MCP PMT aging

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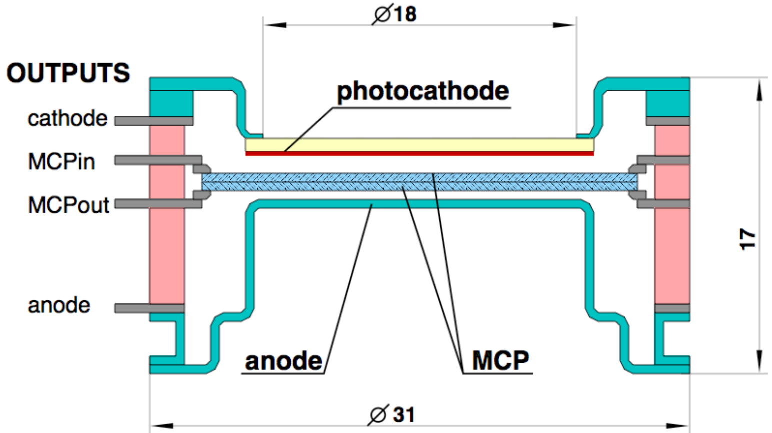
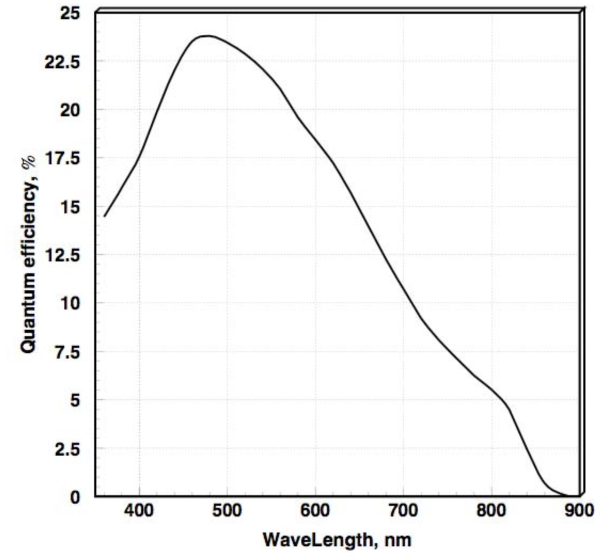
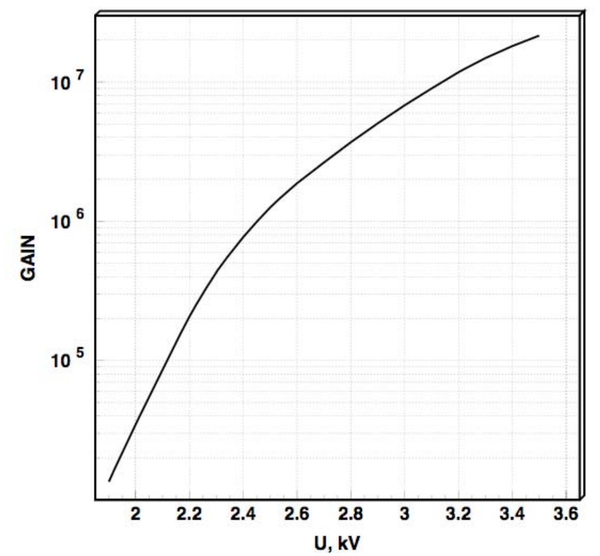
Design of MCP PMT



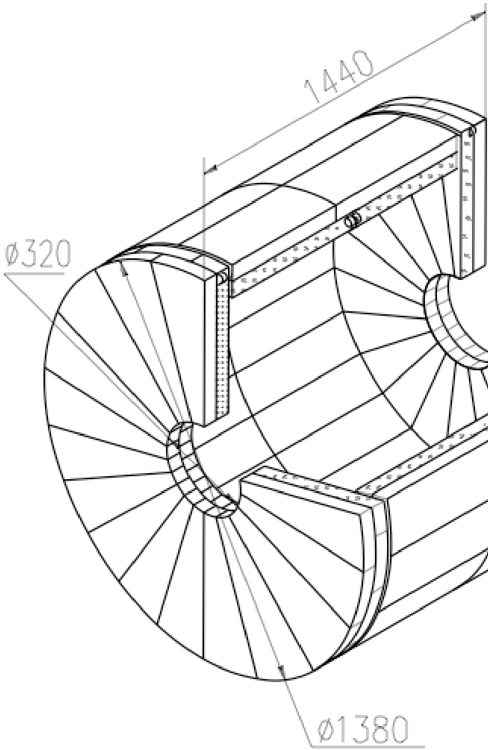
- Borosilicate glass window
- Multialkali photocathode
- Two MCPs with channel diameter of 8 μm
- Channel bias angle 5°
- MCP open area ratio ≈ 0.6
- Dark counting rate < 10^5 cps
- Gain deterioration in axial magnetic field of 2 T is less than 5 times
- Transit time spread ≈ 30 ps (M.Akatsu, et al., NIM-A 528(2004)763)



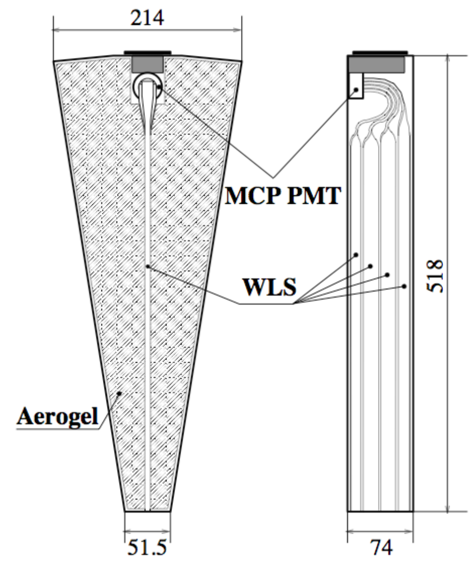


MCP PMT at BINP

ASHIPH counters of the KEDR detector



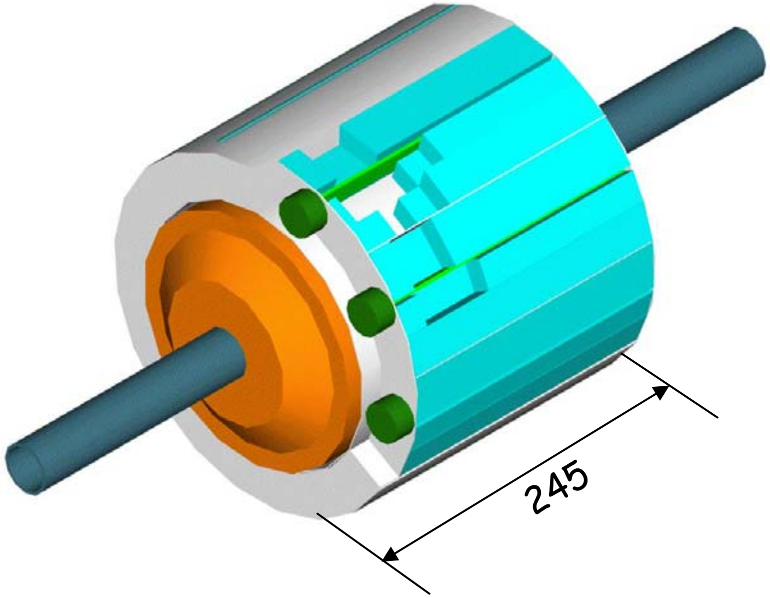
- π/K separation in momenta range 0.6 ÷ 1.5 GeV/c
- 160 MCP PMT
- Magnetic field up to 1.8T
- Aerogel n=1.05 (1000 litres)



- Why MCP ?
  - Immunity to magnetic field
  - Compactness

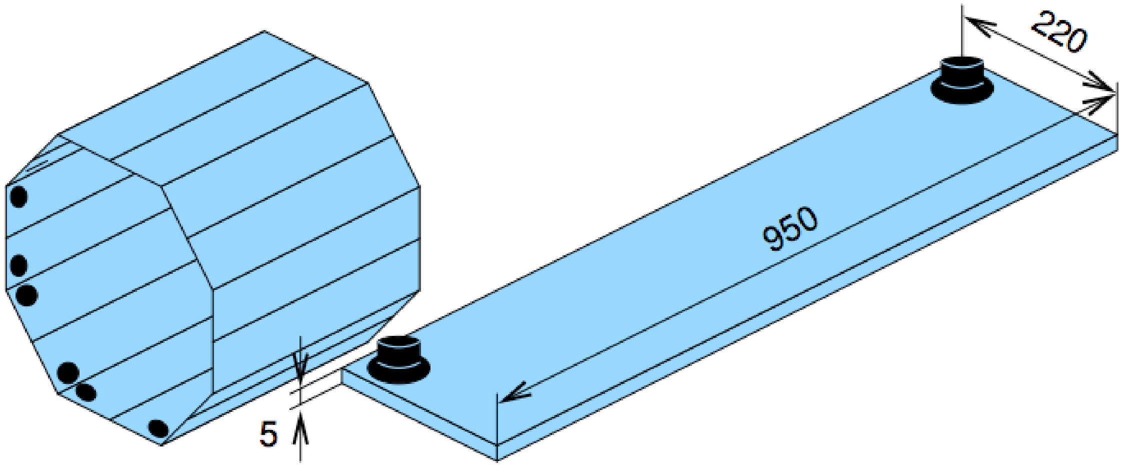
80 counters have worked since 2003

ASHIPH counters for SND detector



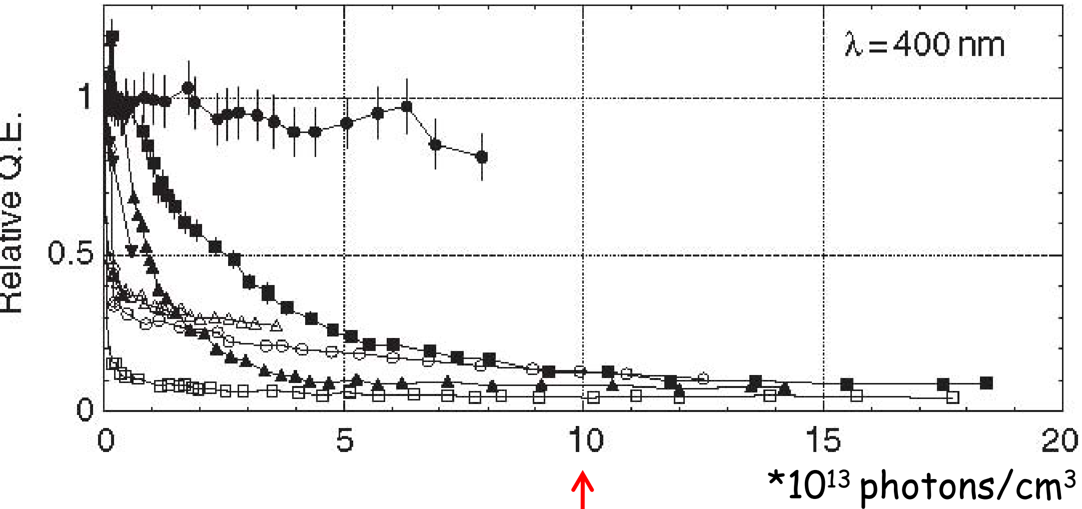
- π/K separation in momenta range 300 ÷ 870 MeV/c
- 9 MCP PMT
- No magnetic field
- Aerogel n=1.13
- Why MCP ?
  - Compactness
  - Availability at the lab

TOF counters for CMD-3 detector



- Antineutron identification
- BC-408 scintillator (16 bars)
- 32 MCP PMT
- Why MCP ?
  - Good time resolution
  - Compactness

University of Nagoya ageing tests



10^{14} photons/cm^3 = 5 years at SuperKEKB TOP

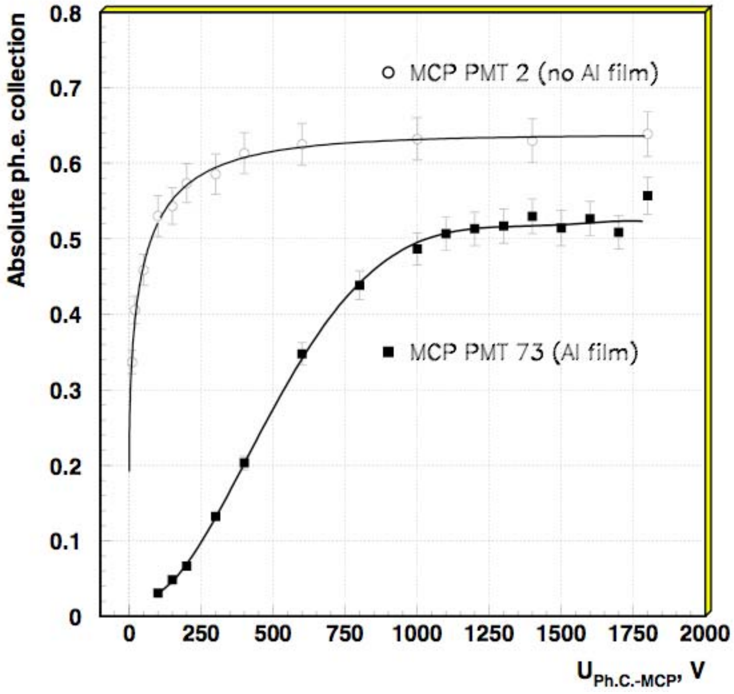
- MCP with protective layers could work at Super B
- The cost of this is 50% drop in photon detection efficiency

• - Hamamtsu with protective layer, o - Hamamatsu without, ▪ Novosibirsk with, ▫ Novosibirsk without

Improvement of lifetime

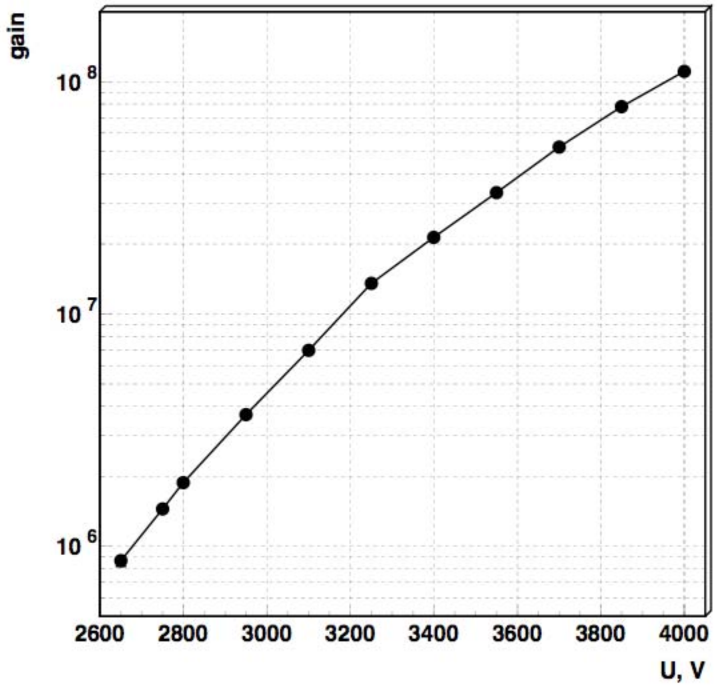
I. Al_2O_3 protective layer

- protection of photocathode versus feedback ions
- decrease of photoelectron collection efficiency



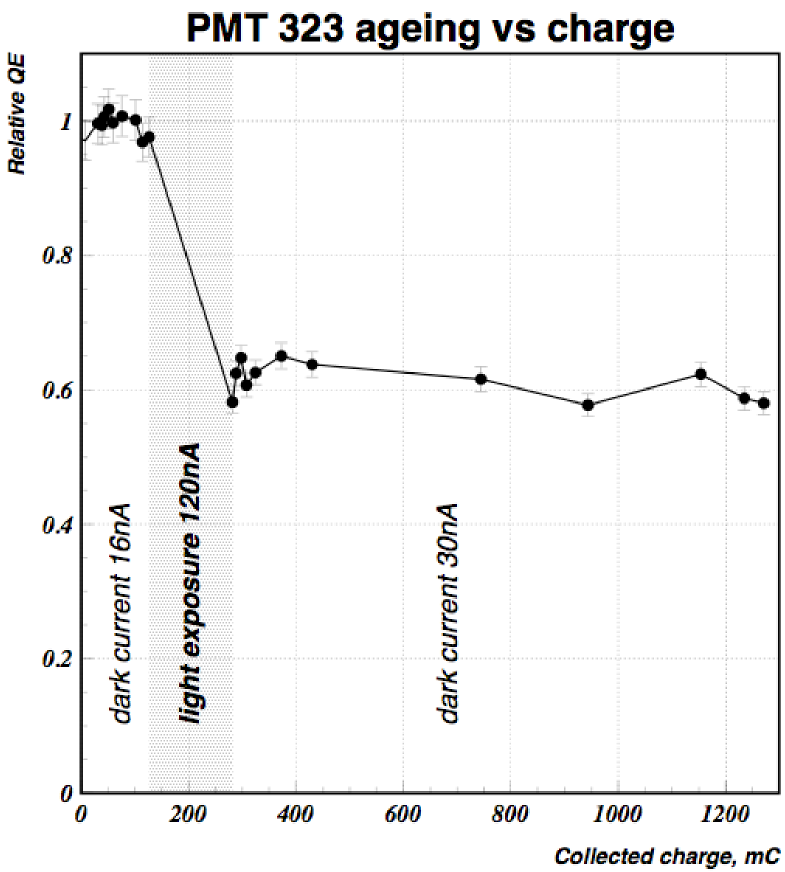
II. Three MCPs

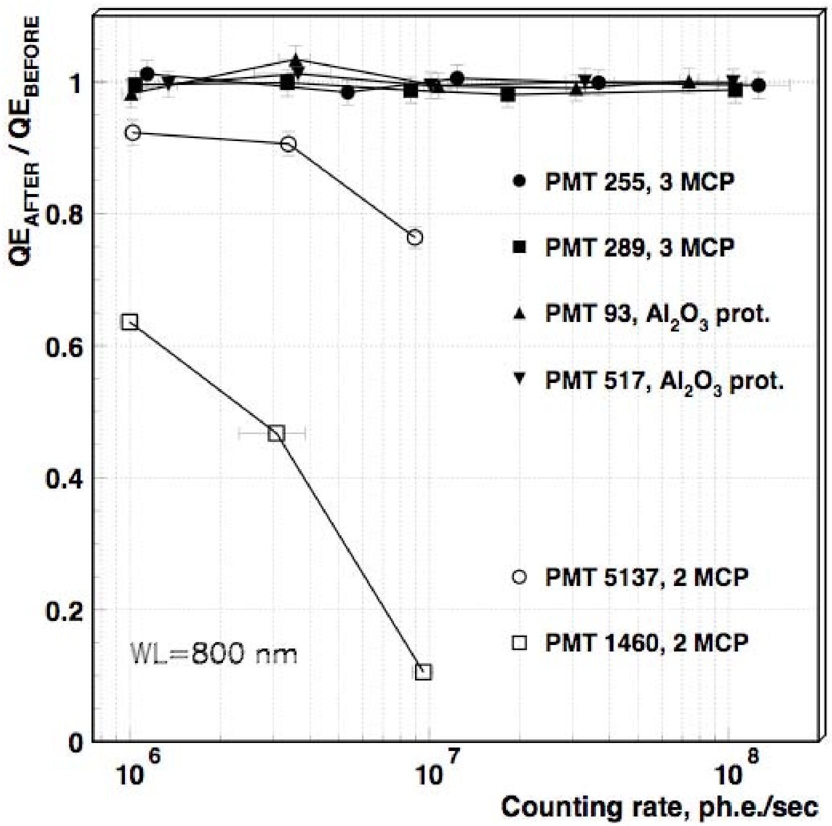
- additional barrier for feedback ions
- higher gain possible



- more sensitive to magnetic field ?
- worse time resolution ?

Speed of QE degradation versus counting rate





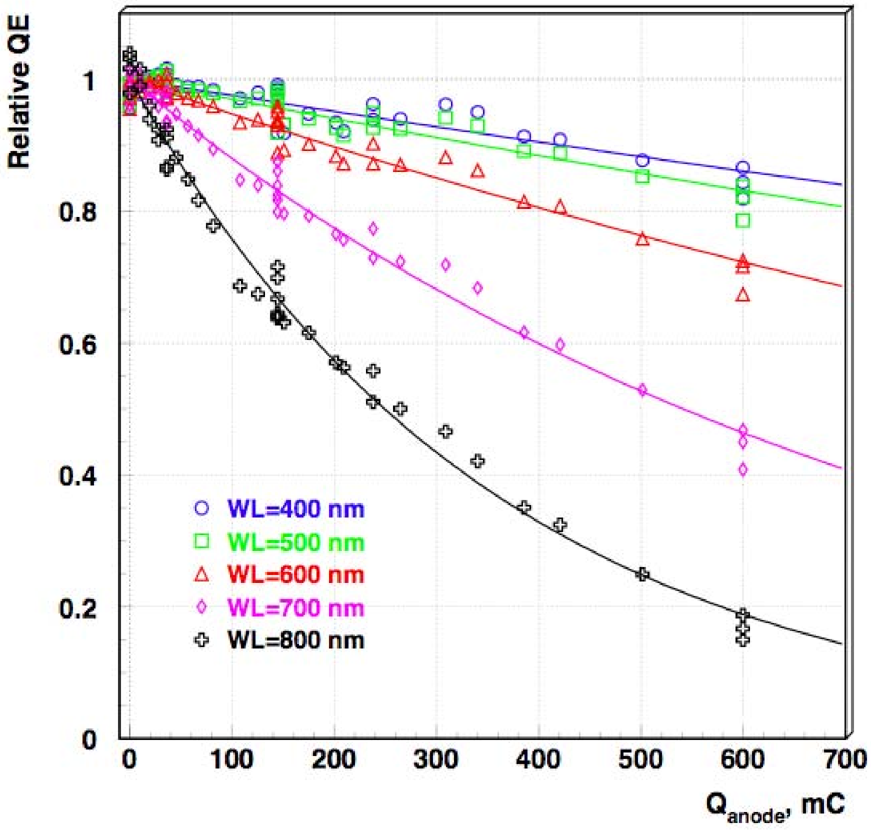
Much faster QE degradation at higher anode current

Higher specific QE degradation ($Q_{CATHODE}$=5nC) at higher counting rate

No dependence observed for PMT with protective layer and Z-stack

QE degradation versus wavelength

MCP PMT #2071 (two MCPs)



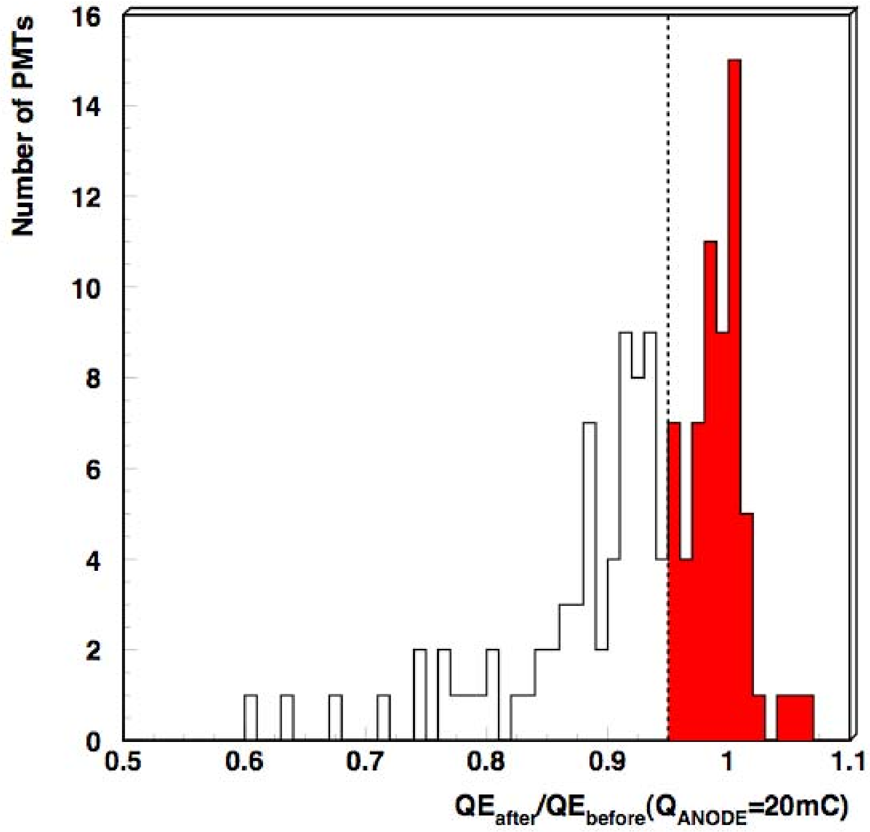
Possibility to control photocathode aging after short exposure

Criterion:

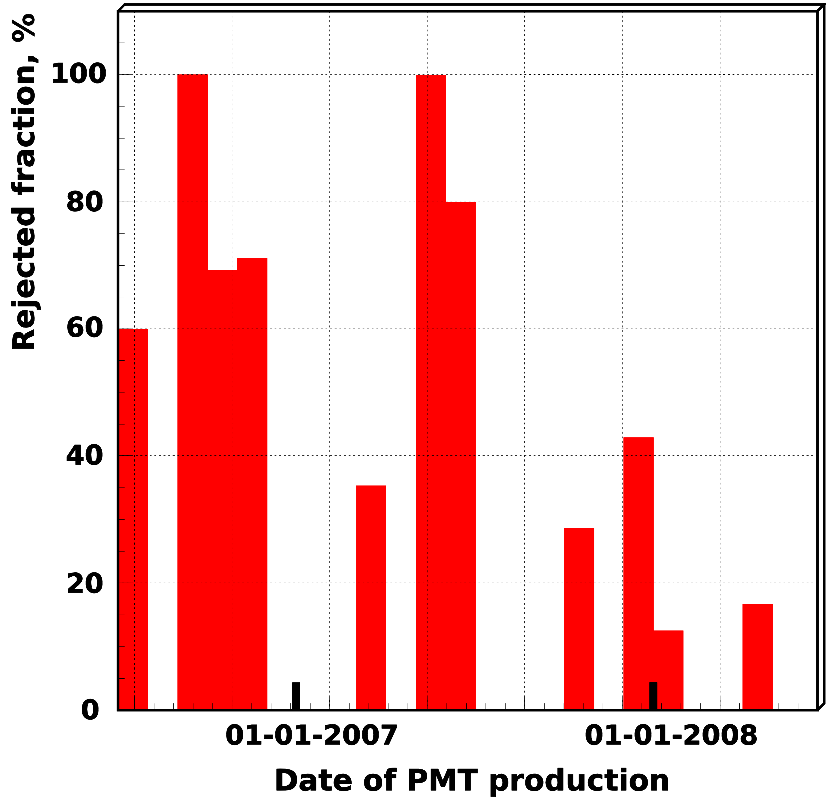
ΔQE(800nm) < 5% @ Q_{ANODE} = 20mC

(~ 7 weeks at working conditions)

Results of aging tests

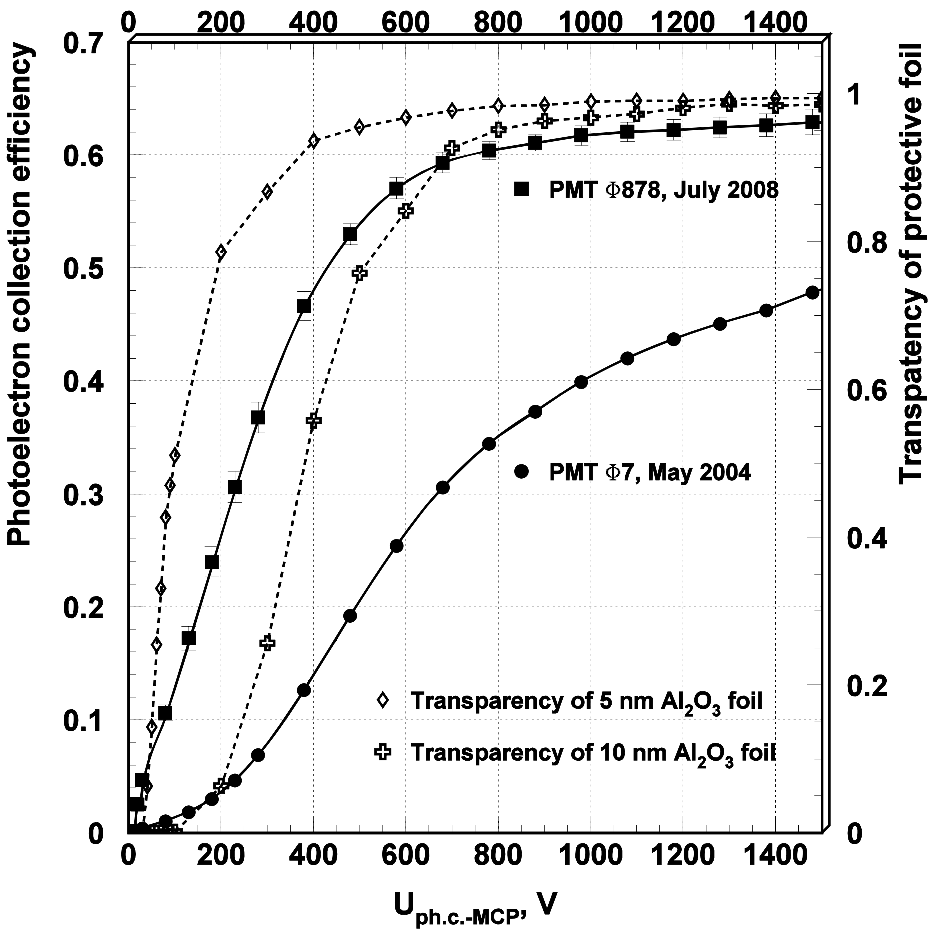


QE(800nm) change after anode charge of 20 mC collected



Production technology improvement

Geant 4 calculations of the protective layer transparency

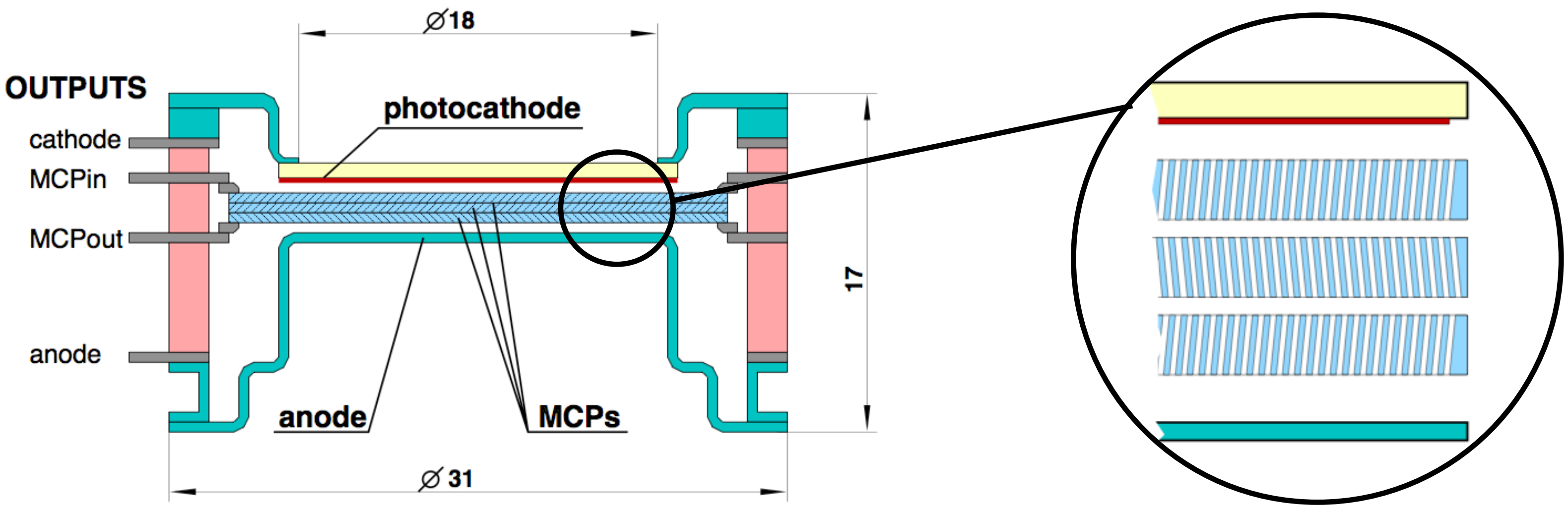


- What is the homogeneity of the protective layer?
- Are there any holes?

Remarks

- Aging strongly depends on vacuum conditions
- The idea of 3 MCP plates works, but not so effective as protection layer.
-

PMT with three MCPs (aka Z-stack)



The same package
Three MCPs with channel diameter of 8 μm

Controlled parameters:

•Quantum efficiency	> 20%@500nm	•Gain	> 10^6
•Photoelectron collection efficiency	> 0.6	•Noise counting rate	< 5×10^4 cps

Fast test of photocathode lifetime is needed

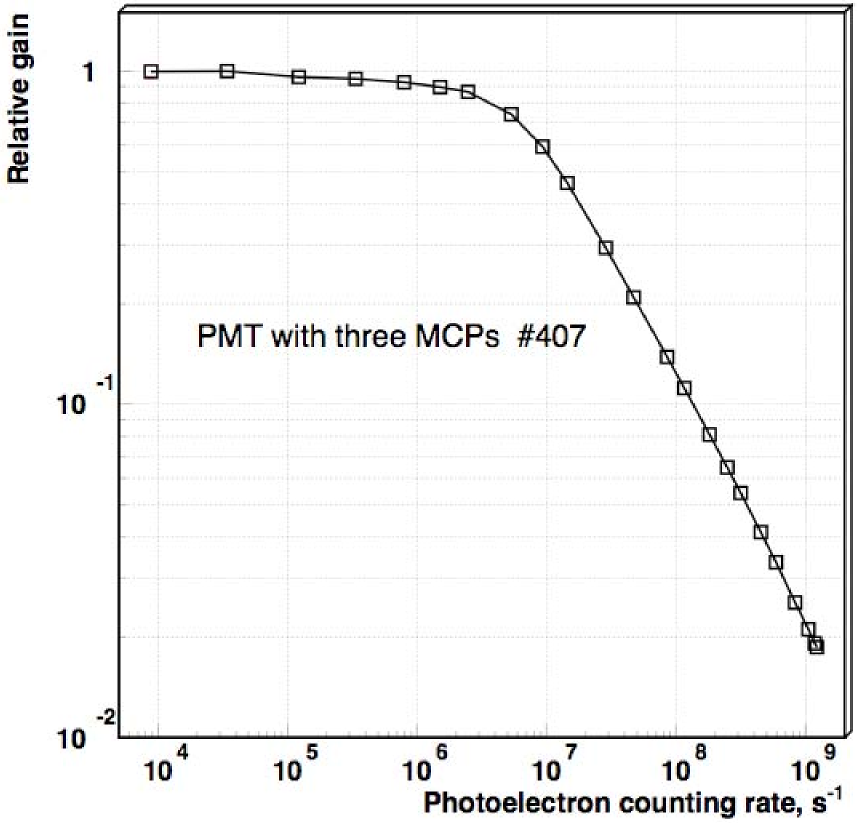
Aging test conditions

"Low rate test"

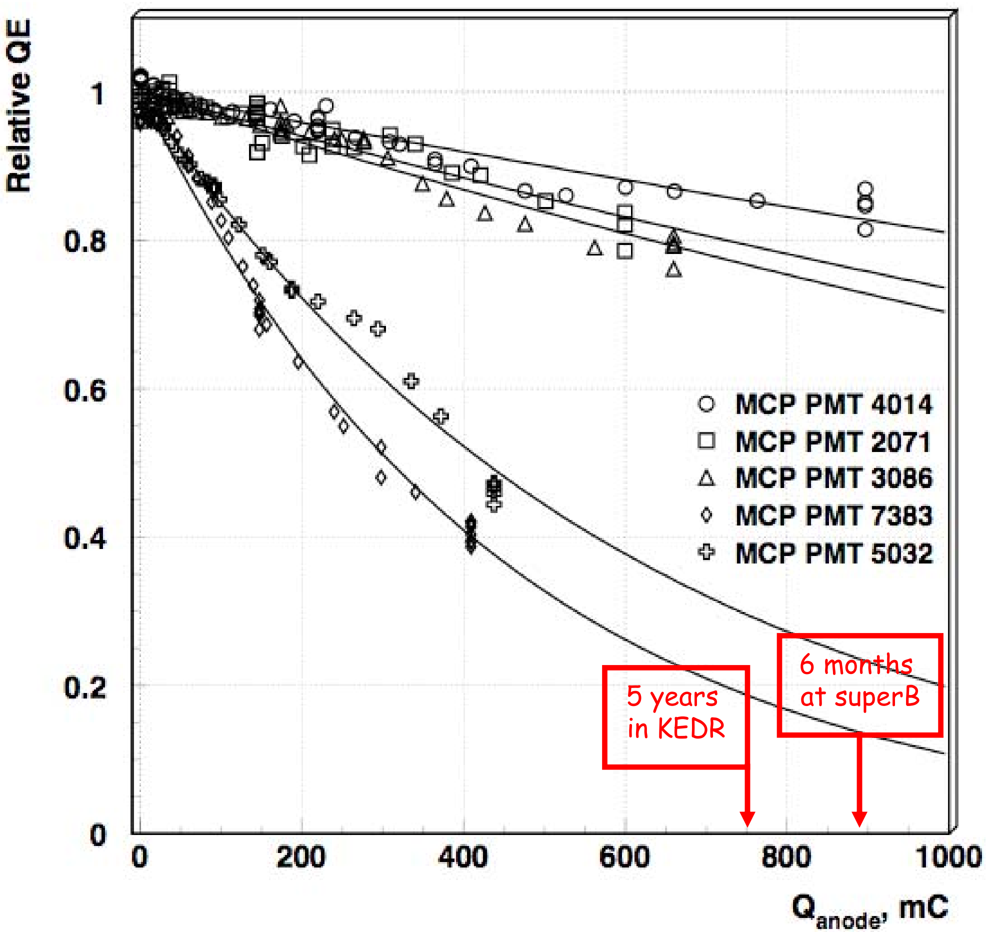
- Gain ≈ 10^6
- Counting rate ≈ 2×10^5 cps
- Exposure time 1 week
  - ➔ Q_{ANODE} ≈ 20 mC

"High rate test"

- Initial gain ≈ 10^6
- Counting rate ≈ 10^9 cps
- Exposure time 30 minutes
  - ➔ $Q_{CATHODE}$ ≈ 300 nC
  - ➔ Q_{ANODE} ~ 6 mC



Photocathode lifetime



Gain = $(0.5 \div 1.0)\times10^6$
Continuous illumination
Photon counting rate ~10^6 cps
Quantum efficiency at λ=500nm
Anode charge from whole area of photocathode 2.54 cm^2

<u>Working conditions</u>

ASHIPH counter of the KEDR:

Gain ≈ 0.3×10^6
Counting rate ≤10^5 cps

➔Anode current ~ 150 mC/year

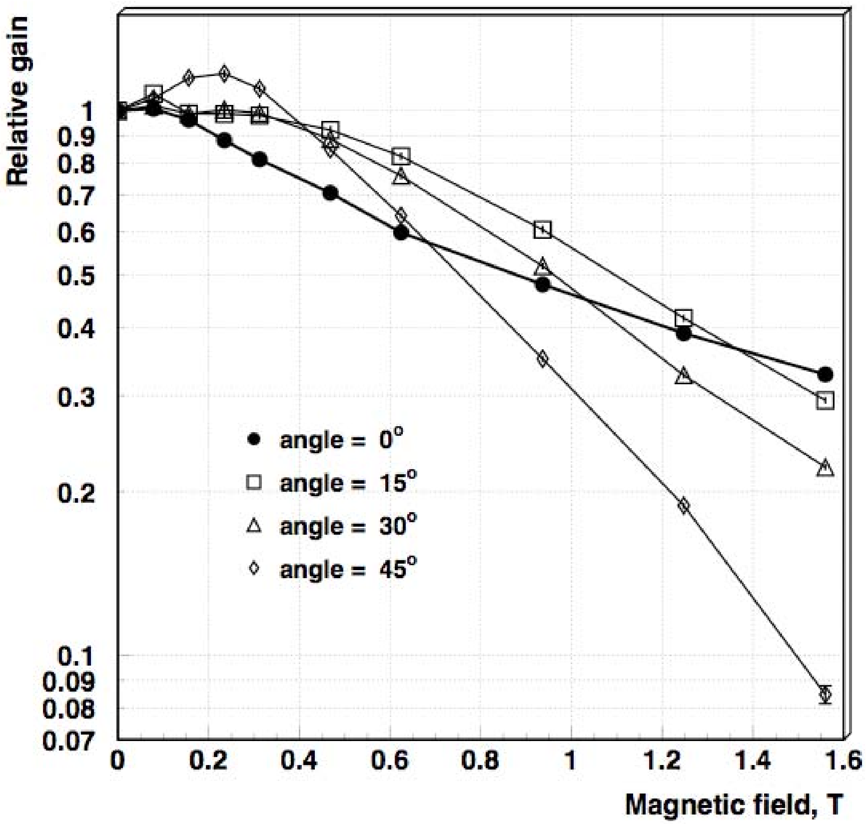
TOP counter at super-B:

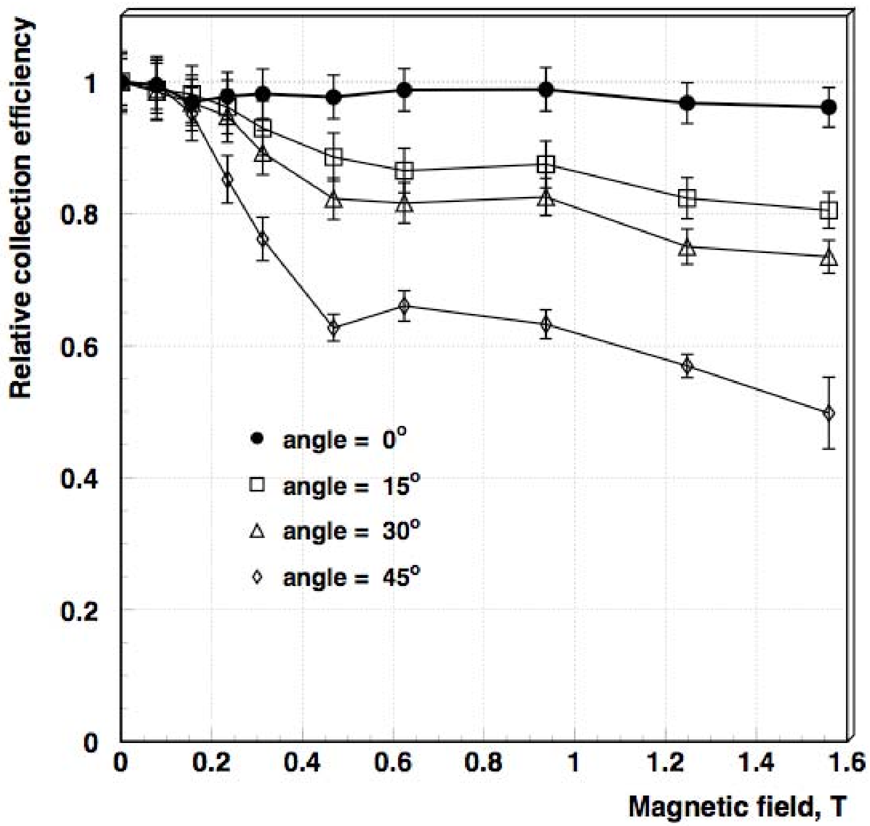
Gain ≈ 2×10^6
Counting rate ≈ 7×10^4 cps/cm^2

➔ Anode current ~ 700 mC/year/cm^2

(N. Kishimoto, NIM-A 564(2006)204)

PMT with three MCPs in magnetic field

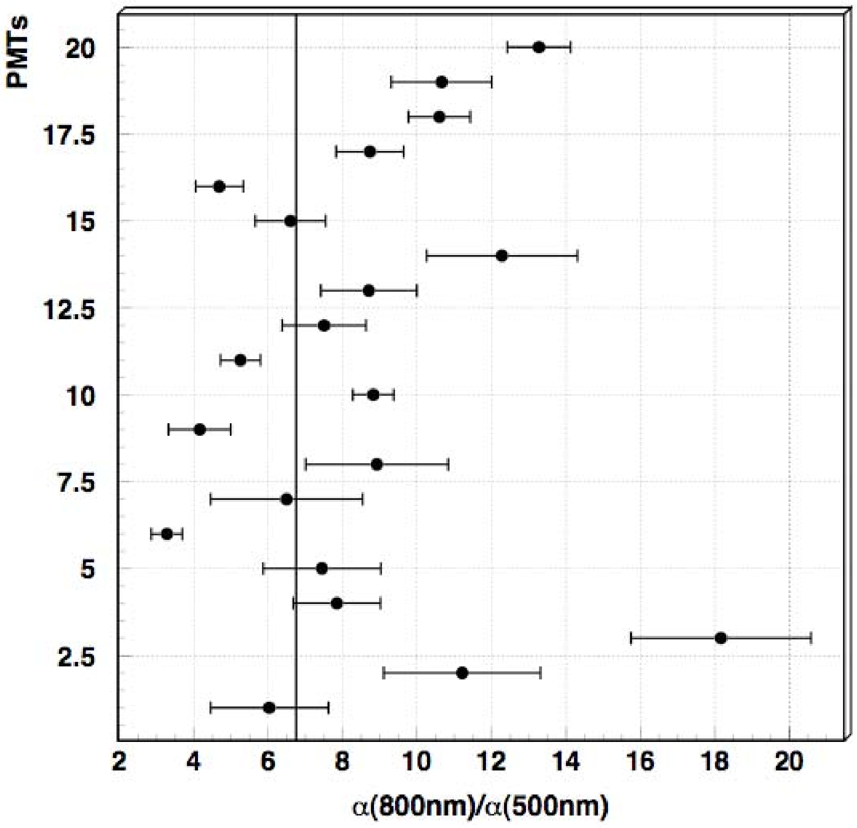




Moderate gain decrease even for tilt angles < 45°

Photoelectron collection efficiency does not change in axial field

QE degradation versus wavelength



Possibility to control photocathode aging after short exposure

Requirements:

• QE(500nm) change < 25% after 5 years of operation in the KEDR

• QE(800nm) change ≥5%

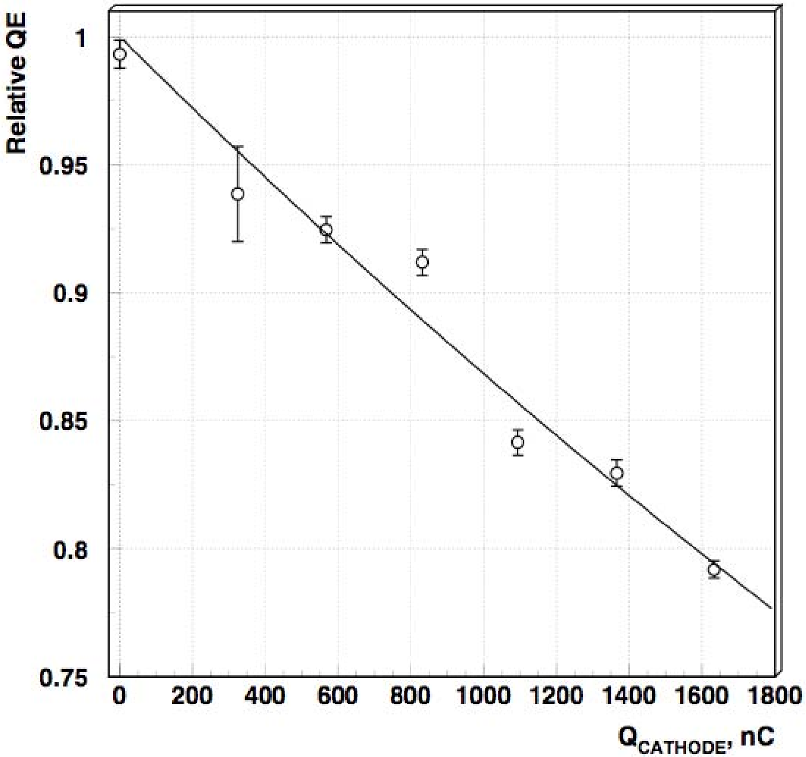
➔ Anode charge ≥ 20 mC

Criterion:

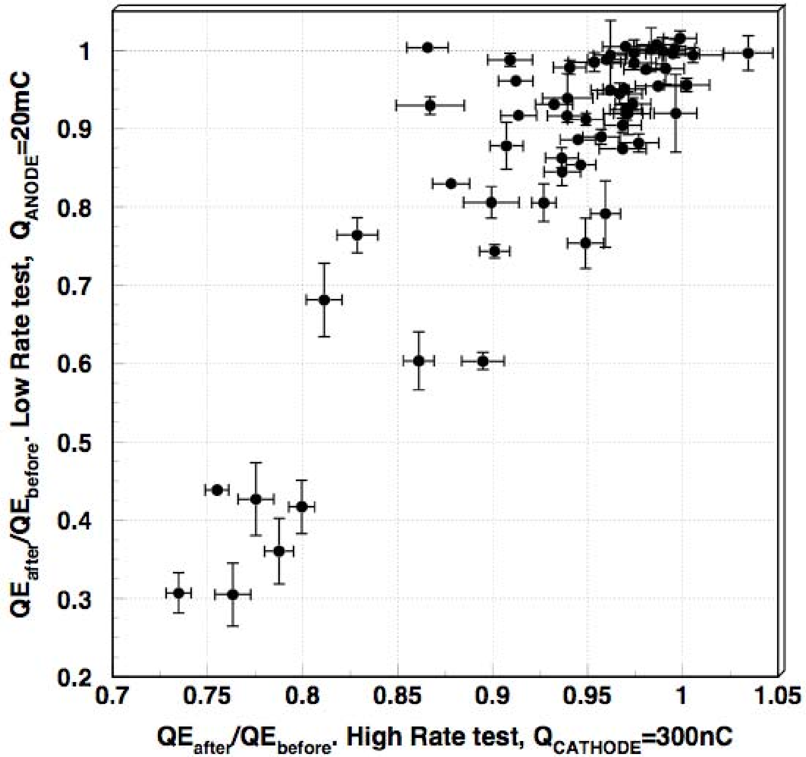
ΔQE(800nm) < 5% @ Q_{ANODE} = 20mC

(~ 7 weeks at working conditions)

Reliability of High Rate test



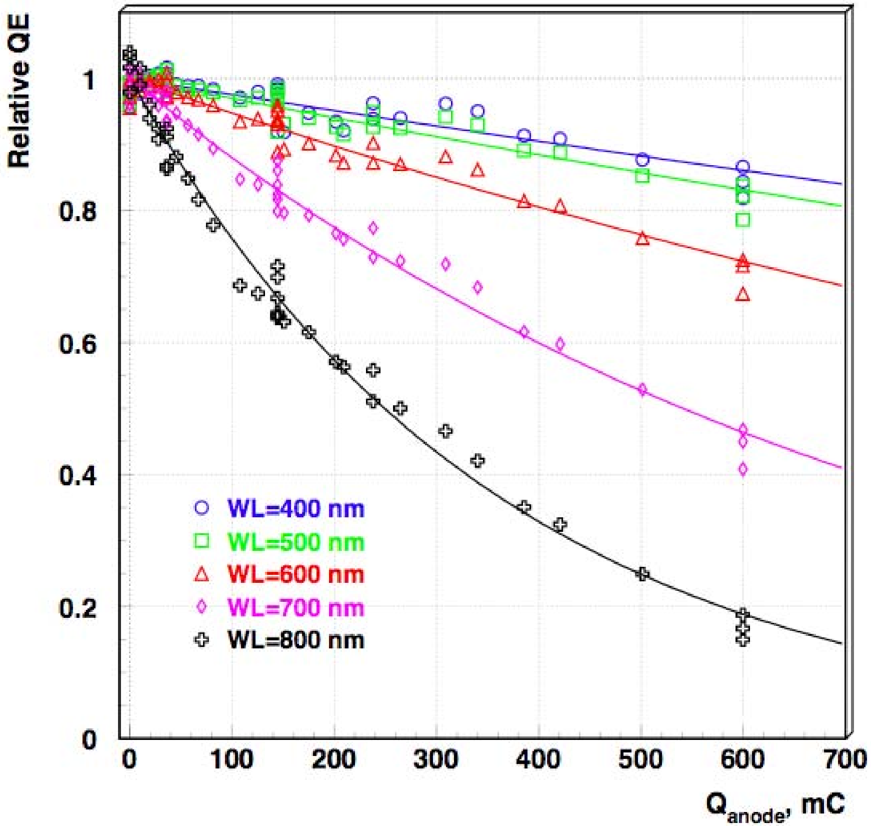
Good reproduction of test results



Correlation with Low Rate test results

Useful for fast comparison of photocathode aging

QE degradation versus wavelength



$$QE = QE_0 \exp(-\alpha Q_{anode})$$

MCP PMT #2071 (two MCPs)