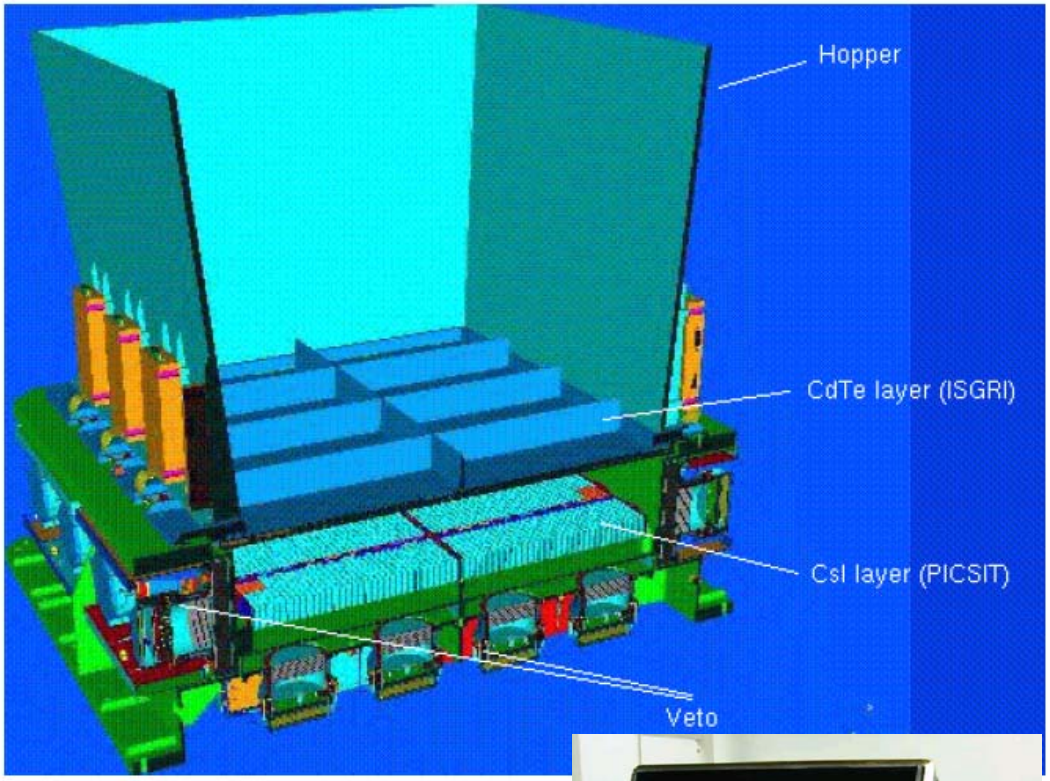
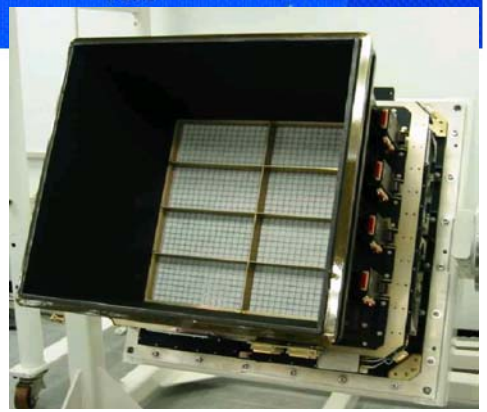
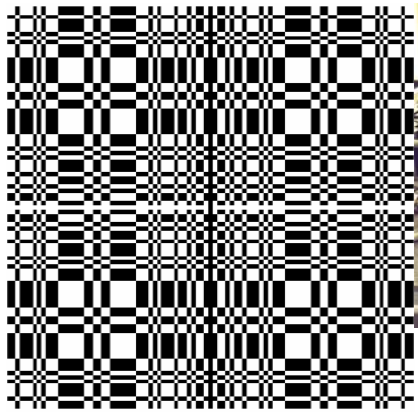
INTEGRAL/IBIS In flight Calibration



IBIS detector assembly





coded mask, placed 3.2m from detector (1m^2)

Collection area ~ 3000 cm^2

Bi-Layer pixellated detector. Thickness: 2mm CdTe + 30mm CsI

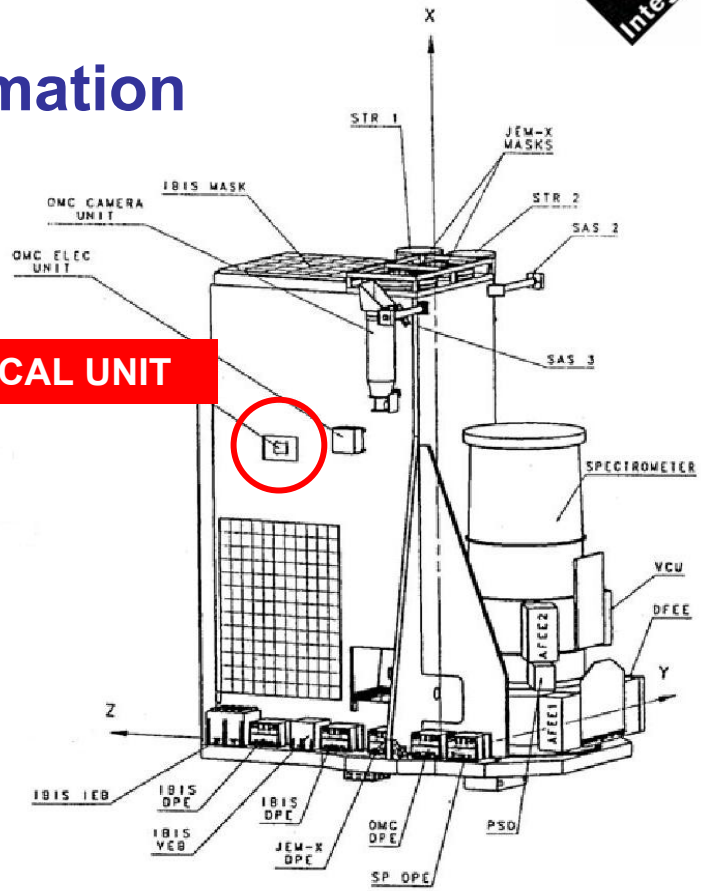
Field-of-view: ±14.5° @zero-response (± 4.5° fully coded)

IBIS Calibration information

In flight continuous calibration by:

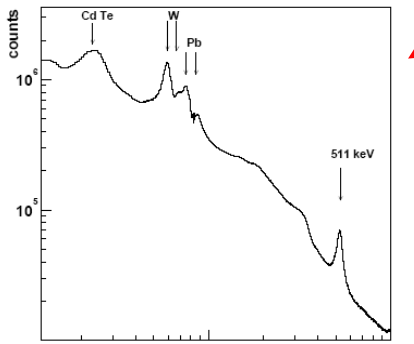
- **on-board calibration source, placed ~1.9m from detector plane**

ON BOARD CAL UNIT



Na^{22} source (lines at 1275 and 511 keV), events are tagged and telemetered as separate data mode

- **tungsten and lead fluorescence lines, plus 511 keV line produced by passive shielding and untagged calibration events,**



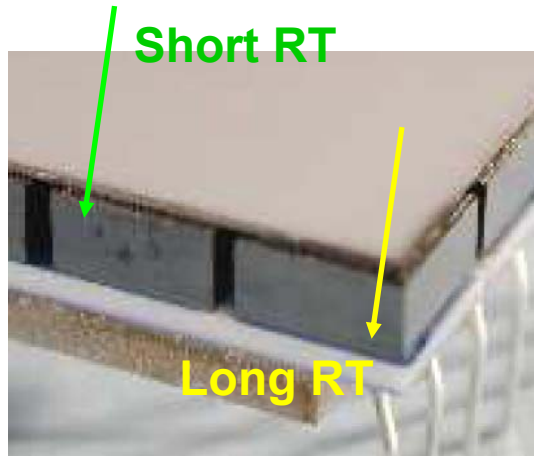
(Terrier et al., A&A 2003)

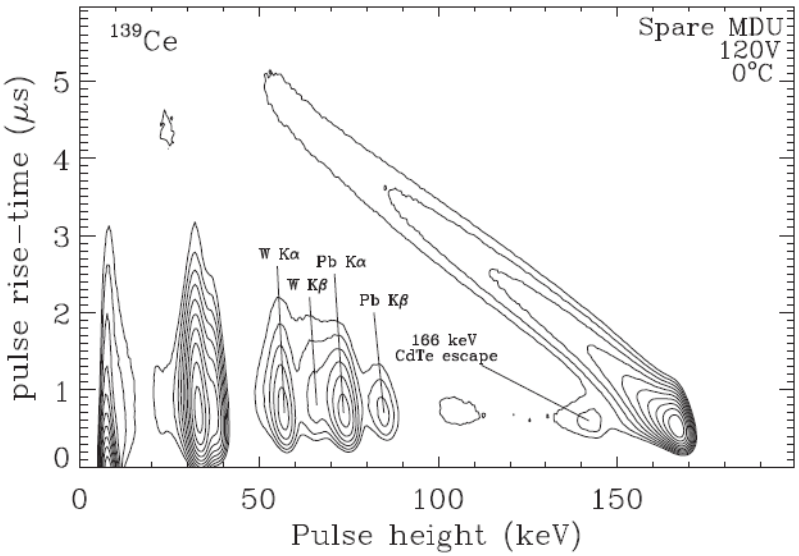
Periodic observations of the Crab: 2/year, max duration 2 orbits (1 in the future) → on-axis and off-axis response calibration

CdTe detector: the data

For a complete reconstruction of the energy of the incident photons, two parameters are necessary: Pulse Height (PH) and Rise Time (RT)

Due to the charge loss in the single CdTe (different mobility of charges and holes) the shape (and amplitude) of the signal is dependent by the interaction depth in detector





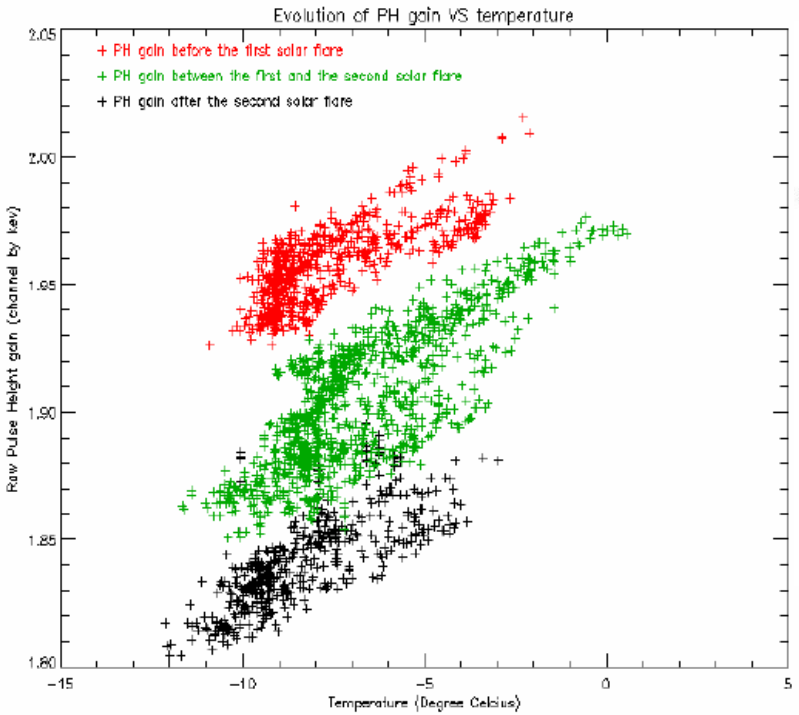
The signal RT is a function of the interaction depth. The amplitude PH for a given energy is then tightly correlated to the RT.

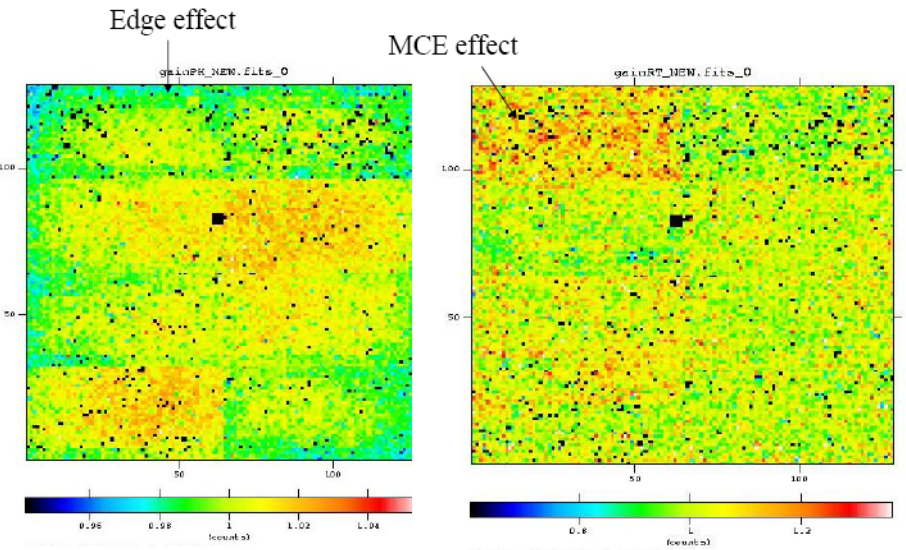
Must be calibrated for energy reconstruction

ISGRI Gain/Offset calibration

Pulse Height and Rise Time are measured for each pixel

- **PH,RT values are then corrected for temperature and time evolution**

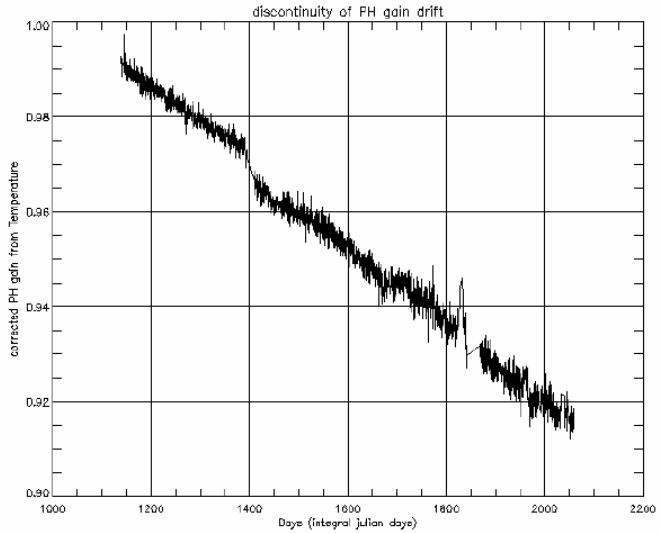




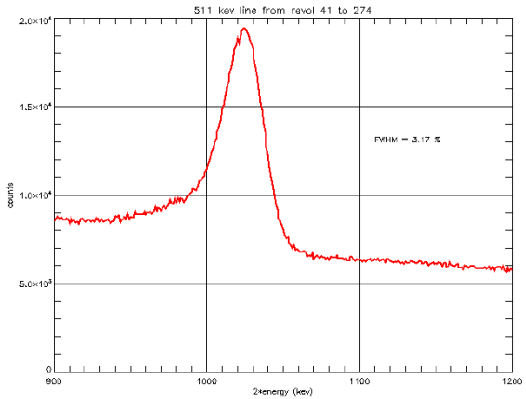
pixel-to-pixel gain variations

raw PH vs temperature. 3 main periods delimited by 2 strong solar flares

ISGRI Gain/Offset calibration (*cont'd*)



Gain vs time (corrected for temperature only). Shows a constant decrease of -2.8%/year, plus discontinuities produced by the solar flares

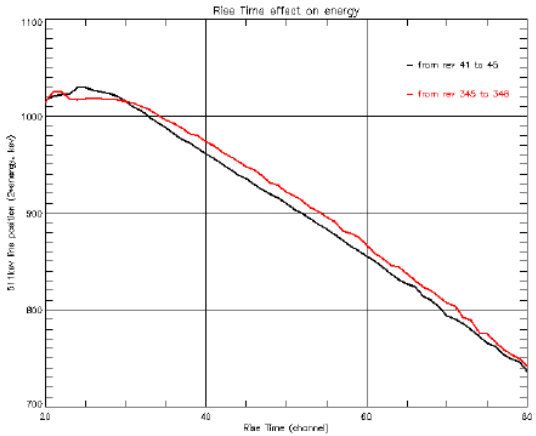


ISGRI 511 keV line (234 orbits)

Correction vs T and time (constant decrease) well recovers peak shape and energy resolution (~3% at 511 keV)

Other effects of gain variation

- Rise time effects on energy
- Gain drift after switch-on: -0.22% after one orbit
- Discontinuity due to solar flares



(Final) GO calibration

Correction for these additional effects are included in the more recent calibration (will be available in next software release, OSA6.0).

Calibration data filled into GO tables (LUT1) as 128x128 gain and offset maps at given T and bias voltage. (corrections are included in S/W module *ibis-isgr-energy*)

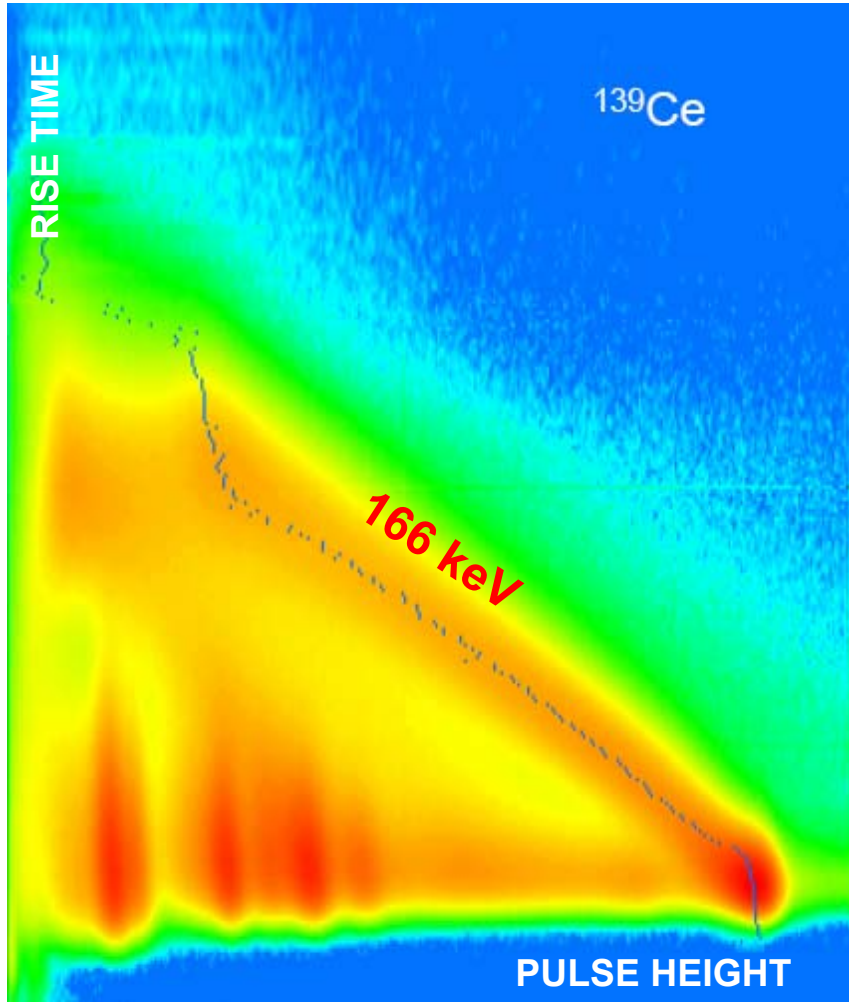
Energy reconstruction: calibration of PH vs RT

Tables for energy reconstruction (LUT2) are computed using bi-parametric diagrams. The deposited energy is then reconstructed as

$$PH(RT)*LUT2(PH,RT)=E$$

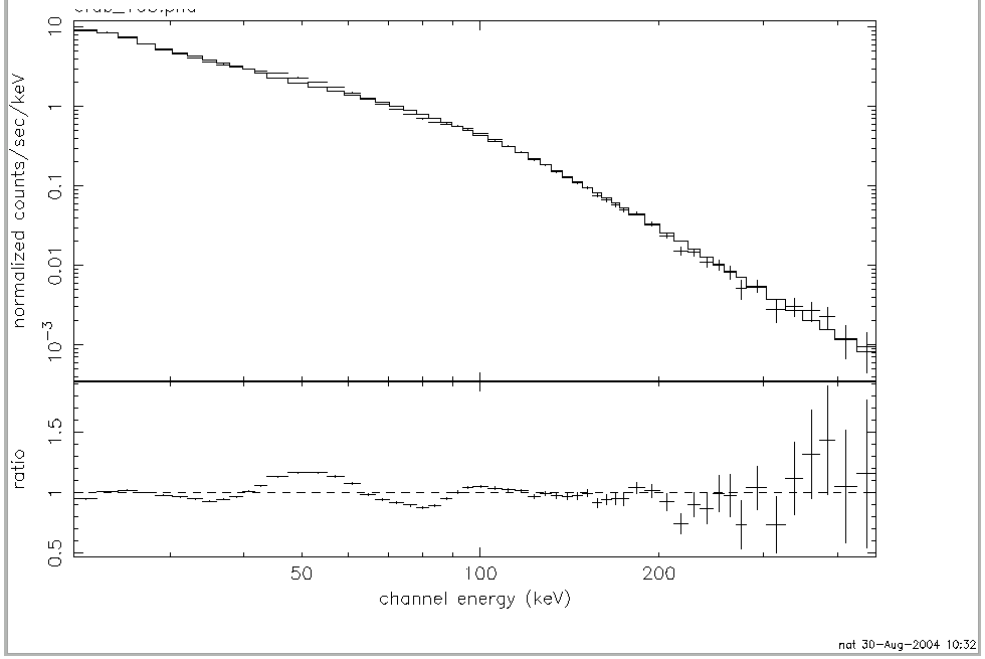
In current calibration (as of OSA-5) the LUT2 uses approximations which can lead to imperfect corrections ("snakes" in reconstructed spectra)

A new LUT2 has been now computed, with more detailed modelling of rise-time dependence (OSA-6)



Fits to Crab *staring* spectra

Rev.102-103, staring (~60 ksec)



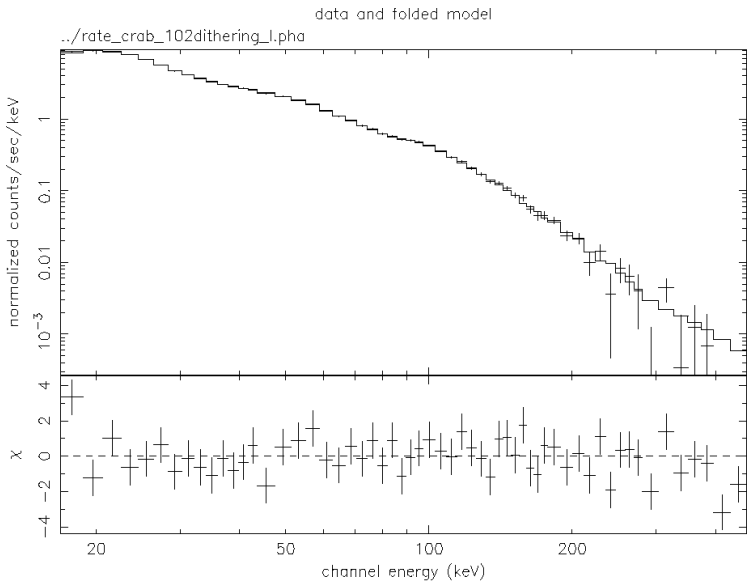
The Crab spectrum (20.6-500 keV) for a staring observation of 63 ksec, fitted by the MC model. And single power-law

- Snake-shaped residuals (caused by LUT2 energy reconstruction)
- Fitting to a PL model is accurate to within ~6%. The resulting spectrum (and slope) depends on the assigned systematic error. Lower syst corresponds to harder spectra.
- The estimated slope is varying in the range 2.15-2.26 (~90% confidence).

By analysis of the different spectra fits, the "best value" of index is computed as Γ=2.225

Response correction

In order to improve spectral performance, the Crab model based on a slope of 2.225 was used to correct the MC response. In this way, the snakes in the reconstructed spectra are suppressed.



Rev.102, dithering, 50 ksec

21.6-460 keV

1% syst., χ_r^2= 0.98

Note that this observation is contiguos to the staring observation on which the RM is calibrated.

Summary of Crab observation analysis, OSA-5

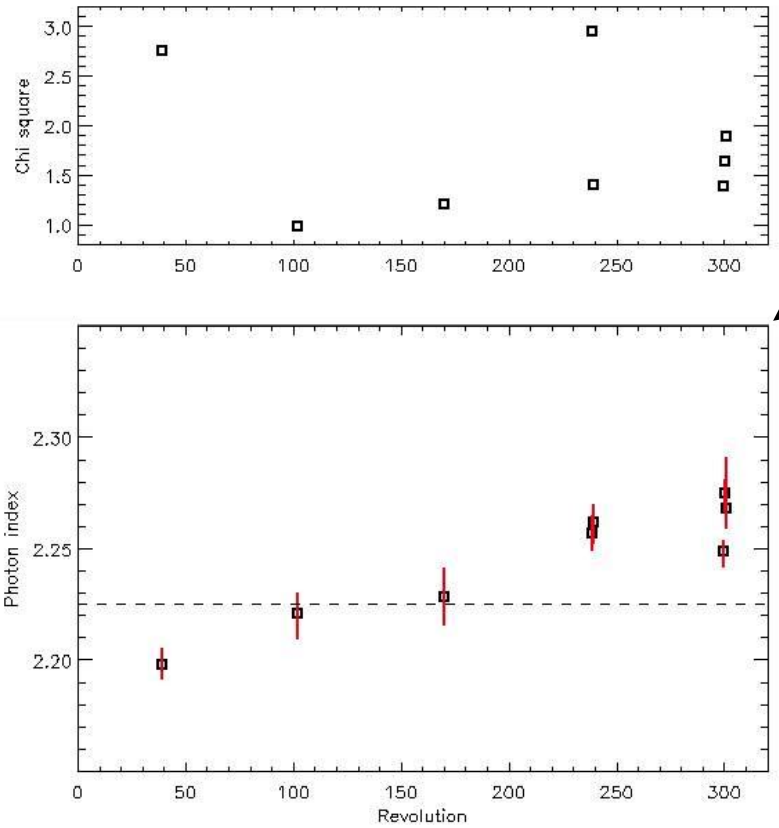
Revolution	Γ	90%conf. interval	χ_r^2	Elapsed time (ks)
39, staring	2.198	2.191-2.205	2.76	80
102, dith	2.221	2.209-2.230	0.98	50
170, dith	2.228	2.215-2.241	1.20	50
239, μdith(*)	2.258	2.249-2.265	2.95	50
239, 4scw onax	2.262	2.252-2.270	1.41	8
300, dith	2.249	2.241-2.254	1.38	50
300, off_ax 1	2.275	2.266-2.281	1.64	41
300, off_ax 2	2.268	2.259-2.276	1.69	50

(*) small dithering pattern with offset angle < 2 deg. The χ_r^2 is good (0.92) only for E > 32 keV.

All results are for energy range: 21.6-460 keV and syst=1%.

For revs. 39, and 239 (μdith) the photon index value and its confidence interval are obtained by setting syst=2%

Summary of Crab observation analysis, OSA-5



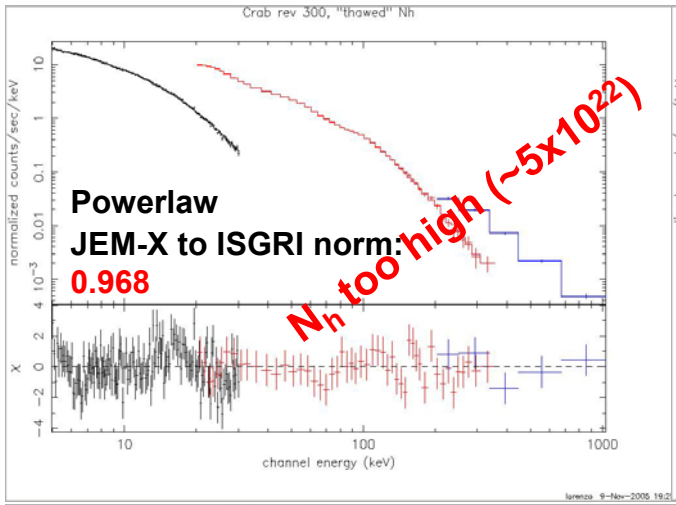
A positive trend in spectral slope is evident. Is it a residual effect of gain/offset correction?

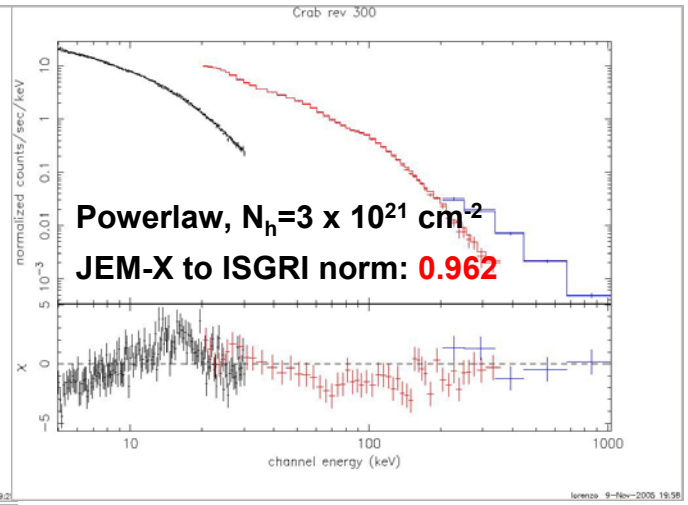
Residual time dependent effects, including low threshold change and solar flare are by now accounted by 4 time dependent ARFs.

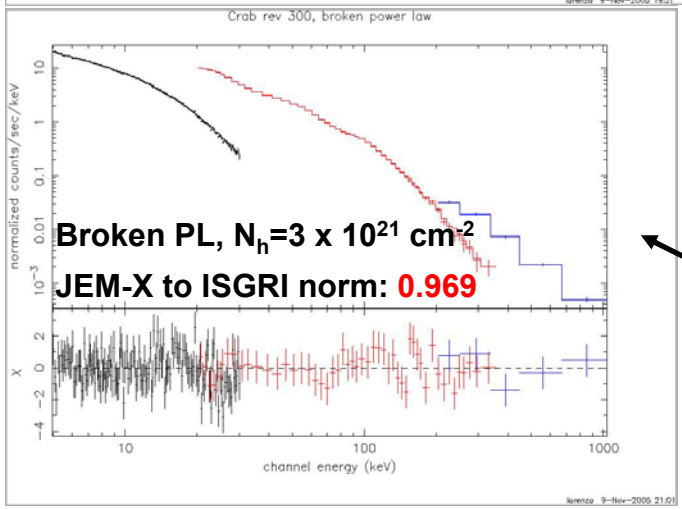
(ARF Validity periods revolutions: 20-64, 65-127,129-255,>256)

Crab spectra IBIS+JEM-X+PICSIT

Fit of composite spectra show a relatively good normalization ISGRI vs JEM-X (within ~5%)







Rev.170, dithering, 26 ks JEM-X, 50 ks ISGRI

Rev.39-45, 625 ks PICsIT

The broken power law gives better result but can be accounted by the different calibration of the two instruments.

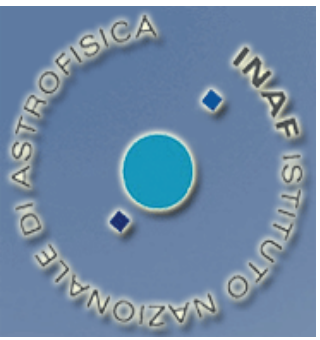
Conclusions

- **Calibration of ISGRI Gain/Offset, and Energy reconstruction completed**
- **Updated Response expected for OSA-6: new complete calibration, new off-axis correction, new ARFs/RMF**
- **Cross-calibration still an issue (see also Roland's talk)**
- **Is the Crab spectrum really a power-law? For ISGRI, a "native" fit with more complex model is not adequate, due to limitations in energy reconstruction algorithm (a broken power law does not improve fit)**
- **Situation will hopefully change with OSA-6**

IBIS/PICsIT Status

L. Foschini (1), V. Bianchin (1), G. Di Cocco (1), G. Malaguti (1), L. Natalucci (2)

(1) INAF/IASF-Bologna (Italy)
(2) INAF/IASF-Roma (Italy)



International Working Group on Cross-Calibration and the Definition of X-ray Standards
Iceland, 14-16 June 2006

PICsIT very basic factsheet

✓ **High-energy (0.17-10 MeV) detector of the imager IBIS** made of 4096 (64×64) CsI pixels organized in 16 semimodules. FOV=29°x29° (zero response), angular resolution ~12′ (sampled in 10′ pixels), PSLA < 5′. See Di Cocco et al. (2003) for more details.

✓ **Valid PICsIT event:** Every event that is **not** in coincidence with ISGRI events (Compton events), calibration unit tags (calibration events), VETO strobes (background event). ***Single event:*** a photon interacts with only 1 pixel (range 175 keV – 6.5 MeV); ***Multiple event:*** a photon interacts with more than 1 pixel (range 350 keV – 13 MeV).

✓ Events are equalized with onboard **L**ook-**u**p **T**ables (LUT), integrated according to binning tables (still into LUT), and transmitted to ground. Last update at the end of rev. 169 (March 2004).

✓ *Because of tight telemetry budget and high background, it is not possible a complete (position, time, energy) transmission photon-by-photon (ppm) of all the PICsIT data* ⇨ ***need for onboard processing***.

✓ The ***Standard mode*** is composed of 2 complementary submodes: ***Spectral Imaging*** *(data cube of 256 ch x 64 pixels x 64 pixels; integration time ≈ 2ks) and* ***Spectral Timing*** *(histograms with no spatial information integrated in up to 8 energy channels and with time resolution from 0.97 to 500 ms).*

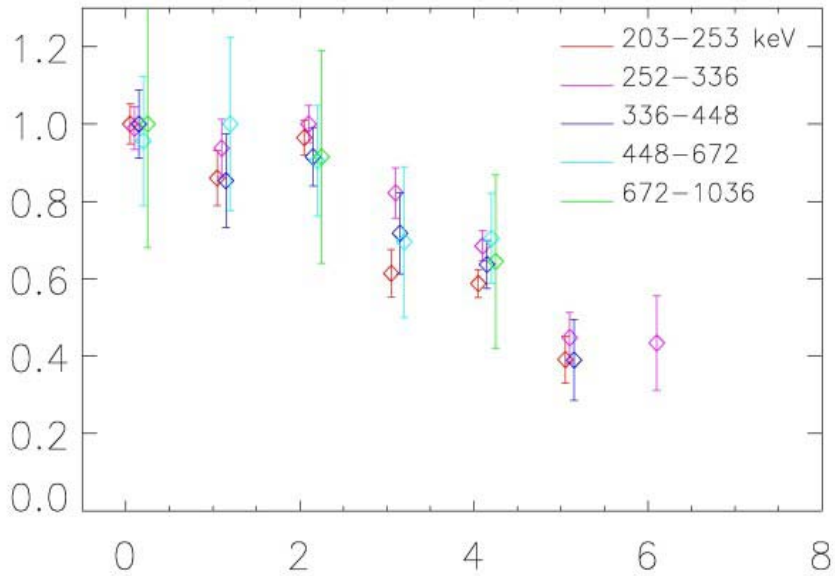
✓ The full photon list [position (y,z), Δt, full energy (1024 channels)] is available only for calibration purposes and with limited energy channels (generally up to 1 MeV). No possibility to fully run PICsIT because of telemetry budget. PPM is activated during slews, because of very short time (≈ 120 s).

✓More information at: **http://www.iasfbo.inaf.it/Research/INTEGRAL** (maintained by F. Schiavone)

Off-Axis Effect in Image deconvolution

- As the source (Crab) moves out of the fully-coded field of view, there is a clear drop in the count rates. This will be corrected in the next sw version.
- Possible causes: cosmic-rays induced events (for E<250 keV), changes in mask transparency, additional shielding from SPI on one side of IBIS, other unknown?

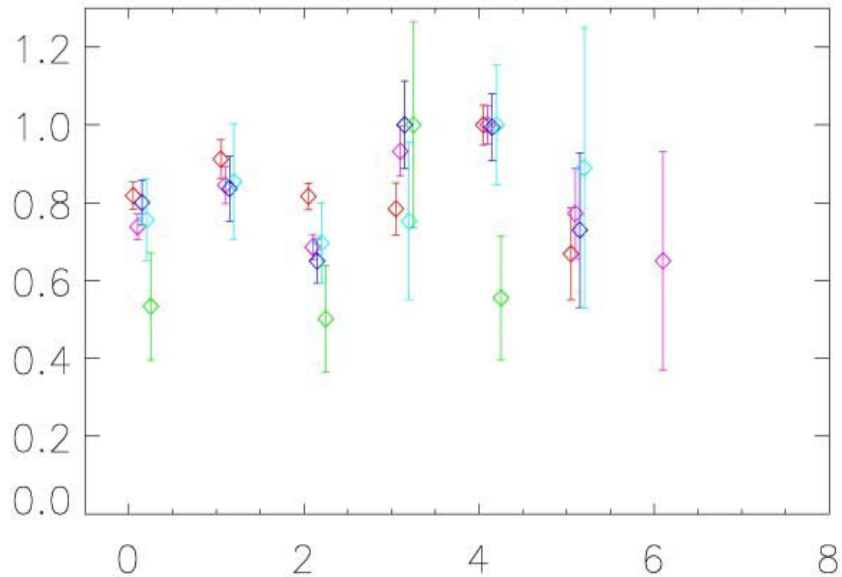
Normalized rates



Distance from centre FOV [degrees]

OSA 5.1 (Present sw version)

Normalized rates



Distance from centre FOV [degrees]

OSA 6.0 β (version under development)

Crab with IBIS (ISGRI+PICsIT)

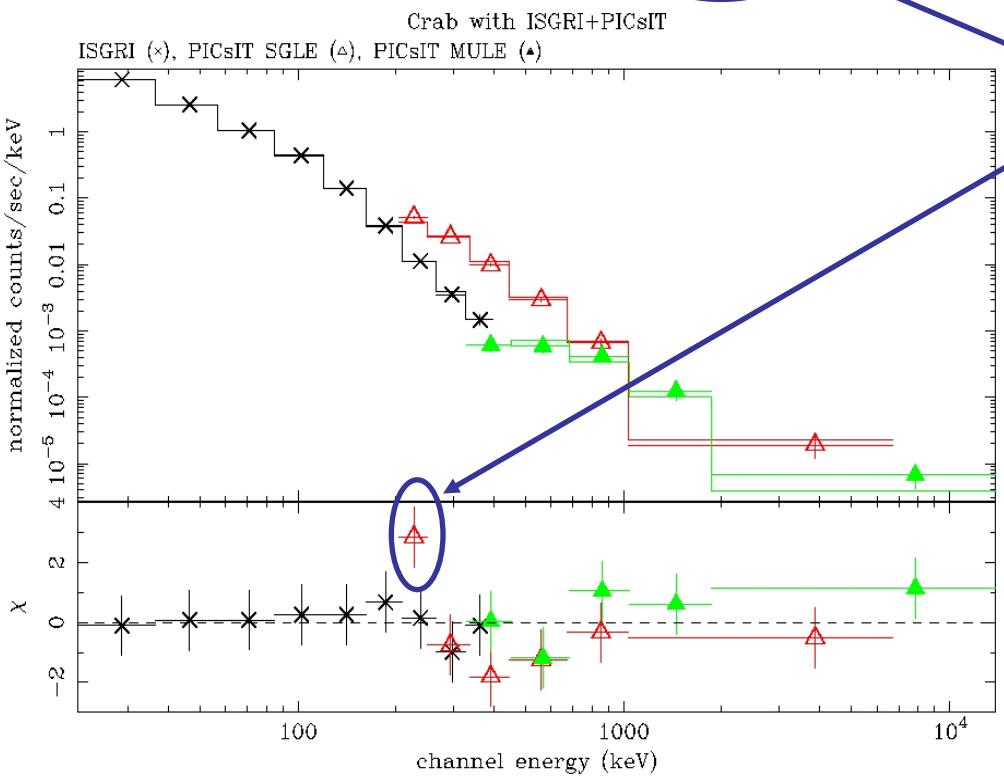
Full energy range (1.1 Ms)

Best fit: Γ=2.24±0.02; Norm = 17±2 ph cm^{-2} s^{-1} keV^{-1}

ISGRI (C=1, reference); PICsIT Single Events (C=0.87±0.06); PICsIT Multiple Events (C=0.38±0.07)

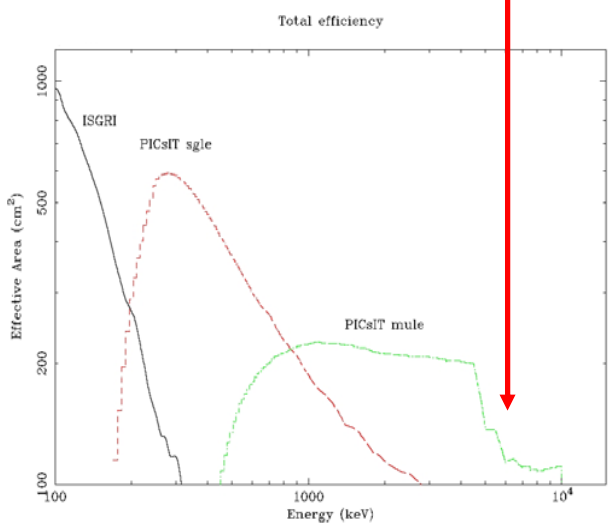
χ^2=25.6 dof=21 Prob.=0.22

sys=5%



Contamination from cosmic-rays induced events (main responsible of 5% sys)

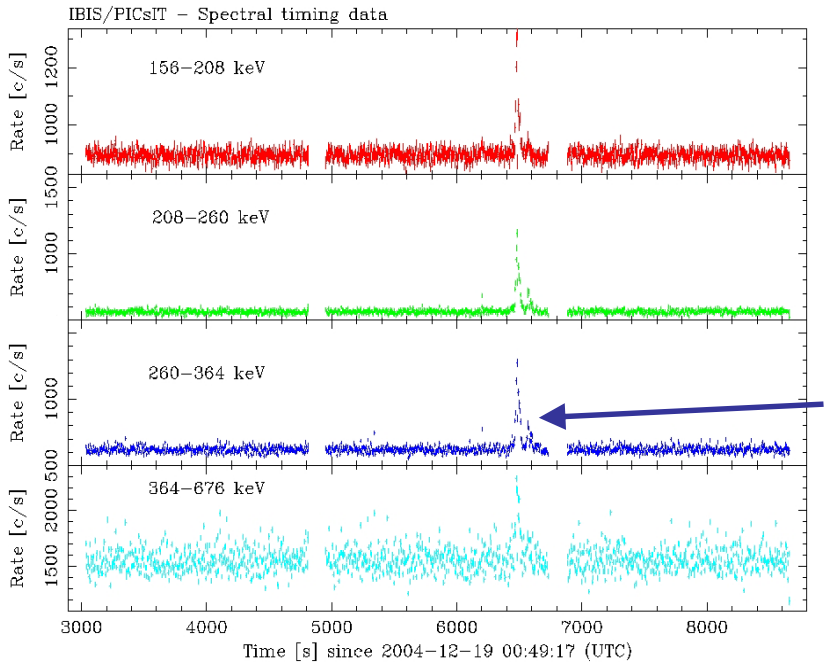
Problems in efficiency for multiples (too low, particularly for E>5 MeV). RMF/ARF under development



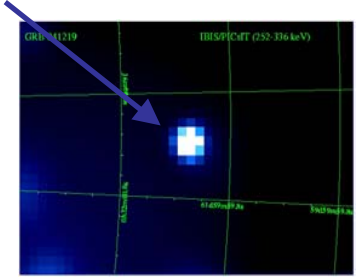
Flux [20 keV – 10 MeV] = 0.313 ph cm $^{-2}$s $^{-1}$

Flux [20 keV – 10 MeV] = 0.327 ph cm $^{-2}$s $^{-1}$(expected)

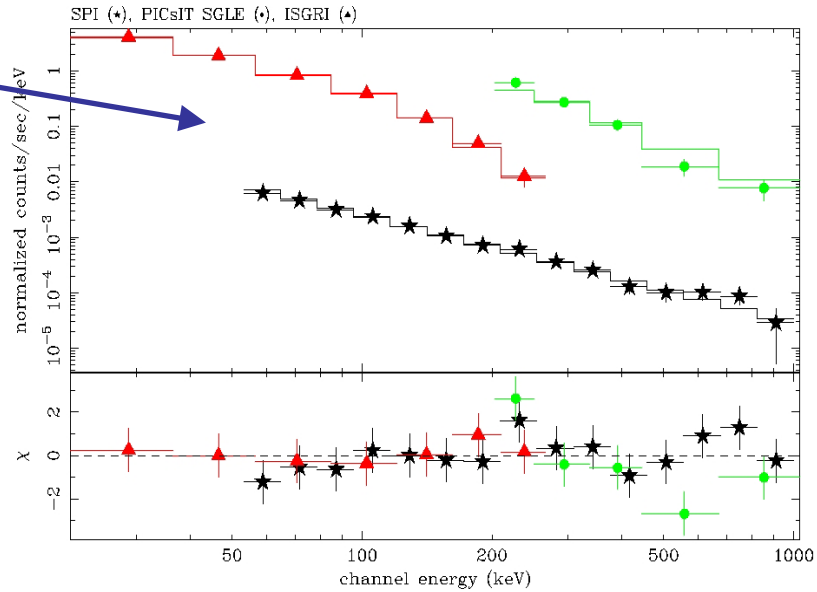
Calibration of Spectral timing data



- Singles and Multiples together: no RMF/ARF available for this mode;
- Crab pulsar too faint to be a valid input;
- We used the very long GRB041219 (≈ 360 s), that was detected in both spectral imaging and spectral timing modes.



GRB 041219



Best fit: Γ=1.9±0.1; Norm = 18±6 ph cm^{-2} s^{-1} keV^{-1}
SPI (C=1, frozen); ISGRI (C=0.20±0.02; saturated);
PICsIT (C=1.0±0.1).
χ^2=25.6 dof=23 sys=10% Prob = 0.32

Energy [keV]	Joint Fit Flux [10^{-2} ph cm^{-2} s^{-1}]	Rate SpTi [c/s]
156-208	4.22	6.3±0.1
208-260	2.47	12.0±0.1
260-364	2.89	14.0±0.1
364-676	3.48	15.0±0.1