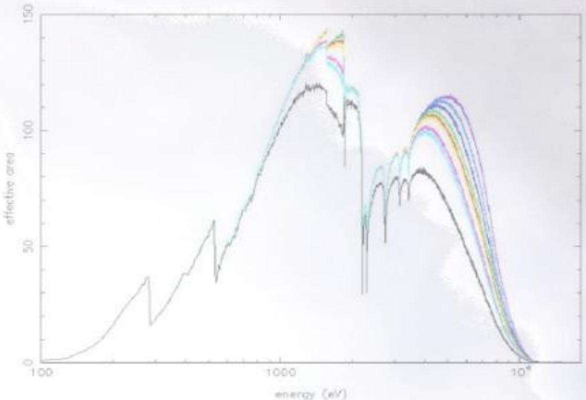
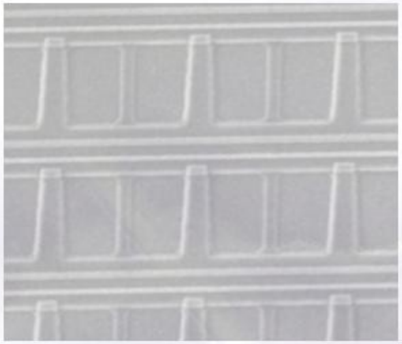
Swift-XRT Calibration Update

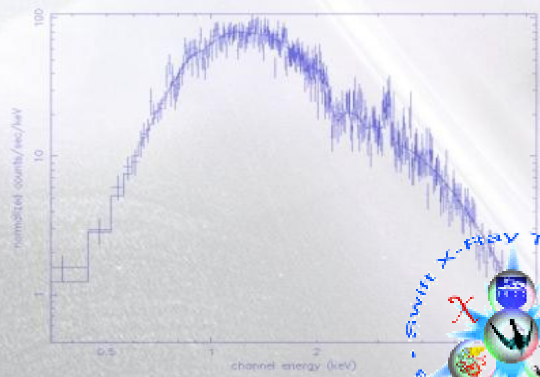
Andy Beardmore

and the

Swift-XRT calibration team



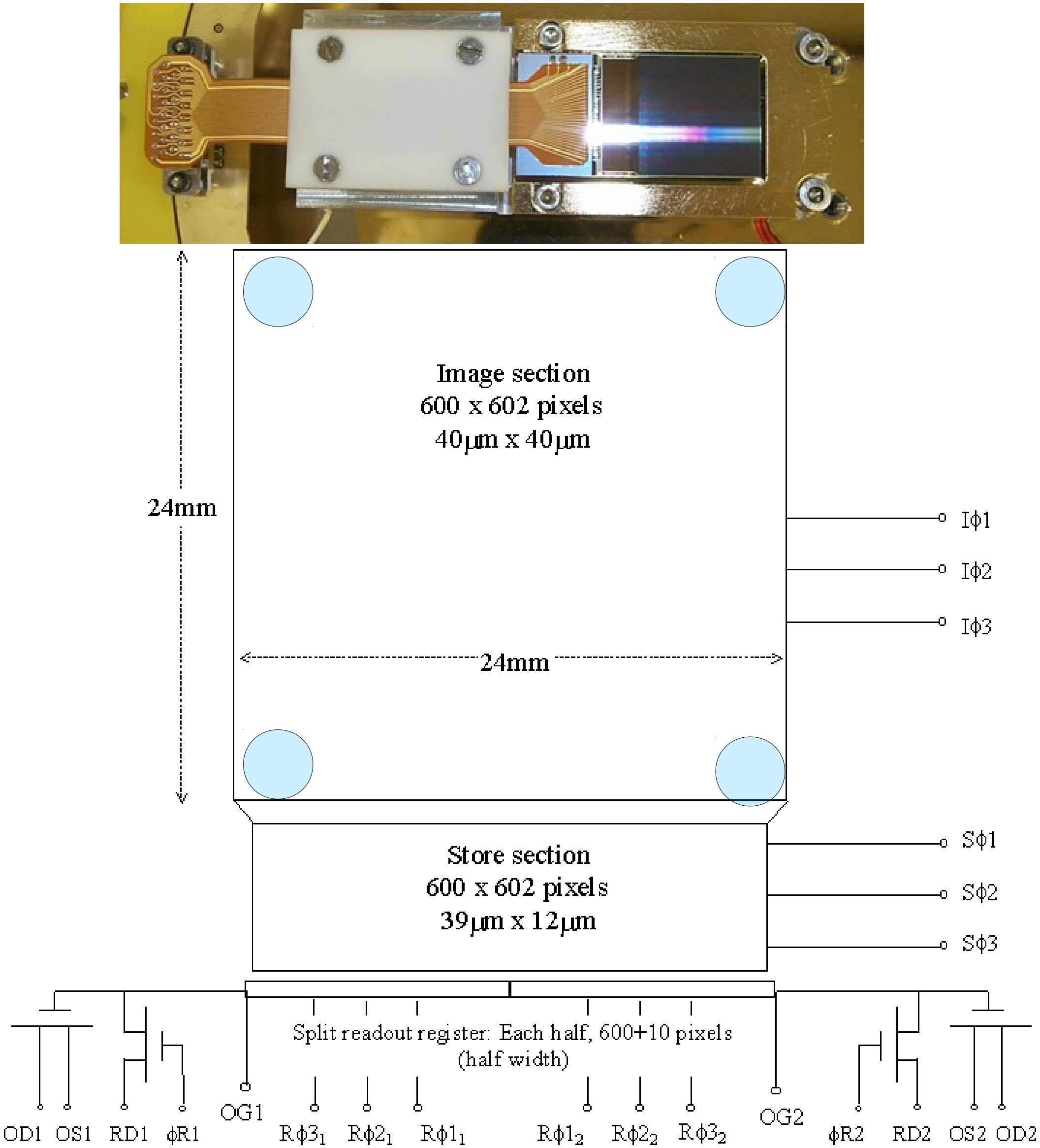




Swift Status

- Swift has now been operating for 8+ years
- Makes 35000 slews per year (>99% within 3' accuracy; ~40 targets per day)
- Approaching 750th Swift detected GRB
- Observing time: <20% GRBs, 35% GI/fill-ins, 30% TOOs (>850 per year), 2% Cal
  - Cal: 300 ks every 6 months; 150 ks on Tycho for trap mapping
- XRT CCD temperature range: -70C to -52C (97% of time below -54C, mean of -60C)

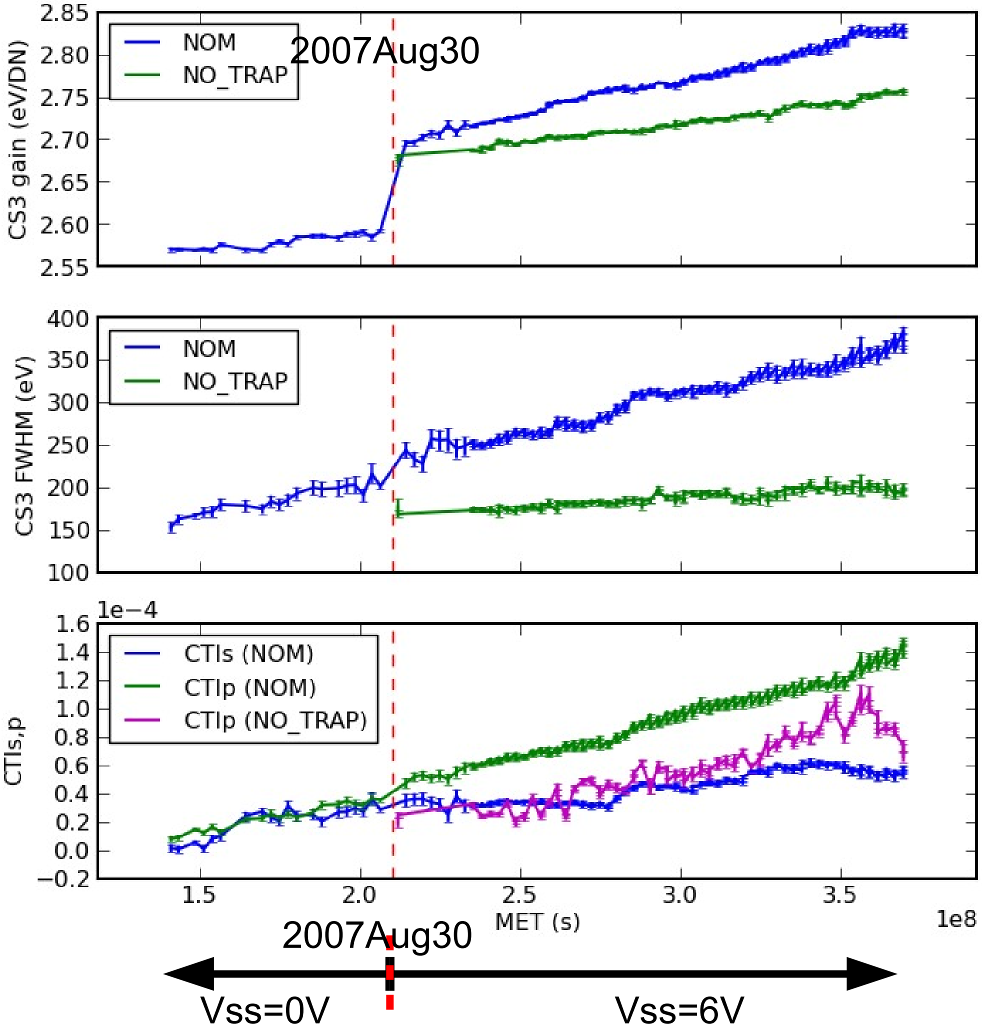
Swift-XRT CCD



- e2v CCD-22 detector (developed for EPIC MOS camera on XMM-Newton)
- Operated in Photon Counting (PC; Δt=2.5s) and Windowed Timing (WT; Δt=1.77ms) mode
- 4 ^{55}Fe corner sources continuously illuminate CCD corners, used to monitor CCD performance
- Spectral resolution at launch: FWHM = 145 eV at Mn K-α (5.895 keV)
- *Swift* in Low-Earth orbit and exposed to high flux of protons during SAA

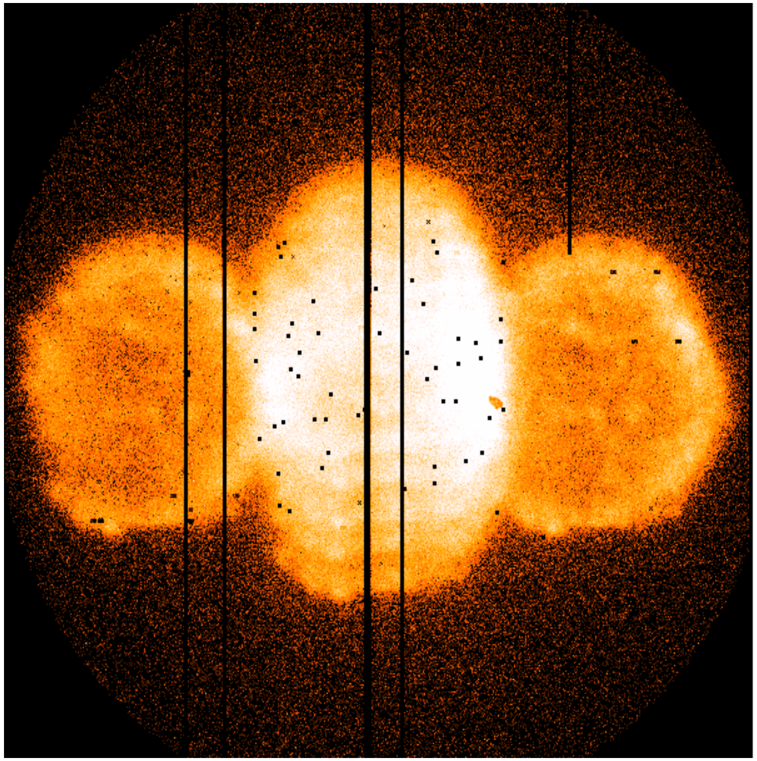
Gain and CTI Evolution

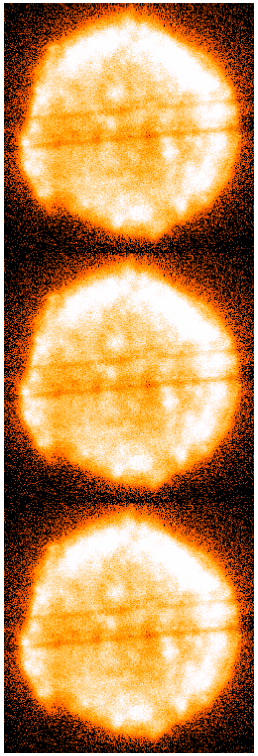
- Gain/CTI measured from corner sources (-60C)



Trap Mapping

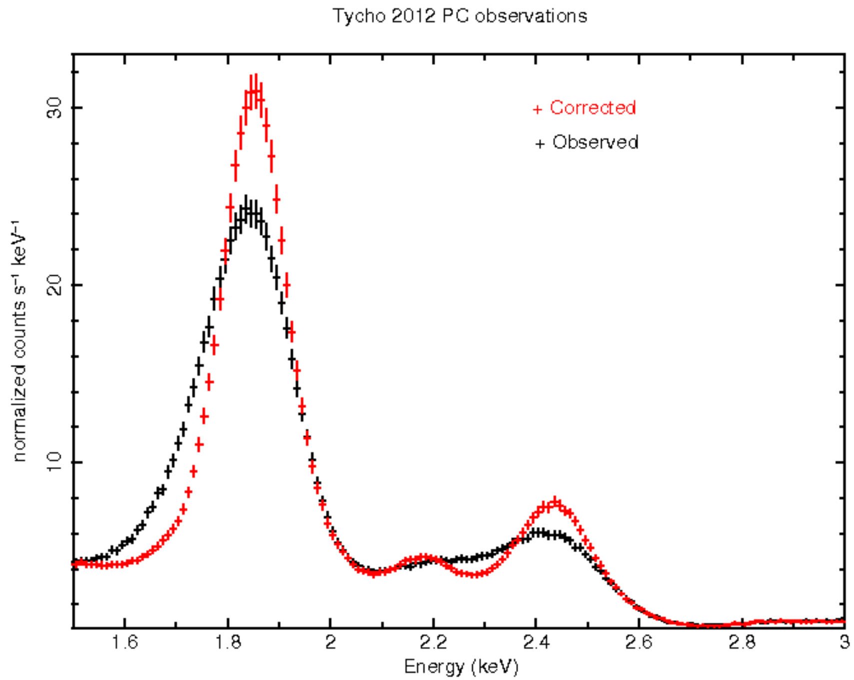
- Tycho SNR observed ~ 6 monthly
- Si-Kα used to map the location and depth of the deepest traps (PC), column offsets (WT)

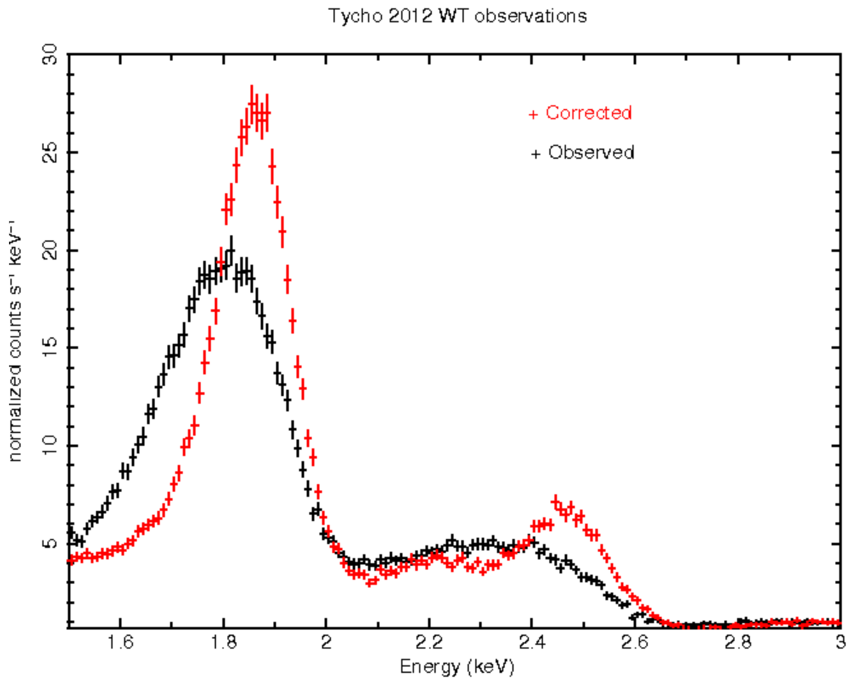




- PC: 7x15ks
- WT: 3x15 ks

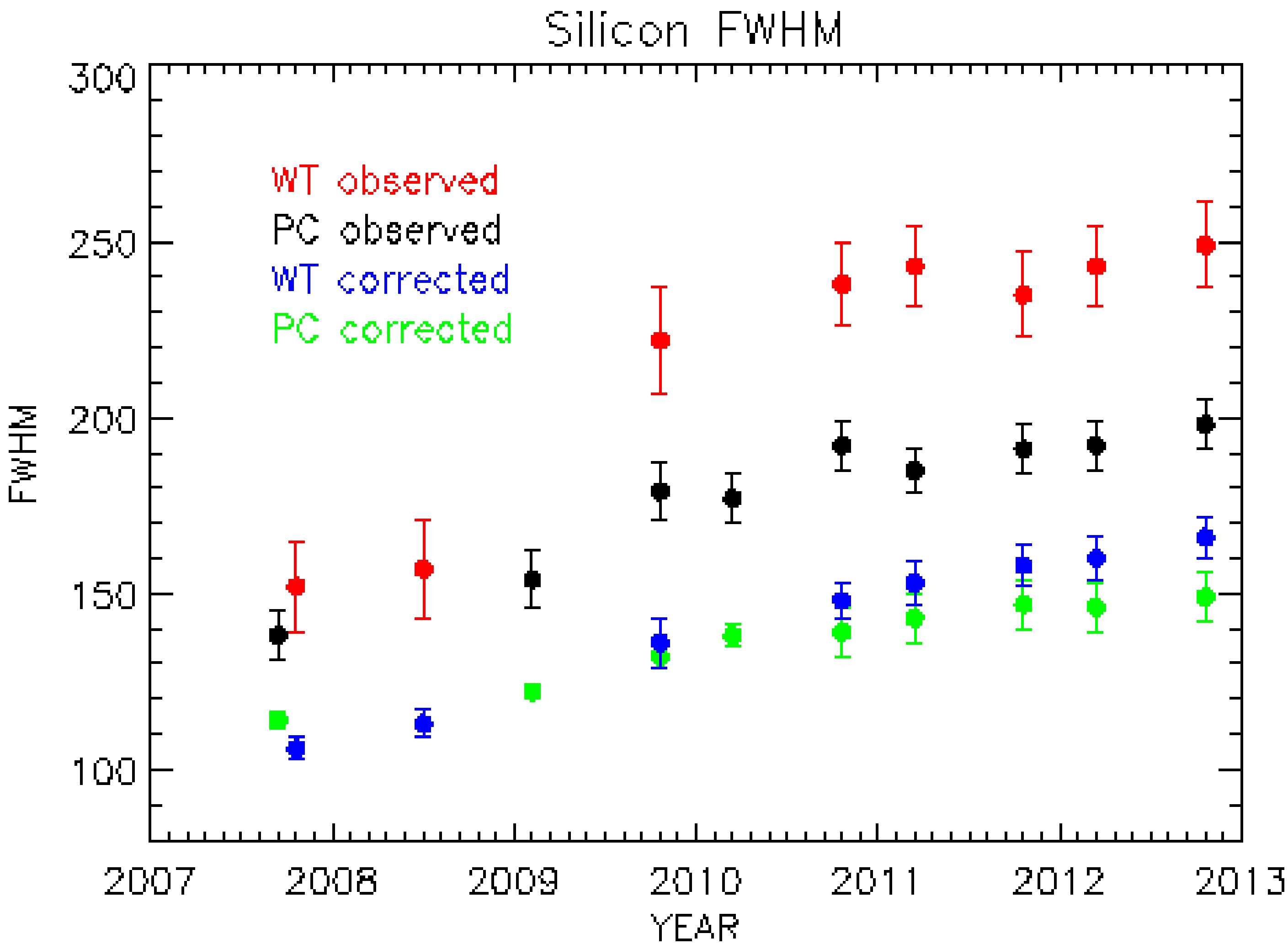
Trap mapping (cont'd)



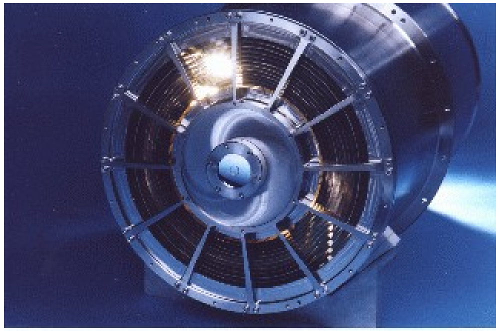


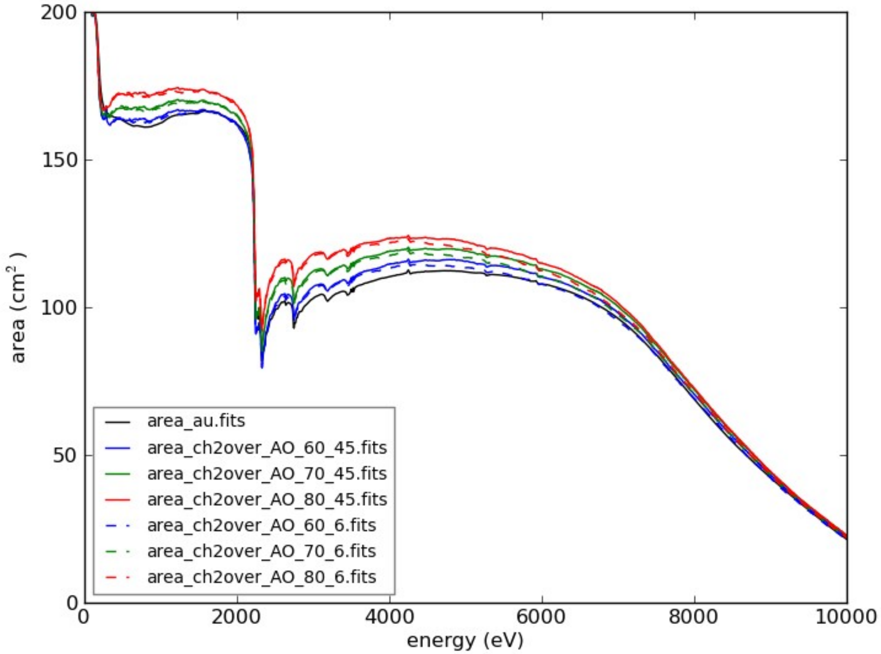
- Energy dependent trap offsets for both PC & WT (modelled as broken powerlaw)
- Temperature dependent trap depths for PC (as thermal noise fills traps when CCD is warmer)

Recovered Resolution



Mirror Area Revisited





Jet-X flight Spare mirror module

- New mirror area calculations, including a hydrocarbon (CH_2) overcoat
- Reflectivity increases with thickness of CH_2 layer
- High energy (> 4keV) area turns over faster as the microrough-ness increases

Micro-roughness (rms):
solid = 4.5 Å
Dashed = 6.0 Å

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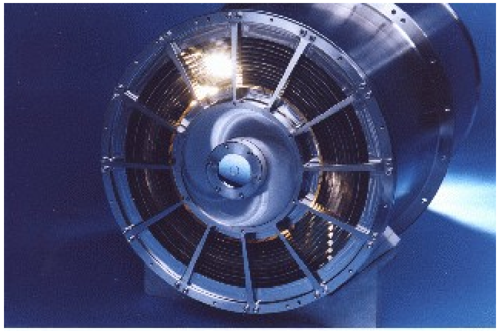

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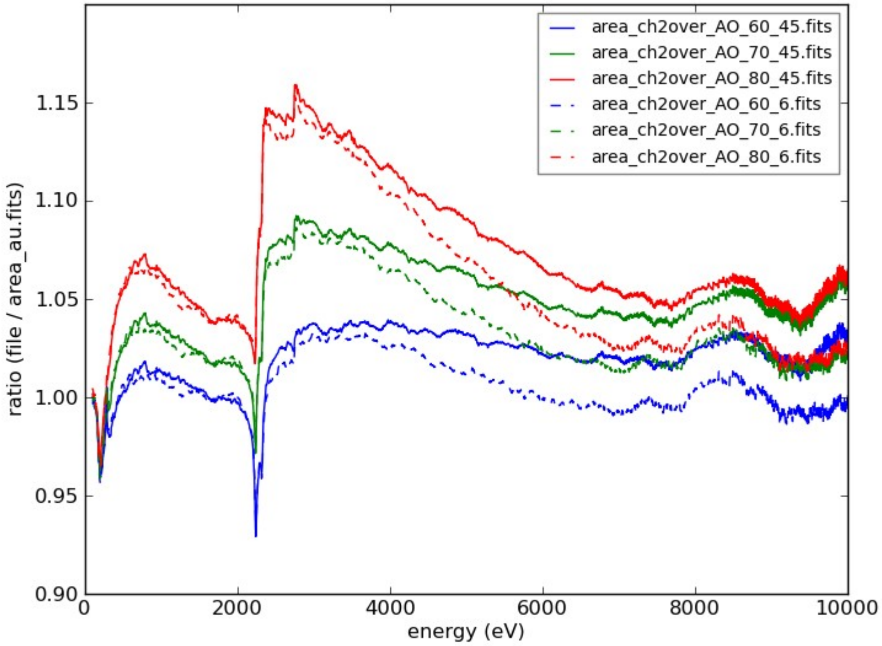

- New mirror area calculations, including a hydrocarbon (CH_2) overcoat
- Reflectivity increases with thickness of CH_2 layer
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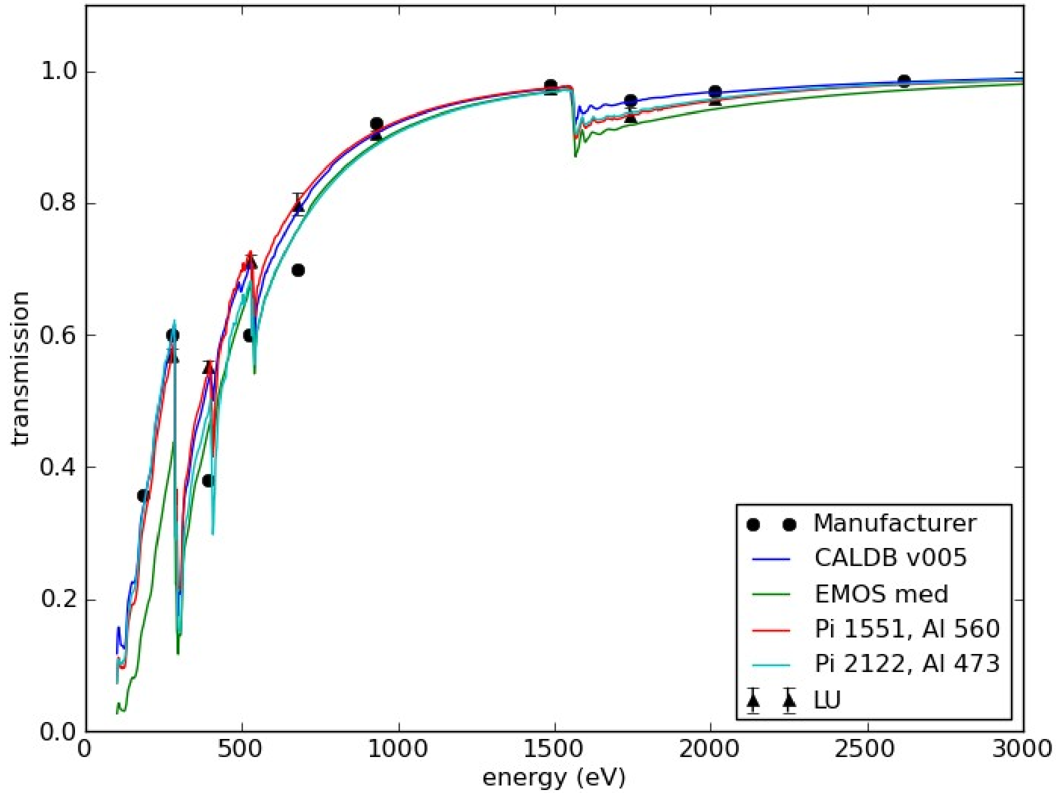
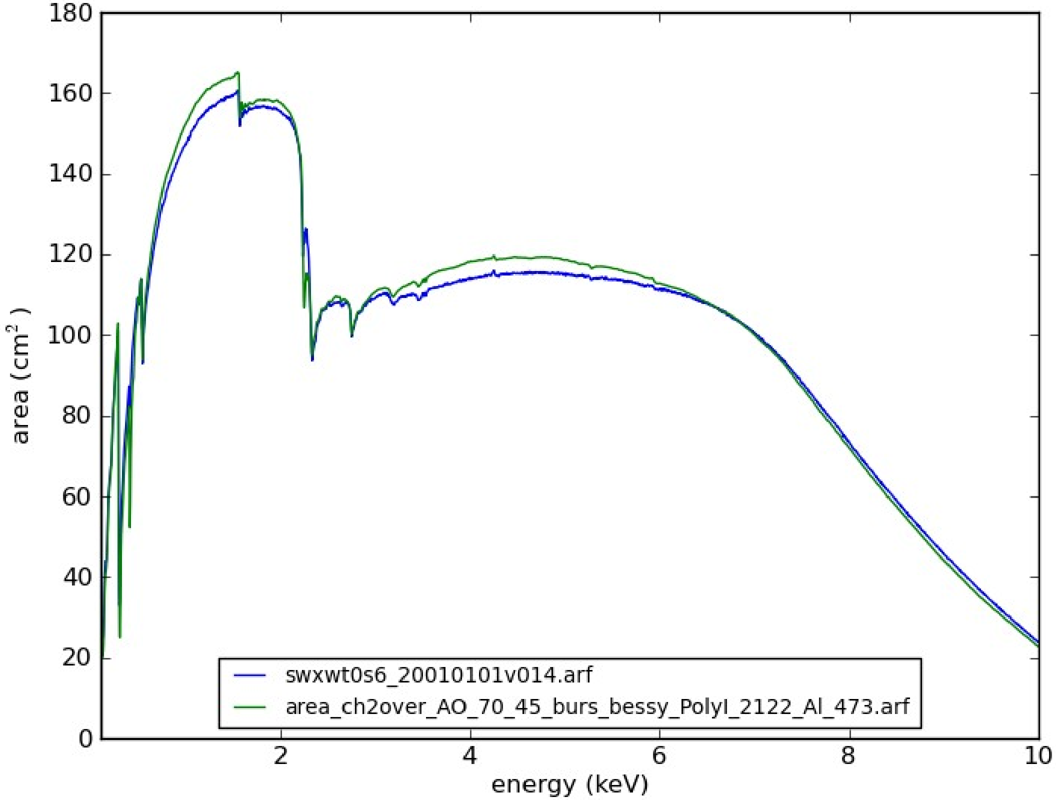
Filter Transmission Revisited

- Fit to LU and manufacturer filter data using new polyimide and aluminium mass absorption coefficients (from M. Barbera, Palermo)



ARF – comparison

- ARF comparison – CALDB (v014) and new preferred mirror area * filter transmission

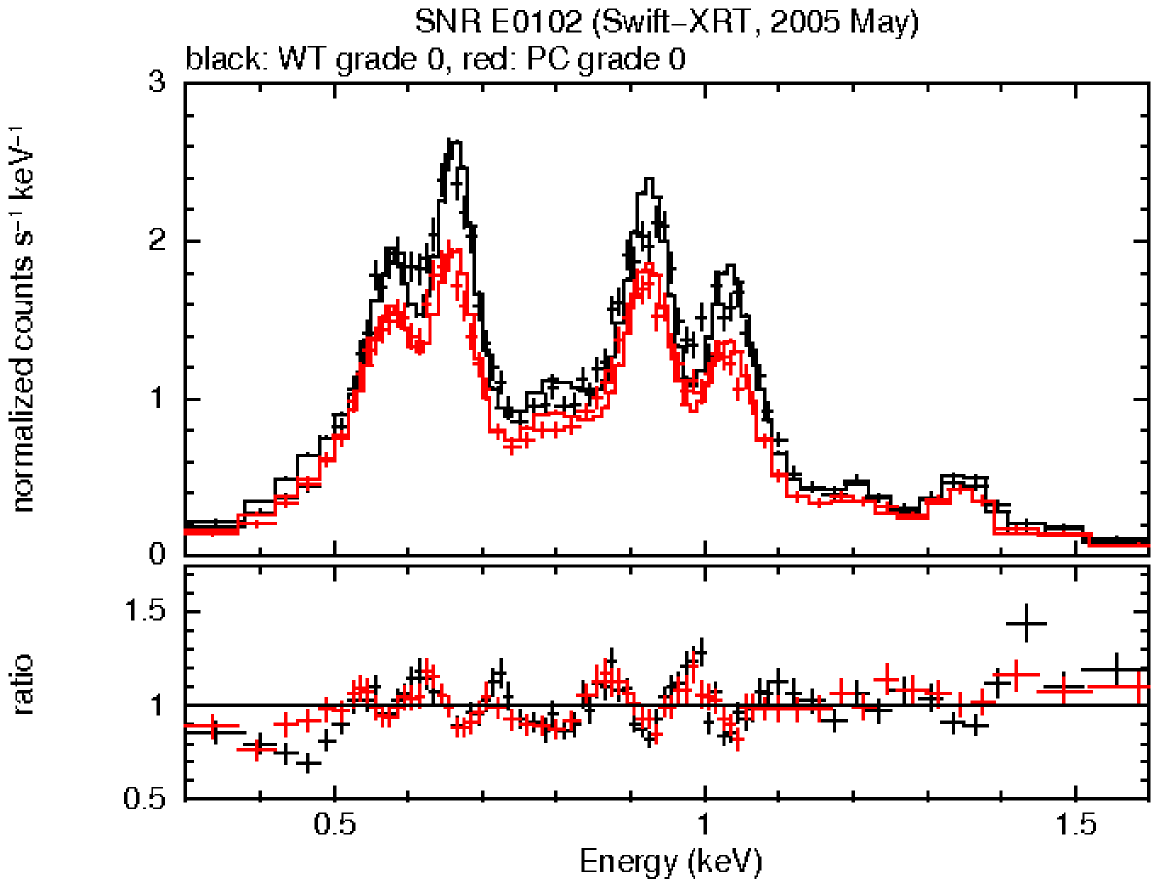


RMF

- CCD22 simulator code described last IACHEC
- Use to generate PC and WT mode RMFs
  - PC : 2D, full-frame readout (Δt=2.5s)
  - WT : 1D readout (Δt=1.77ms) → 10 rows at a time clocked into serial register
- Matched the line broadening to data (2005 & 2007) by increasing the electron noise and CTI
  - EN = 6.75 e^- (2005), 8.75 e^- (2007 Vss = 0V) and 7.5 e^- (2007 Vss=6V)
  - CTIs,p =4e-6, 8e-6 (2005); 3.5e-6 (2007, both Vss=0V and 6V)

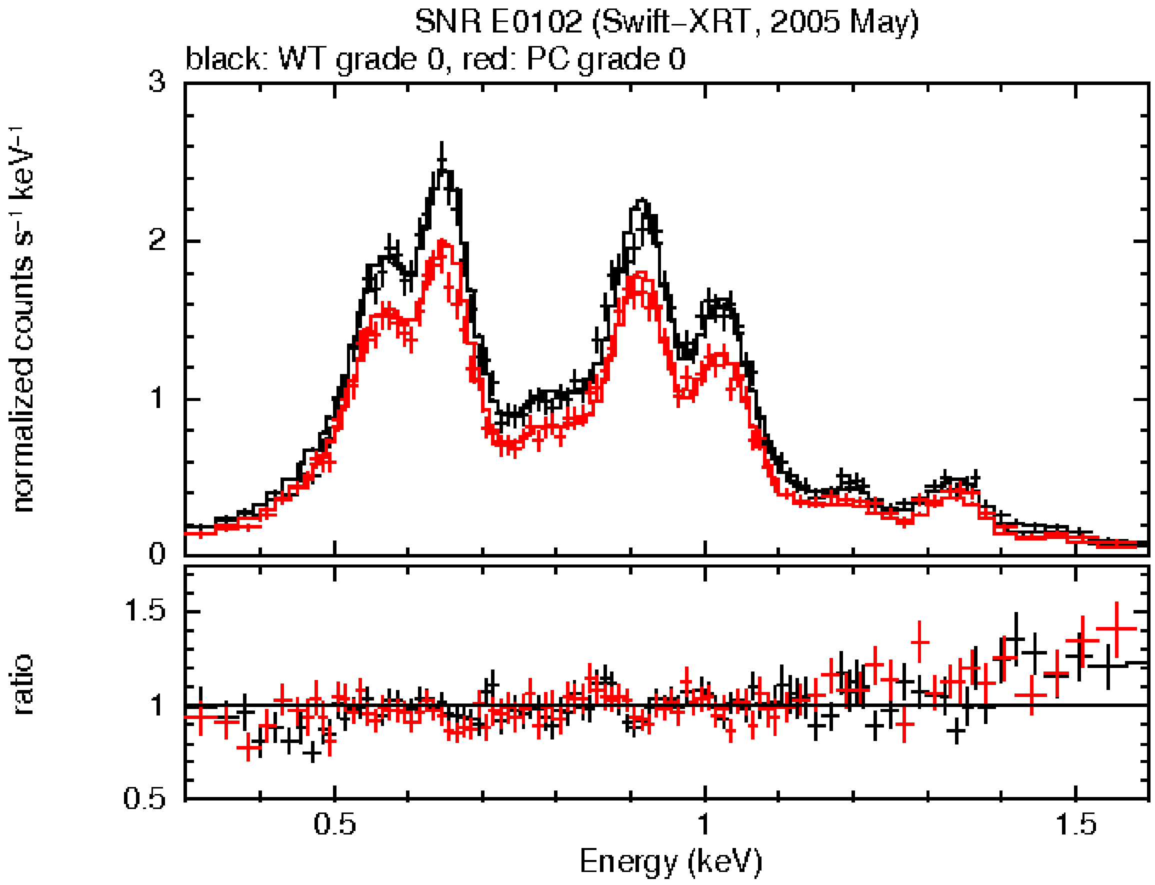
RMF (cont'd)

- V011 RMF



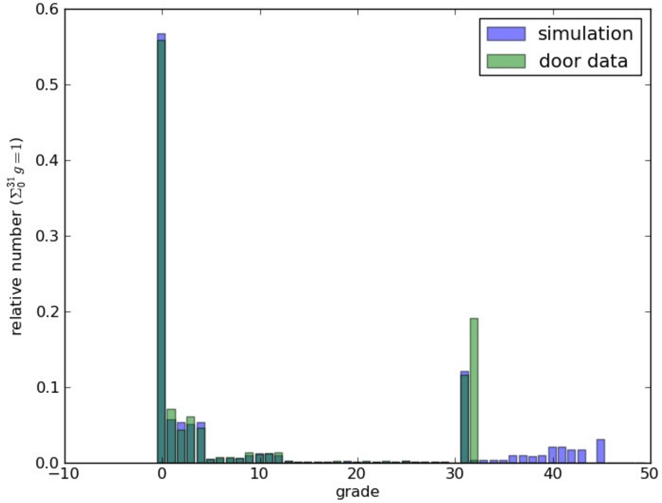
RMF (cont'd)

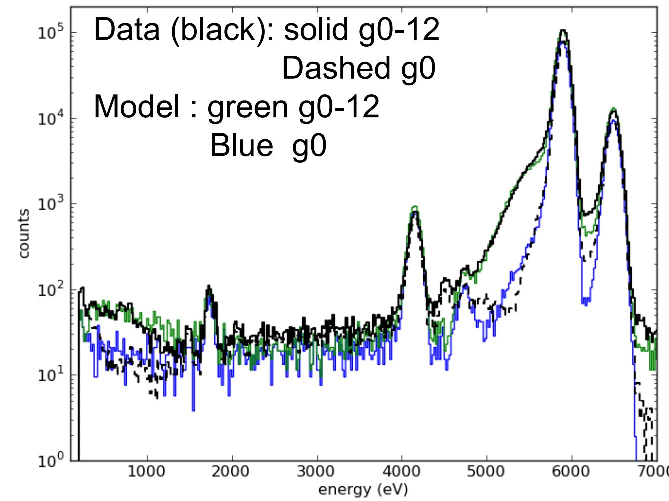
- New 2005 Vss=0V RMF



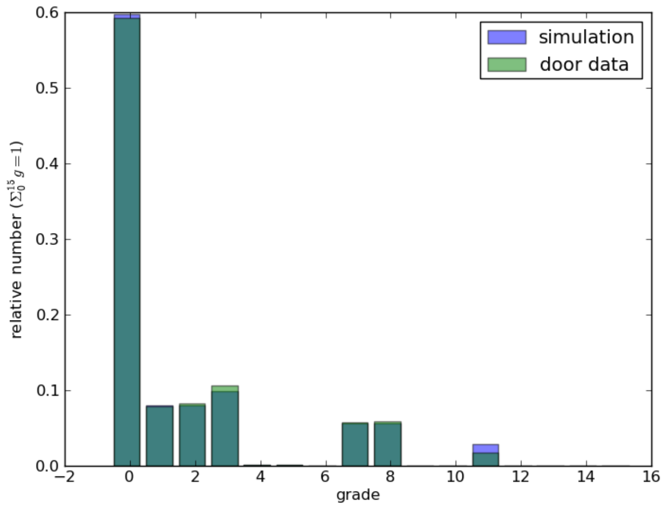
RMF (cont'd)

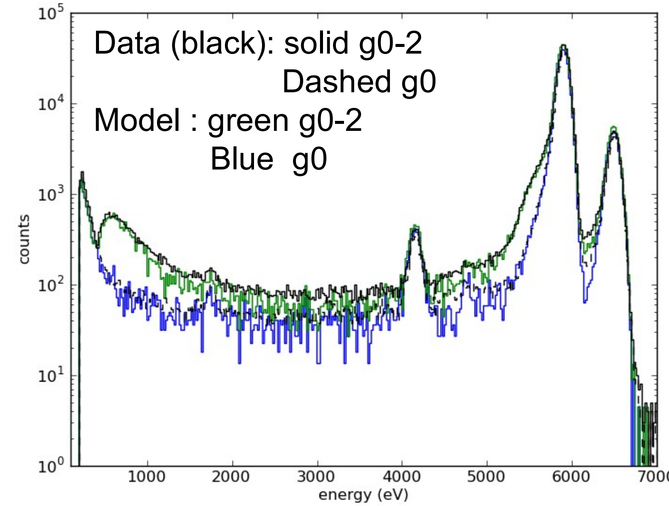
- Improved LEO door source data modelling (Vss=0V)





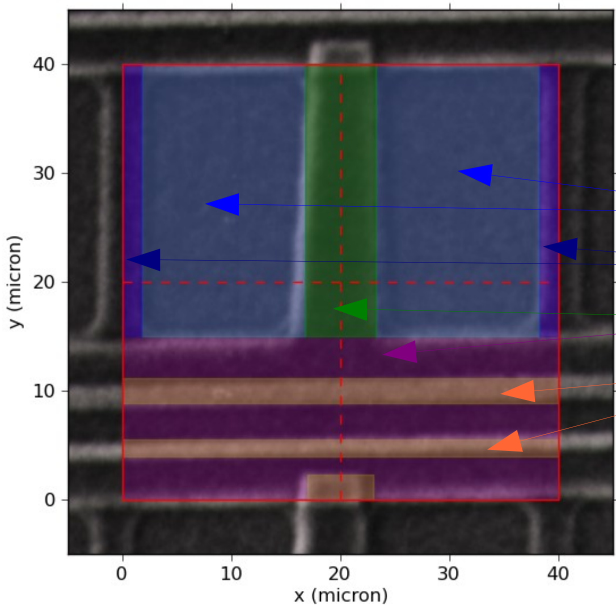
PC





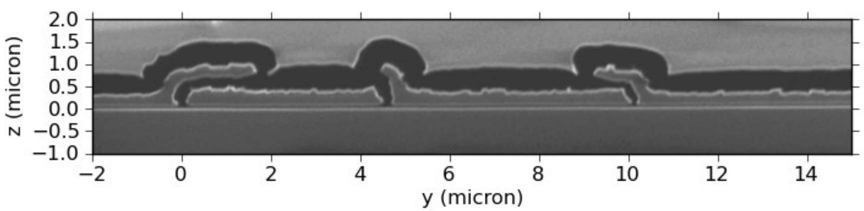
WT

Electrode Structure revisited



Original Electrode Structure

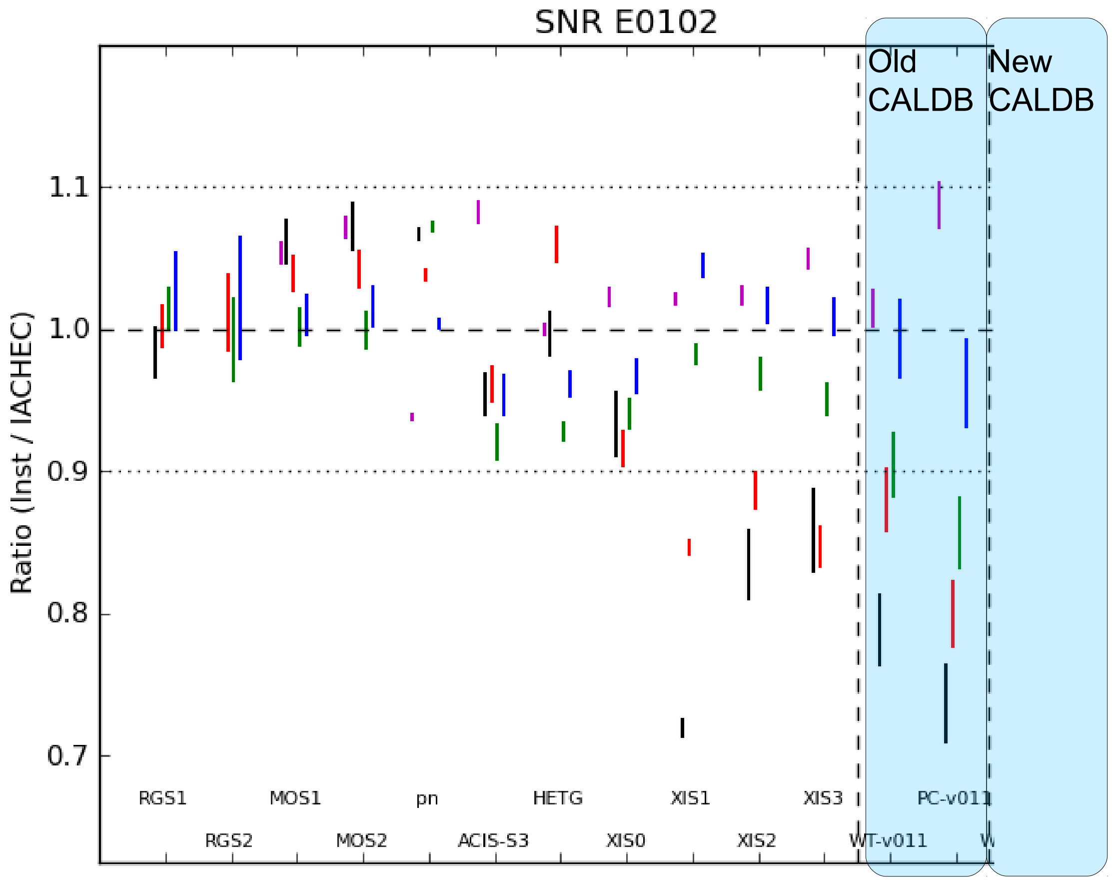
$$T_1 = \exp(-0.1\,\mu_{SiO_2})$$
$$T_2 = T_1\,\exp(-0.1\,\mu_{Si_3N_4})\,\exp(-0.4\,\mu_{SiO_2})$$
$$T_3 = T_2\,\exp(-0.25\,\mu_{Si})\,\exp(-0.3\,\mu_{SiO_2})$$
$$T_4 = T_3\,\exp(-0.25\,\mu_{Si})\,\exp(-0.4\,\mu_{SiO_2})$$



Are the SiO2 and Si layers thick enough ?

Electrode structure (cont'd)

- E0102 WT data from 2005 used to refine the electrode transmission model



Electrode structure (cont'd)

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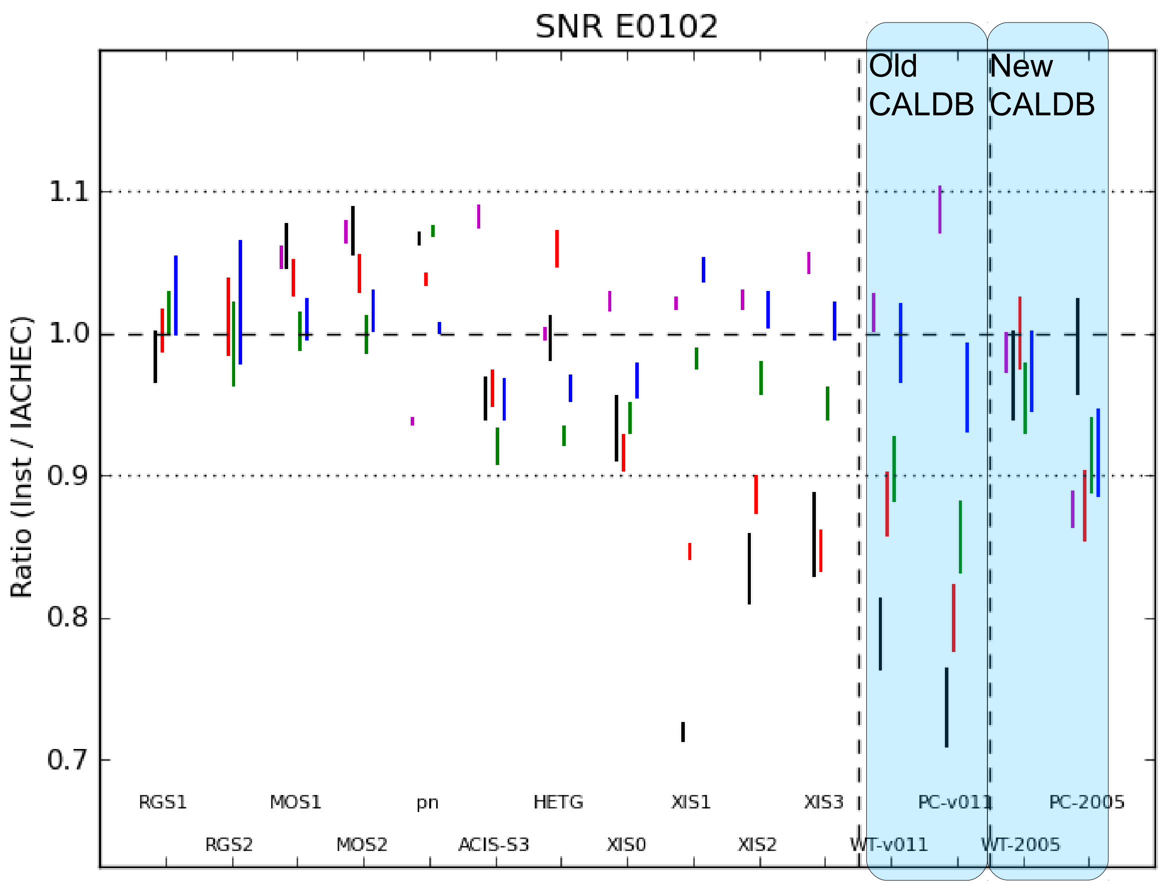
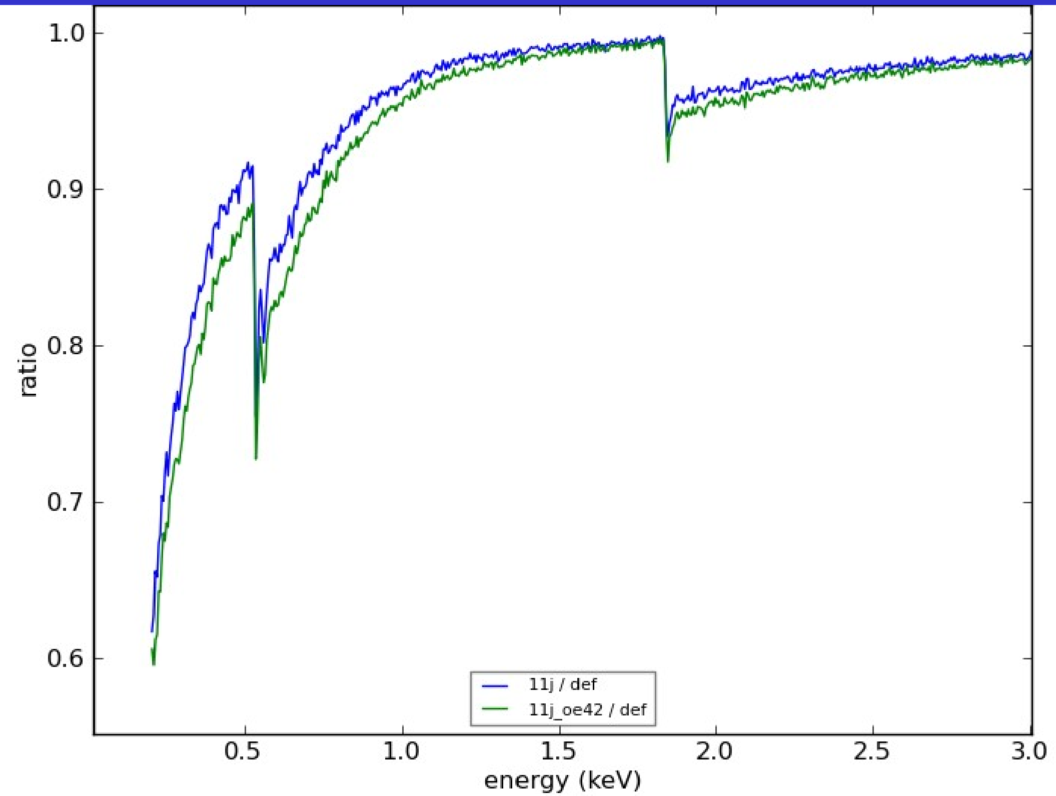


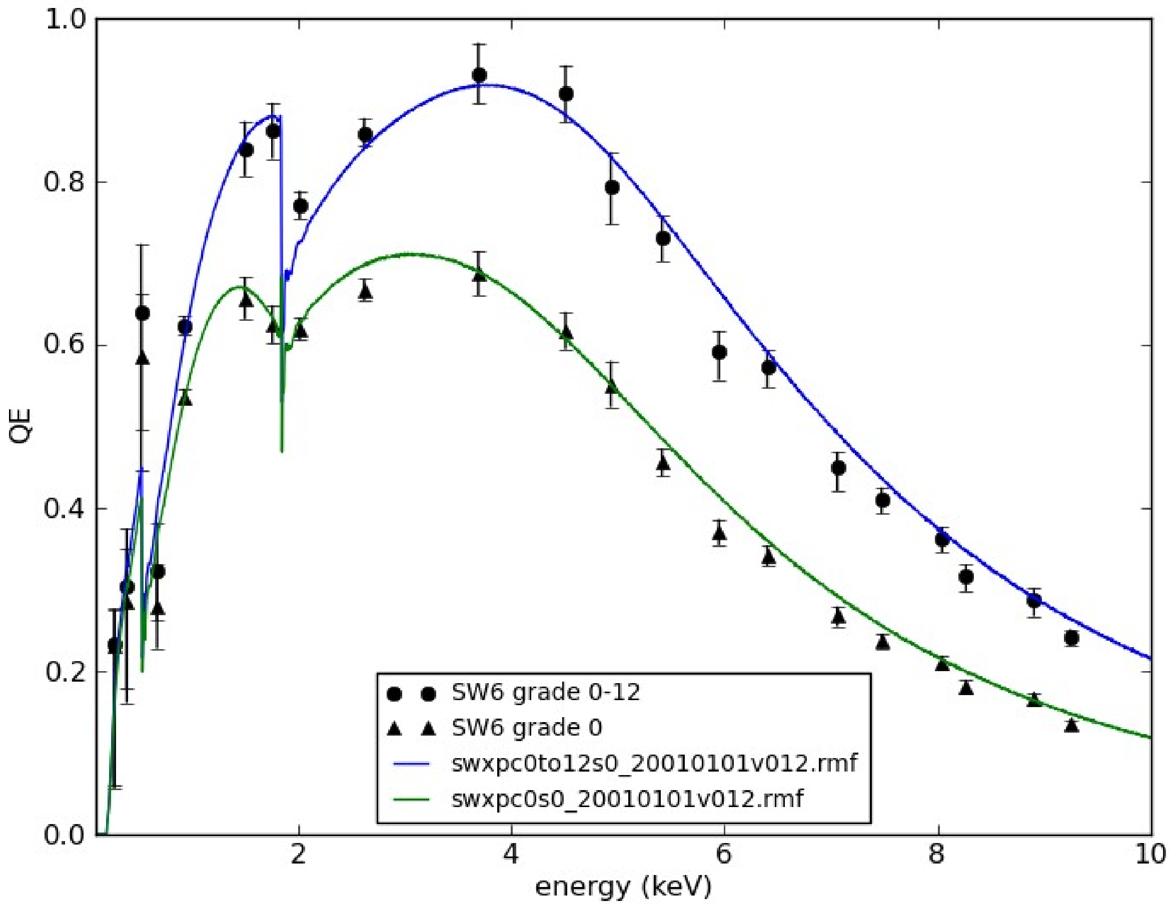
Electrode Structure (cont'd)



- Blue - QE ratio new electrode / original electrode
  - Base SiO_2 layer : 0.1 → 0.15 micron
  - Si layers : 0.25 → 0.35 micron
- Green - QE ratio new (OE area -5%) / original

QE (Vss=0V)

- Comparison with (Astrosat) CCD Lab QE



Vss=0V Effective Area tests

- 2 RMFs * 3 mirror area files * 3 filter files
- Tested on
  - RXJ1856 (WT, PC)
  - Clusters (PC, 90-150 arcs)
    - Abell 1795 (Gal NH=0.012e22 cm^2)
    - Abell 2029 (Gal NH=0.033)
    - PKS0745-19 (Gal NH=0.42)
  - H1426 (Gal. NH=0.012) (PC, XMM 2005-Jun)
  - SNRG21.5 (NH=3.1) (PC)
  - 3c273 (Gal. NH=0.017) (WT, XMM 2005-Jul)
  - Mkn421 (Gal. NH=0.019) (WT, MOS1T 2006-Dec)

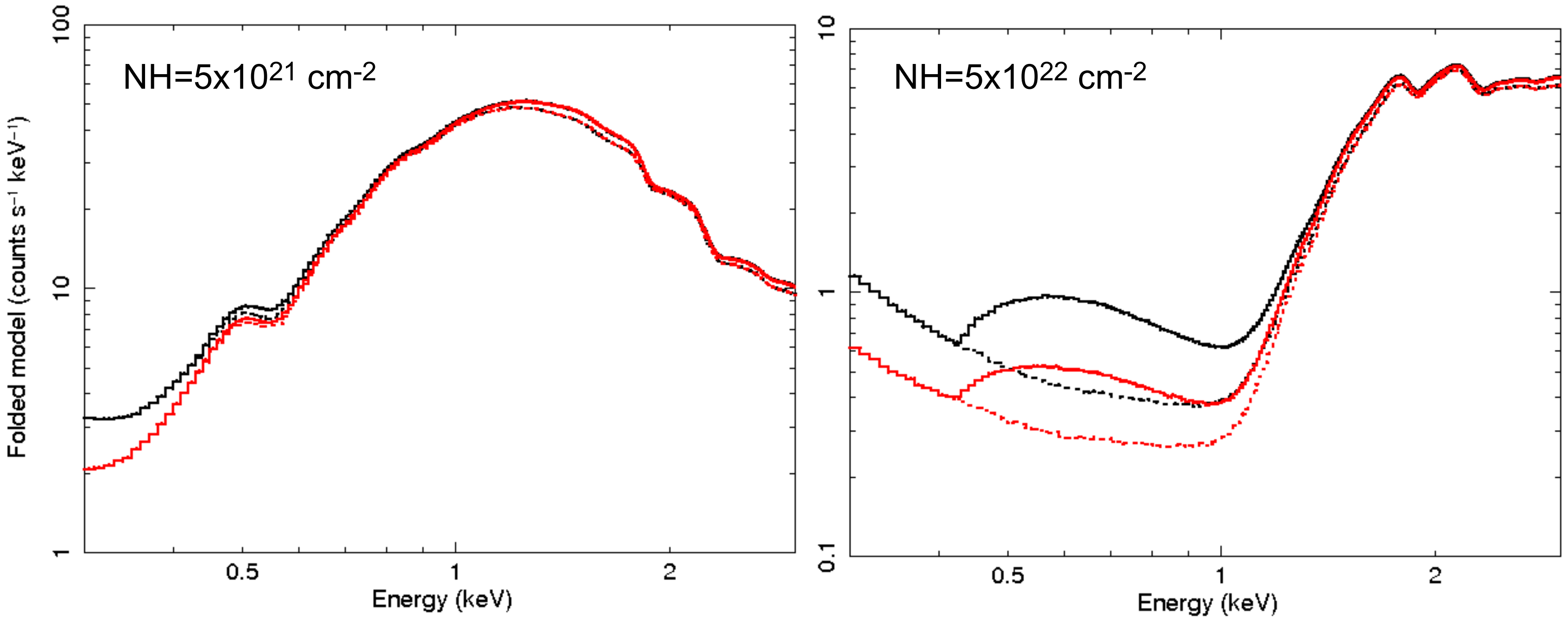
Test results

- Favourite combination has
  - RMF: dd=22/35 micron, ff=48/35 micron, Na=2.5, s=1, Lf=250 micron, Ls=0.75 micron
  - Mirror area: CH_2 thickness=70 Å, roughness=4.5 Å
  - Filter: Polyimide thickness=2122 Å, Al thickness=473 Å
- Became latest Vss=0V CALDB release (2013-Mar-15)

Recent WT RMF Development

- Current WT RMFs generated assuming uniform illumination of the CCD
- Point source illumination can produce slightly different redistribution properties depending on the source position w.r.t. the 10-row binning boundaries
  - Source on the 10-row binning boundary suffers more event splitting (and more redistribution) than one 5 pixels away.
- NH dependent
  - kicks in when NH above a few x 10^{21} cm^{-2}

WT Point source RMFs



- Absorbed powerlaw (Γ=2) folded models
- Source at DETY=300.5 (black) and 305.5 (red)
- Grade 0-2 (solid), grade 0 (dashed)

Preliminary Vss=6V RMF

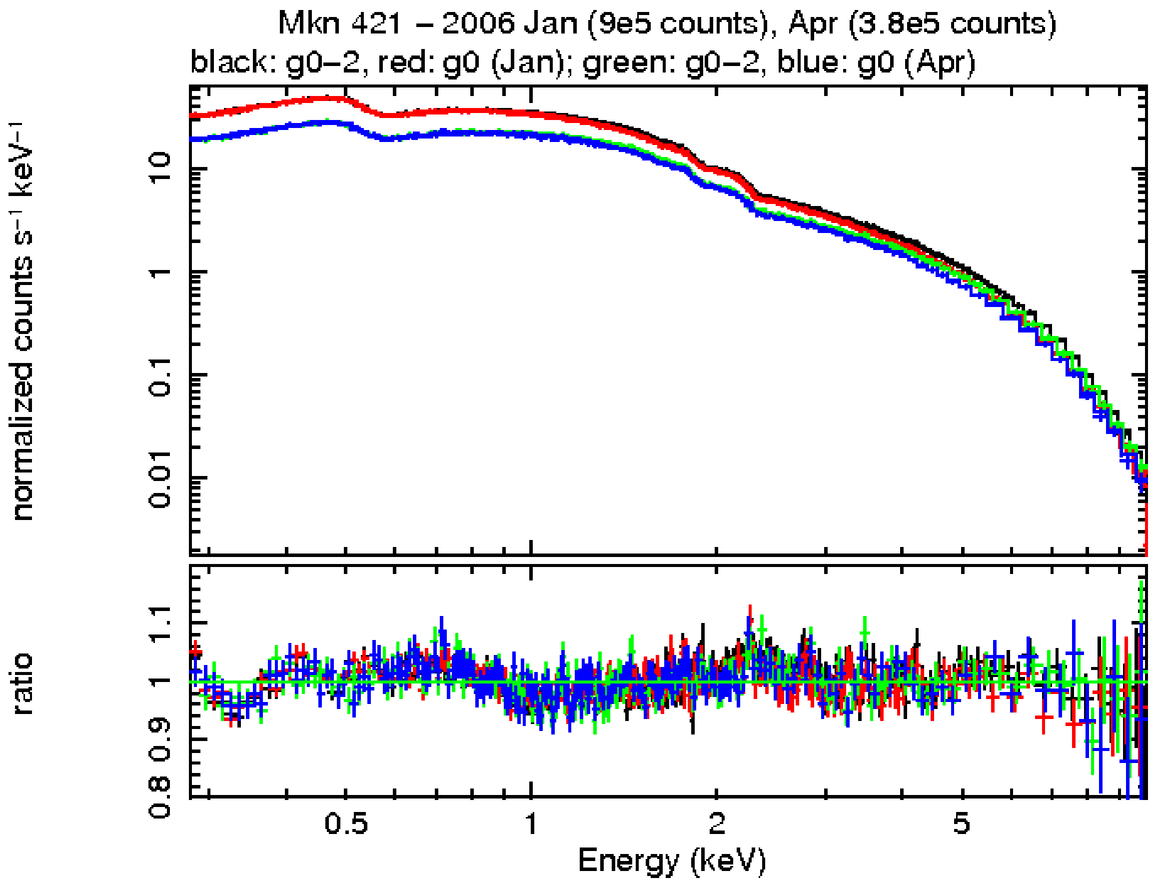
- After the substrate voltage change, expect a drop in QE at high E due to a reduction in depletion depth
  - confirmed with SNRG21.5 data
- Reduction in QE can be modelled by decreasing the depletion depth to ~20 micron.
  - However, this broadens the kernel (due to more field-free interactions) below Si edge → slight higher NH for g0-12.

Summary

- Gain files updated 2013-Mar-15 (~6-12 monthly)
- New Vss=0V RMF/ARF released 2013-Mar-15
- New Vss=6V RMF/ARF needs further refinement and testing
  – Try and reduce the g0-12 redistribution shoulder below Si edge
  – Need to handle loss of QE at lowest E due to traps ?
- Expect WT redistribution to vary with point source location (DETY) on the CCD
  – Investigating how best to handle this

Test results

- 3-5% residuals with high S/N Mkn421 data



Test Results

- RXJ1856: CF=1.07 WT (g0), 0.89 PC (g0)
- Clusters (PC):
  - kT~1-2 keV higher than PN/MOS (more in-line with Chandra ACIS). NH similar to CALDB
- Mkn421 (WT) : Gamma ~ 0.1 harder than MOS1, NH in agreement
- H1426 (PC) : slightly less curvature than MOS1; 0.1 harder than PN, NH in agreement
- 3c273 (WT) : Gamma, kTbb in agreement with MOS1, Gamma ~0.05 harder than PN
- SNRG21.5 (PC) : made to agree with IACHEC average!