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 $\lambda=500\text{nm}$
Two MCPs with channel diameter of 7 $\mu\text{m}$
Channel bias angle 13°
Single anode

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ASHIPH counters for KEDR

- \( \pi/K \) separation in momenta range 0.6 \( \div \) 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

M.Barnyakov  NDIP11, Lyon, 06.07.13
ASHIPH counters for SND

- $\pi/K$ separation in momenta range $300 \div 870$ 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):
\[ K = \frac{R_{PMT}}{I_{MONI}} \]

High light intensity (direct current mode):
\[ R_{PMT} = I_{MONI} K \]

Quantum efficiency measurements:

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

M.Barnyakov, et al.

INSTR08, Novosibirsk
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

Rate $\sim 10^{10} - 10^{11}$ cps/cm$^2$
Best sample: comparison with old tubes

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

M.Barnyakov   NDIP11, Lyon, 06.07.19
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,

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

where

\[ F = \ln(G_0) + \ln(1+I_{in}/I_s) - \ln(1+I_{in}/I_s \cdot G_0) \]
\[ \alpha = \ln(G_0)/L \]

Gain decrease at high counting rate

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Calculation of 1st MCP current

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

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

$G_0$ and $I_s$ - free parameters

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.

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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 electron scrubbing

Two times slower QE degradation

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Photocathodes: spectral response

Type 1: $\text{Na}_2\text{KSB}(\text{Cs})$
Dark rate $\sim 0.5$ kcps/cm$^2$

Type 2: $\text{Na}_2\text{KSB}(\text{Cs}) + \text{Cs}$
Dark rate $\sim 5$ kcps/cm$^2$

Type 3: $\text{Na}_2\text{KSB}(\text{Cs}) + \text{Cs}_3\text{Sb}$
Dark rate $\sim 50-100$ kcps/cm$^2$
Photocathodes: aging comparison

![Graphs showing the aging comparison of photocathodes.](image)

- Relative QE ($\lambda \leq 500$ nm)
- Q$_{1\text{st \ MCP}}$ mC/cm$^2$
- Wavelength, nm

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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%

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MCP PMT #91110: photocathode lifetime

2 C/cm² of accumulated anode charge

7% degradation of QE

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