Photocathode aging in MCP PMT

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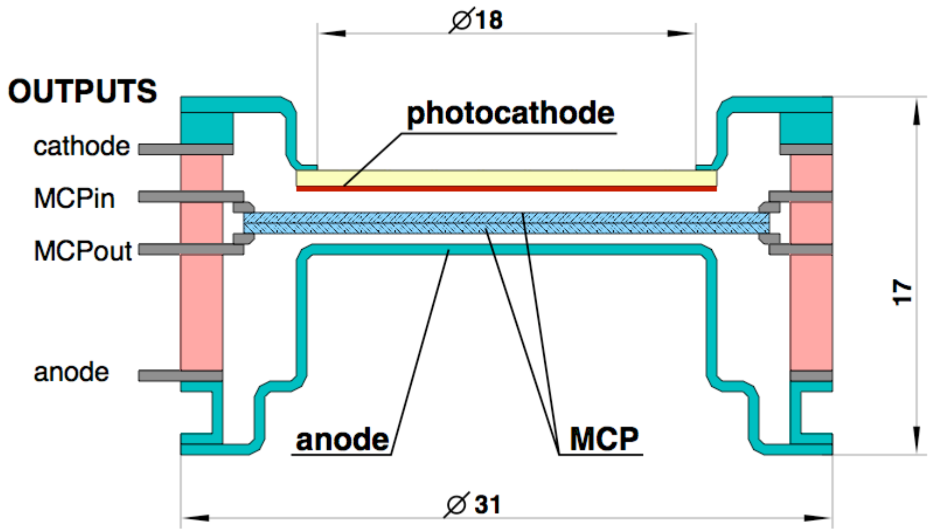
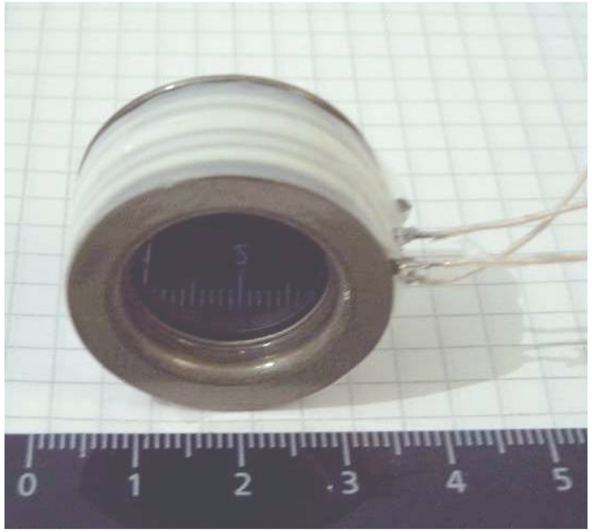
Outline:

- MCP PMT and experimental setup
- Photocathode aging vs. photon counting rate
- MCP degassing enhancement
- Comparison of different photocathodes
- Lifetime of the best sample
- Conclusion

MCP PMT under investigation





Manufacturer: “Ekran FEP” (Novosibirsk)

Borosilicate glass window

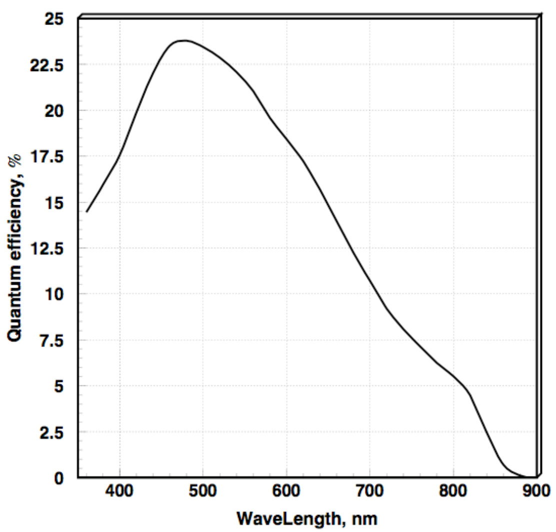
Multialkali (Sb-Na-K-Cs) photocathode

Maximum QE at λ=500nm

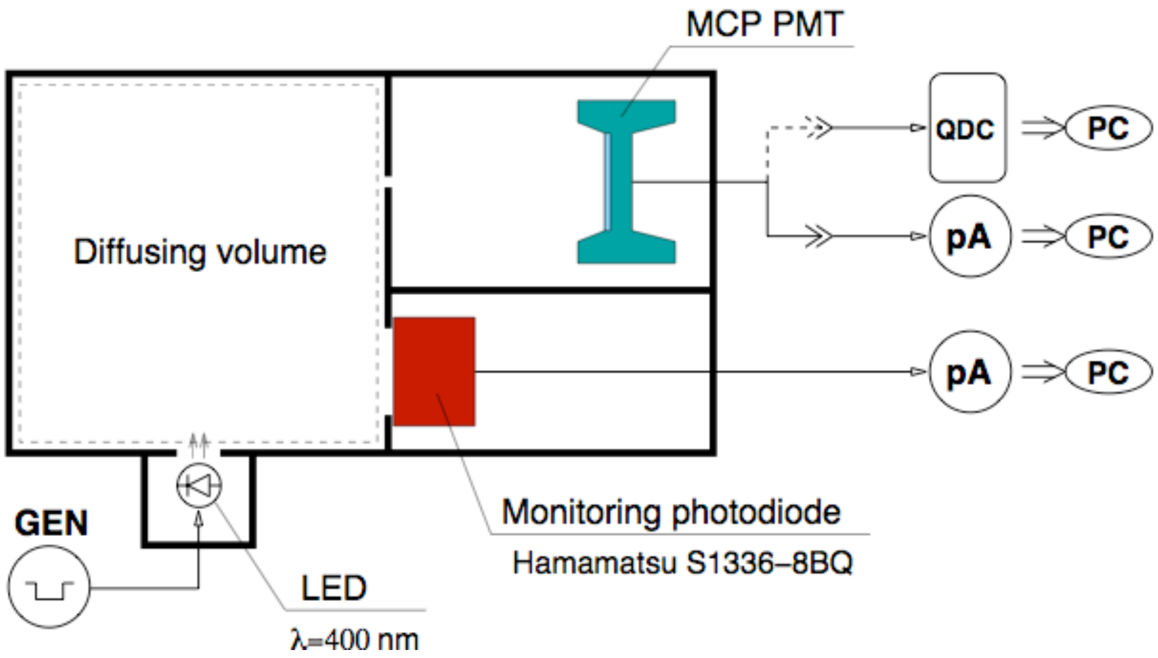
Two MCPs with channel diameter of 7 μm

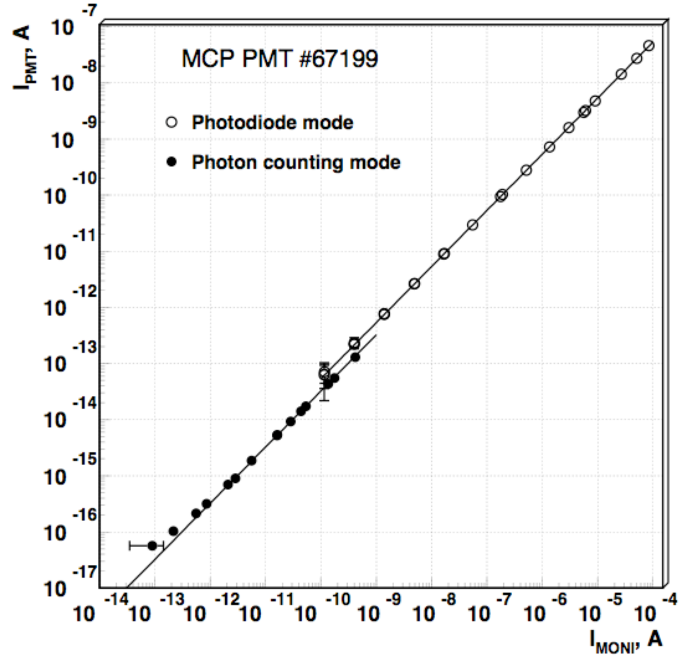
Channel bias angle 13°

Single anode



Setup for MCP PMT aging study





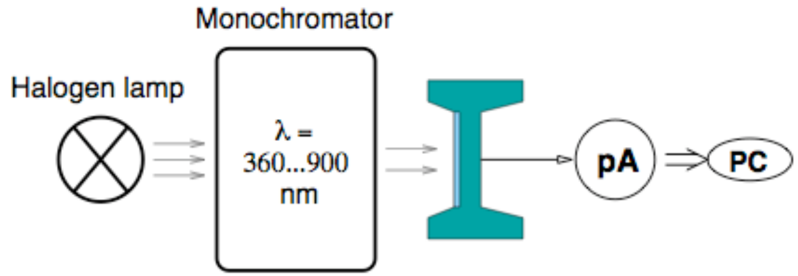
Low light intensity (photon counting mode):

$K = R_{PMT}/I_{MONI}$

High light intensity (direct current mode):

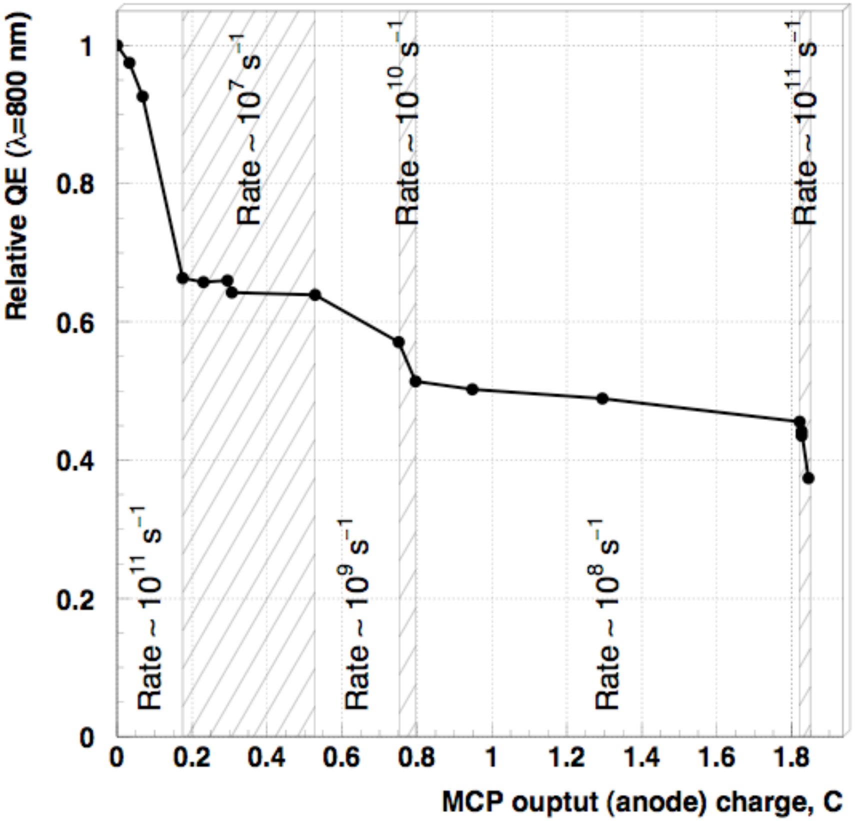
$R_{PMT} = I_{MONI} K$

QE measurement:

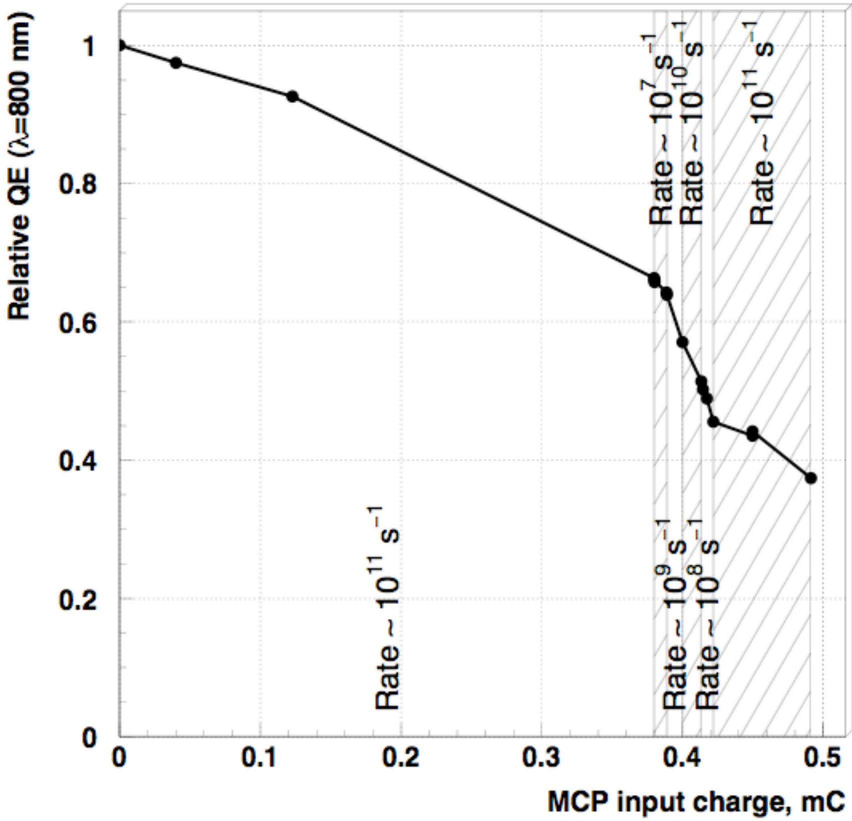


Reference PD: Hamamatsu S1227-1010BQ

QE degradation at different counting rates



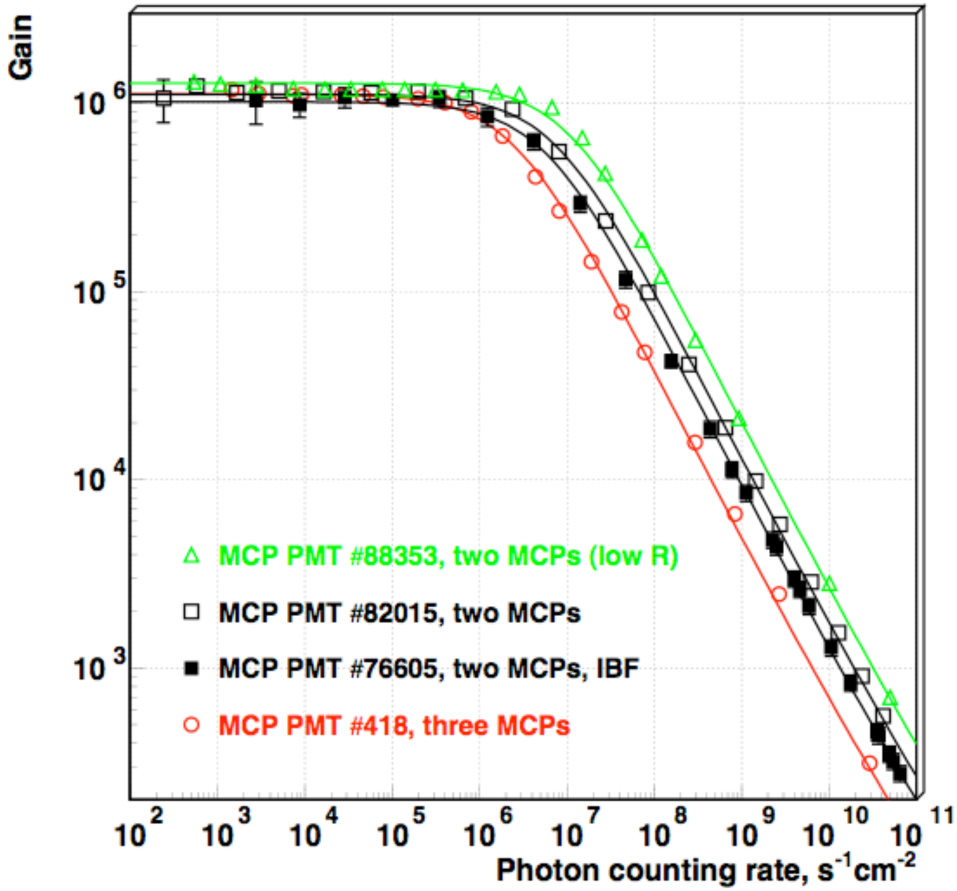
The higher counting rate the faster QE degradation per unit of anode charge

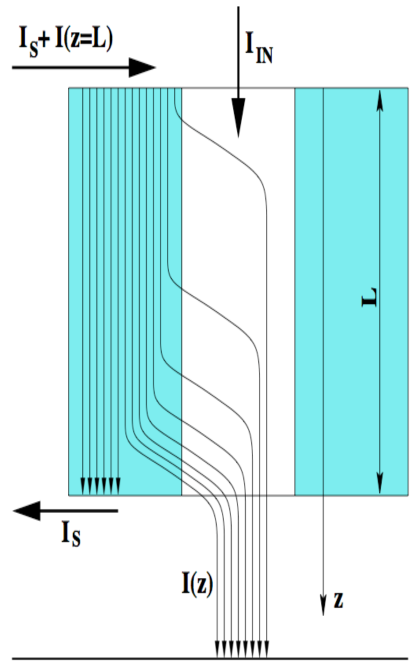


The higher counting rate the slower QE degradation per unit of cathode charge

Gain decrease at high counting rate

A.B.Berkin and V.V.Vasilyev,
Technical Physics, 2008, Vol. 53, No. 2, p.272





$$I(z) = I_{in} e^{\alpha z} \ln(G_0) / F / (1+I_{in}/I_s \cdot e^{\alpha z})$$

where

$$F = \ln(G_0) + \ln(1+I_{in}/I_s) - \ln(1+I_{in}/I_s \cdot G_0)$$

$$\alpha = \ln(G_0)/L$$

$$G = G_0 \cdot \ln(G_0) / F / (1+I_{in}/I_s \cdot e^{\alpha z})$$

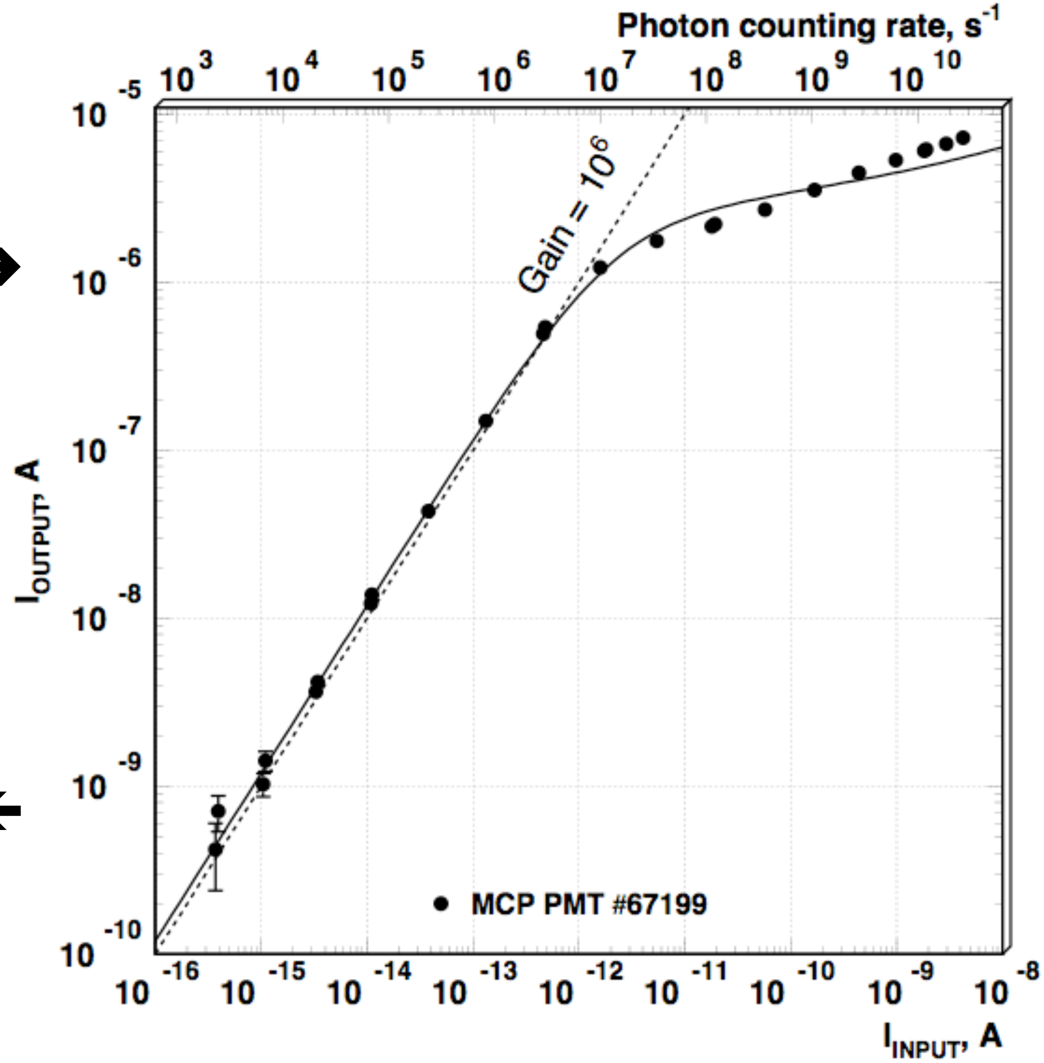
Calculation of 1st MCP current

Approximation of dependence $I_{OUTPUT}(I_{INPUT})$:

$I(z=L) = f(I_{in}, G_0, I_s)$

G_0 and I_s - free parameters

➔



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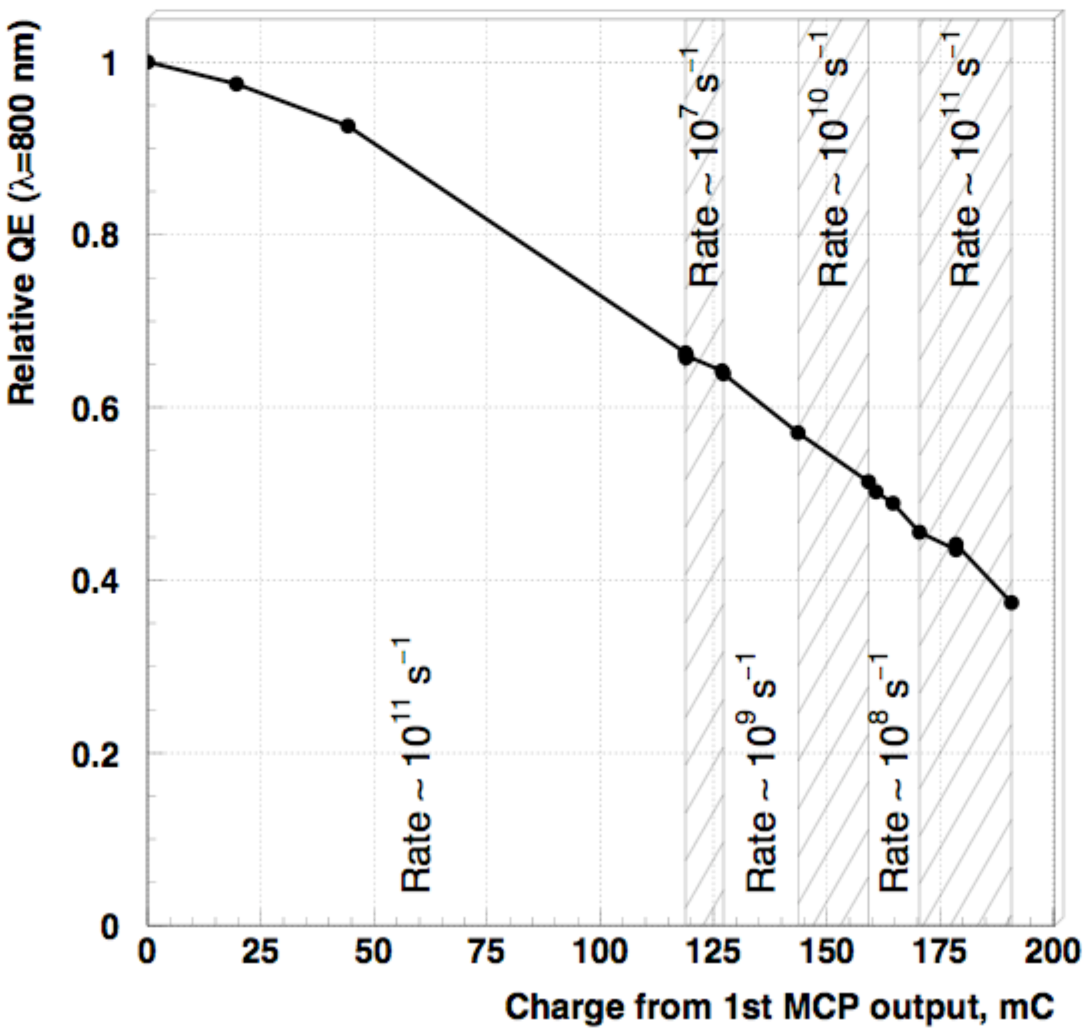
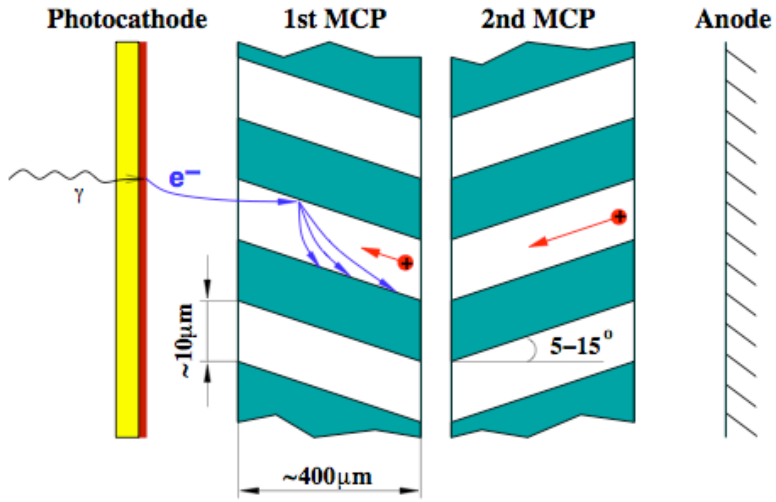
Calculation of the current extracted from 1st MCP :

$I(z=L/2)$ using G_0 and I_s obtained from approximation

QE degradation vs. charge from 1st MCP





Correlation between QE degradation rate and photon counting rate is not observed !

Use of the result:

- Correct comparison of the aging of different samples of PMT.
- Lifetime improvement by redistribution of gain between 1st and 2nd MCP.

Enhancement of MCP degassing: gain

Two stage of MCP degassing:

1. Heating
2. Electron scrubbing

+ Photocathode lifetime increase

- Gain degradation

Duration of electron scrubbing has been increased in 2 and 3 times

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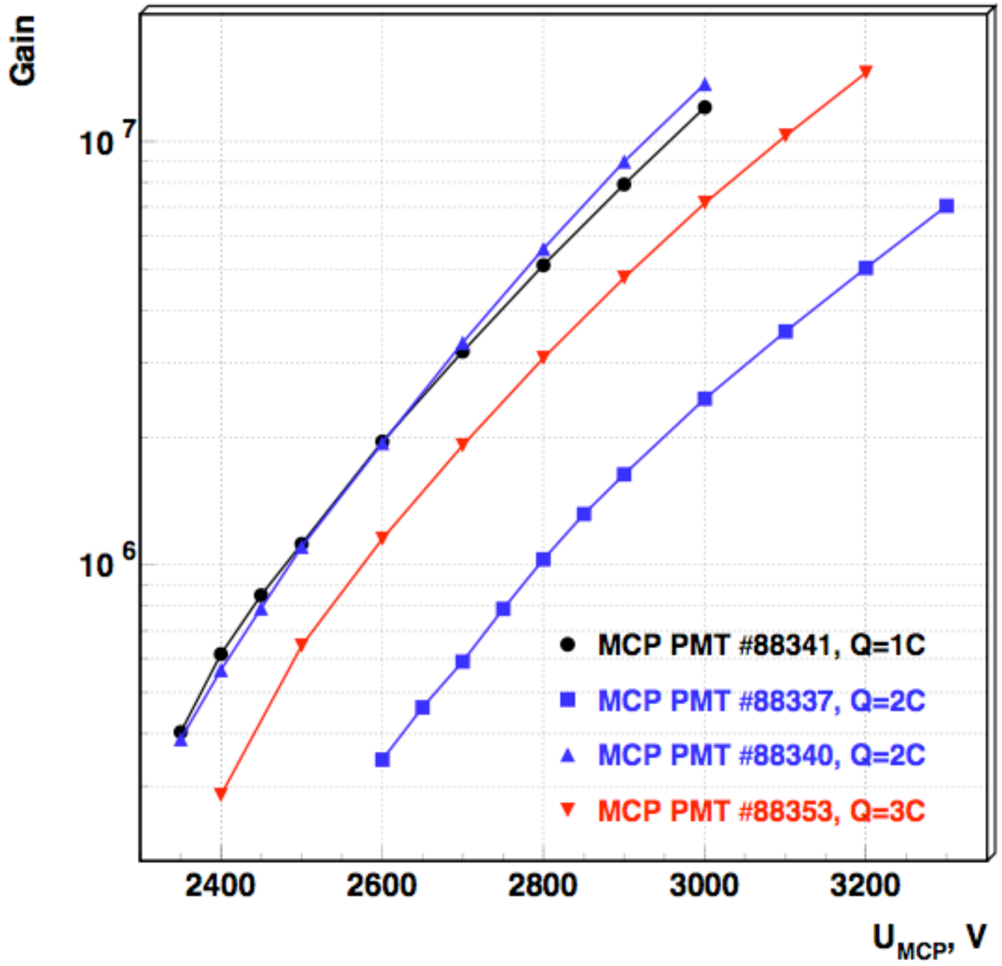
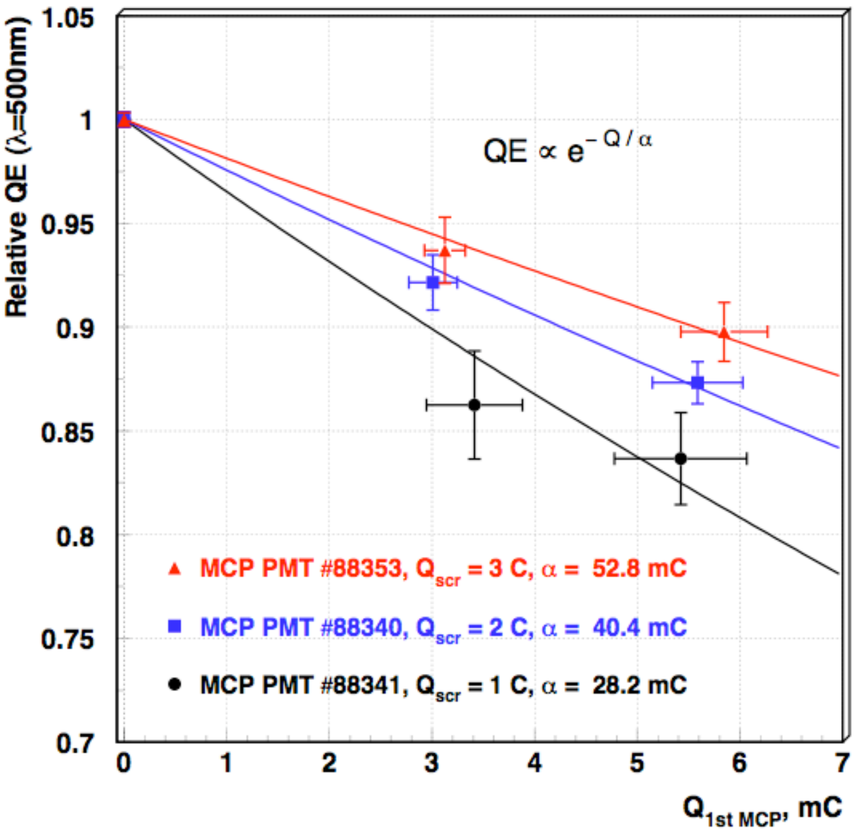
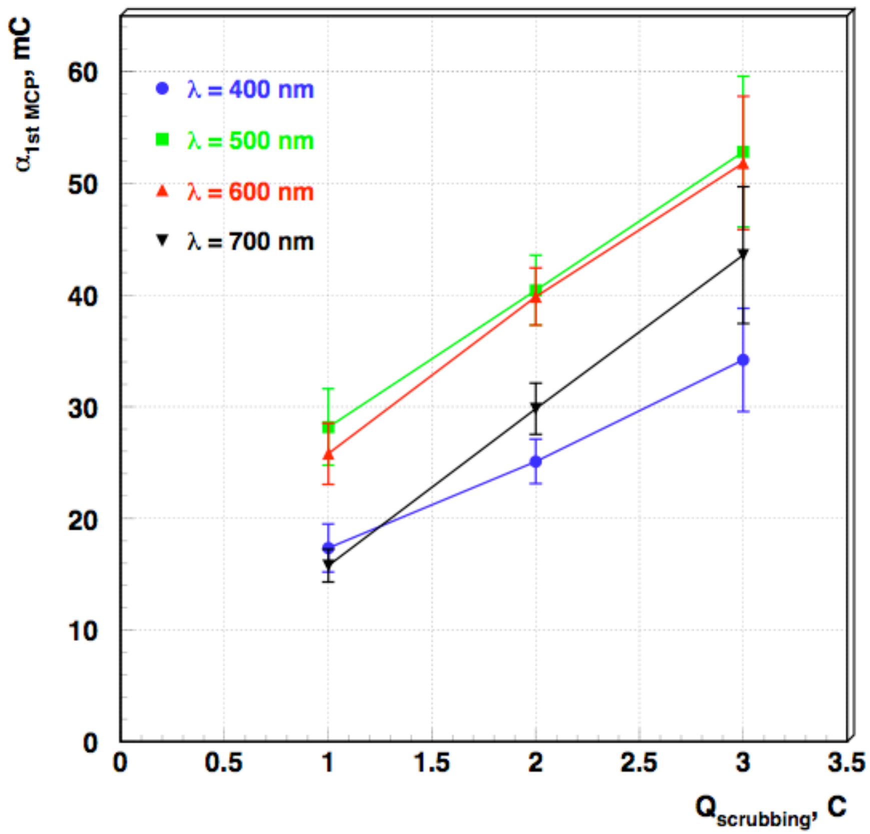
MCP gain is not affected

(large spread of initial MCP quality)



Enhancement of MCP degassing: aging





Three times better electon scrubbing

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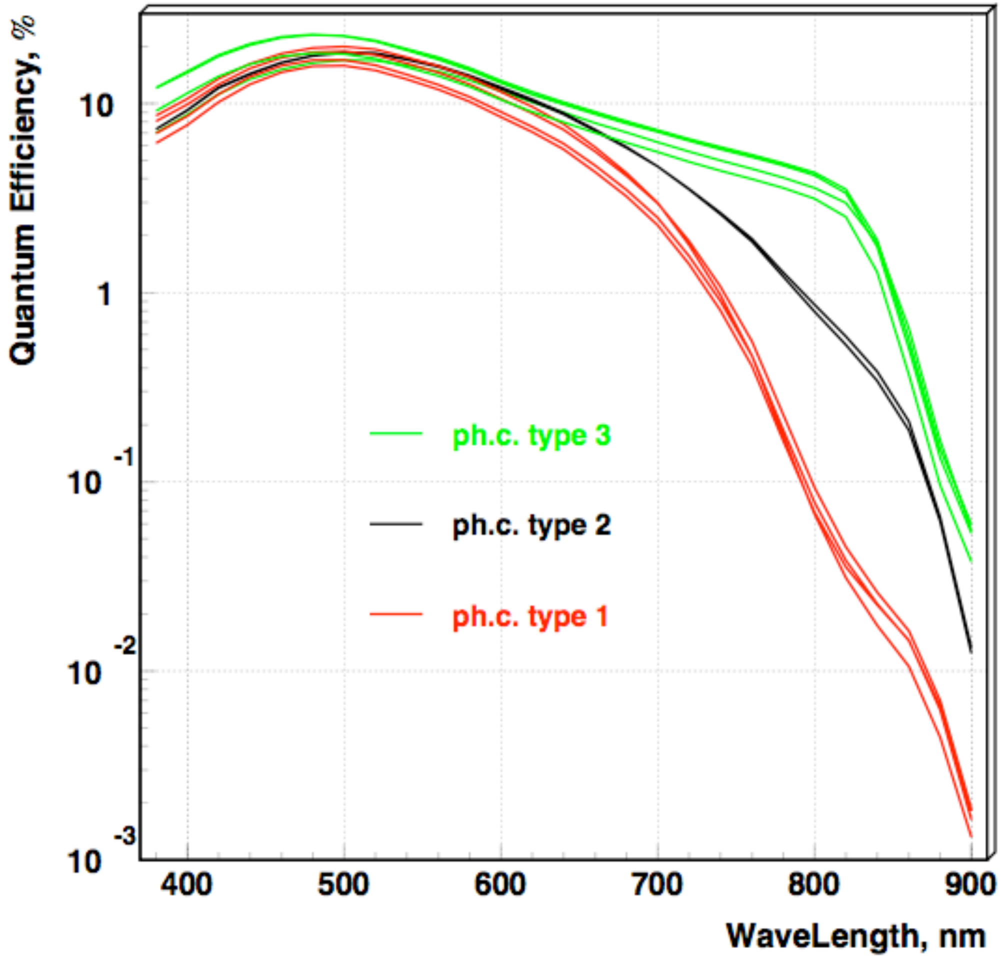
Two times slower QE degradation

Photocathodes: spectral response

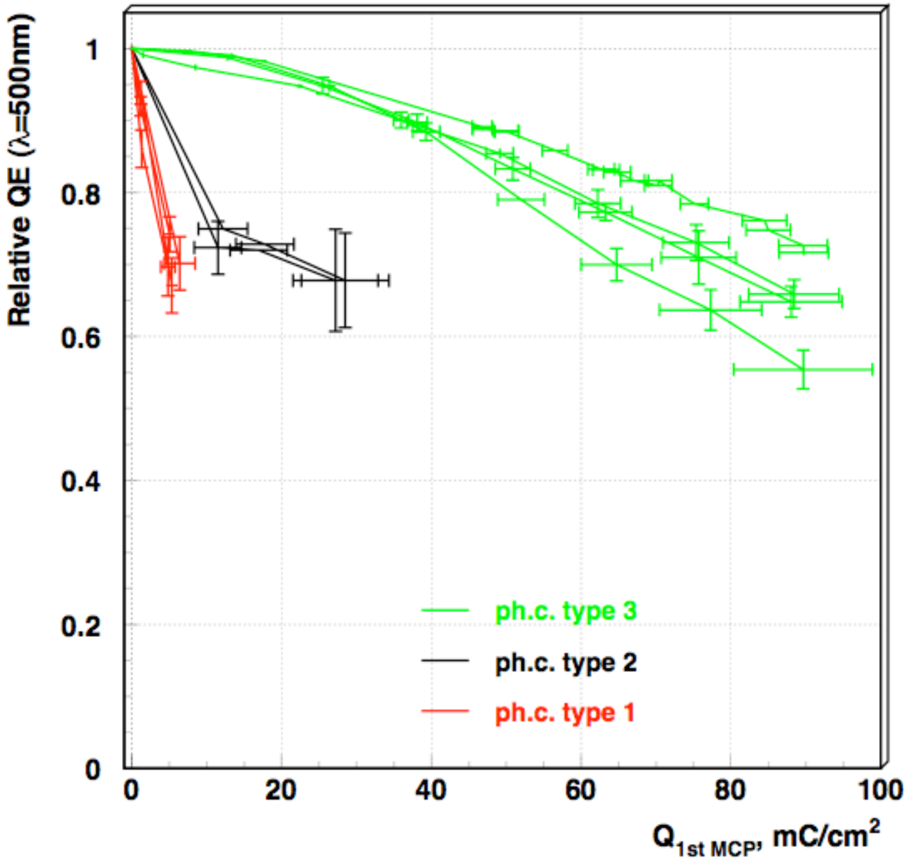


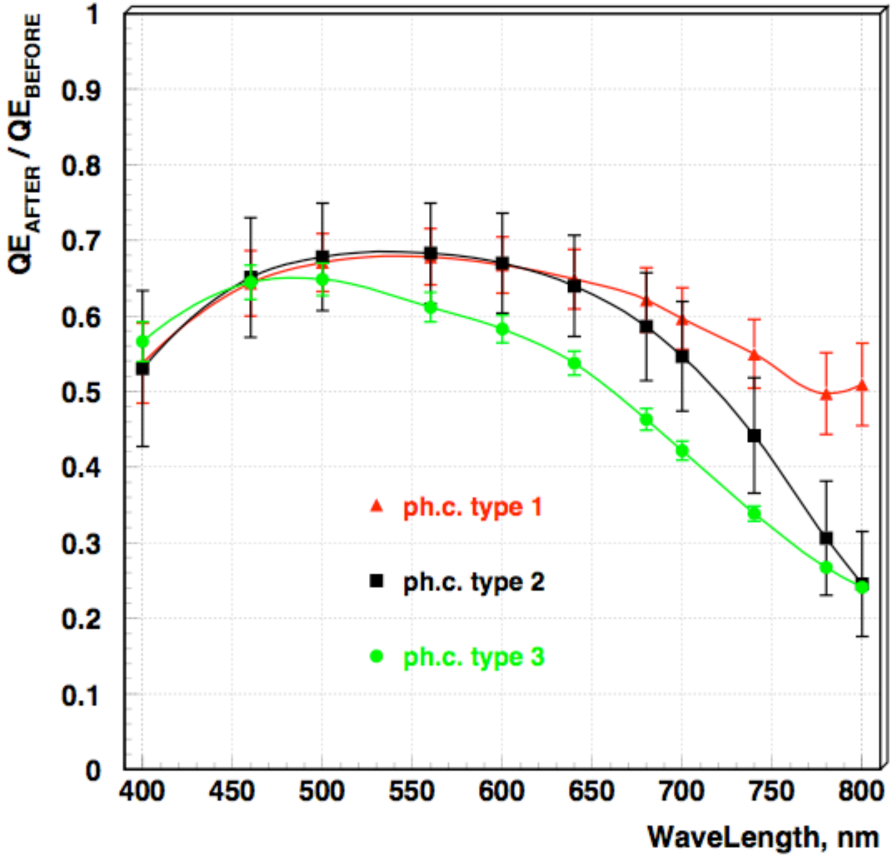
Type 1: $Na_2KSb(Cs)$
Dark rate ~ 0.5 kcps/cm^2

Type 2: $Na_2KSb(Cs)$ + Cs
Dark rate ~ 5 kcps/cm^2

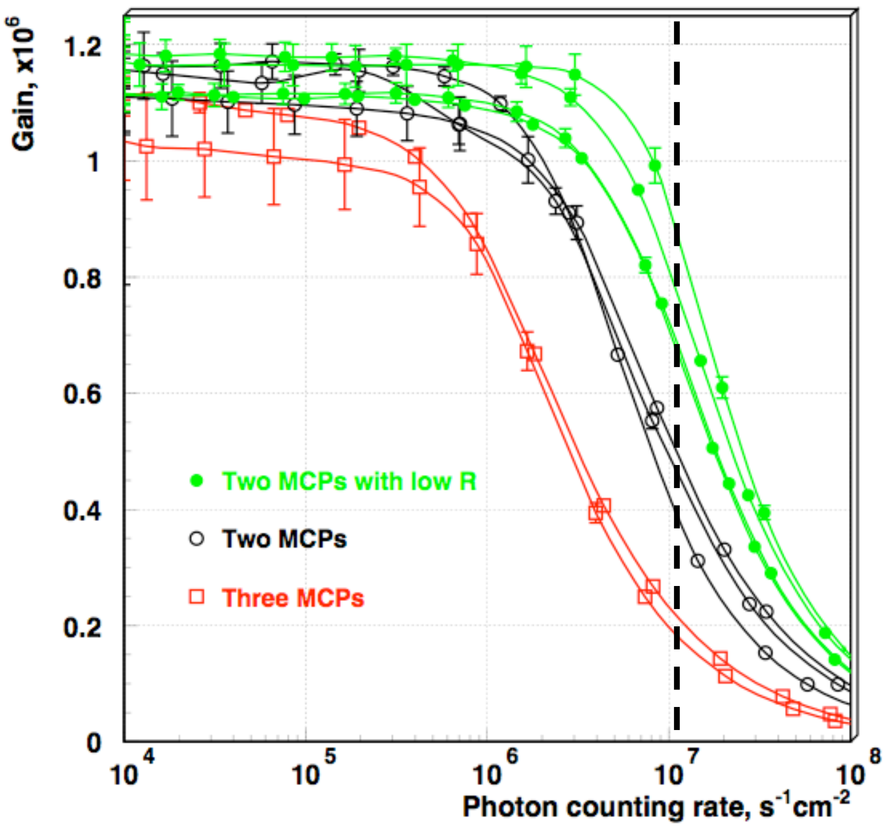
Type 3: $Na_2KSb(Cs)$ + Cs_3Sb
Dark rate ~ 50-100 kcps/cm^2

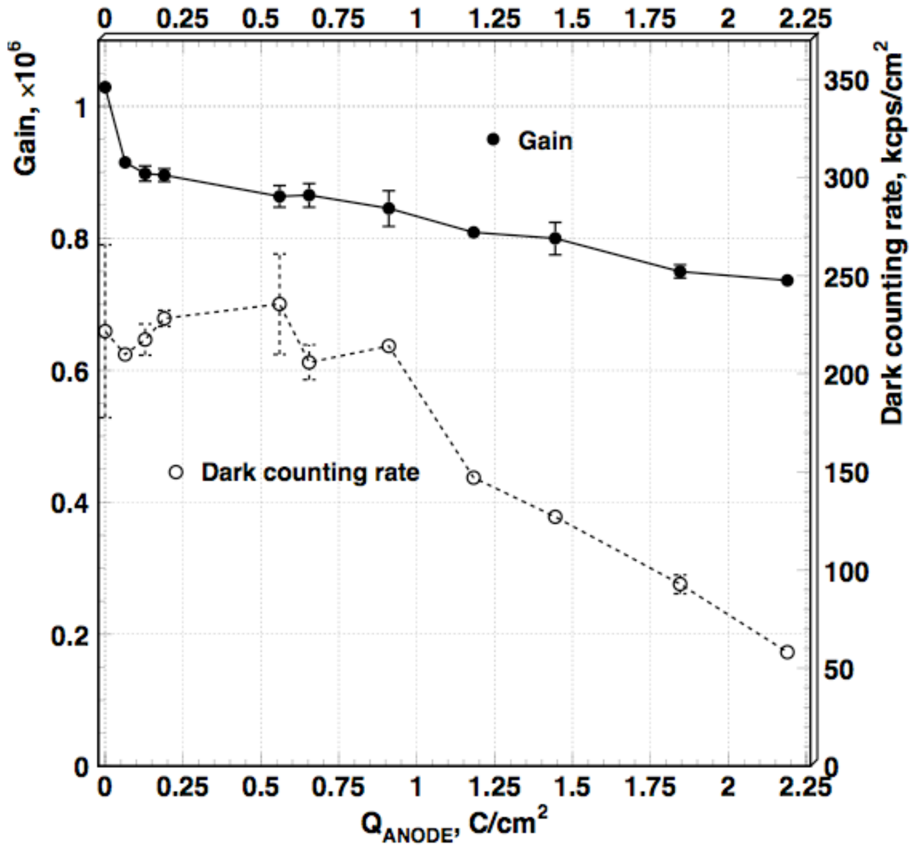
Photocathodes: aging comparison





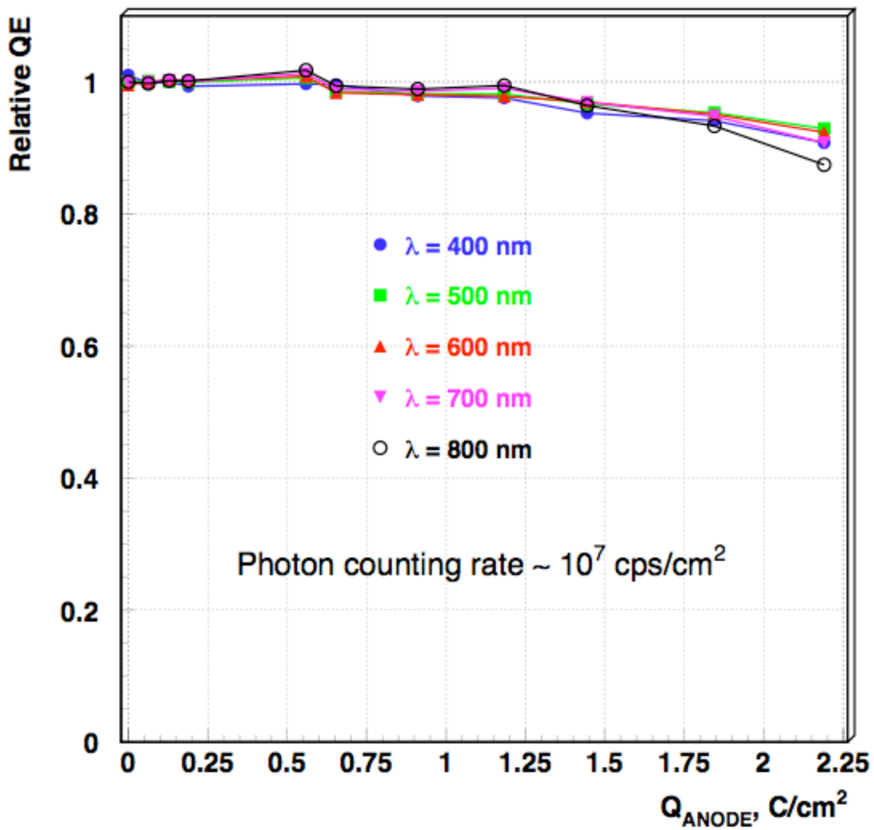
MCP PMT #91110: gain and dark rate

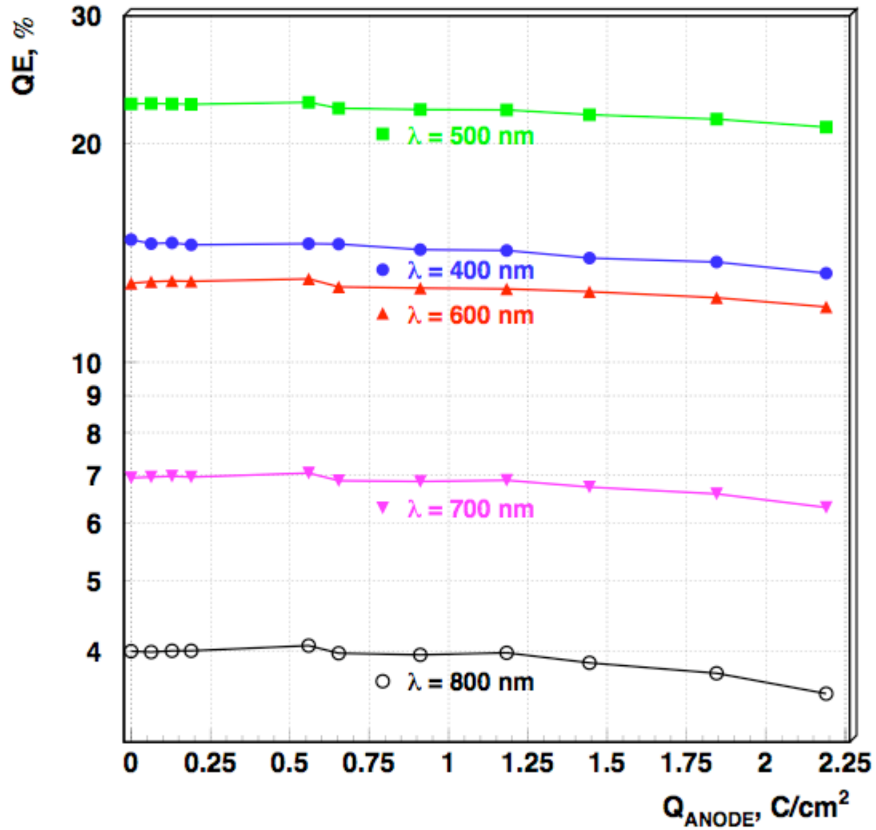




Lifetime measurements at counting rate of 10^7 $s^{-1}cm^{-2}$
where gain decreases by 20-30%

MCP PMT #91110: photocathode lifetime





2 C/cm^2 of accumulated anode charge

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7% degradation of QE

Summary

- QE degradation is proportional to the charge extracted from the 1st MCP.
- Enhancement of MCP electron scrubbing did not affect MCP gain and decreased the photocathode aging rate.
- Optimization of the photocathode can decrease aging rate by order of magnitude.
- The photocathode lifetime of the best MCP PMT sample is more than 2 C/cm^2 of accumulated anode charge.