CTE study

BNL Cosmology group meeting

06/07/2016

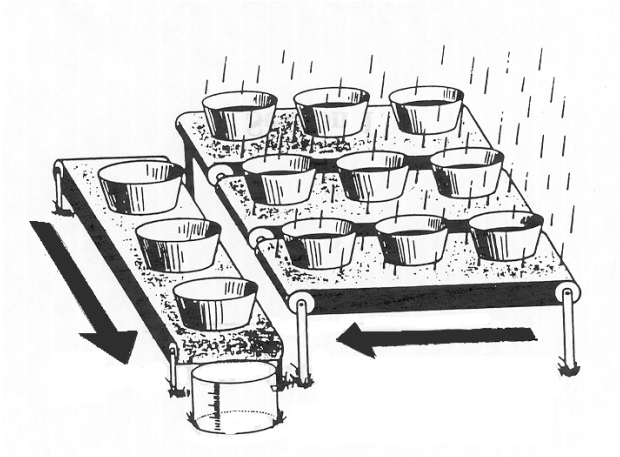
HyeYun Park

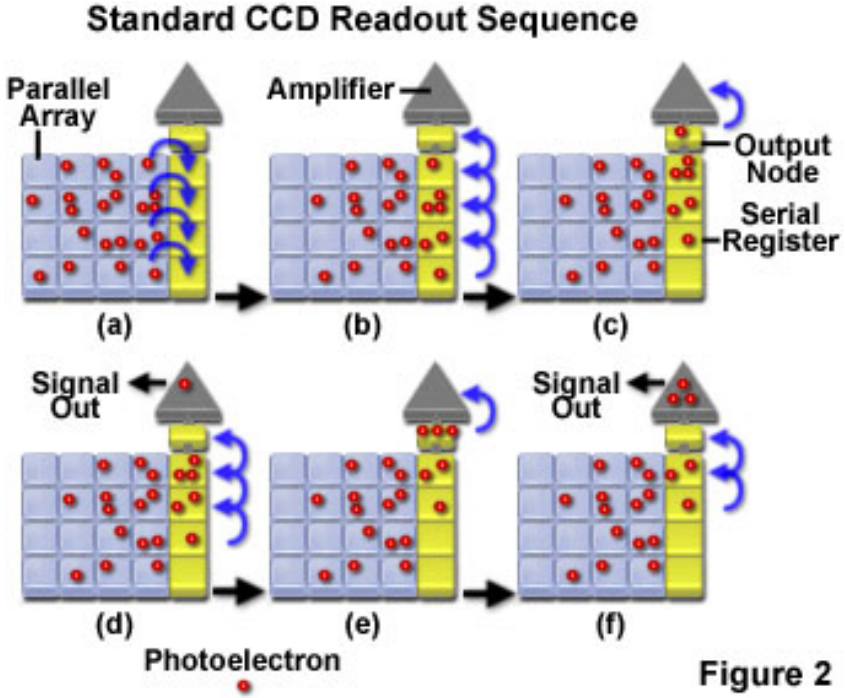
CTE(Charge Transfer Efficiency)

- Some of the electrons remain behind when transferring from one column(row) to next column(row).
- CTE is a measure of ability of the device to transfer charge

$$CTE = 1 - CTI$$

Due to
remaining charges





CTE measurement techniques

1. Fe55 x-ray transfer
2. EPER(Extended Pixel Edge Response)-used by the project
3. CVF(Change in Variance in Flat filed)

CTE measurement techniques

1. Fe55 x-ray transfer
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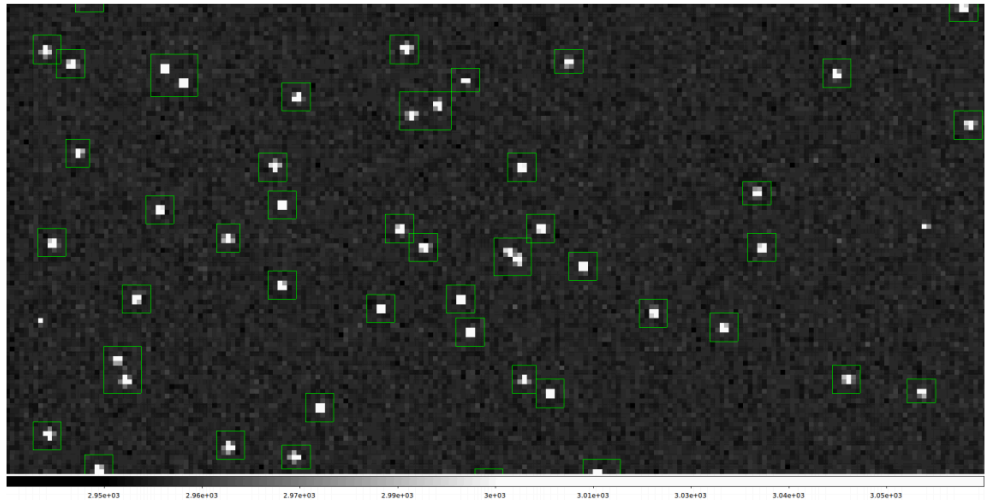

Figure 1. Typical x-ray exposure with found footprints.

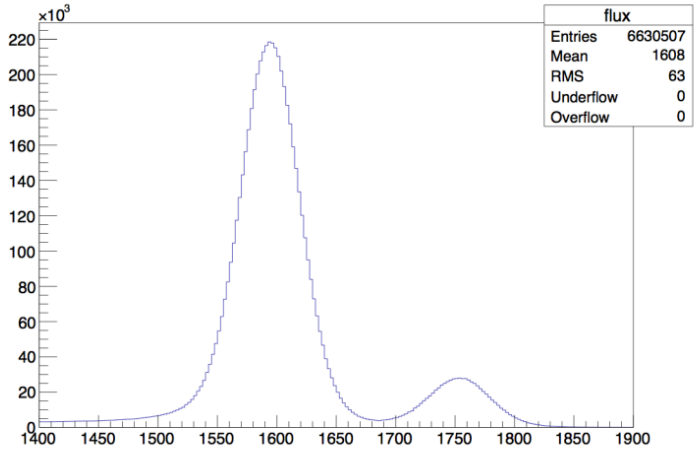

Figure 3. Distribution of measured flux, in electrons, for reconstructed ^{55}Fe x-rays.

CTE measurement techniques

1. Fe55 x-ray transfer
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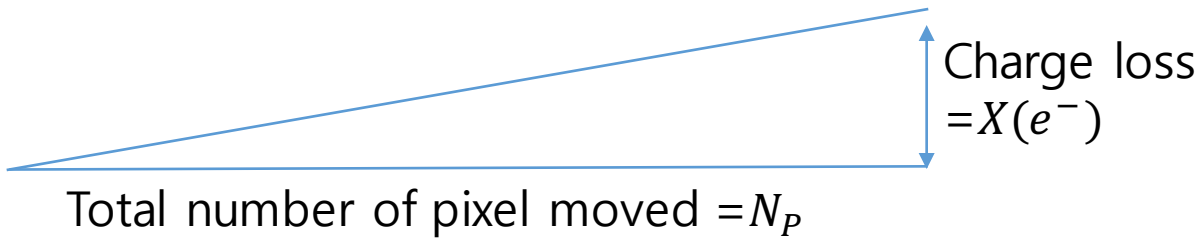

X =x-ray signal=1620e$^-$ for Fe55

$$CTE = 1 - \frac{S_D(e^-)}{X(e^-)N_P}$$

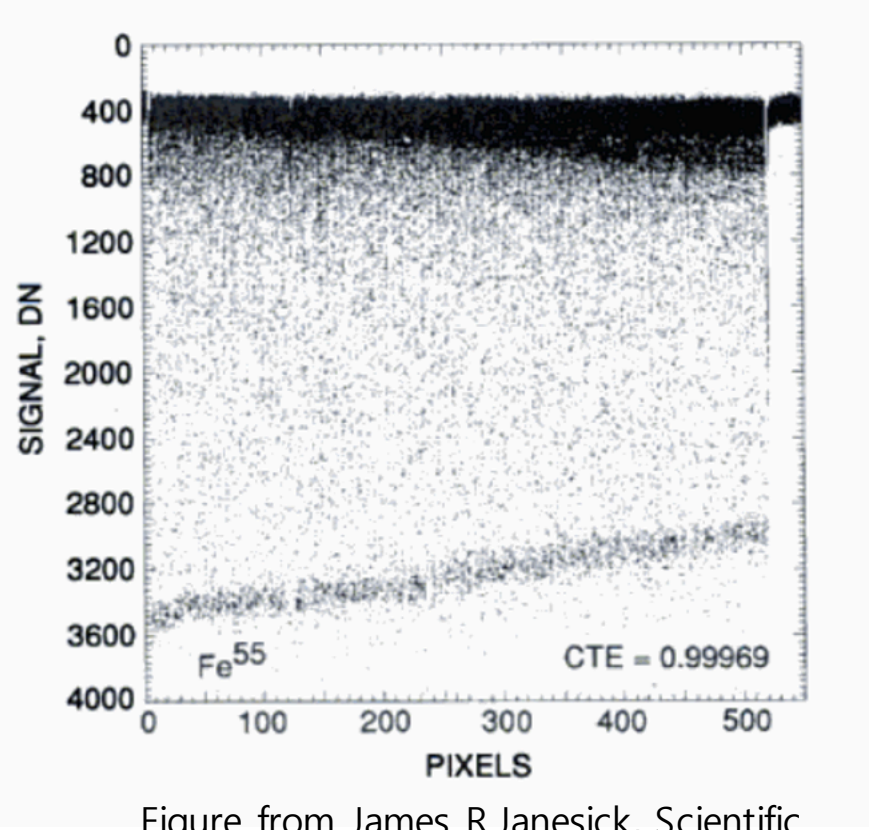

Figure from James R.Janesick, Scientific Charge-Coupled Devices, 419p

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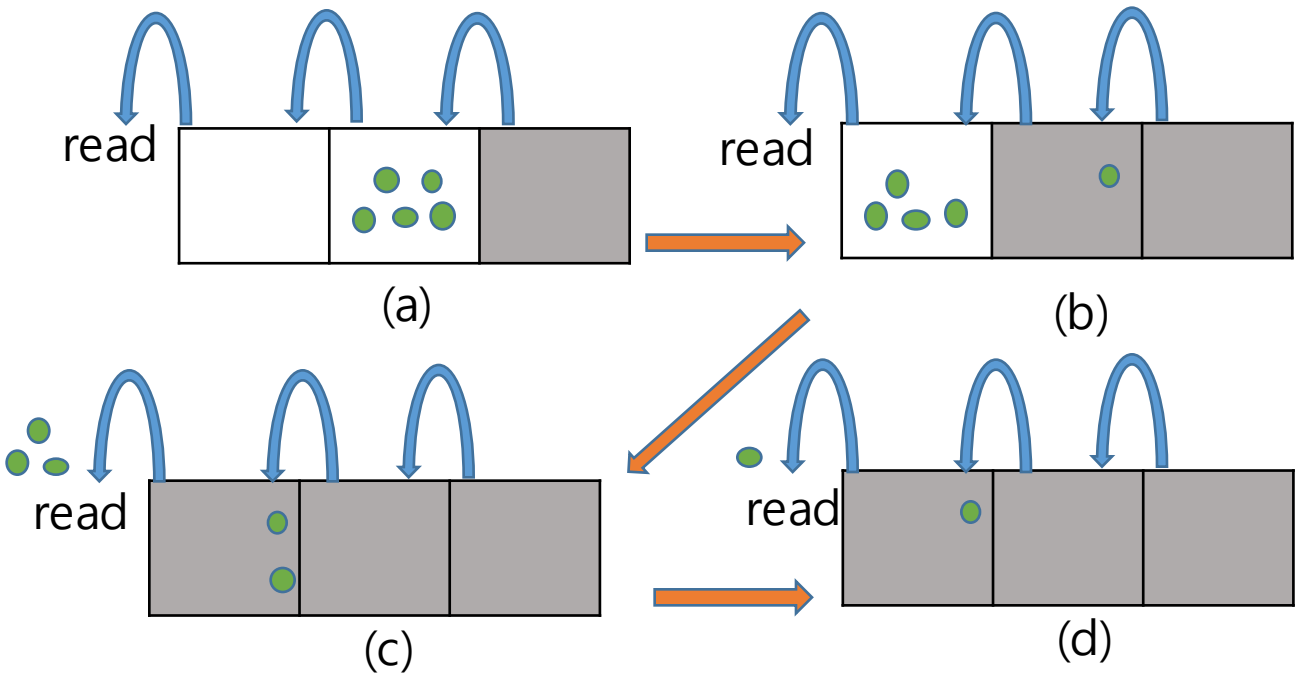

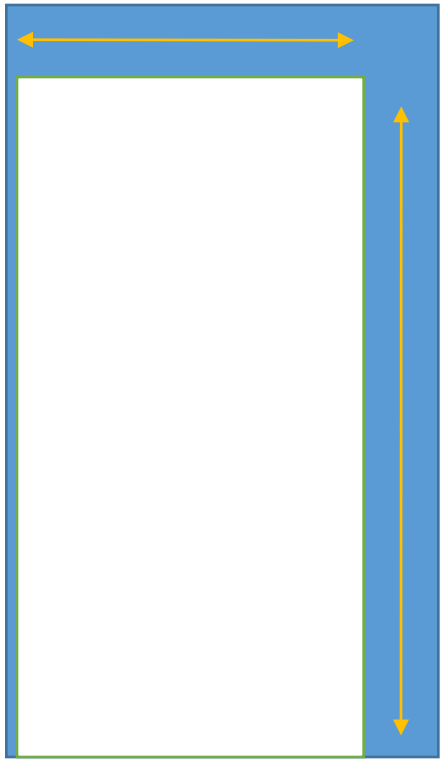

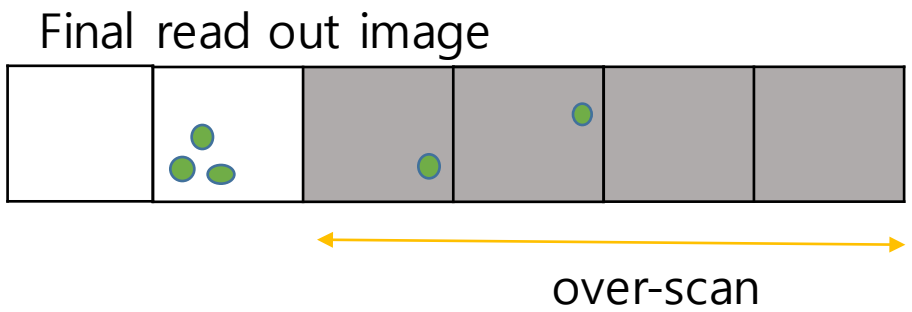

CTE measurement techniques

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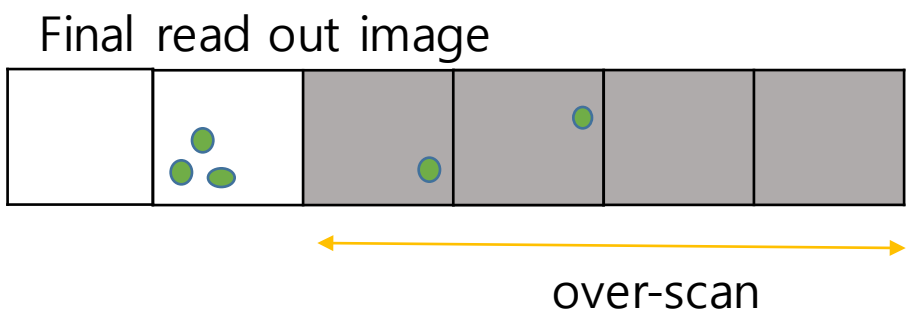

$$CTE = 1 - \frac{F_0}{F_i N_i} = 1 - CTI$$

- N_i : number of image columns(rows) + number of prescan columns(rows)
- F_i : sum of all pixels in last imaging column
- F_0 : sum of all pixels in first and second overscan columns(rows) after to last imaging column(row)

CTE measurement techniques

1. Fe55 x-ray transfer
2. EPER
3. CVF

$$\begin{aligned}\sigma_e^2(i) &= a^{2i}N_e + \binom{i}{1}^2 a^{2i-2}b^2N_e + \ldots + \binom{i}{i-1}^2 a^2b^{2i-2}N_e \\ &= a^{2i}N_e + o(b^2) \\ \sigma_e^2(i) &= N_e - 2ibN_e + o(b^2) \\ \sigma_a^2(i) &= \sigma_{a0}^2 - 2b\sigma_{a0}^2 i + o(b^2)\end{aligned} \qquad \text{.....(*)}$$

$$image\ R = \frac{flat1 - bias1}{flat2 - bias2} * mean(flat1 - bias1)$$

$$\sigma_{flat,i}^2 = \frac{\sigma_{R,i}^2}{2} = \mu - \nu i$$

i=column(row) number

$$CTE = a = 1 - b = 1 - \frac{\nu}{2\mu}$$

*Fabrice Christen et al. CCD Charge Transfer Efficiency (CTE) Derived From Signal Variance in Flat Filed Images

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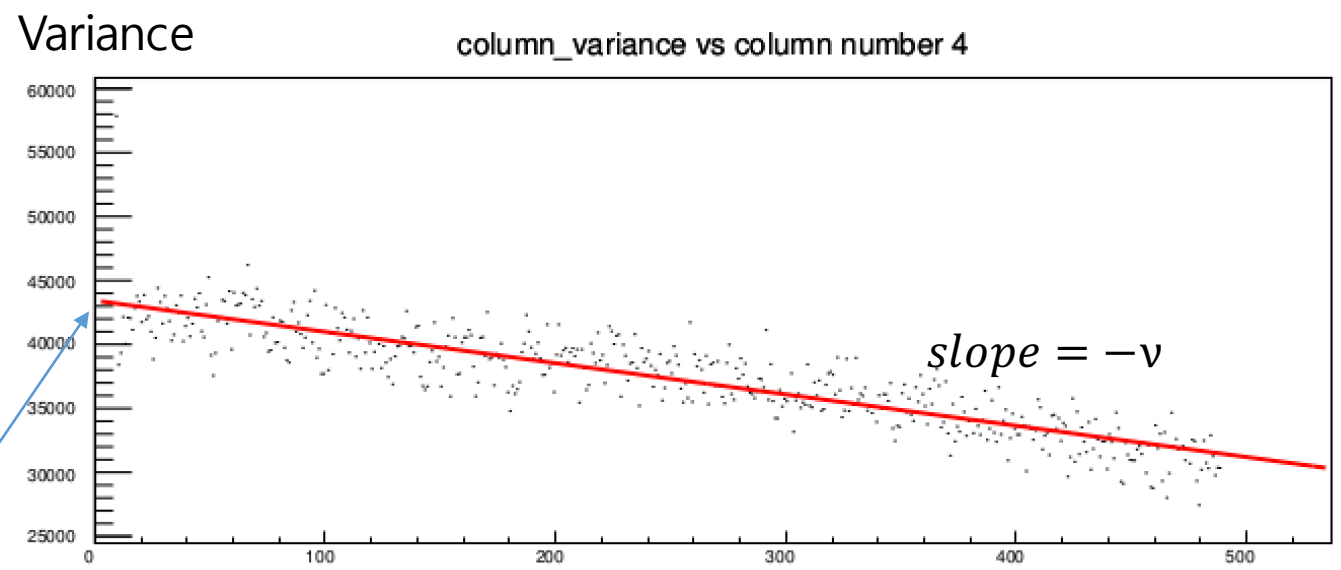
$$\sigma_{flat,i}^2 = \frac{\sigma_{R,i}^2}{2} = \mu - \nu i$$

i=column(row) number

$$CTE = 1 - \frac{\nu}{2\mu}$$

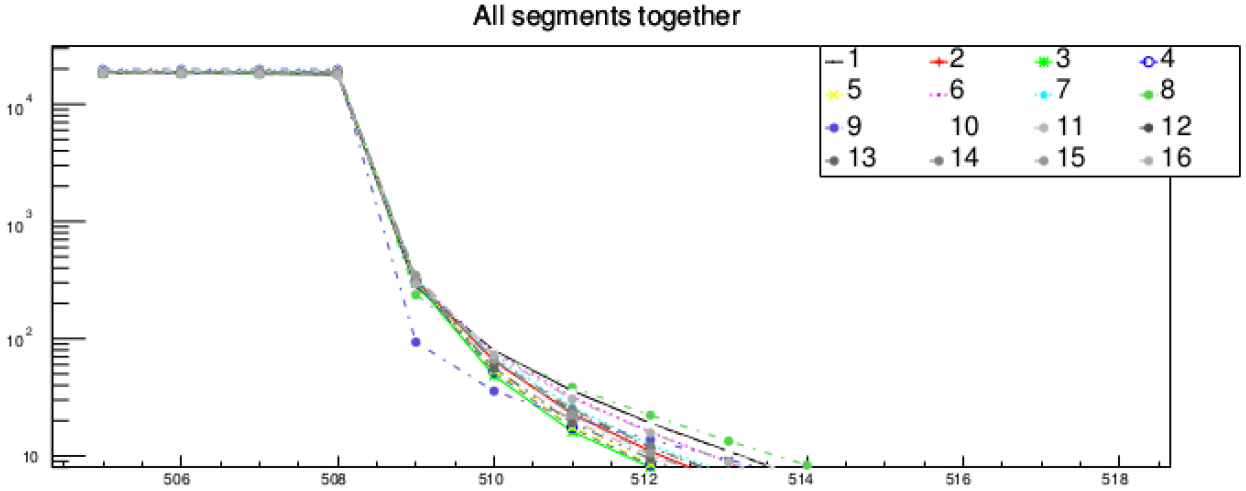


μ =y-axis intercept

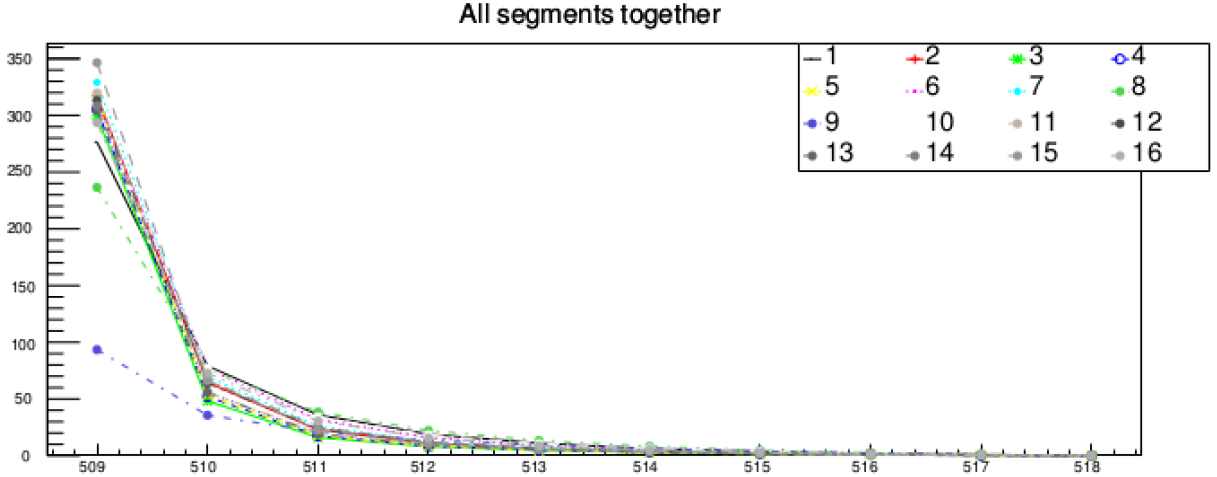
Column(row) number, i

EPER Results, ITL-3800C-097

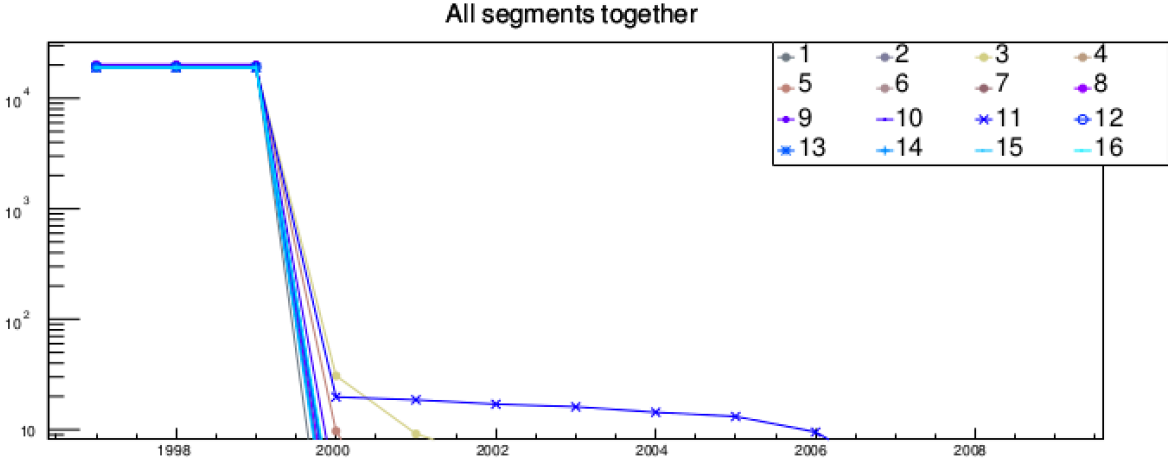
Log scale, x=505~518



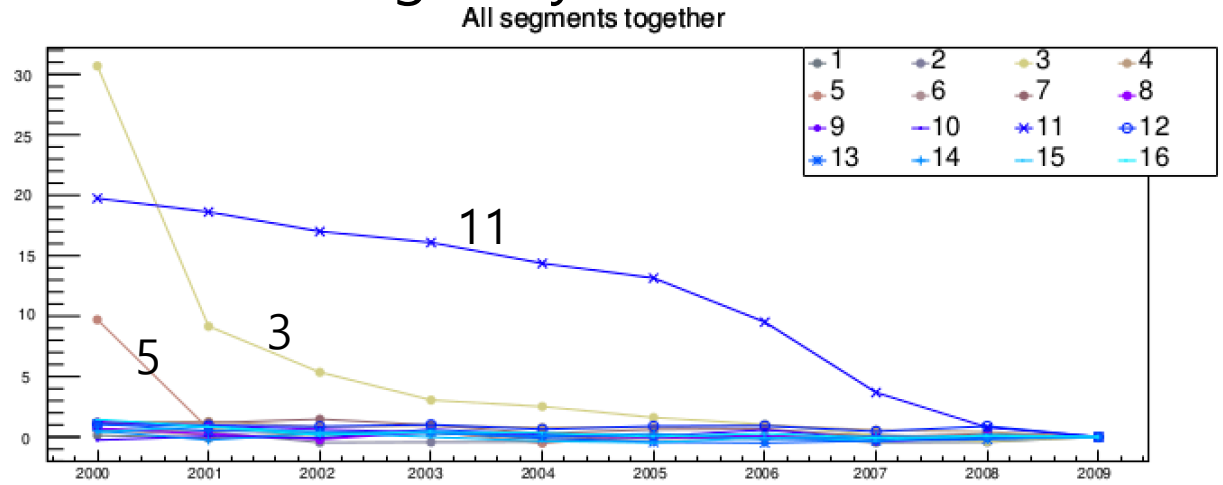
Overscan region, x=509~518



Log scale, y=1997~2010



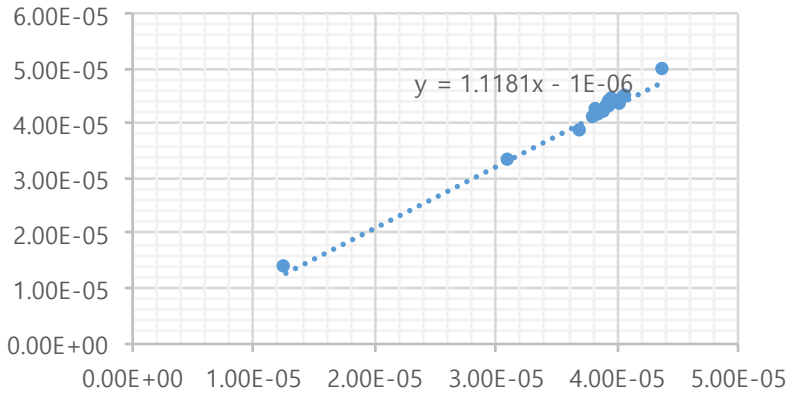
Overscan region, y=2000,2010



EPER Results – high flux(50000e-)

Total:
HCTE=$1-3.73\times10^{-5}\pm7.09\times10^{-6}$
VCTE=$1-1.74\times10^{-7}\pm3.42\times10^{-7}$

Amp	HCTI(serial)	HCTE(serial)	VCTI(parallel)	VCTE(parallel)
1	3.89e-05	0.999961	1.31e-09	1.000000
2	4.03e-05	0.999960	2.85e-08	1.000000
3	3.69e-05	0.999963	1.06e-06	0.999999
4	3.80e-05	0.999962	6.57e-08	1.000000
5	3.85e-05	0.999961	2.68e-07	1.000000
6	3.95e-05	0.999960	1.89e-08	1.000000
7	4.06e-05	0.999960	5.87e-08	1.000000
8	3.10e-05	0.999969	2.43e-08	1.000000
9	1.26e-05	0.999987	5.45e-08	1.000000
10	3.92e-05	0.999961	-5.30e-09	1.000000
11	3.93e-05	0.999961	1.01e-06	0.999999
12	3.97e-05	0.999960	5.22e-08	1.000000
13	3.84e-05	0.999962	4.15e-08	1.000000
14	3.96e-05	0.999960	6.89e-09	1.000000
15	4.38e-05	0.999956	3.42e-08	1.000000
16	4.08e-05	0.999959	6.04e-08	1.000000



Compare with LSST test report:

Amp	Serial CTE	Parallel CTE
1	$1-4.33\times10^{-5}\pm9.54\times10^{-8}$	$1-1.98\times10^{-7}\pm4.35\times10^{-8}$
2	$1-4.43\times10^{-5}\pm8.52\times10^{-8}$	$1+4.62\times10^{-8}\pm4.04\times10^{-8}$
3	$1-3.99\times10^{-5}\pm8.81\times10^{-8}$	$1-1.43\times10^{-6}\pm4.29\times10^{-8}$
4	$1-4.12\times10^{-5}\pm8.36\times10^{-8}$	$1+5.02\times10^{-8}\pm3.96\times10^{-8}$
5	$1-4.18\times10^{-5}\pm8.34\times10^{-8}$	$1+6.67\times10^{-8}\pm3.95\times10^{-8}$
6	$1-4.38\times10^{-5}\pm8.64\times10^{-8}$	$1-6.59\times10^{-8}\pm4.10\times10^{-8}$
7	$1-4.47\times10^{-5}\pm8.48\times10^{-8}$	$1-3.26\times10^{-8}\pm4.03\times10^{-8}$
8	$1-3.42\times10^{-5}\pm9.45\times10^{-8}$	$1-5.57\times10^{-8}\pm4.59\times10^{-8}$
9	$1-1.34\times10^{-5}\pm9.20\times10^{-8}$	$1-7.42\times10^{-8}\pm4.52\times10^{-8}$
10	$1-4.31\times10^{-5}\pm8.41\times10^{-8}$	$1-7.65\times10^{-8}\pm3.97\times10^{-8}$
11	$1-4.26\times10^{-5}\pm9.03\times10^{-8}$	$1-8.27\times10^{-6}\pm4.54\times10^{-8}$
12	$1-4.36\times10^{-5}\pm8.73\times10^{-8}$	$1+3.64\times10^{-8}\pm4.12\times10^{-8}$
13	$1-4.19\times10^{-5}\pm9.28\times10^{-8}$	$1+2.33\times10^{-8}\pm4.44\times10^{-8}$
14	$1-4.37\times10^{-5}\pm8.84\times10^{-8}$	$1+2.39\times10^{-8}\pm4.20\times10^{-8}$
15	$1-4.80\times10^{-5}\pm9.07\times10^{-8}$	$1+3.53\times10^{-8}\pm4.32\times10^{-8}$
16	$1-4.50\times10^{-5}\pm9.17\times10^{-8}$	$1-4.24\times10^{-8}\pm4.14\times10^{-8}$

EPER Results – low flux(1000e-): same results

Amp	HCTI(serial)	HCTE(serial)	VCTI(parallel)	VCTE(parallel)
1	3.89e-05	0.9999611	9,21e-07	0.9999991
2	3.92e-05	0.9999608	1.34e-06	0.9999987
3	3.49e-05	0.9999651	3.30e-07	0.9999997
4	3.77e-05	0.9999623	1.55e-07	0.9999998
5	3.96e-05	0.9999604	1.31e-06	0.9999987
6	3.94e-05	0.9999606	2.81e-07	0.9999997
7	3.96e-05	0.9999604	1.51e-06	0.9999985
8	2.99e-05	0.9999701	-7.16e-07	1.0000007
9	1.27e-05	0.9999873	7.26e-07	0.9999993
10	4.08e-05	0.9999592	9.43e-07	0.9999991
11	4.11e-05	0.9999589	4.01e-06	0.9999960
12	4.25e-05	0.9999575	1.26e-06	0.9999987
13	3.99e-05	0.9999601	7.27e-07	0.9999993
14	4.04e-05	0.9999596	1.02e-06	0.9999990
15	4.63e-05	0.9999537	-9.37e-07	1.0000009
16	3.75e-05	0.9999625	1.25e-06	0.9999988

Total:

HCTE=$1 - 3.75\times10^{-5} \pm 7.47\times10^{-6}$

VCTE=$1 - 8.81\times10^{-7} \pm 1.13\times10^{-6}$

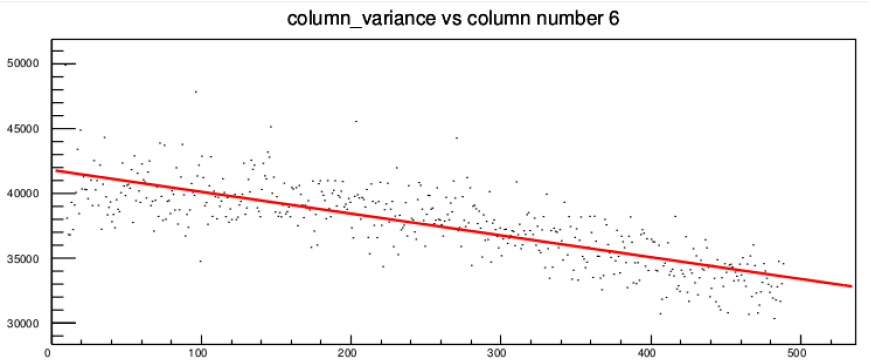
Compare with LSST test report(low flux):

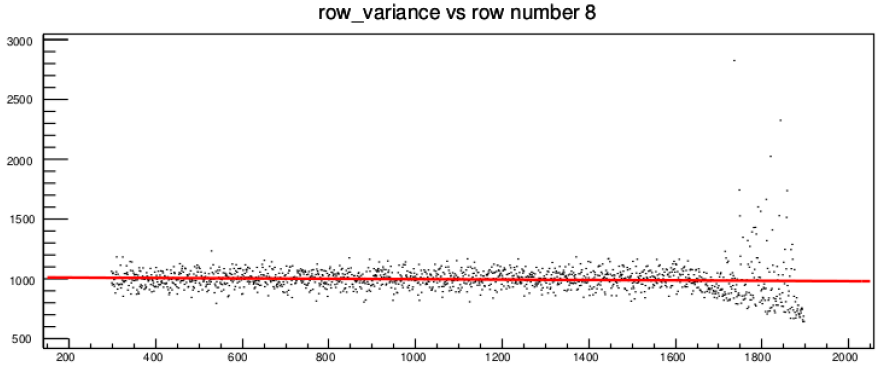
Amp	Serial CTE	Parallel CTE
1	$1 - 4.16 \times 10^{-5} \pm 4.52 \times 10^{-6}$	$1 - 8.70 \times 10^{-6} \pm 2.17 \times 10^{-6}$
2	$1 - 4.33 \times 10^{-5} \pm 4.00 \times 10^{-6}$	$1 + 2.76 \times 10^{-6} \pm 2.05 \times 10^{-6}$
3	$1 - 3.82 \times 10^{-5} \pm 4.18 \times 10^{-6}$	$1 + 5.53 \times 10^{-6} \pm 2.16 \times 10^{-6}$
4	$1 - 4.05 \times 10^{-5} \pm 3.93 \times 10^{-6}$	$1 + 2.06 \times 10^{-6} \pm 2.00 \times 10^{-6}$
5	$1 - 4.10 \times 10^{-5} \pm 3.92 \times 10^{-6}$	$1 + 6.29 \times 10^{-6} \pm 2.01 \times 10^{-6}$
6	$1 - 4.28 \times 10^{-5} \pm 4.05 \times 10^{-6}$	$1 - 3.58 \times 10^{-6} \pm 2.06 \times 10^{-6}$
7	$1 - 4.39 \times 10^{-5} \pm 3.96 \times 10^{-6}$	$1 + 1.80 \times 10^{-6} \pm 2.04 \times 10^{-6}$
8	$1 - 3.33 \times 10^{-5} \pm 4.53 \times 10^{-6}$	$1 - 1.61 \times 10^{-6} \pm 2.32 \times 10^{-6}$
9	$1 - 1.34 \times 10^{-5} \pm 4.50 \times 10^{-6}$	$1 - 9.65 \times 10^{-7} \pm 2.27 \times 10^{-6}$
10	$1 - 4.26 \times 10^{-5} \pm 3.92 \times 10^{-6}$	$1 - 3.30 \times 10^{-6} \pm 1.99 \times 10^{-6}$
11	$1 - 4.34 \times 10^{-5} \pm 4.27 \times 10^{-6}$	$1 - 2.99 \times 10^{-6} \pm 2.20 \times 10^{-6}$
12	$1 - 4.36 \times 10^{-5} \pm 4.09 \times 10^{-6}$	$1 + 2.80 \times 10^{-6} \pm 2.07 \times 10^{-6}$
13	$1 - 4.21 \times 10^{-5} \pm 4.40 \times 10^{-6}$	$1 + 3.74 \times 10^{-6} \pm 2.24 \times 10^{-6}$
14	$1 - 4.40 \times 10^{-5} \pm 4.15 \times 10^{-6}$	$1 + 2.68 \times 10^{-6} \pm 2.12 \times 10^{-6}$
15	$1 - 4.92 \times 10^{-5} \pm 4.25 \times 10^{-6}$	$1 + 3.05 \times 10^{-6} \pm 2.18 \times 10^{-6}$
16	$1 - 4.46 \times 10^{-5} \pm 4.30 \times 10^{-6}$	$1 - 4.61 \times 10^{-7} \pm 2.08 \times 10^{-6}$

CVF Results

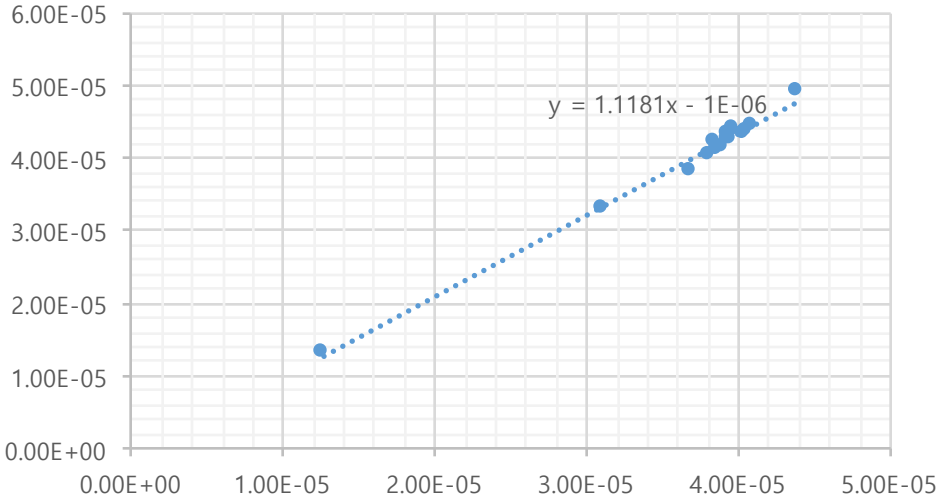
(E2V-113-03_flat_0085.83_flat1_20160131050350, E2V-113-03_flat_0085.83_flat2_20160131050827)

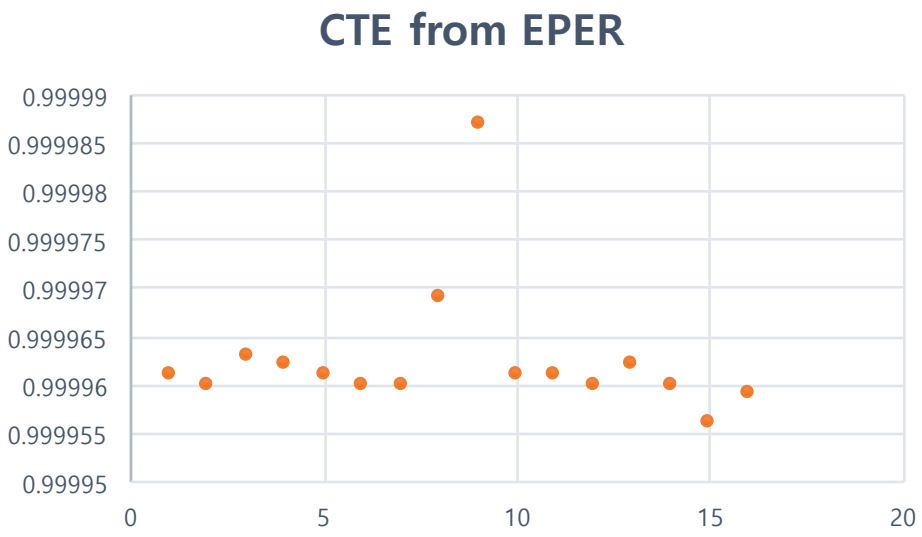
Amp	HCTE from CVF	HCTE(serial) from EPER	VCTE from CVF	VCTE(parallel) from EPER
1	1.0001023	0.999778	0.9999317	0.999955
2	0.9996456	0.999807	0.9999327	0.999961
3	1.0004361	0.999797	0.9999363	0.999956
4	0.9997115	0.999814	0.9999477	0.999962
5	0.9998527	0.999813	0.9999602	0.999962
6	0.9997659	0.999802	0.9999308	0.99996
7	0.9998086	0.999808	0.9999526	0.999961
8	0.9998822	0.999774	0.9999919	0.99995
9	0.9989405	0.999793	0.9999973	0.999951
10	0.9997312	0.999811	0.9999975	0.999962
11	0.9993335	0.999784	0.9999983	0.99995
12	1.0000563	0.999797	0.9999992	0.999959
13	0.9994709	0.999775	0.9999988	0.999953
14	0.9997538	0.999795	0.9999983	0.999958
15	0.9999666	0.999783	0.9999991	0.999956
16	0.9999884	0.999792	0.9999957	0.999959

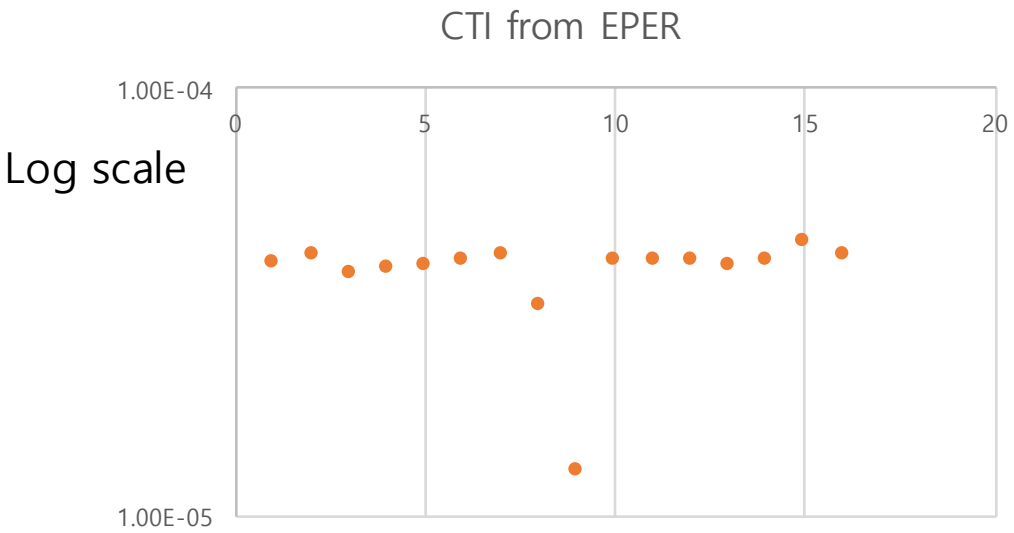




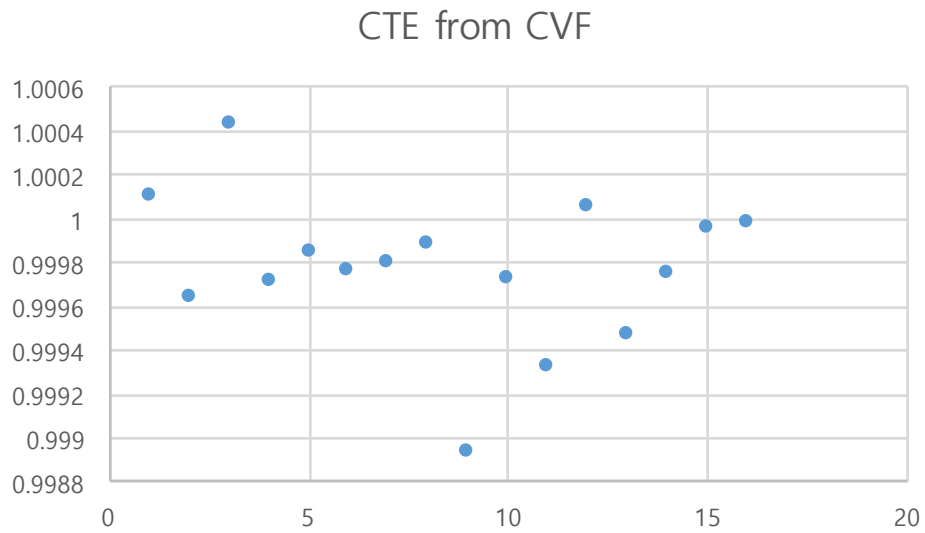
ITL-3800C-097 with EPER method



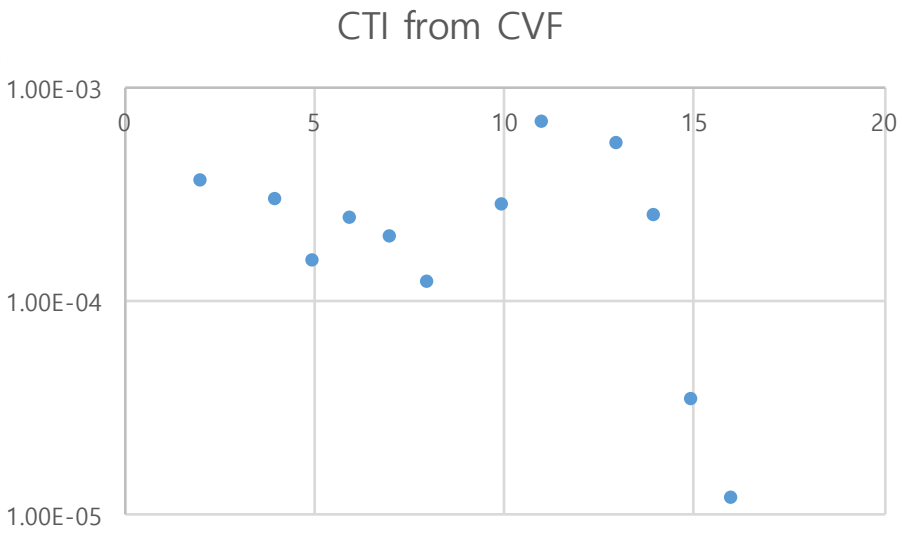


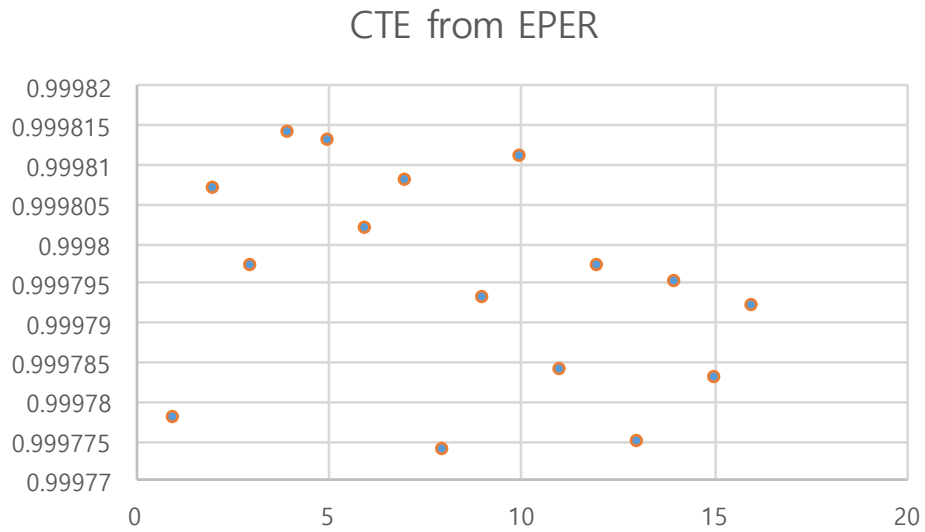


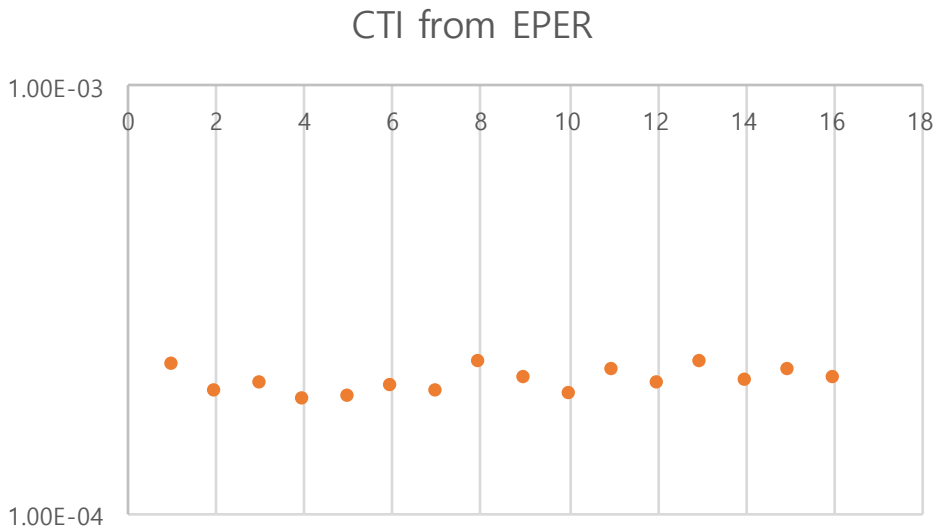
E2V-113-03 with CVF&EPER method



Log scale







Summary

- I used three different methods to measure the CTE
  - Fe55 x-ray
  - EPER
  - CVF

- Goal is to understand CTE by cross-correlating results for same sensor.
- Fe55 CTE is work in progress, use DM to find hits and calculate flux.