Summary of Noise Measurements on Detectors with FE-B

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Summary of expected performance

Summary of measurements

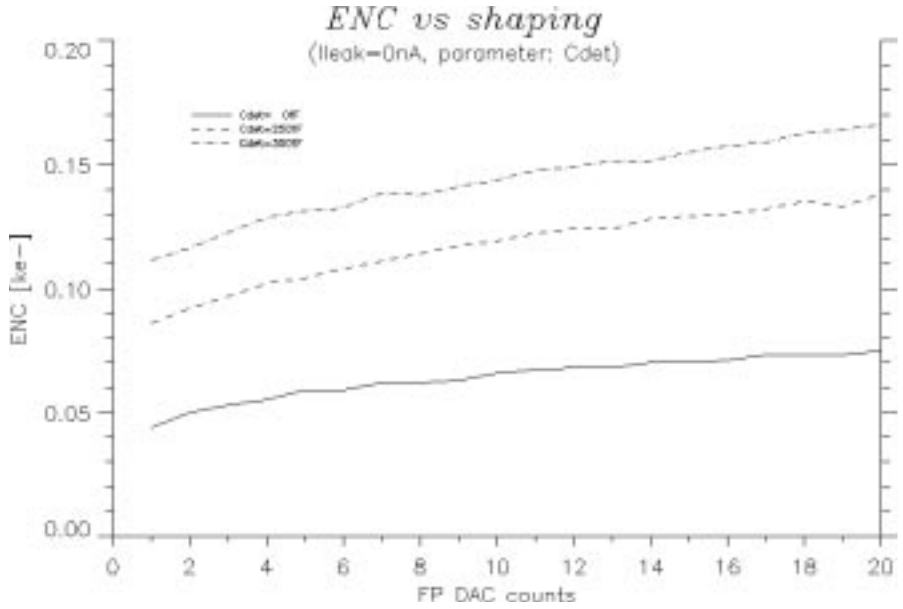
Expected Noise Performance of FE-B

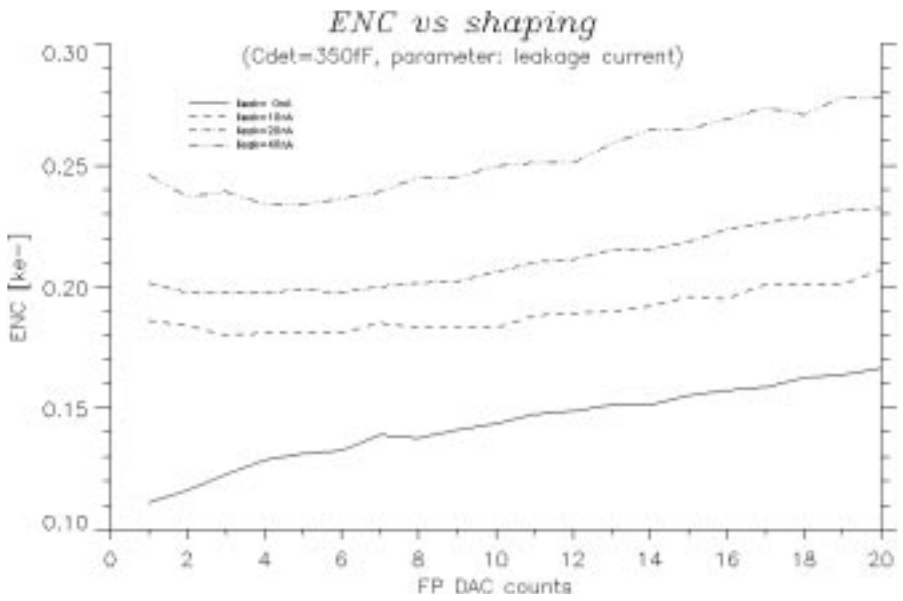
Noise performance measured using analog test chip:

- Test chip has cells with different C(Load) to ground to examine performance of preamplifier as a function of total capacitance to ground.
- This is not an accurate detector model, but is for performance comparisons between simulation and actual chips
- Test chip also has capability to inject externally-controlled leakage current with realistic “noise spectrum” into preamplifier

Summary:

- With a purely capacitive load, noise has a weak dependence on the preamplifier "shaping time" (return-to-baseline time adjusted using feedback current).
- With a return-to-baseline time of 500ns or 1500ns for 20Ke input, noise for 350 fF load varies from 170e to 140e
- With a 20 nA/pixel leakage current, noise is significantly increased, and the dependence on shaping time is reduced.



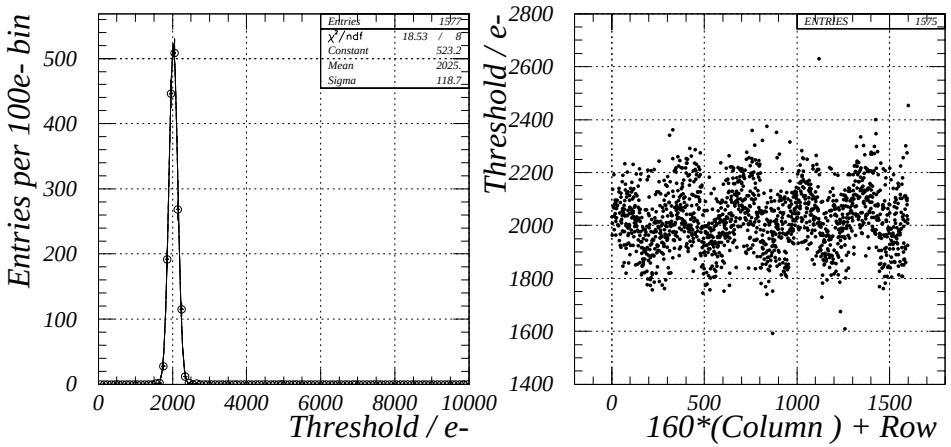


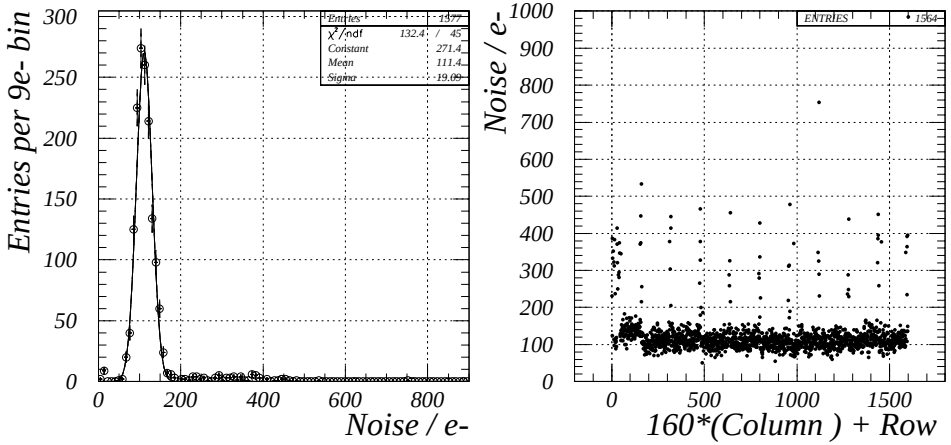
- With leakage current, for a given feedback current, noise increases both because of parallel noise from leakage, and from additional series noise from reduced shaping time. Example: I(leak) = 0 FP=20 is similar to I(leak)=20 FP=5.

Measurement Results

- Evaluate noise using external charge injection and scanning across individual pixel thresholds. Noise derived from error function fit to threshold curve.
- An example is shown here:

CIS ST2_02 64/5/20/96/85/80/64/134 tuned 150V 7.6uA





Threshold = 2.02 Ke

Dispersion = 119e

Noise = 111e

Noise for a given detector type (ST2) are consistent:

- ST2(A) with FP = 5, T = 2.02Ke, D = 119e, N = 111e
- ST2(A) with FP = 5, T = 3.08Ke, D = 111e, N = 120e
- ST2(B) with FP = 5, T = 1.97Ke, D = 133e, N = 106e
- ST2(C) with FP = 5, T = 2.06Ke, D = 135e, N = 107e

Noise depends on shaping time:

- ST2(A) with FP = 5, T = 3.08Ke, D = 111e, N = 120e
- ST2(A) with FP=20, T = 2.94Ke, D = 190e, N = 177e

Noise depends on leakage current (also C(det) changes):

- ST2($5x10^{14}$) with FP=1, T = 2.45Ke, D = 183e, V = 600V, I = 31μA, N = 216e
- ST2($5x10^{14}$) with FP=1, T = 2.40Ke, D = 177e, V = 300V, I = 24μA, N = 208e
- ST2($5x10^{14}$) with FP=1, T = 2.31Ke, D = 175e, V = 150V, I = 18μA, N = 193e
- ST2($5x10^{14}$) with FP=1, T = 2.22Ke, D = 168e, V = 75V, I = 12μA, N = 174e

Higher fluence:

- ST2($10x10^{14}$) with FP=1, T = 2.53Ke, D = 232e, V = 600V, I = 63μA, N = 262e
- ST2($10x10^{14}$) with FP=1, T = 2.45Ke, D = 222e, V = 500V, I = 55μA, N = 239e
- ST2($10x10^{14}$) with FP=1, T = 2.32Ke, D = 207e, V = 300V, I = 39μA, N = 211e
- ST2($10x10^{14}$) with FP=1, T = 2.21Ke, D = 203e, V = 150V, I = 26μA, N = 181e
- ST2($10x10^{14}$) with FP=1, T = 2.12Ke, D = 197e, V = 75V, I = 17μA, N = 167e

Variation of temperature:

- ST2($10x10^{14}$) with FP=1, T = 3.39Ke, D = 218e, V = 600V, I = 65μA, N = 256e
- ST2($10x10^{14}$) with FP=1, T = 3.94Ke, D = 290e, V = 600V, I = 153μA, N = 340e

Noise depends on detector type:

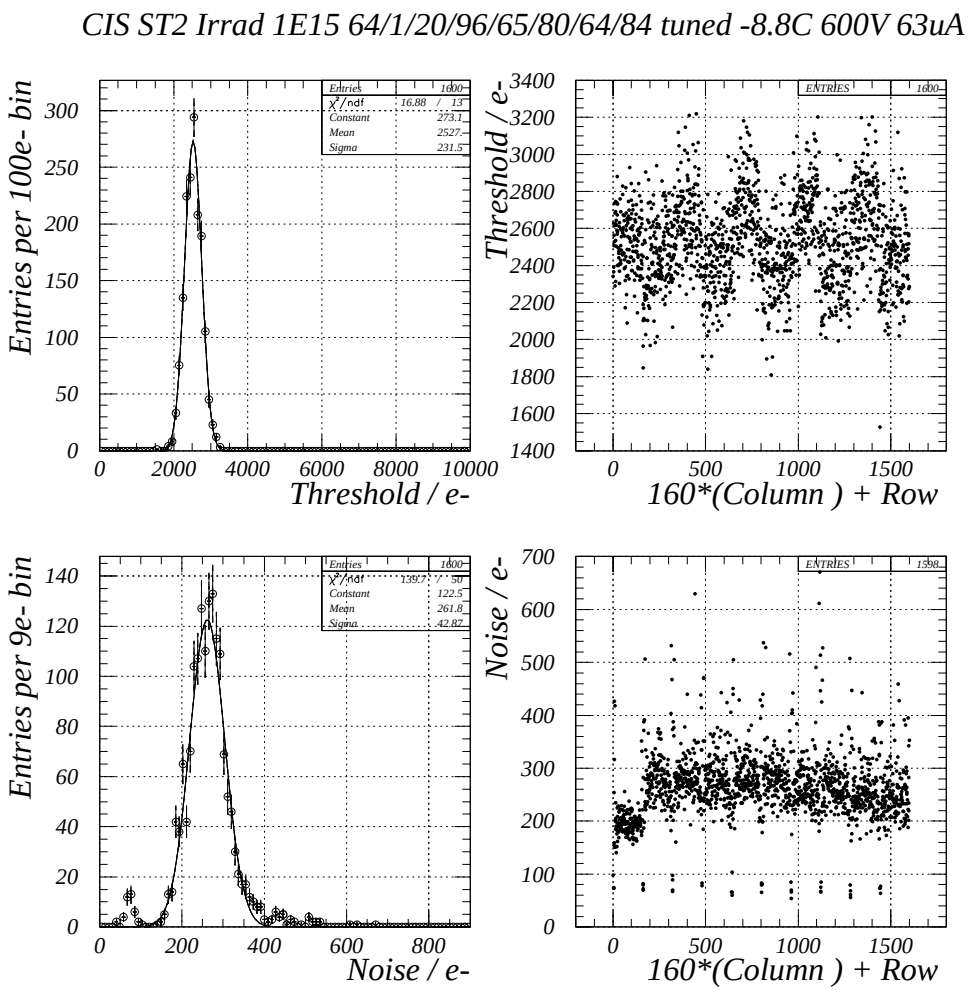
- ST1 with FP = 5, T = 2.20Ke, D = 138e, N = 121e
- ST1 with FP = 5, T = 3.15Ke, D = 110e, N = 122e
- ST2 with FP = 5, T = 2.02Ke, D = 119e, N = 111e
- ST2 with FP = 5, T = 3.08Ke, D = 111e, N = 120e
- SSG with FP = 5, T = 2.34Ke, D = 156e, N = 220e
- SSG with FP = 5, T = 3.38Ke, D = 120e, N = 205e
- SXT with FP = 5, T = 2.10Ke, D = 177e, N = 352e
- S7O with FP = 5, T = 2.05Ke, D = 128e, N = 179e

Within S7O, there are 7 detector types:

- S7O(0-17) with FP = 5, T = 2.06Ke, D = 127e, N = 156e “large gap”
- S7O(20-37) with FP = 5, T = 2.04Ke, D = 125e, N = 182e “small gap” (**OK**)
- S7O(40-57) with FP = 5, T = 2.06Ke, D = 122e, N = 160e “low crosstalk” (**Low ??**)
- S7O(60-77) with FP = 5, T = 2.05Ke, D = 106e, N = 108e “tile 2” (**OK**)
- S7O(80-119) with FP = 5, T = 2.05Ke, D = 124e, N = 198e “analog”
- S7O(122-139) with FP = 5, T = 2.05Ke, D = 133e, N = 230e “bricked small gap”

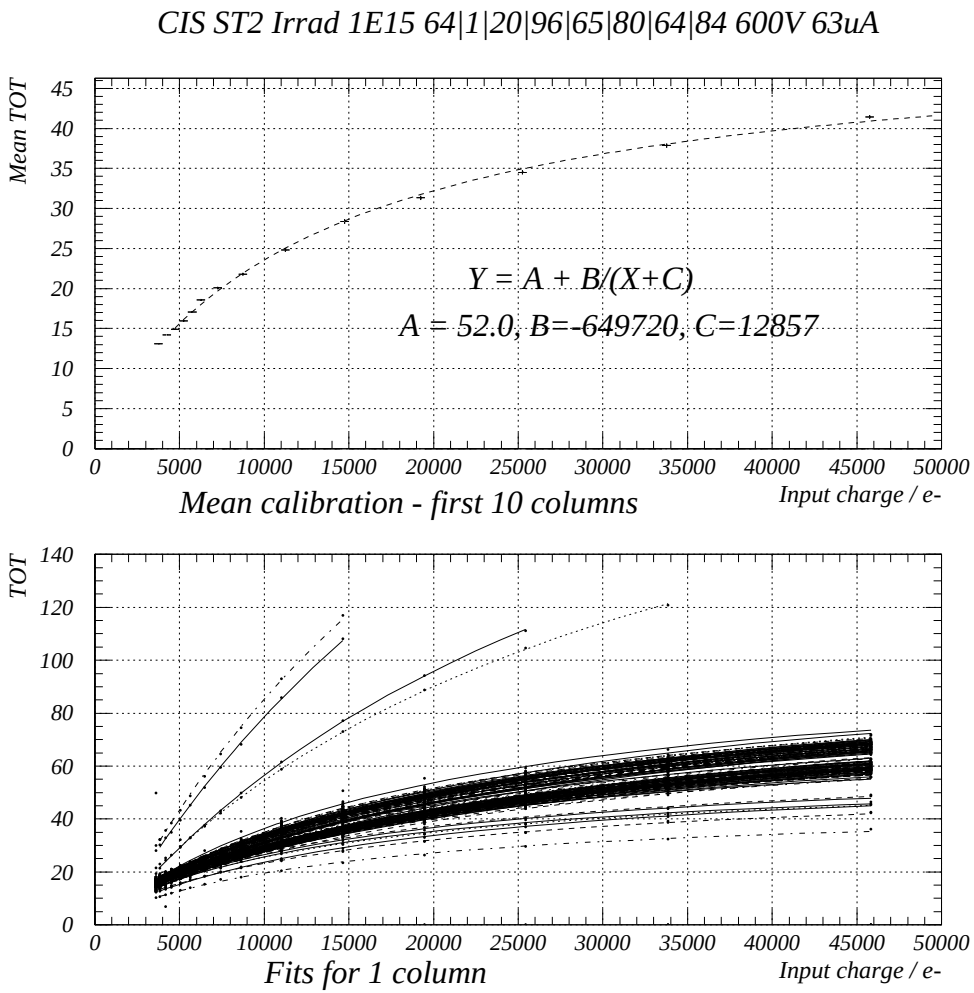
- S7O(142-159) with FP = 5, T = 2.05Ke, D = 129e, N = 167e “bricked tile 2”

- Have characterized detectors irradiated to 10^{15} dose (leakage of 25 nA/pixel).



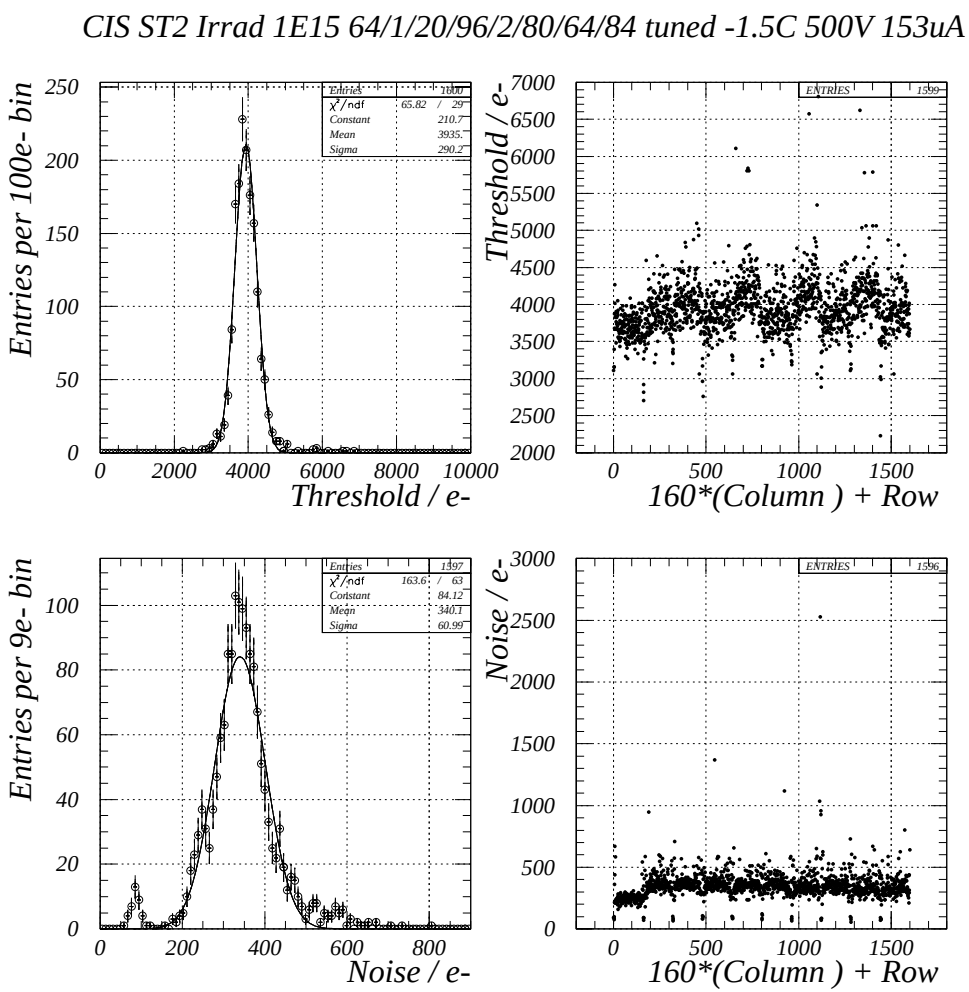
- ST2 Irradiated and biassed to -600V and operated at about -10 C
- Threshold 2500e
- Dispersion = 230e
- Noise = 260e (roughly as expected given shaping time and large leakage current).
- ATLAS spec: noise and dispersion in quadrature less than 400e (350e seen here).
- Minimal feedback current used to give best charge resolution

- TOT calibration for this detector



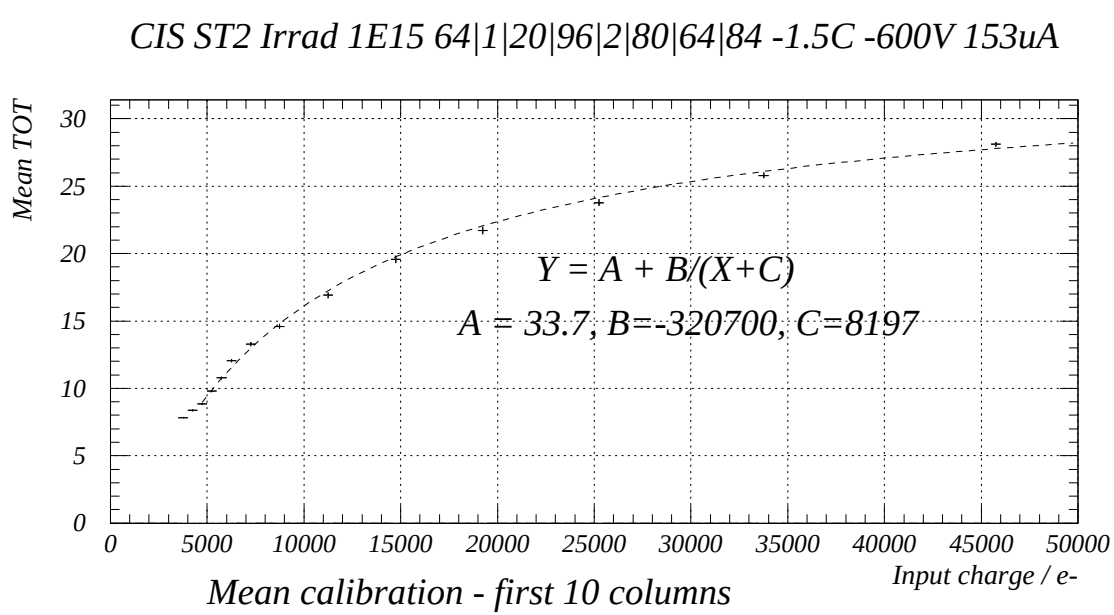
- Expected depletion voltage about 1200V. Operation at 600V should give 70% depletion.
- Dortmund charge prediction is about 7.5 Ke (I would have expected about 10 Ke ?)

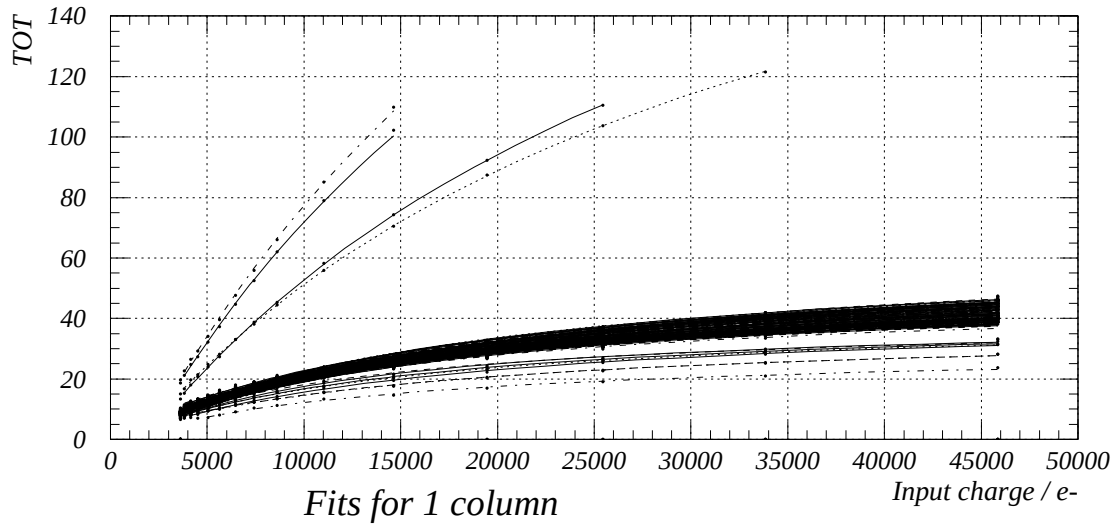
- Same detector operated at higher temperature to double leakage current (about 50 nA/pixel):



- Total leakage about 150 μA at -600V
- Threshold = 3900e, increases for same DAC settings due to larger leakage current (stronger shaping).
- Dispersion = 290e
- Noise = 340e
- Quadrature sum is about 450e, so could probably have operated this detector at 3000e threshold.

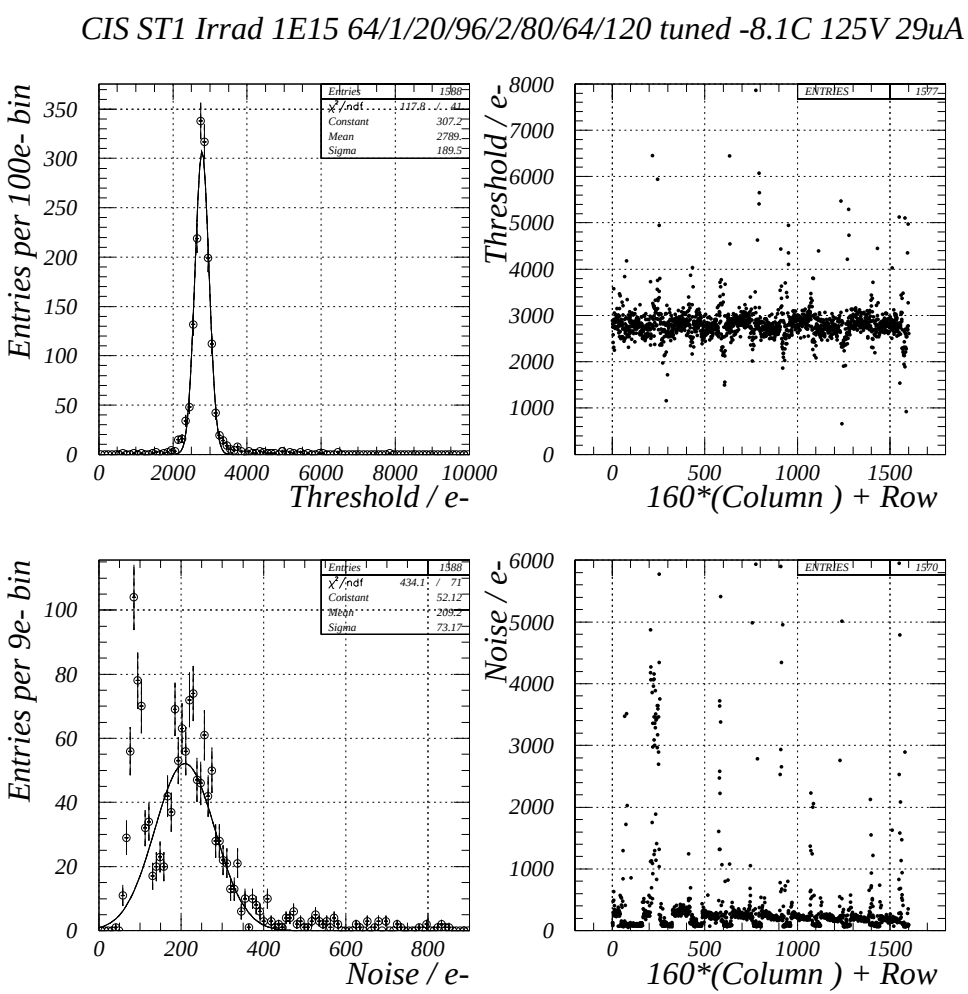
- TOT calibration with larger leakage current:





- Even with minimum feedback, there is not very much TOT information left at this leakage.

- ST1 detector irradiated to 10^{15} fluence:



- Irradiated ST1 biassed to 125V (expected depletion voltage is about 1200V).
- Threshold = 2800e
- Noise = 210e, but many channels already have very large noise
- Extremely noisy operation in H8 environment, essentially not useful.
- In order to find quiet operation (no large regions of hot pixels), bias was even reduced to 10V. Some signals correlated with strips still observed.

Comments on relative performance:

- ST1 and ST2 seem to have similar capacitance (noise).
- Comparison to test chip measurements indicates that if noise sources are the same, then ST1/ST2 both present a total capacitive load of about 250 - 350 fF. However, perhaps there are additional noise sources...
- Medium gap p-spray has higher noise, but not too bad.
- Bricking as implemented in S7O has small noise penalty
- Analog design has relatively high noise
- Low crosstalk design has different behavior in S7O and SXT ???

Comments on irradiated ST2 detectors:

- Behavior of ST2 detector after irradiation seemed to be just as expected.
- No noisy pixels were observed in two different detectors. No indications of large leakage dispersion (which would cause threshold dispersion) were seen.
- Operation at 600V was straightforward and no difficulties were observed

Comments on irradiated ST1 detectors:

- Behavior of ST1 after irradiation was very poor.
- Excess current was observed (above ST2 at same V and fluence) for both detectors. Operation at high voltage was not possible, particularly in testbeam.
- Large numbers of noisy pixels were observed in testbeam for essentially any bias voltage.
- These two detectors were a limited sample from one vendor, but they seem to indicate that there are major problems in operating p-stop isolated detectors after high fluence irradiations...