Performance of multi-anode PMT employing an ultra bi-alkali photo-cathode and rugged dynodes

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Contents

MAPMT (R8900 series) for space use

R8900-200-M16MOD-UBA

- Low noise
  (1 p.e. level detectable)
- Position sensitive PMT
- Large effective surface
  > 80 % physical area
- Compact
  26 x 26 x 27 mm^3
- Operate at low voltage
  ~ 900 V, gain ~ 2×10^6

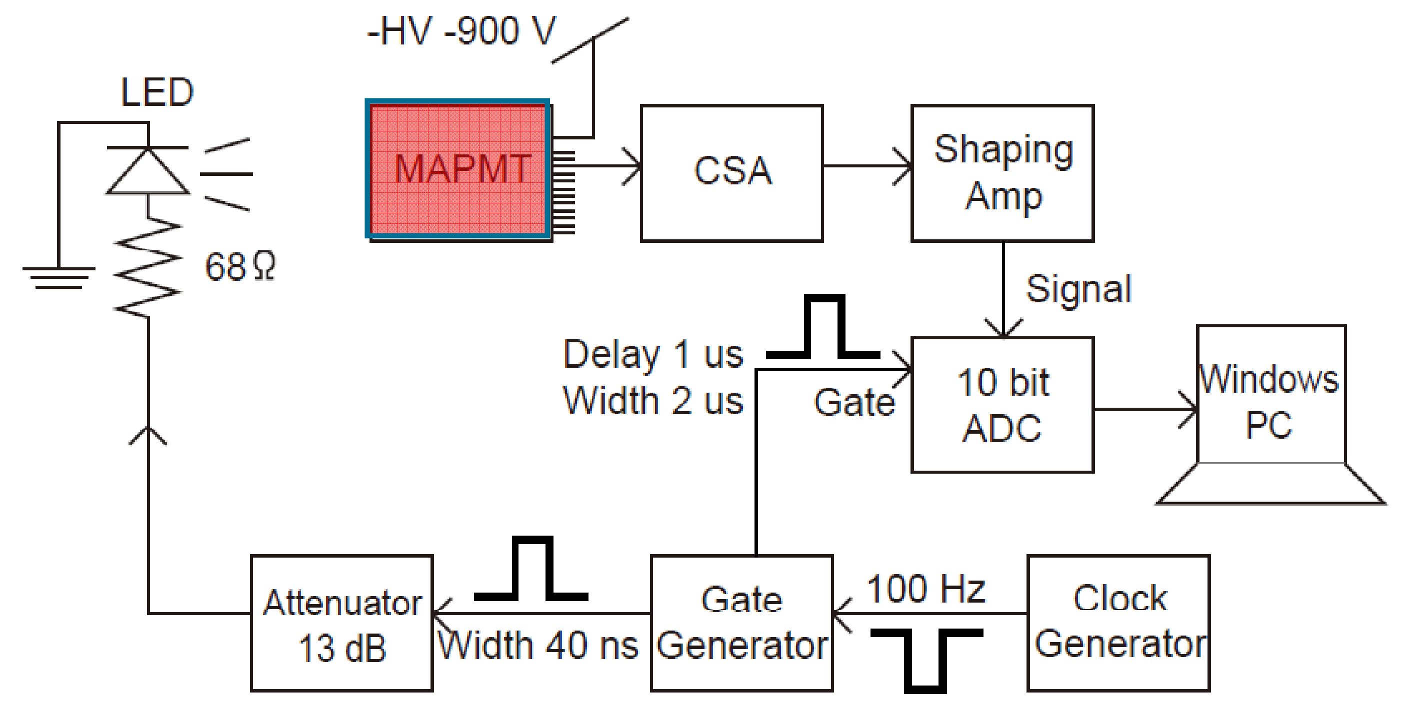
We have made two additional improvements

- Ultra bi-alkali photo-cathode Q.E. > 40 %
- Rugged dynodes
  tolerant of vibration for launching rocket

Basic Characteristics

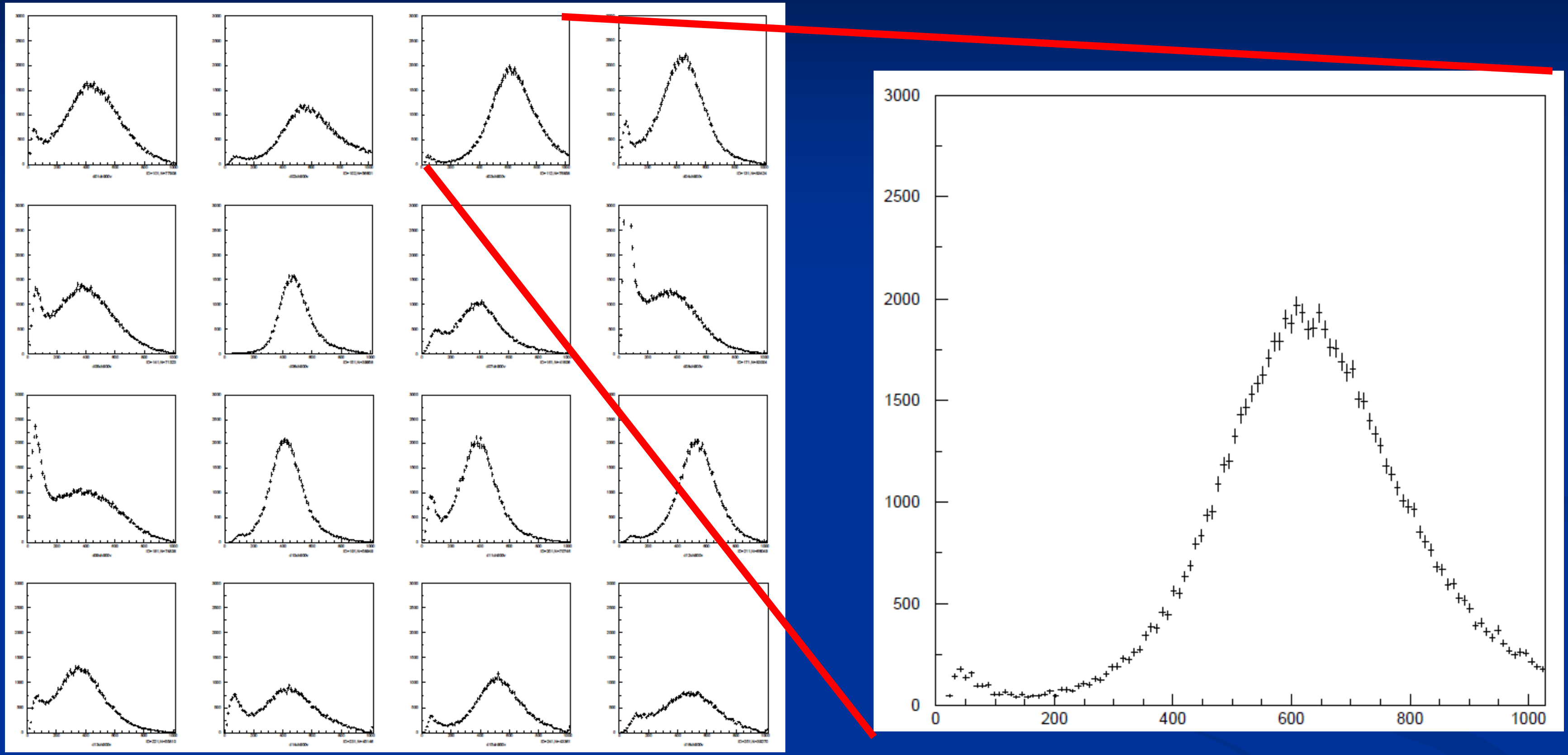
- 1 p.e. spectra
- MAPMT gain
- HV dependence of gain
- Temperature dependence

Setup for evaluation test



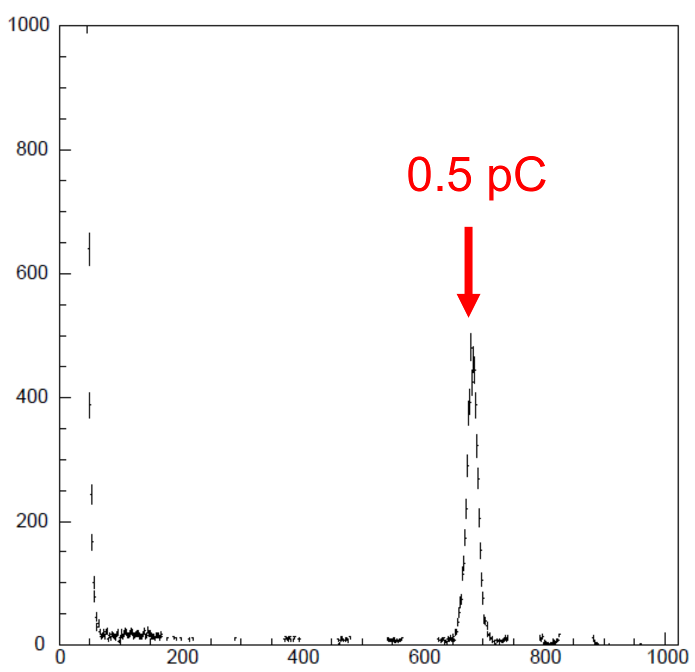
- We use the single photoelectron of minimum signal for MAPMT
- We obtained the signal with a trigger synchronizing with the LED.
- Intensity of LED is attenuated to 1 p.e. level.

1 p.e. spectra



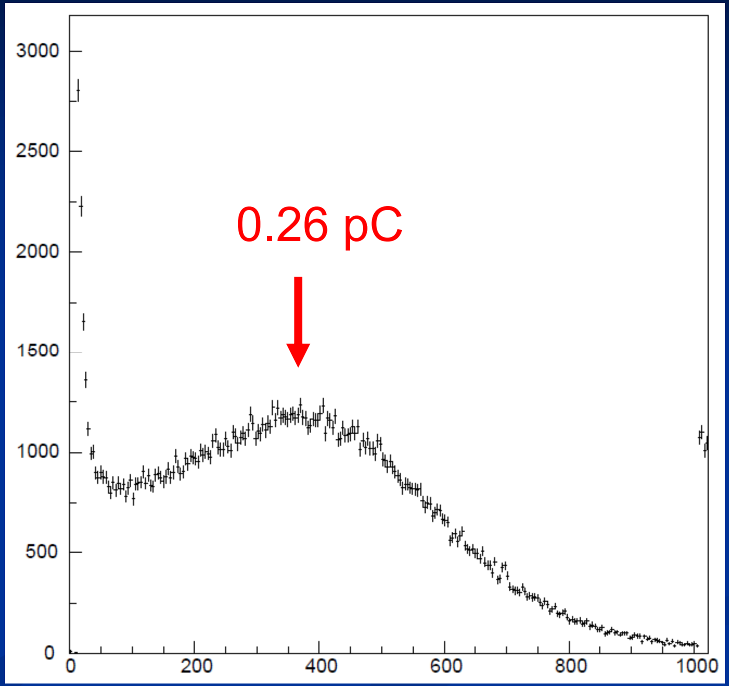
- We obtained the 1p.e. spectra and estimated
  1. MAPMT gain (Gain, HV dependence, uniformity)
  2. Temperature dependence of dark counts

MAPMT Gain



Spectrum of test pulse (0.5 pC)

comparing

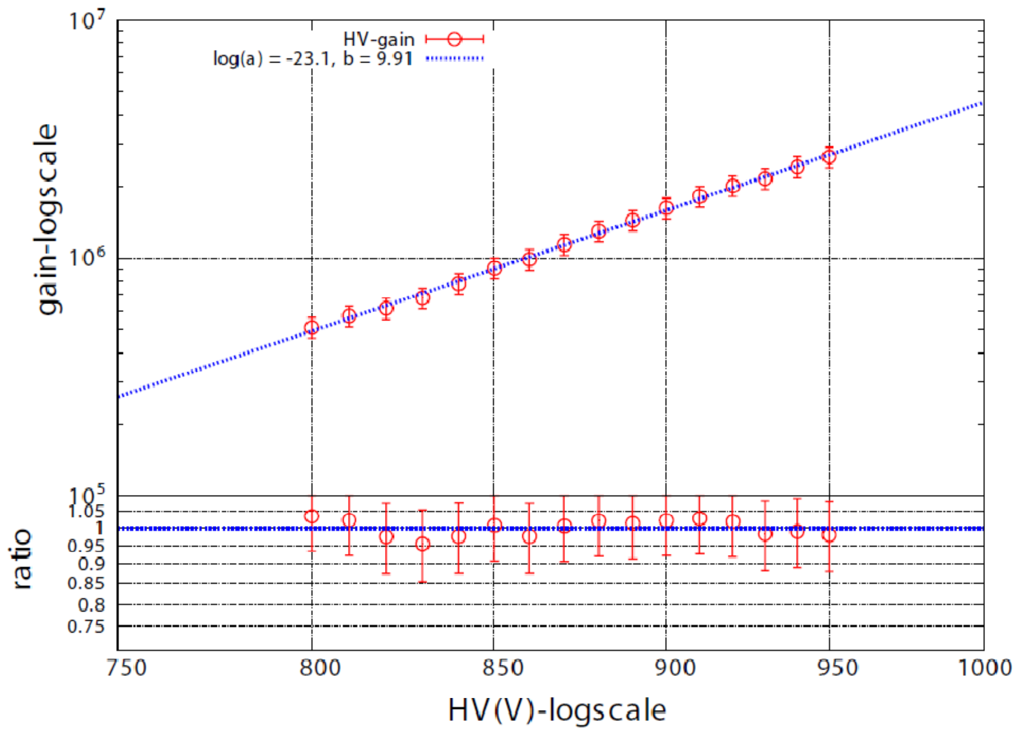


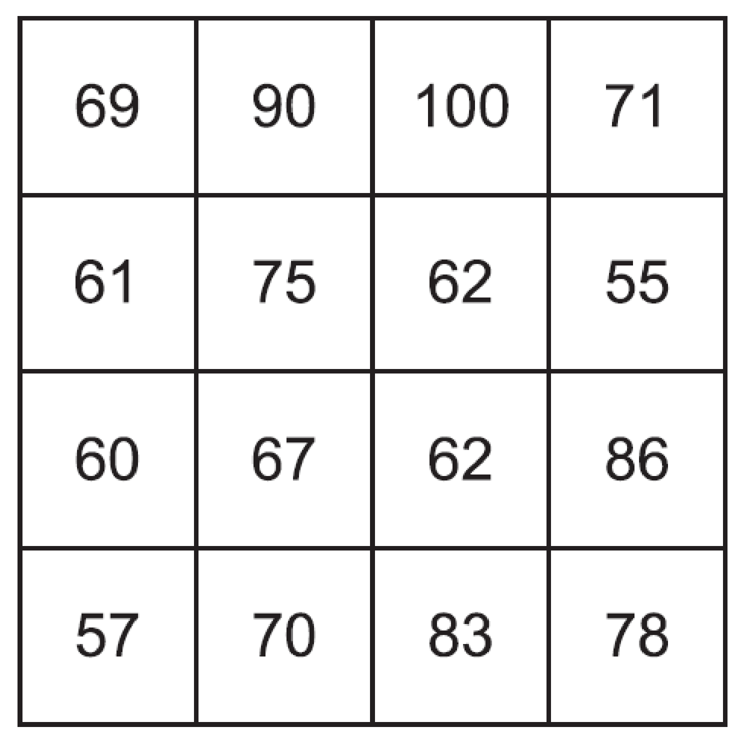
1 p.e. spectrum
(pixel 3, —900 V)

$G = 1.6 \times 10^6$ (error ~10 %) at -900 V

- To determine the MAPMT gain, we first make the test pulse for a certain input charge (0.5 pC) , then compare its pulse height with actual 1 p.e. signal from the MAPMT, and obtain the charge of 1p.e.

HV Dependence and Uniformity of Gain

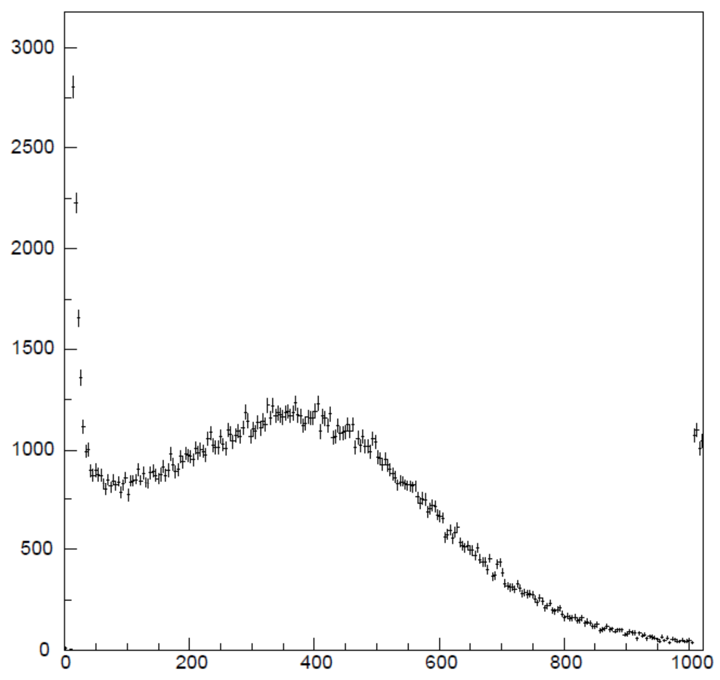




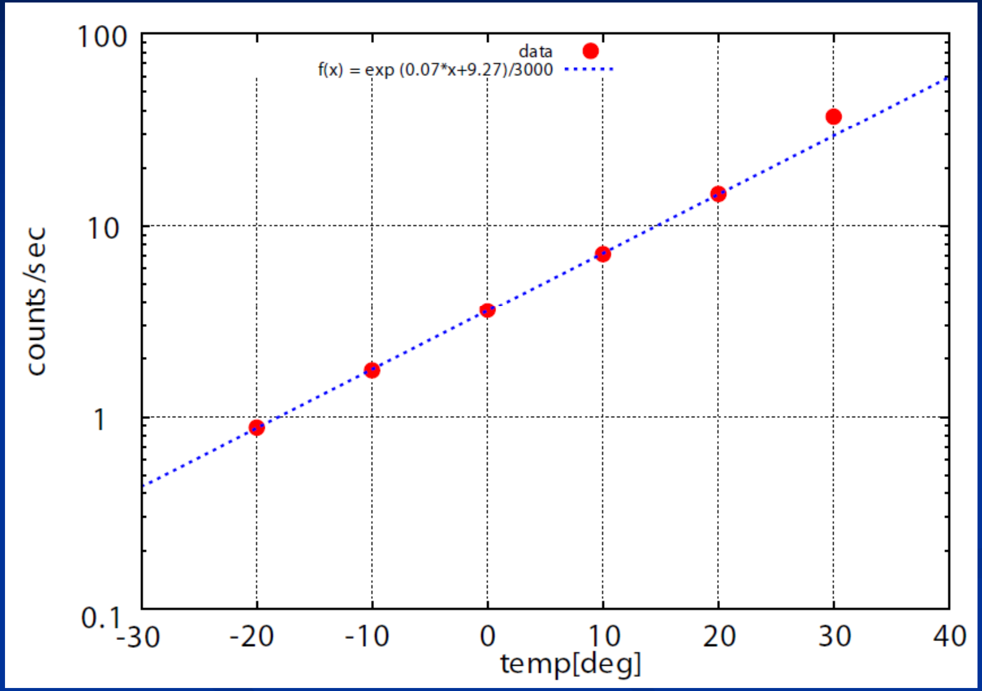
69	90	100	71
61	75	62	55
60	67	62	86
57	70	83	78

- (left) HV dependence of gain
  $G = a \times HV^b$, $\log_{10}a = -23.1$, $b = 9.9$
- (right) The ratio of gain obtained by 1 p.e. spectra by using pixel3 reference 100.

Temperature Dependence



Thermal electron spectrum
at 20 degree (1000 s)



Counts/s vs. temperature

$N = N_0 \times \exp(aT)$, $N_0 = 3.6$, $a = 0.07$

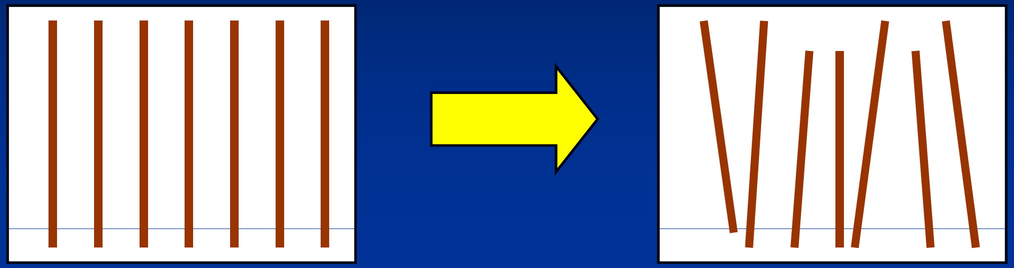
- We obtained the spectra of thermal electrons at any temperature. and obtained the count rates.
- In this measurement, we obtain only thermal electrons

Result from two improvements

- Rugged dynode
- Ultra bi-alkali photo-cathode

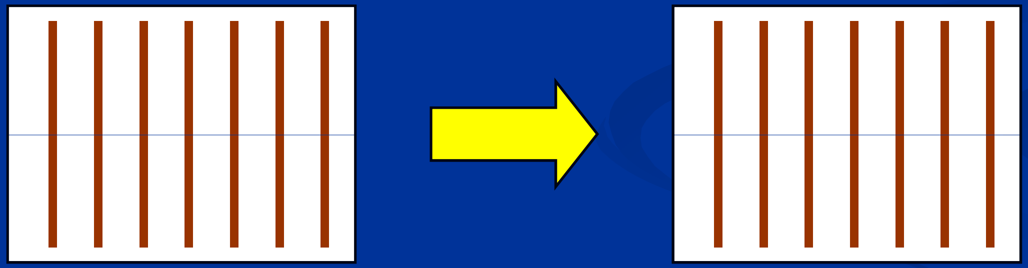
Rugged Dynode

Standard dynode (not rugged)



Dynode is damaged and gain is changed

Rugged dynode

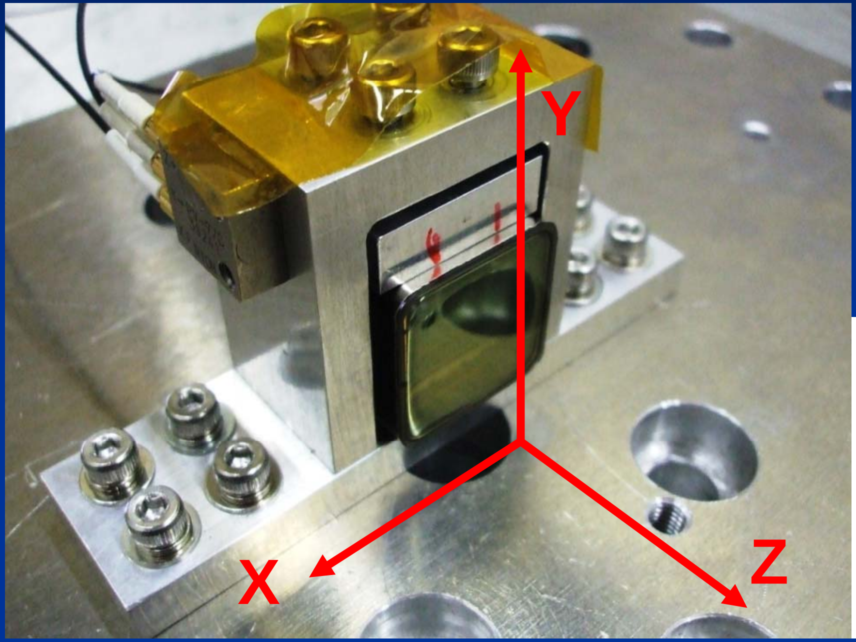


Dynode is not damaged and gain is not changed

- Standard dynode was damaged by the vibration for the launching a rocket
  →Necessity for tolerance to vibration
- We improved tolerance of MAPMT to vibration in possible launching vehicles

Setup for Random Vibration Test

Picture of setup



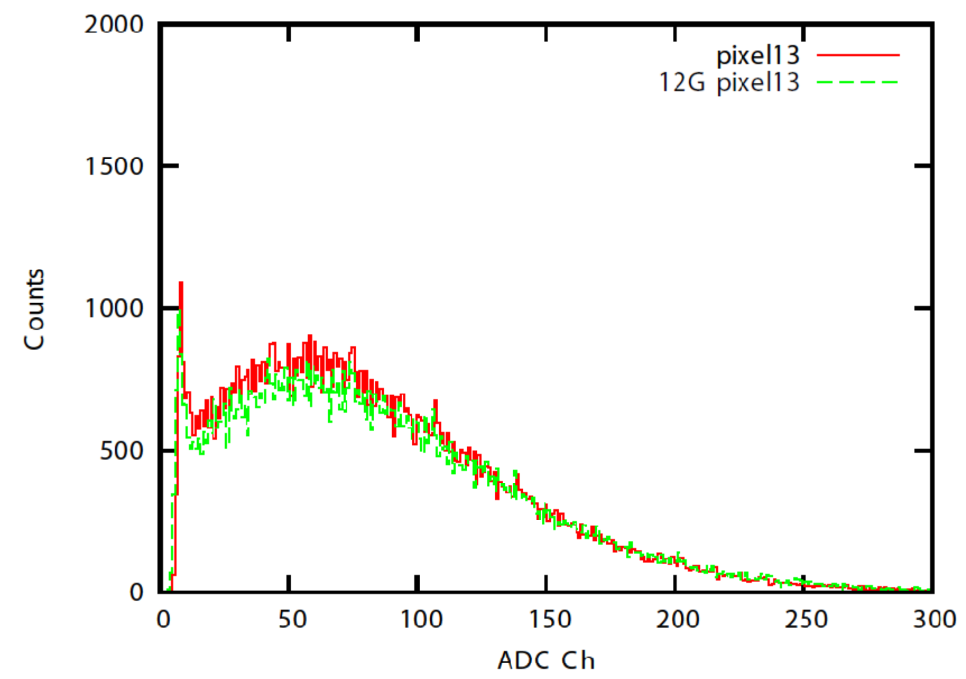
MAPMT was fixed like this photograph.

Vibration profile (HIIA profile)

Frequency range(Hz)	Vibration profile
20 ∼ 200	+3.0 dB/oct
200 ∼ 2000	0.032 G^2/Hz (for 7.8 G_{rms})

- Duration of vibration was 2 min (120 s) / 1 axis.
- Random vibration was given to 3 axes X, Y, and Z.
- We examined the gain of MAPMT by 1 p.e. spectra.
- At first, we tested at 12 G_{rms} (1.5 times HIIA profile)
- The acceleration had been increased from 5 to 17 G_{rms} in increments of 3 G_{rms}

Result for Vibration Test

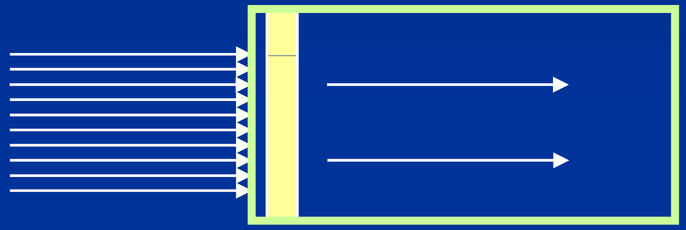


Pixel 13 spectrum before vibration (red) and after 12 G_{rms} (green)

- The result of spectrum before vibration and after 12 G_{rms}
- The signal output was not significant change before vibration and after.
- Vibration level up to 17 G_{rms} (double of expected HIIA profile).
- After vibration at 17 G_{rms}, no significant change in signal output in all pixels.

Ultra Bi-alkali Photo-cathode

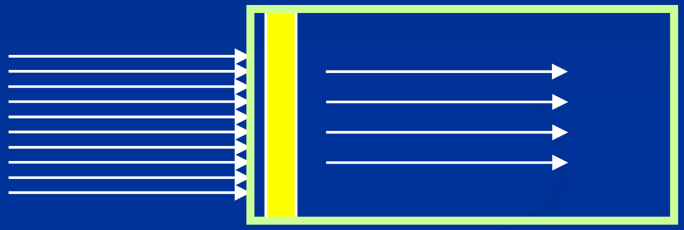
Bi-alkali photo-cathode



100 photons 20 photoelectrons

Q.E. ~ 20 %

Ultra bi-alkali photo-cathode

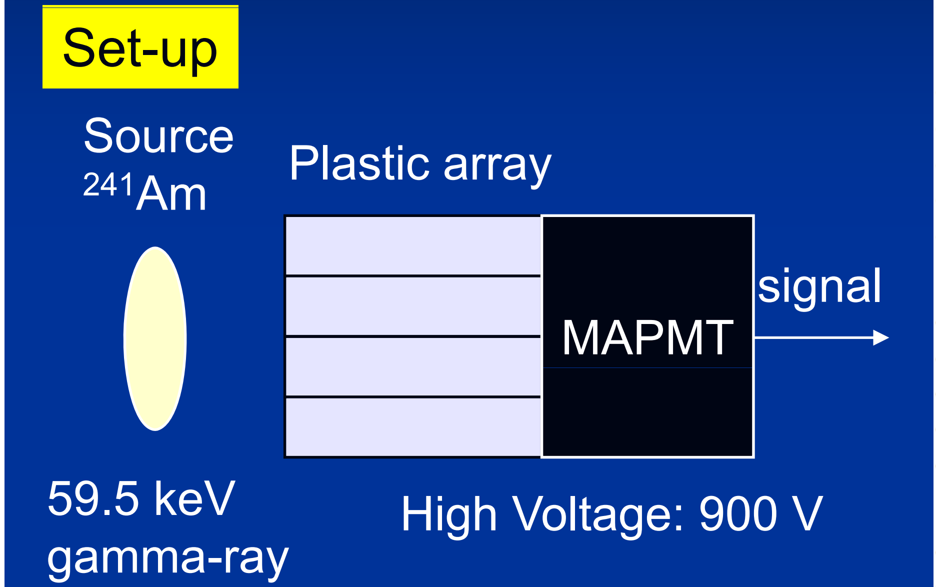


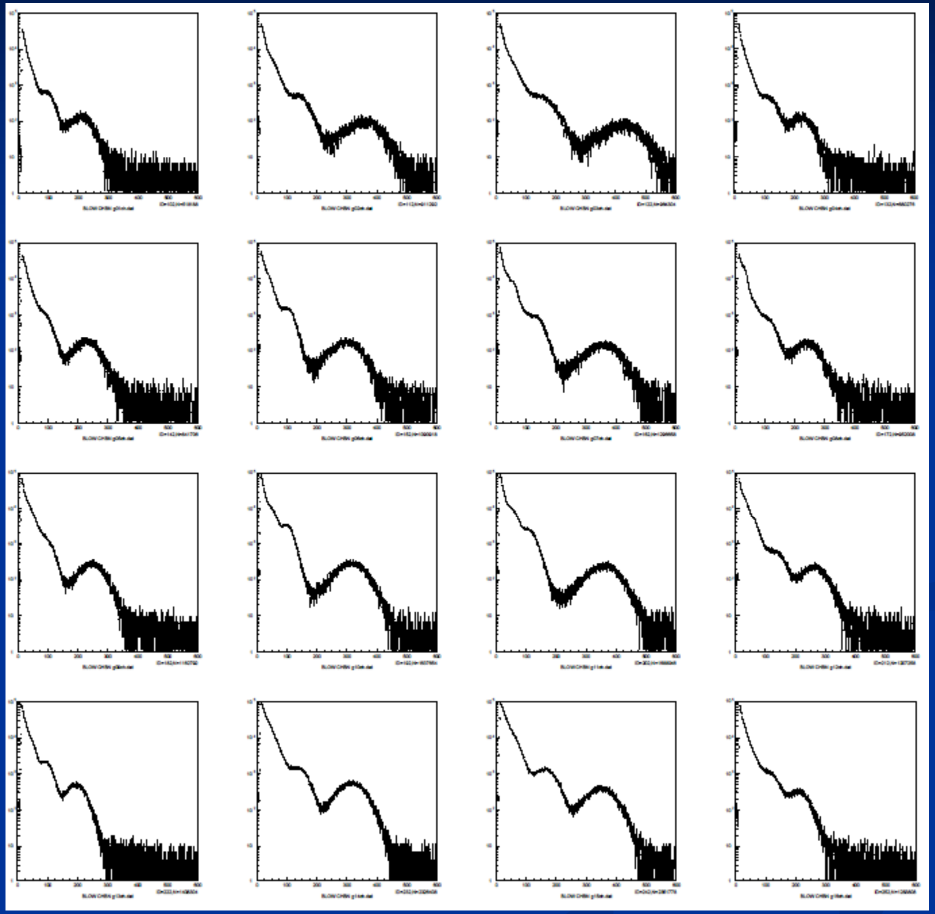
100 photons 40 photoelectrons

Q.E. > 40 %
(double of Bi-alkali)

Ultra bi-alkali has more than 40 % of Q.E and it is double of bi-alkali
It means that sensitivity is doubled.
UBA has been made by Hamamatsu Photonics K.K. in last year.
UBA proto-type of R8900 series is improved Feb. 2008.

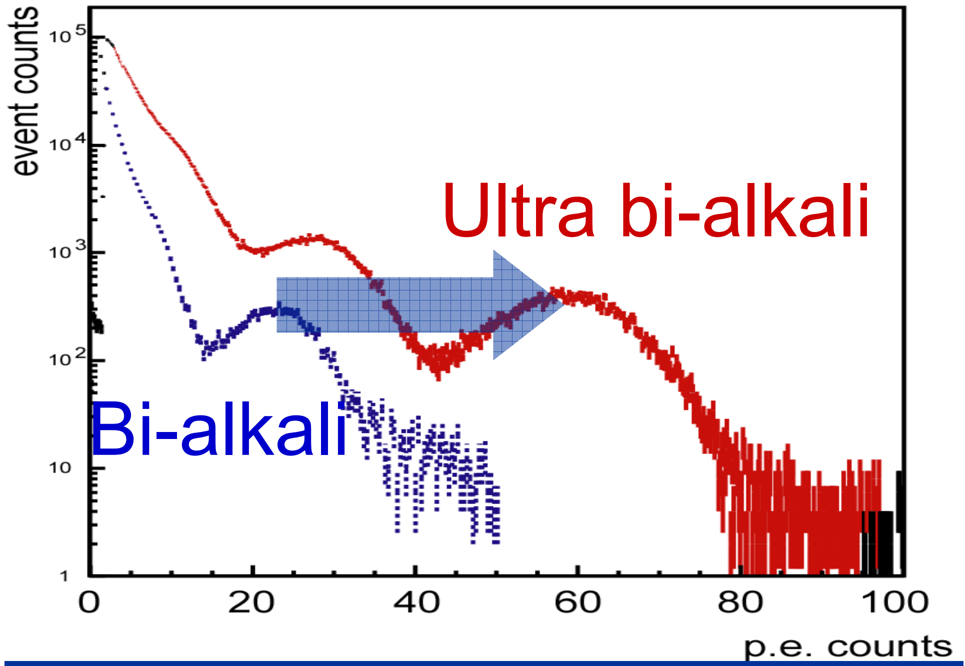
Gamma-ray Spectra with Plastic Scintillator





- UBA-type MAPMT can resolve a photoelectric peak for all pixels thanks to high Q.E which had been greatly improved.
(standard BA-type , the 59.5 keV peak is irresolvable in some pixels)

Energy Resolution at 60 keV

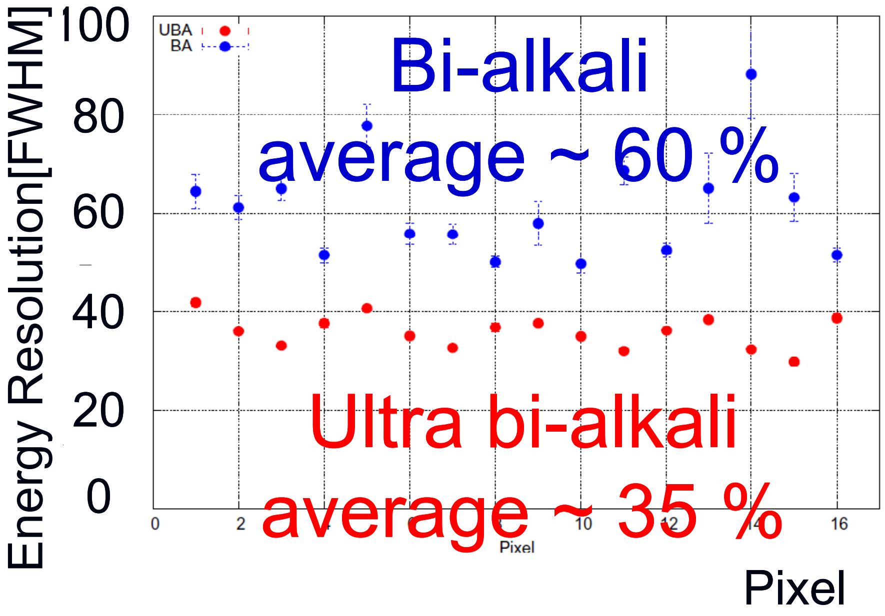


Compared **the ultra bi-alkali** with **the bi-alkali** in the same condition.

Ultra bi-alkali has **60 photoelectron** more than twice as bi-alkali (**~25 photoelectron**)

- Comparing energy resolution at 60 keV photoelectric peak

  UBA-type has better resolution than BA-type in all pixels.
- The best resolution at 60 keV
  - 49.8 % (FWHM) by using BA
  - 29.9 % (FWHM) by using UBA



Conclusions

- We have improved a new type of MAPMT featuring UBA photo-cathode and rugged dynodes
- We evaluated basic MAPMT performance by using the single photoelectron signals
- Improved MAPMT withstood the 17 Grms vibration
- Thanks to high Q.E (> 40 %), good energy resolution of 29.9 % (FWHM) was obtained for 60 keV gamma-rays.