TOP counter for Belle II – post installation R&Ds

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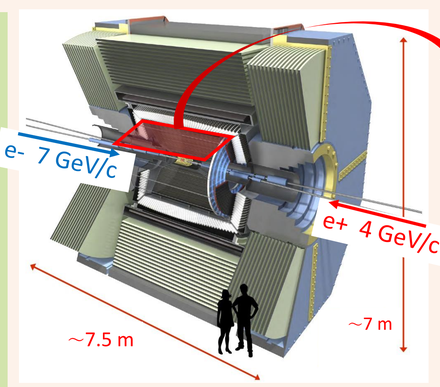
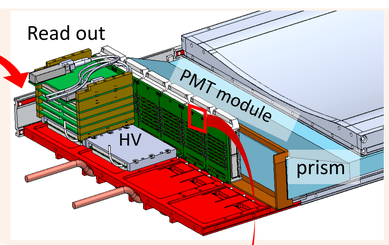
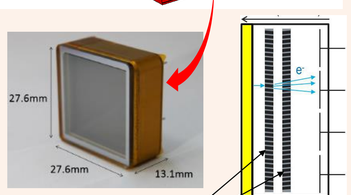
Belle II experiment

Belle ll experiment is the B-factory experiment and designed to collect 50 ab^{-1} e^+ e^- colidion data at the SuperKEKB which is a luminosity frontier accelerator. Its aims are precision measurement of the standard model and searches for new physics. The particle identification (PID) performance largely influences the physics sensitivity.

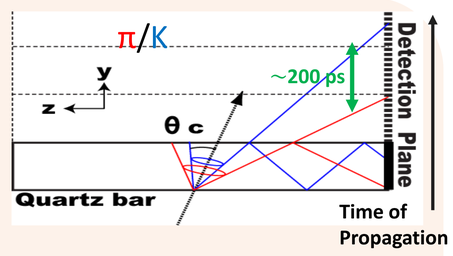






Barrel PID system (TOP counter)

The Time Of Propagation (TOP) counter is a ring image Cherenkov detector. We measure the time of propagation of the photons and separate π and K meson.

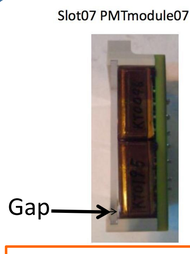


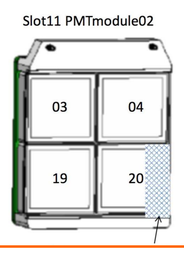
Micro Channel Plate Photomultiplier Tube (MCP-PMT)

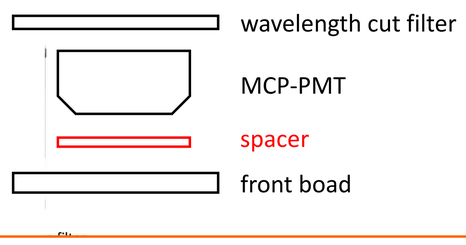
MCP-PMT is the photon detector with the best time resolution. The time resolution for a single photon is less than 50 ps. It is necessary for excellent PID performance of the TOP counter.

After TOP counter installation, we found a problem that PMT rotates in B-field. First section is the study to fix against the magnetic force. Second section is the status of TOP after installation. And the last section, we introduce the study for improvement MCP-PMT lifetime.

The measures for PMT rotation problem





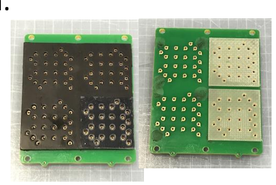


In B-field, MCP-PMT receives magnetic force(about 1 kgf), then it rotates in module and comes off the filter.
The cause is space between PMT and front board.
We consider to put spacer in that space.
There is a difference in thickness between each PMT, so we also prepare various size of shim.

	upper side	right side	down side	left side
DM0031	16.75 mm	16.78 mm	16.88 mm	16.82 mm
DM0042	16.83 mm	16.84 mm	16.87 mm	16.83 mm

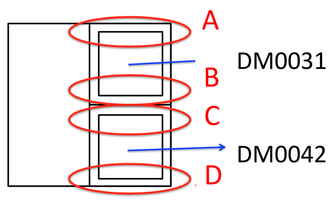
DM0031 is thinner than DM0042 and uneven.
This is caused by silicone potting on the PMT bottom.

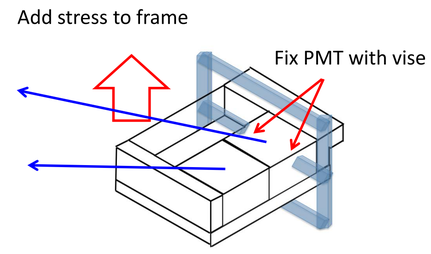
EPDM gum spacer (left, 1.5 mm) with shim(0.5 mm)
Glass epoxy spacer (right, 1.6 mm)



Destructive testing

Recording the load when PMT peel off from filter.
Fix PMT with vise and add stress to only module frame.





	DM0031		DM0042		comment
position	A	B	C	D	
epdm gum 1st	4 kgf	---	4 kgf	3 kgf	Can not record when start peeling off
epdm gum 2nd	2.4 kgf	2.5 kgf	4 kgf	3 kgf	Same sample with upper test
glass epo 1st	---	---	4 kgf	2.9 kgf	Same sample with upper test
glass epo 2nd	---	---	4 kgf	3.2 kgf	Same sample with upper test
epdm gum + shim 1st	4 kgf	4 kgf	2 kgf	2 kgf	New sample Shim is laid under DM0031
epdm gum + shim 2nd	4 kgf	4 kgf	---	---	Same sample with upper test

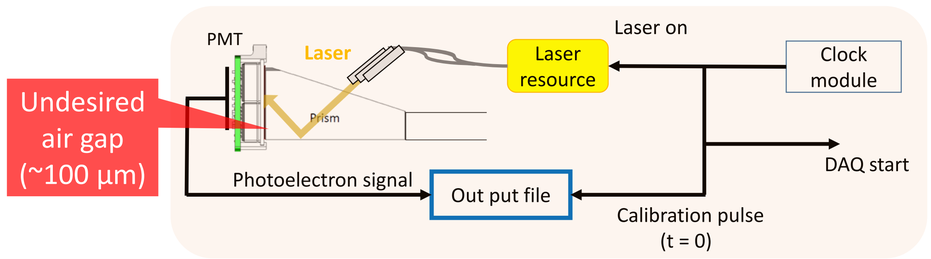
Red means PMT already peel off at before test, so recording the load when peeling off is proceeded.
Green means PMT already peel off at fixing with vise.
Blue means PMT is peeling off after making module.

In the shrot term, PMT with spacer did not peel off from filter around 1 kgf force.
We are planning a long term test.

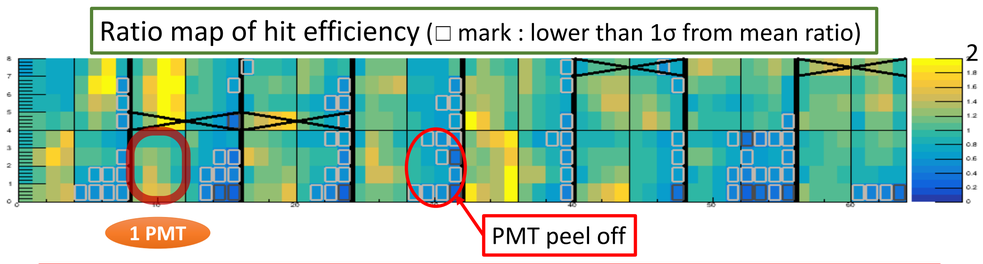
Damage to PMT optical contact

PMT rotation causes loss of photon !!

We compare laser hit efficiency at B=0 T with 1.5 T. The hit efficiency decrease at some PMTs due to optical contact breaking.



Ratio map of hit efficiency (□ mark : lower than 1σ from mean ratio)



We estimate that the bad effect of PMT rotation toward PID performance down is less than 3% .

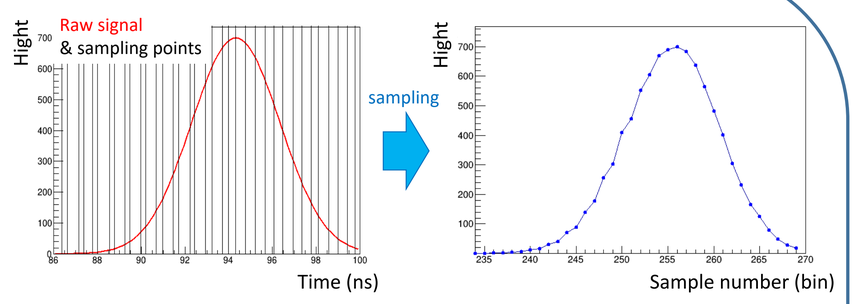
(These will be repaired during the term between superKEKB Phase 2 and Phase 3.)

Time resolution of read out electronics

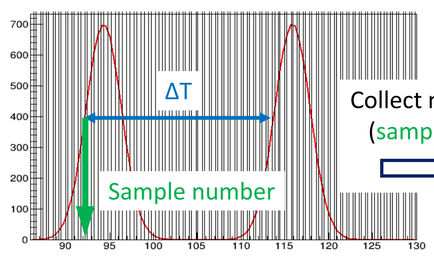
~ 50 ps resolution is also required for electronics

Read out Asic do wave form sampling every ~400 ps (**different size bin by bin !**).

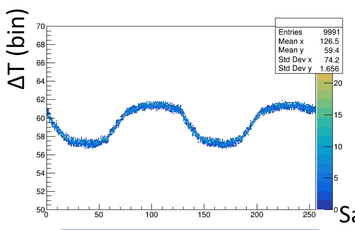
We must measure 256 bin size



1. Input 2 calibration pulses with constant time difference (ΔT) to TOP electronics
2. Get input sample number vs ΔT (bin) plot and fit 256 bin size
3. If we get constant ΔT (ns) value for all sample number, the set of bin size is correct

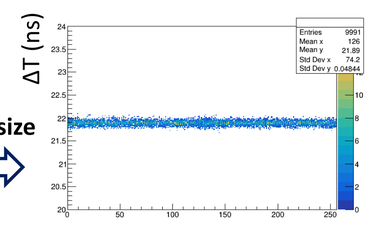


Collect many data (sample vs ΔT)



Time resolution ~600 ps

Optimize bin size



Time resolution ~50 ps

Next : We measure time resolution of laser signal (including PMT time resolution)
That is the time resolution for Belle II TOP physics run.

The measurement of after pulse for improvement MCP-PMT lifetime

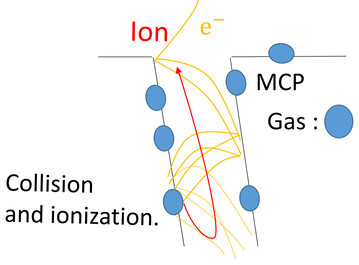
<Motivation>
- The background of Belle ll may increase more than the current estimation.
⇒MCP-PMT is required to have longer lifetime.
- The lifetime is defined by Quantum Efficiency (QE) drop of photocathode.
⇒If QE drop happen, the PID performance of TOP counter also decreases.
⇒Want to understand the mechanism of QE drop to improve the lifetime.
- The photocathode is reacted with and/or damaged by neutral gas and ion from MCP.
⇒In this study, measurement of ion's effect.

<Approach>
- When the ion interacts, it will emit electron.
- This electron can be observed as second pulse.
⇒This is called after pulse.
⇒The time difference between after pulse and main pulse relates to mass of ion : $t \propto \sqrt{m_{ion}}$

Measure three type of sample PMTs which have different lifetime.
Normal : 1 year
ALD : 8 years
Life-extended ALD : 15 years
} Lifetime of each PMT in Belle ll

Lifetime define $\frac{\text{QE}}{\text{Initial QE}} = 0.80$

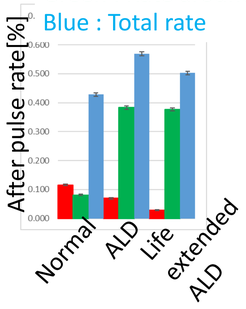
The mechanism of emitting ion



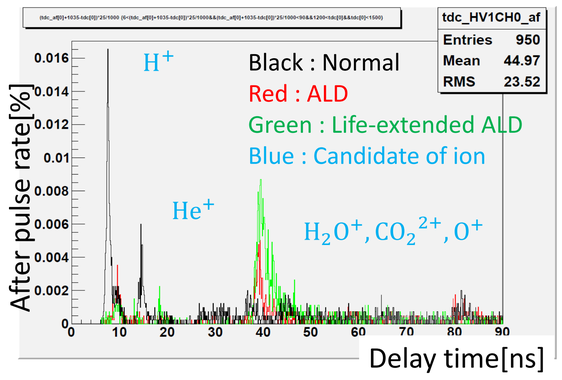
ALD stands for Atomic Layer Deposition. It is intended to suppress residual gas emitting.

The weighted mean after pulse rate of each type PMT

Red : Rate around 10 ns
Green : Rate around 40 ns
Blue : Total rate



Delay time distribution of after pulse by TDC



<Summary>
- In each PMT, the different ion arrives at the photocathode.
⇒Normal : H^+, He^+
ALD coating : H_2O^+, CO_2^{2+}, O^+
- The total after pulse rate is no correlation of PMT type.
- ALD and life-extended ALD don't have clear difference.