Particle ID at Belle-II

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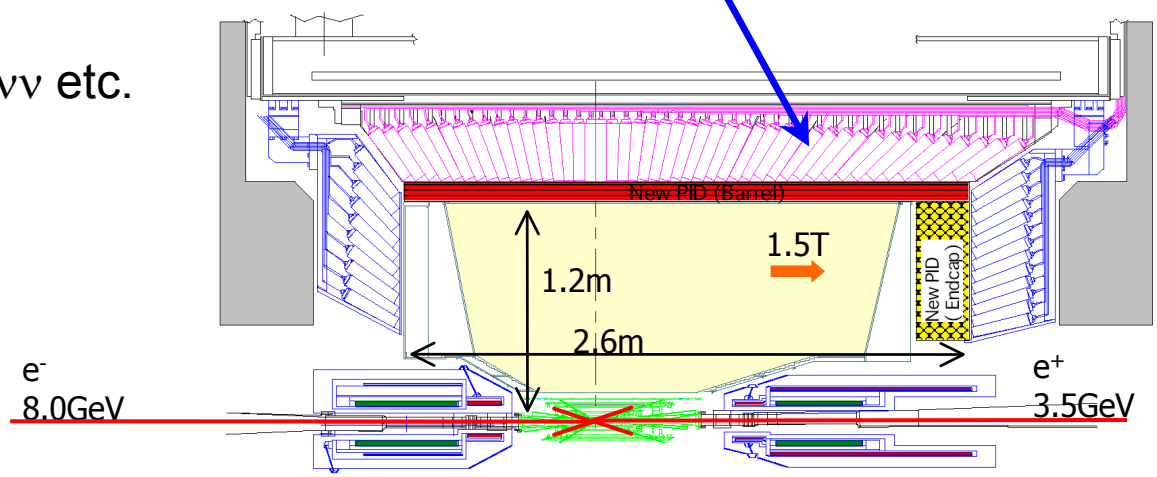
Introduction

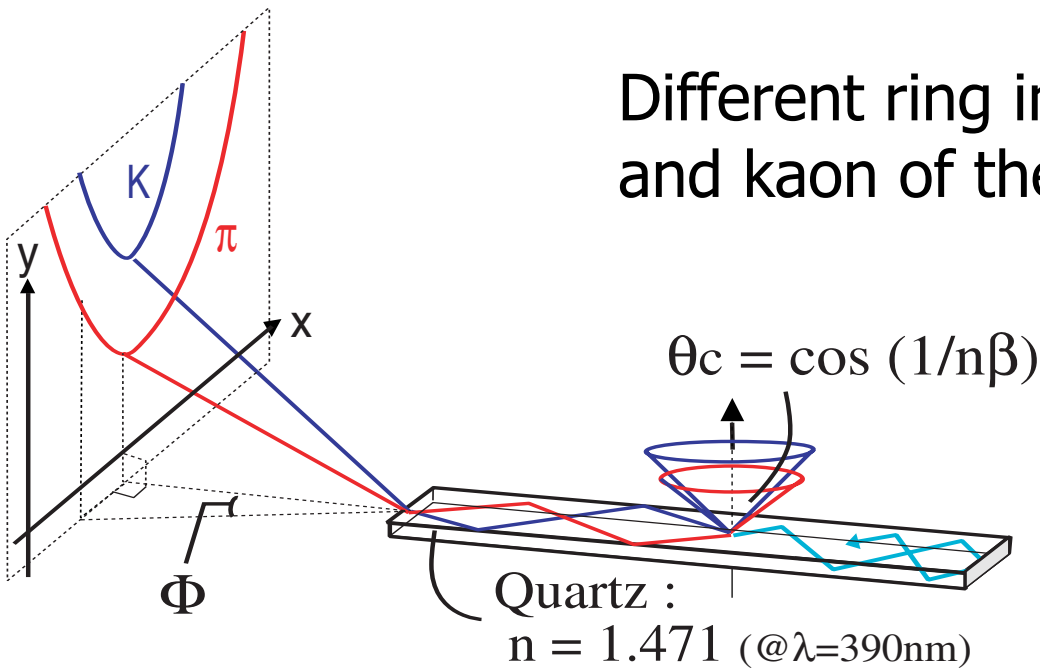
- TOP (Time Of Propagation) counter
  - Developing to upgrade the barrel PID detector
  - For super KEKB/Belle-II
    - L_{peak}~8x10^{35}/cm^2/s, ~50 times higher than present
      - Need to work with high beam BG
  - To improve K/π separation power
    - Physics analysis
      - B→$\pi\pi$/Kπ, $\rho\gamma$, K$\nu\nu$ etc.
    - Flavor tag
    - Full reconstruction



Side view of **Belle II** detector

TOP counter

- Cherenkov ring in quartz bar
  - Reconstruct ring image using ~20 photons on the screen reflected inside the quartz radiator as a DIRC.
    - Photons are detected with photon detectors.



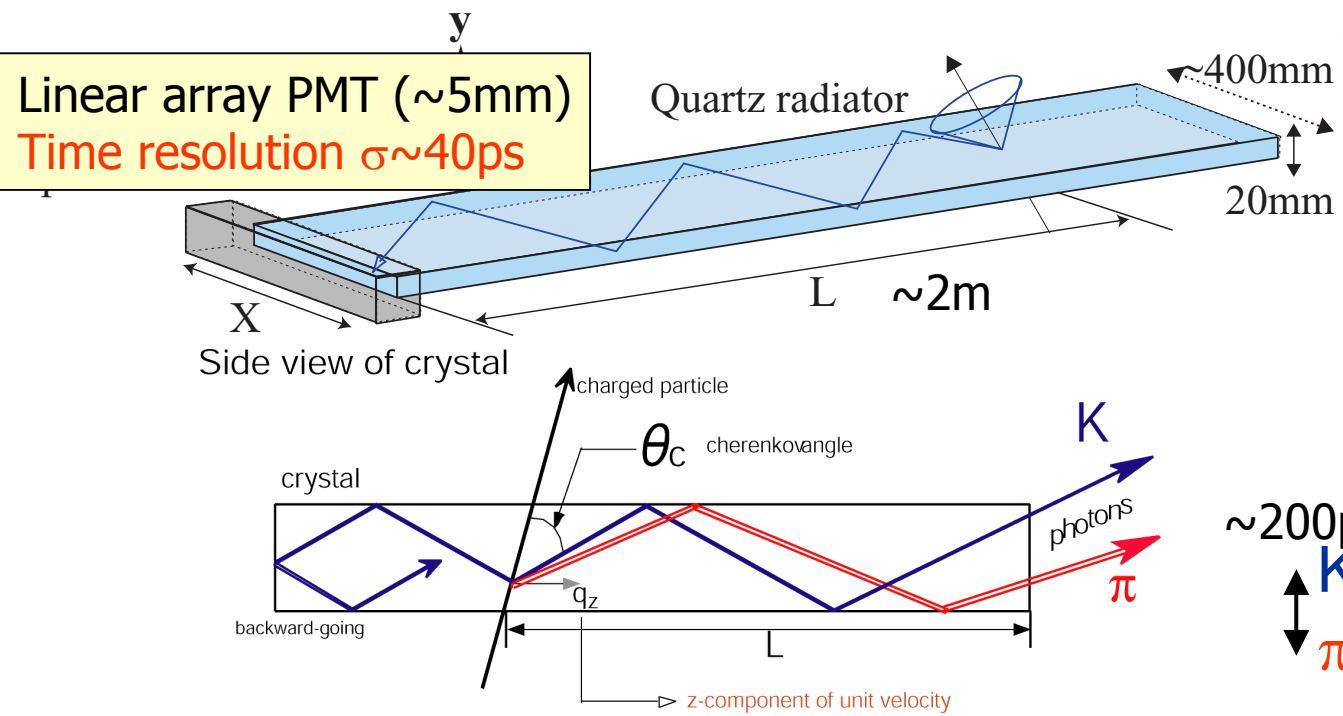
Different ring image for the pion and kaon of the same momentum

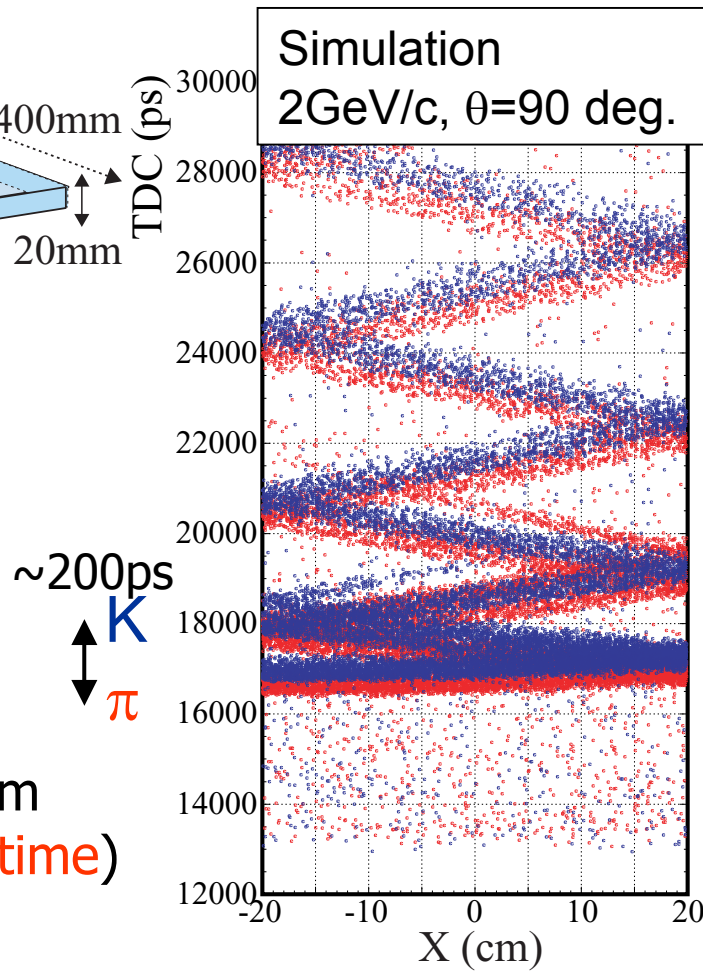
Need large screen...

TOP counter

- 2D position information → Position+Time
  - Compact detector!

Linear array PMT (~5mm)
Time resolution σ~40ps

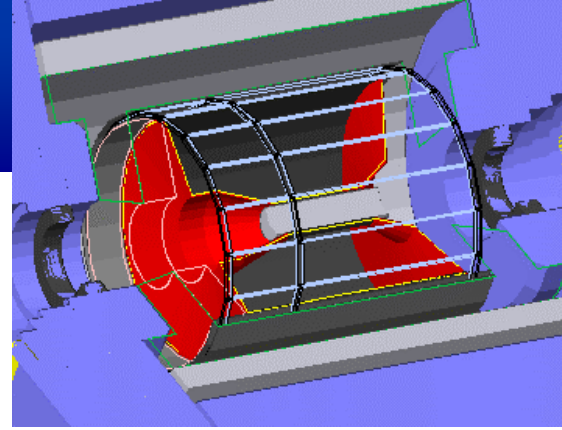




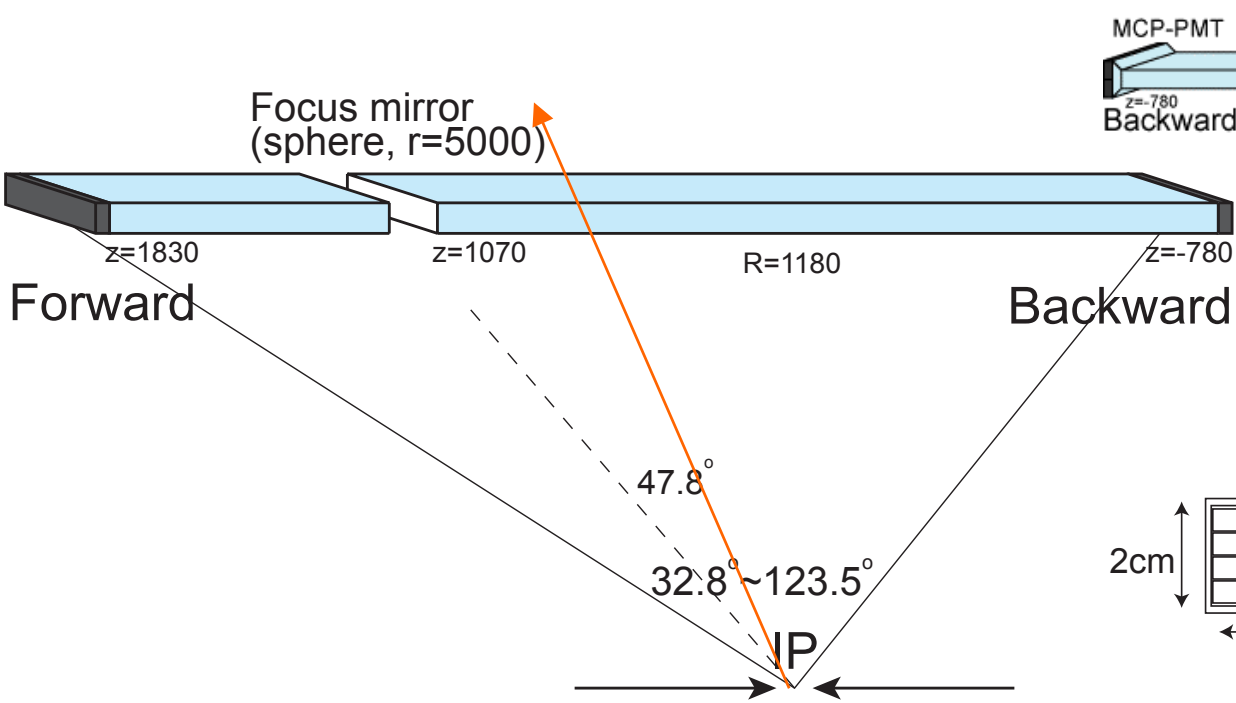
Different opening angle for the same momentum
→ Different propagation length(= propagation time)

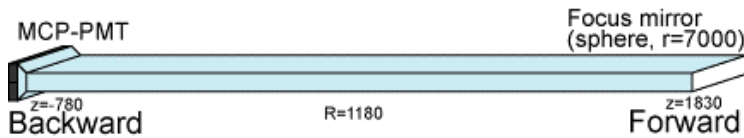
+ TOF from IP works additively.

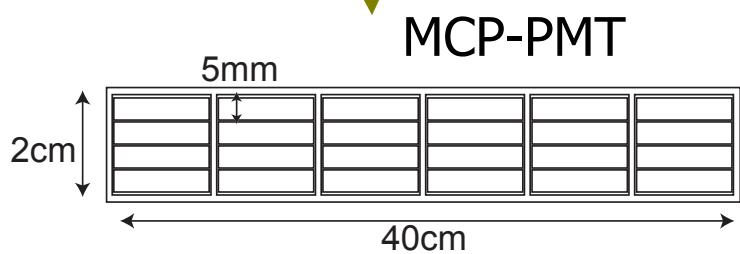
TOP counter



- Quartz: 255cm^{L} x 40cm^{W} x 2cm^{T}
  - Focus mirror at 47.8deg.
    to reduce chromatic dispersion
- Multi-anode MCP-PMT
  - Linear array (5mm pitch), Good time resolution (<~40ps)
  - → Measure Cherenkov ring image with timing information

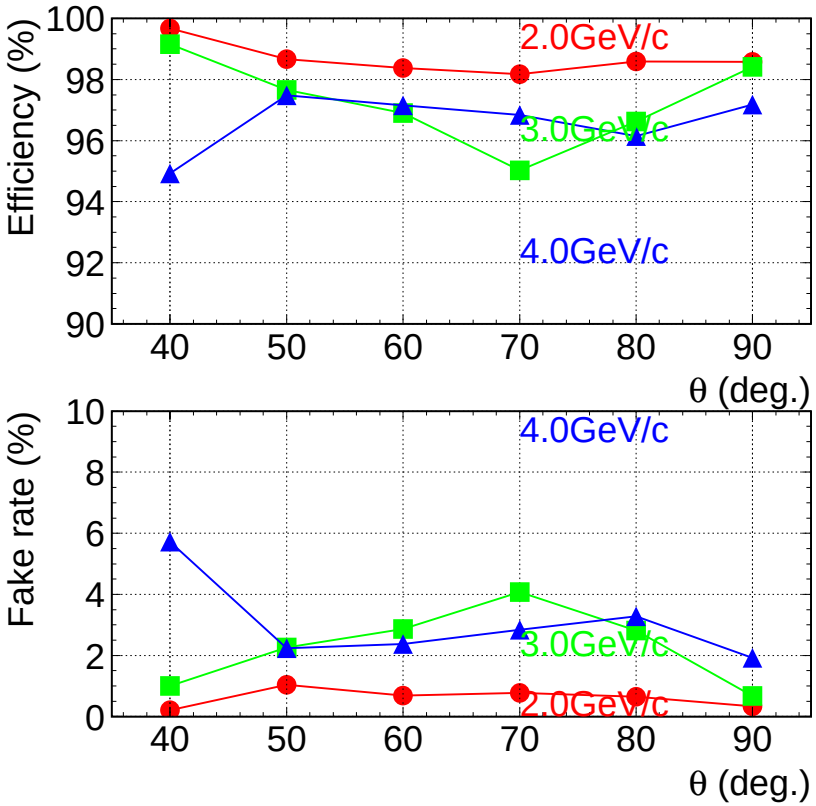






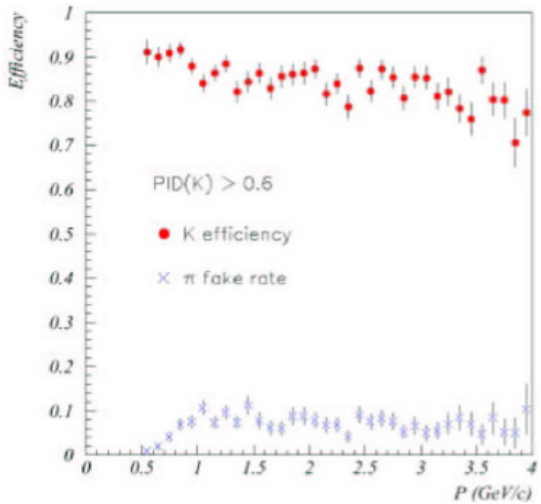
Expected performance

- K/π separation power
  - Multi-alkali photo-cathode + Focusing mirror



Efficiency; 99~95%

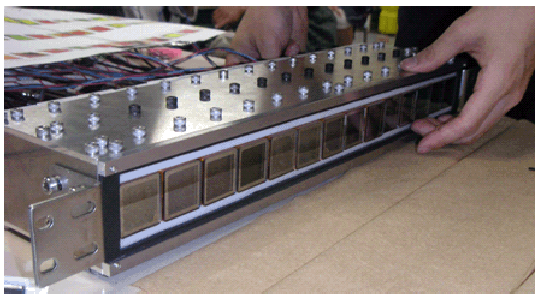
Fake rate; 1~4%

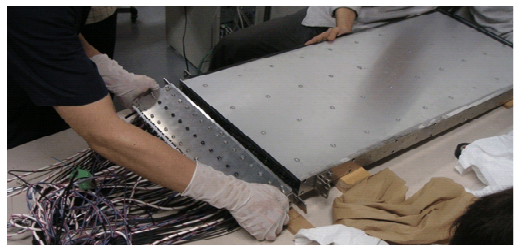


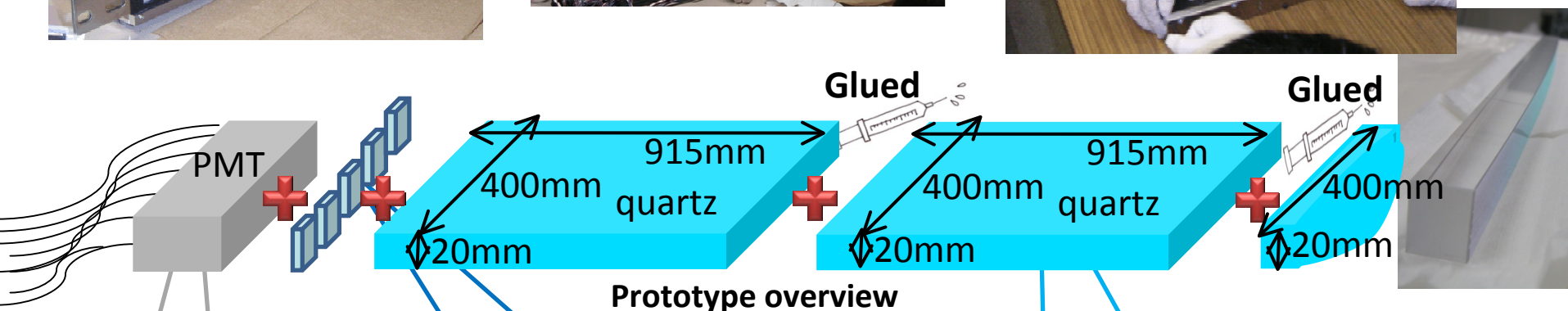
- Current Belle performance
  - Efficiency; 90~80%
  - Fake rate; 5~10%

Prototype development

- Demonstration of the performance







Prototype overview

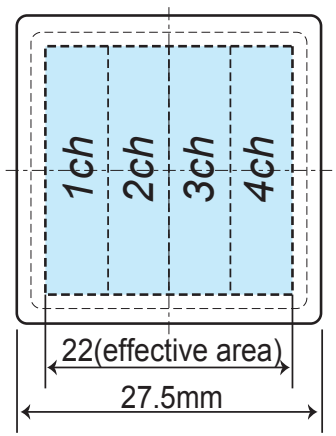
Photon detector
- Time resolution
- Efficiency

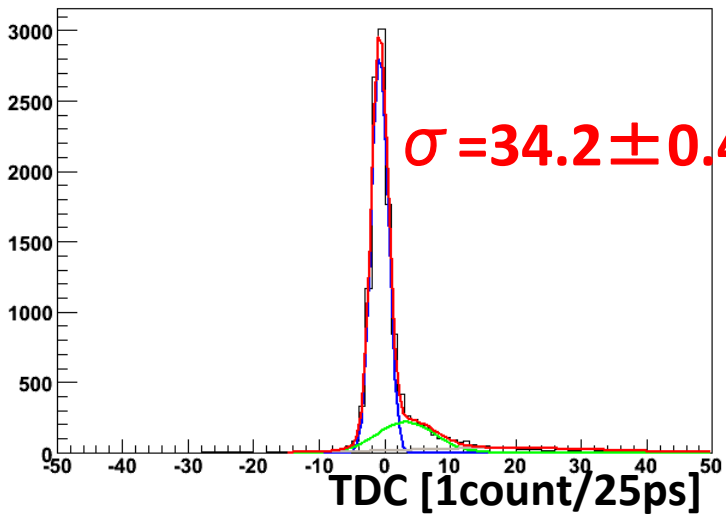
Filter (λ>400nm)
- Suppression of dispersion

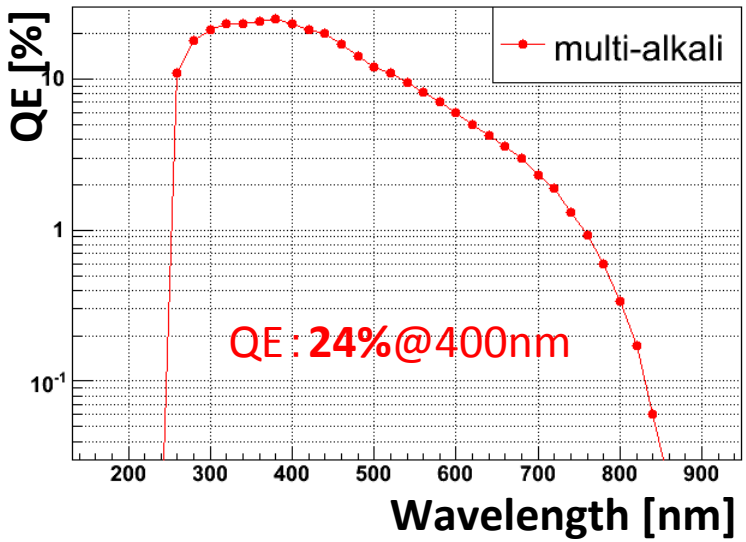
Quartz radiator (Fused silica)
- Flatness:<1.2μm/m
- Roughness:0.5nm

Photon detector

- Square-shape multi-anode MCP-PMT
  - Multi-alkali photo-cathode
  - Single photon detection
  - Fast raise time: ~400ps
  - Gain=1.5x10^6 @B=1.5T
  - T.T.S.(single photon): ~35ps @B=1.5T
  - Position resolution: <5mm
- Semi-mass-production (14 PMTs)



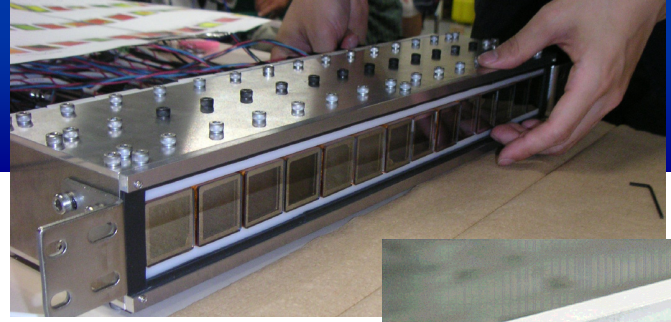


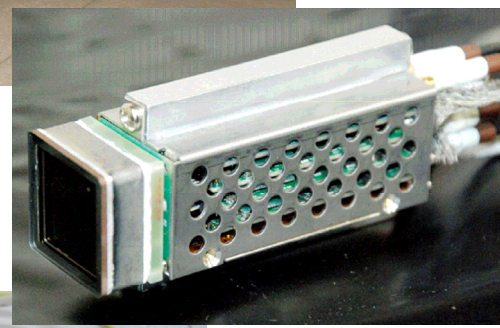


TTS＜40ps for all channels

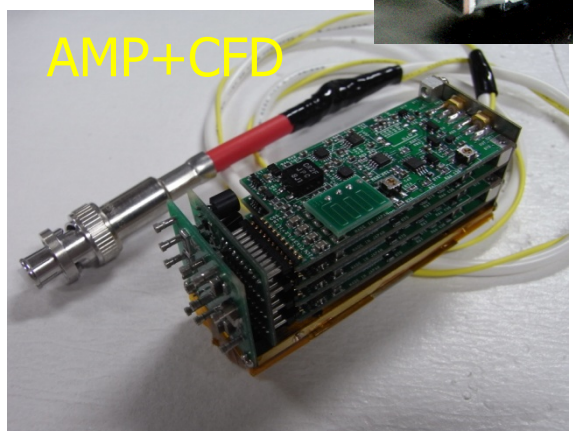
Ave. QE : **17%**@400nm

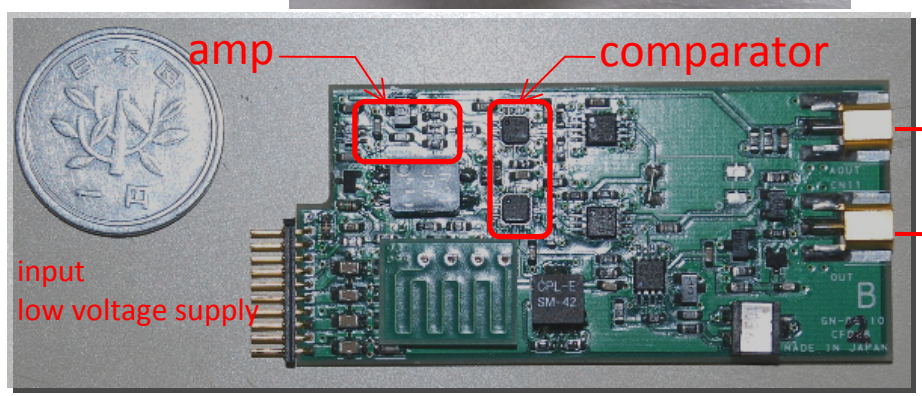
PMT module





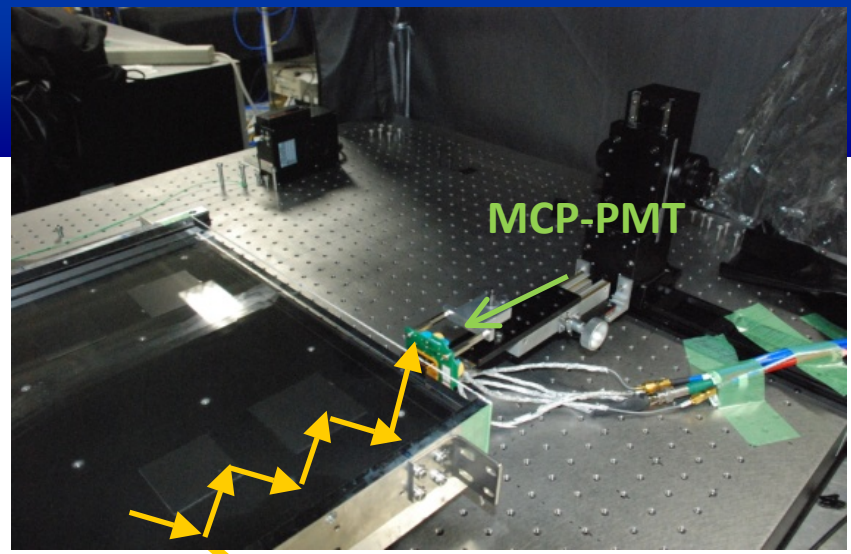
- HV divider + AMP + Discriminator
- Small size (28mm^{W})
- Prototype
  - Fast AMP (MMIC, 1GHz, x20)
  - Fast comparator (180ps propagation)
  - CFD with pattern delay
- Performance
  - Test pulse
    - ~5ps resolution
  - MCP-PMT
    - σ<40ps
    - Working well

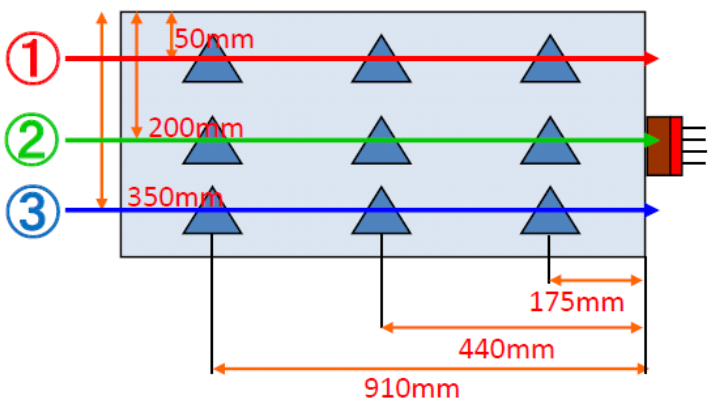


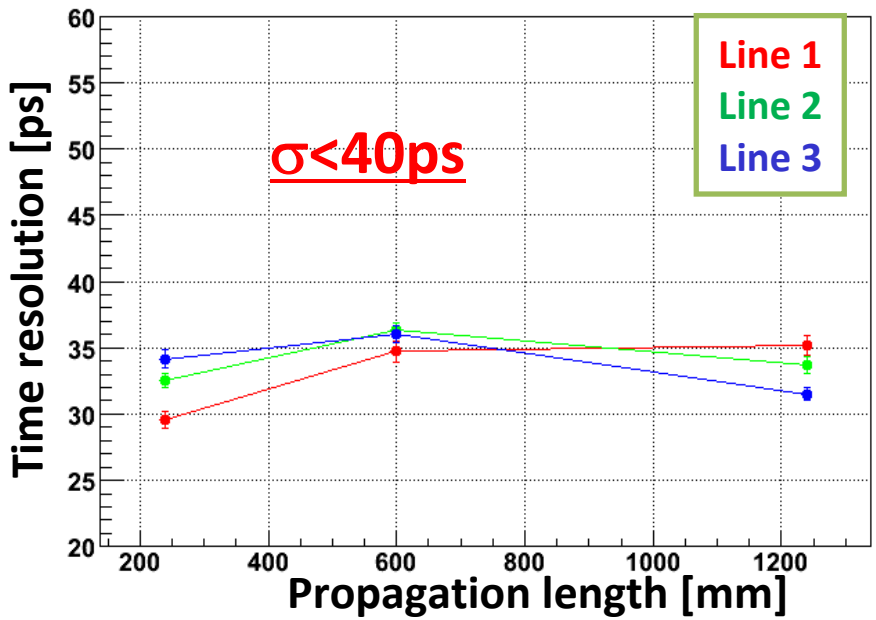


Quartz radiator

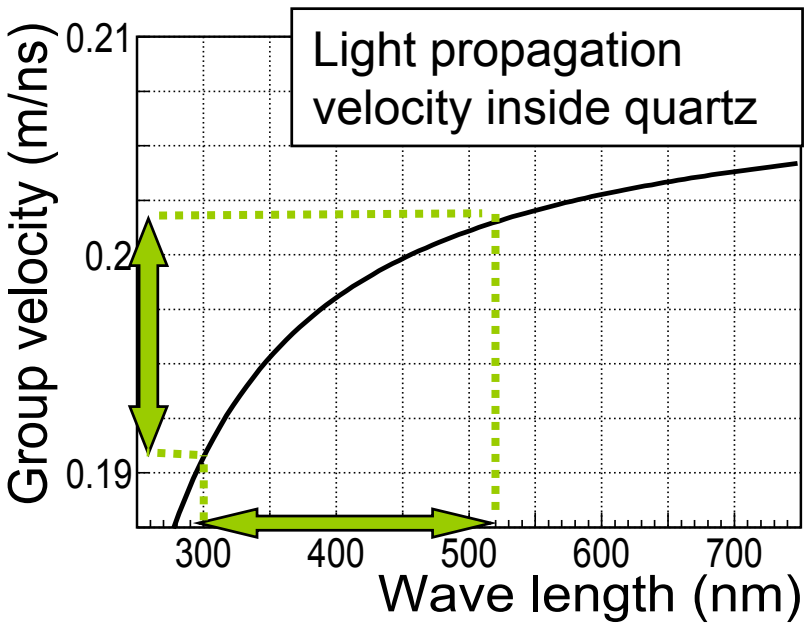
- Made by Okamoto optics
- Check the quality for time resolution
  - Single photon pulse laser
    - λ=407nm
  - MCP-PMT
  - Several incident position
- → No degradation of time resolution
  - Enough quartz quality

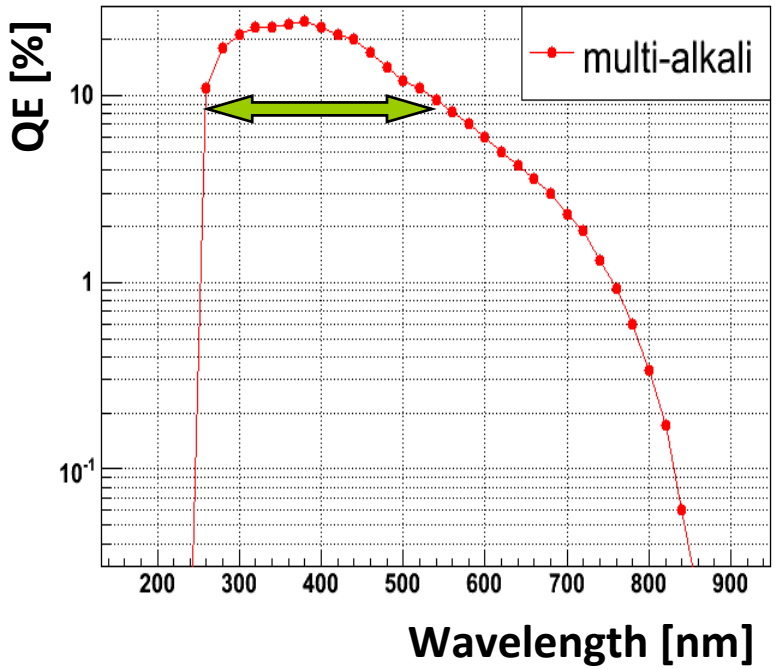






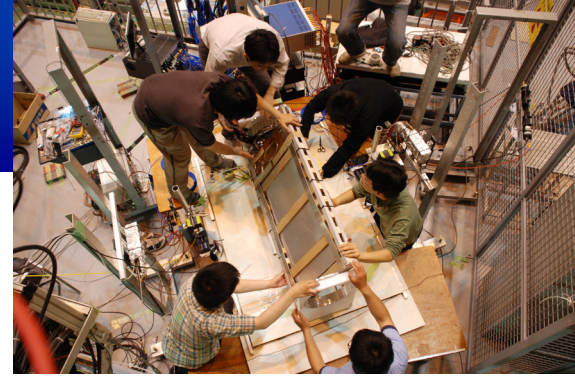
Chromatic dispersion effect





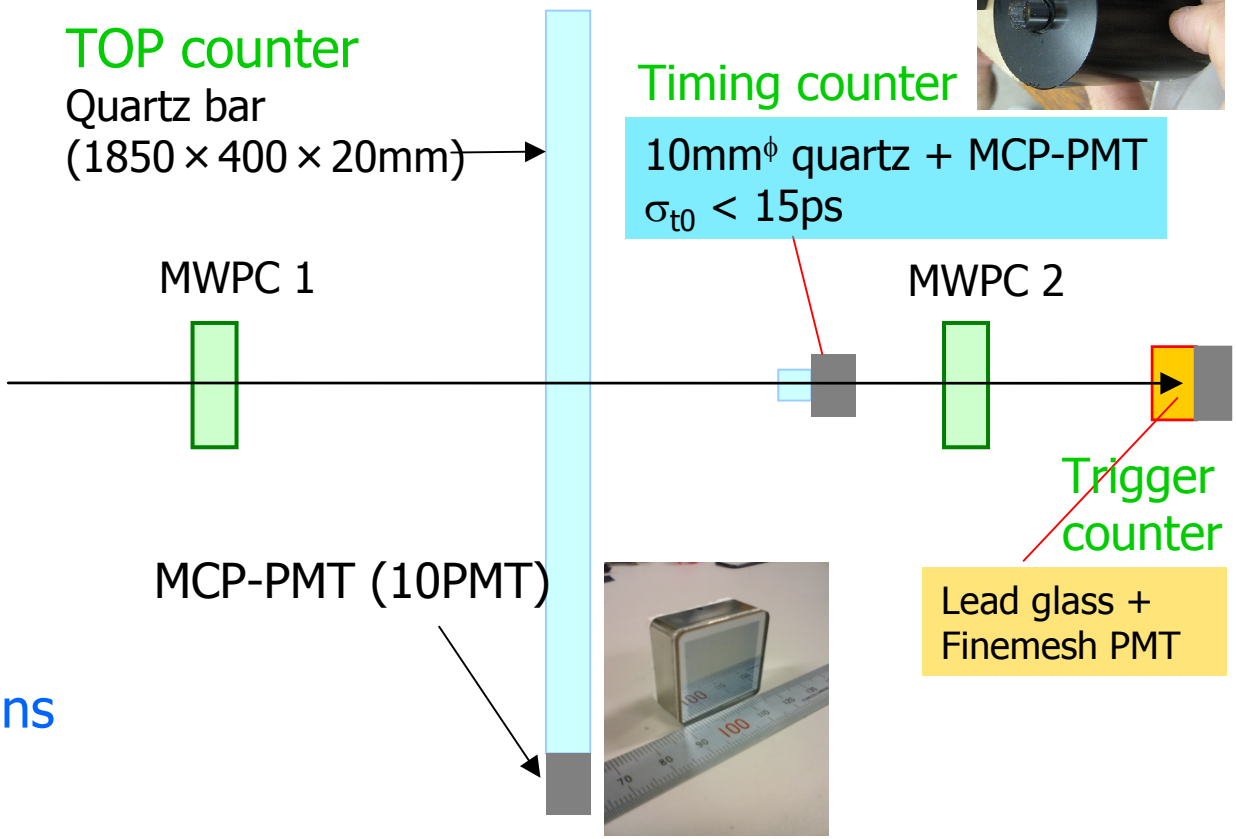
- Range of detectable wavelength of Cherenkov photons
  → Time fluctuation of the Cherenkov ring image
    → Time resolution depends on the propagation length.
- Check the degradation of time resolution by beam test

Beam test



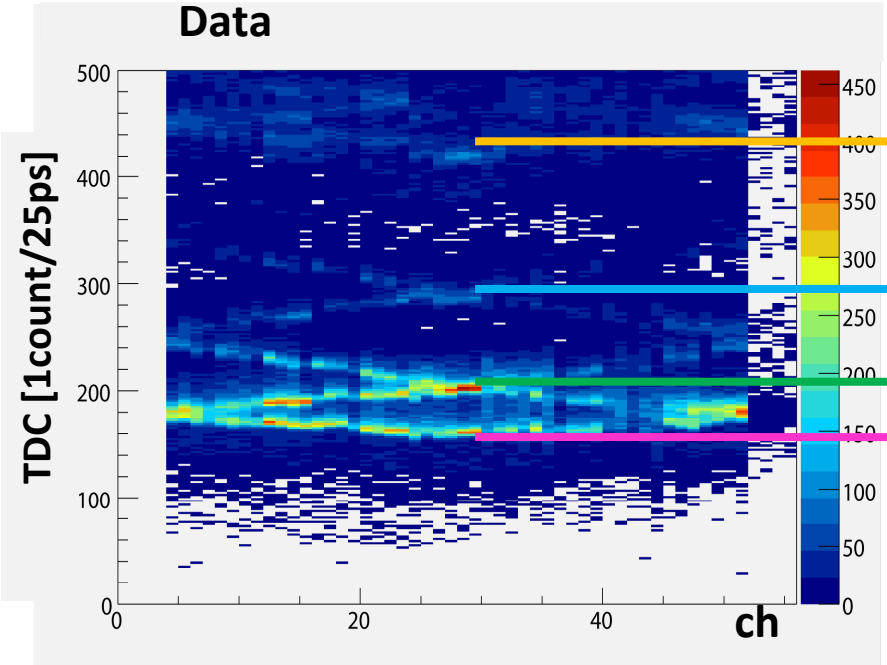
- At Fuji beam line in June and Dec.
- Using real size quartz and MCP-PMT
  - MCP-PMT: Multi-alkali p.c., C.E.=60%

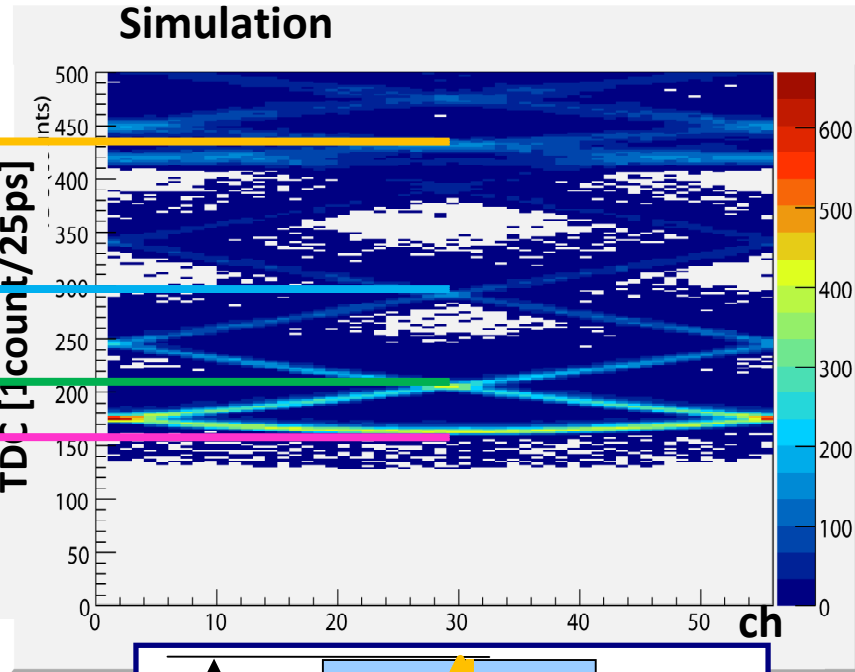
Quartz + support jig



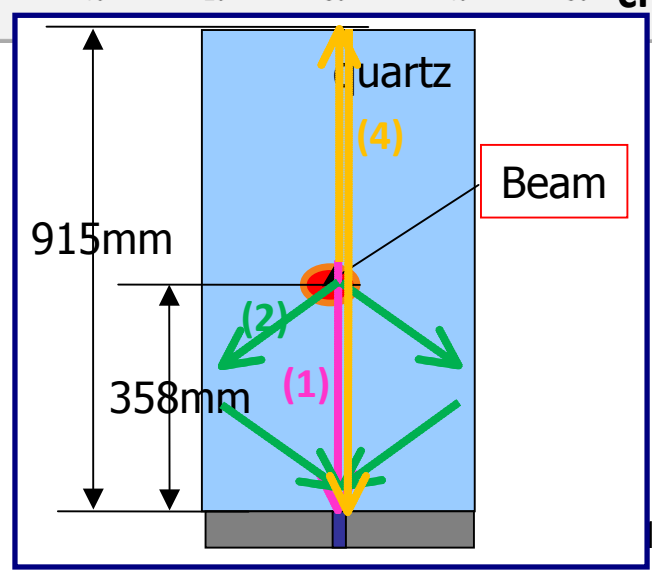
- Check
  - Ring image
  - Number of photons
  - Time resolution

Ring image

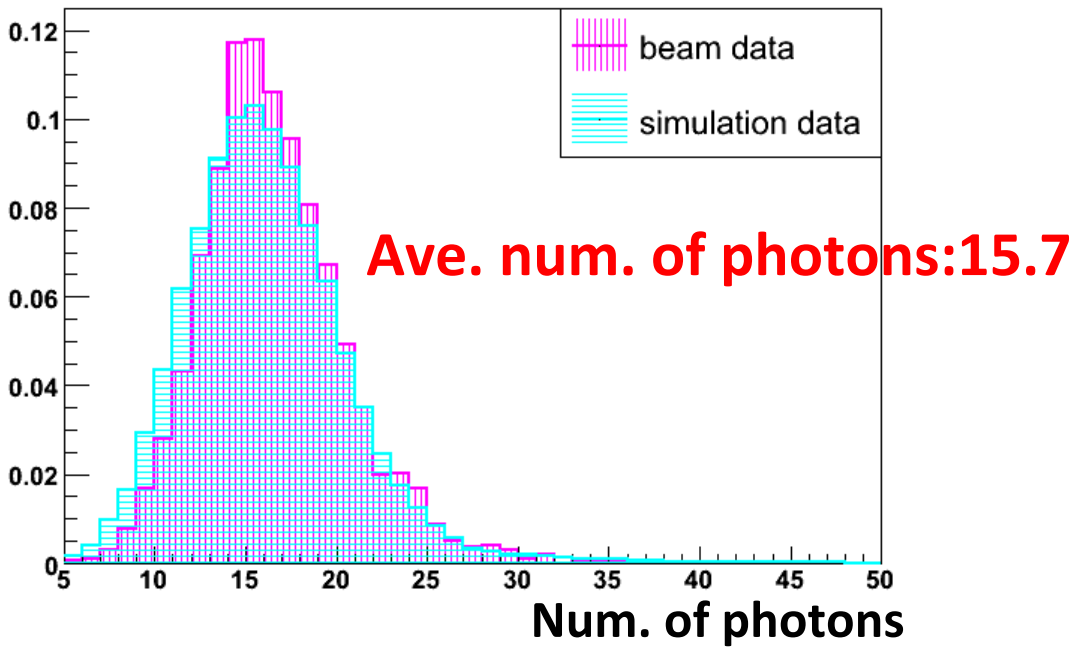




- Proper ring image
  - Same time interval with simulation



Number of detected photons

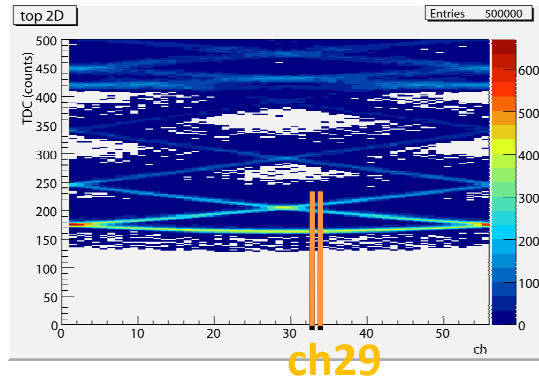


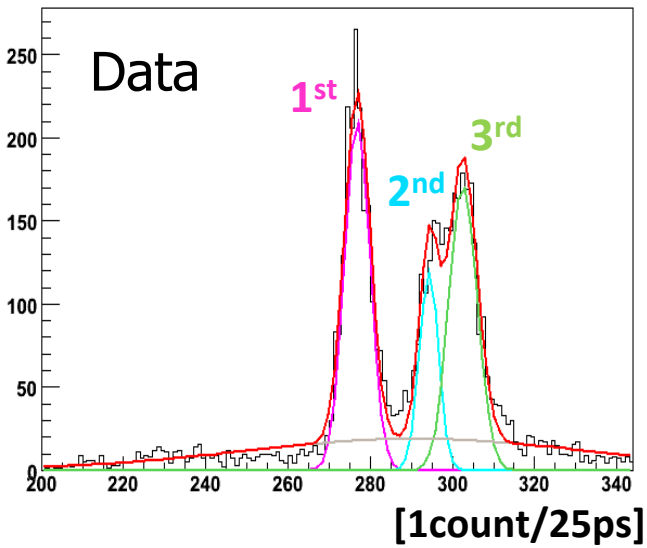
- Normal incidence (90 deg.)
- Obtained number of photons as expected

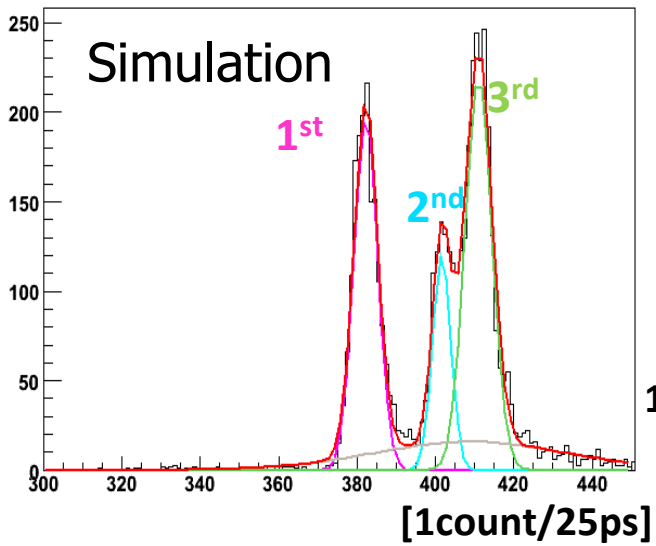
- → We can expect ~22 photons/event, if we use 14 PMTs.
  - Normalized by active area (10→14 PMTs)

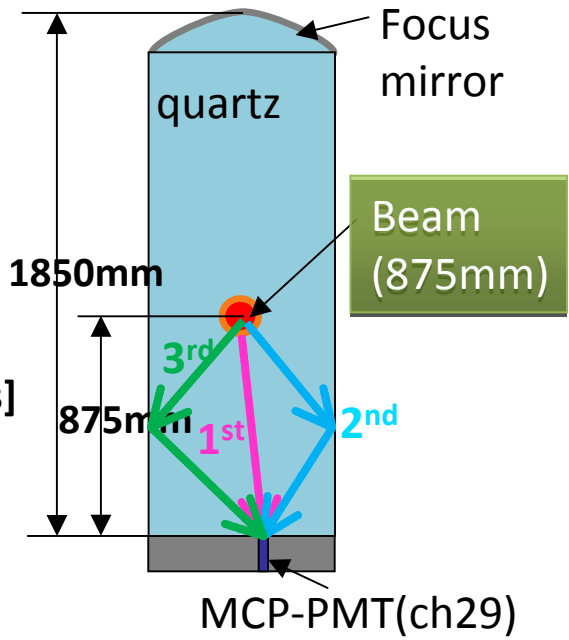
Time resolution

- TDC distribution of ch.29
  - Compare with the distribution expected by a simulation including PMT resolution and chromatic dispersion effect





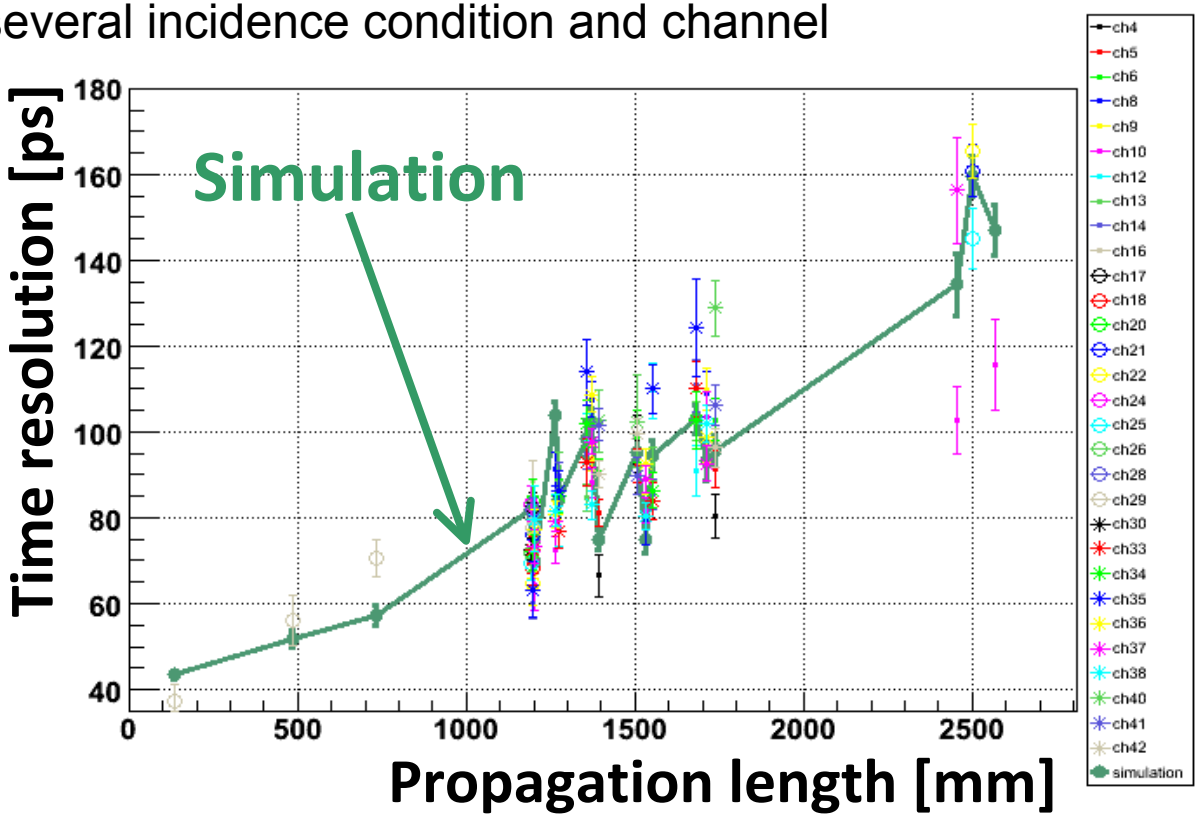




	Resolution(1st peak)
Data	76.0±2.0 [ps]
Simulation	77.7±2.3 [ps]

Time resolution vs. propagation length

- Check time resolution
  - For several incidence condition and channel



- Data agrees well with simulation expectation.
  → Confirmed the level of chromatic dispersion effect

Summary

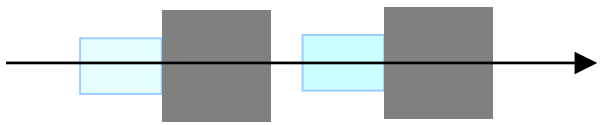
- TOP counter for barrel PID upgrade at Belle-II
  - Cherenkov ring imaging with precise timing information (σ<40ps)
  - Design studies are going.

- Prototype development
  - Multi-anode MCP-PMT
    - Enough performance of TTS, QE for TOP counter
    - Integrated module with amplifier and CFD
  - Quartz radiator
    - Enough quartz quality for single photon detection

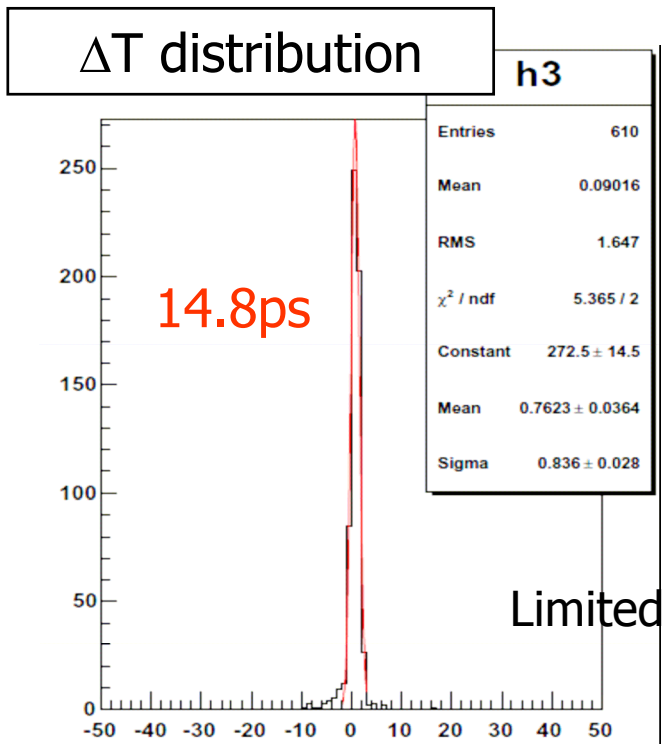
- Performance test with beam
  - Proper ring image, number of detected photons (15.7 photons)
  - Time resolution as expected by simulation
    → Confirmed chromatic dispersion effect

Timing counter

- Based on our high resolution TOF
  - σ=6.2ps with 6μm MCP-PMT, Cherenkov light in quartz
  - and special electronics
- Time difference btw two counters
  - Check time resolution

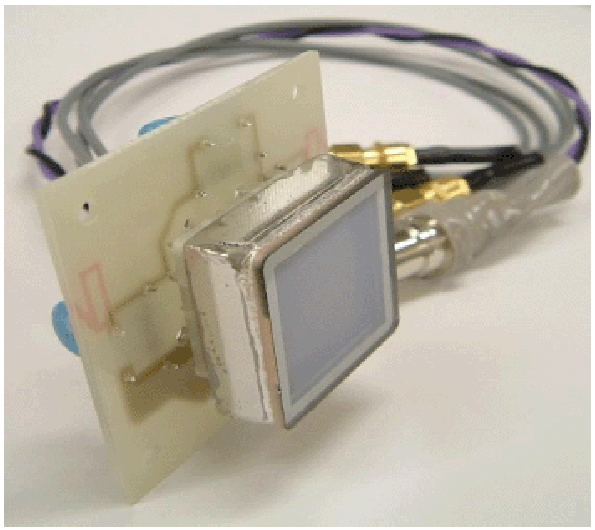


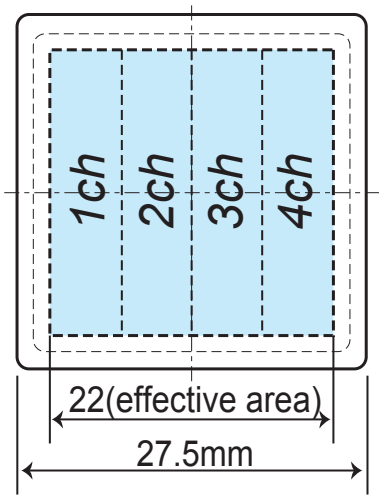
10mmϕ quartz + MCP-PMT



Limited by elec.

Multi-anode MCP-PMT (1)





Size	27.5 x 27.5 x 14.8 mm
Effective area	22 x 22 mm(**64%**)
Photo cathode	Multi-alkali
Q.E.	~20%(λ=350nm)
MCP Channel diameter	10 μm
Number of MCP stage	2
Al protection layer	No
Aperture	~60%
Anode	4 channel linear array
Anode size (1ch)	5.3 x 22 mm
Anode gaps	0.3 mm

SL10

R&D with Hamamatsu
for TOP counter

- Large effective area — 64% by square shape
- Position information — 4ch linear anode (5mm pitch)

Multi-anode (2)

- Single photon detection
- Fast raise time: ~400ps
- Gain=1.5x10^6 @B=1.5T
- T.T.S.(single photon): ~30ps @B=1.5T
- Position resoltion: <5mm
- Correction eff.: ~50%
  - Nucl. Instr. Meth. A528 (2004) 768.

- Basic performance is OK!
  - Same as single anode MCP-PMT