GLAST Internal Note
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Readout for the Anticoincidence Detector (ACD)

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Summary

The baseline GLAST Anticoincidence Detector (ACD) uses plastic scintillators with waveshifting fibers and photomultiplier tube readout. We have examined alternative readout methods, including PIN photodiodes, avalanche photodiodes (APDs), hybrid photodiode tubes (HPDs), miniature phototubes, and multianode phototubes. At the present time, none of these appears to offer a simple substitute for traditional phototubes in this application. Development efforts, if funded, might change this conclusion.

1. Introduction

Because GLAST will operate in a space environment where charged particle cosmic rays are several orders of magnitude more numerous than the gamma rays of interest, discrimination between ionizing particles and neutrals must be carried out with very high efficiency. As the outermost active detector in GLAST, the ACD is one key element of the discrimination process. The critical requirement on the ACD is that it detect impinging cosmic rays with high (~99.9%) efficiency.

All previous gamma-ray telescopes have used plastic scintillators with photomultiplier tube readout as anticoincidence detectors. Plastic scintillator has the required high intrinsic detection efficiency for charged particles, and phototubes are reliable, high-gain detectors of the scintillation light.

GLAST will be built with constrained power, mass, and funding; therefore, alternative detector elements should be considered at each step. “We have always done it that way” is not a good enough reason for using a particular approach. In particular, this note is a first look at possible alternatives to traditional phototubes. We approach the ACD development with two questions in mind:

1. What do we gain by changing the design?
2. What does the change cost?

2. Baseline Detector – Photomultiplier Tubes

Examples from Hamamatsu: R647 – 13 mm diameter tube used in HEXTE, but a space-qualified version is not currently available; R5611-01 – 19 mm tube is available in ruggedized version (larger than needed for GLAST ACD); R1635 – 10 mm tube is available in space-qualified version.

Benefits

- High gain (10^6) gives high signal to noise with simple electronics
- Proven technology, with space-qualified units available off-the-shelf
- Performance demonstrated at 1997 SLAC beam test

Limitations

- Relatively large (~15 cm)
- Relatively high power (~65 mW/unit, with ~160 units required)
- Requires high voltage

Evaluation – will work with minimal development

3. PIN Photodiodes

Examples: S3590-03 – 1 cm^2; S3204-03 – 1.8 x 1.8 cm^2
These were tested by NRL group, with preliminary report in Feb. 10-11 GLAST meeting documents (Grove et al. 1998). PIN photodiodes are planned for use with the CsI calorimeter.

Benefits

- Small, rugged detectors could be mounted directly to scintillators
- Low power (< 50 mW)
- No high voltage

Limitations

- Spectral mis-match with conventional scintillators; little experience with red scintillators like BC-430
- Would require high-gain electronics, possibly ASIC development, which is relatively expensive
- Preamplifier noise is typically comparable to signal from a minimum ionizing particle (MIP), see report by Grove et al.; therefore achieving high efficiency would be very difficult

Evaluation – extensive development effort would be required, with no guarantee of success due to signal/noise problem.

4. Avalanche Photodiodes

Because avalance photodiodes (APDs) are solid-state equivalents of photomultiplier tubes, they are a potential substitute. Examples: Hamamatsu S5344 SPL5402, tested for luminosity monitor using wavelength shifting fibers for ALEPH (Bartolomé et al. 1997) and with direct coupling to scintillator by Holl et al. (1995); Advanced Photonix 197-70-72-520, tested with scintillating fibers by Okumura et al (1997).

Benefits

- Compact; might be attached directly to scintillators
- High quantum efficiency (> 60%)
- Better signal to noise than PIN photodiodes

Limitations

- Requires high voltage, though not necessarily as high as phototubes
- Spectral mis-match with conventional scintillators
- High efficiency for MIP detection has not yet been demonstrated
- Gain typically 100 compared to 10^6 for phototubes; higher-gain electronics required
- Gain is a strong function of temperature

Evaluation – we contacted Ekart Lorenz at MPI, who has worked with APDs on scintillator. He is optimistic that APDs could be developed for use with the GLAST ACD, but he acknowledged that the high efficiency needed for anticoincidence has not yet been demonstrated. Stan Hunter at Goddard has also tested APDs on scintillator with promising results, but he agrees that further development is needed. APDs are potentially useful if someone wants to fund a development effort.

5. Hybrid Photo Diode Tubes

HPDs are also known as hybrid phototubes. The principal commercial source is Delft Electronic Products. HPDs were developed at CERN (Anzivino, et al. 1995).

Benefits

- Low power (no voltage divider)
- Very stable

Limitations

- Very high voltage (10-15 kV)
- Gain of 1000-5000 would require higher-gain electronics than traditional PMTs

Evaluation

<u>Space qualification unknown. Available sizes unknown. Further investigation seems worthwhile. HPDs would certainly involve some development and testing.</u>

6. Miniature Phototubes and Multi-anode Phototubes

Examples from Hamamatsu: R5600 series miniature tubes (TO-8); R5900 series small and multi-anode tubes (1.8 cm x 1.8 cm effective area; total size 3 cm x 3 cm x 2.2 cm; available as single, 4, 16, and 64 channel models).

Benefits

- Same high gain as conventional photomultiplier tubes
- Compact, though not as small as photodiodes
- Multi-anode models could save power

Limitations

- We contacted Hamamatsu about space-qualified versions of these units. The representative we spoke to said that all these tubes were susceptible to vibration. He was very pessimistic about the possibility of space-qualifying these tubes due to the close spacing of the detector elements. Nevertheless, AMS is using the 5600 and 5900 (single-anode) series tubes. LSU tested the 5600 under vibration at Shuttle levels and Hamamatsu tested the 5900 to a lower level (Joachim Isbert, private communication).

<u>Evaluation – the requirement to space qualify these phototubes appears to require a development effort, with no guarantee of success for the GLAST launch conditions.</u>

7. Conclusion

As nice as it would be to have a more-compact, lower-power, higher-gain, space-qualified sensor to read out plastic scintillator, the best approximation still appears to be the traditional photomultiplier tube. A first look indicates that PIN photodiodes have a signal to noise limitation, avalance photodiodes have not demonstrated the needed efficiency, hybrid photo diode tubes involve very high voltages, and miniature and multi-anode phototubes require testing and/or modification to meet the requirements of launch survivability. Avalanche photodiodes or hybrid photo diode tubes appear to be the most promising alternative, but significant development effort would be required. More information may be available or forthcoming in the near future to change this conclusion. We encourage the GLAST team to continue to pass along specific information to us.

References

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