ACIS Memo #205

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To: ACIS Team
From: Catherine Grant
Subject: Reproducibility of soft-proton damage in laboratory irradiations of ACIS CCDs.
Date: 20 May 2004

This memo is a summary of the low-energy proton irradiation tests conducted at GSFC with ACIS and ACIS-like CCDs. The primary purpose is to better understand the CCD-to-CCD variance in the CTI change as a function of particle fluence. Much of this information has been presented before in ACIS memos and SPIE proceedings. Five CCDs have been irradiated at a number of proton energies from 49 to 390 keV. Some of the basic information, such as date, detector, proton energy and fluence, are listed in the table.

The value we are attempting to quantify is δCTI/δfluence, the change in CTI as a function of the proton fluence. These values for each irradiation are shown in the table and in the top panel of the figure. The energy dependence of δCTI/δfluence determined by a fit to the w282c2 data is

$$\delta CTI/\delta fluence = 4.2 \times 10^{-12} \, (E/100\, keV)^{-1.68}.$$

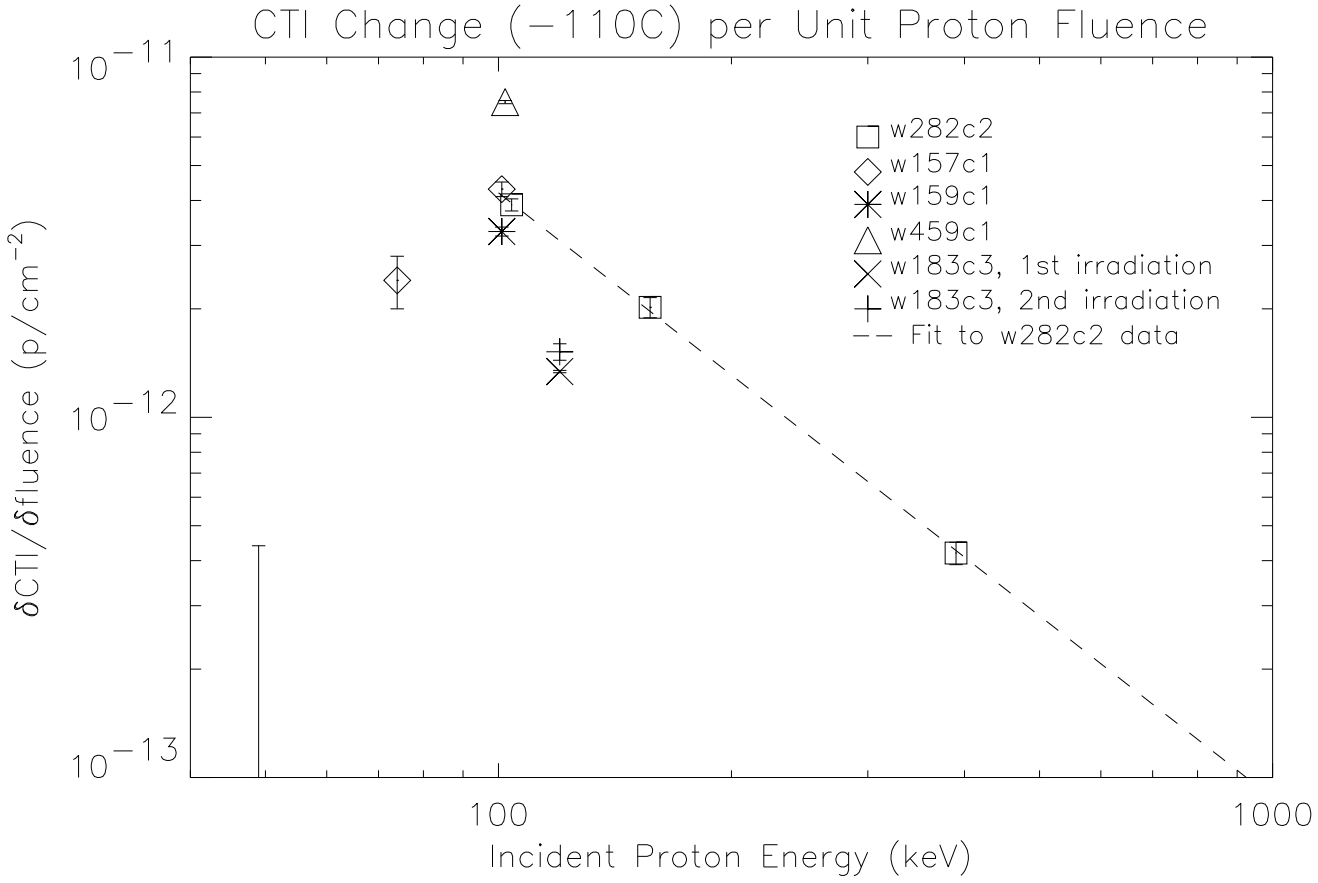
Below 100 keV the data clearly fall below this relation. The last column in the table shows the δCTI/δfluence normalized to a proton energy of 100 keV using the above relation.

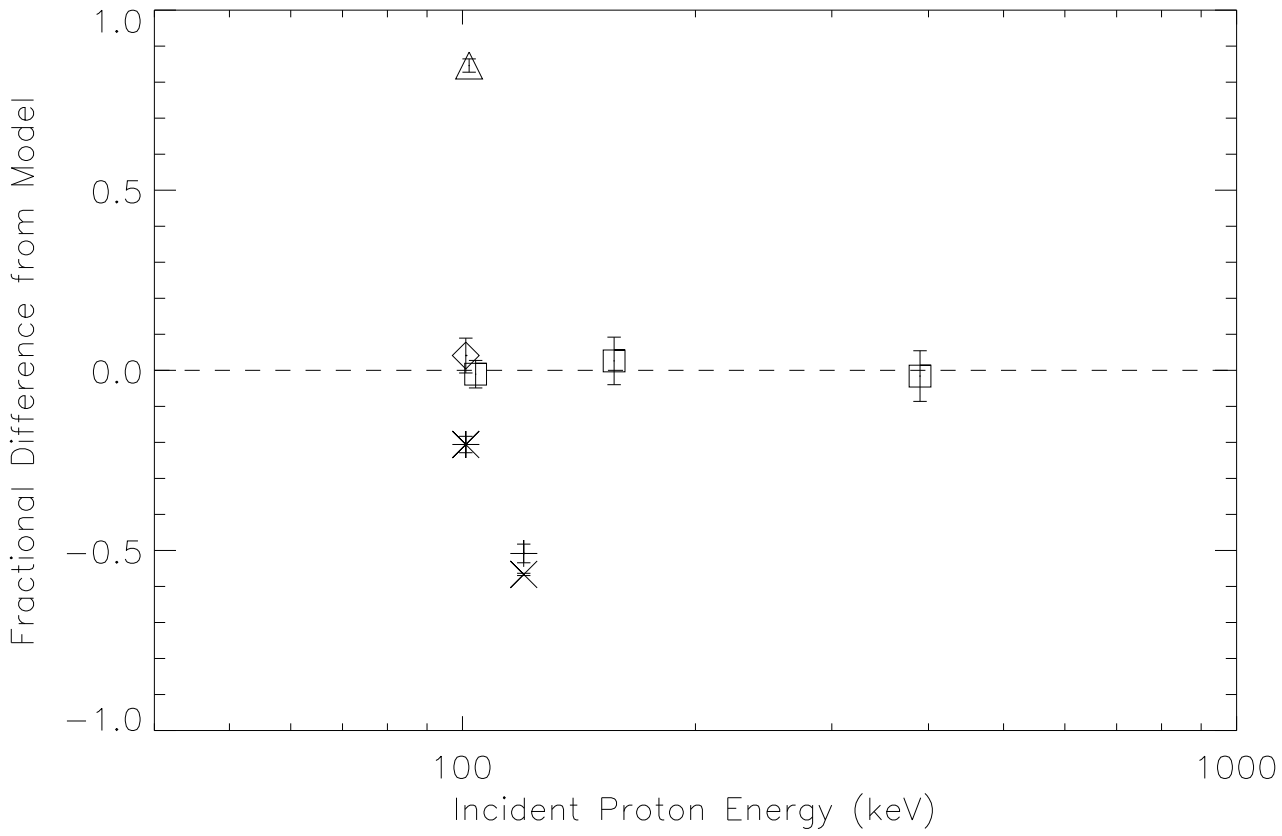
The five CCDs were not irradiated in identical setups. The October/November 1999 irradiations of w282c2, w157c1 and w159c1 were all conducted at the van de Graaff accelerator with the CCDs at room temperature. The January 2000 irradiation of w459c1 was conducted at the small accelerator at room temperature with the CCD on a rotating platform to damage a larger region. The September 2002 irradiations of w183c3 were conducted at the small linear accelerator with the CCDs at -100C. The CTI of w183c3 was measured at -100C, while all other CTI measurements are at -110C, and has been scaled to -110C using the September 1999 S2 data. The w183c3 CTI difference measurements include both an irradiation and a room temperature bakeout[1].

The scaled δCTI/δfluence numbers can be used to estimate the CCD-to-CCD variance. The small scatter of the w282c2 (2% rms) and w183c3 (6% rms) data points is comparable with the estimated measurement errors. Comparing the three CCDs which were irradiated under the same conditions (w282c2, w157c1 and w159c1), the CCD-to-CCD rms is $\sim$ 11%, while the statistical error is just 2%. Adding w183c3, the CCD-to-CCD rms increases to 28%. For all five CCDs, the rms increases to 43%.

[1]. δCTI/δfluence for the irradiation alone is much smaller at 0.56 and 0.81 $\times 10^{-12}$ p^{-1} cm^2 (after scaling to -110C)

Date	Detector	Energy (keV)	Fluence (10^7 p cm^{-2})	dCTI/dFluence (10^{-12} p^{-1} cm^2)	dCTI/dFluence at 100 keV
19 Oct 99	w282c2	390	13.70	0.42 ± 0.03	4.13 ± 0.30
22 Oct 99	w282c2	157	4.60	2.02 ± 0.13	4.31 ± 0.28
22 Oct 99	w282c2	104	3.80	3.89 ± 0.15	4.15 ± 0.16
04 Nov 99	w157c1	101	3.00	4.3 ± 0.2	4.4 ± 0.2
04 Nov 99	w157c1	74	0.99	2.4 ± 0.4	···
04 Nov 99	w157c1	49	0.68	< 0.44	···
04 Nov 99	w159c1	101	2.00	3.28 ± 0.09	3.34 ± 0.10
10 Jan 00	w459c1	102	3.60	7.5 ± 0.1	7.8 ± 0.1
17 Sep 02	w183c3	120	10.20	1.34 ± 0.01	1.82 ± 0.02
18 Sep 02	w183c3	120	3.00	1.52 ± 0.08	2.06 ± 0.10


CTI Change (−110C) per Unit Proton Fluence
10^{-11}
10^{-12}
10^{-13}
δCTI/δfluence (p/cm^{-2})
w282c2
w157c1
w159c1
w459c1
w183c3, 1st irradiation
w183c3, 2nd irradiation
Fit to w282c2 data
100
1000
Incident Proton Energy (keV)


1.0
0.5
0.0
−0.5
−1.0
Fractional Difference from Model
100
1000
Incident Proton Energy (keV)