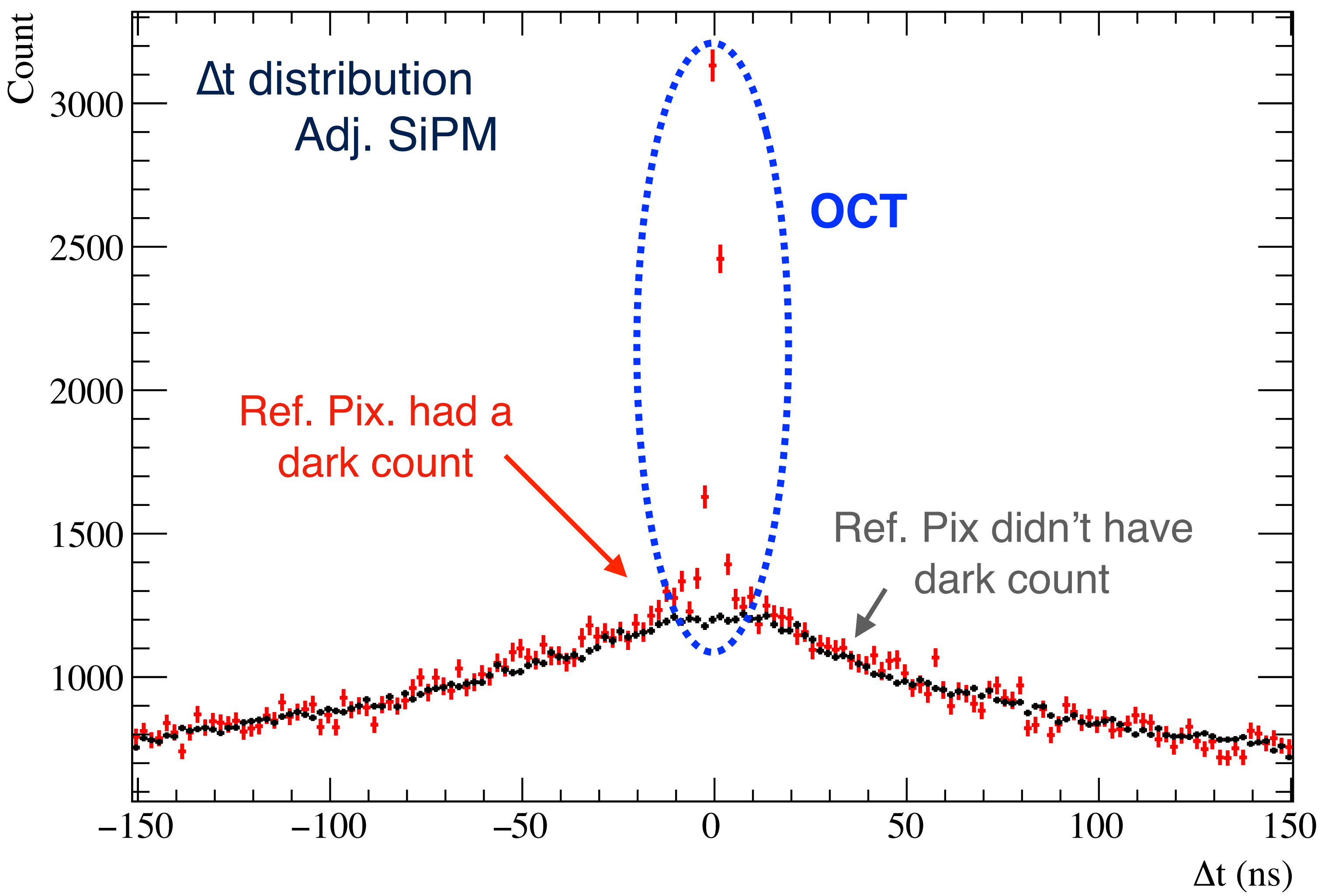
Extraction of OCT rate



- **Distinguished OCT and dark count from Δt distribution**
  - Subtracted dark count component (black distribution)
  - Black distribution shows events with no p.e. signal in Ref. SiPM (no OCT from Ref.)
- Calculated OCT rate from integrate residual events between ±32 ns

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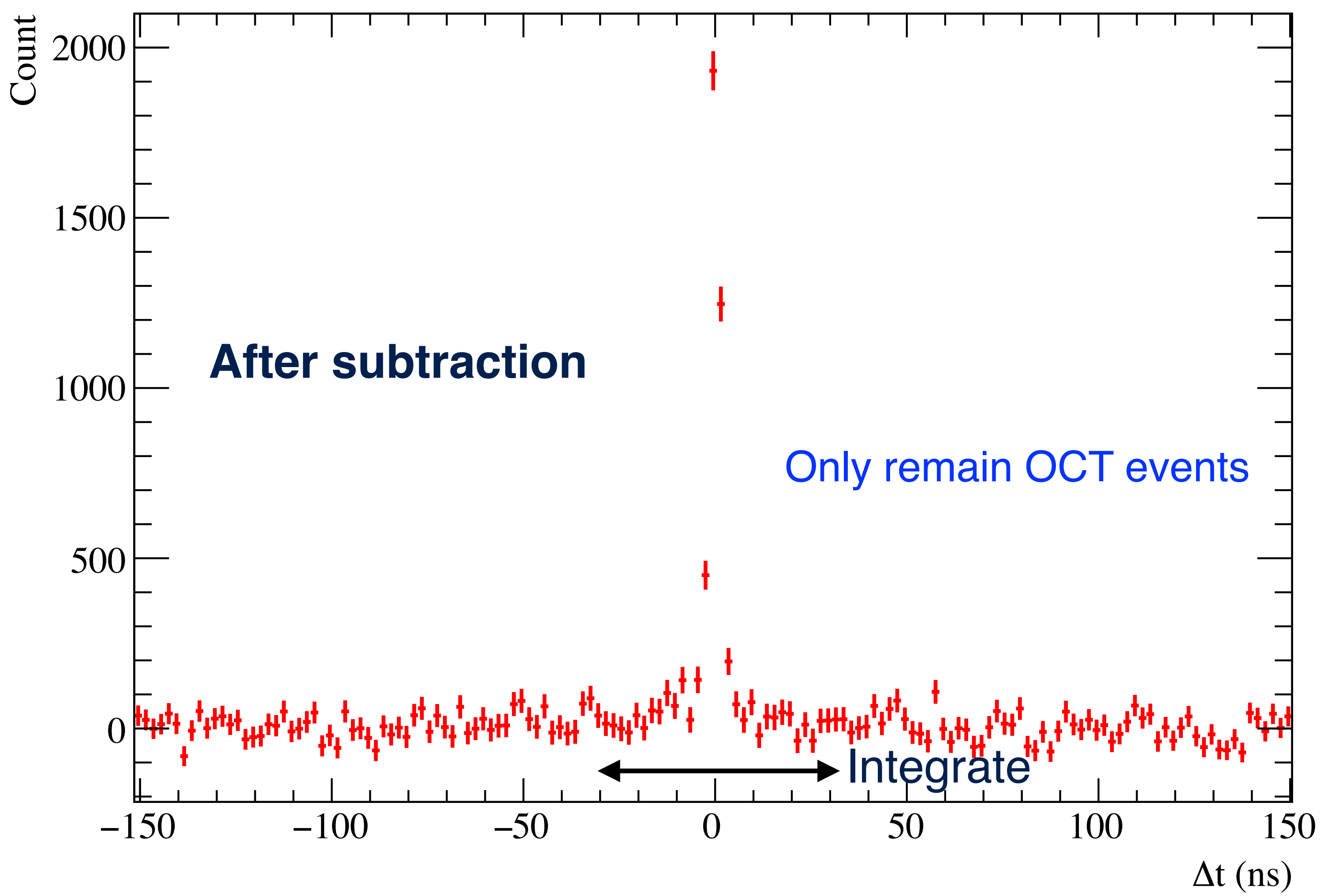

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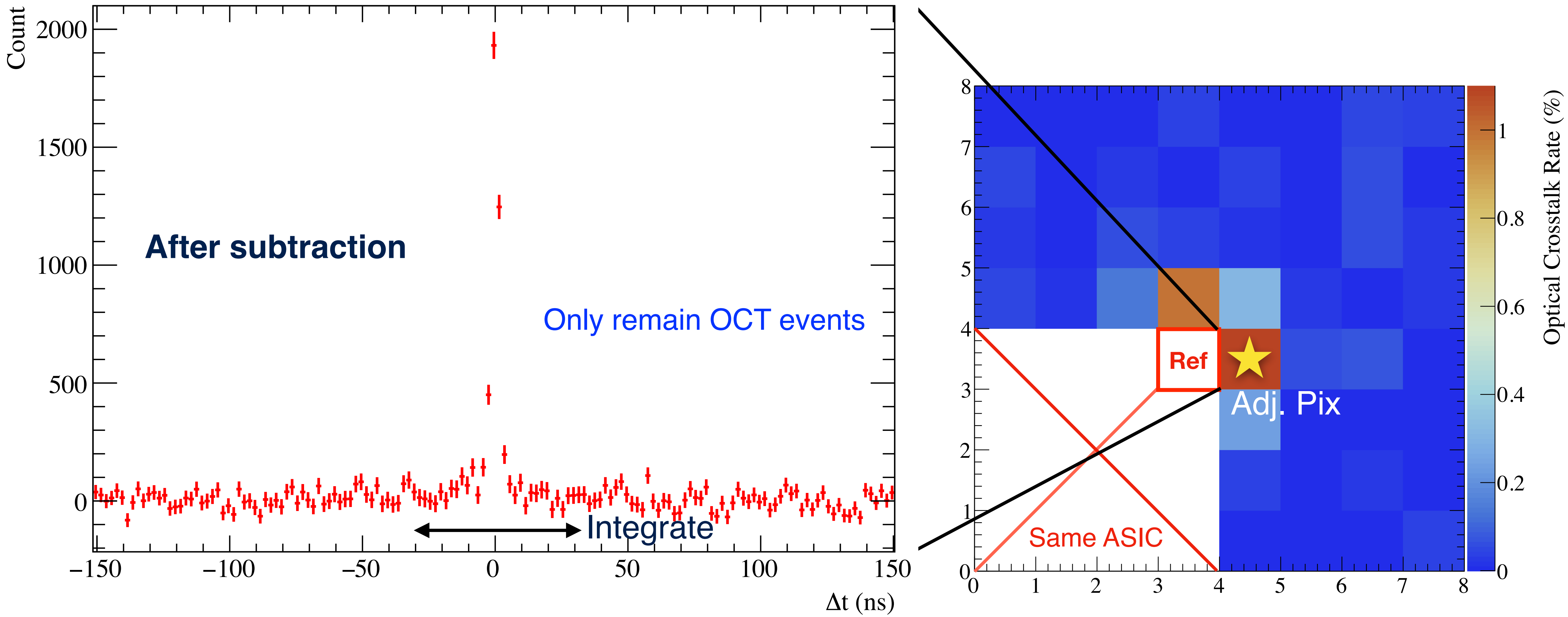

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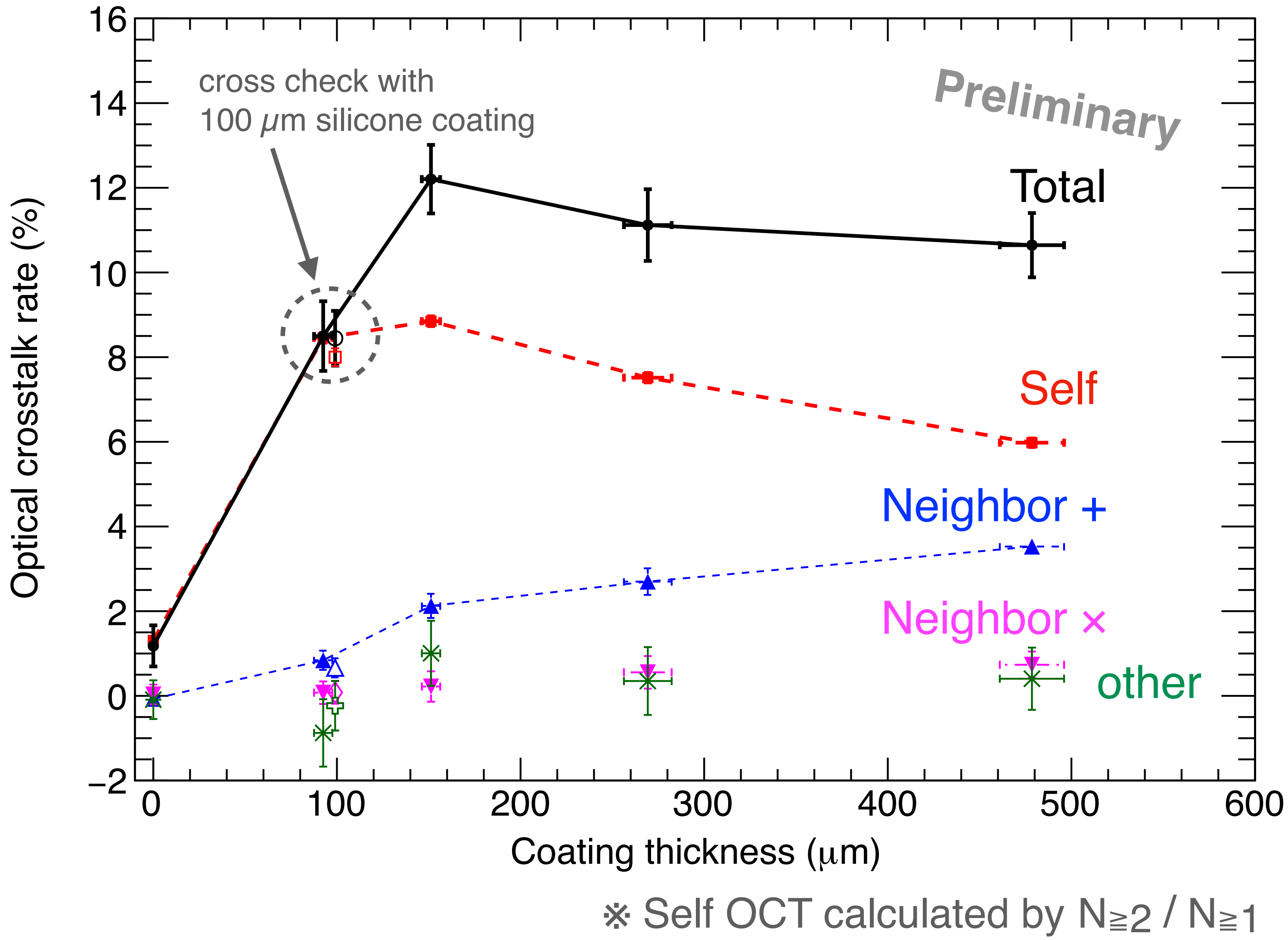
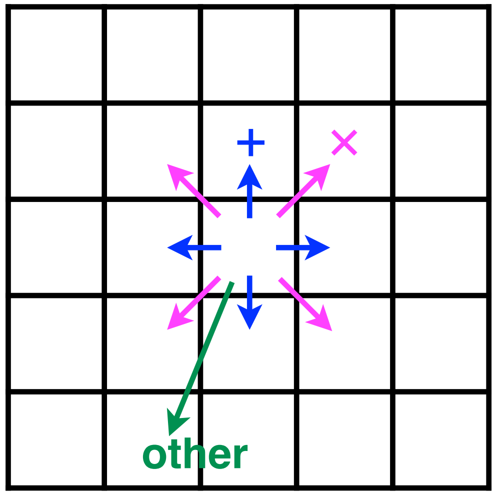
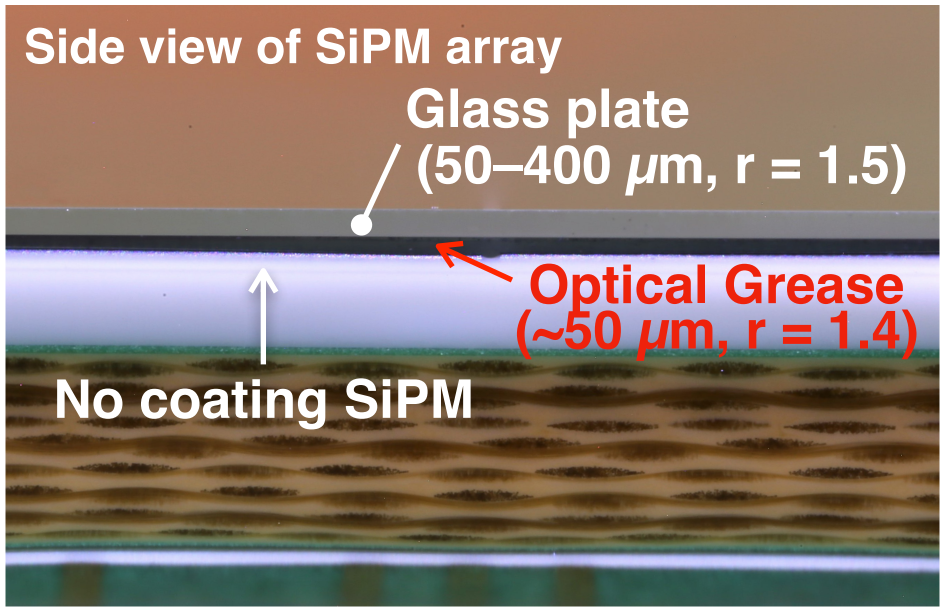
Coating Thickness Dependence

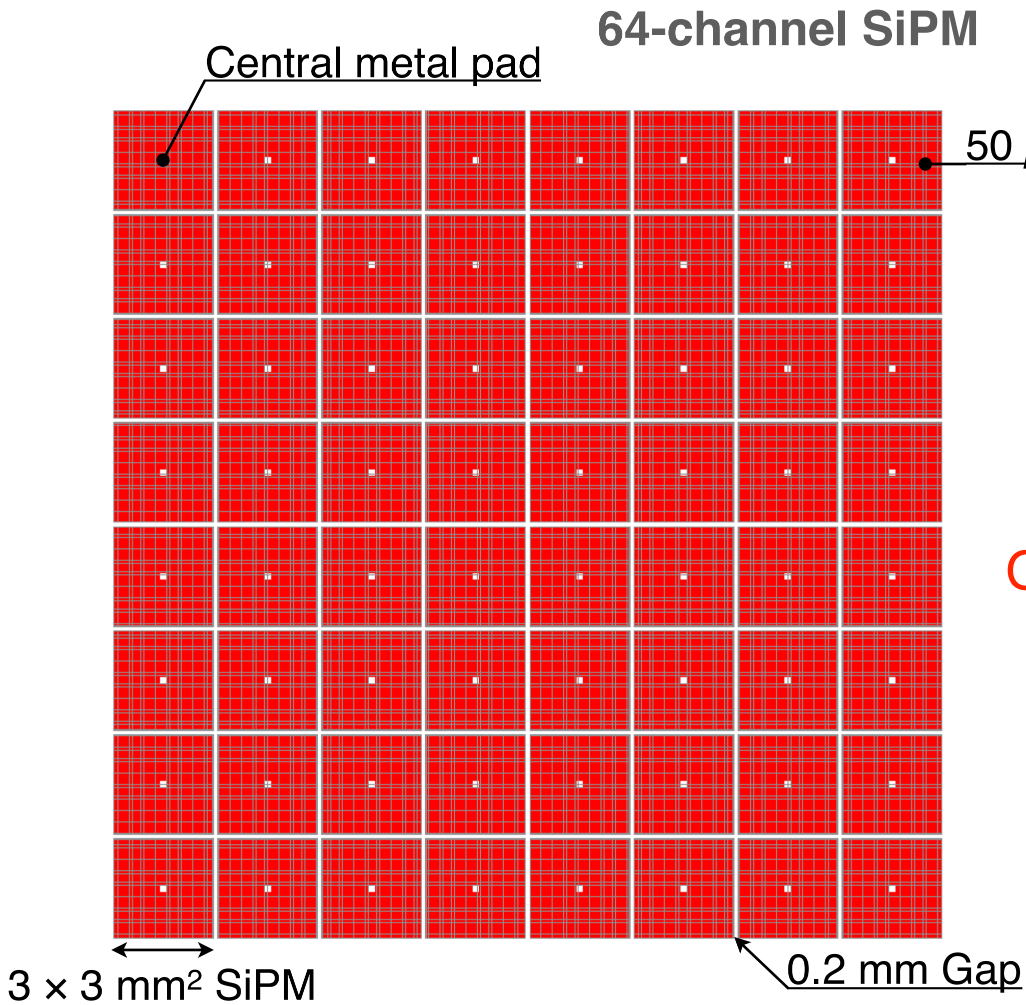


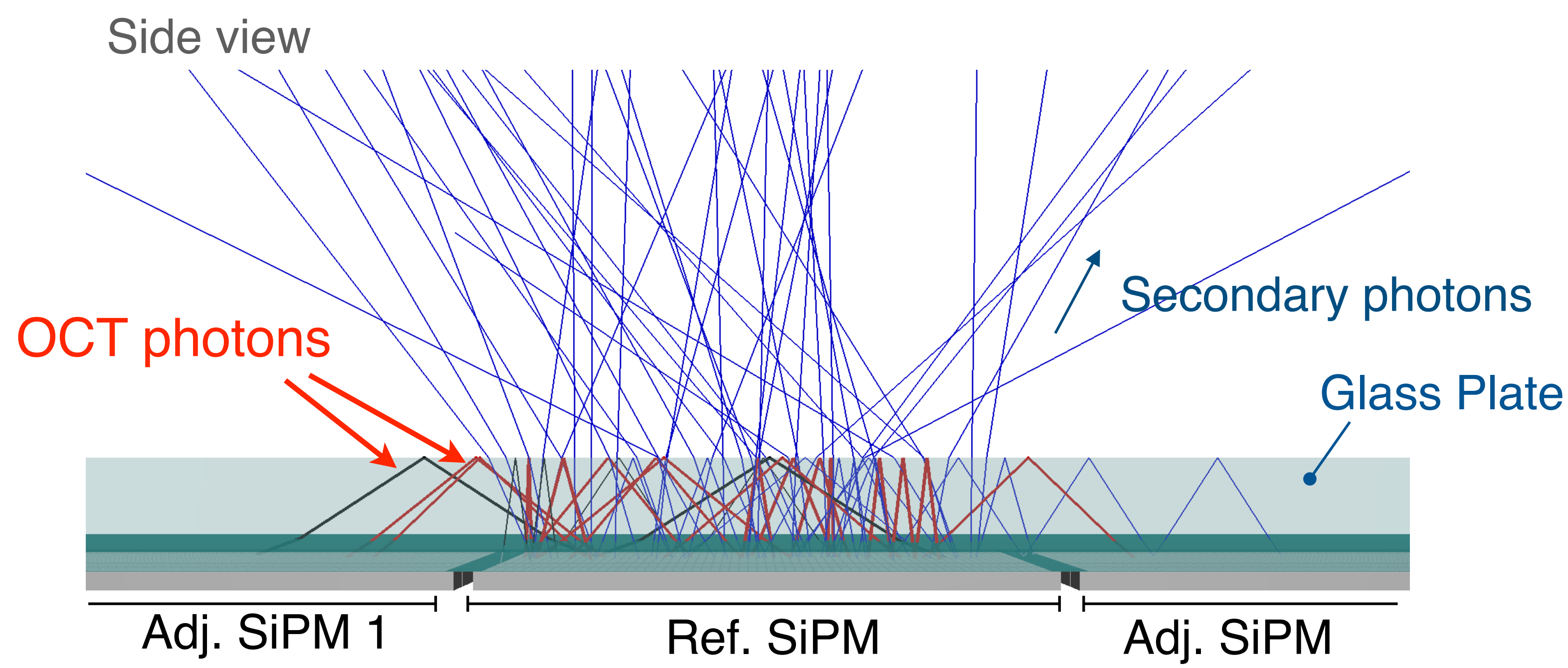




- » Changed the thickness by glass plate (pasted with optical grease)
- » Thicker coating decrease "Self OCT", but increase Neighboring SiPMs
- » Conserve Total OCT rate in > ~100 μm

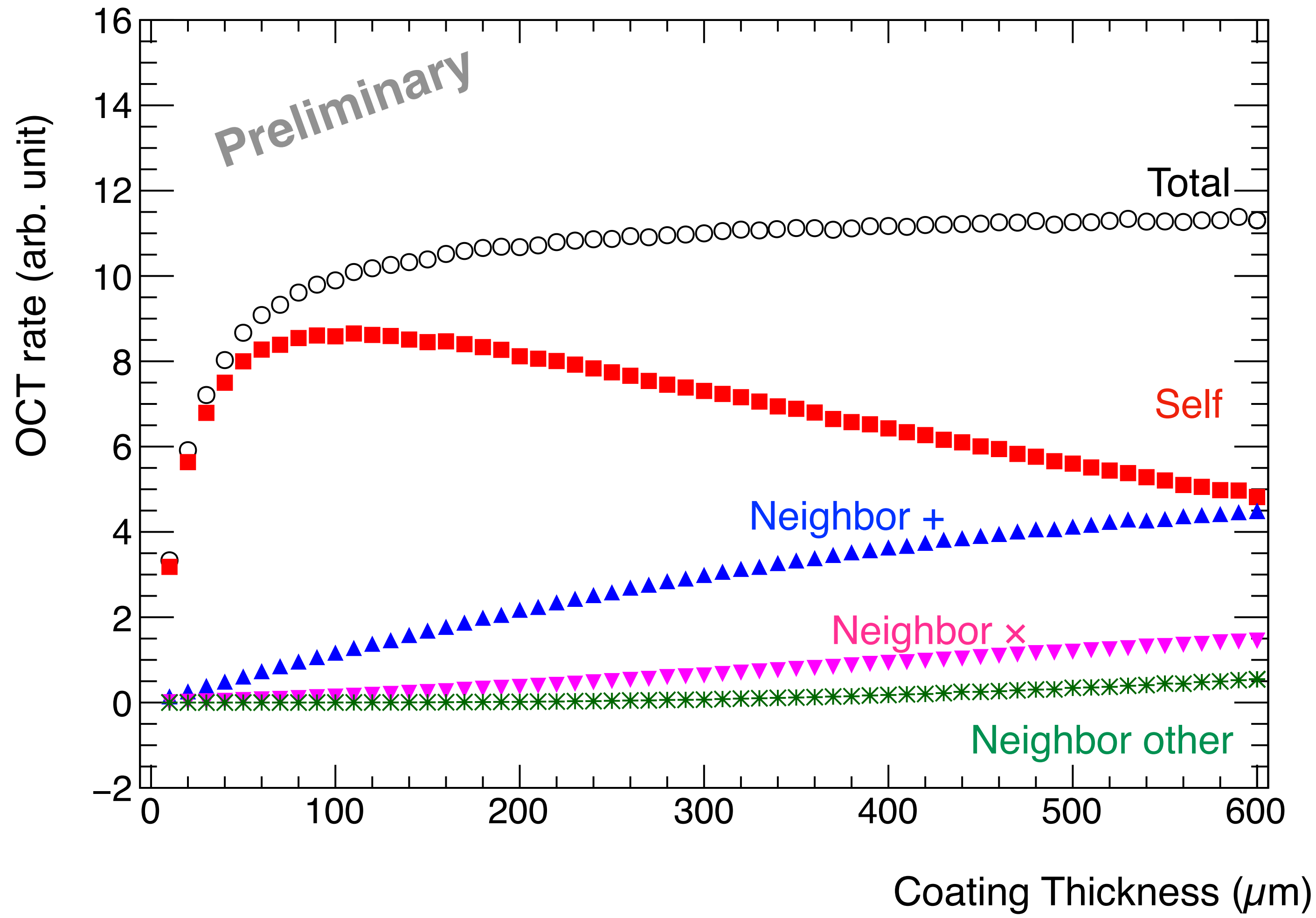
Ray-tracing Simulation





- To verify the thickness dependence by photon propagation
- Emitted photons from Ref. SiPM
  - Direction : isotropic
  - Position : uniform in the Ref. SiPM
- Propagation in silicon substrate was not taken into account

Simulation Result



- Reproduced the experiment well
  - Normalized with the best scale
  - Self OCT of no coating SiPM coming through the Si substrate, added it to the simulation results as offset
- **Very thin coating < 50 μm (cell size) is preferred in order to suppress Total OCT rate**

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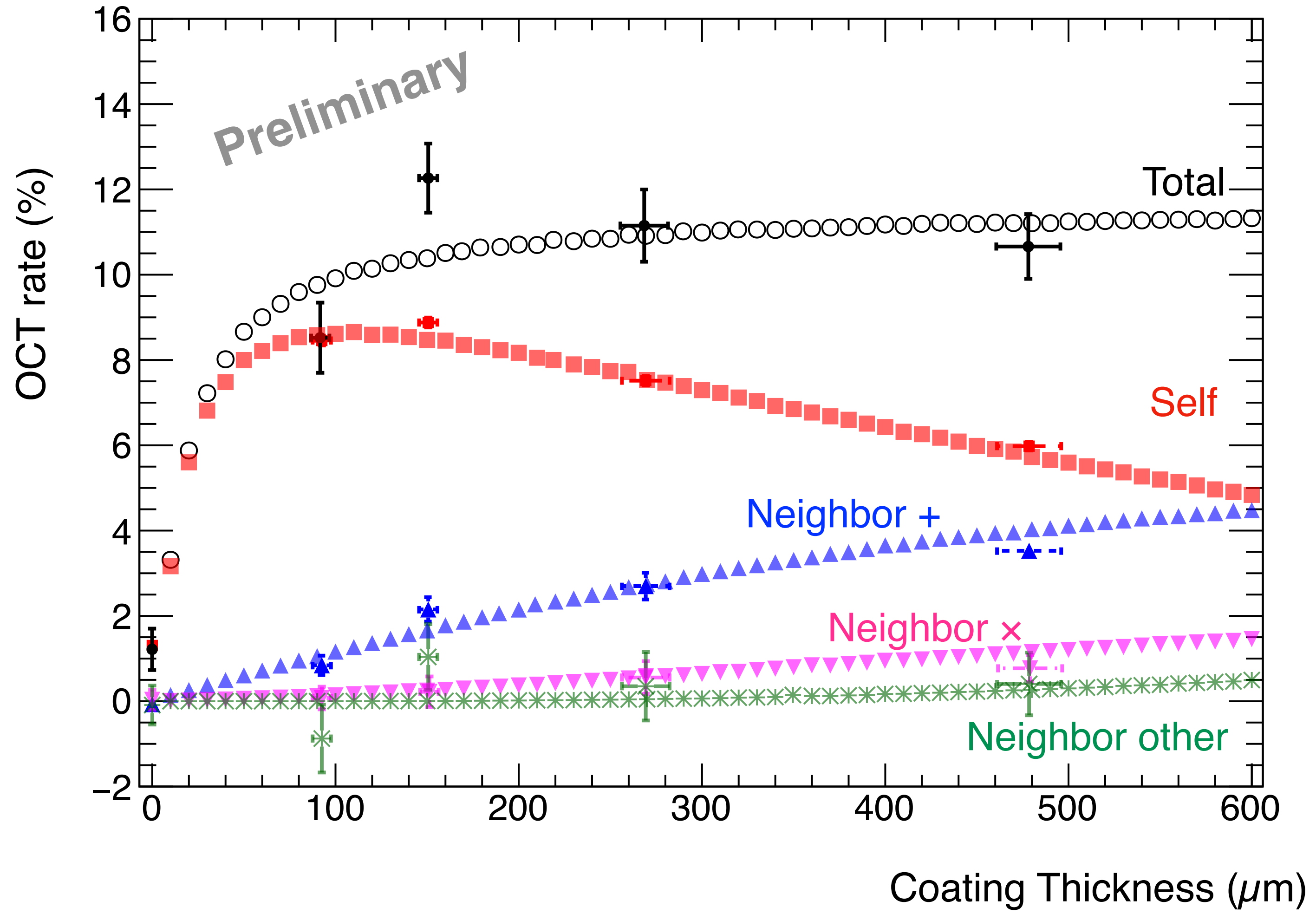

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Summary

- Evaluated a thickness dependence of neighboring-SiPMs OCT rate
  - Neighboring-SiPMs OCT is not negligible (self : neighbor ~ 2 : 1 at 300 μm)
  - Can be negligible w/o resin coating
  - Total OCT rate conserve (t > ~100 μm)

- Simulation reproduces the measurement well

- **Very thin coating SiPM is the best solution** to suppress OCT for Cherenkov telescopes
  - ※ We apply thin film during assembly