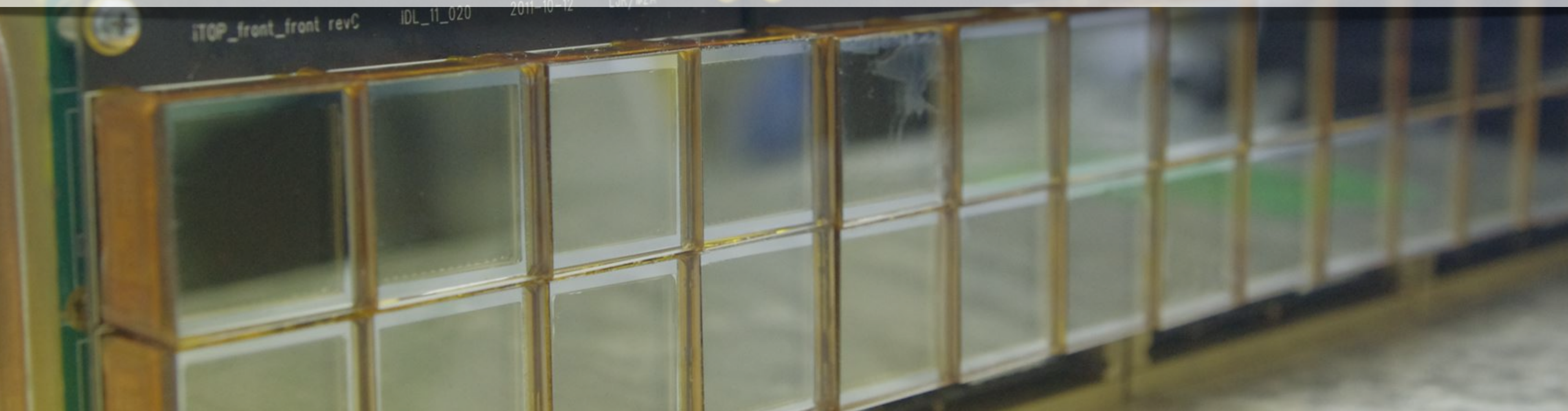
Performance of the MCP-PMTs for the TOP counter in the Belle II experiment



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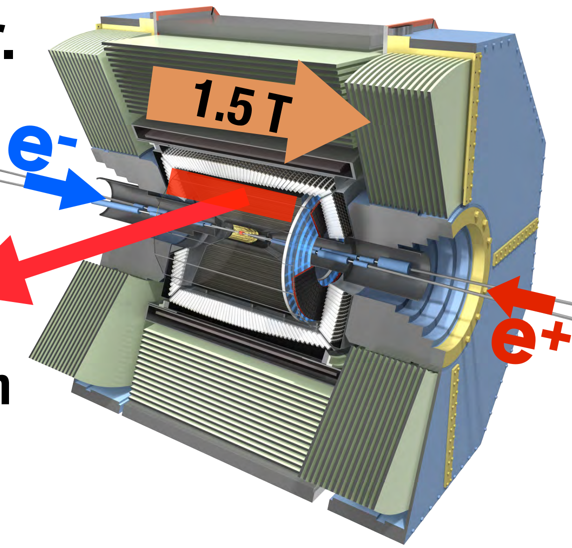
TOP(Time Of Propagation) counter in Belle II

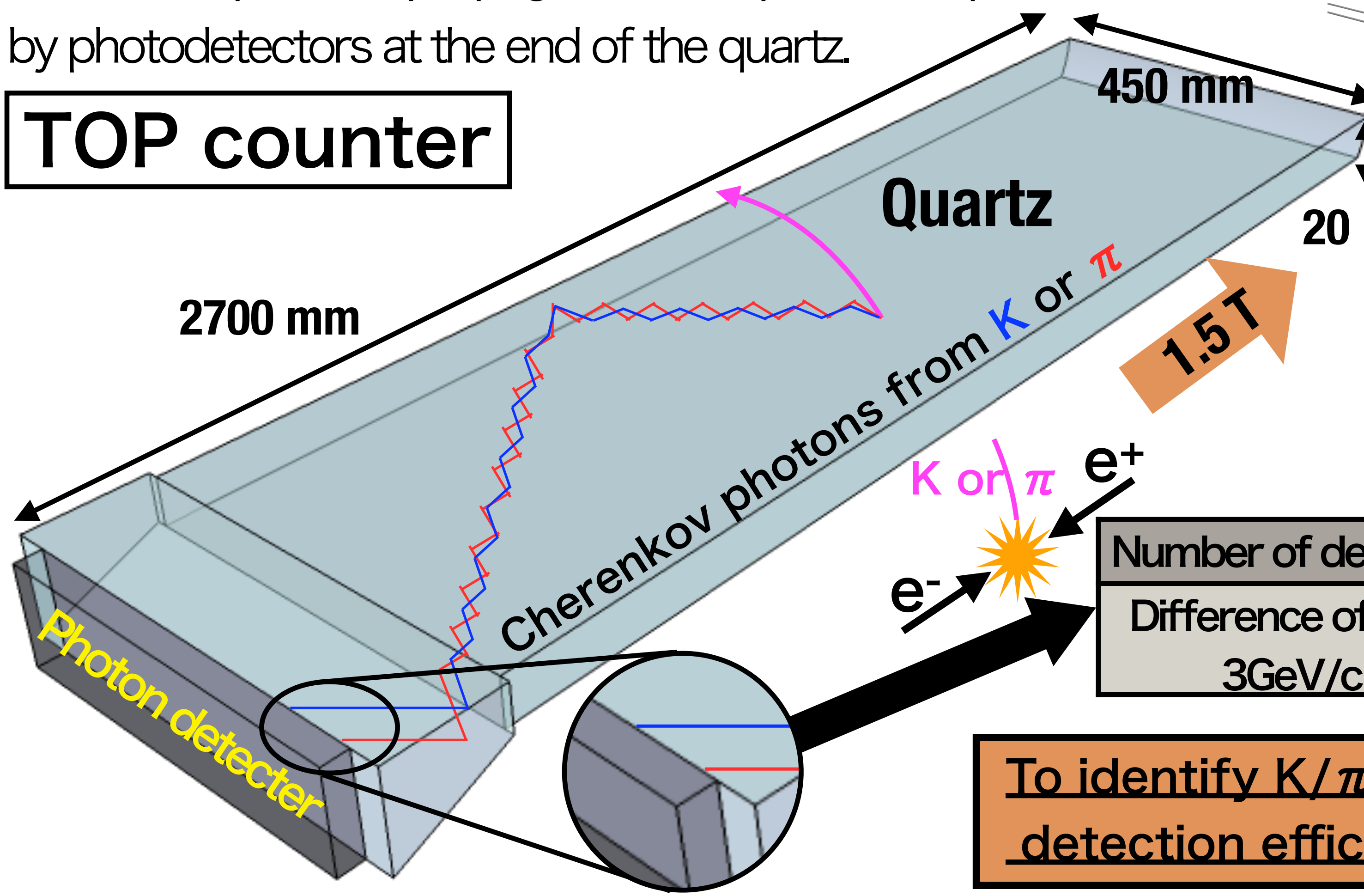
A novel RICH (Ring Imaging Cherenkov) detector.

Cherenkov photons propagate in the quartz. The photons are measured by photodetectors at the end of the quartz.

Belle II detecter



TOP counter



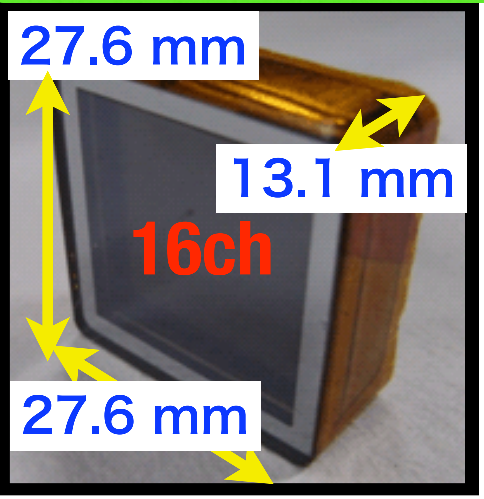
Number of detected photons	~20 photons
Difference of TOP between 3GeV/c π and K	~100 ps

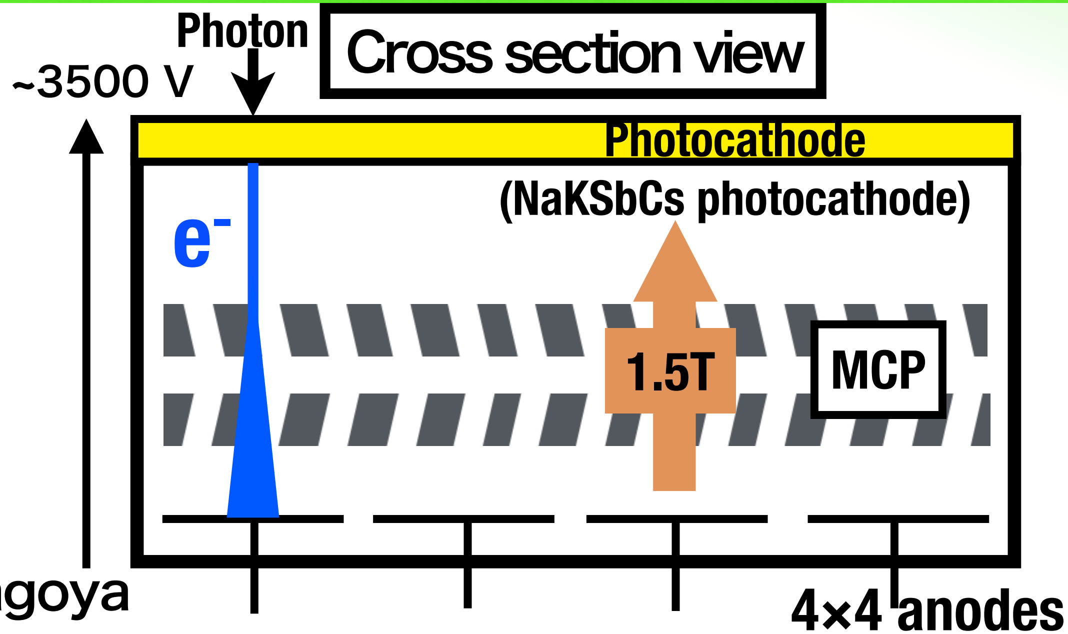
To identify K/π, TTS (≤50 ps) and high detection efficiency are necessity.

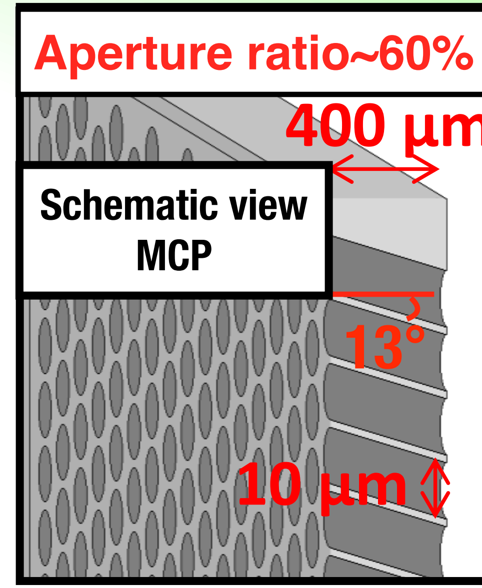
- **Used in 1.5 T**
- 1MHz/PMT BG photons→**Long lifetime of photon detector is necessity.**

We use the MCP-PMT

MCP (Micro-Channel-Plate) -PMT







- Developed at Nagoya and HAMAMATSU photonics.
- Square shape
- Small dead region (~28%)
- Work in 1.5 T.
- Use 2 types of MCP
  - -Conventional-MCP
  - -ALD (Atomic Layer Deposition)-MCP (To extend the lifetime).

	Requirement
TTS	TTS ≦ 50 ps
Gain	Enough gain to detect single photon (> 5×10^{5} in 1.5T)
QE	QE ≧ 24%, 28% on average (at peak)

We succeeded in developing the MCP-PMT.

Need 512 PMTs for the TOP counter→Mass production

Motivation

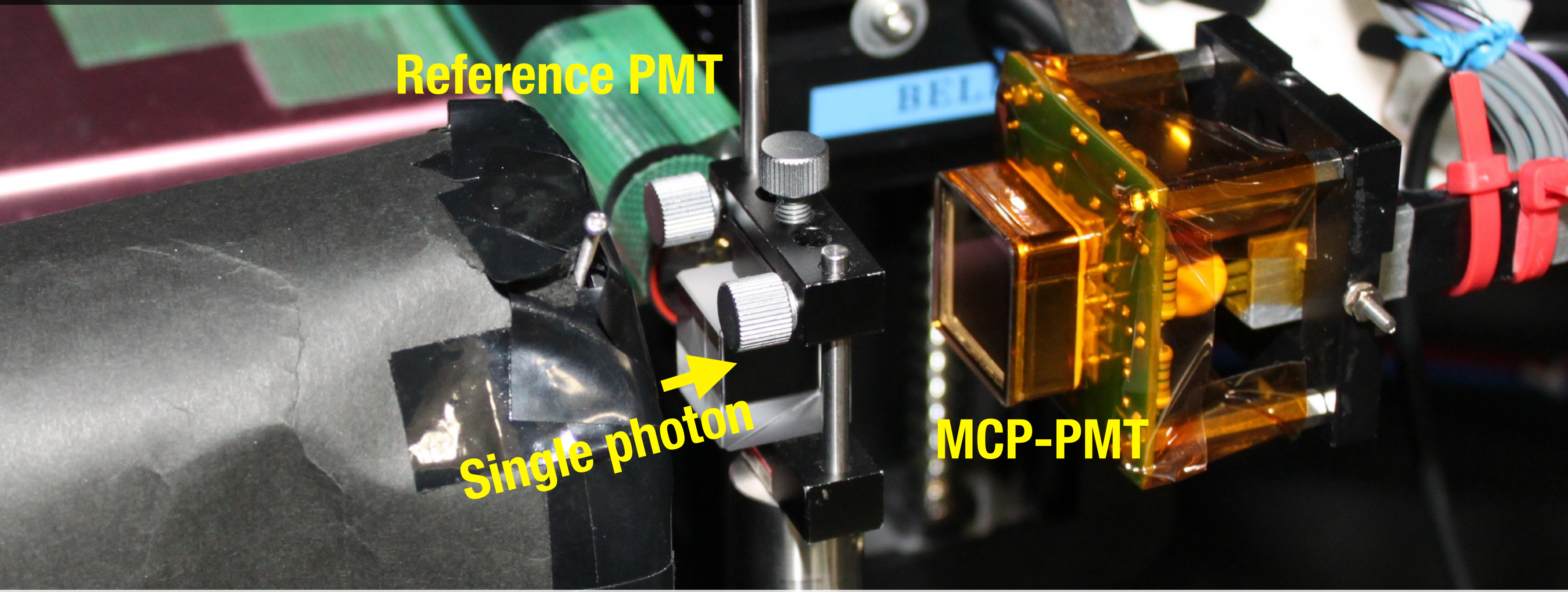
Produce 512 MCP-PMTs which satisfy the requirement.

Check the performance of every PMT and feed back to the mass production.

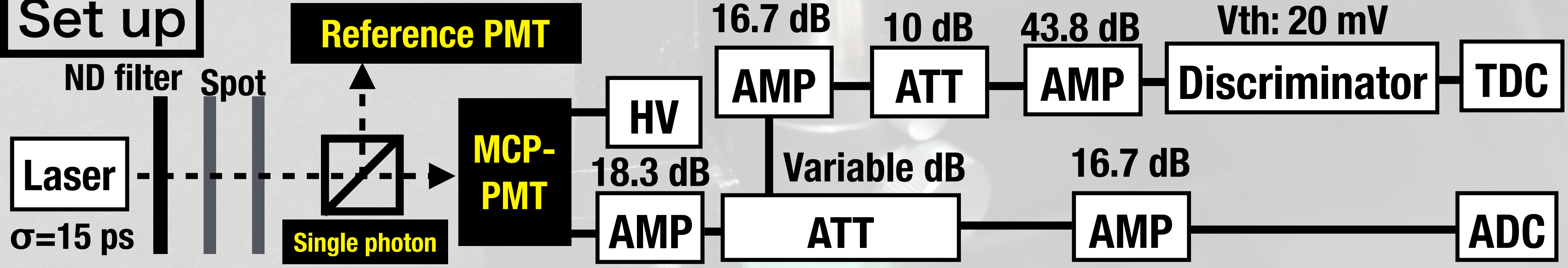
- Laser test in 0T and 1.5T (Gain, TTS, Efficiency)
- QE measurement
- Lifetime of photocathode test

Measurement of gain, TTS, efficiency

Measure all the 16 channels.
In 0T

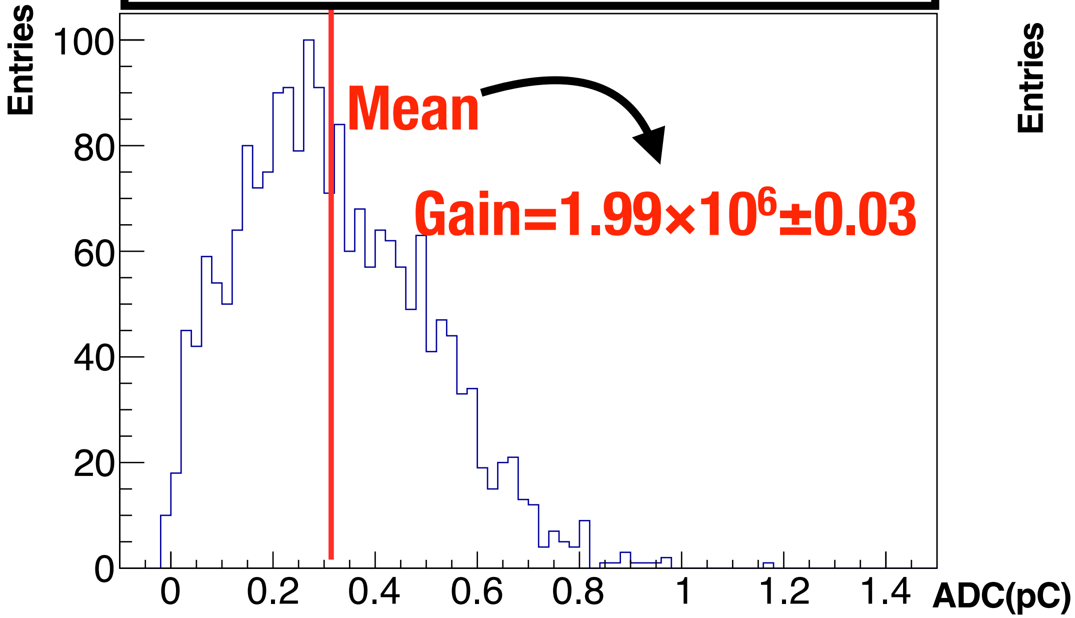


Set up

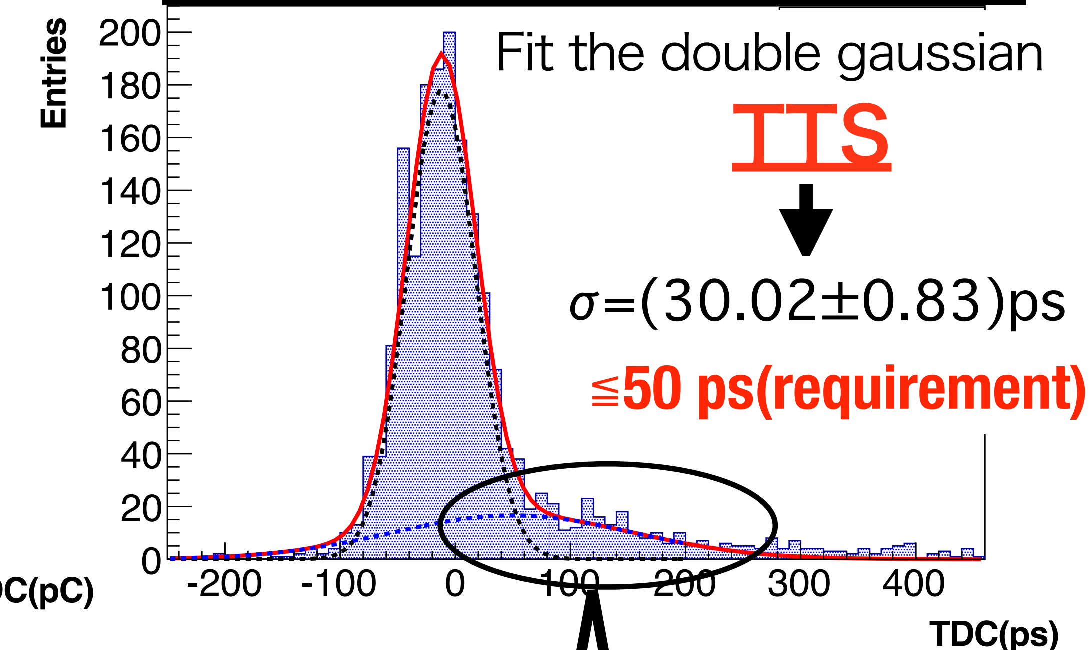


Gain, TTS and efficiency in OT

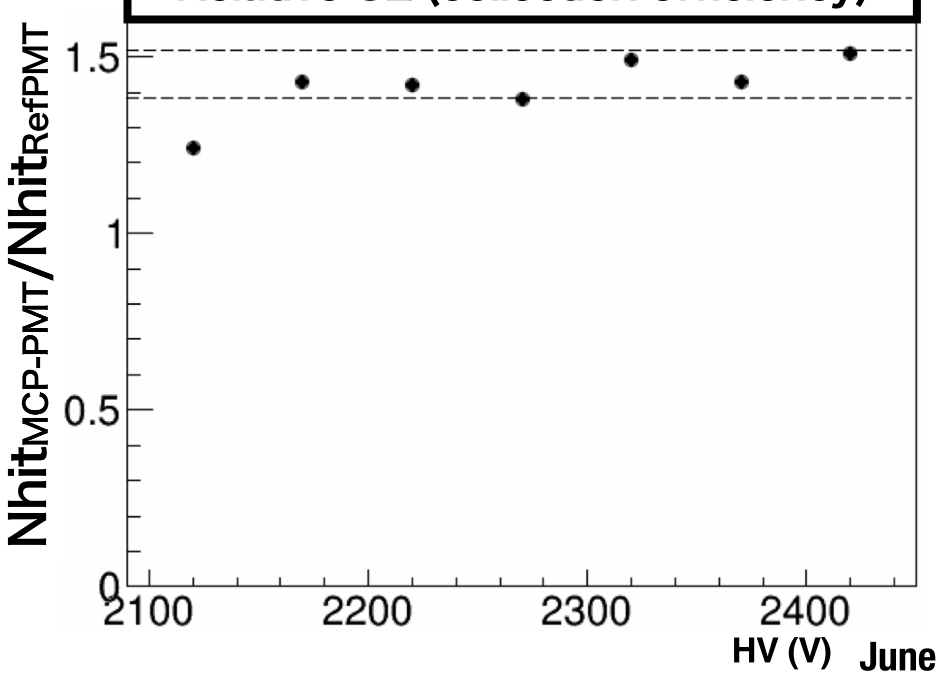
Typical ADC distribution

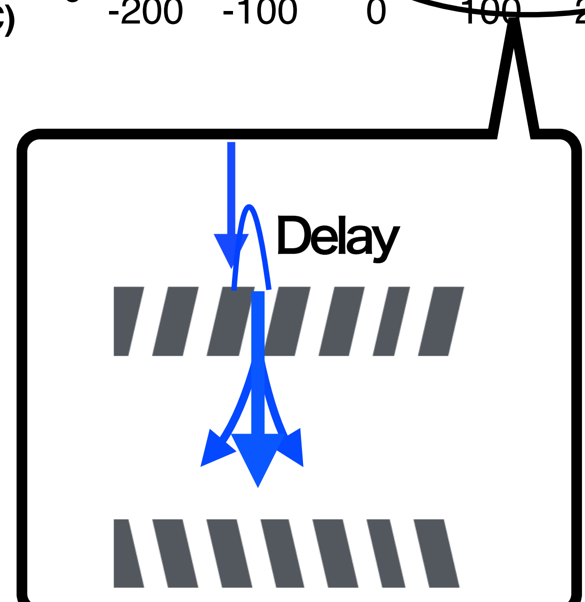


Typical TDC distribution



Relative CE (collection efficiency)





Recoil of photoelectron

Performance in 1.5T

Gain of the MCP-PMT drops in 1.5 T.

Cause of gain drop

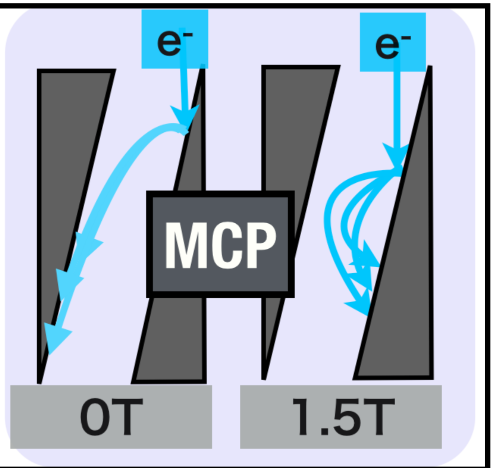
e⁻ hits MCP in a shorter distance and with a lower energy.

↓

Number of secondary electrons is reduced.

↓

Gain drop.



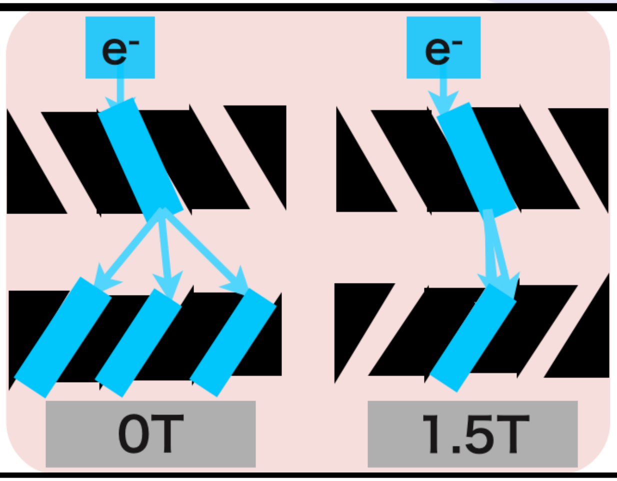
Electrons are converged.

↓

Amplification saturation.

↓

Gain drop.



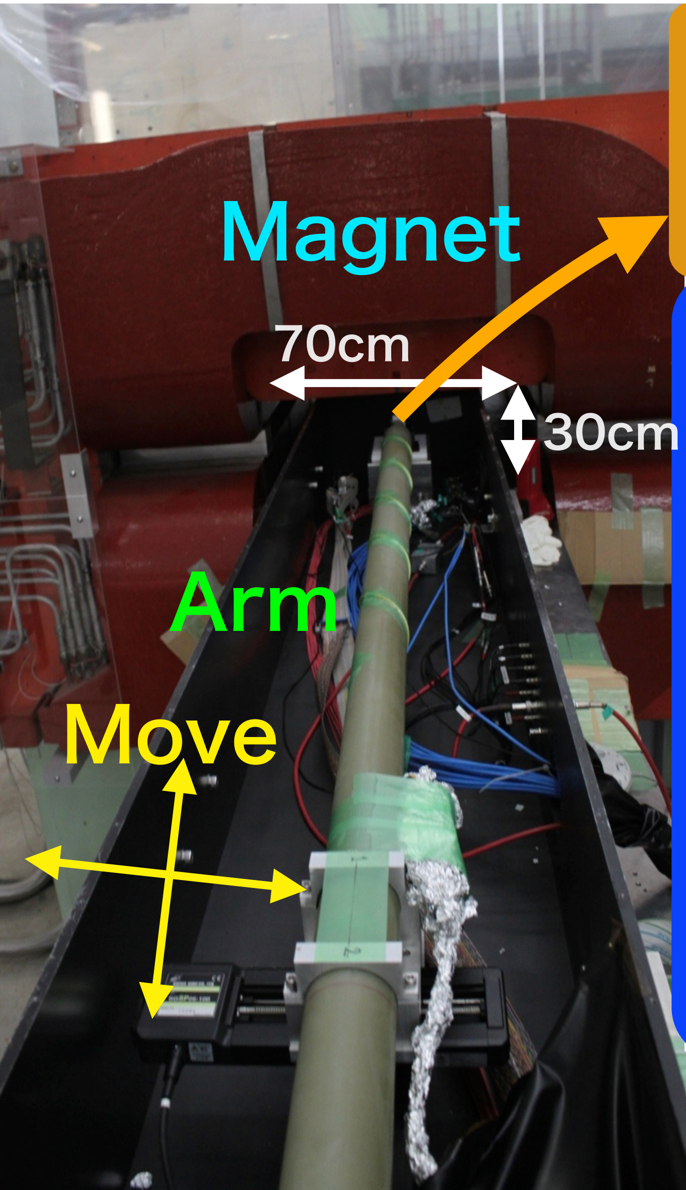
Gain drop in 1.5 T makes S/N ratio lower. →Worse TTS.

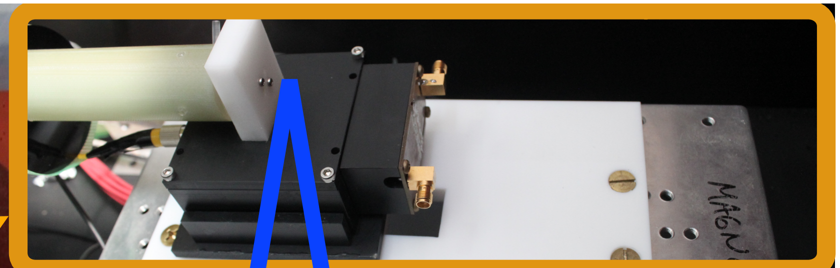
Therefore, it is necessary to measure the TTS and gain in 1.5 T.

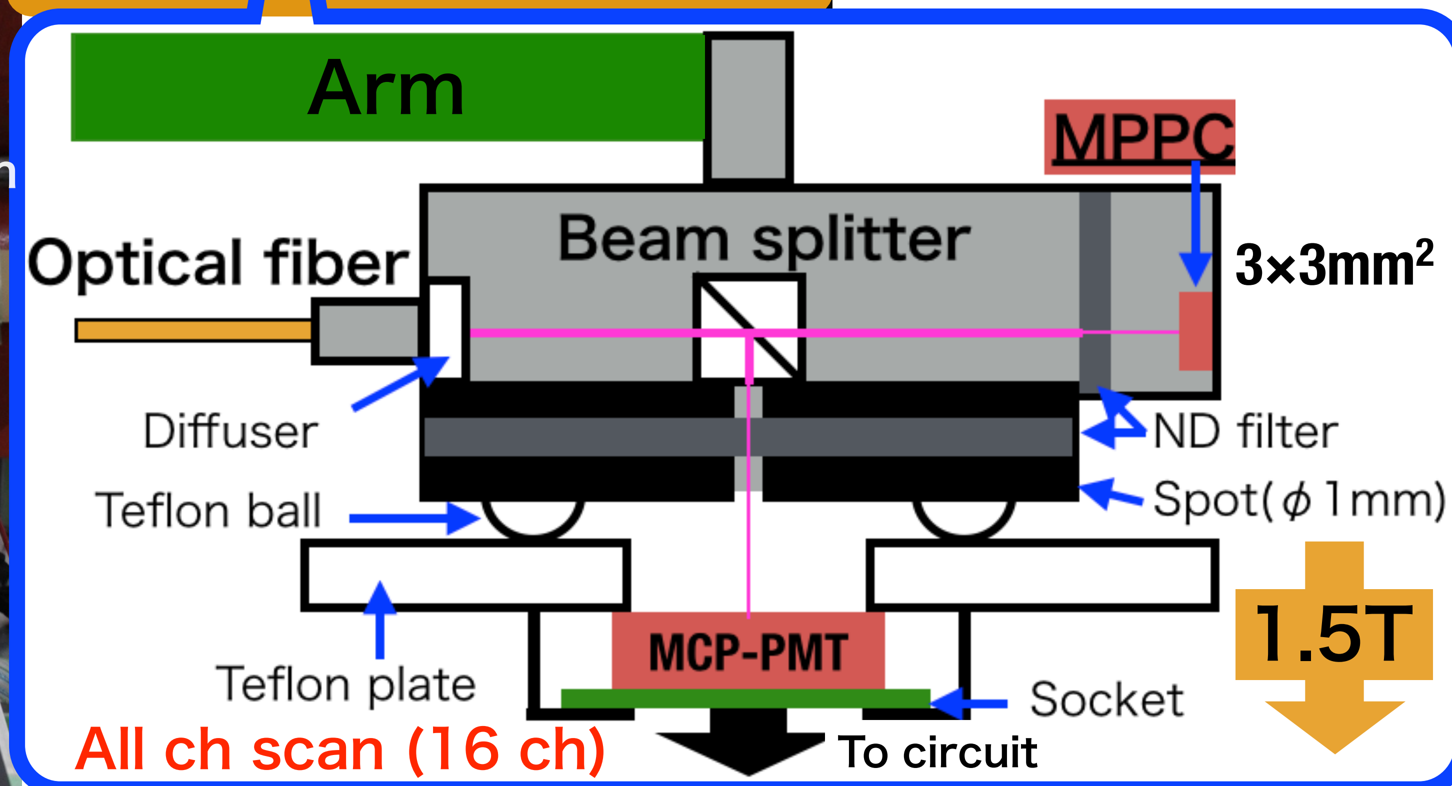
Measurement in 1.5T

Basically the setup is the same as one in 0T except for

- Put the movable stage outside of the magnet and move the jig using the G10 arm.
- Laser intensity is monitored by an MPPC.

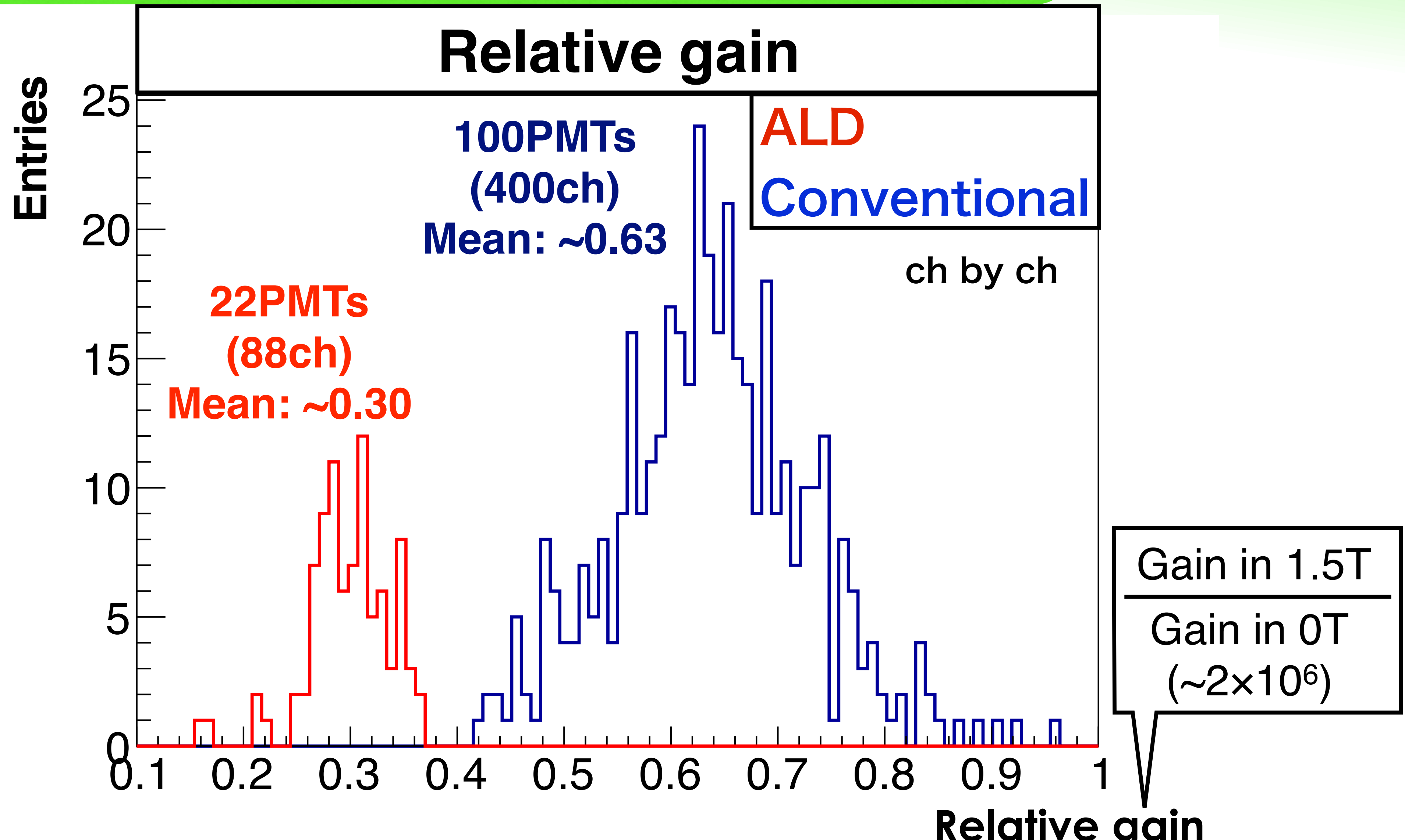






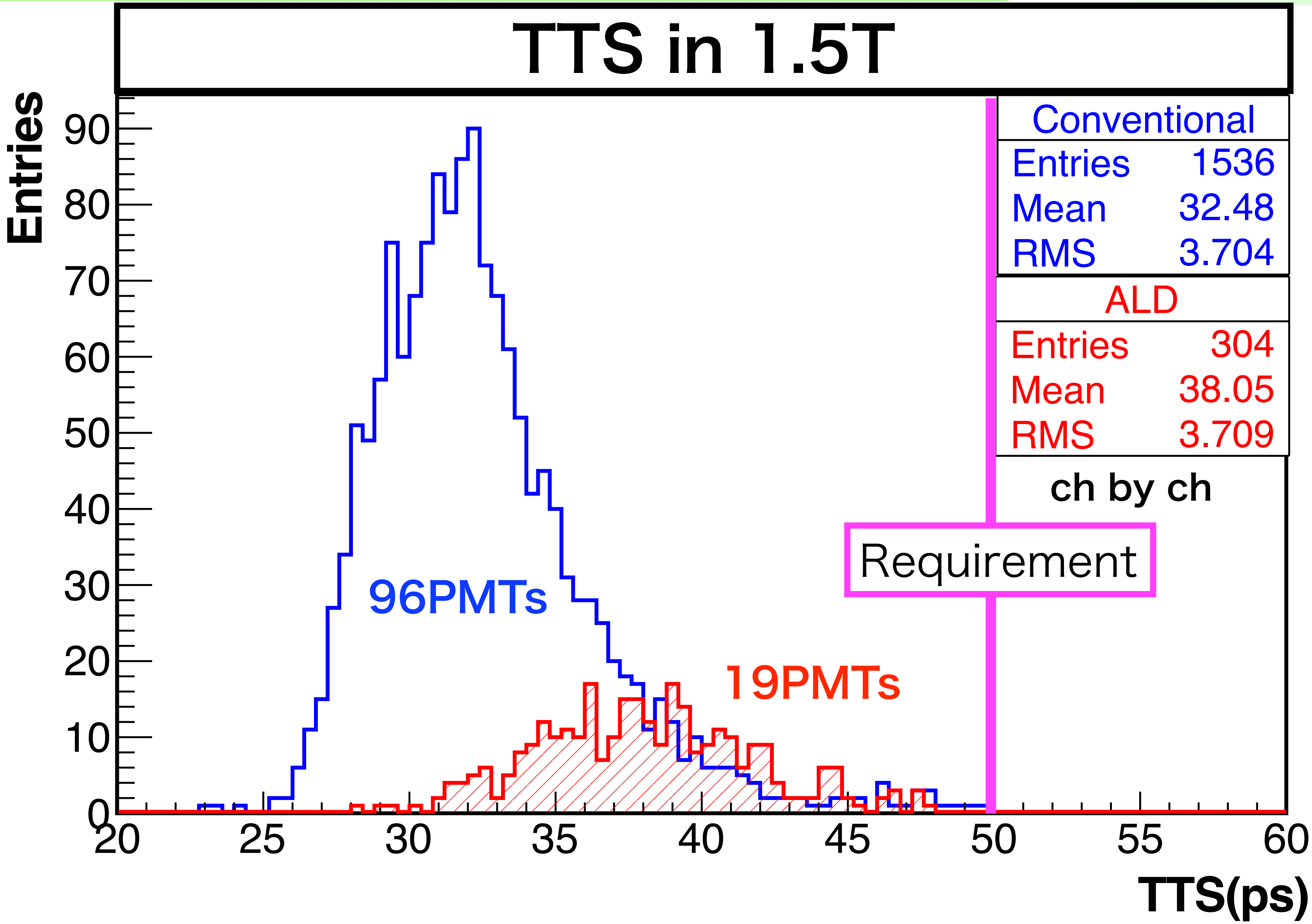
→<u>Mass measurement in this setup.</u>

Relative gain (1.5T/0T)



The relative gain of the ALD type is smaller than the conventional MCP, but it is enough to detect single photon. We can obtain enough gain to keep good TTS of less than 50 ps in 1.5 T.

1.5T TTS variation

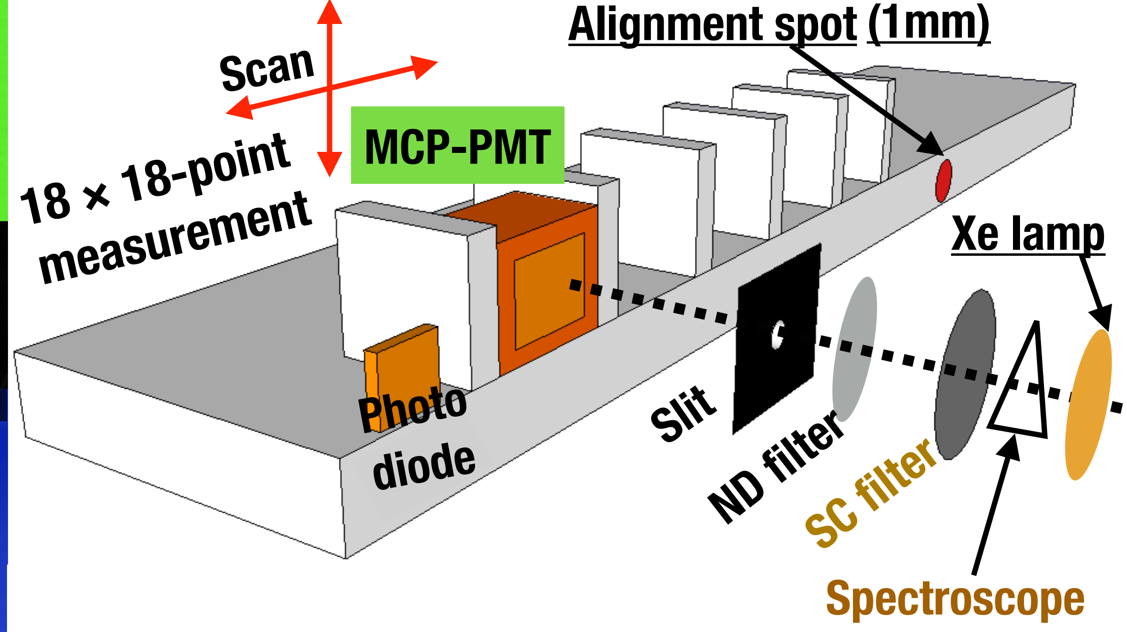


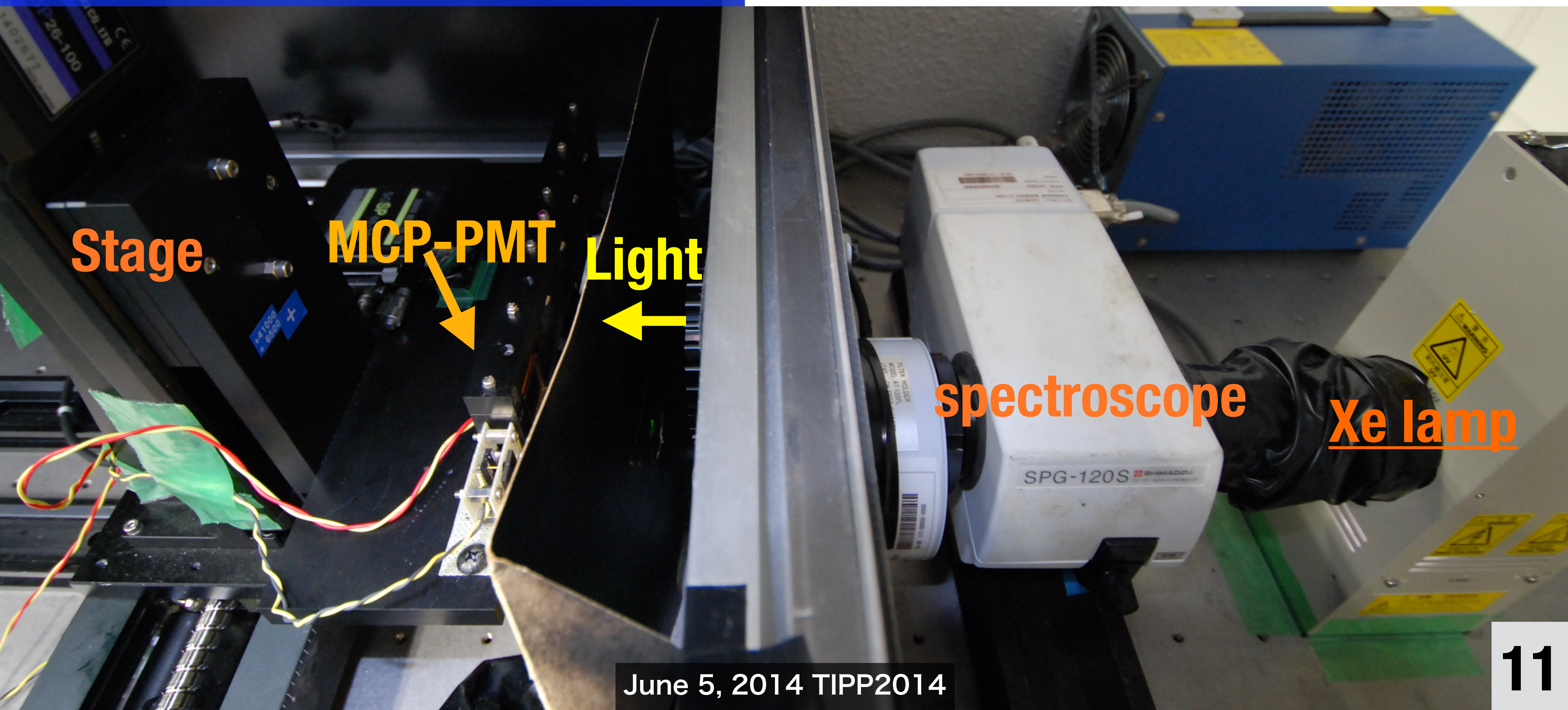
Better TTS than the requirement of 50 ps.

QE measurement

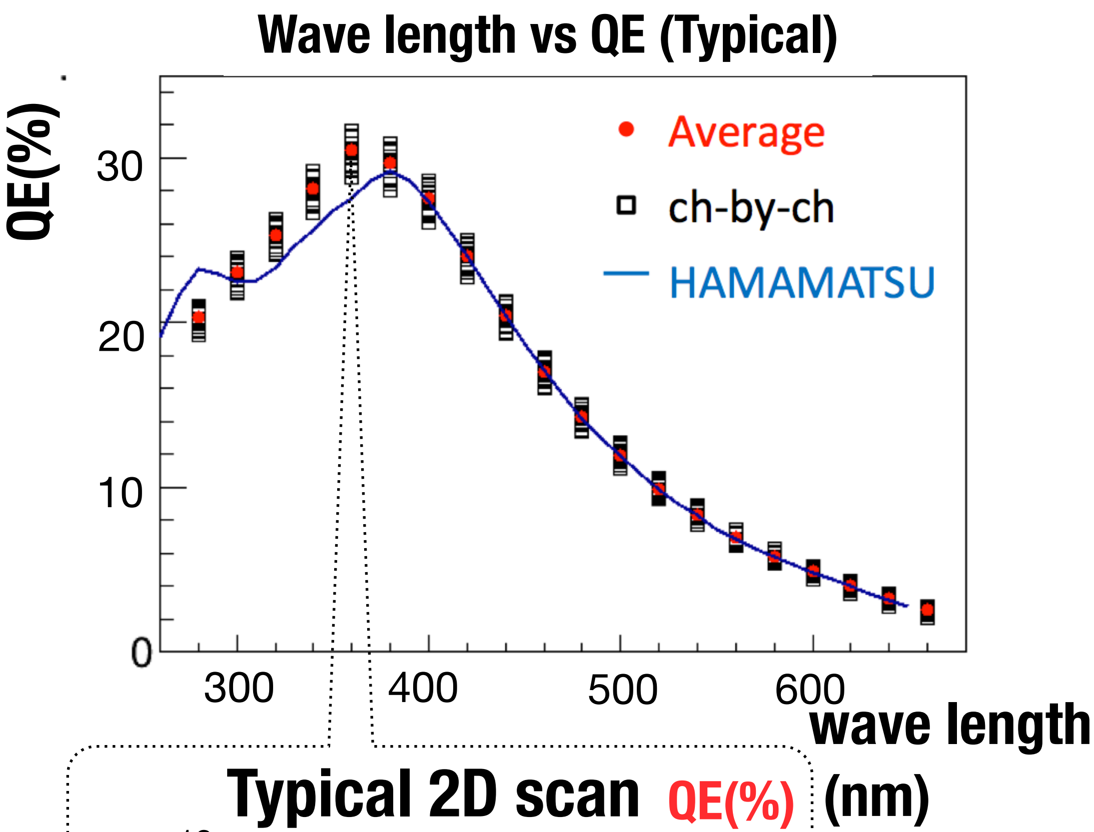
Measure the current on the photo cathode with a picoammeter.

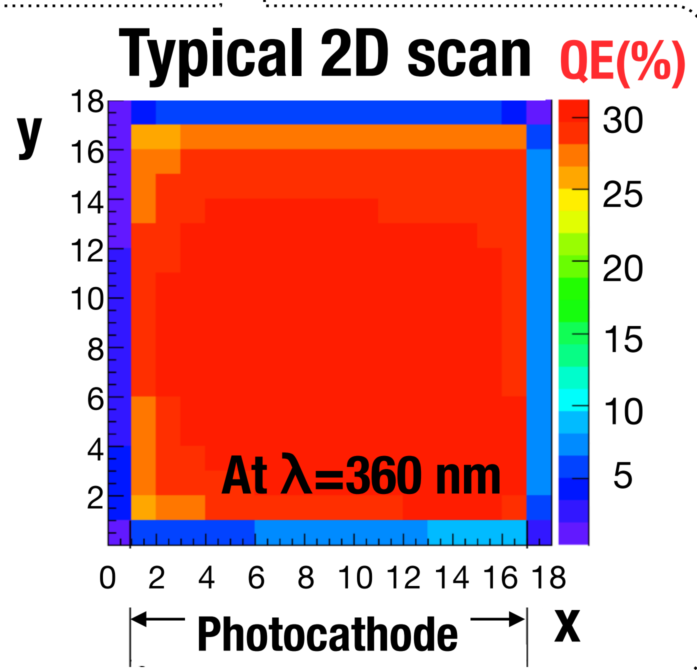
$$QE_{MCP-PMT} = \frac{I_{MCP-PMT}}{I_{PD}} \times QE_{PD}$$

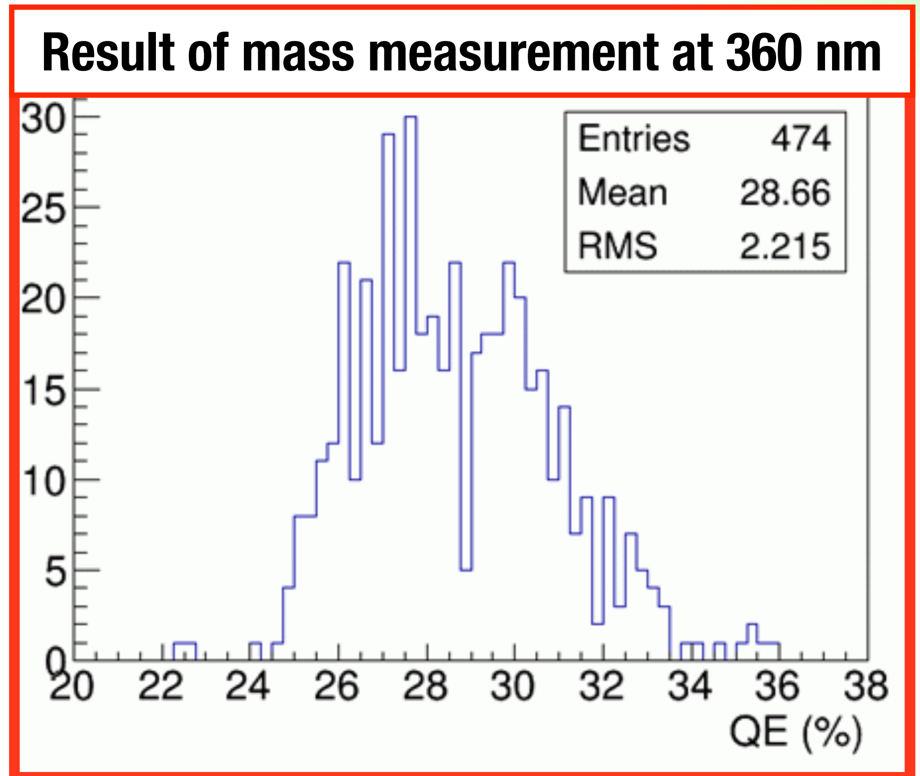




Result of QE measurement







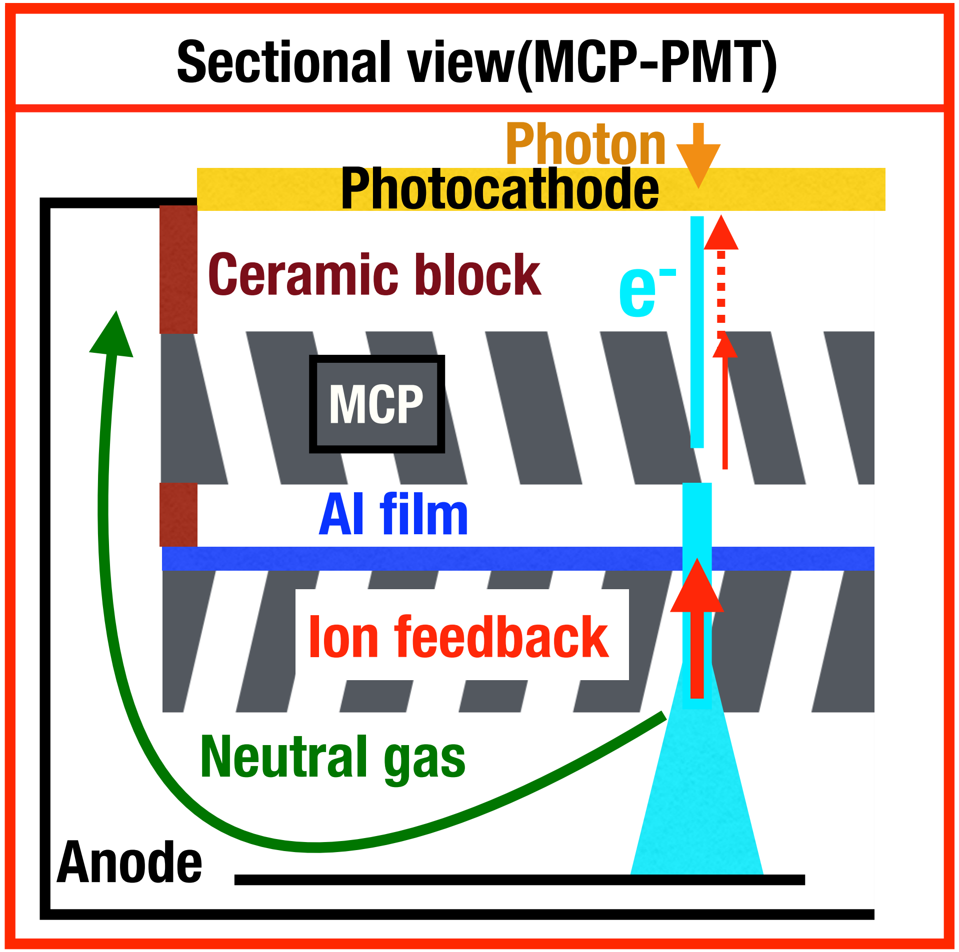
Average QE of 474 PMTs : 28.7%

Lifetime of photocathode

The photocathode is degraded by neutral gas and feed back ions desorbed from MCP by electrons.

QE drops as a function of the integrated output charge.
Define the lifetime of photocathode as the output charge where QE decreases to 80%.

Total output charge expected in Belle II is 2-4 C/cm^2/50 ab^{-1} at the 5×10^5 gain.



We checked the lifetime of the conventional and ALD MCP-PMT.

We expect a longer lifetime for ALD type, because of less out gas and ion.

Lifetime test set up of MCP-PMT

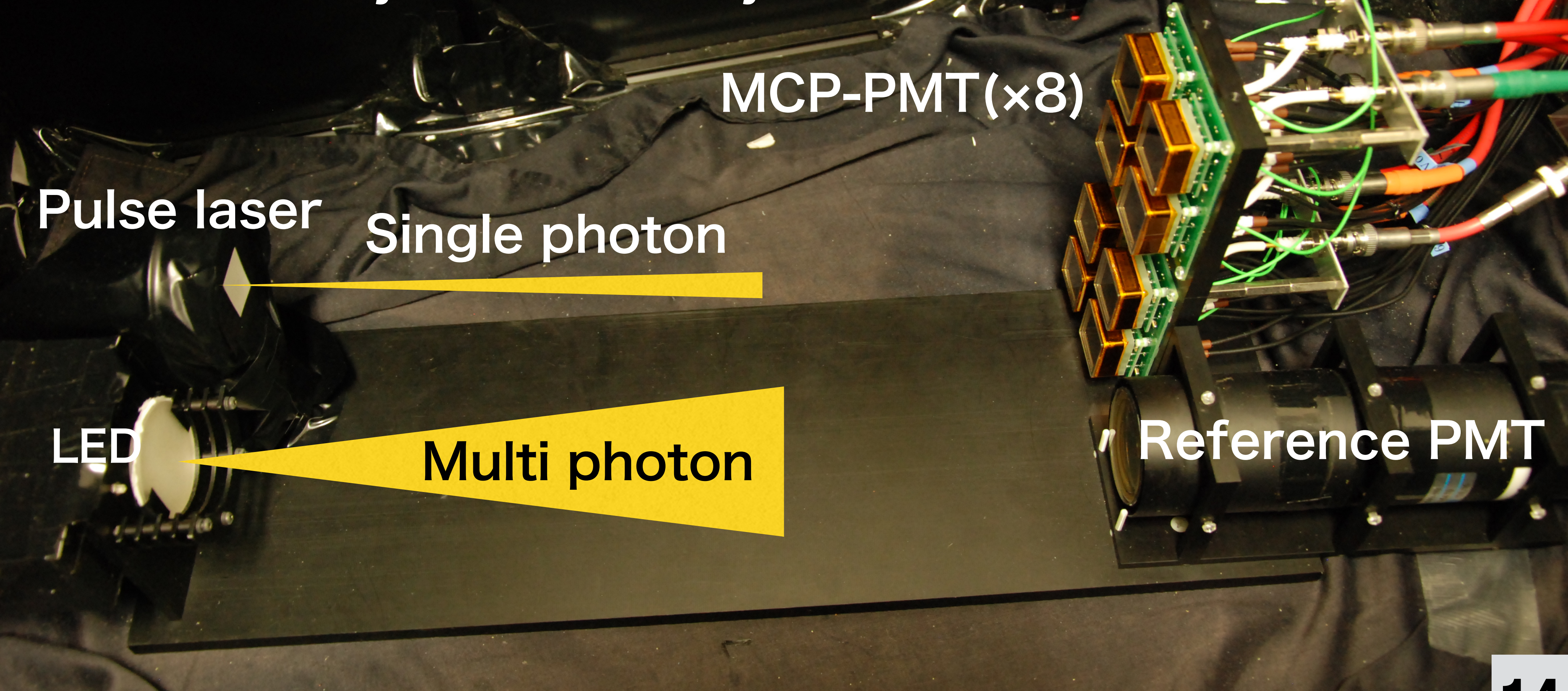
- Degrade the photocathode with LED light.

-~1 C/cm^2/month.

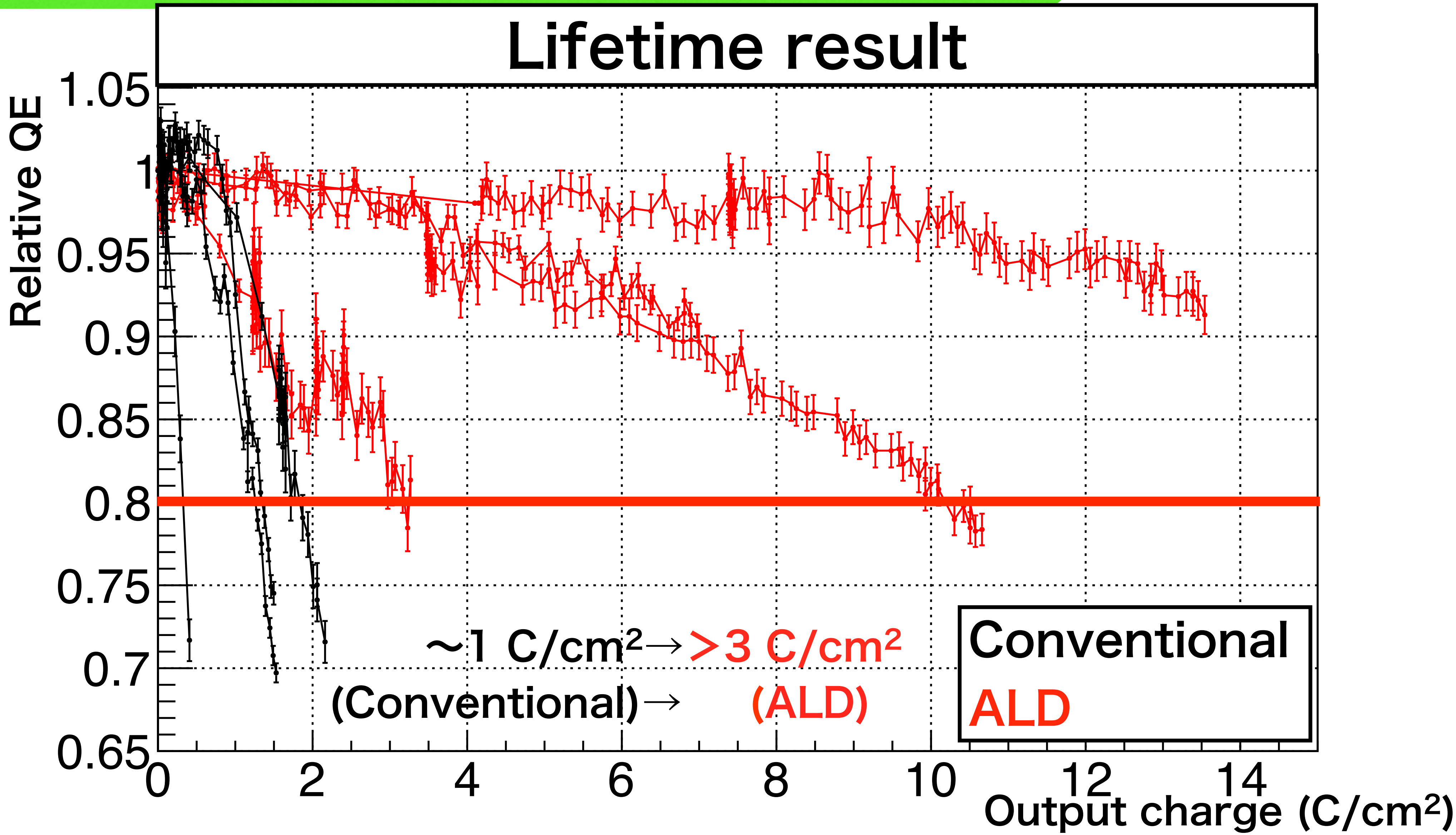
-Output charge of the MCP-PMT is measured by a CAMAC ADC.

- Monitor the hit rate(∝QE) with the laser pulse

-Laser intensity is corrected by the reference PMT.



Result of lifetime test



The lifetime of the conventional MCP is about 0.5 to 2 C/cm^2.

The ALD-MCP-PMT has a longer lifetime than the conventional one.

We are still trying to improve the lifetime further.

Summary

MCP-PMT mass production is successfully on going.

QE : ~28.7% at λ=360 nm(474 PMTs)

Gain in 1.5 T: Keep enough gain to detect single photon (122 PMTs)

TTS in 1.5T : ~40 ps (117 PMTs)

…Measurement is underway.

Lifetime of photocathode

The lifetime of the conventional MCP-PMT is about 0.5 to 2 C/cm^2 and the lifetime of the ALD-MCP-PMT is longer than 3 C/cm^2. We are still trying to improve the lifetime further.

Back up slide

Usage environment and individual difference

Individual difference

Gain

Different per ch and PMT

TTS

Degraded in less than 5×10^5 Gain.

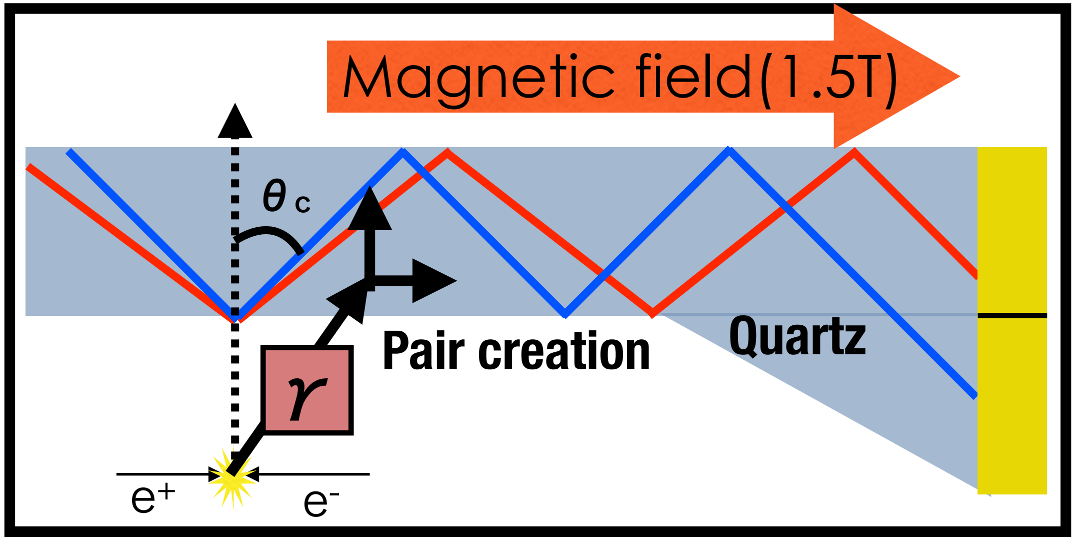
Efficiency

There is a PMT lower than 24% and non-uniform.

Measure each PMT.
→Creating a database to know the different of performance.

Usage environment

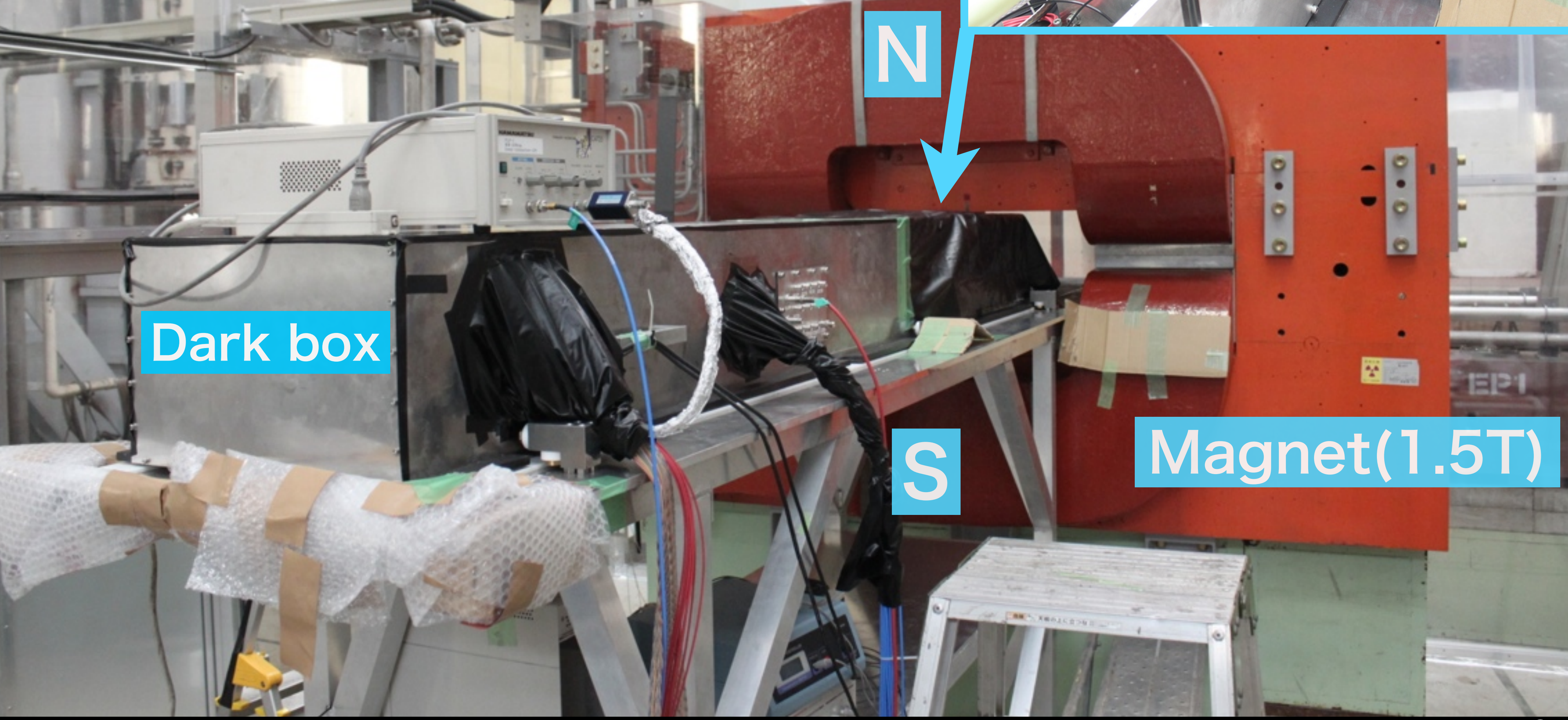
・TOP counter used in the 1.5T.
→Performance of MCP-PMTs in the 1.5T changes.
・Cherenkov photon from the background.
→Lifetime of the MCP-PMT is shorter

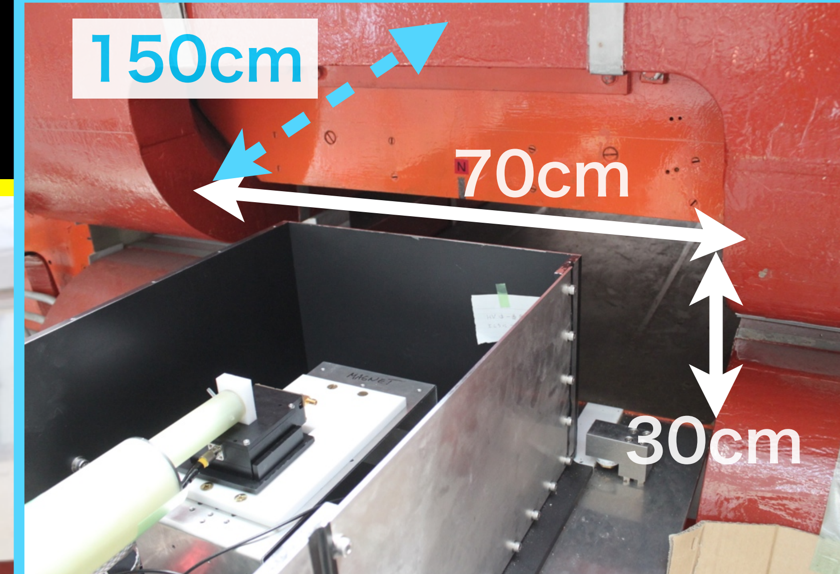


Need to measure in a 1.5T and test to lifetime.

Measurement system

North counter Hall in KEK





Measurement procedure(Gain,TTS)

<Measurement procedure>

Calibrate the amplifier and TDCs	2min
Set a MCP-PMT and scan across a channel to get its center	5min
Measure at 0T (Four ch, 1, 6, 11, and 16)	10min
Measure at 1.5T.	10min
Remove the MCP-PMT and calibrate the amplifiers and TDCs	3min
Total	30min