2007/10/15-20

6th International Workshop on Ring Imaging Cherenkov Counters

Development of TOP counter for Super B factory

- Introduction
- Design study
  - PMT property
  - Focusing system
- Summary

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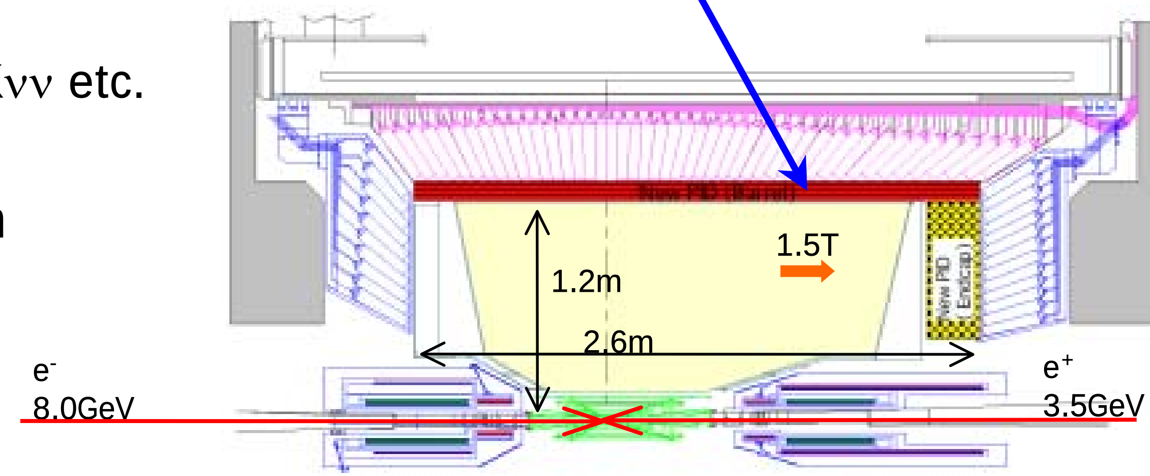
Introduction

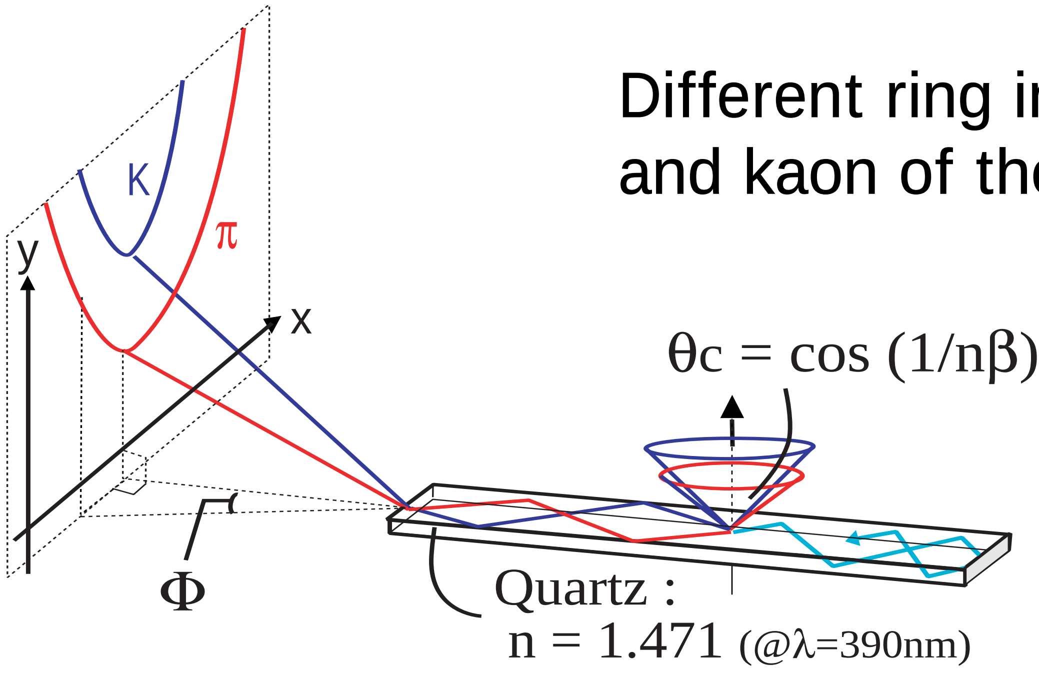
- TOP (Time Of Propagation) counter
  - Developing to upgrade the barrel PID detector
  - For Super B factory
    - $L_{peak} \sim 10^{35\sim36}/cm^2/s$, 20~100 times higher than present
      - Need to work with high beam BG
  - To improve K/π separation power
    - Physics analysis
      - $B \rightarrow \pi\pi/K\pi$, $\rho\gamma$, $K\nu\nu$ etc.
    - Flavor tag
    - Full reconstruction
  - Target; 4σ for 4 GeV/c



Side view of Super Belle detector

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.



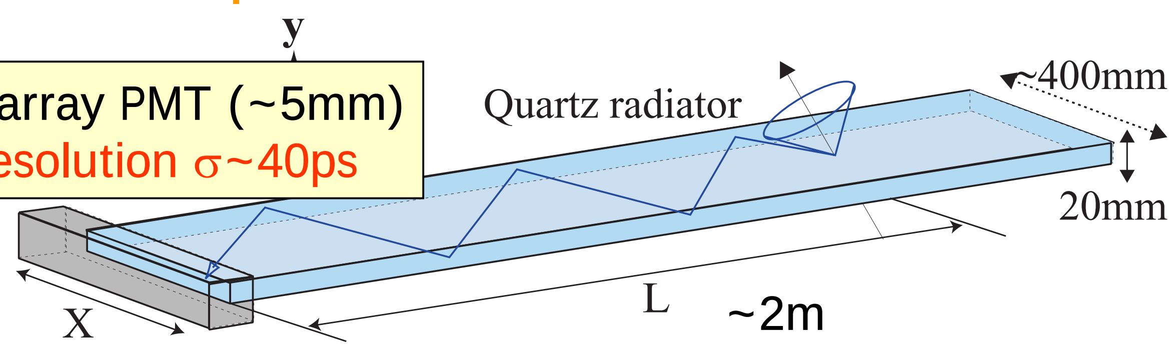
Different ring image for the pion and kaon of the same momentum

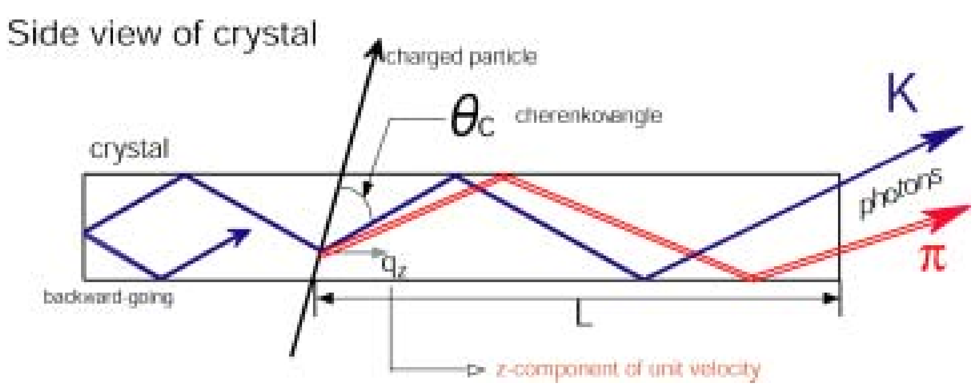
Need large screen...

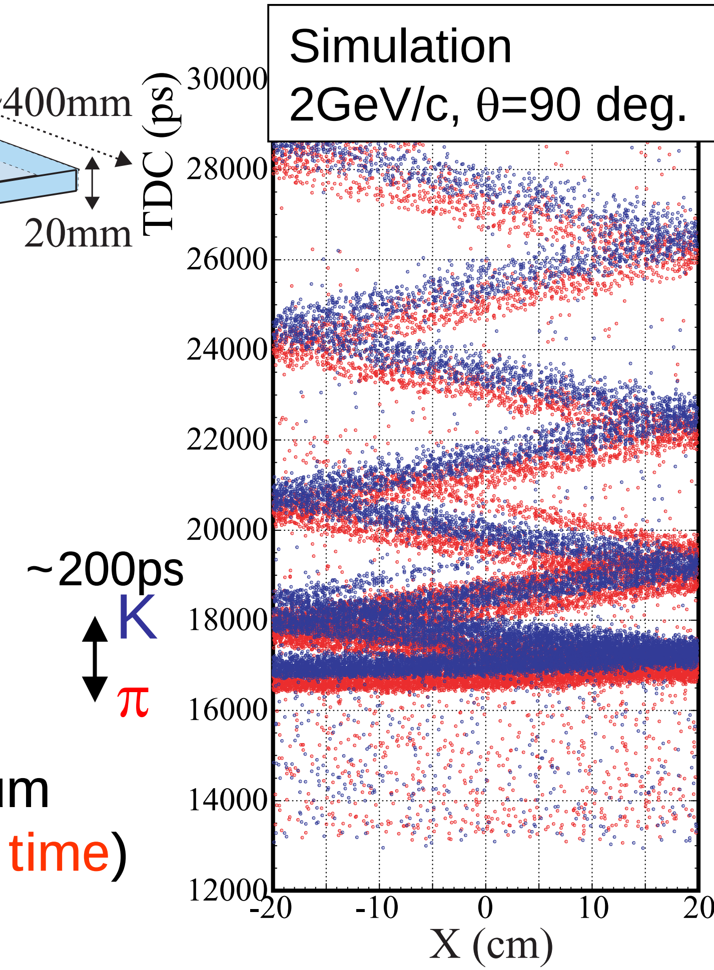
TOP counter

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

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





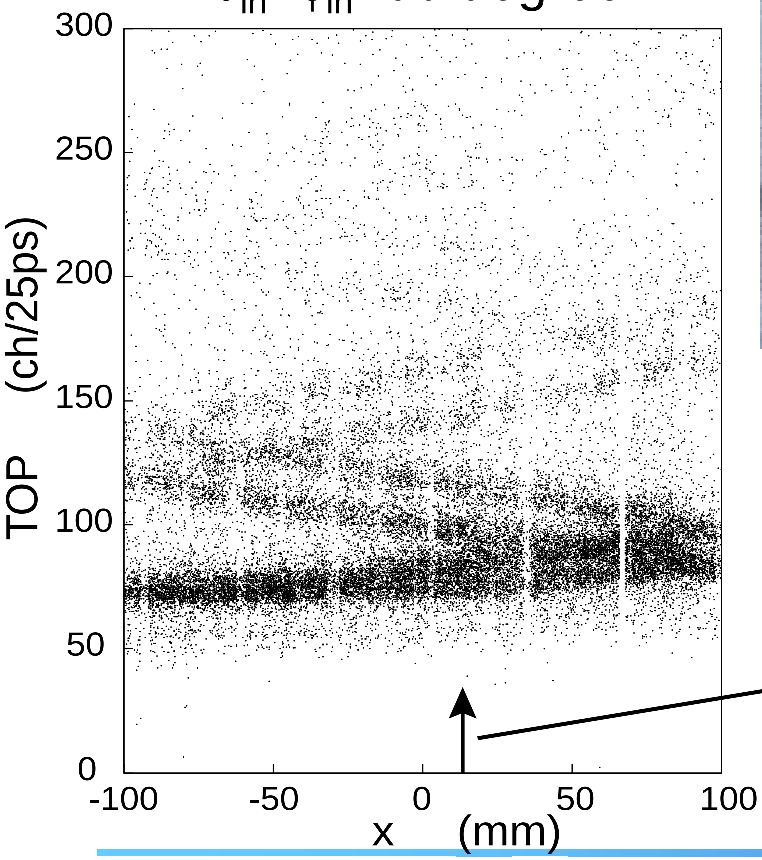


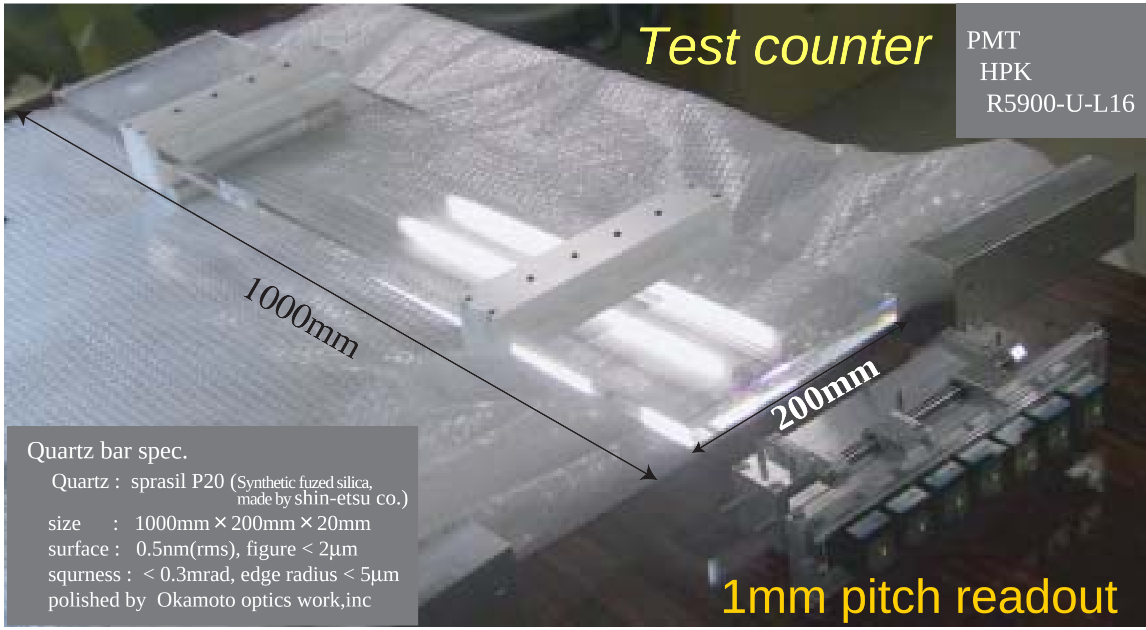
Different opening angle for the same momentum
→ Different propagation length(= propagation time)

+ TOF from IP works additively.

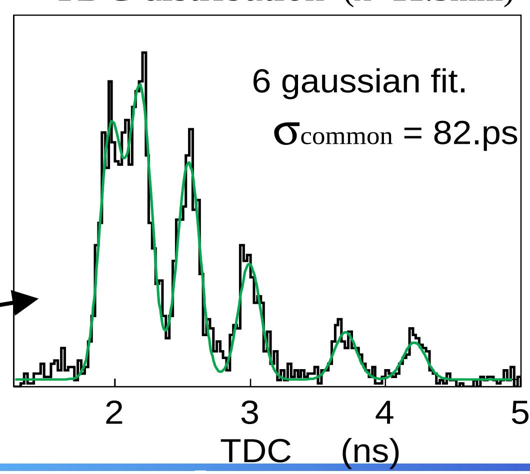
Test counter

Beam test
@ KEK PS π2 line
3 GeV/c π^- beam
$\theta_{in}=\phi_{in}$=90 degree





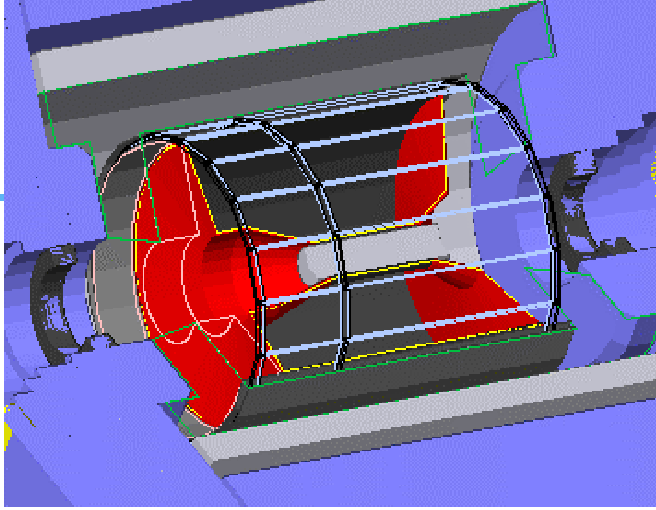
TDC distribution (x=11.3mm)

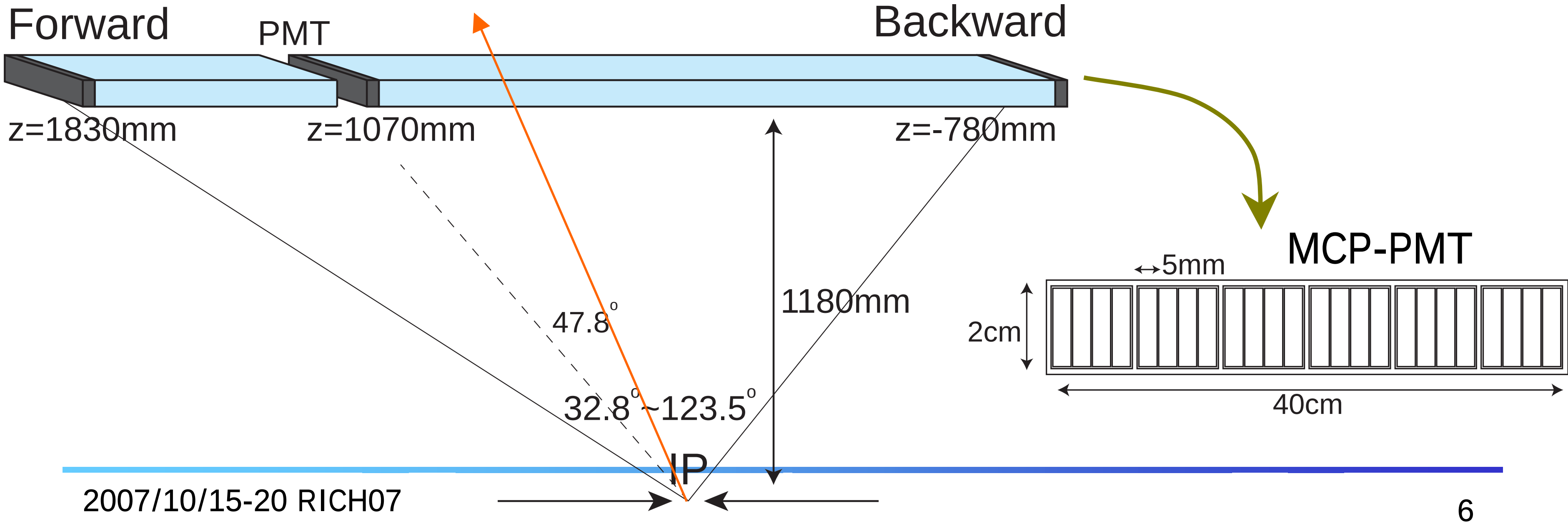


- Clear ring image
- Reasonable time resolution
- Enough bar quality

Design

- Quartz: 255cm^{L} x 40cm^{W} x 2cm^{T}
  - Cut at 47.8deg.
    to reduce chromatic dispersion
- Multi-anode MCP-PMT
  - Good time resolution (<~40ps), Linear array (5mm pitch)
  - Three readout planes

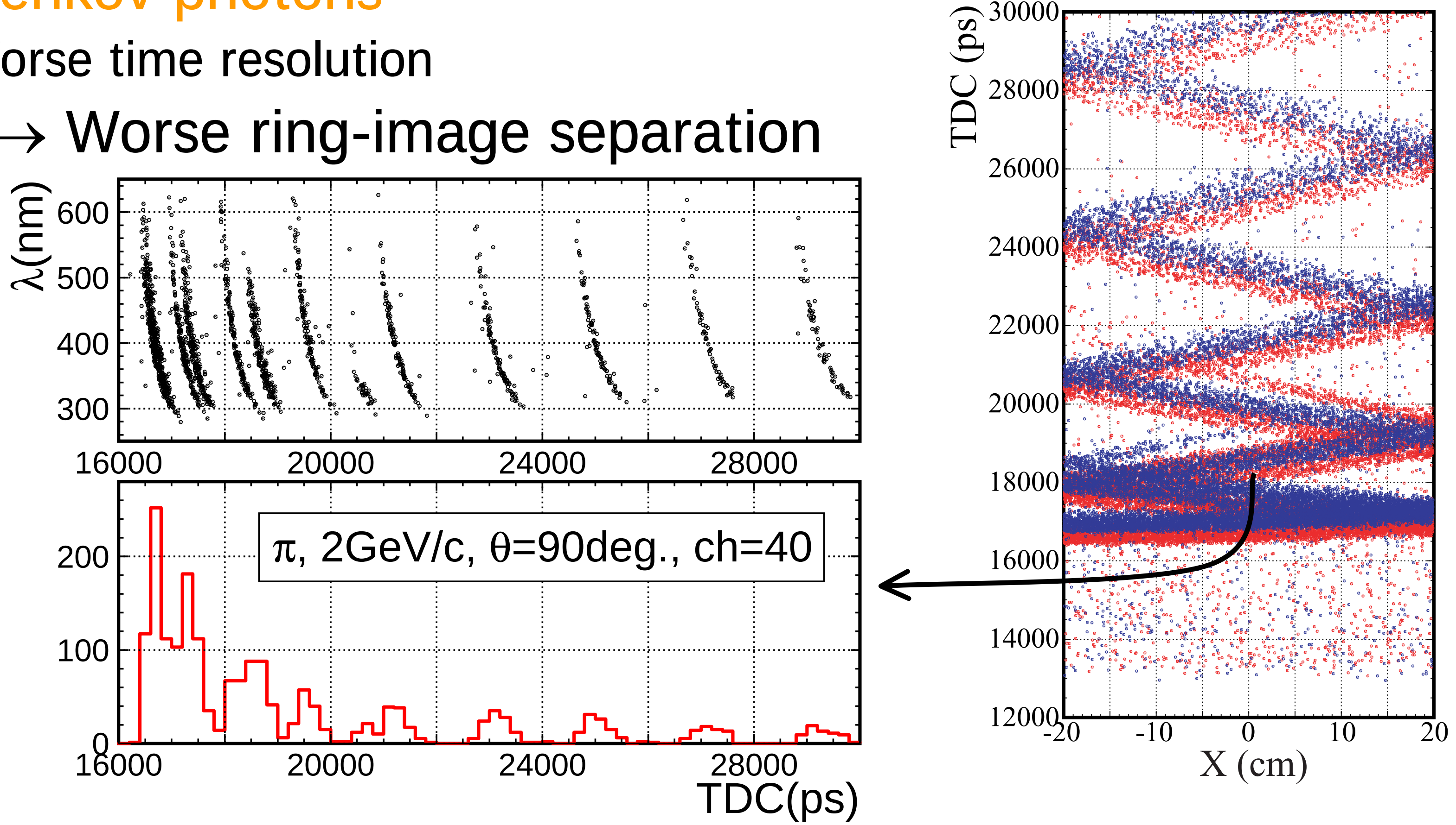




Chromaticity

- Detection time depending on the wavelength of Cherenkov photons
  - Worse time resolution

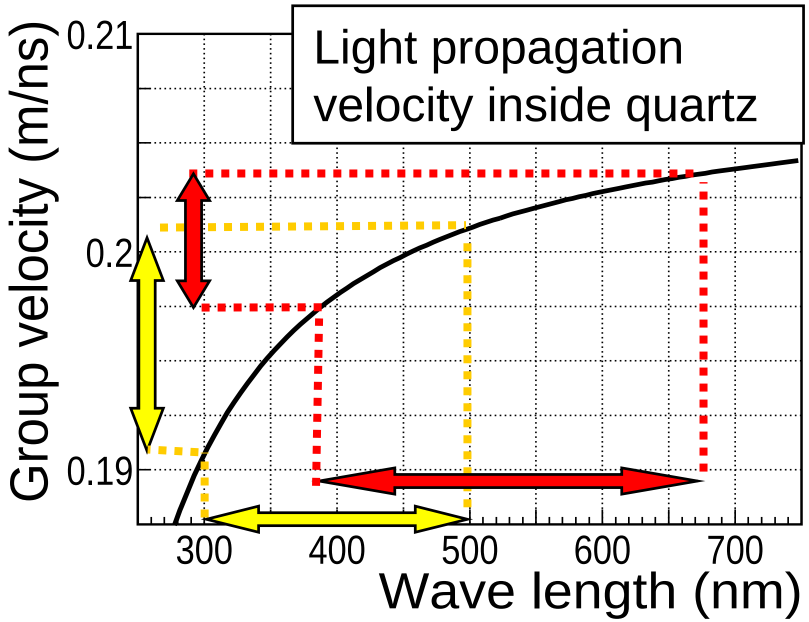
    → Worse ring-image separation

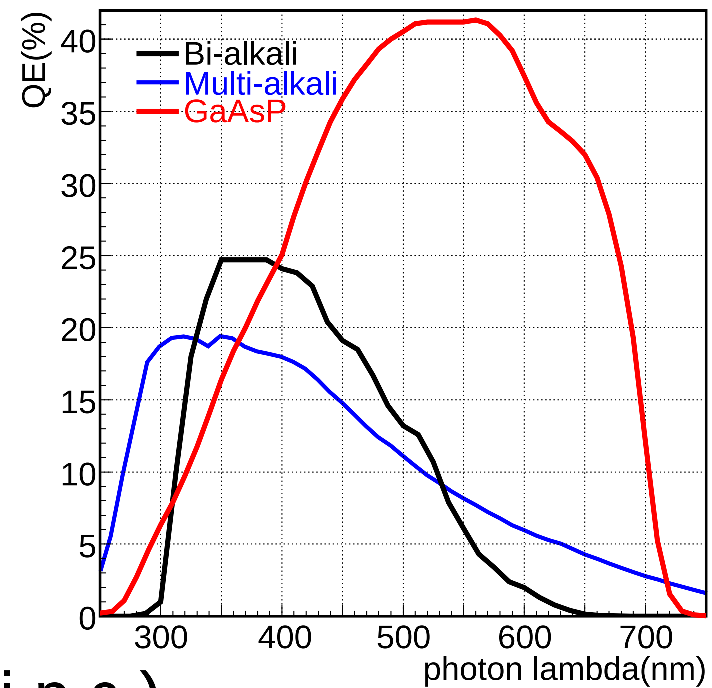


- ➔ Propagation velocity depending on λ in the quartz bar

Chromatic dispersion

Variation of propagation velocity depending on the wavelength of Cherenkov photons





- GaAsP photo-cathode (←→ alkali p.c.)
  - Higher quantum-efficiency
  - at longer wavelength → less chromatic error

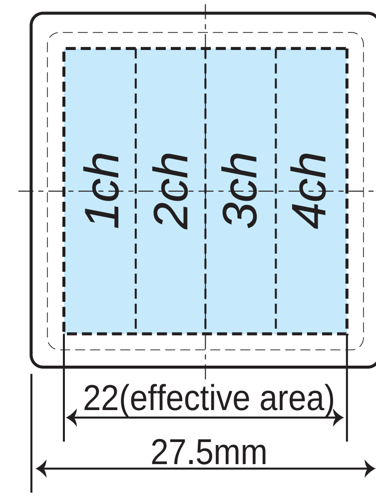
Photon sensitivity at longer wavelength shows the smaller velocity fluctuation.

GaAsP MCP-PMT development

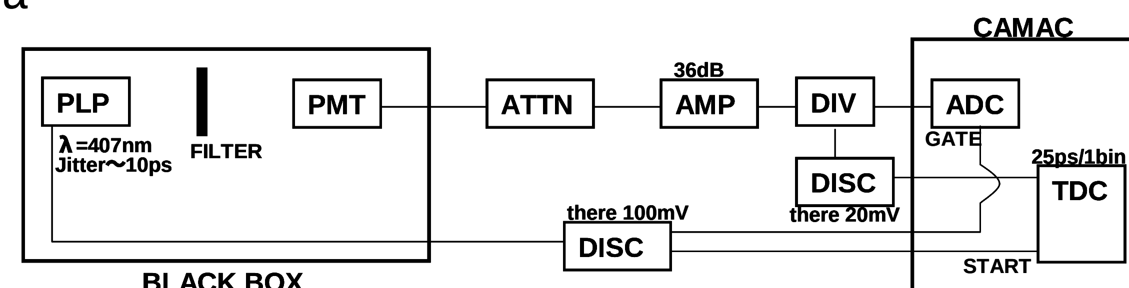
- Square-shape MCP-PMT with GaAsP photo-cathode is developed with Hamamatsu Photonics.

- Prototype
  - GaAsP photo-cathode
    - Al protection layer
  - 2 MCP layers
    - ϕ10μm hole
  - 4ch anodes
  - Slightly large structure
    - Less effective area

Target structure

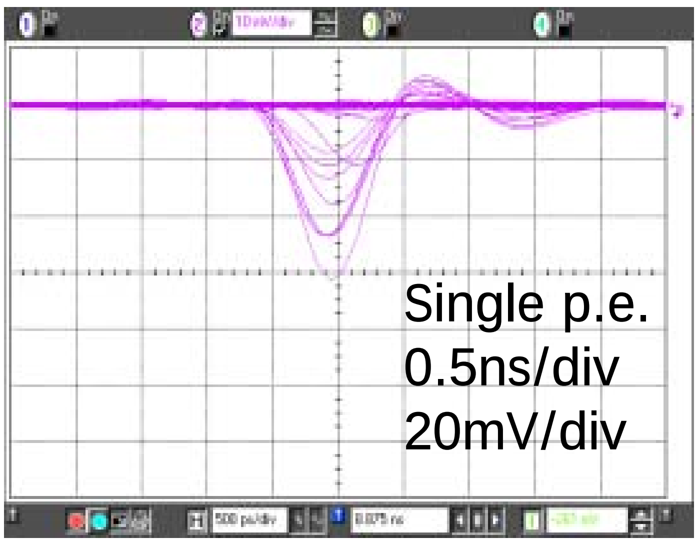


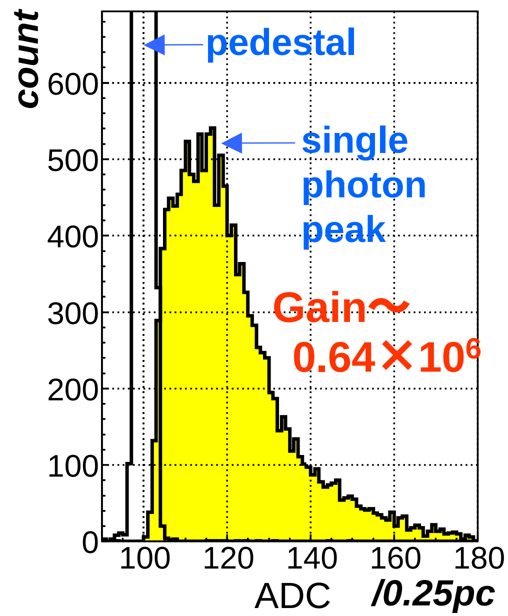
- Performance test
  - Time resolution

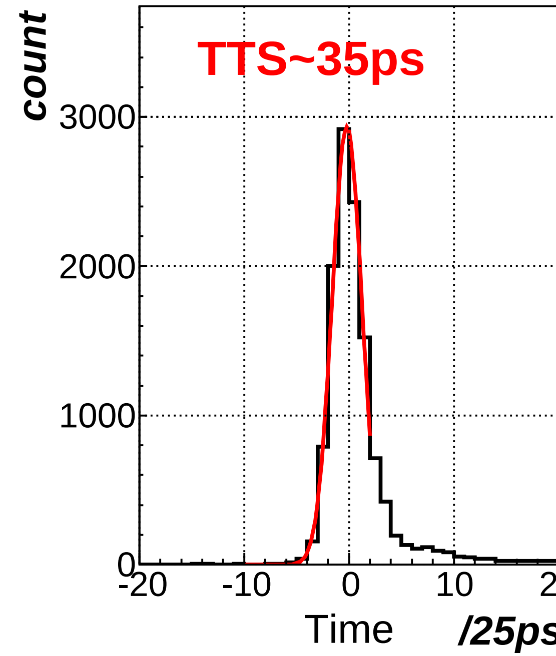


GaAsP MCP-PMT performance

- Wave form, ADC and TDC distributions for single photon

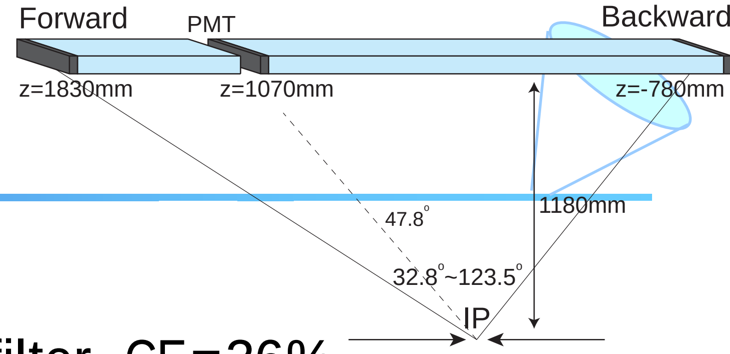




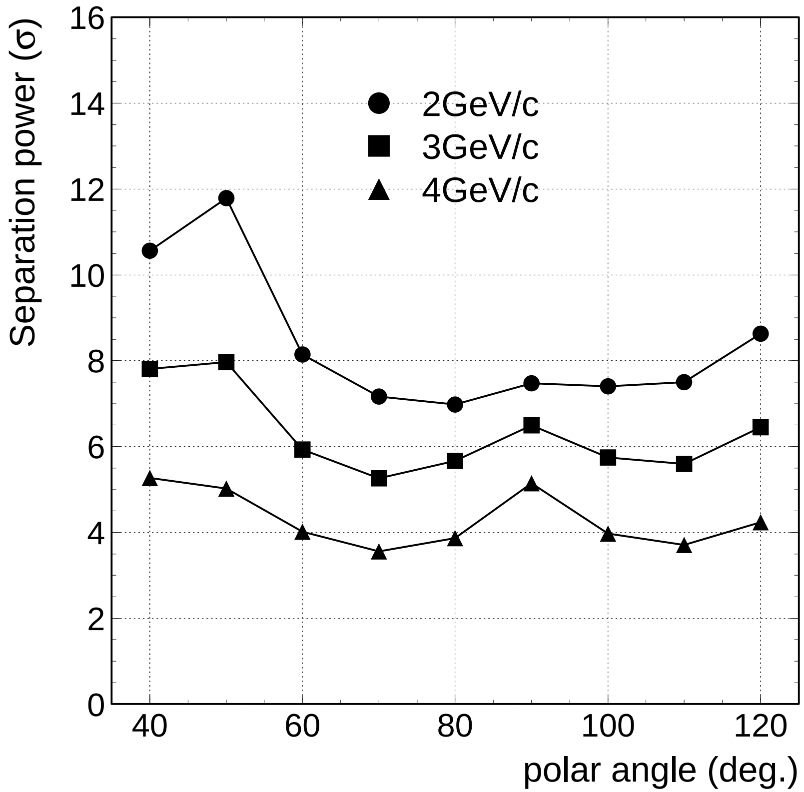


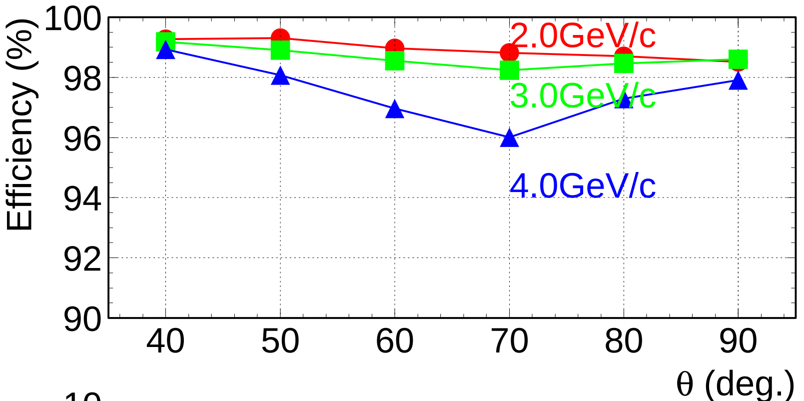
- Enough gain to detect single photo-electron
- Good time resolution (TTS=35ps) for single p.e.

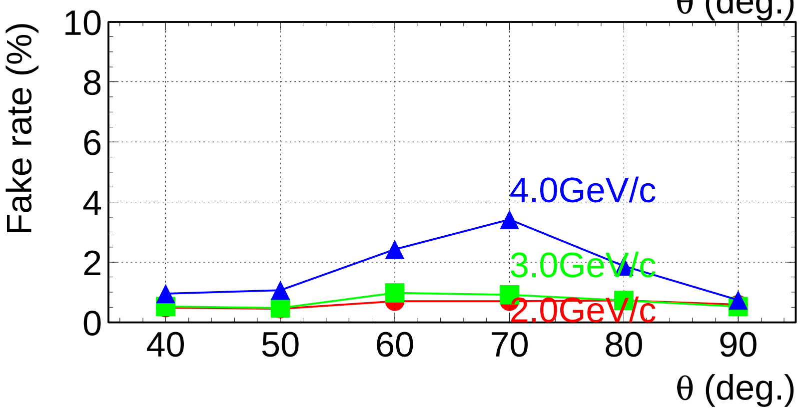
Performance with GaAsP



- K/π separation power
  - GaAsP photo-cathode + >400μm filter, CE=36%







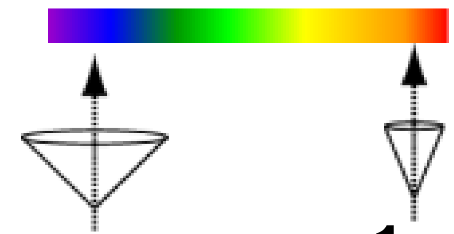
3.5σ K/π for 4 GeV/c, θ=70°

Focusing TOP

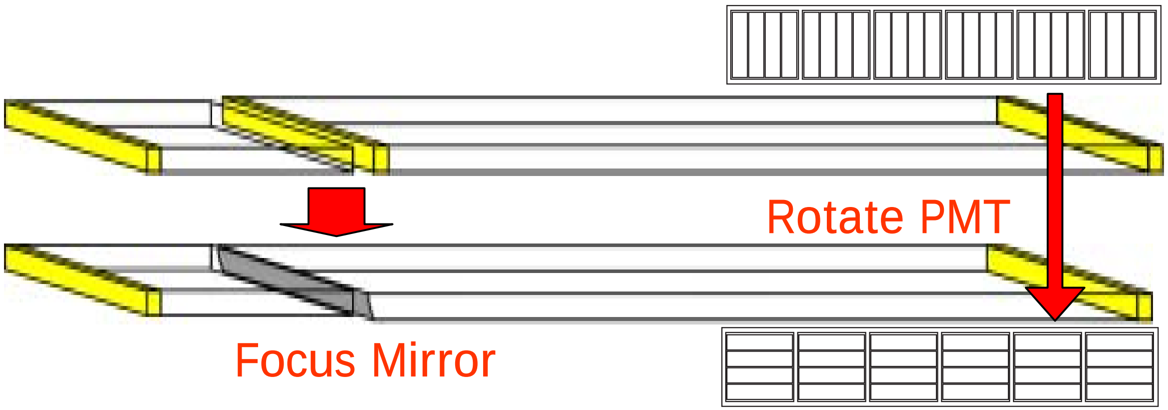
- Remaining chromatic effect makes ~100ps fluctuation for TOP.
- Use λ dependence of Cherenkov angle to correct chromaticity

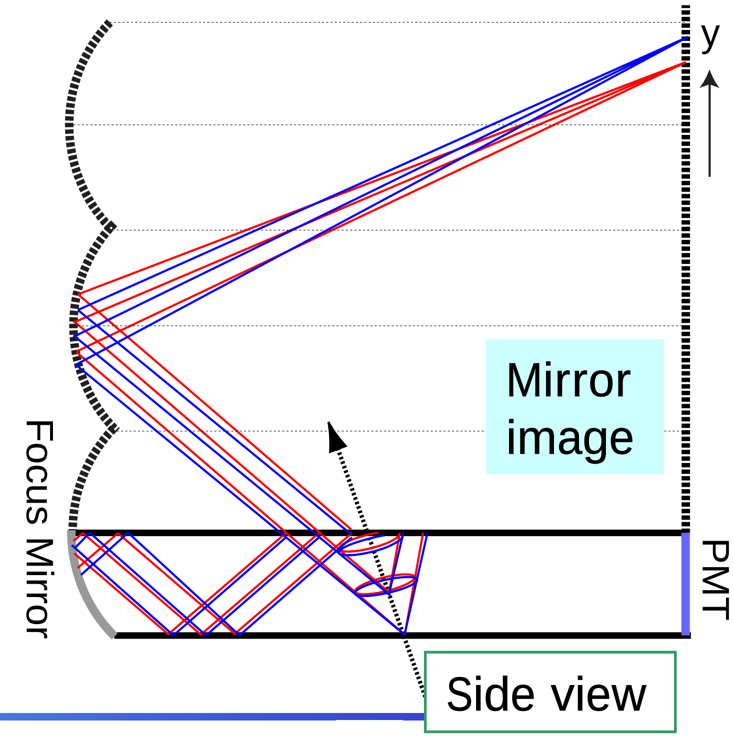
➔ Focusing system to measure θ_c

  - $\lambda \leftarrow \theta_c \leftarrow$ y position
  - Reconstruct ring image from 3D information (time, x and y).



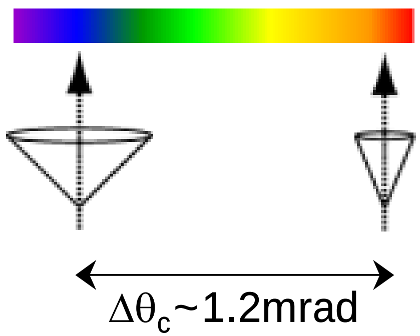
$$\theta_c(\lambda) = \cos^{-1}\left(\frac{1}{n(\lambda)\beta}\right)$$



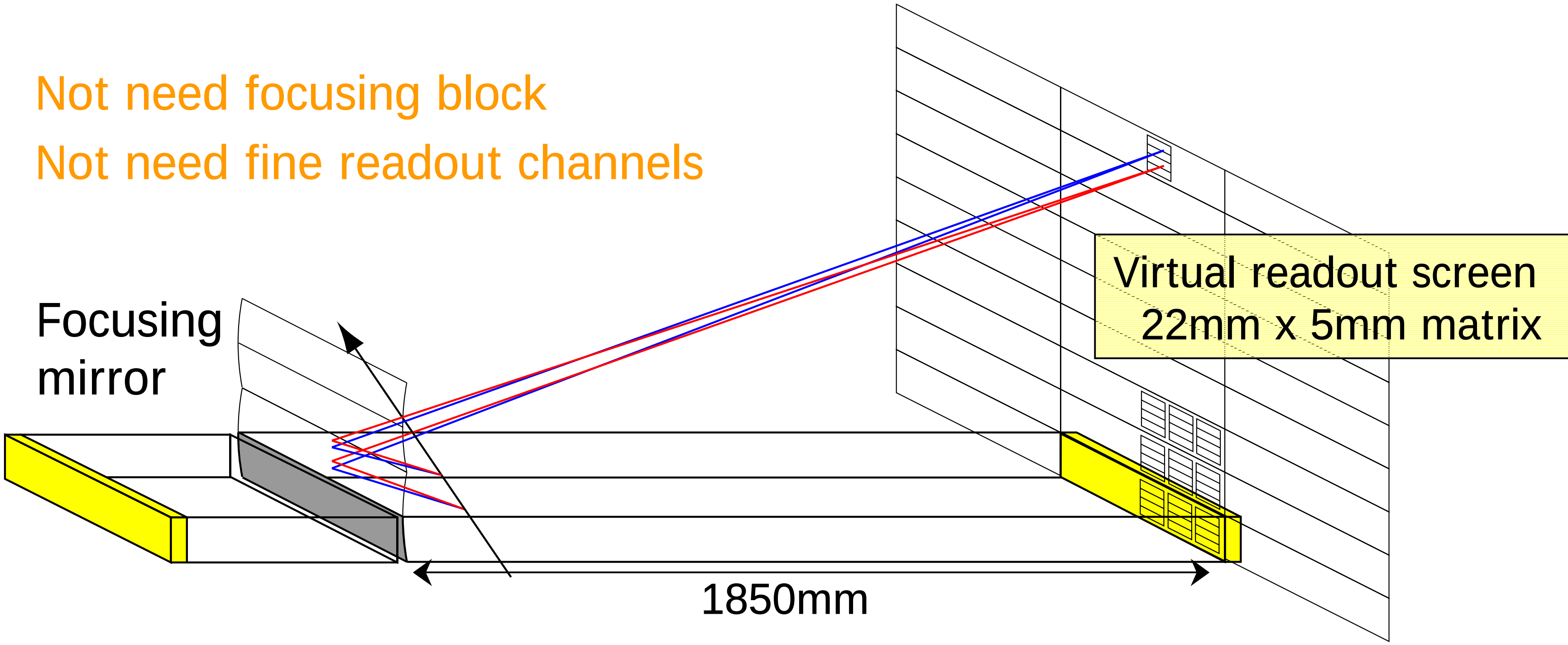


Focusing TOP (2)

- $\Delta\theta_c$~1.2mrad over sensitive λ range
- → Δy~20mm (~quartz thickness)
  - We can measure λ dependence and obtain good separation even with narrow mirror and readout plane, because of long propagation length.



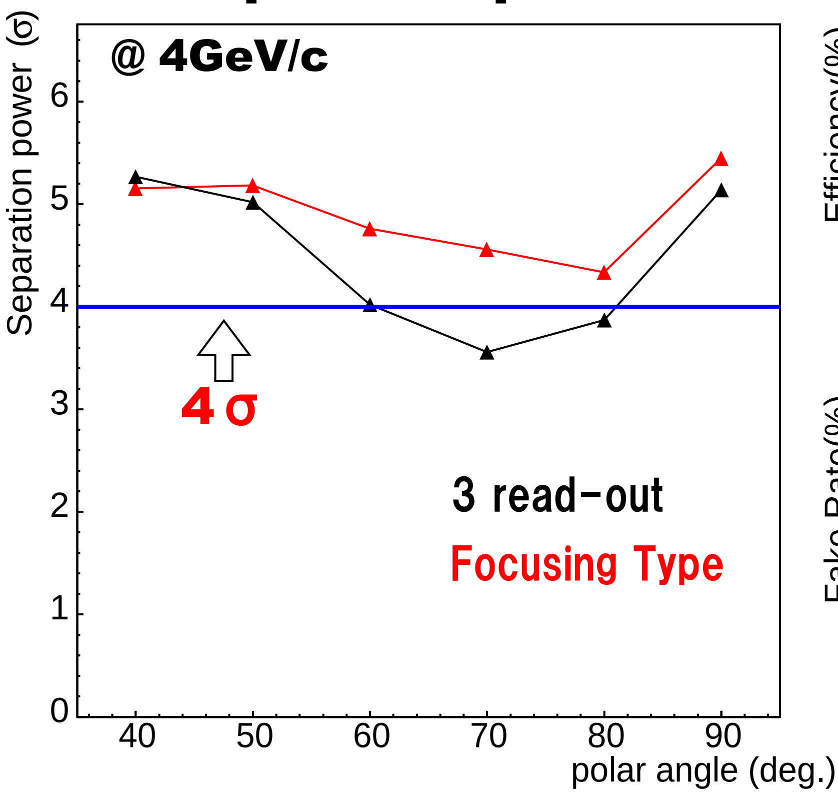
  - Not need focusing block
  - Not need fine readout channels



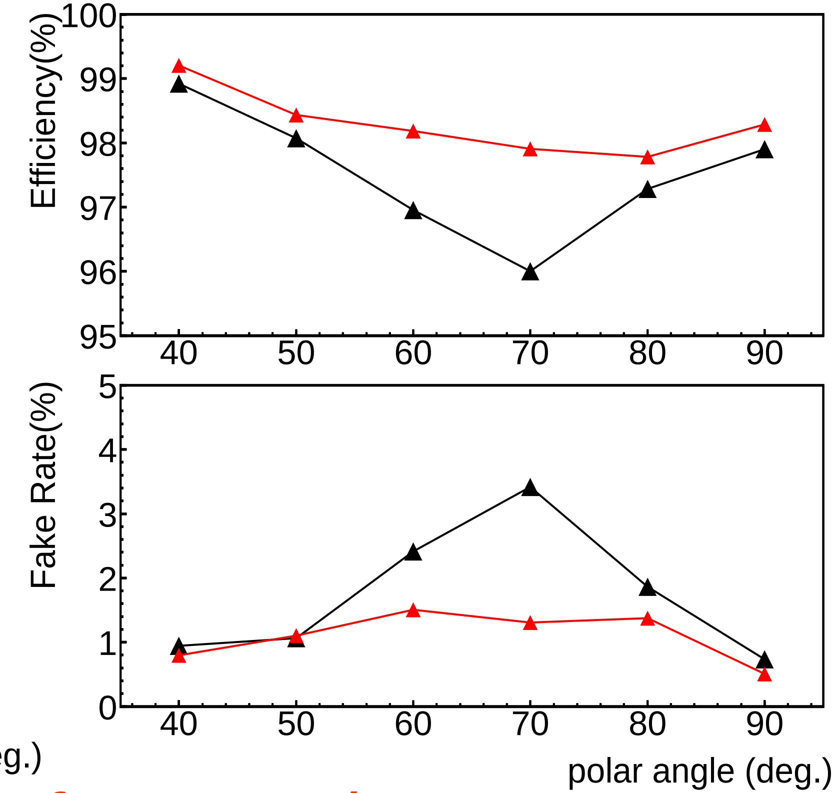
Performance of focusing TOP

- K/π separation power
  - GaAsP photo-cathode(+>400μm filter), CE=36%

Separation power



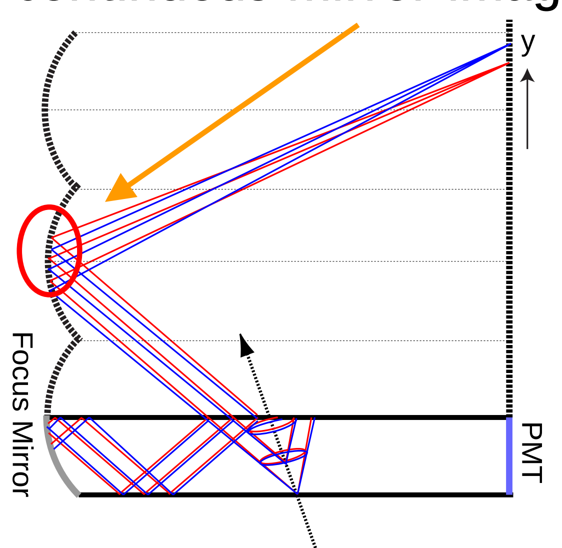
Efficiency,Fake rate



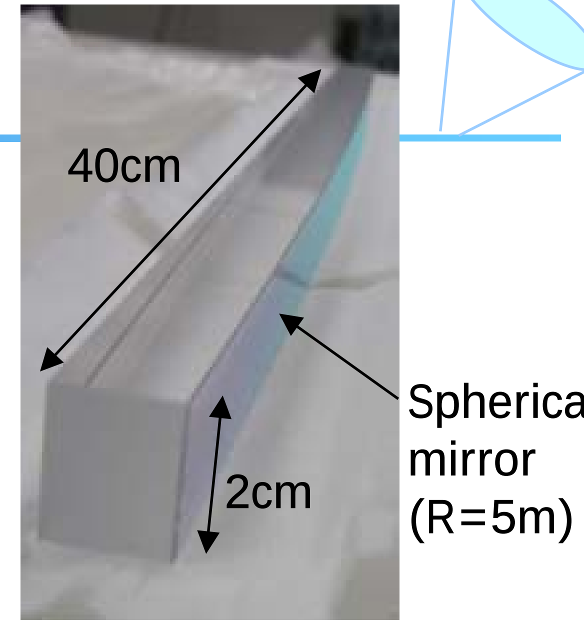
<u>4.3σ separation for 4GeV/c</u>

Mirror test

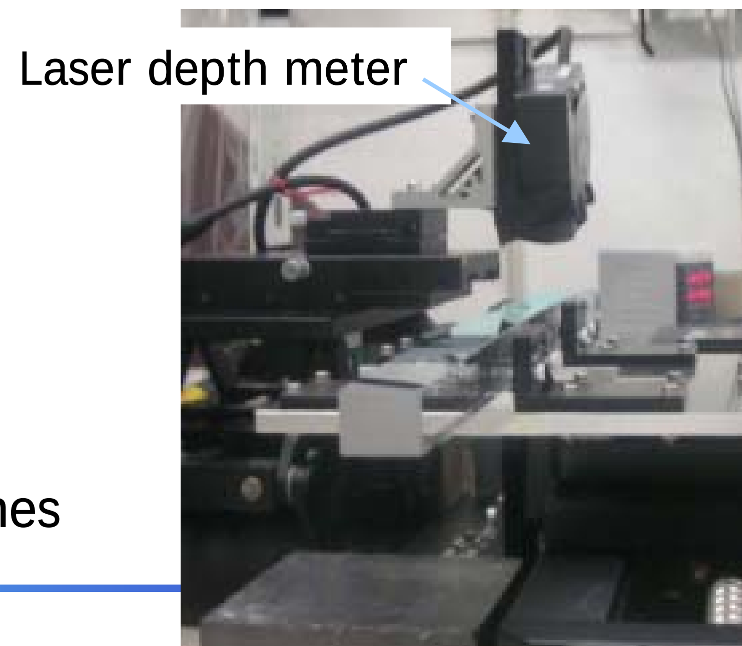
- Prototype by Okamoto-optics
  - 40x2x2cm, R=5m
  - Attached at the end of quartz bar
- Shape measurement
  - Need continuous mirror image



  - Found (4.9±0.2)mm shift
  - ➔ Adjusted by re-polishing flat planes



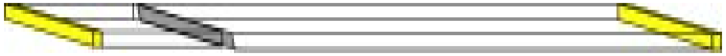
Focusing mirror



Summary

- R&D of TOP counter is in progress!
  - To install super B factory
- Design studies
  - To suppress the influence of chromaticity
  - GaAsP photo-cathode MCP-PMT
    - Prototype shows the enough performance
      - Gain = 0.64×10^6, TTS = 35ps for single photon
      - High Q.E. (>40% at 500nm)

  - Focusing system



    - Narrow mirror and narrow readout plane
    - Form large virtual readout screen
      - Not need focusing block and fine PMT channels
    - Improved performance (4.3σ for 4GeV/c)
- → Prototype production