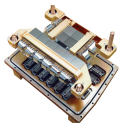
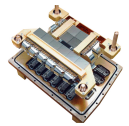


Evolution of temperature-dependent CTI correction for ACIS

Catherine E. Grant (MIT)

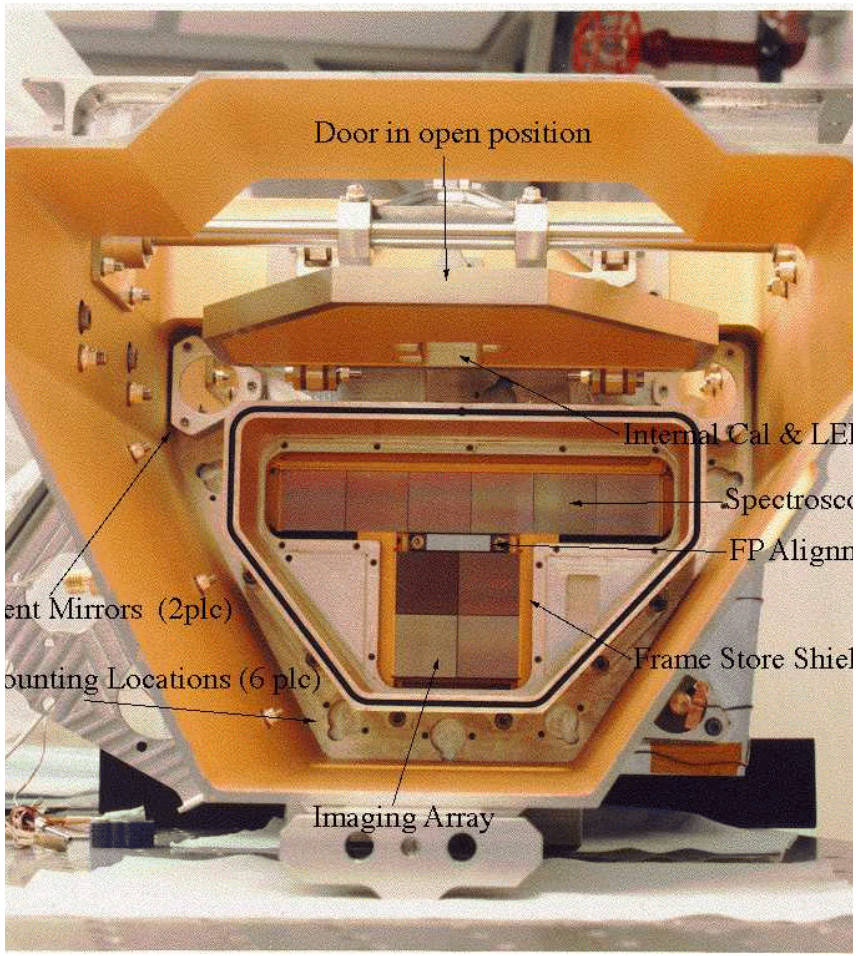
R. Nick Durham (CXC)

Summary



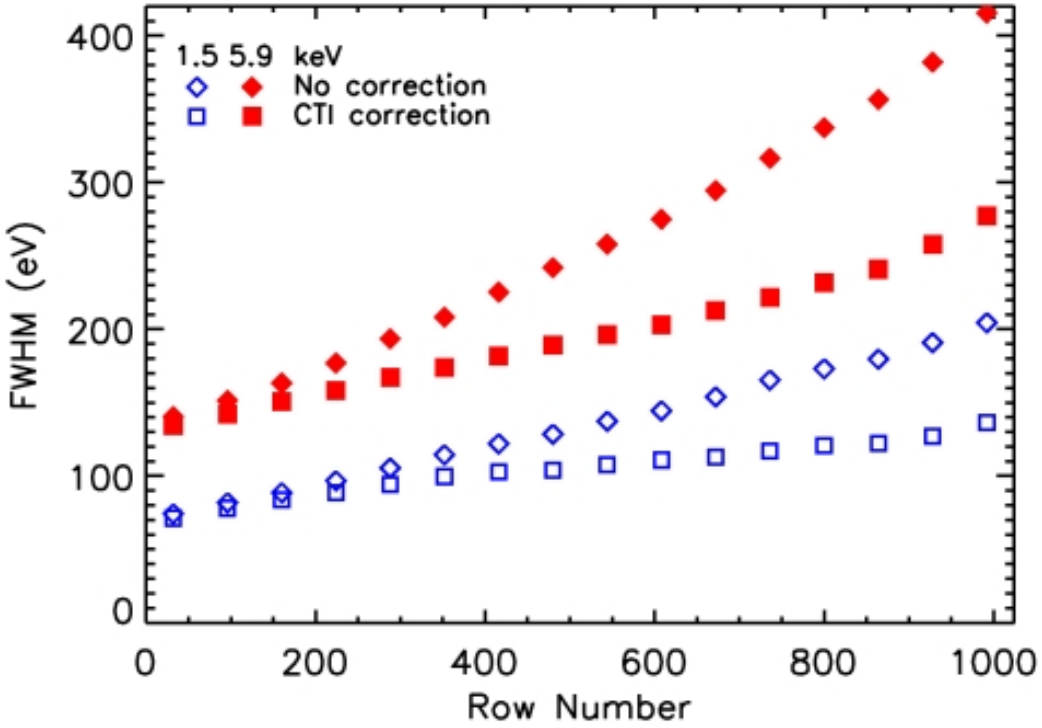
- ACIS CTI correction last calibrated in 2005
  - Pulseheight corrected with time-dependent gain
  - Width changes are smaller, not currently corrected
- Temperature-dependence added in 2010
- Continuing radiation damage:
  - dCTI ~ 2×10^{-6} / yr (FI); 1×10^{-6} / yr (BI)
- Changing thermal environment
- How's the current calibration doing?

Advanced CCD Imaging Spectrometer



- Frame transfer design
  - 1024 x 1024 pixels / CCD
  - 24 μm / pixel
- 8 front-illuminated CCDs (FI)
  - Depletion depth: 64–76 μm
- 2 back-illuminated CCDs (BI)
  - Depletion depth: 30–40 μm
- Temperature set point -120° C
- Initial CTI
  - CTI (FI) << 10^{-6}; CTI (BI) ~ 10^{-5}
- Radiation belt passages in 1999
  - dCTI (FI) ~ 10^{-4}; dCTI (BI) ~ 0
- Continuing radiation damage
  - dCTI (FI) ~ 3 x 10^{-6} / yr
  - dCTI (BI) ~ 1 x 10^{-6} / yr

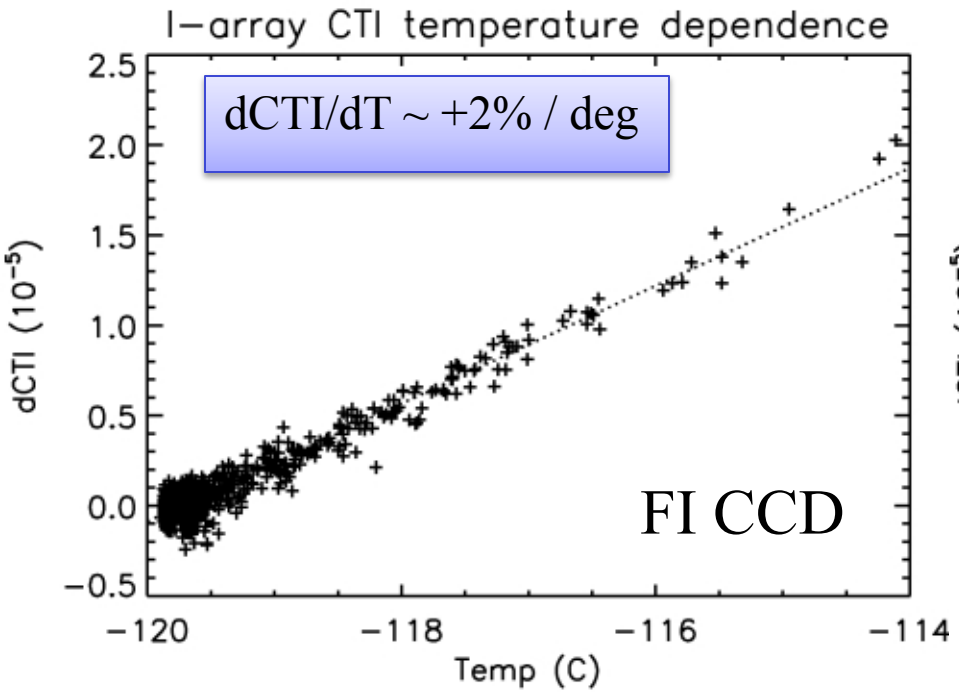
ACIS CTI correction

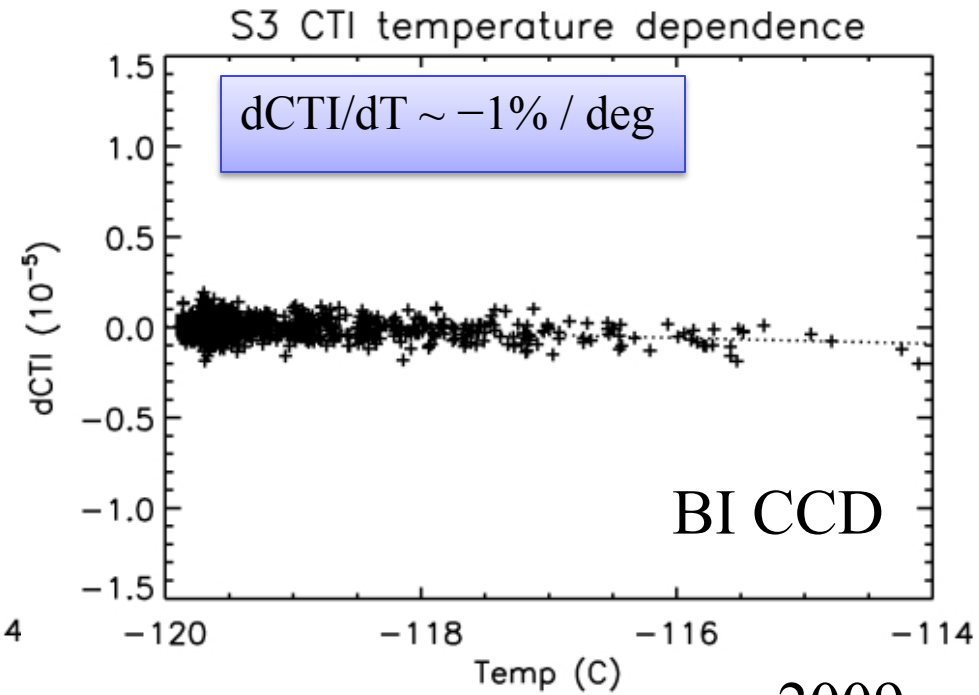


- Incorporated into *CIAO* tool `acis_process_events`
- Reconstruction of original X-ray event island in the absence of CTI
- Removes position dependence of pulseheight
- Significantly improves spectral resolution and detector uniformity
- Charge loss is stochastic – cannot recover all of lost performance

Grant+ 2004, Proc. SPIE 5501

CTI dependent on temperature

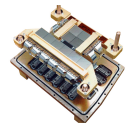


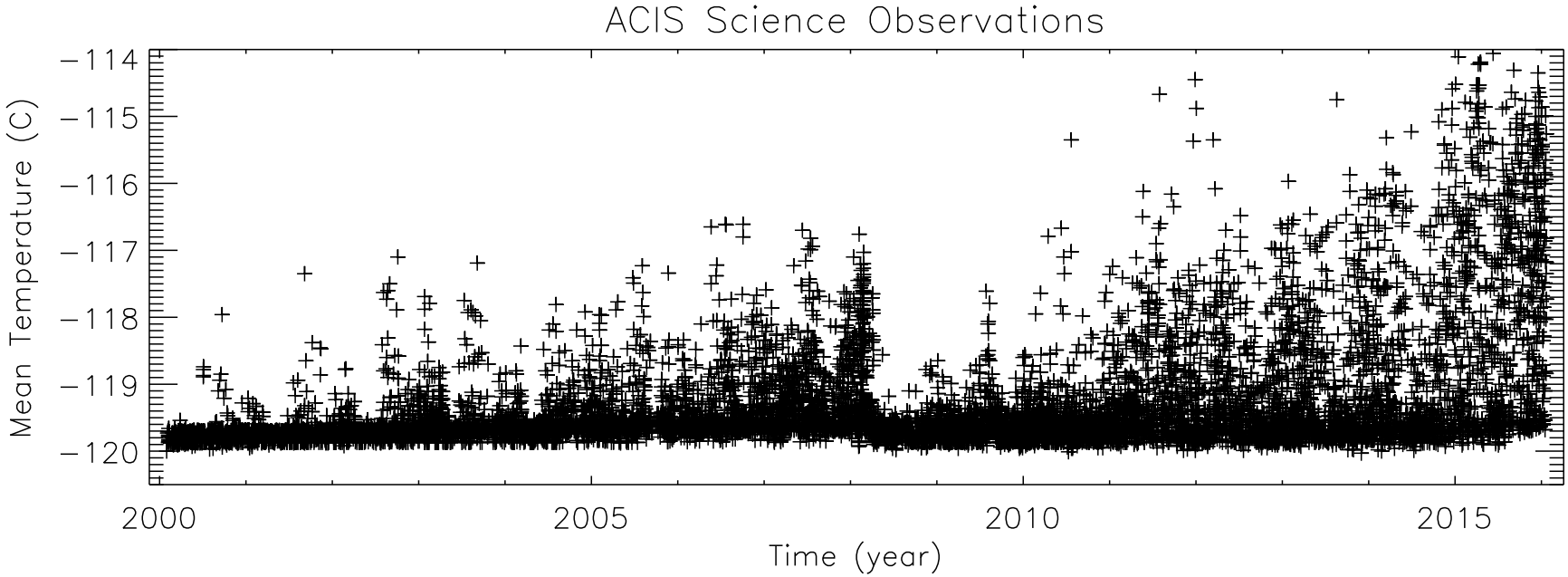


ca. 2009

- Charge traps have temperature dependent re-emission time constants
- Roughly linear for small temperature deviations
- Causes temperature-dependent performance
- More important for FI than BI CCDs

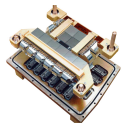
Focal plane temperature excursions





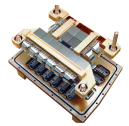
- Thermal control has become more difficult with time
  - ACIS cooling is less efficient for some spacecraft orientations
  - Constraints of other Chandra components not always favorable for ACIS
- Observations with "cold" temperatures (T < -119.2° C)
  - 99% in 2000; 68% in 2007; 33% in 2015

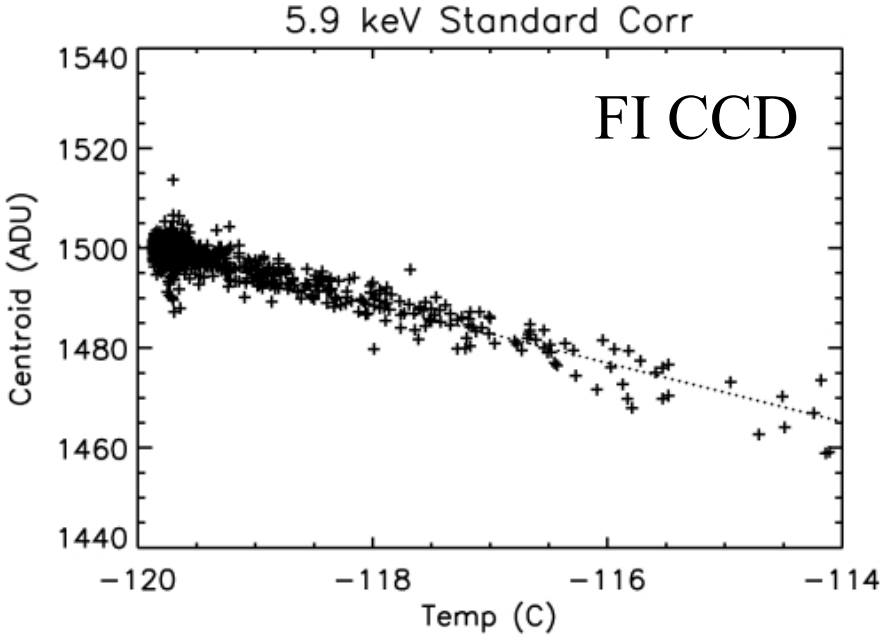
Implication for Calibration

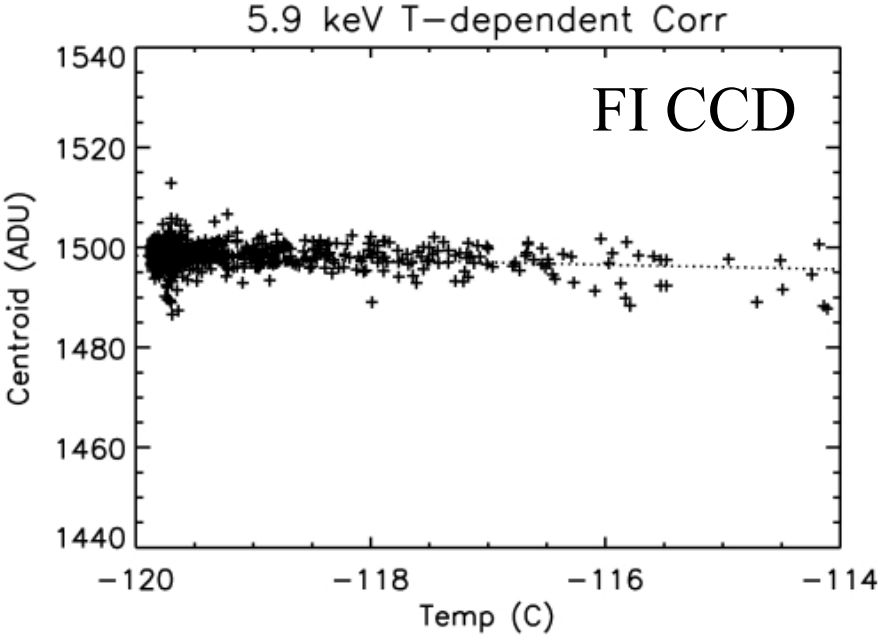


- Temperature variations can produce significant calibration changes for some locations on some CCDs
- Warmer temperatures are uncontrolled
  - Variation within a single observation as high as 4-5°C
- Scientific impact varies:
  - High: line-rich spectrum, ACIS-I (FI CCD), high S/N
  - Low: continuum spectrum, ACIS-S3 (BI CCD), low S/N
- Mitigation strategies:
  - ✓ T-dependent CTI correction added to standard pipeline in 2010
  - ✓ Mission Planning has constraints on orientation to keep T < -114°C
  - Increase nominal FP temperature (degrades performance; requires lengthy recalibration)

Performance of adjusted corrector





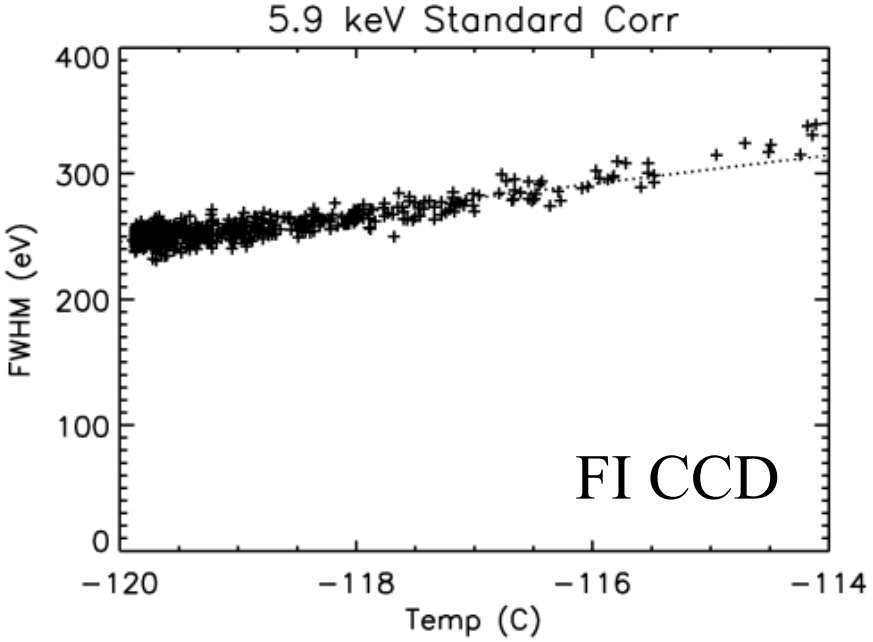


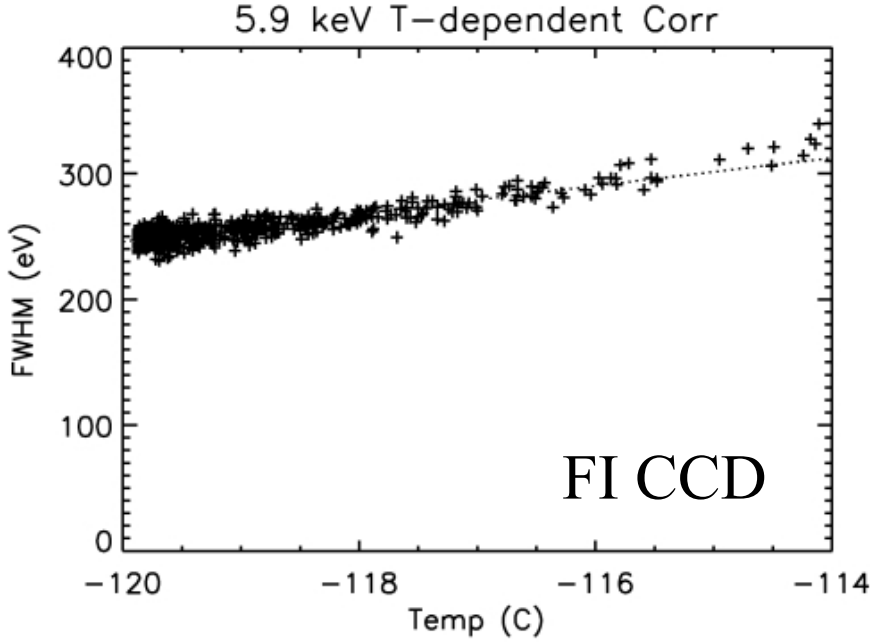
Temperature-dependent pulseheight change (% / deg) ca. 2009

	1.5 keV	6 keV
Standard	–0.7%	–0.4%
T-dependent	+0.03%	–0.07%

- Top 64 rows of CCD (worst case)
- Smaller effect at lower rows
- Calibration accuracy goal is 0.3%
- Reduces temp-dependence of pulseheight

Performance of adjusted corrector





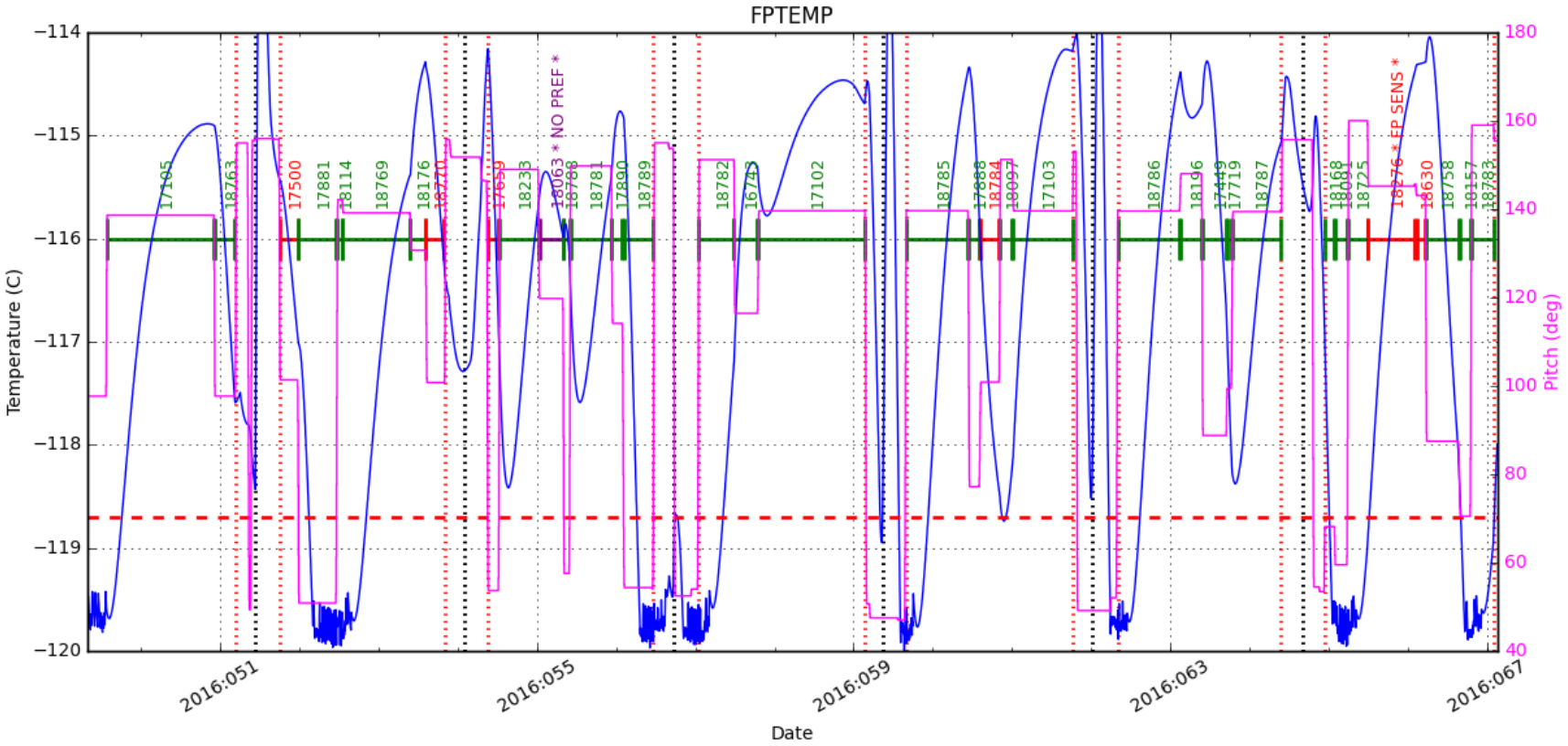
Temperature-dependent FWHM change (eV / deg)

ca. 2009

	1.5 keV	6 keV
Standard	+3.8 eV	+11.2 eV
T-dependent	+3.2 eV	+10.6 eV

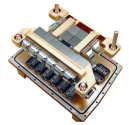
- Very small reduction in temperature dependence of line width
- Stochastic charge loss – may not be possible to do much better
- FWHM change negligible for ACIS-S3 (BI CCD)

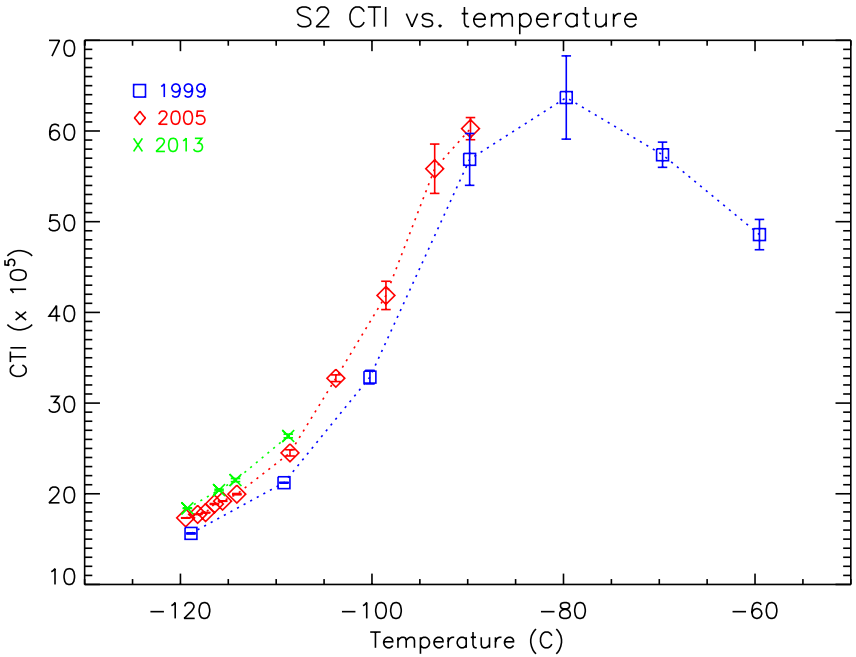
Current thermal conditions

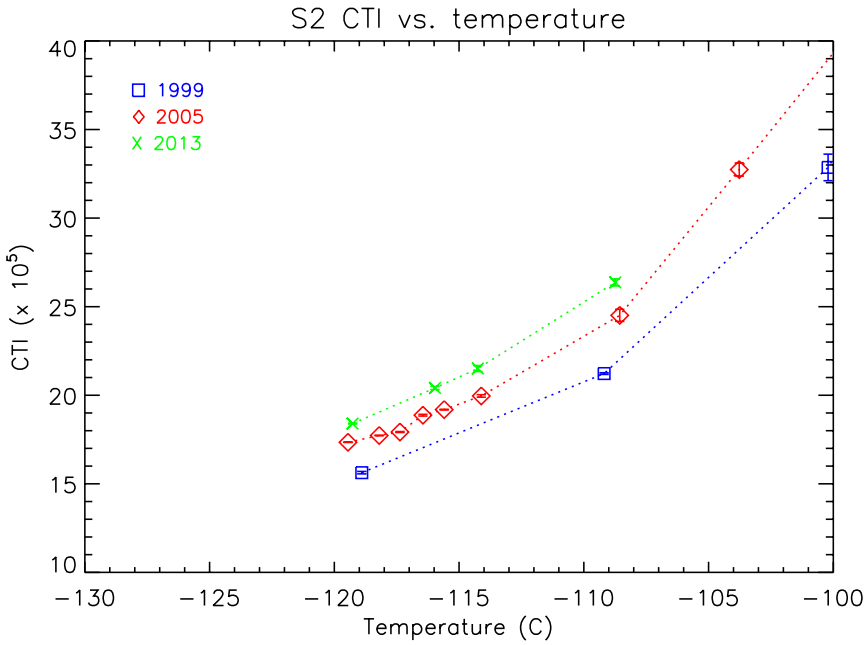


- Algorithm assumes deviations are small; temperature-dependence is linear
- Original calibration data primarily T < -116°C
- Neither is true at present
- If trap population is changing, T-dependence may be evolving

Is temperature-dependence changing?

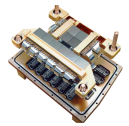


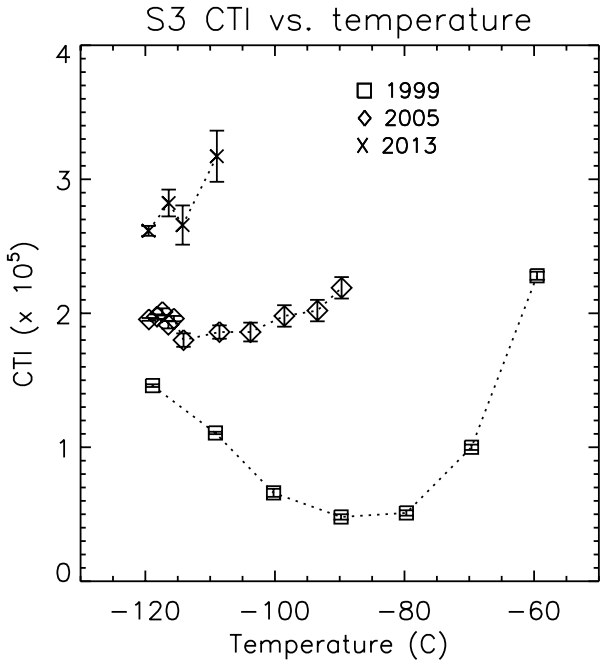


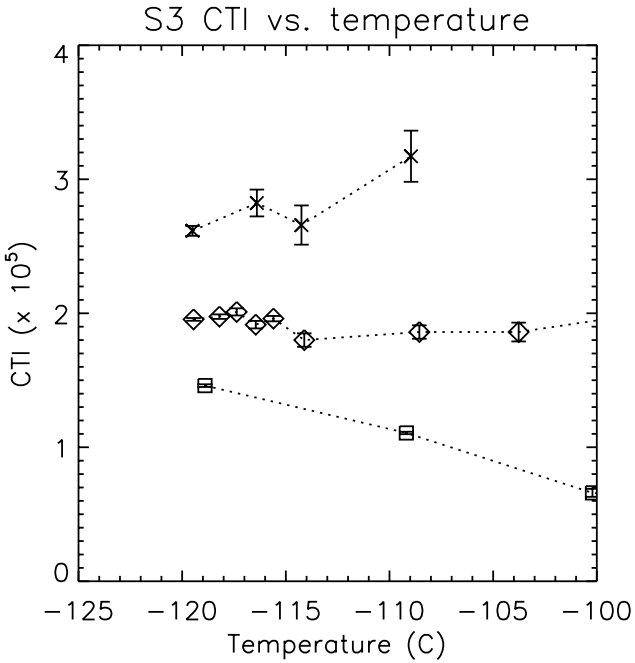


- For FI CCDs, change is minimal, but…

Is temperature-dependence changing?

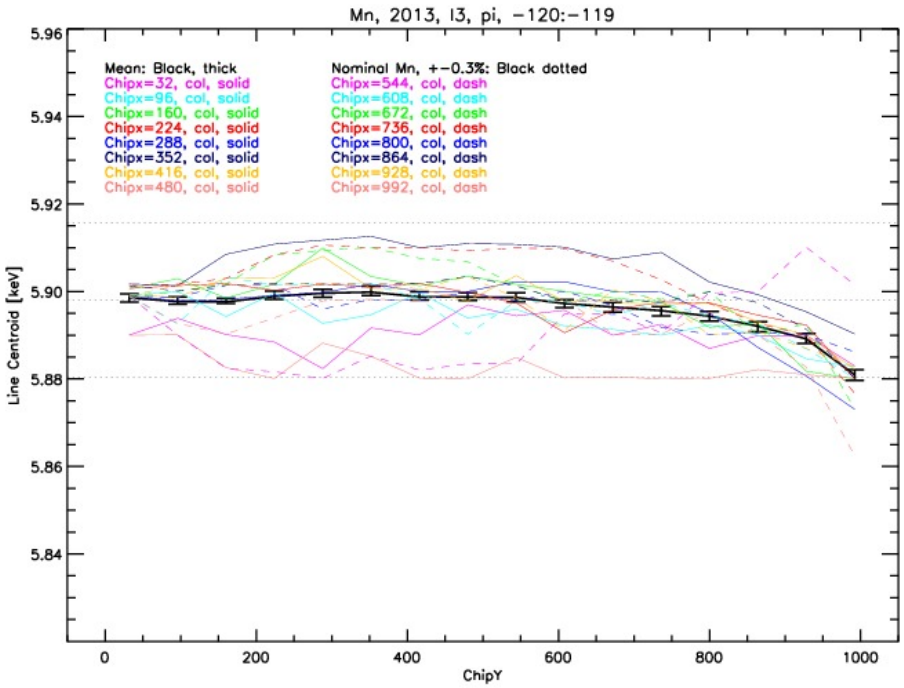


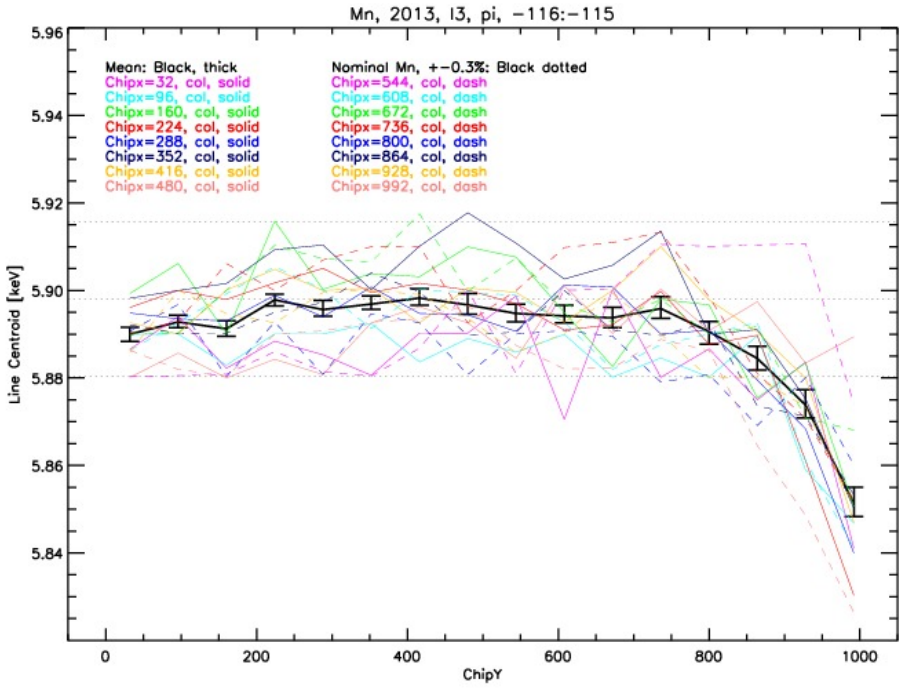




- For FI CCDs, change is minimal, but…
- BI CCDs have changed sign of dCTI/dT
- Radiation-produced CTI now as important as initial CTI for BI CCDs
- FI CCDs had little initial CTI at launch ($< 10^{-6}$), subsequent radiation damage similar enough to radiation damage from the belts

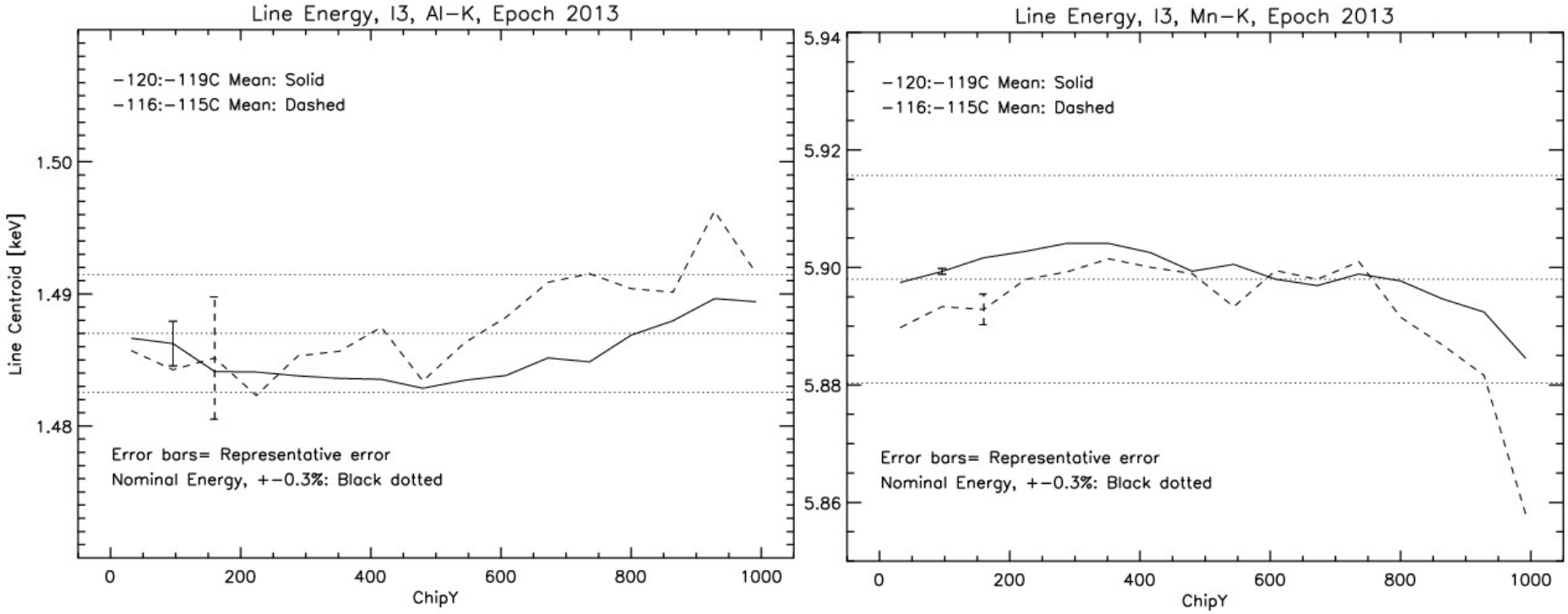
Testing calibration accuracy





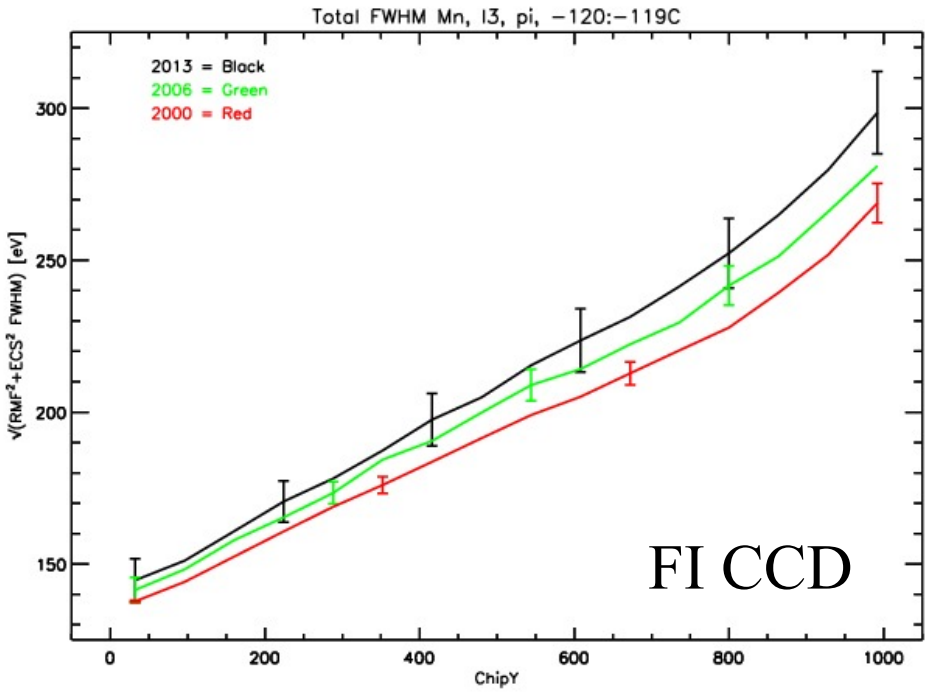
- Data goes through standard pipeline, same as user following CIAO threads
- 64 x 64 pixel regions, one-year time bins, one-degree temperature bins
- Fit Al-K and Mn-Kα lines using standard response products
- Line energy should be 5.89 keV; width should be consistent with zero
- Calibration is OK for many regions even at high temp and late times!

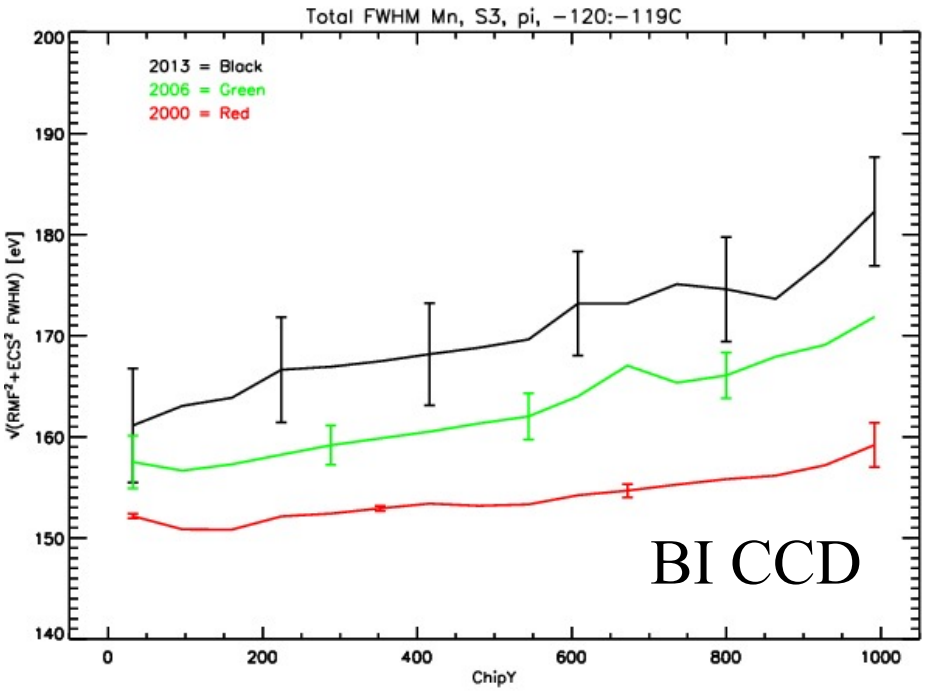
Calibration Problem Areas: FI CCDs



- Calibration is OK for many regions even at high temp and late times!
- 5.9 keV undercorrects at high Chipy; 1.5 keV overcorrects at high ChipY
- Temperature worsens the problem
- Suggests CTI correction needs adjustment

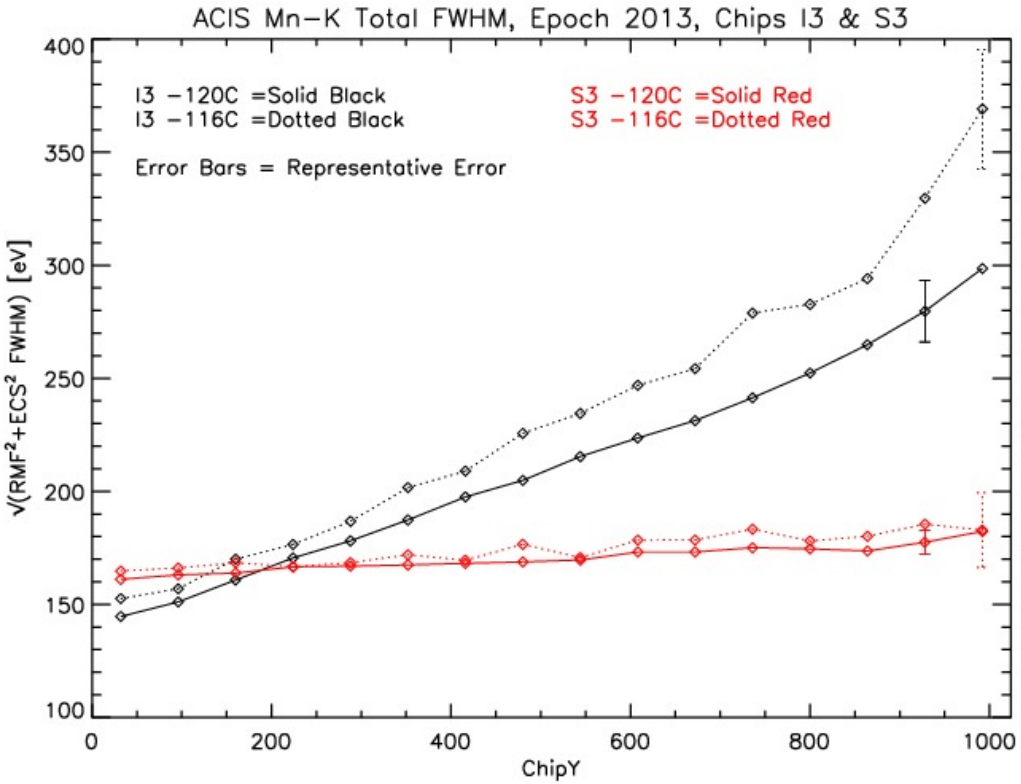
Calibration Problem Areas: FWHM





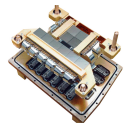
- Line width increase with time for all regions/CCD type
- Increase larger at 5.9 keV than 1.5 keV
- Implies a recalibration of CTI correction may be necessary

Calibration Problem Areas: FWHM



- As already shown, temperature-dependent CTI correction does not correct for additional line width
- Need separate response products for warm temperature data

Summary



- ACIS CTI correction last calibrated in 2005
- Temperature-dependence added in 2010
- Continuing radiation damage:
  - dCTI ~ 2×10^{-6} / yr (FI); 1×10^{-6} / yr (BI)
- Changing thermal environment
- How's the current calibration doing?
  - Energy calibration not bad except FI CCDs at high rows
  - Line width is harder to improve in the correction
  - Improved response products may be a better fix
- More to come at SPIE this summer