R&D of microchannel plate PMT for DIRC detectors of PANDA.

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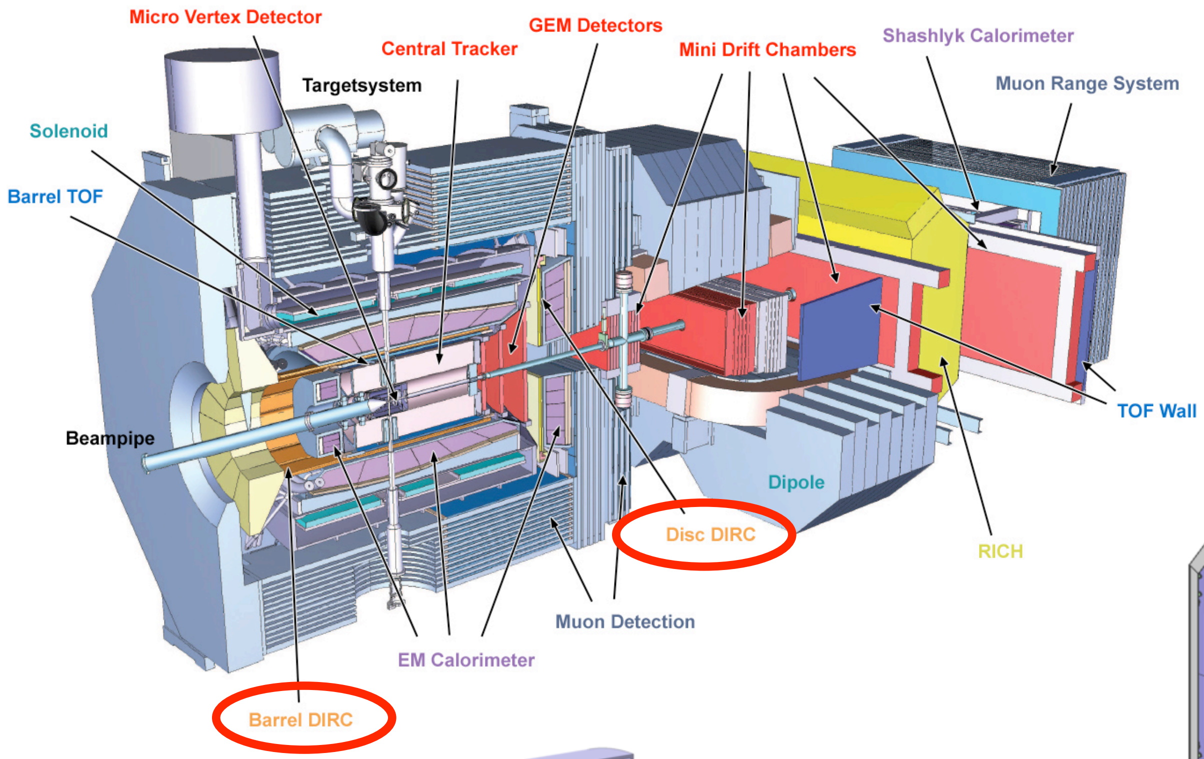
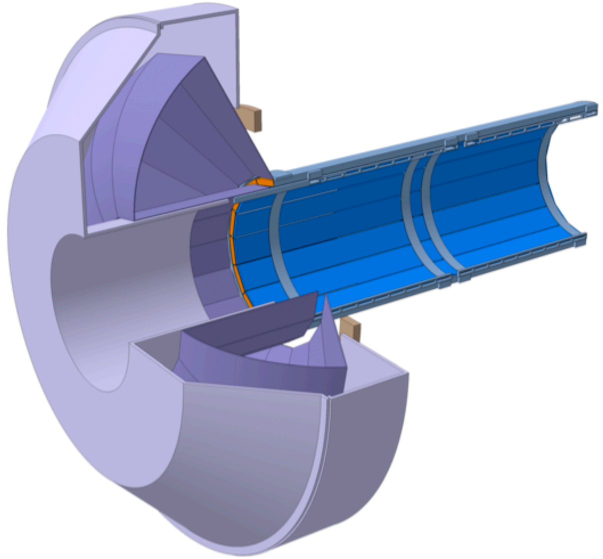
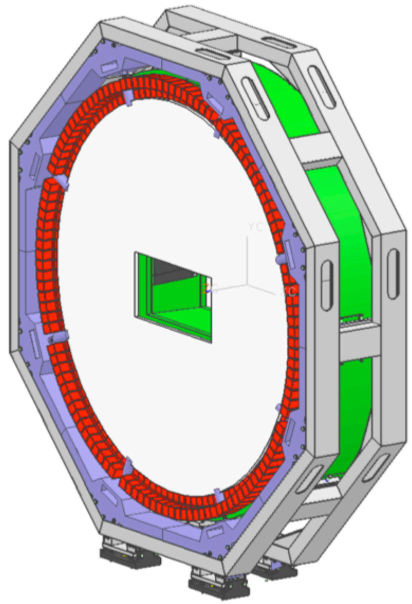
Outline:

- MCP PMT for PANDA
- Counting rate capability
- Photocathode aging
- Lifetime of the best sample
- Conclusions

DIRCs of PANDA

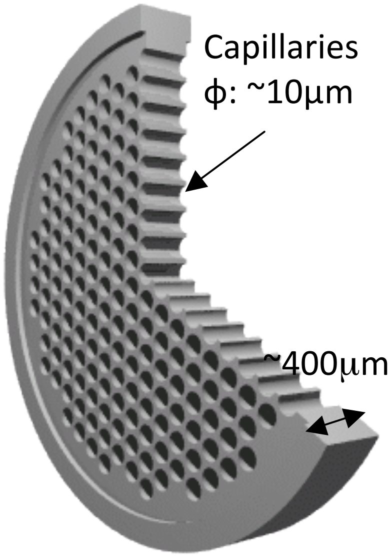




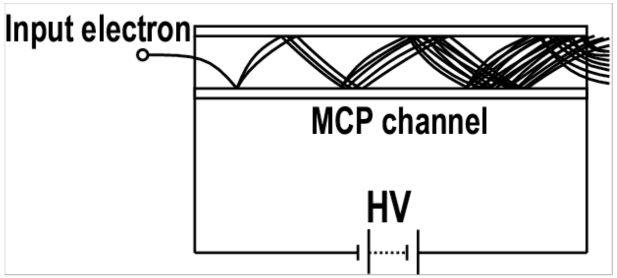


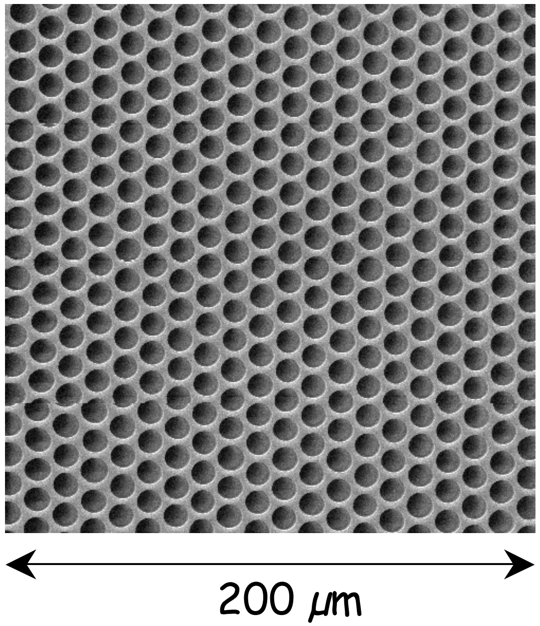
Single photon detection
Magnetic field ~1 T
Space resolution ~1 mm
Time resolution ~100 ps

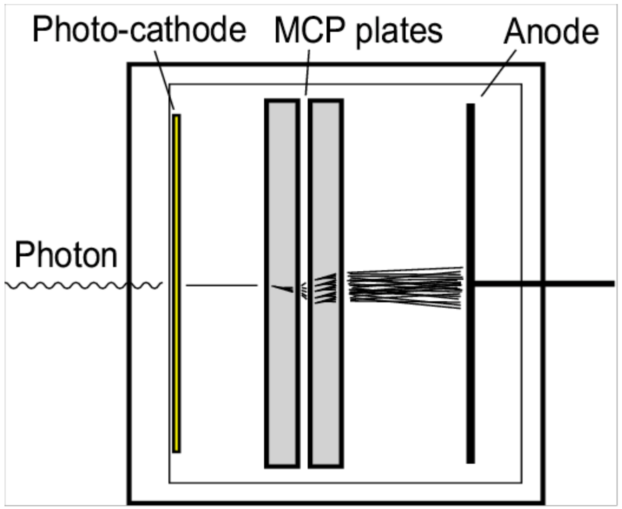
Microchannel plate PMT



Micro Channel Plate (MCP)

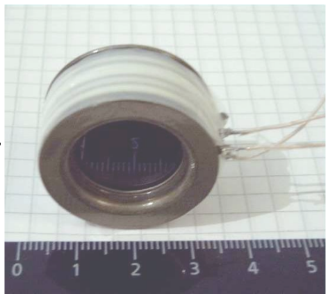


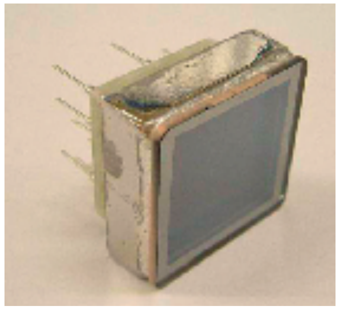


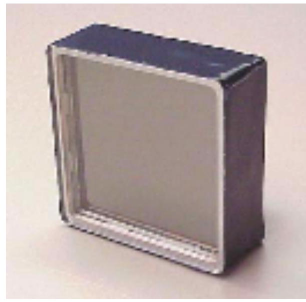


MCP PMT in HEP experiments (present & future)

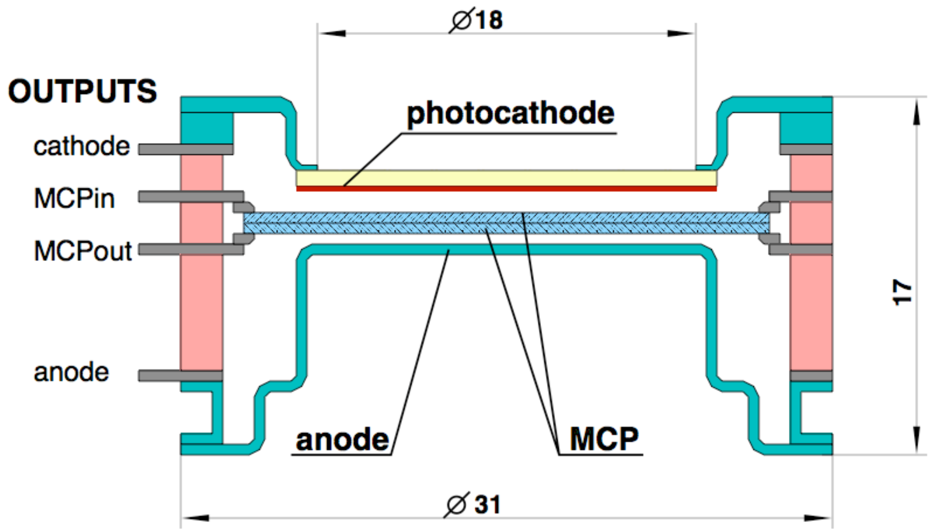
Experiment	*System*	*# PMTs*	*B-Field*	*Gain*	*Rate, $s^{-1}cm^{-2}$*	*I_{ANODE}, $C/cm^2/year$*	
KEDR	ASHIPH	160(80)	≤ 1.5T	$3{\cdot}10^5$	~10^4	< 0.03	BINP
SND	ASHIPH	9	0 T	$5{\cdot}10^5$	~10^4	< 0.05	
CMD-3	TOF	32	~0.02 T	~10^6	~10^4	< 0.10	
Belle II	TOP	256	1.5 T	10^6	10^5	0.16	Hamamatsu SL10
PANDA	Disk DIRC	250	~ 1 T	10^6	~ 10^6	~ 5	
PANDA	Barrel DIRC	256	~ 1 T	10^6	≤ $2{\cdot}10^5$	≤ 1	Burle/Photonis Planacon
LHCb	TORCH	198	0 T	?	?	~ 5	

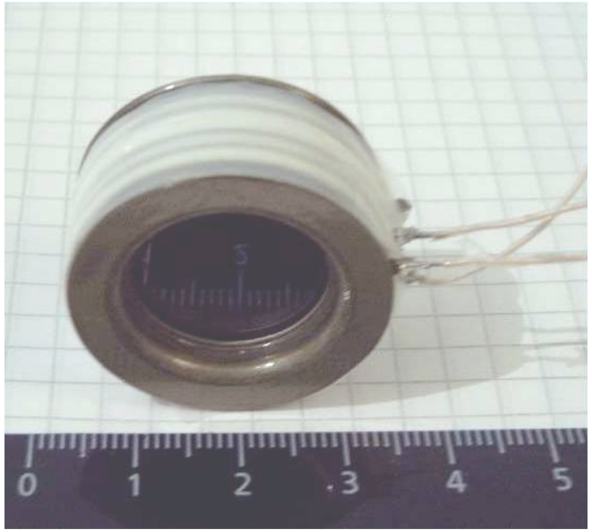
BINP

Ø 18mm

Hamamatsu

2x2 cm

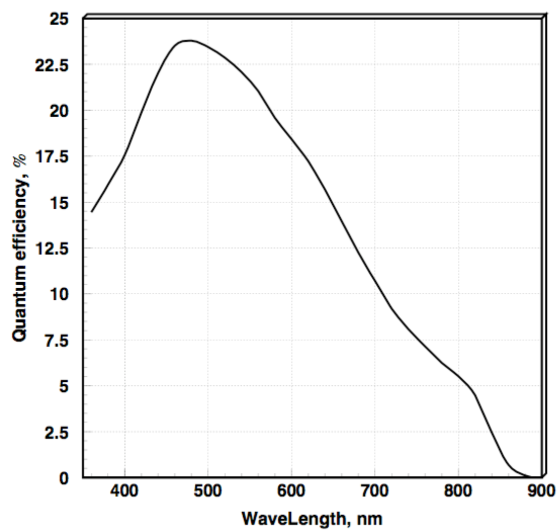
Photonis

5x5 cm

MCP PMT under investigation

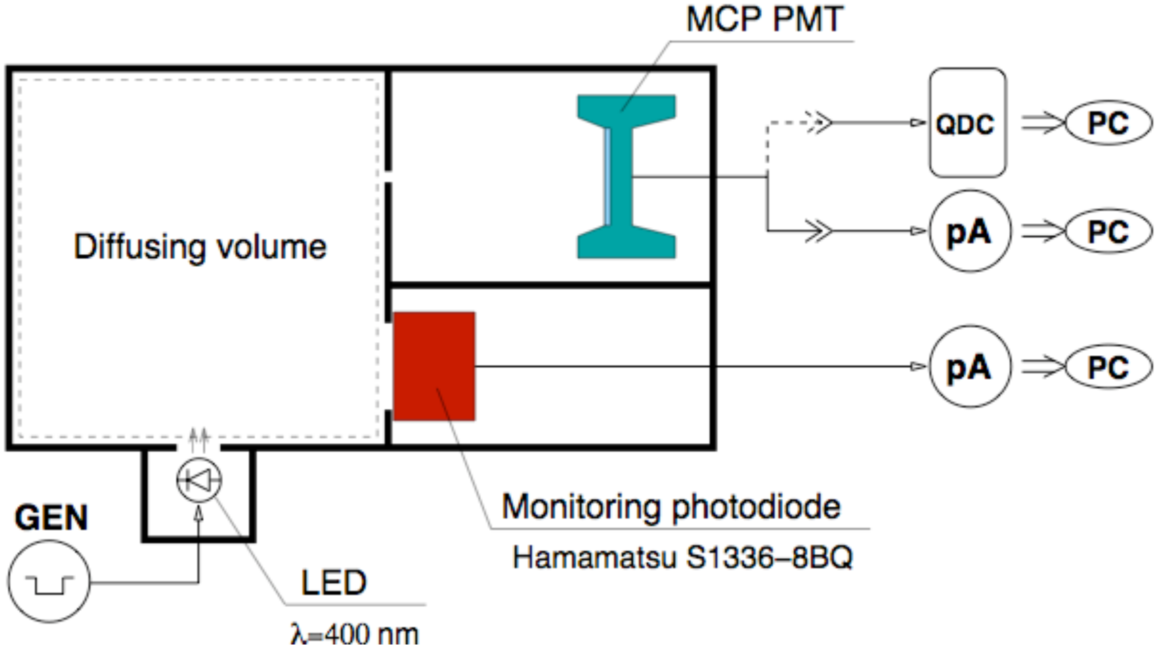


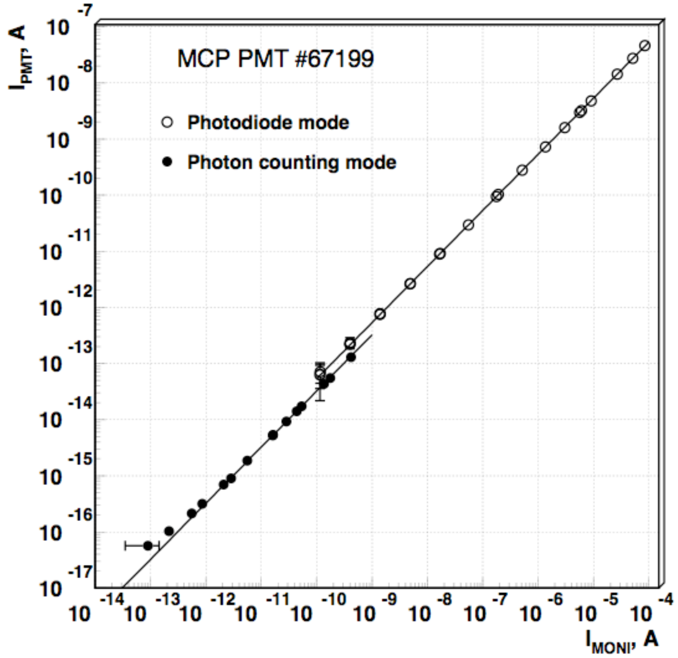


Manufacturer: "Ekran FEP" (Novosibirsk)
Borosilicate glass window
Multialkali (Sb-Na-K-Cs) photocathode
Maximum QE at λ=500nm
Two MCPs with channel diameter of 7 μm
Channel bias angle 13°
Single anode



Experimental setup





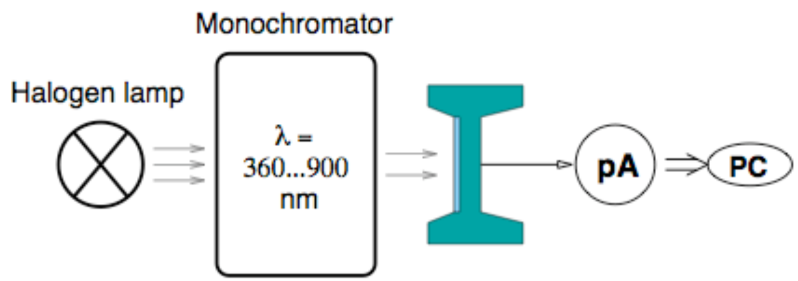
Low light intensity (photon counting mode):

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

High light intensity (direct current mode):

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

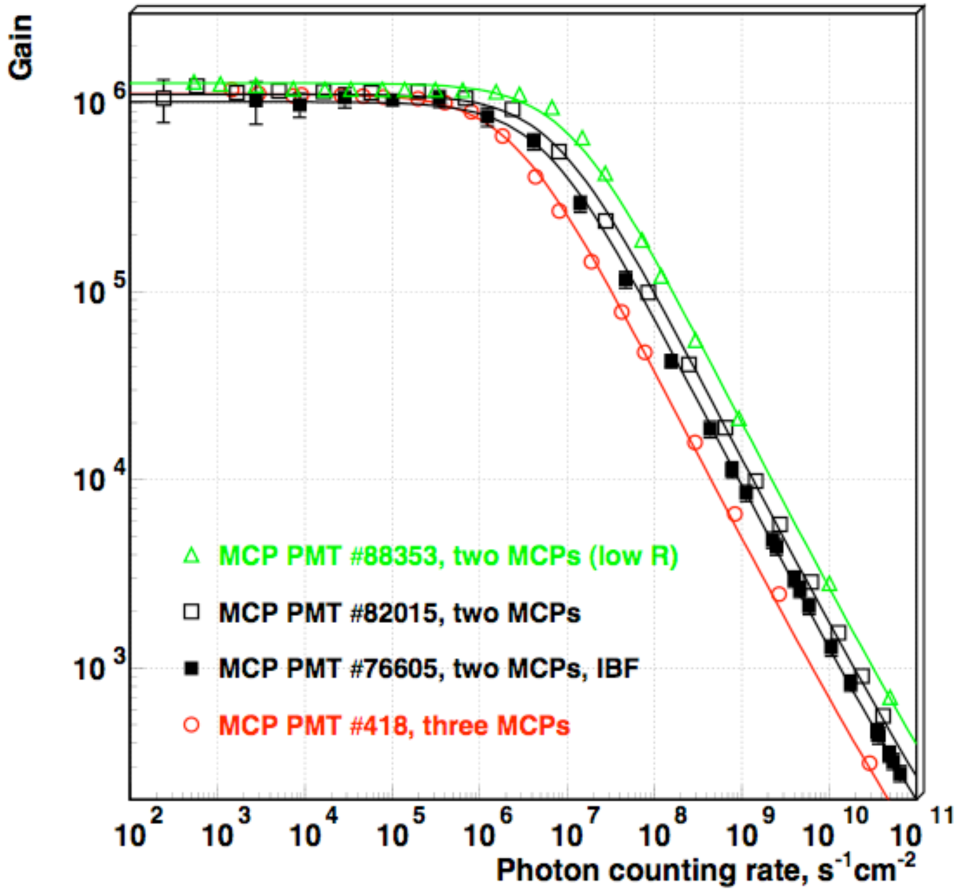
QE measurement:

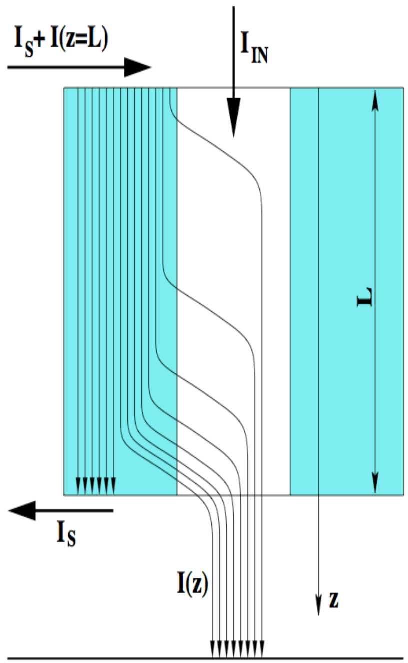


Reference PD: Hamamatsu S1227-1010BQ

Gain decrease at high counting rate

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





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

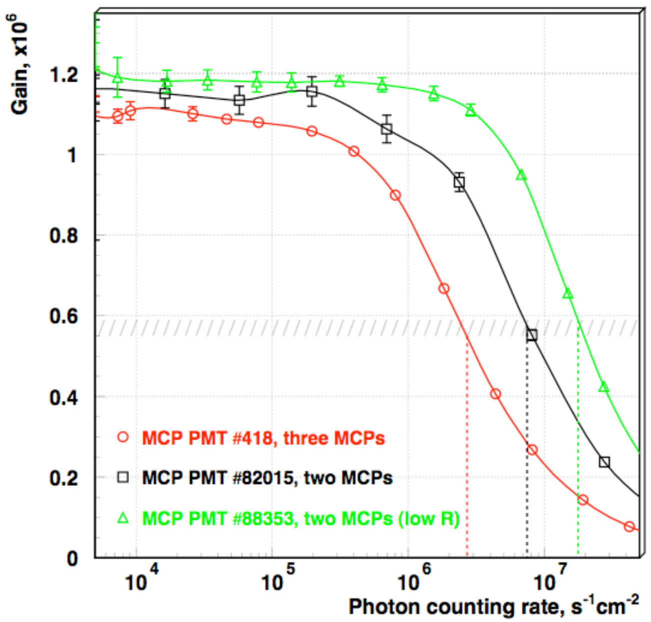
$$I(z) = I_{in} e^{\alpha z} \ln(G_0) / F / (1+I_{in}/I_s \cdot e^{\alpha z})$$

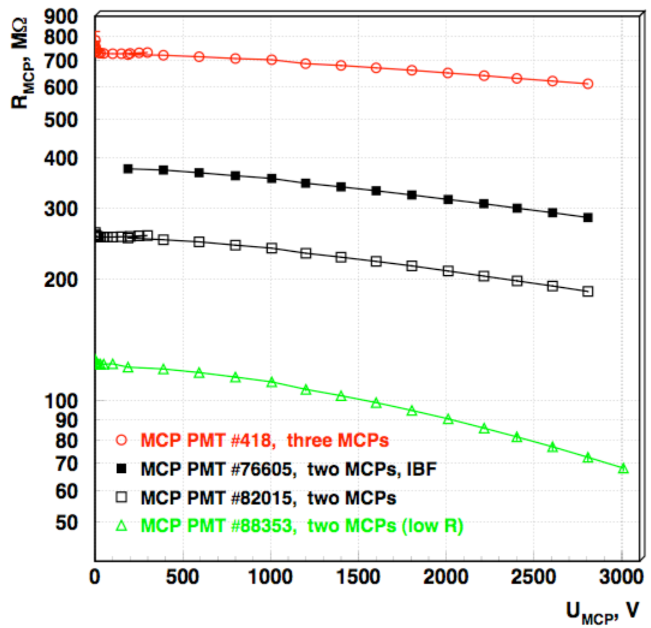
where

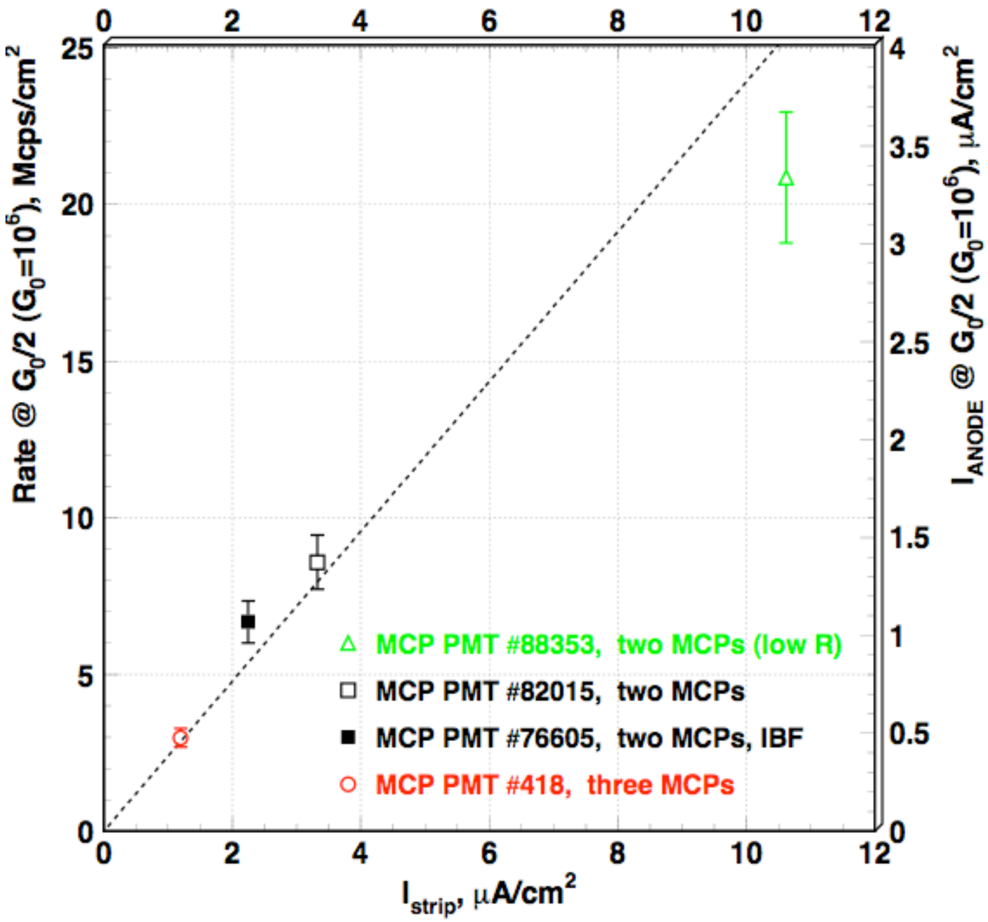
$F = \ln(G_0) + \ln(1+I_{in}/I_s) - \ln(1+I_{in}/I_s \cdot G_0)$

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

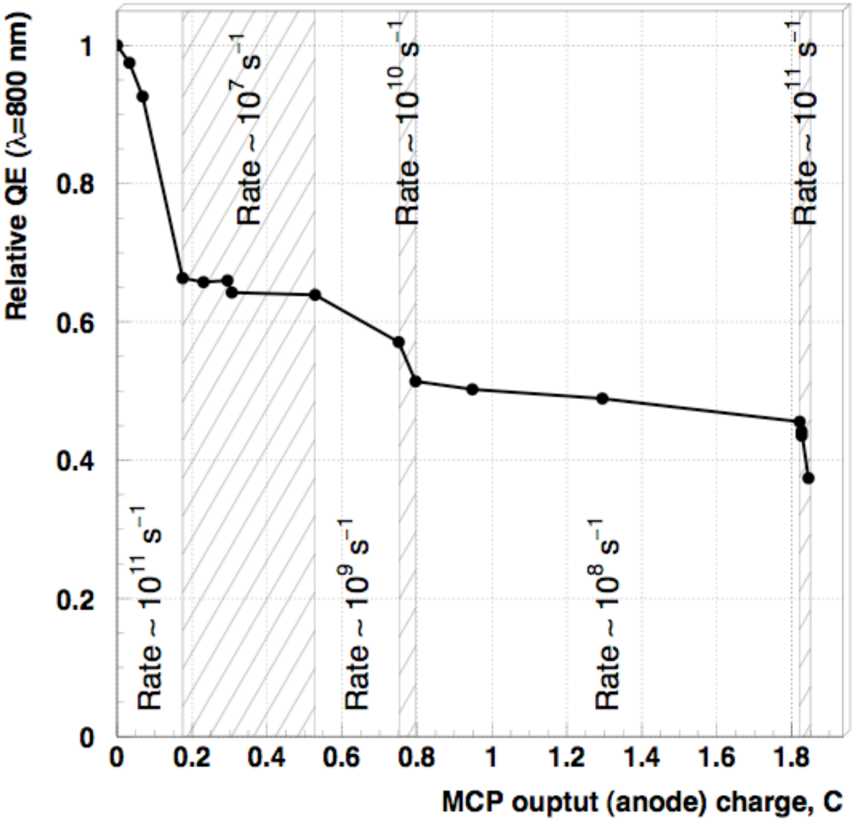
Rate capability vs. strip current

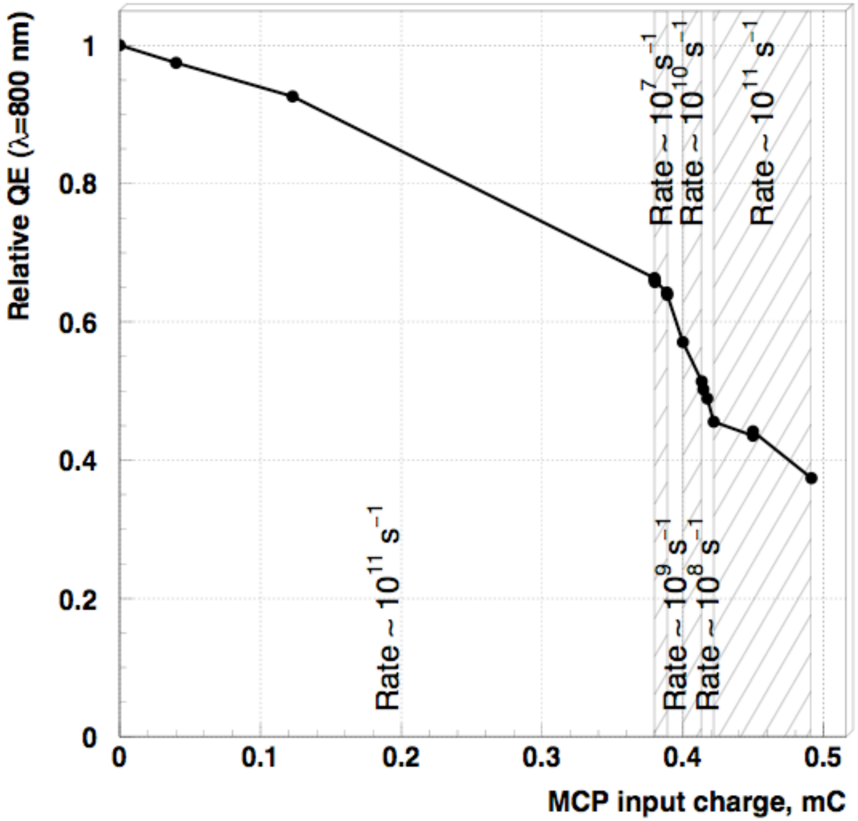






QE degradation at different counting rates





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

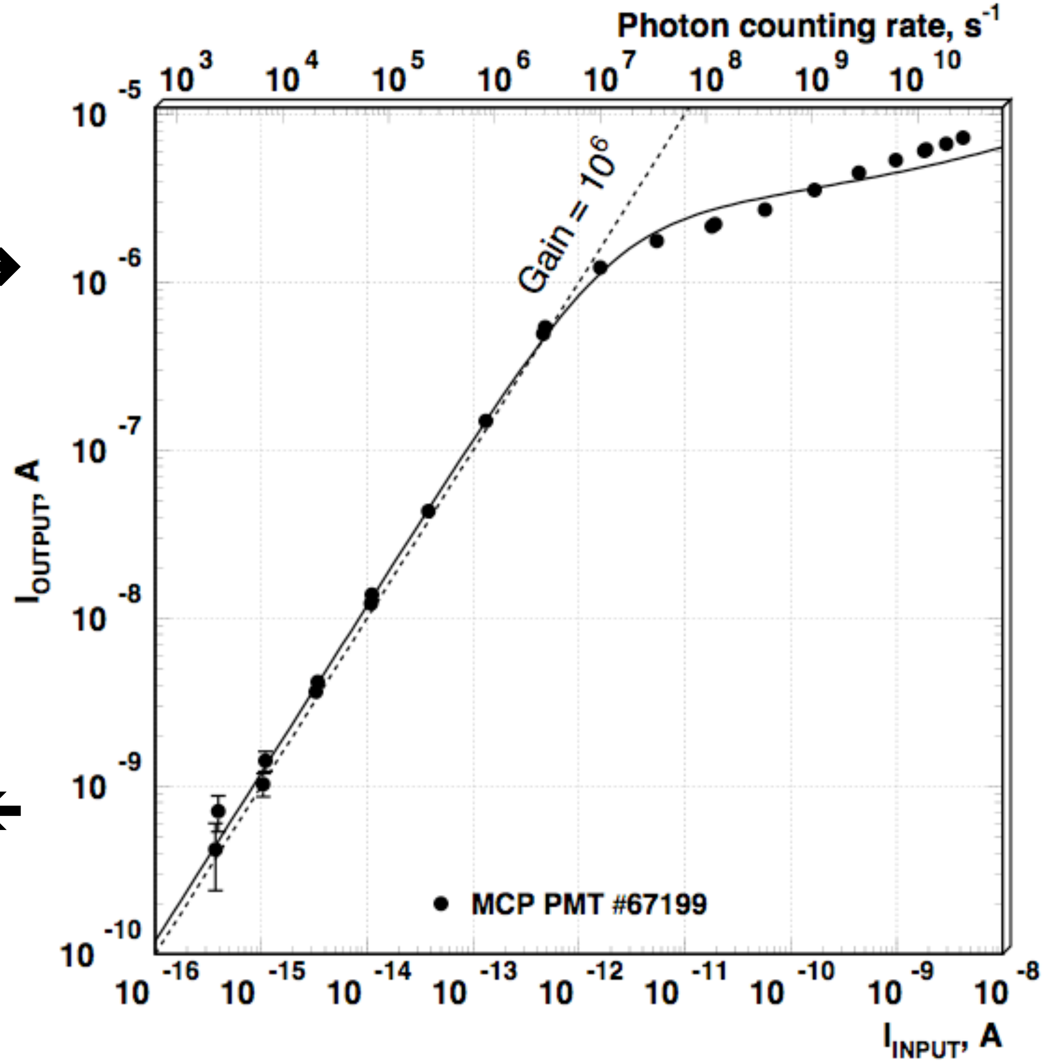
The higher counting rate the slower QE degradation per unit of cathode charge

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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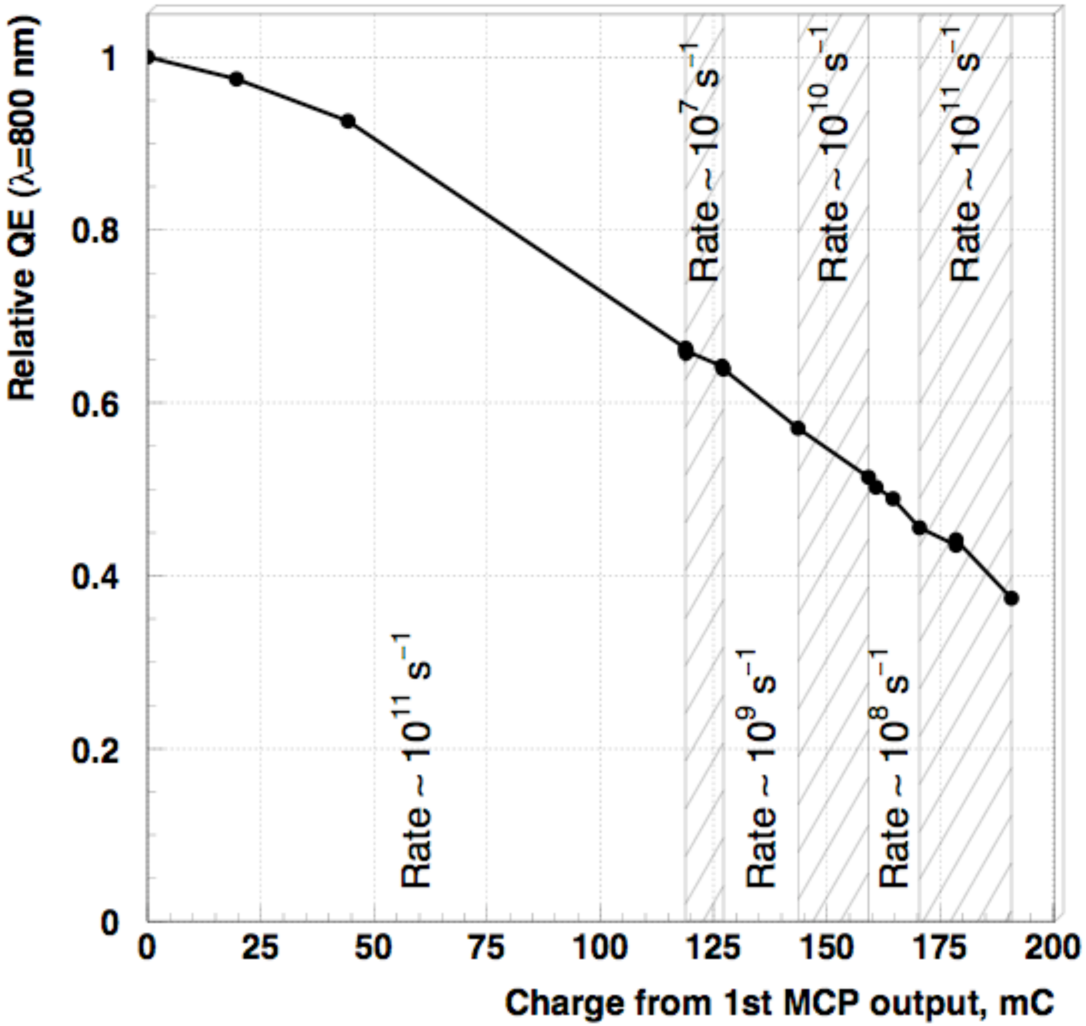
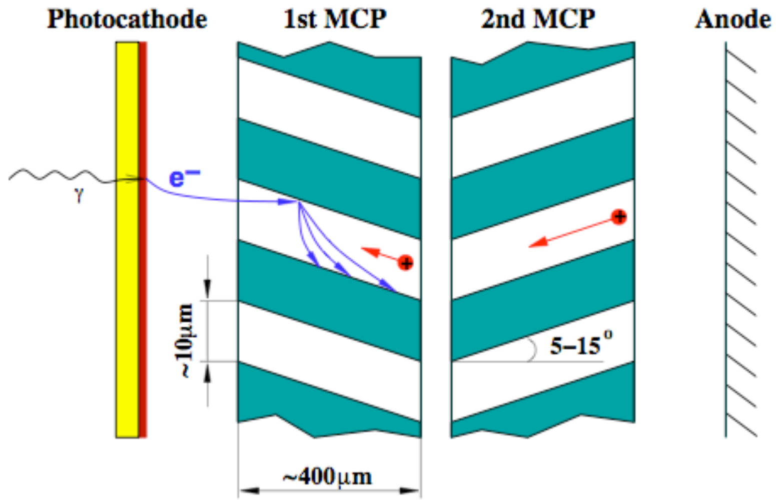
Calculation of the current extracted from 1st MCP :

$I(z{=}L/2)$ 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:

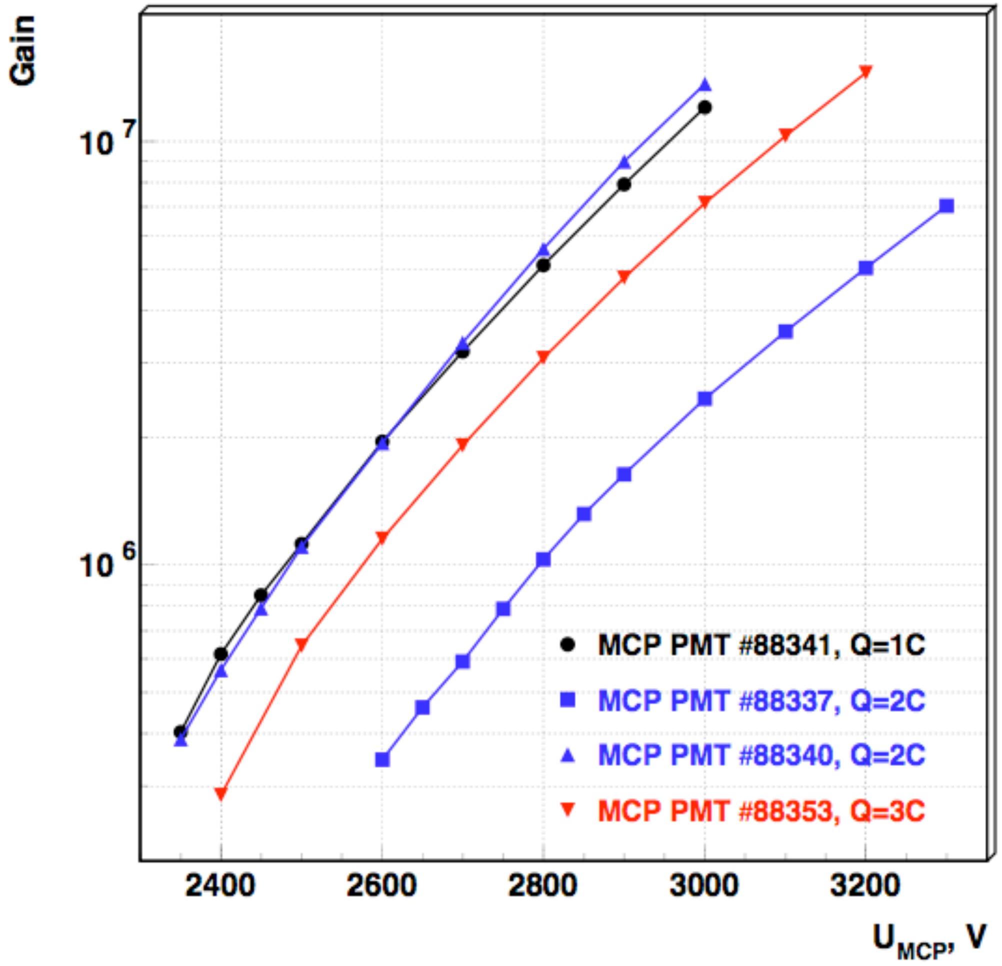
- Correct comparison of the aging of different samples of PMT.
- Lifetime improvement by redistribution of gain between 1st and 2nd MCP.

Enhancement of MCP degassing: gain

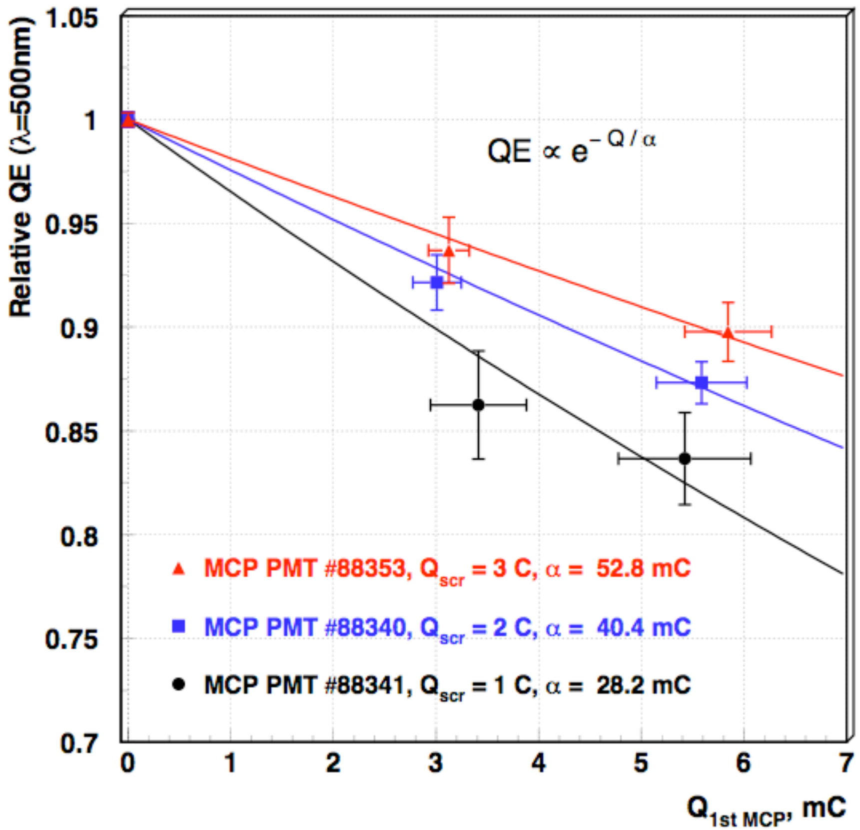
Two stage of MCP degassing:
1. Heating
2. Electron scrubbing

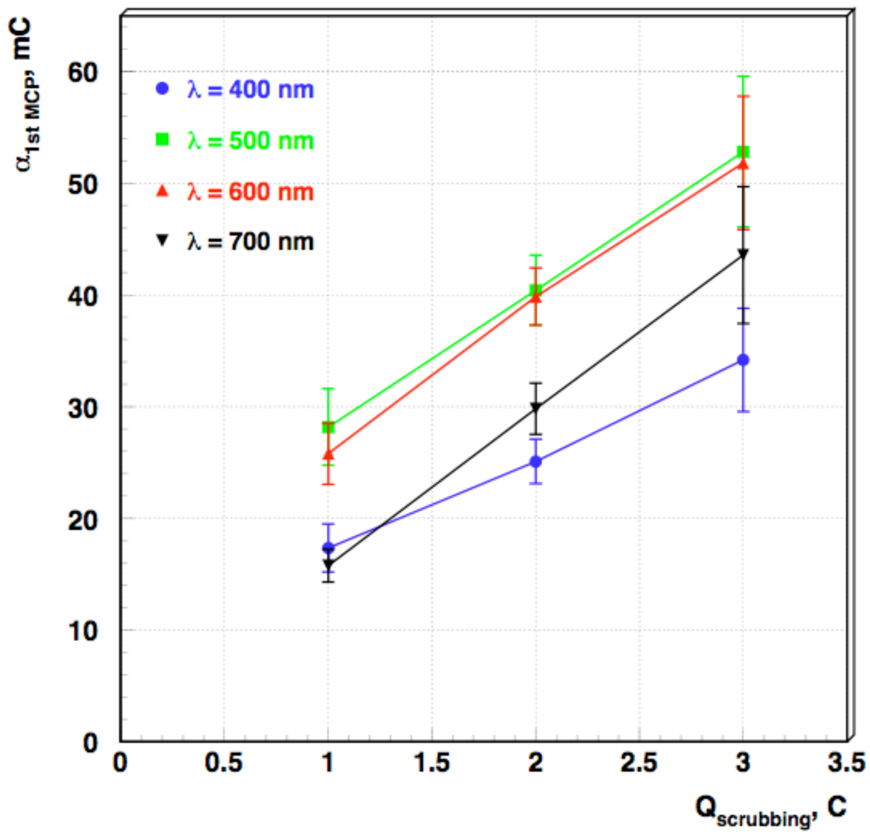
+ Photocathode lifetime increase
- Gain degradation

Duration of electron scrubbing has been increased in 2 and 3 times
↓
MCP gain is not affected
(large spread of initial MCP quality)



Enhancement of MCP degassing: aging



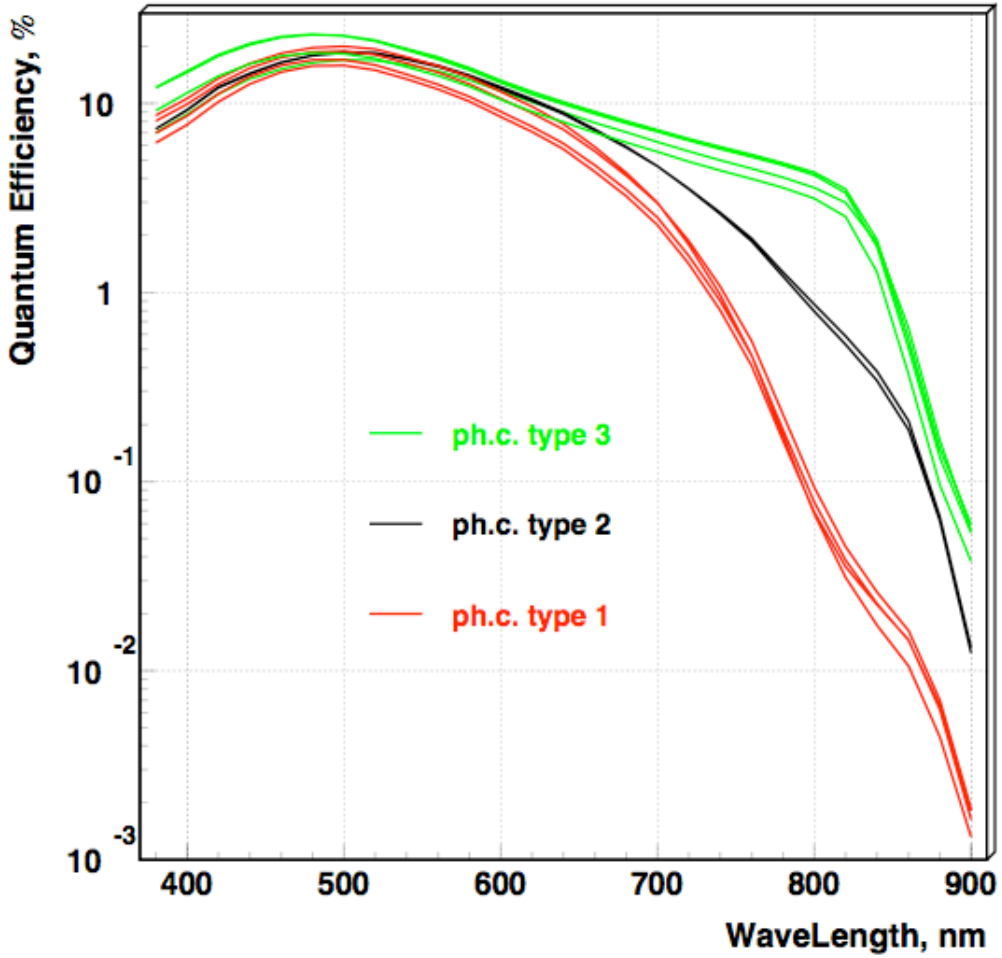


Three times better electon scrubbing

↓

Two times slower QE degradation

Photocathodes: spectral response

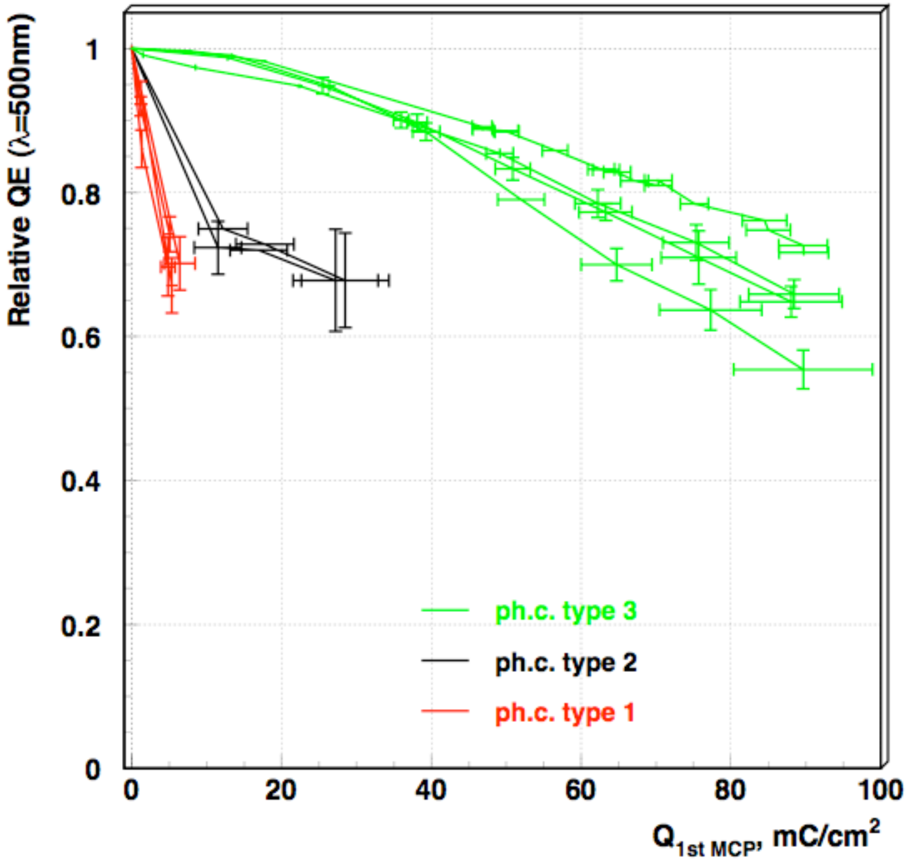


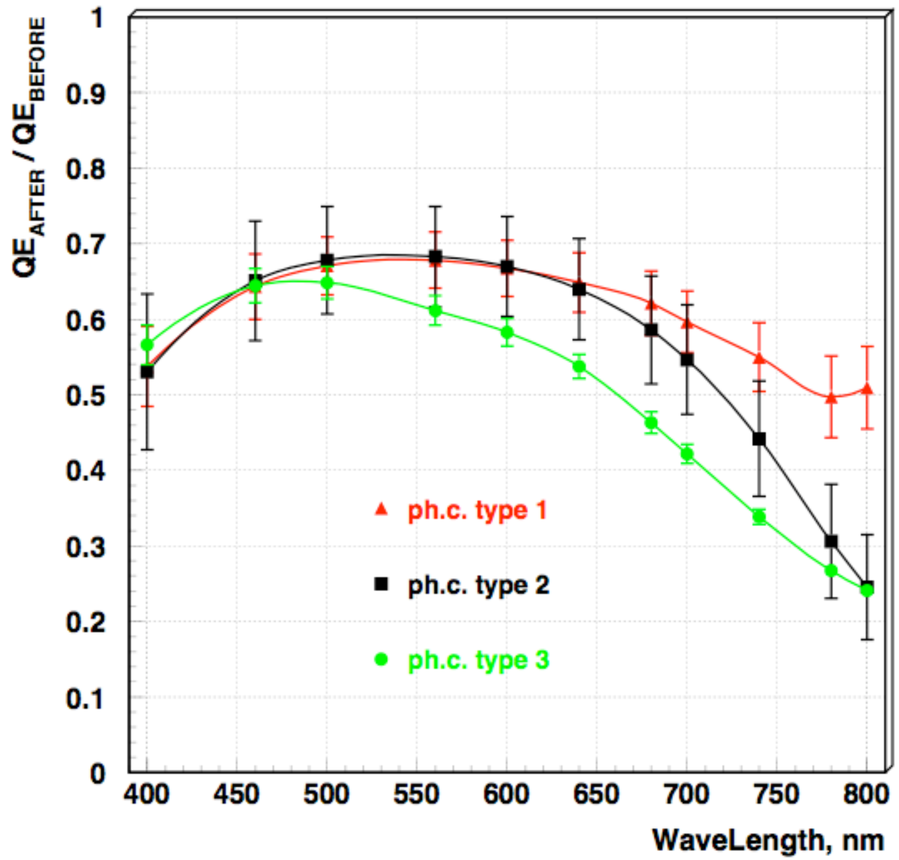
Type 1: $Na_2KSb(Cs)$
Dark rate ~ 0.5 kcps/cm^2

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

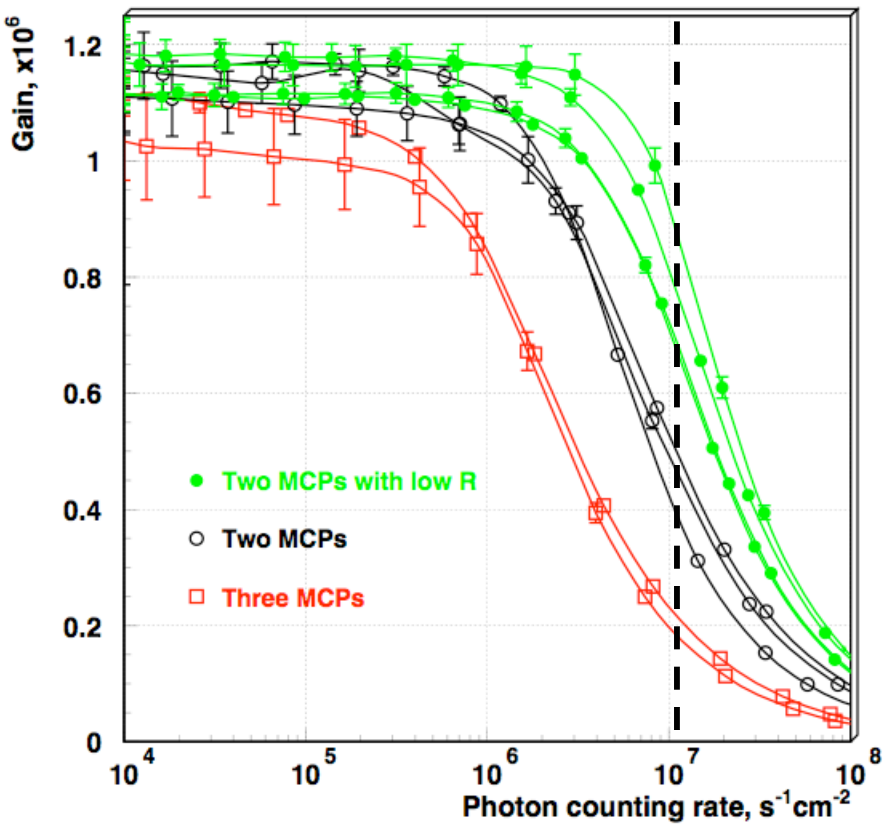
Type 3: $Na_2KSb(Cs) + Cs_3Sb$
Dark rate ~ 50-100 kcps/cm^2

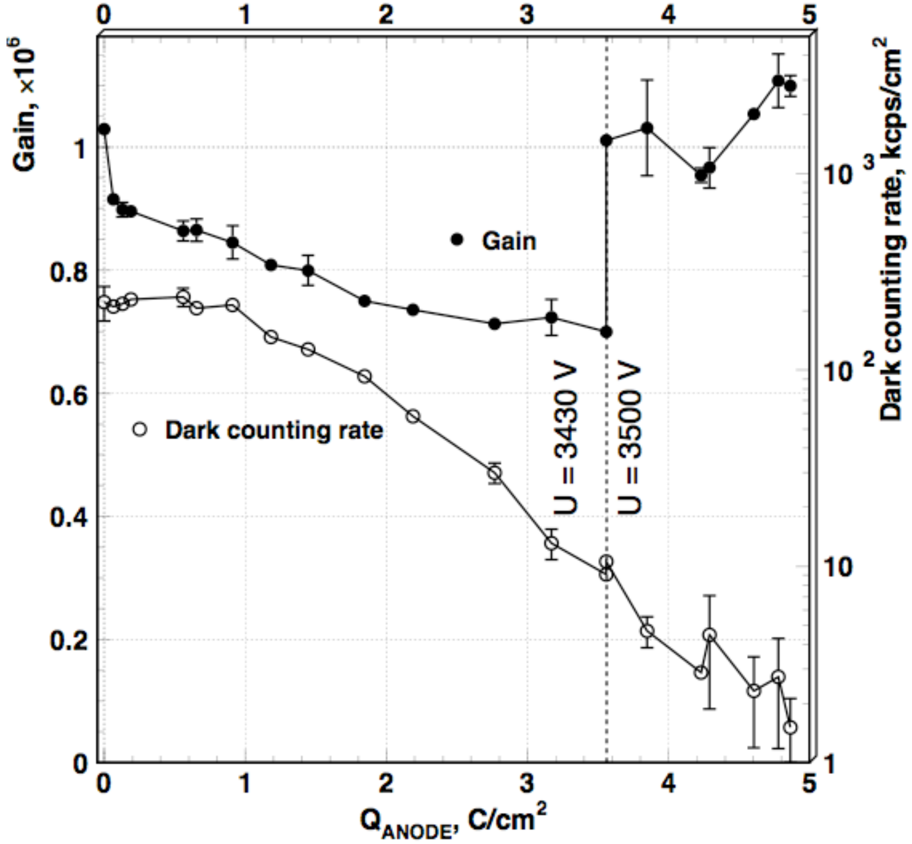
Photocathodes: aging comparison





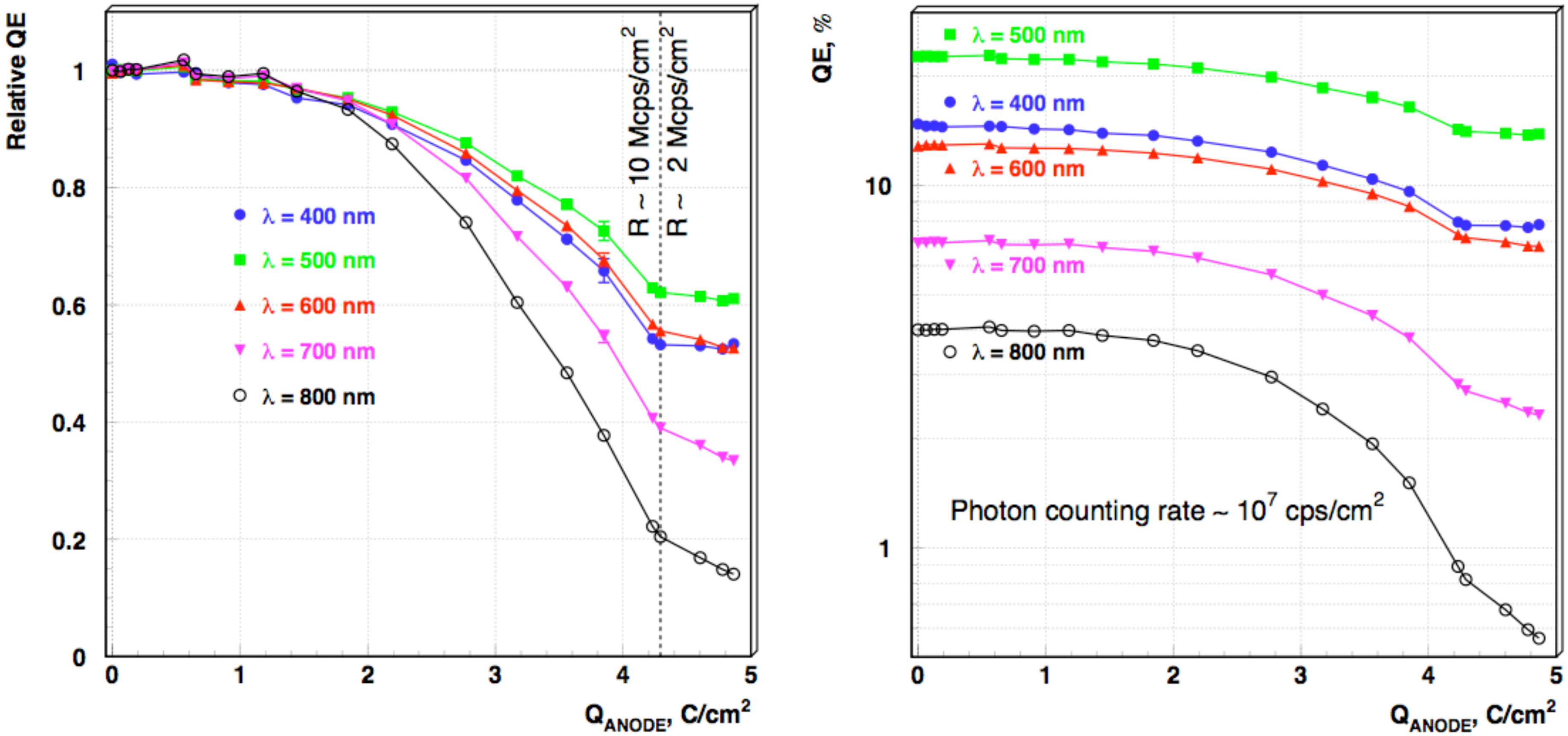
MCP PMT #91110: gain and dark rate





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

MCP PMT #91110: photocathode lifetime

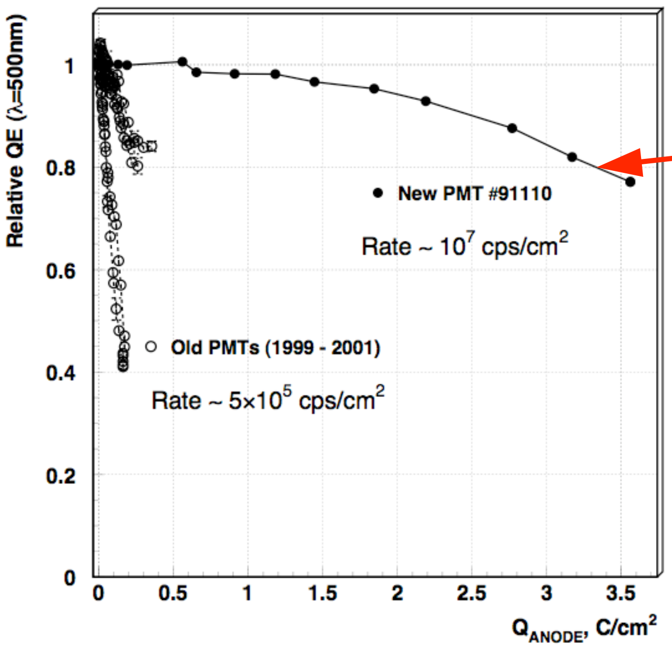


3.3 C/cm² of accumulated anode charge

↓

20% degradation of QE(500nm)

MCP PMT lifetime comparison

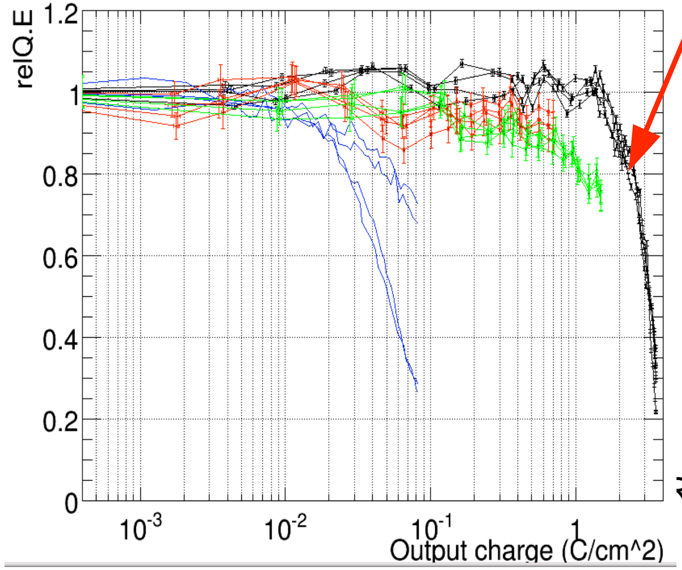


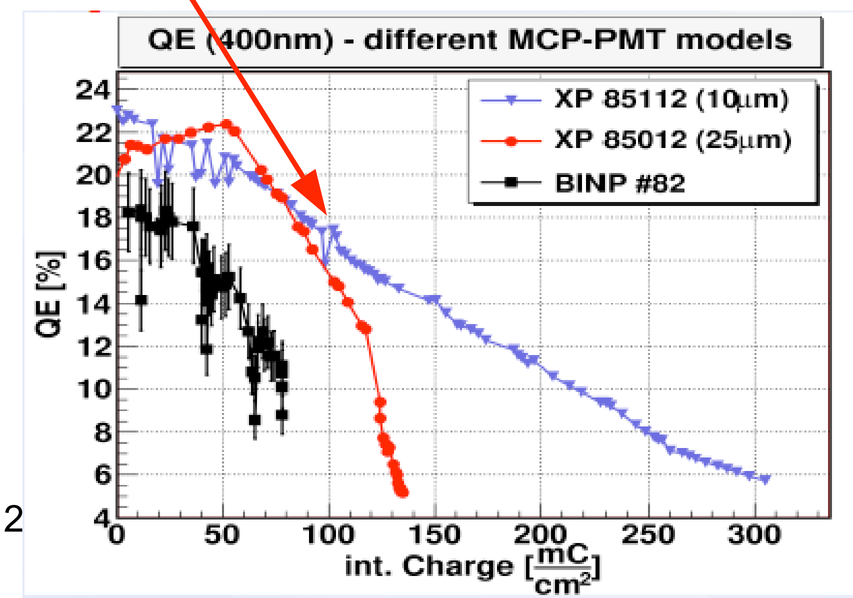
Novosibirsk : 3.0 C/cm^2 ($R \sim 1x10^7\ s^{-1}cm^{-2}$)

Hamamatsu : 2.5 C/cm^2 ($R \sim 5x10^5\ s^{-1}cm^{-2}$)

Photonis : 0.1 C/cm^2 ($R \sim 2x10^5\ s^{-1}cm^{-2}$)

($G_0 \sim 10^6$)





Summary

- The counting rate capability is determined by MCP strip current and can be incresed by decrease of MCP resistivity.
- QE degradation is proportional to the charge extracted from the 1st MCP (at high counting rate).
- Enhancement of MCP electron scrubbing did not affect MCP gain and decreased the photocathode aging rate.
- Optimization of the photocathode formation process can decrease aging rate by order of magnitude.
- The photocathode lifetime of the best MCP PMT sample is more than 3 C/cm^2 of accumulated anode charge.

Plans

If enough money for R&D are found:

Development of square-shaped multianode MCP PMT

If “Ekran FEP” is interested:

Further enhancement of MCP degassing

BiAlkali photocathode study

Else:

Investigation of the rate capability and
the photocathode aging in magnetic field