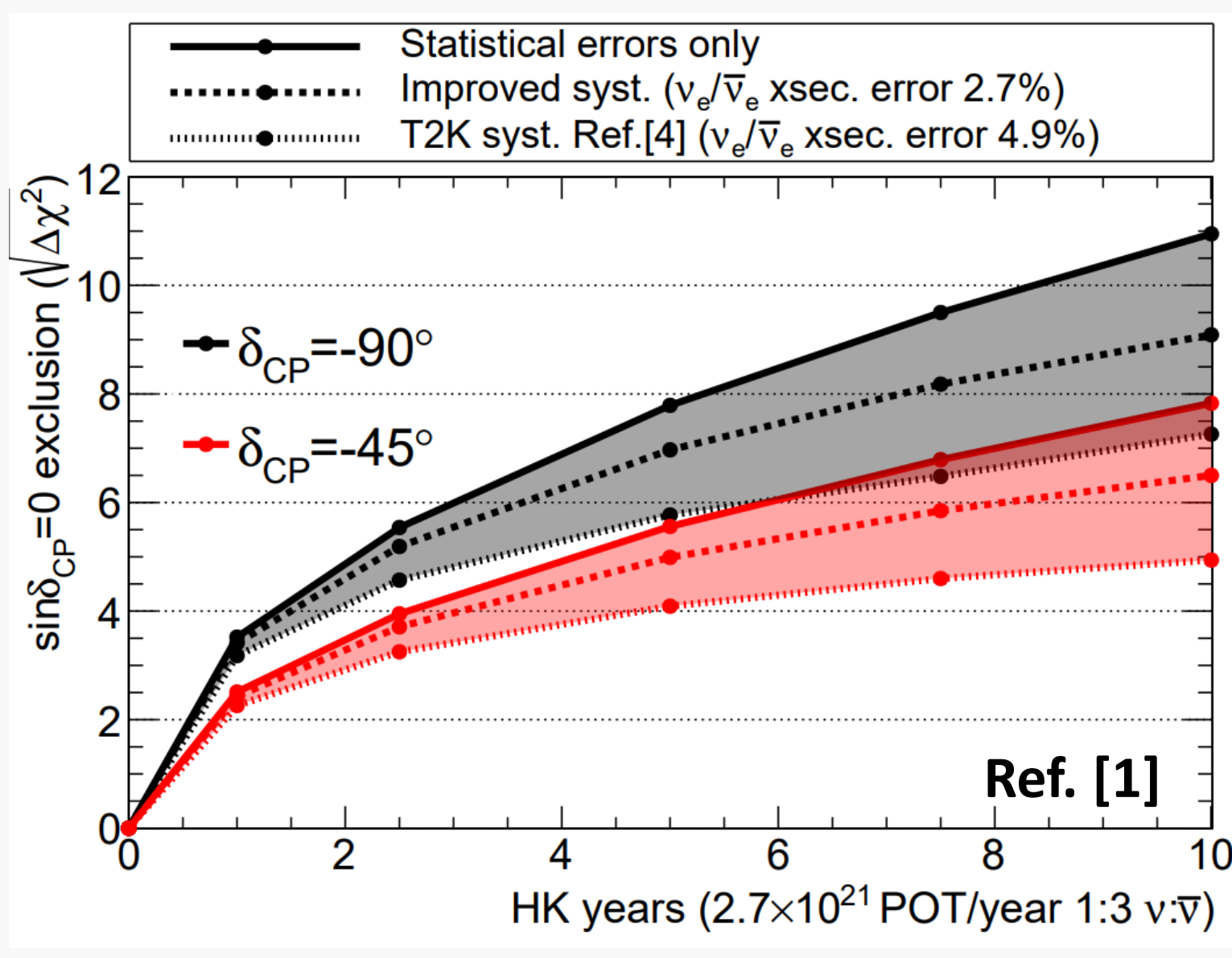


Background and physics motivations

ND280 is a magnetised (0.2T B-field) near detector for long-baseline neutrino experiments, used in T2K since 2010, to be inherited by Hyper-K in 2028. Hyper-K will measure CP-violation, δ_{CP} , by comparing $P(\nu_\mu \rightarrow \nu_e)$ and $P(\bar{\nu}_\mu \rightarrow \bar{\nu}_e)$. The ν_μ ($\bar{\nu}_\mu$) beam generated at J-PARC in Tokai Japan has $\sim 1\%$ contamination of ν_e ($\bar{\nu}_e$), so ND280 is needed to constrain pre-oscillation neutrino fluxes. Hyper-K will be operating at high beam-power (1.3MW) to provide high statistics, so from ~ 2030 , systematic uncertainties will dominate.



Precision of σ_{ν_e} is limited by the uncertainty from scaling ν_e /nucleon interactions from carbon in the Near Detector to oxygen in the Far Detector.

- Upstream detectors installed in the ND280 upgrade [3] in 2024 will be retained:
- Super Fine Grained Detector (SFGD)
- High-angle Time Projection Chambers (HAT)
- Time of Flight detectors
See poster nos. 88 by N. Baudis, 109 by H. Kobayashi, and 336 by C. Forza

ND280++ The multi-ton upgrade of the magnetised near detector for the Hyper-Kamiokande high-statistics phase



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ND280++ overview

Replacing the downstream legacy ND280 detectors will free up volume for ~10 tonnes of neutrino target mass. A large fraction of water is prioritised to reduce sigma_nu_e uncertainty. High granularity needed for low momentum protons and for nu_e/gamma separation. Also, a target larger than the SFGD is needed to capture more neutrons from anti-nu interactions. In addition to the detectors listed below, a refurbishment of the Electromagnetic Calorimeter is planned to replace electronics to recover light yield and performance after years of operation [4].

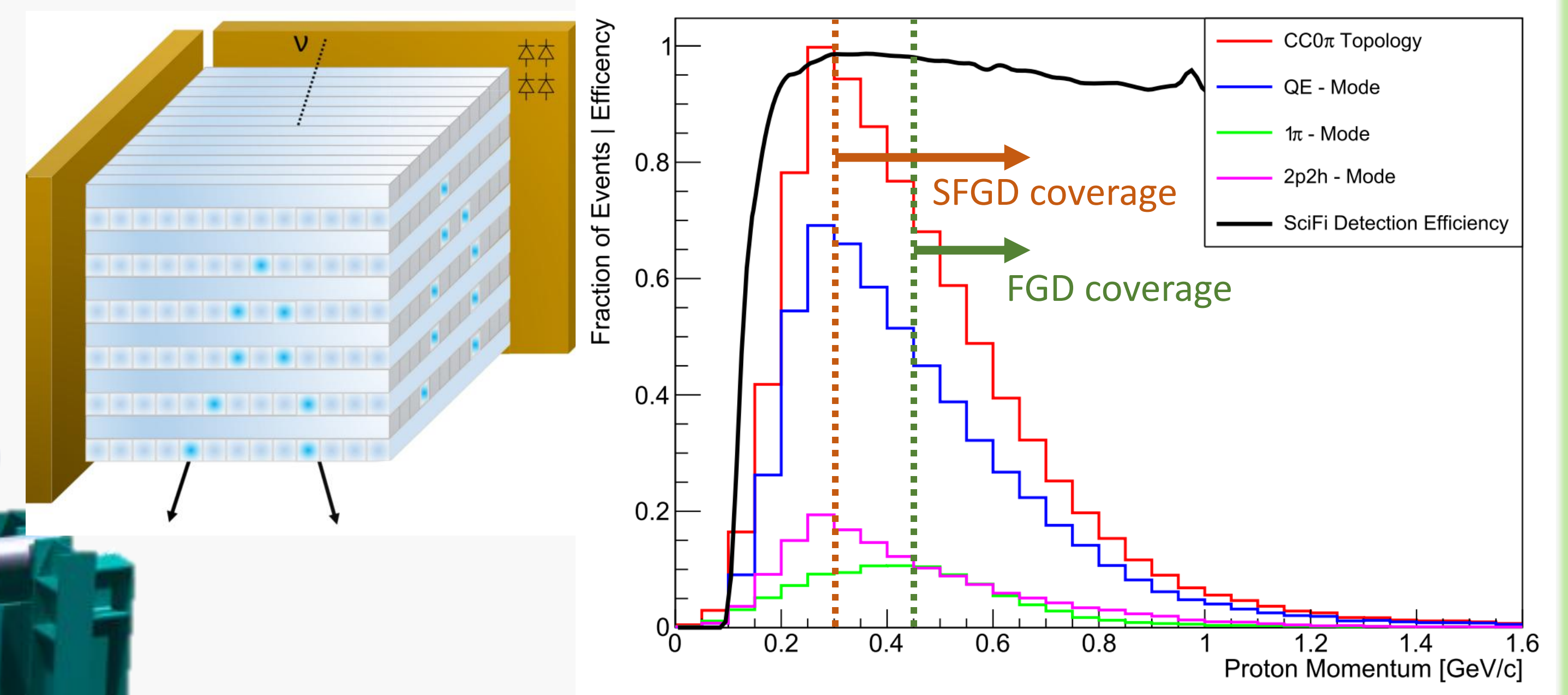
Vertical TPC

Simulating a vertical TPC with technology used in HATs. New technologies are explored to reduce volume and maintain performance: using smaller charge pads or an optical readout.

Scintillating Fibres

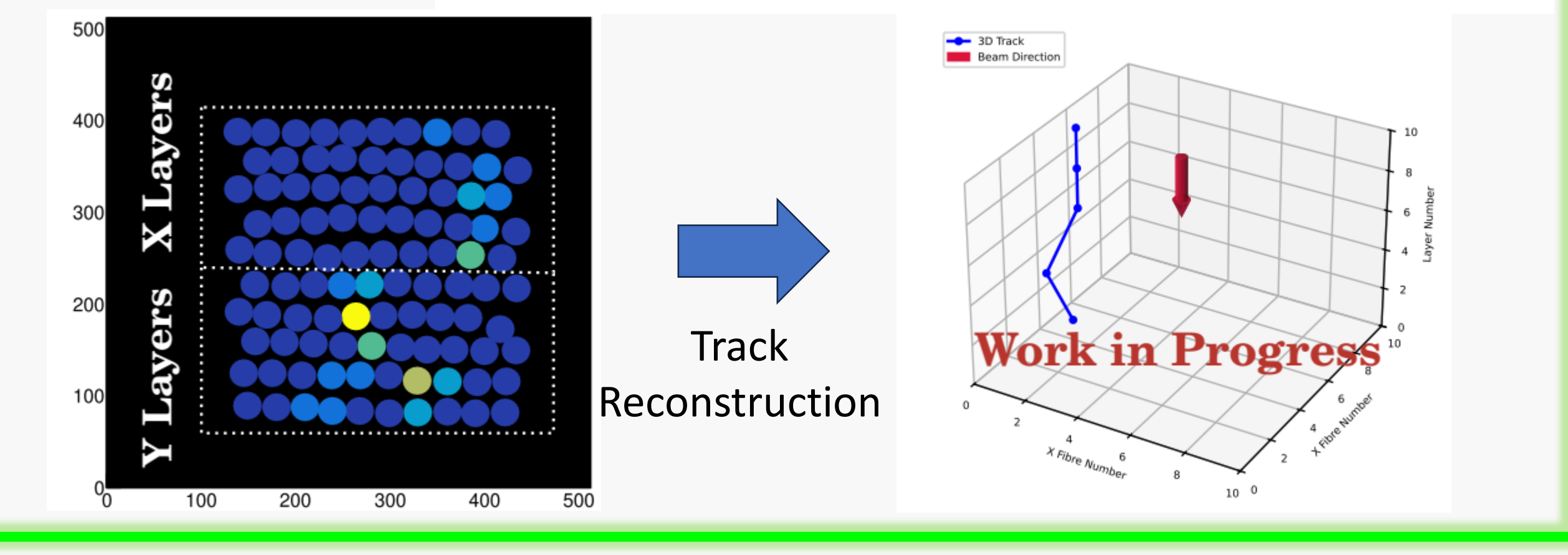
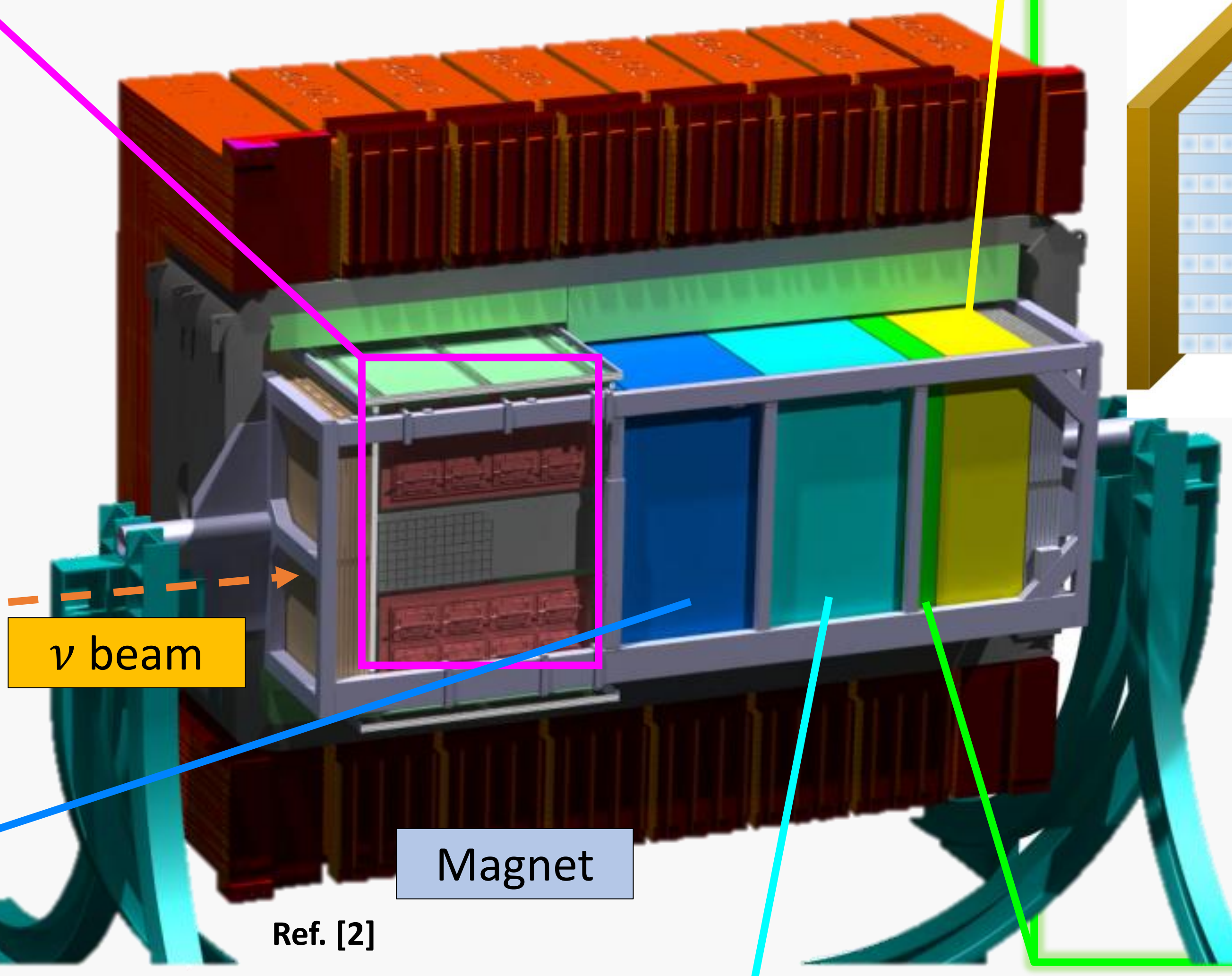
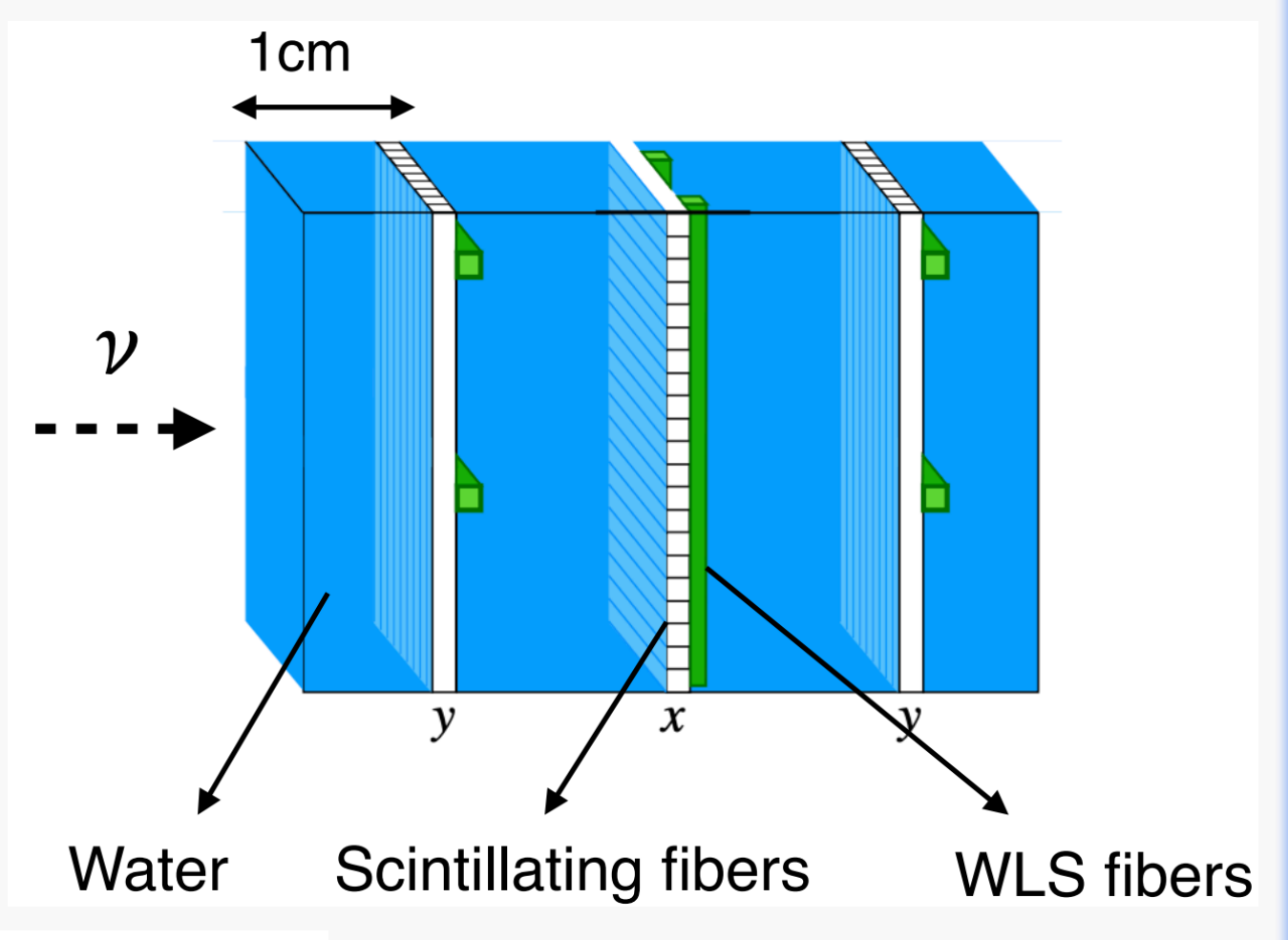
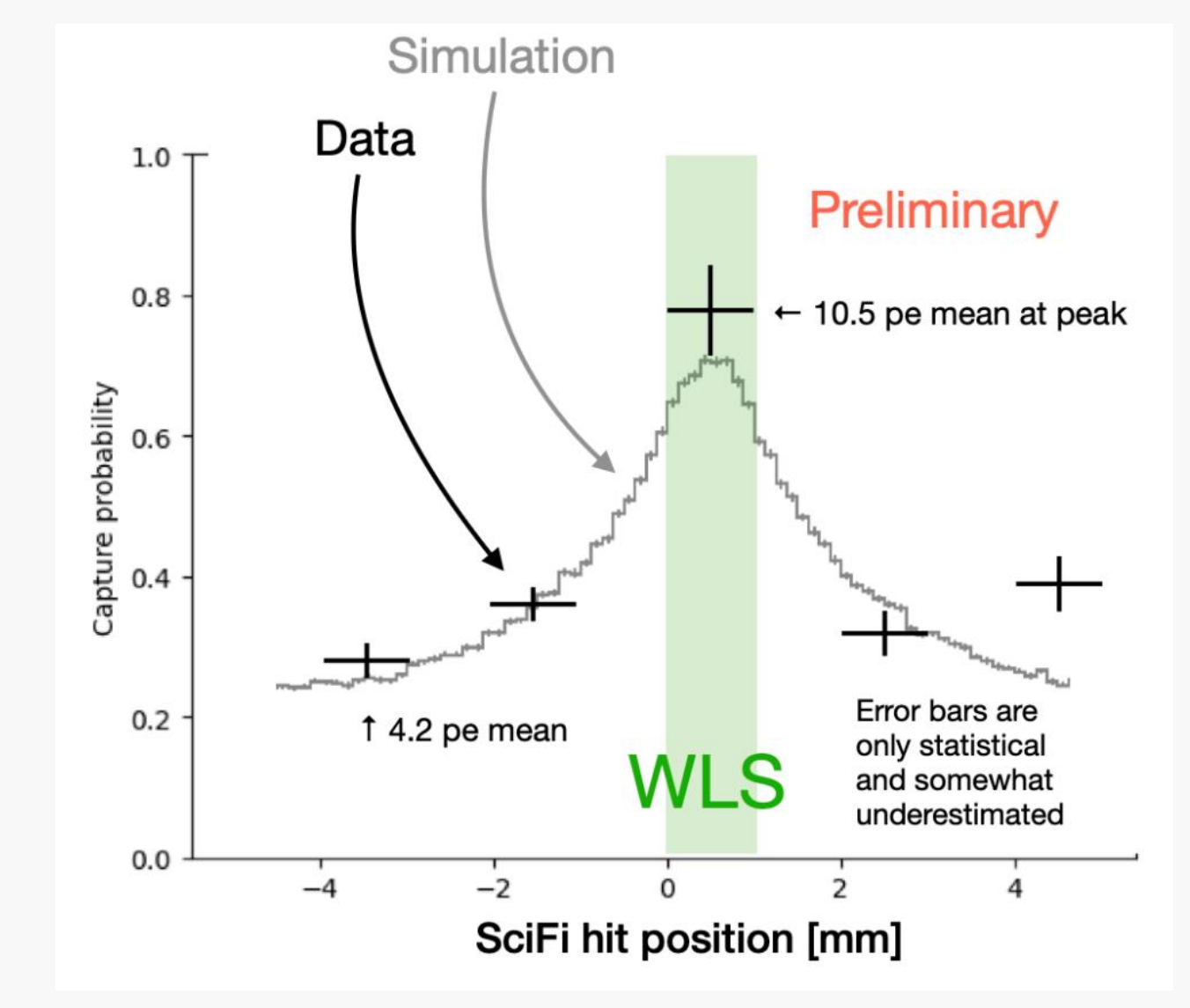
By using scintillating fibres as the active target (Luxium fibre mat with 500um diameter), proton tracking down to 150MeV/c is possible [5]. A 1 tonne detector would need ~10M SiPMs (compared to the SFGD's 56k). Use single-photon avalanche diode arrays instead to cover hundreds of fibres (SwissSPAD2).

Successful characterisation of a 1x1m^2 single-layer mat was performed.



Inactive water detector

A large volume of water to measure the nu_e-water cross section and nuclear effects. For 500MeV gamma, e+e- is separated by +/- 3mm over 15cm so we need mm-level granularity.

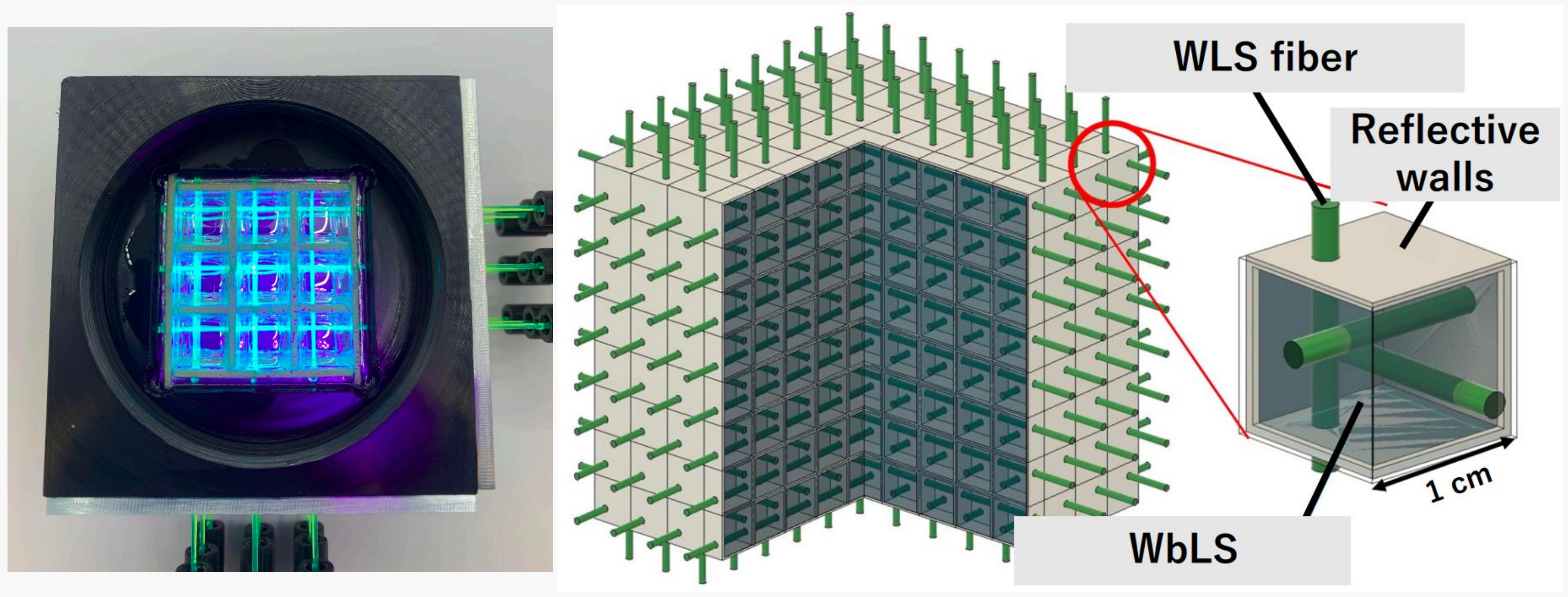


Water-based Liquid Scintillator 3D detector (WbLS)

We are further developing the design of the SFGD to obtain a larger target mass with high granularity, with maximal water content. Testing different materials for the vessel design is being done to ensure chemical stability [6]. Further development of the WbLS composition and its characterisation has been performed, see poster no. 104 by K. Hayashi. Early prototypes have been developed [7], but to achieve good particle identification, need to push the light yield above 10p.e. for MIPs.

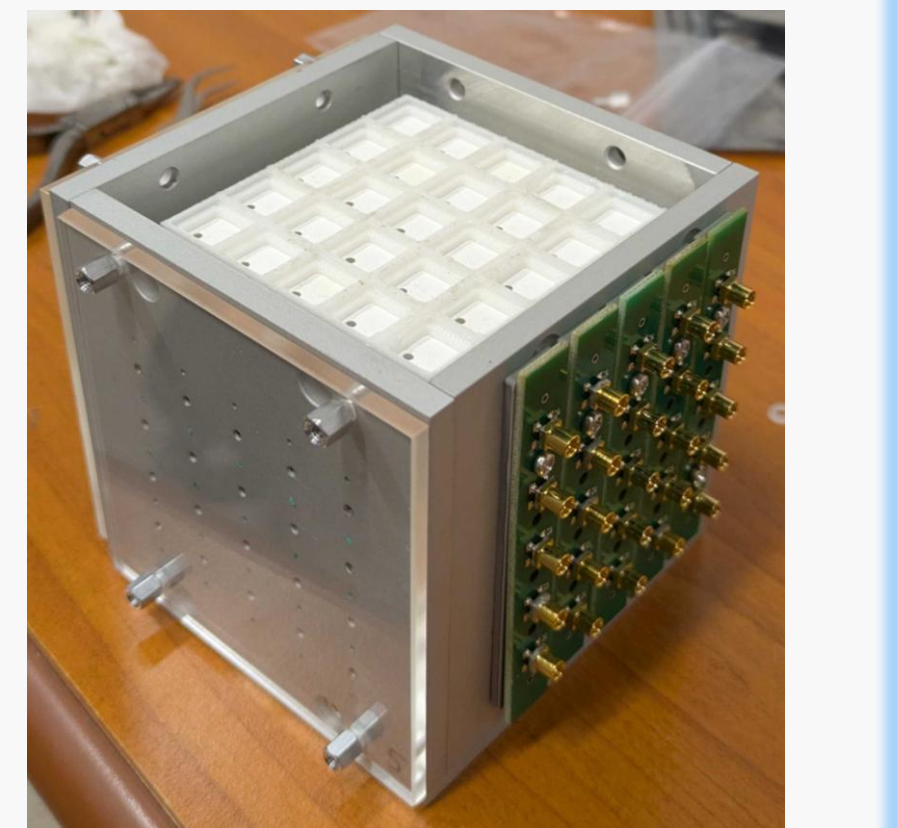
Table with 4 columns: Target, Water content of scint. [%], Mean L.Y/fibre [p.e.] for MIPs, Cross-talk [%]. Rows include SFGD, LS, and WbLS.

Ref. [7] used rigid foam for the cubic structure but replacing it with lighter alu-mylar has found similar performance while improving the water weight fraction.



Work is ongoing to maximise light yield from different detector configurations. A "microSFGD" has been set up with 5x5x5 SFGD cubes and 40 channel readout. Cosmic data analysed to measure the impact of using different SiPMs, or having PMMA between fibre and SiPM, or the use of reflectors at the other fibre end.

Table with 4 columns: SiPM size, Reflector, PMMA, Mean L.Y/fibre [p.e.]. Rows show configurations for 1mm and 3mm SiPM sizes with and without reflectors and PMMA.



References:
[1] Eur.Phys.J.C 86 (2026) 2, 170
[2] arXiv:2506.16641
[3] arXiv:1901.03750
[4] JINST 17 (2022) 10, P10028
[5] Eur.Phys.J.C 84 (2024) 2, 202
[6] NIM A 660, 51-56 (2011)
[7] JINST 21 (2026) 01, P01012