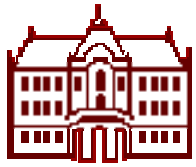
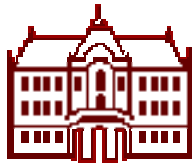


Tests of the BURLE 64-anode MCP PMT as the detector of Cherenkov photons

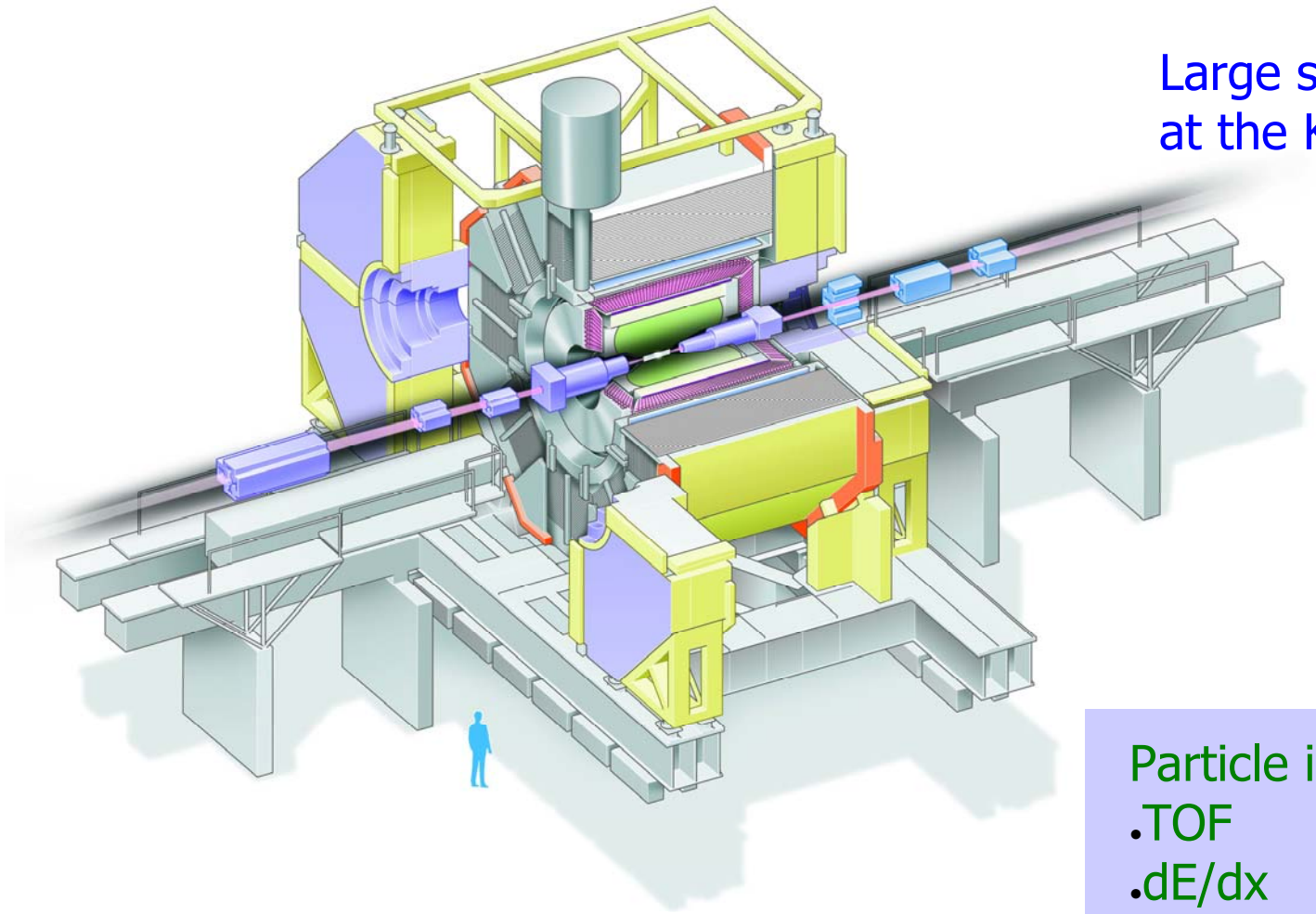
Peter Križan

University of Ljubljana and J. Stefan Institute

Contents



Belle Spectrometer - PID

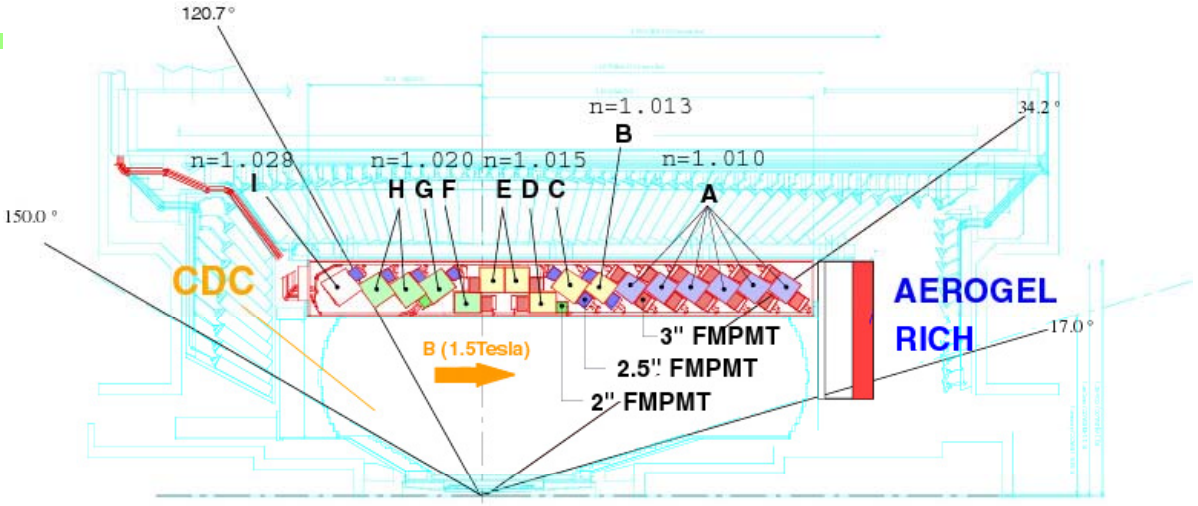


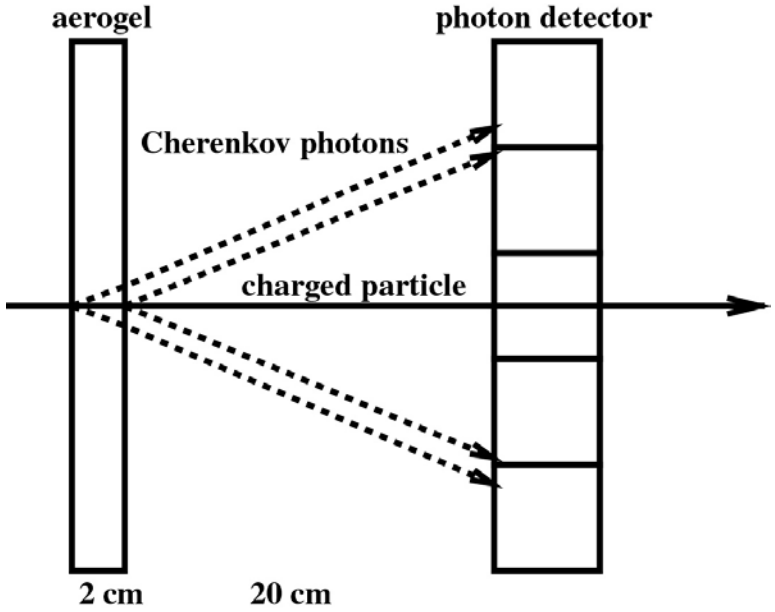
Large solid angle detector
at the KEKB e^+ e^- collider

Particle identification:
- TOF
- dE/dx
- ACC: threshold aerogel Cherenkov counter

Belle PID system upgrade

requirement: ~ 5σ K/π separation @ 4 GeV/c

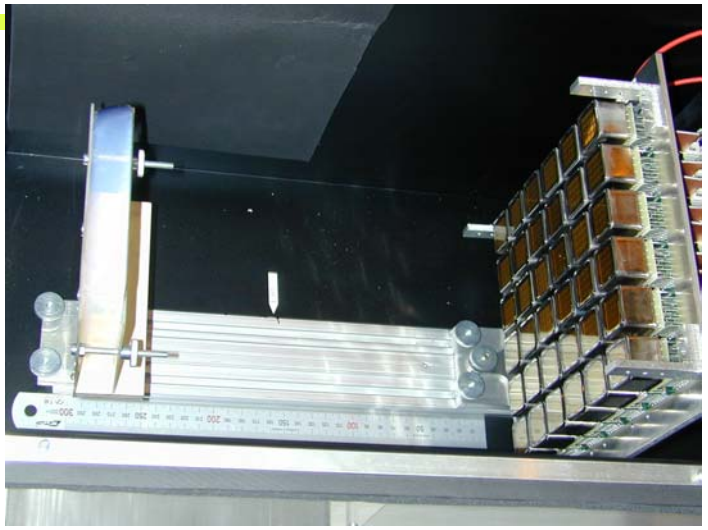




proximity focusing RICH with aerogel radiator in the forward direction

- n ~ 1.05
- $\vartheta_c(\pi)$ = 310 mrad @ 4 GeV/c
- $\vartheta_c(\pi) - \vartheta_c(K)$ = 23 mrad @ 4 GeV/c
- pion threshold 0.44 GeV/c

Proximity focusing RICH with aerogel radiator: R+D hystory 2001-2004

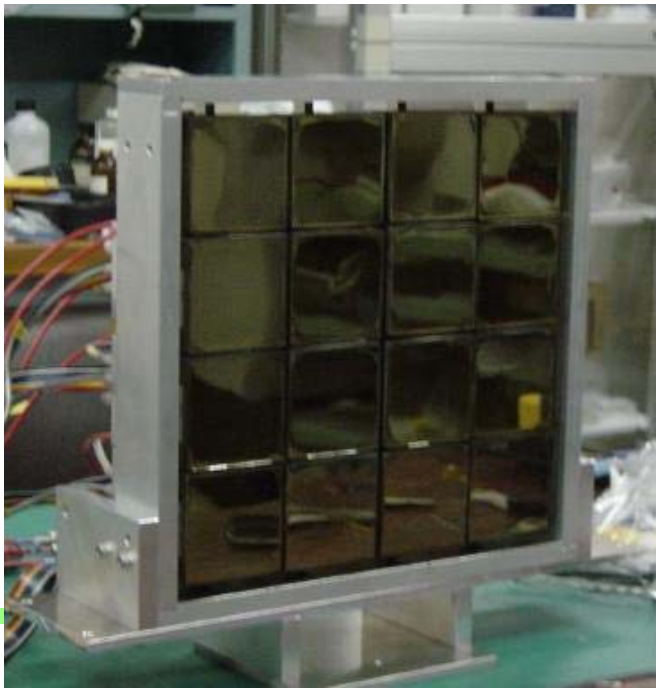


Beam Test Nov. 2001: proof of principle

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



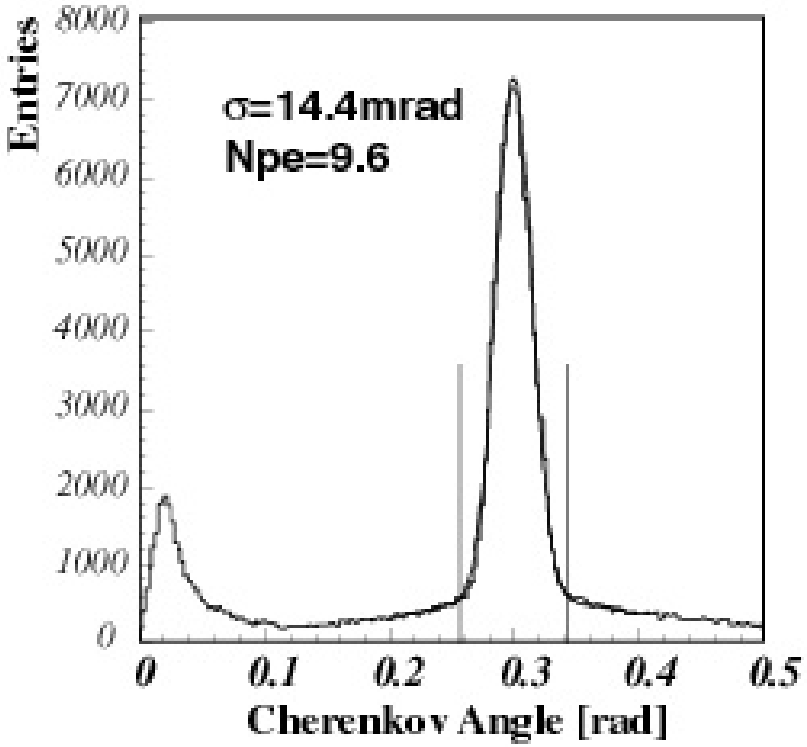
Beam tests Nov. 2002 - 2004

- new aerogel samples
- new photon detector Hamamatsu H8500 (flat pannel PMT) with 89% eff. area
- new readout electronics (1024 channels)

->NIM A518 (2004) 582

Beam test: Cherenkov angle resolution and number of photons

Beam test results with 4cm thick aerogel tiles in the focusing configuration: >5σ K/π separation at 4GeV/c



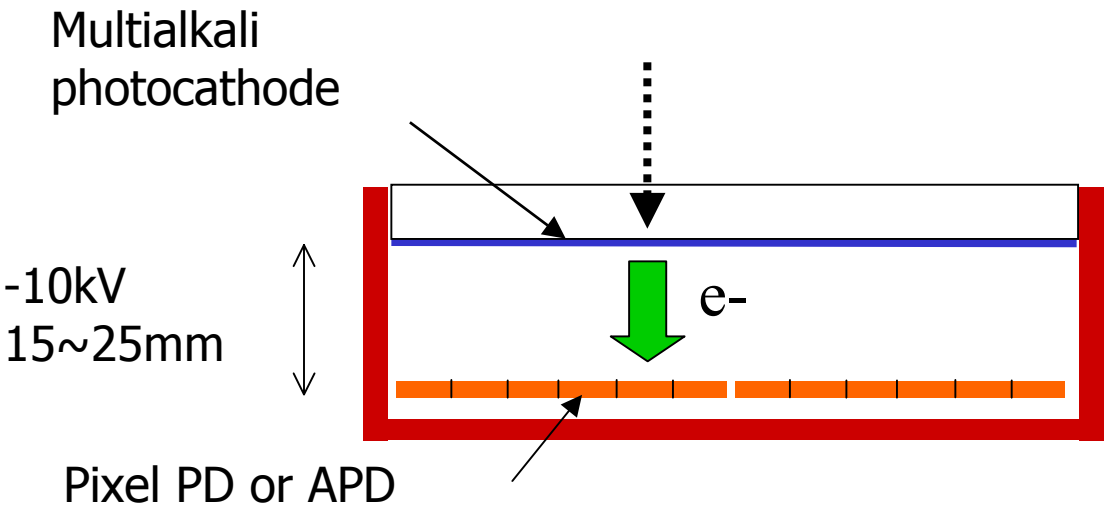
->e-Print: physics/0504220,
to be published in NIM

Hamamatsu H8500 (flat panel PMT) good for the understanding of the counter behavior → intermediate step in our R+D

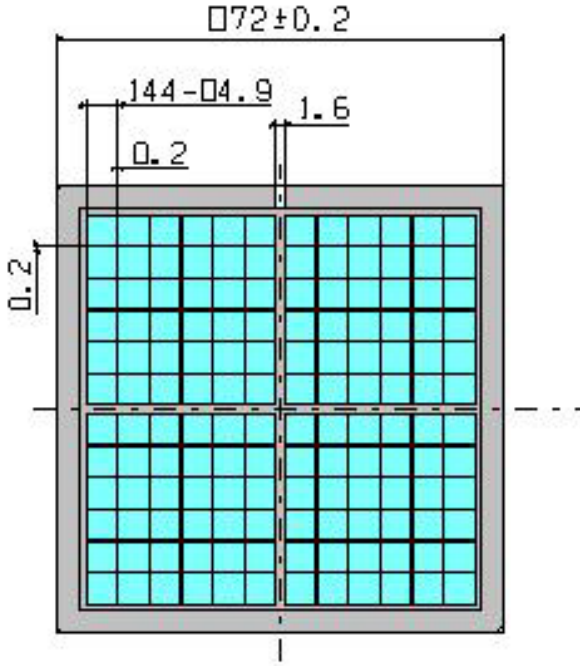
but: not suitable for operation in magnetic field

Development and testing of photon detectors for 1.5 T

Baseline: large area HPD of the proximity focusing type



12x12 channels,
active area 65%



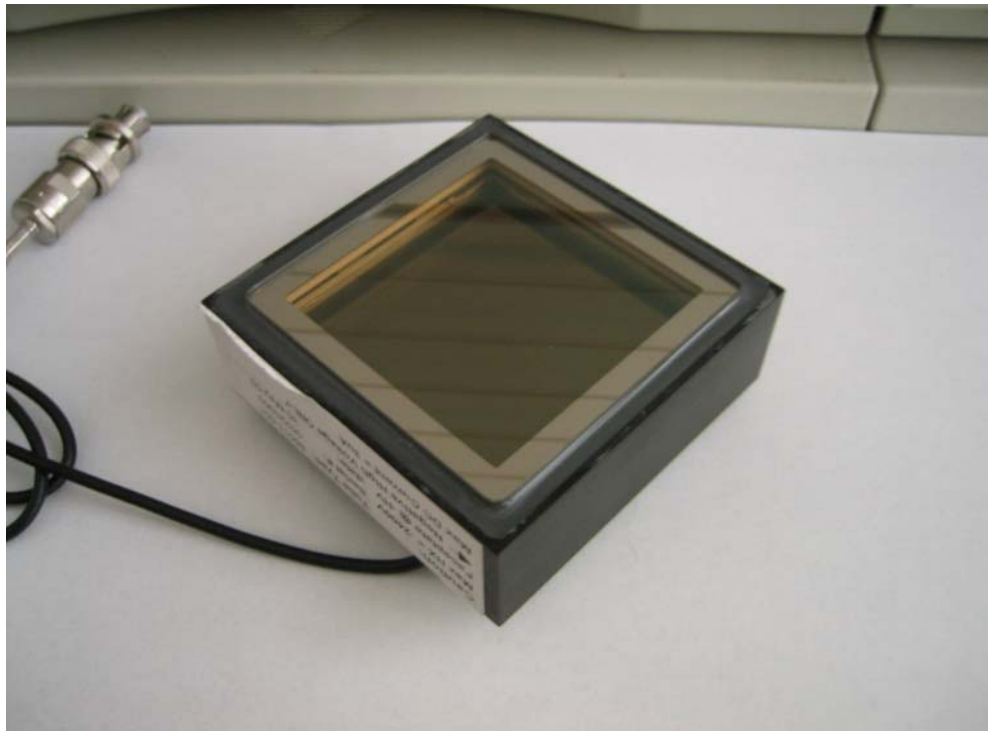
R&D project in collaboration with Hamamatsu

Is there a backup solution?

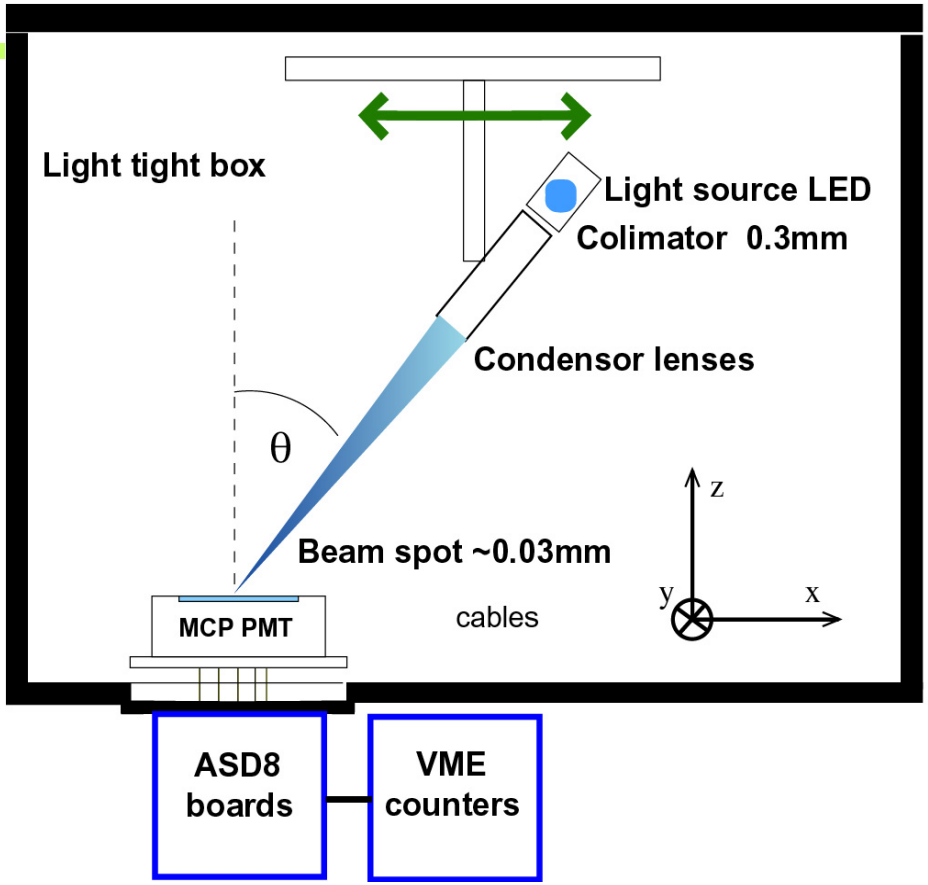
Photon detector backup option: Burle MCP-PMT

BURLE 85011 MCP-PMT:

- multi-anode PMT with 2 MCPs
- 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%



Bench test set-up



LIGHT SOURCE:

- blue LED (470nm) focused by microscope to ~ 30 μm
- 2D position of the light source is computer controlled in steps of 12.5 μm

READOUT ELECTRONICS:

- signals from anodes are amplified and discriminated by ASD8 boards
- digital signals are converted to ECL levels and fed to VME modules

ASD8 BOARDS:

- used in the HERA-B RICH
- 16 channels (2 x ASD8 chips)

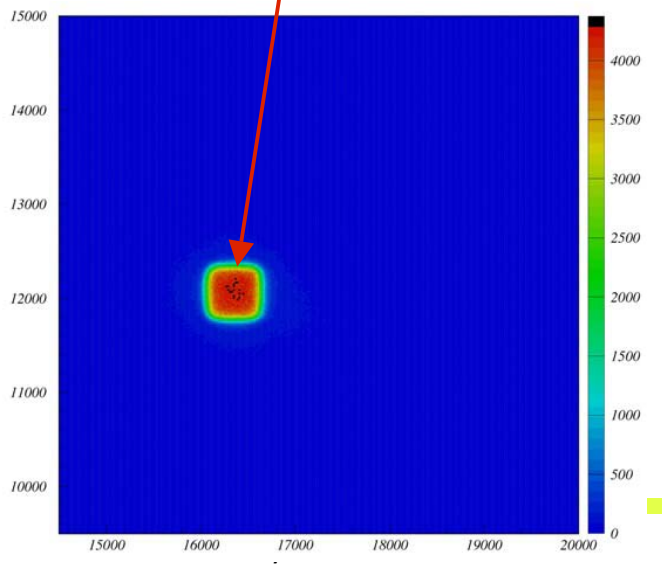
ASD8 = 8 channel amplifier, shaper and discriminator:

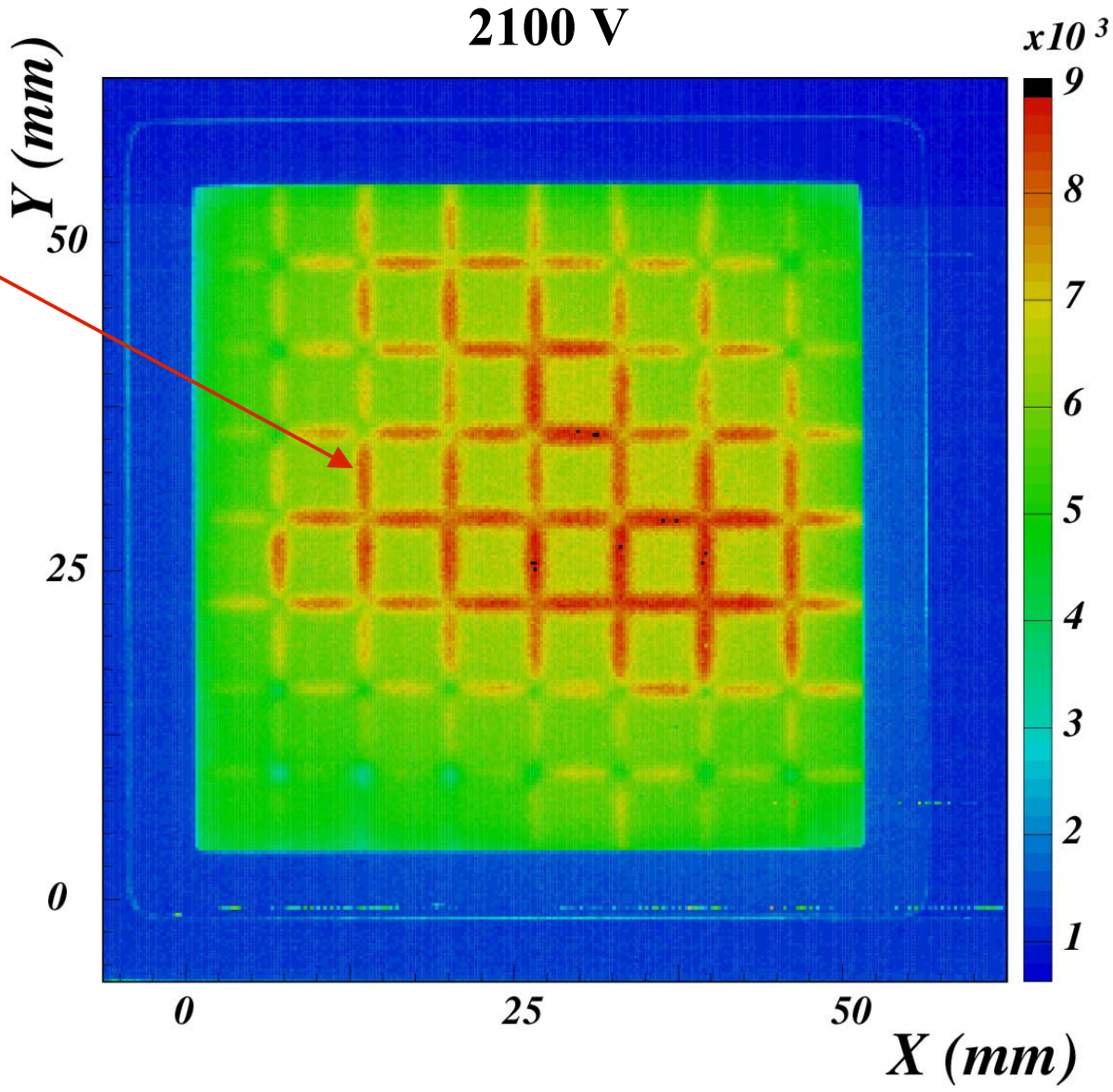
- ENC ~ 900 + 70/pF
- shaping time ~ 10ns
- sensitivity ~ 2.5mV/fC

Single photon counting vs position on the tube

count rates - all channels:
- charge sharing at pad boundaries

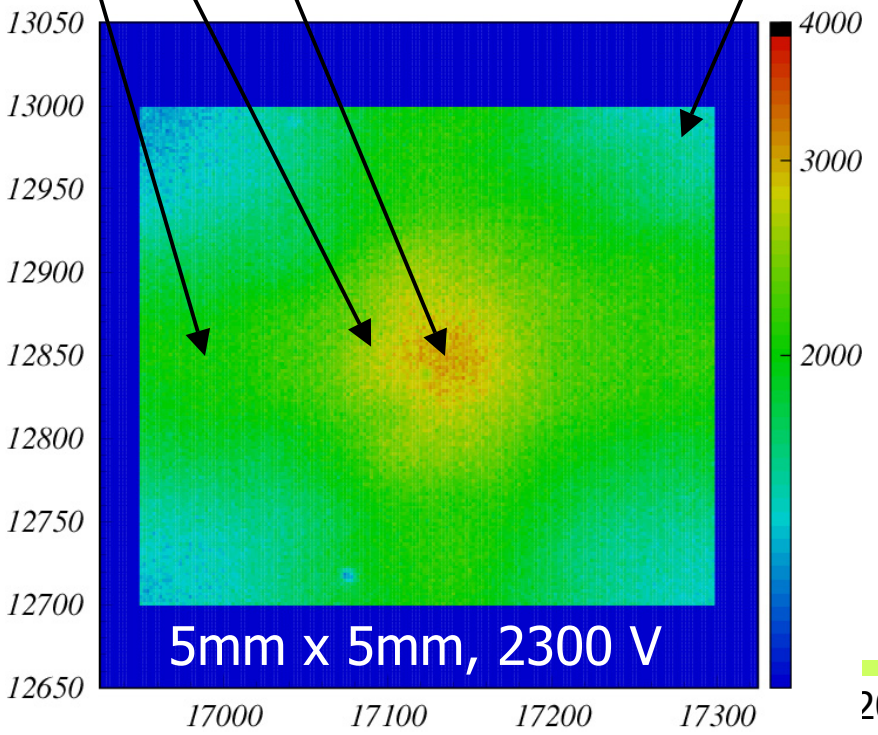
single channel response:
- uniform over pad area
- extends beyond pad area (charge sharing)

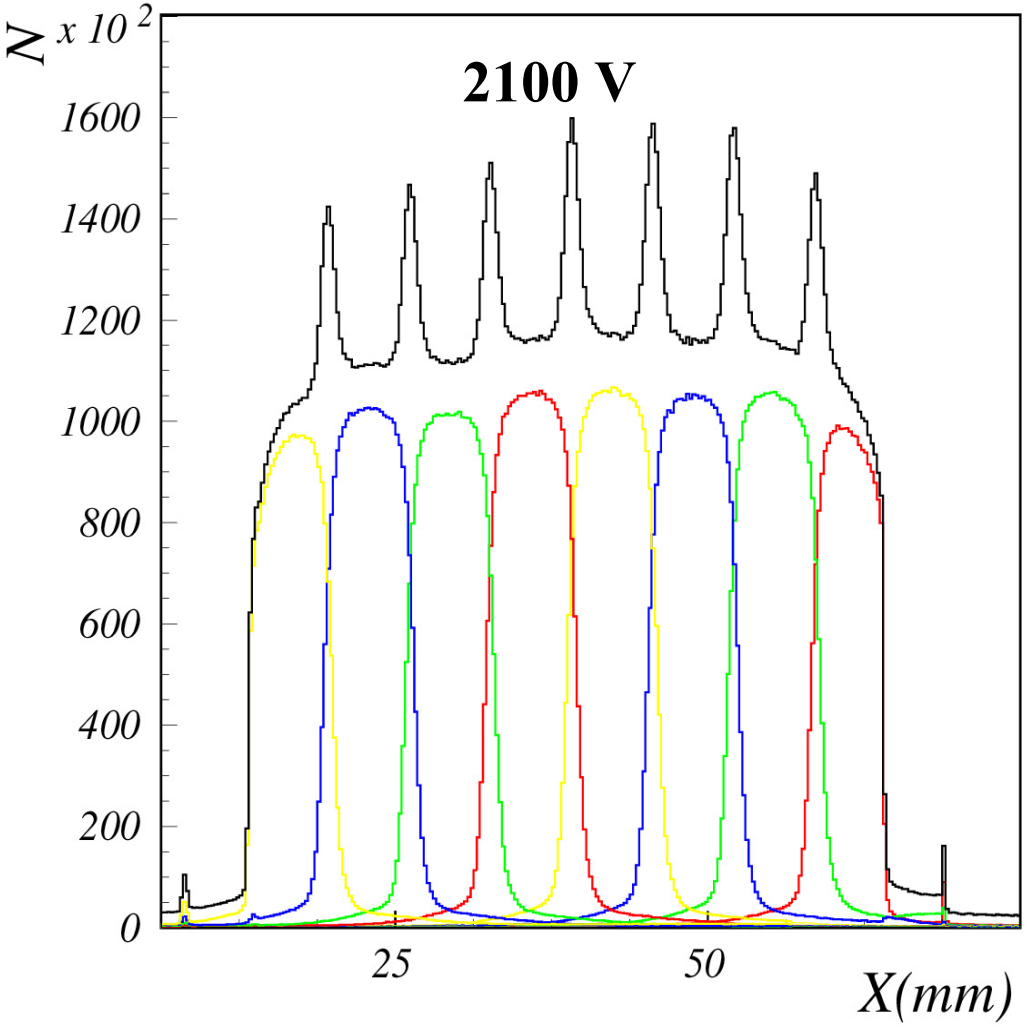




Charge sharing

- variation of the counting rate at the corner of four pads
- single photon detected by 1, 2, 3 or 4 channels

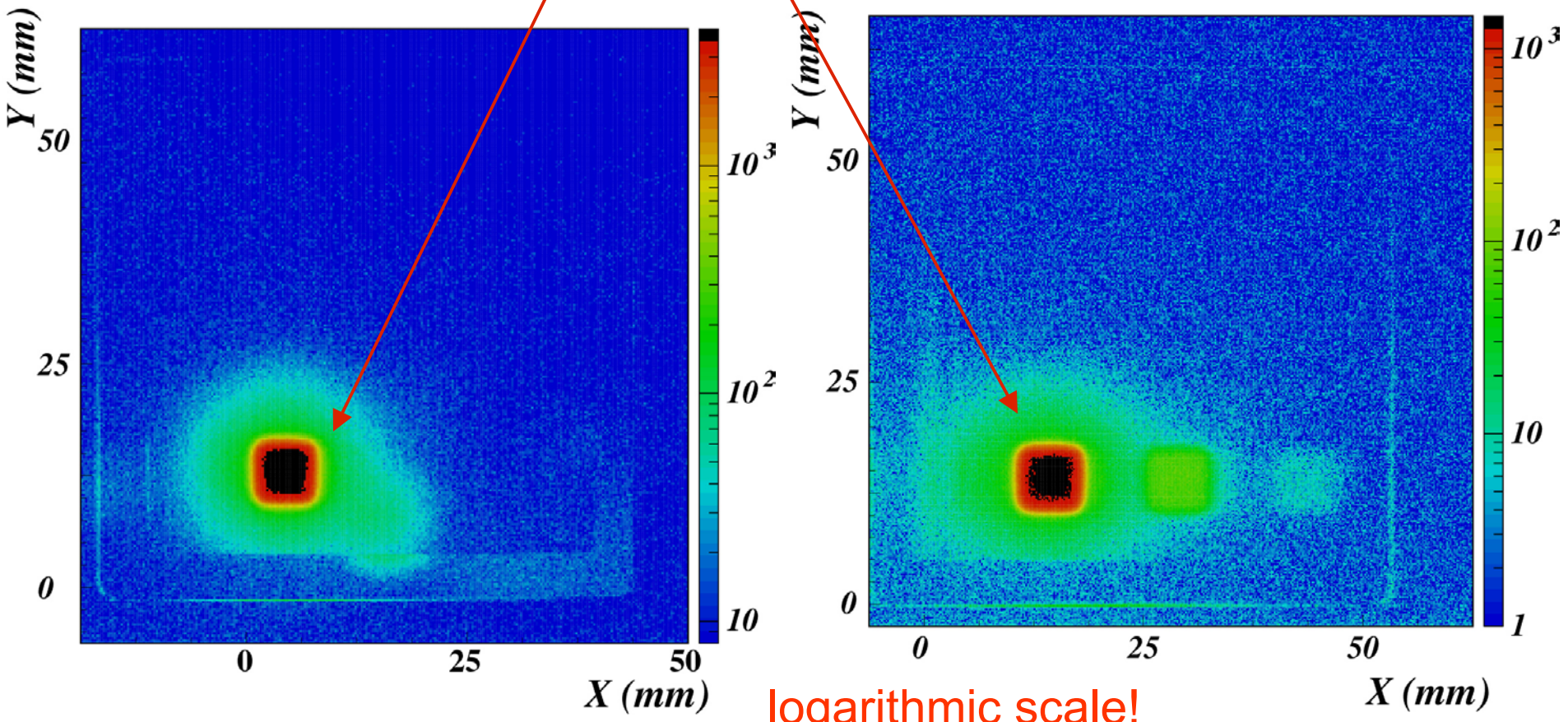




Slice of the counting rate distribution including the central areas of 8 pads (single channels - colored, sum of all channels - black)

Effect of photon incidence angle

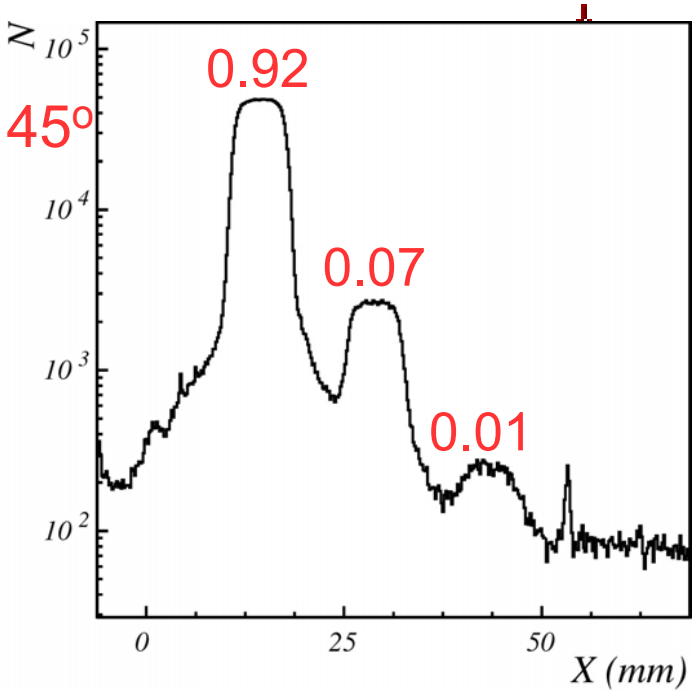
Single channel response for photon incidence angles of 0° and 45° (reflections)

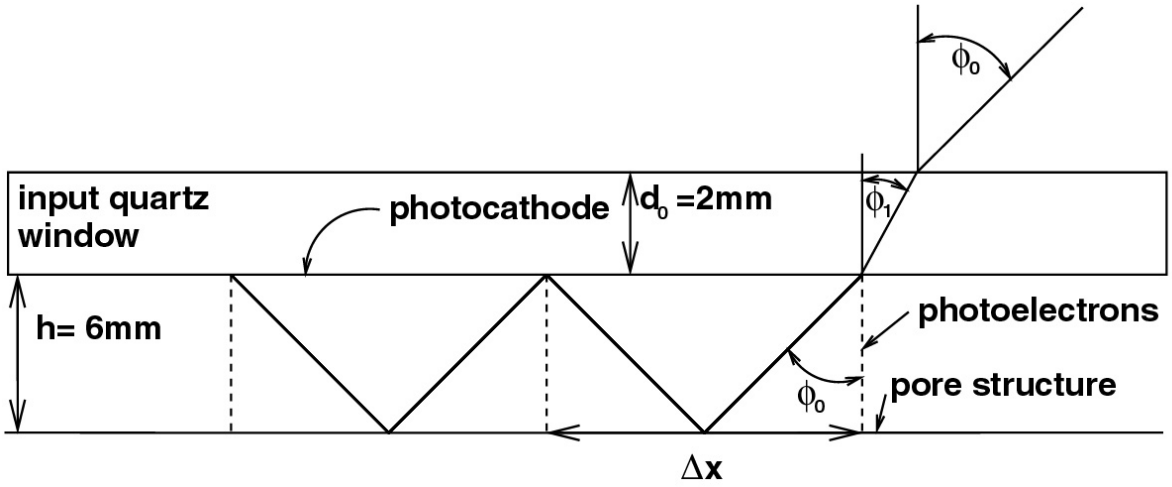


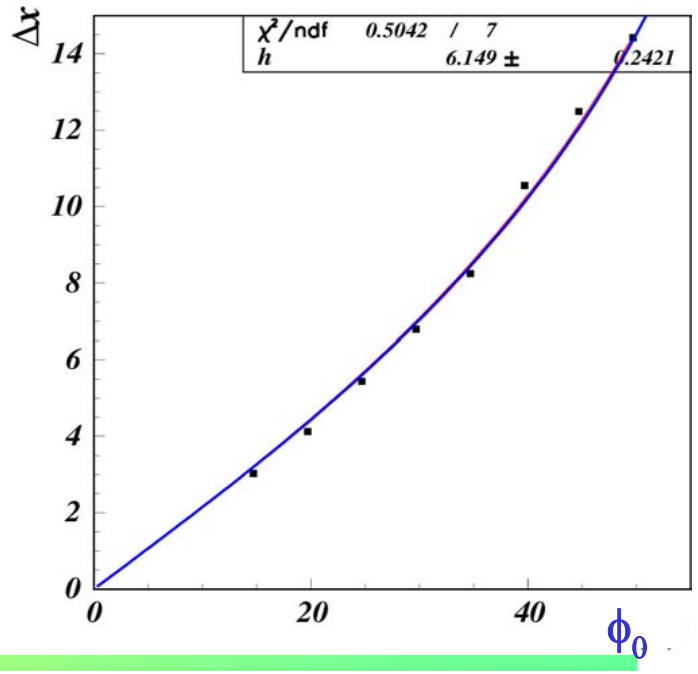
logarithmic scale!

Internal reflections

- relative intensities of the main peak, first and second reflections are 0.92, 0.07 and 0.01 respectively
- displacement of secondary image consistent with reflection from MCP surface



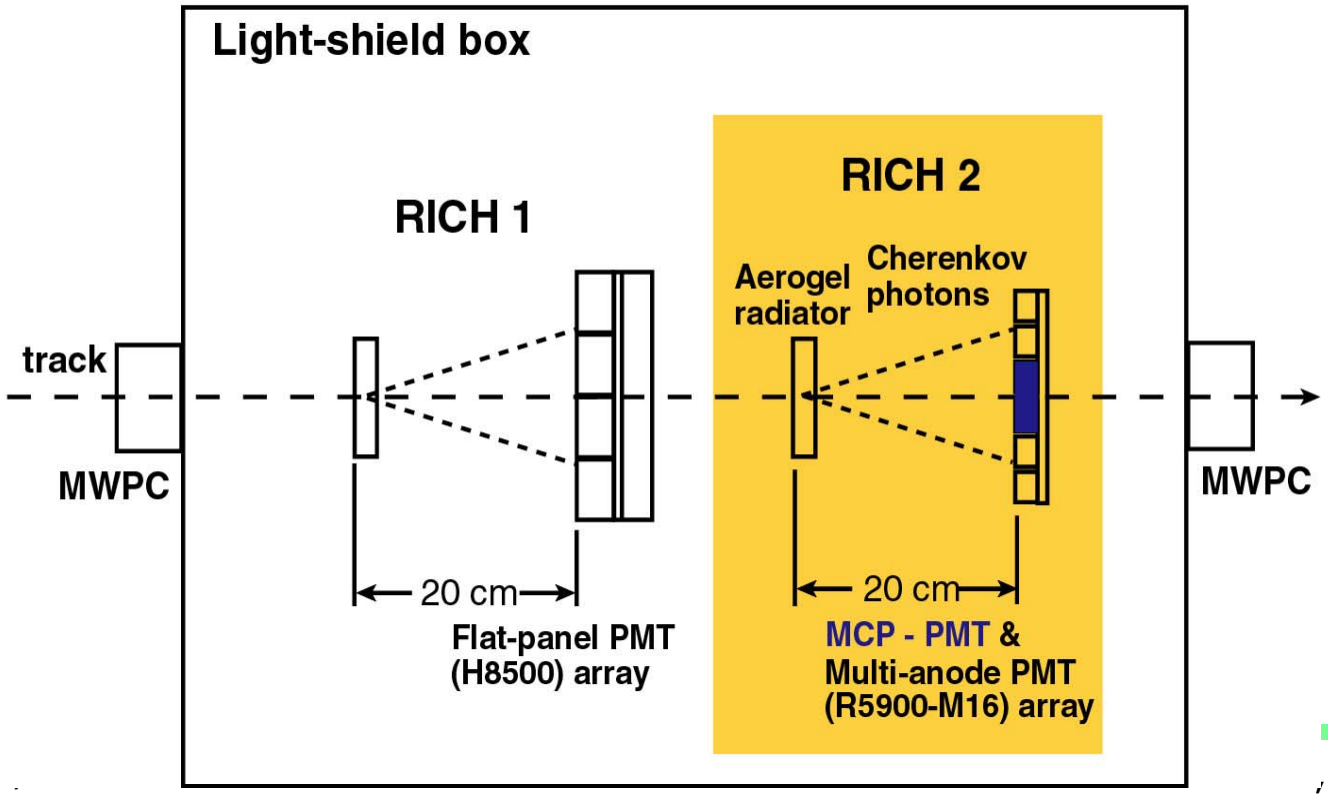




- impact on spatial resolution (+10% @18°)
- impact on timing resolution Δt ~ 40ps

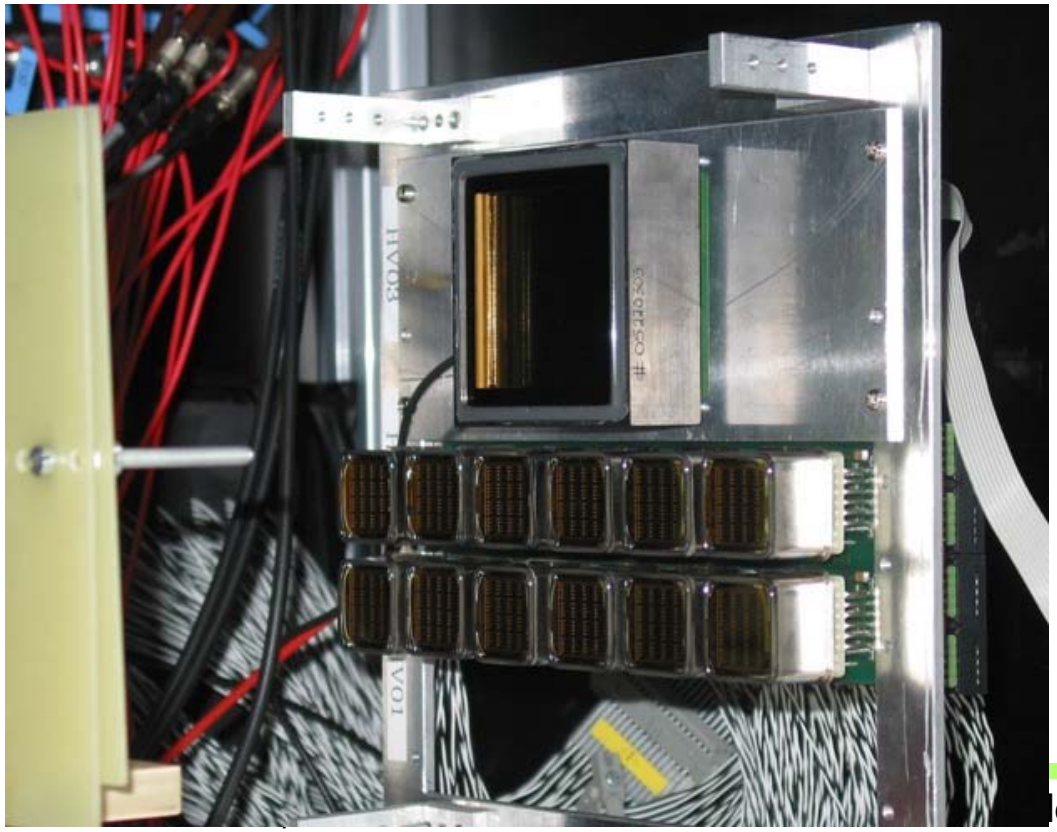
Beam test set-up

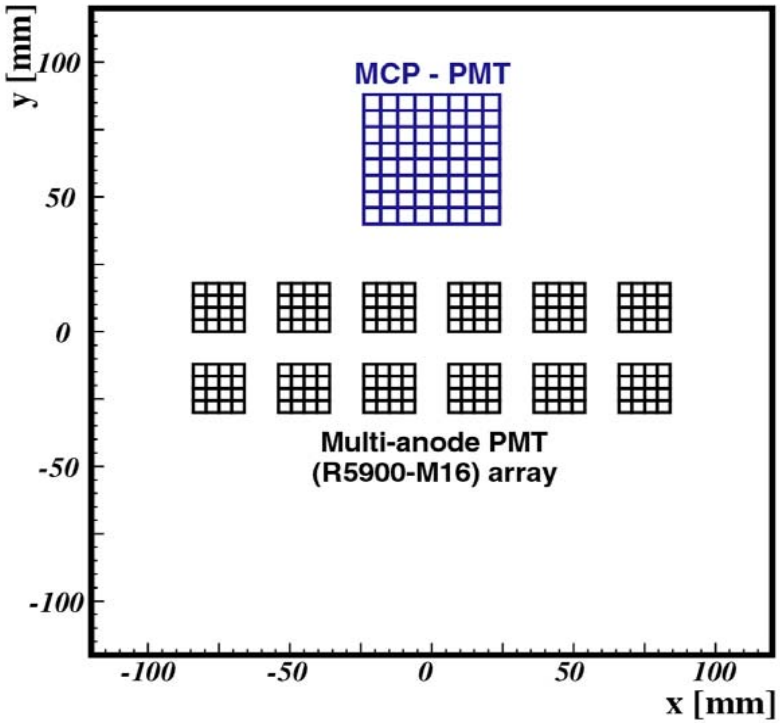
- pion beam 0.5 GeV/c - 4 GeV/c
- two MWPCs for tracking
- same front end electronics (ASD8) as bench tests
- digital signals read out by VME TDCs
- different aerogel samples used



Beam test set-up 2

- **BURLE MCP-PMT** mounted together with an array of 12(6x2) **Hamamatsu R5900-M16 PMTs** at 30mm pitch (reference counter)



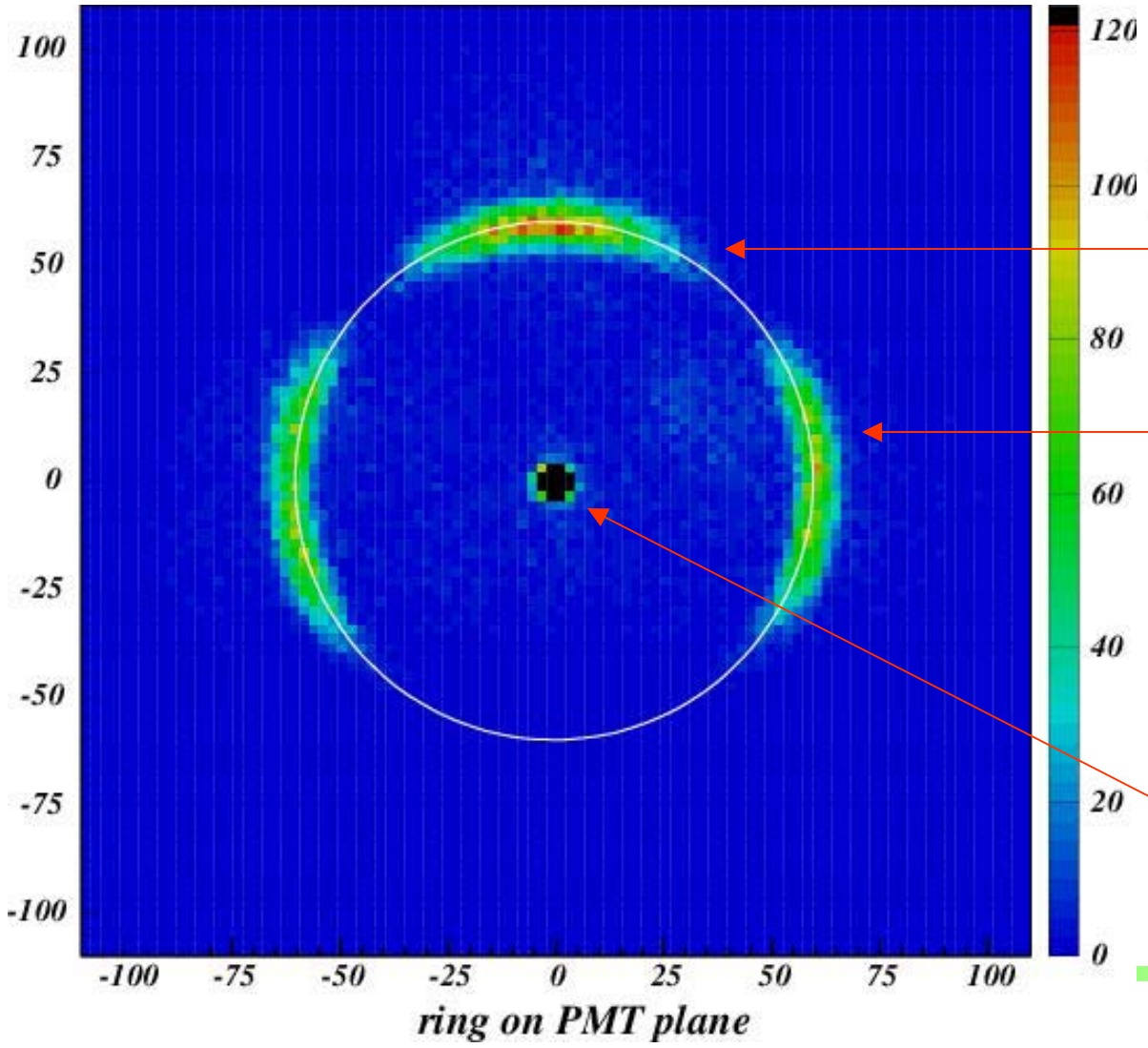


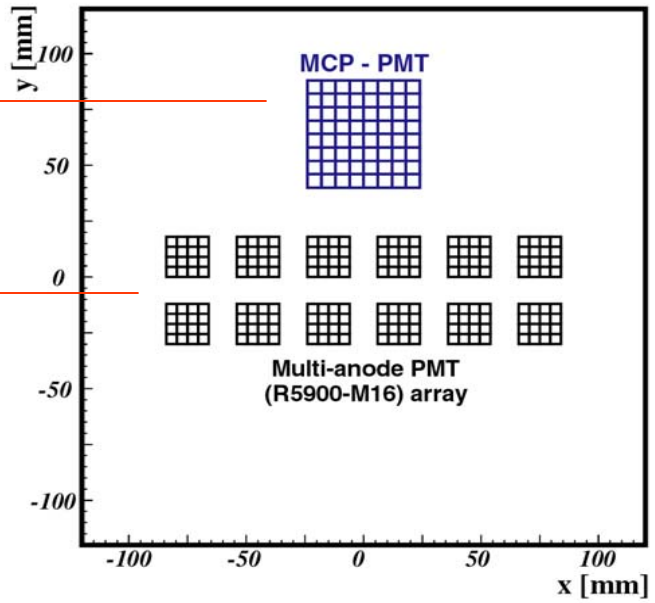
R5900-M16 characteristics:

- bialkali photocathode
- 16 (4x4) pads, pitch 4.5mm
- active area fraction ~ 36%
- collection efficiency ~ 75%

Cherenkov ring

- accumulated rings on MCP-PMT and M16 PMTs



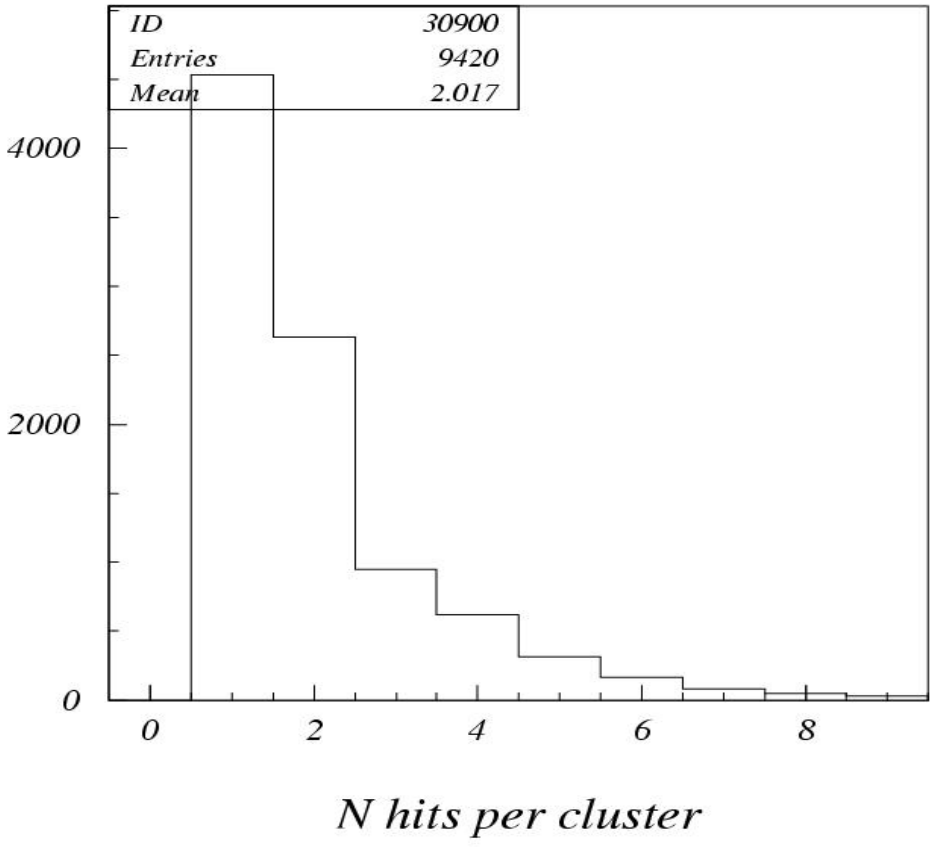


Cherenkov photons emitted in the PMT window

Hit clustering

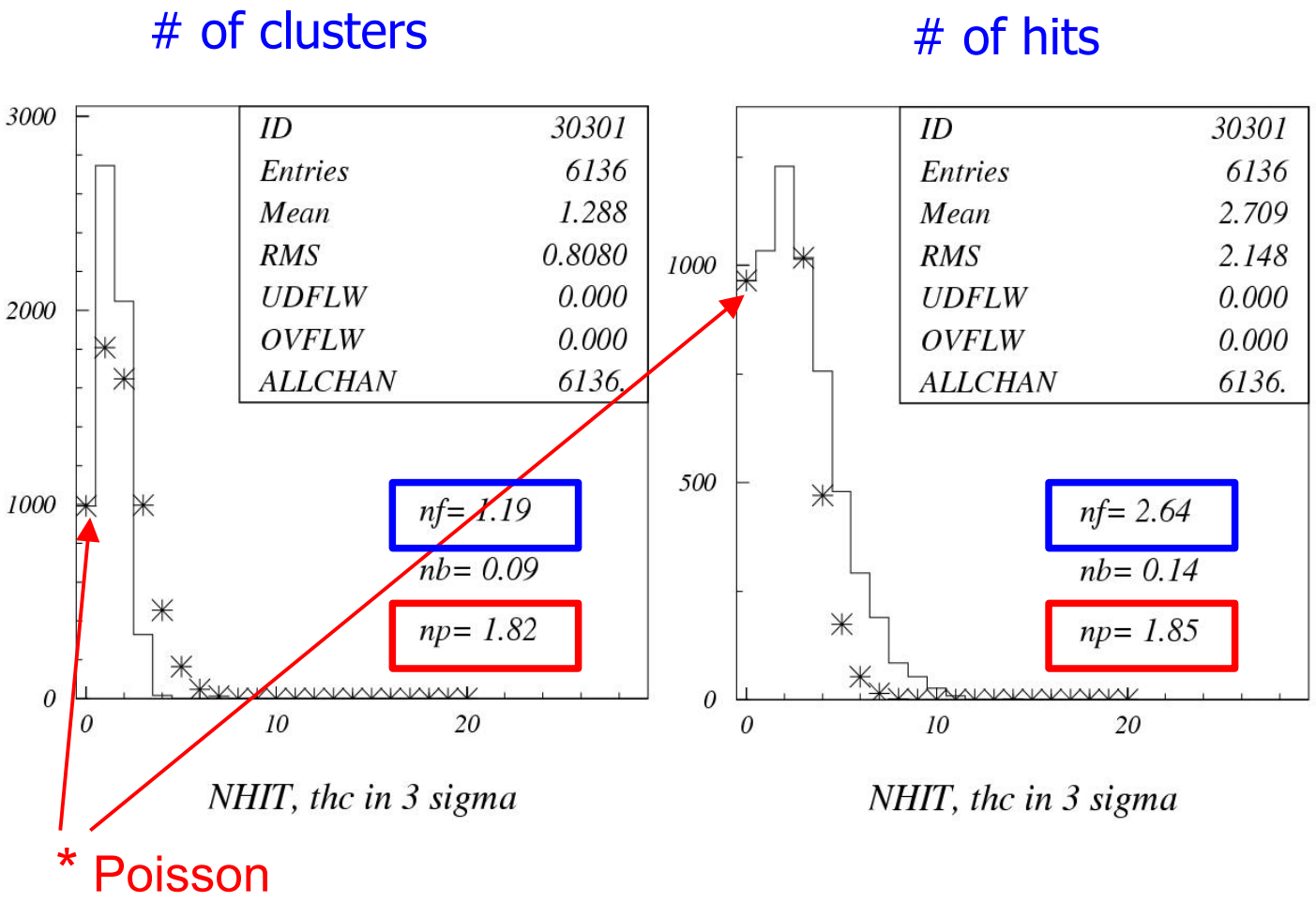
Charge sharing -> expect clusters instead of single hits

Number of hits per cluster



Impact on
-> resolution
-> # of rec. photons

Number of hits



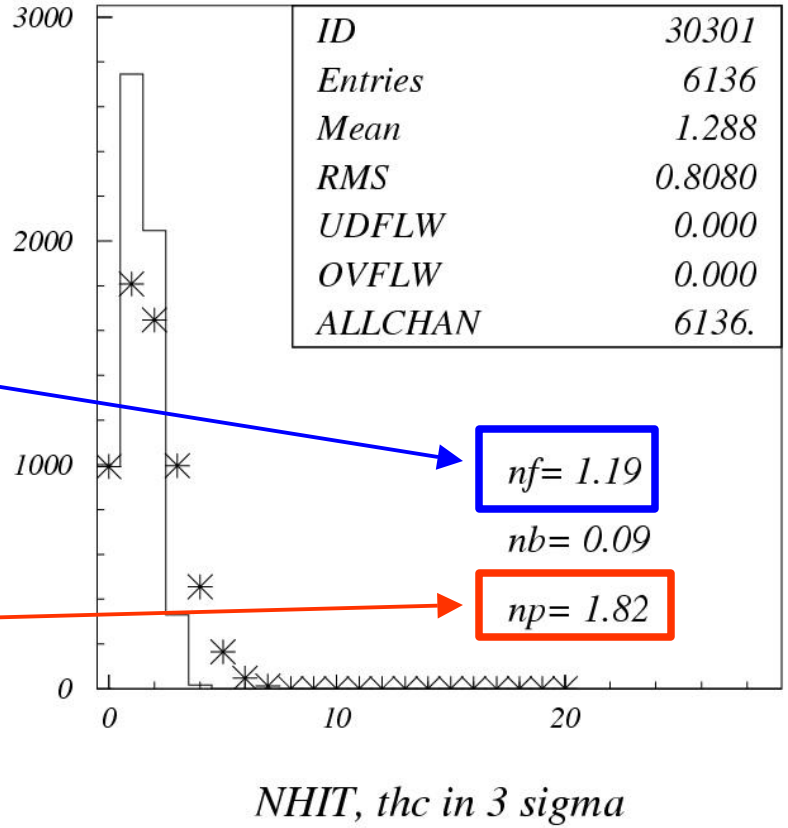
Number of hits 2

clusters

- N = ~ 1.2 (@ 13%)
- full ring ~ 9
- full coverage ~ 4.5 (@ 52%)

photons (from Poisson zero hit probability P(0))

- N = ~ 1.8 (@ 13%)
- full ring ~ 14
- full coverage ~ 7 (@ 52%)



Number of hits 3

Cross-check: comparison with the reference detector

MCP-PMT photons (from Poisson)

- N = ~ **1.8** (@ 13%)
- full ring ~ **14**
- full coverage ~ 7 (@ 52%)

R5900-M16-PMT photons

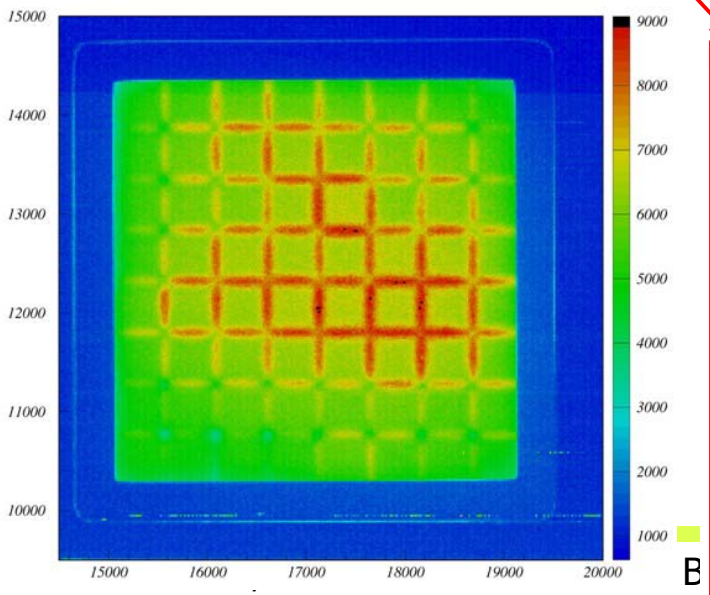
- N = ~ **1.95** (@ 11%)
- full ring ~ **17.5**
- full coverage ~ 6.5 (@ 36%)

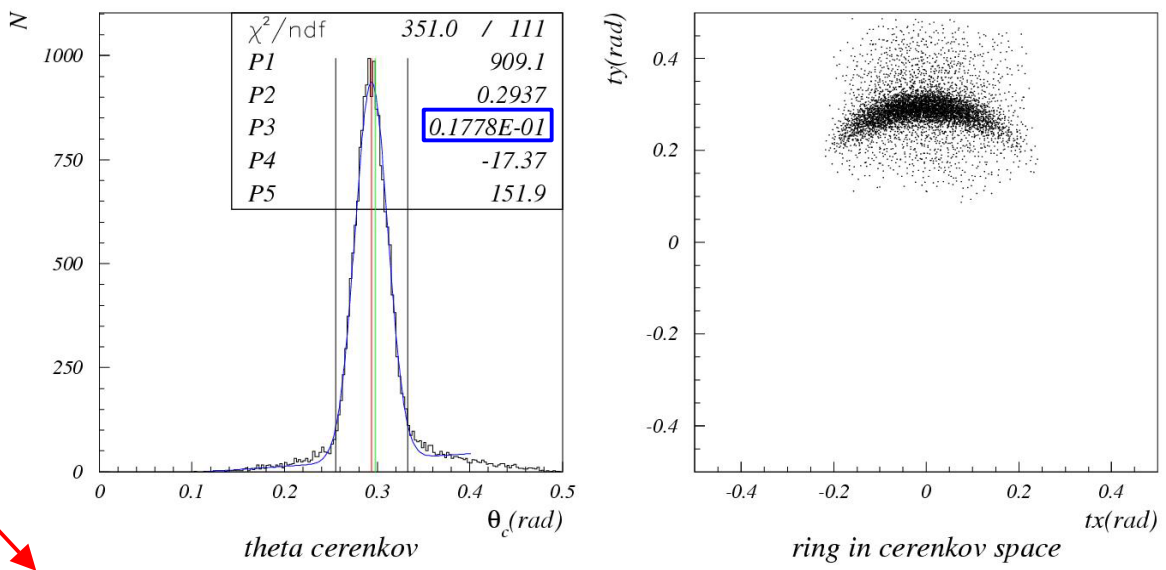
Photons per ring MCP-PMT: **14** R5900-M16: **17.5**
consistent with the ratio of collection eff. **60%** vs **75%**

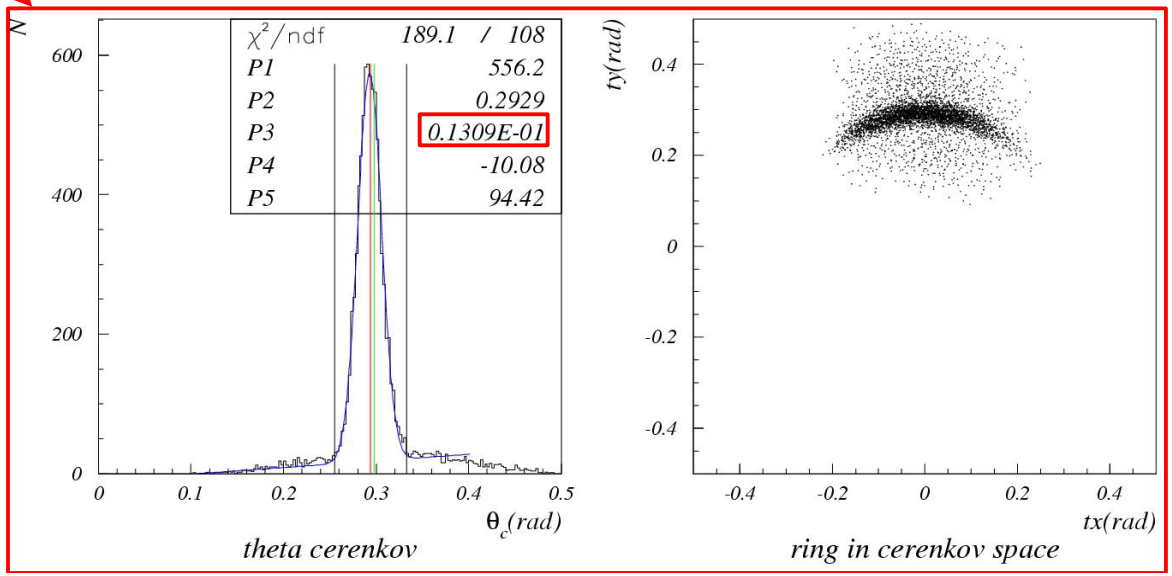
Resolution

- charge sharing at the edges of pads ->
  resolution improves if using center of gravity of the cluster

s_J: 17.8 mrad -> 13.1 mrad







Resolution per track

- 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**

->marginal

Open questions

Operation in high magnetic field:

- the present tube with 25μm pores only works up to 0.8T
- for operation at 1.5T – pores size ~10μm

Number of photons per ring: too small.

Possible improvements (producer):

- bare tubes (52%->63%)
- increase active area fraction (bare tube 63%->85%)
- increase the photo-electron collection efficiency

(from 60% at present up to 70%)

Open questions

Extrapolation from the present data

4.5 hits per ring -> 8.5

σ_ϑ per track: 6 mrad -> 4.5 mrad

-> >5 σ π/K separation at 4 GeV

-> looks OK on paper, see what Burle manages

Operation in 1.5T mag. field: test MCPs with 10μm pores

Aging of the MCP-PMTs

Can we get the 10μm tube at all???

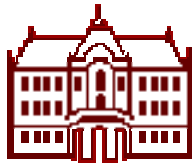
Summary

- BURLE MCP multianode PMT performed very well as a single photon detector both on the bench and in the test beam.
- The Cherenkov angle resolution and yield are in good agreement with expectations.
- For the specific application (RICH counter with aerogel radiator) the photon yield is too low. Improvements foreseen (larger active area fraction, collection efficiency).

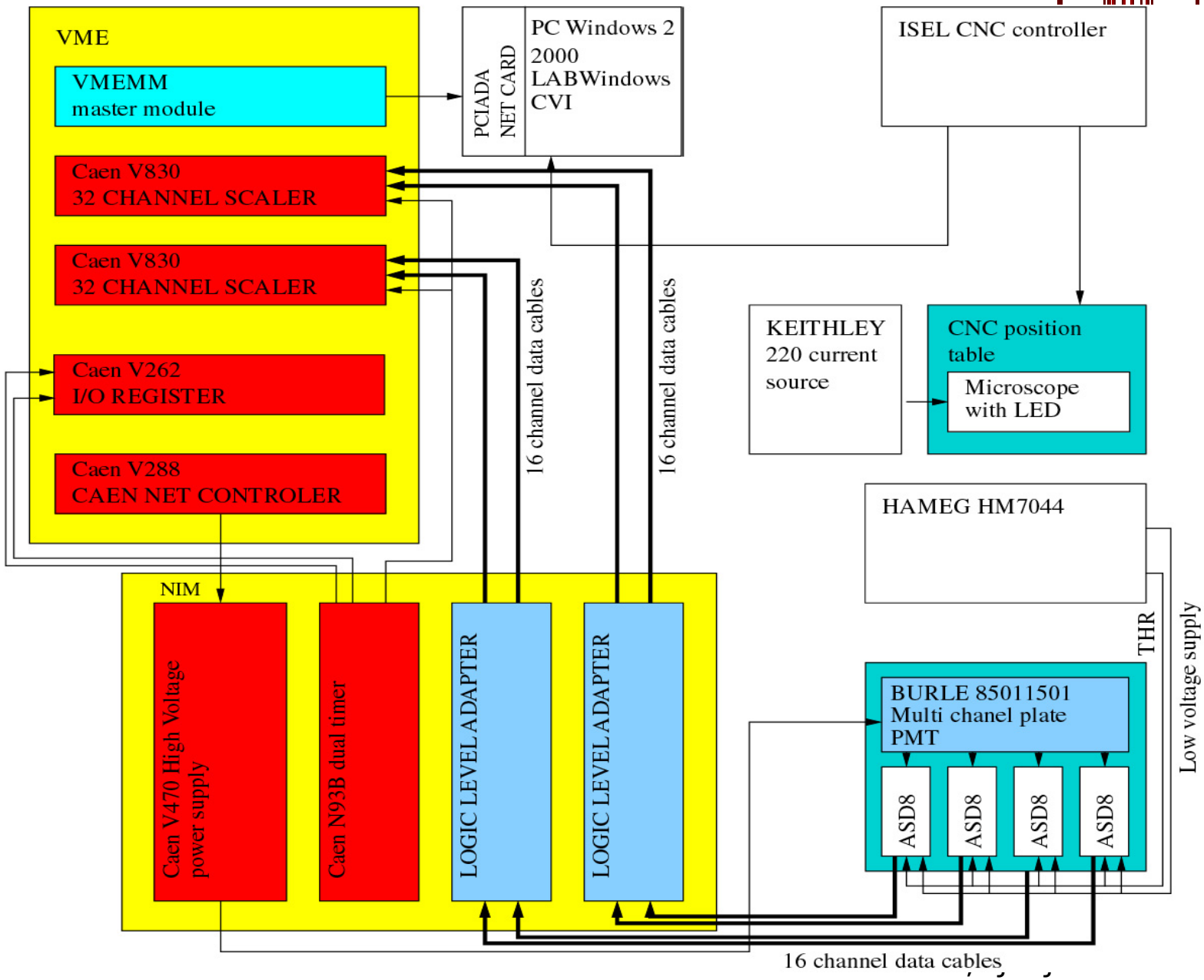
R&D issues:

- Testing of the versions with 10 μm pores (for operation in B=1.5T) and with larger active area fraction.
- Photo-electron collection efficiency: 60% -> 70%?
- Read-out electronics
- Ageing

Back-up slides

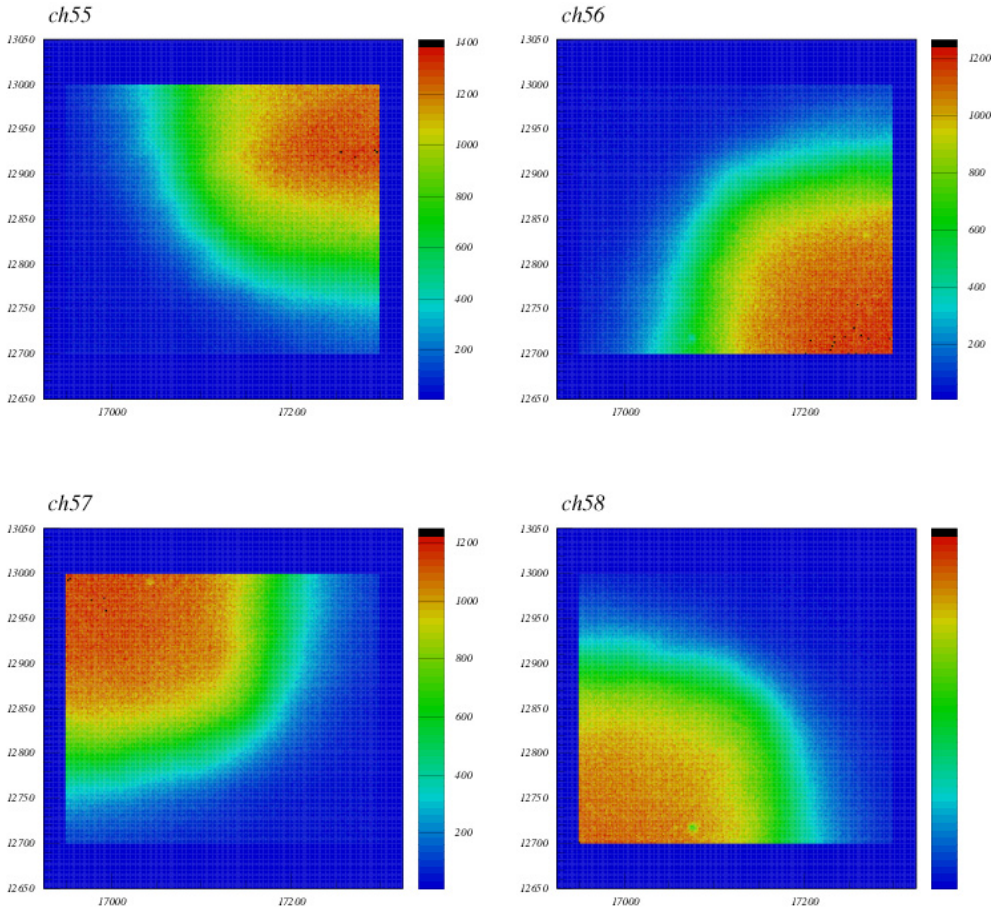


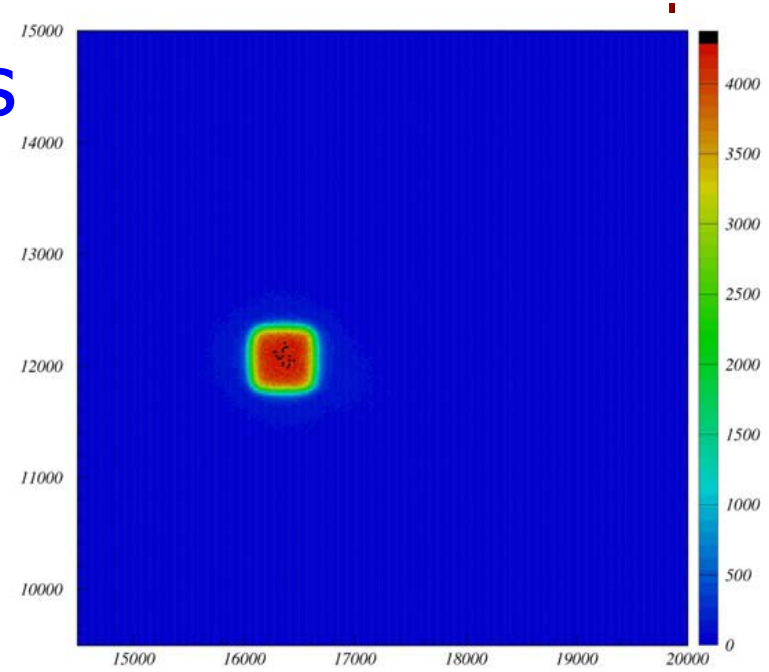
Bench test set-up - electronics

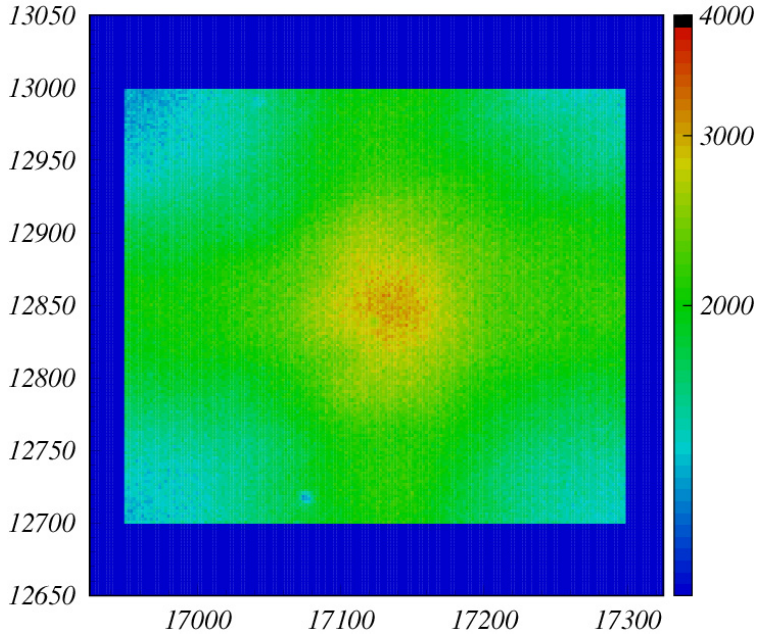


Surface scan - details

- uniform single channel response (right)
- fine scan over the boundary of 4 pads

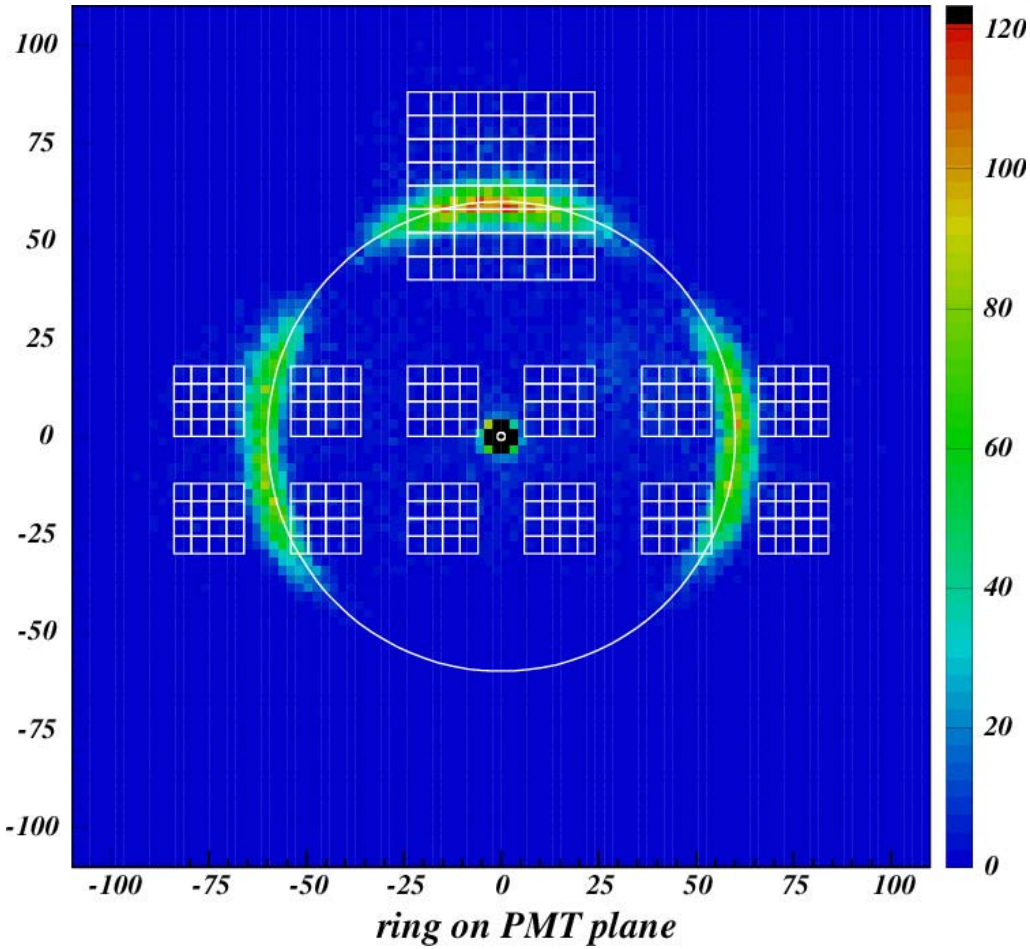


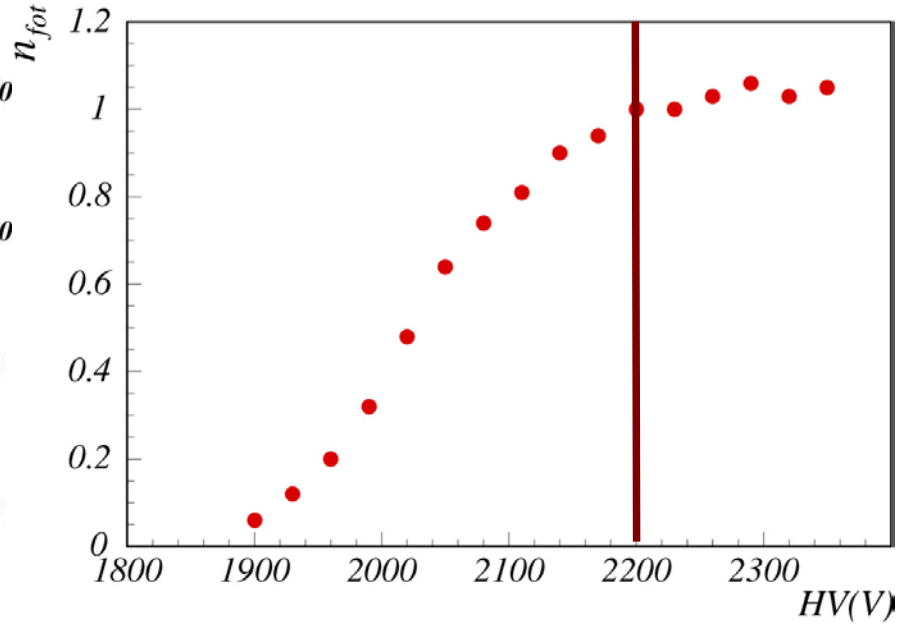




MCP-PMT: Cherenkov ring & HV scan

- accumulated rings on MCP-PMT and M16 PMTs

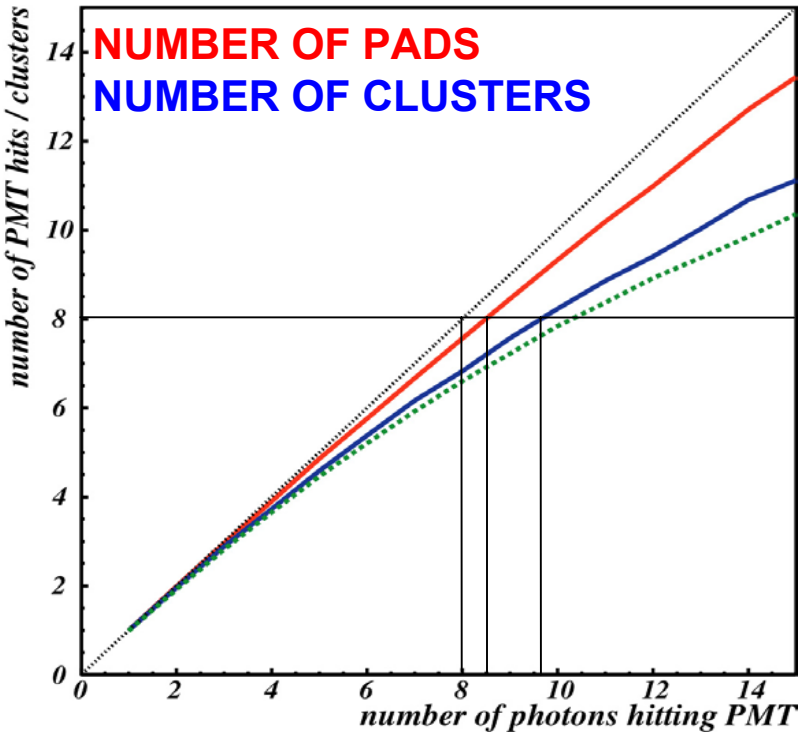




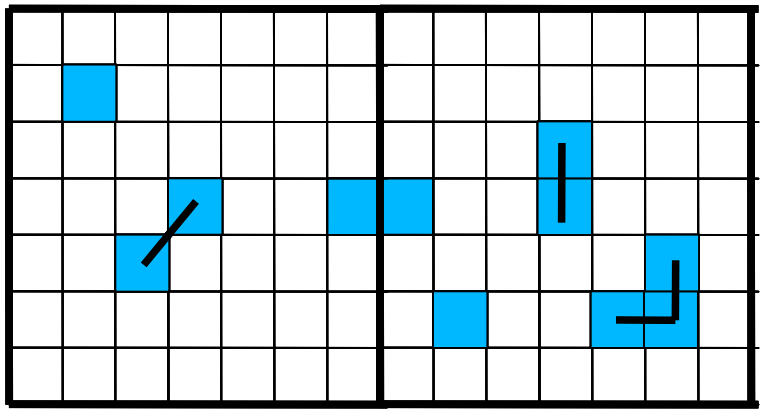
- HV scan: number of clusters in Cherenkov ring as a function of high voltage applied to MCP-PMT
- number of clusters reaches plateau at ~ 2200V

MCP-PMT: hit clustering

number of clusters <
number of incident photons < number of pads



An example:



- 11 pads
- 7 clusters

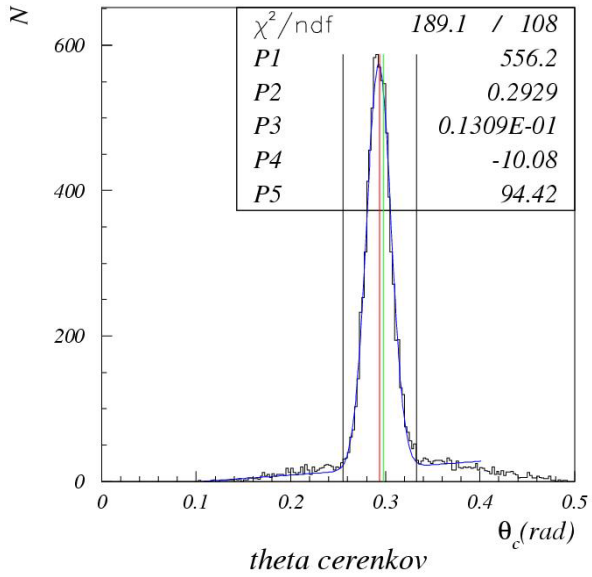
MCP-PMT: number of hits 2

clusters

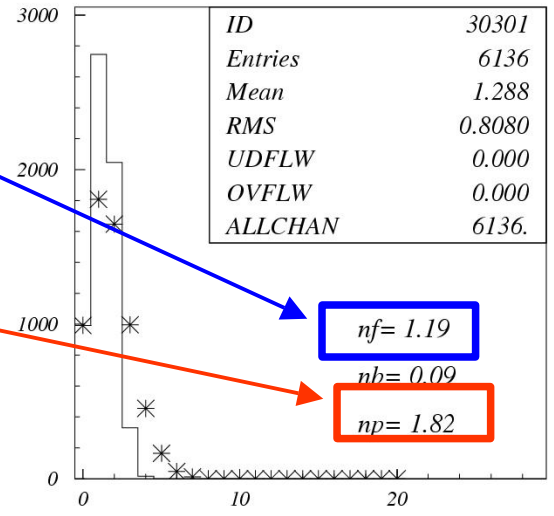
- N = ~ 1.2 (@ 13%)
- full ring ~ 9
- full coverage ~ 4.5 (@ 52%)

Photons (from Poisson zero hit probability P(0))

- N = ~ 1.8 (@ 13%)
- full ring ~ 14
- full coverage ~ 7 (@ 52%)



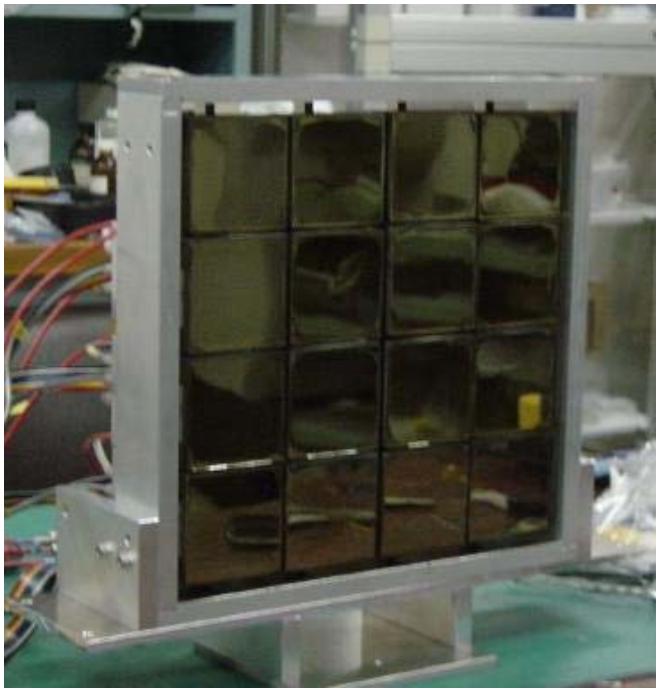
theta cerenkov



NHIT, thc in 3 sigma

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)

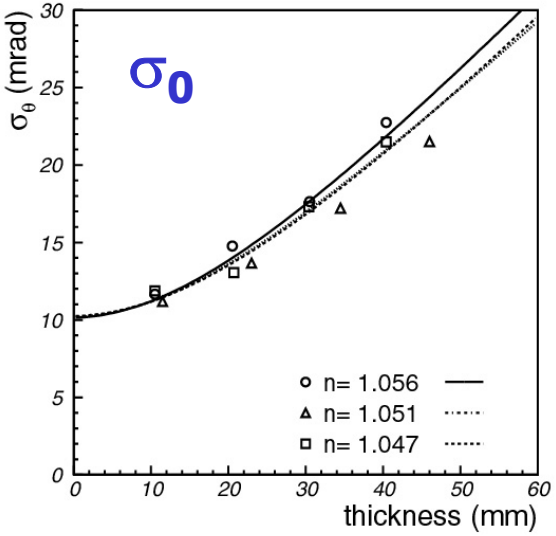


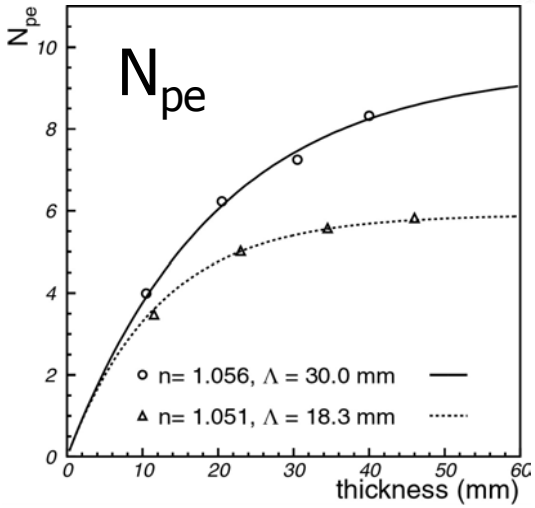
Not suitable for operation in magnetic field, but still good for the understanding of the detector behavior → intermediate step in our R+D

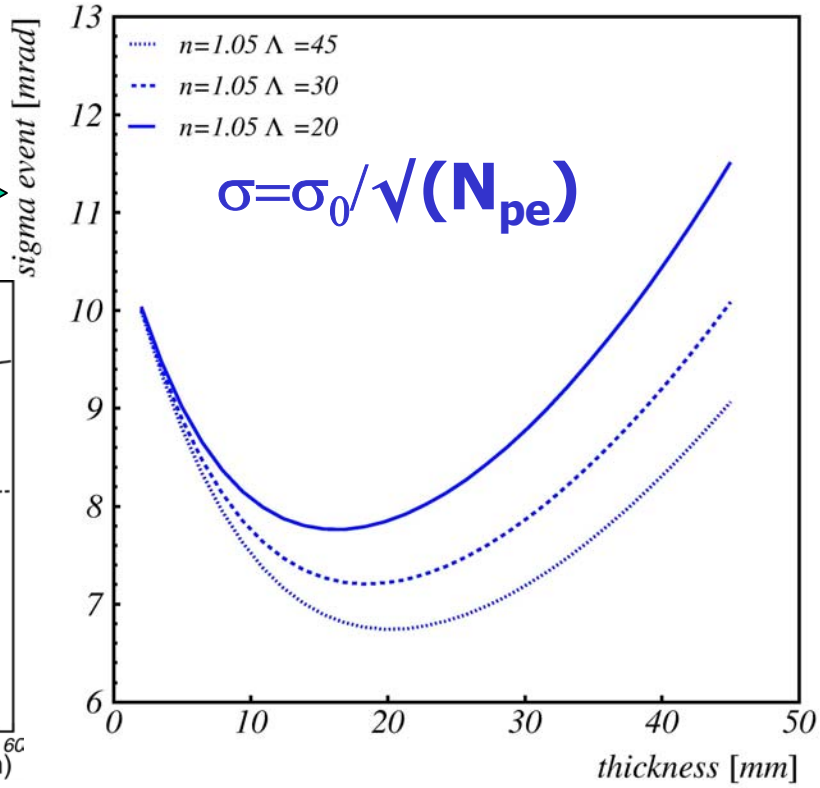
How to increase the number of photons?

What is the optimal radiator thickness?

Use beam test data on σ_0 and N_{pe}



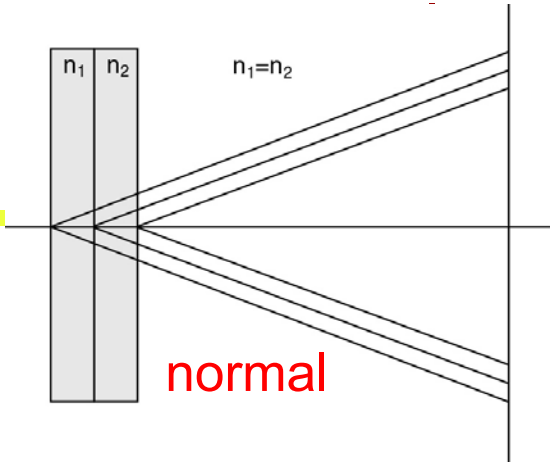




Minimize the error per track: $\sigma=\sigma_0/\sqrt{(N_{pe})}$

→ Optimum is close to 2 cm

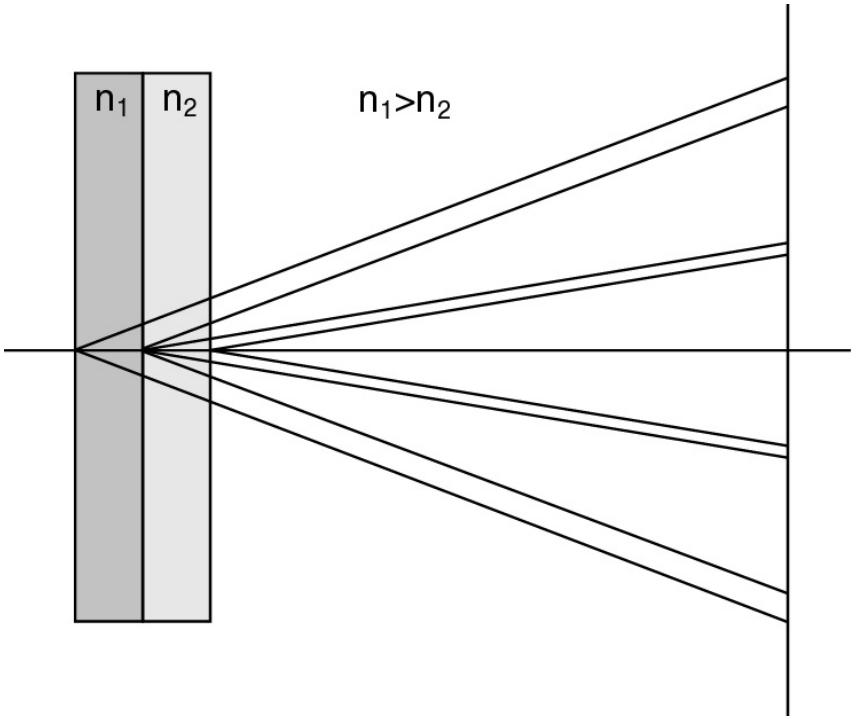
Radiator with multiple refractive indices



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

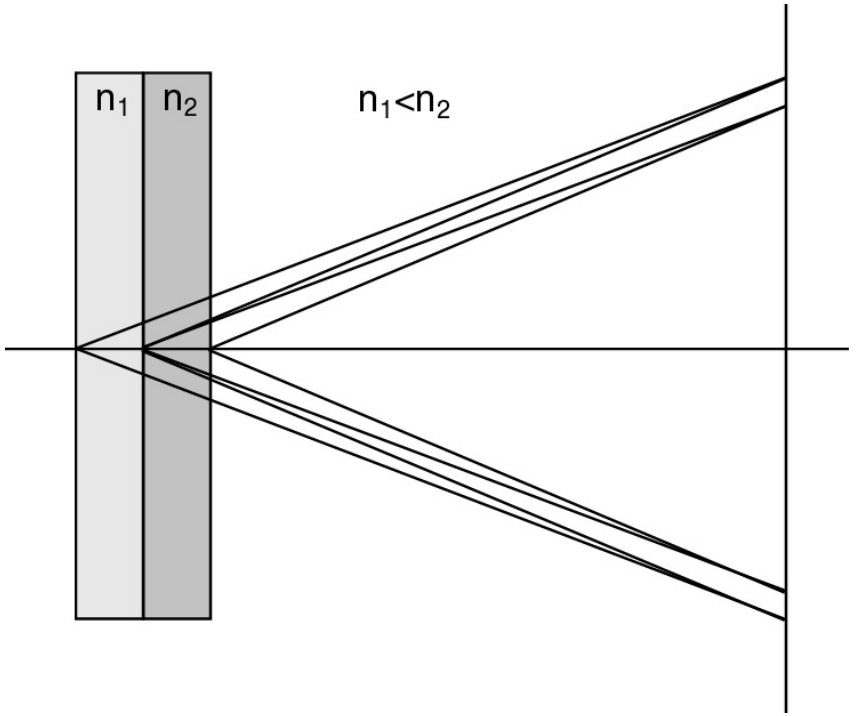
- measure two separate rings

"defocusing" configuration

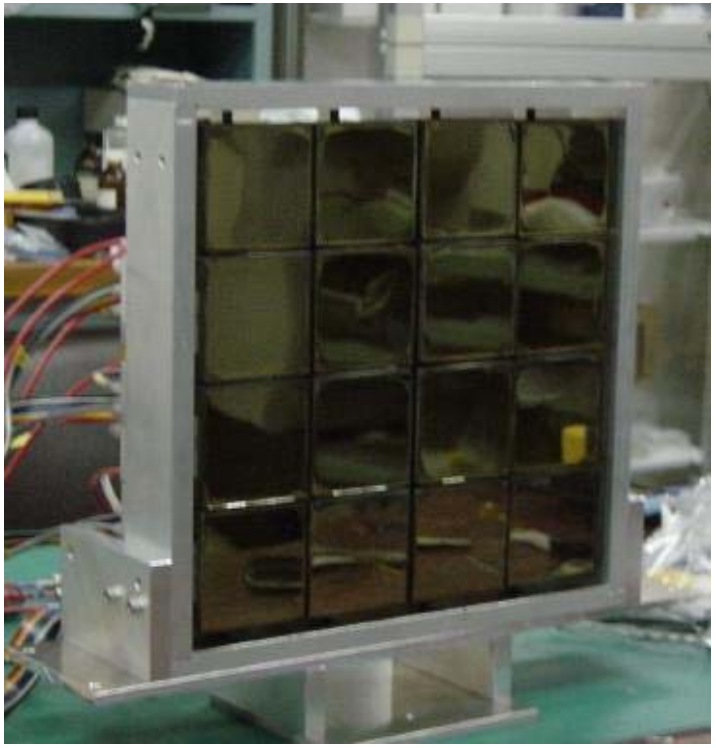


- measure overlaping rings

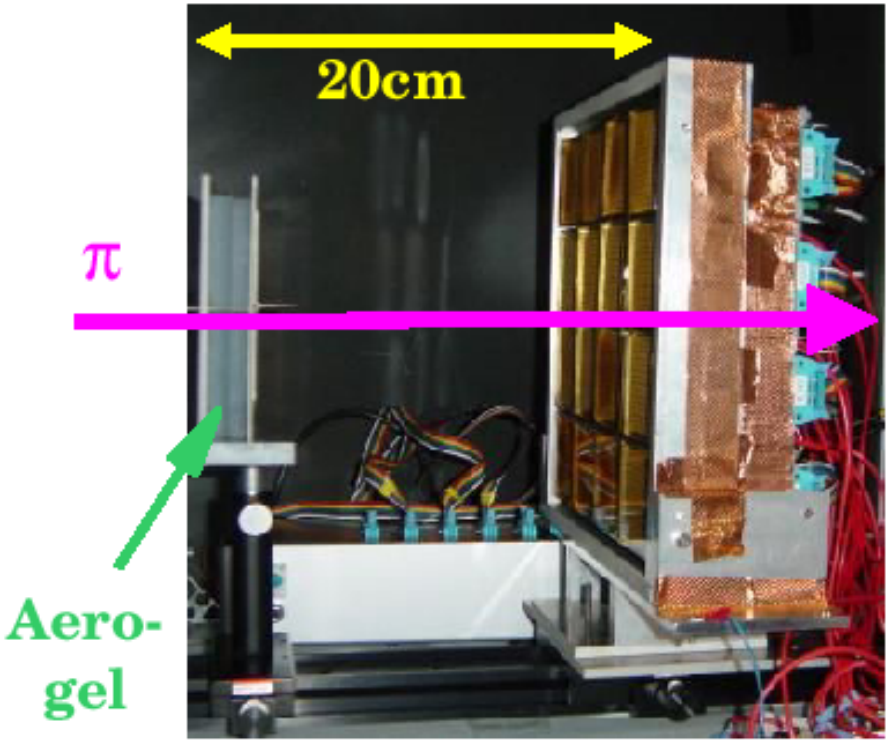
"focusing" configuration



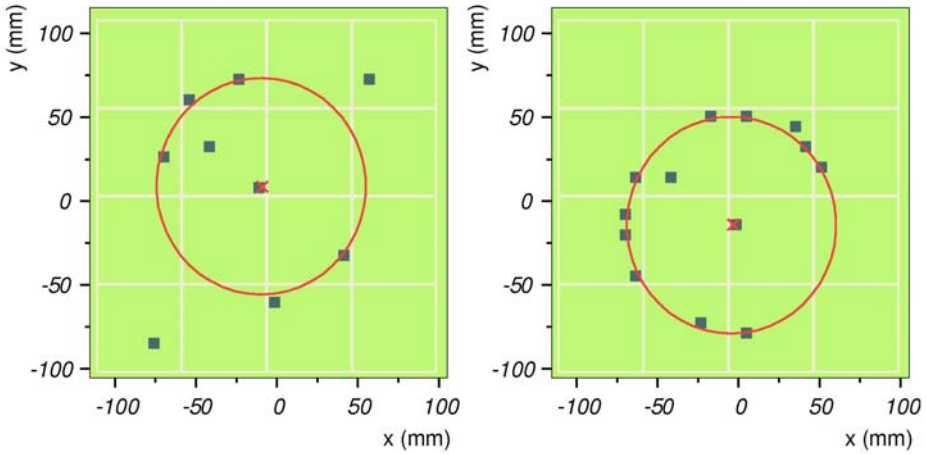
Beam tests



Photon detector: array of 16 H8500 PMTs

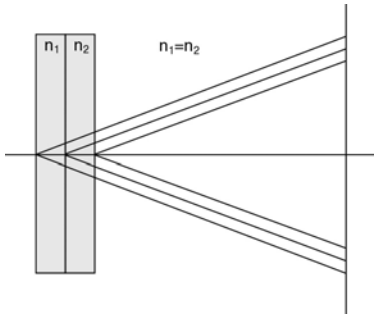


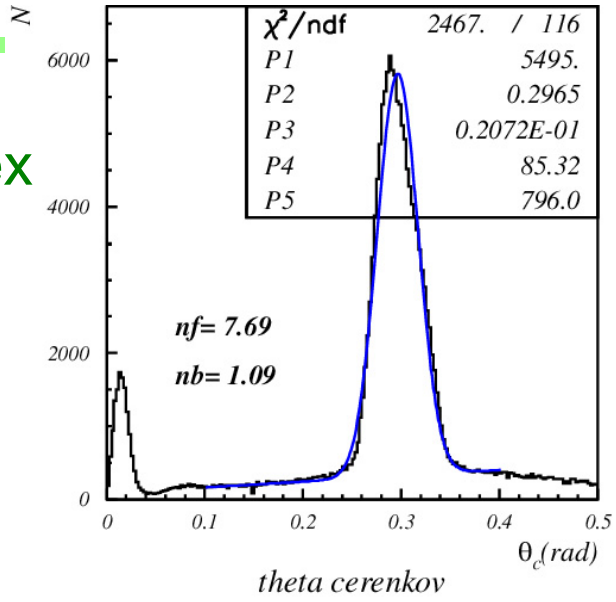
Clear rings, little background



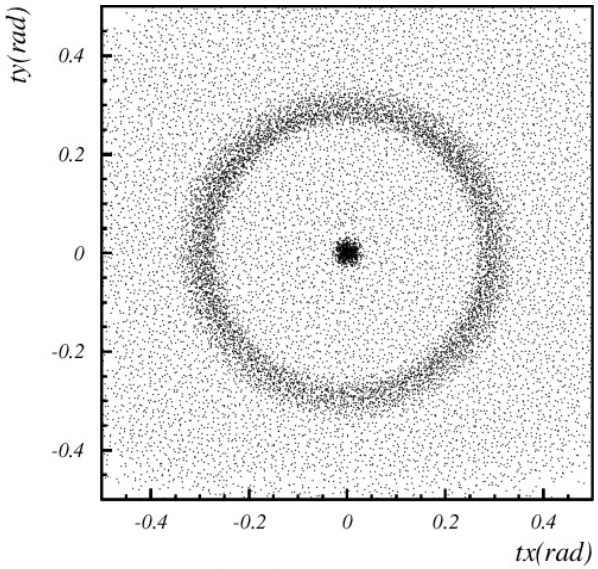
Focusing configuration - data

4cm aerogel single index





theta cerenkov



ring in cerenkov space

2+2cm aerogel