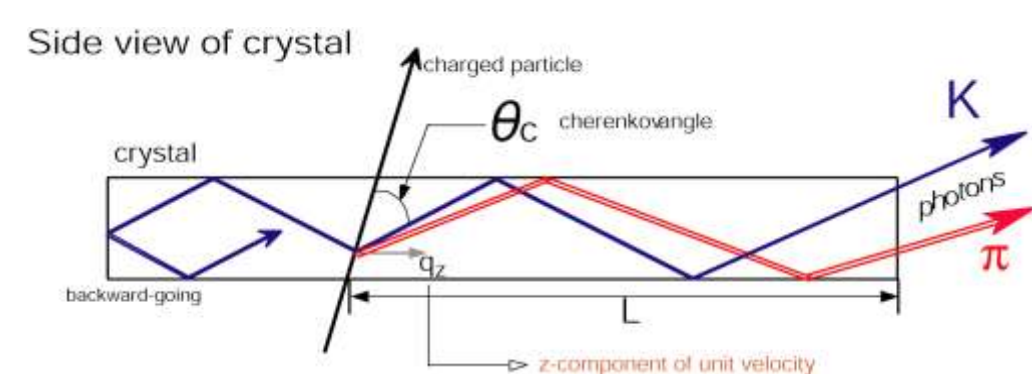
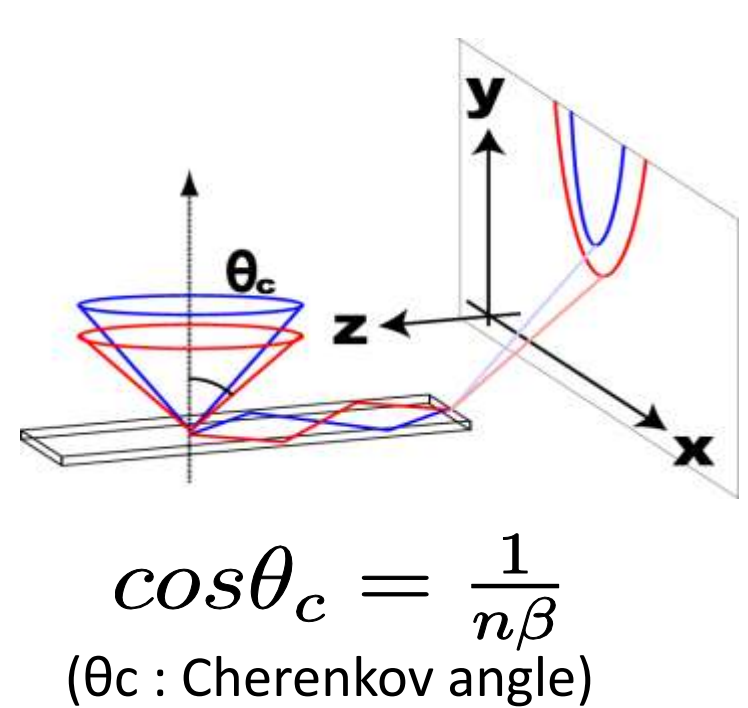


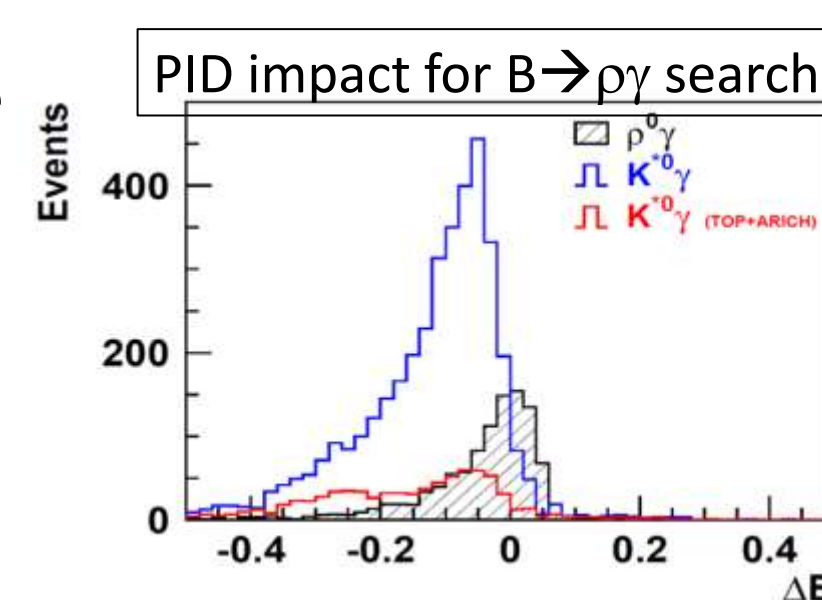
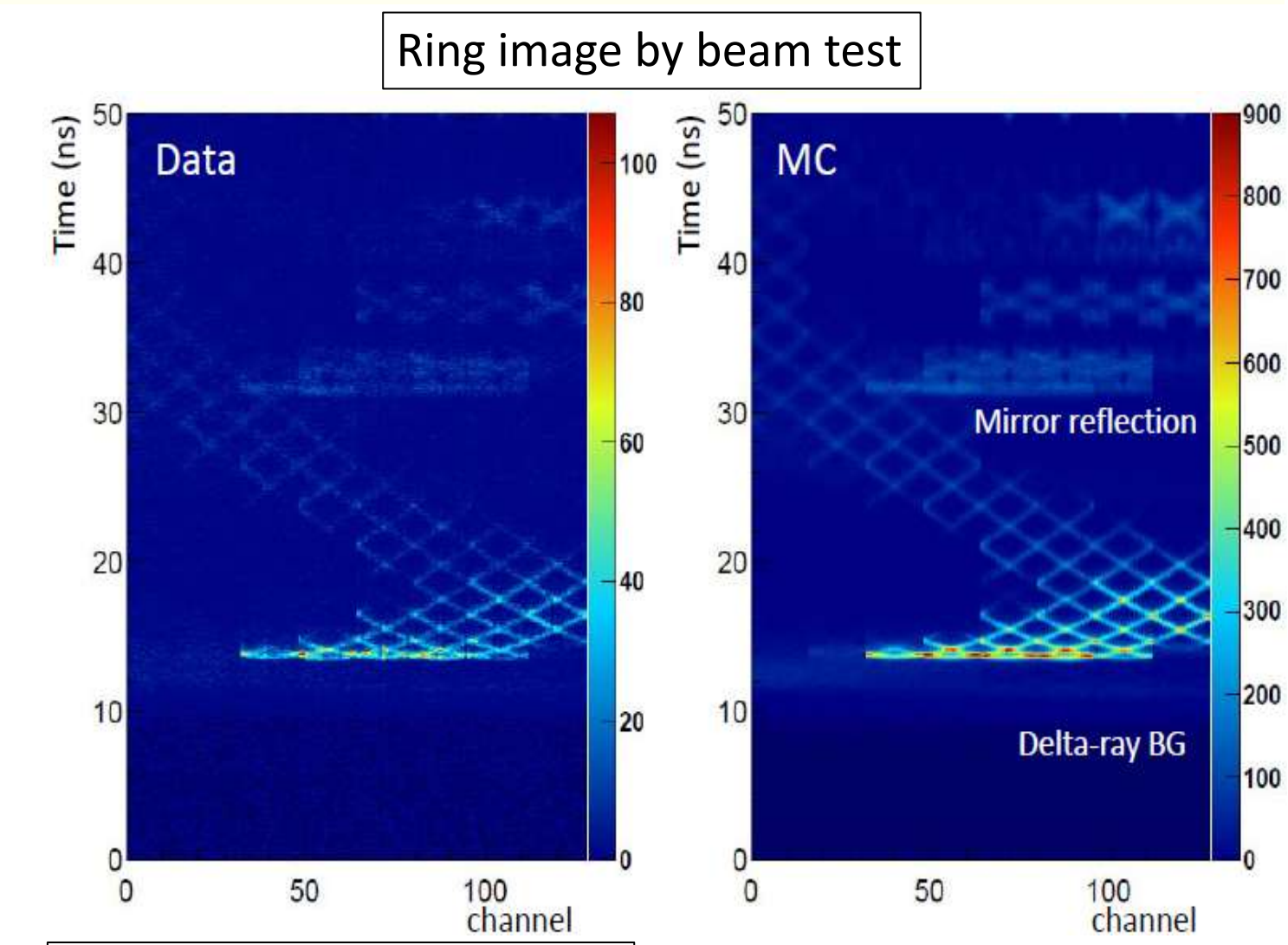
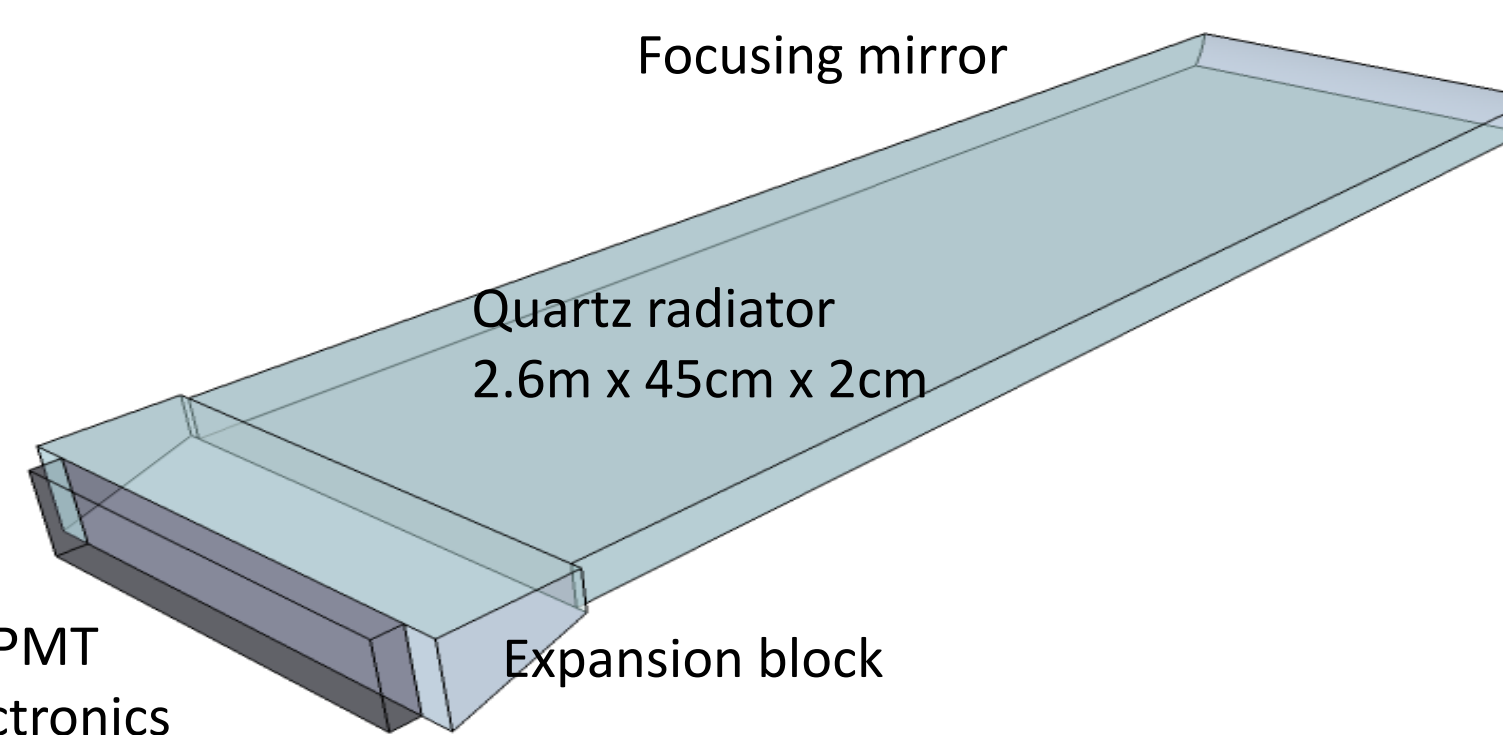
Abstract: We have developed 1-inch square-shaped Micro-Channel-Plate PMT (MCP-PMT) for the barrel particle identification detector, named Time-Of-Propagation (TOP) detector, at the Belle II experiment. The TOP detector utilizes the precise timing measurement to reconstruct the charged particle velocity through the Cherenkov ring image and the time-of-flight information. The MCP-PMT realizes the timing measurement with <50ps precision for single photon detection.

We have tested over 600 MCP-PMTs including spares, and installed 512 of those into the Belle II TOP detector. Along with the mass production, we have studied to improve the MCP-PMT photo-cathode lifetime. By applying Atomic-Layer-Deposition (ALD) technique on MCP and further residual gas reduction process, the lifetime have improved significantly. The improved PMTs are also installed. To understand the mechanism of photo-cathode deterioration, we measure feed-backed ion's signals using developed MCP-PMTs and studied the correlation between the rate and the lifetime.

New ring imaging Cherenkov detector, named "TOP detector" will be used for K/π particle identification in Belle-II barrel region, which measures the time-of-flight and time-of-propagation of internal reflected photons. TOP detector consists of the quartz radiators, a focusing mirror and an image expansion block, in order to correct for chromaticity and increase the number of effective detected photons.



Cherenkov photons are emitted in the quartz bar, and propagate to the MCP-PMT. Cherenkov ring image is reconstructed not only by x-y position but also with time information. TOP detector utilizes the time-of-flight information additively. Therefore, TOP detector requires a good time resolution, less than an order of 100ps for single photon detection.



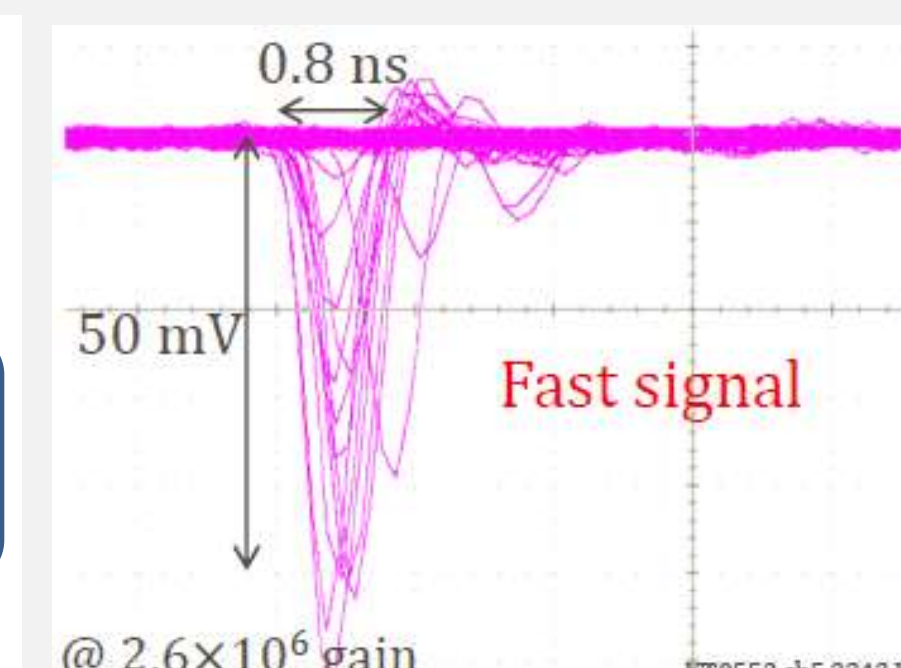
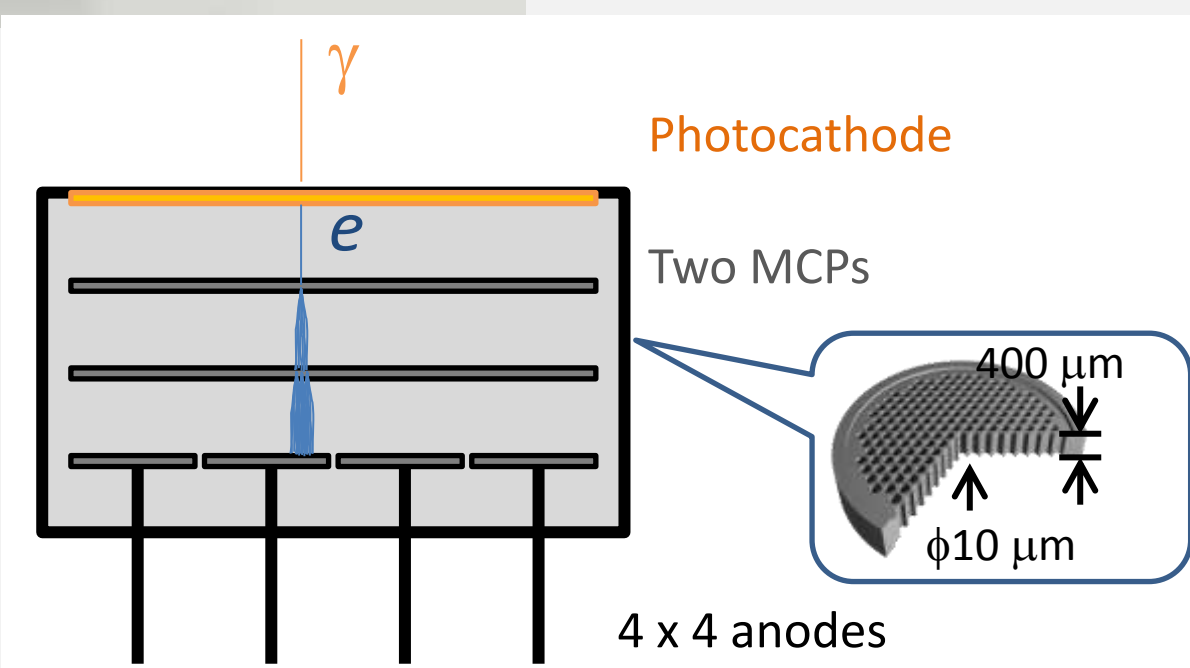
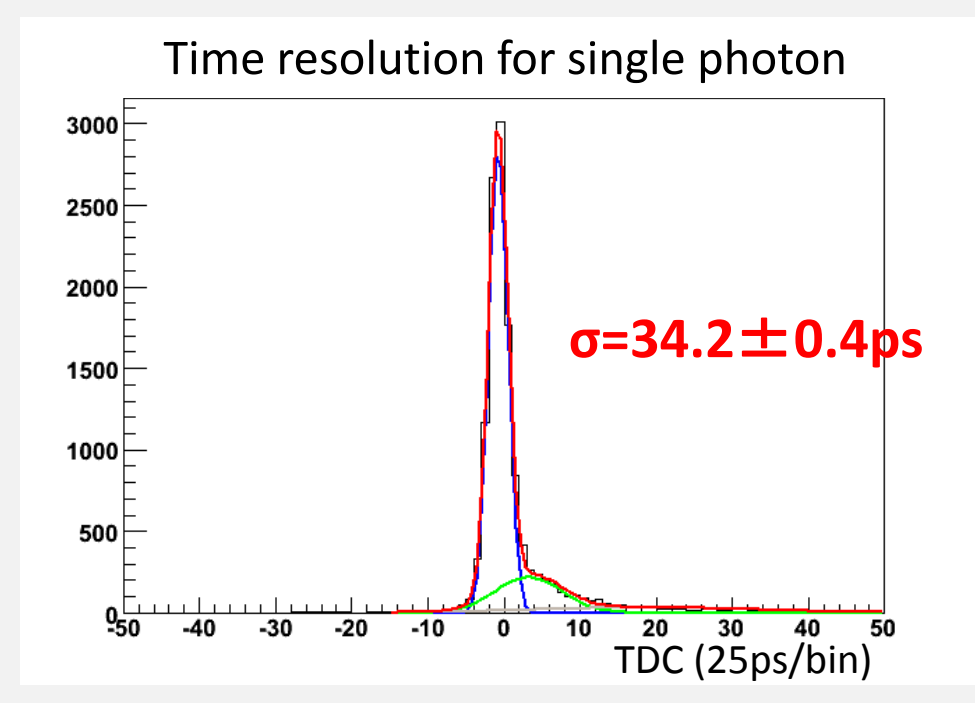
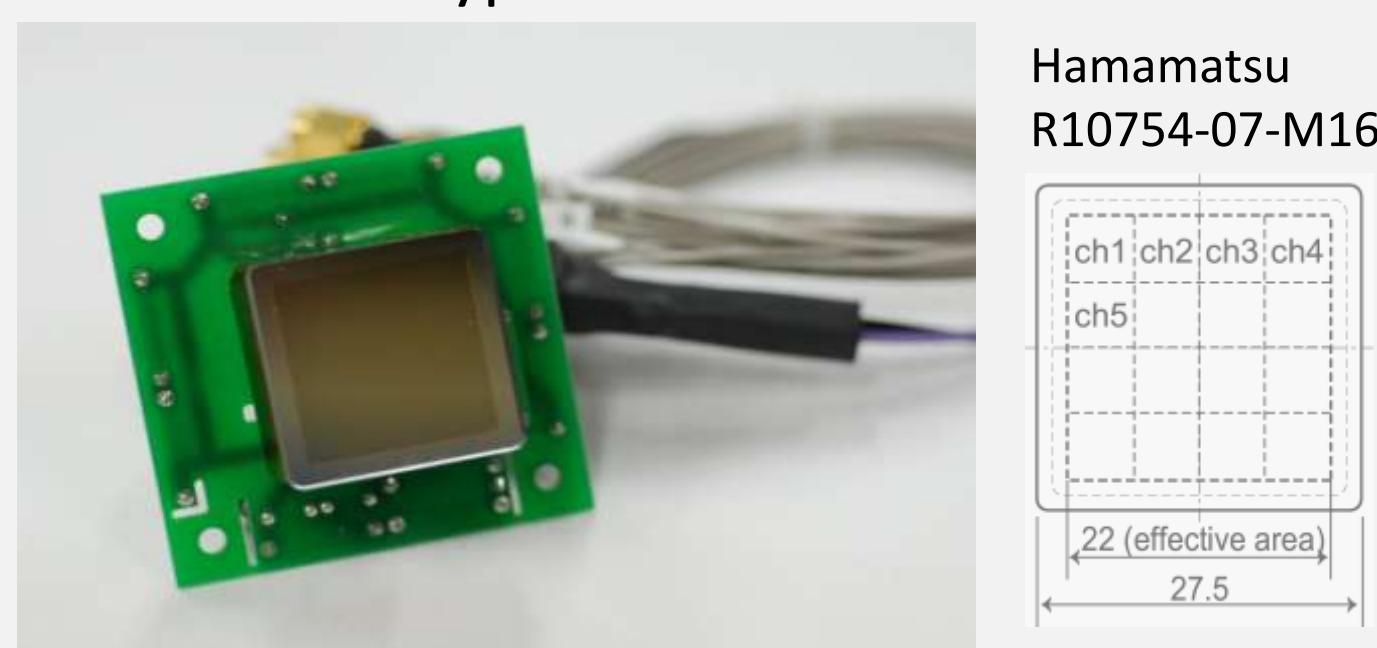
Target PID performance

π/K separation	Belle (ACC+TOF)	New PID (TOP counter)
Efficiency	90%	97%
Fake rate	11%	2%

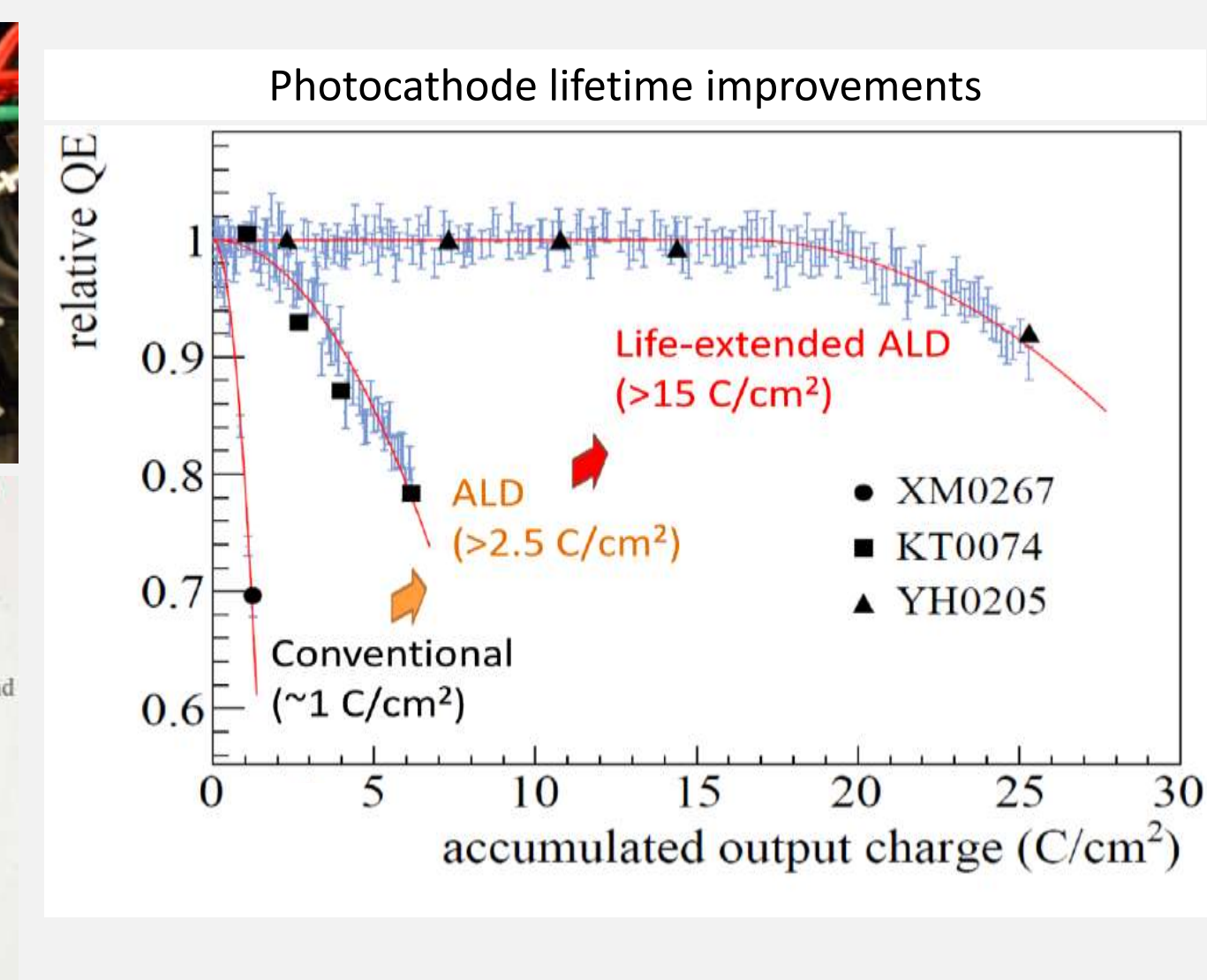
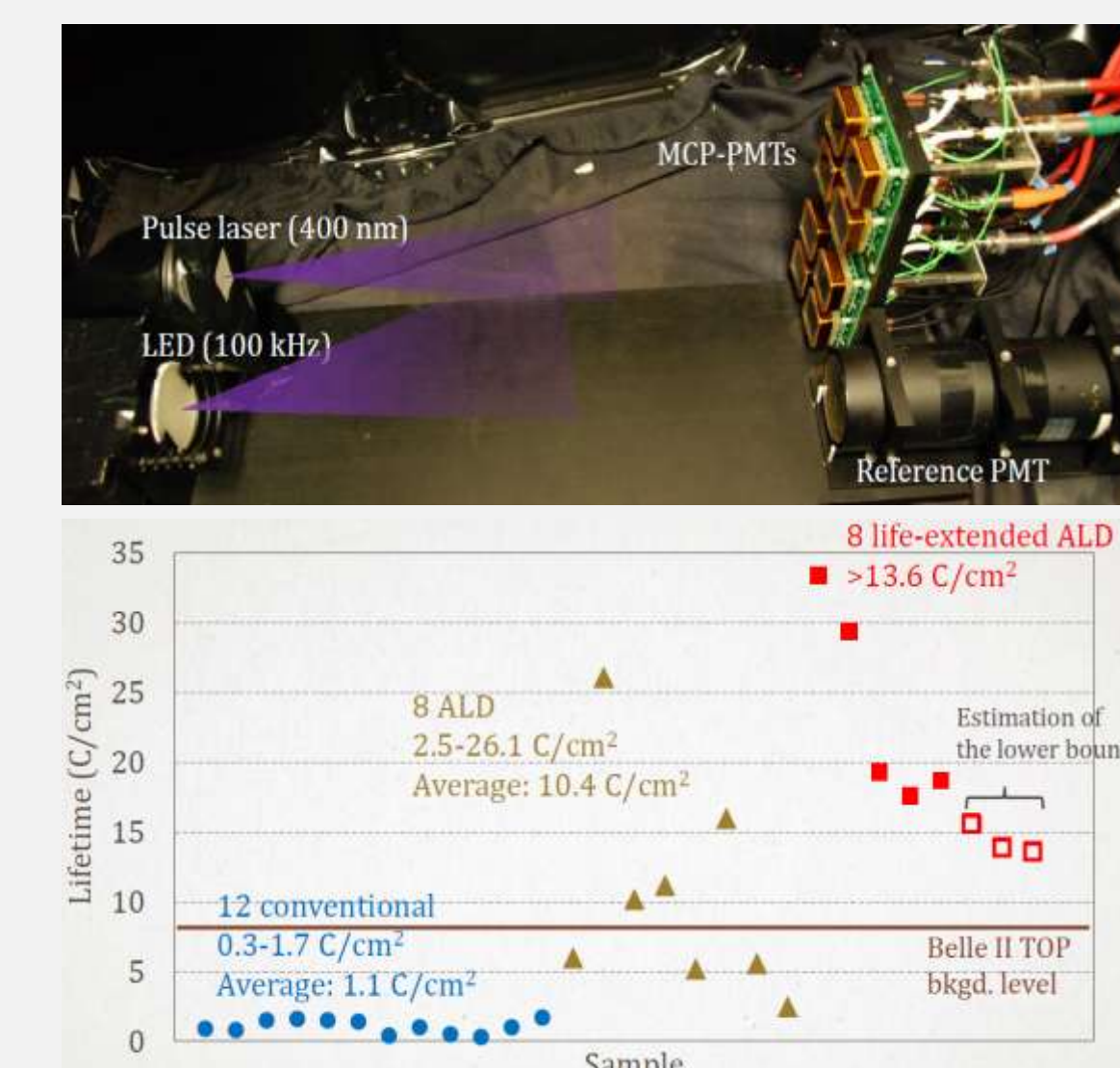
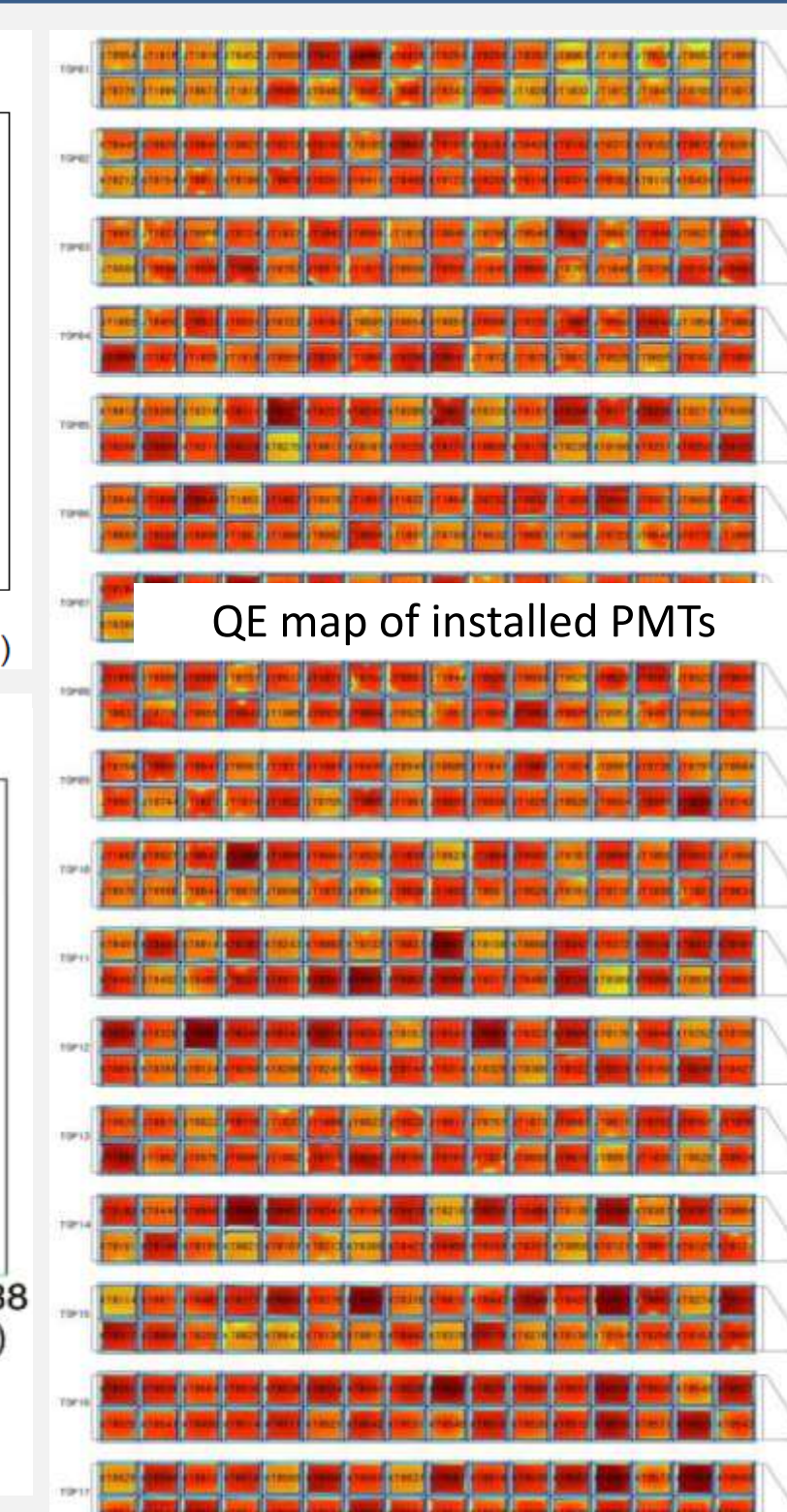
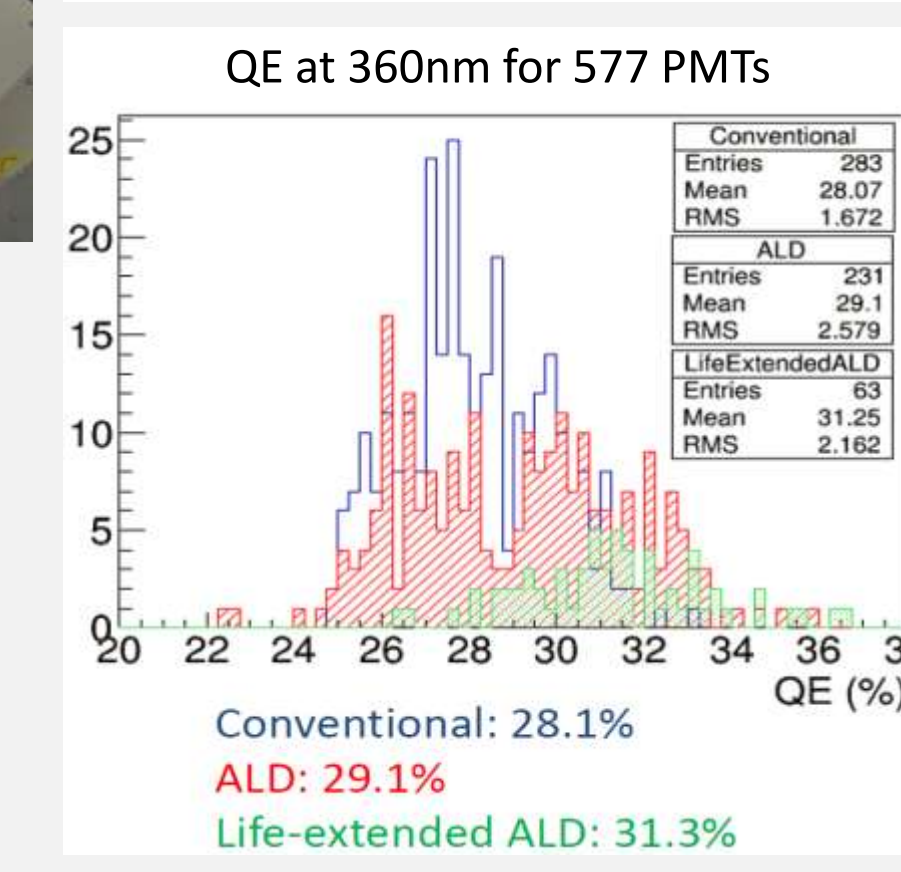
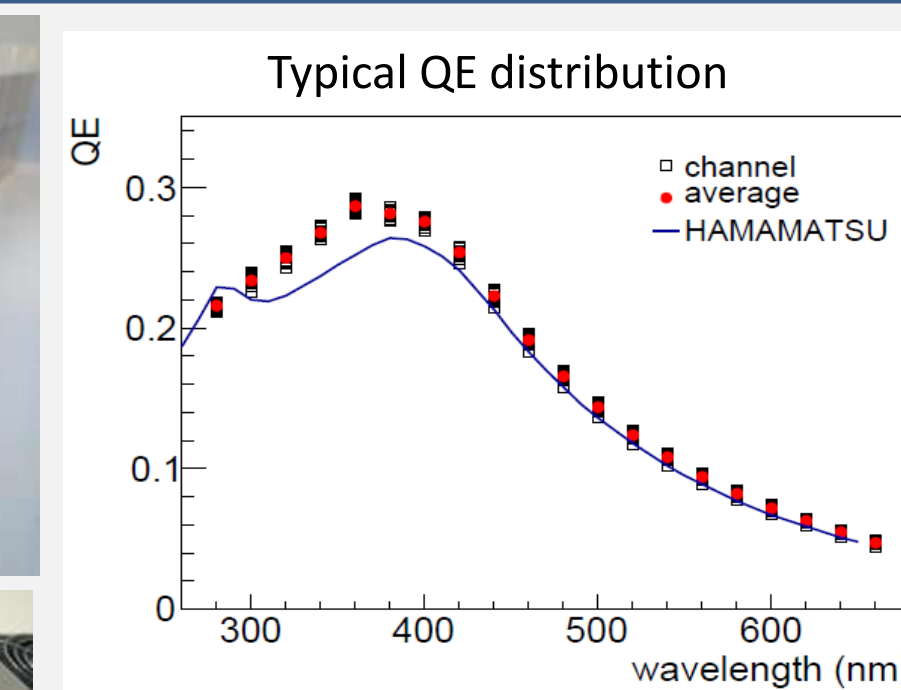
Micro-Channel-Plate (MCP) PMT for Belle II TOP

MCP-PMT enables to detect single photon with a high timing precision of $\sigma < 40ps$ even under a 1.5T magnetic field. It is suitable for TOP detector which utilizes small number of Cherenkov photons inside solenoid magnet. Enhanced photocathode has been adopted to increase the number of detected photons. Mass production for Belle II TOP detector has been performed with the stable performance of TTS $\sigma < 40ps$ and QE 28-31%. During the mass production, photocathode performance was improved gradually. We checked the performance of >600 PMTs and installed 512 PMTs. The lifetime was also improved during production by adopting ALD coated MCP. We also have developed further life-extended MCP-PMT with Hamamatsu photonics K.K.

The half of installed PMT have the conventional MCP and are expected to reduce the QE less than 80% of initial value during Belle II run. We plan to replace those conventional PMTs at around 2020 and already started second mass production of life-extended type.



Measurement system



Study on photocathode lifetime

We have successfully improved the lifetime of photocathode in MCP-PMT, however it is still shorter than traditional PMTs. To understand the reason, we have performed the measurement of feed-backed ions and checked the correlation with lifetime. We found larger ion rate for ALD type than conventional one, and no clear correlation between those ions and the lifetime. It indicates that the feed-backed ions do not damage the photocathode condition primarily and other contribution, such as neutral gas, determines the lifetime for ALD type.

