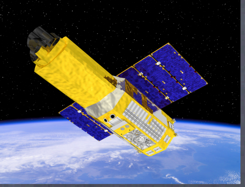
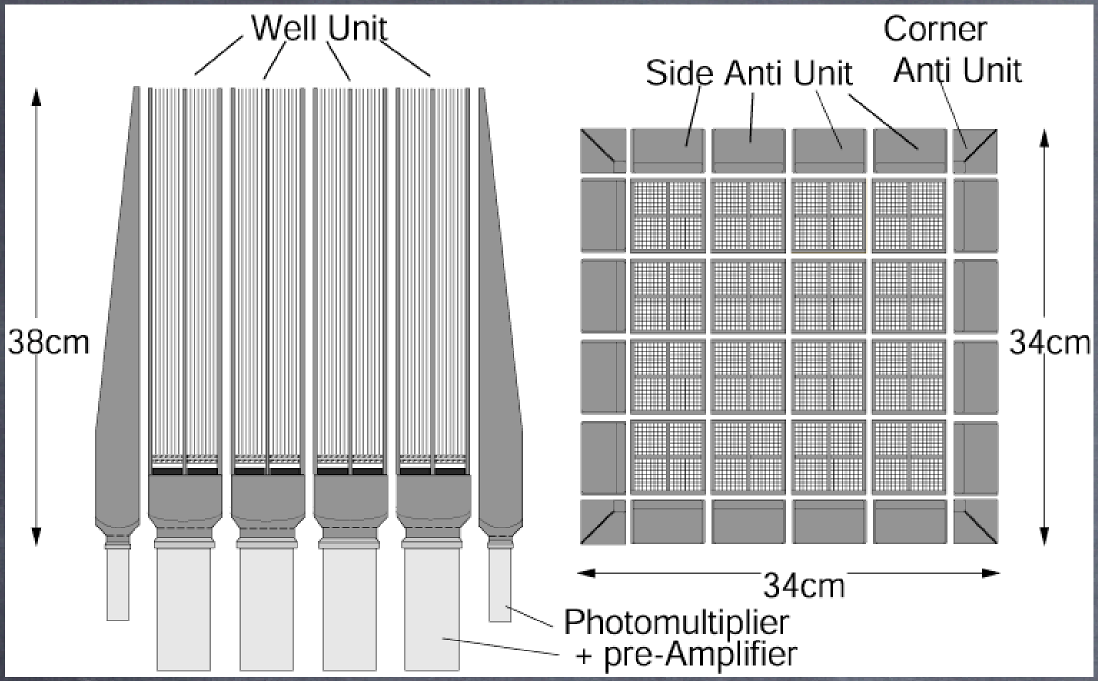
# Status of the Suzaku HXD

T.Takahashi (ISAS/JAXA)
on behalf of the Suzaku HXD team

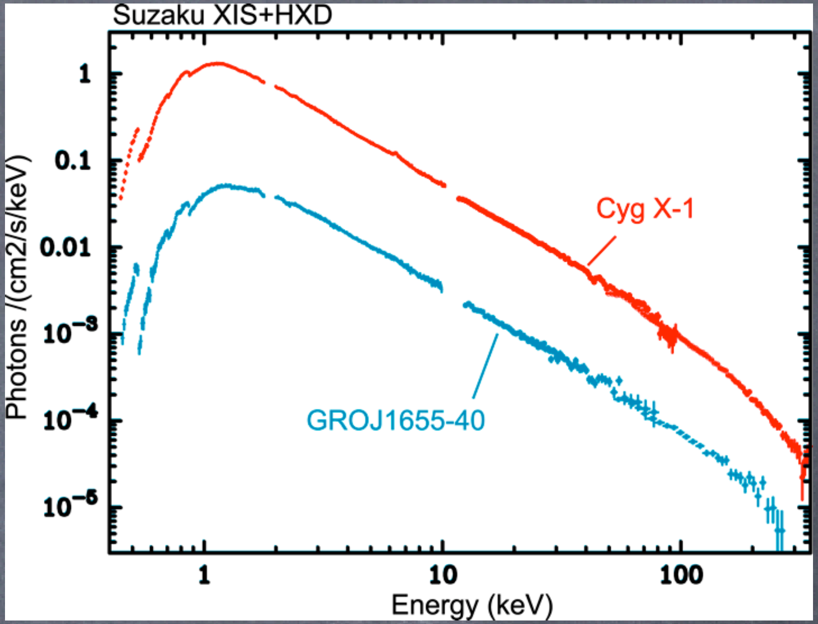
T.Takahashi et al., PASJ, 59SP1, 35 (2007)
M.Kokubun et al., PASJ, 59SP1, 53 (2007)



# Hard X-ray Detector



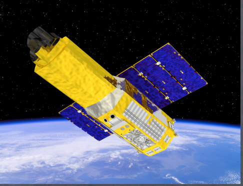

Suzaku wide-band spectra




64 PIN-Si diodes : 10-70 keV, dE~4keV(FWHM)

16 well-type phoswich (GSO) : 40-600 keV

Wide-band All-sky Monitor (WAM) as a GRB detector



# In-orbit important events of HXD

2005-07,08 : Initial operation/tuning phase

2005-08-17 : First light

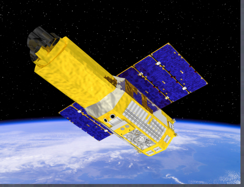
2005-08,09 : Calibration observations

SWG observations

2006-03: GSO LD level changed

2006-05: 1 of 64 PIN diodes showed the breakdown.
One high-voltage bias was changed from 500 to 400 V.
(affects 16 PIN diodes).

2006-10: Another high-voltage bias was also changed from 500 to 400 V. In total, 32 PIN diodes are biased with 400 V.



# Calibration results of PIN/GSO

## PIN calibration

- Energy scale
- Alignment
- Response function

## GSO calibration

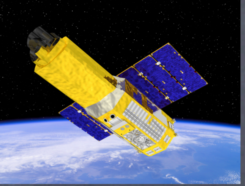
- Energy scale
- Gain variation
- Response function

## Common issue

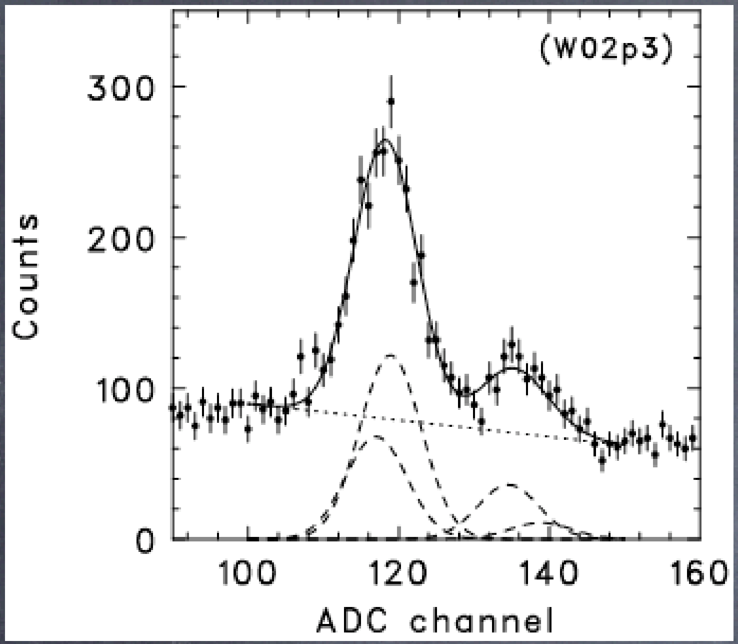
- Temperature
- Dead time
- Timing

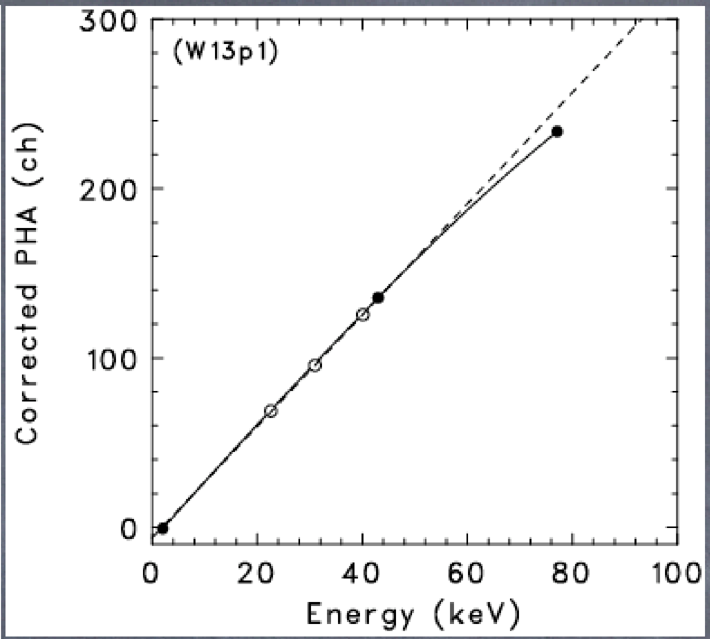
## Background

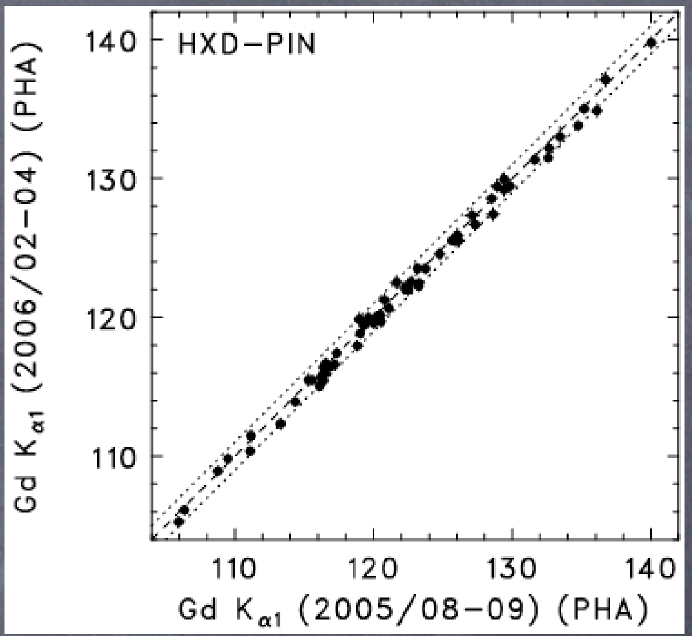
- Properties
- PIN bgd model
- GSO bgd model



# Energy scale of PIN



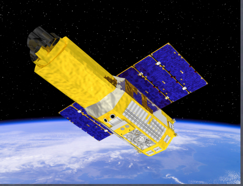




Gd-K fluorescent line in the "rejected event spectrum" can be utilized for cal.

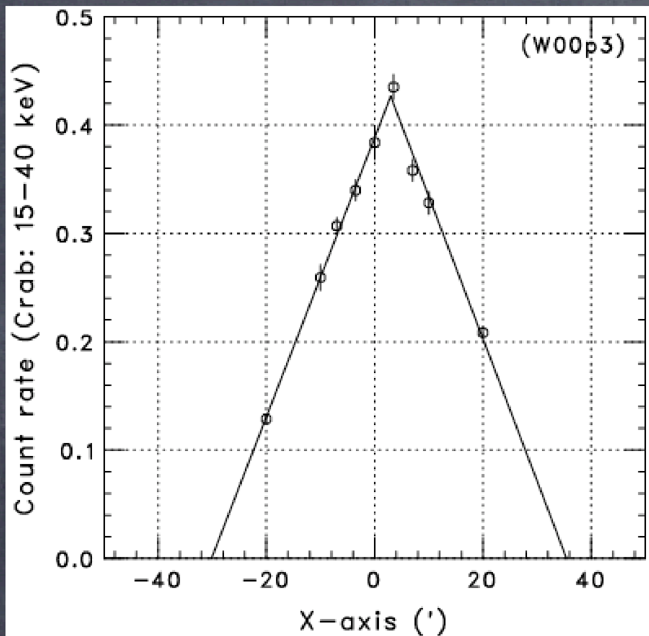
Slight non-linearity at a high energy range (Bi-K from BGO).

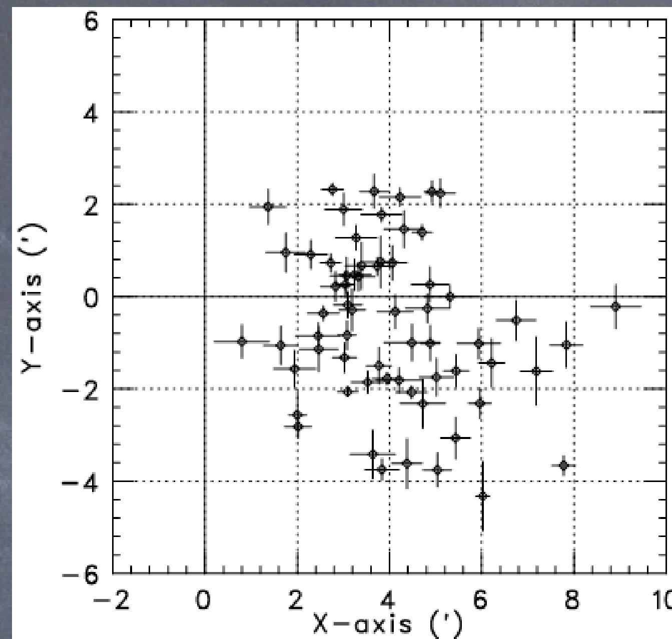
The gain of PIN is stable during a year.

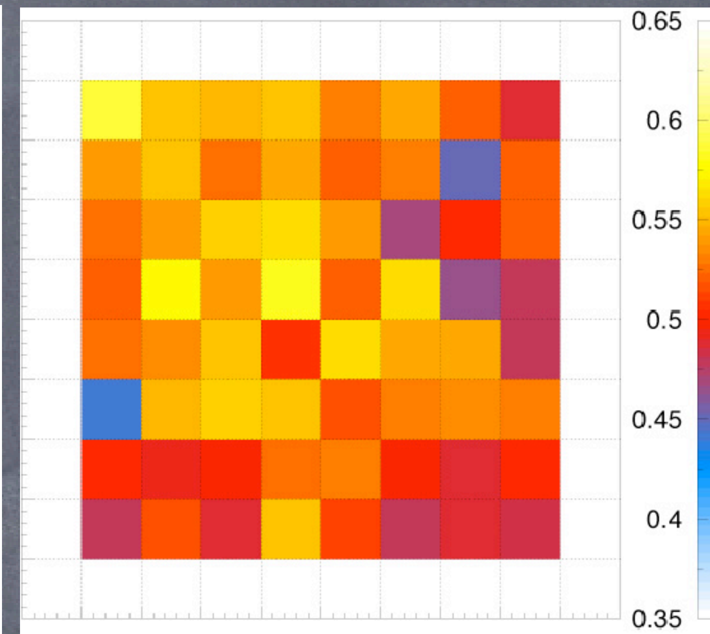
Uncertainties in the PIN energy scale is small as ~1% over the entire energy range of 7-70 keV.



# Alignment of PIN (fine collimator)

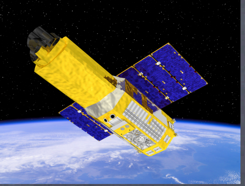


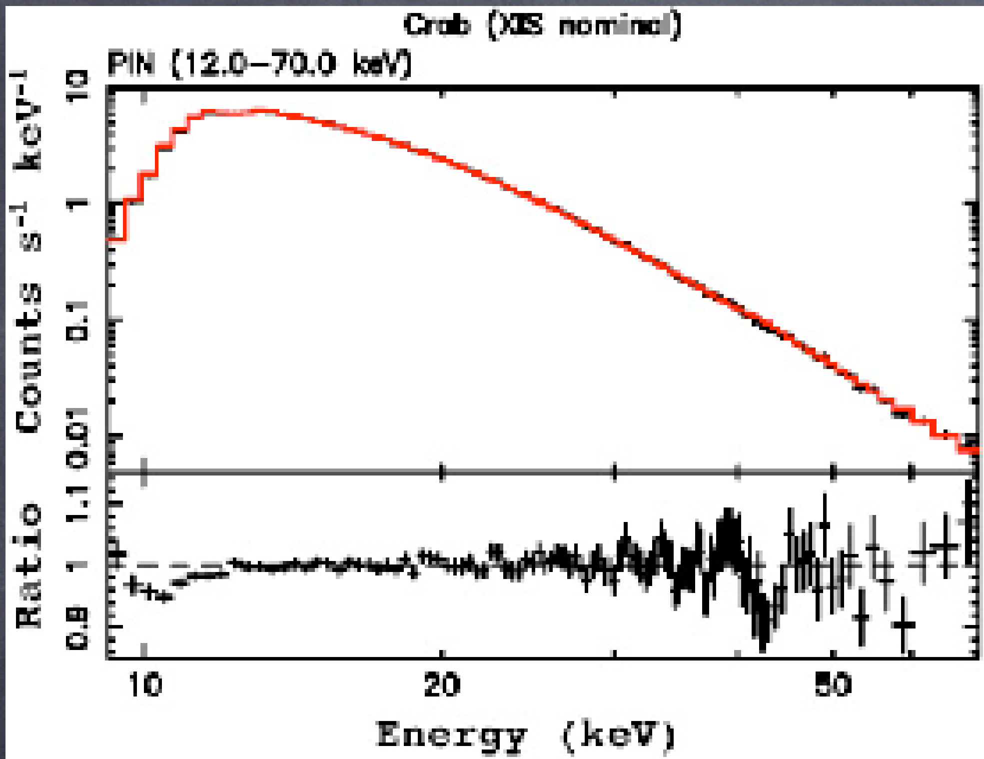

Crab flux map (15-40 keV)

Individual alignments of the 64 fine-collimators were measured with the Crab scanning (9 points for X- and Y-axis). They are aligned within 3.5′ (FWHM), while the weighted mean shows a slight offset by ~4′ in the X-direction.

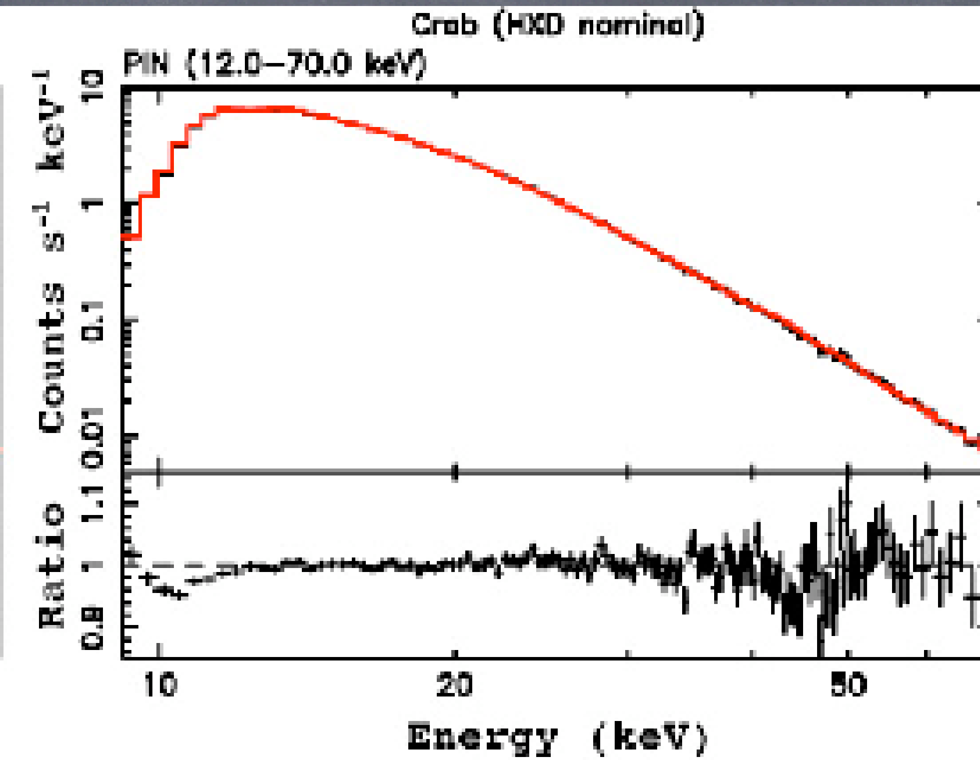


# Energy response of PIN

ae_hxd_pinxinom_20060814.fits



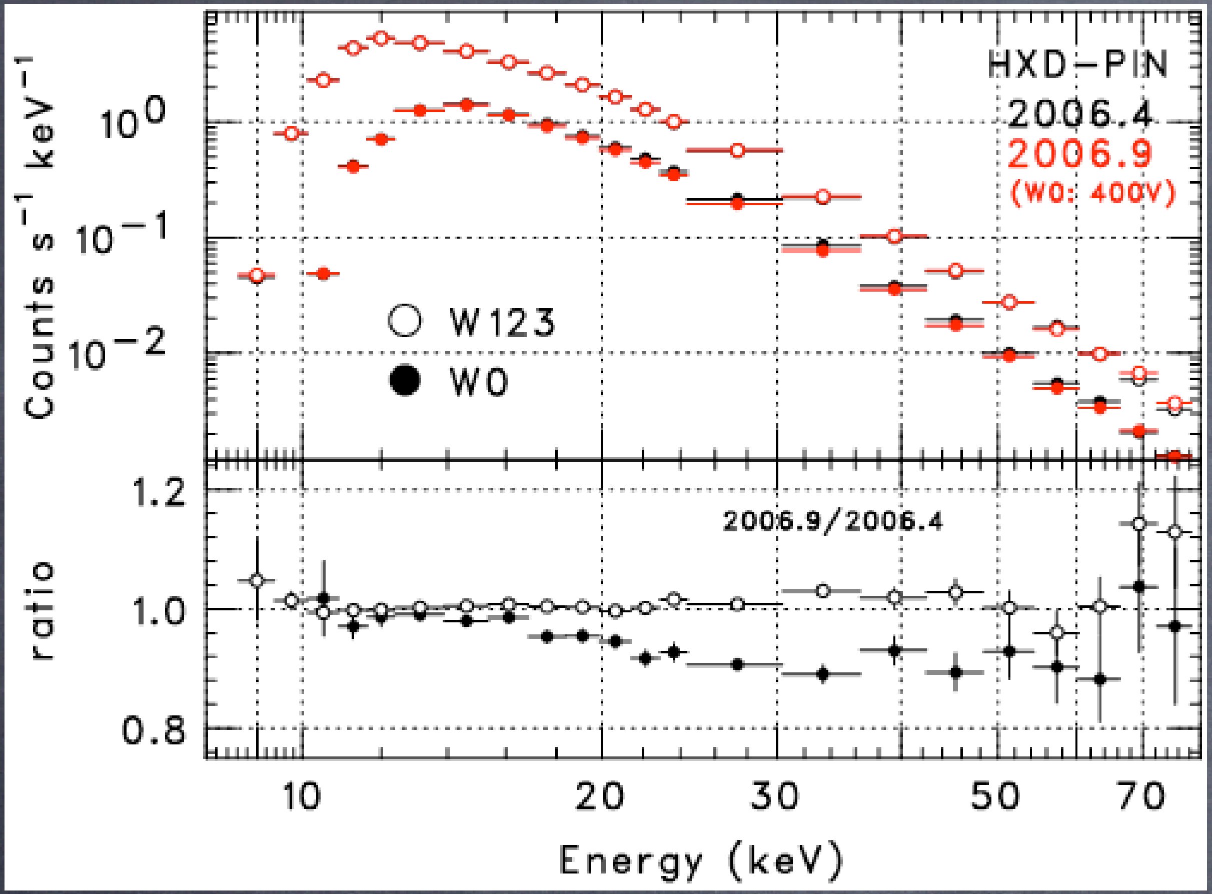

ae_hxd_pinhxnom_20060814.fits




| position | XIS nom. | HXD nom. |
| --- | --- | --- |
| index | 2.12+/-0.01 | 2.10+/-0.01 |
| norm | 11.9+/-0.1 | 11.1+/-0.1 |

The residuals of the Crab fitting resides within a few % at the energy range of 12-40 keV, while they become larger (~10%) below 12 keV. The results obtained at the XIS- and HXD-nominal positions give slightly different answers.

# Energy response of PIN @400V



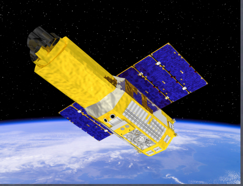

On 2006 May, one of four PIN-HV voltage was reduced down to 400 V.

2006-09-05 : XIS nominal x 40 ks

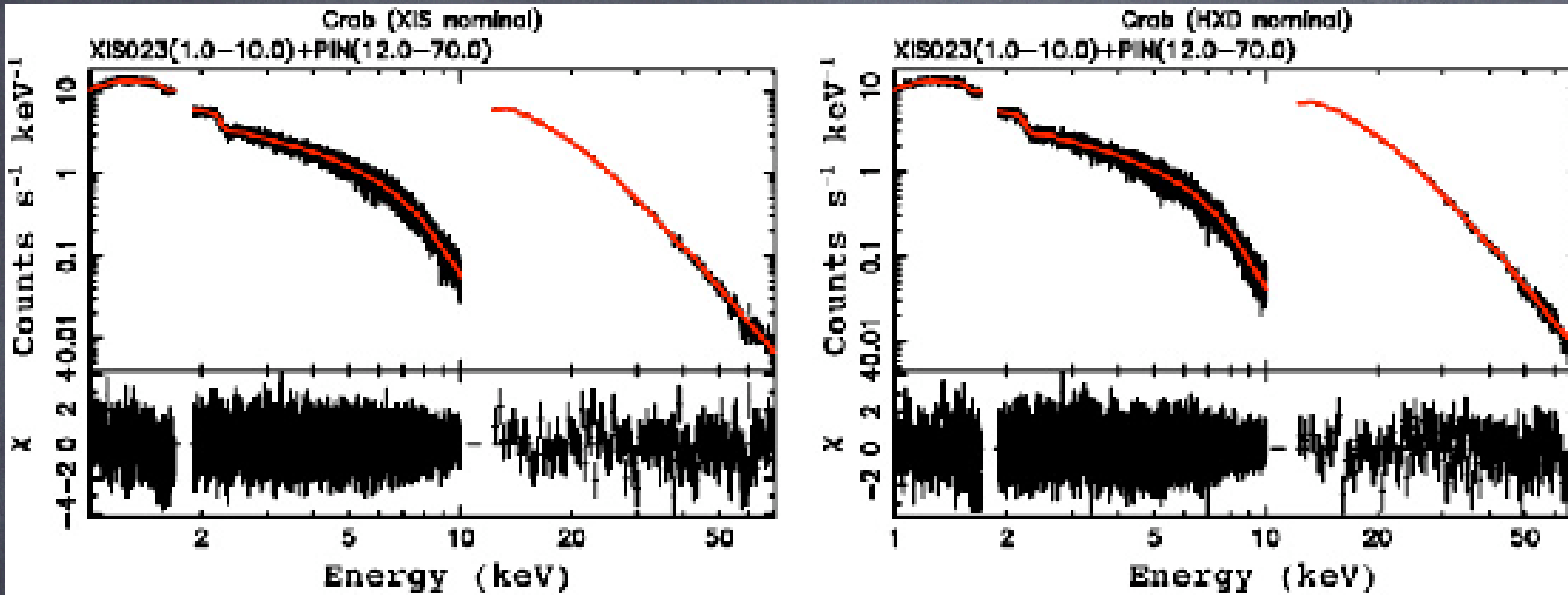
HV-P0: 400V

HV-P1,2,3: 500V

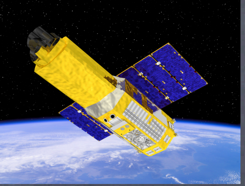
Above 20 keV, the effective area of 16 PIN diodes biased with 400 V decreased ~10% from those with 500 V, which means ~3% loss of the total effective area. The modified response matrices for "W123-only" analysis are available on the Suzaku web.



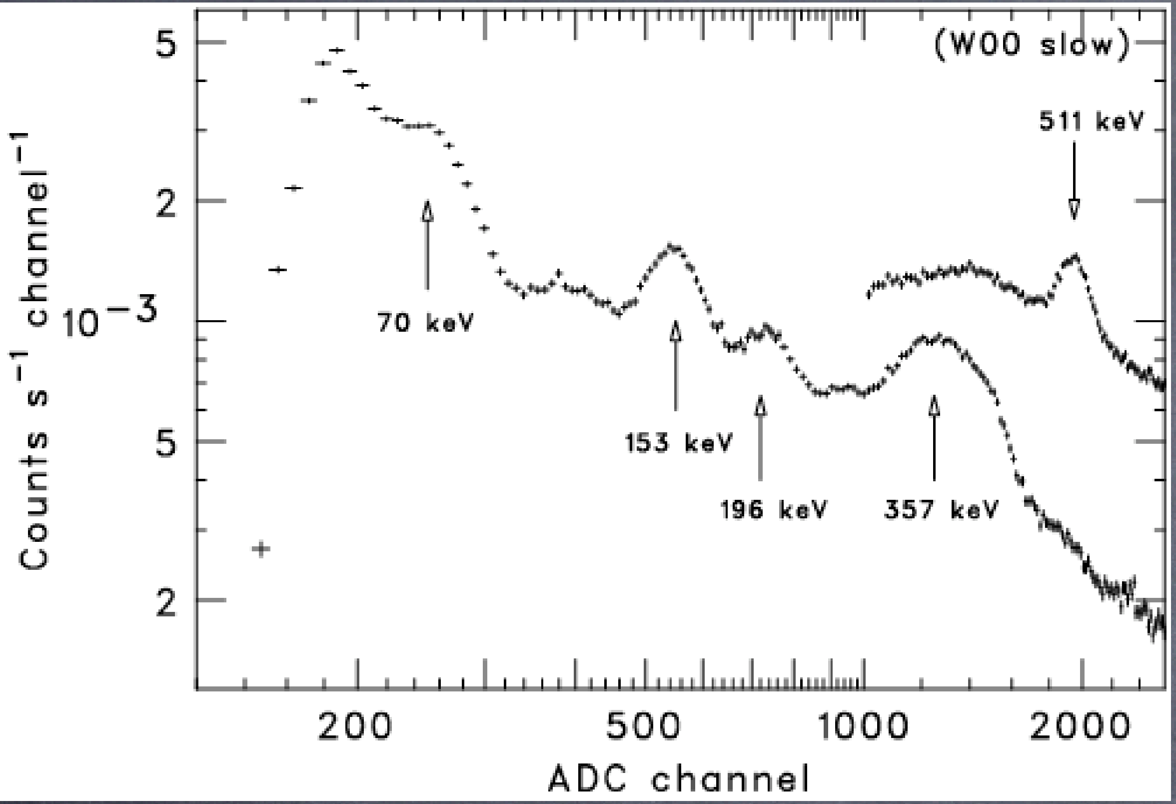
# Relative normalization to XIS

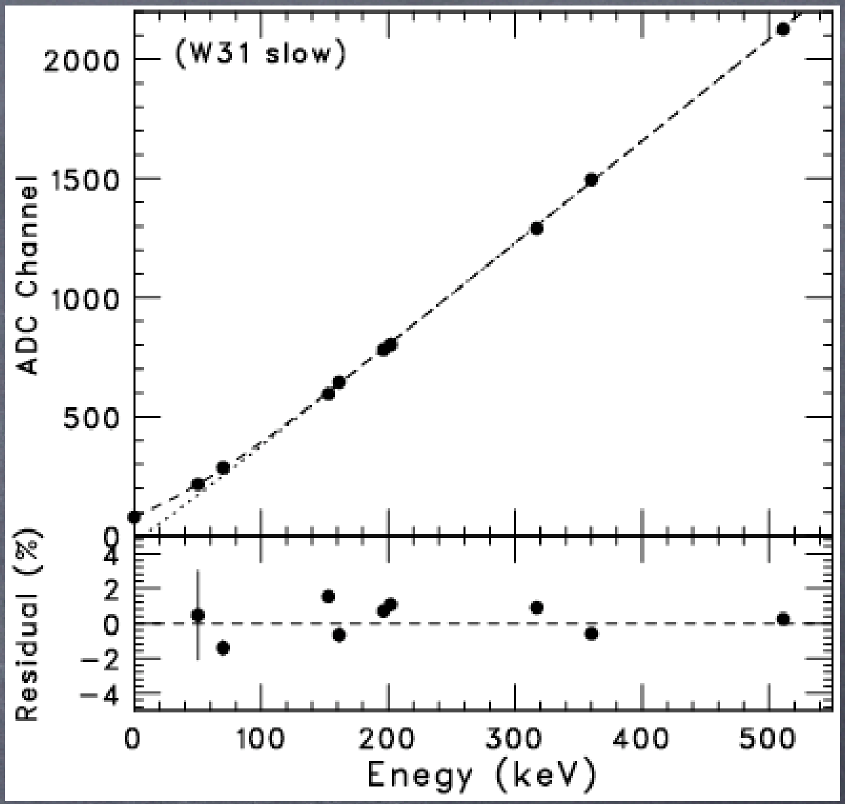



Cross-normalization factor of ~13% at XIS nominal ~15% at HXD nominal are required. The effort to improve the energy response is underway.

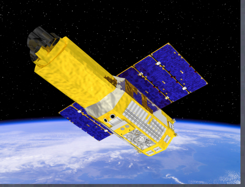


# GSO energy scale

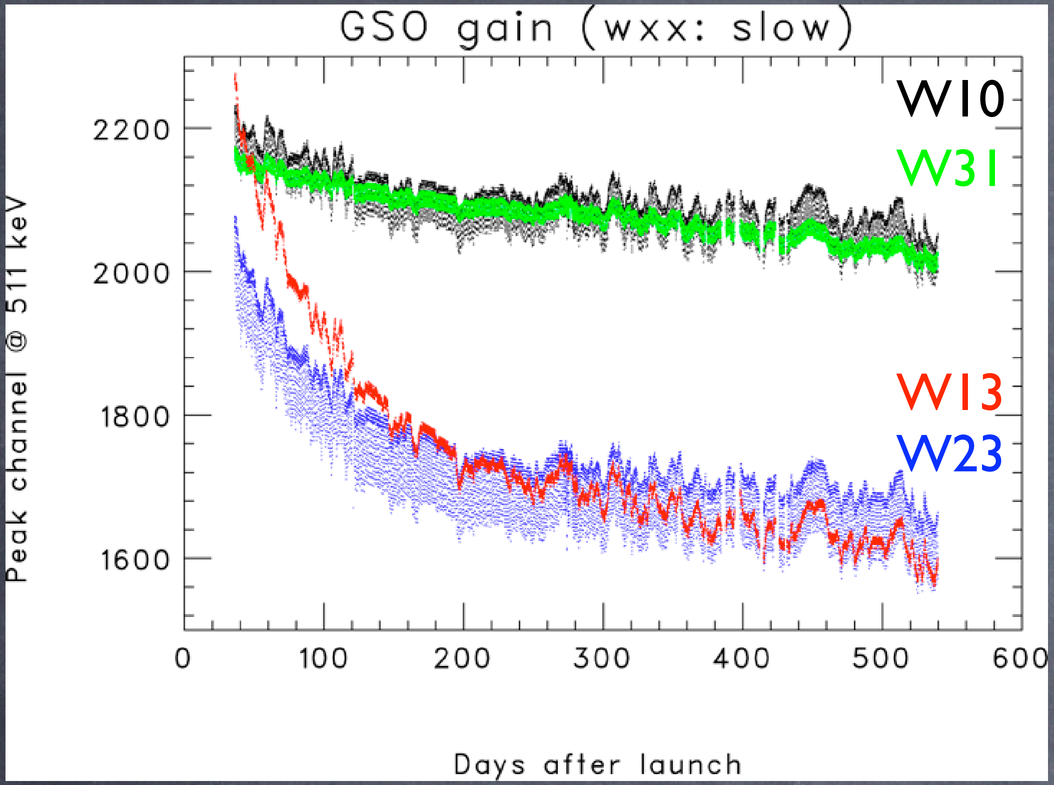


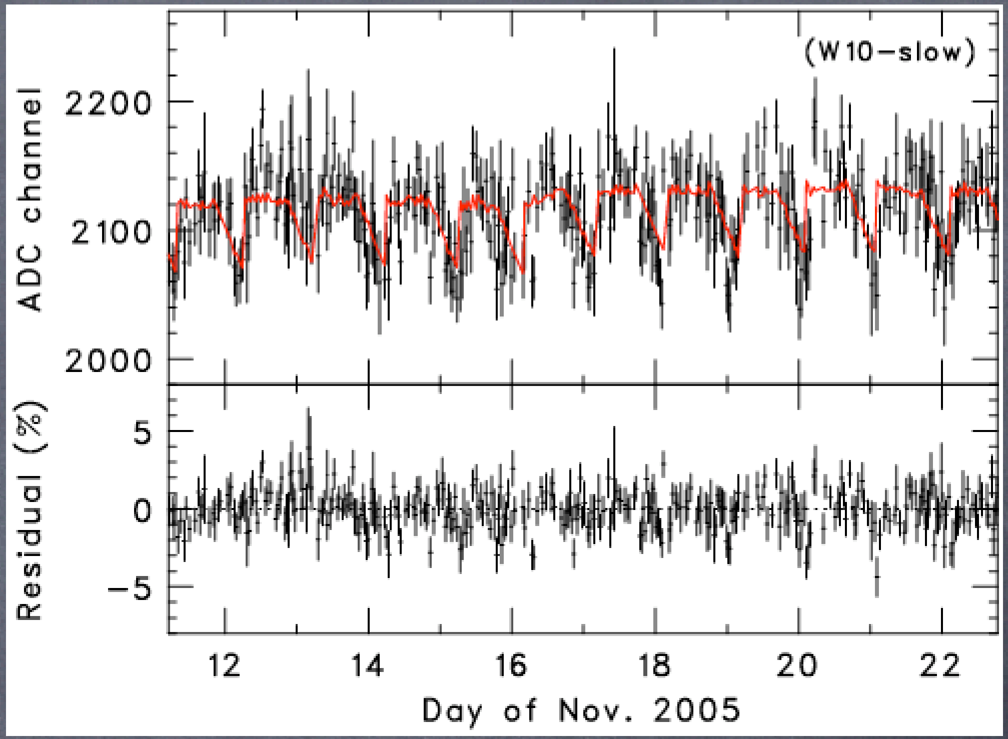




In-orbit GSO energy scale is derived by use of the EC-decay peaks in the background spectrum, together with the 511 keV line.
Since a significant non-linearity appears below 100 keV, the uncertainties become larger in this energy range.

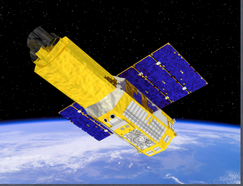


# GSO gain variation

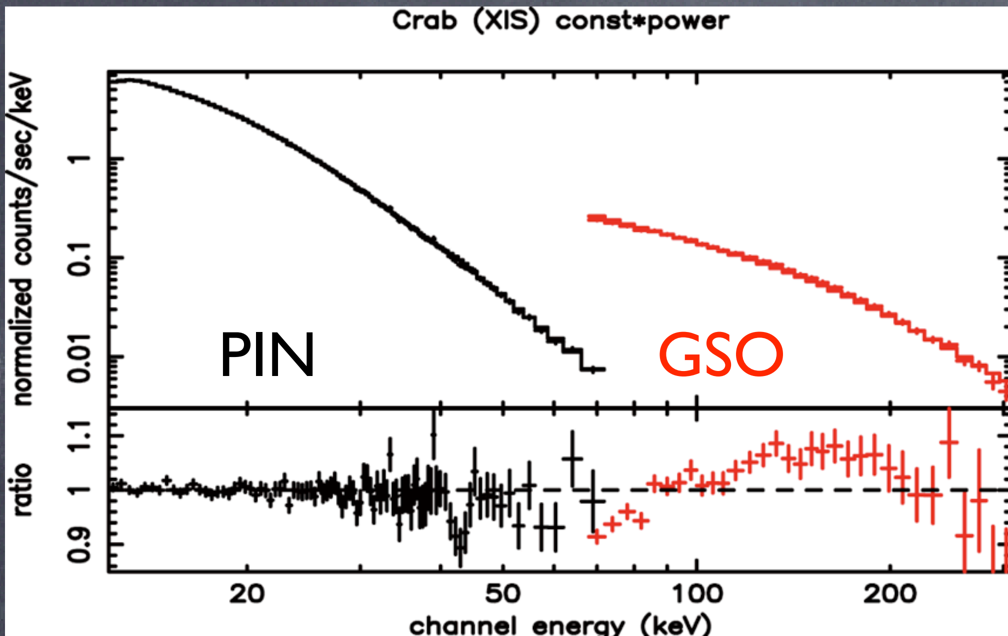


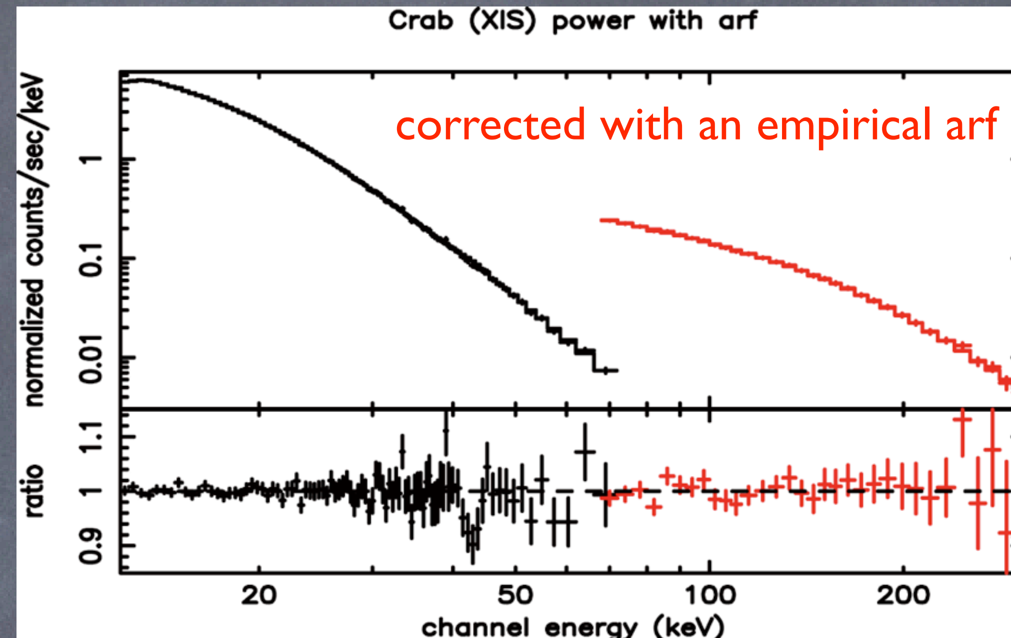




The long-term and short-term gain variations are observed.
The former is caused by the degradation of the PMT gain,
while the latter is due to both of the temperature dependence
of the GSO light-yield and aging effect in PMT gain during the SAA.



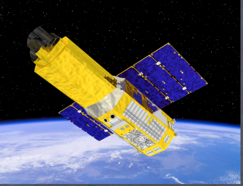
# GSO energy response



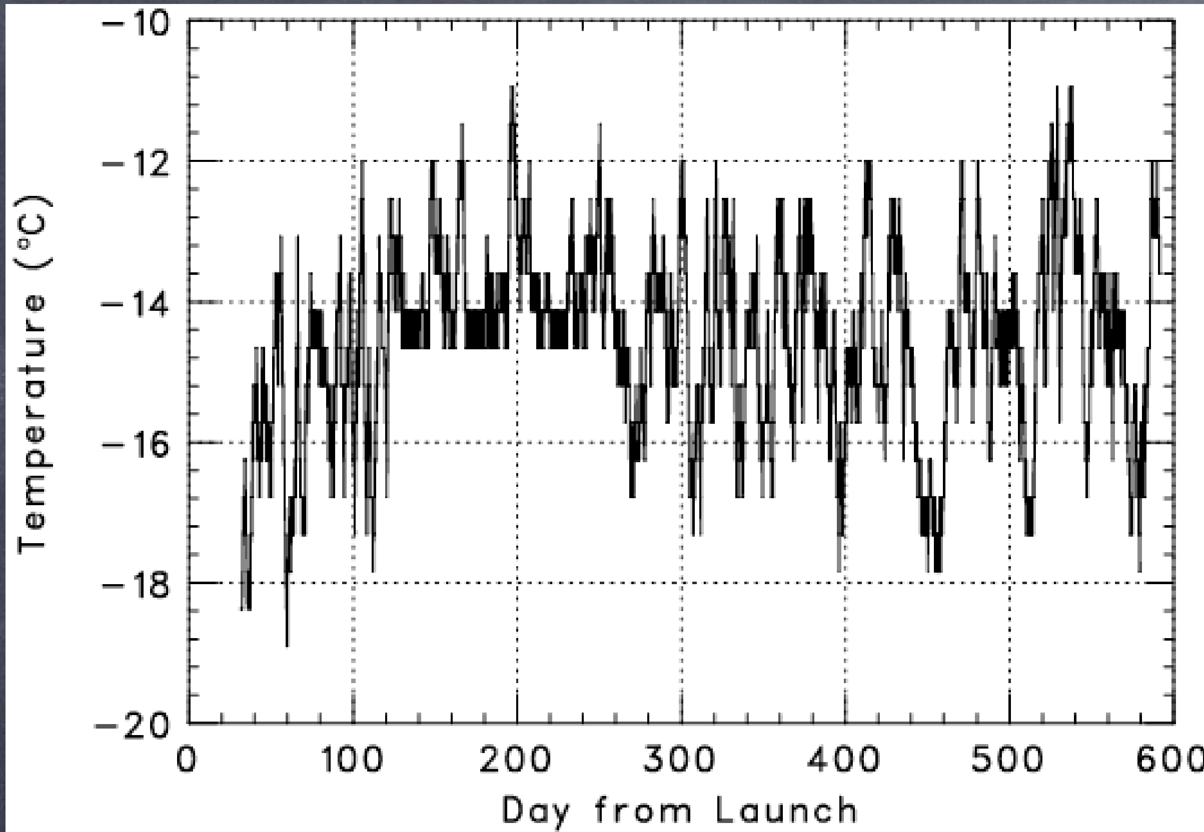




The residuals of the Crab fitting are less than 10% at 70-200 keV, but significantly larger outside that energy range. We are now investigating various parameters in the MC simulation.

As a temporal solution, the HXD team has created an empirical ARF file, which can compensate the discrepancy.



# Temperature variation




Design : -20 +/- 1 C

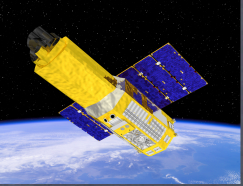
Actually : -15 +/- 3 C

Due to the failure of one of two heat-pipes

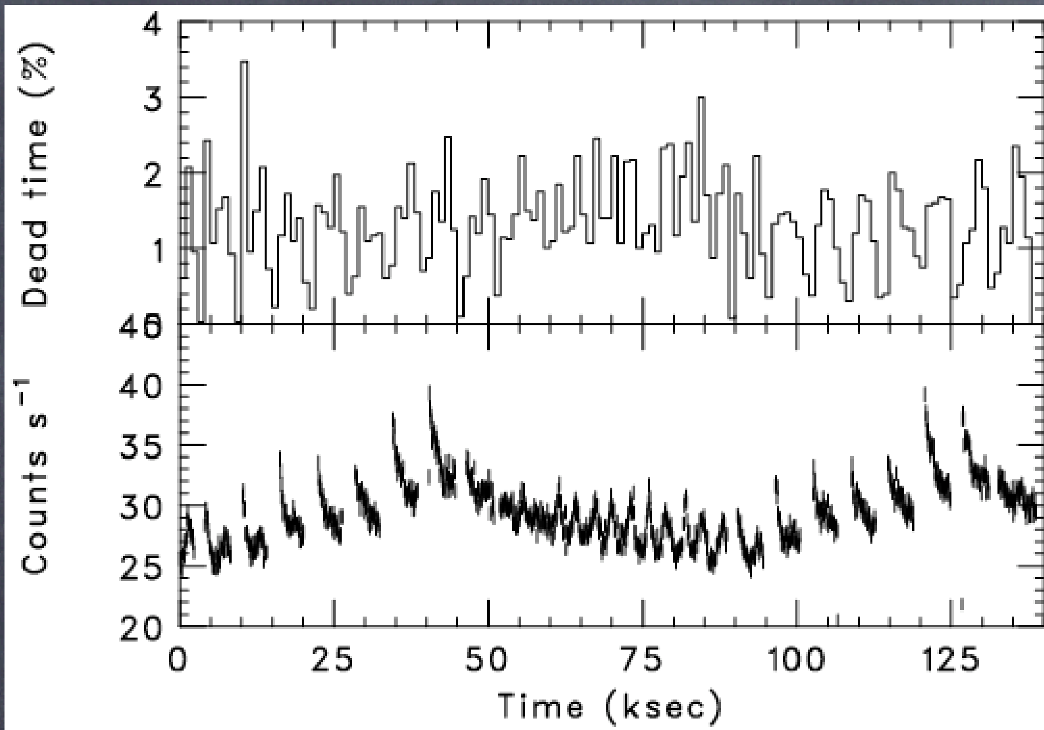
Large XRT-Sun angle (>90) raise the temperature

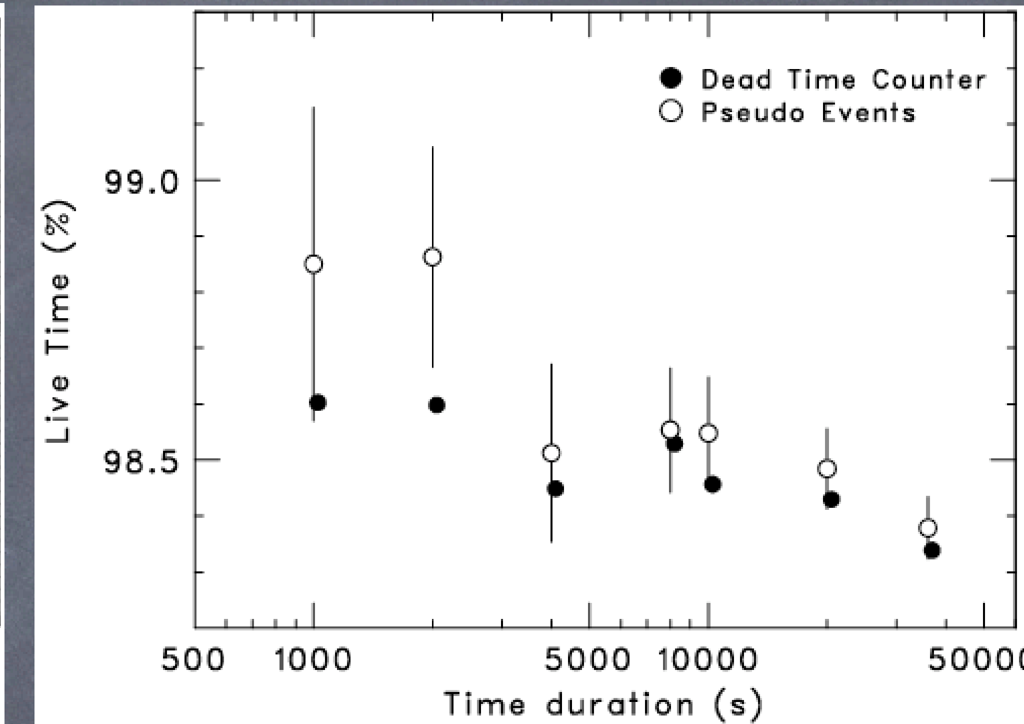
Higher temperature results in

- Higher thermal noise in PIN-Si at lower energy end (<12 keV)
- Smaller light-yield of GSO scintillators and PMT gains



# Dead time

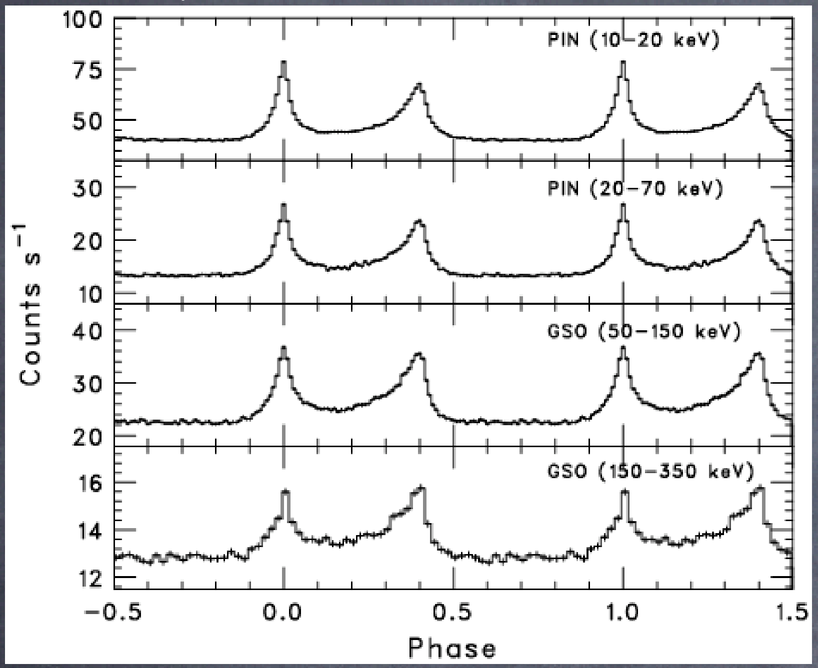


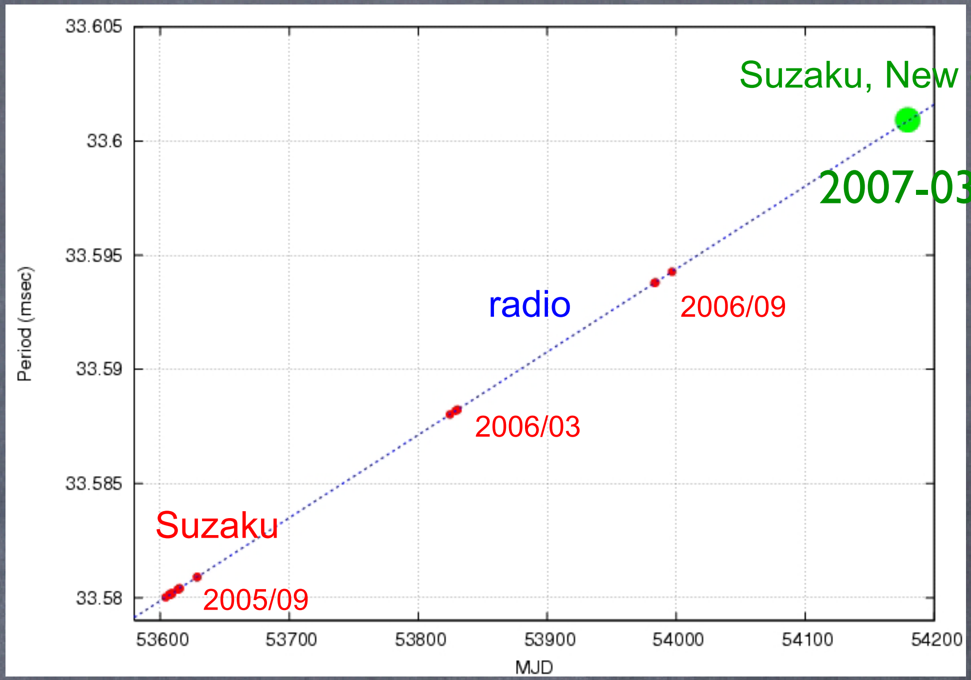




Both the dead-time in the electronics and the signal loss due to the chance coincidence can be corrected by counting "the pseudo events" which are periodically produced in the onboard electronics. The time interval when the telemetry saturation has occurred are already excluded from the GTI of cleaned event files.

# Timing accuracy

Folded light-curve of Crab pulsar (PIN/GSO)

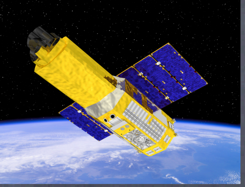


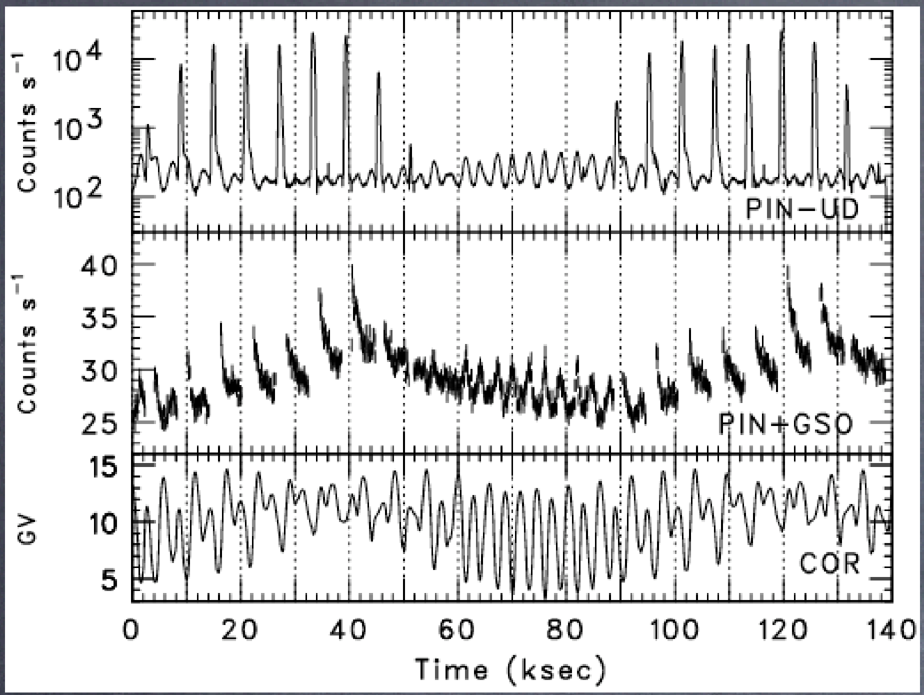

After the correction of

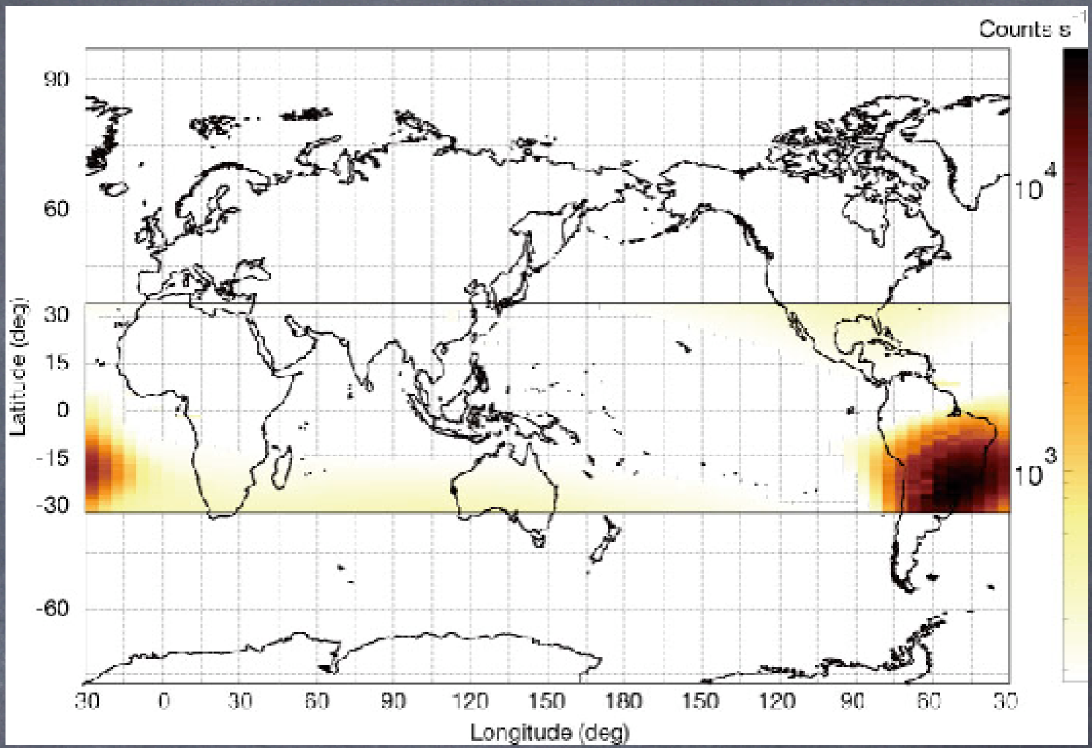
- Temperature drift of the onboard clock
- Barycentric correction

Period
consistent within $10^{-9}$ sec order
Arrival time
consistent within 200—400 usec



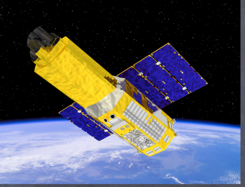
# Background properties



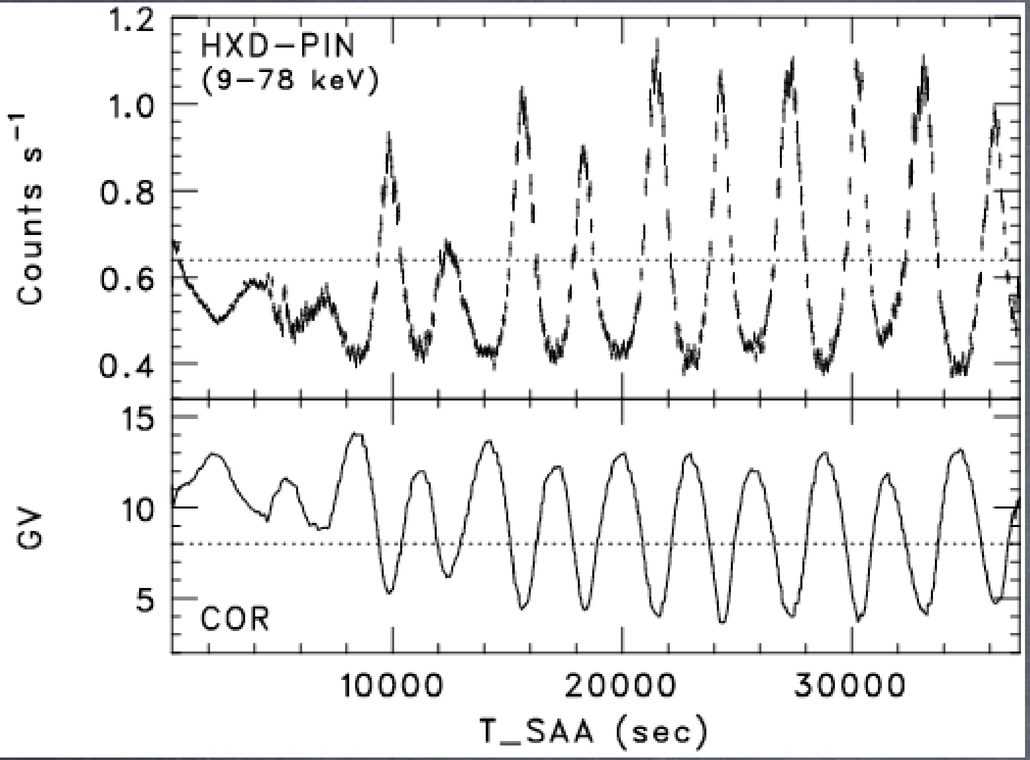



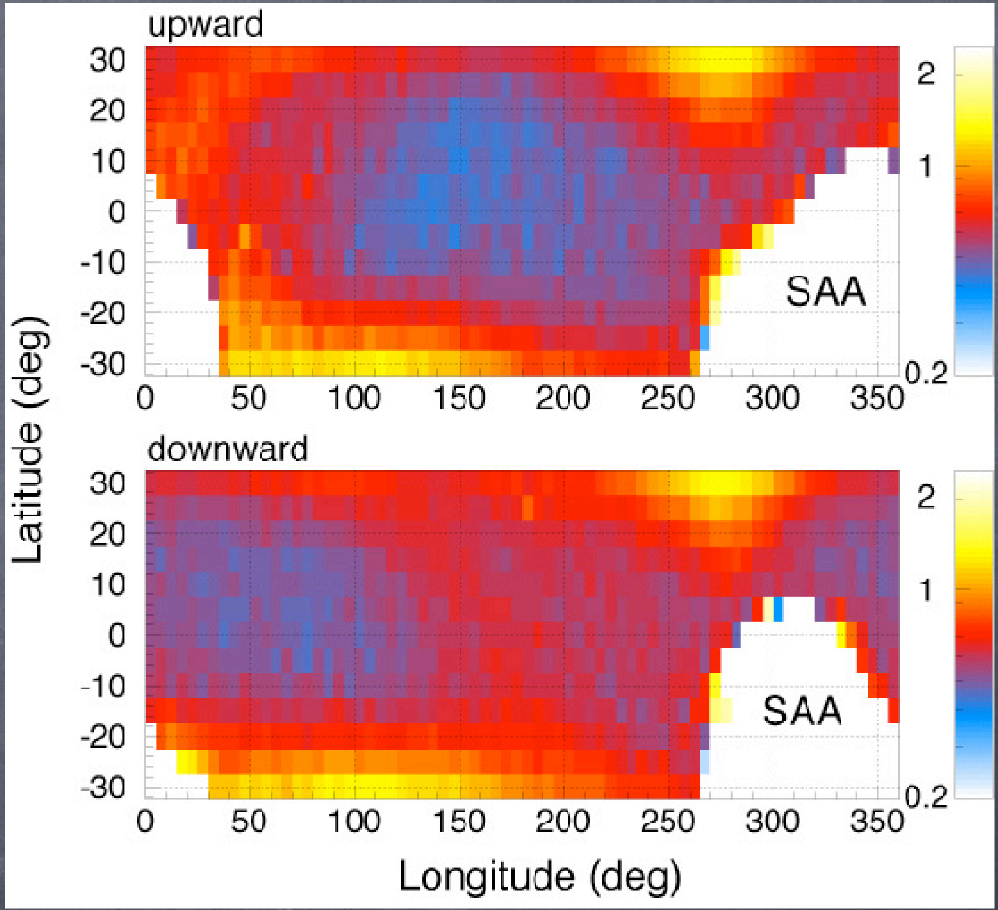

## Suzaku orbit : Alt. 580 km, 32 deg inclination

- Cosmic-ray particles with higher energy than the Cut-off rigidity
- SAA trapped protons and delayed emissions due to the activation



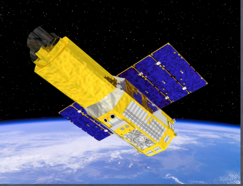
# PIN background properties



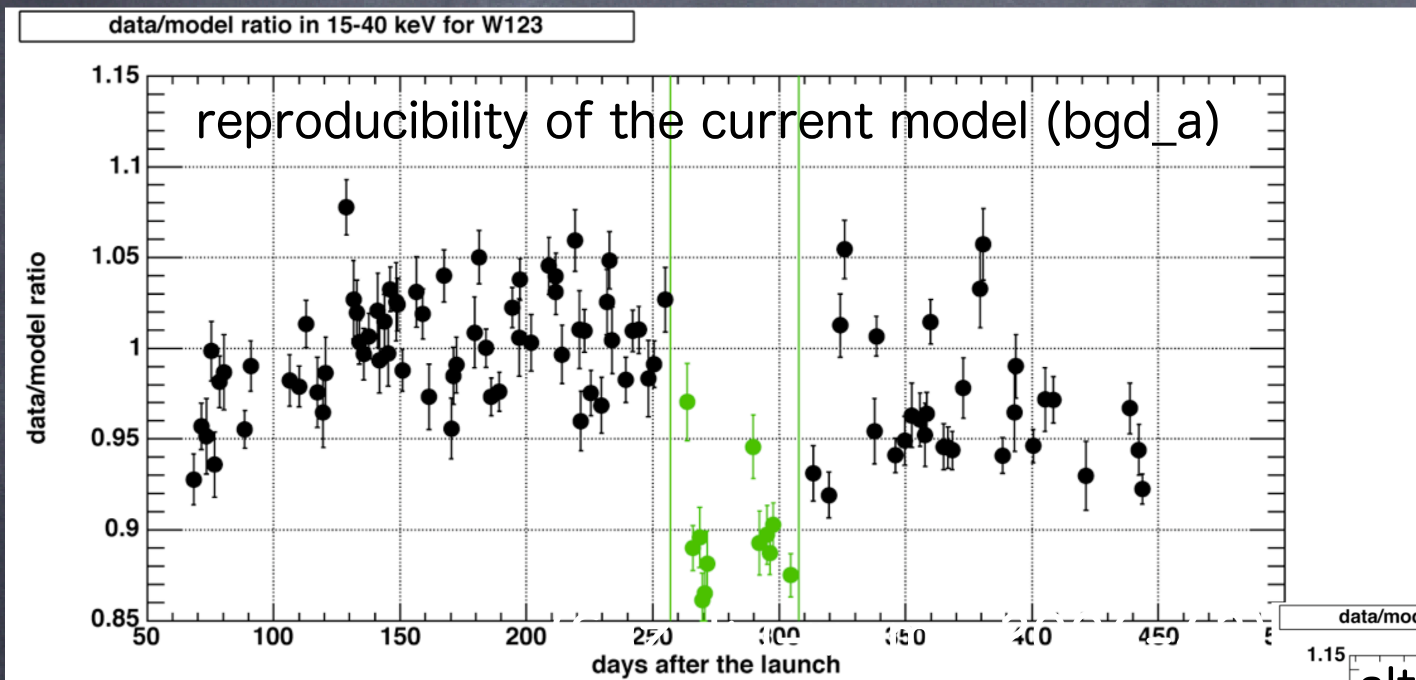

PIN background shows a strong anti-correlation with the COR, while the activation component is much less significant.

When plotted on the Earth longitude and latitude, clear enhancements appear at the low COR regions.

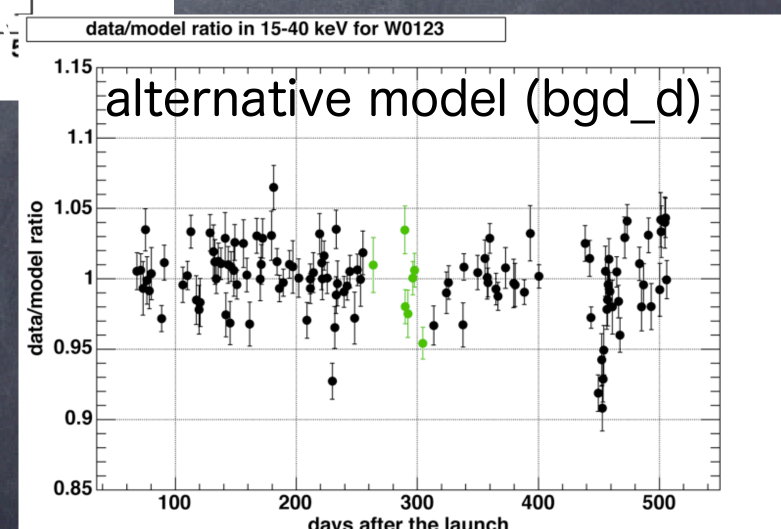


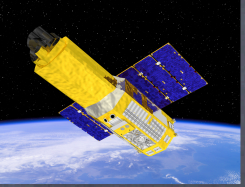
# Reproducibility of PIN bgd

PIN background model is built based on the empirical relationship between the cosmic-ray flux counted by PIN and the residual detector background, by use of the earth occultation database.




The reproducibility of the PIN background can be estimated to be smaller than 5% if the observation include the sufficient earth occultation, while some periods still show significantly large deviations.



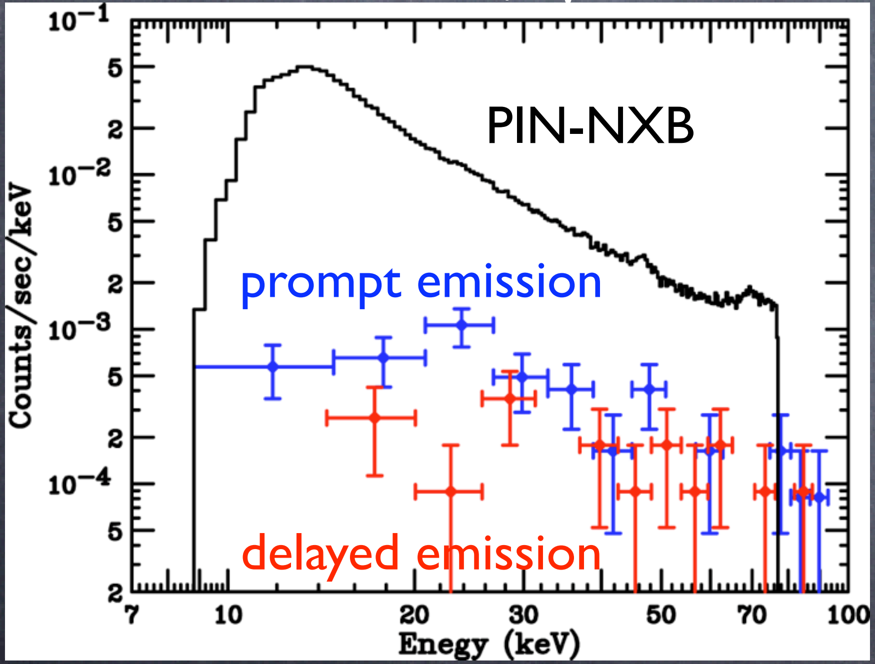


# Possible origin of PIN bgd.

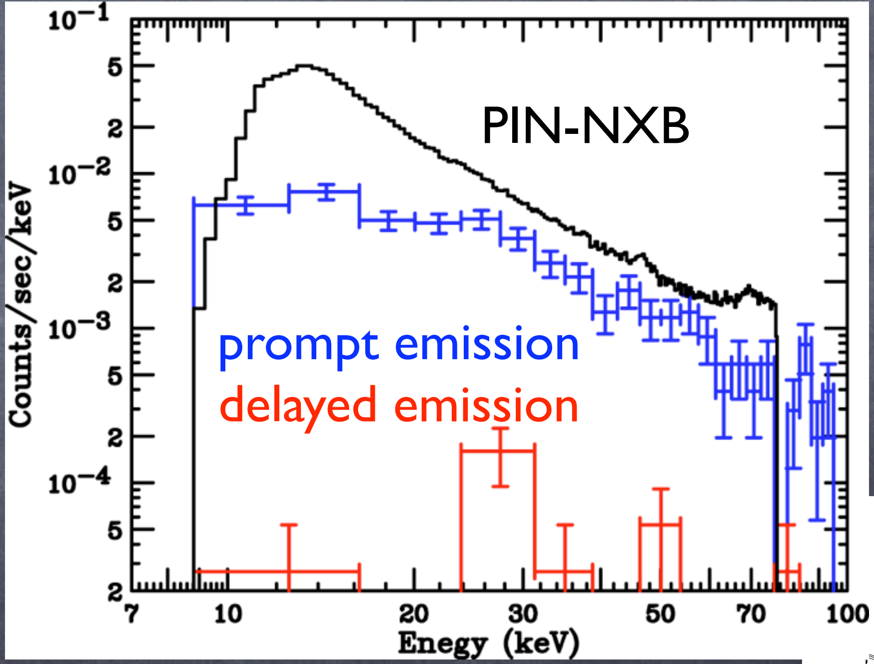
(c) T.Kitaguchi (U.Tokyo) and A.Zoglauer (UCB/SSL)

- From the MC simulation based on the MGGPOD, the atmospheric neutrons were suggested as a possible origin.

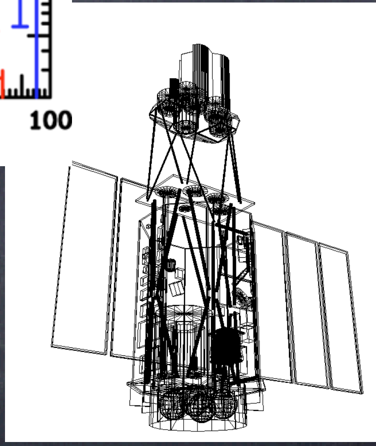
Cosmic-ray proton



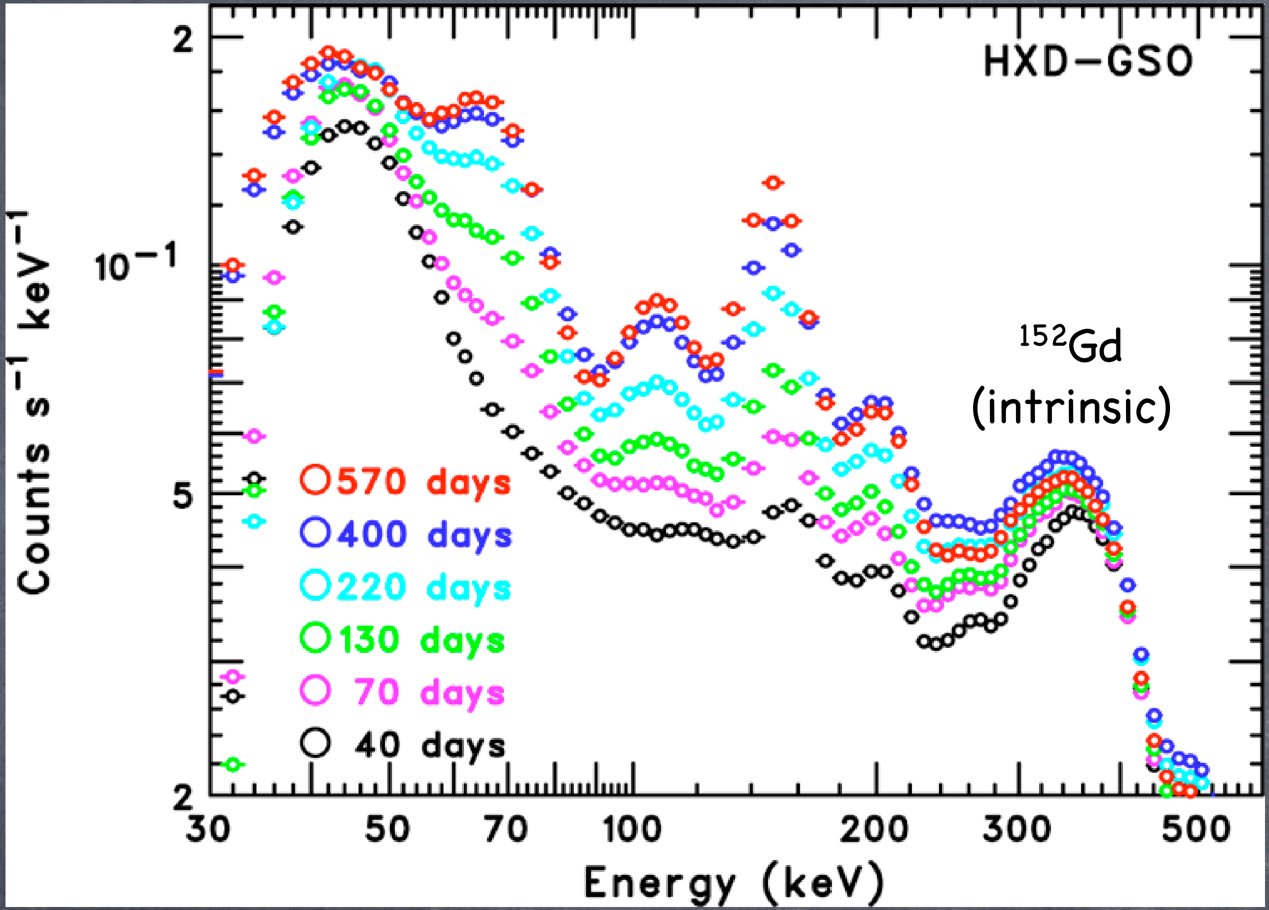

Atmospheric neutron



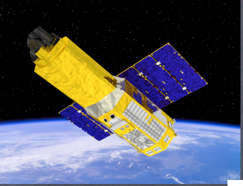

Suzaku mass-model on MGGPOD



# Long-term variation of GSO bgd.

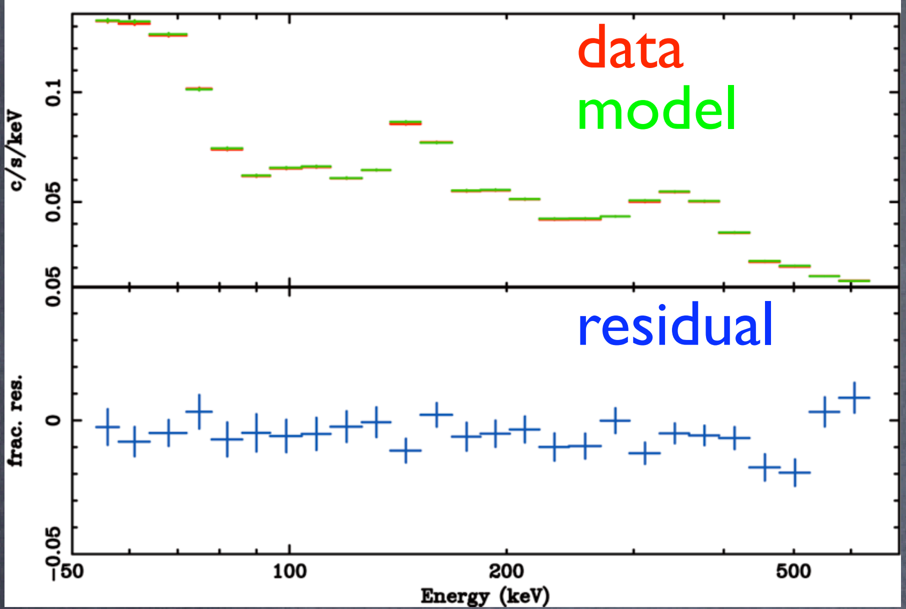


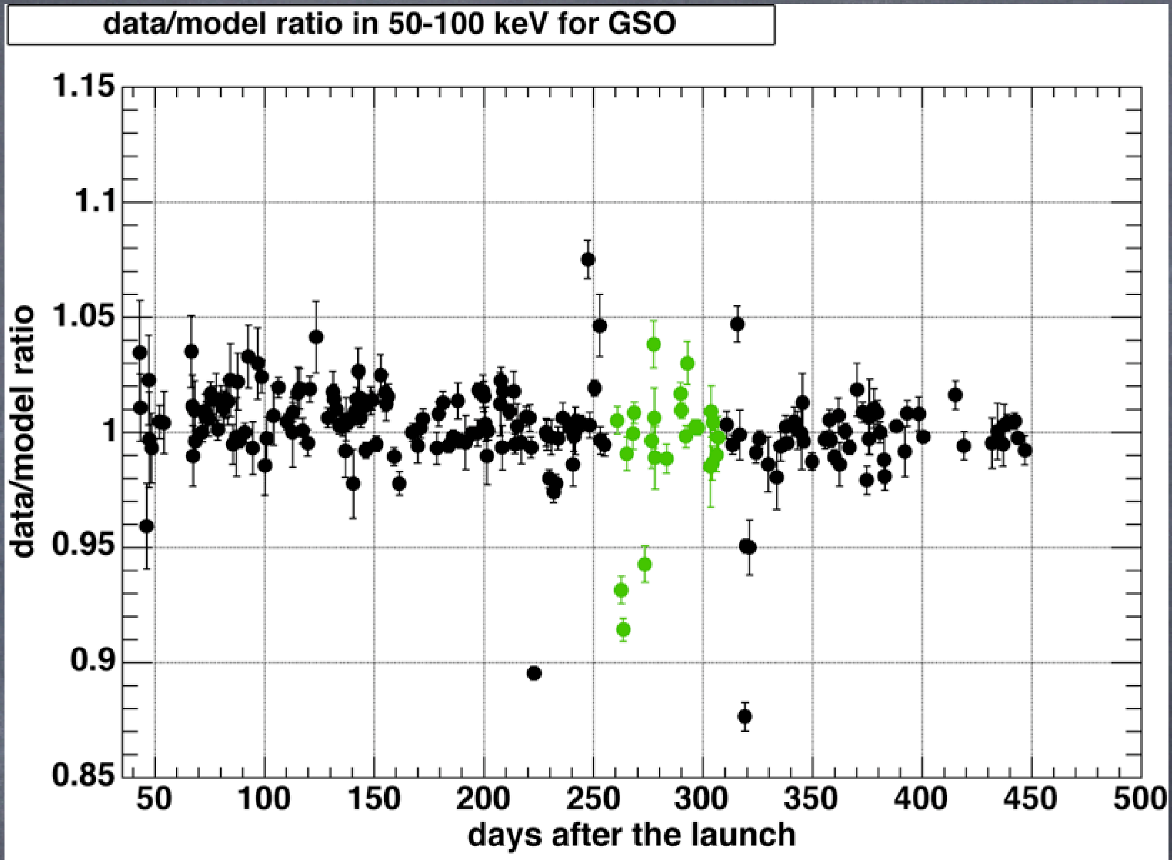

Characteristic peaks correspond the delayed emissions from RI products of the in-orbit activation. They showed rapid growths after the launch, but most of them have recently reached the equilibrium.



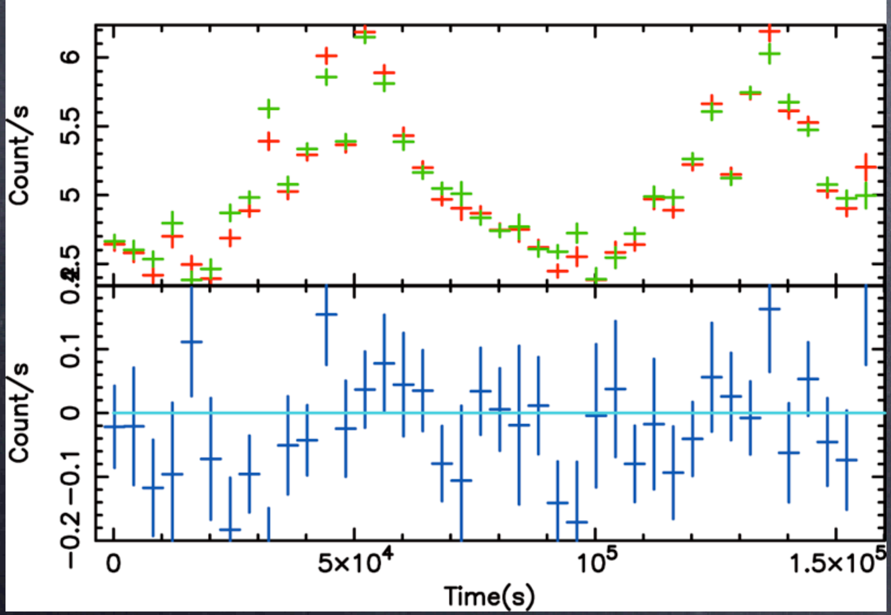
# Reproducibility of GSO bgd.

Comparison of spectrum




Comparison of light-curve




(Suzaku-memo-2006-43)

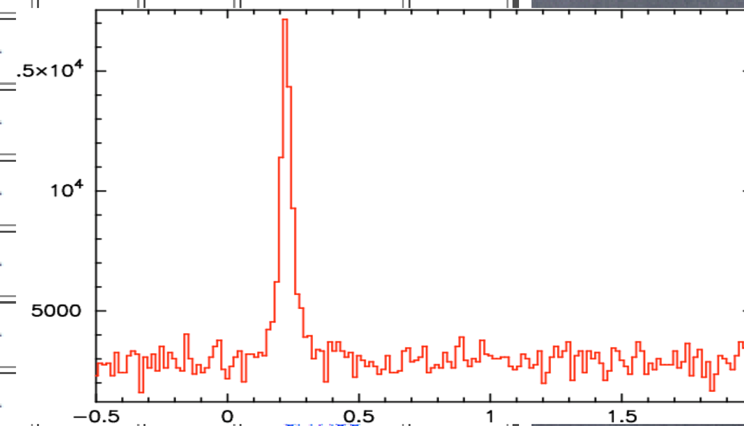
GSO background model is also built by use of the earth occultation database. Since the bgd level is much higher than PIN, sufficient photon statistics brought better reproducibility than PIN bgd.

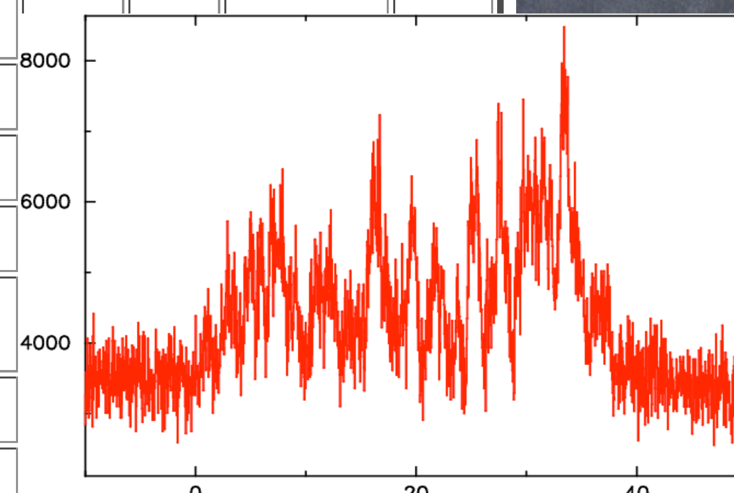
# WAM

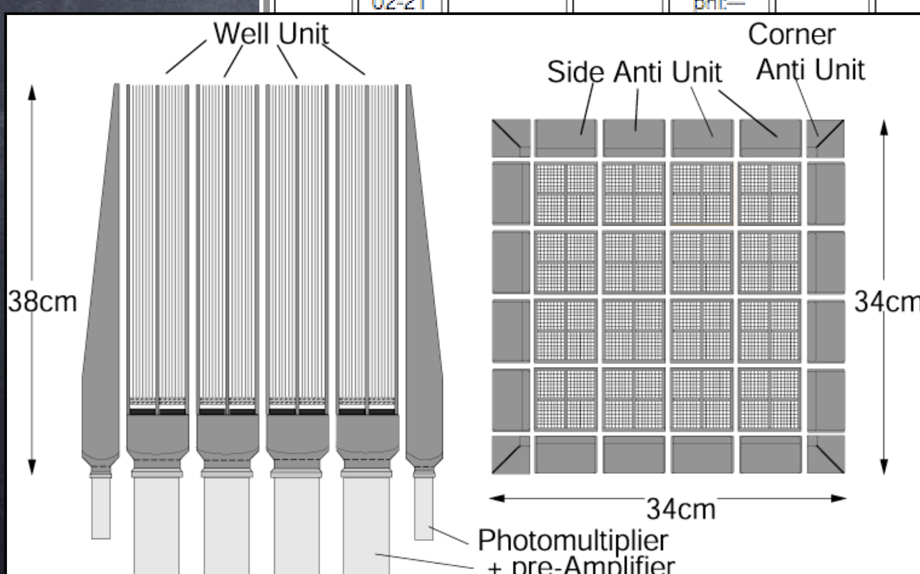
# Suzaku GRB Web

GRB Trigger Table (2007)

| Trigger No. | Date [yyyy-mm-dd] | Trigger Time UTC [hh:mm:ss] | Detector | Incident angle [degree] | Duration T90 | Fluence | Light Curves | Spectra | Download Data | GCN Circulars | Other Detections | Comment |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0590 | 2007-04-02 | 15:48:35 | 0,1,2,3 | theta:123 phi:61 | 17 | — | Click | — | Click | 6241 | Konus-Wind SPI-ACS Mars Odyssey | — |
| 0588 | 2007-03-29 | 14:59:20 | 0,2,3 | theta:— phi:— | 48 | — | Click | — | Click | — | Konus-Wind SPI-ACS | — |
| 0585 | 2007-03-28 | 03:53:46 | 0,1,2 | theta:92 phi:7 | 37 | — | Click | — | Click | — | Swift Konus-Wind | — |
| 0584 | 2007-03-26 | 00:45:24 | 0,2,3 | theta:— phi:— | 65 | — | Click | — | Click | — | SPI-ACS | — |
| 0582 | 2007-03-24 | 23:26:21 | 2 | theta:— phi:— | 9.5 | — | Click | — | Click | — | Konus-Wind | — |
| 0580 | 2007-03-21 | 18:52:15 | 2 | theta:— phi:— | 0.34 | — | Click | — | | | | |
| 0578 | 2007-03-18 | 07:28:56 | 0,1 | theta:101 phi:47 | 47 | — | Click | — | | | | |
| 0577 | 2007-03-11 | 20:51:49 | 3 | theta:— phi:— | 57 | — | Click | — | | | | |
| 0571 | 2007-03-05 | 00:11:32 | 0,3 | theta:— phi:— | 5.5 | — | Click | — | | | | |
| 0566 | 2007-02-27 | 21:39:24 | 1,2 | theta:— phi:— | 20 | — | Click | — | | | | |
| 0562 | 2007-02-21 | 21:06:45 | 2 | theta:— phi:— | 9.2 | — | Click | — | | | | |
| | | | | | | | Click | — | | | | |
| | | | | | | | Click | — | | | | |
| | | | | | | | Click | — | | | | |
| | | | | | | | Click | — | | | | |
| | | | | | | | Click | — | | | | |
| | | | | | | | Click | — | | | | |
| | | | | | | | Click | — | | | | |
| | 01-07 | | | phi:178 | | | Click | — | Click | 6016 | Swift | — |



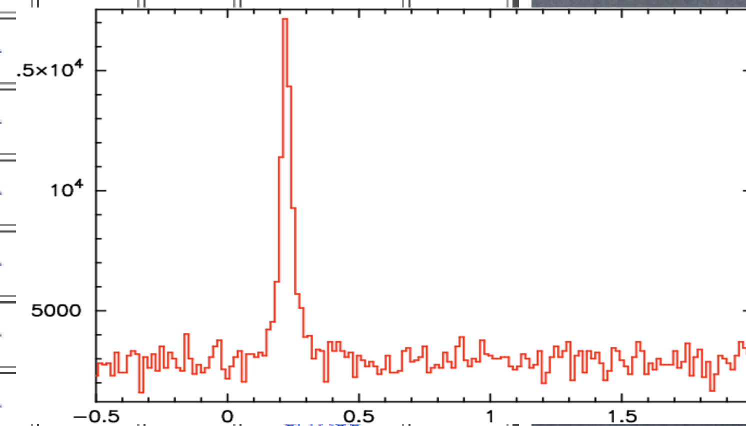



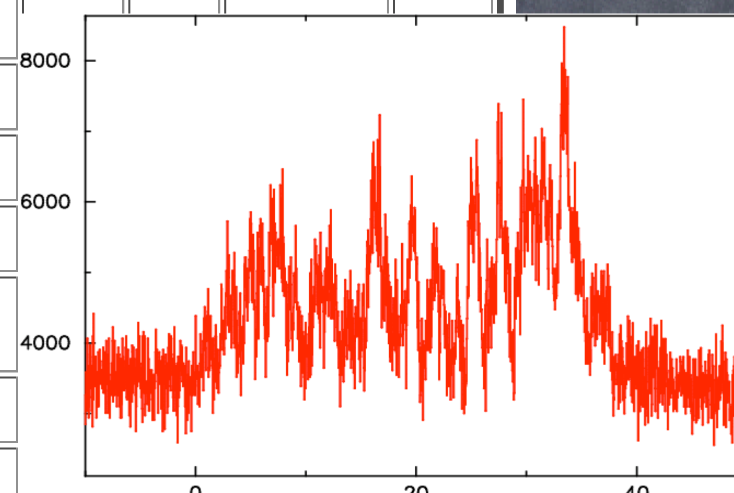
# WAM

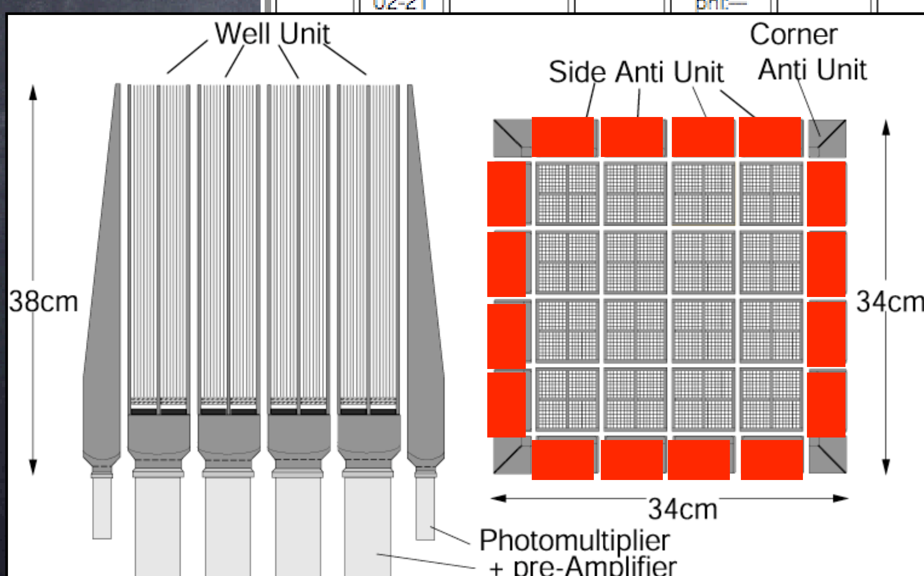
Suzaku GRB Web

GRB Trigger Table (2007)

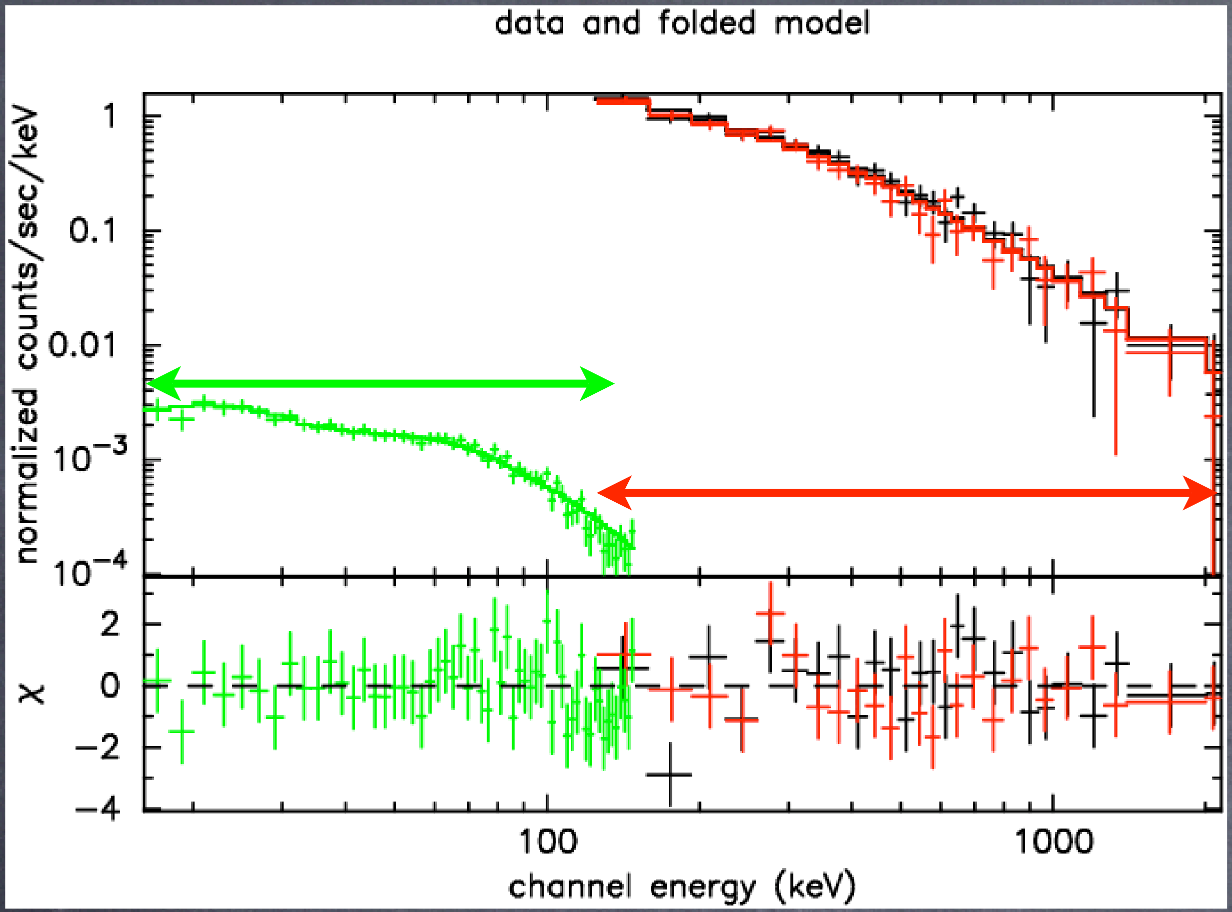
| Trigger No. | Date [yyyy-mm-dd] | Trigger Time UTC [hh:mm:ss] | Detector | Incident angle [degree] | Duration T90 | Fluence | Light Curves | Spectra | Download Data | GCN Circulars | Other Detections | Comment |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0590 | 2007-04-02 | 15:48:35 | 0,1,2,3 | theta:123 phi:61 | 17 | — | Click | — | Click | 6241 | Konus-Wind SPI-ACS Mars Odyssey | — |
| 0588 | 2007-03-29 | 14:59:20 | 0,2,3 | theta:— phi:— | 48 | — | Click | — | Click | — | Konus-Wind SPI-ACS | — |
| 0585 | 2007-03-28 | 03:53:46 | 0,1,2 | theta:92 phi:7 | 37 | — | Click | — | Click | — | Swift Konus-Wind | — |
| 0584 | 2007-03-26 | 00:45:24 | 0,2,3 | theta:— phi:— | 65 | — | Click | — | Click | — | SPI-ACS | — |
| 0582 | 2007-03-24 | 23:26:21 | 2 | theta:— phi:— | 9.5 | — | Click | — | Click | — | Konus-Wind | — |
| 0580 | 2007-03-21 | 18:52:15 | 2 | theta:— phi:— | 0.34 | — | Click | — | | | | |
| 0578 | 2007-03-18 | 07:28:56 | 0,1 | theta:101 phi:47 | 47 | — | Click | — | | | | |
| 0577 | 2007-03-11 | 20:51:49 | 3 | theta:— phi:— | 57 | — | Click | — | | | | |
| 0571 | 2007-03-05 | 00:11:32 | 0,3 | theta:— phi:— | 5.5 | — | Click | — | | | | |
| 0566 | 2007-02-27 | 21:39:24 | 1,2 | theta:— phi:— | 20 | — | Click | — | | | | |
| 0562 | 2007-02-21 | 21:06:45 | 2 | theta:— phi:— | 9.2 | — | Click | — | | | | |
| | | | | | | | Click | — | | | | |
| | | | | | | | Click | — | | | | |
| | | | | | | | Click | — | | | | |
| | | | | | | | Click | — | | | | |
| | | | | | | | Click | — | | | | |
| | | | | | | | Click | — | | | | |
| | | | | | | | Click | — | | | | |
| | 01-07 | | | phi:178 | | | Click | — | Click | 6016 | Swift | — |

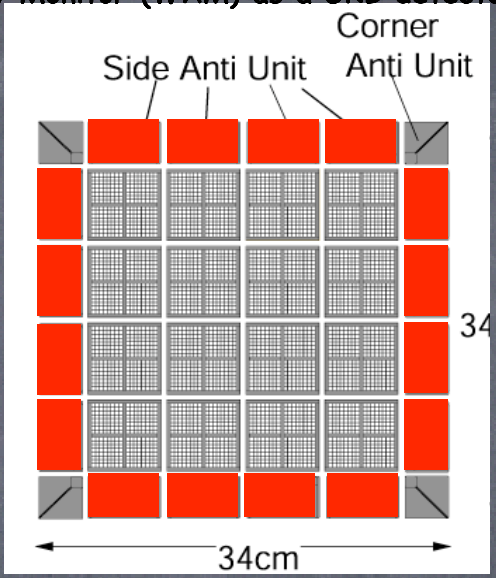


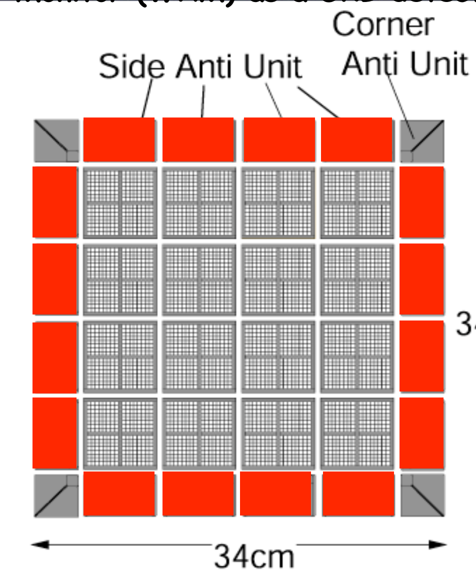
Wide-band All-sky Monitor (WAM) as a GRB detector

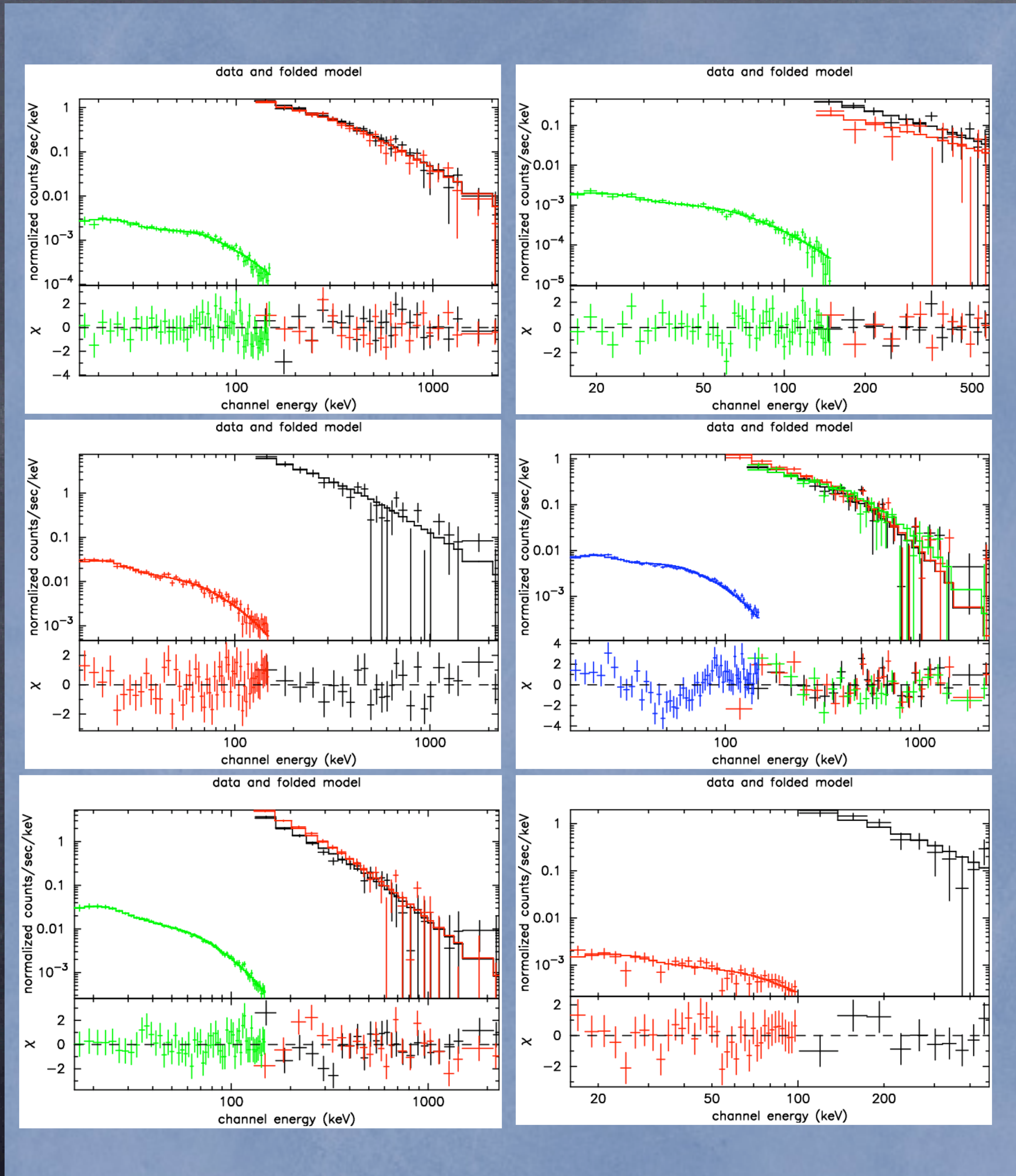



Suzaku/WAM +Swift/BAT
+Konus-Wind
© Ohno and cross cal. collab.

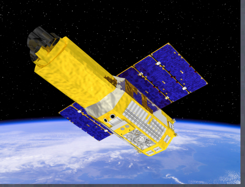
## Wide-band All-sky Monitor (WAM) as a GRB detector




| | Z | Epeak (keV) |
|---|---|---|
| 050904 | 6.29 | 1180 |
| 051111 | 1.55 | 670 |
| 051221A | 0.54 | 333 |
| 060124 | 2.30 | 992 |
| 060502A | 1.51 | 376 |
| 061007 | 1.26 | 1350 |

Suzaku/WAM +Swift/BAT
+Konus-Wind
© Ohno and cross cal. collab.



# Summary