

Dynode readout and UV laser calibration of photomultiplier tubes for ALPACA experiment

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Abstract

The ALPACA experiment aims to pioneer high-energy gamma-ray astronomy in the southern sky. Using the dynode readout, we extended the dynamic range of 2-inch PMT which will be used at the scintillation detectors of ALPACA experiment.

1. Introduction

1) What is ALPACA experiment?

High-energy gamma-ray astronomy in the Southern Sky

- The project of the ALPACA experiment aims to search the origins of cosmic rays with Knee energy. → PeVatron (SNRs?)
- We will observe several hundred TeV gamma-rays produced by PeV cosmic rays.

Air shower array

- The observation site is Mt Chacaltaya, Bolivia, at an altitude of about 4,740 m.
- 404 scintillation detectors are installed over an area of about 83,000 m².
- 2-inch photomultiplier tubes are installed at each detector.

2) What is the PMT dynamic range?

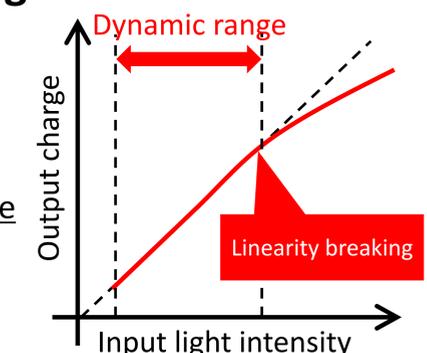
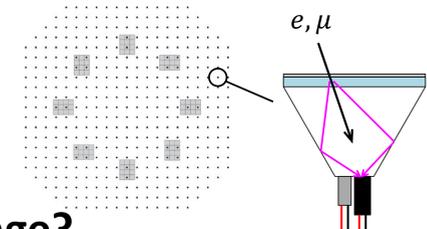
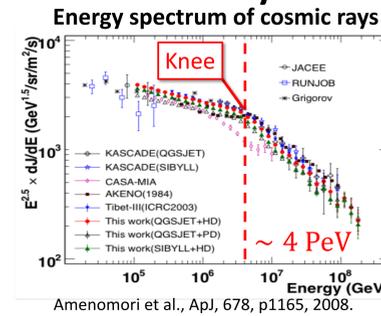
Linearity of output to input breaking

As the intensity of the incident light increases, the charge of the output signal is no longer proportional to the intensity.
→ Range of linearity preserved: Dynamic range

Cause of the linearity breaking

- Space charge effect
- Lack of current at the voltage divider

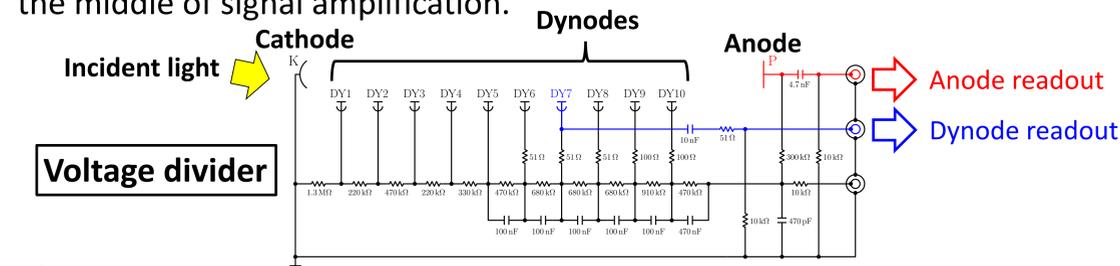
Wide dynamic range of 2-inch PMT is important!



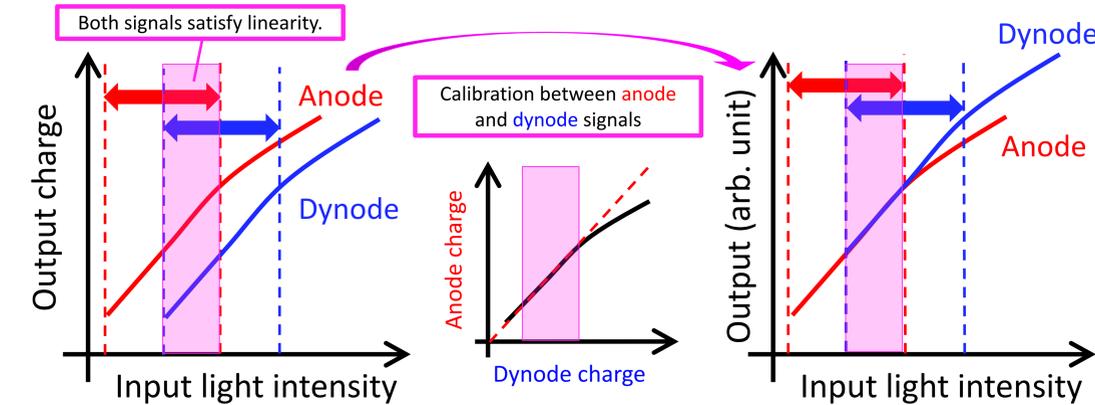
2. Extending the dynamic range of 2-inch PMT

1) Dynode readout

Before the linearity is broken, the signal is read out from the dynode in the middle of signal amplification.

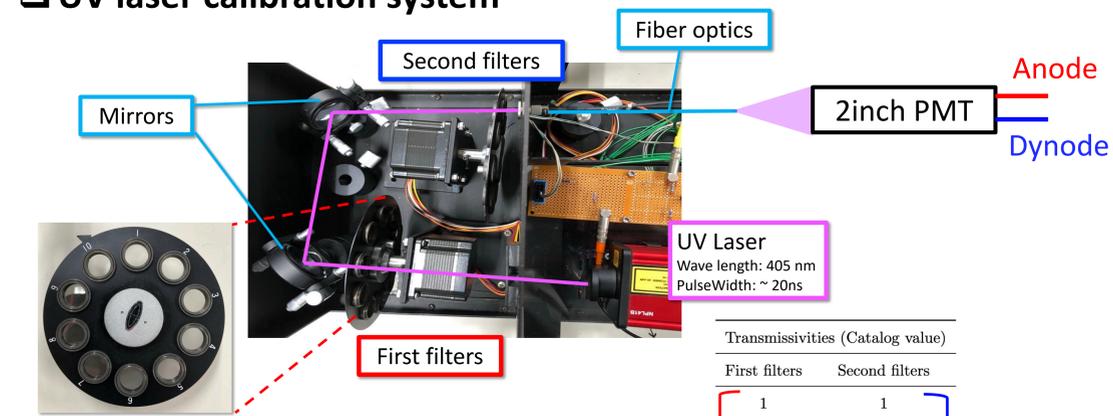


2) Calibration between anode and dynode signals



3. Measurement of dynamic range

UV laser calibration system



✓ By changing the filter by rotating the stepping motor, 8×10 = 80 different laser intensities can be achieved.

8 patterns }
10 patterns }

4. Results of extending the dynamic range

- R7724 (2inch PMT of Hamamatsu, 10-stage dynode) was used.
- Dynode readout was performed from the seventh dynode.

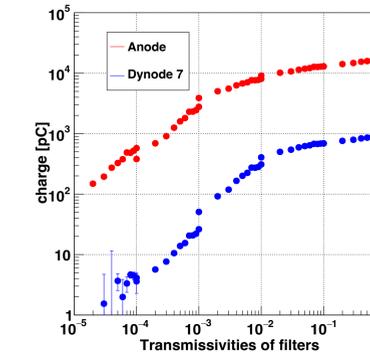


Fig. 1: Linearity of anode and dynode signals. The horizontal axis is the product of the filter transmissivities and the vertical axis is the signal charge.

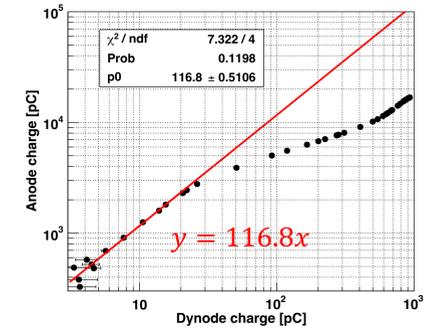


Fig. 2: Correlation between anode and dynode signals fitted by $y = ax$ in the range of 5 to 20 pC.

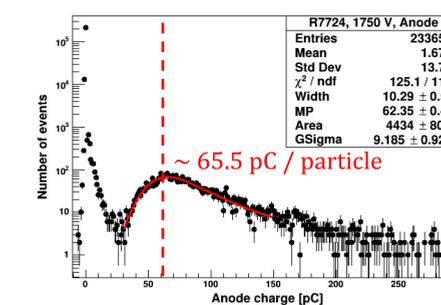


Fig. 3: Anode charge distribution measured with a scintillation detector. The peak value, ~ 65.5 pC, was defined as the charge of "one particle".

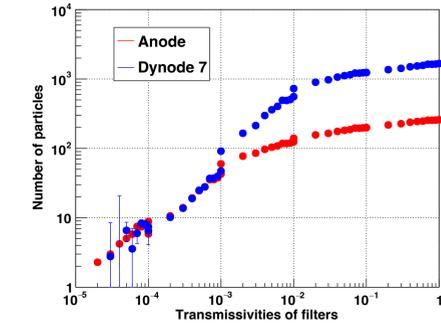


Fig. 4: Linearity of anode and dynode signals. The vertical axis was changed from charge to the number of particles by 65.5 pC / particle.

Points of these results

- Figure 1 shows the step changes in each linearity. It seems to be due to systematic errors in filter transmissivities.
- Figure 4 shows that the dynamic range was extended compared to the case of anode signal only.

5. Summary and Prospects

Summary

Using a signal from the seventh dynode, the dynamic range of the 2-inch PMT was extended compared to the anode signal only. However, the errors of filter transmissivities for the measurement system were identified.

Prospects

- Measurement of filter transmissivities for UV laser (405nm)
- Extending the dynamic range to a target value of 1,000 particles
 - Readout from more previous dynodes
 - Improvement of the voltage divider (Resistance ratio, capacitor, etc.)