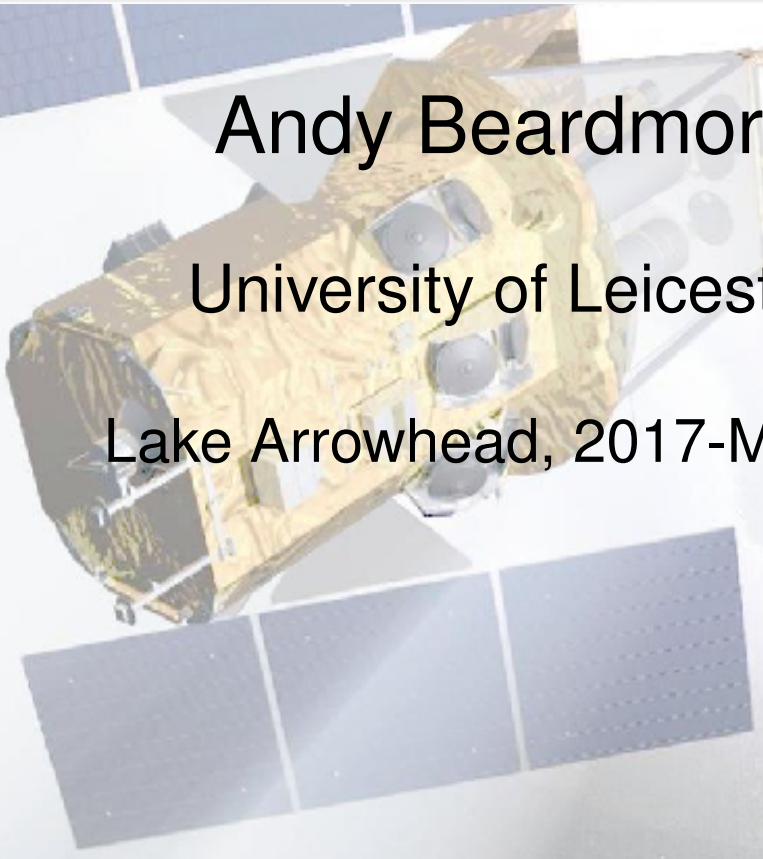
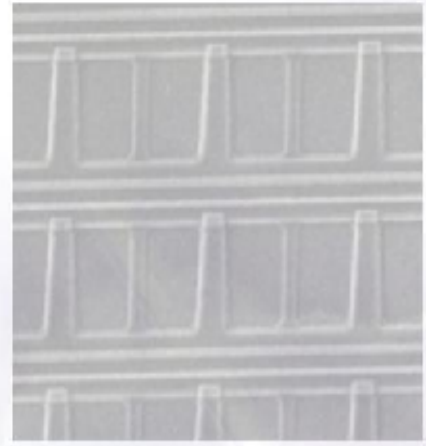
XRT Windowed Timing Mode – Trailing Charge

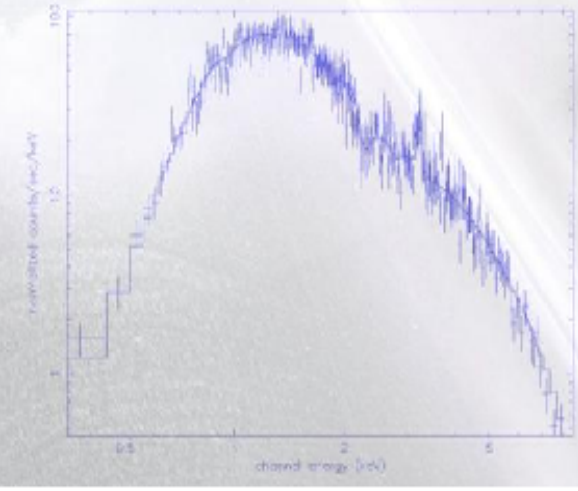
Andy Beardmore

University of Leicester

Lake Arrowhead, 2017-Mar-29





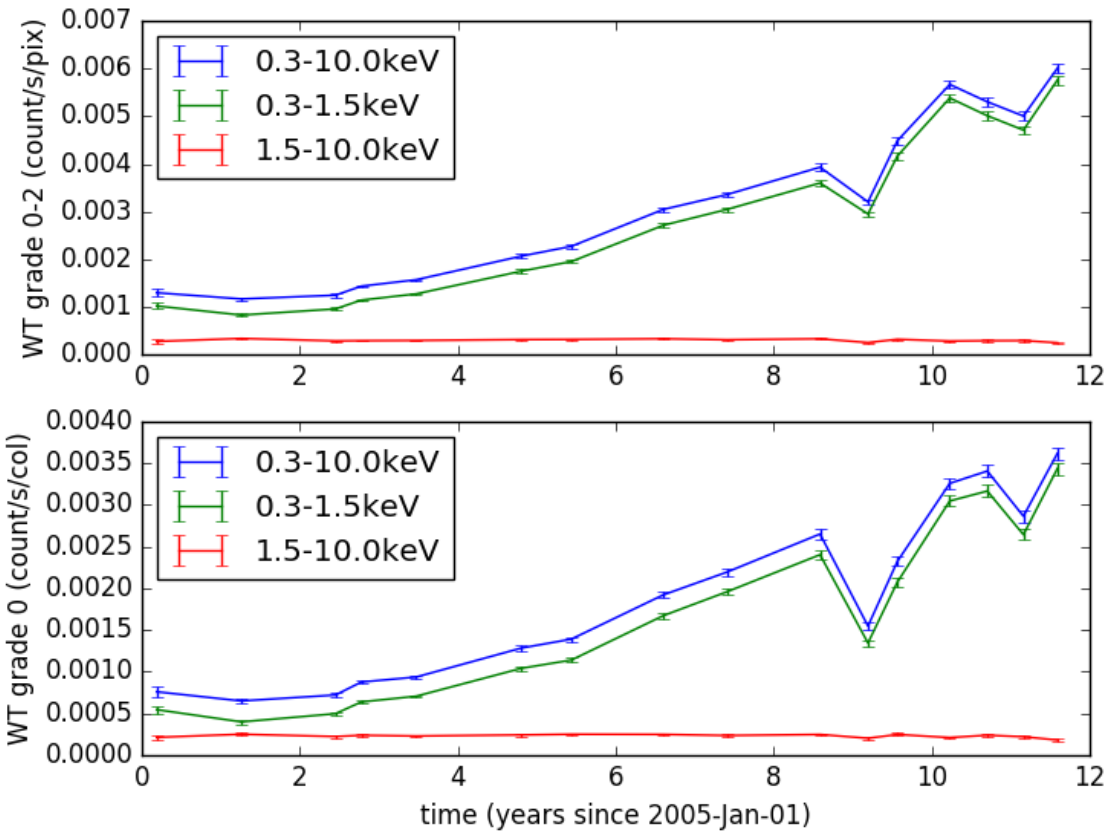


Swift-XRT WT Mode

- CCD is clocked at a regular rate
- 10 rows are clocked into the serial register
- Central 200 columns are then read out of the serial register
  - readout time is 1.78 ms per output row
    - $10 \times 15\mu$s (parallel) $+$
    - $205 \times 1.5\mu$s $+ 200 \times 6.5\mu$s (serial)
- Pseudo-frames (for telemetry) comprise 600 output rows
- WT mode selected automatically above $\sim$ 5 c/s
- Piled-up above $\sim$ 150 c/s (though depends on source spectrum)

WT background

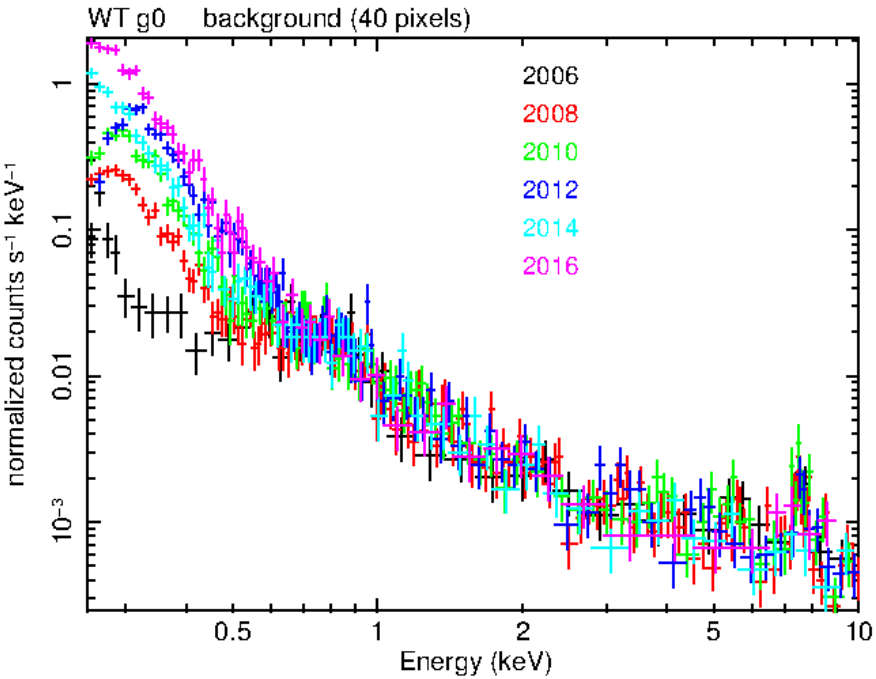
- WT background has been increasing with time – e.g. RXJ1856 :

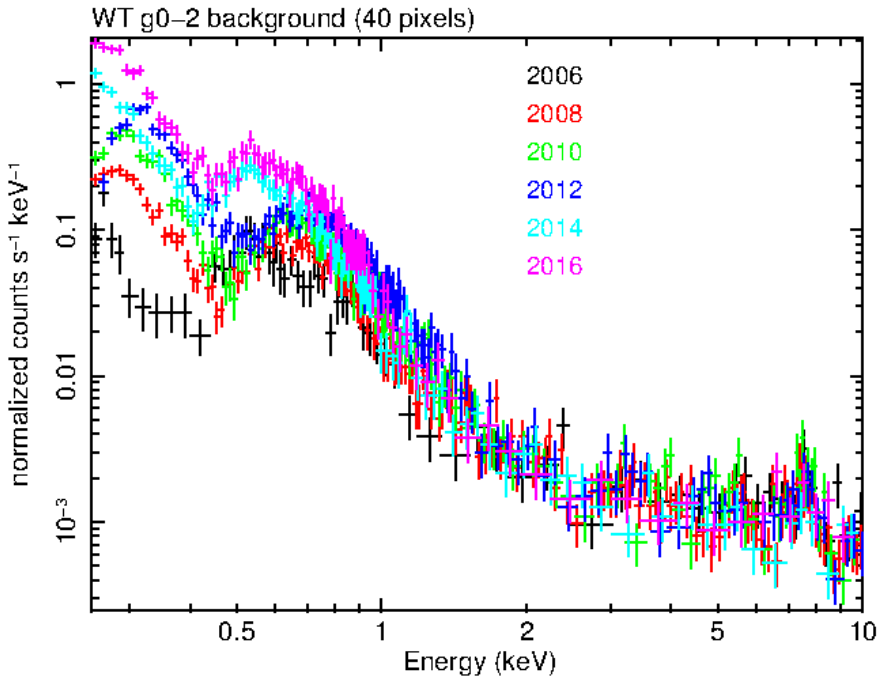


- Background increases at low E (below $\sim$ 1 keV)
- Low-E background $\sim 9\times$ higher in 2016 c.f. 2006

WT background (cont'd)

- RXJ1856 WT background spectra
  - Observed 1 or 2 times per year since launch
  - 20 ks per observation — i.e. up to 40 ks per year

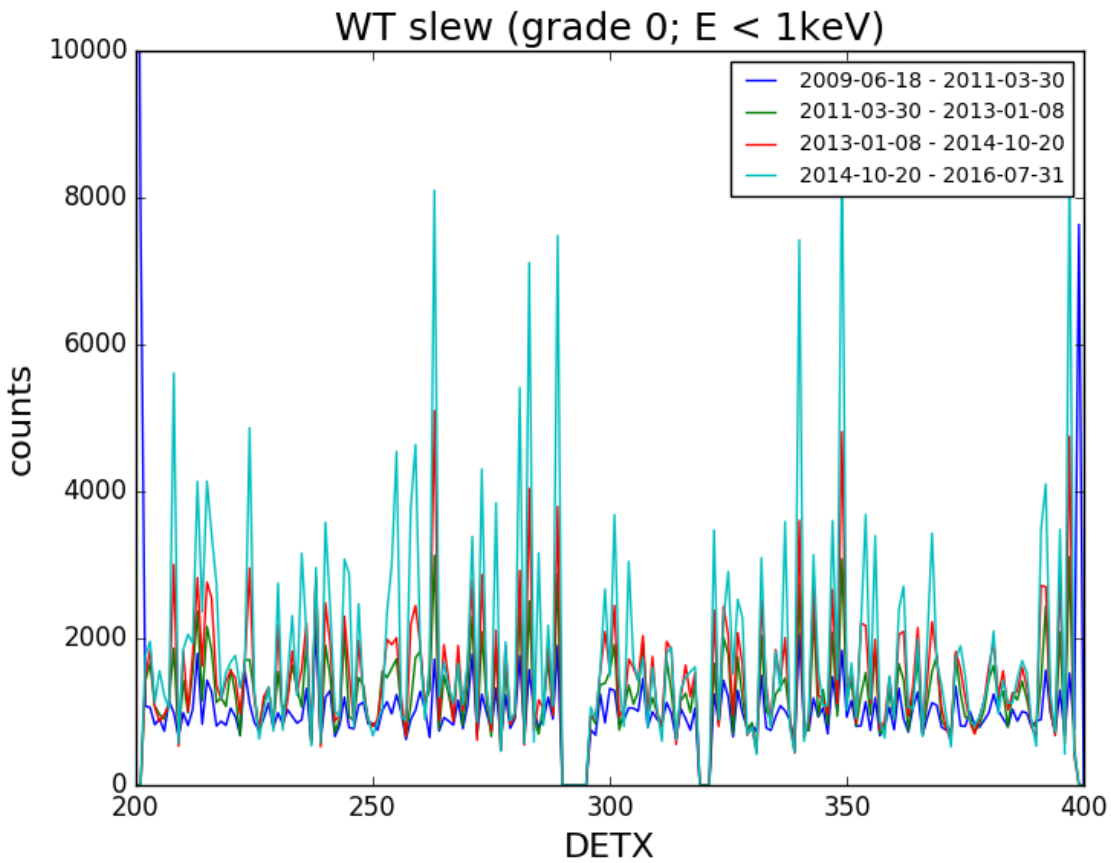




- Onboard event Threshold changed 80 → 60DN on 2013-Dec-11
  - Slight reduction in grade 0 low energy rise after change

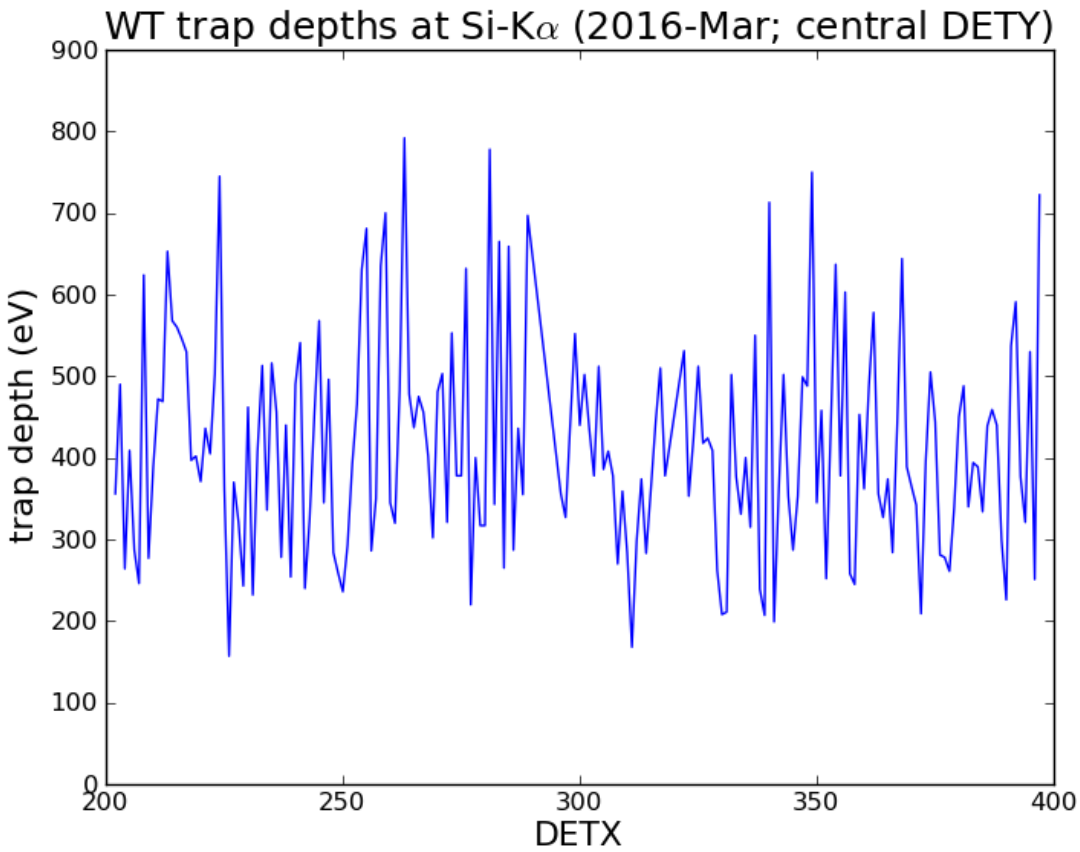
WT Slew Background

- WT slew data – count level evolution :



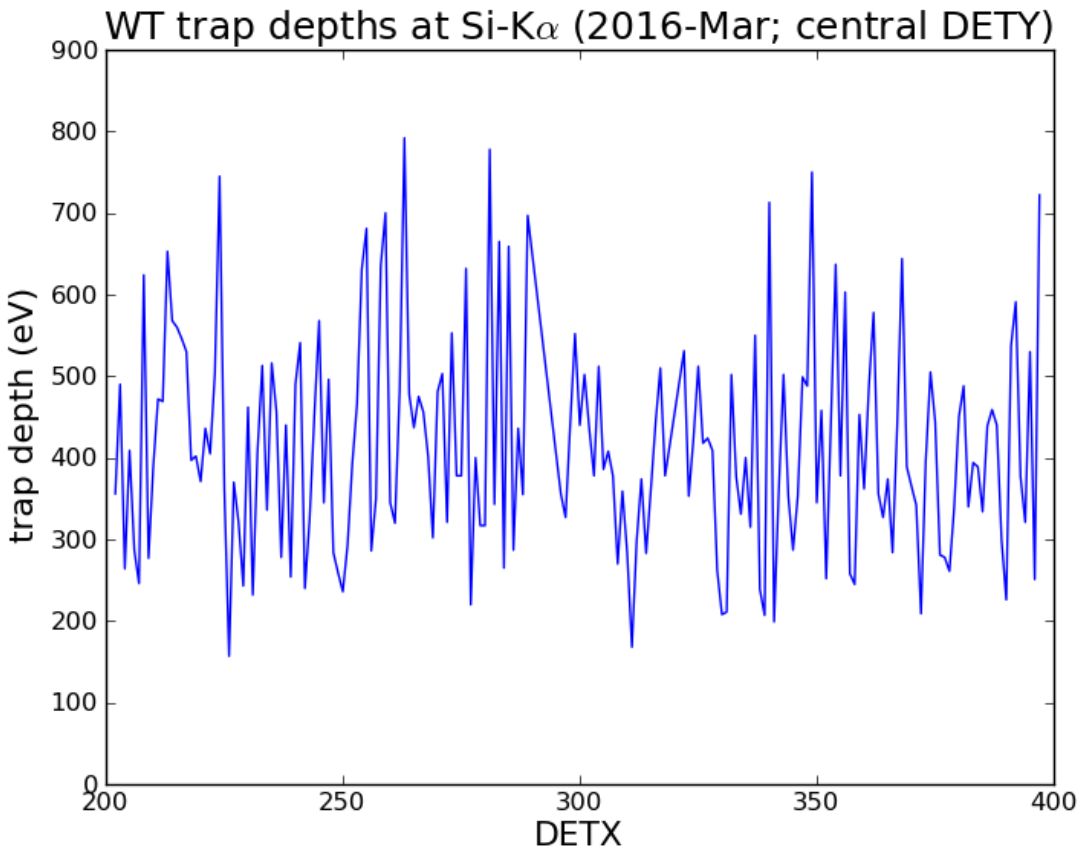
WT Trap Depths

- WT trap depths in 2016 (from Beatriz) :



WT Trap Depths

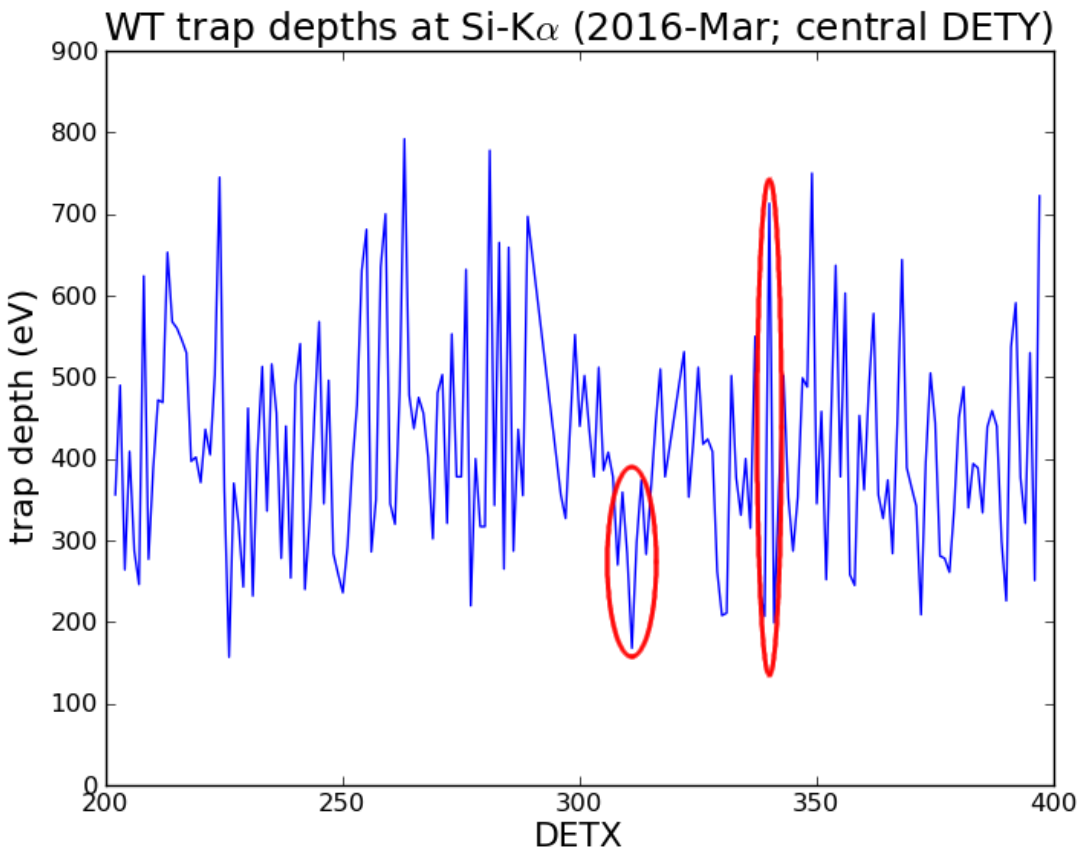
- WT trap depths in 2016 (from Beatriz) :



- → background count rate increase associated with columns containing deep traps.

WT Trap Depths

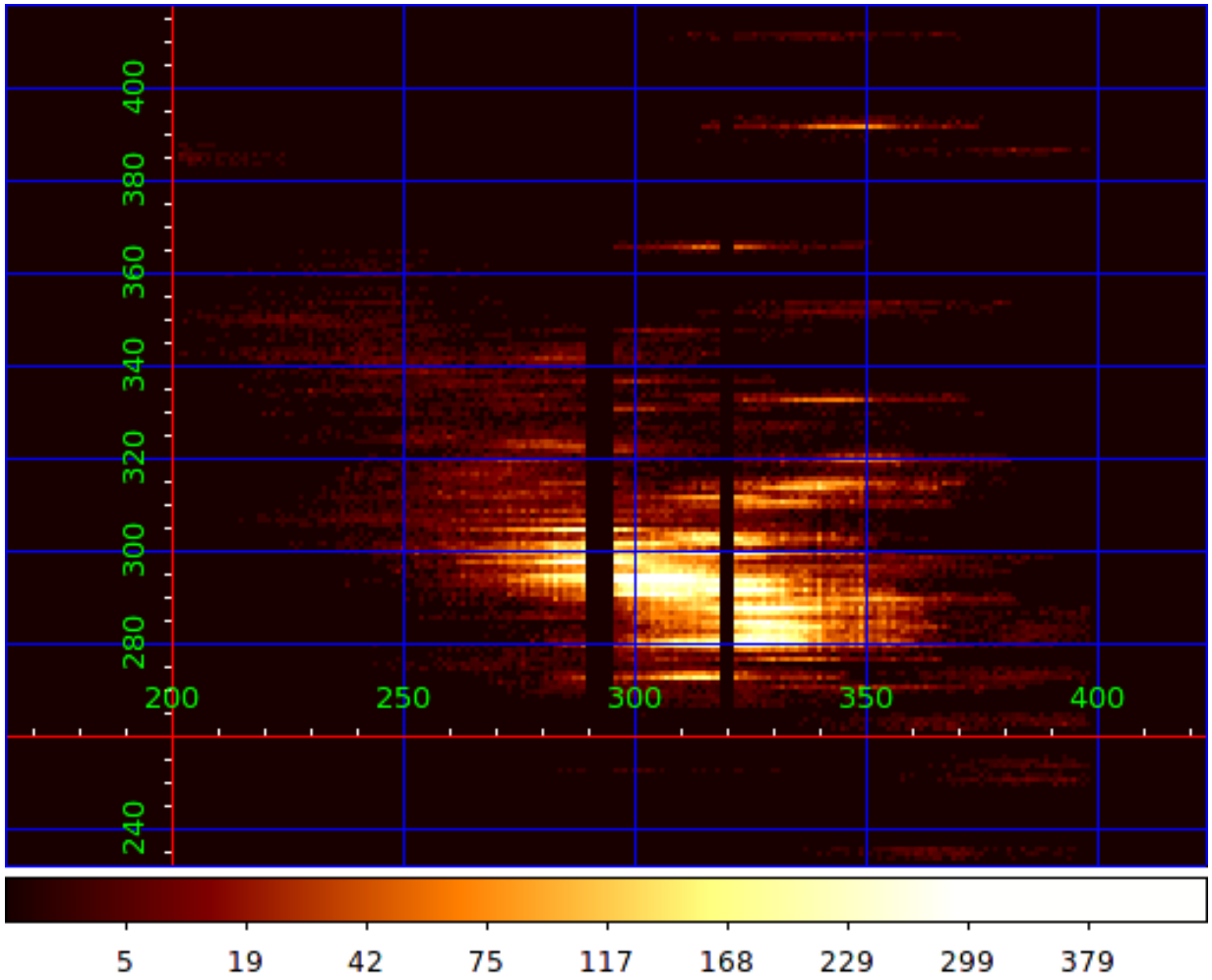
- WT trap depths in 2016 (from Beatriz) :



- Highlighted columns show DETX=311 (shallow trap) and 340 (deep trap)

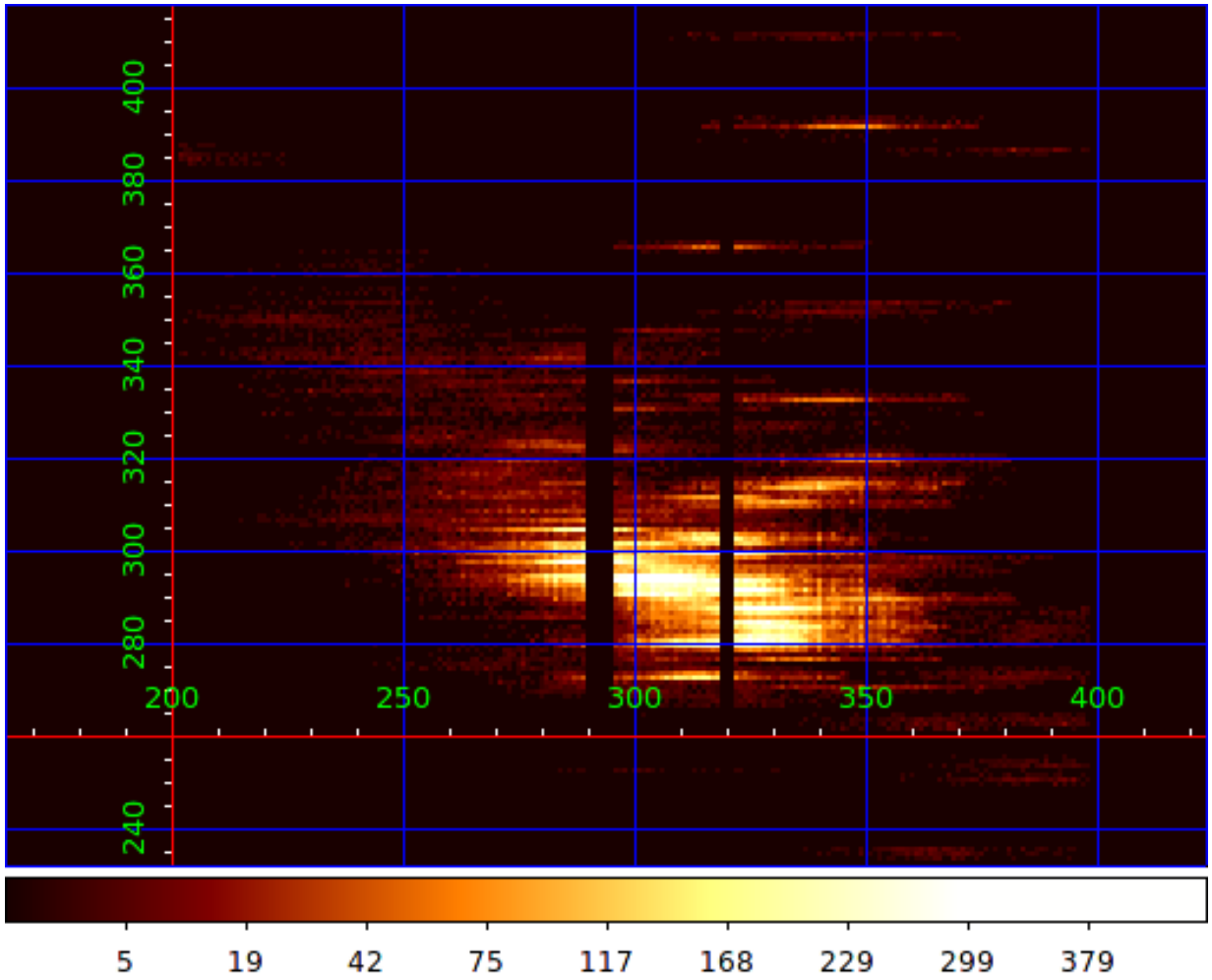
WT Column Spectra

- Merged E0102 2013–2016 data



WT Column Spectra

- Merged E0102 2013–2016 data

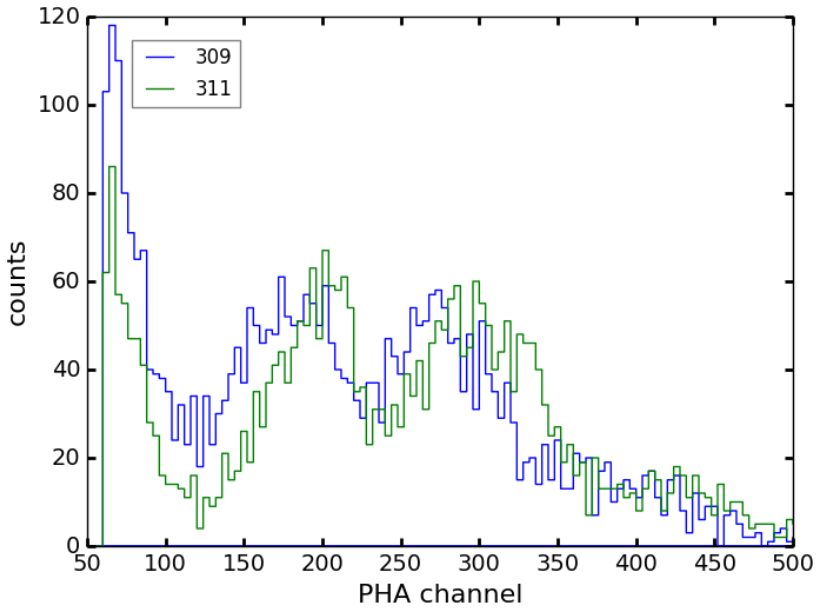


- Compare spectra from columns with different trap depths.

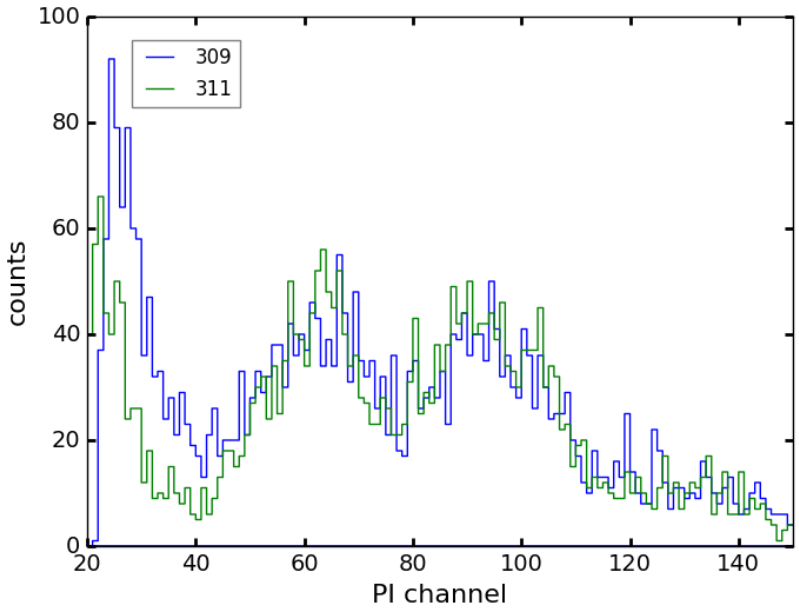
WT Column Spectra (cont'd)

- Merged E0102 2013–2016 data

- DETX : 309 (blue: medium trap), 311 (green: shallow trap) in PHA



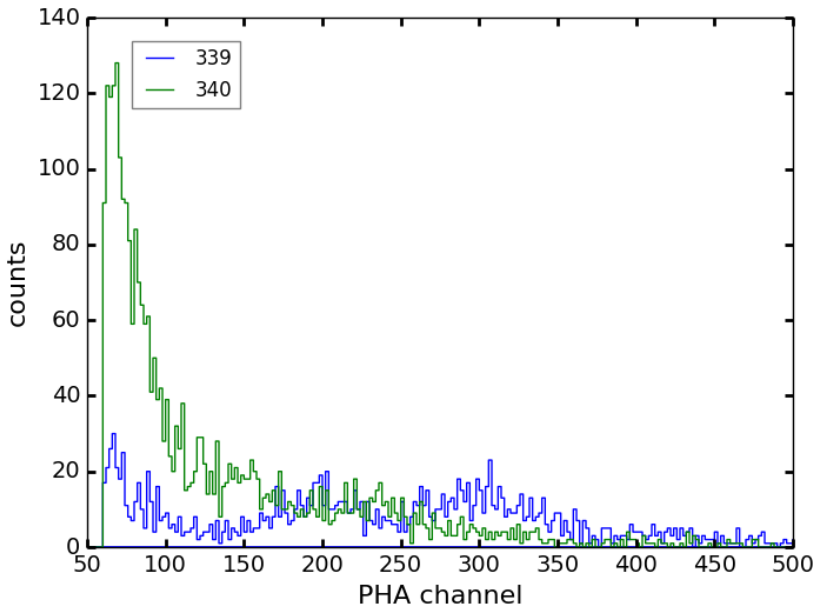
- DETX : 309 (blue: medium trap), 311 (green: shallow trap) in PI



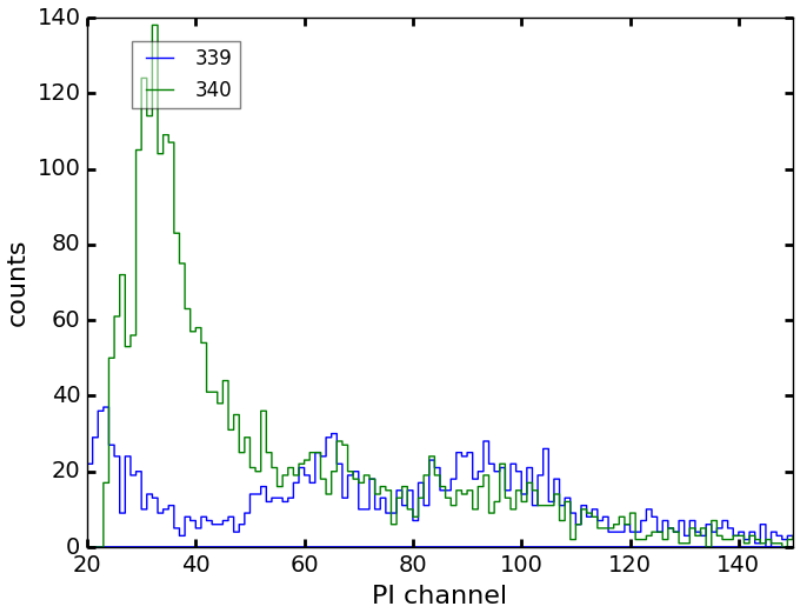
WT Column Spectra (cont'd)

- Merged E0102 2013–2016 data

- DETX : 339 (blue: shallow trap), 340 (green: deep trap) in PHA



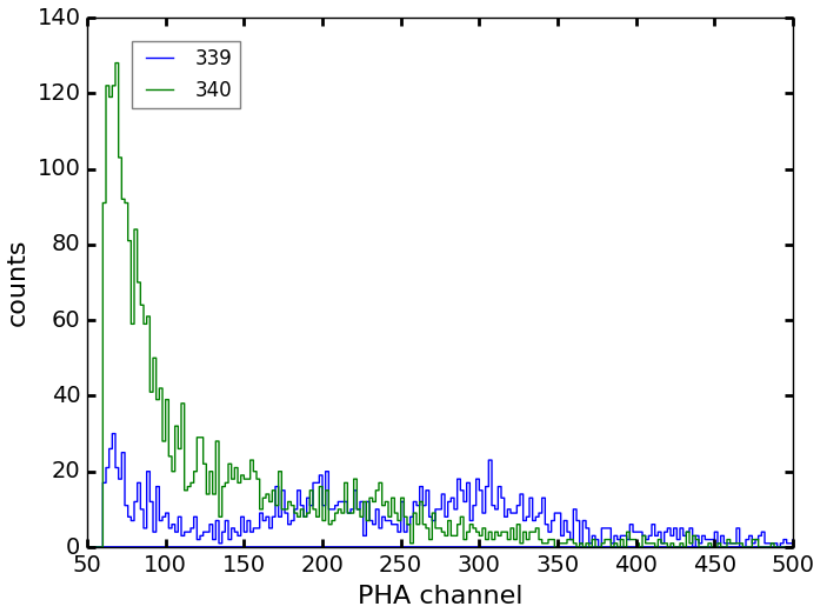
- DETX : 339 (blue: shallow trap), 340 (green: deep trap) in PI



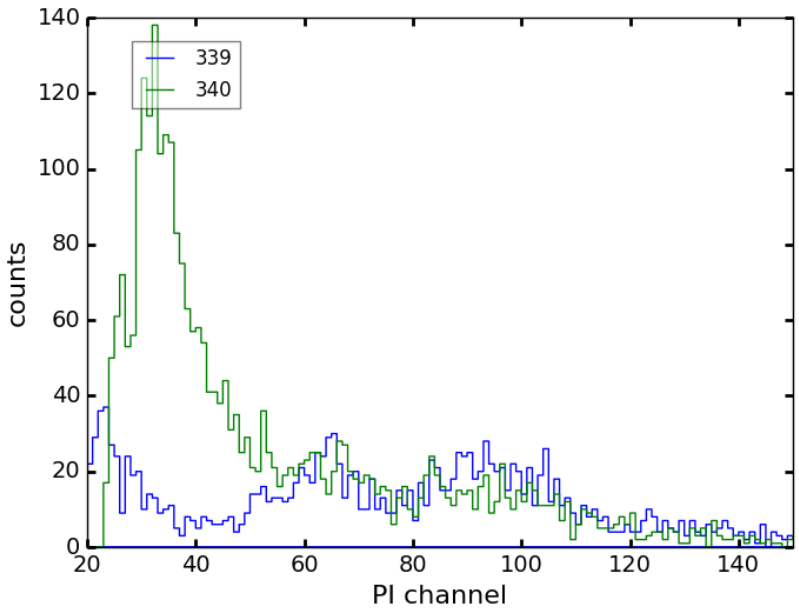
WT Column Spectra (cont'd)

- Merged E0102 2013–2016 data

- DETX : 339 (blue: shallow trap), 340 (green: deep trap) in PHA



- DETX : 339 (blue: shallow trap), 340 (green: deep trap) in PI

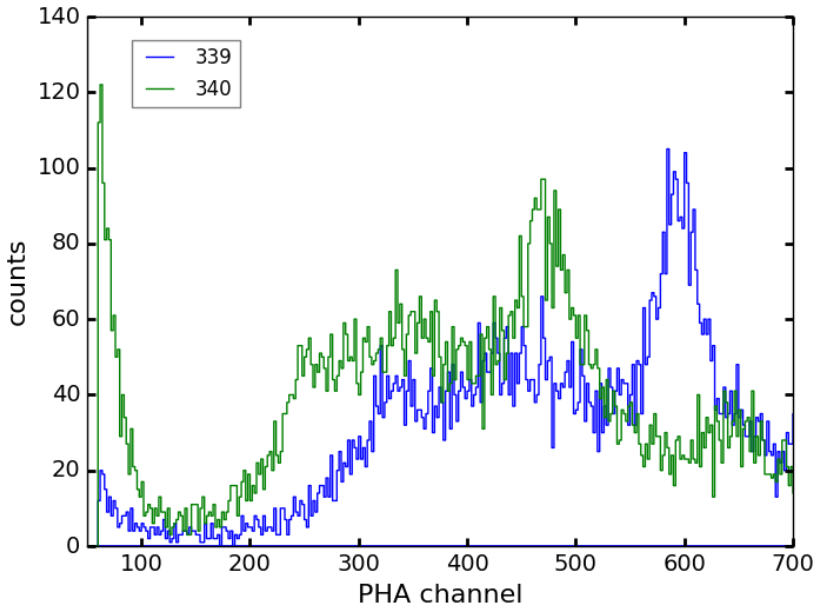


- Columns with deep traps show a significant low energy excess

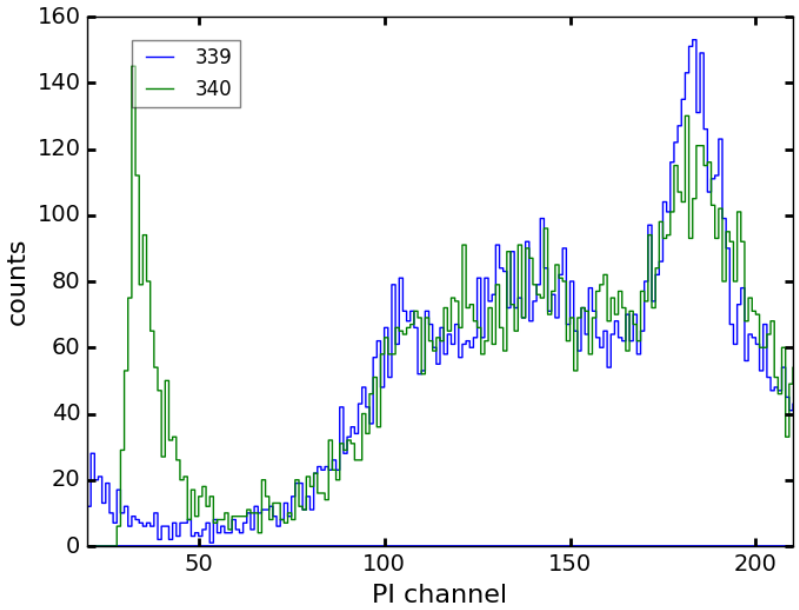
WT Column Spectra (cont'd)

- Cas A 2015 data (central DETY)

- DETX : 339 (green: deep), 340 (blue: shallow) in PHA



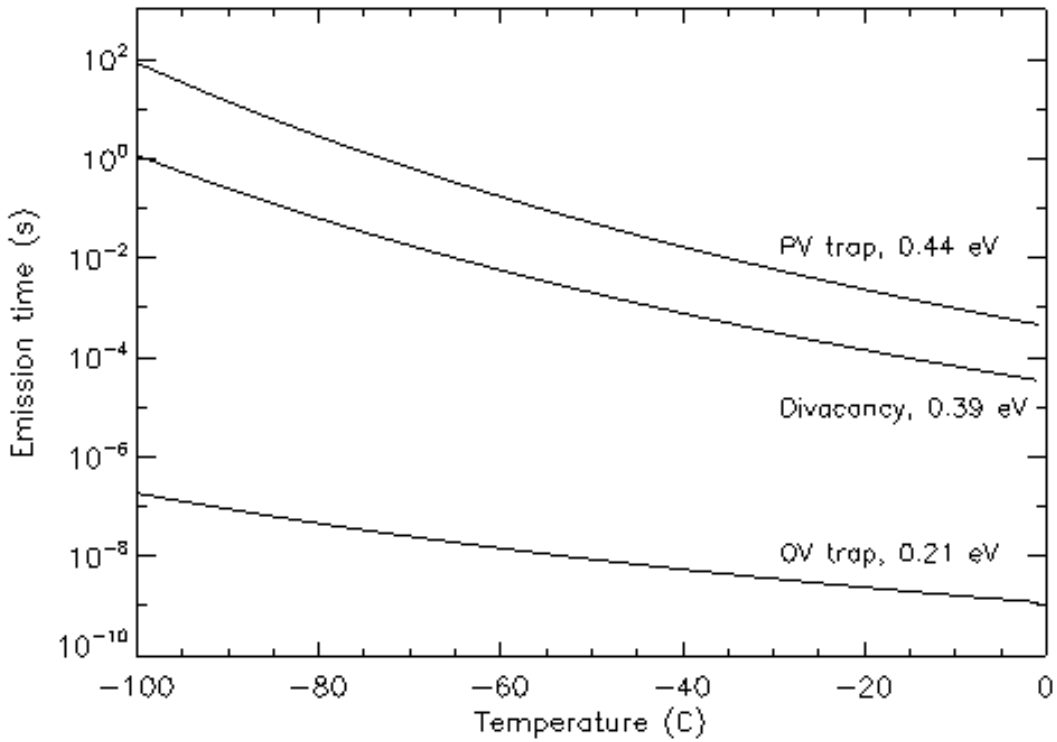
- DETX : 339 (green: deep), 340 (blue: shallow) in PI



- Columns with deep traps show a significant low energy excess

Deferred Charge

- Origin of the low energy excess is thought to be deferred charge released from charge traps $\rightarrow$ causing trailing charge
- Trap emission time scale :



- Claudio found trap energy level $\sim 0.35\,\mathrm{eV}$ and emission times $\sim 10\times$ parallel transfer time – i.e. of order the WT readout timescale (1.78ms)

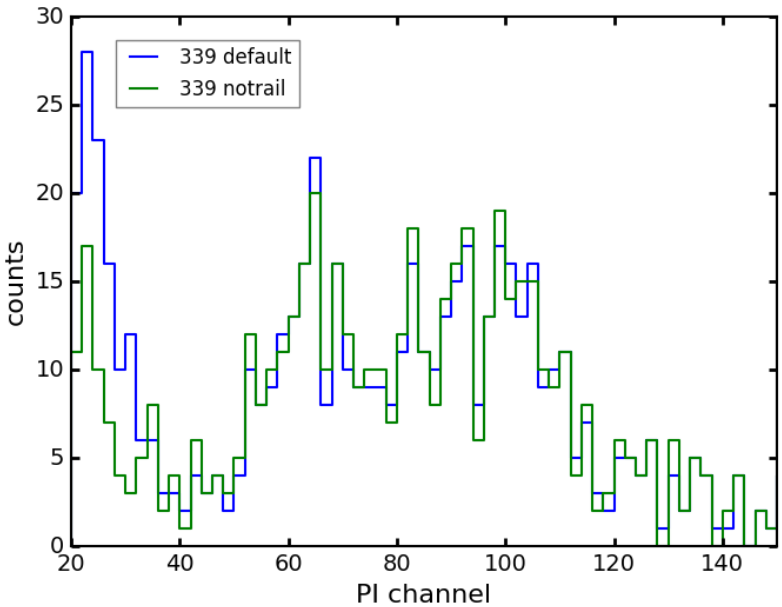
Deferred Charge (cont'd)

- Expect charge traps to release a fraction of the trapped charge into rows following the one the X-ray interaction occurs in.
- In WT mode, 10 parallel rows are clocked into the serial register before the latter is read out.
  - assigned a RAWY coordinate (range 0–599) in each WT pseudo-frame
- Wrote C++ code to test if an event occurs in the same column as, but immediately following, an event in the previous row (based on RAWY) $\rightarrow$ flag as a TRAILING event, if so. Two methods :
  - (i) : Only flag if PHA is less than PHA in previous row
  - (ii) : Flag is PHA is less than a threshold PHA
- Flagged events can then be removed from the event list

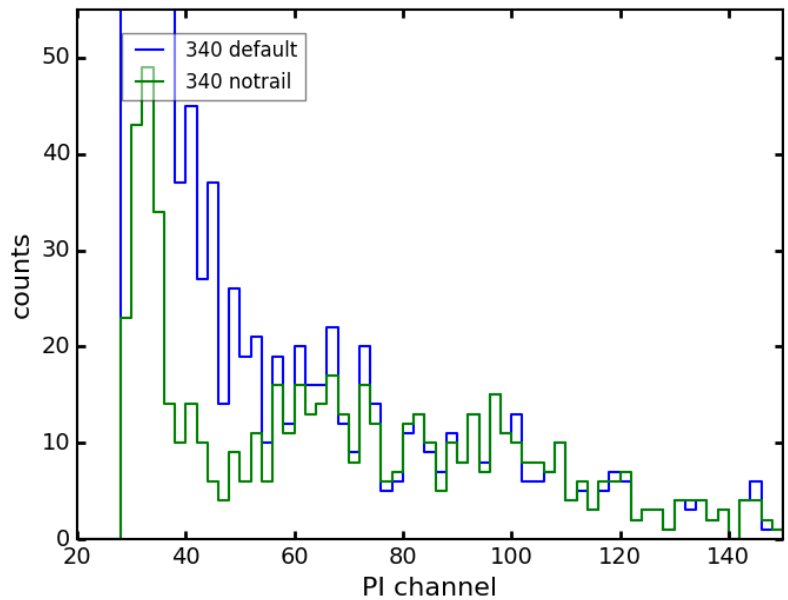
Deferred Charge (cont'd)

- E0102 2016 data

- DETX : 339 (shallow trap)



- DETX : 340 (deep trap)

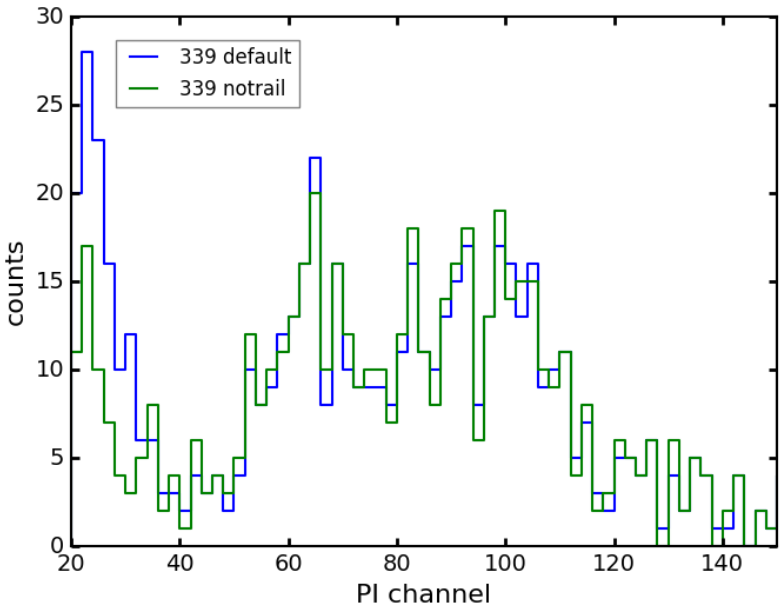


NB : blue peaks at 125 counts !

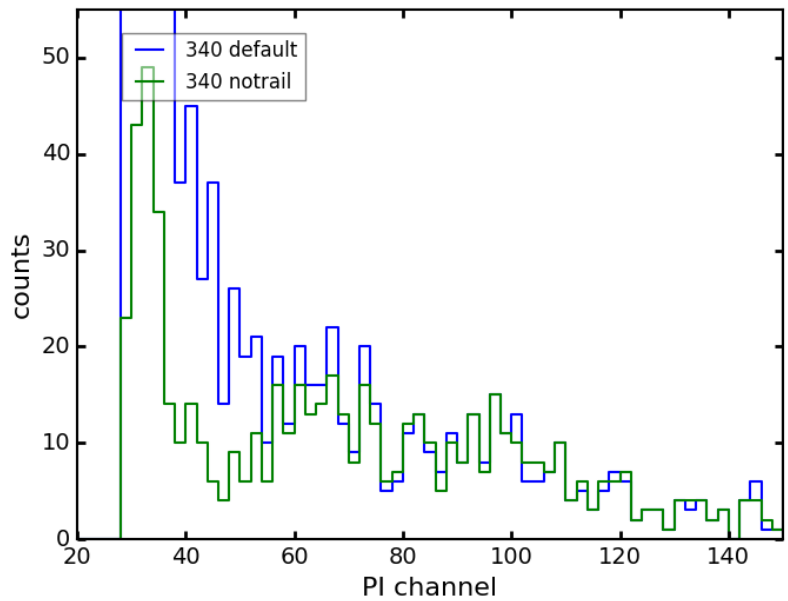
Deferred Charge (cont'd)

- E0102 2016 data

- DETX : 339 (shallow trap)



- DETX : 340 (deep trap)



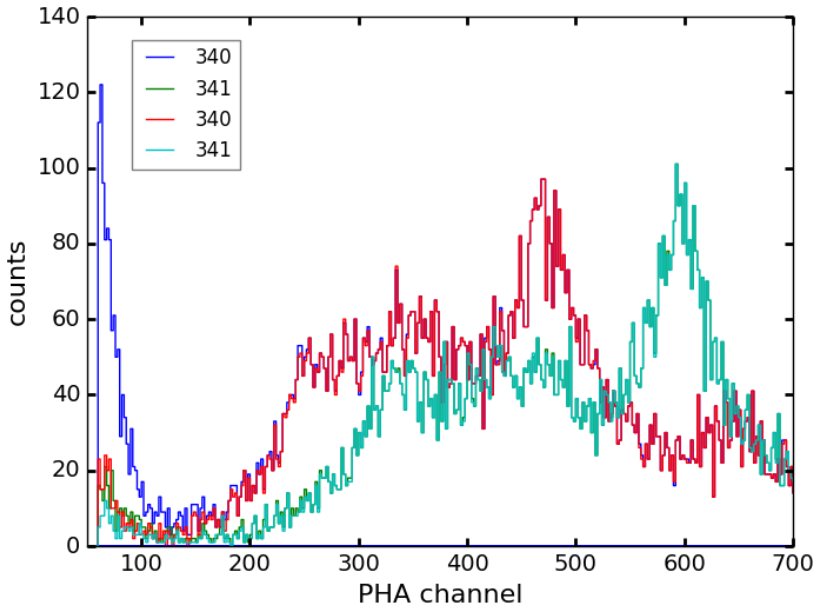
NB : blue peaks at 125 counts !

- Low E excess considerably reduced

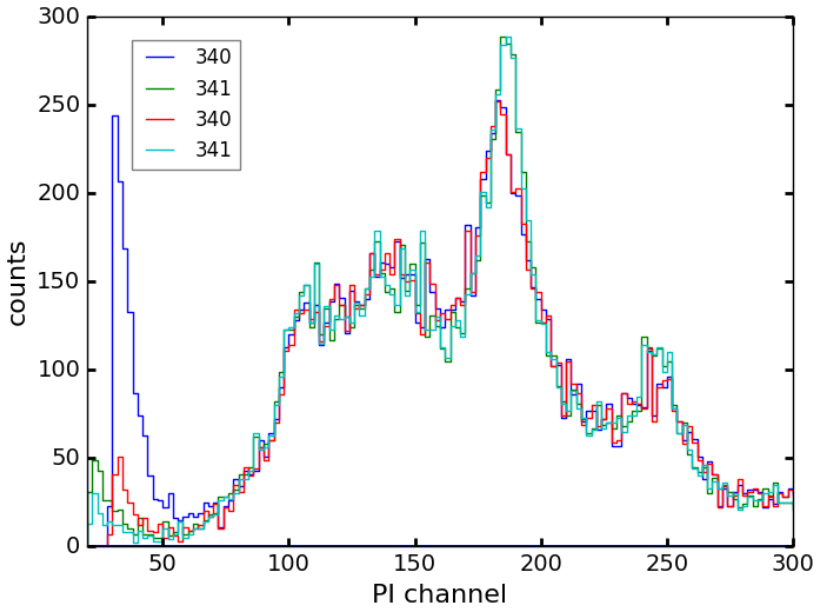
Deferred Charge (cont'd)

- Cas A (2015)

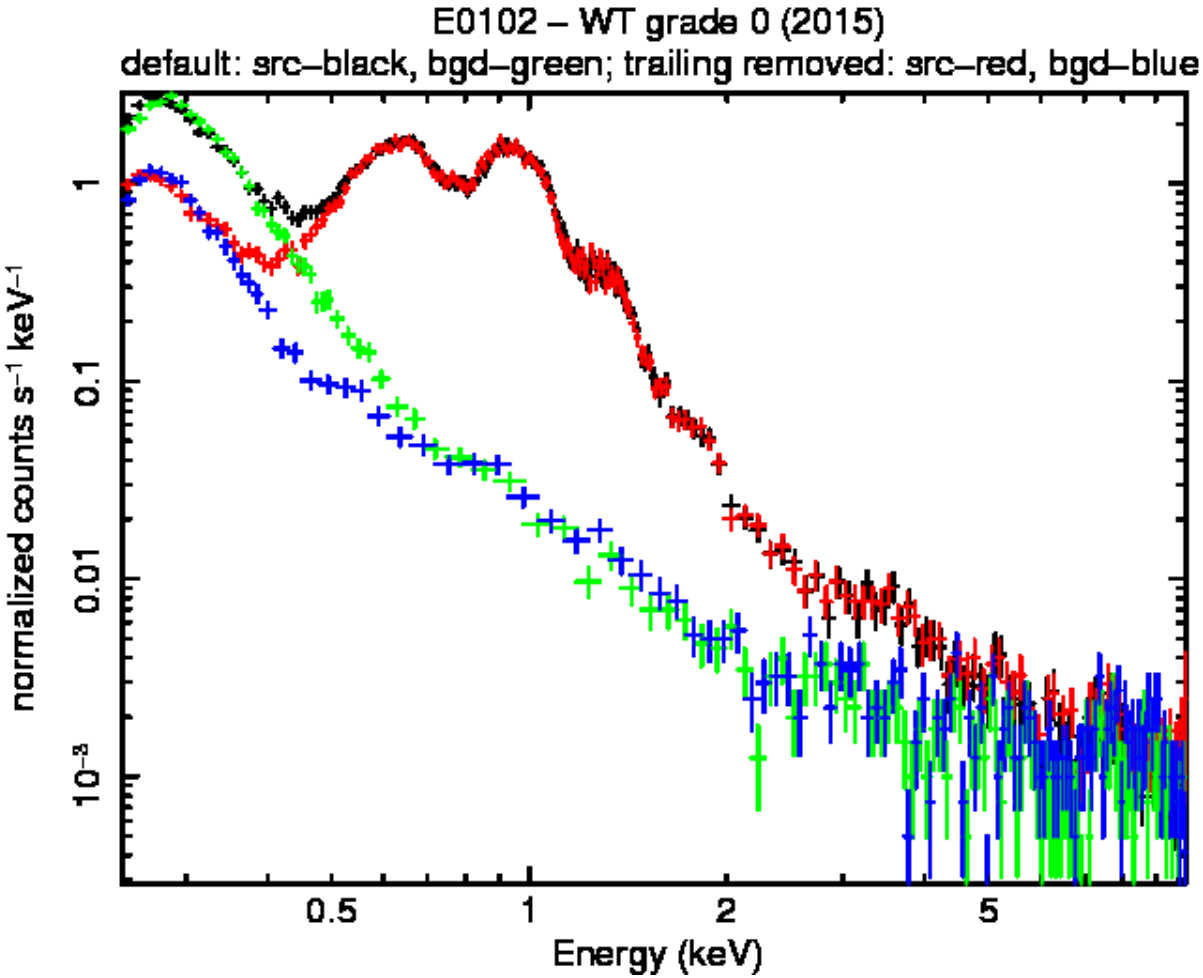
- PHA



- PI



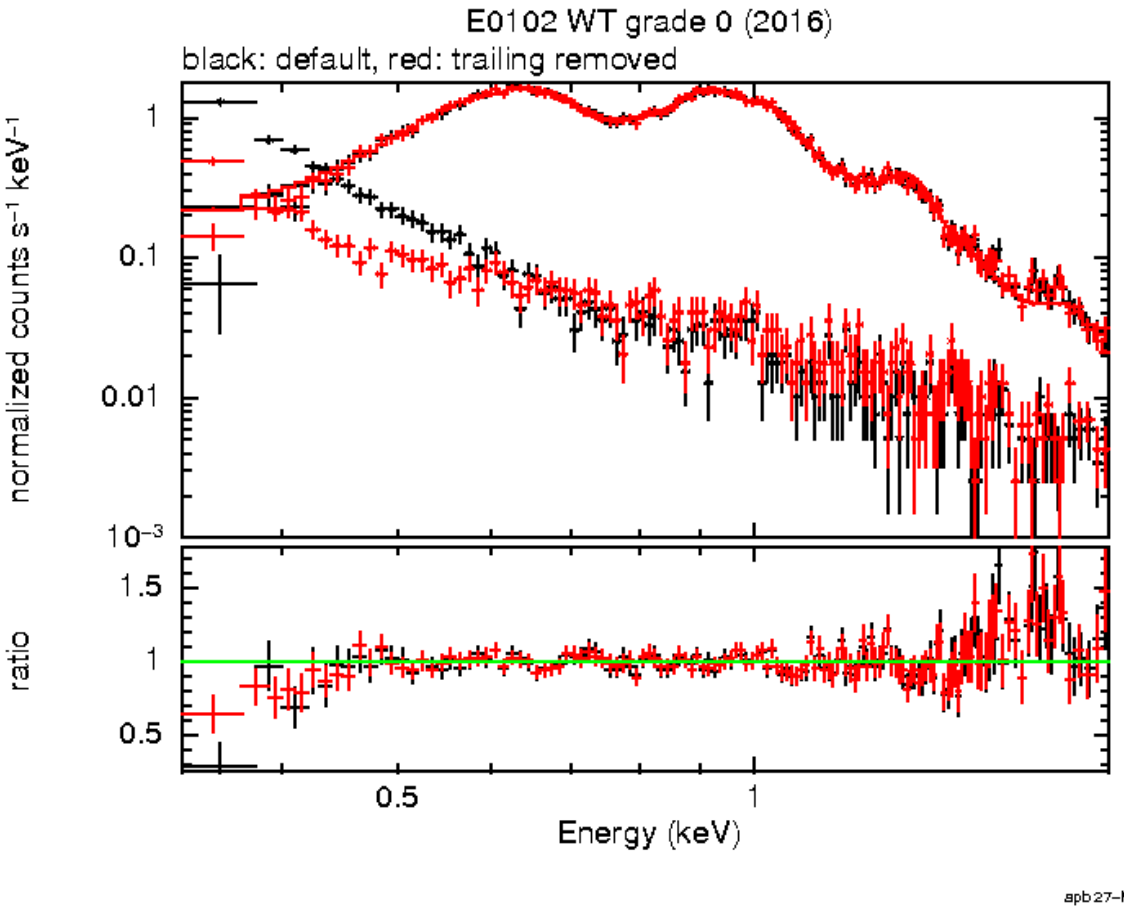
- E0102 – grade 0



- Factor of 2 decrease in background below 0.5 keV

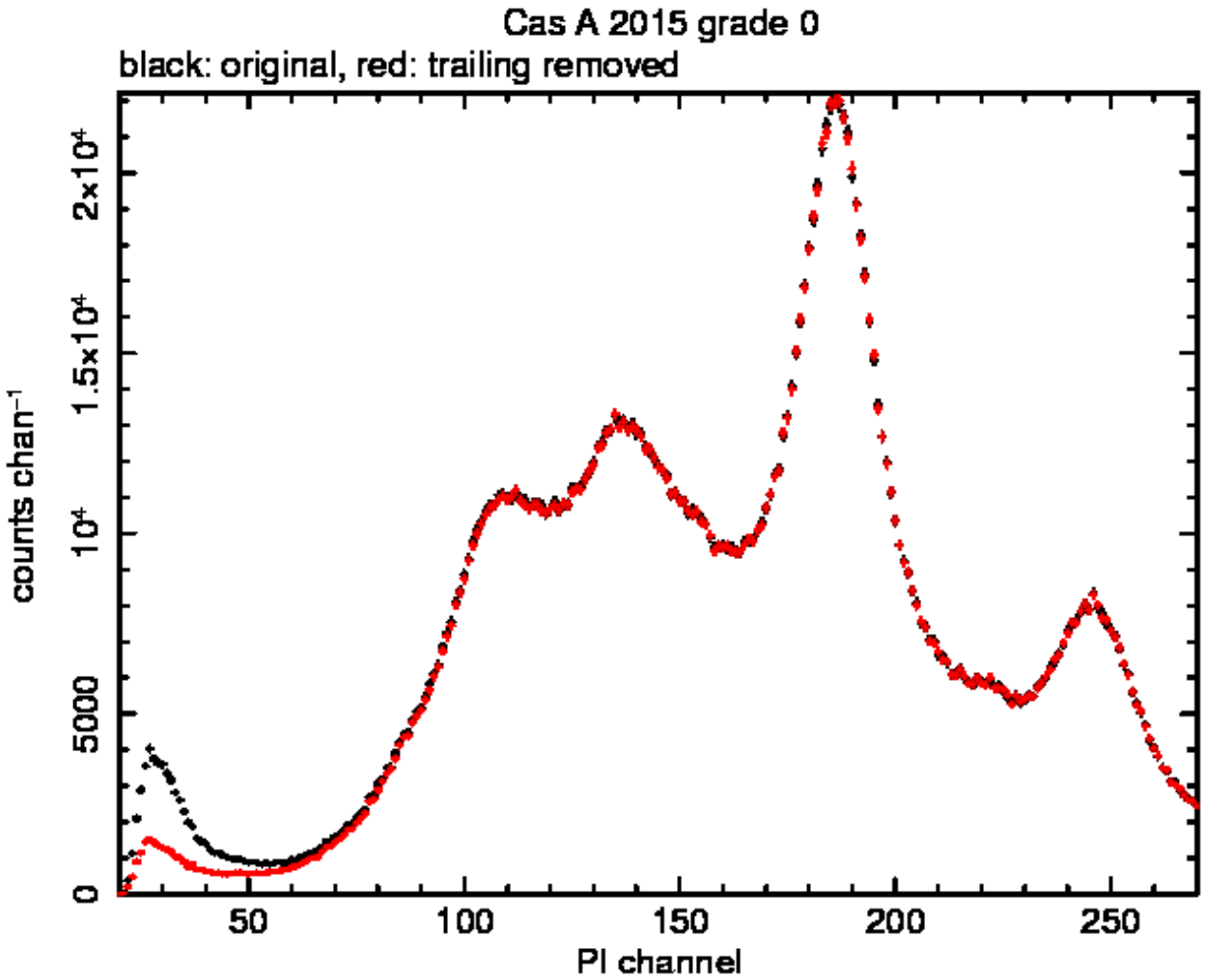
Real World (cont'd)

- E0102 – grade 0



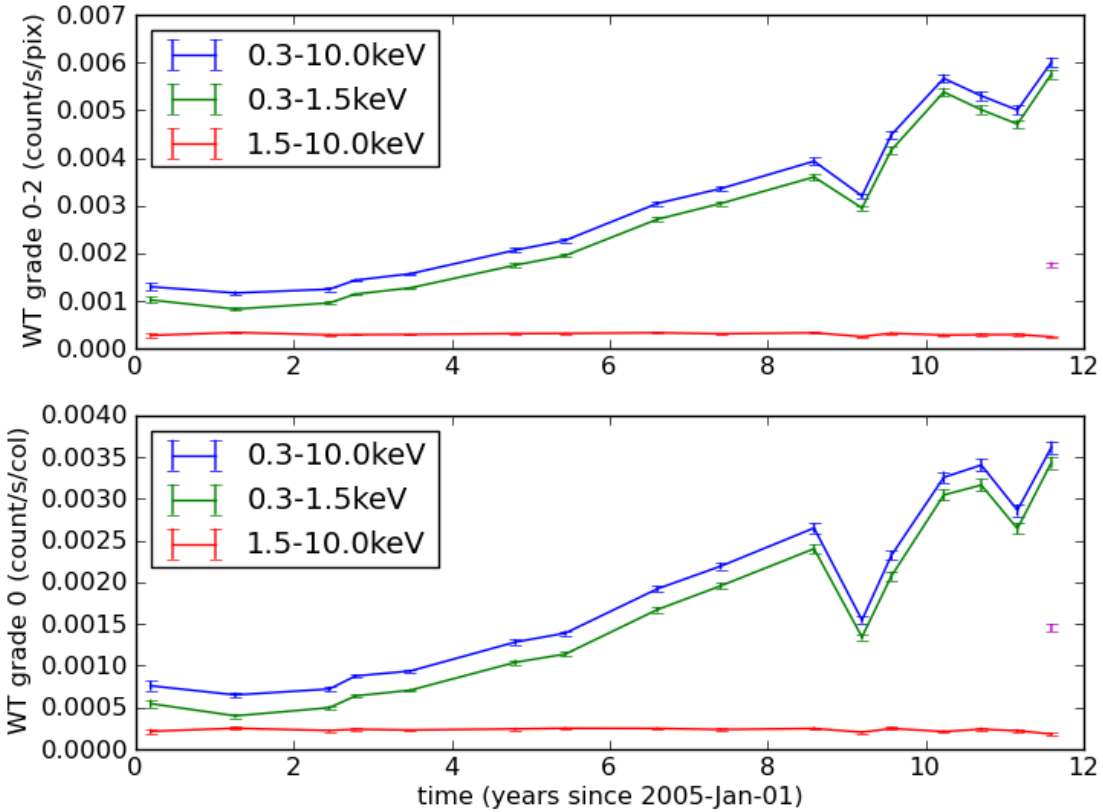
- Data with trailing charge removed (red) has better low energy background subtraction

- Cas A – grade 0


Cas A 2015 grade 0
black: original, red: trailing removed
counts chan^{-1}
0
5000
10^4
1.5×10^4
2×10^4
50
100
150
200
250
PI channel

WT background

- Previously noted that the WT background is increasing – e.g. RXJ1856 :



- Removing trailing charge reduces background by 40 per cent (below $\sim$ 1 keV)
- Equivalent to level of 6 years ago

Summary

- WT background has increased slowly with time
- Identified with trailing charge released from the deepest charge traps $\rightarrow$ forms low energy events in following rows
- Wrote code which attempts to isolate the trailing charge
  - Preprocess unfiltered event files files to tag the trailing events then remove them
  - Can identify/remove $\sim$ 60 per cent of low E events in trapped columns
- Can algorithm be improved ?
  - Could, in principle, recombine trailing charge with its parent event.