Evolution of dark currents in LYRA detectors - Update due to a new campaign

IED 17 Aug 2018

After an extensive campaign (covers closed all day 22 Mar 2018) with temperatures between 48 and 56 degrees C, the approach to estimate the dark currents had to be modified. For comparison, please see the previous reports
http://solwww.oma.be/users/dammasch/IED_20180119_DevelopmentDC2017Update.pdf
and
http://solwww.oma.be/users/dammasch/IED_20160307_EvolotionDC.pdf

Model parameters

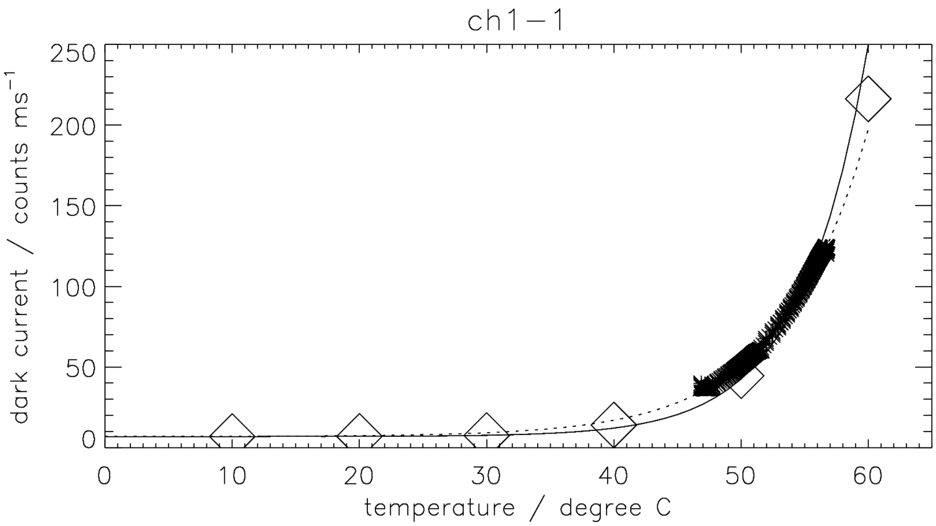
As mentioned in the 2016 report, the dark currents as a function of temperature appear to follow an exponential curve, for all detectors except the PIN detectors:
DC = f(T) = a + exp(b*T + c)
But these parameters appear to change with time. - For all channels, parameter a was chosen as the dark current level below 20 deg C, measured pre-launch in the lab. This parameter represents the basic level of the dark currents: Even for low temperatures, it is always present, and always around 6 to 7 counts/ms. When this value is subtracted and the logarithm of the rest is fitted with a linear polynomial, one observes large variations of parameters b and c, which did not appear to be independent from each other. As a solution, parameter c was chosen constant from the pre-launch data fit, and only parameter b was fitted for the various campaigns over time. The resulting time series of parameter b was smoothed by hand. This approach did not work any longer with the values from the 2018 campaign, especially for ch1-1, ch1-3, ch3-3, ch3-4, which are marked with a "?" in Fig 1 and Fig 3. Figures 1, 2, 3 show the results of fitting the parameters b and c before launch and after eight years of LYRA operation.

It was said that large variations of parameters b and c were observed - when one parameter went up, the other went down. This was due to the fact that most campaigns consisted only of very few observations (several minutes), where the temperatures did not change much. These point-like sets could be fitted by quite different combinations of parameters b and c. Only the pre-launch measurements covered temperatures from very low up to 60 degree C. Therefore it seemed to make sense to fix one parameter (c) to the pre-launch fit and estimate the variation of the other parameter (b) over time. With the extensive set of observations during the 2018 campaign and its wider range of temperatures, there were now two sets of values that were not "point-like", and it became obvious that these could not be fitted with one parameter fixed. Both parameters, b and c, obviously varied over time.

What is the significance of these parameters? While parameter a determines the basic dark current observed even for low temperatures, parameters b and c control the exponential rise of the dark current for higher temperatures. Parameter b (always positive) controls the velocity of this rise, while parameter c (always negative) inhibits this rise for a while. The relation of the two parameters determines, e.g., a threshold temperature where the dark current reaches 1 count/ms above the basic value a. Let us call this temperature T1.

The fits "before" and "after" as shown in Fig 1, 2, 3 demonstrate the following: Parameter b almost always diminishes (the only exception is ch1-4, but not very significant). In other words, the velocity of the temperature-dependent rise of the dark currents becomes generally slower with time. For parameter c, there are two possibilities. In unit 1 and unit 3, the inhibition controlling the rise becomes smaller, in unit 2 it becomes bigger. As a net result, the threshold T1 is shifted to lower temperatures in unit 1 and unit 3, but to higher values in unit 2. Since both effects work in the same direction for all-MSM unit 2 (slower rise, stronger inhibition) the dark currents become generally weaker over time. For unit 1 and unit 3 it depends: Dark currents become stronger in the mid-temperature range, but not at 60 degree C, for ch1-1 and ch1-3 (MSM), but they become stronger all over for ch1-4, ch3-1, ch3-3, ch3-4 (Si). [One has to observe the model exceptions of unit 3, though: ch3-1 is compared to its first on-board observation, and ch3-3 and ch3-4 are mirrored at the level of parameter a.]

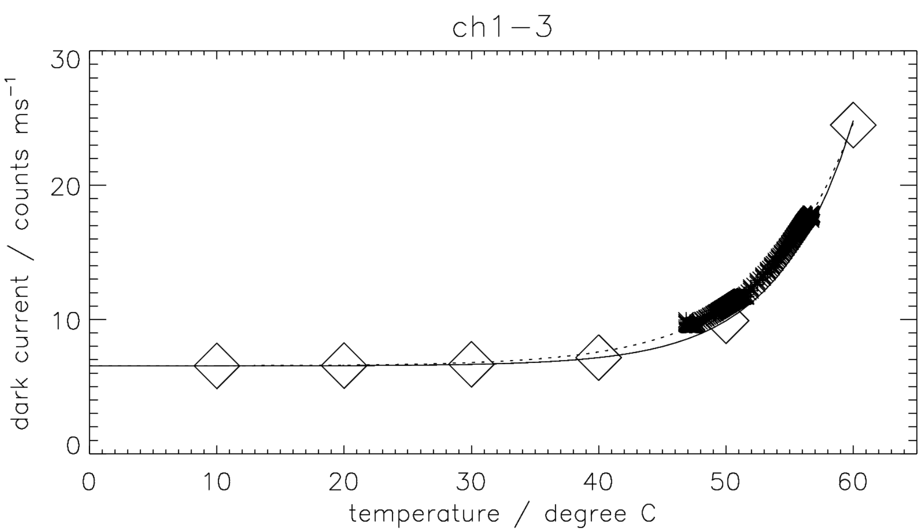
So the dark currents are now estimated with the help of two parameters changing in time (for unit 2, parameter c is still kept constant for simplicity reasons), as can be seen in Fig 4, 5, 6. This new approach leads to good results, as can be seen in Fig 7 - 15.



2009:
b= 0.191958
c= - 6.02436
T1= 31.4 deg C

2018:
b= 0.146875 (-23.5%)
c= - 3.56243 (-40.9%)
T1= 24.3 deg C

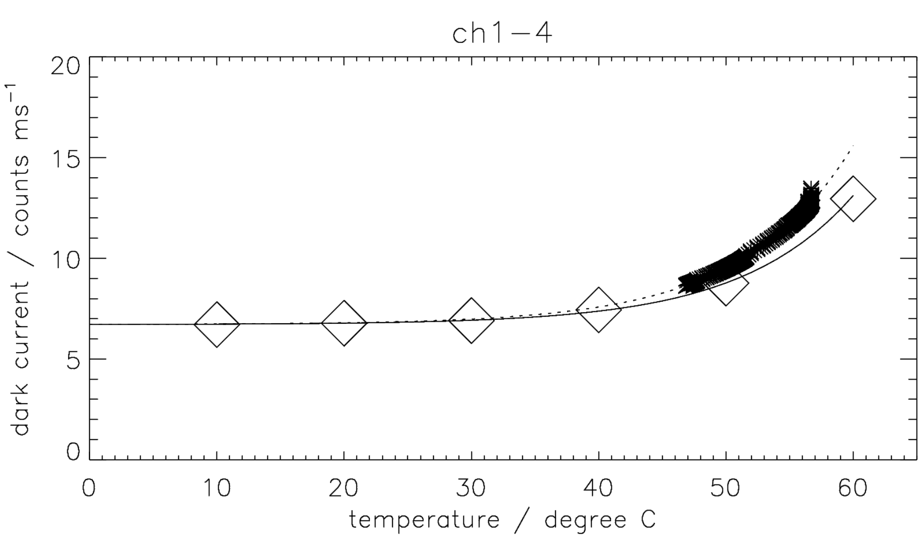
(?)



2009:
b= 0.169333
c= - 7.25499
T1= 42.8 deg C

2018:
b= 0.142840 (-15.6%)
c= - 5.67501 (-21.8%)
T1= 39.7 deg C

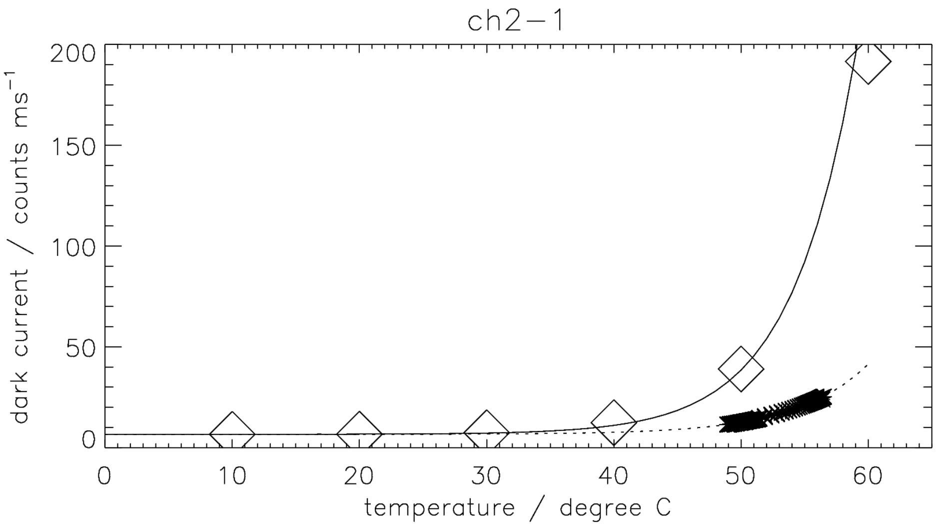
(?)



2009:
b= 0.113158
c= - 4.93195
T1= 43.6 deg C

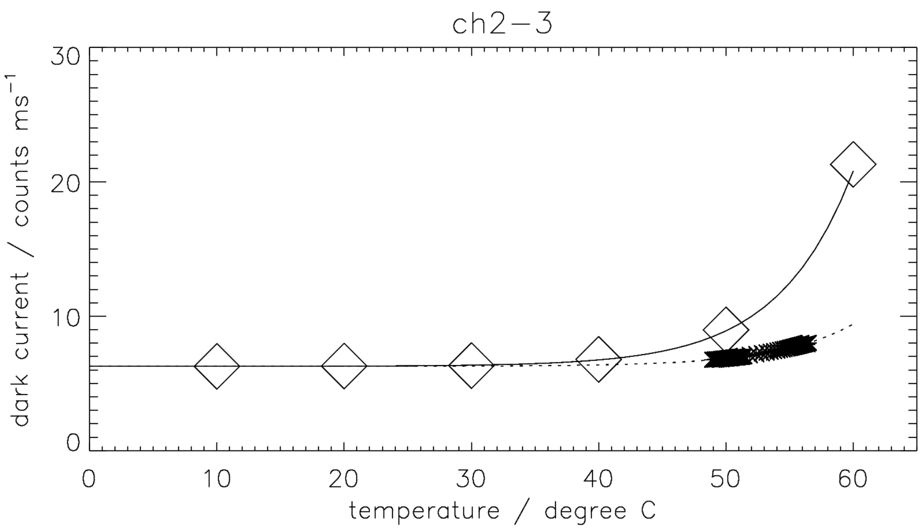
2018:
b= 0.116009 (+2.5%)
c= - 4.77614 (-3.2%)
T1= 41.2 deg C

Fig 1: Unit 1 before/after



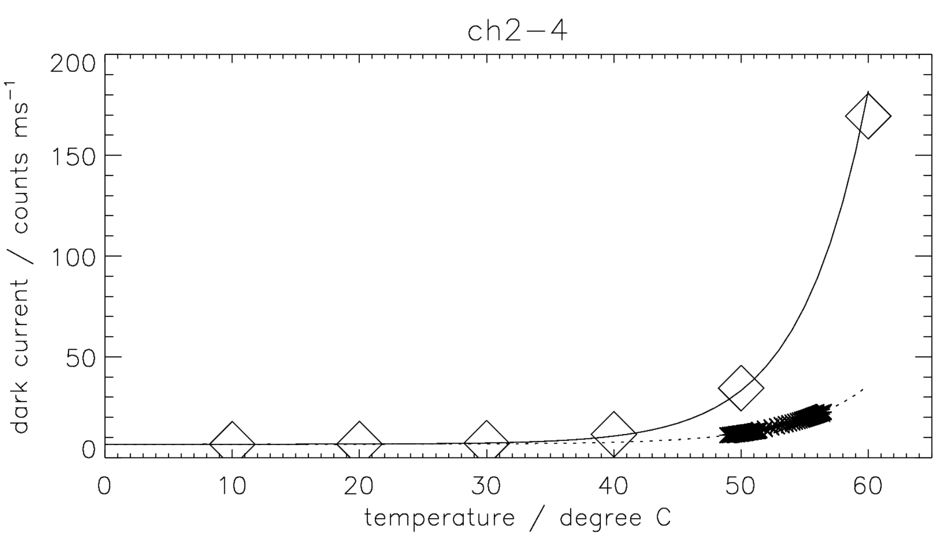
2009:
b= 0.197441
c= - 6.40979
T1= 32.5 deg C

2018:
b= 0.176632 (-10.5%)
c= - 7.04868 (+10.0%)
T1= 39.9 deg C



2009:
b= 0.170558
c= - 7.55667
T1= 44.3 deg C

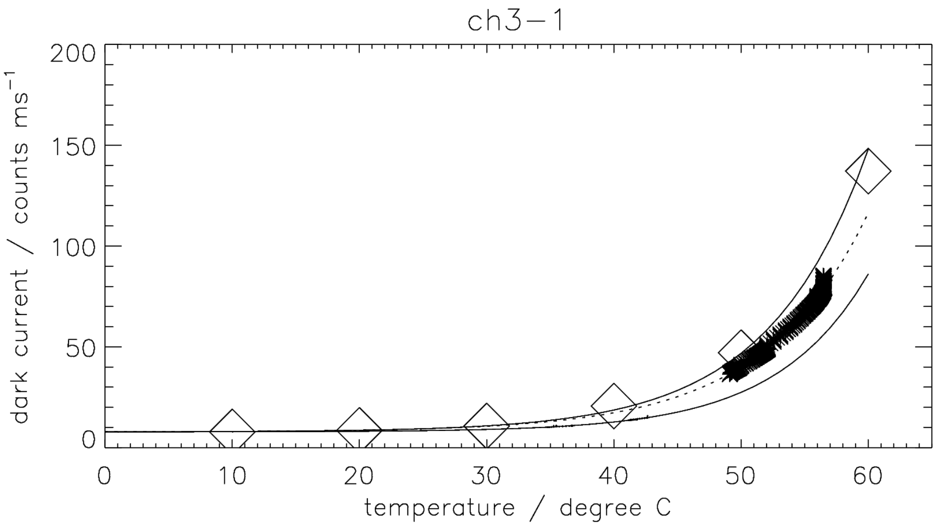
2018:
b= 0.167935 (-1.5%)
c= - 8.92997 (+18.2%)
T1= 53.2 deg C



2009:
b= 0.188306
c= - 6.13248
T1= 32.6 deg C

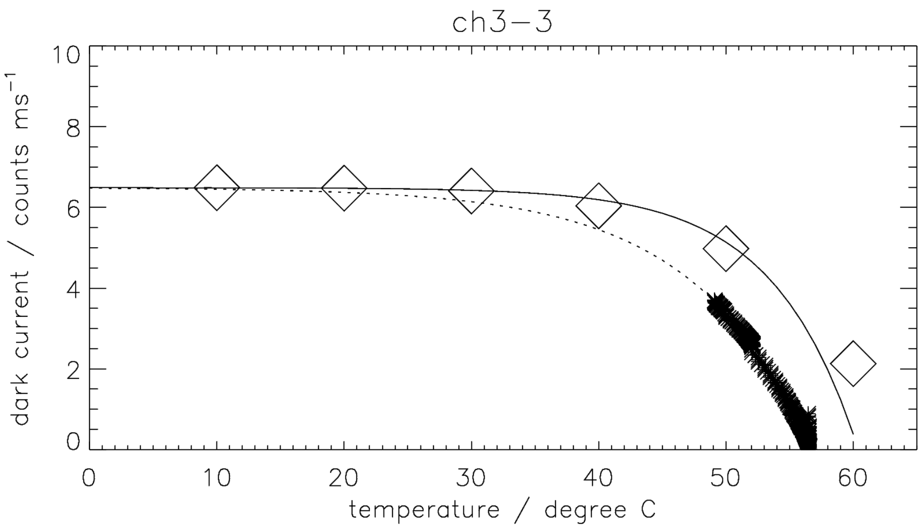
2018:
b= 0.169855 (-9.8%)
c= - 6.82008 (+11.2%)
T1= 40.2 deg C

Fig 2: Unit 2 before/after



2010:
b= 0.138455
c= -3.94643
T1= 28.5 deg C

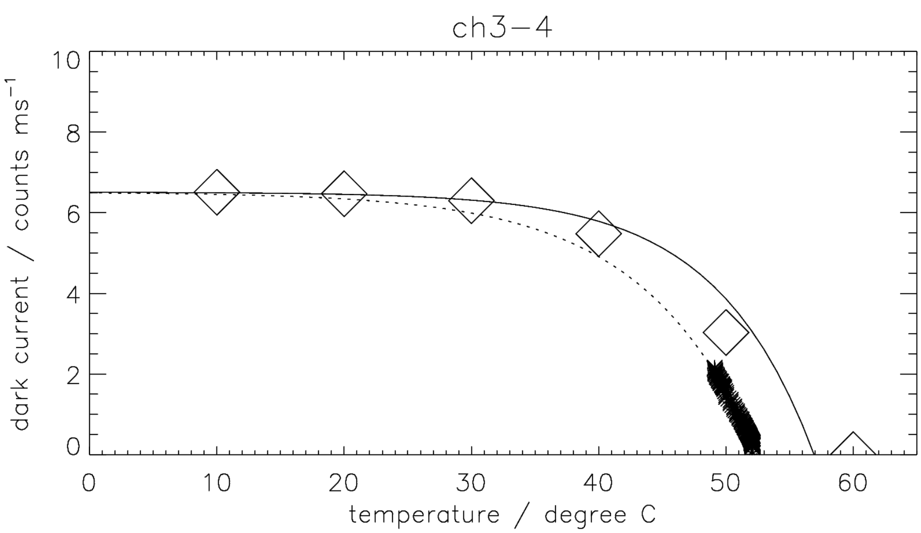
2018:
b= 0.121698 (-12.1%)
c= - 2.61418 (-33.8%)
T1= 21.5 deg C



2009:
b= 0.150932
c= -7.24624
T1= 48.0 deg C

2018:
b= 0.109534 (-27.4%)
c= - 4.34215 (-40.1%)
T1= 39.6 deg C

(?)

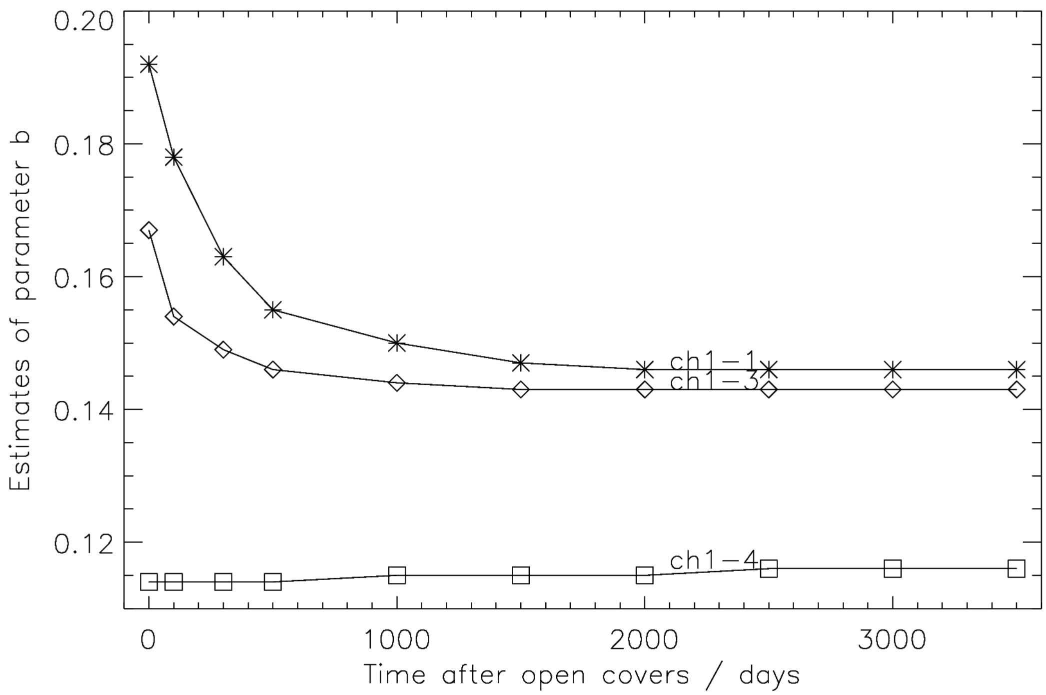


2009:
b= 0.129921
c= -5.52275
T1= 42.5 deg C

2018:
b= 0.112750 (-13.2%)
c= - 4.03966 (-26.9%)
T1= 35.8 deg C

(?)

Fig 3: Unit 3 before/after



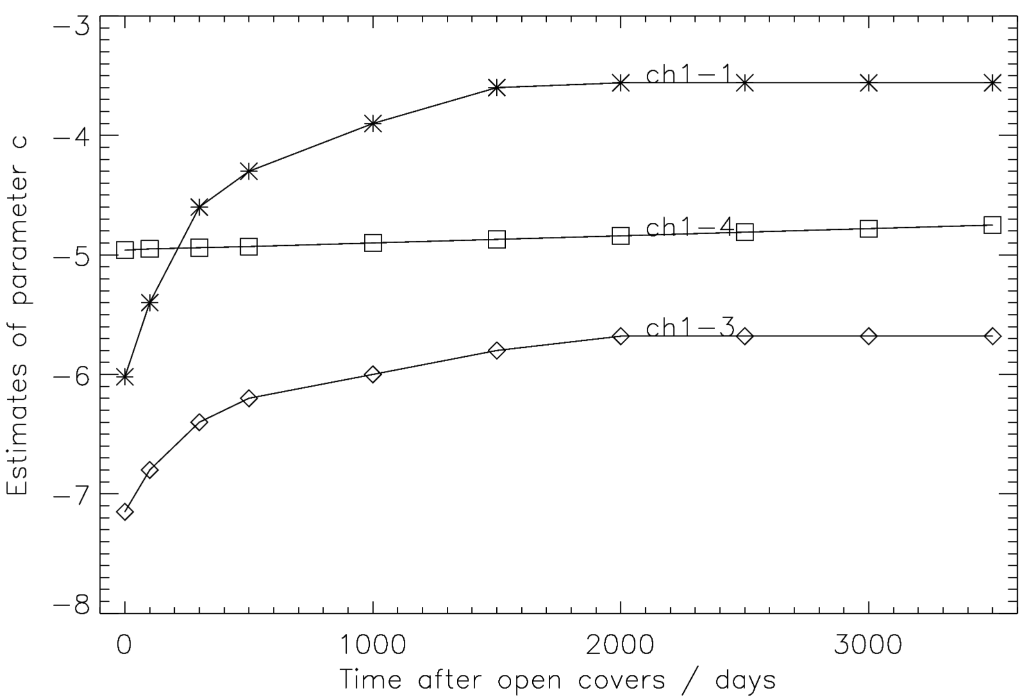


Fig 4: Unit 1 parameter estimates

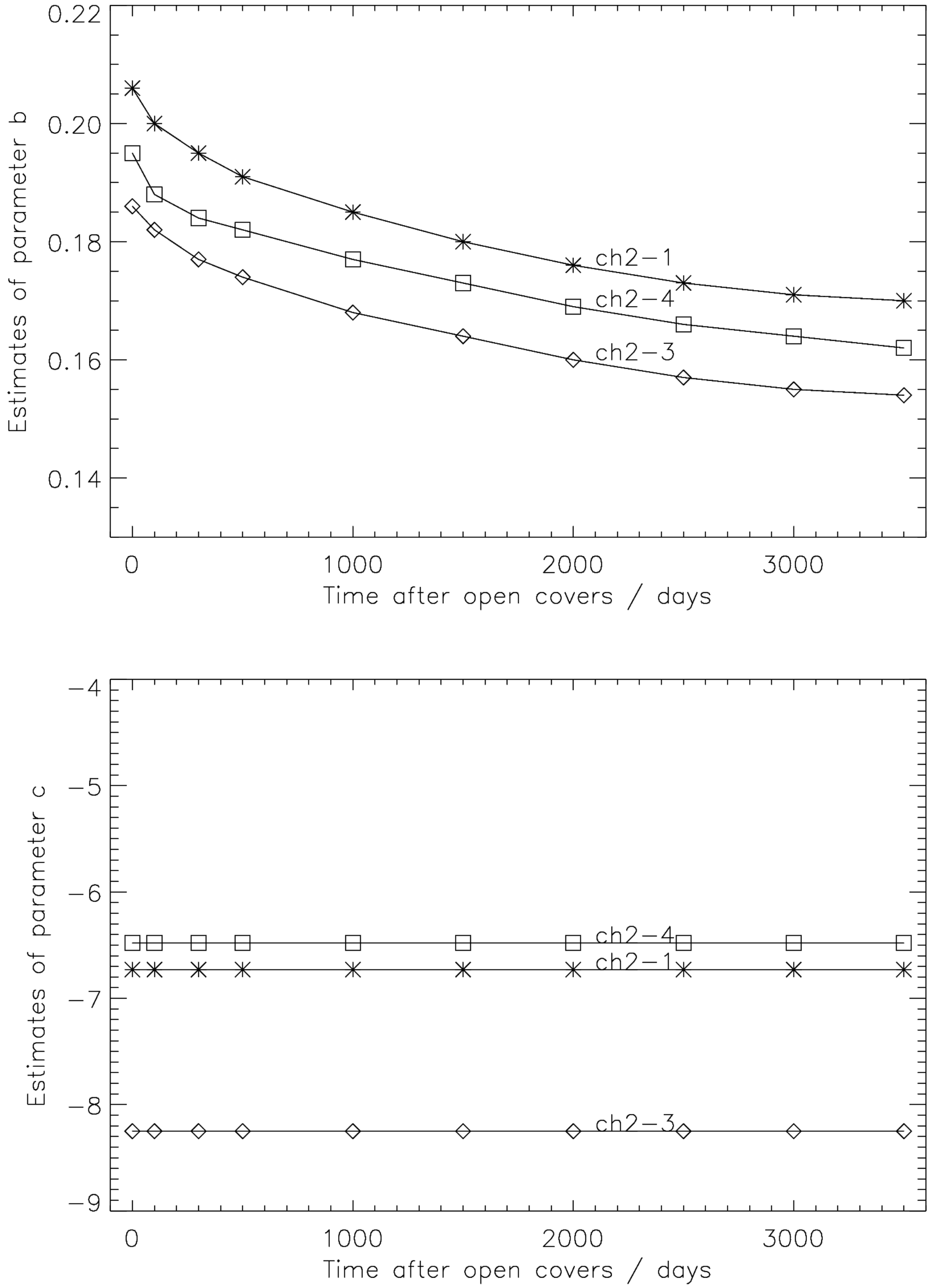


Fig 5: Unit 2 parameter estimates

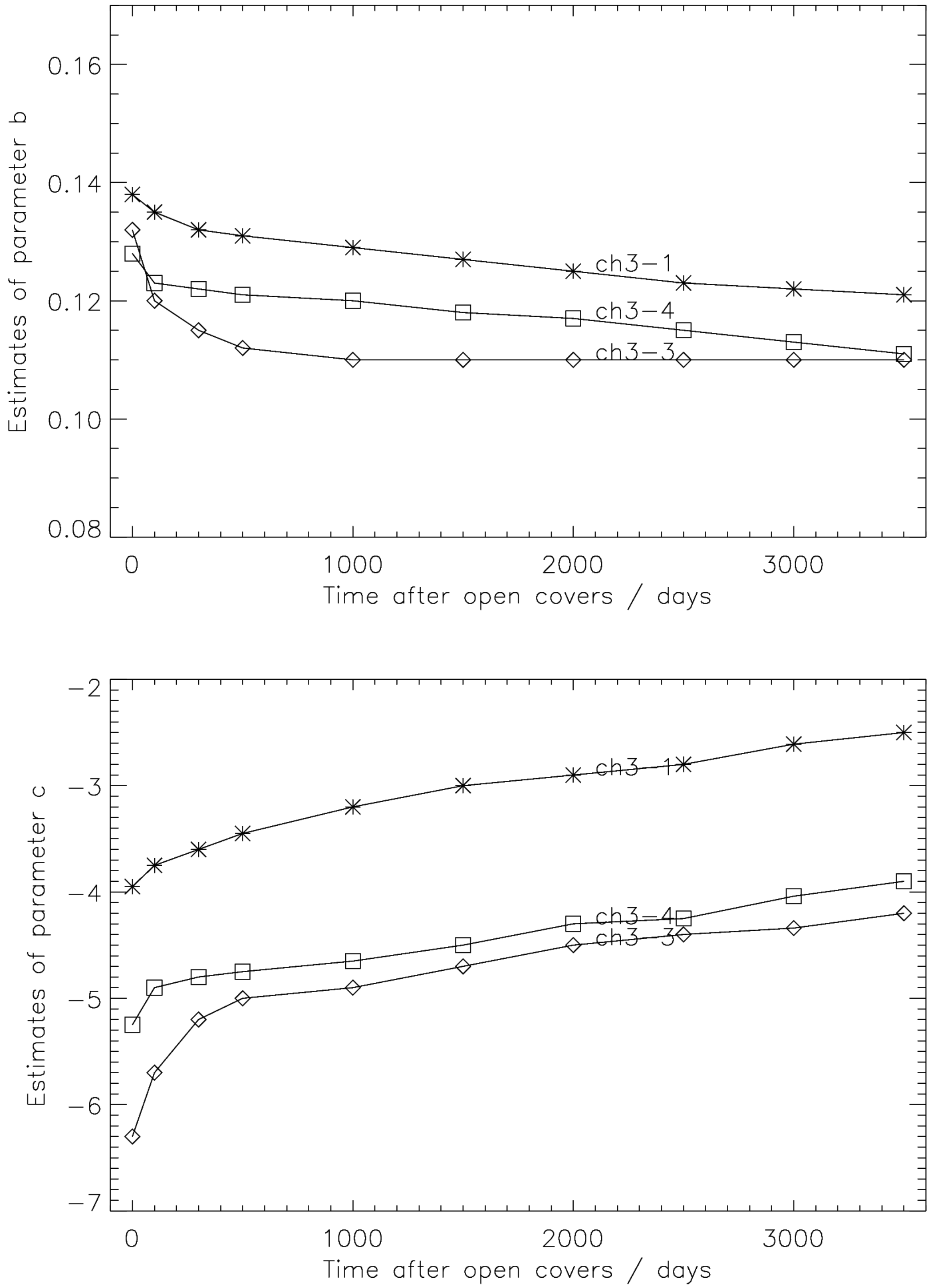


Fig 6: Unit 3 parameter estimates

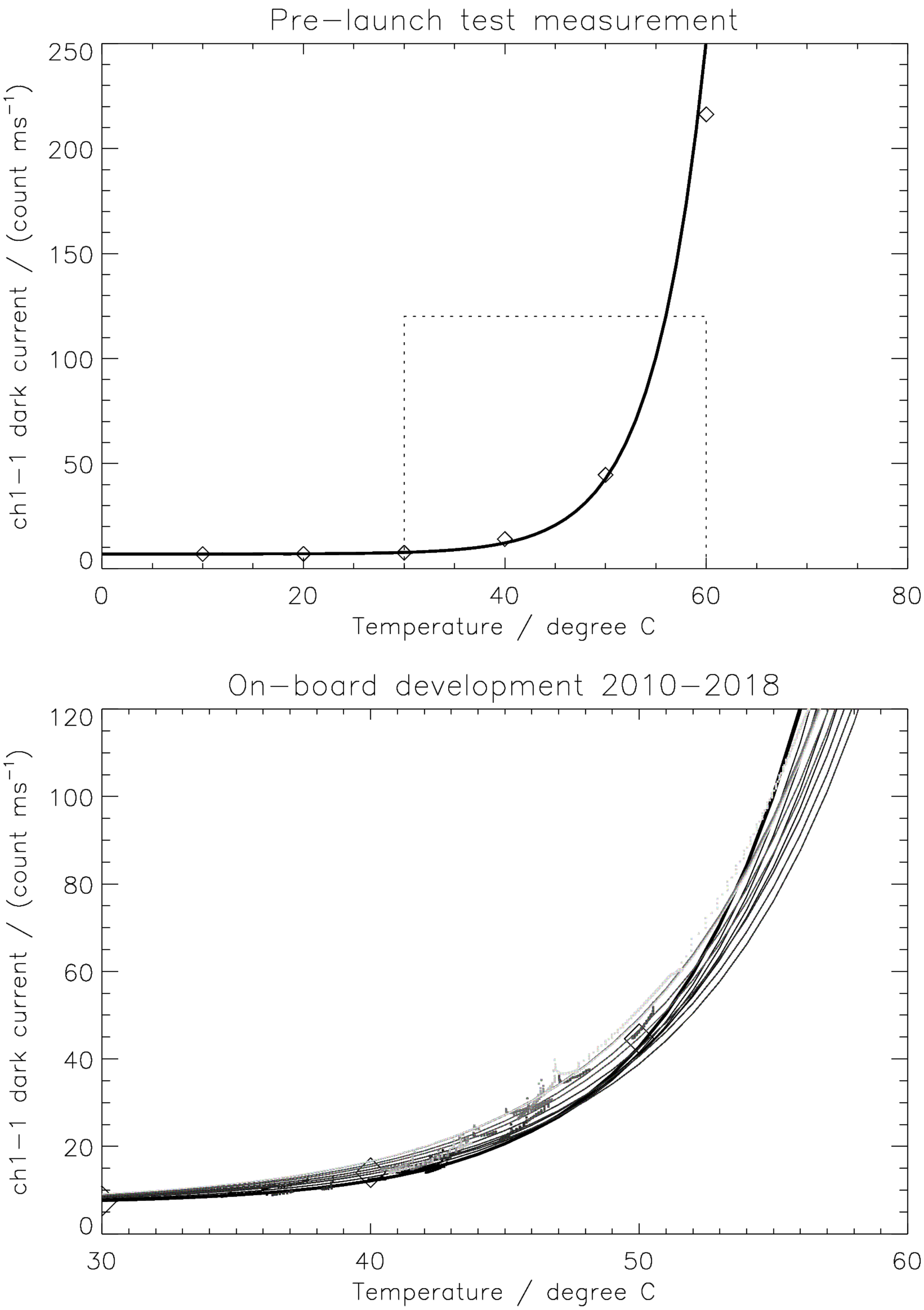


Fig 7: Channel 1-1 Lyman-alpha + MSM, campaigns vs. fits (black=earlier, gray=later)

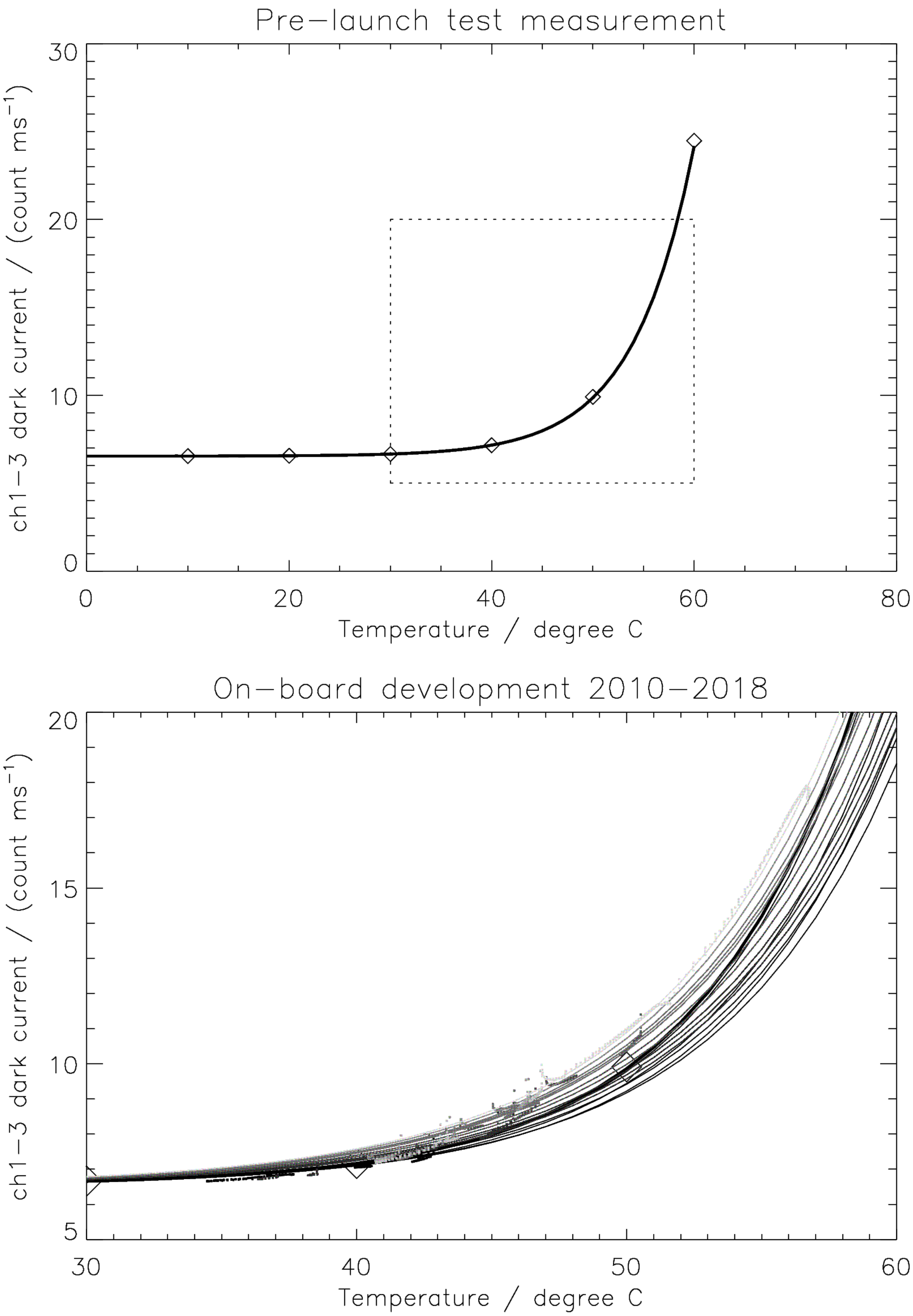


Fig 8: Channel 1-3 Aluminium + MSM, campaigns vs. fits (black=earlier, gray=later)

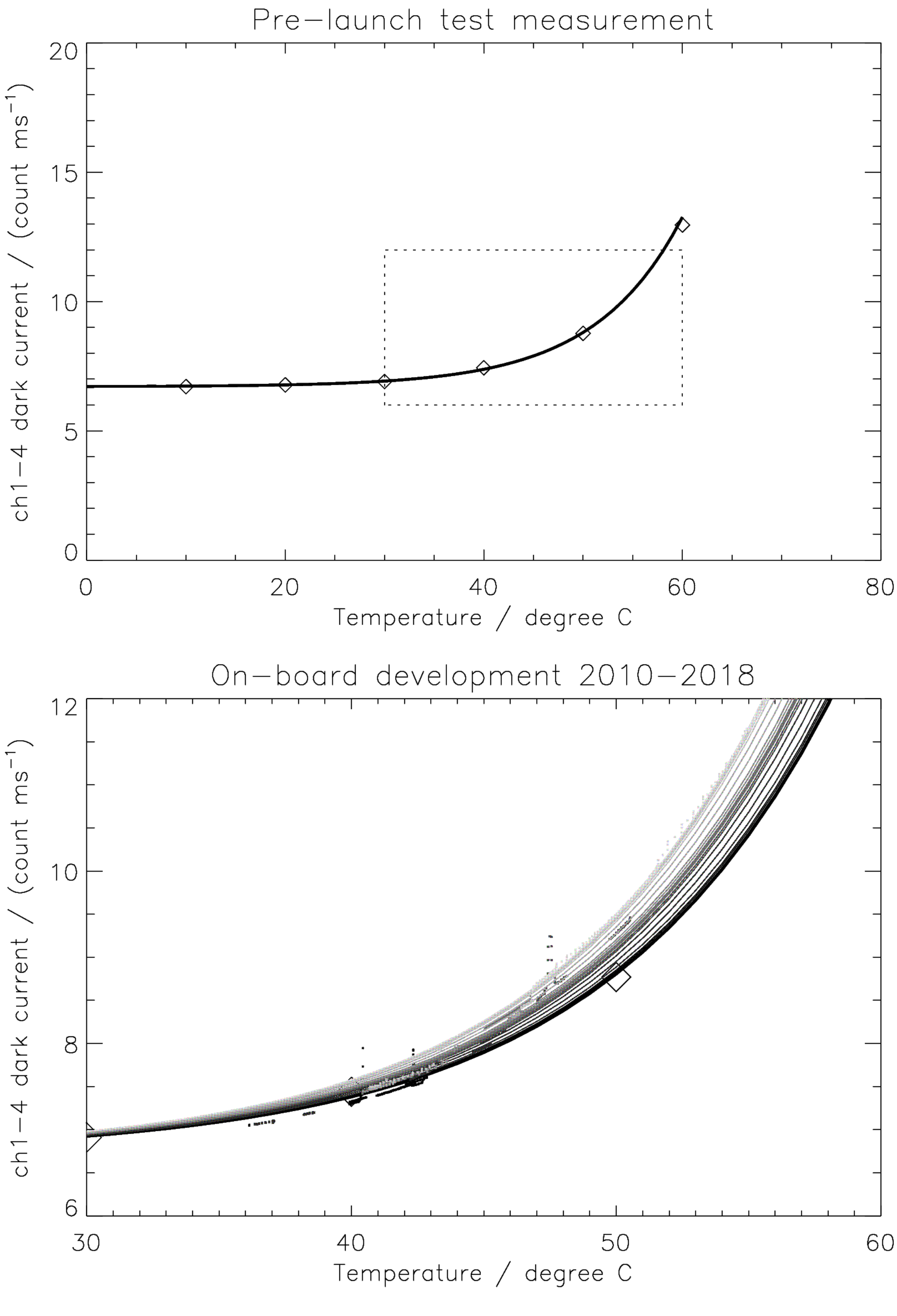


Fig 9: Channel 1-4 Zirconium + Si, campaigns vs. fits (black=earlier, gray=later)

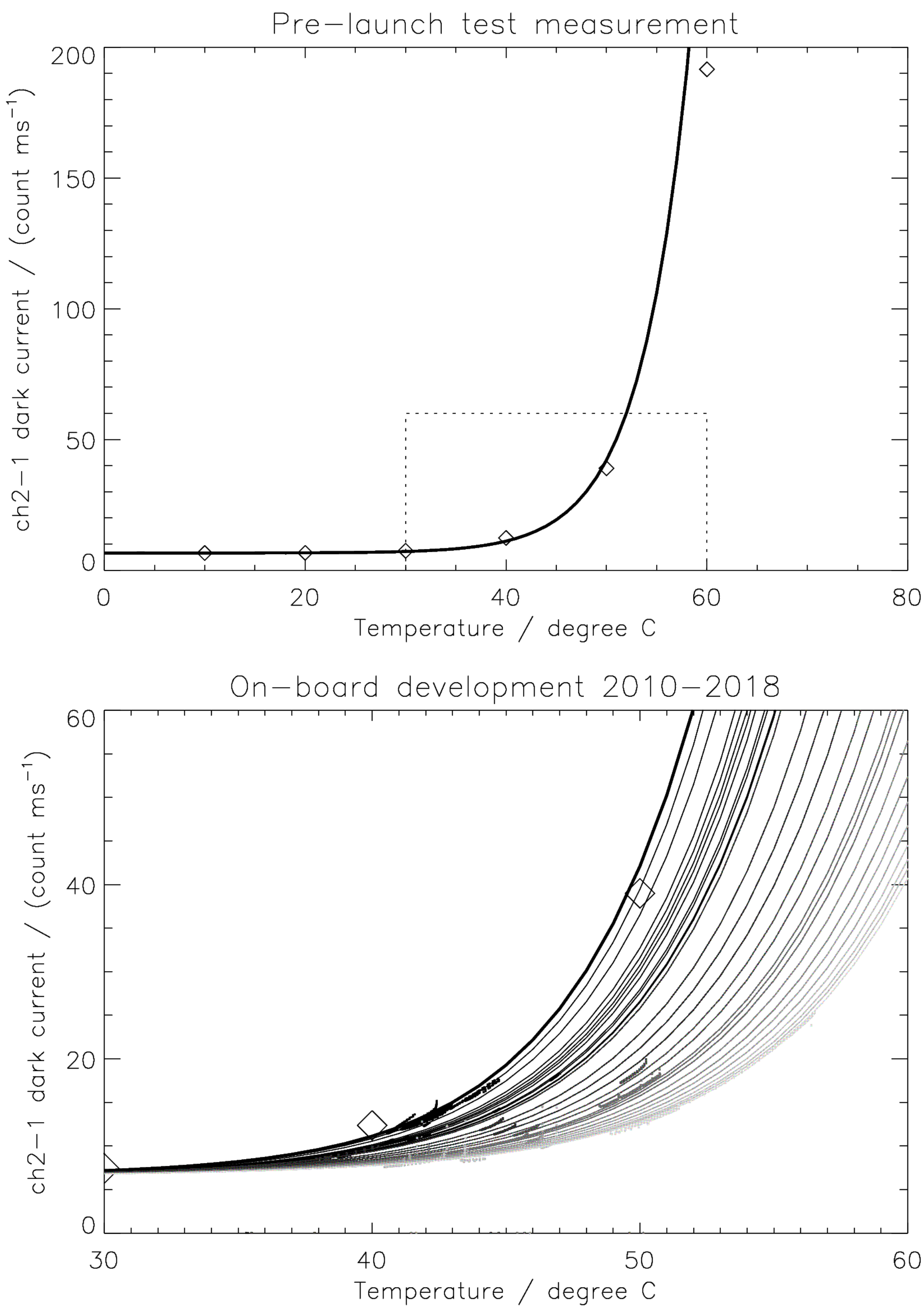


Fig 10: Channel 2-1 Lyman-alpha + MSM, campaigns vs. fits (black=earlier, gray=later)

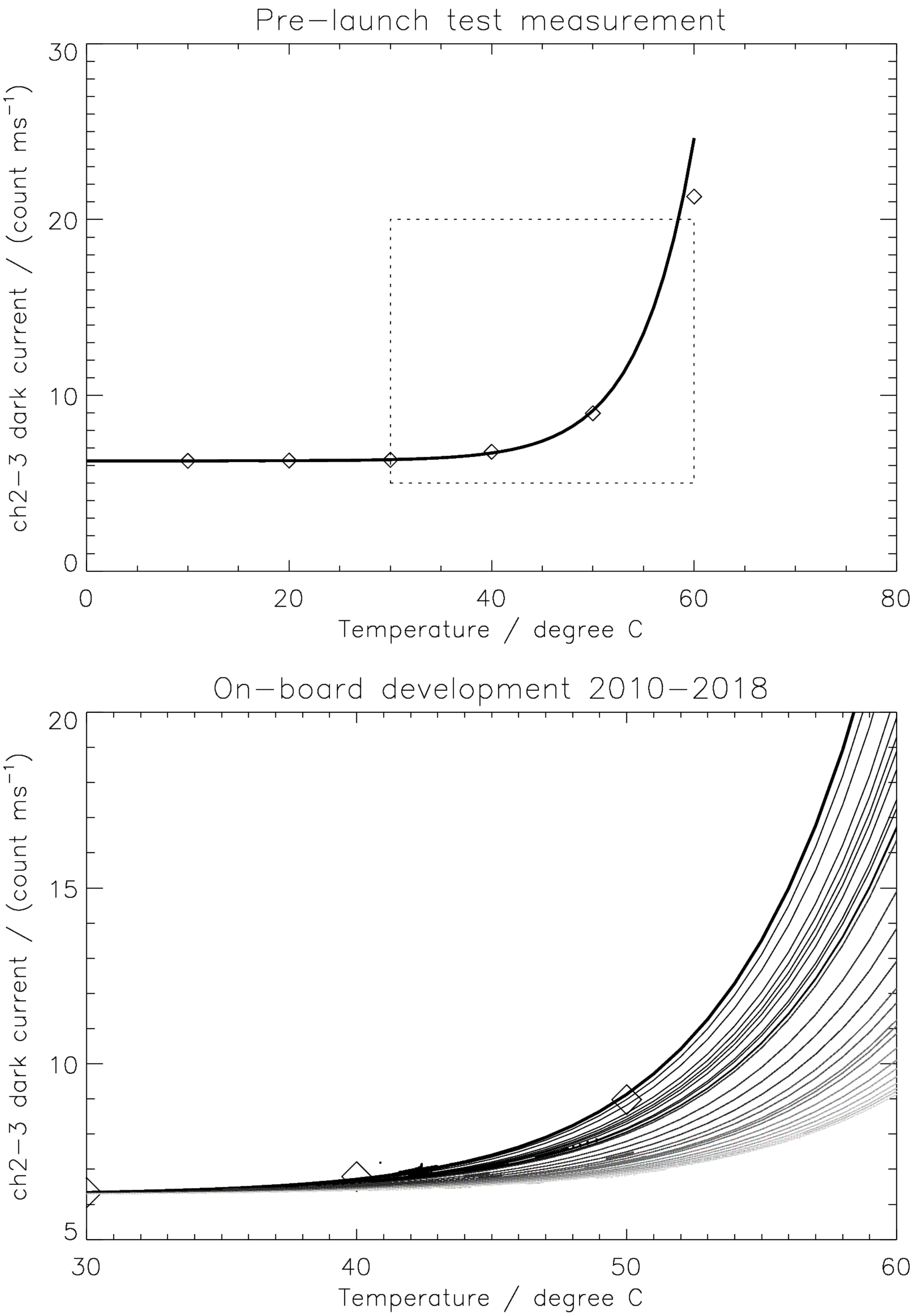


Fig 11: Channel 2-3 Aluminium + MSM, campaigns vs. fits (black=earlier, gray=later)

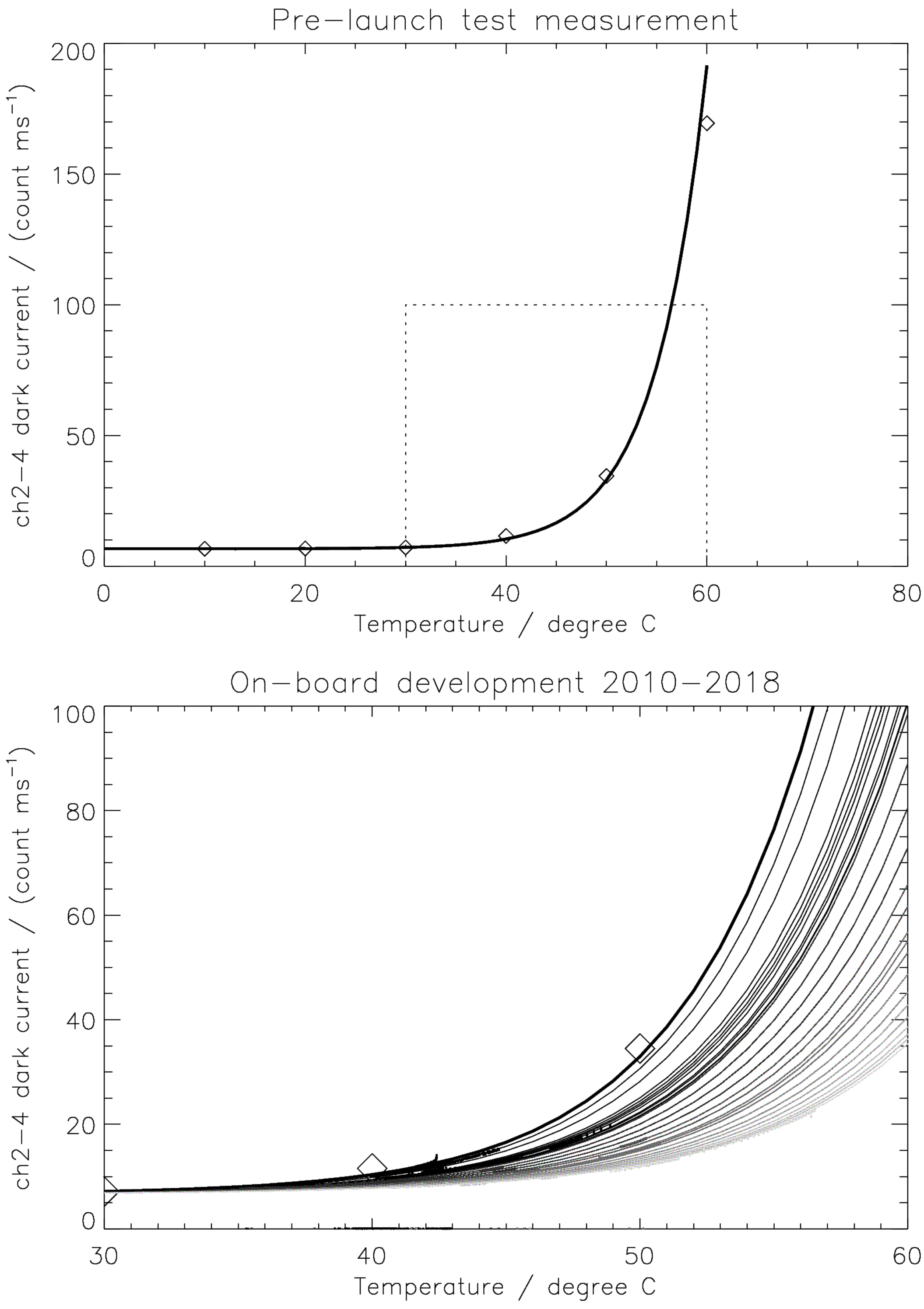


Fig 12: Channel 2-4 Zirconium + MSM, campaigns vs. fits (black=earlier, gray=later)

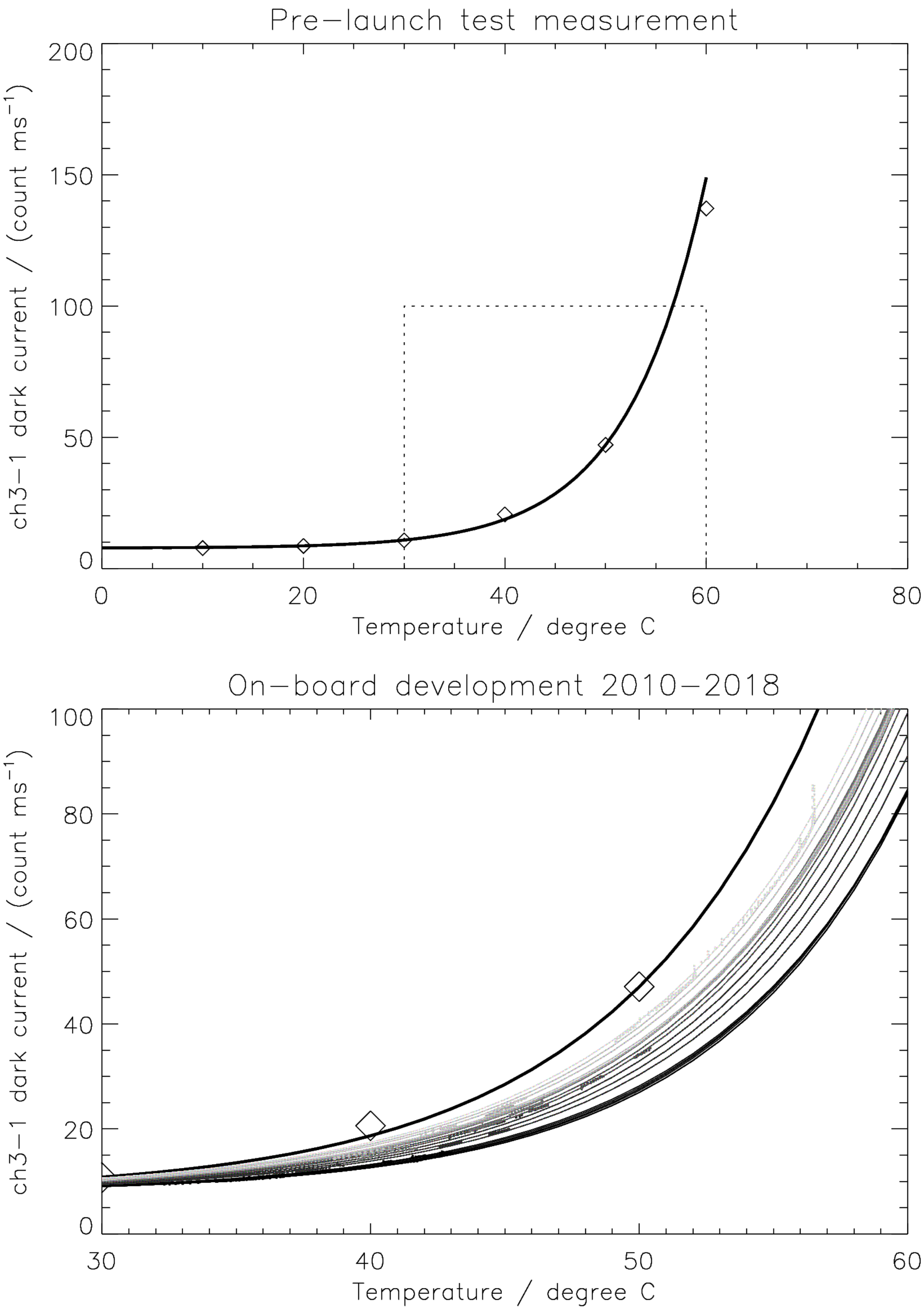
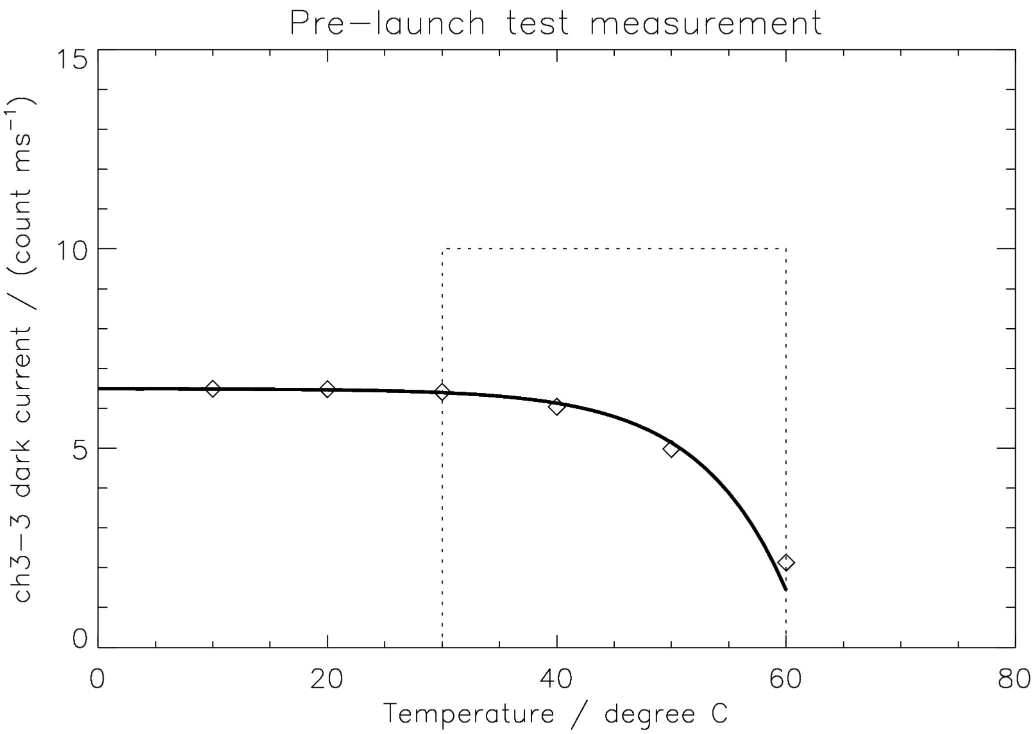


Fig 13: Channel 3-1 Lyman-alpha + Si, campaigns vs. fits (black=earlier, gray=later)



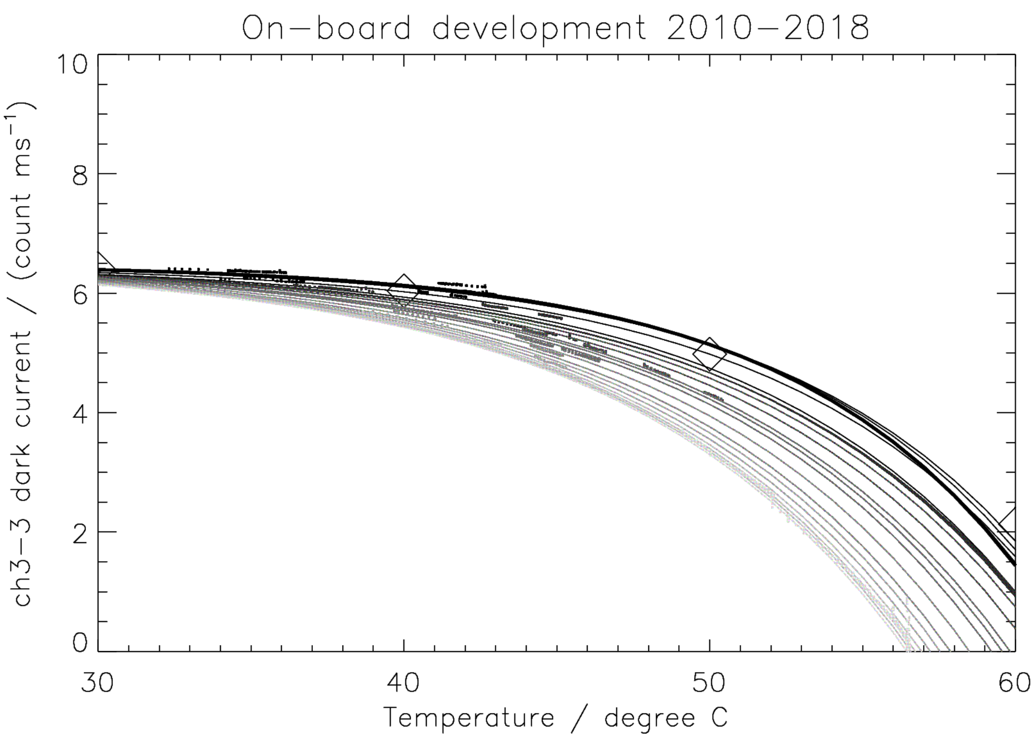


Fig 14: Channel 3-3 Aluminium + Si, campaigns vs. fits (black=earlier, gray=later)

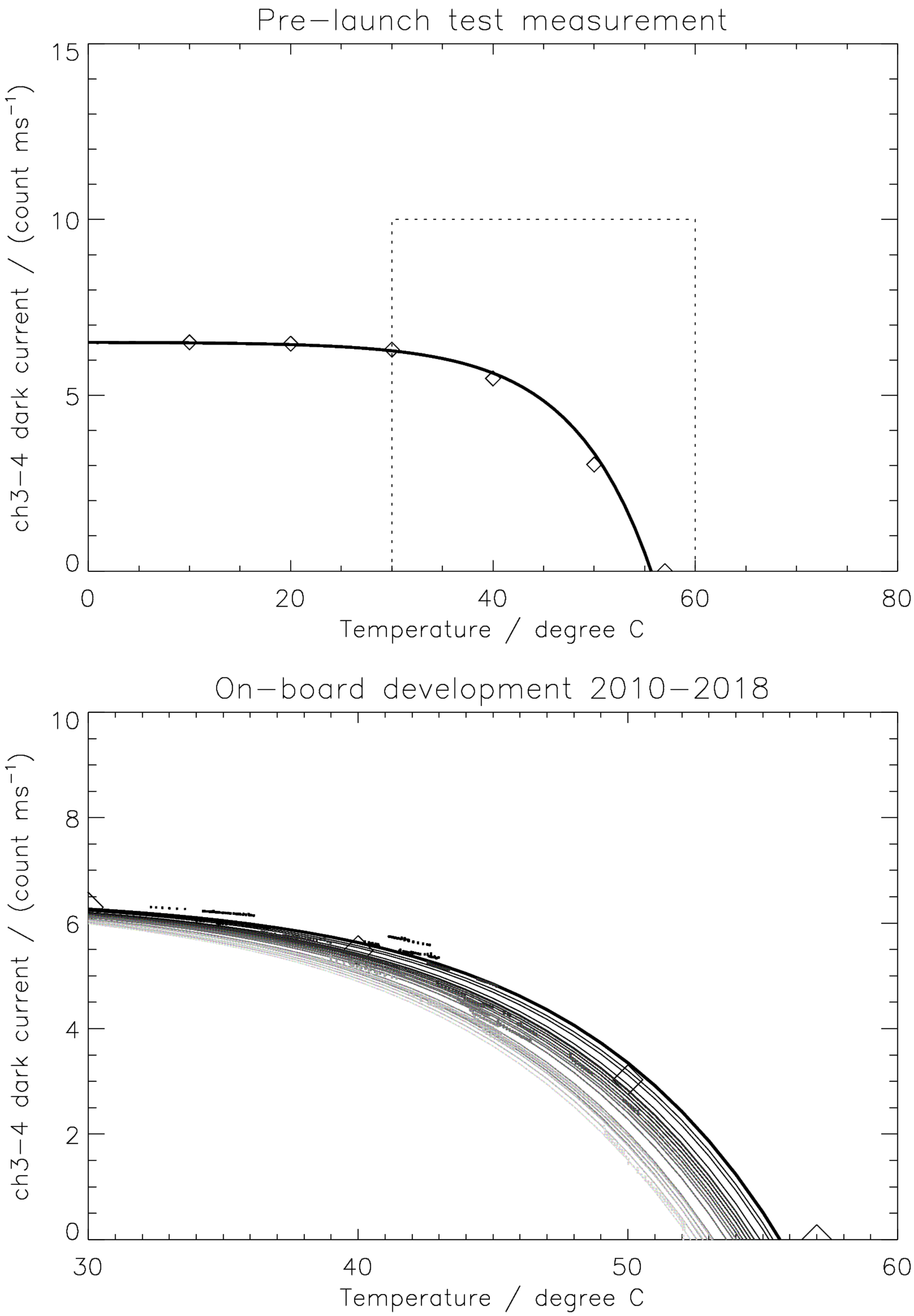


Fig 15: Channel 3-4 Zirconium + Si, campaigns vs. fits (black=earlier, gray=later)