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PROJECT REF.:	**PL-LFI-PST-RP-071** **PAGE: I of IV, 11**
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Approved by	**N. MANDOLESI** **LFI Principal Investigator**	**Date:** **Signature:**	October, 2009

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CHANGE RECORD

Issue	Date	Sheet	Description of Change	Release
1.0	October 2009	All	First draft of document	1.0

TABLE OF CONTENTS

1 ACRONYMS

AIV	Assembly, Integration, Verification
ASW	Application Software
BEM	Back End Module
BEU	Back End Unit
CCS	Central Check-out System
CDMU	Central Data Management Unit
CPV	Calibration Performance Verification
CSL	Centre Spatiale de Liège
DAE	Data Acquisition Electronics
DPU	Digital Processing Unit
EGSE	Electrical ground Support Equipment
FEM	Front End Module
I-EGSE	Instrument EGSE
IST	Integrated Satellite Test
OBC	On Board Clock
RAA	Radiometer Array Assembly
REBA	Radiometric Electronic Box Assembly
S/C	Spacecraft
SCOE	Spacecraft Control and Operation System
SCS	Sorption Cooler System
SPU	Signal Processing Unit
SUSW	Start- Up Software
SVM	Service Module
TBC	To Be Checked
TBW	To Be Written
TC	Telecommand
TM	Telemetry
UFT	Unit Functional Test

2 APPLICABLE AND REFERENCE DOCUMENTS

2.1 Applicable Documents

[AD1] Herschel/Planck Instrument Interface document Part A, SCI-PT-IIDA-04624 Issue 3.3

[AD2] Herschel/Planck Instrument Interface document Part B, SCI-PT-IIDB-04142 Issue 3.1

[AD3] Herschel/Planck Instrument Interface document Part B, SCI-PT-IIDB-04142 Issue 3.1, Annex 3, ICD 750800115

[AD4] Herschel/Planck Instrument Interface document Part A, SCI-PT-IIDA-04624 Issue 3.3 Annex 10

[AD5] Data analysis and scientific performance of the LFI FM instrument, PL-LFI-PST-AN-006 3.0

[AD6] Planck-LFI TV-TB test report: executive summary, PL-LFI-PST-RP-040 1.1

[AD7] Testing plan of the LFI instrument during the Planck Commissioning and CPV phase, PL-LFI-PST-PL-043 (4.2)

2.2 Reference Documents

[RD1] Planck Instrument Testing at PFM S/C levels, H-P-3-ASP-TN-0676, Issue 1.0

[RD2] Planck LFI User Manual, PL-LFI-PST-MA-001 Issue 2.1

[RD3] Quick Look Data Analysis Of LFI Spikes during SPIKE_01 test (Ph-5-01-b of TV/TB tests), PL-LFI-PST-RP-034

3 Introduction

Tuning of the LFI has been accomplished at several stages of integration, with different procedures. During these procedures, the system noise temperature (Tsys) and isolation have been used as the figures of merit for optimising performance, since they can be estimated with high signal to noise in a short period of time. In fact, for the LFI receivers, the calibrated noise and 1/f characteristics are the true indicators of scientific performance.

In principle, calibrated white noise can be derived directly from the system temperature and noise effective bandwidth, but in practice there are noise contributions and other complications which make it hard to be sure that white noise predicted by Tsys and bandwidth will be achieved. With a receiver topology as complex as LFI, it is even possible that optimising Tsys and isolation may cause us to miss the actual optimum white noise bias point.

With this in mind we developed the following verification test based on the Hypermatrix tuning:

- Set LFI for nominal operations (DAE gain and offset tuned to allow measurement o f the true radiometer white noise)
- Acquire data (30 seconds) at each of the nominal hypermatrix tuning bias points, in the same manner as was done for the hypermatrix tuning. This samples the LFI bias space around the points most likely to yield good performance.
- Change the 4K load temperature by a known amount. This change is provided by the HFI team using the PID controller of the 4K stage.
- Again acquire data at all the hypermatrix bias points.
- White noise is estimated from each 30 second period, and then calibrated using the corresponding data from the known temperature step of the 4K load.

4 Pretest

During OD65, before the bias validation test itself, there was an opportunity to make a detailed comparison of calibrated white noise for two different bias setpoints: "CSL" biases, determined from the satellite integration tests done before launch in Liege, and "CPV" biases, the result of hypermatrix tuning and analysis carried out earlier in the CPV. Approximately 5000 seconds of data were obtained for each bias set.

- CSL biases from 2009-07-17T19:55:31Z to 2009-07-17T21:20:38Z
- CPV biases from 2009-07-18T01:59:55Z to 2009-07-18T03:28:54Z

We bin these data in phase angle, and then fit to the CMB dipole and obtain a calibration. With 5000 seconds of data, both the calibration from the 3 mK dipole signal and the white noise were well determined. Some sample plots are shown below. As will be seen below, these results turned out to be critical in assessing the systematic errors in the tuning verification test.

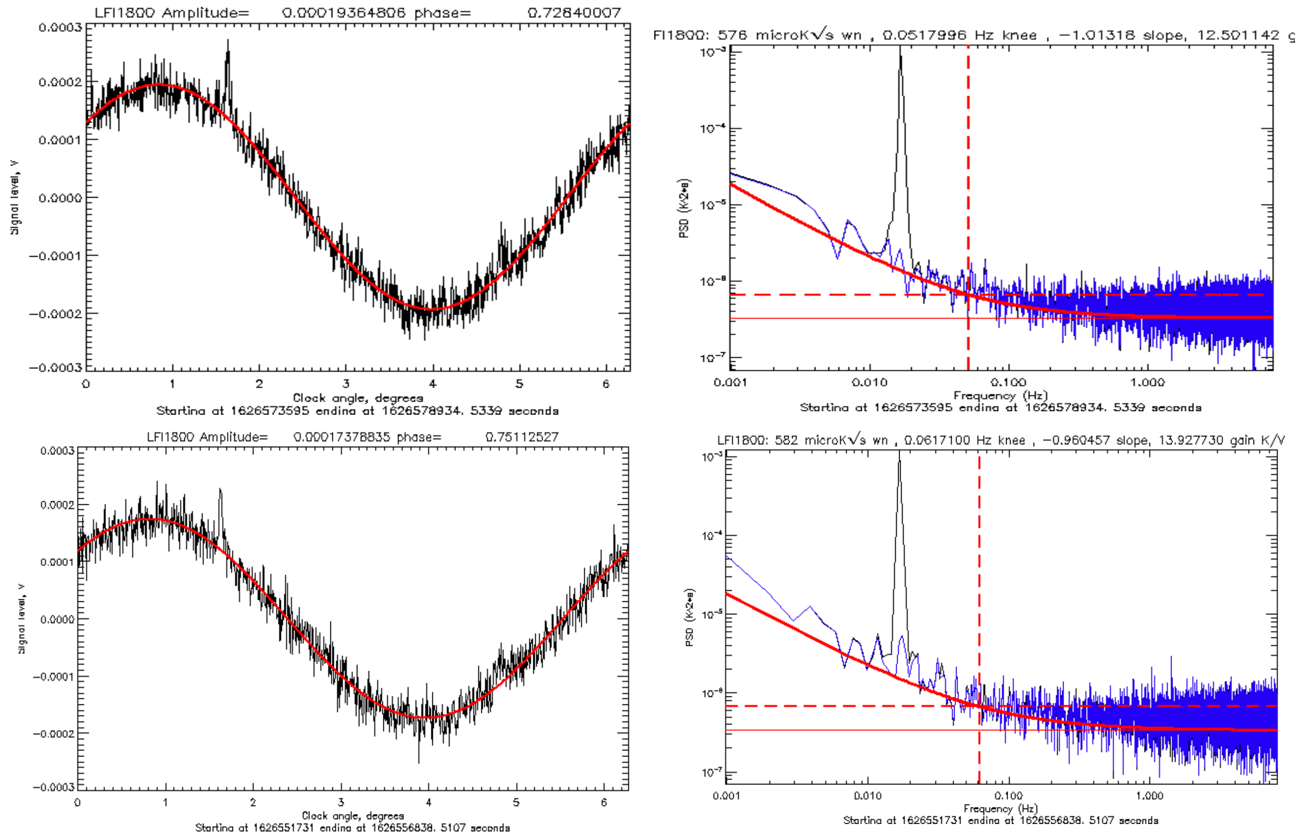


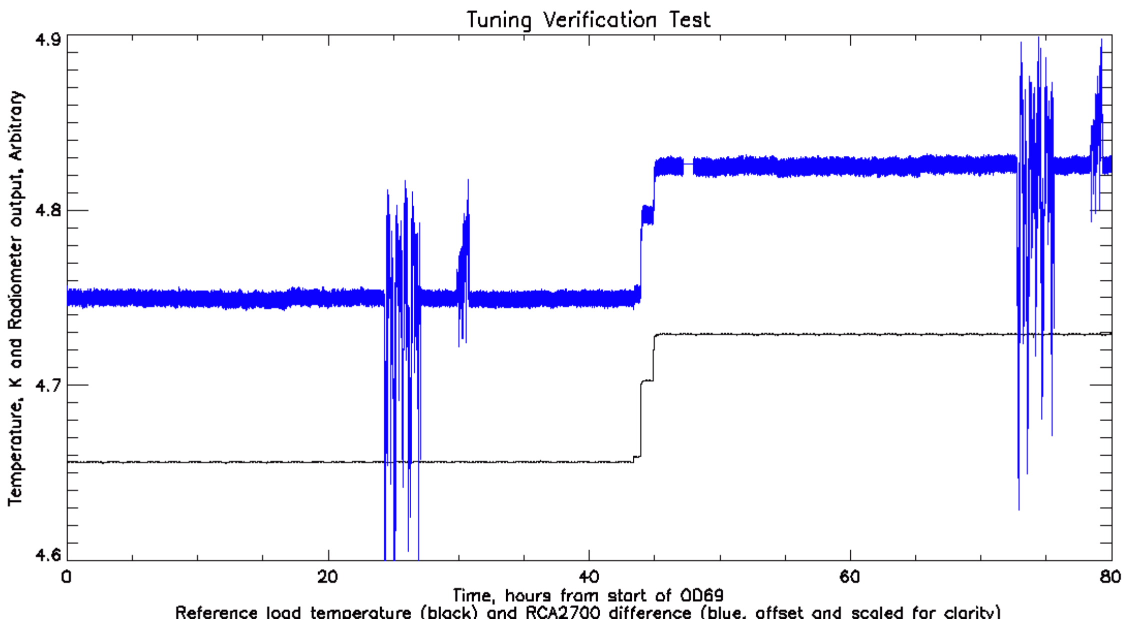
Figure 1. Calibration using the CMB dipole on the left, calibrated PSD on the right. Top row are with CPV biases, bottom row with CSL biases. The blue PSDs are after removing the scan synchronous signal.

5 Test execution

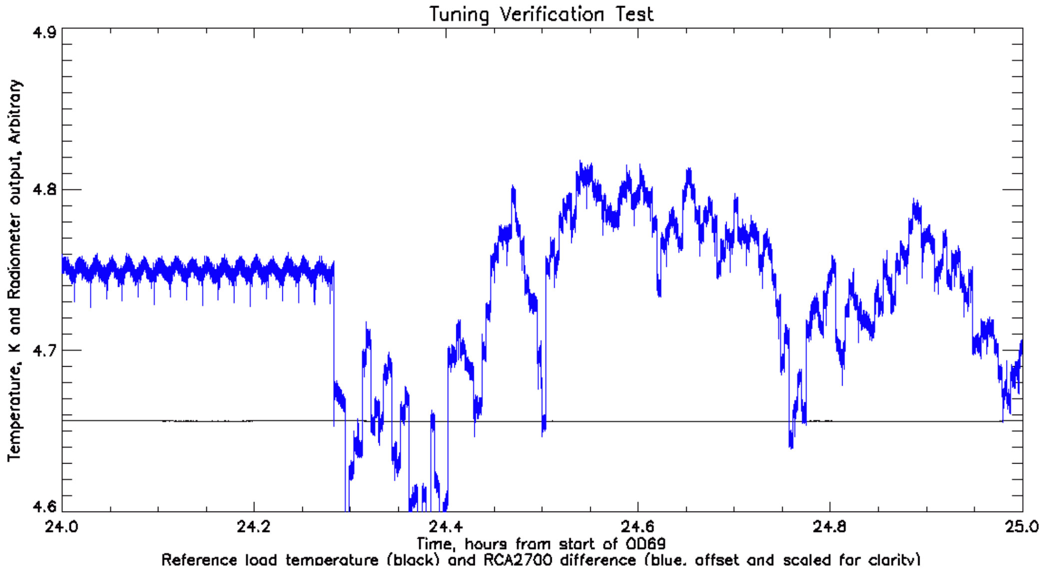
5.1 Procedure

The two plots below illustrate the test procedure. In the first plot the entire time range of the test is shown. The black line gives one of the temperature sensors of the 4K stage best related to the reference load temperatures. As can be seen, this temperature is held quite stable at 4.65 K for just over 42 hours. It is then changed to 4.73K and held there for the same amount of time. The HFI PID controller worked wonderfully for this test.

In blue we have overplotted the RCA 2700 difference data (scaled and offset for clarity). The temperature step(s) are obvious. In addition, the two periods when this radiometer was biased at its various hypermatrix values are clear at 24 hours and 72 hours.



The second plot below is a zoom of the tuning procedure. The changes in output with bias points are obvious. It is also clear that the dipole and galaxy signal contributions are significant at the level of differences among bias points. This may contribute to the scatter seen in the analysis plots below.



5.2 Analysis

Data were extracted using the tools developed for the hypermatrix tuning, associating each bias step from the 4.565 K step with the corresponding one at 4.729K. Calibration was computed from the step change of 72.9 mK and measured receiver output changes. White noise was estimated from each ~30 second interval. The resulting data are difficult to visualize in all dimensions, but the plots below bring out the relevant information.

Each bias setting is represented by a point in the Tsys, White noise plane. General consistency between the two methods would produce a correlation with some noise. We add the high accuracy data from the dedicated test mentioned above to the plot as a check of the systematic accuracy of the particular data set.

Green 'X' symbols are for diode 1, Black '+' symbols for diode 0. The large bold symbols denote the bias points associated with the CPV (Blue) and CSL(red) bias settings. The straight lines show the calibrated white noise from those tests. We look for several things from these plots:

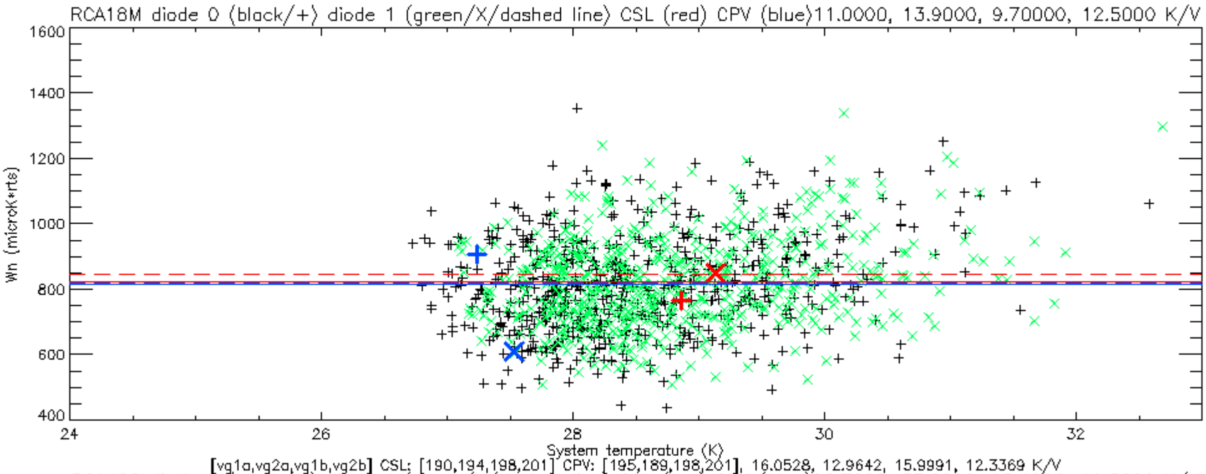
- White noise estimates from the OD 65 tests should be consistent with these data
- We expect a correlation between Tsys and white noise (lower white noise for lower Tsys)
- The relationship between the calibrated white noise for the CPV and CSL biases should be the same for the full hypermatrix verification test as for the OD 65 test indicated on the plot.

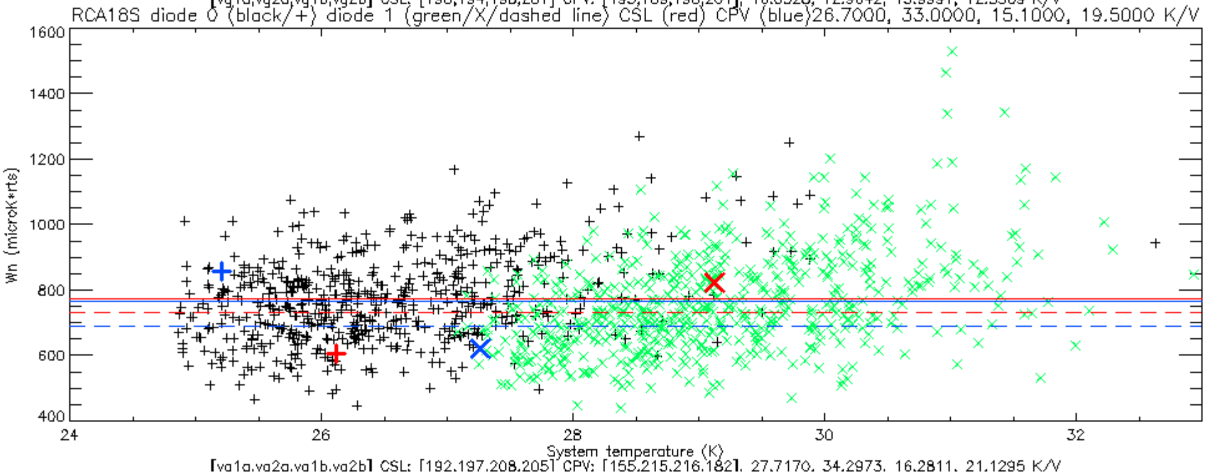
Examination of the plot below reveals some problems in using these data for tuning:

- The OD65 tests results are consistent with the results of the hypermatrix verification, but the scatter is very large

- Any correlation between Tsys and white noise is dominated by the noise.

- The measured relationships of calibrated white noise between CSL and CPV biases are not visible in the Hypermatrix verification data, where the noise seems to prevent us from distinguishing usefully among bias points.



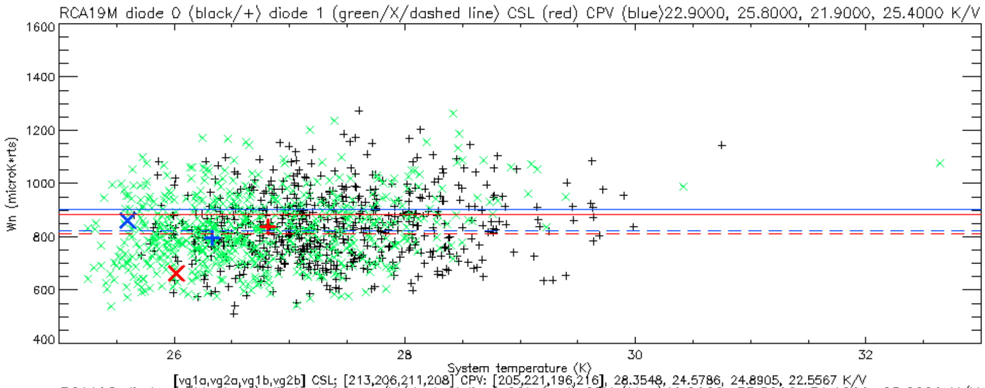


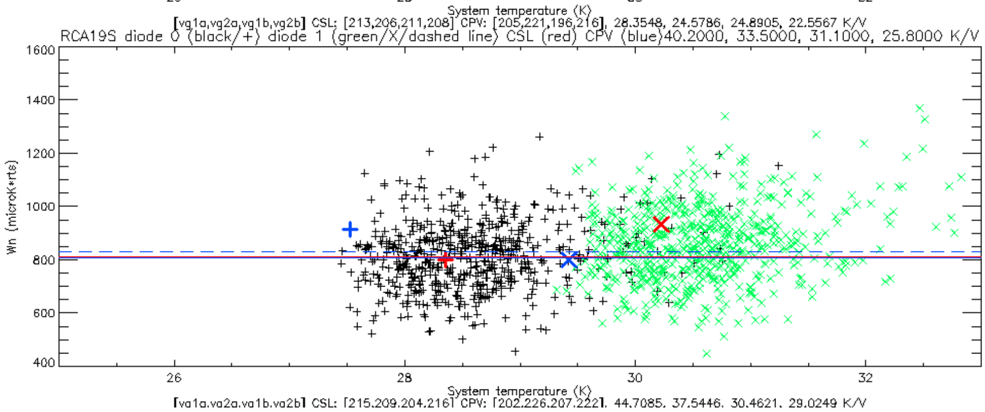
5.3 Discussion

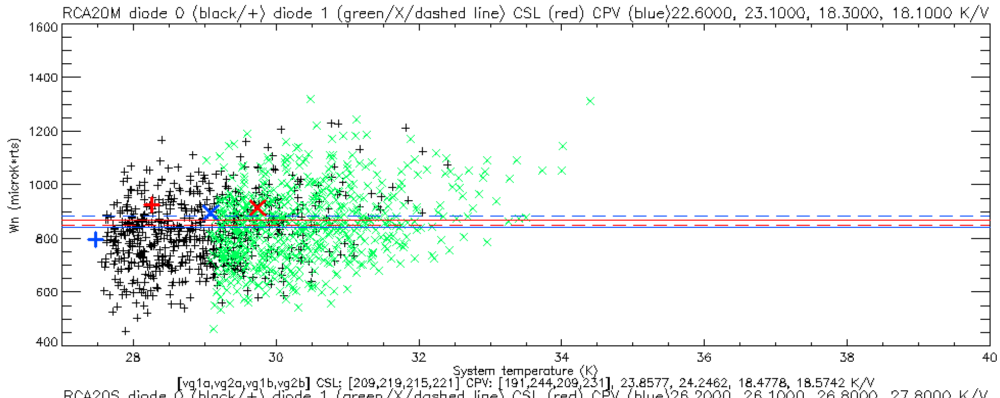
Similar plots from each of the radiometers are included below, but the overall result is the same, the results of the white noise hypermatrix are consistent with the normal hypermatrix tuning but provide no extra power to optimise the bias. This result was unexpected. Based on both analytical and monte carlo calculations before flight we estimated only a few percent error in the calibrated white noise, which would have been sufficient.

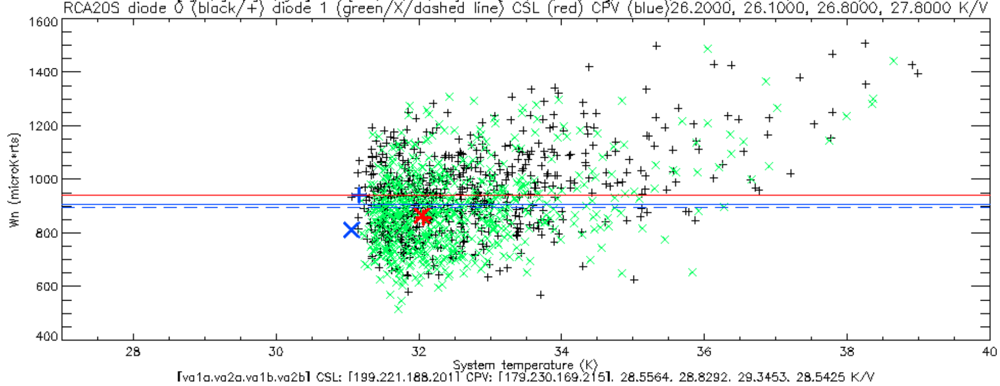
Based on extensive tests with other data from the CPV campaign, the large scatter is **not associated with the receivers** per se, but probably with the very short periods available for white noise estimation. Our preflight estimates did not account for signal, which is problematic for integration times shorter than a single rotation of the telescope (see the figures in section 2 above for example). Still, with an amplitude of 3 mK from the CMB dipole, we still shouldn't expect such large scatter. A possible explanation is in the settling time for the receivers after bias changes. In analyzing this test we allow a few seconds settling time, but it is possible that the noise characteristics are not stable in this short a time. Given the time limitations on the test, we could not consider integrations times of order 5 minutes or more per bias point, which might have given more stable and discriminatory results.

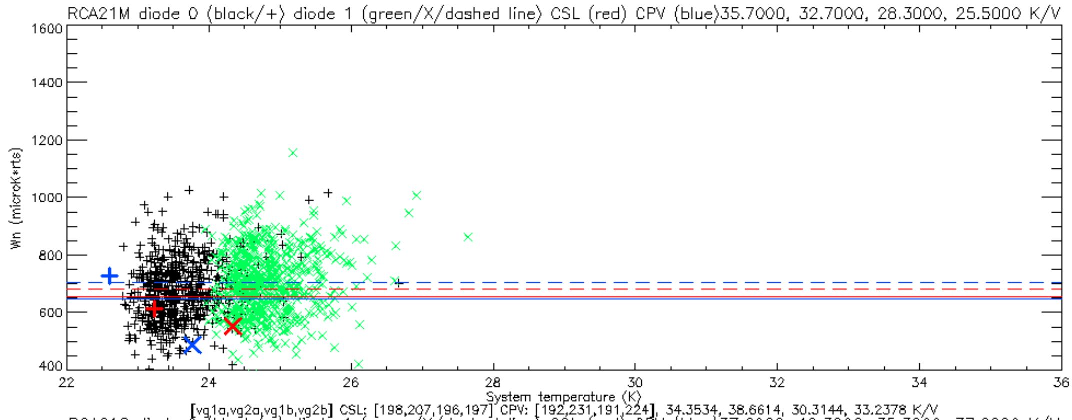
6 Plots

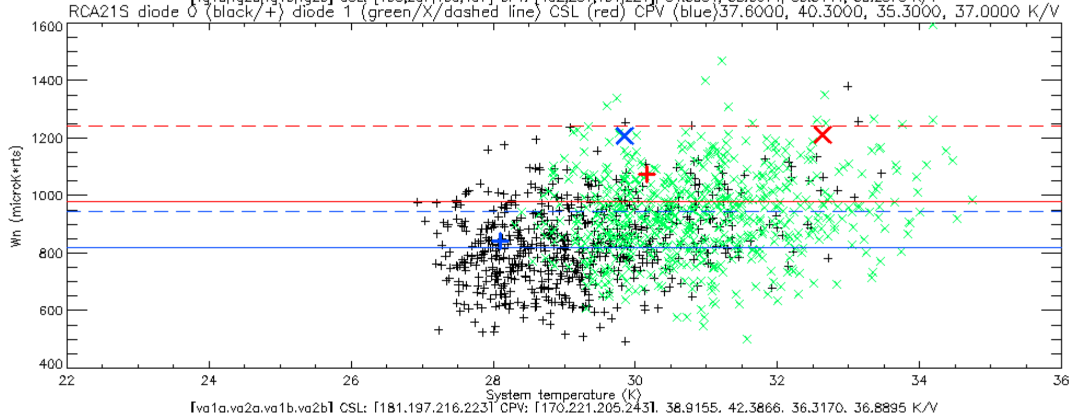

RCA19M diode 0 (black/+) diode 1 (green/X/dashed line) CSL (red) CPV (blue)22.9000, 25.8000, 21.9000, 25.4000 K/V
Wn (microK*rts)
System temperature (K)
[vg1a,vg2a,vg1b,vg2b] CSL: [213,206,211,208] CPV: [205,221,196,216], 28.3548, 24.5786, 24.8905, 22.5567 K/V

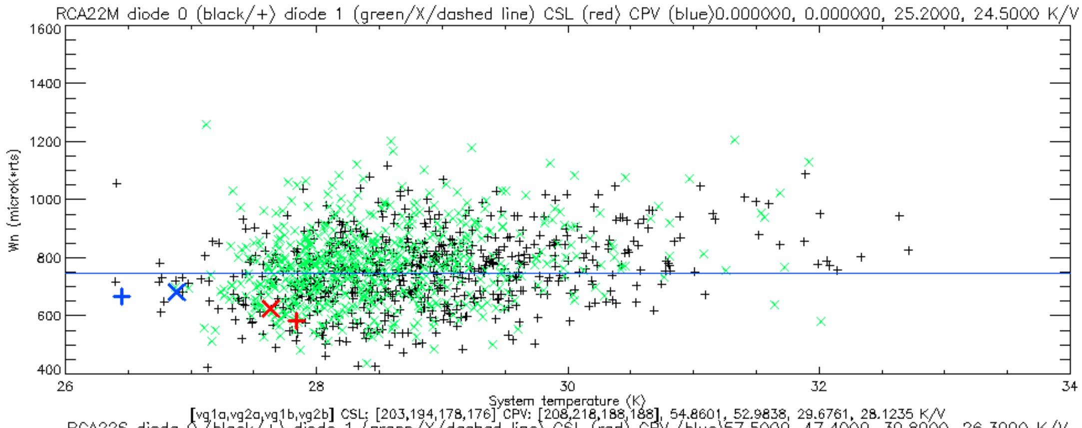

RCA19S diode 0 (black/+) diode 1 (green/X/dashed line) CSL (red) CPV (blue)40.2000, 33.5000, 31.1000, 25.8000 K/V
Wn (microK*rts)
System temperature (K)
[va1a,va2a,va1b,va2b] CSL: [215,209,204,216] CPV: [202,226,207,222], 44.7085, 37.5446, 30.4621, 29.0249 K/V


RCA20M diode 0 (black/+) diode 1 (green/X/dashed line) CSL (red) CPV (blue)22.6000, 23.1000, 18.3000, 18.1000 K/V
Wn (microK*rts)
System temperature (K)
[vg1a,vg2a,vg1b,vg2b] CSL: [209,219,215,221] CPV: [191,244,209,231], 23.8577, 24.2462, 18.4778, 18.5742 K/V


RCA20S diode 0 (black/+) diode 1 (green/X/dashed line) CSL (red) CPV (blue)26.2000, 26.1000, 26.8000, 27.8000 K/V
Wn (microK*rts)
System temperature (K)
[va1a,va2a,va1b,va2b] CSL: [199,221,188,201] CPV: [179,230,169,215], 28.5564, 28.8292, 29.3453, 28.5425 K/V


RCA21M diode 0 (black/+) diode 1 (green/X/dashed line) CSL (red) CPV (blue)35.7000, 32.7000, 28.3000, 25.5000 K/V
Wn (microK*rts)
System temperature (K)
[vg1a,vg2a,vg1b,vg2b] CSL: [198,207,196,197] CPV: [192,231,191,224], 34.3534, 38.6614, 30.3144, 33.2378 K/V


RCA21S diode 0 (black/+) diode 1 (green/X/dashed line) CSL (red) CPV (blue)37.6000, 40.3000, 35.3000, 37.0000 K/V
Wn (microK*rts)
System temperature (K)
[vg1a,vg2a,vg1b,vg2b] CSL: [181,197,216,223] CPV: [170,221,205,243], 38.9155, 42.3866, 36.3170, 36.8895 K/V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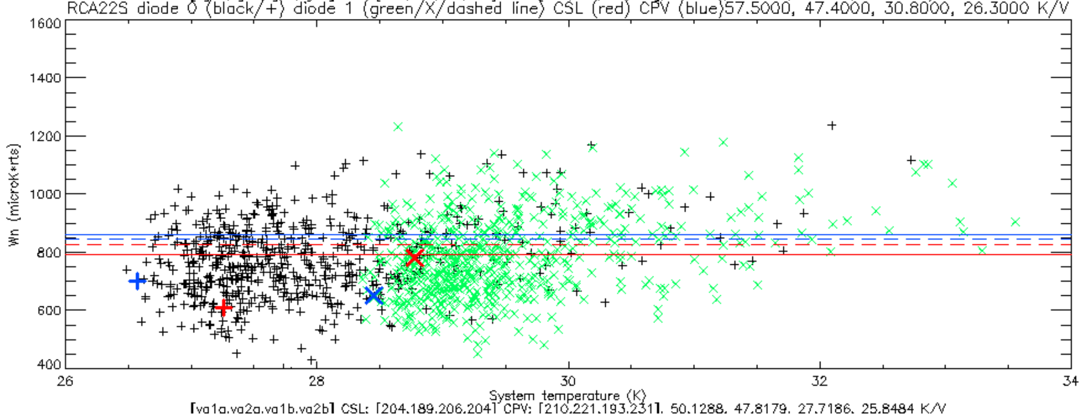
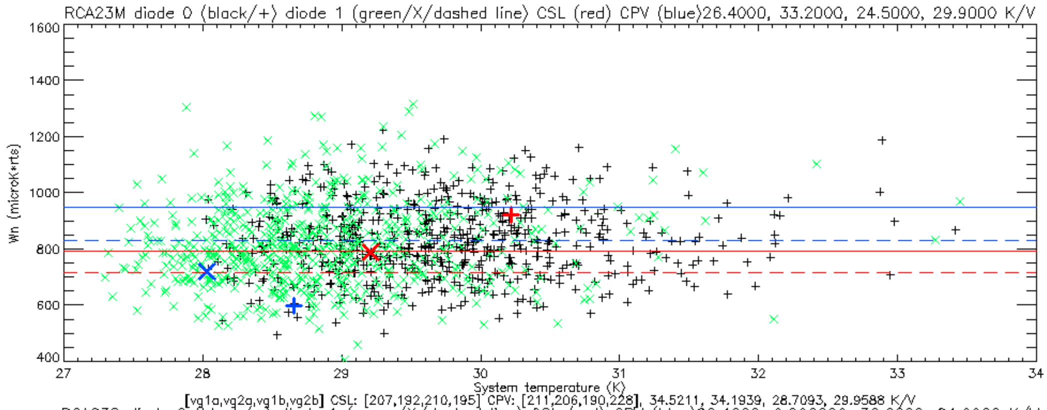
Wn (microK*rts)
System temperature (K)
[vg1a,vg2a,vg1b,vg2b] CSL: [203,194,178,176] CPV: [208,218,188,188], 54.8601, 52.9838, 29.6761, 28.1235 K/V


RCA22S diode 0 (black/+) diode 1 (green/X/dashed line) CSL (red) CPV (blue)57.5000, 47.4000, 30.8000, 26.3000 K/V
Wn (microK*rts)
System temperature (K)
[vg1a,vg2a,vg1b,vg2b] CSL: [204,189,206,204] CPV: [210,221,193,231], 50.1288, 47.8179, 27.7186, 25.8484 K/V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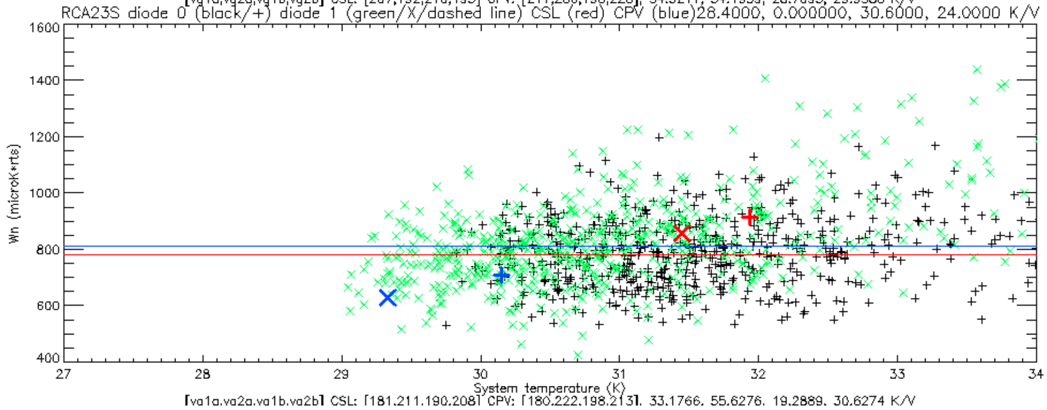
Wn (microK*rts)
System temperature (K)
[vg1a,vg2a,vg1b,vg2b] CSL: [207,192,210,195] CPV: [211,206,190,228], 34.5211, 34.1939, 28.7093, 29.9588 K/V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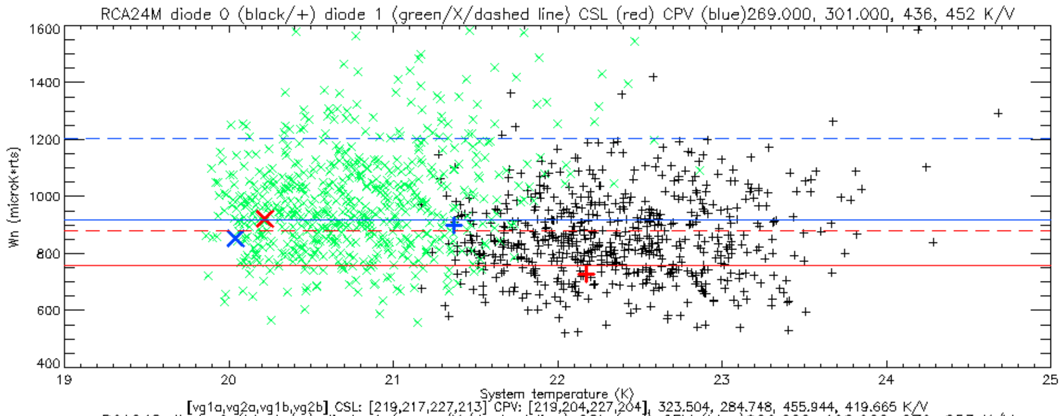
Wn (microK*rts)
System temperature (K)
[vg1a,vg2a,vg1b,vg2b] CSL: [181,211,190,208] CPV: [180,222,198,213], 33.1766, 55.6276, 19.2889, 30.6274 K/V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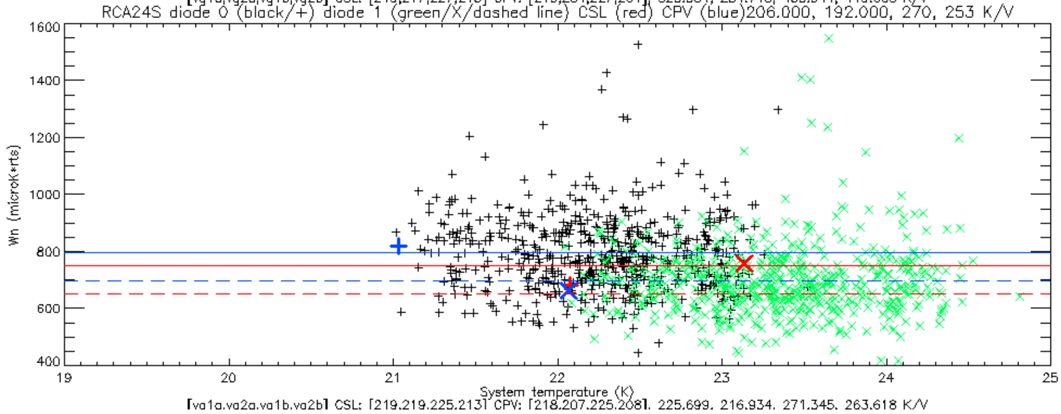
Wn (microK*rts)
System temperature (K)
[vg1a,vg2a,vg1b,vg2b] CSL: [219,217,227,213] CPV: [219,204,227,204], 323.504, 284.748, 455.944, 419.665 K/V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Wn (microK*rts)
System temperature (K)
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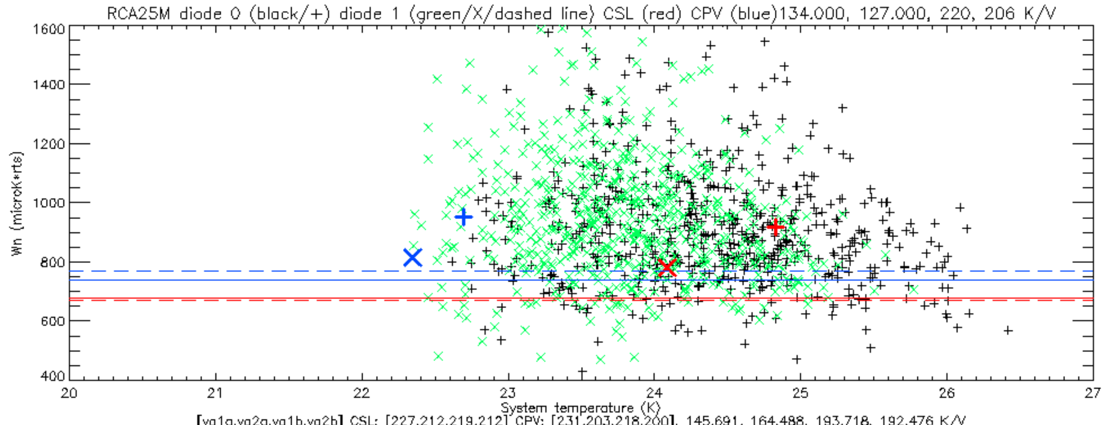
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System temperature (K)
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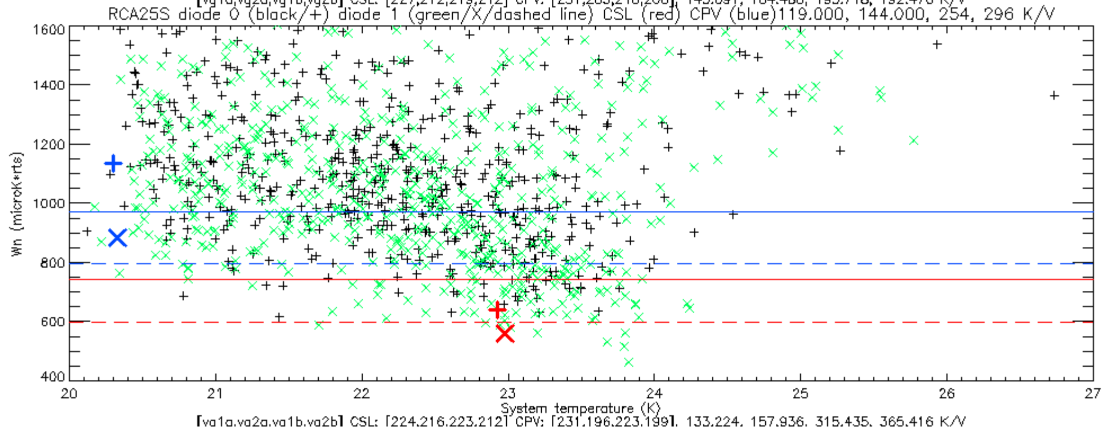
RCA25S diode 0 (black/+) diode 1 (green/X/dashed line) CSL (red) CPV (blue)119.000, 144.000, 254, 296 K/V
Wn (microK*rts)
System temperature (K)
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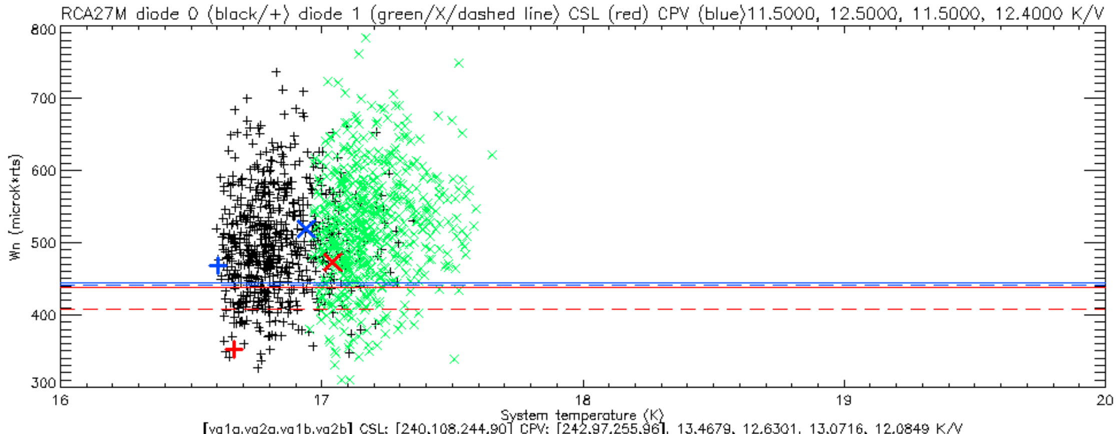
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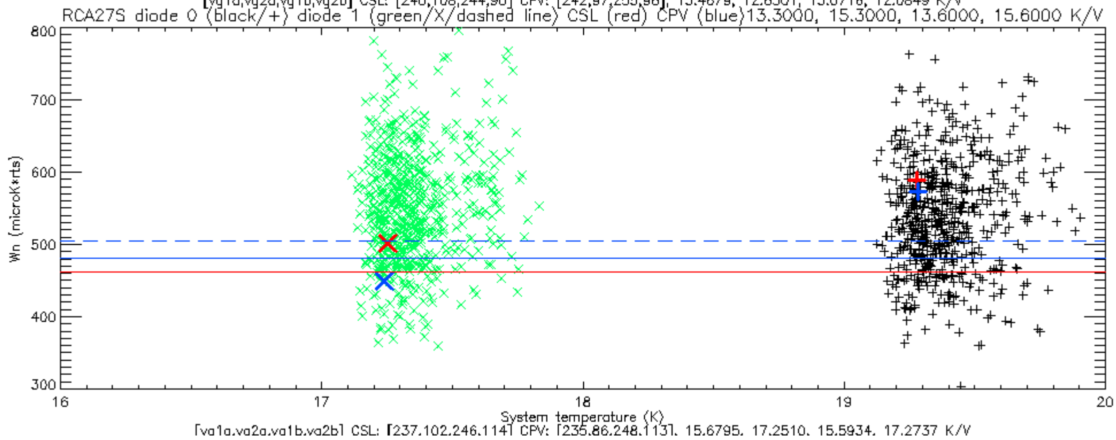
[vg1a,vg2a,vg1b,vg2b] CSL: [240,108,244,90] CPV: [242,97,255,96], 13.4679, 12.6301, 13.0716, 12.0849 K/V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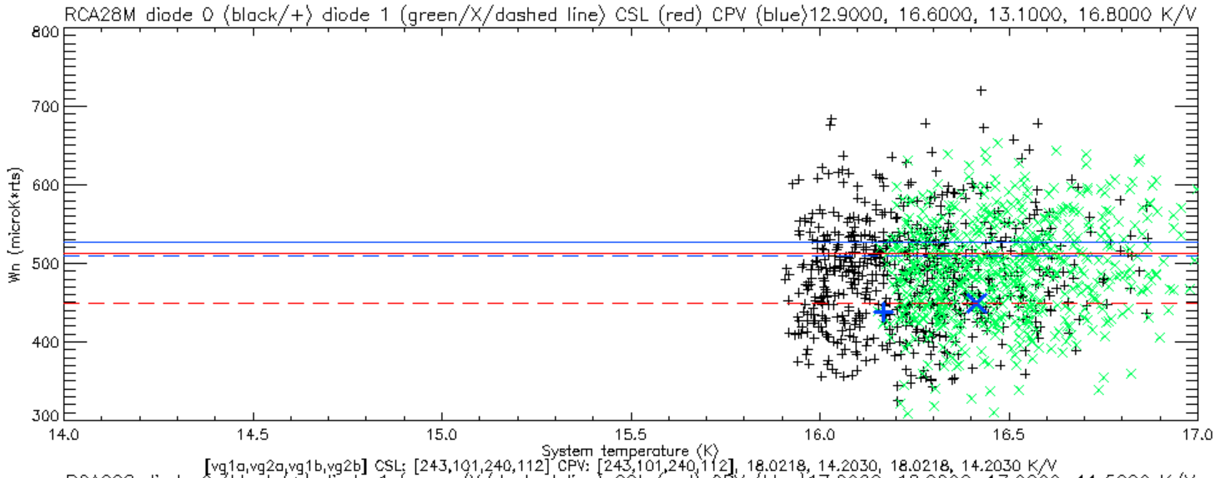
[va1a,va2a,va1b,va2b] CSL: [237,102,246,114] CPV: [235,86,248,113], 15.6795, 17.2510, 15.5934, 17.2737 K/V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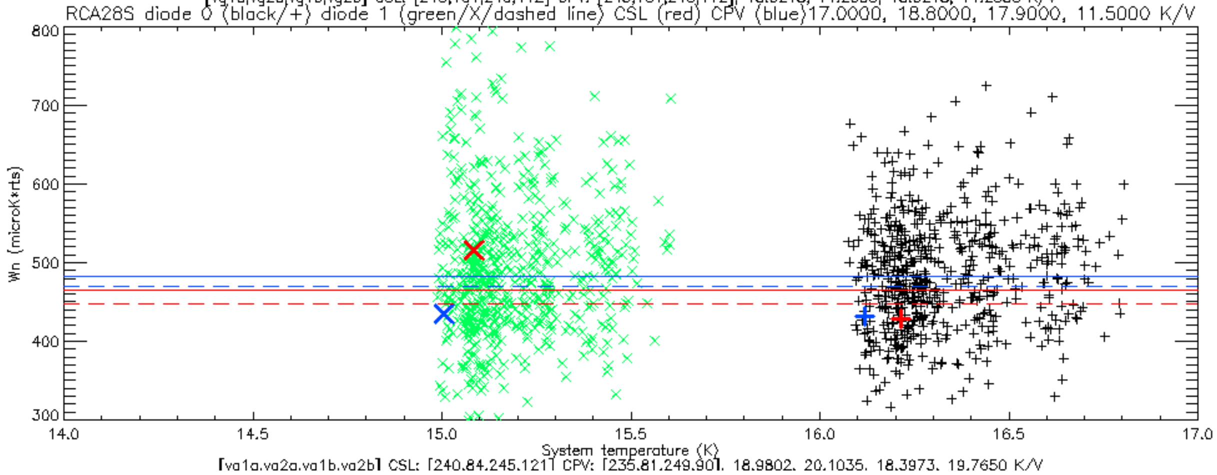
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Wn (microK*rts)
System temperature (K)
[va1a,va2a,va1b,va2b] CSL: [240,84,245,121] CPV: [235,81,249,90], 18.9802, 20.1035, 18.3973, 19.7650 K/V