# Science Requirements Review
# GLAST Burst Monitor


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# Agenda

1. Introduction
2. Simulations
3. Energy Range (Rqmts 19 & 20)
4. Field of View (Rqmt 21)
5. Energy Resolution (Rqmt 22)
6. On-board burst location accuracy (Rqmt 23)
7. GRB notification time (Rqmt 24)
8. Dead time (Rqmt 25)
9. Timing accuracy (Rqmt 26)
10. Burst Sensitivity (Rqmts 27 & 46)
11. Summary

# GLAST Burst Monitor

"It is a GLAST requirement to have onboard low-energy and medium-energy measurements by the secondary GBM instrument for gamma-ray bursts. The key objectives of the GBM are to:

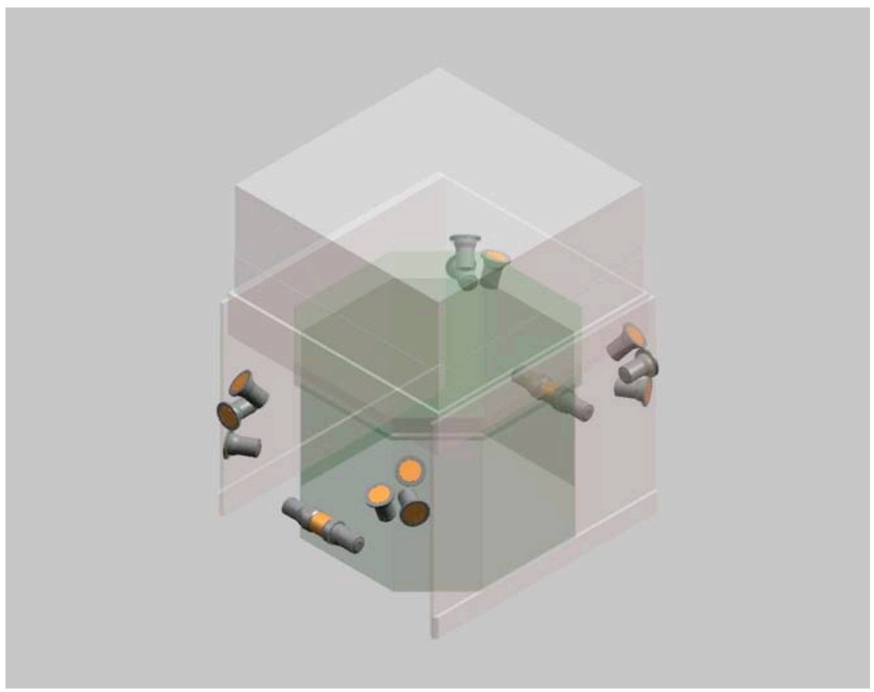
1) provide lower energy and medium energy context measurements of the light curve and spectrum of bursts for comparison with high energy measurements of the LAT;

2) provide positions for bursts over a wide field of view to few-degree accuracy to allow repointing of the spacecraft to position the LAT on the burst source,

3) provide the rapid burst positions to the spacecraft for transmission to the ground for correlated observations by other ground-based and space-based telescopes."

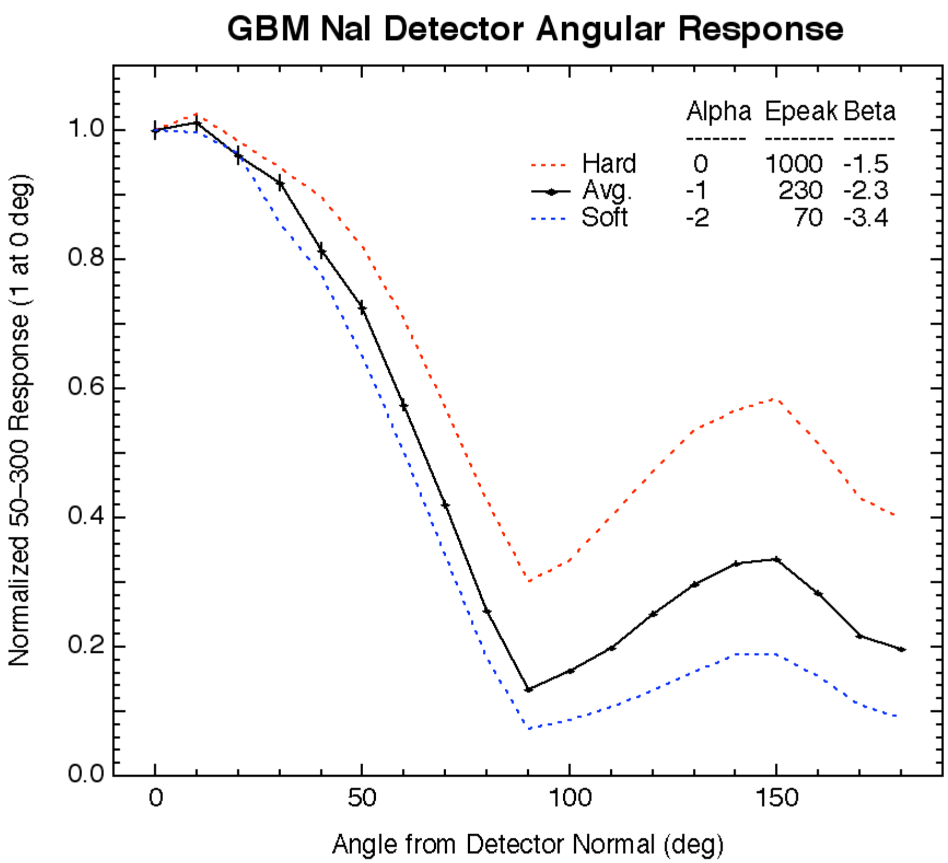
# Simulations - geometry

- Several GBM science requirements verified by simulation
- Simple geometric model of observatory
  - Includes LAT and LAT radiator,
  - Includes partial blocking of detectors
  - Includes partial blockage of NaI 2 & 8 by NaI 1 and 7
  - Does not include solar panels
- Uses measured NaI mounting ring positions and angles



# Simulations – detector response

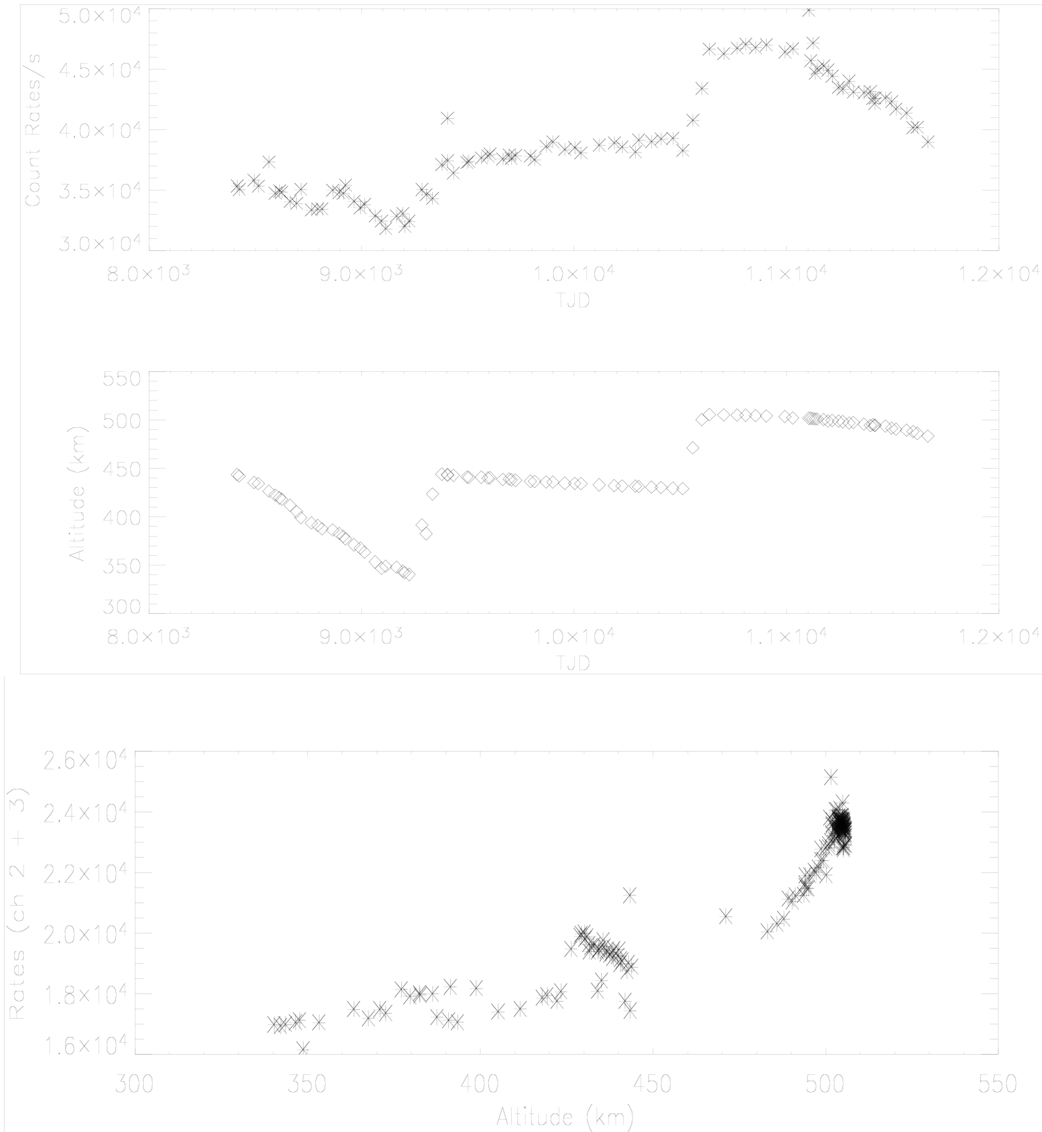
- Uses GEANT code to determine efficiency 50-300 keV
- Three burst spectra: typical, hard, and soft.
- Atmospheric scattering included for location accuracy simulation



# Simulations – background rates

- Background inferred from BATSE data
  - Measurements from 450 km to 500 km
  - Rates $\propto$ altitude$^{1.7}$
  - Variation with orientation ~5% (1$\sigma$)
  - Variation with orbit 10-20% (1$\sigma$, 26° inclination)
  - Extrapolation to 565 km for GLAST
  - GBM Rates: 195 cps @ 450 km; 290cps @ 565 km

# BATSE Rate & Altitude History



# Energy Range Requirement

"GBM shall have an energy range from 10 keV to 25 MeV to cover the classical gamma-ray band where most of the burst photons are emitted."

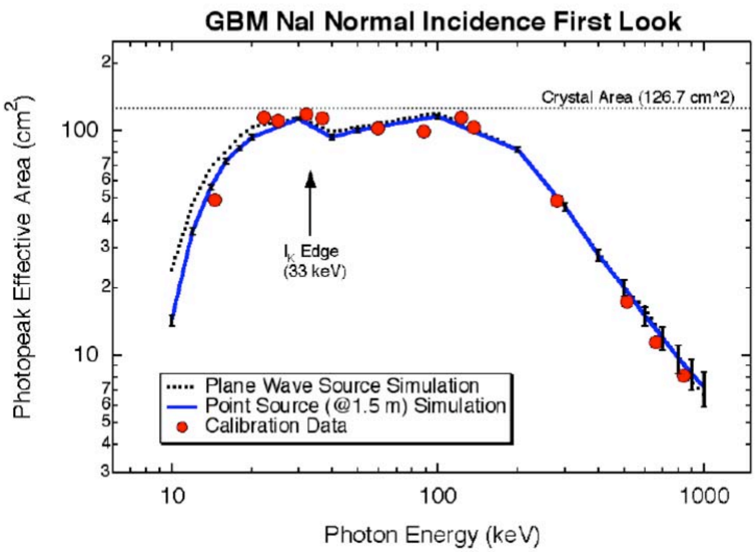
| No. | Quantity | Requirement | Goal | Minimum | Actual Performance |
|---|---|---|---|---|---|
| 19 | Low Energy | < 10 keV | < 5 keV | < 20 keV | ~8 keV |
| 20 | High Energy | > 25MeV | > 30MeV | > 20 MeV | ~30 MeV |

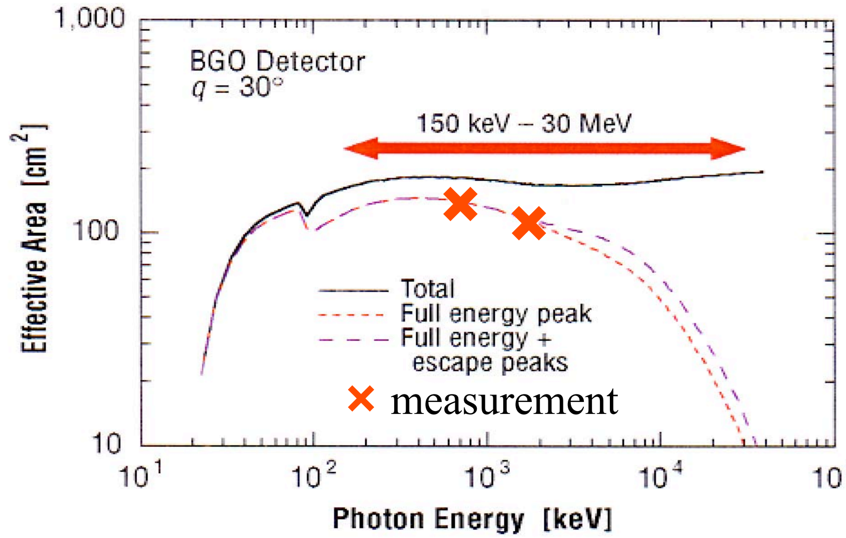
Low energy limit determined by:
- NaI window transmission
- Noise threshold
- ADC range

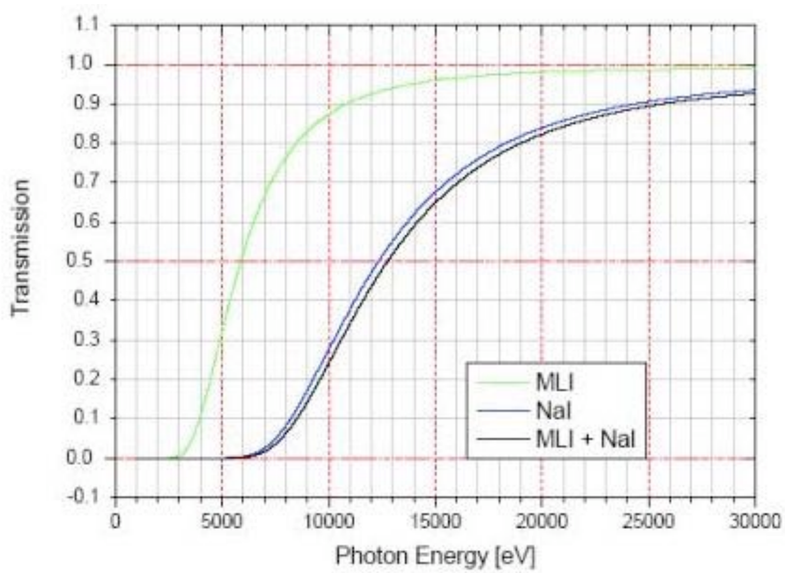
High energy limit determined by
- BGO crystal efficiency
- ADC range

Required dynamic range of ADC is ~100.
DPU testing verified ADC dynamic range of >200.
Calibration sources verified dynamic range >100.

# Detector Efficiency




At 10 keV, NaI effective area is ~20 cm$^2$ .

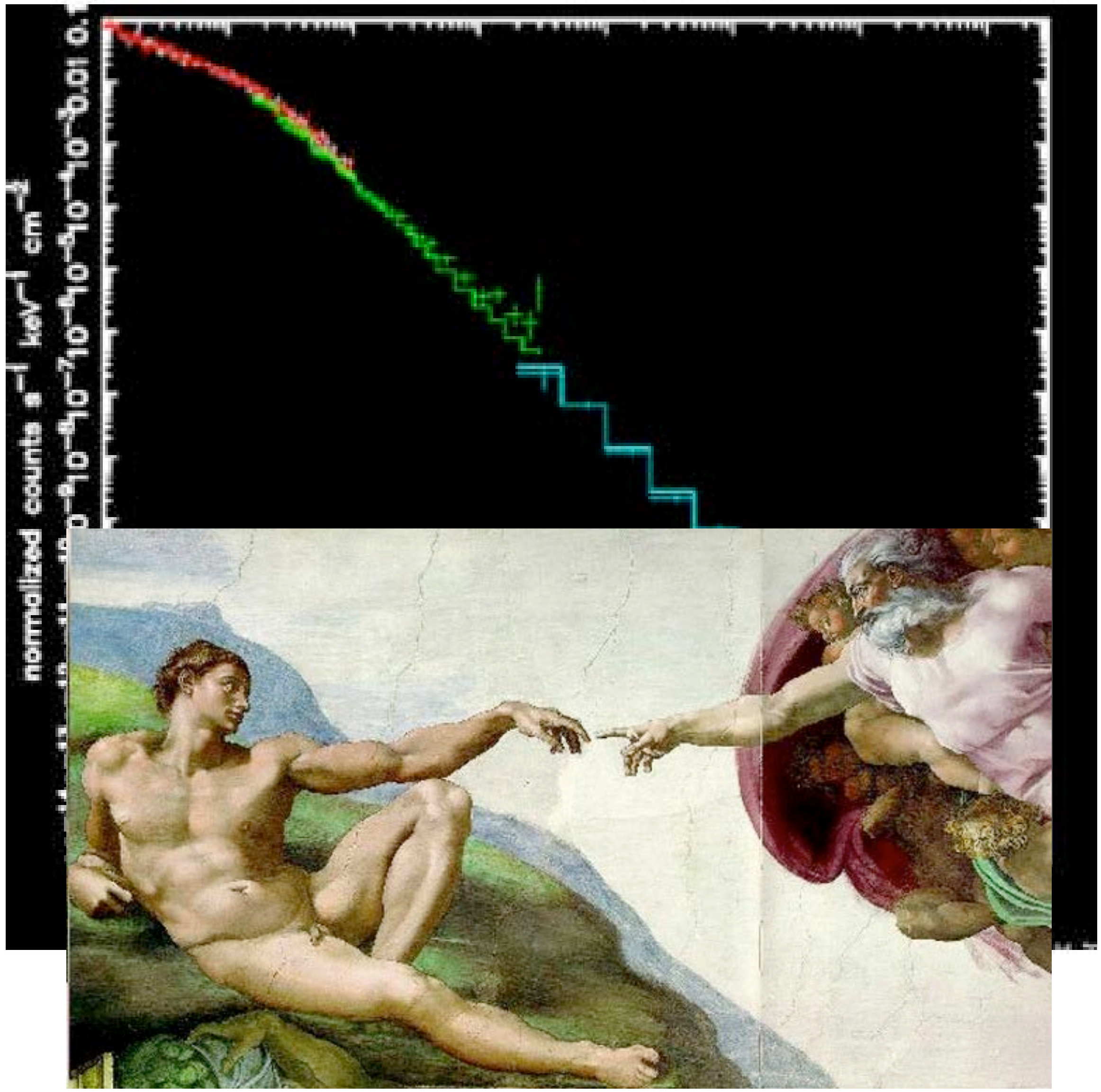
At 25 MeV, BGO effective area is ~13 cm$^2$.

# Noise Threshold

Noise threshold is defined as the lowest channel having a noise rate of <100 cps/keV. Channels are 0.25 keV wide for this test.

| Detector # | Noise Threshold (keV) Main Board | Noise Threshold (keV) Redundant Board |
|---|---|---|
| 1 | 3.8 | <2.5 |
| 2 | 4.2 | 3.5 |
| 3 | 3.2 | 5.2 |
| 4 | 4.2 | <2.5 |
| 5 | 4.0 | <2.5 |
| 6 | 4.2 | <2.5 |
| 7 | <2.5 | <2.5 |
| 8 | 3.8 | <2.5 |
| 9 | <2.5 | 4.2 |
| 10 | 4.0 | 3.2 |
| 11 | 4.8 | 4.2 |
| 12 | 4.2 | <2.5 |

# Simulated LAT/GBM Joint Spectrum



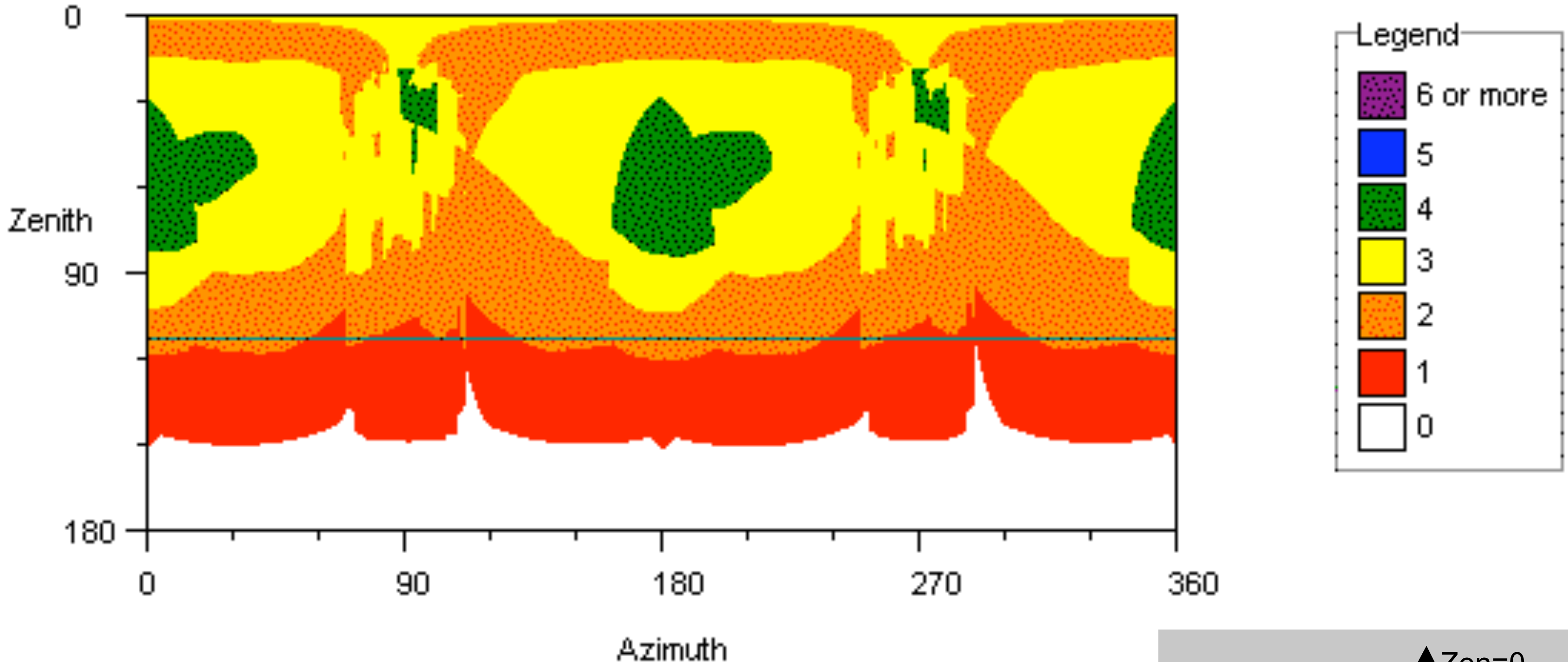
# Field of View Requirement

"GBM shall have a field of view of 8 sr to cover all of the visible sky from low-Earth orbit. The GBM field of view shall overlap that of the LAT."

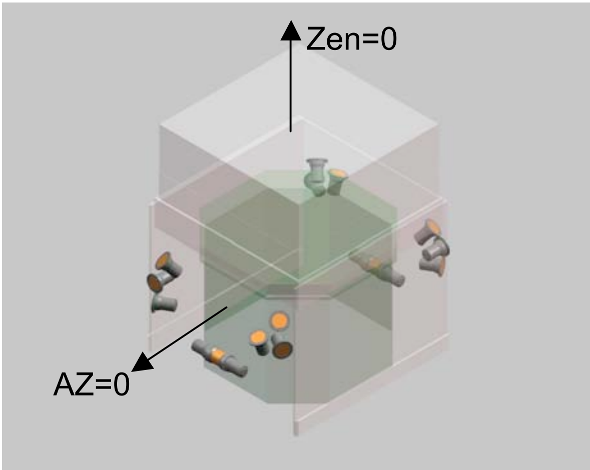
| No. | Quantity | Requirement | Goal | Minimum | Actual |
|---|---|---|---|---|---|
| 21 | Field of View | > 8 sr | > 10 sr | > 6 sr | 9.05 sr |

Field of view is defined as the integral of effective area over solid angle divided by peak effective area. For GBM, the area is the projected visible effective area (50-300 keV) of the NaI detectors.

# NaI Effective Area




Effective area of NaI detectors as a function of spacecraft coordinates, in units of detector area (126.7 cm$^2$).



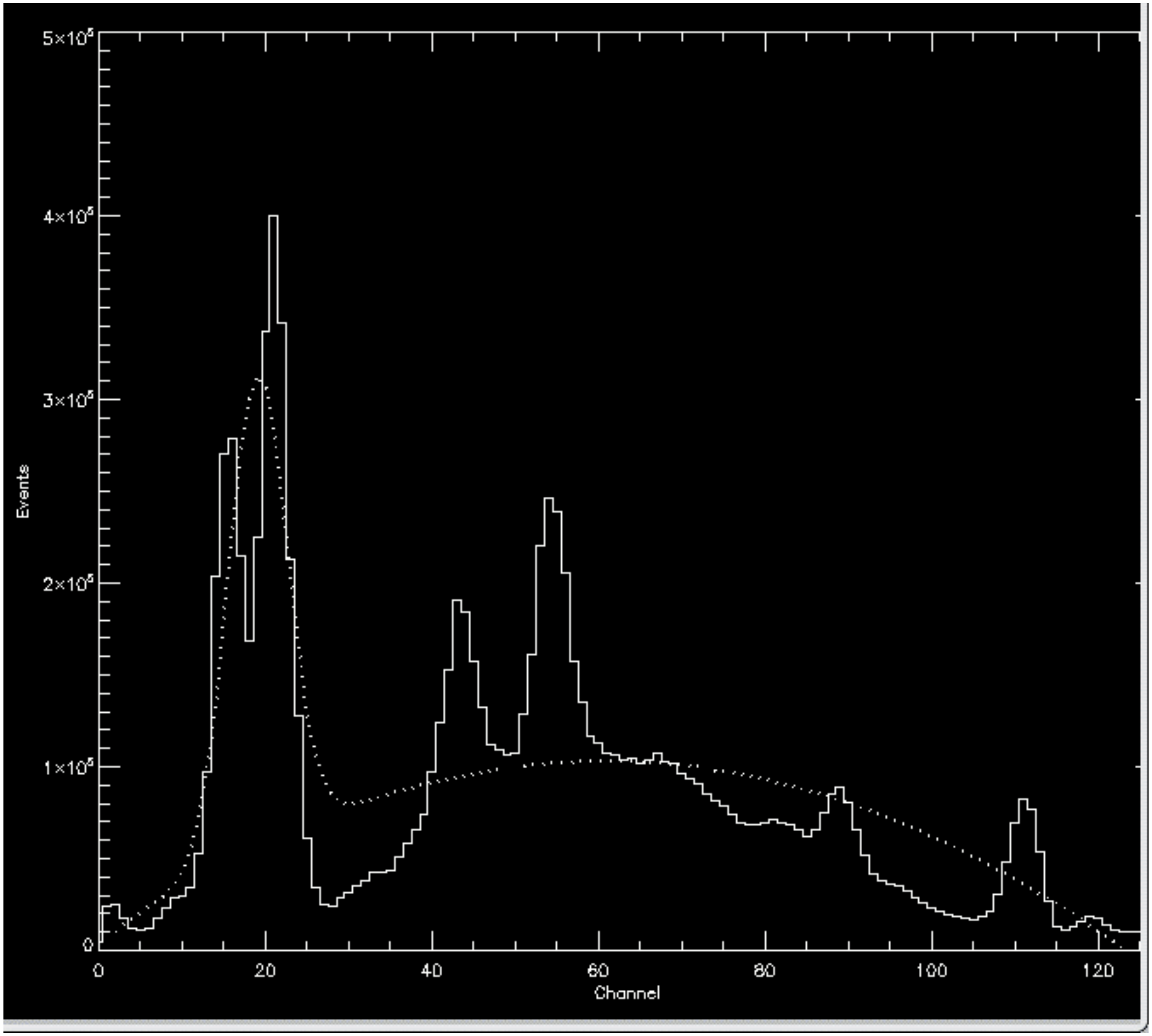
# Energy Resolution Requirement

| No. | Quantity | Requirement | Goal | Minimum | Actual |
|---|---|---|---|---|---|
| 22 | Resolution | < 10% | < 7% | < 12 % | 6.3% – 7.3% |

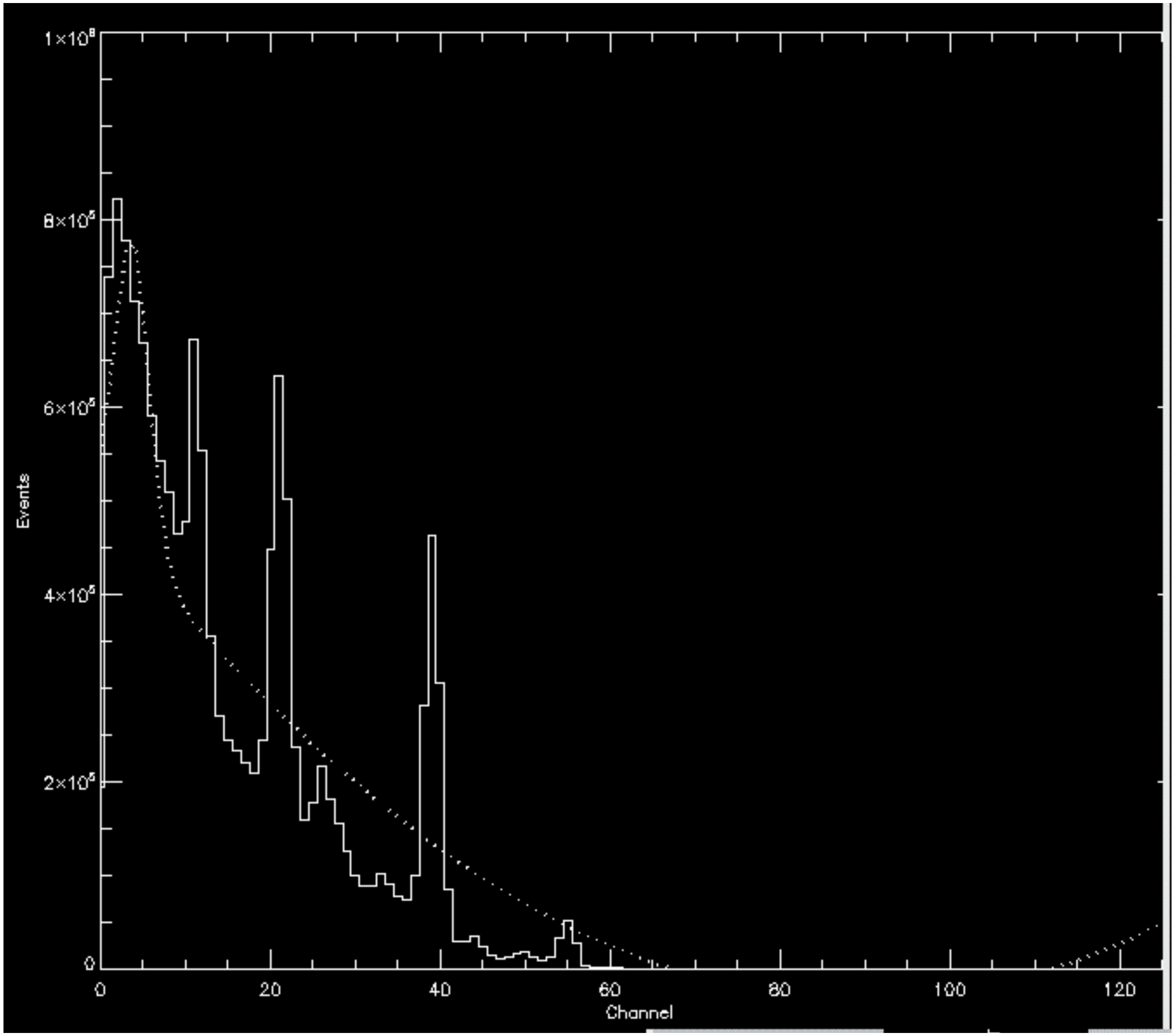
Gaussian equivalent 1 $\sigma$ value; on-axis; energy range of 0.1 – 1.0 MeV.

The worst-case measured resolution at 88 keV is 7.3% (1$\sigma$)

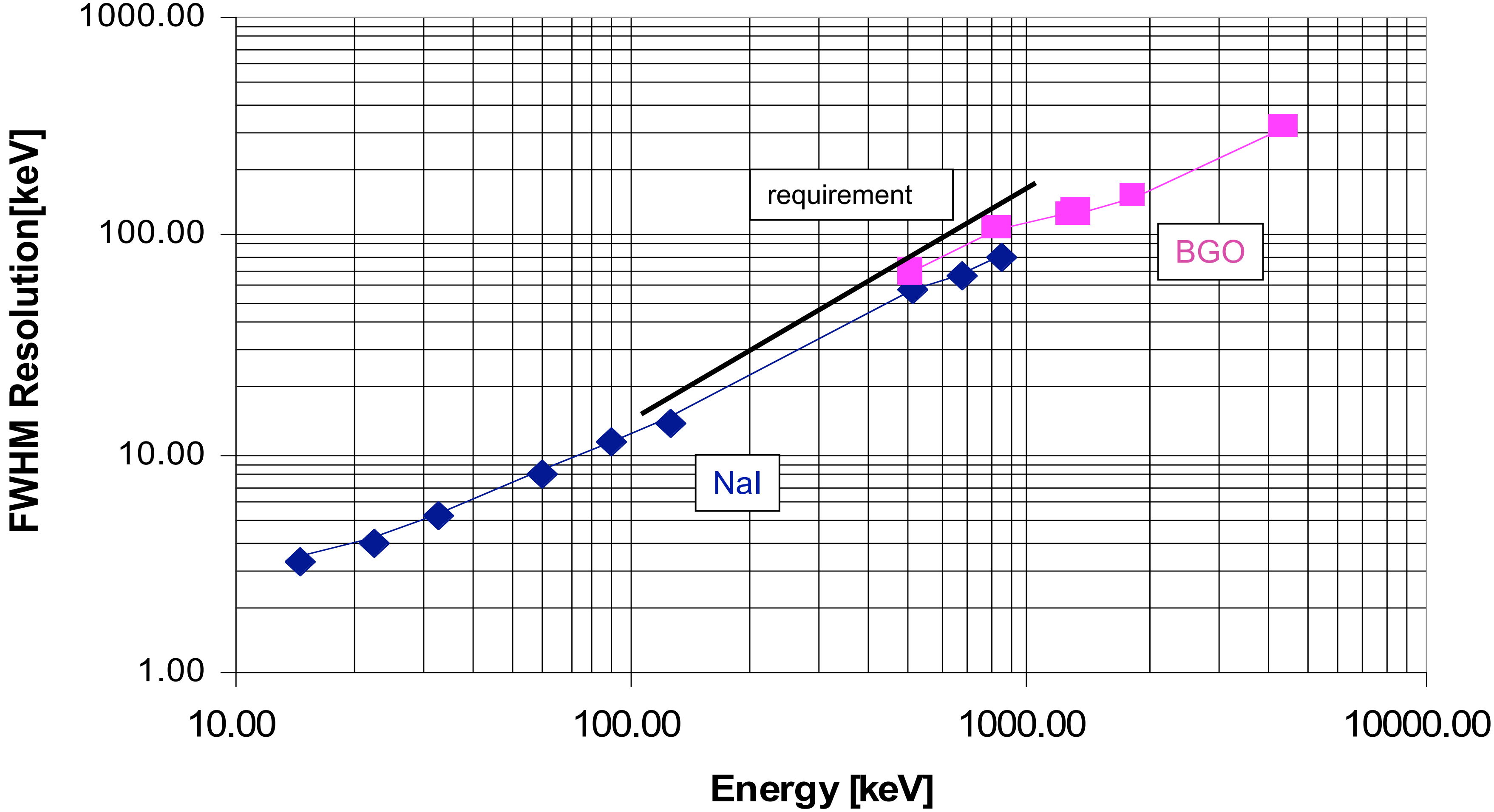
# NaI Detector Spectrum



# BGO Detector Spectrum



# Energy Resolution Measurements



# Gain Stability

- Temperature Effects
  - Worst-case thermal profile over an orbit
  - 0.8% gain dispersion (NaI and BGO)
- HV stability
  - HVPS spec ±1 volt
  - 0.8% gain dispersion
- Magnetic Fields
  - Calibration of NaI EQM to 2 Gauss
  - Worst-case torquer bar variations
  - Gain dispersion of 1.2% for NaI and 0.5% for BGO
- Total dispersion: <2% on orbital timescale
- High Rate Effects (pulse pile-up)
  - Measurements with sources at MSFC
  - ~4% spectral distortions at 100 kcps
- Automatic Gain Control
  - On-board monitoring of 511 keV line
  - Integration times ~1 hr.

# GRB Alerts Requirements

GBM shall have a capability as a goal to rapidly (< 2 seconds) determine burst positions to an accuracy of < 15 degrees ($1\sigma$) for purposes of notifying other observers and repointing the spacecraft to optimize LAT observations.

(Burst is 1 s long with flux of 10 $cm^{-2}s^{-1}$, 50 to 300 keV.)

| No. | Quantity | Requirement | Goal | Minimum | Actual |
|---|---|---|---|---|---|
| 23 | Location | NA | < 15° | NA | < 8° |
| 24 | Time | < 2 s | < 1 s | < 5 s | 1.8 s |

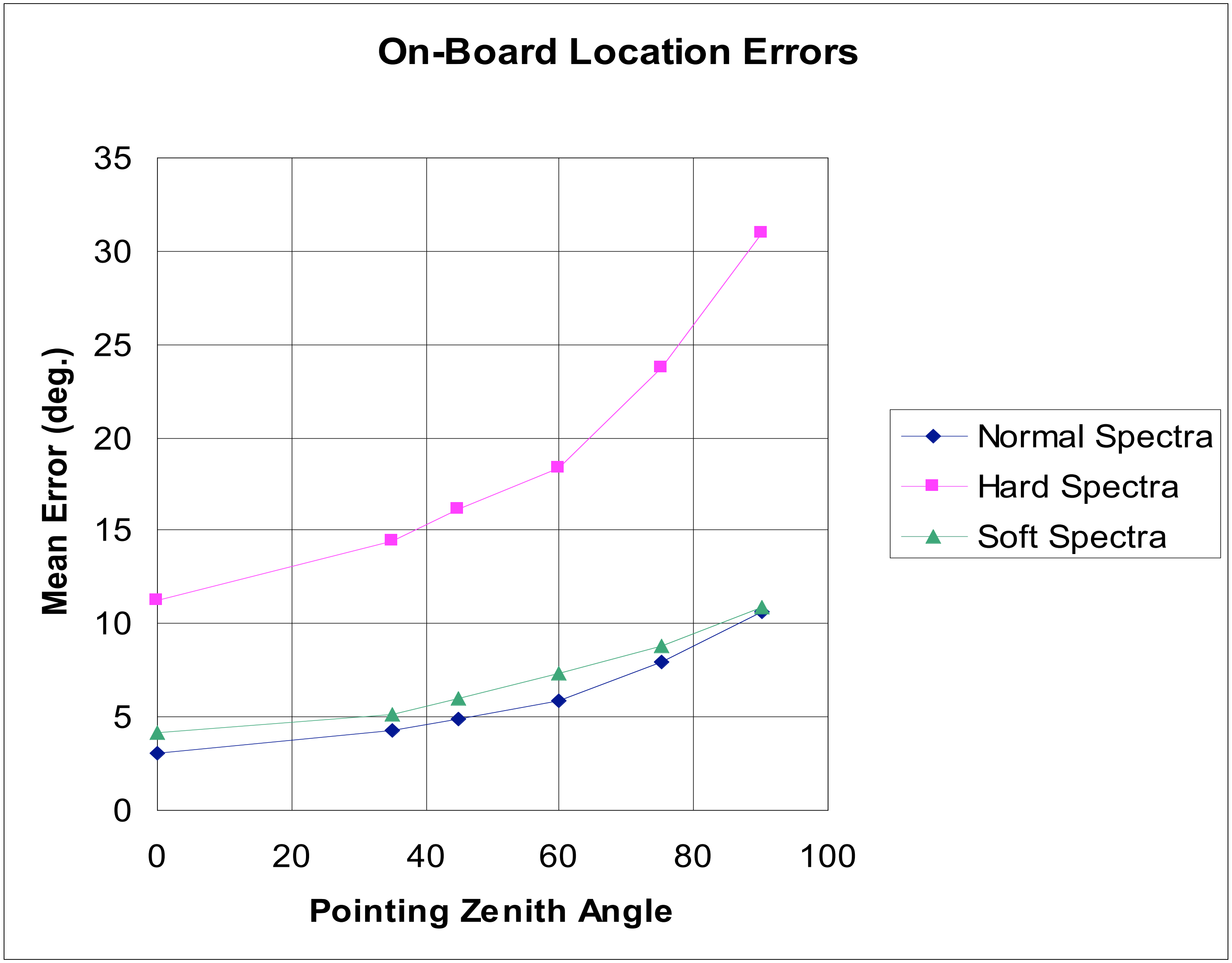
<u>Timing</u>

- Computation time required is 0.3 s
- Integration time is an adjustable parameter
- Longer integration would improve accuracy for weak events

# On-Board GRB Locations

- Algorithm
  - Compare NaI rates to a table of 1634 points on sky
  - $\chi^2$ test with floating normalization
  - Table includes atmospheric & S/C scattering (zenith pointing)
  - Typical burst spectrum assumed
- Errors
  - Grid resolution – 5°
  - Range of actual burst spectra
  - Atmospheric scattering, particularly variation with off-axis pointing
  - Systematic errors in table (DRMs, S/C scattering)

# Simulation Results




$\beta = -2.3$

$\beta = -1.5$

$\beta = -3.4$

# Event Dead Time Requirement

| No. | Quantity | Requirement | Goal | Minimum | Actual |
|---|---|---|---|---|---|
| 25 | Dead Time | < 10 μs | < 3 μs | < 50 μs | 2.6 μs |

On GBM, the deadtime is set by command and is nominally 2.6 μs. This is a tradeoff between energy resolution and high rate performance.

Events in the overflow channel have 10 μs deadtime.

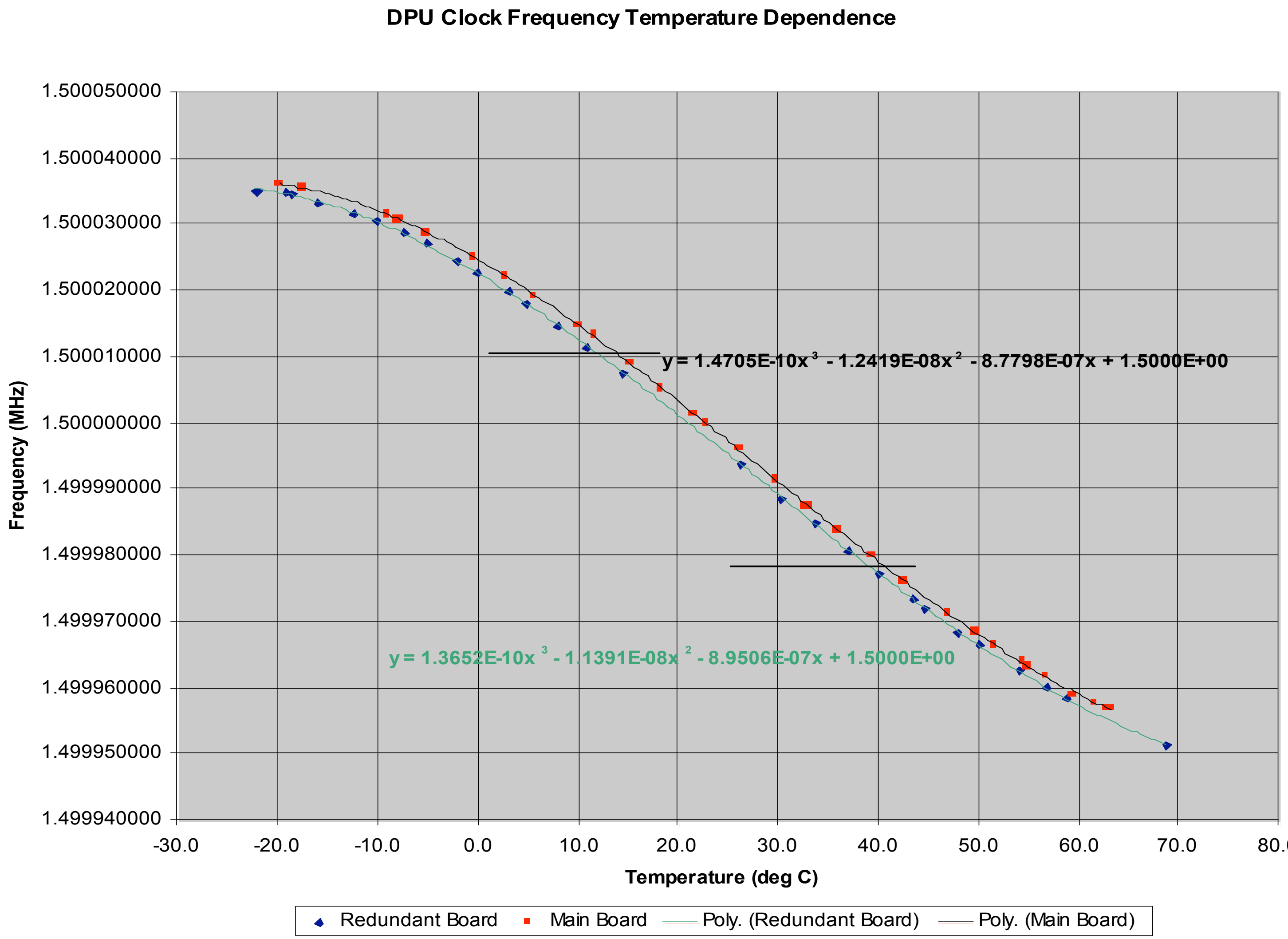
# Absolute Time Accuracy Requirement

GLAST shall have absolute timing knowledge to 10 μsec and absolute position knowledge to 3.3 km to facilitate searches for pulsations from millisecond pulsars and characterization of pulse profiles of detected pulsars.

| No. | Quantity | Requirement | Goal | Minimum | Actual |
|---|---|---|---|---|---|
| 26 | Inst. Time Accuracy | < 10 μs | < 2 μs | < 30 μs | 4 μs (corrected)<br>20 μs (uncorr.) |

Although GBM will not be observing fast pulsars, good timing accuracy is important to compare GRB pulse profiles to LAT observations. The 20 μs accuracy of the uncorrected time tags will usually be adequate. In rare instances, simple corrections can be made to achieve 4 μs accuracy.

# GBM Clock Frequency



# GRB Sensitivity Requirement (Ground)

| No. | Quantity | Requirement | Goal | Minimum | Actual |
|---|---|---|---|---|---|
| 27 | Sensitivity | < 0.5 $cm^{-2}s^{-1}$ | < 0.3 $cm^{-2}s^{-1}$ | < 1.0 $cm^{-2}s^{-1}$ | 0.44 $cm^{-2}s^{-1}$ |

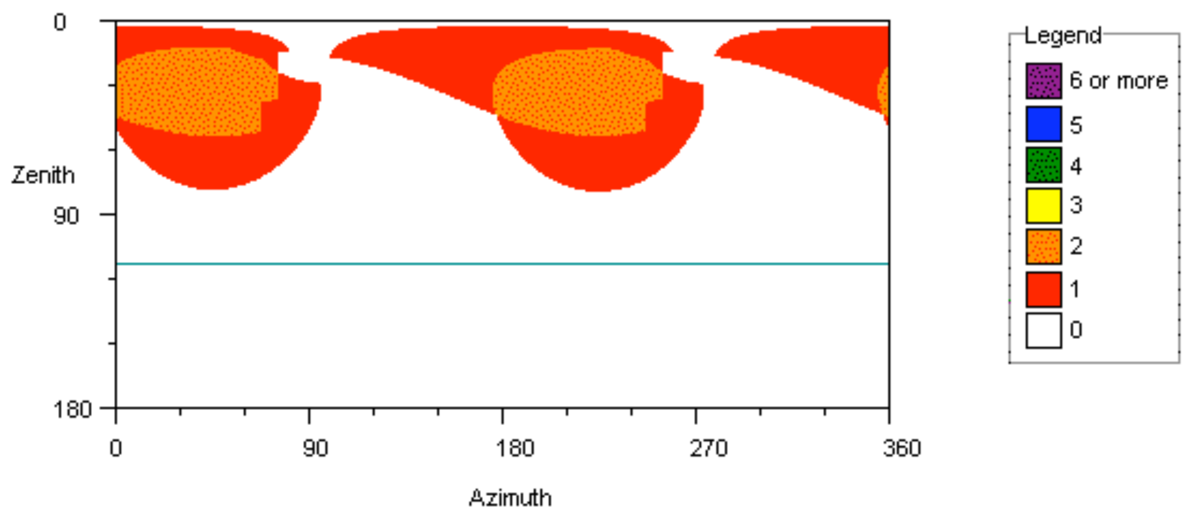
GRB peak brightness sensitivity, 50 – 300 keV range, 5 $\sigma$ detection.

Interpreted as a threshold for detection, 1 second duration, typical spectrum.

Trigger algorithm unspecified.

# Ground Detection Algorithm

- Consider only 2 pairs of detectors (1&7 and 2&8).
- Require coincident rate increase of both detectors in either pair.
- Require 5 $\sigma$ significance ($2.867 \times 10^{-7}$)
- Single detector significance = 3.37 $\sigma$ ($3.786 \times 10^{-4}$)
- At predicted background rate, threshold is 0.44 photons $cm^{-2}$ $s^{-1}$
- At 0.5 photons $cm^{-2}$ $s^{-1}$, effective area is 0.86 steradians




Triggered detectors at 0.5 photons $cm^{-2}$ $s^{-1}$

# GRB Sensitivity Requirement (On-Board)

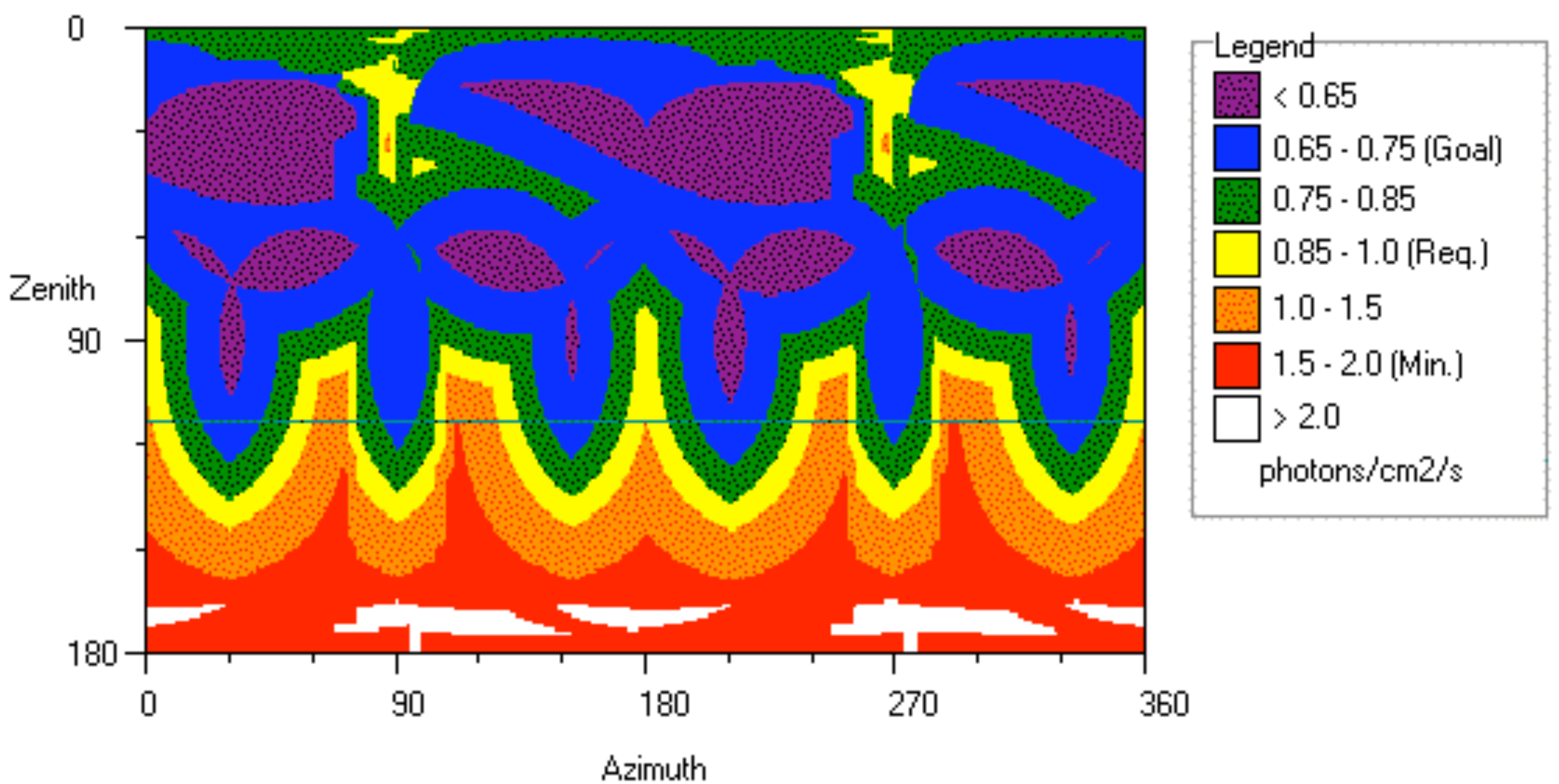
| No. | Quantity | Requirement | Goal | Minimum | Actual |
|---|---|---|---|---|---|
| 46 | Sensitivity | $< 1.0\ cm^{-2}s^{-1}$ | $< 0.75\ cm^{-2}s^{-1}$ | | $0.71\ cm^{-2}s^{-1}$ |

50% efficiency level for bursts occurring within the GBM FOV, excluding observational inefficiencies such as SAA passages and earth occultations, 50-300 keV range

**Algorithm**

Simultaneous increases in count rates of 4.5 $\sigma$ above background in two or more NaI detectors in 1 second.

# On-Board Trigger Threshold



# Solar Flare Goal

"GBM and LAT shall have a goal to provide data that allow rapid determination of the likelihood of a transient event being a solar flare as compared to a GRB or AGN flare."

- GBM flight software includes Bayesian inference to categorize triggers
  - GRB
  - Solar Flare
  - Particle precipitation
  - Specific sources (Cyg X-1, transients)
- Solar flares are relatively easy to distinguish from GRBs
  - Location
  - Spectral hardness
- Probability of a solar flare being classified as a GRB ≅ 6%
- Probability of a GRB being classified as a solar flare <1%

# Altitude Effects on Key Parameters

| | 450 km | 565 km | Delta |
|---|---|---|---|
| NaI background Rate (50-300 keV) | 195 | 290 cps | 49% |
| Unocculted Field of View* | 8.5 sr | 8.8 sr | 4% |
| On-Board Location Accuracy | 4.7° | 4.3° | 8% |
| On-Board Trigger Threshold | 0.59 $cm^{-2}s^{-1}$ | 0.71 $cm^{-2}s^{-1}$ | 20% |
| Ground Trigger Threshold | 0.37 $cm^{-2}s^{-1}$ | 0.44 $cm^{-2}s^{-1}$ | 20% |

* Altitude has no effect on effective FOV

# Summary

- Timing accuracy of 10 μs demands ground correction
- Sensitivity depends on background rate
  - Based on BATSE observations
  - Simulations extrapolate to higher altitudes than CGRO
- Location accuracy depends strongly on pointing zenith angle and spectrum
- <u>GBM Meets Level 2 Requirements</u>