Evolution of dark currents in LYRA detectors - Update 2021

IED 11 May 2021

Laboratory tests of the LYRA detectors before launch showed that the dark currents depend on temperature and follow an exponential function

$DC = f(T) = a + \exp(b*T + c)$

After a while in orbit, it became clear that some of these parameters changed with time, and it was tried to estimate this development, see earlier reports, e.g.

http://solwww.oma.be/users/dammasch/IED_20200218_DarkCurrents.pdf

Longer samples covering a bigger temperature interval proved to be more useful to estimate the parameters than short samples. So, in this report a new approach was chosen to estimate the parameter status during the occultation seasons 2019/20 and 2020/21.

Parameters b and c for channels 1, 3, 4 of all three units were estimated by taking the closed-door campaigns of October thru February, all together instead of separately. In addition, some measurements during total occultation were also taken into account. The result was twice a sets of a dozen campaigns, covering a much bigger temperature interval - like, from 41 to 53 deg C, or from 43 to 56 deg C, resulting in a more reliable exponential fit.

In the end, the parameters of the old and new approach may be different, but the resulting dark currents are basically consistent with the earlier approach. Since the new approach is time-consuming (and also to limit re-processing), it was decided to stay with the old estimated dark currents until 31 Dec 2019, and apply the new estimated dark currents after 01 Jan 2020.

The following page shows - as an example for jumps, to be expected due to these changes - data from the recent calibration campaign of 15 May 2021. On this day, unit 1 was tested 105 minutes, unit 3 was tested 15 minutes, and unit 2 was running in parallel all the time. The table demonstrates the differences that result from using the old and new software - they are quite small, which is not a surprise, because these average temperatures (45 - 51^{0}C) were always well covered and estimated.

Page 3 shows - as an example - the result of the parameters' exponential fitting for ch1-1, both for the season 2019/20 and the season 2020/21. The dotted lines were the previous estimates. One campaign (squares) had to be excluded from the fit, due to incomplete occultation.

Thereafter, the following nine pages show the development of the dark-current vs. temperature curves from the laboratory tests until 2021. Other than in earlier reports, just one curve per year is shown here, starting with black for the lab test, blue for Jan 2011 until yellow for Jan 2019, followed by orange for (new) Jan 2020, red for (new) Jan 2021, and red dotted for (projected) Jan 2022.

Several earlier assumptions stayed the same, or were confirmed:
- parameter a is always positive and remains constant over time
- parameter b is always positive and may change over time
- parameter c is always negative and may change over time
- the DC-temperature relation gets steeper in units 1 and 3
- the DC-temperature relation gets flatter in unit 2

The dark currents of the PIN detectors in channels 2 of all three units are not really temperature dependent and have not changed significantly over time, i.e., less than 2.2% in more than ten years, and are apparently not changing any more (all values in count/ms):

- ch1-2:	6.61 (lab)	6.4847 (2019/20)	6.4851 (2020/21)
- ch2-2:	6.39 (lab)	6.4502 (2019/20)	6.4605 (2020/21)
- ch3-2:	6.54 (lab)	6.4032 (2019/20)	6.4009 (2020/21)

Table of data from 15 May 2021

unit 1 temperature range: 45.8 - 50.3ºC

dark currents and irradiances at maximal temperature:

before	51.0 (ch1-1)	6.6 (ch1-2)	11.1 (ch1-3)	9.6 (ch1-4)	count/ms
	6.152	717.5	2.526	0.9822	mW/m^2
after	54.3	6.5	11.0	9.8	count/ms
	6.135	717.6	2.532	0.9764	mW/m^2

unit 2 temperature range: 49.4 - 51.0^{0}C

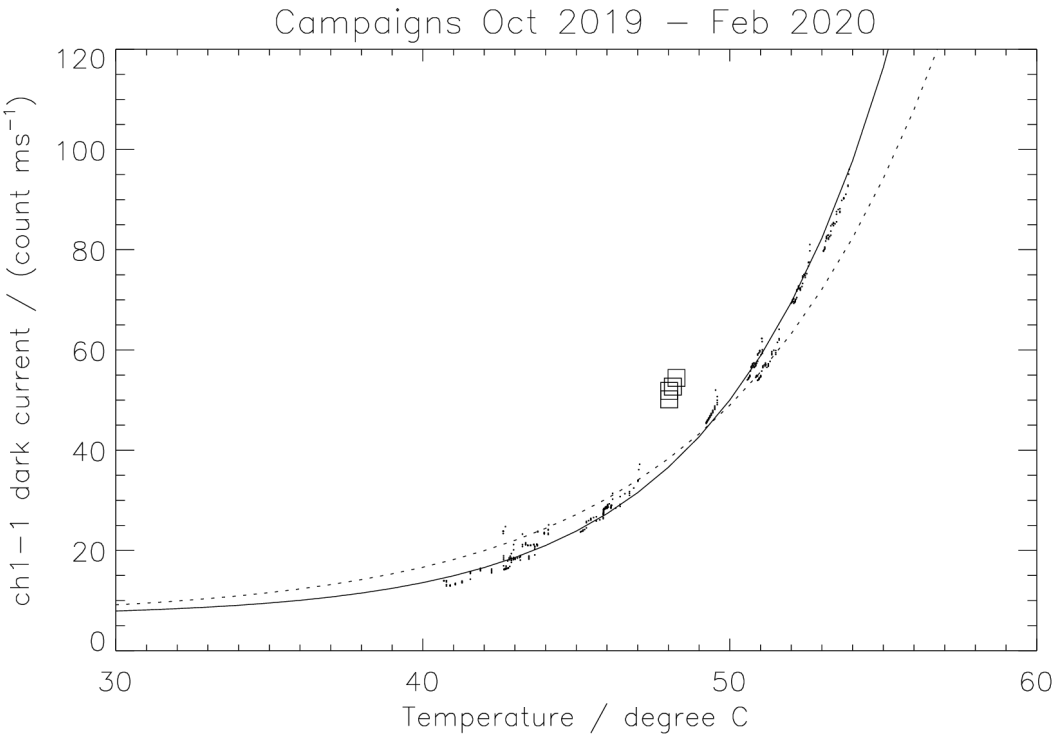
dark currents and irradiances at maximal temperature:

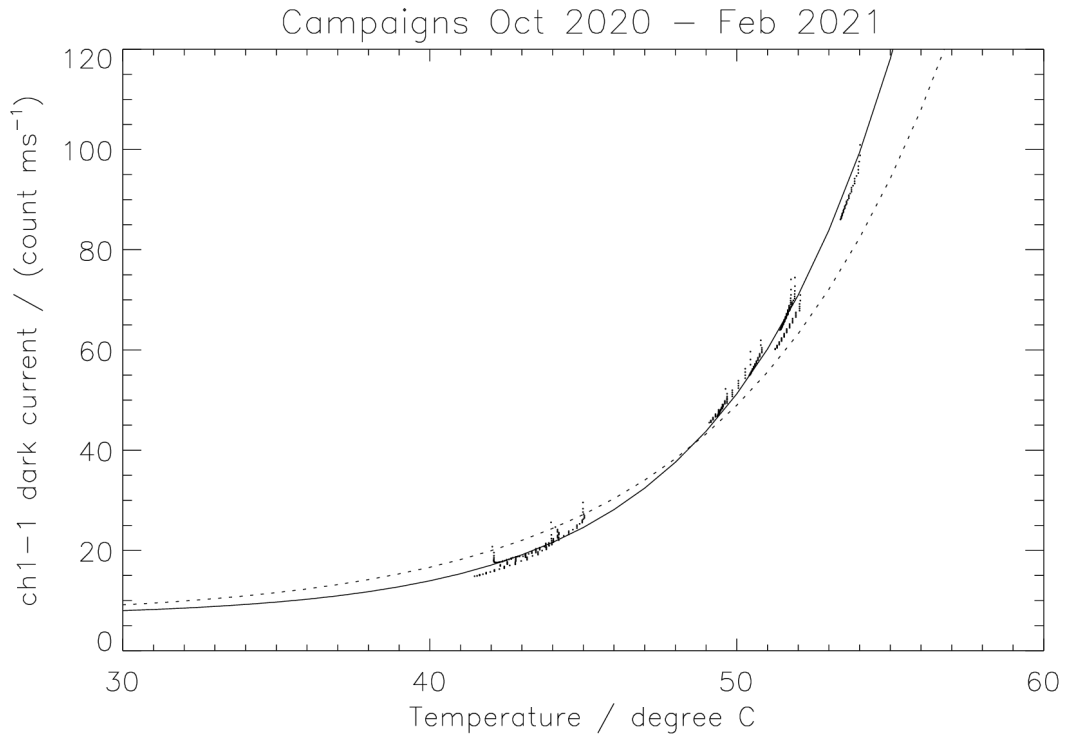
before	12.5 (ch2-1)	6.5 (ch2-2)	6.8 (ch2-3)	11.2 (ch2-4)	count/ms
	6.276	696.5	2.264	0.8132	mW/m^2
after	11.4	6.5	6.8	11.0	count/ms
	6.290	696.5	2.267	0.8186	mW/m^2

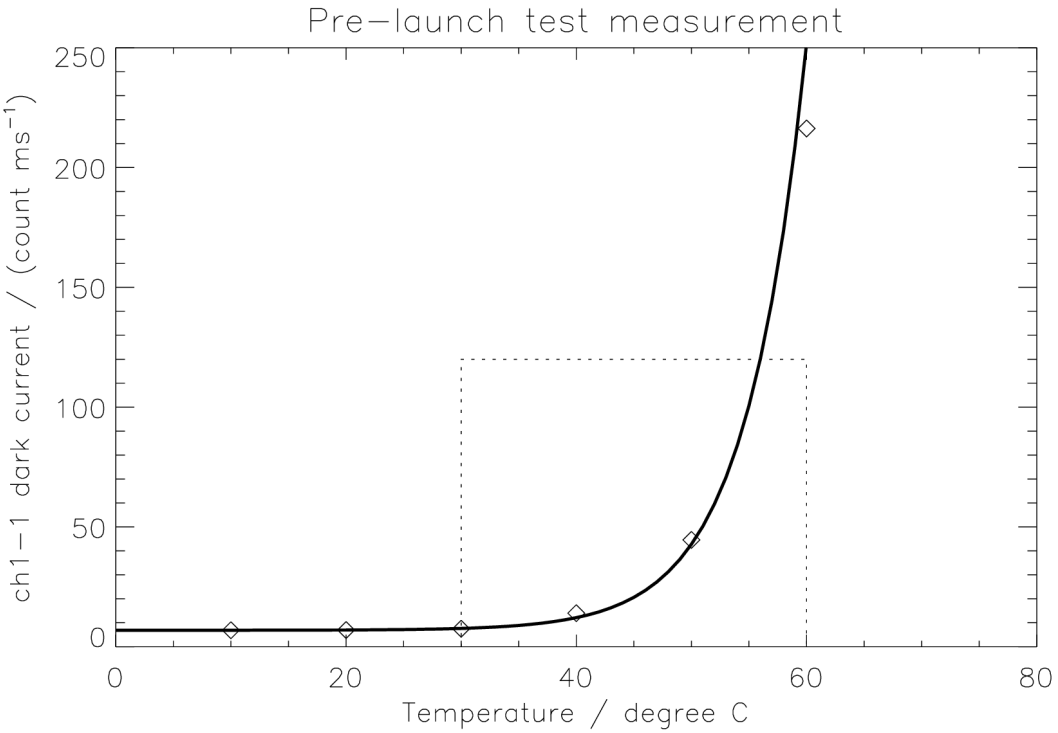
unit 3 temperature range: 45.5 - 47.2^{0}C

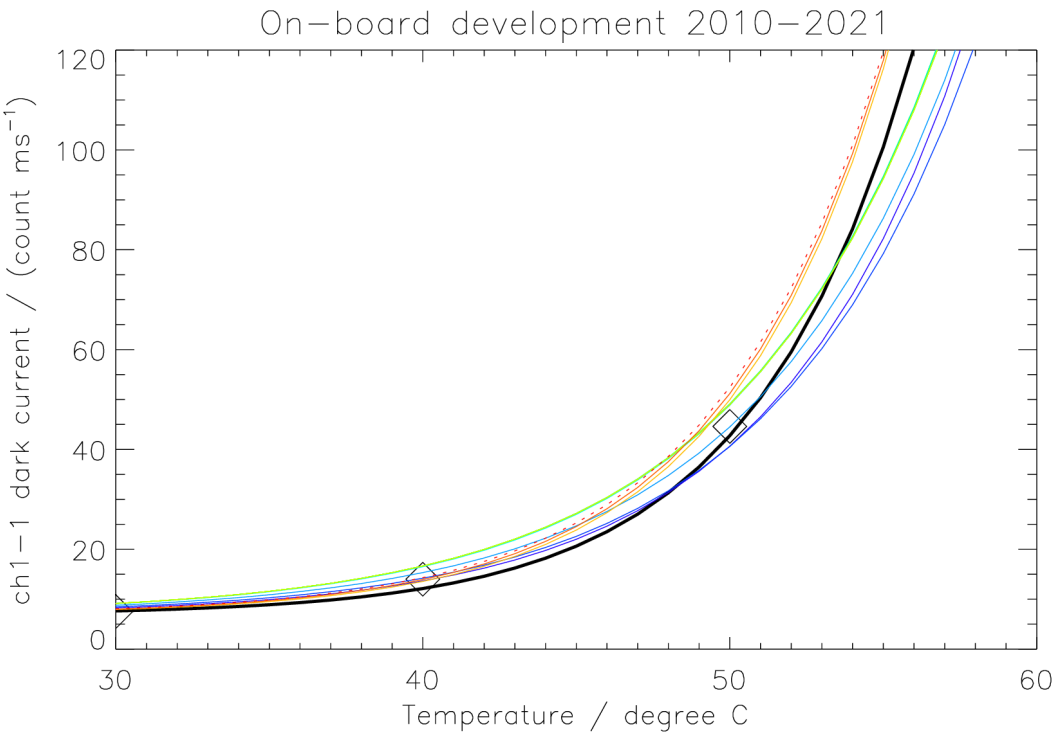
dark currents and irradiances at maximal temperature:

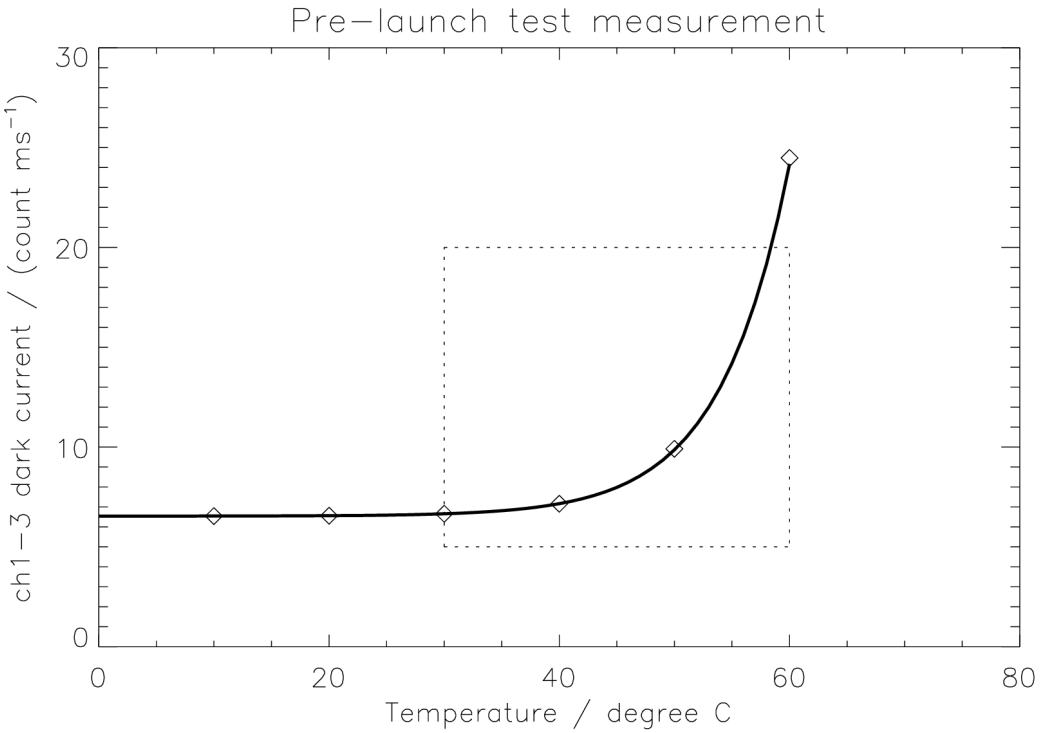
before	34.3 (ch3-1)	6.5 (ch3-2)	3.9 (ch3-3)	2.7 (ch3-4)	count/ms
	6.246	695.7	2.294	0.8783	mW/m^2
after	38.4	6.4	3.8	2.5	count/ms
	6.217	695.8	2.294	0.8817	mW/m^2

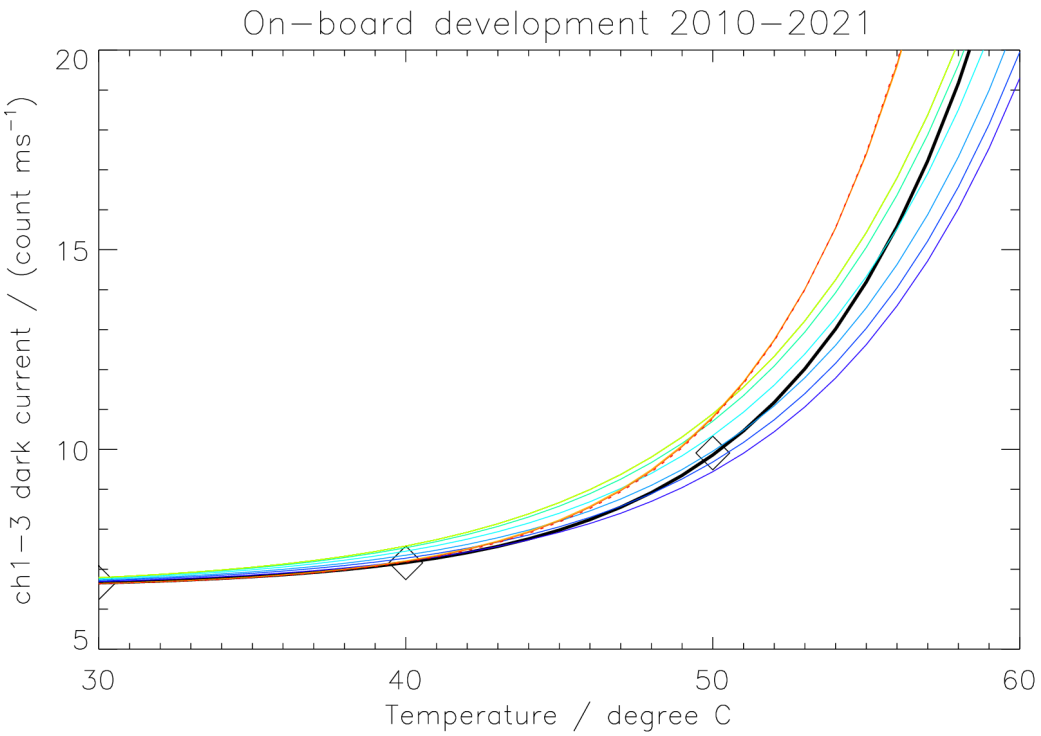

Campaigns Oct 2019 – Feb 2020
ch1–1 dark current / (count ms^{-1})
120
100
80
60
40
20
0
30
40
50
60
Temperature / degree C

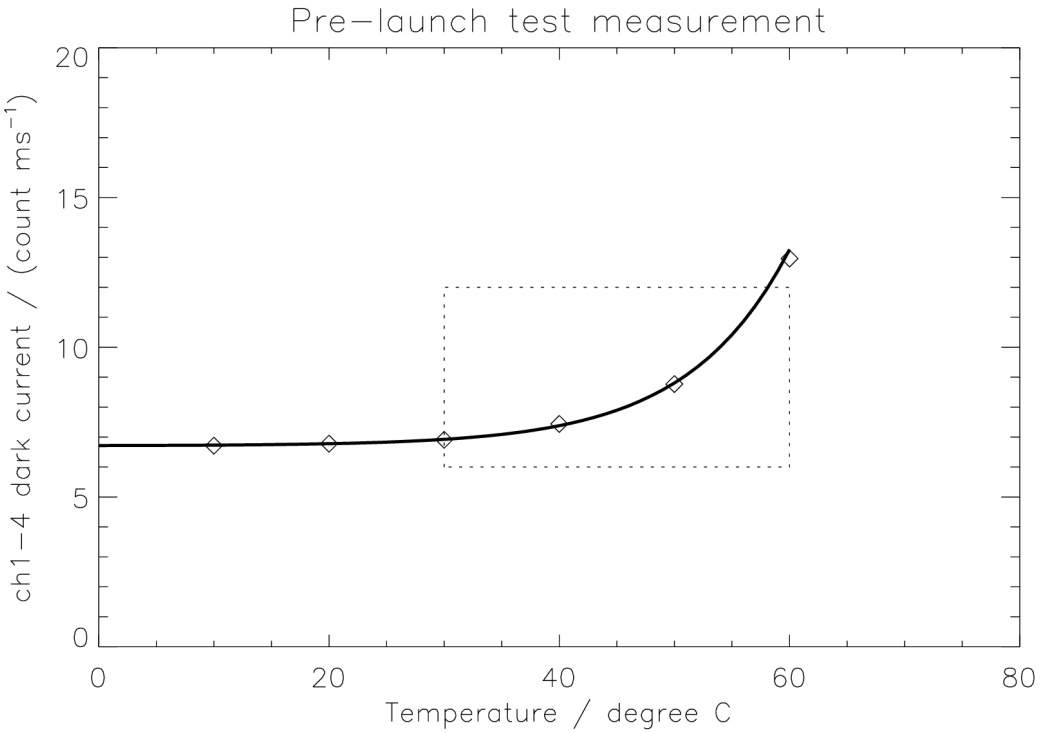

Campaigns Oct 2020 – Feb 2021
ch1–1 dark current / (count ms^{-1})
120
100
80
60
40
20
0
30
40
50
60
Temperature / degree C

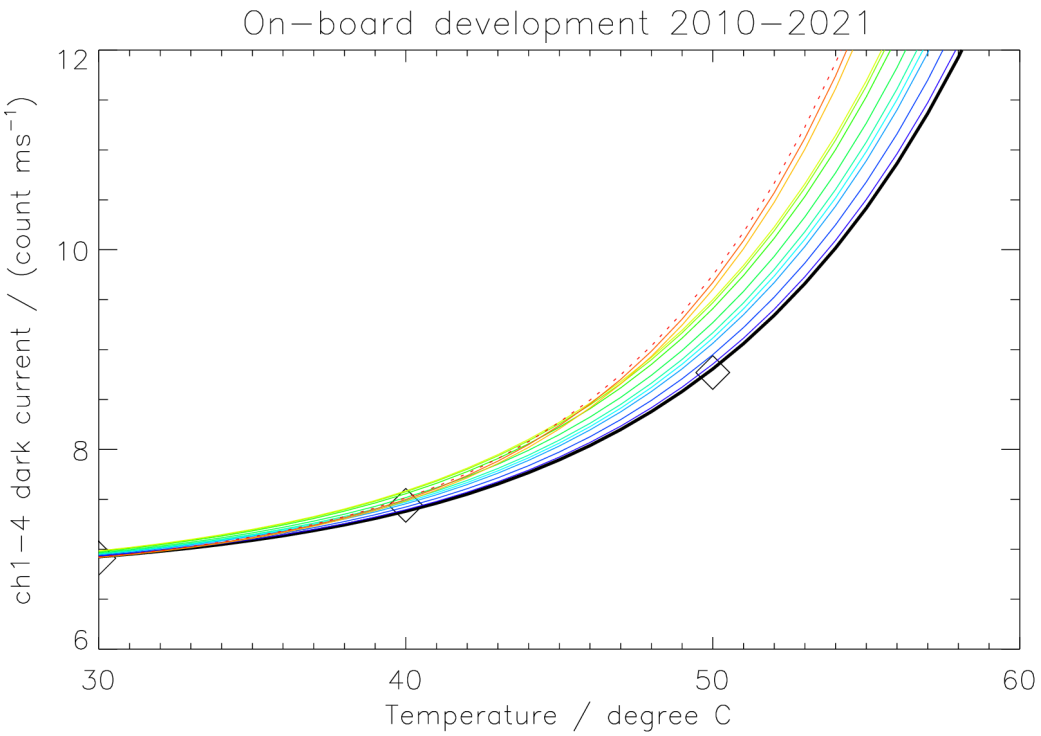

Pre−launch test measurement
ch1−1 dark current / (count ms^{-1})
250
200
150
100
50
0
0
20
40
60
80
Temperature / degree C

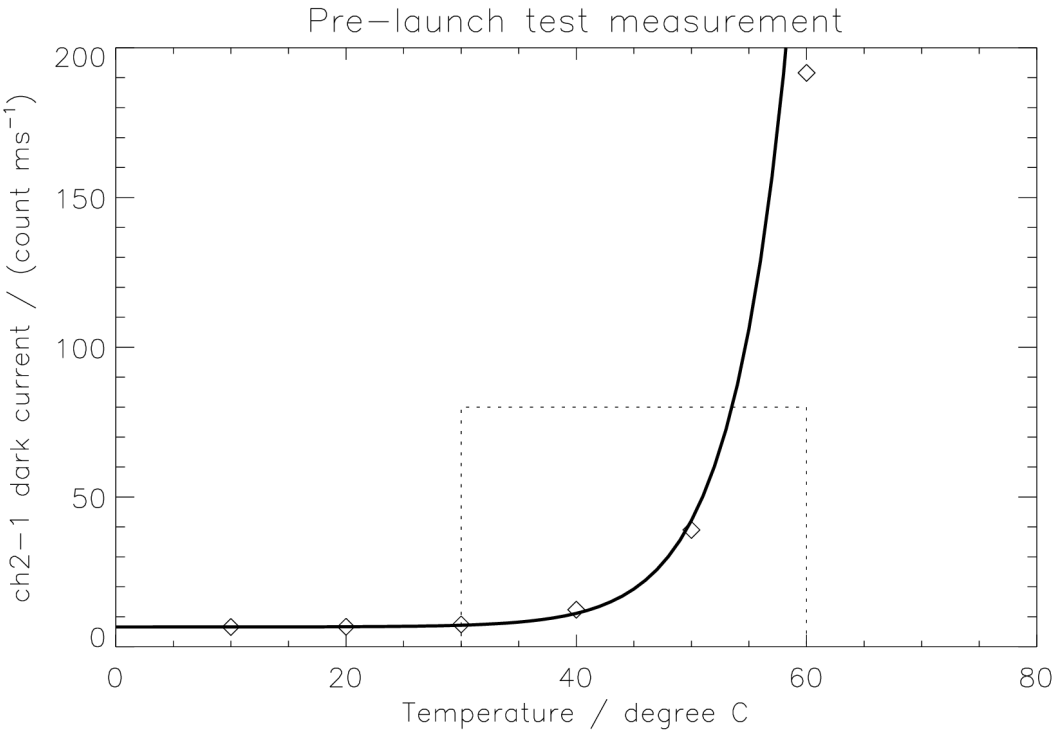

On−board development 2010−2021
ch1−1 dark current / (count ms^{-1})
120
100
80
60
40
20
0
30
40
50
60
Temperature / degree C

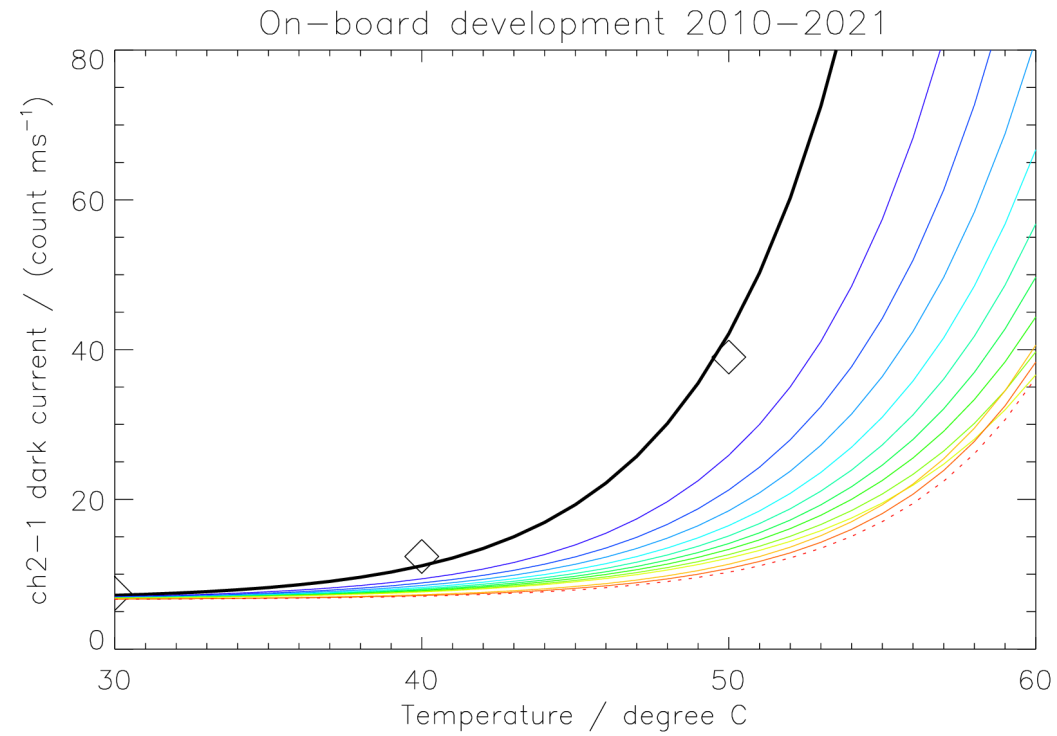

Pre−launch test measurement
ch1−3 dark current / (count ms^{-1})
Temperature / degree C
0
10
20
30
0
20
40
60
80

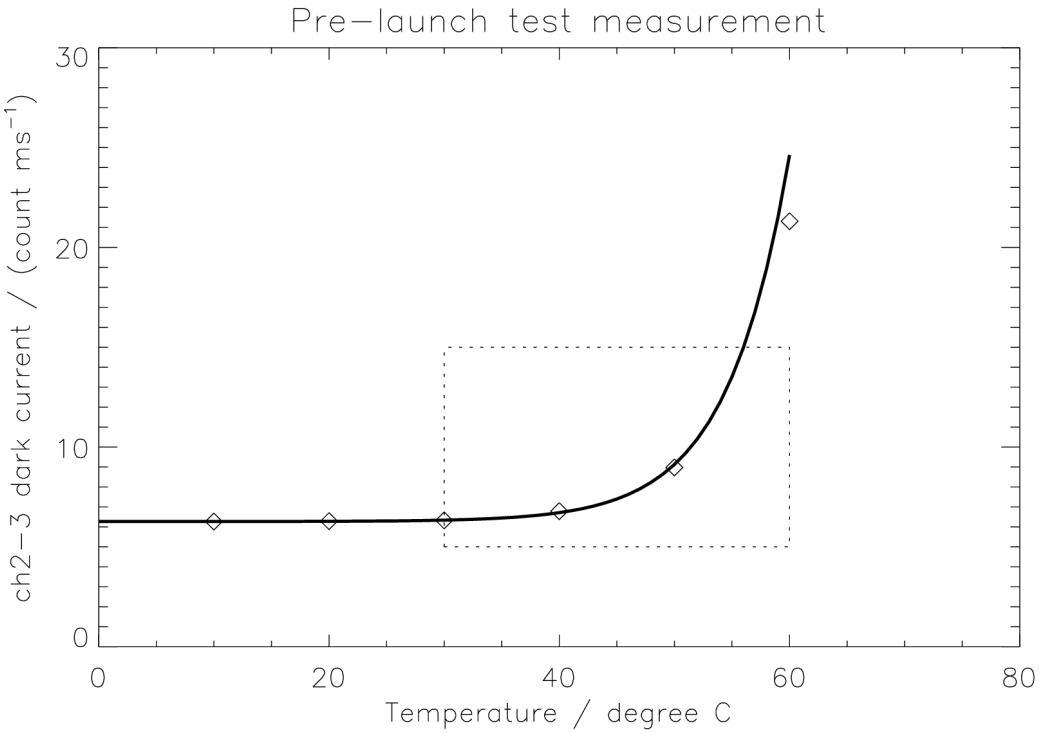

On−board development 2010−2021
ch1−3 dark current / (count ms^{-1})
Temperature / degree C
5
10
15
20
30
40
50
60

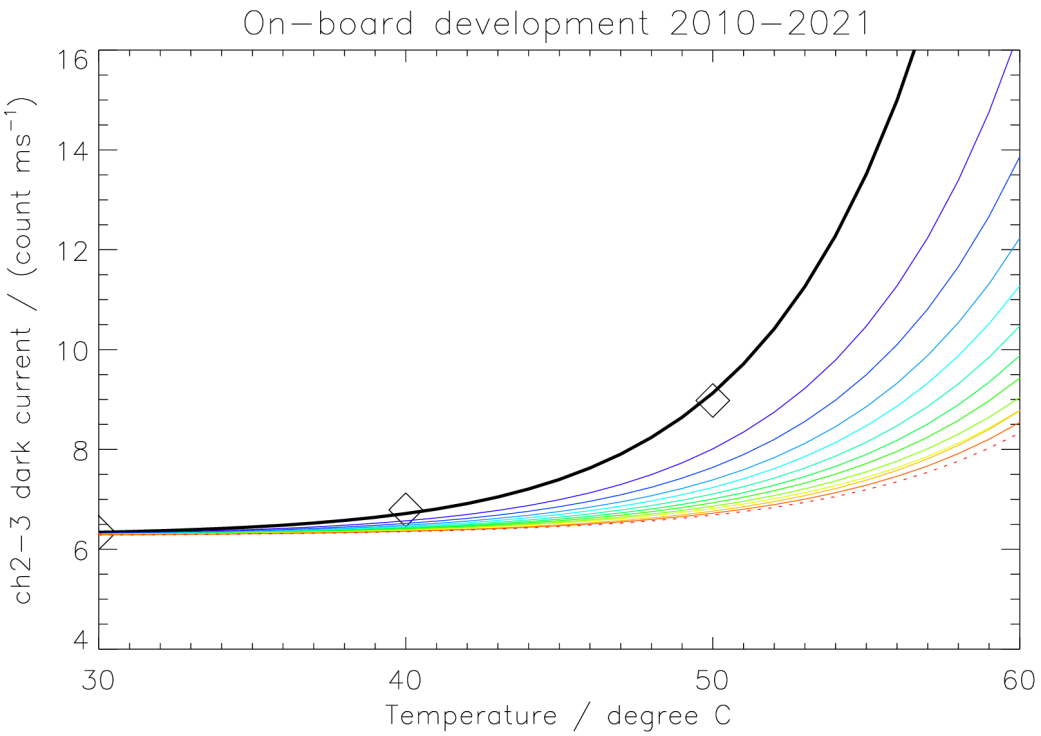

Pre−launch test measurement
ch1−4 dark current / (count ms^{-1})
Temperature / degree C
0
5
10
15
20
0
20
40
60
80

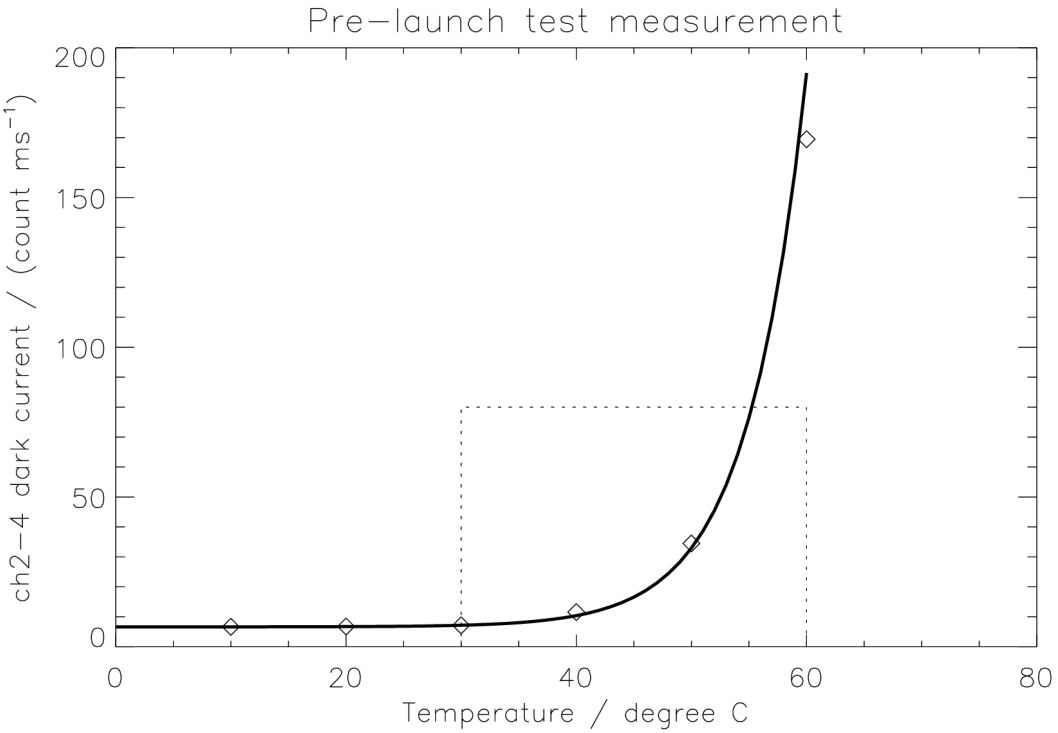

On−board development 2010−2021
ch1−4 dark current / (count ms^{-1})
Temperature / degree C
6
8
10
12
30
40
50
60

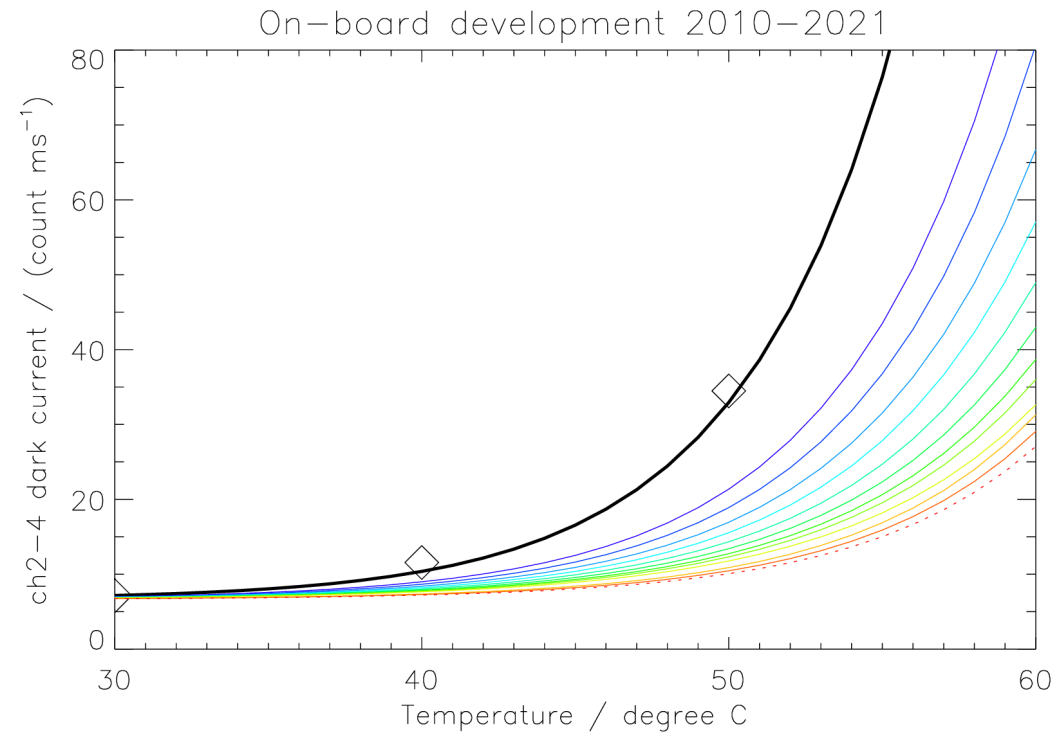

Pre−launch test measurement
ch2−1 dark current / (count ms^{-1})
200
150
100
50
0
0
20
40
60
80
Temperature / degree C

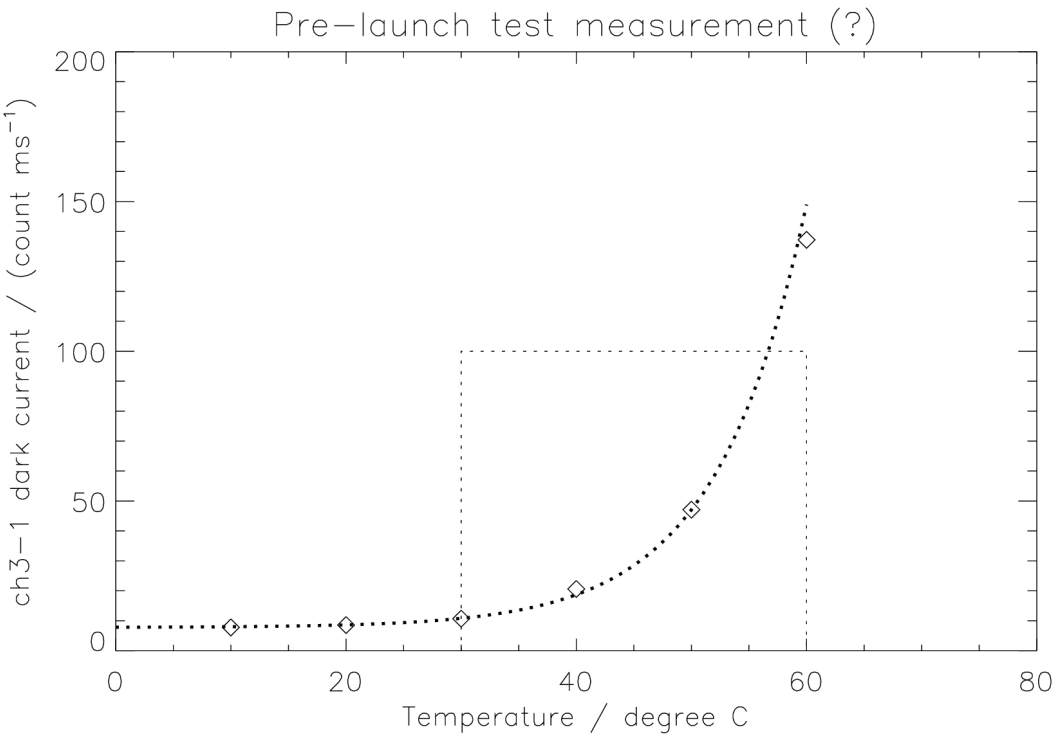

On−board development 2010−2021
ch2−1 dark current / (count ms^{-1})
80
60
40
20
0
30
40
50
60
Temperature / degree C

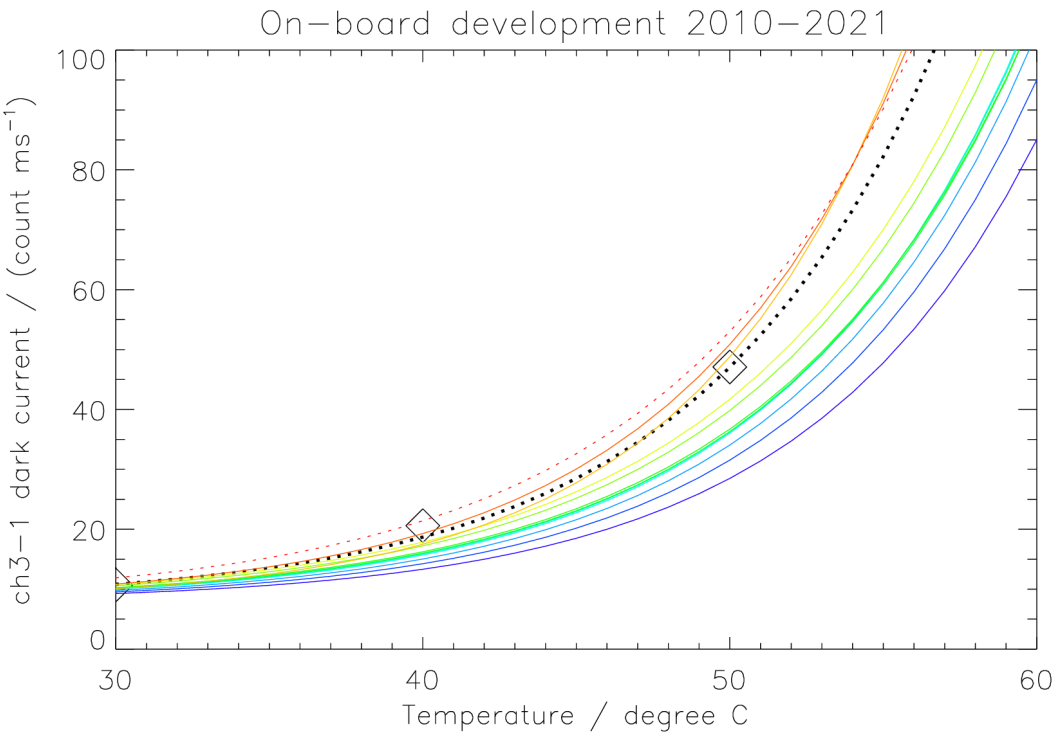

Pre−launch test measurement
ch2−3 dark current / (count ms^{-1})
Temperature / degree C
0
10
20
30
0
20
40
60
80

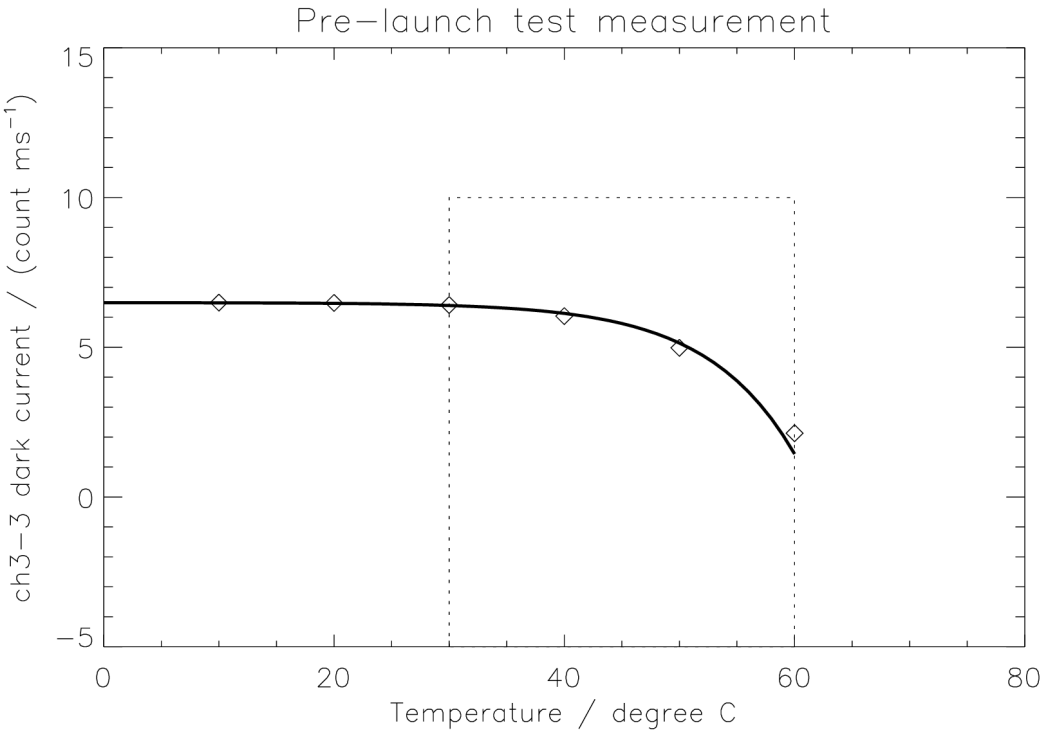

On−board development 2010−2021
ch2−3 dark current / (count ms^{-1})
Temperature / degree C
4
6
8
10
12
14
16
30
40
50
60

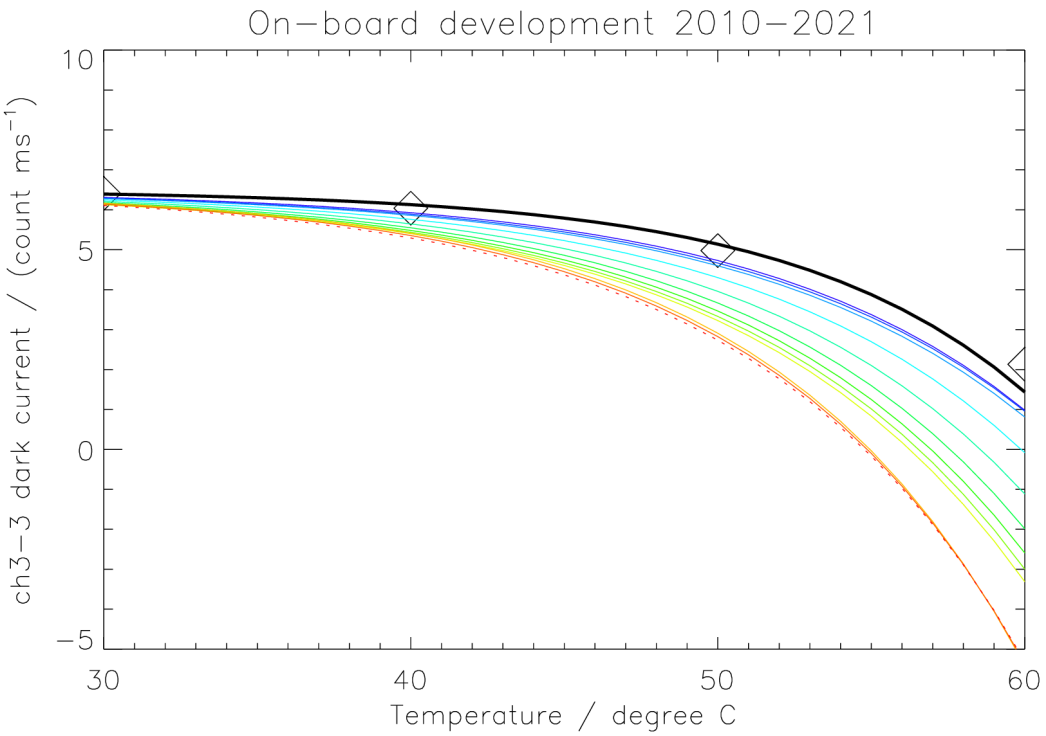

Pre−launch test measurement
ch2−4 dark current / (count ms^{-1})
200
150
100
50
0
0
20
40
60
80
Temperature / degree C

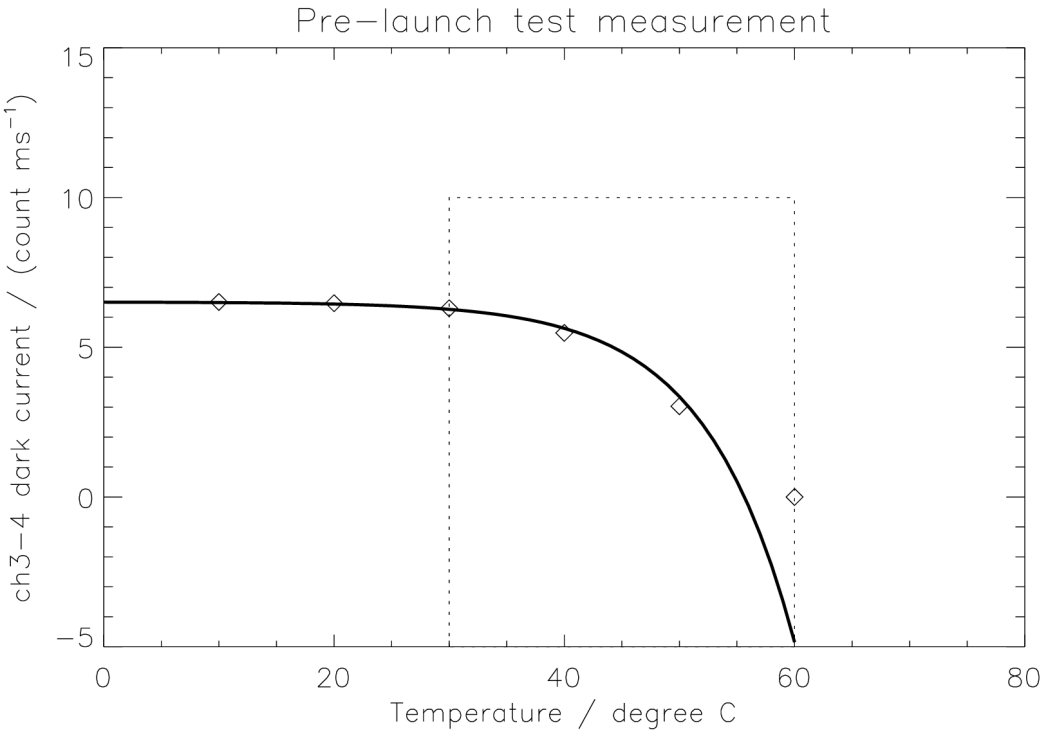

On−board development 2010−2021
ch2−4 dark current / (count ms^{-1})
80
60
40
20
0
30
40
50
60
Temperature / degree C

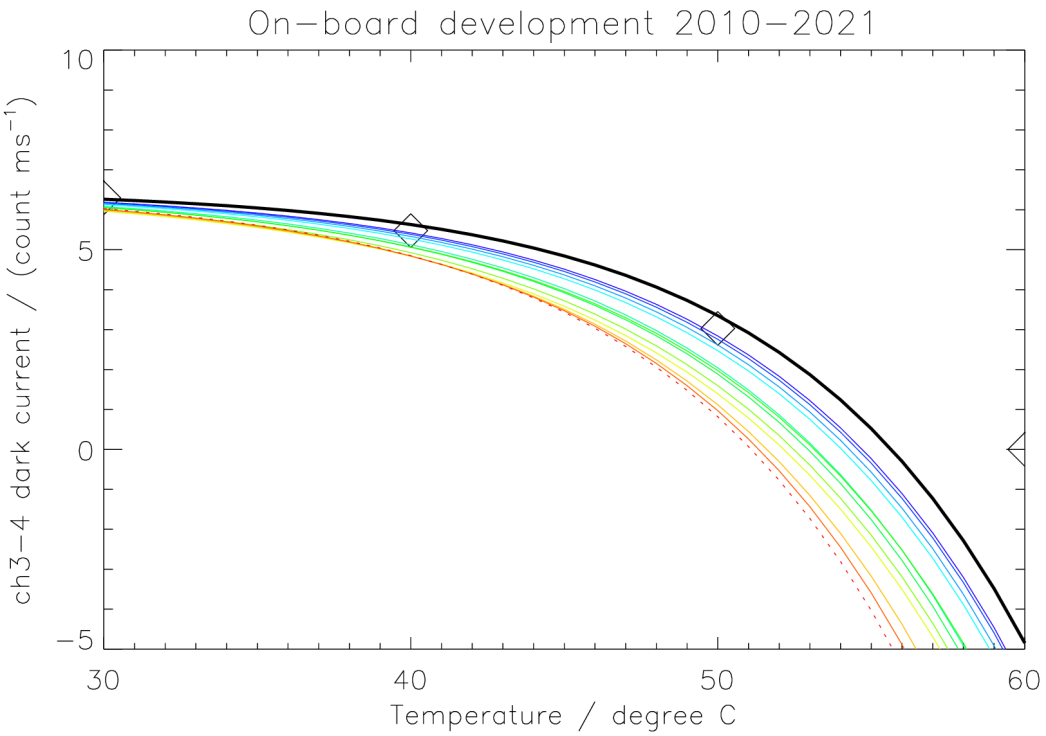

Pre−launch test measurement (?)
ch3−1 dark current / (count ms^{-1})
200
150
100
50
0
0
20
40
60
80
Temperature / degree C


On−board development 2010−2021
ch3−1 dark current / (count ms^{-1})
100
80
60
40
20
0
30
40
50
60
Temperature / degree C


Pre−launch test measurement
ch3−3 dark current / (count ms^{-1})
15
10
5
0
−5
0
20
40
60
80
Temperature / degree C


On−board development 2010−2021
ch3−3 dark current / (count ms^{-1})
10
5
0
−5
30
40
50
60
Temperature / degree C


Pre−launch test measurement
ch3−4 dark current / (count ms^{-1})
15
10
5
0
−5
0
20
40
60
80
Temperature / degree C


On−board development 2010−2021
ch3−4 dark current / (count ms^{-1})
10
5
0
−5
30
40
50
60
Temperature / degree C