



Subject: CCD Working Group #8 meeting minutes		Location: Centre for Electronic Imaging, Open University, UK
Present:		Date: 10 July 2013
Mark Cropper	MSSL-UCL	Reference:
Magdalena Szafraniec	MSSL-UCL	EUCL-MSSL-MOM-6-008 iss 1.0
Alex Short	ESA	No. of pages:
Ralf Kohley	ESA	Notes taken by: Magdalena/Mark
Andy Grey	e2v	Date of next meeting: 10 December 2013
Neil Murray	Open University	
David Hall	Open University	
Andrew Holland	Open University	
Edgar Allanwood	Open University	
Konstantin Stefanov	Open University	
Andy Clarke	Open University	
Matt Soman	Open University	
Holger Israel	Durham University	
Michel Berthe	CEA	
Apologies		
Richard Massey	Durham University	
Thibaut Prod'homme	ESA	
James Endicott	e2v	
Sami Niemi	MSSL-UCL	
Jason Gow	Open University	
Vincent Moreau	CEA	

<p>Agenda</p> <ol style="list-style-type: none"> 1. 10:00 Introduction (MC) 2. 10:10 Report on CCD273 flight development with e2v up to MRR (AS, AG) 3. 10:45 Slow trap behaviour (NM, DH, KS) 4. 11:30 Fast trap CTI (NM, DH, KS) 5. 11:45 Updates on charge redistribution (NM, DH, KS) 12:30 lunch 6. 14:00 Review of pre-development device issues (NM, DH, KS) 7. 14:30 Reconciliation of TP'h/MSSL evaluation of CTI effects on galaxy shapes MC) 8. 15:15 Saclay testing (MB) 9. 15:35 MSSL testing (MS) 10. 15:45 MSSL ROE+RPSU status (MC) 11. 16:00 review of recent actions 12. 16:30 AOB 17:00 end of meeting 	
	Actions
<p>The Agenda was adopted as circulated.</p> <p>1. Introduction and aims (MarkC)</p> <p>Mark Cropper identified the main aims of the meeting as:</p> <ol style="list-style-type: none"> 1.1. updating ourselves on the CCD273 flight development 1.2. continuing examination of charge leakage on flat field 1.3. understanding slow traps better <p>MC mentioned about the progress made with the flight development of CCD273 and said that the e2v Manufacturing Readiness Review was passed on the 24th of June.</p> <p>MC thanked Neil and OU for providing CCD training to MS and summarized the recent activities of MS and Dave Walton at MSSL and commented on the status of the development of the EVM III electronics at MSSL.</p> <p>2. Flight production overview (Alex S.)</p> <p>Alex described the status of the CCD contract between e2v and ESA based on the results of the e2v Manufacturing Readiness Review. The fabrication of 6 batches has already started. Each batch comprises of</p>	

24 wafers, each with 2 devices. Lead time for completion of each batch is 16 weeks maximum. The starting material is 1500 Ωcm /50 μm epitaxial silicon thinned to 40 μm . e2v will process the devices in a similar way as in the pre-development phase with 2 exceptions: 1) the LAM plasma dry etcher will be used to address the amplifier imbalance, and 2) tighter tolerances will be used on tuning fork measurements to avoid processing wafers with significant variations in the poly widths. A new machine will be used to measure the line widths for the poly-etches.

The first (of 2) Euclid cameras at e2v is ready for upgrade. The upgrade requires a new sequencer PC, new acquisition PC, new PI units for biases/clocks; new power supplies, new digitiser, improved headboard design, construction of new cryostats, and a general evolution of test software. The commissioning of the new camera is scheduled for October 2013 for TRR late Jan 2014. AS worries this is a bit late. Clock rise and fall times will be shorter (hence less overlap). AS noted that it was a major change for e2v. MC said that we should stick with the known testing parameters. AG said that the e2v still has the old cards and enough in stock. AG said that they'd like to do a comparison between the old and new cards. AS noted that if there would be a change in the ICD this would need to be agreed. *AS and MC to discuss this.*

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AS specified the contract changes to include the following: 1) cutting corners of the flexi for alignment purposes, 2) increasing the length of studs and changes to their design for the STM-III (the preload applied to the studs is still TBD); 3) schedule contract change request is written; 4) flatness and torque loadings for the package; 5) fatigue test of flexes (e2v to see if feasible).

AS discussed the changes made in the schedule to start the FM wafer batches immediately after EM (i.e. in January 2014) and store them. The risk is that if there is a change to the devices at CCD level, then new devices will need to be manufactured again in phase II. The potential cost risk is accepted by ESA. AS showed the history of the changes. MC said that it was very helpful to bring the schedule back. The EM prototypes for consortium laboratory work will be ready in August next year.

AS reported that there'd been a lot of discussion on the flatness of the package feet and the torque that can be applied (item (4) above). AS argued that the requirements will be met as long as the shims are not 10 μm different in height (e2v to confirm). AG said that e2v can get shims good to 10 μm . *MC requested that CEA reviews Alex's viewgraph and confirm if it is correct.* MB said it was a crucial element

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and suggested involving one of the mechanical experts from ESTEC (perhaps J-C Salvignol) and Astrium.

AS showed the results from the δ -evaluation contract on the mechanical tests. Two tests have been performed: flexi peel test and flexi shear test. AS said that the results were satisfactory. MC asked about a twist testing of the flexes in order to specify how much the flex can be moved sideways with respect to the centreline. *It was agreed that this should be raised at the next e2v Progress Meeting (or δ -evaluation report on 18 July).* AS continued with the delta evaluation results. Two devices have been cycled to 153K and tested at warm. Both of them survived the temperature of 143K. MC asked if the additional bonding investigated by ESTEC would be used. *It was agreed that this would also be discussed at the next progress meeting (or δ -evaluation report on 18 July).*

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ECWG0713_04

3. ESTEC testing of CCD273 (Alex S.)

AS presented the results of the testing on the CCD273-84-2-F15 (SN: 11263-07-01) at 153K.

Peter Verhoeve had examined the channel potential. PV found the same problem as before (i.e. that the measured reset drain values are higher for E and H quadrants of the CCD than for F and G). This is a known issue and is ascribed to the use of the old etcher. The measured values do not change after irradiation. The dark current does increase after irradiation. The results of the QE measurements shown higher QE values than specified. PV was not sure of the systematic error in the QE measurements, though. PV has included the results of the flat field measurements, showing fringing for 2.5nm beam width. Trap pumping is currently being under investigation. A lot of data have been taken (pre and post-irradiation), but now need to be analysed. Optical masks have been procured. This will be presented at the next meeting – PV should be on distribution list. NM said that ESA have the only back-illuminated irradiated device.

4. Trap species update from David Burt (presented by Andrew H.)

AH presented the results of David Burt's work on the traps species base on CCD204 and other devices. A storage volume for 12 μ m pixel was simulated. This work will continue as a Case studentship (Dan Wood).

AH will check whether the slides can be circulated. Leaves out most of Neil's work he says. AS said that the numbers derived depend a lot

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on the β parameter, and the answers depend on the assumptions. DH said that the emission time can be derived independently from the density/ β issues. DH said also that the A-centre is actually 2 peaks once the data becomes good enough.

5. The impact of slow traps (David H.)

At MC's request, DH provided a clarification of the previous work he'd reported, regarding the slow traps. DH showed a plot of the energy loss as a function of row and explained that there is a constant loss of energy per transfer after the initial steep drop. The first part of the plot reflects the impact of the slow traps while the second part to the fast traps. Fast traps are those which have an emission time similar to the pixel-to-pixel transfer time, while slow traps which have an emission time much longer than pixel-to-pixel transfer time multiplied by the number of pixels between the X-ray events used for the testing. For each measurement, the pixels were flushed and a delay time of 500 seconds between the readouts was used to allow slow traps to empty, leaving barrier phase slow traps empty before transfer to read out the signal. The image clock pulse edge overlap (t_{oi}) was 500 μ s.

DH said that it was important to understand that half the Si is not holding electrons during the integrating, as these are swept to the phases held low during the time. This means that the slow traps in the phases high can empty during the integration and are available to trap during the readout. Therefore the charge loss increases more than would be expected only from the fast traps. DH did see a variation with X-ray density and integration times (with which it scales quite nicely). DH made a rough estimation that there will be 1 slow trap in 3-4 pixels at the EOL and 1 fast trap in about 50 pixels). DH showed the same information about the charge loss due to slow and fast traps plotted differently (i.e. charge lost vs. row number) and removed the fast trap component to make it clear that the charge loss due to slow traps increase more than the charge loss due to fast traps.

RK said that it would be possible to deal with this using clocked-anti-blooming (cf last WG presentation by NM). NM also suggested that cosmic rays will help ameliorate the effect.

6. Slow trap behaviour (Neil M.)

NM presented results of the slow traps investigation at one quarter the end of life dose in one quadrant of the Front Illuminated CCD273. These were also scaled to estimate the end of life dose. During the experiment, a clock-induced block of a very uniform charge was induced (more even than can be obtained using charge injection). The

EPER and FPR values are available at the same time (both on forward and backward-clocked) block. A signal loss of ~280 electrons was observed in FPR for a total signal of 22000 and for frame integration time of ~500 s – approx. 1%. NM showed the effect of the loss per signal in two graphs (this is for 1.2×10^{10} Mev equivalent fluence, or $\frac{1}{4}$ of that For Euclid at EOL), one as a function of CCD temperature and the other as a function of signal level, including a background of 100 e⁻ in one case. He found that 1 slow trap occurred in every 4 pixels – in agreement with DH's X-ray analysis.

NM investigated the impact of the slow traps on the charge *collection* efficiency. Do the slow traps in the Si (not the transport (buried) channel) which is accumulating the signal, simply trap the photoelectron before it gets to the buried channel? This would give rise to persistence. The experiment was performed on the front-illuminated CCD by filling the device with blue, green and infrared light (the wavelength of the infrared (IR) light was about 950nm) clocking at a standard readout rate (4 phase, tri-level clocking), exposing in the dark for 565 s and reading out. At least 50 frames were taken. NM showed the histograms of the persistent signals. He noted that there was some persistence in the pre scan region, and the same was seen in the "control". In the end, NM concluded that there are ~~no~~ such traps, but perhaps mainly in the buried channel only. These sites would be not normally reached by the charge moving through the device.

7. Fast traps (Neil M.)

NM showed the CTE as a function of signal level in a CCD273 which seems to have annealed. 99.9994% measured by e2v (EUCV-E2V-RP-017 page 31) and 99.9997 by OU. In his forward-backward clocking he found that the CTE appears to be directional, probably because of the 2-4-2-4 electrode pattern. But this can be over-ruled by the tri-level clocking scheme.

8. Review of the Pre-development device issues (Neil M.)

NM provided a summary review of the Pre-Development devices as follows:

- Register Well Capacity

The register full well is limited by potential well formed under R3 owing to the poly-1 over-etch. This is because the R3 is physically smaller than R1 and R2. Register full well can also be limited by the barrier formed by R3 if 100% overlaps are used. This should be fixed with the tighter tolerances on tuning forks.

- Register back-spill

The potential level of the transfer gate could vary across the device, so charge could fall back into the array. The new etching process should solve this problem.

- Output imbalance

NM summarized the results of the responsivity ($\mu\text{V}/\text{e}^-$) and noise (e.r.m.s.) measurements and noted that there was a variation between the devices owing to plasma etch charging of electrode structures. Different biases should be applied to the separate pairs for optimal performance.

- Buried channel levels

NM noted that there was a missing implant in the output source follower in batch 10401 only. The buried channel parameter was found to be higher than expected, i.e. 10V rather than 7V. The value of 10V was kept for all subsequent devices and the ICD was updated to reflect the changes in the operating potentials.

- Studs shearing

Original invar studs can be sheared after having it in a vacuum for some months. He noted that the stud material is now changed to titanium. Care should be taken when un-mounting the CCD from the chamber plate after the measurements.

- Edge effects

There is a roll-off in sensitivity towards the middle of the device (*i.e.* at the junction of the two halves). Also, a brighter row is expected at the bottom (closest to the readout register) because of different electrodes. While this effect does not affect the response of a star up to the edge of the device, the flat fields may be disturbed. AG said that e2v is reducing the drain level, so that the roll-off should be less of a problem in the next devices.

- Horizontal blooming

An unexpected horizontal blooming was observed and was ascribed to the fact the column isolation was not sufficient. To avoid this problem, the image clocks were to be operated at 8V instead of 10V. However, NM proposed to use clock dithering and run the image clocks at 10V, as the blooming then flips back to the nominal vertical, with the advantage of additional full-well capacity. However, MC was not sure whether we should consider this for Euclid.

- Notched injection asymmetry

The charge injection structure is not symmetrical in fabrication owing to the polysilicon overlaps and lack of mirror symmetry in the device. It is possible that fringing from adjacent gates alters the notch. As a result, the A-section receives a different level of notched charge injection than the D-section. There is nothing that could be done about it, even though the poly-1 fix would improve it. There is still a need to search for optimal parameters for timing of the injection pulse. Uniform injection will be available from the new devices.

- Charge redistribution

NM showed the results of the spot illumination of the FI-CCD273 at different signal levels. As the signal increase, the point source becomes more and more elliptical demonstrating a column-wise charge shearing. The aspect ratio in the PTC curve begins to become visibly altered at about 95 ke⁻, before reaching the full well.

NM summarized in a final slide all the pre-development CCD273 issues and gave a list of solutions. MC said it was very helpful.

9. Updates on Charge Redistribution (Konstantin S.)

KS showed results of a SILVACO simulation of the point spread function in a 10µm device (i.e. non-Euclid-like). KS said that the potential collapses as the charge increases. The charge sum from all neighbouring pixels is maintained. A formula which describes this can be found in Janesick's book. MC expressed surprise, given plots of the potential distribution shown by the OU group at previous CCD-WG meetings.

KS then showed that there is a charge sharing in the integration (as above) but also in the readout. The 2-2-2 and 2-3-2 schemes correspond to a read out is always under 2 or 2 to 3 than back to 2, respectively. MC wondered whether it could also be in the transition between the integration and the readout. NM said that charge shuffling could also be used which allows the image clocks to be higher, and then to get more full well, and consequently less charge sharing.

KS also presented his work on the expectation of the Poisson statistics and charge sharing. KS showed quadratic fits for different wavelengths. He suggested using the linear term to estimate the gain. Longer wavelengths make the variance more linear. KS noted that signal dependent charge sharing is likely to be lower than the ordinary charge sharing.

10. Spot measurements (Ed A.)

EA reported measurements of a 10 µm FWHM spot projected by THorLabs lens tube on to a FI CCD273. An LED with a wavelength of 639nm was used and an algorithm for autofocus was written. EA noted systematic errors due to: 1) vibration across the rows, 2) "drift" of the cold bench with time, 3) subtle misalignment of the device and 4) repeatability of the translation stage position and the light source intensity.

EA also showed measurements of the charge redistribution from a charge-injected line. He found charge sharing was clearly visible.

For the projected spot, EA observed that the charge was *increased* in the middle pixel, which would indicate an anti-charge sharing. The exercise was repeated for different image clock biases (8V, 9V and 10V). MC suggested a similar test in the row and column direction instead of placing the spot in the centre of the pixel.

There was some discussion on the possible cause of this. NM indicated that there may be errors in interpretation of these preliminary results, and they should be taken with caution.

11. MSSL ROE and RPSU status (Mark C.)

MC reported on the 2 EVM 3 boards commissioned at MSSL: EVM III A (to act as a reference board) and EVM III B for modification. Each board consists of 12 channels and was designed to operate 3 CCDs. The FPGA was coded from scratch. More communication capability was enabled via a SpaceWire link.

The next generation of board, the Demonstration Model (DM) has been laid out and populated as for flight. A single board carries insufficient space for all the components, so the design was slightly changed, and consists of a digital board and 2 similar video boards. MC showed the layouts of the ROE DM video and digital board, a schematic of the ROE interfaces and of the FPGA architecture.

A Flight Layout mechanical enclosure has been designed and optimised for thermal conductivity to extract the heat from the 12 tightly spaced ROEs. The mechanical design has been stable, with the exception of the placement of the connectors, which is now on the side rather than on the edge.

MC reported that a new MSSL CCD Readout Baseline document has been prepared by Massimiliano Canali and showed the MSSL parallel (tri-level) and serial clocking schemes. MC also summarized the specifications of all MSSL electronics boards.

12. Recoincilation of TP'h/MSSL evaluation of CTI effects on galaxy shapes (Mark C. on behalf of Sami N.)

MC recollected TP'h talks given at the CCD-WG6 and 7 regarding the effects of radiation damage on images in the Euclid context. The implications were that the uncorrected ellipticities founded by TP'h were larger (25%) than those found by the EC (<5%) and used in the weak lensing performance prediction. SN has investigated the differences and written a document: Charge Transfer Inefficiency Modelling: CDM03 Parameters (EUCL-MSS-RP-6-023). Both studies

used the SSTL data on the CCD204 analyzed by Gordon Hopkinson for inputs, scaled by appropriate factors identified by Ralf Kohley (CCD-WG#5). In particular, the results were for the 200 kHz readout rate and the very old SSTL readout scheme (prior to VIS baseline).

TP'h simulations used galaxies randomly sized, orientated and placed, in a noise-free environment; EC studies (Massey) used circular galaxies in a worst-case position. Both studies used the standard Euclid recipe for calculating ellipticity and size. Both studies used Alex Short's CDM03 code – TP'h used the Java instance from GaiaTools while SN used the Fortran instance for standard exposures (non-TDI) from Alex Short.

Possible reasons for the differences between simulations can be the following:

- different simulation code
- different parameters for the code
- different measurement techniques of the ellipticity (especially pre-centroiding techniques for the weight function)

NM said that the difference between models could be because of the slow traps. AS suggested that TP'h might have used more traps than in the MSSL study. The difference could also be in the initialisation prior to the readout. SN varied the β parameter to show that its impact on the simulation is significant. If β is small, then approximately the same number of traps is seen for small signals as for large ones. If β is close to 1, then the number of traps scales proportionally to the signal. TP'h had indicated that the values he'd found from *Gaia* data are all in the region $b < 0.3$. Further discussion is planned to find the correct β . SN reported that work done by the Open University Group (Hall et al) find that $\beta = 0.42$ to 0.45

13. Silvaco and CDM. Initial compatibility analysis (David H.)

DH listed the trap species used for simulations based on work with David Burt. The parallel and serial Silvaco models show steep probability contours for electron capture. The model was compared with the CDM03 assumptions and a good agreement for the behaviour of the volume parameter β was found. However, AS said that an instantaneous capture can't be assumed in CDM03, given results from real data in Gaia. AndyC noted that in the serial the CDM03 doesn't really agree as well with the Silvaco model.

AS said that measurements with low levels of flux and different low levels is the best way to get β . We currently don't have the data for Euclid, but for the Gaia results he referred to the Gaia campaign #2 data.

DH said that the problem could be that the CDM03 model assumes a pure power law with exponent β , whereas the Silvaco modelling by AC indicated that there should be a power law in β plus a constant (cf Andy's work previously reported). DH agreed with AS regarding the necessity of obtaining a range of CCD273 low light level data. MC agreed we need to obtain the appropriate CCD273 low level data and consider a constant parameter in addition to the power law.

14. CEA testing (Michel B. on behalf of the CEA team)

MB showed the Offner optical test bench developed at CEA-Saclay for the shape measurements. A chromium mask provides illumination via holes of different sizes and shapes. A Shack-Hartmann wave-front sensor was used to measure the wave front map. The PSF can be reconstructed from the measured Zernike polynomials and the RMS value of the Offner system is $\sim 10\text{nm}$, which means that the system is diffraction limited.

MB showed the linearity plots and the effect of the signal on the shape measurement. Linearity was good at all exposures and for all levels of signal. MB also reported an ongoing analysis of the change in the ellipticity for different signal levels (SNR=20, SNR=50).

The loan agreement for the development phase CCD273 between ESA and CEA is to be signed soon and CEA expects to get the CCD by the end of July.

CEA is building another bench for the intra-pixel response maps via a global imaging Talbot effect, which produces high frequency patterns on the detector. The goal is to obtain a response map at the intrapixel level on a grid of 10×10 or 12×12 per pixel. CEA has signed a contract with ONERA. MB noted that the one of the two deconvolution methods proposed, the direct model, requires a high computational load. The other one, the pixel model is lighter and more accurate, but requires an initial "pixel map" as start point. MB asked for a preliminary QE map at within each pixel to start their analysis technique. *NM said OU can provide this information.*

MC said that an explanation of the Talbot effect would be appreciated at the next meeting.

15. MSSL testing (Magdalena S.)

MS gave a brief overview of the status of setting up the MSSL Testing Bench. The cryogenic chamber has been fully commissioned. The

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CCD plate has been equipped with two resistors to provide a stable thermal environment and two thermistors to ensure an accurate temperature readout.

The EVM III board has been populated, programmed and tested. Preliminary tests of the CCD273 were performed by DW and MS at room temperature. MS showed photon transfer curves obtained for four quadrants of the CCD273. The dark noise and gain values agree with the expectations. The dark noise was found high because it was dominated by the room temperature dark current.

16.AOB

MB raised the issue of interference of the FGS between the CCDs. MC agreed that this was a significant concern which was being addressed at the level of ESA and Prime.

CCD Working Group Meeting #8

Open University
10 July 2013

- 10:00 Introduction (MC)
- 10:10 Report on CCD273 flight development with e2v up to MRR (AS, AG)
- 10:45 Trap species update (AH)
- 11:00 Slow trap behaviour (NM, DH, KS)
- 11:45 Fast trap CTI (NM, DH, KS)
- 12:00 Updates on charge redistribution (NM, DH, KS)

12:45 lunch

- 14:00 Review of pre-development device issues (NM)
- 14:30 Reconciliation of TP'h/MSSL evaluation of CTI effects on galaxy shapes (MC)
- 15:15 Saclay testing (MB)
- 15:35 MSSL testing (MS)
- 15:45 MSSL ROE+RPSU status (MC)
- 16:00 review of recent actions
- 16:30 AOB

17:00 end of meeting

1. To update ourselves on the CCD273 flight development
2. To continue our examination of charge leakage on flat fields
3. To understanding slow traps better

- Progress with flight development of CCD273, with passing of Manufacturing Readiness Review on 24 June
- Magdalena Szfraniec is the Euclid Detector Scientist from 1 June
 - thanks to Neil and OU team for the training this week
 - Magdalena has mainly concentrated in recommissioning of the the MSSL test equipment to:
 - prevent further failures in handling flexis and greater automation
 - Dave Walton providing support
- Testing of CCD273 with next generation electronics EVM-3 started at MSSL

CCD Contract Status

A.D. Short
(Partly based on e2v slides from last PM)

10th July 2013

- A successful QM/EM Manufacturing Readiness Review was held on 24th June 2013
- The plan to start wafer batches is as follows:
 - 2 batches started in week 26 (w/b 24th June)
 - 1 batch starts week 29 (w/b 15th July)
 - 2 batches start week 30 (w/b 22nd July)
 - 1 batch starts week 35 (w/b 26th August)
- Each batch comprises 24 wafers (6" diameter)
- Starting material is 1500 Ω cm/50 μ m epitaxial silicon
- There are 2 devices per wafer.
- Time for completion of a batch is 16 weeks (maximum)

e2v have held their internal Euclid batch start review. Wafer processing will be as for the pre-development devices with the following exceptions:

- LAM plasma dry etcher will be used to address the amplifier imbalance seen on the pre-development batches
- Tighter tolerances will be used on tuning fork measurements to avoid processing wafers with significant variations in the poly widths
- In the future, flight batches will benefit from line width measuring equipment allowing measurement of on chip poly widths!

The first Euclid camera is ready for an upgrade to increase efficiency, absorb design and setup improvements and replace worn parts. The list of proposed upgrades is quite extensive including:

- New Sequencer PC
- New Acquisition PC
- New PI units for biases/clocks
- New Power supplies
- New digitizer design
- Improved headboard design
- Construction/commissioning of new cryostats
- General evolution of test software, e.g. acquisition software

Start commissioning Oct 2013 for TRR late Jan 2014.

This sounds very challenging!

Contract Changes in The Pipeline



Flex corners

CCR issued and CCN received

Stud length and preload

Draft sent to VIS for inputs

Schedule

CCR written at ESA

Flatness & Torque

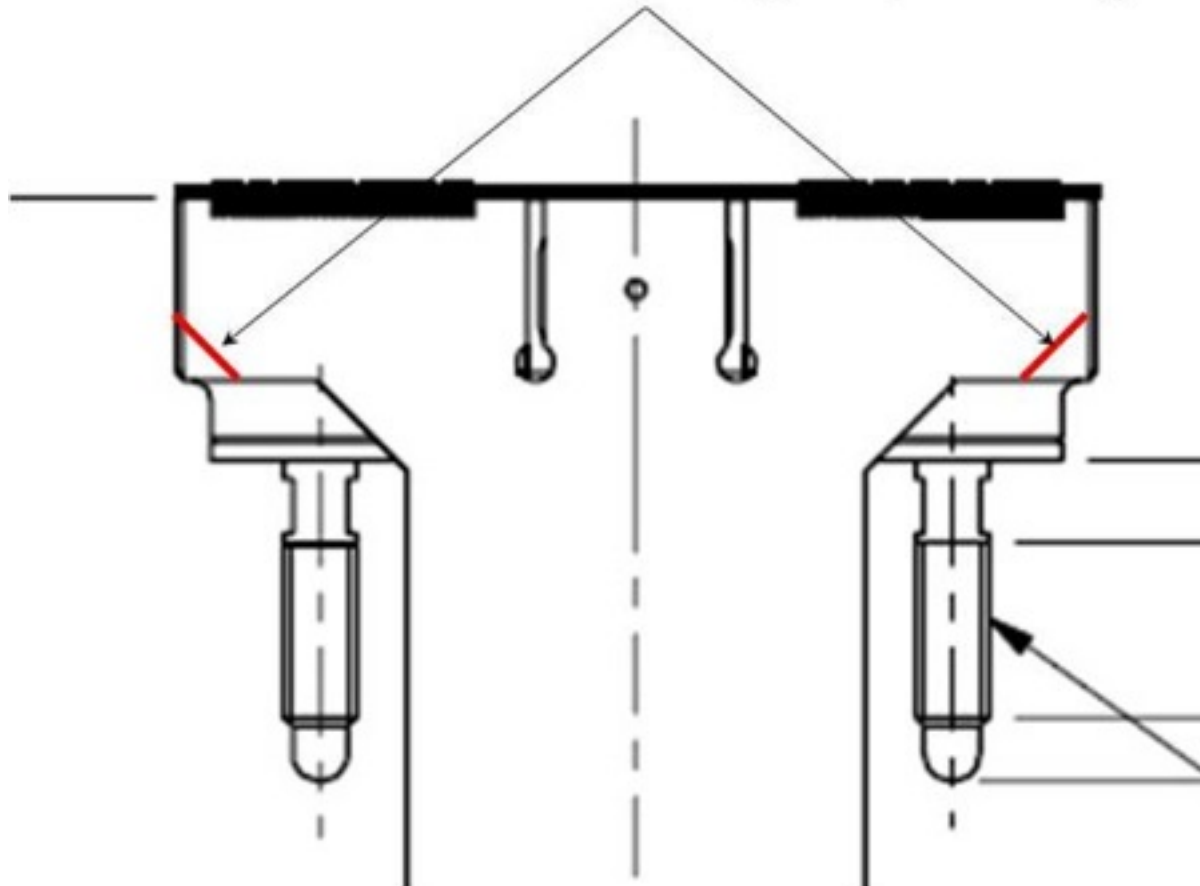
CCR written at ESA

Fatigue test of the flexes

To be written

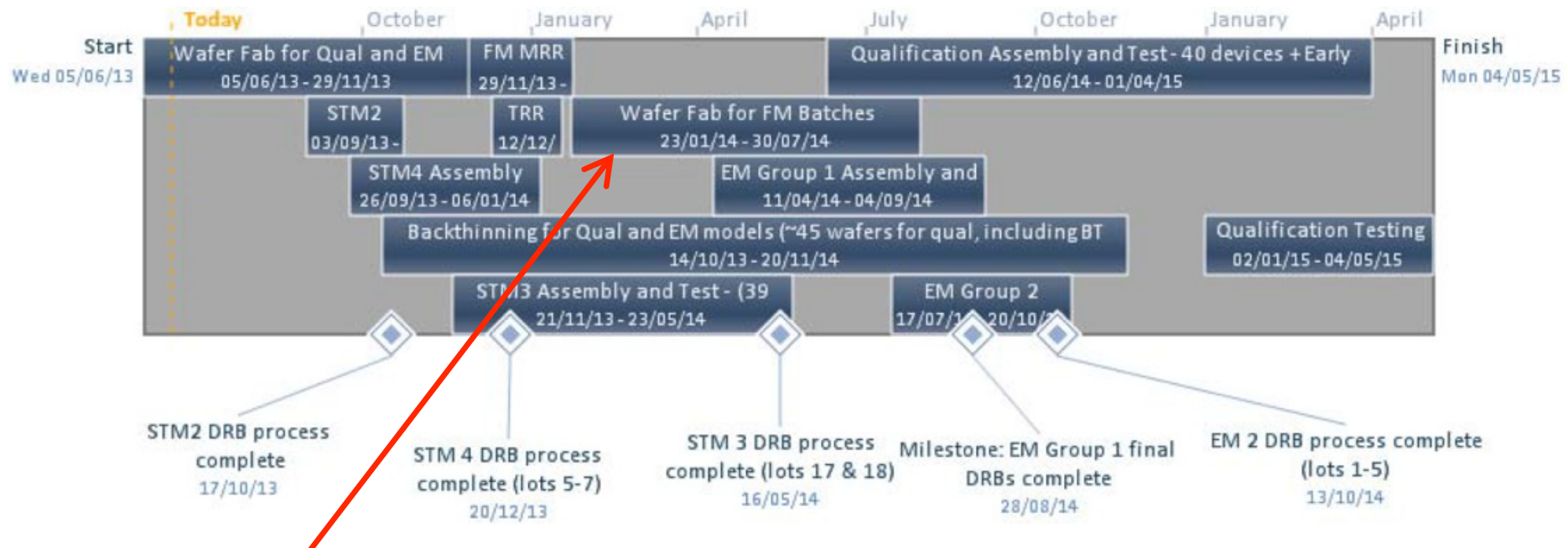
Flex Corners CCR

Possible access to SiC package for positioning?



This modification requested by the VIS team has been implemented immediately

Schedule for FM Deliverables CCR



- e2v to conduct wafer fabrication for FM CCDs during phase 1
- Saves considerable time and reduces programmatic and schedule risks
- Potential cost risk **if** design changes after qualification (but this should be avoided anyway). Risk accepted by ESA

Schedule for FM Deliverables



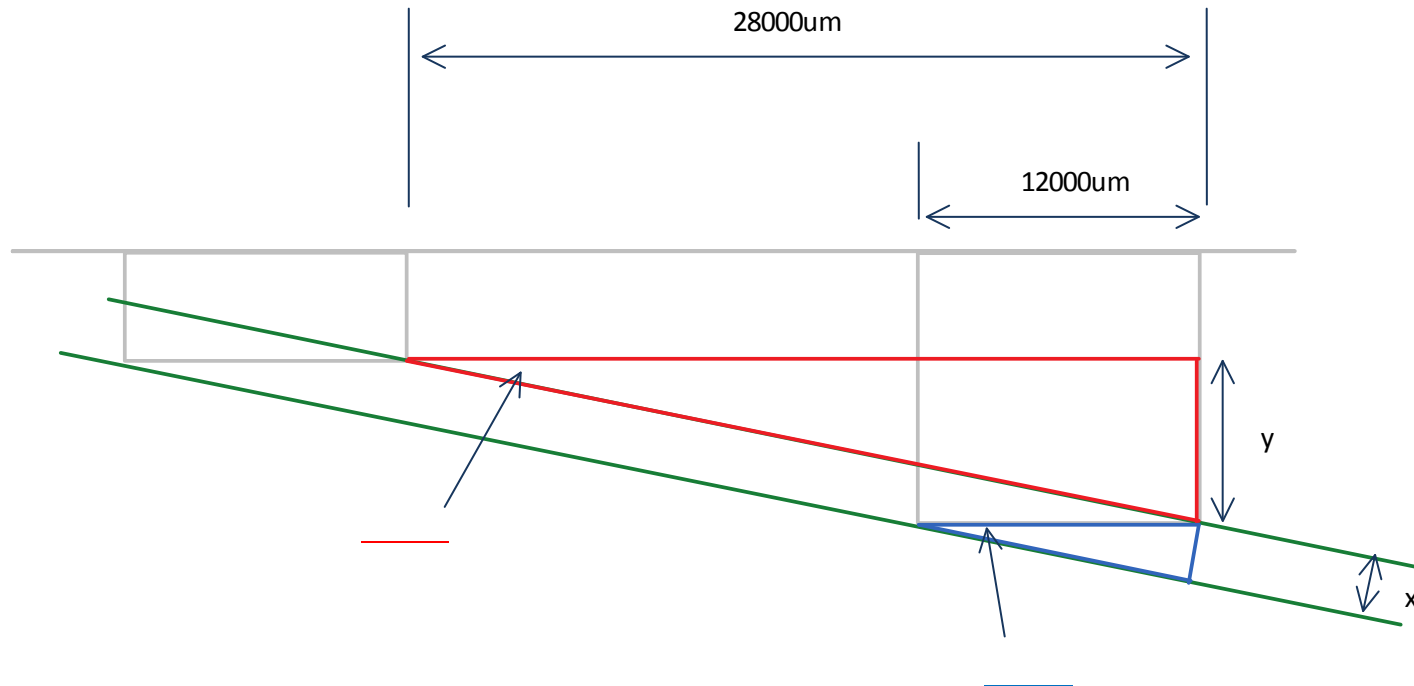
ESA Ref.	Deliverable	Intended Use	Quantity (incl. spares)	Schedule Milestone	Due Date	Expected Date
HW1	STM type 1	To be used in the VIS-TM1 prototype	7	STM type 1 DRB	May-13	Apr-13
HW2	STM type 2	To be used in the VIS-TM2 prototype	7	STM type 2 DRB	Oct-13	Oct-13
HW3	EM 1st Group	Prototypes for consortium laboratory work	11	1st Group EM DRB	Aug-14	Aug-14
HW4	STM type 4	To be used in the VIS-STMO FPA	13	STM type 4 DRB	Jan-14	Dec-13
HW5	EM 2nd Group	To populate the VIS-EM Focal Plane	8	2nd Group EM DRB	Oct-14	Oct-14
HW6	STM type 3	To populate the VIS-STM Focal Plane	39	STM type 3 DRB	Jun-14	May-14
HW7	EM 3rd Group	CCDs from flight production batches to be used in consortium radiation testing	4	3rd Group EM DRB	Sep-16	Dec-15
	FM3	To populate the VIS-FM Focal Plane	3	FM3 DRB	Mar-16	Dec-15
	FM36	To populate the VIS-FM Focal Plane	36	FM36 DRB	Jul-16	Jul-16

Schedule for FM Deliverables (History)



CCD Model	VIS schedule at IDCR	SoW (based on an e2v TN)	e2v baseline after proposal and negotiation	Current baseline assuming CCR
STM 2	11/06/2013	11/06/2013	01/10/2013	01/10/2013
EM 1	01/02/2014	03/12/2013	01/08/2014	01/08/2014
STM 4	03/09/2013	03/09/2013	01/01/2014	01/01/2014
EM 2	01/10/2014	29/04/2014	01/10/2014	01/10/2014
STM 3	03/11/2014	01/04/2014	01/06/2014	01/06/2014
EM 3	01/03/2016	05/05/2015	01/09/2016	01/09/2016
3rd FM	01/03/2016	31/03/2015	01/01/2017	01/03/2016
36th FM	01/08/2016	26/04/2016	01/06/2017	01/07/2016

Flatness and Torque CCR



x= flatness required across all 3 mounting surfaces (i.e. 5um)
y= difference in shim thickness

So if x must be less than 5um then y must be less than $\approx 11.5\mu\text{m}$

Allowing for some other contributions (e.g. from the shims themselves), this is probably why e2v have proposed selecting shims with a dispersion less than 10um (**e2v to please confirm this understanding**)

Flexi shear

Sample1 – 194N

Sample2 – 161N

Flexi Peel

Sample1 – 18N

Sample2 – 19N

Temperature cycling

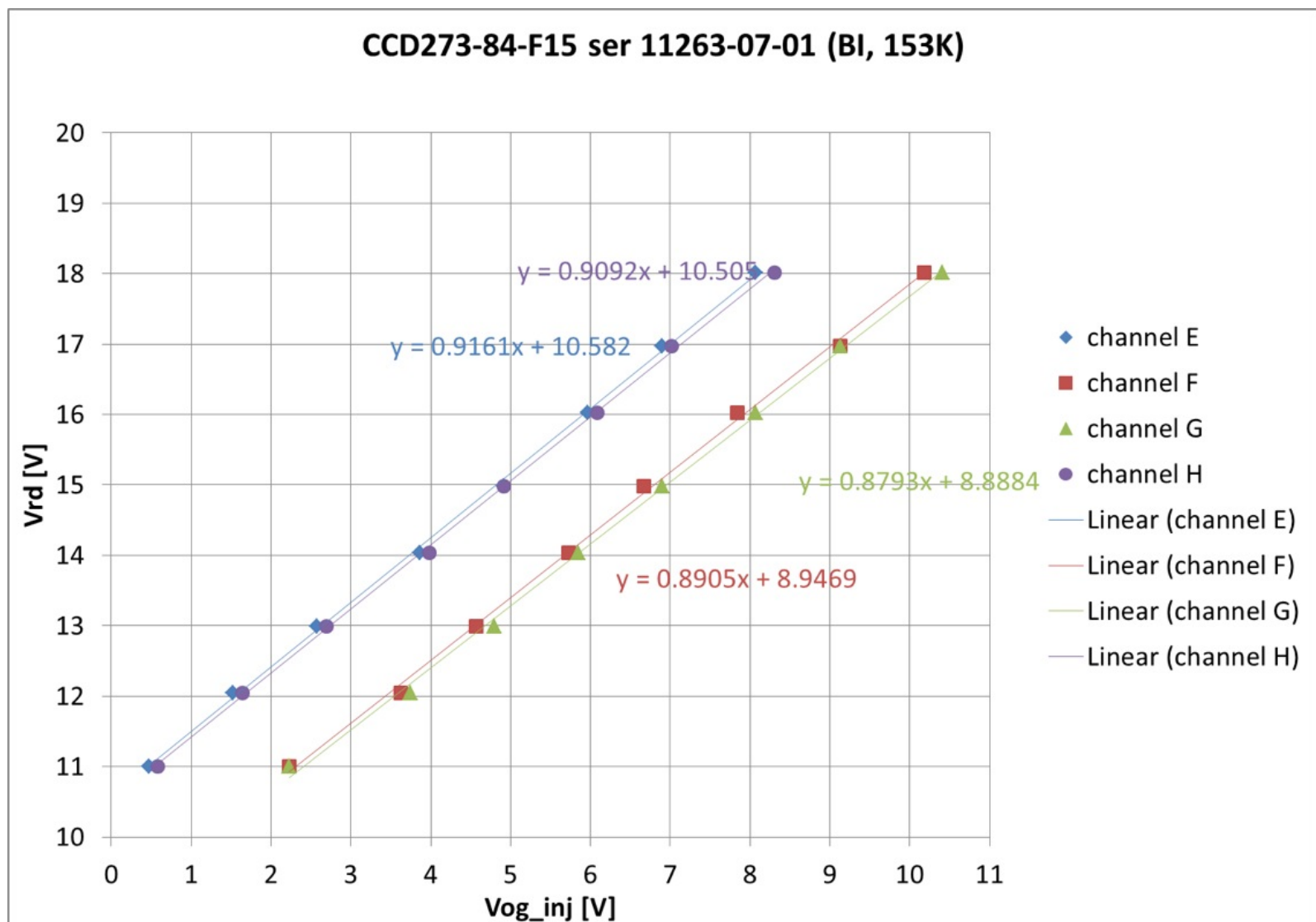
- Two devices have been cycled:
+15°C to -123°C, -133°C, -143°C, -148°C and -153°C
- Initial observation reveals no significant change
- Awaiting report from e2v following formal inspection

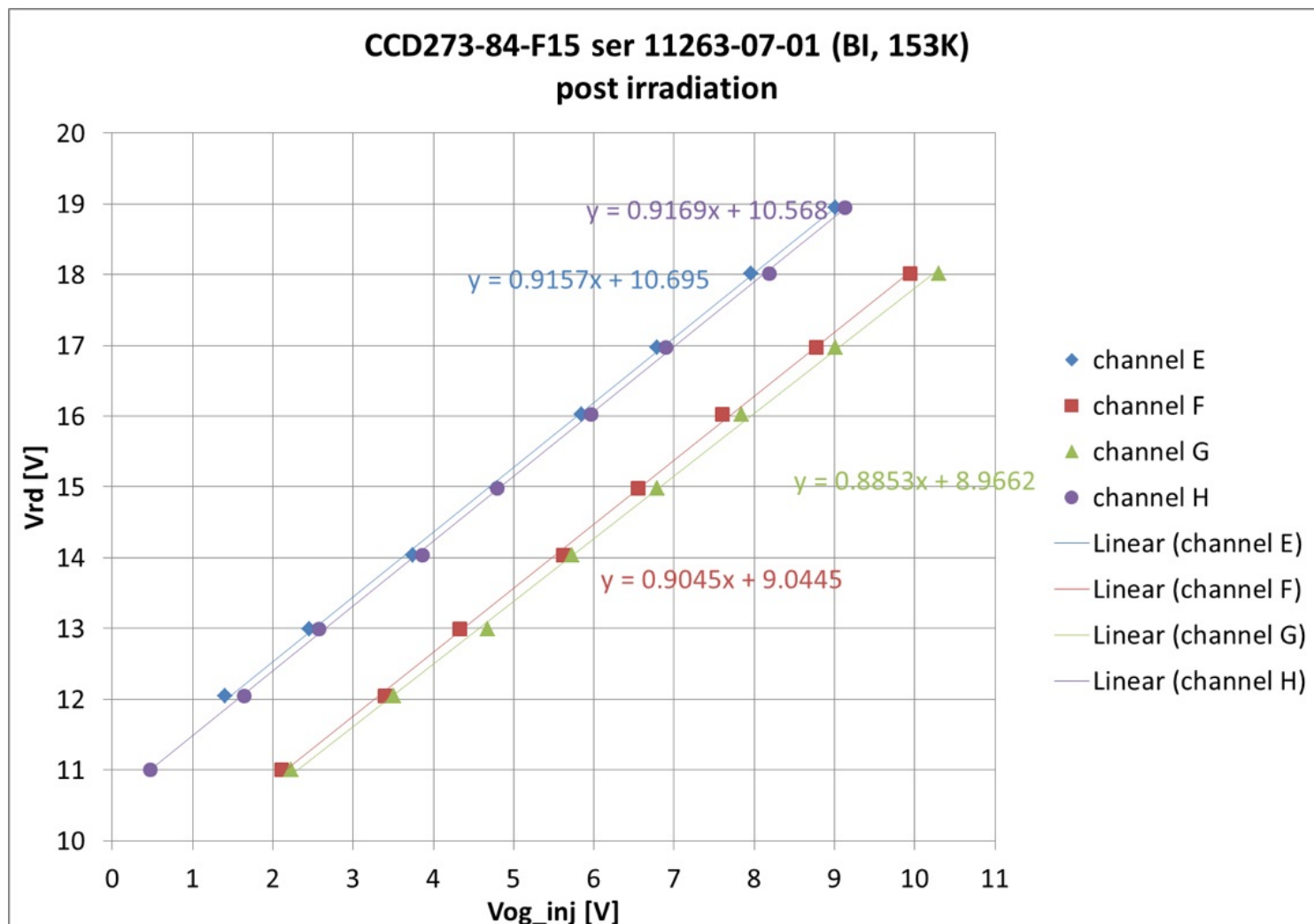
ESTEC Testing of CCD273-84-2-F15 ser11263-07-01

Peter Verhoeve

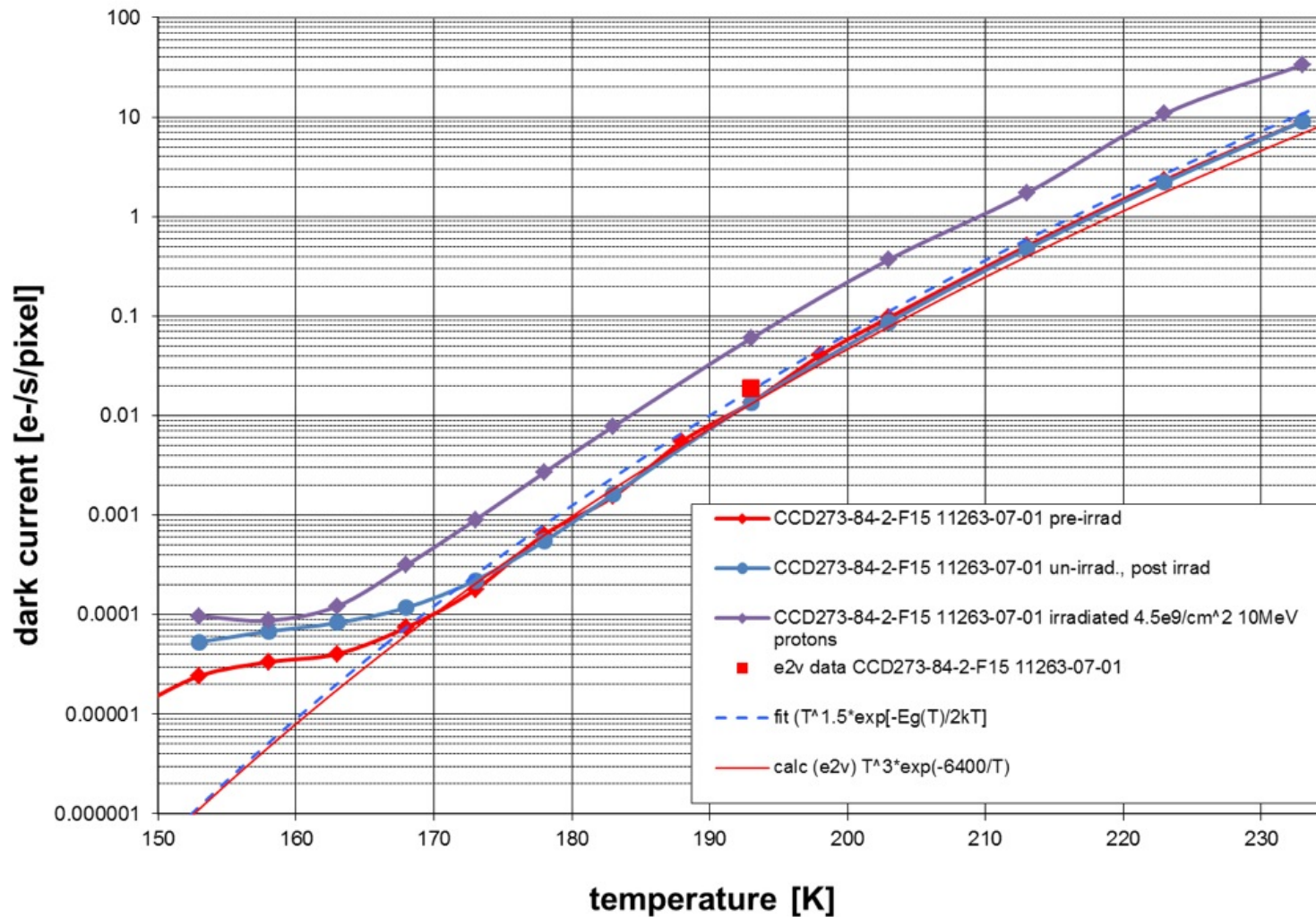
10th July 2013

Channel potential



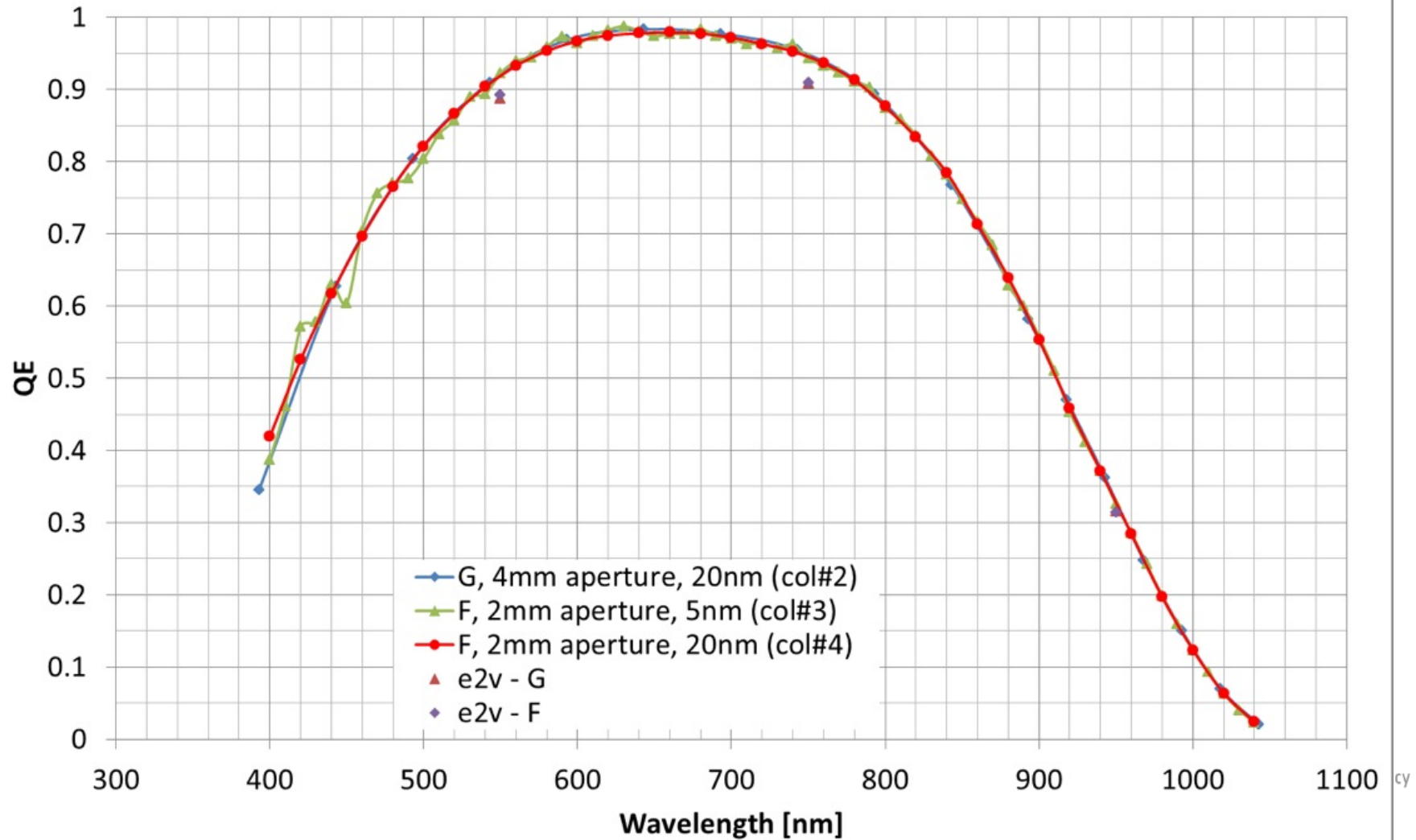


Dark current

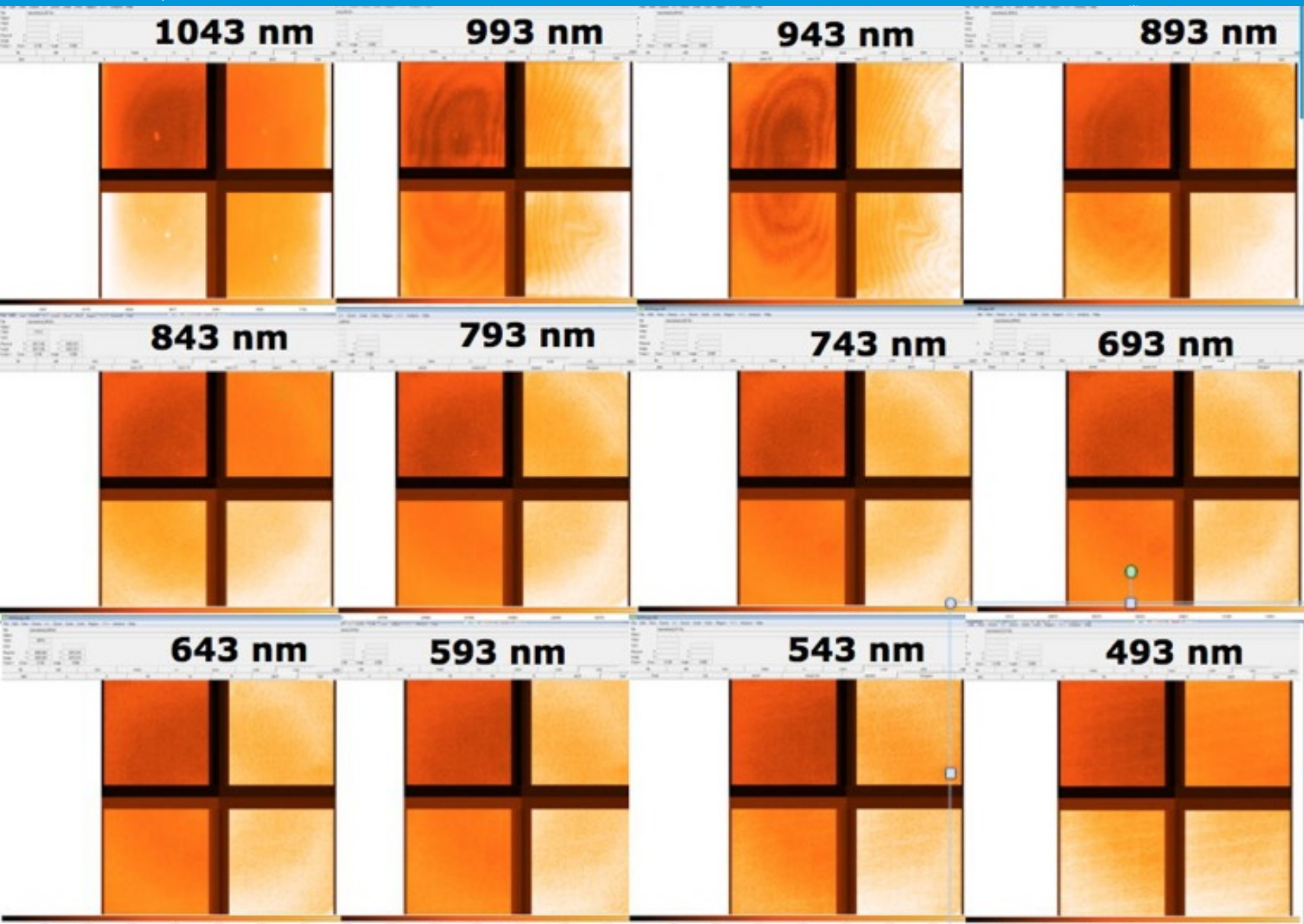


QE (collimated beam)

CCD273-84-F15 ser 11263-07-01, 153K

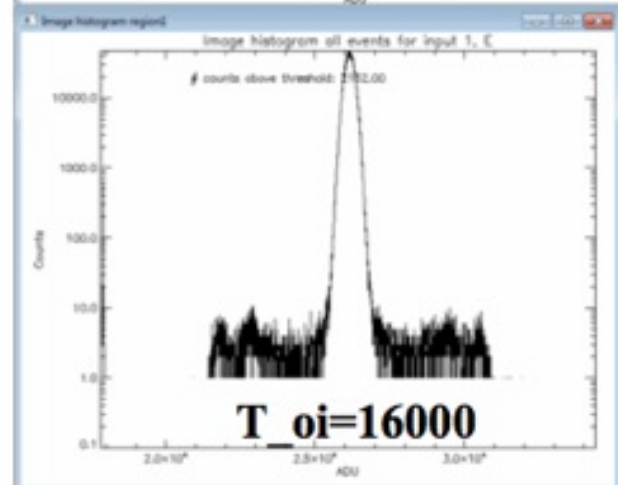
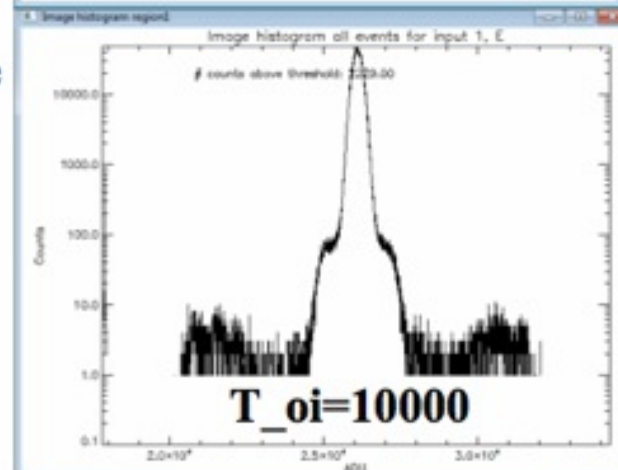
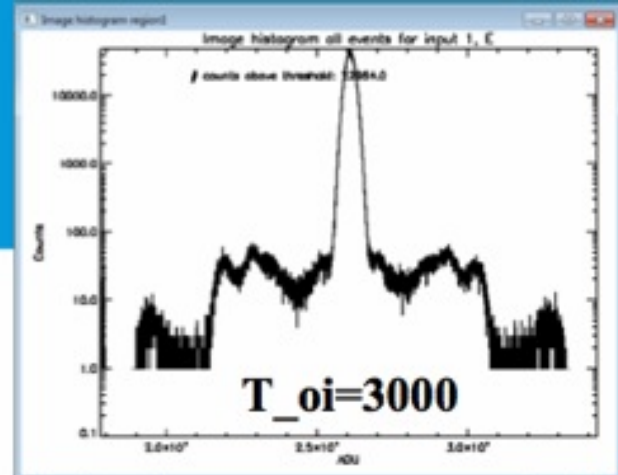
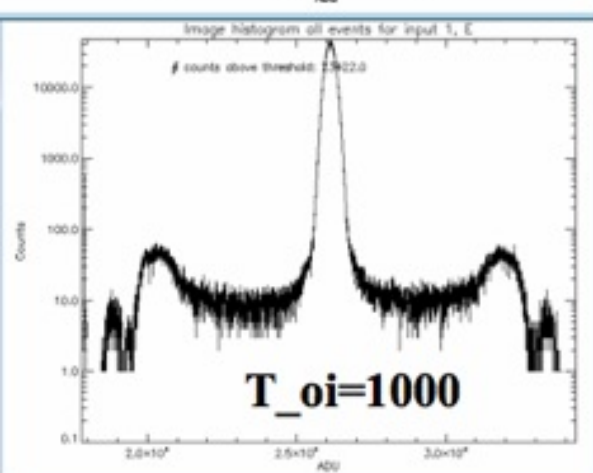
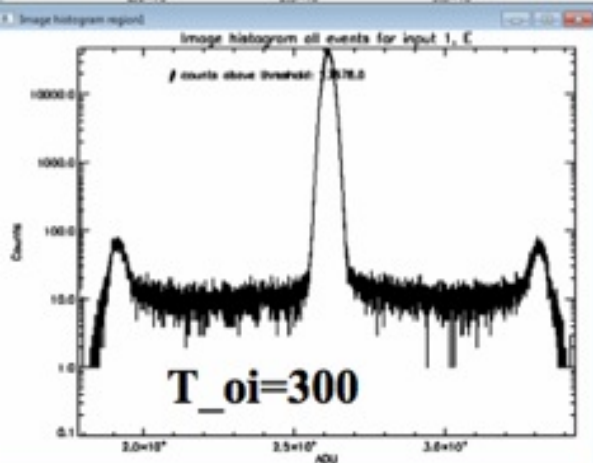
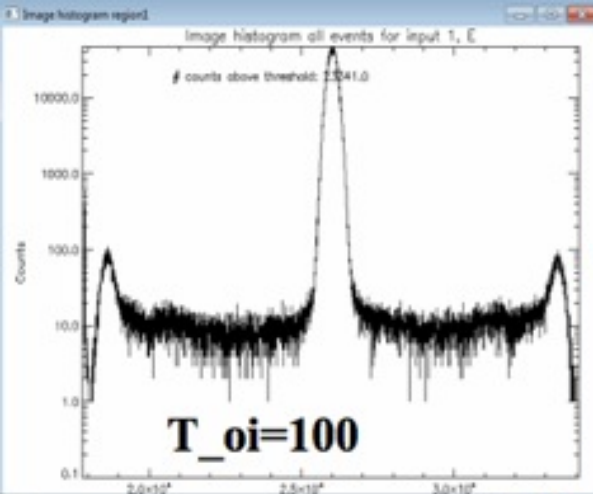


Flatfields, $\Delta\lambda=2.5\text{nm}$



Trap pumping (parallel)

$T=153\text{K}$
Signal $\sim 4500\text{ e-}$
4000 pump cycles
 T_{oi} = parallel clock overlap time



Results From ESTEC Testing



- These slides were provided by Peter at very short notice, just to give a taste of the testing that is being done at ESTEC
- A great deal more data has already been acquired including pre and post irradiation CTI. These data need to be analyzed.
- Optical masks are being procured to conduct “Euclid-like” image testing pre and post irradiation
- Neither Peter nor Thibaut were able to attend this meeting but we propose that they should present ESTEC measurements and analysis properly at the next meeting.

e2v centre for electronic imaging

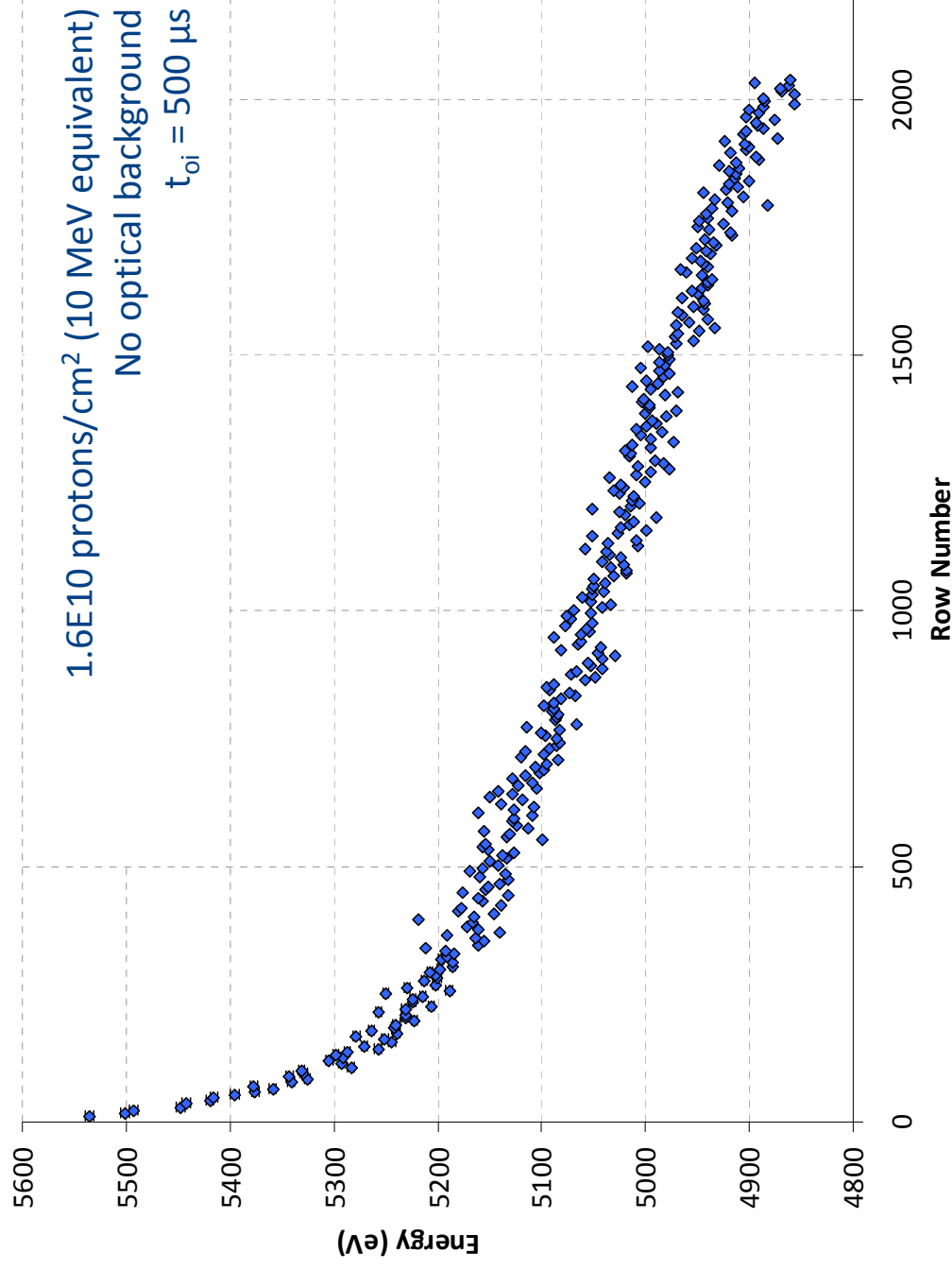


The impact of slow traps

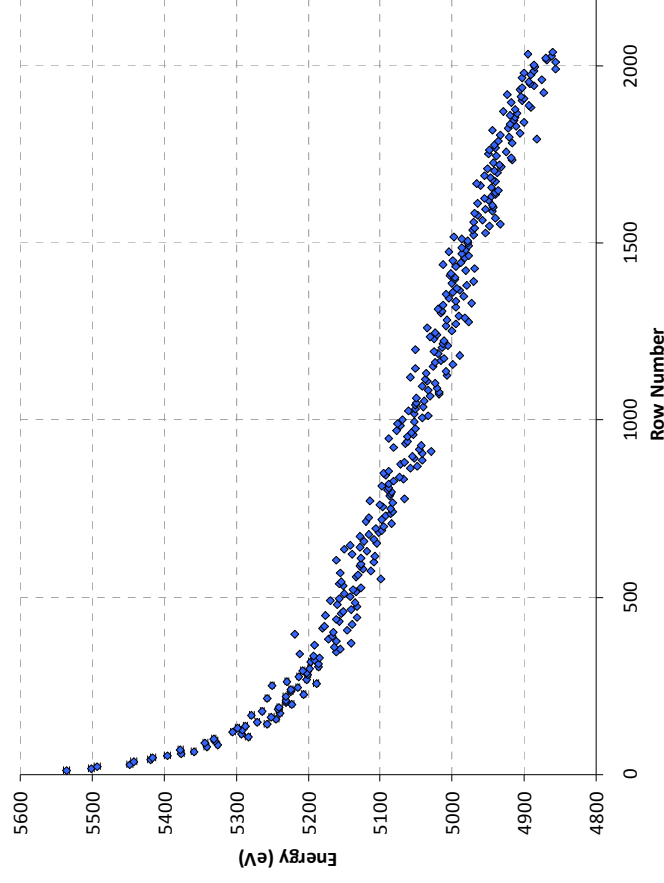
Clarification of previous work

David Hall

Parallel transfer signal loss curves

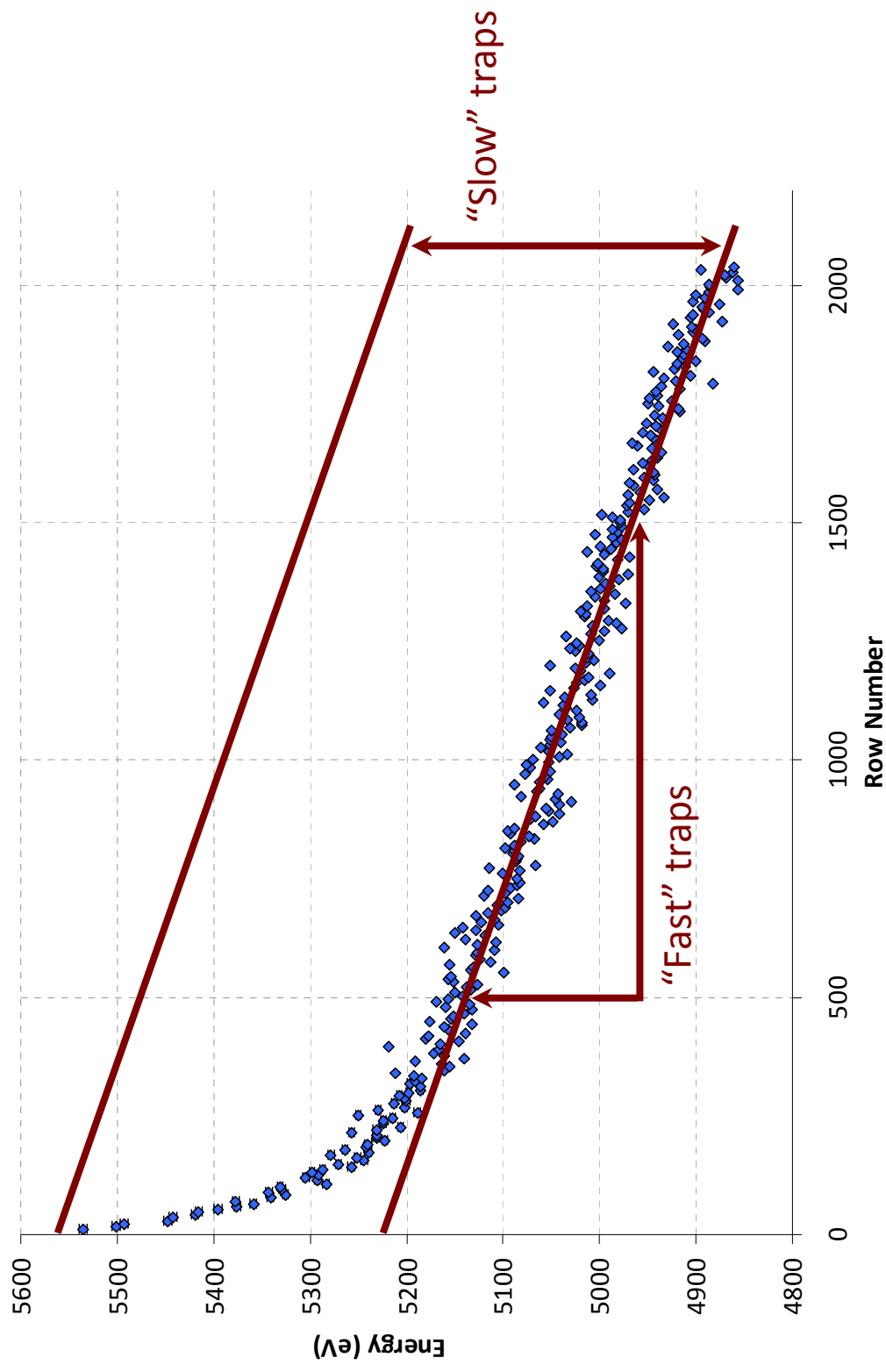


Signal loss curves: Parallel transfers

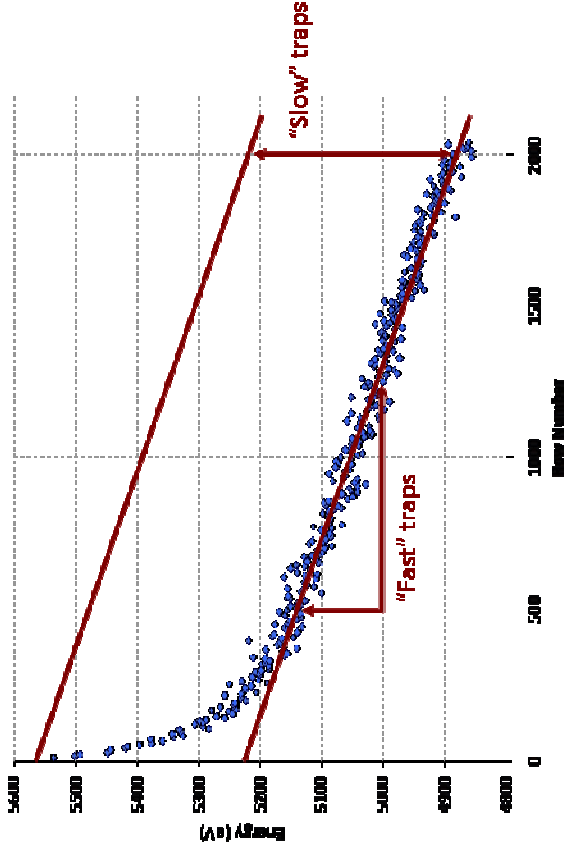


- Input signal here is 5898 eV;
- Peak signal here is below 5898 eV because these data average the loss over the serial register transfers (mean signal across all columns);
- Initial steep drop in signal with increasing number of transfers;
- Constant “loss per transfer” after approximately 100-200 transfers.
- There is a 500 second delay (integration) between successive readouts of the device.

Hypothesis



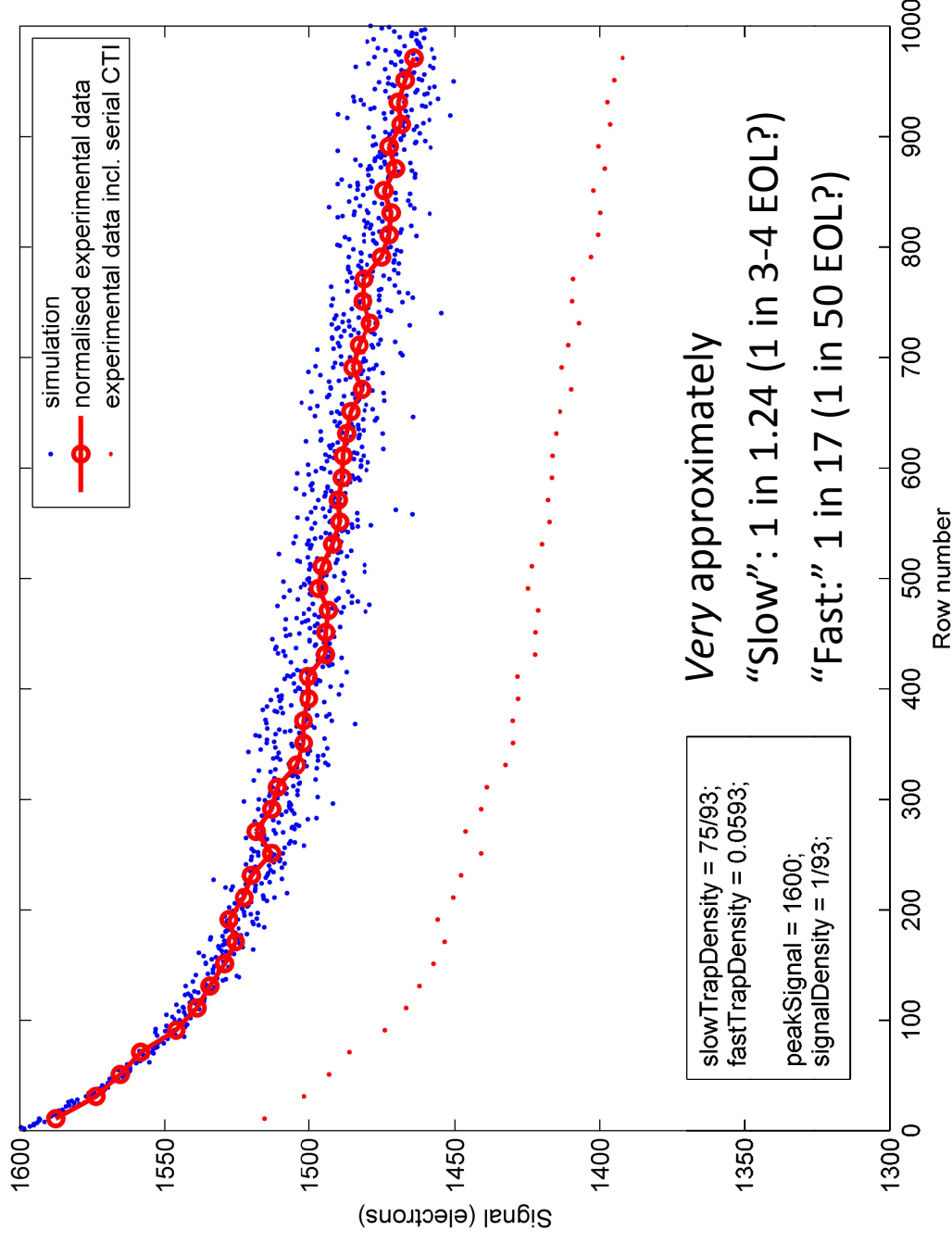
Hypothesis



- “Fast” traps are those which have an emission time similar to the pixel-to-pixel transfer time (e.g. Si-A, (V-V)--);

- “Slow” traps are those which have an emission time much longer than the pixel-to-pixel transfer time multiplied by the number of pixels between X-ray events (e.g. Si-E, (V-V)-);
- These “slow” traps would be “faster” in Hubble, for example, with a warmer temperature at -90°C , whereas with Euclid running colder aiming to freeze these out, they are “slow” .
- Between successive read outs, the delay (integration) allows slow traps to empty, leaving barrier phase slow traps (and a proportion of integrating-phase slow traps depending on testing conditions) empty before transfer to read out the signal.

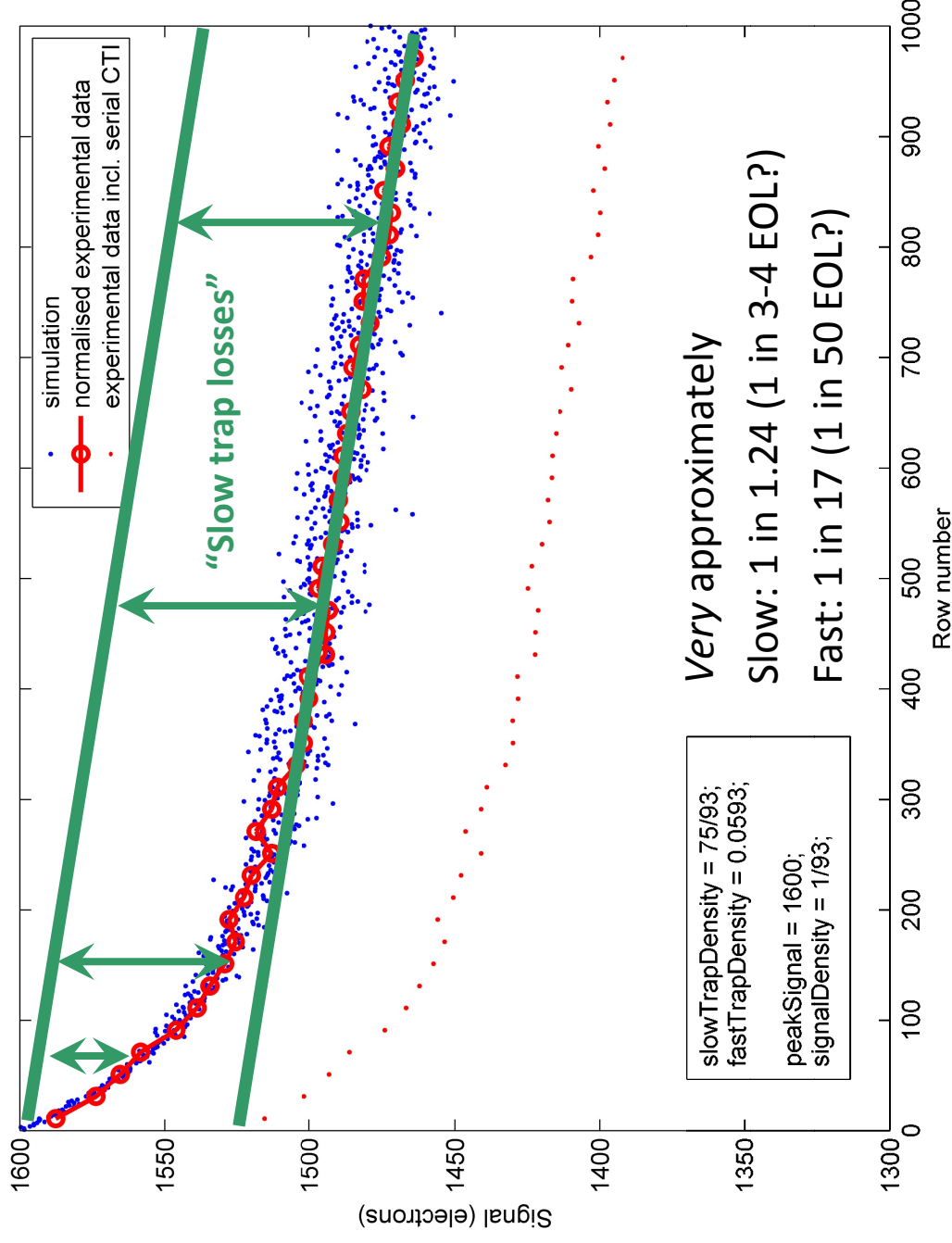
Clarification from WG#6 and WG#7



“Slow” means slower than X-ray spacing (some may be pumped inefficiently, some may not at all).

Just to clarify, here “slow” and “fast” traps are classed based on X-ray flux and therefore spacing between events in time. Some “slow” traps may be faster with different conditions etc.

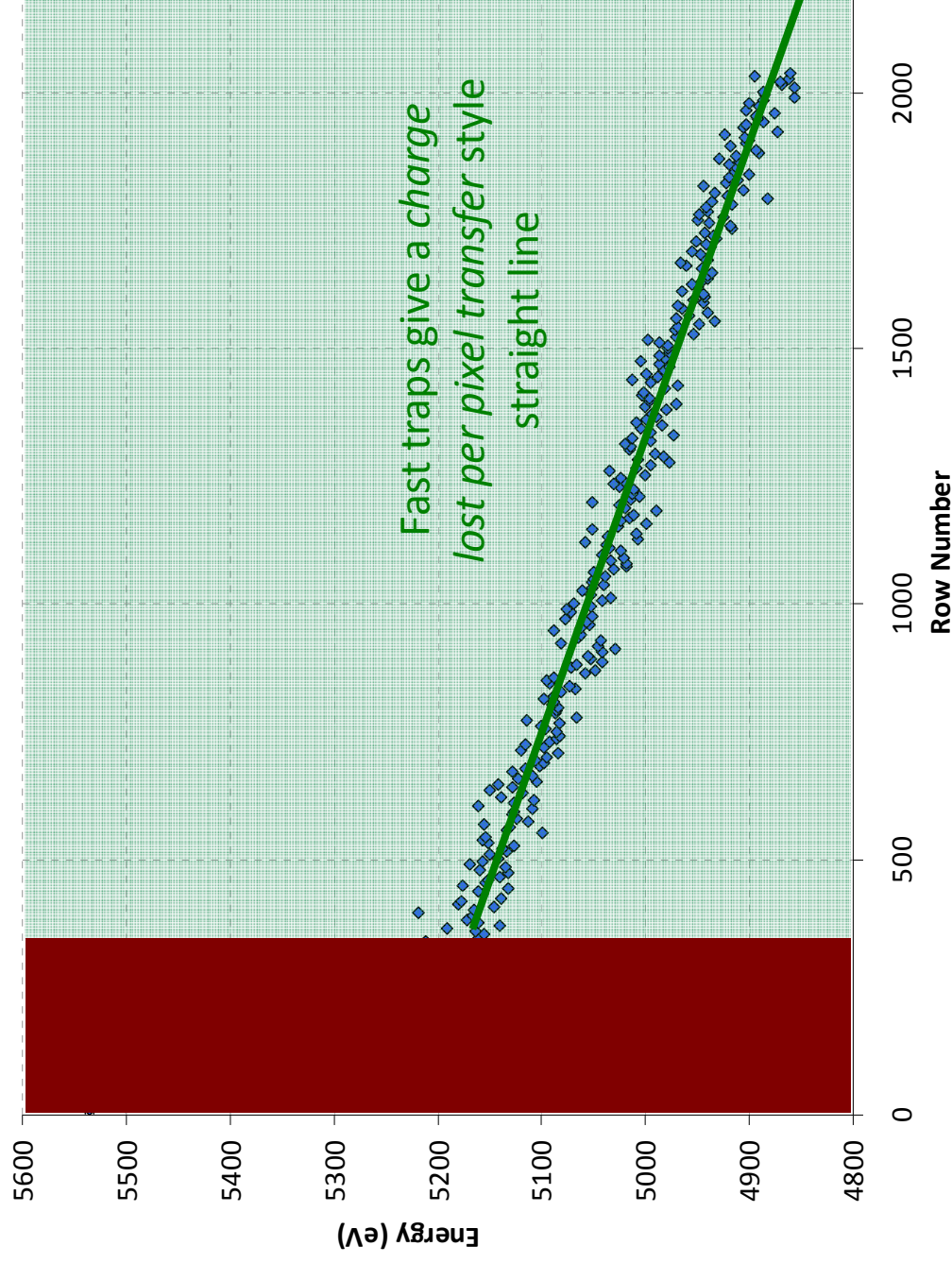
Clarification for earlier plots



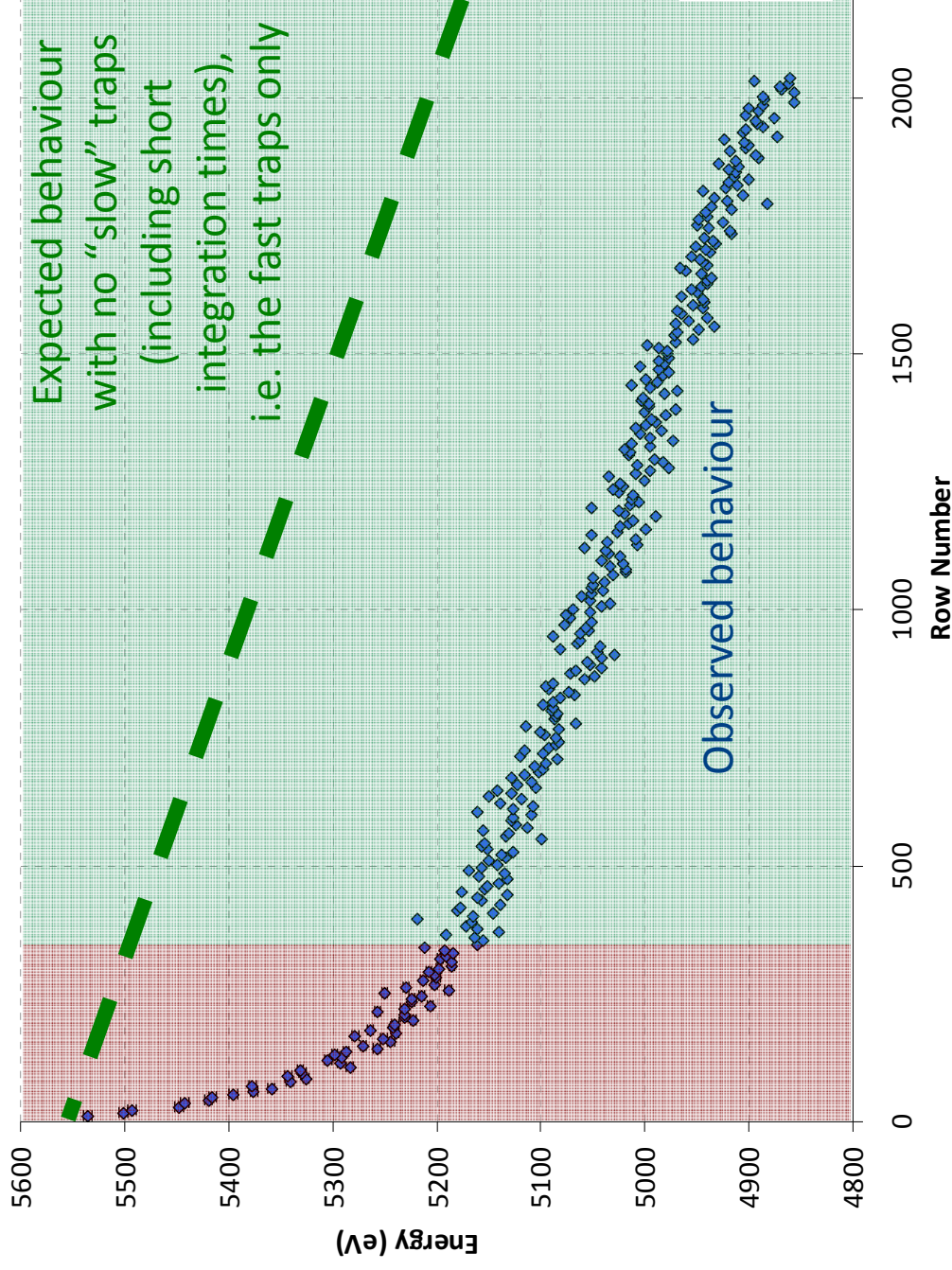
Note that *all* signal drops wherever it is in the CCD, not just those near the register

In fact, the signal *closest* to the serial register sees the *lowest* losses due to trapping.

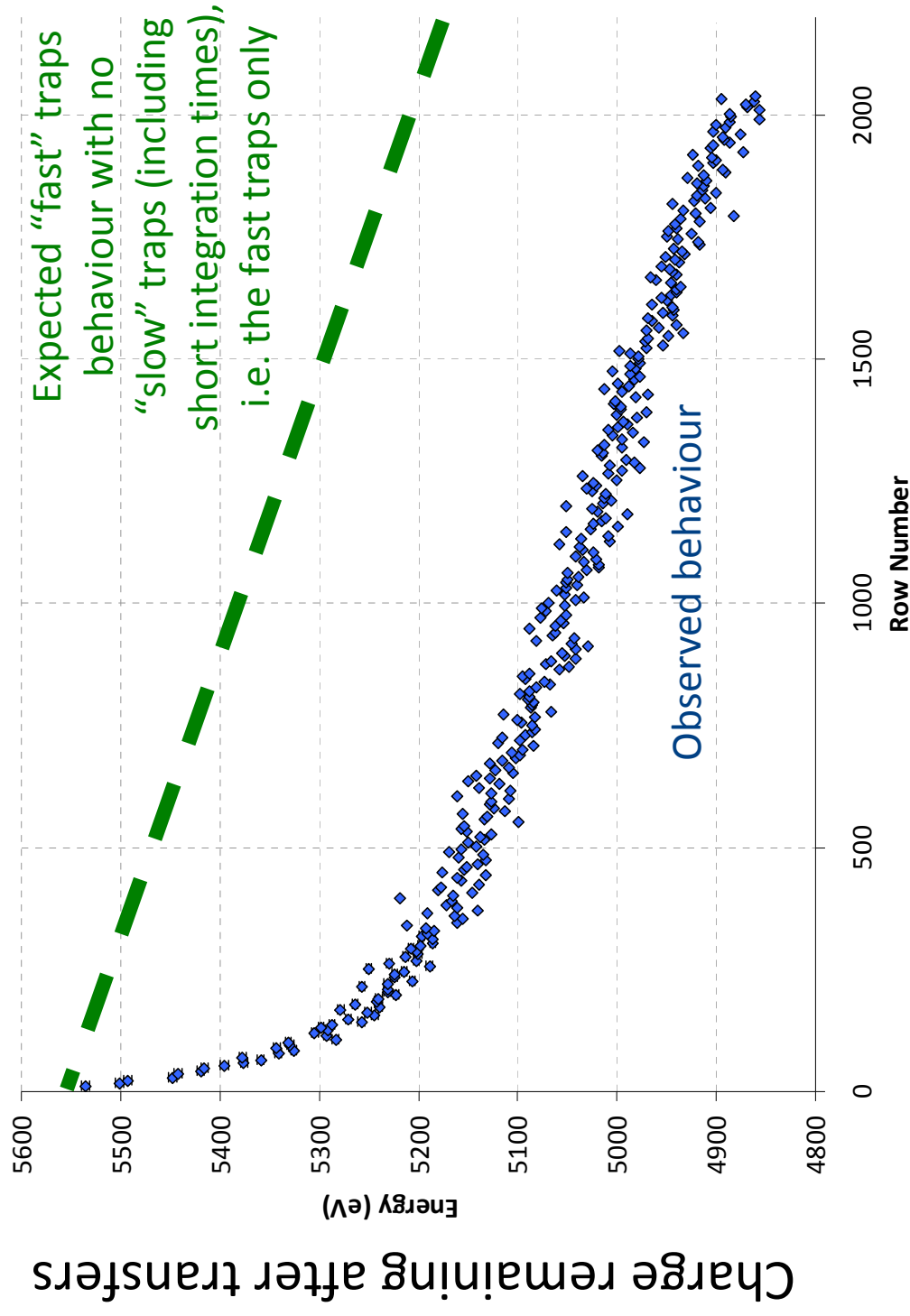
Standard behaviour



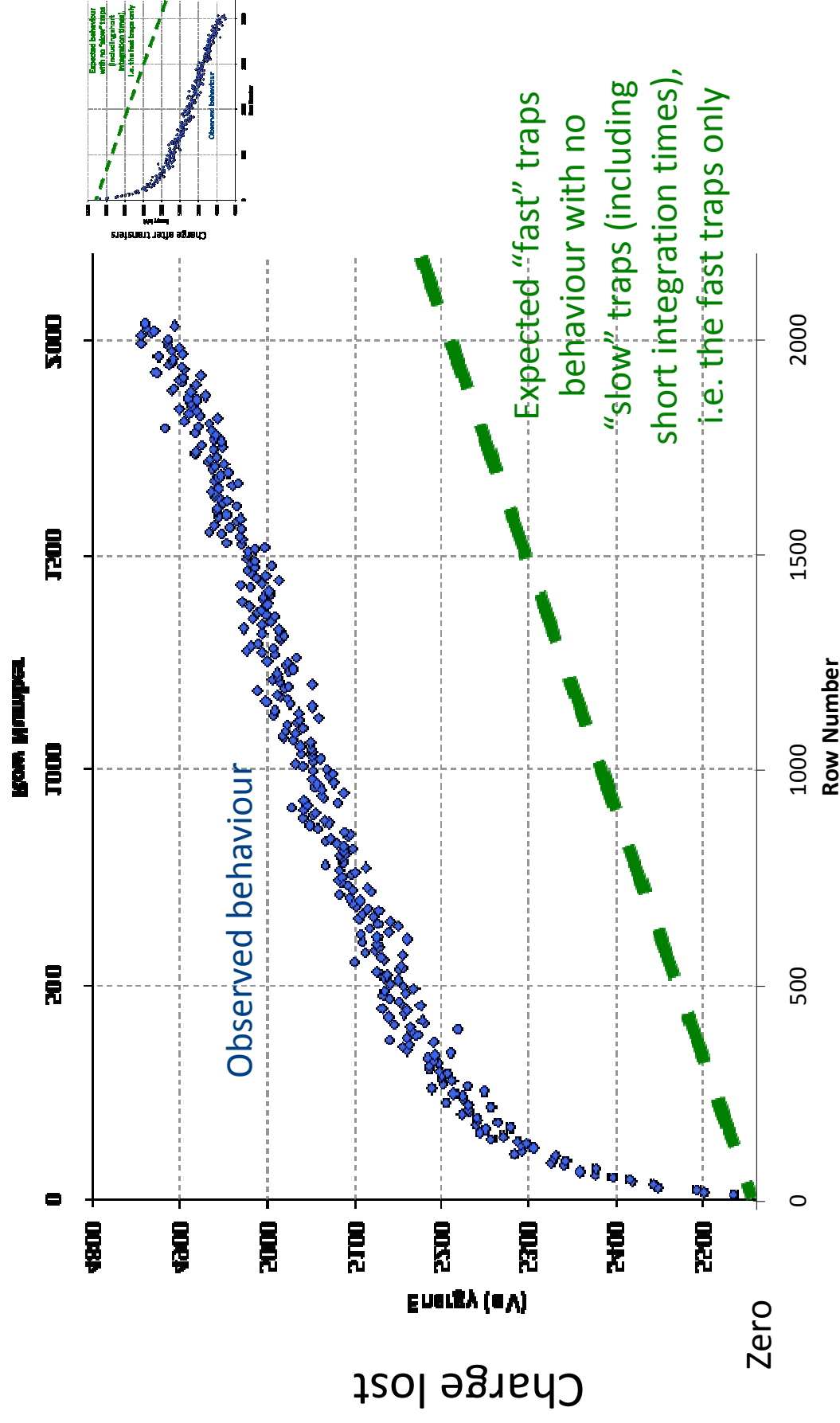
Slow traps cause losses for all rows



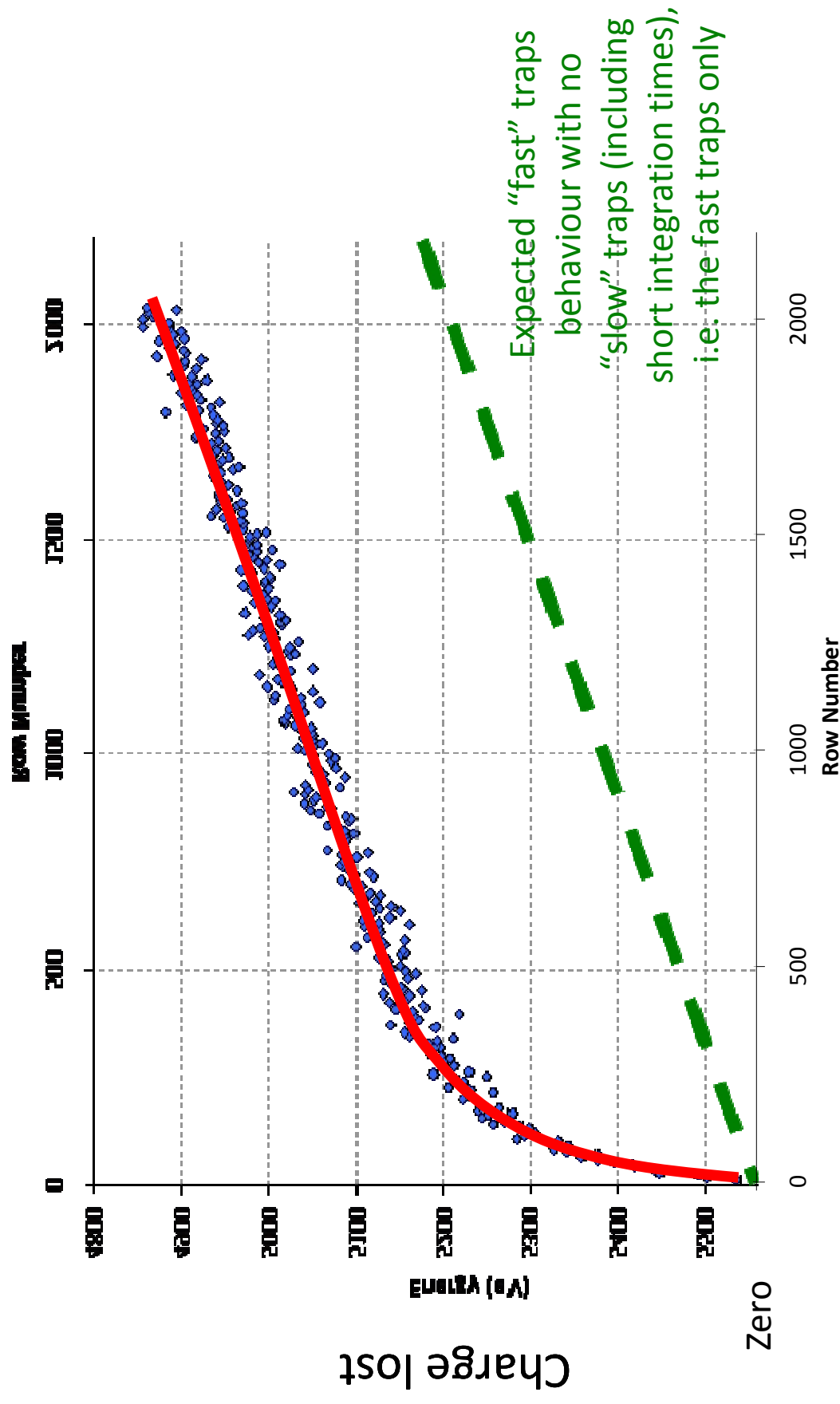
Looking at it another way...



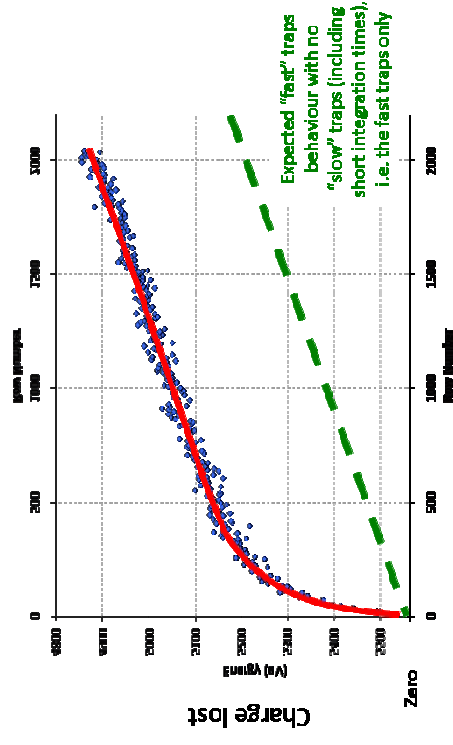
Looking at it another way...



Looking at it another way...



Looking at it another way...



Slow trap component

Fast trap component removed

Charge lost

Zero

2000

1500

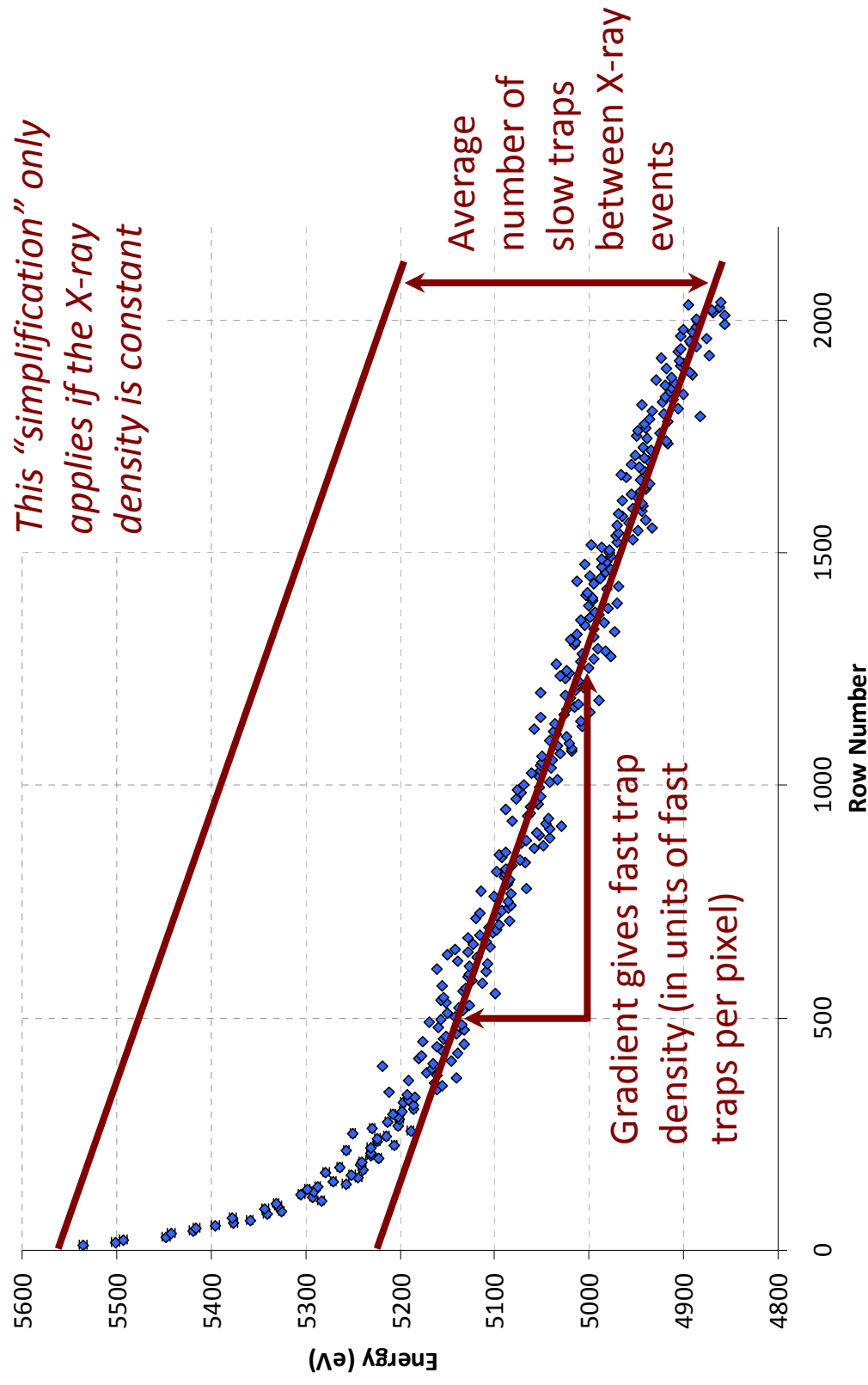
1000

500

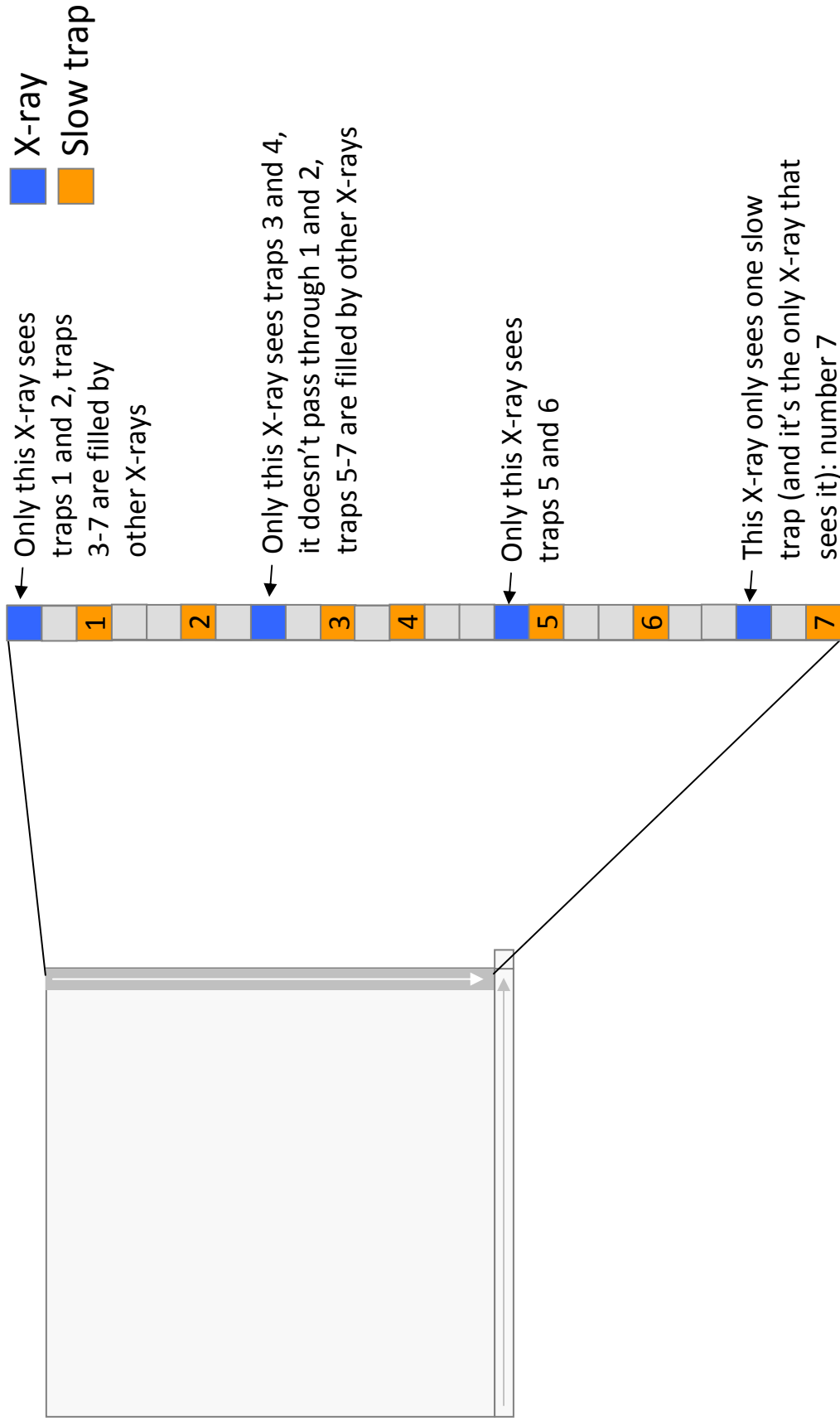
0

Row Number

Hypothesis



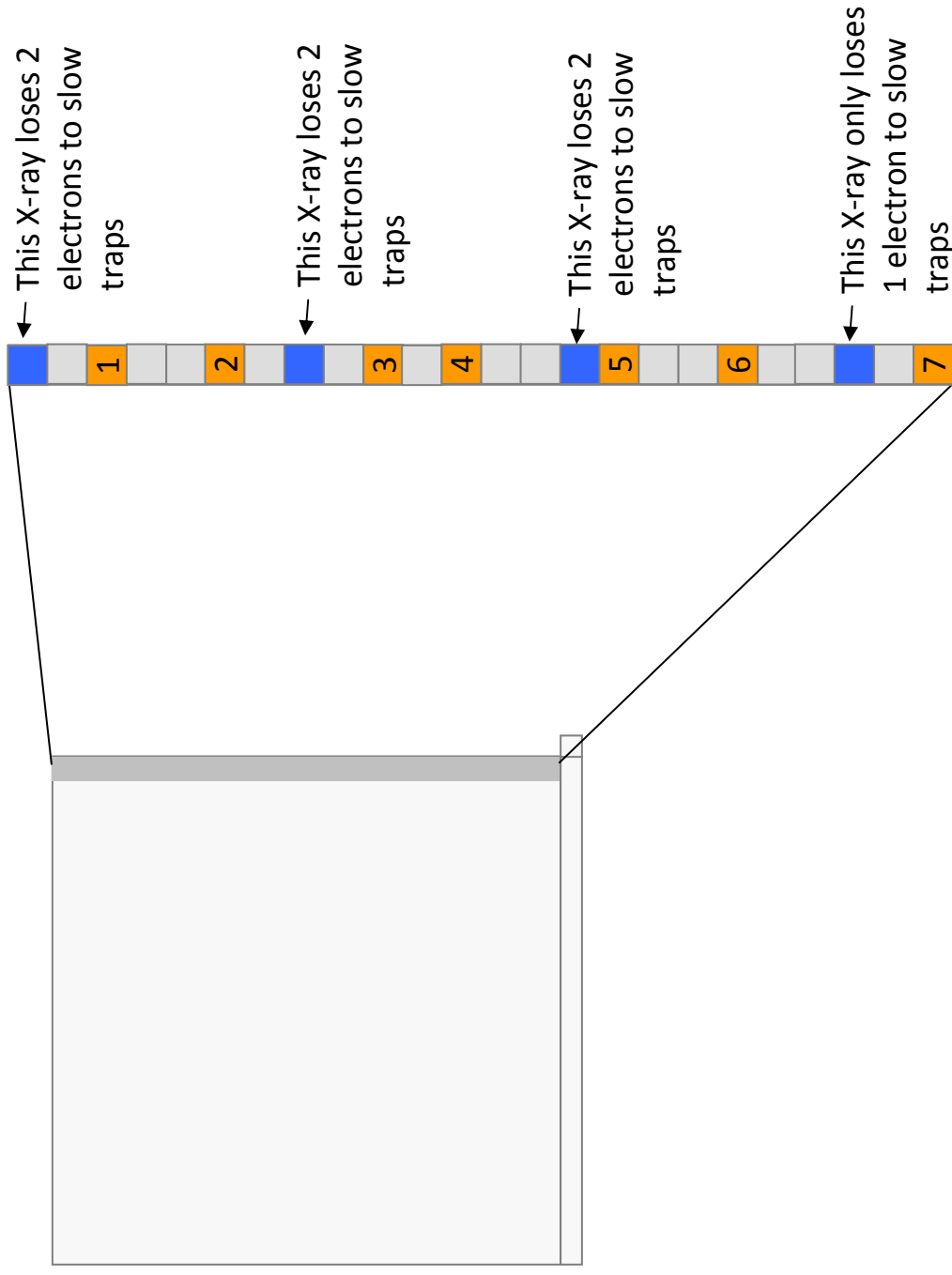
Slow traps



Slow traps



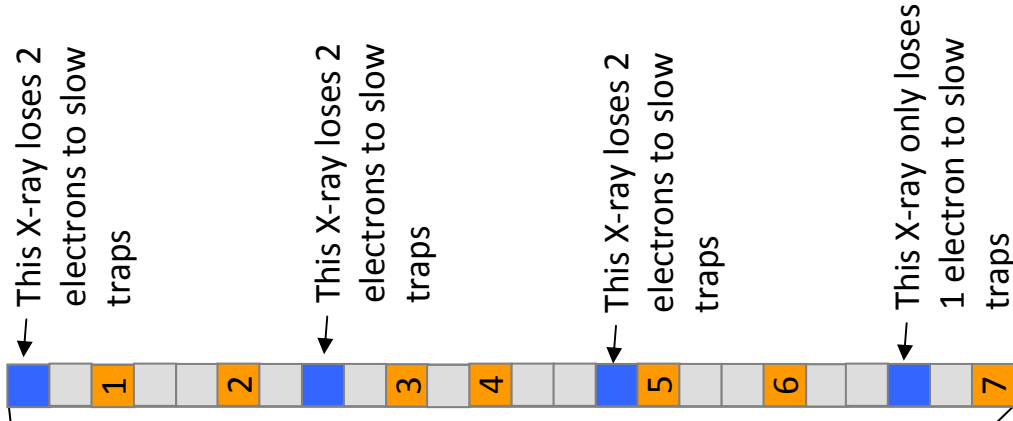
■ X-ray
■ Slow trap



Slow traps

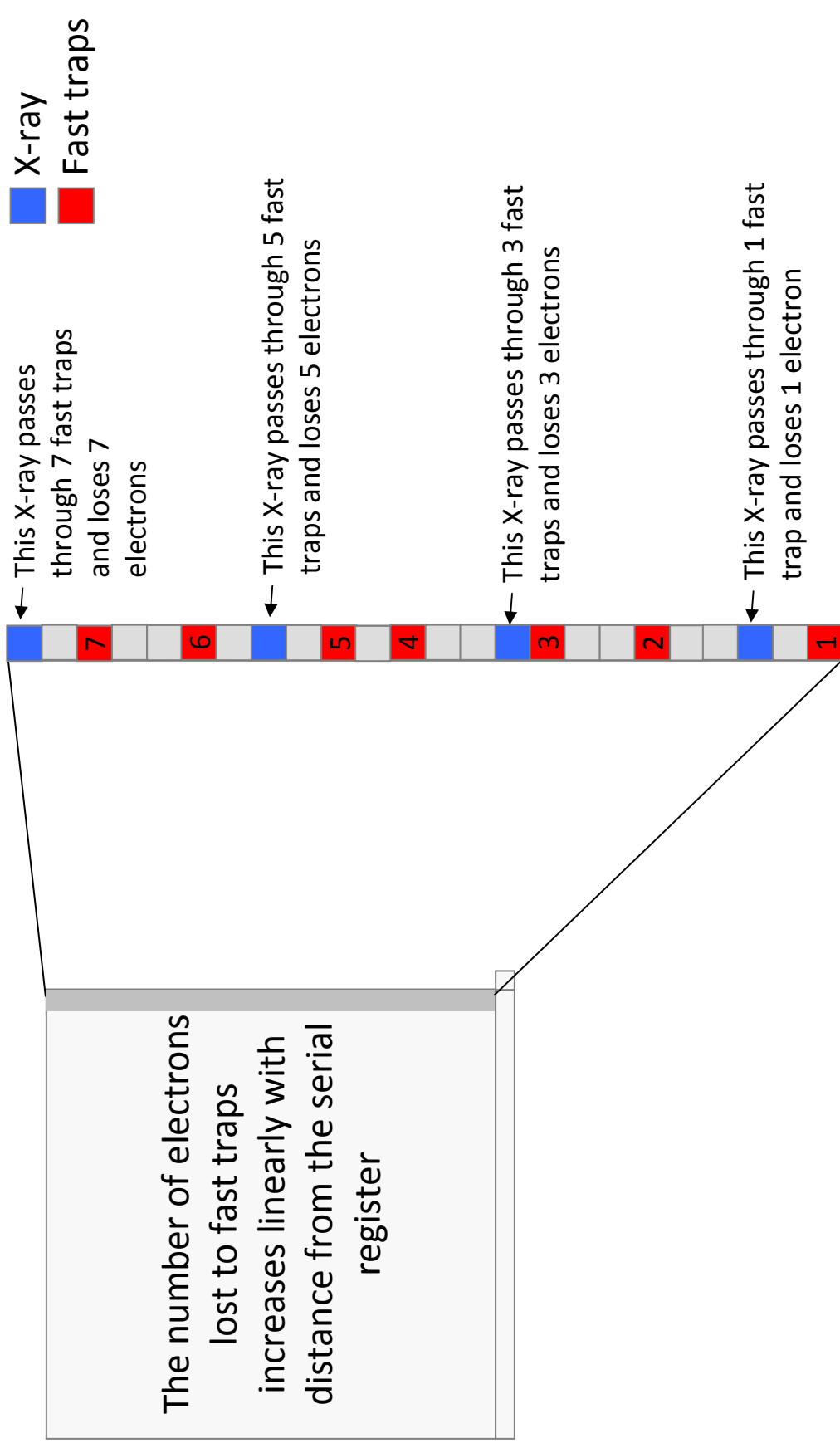


■ X-ray
■ Slow trap



Every X-ray loses 2 electrons except for those near the readout register (then the number of electrons lost increases with distance from readout register)

Fast traps

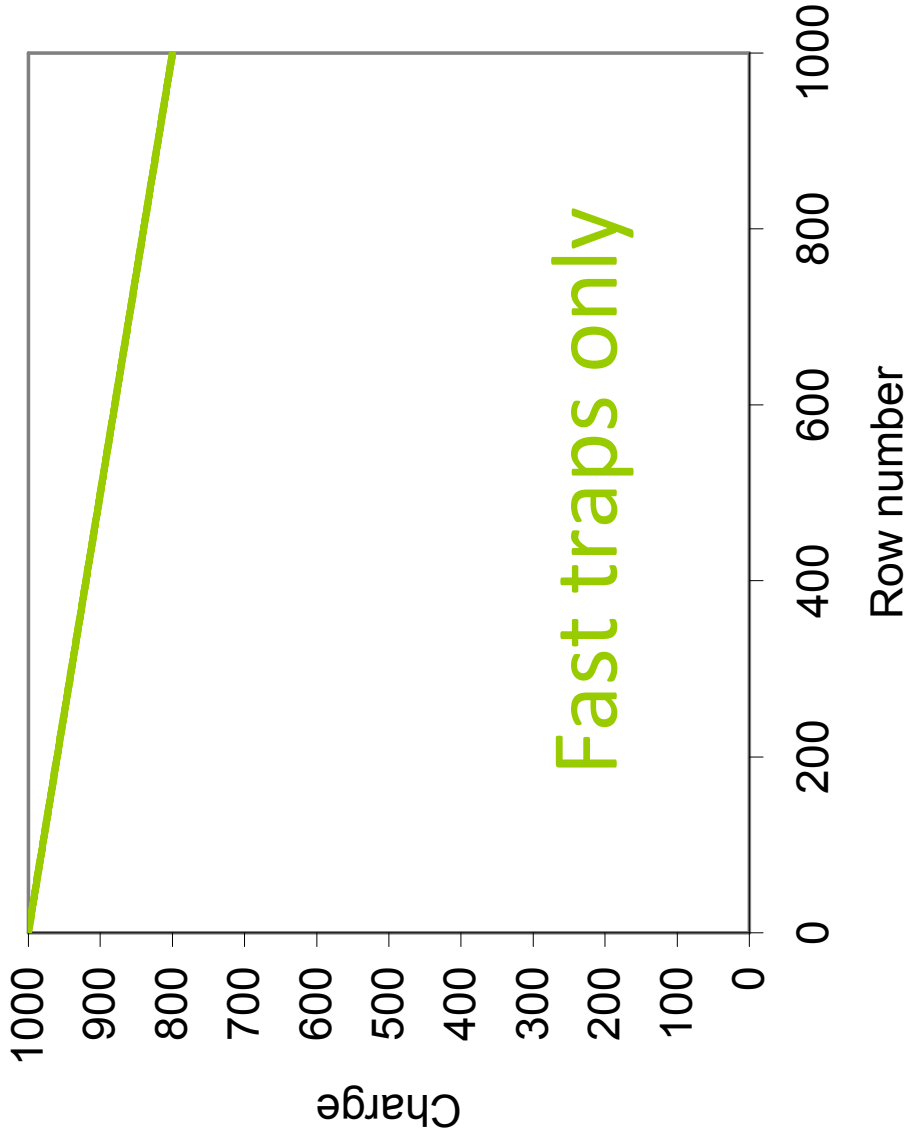


Basic case: an Excel simulation



With 1 fast trap in every 5 pixels, this means that 0.2 electrons are lost in every pixel.

- 1000 electrons per X-ray
- 1 X-ray every 100 pixels
- 1 slow trap in every pixel
- 1 fast trap in every 5 pixels (gradient of 0.2)

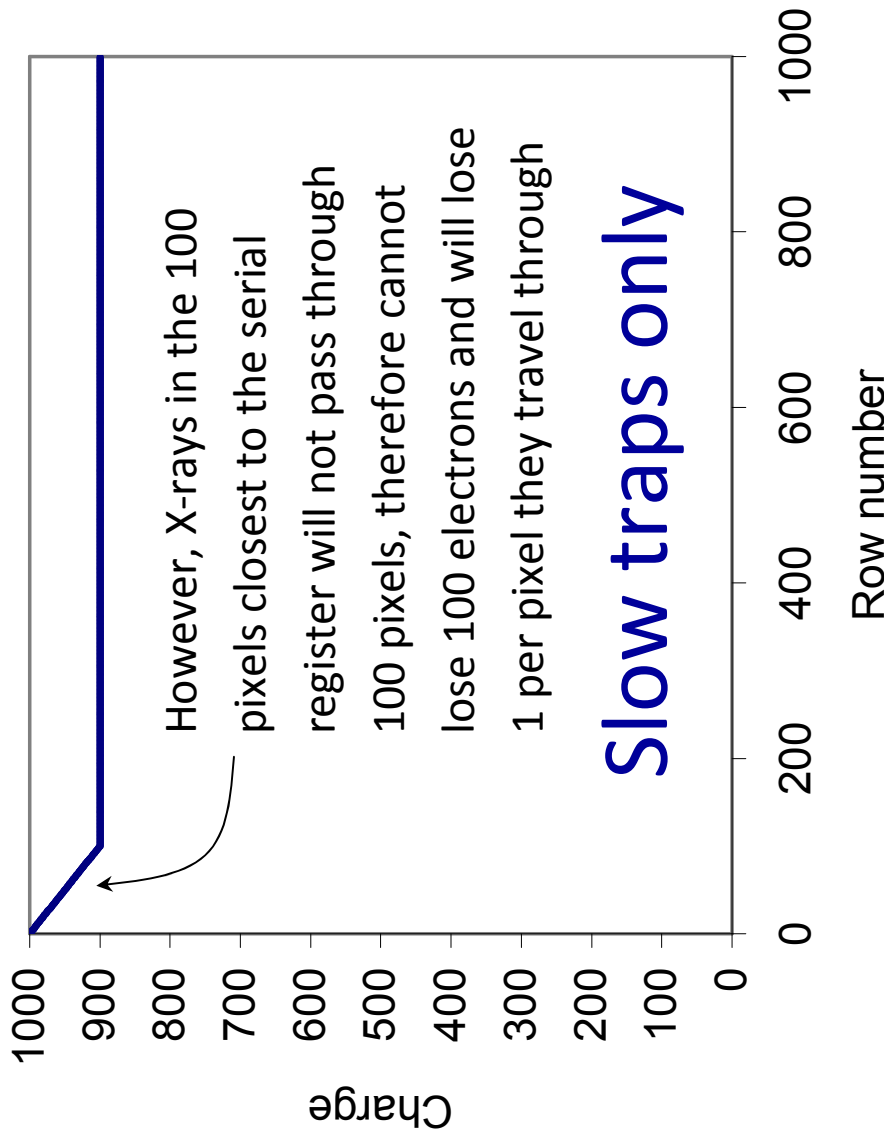


Basic case: an Excel simulation

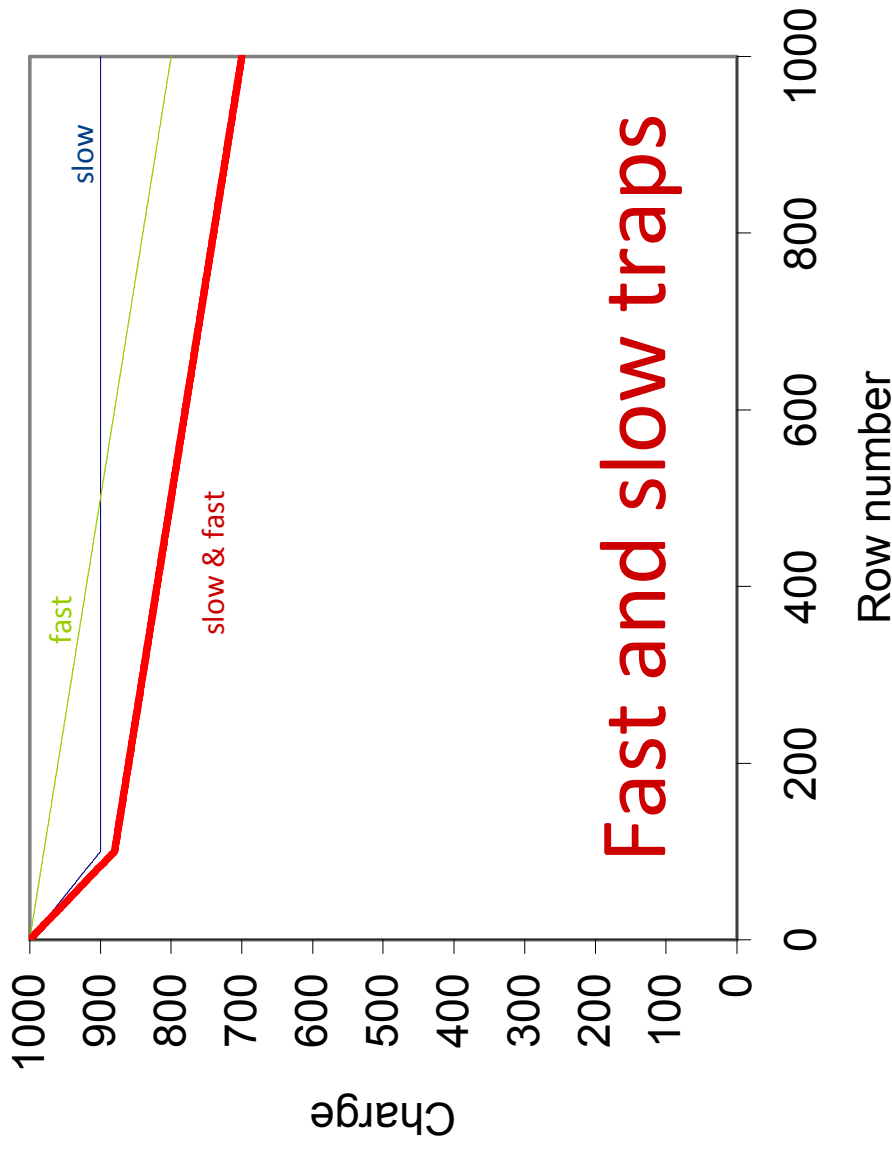
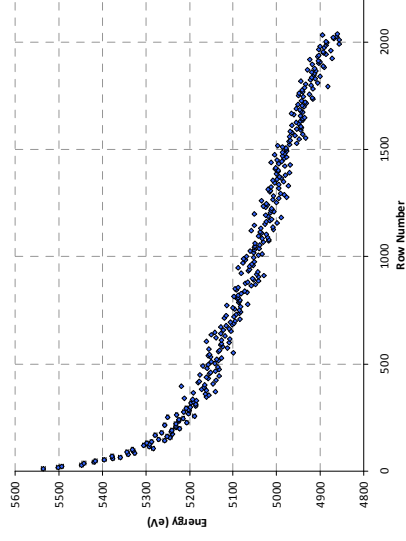


With 1 slow trap in every pixel and 1 X-ray in every 100 pixels, all X-rays will travel through 100 pixels (and therefore 100 slow traps) before reaching the point where the preceding X-ray started, after which all slow traps will be filled.

1000 electrons per X-ray
1 X-ray every 100 pixels
1 slow trap in every pixel
1 fast trap in every 5 pixels (gradient of 0.2)



Basic case: an Excel simulation

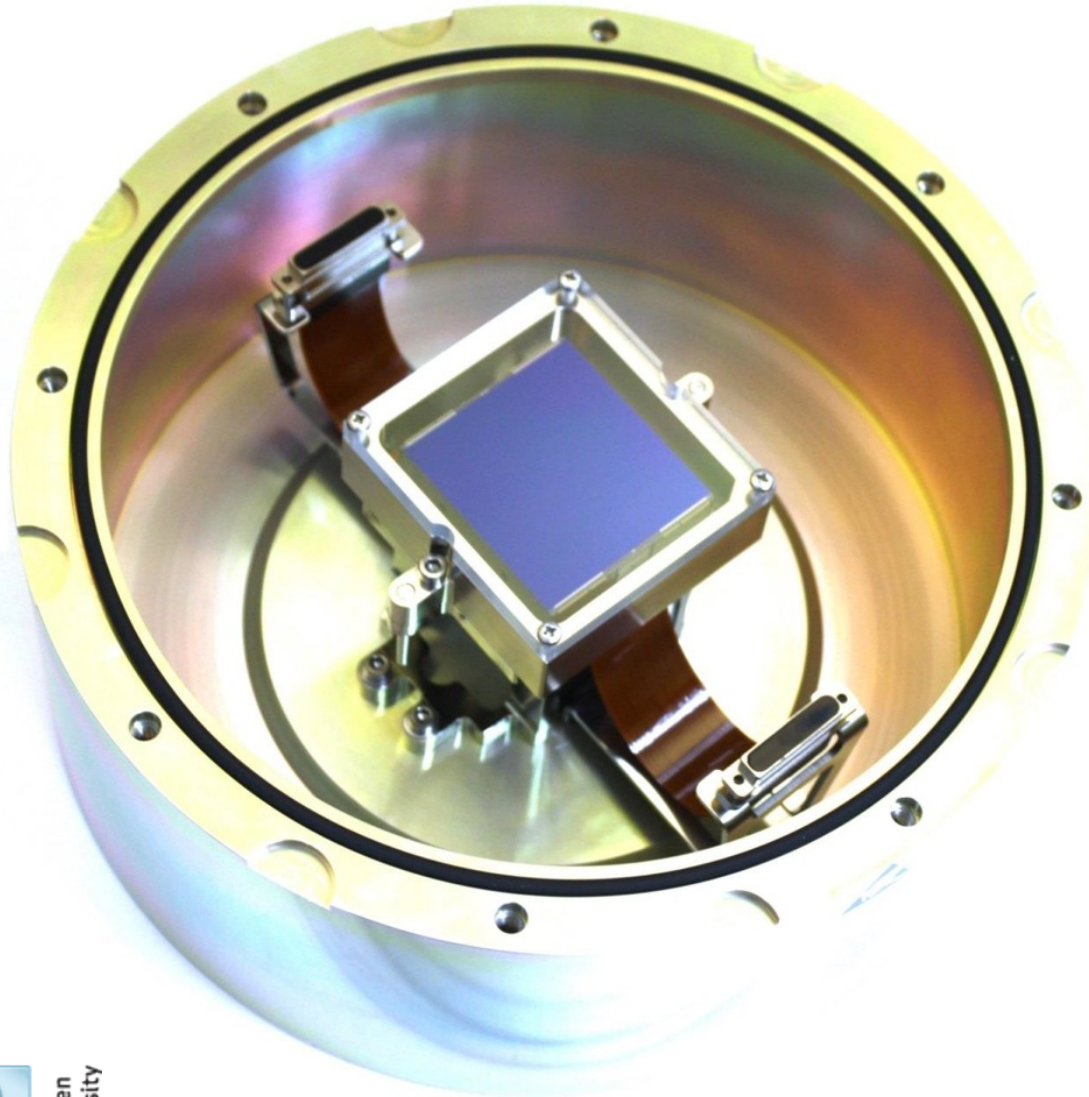


1000 electrons per X-ray

1 X-ray every 100 pixels

1 slow trap in every pixel

1 fast trap in every 5 pixels (gradient of 0.2)

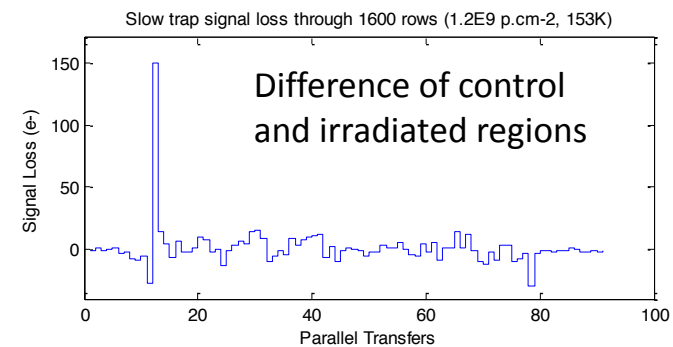
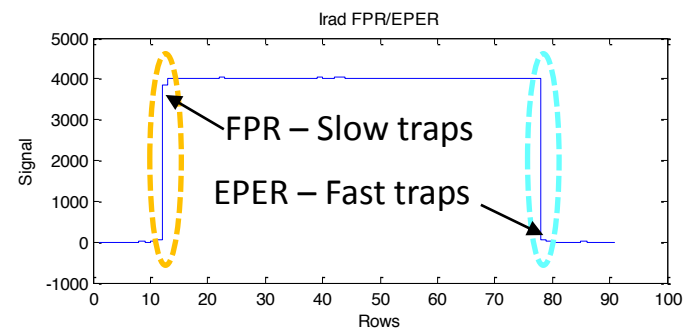
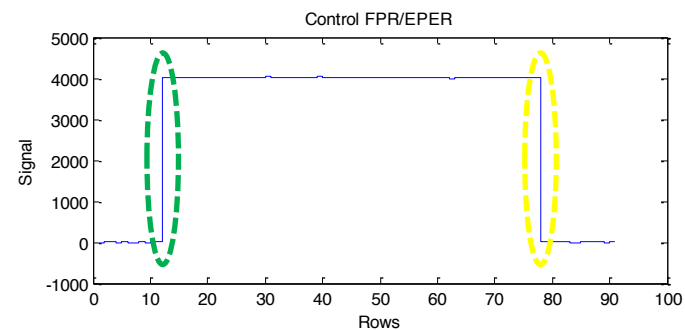
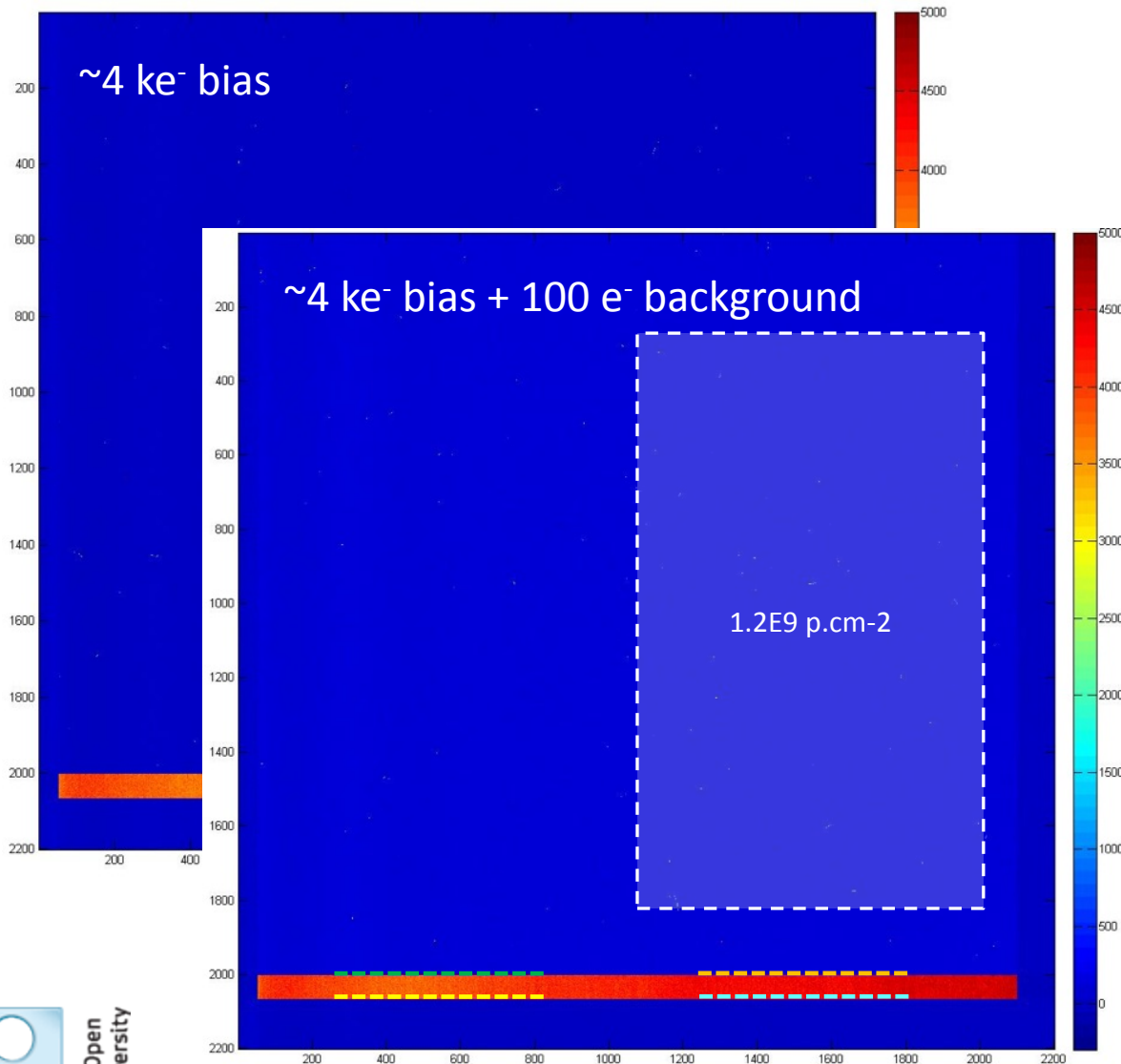


Euclid CCD Working Group 8

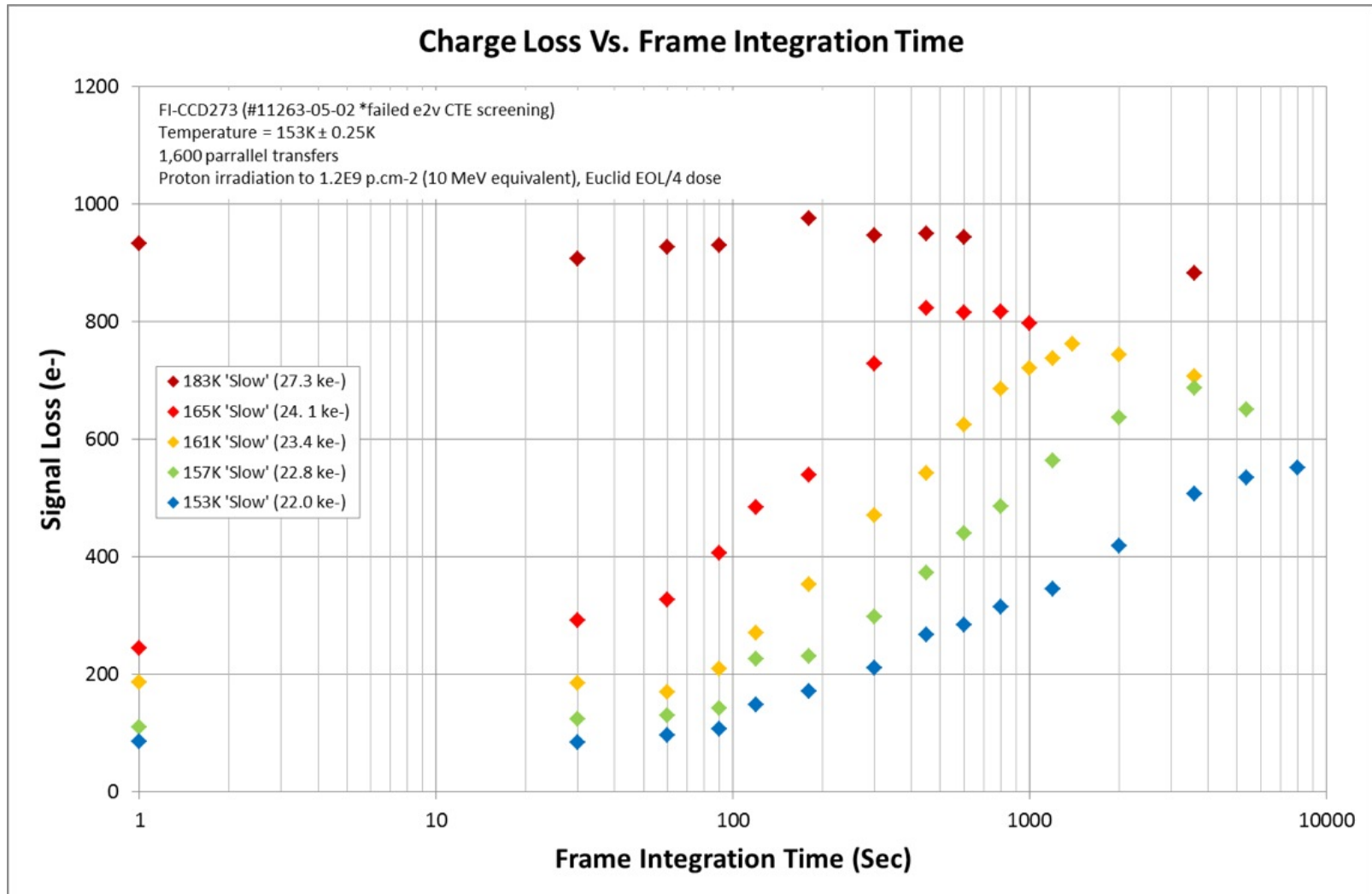
Neil Murray
10th July 2013

Slow trap behaviour

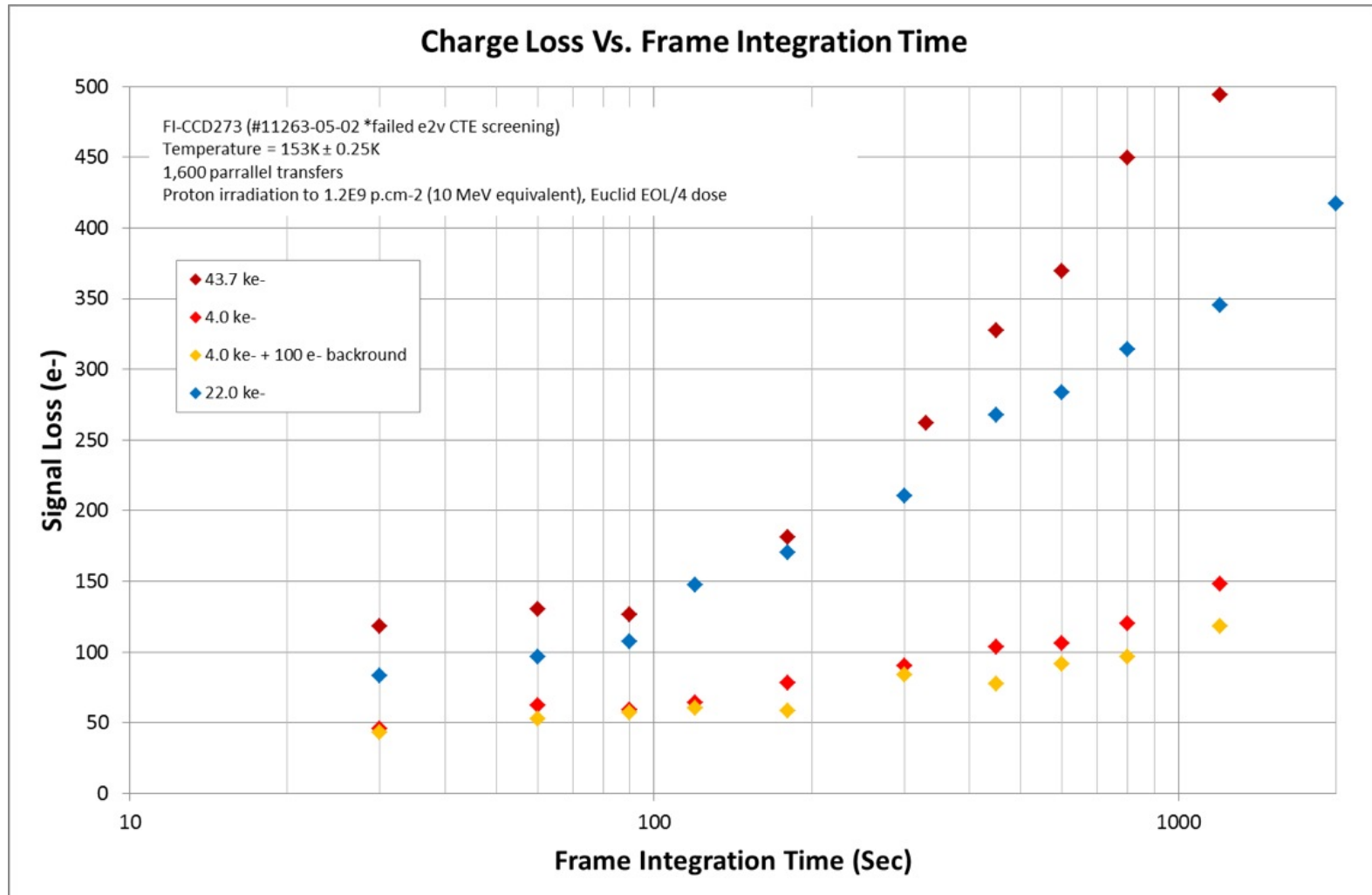
F/EPER-CIC Method



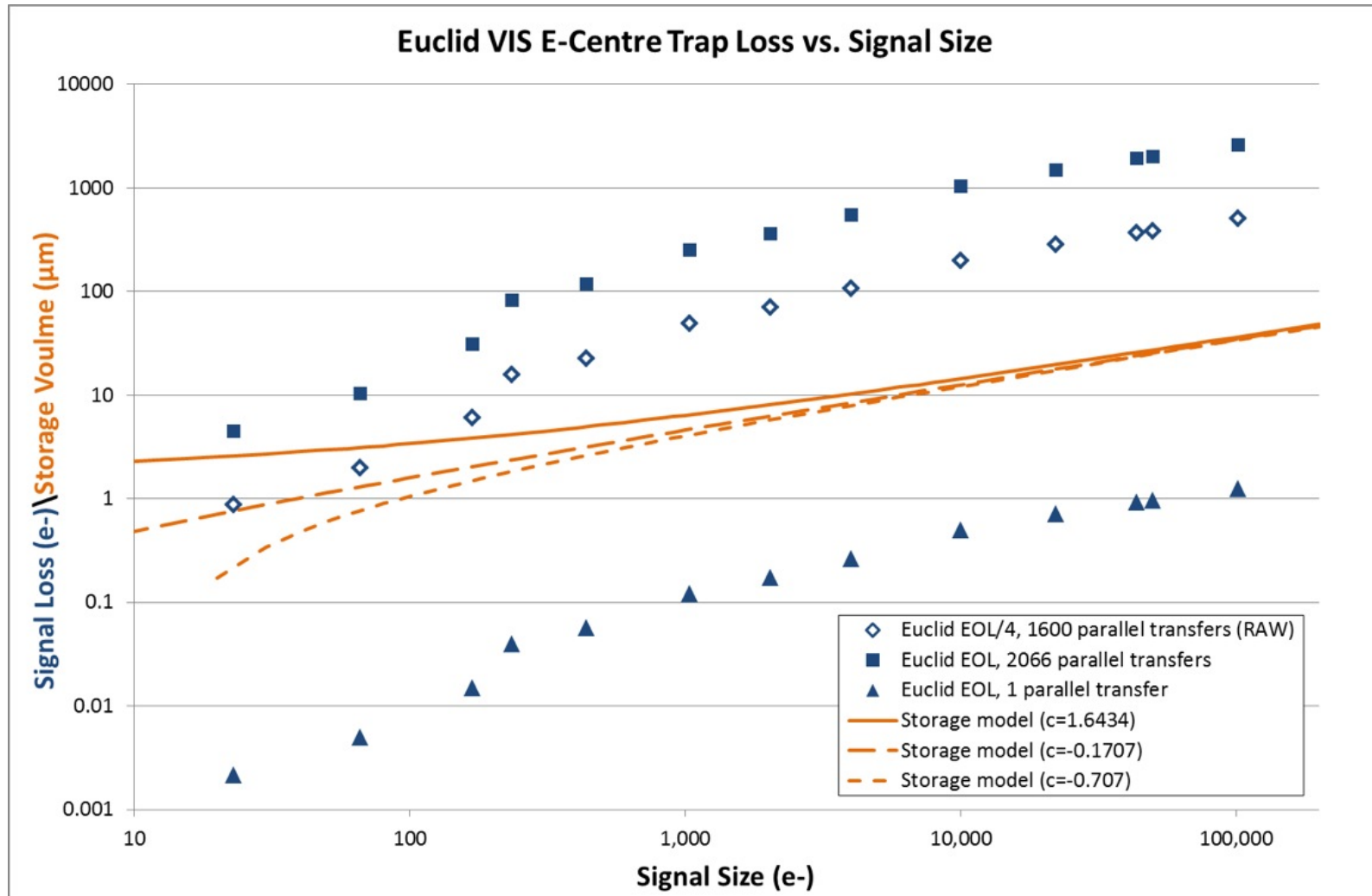
Slow Traps vs. Temperature



Slow Traps vs. Signal



Slow Traps Loss vs. Signal Size



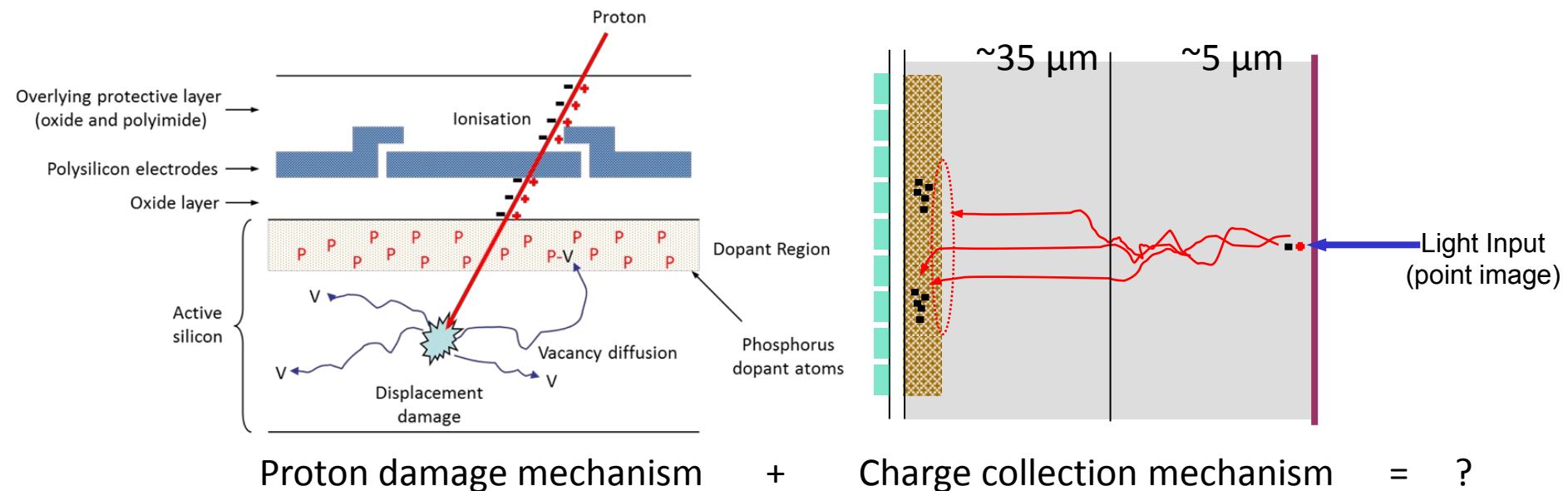
Slow Traps and Charge Collection Efficiency?



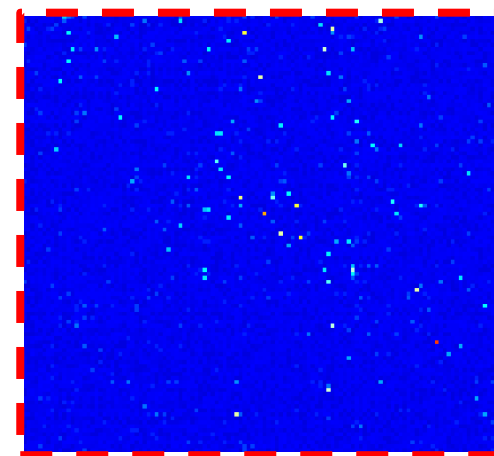
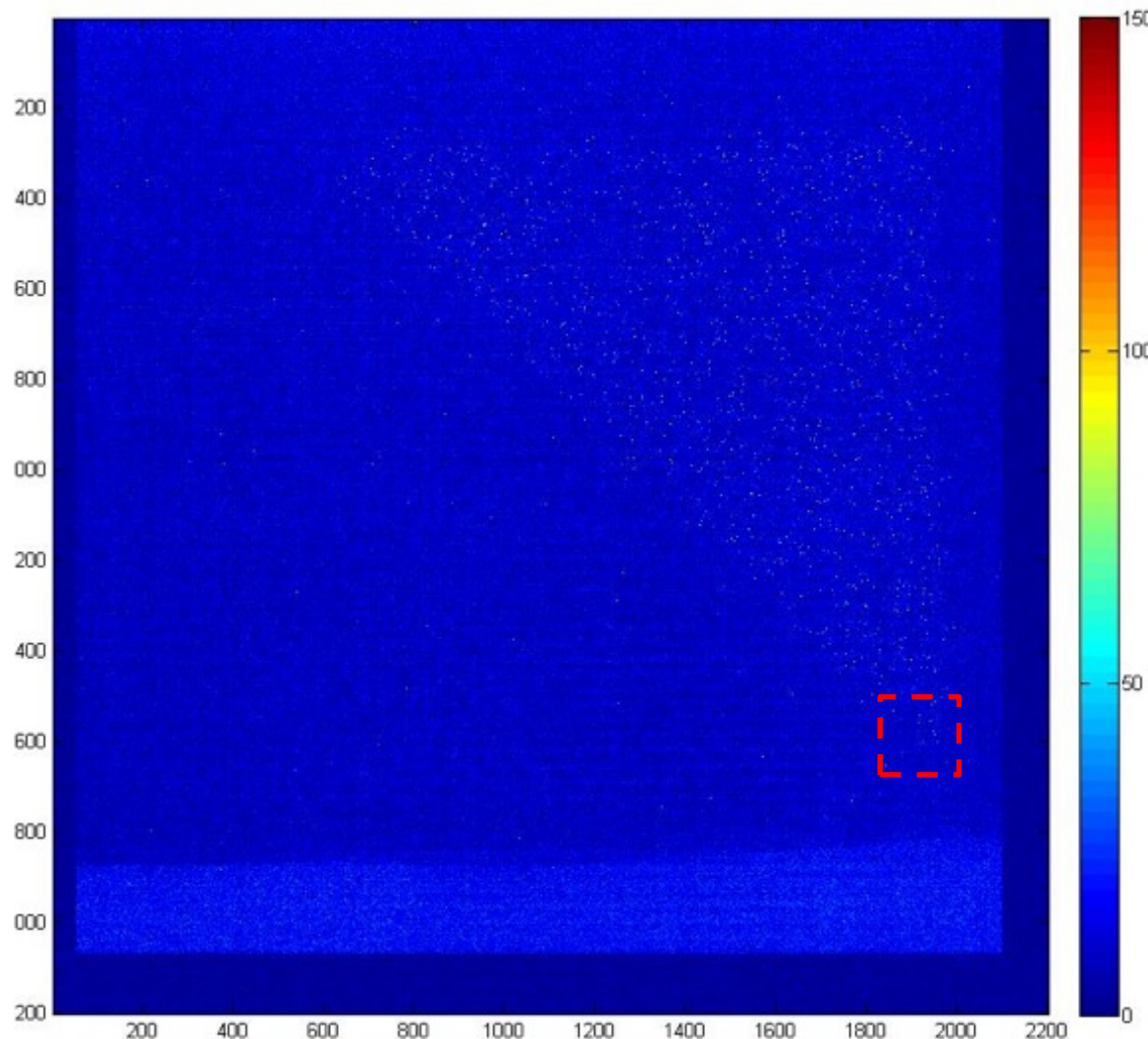
The ratio between the signal size curves can give us an indication of the charge transport cross-section. Hopefully these can be verified by our Silvaco models of the CCD273 pixel.

We can estimate 0.25 slow traps per pixel in the charge transport volume (for 4 ke⁻ signal size with 100 e⁻ background) based on these new data at ¼ EOL dose. As the transport volume is only a fraction of the light sensitive silicon, there could be many 10's of thousands empty slow traps during integration.

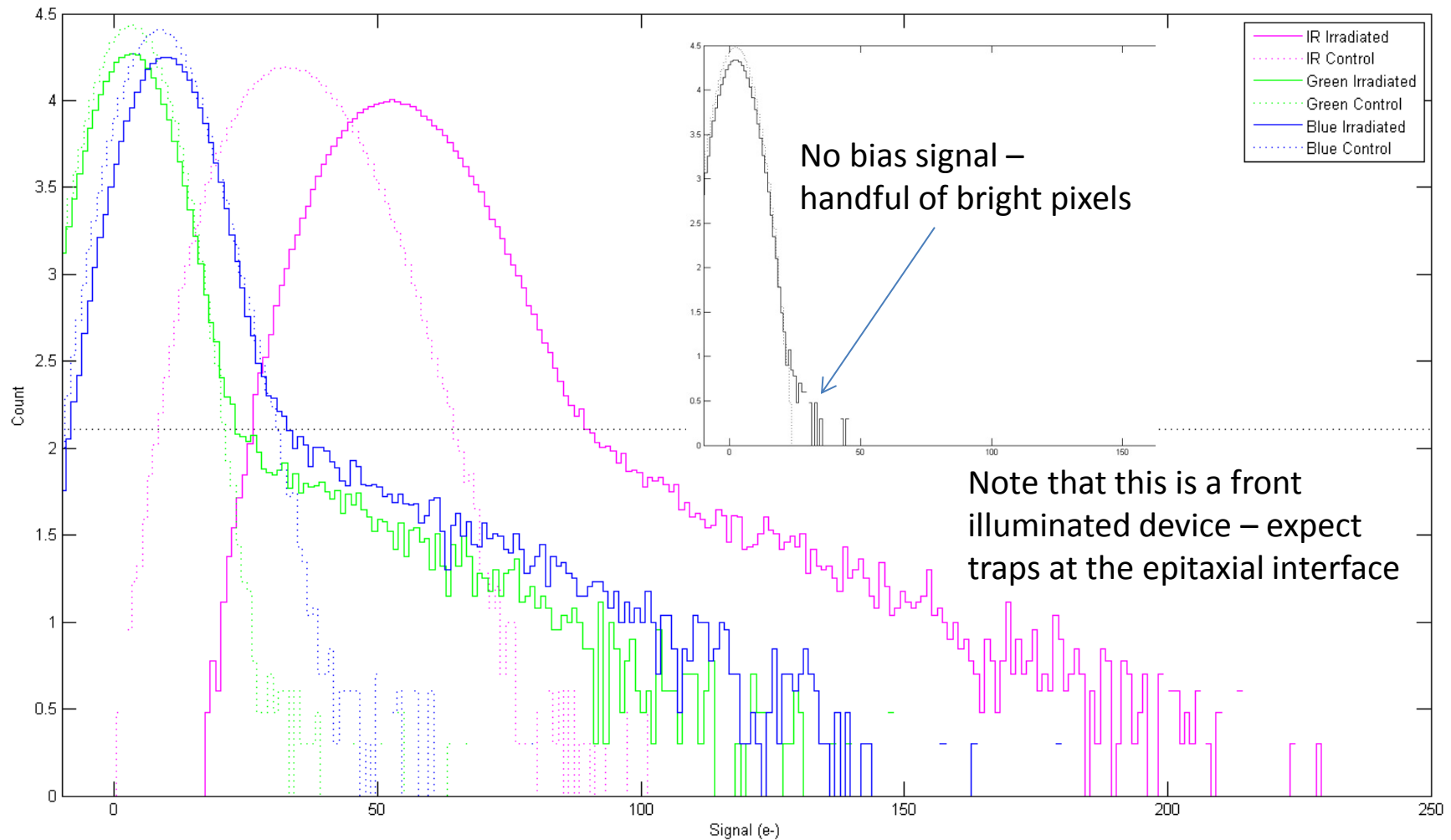
Could these slow traps in the bulk capture charge that does not get sampled and look like reduced QE as a function of radiation damage? It is unlikely this has ever been tested!



Persistence frame – front illuminated

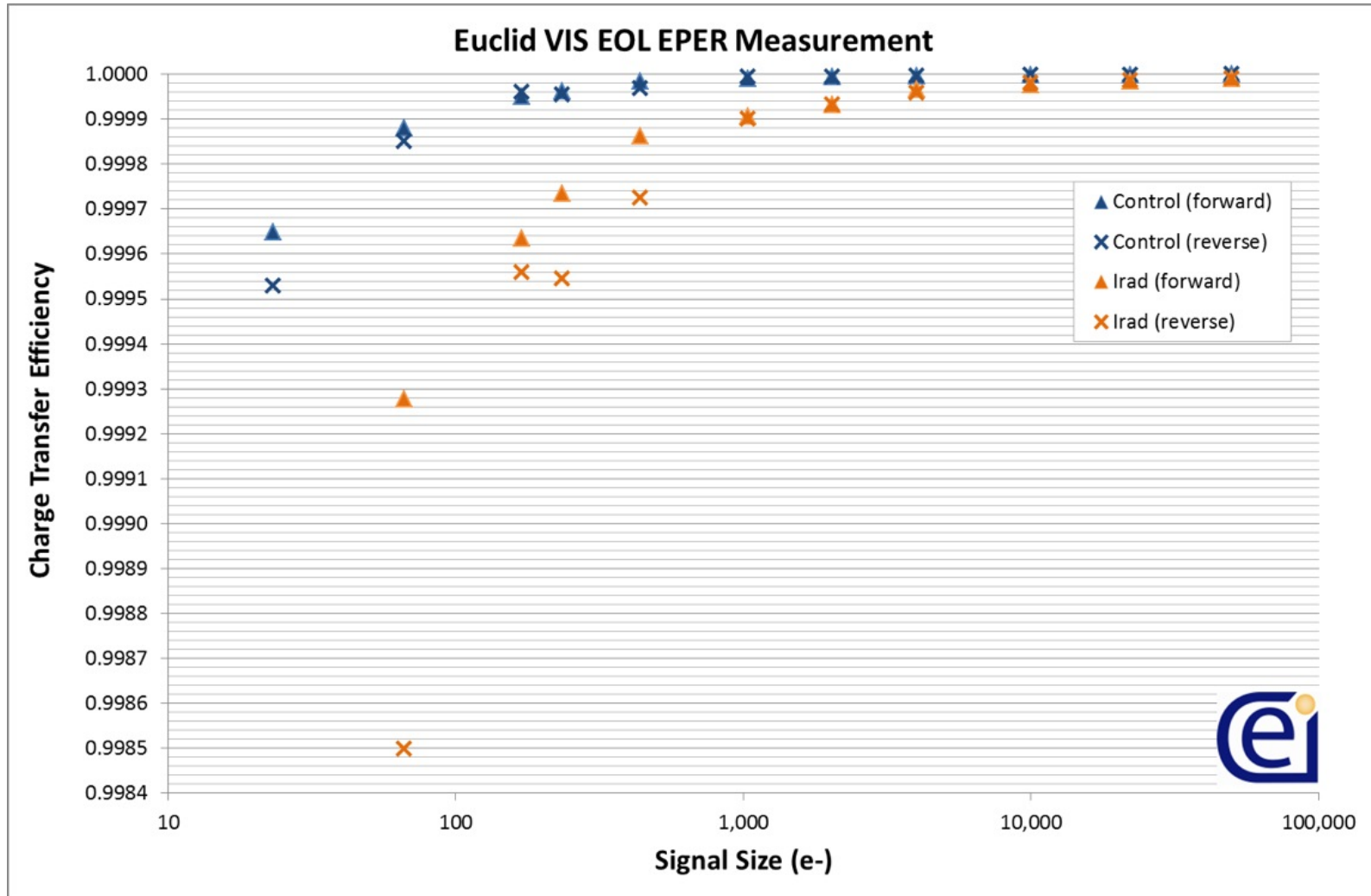


Histogram of persistent signals

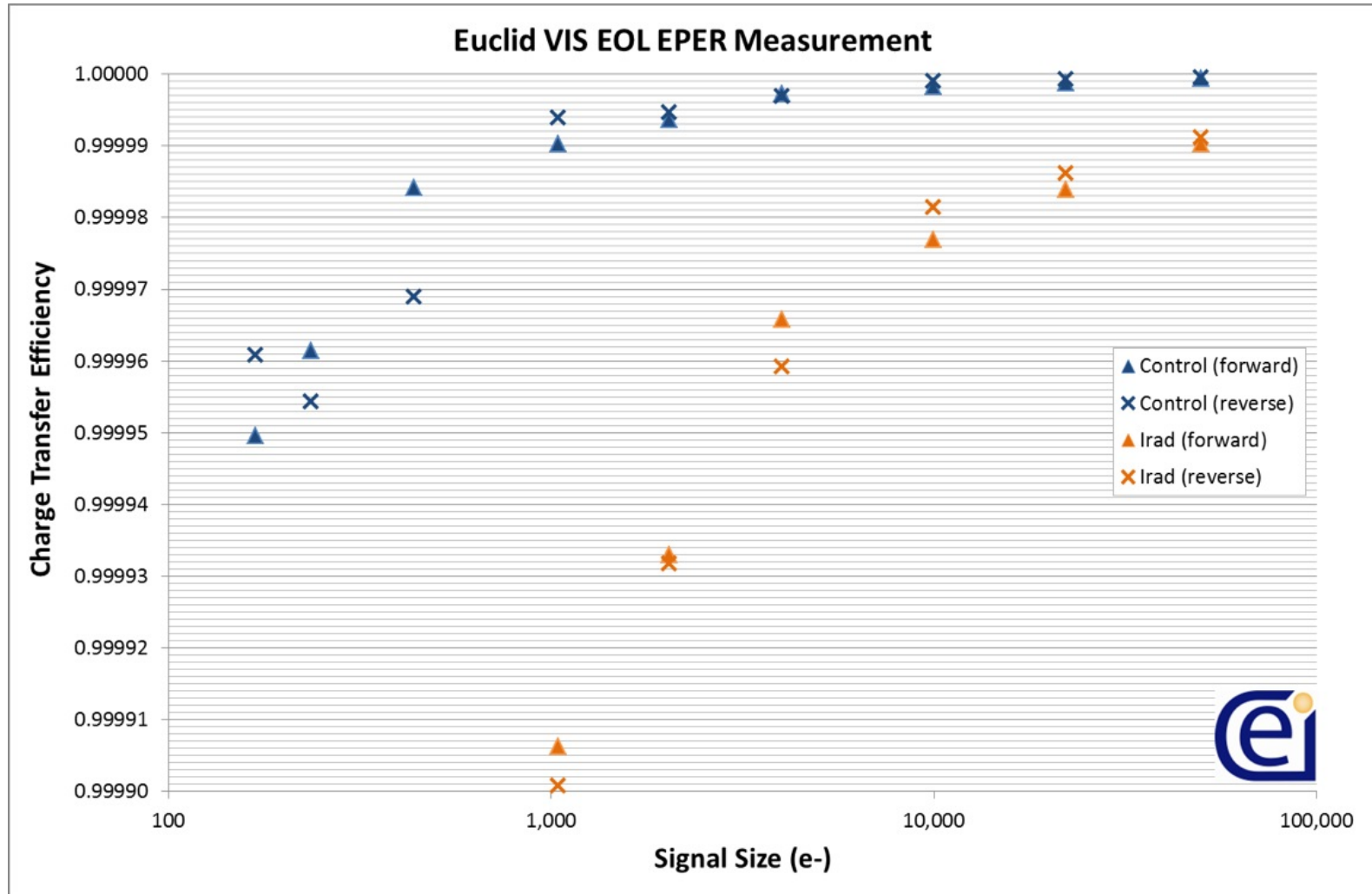


Fast trap CTI

Fast Traps CTE vs. Signal Size



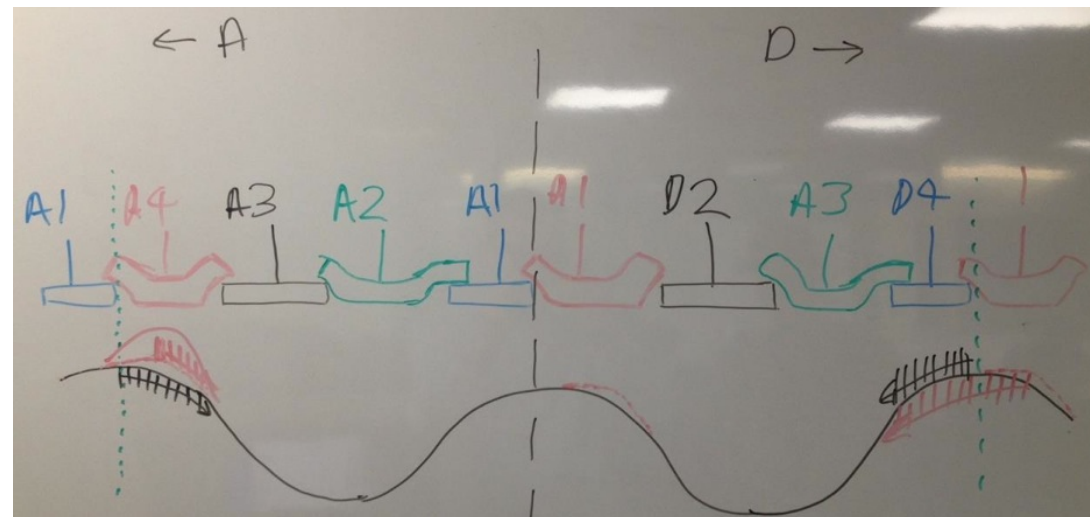
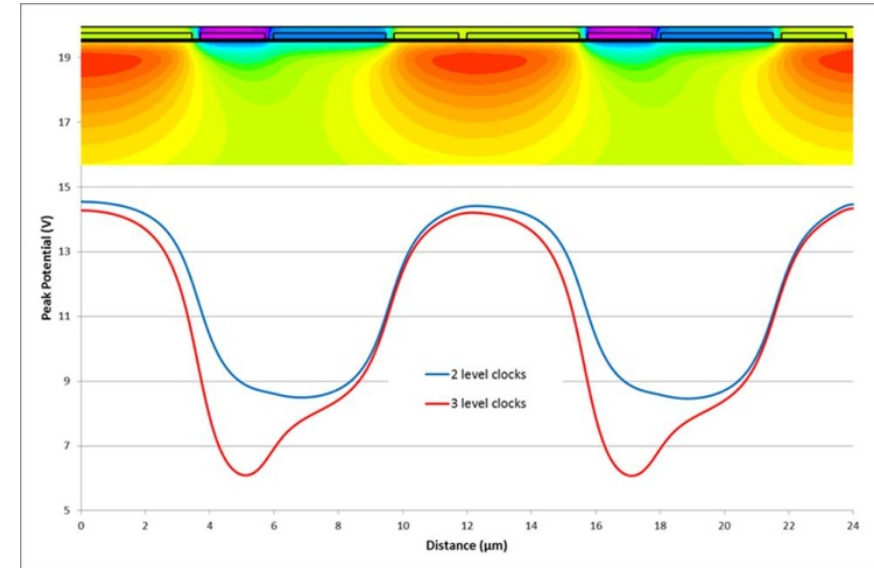
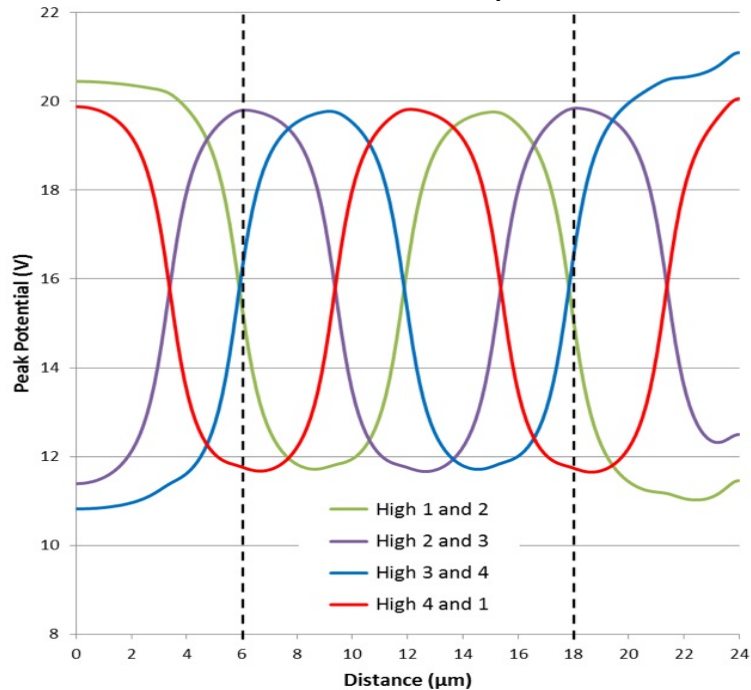
Fast Traps CTE vs. Signal Size



Could there be directional CTE?

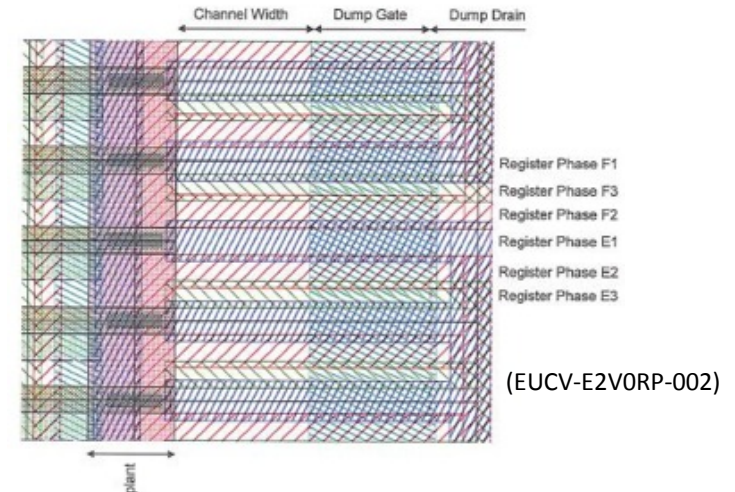
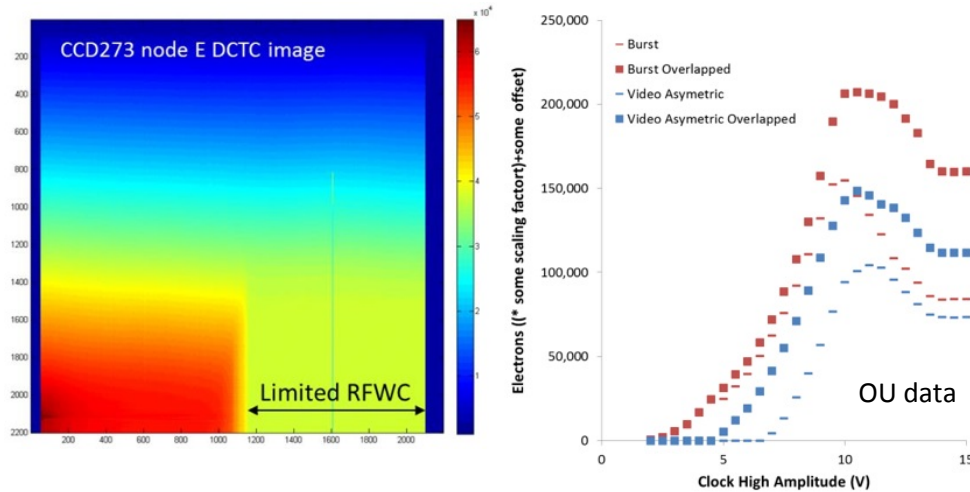


Does the 4-phase architecture build in tri-level clocking? But only in one half of the split-frame as the electrode pattern is not symmetrical about the middle. This may explain why 2nd tri-level measurements with the CCD273 in the D-section did not show as much promise as the 1st measurements in the only A-section of the CCD204 - it's already there!



Pre-development device issues

Register Well Capacity – 1



CCD273 Microscope Images

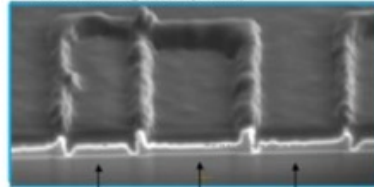


SEM Images of a 10401 batch CCD273 Readout Register (optical)



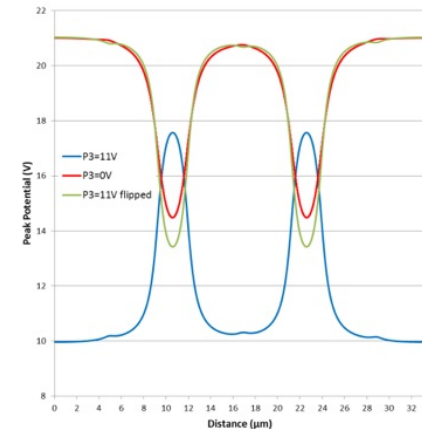
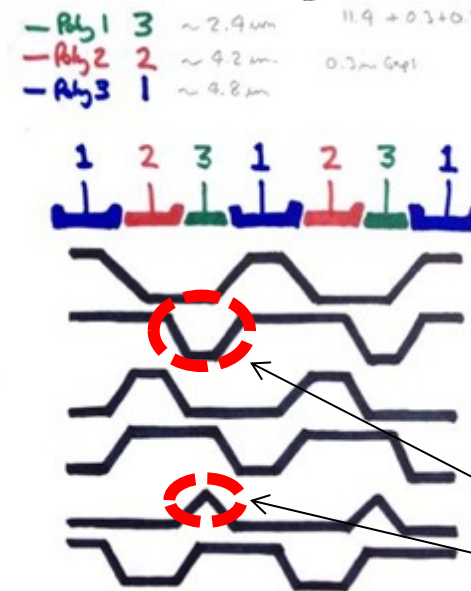
(EUCV-E2VORP-017)

Readout Register (SEM)

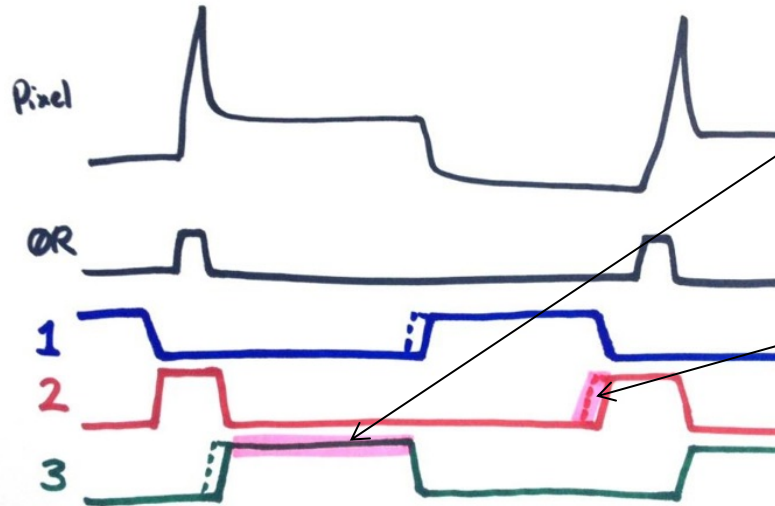


Poly 1 Poly 3 Poly 2

Figure 13 SEM Images of the CCD273 Readout Register (provided by the OU)



Register Well Capacity – 2



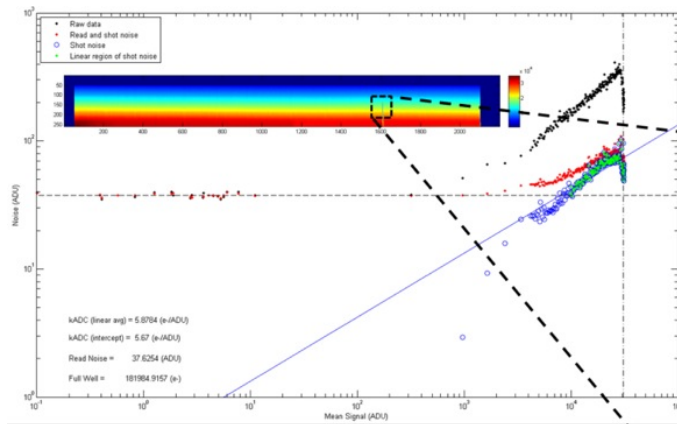
Register full well is limited by potential well formed under R3 due to the poly-1 over-etch – it is physically smaller than R1 and R2

Register full well can also be limited by the barrier formed by R3 if 100% overlaps used

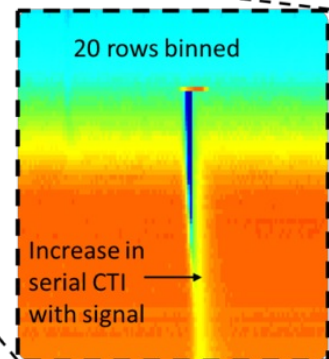
Back in June 2011



Best RFWC by code mistake



Register full well < 200k e⁻



~~Row-binned DCTC Method appears to under-measure the register well capacity. New method being developed..~~

Neil Murray , Euclid CCDWG#8

10th July 2013

Register Well Capacity – 3



EUCLID CCD273

Front-Illuminated Electro-Optical Test Report

Document: EUCV-E2V-RP-017
Issue: 1
Page: 21/57
Date: 5th April 2012

5.3.4 Register Pixel Full-Well Capacity

Register Pixel Full-Well Capacity is analysed using both SatCTE and SatLin analysis tools (described in [AD3]). As for Image Pixel Full-Well Capacity SatCTE will be used to determine the meeting of the Register capacity specification, however SatLin results are also provided in Appendix A as agreed during the TRR.

5.3.4.1 SatCTE Results

5.3.4.1.1 11263-09-01

Amp	Register FWC (ke ⁻)	Specification	Pass/Fail
E	221	>300ke ⁻	Fail
F	352		Pass
G	332		Pass
H	216		Fail

Table 5-20 11263-09-01 Register Full Well Capacity Sat CTE Results

5.3.4.1.2 11263-05-02

Amp	Register FWC (ke ⁻)	Specification	Pass/Fail
E	303	>300ke ⁻	Pass
F	207		Fail
G	241		Fail
H	319		Pass

Table 5-21 11263-05-02 Register Full Well Capacity Sat CTE Results

5.3.4.1.3 11263-10-01

Amp	Register FWC (ke ⁻)	Specification	Pass/Fail
E	258	>300ke ⁻	Fail
F	379		Pass
G	379		Pass
H	202		Fail

Table 5-22 11263-10-01 Register Full Well Capacity Sat CTE Results

5.3.4.1.4 11263-21-01

Amp	Register FWC (ke ⁻)	Specification	Pass/Fail
E	273	>300ke ⁻	Fail
F	373		Pass
G	339		Pass
H	266		Fail

Table 5-23 11263-21-01 Register Full Well Capacity Sat CTE Results

EUCLID CCD273

Front-Illuminated Electro-Optical Test Report

Document: EUCV-E2V-RP-017
Issue: 1
Page: 22/57
Date: 5th April 2012

5.3.4.1.5 11263-17-01

Amp	Register FWC (ke ⁻)	Specification	Pass/Fail
E	273	>300ke ⁻	Fail
F	373		Pass
G	339		Pass
H	266		Fail

Table 5-24 11263-17-01 Register Full Well Capacity Sat CTE Results

5.3.4.1.6 11312-05-01

Amp	Register FWC (ke ⁻)	Specification	Pass/Fail
E	233	>300ke ⁻	Fail
F	376		Pass
G	375		Pass
H	208		Fail

Table 5-25 11312-05-01 Register Full Well Capacity Sat CTE Results

5.3.4.1.7 11312-01-01

Amp	Register FWC (ke ⁻)	Specification	Pass/Fail
E	300	>300ke ⁻	Pass
F	362		Pass
G	366		Pass
H	239		Fail

Table 5-26 11312-01-01 Register Full Well Capacity Sat CTE Results

5.3.4.1.8 11312-01-02

Amp	Register FWC (ke ⁻)	Specification	Pass/Fail
E	365	>300ke ⁻	Pass
F	336		Pass
G	266		Fail
H	368		Pass

Table 5-27 11312-01-02 Register Full Well Capacity Sat CTE Results

5.3.4.2 Conclusion

None of the tested devices demonstrate compliance to the specification defined in [AD1] for all Amp. For Chip_01 devices (BBBBB-WW-01) the out of specification performance is seen on Amps E and with the exception of AmpE on device 11312-01-01 that just meets the minimum limit of 300ke⁻. For the Chip_02 device (11263-05-02) the out of specification performance is seen on Amps F and G. This out of specification performance is believed to be due to charge spilling back from the register and into the image area during serial transfer. This phenomenon is currently being investigated by e2v and discussed as part of the Euclid Working Group.

-01 devices FG pass spec in middle of wafer

-02 devices EH pass spec in middle of wafer

Variation could be attributed plasma etch charging to be fixed in future devices

Register Back-Spill

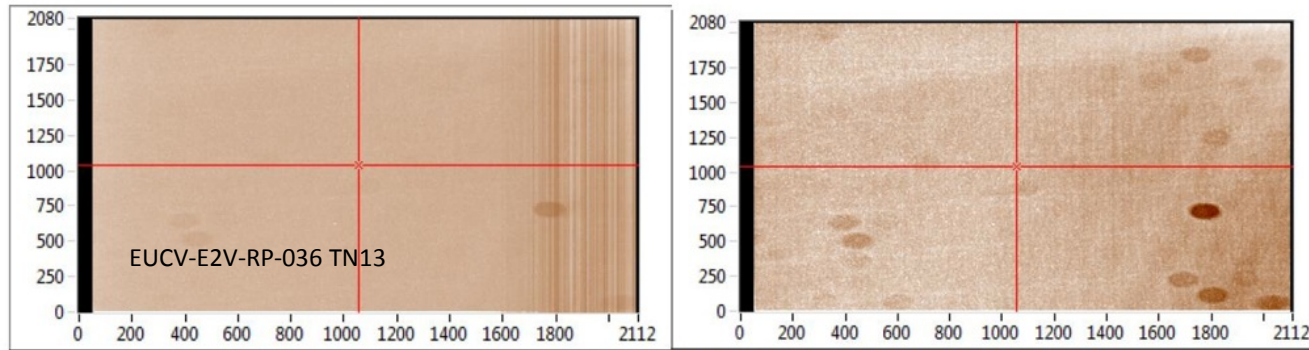


Figure 2 Frame before image spill (Left with $TG_L = -1V$ and Right with $TG_L = -2V$)

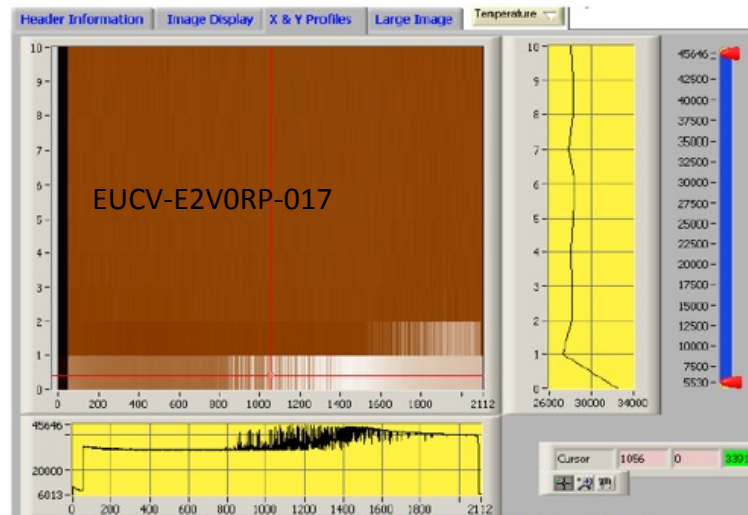
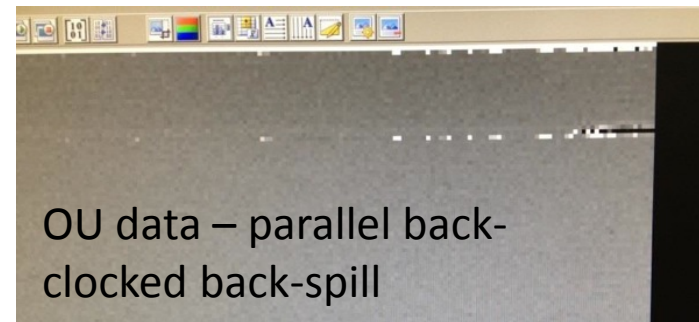


Figure 9 First image row profile with long integration time

Variation of potential along the Transfer Gate allows a full-ish register to spill some charge back into the lower rows of the image array. ICD was updated to apply TG low of -1V to compensate for any potential variations. Variation could be attributed plasma etch charging to be fixed in future devices



Output Imbalance



		Responsivity ($\mu\text{V/e-}$)				Noise (e- r.m.s.)			
		E	F	G	H				
JG-OU	11263-05-01	8.52	8.19	8.33	8.64	5.7	5.6	5.5	2.4
	11263-09-01	8.91	8.5	8.68	8.95	5.6	5.4	5.2	5.7
DW-MSSL	11263-10-01	7.67	7.51	7.43	7.7	7.7	26.9	24.3	6.6
PV-ESA	11263-17-01	8.44	8	8.03	8.62	5.7	5.5	5.3	5.7
JG-OU	11263-21-01	8.28	7.93	8.27	8.35	5.6	5.6	5.1	5.8
NM-OU	11263-05-02								
	11312-01-01	8.16	8.02	8.23	8.54	5.8	5.6	5.4	5.7
	11312-01-02	7.89	8.23	8.35	8.2	5.5	6	5.5	5.9
EA-OU	10401-17-02								

Variation in output circuit responsivities and noise attributed to plasma etch charging of electrode structures. Need to bias separate pairs of amplifiers per device for optimal performance. LAM etch process to fix this in future devices.

EUCLID CCD273
Pre-Development Phase Back-Illuminated Detailed Tests Report
Document: EUCLID-CCD-036
Issue: 1
Page: 40/60
Date: 2011/2012

5.2.15.1.5 11312-17-01

Output	V_{DD} (V)	V_{DD} (V)	R_{L} (k Ω)	Power Dissipation (mW)
E	23.3	20	10	6.5
F	22.4	20	10	8.1
G	22.1	20	10	8.6
H	23.1	20	10	6.7
Total				29.7

Table 5-174 11312-17-01 Static Power Dissipation

5.2.15.1.6 11312-09-01

Output	V_{DD} (V)	V_{DD} (V)	R_{L} (k Ω)	Power Dissipation (mW)
E	23.3	20	10	6.5
F	22.4	20	10	8.1
G	21.8	20	10	9.2
H	23.1	20	10	6.7
Total				31.4

Table 5-175 11312-09-01 Static Power Dissipation

5.2.15.1.7 11312-19-01

Output	V_{DD} (V)	V_{DD} (V)	R_{L} (k Ω)	Power Dissipation (mW)
E	23.3	20	10	6.5
F	22.4	20	10	8.1
G	22.1	20	10	8.6
H	22.0	20	10	6.9
Total				30.1

Table 5-176 11312-19-01 Static Power Dissipation

5.2.15.1.8 11312-22-01

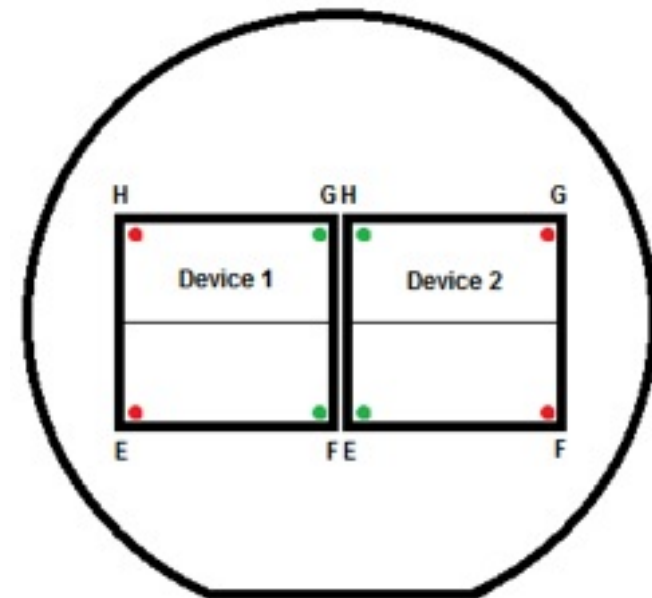
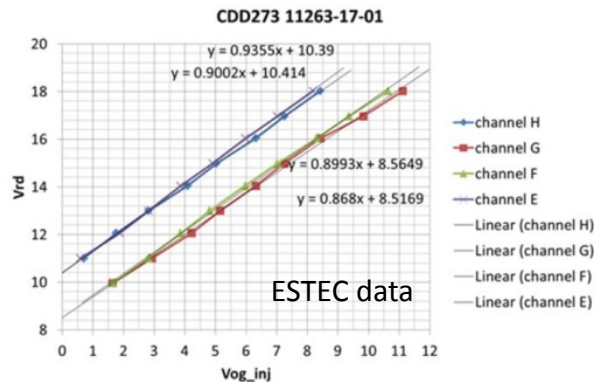
Output	V_{DD} (V)	V_{DD} (V)	R_{L} (k Ω)	Power Dissipation (mW)
E	23.3	20	10	6.5
F	22.4	20	10	8.1
G	22.2	20	10	8.4
H	23.2	20	10	6.5
Total				29.5

Table 5-177 11312-22-01 Static Power Dissipation

5.2.15.1.9 11312-23-01

Output	V_{DD} (V)	V_{DD} (V)	R_{L} (k Ω)	Power Dissipation (mW)
E	23.3	20	10	6.5
F	22.5	20	10	7.9
G	22.2	20	10	8.4
H	23.2	20	10	6.5
Total				29.1

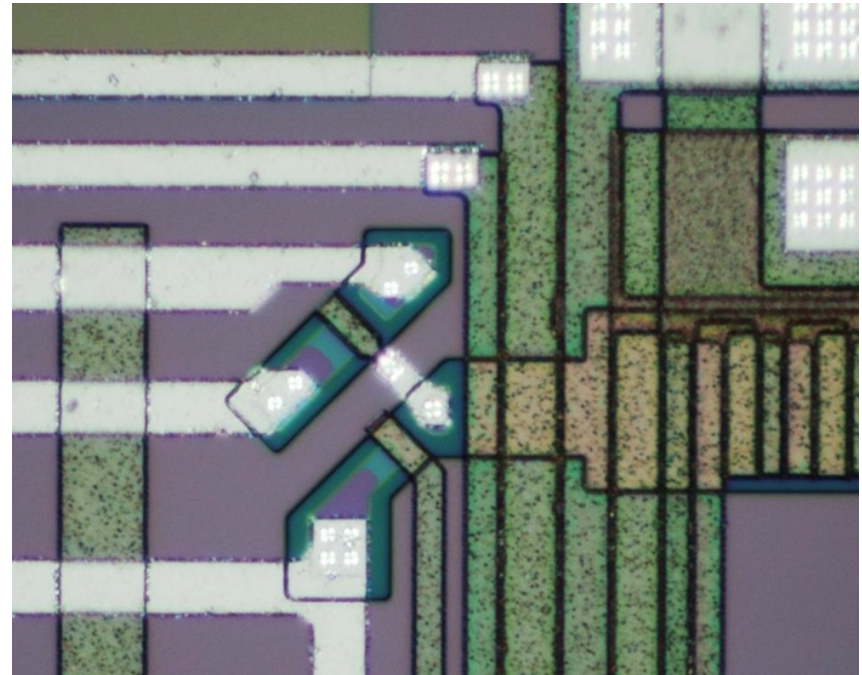
Table 5-178 11312-23-01 Static Power Dissipation



Buried Channel Levels

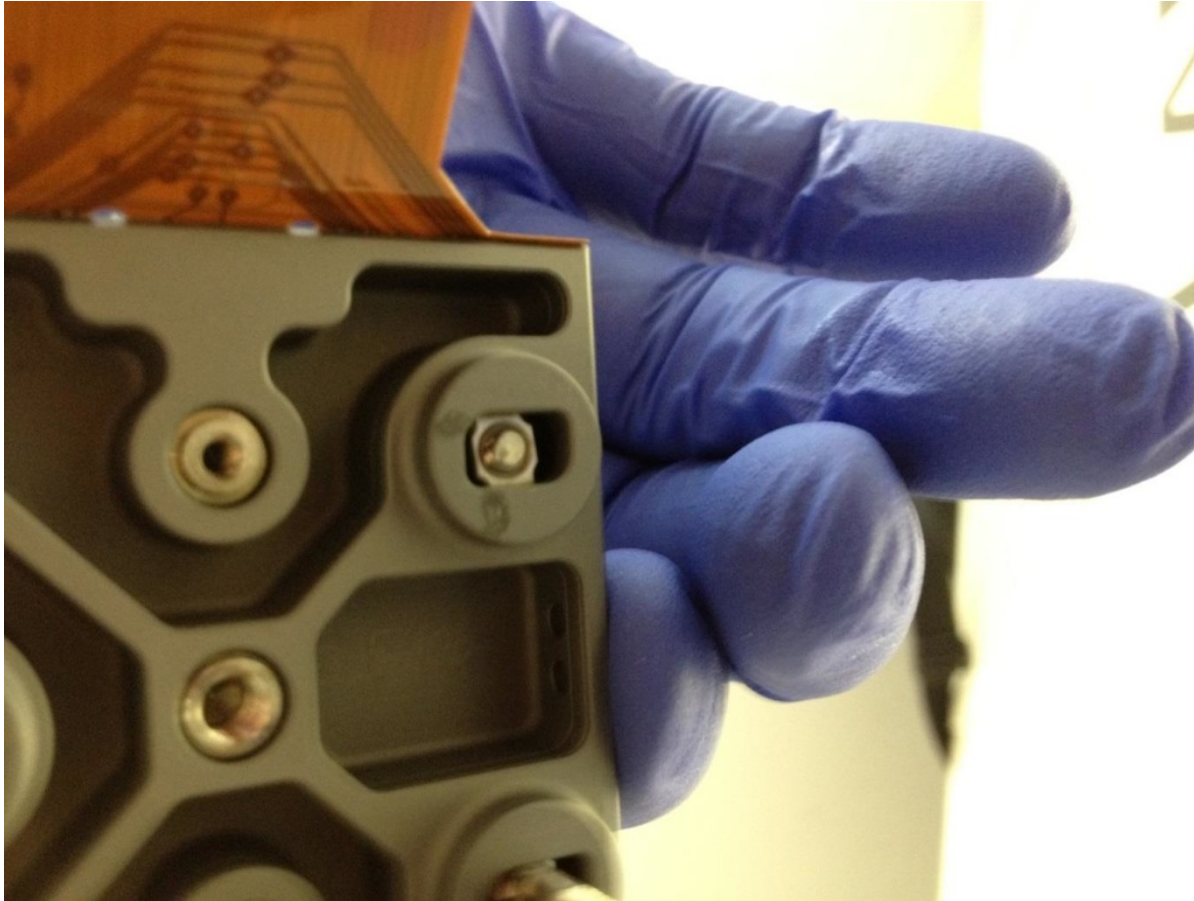


- Missing implant in output source follower (10401 batch only)
 - Higher noise floor 6-8 e- r.m.s



- Buried channel parameter was higher than expected ~ 10 V rather than 7 V. This was kept at 10V for all subsequent devices and the ICD updated to reflect changes in operating potentials

Studs shearing



- Original invar studs could shear
- I think I have the record for 2 studs sheared off 1 device and can still cool to 153K
- Studs shear during dismantling not assembly – assume nuts are vacuum welding to the studs
- Stud material has been changed to titanium

Image area asymmetry

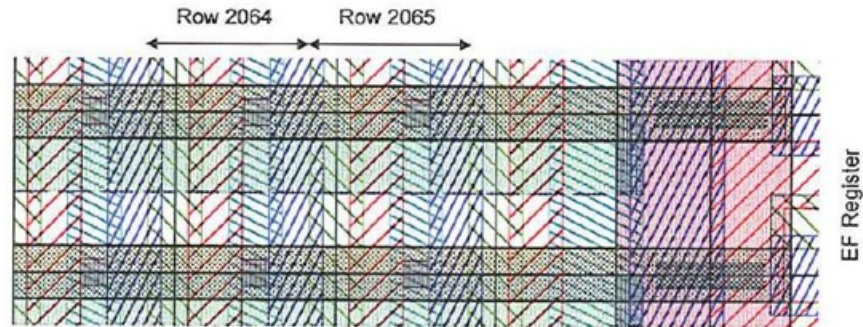
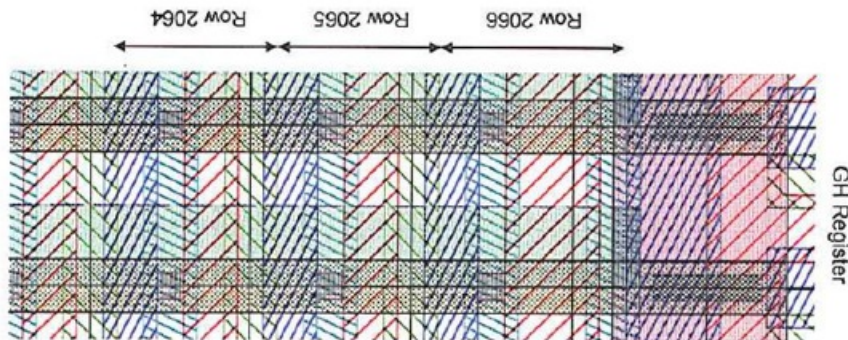


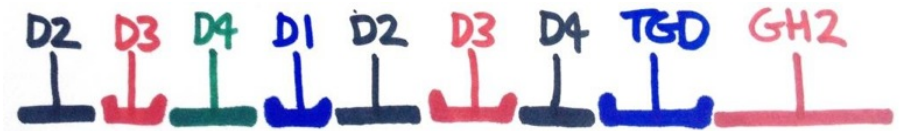
Image Phase (A4)
Image Phase (A1)
Image Phase (A2)
Image Phase (A3)
Transfer Gate (TGA)



Built in tri-level effect in this half?



Transfer Gate (TGD)
Image Phase (D4)
Image Phase (D3)
Image Phase (D2)
Image Phase (D1)
Image Phase (D4)



Edge Effects – roll off and bright row



As shown by the PR defects results, there are darker pixels in the last couple of image rows next to the charge injection structure.

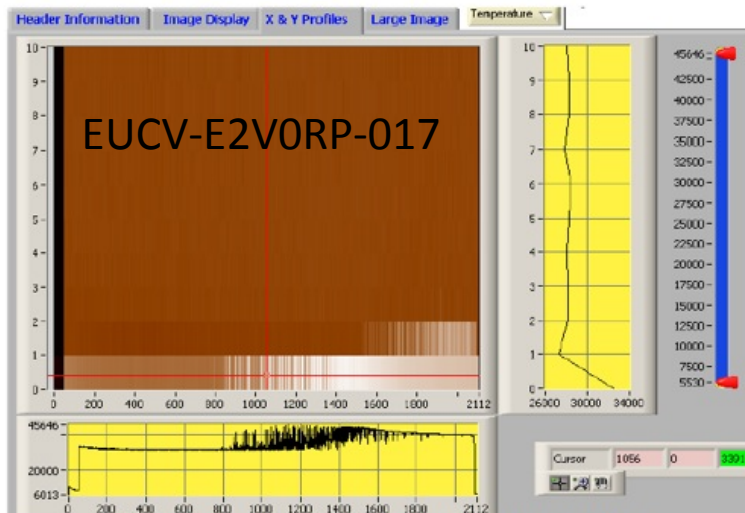
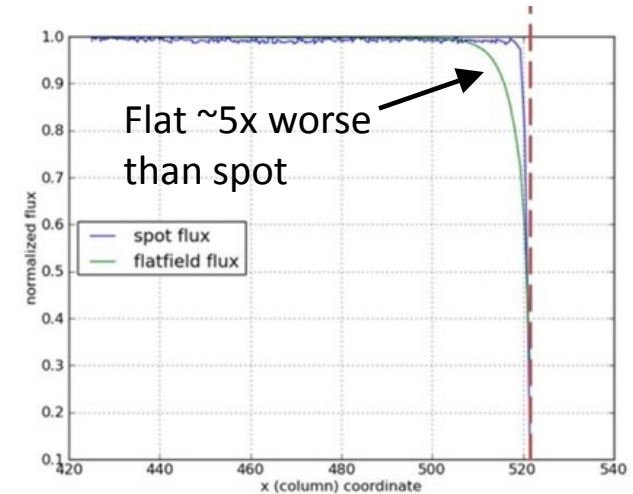
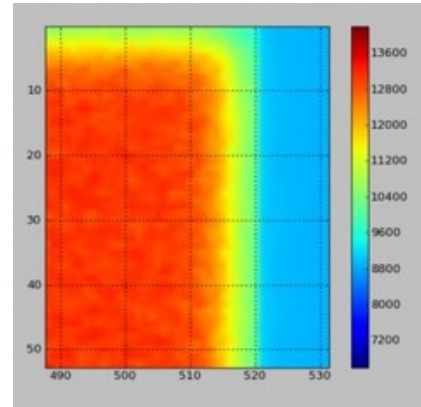
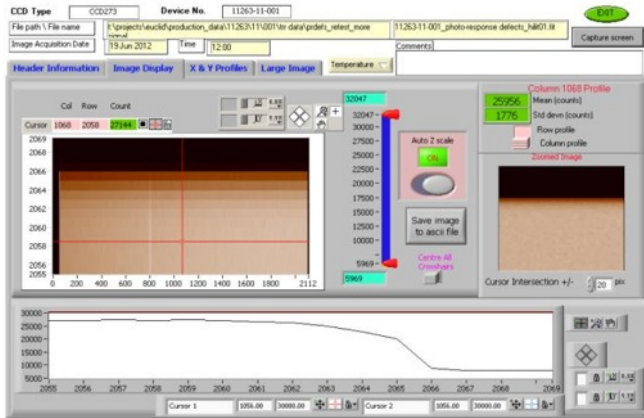
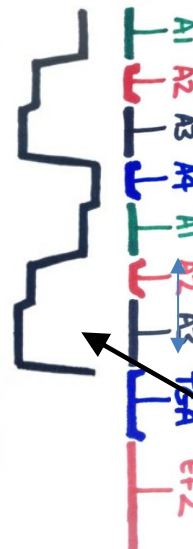


Figure 9 First image row profile with long integration time

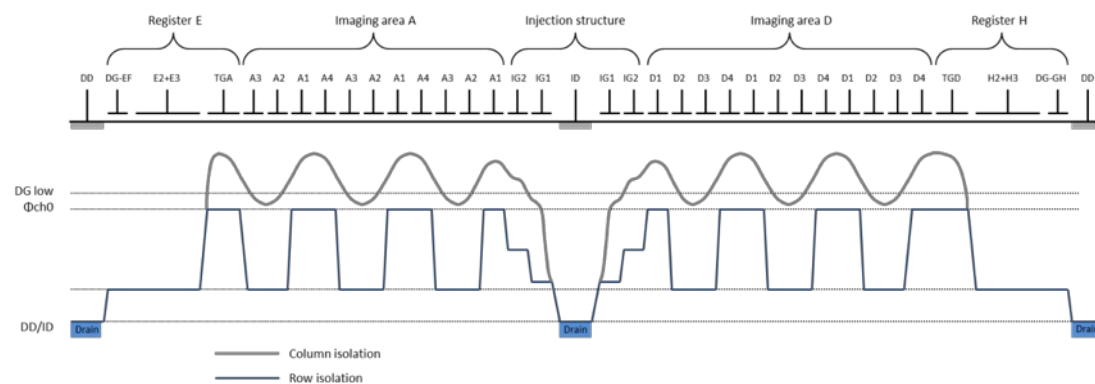
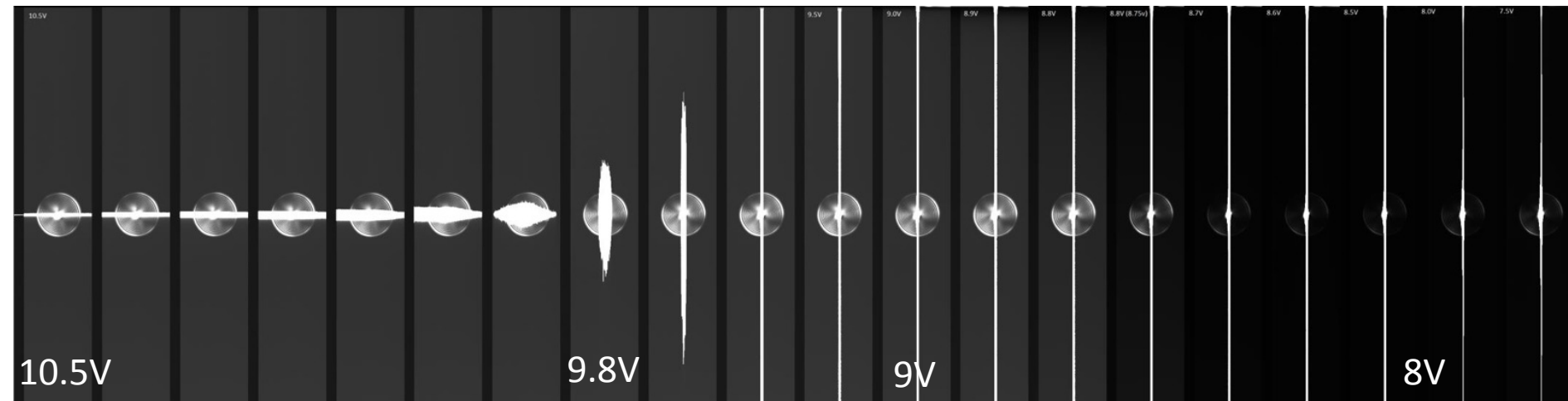


- Edge roll off in BI devices due to peripheral drain structures – not nearly as bad for point sources!
- If you want EPER from parallel overscan – parallel back clock 10 rows or so. Set IG1=14 and IG2=12, so the rows are dumped into the injection drain
- Bigger potential well in last row of A and D-section due to increased A3/D3 gate widths in last row.

Horizontal blooming

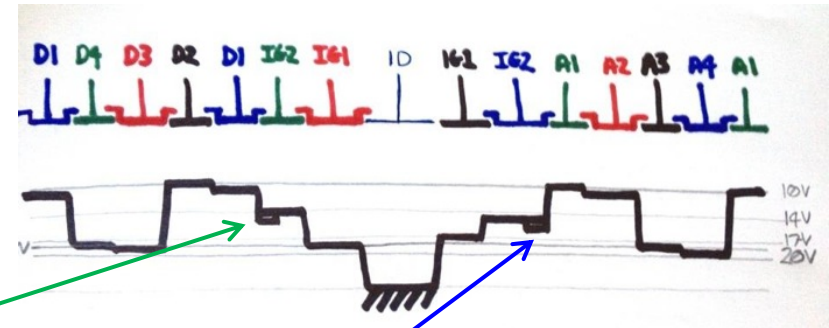
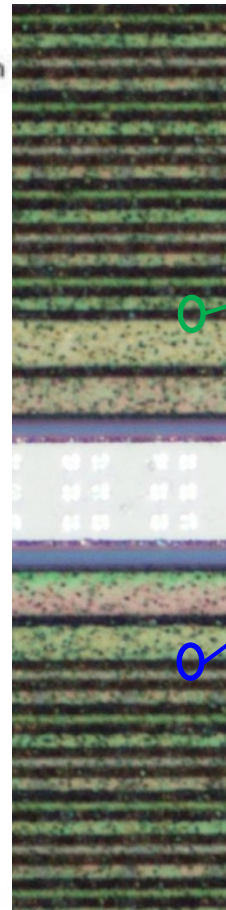
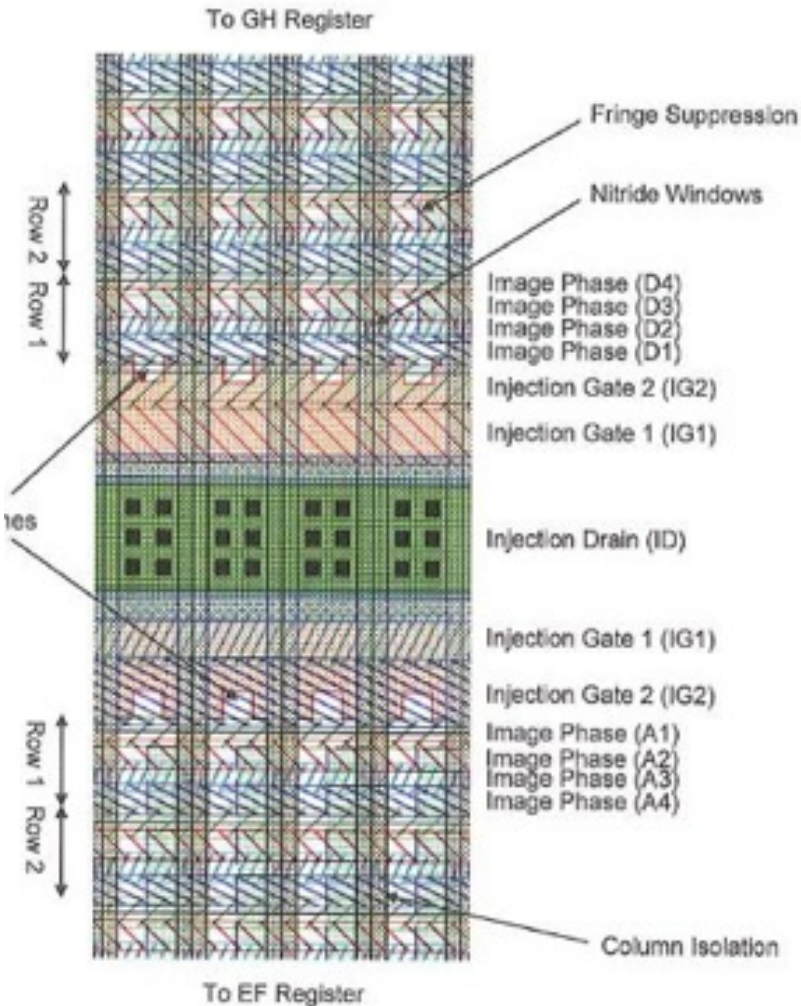


← Increasing Image high →



- With thin gates, column isolation is closer in potential to the buried channel row isolation. This can lead to horizontal blooming at nominal image clock levels.
- ICD updated to a lower level (8V) to promote traditional vertical blooming.

Notched injection asymmetry



Charge injection structure is not asymmetrical in fabrication due to the polysilicon overlaps. Possible that fringing from adjacent gates alters the notch.

A-section receives a different level of notched charge injection to the D-section.

Notched Injection Uniformity

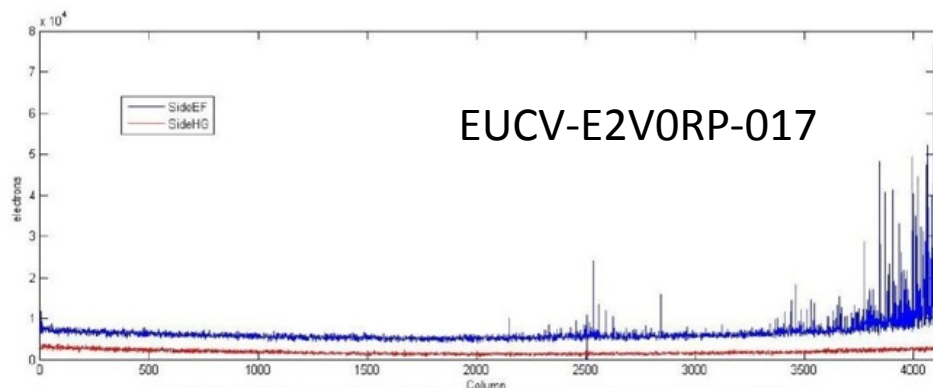


Figure 4 11312-01-01 Fixed Quantity Charge Injection Row Profile

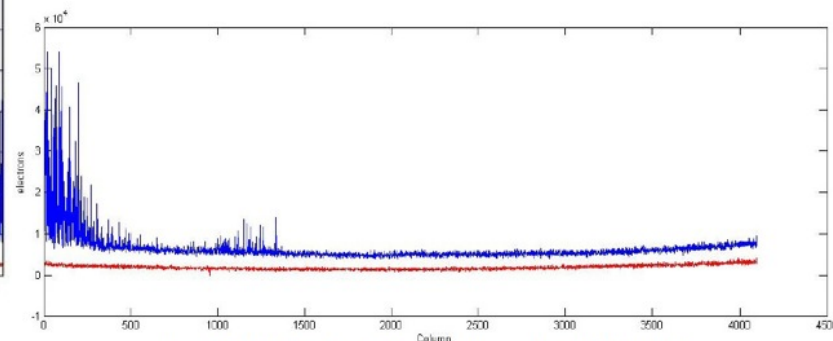
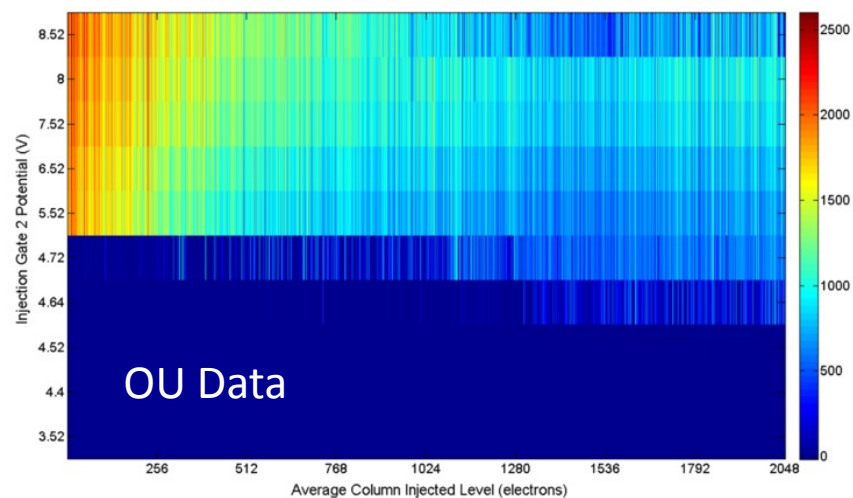
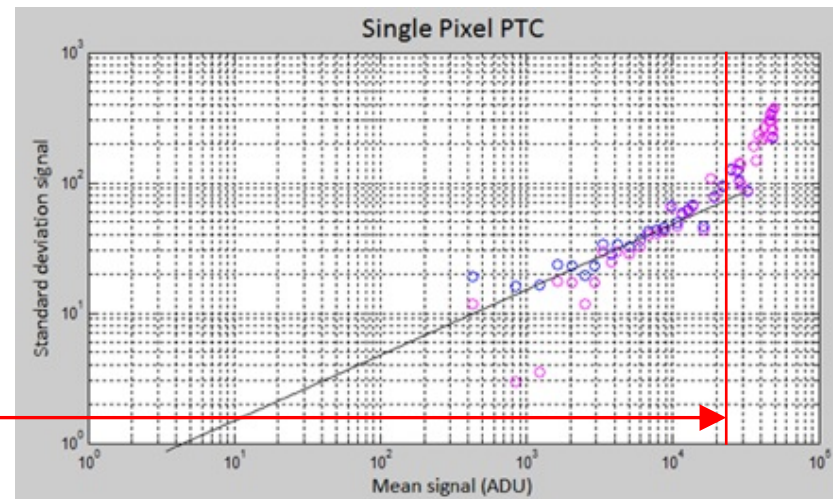
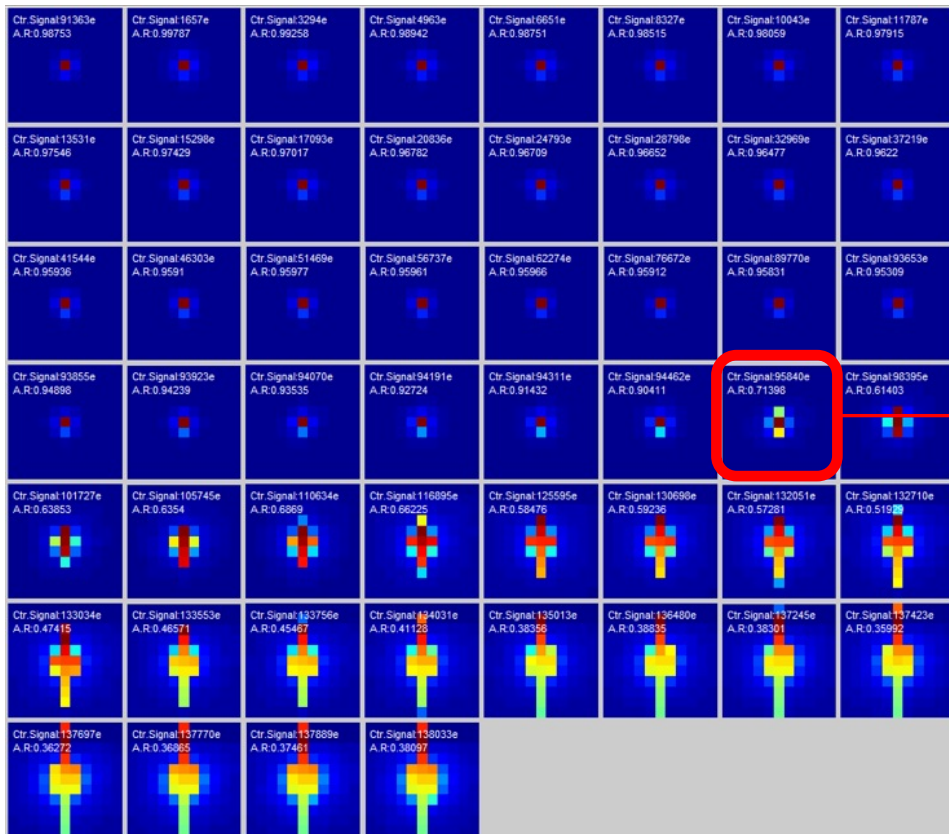


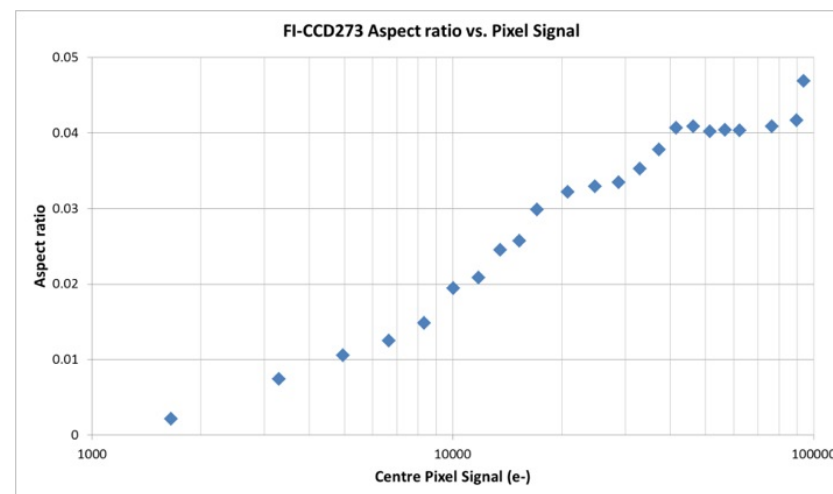
Figure 5 11312-01-02 Fixed Quantity Charge Injection Row Profile



Charge Redistribution



Here FI-CCD273 response to spot projection is shown at many signal levels. The aspect ratio begins to become visibly altered at $\sim 95 \text{ ke}^-$, however our PTC is clearly not demonstrating signs of full well.



Summary of pre-development CCD273 issues



Issue	Potential cause	Solution in pre-development devices	Subsequent device solution
Reduced register well capacity	Poly-1 over etch and plasma etch charging of register electrodes and dump gate	50% max overlap of R1 and R2. Dump gate low level negative to compensate (-3V). Two phase register clocking scheme?	Process control checks for poly-1 and new LAM etch process
Register back-spill	Plasma etch charging of transfer gate	Transfer gate low level negative to compensate (-1V)	New LAM etch process
Output circuit imbalance	Plasma etch charging of various structures	Set output circuit biases individually	New LAM etch process
Buried channel potential	Higher channel parameter implant than designed, giving Φ_{ch0} of ~10 to 11V.	ICD updated for clock and bias levels accordingly	ICD updated for clock and bias levels accordingly
(Surface channel output circuit – 10401 batch only)	(Missing source follower implant)	(Accept CCD noise floor of 6 to 8 e- r.m.s.)	(Source follower implanted)
Stud shearing	Weak material (Invar), further weakened by slot release vents. Cold welds under vacuum and shears when dismantled - NOT BY OVERTIGHTENING!	Vacuum grease studs	Redesigned studs (titanium)
Image area asymmetry	Different layout design for A and D-image sections – different polysilicon layers	Tri-level parallel clocking may dominate effect?	Tri-level parallel clocking may dominate effect?
Edge effects – roll off in BI devices	Peripheral drain structures	None	None
Edge effects – bright 1 st row	Wider gate in 1 st row by design	None	None
Horizontal blooming	Reduced column isolation with thin gates?	Reduce Image clock high from ideal to 8V	Reduce Image clock high from ideal to 8V
Notched injection asymmetry	Different layout design for A and D-sections – different polysilicon layers	None	None
Notched injection uniformity	Poly-1 over etch of IG2 in D-section and plasma etch charging of IG2	None	Process control checks for poly-1 and new LAM etch process
Charge redistribution	Increased PSF ellipticity with signal	None	None



- 1. Point Spread Function in Device Simulation**
- 2. Full Well Capacity Studies in CCD204**
- 3. Non-linear Signal Variance**

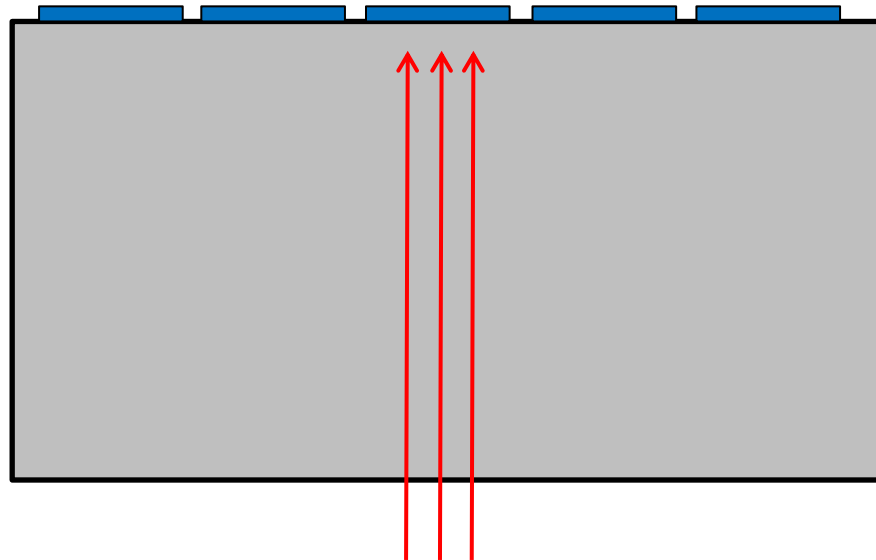
CCD WG8
10 July 2013

Konstantin Stefanov

Point Spread Function in Device Simulation



Investigate the collected charge in 5 adjacent pixels using narrow light beam illumination

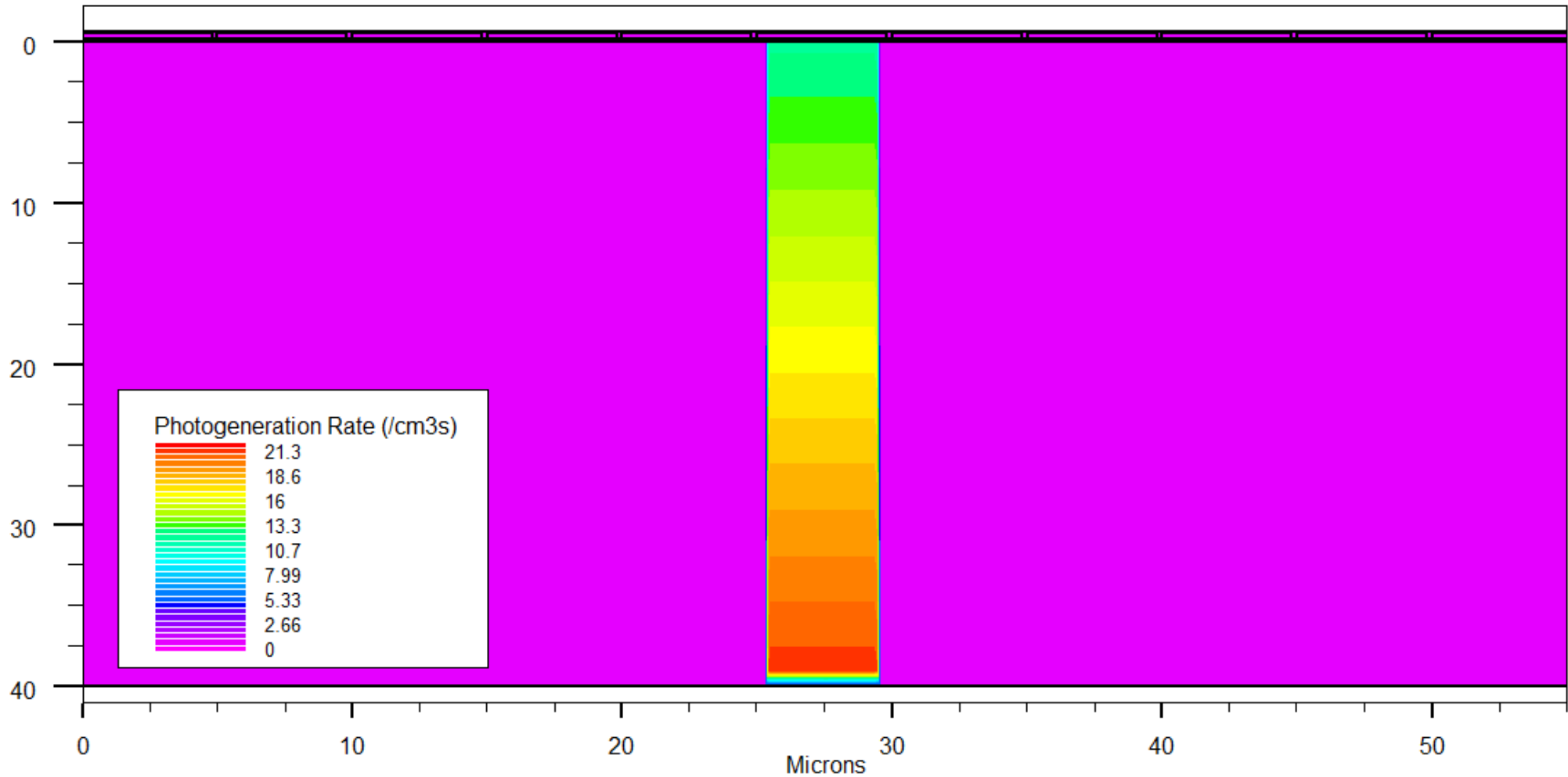


4 μm wide beam
@ 600 nm

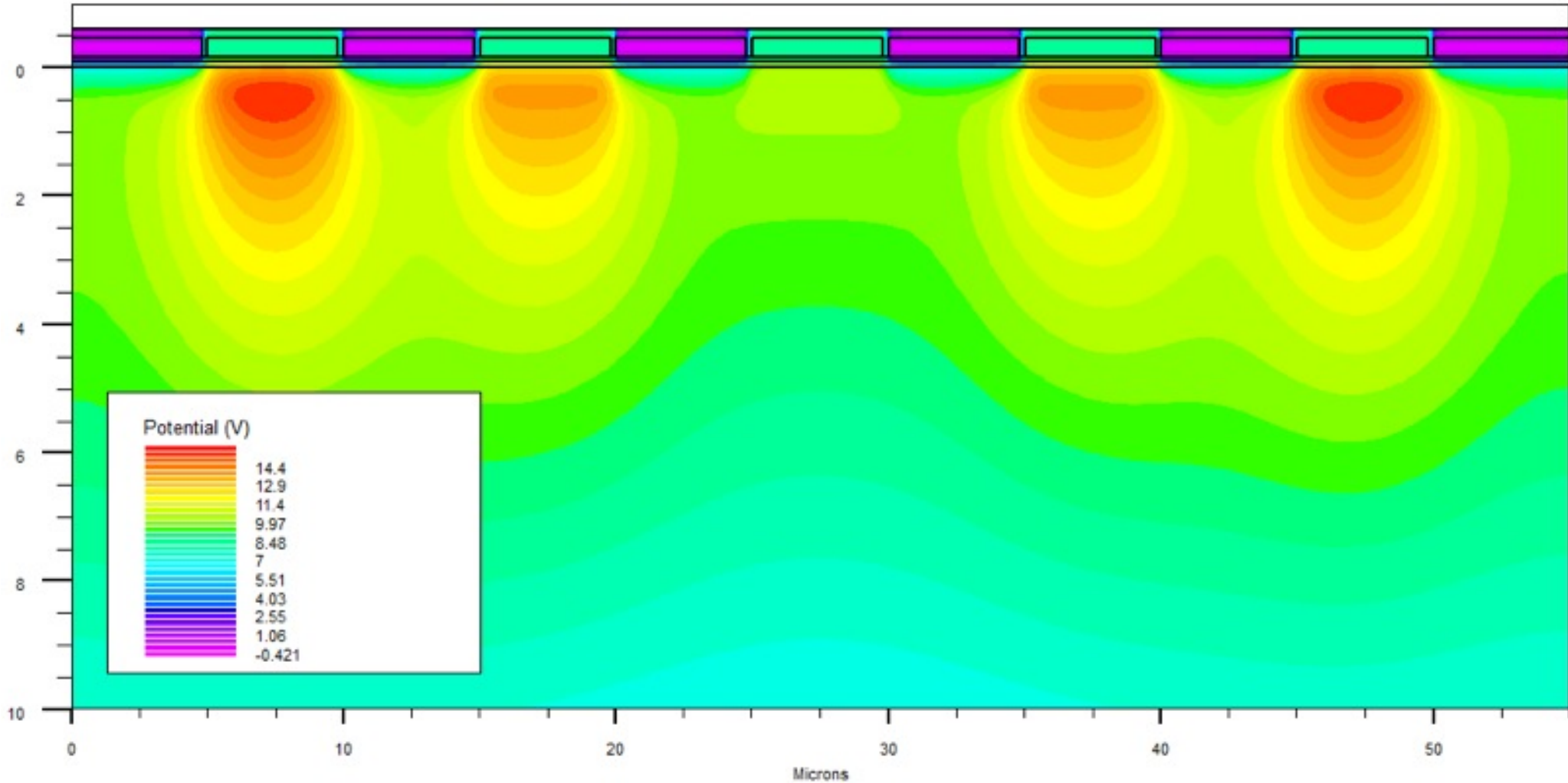
For this simulation in SILVACO:

- 10 μm pixels (5 μm + 5 μm gates)
- 40 μm thickness
- Fully depleted
- 600 nm beam from the back
- Beam width = 4 μm centred on a **potential well**
- Only beam intensity changes, integration time is fixed
- 2D simulation (1 μm thick in Z)

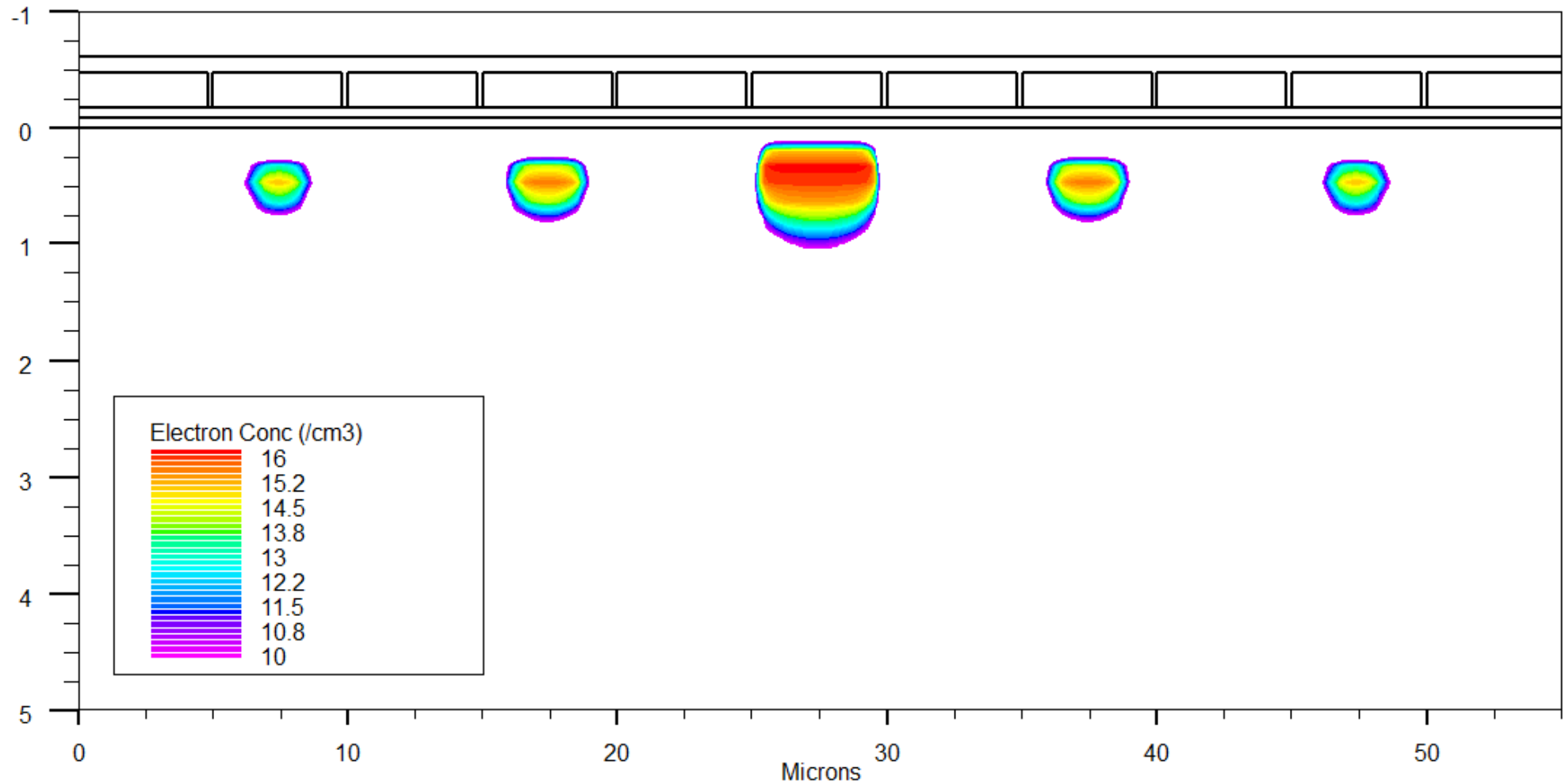
Photogeneration Rate



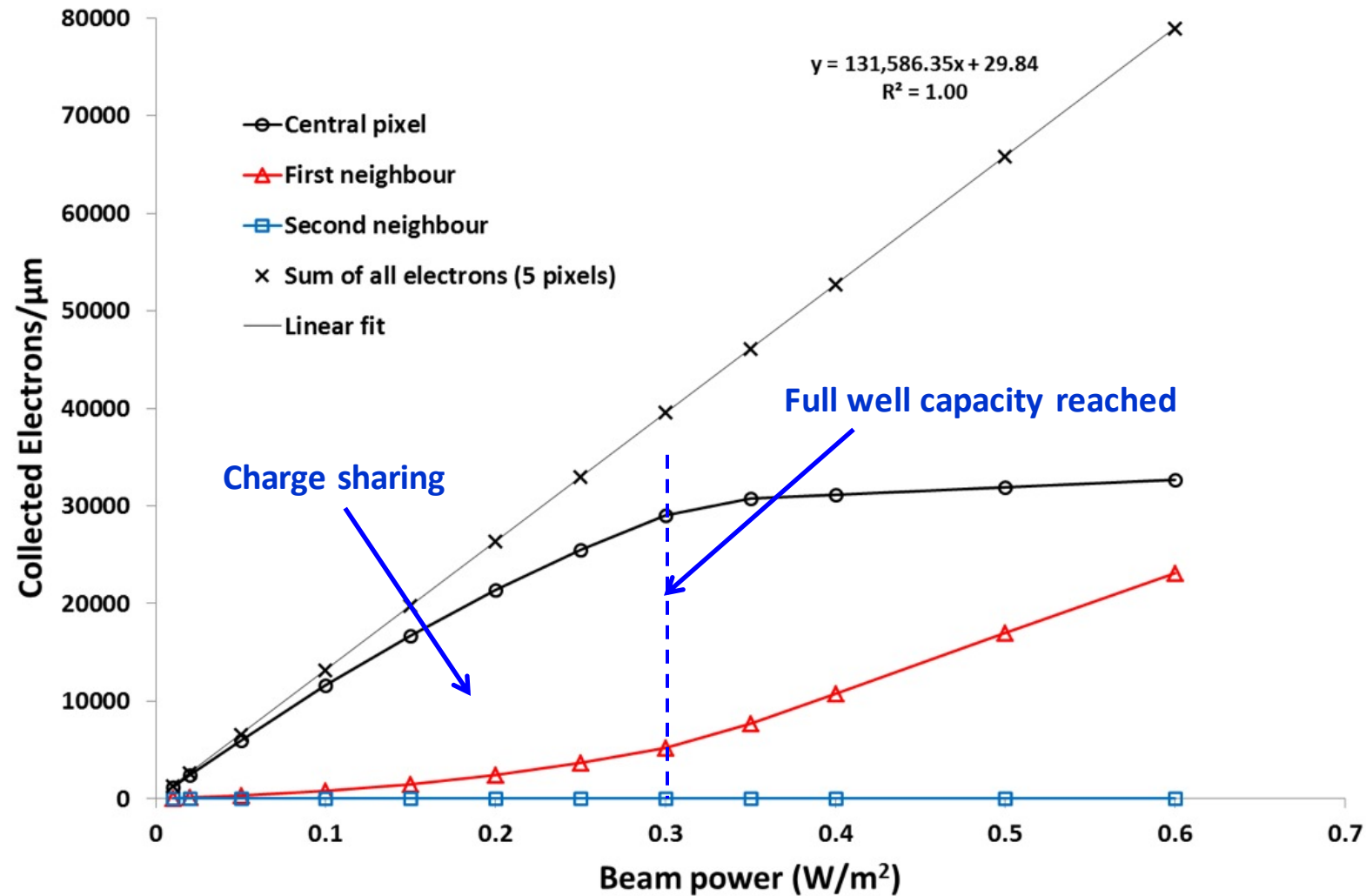
Potential



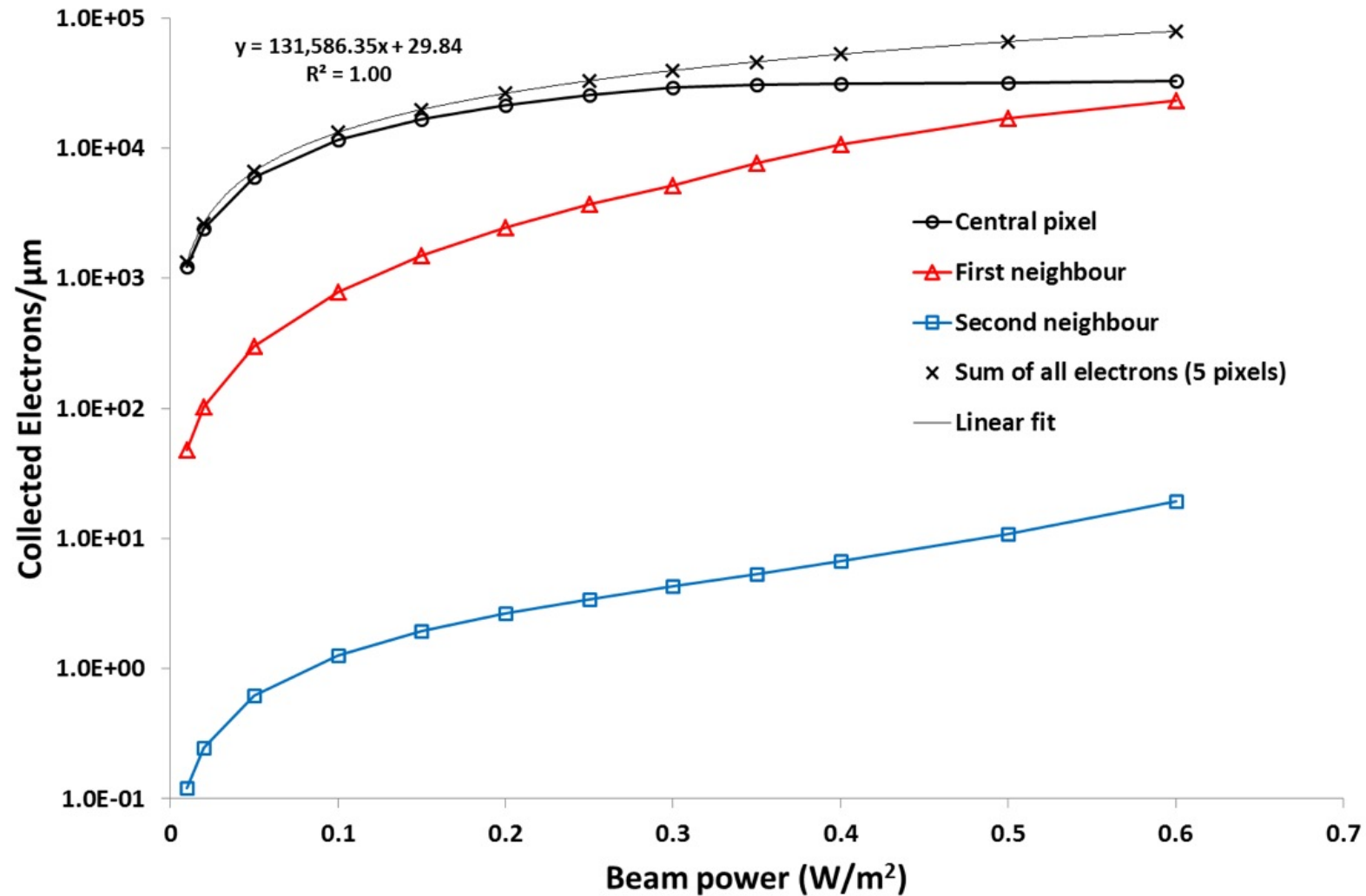
Electron Density



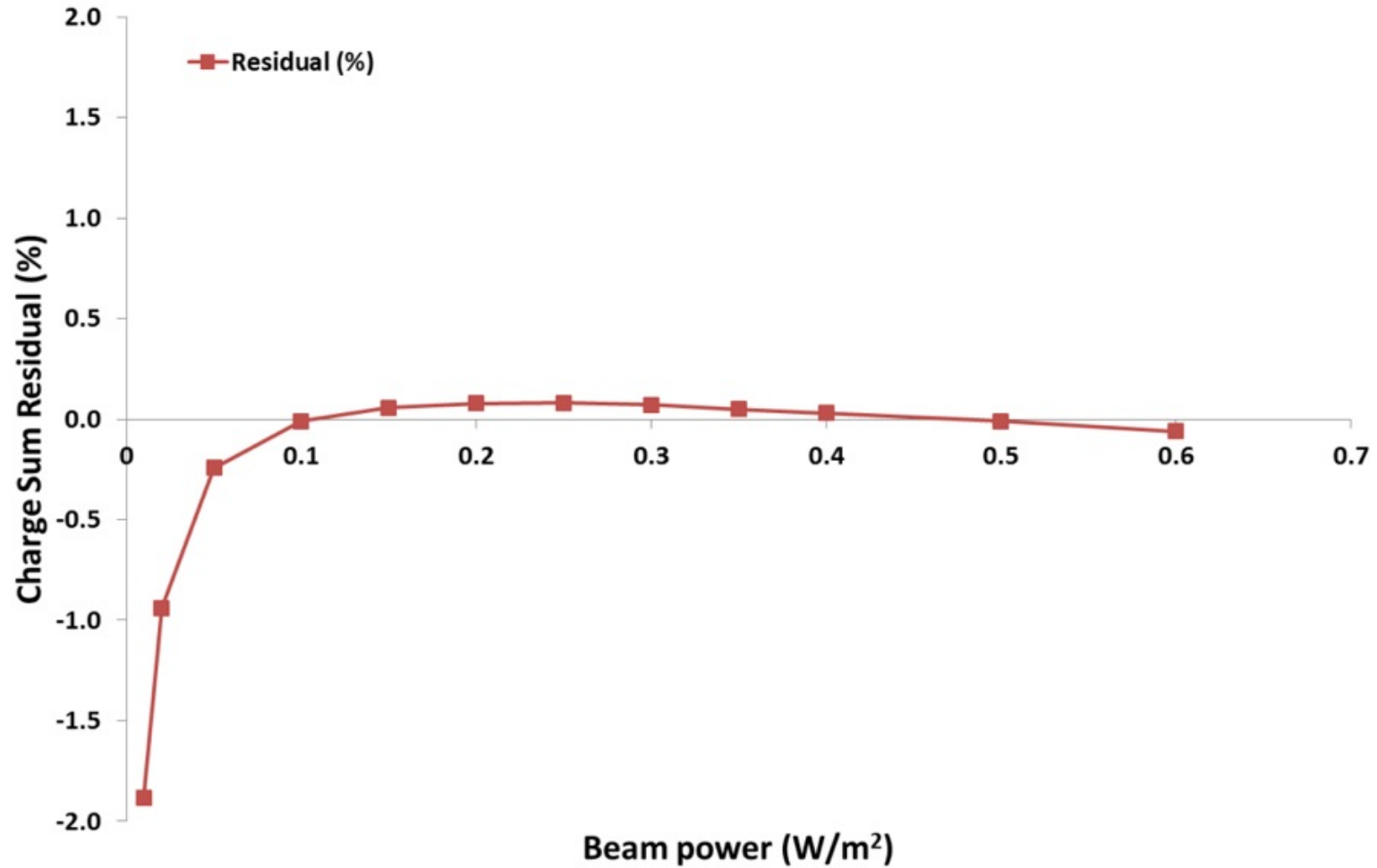
Charge Collection – Results



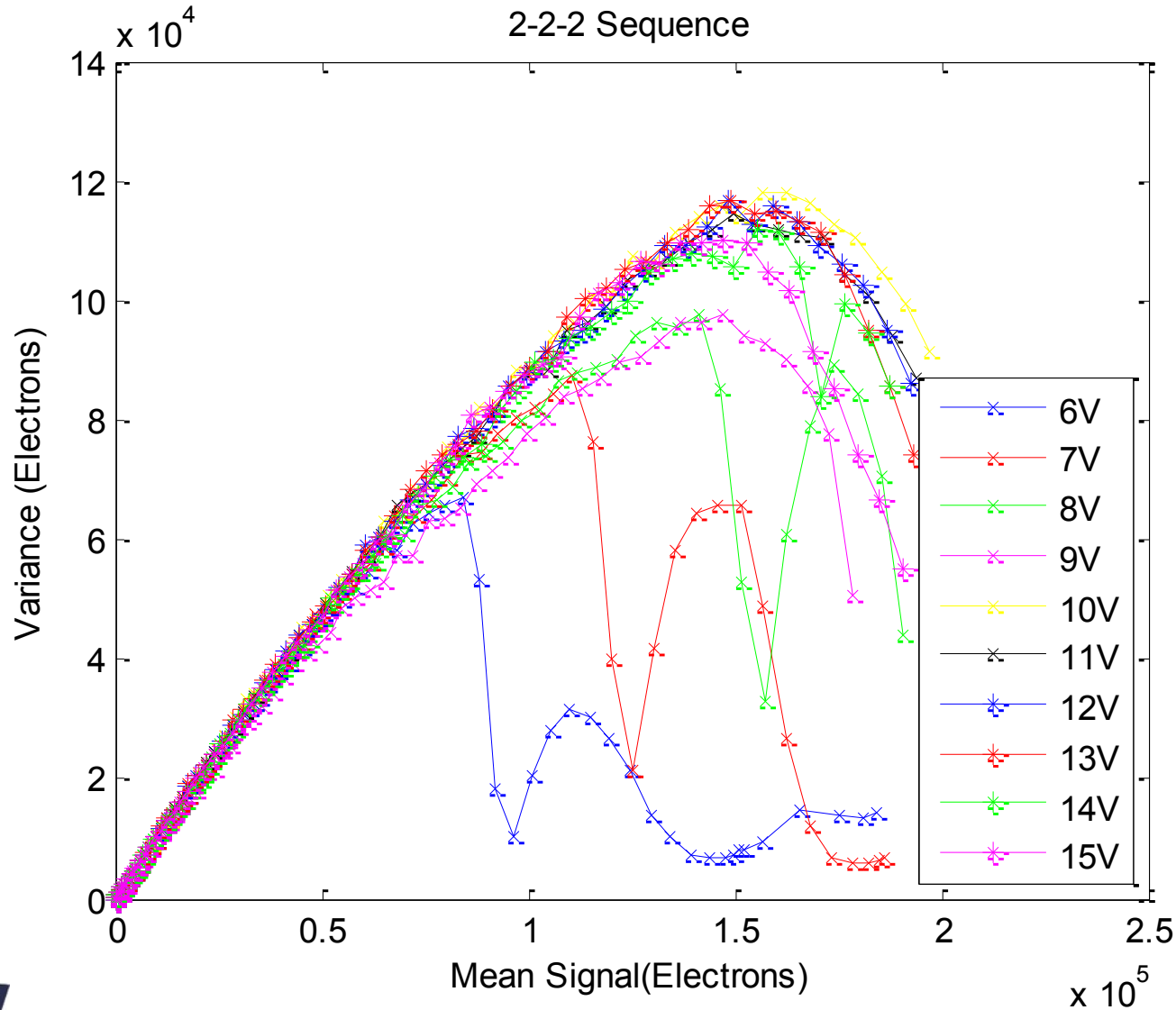
Results (Log scale)



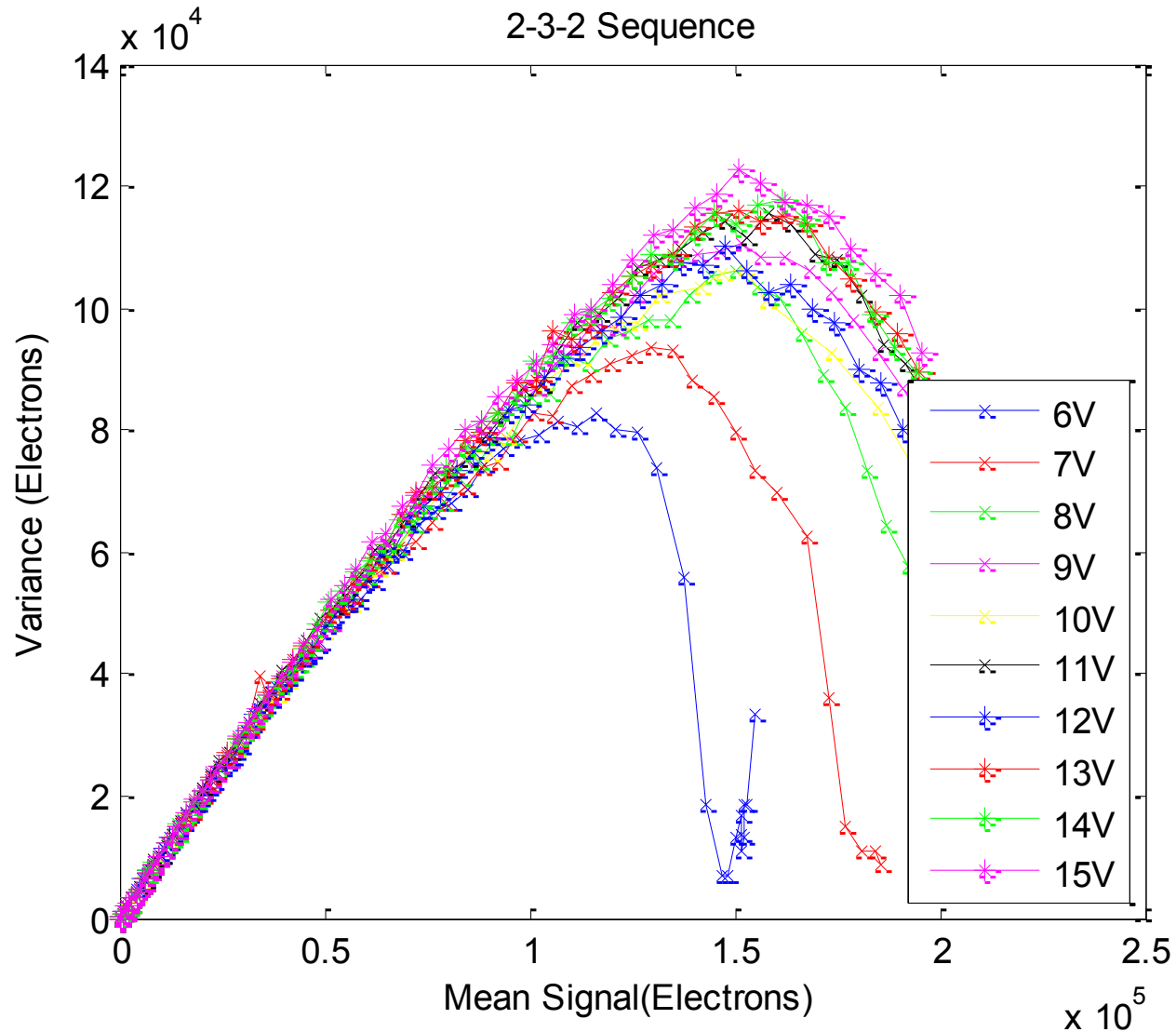
Charge Sum – Deviation from Linearity



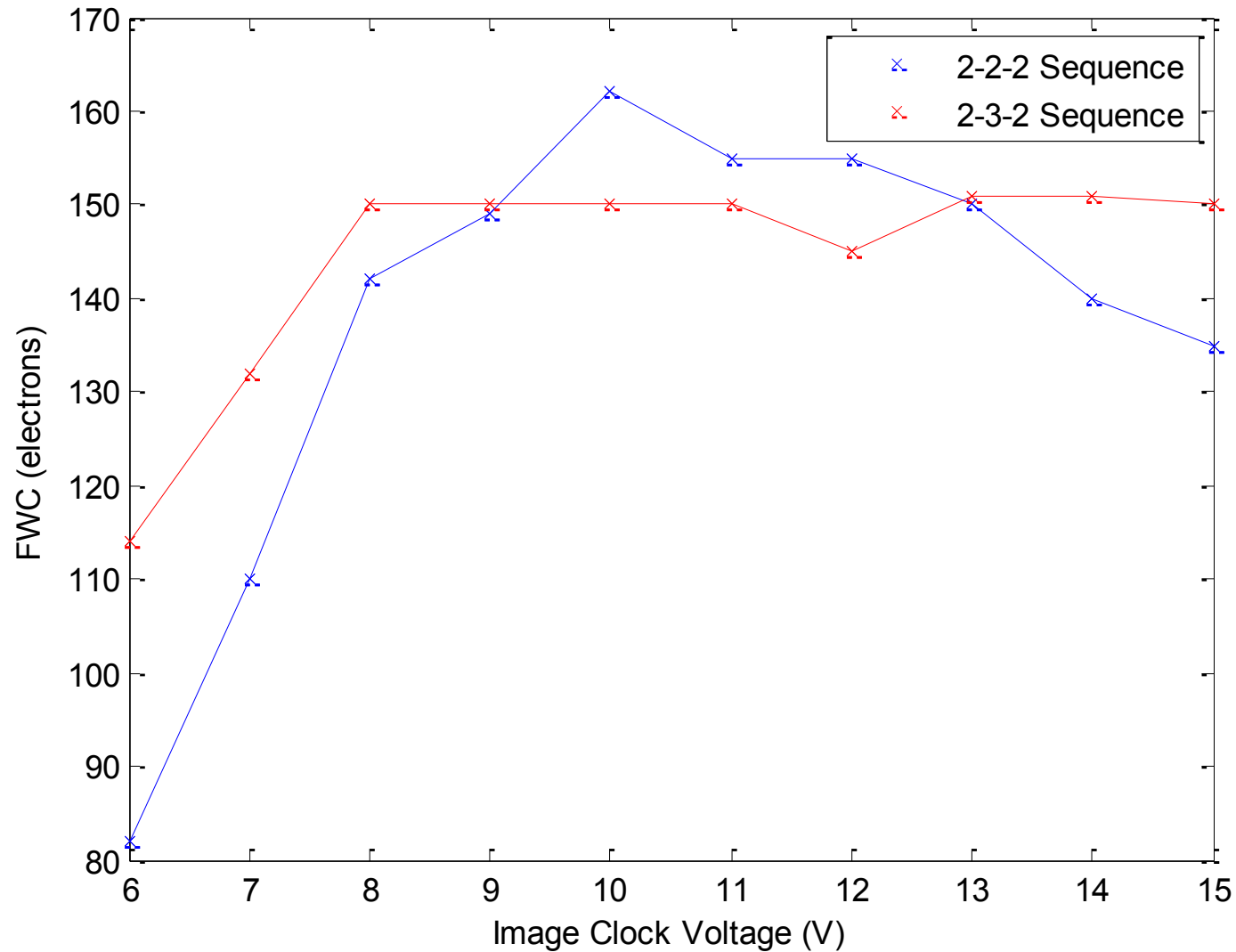
Full Well Capacity Studies in CCD204



Full Well Capacity Studies in CCD204

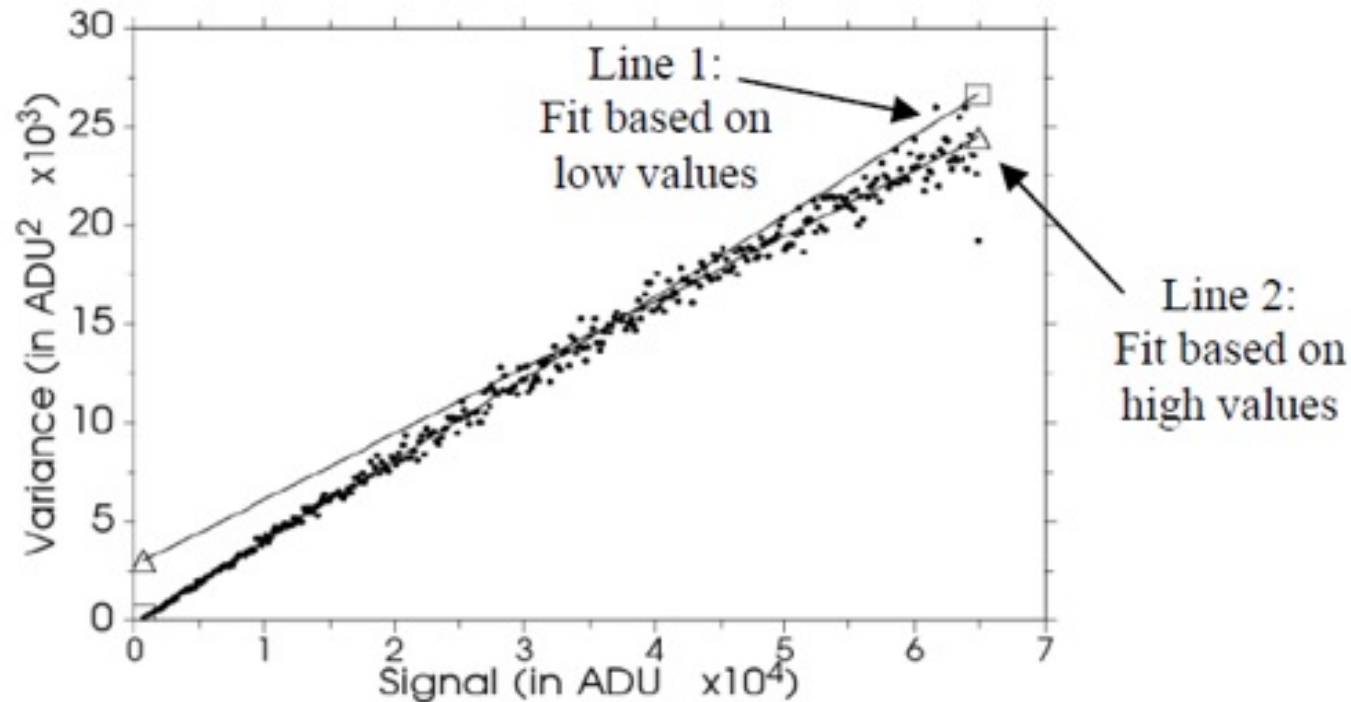


Full Well Capacity Studies in CCD204



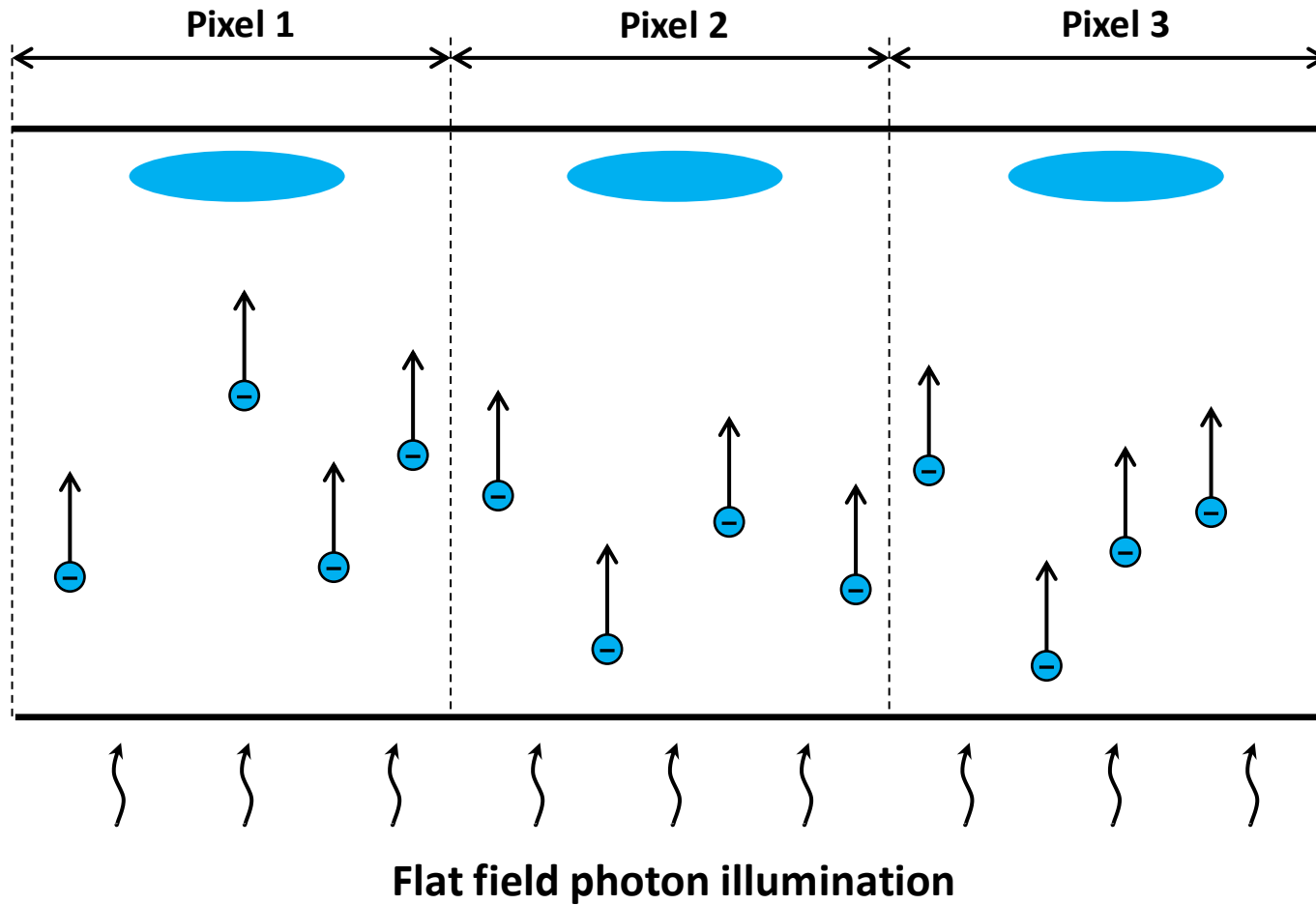
- Suppose that 1000 photoelectrons are collected (on average) in a CCD well.
 - What can we say about the variance of this signal?
 - Without knowing **how** the signal is generated and collected we can only **assume** that the signal is Poisson-distributed
 - Fano factor is the obvious example.
- Poisson statistics is valid if each photon generates an electron (the variance is equal to the mean)
- Poisson statistics needs **random, non-correlated (i.e. statistically independent)** charge generation and collection.
- The Photon Transfer Curve (used for system gain calculation) is explicitly dependent on the Poisson distribution.
- What if charge collection (or generation) deviates from the Poisson statistics?
 - Variance will not be equal to the mean
 - An error is introduced in the gain calculation

The Problem

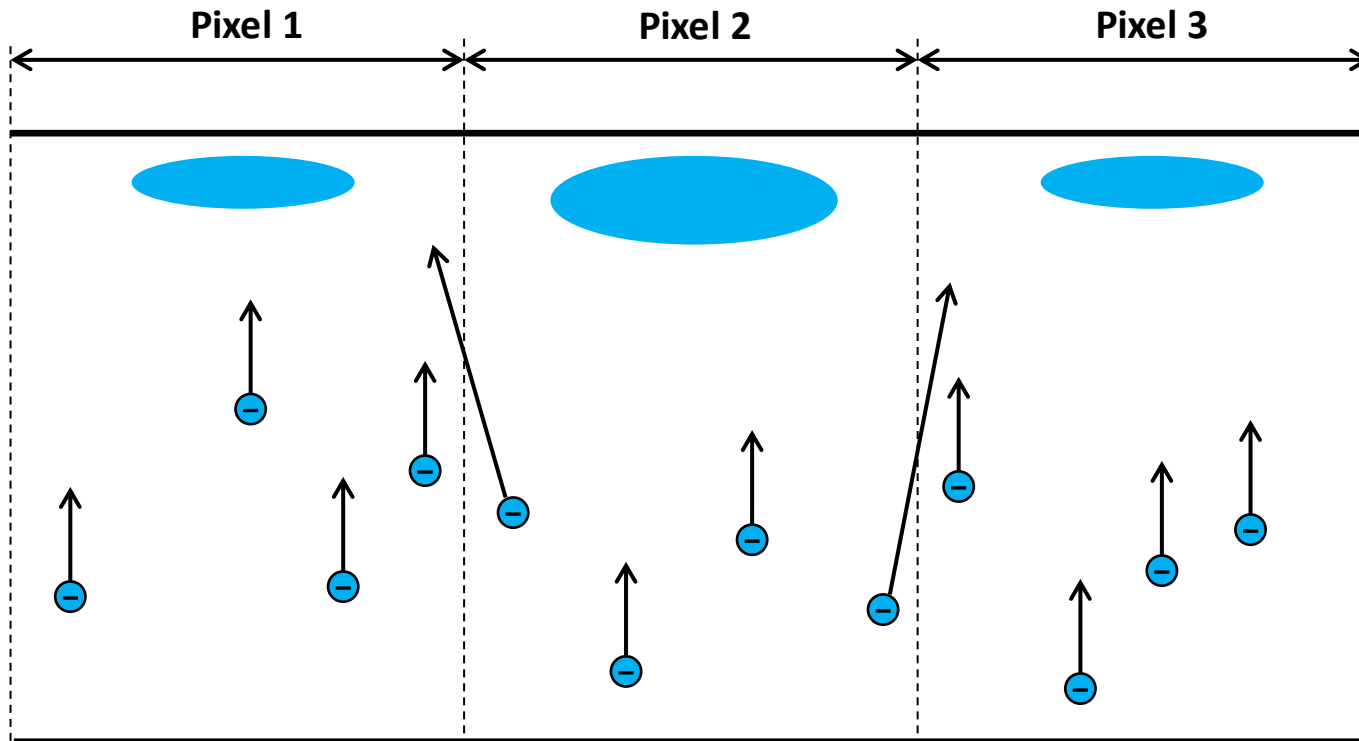


- Despite the CCD being very linear the variance vs signal plot is clearly non-linear
- From Mark Downing's 2006 SPIE paper inviting people to help with an explanation:
 - The effect gets stronger in thick, fully depleted devices
 - The effect occurs in the image area and has something to do with charge collection.

Ideal Charge Collection

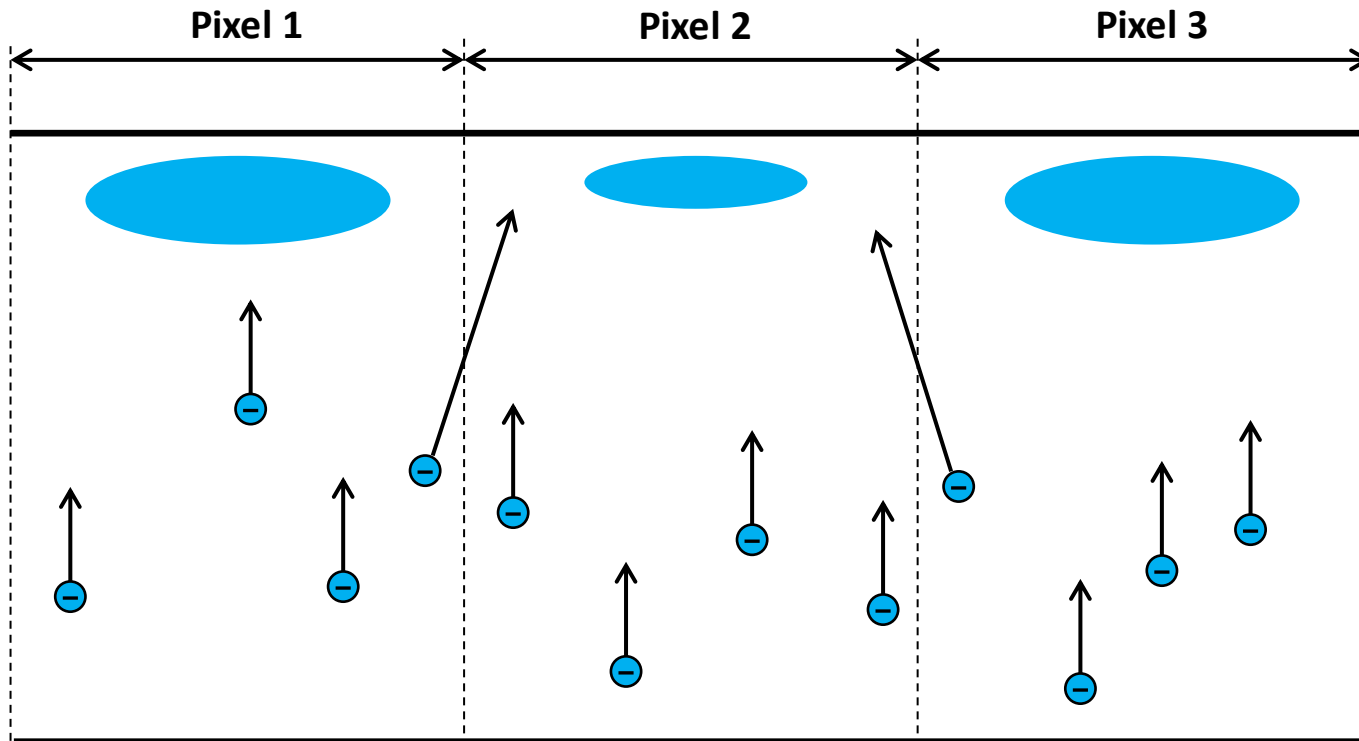


Statistical Variations (1)



- Charge collection is a statistical process
- If Pixel 2 has collected more electrons than the neighbours:
 - Incoming electrons have **slightly higher chance** of going to the neighbour pixels

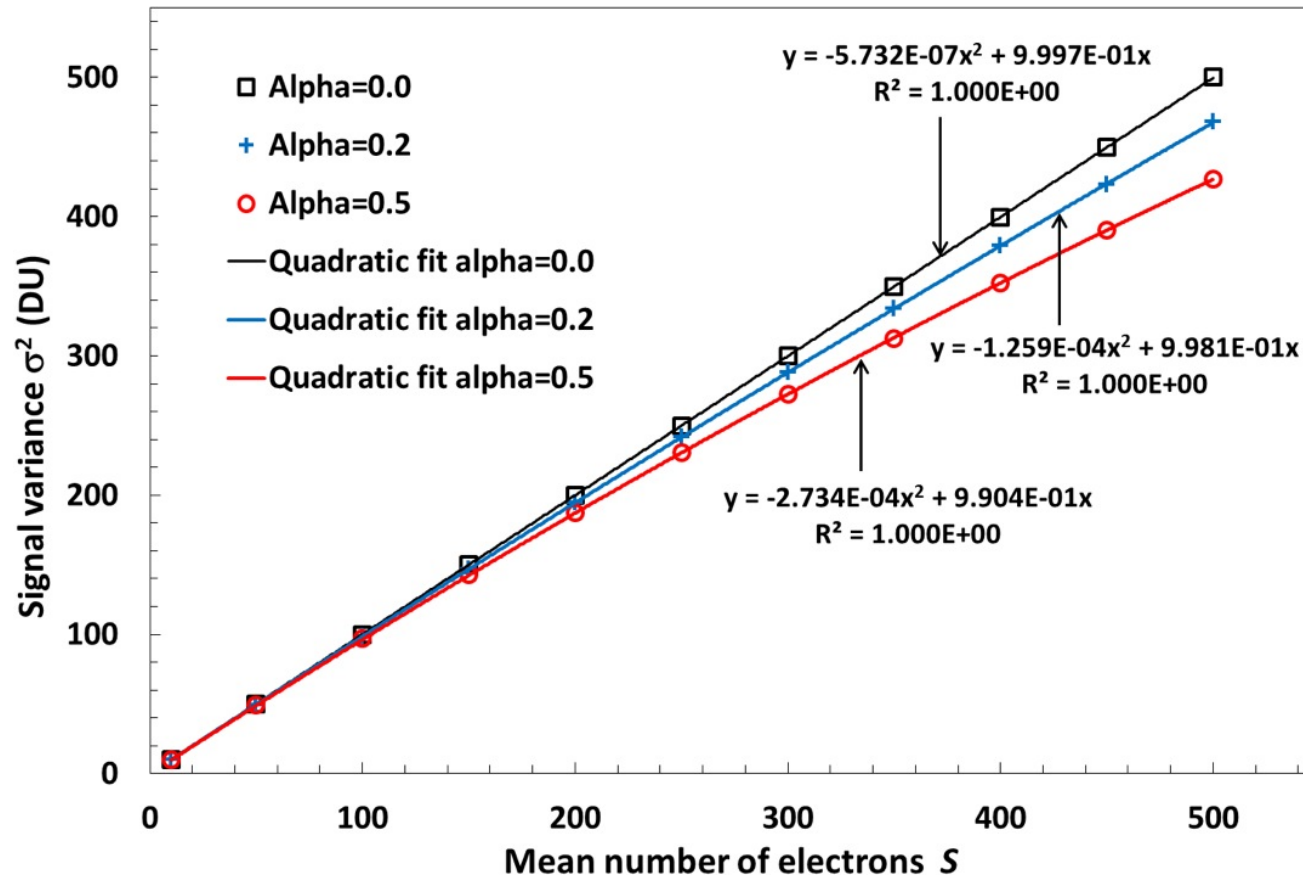
Statistical Variations (2)



- Charge collection is a statistical process
- If Pixel 2 has collected fewer electrons than the neighbours:
 - Incoming electrons from neighbour pixels have **slightly higher chance** of going to Pixel 2.

- In the presence of signal-dependent sharing:
 - Charge collection becomes correlated and **less random**
 - Charge collection rate becomes more uniform (fluctuates less)
 - Signal variance becomes **sub-Poisson**
- Calculating the variance analytically is very difficult
- Monte Carlo model is much more practical
- Charge sharing probability proportional to:
 - *Instantaneous signal – Mean instantaneous signal over neighbours*
- Results compared with experimental data
- Thanks to Andy Clarke for the data with the BI CCD204
- Thanks to Mark Downing for his data from 2009

Monte Carlo Model



Probability of charge sharing:

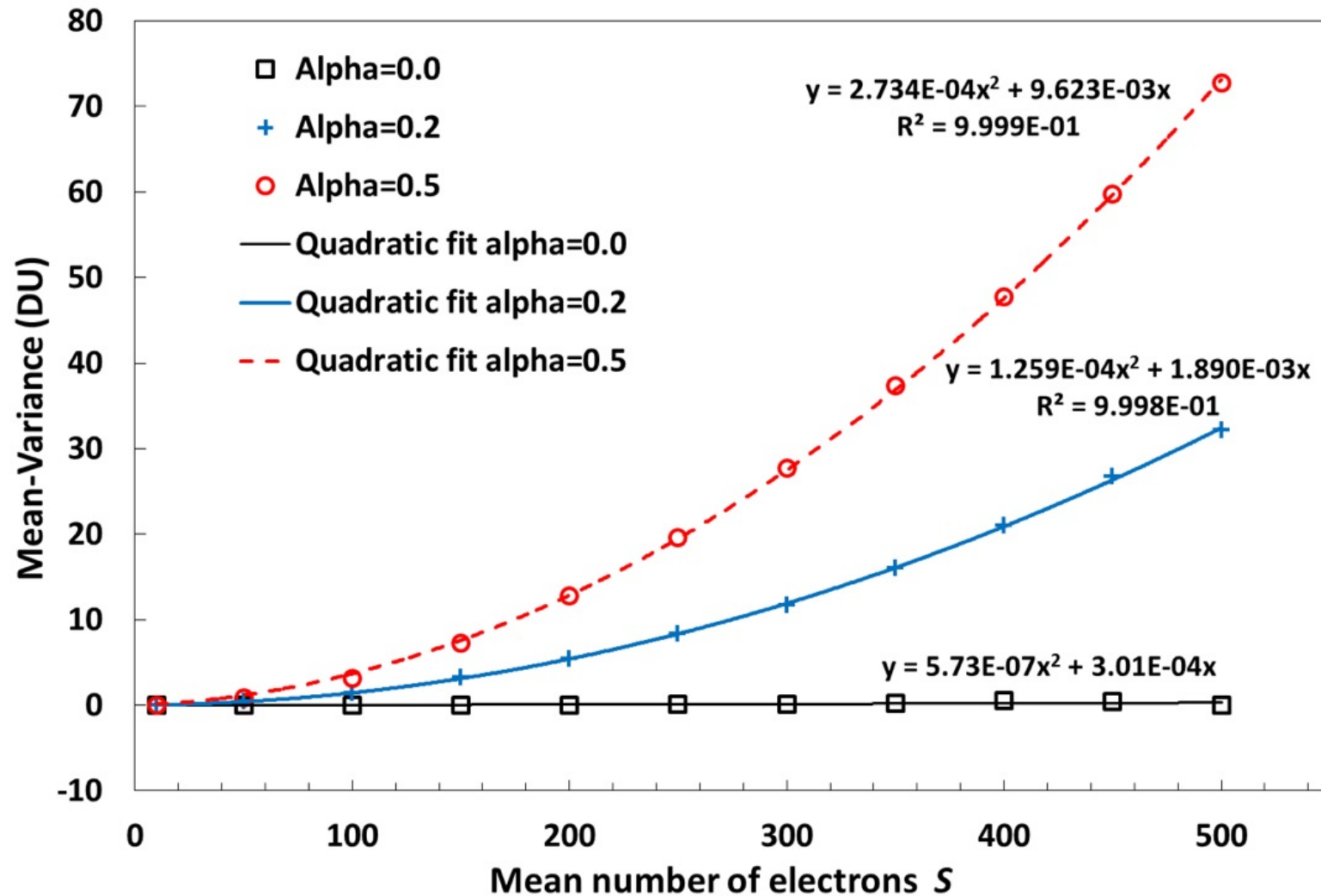
$$P_i = \left(\frac{\alpha}{FW} \right) \left(n_i - \frac{1}{3} \sum_{j=1}^3 n_j \right)$$

- Shows sub-Poisson variance introduced by charge sharing
- Quadratic fit is a very good match:

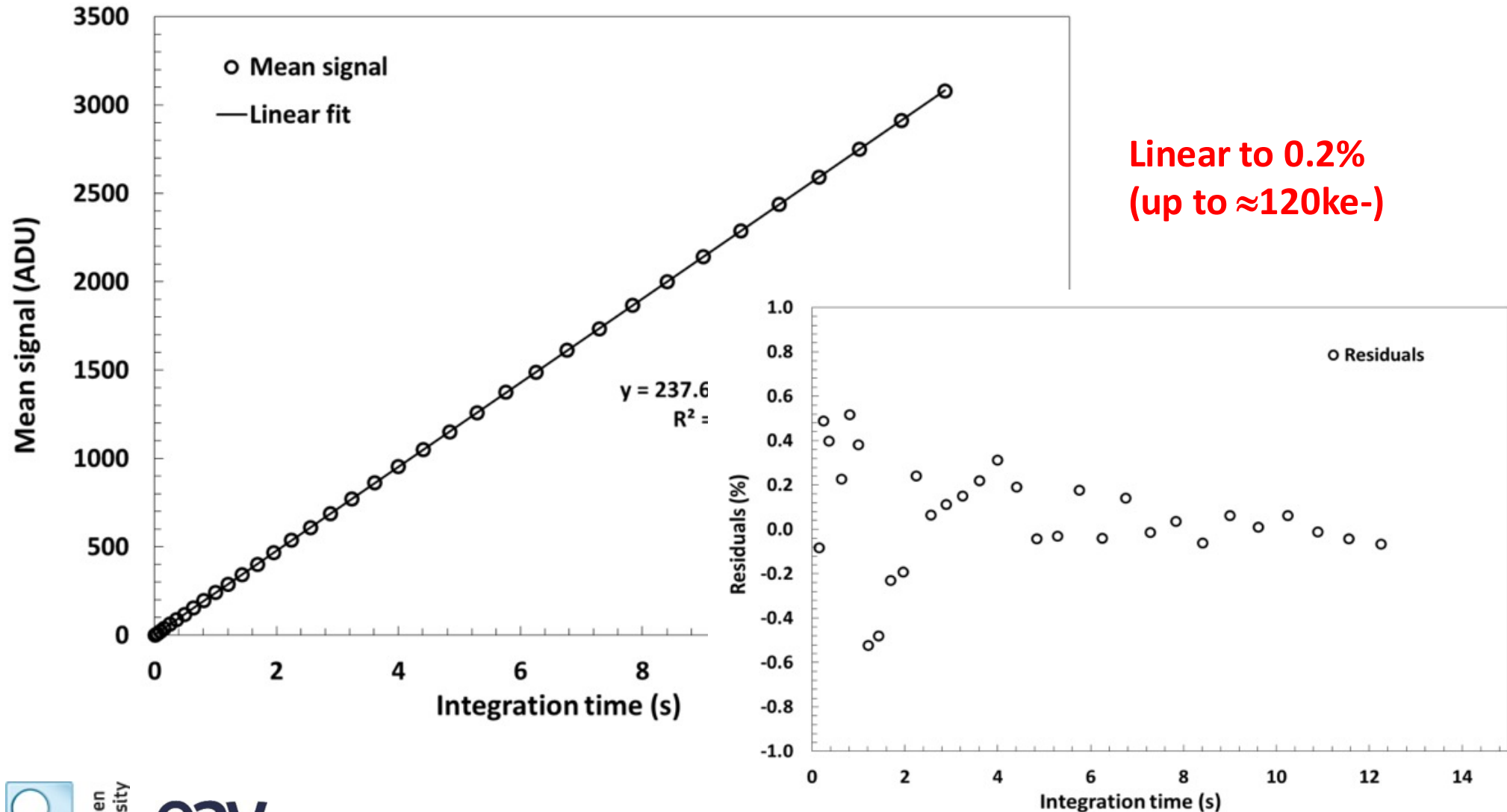
$$Var = \gamma S - \nu S^2$$

$$\gamma \approx 1$$

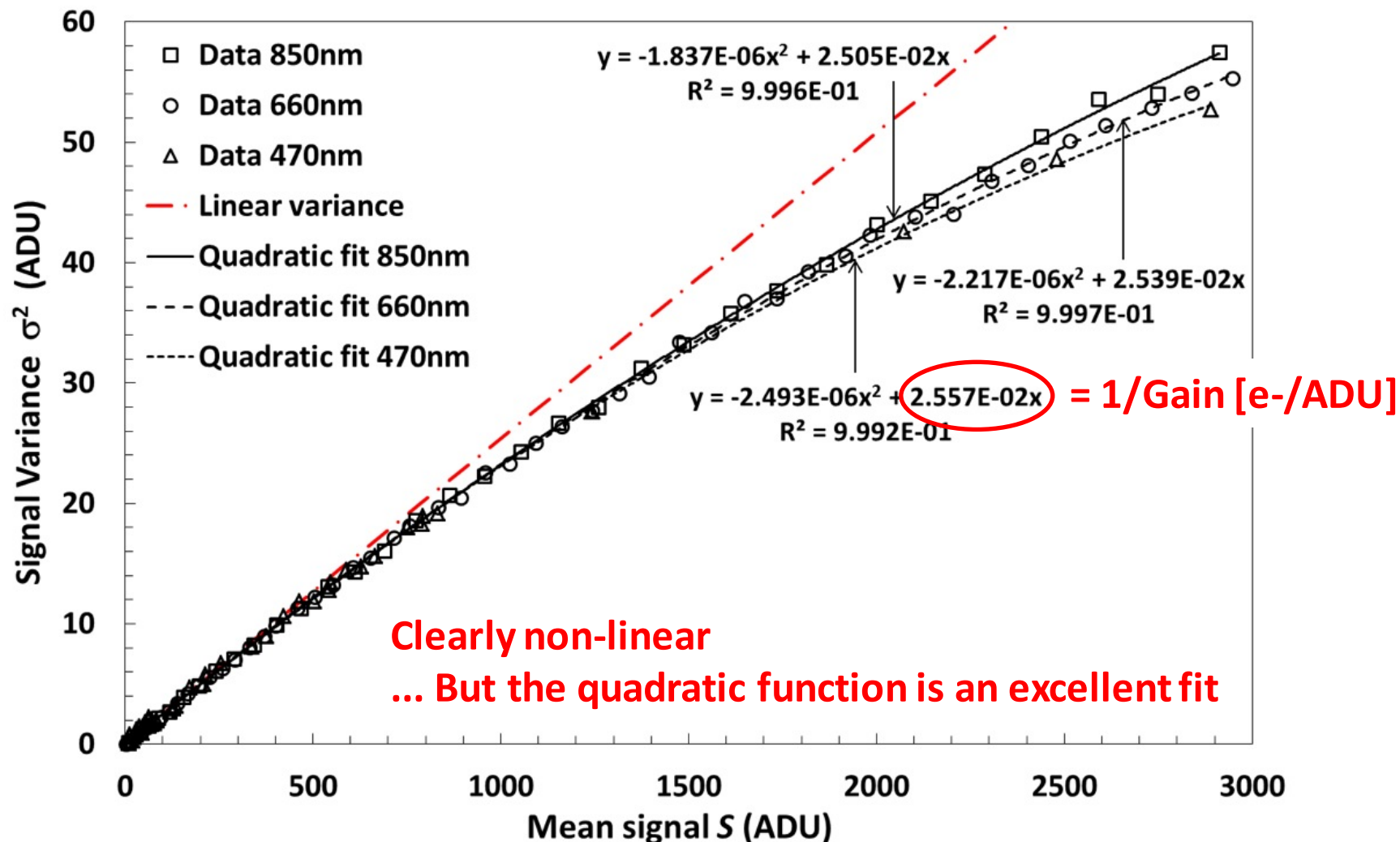
Mean – Variance



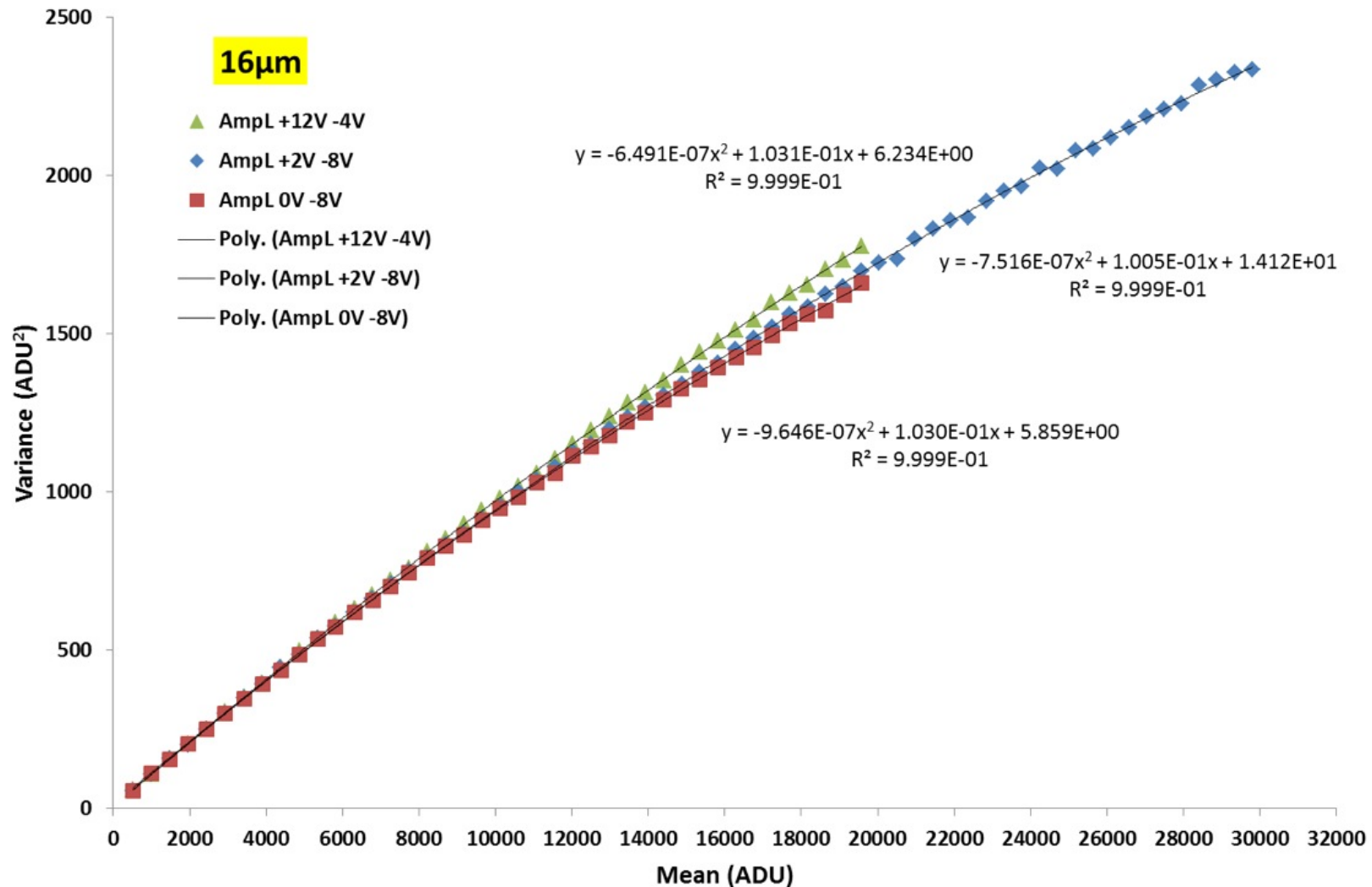
Data from CCD204 – Linearity



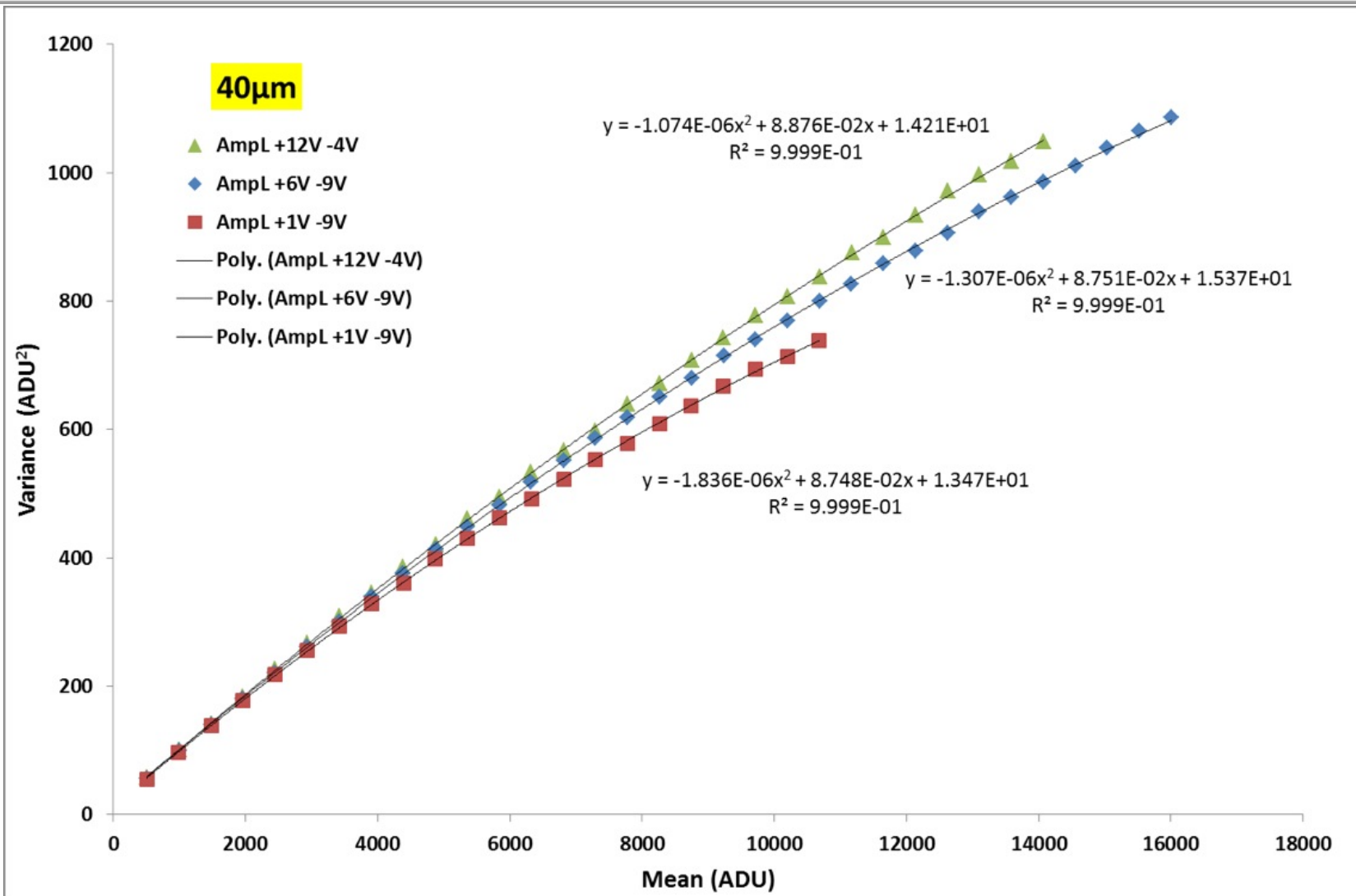
Data from CCD204 – Variance



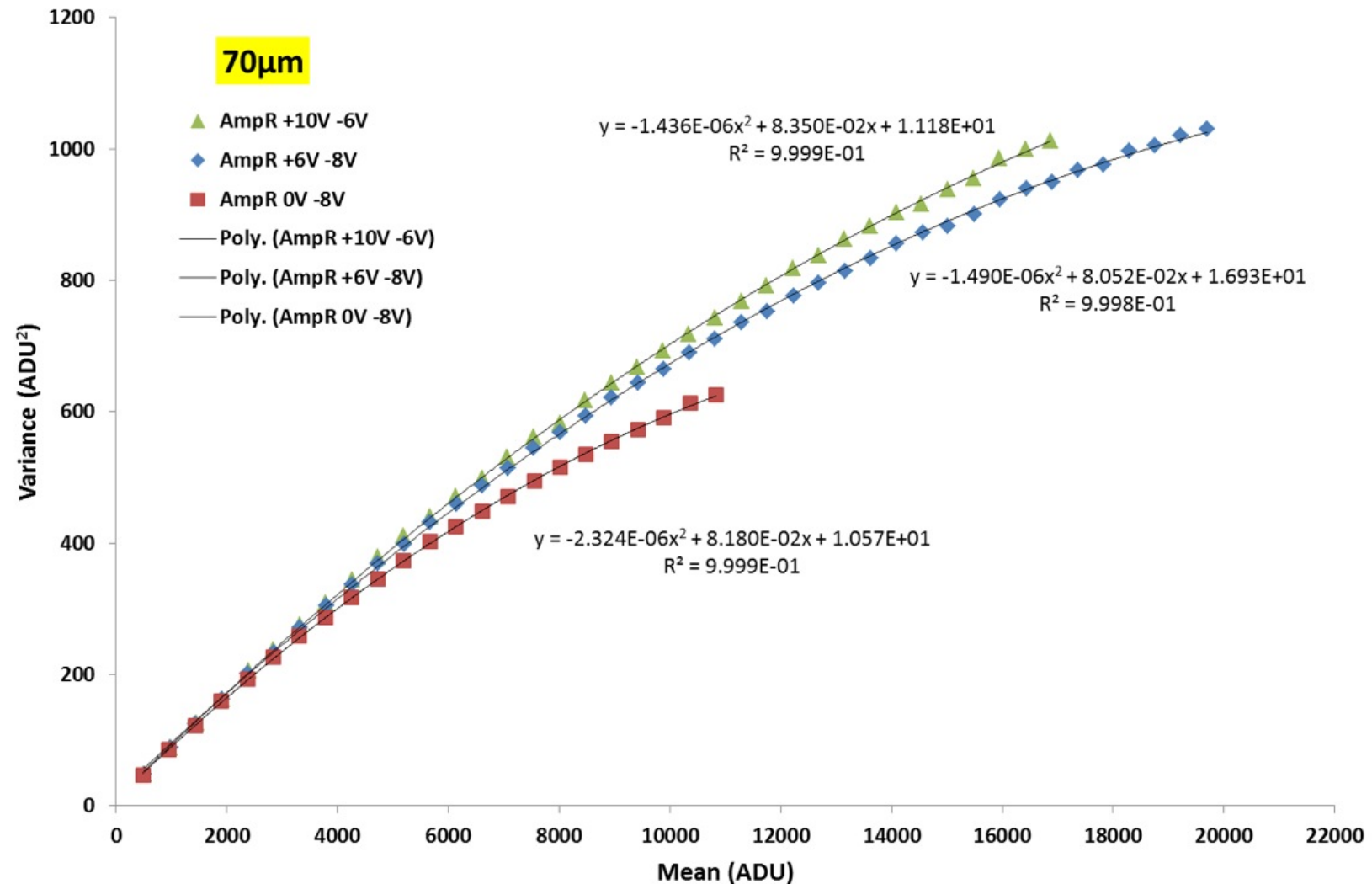
Data from Mark Downing – 16μm thick CCD



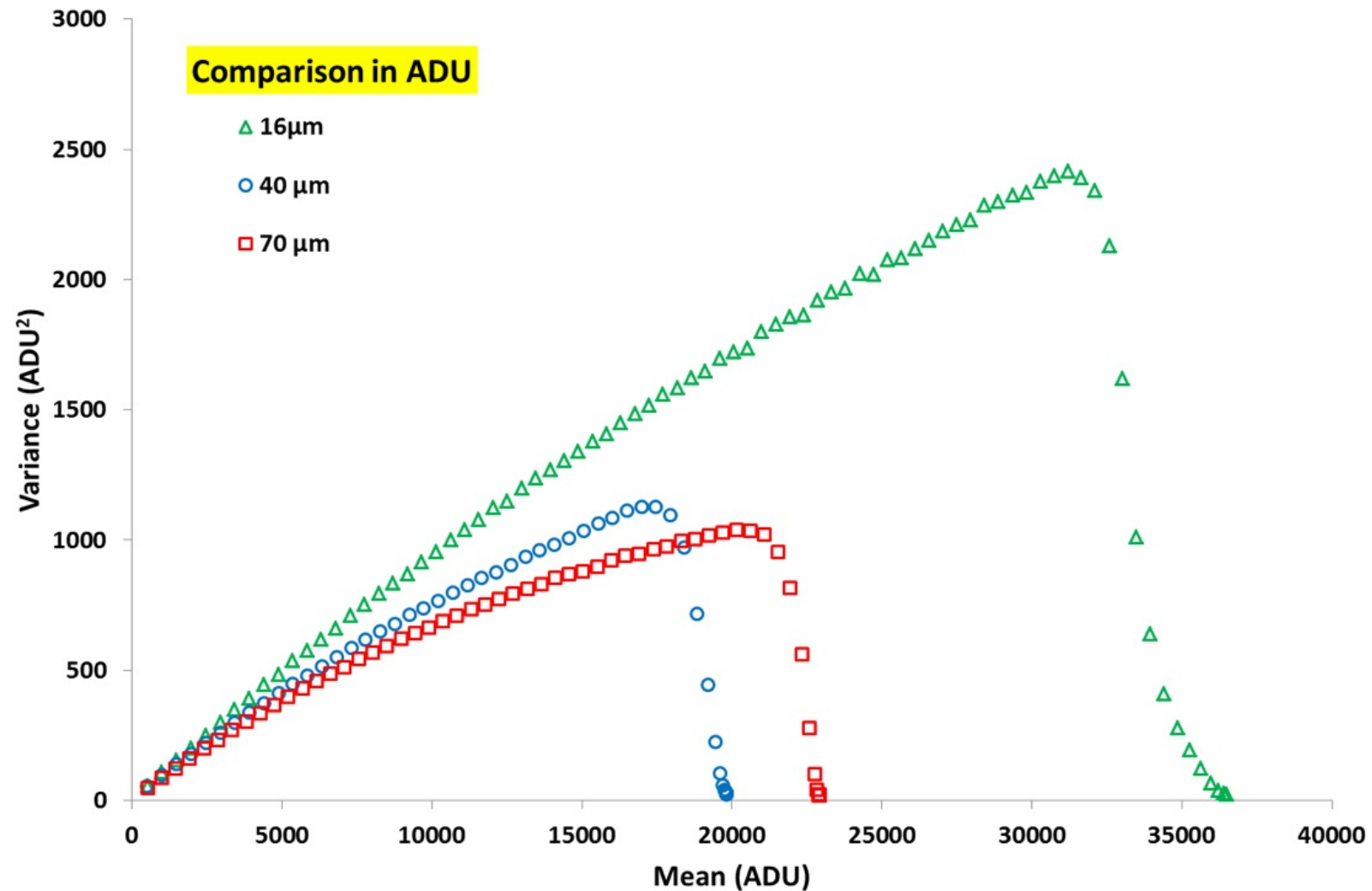
Data from Mark Downing – 40μm thick CCD



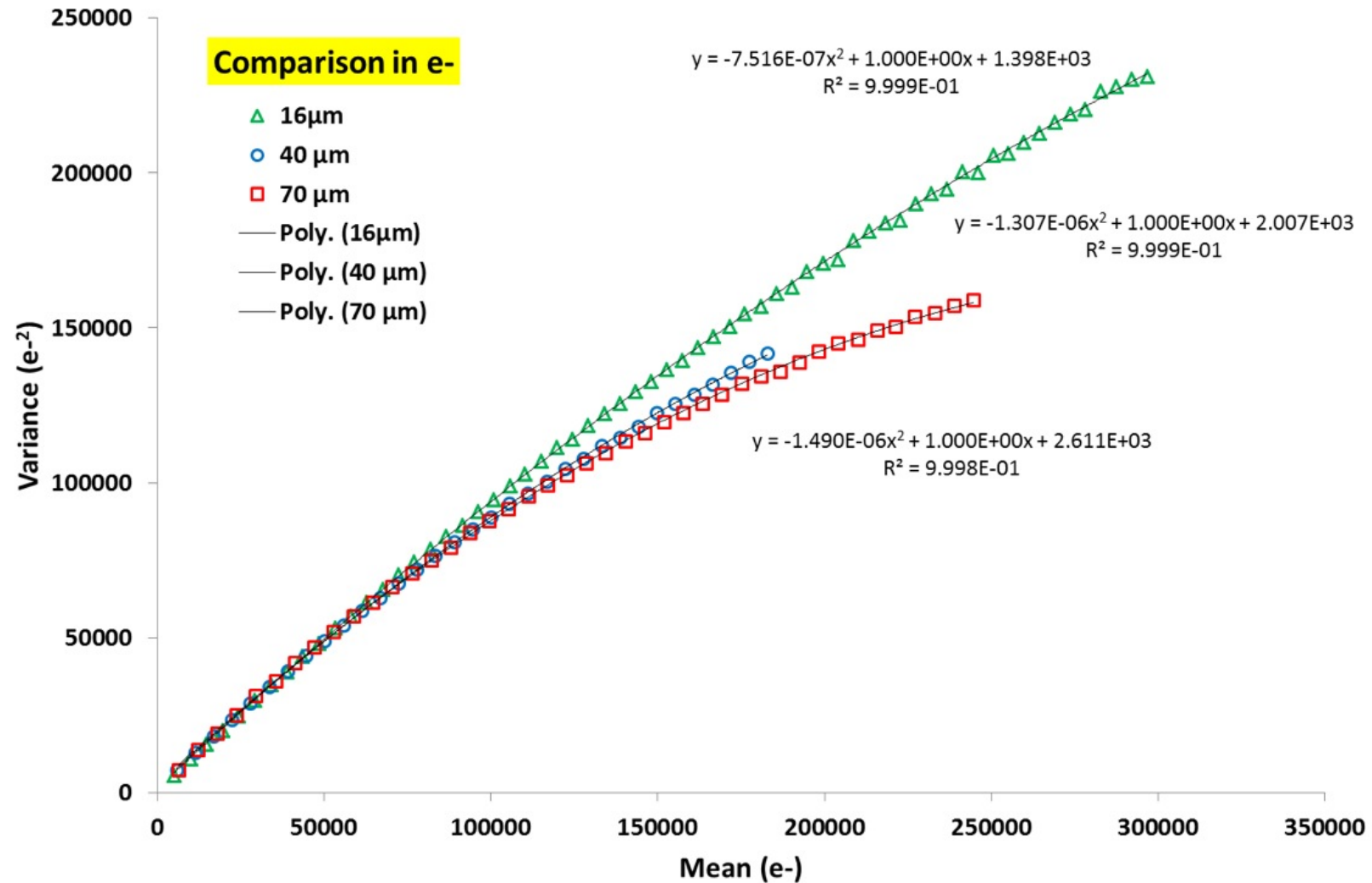
Data from Mark Downing – 70μm thick CCD



Non-linearity as a Function of CCD thickness



Non-linearity as a Function of CCD thickness

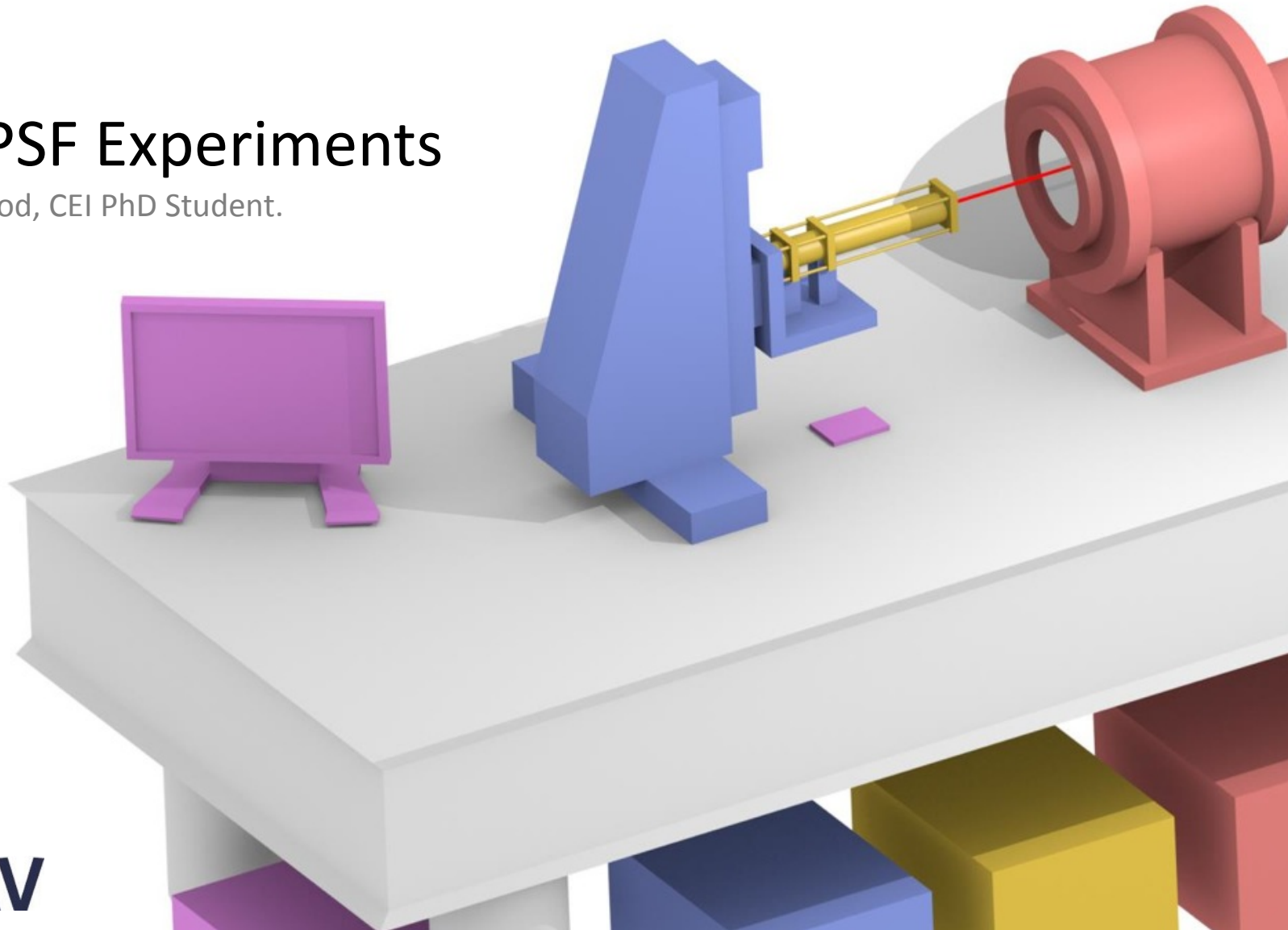


- The PTC is **more non-linear**:
 - At shorter wavelengths (longer electron path, higher chance of sharing)
 - In thicker CCDs (longer electron path, higher chance of sharing)
 - At lower electric fields (higher chance of sharing due to lower attraction to the wells, barrier phase influence?)
- This could be a better way to derive system gain from the PTC:
 - All data up to full well can be used, there is no need to choose linear-looking part at low signals
- In the CCD204 data:
 - The gain difference between a linear fit to **all points** and the quadratic fit is 23%.
 - The gain difference between linear fit to the first few points (almost linear PTC) and the quadratic fit is 8%.
- A paper has been submitted to IEEE Transactions on Electron Devices.

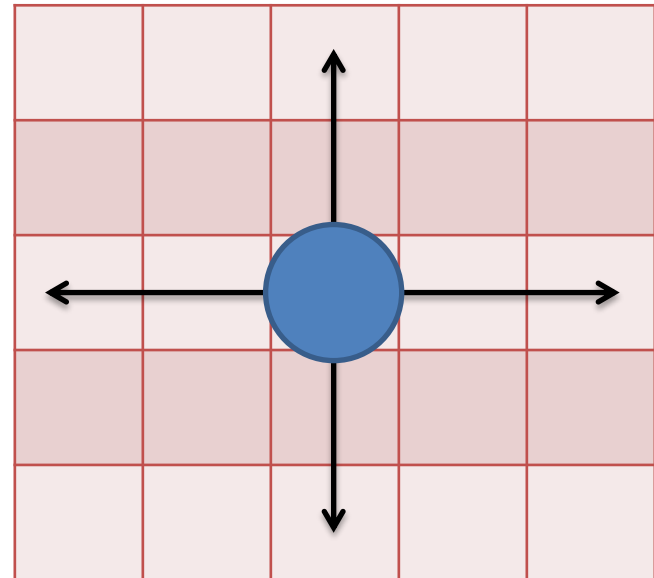
- **What is the relationship between signal-dependent and signal-independent charge sharing?**
- Signal-independent charge sharing is calculated and modelled using drift and diffusion equations in semiconductors (they cannot model charge collection statistics)
 - Charge sharing is significant: of the order of 10%
- Signal-dependent sharing appears to be a much smaller effect:
 - Experimentally measured probability of sharing α/FW is of the order of 10^{-5}
 - Charge sharing is likely to be much below 1%
- Work in progress: applying the Monte Carlo model to the “narrow beam” scenario
 - First indications are that this is correct (sharing is $\sim 0.1\%$);
 - There are some other interesting results;
 - Confirming this experimentally can be challenging.

Euclid PSF Experiments

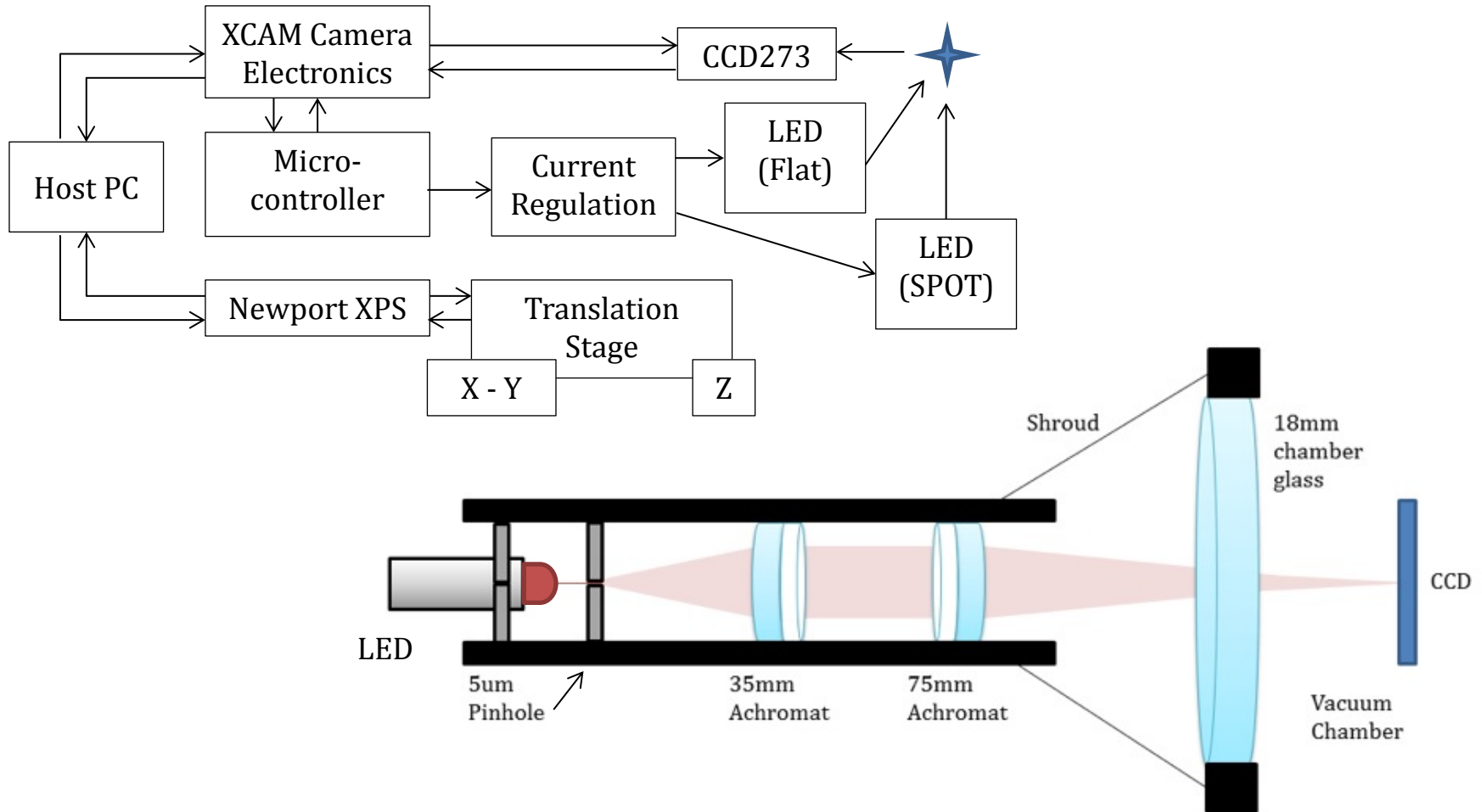
Edgar Allanwood, CEI PhD Student.



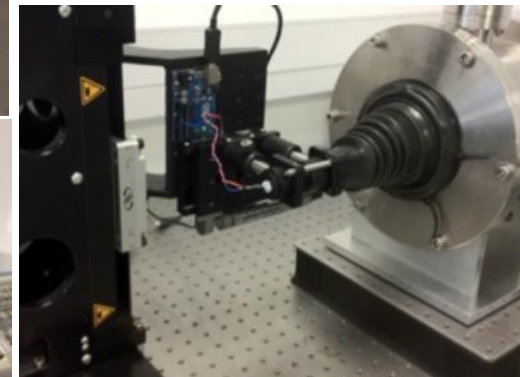
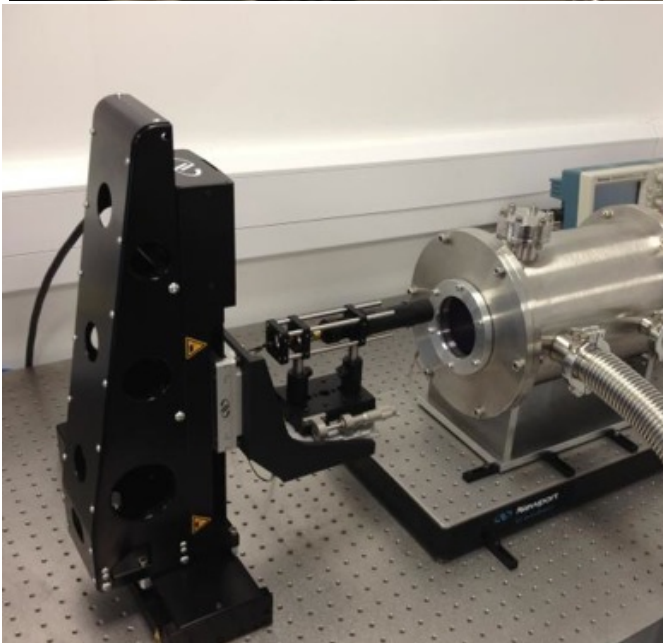
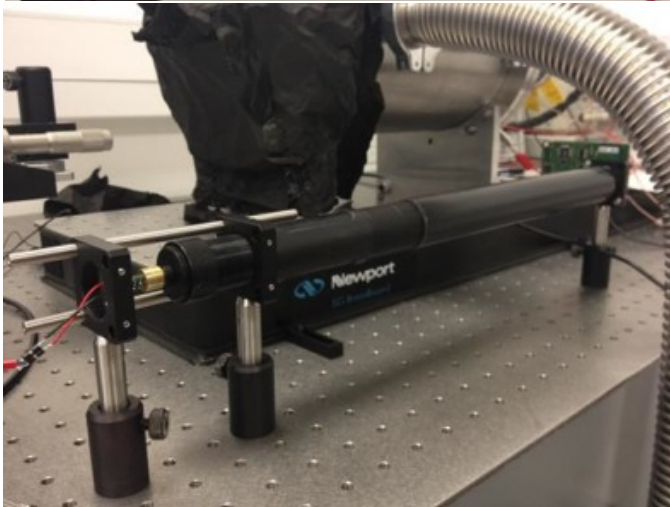
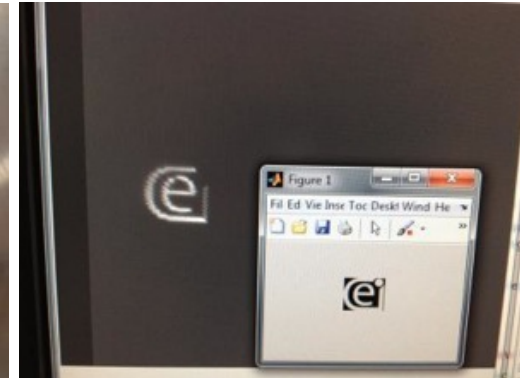
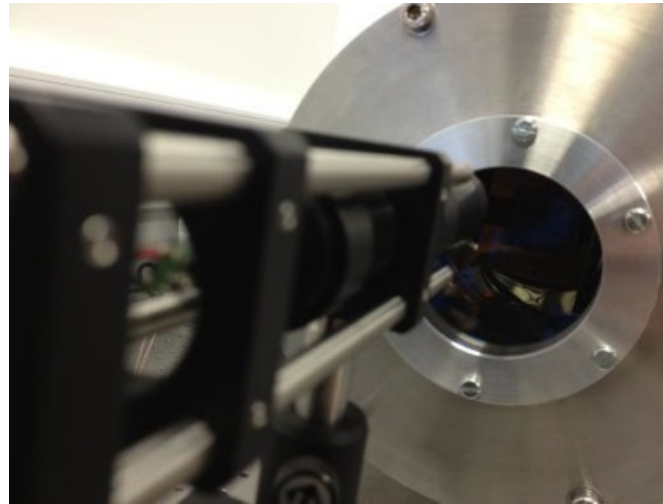
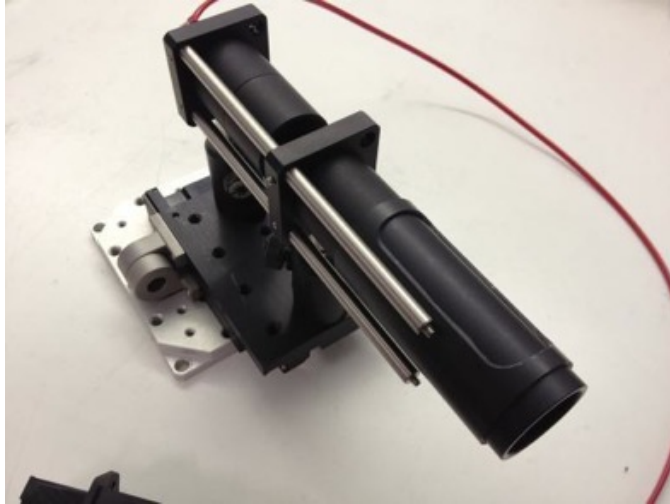
- General aim of the study is to investigate the effect of various device operating parameters and radiation damage on shape measurements
- An optical test bench has been developed to measure the point spread function of a spot projected on to a front-illuminated e2v CCD273



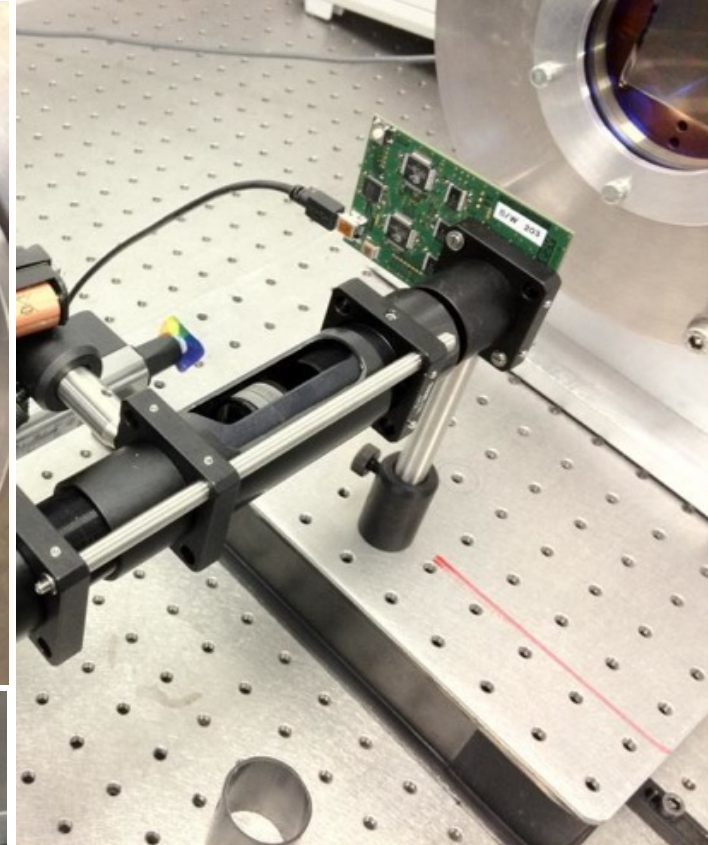
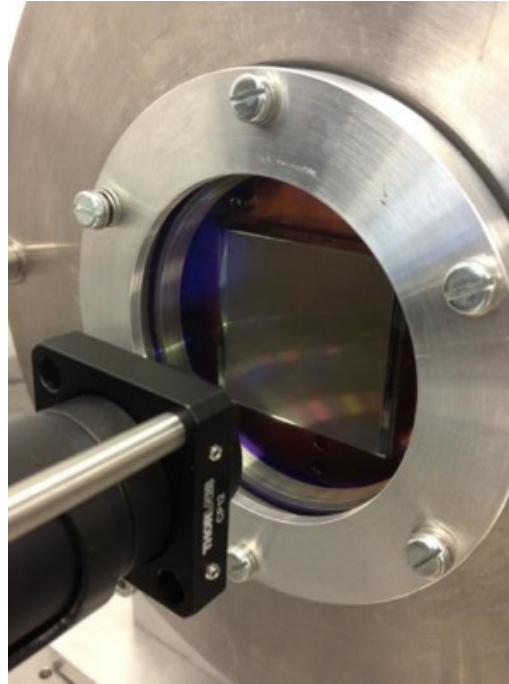
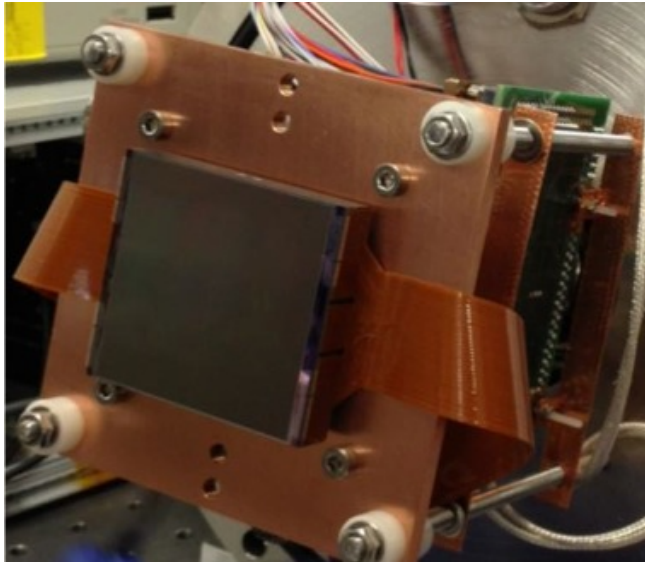
Projection System Design



Projection System Design



Projection System Design



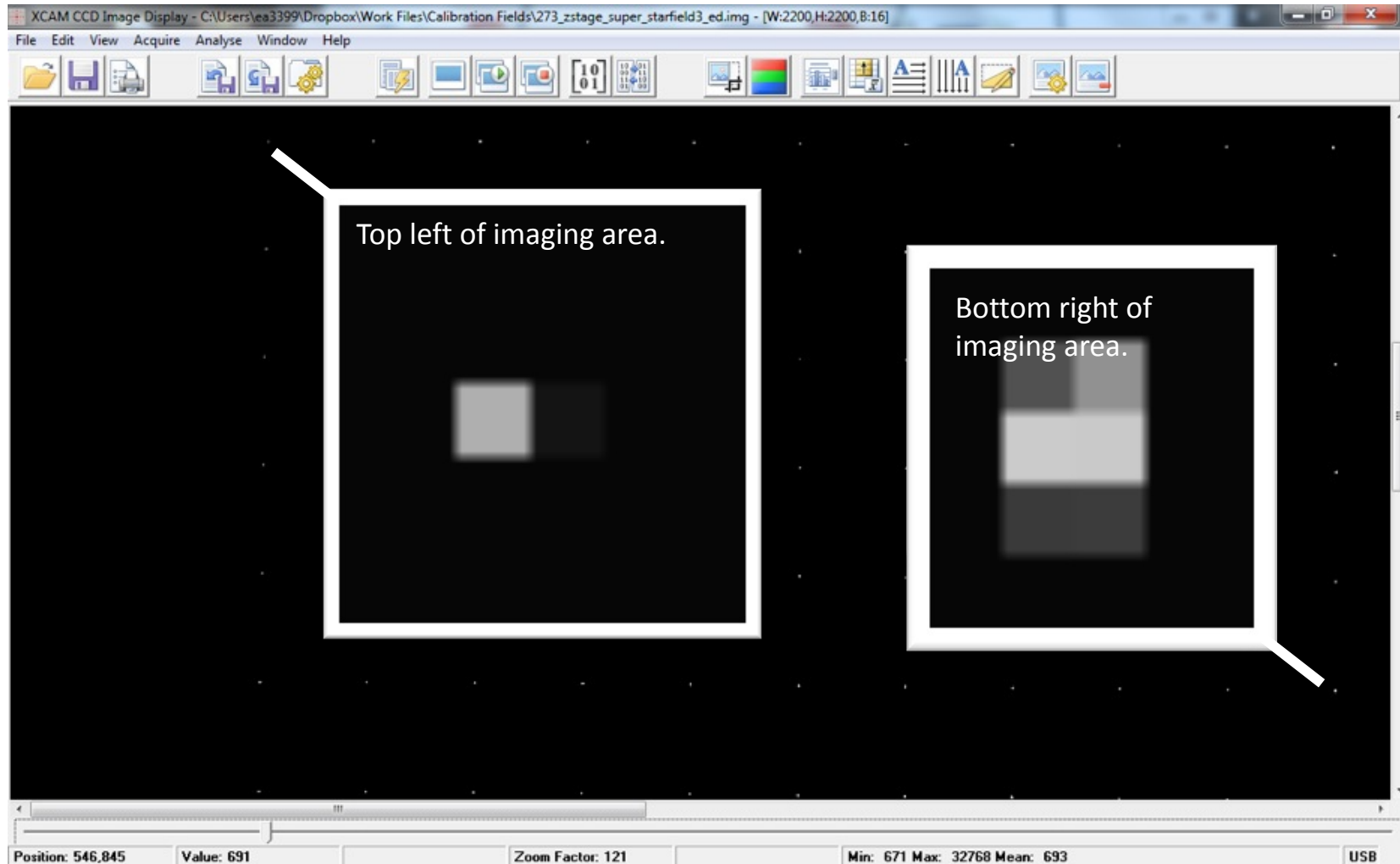
- Spot projection optics constructed from LED light source and Thorlabs lens tube system
- Projection optics mounted on translation stage
- FI-CCD273 mounted $\sim 1\text{mm}$ from window on cold bench, supported by steel studs protruding from rear of chamber
- Autofocusing algorithm developed in order to achieve sharpest PSF
- Systematic errors noted
 - Vibration
 - “drift” of the cold bench with time
 - Subtle misalignment of the device requiring correction
 - Repeatability
 - Translation stage position
 - Light source intensity

Experimental information



- Useful information:
 - The projected spot FWHM is between 9 and 10 microns
 - Euclid pixel geometry is 12 micron, square pixels
 - 2 – 2 – 2 readout is used in experiments as one clock phase is over-etched, thus 2-3-2-3-2 clocking may cause deferred charge to manifest
 - Measurements taken using red $\sim 639 \pm 10$ nm LED light source (spot and flat illumination)
 - Spot is positioned using a 3x3 pixel ROI and centre of mass measurement for on-the-fly repositioning
 - Spot is focused and positioned using an autofocus algorithm which compares the centre pixel charge to the surrounding eight pixels as the XYZ translation stage is swept in the z-axis. The peak centre charge vs ROI charge z-position is chosen as experiment focus
 - Focusing is repeatable although spot PSF is vibration-limited in long exposures

Obtaining a repeatable spot



Long integration time, translation stage point projection routine.



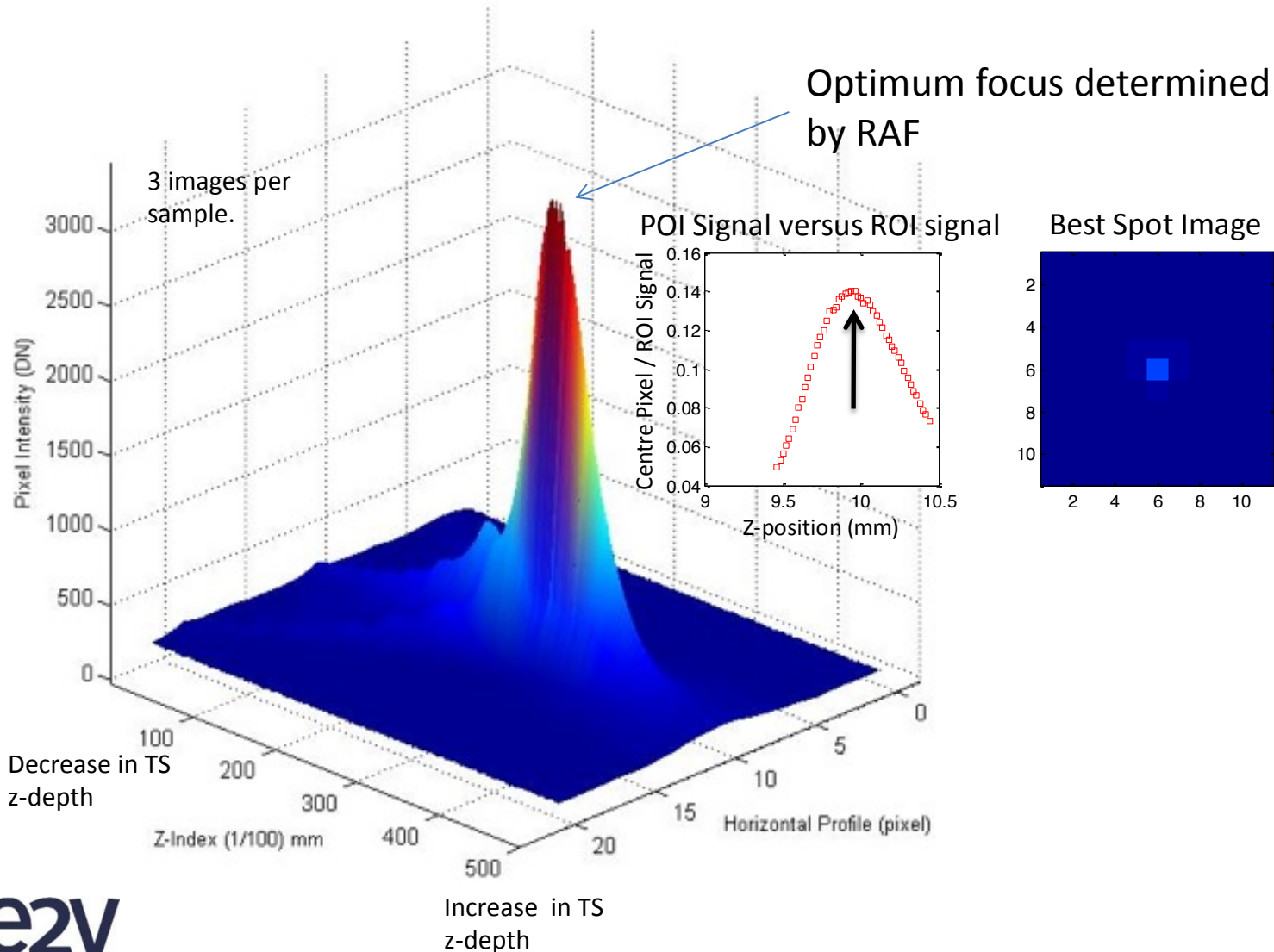
The Open
University

e2v

Obtaining a repeatable spot



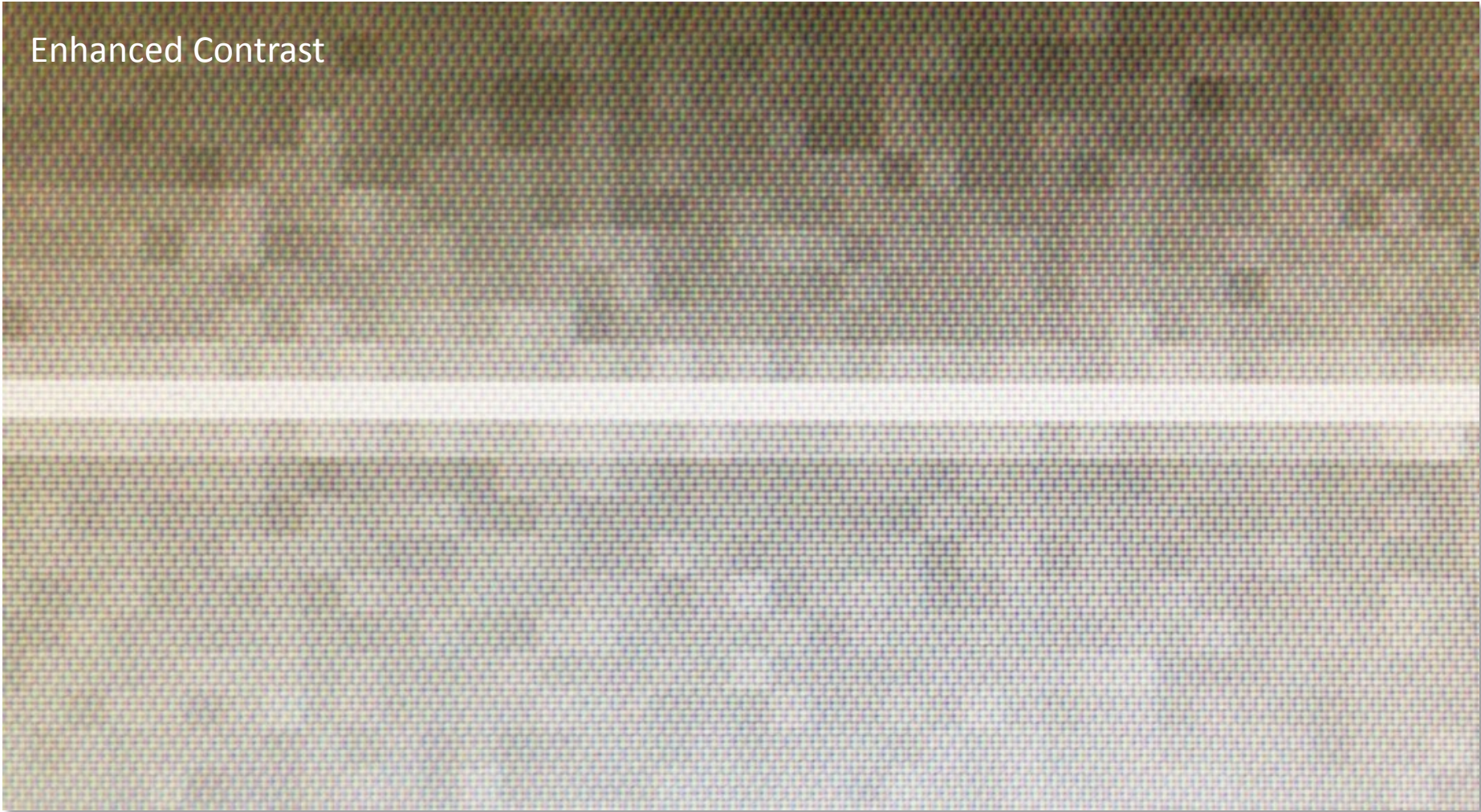
Horizontal Spot Profile During Focus Sweep



Charge “redistribution”



Enhanced Contrast

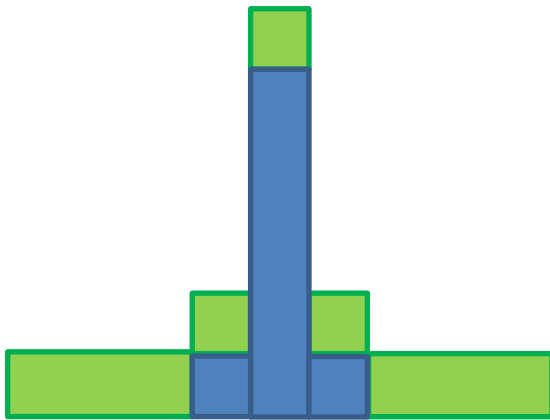


Charge redistribution experiment

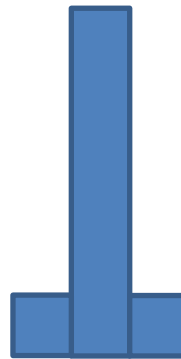


Ideally...

Frame 1 (100 stats)



Frame 2 (100 stats)



Frame 1 average minus
frame 2 average



Spot, followed by a **flat illumination** (diffuse LED) – not to be confused with “flat fielding”.

Spot only.

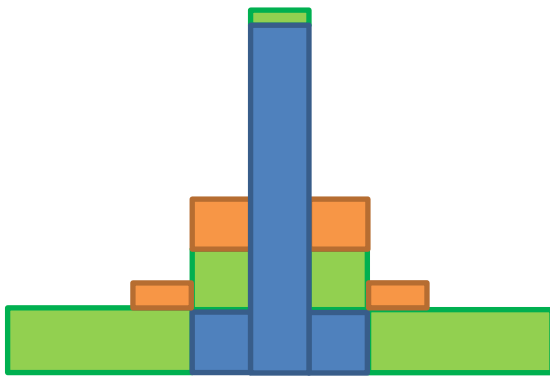
This is what should be observed in the absence of any charge sharing.

Charge redistribution experiment



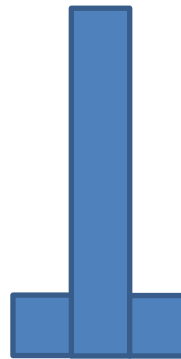
...but based on what was seen in charge injection experiment...

Frame 1 (100 stats)



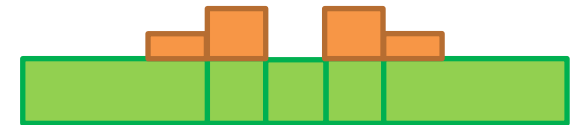
Spot, followed by a **flat illumination**, showing **redistributed charge**.

Frame 2 (100 stats)



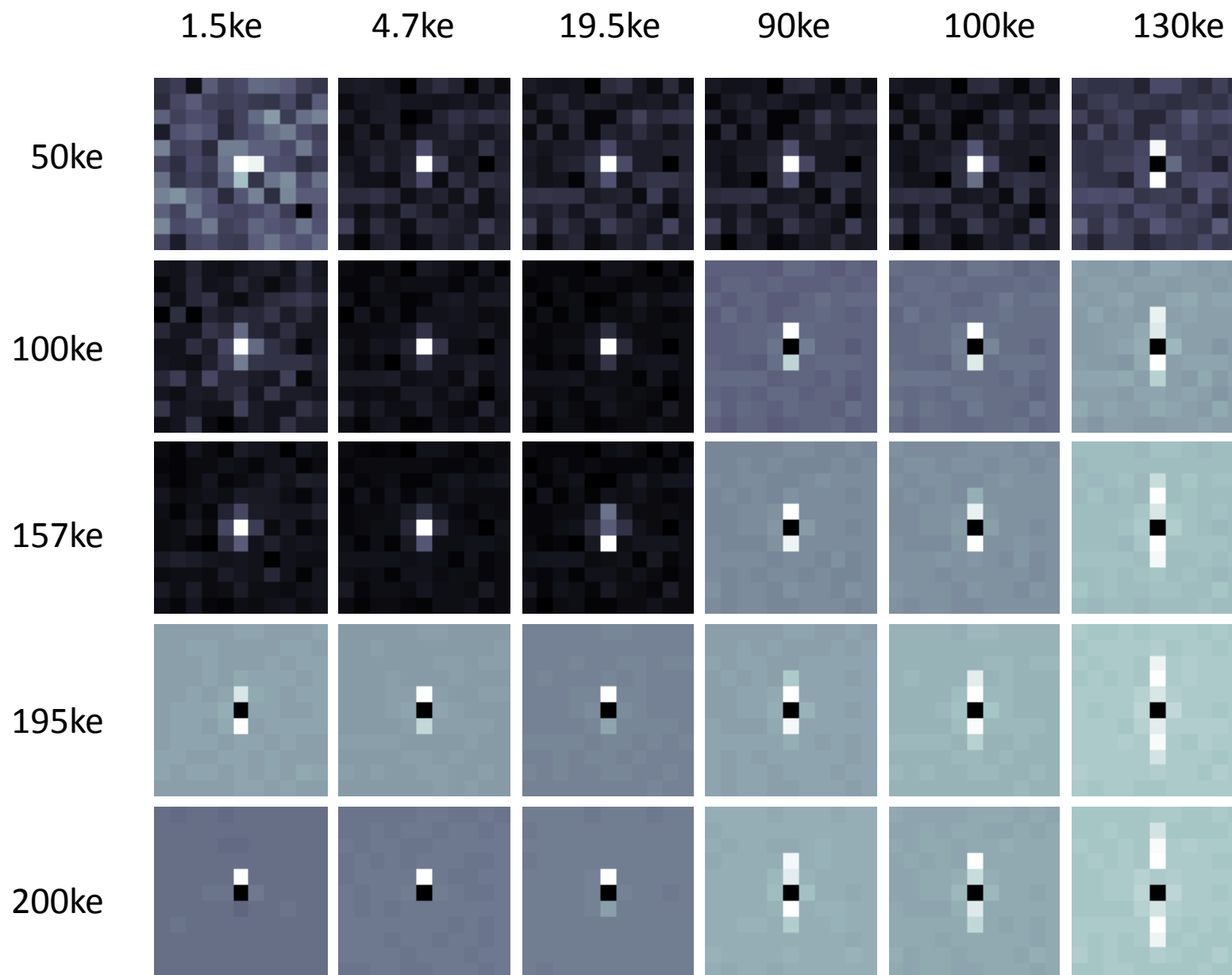
Spot only.

Frame 1 average minus frame 2 average

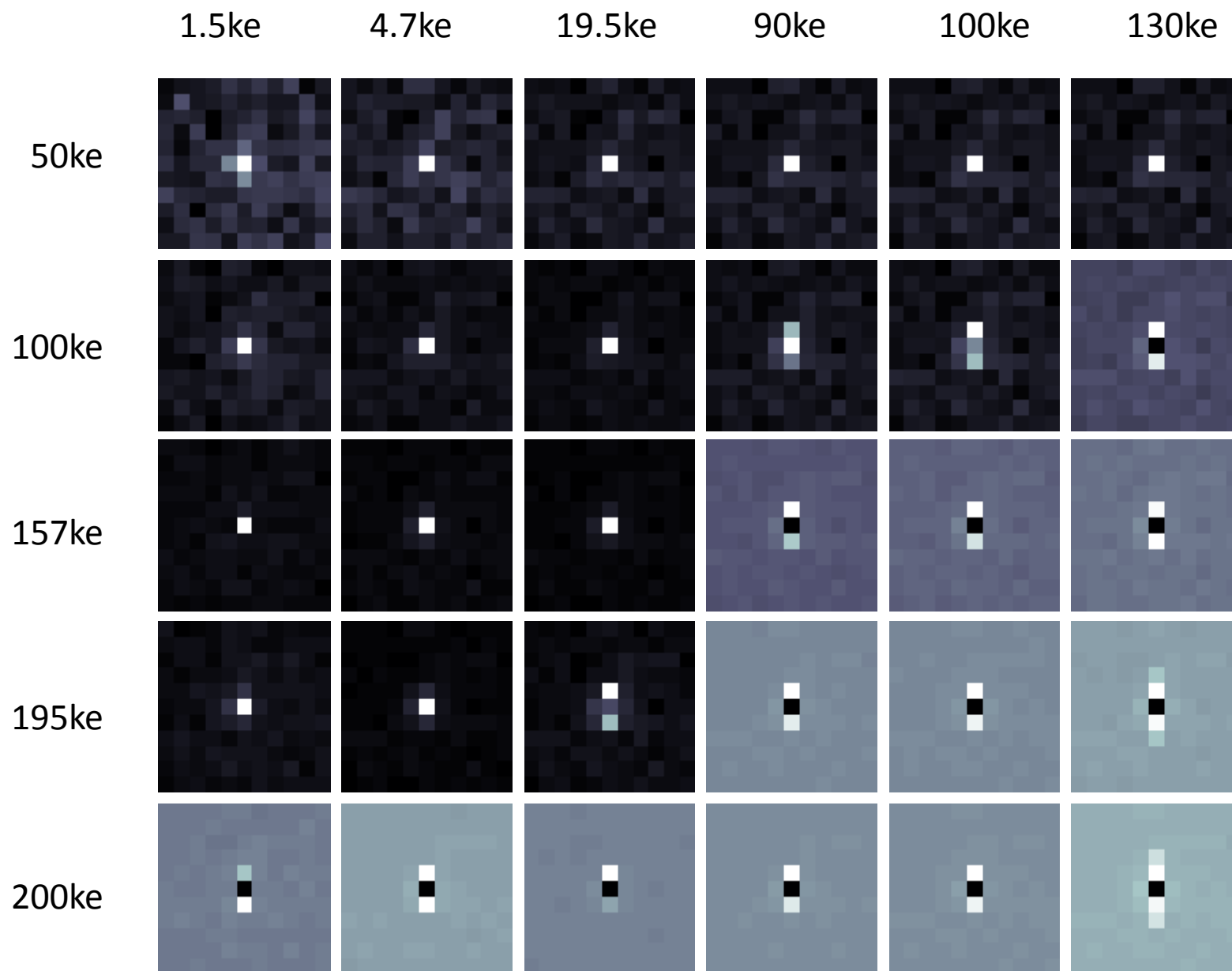


Theoretical result of subtraction in the presence of charge redistribution.

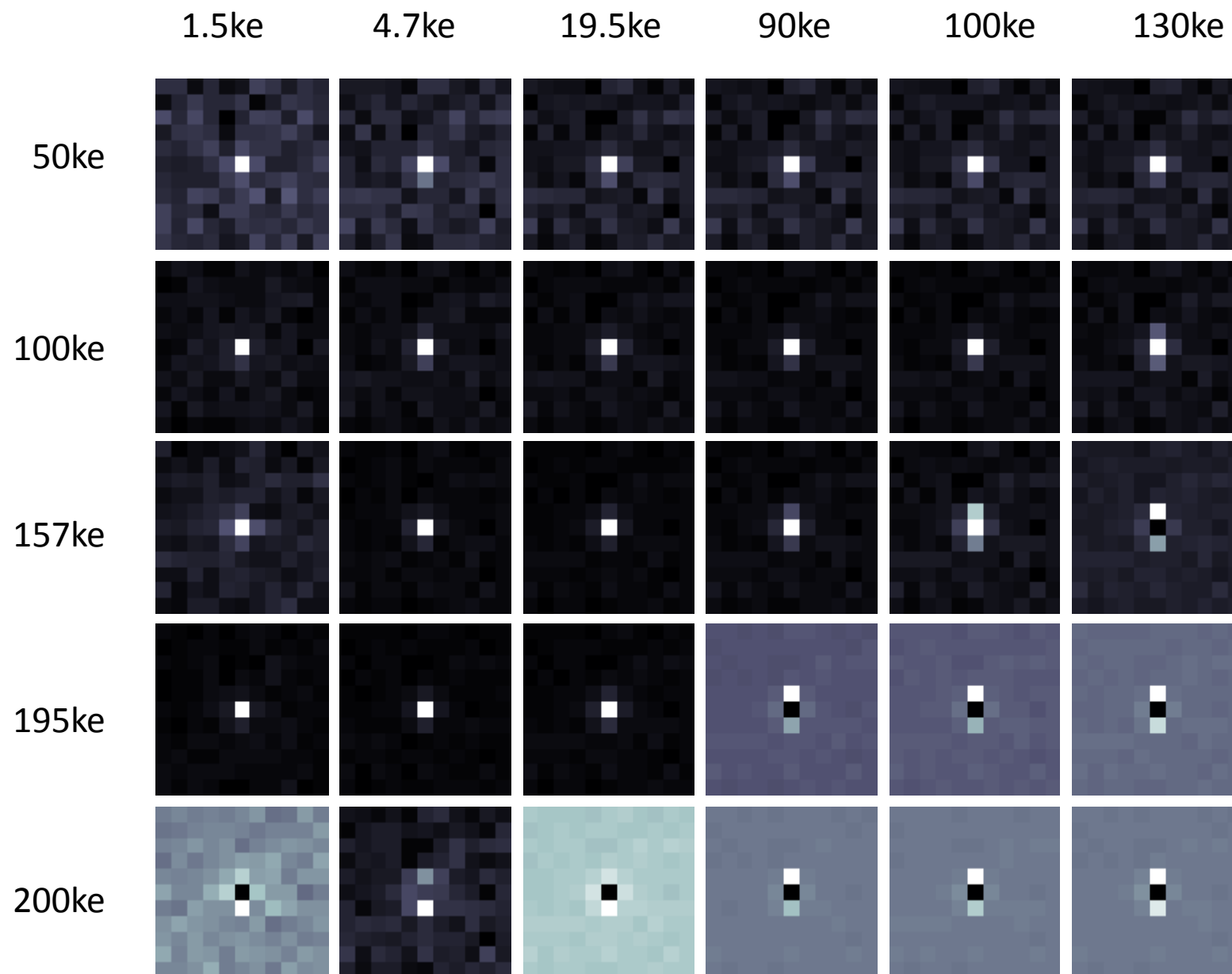
8V Image Clocks



9V Image Clocks

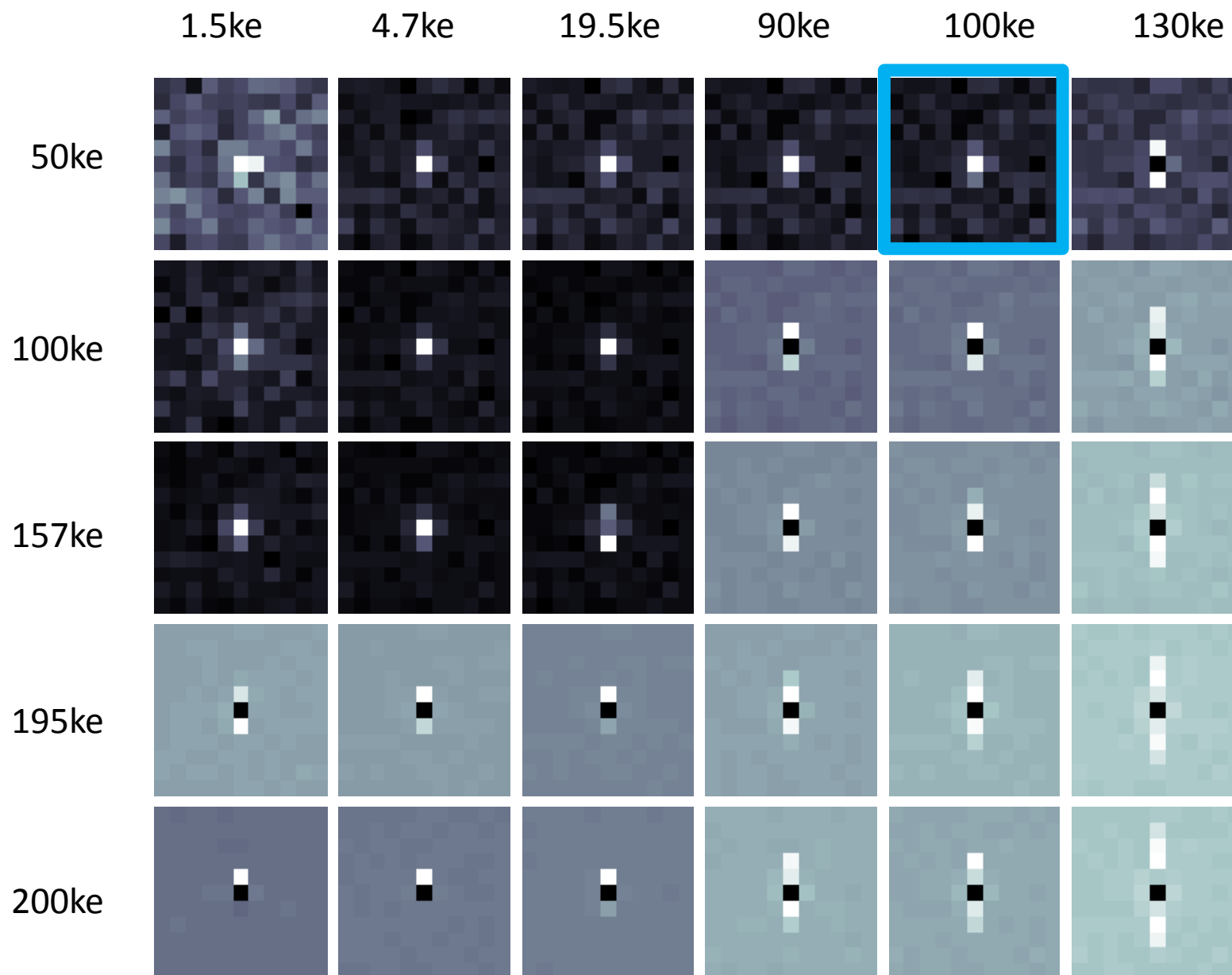


10V Image Clocks

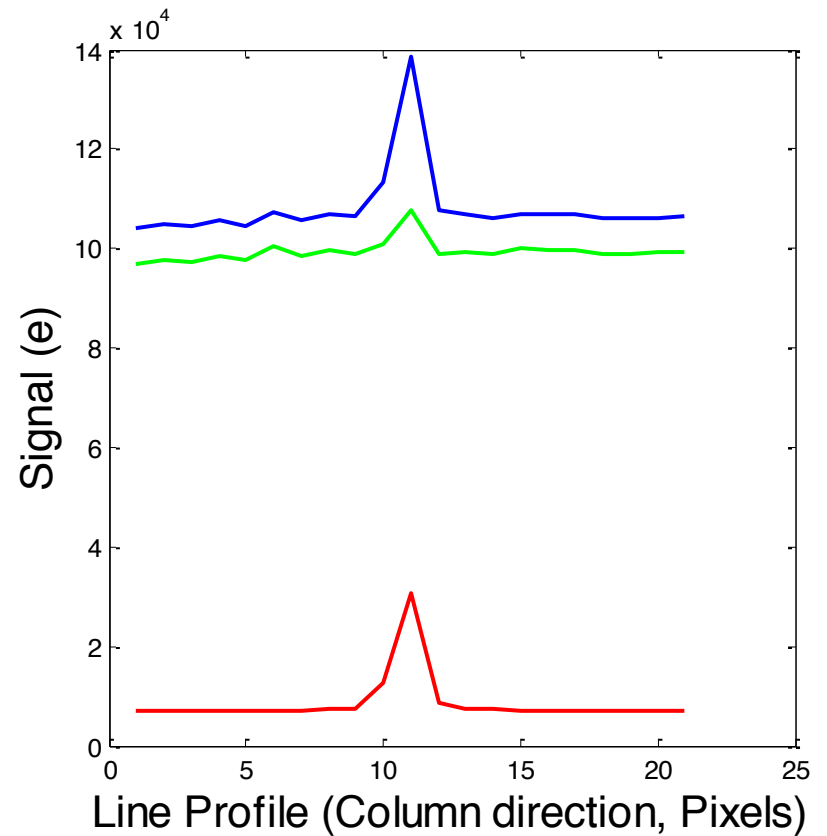
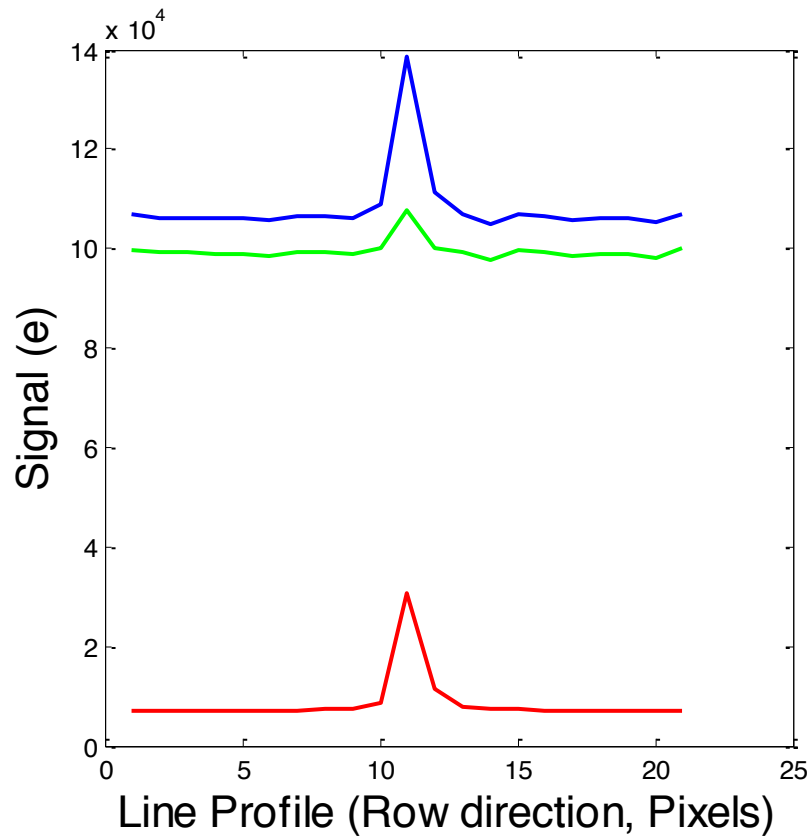
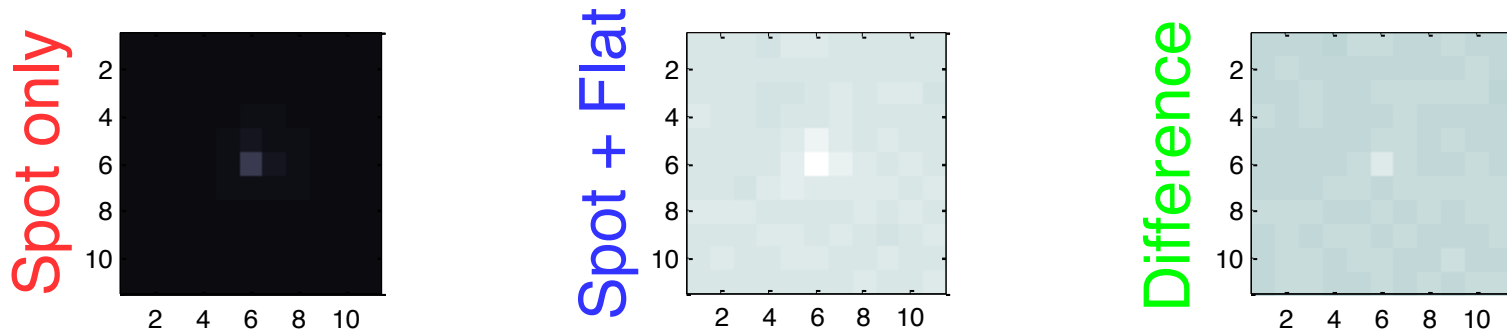


8V Image Clocks

Case Study



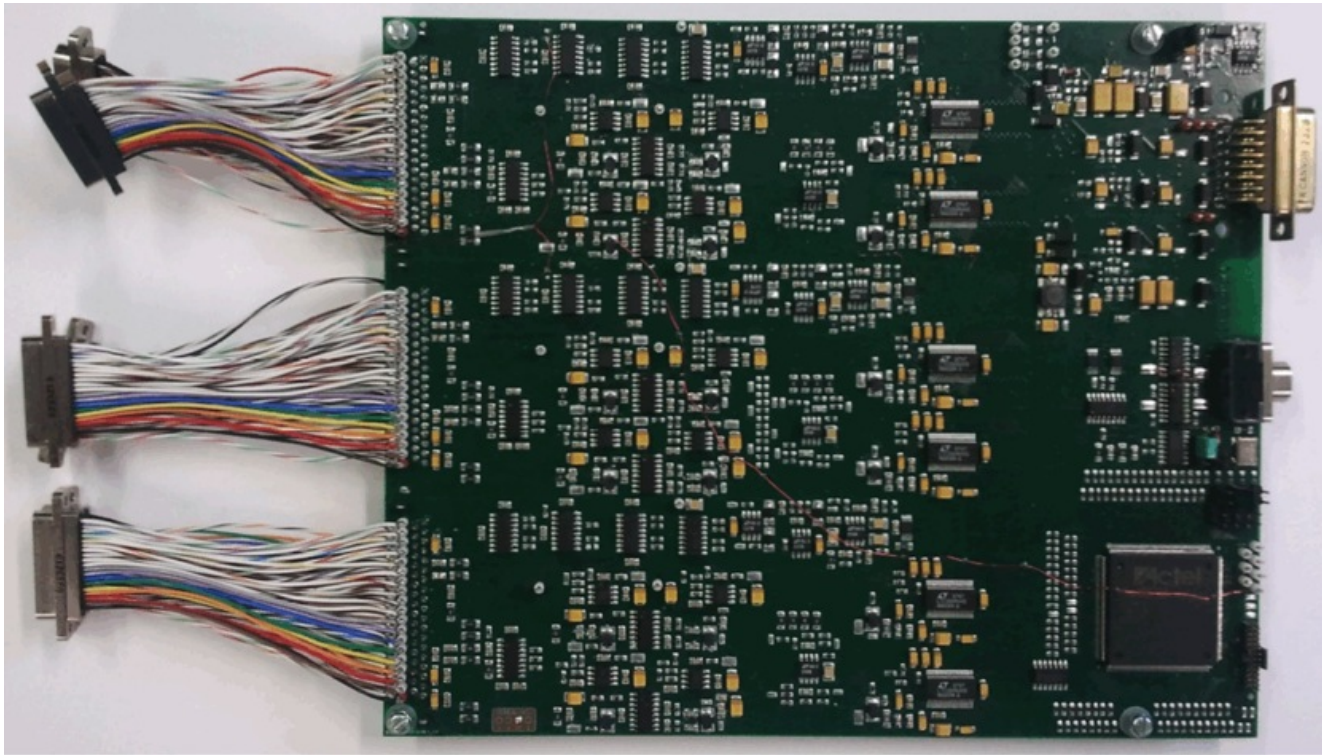
Case Study: Spot and Spot + Flat Differencing.



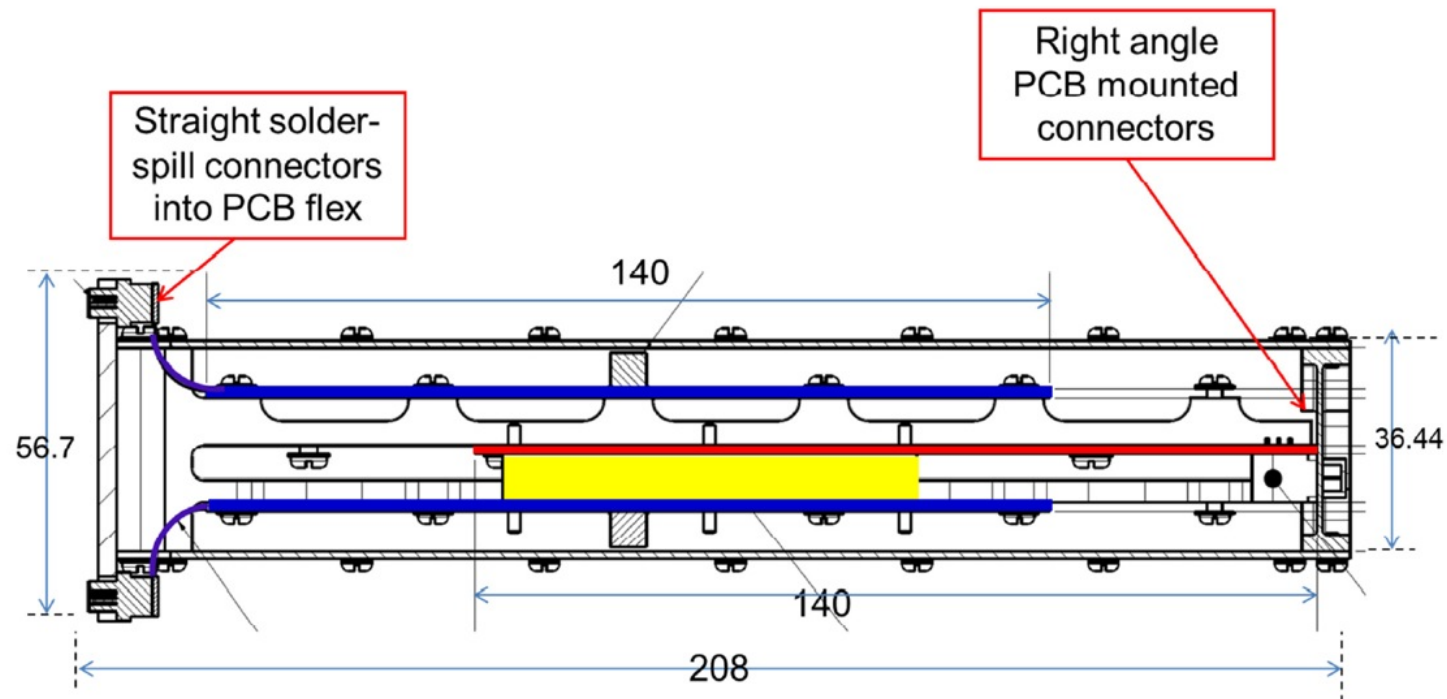
MSSL ROE+RPSU status

Mark Cropper
on behalf of MSSL VIS Team

- After some delay, 2 off EVM-3 boards have now been (mainly) commissioned : EVM-3a is reference; EVM-3b is for modification
 - 12 channels, 3 CCDs
 - rewritten FPGA code from scratch
 - more communication capability (status etc) via Spacewire link

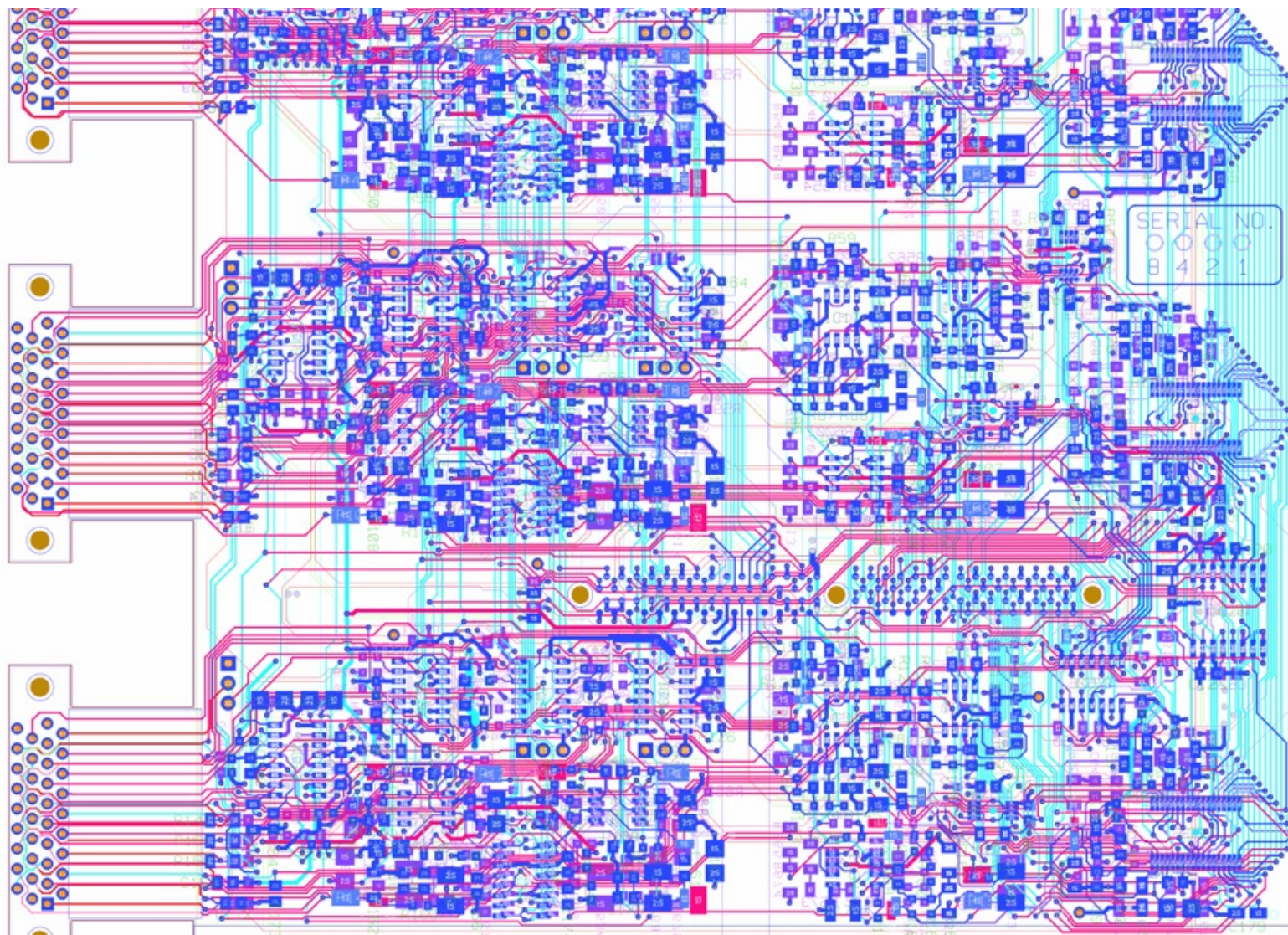


- The next generation of boards, the Demonstration Model, have been laid out and populated.
- Layout as for flight
- Single board carries insufficient space, so separated into:
 - 2 similar video boards (3 top halves of the CCD, 3 bottom halves)
 - digital board



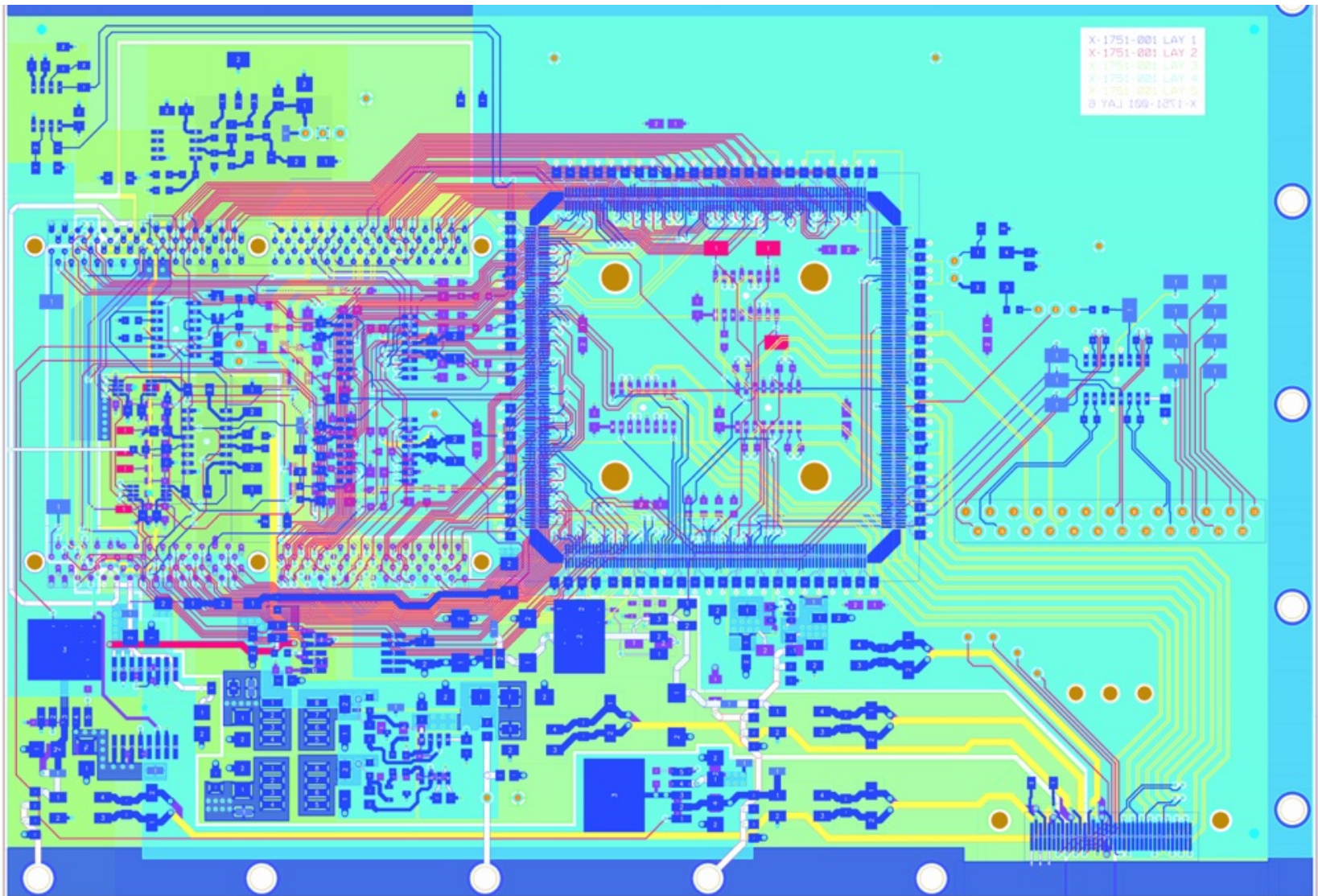
ROE DM video board layouts

EUCLID
CONSORTIUM

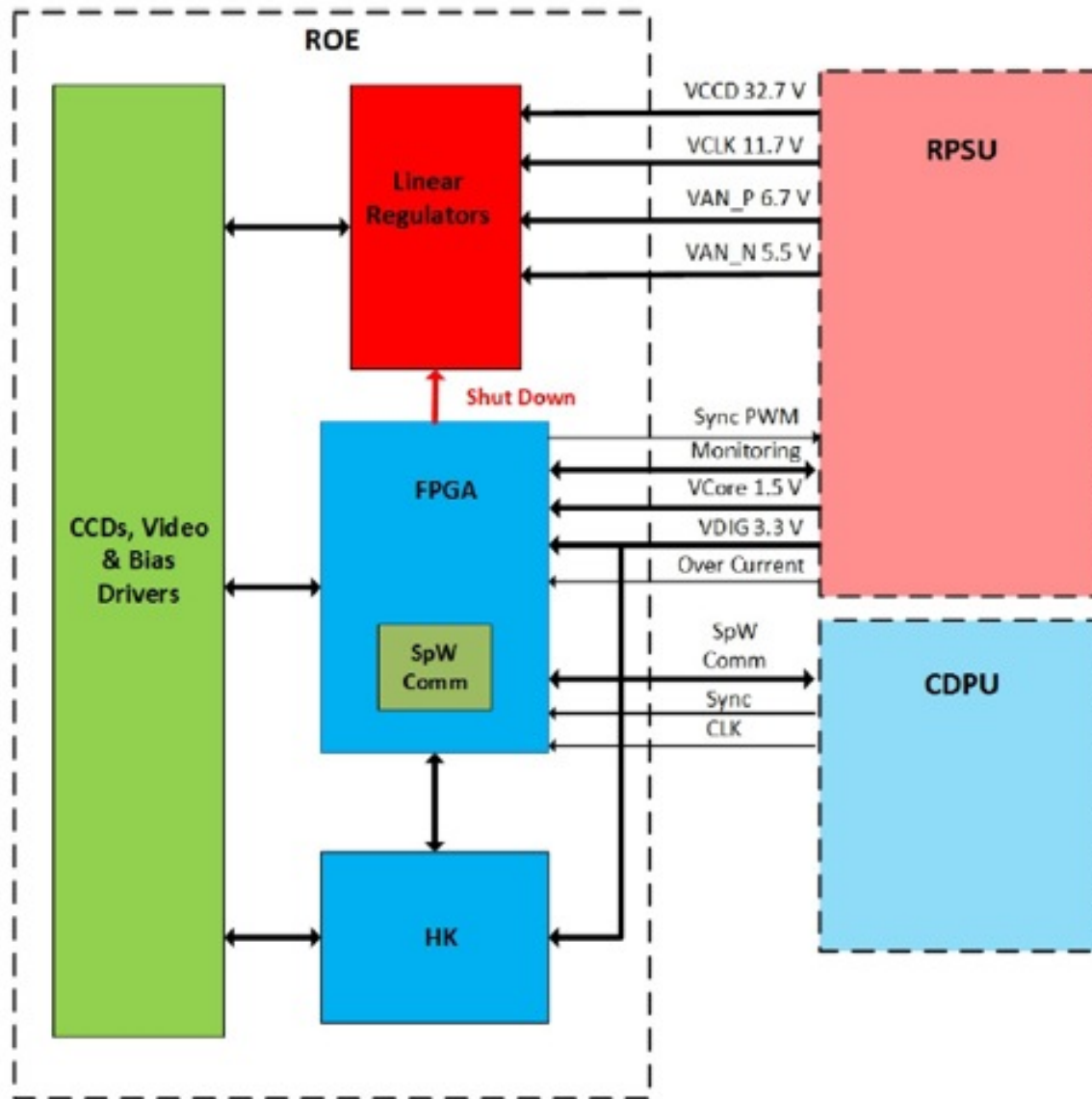


ROE DM digital board layouts

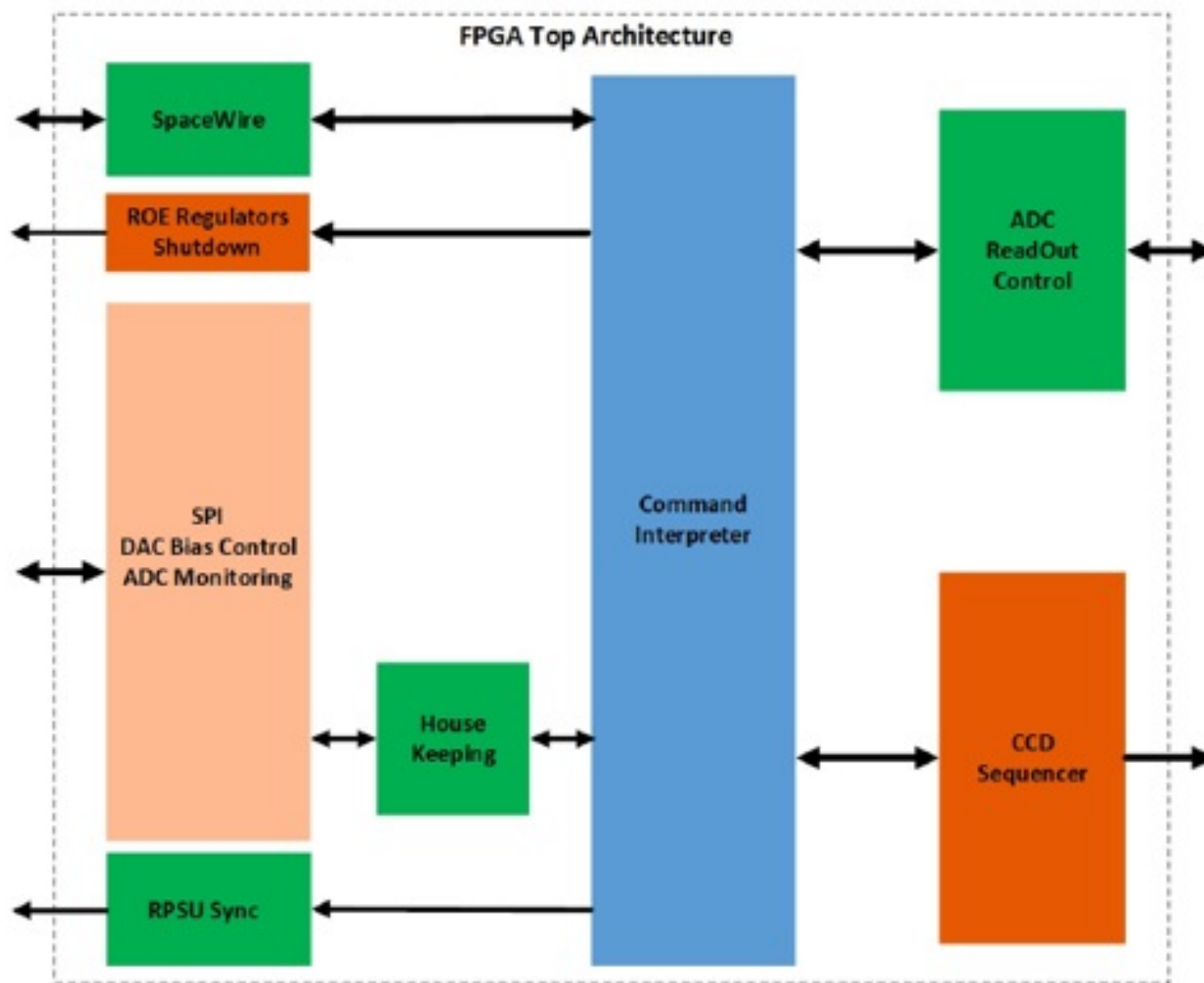
EUCLID
CONSORTIUM

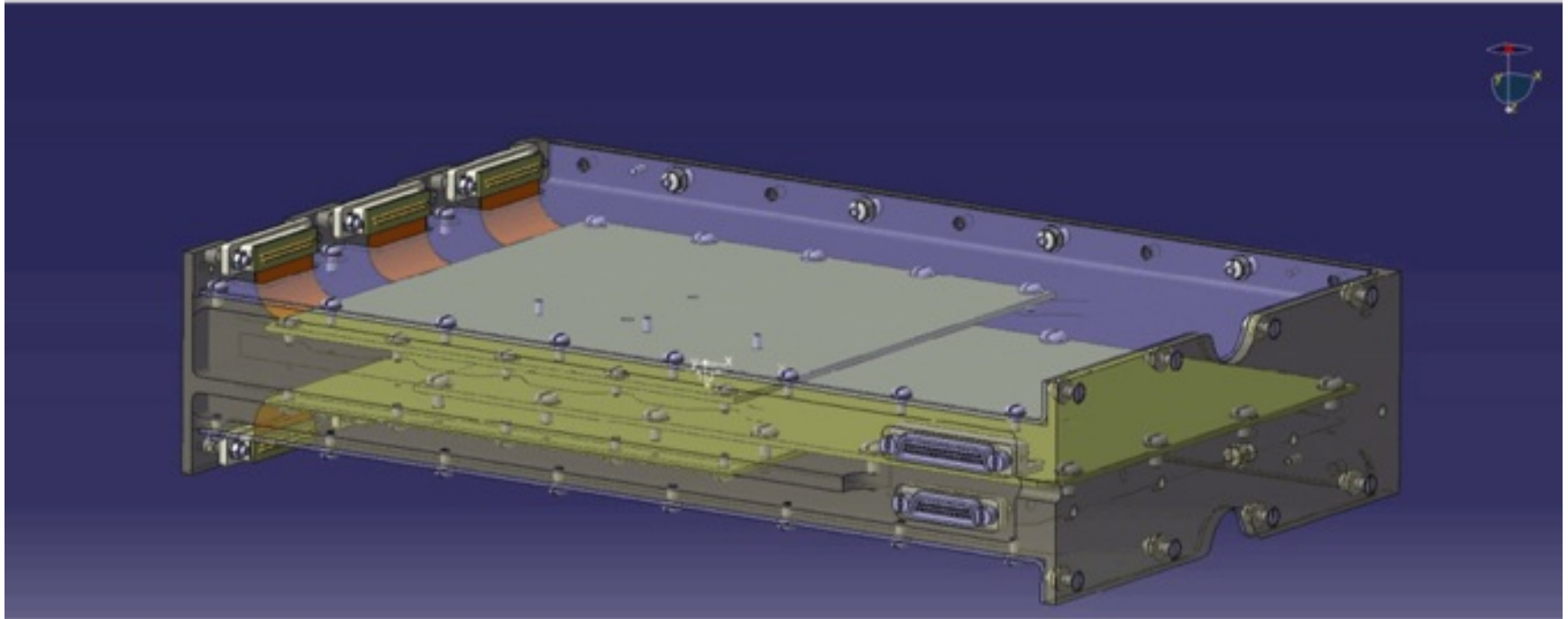


• ROE Interfaces




- ROE communicates with RPSU
- CDPU communicates with ROE





- Mechanical layout optimised for thermal conductivity (12 units tightly spaced)
- Mechanical design stable, except for placement of connectors on side rather than on edge
- Each ROE is fully symmetrical

	Project: Euclid Visible FPA	
	MULLARD SPACE SCIENCE LABORATORY	
	UNIVERSITY COLLEGE LONDON	
	Author: Phil Thomas	

Euclid VisFPA

CCD Readout Requirements
for the Electrical Verification Model (EVM) Readout Electronics

Document Number: MSSL/Euclid/TN/09010.02 Date 22/09/09

Distribution:

Saclay CEA	Alexandre Refregier	<input checked="" type="checkbox"/>
	Jerome Amiaux	<input checked="" type="checkbox"/>
	Christophe Cara	<input checked="" type="checkbox"/>
	Jean Louis Augueres	<input checked="" type="checkbox"/>
ESA	Dave Lumb	<input checked="" type="checkbox"/>
	Ludovic Duwet	<input checked="" type="checkbox"/>
		<input type="checkbox"/>
OU	Andrew Holland	<input checked="" type="checkbox"/>
		<input type="checkbox"/>
Mullard Space Science Laboratory	Mark Cropper	<input checked="" type="checkbox"/>
	Kerrin Rees	<input checked="" type="checkbox"/>
	Phil Thomas	<input checked="" type="checkbox"/>
	Dave Walton	<input checked="" type="checkbox"/>
	Alan Spencer	<input type="checkbox"/>
	Phil Guttridge	<input checked="" type="checkbox"/>

Author: Phil Thomas Date: 21/9/09
 Manager/Project Office: Phil Guttridge Date: 22/9/09
 PA: _____ Date: _____

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	Project: Euclid Vis	
	MULLARD SPACE SCIENCE LABORATORY	
	UNIVERSITY COLLEGE LONDON	
	Author: Massimiliano Canali	

Euclid VisFPA

CCD Readout Requirements
for the Development Model (DM) ROE

Document Number: MSSL/Euclid/TN/xxx

Distribution:

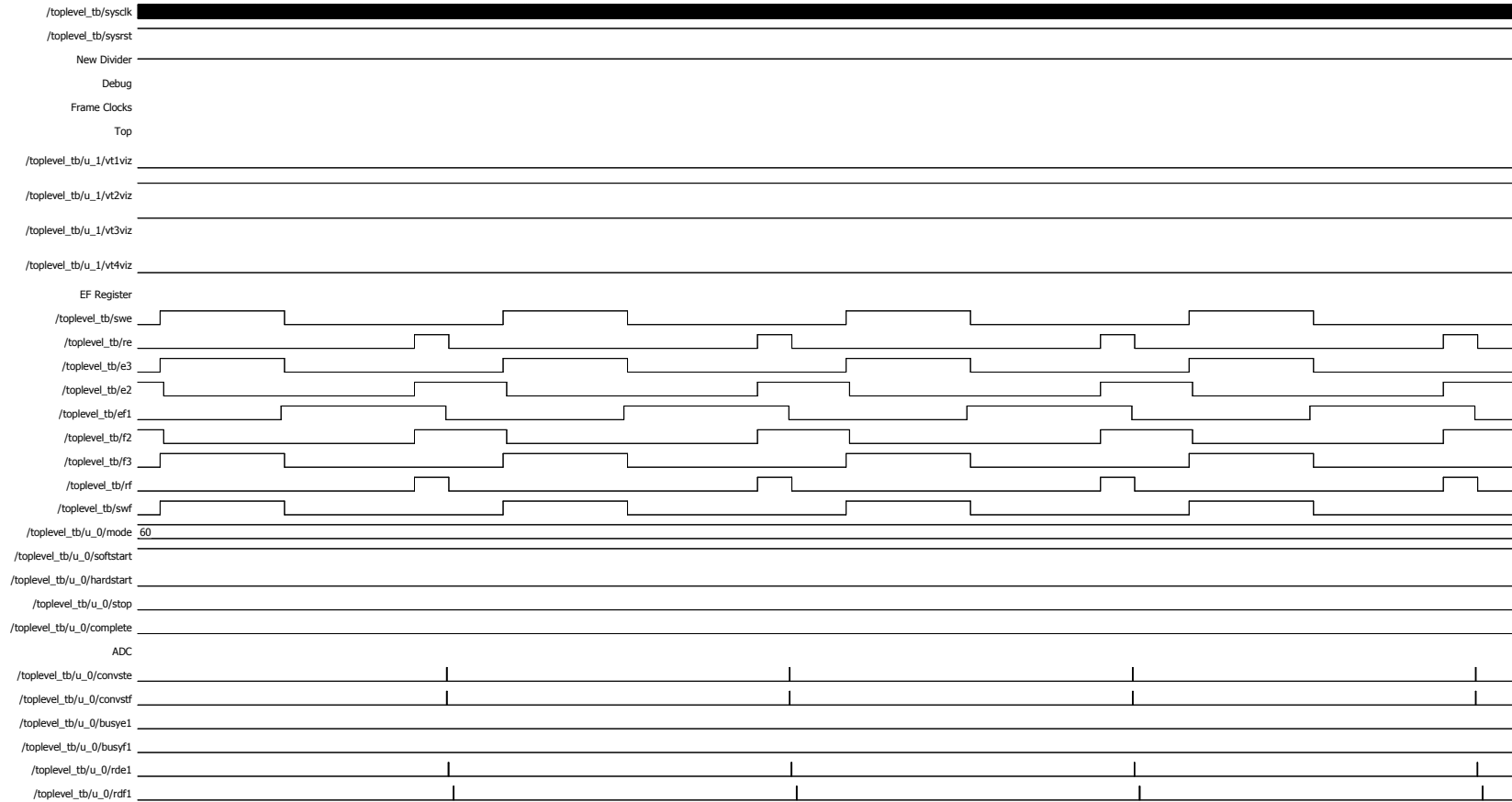
Mullard Space Science Laboratory	Mark Cropper	<input type="checkbox"/>
	Christophe Cara	<input type="checkbox"/>
	Jean Louis Augueres	<input type="checkbox"/>
	Dave Lumb	<input type="checkbox"/>
	Ludovic Duwet	<input type="checkbox"/>
	Andrew Holland	<input type="checkbox"/>
	Mark Cropper	<input type="checkbox"/>
	Kerrin Rees	<input type="checkbox"/>
	Phil Guttridge	<input type="checkbox"/>
	Jamie Denniston	<input type="checkbox"/>
	Dave Westwood	<input type="checkbox"/>

Contributors: Massimiliano Canali Date: 28/06/13
 Dave Westwood
 Manager/Project Office: Phil Guttridge Date: 28/06/13
 PA: _____ Date: _____

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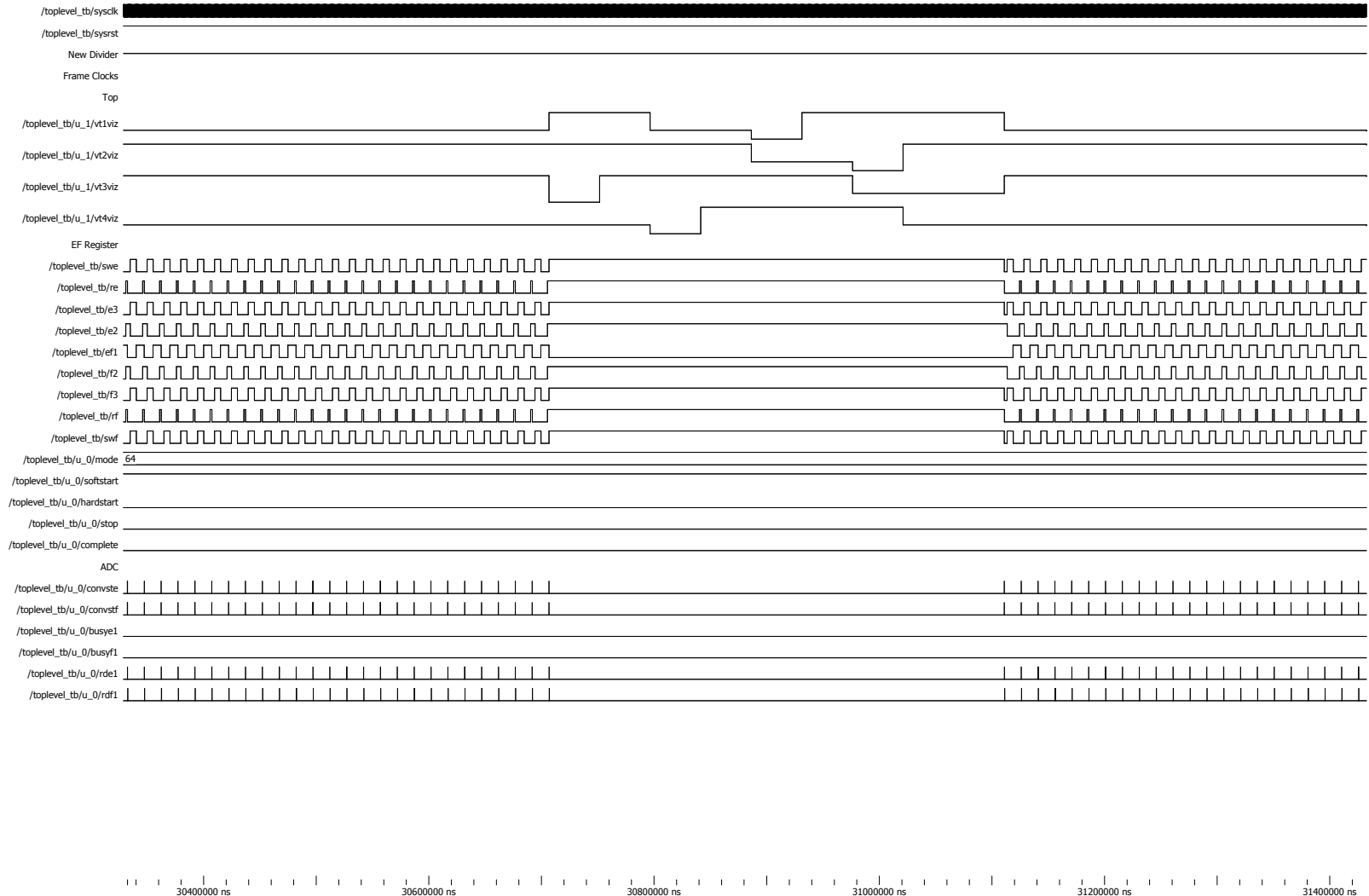
still needs to be thoroughly checked

EVM3b clocking: serial



31220000 ns 31230000 ns 31240000 ns 31250000 ns 31260000 ns 31270000 ns

EVM3b clocking: parallel tri-level

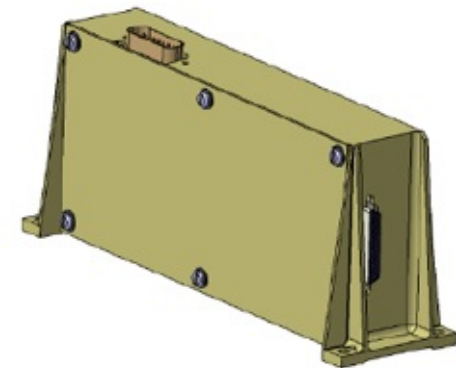


Specification Summary (5 Sep13)

Cat	Update	Mand- atory for EVM3	HW chang e	EVM3- A	EVM3- B	DM
A	ROE meets CCD273 operational voltages	X		X (st)		
B:a	Slowing down the parallel transfer				X	
B:b	Use of coincident clocking scheme		?		X	
B:c	Equal Video Clocking		?		X	
B:d	Revision of the current pattern of charge injection		?		X	
B:e	Pocket pumping		?		X	
B:f	Tri-state clocking		X??			X
C	Image Persistence		X			X
D	Filter Bandwidth and Readout Noise	X	X		X	
E	Read overscan		?		X	
F	Accommodation to mechanical form		X			X
G	Change to 70kHz and 4.5e- spec	X	X	X		

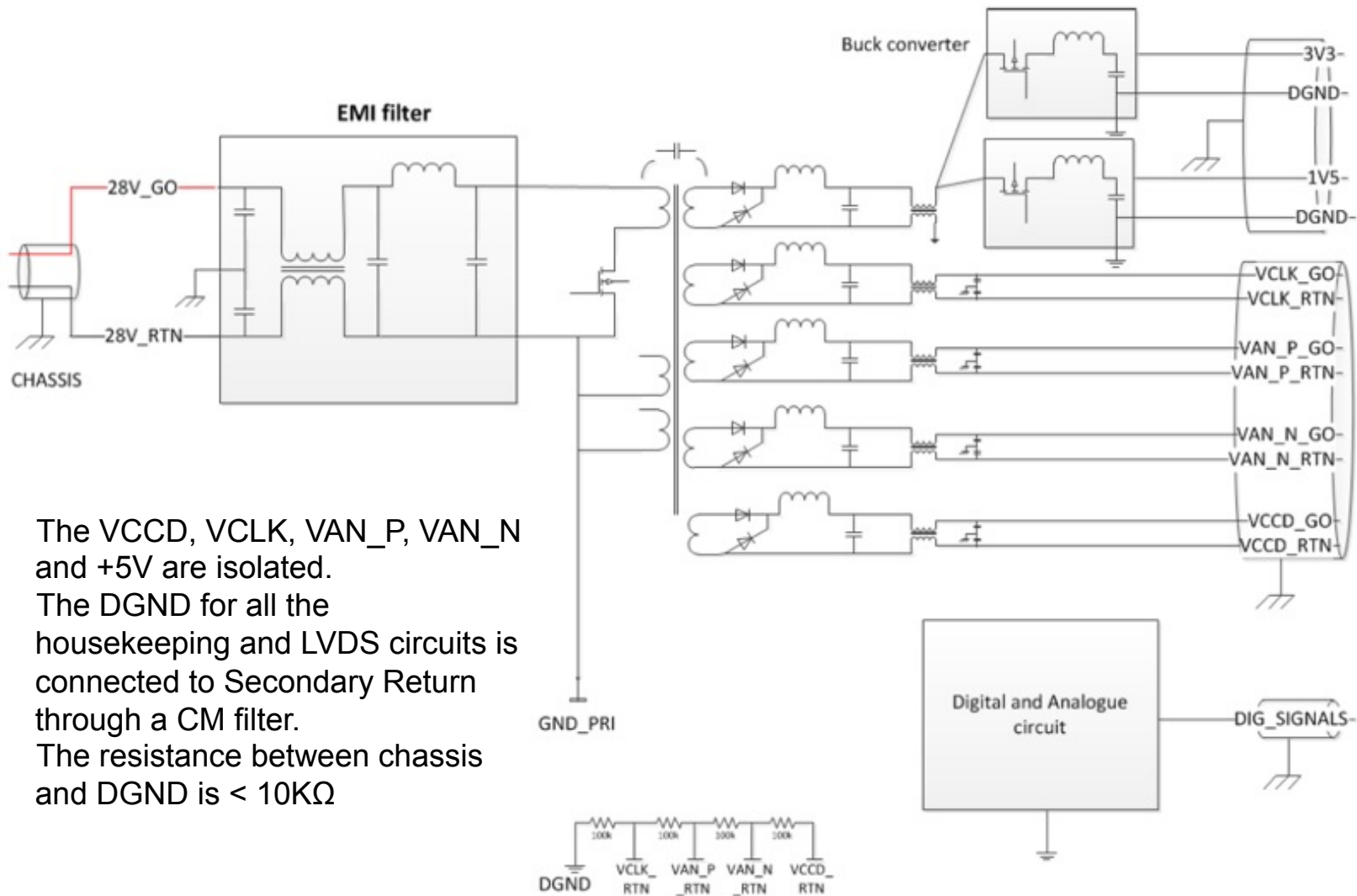
still needs to be thoroughly checked

**EUCLID
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- Board layout complete
- Board population commencing


RPSU Grounding Scheme

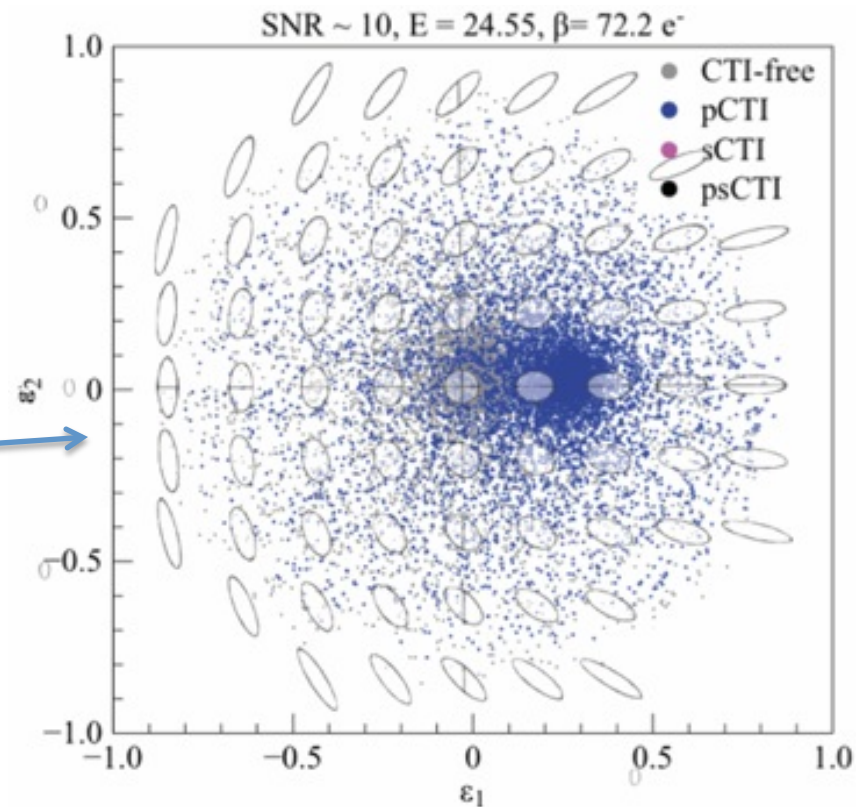


- The VCCD, VCLK, VAN_P, VAN_N and +5V are isolated.
- The DGND for all the housekeeping and LVDS circuits is connected to Secondary Return through a CM filter.
- The resistance between chassis and DGND is $< 10K\Omega$

Reconciliation of TP'h/MSSL evaluation of CTI effects on galaxy shapes

Sami Niemi, Mark Cropper, Thibaut Prod'homme

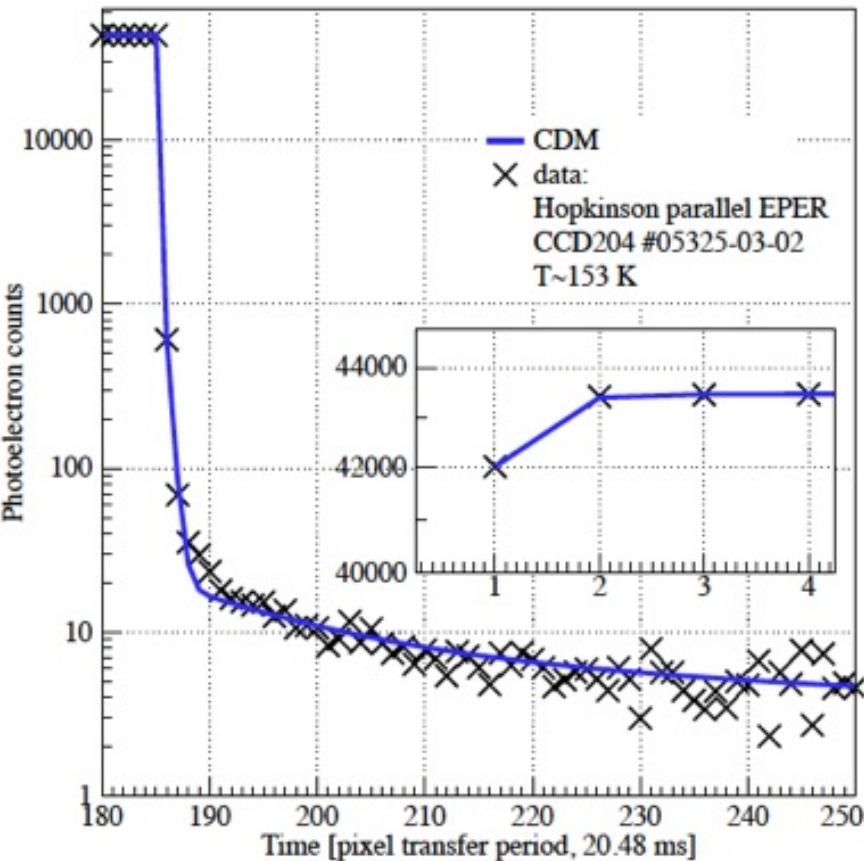
- At CCD-WG#6 and #7, TP'h et al (16Jan13) had examined the effects of radiation damage on images in the Euclid context:
CTI effects on the determination of galaxy image parameters in the context of Euclid Part 1: a noise free study
- The implications were that the uncorrected ellipticities were larger than that found by the EC and used in the weak lensing performance prediction:
EC <5% (Massey)
TP'h ~25%

- Investigation by S. Niemi (27Jun13) into the differences:
Charge Transfer Inefficiency Modelling: CDM03 Parameters



- Both studies used the SSTL data on the CCD204 analysed by Gordon Hopkinson for inputs, scaled by appropriate factors identified by Ralf Kohley (CCD-WG#5)
 - 200 kHz readout rate
 - very old SSTL readout scheme (prior to VIS baseline)
- TP'h believed that the serial CTI was not reliable in his studies (and the EC studies?) and should be discounted
- TP'h simulations used galaxies randomly sized, orientated and placed, in a noise-free environment; EC studies (Massey) used circular galaxies in a worst-case position
- Both studies used standard Euclid recipe for calculating ellipticity and size
- Both studies used Alex Short's CDM03 code
 - TP'h used Java instance from GaiaTools
 - SN used Fortran instance for standard exposures (non-TDI) from Alex Short

- Differences could lie in
 - ① different simulation code
 - ② different parameters for the code
 - ③ different measurement techniques of the ellipticity (especially pre-centroiding techniques for the weight function)
 - Reason could be all three...
 - For (2) above, fits to EPER data were claimed by both TP'h and SN but are inconsistent.
 - Niemi fit to SSTL data with own CDM03 parameters OK
 - Prod'homme fit to SSTL data with own CDM03 parameters OK
 - Niemi fit to SSTL data with Prod'homme CDM03 parameters not-OK
- ⇒ codes inconsistent; TP'h using TDI mode?

Prod'homme

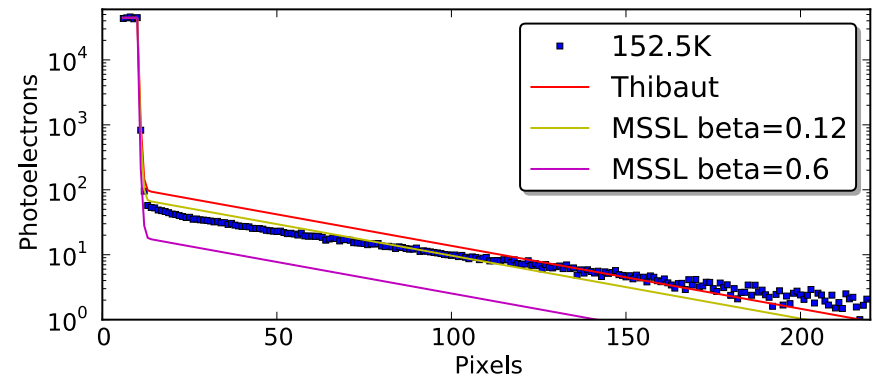
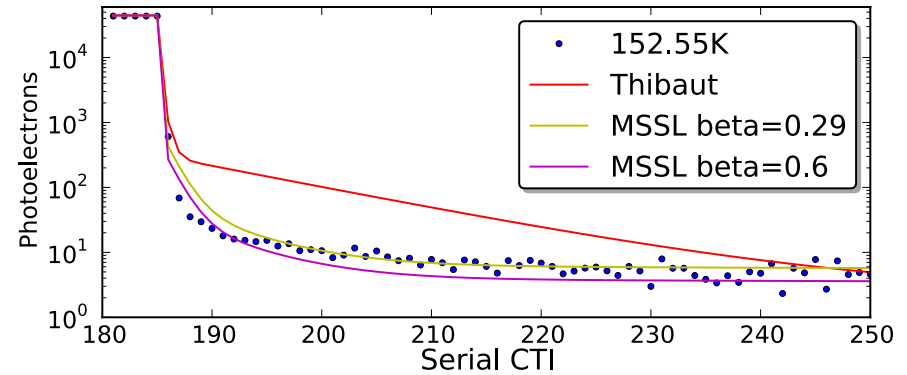


Niemi

(but using TP'h parameters for the Thibaut curve)

CCD204 05325-03-02 Hopkins EPER at 200kHz, with 20.48ms, 8e9 at 10MeV

Parallel CTI



Some parameters were different, however...

CDM03 Parameter Comparison							
MSSL				Thibaut			
parameter	variable	value	unit		variable	value	unit
charge cloud expansion in parallel direction [0, 1]	beta_p	0.29		TRUE		0.29	
charge cloud expansion in serial direction [0, 1]	beta_s	0.12		TRUE		0.12	
full-well capacity (pixel)	fwc	200000.0		TRUE		200000	
serial (readout register) pixel full-well capacity	sfwc	730000.0		FALSE		1450000	
electron thermal velocity	vth	1.168E+07	cm/s	FALSE		1.62E+07	
parallel line speed	t	2.048E-02	s	FALSE		2.10E-02	
serial pixel transfer period	st	5.00E-06	s	TRUE		5.00E-06	
geometric confinement volume (parallel)	vg	6.00E-11	cm**3	FALSE		1.44E-10	cm**3
geometric confinement volume (serial)	svg	1.00E-10	cm**3	FALSE		6.00E-10	cm**3
radiation dosage	rdose	1.60E+10		FALSE		8.00E+09	
trap occupancy level initialization	sdob	0.00	e/pix/transit	TRUE		0.00	
charge injection duration (parallel)							
charge injection duration (serial)							
number of parallel transfers							
number of serial transfers							

Trap Parameters (parallel only)

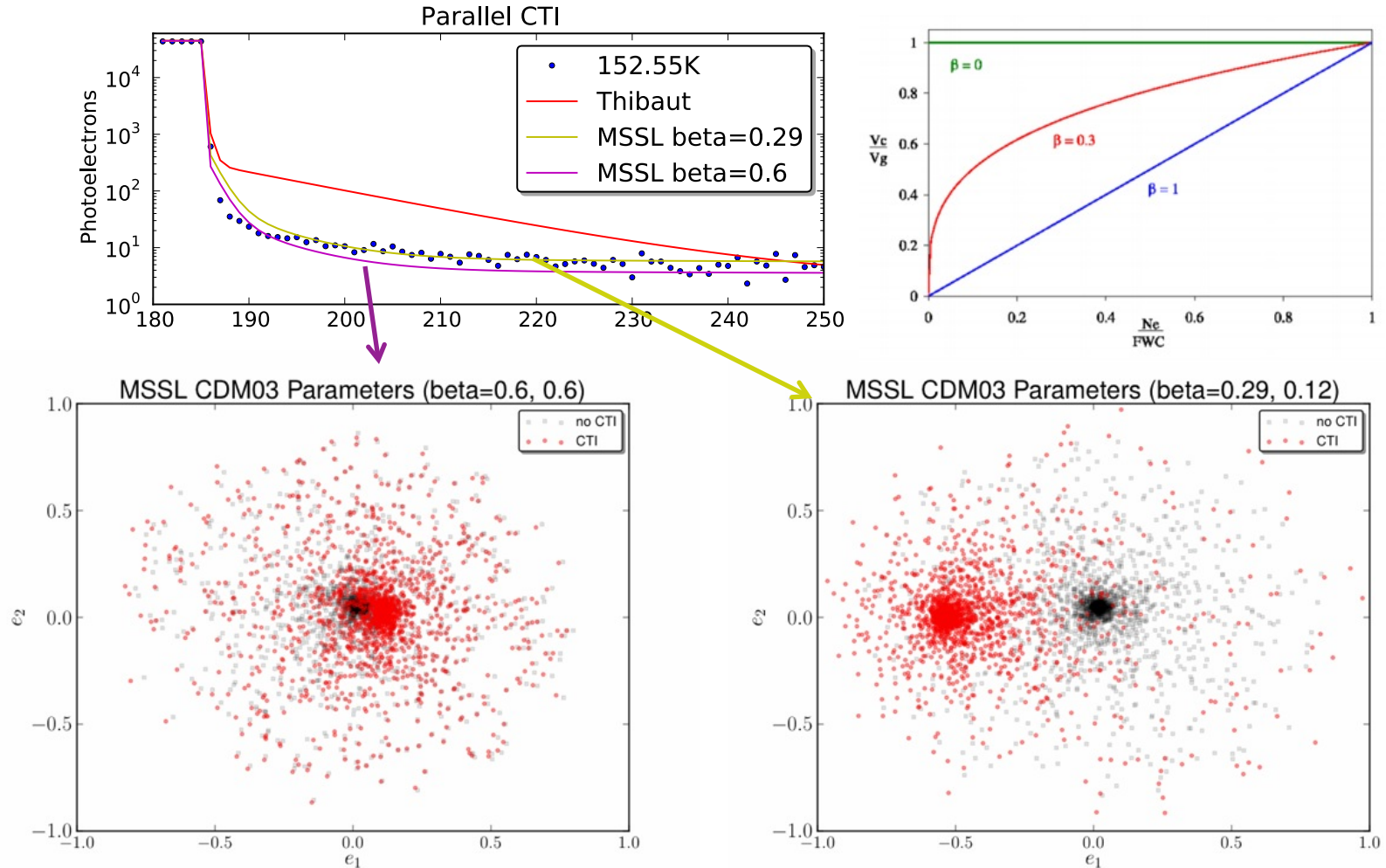
Niemi

Prod'homme

trap species	parallel								
relative density of trap species	nt1	40.00			rho1	10.07	per pixel		
capture cross-section	sigma1	2.20E-13	cm**2		sigma1	5.14E-23	m**2	5.14E-19	cm**2
trap release time constant	tau1	8.20E-07	s		tau1	9.33E-03	s		
relative density of trap species	nt2	1.20			rho2	5.76	per pixel		
capture cross-section	sigma2	2.20E-13	cm**2		sigma2	1.65E-25	m**2	1.65E-21	cm**2
trap release time constant	tau2	3.00E-04	s		tau2	2.74E-01	s		
relative density of trap species	nt3	1			rho3	0.69	per pixel		
capture cross-section	sigma3	4.72E-15	cm**2		sigma3	4.42E-18	m**2	4.42E-14	cm**2
trap release time constant	tau3	2.00E-03	s		tau3	3.04E+00	s		
relative density of trap species	nt4	1			rho4	0.27	per pixel		
capture cross-section	sigma4	1.37E-16	cm**2		sigma4	1.33E-18	m**2	1.33E-14	cm**2
trap release time constant	tau4	2.50E-02	s		tau4	1.77E-03	s		
relative density of trap species	nt5	0.23							
capture cross-section	sigma5	2.78E-17	cm**2						
trap release time constant	tau5	1.24E-01	s						
relative density of trap species	nt6	2.9							
capture cross-section	sigma6	1.93E-17	cm**2						
trap release time constant	tau6	1.67E+01	s						
relative density of trap species	nt7	10							
capture cross-section	sigma7	6.39E-18	cm**2						
trap release time constant	tau7	4.92E+02	s						

- Parameter β in CDM03 is significant.

CCD204 05325-03-02 Hopkinson EPER at 200kHz, with 20.48ms, 8e9 at 10MeV



- Effectively,
 - if β is small, then \sim the same number of traps is seen for small signals as for large ones
 - if $\beta \rightarrow 1$ then number of traps scales \sim proportionally to signal
- TP'h indicates that the values he's found from *Gaia* data are all in the region $\beta < 0.3$
- Work done by the Open University Group (Hall et al) find that $\beta = 0.42$ to 0.45
- Cause? (TDI mode in *Gaia*?)
- Needs resolution...
- Further discussion planned

e2v centre for electronic imaging



Silvaco and CDM

Initial compatibility analysis

David Hall

Trap species used

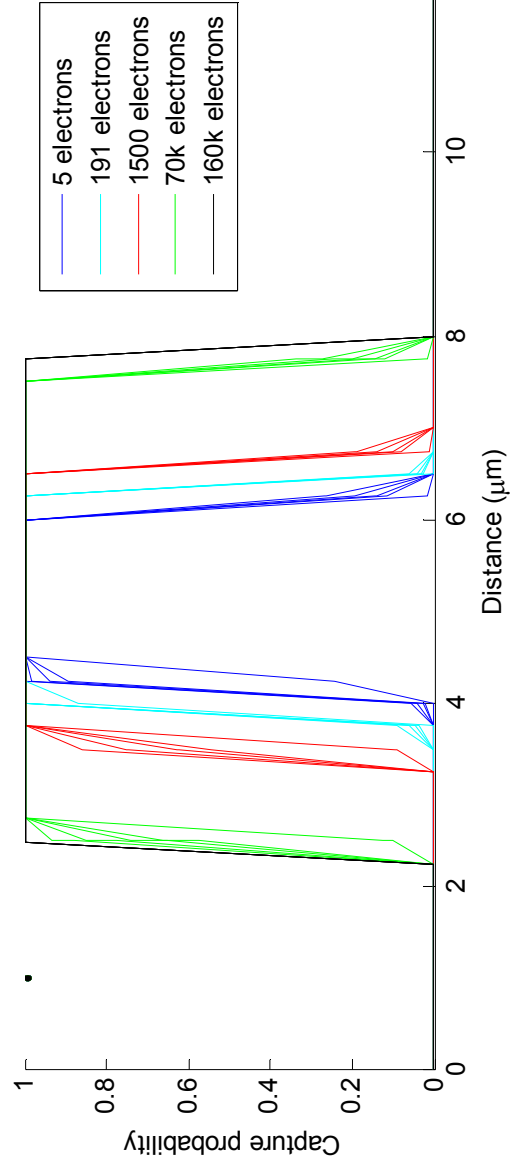
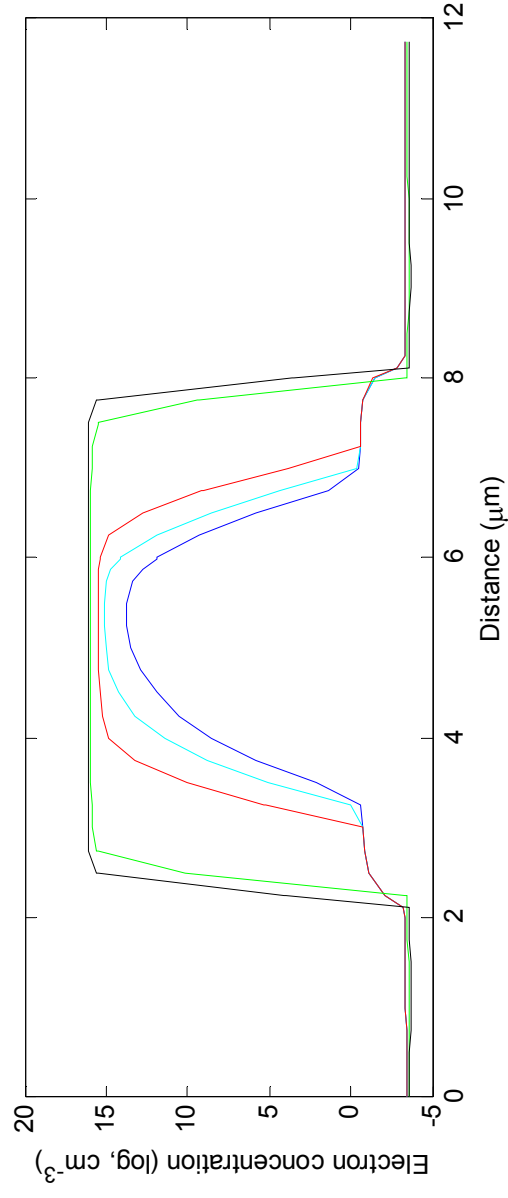


- Based on work with David Burt:

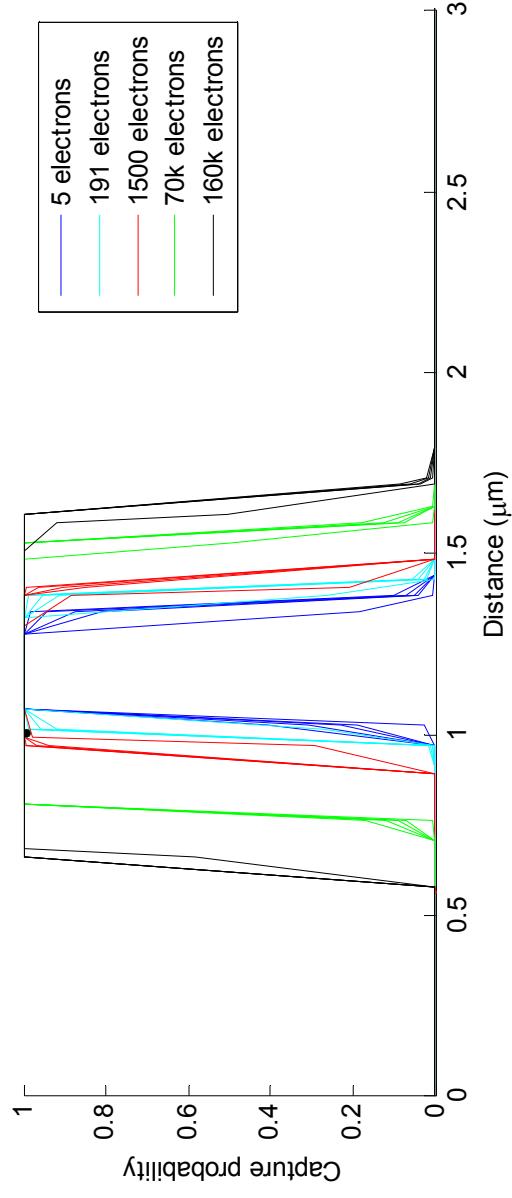
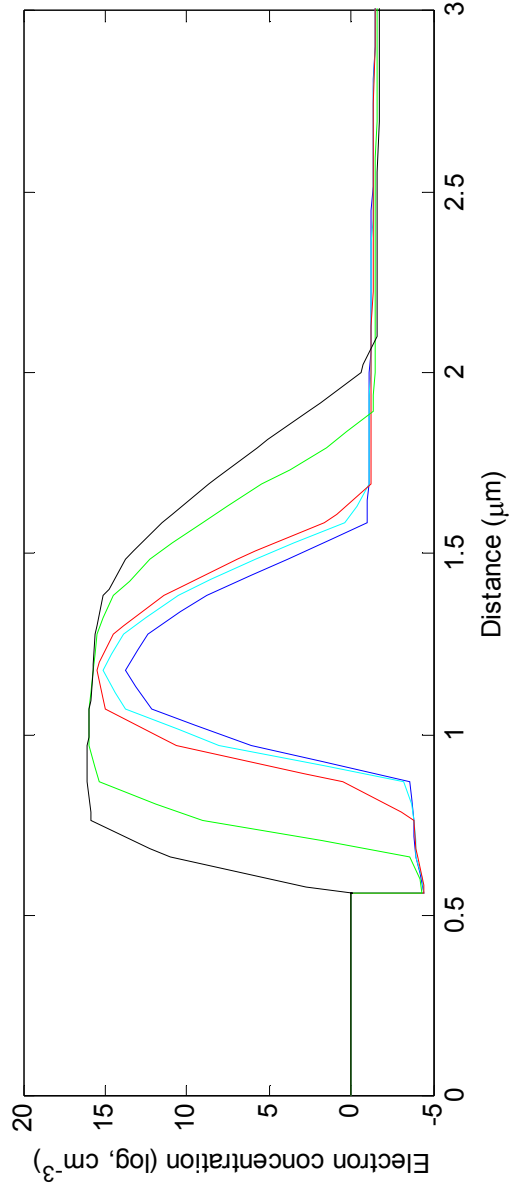
Trap	E_T eV	$\sigma \times 10^{-15} \text{ cm}^2$	Possible type	Density
A	0.46	4	E-centre (P-V)	$2 \times 10^{10} / \text{cm}^3$
B	0.39	7	Divacancy (V-V-)	$1 \times 10^{10} / \text{cm}^3$
C	0.30	5	?	None
D	0.21	0.5	Divacancy (V-V--)	$1 \times 10^9 / \text{cm}^3$
E	0.17	10	A-centre (O-V)	TBD

Best-fit to the limited amount of reliable data and may not be fully representative of all trap types

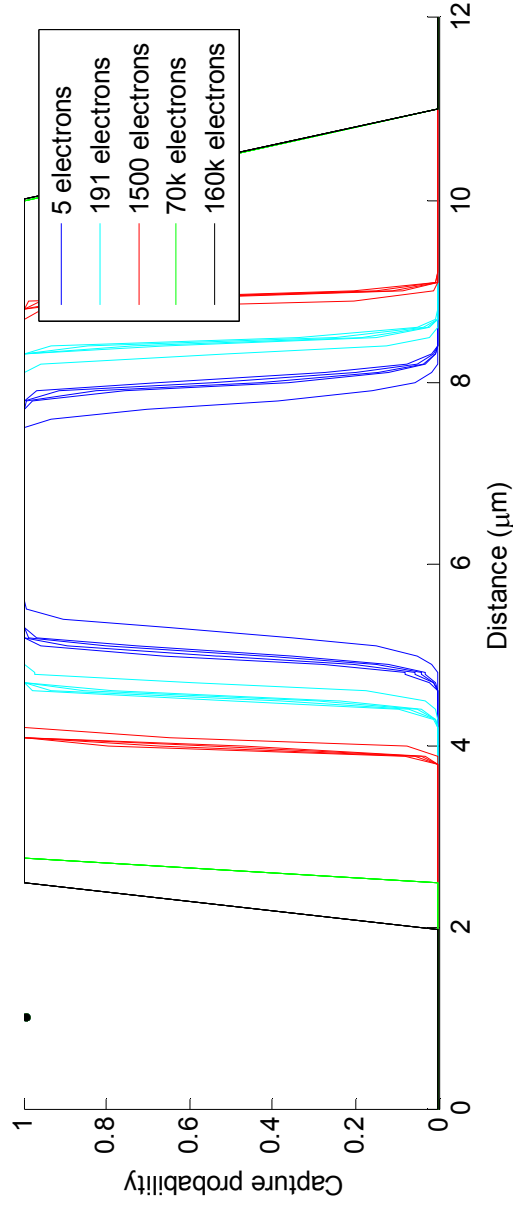
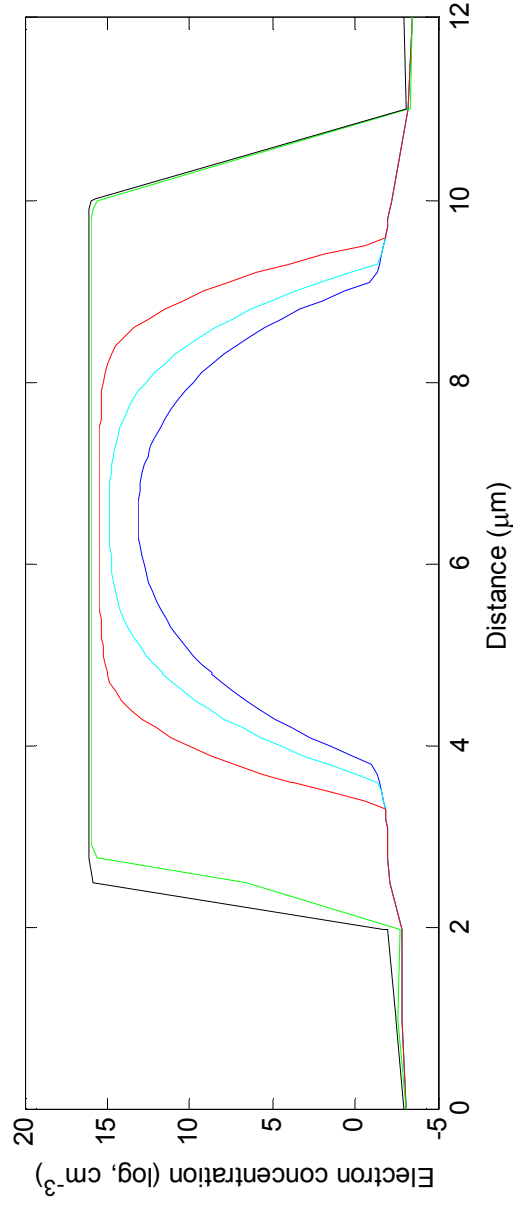
Parallel Silvaco model



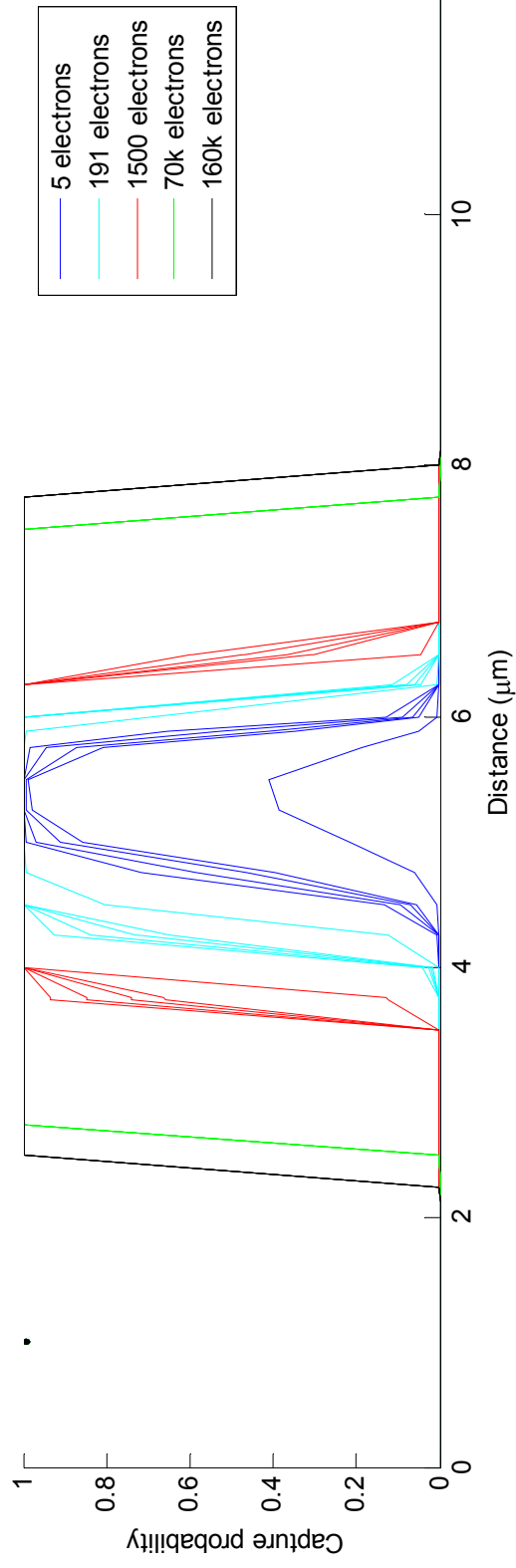
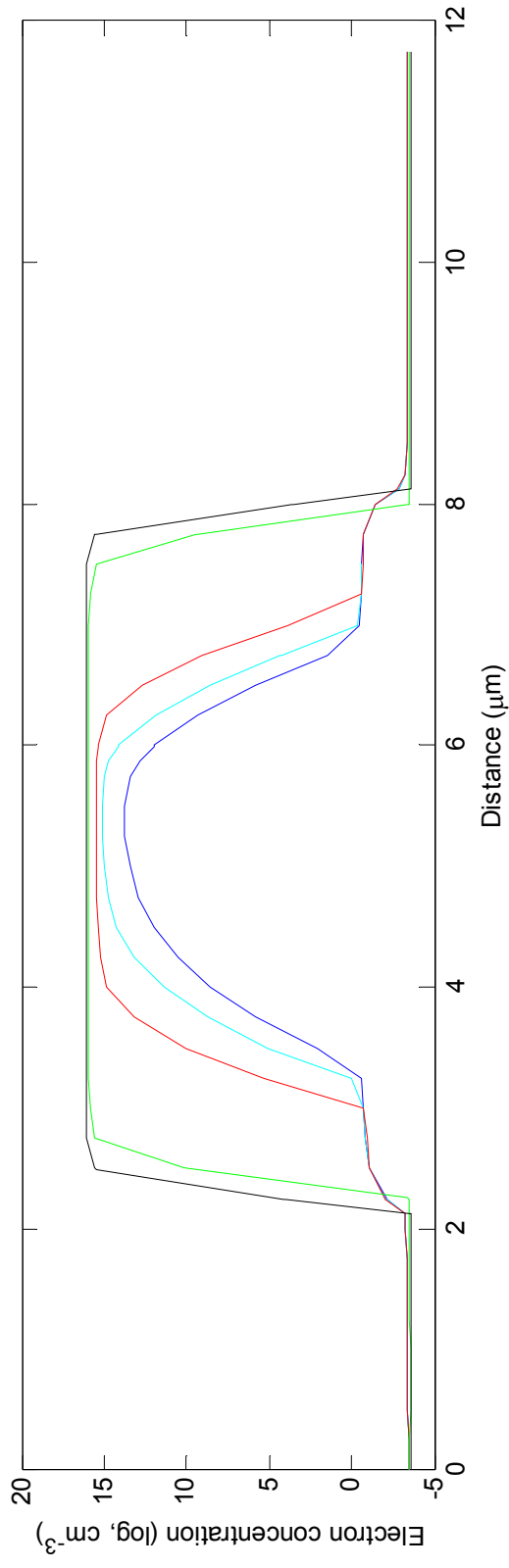
Parallel Silvaco model



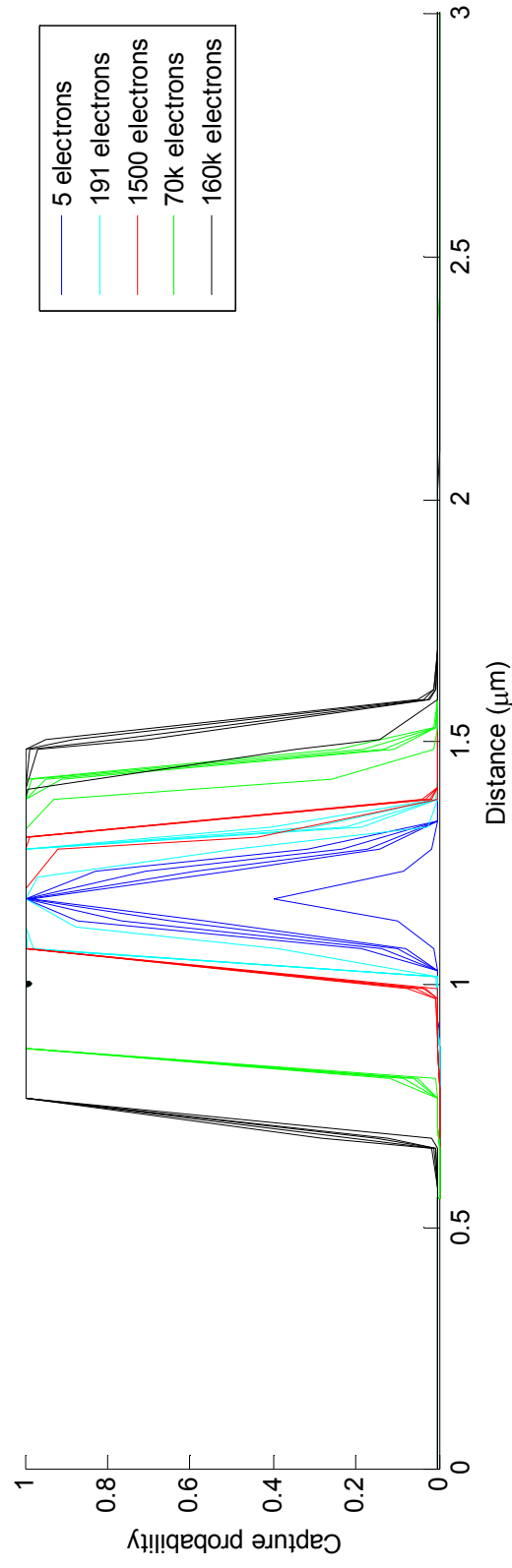
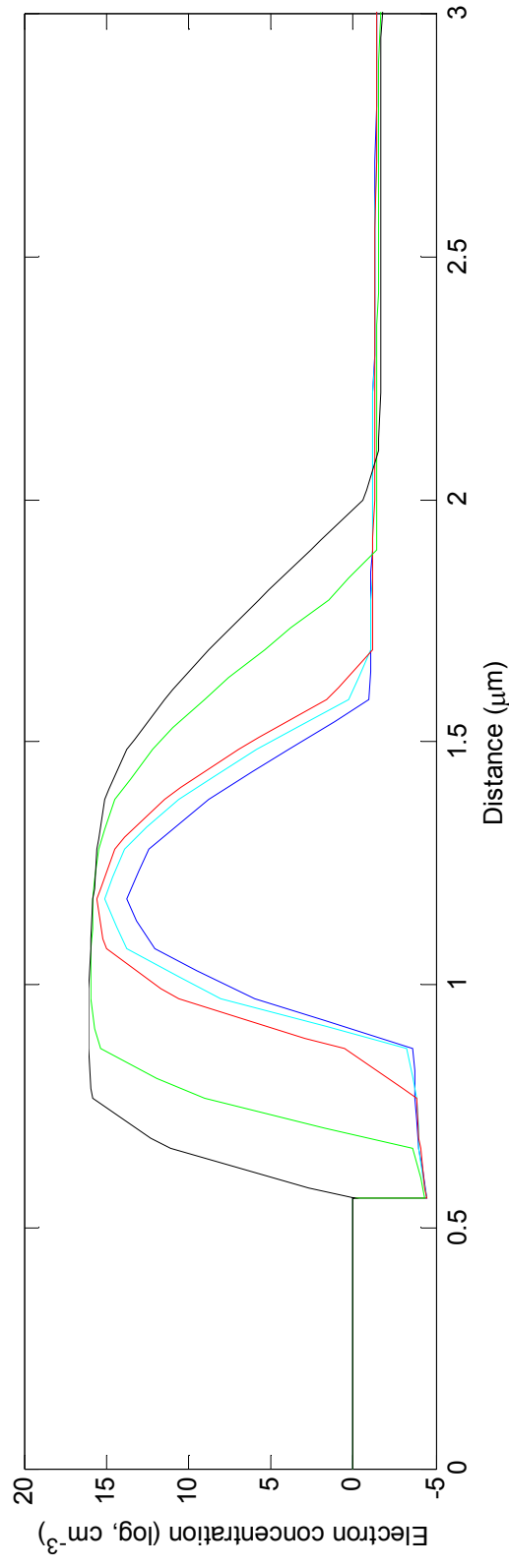
Parallel Silvaco model



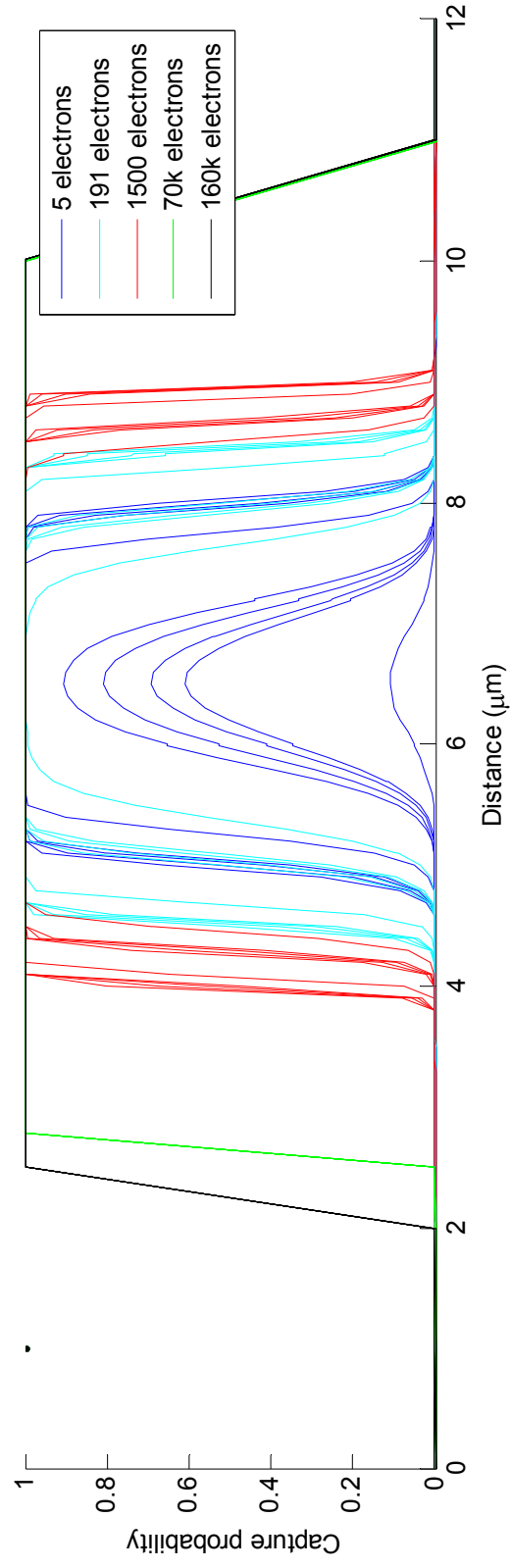
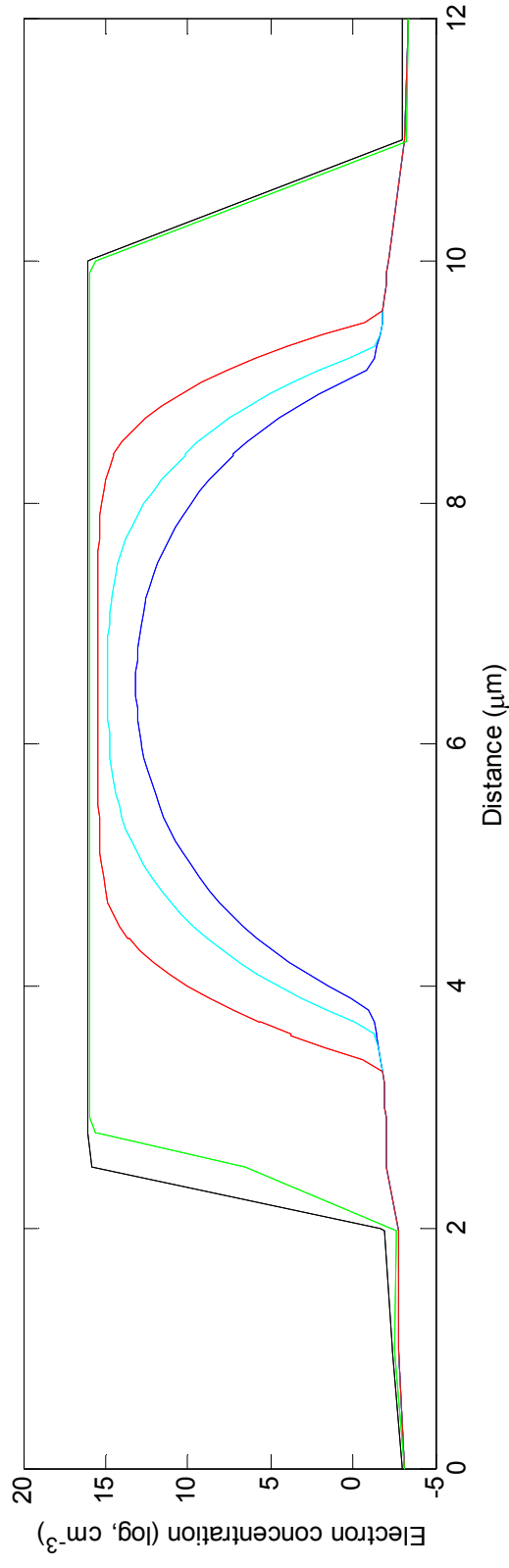
Serial Silvaco model



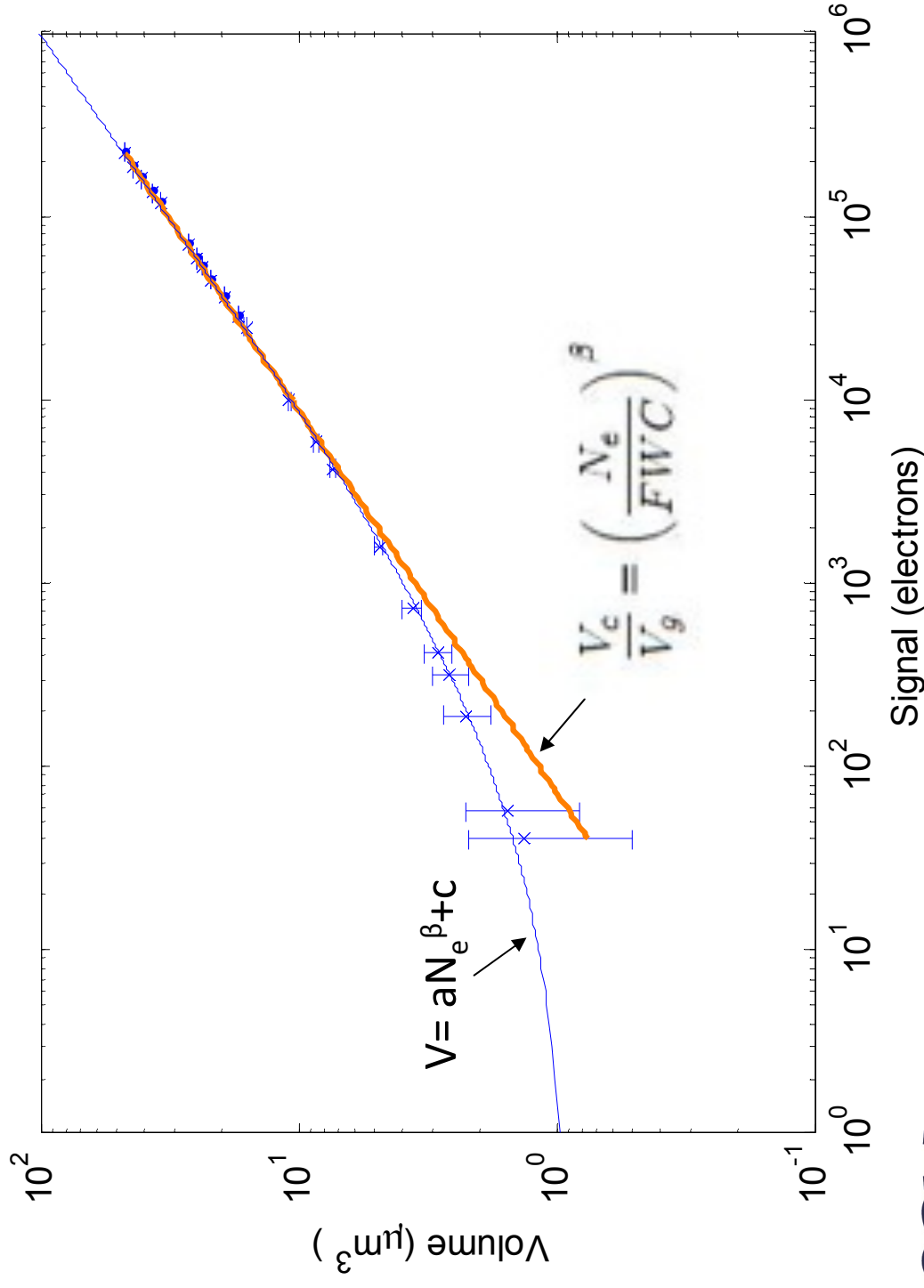
Serial Silvaco model



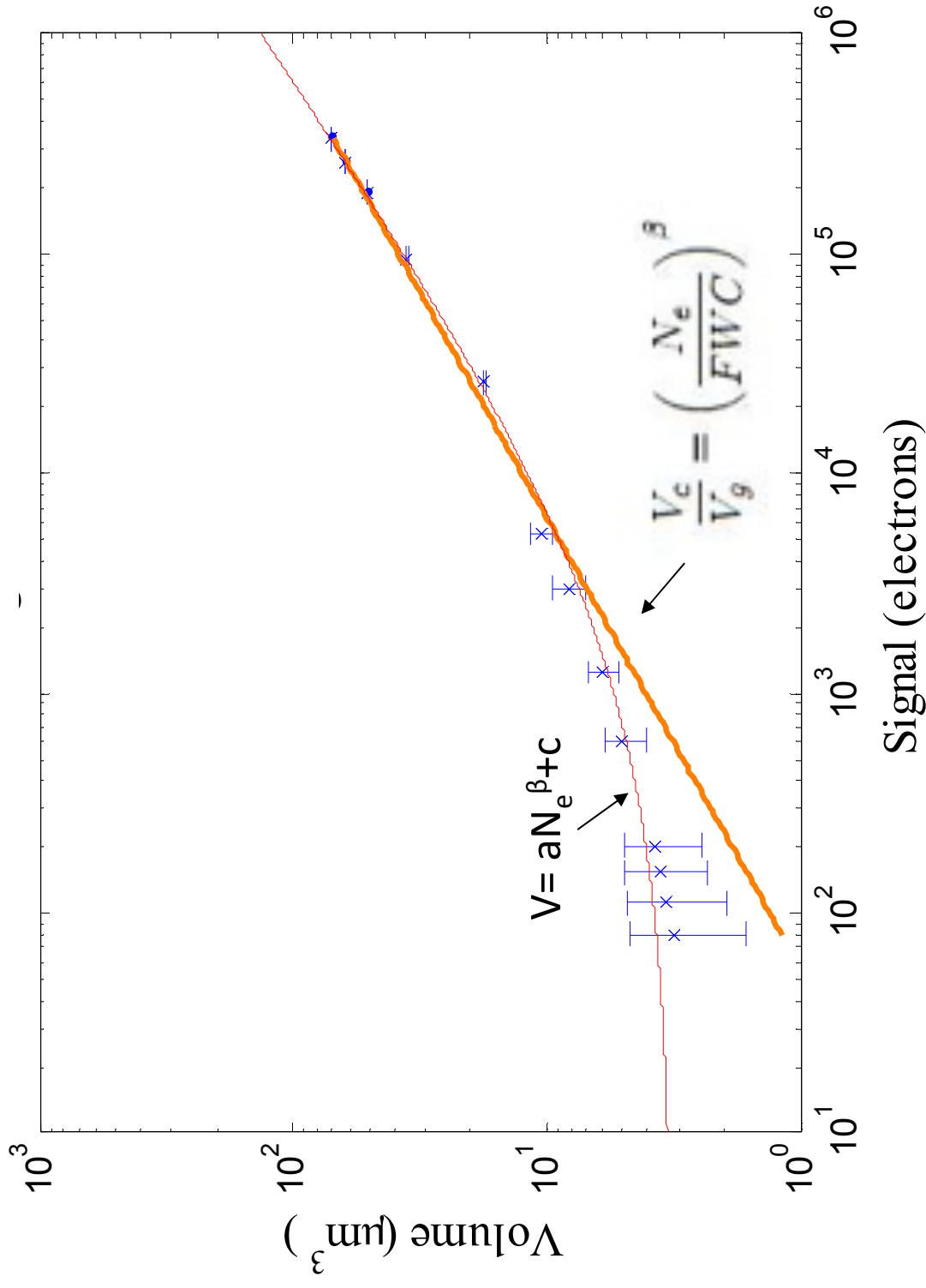
Serial Silvaco model



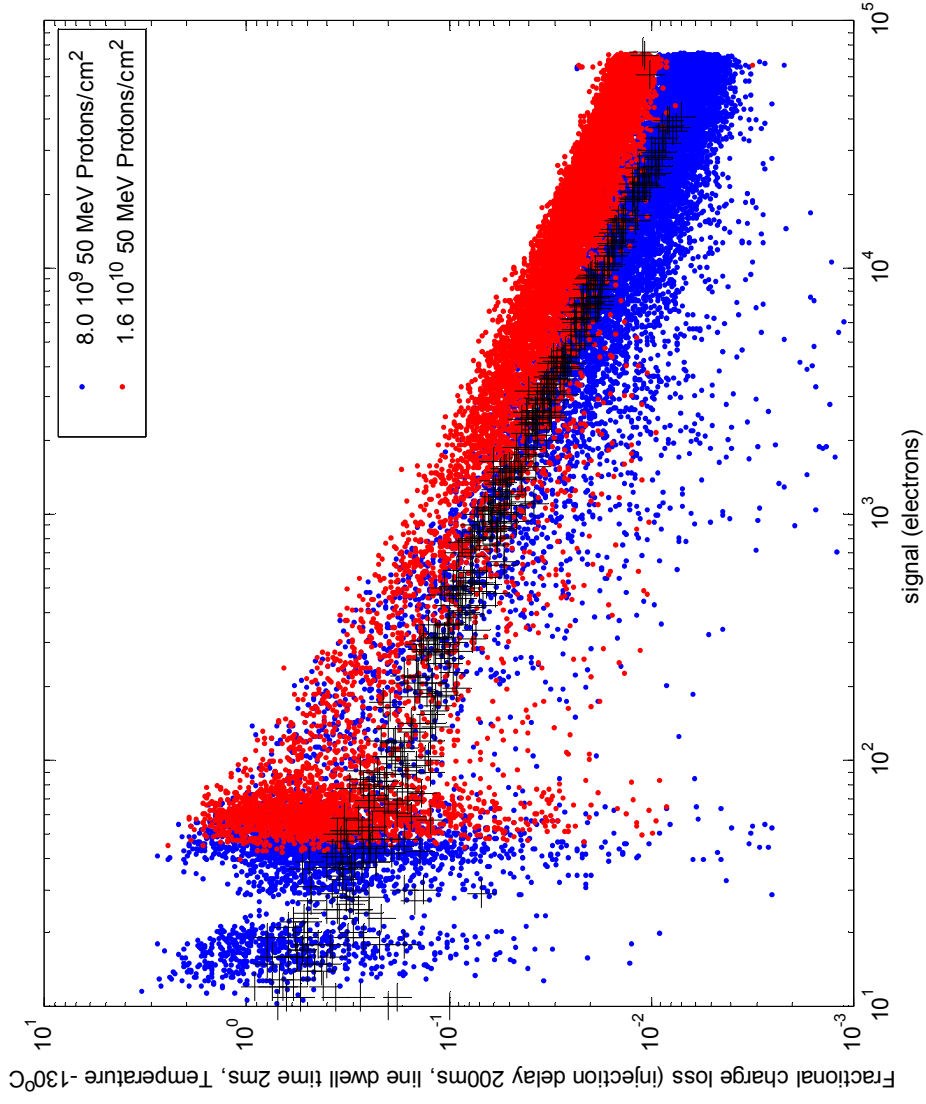
Comparison of the two models - Pixel



Comparison of the models - Register



β and fractional charge loss



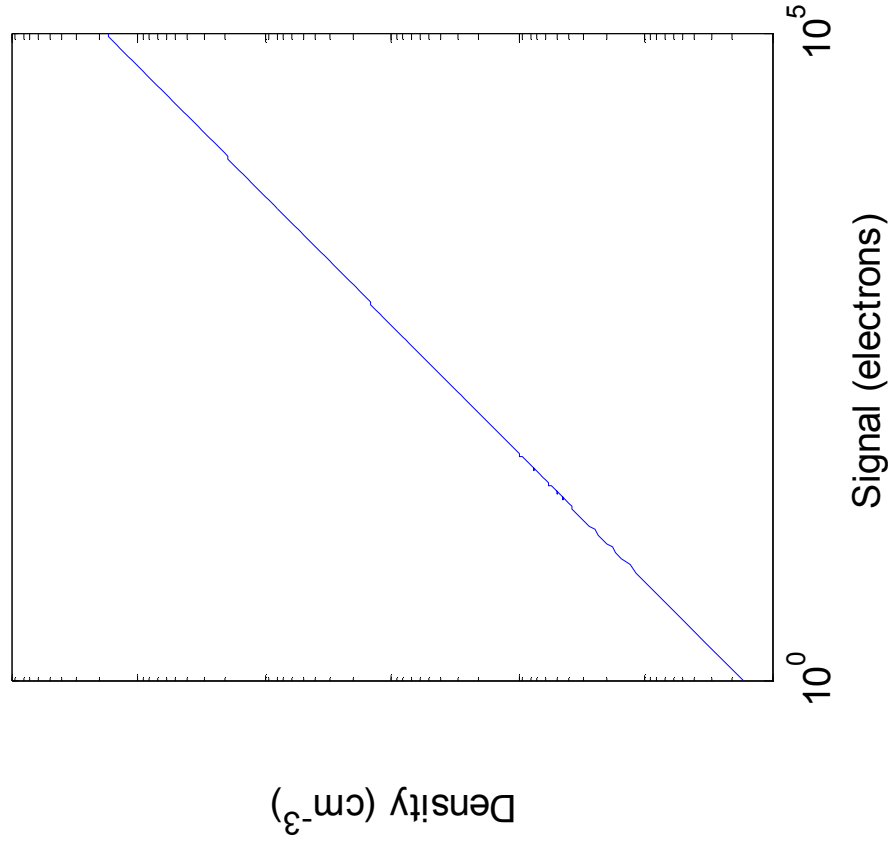
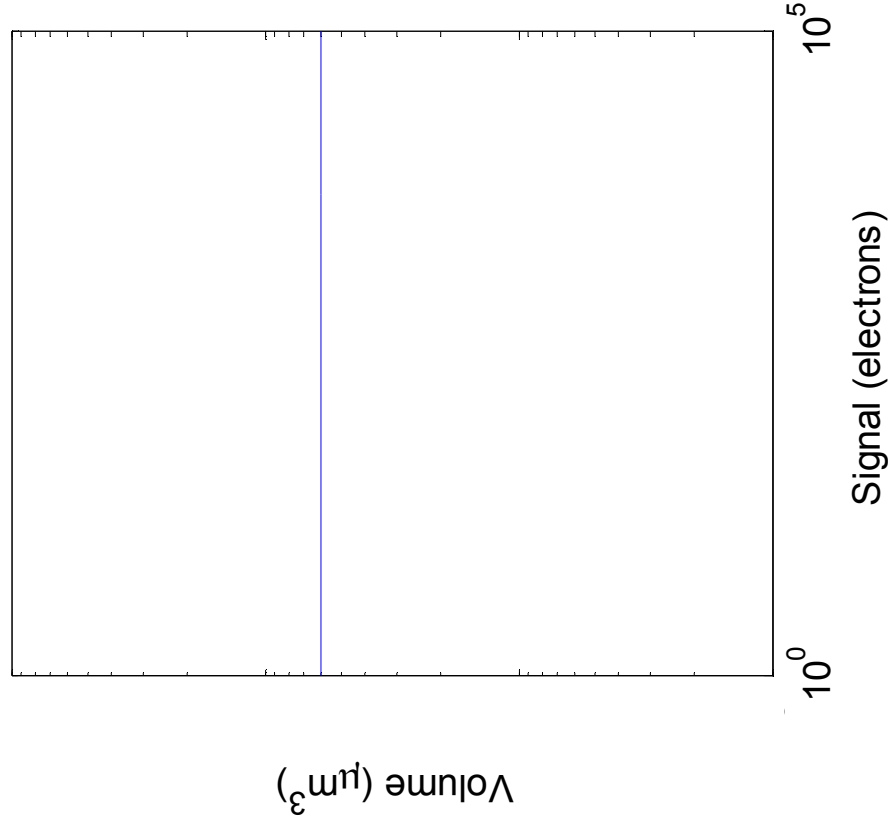
CDM beta parameter



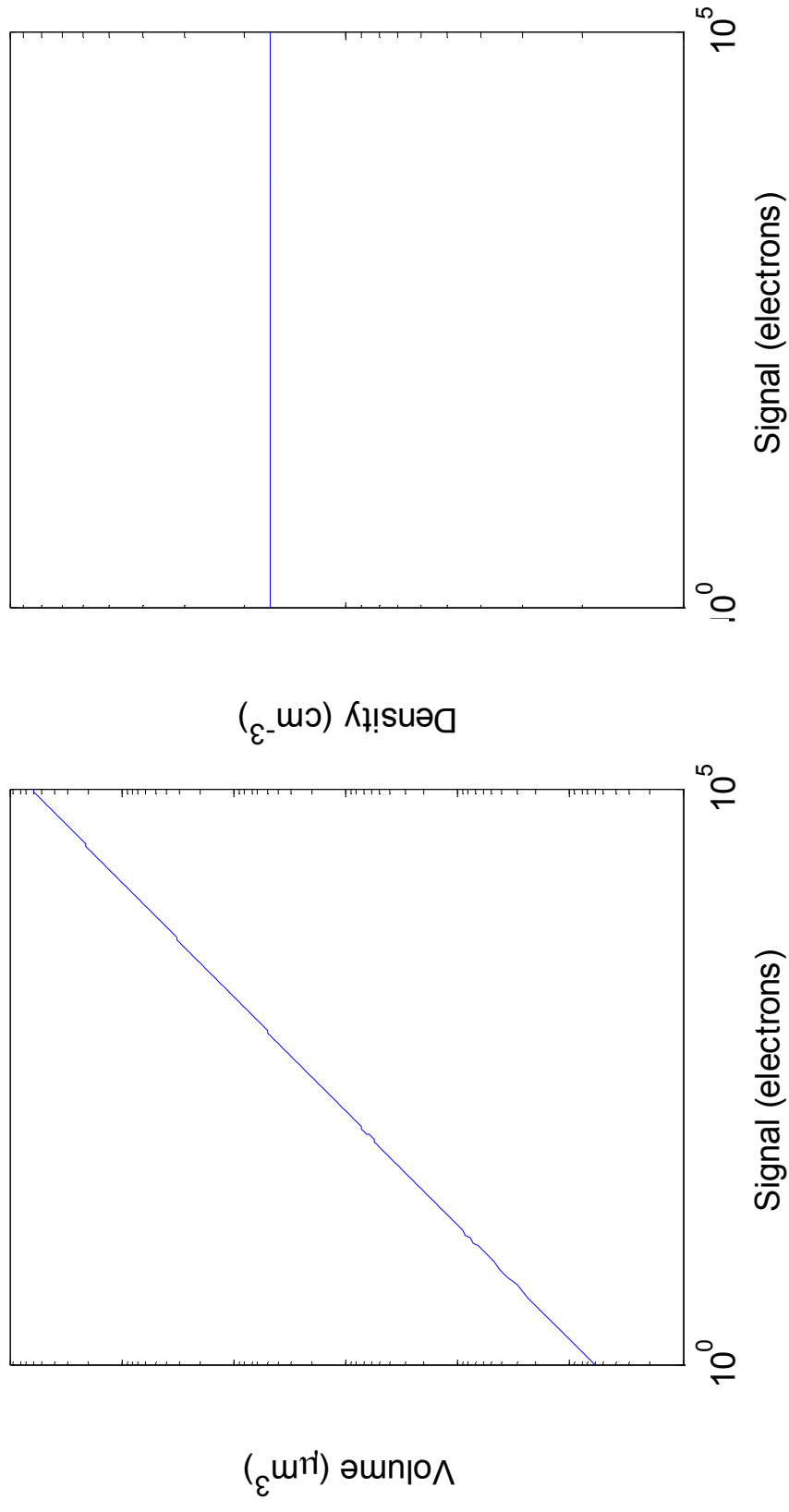
- CDM beta parameter determines how the volume grows with signal size.

$$\frac{\text{Volume of signal}}{\text{Volume at FWC}} = \left(\frac{\text{Signal}}{\text{Signal at FWC}} \right)^{\beta}$$

CDM beta = 0



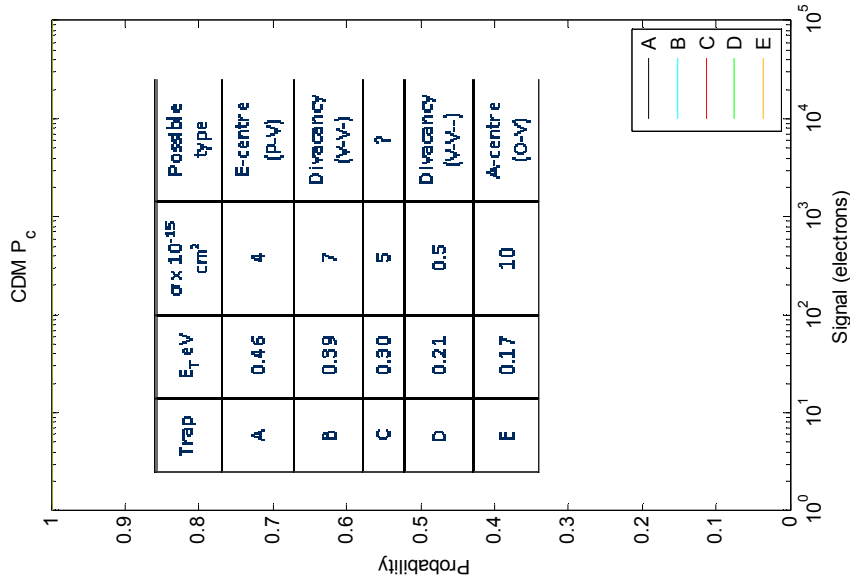
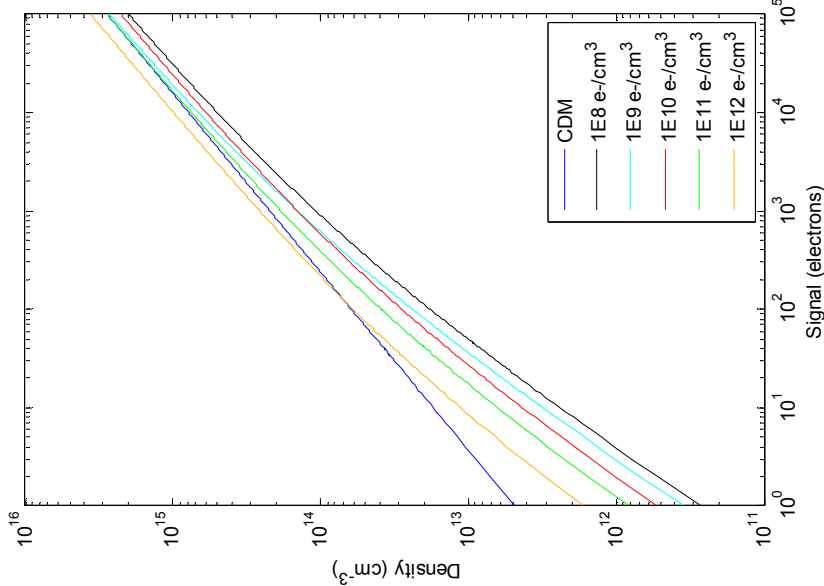
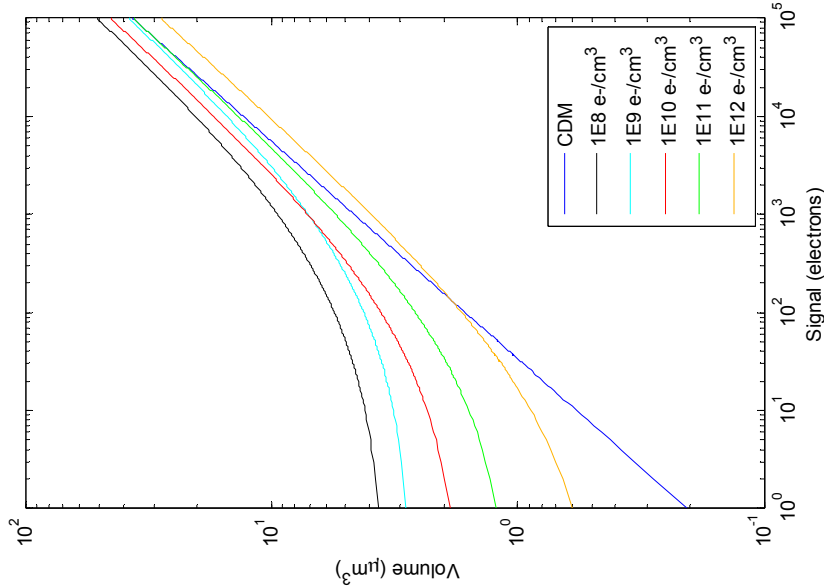
CDM beta = 1



Parallel: CDM vs. Silvaco/OU



- Using the models, but using Silvaco/OU beta, V_{FWC} , N_{FWC} .

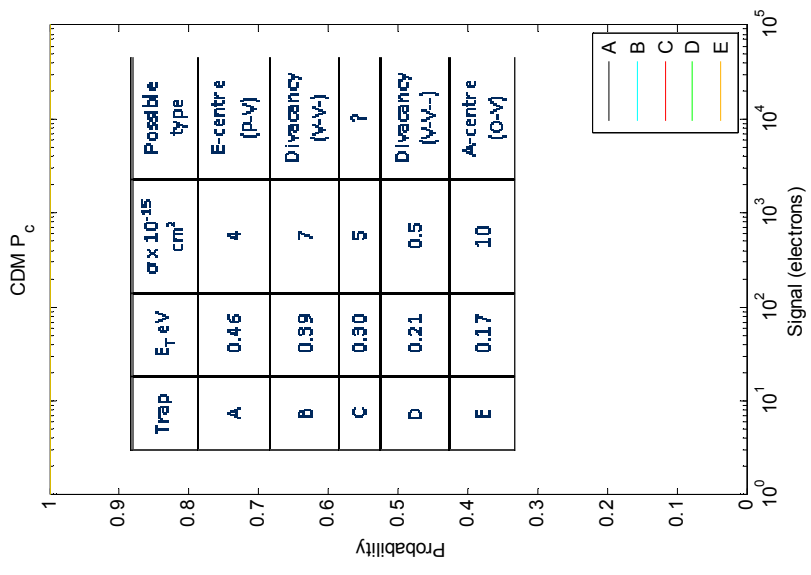
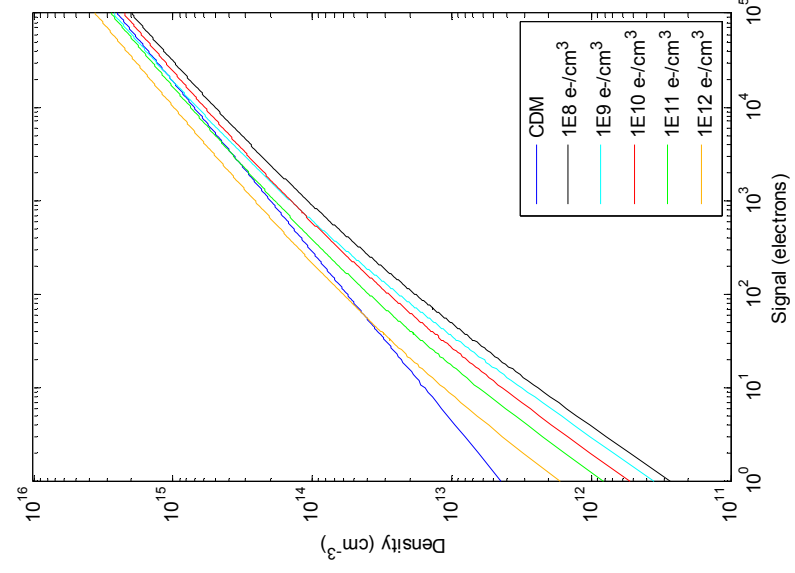
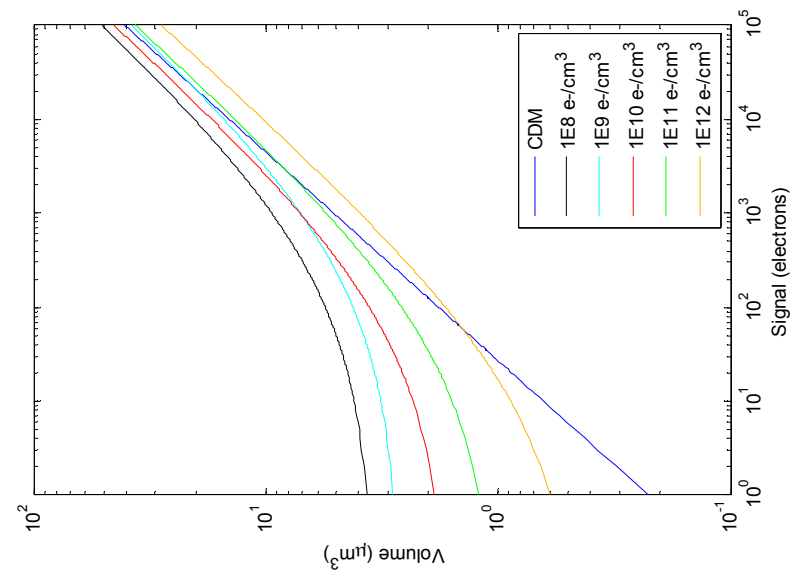


$V_{FWC_um} = 55$;
 $N_{FWC} = 250000$;
 $\text{beta} = 0.45$;

Parallel: CDM vs. Silvaco/OU



- Using the models, but using MSSL beta, V_{FWC} , N_{FWC} .

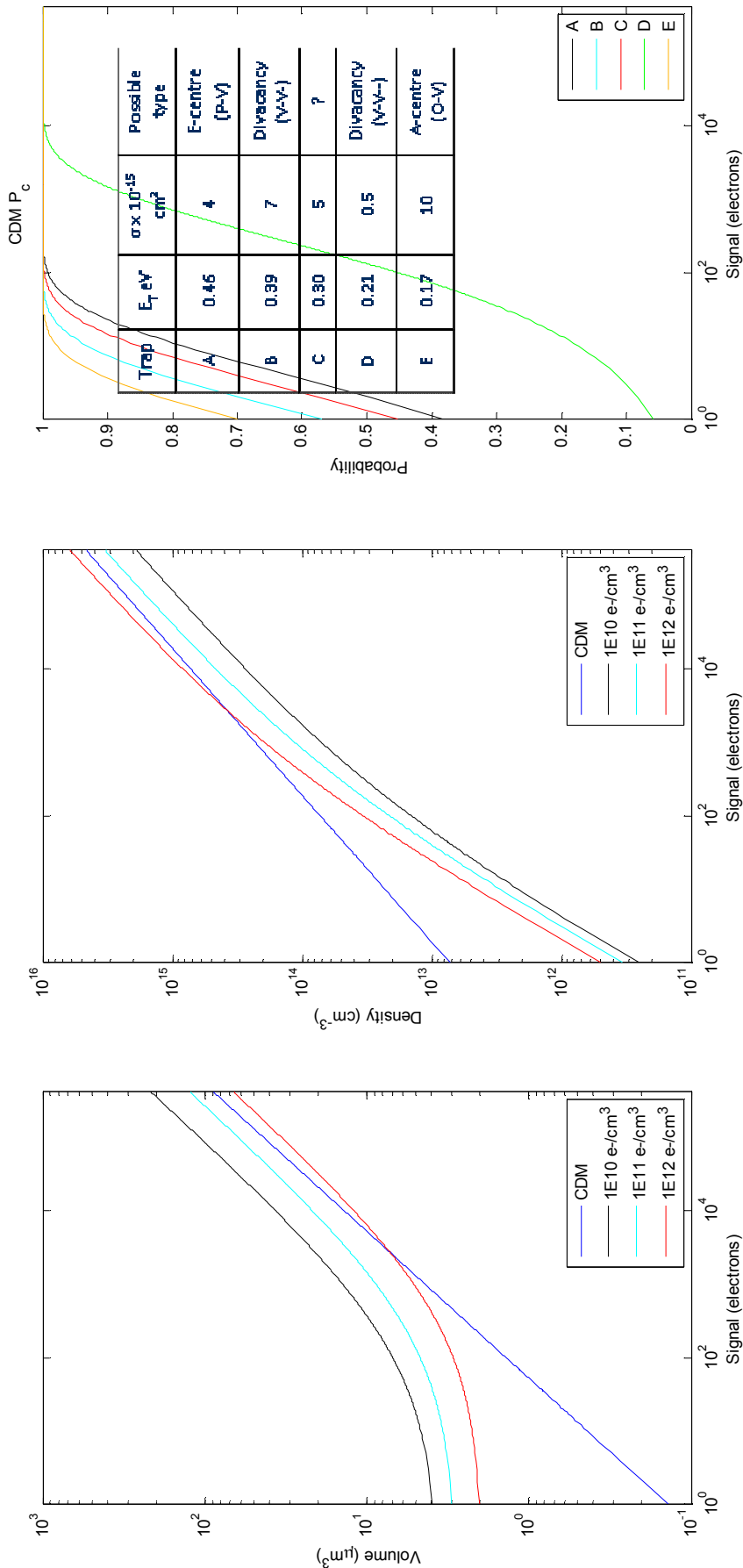


$V_{FWC_cm} = 60$;
 $N_{FWC} = 200000$;
 $\text{beta} = 0.29$;

Serial: CDM vs. Silvaco/OU



- Using the models, but using Silvaco/OU beta, V_{FWC} , N_{FWC} .

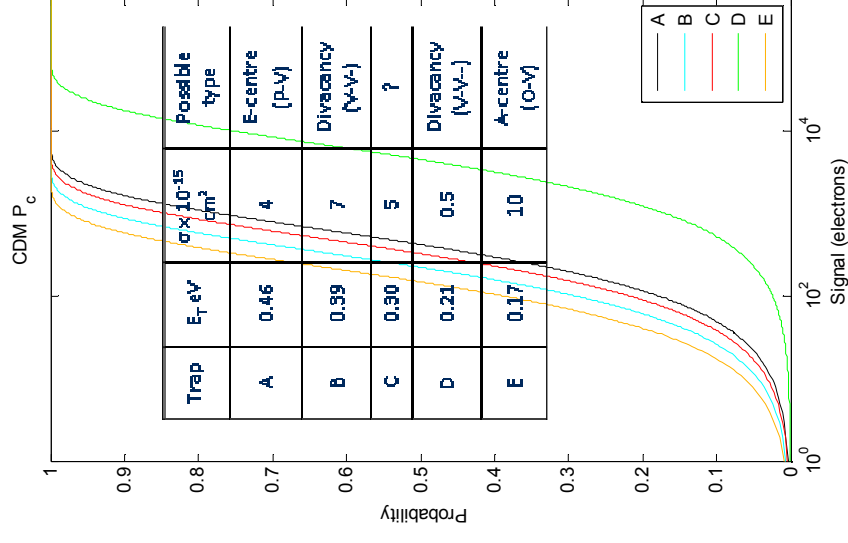
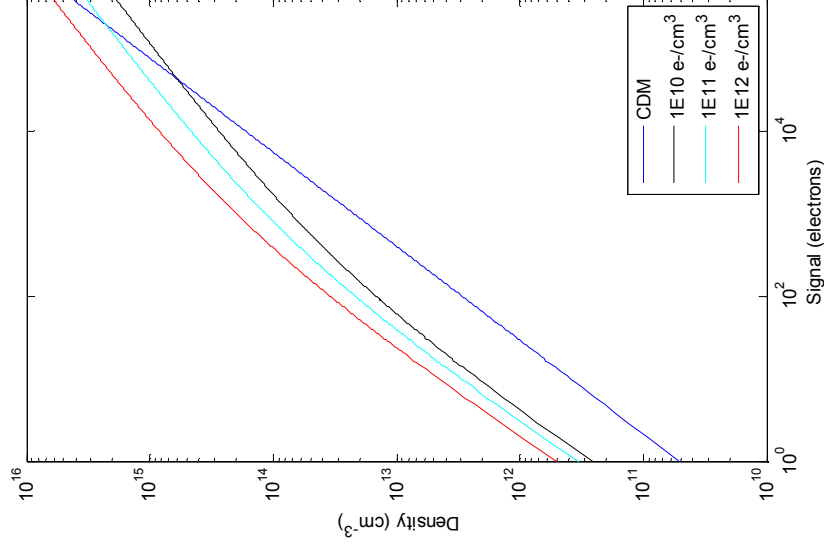
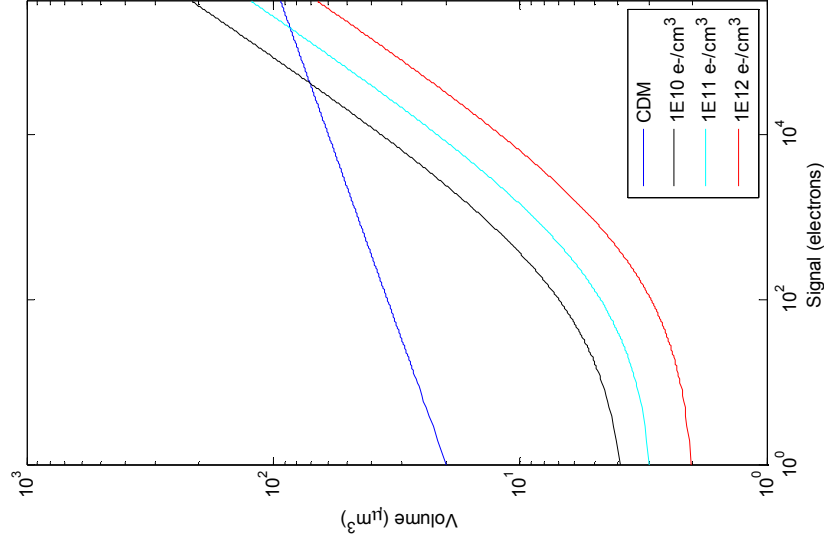


$V_{FWC_um} = 80$;
 $N_{FWC} = 335000$;
 $\beta = 0.5$;

Serial: CDM vs. Silvaco/OU



- Using the models, but using MSSL beta, V_{FWC} , N_{FWC} .



$V_{FWC_um} = 100$;
 $N_{FWC} = 730000$;
 beta = 0.12;

Euclid / VIS
CCD Working Group 8

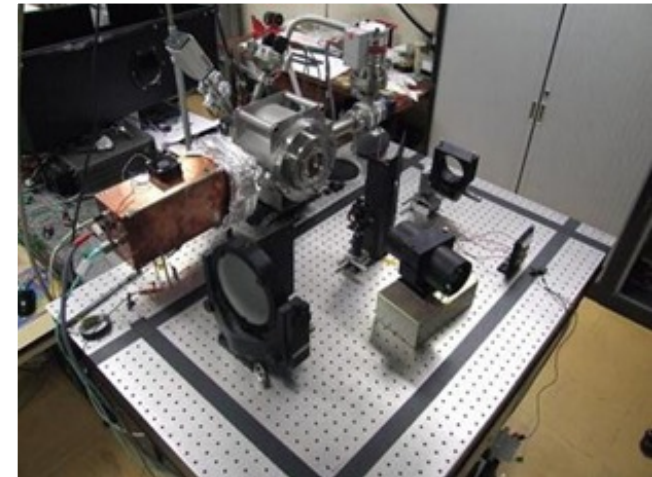
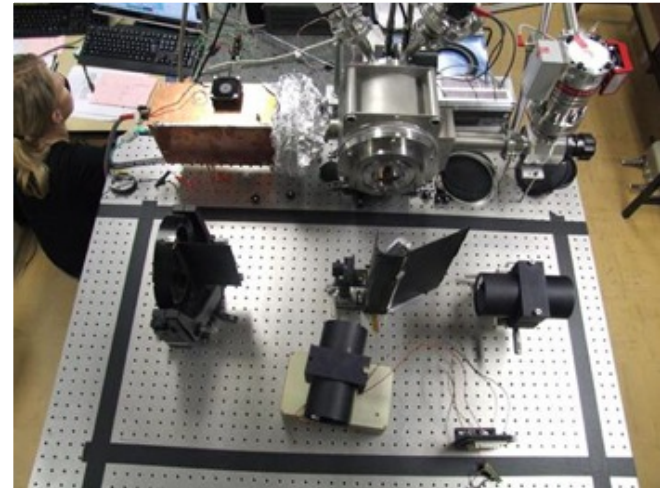
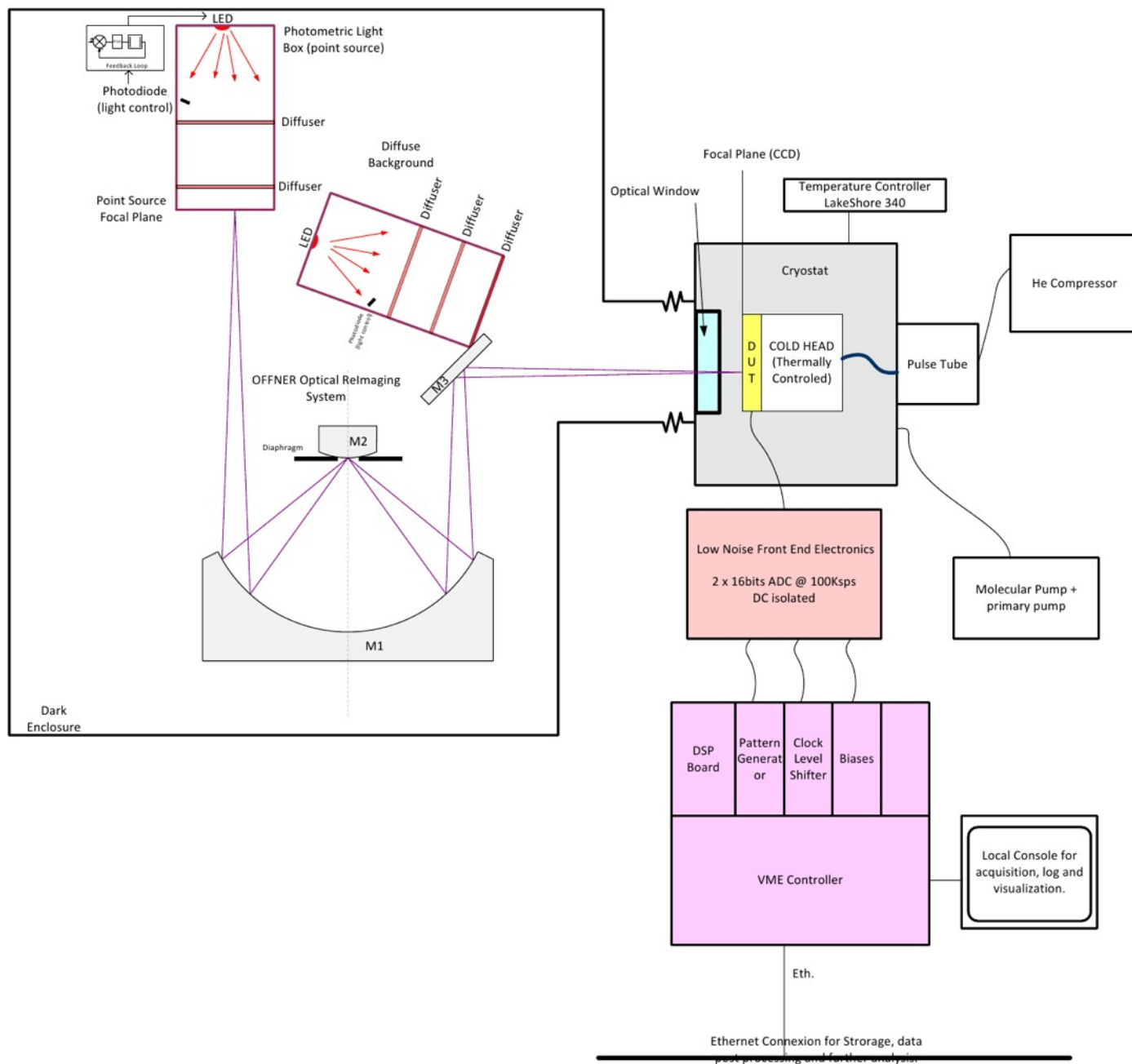
CEA status

Open University , July 10th, 2013

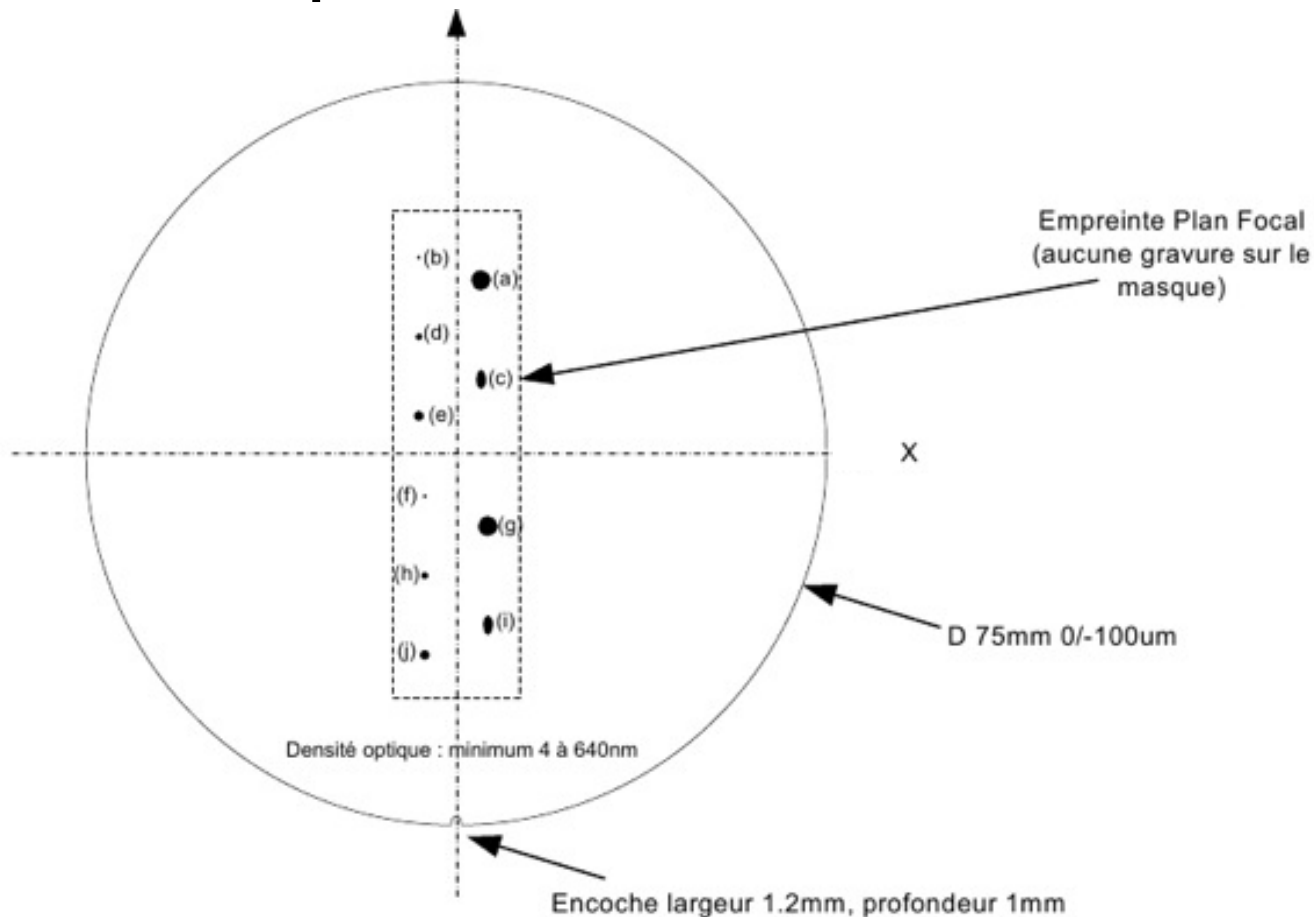
Michel Berthé on behalf of the CEA team

Test Bench developped at CEA-Saclay

EUCLID CCD TEST BENCH @ CEA

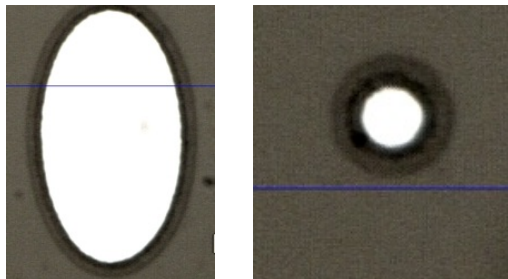


Shape Measurements

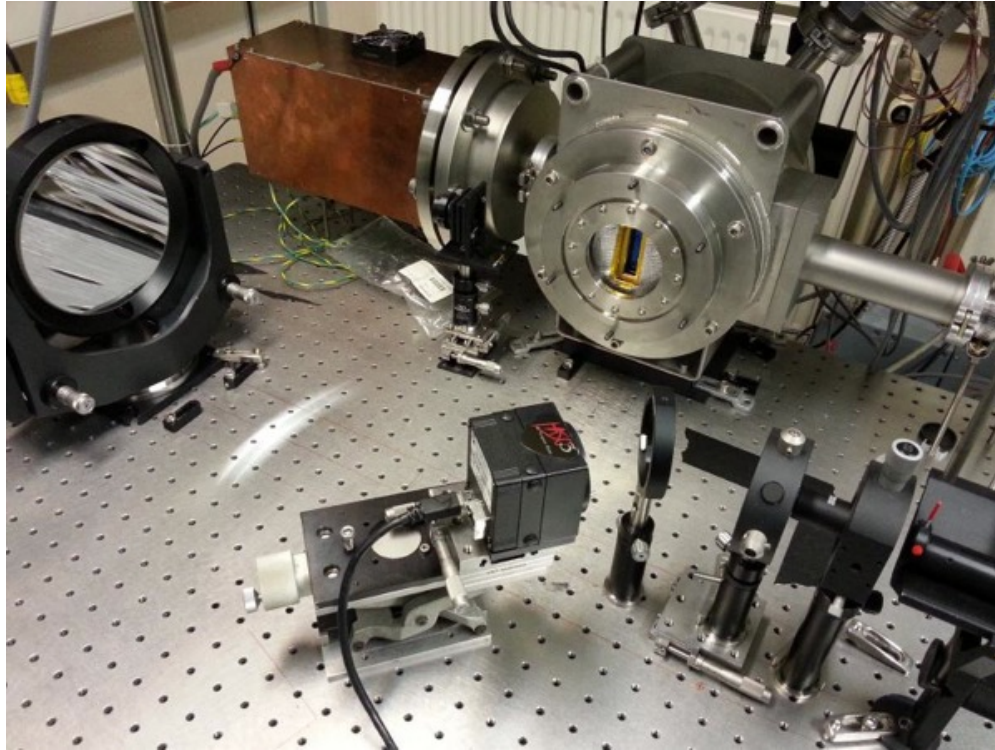


Optical design includes:

- Chromium mask with different size and shapes
 - round point sources with diameter $2 \rightarrow 24 \mu\text{m}$
 - elliptical sources $12 \times 24 \mu\text{m}$
- XYZ θ stage to cover all the CCD + focus
- Led illumination system at 640nm, shutter like controlled (optically feedback for flux control and repeatability)



PSF measurements of CEA shape measurement bench (1/2)



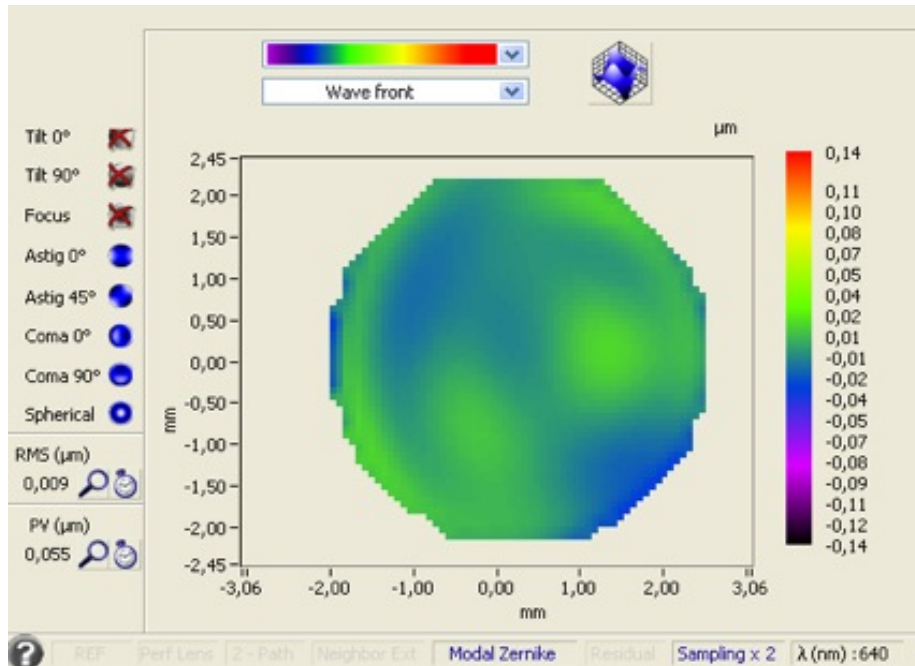
Set-up for measuring the primary mirror. A point source is made with a laser and a pinhole, and the reflected beam is sent on the wavefront sensor using a beam-splitter

A Shack-Hartmann wavefront sensor has been rented for two weeks (model HASO32 from the company Imagine-optic) in may 2013

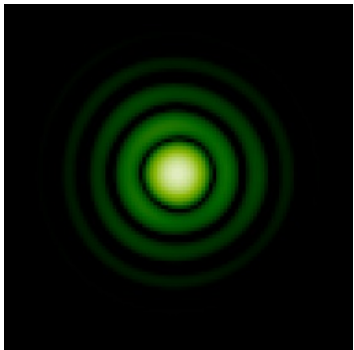
Measurement of the primary mirror shape (photo) and of the optical quality of the whole Offner system acquired

Data are used to build a model PSF (ongoing work). Only the cryostat window is missing during the measurement, but its effect are readily modeled with Zemax.

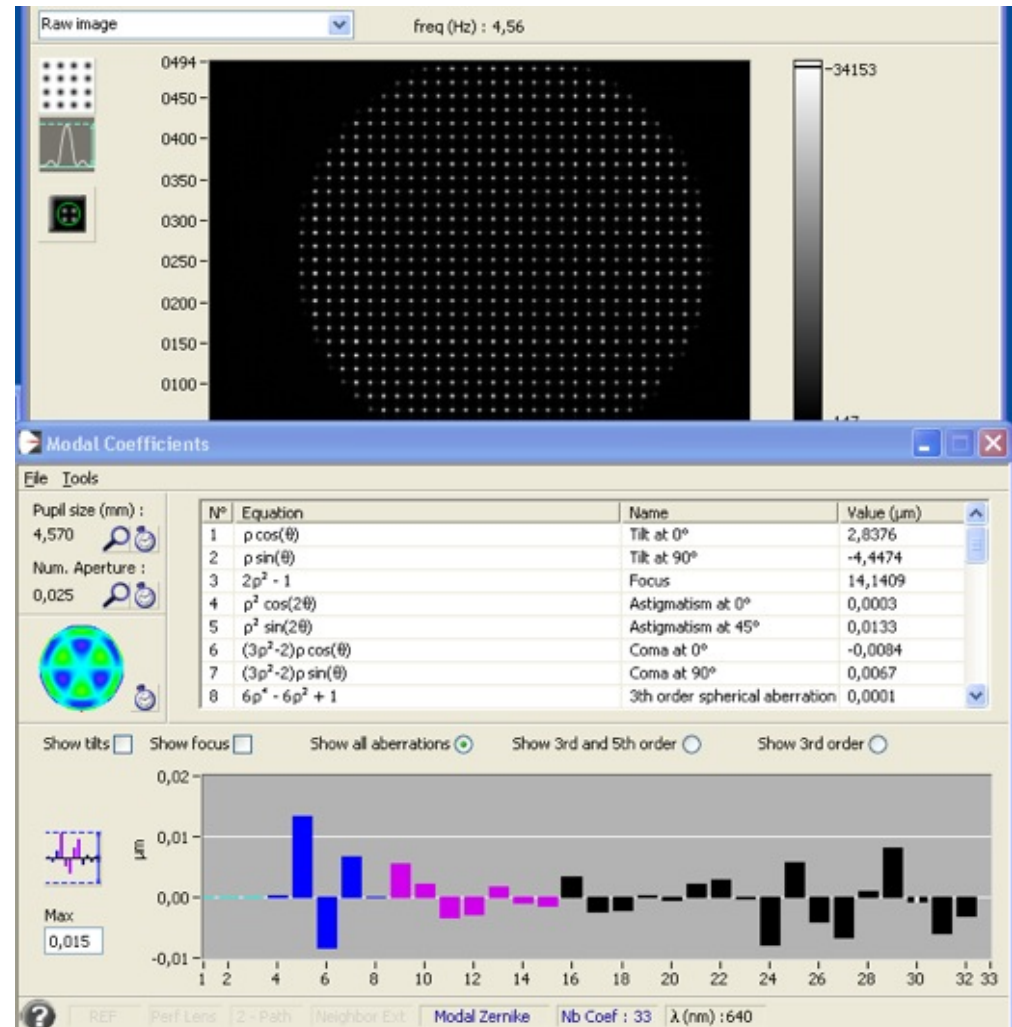
PSF measurements of CEA shape measurement bench (2/2)



Map of the wavefront as measured on the full optical train of the Offner system ($M1 \rightarrow M2 \rightarrow M1 \rightarrow \text{Flat}$). The RMS value of the wavefront error is about 10 nm, which mean that the system is diffraction limited.



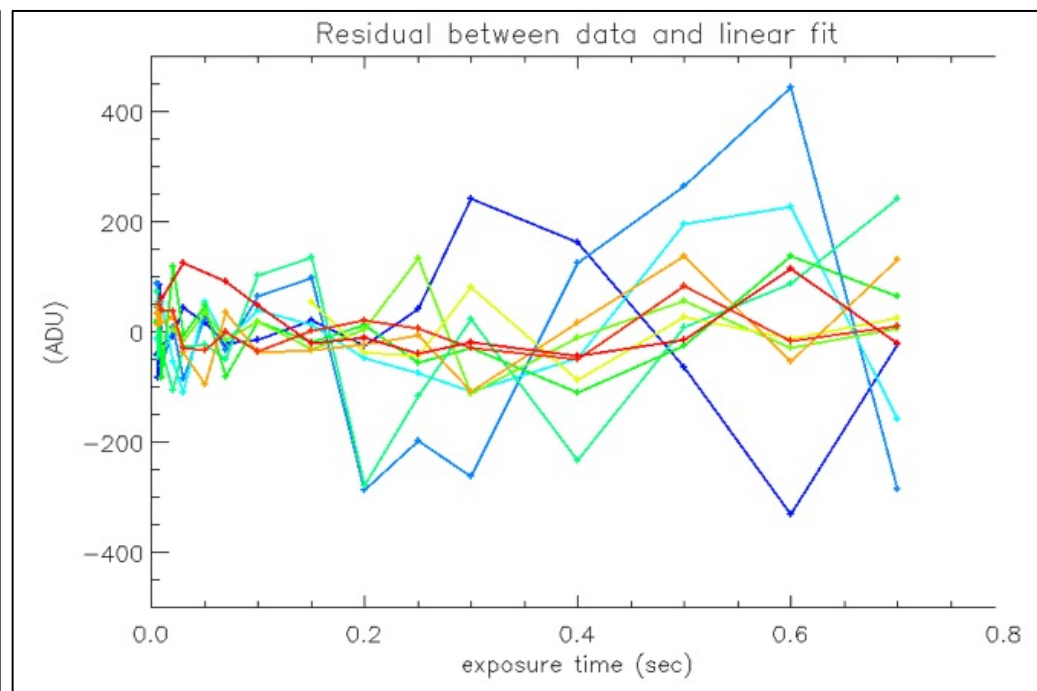
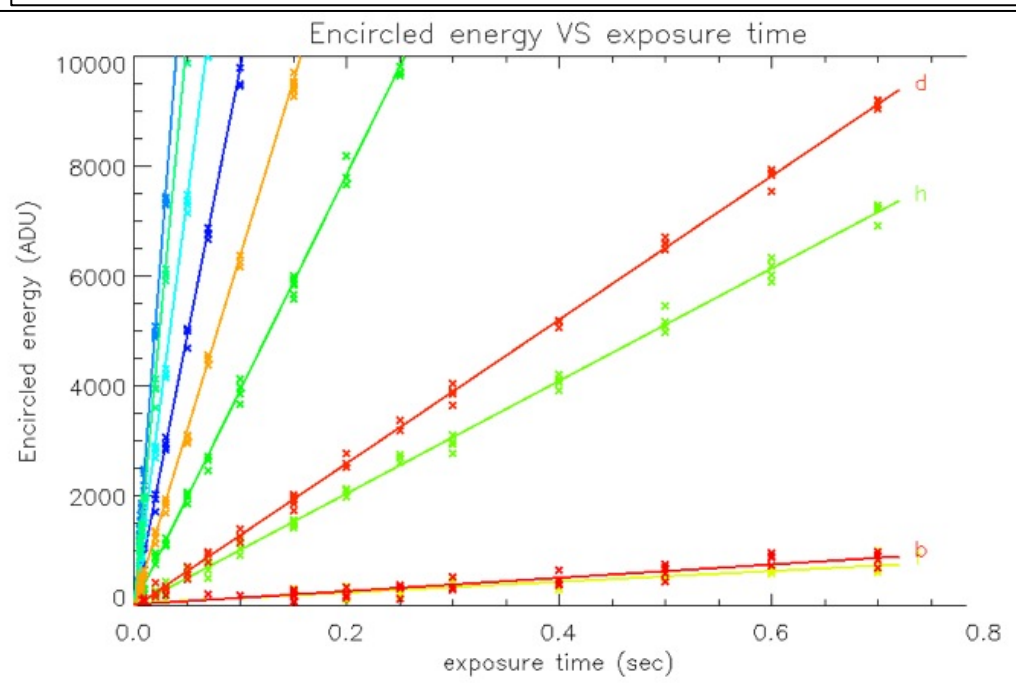
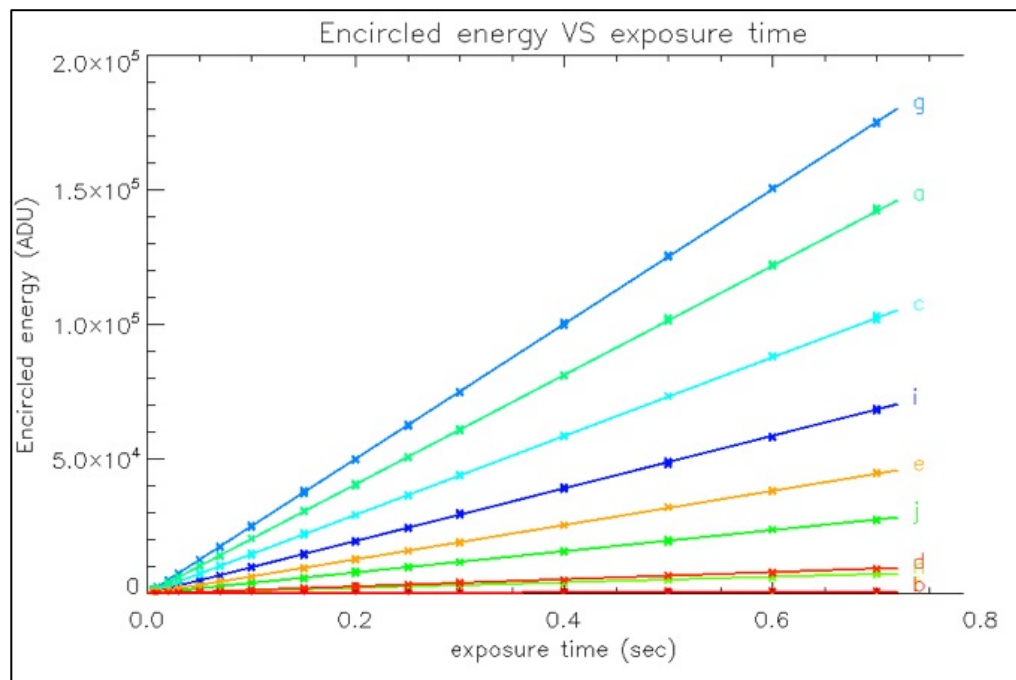
The PSF reconstructed from the measured Zerniks polynomials



The camera signal (above) showing the grid of micro-lenses that sample the wavefront, and the corresponding Zernikes coefficients measured (below)

Linearity : signal VS exposure time for elliptic shaped images

- The signal measured is the encircled energy within the core of the PSF.
- It is measured for different exposure times, and for all sources.
- The variations between the different images (for a given source and a given exposure time) show the photon noise.
- Linearity seems very good at all exposures and for all level of signal



(Zoom in for low signal)

Image deconvolution for different signal levels

- Two series of ellipse shaped images are recorded, with a different signal level (different exposure time)
- The aim is to verify whether the measure of ellipticity is affected by the level of the signal, the "equivalent" SNR being the same for the two series, e.g. :
 - First data set : 341 images at SNR 20
 - 2nd data set : 56 images at SNR 50
$$\left. \begin{array}{l} \text{First data set : 341 images at SNR 20} \\ \text{2nd data set : 56 images at SNR 50} \end{array} \right\} \rightarrow \sqrt{(341)} \times 20 = \sqrt{(56)} \times 50$$
- Data reduction and analysis is ongoing , no results available today

Delivery of CCD 273 through ESA

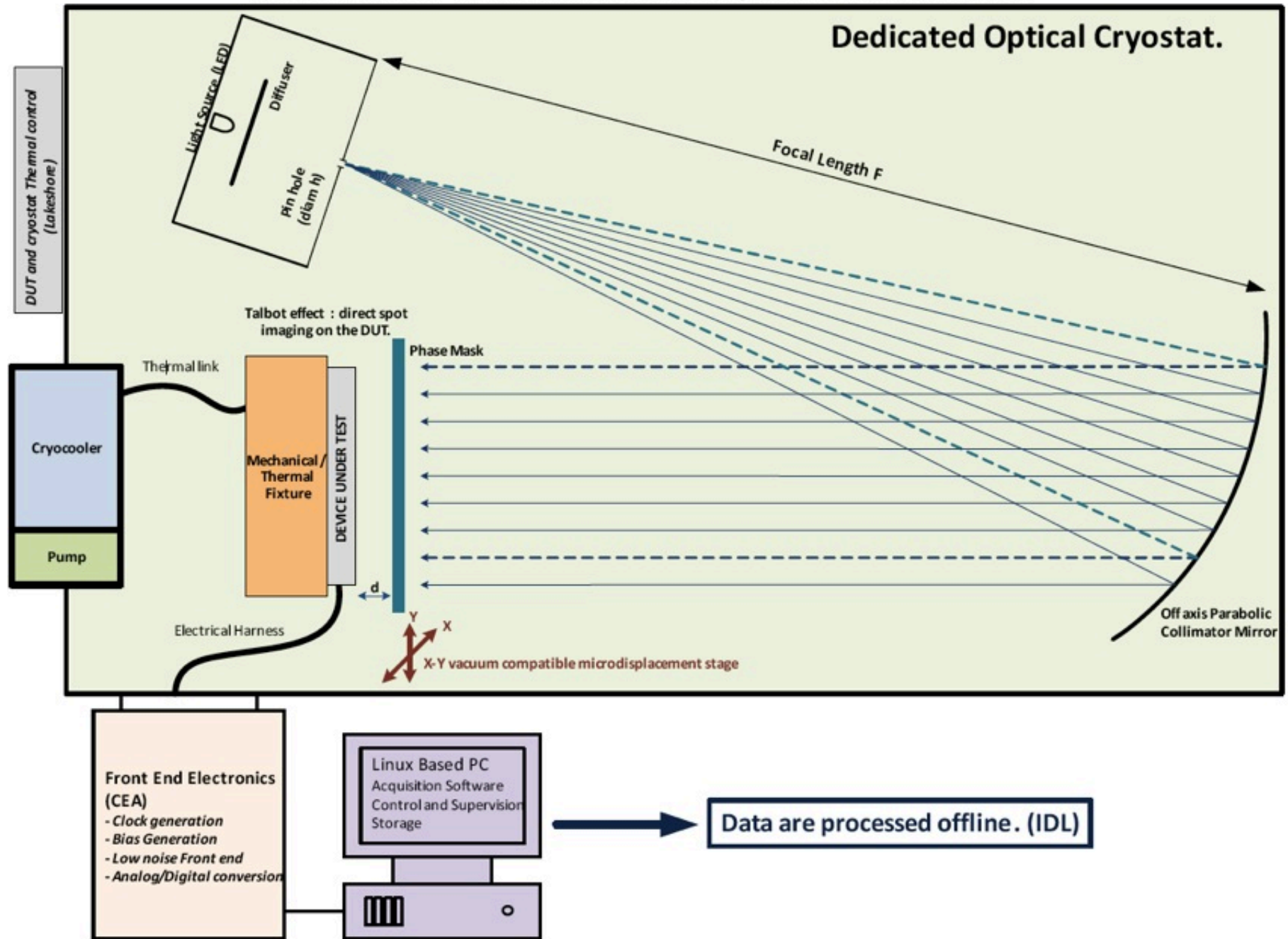
- Loan agreement between ESA and CEA still in signature loop
- Device expected by end of July !
- Test bench upgrade initiated to host CCD 273

Intrapixel response map (1/2)

- Contract signed and Kick-Off performed with ONERA
- Goal : obtain a response map at intrapixel level (12 x 12 grid), for all pixels of a detector
- Method : self imaging (Talbot effect) by projection of high frequency patterns on the detector + data processing
- 6 month feasibility phase and bench sizing
- 15 month bench implementation
- First test with ONERA equipment could be performed at CEA on shape measurement bench in 2013 (TBC)
- 2 deconvolution methods :
 - Direct model : requires huge computer resources
 - Pixel model : lighter and more accurate, but requires an initial “pixel map” as start point. Could results of pixel electrical map model from O.U. made be useful and available to CEA ?

Intrapixel response map (2/2)

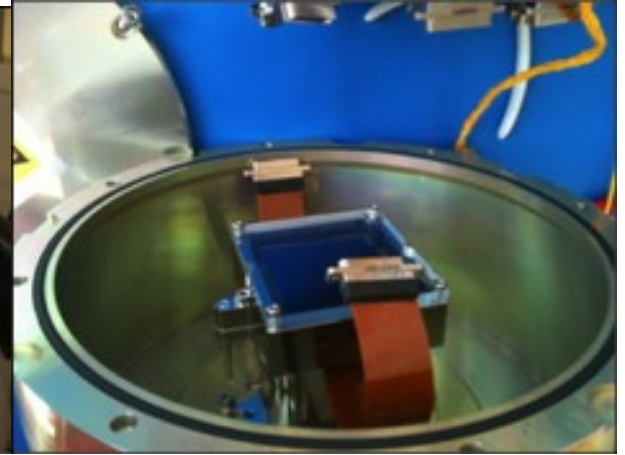
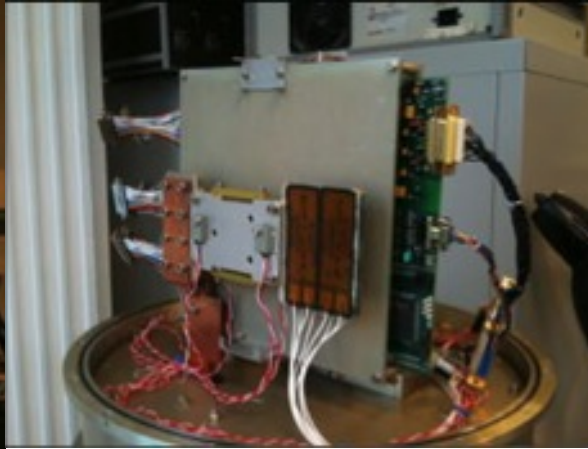
EUCLID : CEA Test Bench for intra pixel characterisation



MSSL Tests

Magdalena Szafraniec and David Walton

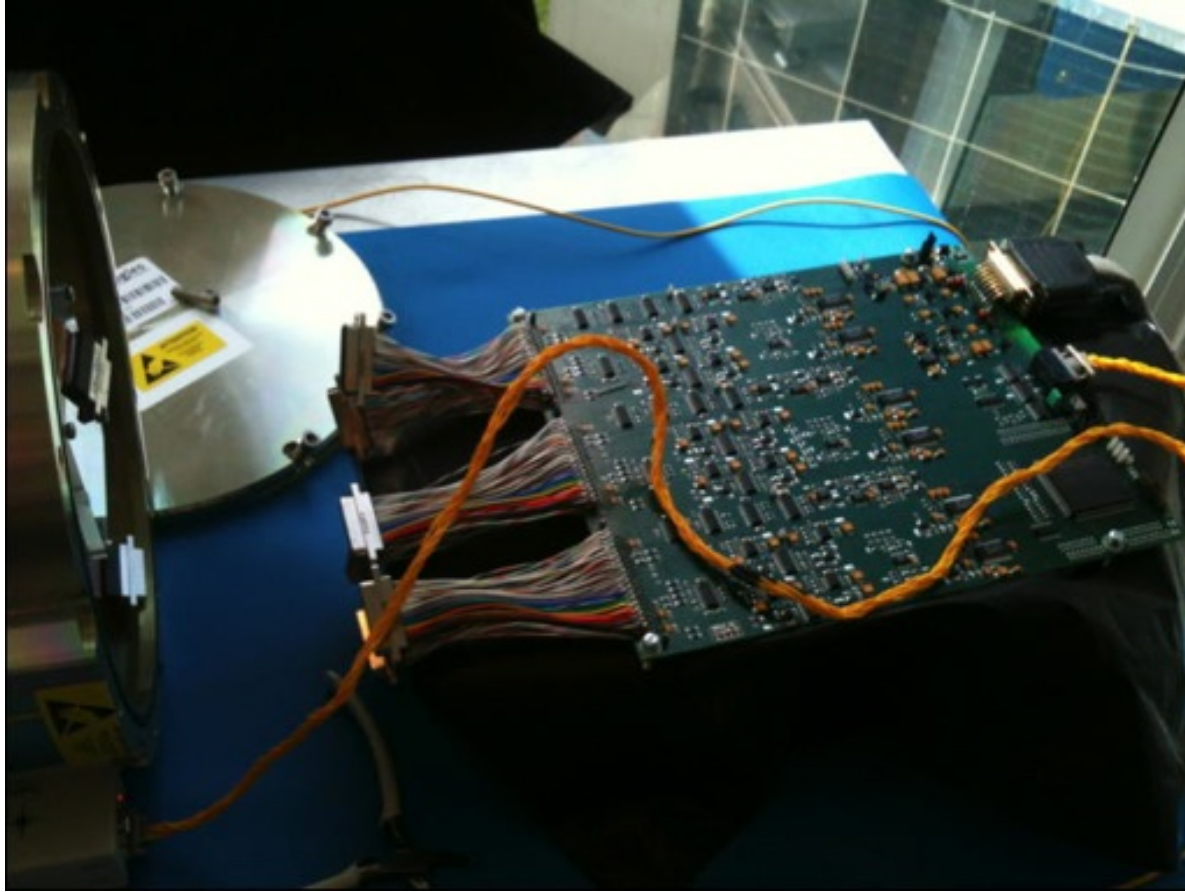
MSSL System Setup



The cryogenic chamber has been setup and tested.

- A cold finger was attached to one side of the CCD plate.
- A stable cooling/heating rate is ensured by means of two heaters attached to the other side of the CCD plate.
- Two resistors have been installed on the CCD plate to measure temperature controlled to $\sim 0.3\text{K}$ by a Eurotherm Controller
- A stable temperature of -120°C can be held for $\sim 11\text{h}$.
- The exposure time is controlled by a shutter.
- The vacuum pump allows for a pressure of $5 \times 10^{-3} \text{ mbar}$.

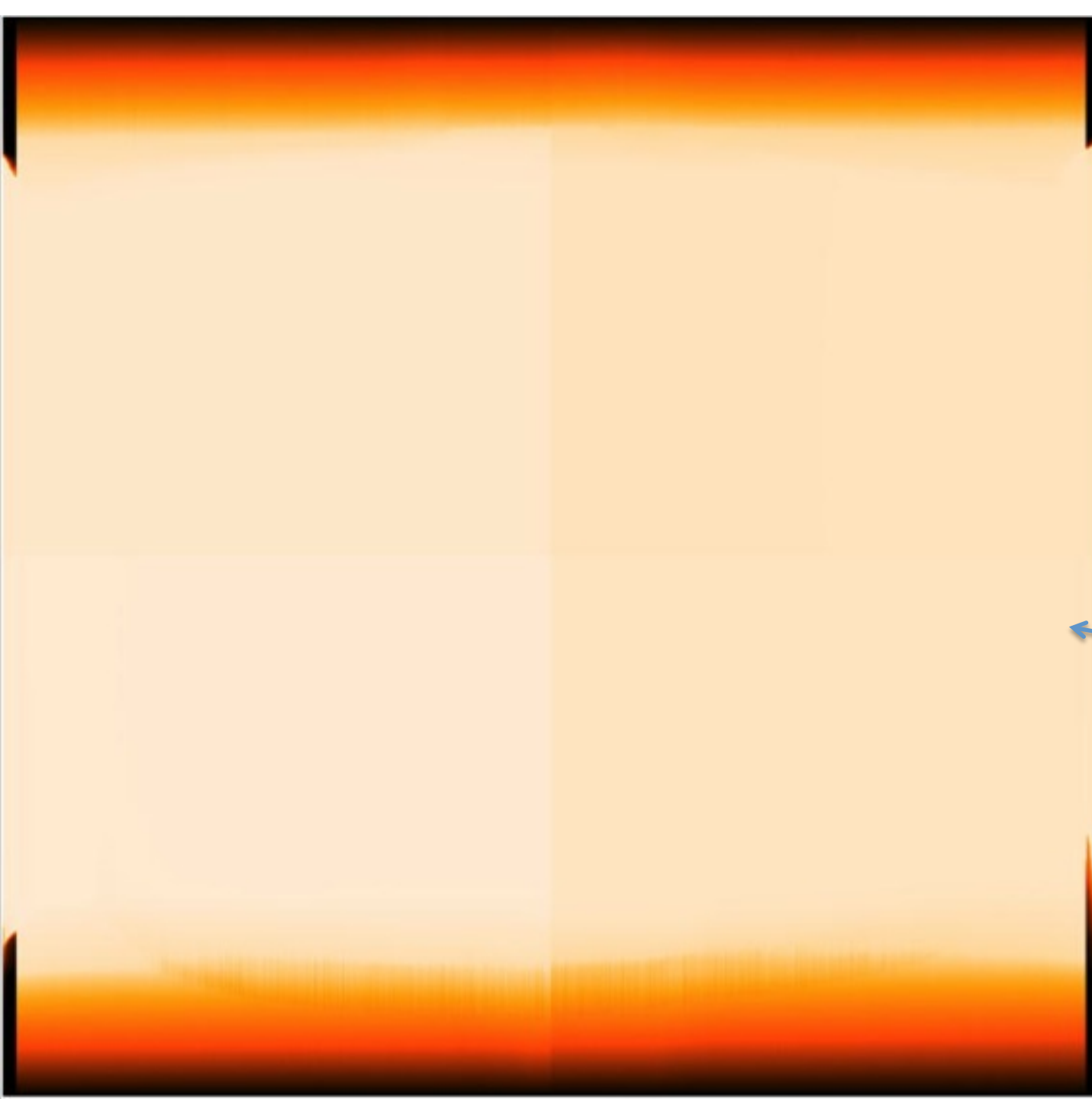
CCD273 + EVM-III



The EVM III board has been programmed and tested.

The CCD273 (SN: 11263-07-02) has been connected to the EVM III board and correct biases were applied. Frames were acquired at ambient.

The data acquisition software has been modified so that four quadrants of the CCD can be readout simultaneously.



First CCD273 +
EVM-III image

saturated region

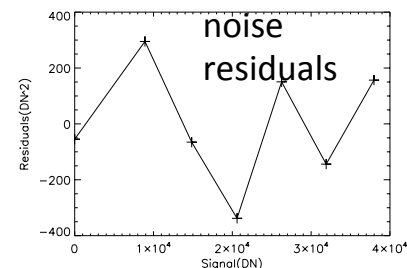
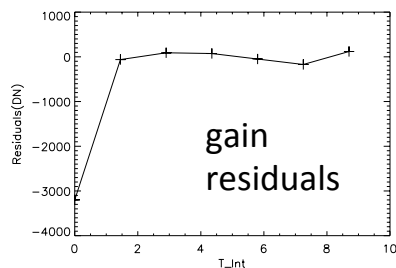
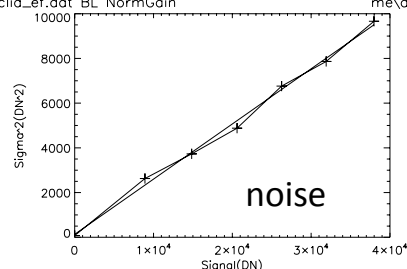
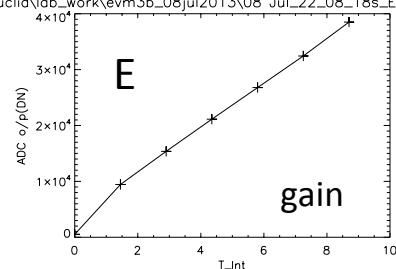
pre-scan

SN: 11263-07-02

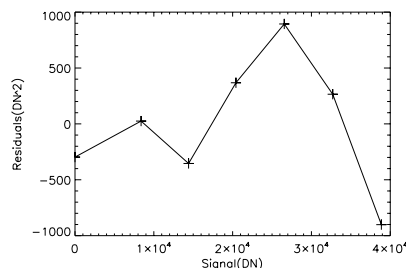
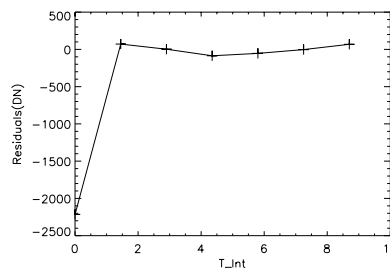
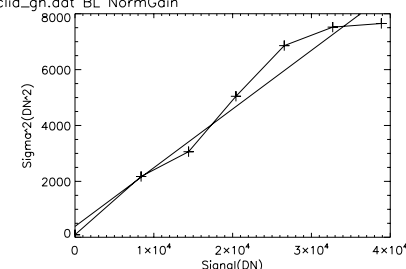
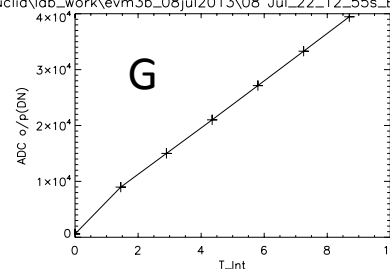
Warm tests: photon transfer curves

CCD273 SN: 11263-07-02

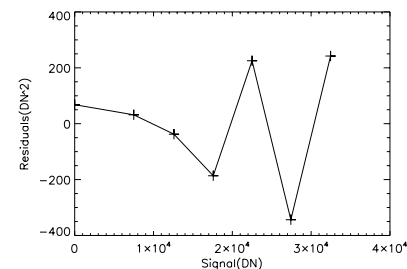
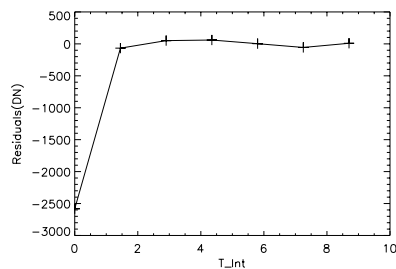
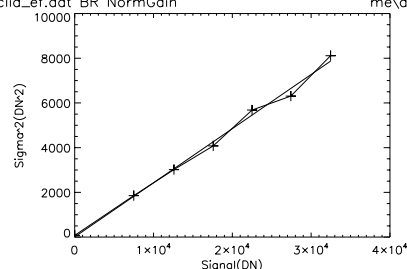
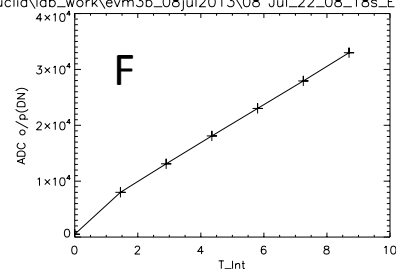
me\dmw\euclid\lab_work\evm3b_08jul2013\08 Jul_22_08_18s_Euclid_ef.dat BL NormGain



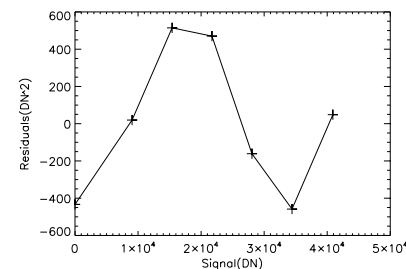
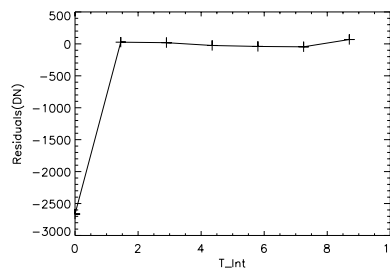
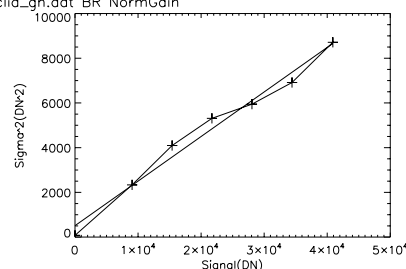
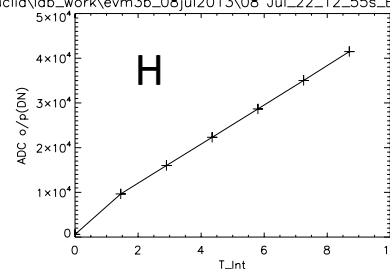
me\dmw\euclid\lab_work\evm3b_08jul2013\08 Jul_22_12_55s_Euclid_gh.dat BL NormGain



me\dmw\euclid\lab_work\evm3b_08jul2013\08 Jul_22_08_18s_Euclid_ef.dat BR NormGain



me\dmw\euclid\lab_work\evm3b_08jul2013\08 Jul_22_12_55s_Euclid_gh.dat BR NormGain



Measured Dark & Read Noise, Gain

Initial Measurements

- Initial measured dark noise and gain values are in line with expectations
- Dark noise is high because it is dominated by room-temperature dark current

		E	F	G	H
For T_Int=0	ADC	529 +/- 1.37E+04	515 +/- 3.02E+03	589 +/- 4.33E+03	599 +/- 2.17E+03
Responsivity	(e-/DN)	4.05 +/- 430	4.13 +/- 94.7	4.76 +/- 136	5.01 +/- 68.1
Signal	(DN/s)	3.98E+03	3.43E+03	4.21E+03	4.39E+03
Signal	(e-/s)	1.61E+04	1.42E+04	2.00E+04	2.20E+04
Signal	(nA cm-2)	1.01	0.887	1.25	1.38
Rd Noise	Sq(DN^2)	77.4 +/- 170	74.2 +/- 168	91.4 +/- 453	75.9 +/- 305
Rd Noise	Sq(e-^2)	1.27E+03 +/- 2.80E+03	1.26E+03 +/- 2.86E+03	2.07E+03 +/- 1.03E+04	1.91E+03 +/- 7.68E+03
Read Noise	(DN)	8.8	8.62	9.56	8.71
Read Noise	(e-)	35.6	35.6	45.5	43.7

Note: E/F and G/H may be incorrectly recorded in this table

Actions Review

ECWG0312_01	Simeon Barber	Provide a date on which the CCD273 radiation testing would commence
ECWG0312_02	James Endicott	Check whether the e2v camera system could read at 70 kHz with the required readout noise performance
ECWG0312_03	James Endicott	Identify the best CCD273 to be sent to the EC for testing; the rest to be held at ESA
ECWG0312_04	James Endicott	Establish a plan of action to understand the unexpected performance of the CCD273
ECWG0312_05	Ludovic Duvet	Check the FWC from the spot measurements made at ESTEC
ECWG0312_06	Mark Cropper	Consolidate the suggested improvements in CCD clocking from the Open University team into a new Euclid VIS baseline
ECWG0312_07	Jason Gow	Discuss with Steve Darby a revision to the radiation test plan to conform to revised timescales
ECWG0312_08	Mark Cropper	Send Jason Gow the nominal durations for VIS exposures and dwell times
ECWG0312_09	Neil Murray	Arrange a date for a 1-day workshop to explain CCD physics and test procedures
ECWG0312_10	Andrew Holland, Mark Cropper	Elaborate the workplan for the proposal to ESA for additional testing
ECWG0312_11	Mark Cropper	Finalise decision on supplementary buried channels after consultation with WL-SWG
ECWG0312_12	James Endicott	Identify the consequences arising from switching back to standard gate dielectrics
ECWG0312_13	Vincent Moreau, Samuel Ronayette	Incorporate realistic images of galaxies for the CEA test equipment
ECWG0312_14	Mark Cropper	Arrange a planning meeting with CEA for CEA testing by end-May 2012

ECWG1112_01	Mark Cropper	Check whether a quarter of the FPA was populated with the EM
ECWG1112_02	Mark Cropper	Check the impact of no serial clock overlaps on FWC
ECWG1112_03	Mark Cropper	Clarify the units of responsivity in the MSSL report by D. Walton
ECWG1112_04	Mark Cropper	Check with D. Walton which 3 phases should be held high during integration
ECWG1112_05	Mark Cropper	Ensure document is written for new baseline clocking schemes to ensure mutual compatibility of tests
ECWG1112_06	Jason Gow	Check whether the Open University measurements on channel potential difference are in agreement with those measured by Peter Verhoeve
ECWG1112_07	Jason Gow	Quantify levels of intrinsic amplifier glow in CCD273s
ECWG1112_08	Magdalena Szafraniec	Check if intrinsic amplifier glow is seen in other CCD273s
ECWG1112_09	Jason Gow	Resolve the discrepancy in the estimates of the trap densities for different trap species
ECWG1112_10	Jason Gow	Examine the effects of a Euclid-like optical background on the readout of the first ~300 rows of the CCD273, where the CTI was worse from unfilled slow traps
ECWG1112_11	Sami Niemi	Clarify the requirements on measuring ellipticity with and without pixellisation
ECWG1112_12	Mark Cropper	Start a testing coordination document and distribute the skeleton for input

ECWG0313_01	Magdalena Szafraniec	Check whether charge sharing occurs with charge injection lines
ECWG0313_02	Sami Niemi	Consider implications of charge sharing on calibrations
ECWG0313_03	Mark Cropper, Sami Niemi	Resolve discrepancy between the CTI- induced ellipticity modelling of T. Prod'homme and previous EC work
ECWG0313_04	Thibaut Prod'homme, David Hall	Examine why the models of T. Prod'homme do not scale linearly with trap density or number of line transfers
ECWG0313_05	David Hall	Explain further at CCD-WG#8 the effects of slow traps in the first lines to be read out of the CCD
ECWG0313_06	David Hall, Sami Niemi & Richard Massey	Check the agreement between a monte-carlo-generated charge transfer and recovery of these through parametric models such as CDM03
ECWG0313_07	Vincent Moreau	Test further the possibility that astigmatism could arise in the CCD
ECWG0313_08	Mark Cropper, Jason Gow, Vincent Moreau, Thibaut Prod'homme, Richard Massey	Provide inputs for testing coordination document by CCD-WG#8