Aerogel RICH R+D in Ljubljana

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Aug. 31, 2002
Mini PID Workshop, Nagoya

- People involved
- Beam test results - update
- Study of light collection systems
- Test of the TO-8 HAPD array
- Comparison of radiators (aerogel/liquid/solid)

People involved

Senior researchers

- Samo Korpar: everything
- Marko Starič: analysis of beam test data, reconstruction algorithms
- Aleš Stanovnik: beam test preparation, write-up
- Peter Križan: mostly giving talks

Young post-docs, doctoral students

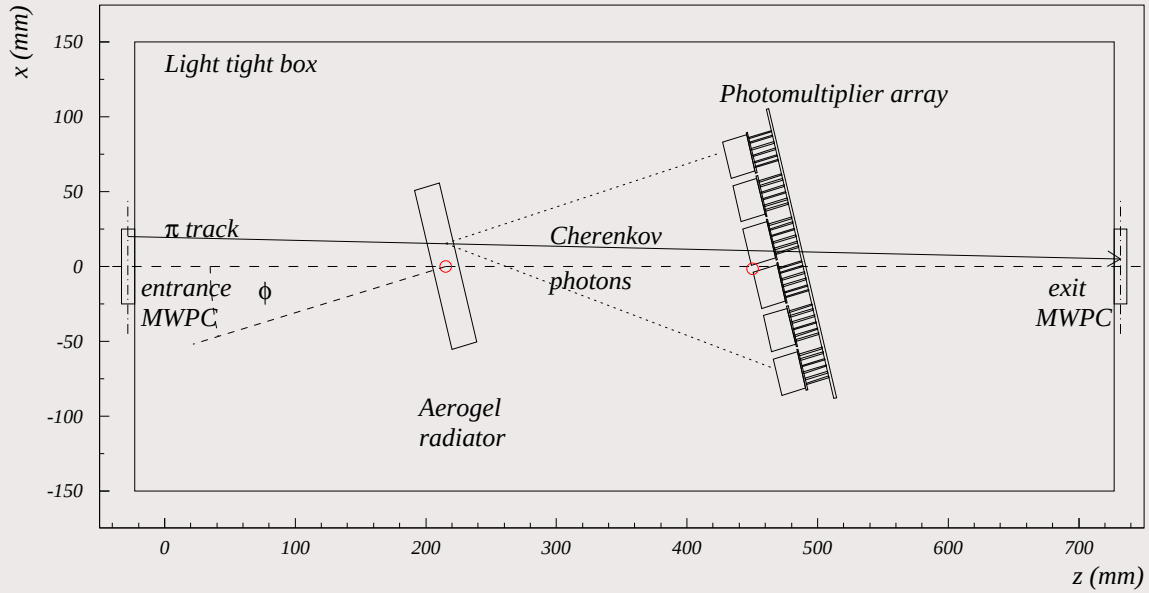
- Rok Pestotnik: beam test preparation and analysis, HAPD testing, aerogel for environmental physics, light collection systems
- Andrej Gorišek: beam test preparation
- Ilija Bizjak: 2D scans of PMTs, lenses, aerogel samples, beam test
- Saša Fratina: starting as a doctoral student in autumn

Summer students, diploma students

- Tina Gale (finished as summer student, maybe diploma): lens system design
- Irena Dolinar: aerogel for environmental physics (most probably)
- Peter Košir: HAPD testing

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

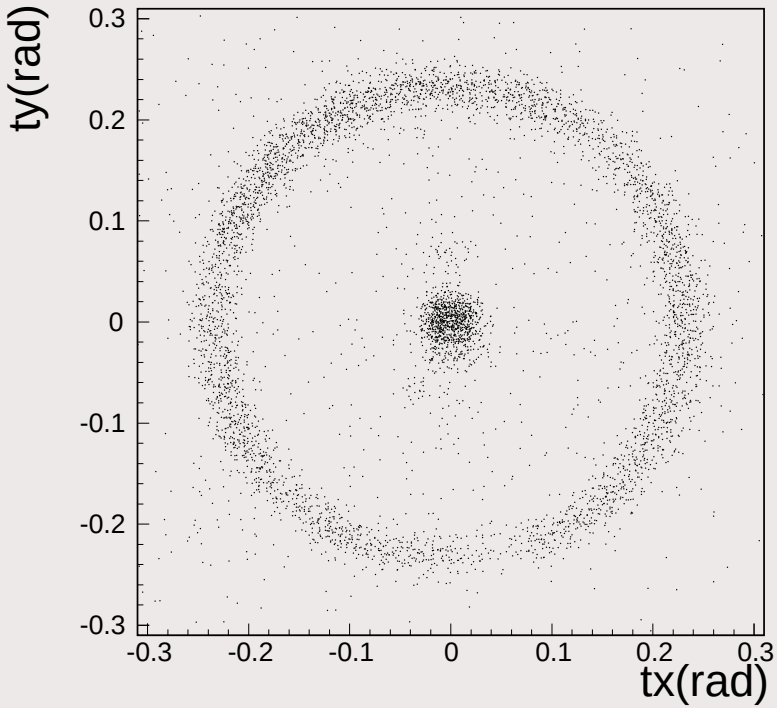


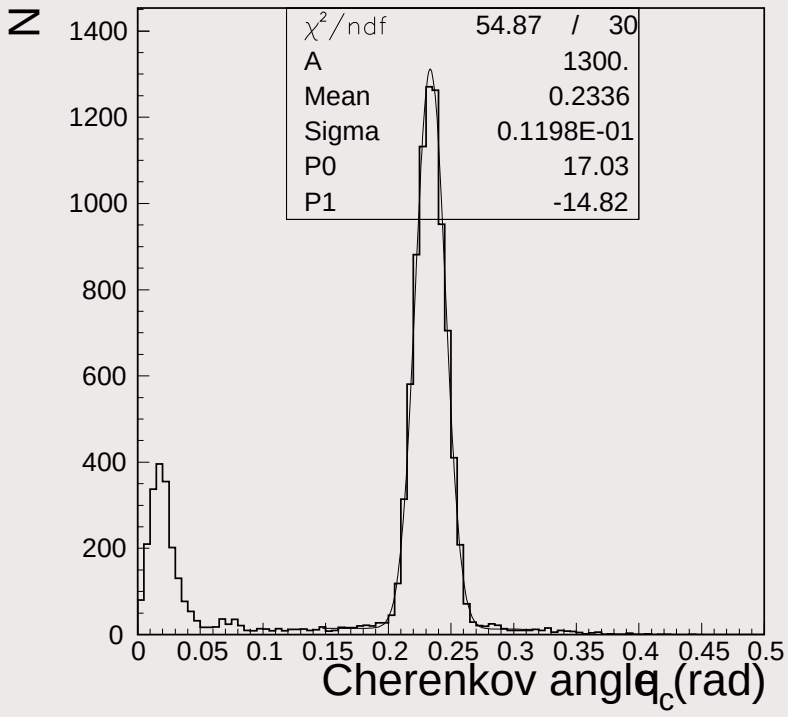
A wide variety of parameters was investigated

- 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

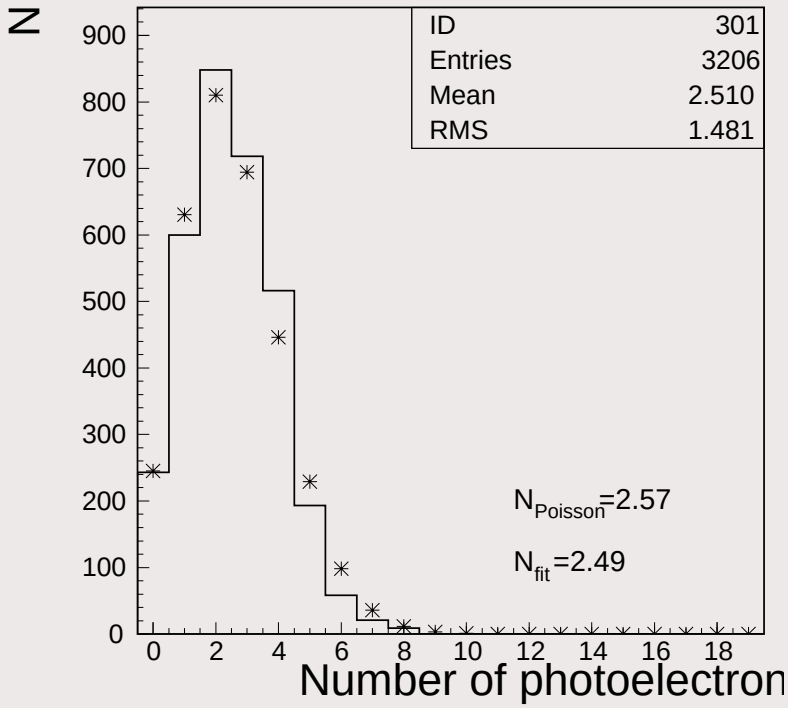


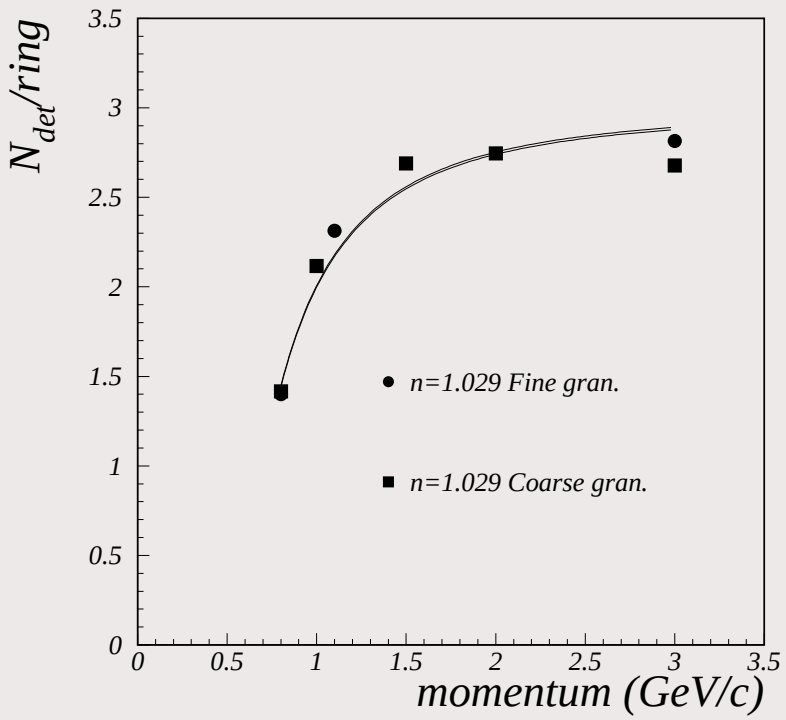


very clean Čerenkov angle distribution

Beam test results - number of photons

number of hits per ring:



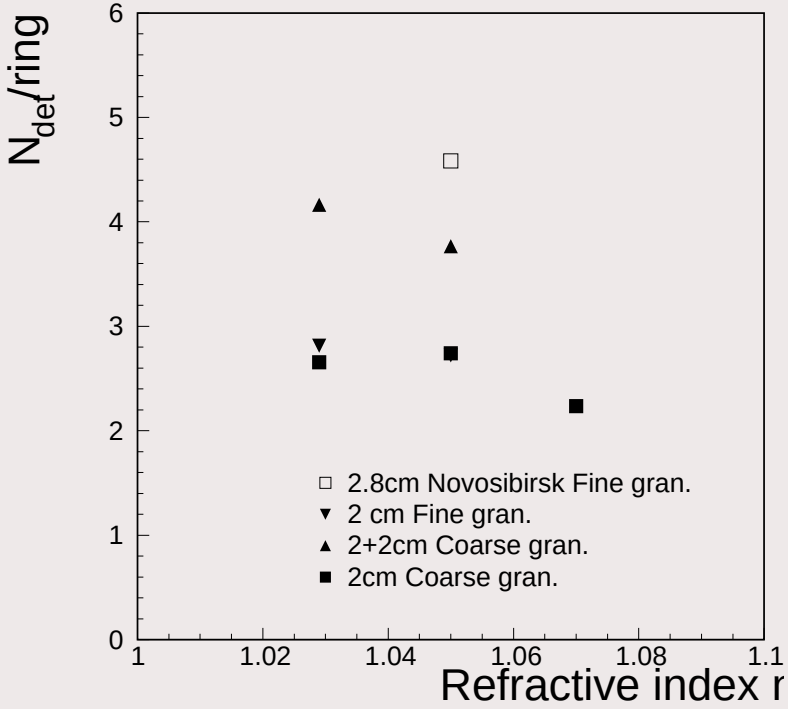


distribution derived from the fraction of events with 0 hits (*) agrees with the observed distribution of the number of hits per ring

number of hits per ring vs momentum

Beam test results - number of photons

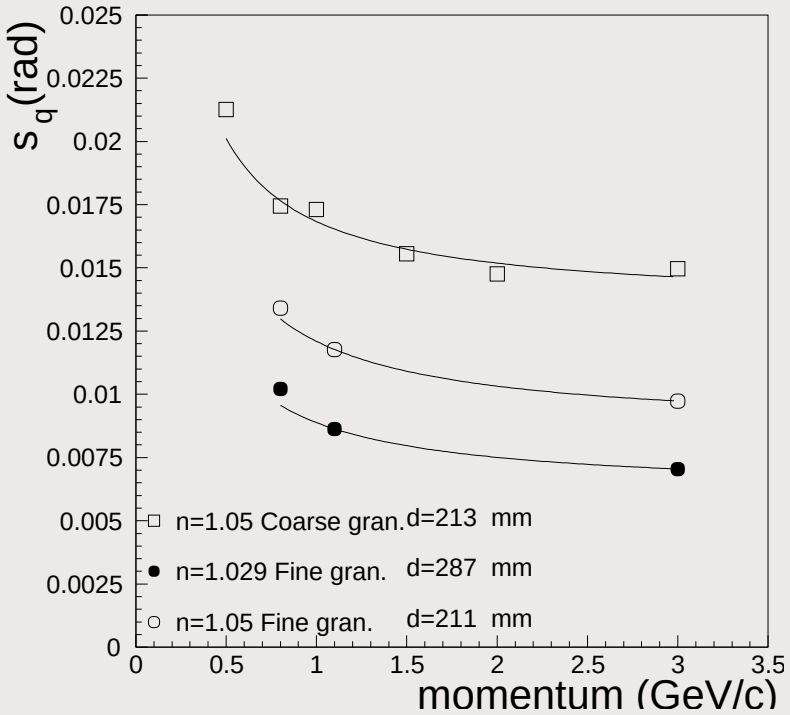
number of hits per ring for different aerogels
(refractive index, production method)



→

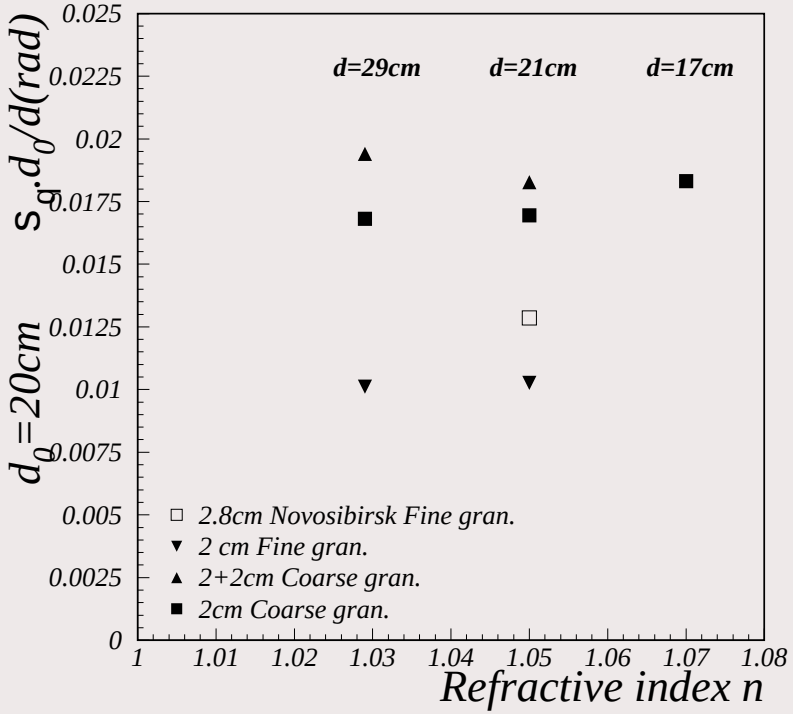
- higher ref. index does not produce more photons because of absorption
- doubling the thickness does not double the photons
- Novosibirsk aerogel has a considerably higher yield

Beam test results - resolution



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

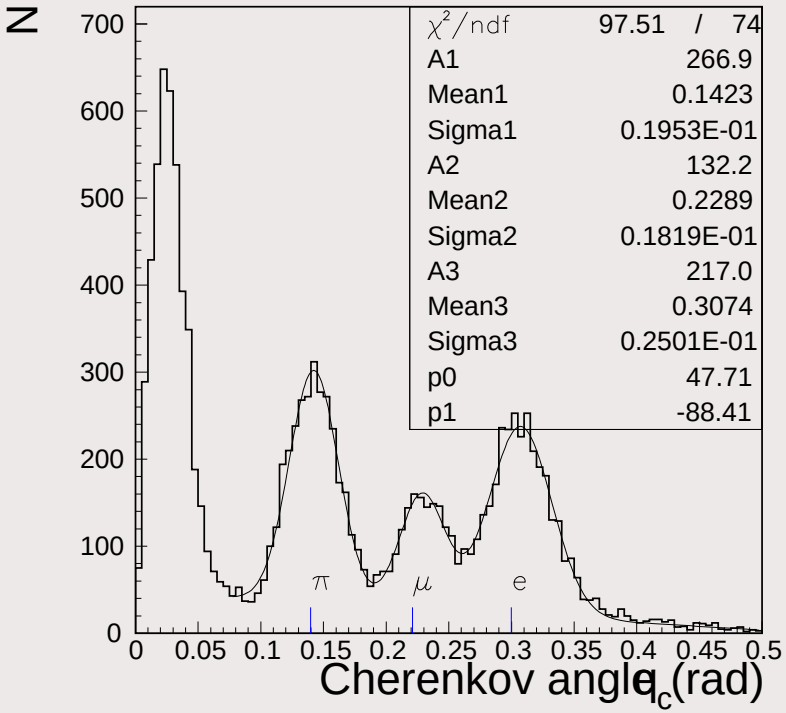
resolution vs ref index



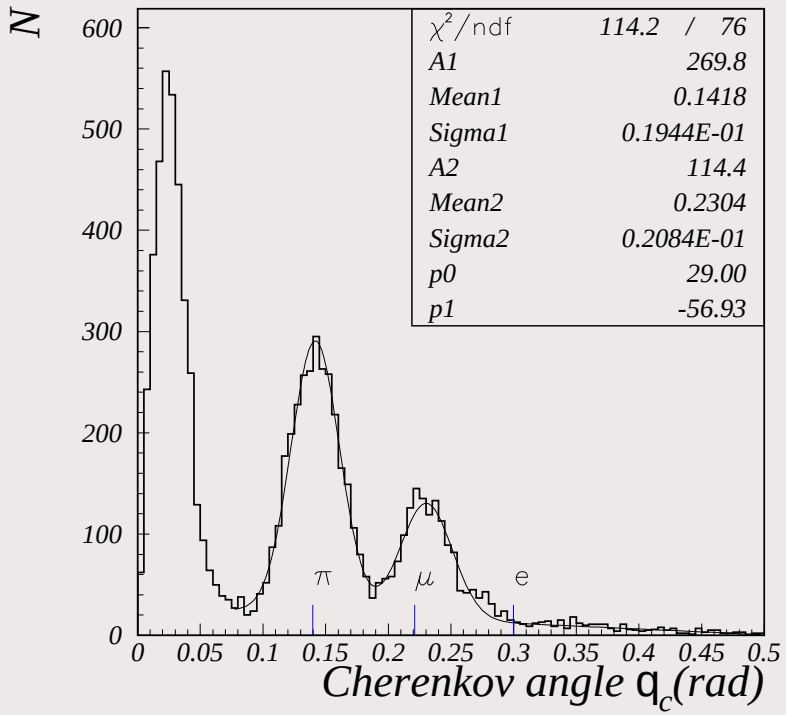
to compare the resolutions with various set-ups (distance was varied to accommodate the full ring on the photon detector) we normalize to a given distance (200nm) between the radiator and the photon detector

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



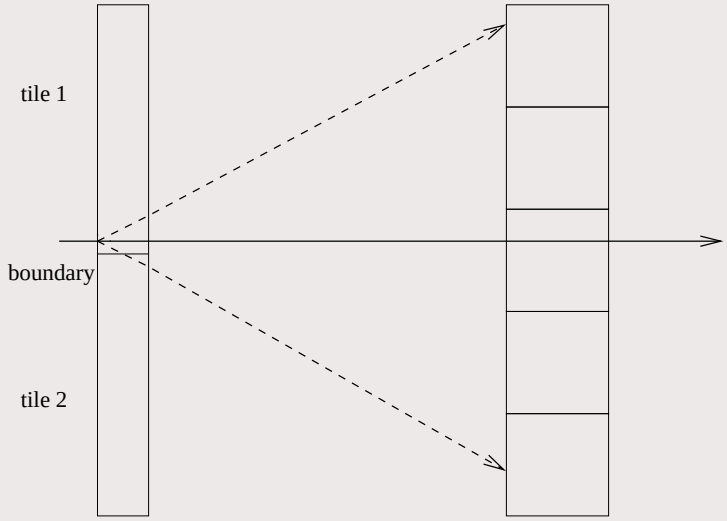
Čerenkov angle distribution for single photons, at $p = 0.8$ GeV/c

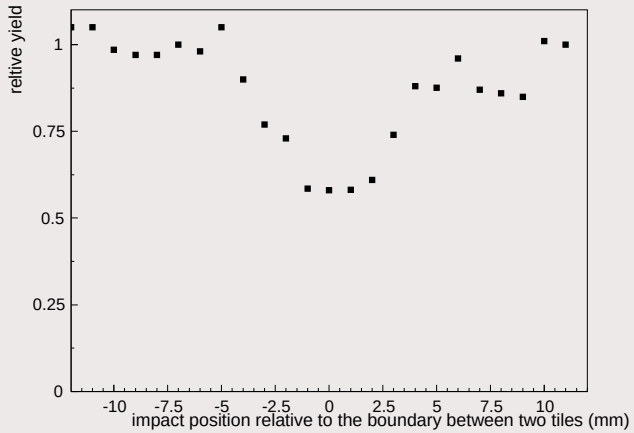


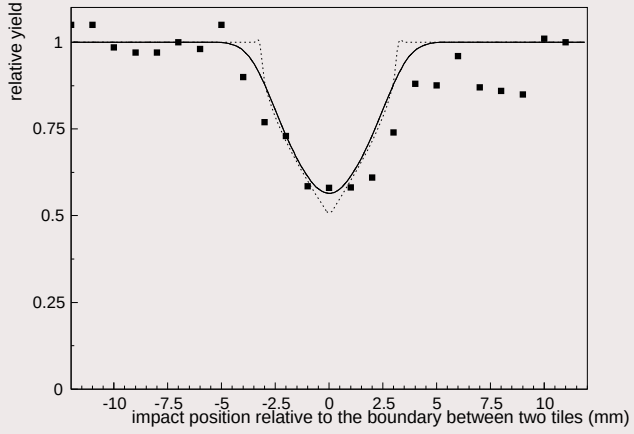
same, but with electrons vetoed with a CO_2 threshold Čerenkov counter

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)







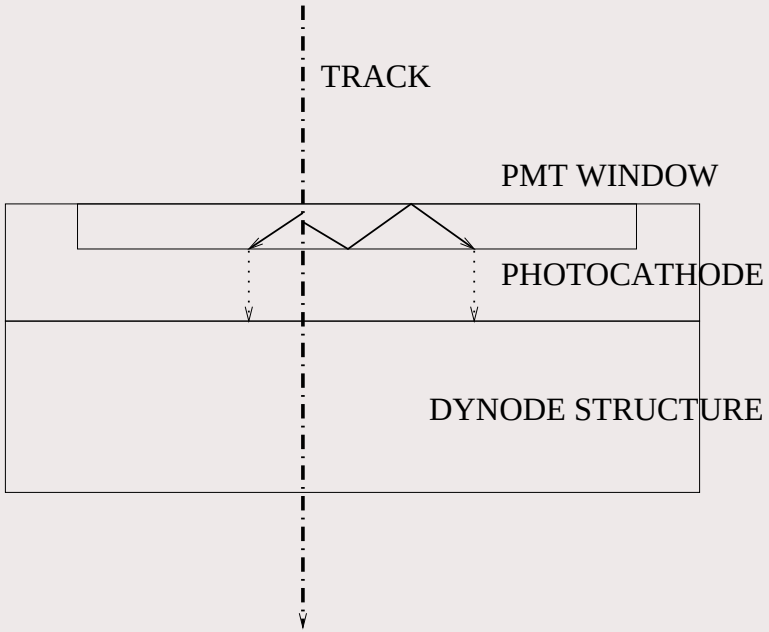
As expected, the yield is affected over a few mm in the vicinity of the boundary.

A simple model (all photons hitting the boundary get lost) accounts for most of the dependence.

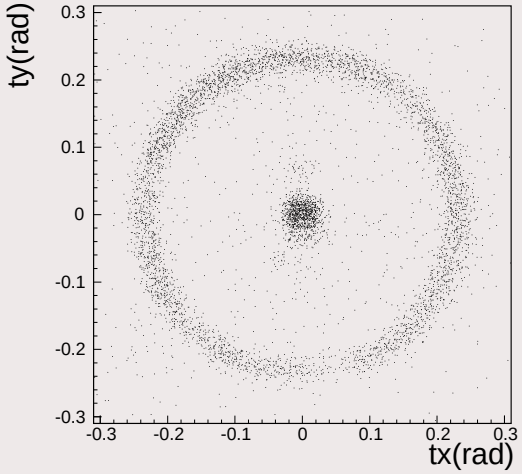
dotted: simple model, full: convoluted with beam position resolution

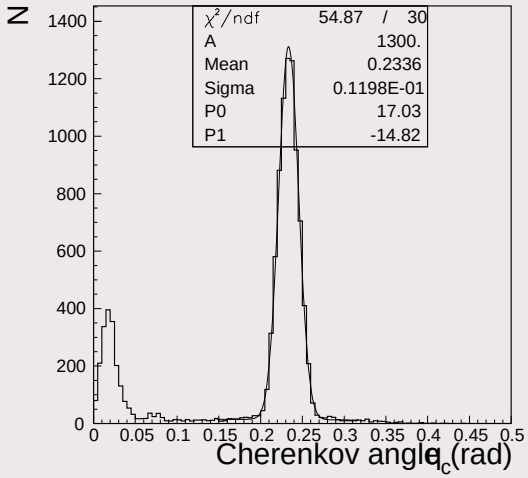
Photon detector window - source of Č. photons

Hits in the ring center (i.e. close to 0 in the θ_c distribution) are due to Čerenkov photons produced by the track in the PMT window

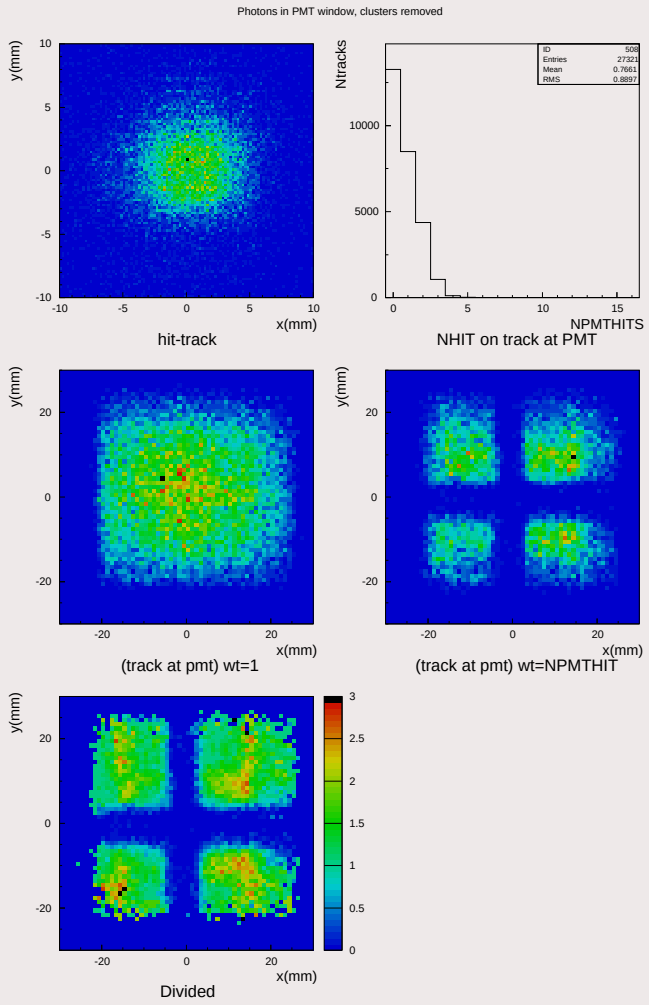


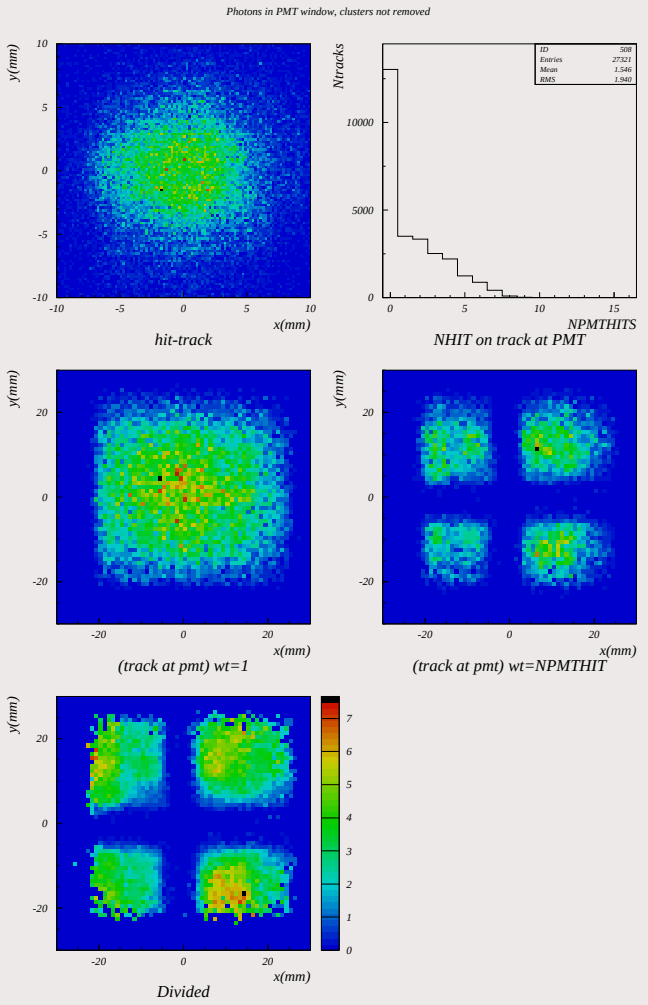
Are they a worry?





Photon detector window Č. photons, run 130, n=1.028





electronics clusters removed

electronics clusters not removed

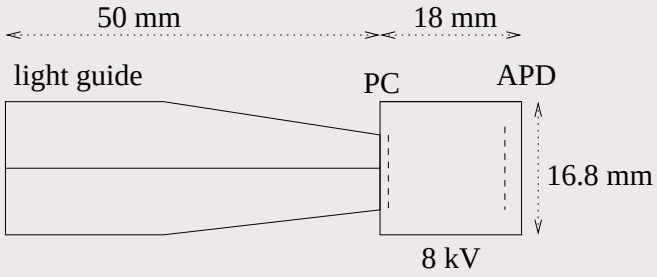
Beam test results - summary

- 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

Test of H(A)PD with a light collection element

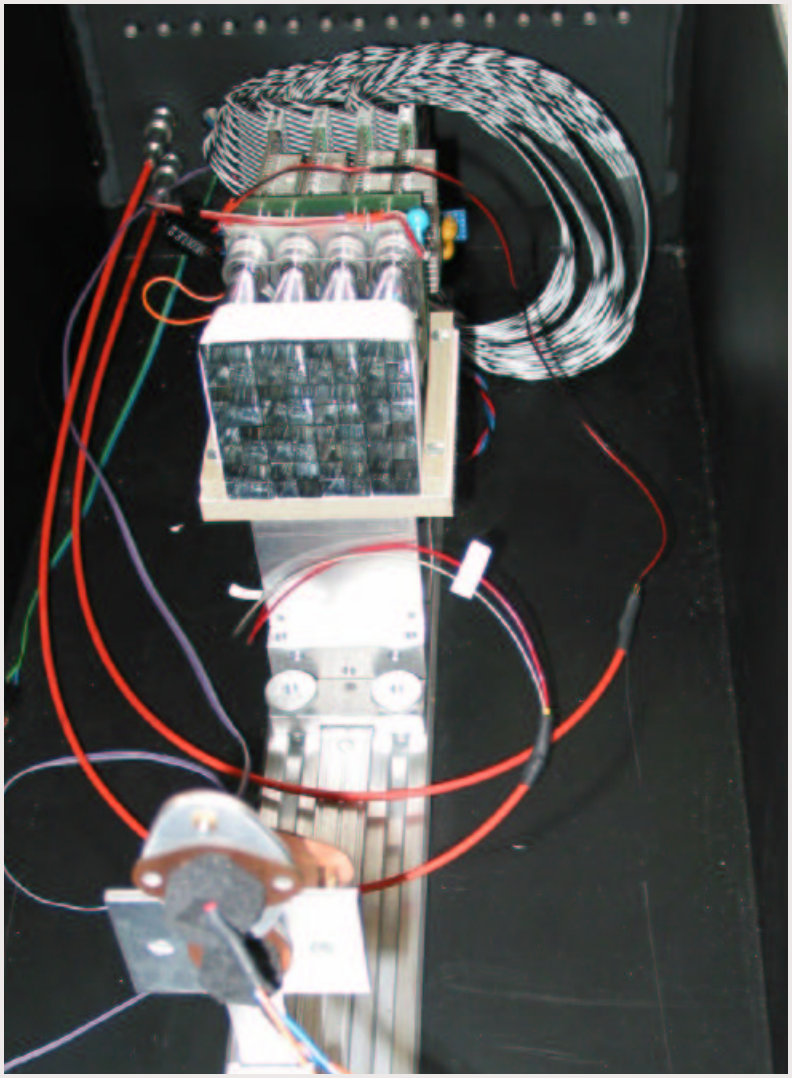
HPK prototype of 16 hybrid avalanche photodiodes, each with 4 channels, with light collection elements.



Test set-up includes

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

all in a light tight box



Test of H(A)PD - status

Apparatus is up and running.

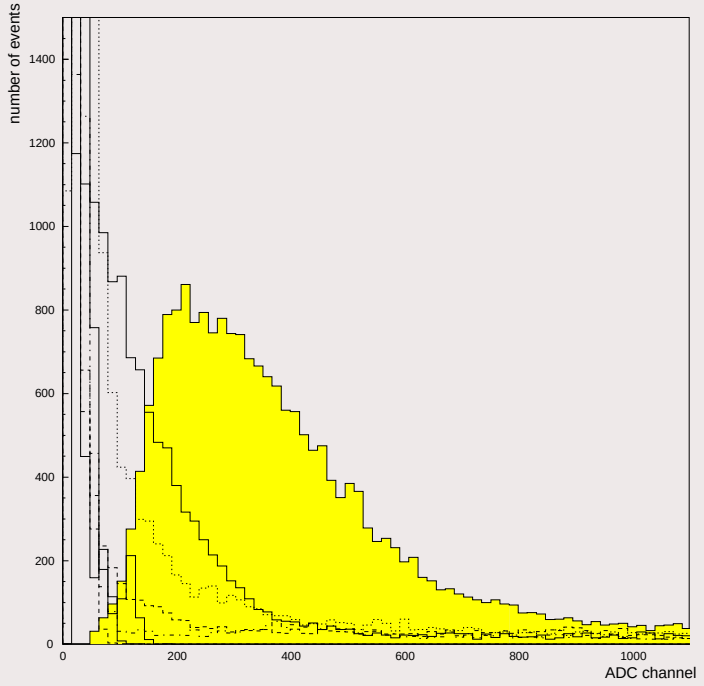
Noise level acceptable.

Single photon peak is not well pronounced yet - rather a broad distribution (but distinctive from noise).

first ADC spectra

yellow: single pulse height distribution of the triggering channel

open histograms: neighbours

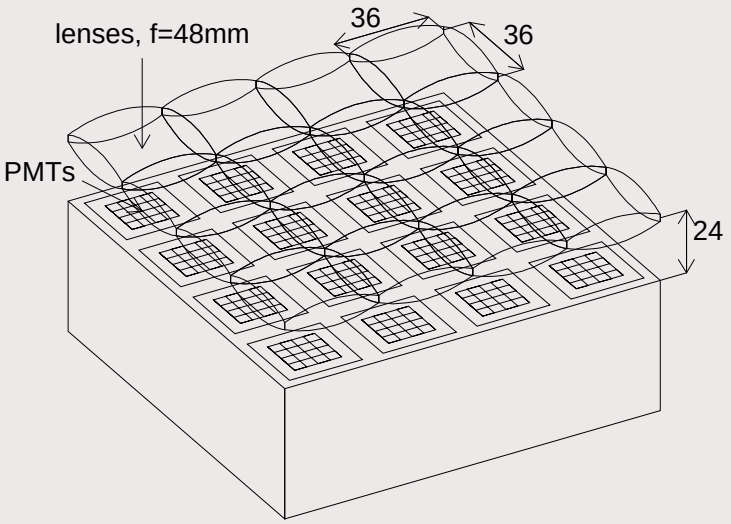


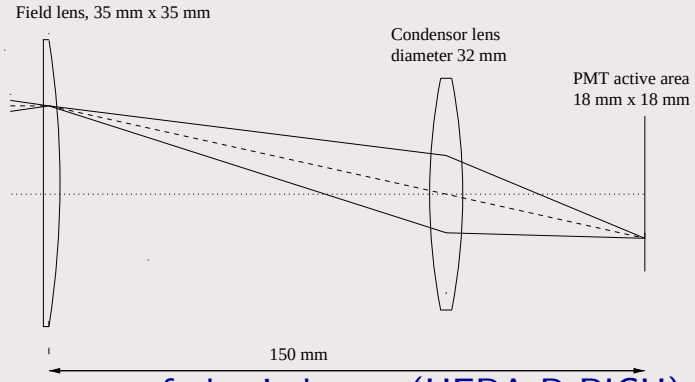
Next possible steps: understand the spectra and correlations, reduce heat dissipation (pre-amps) in the light tight box

Light collection systems R+D

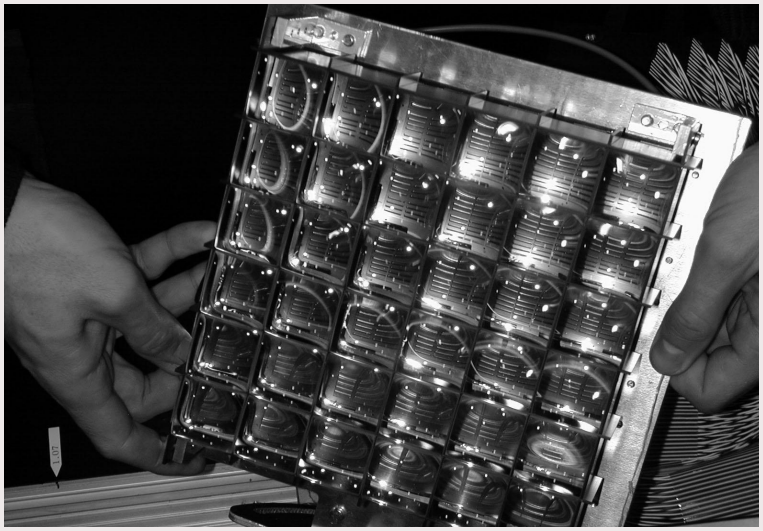
Increase the number of photons by using a light collection system (and thus reduce increase the active area fraction of the photon detector)

- single lens system
- two lens device
- light guides



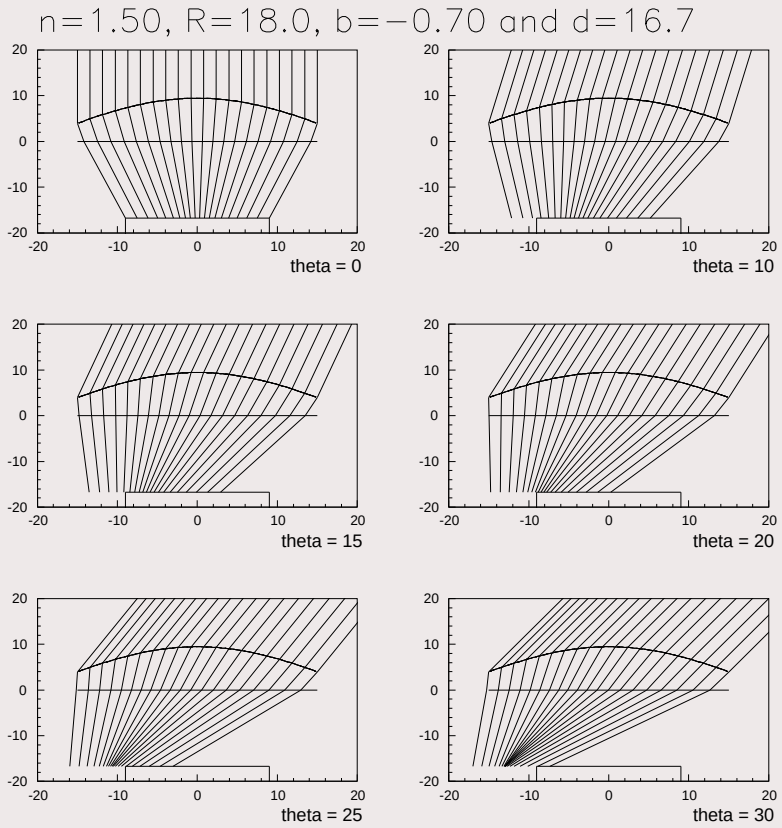


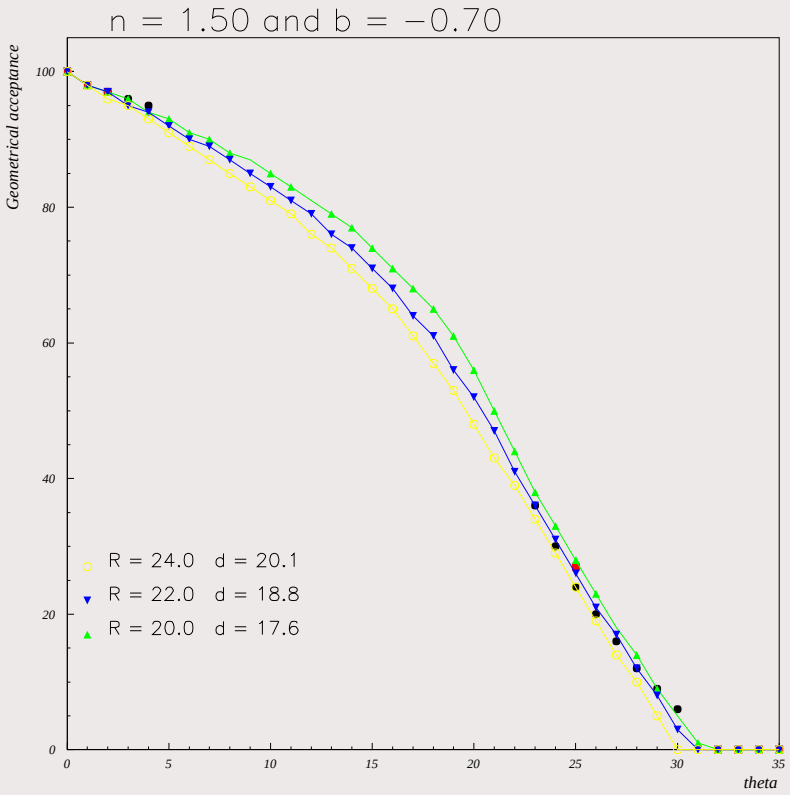
system of plastic lenses (HERA-B RICH)



Single lens as a light collection system

ray tracing vs angle of incidence



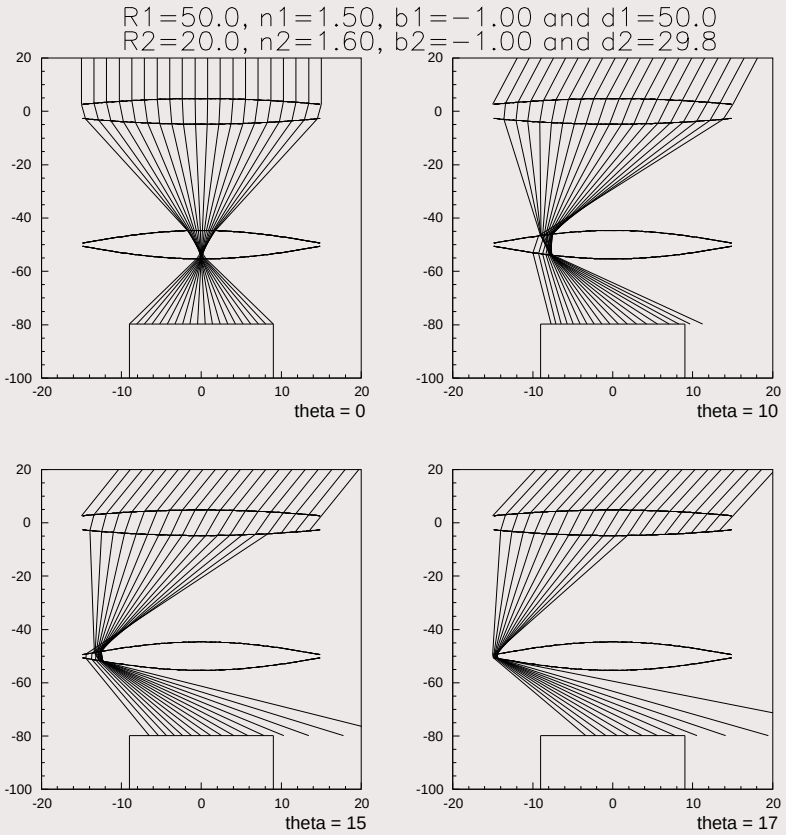


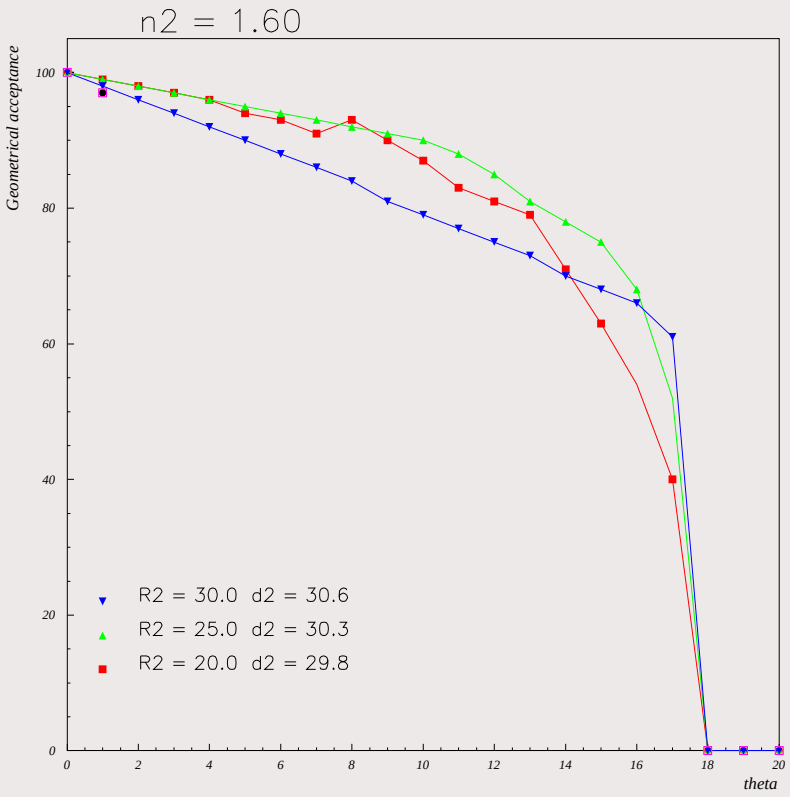
acceptance vs angle

optimize the parameters (focal length, distance, asphericity) of the lens
but: not much free room for improvement

Two lenses as light collection system

ray tracing vs angle of incidence

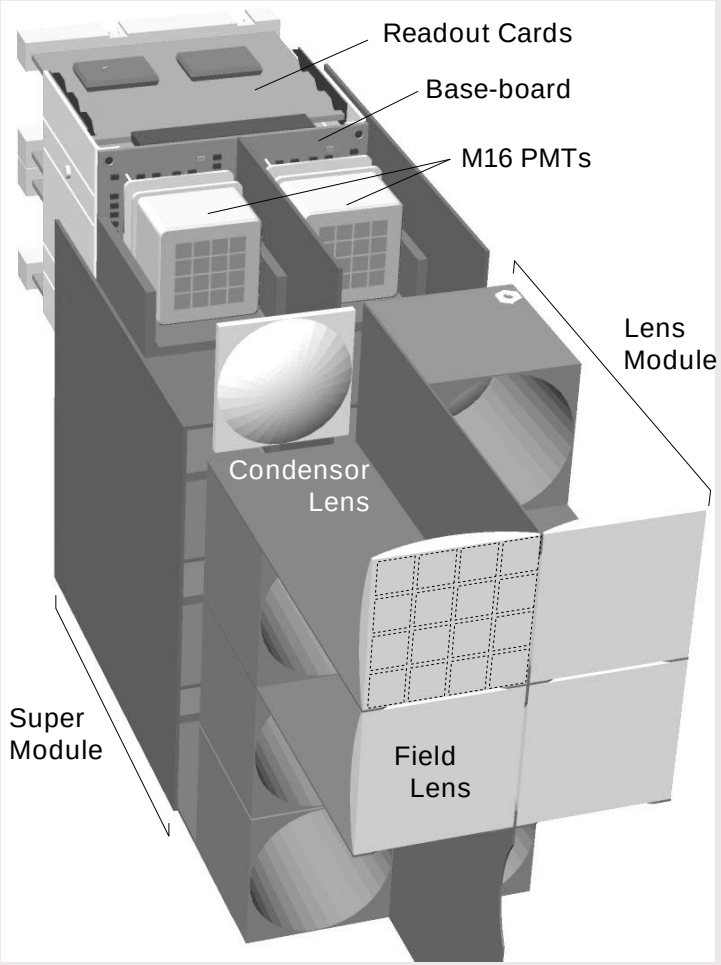


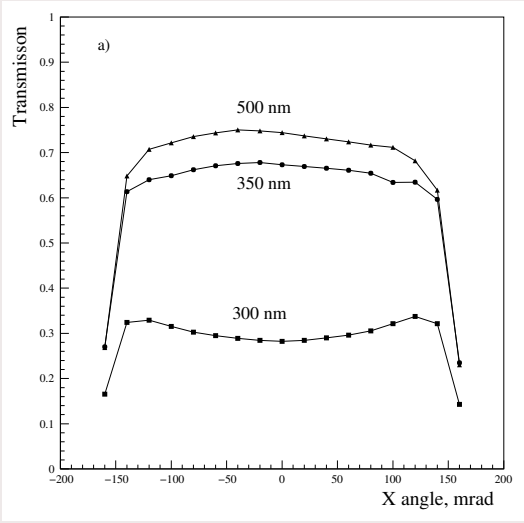


acceptance vs angle

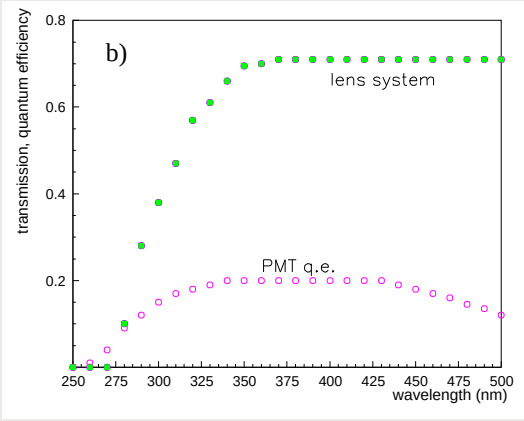
optimize the parameters of the two lenses

HERA-B RICH lens system



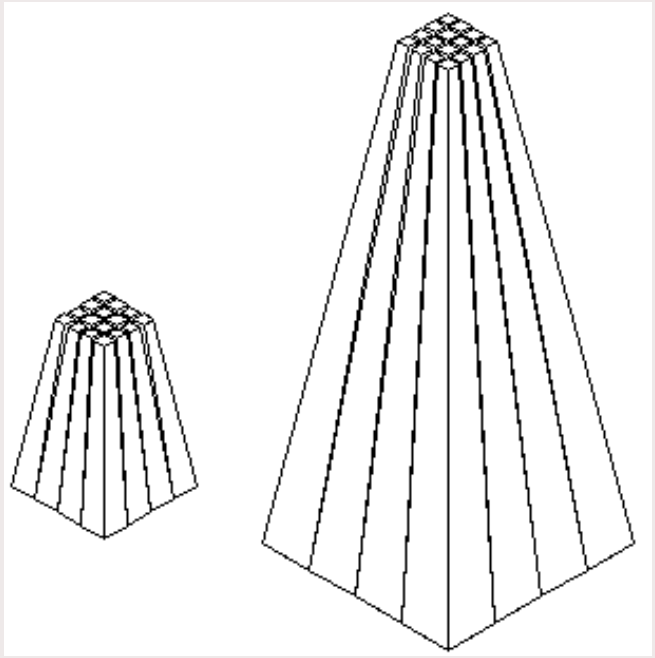


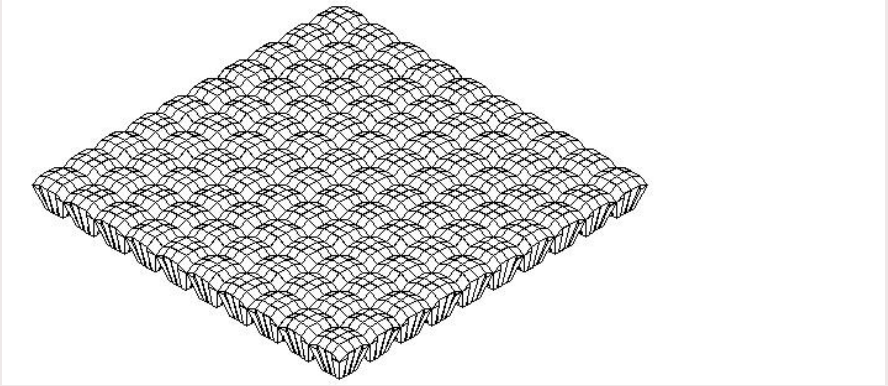
acceptance vs angle



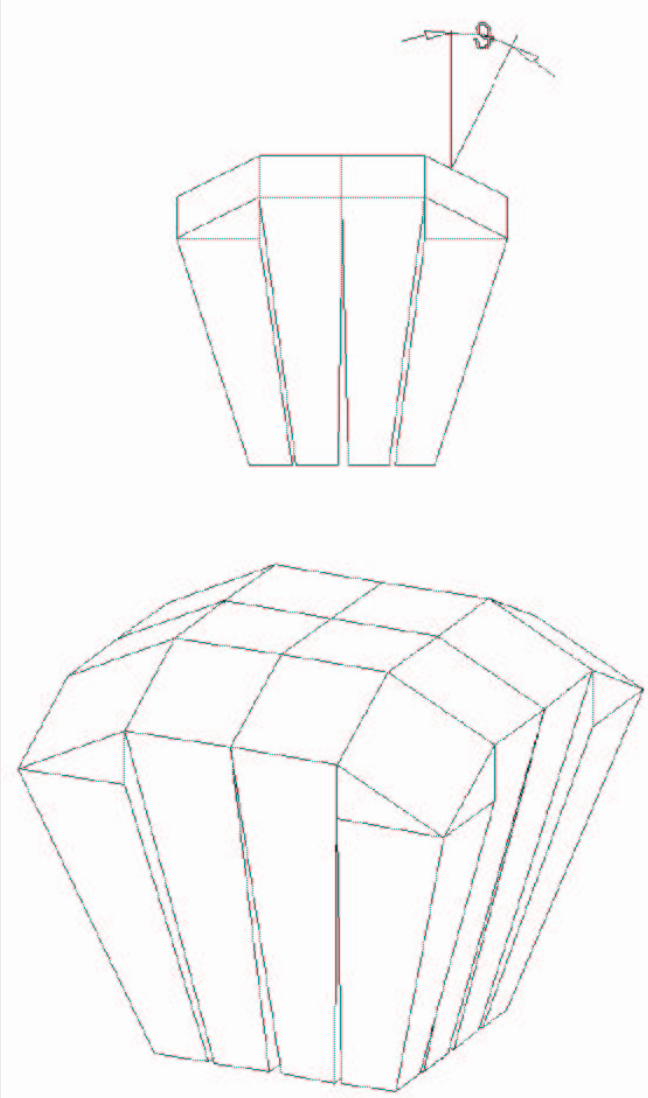
Light guides as light collection system

single module with flat entrance window





array of modules with 'focusing' sides

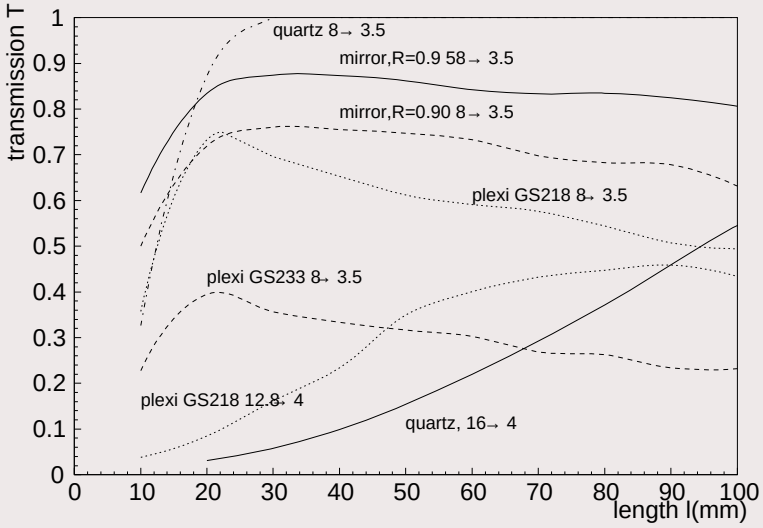


module with 'focusing' sides

Light guides as light collection system 2

Simulation of transmission vs guide length

- light guide with no absorption and optical contact with PMT window (quartz)
- acrylic light guides
- light guides with reflective walls
- different demagnifications ($8 \rightarrow 4$ etc)

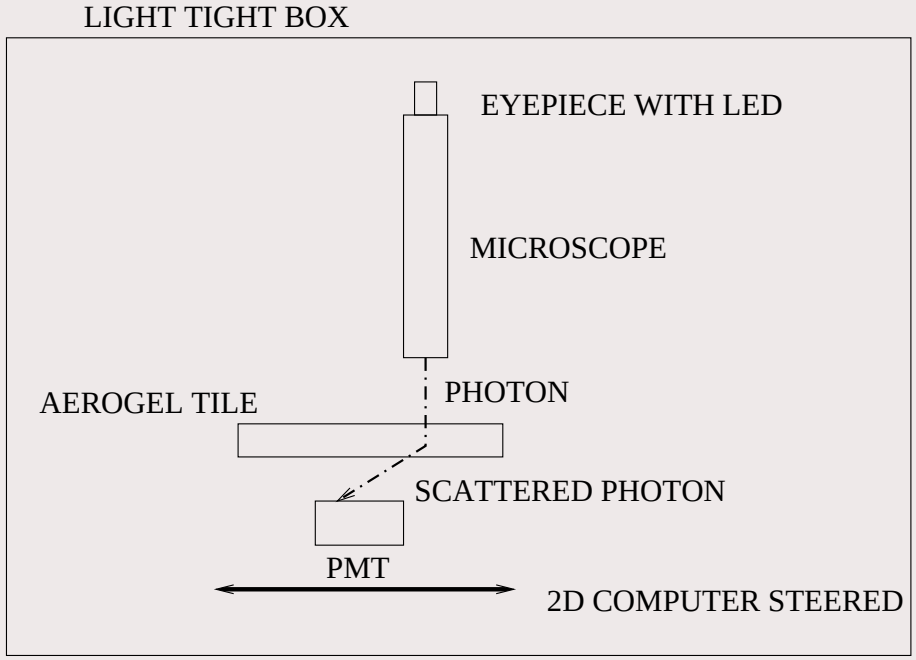


transparency of various light guides vs light guide length

N.B. Study would have to be repeated for the expected photon impact angular distribution.

Aerogel radiator testing

- forward scattering in aerogel: does it contribute to the resolution
- impact of ref. index variation on the resolution

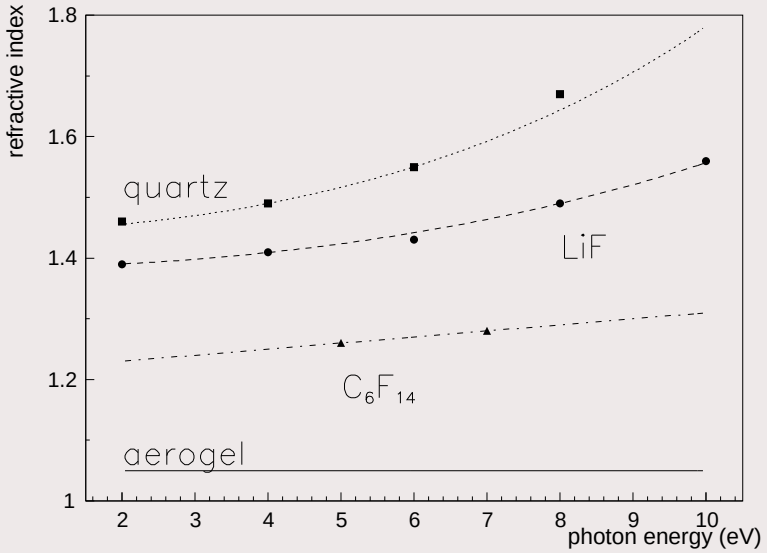


2 dimensional surface scan apparatus

- backing out degraded (not hydrofobic) aerogel samples

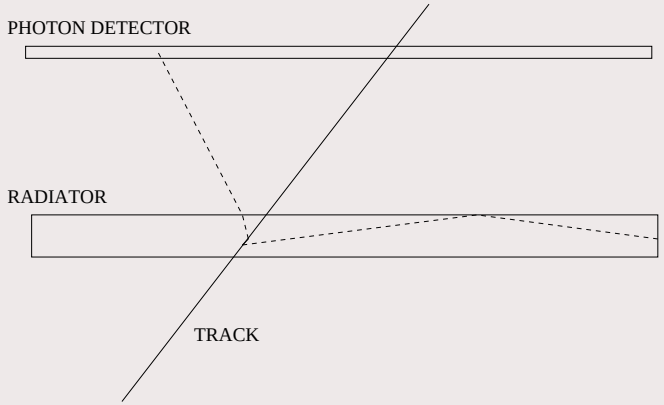
Can we use other radiators?

Solid or liquid instead of aerogel?

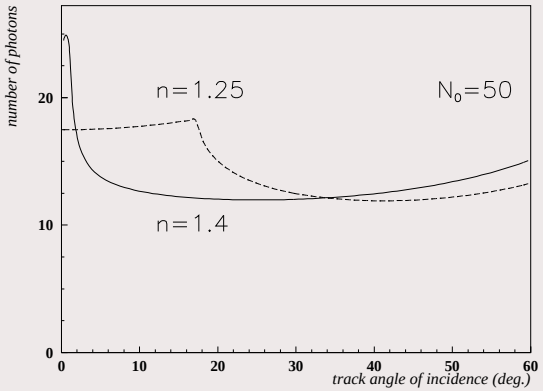


If visual light Č. photons are detected, chromatic aberration becomes less problematic!

Note: Part of the light does not get out due to total internal reflection



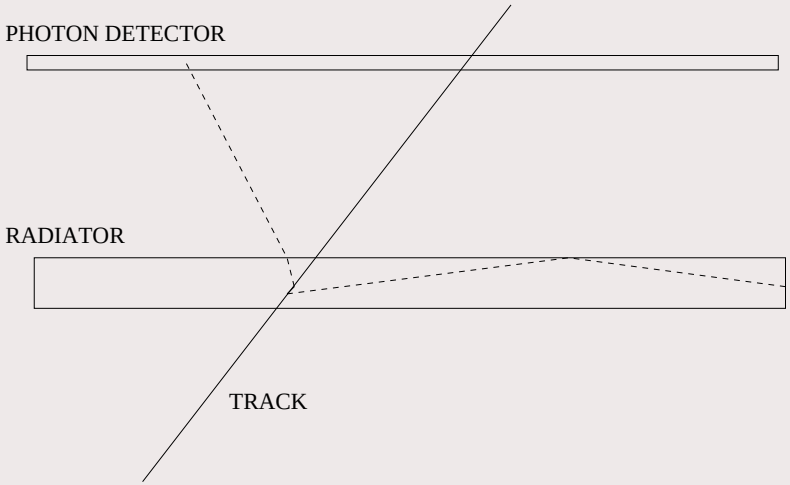
Number of photons vs. track impact angle for two radiators (LiF and C_6F_{14})



Can we use other radiators? - 2

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

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 is going on, more manpower than before
- We are looking forward to the next beam test in November