Investigation of PMT aging in Novosibirsk

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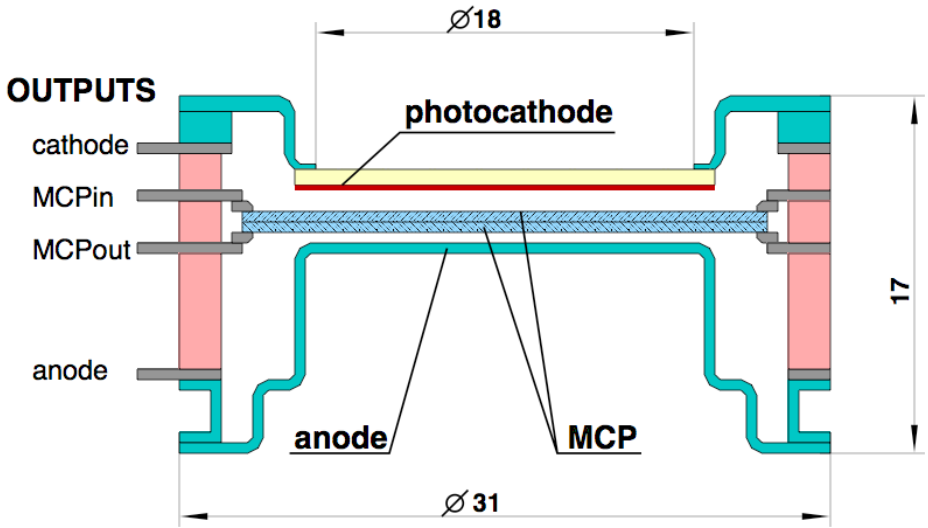
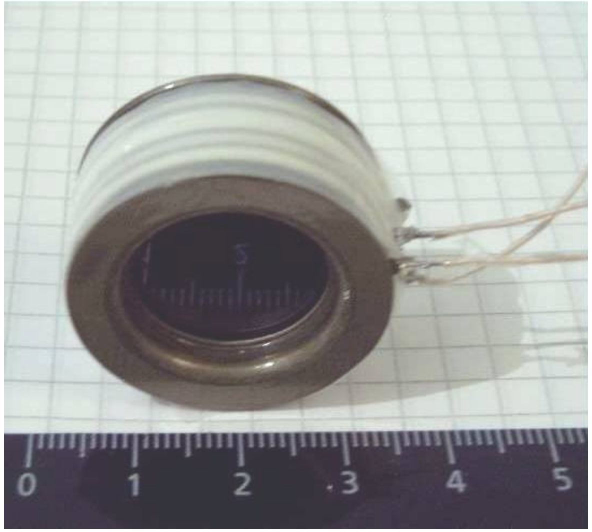
Outline:

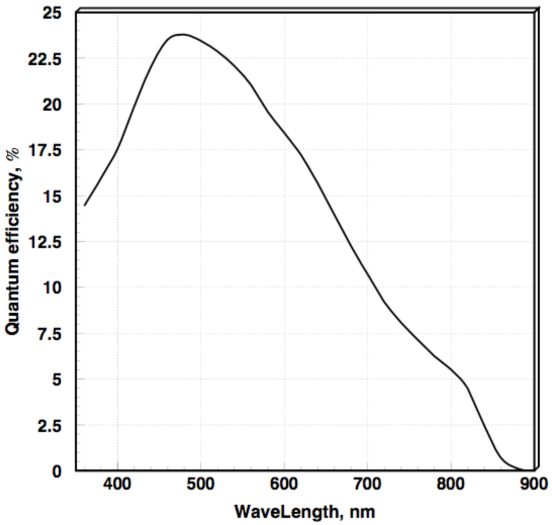
- Use of MCP PMTs in BINP detectors
- Experimental setup
- QE degradation versus wavelength
- QE degradation at different countin rates
- Example of aging test results
- Questions and suggestions to H8500 aging tests

MCP PMT under investigation



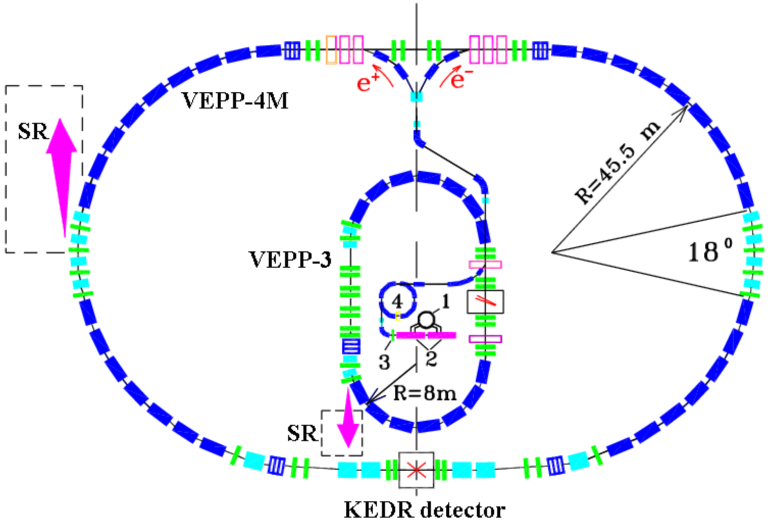


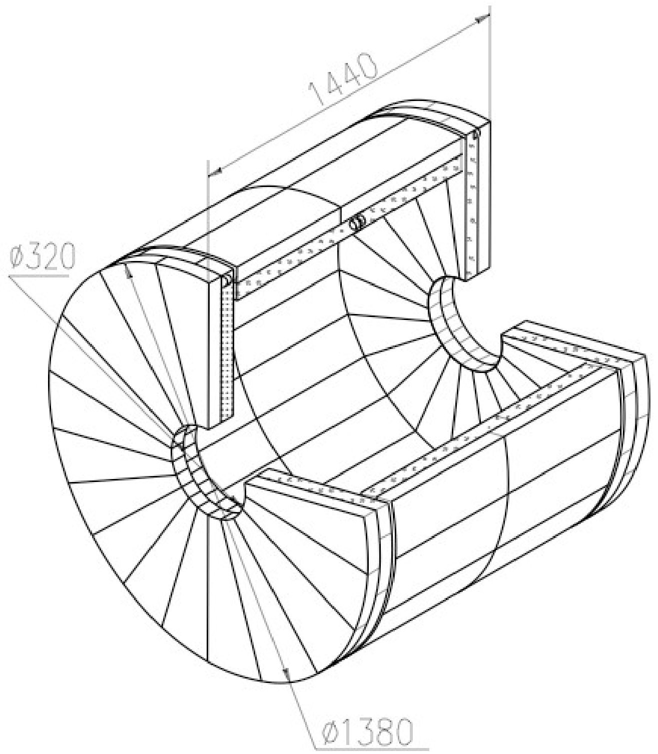
Manufacturer: "Ekran FEP" (Novosibirsk)
Borosilicate glass window
Multialkali (Sb-Na-K-Cs) photocathode
Maximum QE at λ=500nm
Two MCPs with channel diameter of 7 μm
Channel bias angle 13°
Single anode

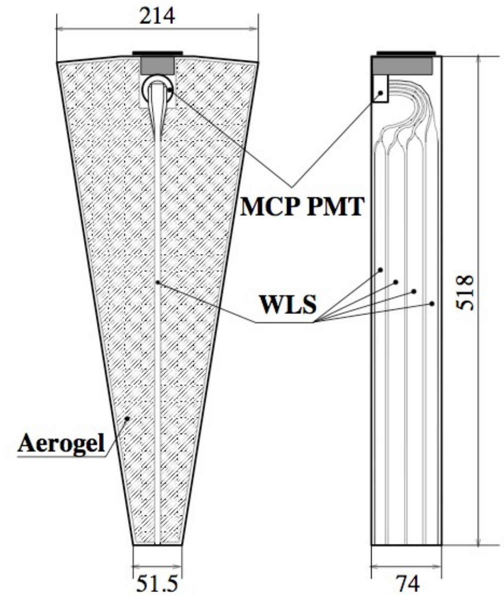


ASHIPH counters for KEDR

- 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



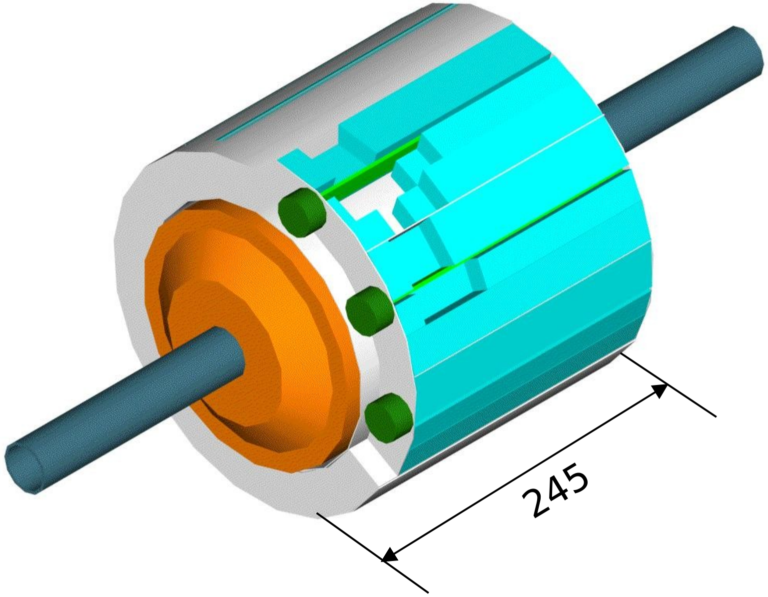




80 counters have been working since 2003

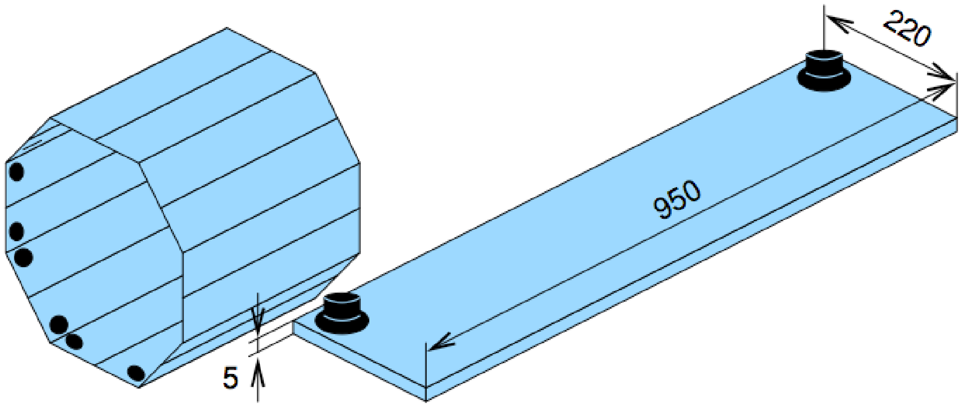
ASHIPH counters for SND

- π/K separation in momenta range 300 ÷ 870 MeV/c
- Aerogel n=1.13
- 9 MCP PMT
- No magnetic field



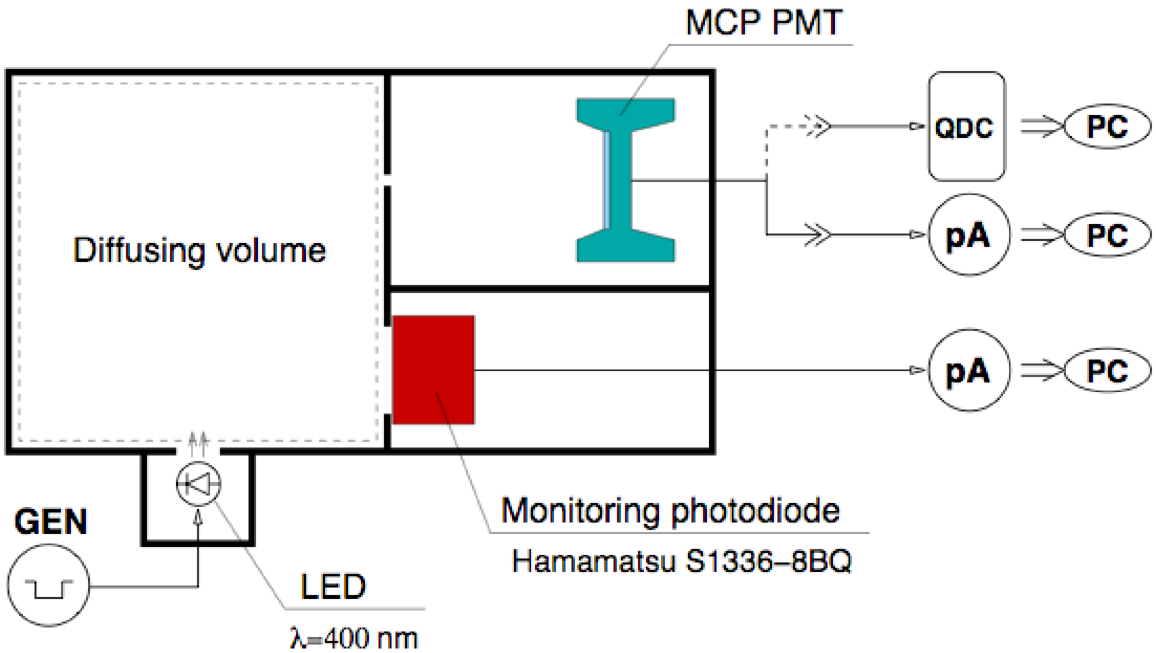
TOF counters for CMD-3

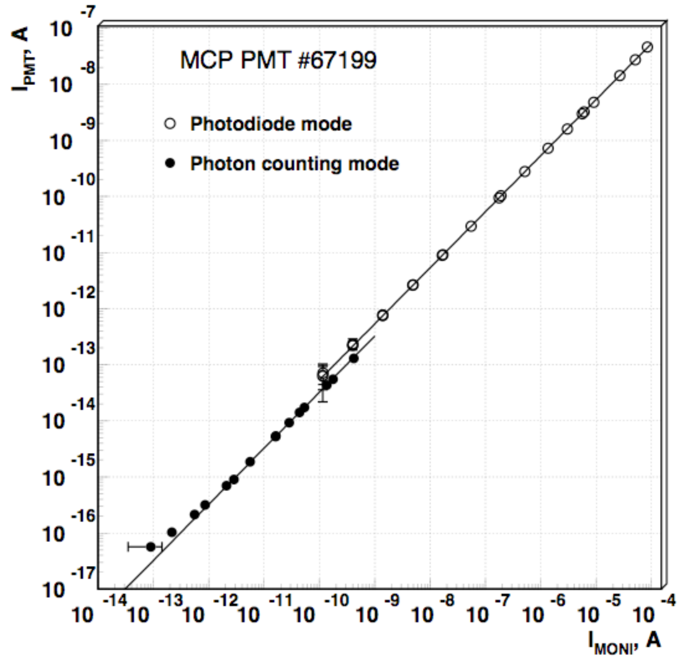
- Antineutron identification
- BC-408 scintillator (16 bars)
- 32 MCP PMT



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

Setup for MCP PMT aging study





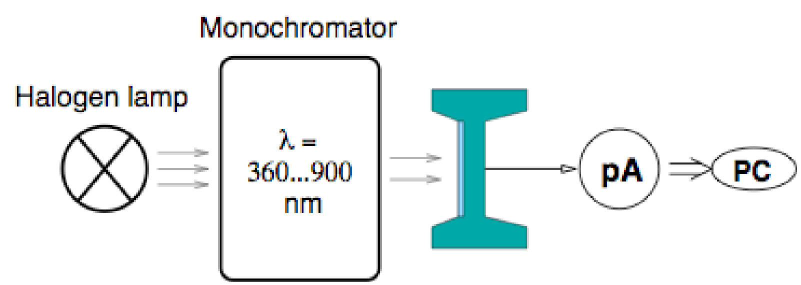
Low light intensity (photon counting mode):

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

High light intensity (direct current mode):

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

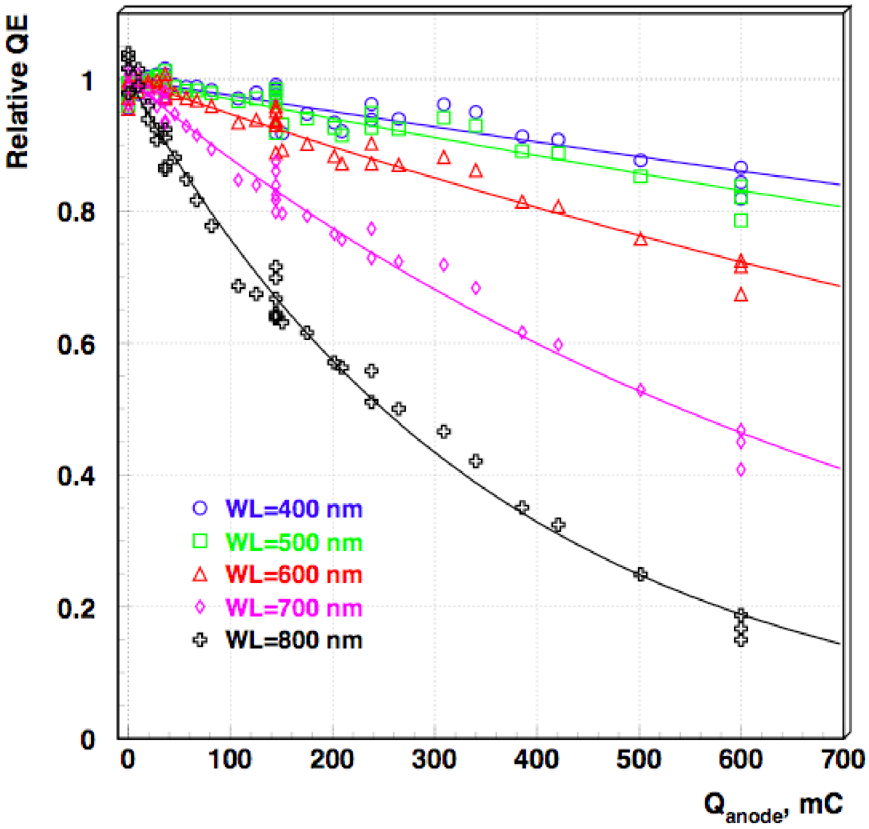
QE measurement:

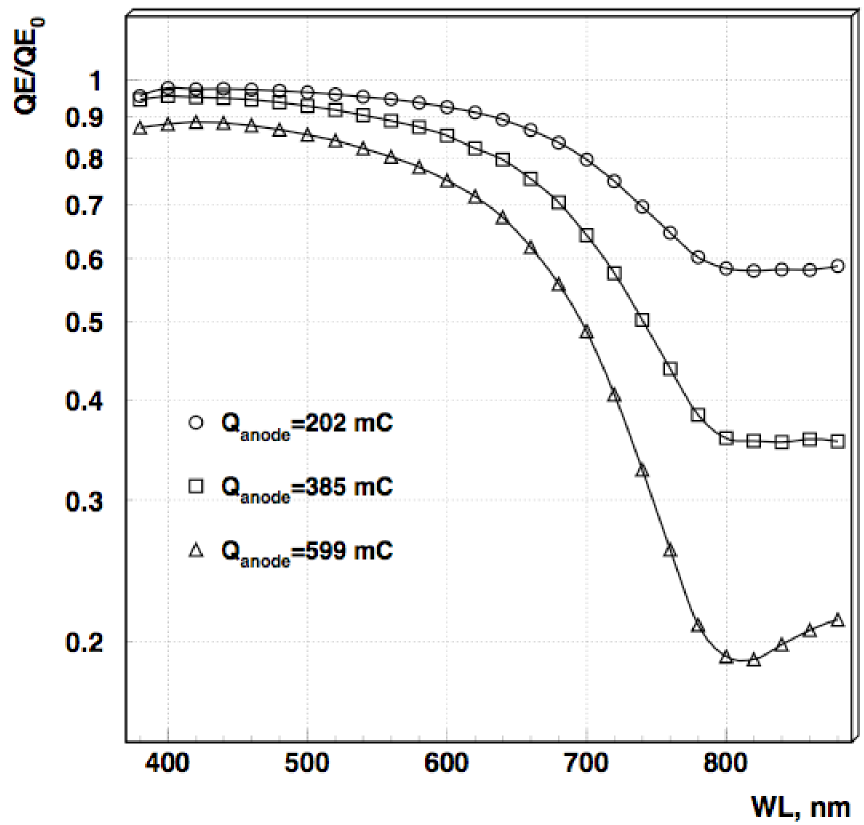


Reference PD: Hamamatsu S1227-1010BQ

QE degradation versus wavelength

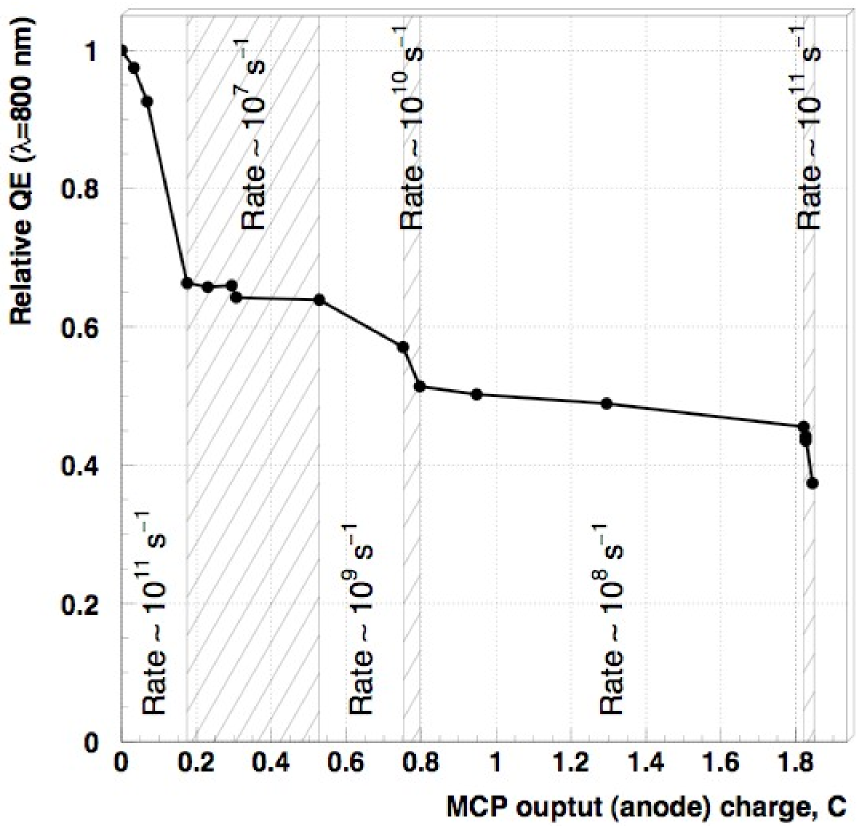
MCP PMT #2071 (two MCPs)

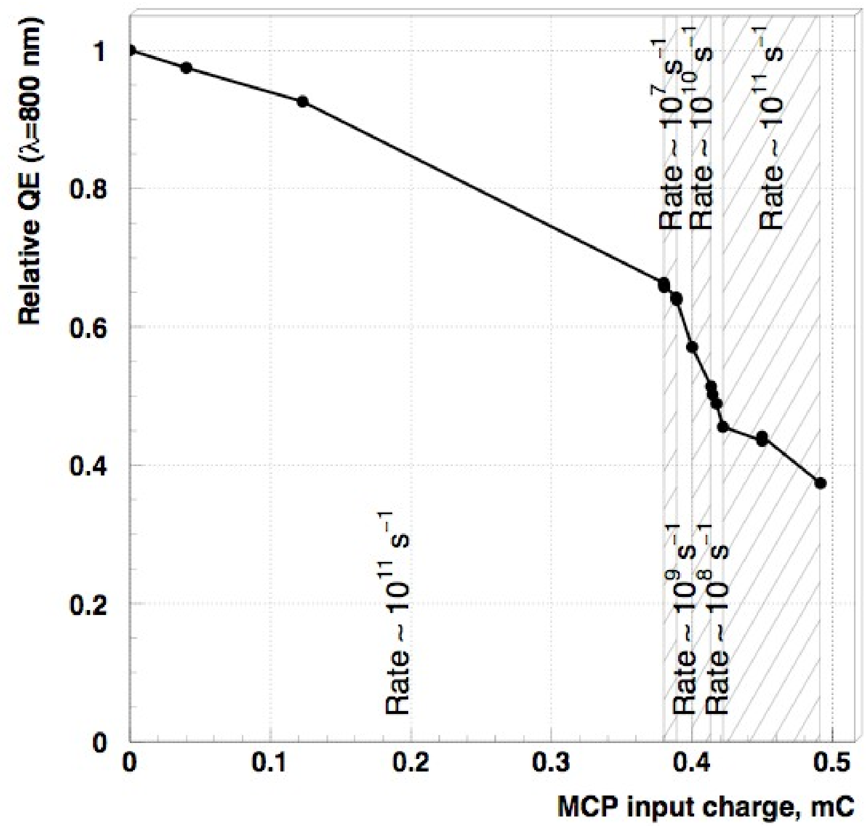




Possibility to control photocathode aging after short exposure not damaging QE in the 'working' region

QE degradation at different counting rates

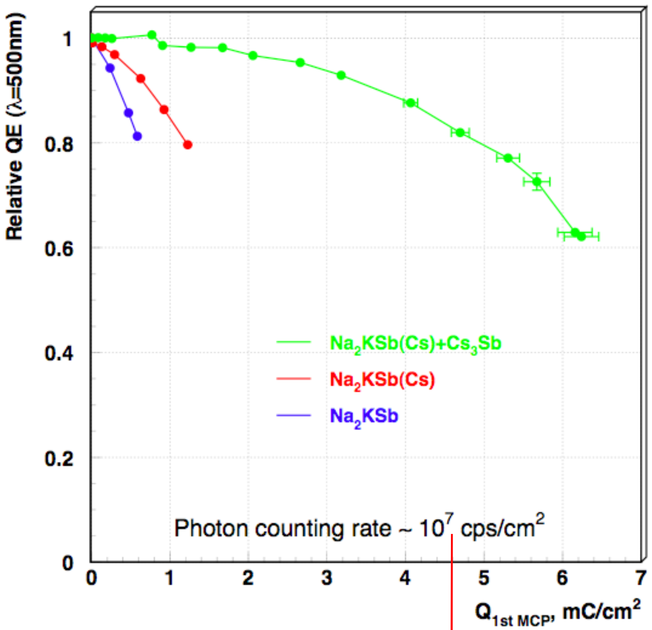


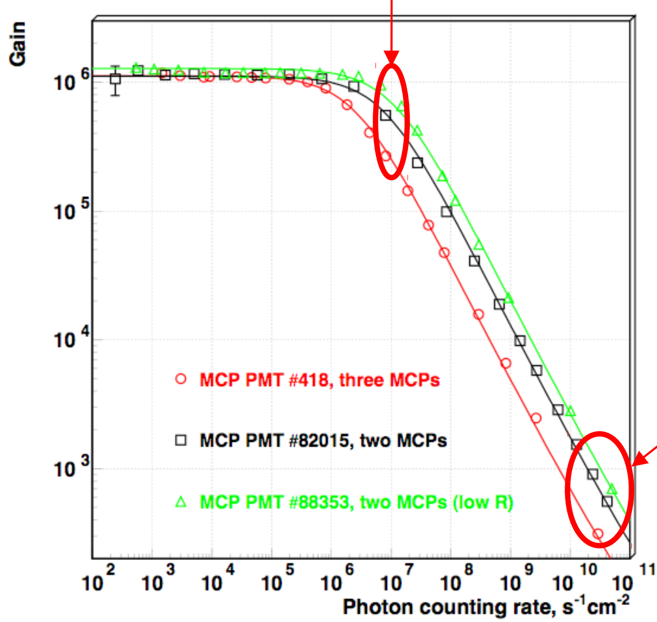


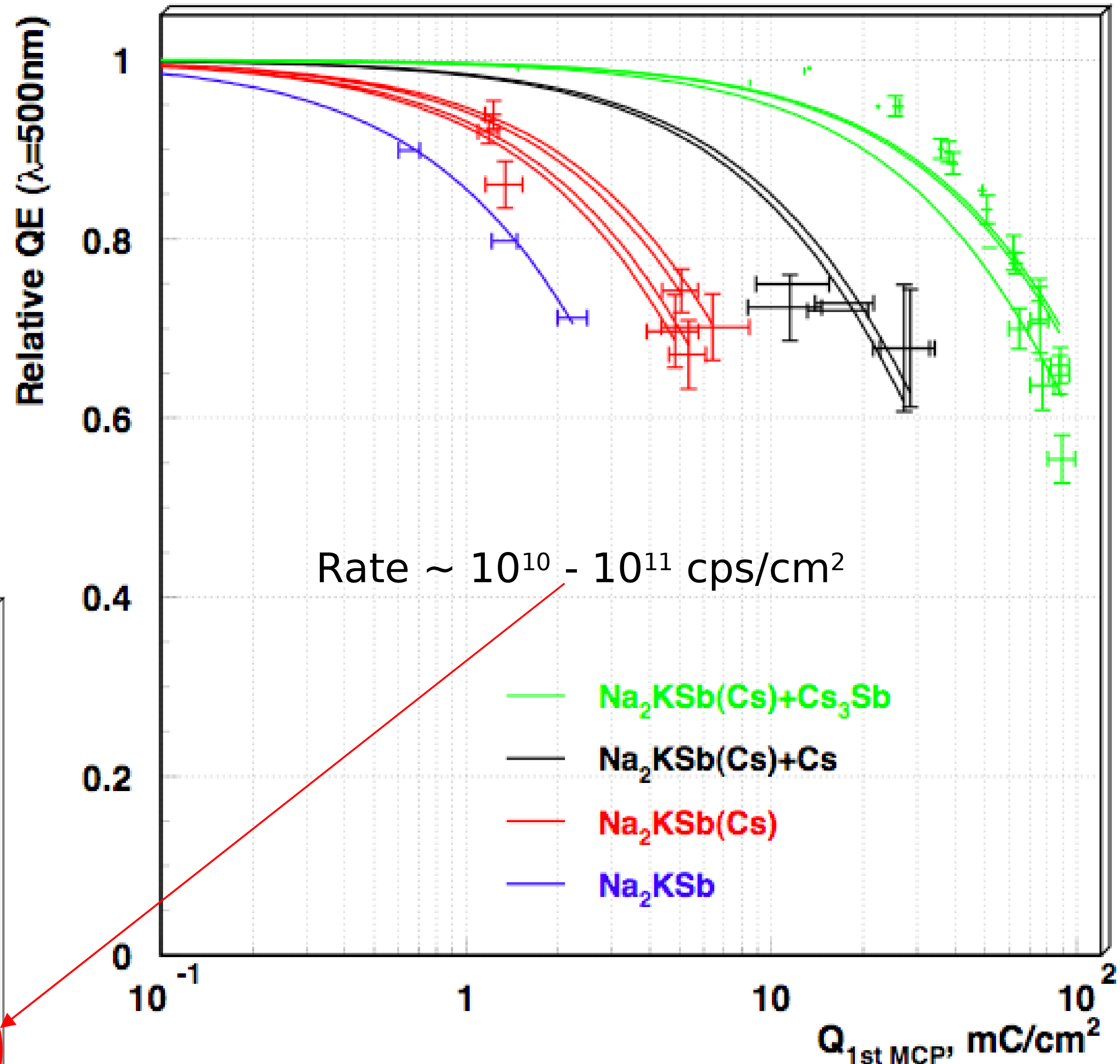
The higher counting rate the faster QE degradation per unit of anode charge

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

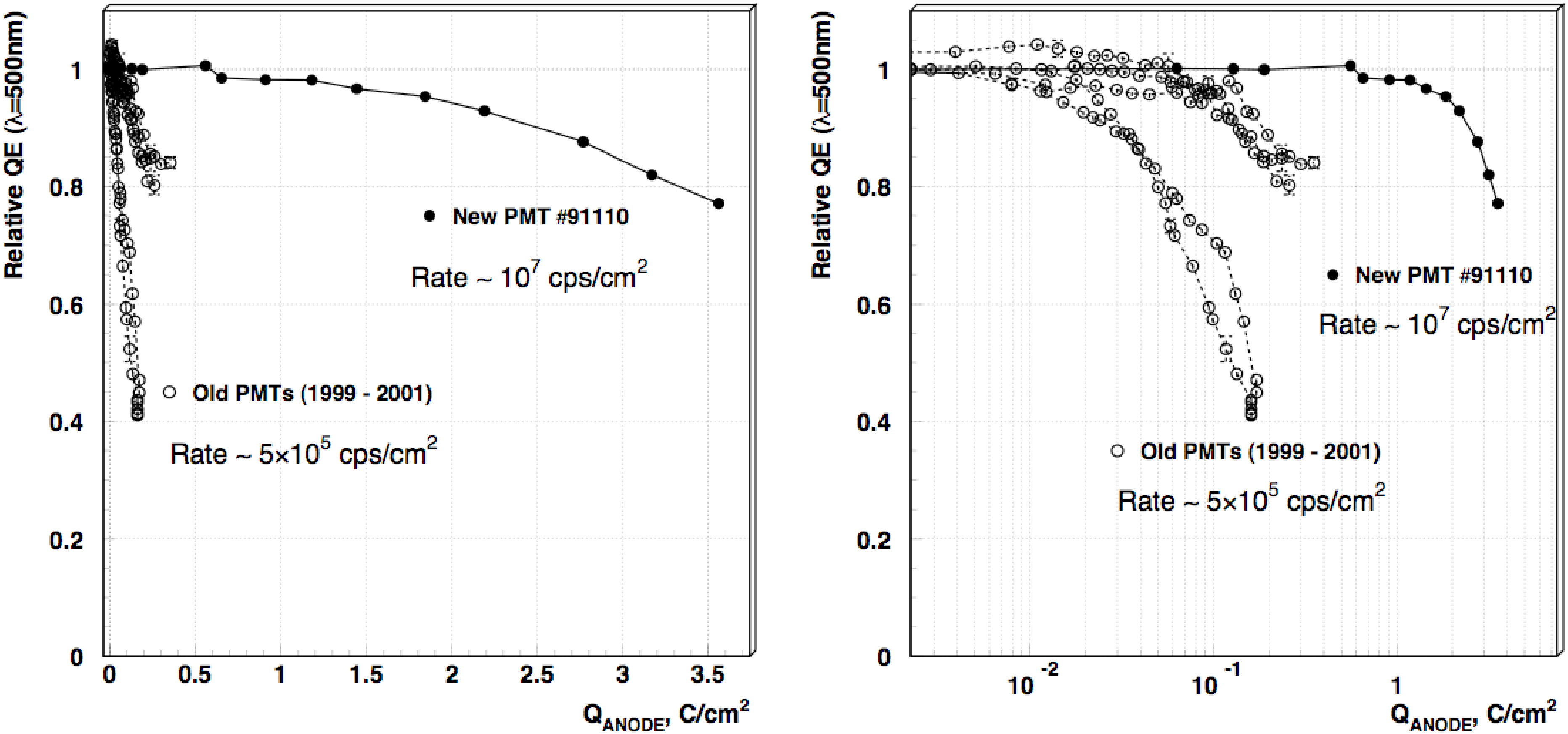
Photocathodes: aging comparison at different rates







Best sample: comparison with old tubes



Lifetime improved by one order of magnitude (at least)!

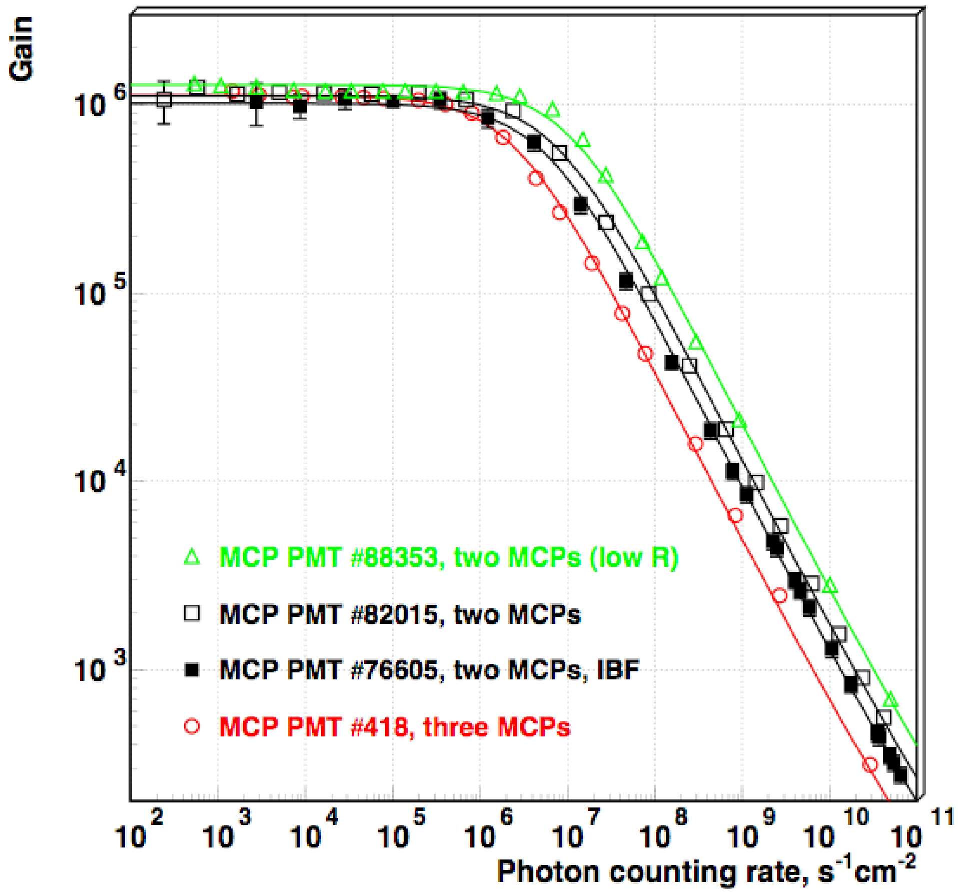
Suggestions for Hamamatsu H8500 aging tests:

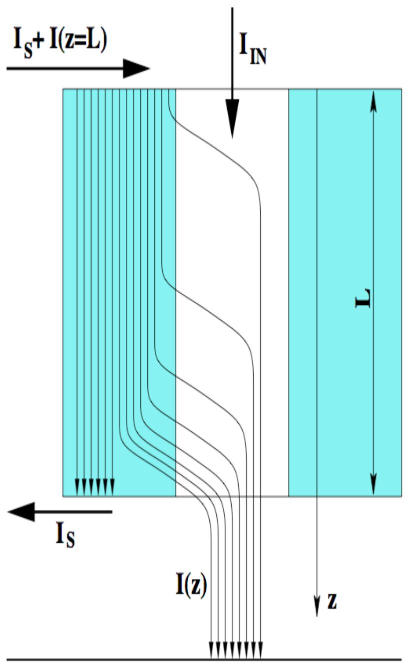
- Preliminary tests:
  - Local illumination ~ 10÷15 mm diameter
  - Series of “short” tests with increasing intensity
  - QE measurement with monochromator in photodiod mode (is it possible?)
- Main tests:
  - Full photocathode illumination
  - Nominal voltage
  - Highest possible rate to have result after 3-6 months of continuous illumination
- Questions:
  - Anticipated photon flux in DIRC at SuperB?
  - Working amplification of PMT?
  - Is it possible to work in photodiod mode (to connect directly to the 1-st dynode)?
  - Who has an extra H8500 for aging tests?

Additional slides

Gain decrease at high counting rate

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





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

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

where

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

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

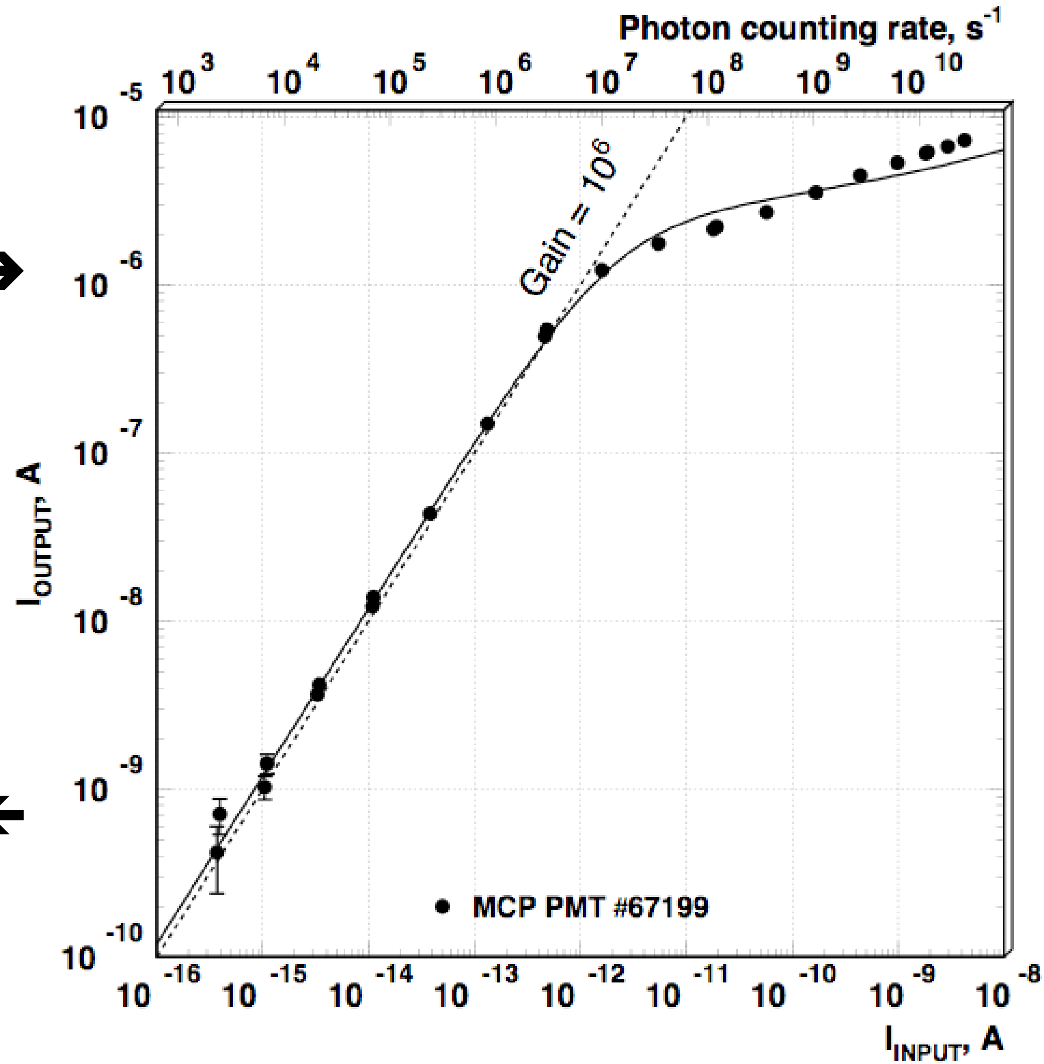
Calculation of 1st MCP current

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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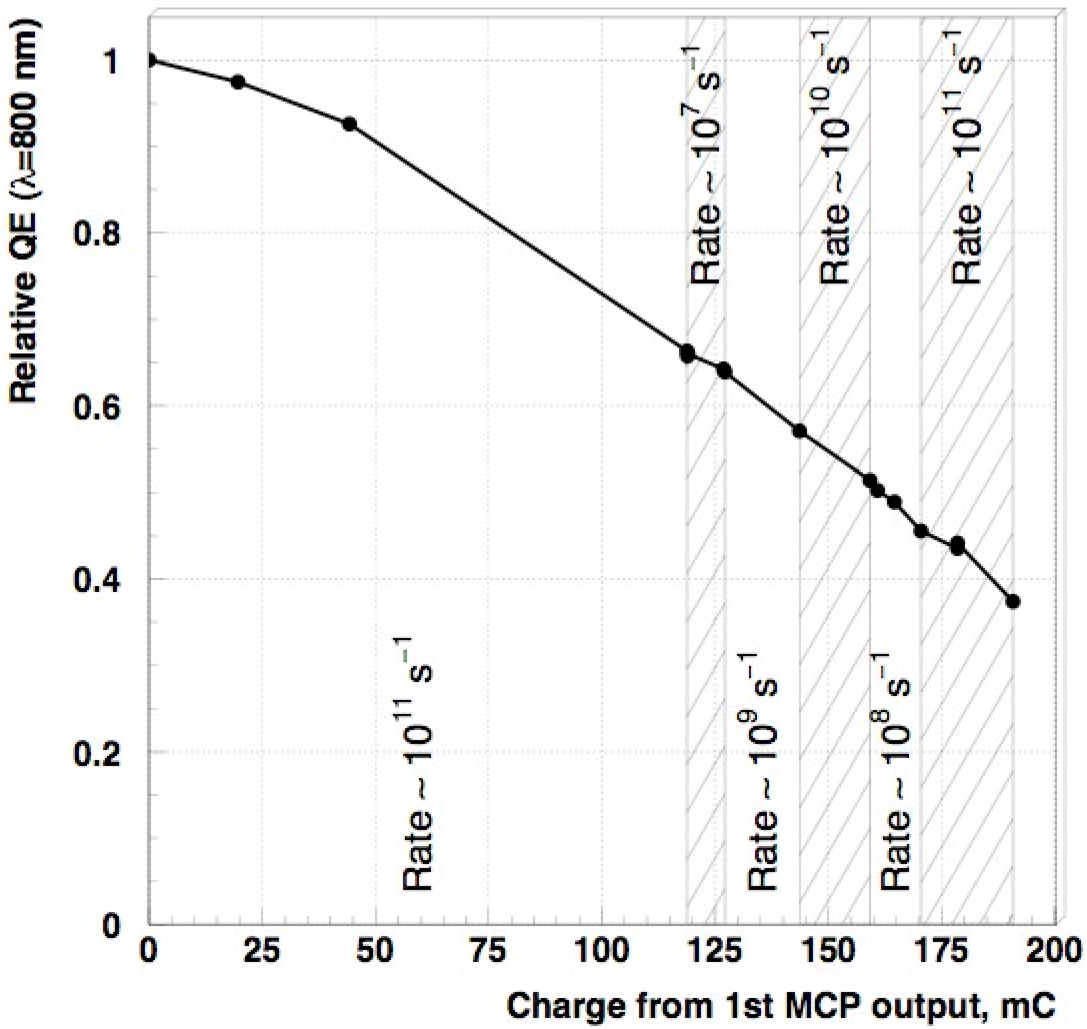
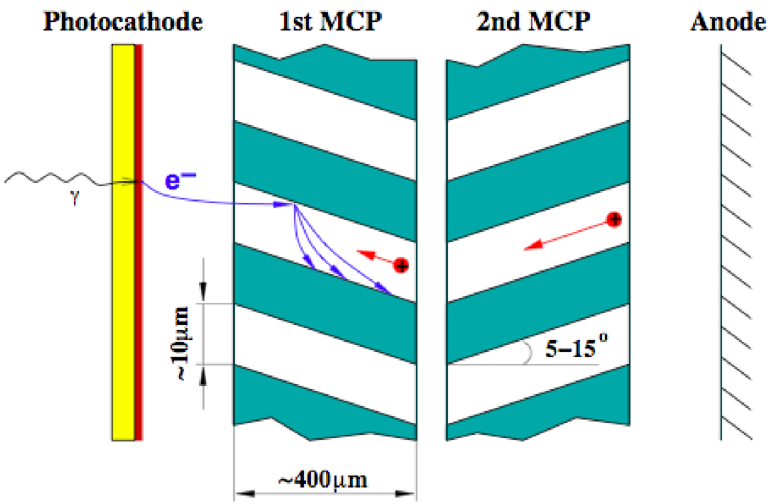
Calculation of the current extracted from 1st MCP :

$I(z=L/2)$ 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.

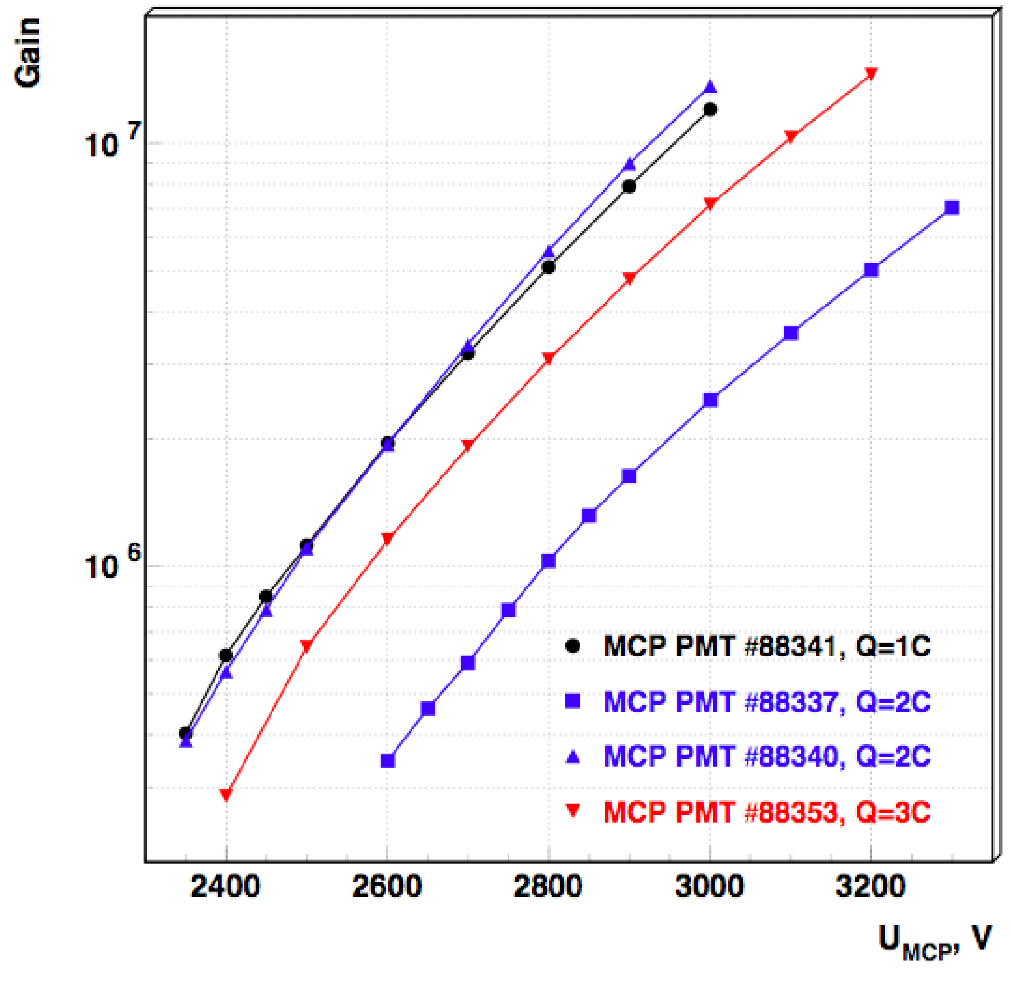
Enhancement of MCP degassing: gain

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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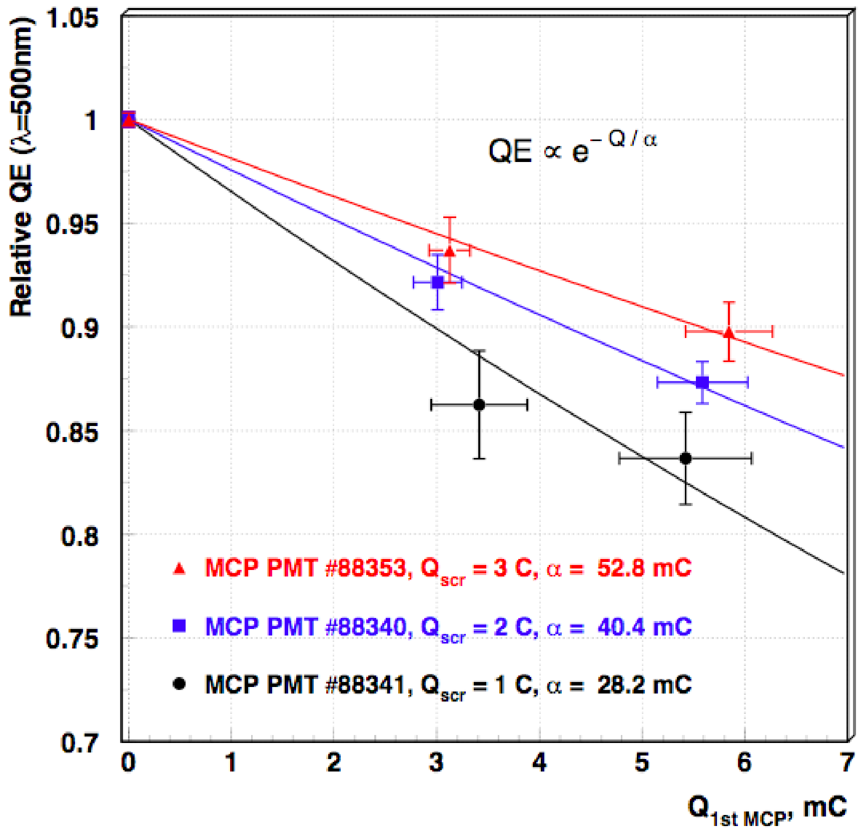
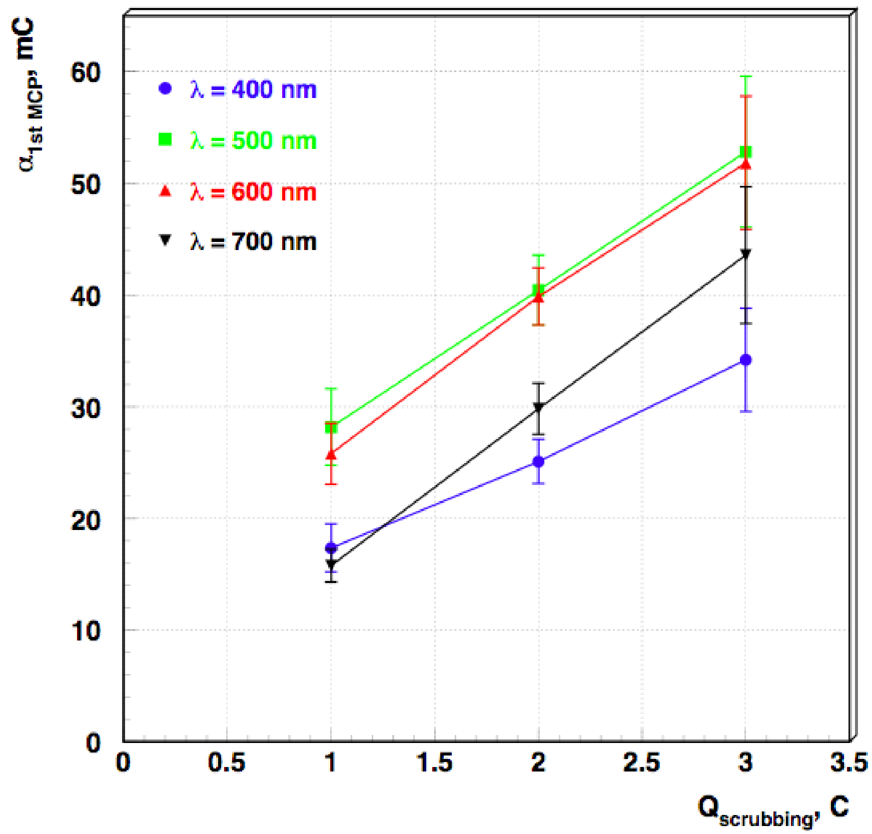
MCP gain is not affected (large spread of initial MCP quality)

Enhancement of MCP degassing: aging





Three times better electon scrubbing

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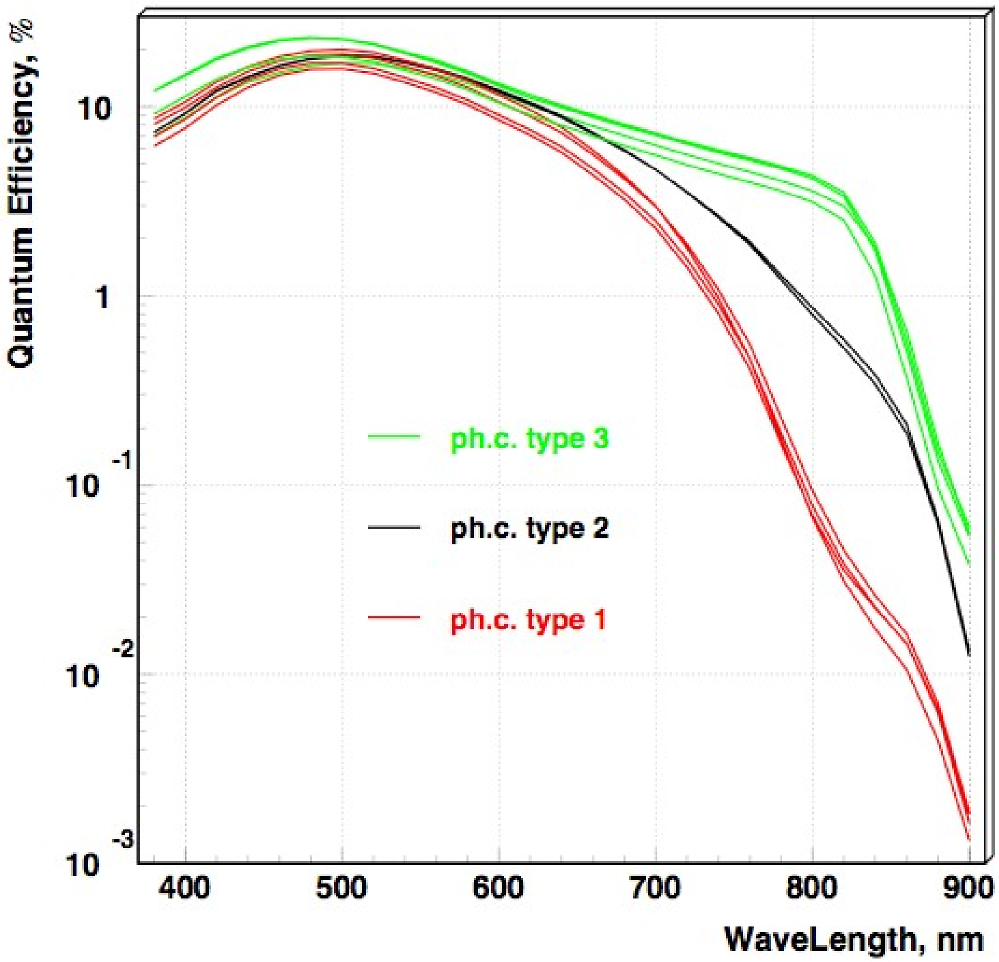
Two times slower QE degradation

Photocathodes: spectral response



Type 1: $Na_2KSb(Cs)$

Dark rate ~ 0.5 kcps/cm²

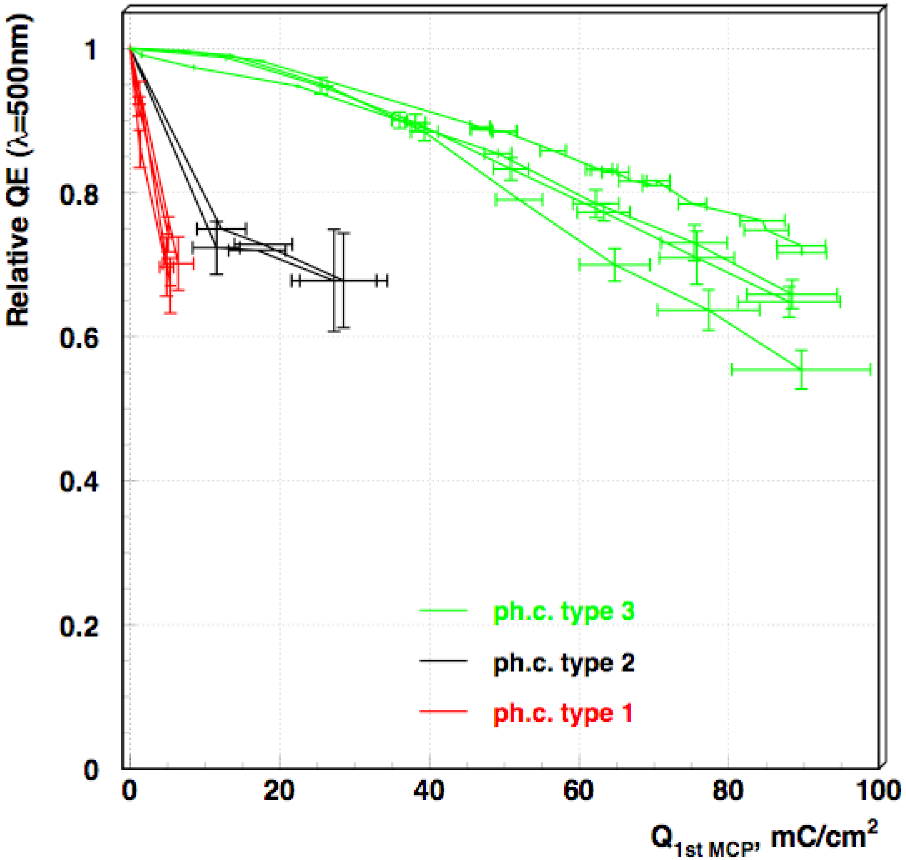
Type 2: $Na_2KSb(Cs)$ + Cs

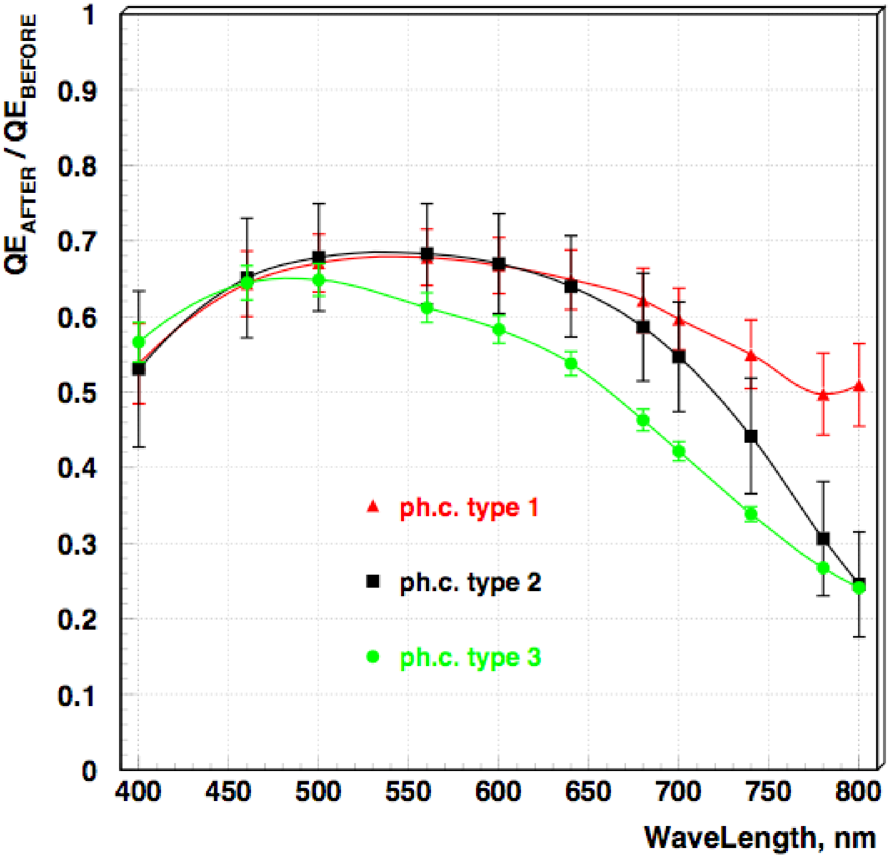
Dark rate ~ 5 kcps/cm²

Type 3: $Na_2KSb(Cs)$ + Cs_3Sb

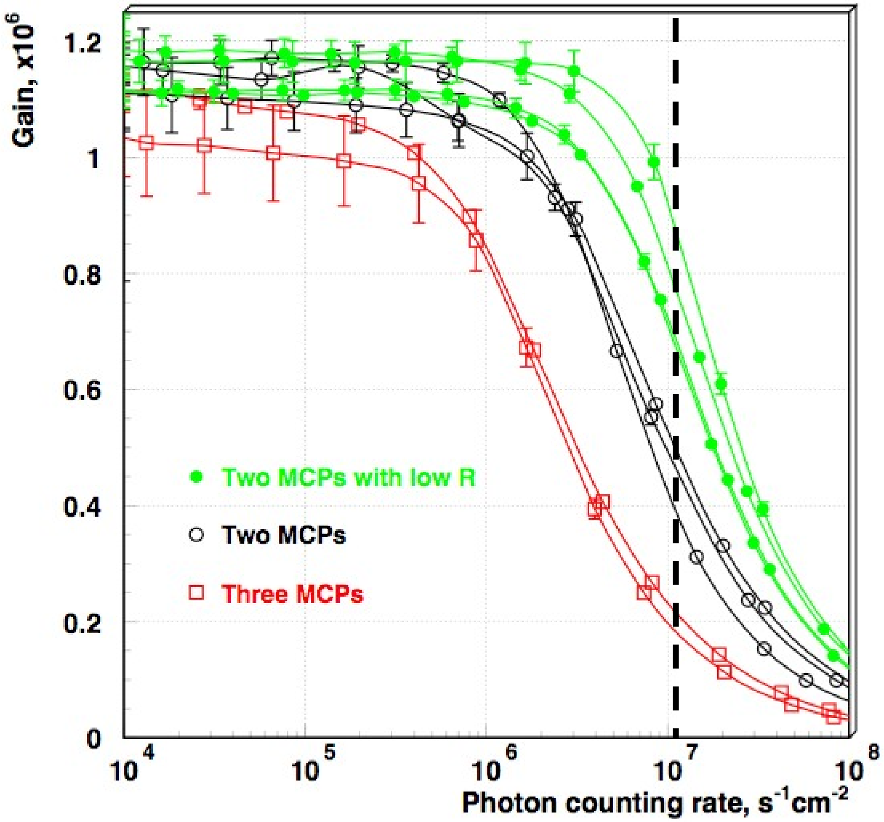
Dark rate ~ 50-100 kcps/cm²

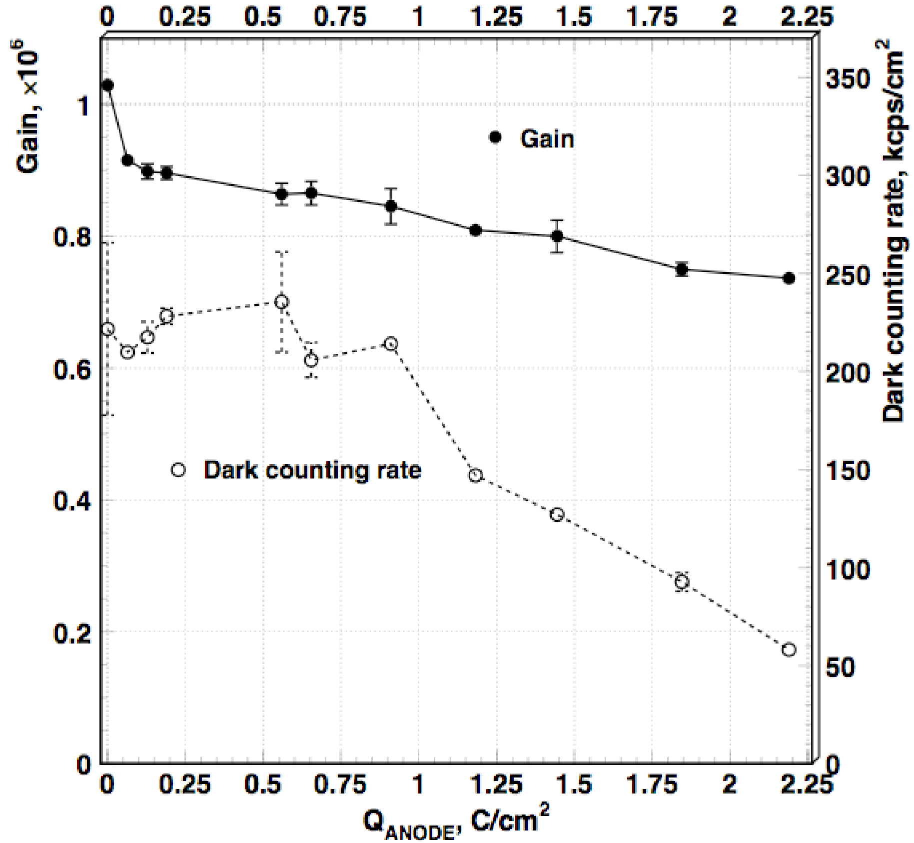
Photocathodes: aging comparison





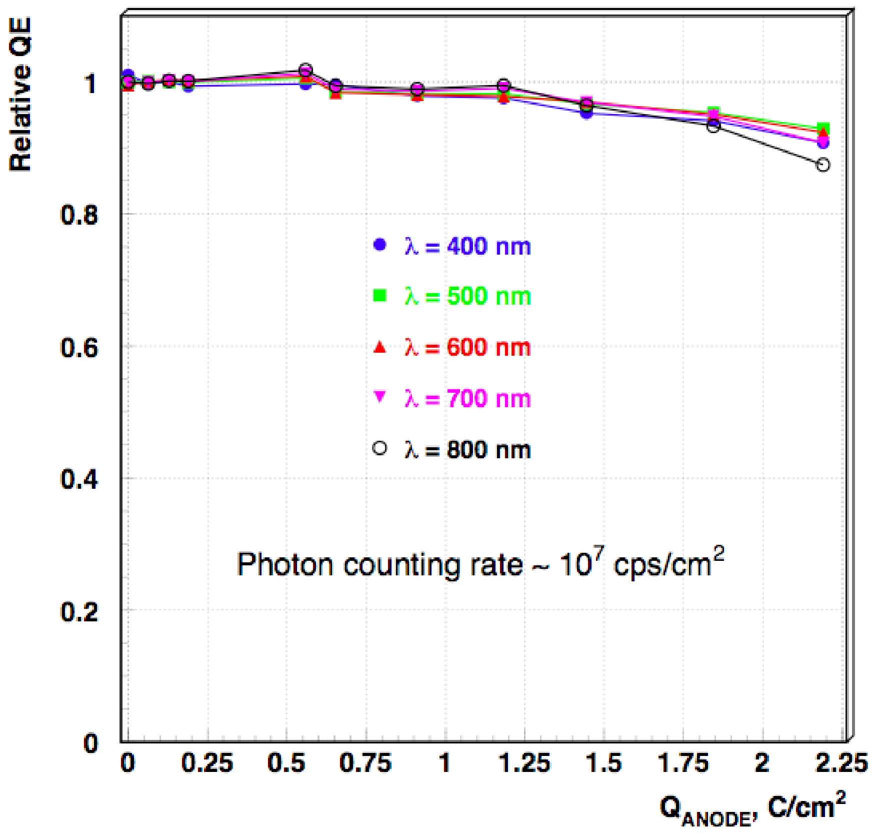
MCP PMT #91110: gain and dark rate

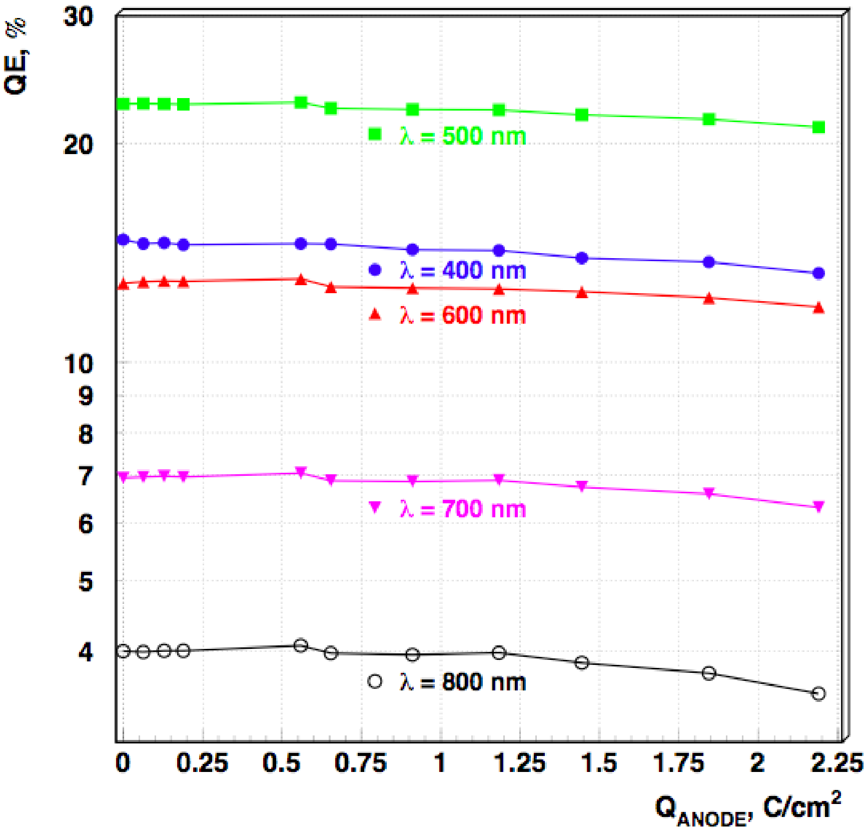




Lifetime measurements at counting rate of 10^7 $s^{-1}cm^{-2}$ where gain decreases by 20-30%

MCP PMT #91110: photocathode lifetime





2 C/cm² of accumulated anode charge

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7% degradation of QE