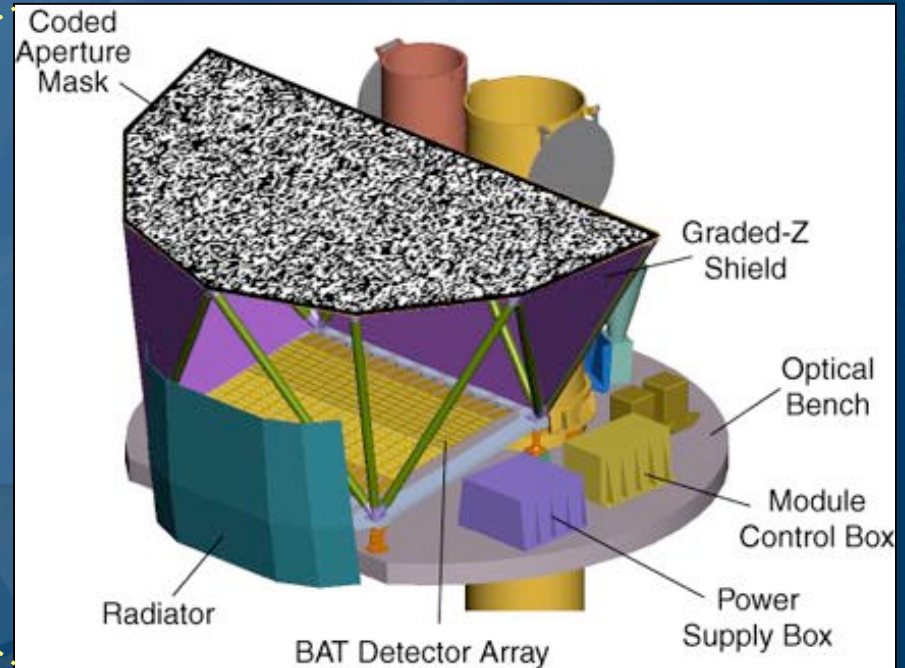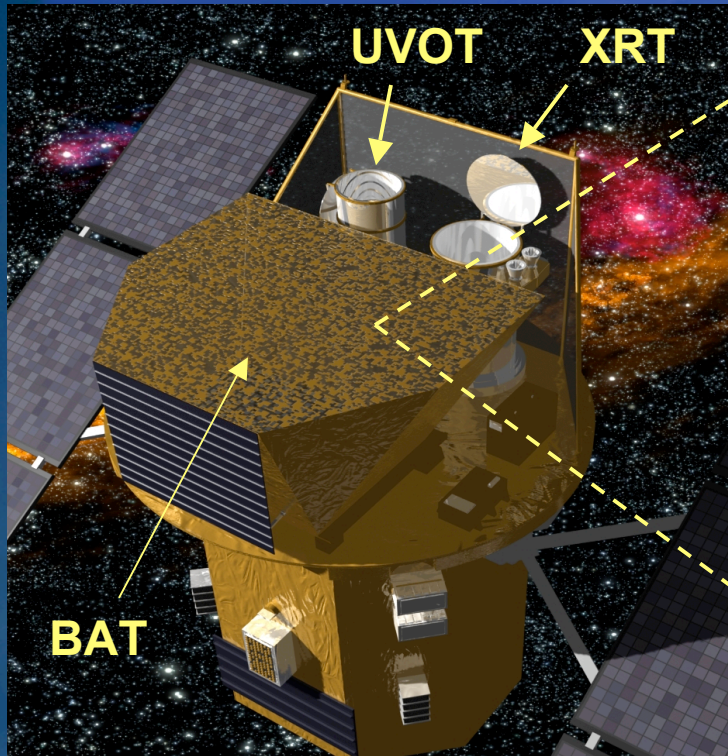# Energy Calibration Status of Swift/BAT

T. Sakamoto

on behalf of BAT team

# Outline
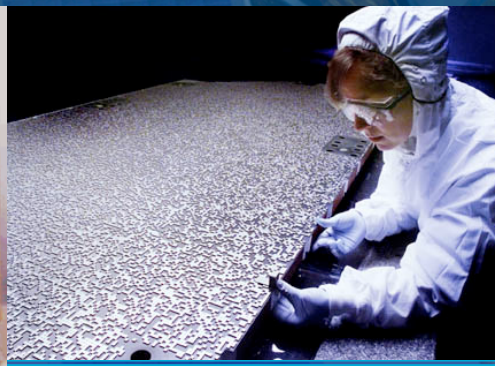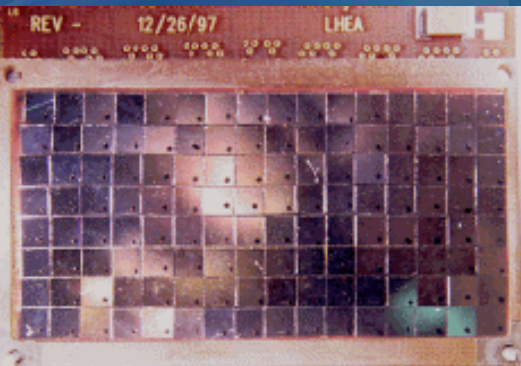
- Update on BAT energy response
- Cross-calibration work using GRBs: Konus-Wind, Suzaku/WAM, and Swift/BAT
- Gain change in BAT (work in progress)

Swift

# Burst Alert Telescope (BAT)



UVOT · XRT · BAT



Coded Aperture Mask · Graded-Z Shield · Optical Bench · Module Control Box · Power Supply Box · BAT Detector Array · Radiator

One sandwich (128 CdZeTe)          Coded Mask





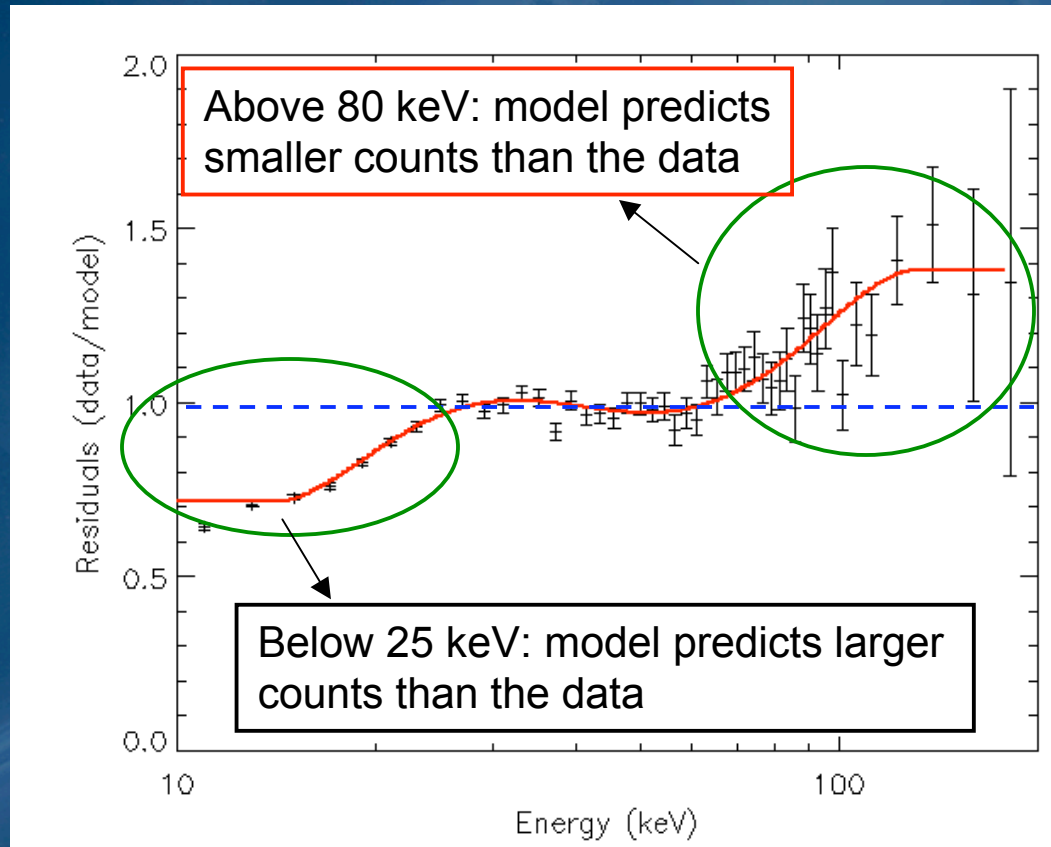| | |
|---|---|
| Energy range | 15-150 keV |
| Area | 5240 cm$^2$ |
| Detector | CdTeZn |
| Size of Det | 4 x 4 x 2 mm$^3$ |
| # of Det | 32768 |
| Energy resolution | ~4 keV@60 keV |
| FOV | 120$^\circ$ x 90$^\circ$ |
| Position Resolution | <3' |

# Update on BAT energy response

Fix in high-energy (>80 keV) part of the response

*Swift*

# Previous energy response

Residuals (data/model) vs. Energy



Above 80 keV: model predicts smaller counts than the data

Below 25 keV: model predicts larger counts than the data

Systematic error (batphasyserr)
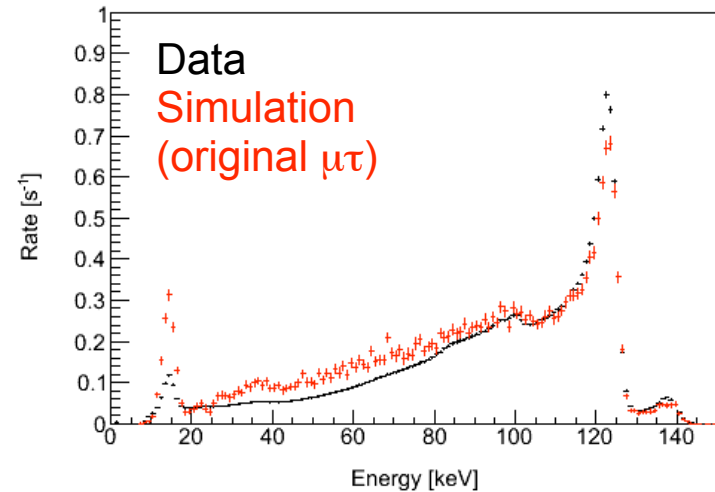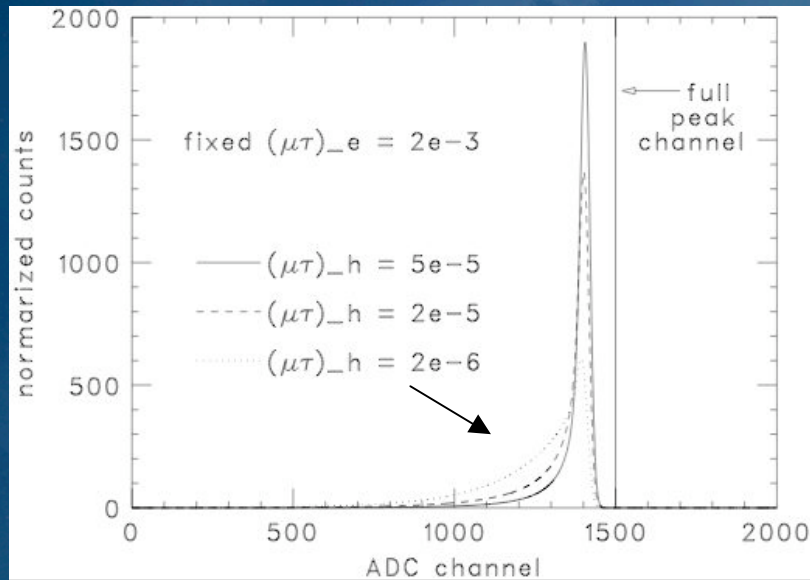


5-30%
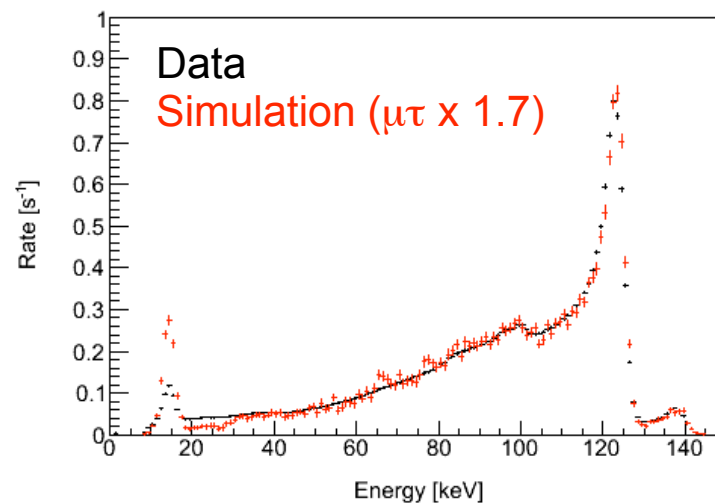
5-15%

5%
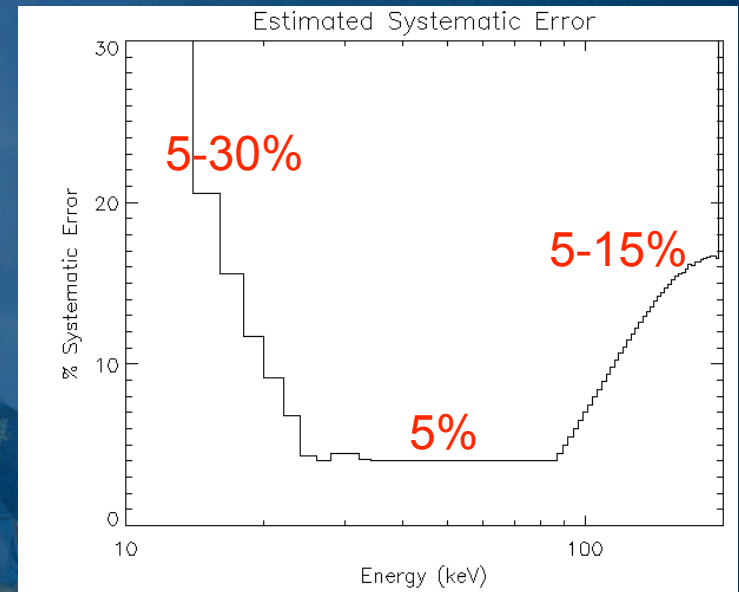
Two corrections in DRMs:
1. Correction at < 20 keV (Correct for unaccounted passive absorption in BAT field of view),
2. Correction at > 80 keV (adjustment in effective area).

# Modification in $\mu\tau$ measurement  (G. Sato)

Effect of $(\mu\tau)_{hole}$



- $\mu\tau$ determination: $^{57}$Co source
  → No scatter due to the source packaging

- MC simulation taking into account the material of the packaging

  → Large excess due to the scattering of the source packaging

**x 1.7 $\mu\tau$ is needed to reproduce the ground calibration data**



$(\mu\tau)$ x 1.7
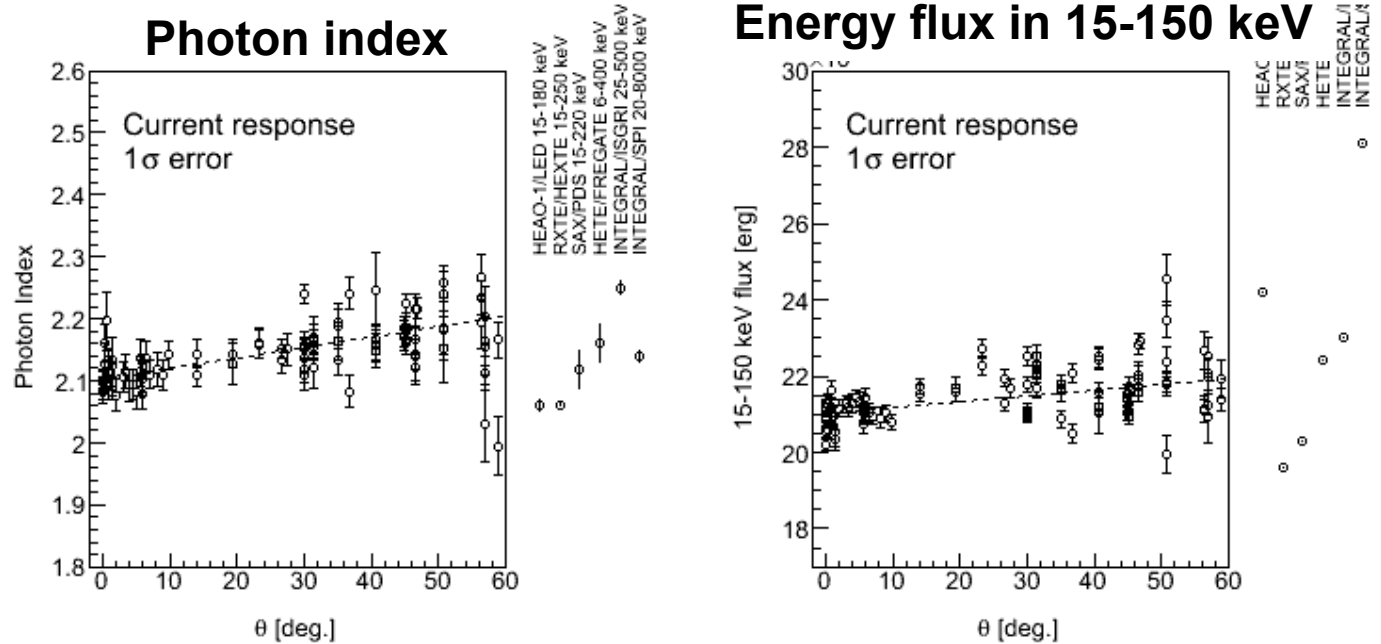
*Swift*

# Fix in response and systematic error

**Fix in BAT energy response**

- Multiplied by 1.7 of current $\mu\tau$ table (CALDB)
- Major update in systematic error vectors > 80 keV (CALDB)
  $\longrightarrow$ Factor of 2-3 smaller at high energies!

*Swift*

# Crab re-analysis

**Photon index**

**Energy flux in 15-150 keV**
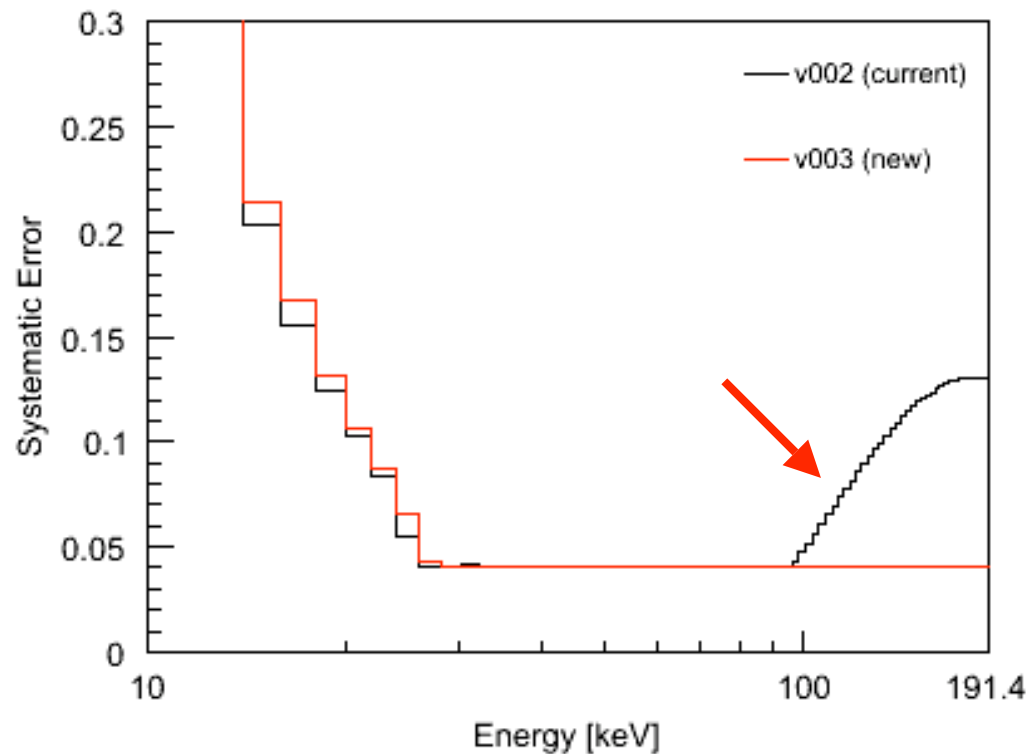
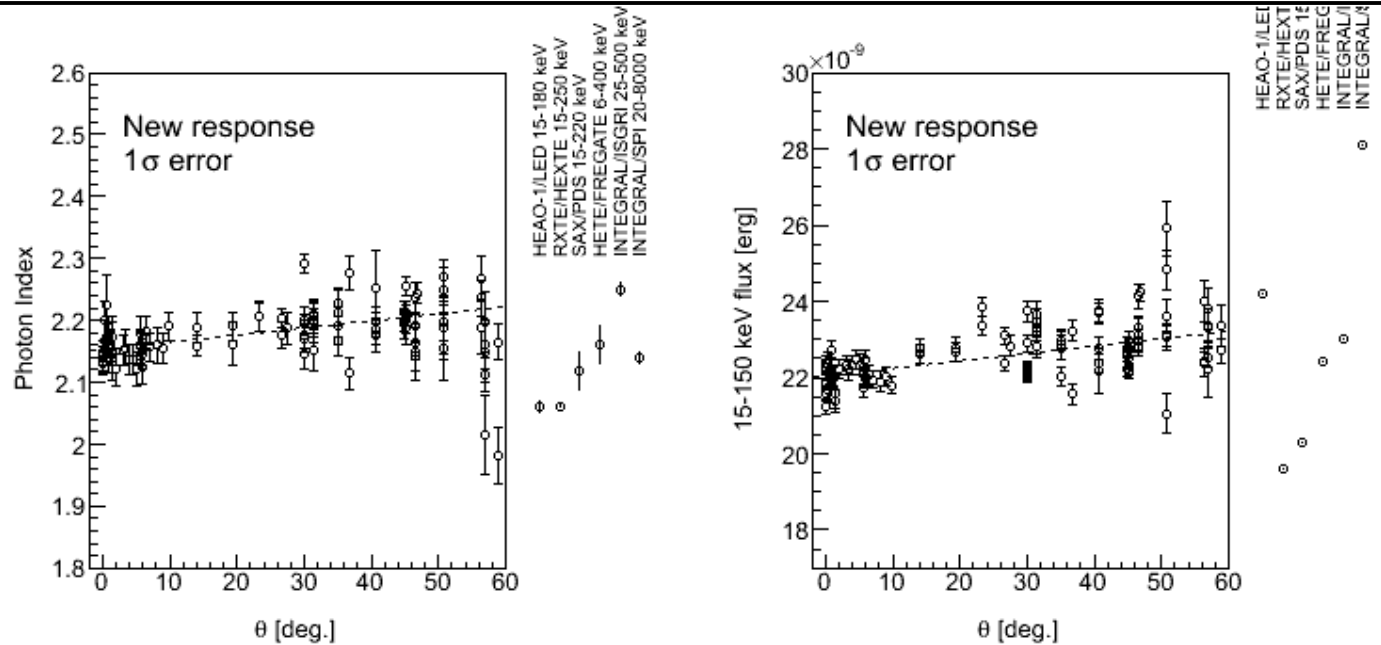**Previous response**



**New response**

# Summary

- High energy part (>80 keV) of the BAT energy response has been updated by increasing the values of $\mu\tau$.

- No correction at the high energy part anymore.

- Systematic error vector >80 keV has been reduced.

- This new response is available at the standard BAT ftools/CALDB.

*Swift*

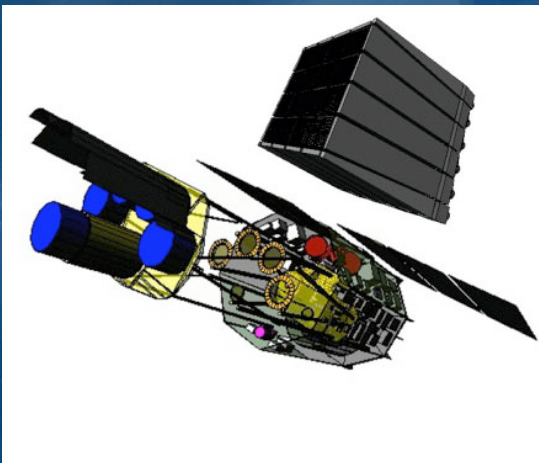# Cross-calibration using GRBs:

# Konus-Wind, Suzaku/WAM and Swift/BAT

# Konus-Wind, Suzaku/WAM and Swift/BAT
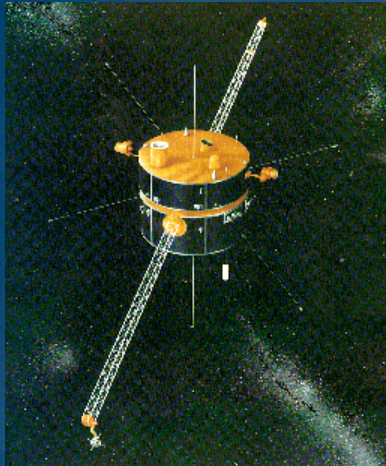


## Konus-Wind

- L1 point (low background)
- Two NaI(Tl): 13 cm (d) x 7.5 cm (h)
- 10-750 keV and 0.2-10 MeV (63 channels)
- Time variable spectral intervals (64 ms- 8.192 s)
- >20 keV is calibrated

## Suzaku-WAM

- BGO ($400\ cm^2$@1 MeV)
- 4 detectors
- 50 keV - 5 MeV (55 channels)
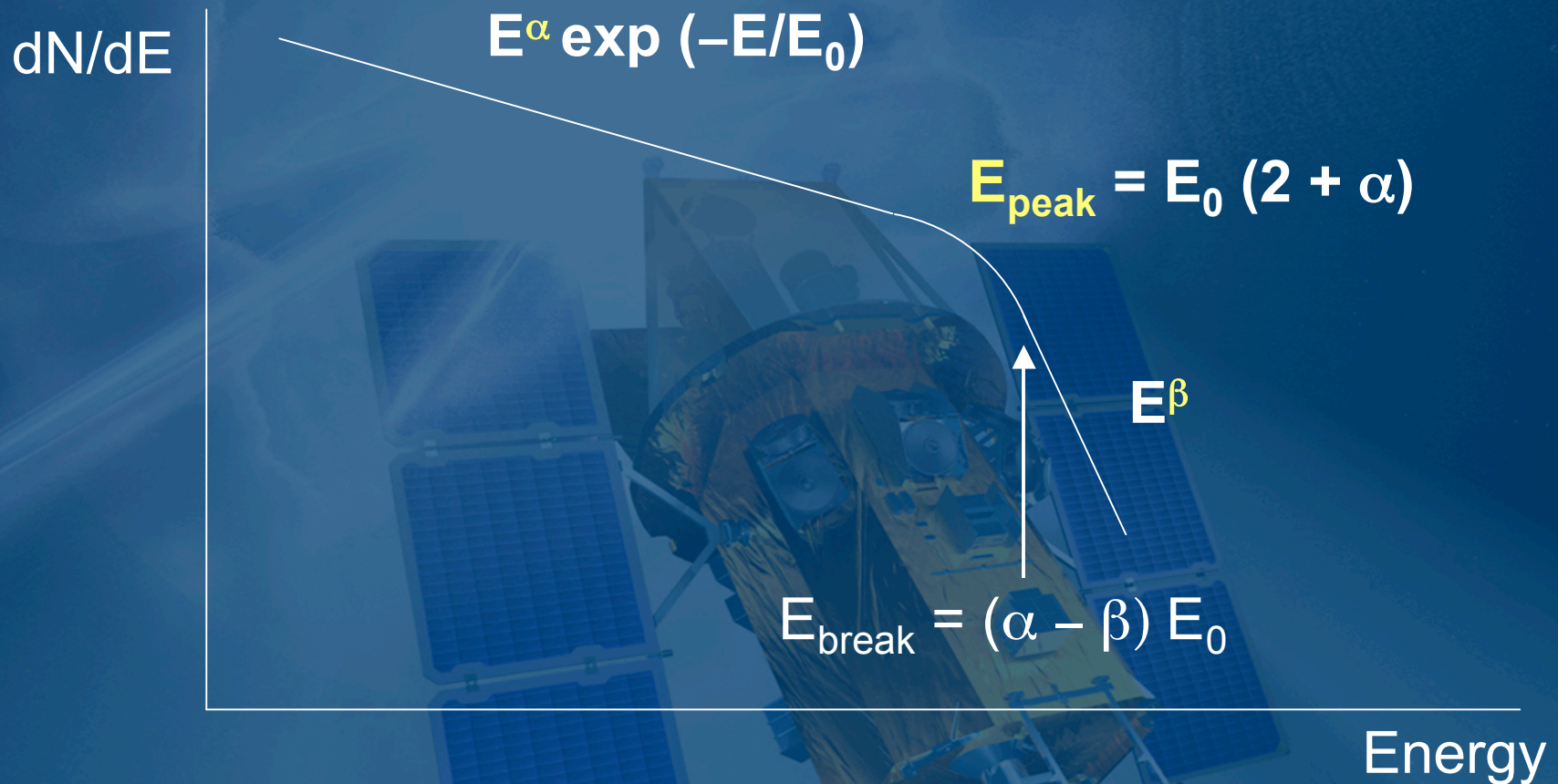- 0.5 s spectra (1 s spectra)
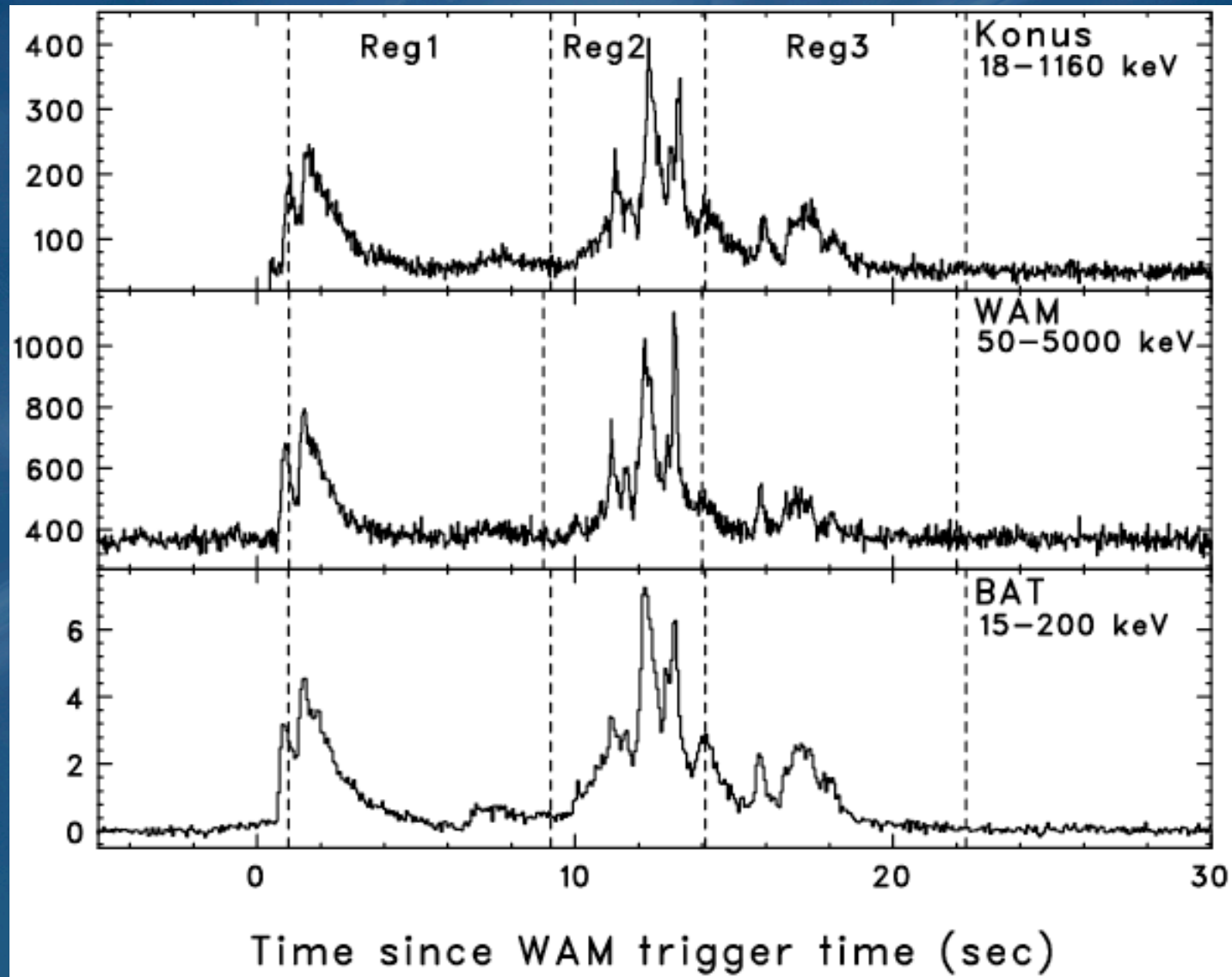- >120 keV is calibrated

## Swift-BAT

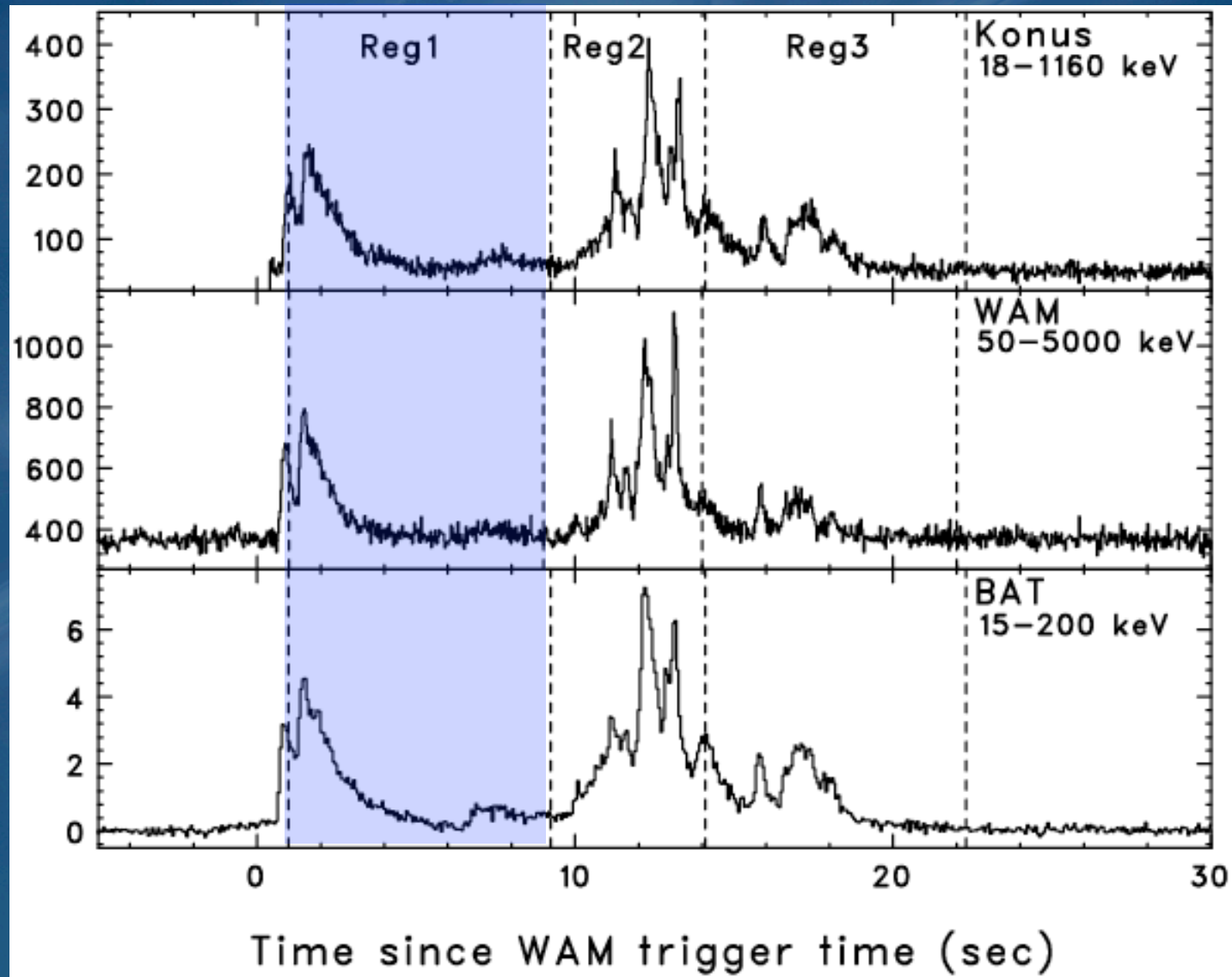# Empirical spectral models of GRBs
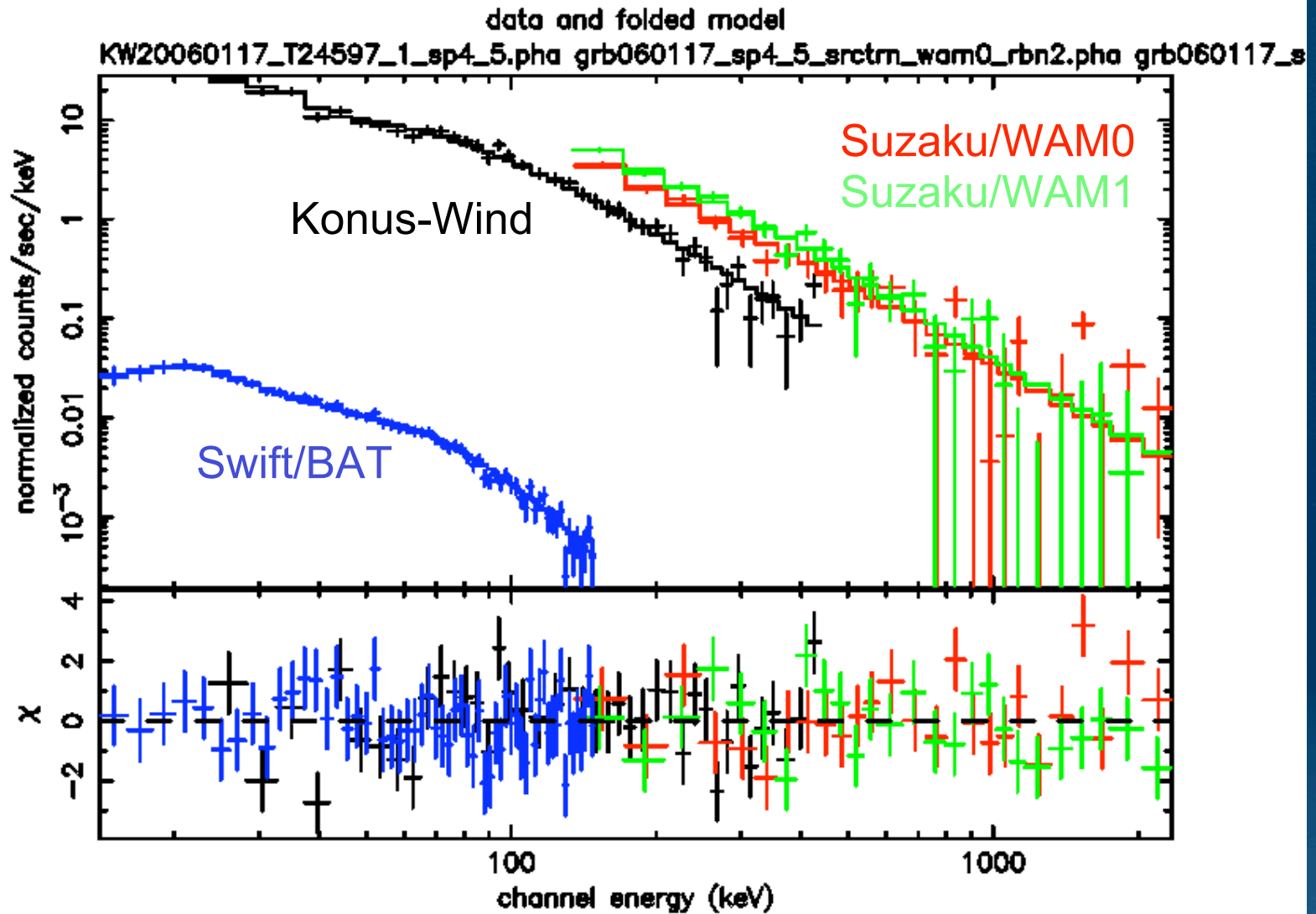
**Band function** (Band et al. 1993)

dN/dE

$$E^{\alpha} \exp(-E/E_0)$$

$$E_{peak} = E_0 (2 + \alpha)$$

$$E^{\beta}$$

$$E_{break} = (\alpha - \beta) E_0$$

Energy

# Example: GRB 060117

# Example: GRB 060117

# Example: GRB 060117



data and folded model
KW20060117_T24597_1_sp4_5.pha grb060117_sp4_5_srctrn_wam0_rbn2.pha grb060117_s

Suzaku/WAM0
Suzaku/WAM1

Konus-Wind
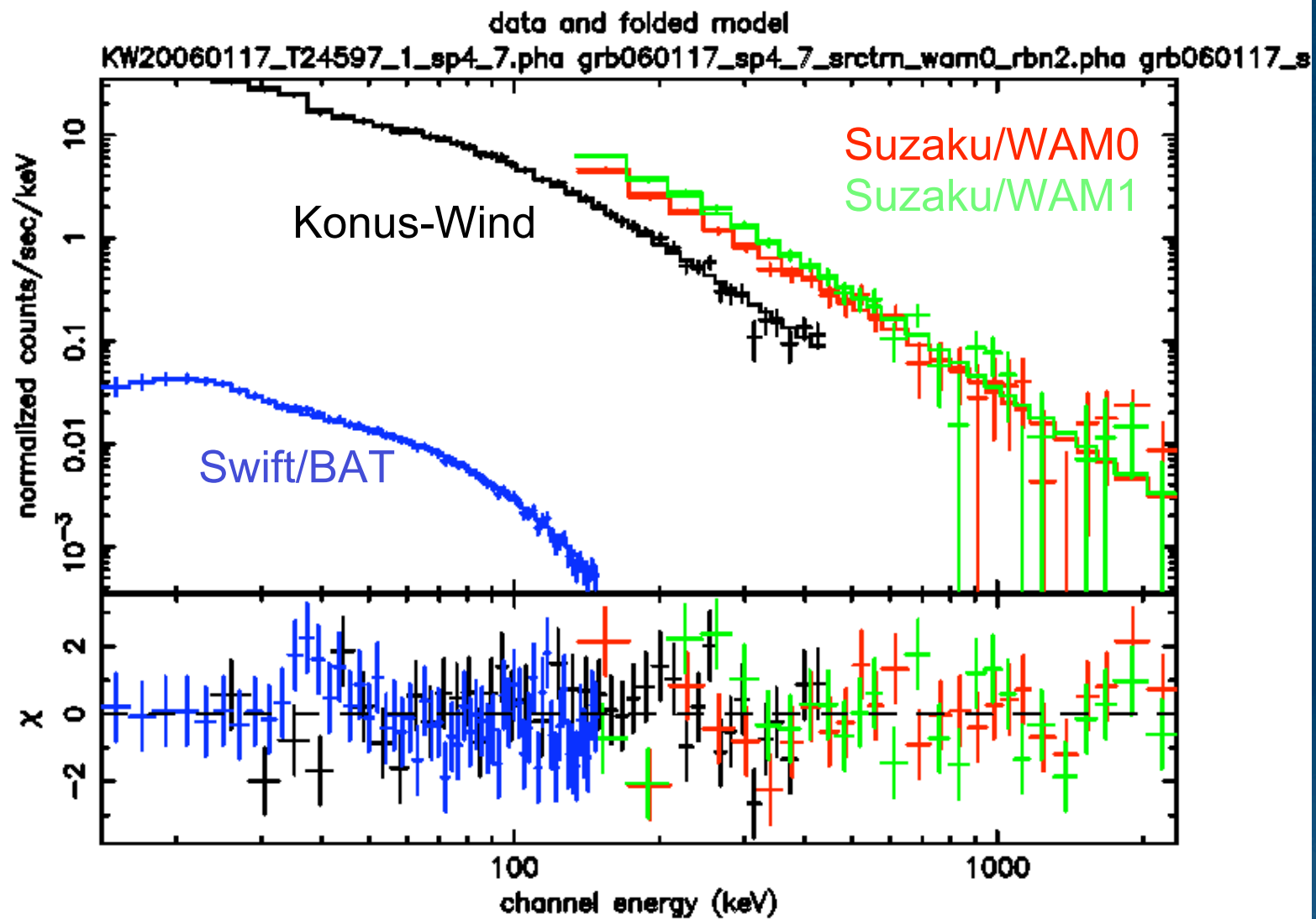
Swift/BAT

normalized counts/sec/keV

χ

channel energy (keV)

takanori 16-Dec-2008 11:52

*Swift*
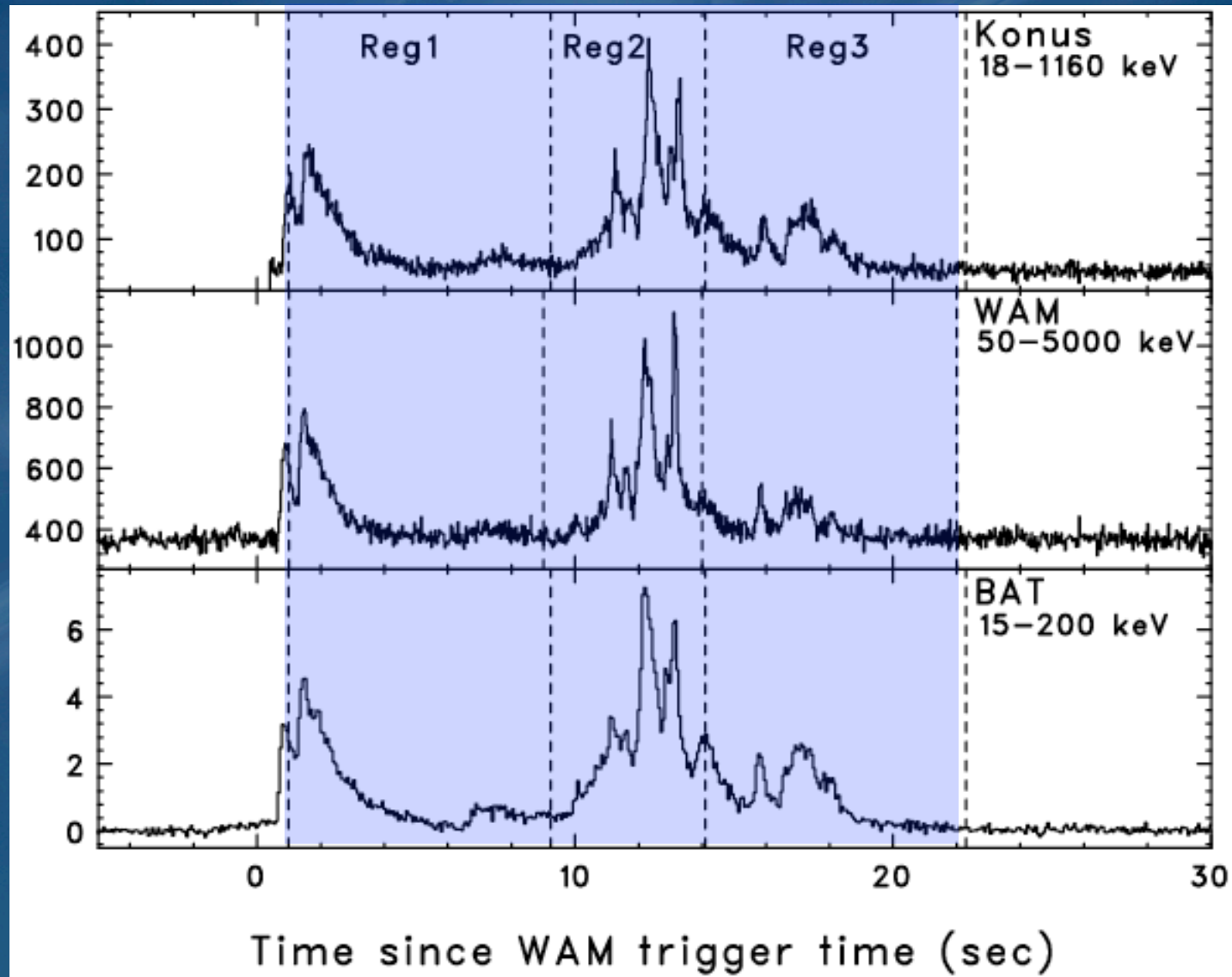
# Example: GRB 060117

# Example: GRB 060117

# Spectral parameters

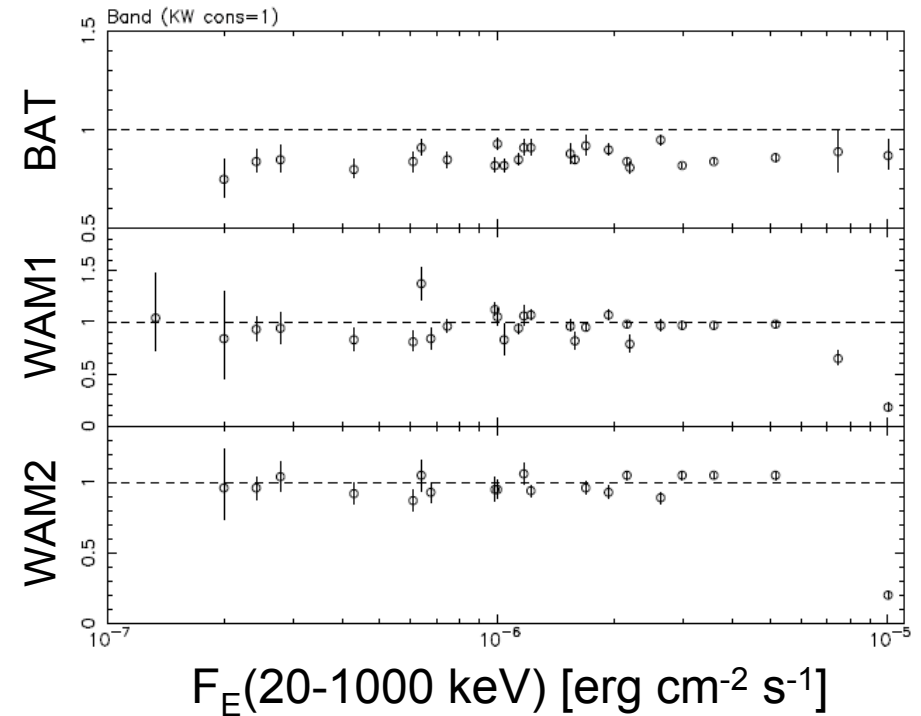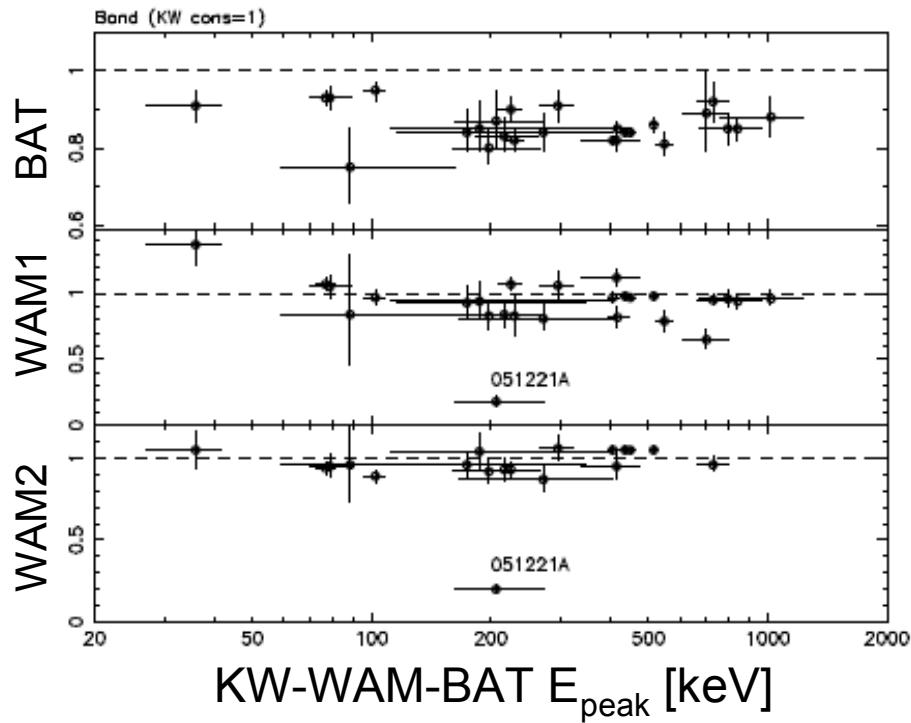| Low energy photon index | High energy Photon index | Peak energy in $\nu F_\nu$ |
|---|---|---|
| $\alpha$ | $\beta$ | $E_{peak}$ |
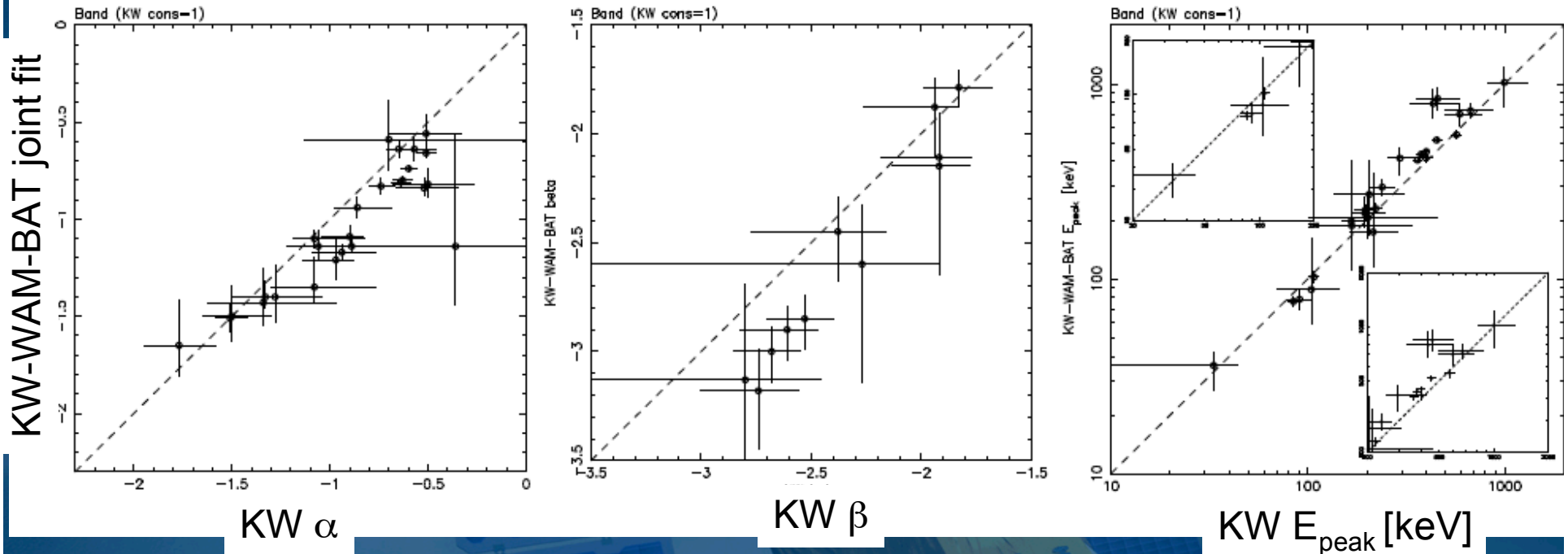


- Systematically steeper (softer) in the joint fits
- Systematically higher $E_{peak}$ ($E_{peak} > 200$ keV) in the joint fits

# Normalization factor



KW-WAM-BAT $E_{peak}$ [keV]

$F_E$(20-1000 keV) [erg cm$^{-2}$ s$^{-1}$]

- WAM constant factor agrees to KW within 20% range (0.8-1.2).
- BAT constant factor is systematically smaller than KW by 10-20%.

# Summary

- Cross-calibration work among Konus-Wind, Suzaku/WAM, and Swift/BAT has been performed using the simultaneously observed GRBs in 2005-2007.

- Systematically softer (steeper) low energy photon index $\alpha$ and higher $E_{peak}$ energy are obtained based on the joint fits comparing to those of the KW fit.

- Constant factor of WAM based on the joint fits is consistent with the KW fits within 10-20% range. However, the constant factor of BAT is systematically smaller by 10-20%.
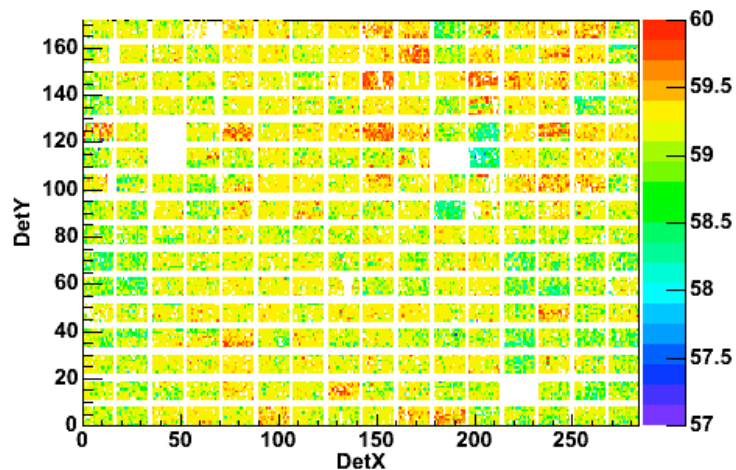
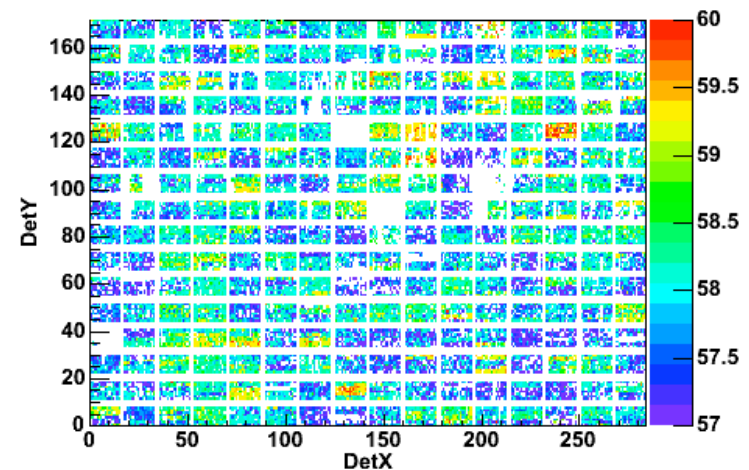# Gain change in BAT
# (work in progress)

# Peak Shift to lower energy

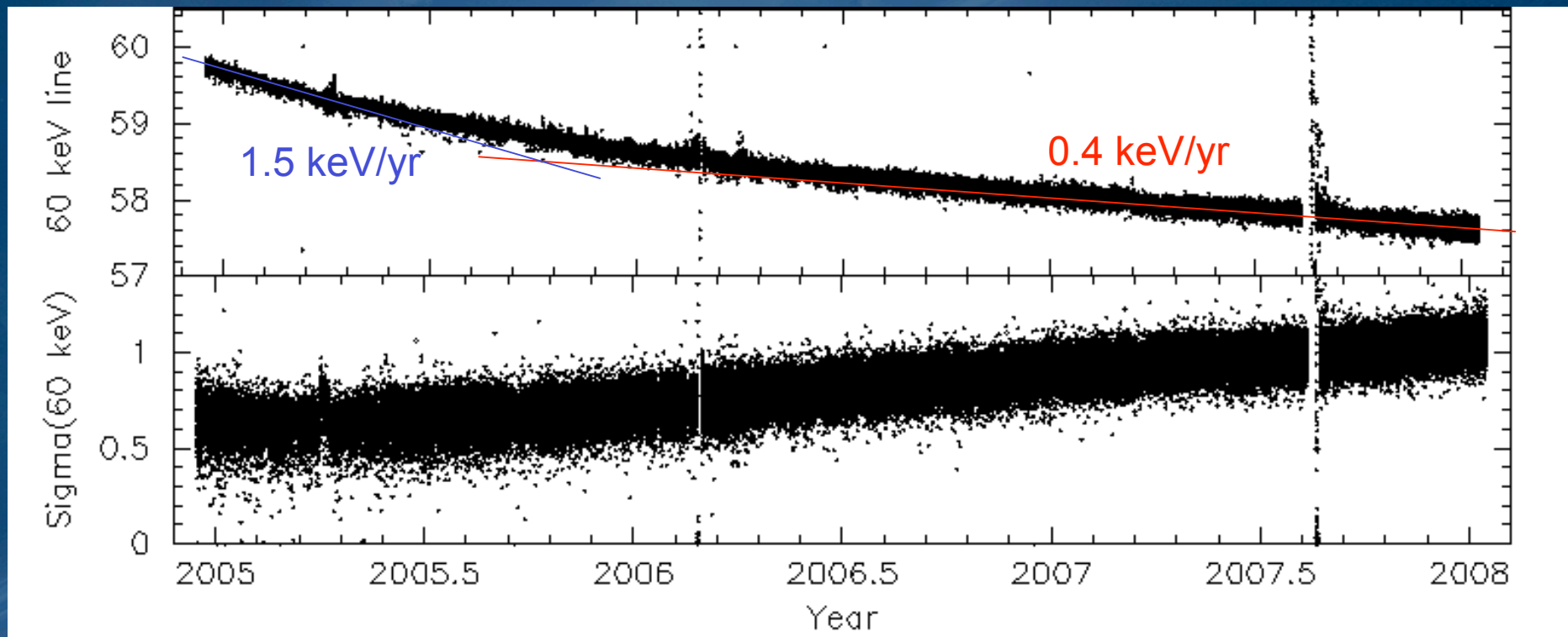$^{241}$Am 59.5 keV line

2005 doy 1-10

2006 doy 152-161



- BAT measurement of 59.5 keV line has been shifted for 1-2 keV in ~1.5 years.

# Long term trend of 59.5 keV line

^{241}Am spectrum: array averaged



- 1.5 (early) - 0.4 (current) keV/yr shift in 59.5 keV line (array averaged).
- The pulse width seems getting wider.

# Summary

- Peak shift of 59.5 keV line to low energy has been seen ($^{241}$Am source).

- Shift rate is 1.5 keV/yr (early) - 0.4 keV/yr (current).

- We believe the shift is due to intrinsic properties of CZT detector rather than electronics (still investigating…).

- We are working on updating the software/CALDB to correct this effect.