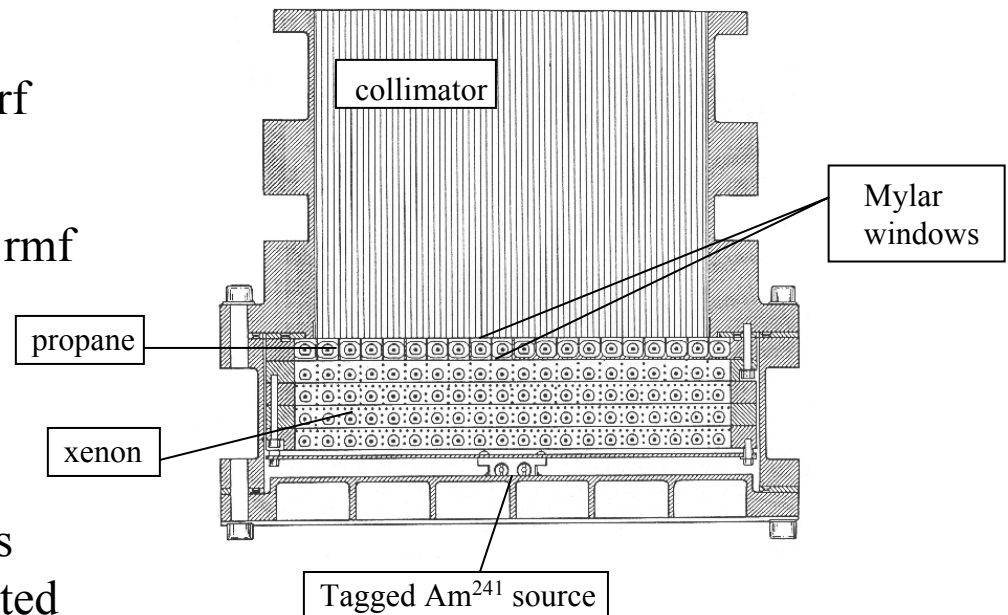


Outline

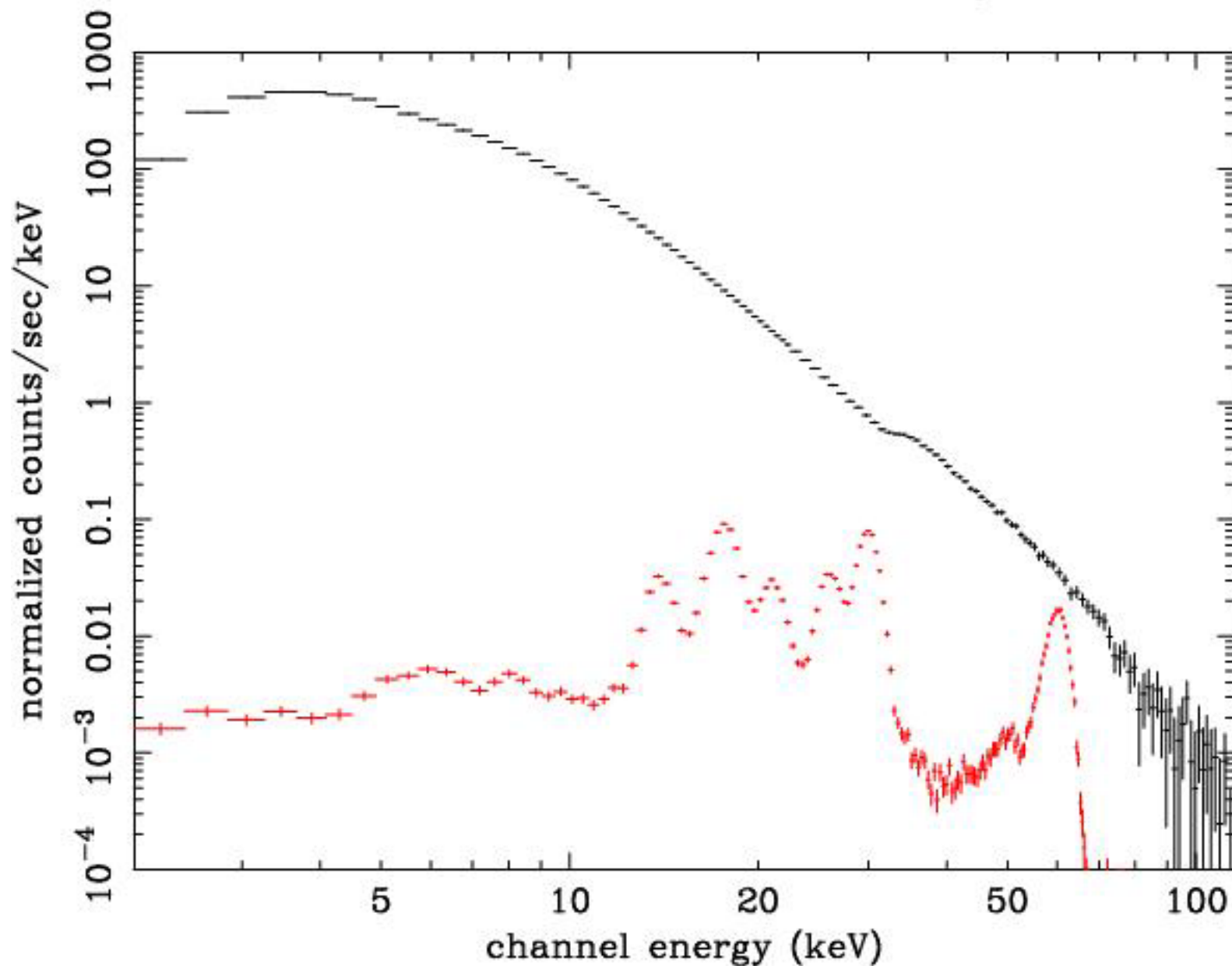
- Characteristics of PCA relevant for calibration
- Philosophy, components of energy response, which seems of highest interest for cross-calibration
- Emphasis on limitations, future prospects for PCA or lessons for community

PCA characteristics

- *Advantages* of PCA
 - No Mirror
 - No energy dependent arf
 - No Imaging
 - No pointing dependent rmf variation
- *Disadvantages*
 - 1500 cm² per detector
 - Even short observations are systematics dominated



PCU 2, L1 – Crab and Americium cal spectrum



Energy Response Philosophy

- Use .pha files as observed
 - Incorporate any time dependence in channel-energy or rmf parameters
- Physical models with reliably determined parameters
- Make calibration parameters accessible, but
 - Energy to channel conversion delivered via CALDB, Ftools distribution, or GOF
 - Rmf parameters delivered via pcarmf.par
 - Result is extra complexity in use

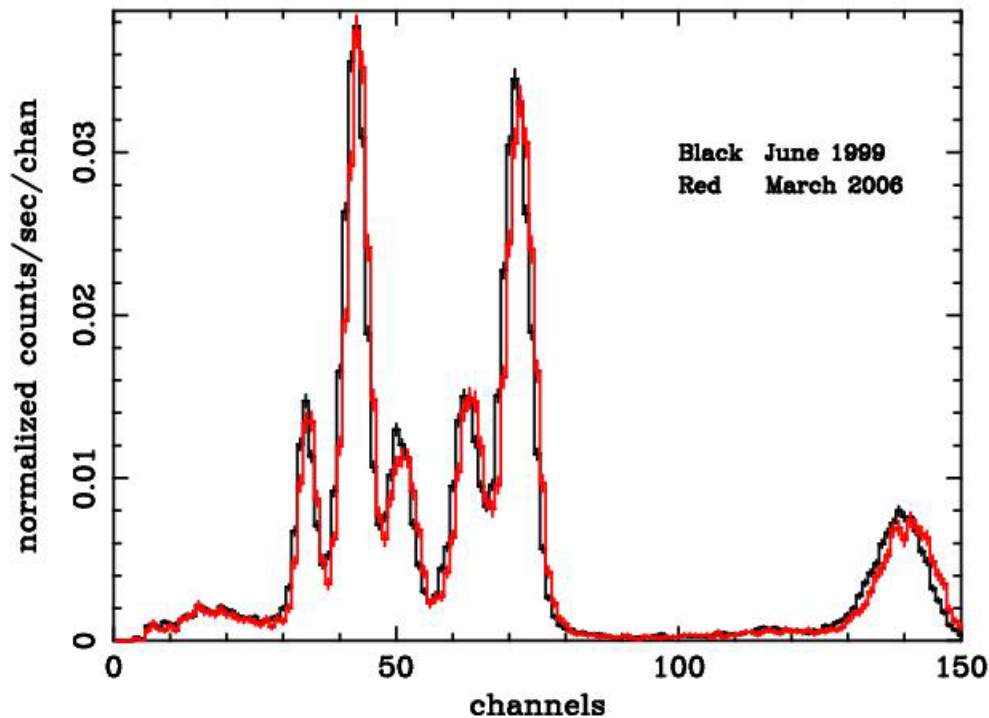
Discontinuous events

- Dec 1995 - launch
- Mar 1996 - intermittent breakdown, PCU 3,4
- Mar 1996 - HV lowered, duty cycle of PCU 3,4 reduced
- April 1996 - HV lowered - SC disables HV during breakdown
- April 1999 - intermittent breakdown, PCU 1
- Apr 1999 - HV lowered, PCU 1 duty cycle reduced
- Mar 2000 - pinhole in anti-coincidence volume, PCU 0
- 2006 - several PCU 0 breakdowns, duty cycle reduced

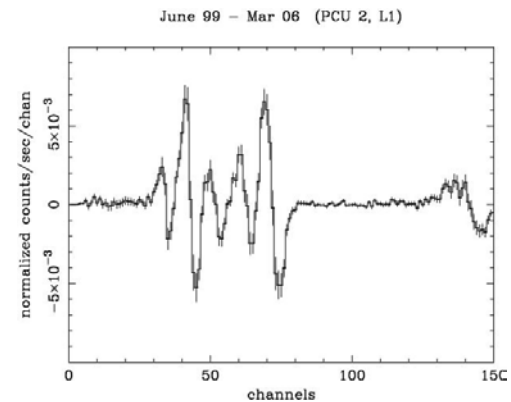
Response matrix generator keeps most parameters (I.e. amount of xenon in first layer) constant across discontinuities. Energy-channel relationship changes discontinuously

Time dependent gain

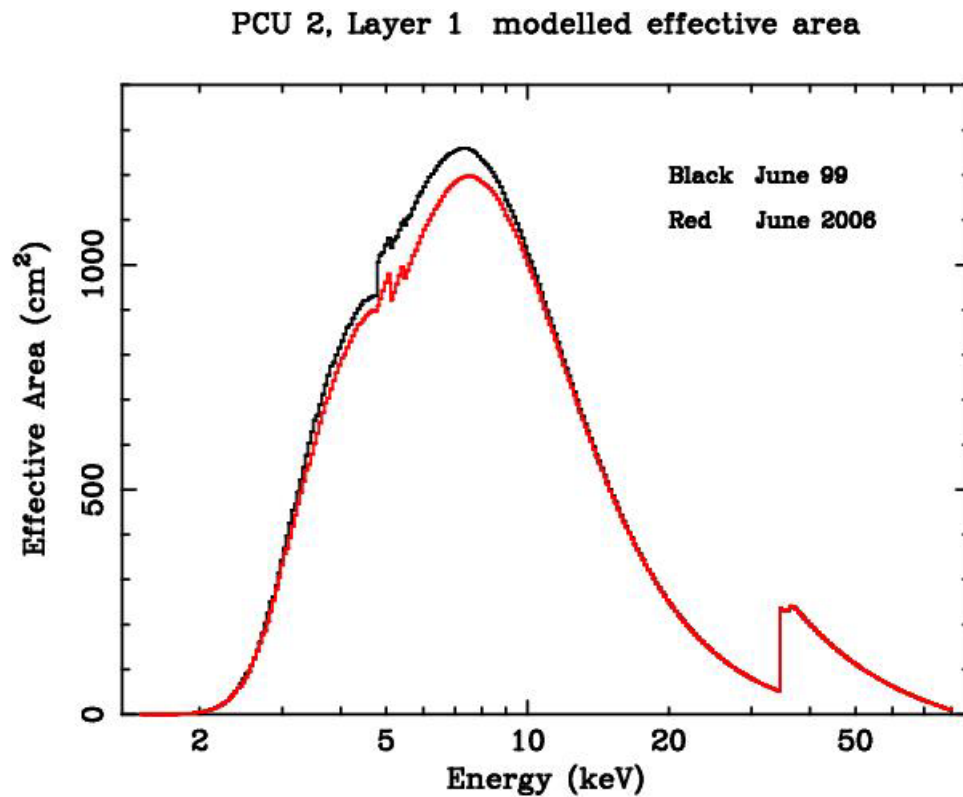
PCU 2 - Layer 1 Calibration spectrum



^{241}Am spectra are continuously available; Gain drifts is slow ($\sim 1\%$ over 7 years) but significant



Time dependent efficiency



Xenon leaks continuously from signal volume into anti-coincidence volume; peak efficiency is reduced by $\sim 1\%/year$

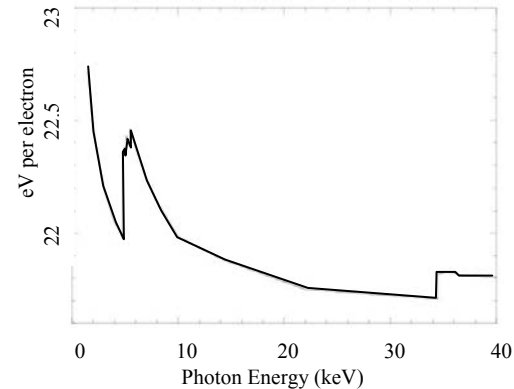
Model assumes linear build-up of Xe in anticoincidence layer; ignores loss of Xe in main layer

Quantum Efficiency

- Parallel slab
 - $\sim 0.0035 \text{ gm cm}^{-2}$ mylar with $\sim 4 \times 10^{-5} \text{ gm cm}^{-2}$ Al
 - 0.026 gm cm^{-2} Propane + $10^{-4} \text{ gm cm}^{-2}$ Xe + ($5 \times 10^{-8} \text{ gm cm}^{-2}$ Xe/day) ΔT
 - 2nd mylar window (identical to first)
 - $\sim 0.0068 \text{ gm cm}^{-2}$ Xe - layer 1
 - $\sim 0.0006 \text{ gm cm}^{-2}$ Xe - dead layer
 - $\sim 0.0055 \text{ gm cm}^{-2}$ Xe - layers 2 and 3
 - Plane parallel slab is a simplification, particularly for PCU 0 after loss of propane layer
- Photo-electric absorption only. Compton scattering becoming important (but ignored) at 60

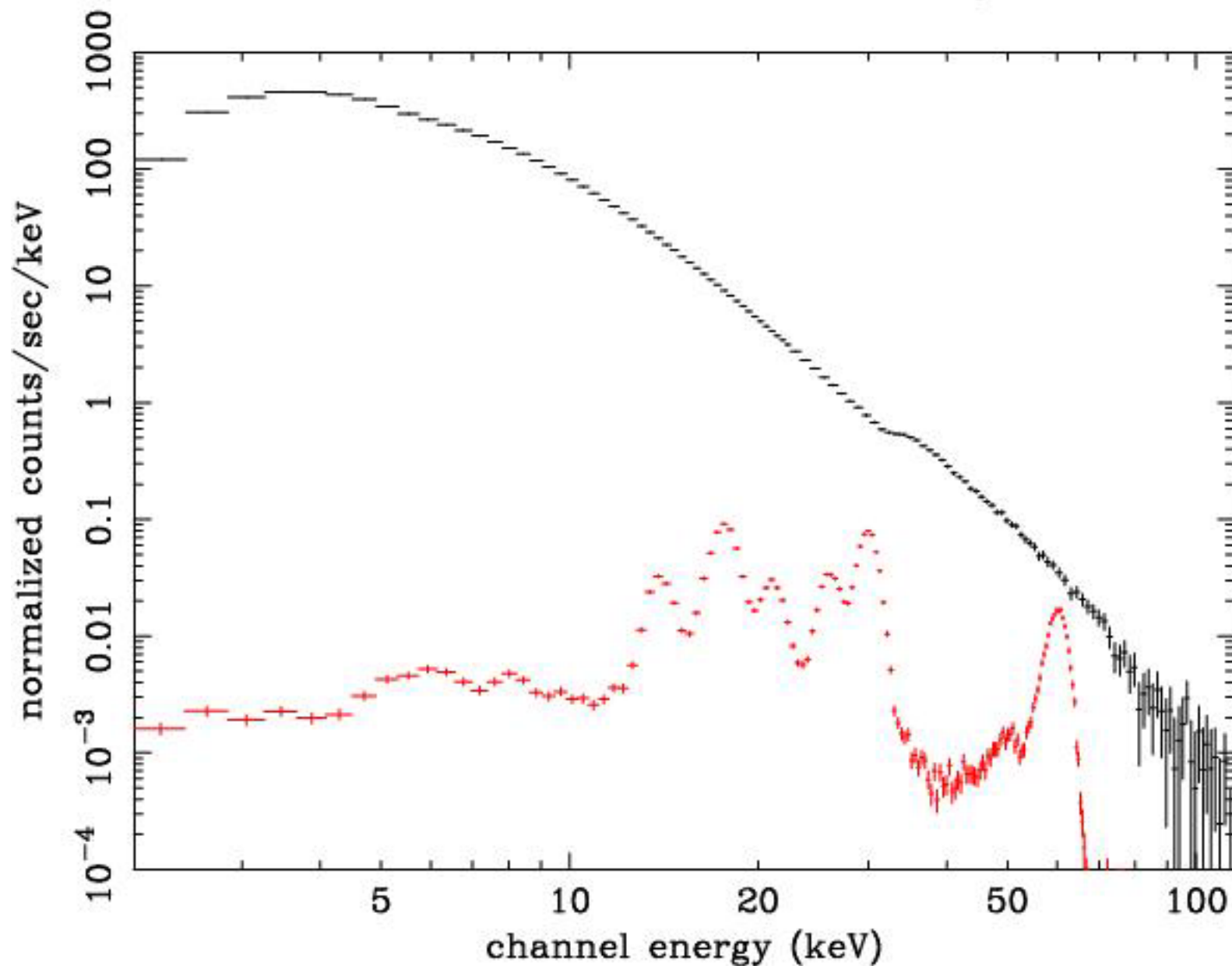
Energy scale

- Proportional counter signal is proportional to amount of ionization
 - NOT proportional to energy
- $E_p = 22 E_\gamma / w_f(E_\gamma)$
- $w_f = (w-22)f + 22$
- $f \sim 0.4$ is best fit for PCA, dominated by L-edge
- $f \sim 1$ gives measured ΔE (170 eV) at K-edge

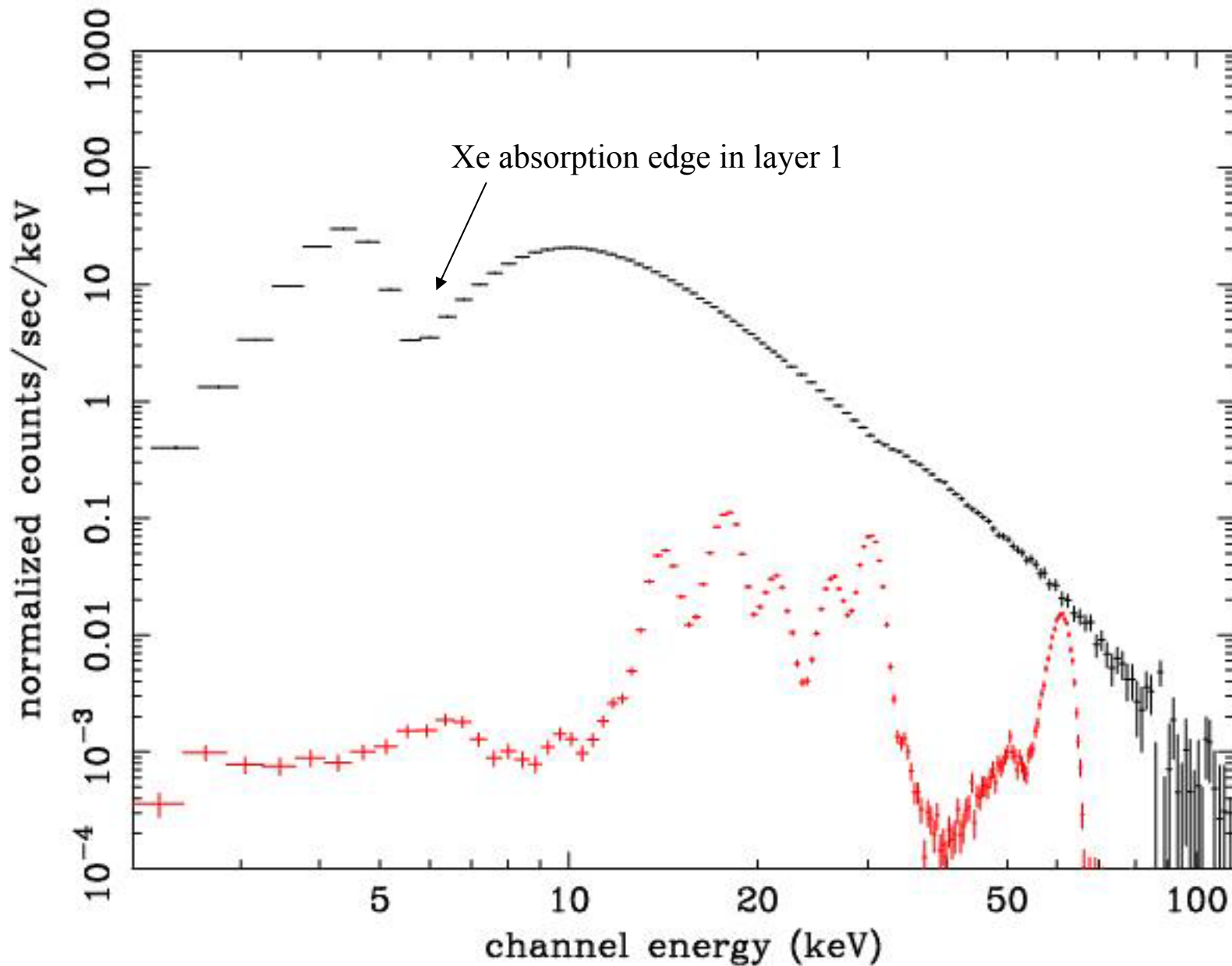


From Dias et al

PCU 2, L1 – Crab and Americium cal spectrum

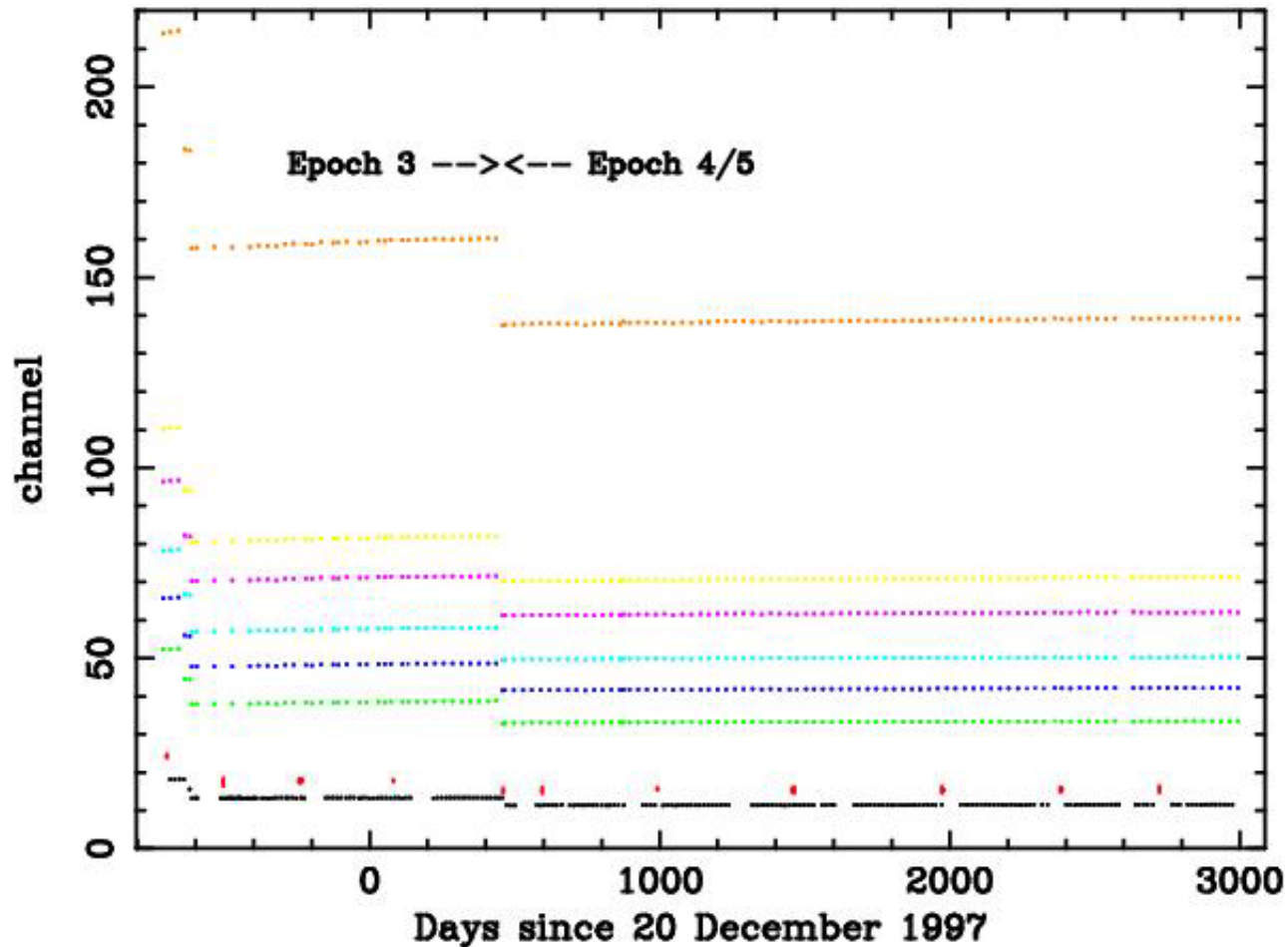


PCU 2, L2 – Crab and Americium



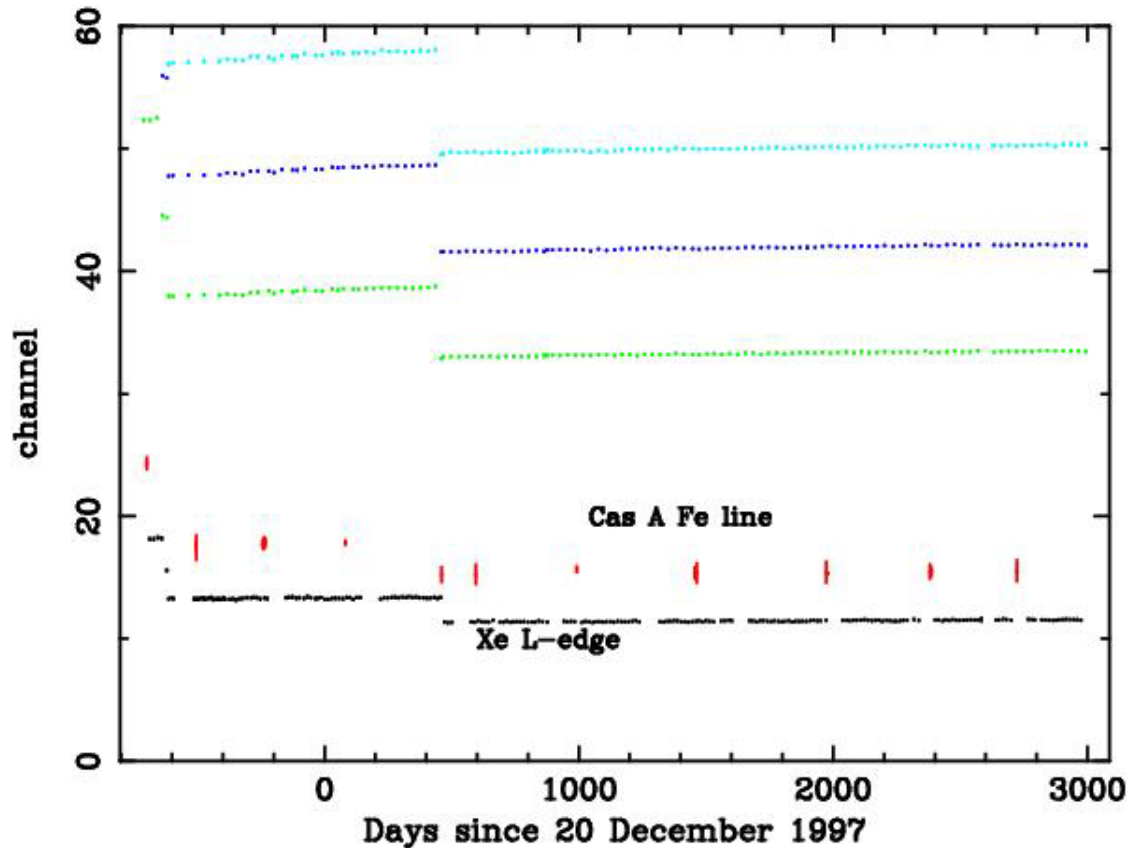
In Flight Energy Scale input

PCU 2, Layer 1



In Flight Energy Scale input

PCU 2, Layer 1

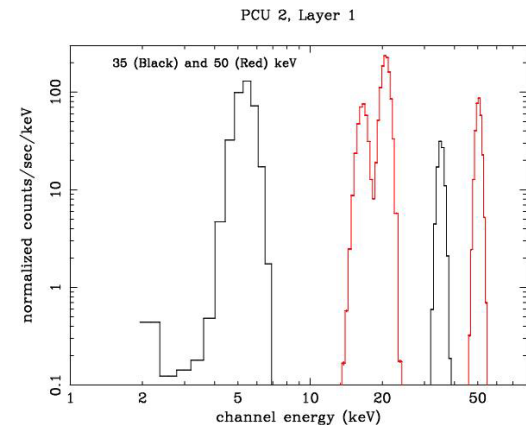
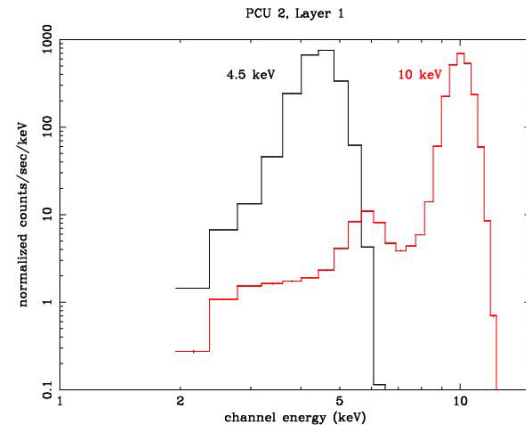


For each epoch: $ch = (A_0 + A_1T + A_2T^2) + (B_0 + B_1T + B_2T^2) E_p + C_0 E_p^2$

time dependence for quadratic term, cubic term don't improve results

Redistribution matrix

- Resolution (FWHM)
 - $\Delta ch = (aE + b)^{1/2}B$
 - $a = 0.121$, $b = 0.44$
 - B is energy to ch slope
 - $\Delta E/E \sim 17\%$ @ 6 keV
 - $\Delta E/E \sim 8\%$ @ 22 keV
- Escape peaks
 - no L escape above K edge
- Partial charge collection
 - Inoue parameterization
 - κ estimated (poorly) from fits to Crab



Putting the pieces together

Pick f , evaluate energy to Channel relationship

For many Crab observations, fit quantum efficiency and redistribution parameters

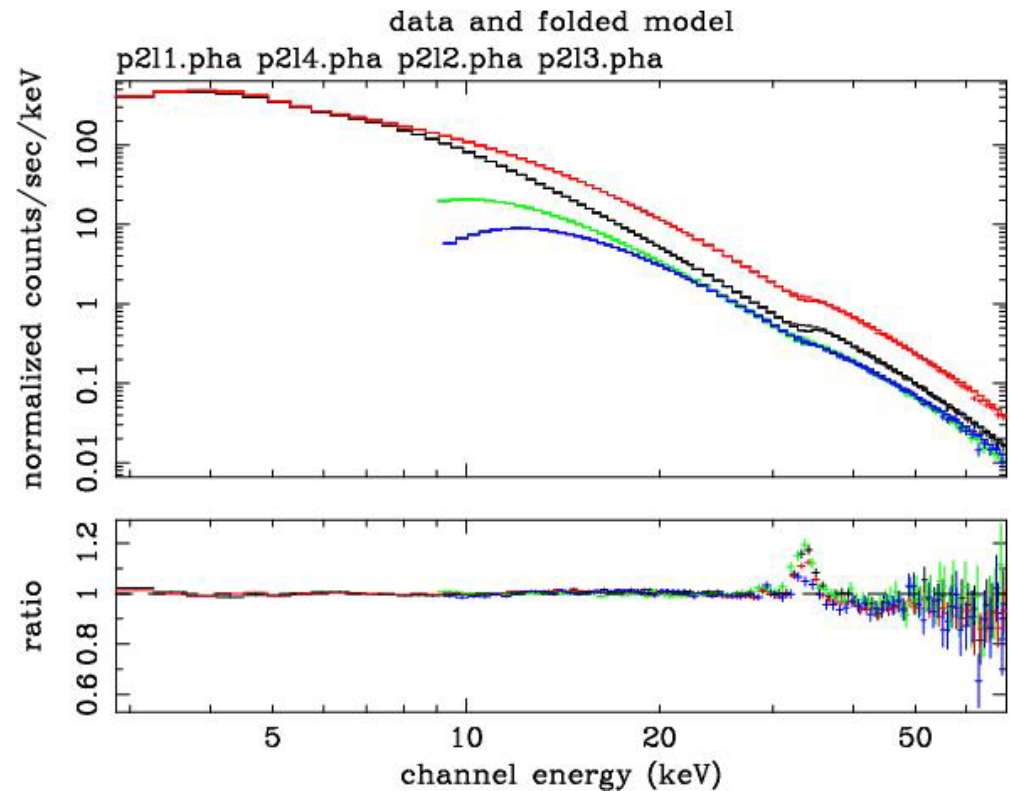
Average q.e. and redistribution parameters

Fit Crab or other sources, develop figure of merit

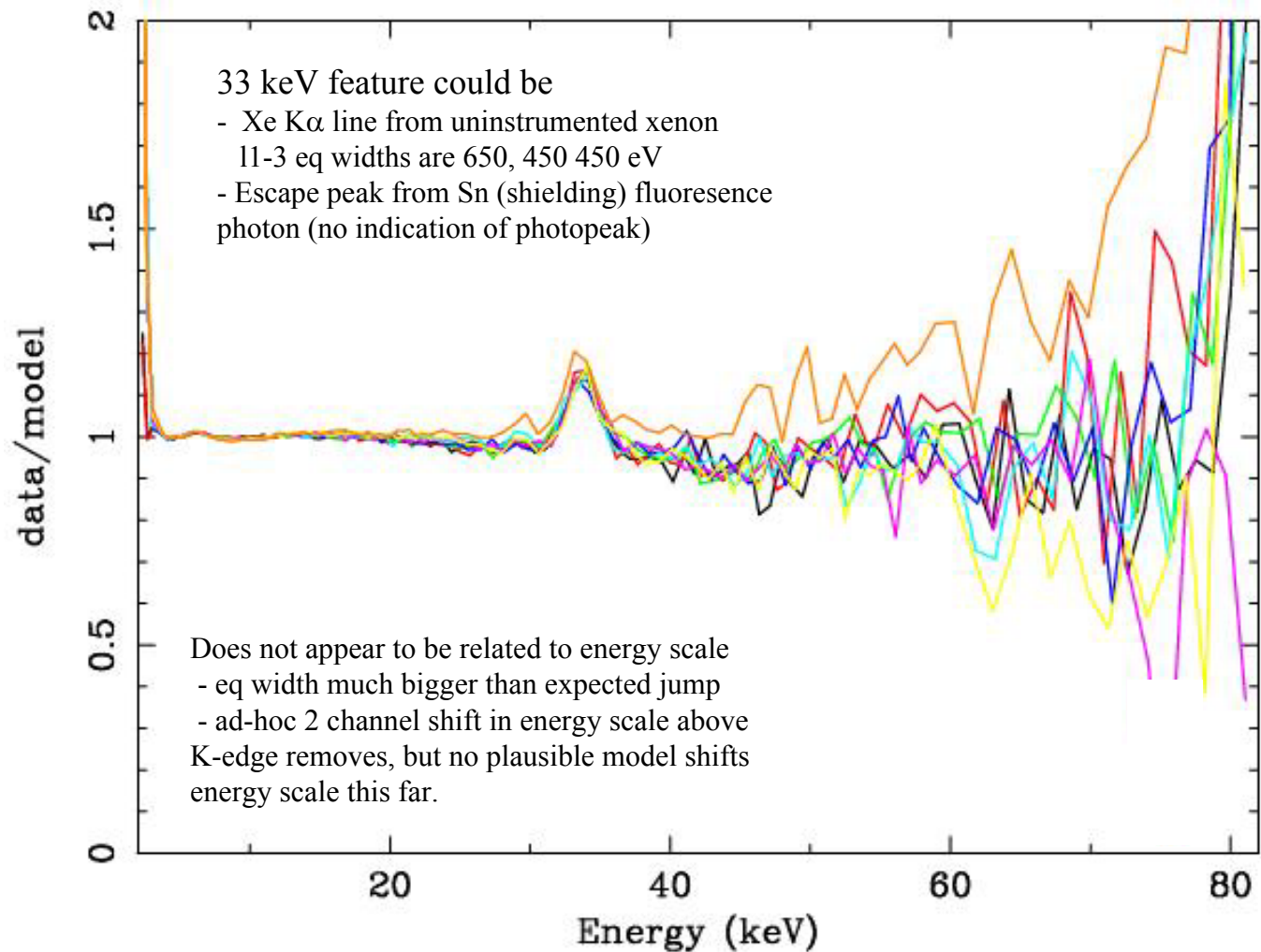
Choose best solution
Ftools v5.3, v6.0, vNext

2003 Crab data PCU 2, layers separately and combined.

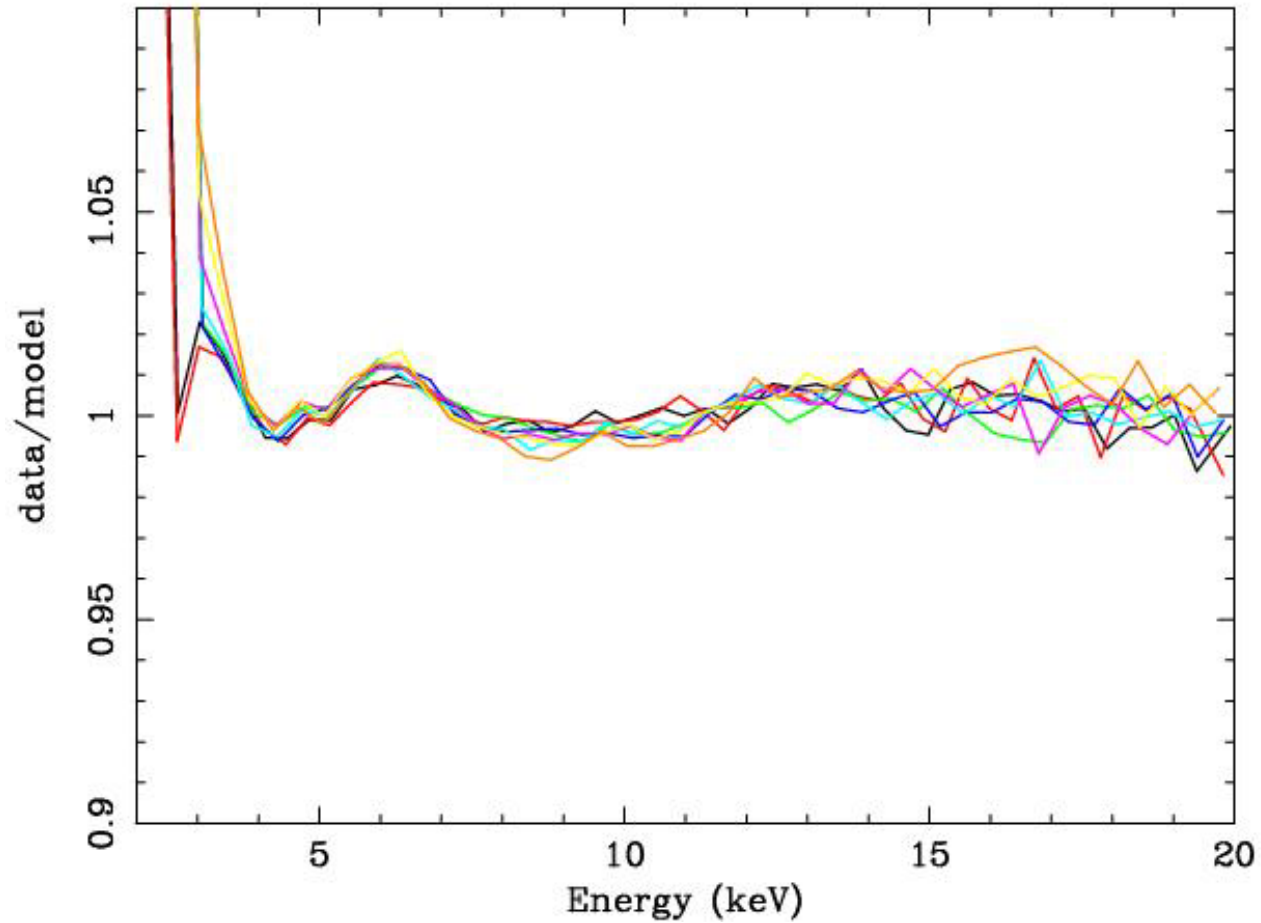
Largest feature in ratio plot is at 33 keV



Each trace is 10–12 monitoring observations from single calander year



Each trace is 10–12 monitoring observations from single calander year



Substantiates claim that systematic residuals are very small below 20 keV

Absolute areas

- For many Crab monitoring observations
- Dead time ($\sim 6\%$) corrections
- γ consistent with 2.1 for all detectors/times
- Area scaled to yield constant flux
- Zombeck Crab parameterization ($A = 10$ phot s $^{-1}$ cm $^{-2}$ keV $^{-1}$ @ 1 keV; $\gamma = 2.05$; $N_{\text{H}} = 3 \times 10^{21}$ cm $^{-2}$) gives 2-10 keV flux of 2.34×10^{-8} ergs s $^{-1}$ cm $^{-2}$. However:

Absolute area (2)



Zombeck is among the highest of the available normalizations

PCA flux scale is likely to be ~10% high wrt to other instruments

Limitations

- (almost) no ground data at mission HV
- No ground data available at current gain, efficiency
- No energy scale monitor below the L-edge; determining the L-edge “channel” is model dependent.
- Too little ground data in vicinity of Xe-L edges
 - Model has three discontinuous features (gain, quantum efficiency, partial charge collection)
- Inadequate appreciation of state of knowledge about the flux of the Crab

Missing tools

- Standard advice
 - Make background model
 - Extract pha data (source and background)
 - Make response matrix
- This procedure
 - Over estimates errors associated with background (artificially reduces χ^2)
 - Does not provide systematic errors (χ^2 increases with total counts)
 - Users often approximate by adding constant (1%) systematic
- PCA team currently trying to develop a more nearly correct procedure