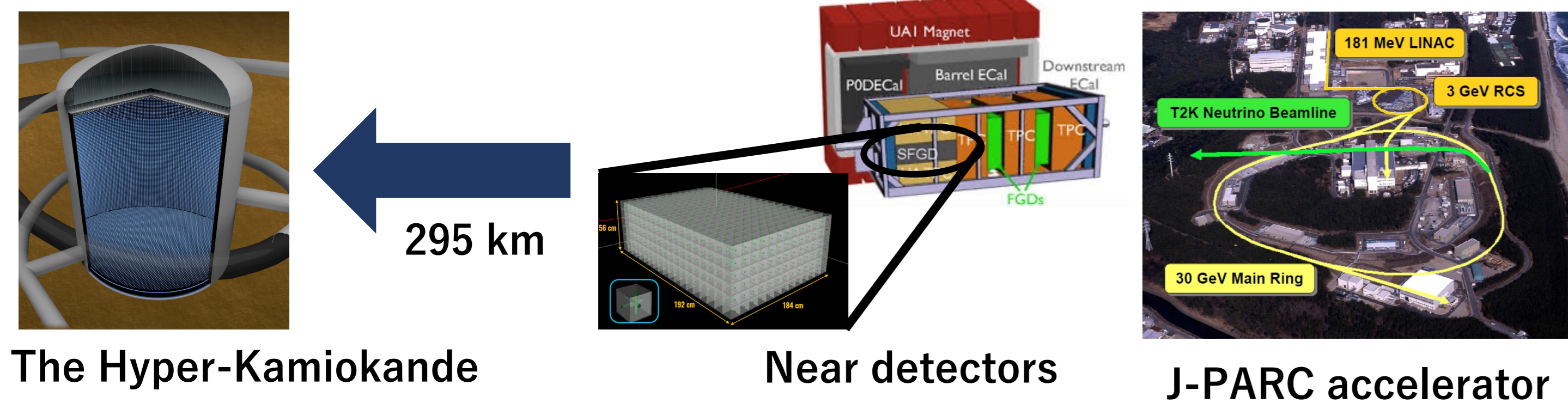


1. Hyper-Kamiokande Experiment

The Hyper-Kamiokande experiment aims to discover leptonic CP violation by measuring the difference between **the neutrino oscillation probabilities** $P(\bar{\nu}_\mu \rightarrow \bar{\nu}_e)$ and $P(\nu_\mu \rightarrow \nu_e)$.



Differences in target nuclei introduce a large systematic uncertainty in neutrino interaction models.

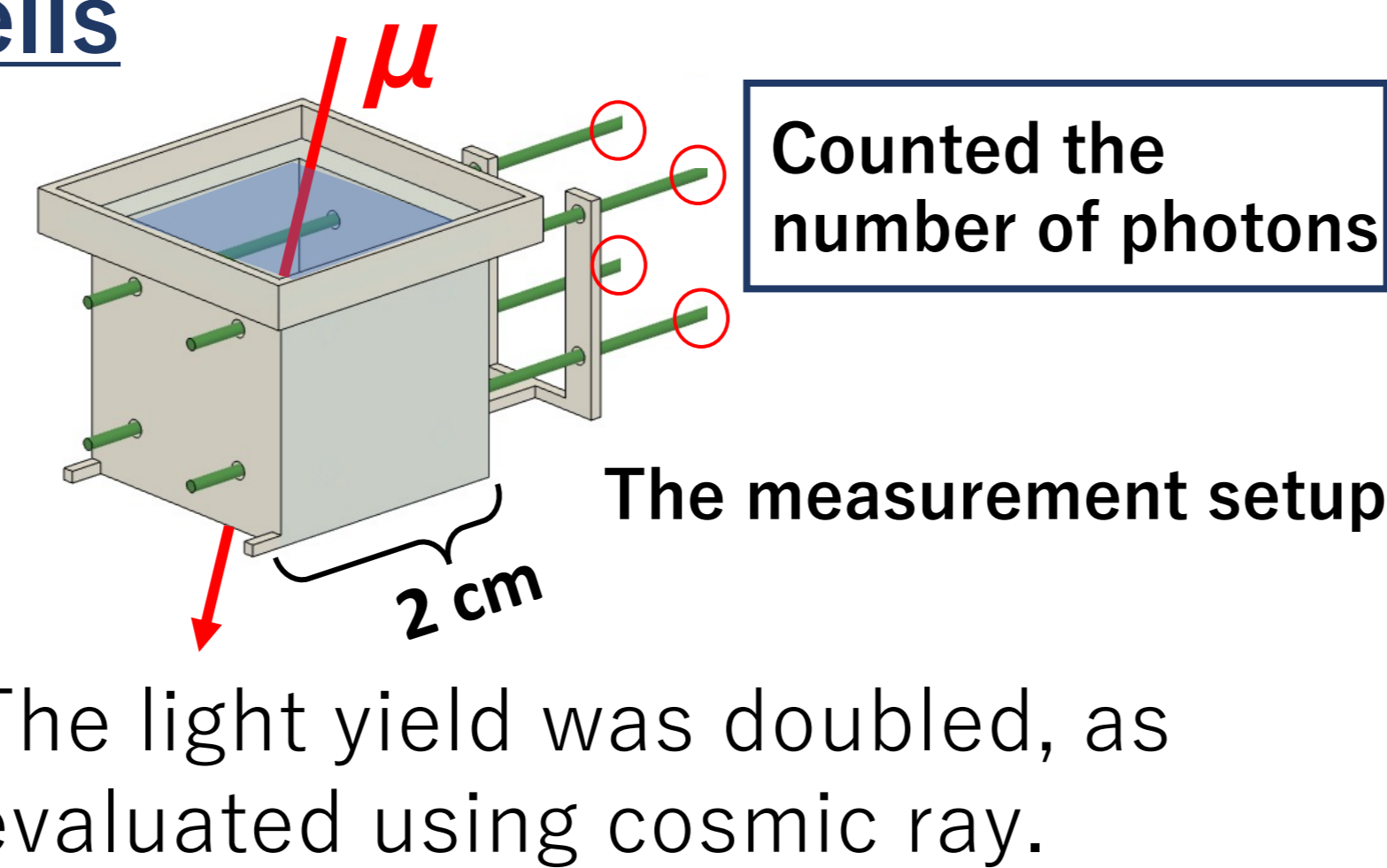
A near detector with a large content of water is necessary.

3. The Development of the Detector

Development goal: Improve the light yield and suppress optical leakage between cells

A) Improvement of Photon Collection Efficiency in Cells

- High reflectivity of the cell walls is important for confining photons within each cell.
- Reflective sheets were attached to the interior of the cell.



Printed using white 3D printer filament. Attaching 3M, DF2000MA sheet

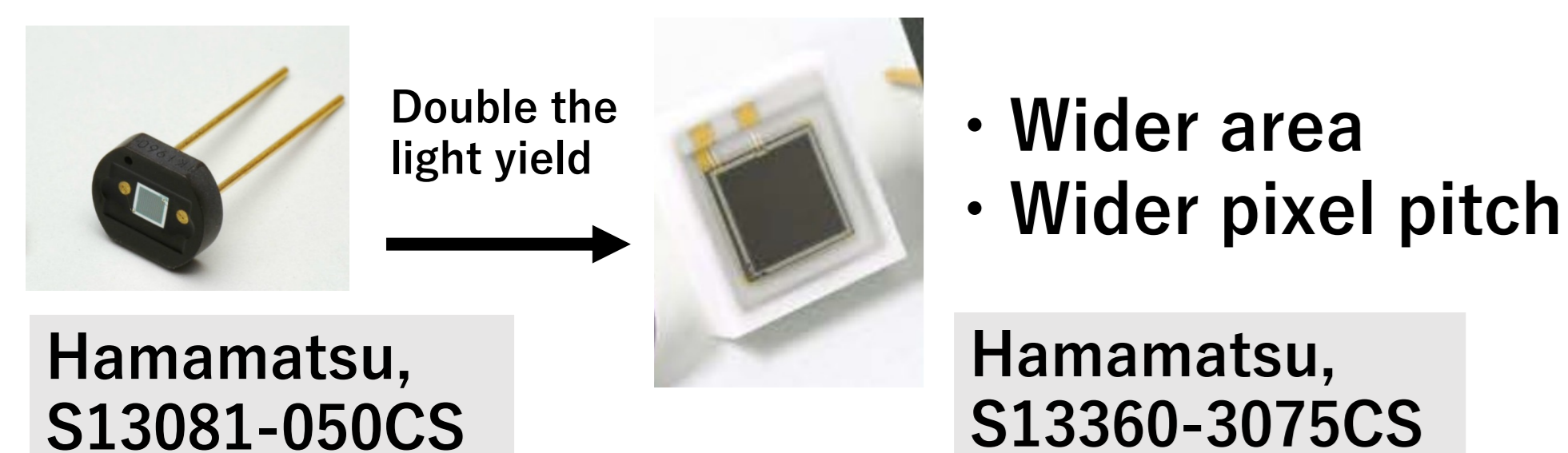
B) Reflective Treatment of Fiber End Faces

The light yield can be increased by reflecting photons at the non-readout end face.



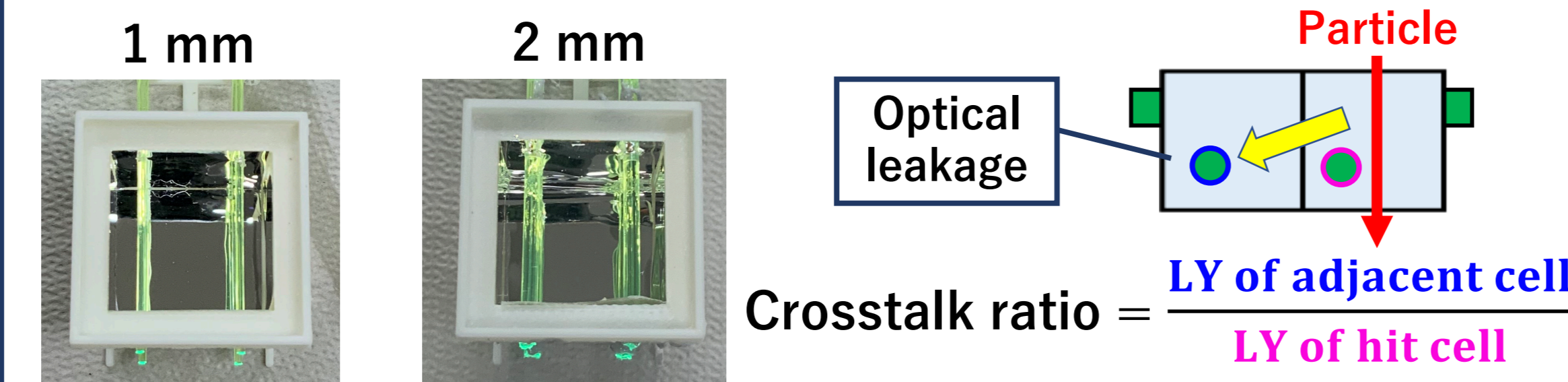
C) Optimization of SiPMs

The photon detection efficiencies were evaluated for multiple types of SiPMs.



D) Effect of Fiber Diameters

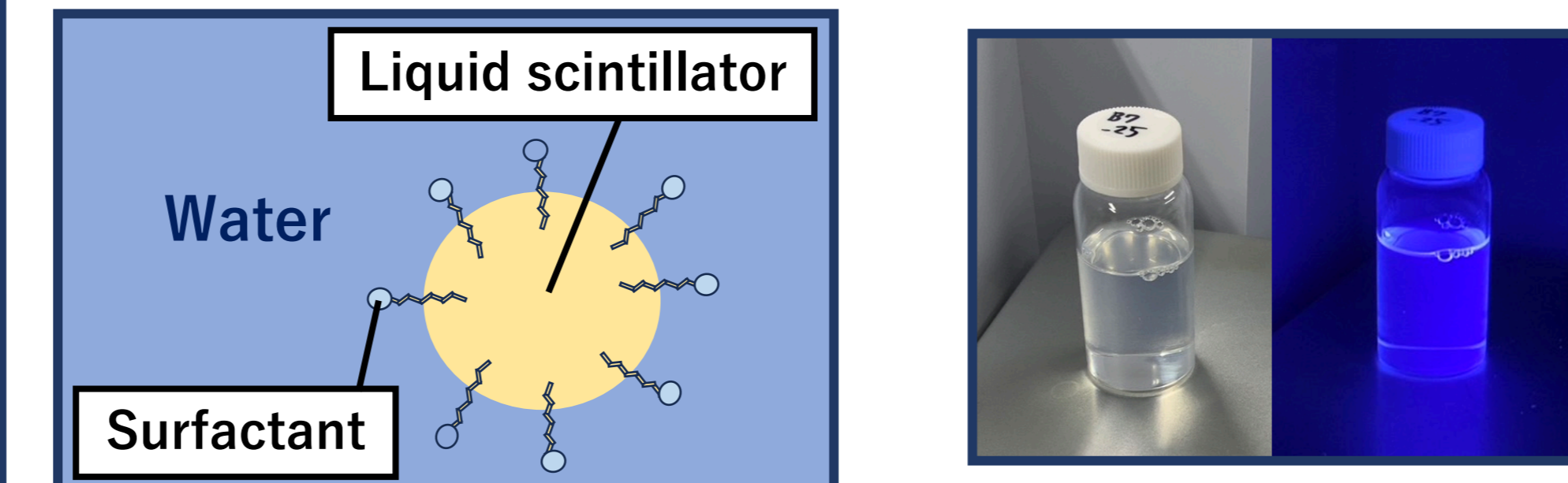
A thicker fiber increases the photon collection efficiency, which affects the crosstalk ratio.



2. The Water-based Liquid Scintillator Detector

Water-based Liquid Scintillator (WbLS)

A mixture consisting mainly of water, in which a liquid scintillator is dissolved using surfactants.

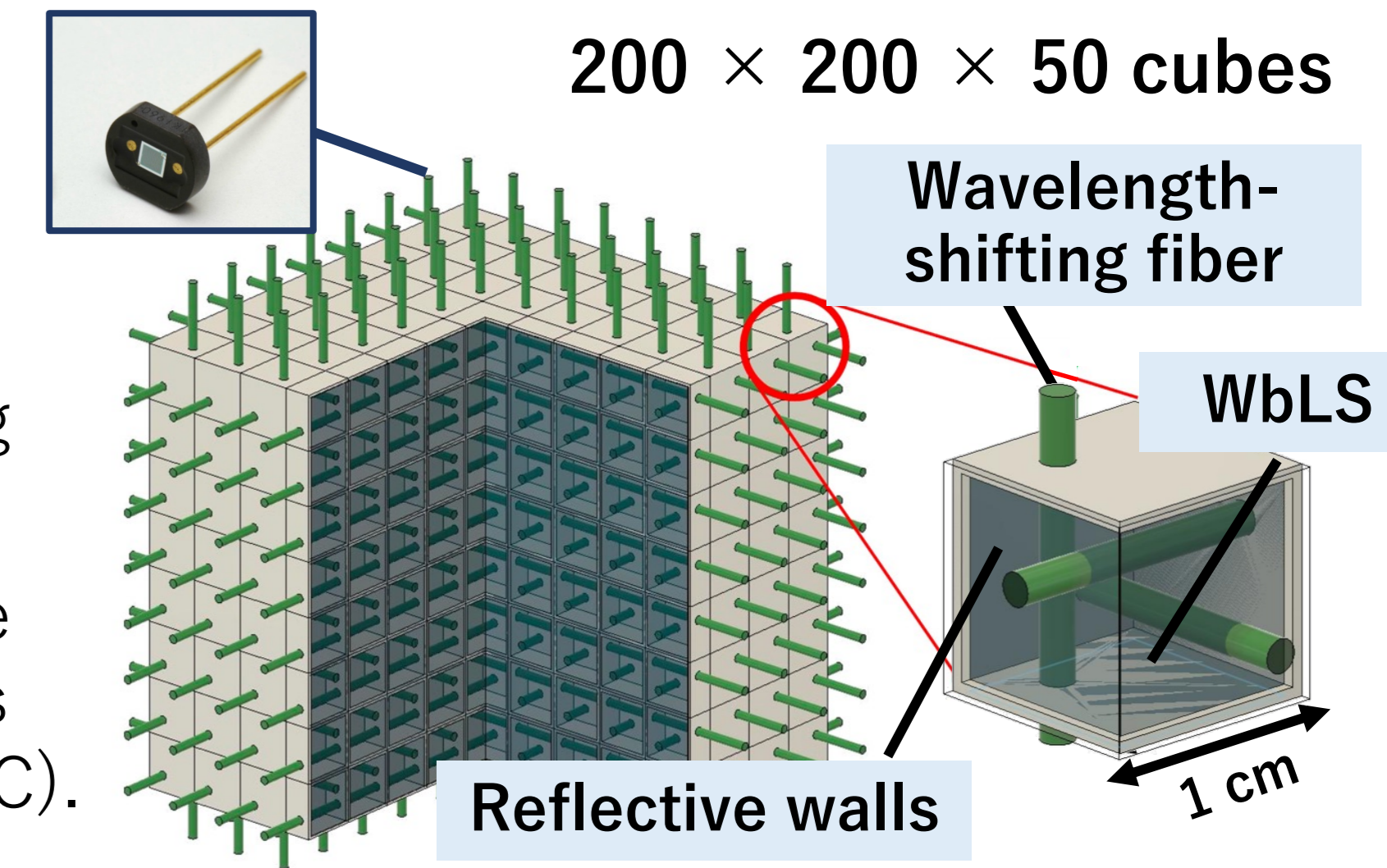


Material composition of the WbLS

	Material	Ratio [wt%]
Water	Pure water (TRUSCO, W10-A2)	70
Surfactant	Nonionic IGEPAL CO-630	14.5
	Anionic Sodium 1-Naphthalenesulfonate	0.5
Liquid scintillator	Solvent Pseudocumene	13.975
	Fluor 2,5-Diphenyloxazole	1
	Wavelength shifter 1,4-Bis (2-methylstyryl) benzene	0.025

The Detector Design

- A tracking detector that uses WbLS as an active water target.
- WbLS is **segmented into cubic cells** using reflective walls.
- Scintillation photons are transported to the side surfaces by wavelength-shifting fibers and read out by SiPMs (Hamamatsu, MPPC).



- ✓ Track reconstruction resolution: 3 ~ 10 mm
- ✓ Isotropic and high detection efficiency
- ✓ Enables measurements of neutrino interactions on a water target



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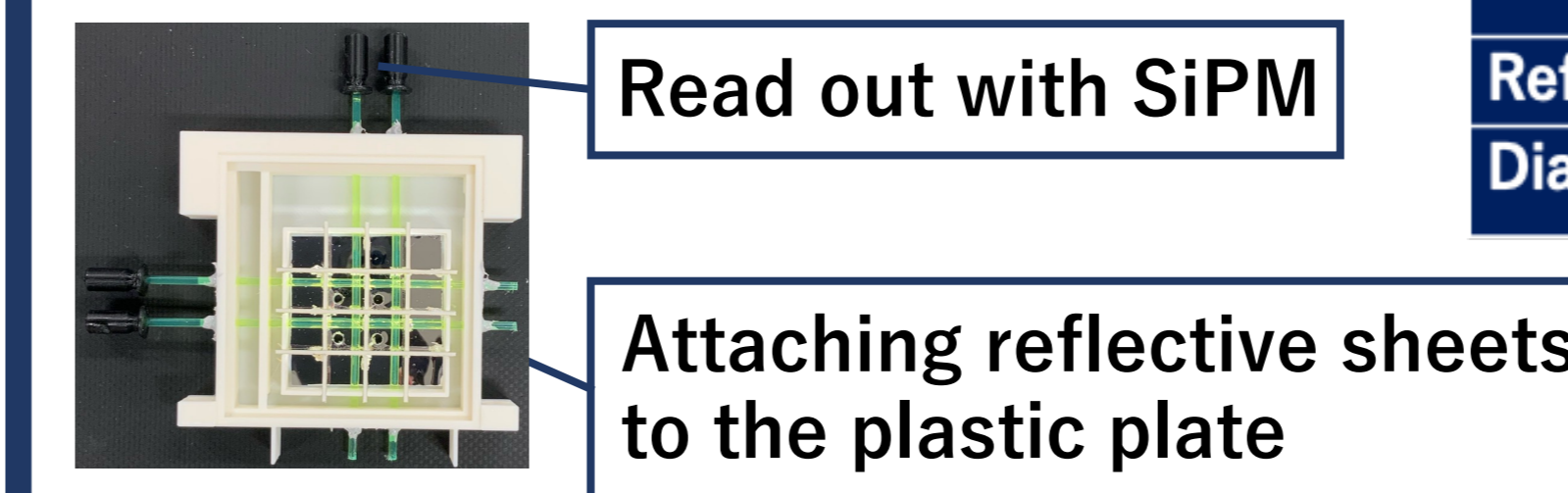


4. Performance Evaluation

Performance Measurement Using an Electron Beam

We evaluated the performance of detector prototypes using an electron beam at test beamline, KEK.

Prototype design



Details of the prototypes

	Sample 1	Sample 2	Sample 3
Reflective Sheet	3M	3M	Lumirror
Diameter of fibers	2 mm	1 mm	2 mm

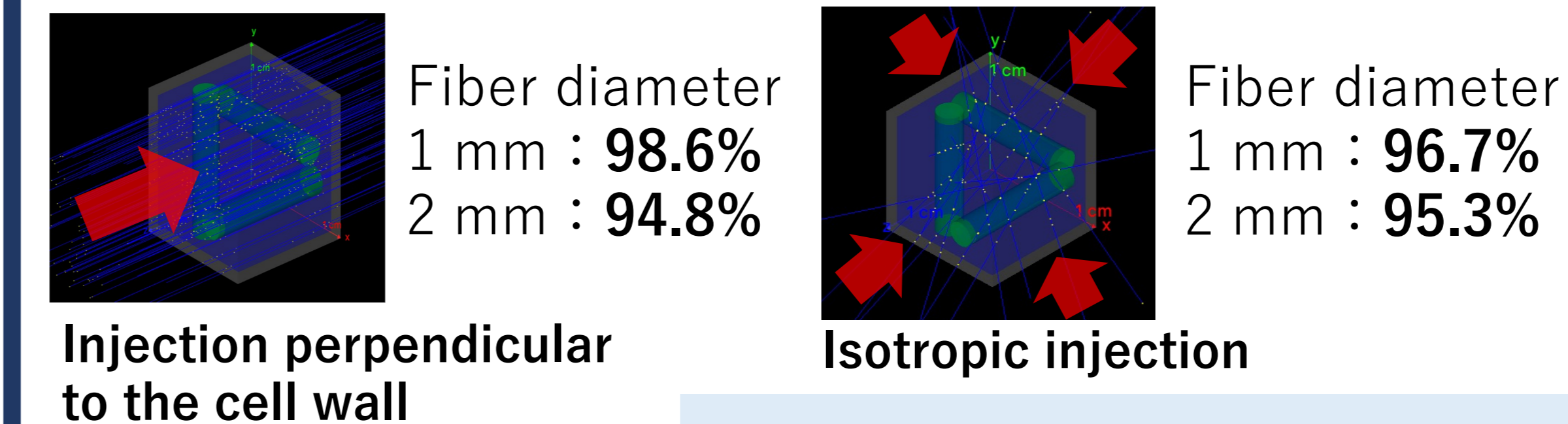
Result

	Sample 1	Sample 2	Sample 3	Requirements
Light yield [p.e./fiber]	24.7 ± 2.4	26.7 ± 1.0	29.3 ± 1.6	More than 20
Crosstalk ratio [%]	2.92 ± 0.35	5.80 ± 0.65	2.85 ± 0.43	Less than 3

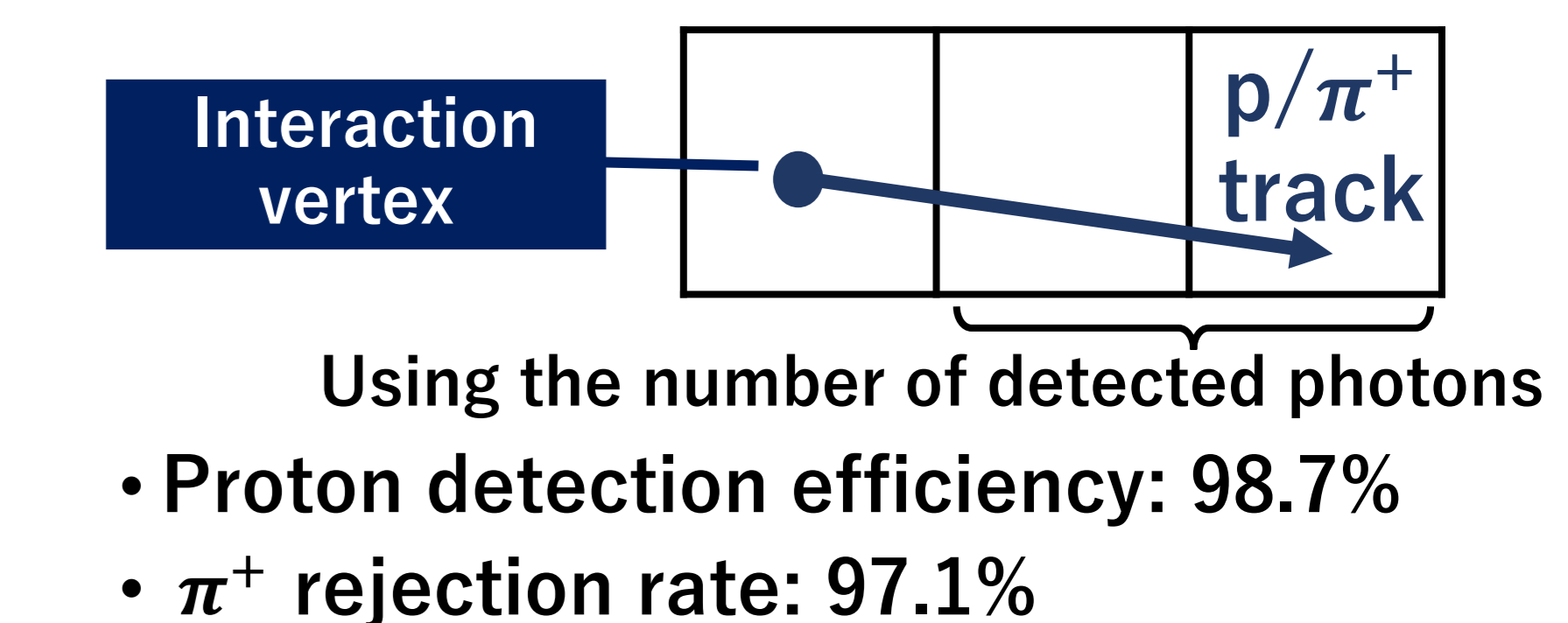
- ✓ The light yield and crosstalk ratio met the requirements.
- ✓ Crosstalk is suppressed when the fiber diameter is 2 mm.
- ✓ The light yield varied depending on the beam position.

Simulation Study

Hit detection efficiency of cells

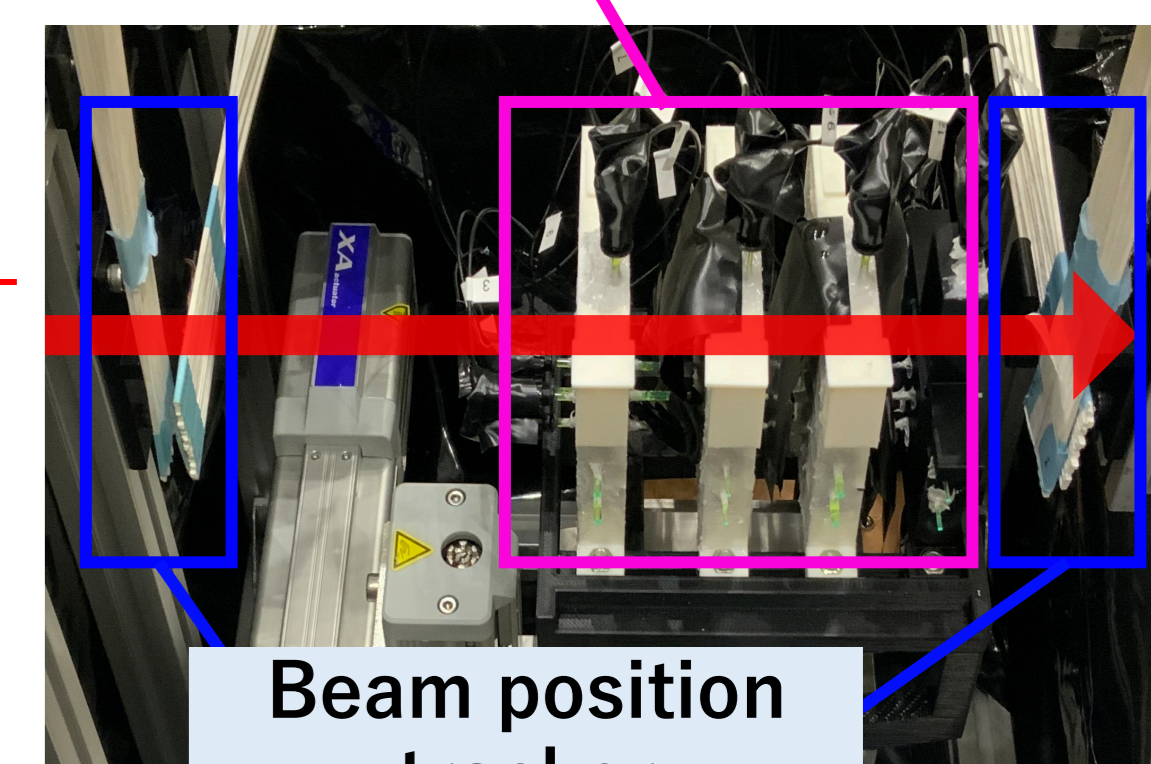


Particle Identification (π^+ /Proton)



Simulations confirmed that the WbLS detector has practical performance.

Three prototypes



The measurement setup

