Efficiency of 3 inch PMT in magnetic field

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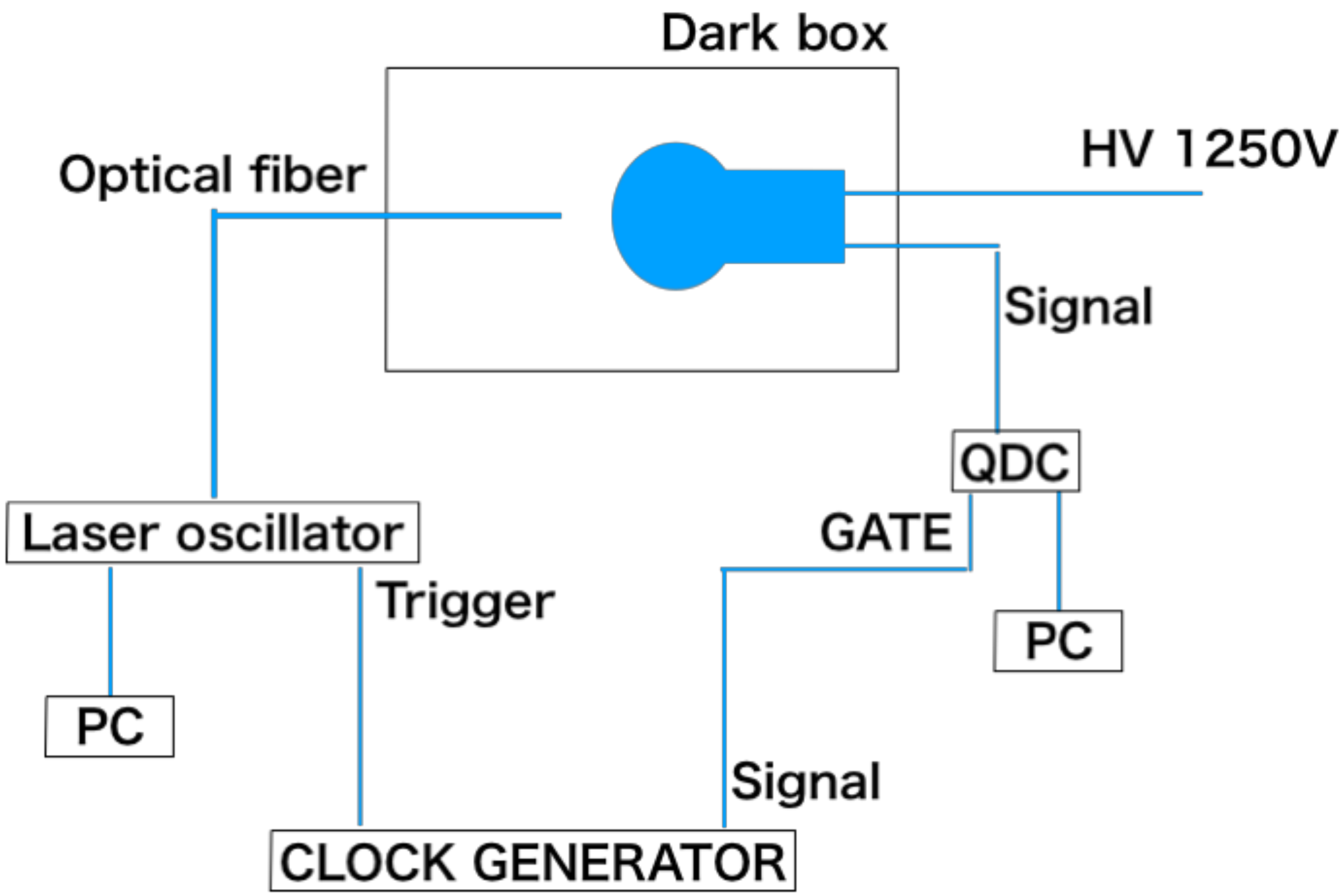
Introduction

Strong magnetic field affects photon collection efficiency of PMT.
Therefore several experiments employ dedicated instruments to cancel Earth's magnetic field.

- SK detector has large coil which covers entire detector.
- In Double Chooz experiment, each PMT is covered with mu-metal.

I measured efficiency of 3 inch PMT in some B-fields at TUS to check whether we need such additional instruments or not.

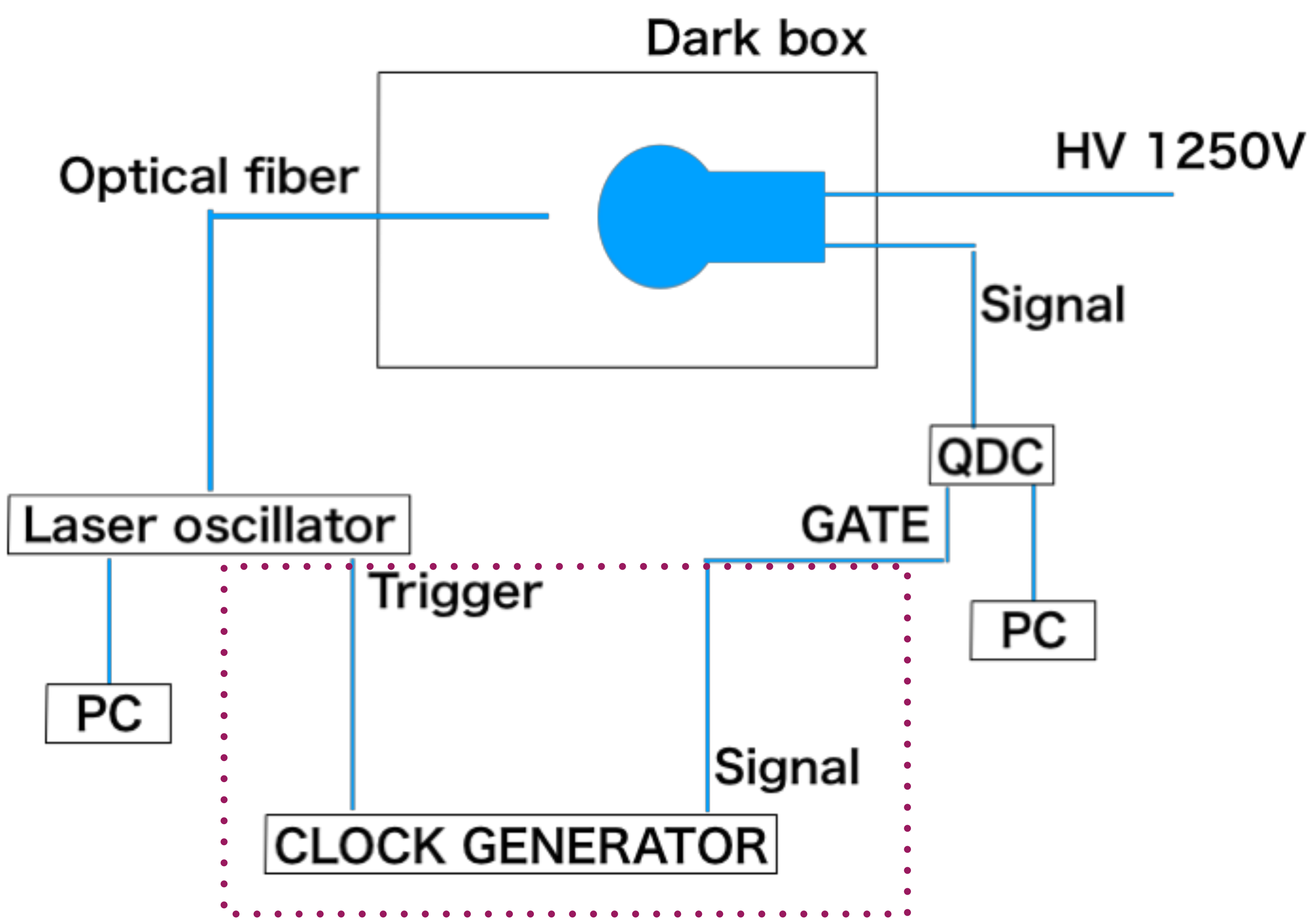
Experimental setup



- Illuminate PMT with laser and readout the signal with QDC (APV8104).
- Count PMT hit signals and calculate the photon detection efficiency.
- Apply magnetic field with coil surrounding dark box and measure the efficiency changing magnitude of B-field.

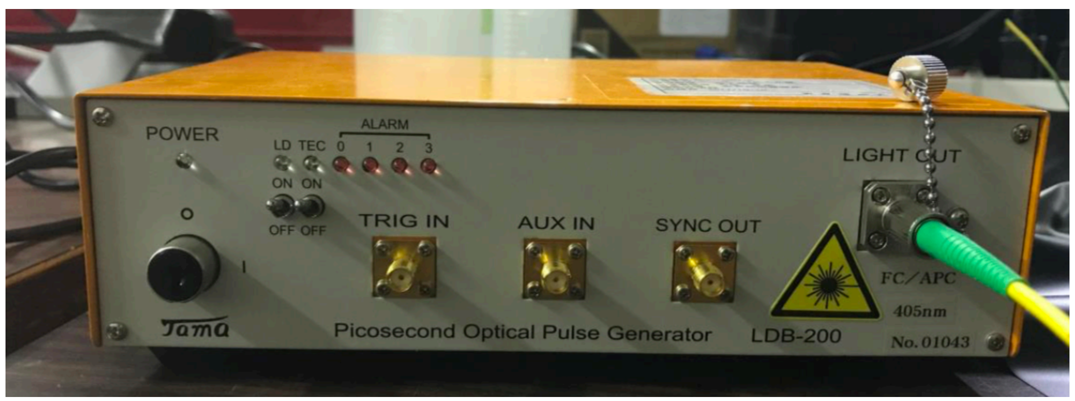
Experimental setup

- 1 kHz signals from clock generator are used to flash laser and trigger QDC.
- 600,000 events are recorded.

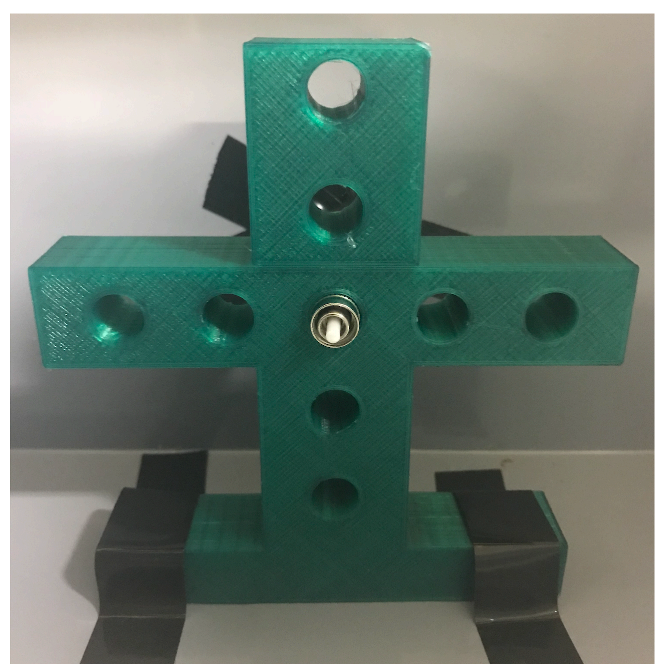


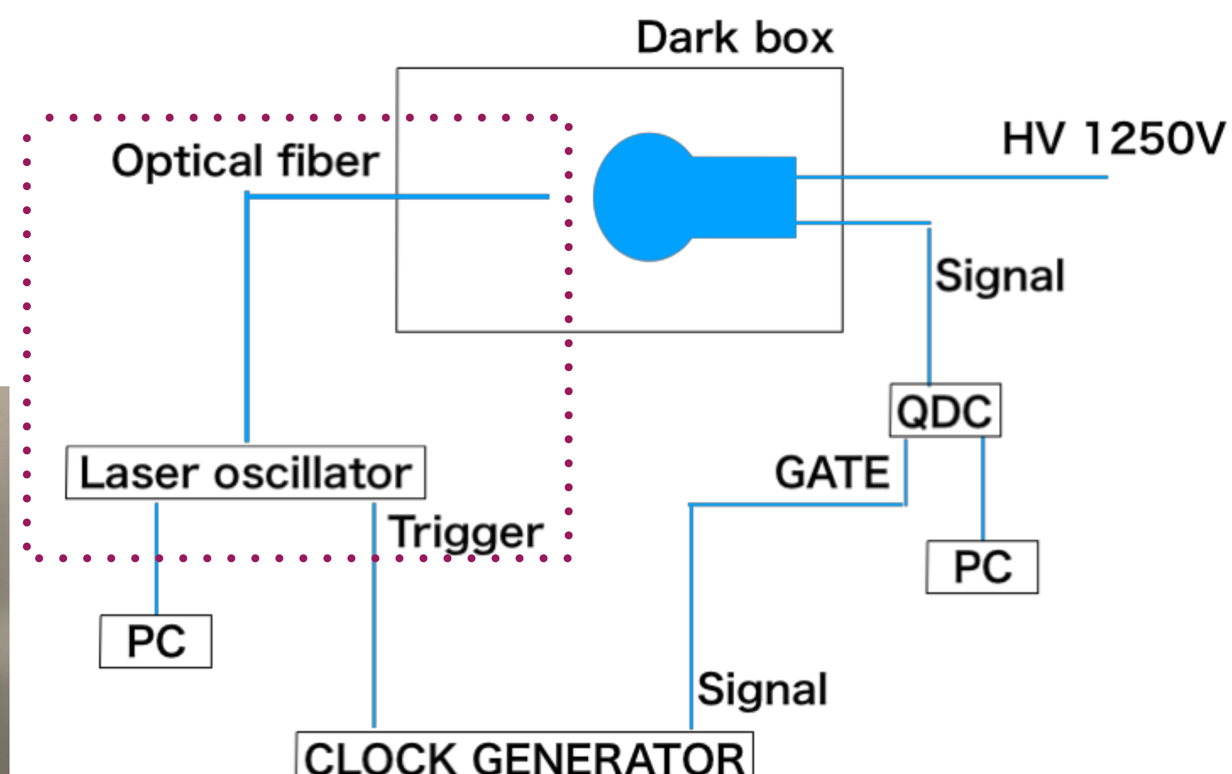
Experimental setup

- Laser oscillator creates 50 picosecond optical pulses.
- The laser lights hit around center of photo-cathode of PMT in black box.



Laser oscillator

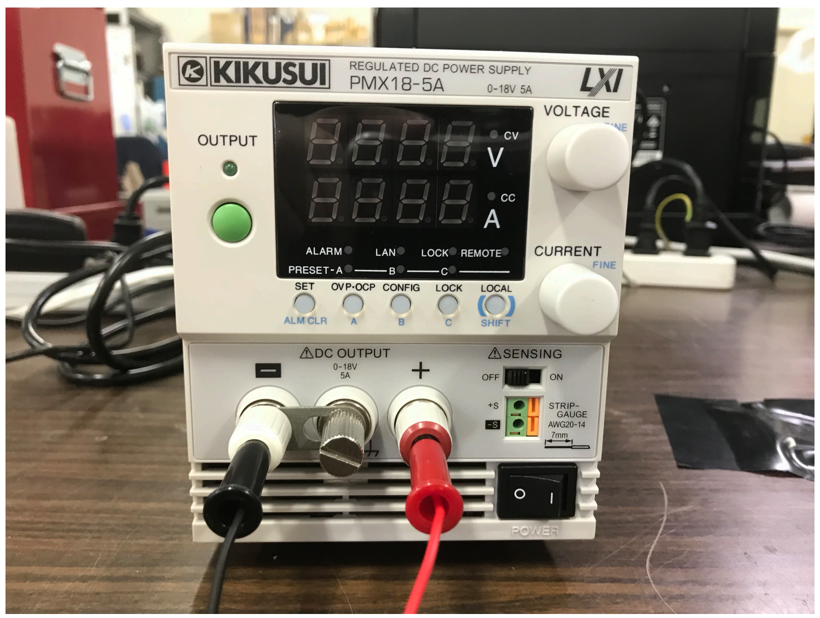




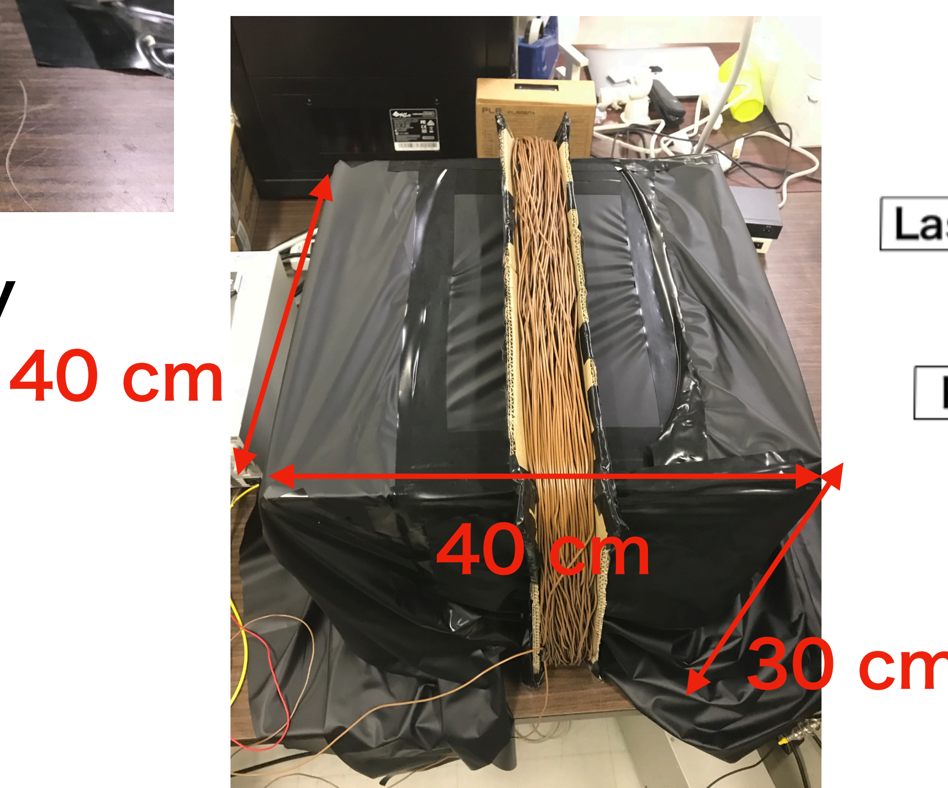
Optical fiber and fixture made by 3D printer

Experimental setup

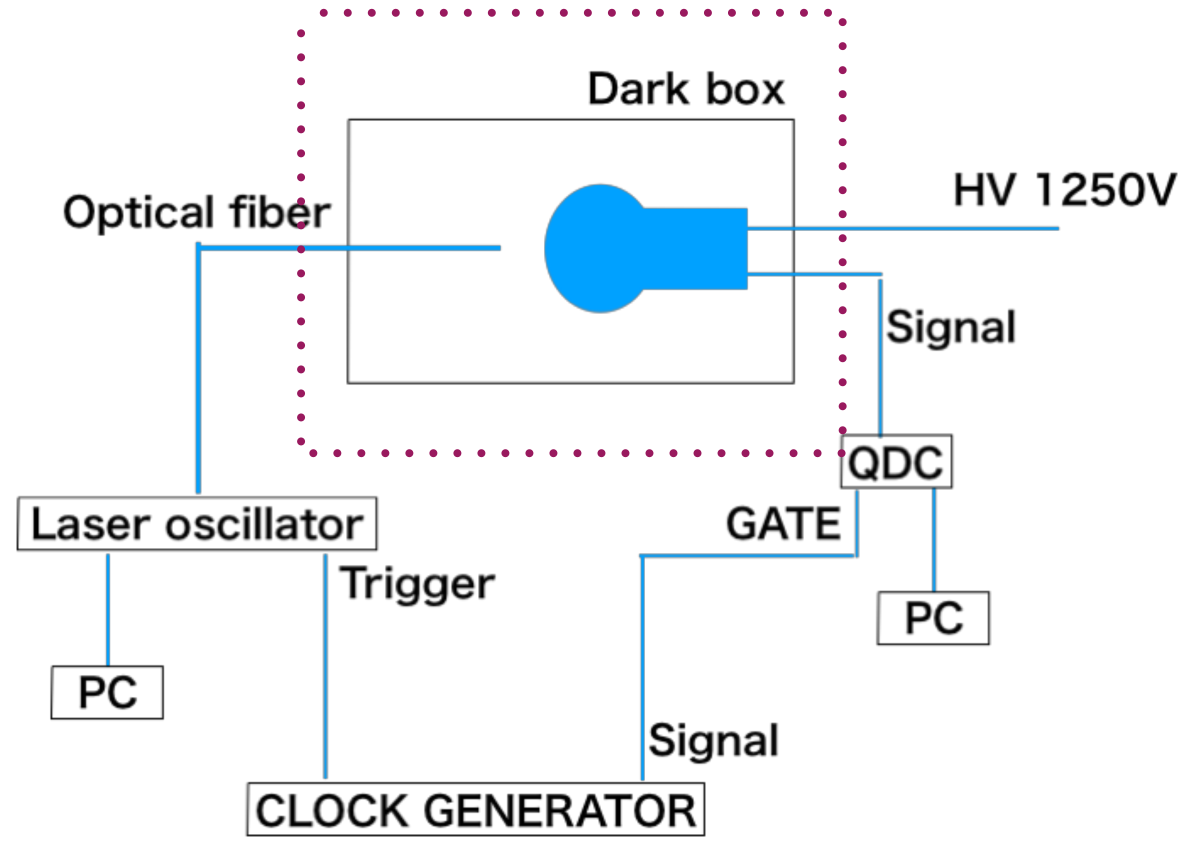
- I wound coil around dark box.
- Using a DC power supply, the coil created some magnetic fields.



DC power supply

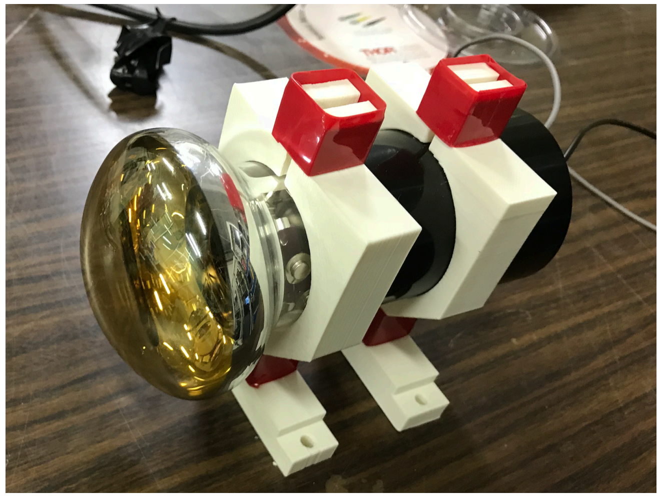


Dark box and coil

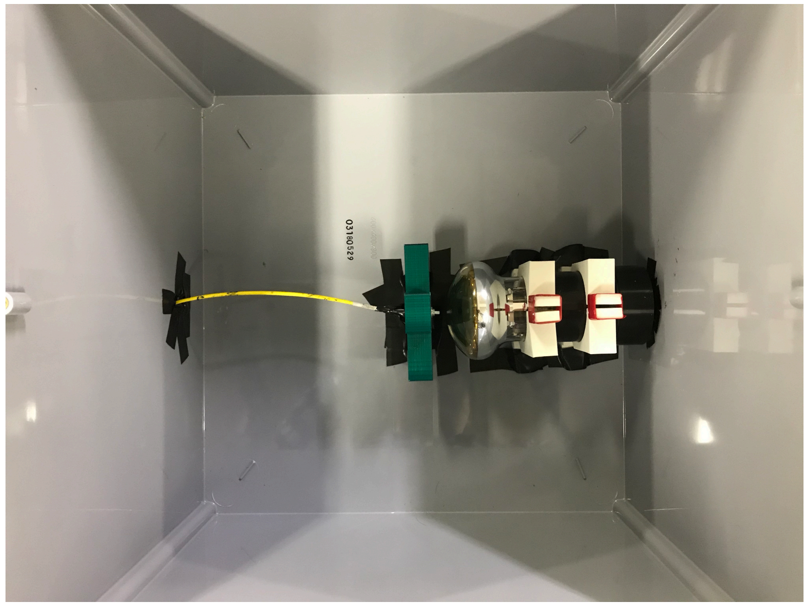


Experimental setup

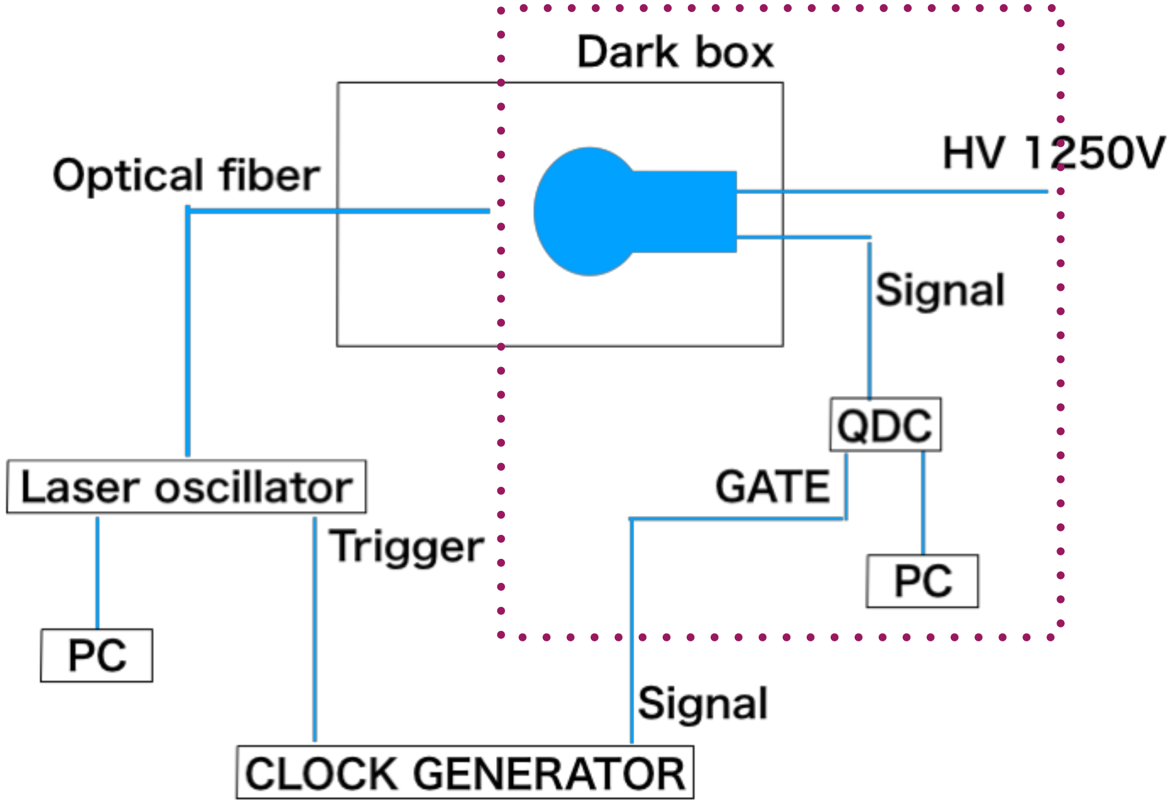
- I measured signals of 3 inch PMT in various B-field.
- I analyzed the signals recorded by QDC.



PMT and fixture made by 3D printer



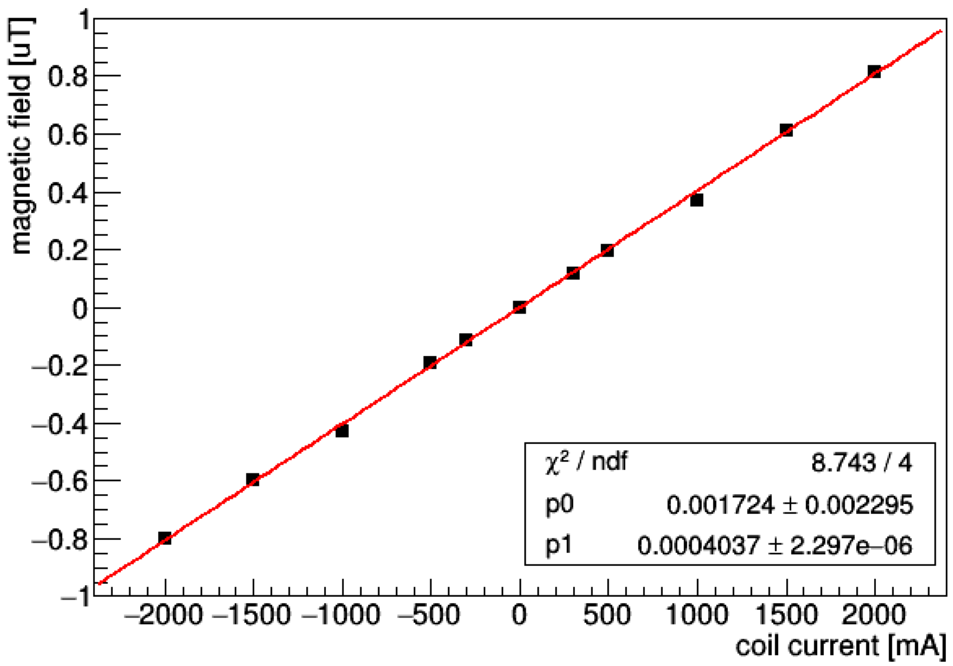
Inside of the dark box

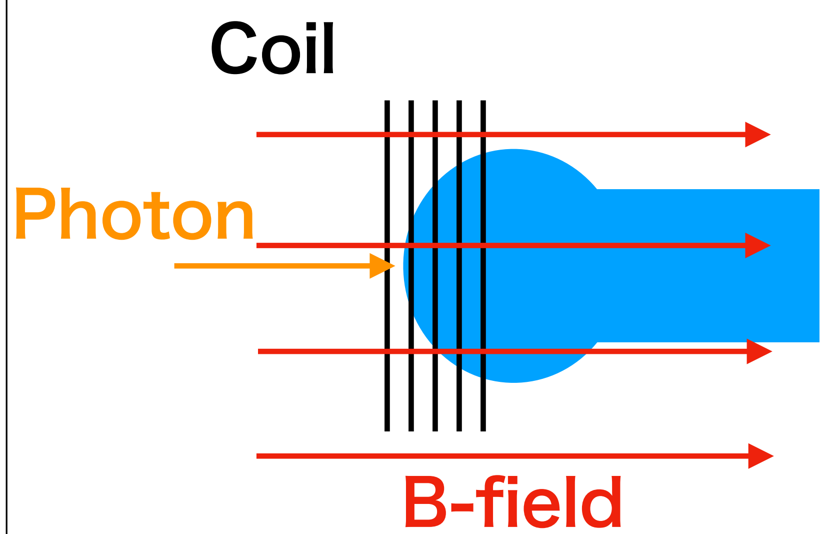


Relation between coil currents and B-fields

I measured B-fields in black box with gauss meter and obtained relation between coil currents and B-fields.

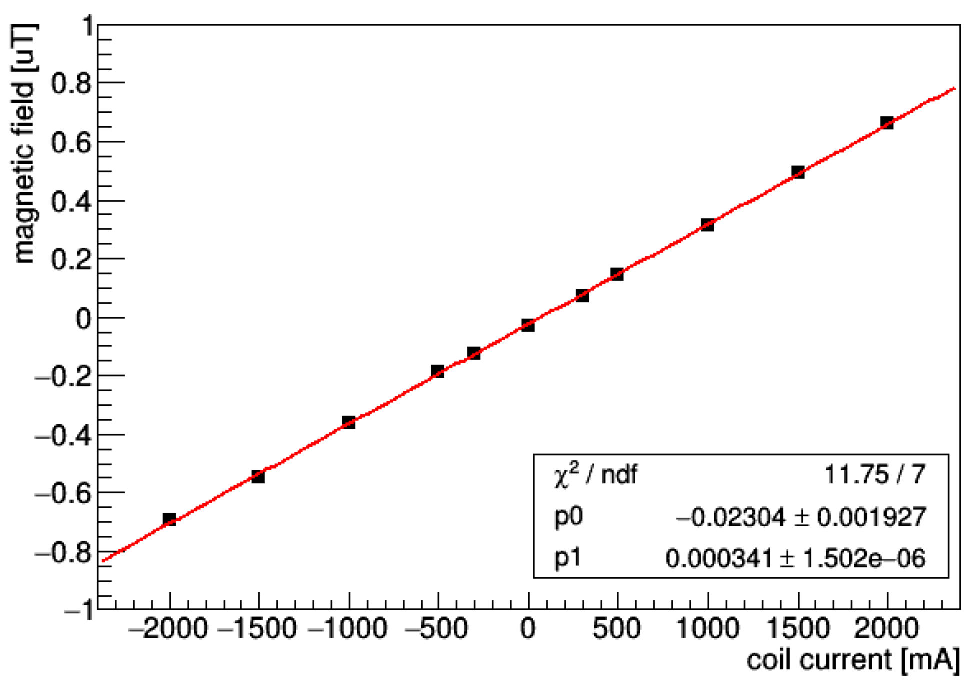
(1) perpendicular B-field to photo-cathode

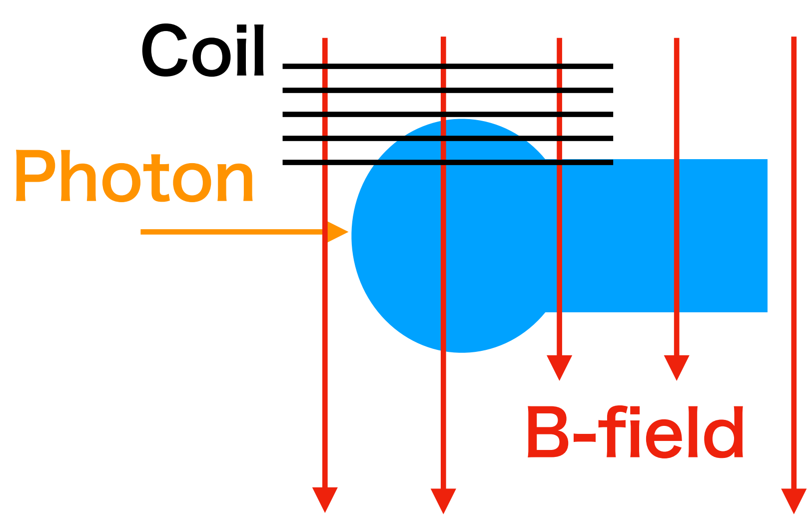




Gauss meter

(2) parallel B-field to photo-cathode



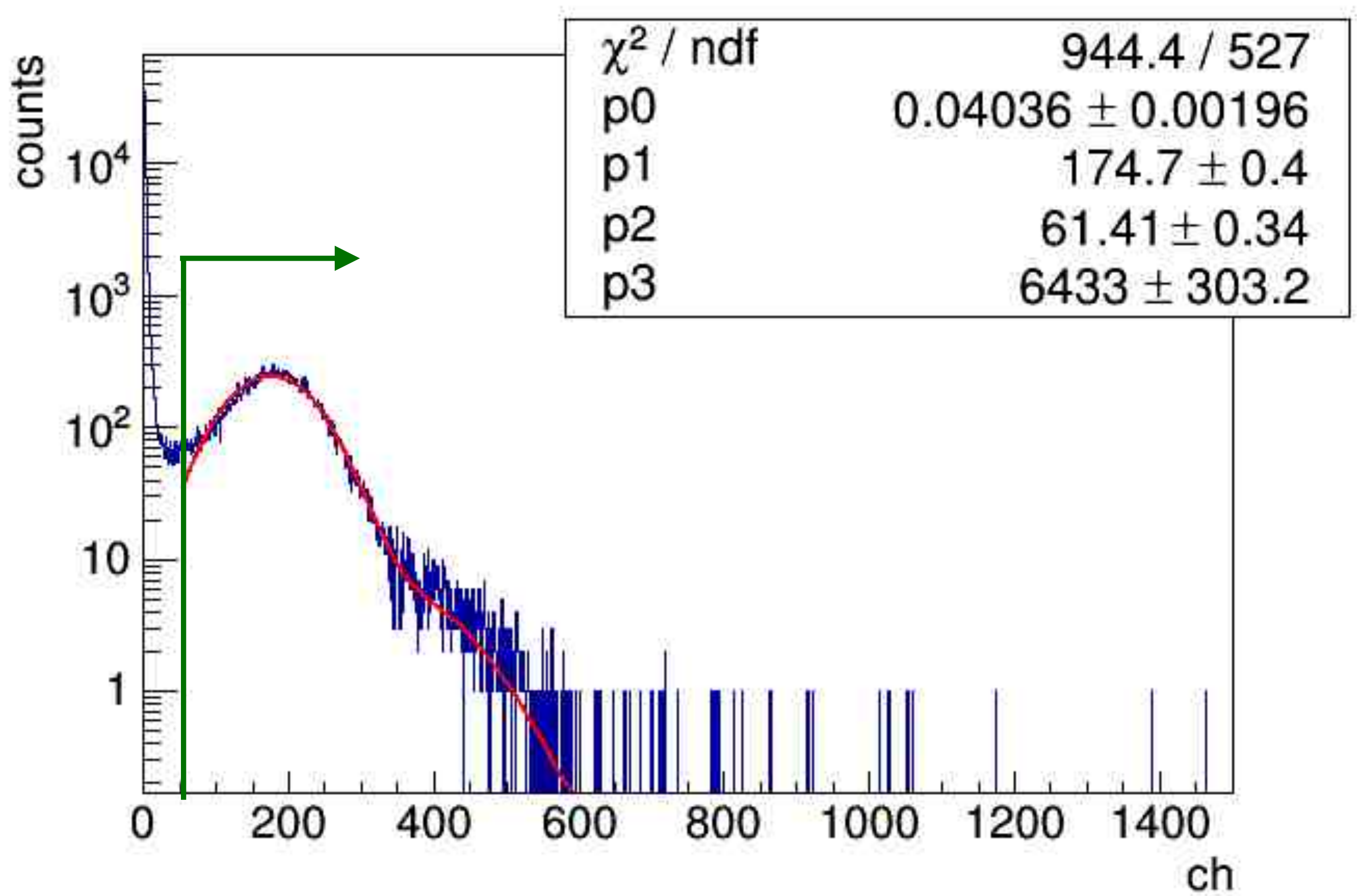


Efficiency

Efficiency is defined as follows:

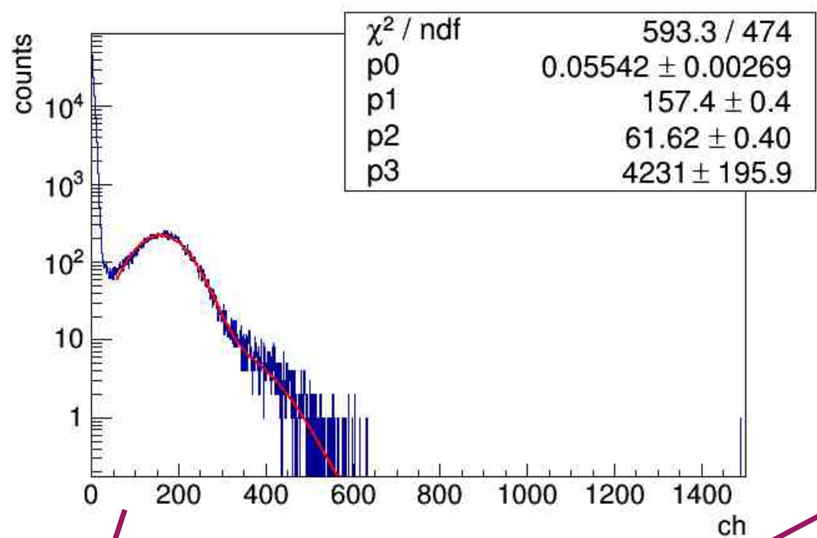
$$\text{Efficiency} = \frac{\text{the number of PMT's signals}}{\text{the number of signals from clock generator}}$$

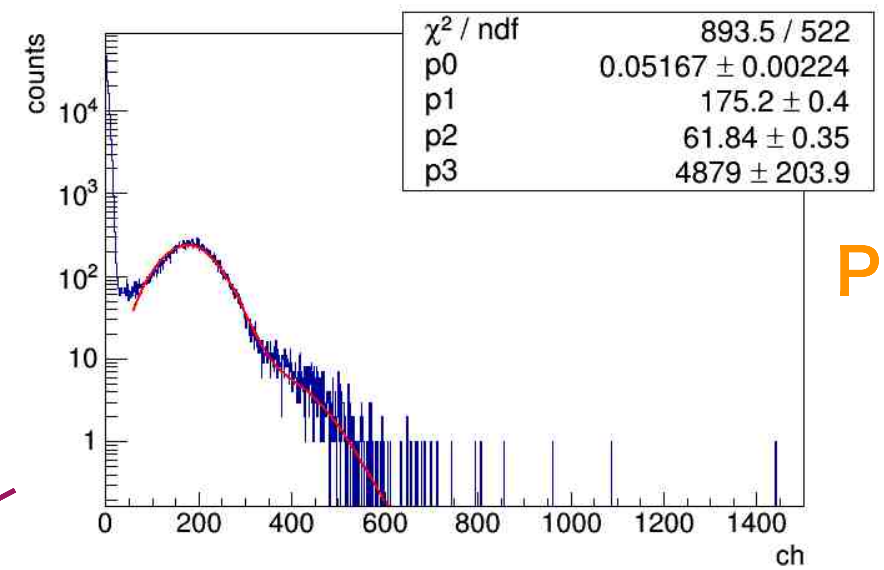
"the number of PMT's signals" is the counts above the threshold.

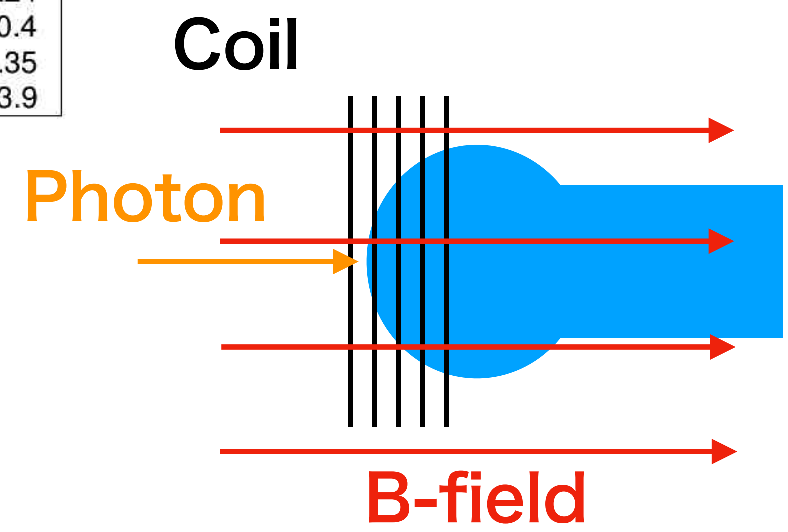


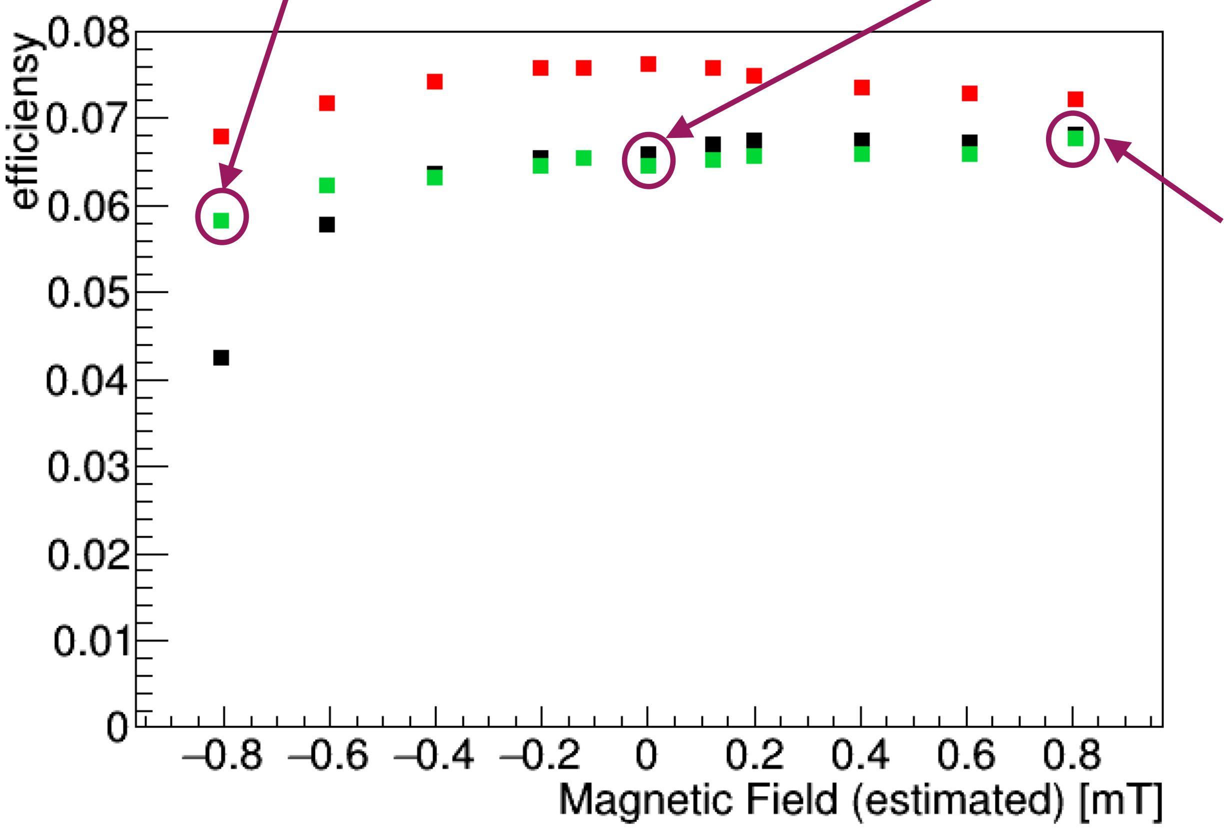
Efficiency

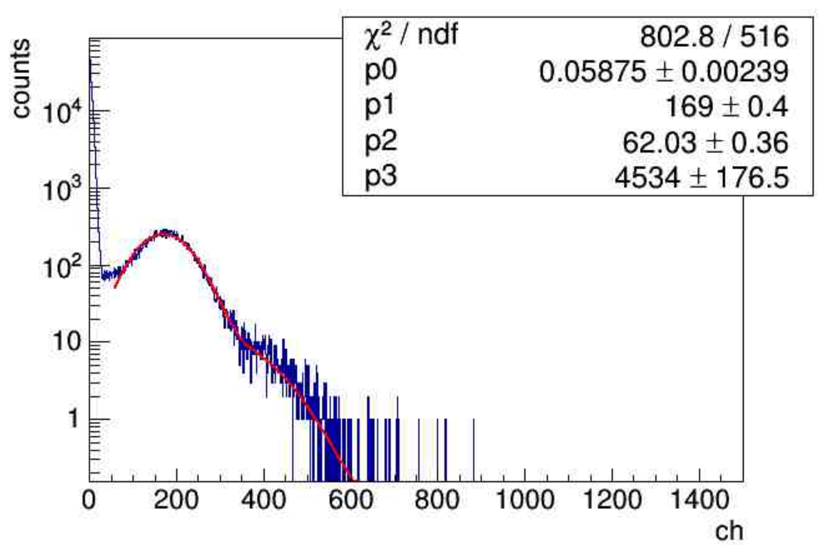
I measured efficiencies of 3 inch PMT with B-field perpendicular to photo-cathode.







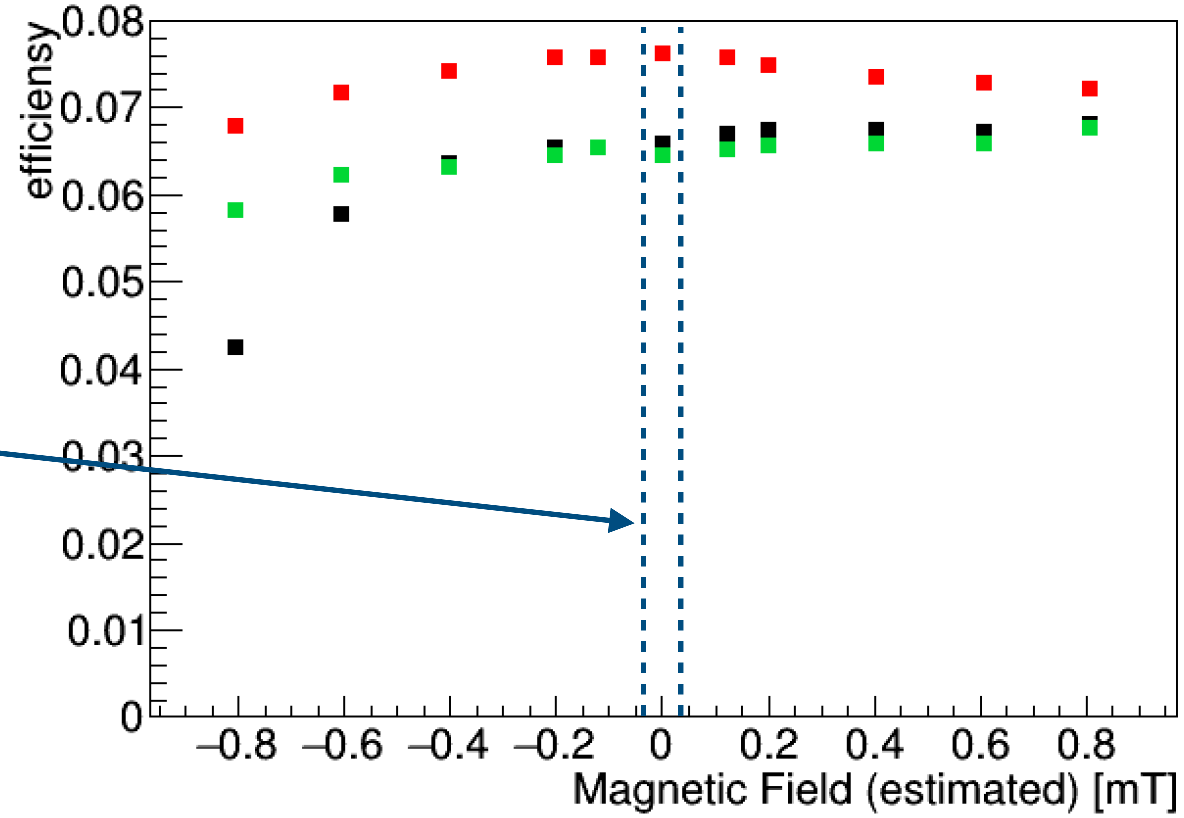




Efficiency

Earth's magnetic field is about 0.046 mT in Japan.

This range is scale
of Earth's magnetic field.

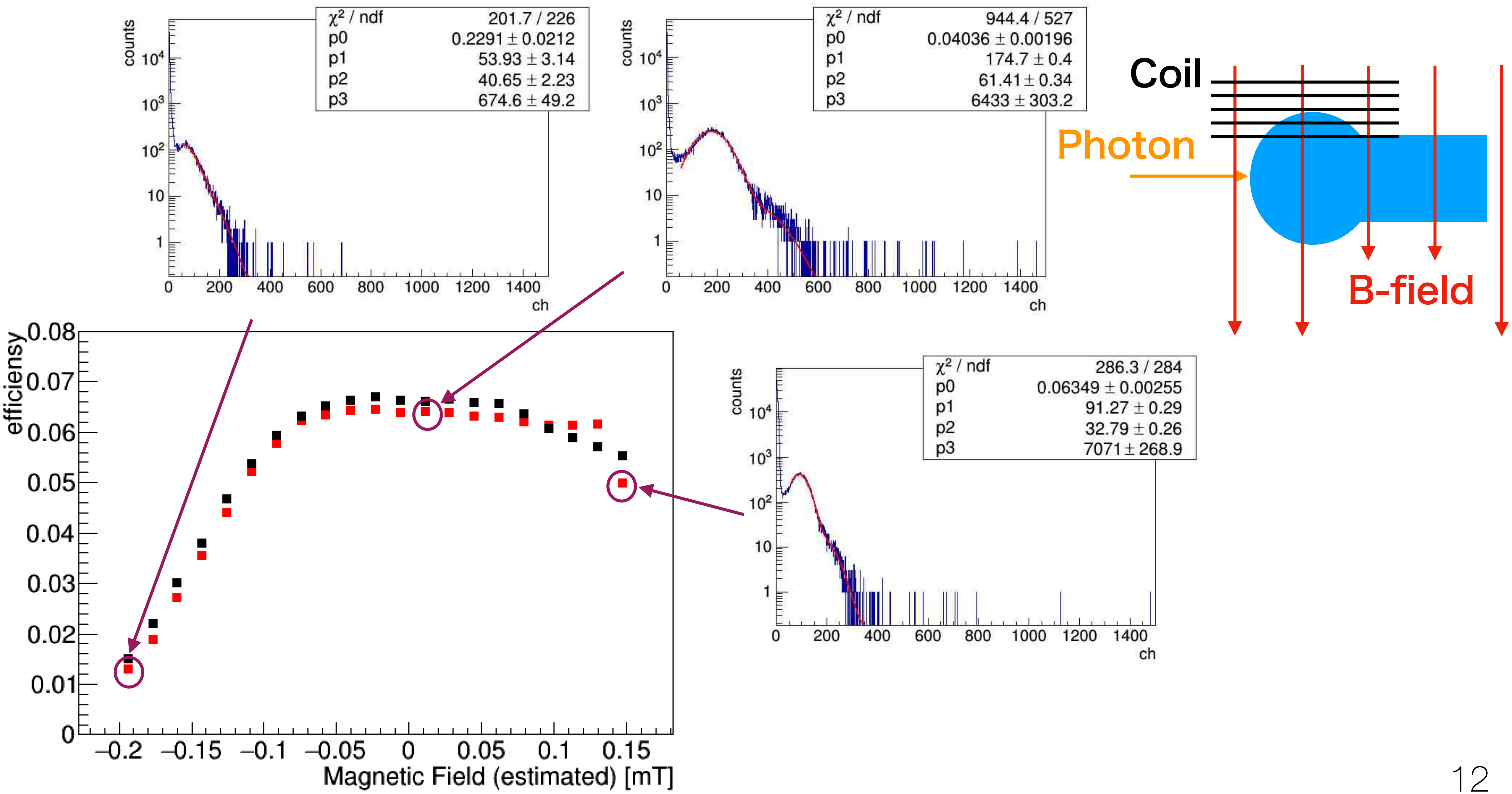


Efficiency is almost stable in range
between -0.2 mT and 0.2 mT.

No significant variation was conformed with the order of Earth's magnetic field.

Efficiency

I measured efficiencies of 3 inch PMT with B-field parallel to photo-cathode.



Efficiency

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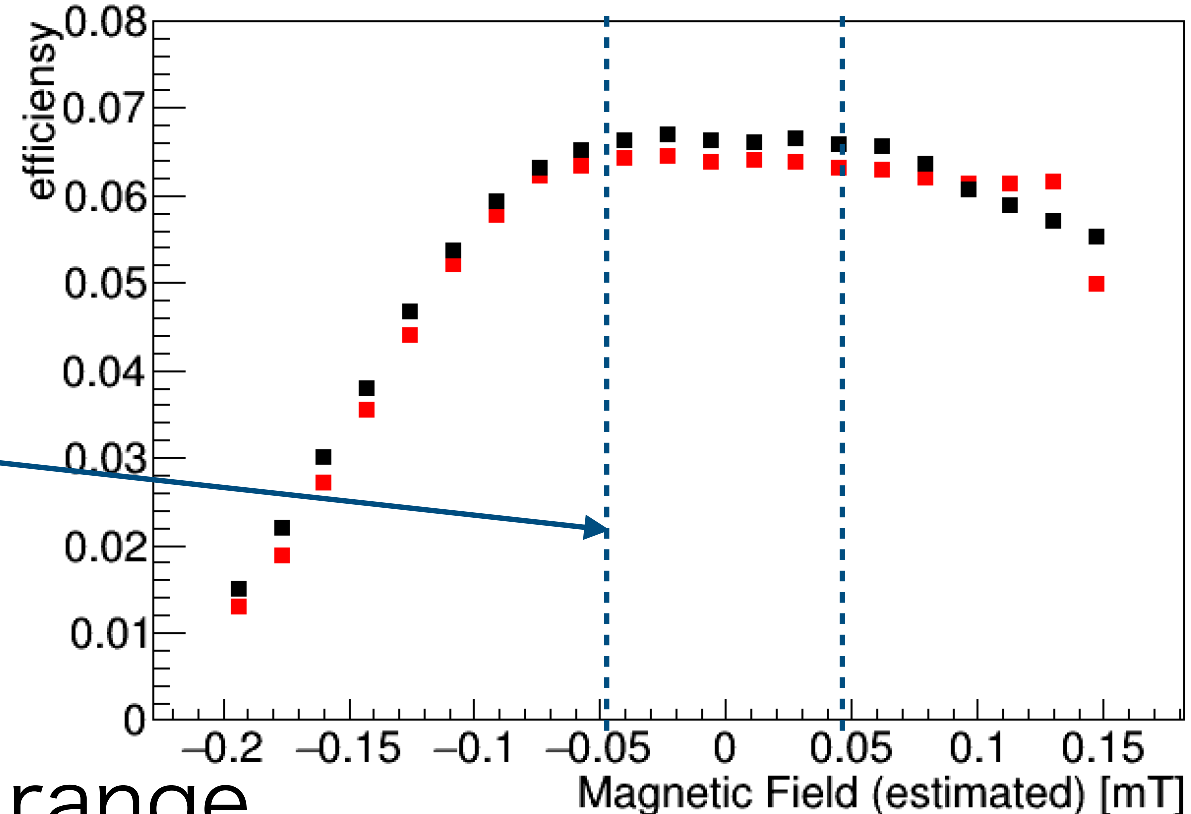

Efficiency is almost stable in range
from -0.06 mT to 0.06 mT.

The efficiency decrease with weaker B-field parallel to photo-cathode compare to the case with B-field perpendicular to photo-cathode.

It is still stable in Earth’s magnetic field but it’s near the edge.

Summary

I built a setup at TUS to measure photon detection efficiency in magnetic field.

I found B-filed parallel to photo-cathode has more impact on the efficiency than one perpendicular to photo-cathode.

It is still stable in the magnitude of Earth's magnetic field (0.046 mT) but it looks close to the limit.

I plan to continue the measurements.

- Examine PMT's phi-symmetry.
- Make B-field map in dark box.

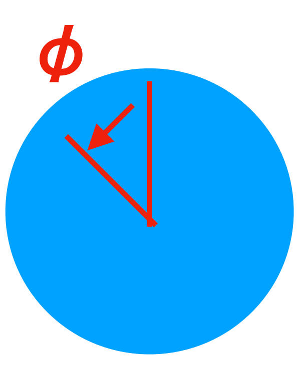

Photo-cathode