CalibrationStatus/ResponseMatrix

Title: BAT Response Matrix

Revision Date:	2005-05-29
Version:	1
Document:	SWIFT-BAT-CALDB-RESPONSE-v1

1. Summary

This document describes the BAT response matrix performance.

2. Component Files

File Name	Valid Date	Release Date	Version	Description
swbdepthdis20030101v003.fits	2003-01-01	2005-06-24	3	Energy deposition look-up tables
swbparams20030101v008.fits	2003-01-01	2005-10-03	8	Response matrix parameters
swbresponse20030101v007.rsp	2003-01-01	2005-09-08	7	Template on-axis response, and Incident energy scale

3. Scope of Document

This document relates to response matrix performance.

4. Reason for Update

Initial document.

5. Overall Spectral Response

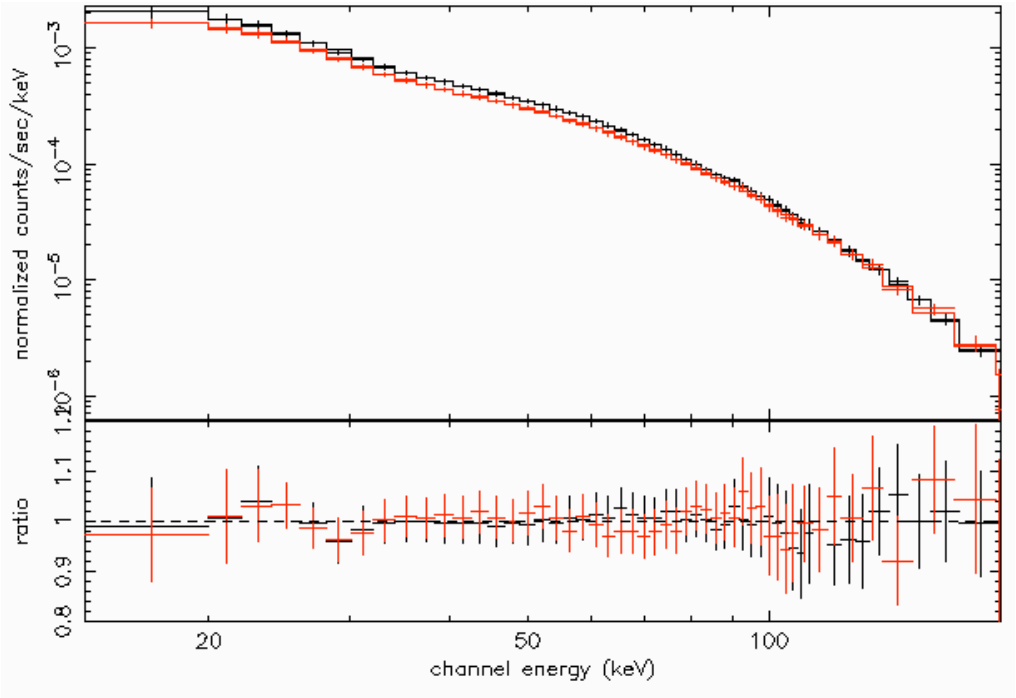

Figure 1. Fit to the Crab using the publicly available corrected response matrix, and including the systematic error vector. The two colors represent on-axis (black) and off-axis 30 degrees (red) long observations.

The pre-launch BAT spectral response file contained significant systematic errors. The response matrix model published with the public Swift software includes extra corrections to force the Crab to fit a canonical model, a power law with photon index 2.15 and normalization of 10.17 ph/cm^2/s/keV at 1 keV. Figure 1 shows a fit to the Crab using the corrected response matrix and the estimated systematic error vector.

6. Corrections to Response

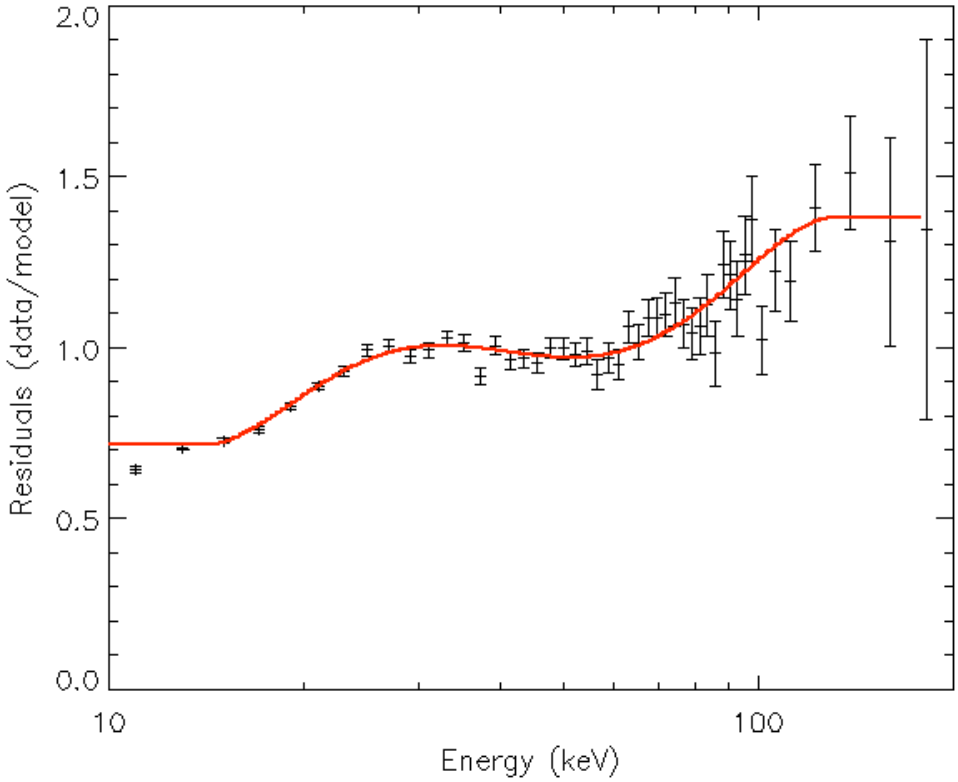

Figure 2. Residuals of a fit to the Crab before "extra corrections" have been applied (points). The smooth line is the form of the extra corrections.

The extra corrections are: (a) addition of empirical absorption which shifts the low energy effective area by ~40% below 25 keV, and (b) a phenomenological adjustment to the effective area over the entire energy range, but which dominated at high energies (~20% for > 100 keV). Figure 2 shows the extent of these corrections in the BAT energy band. While it is believed that these errors are in part due to incorrect modeling of all the passive material in the beam, the exact details are not well understood.

7. Residual Features

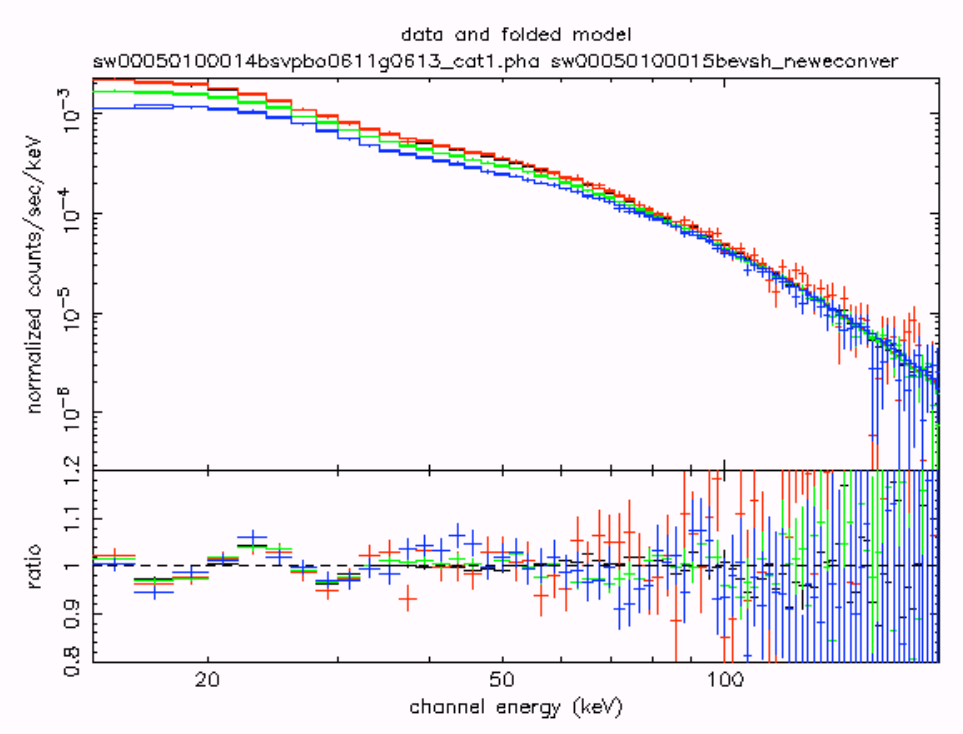

Figure 3. Crab spectrum without applying the systematic error vector, which shows features around 17 and ~30 keV. The different points are at different positions off axis: 0 degrees (red), 30 degrees (green) and 45 degrees (blue).

Features at 17, 27, and 31 keV are still evident in Figure 3. The BAT CdZnTe detectors have K-edges at 27 keV (Cd) and at 31 keV (Te). The response matrix does not yet entirely account for spectral features resulting from these edges, so any such features at these energies should be interpreted with caution. There is also an as-yet unidentified feature at 17 keV.

8. Flux and Photon Index Systematic Errors

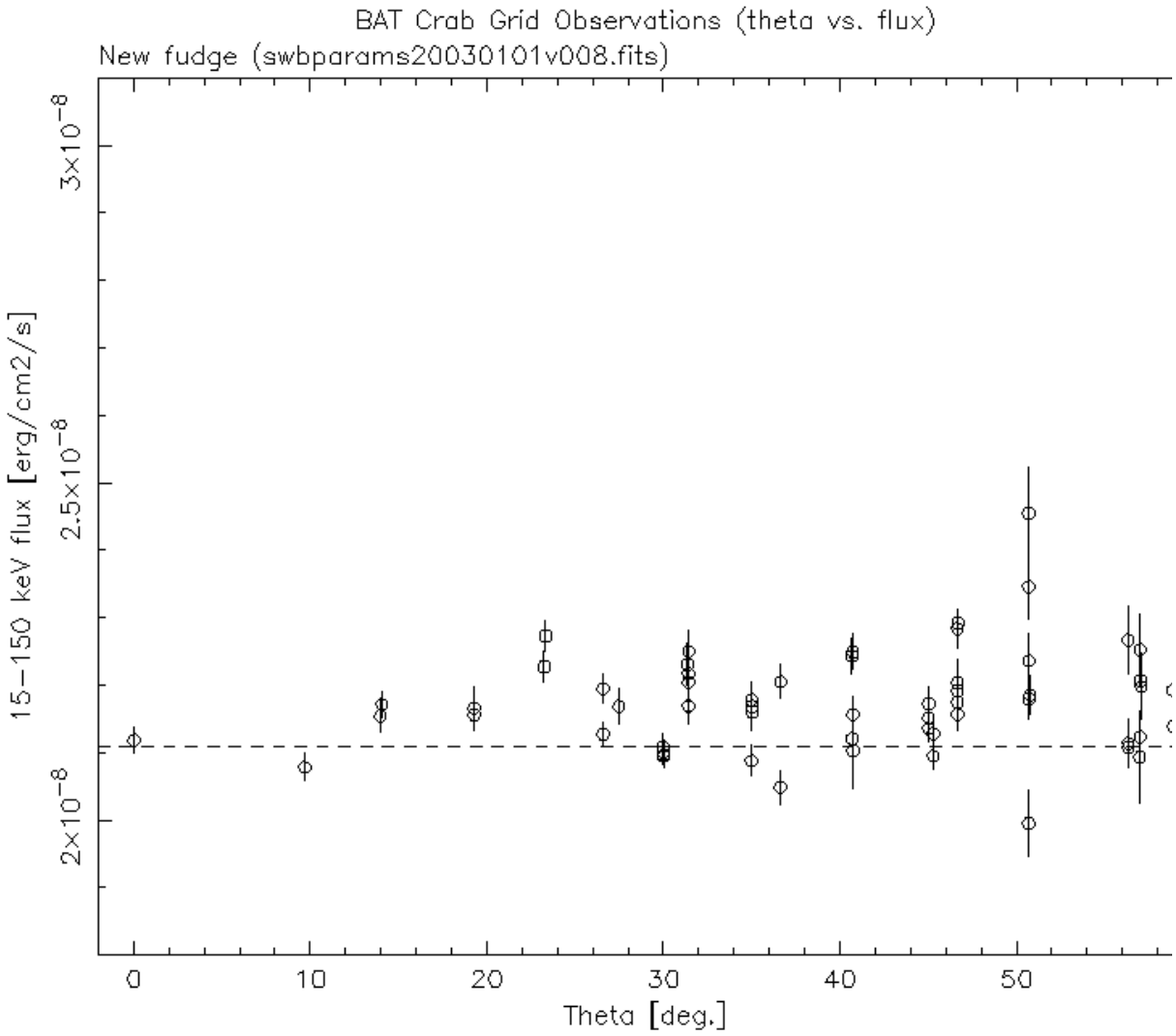

Figure 4. Measured Crab fluxes (14-150 keV) as a function of off-axis angle (theta). The canonical spectrum has a flux of 2.20 x 10^{-8} erg/cm^2/s in this band.

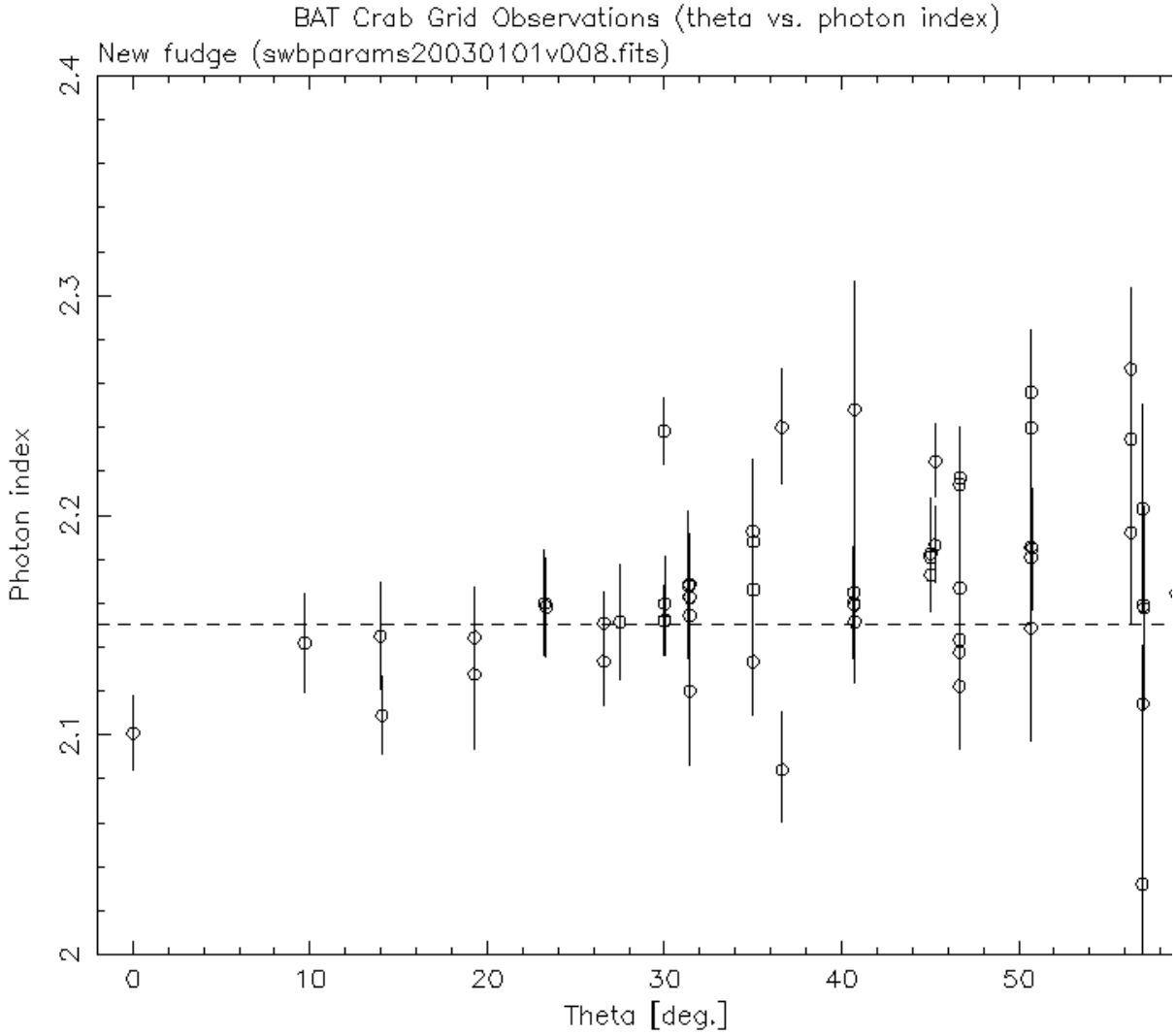

Figure 5. Measured Crab photon indices as a function of off-axis angle. The canonical photon index is 2.15.

Systematic flux and spectral variations as a function of off-axis angle, theta, are shown in Figures 4 and 5 (as of version 008 of the response matrix parameter file. The Crab was observed using a set of 44 grid locations in the BAT FOV (including on-axis, and periodic spacings in tangent plane coordinates all the way out to the 0%-code edge of our field of view). The flux variations are +/-8% peak to peak throughout the field of view. The cause of some of the systematic variations is known and will be addressed in the next CALDB release (version 008 of the response matrix parameter file). Also, the user must be careful to avoid occultation by the earth/moon for off-axis angles larger than 30 degrees (see the "Occultation" analysis issue). Response matrices were generated for these fits using `batdrmgen` with the default method=MEAN parameter.

9. Hard Spectra

The response matrix was generated (a) from a set of ground calibrations with monochromatic lines from radioactive sources and (b) from a forced-adjustment fit to the canonical Crab spectrum (PLI=2.15, Norm=10.17). Given the deviation from ideal discussed above, we recommend caution when fitting sources that have significantly harder spectra than the Crab, in particular GRBs having spectral indices around 1.0 or flatter. While they were to some extent adjusted to match the Crab spectra, the large off-diagonal elements in the response matrix may not be correctly handling the scattering.

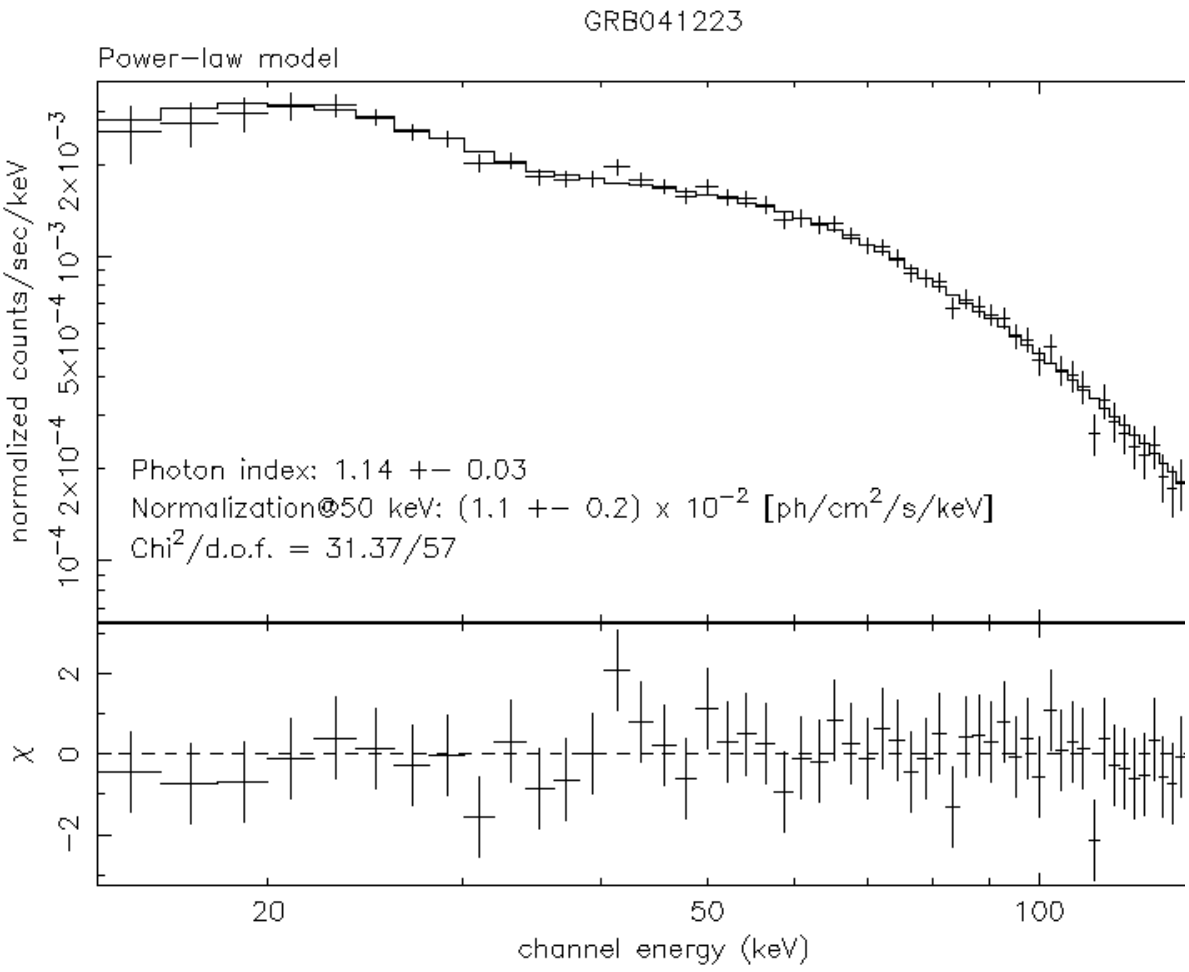

Figure 6. The BAT spectrum of GRB 041223 is well fitted with a simple power-law.

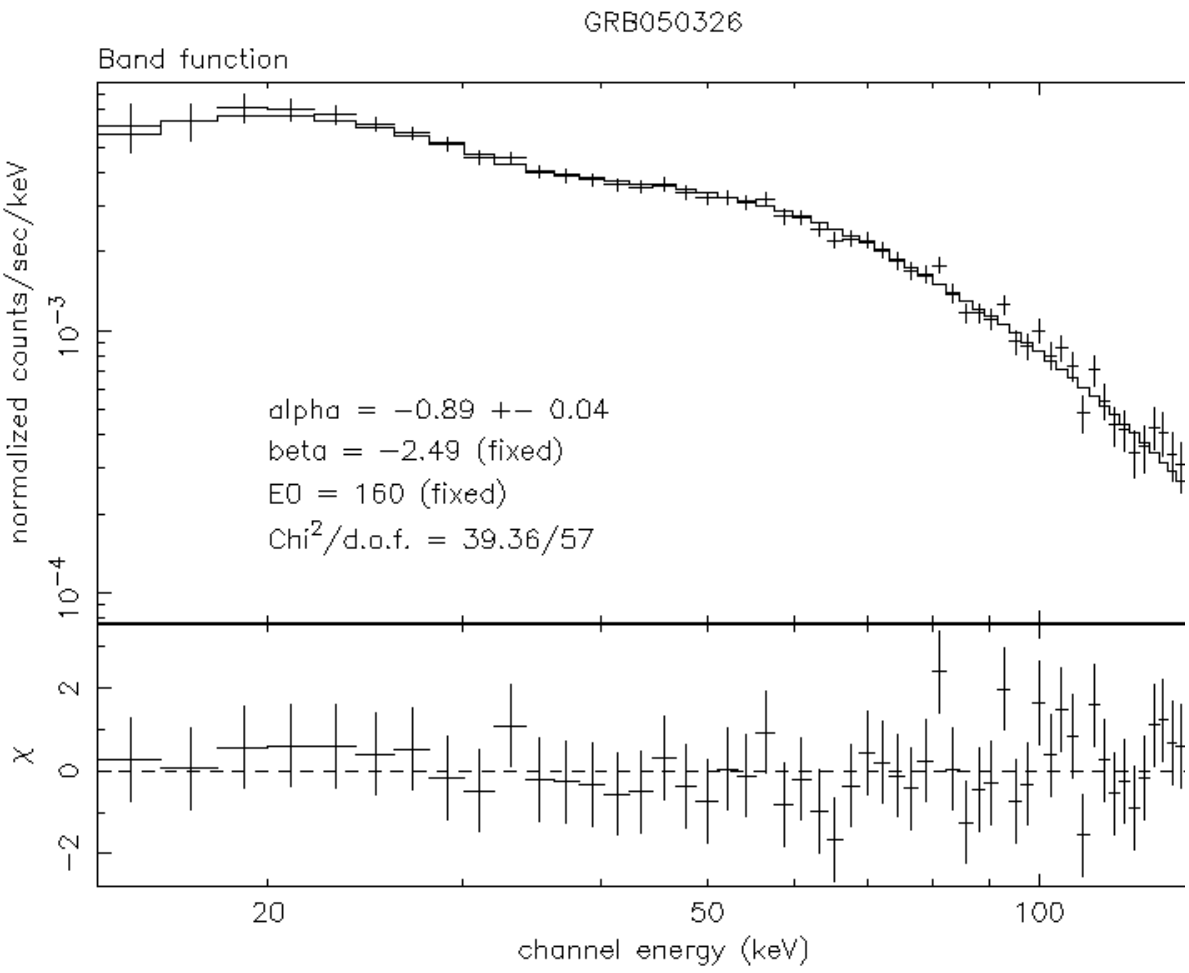

Figure 7. The BAT spectrum of GRB 050326. If we fixed the E0 and the beta to the KONUS spectrum, both the alpha and the observed fluence are consistent with the KONUS values.

However, the fit to GRB 041223 shows the spectrum to be well fit by a simple power-law model, and the residuals show no sign of any bend in the spectrum (Figure 6). Also, the BAT spectrum for GRB 050326 agrees well with the KONUS spectrum (GCN Circ. #3152) for that burst (Figure 7).

10. Energy Range

Spectral analysis should be limited to channels between 14 keV and 150 keV. Due to varying threshold levels in individual detectors, channels below 14 keV should not be used for spectral anaylysis. Likewise, channels above 150 keV are unreliable due to a

lack of calibration data at those energies.

11. Effective Area

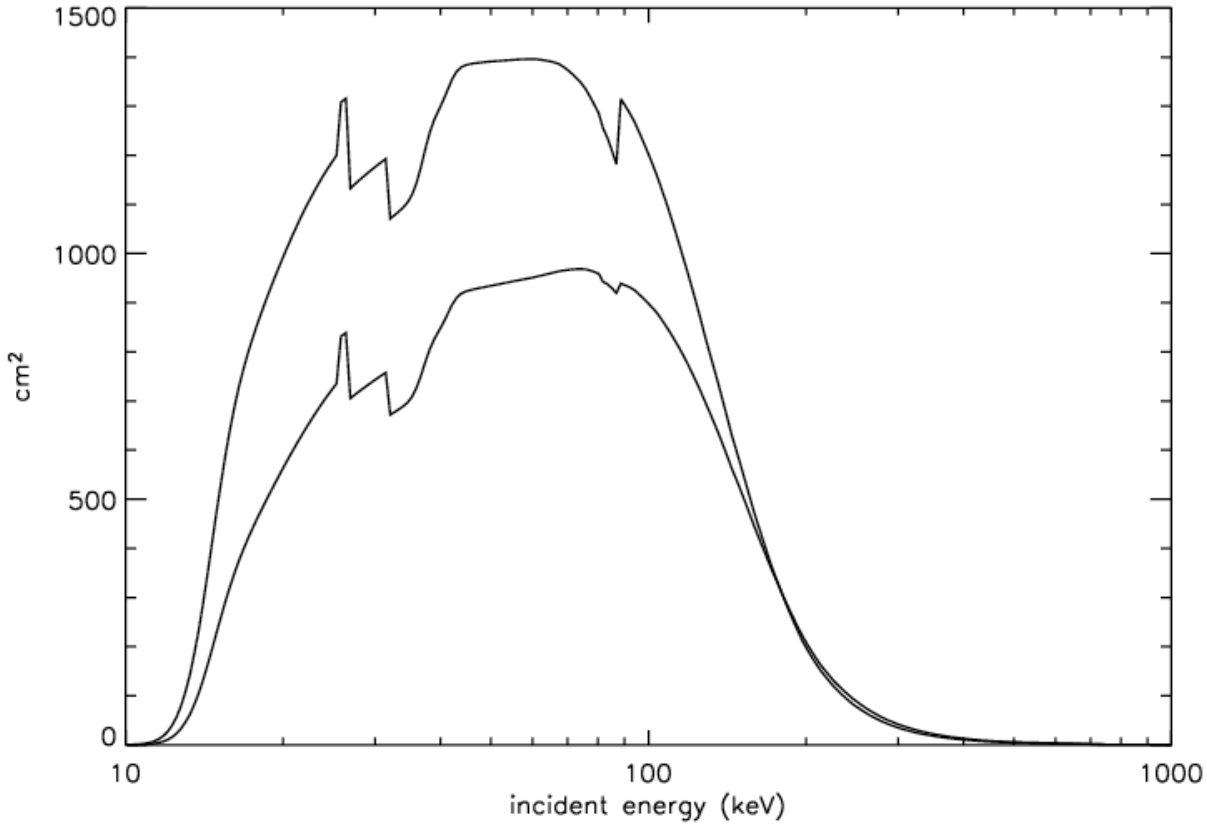

Figure 8. Effective area of the BAT for on- and off-axis (45 deg.) sources.

Figure 8 shows the effective area for a source (a) on axis, and (b) a source 45 deg off-axis. This effective area contains the Mask transmission and the 56% efficiency factor due to the cross-correlation technique used for imaging and mask weighted flux determination. Edge features include 25.5 keV (Ag), 26.7 keV (Cd), 31.8 keV (Te), and 88 keV (Pb). The extra silver absorption used to fit the Crab may have produced an unrealistically pronounced silver K edge in the matrix.

Users can also estimate BAT count rates on-line using WebPIMMS.

12. Calibration Files

The **depth distribution** file is a precomputed grid of energy deposition by X-rays in CdZnTe, based on a Monte Carlo. The deposition is a function of depth, energy, and

angle. This file is not expected to change.

The **parameter** file is a database of response matrix parameters which vary as a function of position in the field of view. The individual detector performance is based on a "mu-tau" model of electron and hole mobility in the semiconductor, and a simplified electronics parameterization.

The **template response** file is a representative on-axis response matrix. By default, this file is used by the response matrix generator to produce the incident photon energy grid portion of the response matrix.

13. Expected Updates

The response matrix parameters may be updated on a ~yearly basis as knowledge of the instrument performance improves.

14. Version History

14.1. Update 03 Oct 2005

```
 * swbparams20030101v008.fits VERSION 8

   This file contains updated response matrix parameters based on
an
   improved analysis of on- and off-axis Crab observations.
   This file applies to all observations, and is not tied to a
   particular software release.
```

14.2. Update 08 Sep 2005

```
 * swbparams20030101v007.fits VERSION 7

   New parameter file which supercedes version 6.  This file
contains
   a new parameter, PB_EDGEN, which controls how lead tile edges
are
   treated.  The new parameter file has been optimized to fit the
Crab
   for multiple angles and at all energies from 15-150 keV.  This
```

```
file
   applies to all observations.

 * swbresponse20030101v007.rsp VERSION 7

   The swbresponse file is a typical on-axis response
   with the above changes to the swbparams file, and batdrmgen
v3.1.
   This file applies to all observations.

   ** These files are meant to be released with Swift build 16. **
```

14.3. Update 20 Aug 2005

```
 * swbparams20030101v006.fits VERSION 6

   New keywords named SIGMA_* which give batdrmgen information it
   needs to produce an energy-dependent noise resolution.  Revised
   GAIN_* keywords that are used by batdrmgen to adjust the model
gain
   so that the peaks line up right (to account for the new noise
   model). A set of new PSV_0 and CCFUNP* keywords so that the
fudge
   correction is appropriate for the cosine-correction change and
the
   noise resolution change.  This file applies to all observations.

   ** This file is meant to be released with Swift build 16. **

 * swbresponse20030101v006.rsp VERSION 6

   The swbresponse file is a typical on-axis response
   with the above changes to the swbparams file, and batdrmgen
v3.0.
   This file applies to all observations.

   ** This file is meant to be released with Swift build 16. **
```

14.4. Update 24 Jun 2005

```
 This calibration file update extends the upper limit of the
```

```
incident
 photon energy range of batdrmgen to 10 MeV.

 * swbdepthdis20030101v003.fits VERSION 3

    Contains additional information about energy deposition in CZT
to
    higher energies than in version 1.  This file applies to all
    observations.

 * swbparams20030101v005.fits VERSION 5

    Keywords have been adjusted so that the passive material
    absorption model is valid up through 10 MeV.  Modified CFUNP*
and
    PSV_0 and GAIN_* keywords so that they give the appropriate
    correction function for the new gain adjustment method of
    batdrmgen 2.9.  This file applies to all observations.

 * swbresponse20030101v005.rsp VERSION 5

    This template response matrix is used for the incident photon
    energy grid.  Version 5 has additional energy bins which extend
up
    to 9000 keV.  This file applies to all observations.
```

14.5. Update 28 Mar 2005

```
 * swbresponse20030101v004.rsp VERSION 4

    This file has been updated for the on-axis response delivered
in
    Swift 2.0.  While the response matrix contents have changed,
the
    energy bins used by batdrmgen have not changed.  This file
    applies to all observations.
```

14.6. Update 18 Mar 2005

```
 * swbparams20030101v004.fits
```

```
    This response matrix file has been improved based on new fits
to
    the ground calibration data, including mu-tau values for some
    blocks that were not available until recently.  Passive
absorption
    coefficients have been updated.  New correction function
    coefficients have been developed.  The exponential tail model
has
    been removed from the response.

    This file applies to all observation times, but REQUIRES BUILD
14
    SOFTWARE.
```

14.7. Updated 31 Jan 2005

```
  * cpf/swbresponse20030101v003.rsp VERSION 3

    On-axis response matrix.  It is primarily used in the response
    matrix generation, to choose the incident photon energy
binning.
    However it can also be used by general users for simulations.
    Changes to the 'params' calibration file have improved the
    response knowledge below 20 keV.  These changes have been
folded
    into this template response using batdrmgen v2.5.
```

14.8. Updated 20 Jan 2005

```
  * swbparams20030101v003.fits VERSION 3

    Contains corrections to the model coefficients for the
attenuation
    of passive materials in the field of view, based on improved
    knowledge (esp. below 20 keV).  Also contains corrections to
the
    mu-tau detector physics coefficients.  Applies to all
observation
    times.
```

14.9. Updated 19 Dec 2004

```
  * swbdepthdis20030101v002.fits

     New version, now in accord with HEASARC format
recommendations.
     Actual contents unchanged from swbdepthdis20040326v001.fits.
     One TUNIT value changed.

  * swbparams20030101v002.fits

     New version, now in accord with HEASARC format
recommendations.
     Actual contents unchanged from version 2.
```

last edited 2006-05-29 17:36:55 by CraigMarkwardt