Study of wavelength-shifting plates for the outer detector Hyper-Kamiokande

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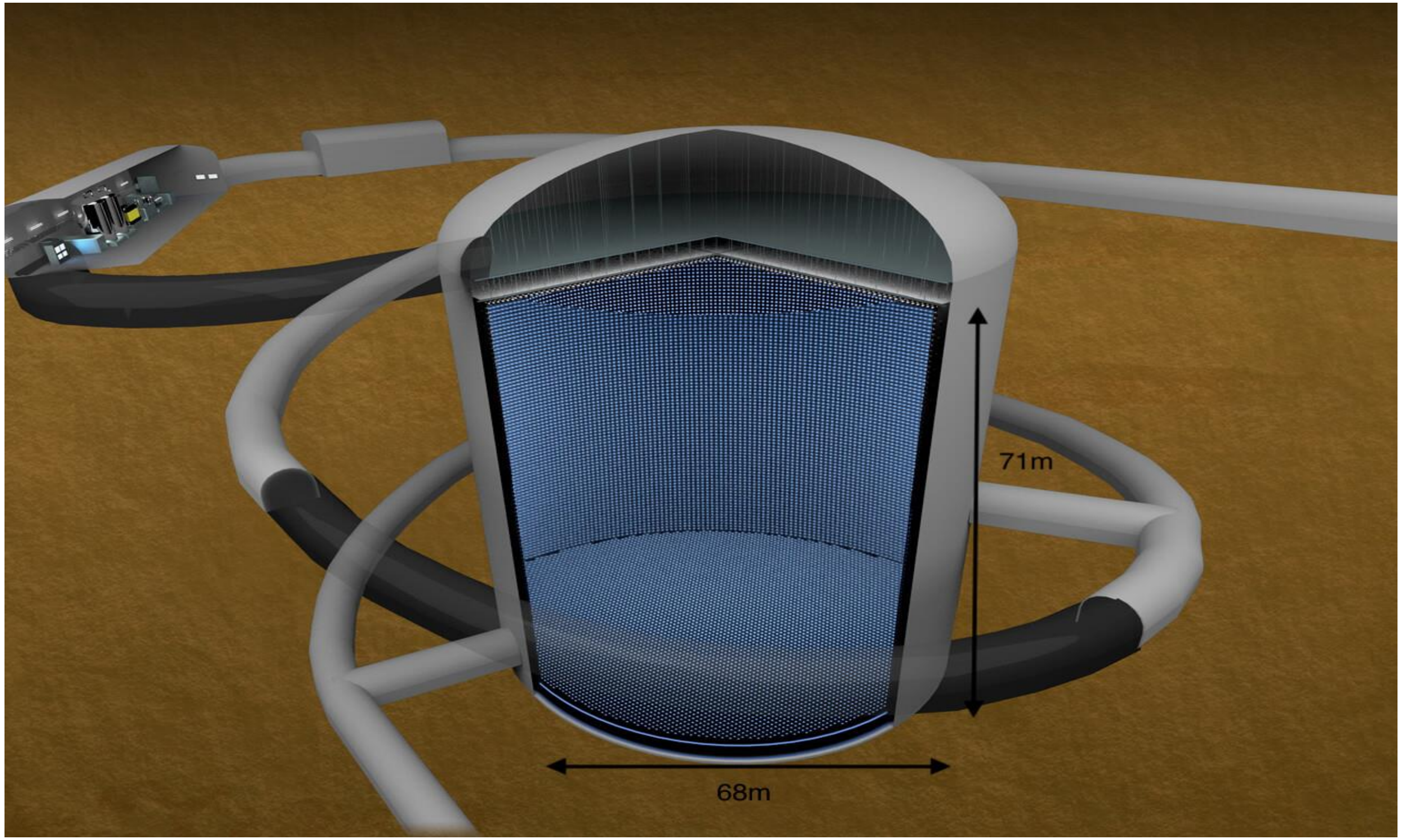
Hyper-Kamiokande

Hyper-Kamiokande is a third-generation water Cherenkov detector. The main tasks of Hyper-Kamiokande are:

- Study of CP invariance violation
- Study of the neutrino mass hierarchy
- Observation of supernova explosions
- Search for proton decay

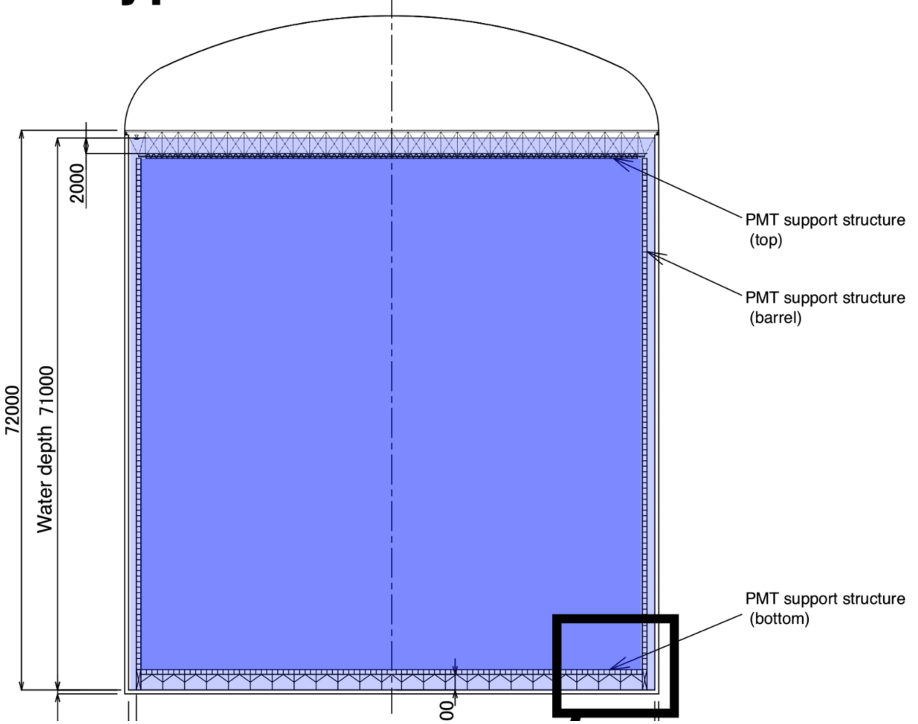


Concept of the Hyper-Kamiokande detector. The planned total volume is 260,000 tons of water (8.4 times larger fiducial mass than its predecessor, Super-Kamiokande).

Outer detector

The detector is divided into two parts: the Inner Detector and the Outer Detector. The Inner Detector is the main detector, with 40,000 max. 50cm-diameter PMTs. The outer detector is an active 4π veto detector and it is planned to use about 3600 PMTs (D=8 cm) together with wavelength-shifting plates.

Cross section of Hyper-Kamiokande detector



Section view of the Hyper-Kamiokande detector

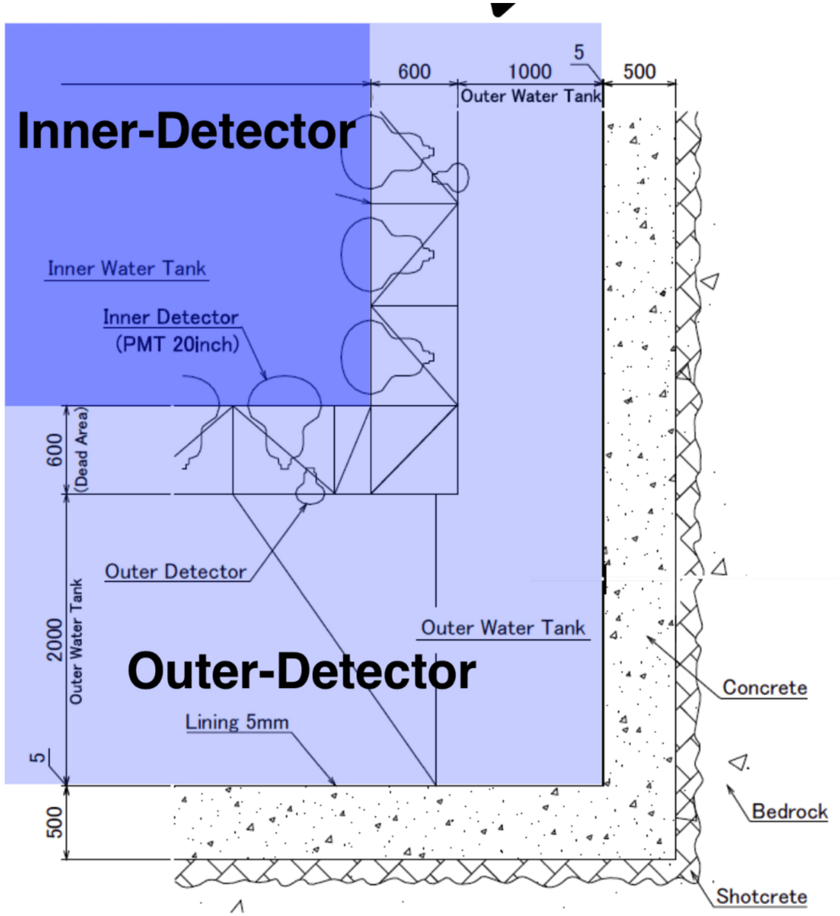
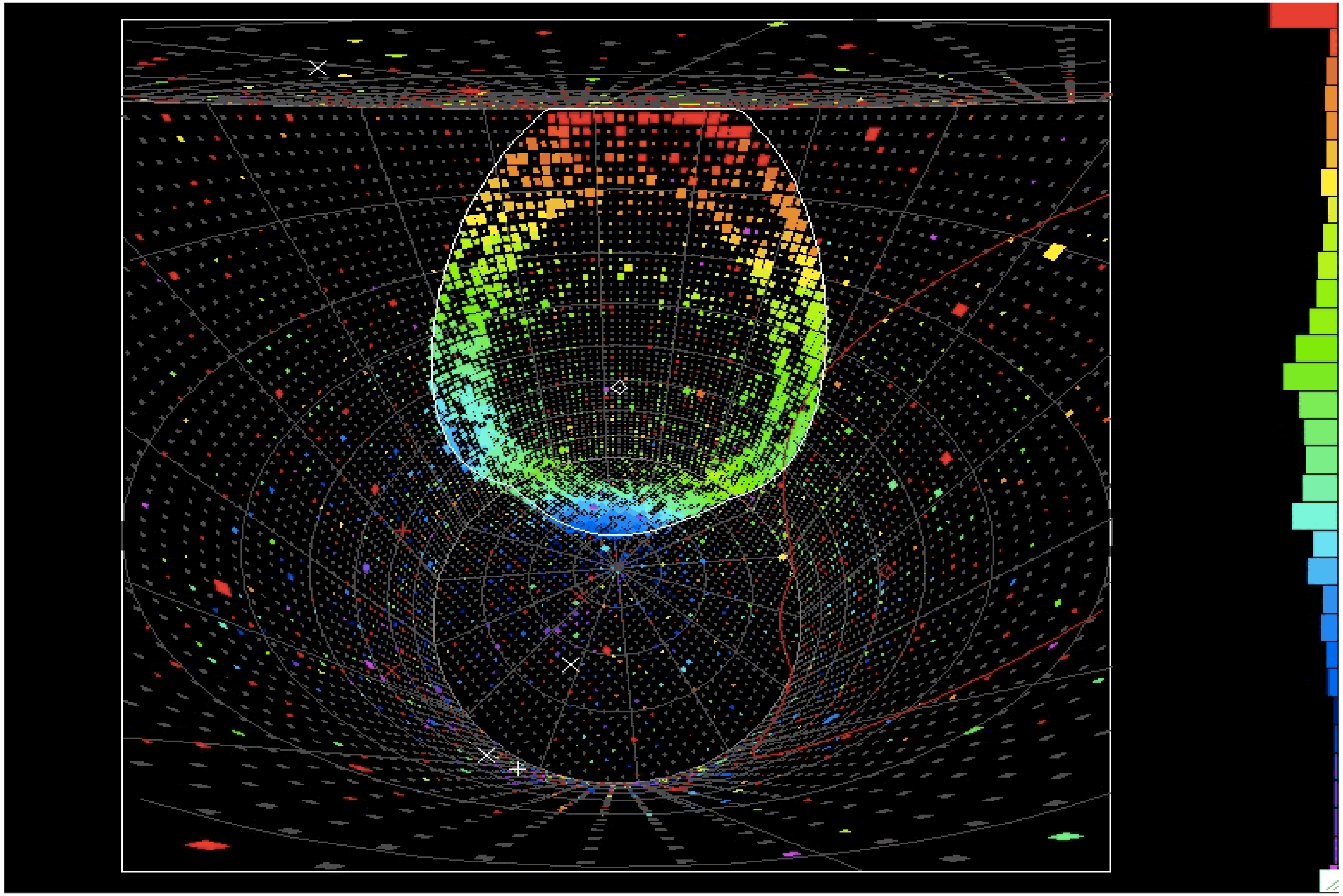


Diagram of the relative location of the photomultiplier tubes in the internal and external detectors.

The working principle of Hyper-Kamiokande

In the detector volume, charged particles moving at a speed greater than light in this medium cause the Vavilov-Cherenkov effect. The Cherenkov radiation front forms a circular cone, the opening angle of which depends on the particle speed and the refractive index of the medium.

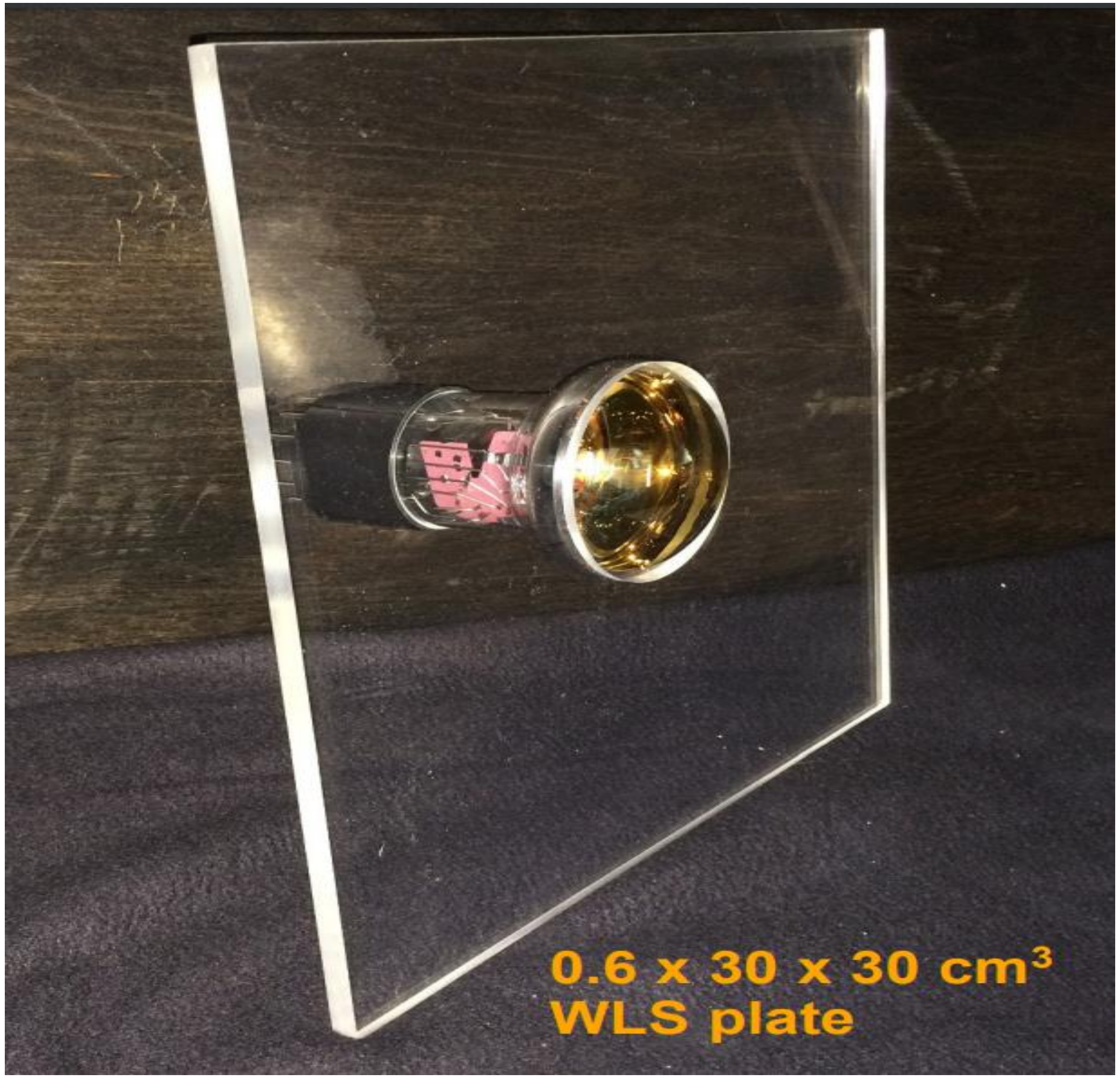
$$\sin \theta_C = \frac{c}{n \cdot v_p}$$



Graphical representation of the measurement results in the internal Super-Kamiokande detector. (Similar for the Hyper-Kamiokande detector.)

Motivation for developing the methodology

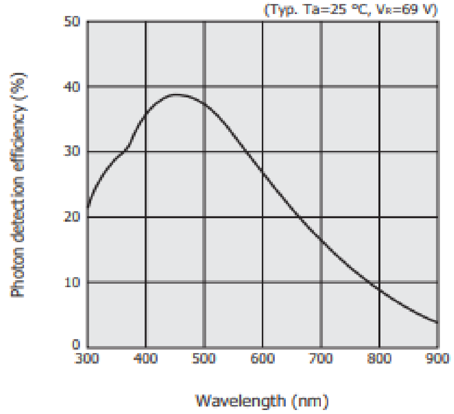
The development of a method for testing WLS-plates is due to the need to control the quality at a pace corresponding to the manufacturing speed and identifying deviations in the quality of plates from the reference sample. To increase the speed of testing it was decided to use MPPC, because they allow using significantly simpler mechanics for positioning.



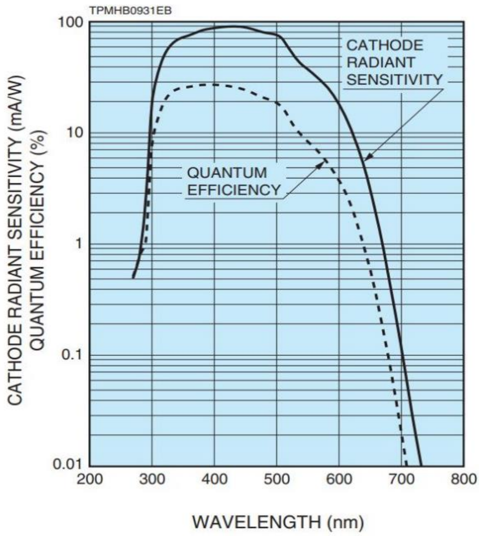
Hyper-Kamiokande Outer Detector Optical Module

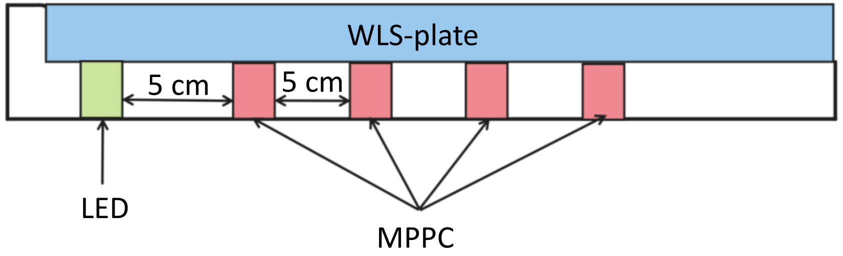
Experimental setup

PDE for Hamamatsu MPPC S13081-050C

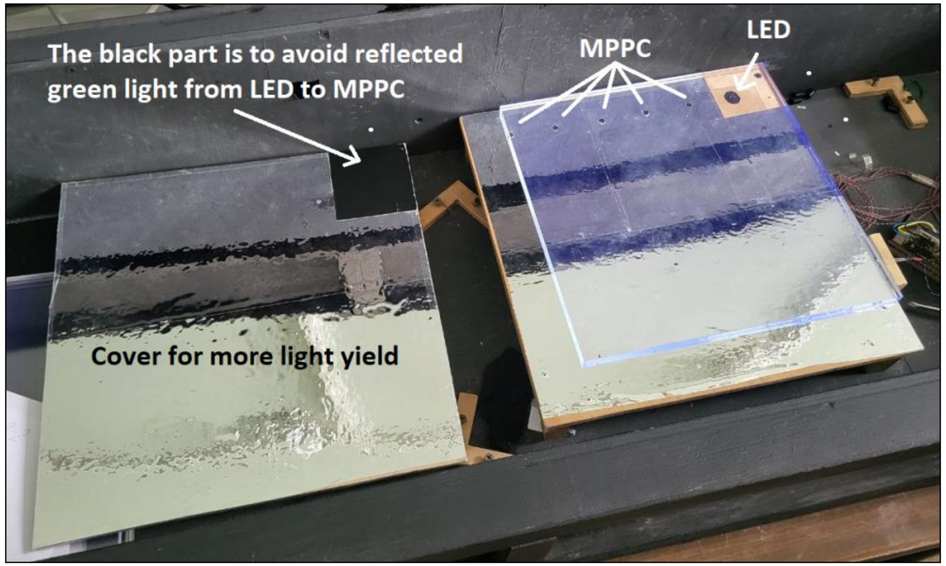


Quantum efficiency for Hamamatsu R14374





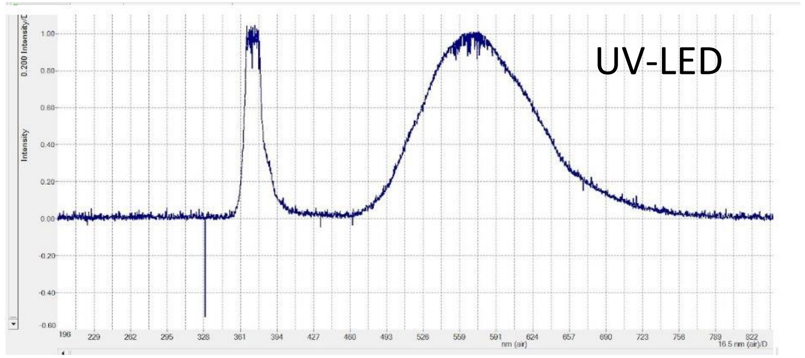
LED is aligned with MPPCs to avoid direct green light hitting MPPCs

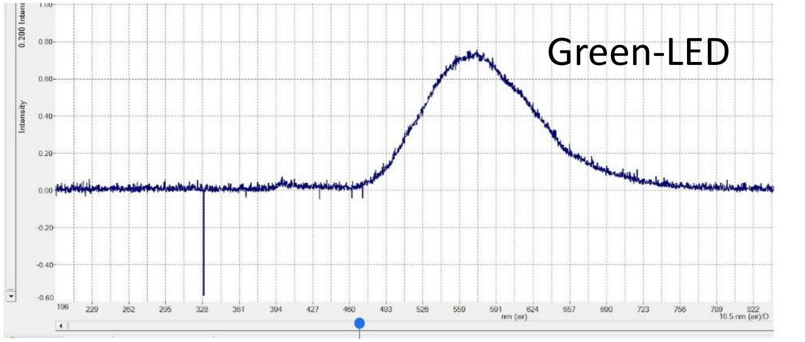


Only re-emitted light from UV component of LED hits MPPCs

Effect signal/no signal		
	UV-LED	Green-LED
With POPOP and PPO	+	-
Without POPOP/PPO	-	-

LEDs spectrum



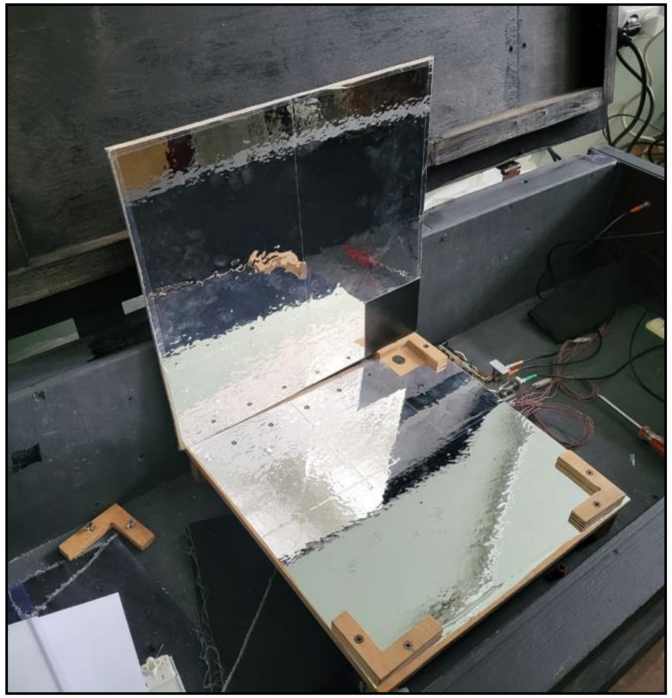


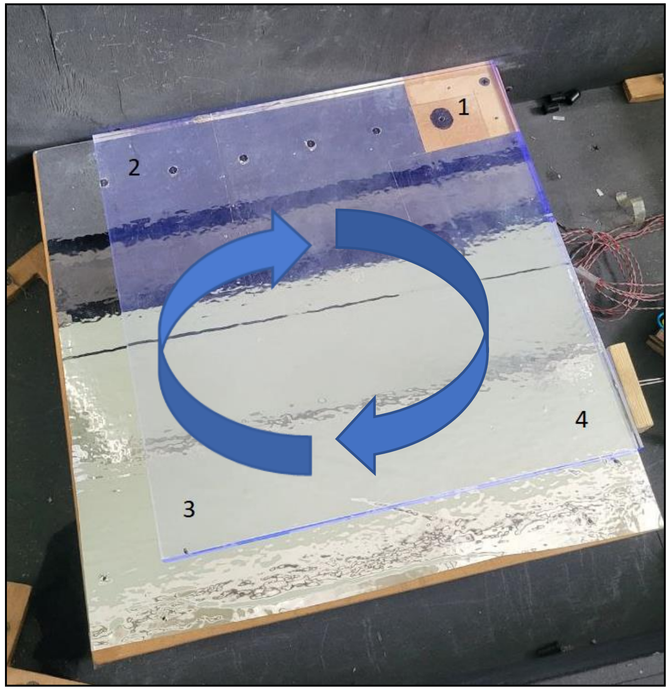
Measurement procedure

Each plate is measured according to following procedure:

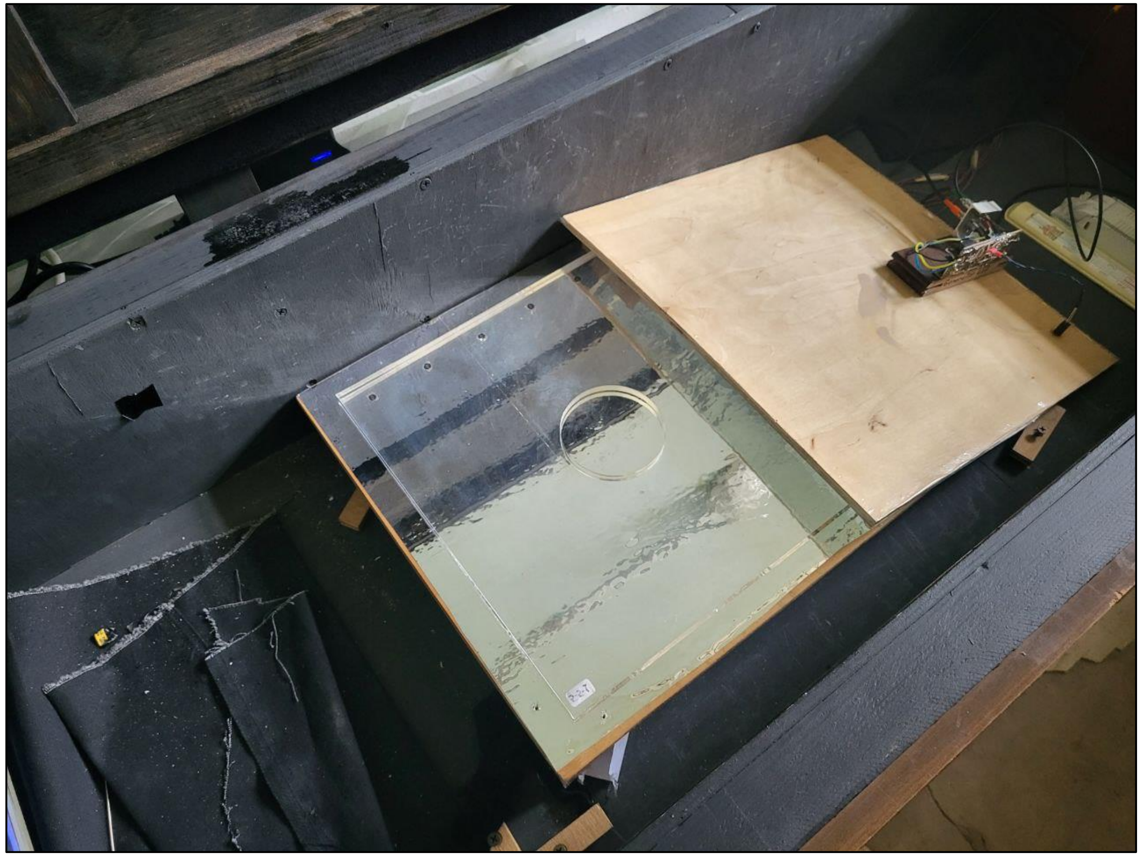
1. Testing plate is placed on the stand and covered with the lid so that black square is above the diode
2. Data is collected in one minute
3. Plate is rotated 90^{o} and the measurements are repeated
4. Each plate is measured in 4 positions, after which results are averaged

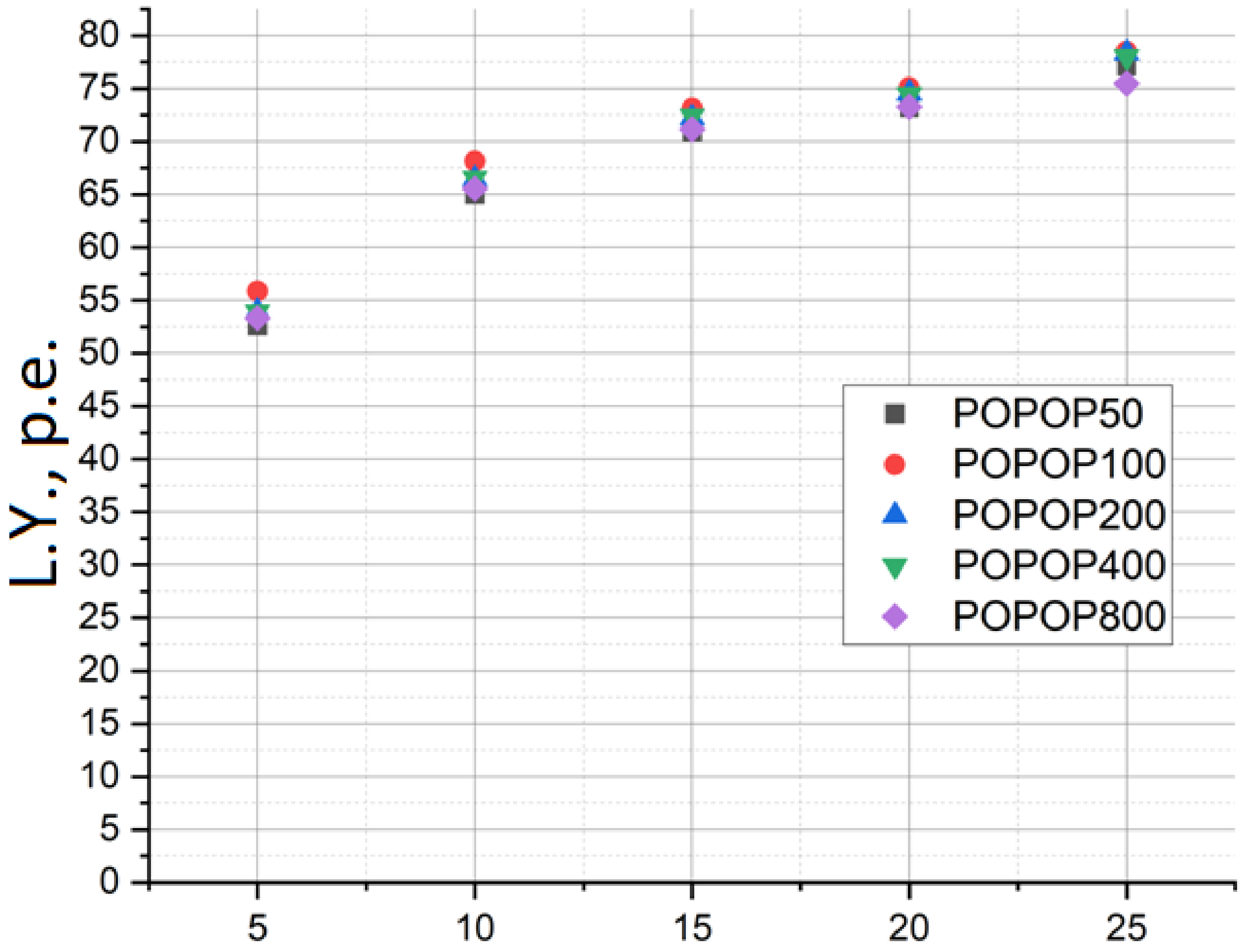
On average, it takes 10-15 minutes to test one plate





Transparency to green light





Concentration of POPOP did not affect the transparency of plates to green light

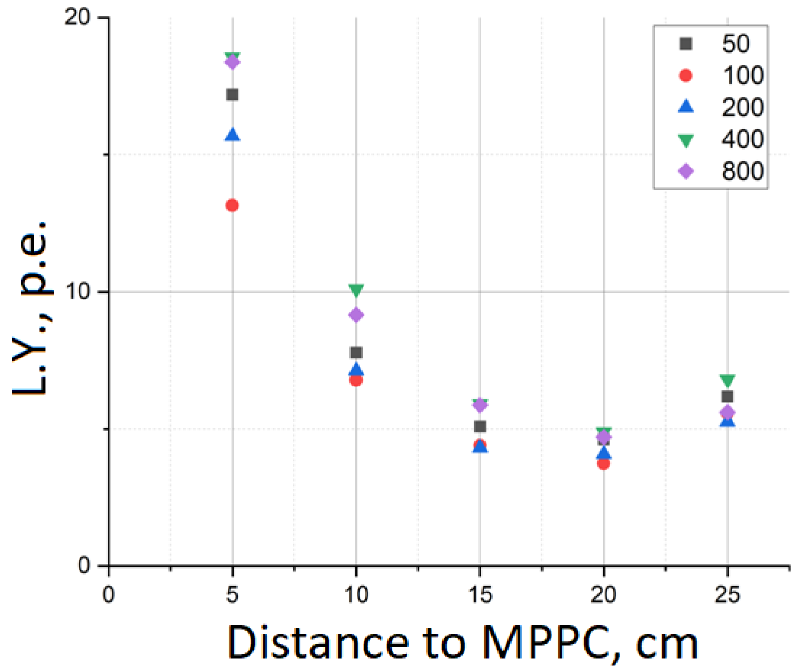
Position of MPPC

Dependence of L.Y. on reflective coating

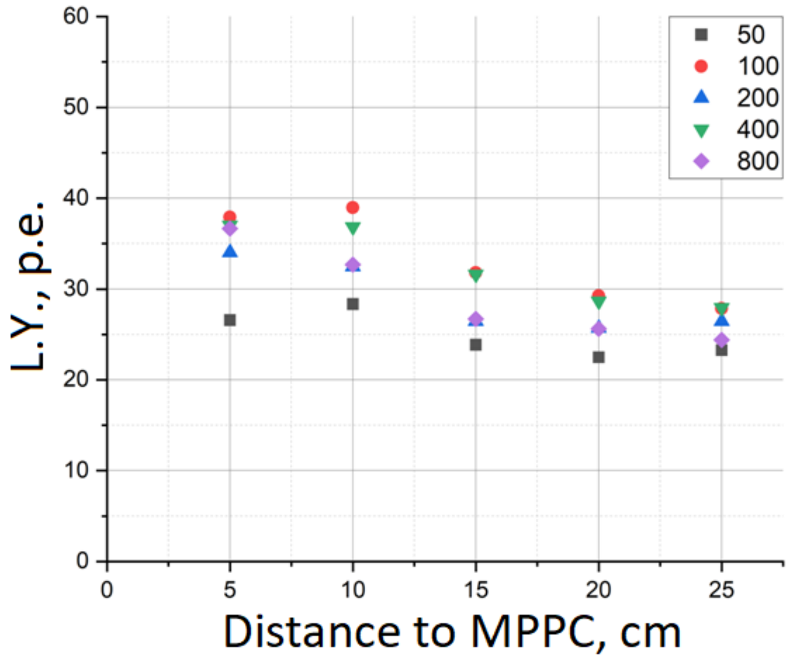
At tests used plates with additives of POPOP with concentration 50, 100, 200, 400, 800 mg/L

- ■ POPOP 50 mg/L
- ● POPOP 100 mg/L
- ▲ POPOP 200 mg/L
- ▼ POPOP 400 mg/L
- ◆ POPOP 800 mg/L

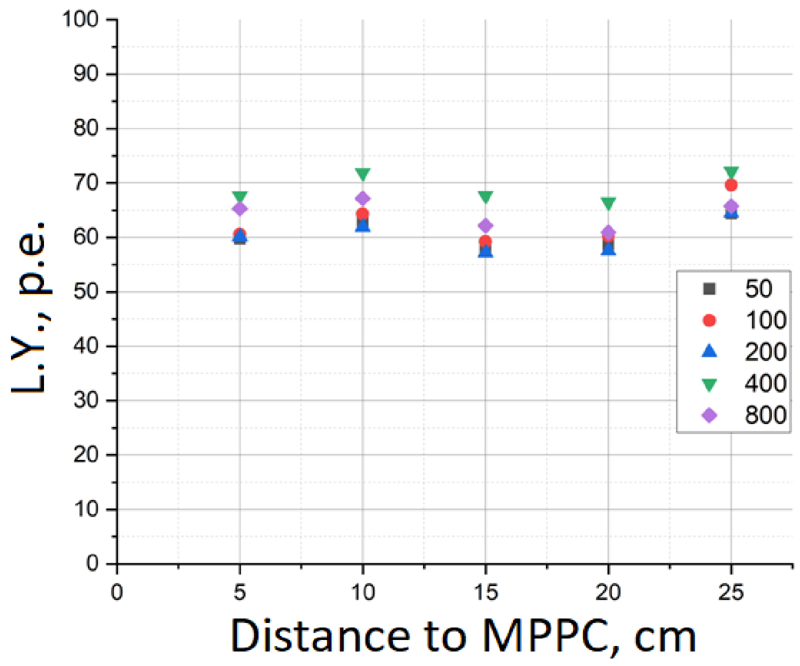
Experimental setup without reflective coating, plates without reflective coating on edges



Experimental setup with reflective coating, plates without reflective coating on edges



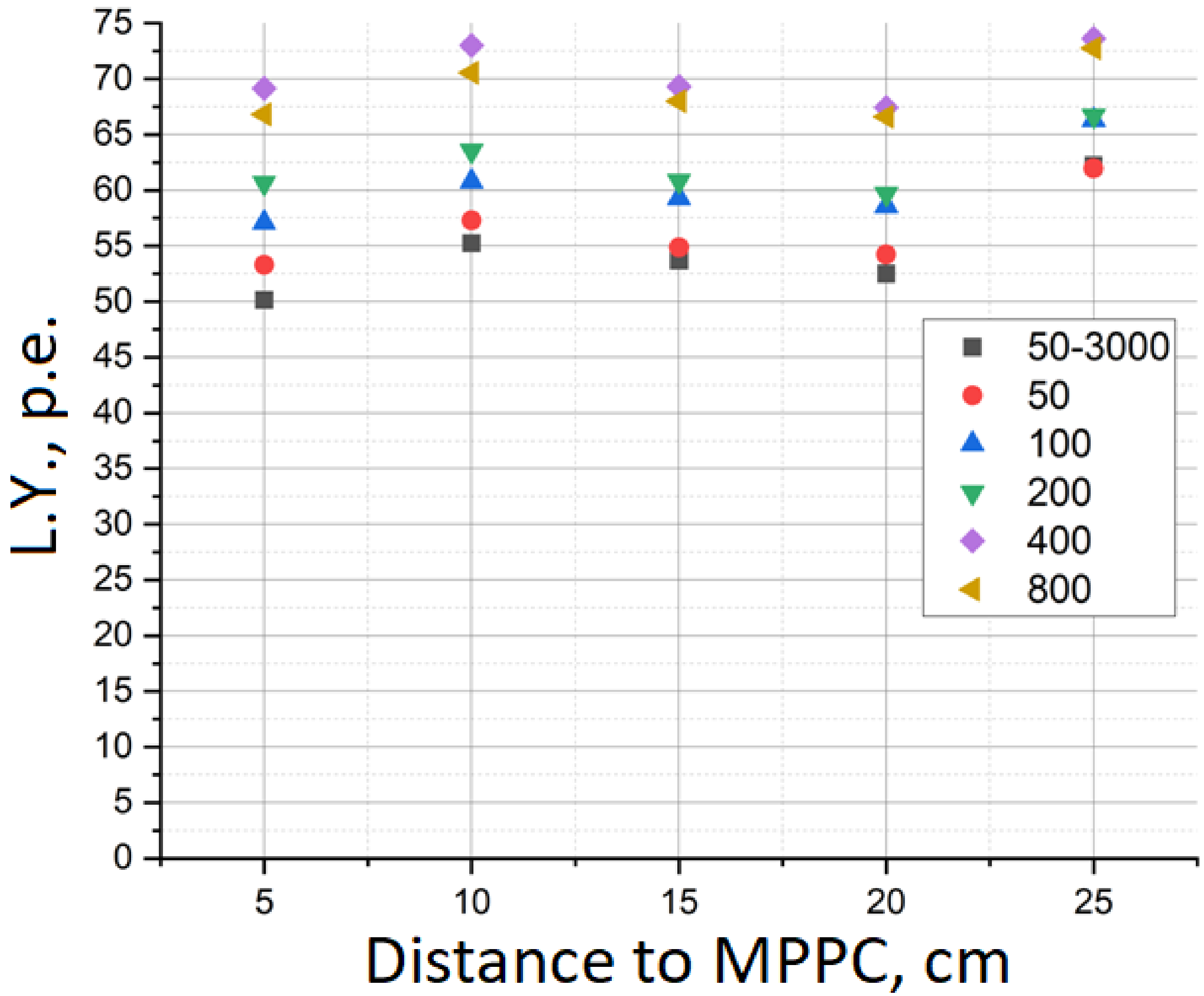
Experimental setup with reflective coating, plates with reflective coating on edges



L.Y. for different type of plates

- ■ POPOP 50 PPO 3000 mg/L
- ● POPOP 50 mg/L
- ▲ POPOP 100 mg/L
- ▼ POPOP 200 mg/L
- ◇ POPOP 400 mg/L
- ◀ POPOP 800 mg/L

A. LED tests are not sensitive to additive PPO
B. L.Y. increases as POPOP concentration increases until it reaches a level of 400 mg/L
C. Short test time allows testing of all plates in mass production



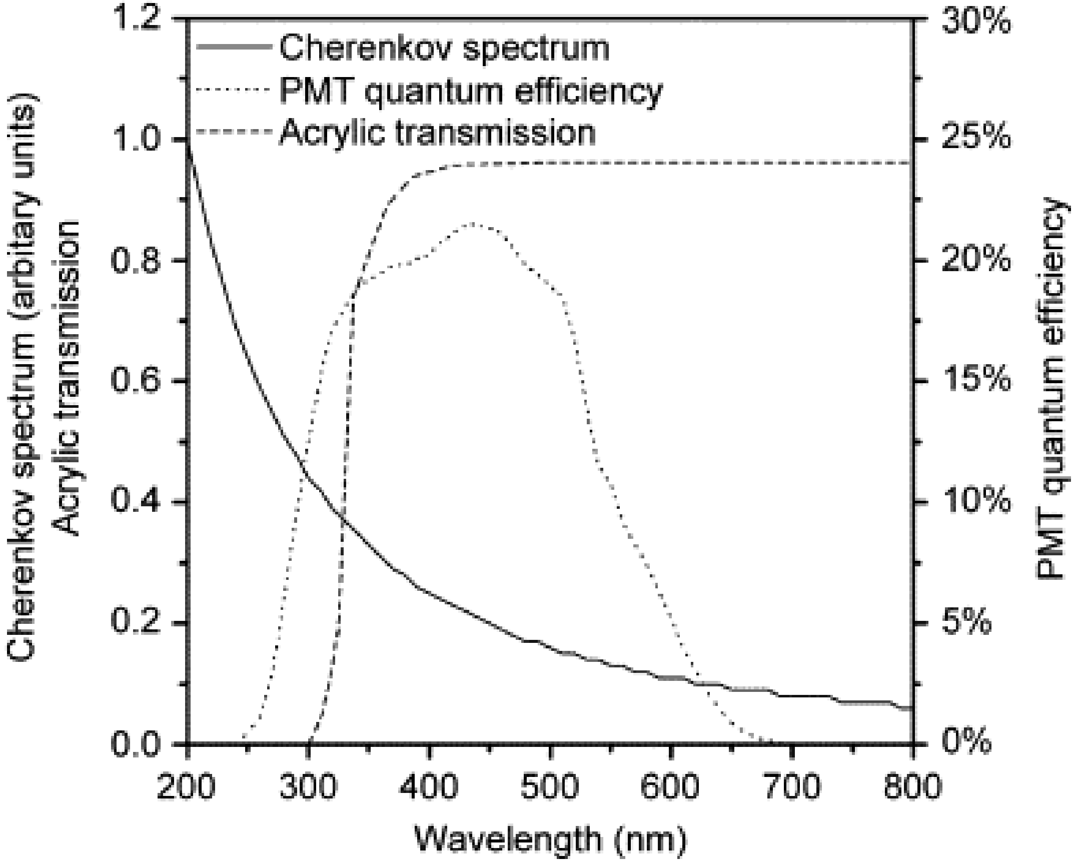
Average for two plates of each type

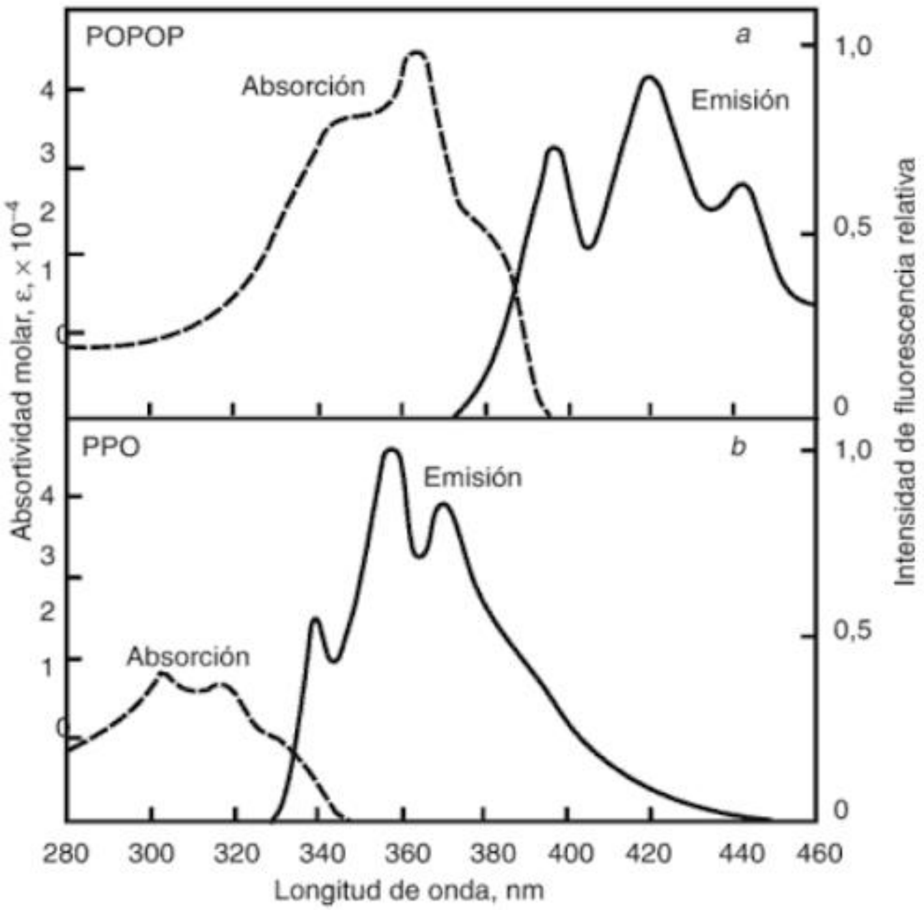
Conclusion

- Has been created an experimental setup for testing wavelength-shifting plates for Hyper-Kamiokande Outer Detector, which allows determining the light output for 5 distances between the MPPC and the LED in one measurement.
- The developed method demonstrates good sensitivity to concentration of POPOP additive. It has been shown that plates with a POPOP concentration of 400 mg/L have a 10-15% higher light yield than plates with a POPOP concentration of 50 mg/L.
- As a result of the study, no differences in transparency for green light were found for plates with different POPOP concentrations (50, 100, 200, 400, 800 mg/L).
- An algorithm for quality control has been developed and tested. About 6 WLS-plates per hour will be testing, which corresponds to the expected speed of their manufacture.

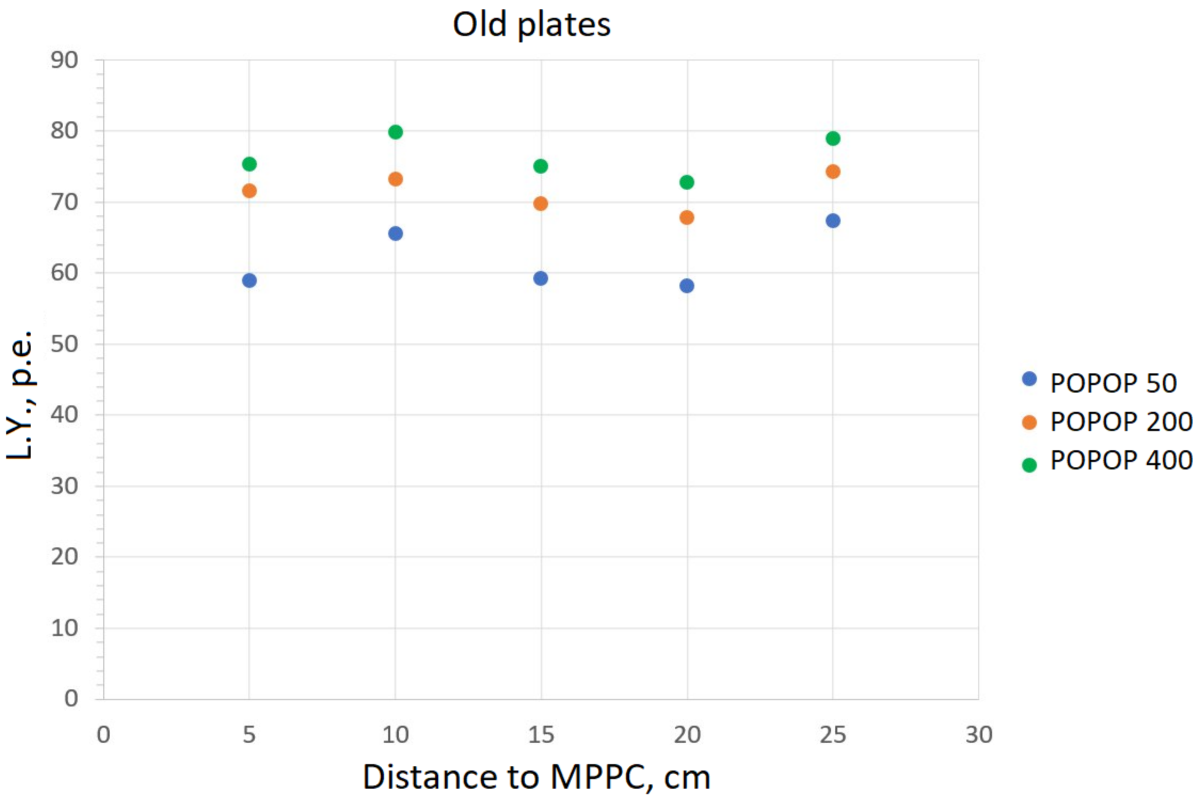
Thank you for your attention!

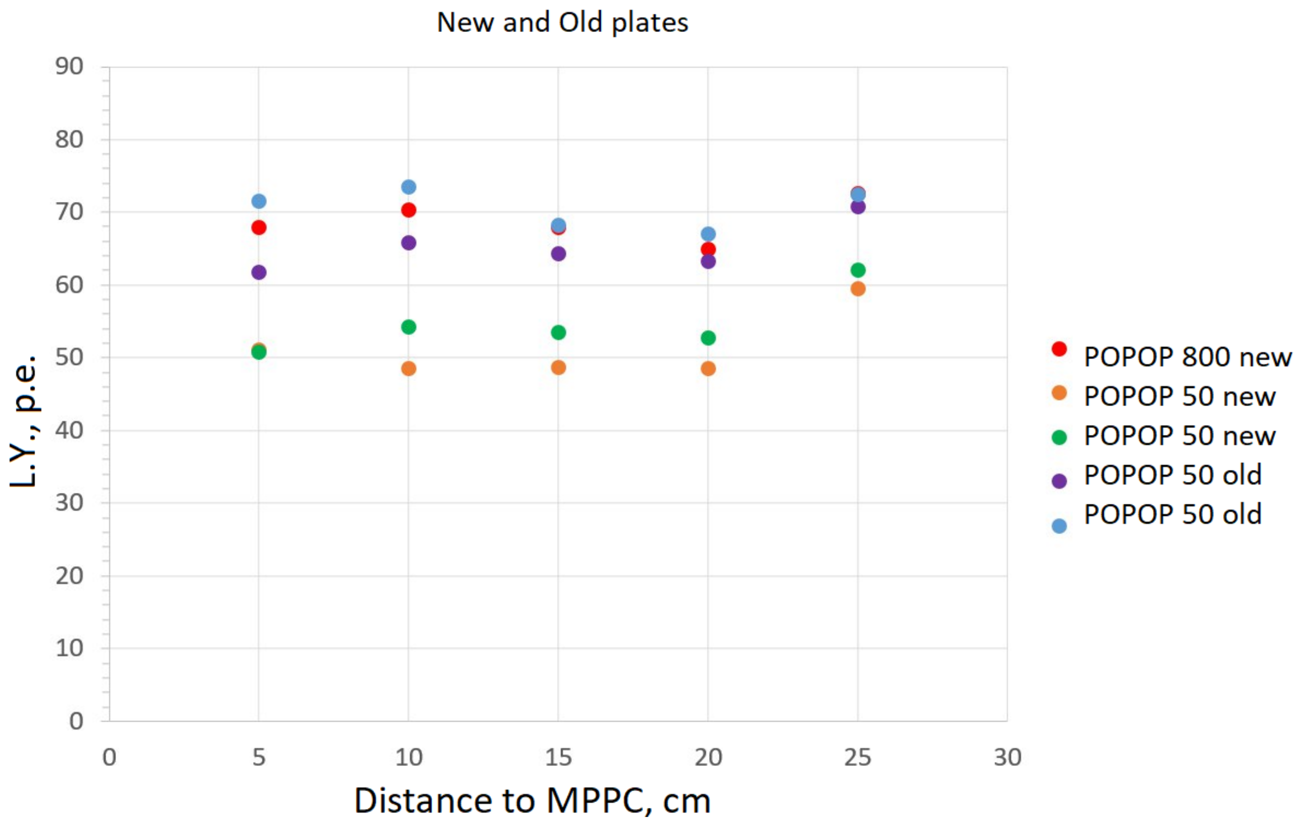
Backup slides


Cherenkov spectrum
PMT quantum efficiency
Acrylic transmission
Cherenkov spectrum (arbitary units)
Acrylic transmission
PMT quantum efficiency
Wavelength (nm)
1.2
1.0
0.8
0.6
0.4
0.2
0.0
30%
25%
20%
15%
10%
5%
0%
200
300
400
500
600
700
800


POPOP
a
Absorción
Emisión
PPO
b
Absorción
Emisión
Absortividad molar, ε, × 10⁻⁴
Intensidad de fluorescencia relativa
Longitud de onda, nm
280
300
320
340
360
380
400
420
440
460
1,0
0,5
0

New plates September 2024





- For new and old plates, the trend of increasing L.Y. with increasing POPOP concentration remains
- But all plates produced in September 2024 have lower L.Y. compared to the previous delivered party