ISOPHOTAL APPROACH TO ^{55}Fe AND ^{109}Cd XRAY ANALYSIS

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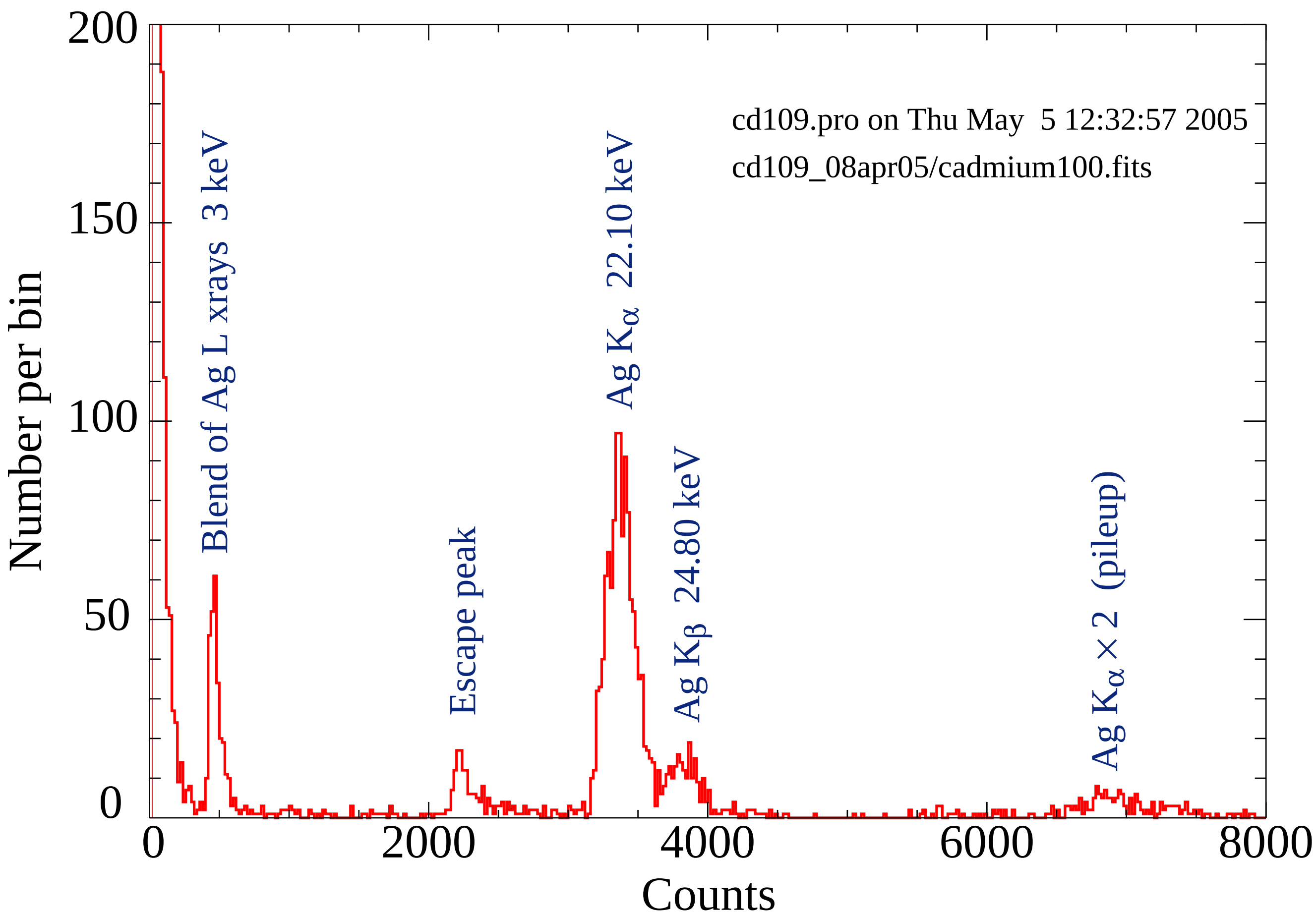


There are (only?) two problems in calibrating CCD's with xrays:

1. Relating the xray energy deposition to the number of e-h pairs produced.
2. Analyzing the CCD image from an xray exposure to obtain a *robust* conversion factor from eV to ADU. There are many pitfalls.

Let me very briefly comment on $w(T)$, the mean energy needed to produce an e-h pair

Both theoretically and experimentally, w can be represented by a linear function of the indirect bandgap energy

$$w(T) = a\,E_g(T) + b\ ,$$

which can conveniently be rewitten as

$$\Delta w(T) = w(T) - w(300\ \ \mathrm{K}) = a\left[E_g(T) - E_g(300\ \ \mathrm{K})\right]\ .$$

In turn, the indirect bandgap energy E_g as a function of temperature has been expressed (Varashi) as

$$E_g(T) = E_g(0) - \frac{\beta T^2}{T+\gamma}\ .$$

where $E_g(0)$, β, and γ are well known to those who know them well. (We use this fuction in our QE modeling)

There have been many measurements of $w(300\ \mathrm{K})$ over the last century. In most cases an error is not quoted or the error is large. Typical (and incomplete) results with quoted and reasonable errors are

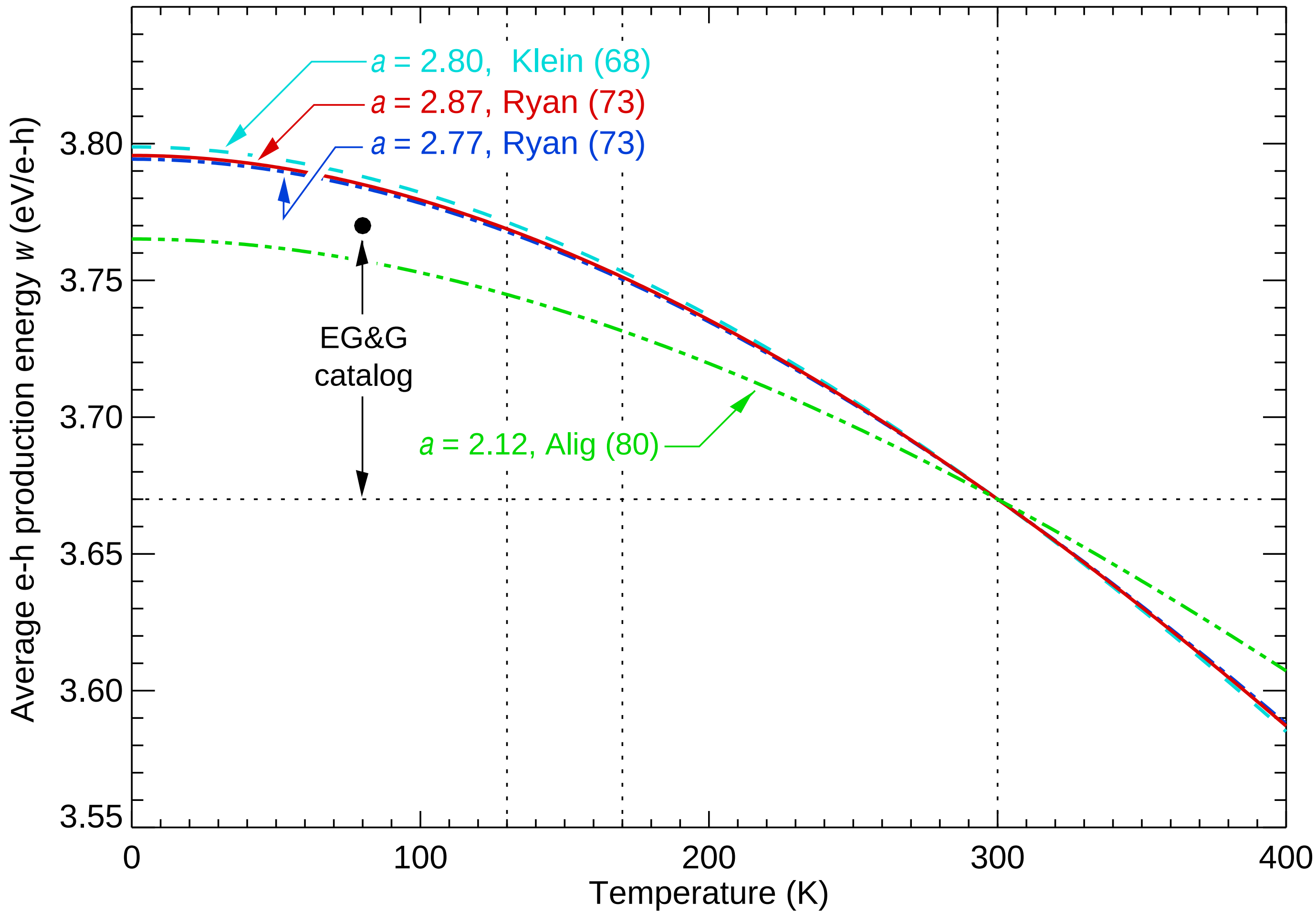
		$w\,(300\ \mathrm{K})$	$E(\mathrm{Mn\ K}_\alpha)/w$
ICRU 31	1979	3.68 ± 0.02 eV/e-h	1603
Krumrey & Tegler	1990	3.63 ± 0.04 eV/e-h	1625
Ahr & Telgler	1992	3.70 ± 0.07 eV/e-h	1595
Scholze *et al.*	2000	3.66 ± 0.03 eV/e-h	1612
Weighted average*		3.669 ± 0.015 eV/e-h	1608 ± 24
(Janesick)	(2001)	$3.65 \pm$?? eV/e-h	1616

* There is *No Way* to justify this weighted average, given arbitrary data selection *etc.* But we lamely recommend

$$\boxed{w(300\ \mathrm{K}) = 3.67 \pm 0.02\ \mathrm{eV/e\text{-}h}}$$

or a *ROOM TEMPERATURE* conversion factor of 1608 ± 32 e-h pairs per Mn K_α xray. *OK IF YOU CALIBRATE WARM CCD's*

I've found a few more measurements since I made this plot, but as of my putting it on CCD-world in December $w(T)$ for silicon looked like this



I conclude

$$2.12 \leq a \leq 2.80$$

which reflects into

$$\Delta w = 0.075 \text{ to } 0.099 \text{ eV/e-h at } 140 \text{ K } (-130 \text{ C})$$
$$\Delta w = 0.061 \text{ to } 0.081 \text{ eV/e-h at } 170 \text{ K } (-100 \text{ C})$$

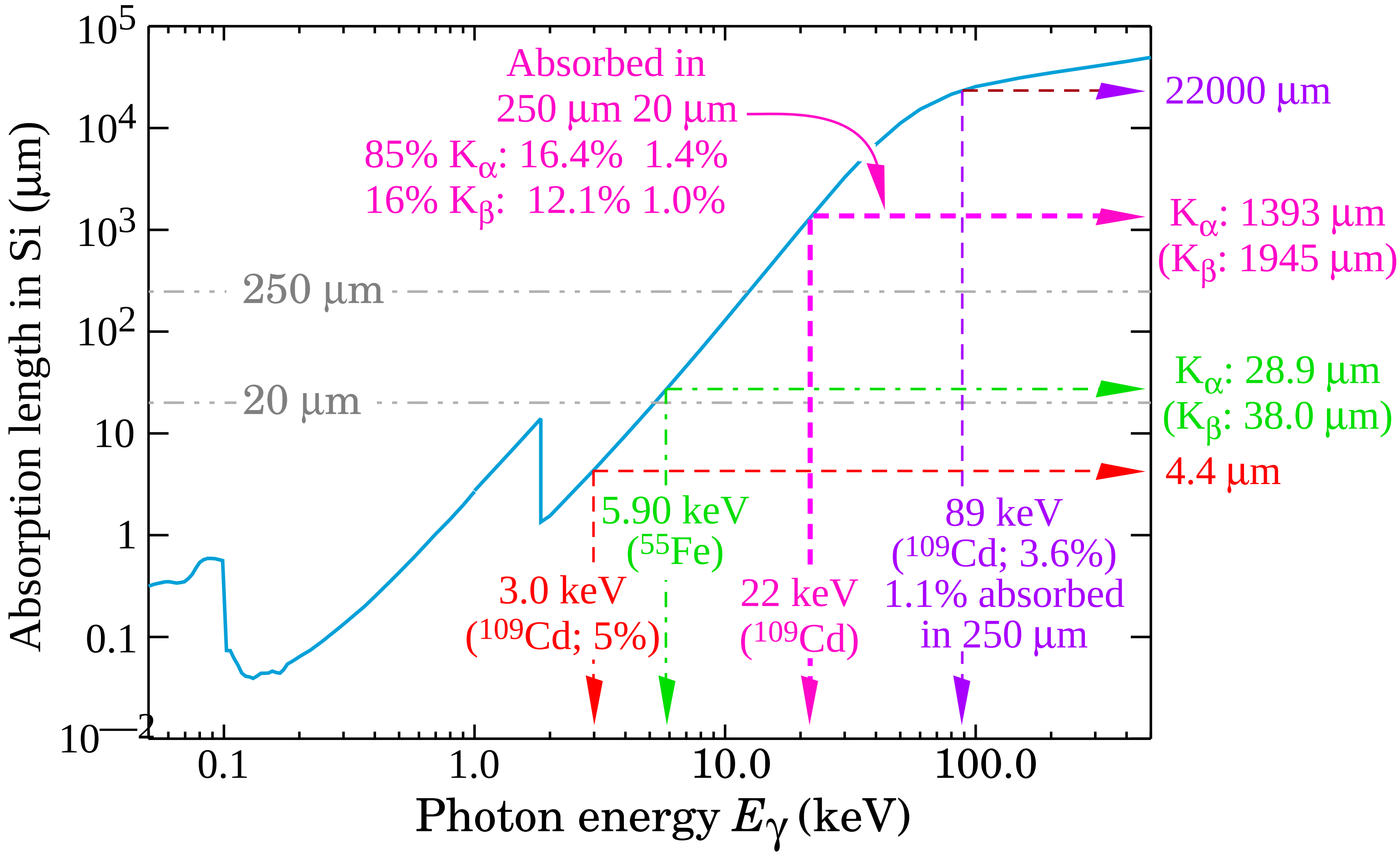
In both cases the full range is about 0.02. Splitting the difference and cautiously taking the error in Δw as 0.01, we recommend

		$w(T)$	$E(\text{Mn K}_\alpha)/w$	$E(\text{Ag K}_\alpha)/w$
140 K	-130 C	3.76 ± 0.02 eV/e-h	1570	5878
170 K	-100 C	3.74 ± 0.02 eV/e-h	1577	5909
300 K	25 C	3.67 ± 0.02 eV/e-h	1608	6022

So at -140 C, $w(T)$ is 3.0% higher than Janesick's (room temperature) value, and 2.4% higher than our best estimate for $w(300\text{ K})$

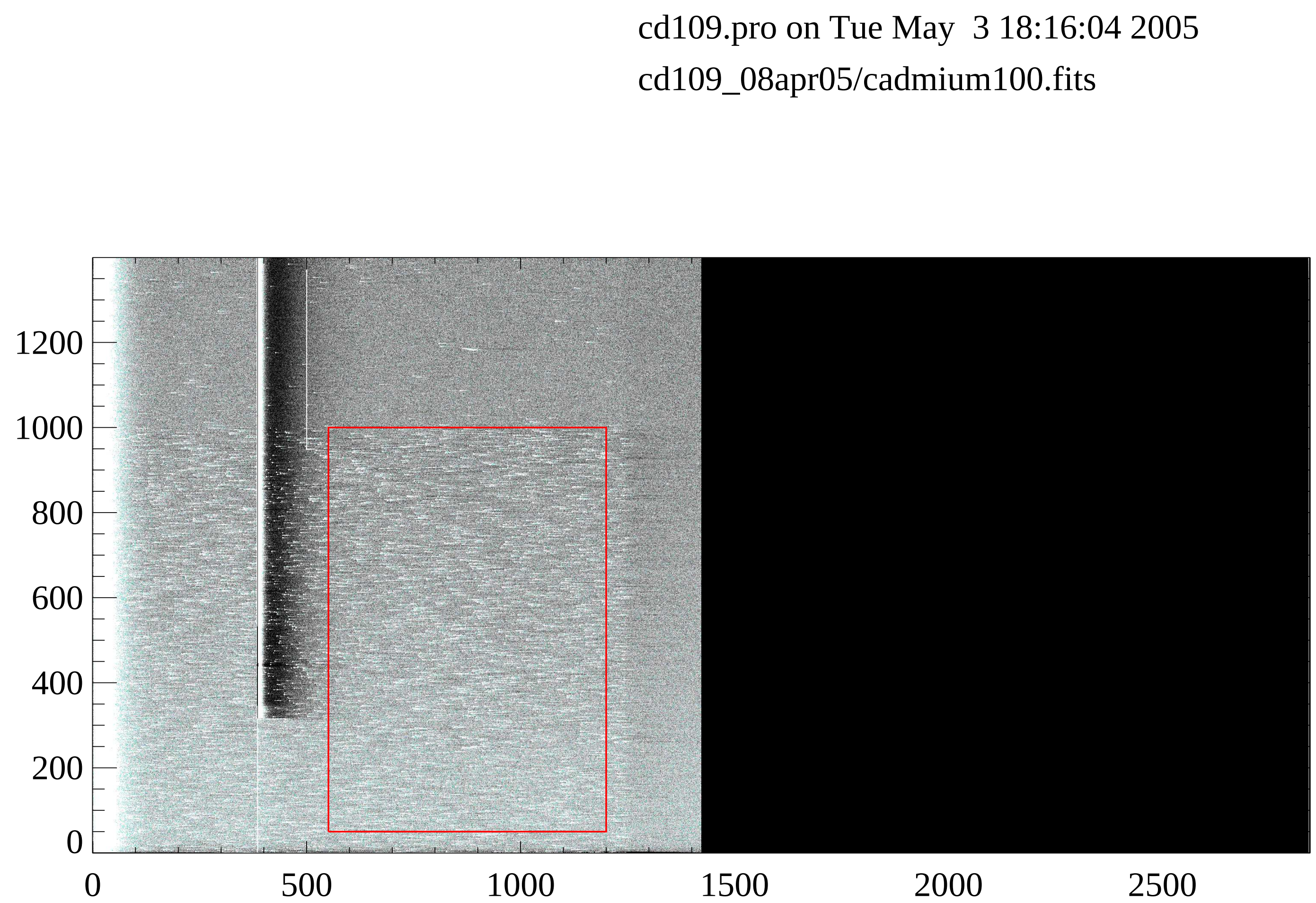
$\Longrightarrow$ This means a corresponding reduction in QE if calibration is via an xray source

—This is an overly busy drawing, but it puts our calibration of thick CCD's in perspective:

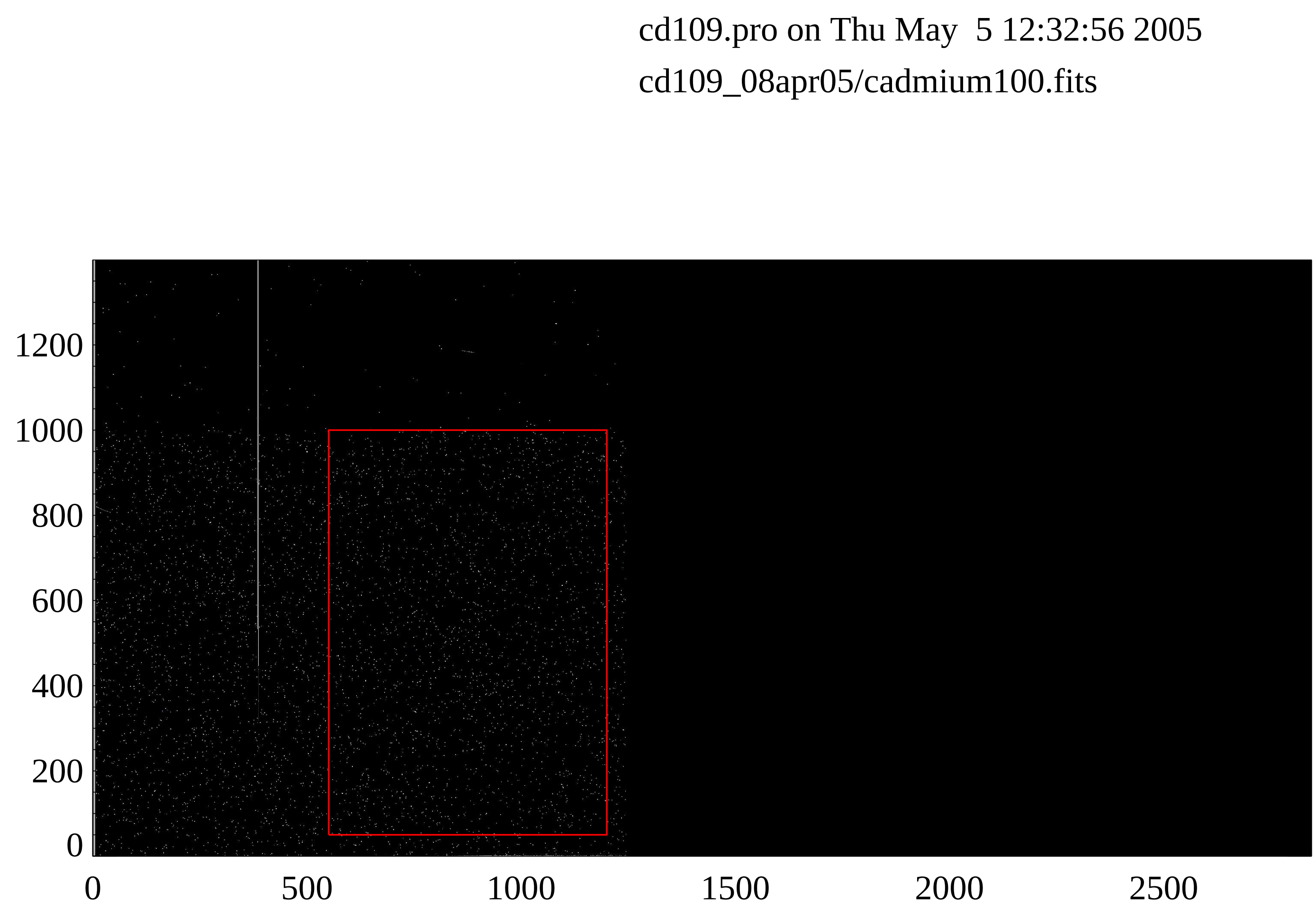


Thanks to Kyle—

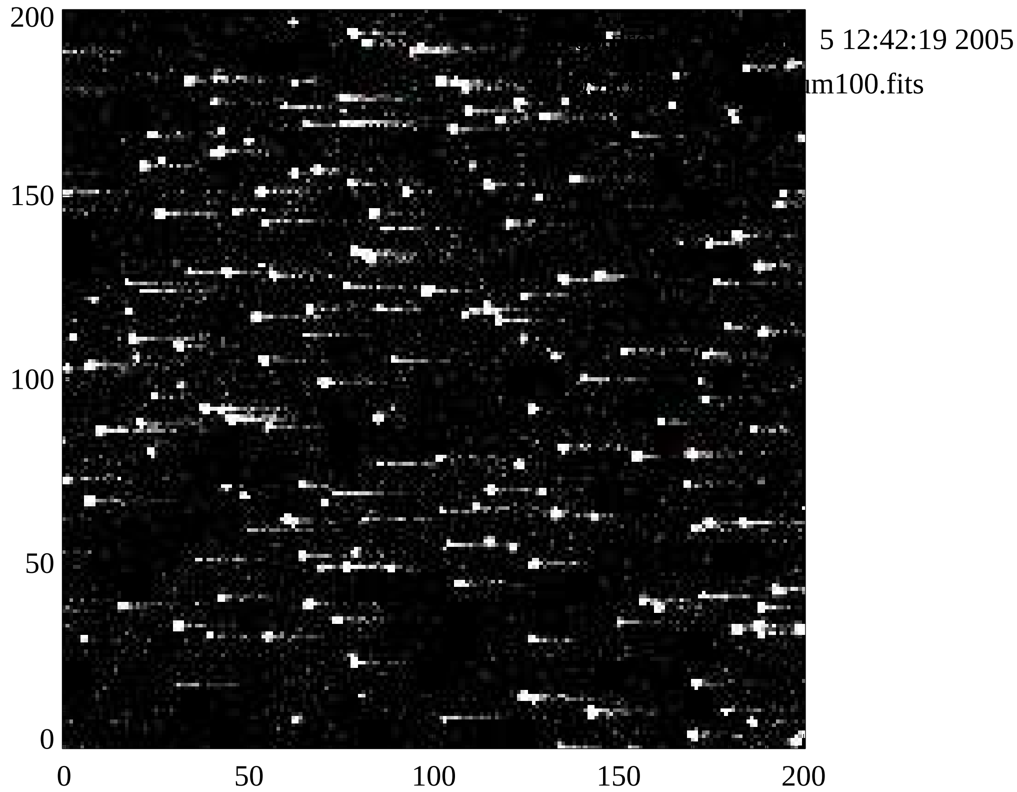
/home/snap2/database/86135/86135.17.13/cadmium100.fits



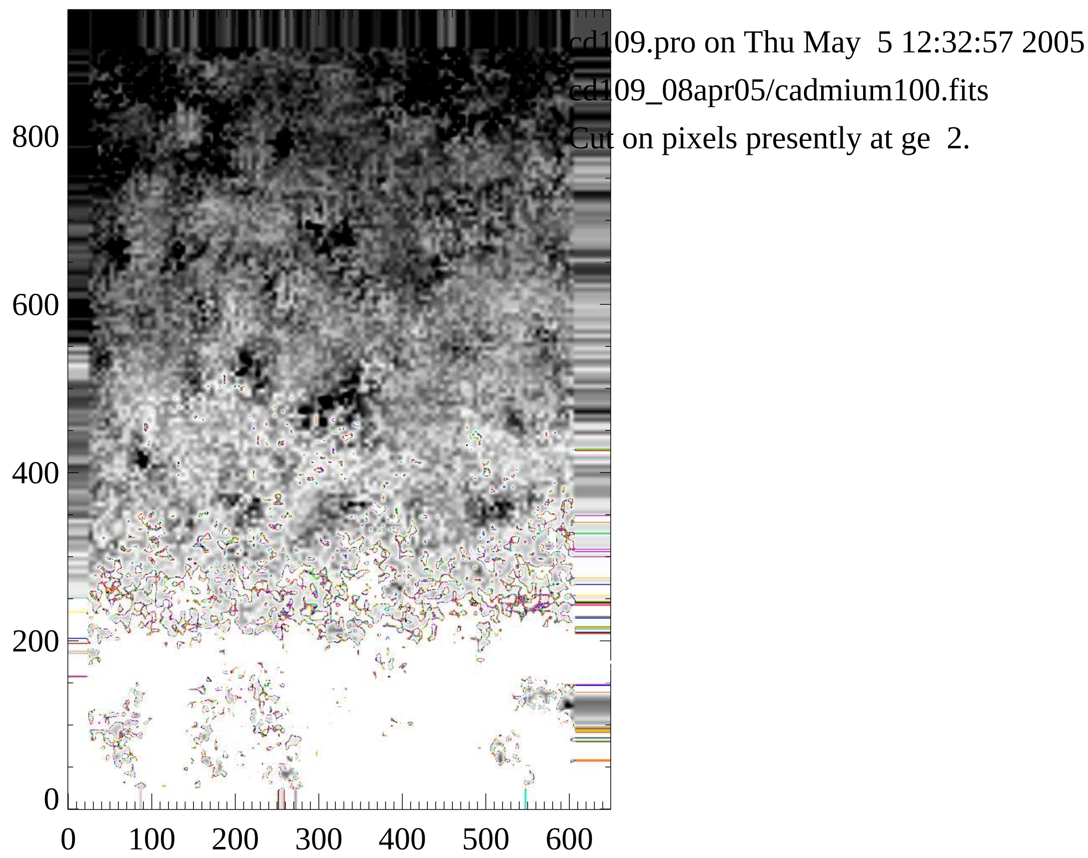
Xrays only inhabit the streaky region



This is not a great exposure, but it's all I have for the moment



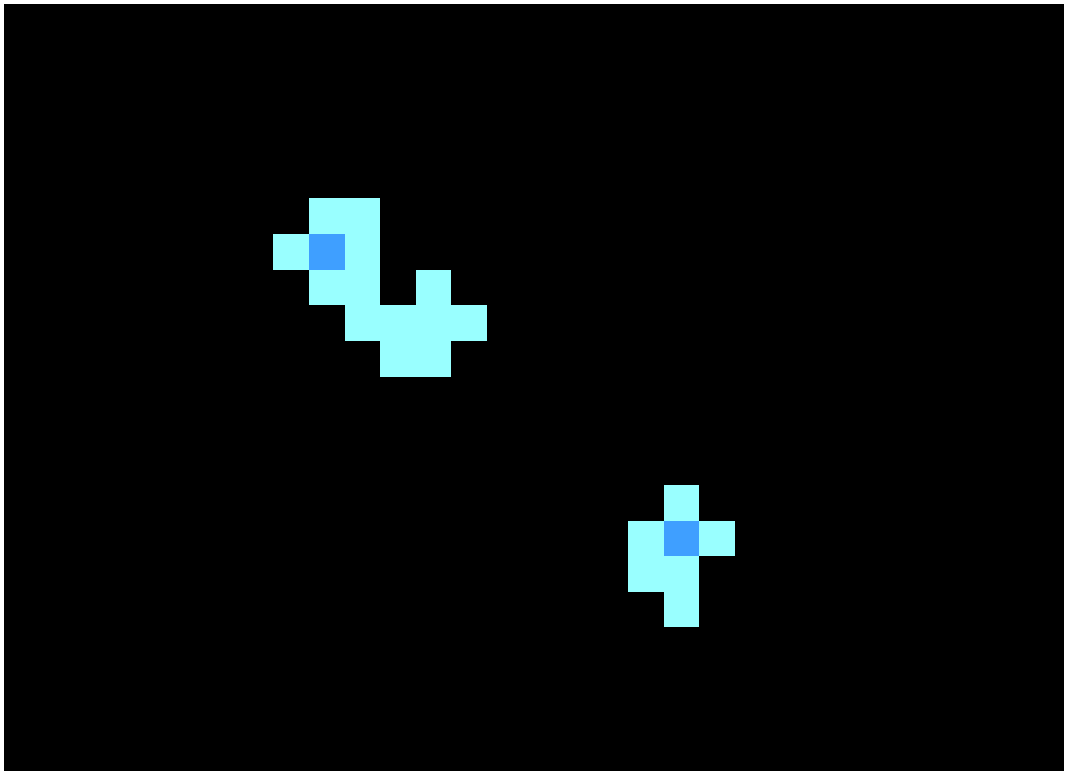
Flatfield made by boxcar averaging, excluding pixels far from the average. The full range in the image is 11 pixels. (Kyle has suggested a better method, zerocombine as in IRAF.)



`isofind.pro:` The idea is to find an xray "event" as though it were a galaxy, without prejudice as to its shape.

Scan to find one pixel > `thresh1` (in this case 5σ) above the mean background, then include all pixels with sides adjacent which are > `thresh2` (in this case 3σ) above background

You don't cut out signal by using a fixed aperture, nor do you include unnecessary pixels



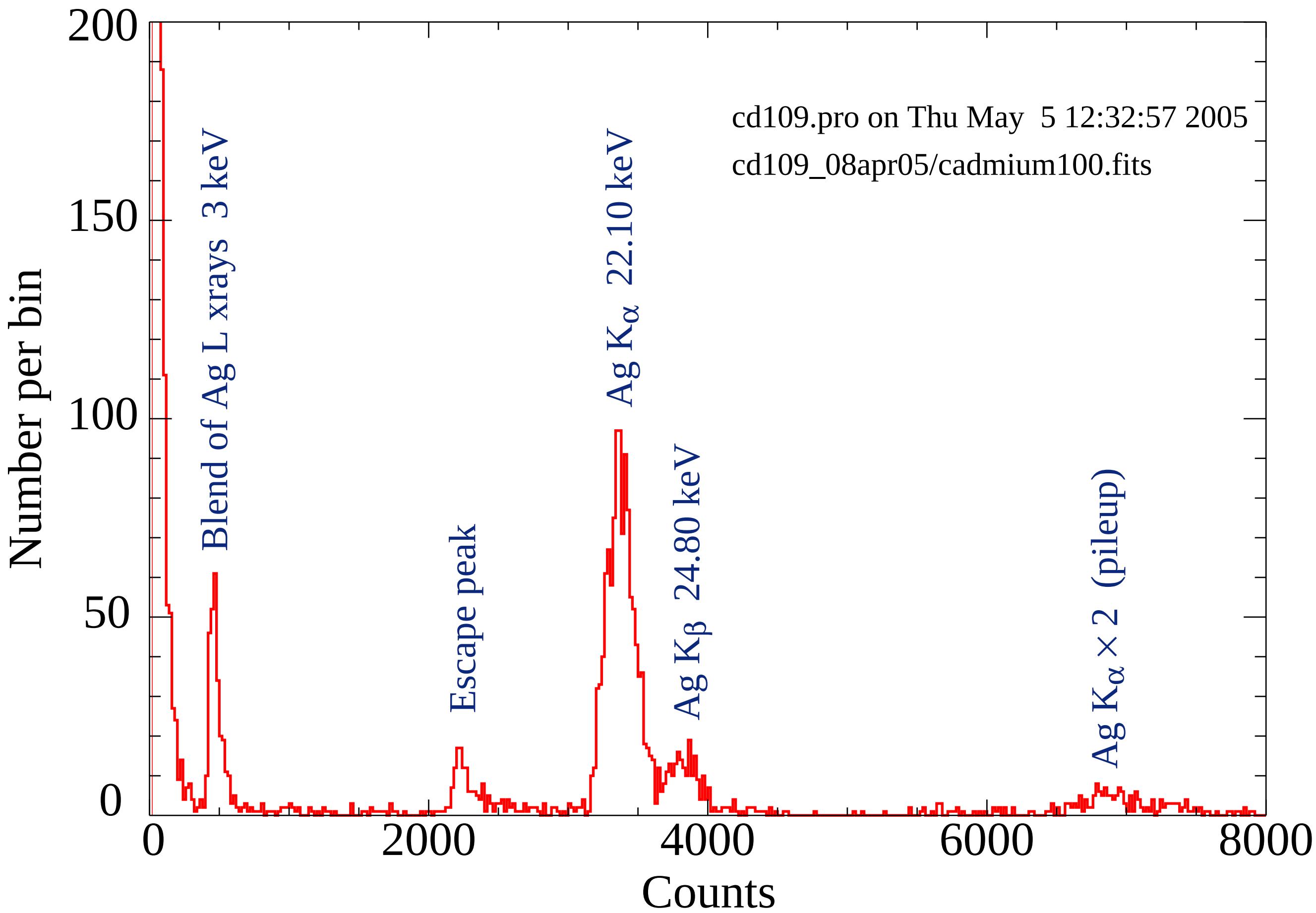
The code returns a structure containing lots of goodies, including—

- `npix` number of pixels in the event
- `isophot` total counts in the event
- x, y position
- xx, yy, and xy moments of the distribution

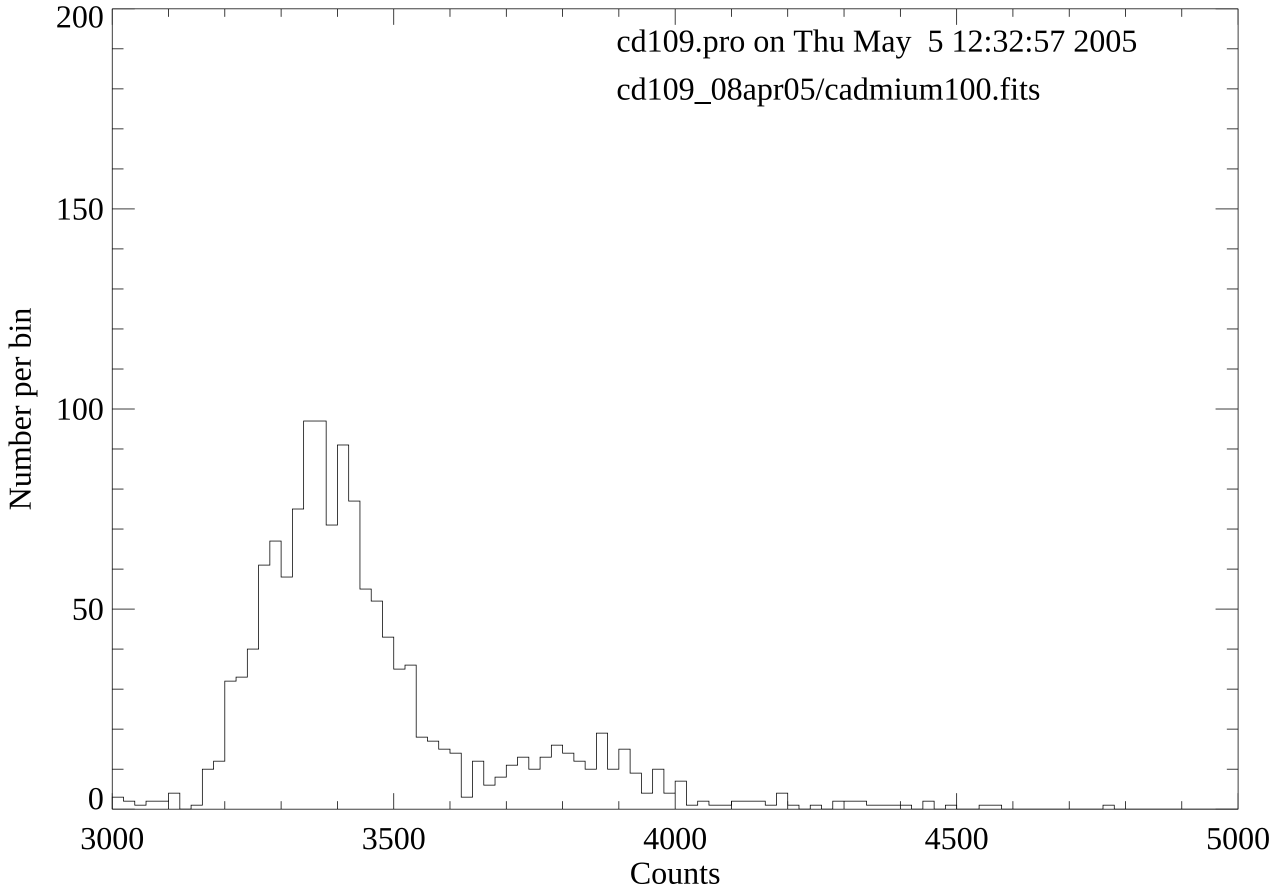
The arrays are sorted by increasing `isophot`

You can also set lower limits on `npix` and `isophot`

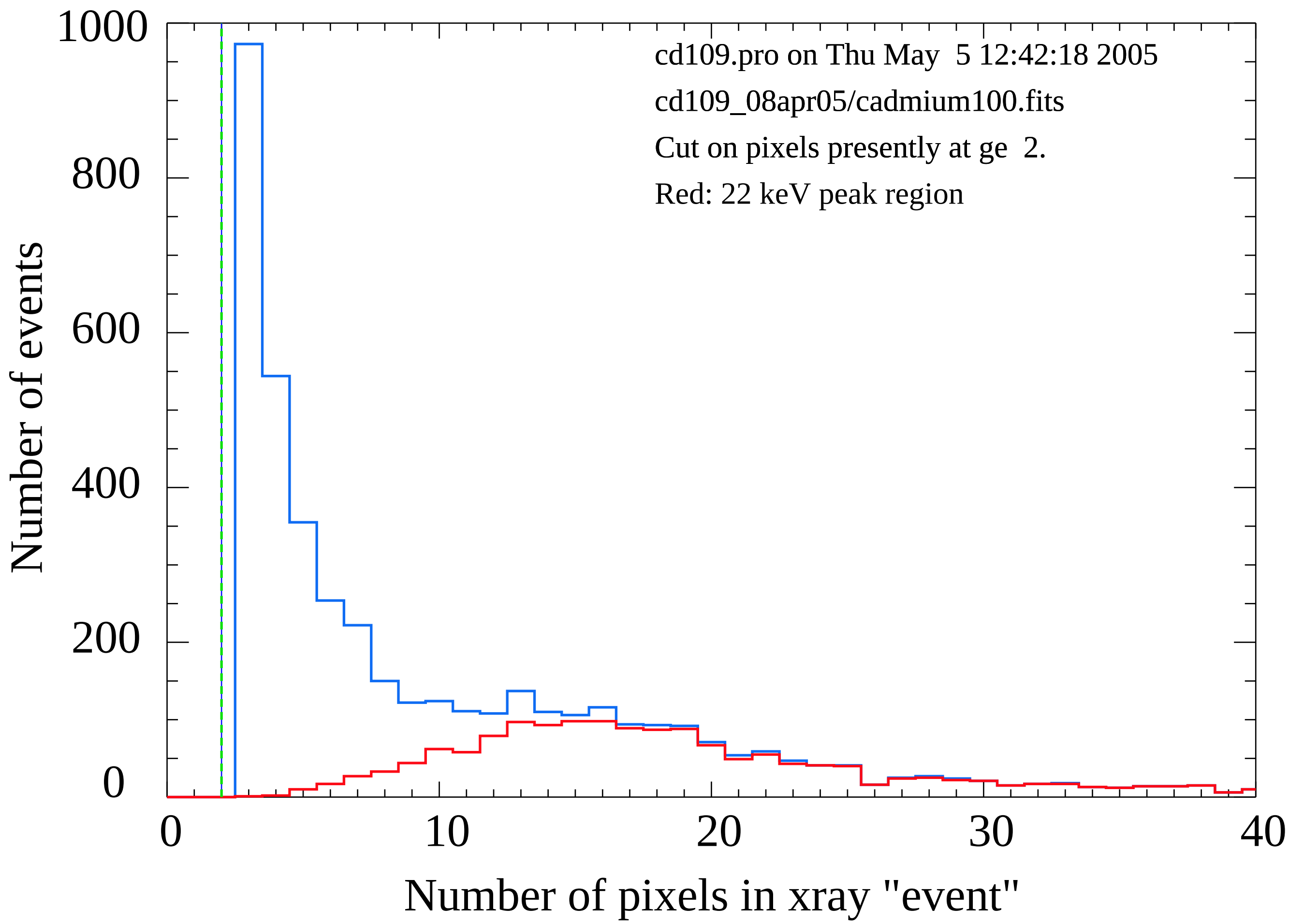
Here's the ADU distribution for the selected field of this rather lousy image:



—and a blowup of the peak region:

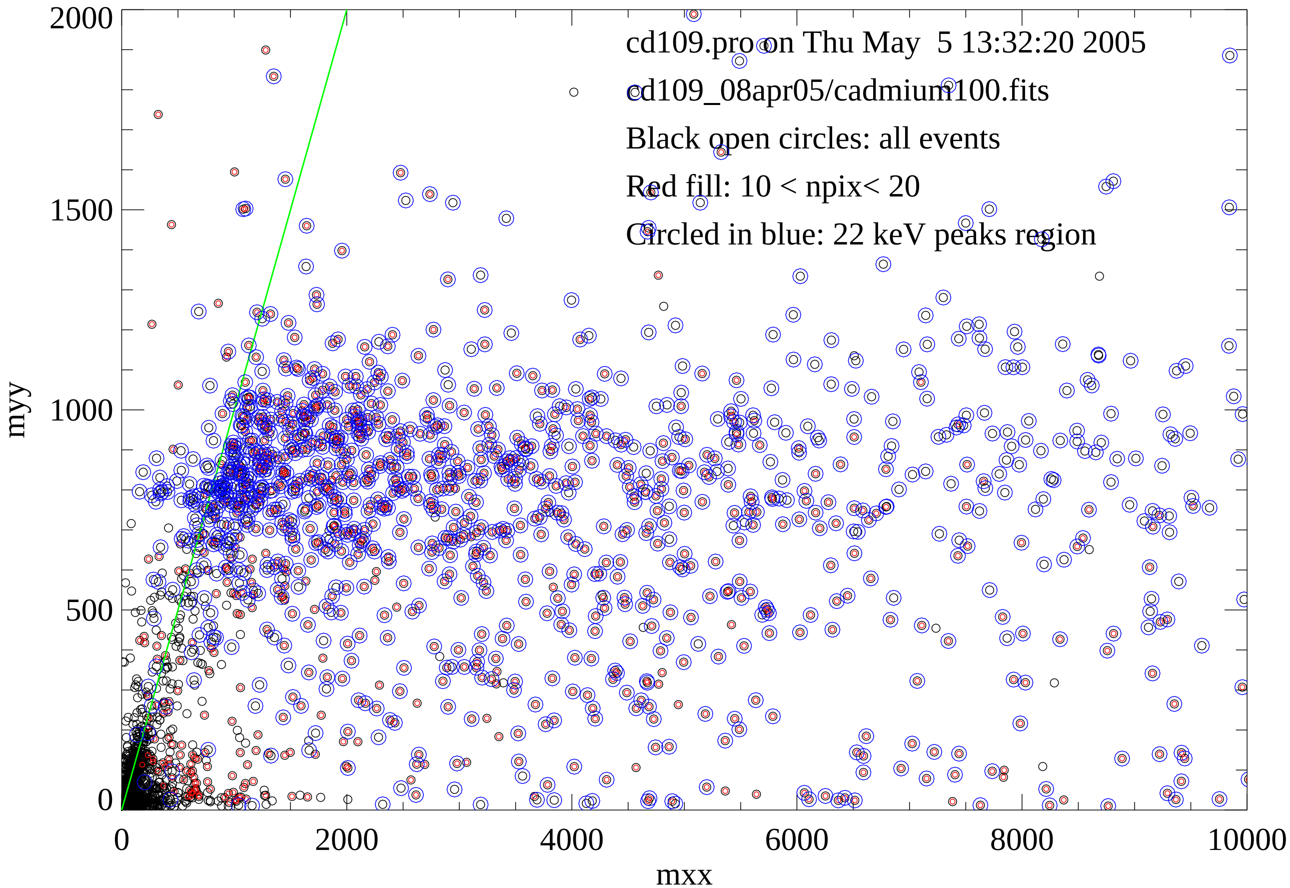


—and the `npix` distribution:



The red histogram shows the distribution of `npix` for the ^{109}Cd K_α and K_β region, $3000 <$ `isophot` < 4000

This plot of the yy moment vs the xx moment is more complicated. A black circle marks each event. A red fill indicates $10 <$ `npix` < 20, and a blue outer circle indicates $3000 <$ `isophot` < 5000 (the peak region)



In a good image, the scatter should be about the green $\texttt{mxx} = \texttt{myy}$ line

The (vain?) hope is that we can isolate events in which nearly all of the charge is in one whonking big pixel. Then an asymmetry in this plot, *e.g.* in the column direction, is a measure of charge left behind due to CTE < 1

There's lots to do:

- Try all this out on GOOD images
- Use multiple (nominally identical) xray exposures to make Kyle's superdark
- Make two-Gaussian fits to the peaks
- Investigate the stability of the calibration result to variations in `thresh2` and other things

TO BE CONTINUED