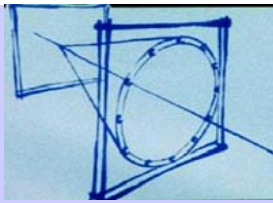

Tests of the BURLE 64-anode MCP PMT as the detector of Cherenkov photons

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RICH2004

November 30 – December 5, 2004

for BELLE Aerogel RICH group:

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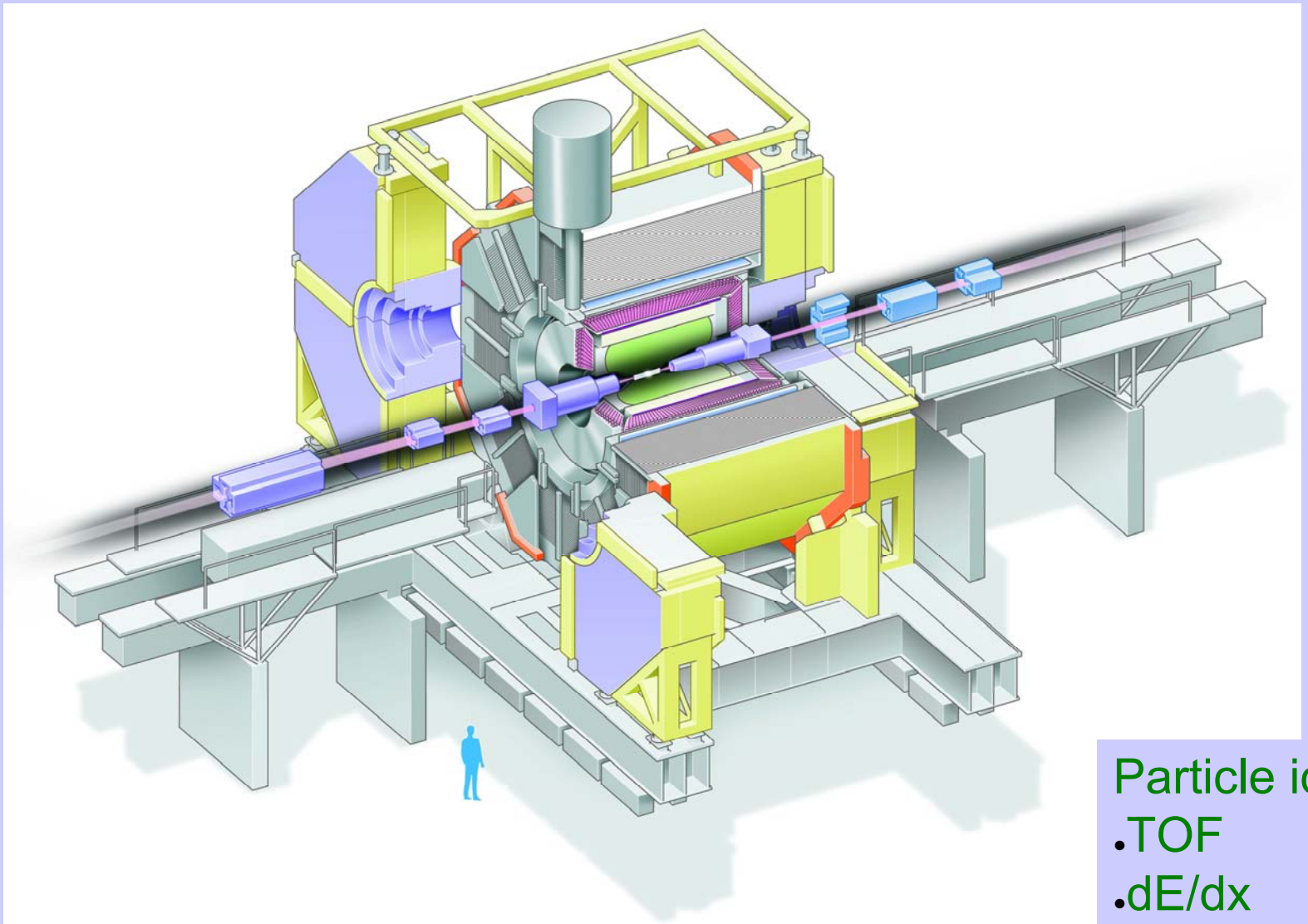
Y. Kozakai, P. Križan, T. Matsumoto, S. Nishida, S. Ogawa, S. Ohtake, R. Pestotnik,
S. Saitoh, T. Seki, A. Stanovnik, T. Sumiyoshi, Y. Uchida, Y. Unno, S. Yamamoto

- motivation - Belle PID upgrade
- BURLE MCP-PMT
- bench tests
- beam tests
- summary

Belle SPECTROMETER - PID

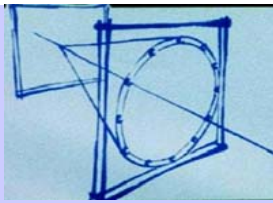
Large solid angle detector at the KEKB e^+ e^- collider



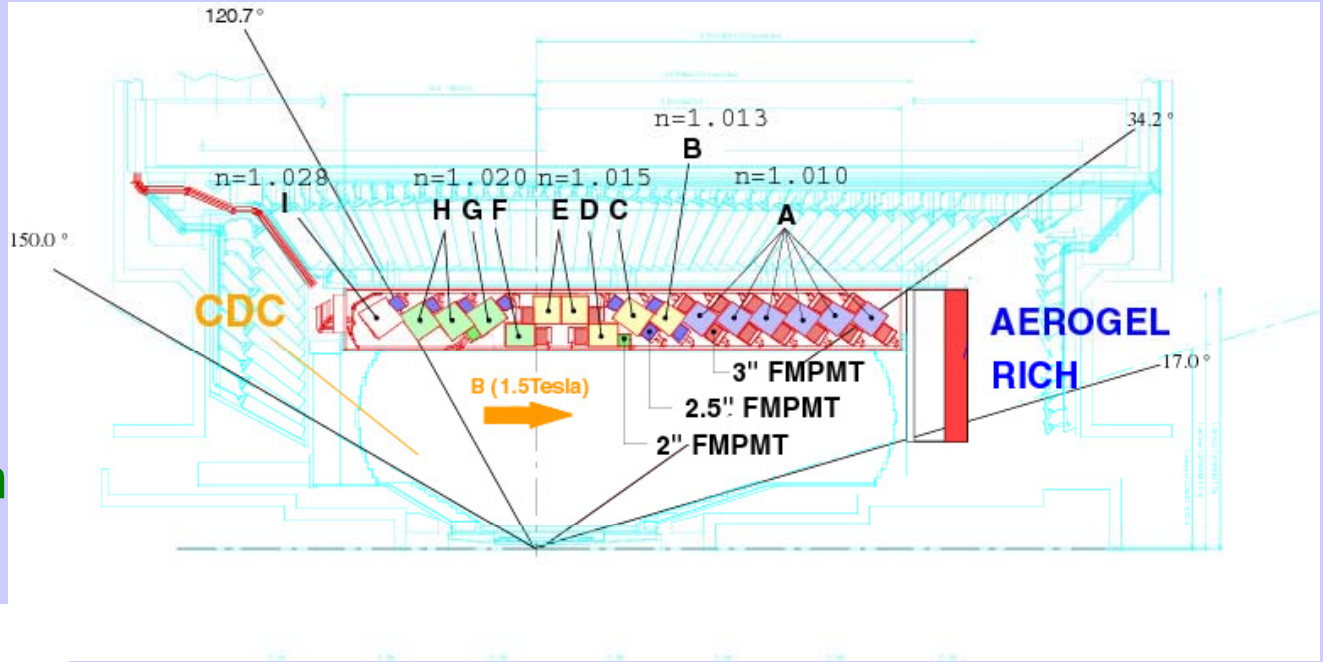
Particle identification:

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

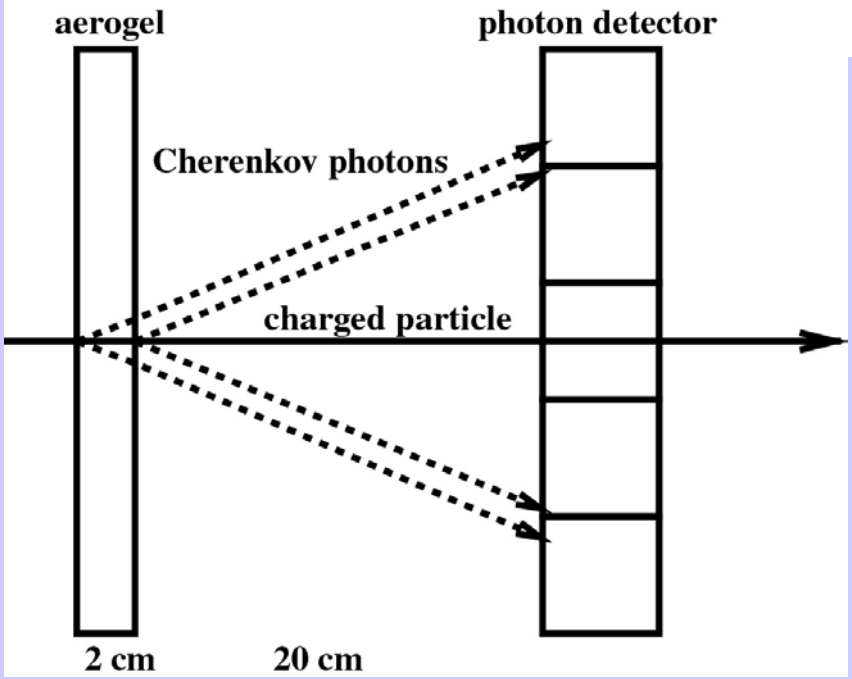
Belle PID UPGRADE



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



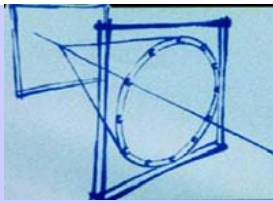
- proximity focusing RICH with aerogel radiator



aerogel RICH in 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

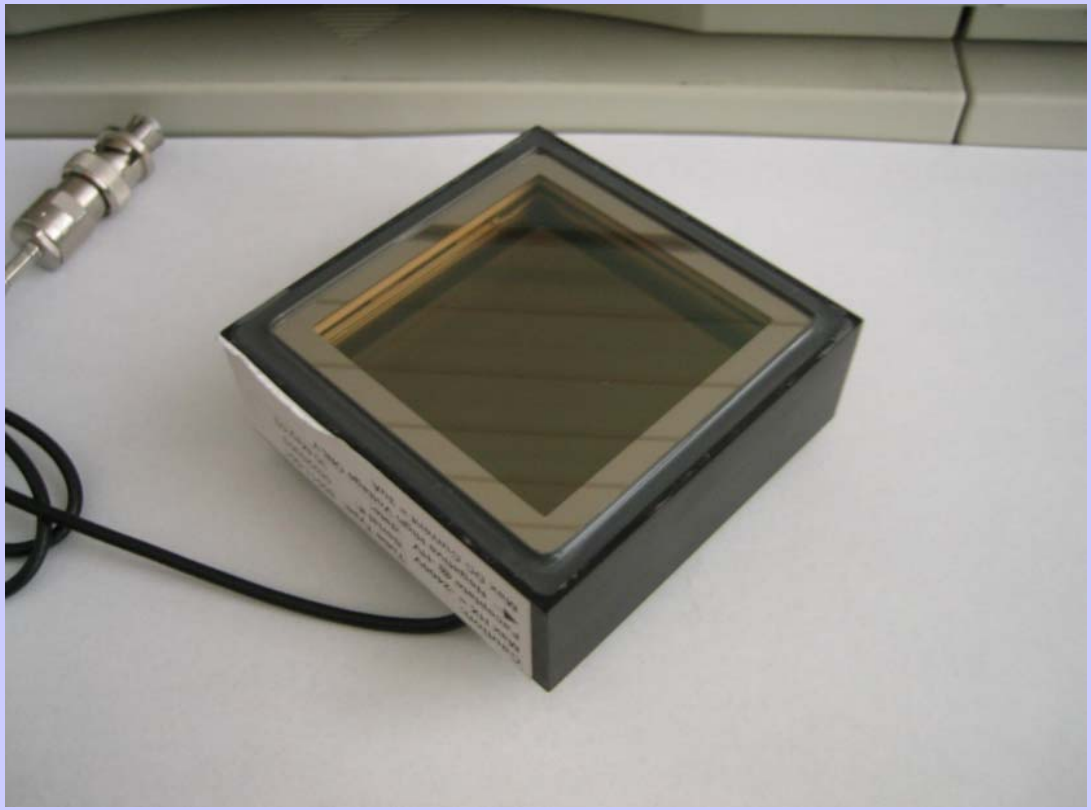
BURLE MCP-PMT CHARACTERISTICS



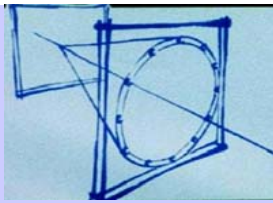
Photon detector has to operate in magnetic field of 1.5T

One of the candidates - BURLE 85011 MCP-PMT:

- multi-anode PMT with 2 MCP steps
- 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 SETUP



LIGHT SOURCE:

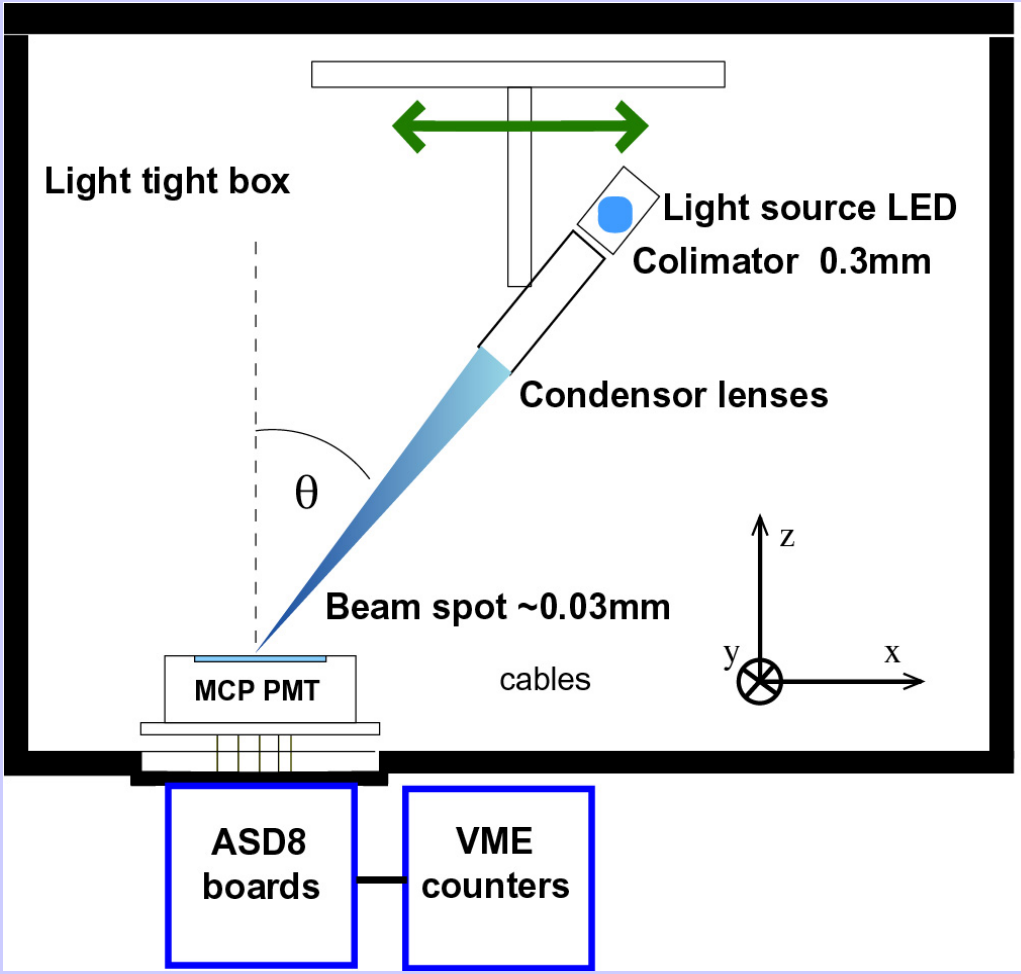
- blue LED (470nm) focused by microscope to ~ 30 μm
- 2D position of the light source is computer controlled in steps of 12.5 μm

READOUT ELECTRONICS:

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

ASD8 BOARDS:

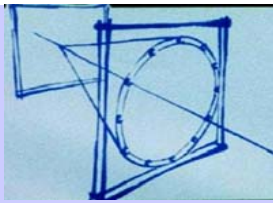
- used in the HERA-B RICH
- 16 channels (2 x ASD8 chips)



ASD8 = 8 channel amplifier, shaper and discriminator:

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

POSITION DEPENDENT SINGLE PHOTON COUNTING

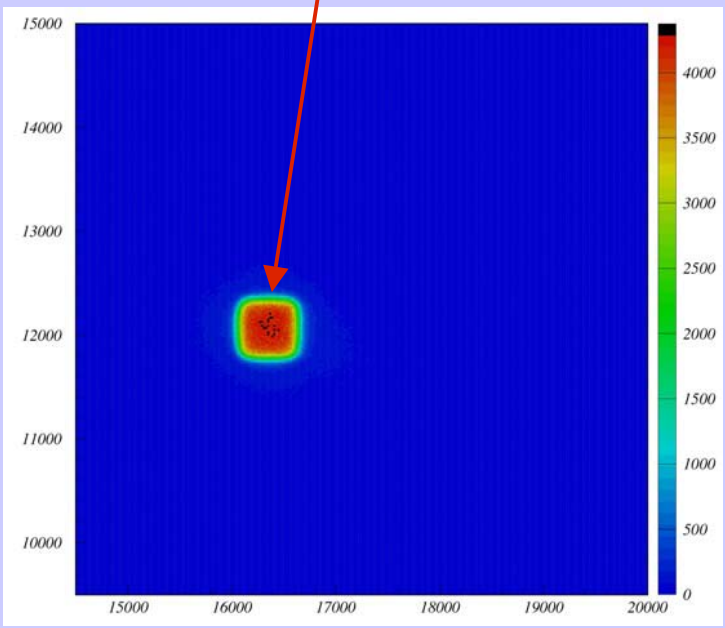


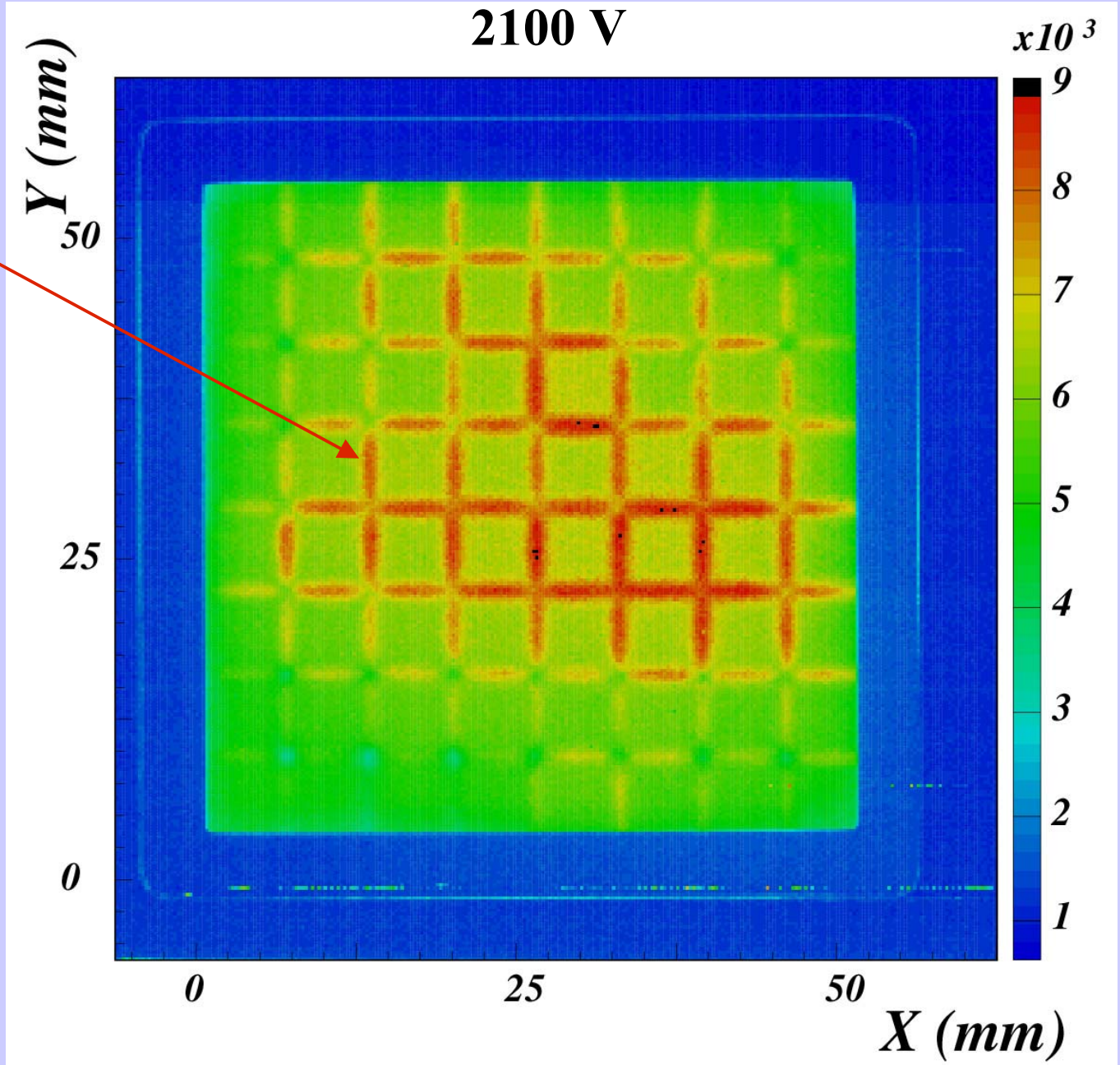
count rates - all channels:

- charge sharing at pad boundaries

single channel response:

- uniform over pad area
- extends beyond pad area (charge sharing)

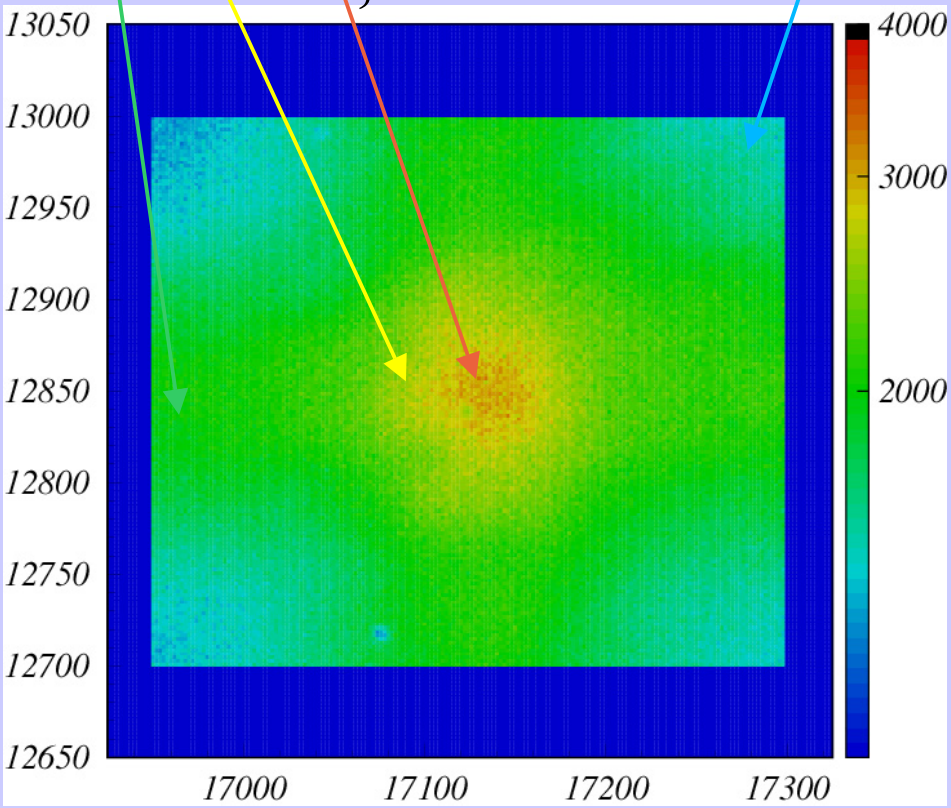


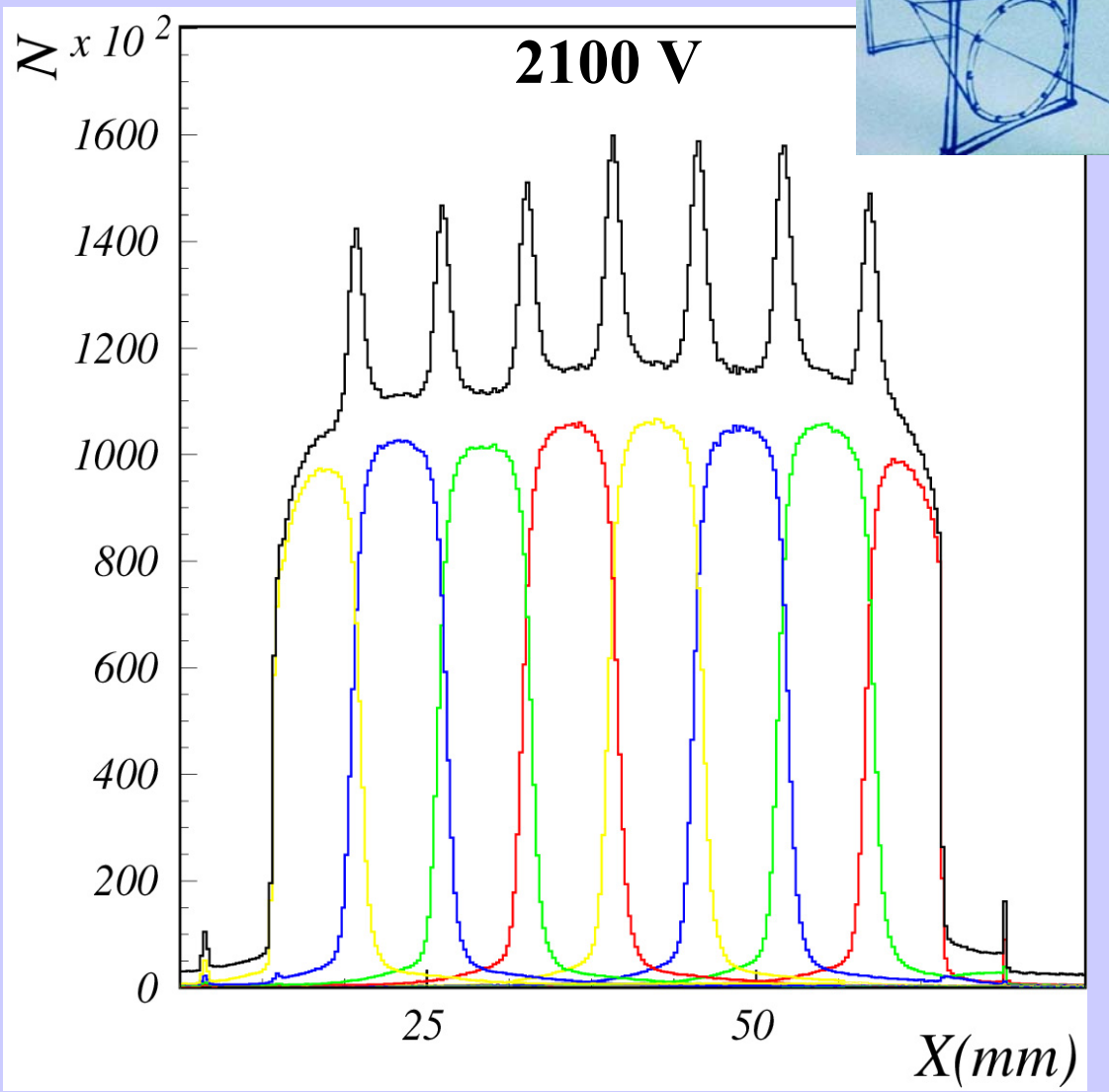


CHARGE-SHARING

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

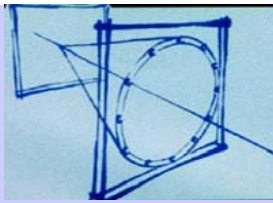
5mm x 5mm, 2300 V



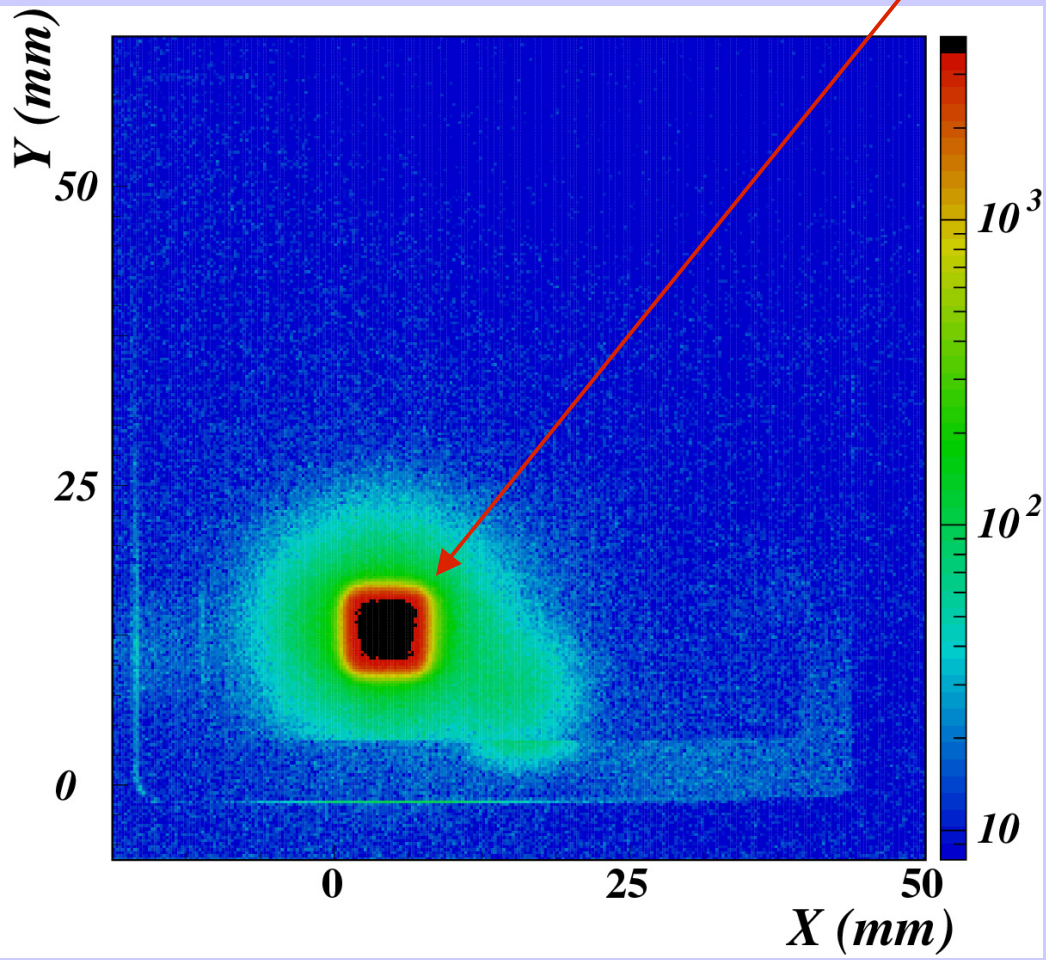


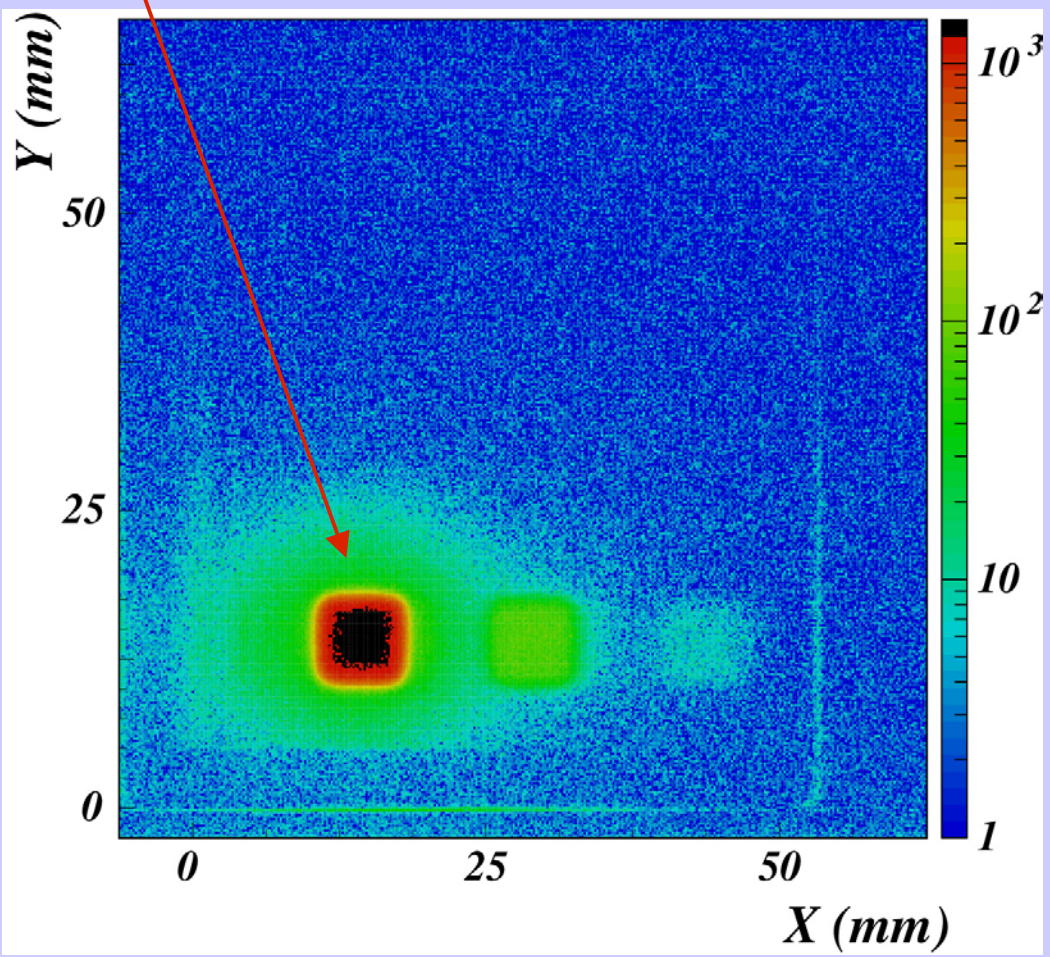
- slice of the counting rate distribution including the central areas of 8 pads (single channels - colored, all channels - black)

DIFFERENT PHOTON INCIDENCE ANGLES



- single channel response
  for photon incidence angles of 0º and 45º (reflections)

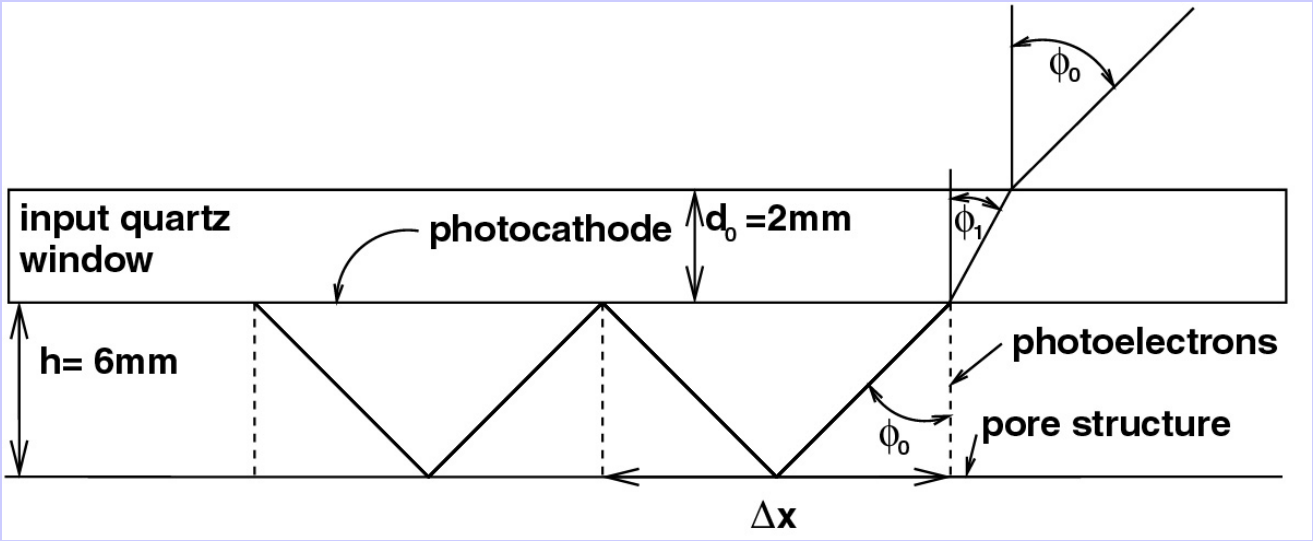


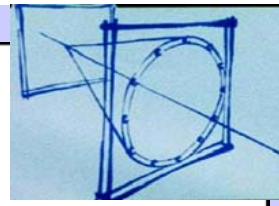


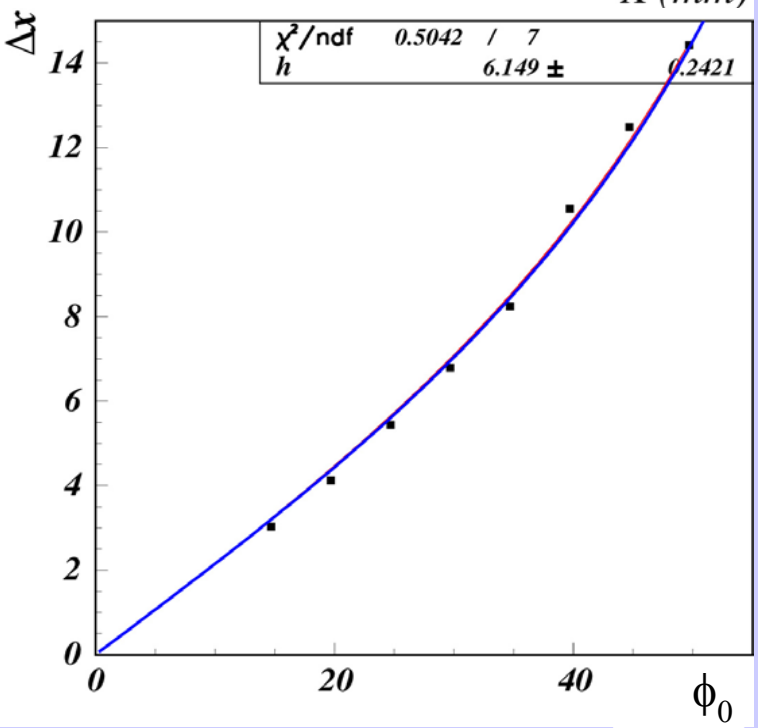
logarithmic scale!

INTERNAL REFLECTIONS

- relative intensities of 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

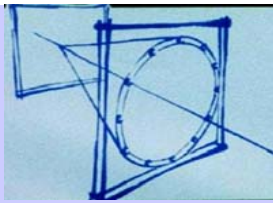




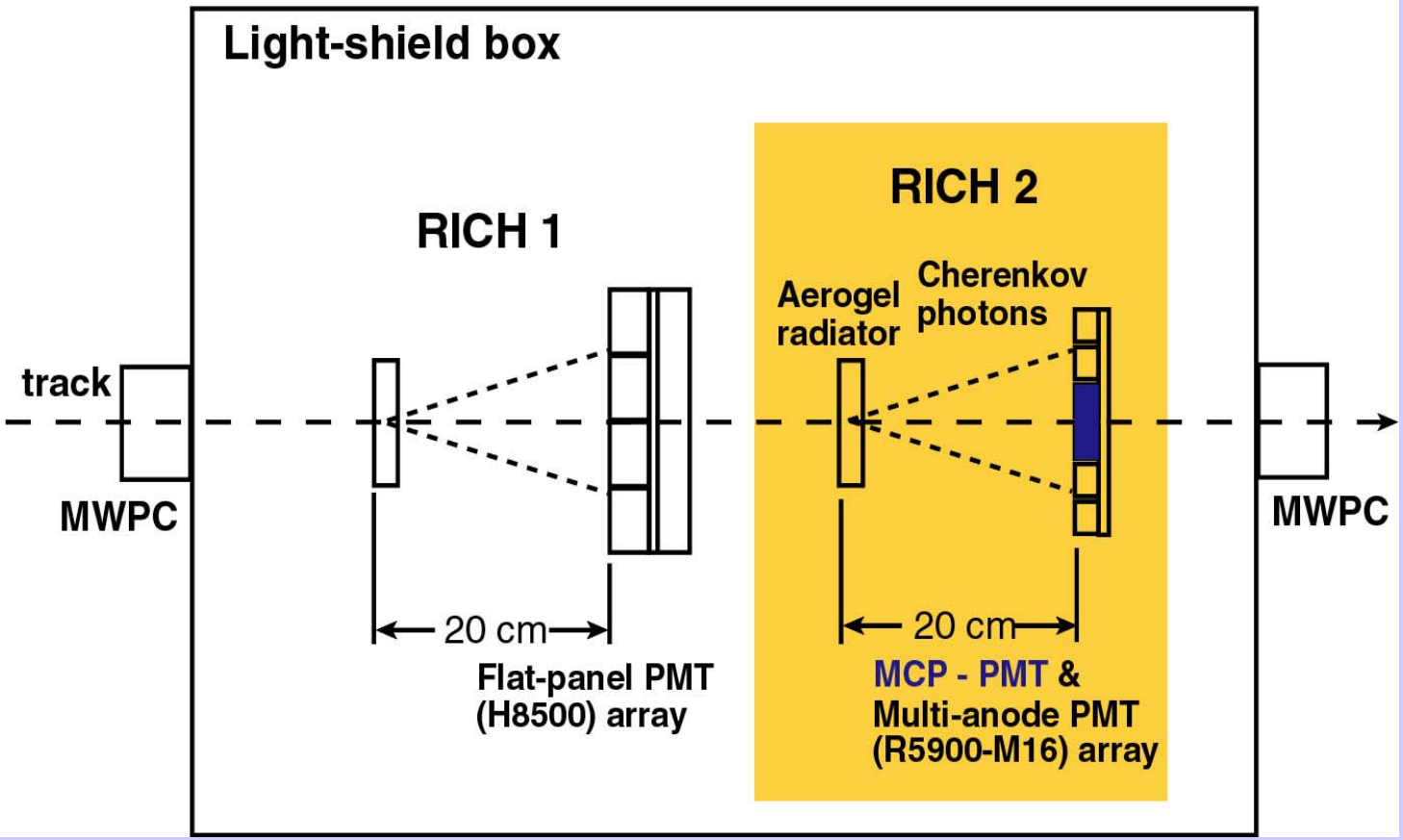


- impact on spatial resolution (+10% @18°)
- impact on timing resolution Δt ~ 40ps

BEAM TEST SETUP



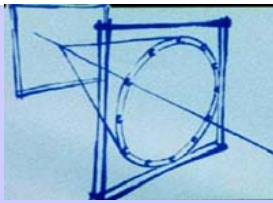
- pion beam 0.5 GeV/c - 4 GeV/c
- two MWPCs for tracking
- same front end electronics (ASD8) as bench tests
- digital signals read out by VME TDCs
- different aerogel samples used



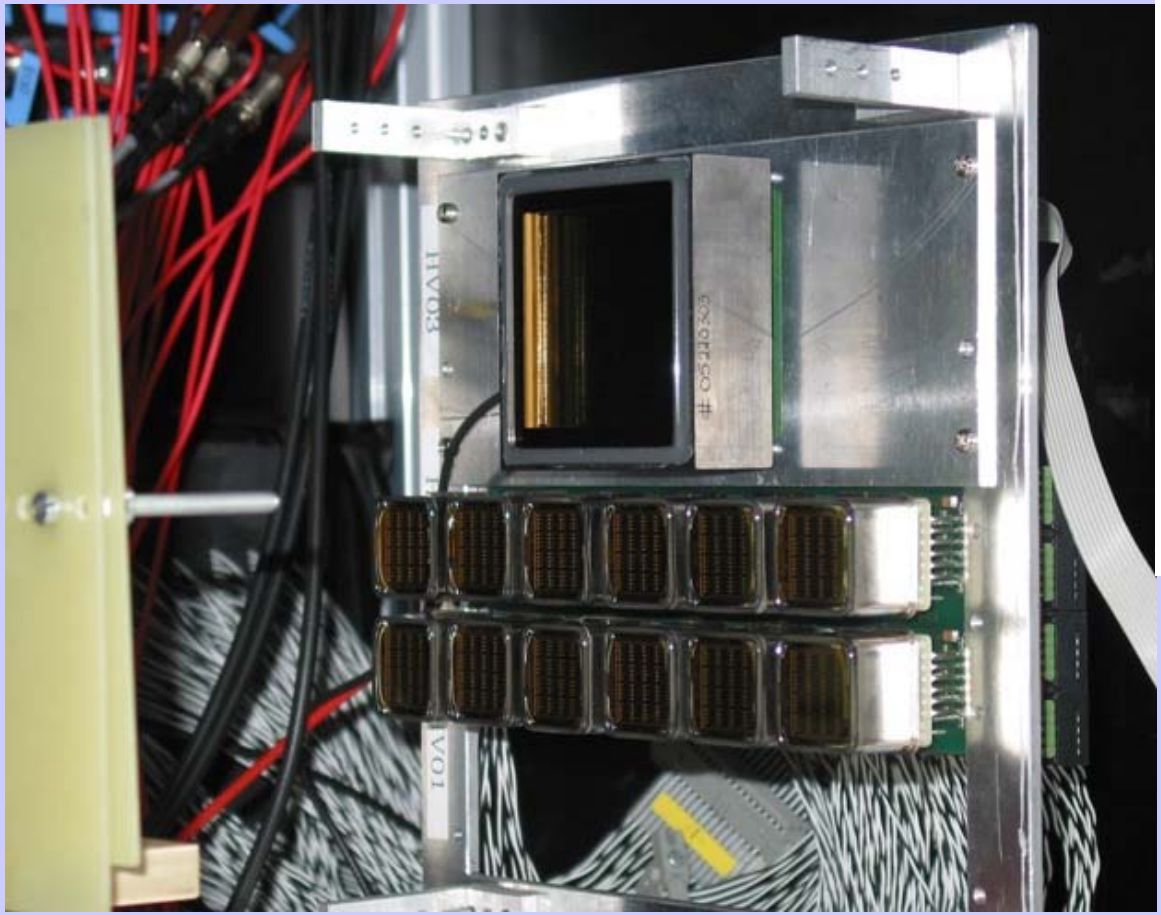
See also contribs. by:

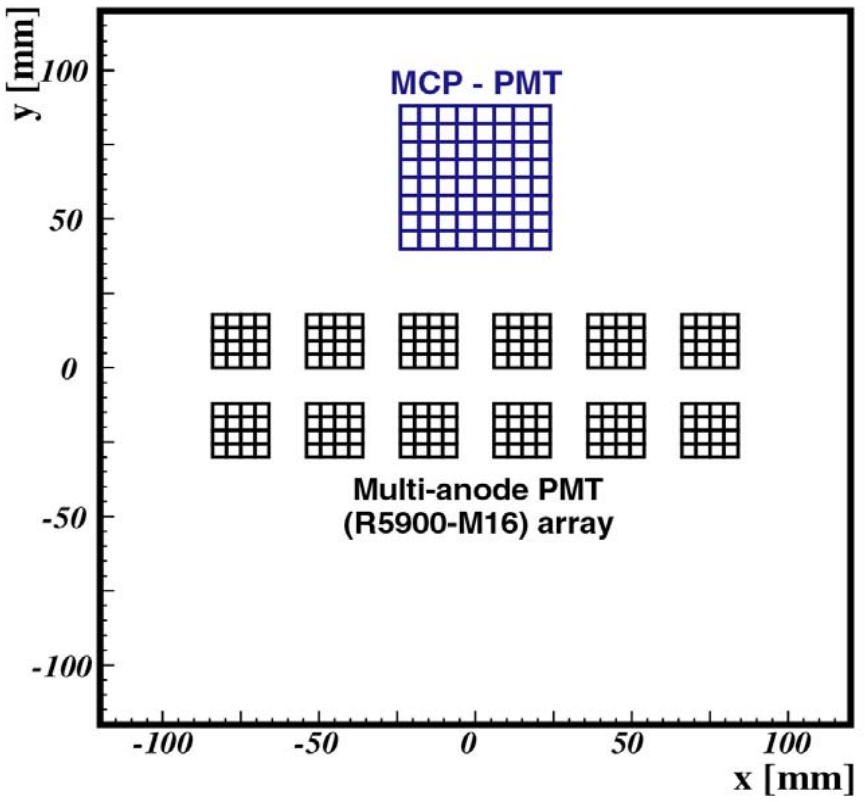
- I. Adachi
- T. Iijima
- S. Korpar
- P. Krizan

BEAM TEST SETUP - 2



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

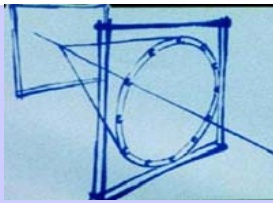




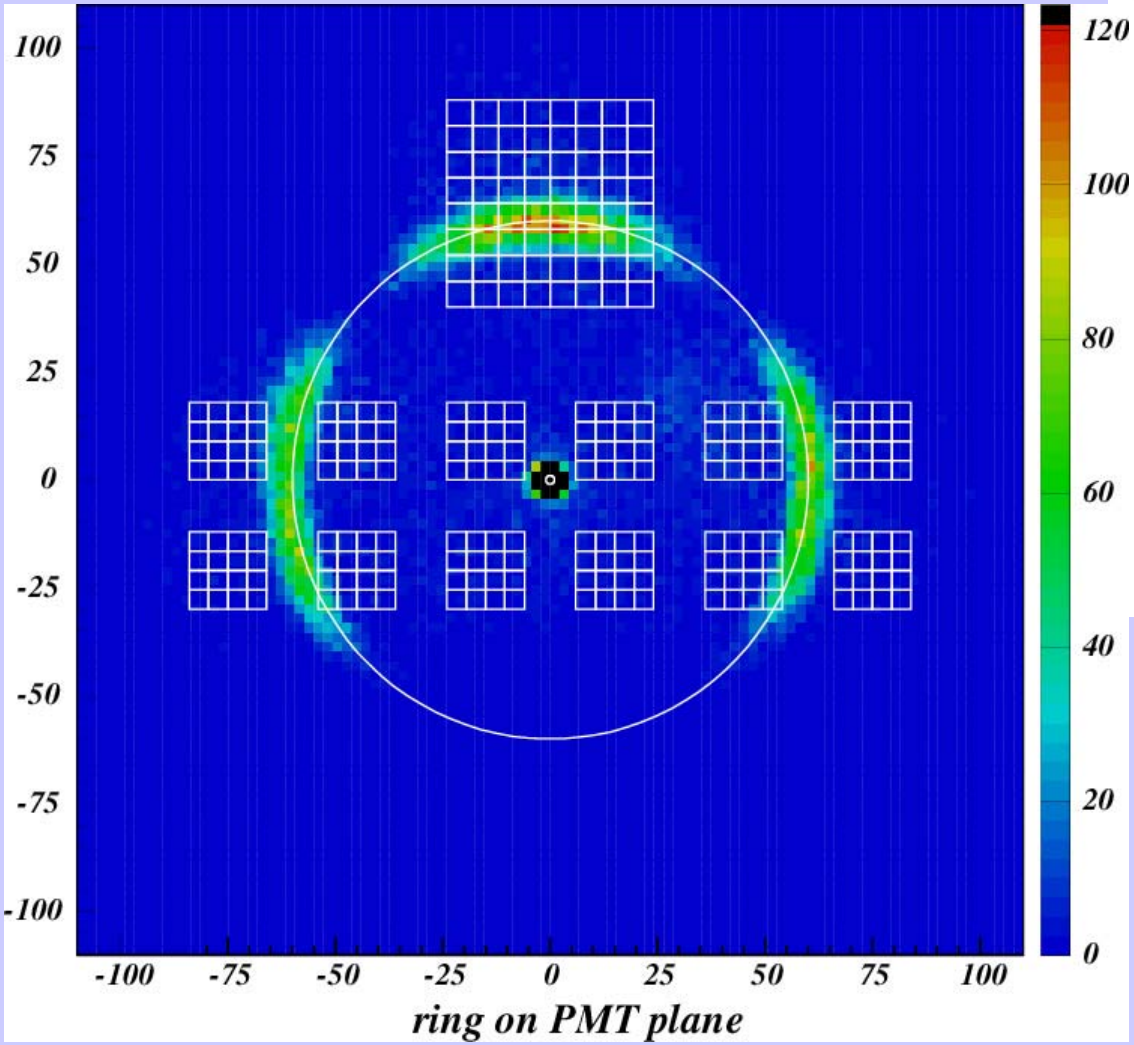
R5900-M16 characteristics:

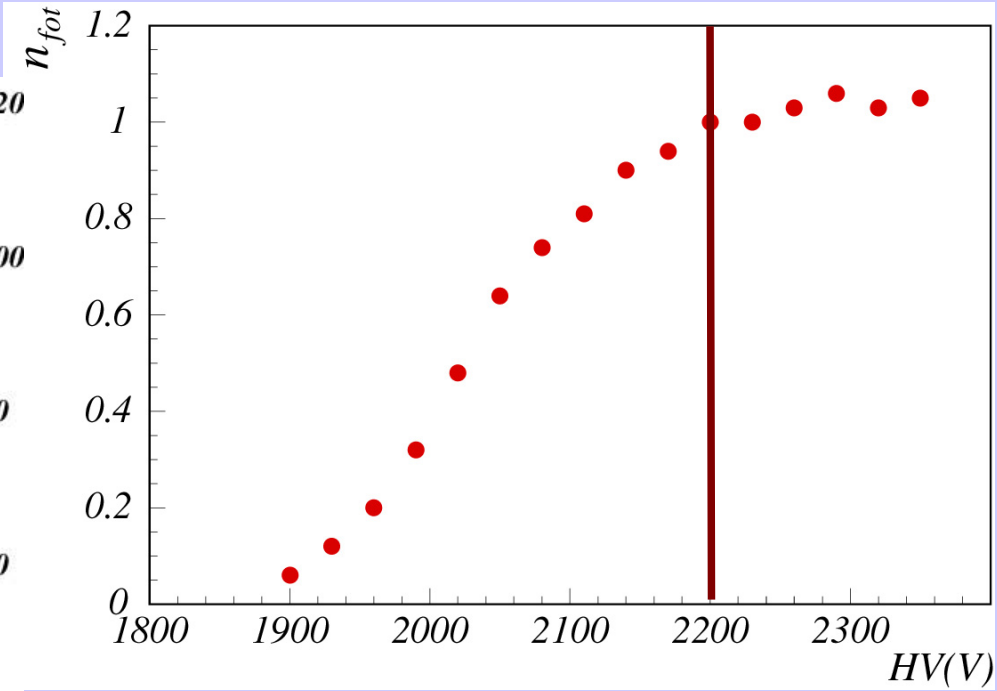
- bialkali photocathode
- 16 (4x4) pads, pitch 4.5mm
- active area fraction ~ 36%
- collection efficiency ~ 75%

MCP-PMT: Cherenkov ring & HV scan



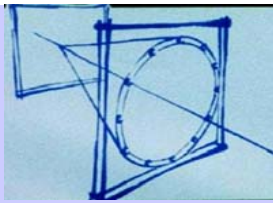
- accumulated rings on MCP-PMT and M16 PMTs





- 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



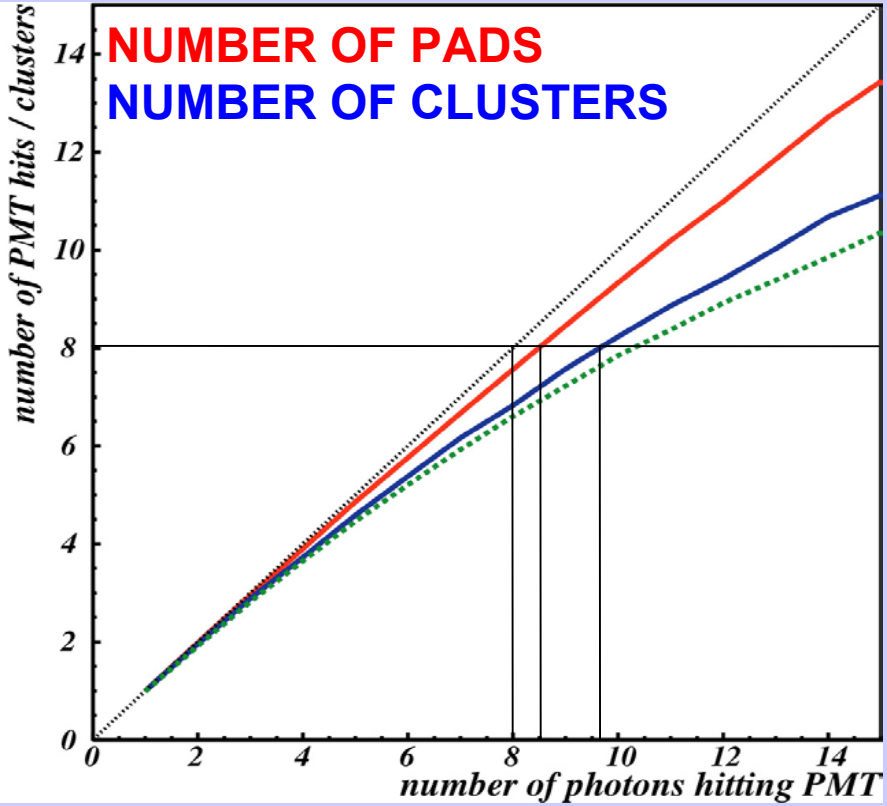
number of incident photons

V

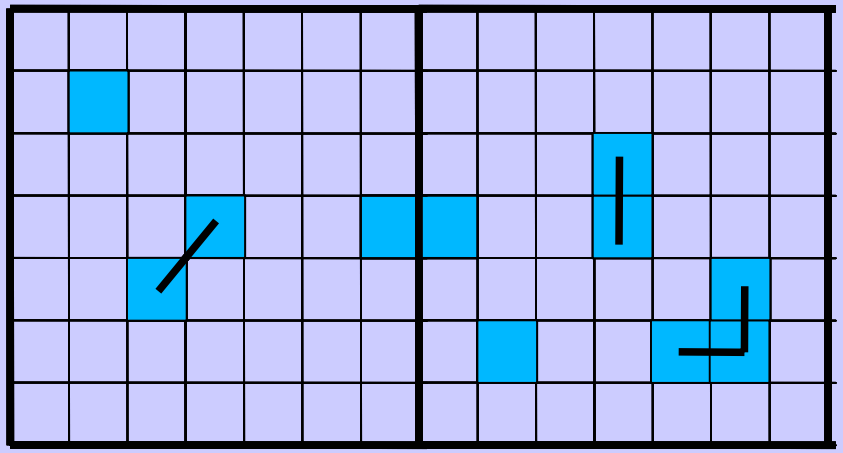
number of pads

V

number of clusters

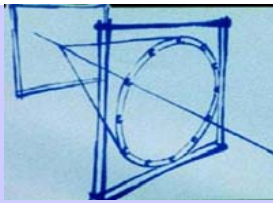


An example:

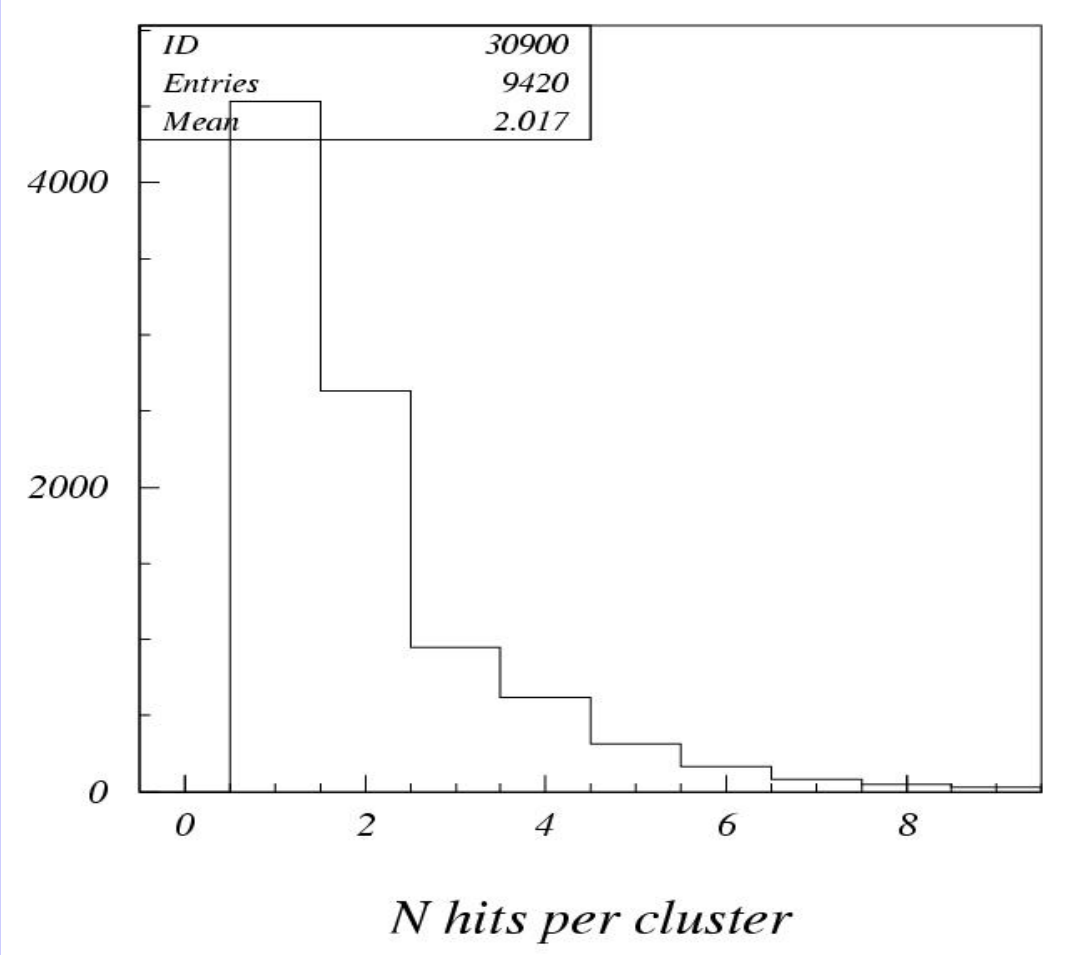


- 11 pads
- 6 clusters

MCP-PMT: HIT CLUSTERING 2



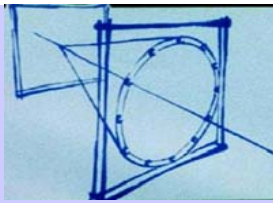
- Number of hits per cluster
  (run 119, 4cm focusing aerogel conf.)



-> resolution

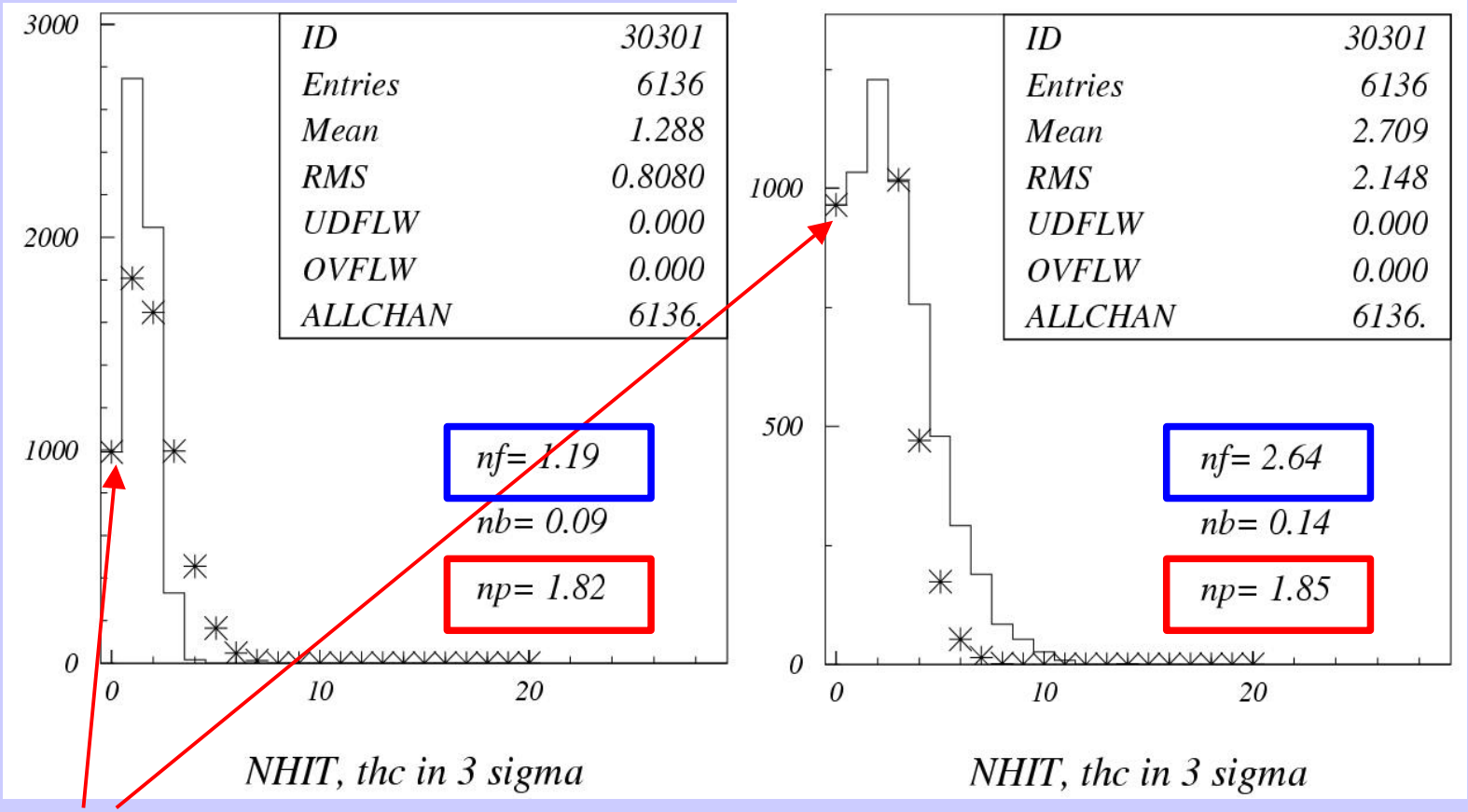
-> # of rec. photons

MCP-PMT: number of hits



with center of gravity (clustering)

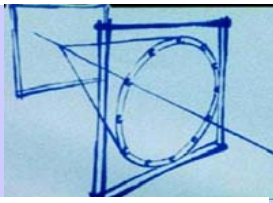
w/o center of gravity (no clustering)



* Poisson

\# of clusters/hits

MCP-PMT: number of hits 2



MCP-PMT

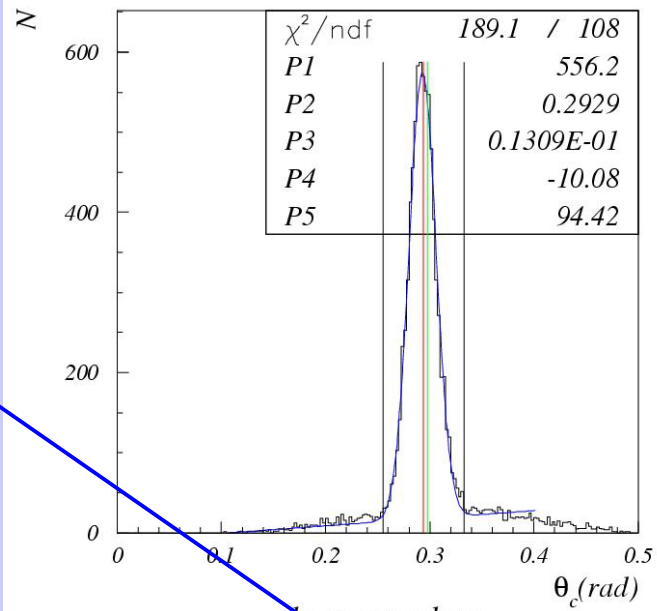
- N = ~ 1.2 **[1.8]** (@ 13%)
- full ring ~ 9 [14]
- full coverage ~ 4.5 [7] (@ 52%)

[ ] Poisson

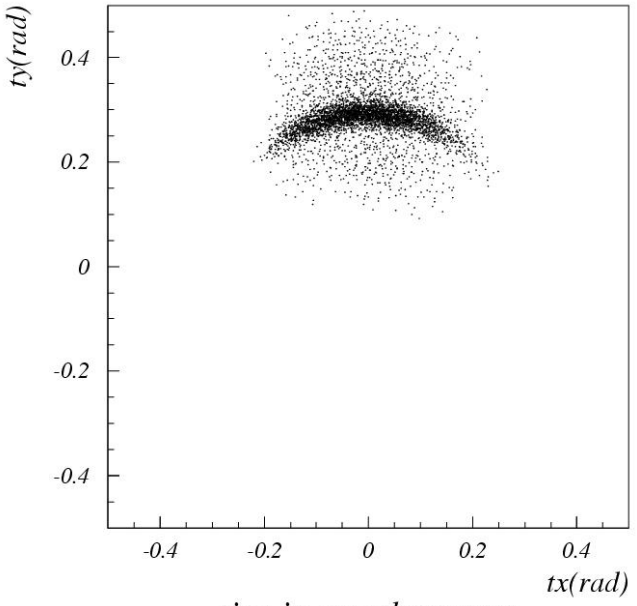
M16-PMTs

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

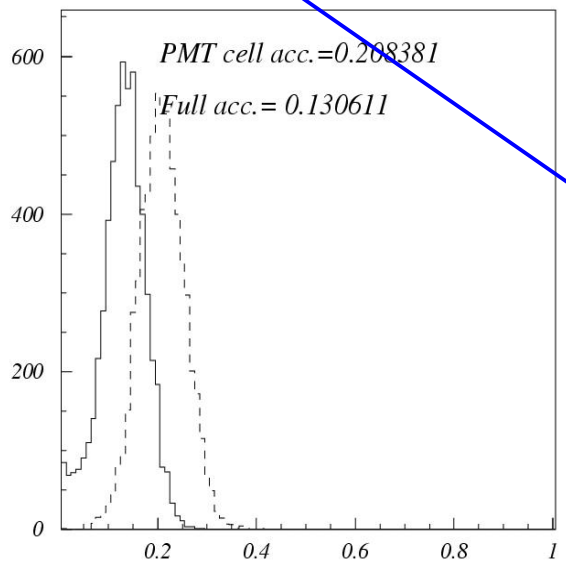
Photons per ring MCP (M16):
14 (17.5)
consistent with ratio of
collection eff. 60% (75%)



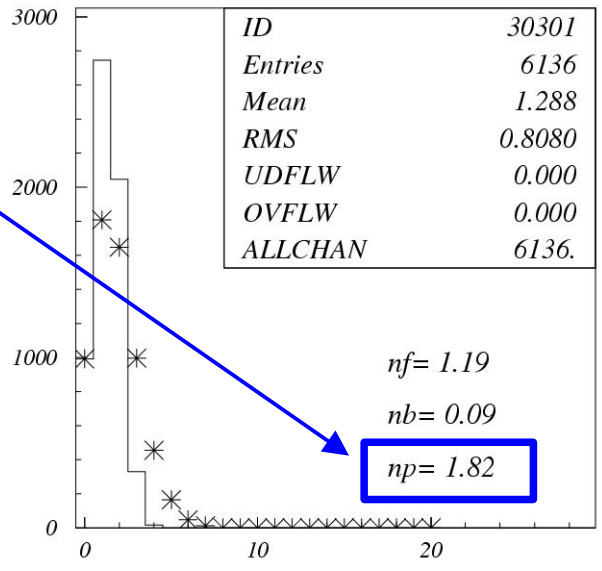
theta cerenkov



ring in cerenkov space

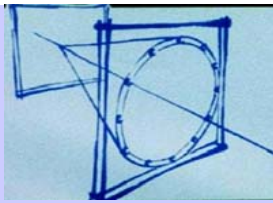


track geo acc1 active surface



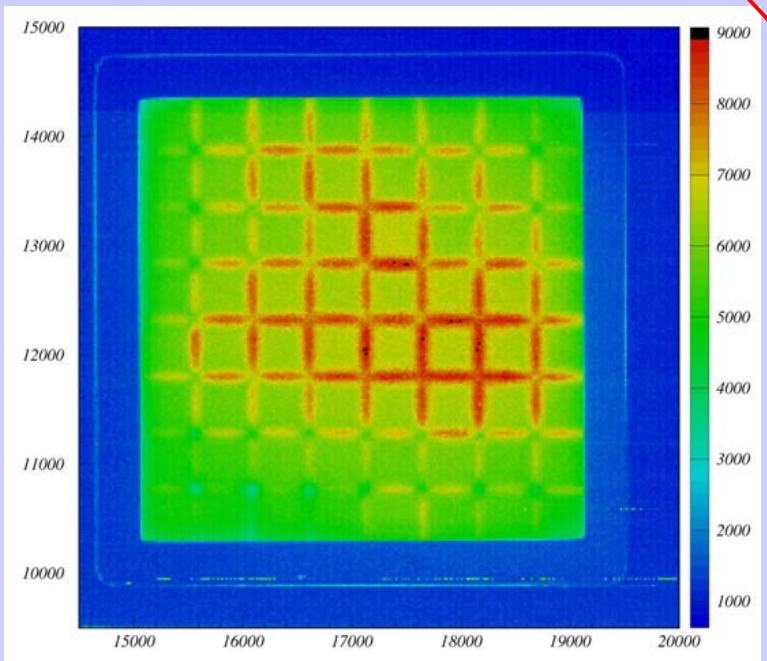
NHIT, thc in 3 sigma

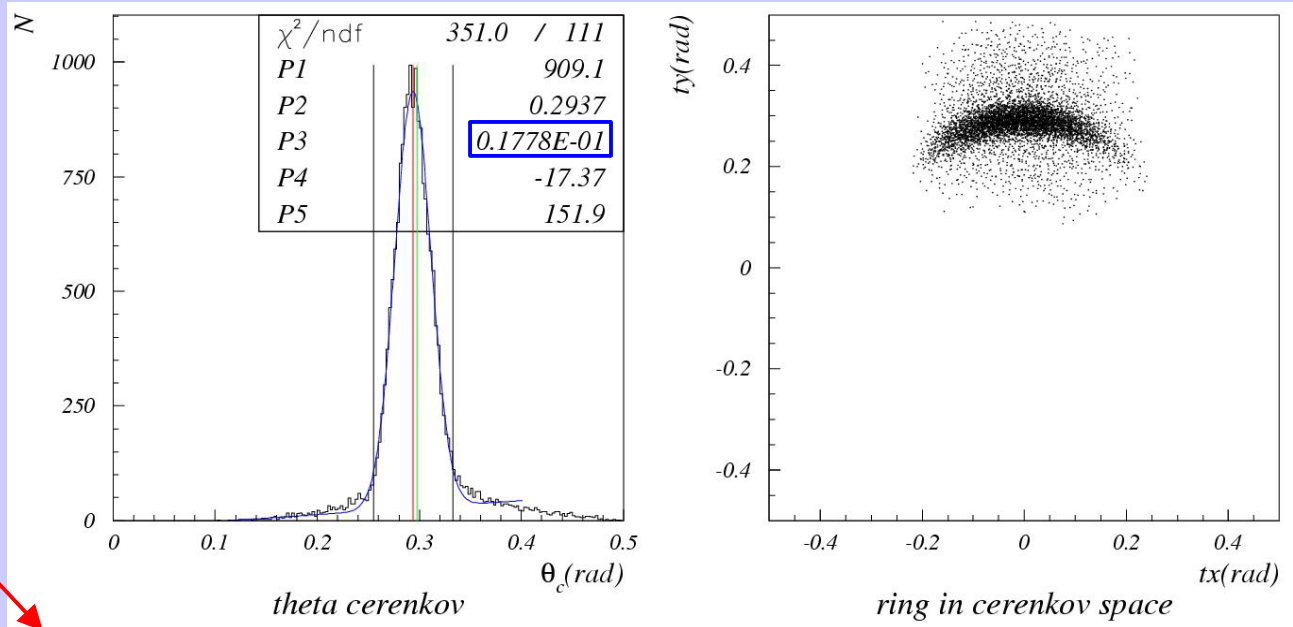
MCP-PMT: resolution

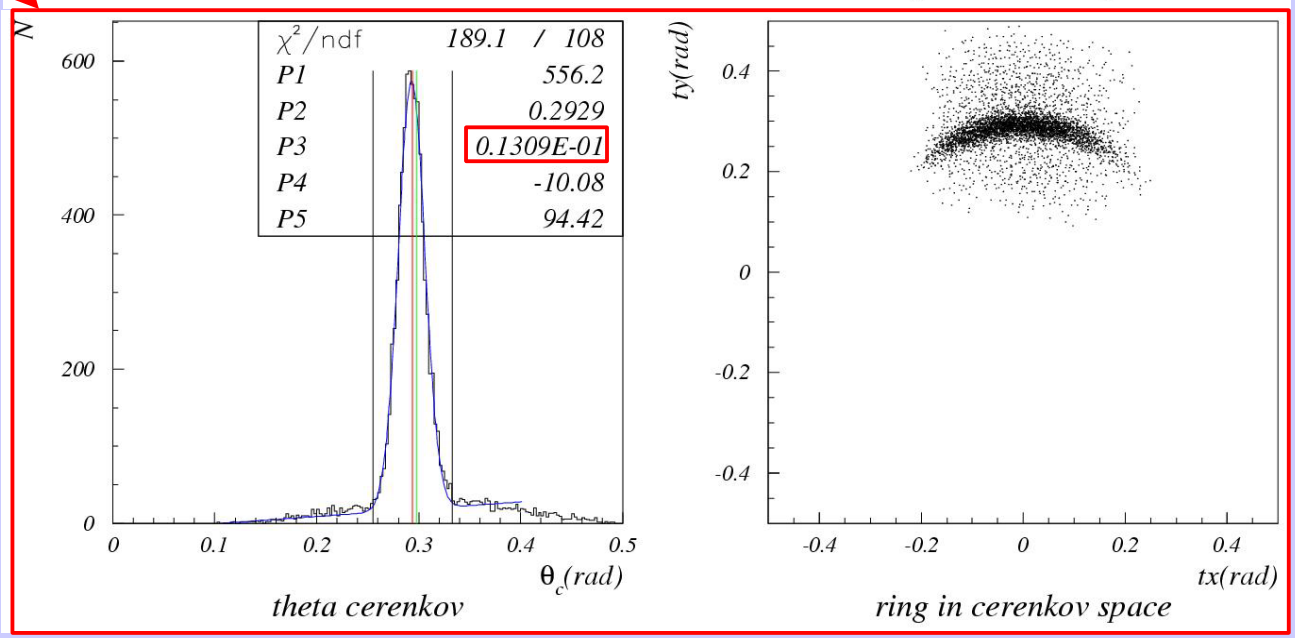


- charge sharing at the edges of pads -> resolution improves if using center of gravity of the cluster

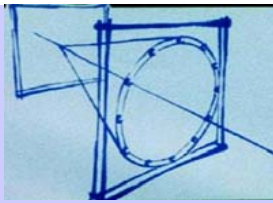
σ_ϑ: 17.8 mrad -> 13.1 mrad







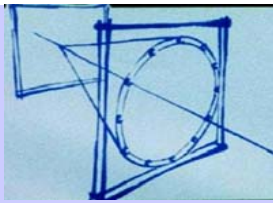
MCP-PMT: resolution per track



- 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

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:

- 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%)

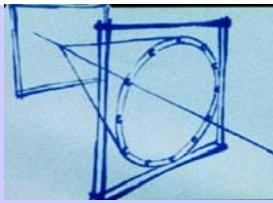
-> Extrapolation from the present data 4.5 ->8.5 hits per ring

σ_ϑ: 6 mrad -> 4.5 mrad (per track)

-> >5 σ π/K separation at 4 GeV/c

Aging of MCP-PMTs ?

SUMMARY

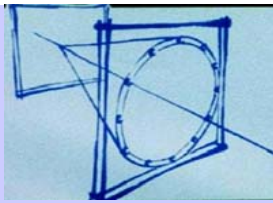


- **BURLE MCP** multianode PMT performed very well as a single photon detector both on the bench and in the test beam.
- The Cherenkov angle resolution and yield are in good agreement with expectations.
- For the specific application (RICH counter with aerogel radiator) the yield is too low. Improvements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

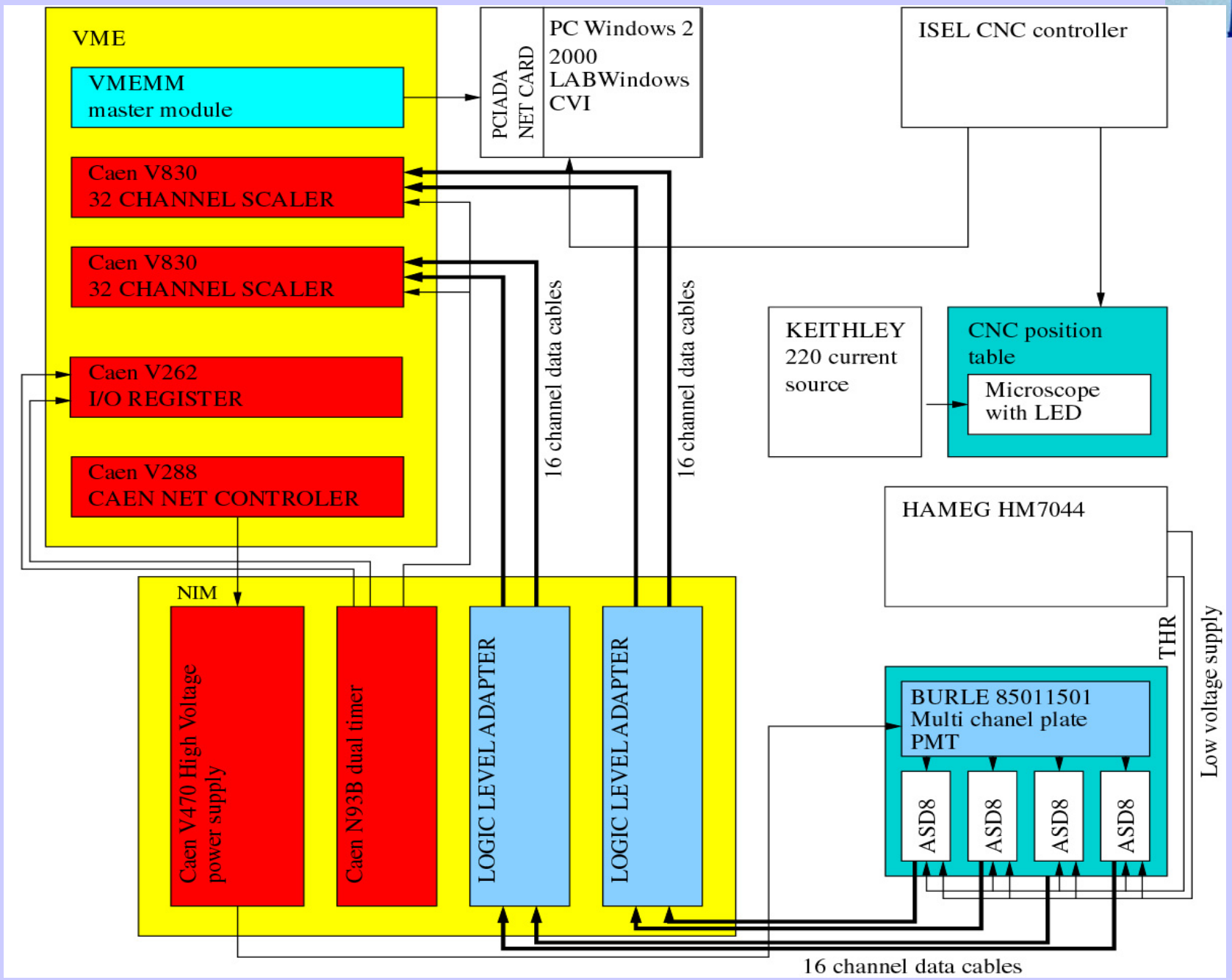
R&D issues:

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

BACKUP SLIDES

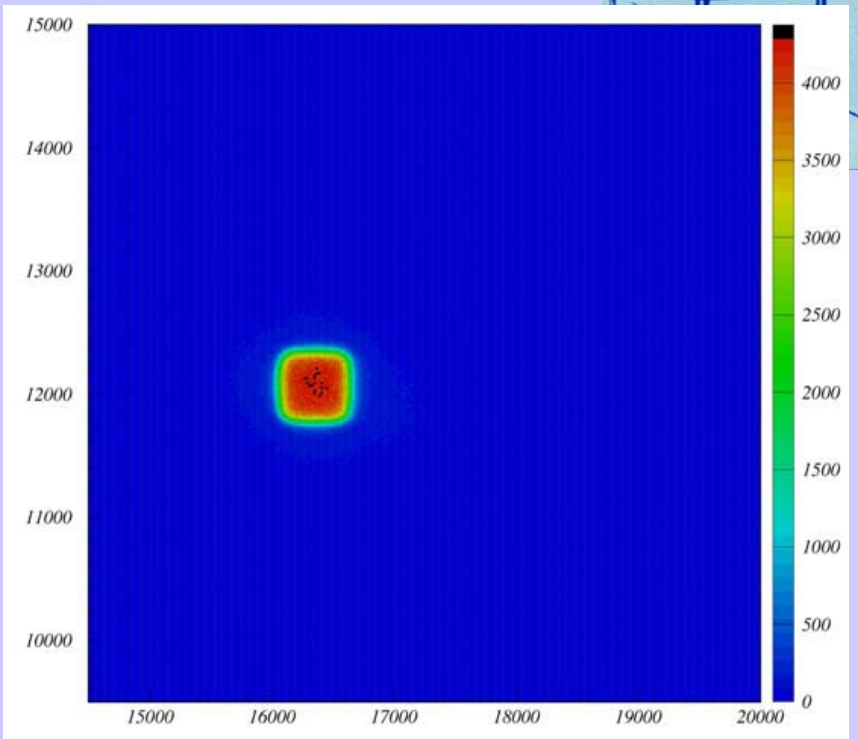


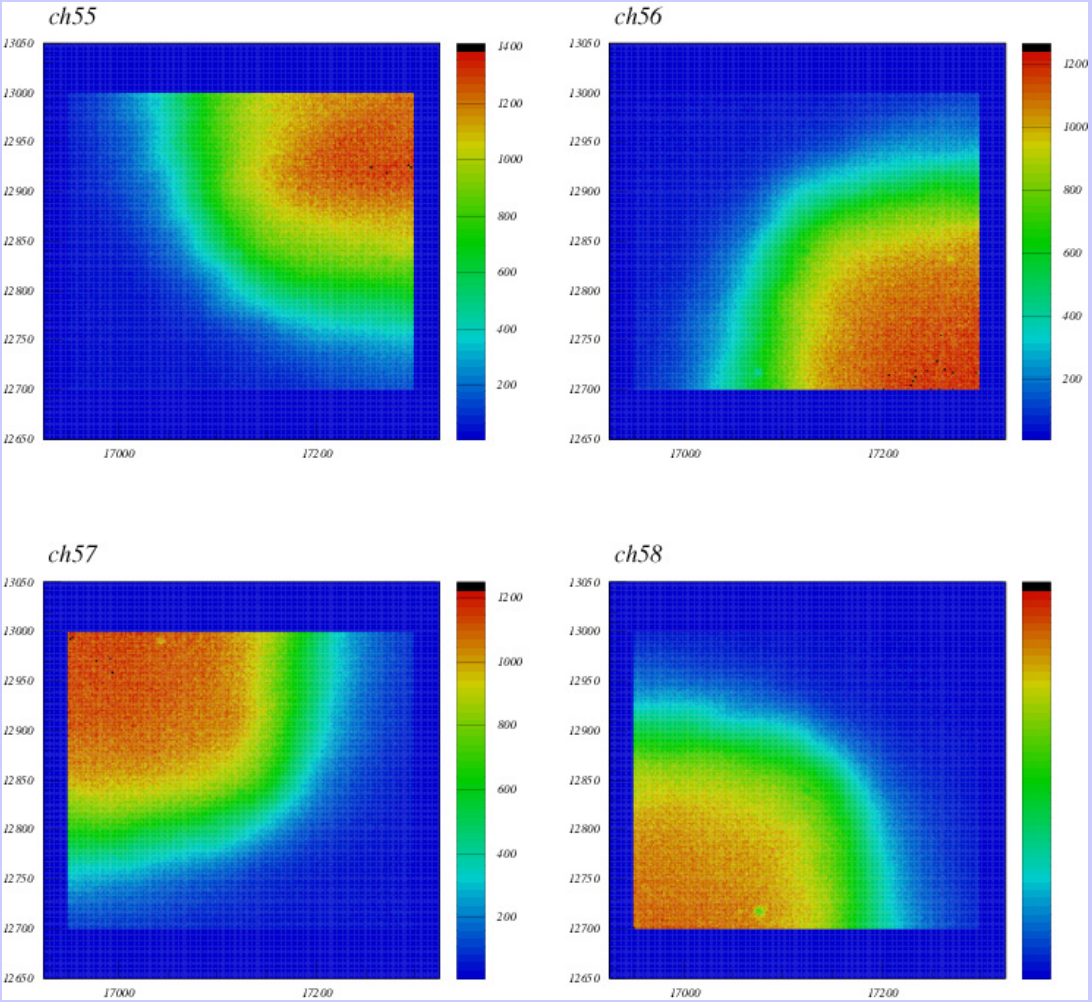
BENCH TEST SETUP - ELECTRONICS

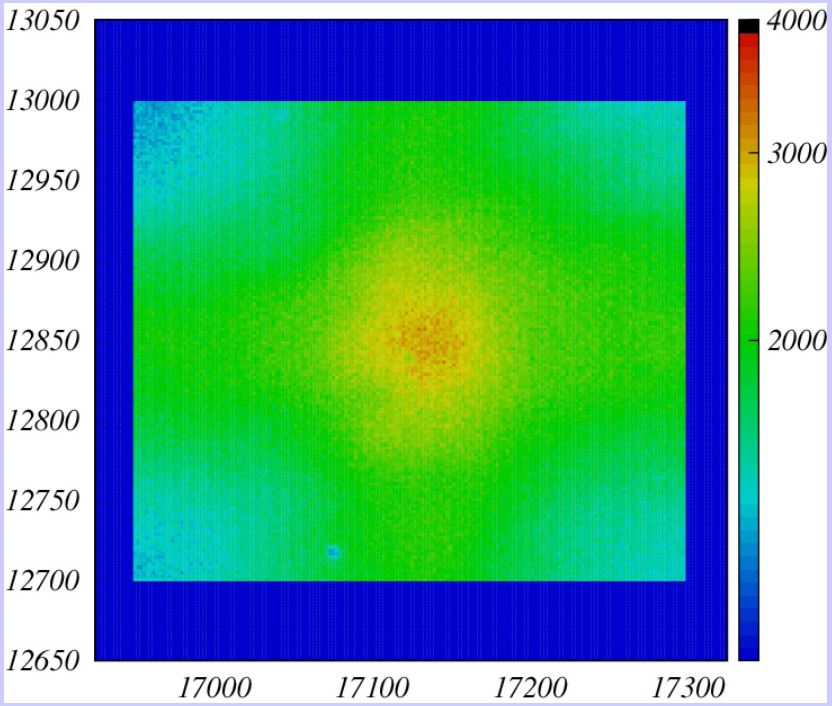


SOME DETAILS

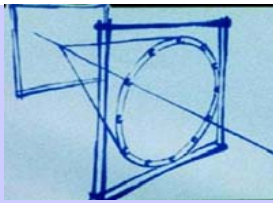
- uniform single channel response (right)
- fine scan over the boundary of 4 pads (bottom)





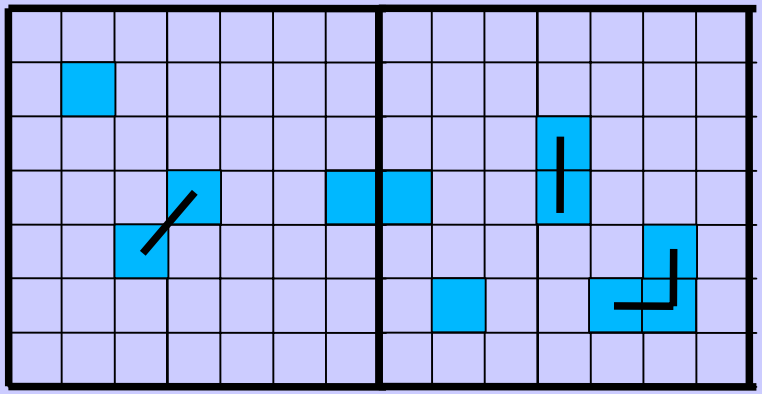


HITS & CLUSTERS



simple simulation:

- generating Cherenkov photons
- counting number of hit pads
- counting number of clusters within the 8x8 channel areas



- 11 pads
- 7 clusters