Light yield study of the scintillating cubes of the SFGD detector

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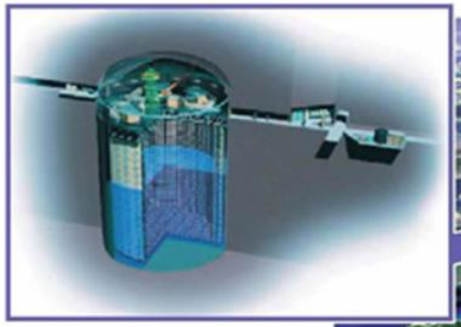
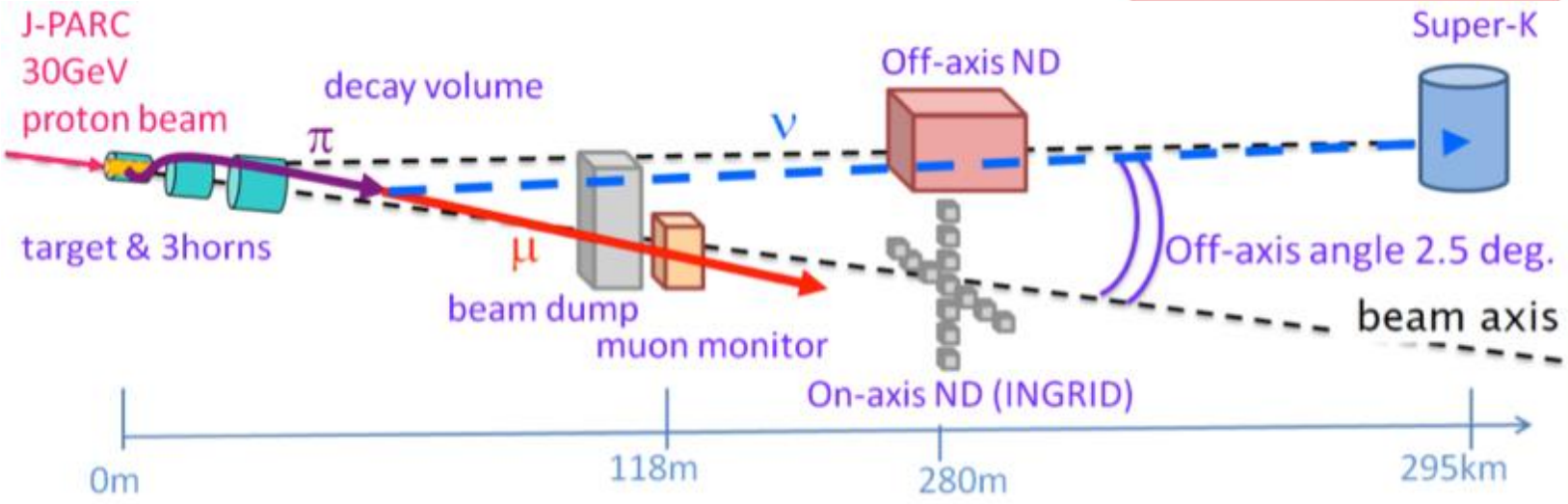
The T2K experiment



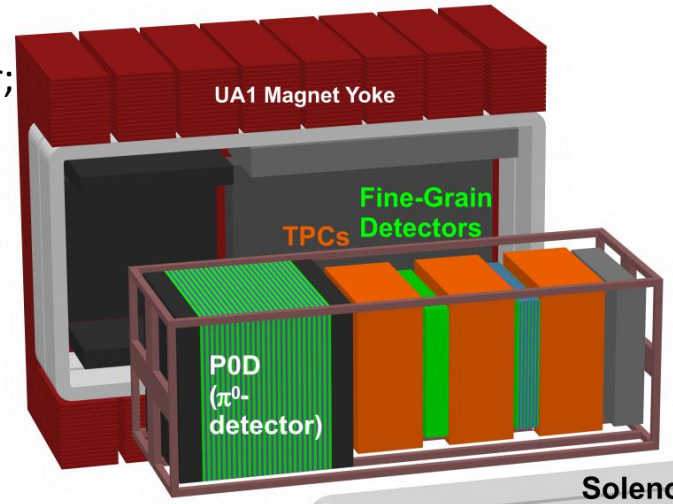
Super-Kamiokande
(ICRR, Univ. Tokyo)

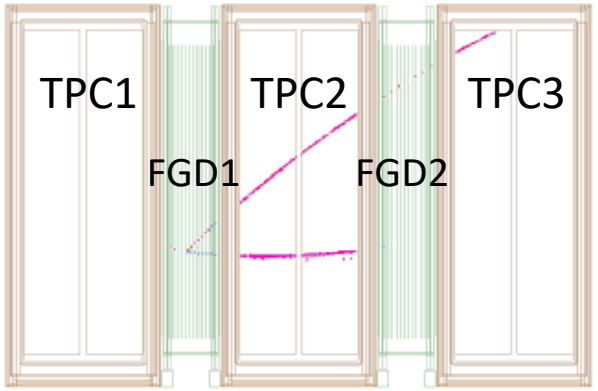
J-PARC Main Ring
(KEK-JAEA, Tokai)



Near detector ND280 (off-axis)

Near detector **ND280**:
- Tracker = **3 TPC** + **2 FGD** in magnetic field **0.2T**
(FGD1: plastic scintillator; FGD2: plastic scintillator +water)
- **P0D**; **ECaL**; **SMRD**





ND280 purposes:
- measurements of the neutrino beam parameters before oscillations;
- ambiguity limitation of the neutrino beam and crossections of the neutrino interactions

TPC -Time projection chamber

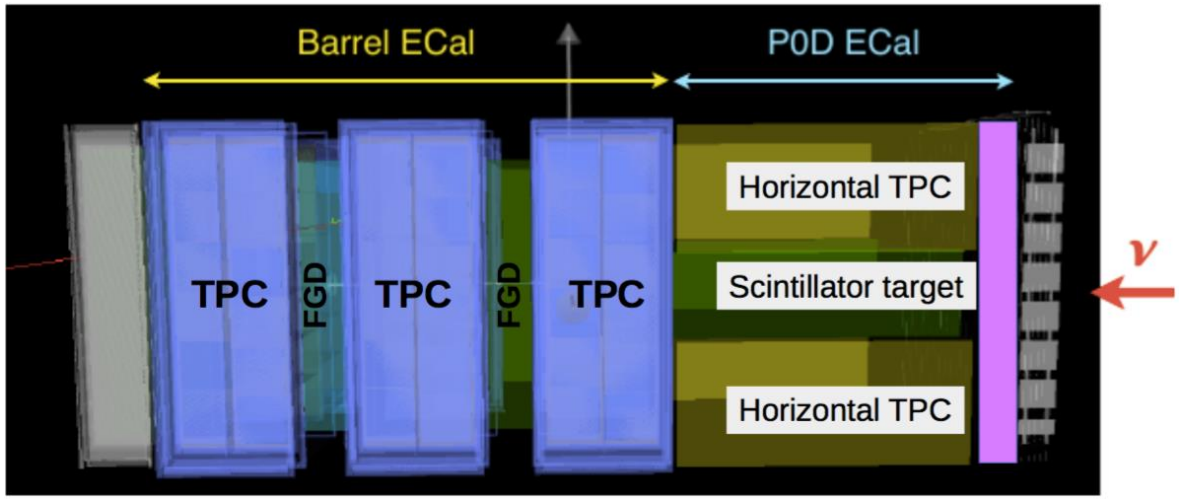
FGD - fine-grained detector

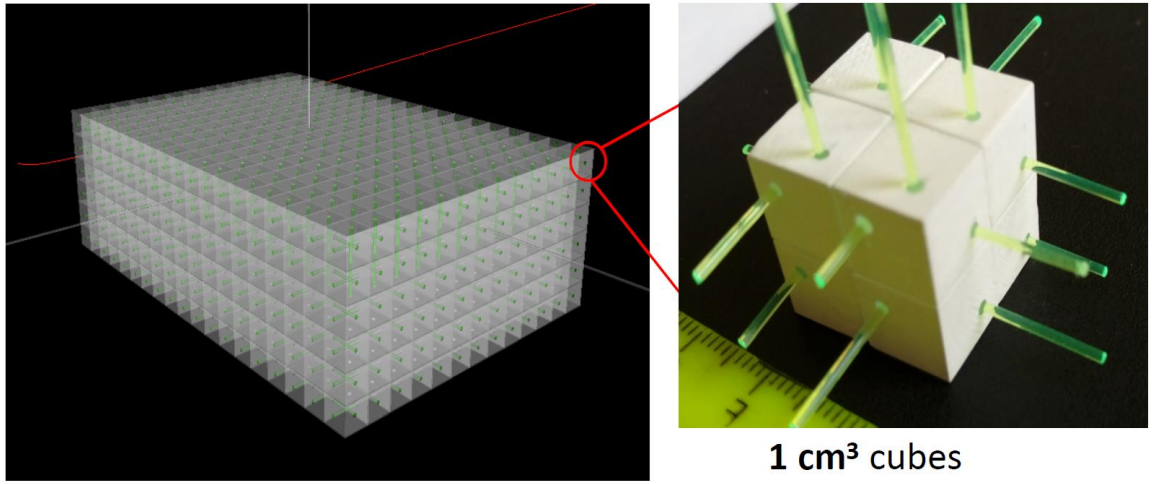
P0D - π0 detector

ECaL - e/m calorimeter

SMRD - Side Muon Range Detector

ND280 upgrade





1 cm³ cubes

Manufacturer: UNIPLAST, Vladimir, Russia
Composition: polystyrene base, 1.5% PTP, 0.01% POPOP

π0-detector (P0D) will be replaced with:

- 3D active target made of scintillating cubes (**Super-FGD**);

- Two horizontal TPC (**HTPC**)

Goals:

- Decrease systematic errors to 3-4%;

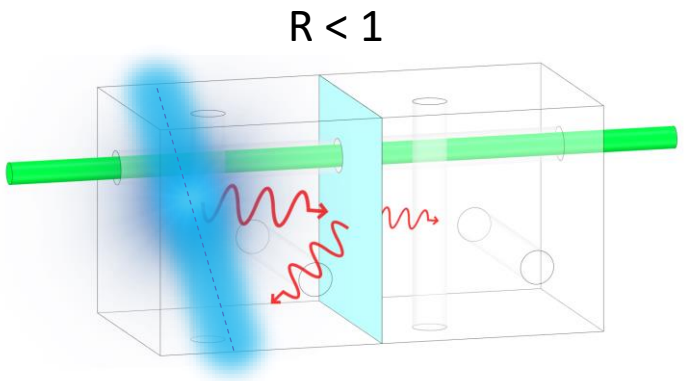
- 4π-acceptance for muons;

- Decrease proton registration threshold(>300 MeV/c);

- Neutron detection

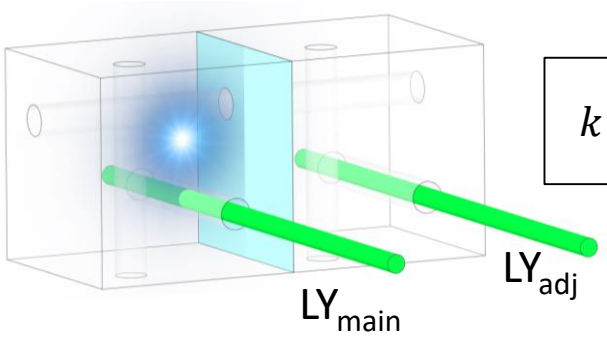
Motivation

- Since the white chemical reflector, like any reflector of the diffuse type, does not fully isolate the scintillation light, the leakage of light from one cube to the neighboring ones is inevitable. Measuring how much light is shared among neighboring cubes is crucial. A large amount of cube-to-cube optical crosstalk significantly complicates the 3D reconstruction because of the increasing ambiguities in the 2D to 3D matching. If the spread of light among cubes is too large, the fine granularity of the detector can be compromised. On top of that, optical crosstalk measurements are key to describe and simulate the detector response.

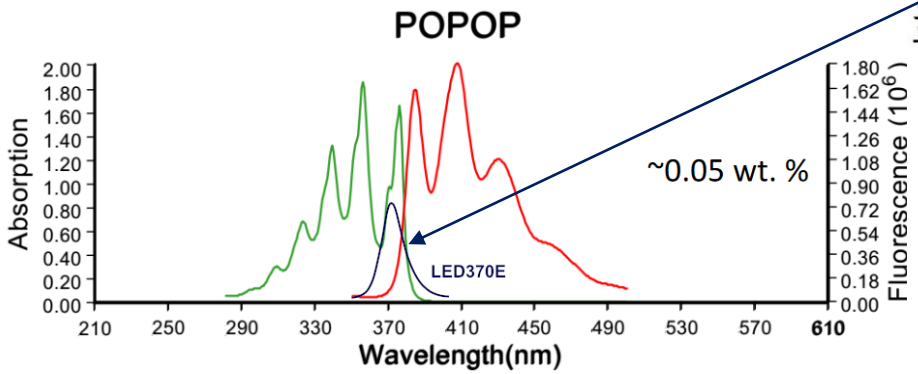


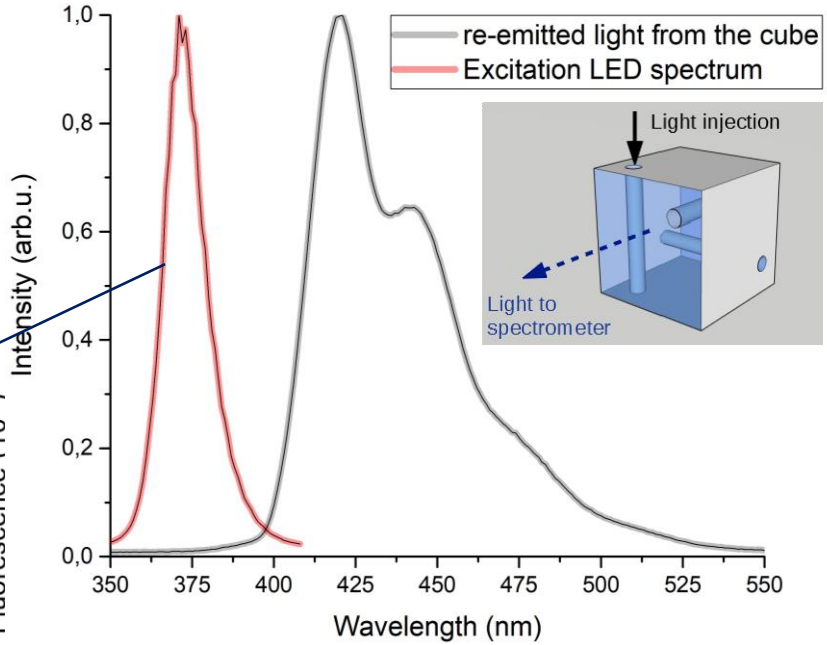
- As the detector elements will be transported from the assembly site to the installation site, it is necessary to study the effect of temperature influence on the reflective coating and the light yield of the cubes.

Experimental technique



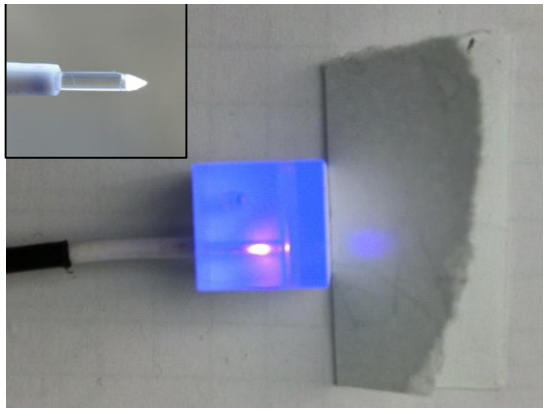
$$k = \frac{LY_{adj}}{LY_{main}}$$



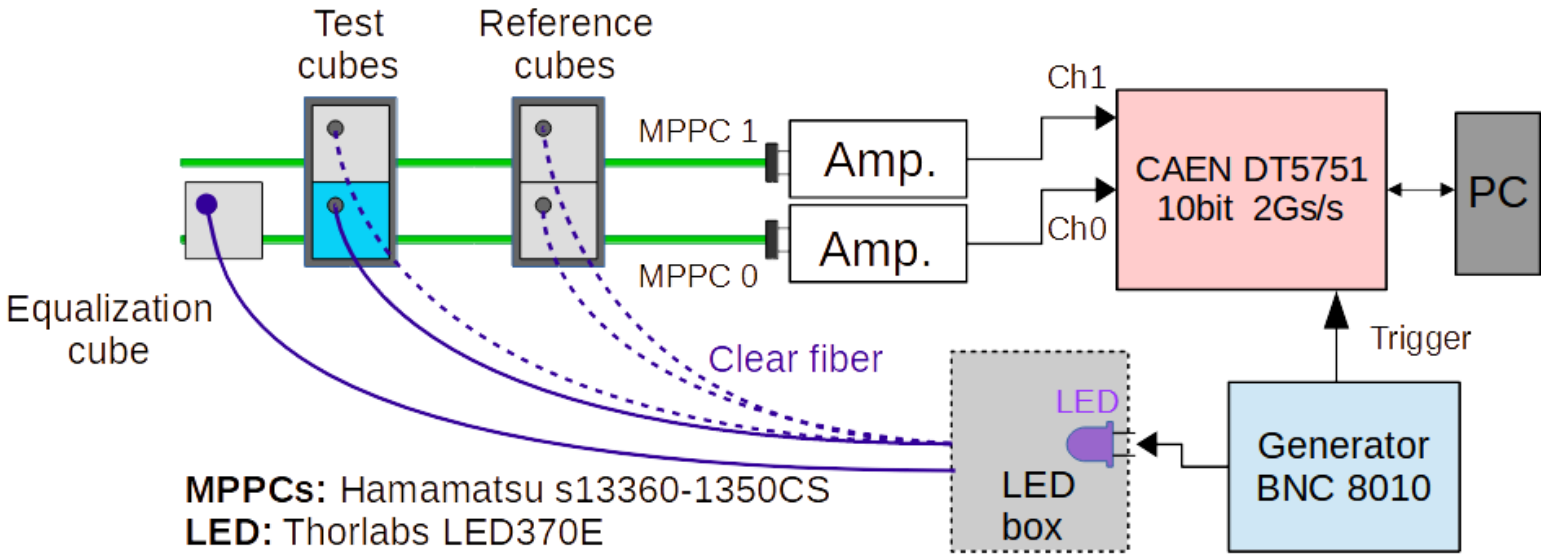


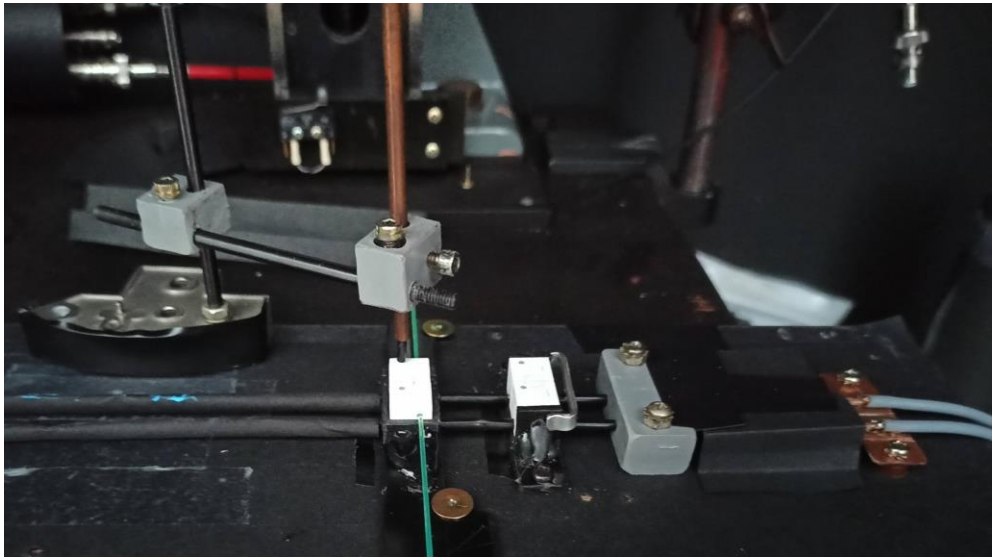
Optical Specifications

	Typical
Center Wavelength	375 nm (±10 nm)
FWHM	10 nm
Half Viewing Angle	19°
Forward Optical Power	2.0 mW @ 20 mA
Total Optical Power	2.5 mW @ 20mA

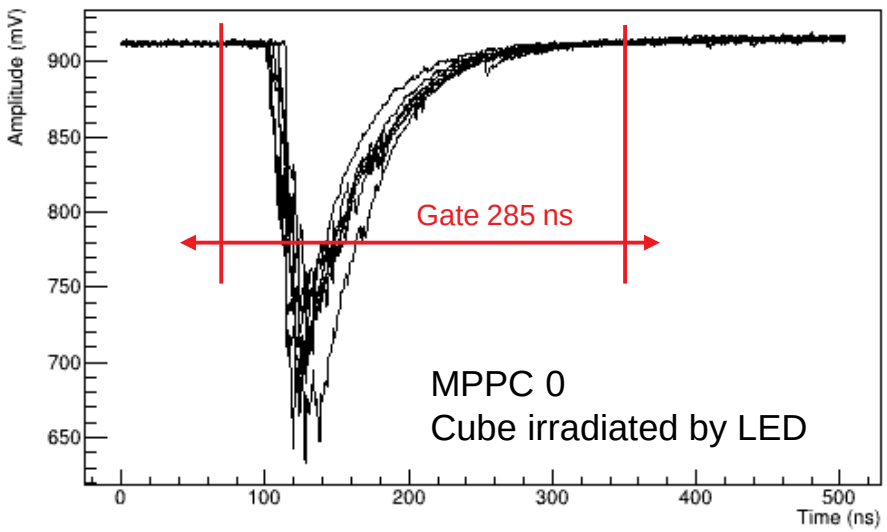


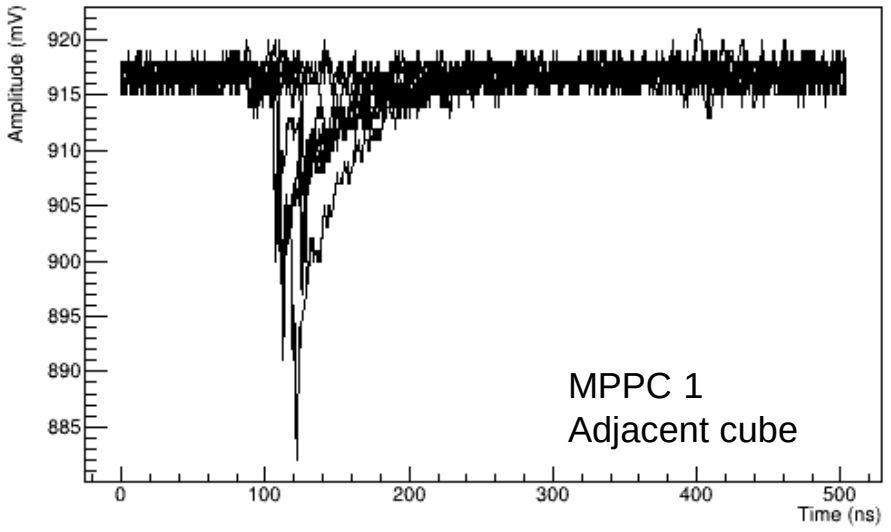
Experimental setup



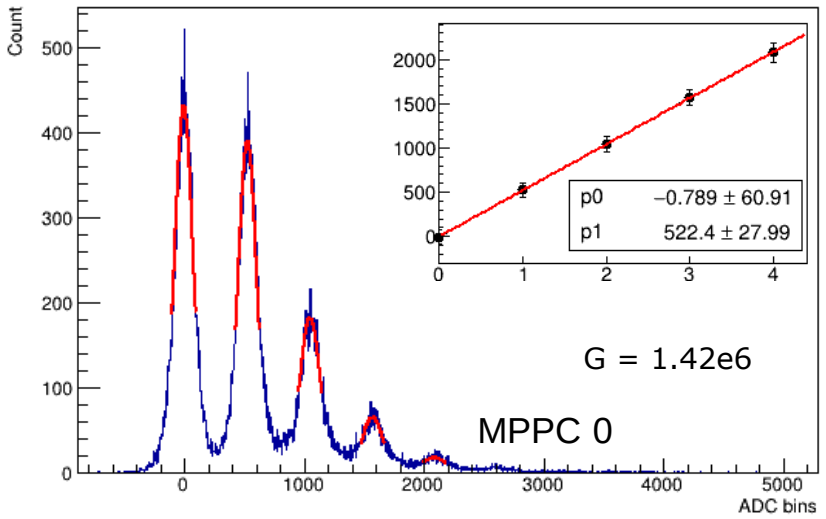


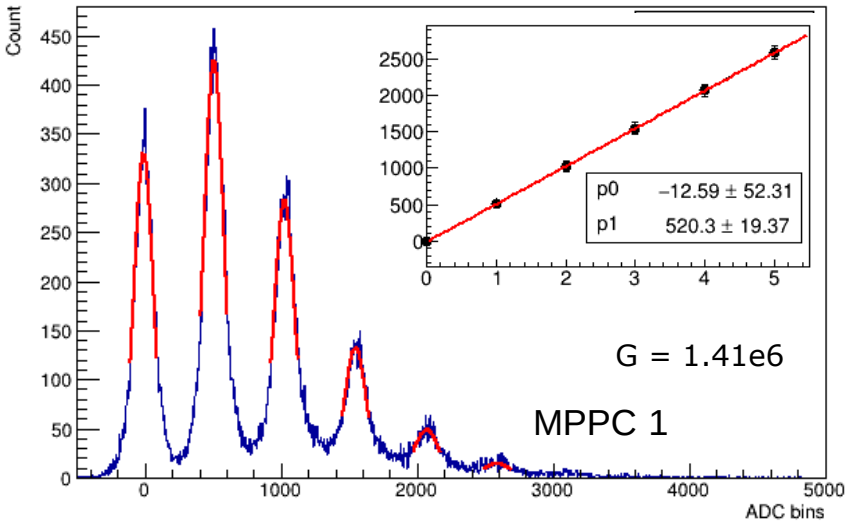
Typical waveforms





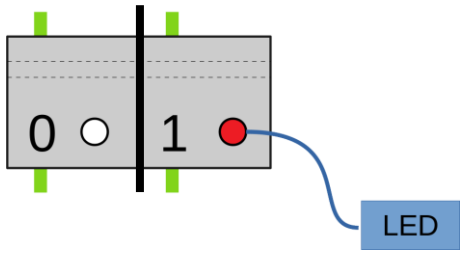
Typical MPPC calibration spectra



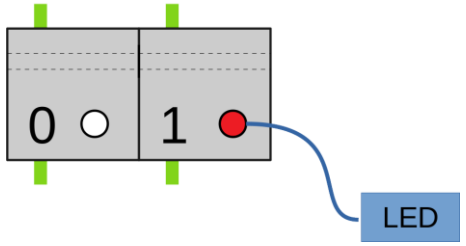


List of measurements performed

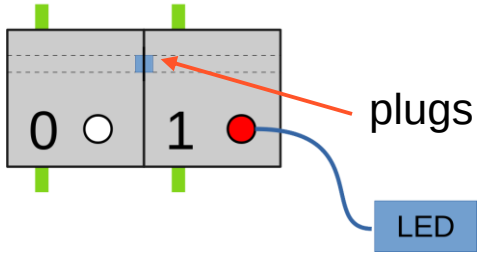
A separator made of black paper is placed between the cubes



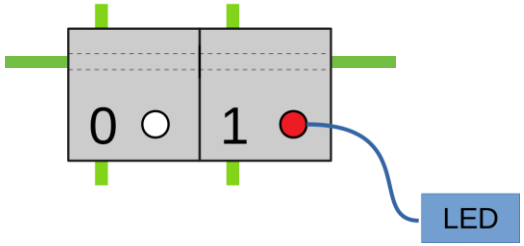
The common holes of the cubes are open



The common holes of the cubes are closed with plugs

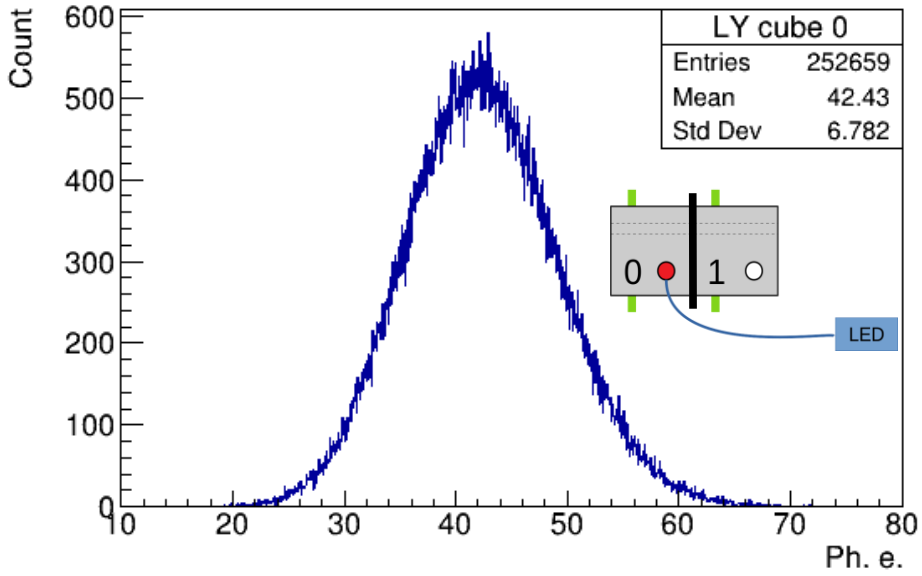


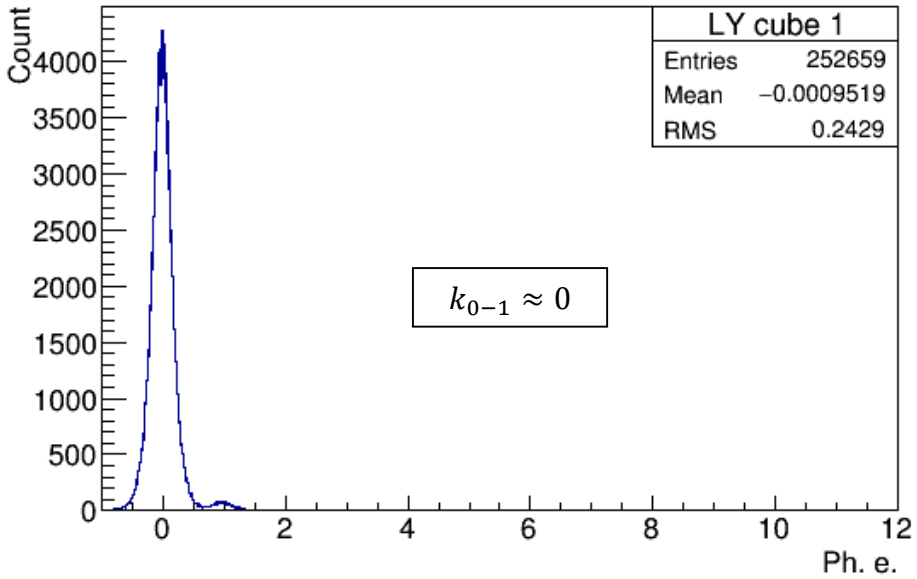
Fiber is inserted into the common holes of the cubes

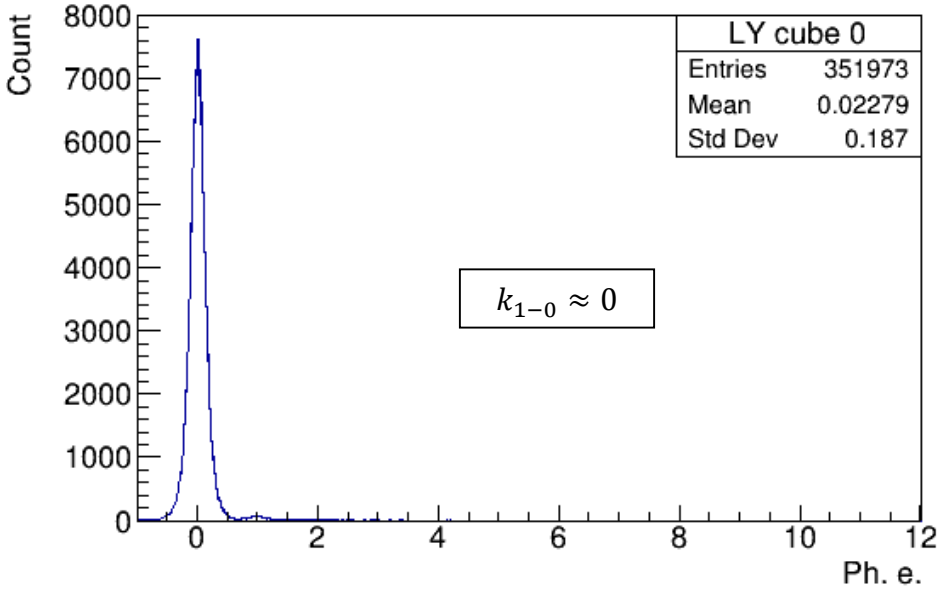


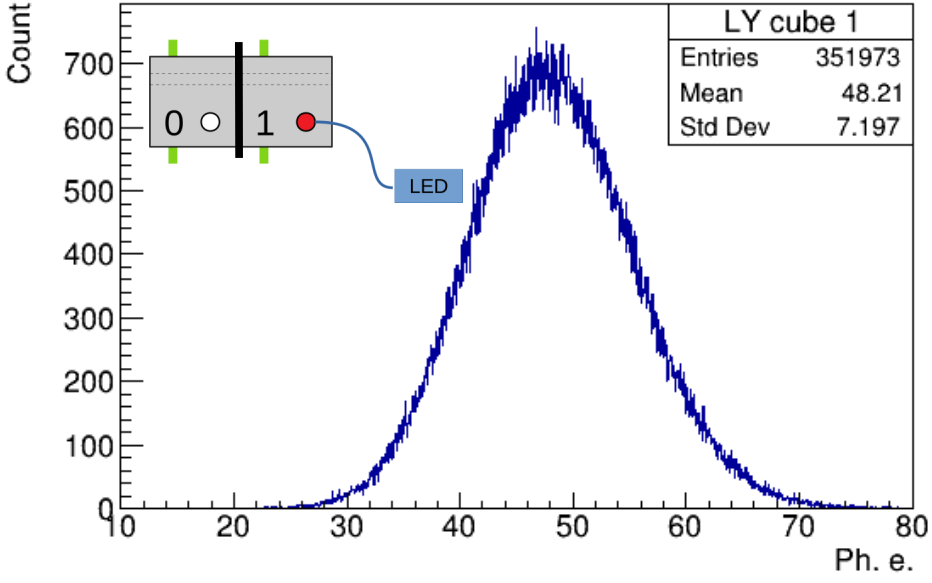
Each type of measurement was also carried out with the injection of light into channel 0.

Optically isolated cubes (black paper separator)

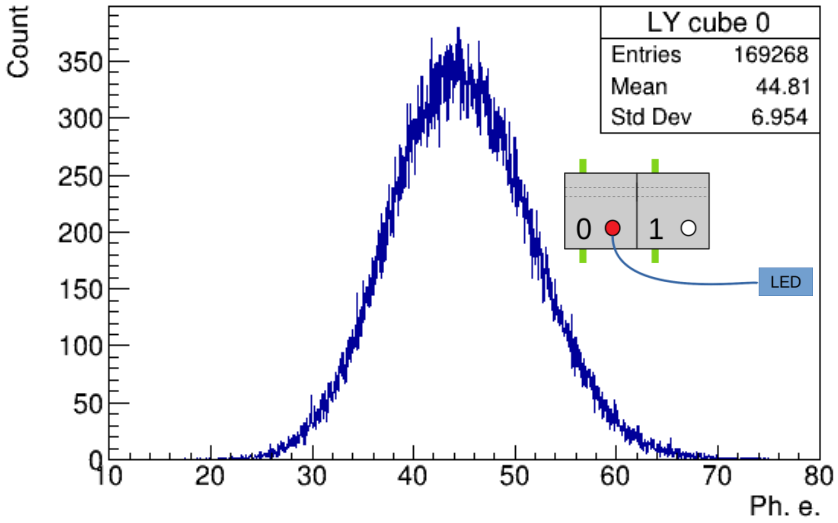


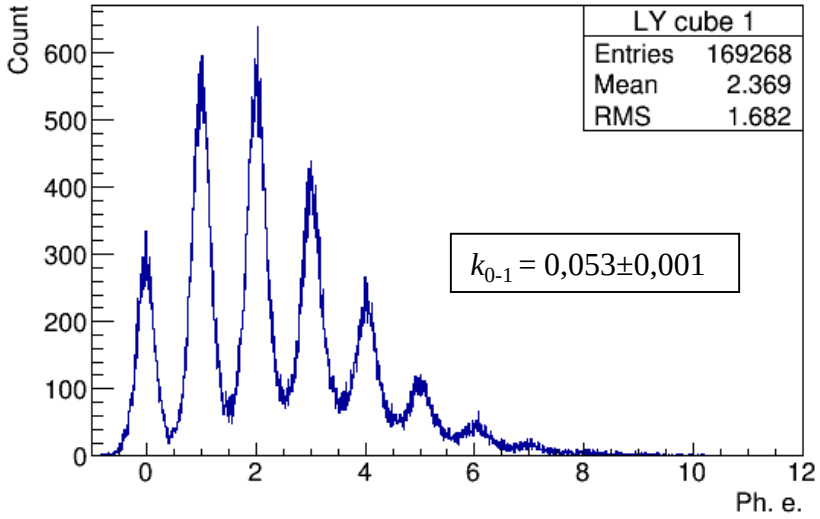


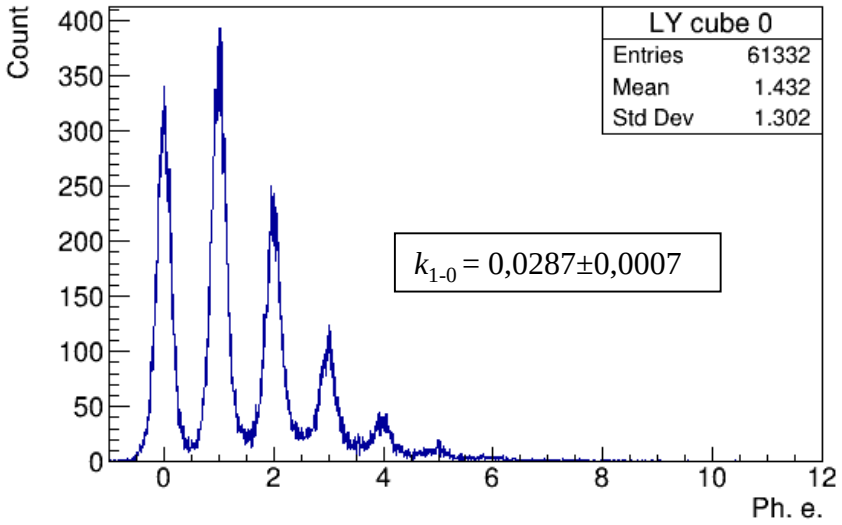


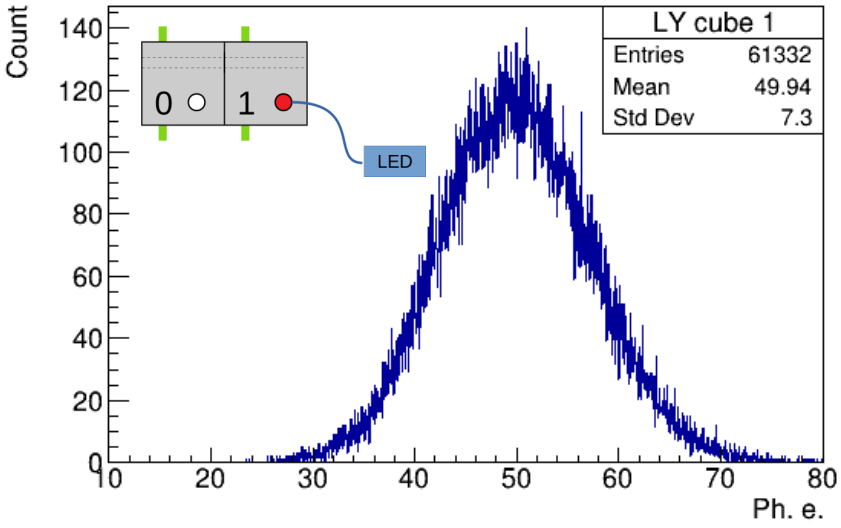


No common fiber, hole is open

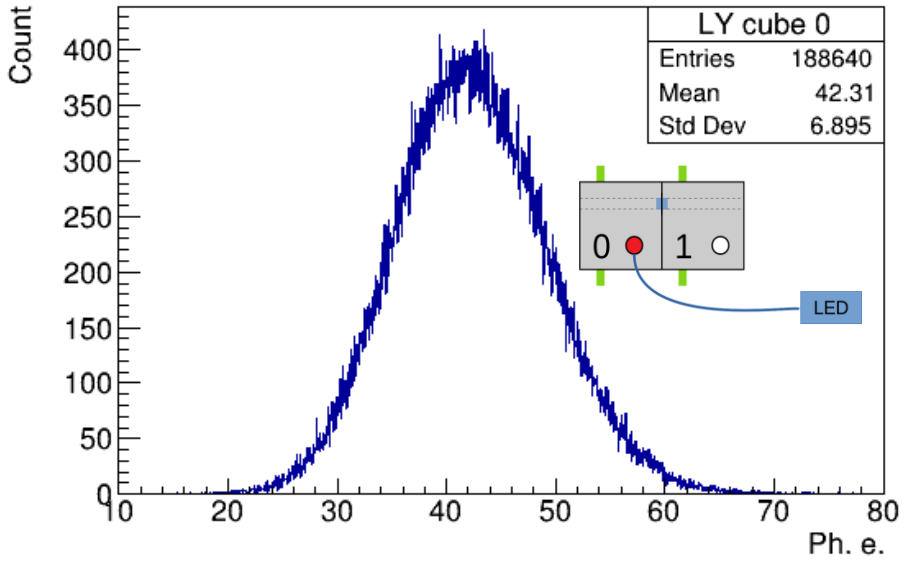


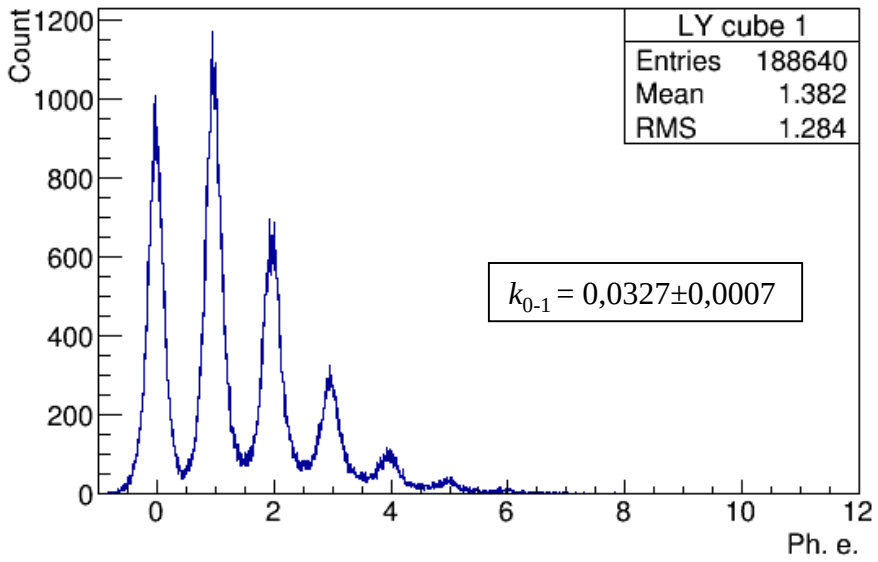


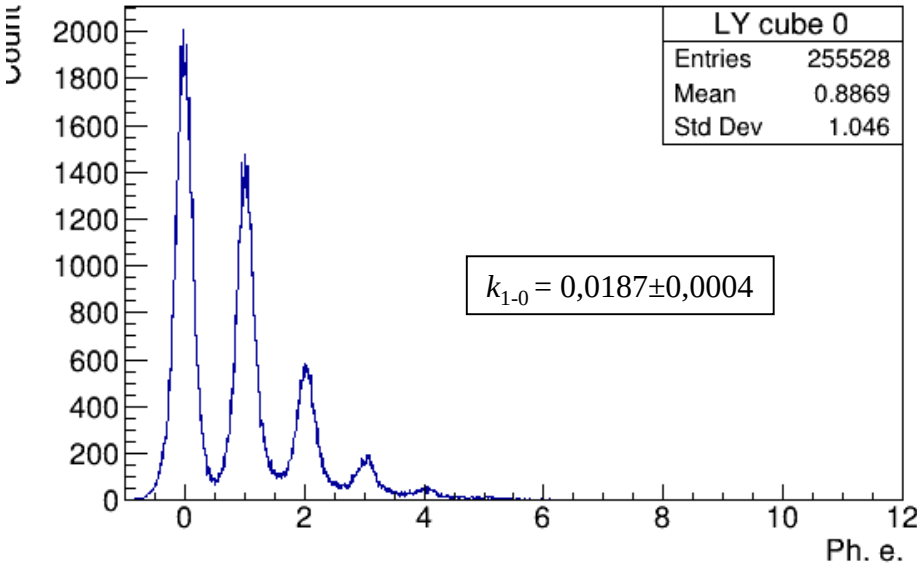


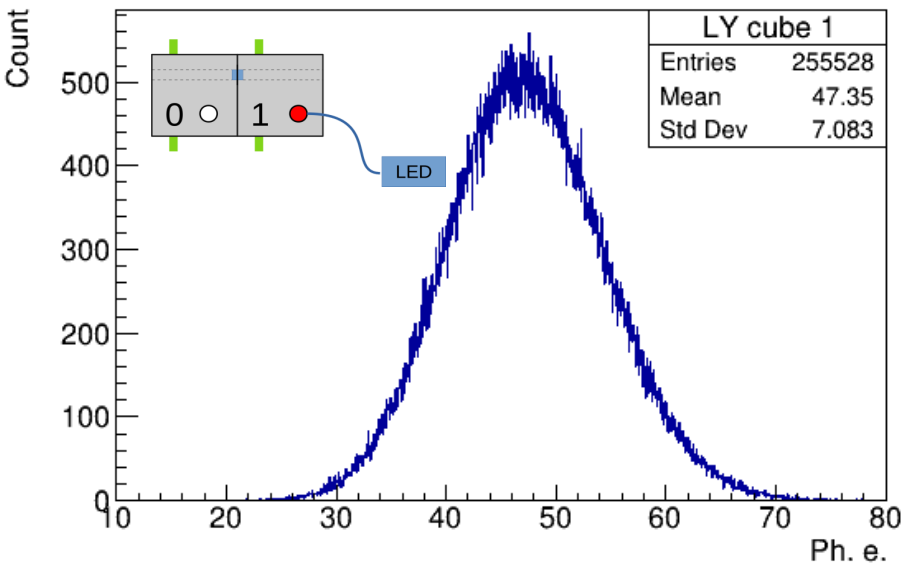


Common fiber hole is closed with plugs

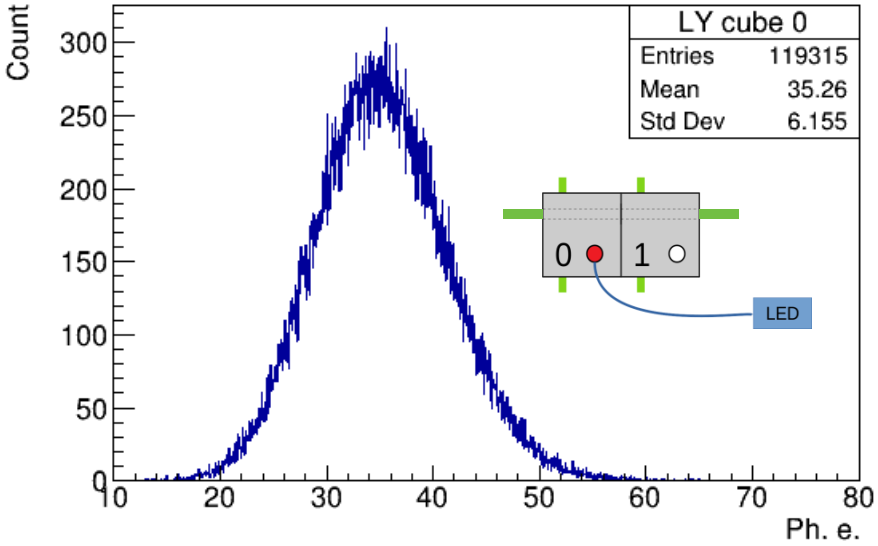


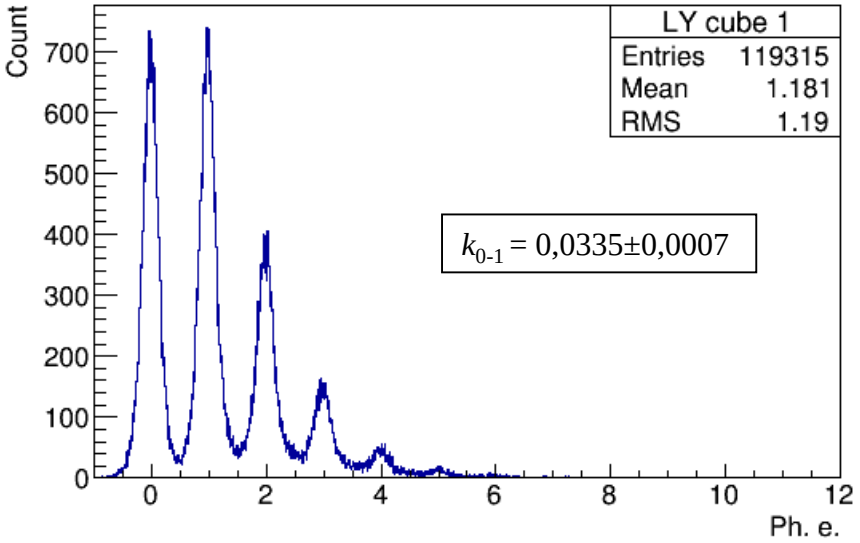


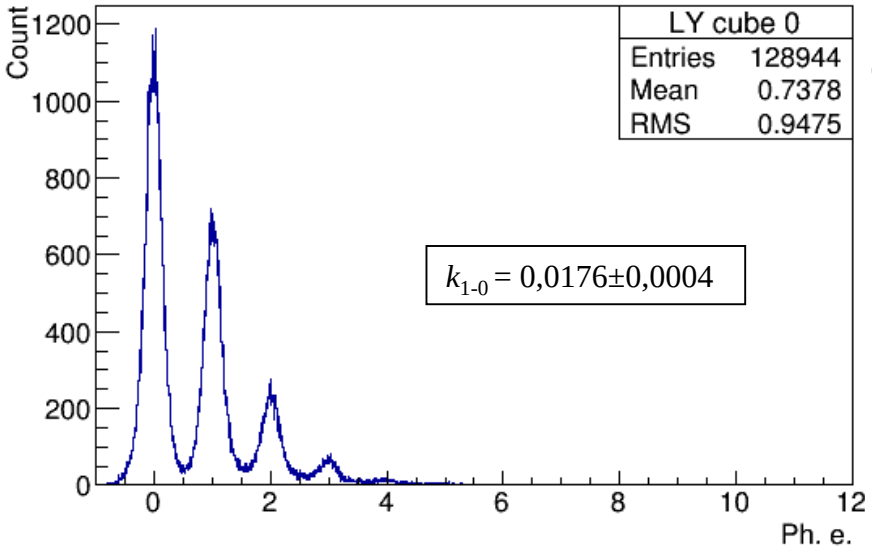


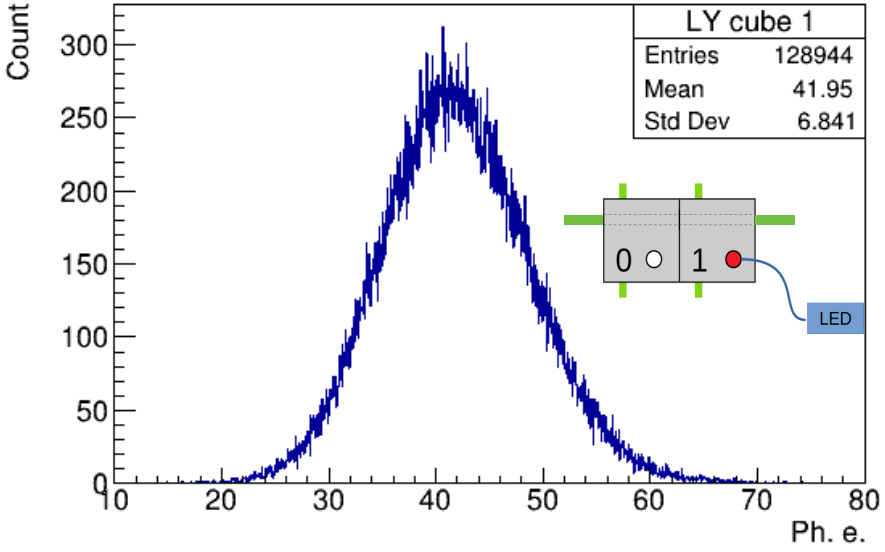


Common WLS fiber inserted



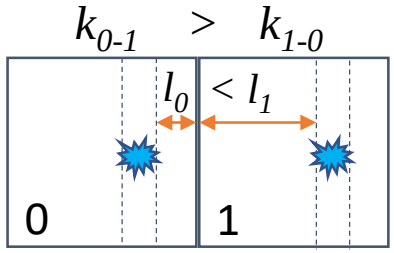






Results and discussion

LED light injection into channel:	$K_{0\text{-}1}$	$K_{1\text{-}0}$	<k>
Optically isolated cubes (black paper separator)	≈ 0	≈ 0	0
No coommon fiber, hole is open	0,053±0,001	0,0287±0,0006	0,041
Common fiber hole is closed with plug	0,0327±0,0007	0,0187±0,0004	0,026
Common WLS fiber inserted	0,0335±0,0007	0,0176±0,004	0,026



$$L = \frac{LY_{adj}}{LY_{main} + 6LY_{adj}} \cdot 100\% = \frac{< k > LY_{main}}{LY_{main} + 6 < k > LY_{main}} \cdot 100\% = \frac{< k >}{1 + 6 < k >} \cdot 100\%$$

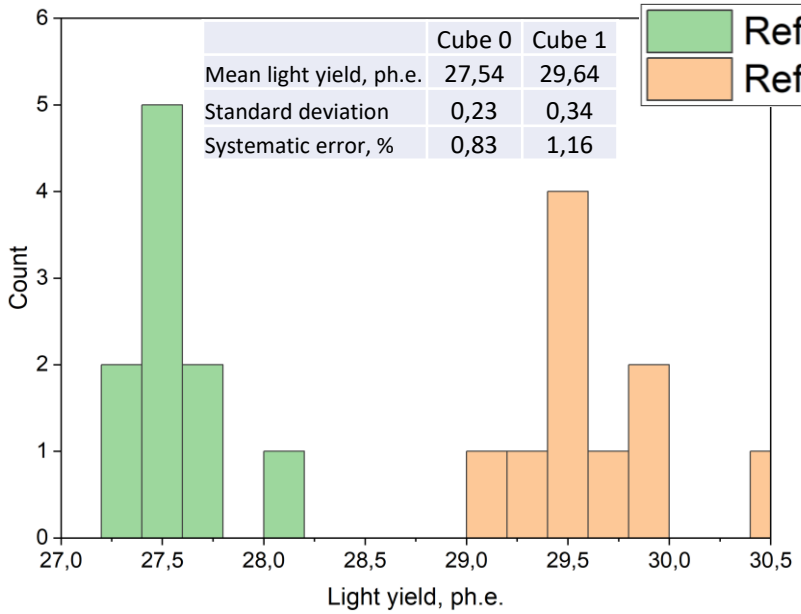
$$L(< k >= 0{,}026) = 2{,}25\%$$

Study of the temperature treatment influence on the light yield and crosstalk of the cubes

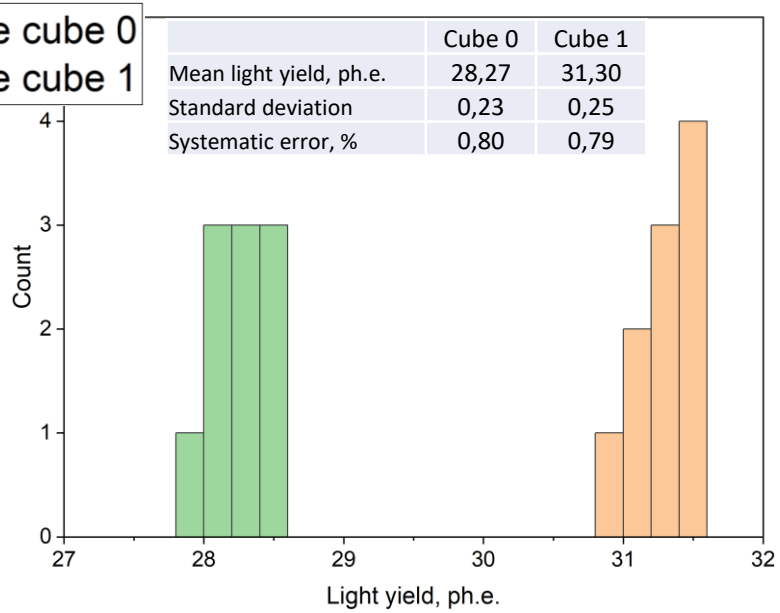
- We used an industrial thermostabilized chamber to heat the cubes.
- We have selected 5 pairs of cubes, measured the light yield and crosstalk before heating and then put it to the thermostabilized chamber and kept under **60 °C for 24 hours**, and then allowed them cool to room temperature for 20 hours before measuring.

- Also we repeated all the measurements with **another 5 pairs** of cubes, that were heated to **60 °C for 72 hours**.
- Each measurement of the test cubes was accompanied by measurement of the reference cubes, thus each reference cube was measured 10 times in the first batch and 10 times in the second batch.

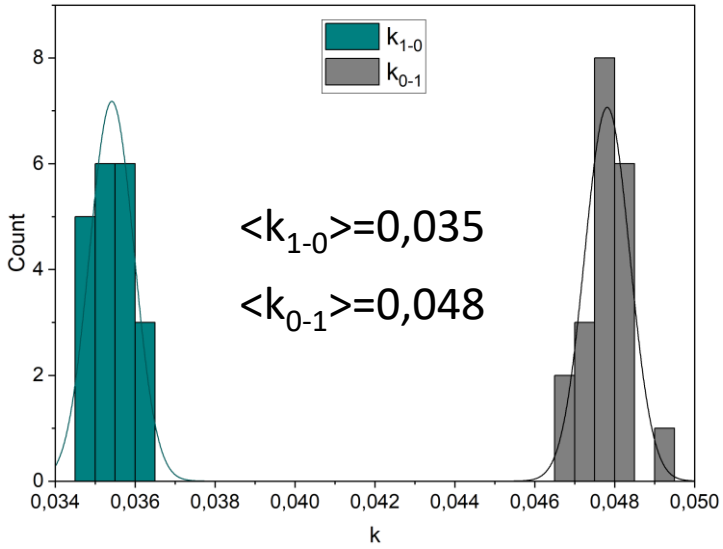
Reference cubes light yield and crosstalk and systematic errors estimation



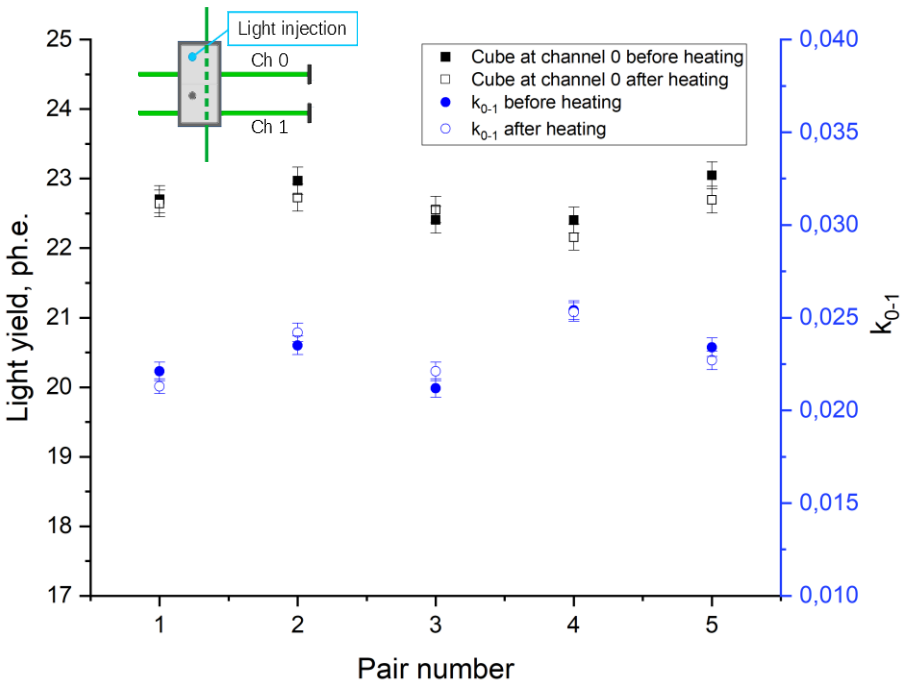
	Cube 0	Cube 1
Mean light yield, ph.e.	27,54	29,64
Standard deviation	0,23	0,34
Systematic error, %	0,83	1,16

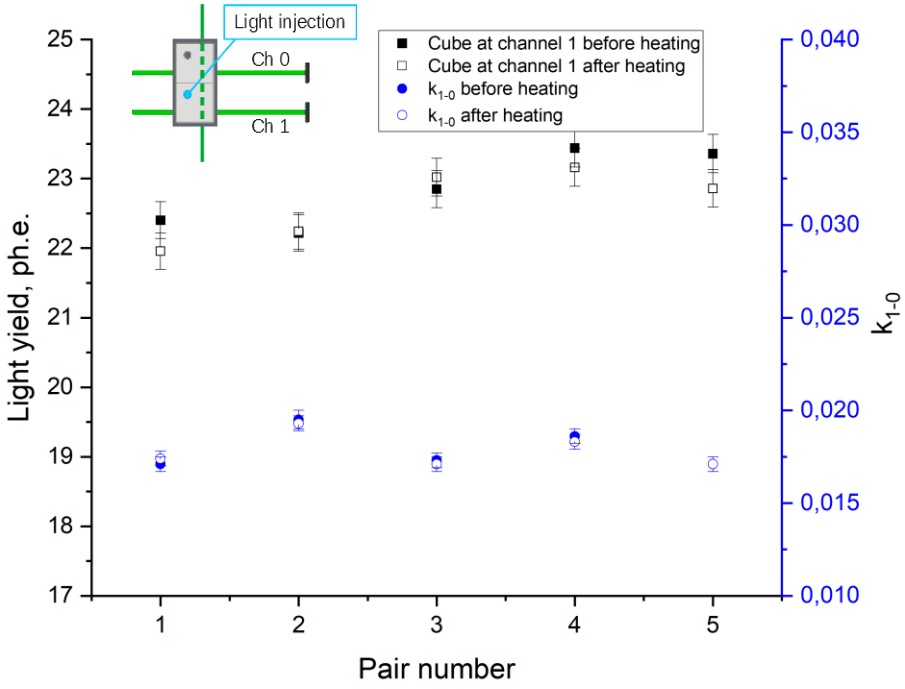


	Cube 0	Cube 1
Mean light yield, ph.e.	28,27	31,30
Standard deviation	0,23	0,25
Systematic error, %	0,80	0,79

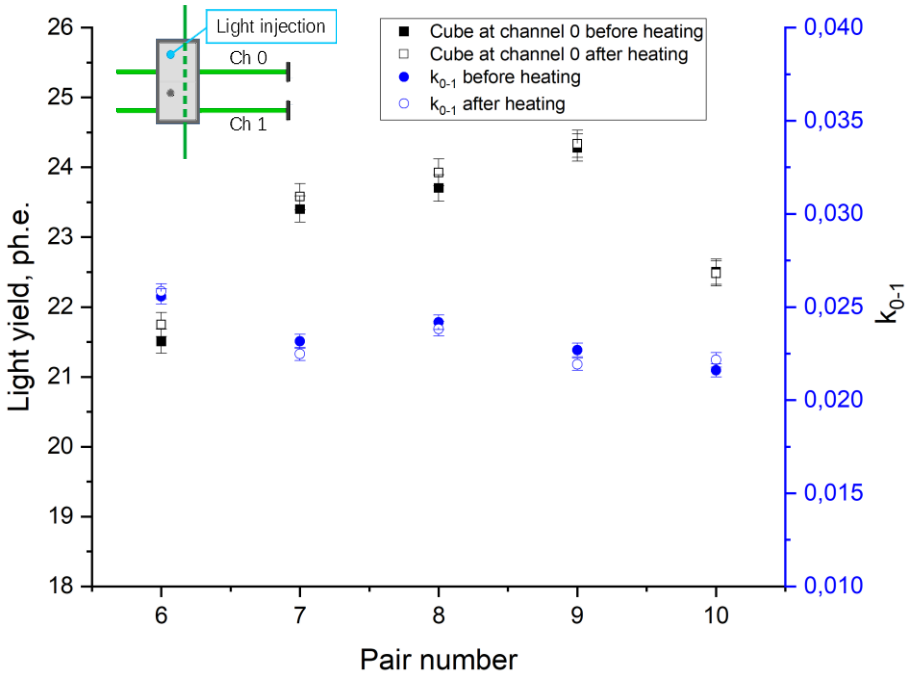


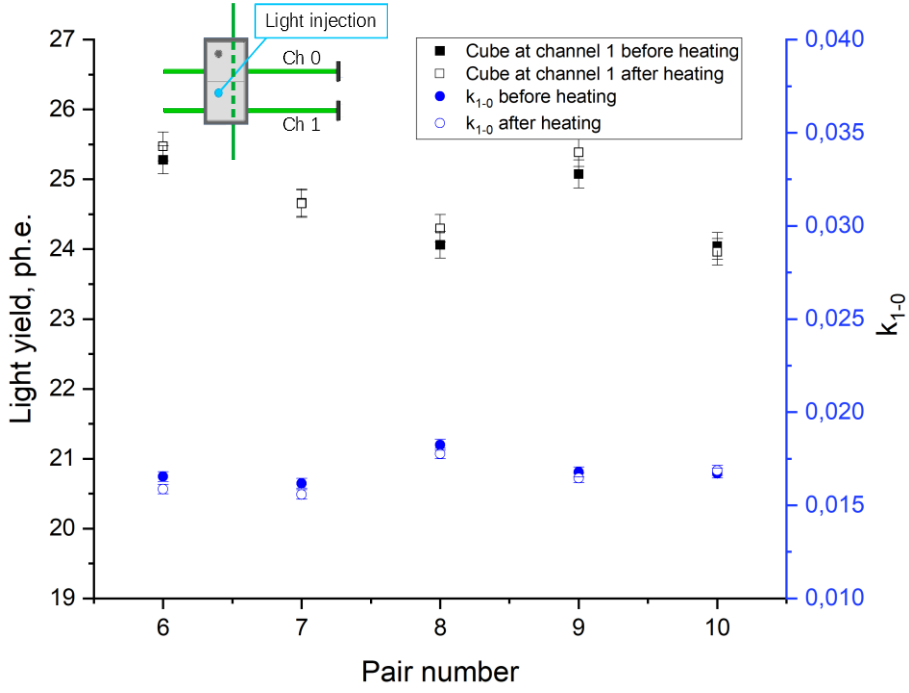
Light yield and crosstalk before & after 24 hours at 60°C





Light yield and crosstalk before & after 72 hours at 60°C





Summary

- Scintillator cube excitation by UV-LED was studied as one of the possible ways to measure optical crosstalk.
- Optical crosstalk coefficient of the two adjacent cubes have been studied for the different cases of common WLS fiber hole conditions (open/closed/fiber inside).
- In case when a WLS fiber is inserted into adjacent holes of the cubes, it was found that the average value of the coefficient k is 0,026, and light leaks from the cube through its face covered with a diffuse reflector, and not through adjacent holes in the cubes with an inserted wavelength-shifting fiber.
- The amount of optical crosstalk depends on the distance from the LED light injection point to the side facing the adjacent cube. This demonstrates the positional sensitivity of the cubes and can be used in track reconstruction.
- The temperature treatment influence on the light yield and crosstalk of the cubes was investigated. After keeping the cubes at 60° C for 24 hours, as well as within 72 hours, no significant changes in the light yield and crosstalk of the cubes were observed.

Thank you for your attention!