Cherenkov detector R&D for super B factory

- Introduction
- Prototype development
- Performance test
- Summary

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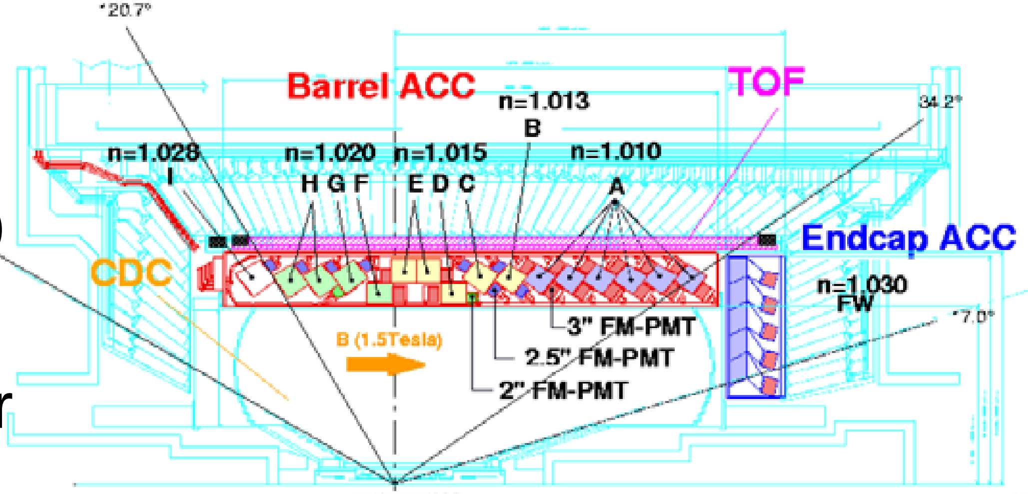
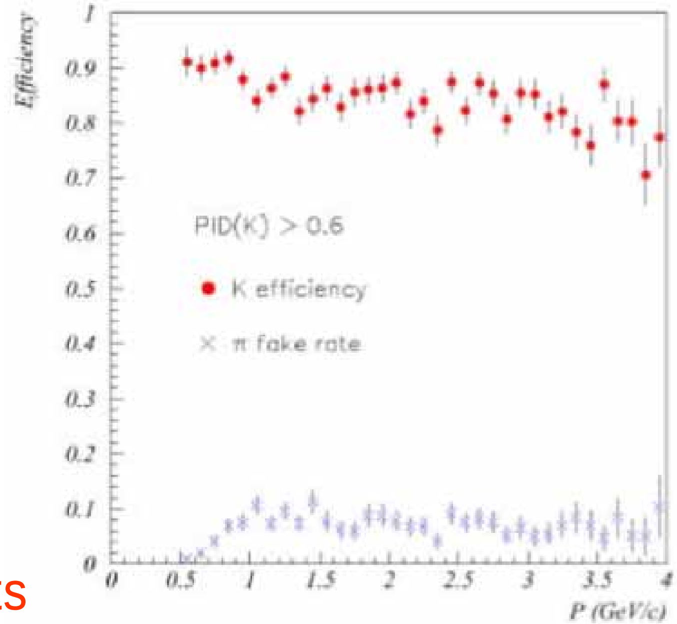
Current Belle detector

- PID of $\pi^{\pm}/K^{\pm}$
  - Aerogel Cherenkov counter (Threshold type)
  - TOF counter
  - dE/dx in drift chamber

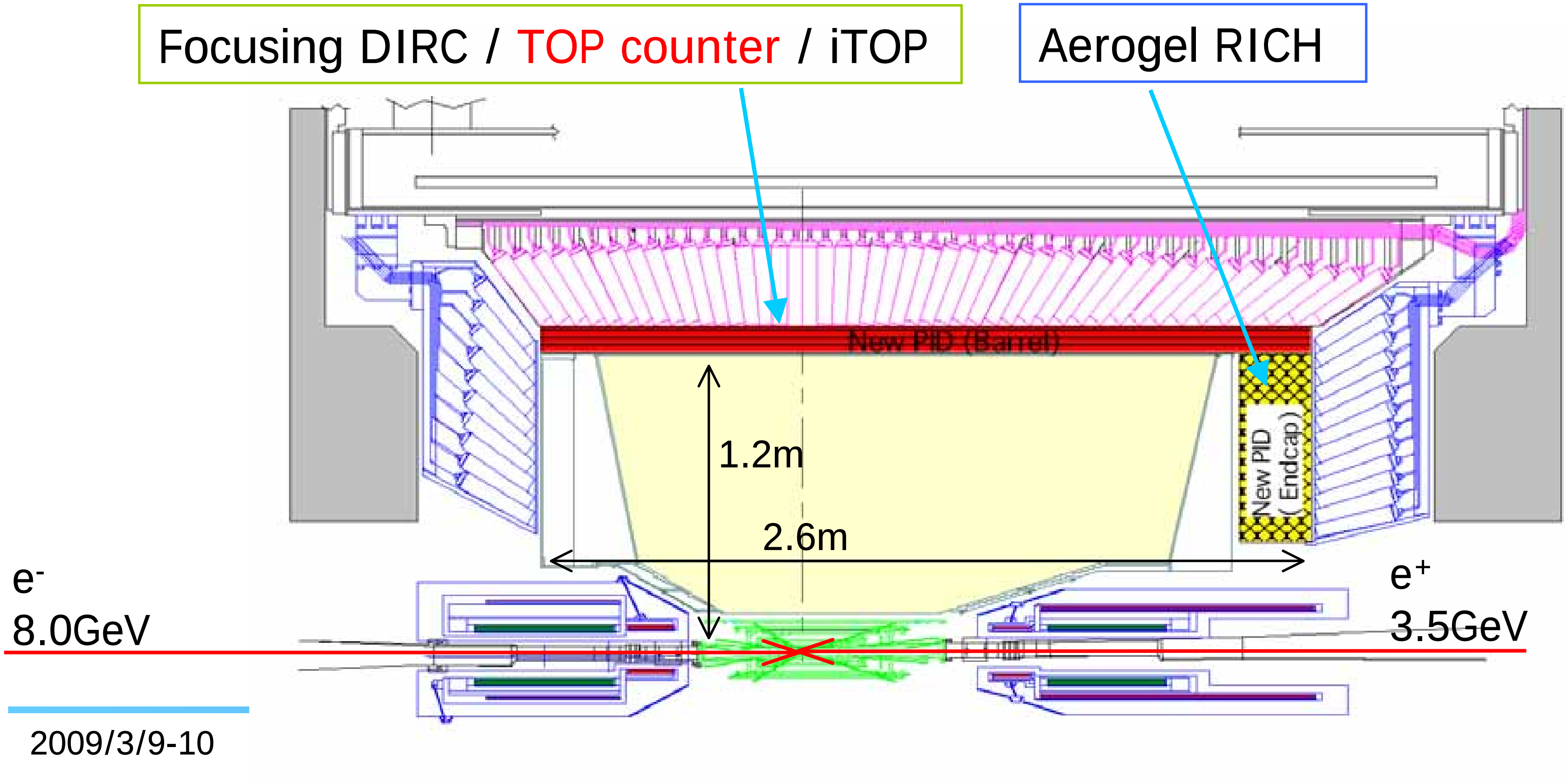


- Contribute to flavor discrimination
  - Physics analysis
    - $B \rightarrow \pi\pi/K\pi$, $\rho\gamma$, $K\nu\nu$ etc.
  - Flavor tag, Full reconstruction
- Current performance
  - Efficiency; 90~80%
  - Fake rate; 5~10%
- Want less fake rate for precise measurements



Belle PID upgrade

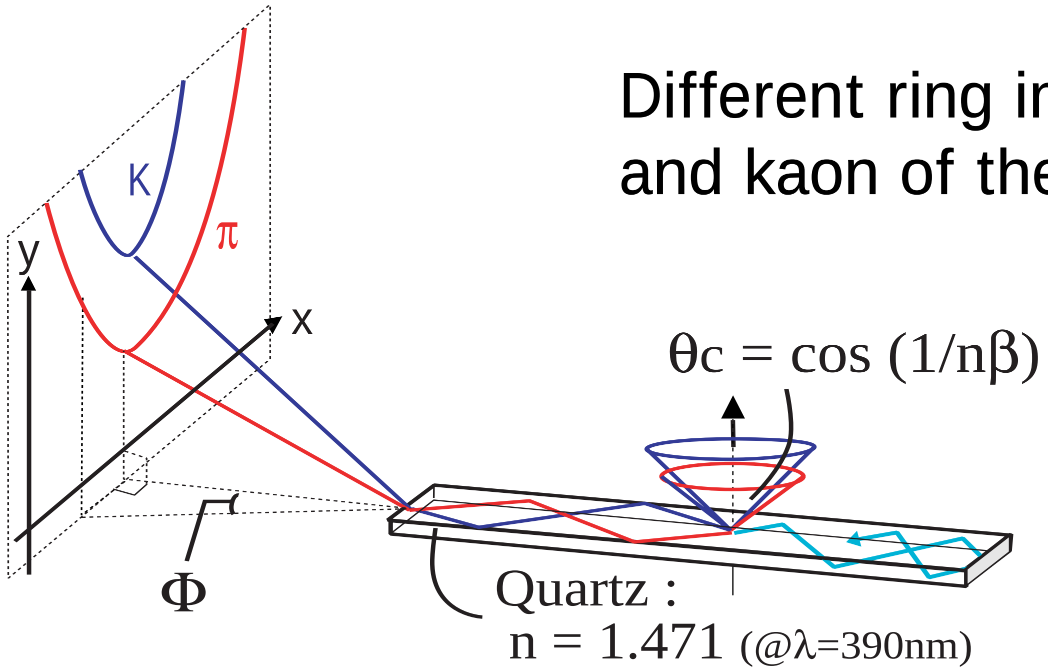
- PID (K/π) detectors
  - Barrel PID and Aerogel RICH counters are both Cherenkov ring imaging detectors.
  - dE/dx in drift chamber



TOP counter

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

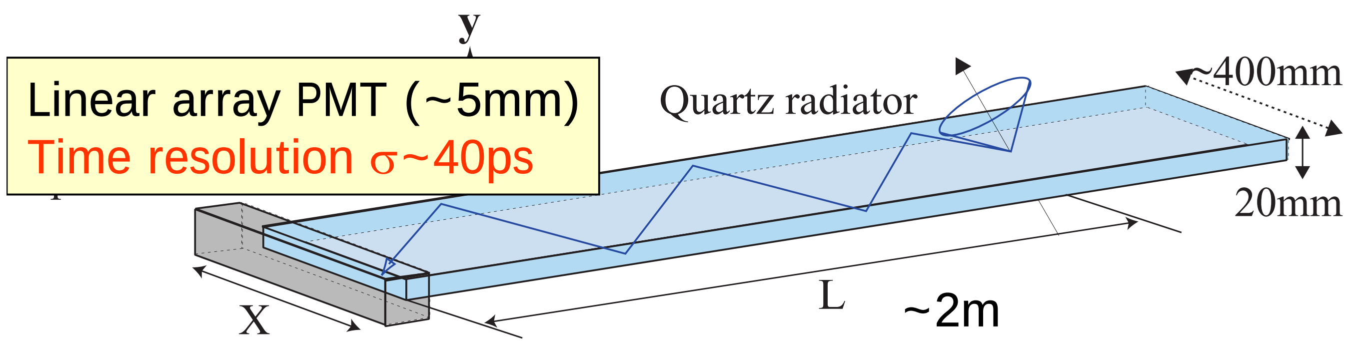
Different ring image for the pion and kaon of the same momentum

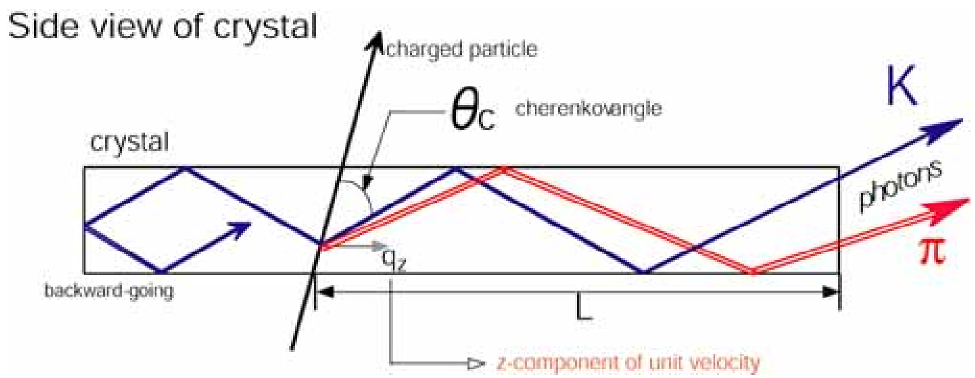


Need large screen…

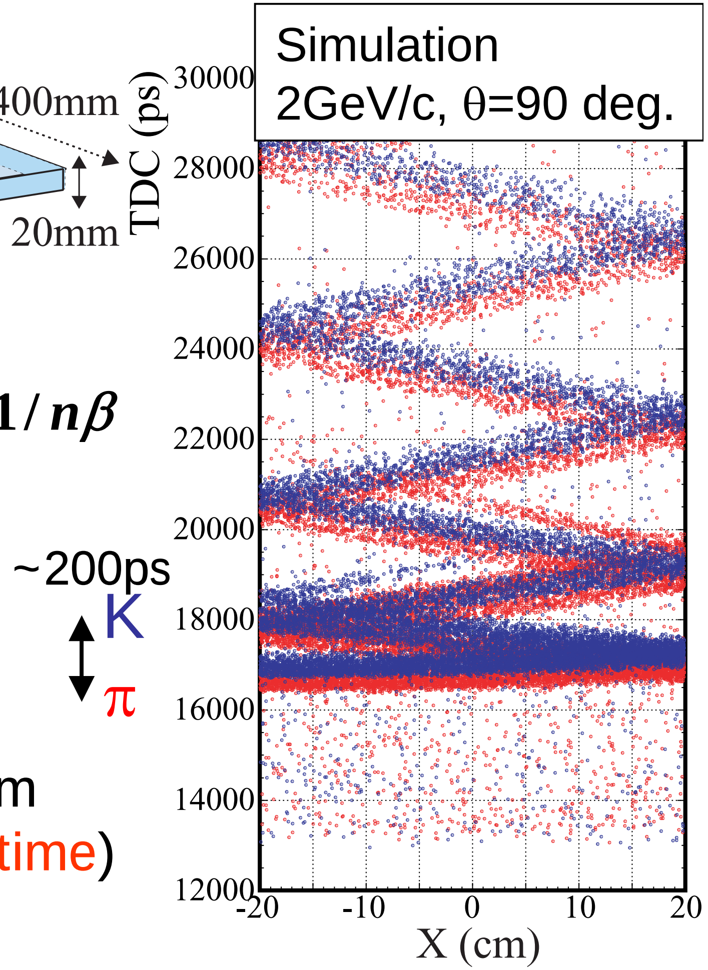
TOP counter

- 2D position information → <u>Position+Time</u>
  - Compact detector!





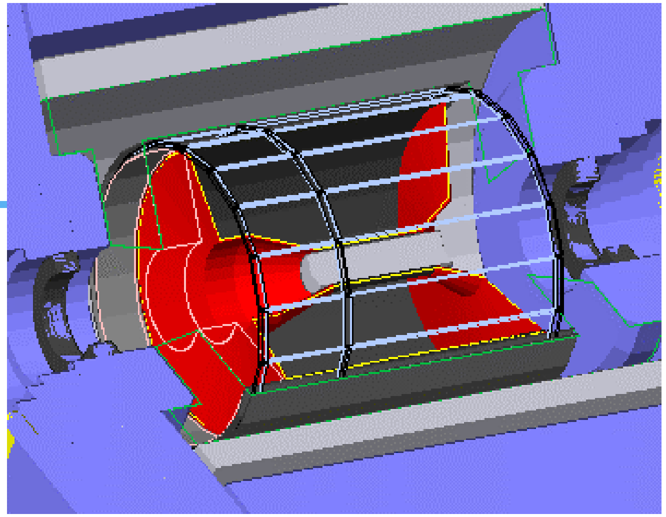
$$\cos\theta_c = 1/n\beta$$



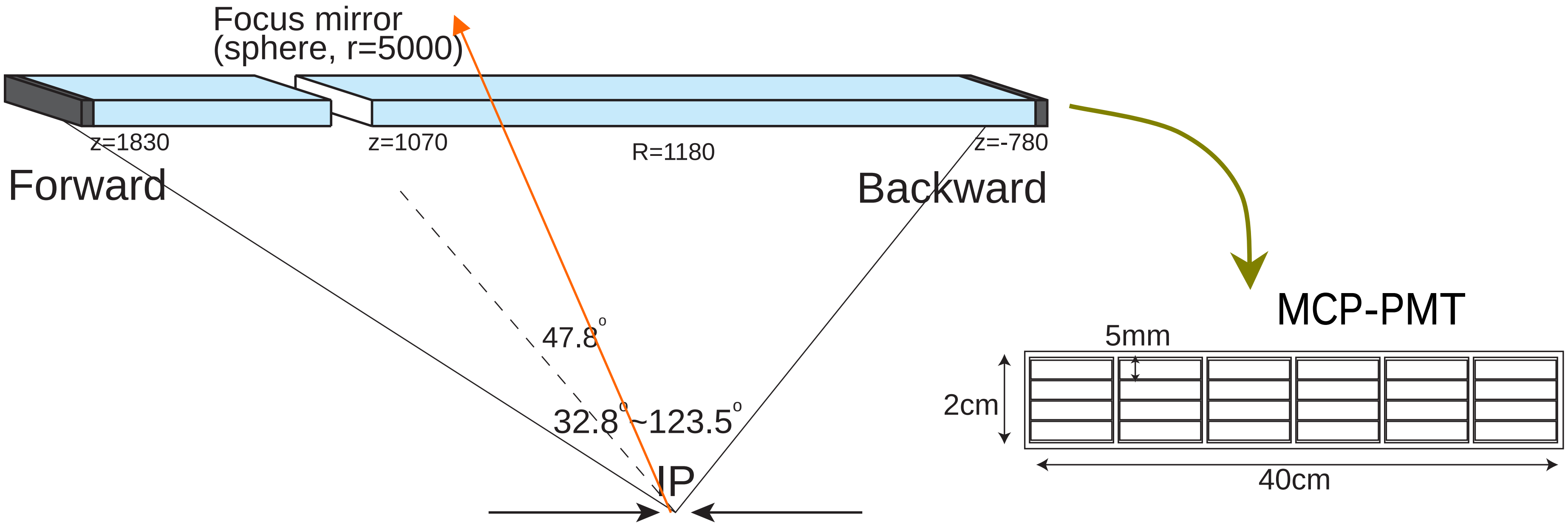
Different opening angle for the same momentum
→ Different propagation length(= propagation time)

+ TOF from IP works additively.

TOP counter

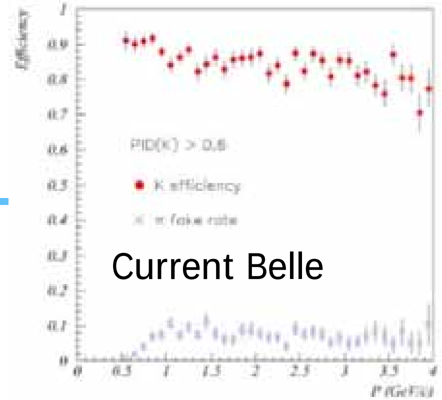


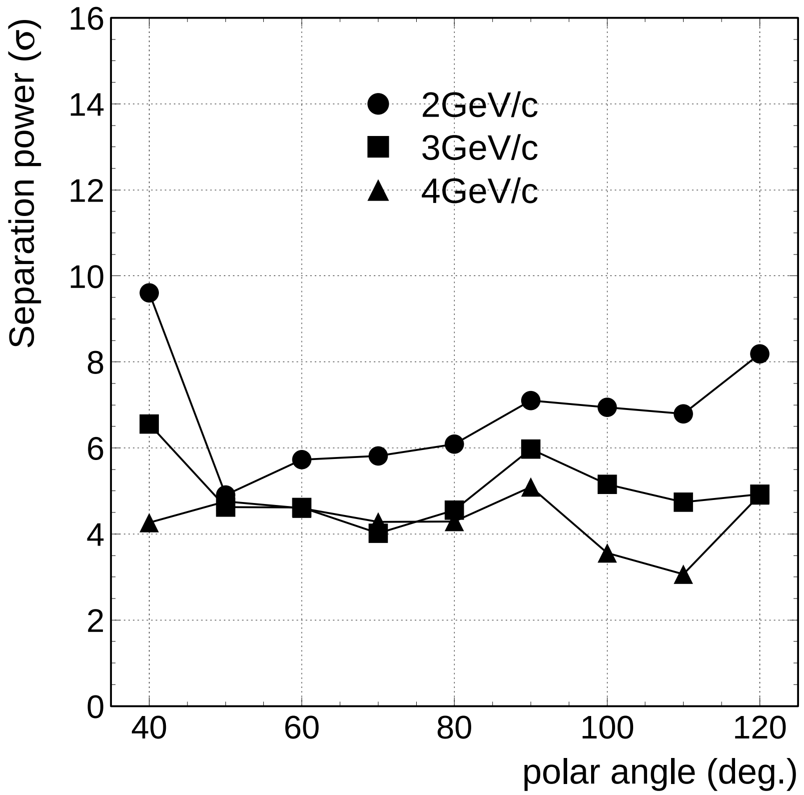
- Quartz: $255cm^{L}$ x $40cm^{W}$ x $2cm^{T}$
  - Focus mirror at 47.8deg.
    to reduce chromatic dispersion
- Multi-anode MCP-PMT
  - Linear array (5mm pitch), Good time resolution (<~40ps)
  - → Measure Cherenkov ring image with timing information

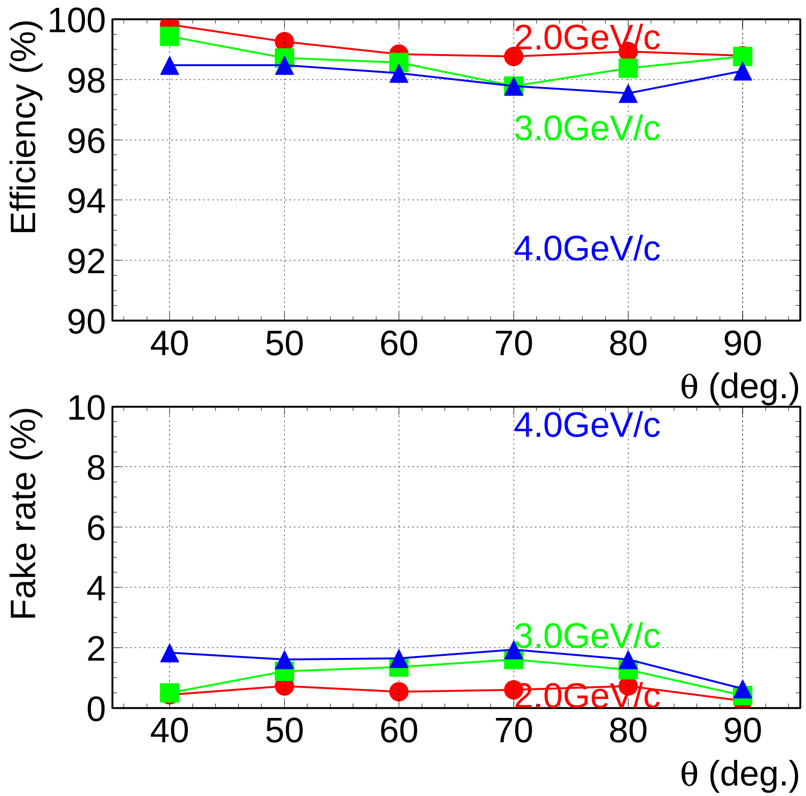


Expected performance

- K/π separation power
  - GaAsP photo-cathode + Focusing mirror



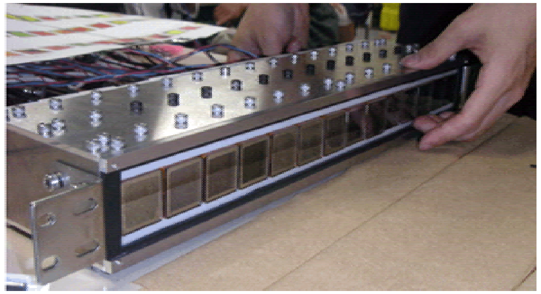


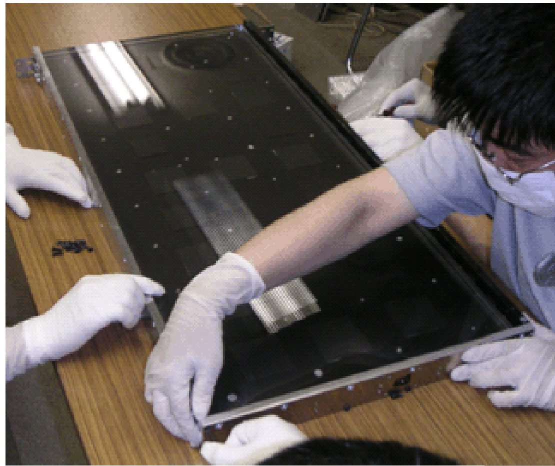


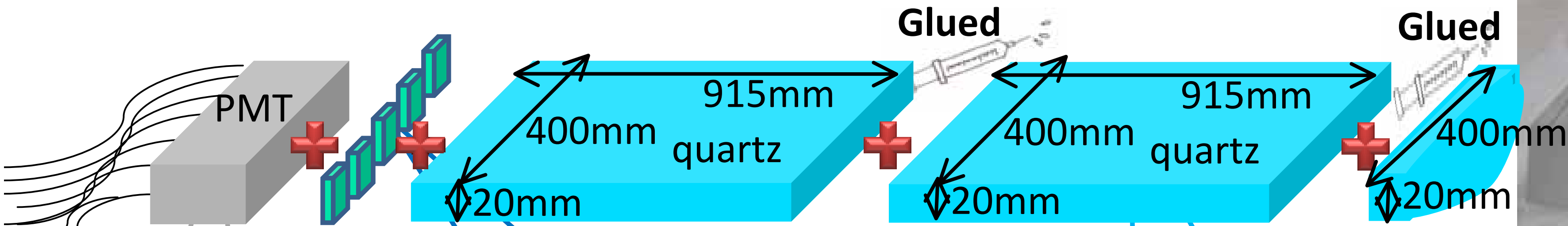
>4σ K/π upto 4 GeV/c, θ<90°, <u><2% fake rate</u>

Prototype development

- Demonstration of the performance







Prototype overview

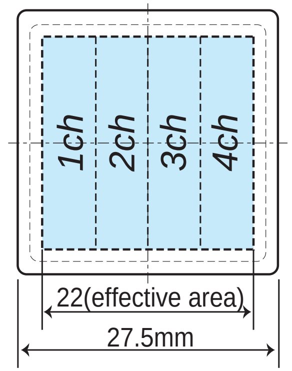
Photon detector
- Time resolution
- Efficiency

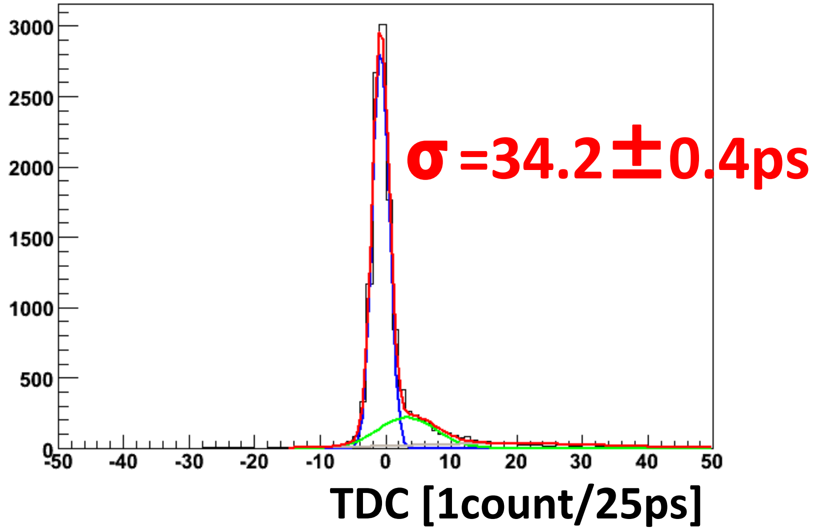
Filter (λ>400nm)
- Suppression of chromatic dispersion

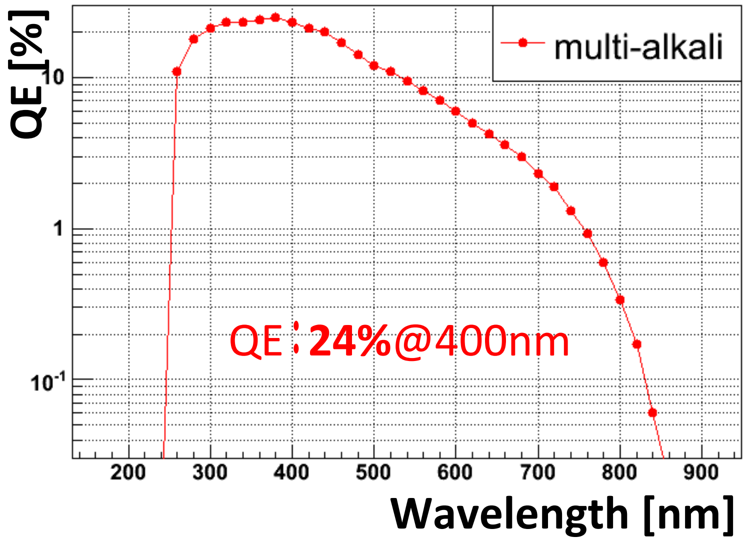
Quartz radiator (Fused silica)
- Flatness:<1.2μm/m
- Roughness:0.5nm

Photon detector

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

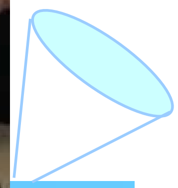






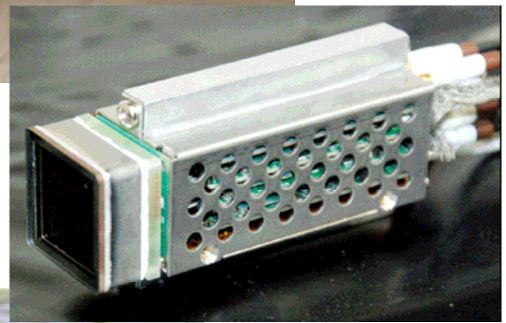
→ TTS＜40ps for all channels

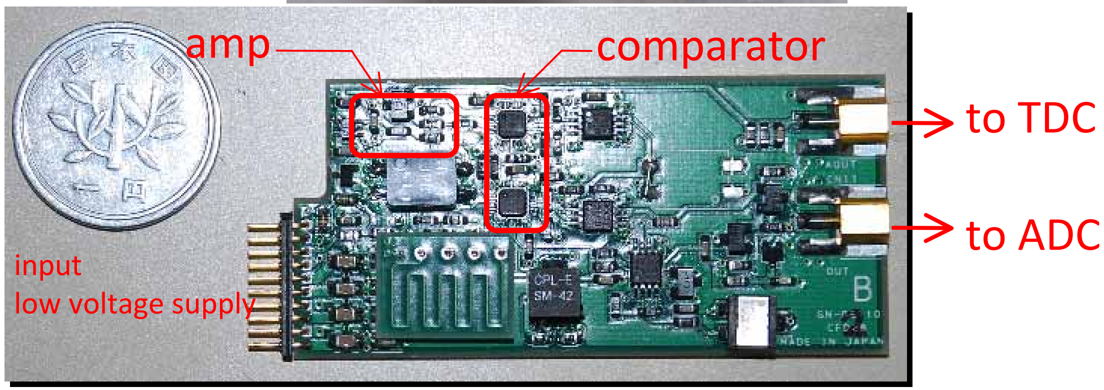
→ Ave. QE：**17%@400nm**



PMT module

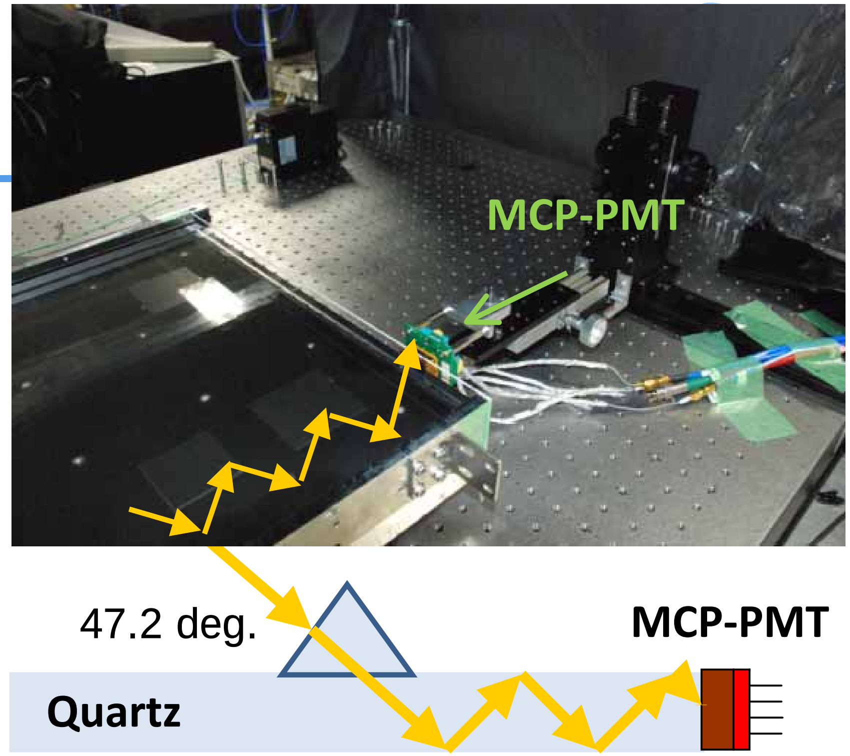
- HV divider + AMP + Discriminator
- Small size (28mm^{W})
- Prototype
  - Fast AMP (MMIC, 1GHz, x20)
  - Fast comparator (180ps propagation)
  - CFD with pattern delay
- Performance
  - Test pulse
    - ~5ps resolution
  - MCP-PMT
    - σ<40ps
    - Working well

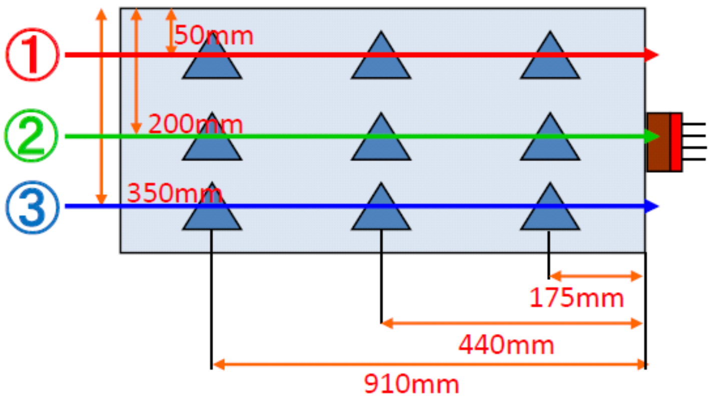


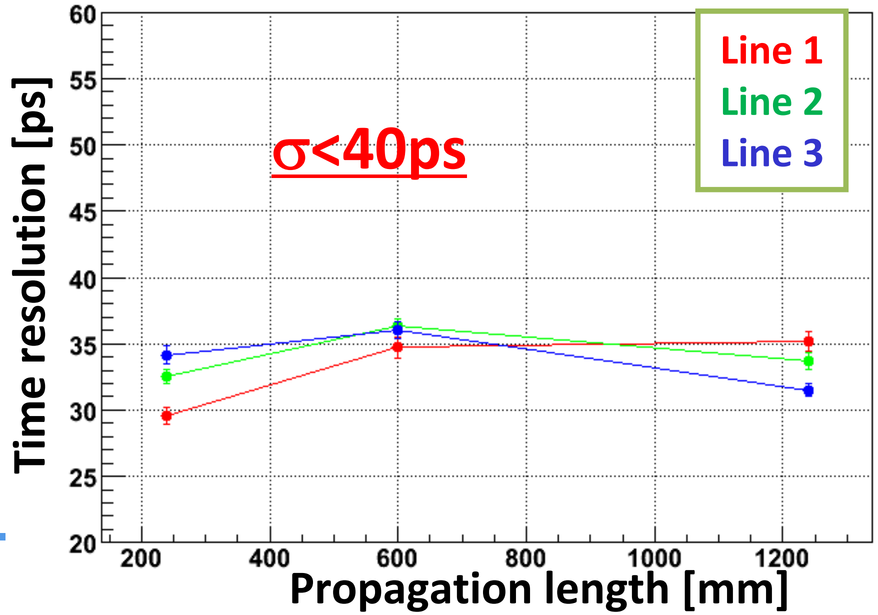


Quartz radiator

- 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

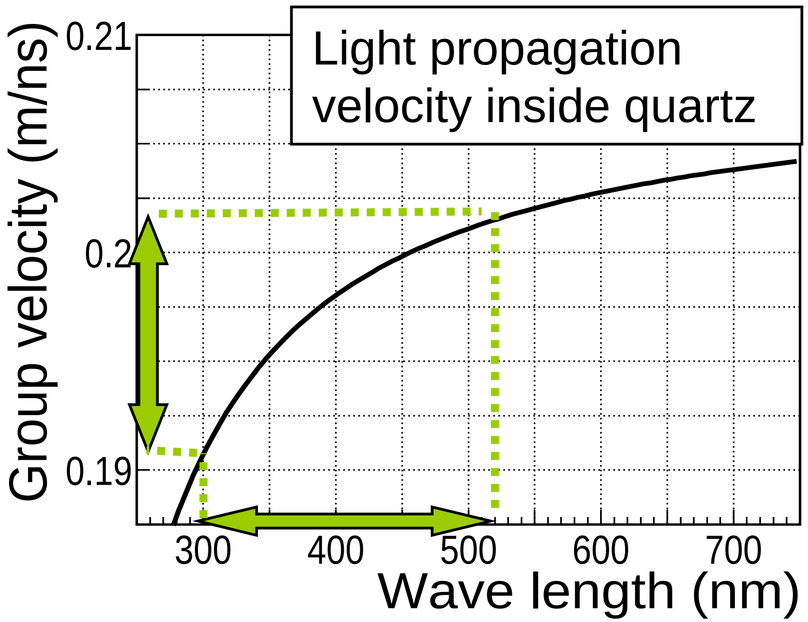


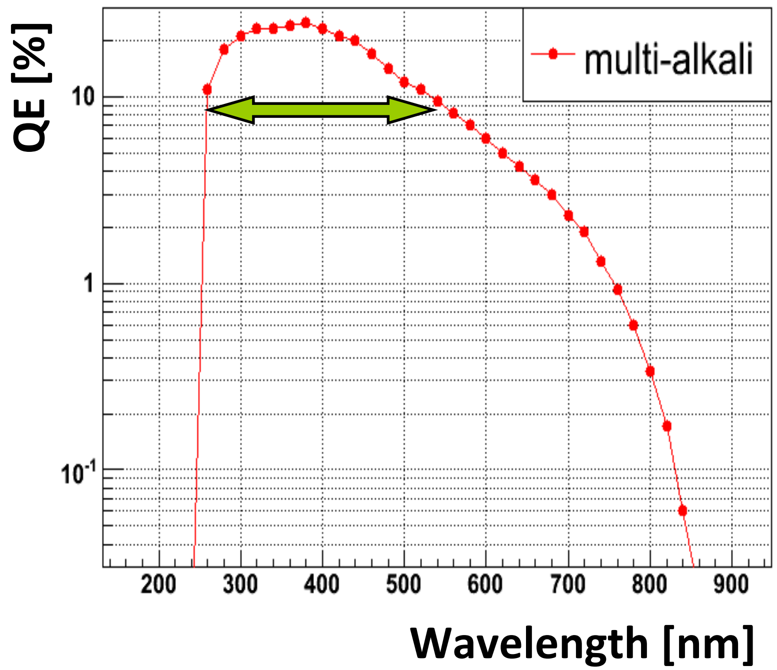




Chromatic dispersion effect

Variation of propagation velocity depending on the wavelength of Cherenkov photons



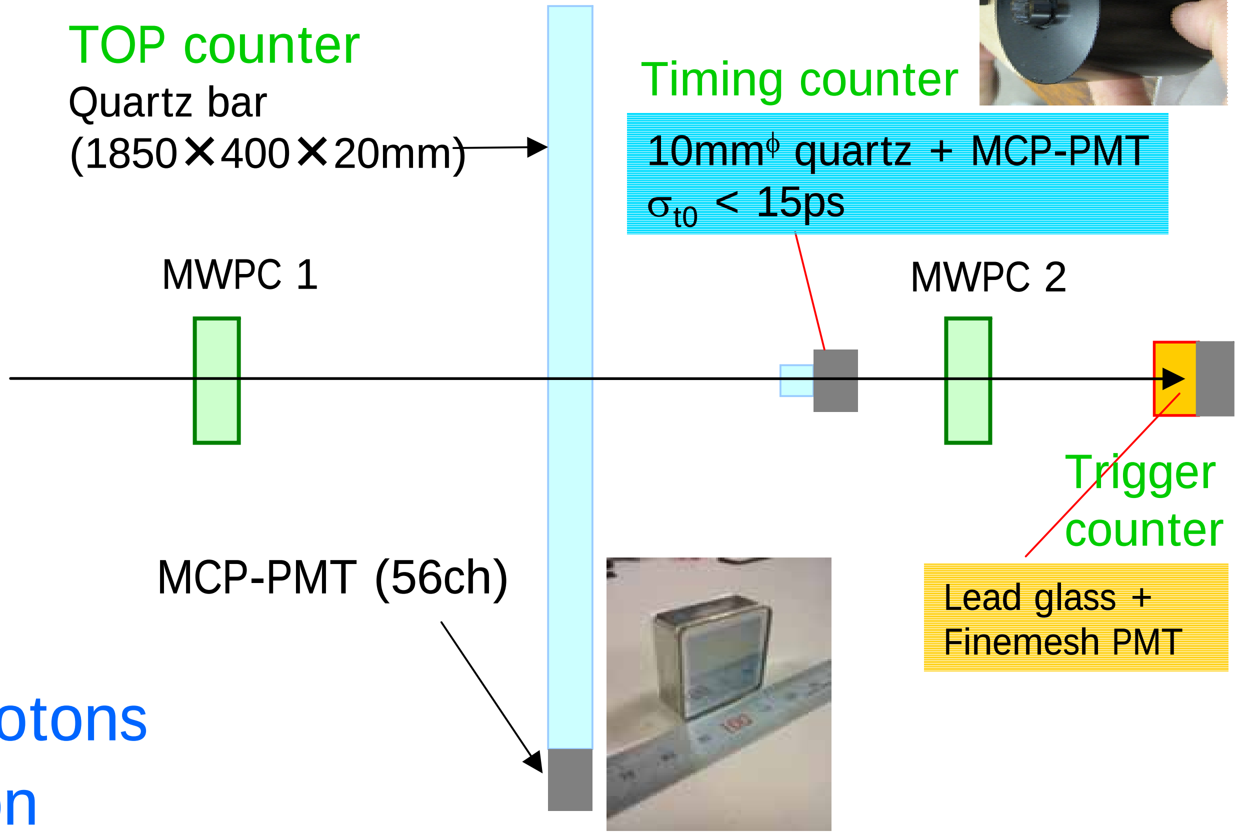


- Range of detectable wavelength of Cherenkov photons
  → Time fluctuation of the Cherenkov ring image
  → Time resolution depends on the propagation length.

Beam test

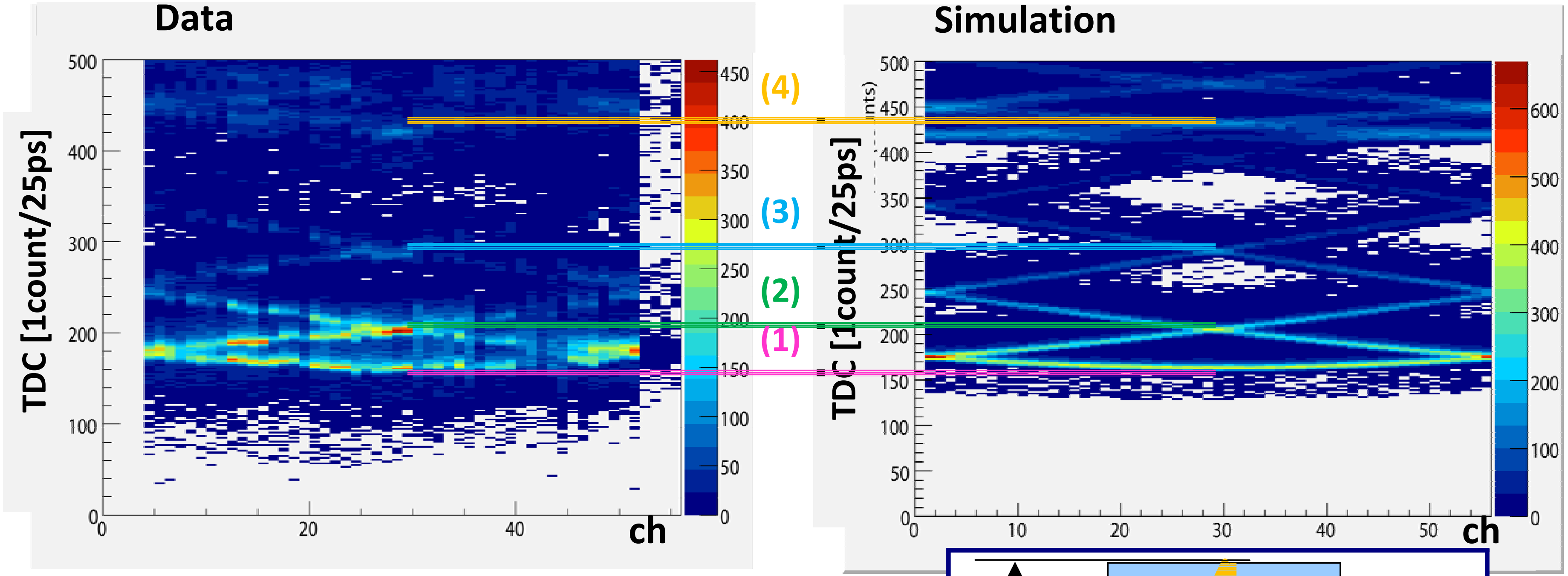
- At Fuji beam line in June and Dec.
- Using real size quartz and MCP-PMT
  - MCP-PMT: Multi-alkali p.c., C.E.=60%

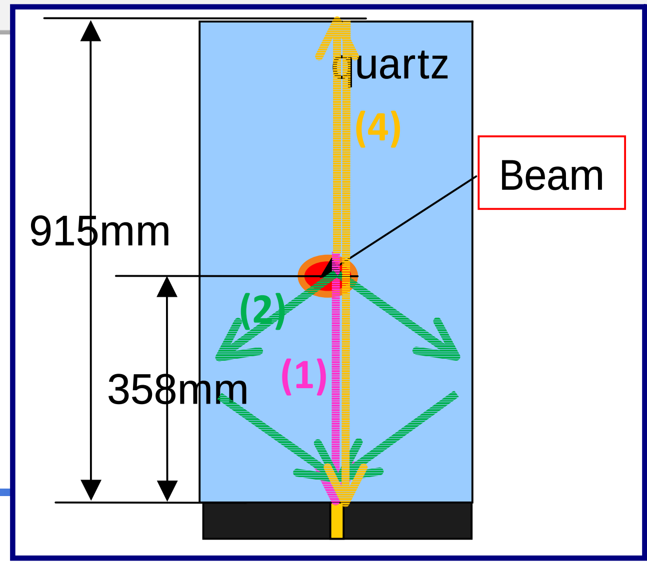
Quartz + support jig



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

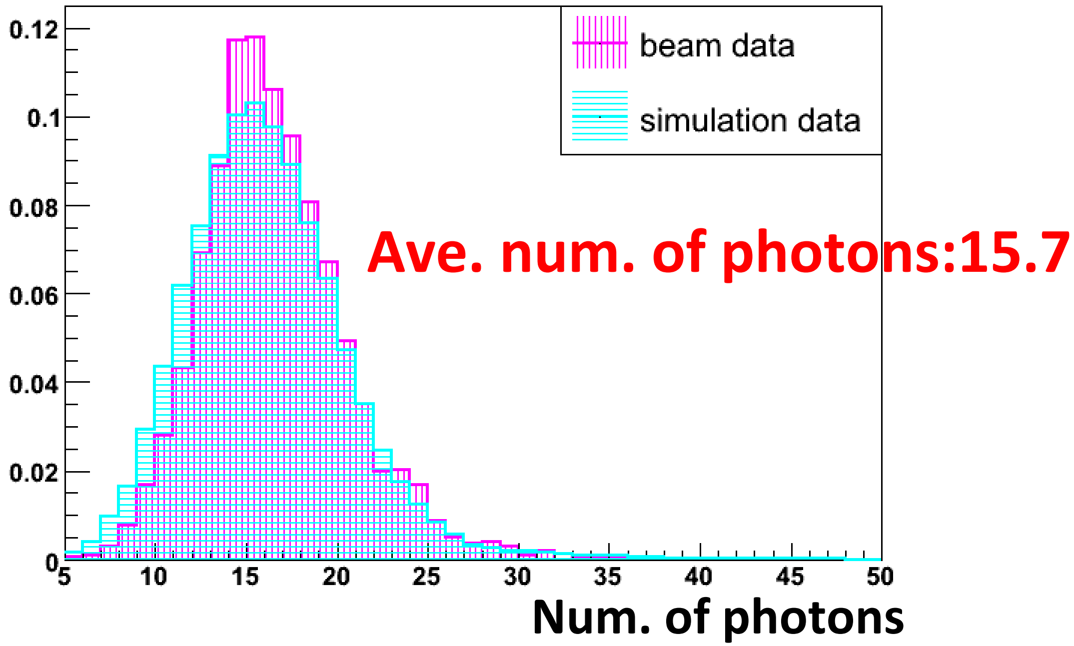
Ring image





- Proper ring image
  - Same time interval with simulation

Number of detected photons

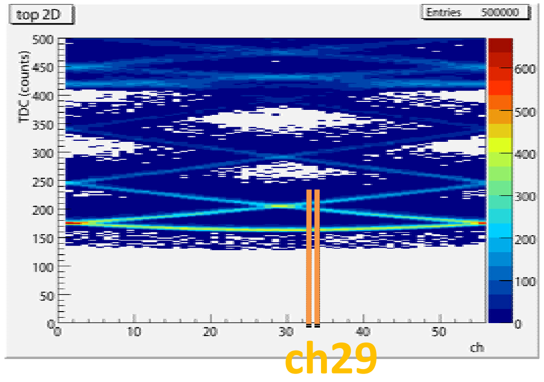


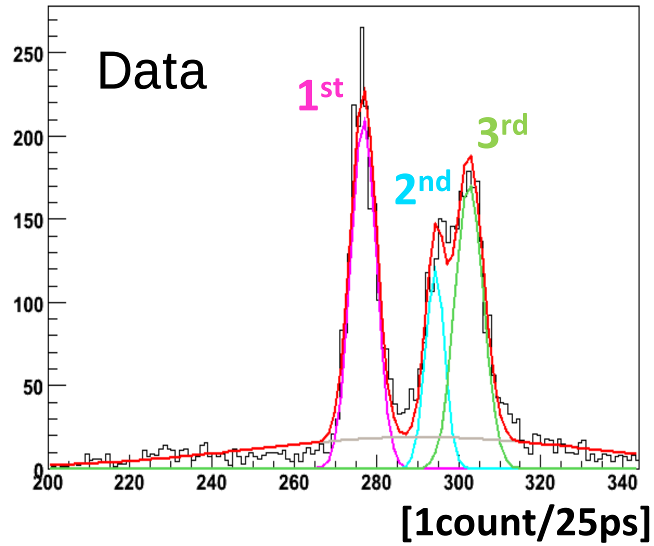
- Normal incidence (90 deg.)
- Obtained number of photons as expected

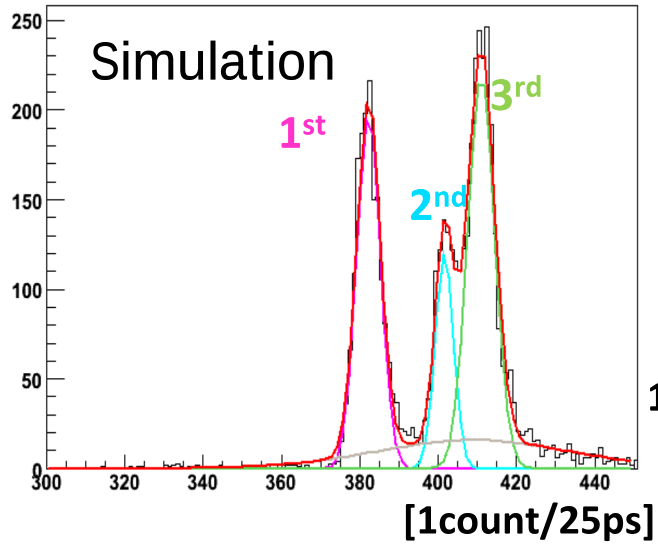
- → We can expect ~22 photons/event, if we use 14 PMTs.
  - Normalized by active area (10→14 PMTs)

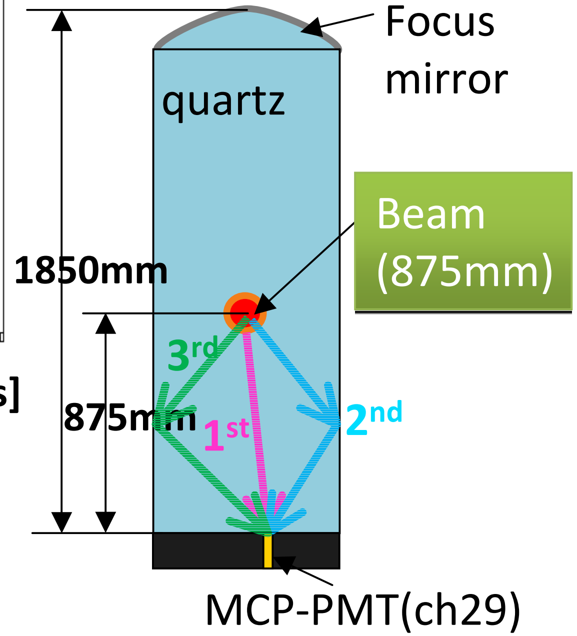
Time resolution

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





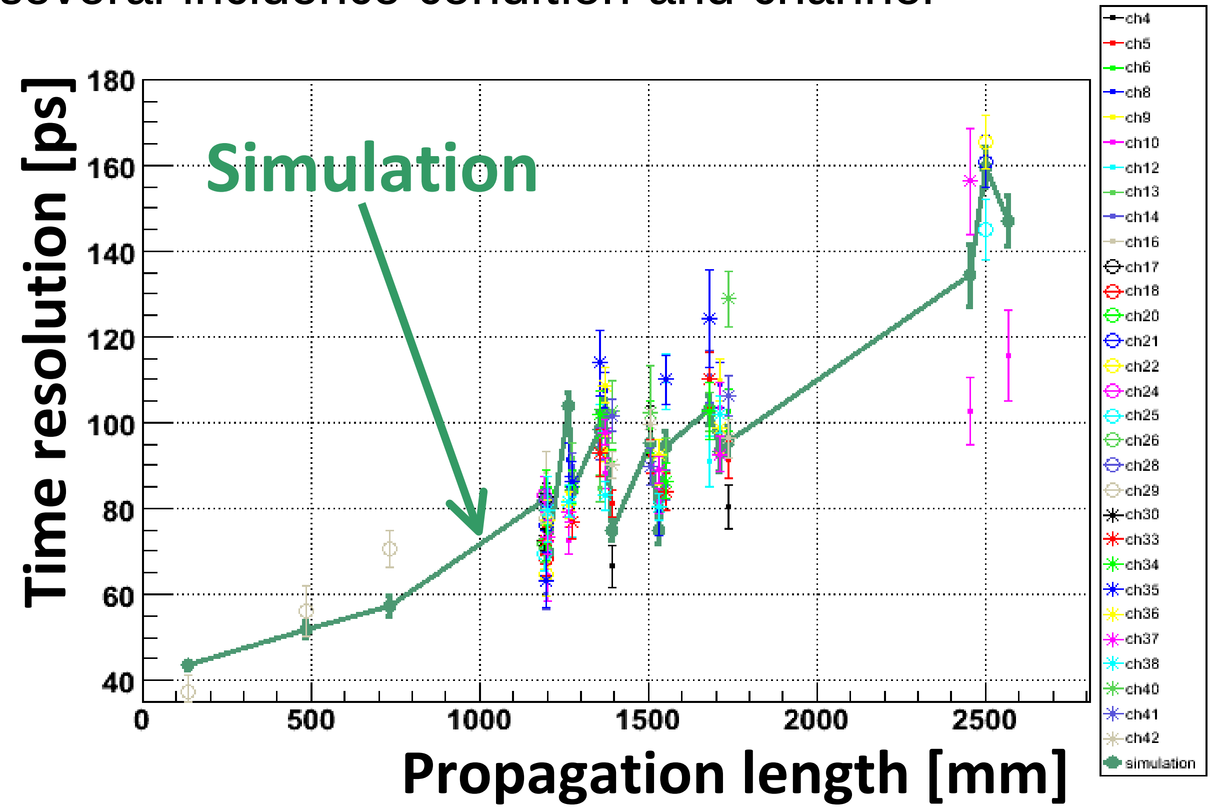




	Resolution(1st peak)
Data	76.0±2.0 [ps]
Simulation	77.7±2.3 [ps]

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

- R&Ds of Cherenkov detectors are in progress!
  - TOP counter for barrel PID upgrade at super B factory
    - Cherenkov ring imaging with precise timing information (σ<40ps)
- Prototype development
  - Multi-anode MCP-PMT
    - 14 prototype PMTs show enough performance
      - TTS < 40ps for single photon for all channels
    - 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