Development of an atmospheric Cherenkov imaging Camera for the CANGAROO-III experiment

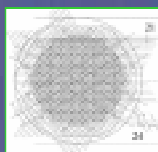
S.Kabuki, K.Tsuchiya, K.Okumura, R.Enomoto, T.Uchida, H.Tsunoo,
Shin.Hayashi, Sei.Hayashi, F.Kajino, A.Maeshiro, I.Tada, C.Itoh,
and CANGAROO collaboration

S.Kabuki

The CANGAROO-III Cherenkov imaging camera consists of 427 pixels, arranged in a hexagonal shape at 0.17 intervals. Each pixel is a 3/4-inch diameter photomultiplier module with a Winston-cone-shaped light guide. The camera was designed to have a large dynamic range of signal linearity, a wider field of view, and an improvement in photon collection efficiency compared with the CANGAROO-II camera.

Camera design

- Aluminum alloy
- Weight 110kg
- Diameter 800mm
- Length 1000mm
- 427 pixels
- Field of view 4°
  0.168°/pixel
- Hexagonal arrangement

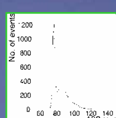


¾ inch PMT module

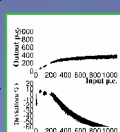
- PMT module design
  Each module consists of a PMT(R3479, HPKK) and Preamps(MAX4107). It is a cylindrical with a diameter of 20.5mm, length of 173.5mm, and weight of 75g.

PMT module performance

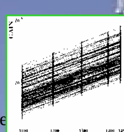
- 1-p.e. histogram
  The typical distribution of a single photoelectron peak is shown. The peak due to a single photon signal can be clearly separated from the background.



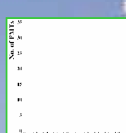
- Linearity from 1 to 1000-p.e.
  The linearity of all the PMT modules for gain (include amplification) $1.2*10^7$ is shown. The average saturation point is
  $202.1 \pm 12.7 (1\sigma)$ p.e..
  The deviation from linear line at 250-p.e. of input light was estimated to be
  $-5.1 \pm 2.0 (1\sigma)$ %.



- High-Voltage dependence of gain
  The gain was measured at HVs of 1100, 1200, 1300, 1400, and 1450 V, and fitted to the following formula,
  Gain=(Voltage)^α
  The parameter α is gain sensitivity for the high voltage, and the average value is
  $4.5 \pm 0.1 (1\sigma)$.



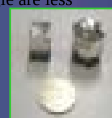
- Time resolution
  The timing resolution at 20-p.e. of input light for all PMT modules was
  $0.96 \pm 0.09 (1\sigma)$ nsec.



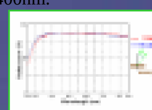
- Quantum efficiency
  The Quantum efficiencies were measured for 10 of the 450PMTs as function of the wavelength.
  The average of the quantum efficiency was estimated to be 25.0±1.4%
  at 400nm.

Light-guide

- Light-guide design
  Light-guide is designed to have a Winston cone shape in order to collect all photons whose incident angle are less than a certain angle.
  Left : First telescope
  Right : New light-guide

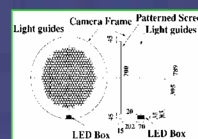


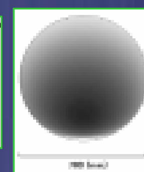
- Light-guide reflectance
  Aluminum vapor was deposited on the inner surface of the light-guide.
  The reflectance of this surface was about 80% at 300~400nm.



Camera LED system

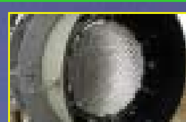
- The gain monitor of the whole camera system
  A new compact monitor system was developed for the camera vessel, consisting of an LED and a specially patterned screen to diffuse the light uniformity to every pixel.



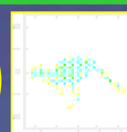


- Light intensity at surface
  The average deviation from uniformly was measured to be 2.6%.

Camera view



Camera front view

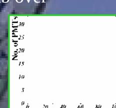


Kangaroo image

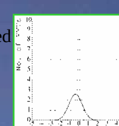
Performance of whole camera system

- Uniformity of gain
  The uniformity of gain is measured with the diffused LED light source located 8m away.

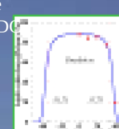
  The Average ADC/Skb over all PMT modules was
  $44.8 \pm 4.8 (1\sigma)$,
  a deviation of 11%



- Cross-talk
  The cross-talk effect among the neighboring 47 pixels was investigated by illuminating one PMT module located at the center of the camera (at 100-p.e. level).
  Cross-talk is less than 0.4%.

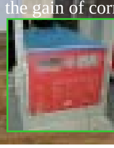


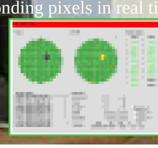
- Incident angle dependence of the photon acceptance
  The efficiency of the light acceptance was defined from the difference of ADC counts measured with and without light-guides after a correction for the difference of the front/back areas of the light guides.



High-Voltage supply

- High-voltage supply system
  A multi-channel and individually controllable system is required in order to obtain a uniform pixel gain. The HV system(CAEN SY 527) controlled up to 10 modules of CAEN A932 AP, each of which contains 24 channels.
- Fast Caenet control
  This system can be programmably controlled via the VME module(CAEN V288).
- HV GUI
  The monitor program calculates the position of a bright stars and controls the gain of corresponding pixels in real time.





Conclusion

The performance of the Cherenkov imaging camera for the second CANGAROO-III telescope was improved over that of the CANGAROO-II telescope with respect to the uniformity of gain, timing resolution and the light-collection efficiency.

The 427 PMTs have been carefully calibrated and the results stored in a database so that the camera performance can be optimized.

This camera performance is suitable for observations with the next generation. of gamma-rays telescopes.