Aerogel RICH

Peter Križan

University of Ljubljana and J. Stefan Institute

For Belle Aerogel RICH R&D group

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PID upgrade in the forward direction

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

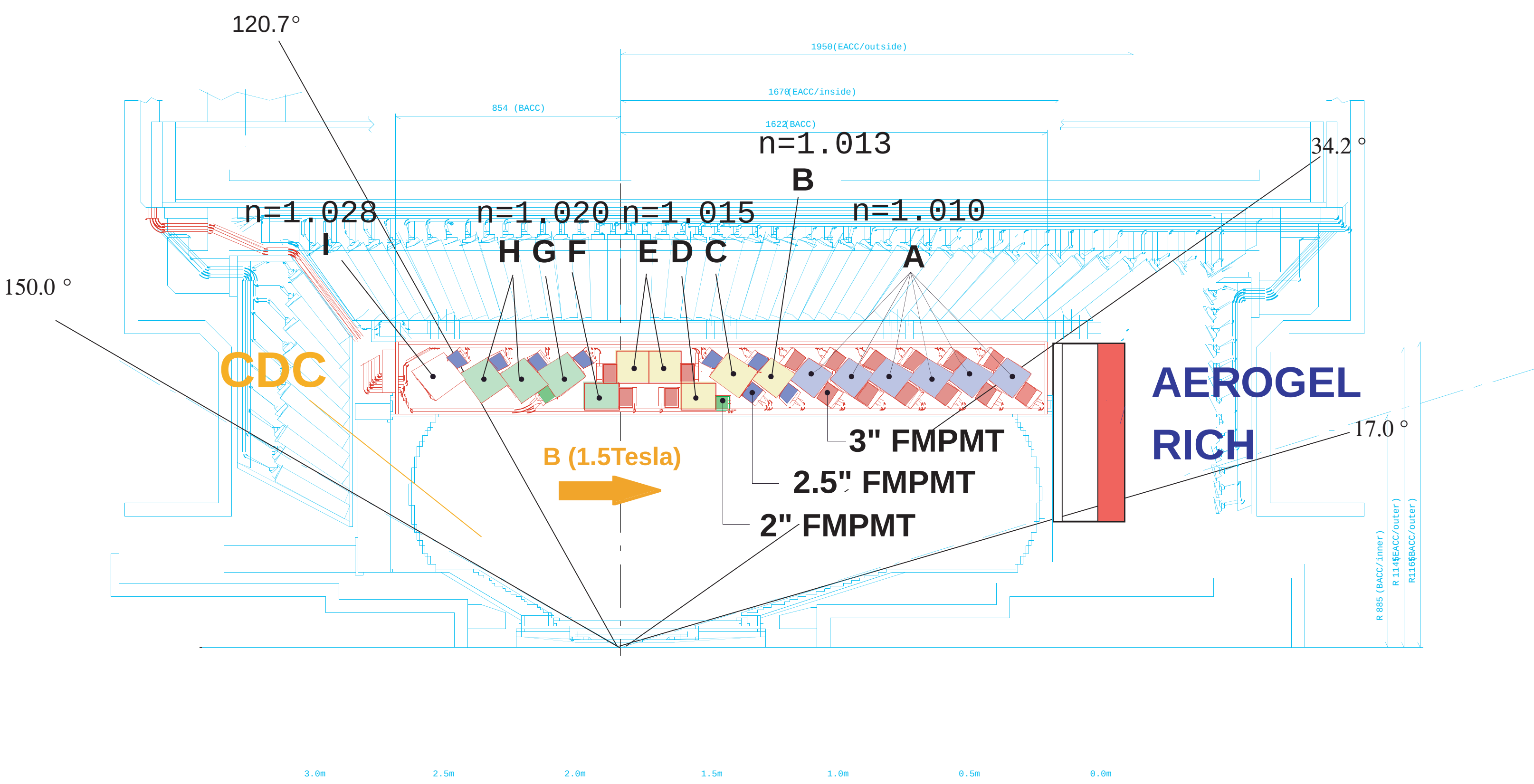
good π/K separation for $b \to d\gamma$, $b \to s\gamma$

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

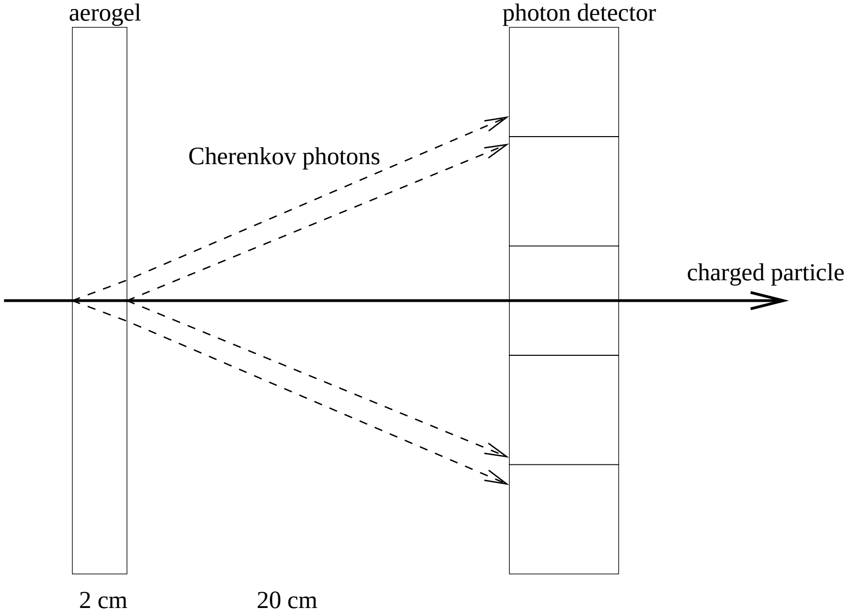
low momentum (<1GeV/c) $e/\mu/\pi$ separation (B ->Kll)

keep high the efficiency for tagging kaons

PID upgrade in the forward direction



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

$\delta\theta_c(\text{meas.}) = \sigma_0 \sim 12$ mrad

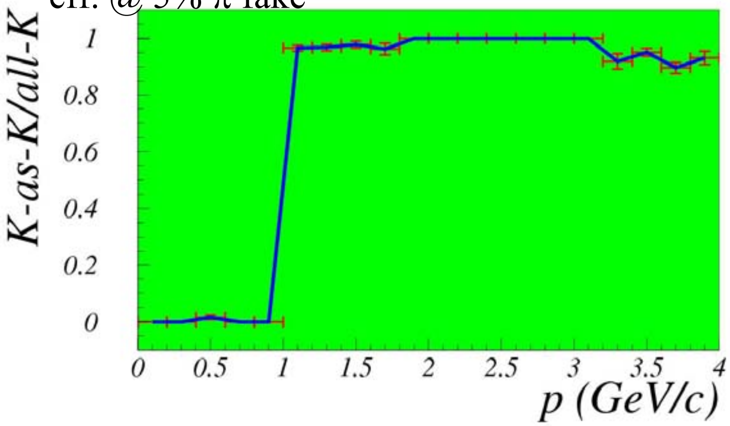
With 20mm thick aerogel and 6mm PMT pad size

→ 6σ separation with $N_{pe} \sim 10$

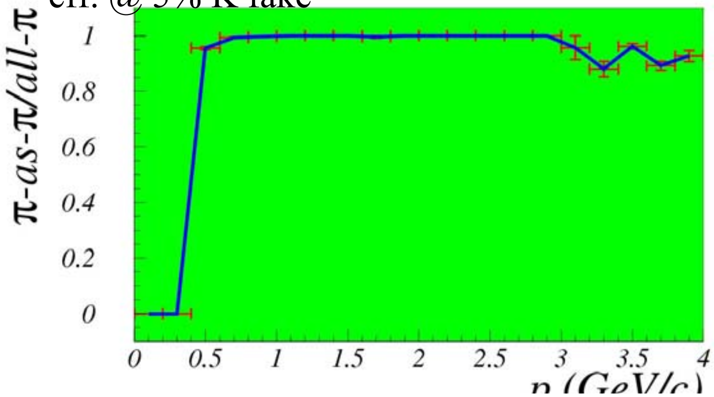
Expected PID performance

With counter performance as deduced from the test beam data (including background), the PID performance can be estimated in MC

eff. @ 5% π fake



eff. @ 5% K fake



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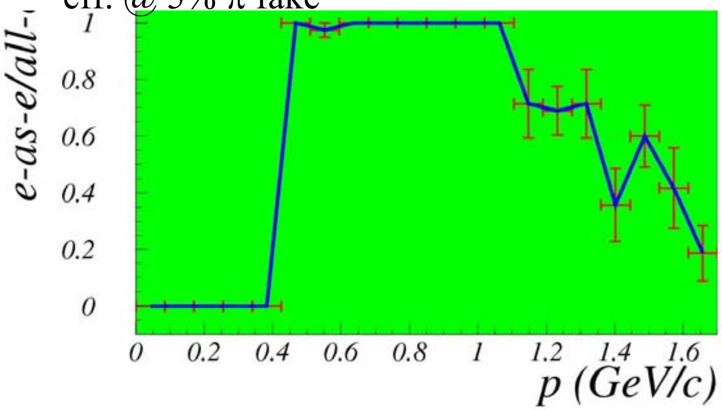
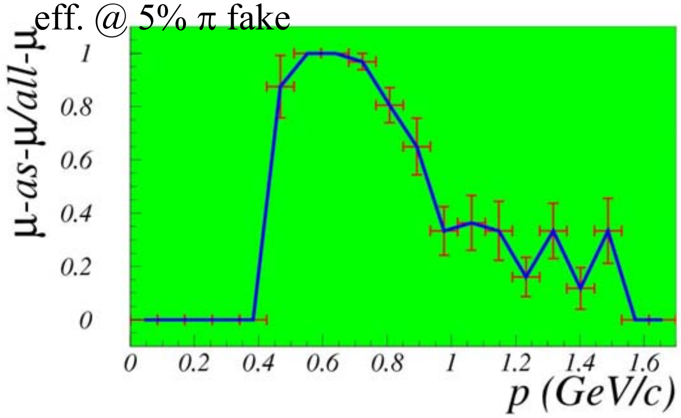


eff. @ 5% π fake



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

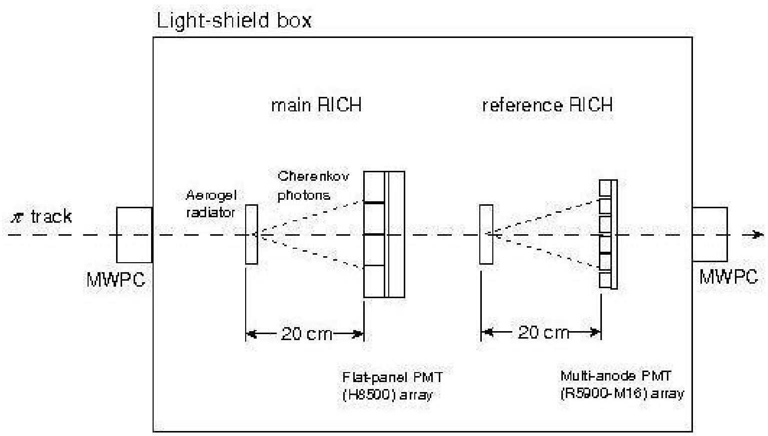
number of photons consistent with expectations, but clearly too low

Beam test Nov. 2002

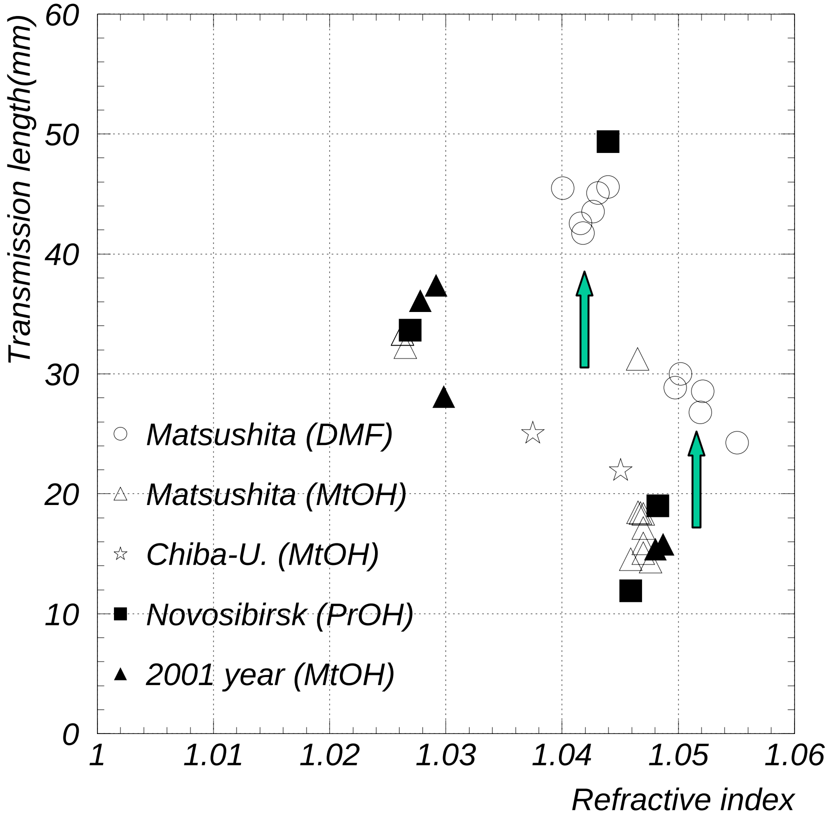
new aerogel samples

new photon detector Hamamatsu H8500 (flat pannel PMT)

new readout electronics (1024 channels)



Aerogel production improvement



R&D in cooperation with Matsushita

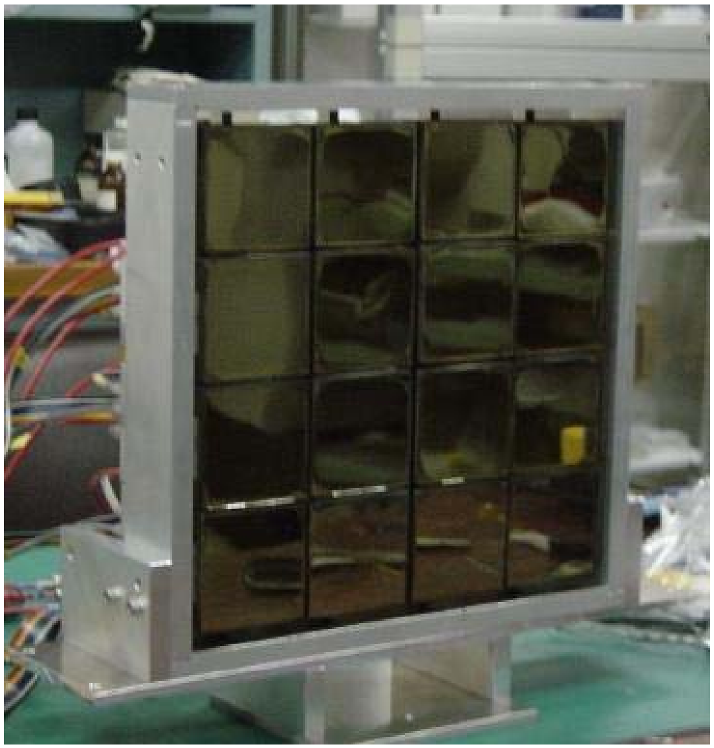
aim: better optical quality for n~1.05 hydrophobic aerogel

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

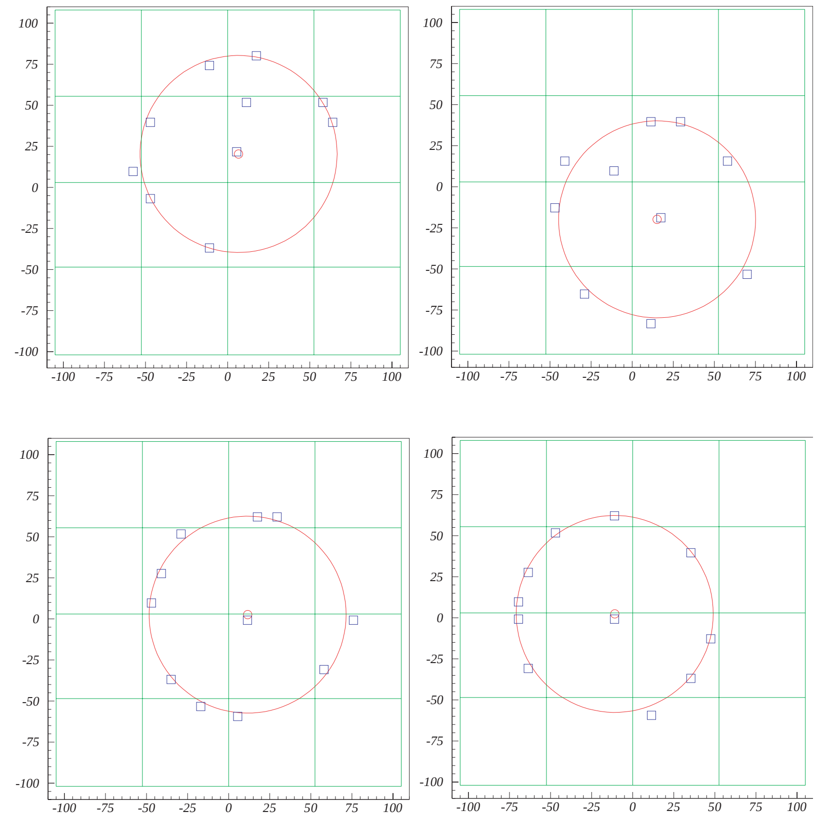
precursor (Methyl-silicate-51) from a different supplier

-> considerable improvement

Beam test results

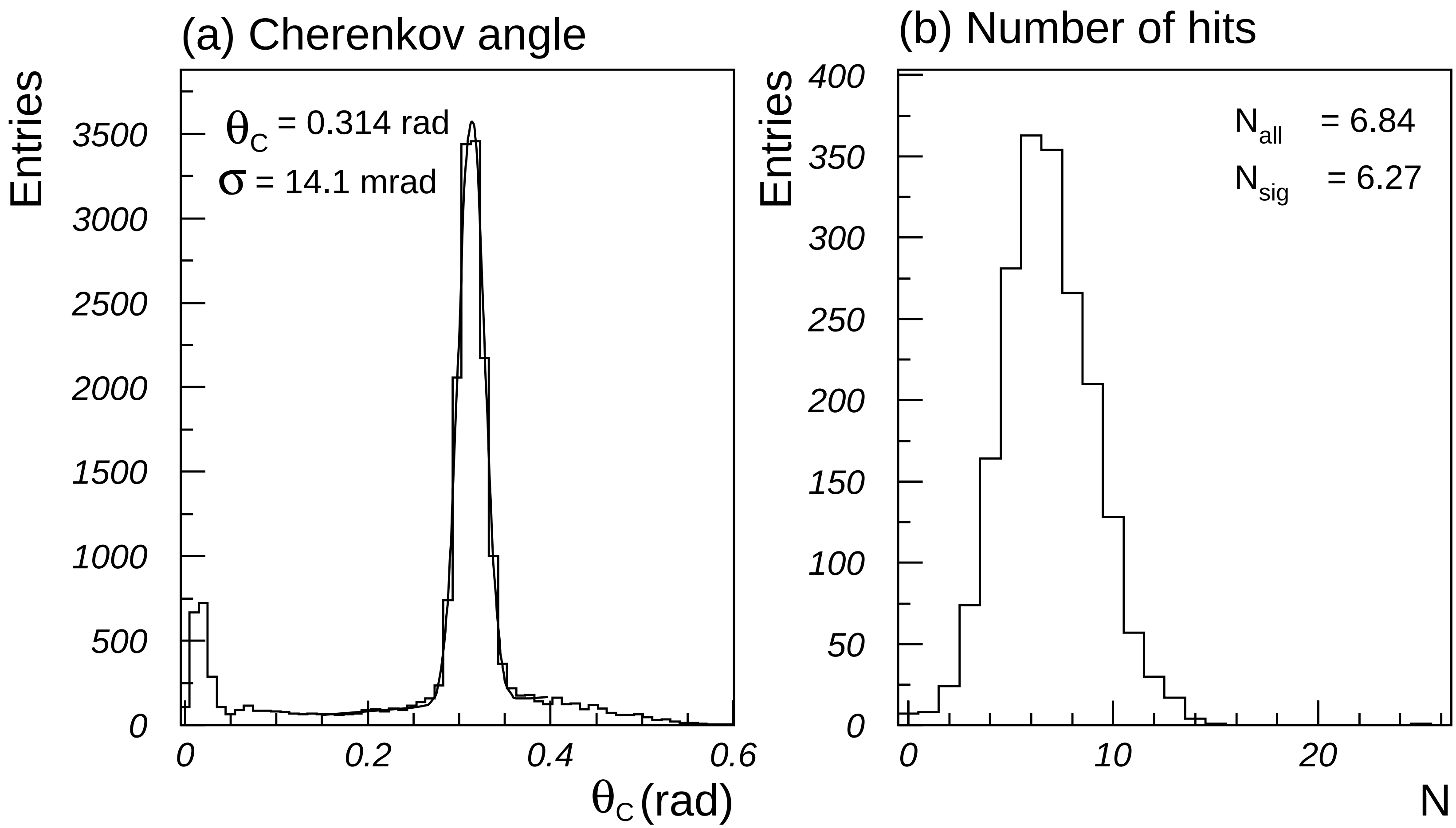


Photon detector: array of 16 H8500 PMTs



Clear rings, little background

Cherenkov angle resolution and number of photons

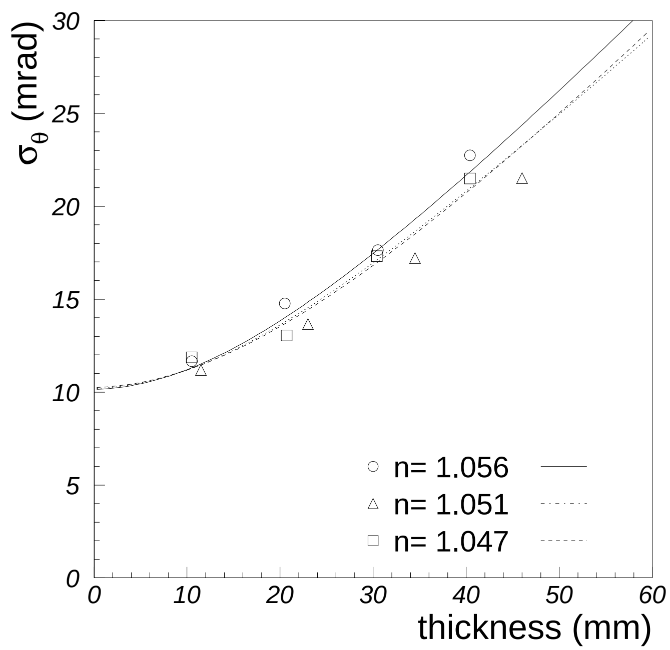


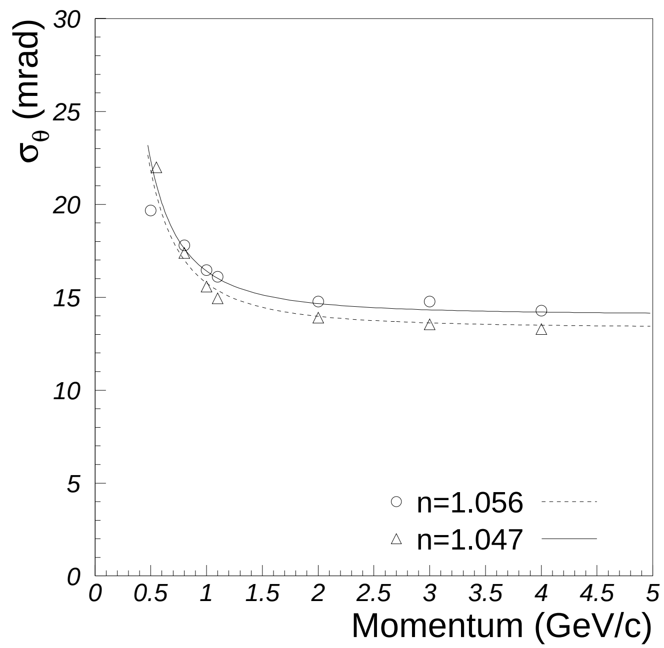
Resolution for single photons

In agreement with expectations

Typically around 13 mrad (for 2cm thick aerogel)

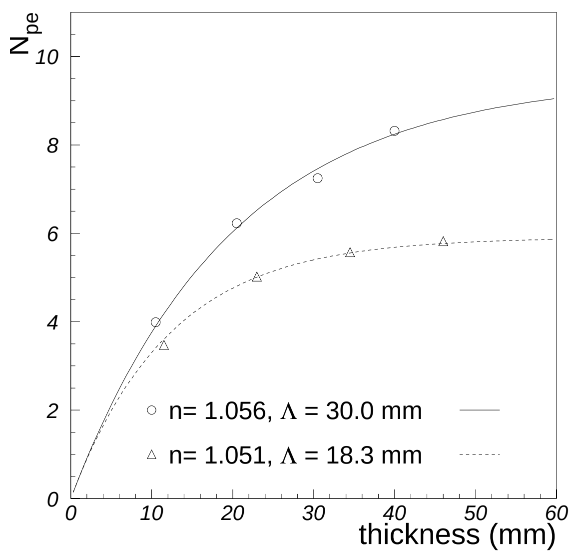
Shown as a function of thickness, momentum

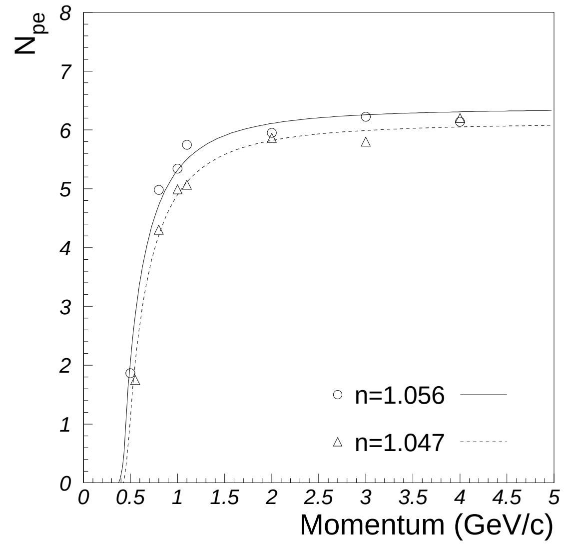


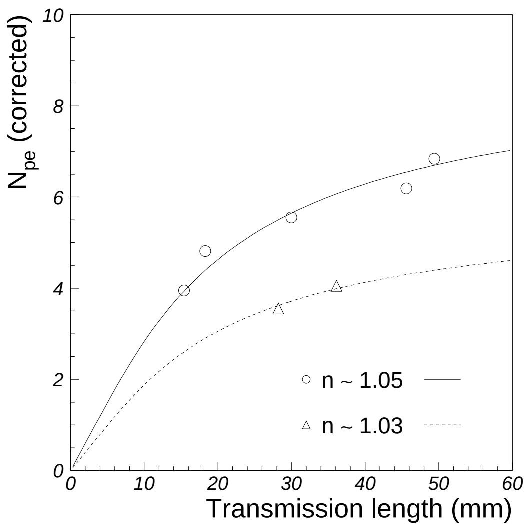


Number of photons

Shown as a function of momentum, thickness, transmission length

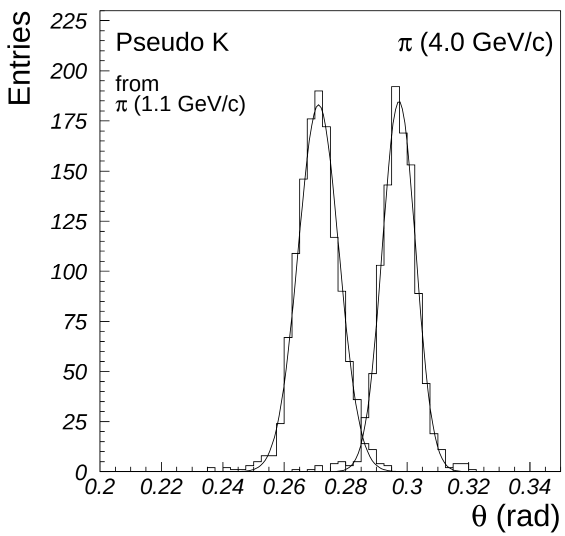






Again: in good agreement with expectations

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;

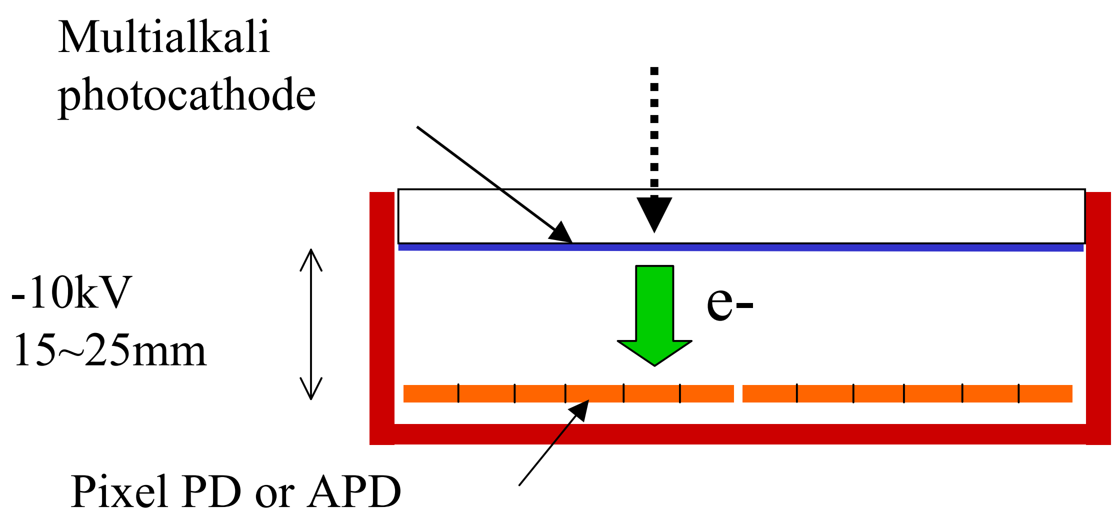
-> 4.3sigma π/K separation at 4GeV/c.

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: physics/0309032 preprint, accepted NIMA paper

Development and testing of photon detectors for 1.5 T

- Baseline: large area HPD of the proximity focusing type
- Backup: MCP-PMT (considered with TOP)

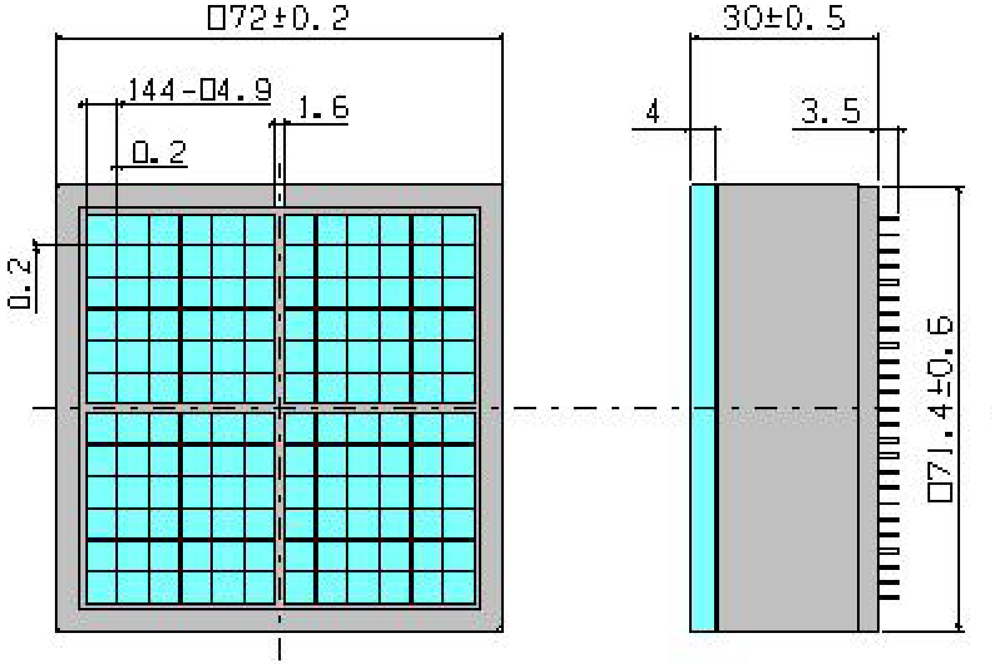


R&D project in collaboration with HPK

HPD development

59mm x 59mm active area (65%)

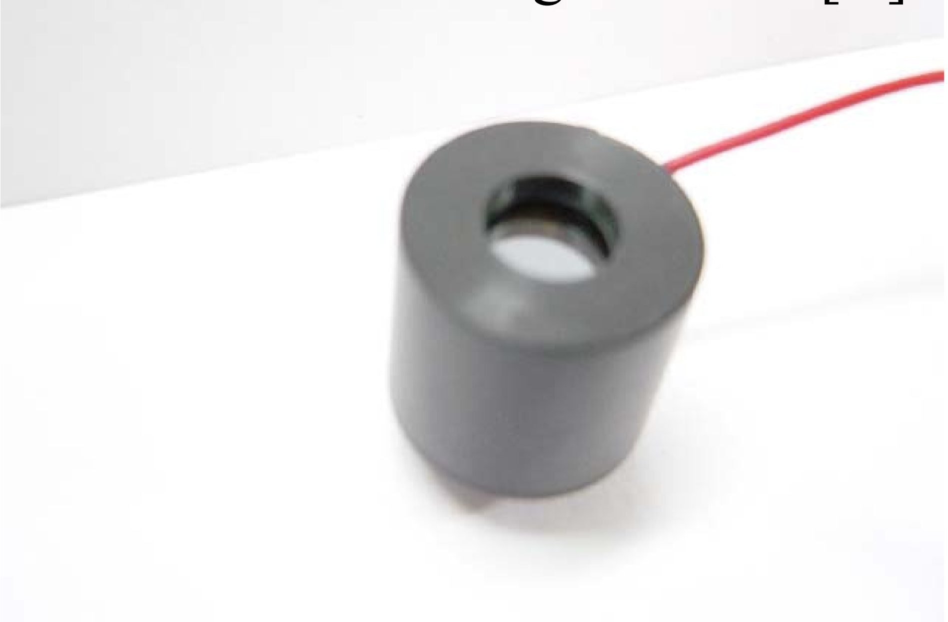
12x12 channels

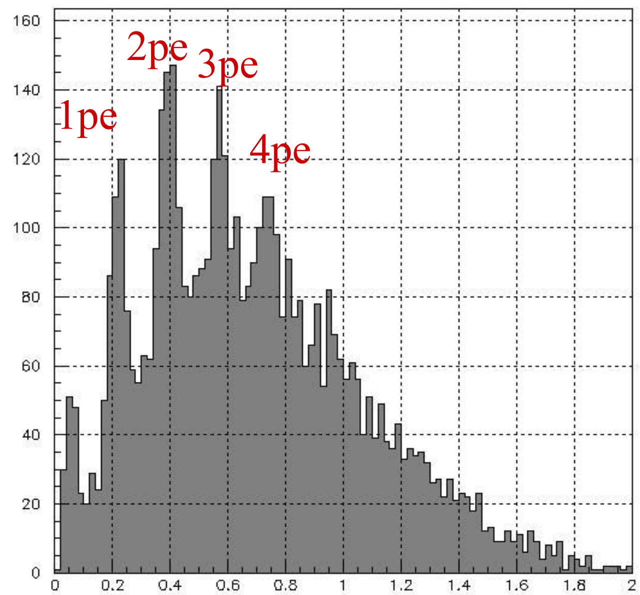


Ceramic HPD box

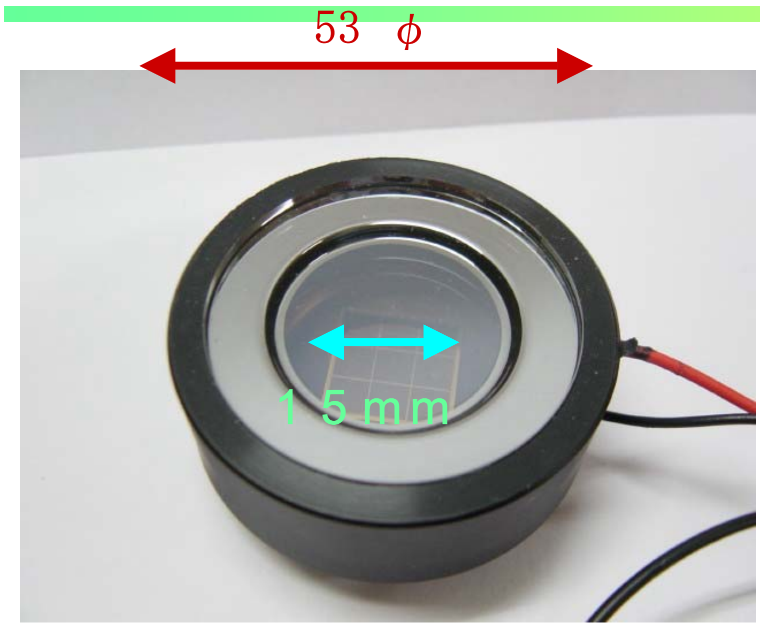
Prototype Test
- single-channel HPD -

Leak current : 4 [nA]
Detector capacitance : 20 [pF]
Gain (8kV) : 1500 [electron/photon]
Bias voltage : 80 [V]

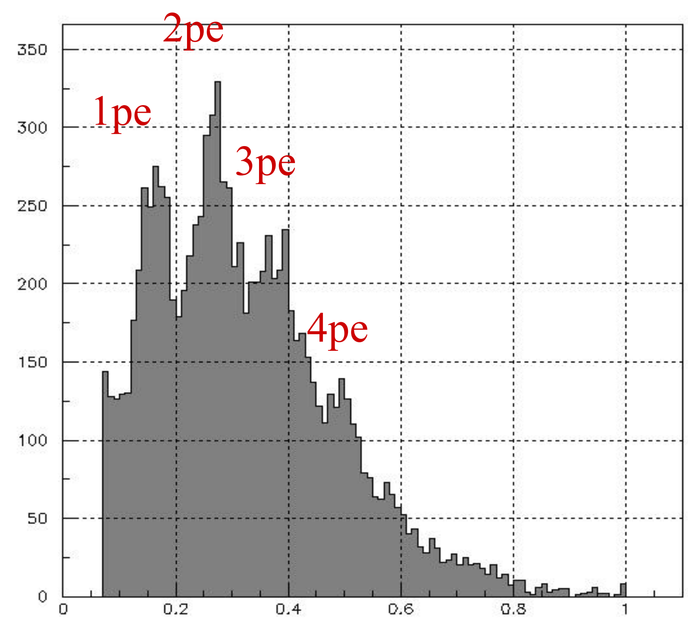




Prototype Test
- 3×3multi-channel HAPD -



- Diode : □5 [mm/ch]
- Gain : 26000 [electron/photon]
- C_d : 73 [pF]
- I_L : 14 [nA] (average/ch)
- Condition: V_{HV}=8[KV], V_{BIAS}=320[V]



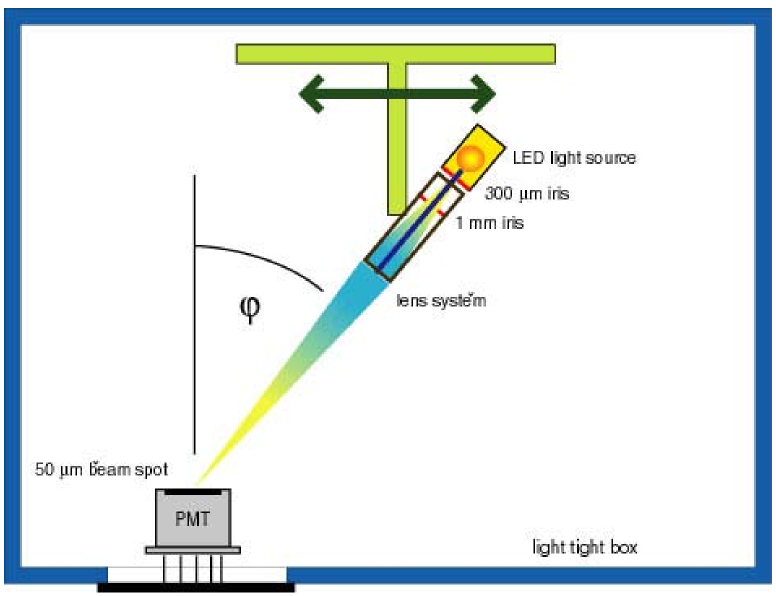
Gain of the HAPD is higher than for the HPD, but the noise level is also higher due to its large detector capacitance.

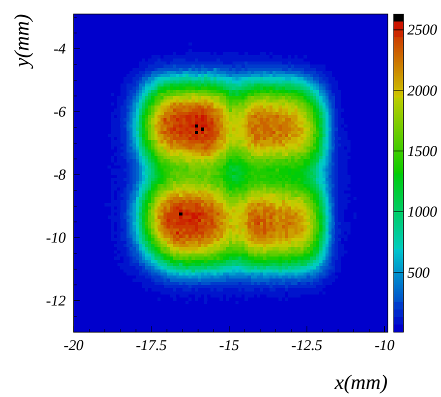
The HPD shows a better single photon response.

Photon detector R&D - plans

Evaluate the first 144 channel prototype in a beam test

Study uniformity of the sensitivity over the surface





Example: single channel response of the H8500 PMT

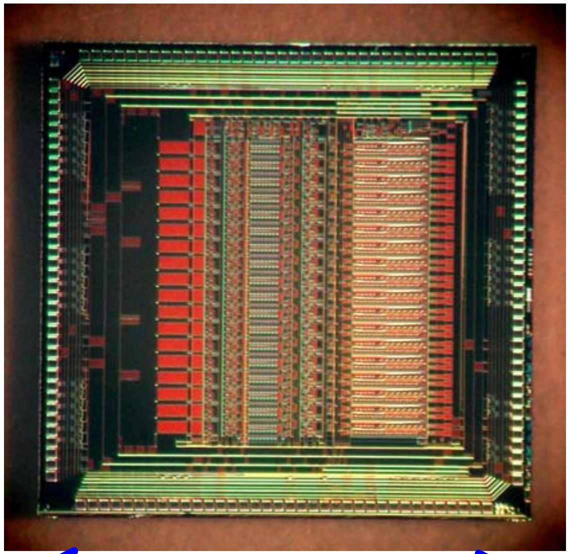
Read-out electronics: ASIC under development

Need high density front-end electronics.
Need high gain with very low noise amplifiers.
Deadtimeless readout scheme-> Pipeline.

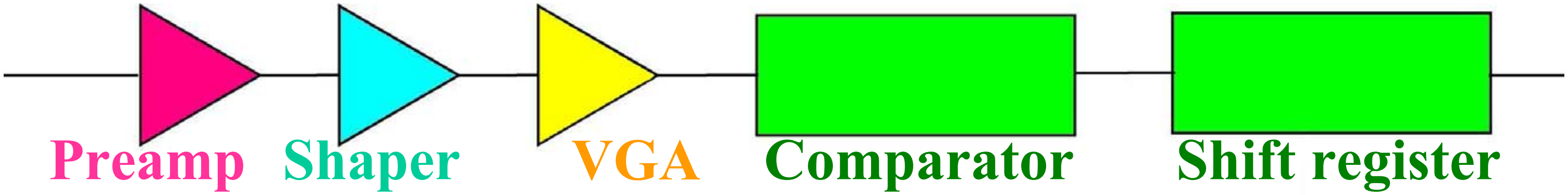
Develop an ASIC for the front-end electronics

- Gain : 5 [V/pC]
- Shaping time : 0.15 [μ s]
- S/N : 8 (@2000[e])
- Readout : pipeline with shift register
- Package : 18 channels/chip

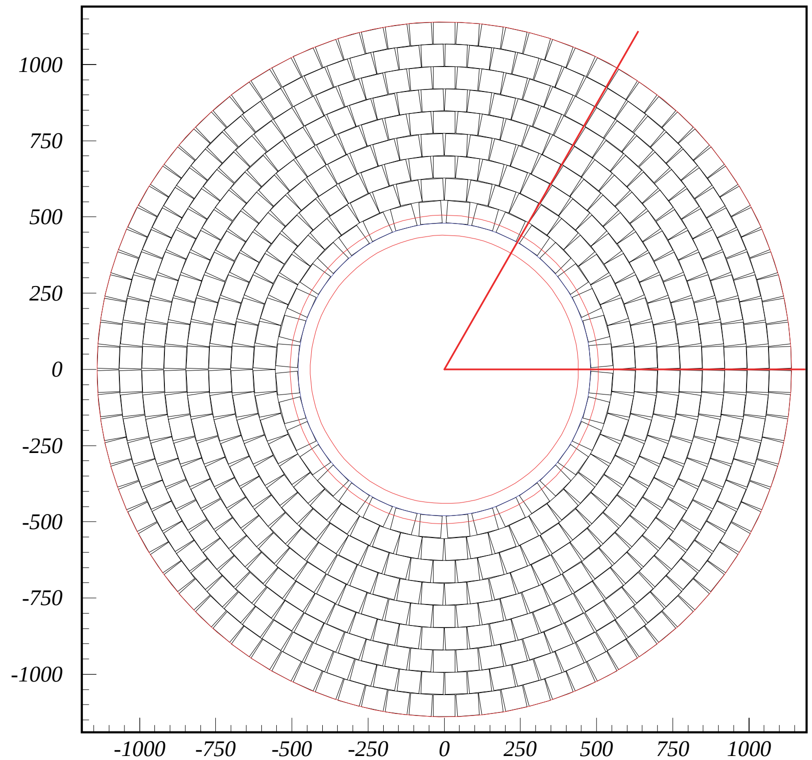
Detailed evaluation is under way.



□4.93[mm]



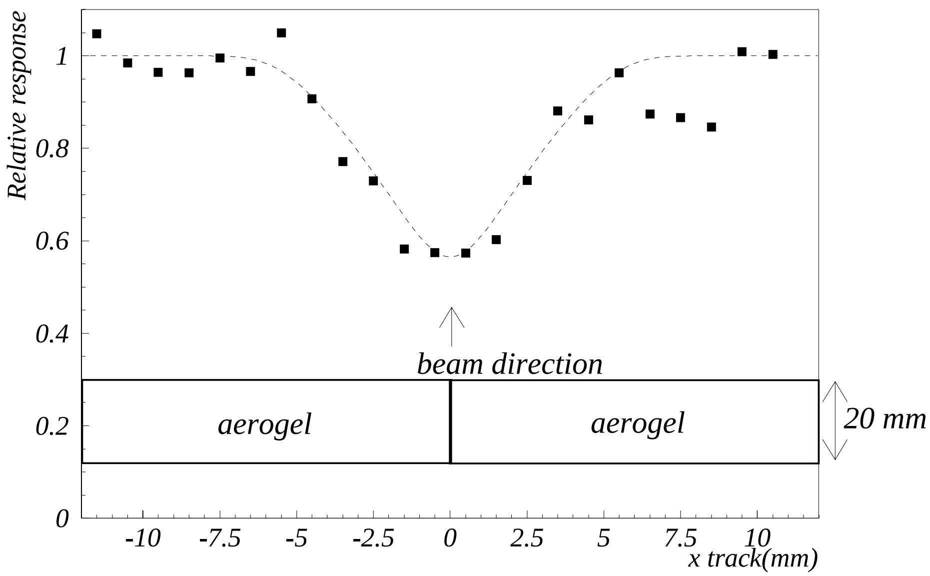
Photon detector tiling



- 92% of the surface covered by HPDs
- minimal distance between modules: 0.5~mm
- max. distance (few mm) allows for feeding in the HV supply cable (has to come to the front side of the HPD)
- six equal sectors

Optimisation of counter parameters 1

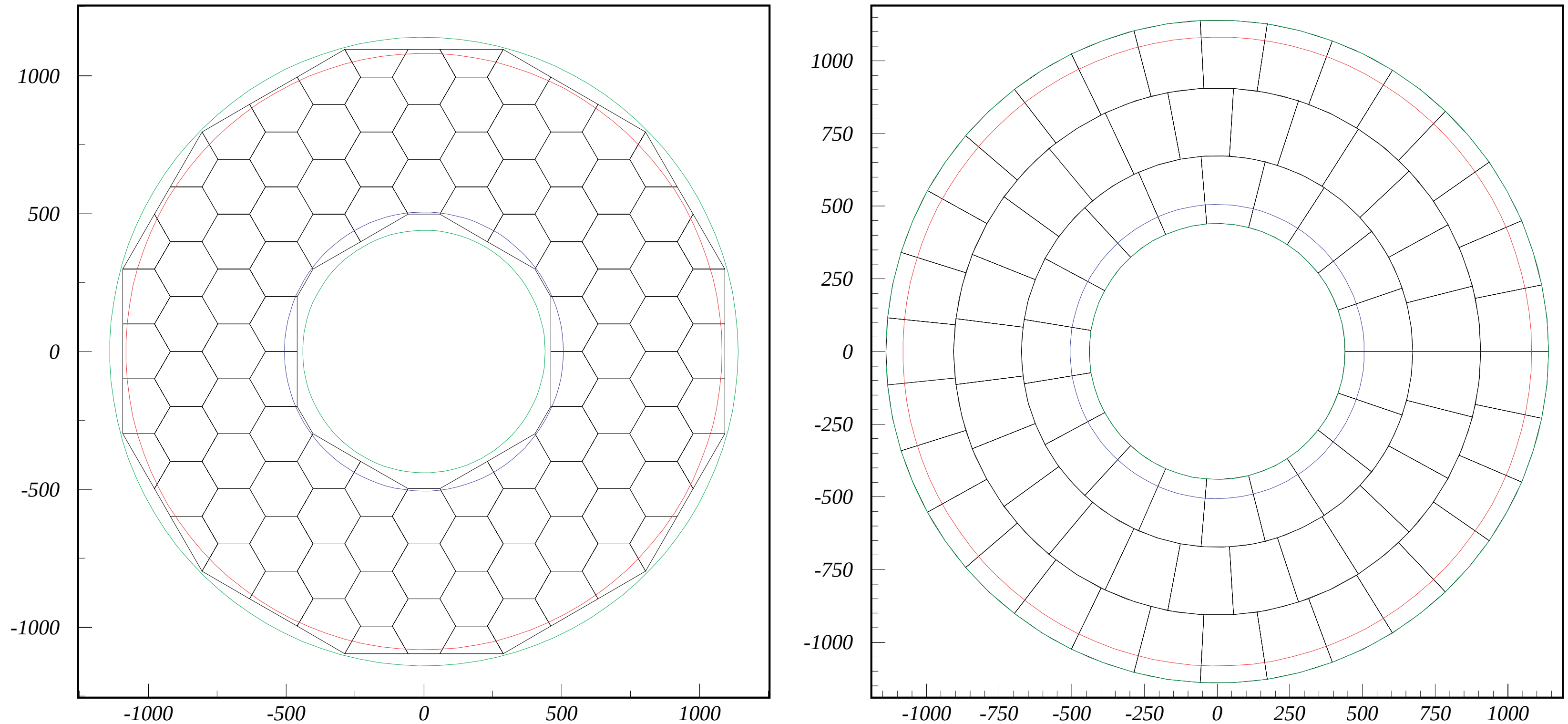
How to design radiator tiles: at the tile boundary photons get lost.



- 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

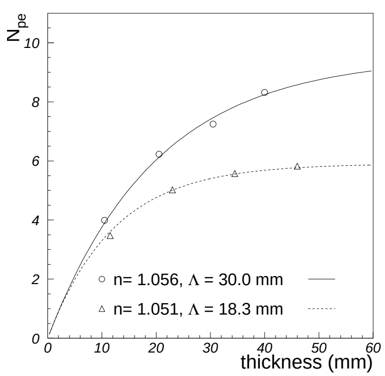


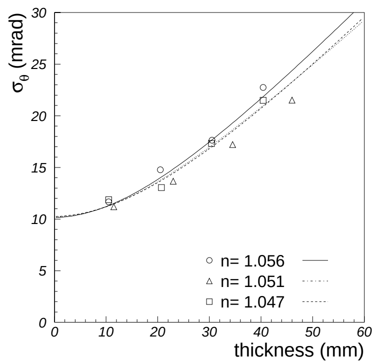
Two aerogel radiator tiling schemes for two max tile size cases

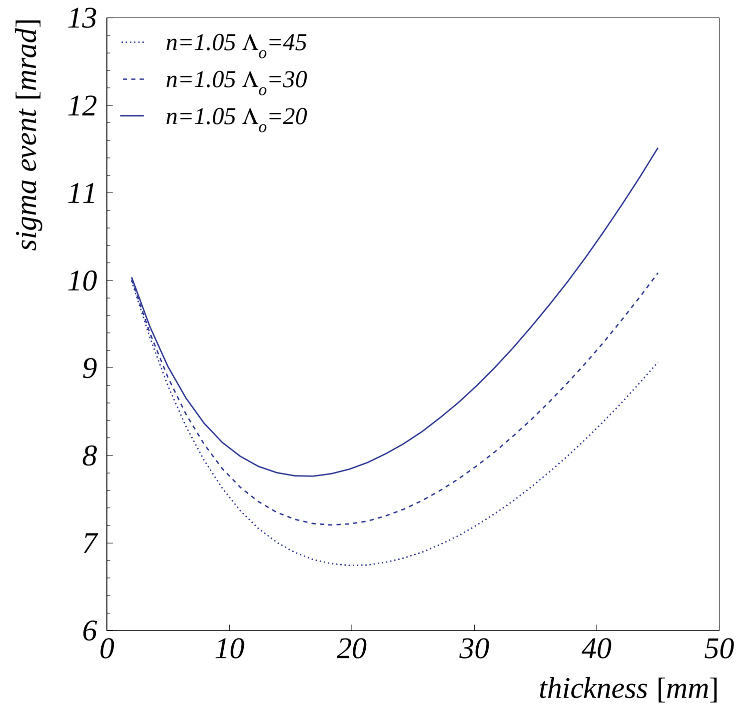
Optimisation of counter parameters 2

What is the optimal radiator thickness?

Use beam test data on σ_0 and N_{pe}







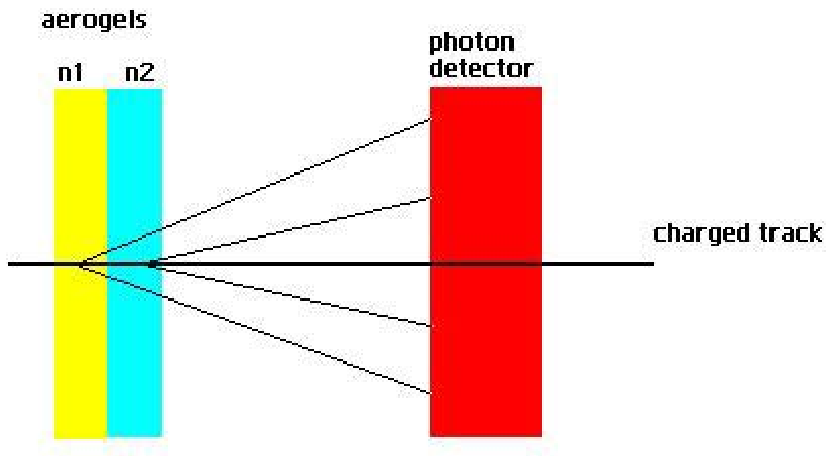
Minimize the error per track: $\sigma=\sigma_0/\mathrm{sqrt}(N_{pe})$

Optimum is close to 2 cm

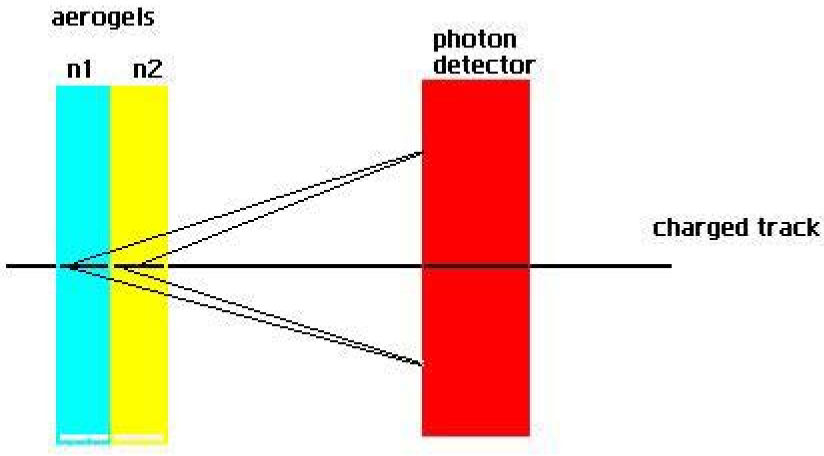
How to increase the number of photons without degrading the resolution?

More photons: need thicker radiator -> poorer resolution
Way around: use two radiators.

n1>n2: two rings



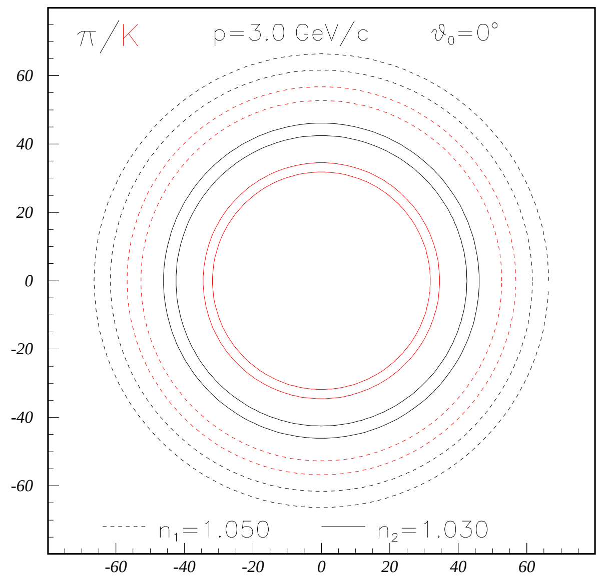
n1<n2: rings can be made to overlap

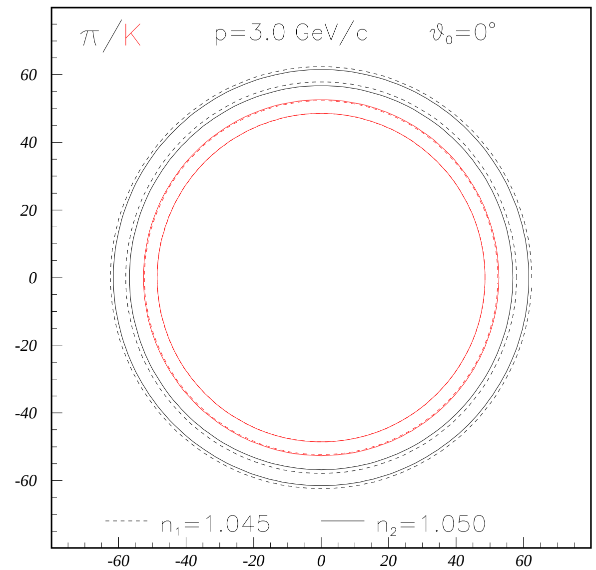


Dual radiator

Pion and kaon rings for the two dual radiator shemes

n1>n2 n1<n2





$p=3\mathrm{GeV}/c,\ \theta_i=0^o$

Conclusions

- Proof of principle: first beam test (Nov. 2001)
- Second beam test: improved aerogel, new high active area PMT and a new read-out system. Better understanding of the detector, enhanced number of photons. Varied many parameters for counter optimisation.
- PID algorithms tested on real and MC data, ready
- R&D issues: development and testing of a multichannel photon detector for high mag. fields
- mass production of large aerogel tiles
- readout electronics

Back-up slides

Read-out electronics

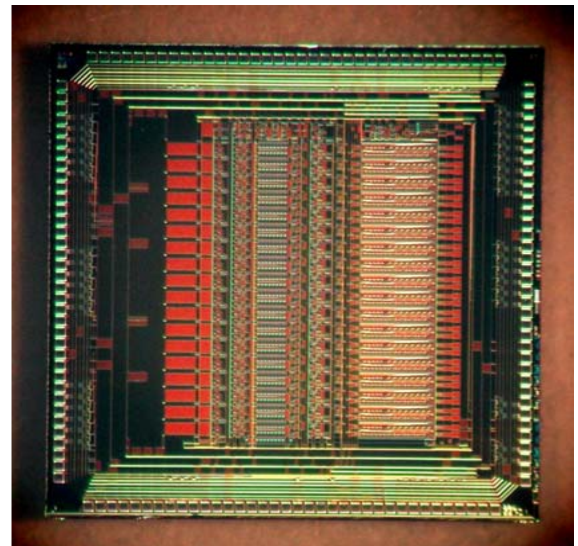
- Total number of readout channels for the full detector amounts to 86k.
- Detector characteristics
  - Leakage current 10 or 25 ［nA］
  - Detector capacitance ; 10 or 70 ［p F /pixel］
  - signal ; 2000 or 20000 [electron/photon]

- Need high density front-end electronics.
- Need high gain with very low noise amplifiers.
- Deadtimeless readout scheme-> Pipeline.

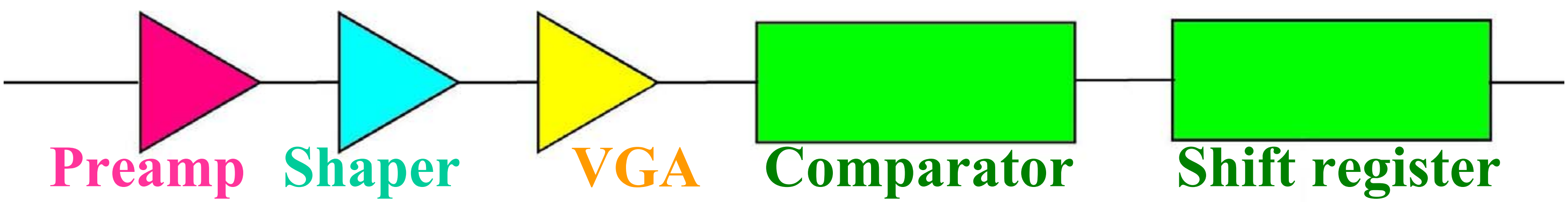
Develop an ASIC for the front-end electronics

Read-out electronics: ASIC under development

- Basic parameters for the ASIC (Rohm CMOS 0.35 μ m)
  - Gain : 5 [V/pC]
  - Shaping time : 0.15 [μ s]
  - VGA : 1-16
  - S/N : 8 (@2000[e])
  - Readout : pipeline with shift register
  - Package : 18 channels/chip
  - Control : LVDS
  - Power consumption : 5 m W/channel
- Detailed evaluation is under way.



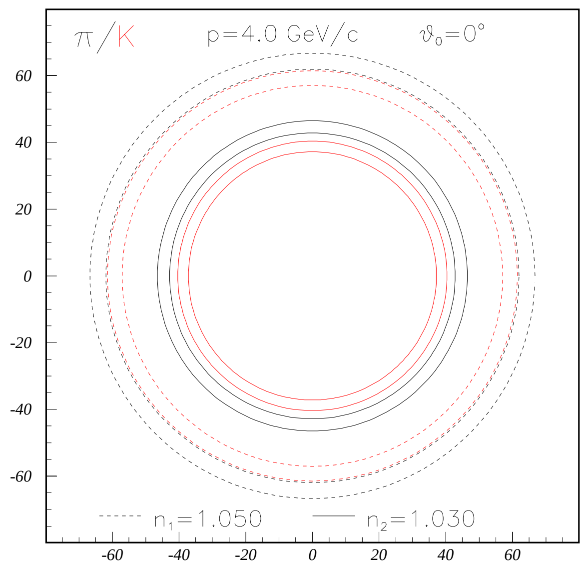
□4.93[mm]



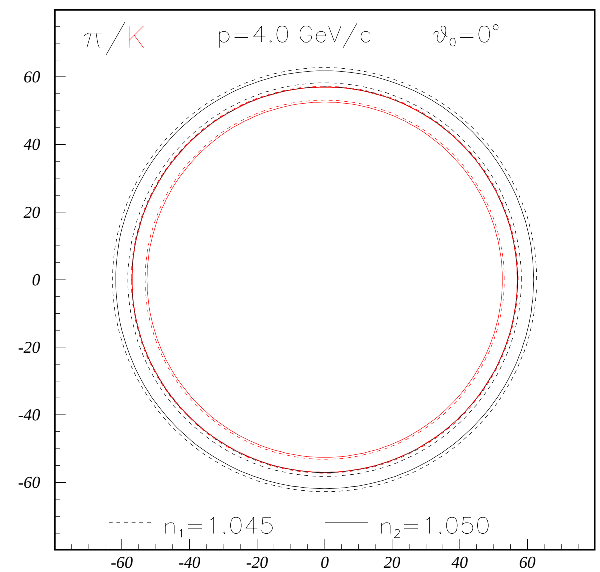
Dual radiator

Pion and kaon rings for the two dual radiator shemes

n1>n2



n1<n2

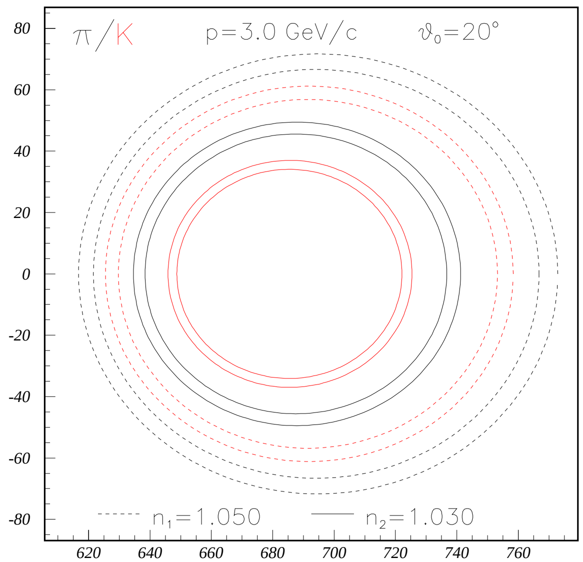


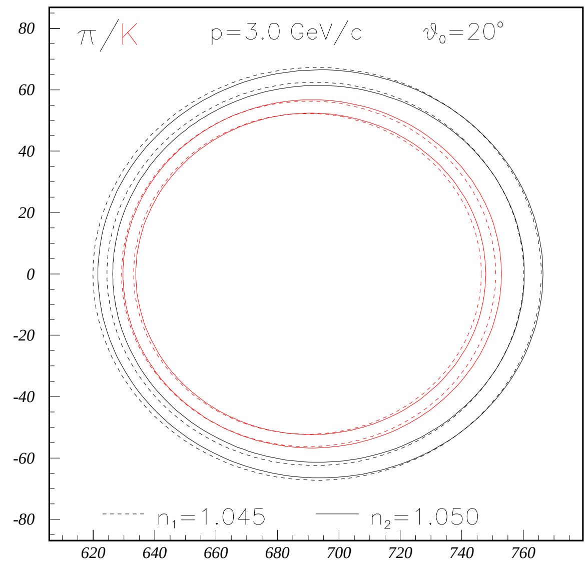
$p=4GeV/c, \theta_i=0^o$

Dual radiator

Pion and kaon rings for the two dual radiator shemes

n1>n2 n1<n2





$p=3GeV/c, \theta_i=20^o$