MCP PMT in colliding beam experiments

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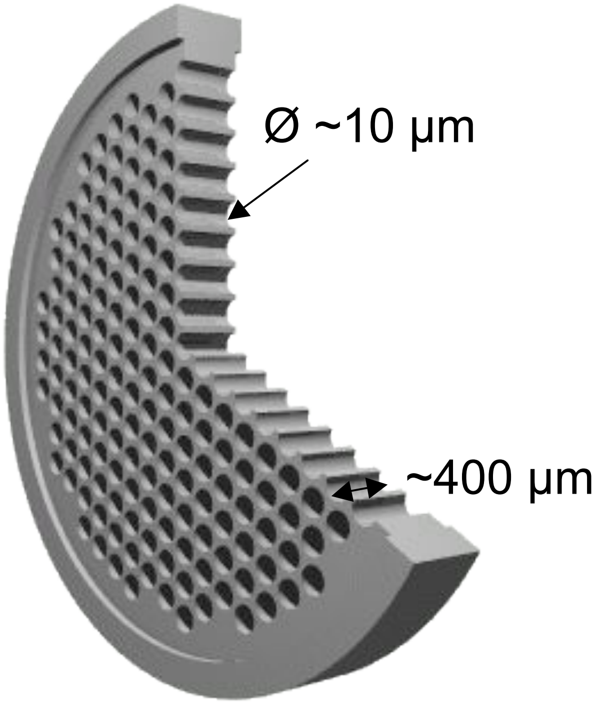
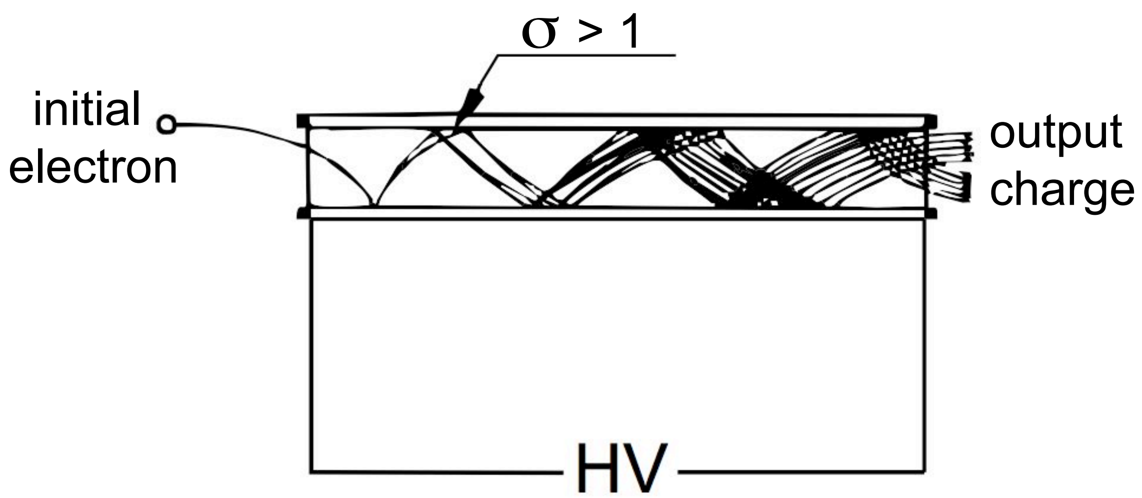
Outline:

- MCP PMT design
- Main properties of MCP PMT
- Photocathode aging
- MCP PMT applications
- Summary

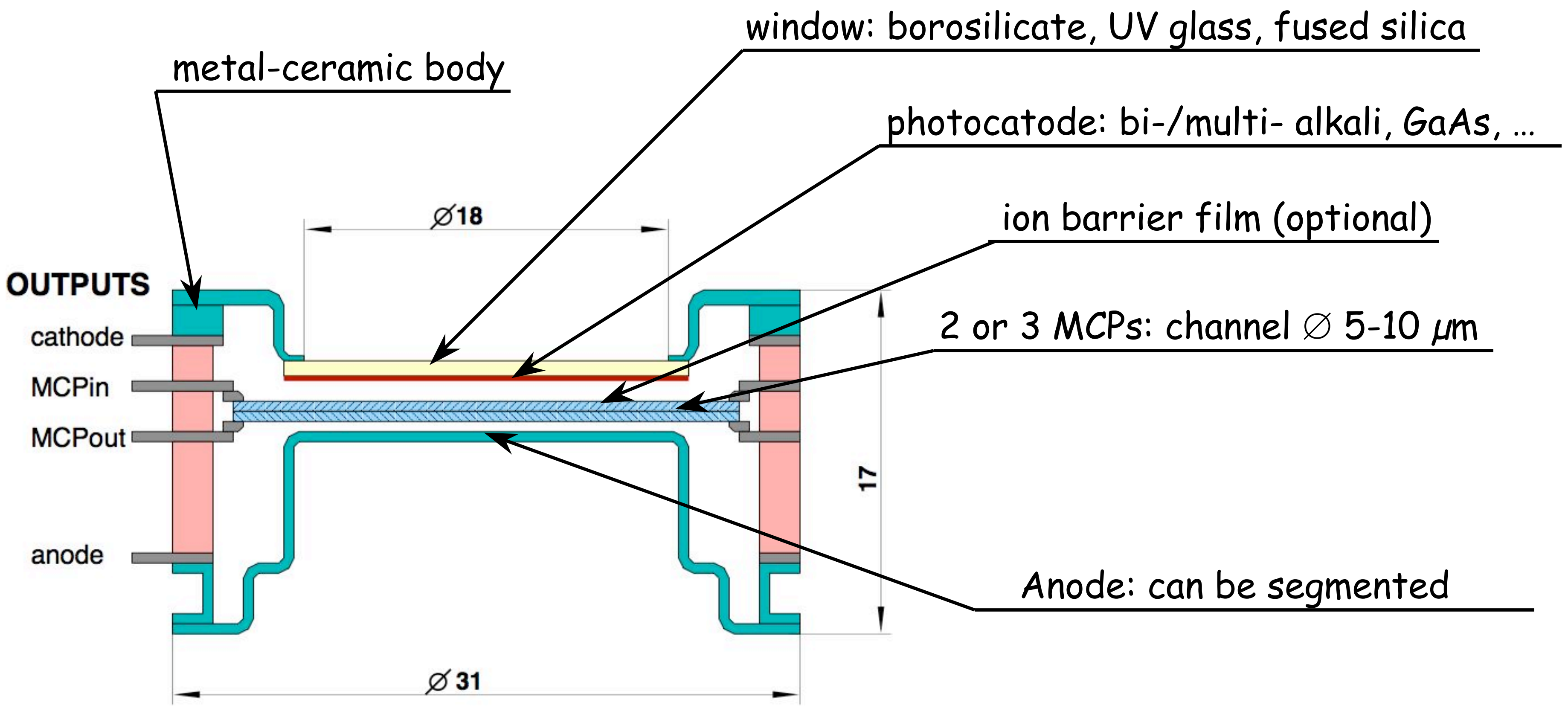
MCP principle of operation





Small channel diameter
Small MCP thickness
➔
Immunity to magnetic field
Excellent time resolution
Good space resolution

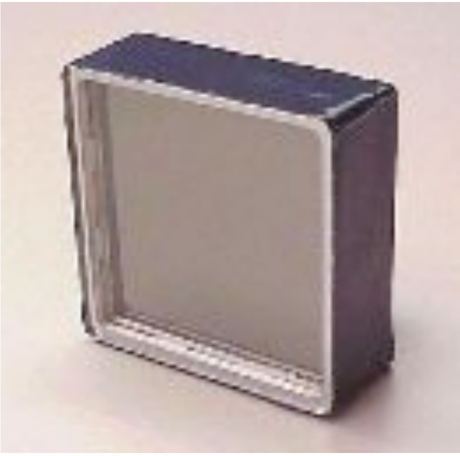
MCP PMT desing



Transfer method: photocathode and MCPs are prepared separately and then assembled in ultra high vacuum.

MCP PMT manufacturers

Photonis



"Planacon"

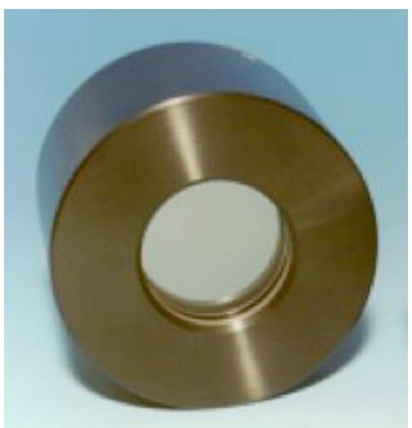
- Bialkali photocatode
- 53x53 mm active area
- Anode array 2x2, 8x8 or 32x32
- Pore size 25 or 10 μm

Hamamatsu

"SL-10"

- Multialkali photocatode
- 22x22 mm active area
- Anode array 1x4 or 4x4
- Pore size 10 μm

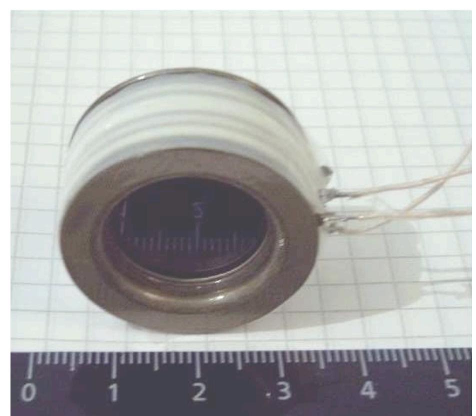
Photek



- active area Ø10-40 mm
- Single anode
- Pore size 5-12 μm

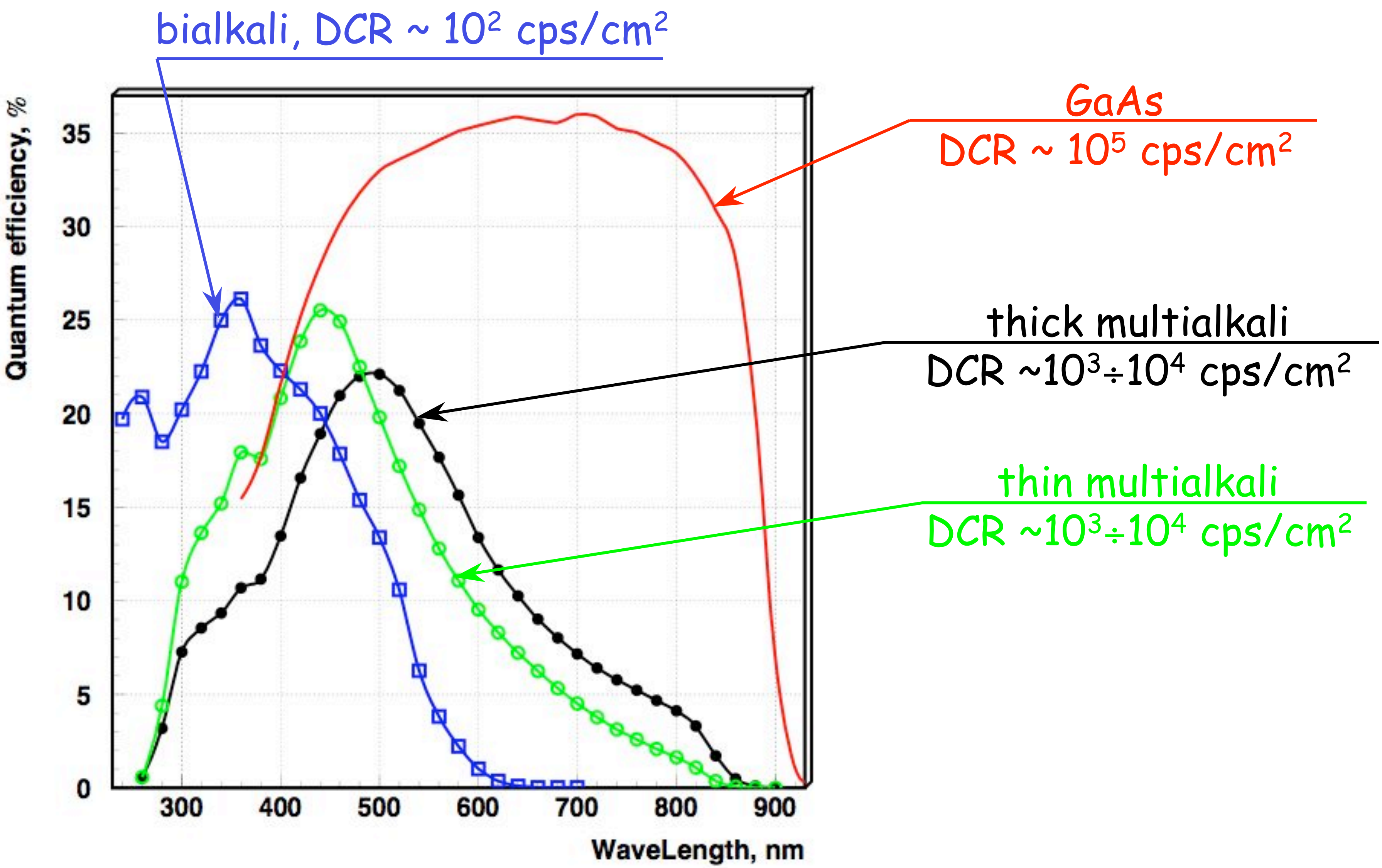
Novosibirsk

BINP + Katod Ekran FEP

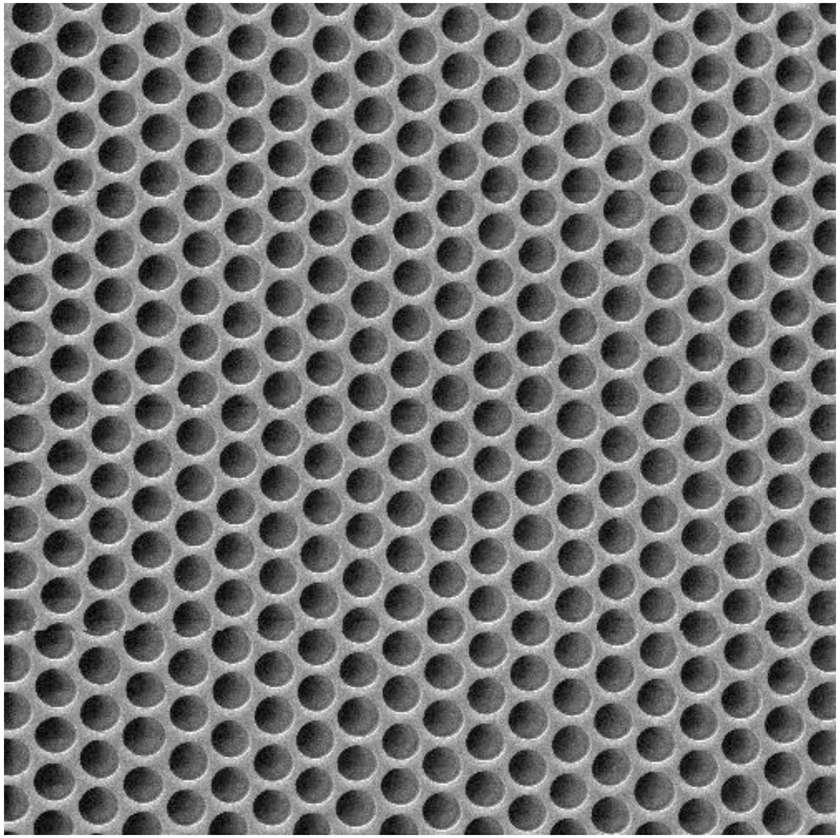


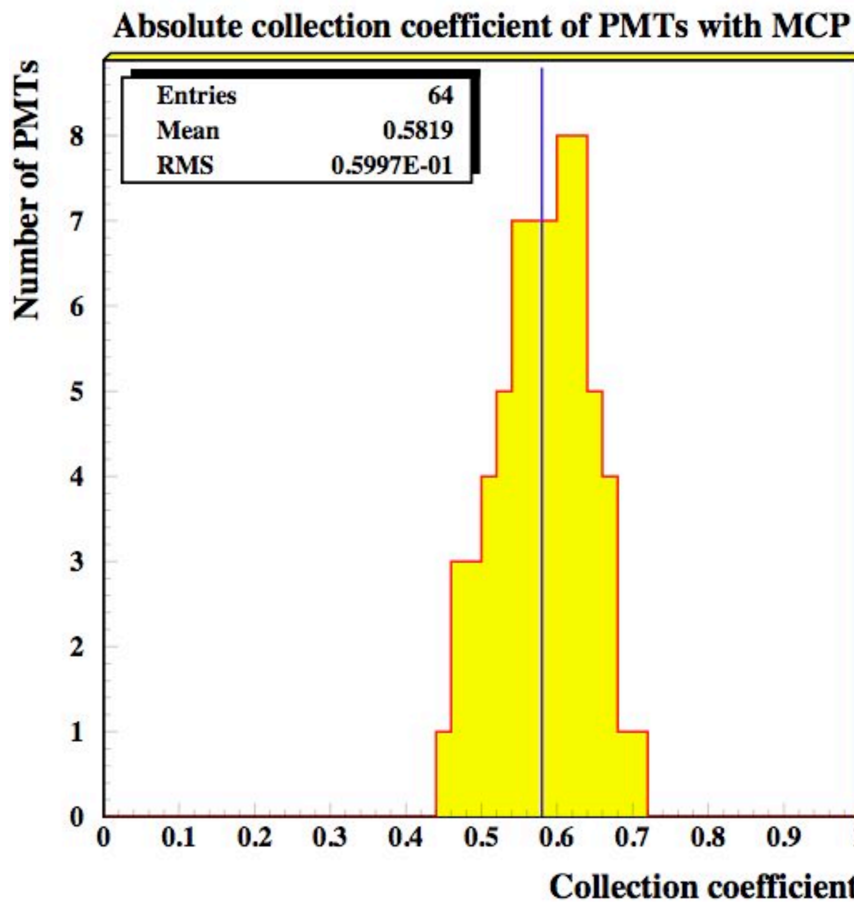
- active area Ø18 mm
- Single anode
- Pore size 6-12 μm

Photocathodes



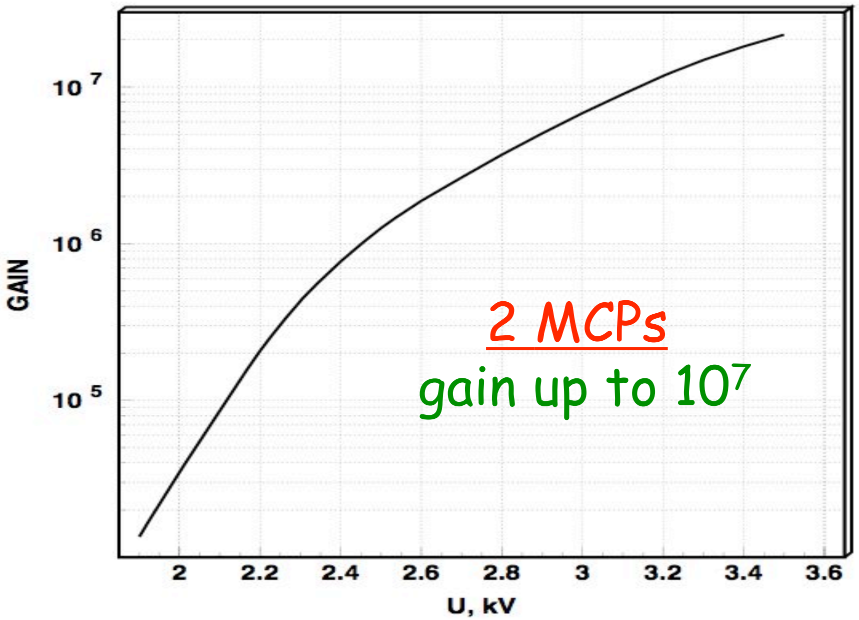
Photoelectron collection efficiency

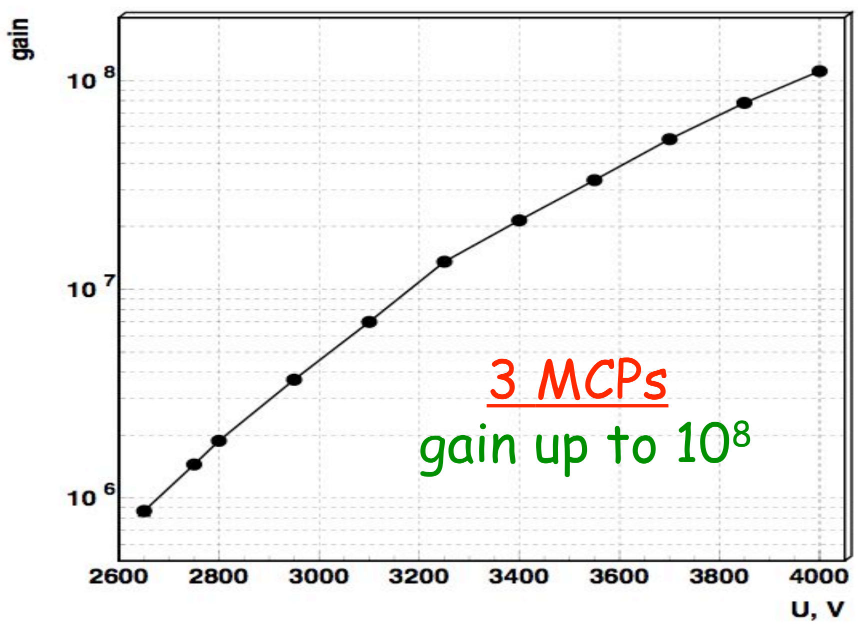


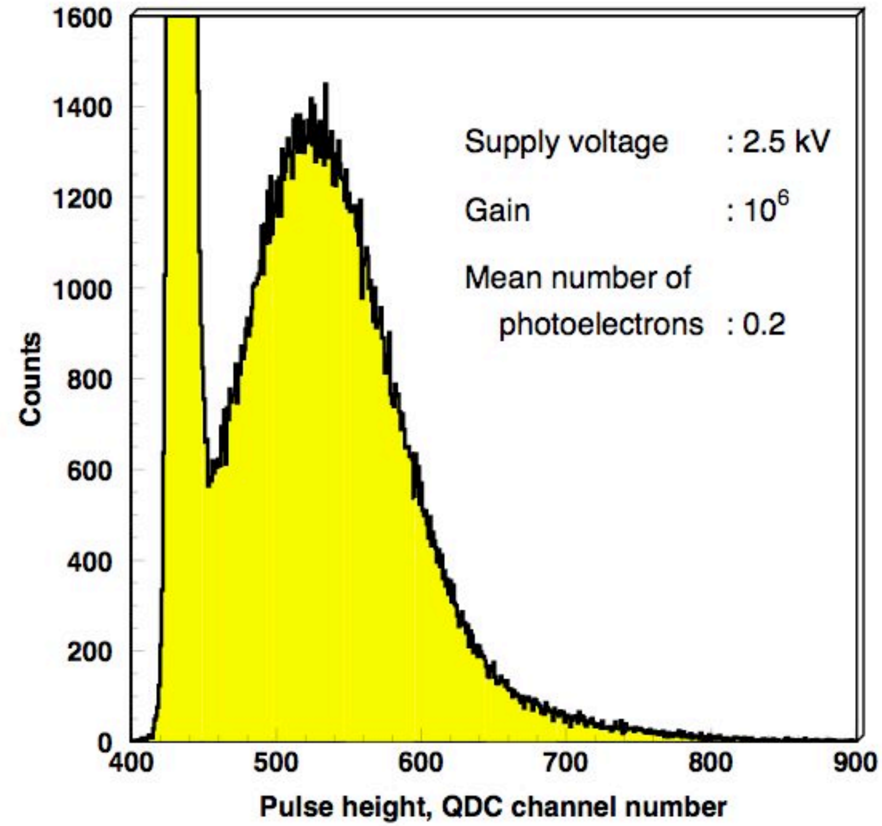


Photoelectron collection efficiency ≈0.6
It is determined by MCP open area ratio

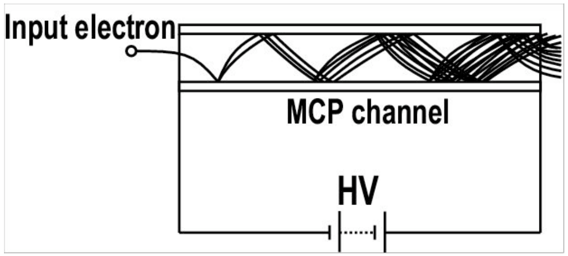
Gain





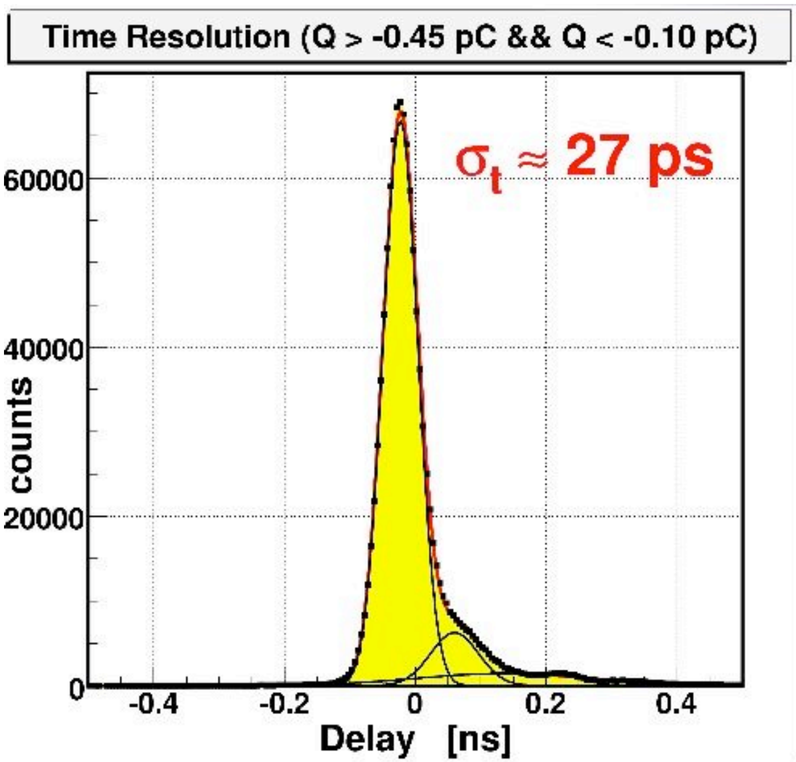


Narrow single photoelectron peak due to the electron avalanche saturation



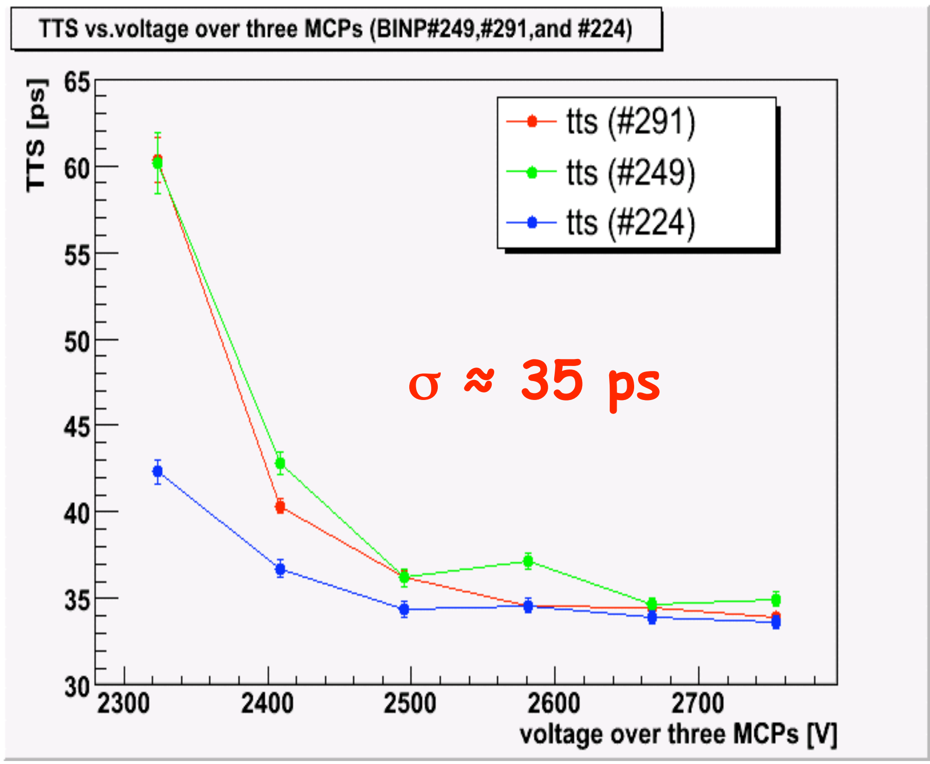
Time resolution

2 MCPs 6 μm
(measured at Erlangen Uni.)



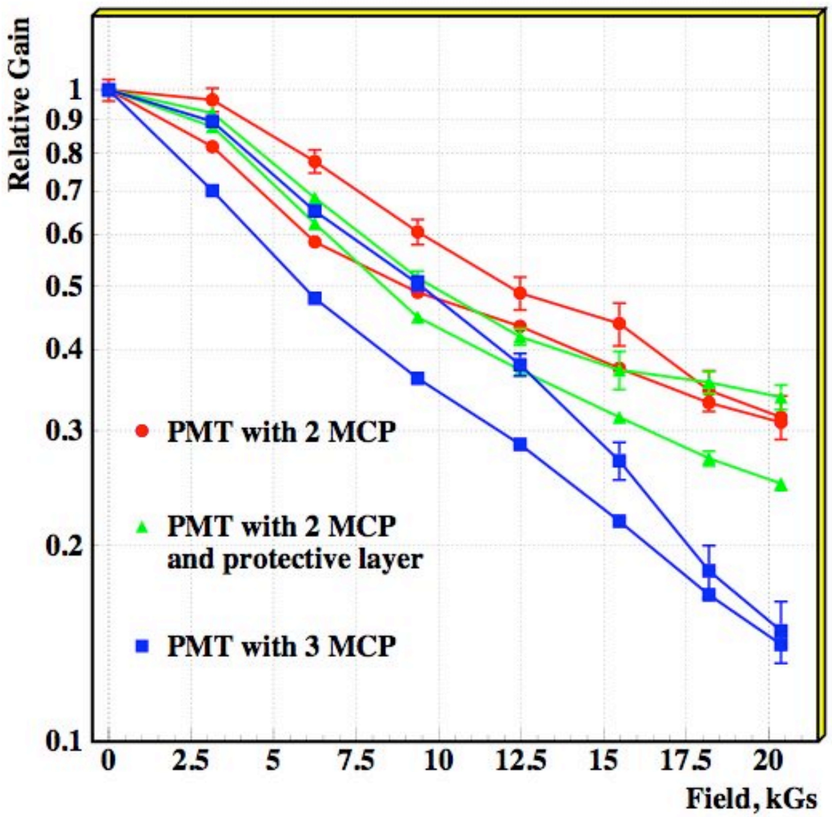
A. Lehmann et al., *Nucl. Instr. and Meth.* **A 595** (2008) 173

3 MCPs 8 μm
(measured at Nagoya Uni.)

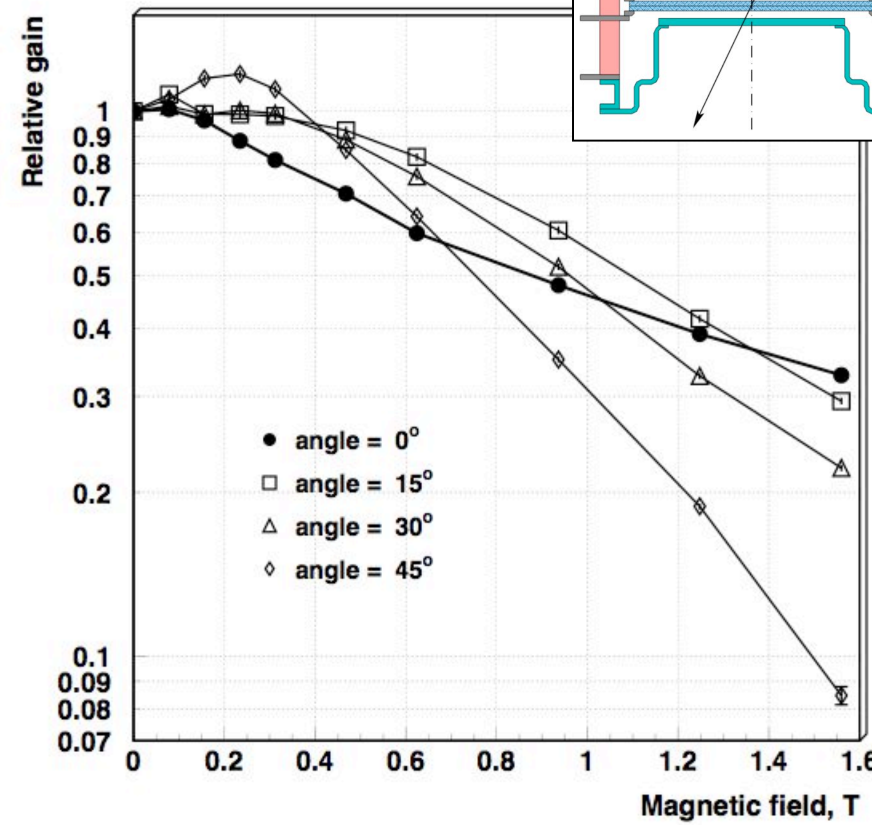


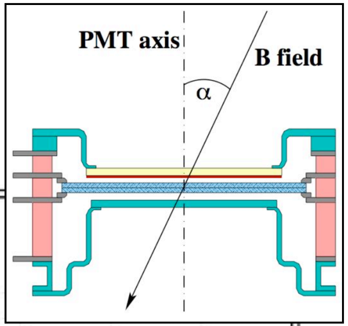
A.Yu.Barnyakov et al., *Nucl. Instr. and Meth.* **A 598** (2009) 160

Magnetic field: gain



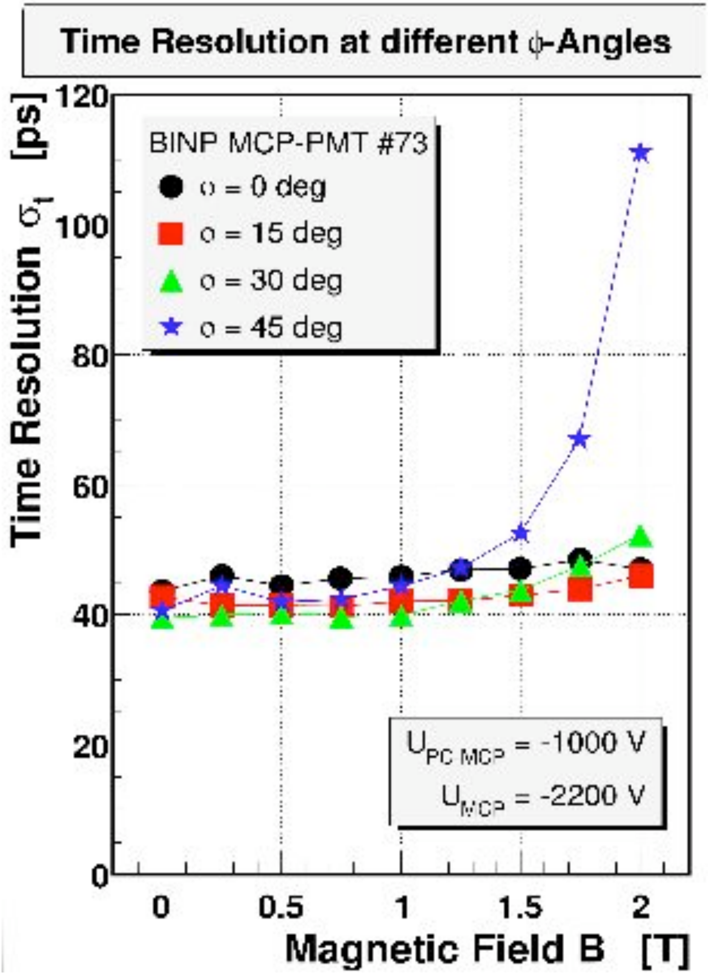
Moderate gain degradation
in axial magnetic field.
Slightly higher degradation
for PMT with 3 MCPs.



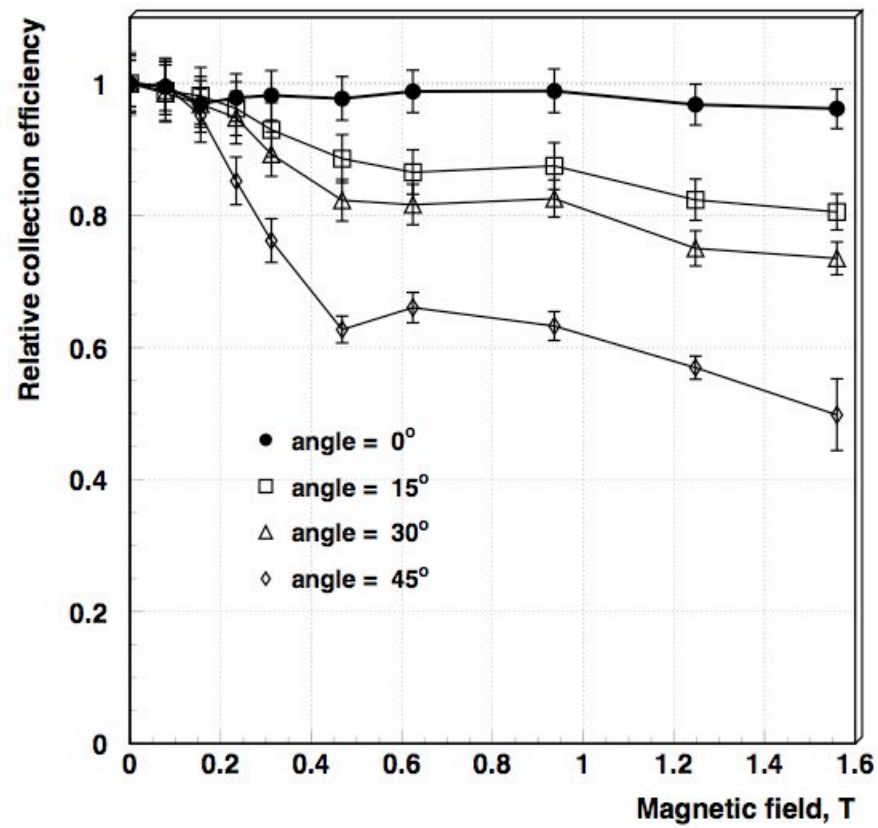


Moderate gain degradation
even at bias angles < 45°

Magnetic field: time resolution and CE

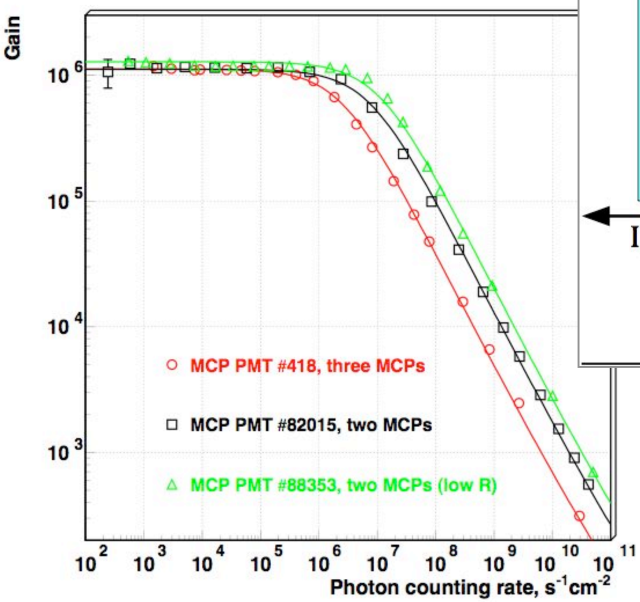


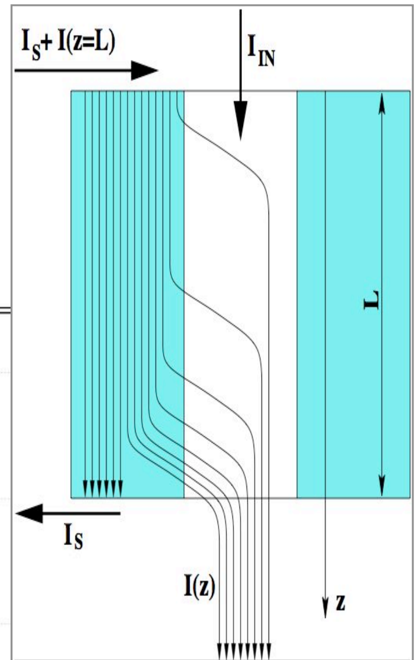
Time resolution is stable in axial magnetic field
(measured at Erlangen Uni.)

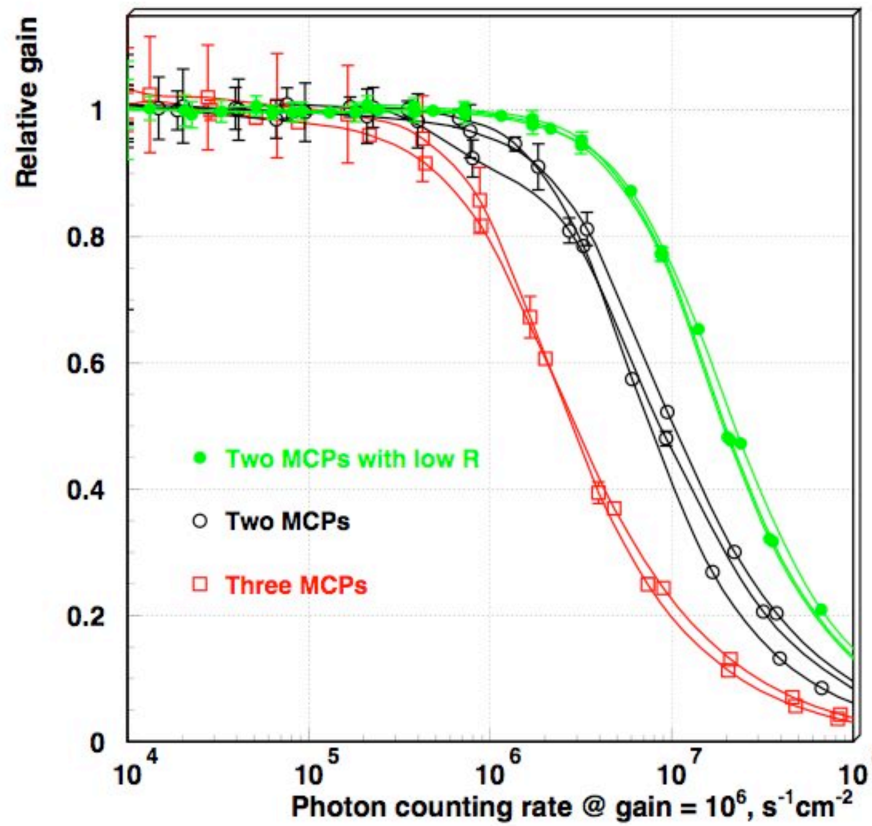


Collection efficiency does not change in axial magnetic field

Gain degradation at high counting rate



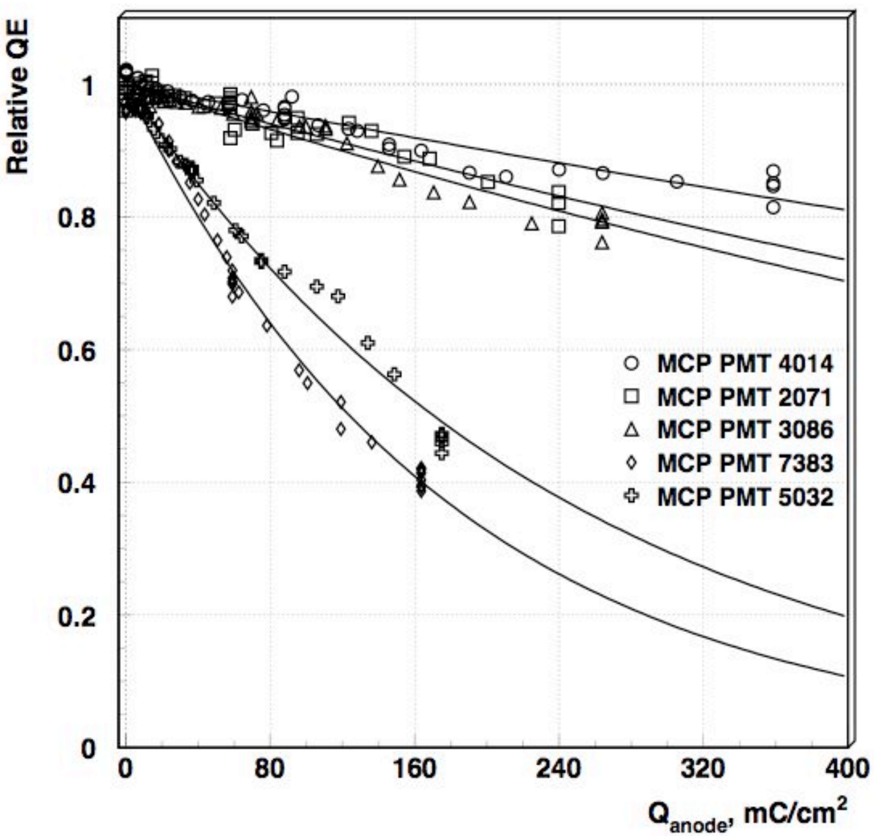




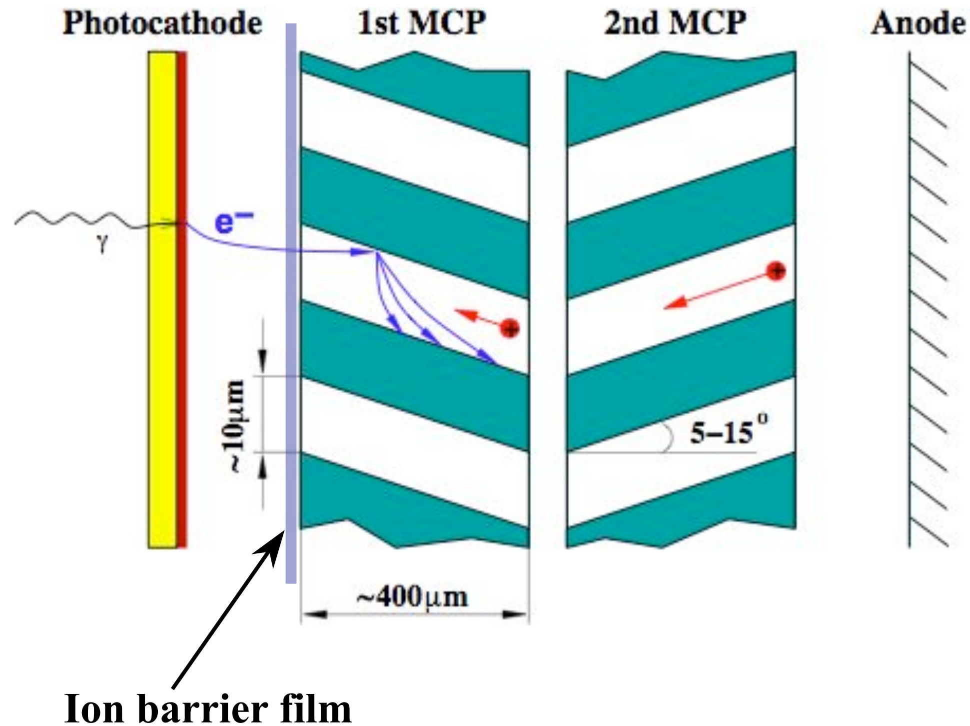
Gain decreases when output current becomes comparable with MCP strip current

MCP with low resistivity can provide counting rate capability up to several MHz/cm^2

Photcathode aging



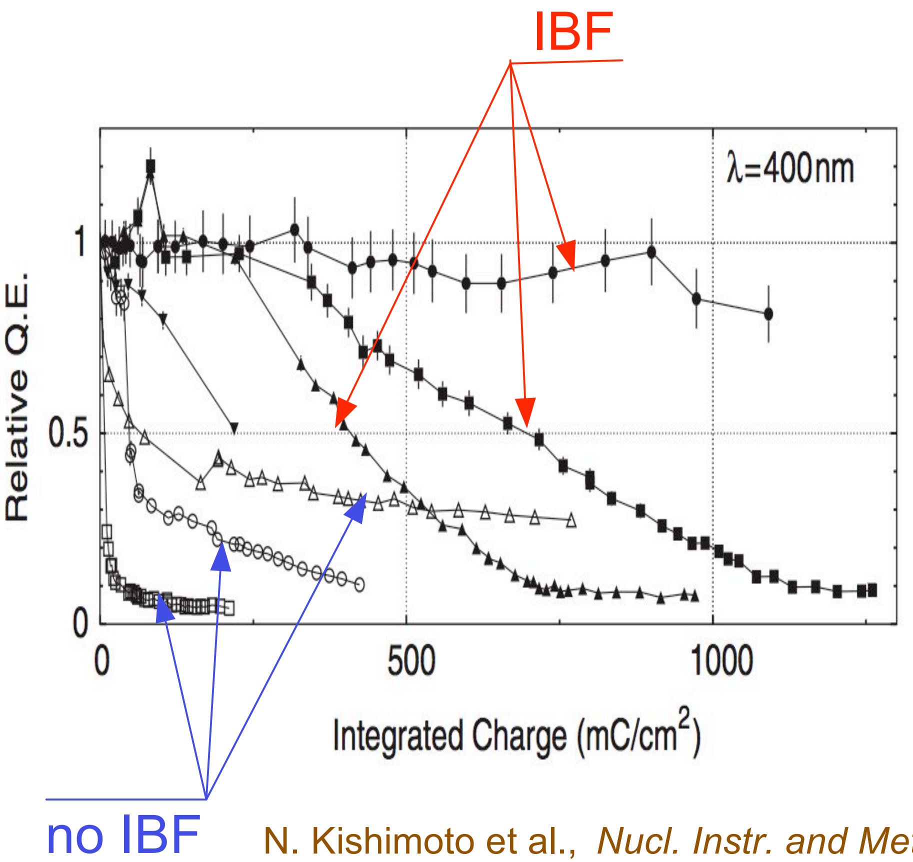
Initial results
(~8 yeas ago)



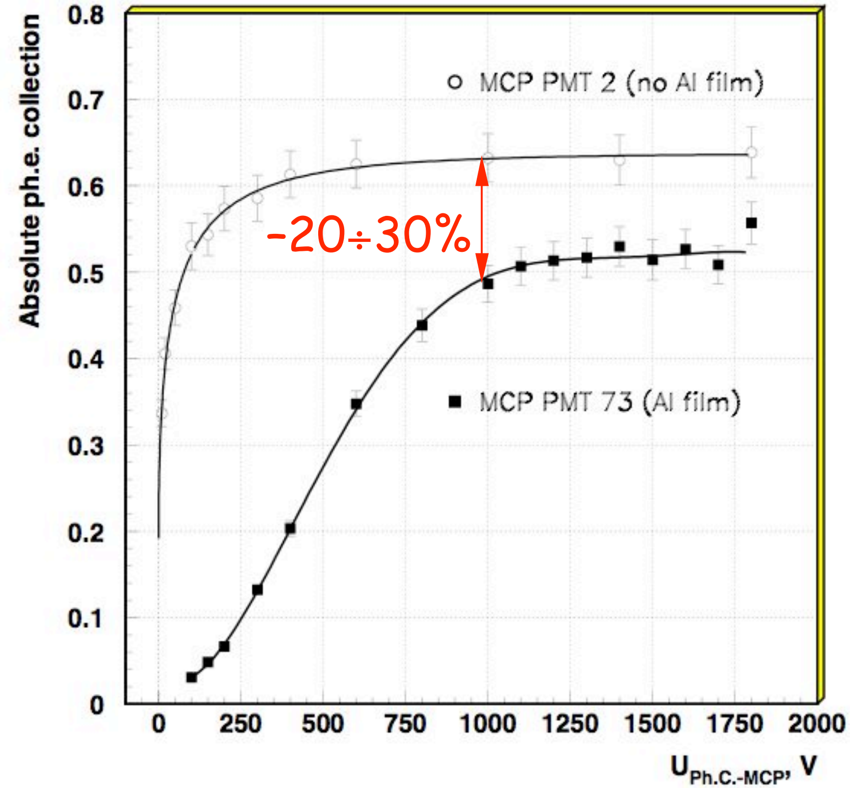
Lifetime improvement approaches:

- Ion barrier film
- Photocathode optimization
- Vacuum improvement (ALD MCP)

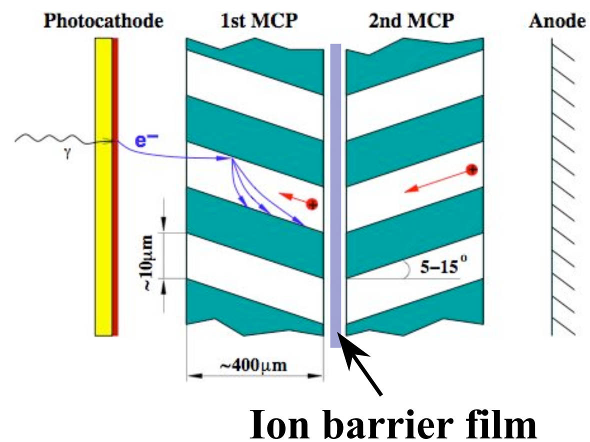
Ion barrier film



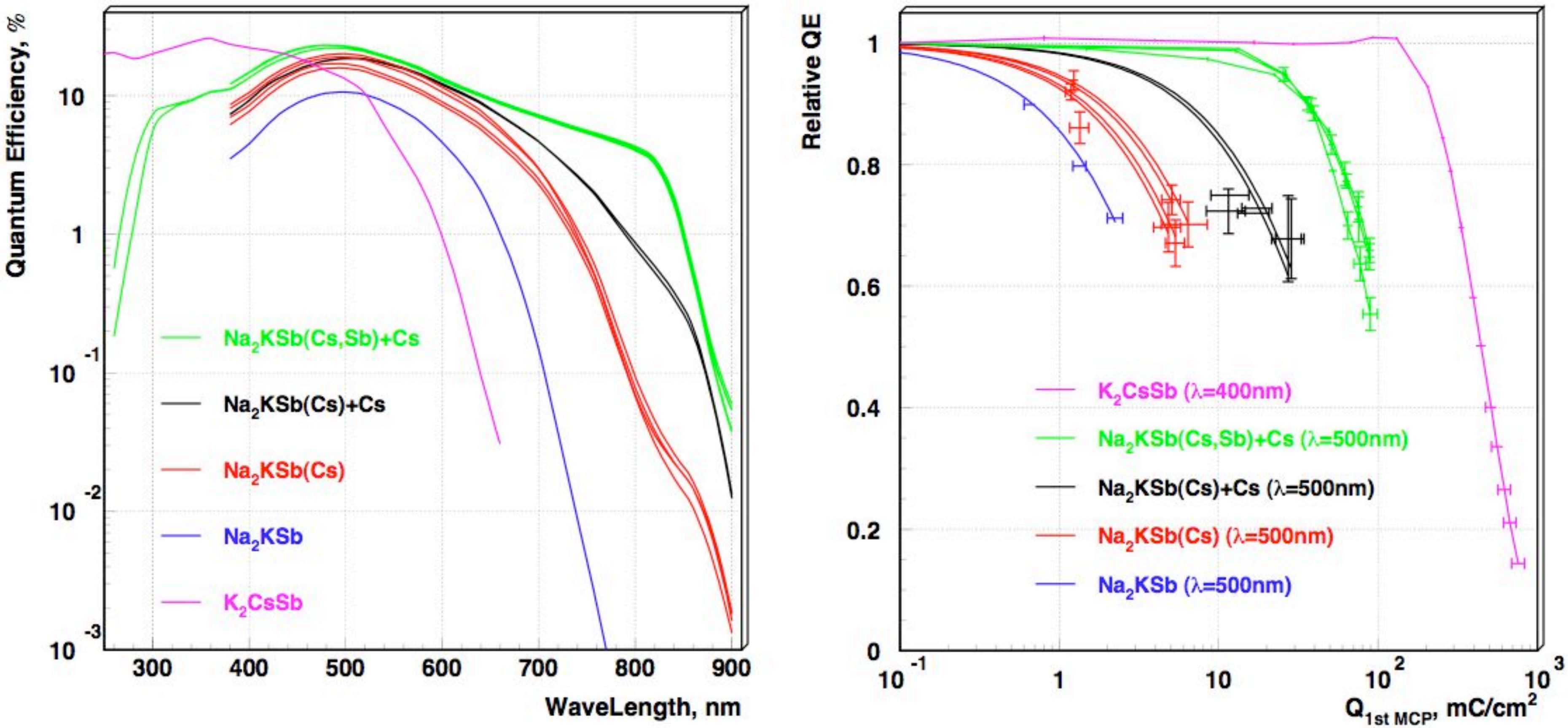
N. Kishimoto et al., *Nucl. Instr. and Meth.* **A 564** (2006) 204



Significant improvement of photocathode lifetime



Photocathode optimization



Optimization of photocathode production technology
can drastically reduce photocathode aging

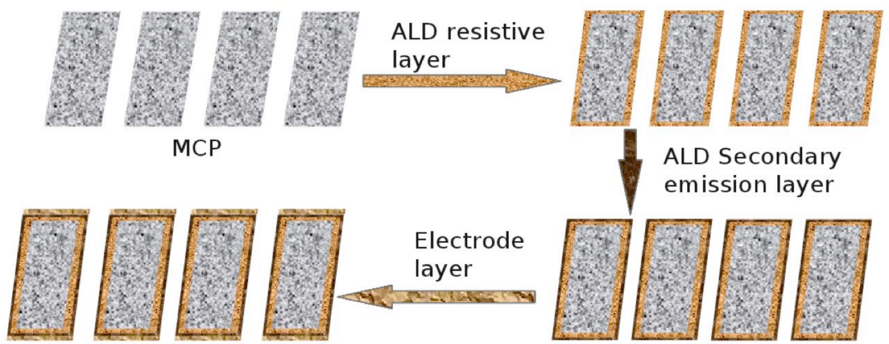
Atomic layer deposition

Traditional technology:
high temperature
hydrogen reduction
of lead glass

➔

- Resistive and SEE layers are formed simultaneously
- It's hard to remove residual hydrogen

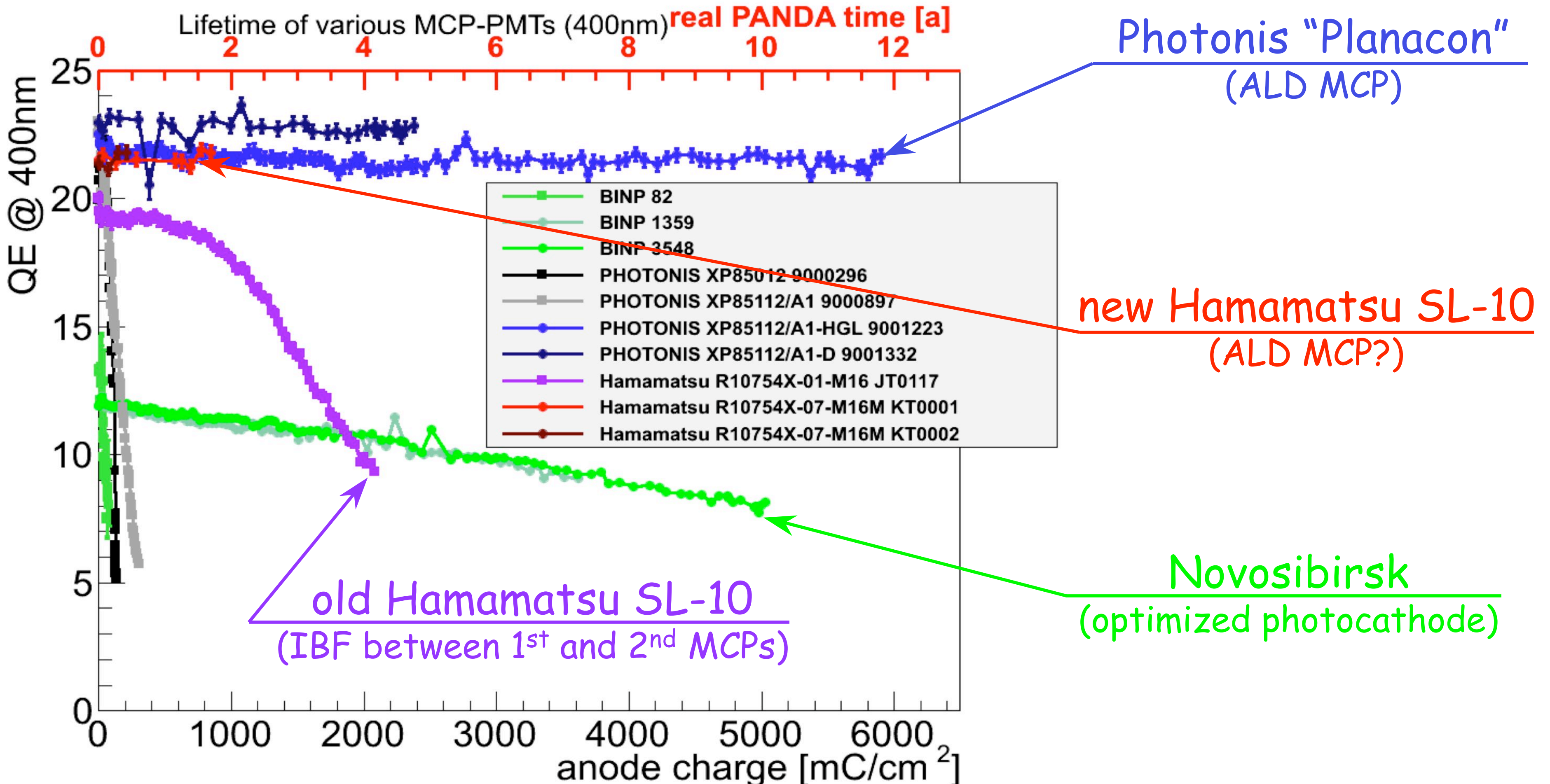
ALD technology:



➔

- Mechanical, resistive and emissive properties can be optimized independently
- Better vacuum

Lifetime comparison

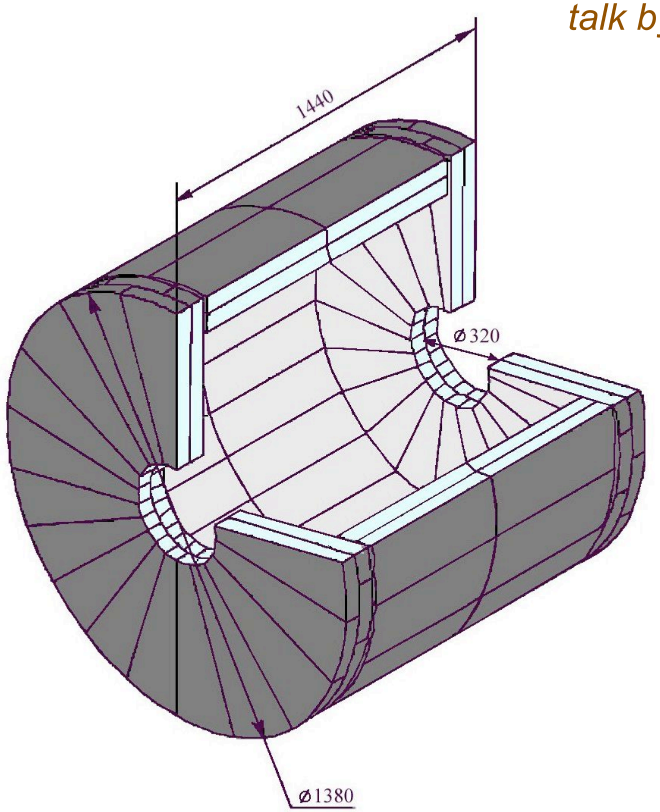


(measured at Erlangen Uni.)

A. Britting, *talk at PID Cherenkov Session at Panda CM XLVII*, 10 December 2013

ASHIPH counters of the KEDR detector

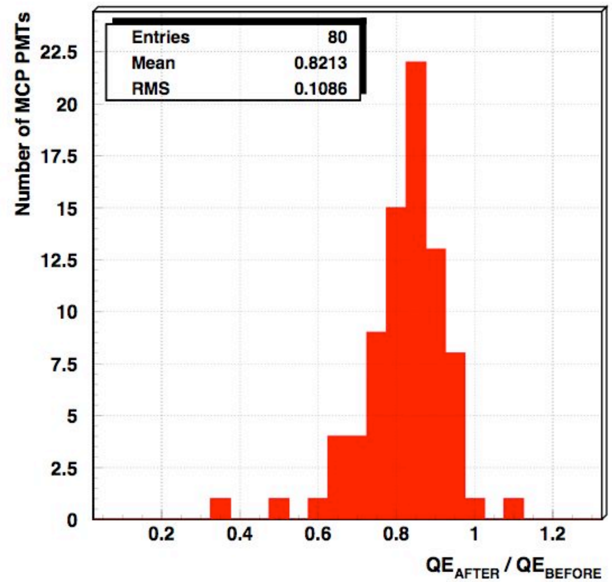
talk by A.Yu.Barnyakov



- π/K separation in momenta range
  0.6 ÷ 1.5 GeV/c
- Aerogel n=1.05 (1000 litres)
- 160 MCP PMT
- Magnetic field up to 1.5 T

80 ASHIPH counters worked in KEDR from 2003 to 2011

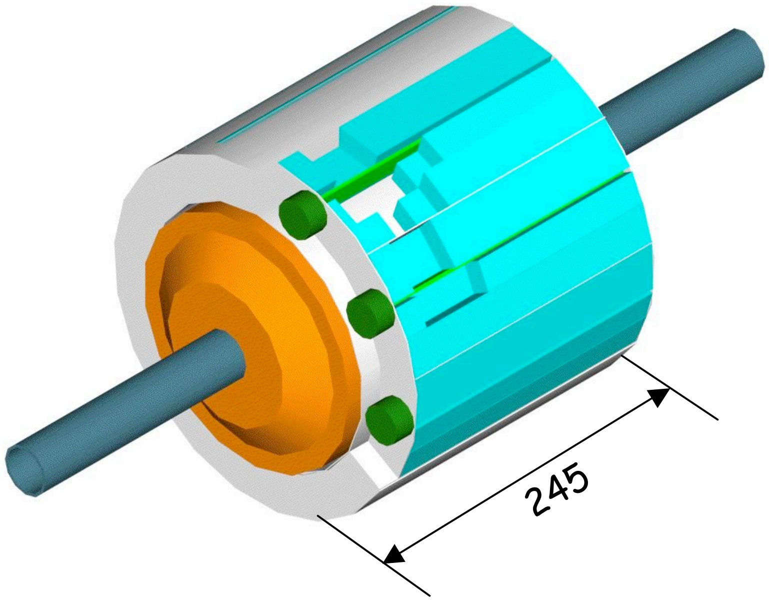
- gain ~$3 \cdot 10^5$
- counting rate $(0.5 \div 20) \times 10^3\ s^{-1}cm^{-2}$
- ON time ~3.5 years
- accumulated anode charge
  $(2 \div 100)\ mC/cm^2$



$QE_{\lambda=500nm}$ decreased by 18% on average

ASHIPH counters for SND

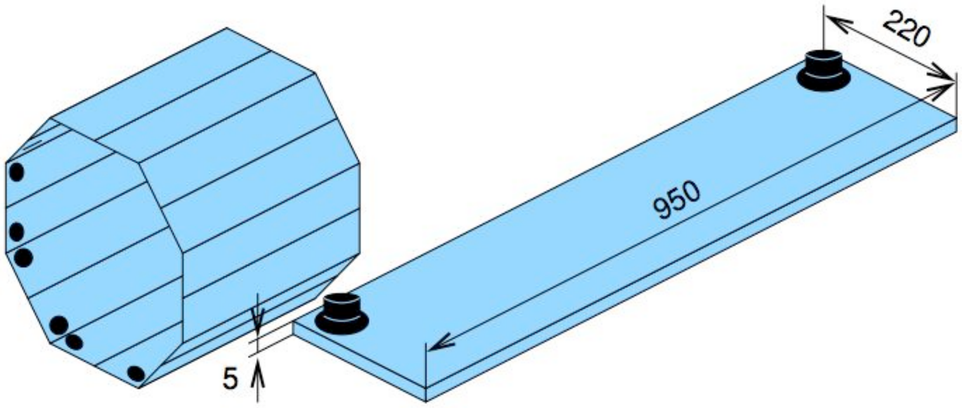
- π/K and e/π separation
- Aerogel n=1.13 and n=1.05
- 2 x 9 MCP PMTs



poster by K.I.Beloborodov
poster by K.A.Martin

TOF counters for CMD-3

- Antineutron identification
- BC-408 scintillator (16 bars)
- 32 MCP PMT

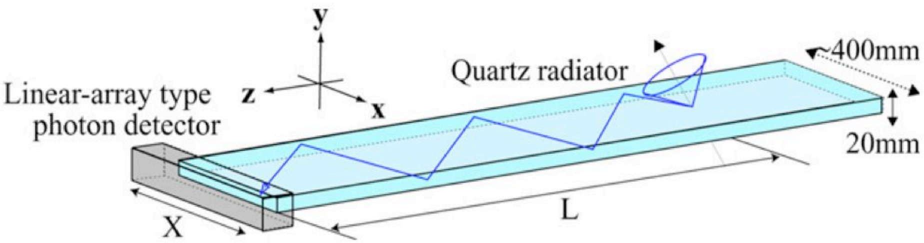


Worked in CMD-3 from 2009 to 2013

D.A. Drozhzhin et al., *Nucl. Instr. and Meth.* **A 598** (2009) 203

SND and CMD-3 are working at VEPP-2000 e^+e^- collider in BINP

Future MCP PMT applications

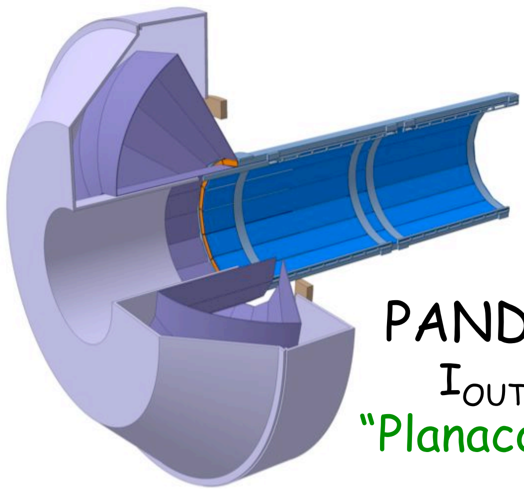


Belle-II TOP

I_{OUT} ~ 0.15 C/cm^2/year

Hamamatsu SL-10

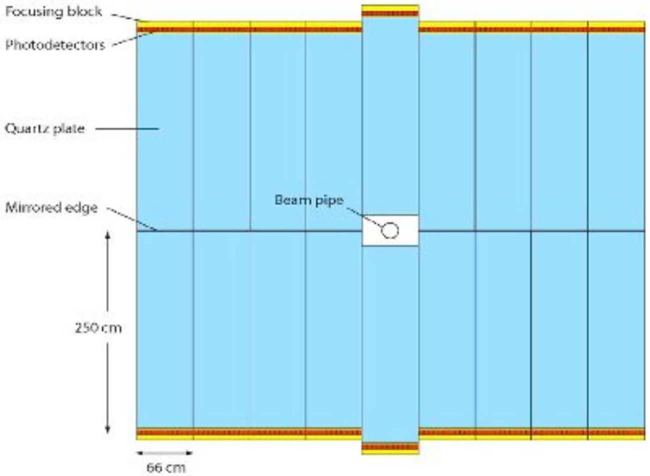
talk by K.Suzuki



PANDA barrel DIRC

I_{OUT} ~ 1 C/cm^2/year

"Planacon" with ALD MCP

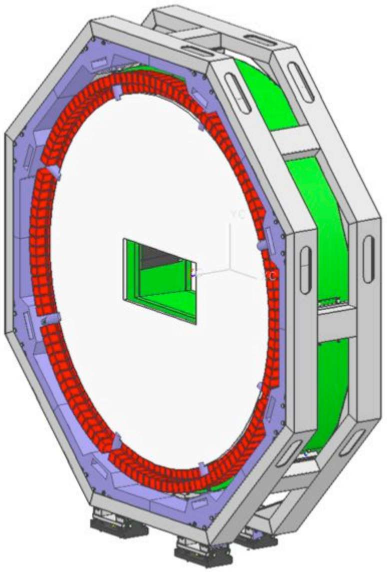


LHCb TORCH

PANDA Disk DIRC

I_{OUT} ~ 5 C/cm^2/year

Lifetime is still unsolved problem!



Summary

- Advantages of MCP PMT:
  - ✓ single photon time resolution ≈30 ps
  - ✓ space resolution ≤ 1 mm
  - ✓ can be used in high magnetic field

- MCP PMTs are successfully used in experiments at VEPP-4M and VEPP-2000 colliders

- Recent progress in the photocathode lifetime (> 6 C/cm^2) opened the way for new applications of MCP PMT