Fitting PACS ramps with analytical models. Part II

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DOCUMENT CHANGE RECORD

Version	Date	Changes	Remarks
Draft 0	1-May-2004	–	New document.
Draft 1	7-June-2004	small changes throughout	Uploaded to document tree.

Reference Documents

RD1 – Alternative concept for data reduction/compression, PACS-ME-TN-040, Draft 1, May 2003
RD2 – Fitting PACS ramps with analytical models. Part I, PICC-KL-TN-009, Draft 1, 18-02-2004

1. Introduction

This technical note is a follow-up to RD2 and describes the second attempt to fit Spectroscopic PACS data with an analytical model within the framework of the PCSS/IA.

Using an analytical model to describe PACS ramps could be useful for OBSW data compression or for the on-ground data reduction. Also it could be useful in numerical simulations of ramps, since the ramps are generally not straight lines.

This document accompanies the two Python scripts PyRamp2Model.py and PlotPyRamp2Model.py that, respectively, implement the mathematical model described below, and plots the output generated. In addition the file (input2.list) which contains the data files analysed is given. All these file are available under CVS at the Leuven site.

2. Model

The (only) model available to describe the shape of the PACS ramps is derived by Albrecht Poglitsch in a unnumbered document (a verbal description and some plots can be found in RD1 however). It is a combination of an analytical description of the CRE circuit plus an ad-hoc description of the "bump".

The functional form derived:

$$V(y) = A\left(\sqrt{\frac{F}{F_0R_1}/\left(\left(\frac{F}{F_0R_1}/V_\mathrm{b}^2+\frac{F}{F_0R_0}\right)\exp\left((2\ \frac{F}{F_0R_1}\ y)/(C_\mathrm{p}+C_\mathrm{f}(1+A)\right)\right)-\frac{F}{F_0R_0}\right)}-V_\mathrm{b}\right)$$

$$+a+b\,(1-\exp(-t/\tau))$$

with t the time and $y = t/256$ (256 Hz read-out frequency). A is de open-loop cascode gain, C_f the feed-back capacitance, C_p the parasitic capacitance, F/F_0 represents a flux scaling factor, V_b the bias voltage, and R_1 and R_0 are resistors to model the equivalent circuit describing the detectors. a is a constant, and b, τ are a ad-hoc description of the "bump".

In RD2 the following mathematical implementation of this *physical* model was chosen, with 8 parameters:

$$f(x,p) = p_0\left(\sqrt{p_1/\left((p_1/p_2^2+p_3)\exp\left((2\ p_1\ y)/p_4\right)-p_3\right)}-p_2\right)$$

$$+p_5+p_6(1-\exp(-x/p_7))$$

with $y = x/256$. In other words:

$$p_0 = A$$
$$p_1 = F/(F_0\,R_1)$$
$$p_2 = V_\mathrm{b}$$
$$p_3 = F/(F_0\,R_0)$$
$$p_4 = C_\mathrm{p}+C_\mathrm{f}(1+A)$$

$$p_5 = a$$
$$p_6 = b$$
$$p_7 = \tau$$

However, some disadvantages of this approach were noted.

First, some of the fitted parameters could become *negative* although the physical meaning of these quantities clearly implies positive values (gain, capacitance). This is now handled by using the exponential of a parameter instead of the parameter directly.

Second, although the model had the fewest parameters, some of the interesting physical quantities were not explicit in the model (the flux $\frac{F}{F_0}$, or C_p and C_f).

In the present case, the following mathematical description was adopted:

$$f(x,p) = \exp p_0 \left(\sqrt{\exp p_1 / \left((\exp p_1 / p_2^2 + 1)\ \exp\left((2\ p_3/p_4\ y)/(\exp p_5 + \exp p_6 (1 + \exp p_0)) - 1 \right) \right.} - p_2 \right)$$

$$+ p_7 + \exp p_8 (1 - \exp(-x/\exp p_9))$$

In other words:

$$p_0 = \ln(A)$$
$$p_1 = \ln(R_0/R_1)$$
$$p_2 = V_\mathrm{b}$$
$$p_3 = F/F_0$$
$$p_4 = R_1$$
$$p_5 = \ln(C_\mathrm{p})$$
$$p_6 = \ln(C_\mathrm{f})$$
$$p_7 = a$$
$$p_8 = \ln(b)$$
$$p_9 = \ln(\tau)$$

2. IA/Python

The necessary files are located at the Leuven CVS server at / develop/ pcss/ herschel/ pacs/ scripts/ obswscripts

The related files are PyRamp2Model.py, input2.list, Ramp2Model.java, PlotPyRamp2Model.py, ADCSaturation.py and DynamicRange.py.

Ramp2Model.java is the actual implementation of the mathematical model as an extension of the NonLinear java class. Compile it with "javac Ramp2Model.java"

input2.list (the name is arbitrary) contains the pathnames to the file(s) you want to analyse[1].

[1]The content of input2.list as uploaded to the CVS server contains the 89 files analysed in this attempt which are all files from the MPE April 2003 data, except the files with 0 or 10 mV bias, or no BlackBody temperature marked in their filename, and T18bb33b30t025c1n256_1.dat that had a deviating file length.

PyRamp2Model.py does the actual fitting. There are loops over the file, the module, the detector and the ramps (loop-index i, j, k, l, respectively). In JIDE one can run the script as is, or execute it line-by-line and set the appropriate i, j, k, l-index manually (and skip the **FOR**-loop) to select a particular ramp.

The output of PyRamp2Model.py are 3 files, "output_of_ramp2model.dat", "failed_of_ramp2.dat" and "weird_of_ramp2.dat". The first file describes the input and output of the fitting in the majority of cases. The second file list the indices l, k, j, i of those ramps where the fitting failed (i.e. A java exception occurred), and the third file lists the indices of those ramps with a very high (arbitrarily chosen) χ^2.

The file "output_of_ramp2model.dat" is read in by PlotPyRamp2Model.py. It automatically generates plots of output (fit) parameters against all input parameters, and all output parameters against all other output parameters.

3. Changes w.r.t. Model 1

Apart from a different mathematical model, some other changes took place in the code.

As already mentioned in RD2, there was a serious performance problem at that time. This has been partly solved in the present version by *not* printing to standard output (only directly to file), and plotting directly to file (instead of having to plot to the screen as well).

In the present version randomly selected ramps + fits are plotted to file. Some more advanced features of PlotXY have been used.

In the present version all Modules (except index=1), and all Channels/Detectors (except index=0 and 17) are fitted of all files in the input list, but (still) for reasons of computational speed, only the first 10 ramps. The results below are based on fitting almost 53 000 ramps in total.

Two auxiliary Python scripts have been written to deal with saturation. The first type of saturation is of the AC-to-DC convertor. ADCSaturation.py looks for the first occurance in the ramp of a specific numerical value (-32767 in this case). All non-destructive readouts (NDRs) after which this value occurs are not considered. The second script, DynamicRange.py, takes an input value (the dynamic range in Volt) and look if there are NDRs (and if so, returns the first occurance) where the voltage drops below the maximum value minus the input value. If so, all NDRs after the dynamical range is exceeded are ignored. In the present version a value of 1.73 Volt has been used. This seems to be sufficient, but there are also clear cases where the dynamical range is larger (1.8-1.9 V), and so fewer NDRs have been used in those fits than could have been. However, to optimise this requires a more detailed investigation of the dynamical range over capacitance and other parameters.

Only ramps where the difference between the maximum and minimum of a ramp exceeded 0.03 Volt (to eliminate some erratic ramps.....)

The first and last NDR are always ignored (as described above, more NDRs at the end of a ramp are ignored if AC-to-DC saturation occurs or if the dynamical range is exceeded).

The option within the Levenberg-Marquardt routine to keep parameters fixed has and had to be used. Although all physical parameters now appear as mathematical parameters in the model, not all are independent. The most clear case are p_3 and p_4, which can not be fitted independently; p_4 (R_1) has been fixed at 100 GΩ.

It was initially the intend to let all other parameters free, but after many test runs this turns out not be a viable option (at the moment). The multi-parameter space appears extremely complex, as evidenced by the fact that the formal errors in the parameters (the root of the covariance matrix elements) are always very large, and also the large scatter in the plots generated by PlotPyRamp2Model of the fitted versus input parameters.

Therefore, in subsequent test runs, the median value of the fit parameters was monitored and "casual trends" determined. For example, if the initial guess for the largest feedback capacitance was 3000 fF then the median of the fitted parameter was larger than 3000 fF, but if this median value was used in a next test run as initial guess than in the next output the

median would still increase. Similarly for other parameters; hence "trends" rather than formal convergence.

In subsequent runs, different parameters have been fixed, and the version of PyRamp2Model.py uploaded to CVS is the one where all parameters except p_3 (F/F_0), p_7, p_8, and sometimes p_9 have been fixed.

The bias has been fixed to its nominal value as is present in the header of the input data files.

The gain has been fixed to 200 (Initially, initial guesses of 1000 have been used but the median of the fitted value systematically was smaller than that).

R_0/R_1 has been fixed at 0.0014 (in all test runs values near this one were found).

$C_{\rm p}$ was fixed at 100 pF (Initially, initial guesses of 5, 30, 60 pF were used, but the median of the fitted value steadily increased).

$C_{\rm f}$ was fixed at 3680/ 1330/ 520/ 280 fF for the nominal values of 3000/ 1000/ 300/ 100 fF, as determined in Heidelberg tests (the true capacitance values have never been determined for the capacitors used in the MPE April 2003 tests).

p_7 is let free and the initial guess is the output voltage at the first NDR.

The leaves, p_8 and p_9, which describe the amplitude and time behaviour of the "bump". After some testing, the initial guess for $\exp p_8$ was set at 3.0 * (max(Volt)-Volt[1]), i.e. three times the difference between the maximum voltage of a ramp and its value at the first readout.

After some testing, the initial guess for $\exp p_9$ was set at 0.75 * (the NDR where the ramp reaches its maximum value).

However, this peak can occur at the first readout, and/or the amplitude of the bump is so small that the fitting was clearly negatively influenced by it. If $\exp p_8 < 0.0033V$ or $\exp p_9 < 0.36$, then parameter p_9 was also kept fixed, in other cases p_8 and p_9 were left free.

4. Results and future work

A total of 52900 ramps has been fitted. Figure 1 shows a randomly selected sample of about 300.

About 200 fits failed in the sense of having a very large Chi-square. Typical examples are shown in Figure 2 (last page of this document).

Issues for the future:

- An "Edge detection" algorithm is needed to replace the (too) simple algorithm to check the dynamic range.

- Considering all ramps for a given file/Module/Detector, what is the distribution of the derived parameters ? Is it Gaussian ? Define a Signal-to-noise, similar to the one use in the (sub)ramp fitting.

- Implementation of the model proposed by IMEC and comparison to present model.

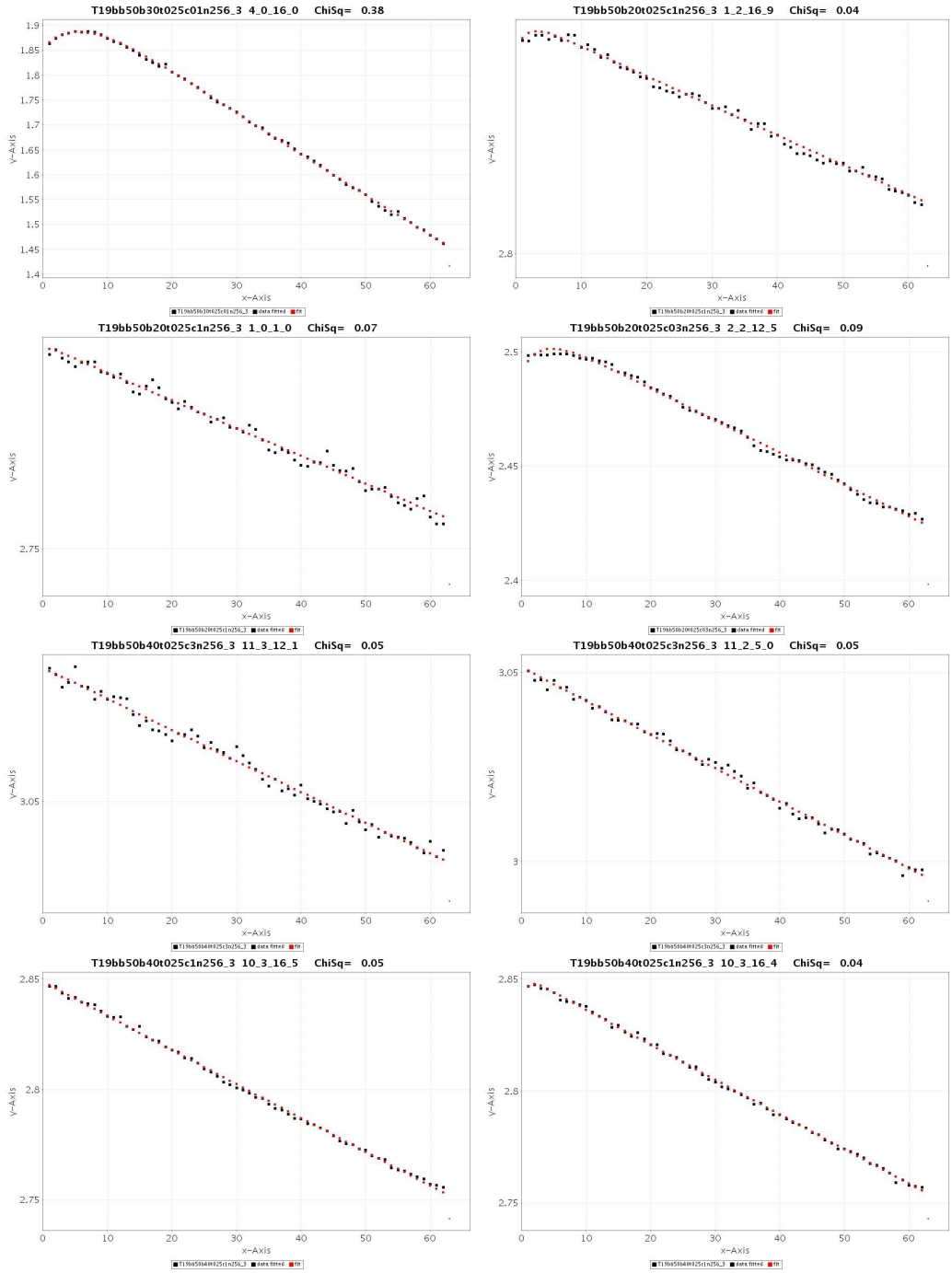
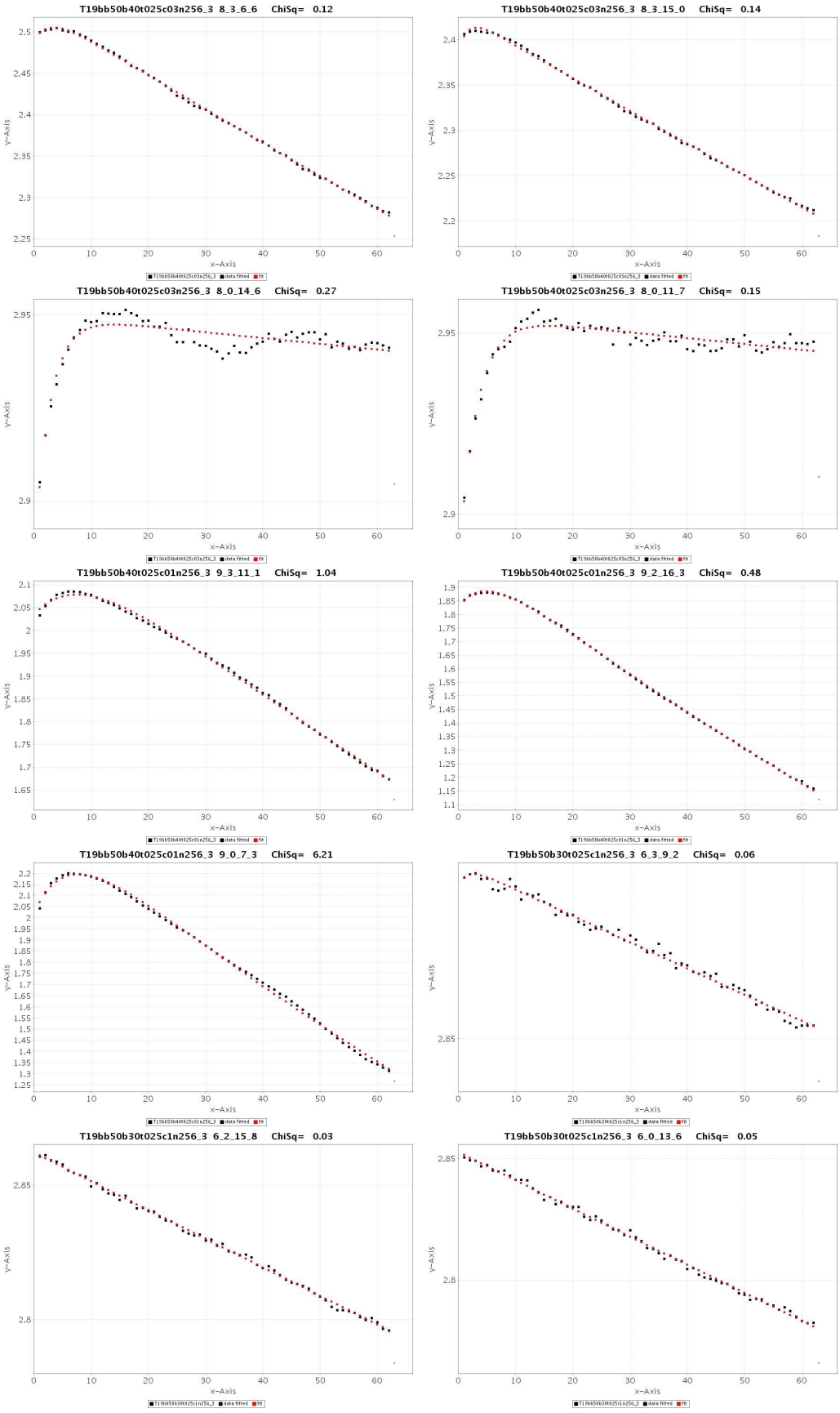


Figure 1: About 300 randomly selected fits out of a total of 52900. The red points are the fits to the thick black points. Smaller black points are read-outs not considered (last read-out, saturation, etc). Plotted are Volts versus read-out number. At the top of the plots are listed: the file name, the indices i_j_k_l, indicating the file number in the full list of files analysed, Module, Detector, Ramp, and the Chi-square.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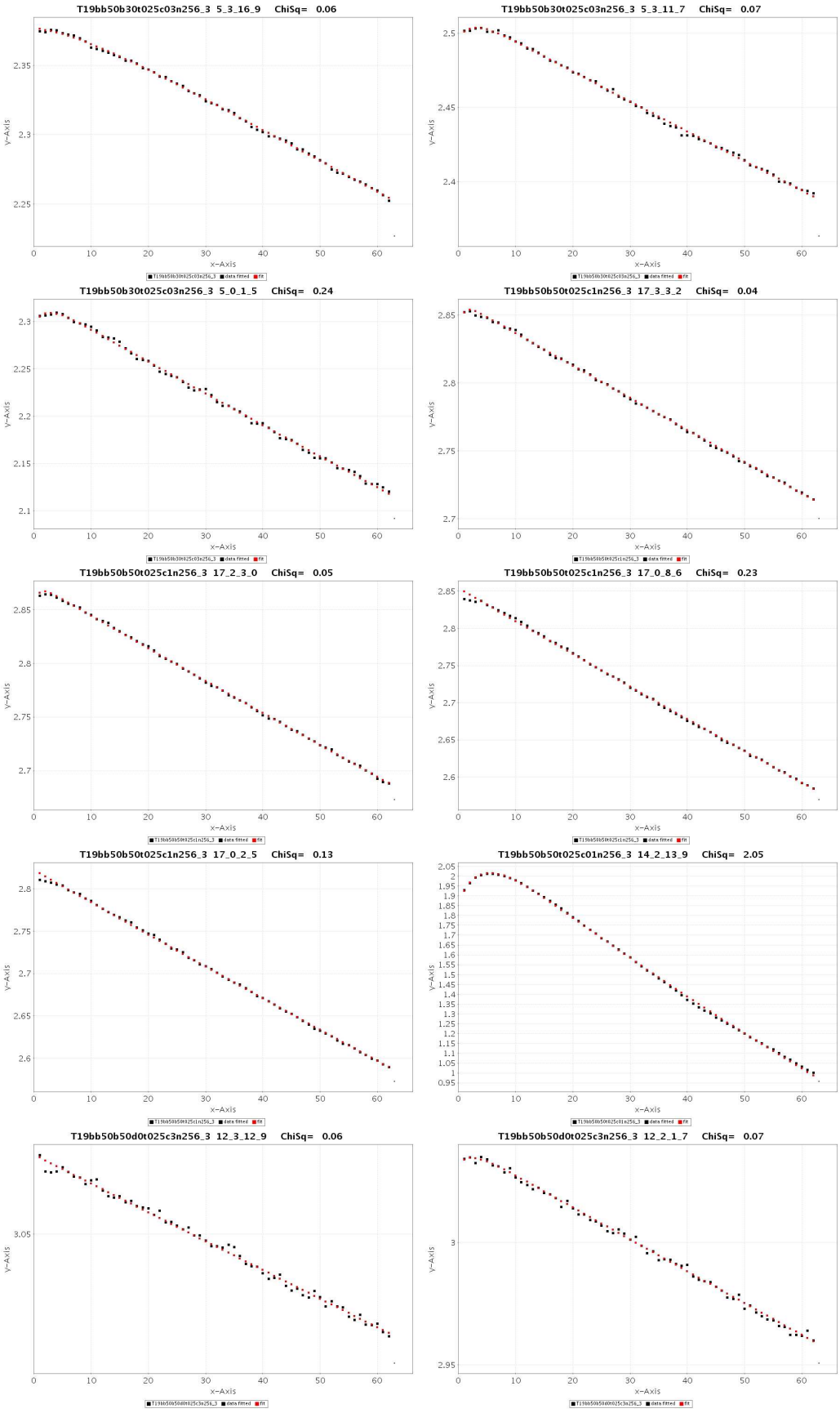
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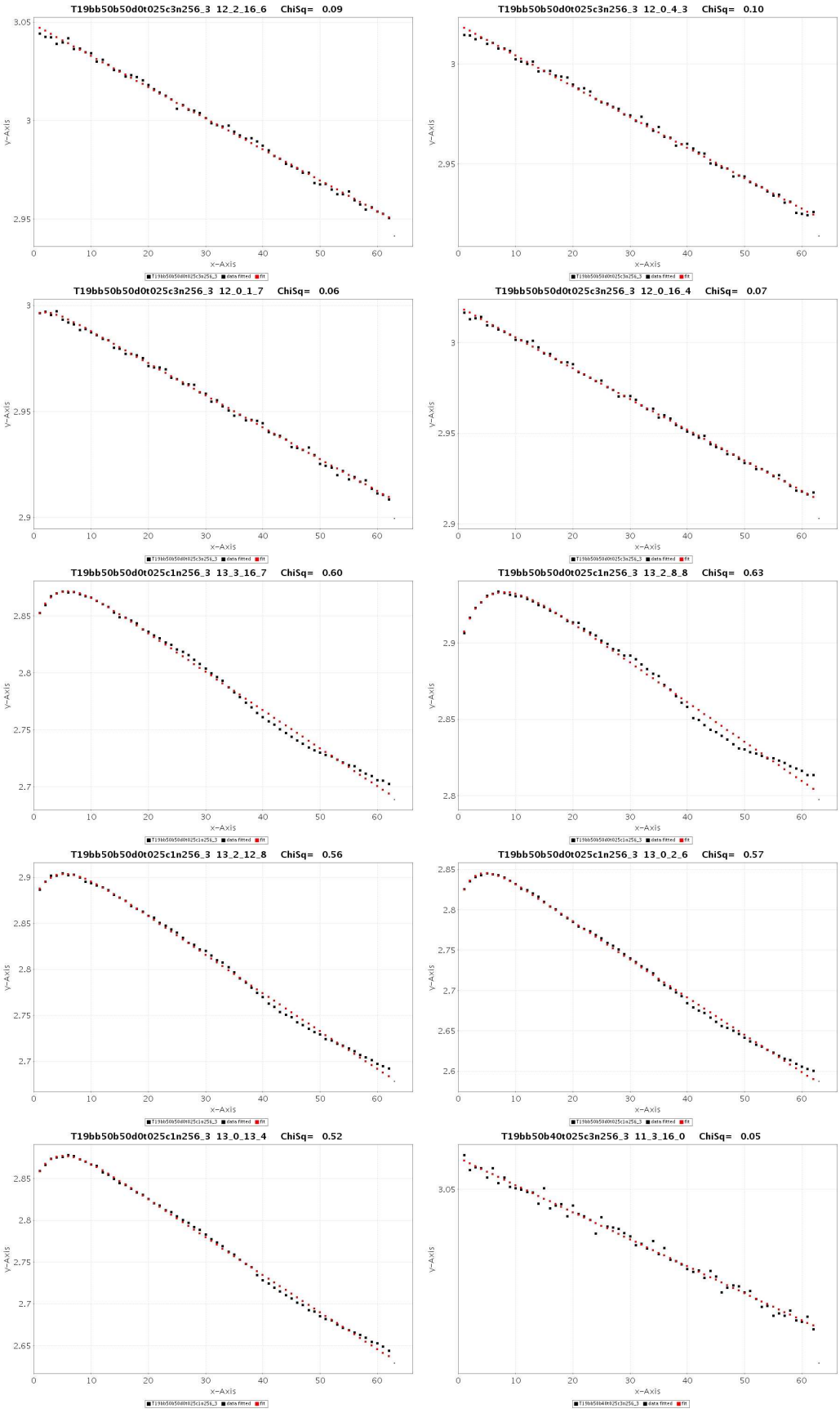
x-Axis
y-Axis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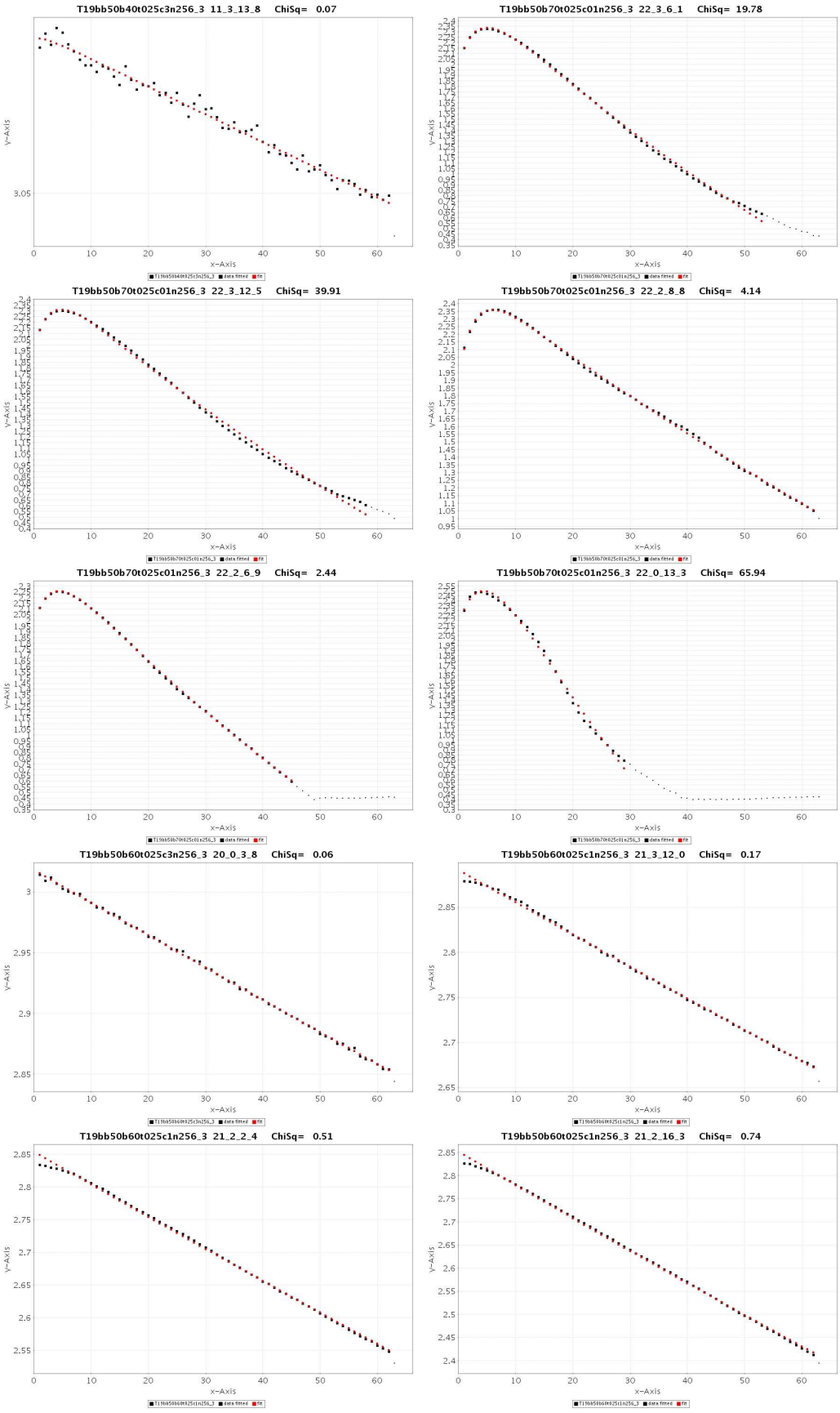
x-Axis
y-Axis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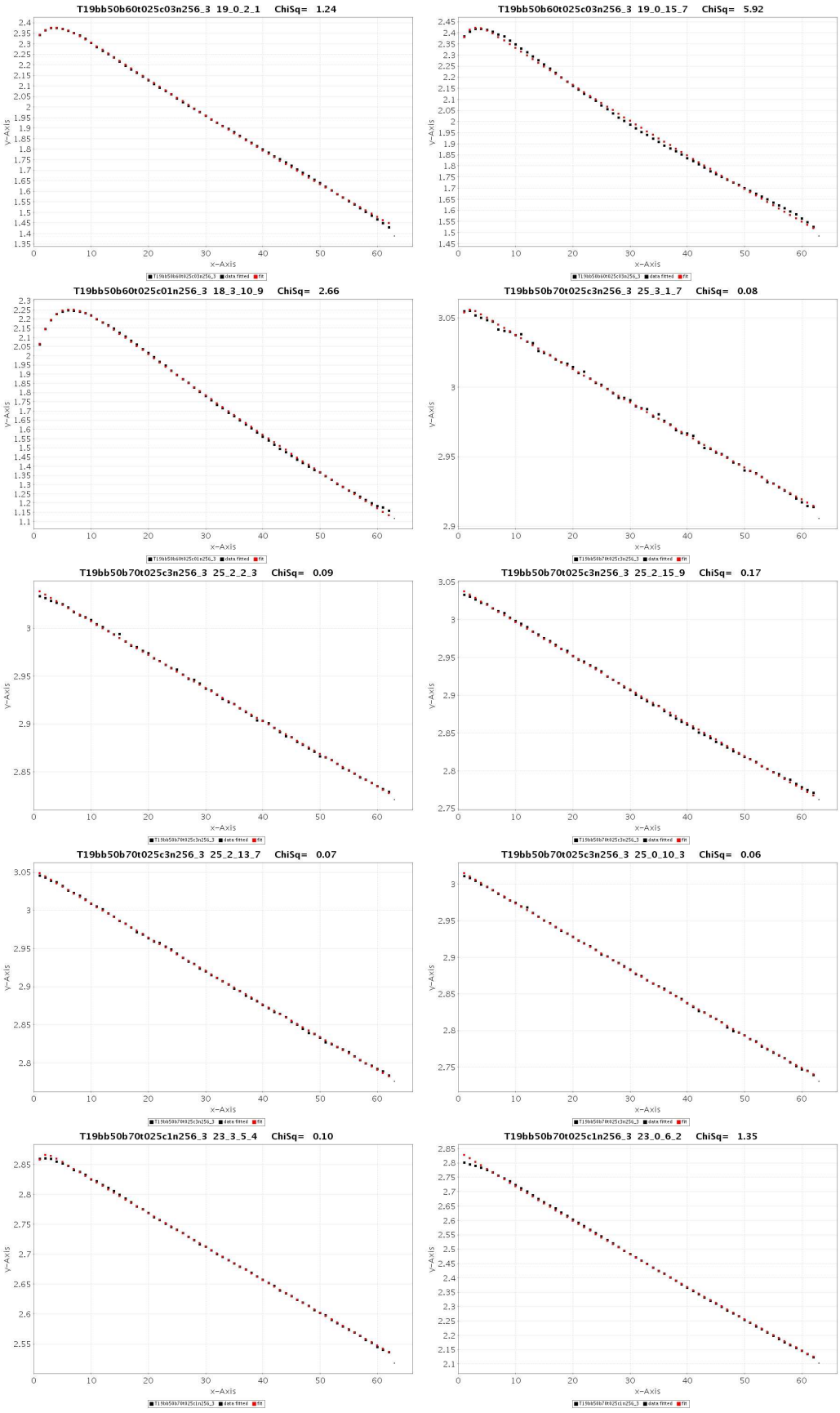
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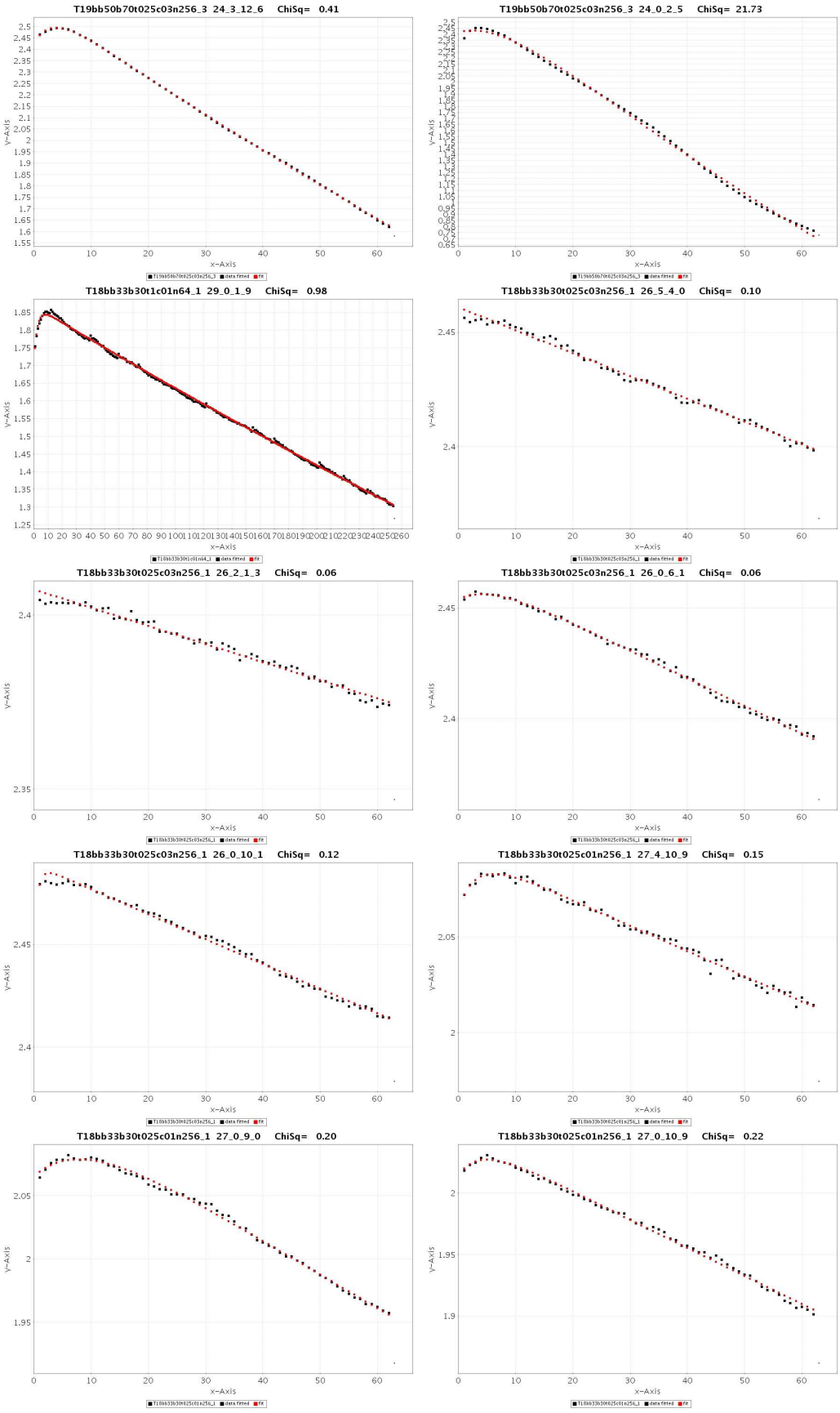
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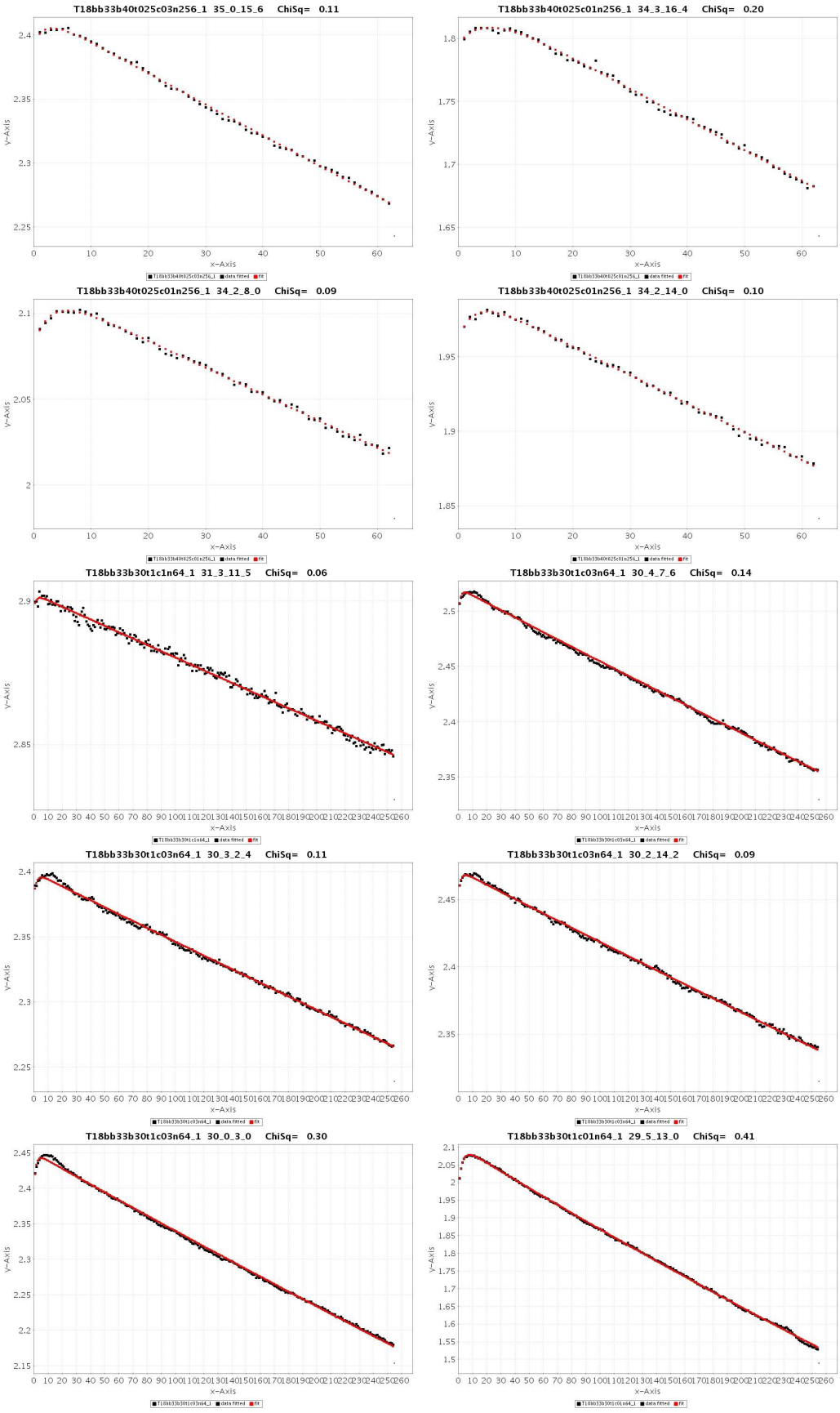
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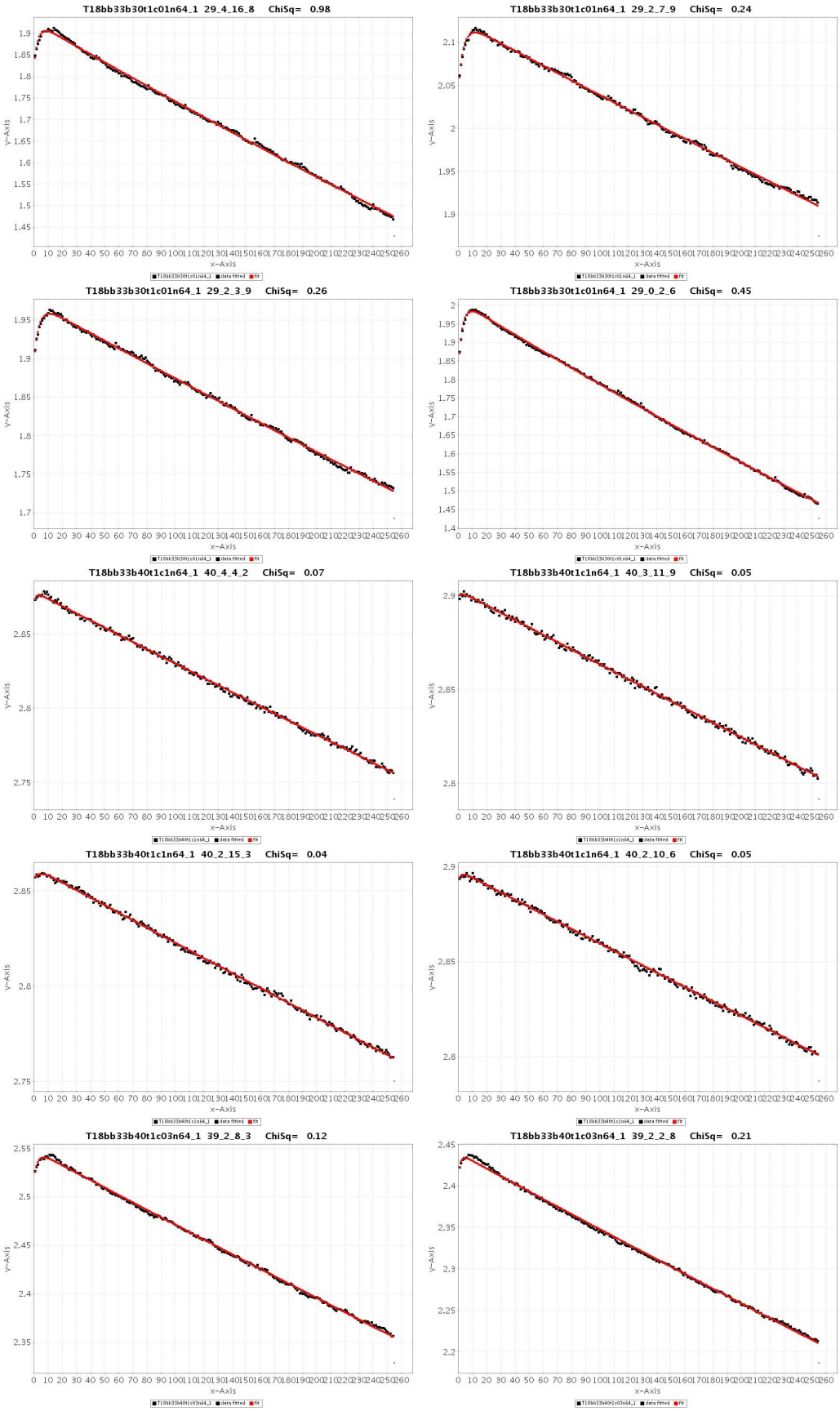
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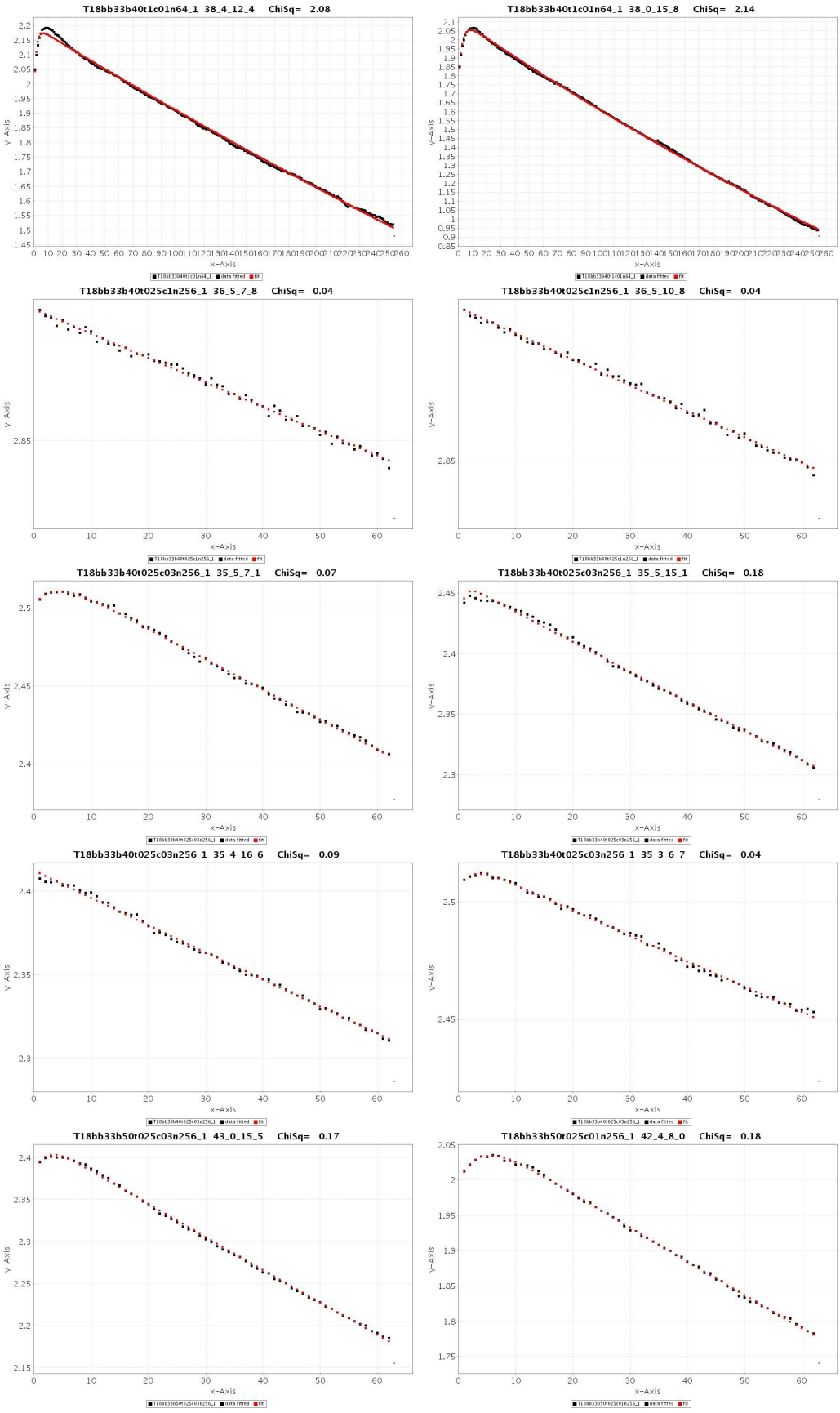
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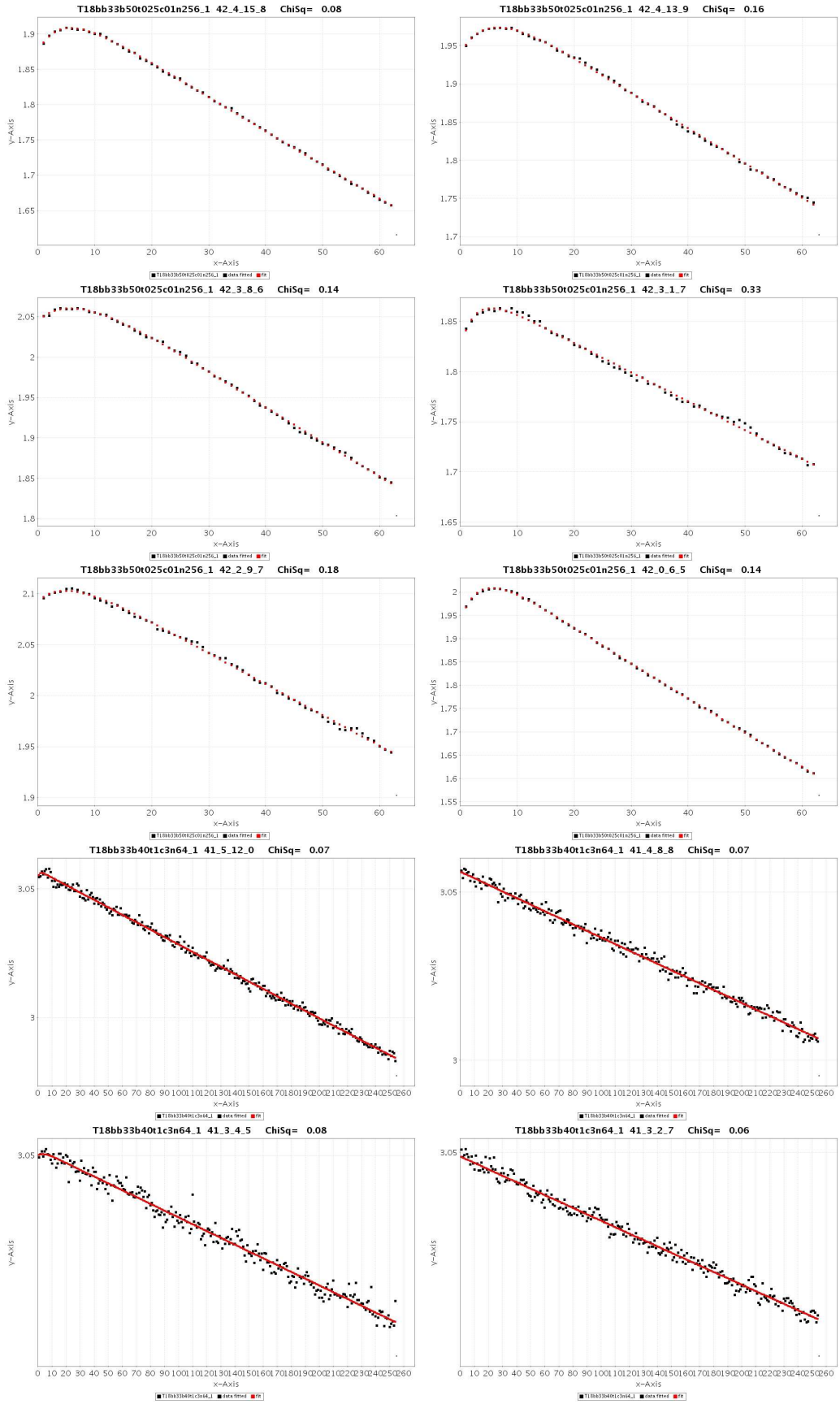
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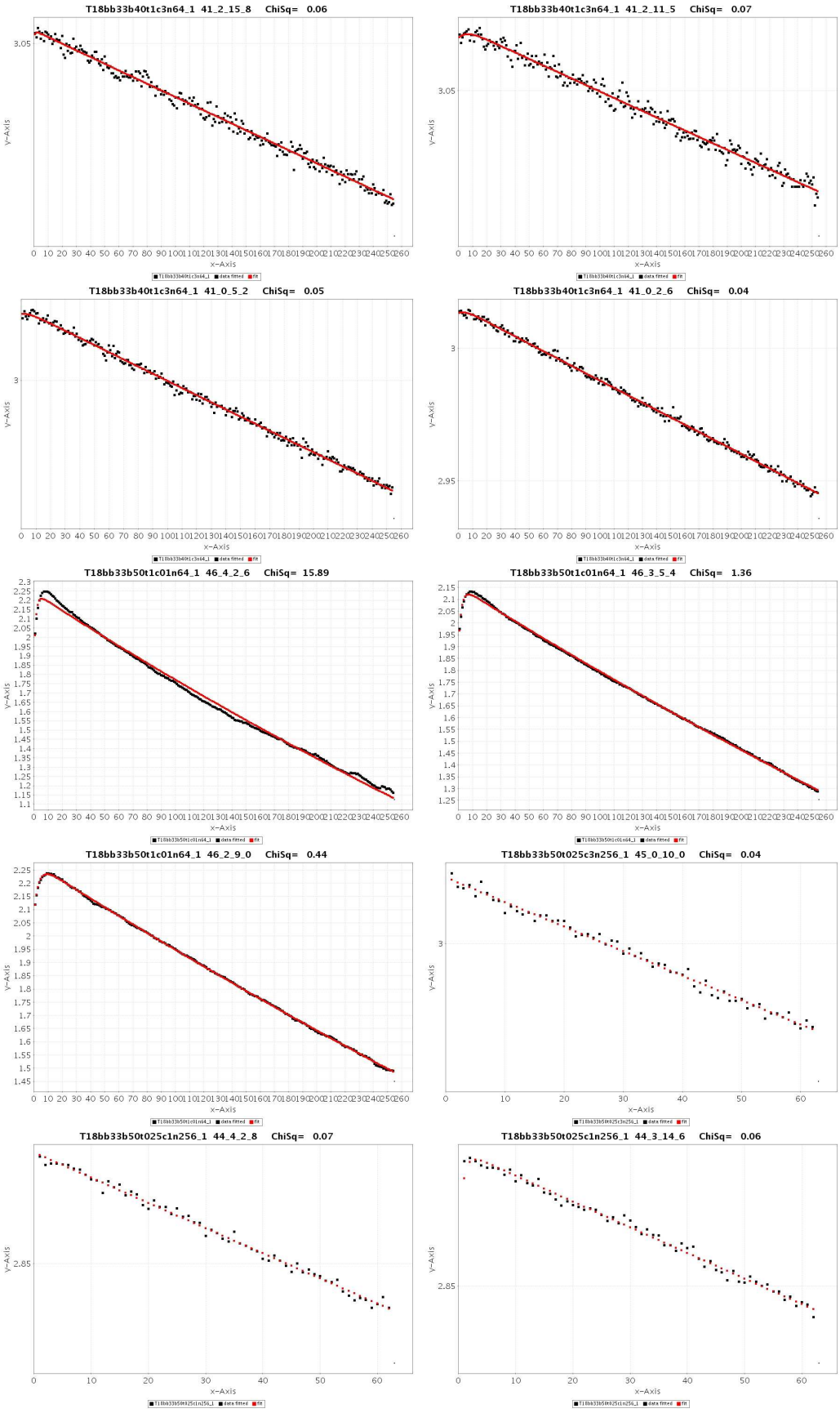
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T18bb33b50t025c3n256_1 45_0_10_0 ChiSq= 0.04
T18bb33b50t025c1n256_1 44_4_2_8 ChiSq= 0.07
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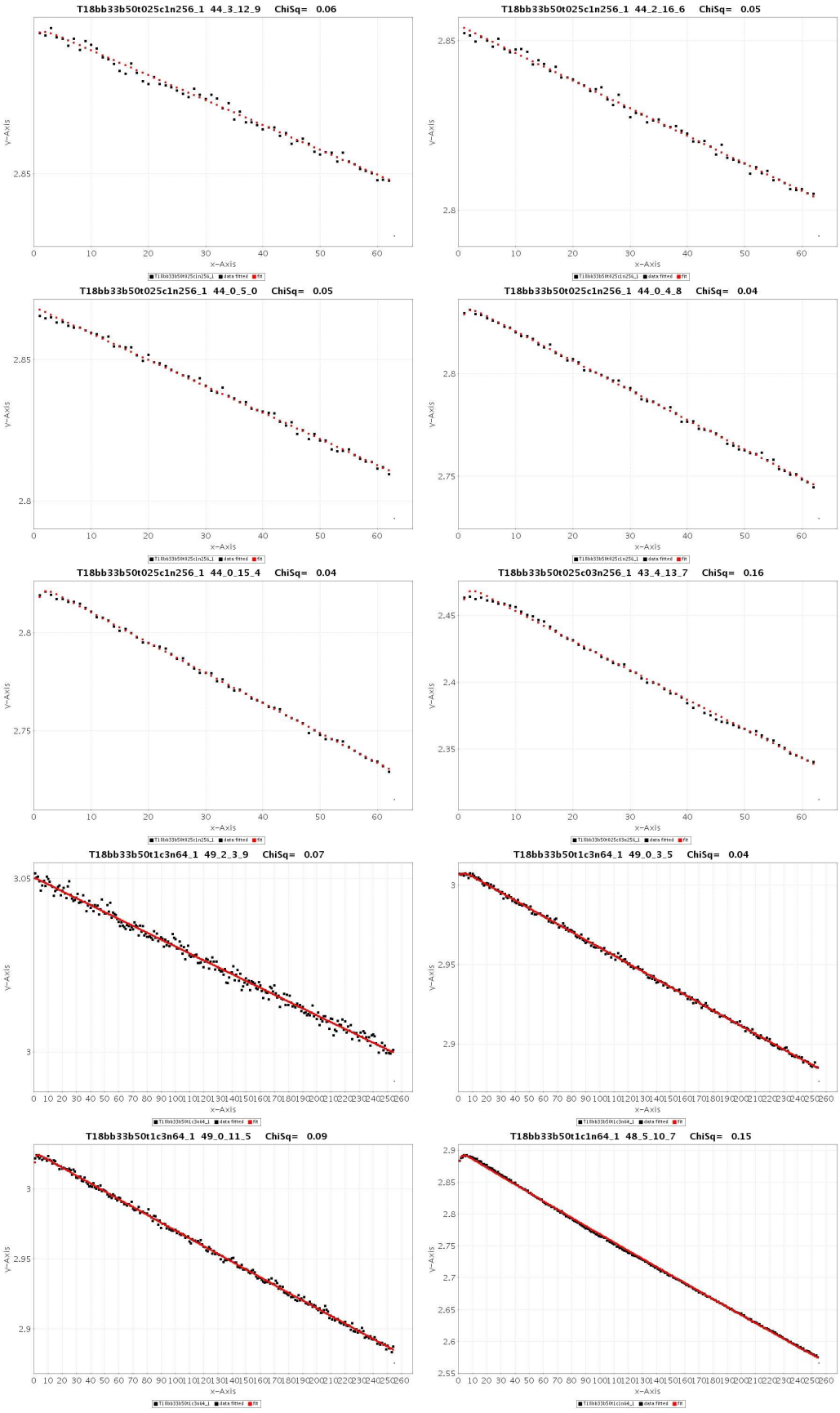
x-Axis
y-Axis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T18bb33b50t025c1n256_1 44_0_4_8 ChiSq= 0.04
T18bb33b50t025c1n256_1 44_0_15_4 ChiSq= 0.04
T18bb33b50t025c03n256_1 43_4_13_7 ChiSq= 0.16
T18bb33b50t1c3n64_1 49_2_3_9 ChiSq= 0.07
T18bb33b50t1c3n64_1 49_0_3_5 ChiSq= 0.04
T18bb33b50t1c3n64_1 49_0_11_5 ChiSq= 0.09
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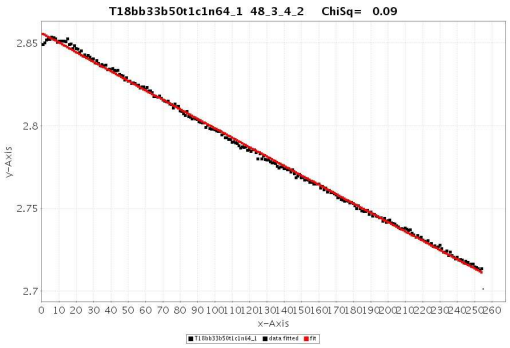
x-Axis
y-Axis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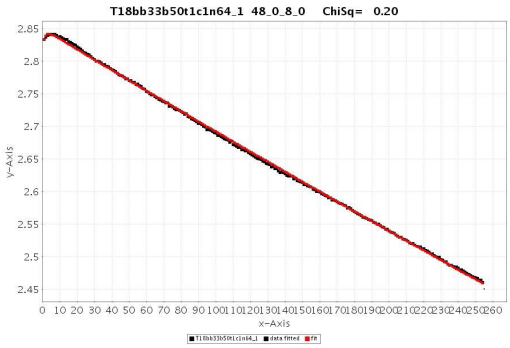
x-Axis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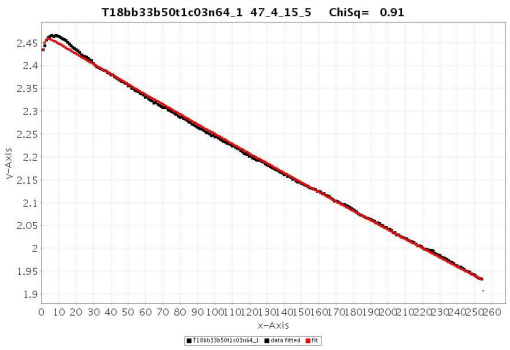
x-Axis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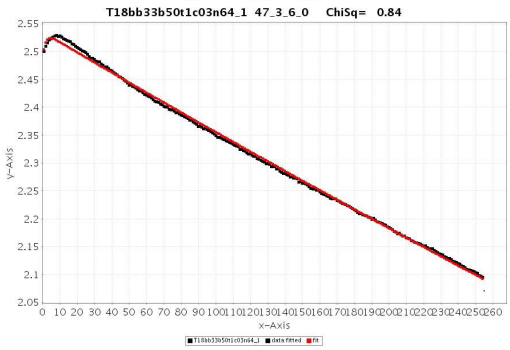
x-Axis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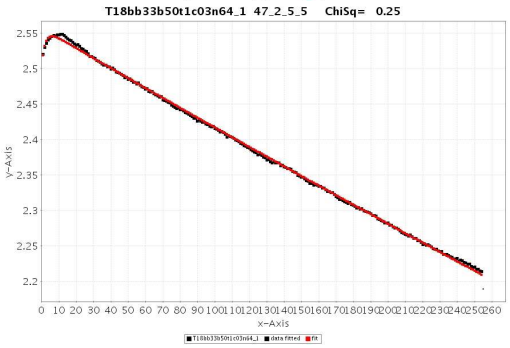
x-Axis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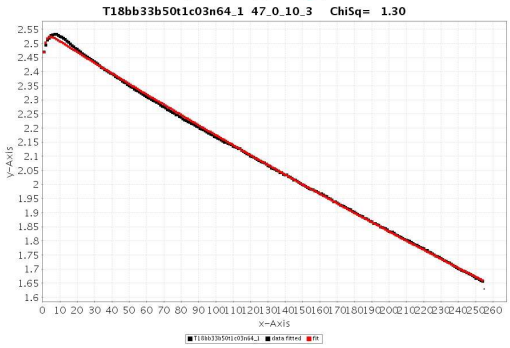
x-Axis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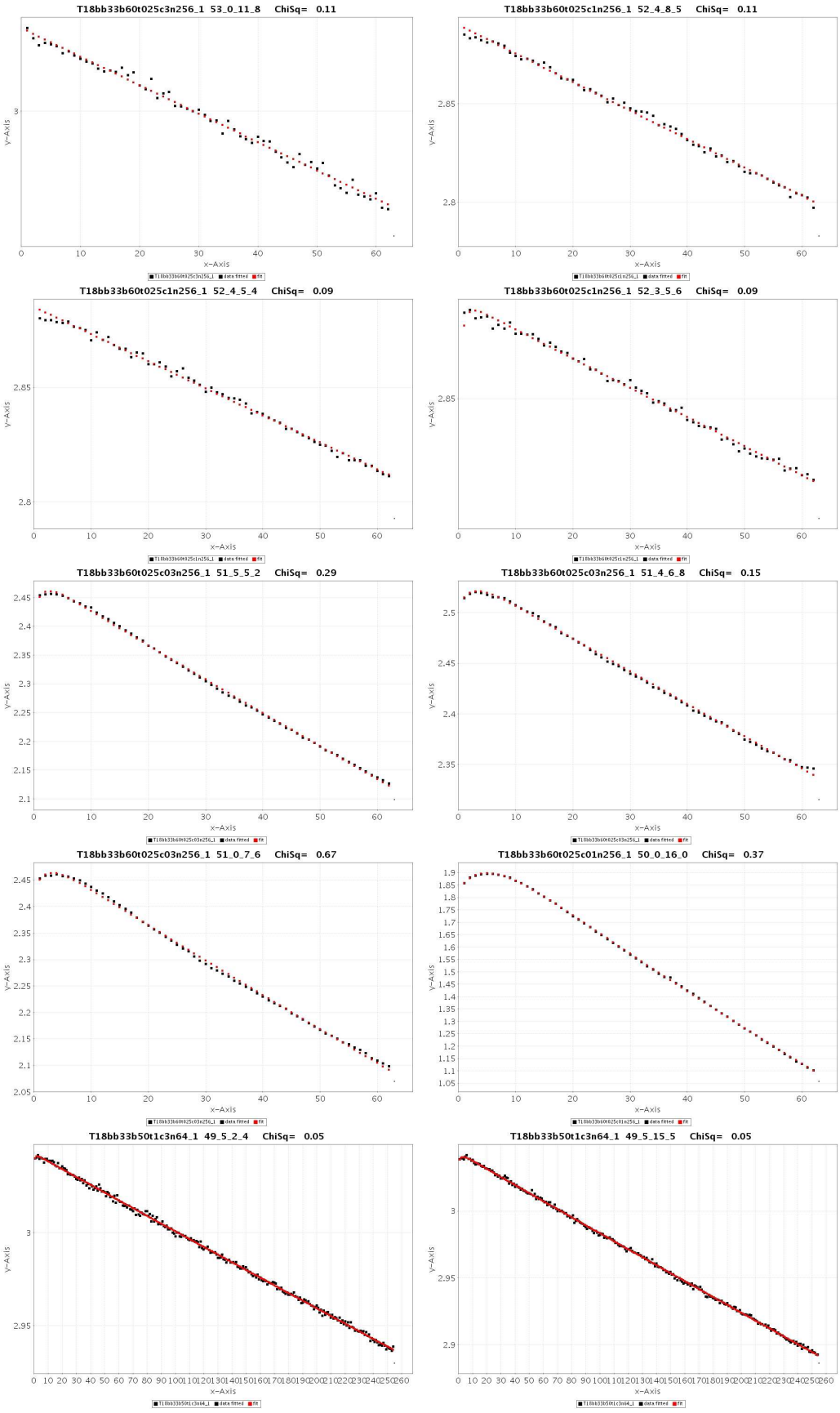
y-Axis
x-Axis


T18bb33b50t1c01n64_1 46_5_9_3 ChiSq= 1.92
y-Axis
x-Axis


T18bb33b50t1c01n64_1 46_4_8_5 ChiSq= 11.83
y-Axis
x-Axis


T18bb33b60t1c01n64_1 54_4_3_6 ChiSq= 79.98
y-Axis
x-Axis


T18bb33b60t1c01n64_1 54_3_6_7 ChiSq= 1.25
y-Axis
x-Axis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T18bb33b60t025c1n256_1 52_4_5_4 ChiSq= 0.09
T18bb33b60t025c1n256_1 52_3_5_6 ChiSq= 0.09
T18bb33b60t025c03n256_1 51_5_5_2 ChiSq= 0.29
T18bb33b60t025c03n256_1 51_4_6_8 ChiSq= 0.15
T18bb33b60t025c03n256_1 51_0_7_6 ChiSq= 0.67
T18bb33b60t025c01n256_1 50_0_16_0 ChiSq= 0.37
T18bb33b50t1c3n64_1 49_5_2_4 ChiSq= 0.05
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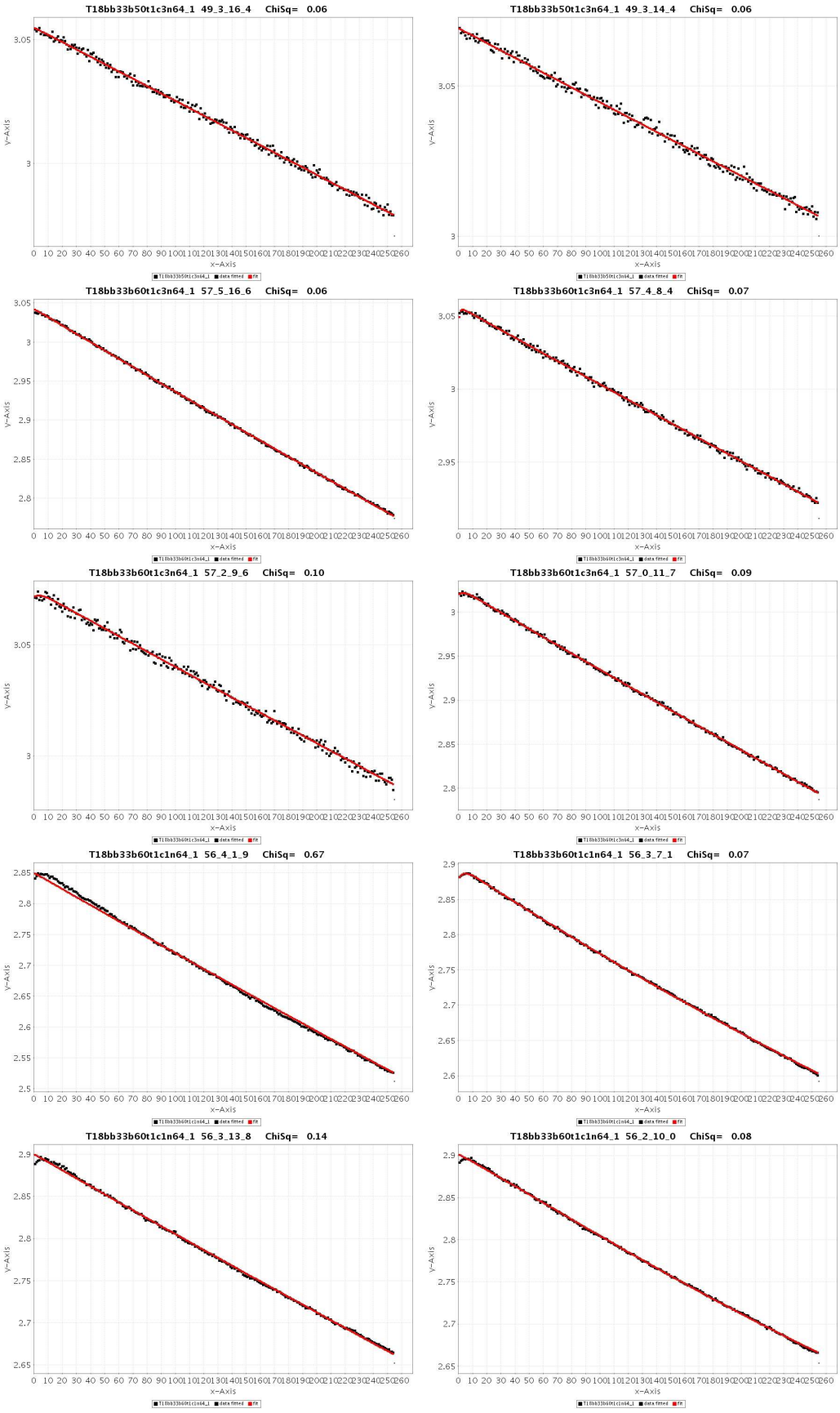
x-Axis
y-Axis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T18bb33b50t1c3n64_1 49_3_14_4 ChiSq= 0.06
T18bb33b60t1c3n64_1 57_5_16_6 ChiSq= 0.06
T18bb33b60t1c3n64_1 57_4_8_4 ChiSq= 0.07
T18bb33b60t1c3n64_1 57_2_9_6 ChiSq= 0.10
T18bb33b60t1c3n64_1 57_0_11_7 ChiSq= 0.09
T18bb33b60t1c1n64_1 56_4_1_9 ChiSq= 0.67
T18bb33b60t1c1n64_1 56_3_7_1 ChiSq= 0.07
T18bb33b60t1c1n64_1 56_3_13_8 ChiSq= 0.14
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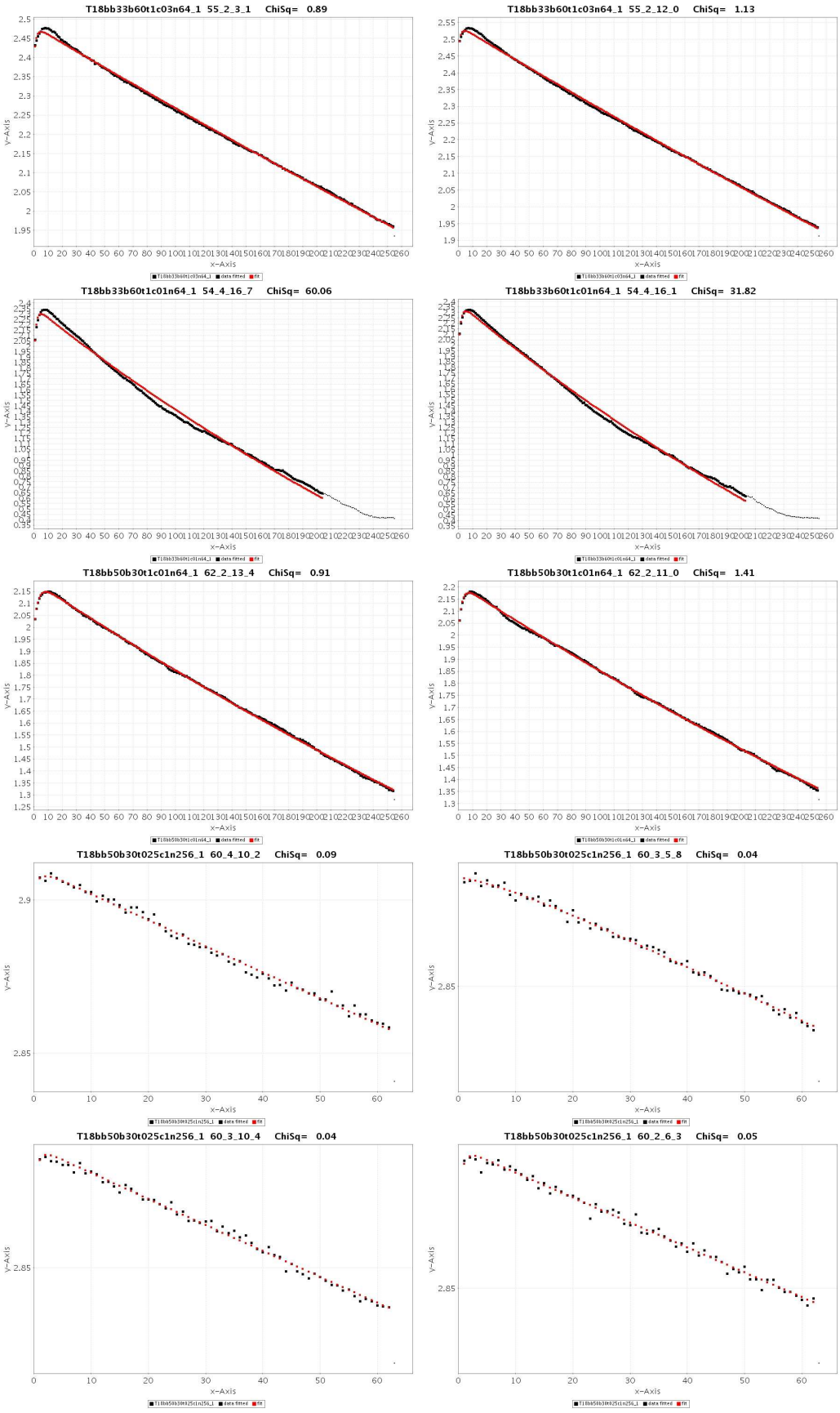
x-Axis
y-Axis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T18bb33b60t1c01n64_1 54_4_16_7 ChiSq= 60.06
T18bb33b60t1c01n64_1 54_4_16_1 ChiSq= 31.82
T18bb50b30t1c01n64_1 62_2_13_4 ChiSq= 0.91
T18bb50b30t1c01n64_1 62_2_11_0 ChiSq= 1.41
T18bb50b30t025c1n256_1 60_4_10_2 ChiSq= 0.09
T18bb50b30t025c1n256_1 60_3_5_8 ChiSq= 0.04
T18bb50b30t025c1n256_1 60_3_10_4 ChiSq= 0.04
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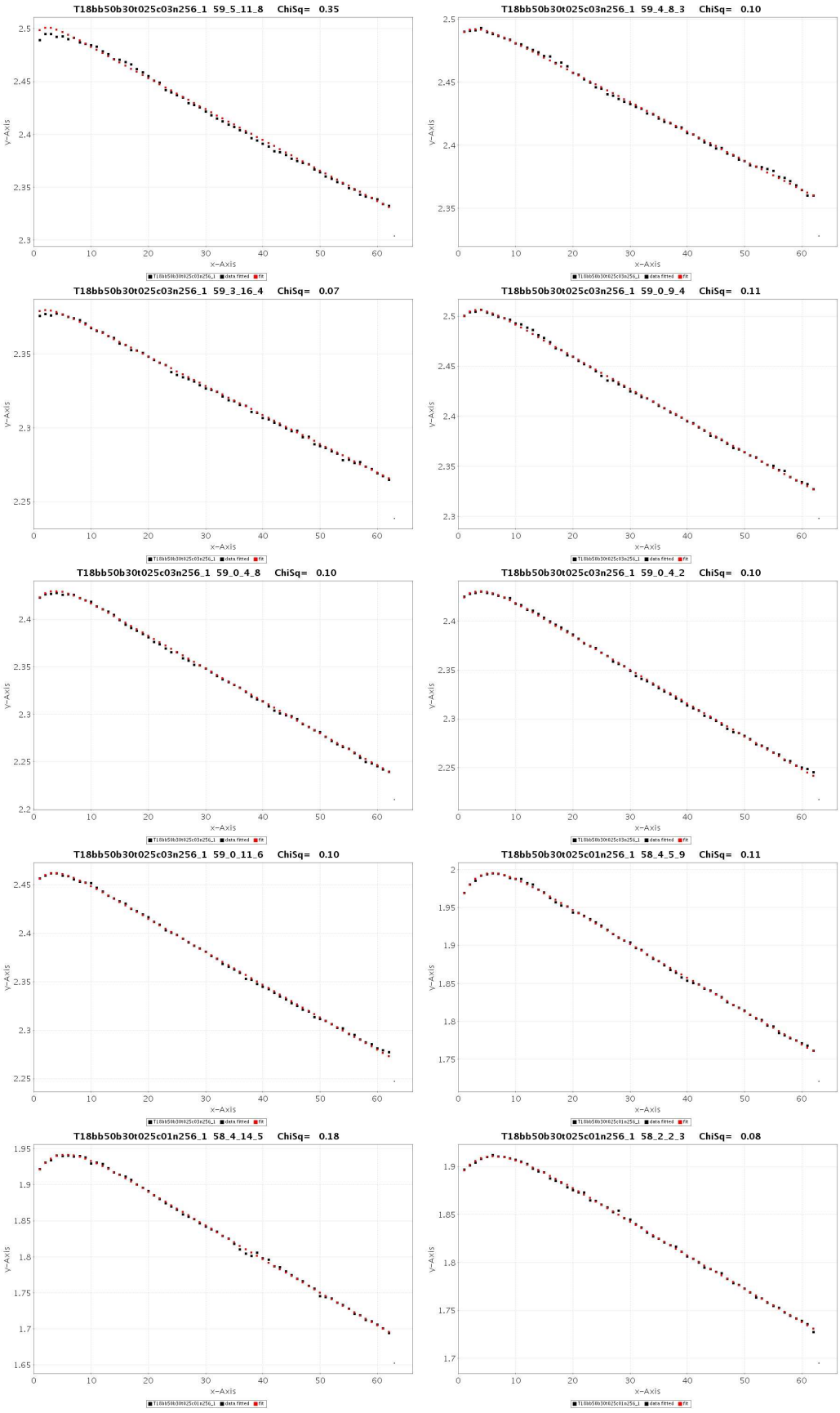
x-Axis
y-Axis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T18bb50b30t025c03n256_1 59_0_11_6 ChiSq= 0.10
T18bb50b30t025c01n256_1 58_4_5_9 ChiSq= 0.11
T18bb50b30t025c01n256_1 58_4_14_5 ChiSq= 0.18
T18bb50b30t025c01n256_1 58_2_2_3 ChiSq= 0.08
x-Axis
y-Axis


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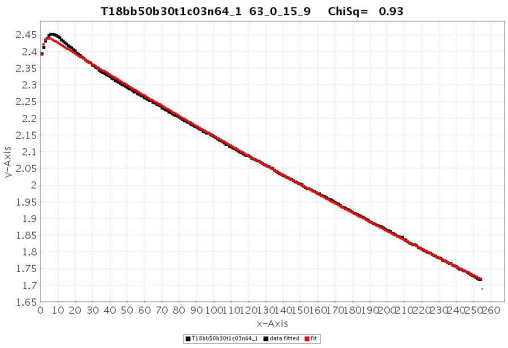
y-Axis
x-Axis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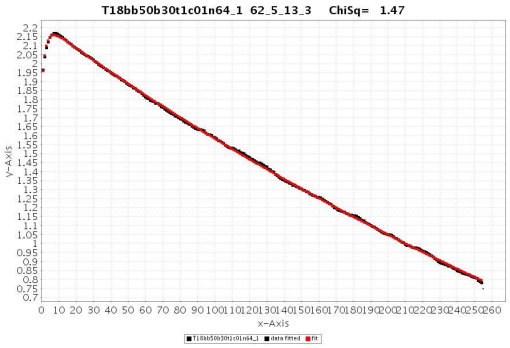
y-Axis
x-Axis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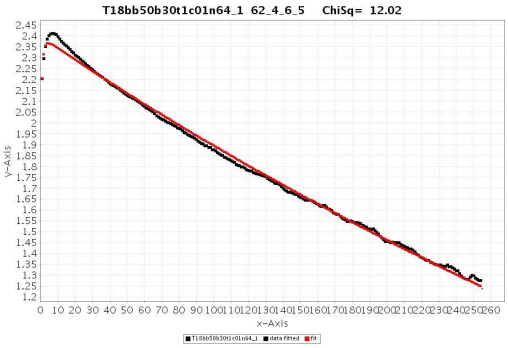
x-Axis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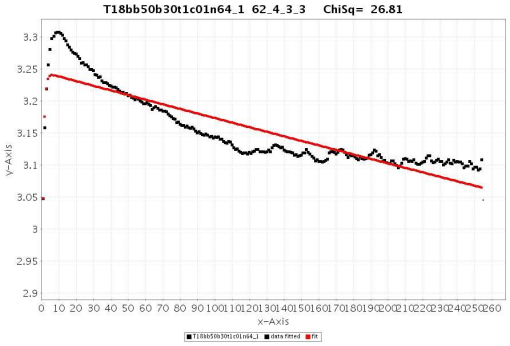
y-Axis
x-Axis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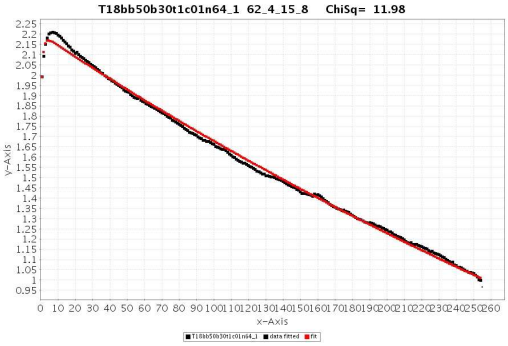
y-Axis
x-Axis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y-Axis
x-Axis


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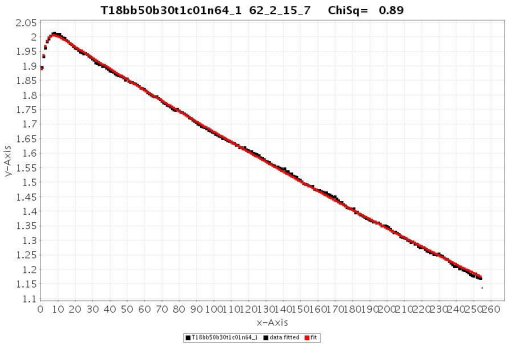
y-Axis
x-Axis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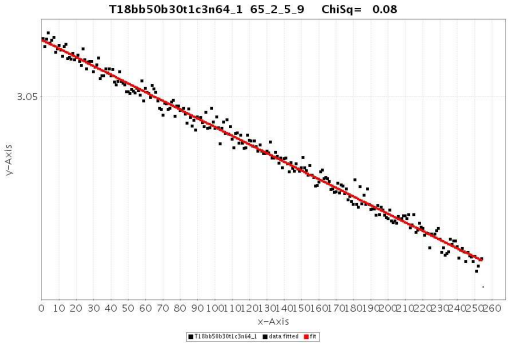
y-Axis
x-Axis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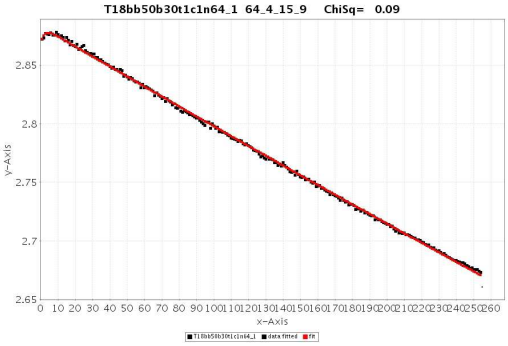
y-Axis
x-Axis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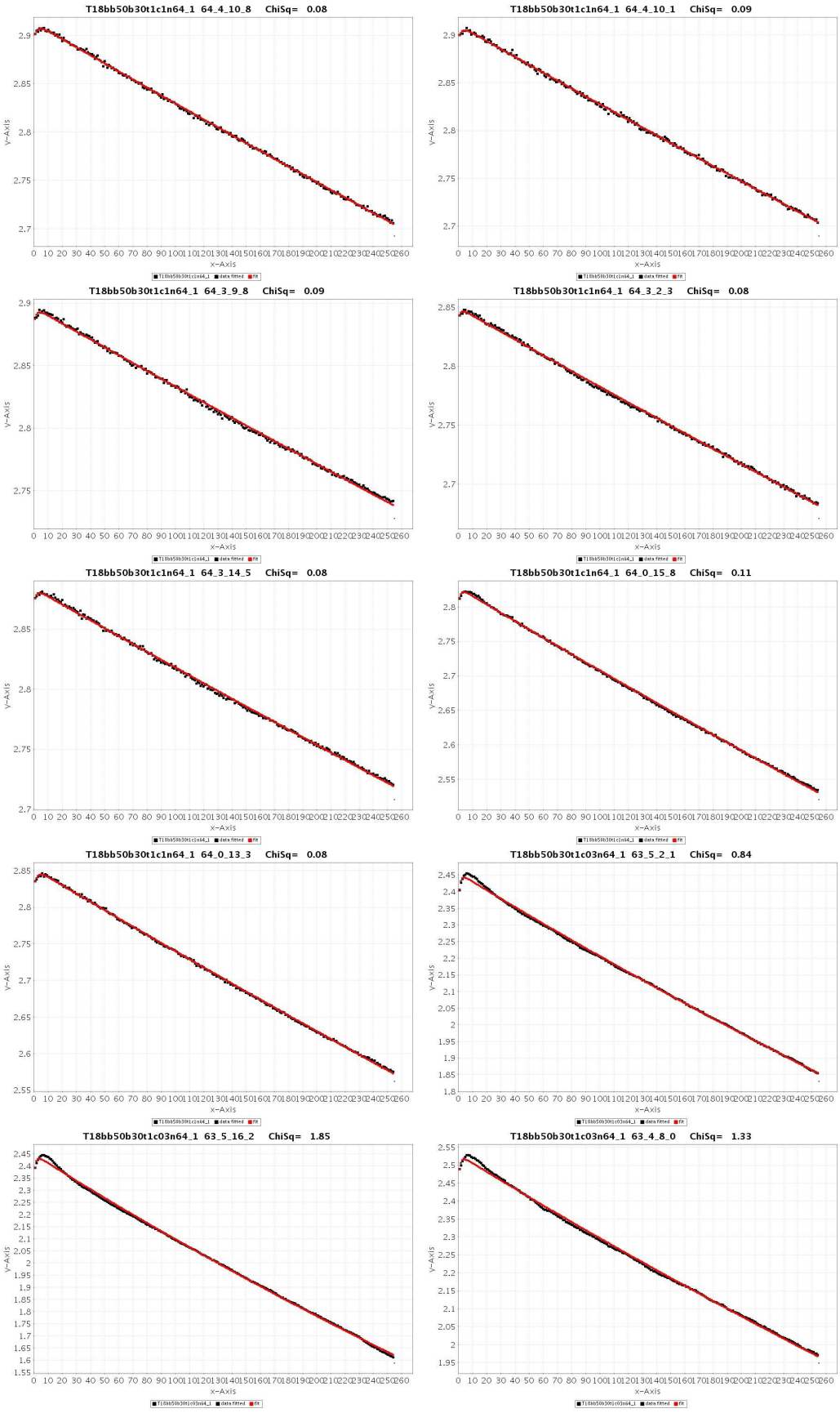
y-Axis
x-Axis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T18bb50b30t1c1n64_1 64_3_2_3 ChiSq= 0.08
T18bb50b30t1c1n64_1 64_3_14_5 ChiSq= 0.08
T18bb50b30t1c1n64_1 64_0_15_8 ChiSq= 0.11
T18bb50b30t1c1n64_1 64_0_13_3 ChiSq= 0.08
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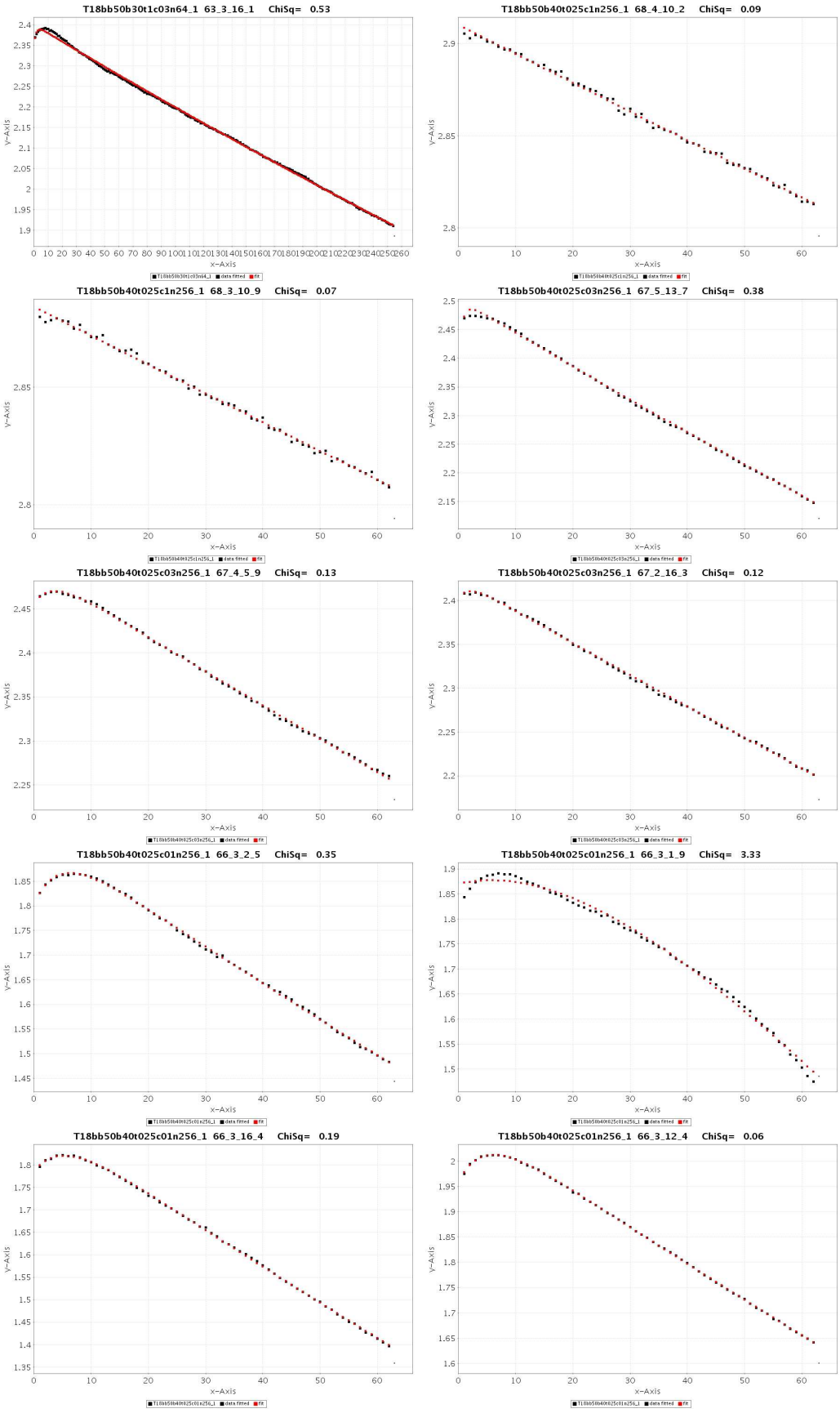
x-Axis
y-Axis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T18bb50b40t025c03n256_1 67_4_5_9 ChiSq= 0.13
T18bb50b40t025c03n256_1 67_2_16_3 ChiSq= 0.12
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T18bb50b40t025c01n256_1 66_3_16_4 ChiSq= 0.19
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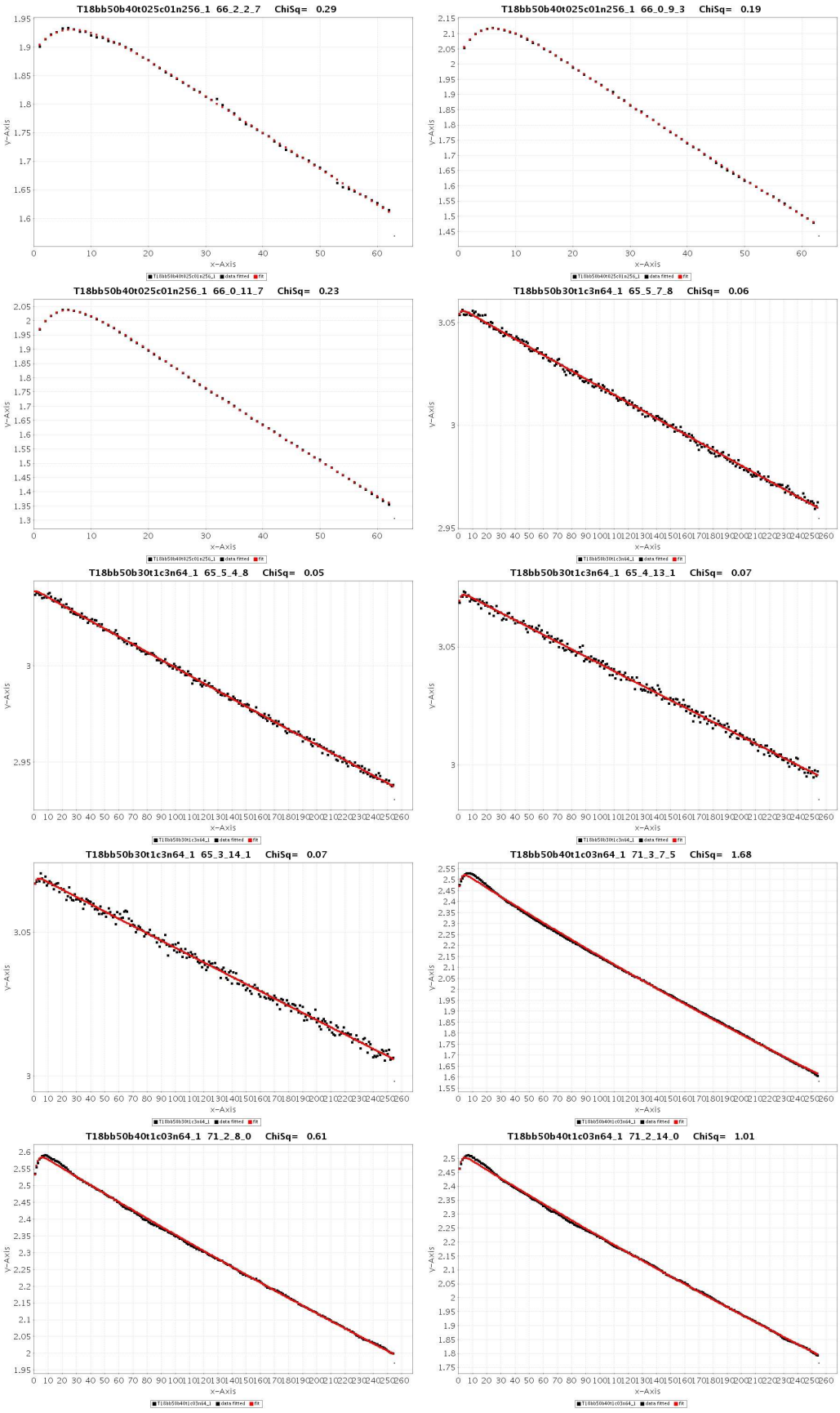
x-Axis
y-Axis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T18bb50b30t1c3n64_1 65_5_7_8 ChiSq= 0.06
T18bb50b30t1c3n64_1 65_5_4_8 ChiSq= 0.05
T18bb50b30t1c3n64_1 65_4_13_1 ChiSq= 0.07
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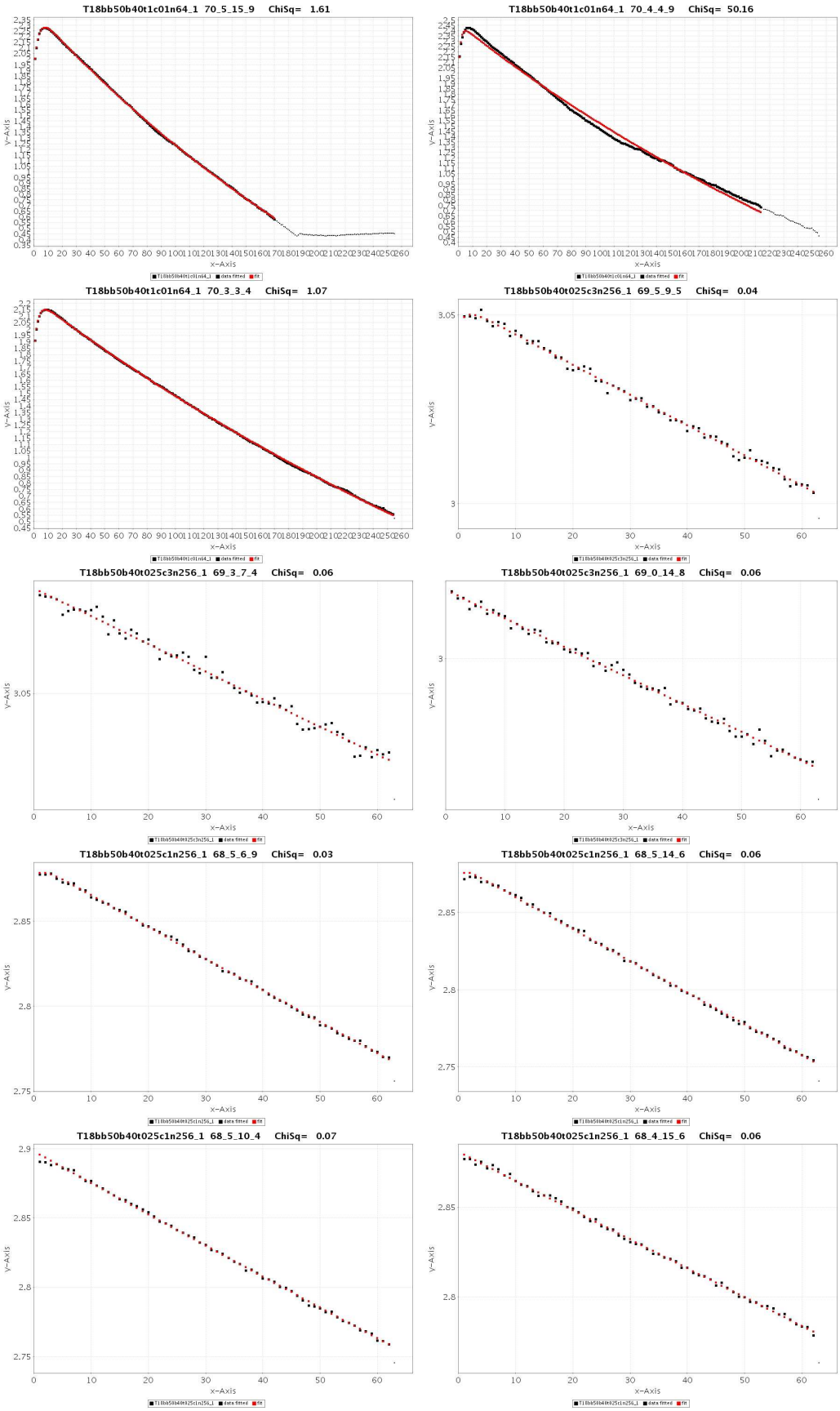
x-Axis
y-Axis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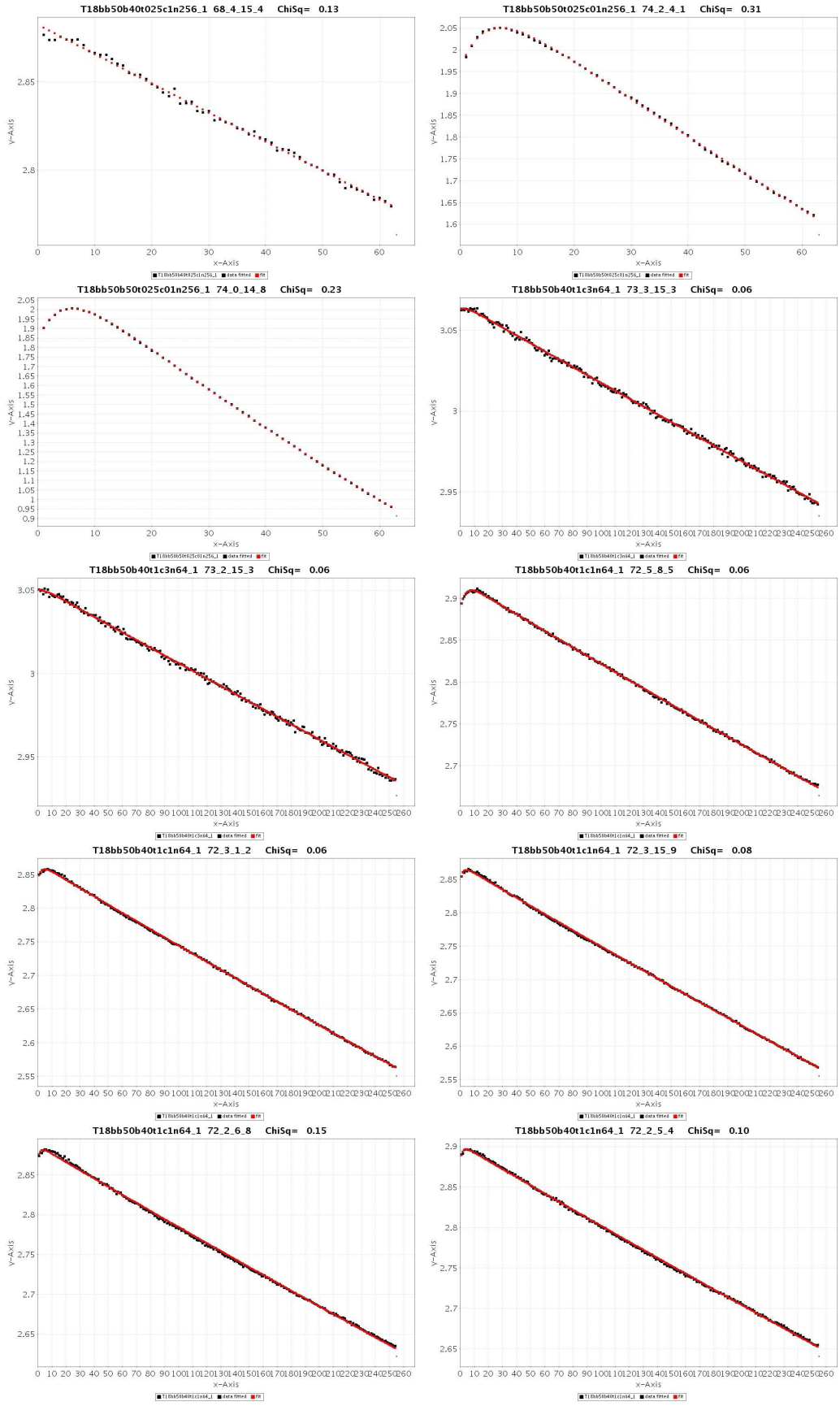
x-Axis
y-Axis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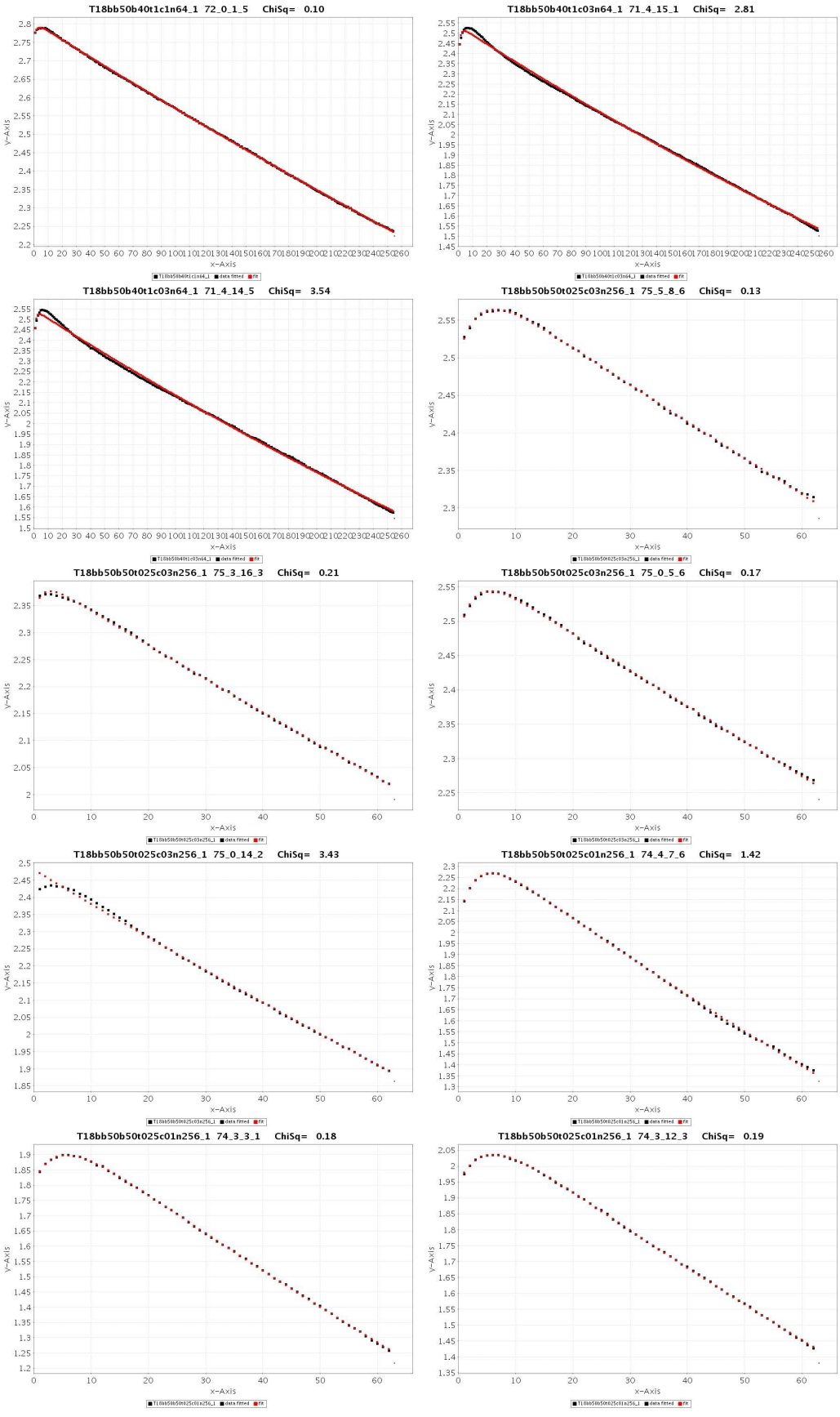
x-Axis
y-Axis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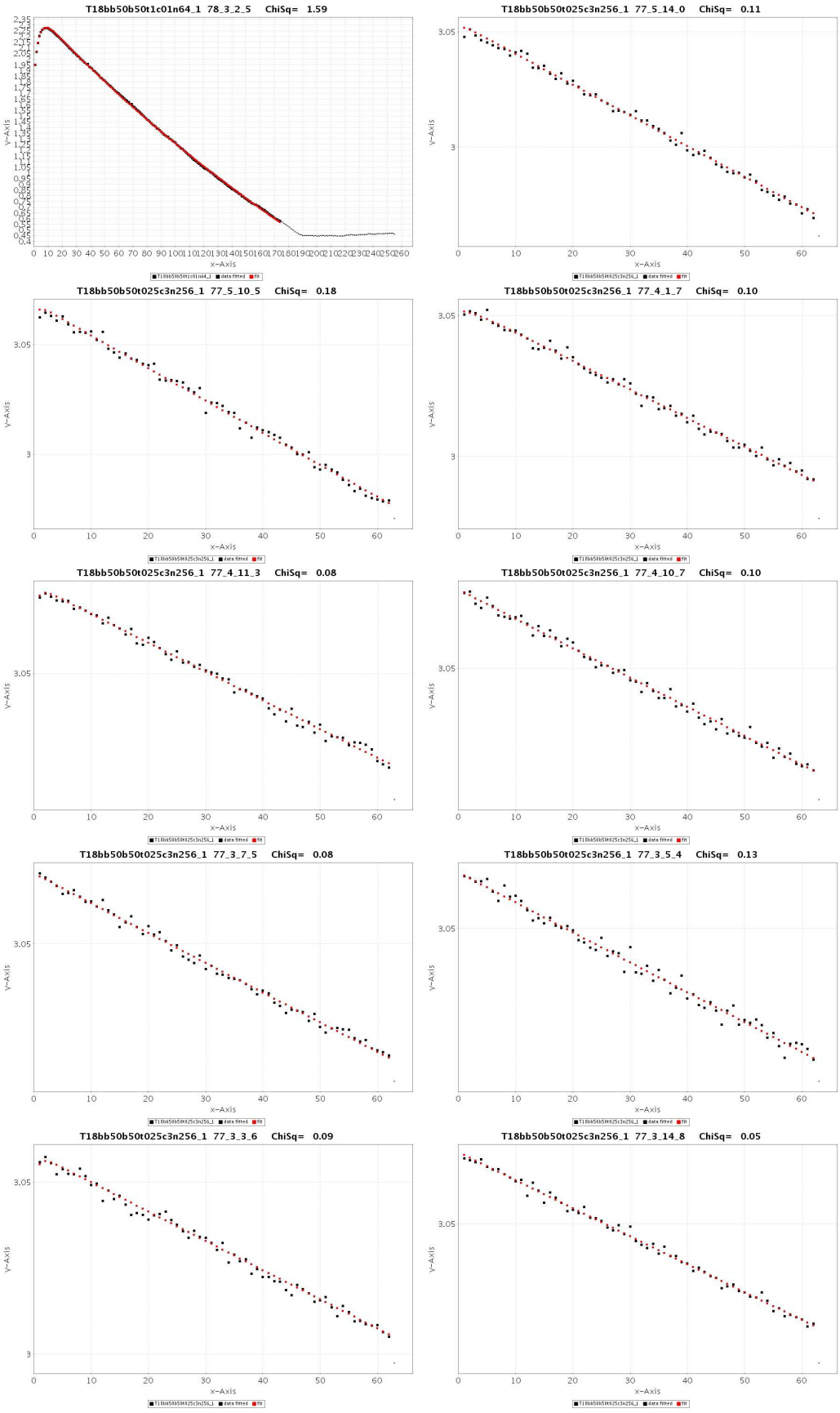
x-Axis
y-Axis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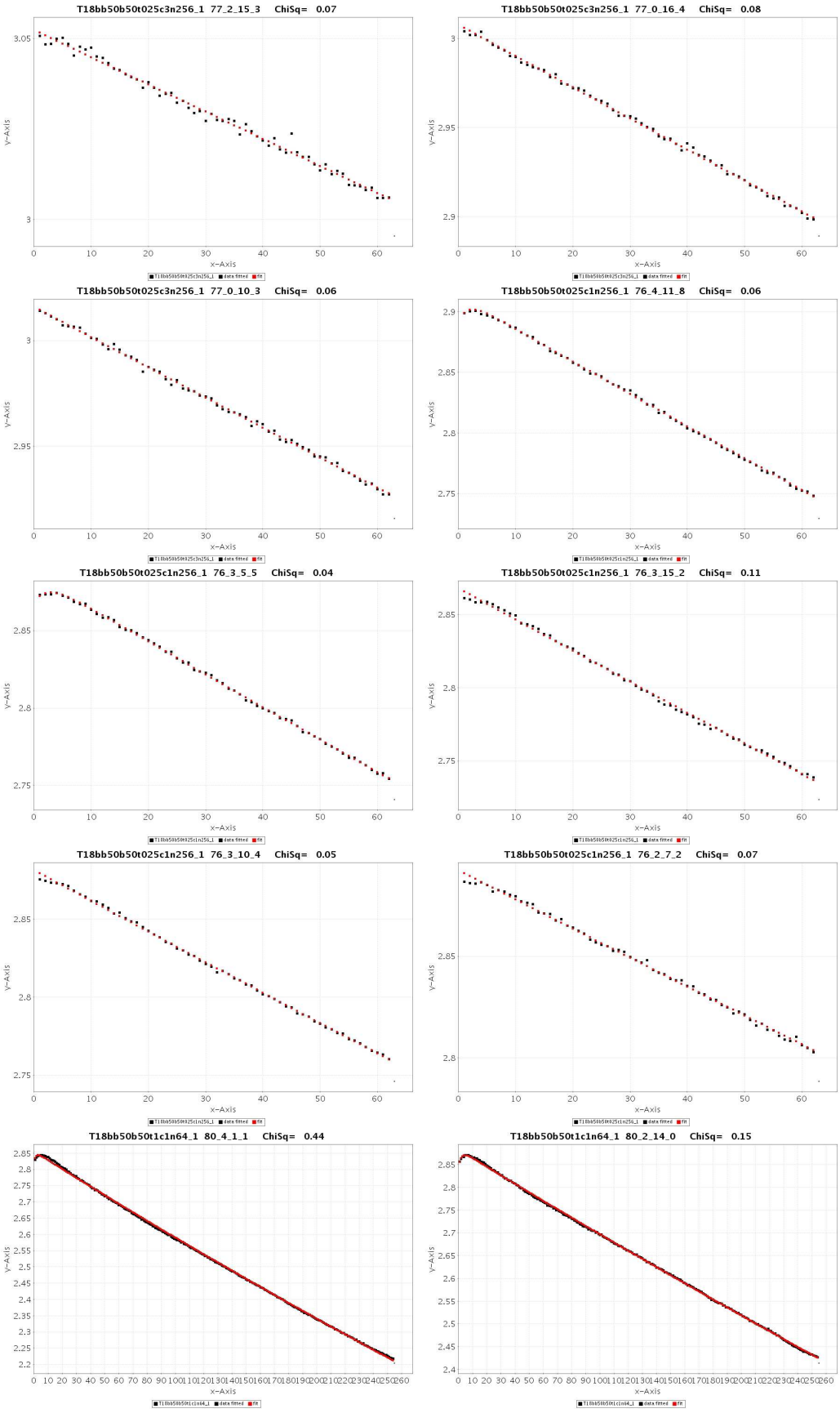
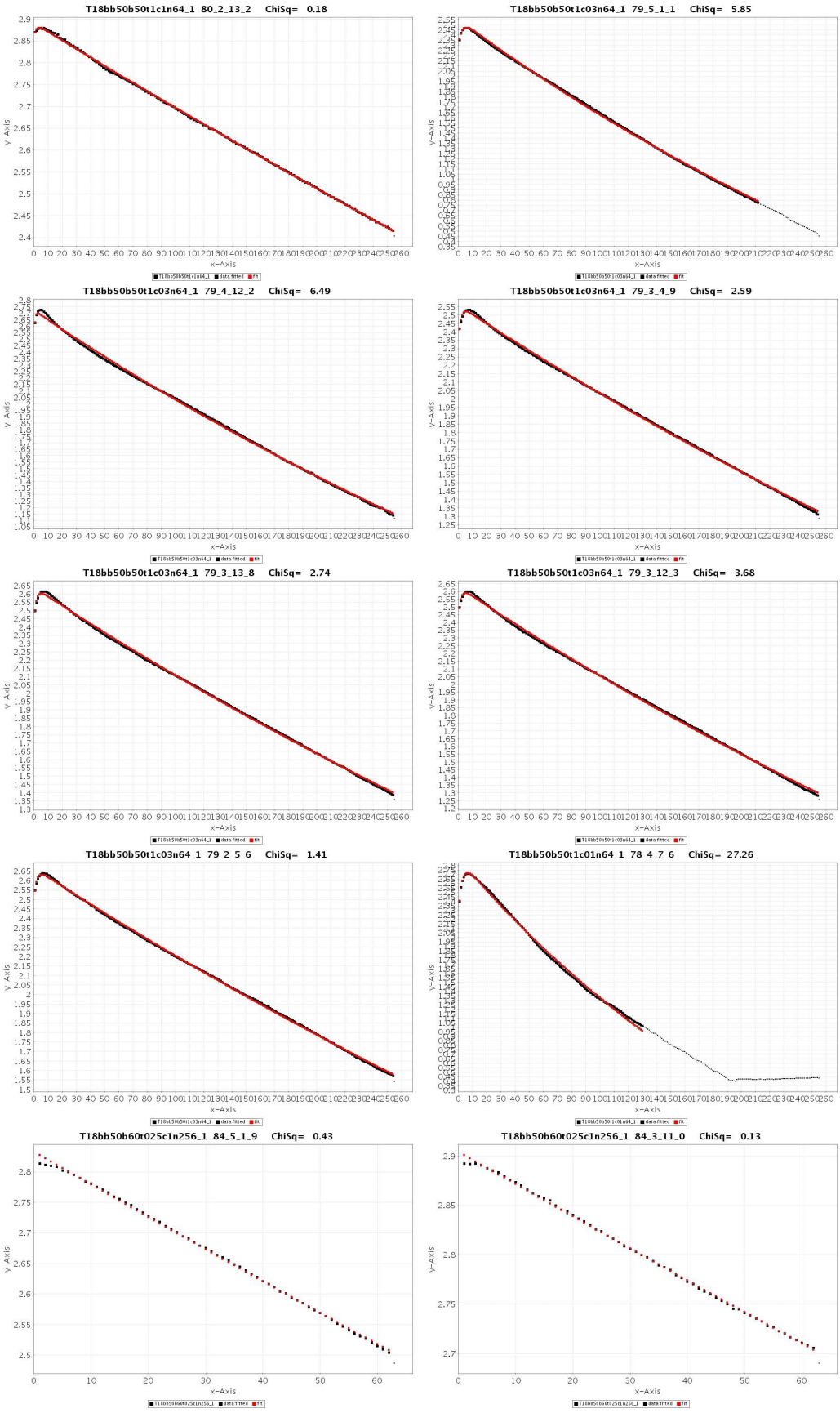
x-Axis
y-Axis


T18bb50b50t025c3n256_1 77_2_15_3 ChiSq= 0.07
T18bb50b50t025c3n256_1 77_0_16_4 ChiSq= 0.08
T18bb50b50t025c3n256_1 77_0_10_3 ChiSq= 0.06
T18bb50b50t025c1n256_1 76_4_11_8 ChiSq= 0.06
T18bb50b50t025c1n256_1 76_3_5_5 ChiSq= 0.04
T18bb50b50t025c1n256_1 76_3_15_2 ChiSq= 0.11
T18bb50b50t025c1n256_1 76_3_10_4 ChiSq= 0.05
T18bb50b50t025c1n256_1 76_2_7_2 ChiSq= 0.07
T18bb50b50t1c1n64_1 80_4_1_1 ChiSq= 0.44
T18bb50b50t1c1n64_1 80_2_14_0 ChiSq= 0.15
x-Axis
y-Axis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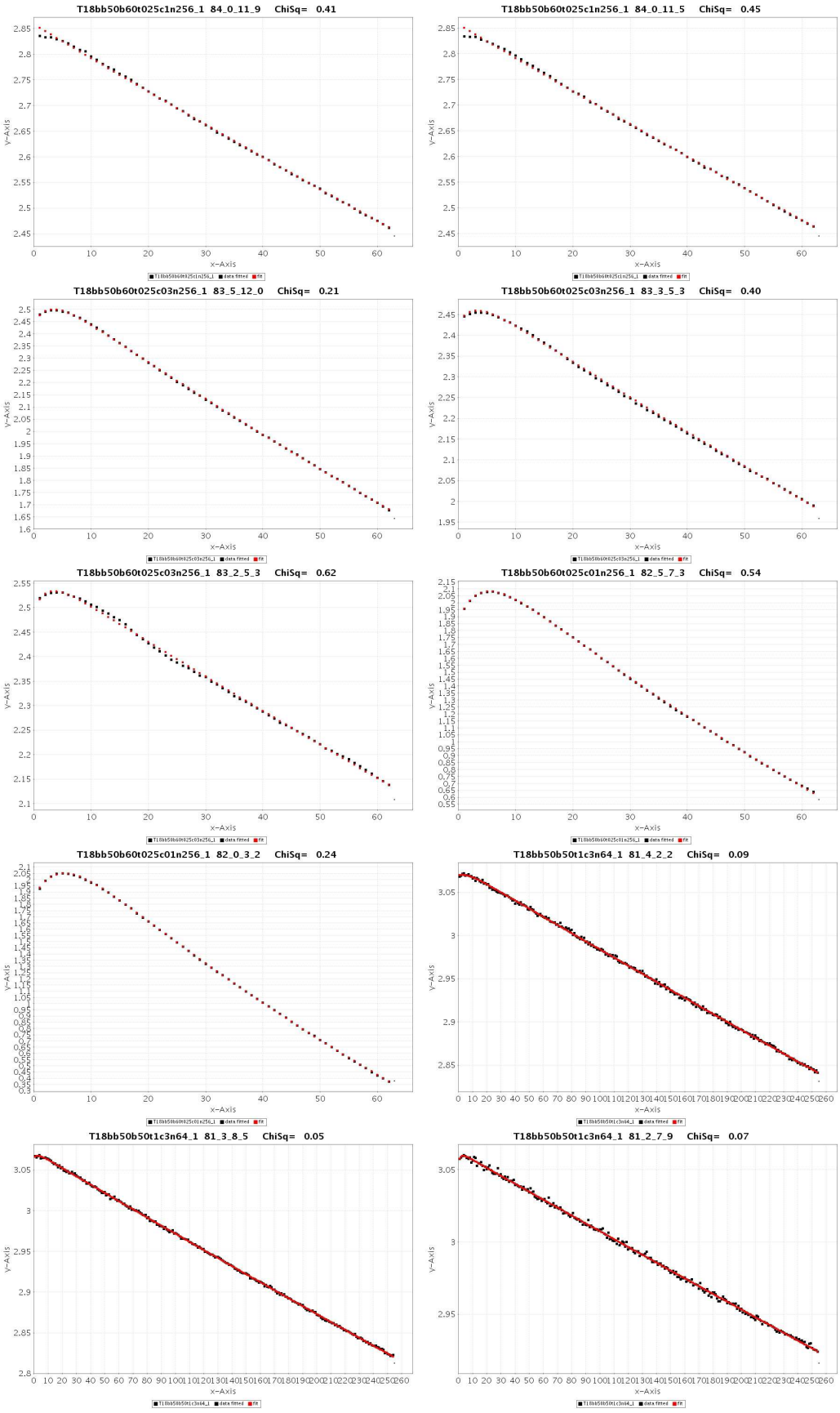
T18bb50b50t1c03n64_1 79_4_12_2 ChiSq= 6.49
T18bb50b50t1c03n64_1 79_3_4_9 ChiSq= 2.59
T18bb50b50t1c03n64_1 79_3_13_8 ChiSq= 2.74
T18bb50b50t1c03n64_1 79_3_12_3 ChiSq= 3.68
T18bb50b50t1c03n64_1 79_2_5_6 ChiSq= 1.41
T18bb50b50t1c01n64_1 78_4_7_6 ChiSq= 27.26
T18bb50b60t025c1n256_1 84_5_1_9 ChiSq= 0.43
T18bb50b60t025c1n256_1 84_3_11_0 ChiSq= 0.13
x-Axis
y-Axis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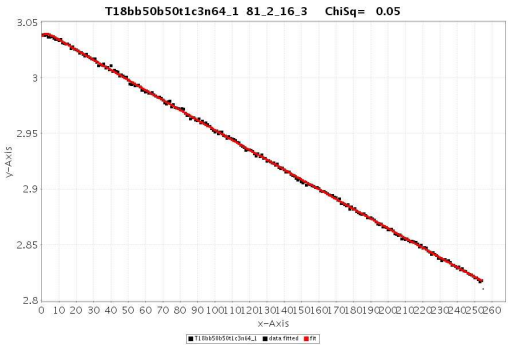
T18bb50b60t025c03n256_1 83_5_12_0 ChiSq= 0.21
T18bb50b60t025c03n256_1 83_3_5_3 ChiSq= 0.40
T18bb50b60t025c03n256_1 83_2_5_3 ChiSq= 0.62
T18bb50b60t025c01n256_1 82_5_7_3 ChiSq= 0.54
T18bb50b60t025c01n256_1 82_0_3_2 ChiSq= 0.24
T18bb50b50t1c3n64_1 81_4_2_2 ChiSq= 0.09
T18bb50b50t1c3n64_1 81_3_8_5 ChiSq= 0.05
T18bb50b50t1c3n64_1 81_2_7_9 ChiSq= 0.07
y-Axis
x-Axis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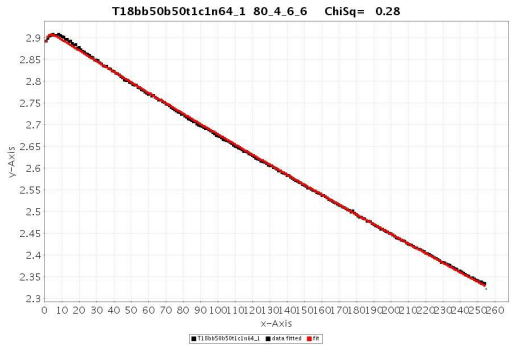
y-Axis
x-Axis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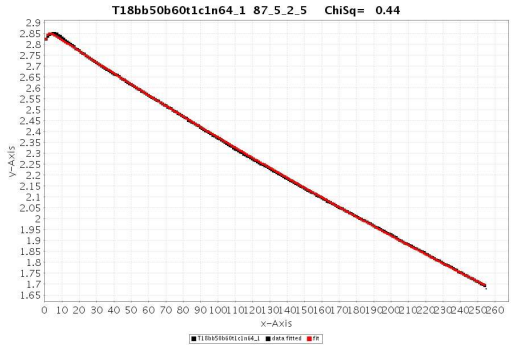
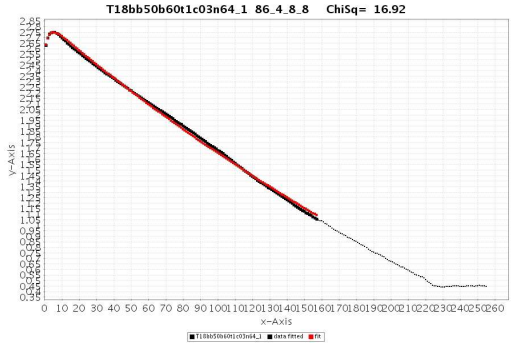
y-Axis
x-Axis

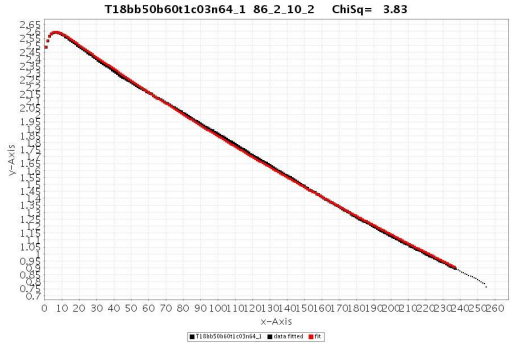

T18bb50b50t1c1n64_1 80_4_1_9 ChiSq= 0.46
y-Axis
x-Axis


T18bb50b60t1c1n64_1 87_5_2_5 ChiSq= 0.44
y-Axis
x-Axis


T18bb50b60t1c03n64_1 86_5_2_2 ChiSq= 5.33
y-Axis
x-Axis


T18bb50b60t1c03n64_1 86_4_8_8 ChiSq= 16.92
y-Axis
x-Axis


T18bb50b60t1c03n64_1 86_4_15_3 ChiSq= 19.34
y-Axis
x-Axis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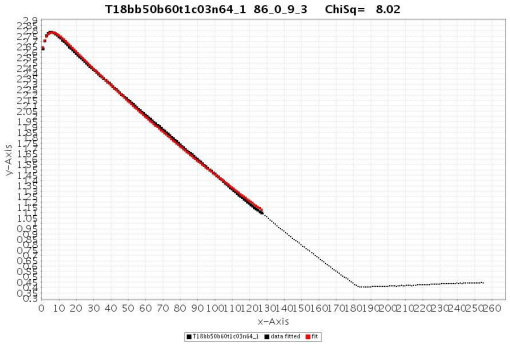
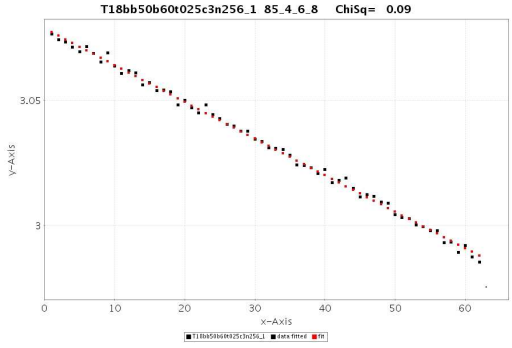
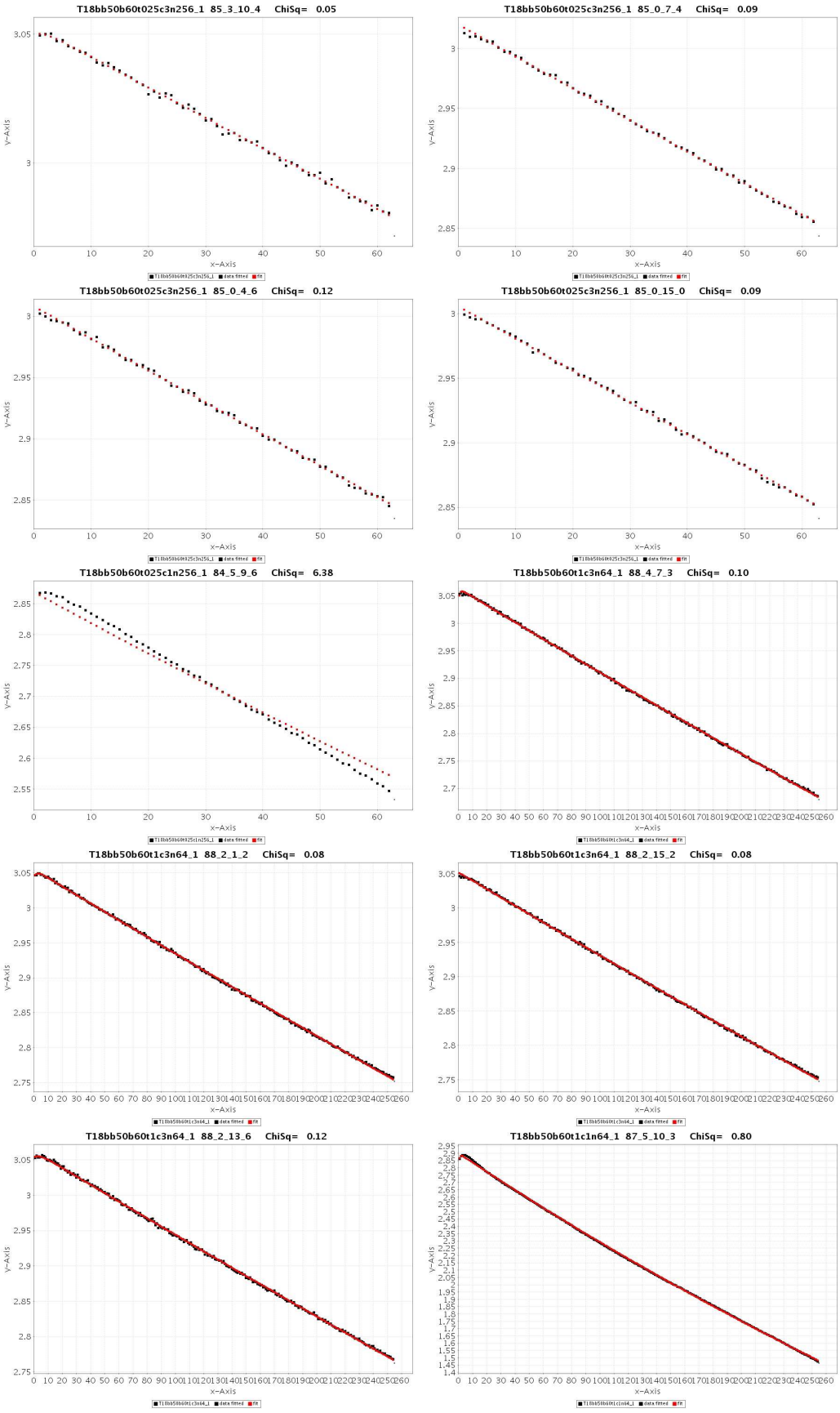
y-Axis
x-Axis


T18bb50b60t1c03n64_1 86_0_9_3 ChiSq= 8.02
y-Axis
x-Axis


T18bb50b60t025c3n256_1 85_4_6_8 ChiSq= 0.09
y-Axis
x-Axis


T18bb50b60t025c3n256_1 85_3_10_4 ChiSq= 0.05
T18bb50b60t025c3n256_1 85_0_7_4 ChiSq= 0.09
T18bb50b60t025c3n256_1 85_0_4_6 ChiSq= 0.12
T18bb50b60t025c3n256_1 85_0_15_0 ChiSq= 0.09
T18bb50b60t025c1n256_1 84_5_9_6 ChiSq= 6.38
T18bb50b60t1c3n64_1 88_4_7_3 ChiSq= 0.10
T18bb50b60t1c3n64_1 88_2_1_2 ChiSq= 0.08
T18bb50b60t1c3n64_1 88_2_15_2 ChiSq= 0.08
T18bb50b60t1c3n64_1 88_2_13_6 ChiSq= 0.12
T18bb50b60t1c1n64_1 87_5_10_3 ChiSq= 0.80
x-Axis
y-Axis

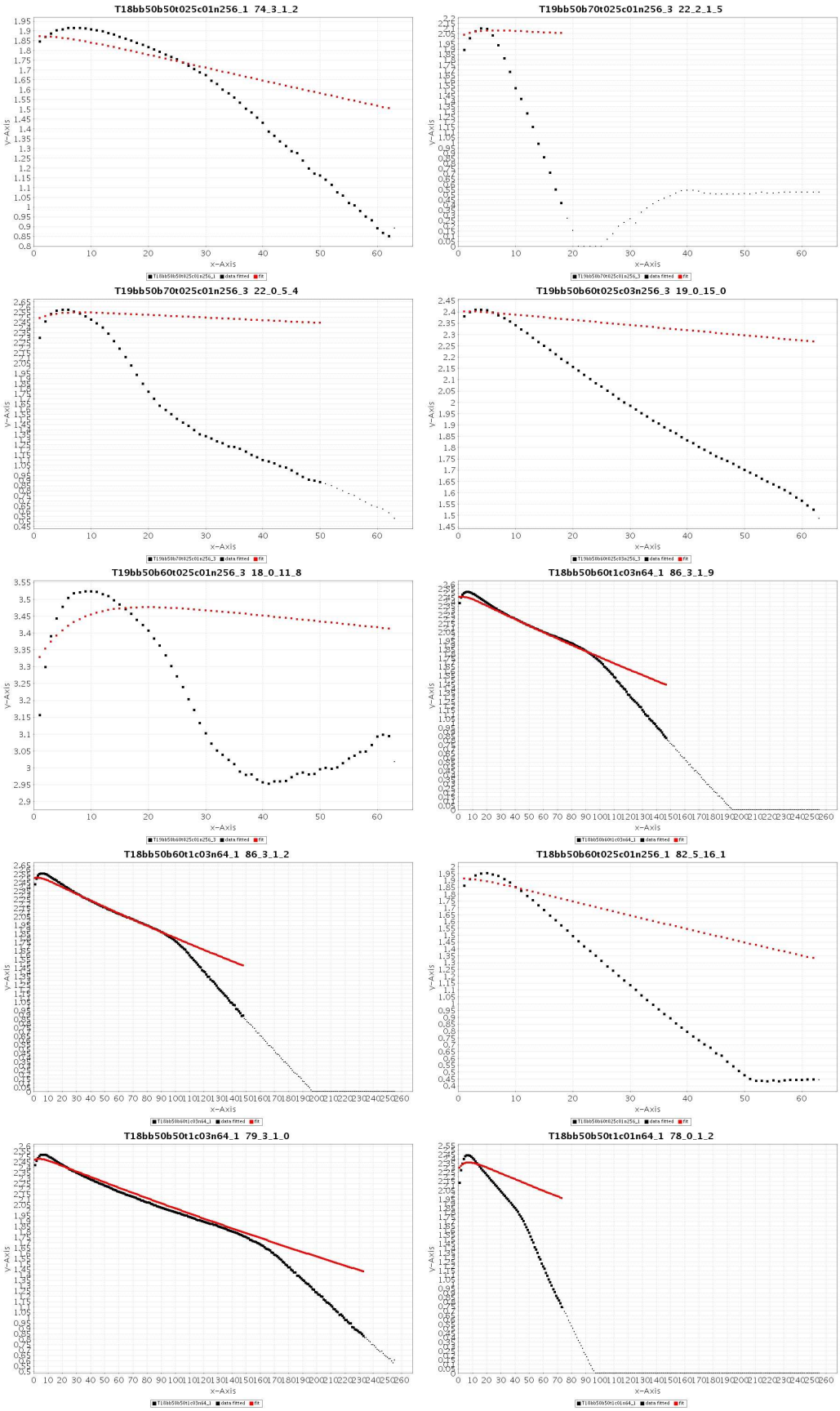


Figure 2: Examples of the fits that failed. Allmost all are pathological ramps.