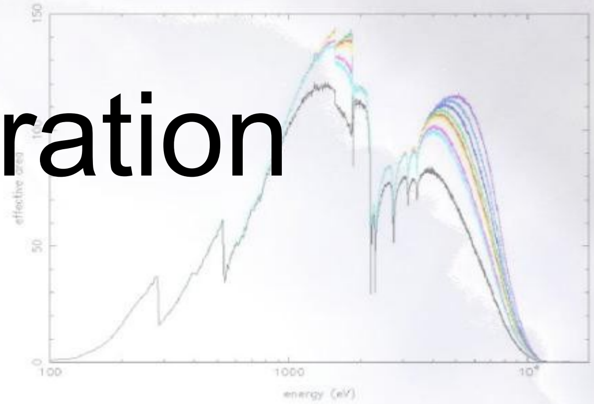
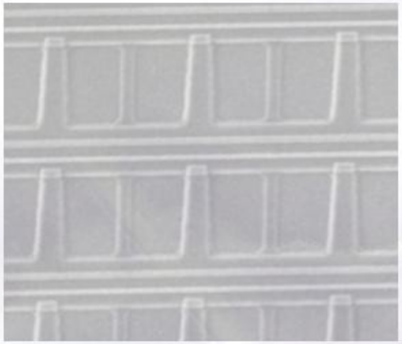
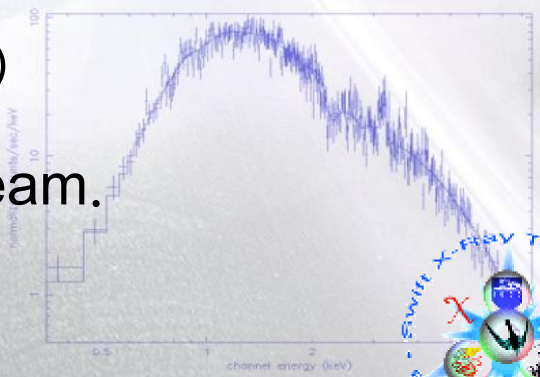
Swift-XRT Calibration Update







Andy Beardmore

With help from
Claudio Pagani
(& Tony Abbey - now retired)

on behalf of the XRT cal team.

Introduction

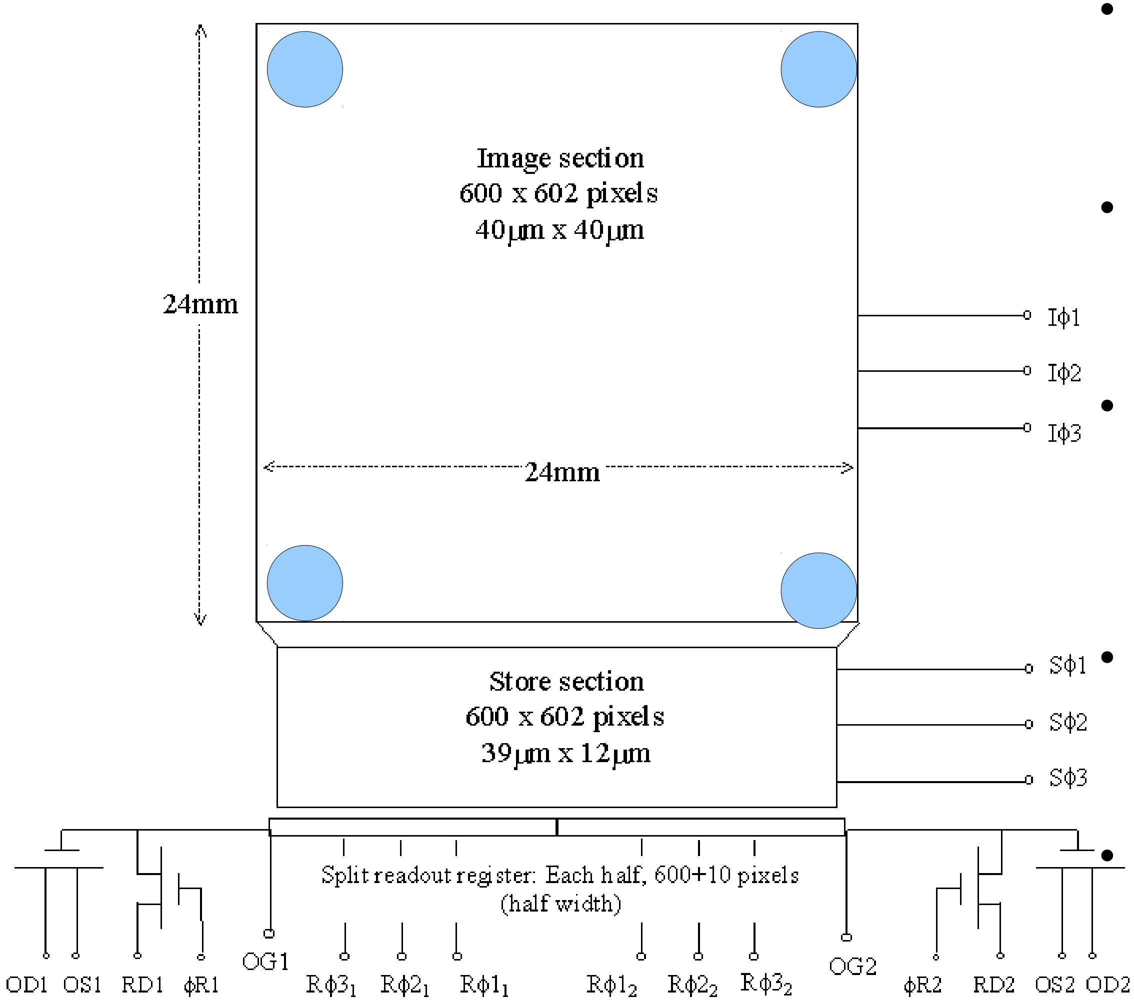
- Swift has now been operating for 7+ years.
- Typically performs 70 slews/day → high observing efficiency
- Last 4 months: 6.5% Cal (c.f. 36% TOOs, 23% GRBs, 26.6% fill-ins, 3.1% GI)

Updates to report on :

- Gain/CTI
- Trap Mapping
  - Lab-work
- New CCD22 modelling code

Cheap plug: Swift-XRT products from www.swift.ac.uk

XRT CCD

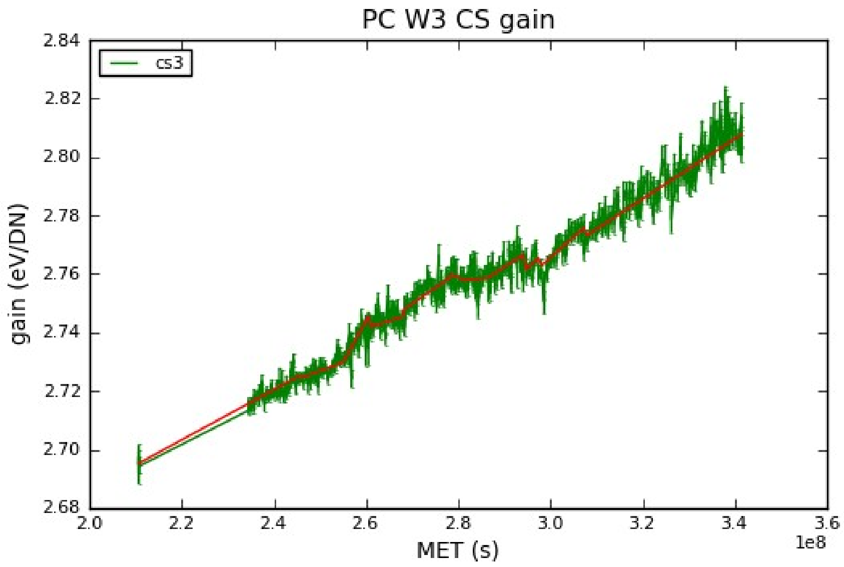


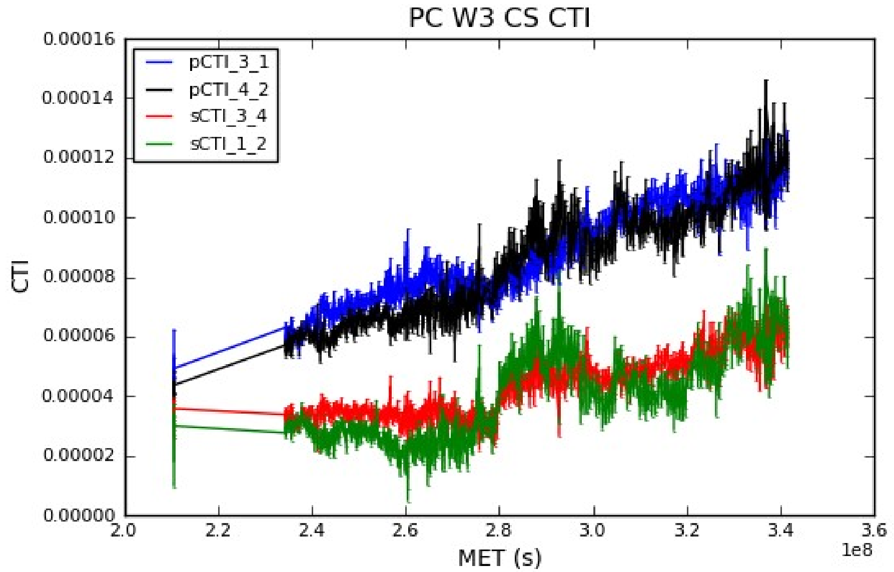
- e2v CCD-22 detector (developed for EPIC MOS camera on XMM)
- Operated in Photon Counting (PC) and Windowed Timing (WT) mode
- 4 ^{55}Fe corner sources continuously illuminate CCD corners, used to monitor CCD performance
- Spectral resolution at launch: FWHM = 140 eV at Mn K-α (5.895 keV)
- *Swift* in Low-Earth orbit and exposed to high flux of protons during SAA

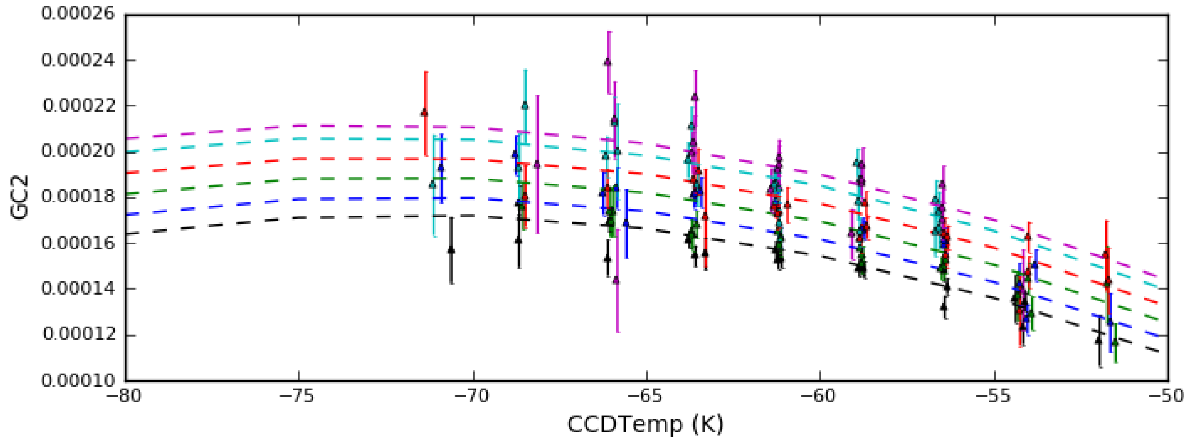
CS3 Gain and CTI

- Gain is measured from the Fe-55 line centroid from CS3 (bottom left, closest to readout node)
- CTI measured from differences in CS centroids
- However, parallel CTI evolution in the CCD imaging section causes gain to increase
- Both gain and CTI are temperature dependent (XRT CCDTemp varies from -75 to -50C)

CS3 Gain and CTI





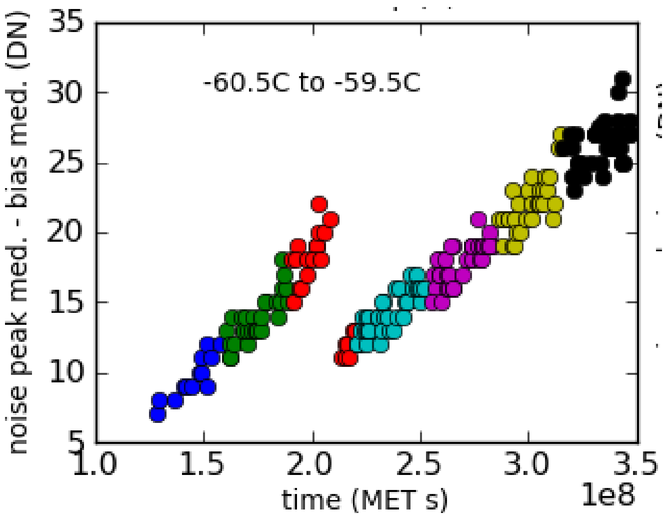


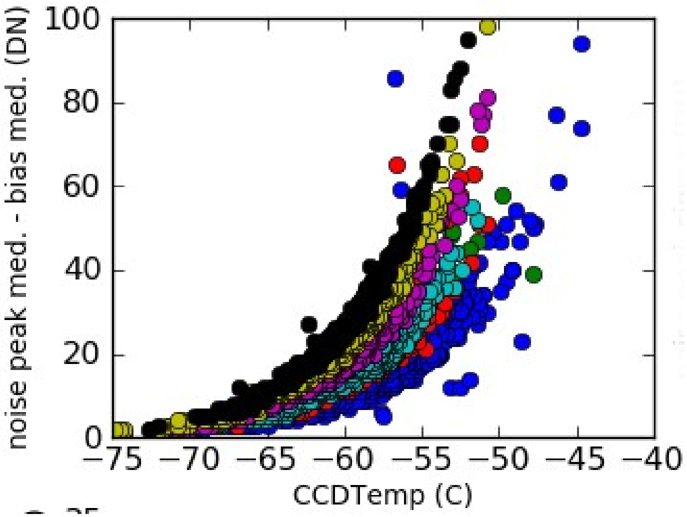
GC2 = GC0 x CTIp

- Time and temperature gain and CTI coefficients are updated in the CALDB ~ 6 monthly

Noise Peak

- Noise peak position (and width) also evolves with time and temperature



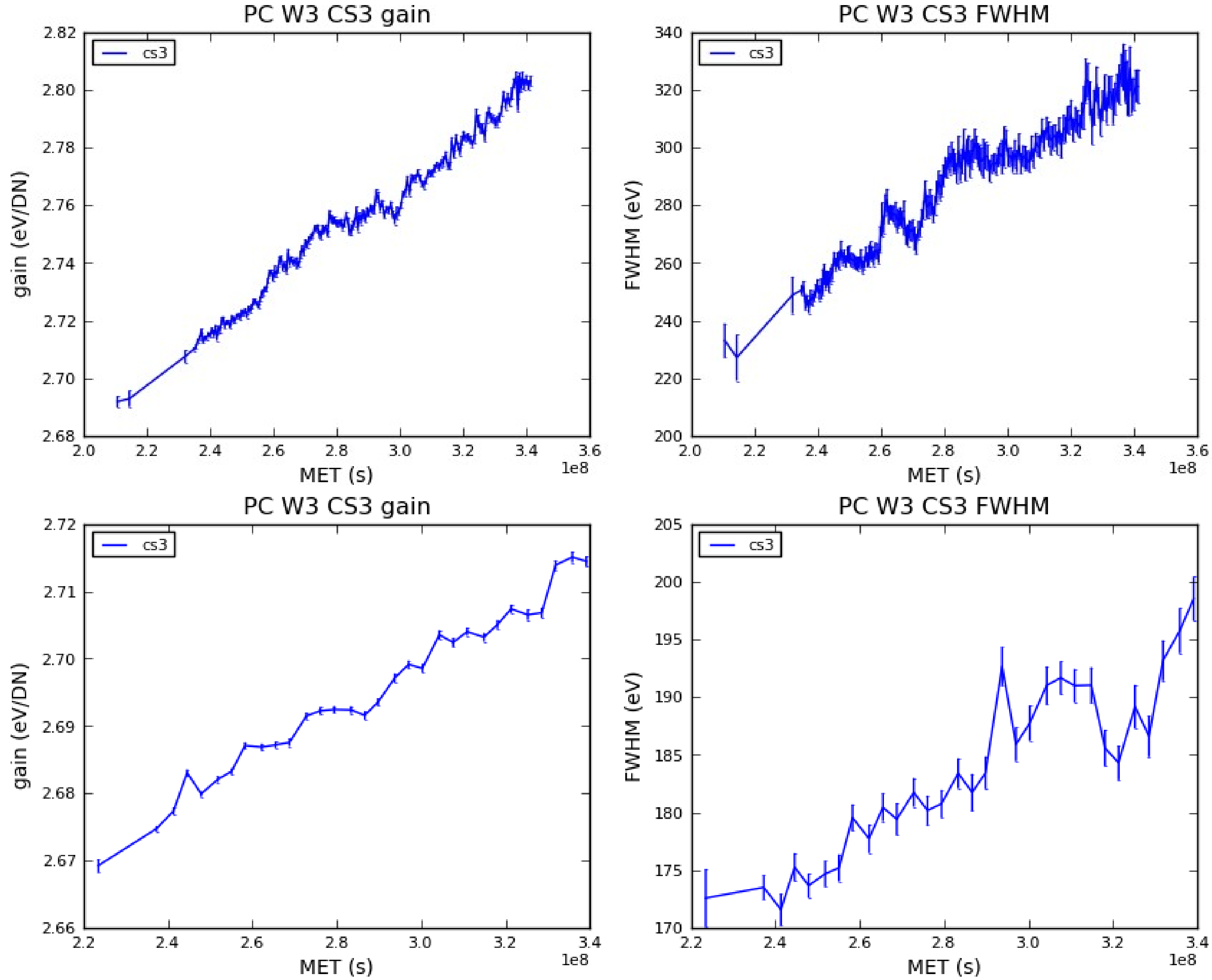


- Jamie has recently updated the on-board temperature dependent threshold tables to improve the telemetry rate

Corner Source 3

2011-04_2011-06_cs3_output.dat

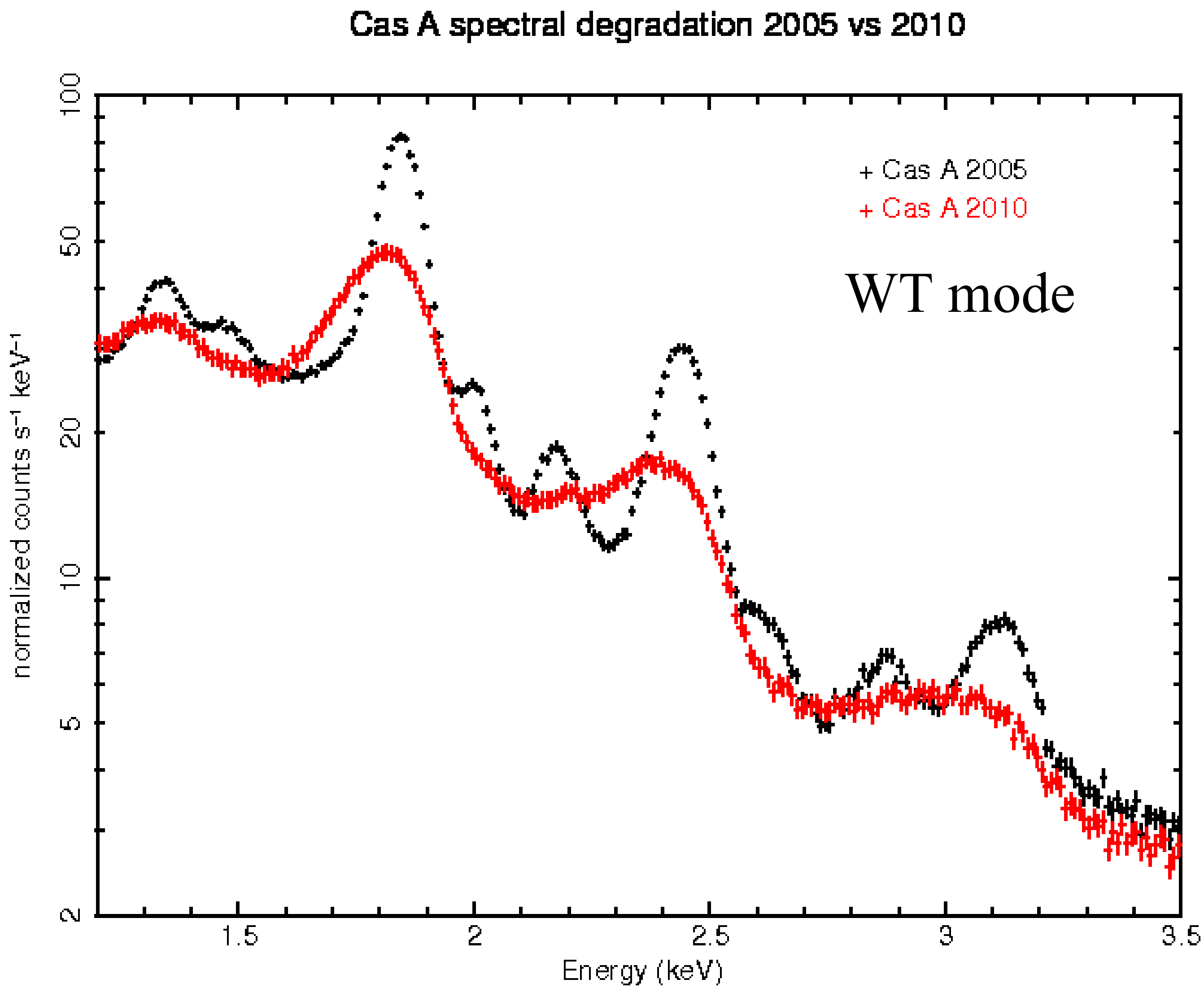
CS3 Gain and FWHM



All cols

'Best' 5 cols

XRT Radiation Damage

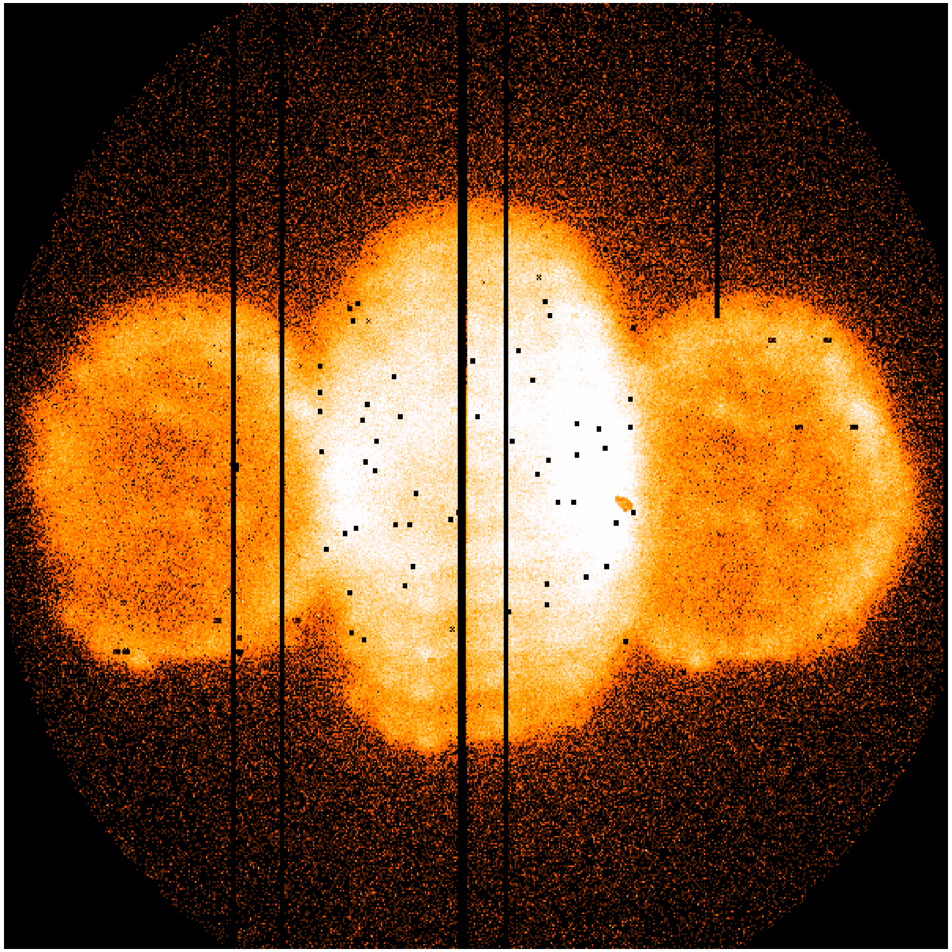


Trap Mapping

- XRT CCD does not have the luxury of charge injection to improve spectral response now significant charge traps have formed
- XRT has no internal calibration source which will illuminate the entire CCD to measure the traps
- Largest charge traps in the central regions of the CCD have been identified using Si Kα observed in Cas A and Tycho
- Updated gain CALDB file format and xrtcalcpi s/w to perform charge trap correction

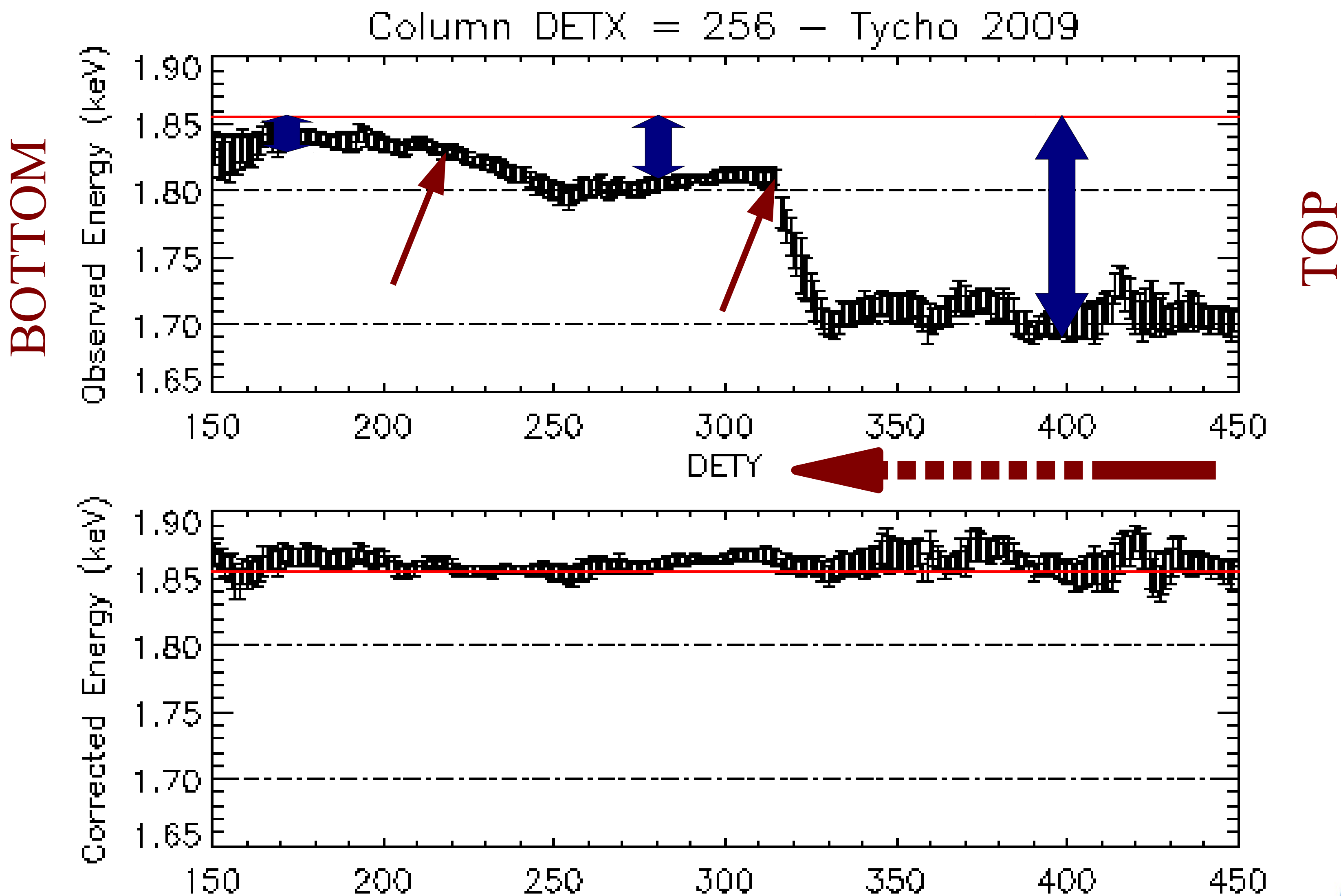
Trap Mapping Observations

Goal: map pixels affected by radiation damage, measure the charge losses of individual pixels

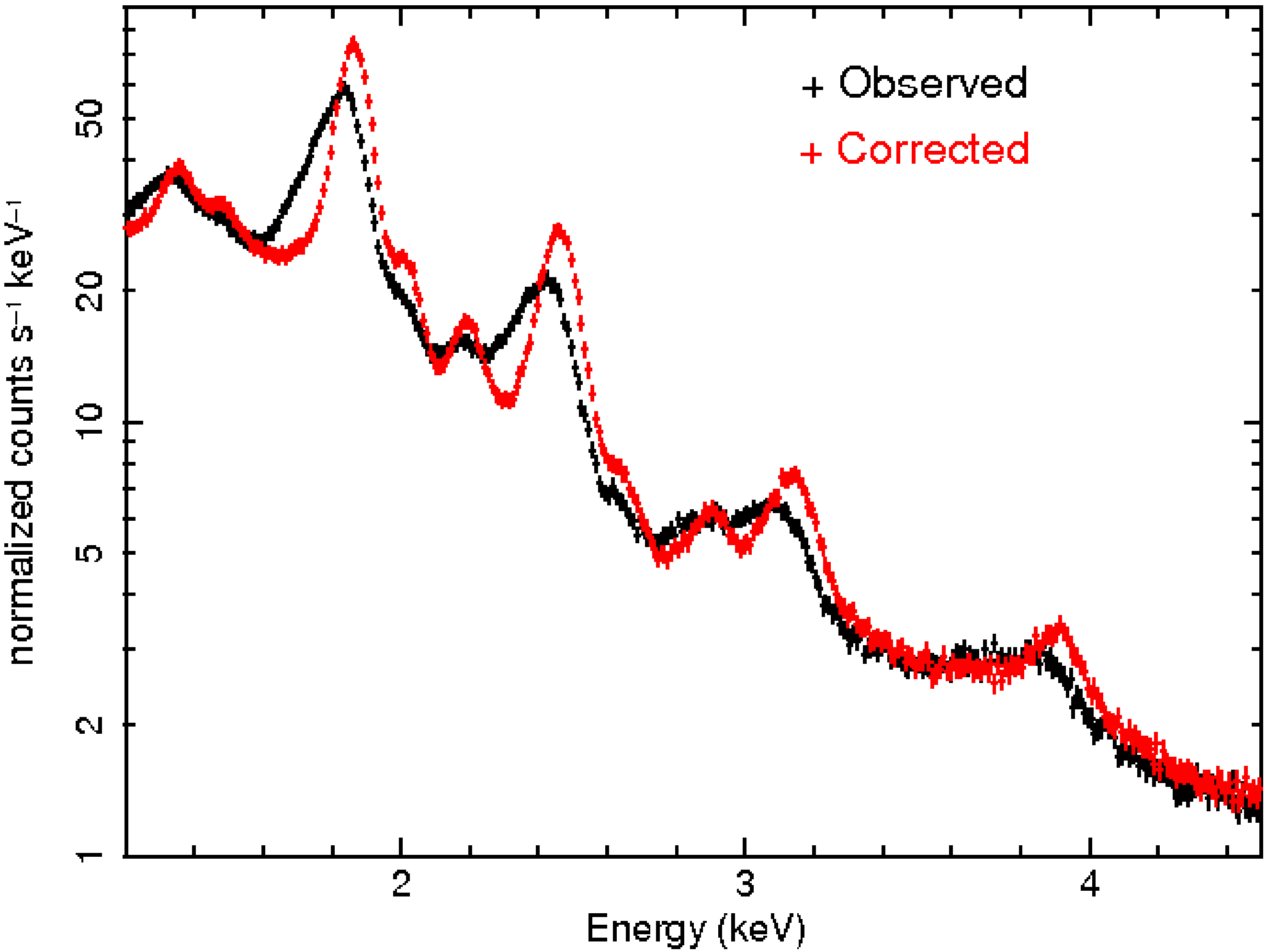


- Cas A, Tycho SNR offset pointings to cover (partially) CCD area (~105 ks)
- Use Si line (1.85 keV) as reference energy, fit line to localize traps and measure individual trap depths and global column offsets

Trap localisation

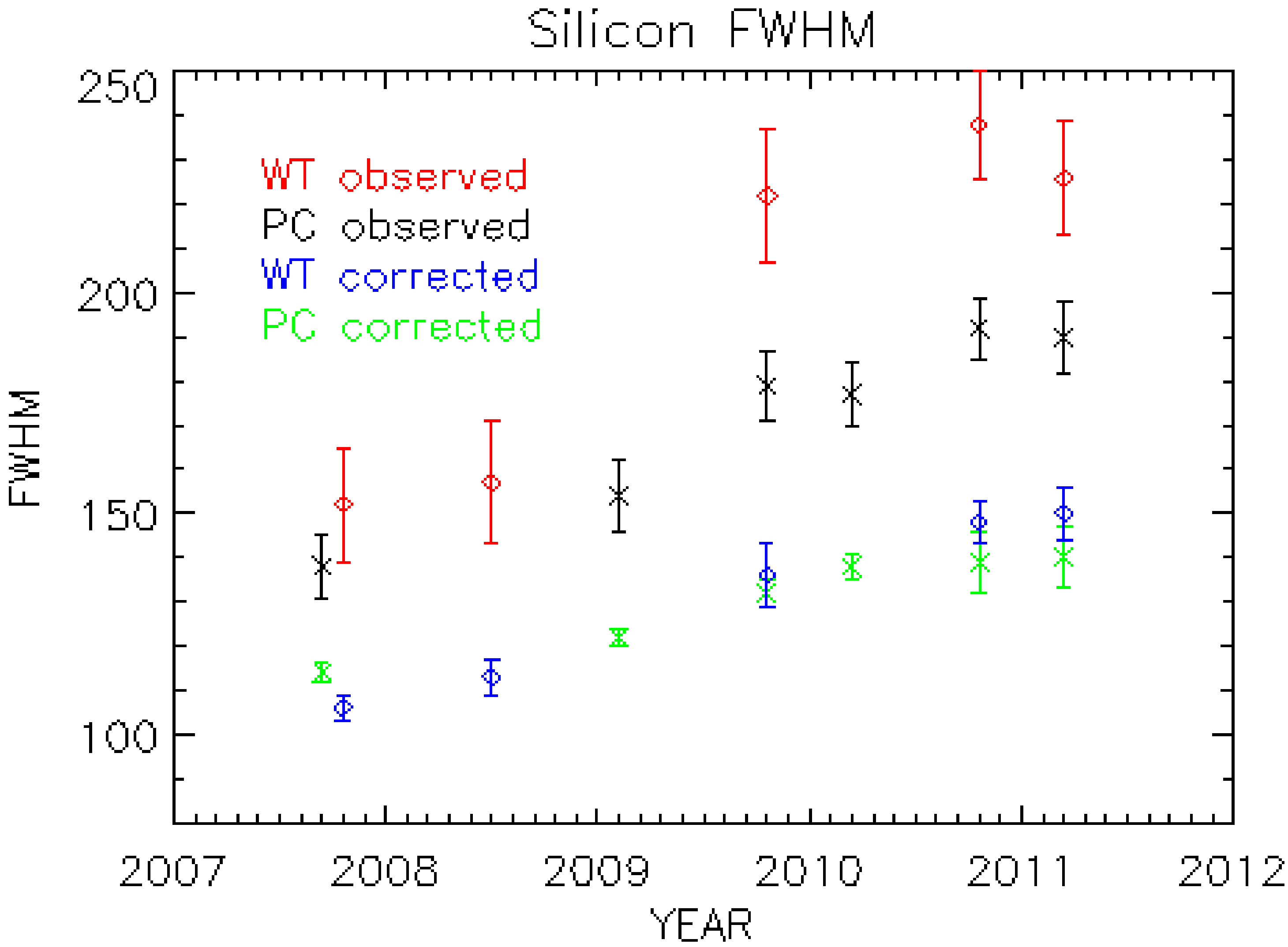


Recovered Energy Resolution

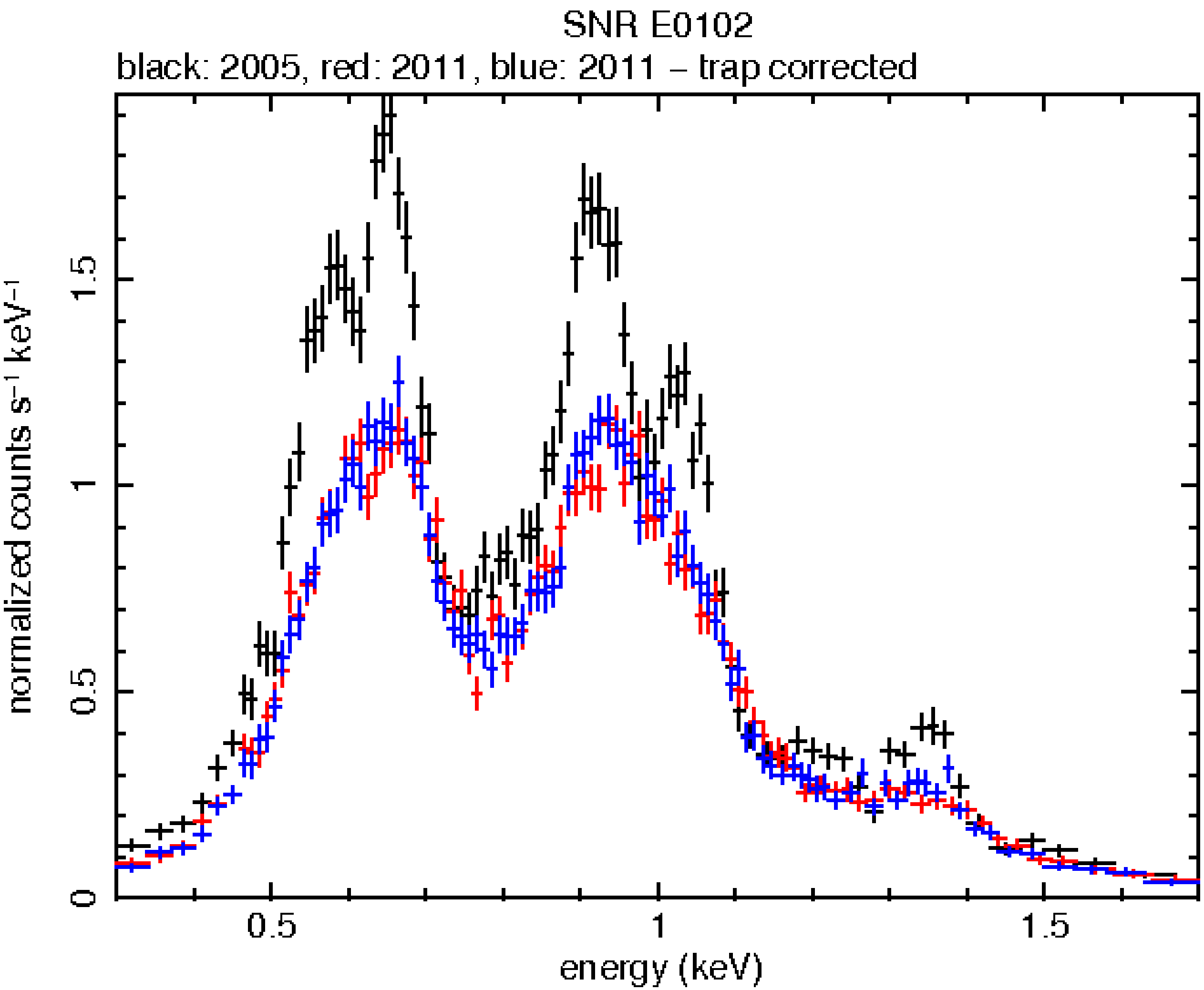


- Trap corrections included in CALDB and xrtcalcpi for the last year.

Reconstructed FWHM



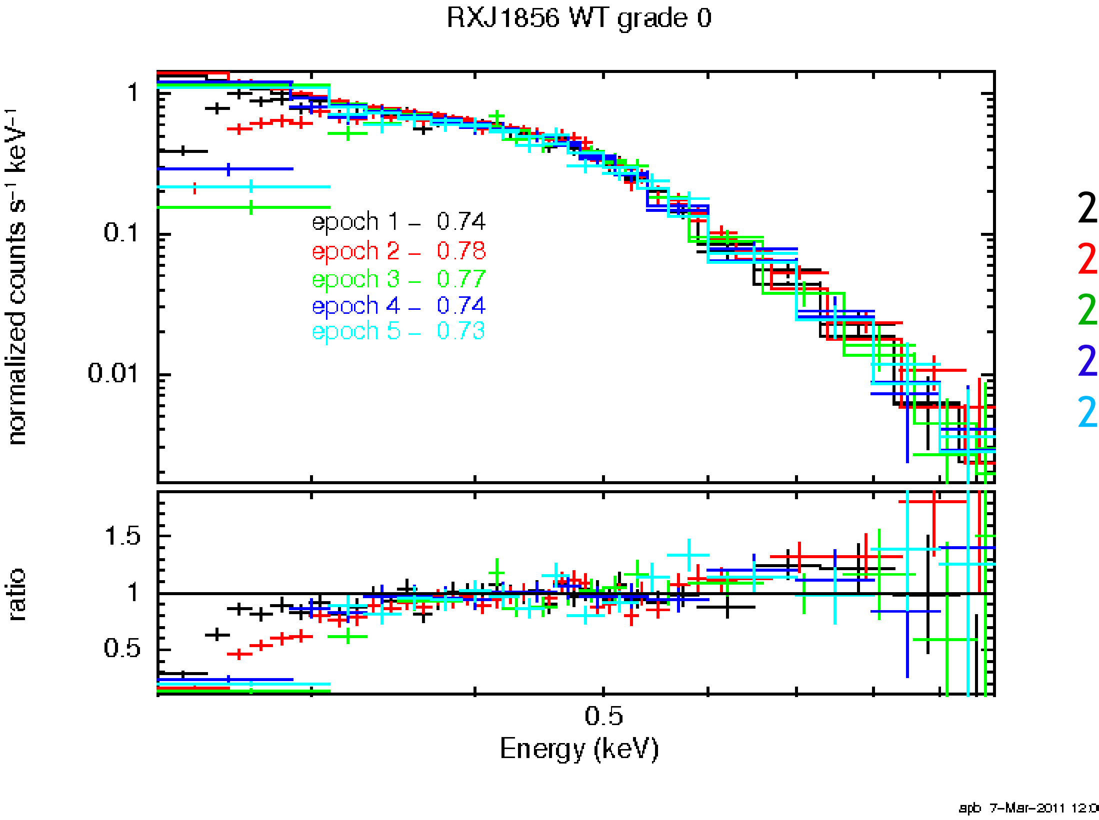
Limitations (1)



•RMF is broadened to match the trap corrected data

Limitations (2)

RXJ1856 (WT)



2007-09/11
2008-09
2009-10/11
2010-04
2010-08

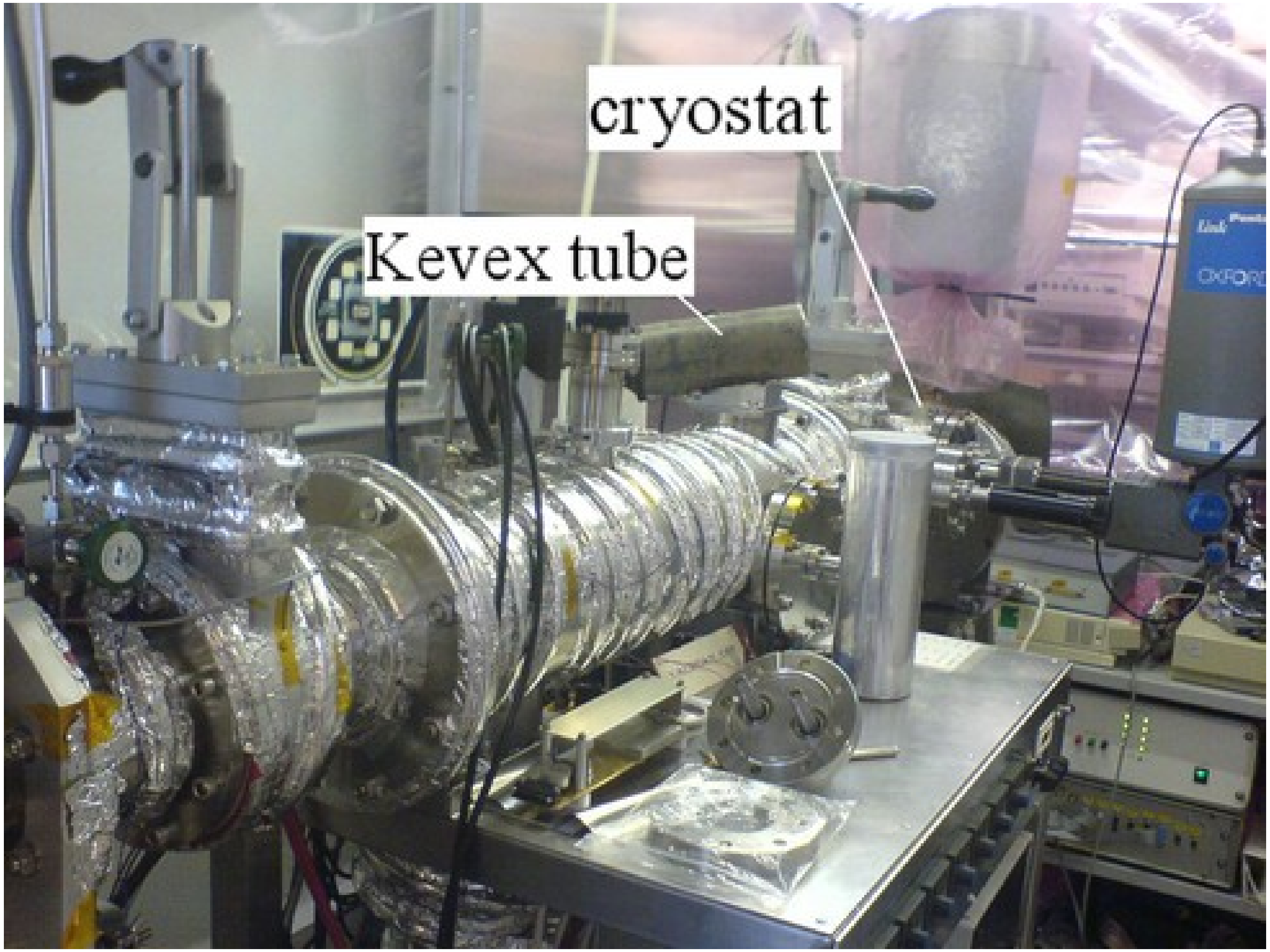
• Performance degrading at low E due to events disappearing below the 80DN (~0.225 keV) event threshold

Difficulties

- Energy dependence - higher energies → larger charge cloud which can interact with more traps
  - E^{β} with $\beta \sim 0.8$ (determined in an averaged manner using Tycho & E0102)
- XRT CCD temperature varies from T~ -75 to -50C (typically -60C)
  - Dark current fills traps at higher T → temperature dependent trap depths
  - Temperature dependent CTI (seen in corner source data)
- Source flux dependence
  - Sacrificial charge effect
  - No astrophysically bright line source!

LU SRC Camera test facility

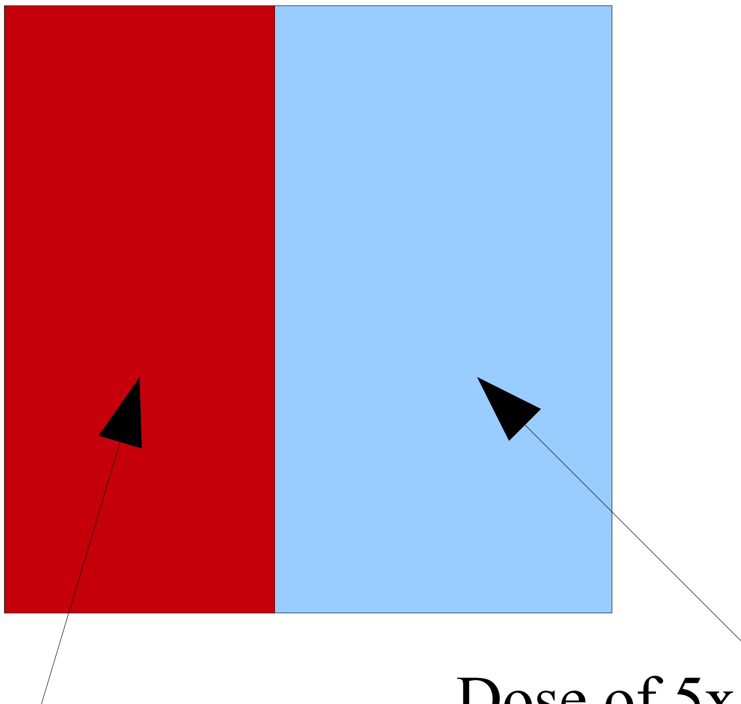
- Lab programme on a damaged CCD



Thanks to *David Vernon, SRC*

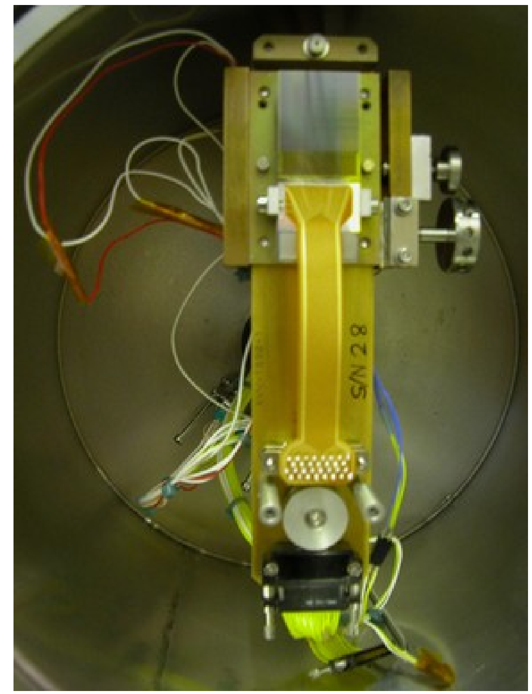
Proton damaged CCD

Copy of XRT e2V CCD-22 irradiated with 10 MeV proton beam at Harwell tandem accelerator facility



Dose of 5×10^8 10 MeV protons

Dose of 2.5×10^8 10 MeV protons



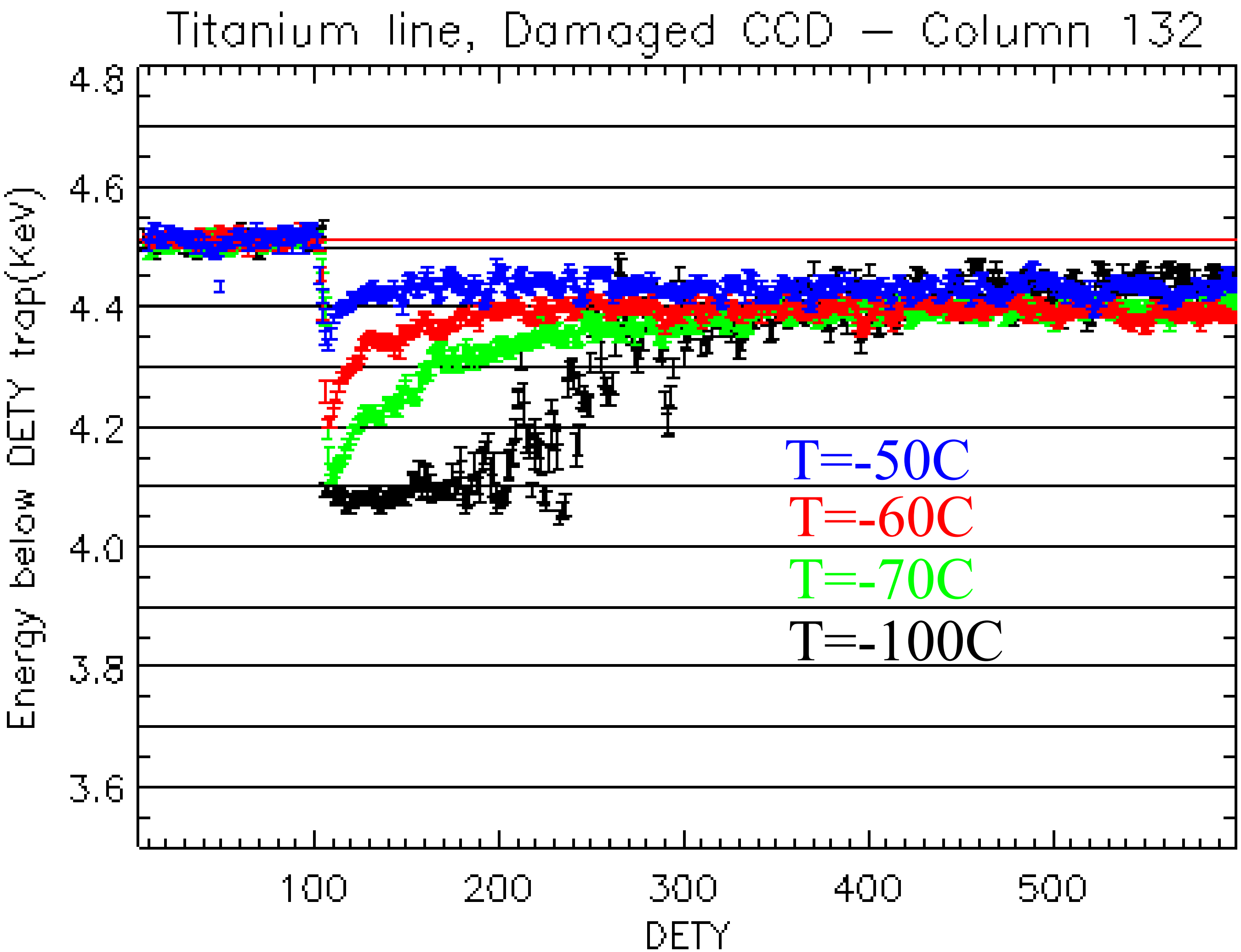
Lab data

High statistics datasets at selected energies and CCD operating temperatures:

- **ENERGY**: Oxygen (0.5 keV), Copper (0.9 keV), Aluminium (1.2 keV), Silicon (1.8 keV), Titanium (4.5 keV) and Iron (6.4 keV)
- **TEMPERATURE**: Camera cooled at set of temperatures comparable to *Swift*/XRT operational range (Ti and Si):

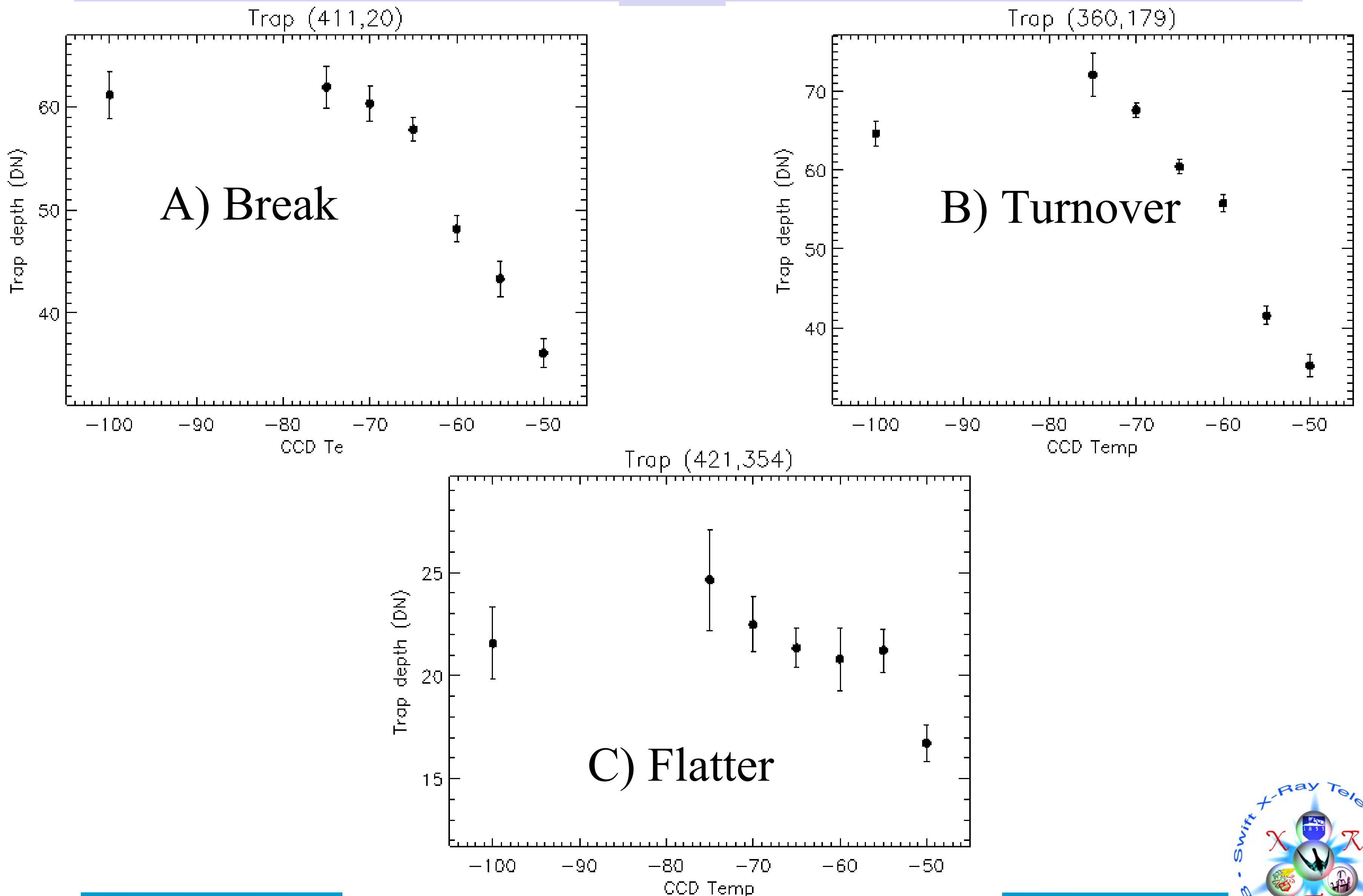
  CCD_T = [-100, -75, -70, -65, -60, -55, -50C]
- CCD uniformly illuminated, 10k frames at each setting, flux of ~ 600 single pixel X-rays/frame.

Deep trap temperature dependence



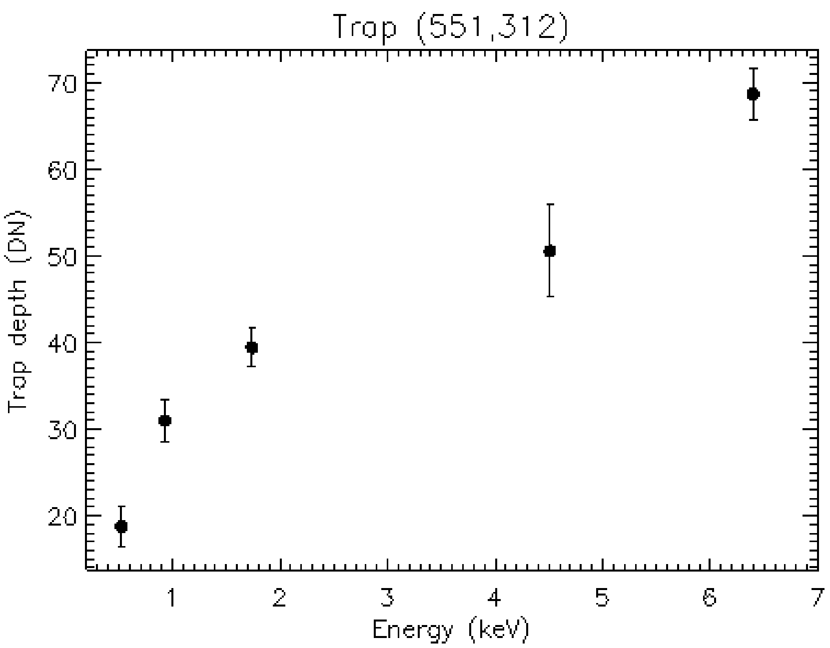
- At -70C no “step” in profile is seen, but gradual “recovery”
- Lower temperatures (-100C) needed to see the step.

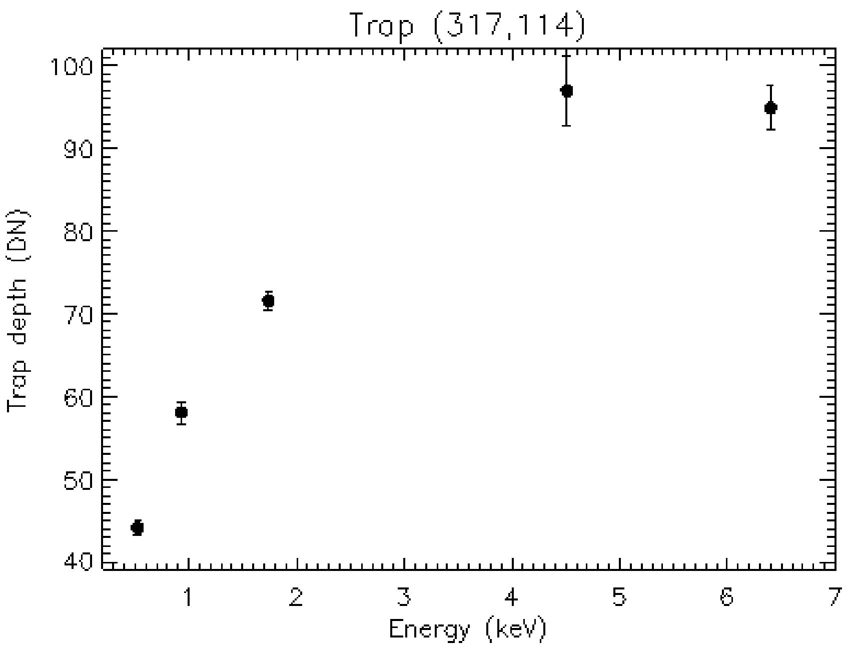
Lab data – Temp dependence



Lab data – energy dependence

Increasing depth vs energy





- Aim to use the average energy and temperature dependences in the gain correction

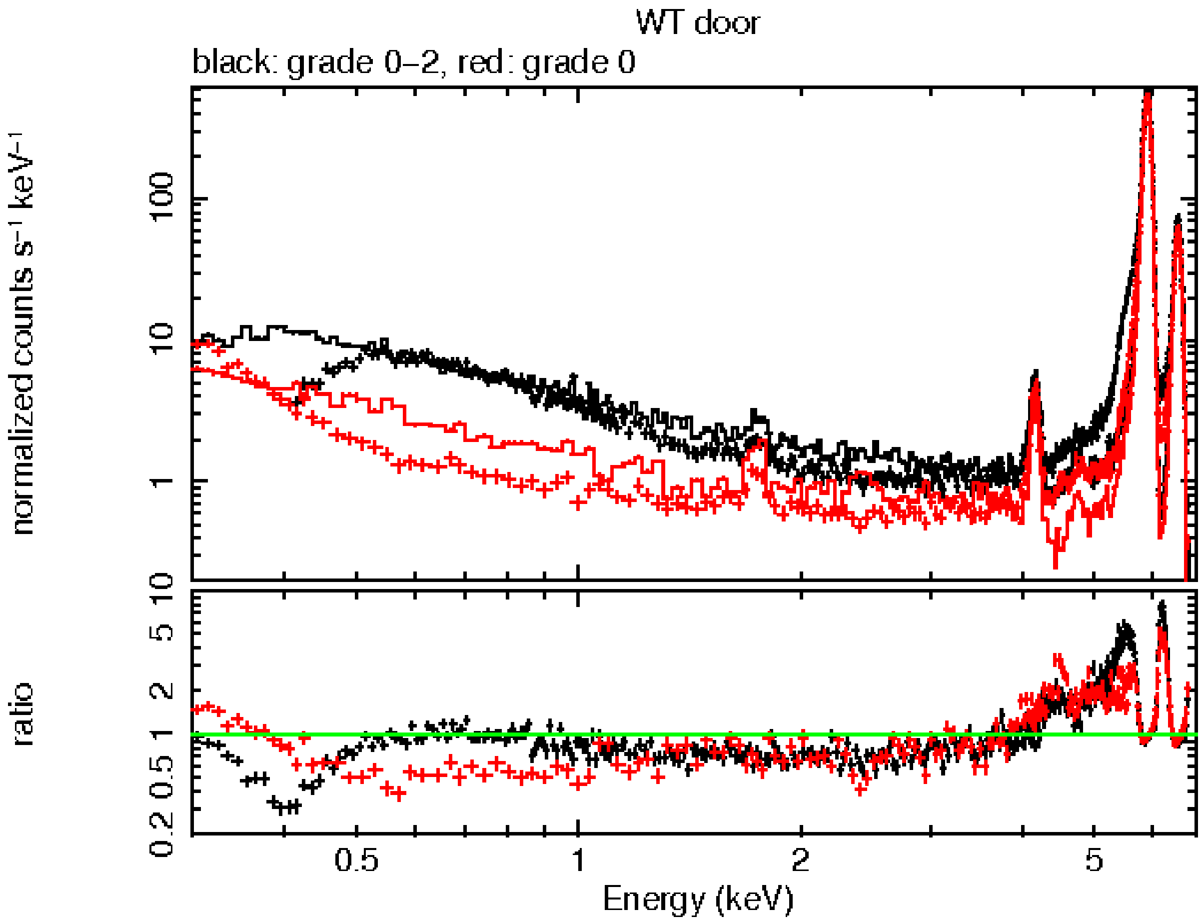
CCD22 Simulator MkII

- Rewrite of our CCD22 simulator (in C++)
- Aims
  - to get back to a single code base for both PC and WT mode (without the need for ad-hoc corrections)
  - Improve WT redistribution modelling
  - Explore WT mode powerspectrum properties
  - Study effects of pile-up
- Full details in working group talk

- CCD simulator model
  - Detailed electrode structure (allowing different depletion depths under the open/closed part of the electrode)
  - Interactions in the depletion, field-free and substrate regions
  - Correct charge-cloud spreading
  - Readout appropriate to either PC or WT mode
  - Event grading (as per ground s/w)

Initial results

- Current CALDB WT RMF



Initial results

- test WT RMF