TOP counter R&Dの成果･現状

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2. Principle
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5. Install to Belle
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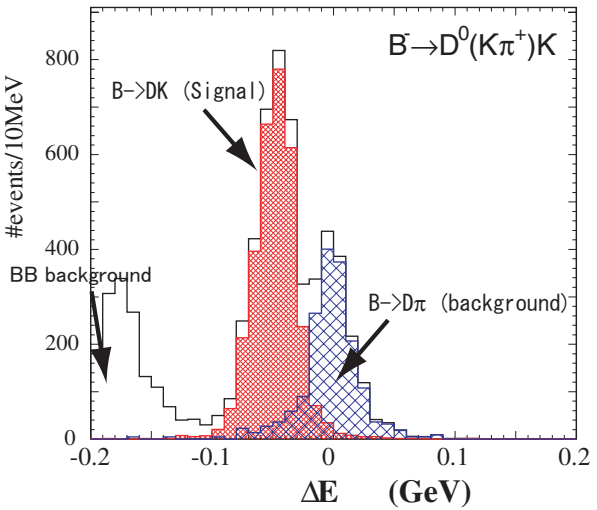
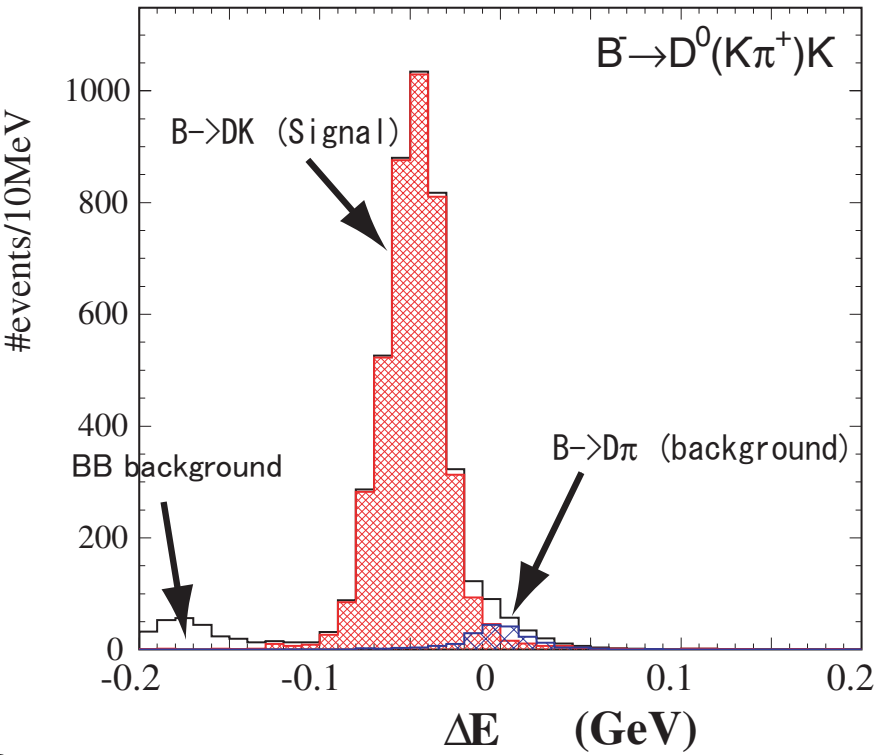
Motivation

Belle実験のupgrade用PID (π/K) deviceの開発



current PID system



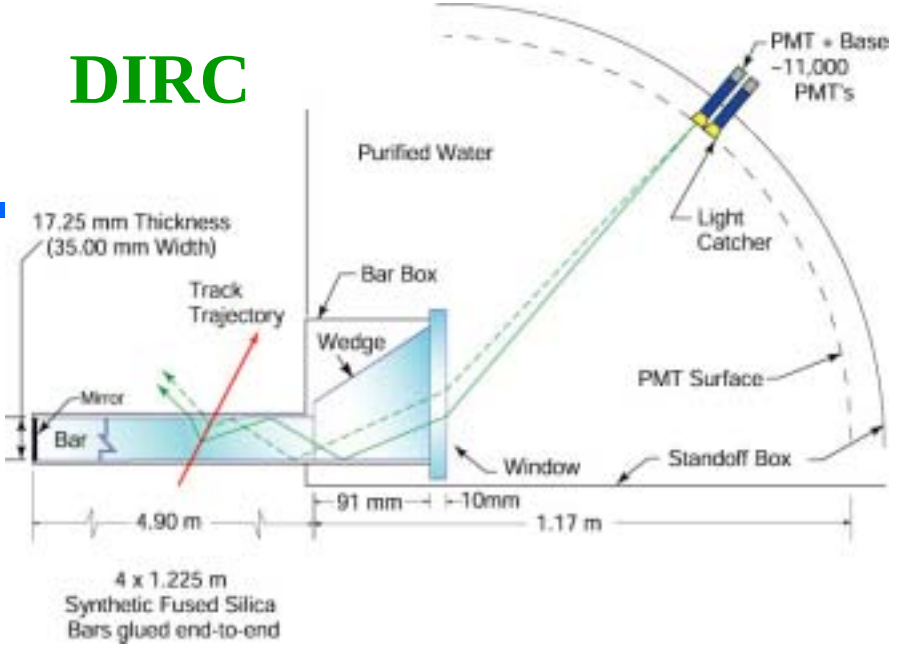
Belle検出器に導入

π/Kを 4σ での識別を目指す。

TOP counter とは

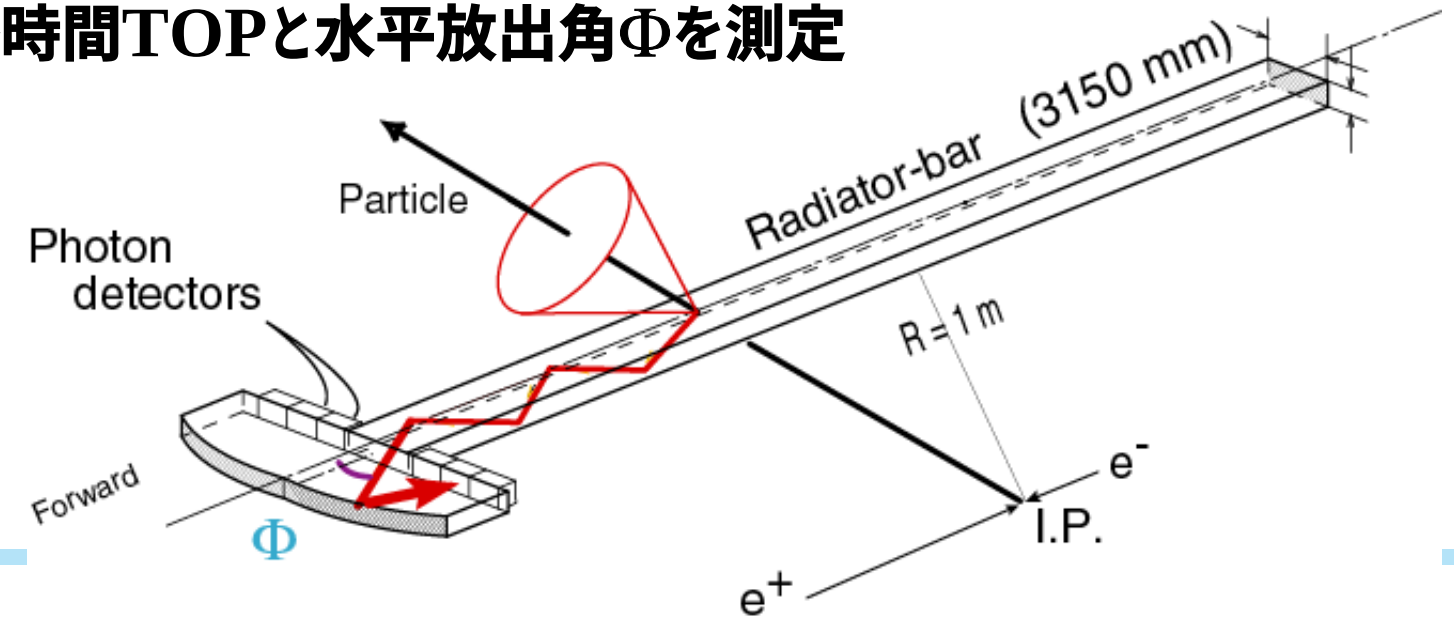
石英を用いた
リングイメージ型粒子識別装置

- simple
- high performance

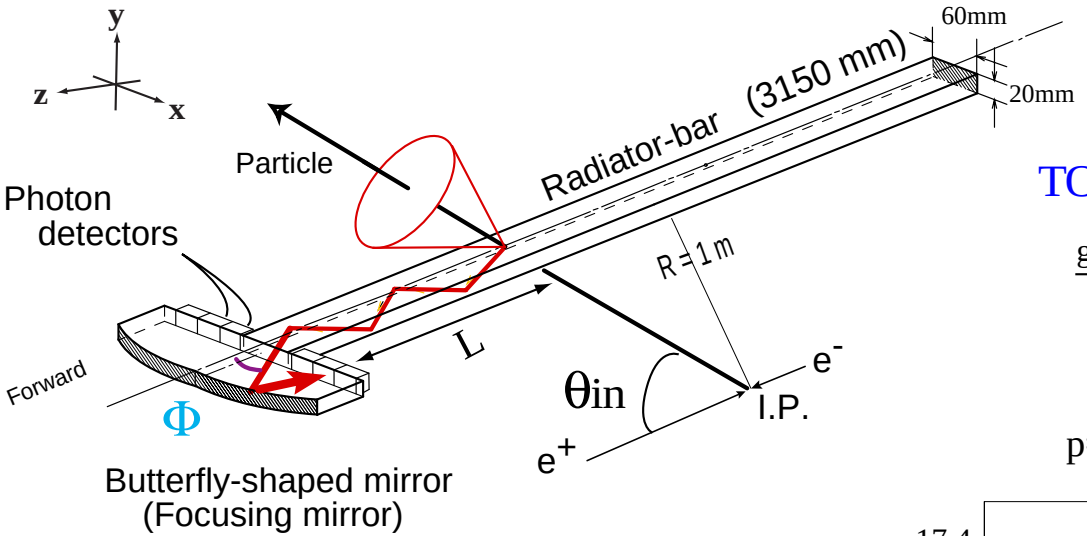


TOP counter

伝播時間TOPと水平放出角Φを測定



Principle



Time Of Propagation

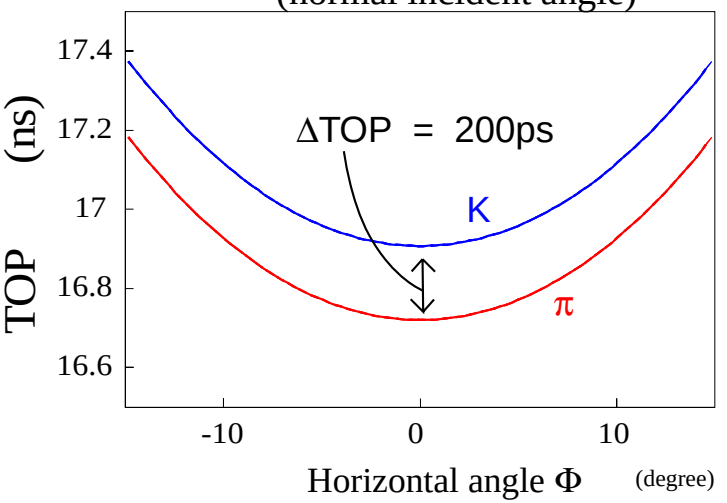
$$TOP(\theta_c,\Phi) = \left(\frac{L}{v_g(\lambda)}\right) \times \frac{1}{q_z(\theta_c,\Phi)}$$

group light velocity

Horizontal angle

q_z ; z component unit vector

p=3GeV/c, L=2m, θin=90.
(normal incident angle)



π/Kの時間差

TOP : $\theta_c^{\pi} > \theta_c^{K}$ → $TOP^{\pi} < TOP^{K}$

TOF : $\beta^{\pi} > \beta^{K}$ → $TOF^{\pi} < TOF^{K}$

→ ΔTime = ΔTOP + ΔTOF

(200ps = 160 ps + 40 ps)

Uncertainty of TOP

- **PMT's T.T.S**

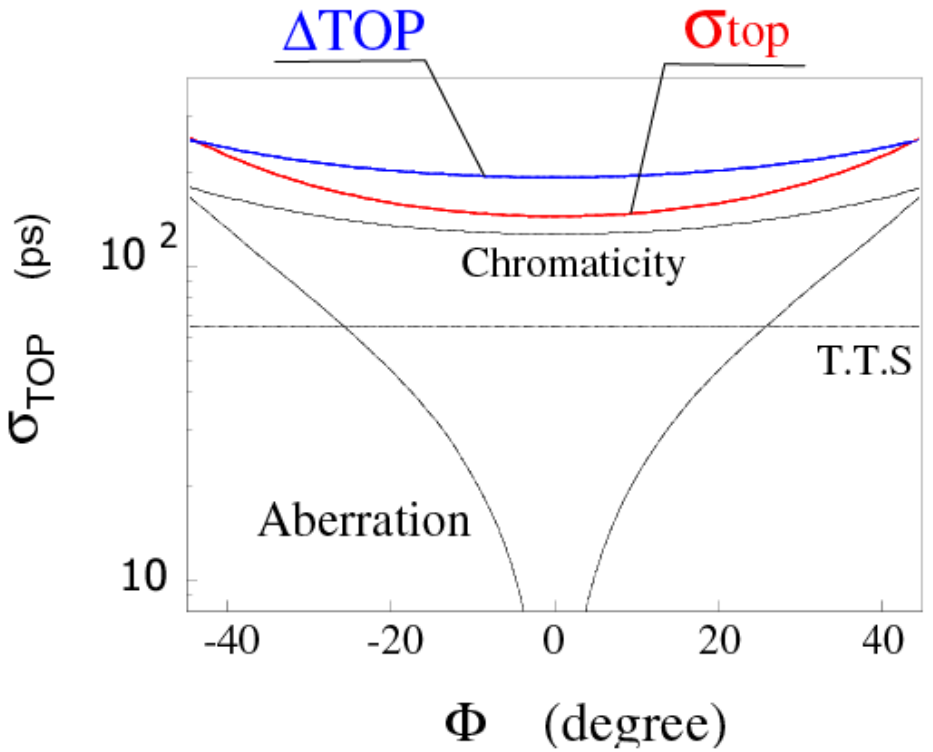
  HPK R5900-U-L16
  T.T.S = 75ps
  Q.E. - 20%(bi-alkali)
  ch.pitch = 1mm

- **Chromaticity (Quartz)**

  reflection index n=1.471
  $\Delta\lambda$ = 65nm (λ=300-600nm)
  σ_n ~100ps @ L=2m, θ_{in}=90,
  (Nγ= 500/10mm)

- **Aberration of Φ**

  r = 250mm, $|\Phi| < 45^\circ$
  $d\Phi/dx$ = 0.5/mm



If σ_{TOP} ~ 150ps,

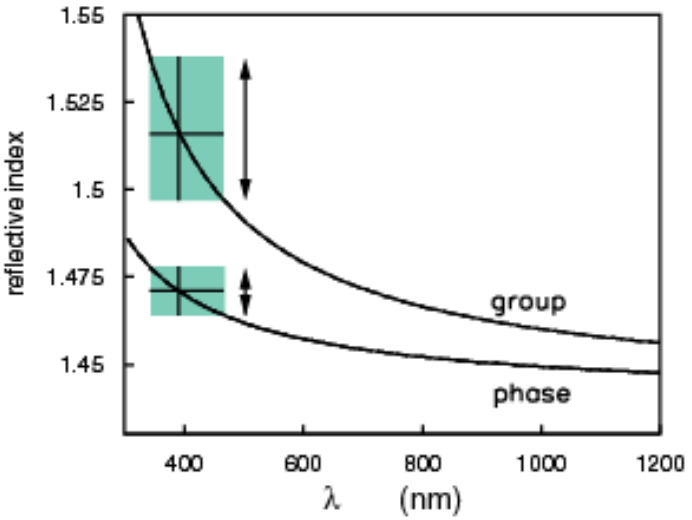
$$\frac{\Delta TOP}{\sigma_{TOP}} \sim 1.2\sigma \longrightarrow S \sim 6.5$$

N_{ph}(exp.)=30

時間分解能 (波長依存性)

Cherenkov Angle
n→大
θ_c → 大
time → 短
(σ_θ = -120ps)

light velocity
n→大
V_g → 小
time → 長
(σ_v = 240ps)



逆向きに働く
→ resolution**は小さくなっている。**
(σ_{chro} = 120ps)

時間を測定することにより、
π/Kの差を大きくし、分解能を小さくしている。

R&D

原理面の研究

- mirror-TOP
- Bar-TOP

Beam test

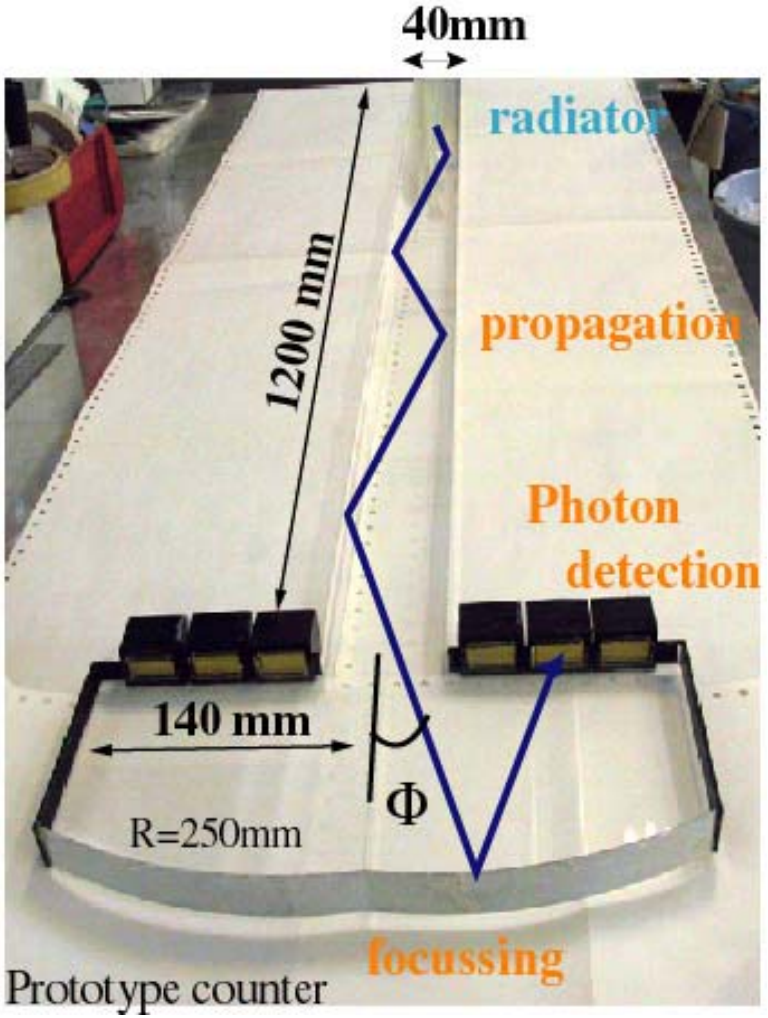
- Ring image
- Time resolution

光検出器開発

good timing resolution
workable under 1.5T
position sensitive

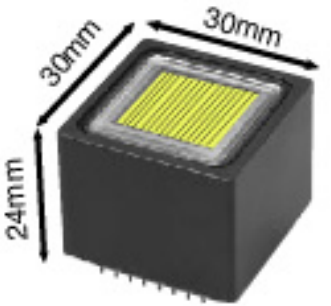
- Fine mesh PMT
- MCP PMT,
- HAPD
- SiPM

proto-type TOP counter



PMT

HPK R5900-U-L16



$\sigma_{T.T.S} = 75ps$

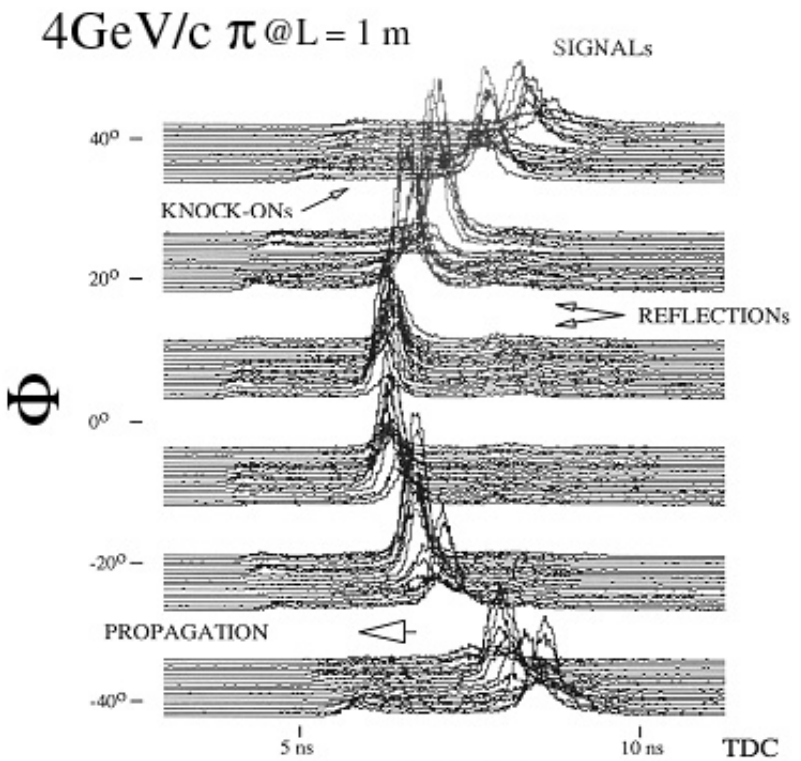
Linear array 16 anode(1mm pitch)

effective area = 40%

collection efficiency = 50%

Total 96ch (6 tubes)

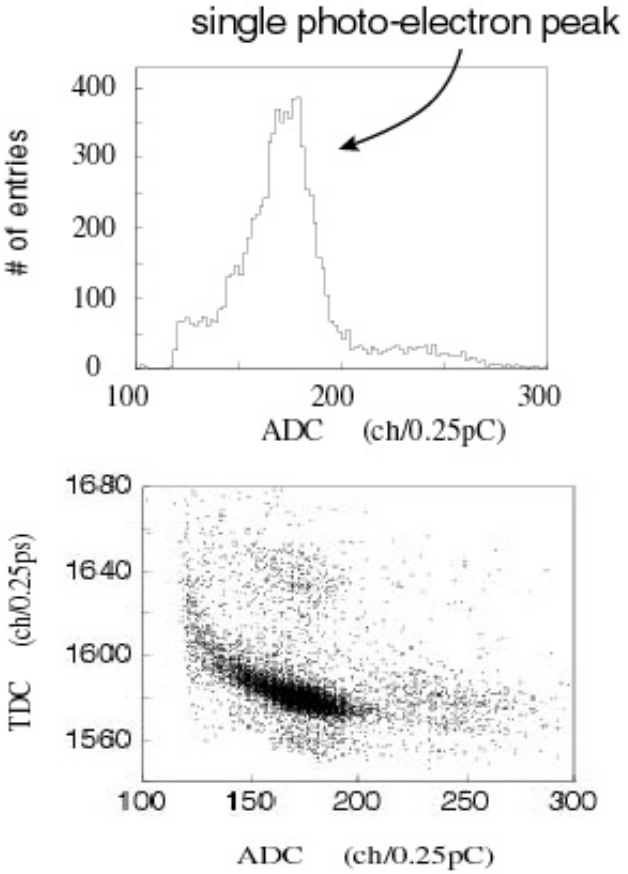
Beam test result : mirror-TOP counter
- Ring image -



TOP

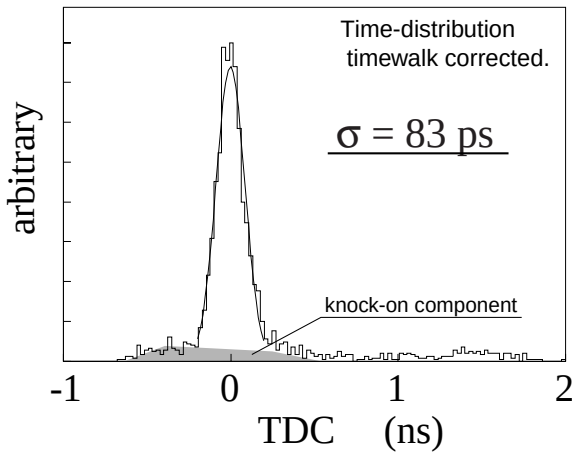
Clear Ring Image !!

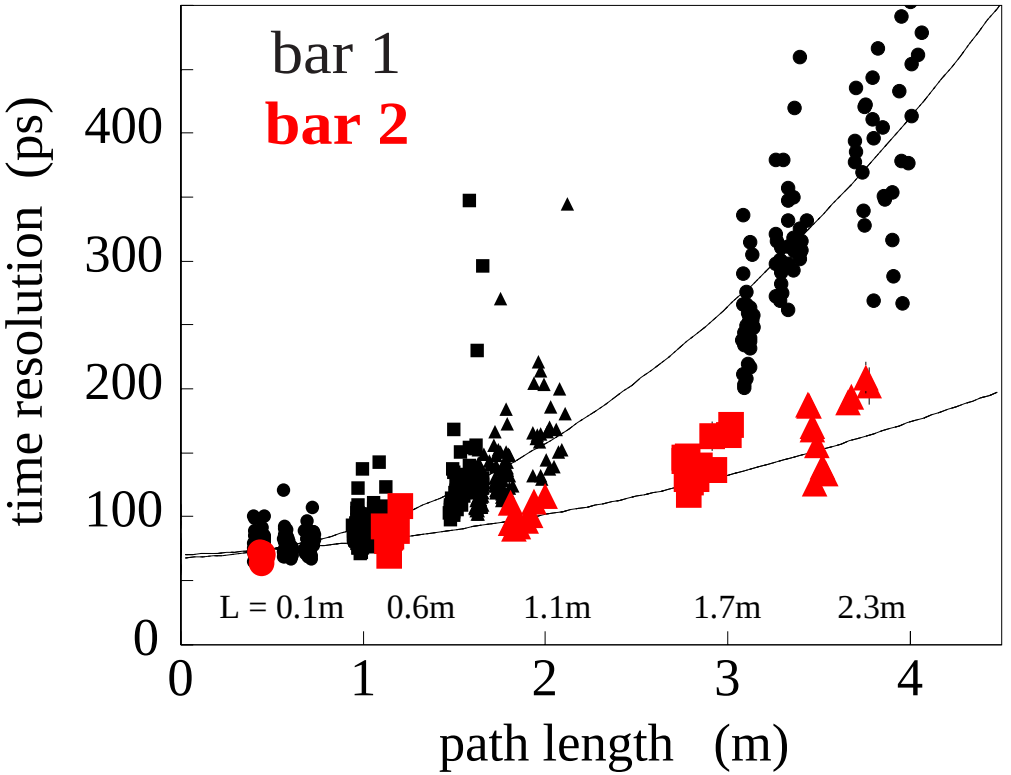
- **ADC & TDC distributions**



Beam test result : mirror-TOP counter
- Time resolution -

TDC distribution





Time resolution (σ_{TOP})

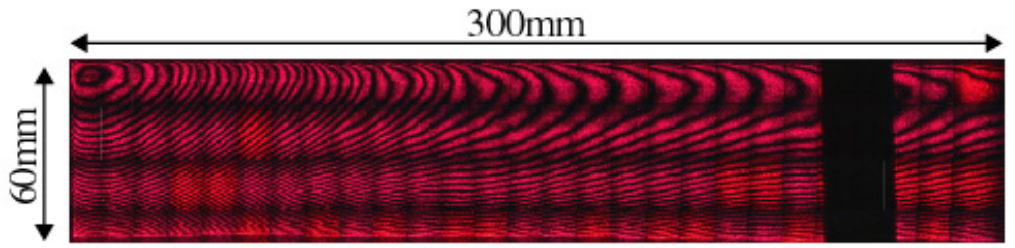
With improved polishing accuracy of the quartz bar,

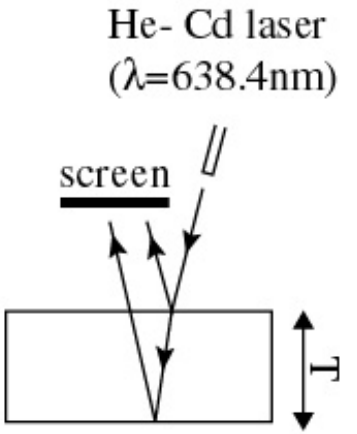
$$\sigma_t = 300\text{ps} \rightarrow 150\text{ps} \quad (@L=2.3\text{m})$$

Crystal bar

Interferograms

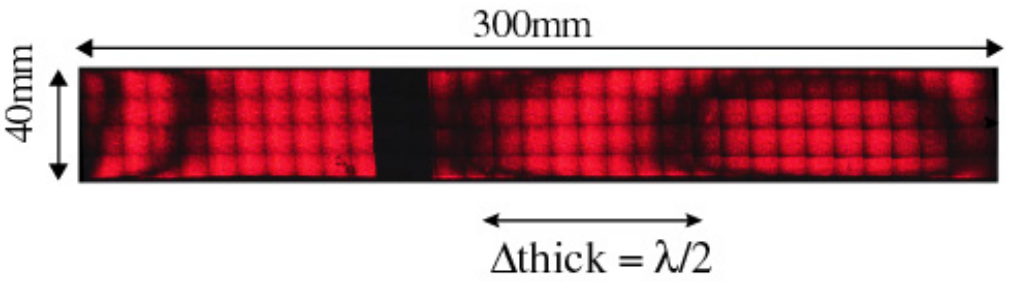
bar 1.





10 times better !!!

bar 2



Polishing accuracy

	bar. 1	bar. 2
polish	2nm	0.5 nm
figure	5μm	0.6 μm
squreness	2 mrad	0.3 mrad
edge radius	50 μm	5 μm

Polish company

- **大面積を光学研磨　(しかも6面体)**
  →普通の研磨会社ではできない。

研磨可能な会社

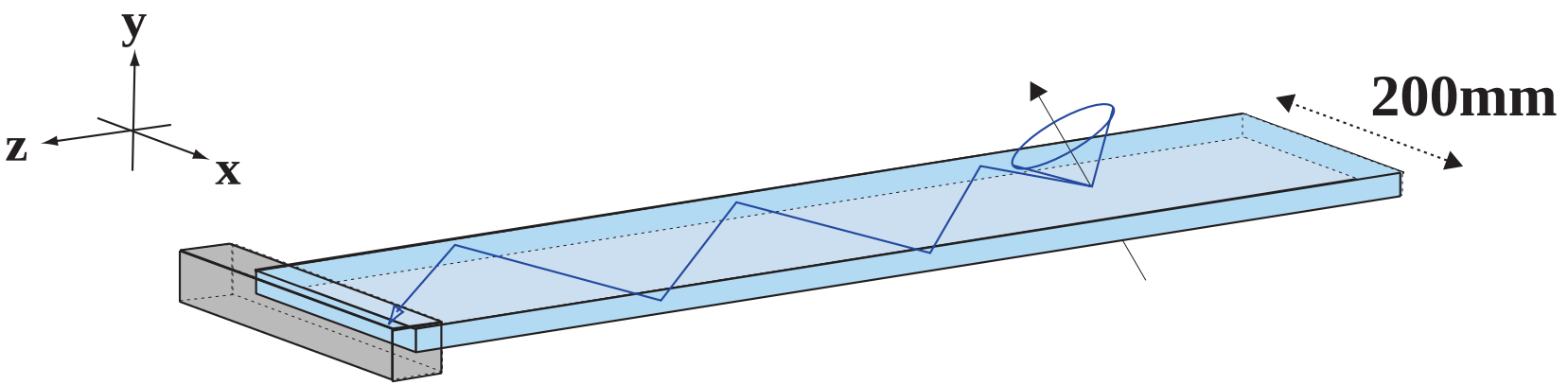
- Zygo
  世界的に有名な会社
- Insync
  DIRC**のバーを作った会社**
- **岡本光学加工所**
  横浜にある。bar-TOP**を発注。**
  望遠鏡「すばる」の副鏡も製作
- BINP (Russia)

直径5mの研磨機

表面粗度	**5Å**
表面精度	**～2λ** (1m)
真直度	**～**0.4mrad

Further simplified TOP counter

TOP counter : simplicity and compactness



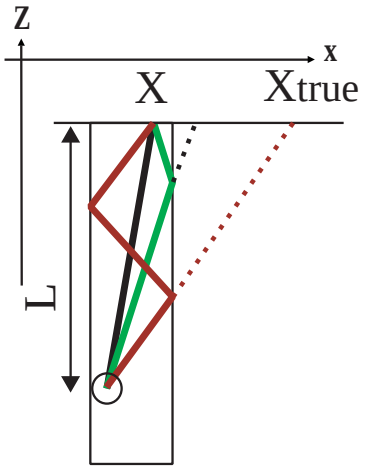
Photon detector

To measure TOP and X

The advantages of simplicity

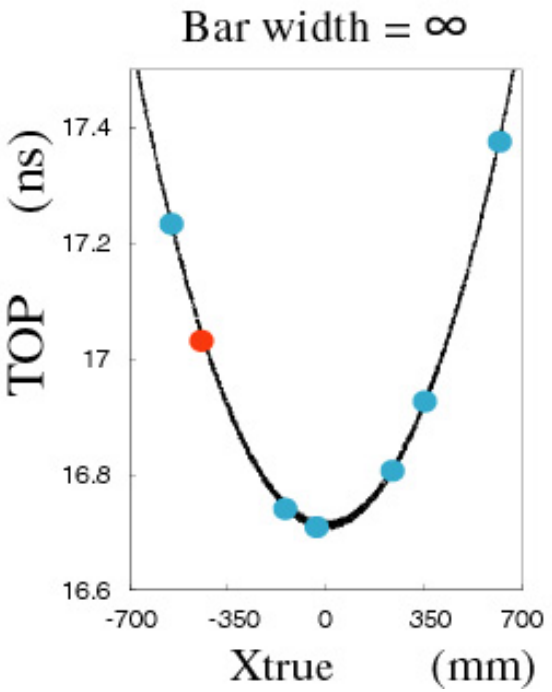
- No extra parts are necessary.
- # of det. photons are increased by 1.7.
  $|\Phi| < 45^{\circ}$ --> $|\Phi| < 80^{\circ}$
- # of channels are decreased by < 1/5.
- total polished area is decreased.
  --> quality is easy to control.

Principle of bar-TOP counter

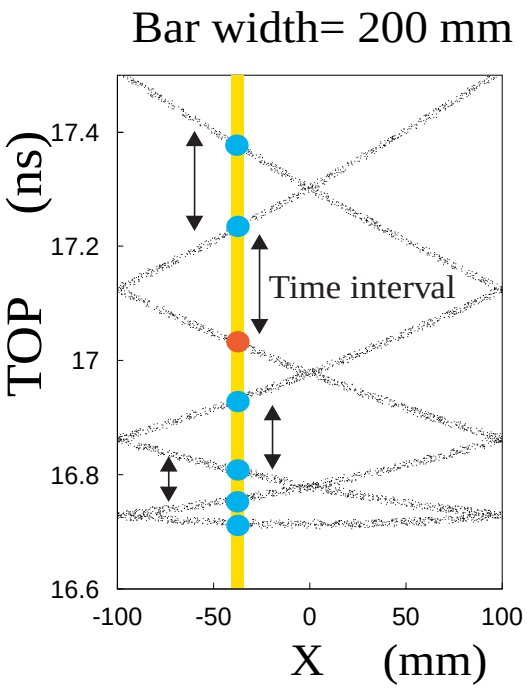


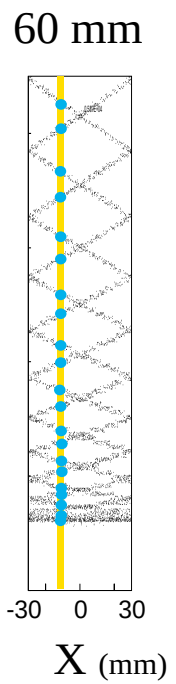
(|X| < 100mm)

To measure
X instead of Φ



The ring image can be obtained
in TOP vs. Xtrue





In practice, the width is finite.
The photon direction is reversed
on the side plane

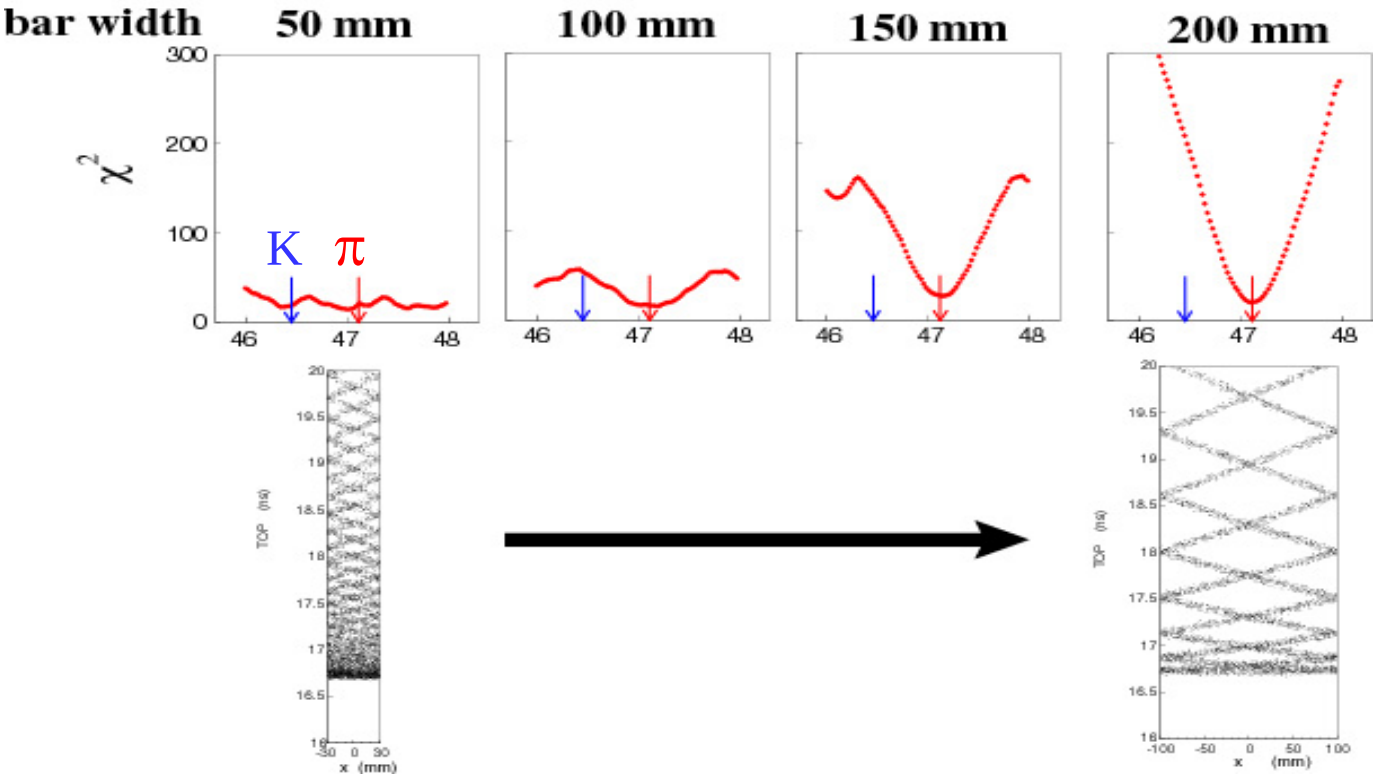
➡

If the time interval is large enough,
we can reconstruct
cherenkov ring by analysis.

simulation study - barTOP counter -

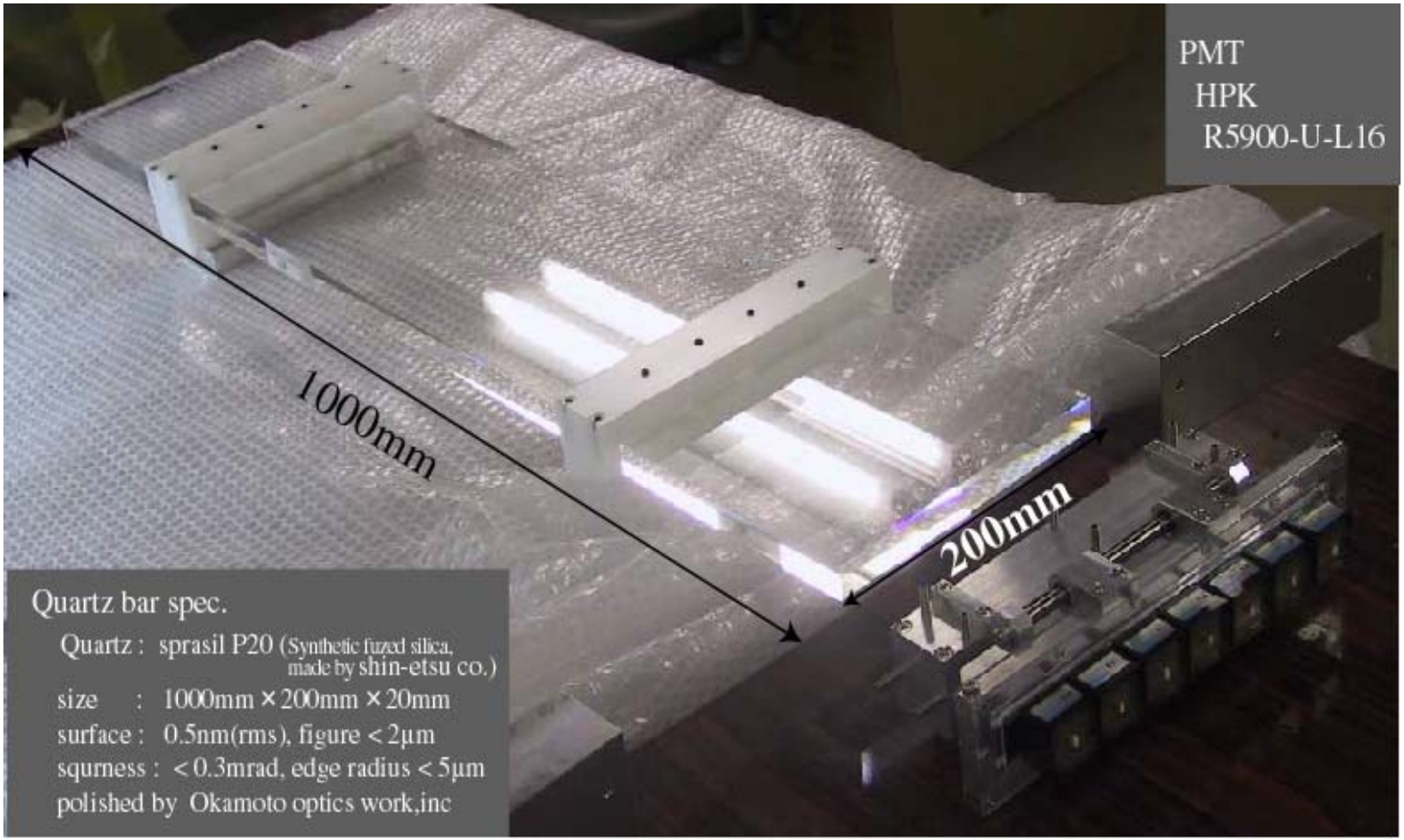
$$\chi^2 = \sum_{n=1}^{N_{ph}} \frac{\left(\tilde{f}_{exp.}(\theta c) - f_{det}\right)^2}{\sigma^2}$$

p=3GeV/c, L=2m, π^-
$N_{ph} \cong 30$



The bar width get wider, we can solve X-TOP correlation.

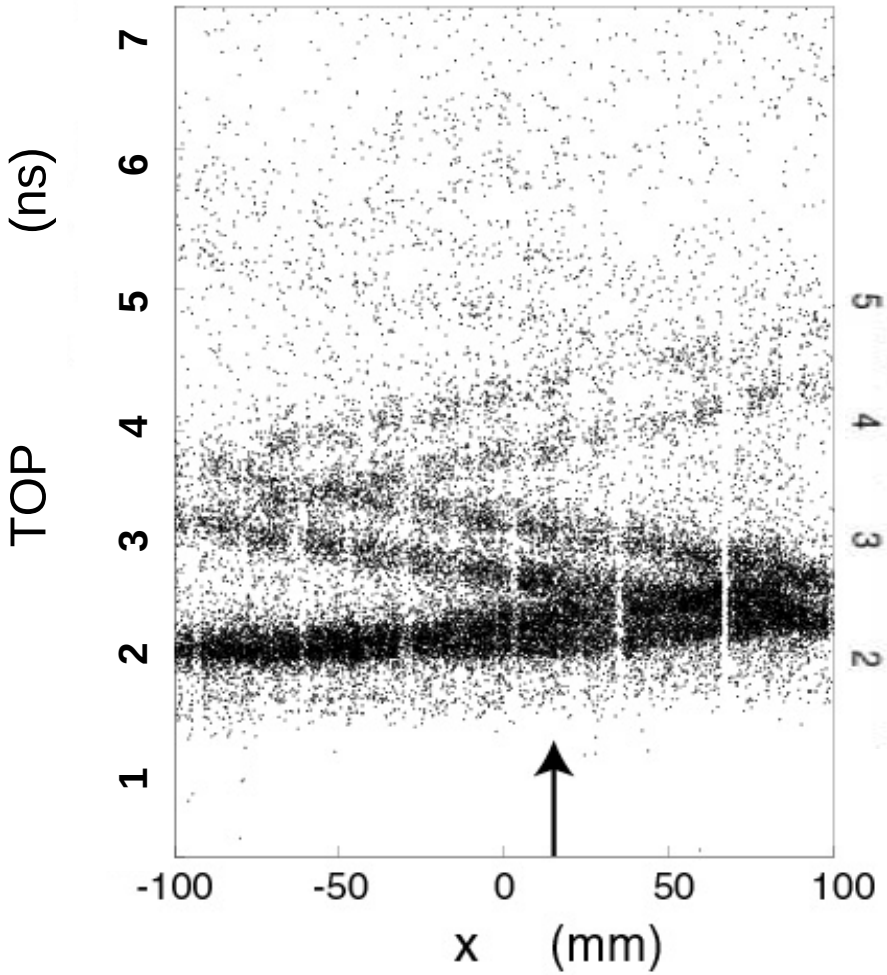
proto-type counter
- bar-TOP -

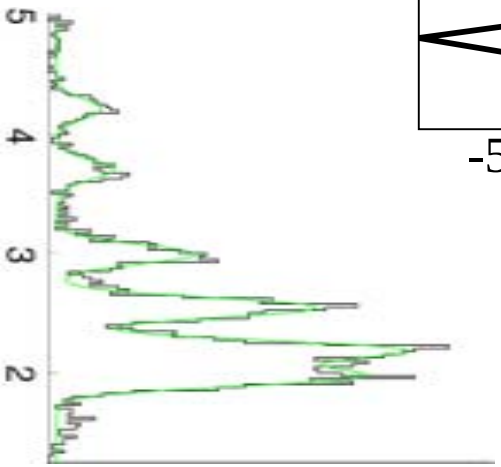


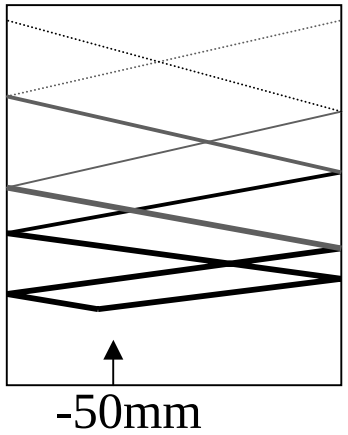
Beam test result
- bar-TOP ring image -

KEKπ2 line, 3GeV/c π^-

x=-50mm, L=30mmにビームを入射

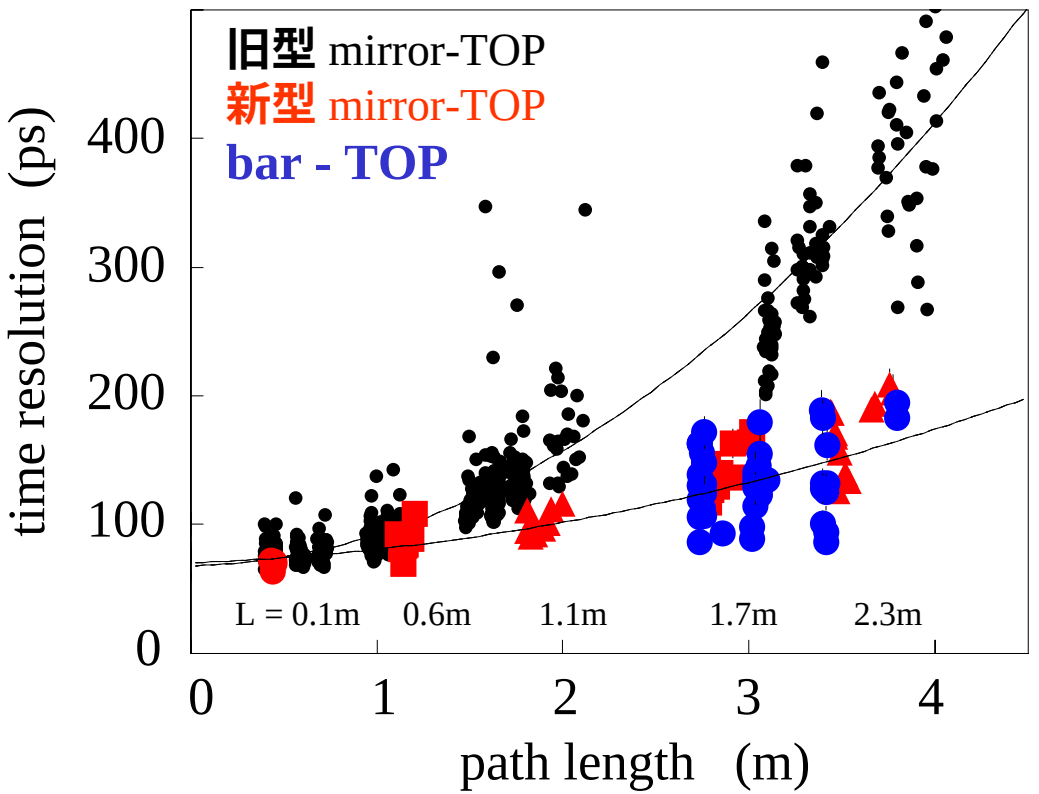






Clear ring image!!

beam test result - resolution -
時間分解能



bar-TOP

20°<Φ<60°**の領域で評価**

σ ≅ 130 ps (@L=1.7m)

mirror-TOP **と同程度**

基本性能として必要不可欠な

時間分解能が出ていること **が確かめられた。**

R&D

原理面の研究

- mirror-TOP
- Bar-TOP

Beam test

ring image

時間分解能

光検出器開発

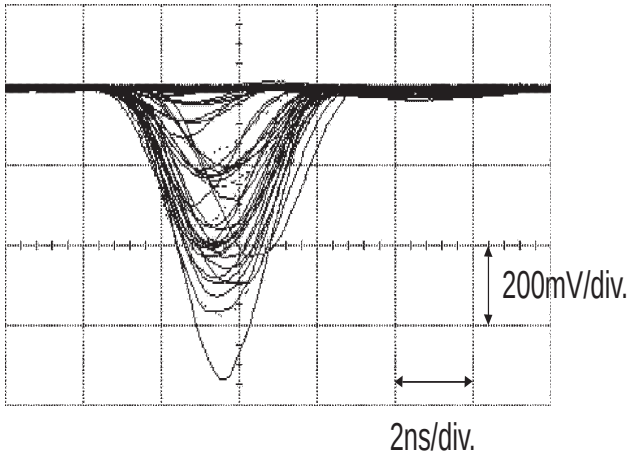
good timing resolution ～100ps
workable under 1.5T
position sensitive ～1mm

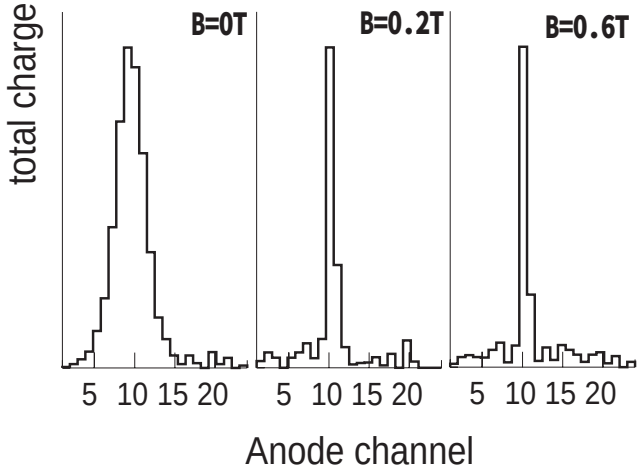
- **Fine mesh PMT**
- **MCP PMT**
- HAPD
- SiPM

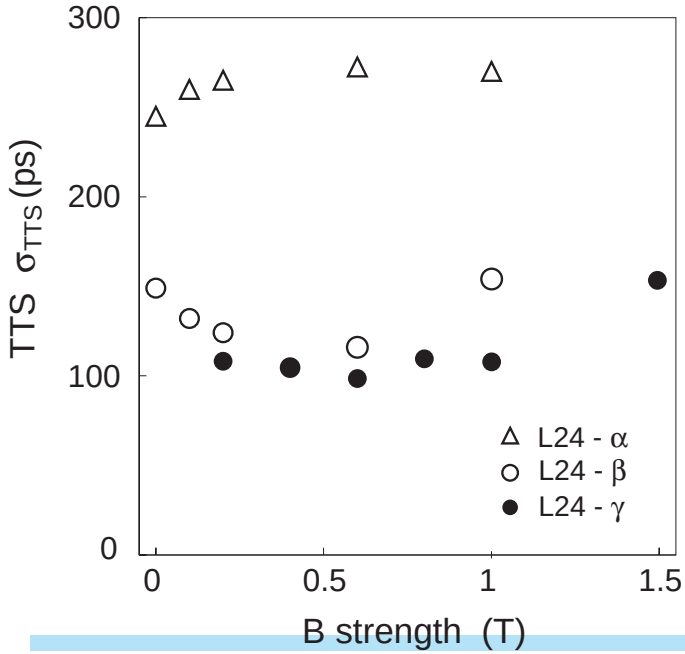
Fine-mesh PMT L24(HPK)

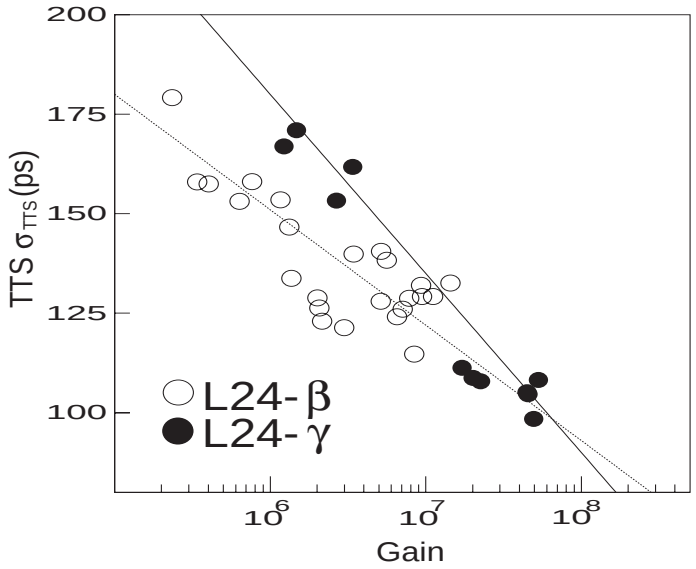
- single photon irradiation -

M.Hirose, et al. NIM-A460(2001) 326





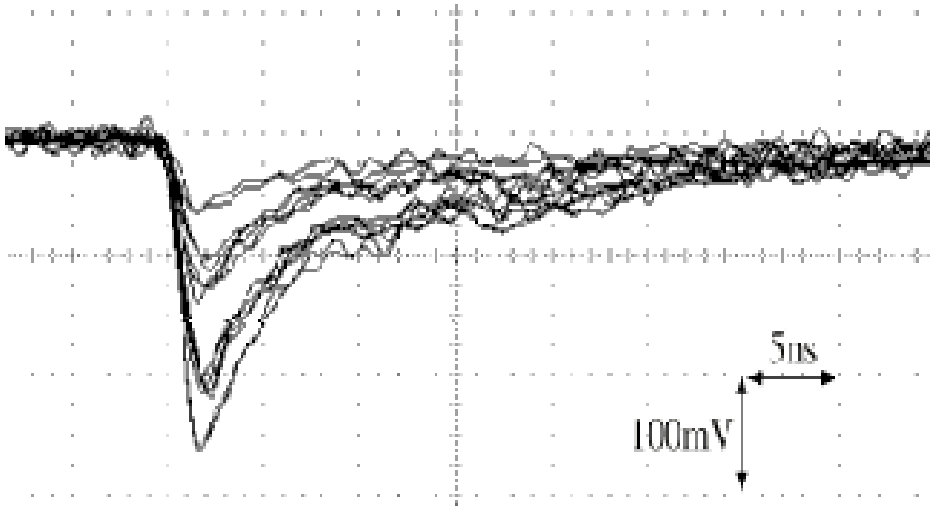


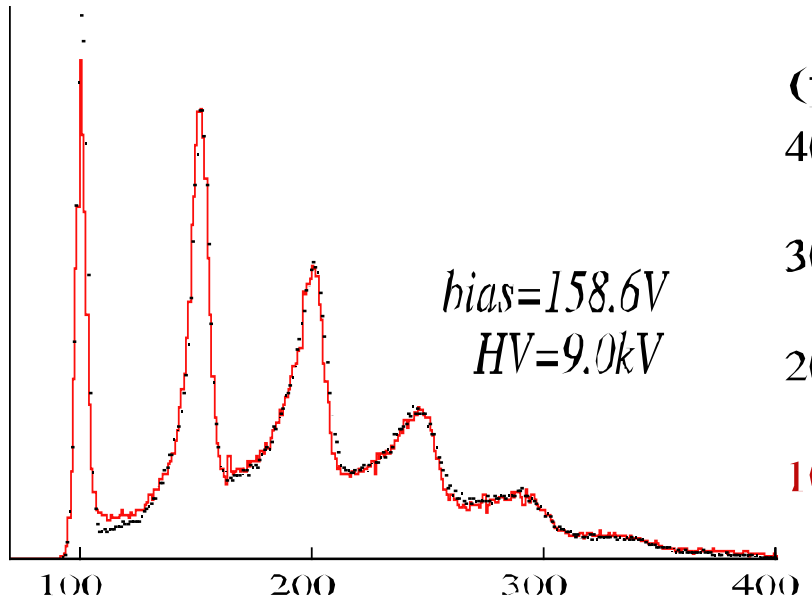


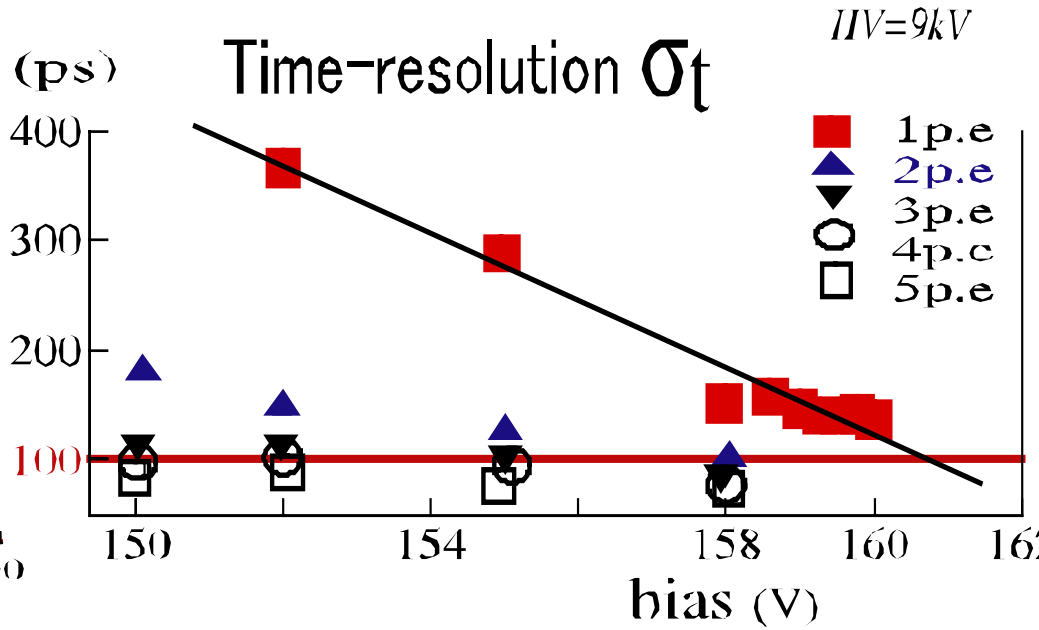
L24-γ：**その他3本が同等の性能を有し、再現性も確かめられている**

HAPD

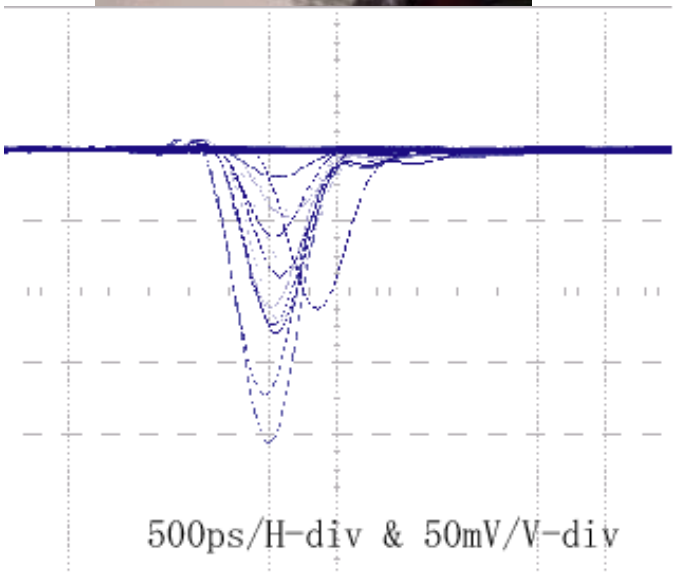
S.Matsui, et al. NIM-A463(2001) 220



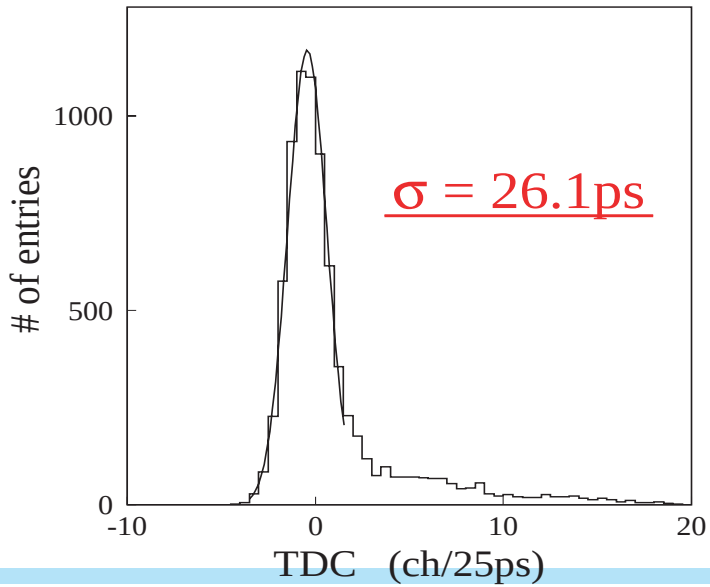




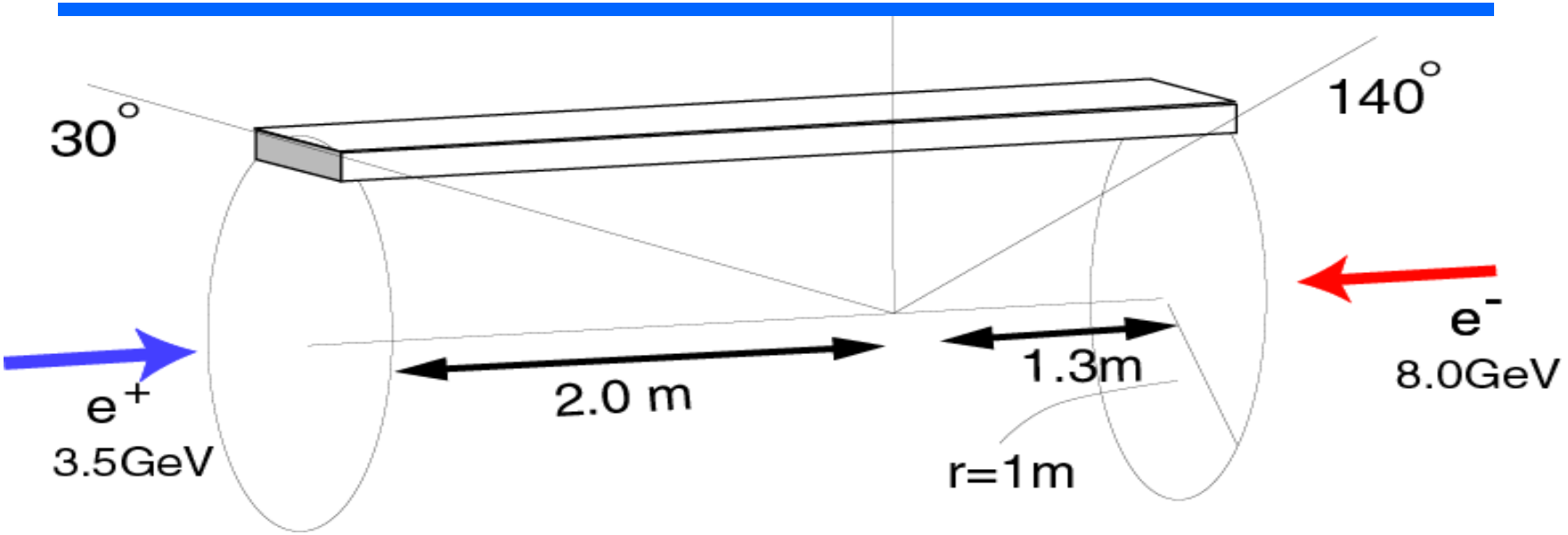
MCPPMT



HPK R3809U-50	
Spectral resopnce	160-650nm
# of MCP	2
Gain	2 × 10^6
pulse shape	
rise time	150 ps
fall time	360 ps
FWHM	300 ps
transit time	350 ps
T.T.S. (FWHM)	25 ps



Belle detectorに導入

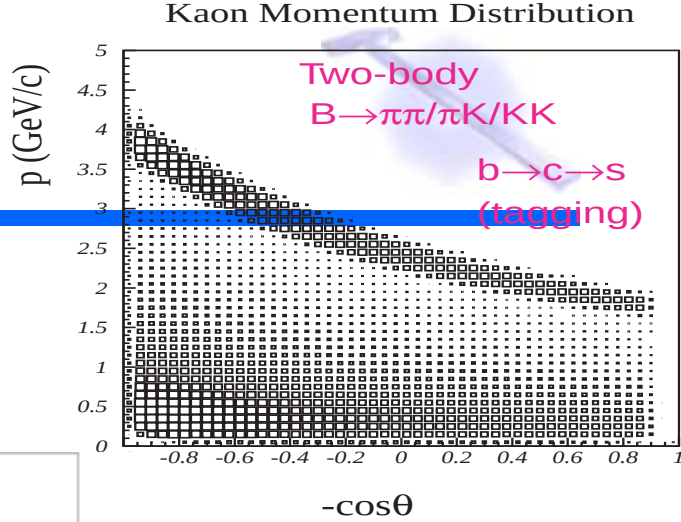


幅400mm**の** bar-TOP**を用いるとする**

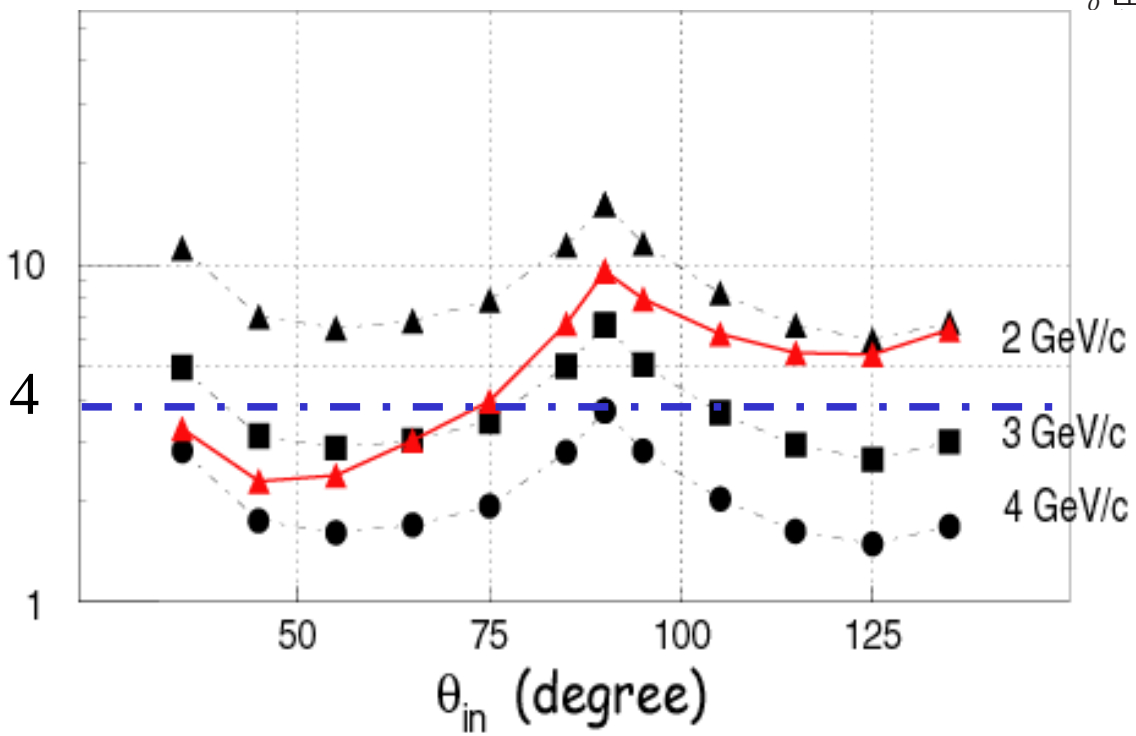
bar**の数** 3.3m **×１６本**

channel**数** (5mm pitch) ‥‥ 1280ch.

expected separation

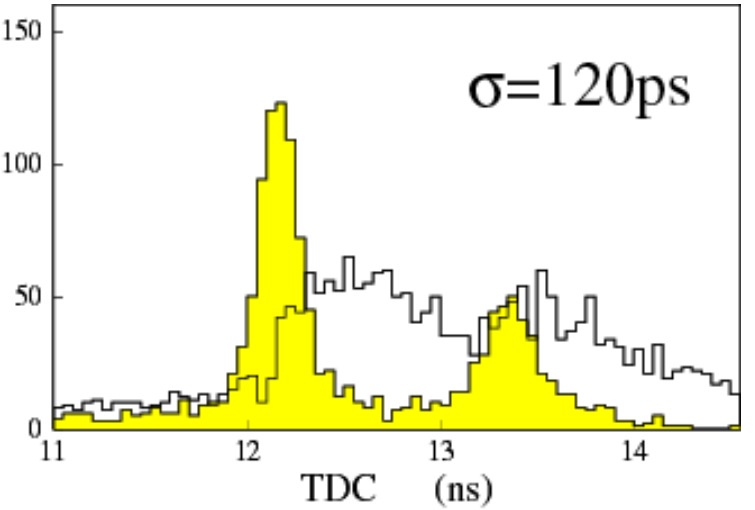


Separation $S = S_{1p.e.} \sqrt{N_{ph}}$



Hard to separate π/K around θin = 45, p=3.5GeV/c region.

Belle detectorに導入するためには....

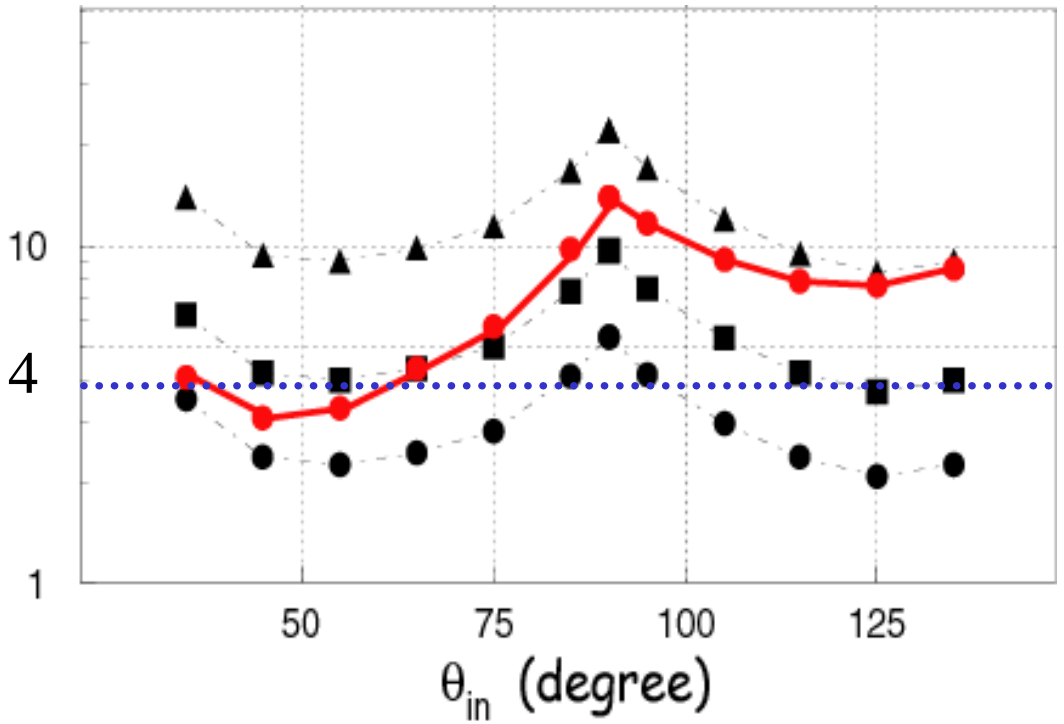


- **時間分解能をさらに向上**
  - **長い波長領域を使う.**
    - → beam test**で確認済み**
- **検出光子数を増やす**
  - **石英の厚みを増やす**?
  - Q.E.（GaAs,GaAsP）**の高い光電面を用いる。**
    - → HPK、BURLE**でMCPに導入できる。**

→ Bar TOP counter & MCP PMT

bar-TOP & MCP PMT

- λ>450nm
- σ_{tts} =50ps



ほとんどの領域で4σ以上のπ/K識別が得られる。
→ MCPが使えれば TOP counter **はBelleに導入可能**

Background**の影響、それに伴いバーのサイズ、**ch**数を最適化する**

まとめ

- **現在までの成果**
  - bar-TOP, mirror-TOP**の考案**、beamtest
    - ring image
    - time resolution

    → 基本的な稼働特性は把握。
- Belle**への導入に向けて**

  bar TOP& MCP**で現実的に実現可能**.

  background**等を考慮しサイズ等を最適化**

  光検出器の開発が最重要課題

  → MCP + Ga･As**光電面が望ましい。**

  multi-ch、**大面積の**MCP

  BURLE**の製品をテスト中、**(50mm×50mm)

  HPK**と** MCPPMT**の共同開発**

  BINP(Russia)**製の**MCP**もテスト中。**