Proximity focusing RICH with flat pannel PMTs as photon detector

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Optimisation of counter parameters

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PID upgrade in the forward direction

improve π/K separation in the forward (high momentum) region for few-body B decays

good p/K separation for b -> d γ , b -> s γ

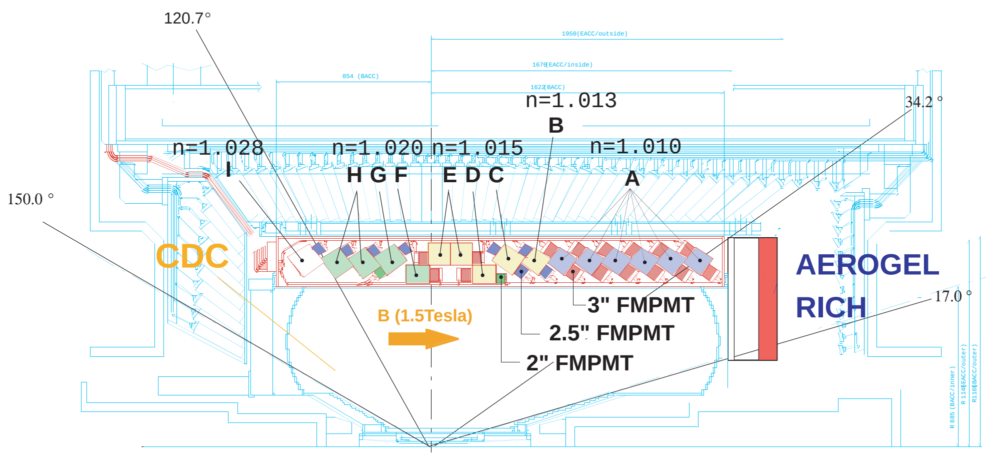
improve purity in fully reconstructed B decays ('full recon. tag')

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

keep high the efficiency for tagging kaons

→ talk by Toru Iijima on Belle PID upgrade (Friday)

PID upgrade in the forward direction



Proximity focusing RICH with aerogel as radiator

K/π separation at 4 GeV/c

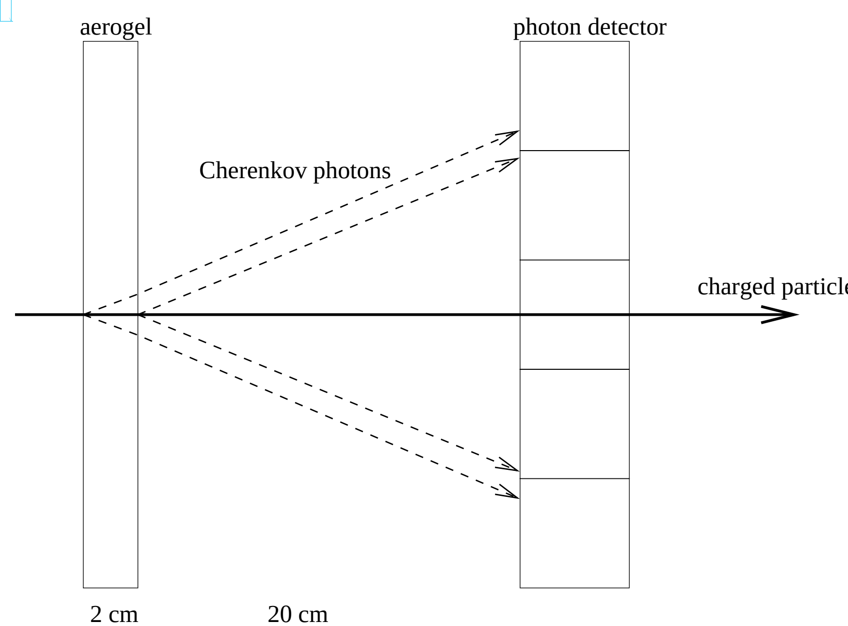
$\theta_c(\pi)$ ~ 308 mrad (n = 1.05)

$\theta_c(\pi) - \theta_c(K)$ ~ 23 mrad

$\delta\theta_c$(meas.) ~ 12 mrad

With 20mm thick aerogel and 6mm PMT pad size

→ 6σ separation with N_{pe}~10



Beam tests

Beam Test Nov. 2001

36 MAPMTs (R5900-M16) @ 30mm pitch, 36% eff. area, 192 readout channels

single photon Cherenkov angle resolution better than 10mrad

number of photons consistent with expectations, but clearly too low

Beam tests Nov. 2002 - 2004

new aerogel samples

new photon detector Hamamatsu H8500 (flat pannel PMT)

new readout electronics (1024 channels)

Aerogel production improvement

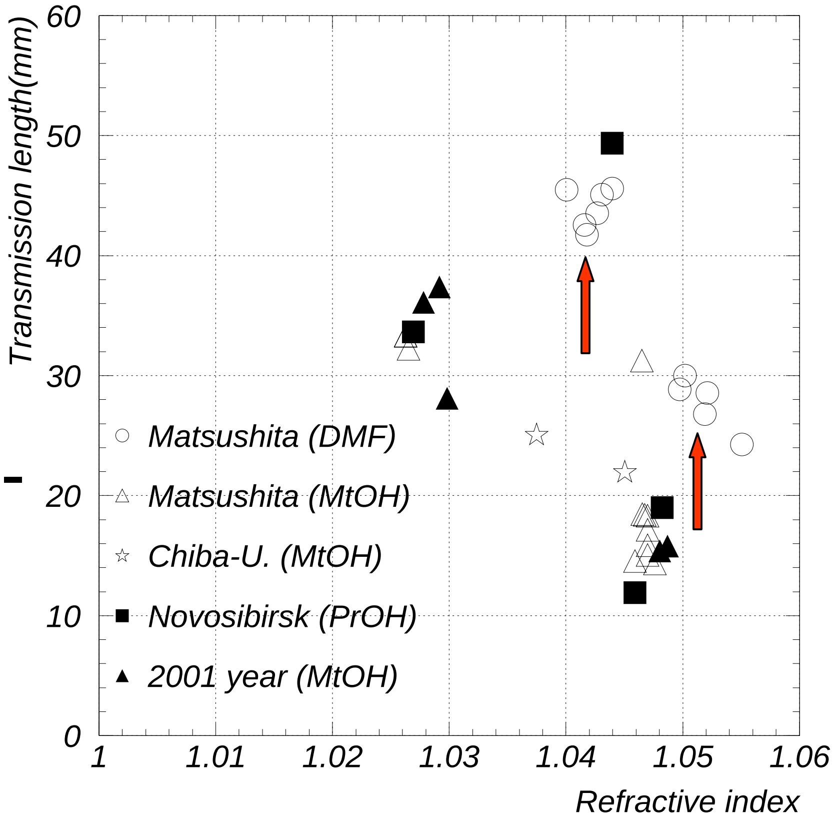
R&D in cooperation with Matsushita

aim: better optical quality for n~1.05 hydrophobic aerogel

a new solvent (Di-Methyl-Formamide instead of Methyl-alcohol)

precursor (Methyl-silicate-51) from a different supplier

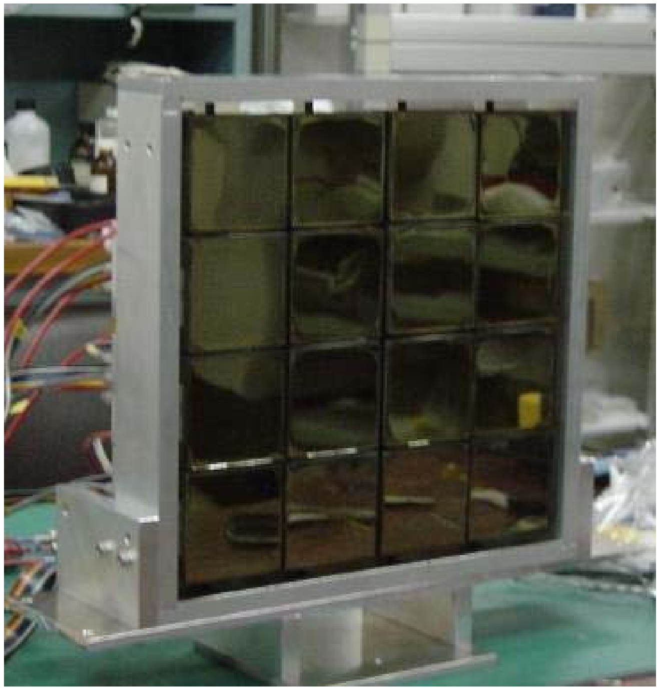
-> considerable improvement



→Ichiro Adachi's talk on aerogel R+D

Hamamatsu H8500 (flat panel PMT) as photon detector

- 8x8 multi-anode PMT (64ch) by HPK
- Effective area=89% (□49mm for □51.7mm package)
- 4x4 array used in beam tests (1024 ch in total)

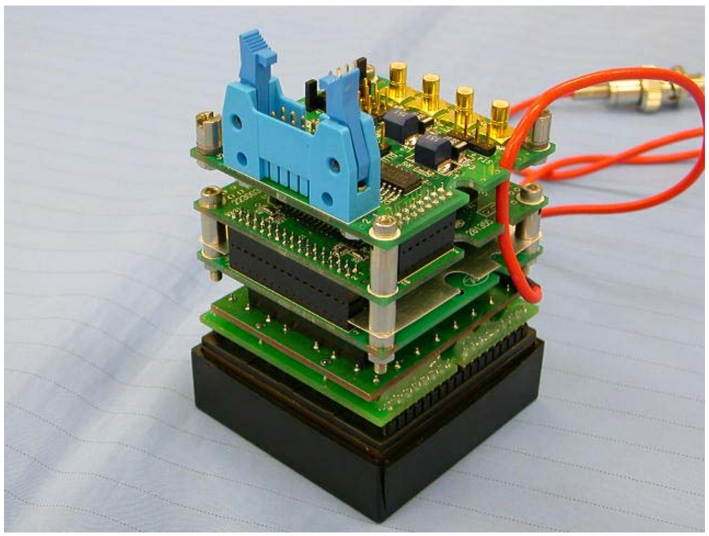


Not suitable for operation in magnetic field, but still good for the understanding of the detector behavior → intermediate step in our R+D

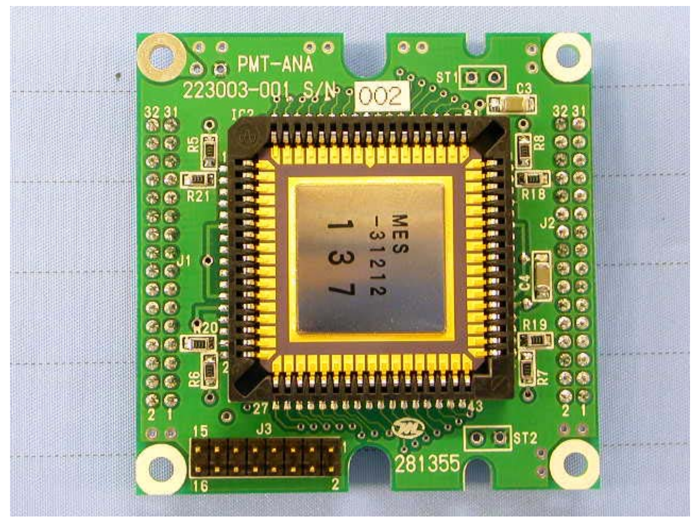
→ talks by Takayuki Sumiyoshi and Andrej Gorišek

Read-out electronics

- IC's with analog memory
- 2 analog memory chips for 1 PMT (each for 32ch)
- 8 step pipe-line (1μs x 8)
- Serial signal sent to VME ADC (10μs period x 256ch)
- Use 4 VME ADC channels for 1024 ch readout



Assembled flat panel PMT with read-out

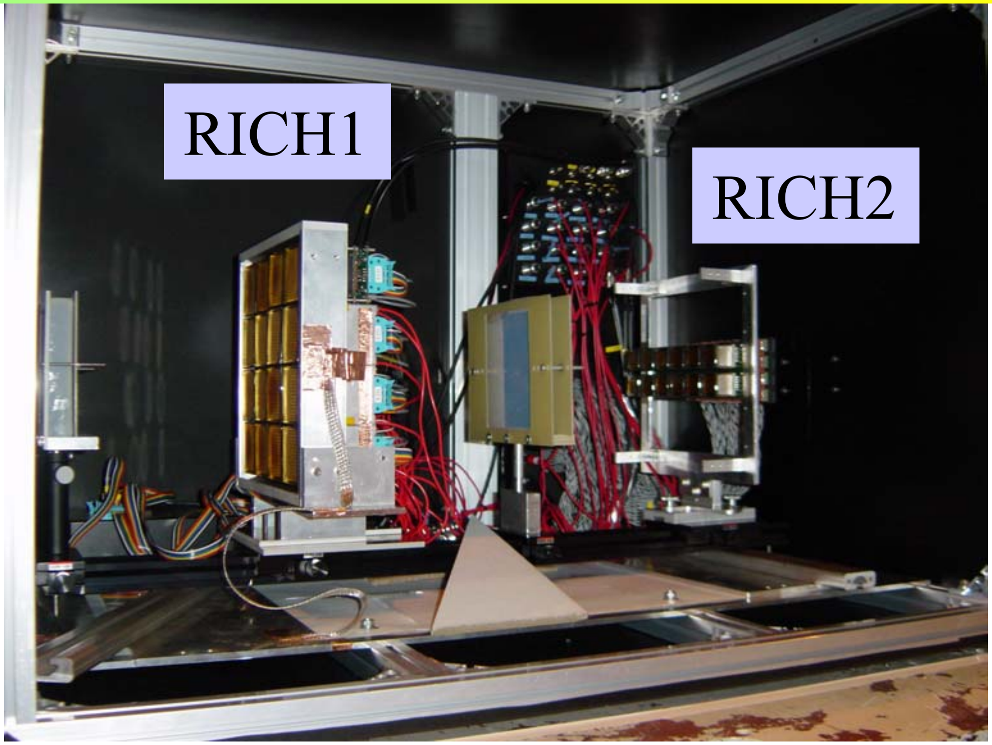


Analog memory board

Beam test set-up

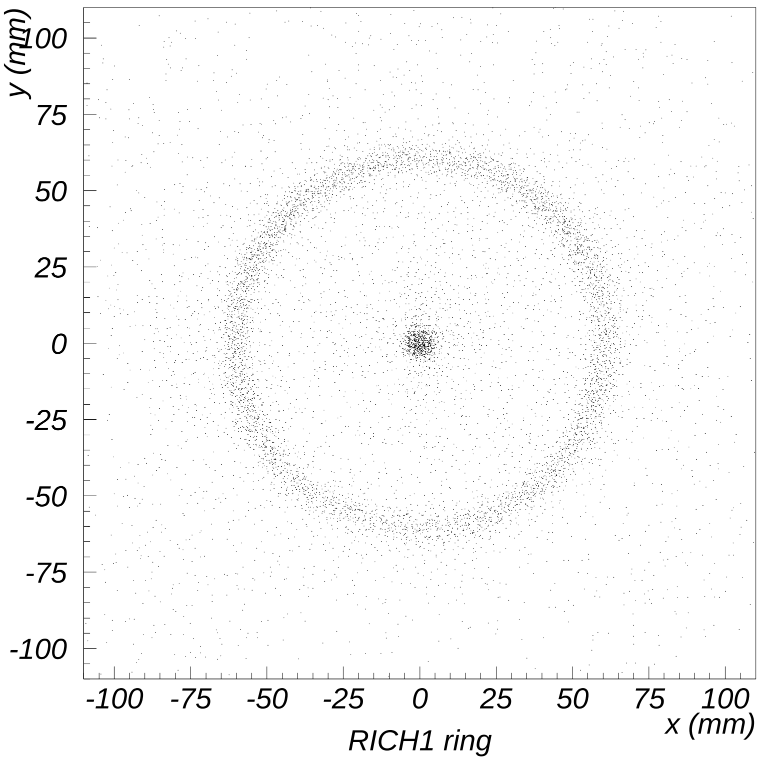
π^- beam

0.5 to 4.0 GeV/c

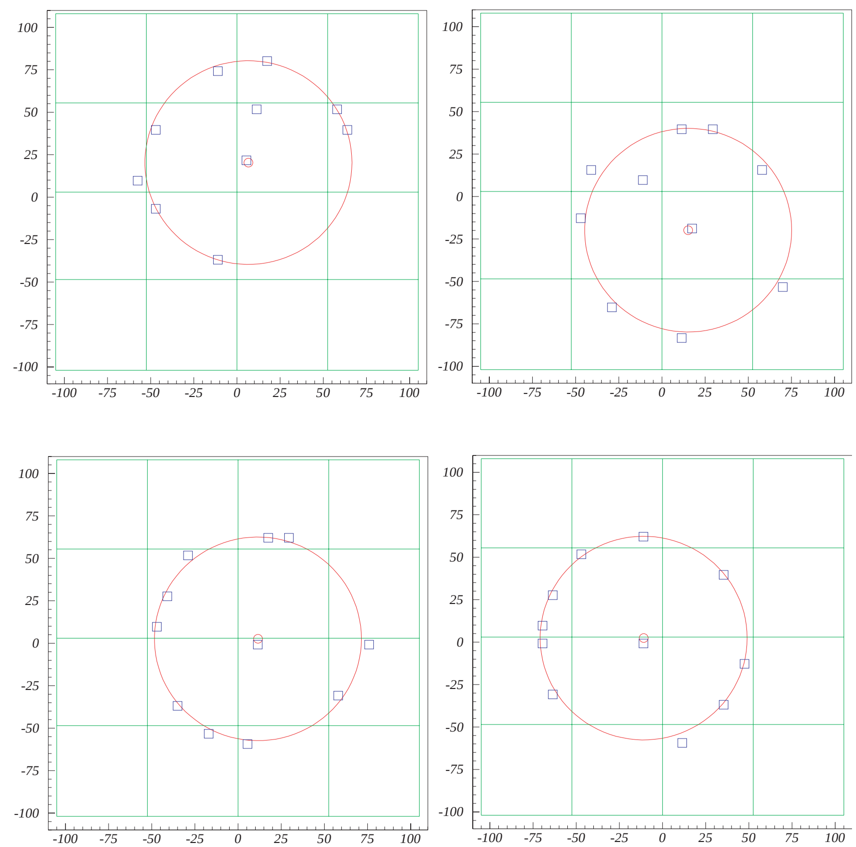


- RICH1: Flat panel PMTs and aerogel radiator
- MWPCs for tracking
- RICH2: as a reference (with R5900-M16 PMTs)
- CO_2 threshold Gas Cherenkov counter for electron veto

Beam test results

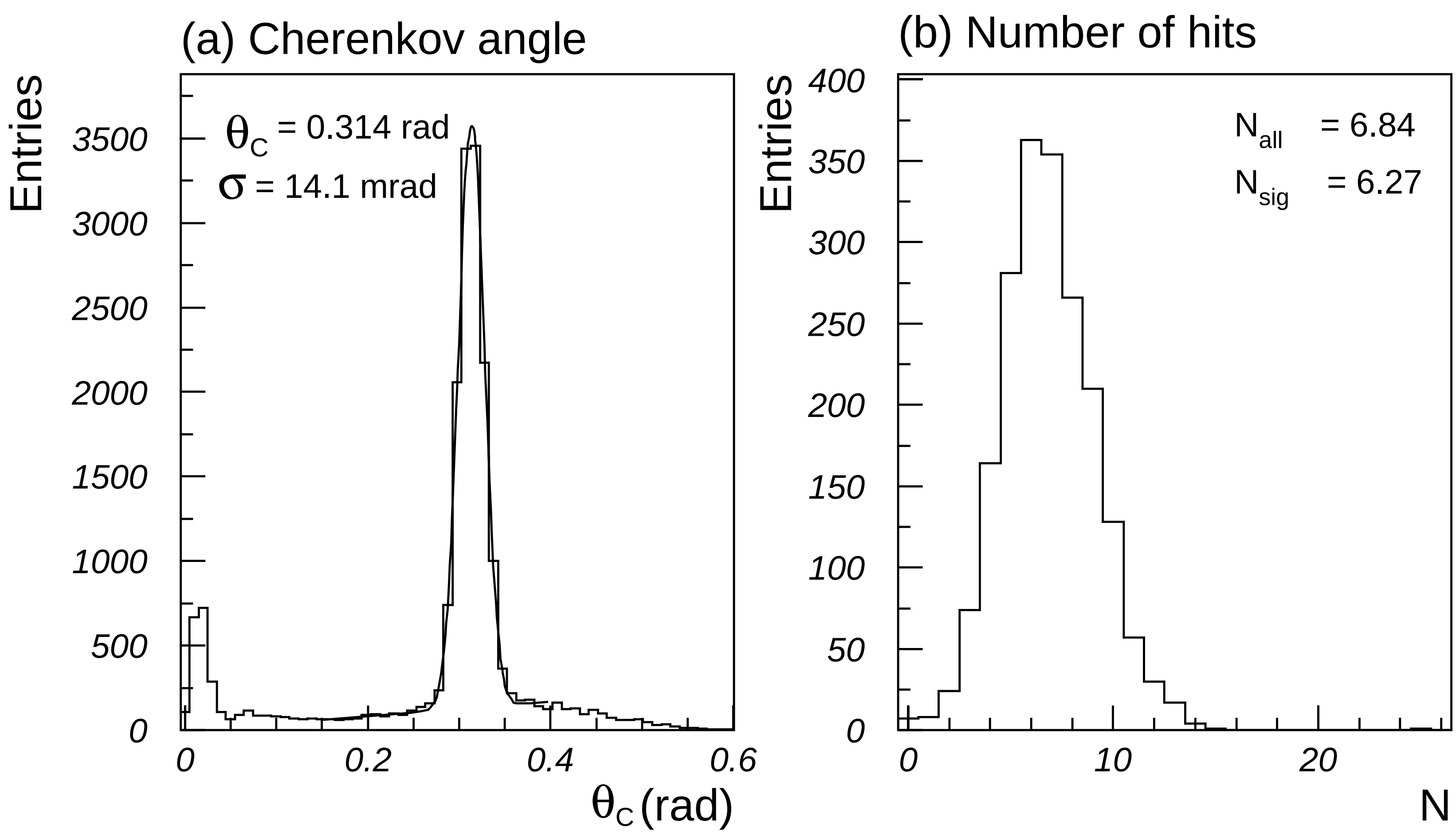


Accumulated hits



Clear rings, little background

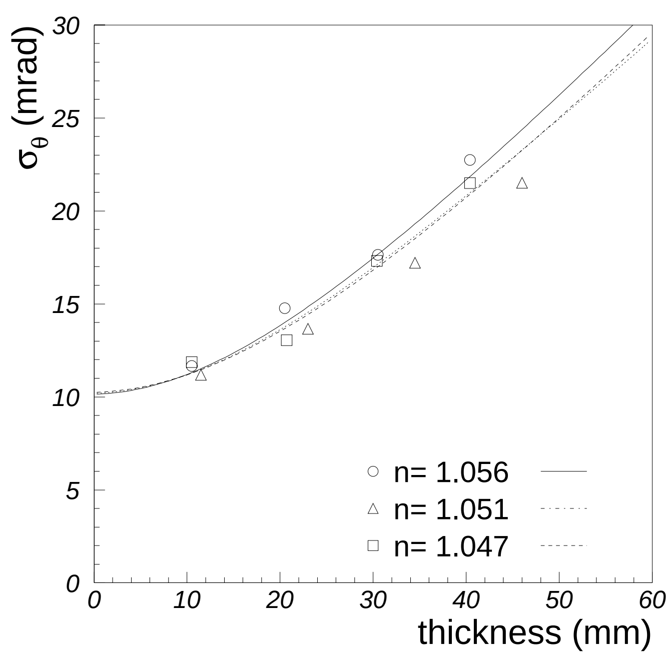
Cherenkov angle resolution and number of photons

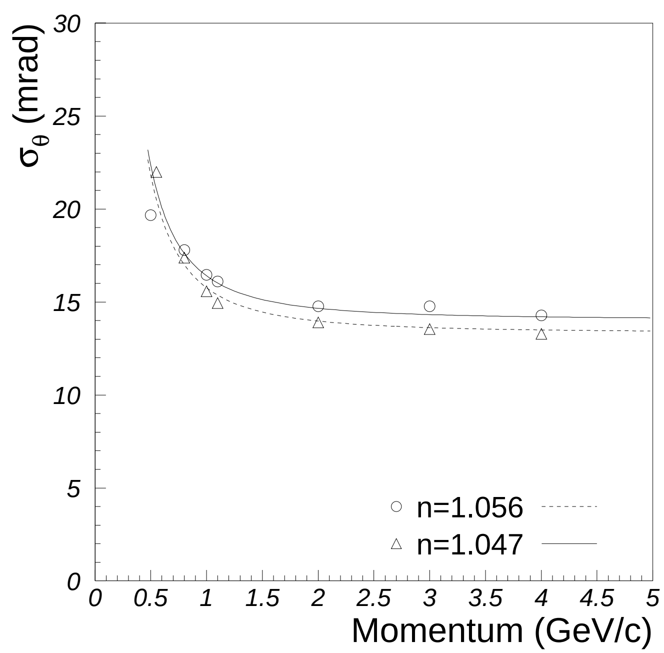


Resolution for single photons

Typically around 13 mrad (for 2 cm thick aerogel)

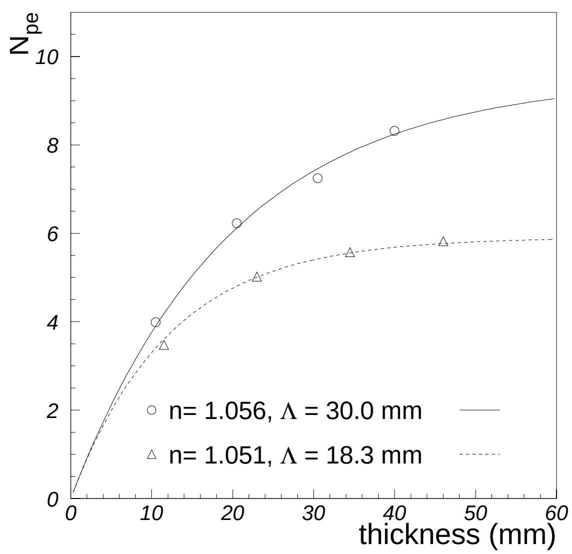
Shown as a function of thickness, momentum

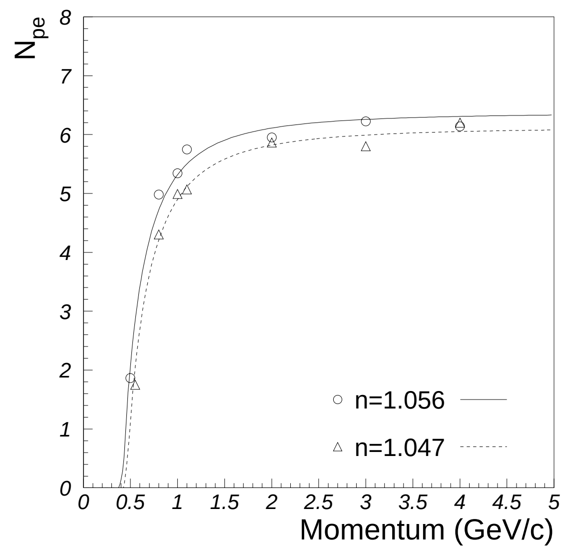


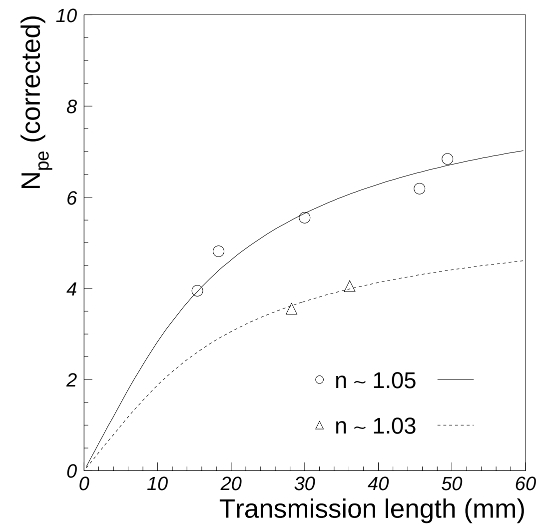


Number of photons

As a function of momentum, thickness, transmission length





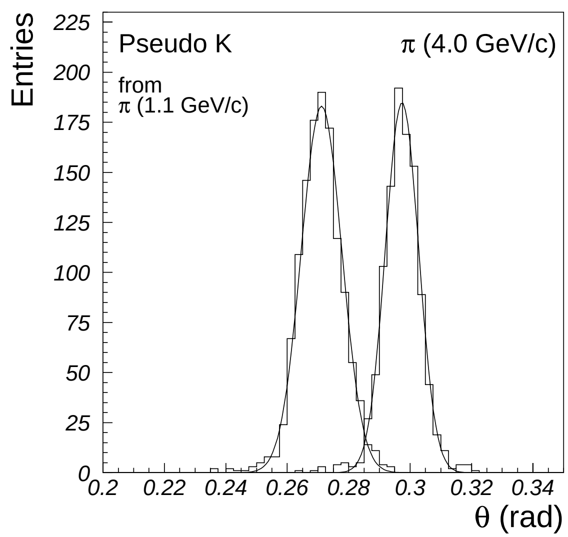


In good agreement with expectations.

Can we increase the number of photons by keeping the good single photon resolution resolution?

→talk by Samo Korpar

PID capability on test beam data



From typical values (single photon resolution 13mrad and 6 detected photons) we can estimate the Cherenkov resolution per track: 5.3mrad

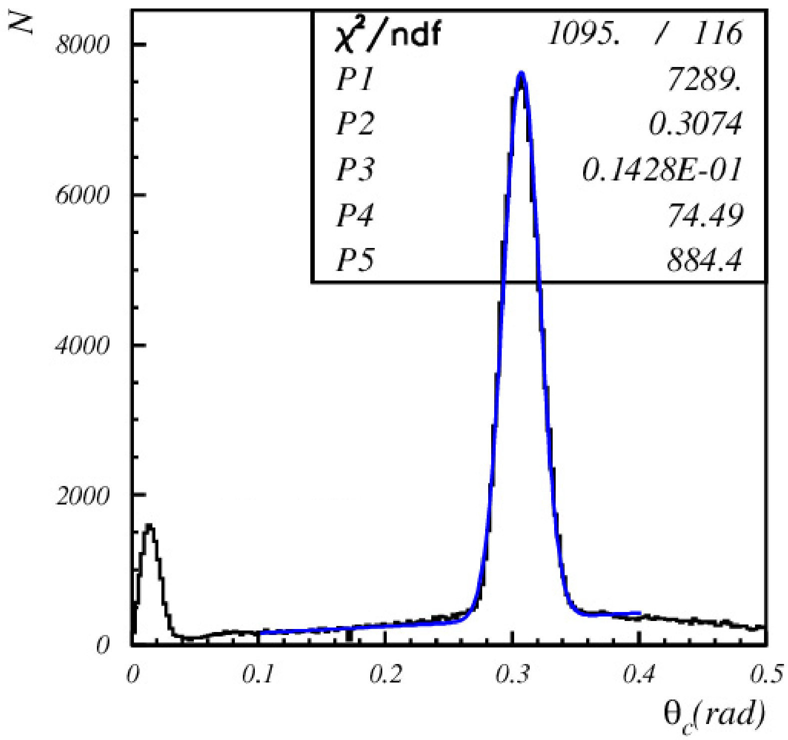
-> 4.3 sigma π/K separation at 4GeV/c.

Illustration of PID performance: Cherenkov angle distribution for pions at 4GeV/c and 'kaons' (pions at 1.1GeV/c with the same Cherenkov angle as kaons at 4GeV/c).

Details on the beam test: NIM A521 (2004) 367 (physics/0309032)

Resolution studies

Cherenkov angle distribution



Radiator: thickness 20.5mm

σ_θ is obtained by fitting the θ distribution Gaussian + background

σ_θ (data)=14.3mrad

$$\sigma_\theta(\text{calc}) = \sqrt{\sigma_{\text{emp}}{}^2 + \sigma_{\text{pix}}{}^2}$$

σ(calc)	11.8 mrad
σ_{pix}	7.8 mrad
σ_{emp}	8.8 mrad

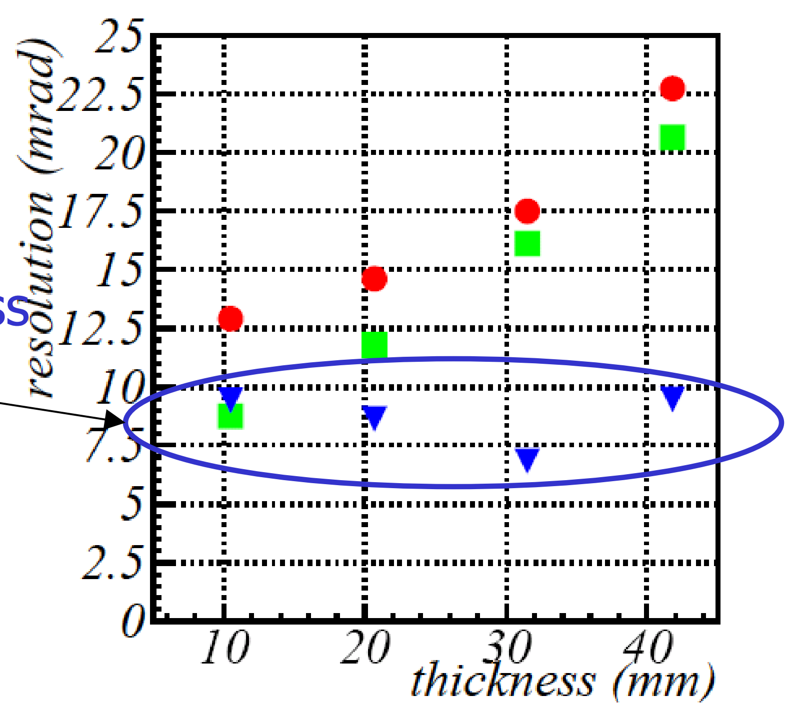
$$\sigma_\theta = \sqrt{\sigma_{\text{emp}}{}^2 + \sigma_{\text{pix}}{}^2 + \sigma_{\text{rest}}{}^2}$$

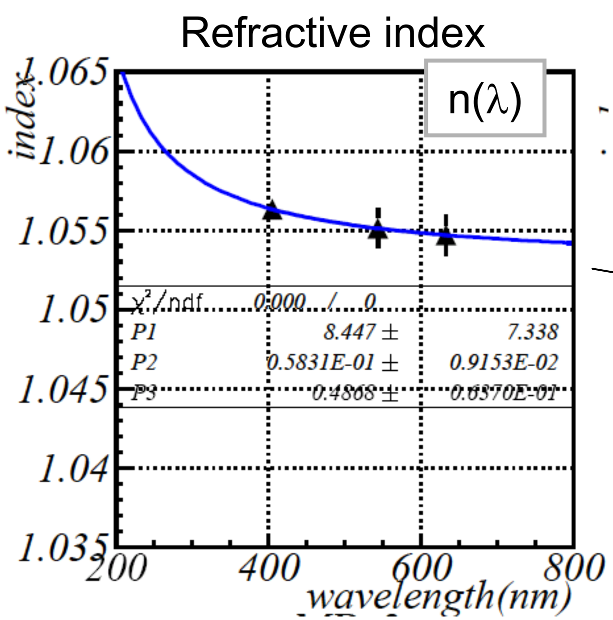
What is rest?

Resolution studies 2

- σ_θ (data) : Data(n=1.046)
- σ_{calc} : Calculated value $(\sigma_{pix}^2 + \sigma_{emp}^2)^{1/2}$
- σ_{rest} : $(\sigma_{data}^2 - \sigma_{calc}^2)^{1/2}$

Rest component σ_{rest}=7~8 mrad
doen not depend on radiator thickness

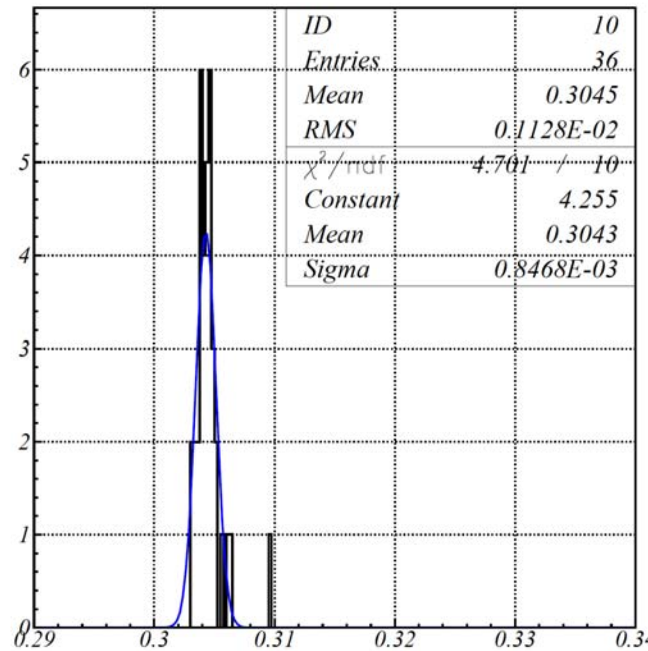




Chromatic error? 2-3 mrad (depends on the sample)

Resolution studies 3

Non-uniformity of the radiator? Group tracks according to the impact position in 5mmx5mm regions, plot Cherenkov angle distribution for each of them:

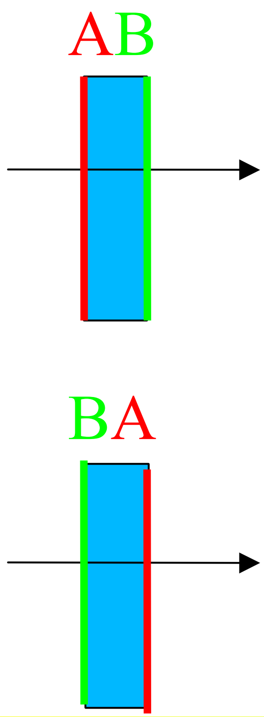


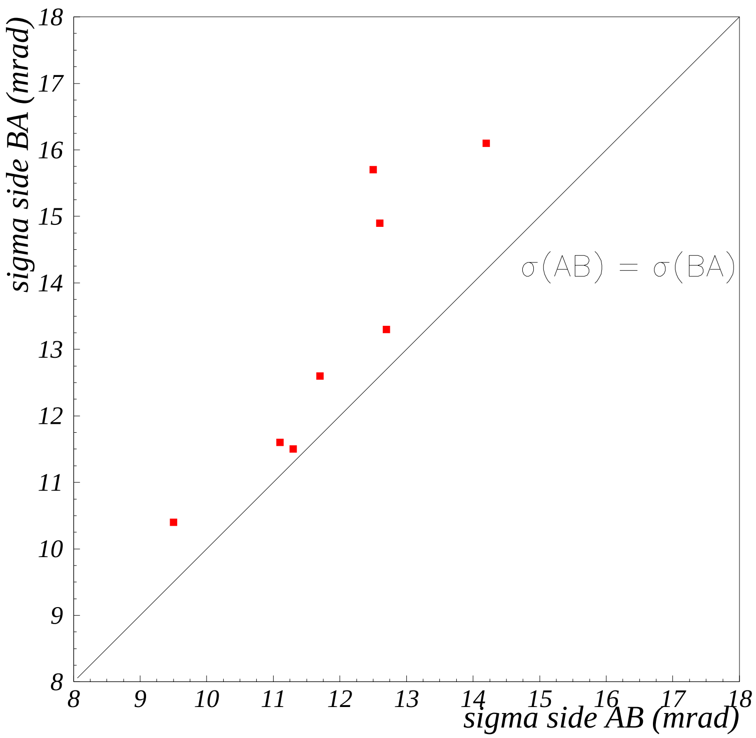
Cherenkov angle variation due to non-uniformity of aerogel: 1 mrad

Resolution studies 4

Does it depend on the orientation of the sample?

Measure the Cherenkov angle and sigma for both orientations of the aerogel tile
→some samples have large difference in sigma for AB and BA cases

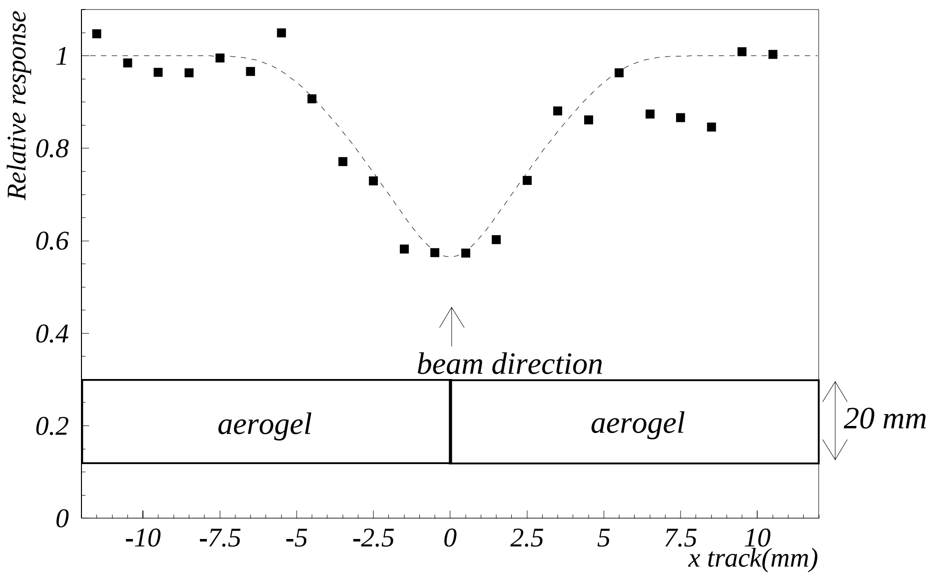




→still under study

Optimisation of counter parameters

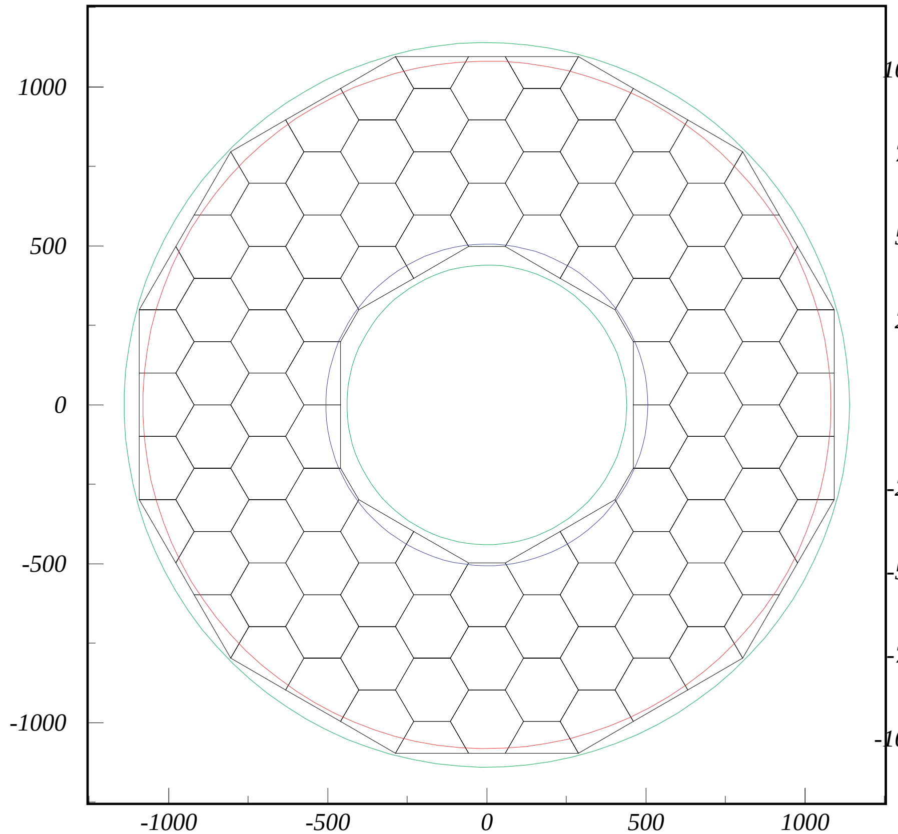
How to design radiator tiles: at the tile boundary photons get lost.

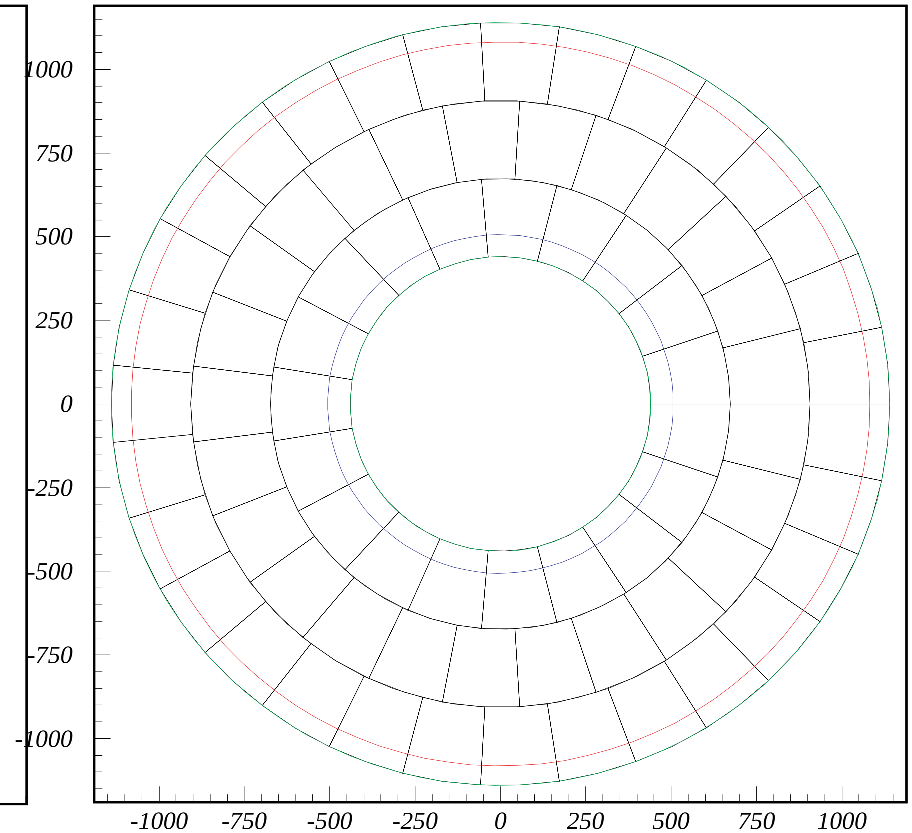


- Scan with the beam across the tile boundary. As expected, the yield is affected over a few mm in the vicinity of the boundary.
- A simple model (all photons hitting the boundary get lost) accounts for most of the dependence →

Reduce the fraction of tracks close to tile boundaries and corners

Tiling of the radiator





Two aerogel radiator tiling schemes for two max. tile size cases

→Ichiro Adachi's talk on aerogel R+D

Summary

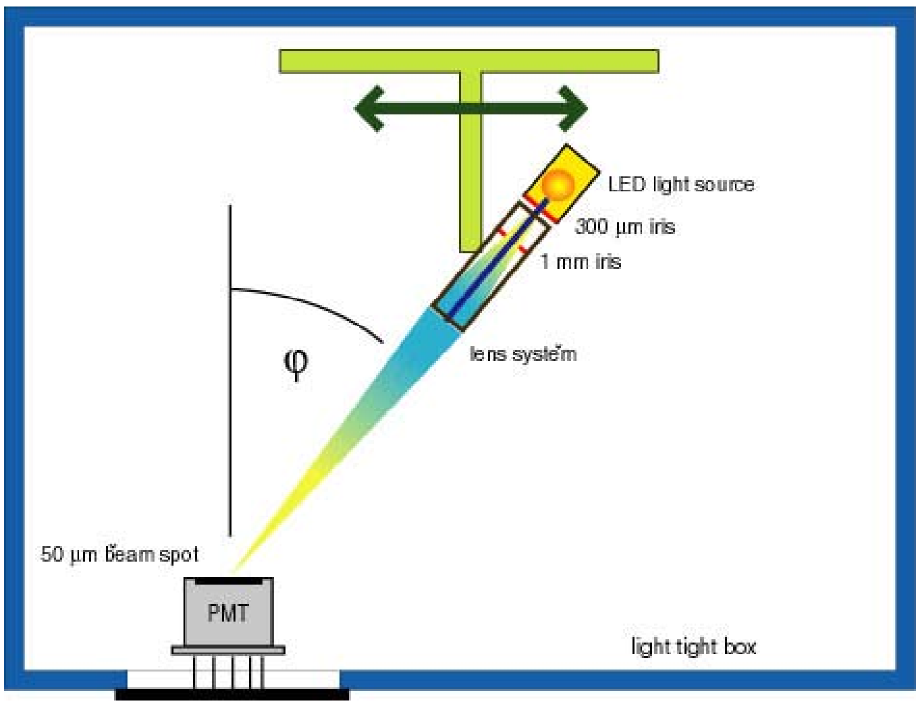
- Proximity focusing RICH with aerogel as radiator looks as a very promissing option for the PID system upgrade of the endcap part of the Belle detector
- Flat panel PMT is an excellent single photon detector, suitable for RICH counters in absence of magnetic field
- Efficiently used to test design options of the Belle endcap PID upgrade, understanding of the system, improved aerogel samples and configirations, read-out systems under development.
- R&D issues for Belle endcap upgrade: development and testing of a multichannel photon detector for high mag. fields
- Mass production of large aerogel tiles
- Readout electronics

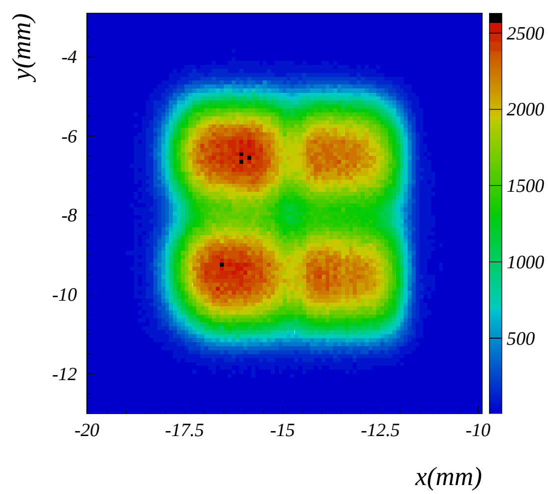
Back-up slides

Surface uniformity

Study uniformity of the sensitivity over the surface

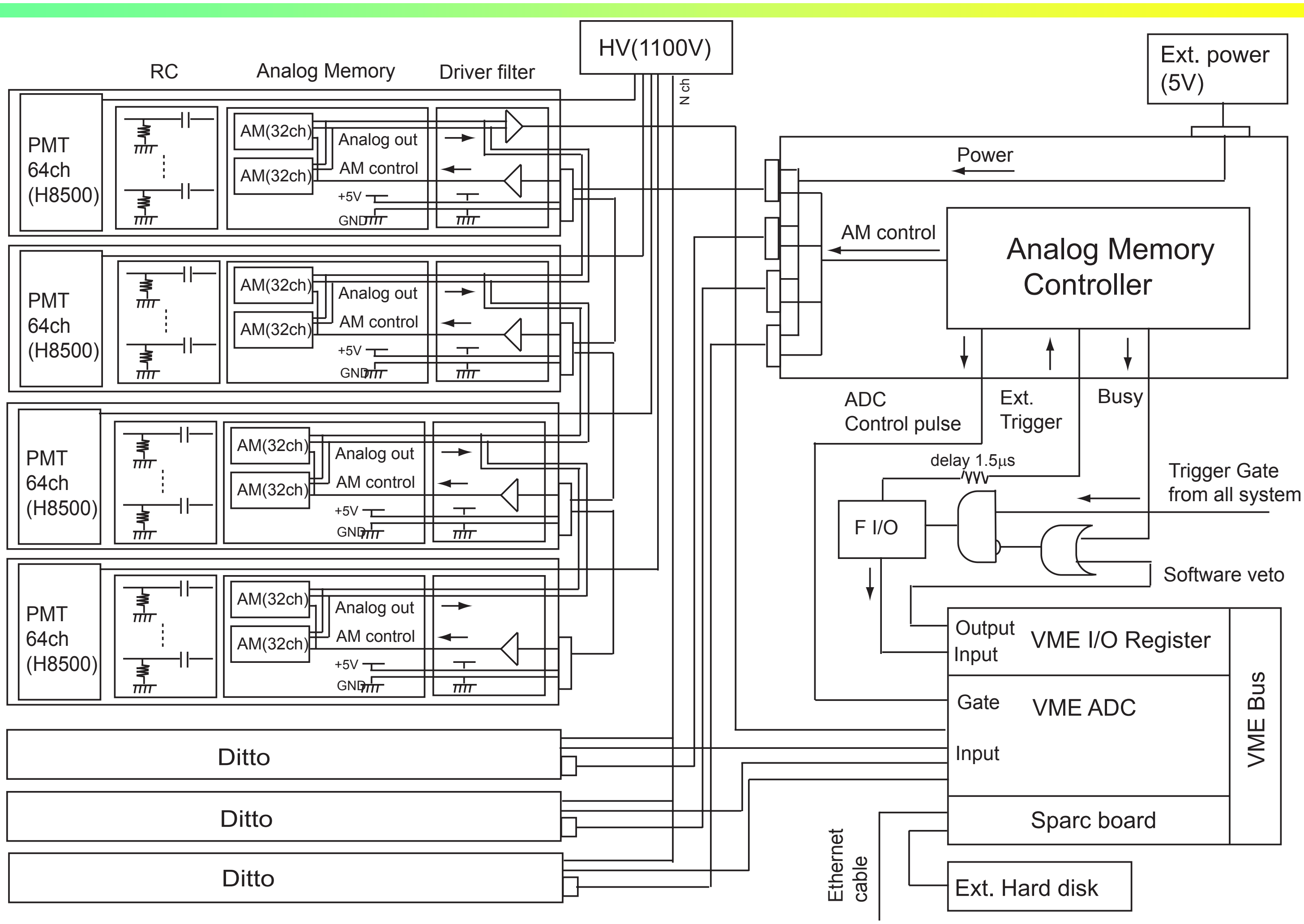
- source: LED in the eyepiece of a microscope on a 2d stage
- spot size 50 μm





Single channel response of the H8500 PMT

Read-out electronics



* System developed by Meisei Co.