Aerogel RICH - Status

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Aug. 6, 2002
3rd Workshop on Higher Luminosity B Factory, Shonan Village

- Introduction, motivation
- Beam test results
- Photon detector R+D
- Radiator R+D

Introduction

Physics motivation for the PID upgrade

- 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 reconstruction tag')
- low momentum (< 1 GeV/c) $e/\mu/\pi$ separation (e.g. in $B \to Kll$)

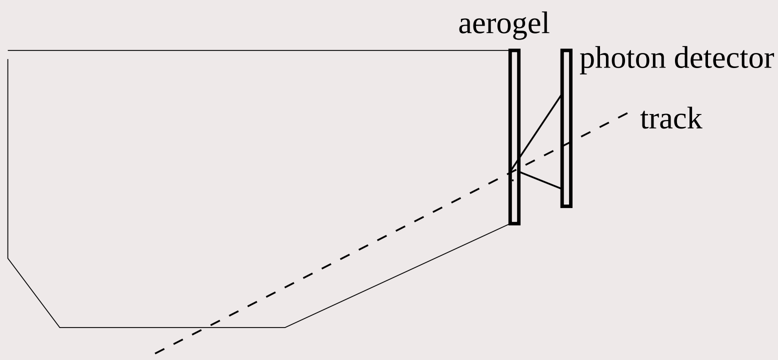
$\to$ For more details see T. Iijima's talk at the 2nd Workshop

Forward direction: a proximity focusing RICH with aerogel as radiator is being studied

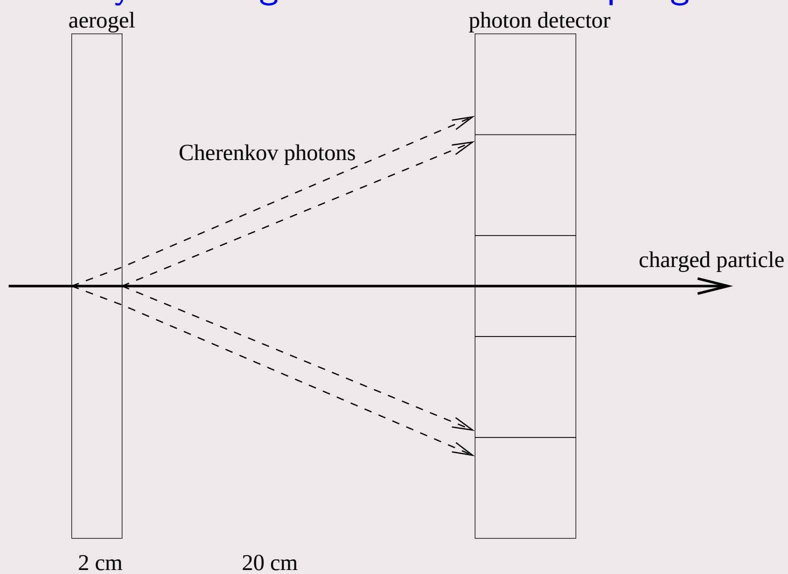
Belle Aerogel-RICH R+D group: Chiba-KEK-Nagoya-TMU-Ljubljana

Proximity focusing RICH in the forward region

Forward region: two-body decay products have momenta of up to 4 GeV/c



Proximity focusing RICH in the end-cap region



Proximity focusing RICH - principle

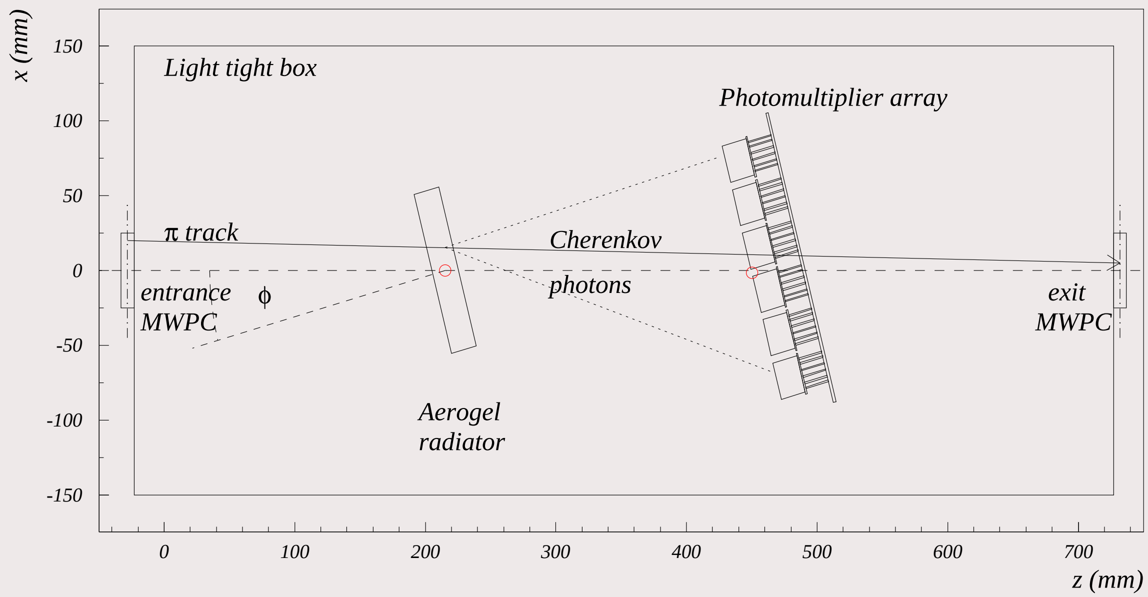
Aerogel as radiator:

n=1.03: $\theta_c(\pi) = 240$ mrad,
$\theta_c(\pi) - \theta_c(K) = 31$ mrad at 4 GeV/c
number of photons in 2 cm of aerogel: 10
($N_0 = 90$/cm, no absorption)

n=1.05: $\theta_c(\pi) = 310$ mrad,
$\theta_c(\pi) - \theta_c(K) = 23$ mrad at 4 GeV/c
number of photons in 2 cm of aerogel: 17
($N_0 = 90$/cm, no absorption)

Beam test results - update

Beam test data collected in November/December running were further analyzed, and a very good agreement was found between expected and measured counter parameters

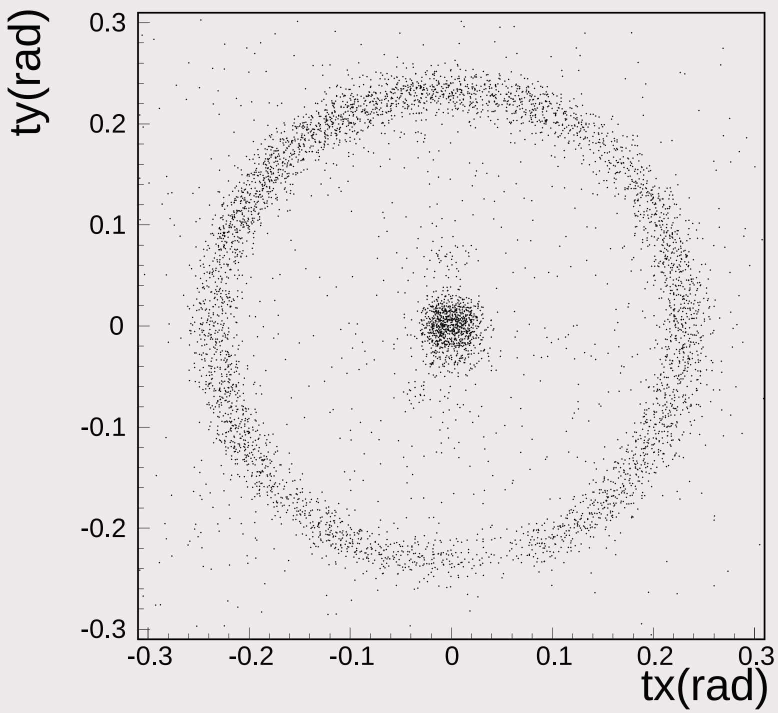


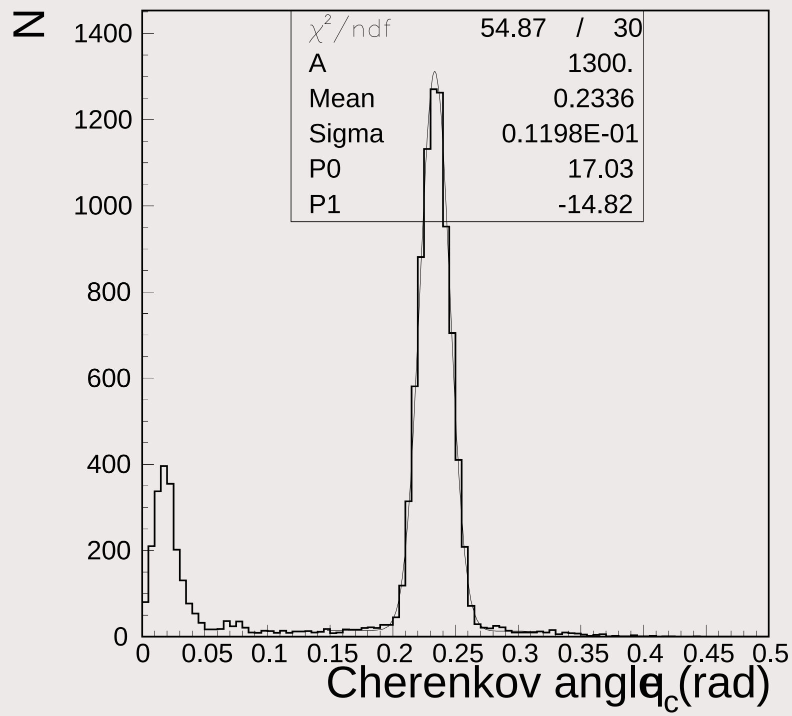
A wide variety of parameters was investigated

- refractive index, thickness and type of aerogel
- beam momentum and angle of incidence
- behavior at the boundary of the aerogel tiles
- use of light collectors

Beam test results - update

accumulated hits on the photon detector

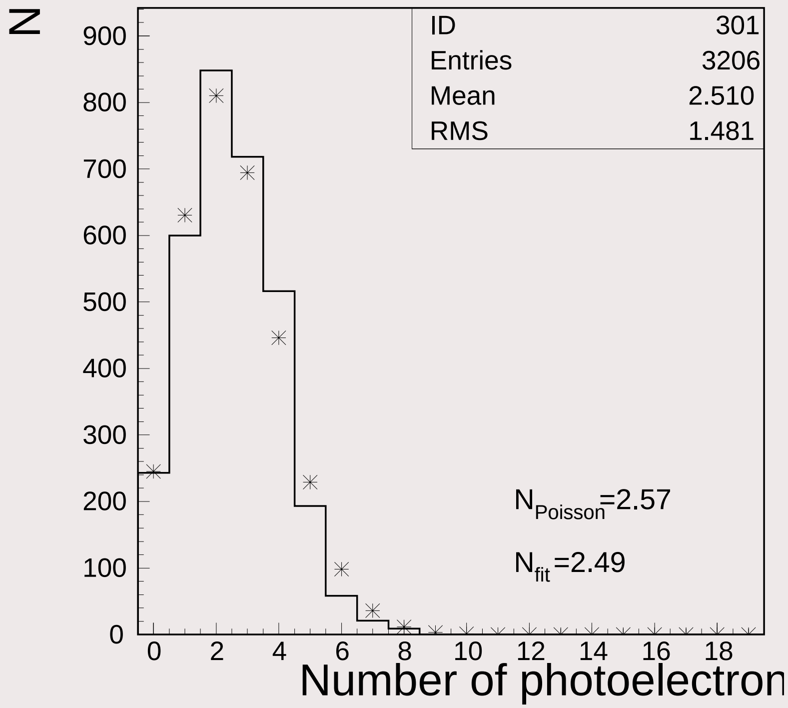


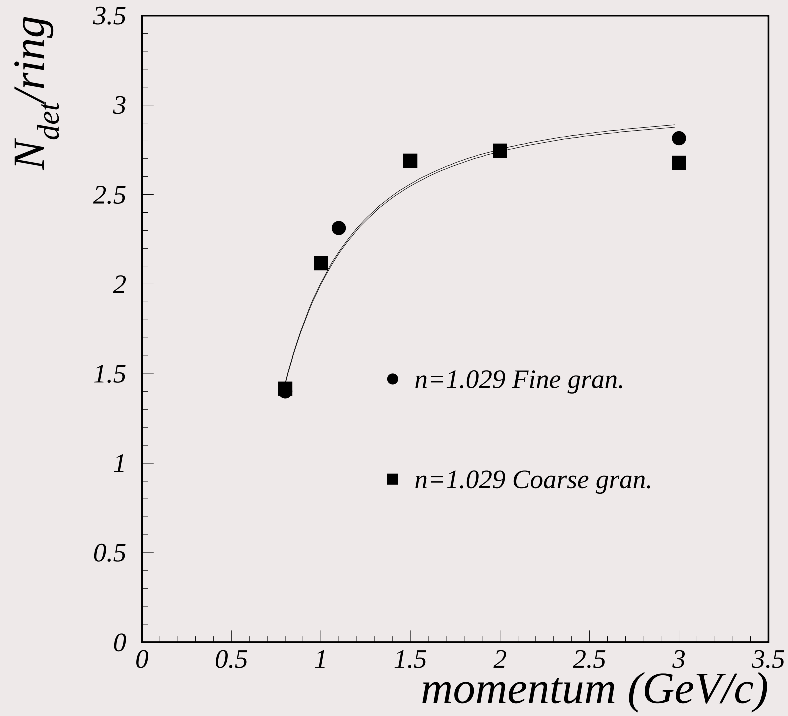


very clean Čerenkov angle distribution

Beam test results - number of photons

number of hits per ring:



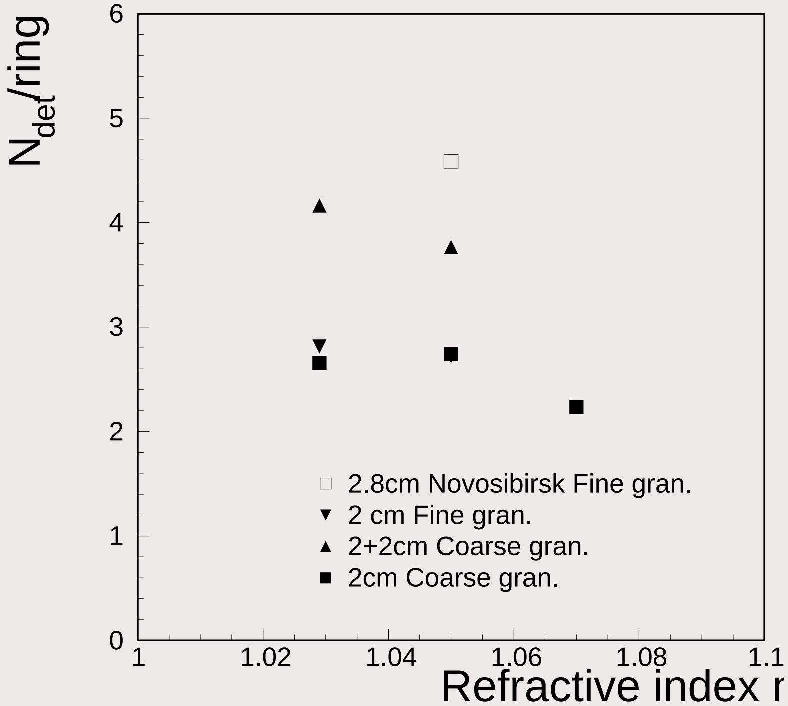


distribution derived from the fraction of events with 0 hits (*) agrees with the observed distribution of the number of hits per ring

number of hits per ring vs momentum

Beam test results - number of photons

number of hits per ring for different aerogels (refractive index, production method)

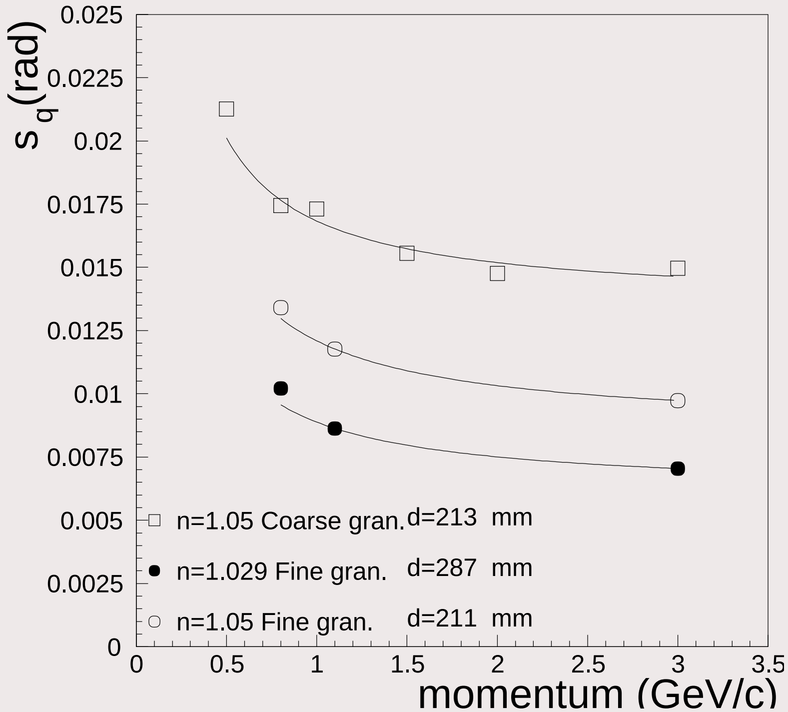


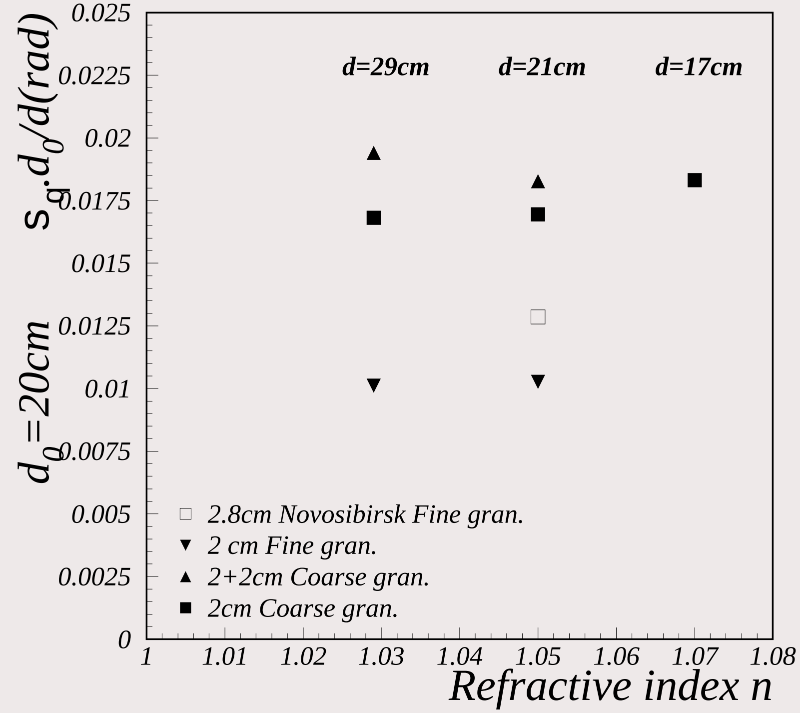
→

- higher ref. index does not produce more photons because of absorption
- doubling the thickness does not double the photons
- Novosibirsk aerogel has a considerably higher yield

Beam test results - resolution

resolution vs ref index



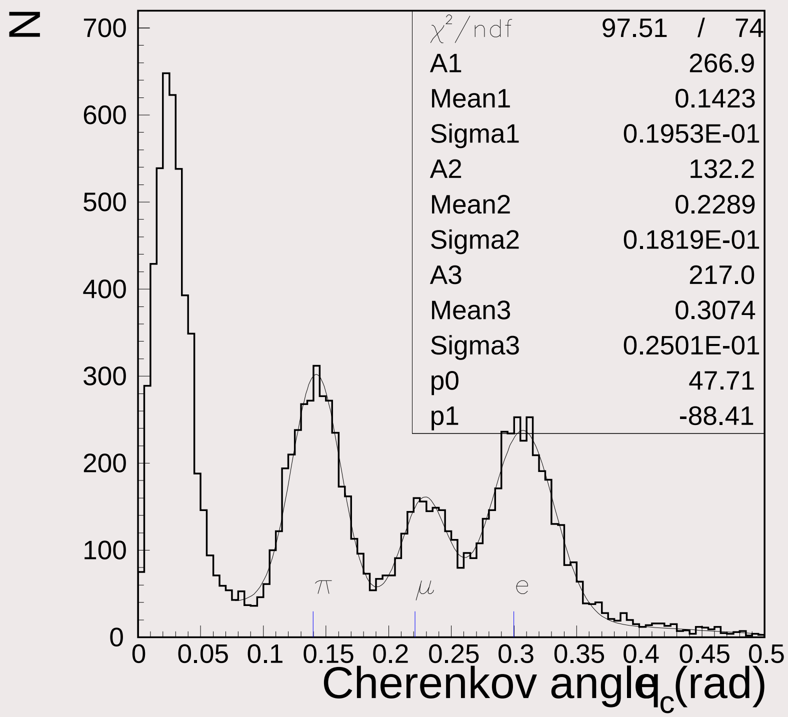


resolution vs momentum: at lower momenta, multiple scattering starts to become important

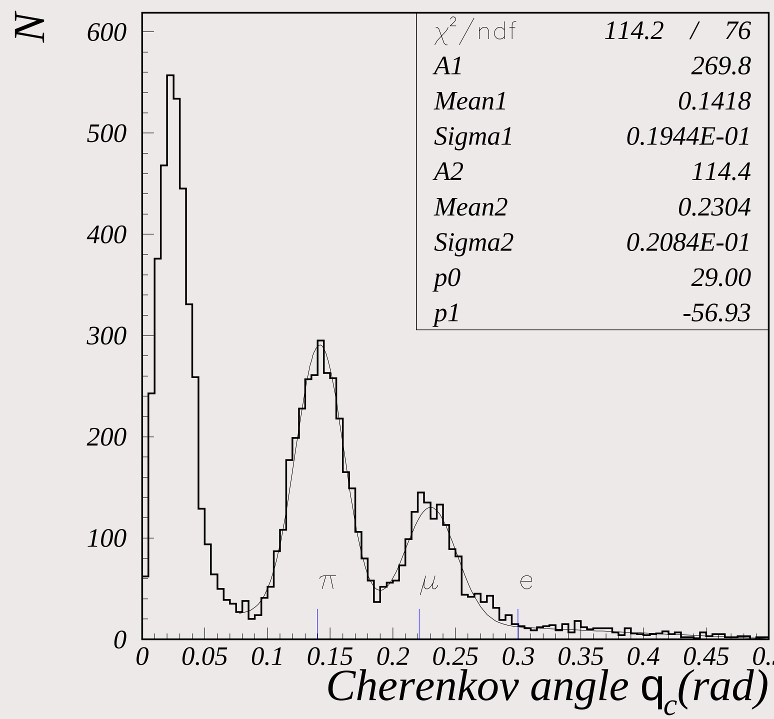
to compare the resolutions with various set-ups (distance was varied to accommodate the full ring on the photon detector) we normalize to a given distance (200nm) between the radiator and the photon detector

Beam test results - $e/\mu/\pi$ separation

Another benefit from such a counter: $e/\mu/\pi$ separation at low momenta, of importance for the $B \to Kll$ decays



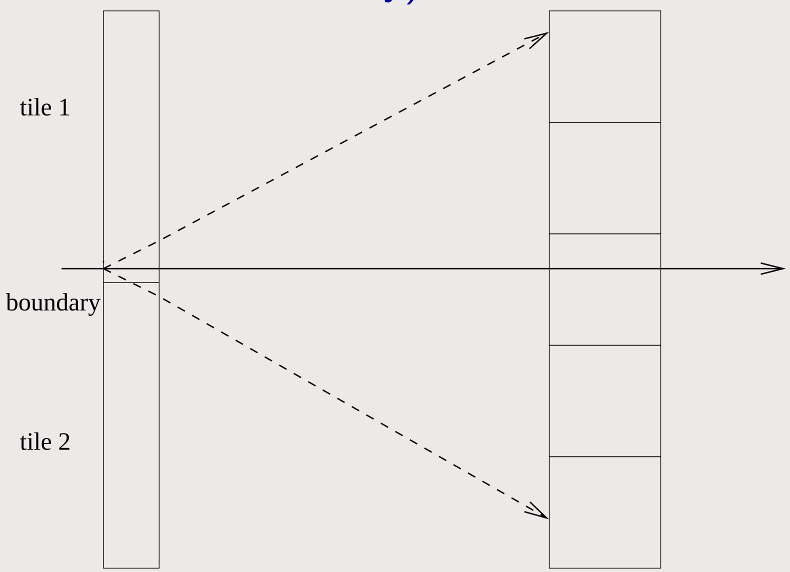
Čerenkov angle distribution for single photons, at $p = 0.8$ GeV/c

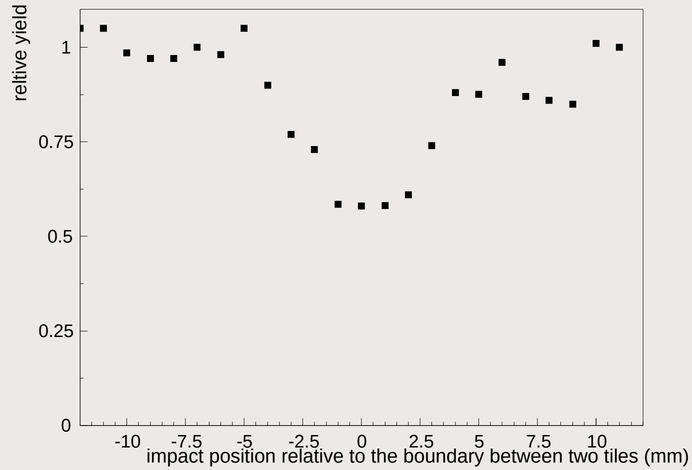


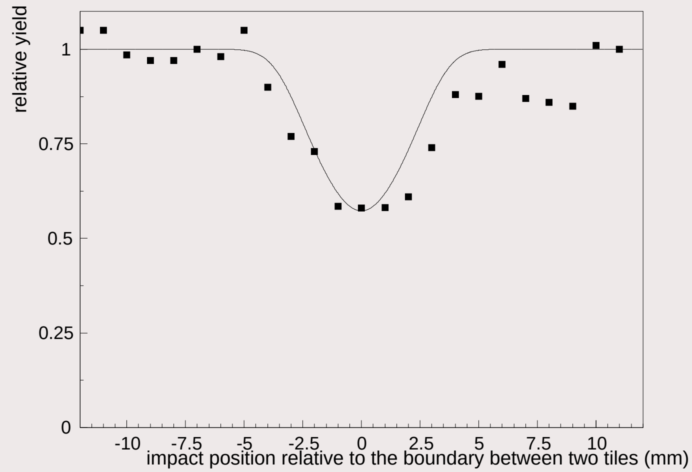
same, but with electrons vetoed with a CO_2 threshold Čerenkov counter

Beam test results - effects of the tile boundary

Scan with the beam over the vicinity of the boundary between two tiles, determine yield as a function of the impact point position (x=0 on the 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.

Beam test results - summary

- the first beam test of a proximity focusing RICH with aerogel as radiator showed that the method is feasible
- the counter performed according to expectations
- the contributions to the resolution are well understood (no contribution from aerogel material)
- the number of photons has to be increased for the detector to become a reliable PID tool
- the test was performed with Hamamatsu R5900-M16 PMTs, a well understood single photon detector (HERA-B RICH) which will not work in a high magnetic field environment

ref. index	Ndet measured	Ndet expected	σ_θ measured	σ_θ expected
1.029	2.6	2.7	7.0	6.7
1.050	2.7	2.9	9.8	9.7

Photon detector R+D

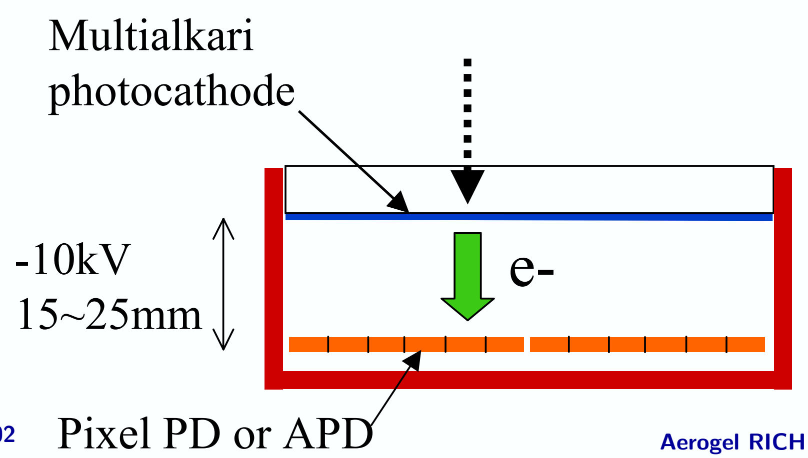
- Develop detector of single photons which works efficiently in a high magnetic field (1.5 T)
- Increase the number of photons by developing photon detectors with a higher active area fraction (multianode PMTs: 36%) or by using light collection systems

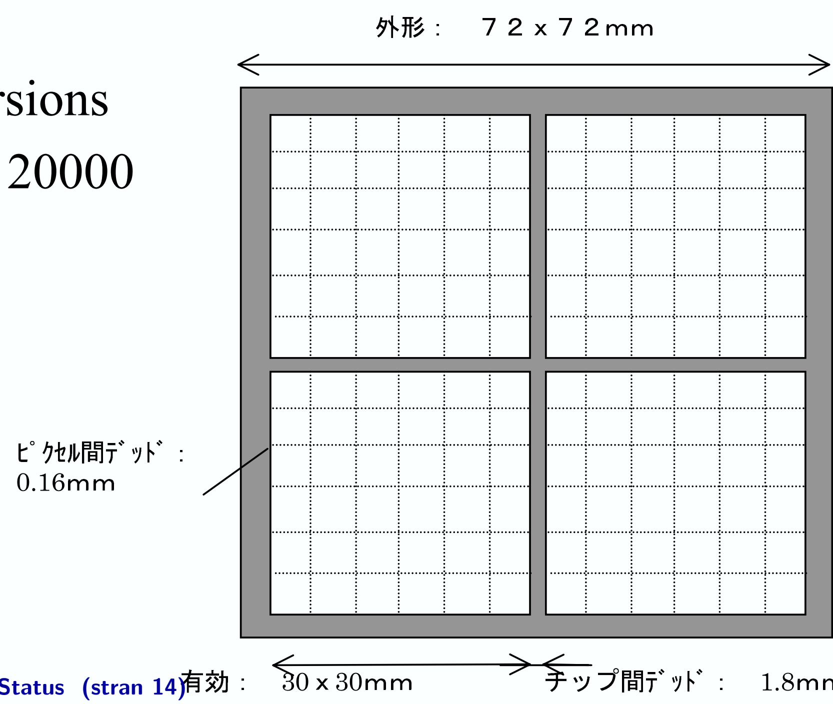
Photon detector development → slides

New Photodetector Development

- We have started 2-year R&D projects with HPK to develop a hybrid photodetector with large effective area.
  - Ideal device for aerogel-RICH
  - Effective area **~70%.**
  - Operate in strong magnetic field (proximity focusing)
  - Good sensitivity for single p.e.
  - Plan to test both HPD/HAPD versions

    Gain w/HPD: 2000, w/HAPD: > 20000

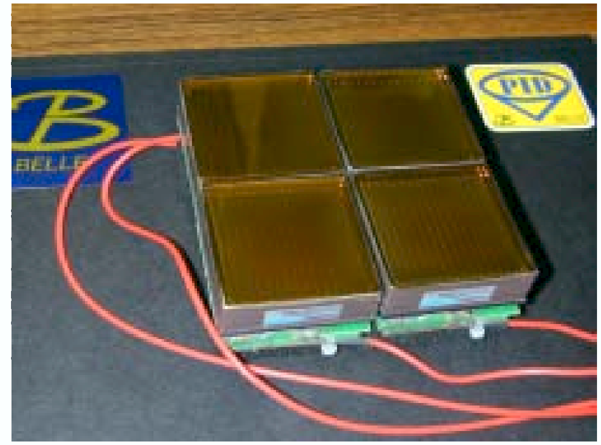


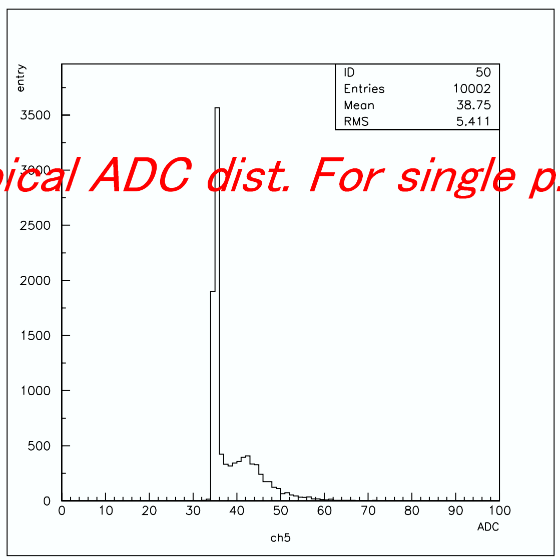


Toru Iijima / Nagoya

Flat Panel PMT

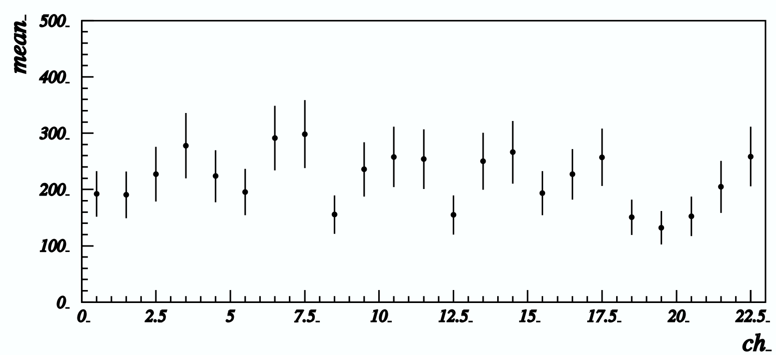
- Flat Panel PMT array will be used for the coming beam test (Nov.)
  - Newly developed 8 × 8 multi-anode PMT
  - Effective area = □49mm for □51.7mm package (90% coverage).
- Now under test by T.Tabata (Chiba-U.)





Typical ADC dist. For single p.e.

ch-by-ch gain variation



Toru Iijima / Nagoya

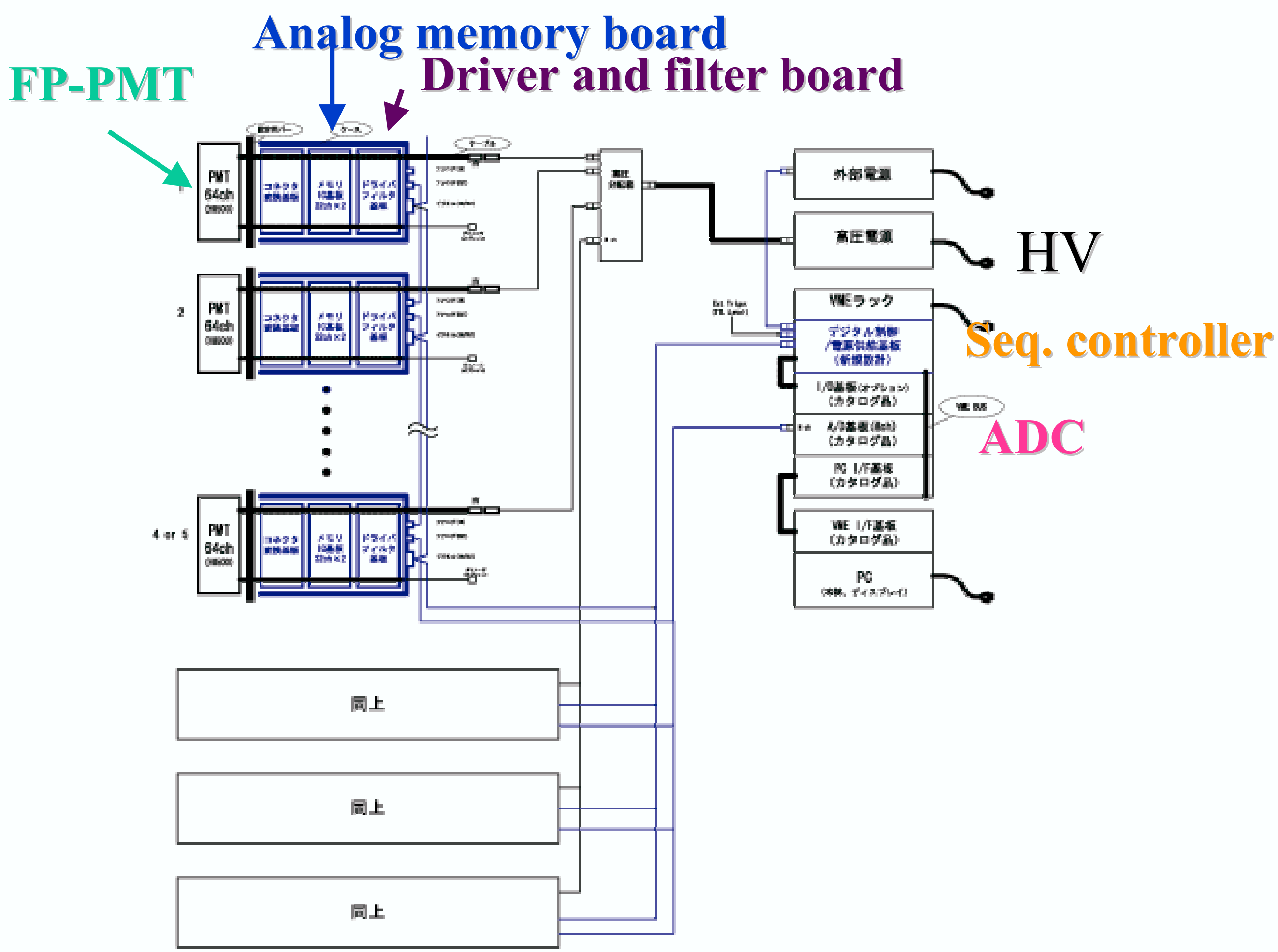
Readout electronics for the flat-panel PMT

- For the next beam test (Nov.), we are preparing a new readout system for the flat-panel PMT's (4x4 arrays: 1024 channels) by utilizing the IC's with analog memories developed by Prof. Ikeda.
  - Each chip can handle 32 readout channels.
  - Each channel has 8 memories for 8 time slices (1μsec x 8).
  - Output signal from each channel is ΔV=V(last)-V(first).
  - Signals are sent to an ADC (12 bits) in serial by a clock (~5μsec).
  - One ADC channel will handle 64x4=256 channels -> 1280 μsec.
    - No sparsification, hence, read all the channels.
  - The ADC has 8 channels, but we will use only 4.

  - This system is under final test at the company (Meisei) and will be ready at the end of this month.

Sumiyoshi, TMU

Schematic of the system



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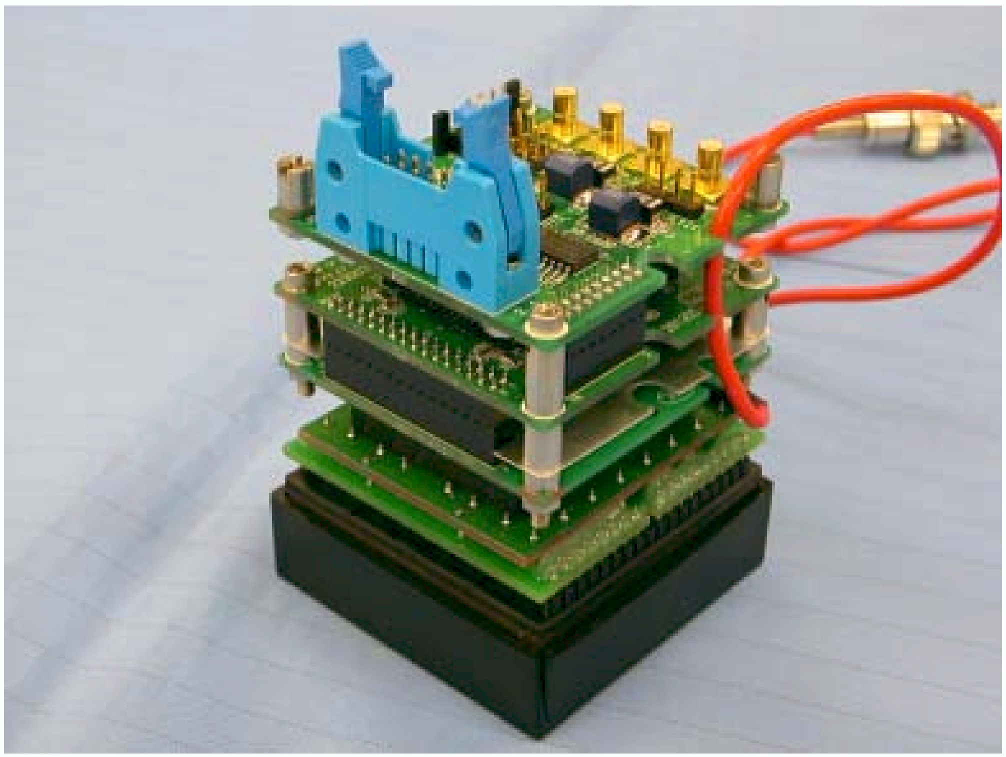
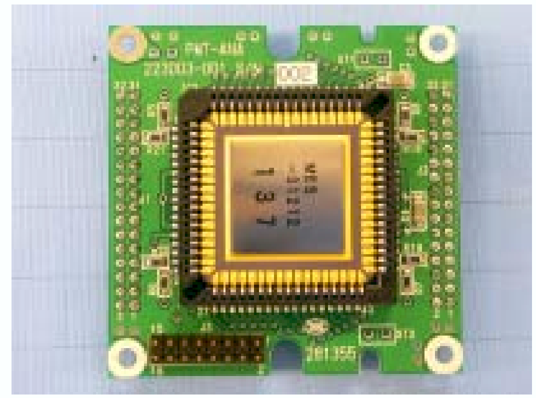
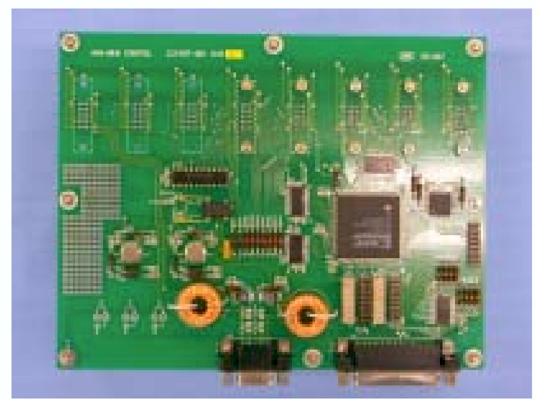
Photos of the system



Assembled on a flat-panel PMT



Analog Memory Board



AM Control Board

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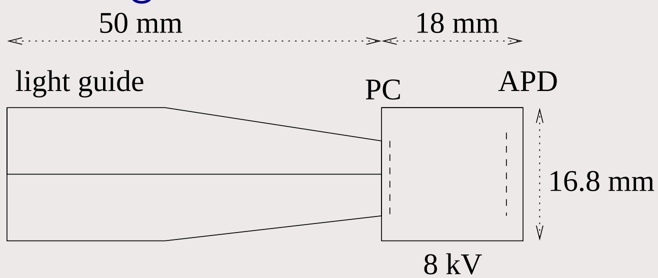
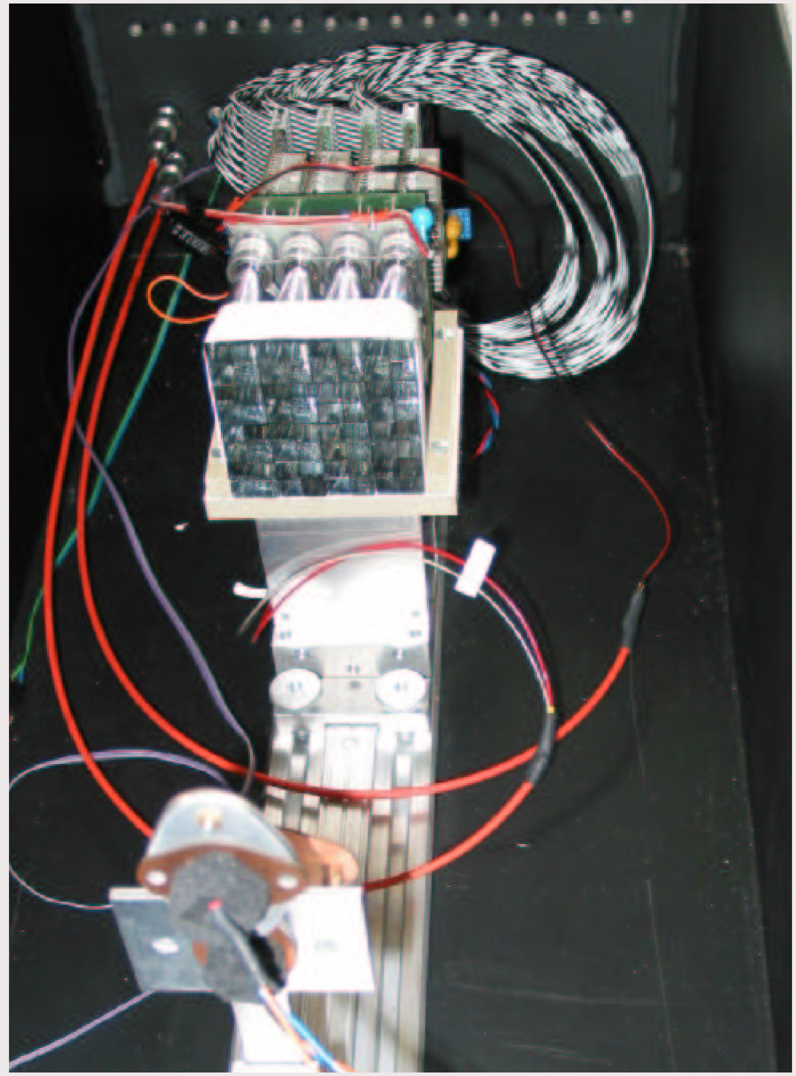
Another candidate: H(A)PD with a light collection element

HPK produced a prototype of 16 hybrid avalanche photodiodes, each with 4 channels, with light collection elements.

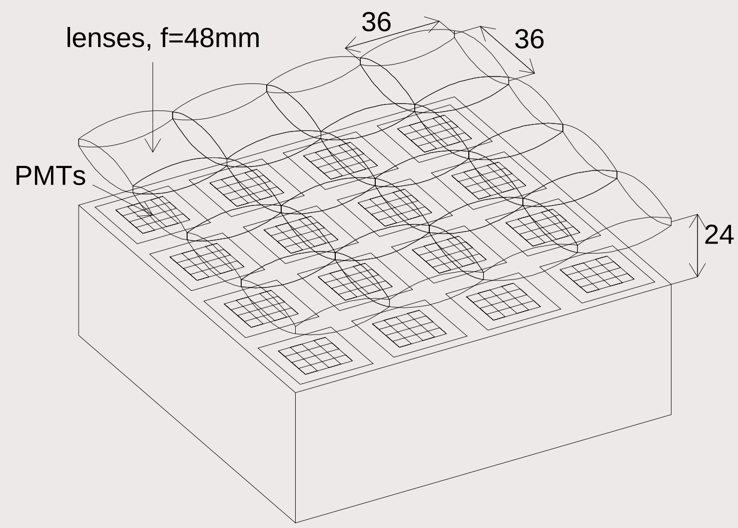


The system is under test in Ljubljana

- HV and signal routing board
- preamplifier hybrids
- VME based read-out and DAQ
- triggered LED

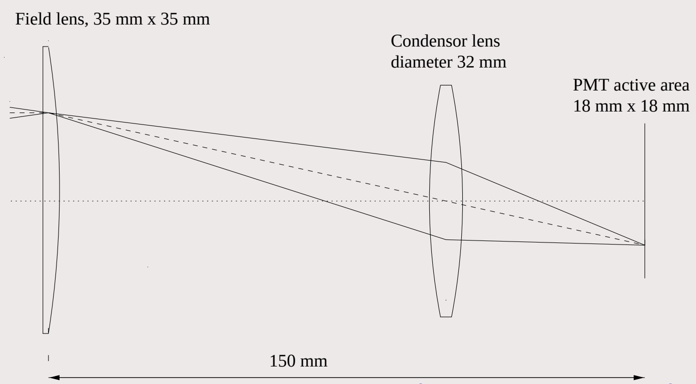


Photon detector R+D - part 2

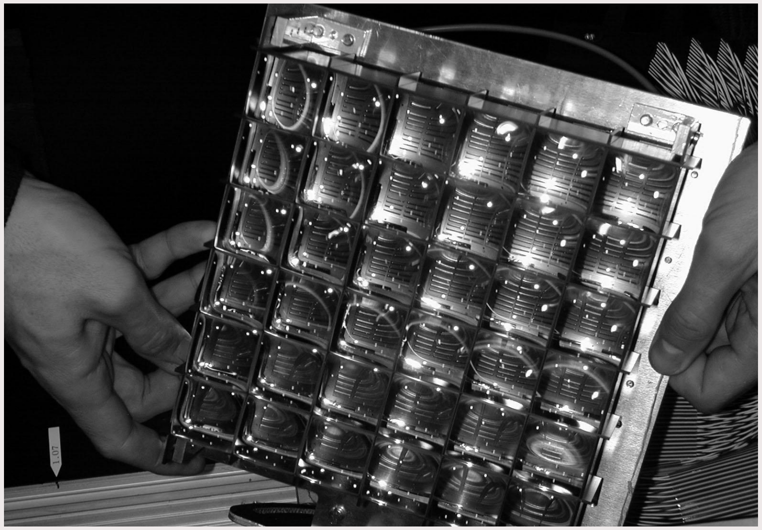


Increase the number of photons by using a light collection systems

- single lens system
- two lens device
- light guides

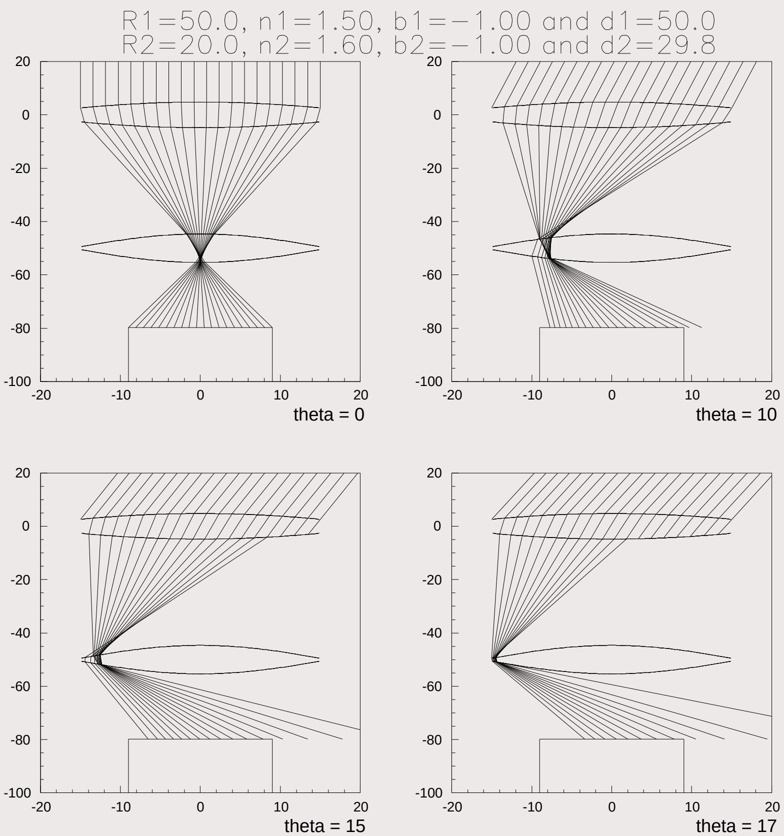


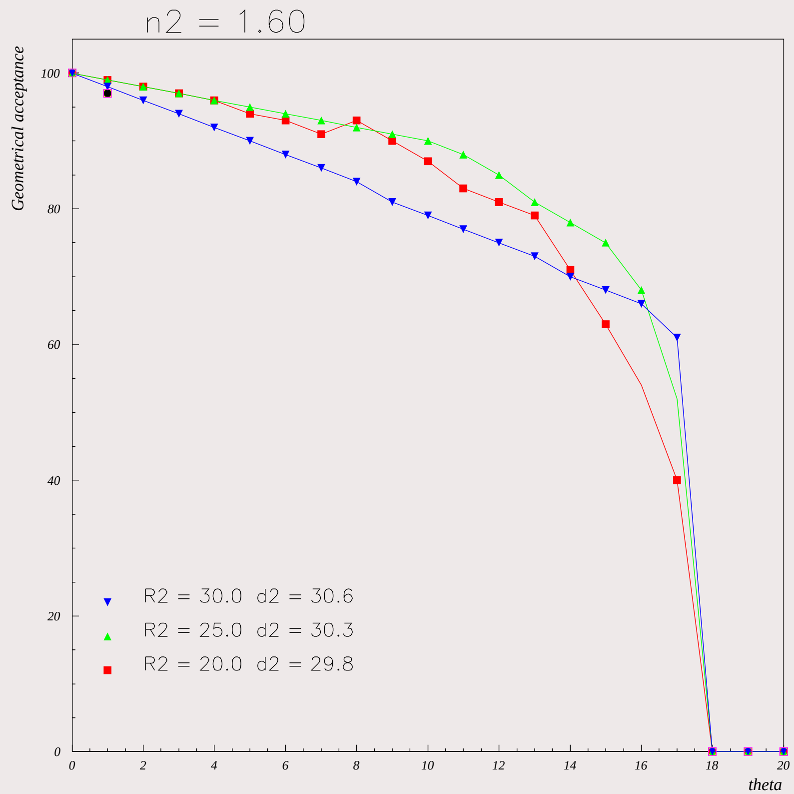
system of plastic lenses (HERA-B RICH)



Two lenses as light collection system

ray tracing vs angle of incidence





acceptance vs angle

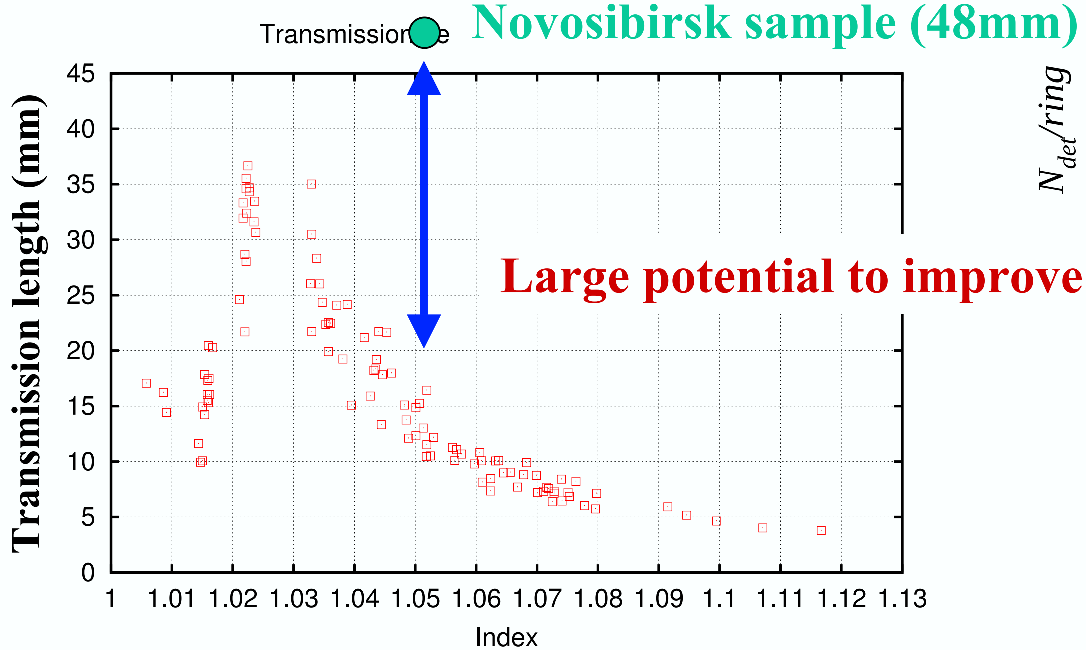
optimize the parameters of the two lenses

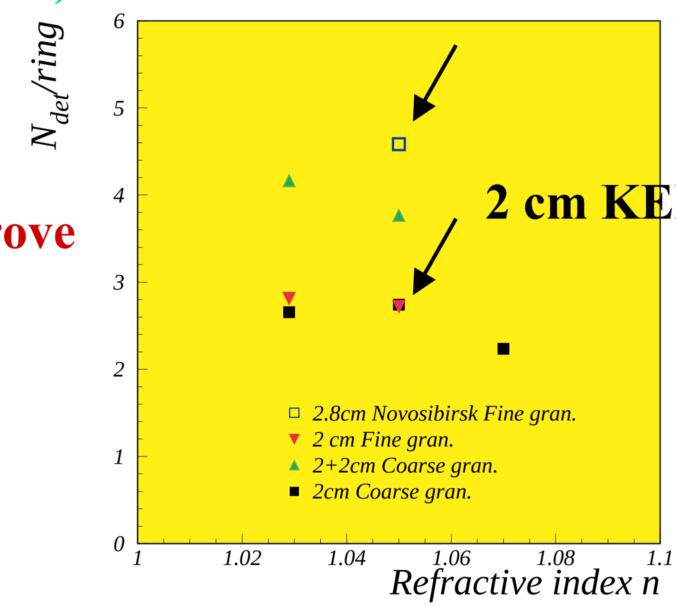
Radiator R+D

Possible improvement of the optical quality of our silica aerogels

We noticed that the optical quality of our silica aerogel of n=1.05 is much inferior to the Nobosivirsk's one.

Due to this problem, the observed light yield of our aerogel was about a half compared with theirs according to the last beam test results.





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Possible improvement of the optical quality of our silica aerogels

- **Matsushita EW Co. Ltd made some tests with different types of precursors: Methyl-silicate-51 from different suppliers.**
  - **The molecule size may be different from each other.**

	Supplier	Transmission Length n =1.015	n = 1.03	n =1.05
Old →	Colcoat	26 mm	40 mm	22 mm
New →	Fuso-Kagaku	36 mm	62 mm	32 mm

- **Another improvement was obtained by using other type of solvents.**
  - **Methyl-alcohol → Di-Methyl-Formamide (Nobosivirsk people use propenol).**
  - **Transmission length improved for n=1.03: 40 mm → 53 mm**
- **The combined improvement will be tested in the next batch.**
  - **We can expect the transmission length (Λ) of 42 mm for n=1.05.**
  - **Hydrophobic aerogel by Nobosivirsk: Λ = ~34 mm.**

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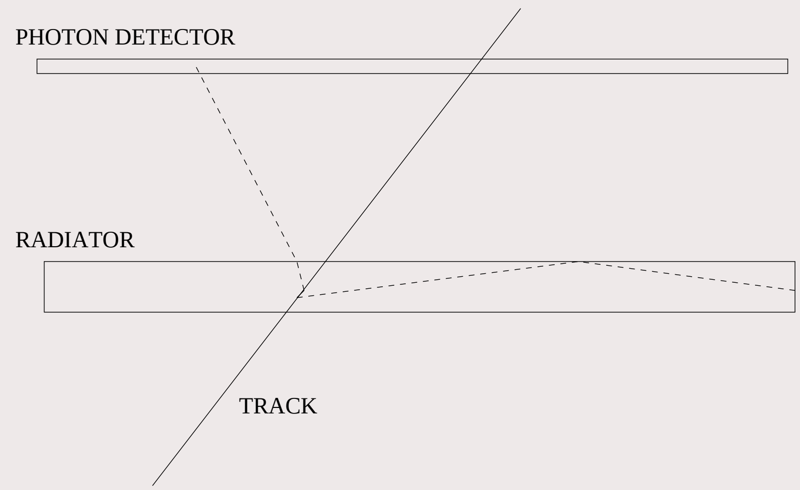
Can we use other radiators?

example 1: LiF

- $\theta_c(\pi) - \theta_c(K) = 7.2$ mrad at 4 GeV/c
- errors:
  - chromatic (dispersion in the radiator): 2.5 mrad
  - photon detector granularity: 3 mrad
  - emission point error: 6-7 mrad
- total: 7-8 mrad per photon
- $\rightarrow$ with 10 detected photons: 3σ π/K separation at 4 GeV/c



example 2: C_6F_{14}

- $\theta_c(\pi) - \theta_c(K) = 9.5$ mrad at 4 GeV/c
- total error: 7-8 mrad per photon
- $\rightarrow$ with 20 detected photons: $\approx 4\sigma$ π/K separation at 4 GeV/c

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Summary

- Beam test was a successful proof of principle
- Beam test confirmed the results of our simulation tools, and showed where further R+D has to go
- A wide range of R+D activities was started (together with the industry) with the aim to develop an efficient photon detector with a high active area to work in high magnetic fields
- Radiator R+D has already given some encouraging results, and backup options exist
- We are looking forward to the next beam test in November/December