Charge transfer efficiency of LSST CCDs with ^{55}Fe x-rays

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Introduction

The Large Synoptic Survey Telescope (LSST), currently under construction in Chile, will conduct a ten-year survey in the search for dark energy and dark matter. BNL is a participant in the construction of LSST, being responsible for the production of the telescope's sensor modules (Science Rafts). Consisting of 21 rafts of 9 charge-coupled devices (CCDs) each, the camera focal plane will contain 3.2 gigapixels, giving 3 gigabytes of raw data every second [1]. These CCD sensor arrays require a very high ratio of charge transferred between pixels, referred to as the charge transfer efficiency (CTE). Typical CTE values on the order of 0.999995 or better are required to ensure accurate imaging. Our focus is on analysis methods to accurately determine CTE values of the detectors to ensure they meet stringent LSST standards.

We analyze x-ray data to determine how flux and ellipticity change as a function of number of pixel transfers for data taken with ^{55}F x-ray source. We are also using Monte Carlo simulations to determine optimal measurement techniques of CTE.

Methods

- Footprint finding
  - Examining three parameters: stamp grow factor (grow), minimum pixels above threshold (npixMin), pixel threshold
  - Locates clusters of pixels above a given threshold from ^{55}Fe x-ray hit
  - Change footprint finding parameters to determine optimal values
  - Fit 2-D Gaussian to the footprint to determine flux, width, ellipticity, location

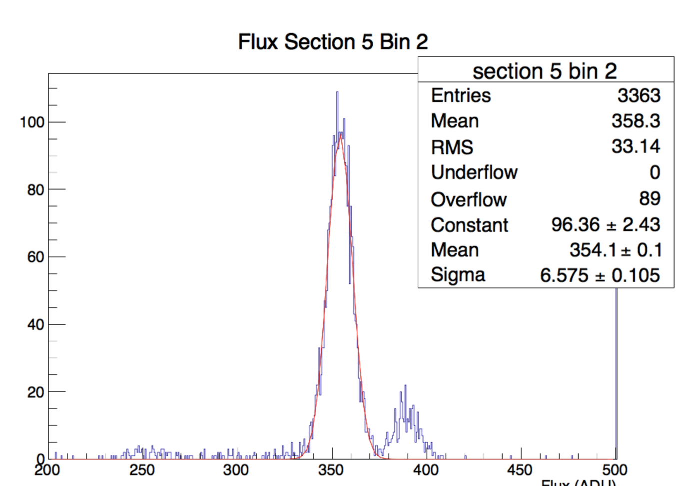

Figure 1. Example of Gaussian fit on Kα peak for ITL-3800C-023 sensor.

- ^{55}Fe Analysis of flux
  - Divide sections of detector into 11 bins
  - Histogram flux of ^{55}Fe hits within each bin, fit K-α peak with Gaussian using ngmix by Erin Sheldon [2]
  - Plot bin flux vs. bin number to see how flux changes across detector

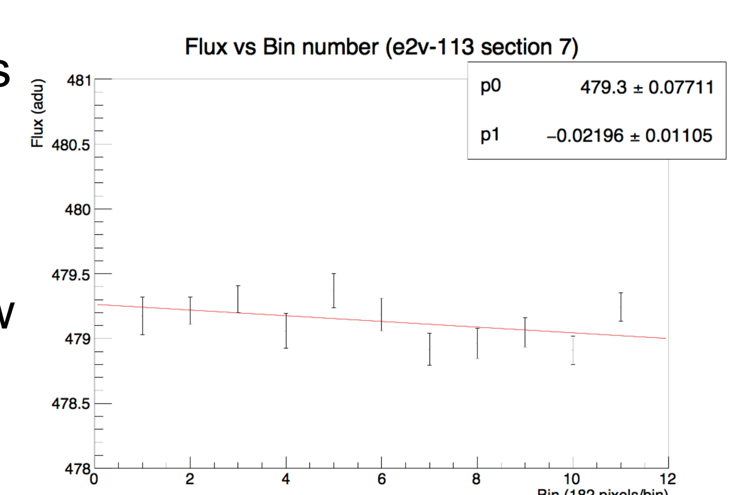

Figure 2. Plot of flux per bin vs bin number on e2v-113-03 sensor.

- Toy Monte Carlo simulations
  - Spawn footprint with known flux, width, ellipticity, location
  - Transfer footprint with a known CTE, fitting 2-D Gaussian with ngmix at transfer intervals [2]
  - Track evolution of the footprint as function of pixel transfers
- Four different CTE estimators being examined
  - Integral of flux over x-ray hit stamp (intFlux)
  - Ellipticity of x-ray hit
  - Difference in flux between trailing and leading pixel fluxes (dFlux)
  - Flux in central pixel of x-ray hit
- Want to optimize algorithms and determine what is the best CTE estimator
  - Analyze measurements from Toy Monte Carlo simulations
  - Compare Monte Carlo to measurements taken from ^{55}Fe data

Figure 3. Examples of x-ray hit measurement being evaluated for CTE determination: central pixel flux (top left), ellipticity (top right), integral of flux (bottom left), difference in flux (arrow denotes transfer direction) (bottom right).

5.13	0.43	-2.49	-1.04
0.01	-1.96	2.32	-2.93
1.74	92.65	249.05	2.50
-0.42	35.43	96.08	-2.01
-1.24	3.25	0.40	-2.72
1.05	-2.63	-2.11	2.34

Figure 4. Example of virtual x-ray hit generated in Toy Monte Carlo simulation. Each element in the array represents the flux in a pixel.

Results

- Footprint Finding
  - Higher growth factor leads to lower footprints found (overlapping)
  - 1 pix minimum leads to region of threshold independence

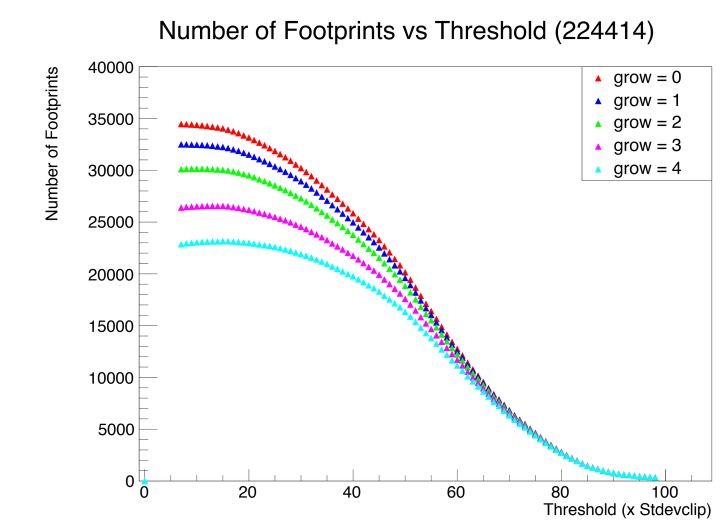

Figure 4. Plot of found footprints vs. threshold for varying growth factors (e2v-113-03).

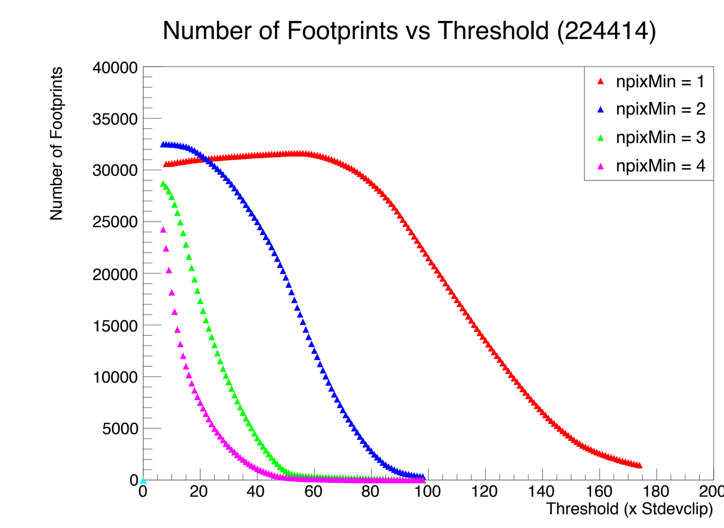

Figure 5. Plot of found footprints vs. threshold for varying minimum pixel numbers (e2v-113-03).

- ^{55}Fe Flux (e2v-113-03 data)
  - CTE values on order of 10^{-7} or better
  - Agreement with previous CTE analysis by Ivan Kotov
  - Average difference of 2.6×10^{-7} between the two analysis methods

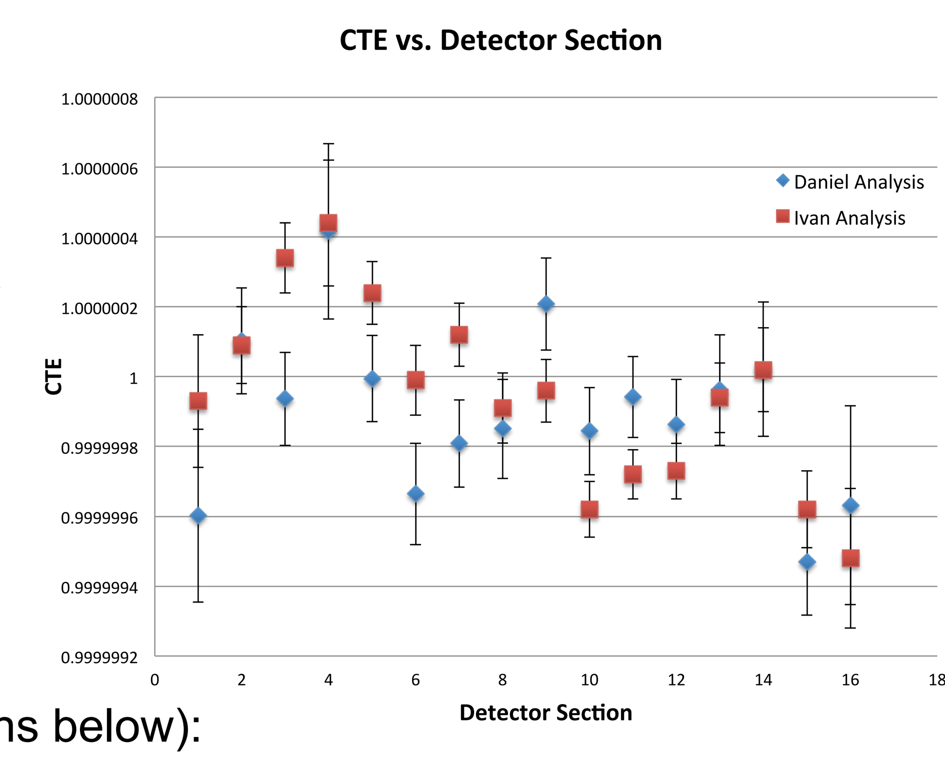

Figure 6. Plot of calculated CTE values using Fe55 flux binning method and Ivan's CTE analysis.

- Toy Monte Carlo results (two graphs below):
  - Integral of flux is not a good CTI estimate as trailed charge is included
  - Difference in flux (dFlux) appears to be a good CTI estimator with linear correspondence between dFlux and CTI

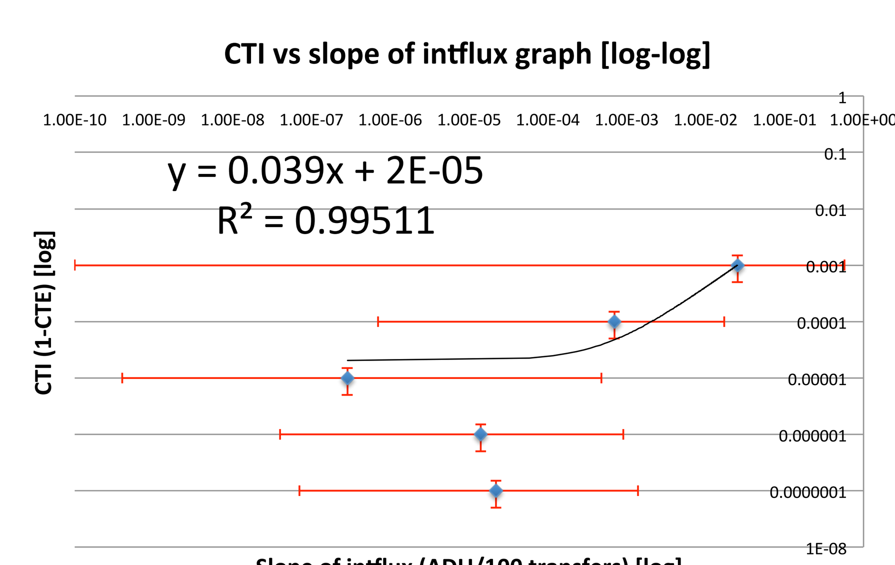

Figure 7. Linear-log plot of CTI vs slope of (integral flux vs Ntransfers) for Monte Carlo simulations at varying CTE.

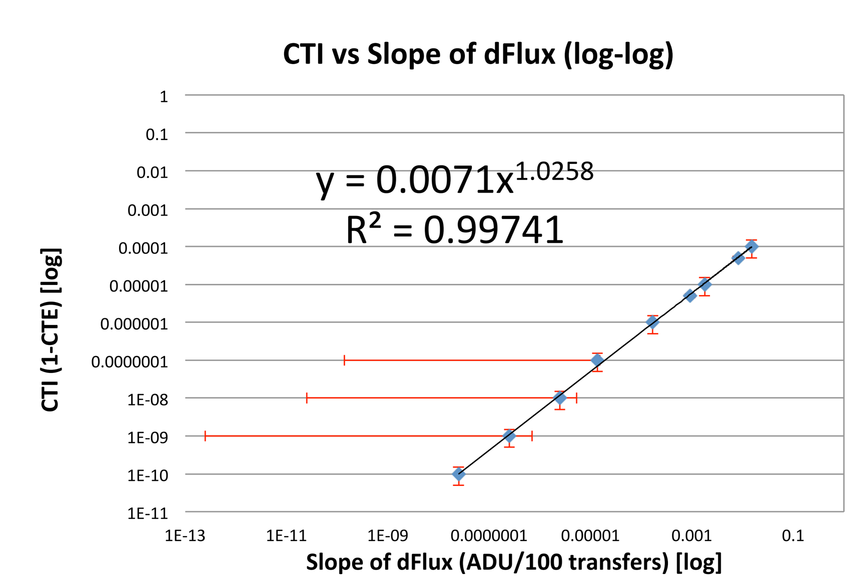

Figure 8. Log-log plot of CTI vs. slope of (dFlux vs. Ntransfers) for Monte Carlo simulations with varying CTE values.

Conclusions

- Footprint Finding
  - Using one or more pixels above threshold results in smaller bias from the threshold value
    - Other studies used upwards of 4 pixels above minimum threshold [4]
  - Growth factor of 2 is adequate for footprint finding parameters
- ^{55}Fe CTE Analysis
  - Binning of flux values across detector gives accurate CTE values consistent with other CTE analysis methods
- Toy Monte Carlo Simulations
  - Differential flux is a better estimator than integral flux as expected
  - Future work will model estimators based on central pixel flux and ellipticity of the hits and will compare all estimators to the ^{55}Fe data

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References

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3. I.V. Kotov, J. Haupt., P Kubánek, P. O'Connor, O. Takacs, Nuclear Instruments and Methods in Physics Research Section A 787 (2015).

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