A proximity focusing RICH with time-of-flight capabilities

Peter Križan

University of Ljubljana and J. Stefan Institute

For the Belle Aerogel RICH R&D group

10th Topical Seminar on Innovative Particle and Radiation Detectors (IPRD06) 1 - 5 October 2006 Siena, Italy

Contents

Introduction, motivation and requirements

Radiator with multiple refractive indices

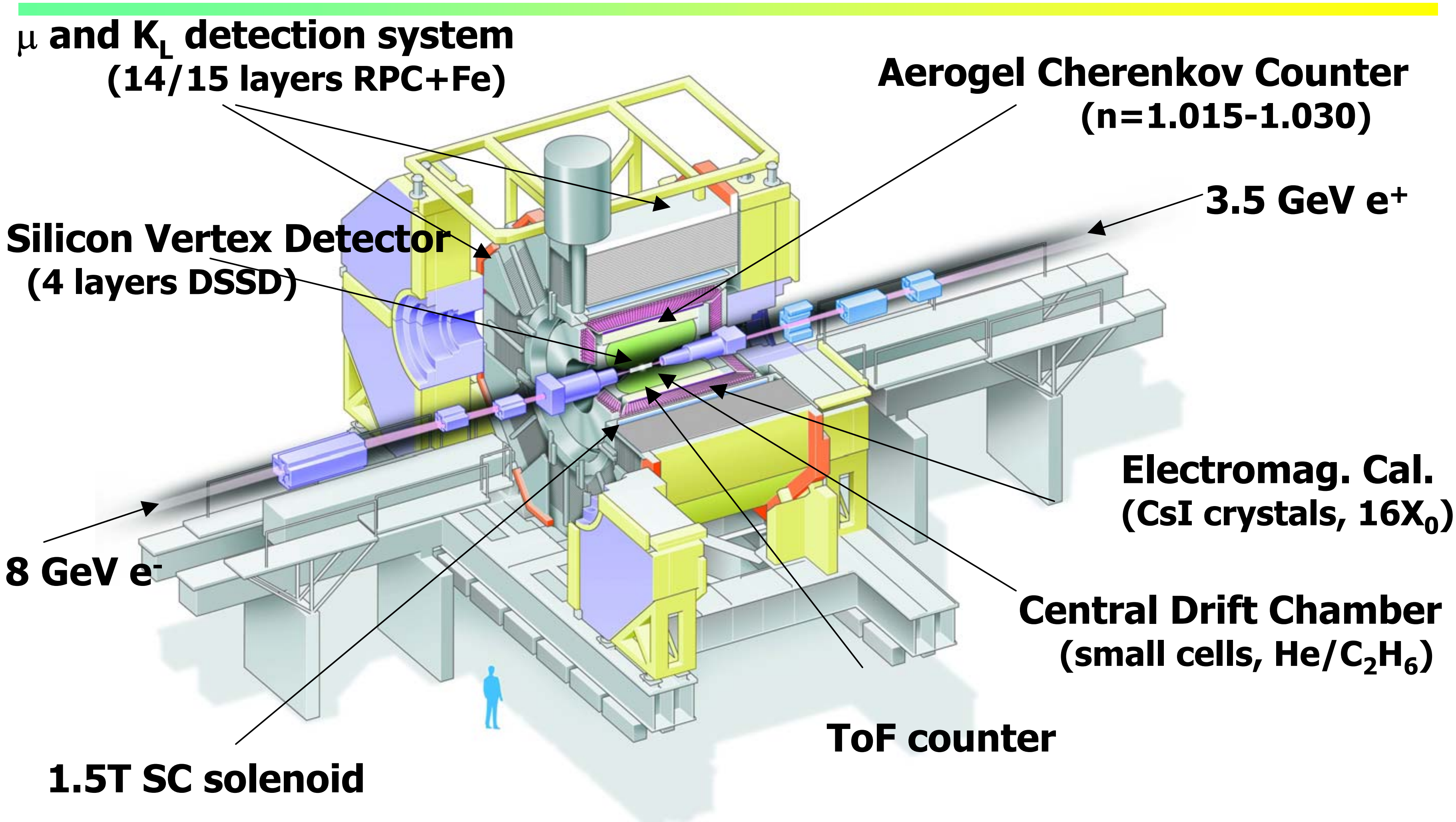
Time-of-flight measurement with a RICH

Beam tests

Summary

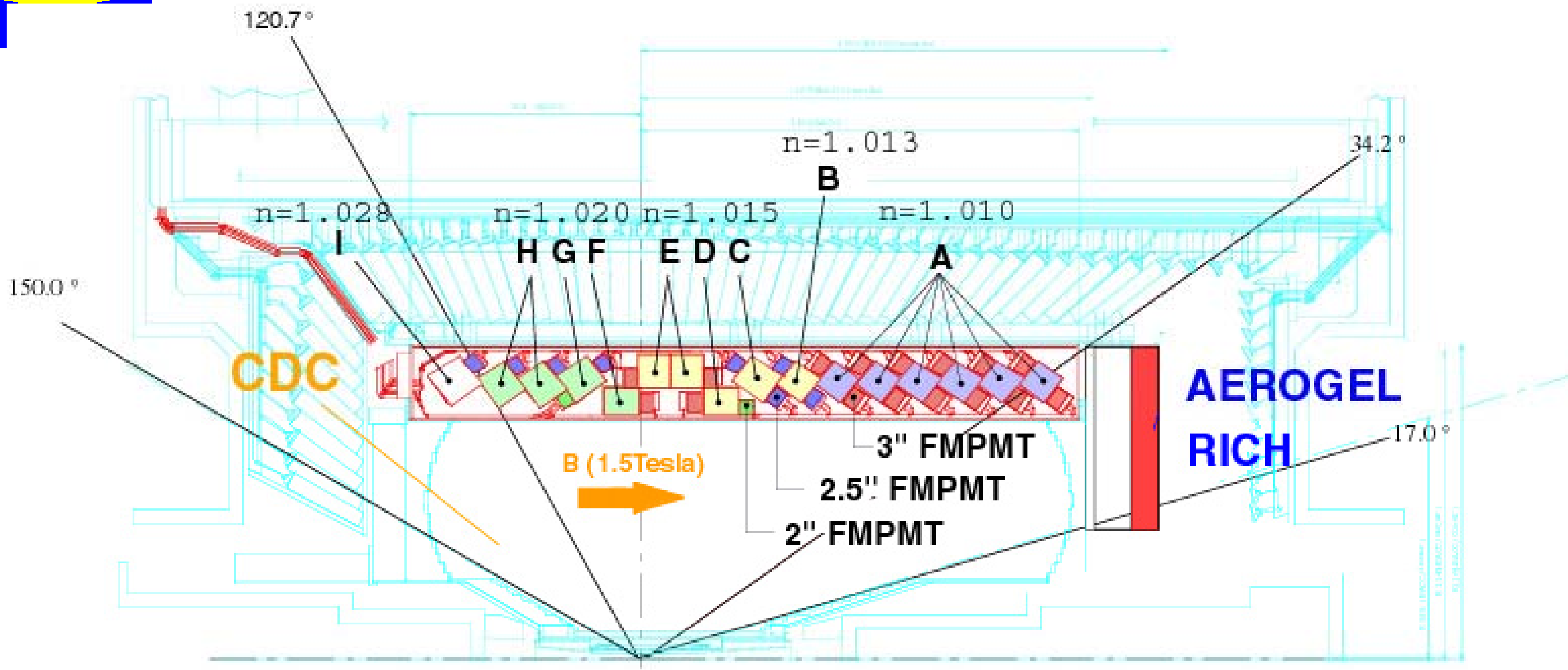
Belle @ KEK-B in Tsukuba

Belle spectrometer at KEK-B



Accumulated data sample >600 M BB-pairs

PID upgrade in the endcap



improve K/π separation in the forward (high mom.) region for few-body decays of B mesons

good K/π separation for b -> dγ , b -> sγ

improve purity in fully reconstructed B decays

low momentum (<1GeV/c) e/μ/π separation (B ->Kll)

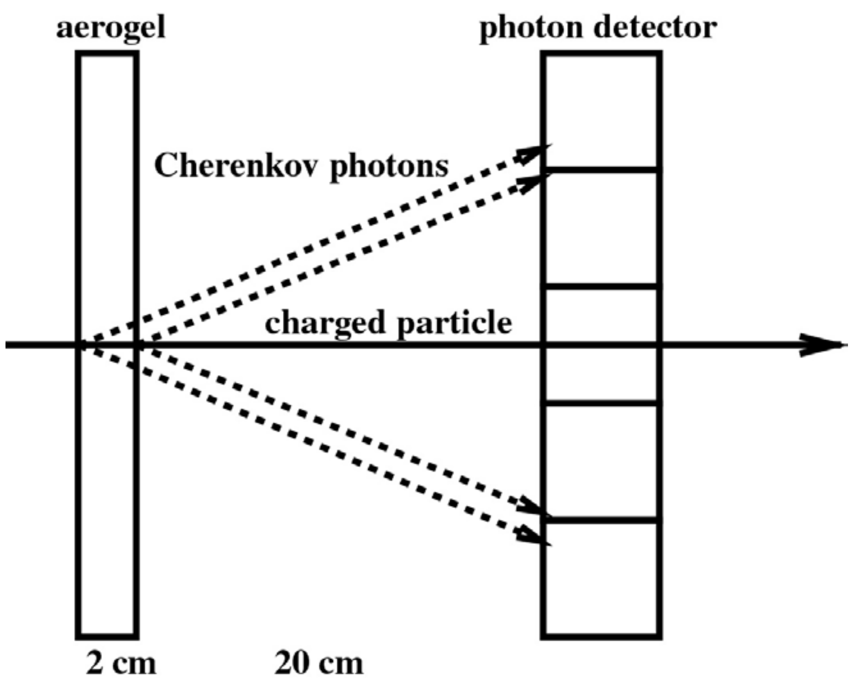
keep high the efficiency for tagging kaons

BELLE Aerogel RICH group

I. Adachi, I. Bertović, S. Fratina, K. Fujita,T. Fukushima, A. Gorišek, D. Hayashi, T. Iijima, H. Kawai, M. Konishi, S. Korpar, Y. Kozakai, P. Križan, A. Kuratani, Y. Mazuka,T. Nakagawa, S. Nishida, S. Ogawa, S. Ohtake, R. Pestotnik, S. Saitoh, T. Seki, A. Stanovnik, T. Sumiyoshi, Y. Uchida, Y. Unno

Chiba University, Japan
Toho University, Funabashi, Japan
High Energy Accelerator Research Organization (KEK), Japan
J. Stefan Institute, Ljubljana, Slovenia
University of Ljubljana, Slovenia
Nagoya University, Nagoya, Japan
Tokyo Metropolitan University

Proximity focusing RICH in the forward region



K/π separation at 4 GeV/c
$\theta_c(\pi) \sim 308$ mrad (n = 1.05)
$\theta_c(\pi) - \theta_c(K) \sim 23$ mrad

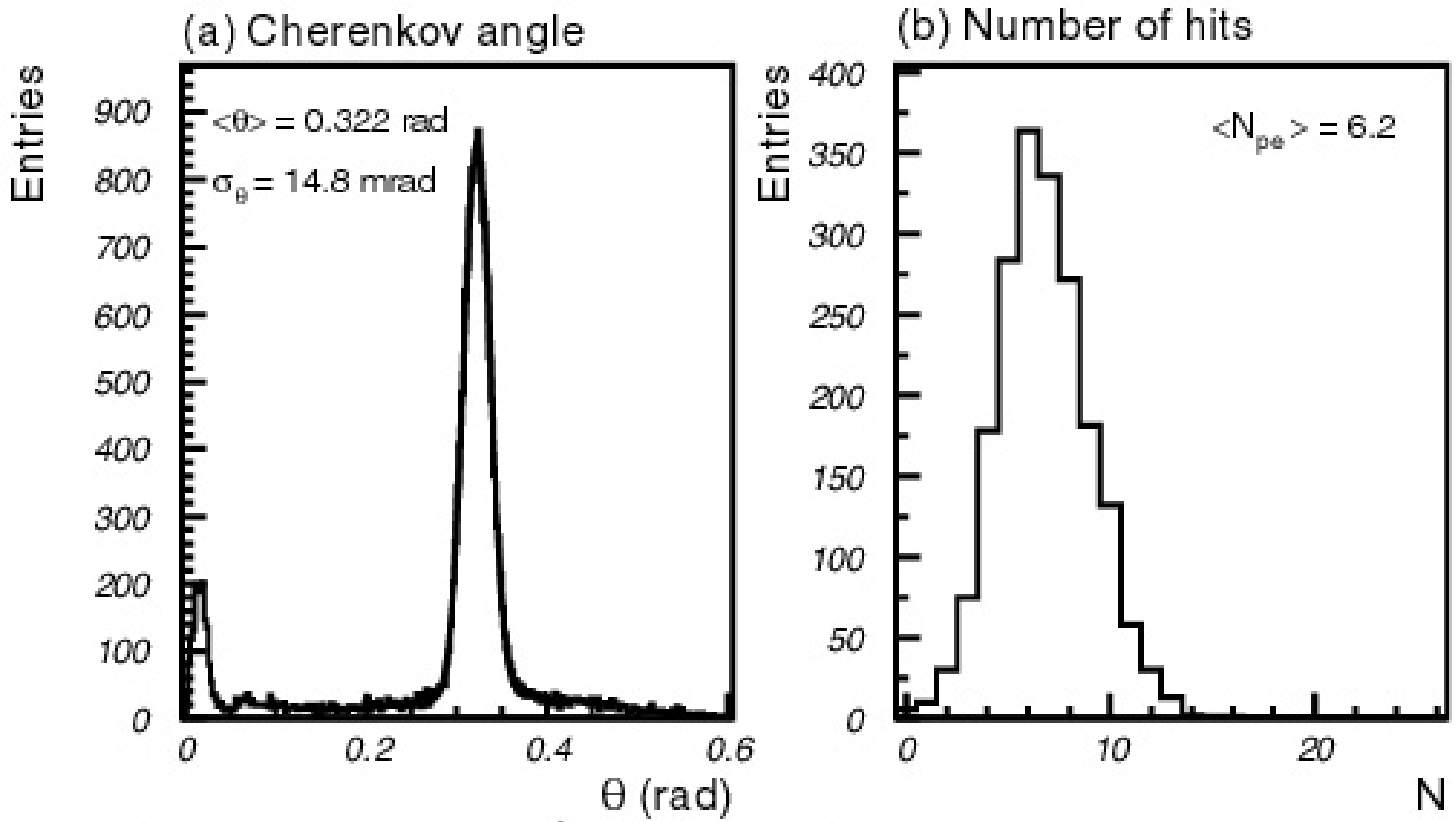
$d\theta_c$(meas.) = $\sigma_0 \sim 13$ mrad
With 20mm thick aerogel and 6mm PMT pad size

→ 6σ separation with $N_{pe} \sim 10$

Beam test: Cherenkov angle resolution and number of photons

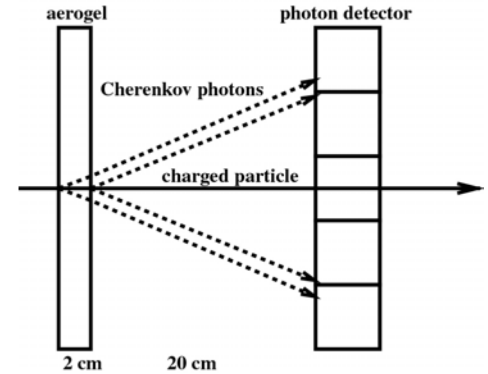
Beam test results with 2cm thick aerogel tiles:
excellent, >4σ K/π separation

NIM A521(2004)367



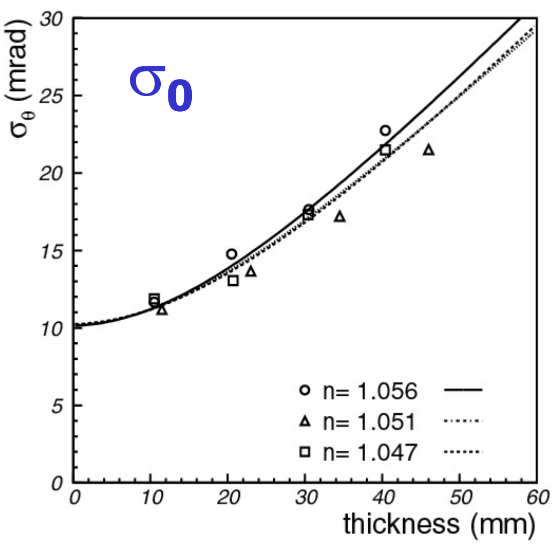
but: Number of photons has to be increased. →

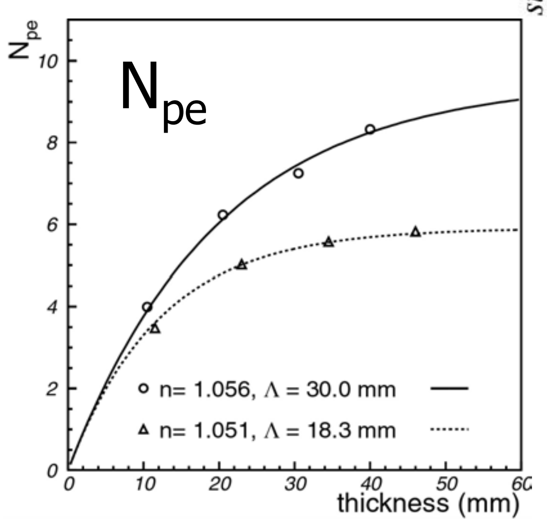
How to increase the number of photons?

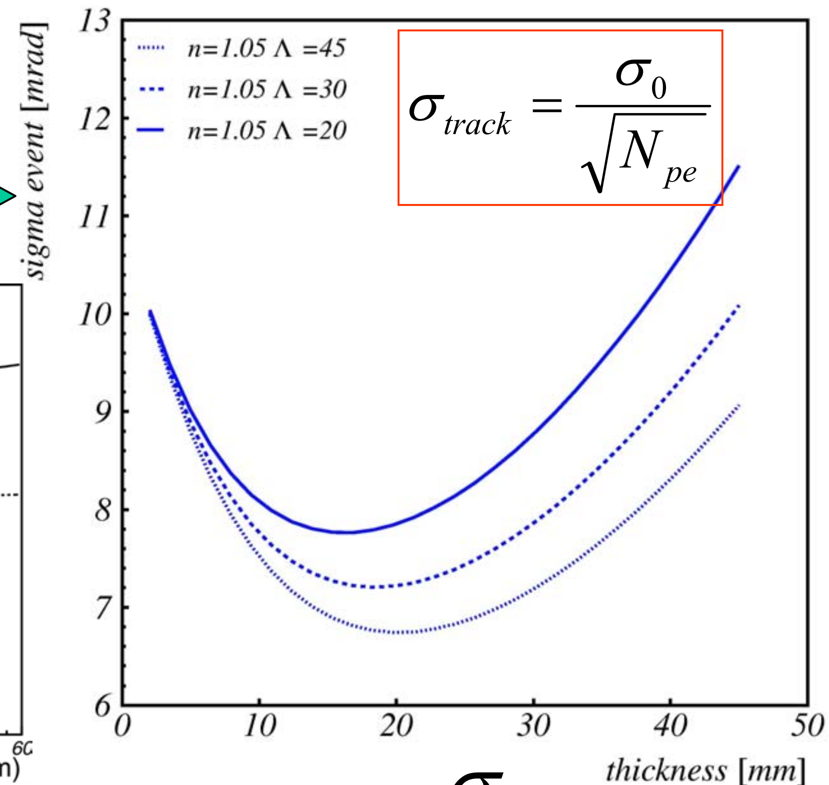


What is the optimal radiator thickness?

Use beam test data on σ_0 and N_{pe}







$$\sigma_{track} = \frac{\sigma_0}{\sqrt{N_{pe}}}$$

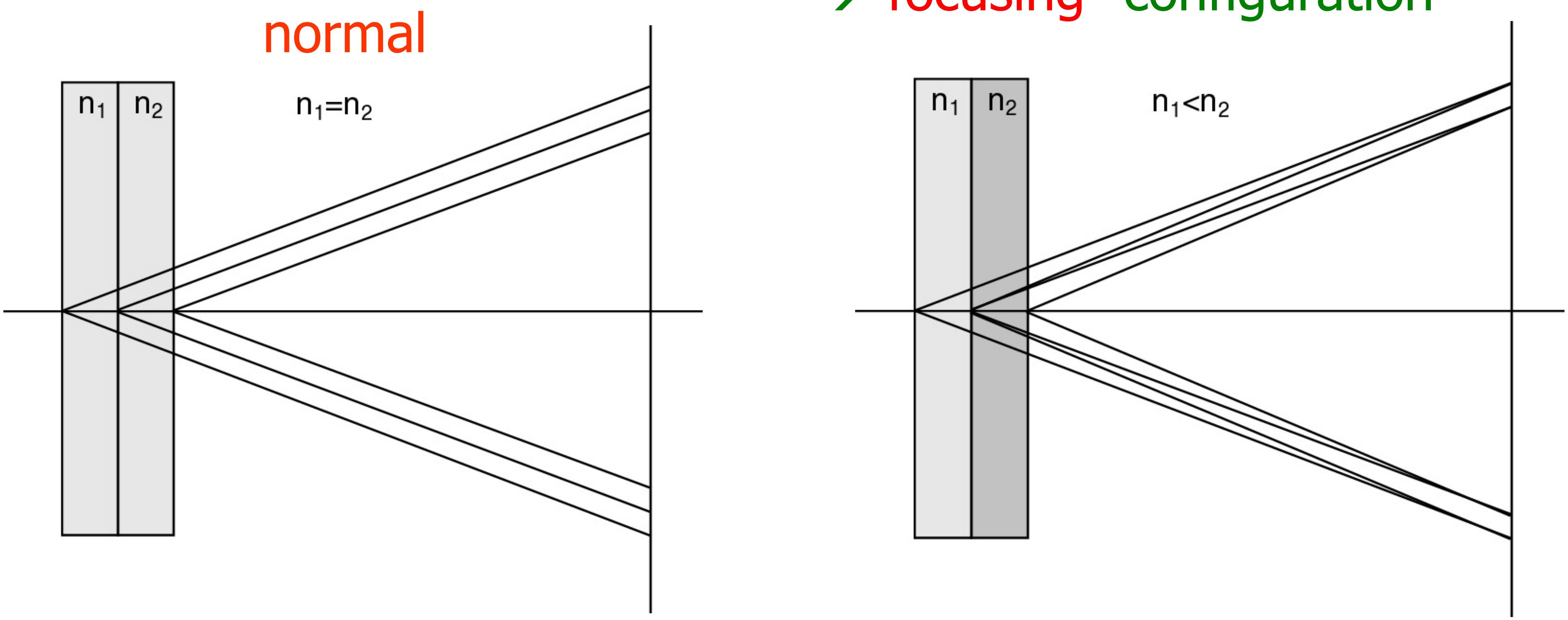
Minimize the error per track: $\sigma_{track} = \dfrac{\sigma_0}{\sqrt{N_{pe}}}$

Optimum is close to 2 cm

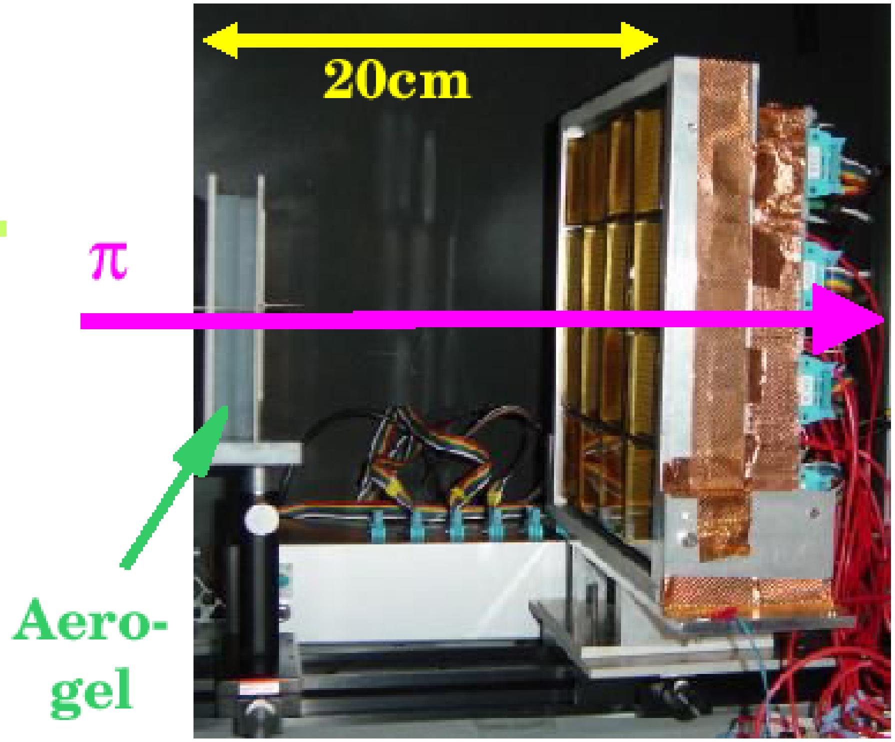
Radiator with multiple refractive indices

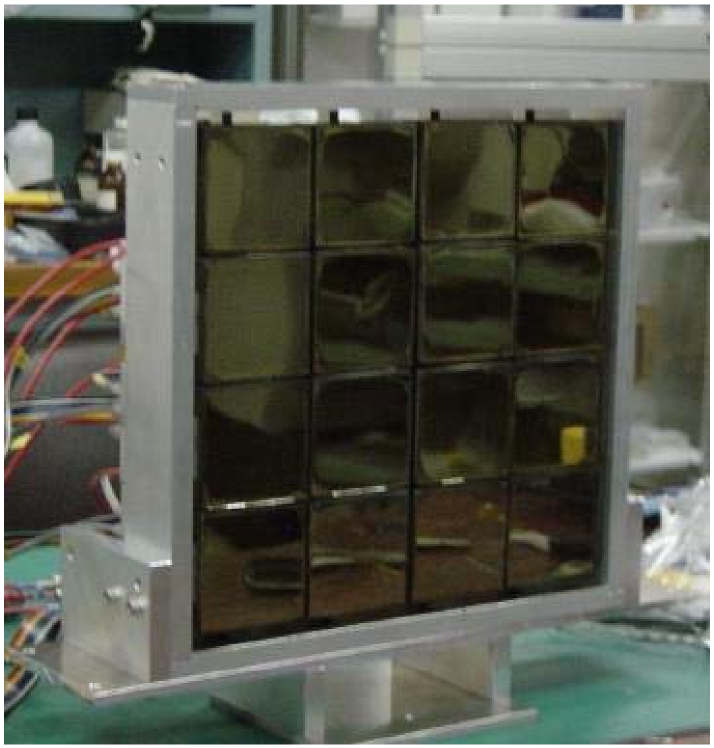
How to increase the number of photons without degrading the resolution?

measure overlaping rings
→"focusing" configuration



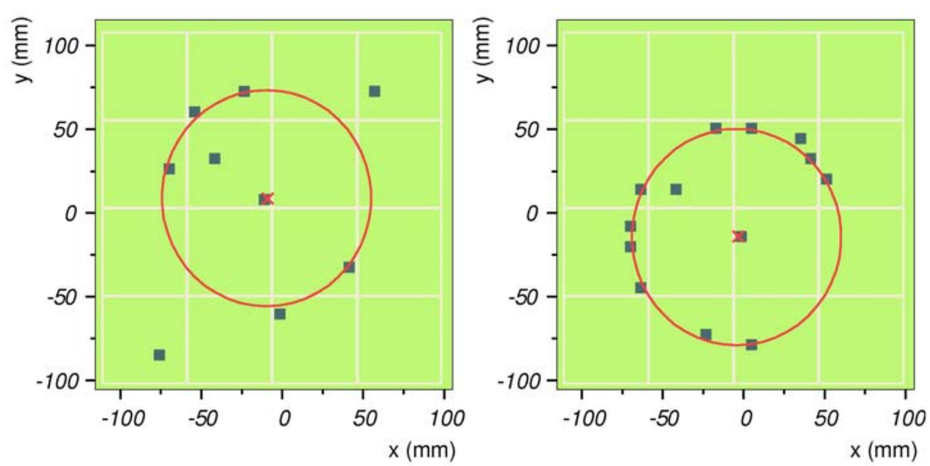
Beam tests





Photon detector: array of 16 H8500 PMTs

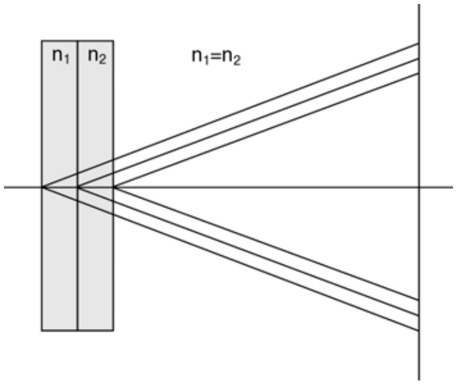
Clear rings, little background

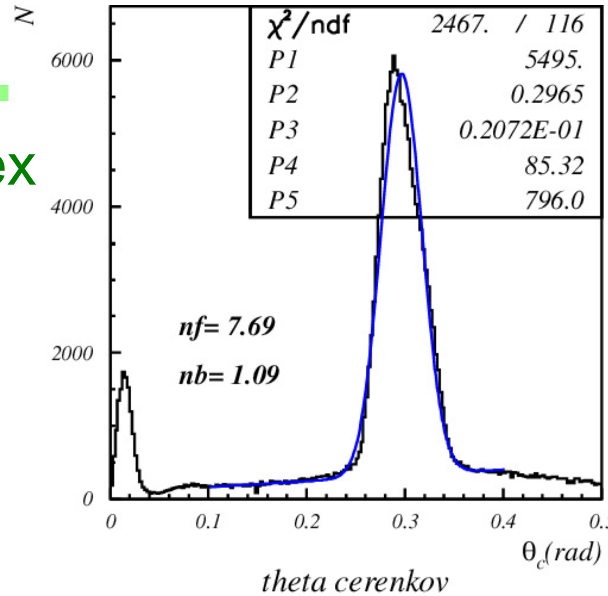


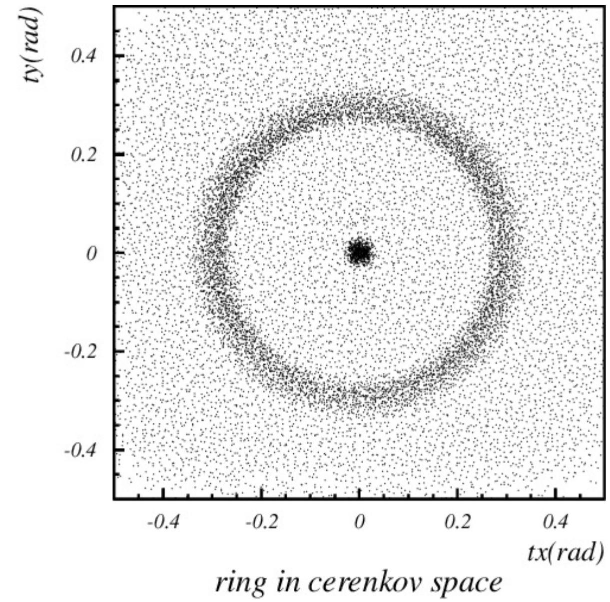
Focusing configuration

NIM A565 (2006) 457

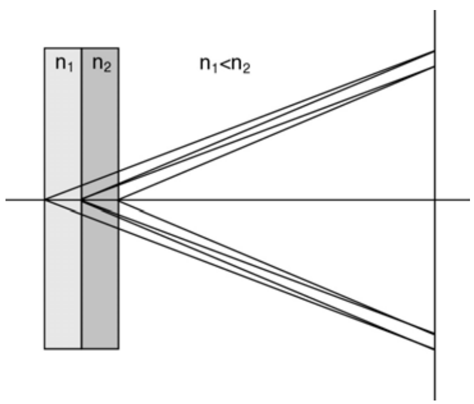
4cm aerogel single index

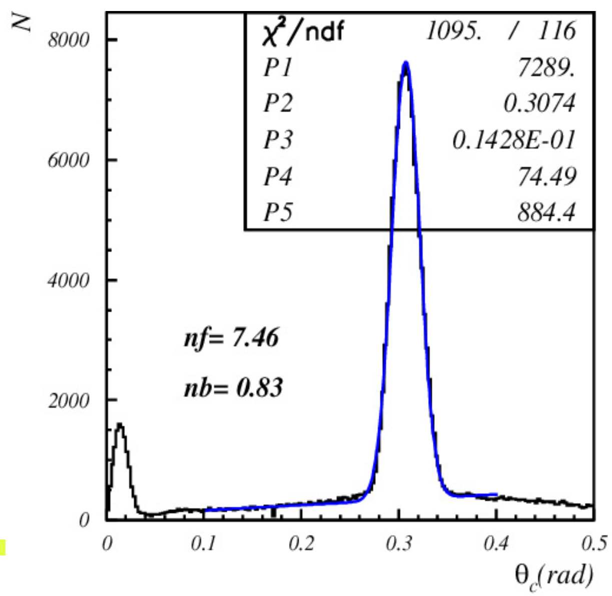


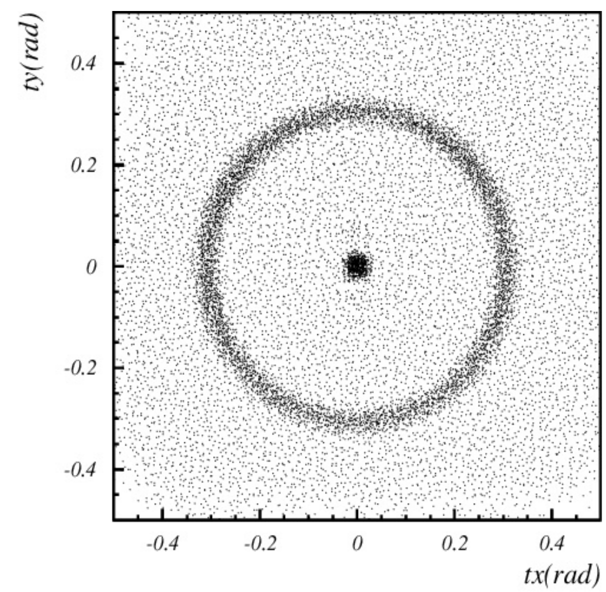




2+2cm aerogel



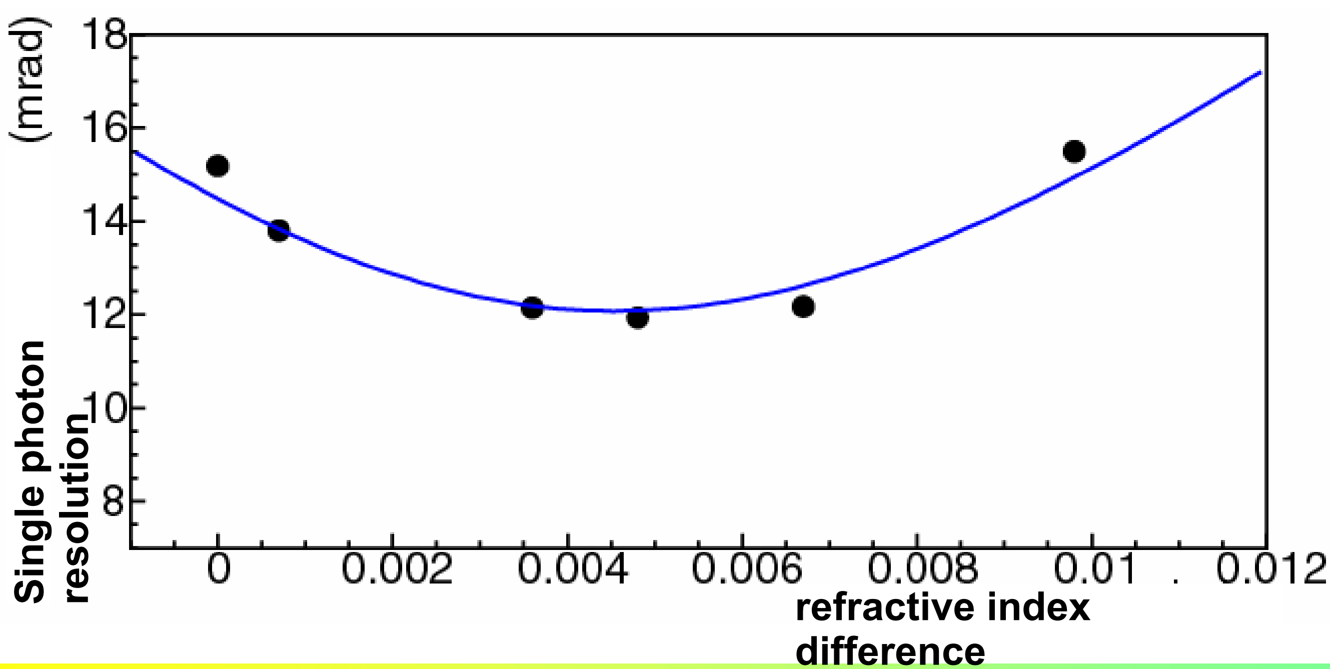




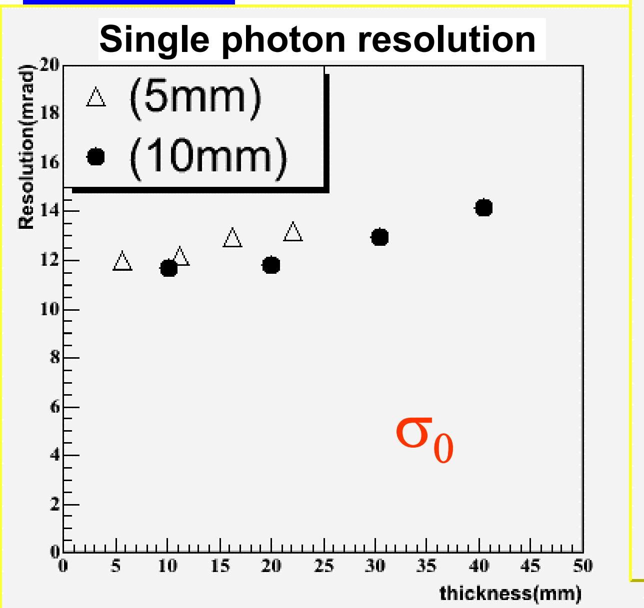
Focusing configuration – n_2-n_1 variation

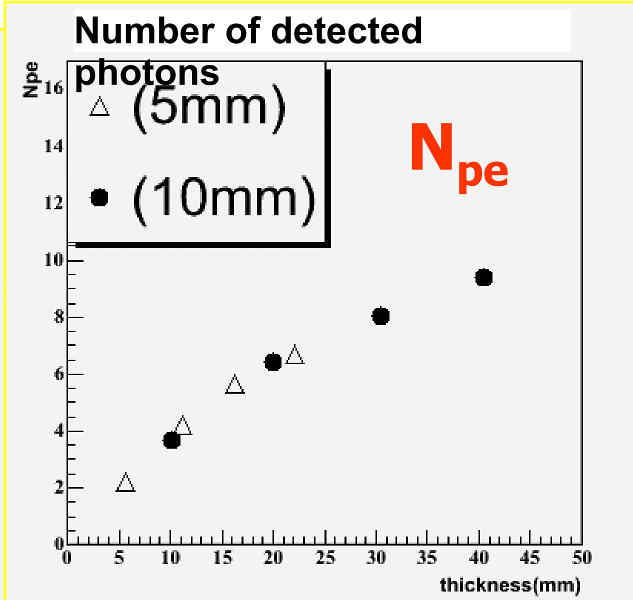
- upstream aerogel: d=11mm, n=1.045
- downstream aerogel layer: vary refractive index
- measured resolution in good agreement with prediction
- wide minimum allows some tolerance in aerogel production

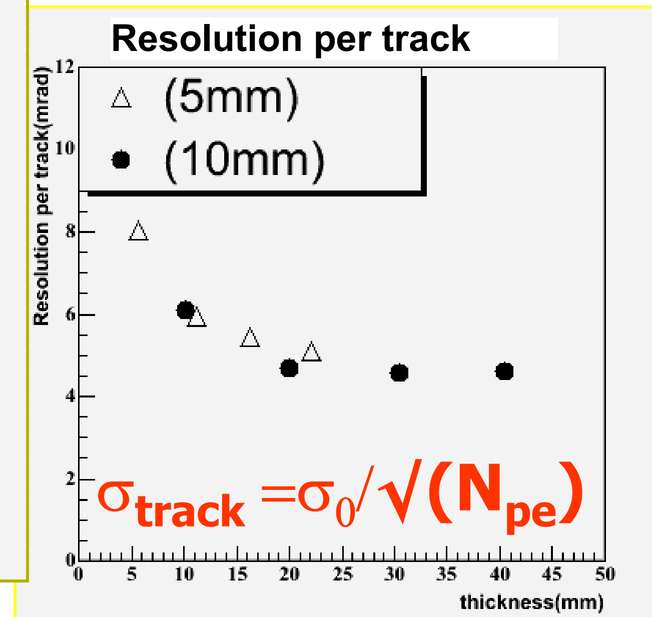
NIM A565 (2006) 457

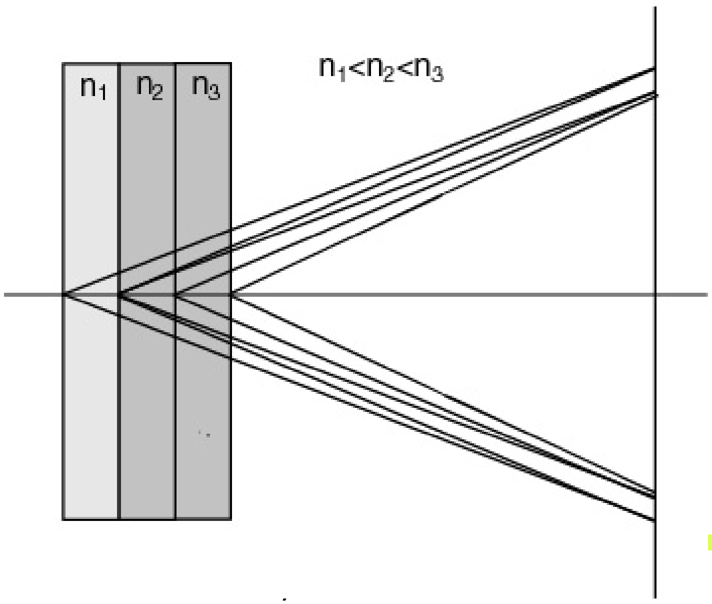


Multilayer extensions





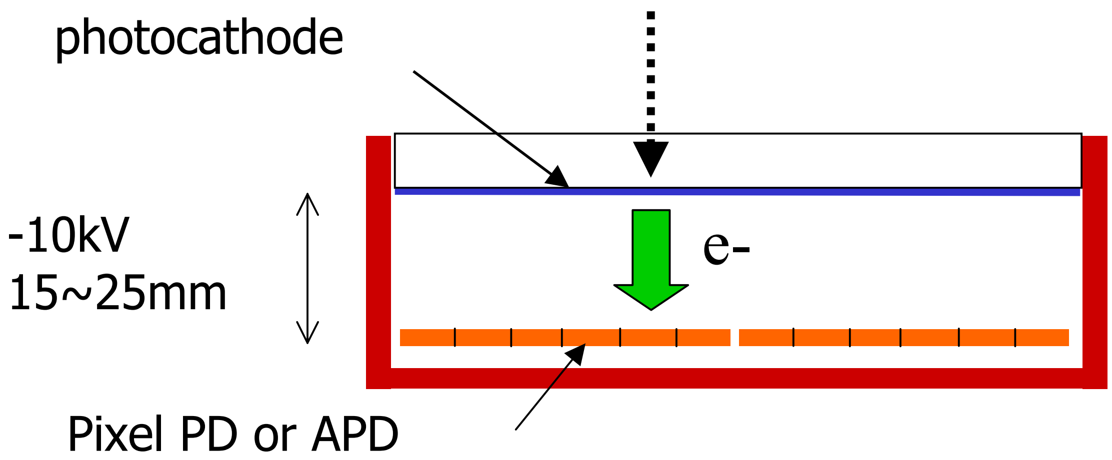




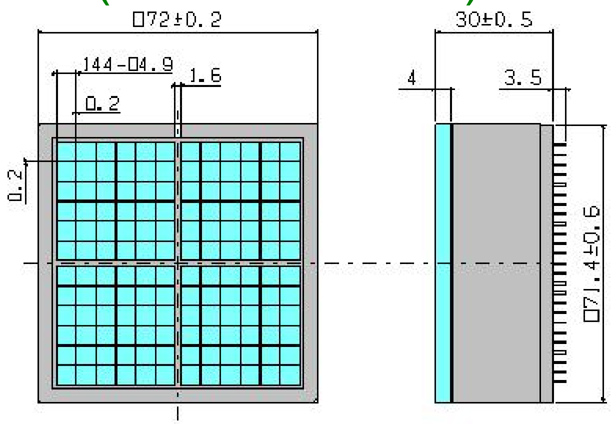
- Multiple layer radiators combined from 5mm and 10mm tiles
- obtained Cherenkov angle resolution per track is around 4.3 mrad

→ π/K separation at 4 GeV better than **5**σ

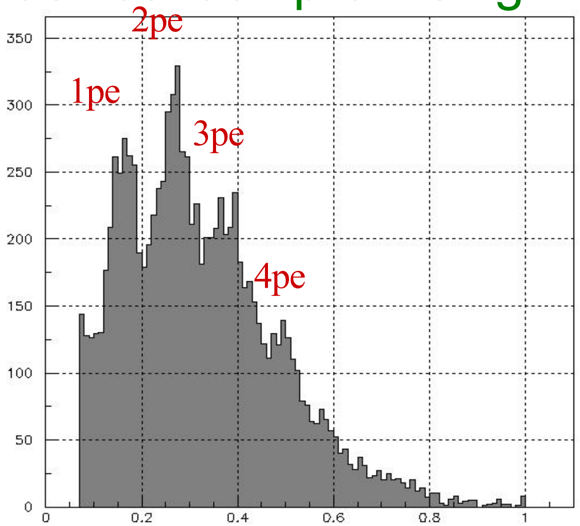
Photon detector: H(A)PD



- 12 x 12 channels
- 65% effective area (59mm x 59mm)



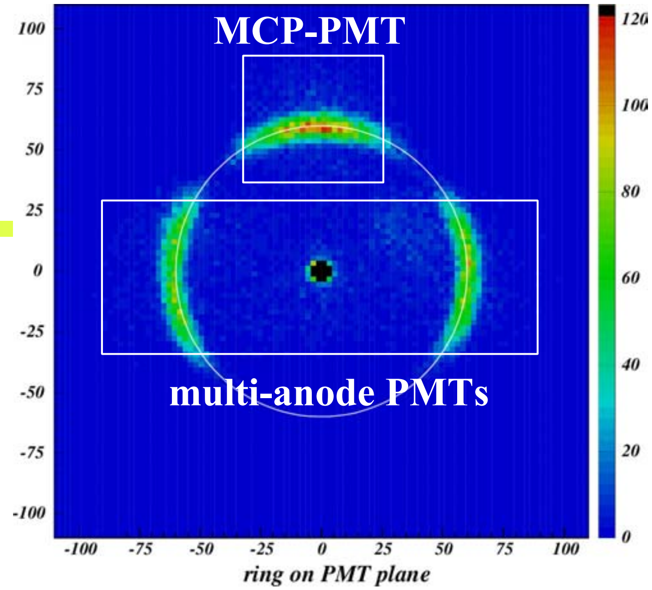
- tests with single channel and 3x3 channel device look promising



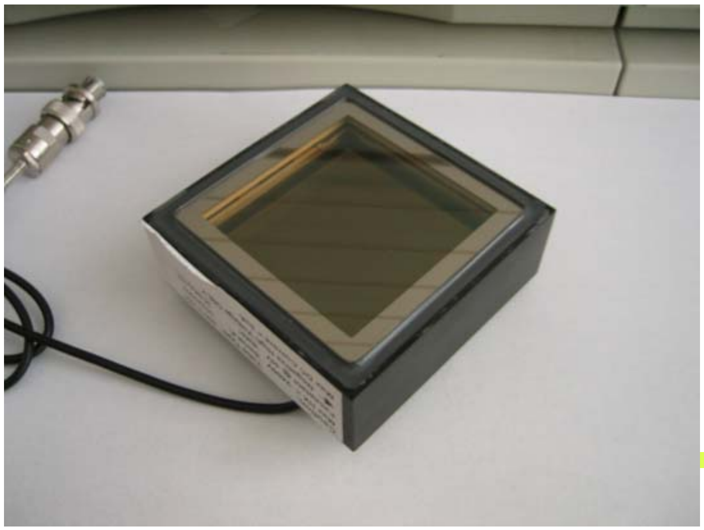
- 12 x 12 channel version: problems with sealing and activation

R&D project in collaboration with HPK

Photon detector: MCP-PMT



BURLE 85011 MCP-PMT:
- multi-anode PMT with two MCP steps
- 25 μm pores
- bialkali photocathode
- gain ~ 0.6 x 10^6
- collection efficiency ~ 60%
- box dimensions ~ 71mm square
- 64(8x8) anode pads
- pitch ~ 6.45mm, gap ~ 0.5mm
- active area fraction ~ 52%



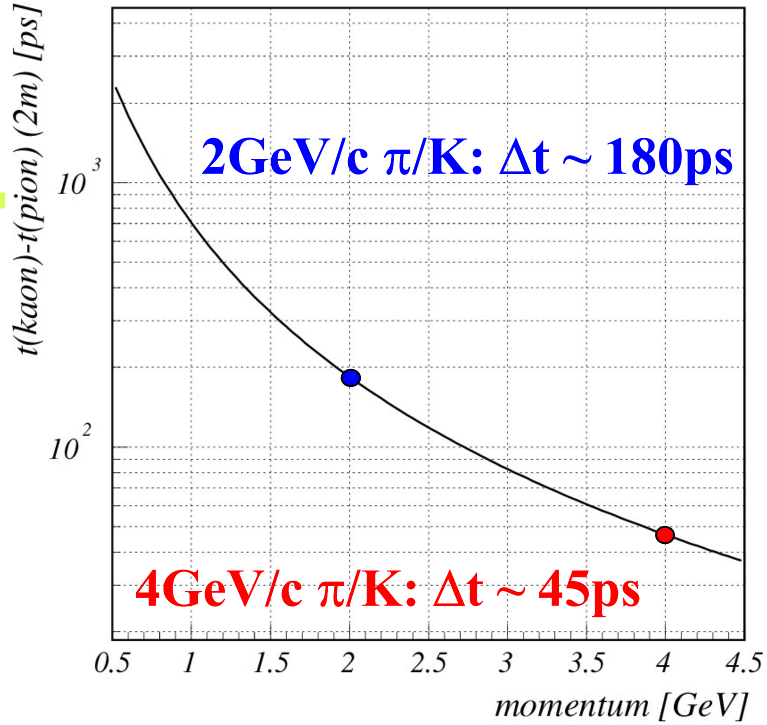
- Tested in combination with multi-anode PMTs

- σ_ϑ~13 mrad (single cluster)
- number of clusters per track N ~ 4.5
- σ_ϑ~ 6 mrad (per track)
- **-> ~ 4 σ π/K separation at 4 GeV/c**

- 10 μm pores required for 1.5T
- collection eff. and active area fraction should be improved
- aging study should be carried out

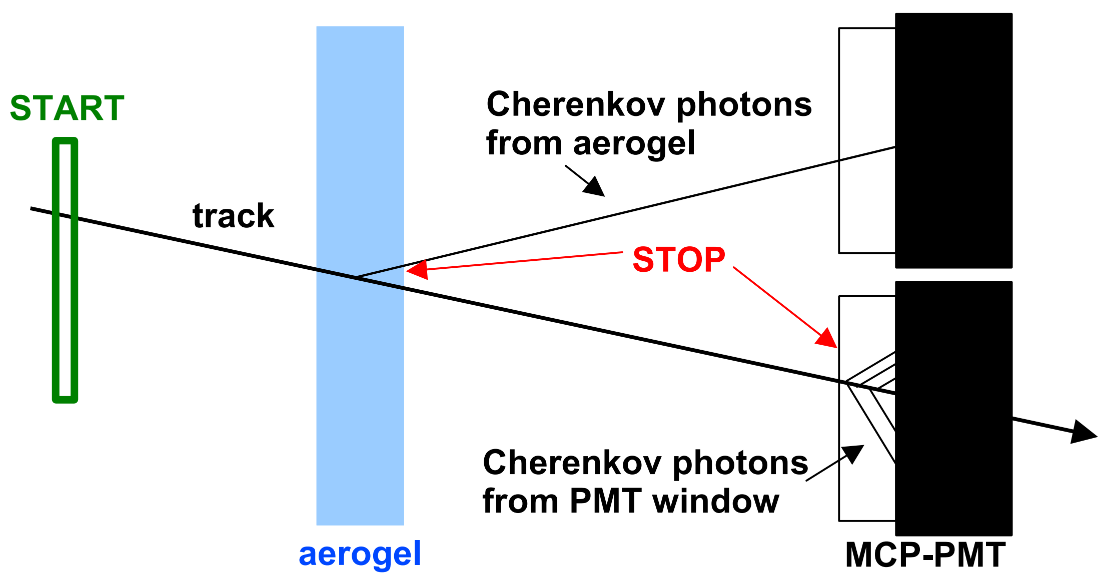
TOF capability

With the use of a fast photon detector, a proximity focusing RICH counter can be used also as a time-of-flight counter.



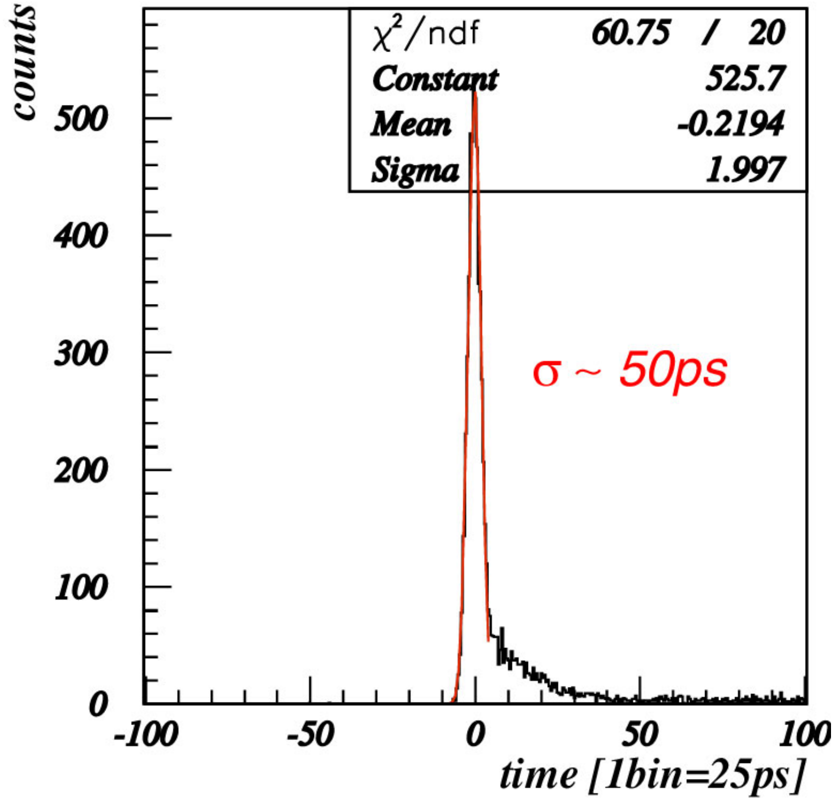
Cherenkov photons from two sources can be used:

- photons emitted in the aerogel radiator
- photons emitted in the PMT window



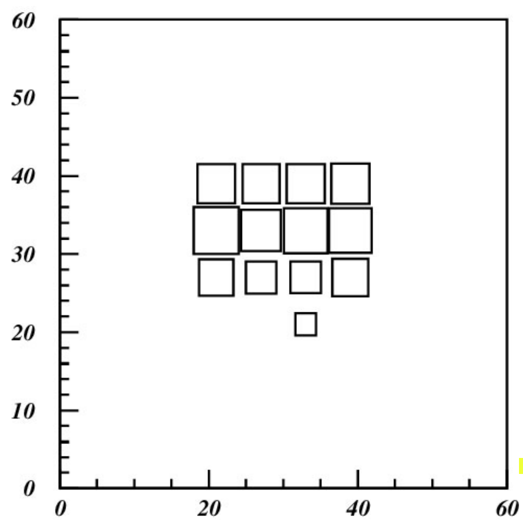
Beam tests: study timing properties of such a configuration.
→

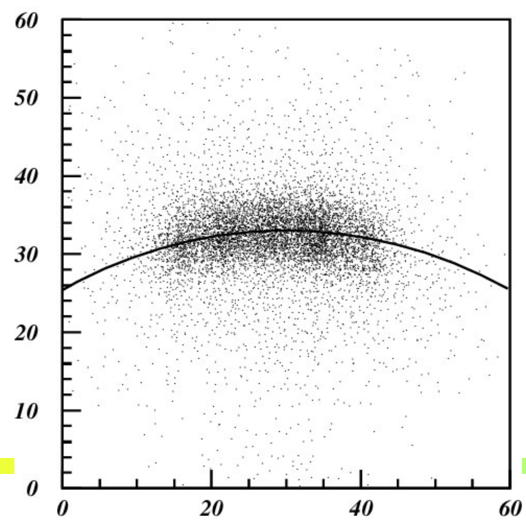
TOF capability: photons from the ring



- obtained time resolution for Cherenkov photons from the aerogel radiator is 50ps, and agrees well with the value from the bench tests

- resolution for full ring (~10 photons) would be around 20 ps

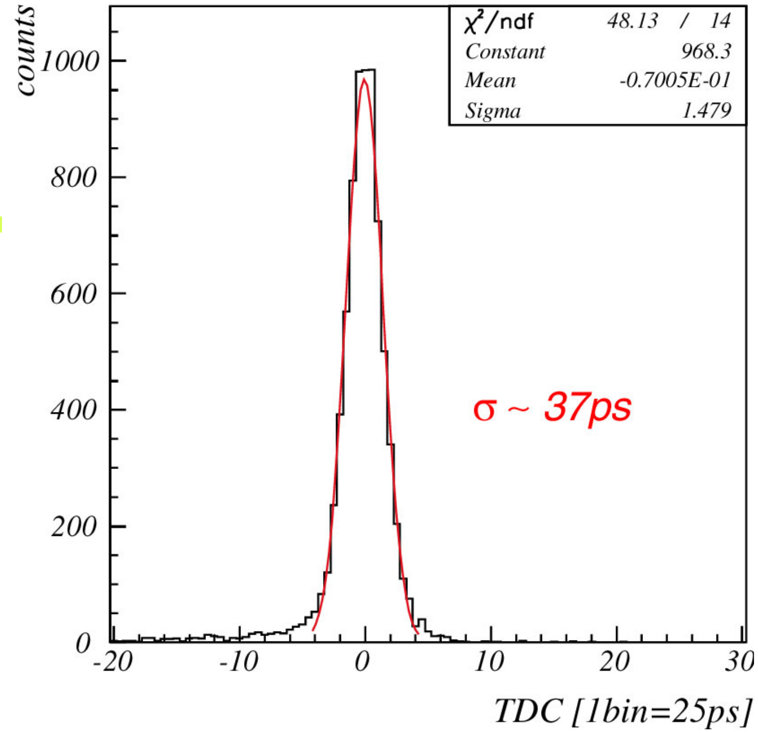


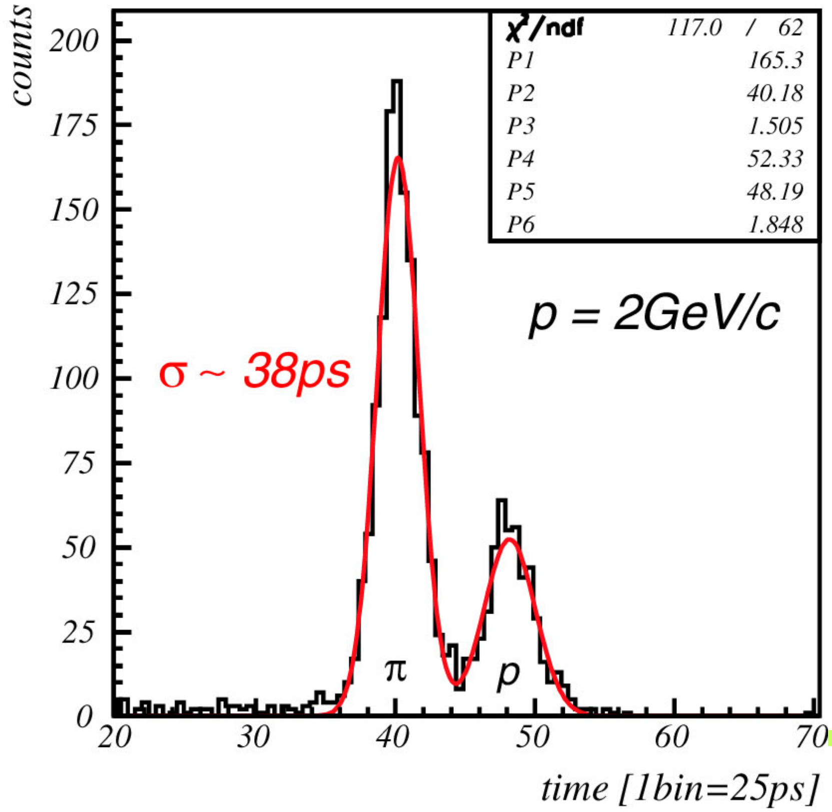


- distribution of hits on the MCP-PMT (13 channels were instrumented) - left
- corrected distribution using the tracking information - left

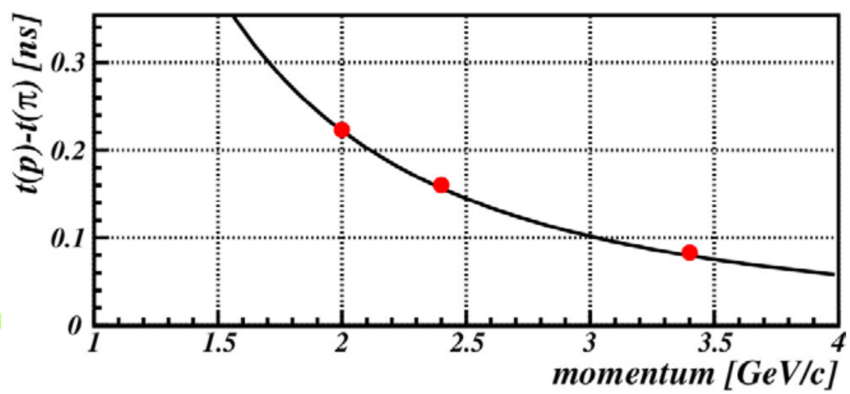
TOF capability: window photons

- expected number of detected Cherenkov photons emitted in the PMT window (2mm) is ~15
- expected resolution ~35 ps →





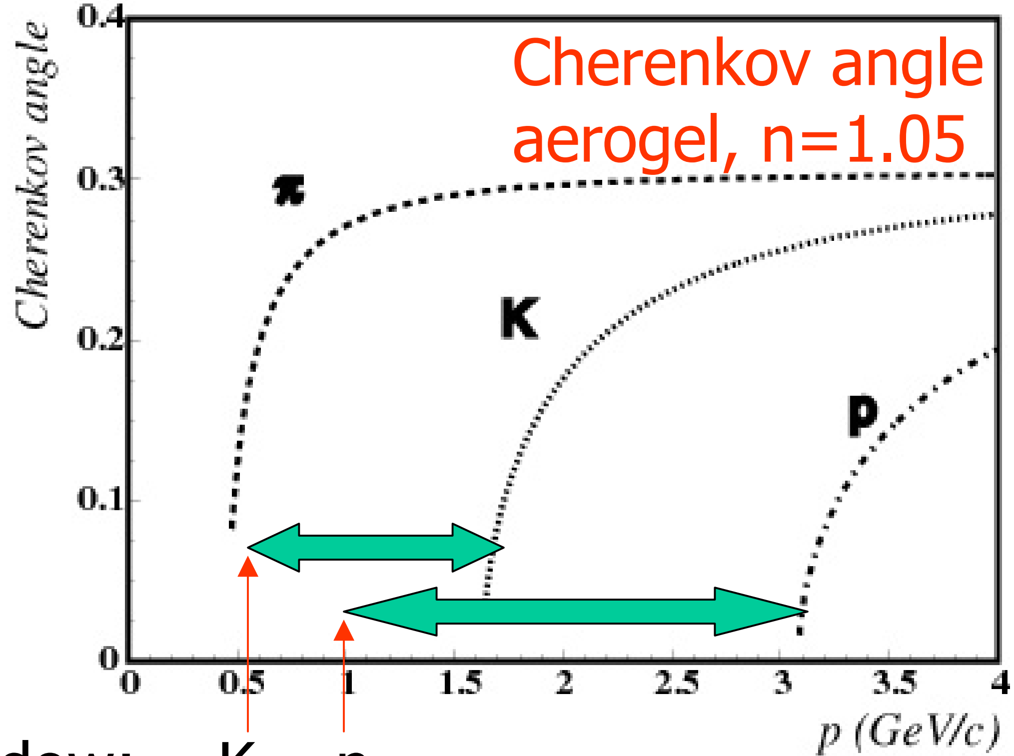
- TOF test with pions and protons at 2 GeV/c
- distance between start counter and MCP-PMT is 65cm



Time-of-flight with photons from the PMT window

Benefits: Čerenkov threshold in glass (or quartz) is much lower than in aerogel.

Aerogel: kaons (protons) have no signal below 1.6 GeV (3.1 GeV): identification in the veto mode.



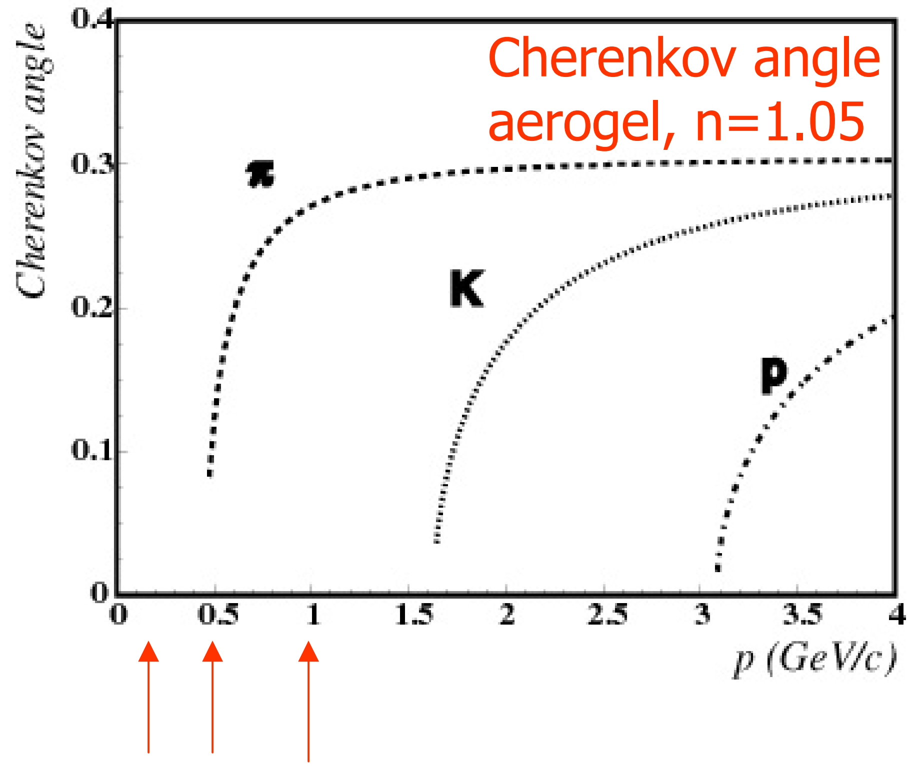
Threshold in the window: K p

Window: threshold for kaons (protons) is at ~0.5 GeV (~0.9 GeV): → positive identification possible.

Time-of-flight with photons from the PMT window - 2

Window: threshold for kaons (protons) is at ~0.5 GeV (~0.9 GeV): → positive identification possible below threshold in aerogel.

Also: pion PID becomes more reliable around the pion threshold in aerogel (~0.5 GeV)



Threshold in the window: π K p

Summary

- A proximity focusing RICH with ~ 20 cm radiator to photon detector distance and ~ 6x6mm^2 pads is being developed for the upgrade of the Belle forward PID.
- Single refractive index radiator has an optimal radiator thickness of ~ 2 cm; increasing the thickness results in degradation of Cherenkov angle resolution per track.
- Way out: use of multi layer radiator with varying refractive index
- Expected performance of the focusing configuration: excellent p/K separation up to 4 GeV/c
- More studies are needed to decide which radiator configuration and photon detector we should use for the Belle PID upgrade

- Such a counter can also be used for TOF measurement

  → extend PID capabilities into low momentum region