

## Introduction to Mantid

The Mantid project provides a framework that supports high-performance computing and visualization of scientific data. Mantid has been created to manipulate and analyse neutron and muon data, but could be applied to many other techniques. The framework is open source and supported on multiple target platforms (Windows, Linux, Mac). Tailor made data reduction and analysis procedures can be formulated using Python scripting. However, this tutorial focuses on the reduction and analysis of Muon data collected from any of the ISIS muon instruments via a Graphical User Interface (GUI). This interface has been specifically designed to guide the user through the data reduction and analysis procedure.

***NB: this Introduction and all subsequent workshop instruction is based on Mantid : Version 3.1.0. All procedures have been tested using the Windows 7 installation.***

Mantid can be downloaded from,

<http://download.mantidproject.org/>

and all the data used for the tutorials can be found as a downloadable ZIP file at:

[www.isis.stfc.ac.uk/groups/muons/downloads/](http://www.isis.stfc.ac.uk/groups/muons/downloads/)

For reliability choose the 'Latest Stable Build'. However, as the interface is developing rapidly, the 'Nightly Development Build' may contain additional features and bug fixes that are useful for data analysis. The accompanying Wiki,

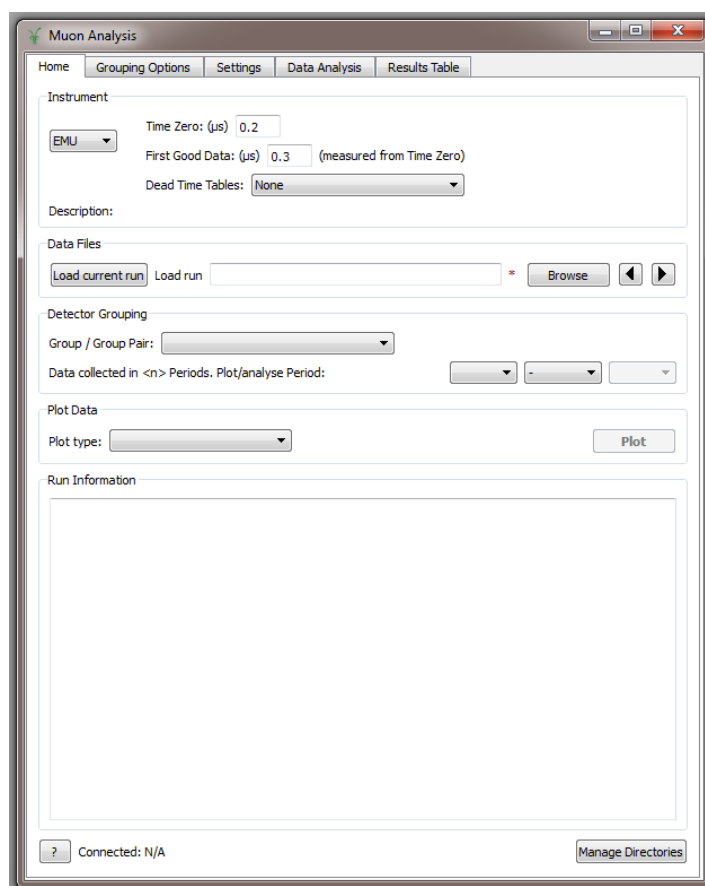
[http://www.mantidproject.org/Main\\_Page](http://www.mantidproject.org/Main_Page)

contains a wealth of information and supplementary information regarding the Mantid project and its functionality.

## Getting Started

The worked examples presented in this workshop will be analysed using a GUI. This GUI is launched by following: [Interfaces](#) > [Muon Analysis](#) from the tool bar at the top of the main MantidPlot window. *NOTE: the manual [Mantid 4  \$\mu^+\$](#)  will be referred to throughout. Make sure you have a copy*

- ✚ Launch the main Mantid interface by clicking on the MantidPlot icon on the desktop

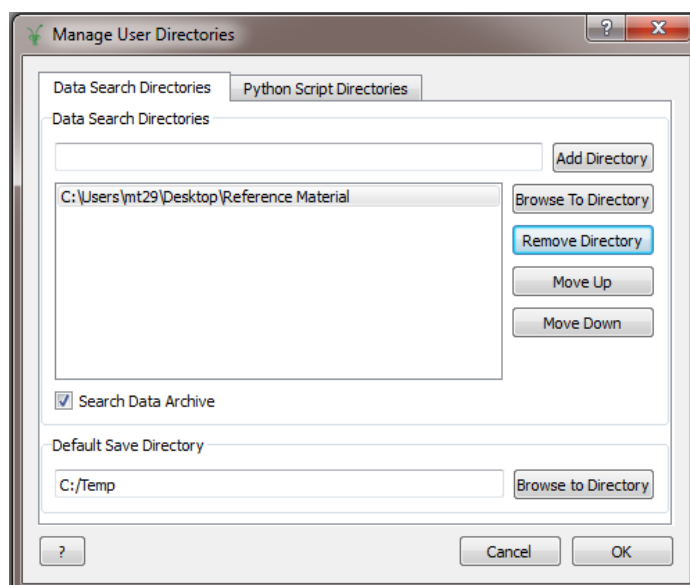


### 1. The [Muon Analysis](#) window

## I. Setting data file locations

Before starting you should ensure that Mantid is configured for your needs. In particular you should add paths to directories which contain the worked example data. All the data used in this workbook can be found in folder [Desktop > Reference Material](#). To set this path, click on [File > Manage User Directories](#). The window below will appear. Data can be added as a path by browsing or typing the directory name in the field below [Data Search Directories](#) and then clicking [Add Directory](#). Once a path has been added, data stored in that location can be accessed simply by entering the run number.

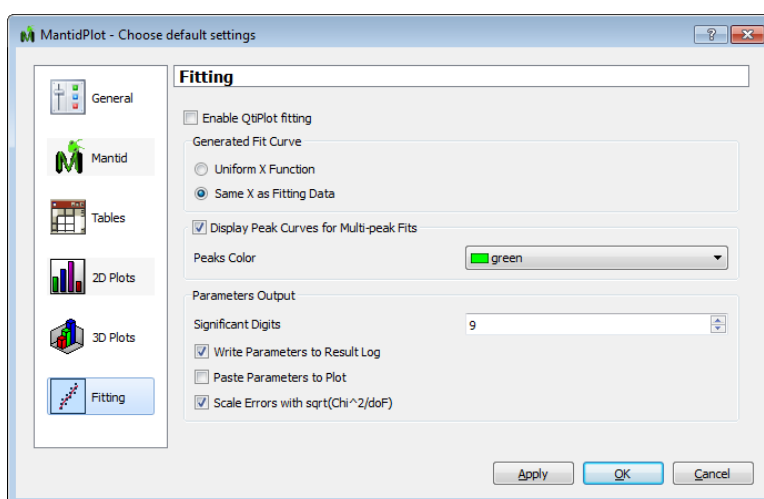
✚ set paths for your raw data and working directories



2. *The [Manage User Directories](#) window*

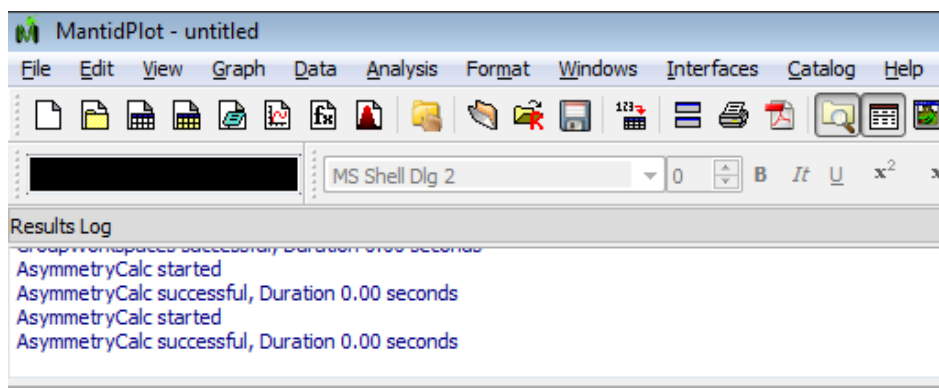
## II. QtiPlot

Enabling QtiPlot allows data sets and workspaces to be analysed using a suite of inbuilt Origin fitting algorithms. To enable QtiPlot follow [View > Preferences > Fitting](#). The following window should appear. Select [Enable QtiPlot Fitting](#)



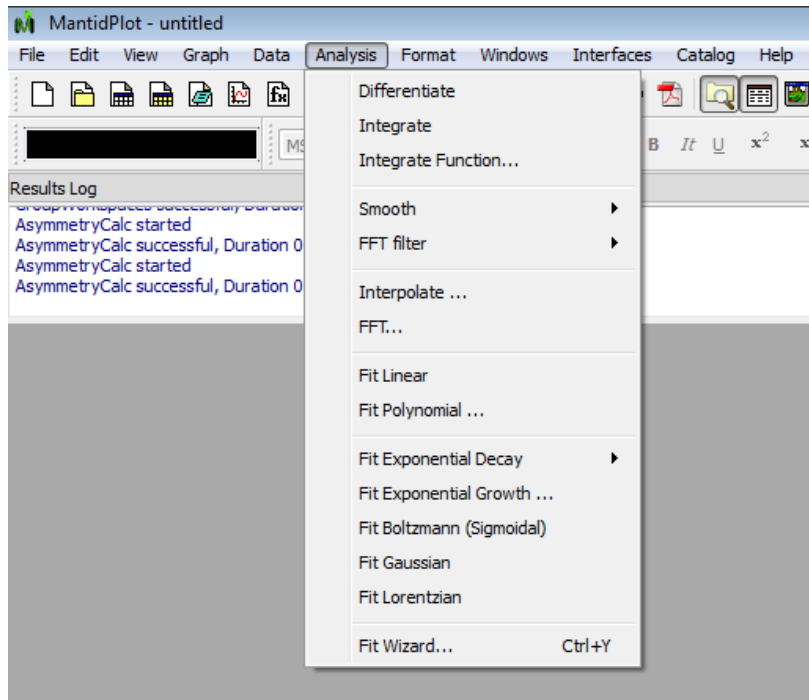
### 3. The *Choose Default Settings* window

When QtiPlot fitting has been enabled, **and a data file has been loaded**, [Analysis](#) appears in the list of options above the main MantidPlot window toolbar.



### 4. Tool bar options at the top of MantidPlot. [Analysis](#) appears when QtiPlot is enabled

The fitting options that will appear under [Analysis](#) are shown below



## 5. The *QtiPlot* analysis options

✚ Ensure QtiPlot is enabled

## Basic Mantid Data Manipulation

In this section you will:

- familiarise yourself with the content of Mantid workspaces
- learn how to examine histograms
- learn how to read / export data
- learn how to overlay data / change plot style

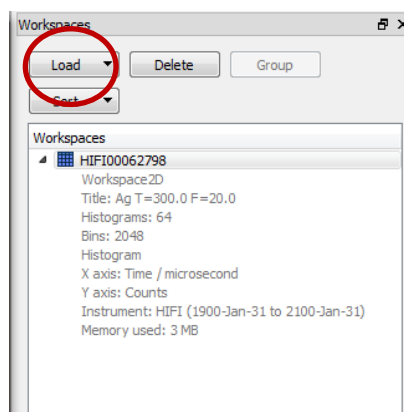
### I. Basic LOAD Command Workspaces

Mantid utilises workspaces to hold data. These come in several forms, but the most common is the [Matrix Workspace](#) which represents XYE data for one, or several, spectra. The data contained in a workspace can viewed as a matrix or as a table, and graphed in many ways including line graphs, contour plots and 3D graphs. Interaction with workspaces is typically through a GUI interface. [Matrix Workspaces](#) are typically created by executing one of Mantid's 'Load' algorithms or are the output of algorithms which take a [Matrix Workspace](#) as input. In addition to data, workspaces hold a [workspace history](#) which lists the algorithms that have been applied to the data.

First we will load a raw data file **WITHOUT USING** the Mantid Analysis GUI and examine its content:

- In the MantidPlot 'Workspaces' pane(see Fig 6) use the LOAD button to import file HIFI00062798.nxs

- Click on the 'arrow' beside the file name – this allows information about the format of data file to be viewed. The following should be seen in the Workspace List pane to the right of the screen.



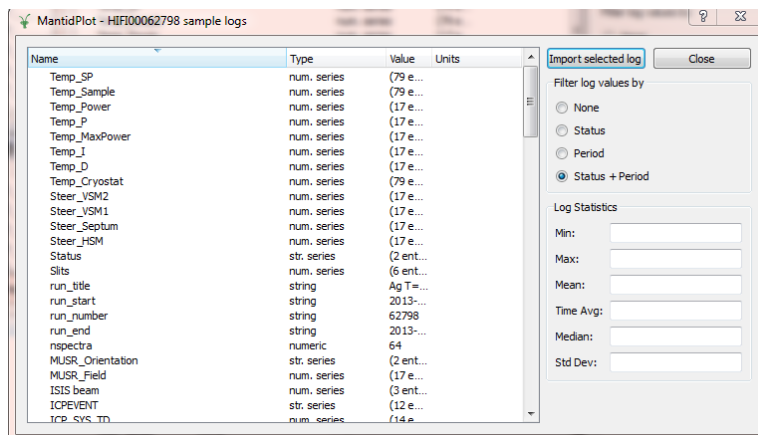
## 6. The *workspace list* window

We find that a workspace called HIFI00062798 is created and ...

- is a 2D array
- the data has been collected from a silver calibration measurement taken in a transverse field of 20G
- it contains 64 spectra (or histograms i.e. one for each HiFi detector),
- There are 2048 time channels, or bins, per plot

However, the NeXuS format allows a lot more information be stored in a data file than that listed above. As an example,

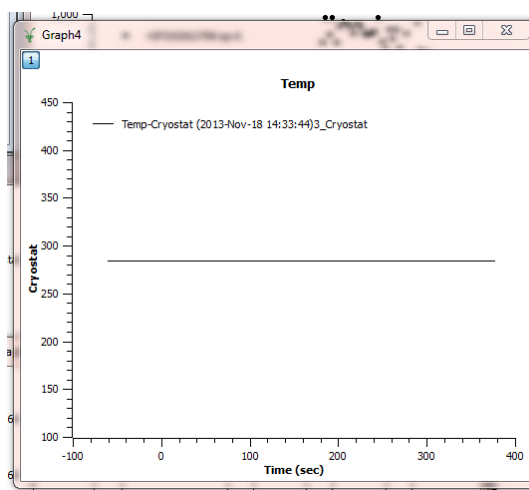
- right click on the file name and select 'Sample Logs'. A list of experiment and instrument parameters that have been logged during a measurement, from magnetic fields to sample temperatures, appears.



7. The Sample Logs window

To interrogate any of these logs double click on the 'Name'.

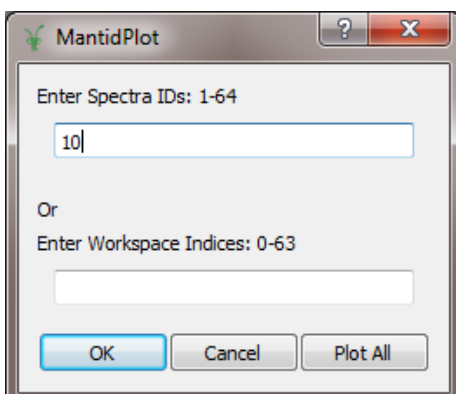
🔍 Examine Temp\_Cryostat – the plot below should appear. Explore other parameter files



8. A plot of log file entry Temp\_Cryostat

As mentioned, since we have simply loaded HIFI00062798.nxs, workspace, [HIFI00062798](#) holds within it raw positron counts / bin for EACH individual HiFi detector. To examine the data collected in a single detector, right click on [HIFI00062798](#) and select **Plot Spectrum**. The following input fields appear.





## 9. Raw data plotting options

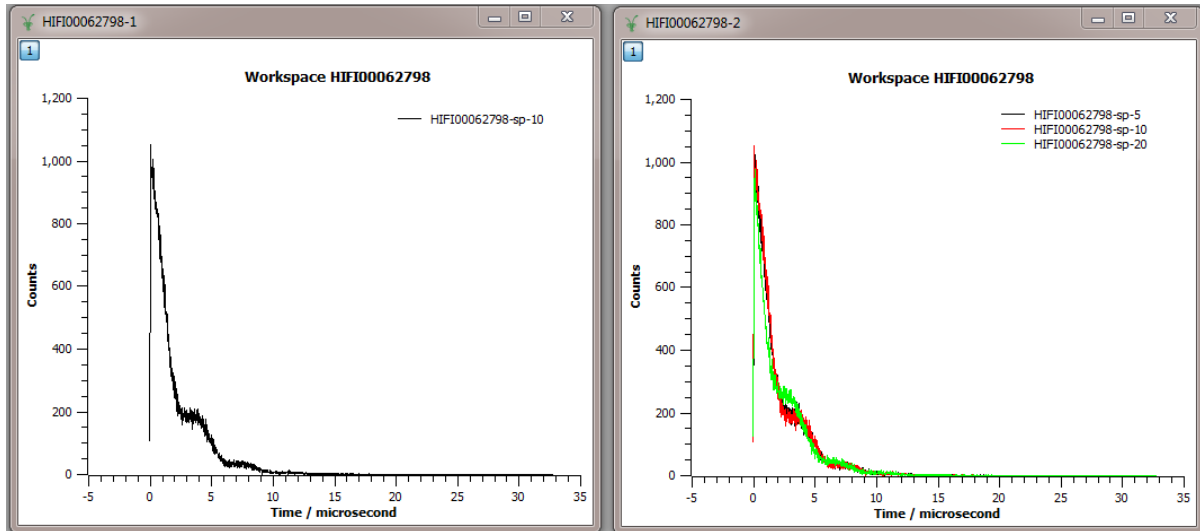
On HiFi, as way of example, there are 64 detectors hence ID numbers: 1-64 (1-32 = upstream detectors, 33-64 = downstream detectors).

- ✚ Enter a detector (ID) number of your choice and click **OK** to plot the associated raw data.

For information:

- **ARGUS** has 192 detectors (usually pre-grouped to 32 histograms in the data analysis software)
- **MuSR** and HiFi have 64 detectors (usually pre-grouped to 32 histograms in the data analysis software)
- **EMu** has 96 detectors (usually pre-grouped to 32 histograms in the data analysis software)

The raw positions counts /  $\mu\text{s}$  for detector 10 are shown below. Alternatively, entering '5,10,20' plots spectra 5,10 and 20 on one graph



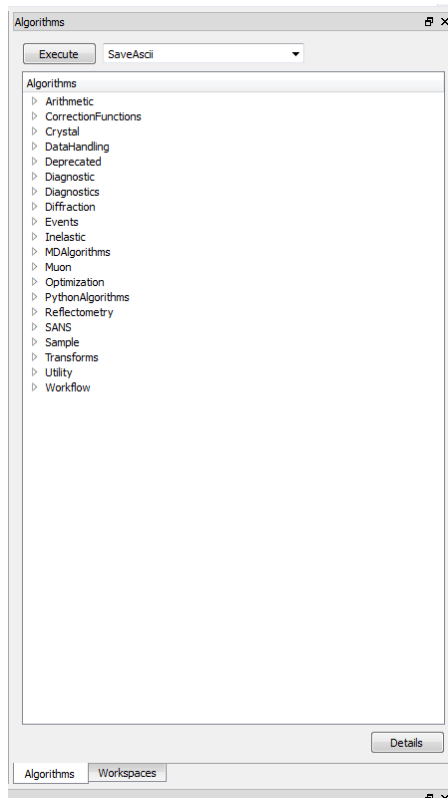
10. Raw data (counts /  $\mu\text{s}$ ) collected in HiFi detector no. 10 (left) and in detectors 5,10,20 (right)

## II. Exporting Data

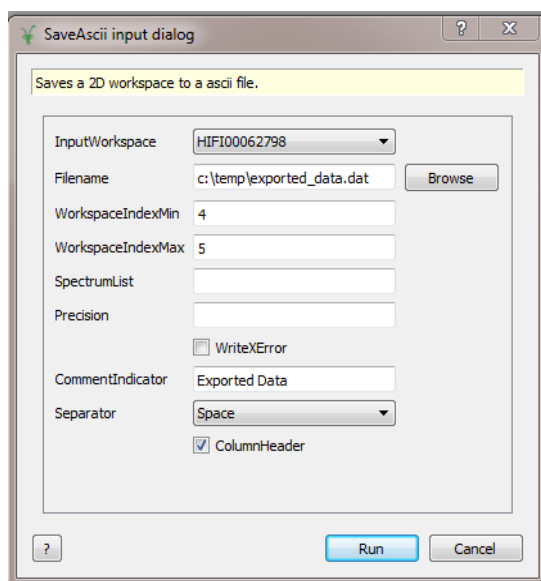
To export the data contained within any listed workspace click on the [Algorithms](#) tab at the bottom of the workspace list pane. The options shown below should appear. Select [SaveAscii](#) from the dropdown menu (beside [Execute](#)) and click [Execute](#).

The [SaveAscii Input Dialog](#) box should appear. Select a directory (for the written data file) and specify a file name. The workspace to be exported can be selected from the dropdown list next to [InputWorkspace](#). The user can also, for example, define which workspace spectra i.e. indices (Min and Max) to export, choose the type of data separator used in the file (CSV is usually a reliable option), add comments and decide whether to [WriteXError](#).

- Export spectra 4 and 5 as directed above. Ensure you can read the written data file using some other plotting package



11. The *Algorithms* options

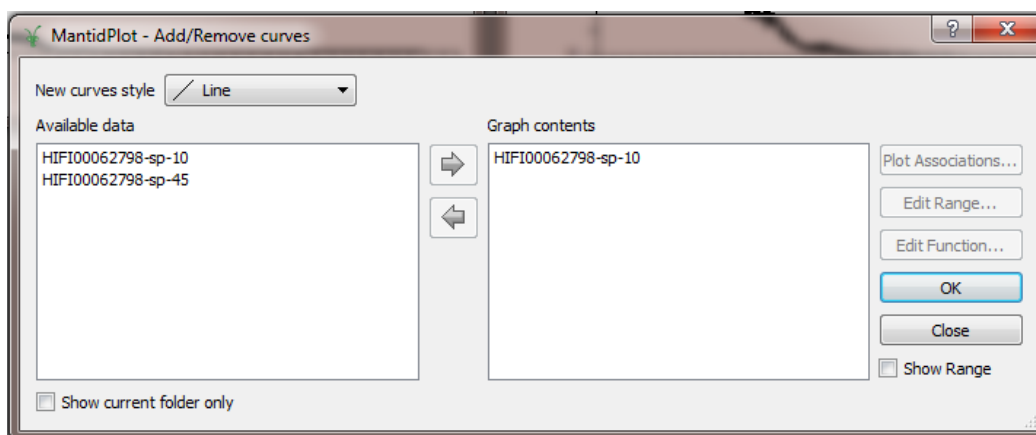


12. The *SaveAscii* dialog box

## III. Overlaying Data

To overlay data, select the plot window in which you wish to compare data. Right click on the plot window and select [Add/Remove Curve](#). A list of available data sets will appear. As an example, in the figure below we have the option of adding the data contained in the workspaces [HIFI00062798-sp-10](#) and [HIFI00062798-sp-45](#) to the plot window of [HIFI00062798-sp-10](#). To do so, first select the two spectra in the left hand pane and then click the 'right' pointing arrow. Reversing this process removes data from a plot window.

- ✚ Create two plots – one showing data from detector 10 and one showing detector 45



13. *Add / Remove Curves options window*

- ✚ Overlay the data from detector 45 on the data from detector 10

The plot style (line, scatter, line + scatter etc) of the changed by double clicking on the plot window and selecting the required data set. The axis settings can be changed by double clicking on the x- or y- axis and entering new limits

- ✚ Familiarise yourself with changing plot styles/colours as well as axis limits

## Basics Of Data Reduction

This section explains:

- the concept of  $t_{\text{zero}}$  and  $t_{\text{good}}$
- the concept of dead time correction
- how to set the detector calibration factor,  $\alpha$
- how to group data

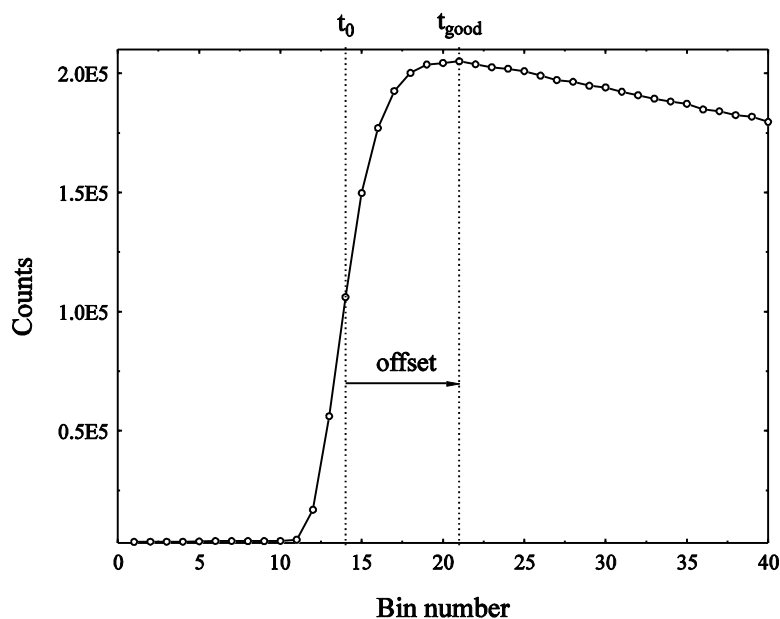
**NOTE:** detailed information about functionality contained under the Mantid Analysis GUI TABS - *Home, Grouping Options, Settings, Data Analysis and Results Table* – will be referred to and can be found in the hand-out [Mantid 4  \$\mu^+\$](#)

**NOTE:** from now on we will load data using the [Muon Analysis interface](#)

### I. the concept of $t_{\text{zero}}$ and $t_{\text{good}}$

Although the timing origin for the muon response in the sample is when the middle of the muon pulse has reached the sample, the *good data* region is not obtained until the entire pulse has arrived at the sample. This time is defined as  $t_{\text{good}}$ .  $t_0$  on the other hand is the time at which the middle of the muon pulse reaching the sample. The difference between  $t_{\text{good}}$  and  $t_0$  is referred to as the  $t_{\text{good offset}}$ .

When using the Muon Analysis GUI,  $t_{\text{zero}}$  and  $t_{\text{good}}$  are loaded from the NeXuS file having been determined by the instrument scientist (**NB: you will determine  $t_{\text{zero}}$  from experimental data later on**) However, for the purpose of demonstration, we will aim to broadly determine these parameters from the raw data and see how they compare with the GUI entries.



14. Diagram of ISIS data near the pulse showing  $T_{zero}$  and  $T_{good}$

## II. the concept of dead-time

After a detector has recorded a positron count there is a small time interval before it is able to detect another count. It is possible, especially at the high data collection rates now available on the muon instruments, that a positron will arrive within this interval and not be recorded. Statistical analysis can be used to correct for this. A silver sample is used to determine dead time values for each detector, the results of which are made into a dead time data file. The NeXuS format stores this data internally. **For further information about the correction of detector deadtime see: Kilcoyne, RAL report RAL-94-080 (1994)**

To explore the effect of dead time:

- Load data file EMU00034998.nxs. Make sure 'none' is selected for Dead Time Correction

✚ Reload the data file but select “From Data File”.

- What happens?

✚ Create a plot to show the effect

### III. the detector calibration factor, $\alpha$

The detector calibration factor,  $\alpha$ , can be determined for any given detector pairing by clicking on Guess Alpha (Grouping Options) and analysis of transverse field data.

✚ Using the GUI, load transverse field measurement MUSR00024563.nxs

✚ Select the Grouping Options TAB

- Notice that when you load a data file using the GUI, the default option for the MuSR spectrometer is to GROUP (or add) all data in detectors 1-32 (a group of detectors referred to as BCK) together. Similarly, data in detectors 33-64 (a group called FWD) is summed.


✚ To generate  $\alpha$ , click on Guess Alpha.

- Reload the data file. What has happened?

✚ You can rename groups fwd and/or bck and/or change the detectors to be summed. Alternatively you can create additional grouping options

- In the Group Table, create two new grouping options with names of your choice that add every 5<sup>th</sup> detector (i.e. 33,38,43 ... )
- Below 'long' enter a new Group Pair name for this new grouping option

 Click 'Guess Alpha'

 Reload the data file BUT before you do choose your new Group Pairing option from the Group / Group Pairing drop down list. What do you notice about alpha?



## The Basics Of Muon Data Analysis

In this section you will reduce and analyse data from a MuSR experiment to investigate the temperature dependence of the muon spin relaxation rate. The data to be used is from a study of spin fluctuations in the spin glass system  $Y(Mn_{1-x}Al_x)$  with all measurements being collected in a longitudinal field of 110G to suppress spin relaxation arising from static internal fields. Further details can be found here: [prb.aps.org/abstract/PRB/v85/i18/e184416](http://prb.aps.org/abstract/PRB/v85/i18/e184416)

You will:

- build up a fit function from pre-installed models and fit data
- export and tabulate specific fits / experimental parameters
- model the dependence of said fit parameters by writing a user specific function

### *Data files*

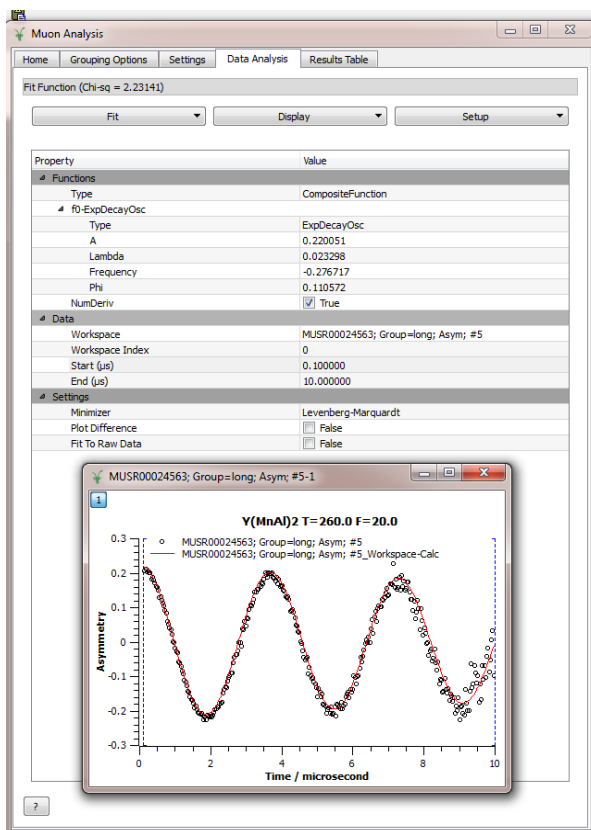
<i>File Name</i>	<i>Sample</i>	<i>Field</i>	<i>Temp</i>
MUSR00024563	YMnAl	TF 20G	265 K
MUSR00024576 - 24590	YMnAl	LF 110G	90 - 290K (check log file)

### I. fitting T20 data

Once calibration factors, detector groupings and dead times have been set, fitting the data can commence.

To get a feel for the fitting process, we will first fit a damped oscillatory depolarisation function to the T20 measurement

- ✚ Using the GUI, load run number MUSR00024563.nxs
- ✚ In Grouping Options, determine  $\alpha$
- ✚ In Settings, rebin the data using a 'step' factor of your choice ('step' = an integer value and defines the number of time bins to average over)
- ✚ Choose the Data Analysis TAB.
- ✚ For details about fitting refer to section 2.IV. Data Analysis in the Mantid 4  $\mu^+$  manual
- ✚ Following the instruction in IV. Data Analysis fit the MuSR T20 data
- ✚ For  $\alpha = 1.22$ , Rebin Data > Fixed Steps > 2, Fit range > 0.1 to 10 us you should get the plots and values shown in 15



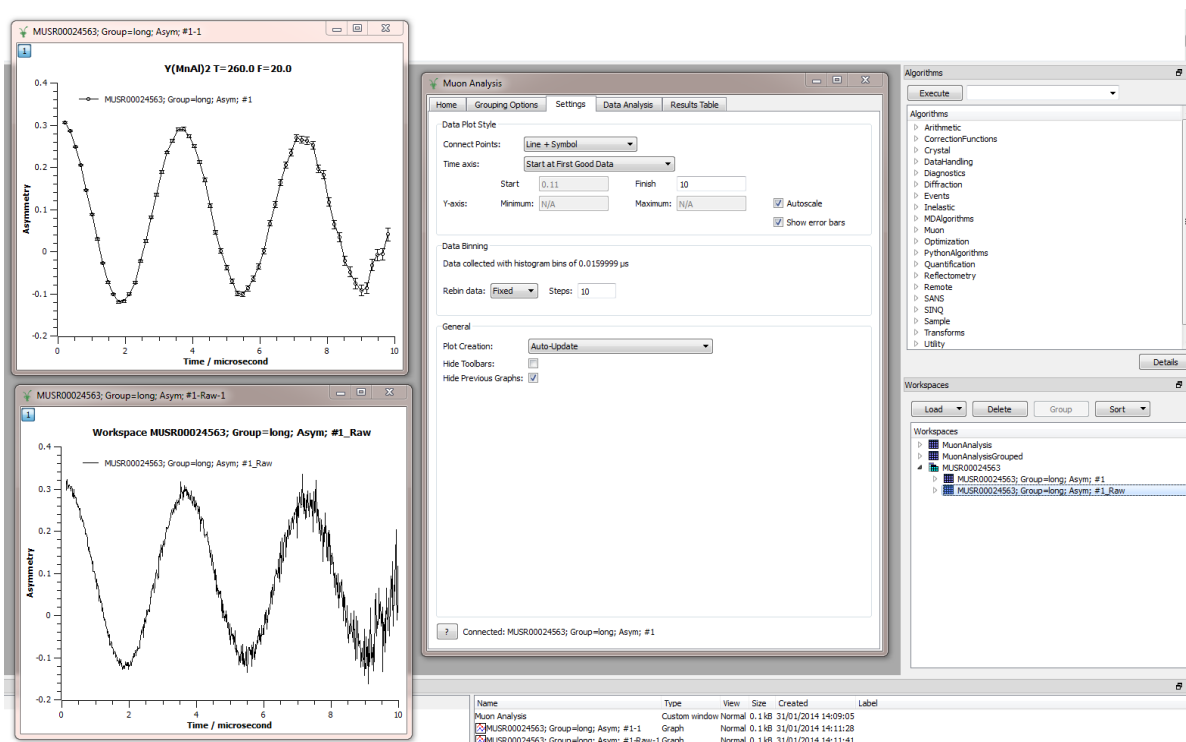
15. Result of fitting MUSR00024563 to ExpDecayOsc

## An aside - Workspaces created using the Mantid Analysis GUI

When a data file is loaded, as an example MUSR00024563.nxs, a top level workspace called, in this case, MUSRSR00024563 is created. Clicking on the side arrow shows the contents of this workspace – namely:

- MUSR00024563 ; Grouping – long ; Asym # 1
- MUSR00024563 ; Grouping – long ; Asym # 1\_Raw

As can be seen in the figure below, the data in these two sub-workspaces is raw data re-binned in steps of 10 and the raw, un-binned, data respectively. Both workspaces are Asym plots and have had Detector Grouping > Long (sum of detectors 1-32 and 33-64) applied

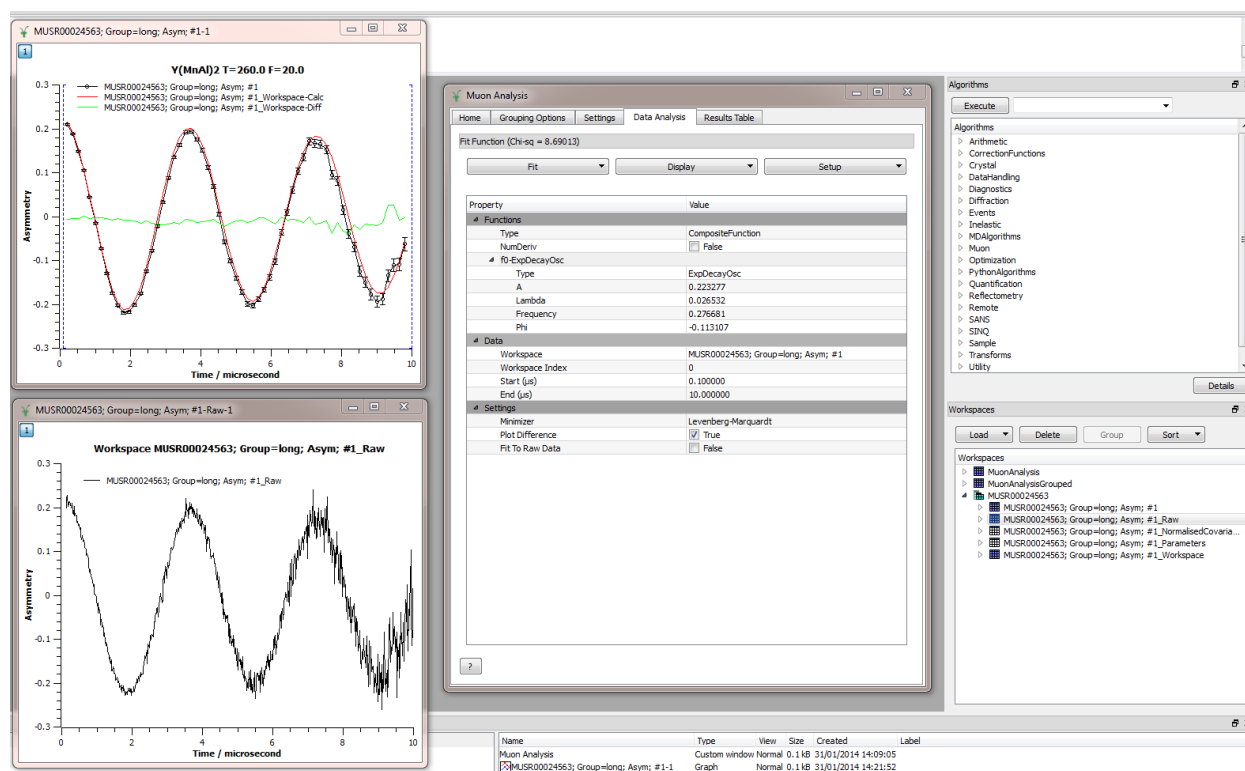


16. Result of fitting MUSR00024563 to ExpDecayOsc

Once a fit has been performed, however, the contents of workspace MUSR00024563 are modified such that three new levels are created. Fitting the T20 data again as an example, we get workspaces:

- MUSR00024563 ; Grouping – long ; Asym # 1\_NormalisedCovarianceMatrix
- MUSR00024563 ; Grouping – long ; Asym # 1\_Parameters
- MUSR00024563 ; Grouping – long ; Asym # 1\_Workspace

Again, clicking allows the type and basic contents of the workspaces to be viewed



17. Result of fitting MUSR00024563 to ExpDecayOsc

The most useful workspace to view is - MUSR000\*\*\*\* ; Grouping – long ; Asym # 1\_Workspace – which contains the data, fit and residual. To view all in one plot, right click, select Plot Spectrum and enter '0-2' (0 = ID for data, 1 = ID for fit, 2 = ID for residual)

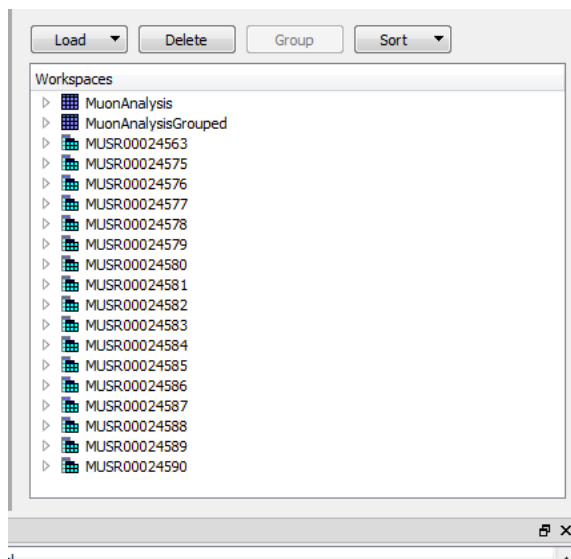
## II. Temperature dependence of the muon spin depolarisation

Next we will investigate the temperature dependence of the  $\mu^+$  spin depolarisation rate,  $\lambda$ .

## a. Fitting the data

First, we need to gauge the percentage of asymmetry that is attributed to instrumental background (which we will assume to be time independent)

- ✚ Load data file MUSR00024576.nxs (YMnAl sample at 90K)
- ✚ Build a function that models both the spin depolarisation and a flat background. Use
  - Functions > Add Function > Muon > StretchExpMuon
  - Functions > Add Function > Background > FlatBackground
- ✚ Fit the data and fix the resulting background level
- ✚ Next determine a value for full t=0 asymmetry. For this, load data file MUSR00024590.nxs (YMnAl sample at 280K)
- ✚ Fix Beta = 1, refit the data and fix parameter A for all subsequent fits
- ✚ Finally, un-tie Beta and fit all the data between 100K and 280K using the Fit > Sequential Fitting option.
  - Note another way to fit the data is to first read in all the data files between 100 and 280K (24580 – 24590). Each time a file is read an associated workspace is created
  - Once all files are loaded, set up your fit function, follow Data Analysis > Data > Workspace and select the file to analyse from the drop down menu.
  - NB: as the run logs will show, the temperature does not increase linearly so keep an eye on 'goodness of fit'

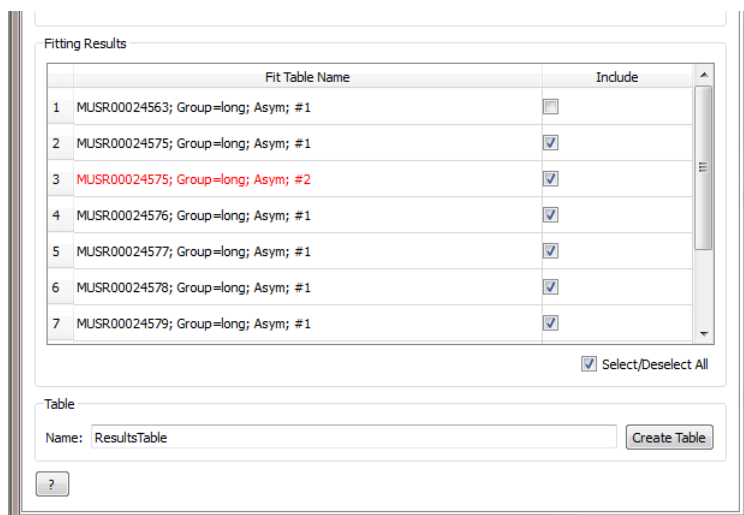


18. Workspaces created after reading in all raw data files

## b. Exporting and plotting parameters

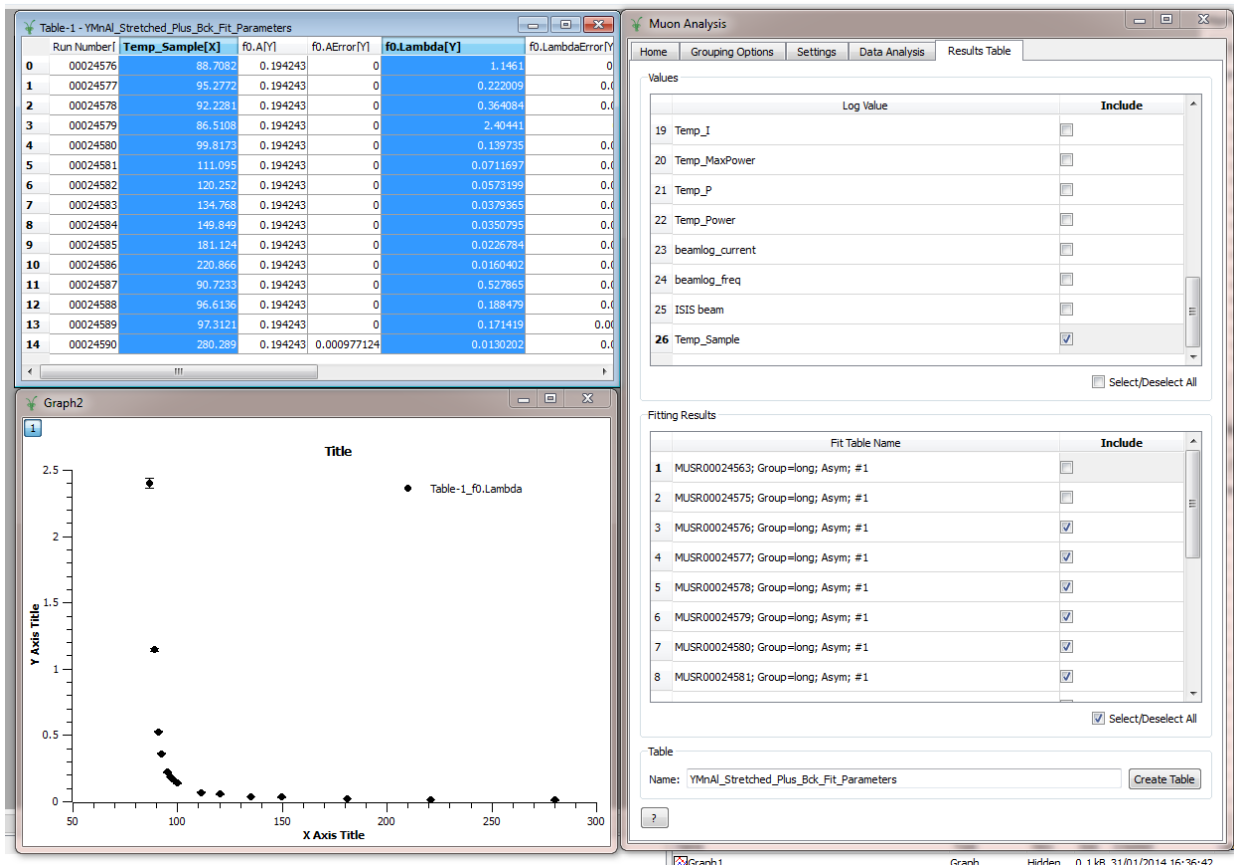
To tabulate, and plot a specific fit parameter, as a function of some experimental factor use the functionality found under Results Table. The Results Table TAB lists all workspaces that have fitted data associated with them, as well as all logged experimental parameters – temp, magnetic field, pressure etc.

**Note:** you may notice that some entries under Fitting Results > Individual Fits have different colours. Different colours delineate between data sets that are the same but were fitted using different functions i.e. they have different parameter sets. For example, in Fig 19, MUSR00024575 has been fitted with first a stretched exponential and background (black entries) AND THEN just a stretched exponential (red entry)



19. Files with different fit parameters are delineated by different colours

- ✚ No matter if you use Individual file or Sequential file fitting, in the Log Value box select the experimental parameter you want to be written out to accompany the fit parameters - in this case check Sample\_Temp
- ✚ Tick all the data workspace files in the Fitting Results (box BAR 24563 - the T20 measurement - if you fitted files individually)
- ✚ Enter a name for your fit parameter table
- ✚ Click Create Table – a table should appear as should the associated workspace
- ✚ Select columns Sample\_Temp (X) and f(0).Lambda(Y) in the fit parameter table
- ✚ Right click and select Plot > Scatter
- ✚ To add error bars, click on the graph to activate it.
- ✚ From the main MantidPlot toolbar select Graph > Add Error Bars
- ✚ Select Source Of Errors > Existing Column and use the drop down menu to select f0.LambdaError
- ✚ The result should look something like >



20. Result of fitting MUSR00024576 -90 using ExpDecayMuon +FlatBackground

## c. Writing functions to fit parameters

Finally we are going to fit a critical form to  $\lambda(T)$  vs. T, namely

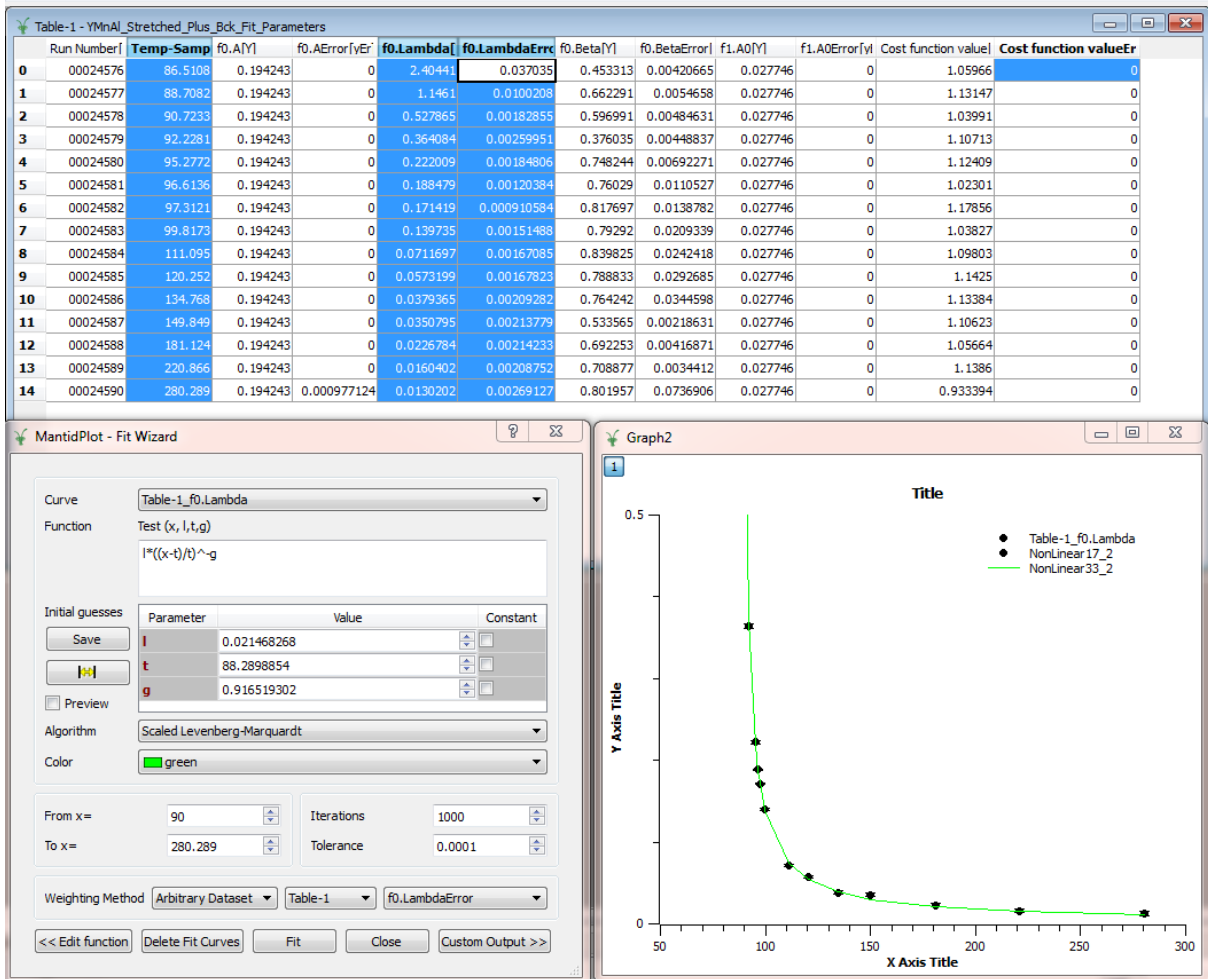
$$\lambda(T) = \lambda_o \left( \frac{T - T_g}{T_g} \right)^{-\gamma}$$

to extract a glass transition temp,  $T_g$ , and a critical exponent,  $\gamma$

To code and fit a user defined function in Mantid:



- ✚ If the x-axis data in the table does not increase linearly then re-sort the data. To do this, select Sample\_Temp, right click on the column and select Sort Table
- ✚ Choose options:
  - Sort columns > together
  - Order > ascending
  - Leading column > -Sample\_Temp
  
- ✚ Click OK and the temperature axis should now be in ascending order accompanied by associated depolarisation rates
- ✚ Re-plot the graph and click on it to activate the plot window
- ✚ Select Analysis from the main MantidPlot tool bar
- ✚ Select Fit Wizard
- ✚ Select Category > User defined
- ✚ Enter a name for your new function
- ✚ Enter the equation into the blank input field. For example,  $y=mx+c$  might be coded:
  - Name: Linear Fit
  - Parameters: m, c
  - Entry on equation field:  $(m*x)+c$
  
- ✚ Save the file and click on Fit to launch the Fit Wizard dialogue box
- ✚ Click Fit – this launches the fit control dialogue box below. Using the parameters shown in Fig 21 should give the fit in green (Note: Fit from 90K to 280K)



21. Result of fitting  $\lambda(T)$  vs.  $T$  using the critical form

## Instrument Calibration Examples

Now that you have the basics of data reduction and manipulation using Mantid we will apply these techniques to analyse typical instrument calibration data.

You will :

- analyse steering curve data to determine the current needed in the horizontal beam line steering magnets to centre the muon beam on the sample
- create a range curve to investigate how thick a sample has to be to ensure all muons are stopped
- analyse data to determine a value of  $t_0$  for the instrument
- analyse frequency response data to determine the upper relaxation rate that can be observed on an instrument

## Example 1: the steering curve

### Aim

To determine the current needed in the horizontal beam line steering magnets to ensure the muon beam is centred at the sample position. The sample used was a 20mm Ag mask covering Fe<sub>2</sub>O<sub>3</sub> (slits 4). Fe<sub>2</sub>O<sub>3</sub> rapidly depolarises the muon spin polarisation such that any asymmetry you observe can be attributed to muons landing in the Ag mask


## Task

By fitting the data sets below using a suitable relaxation function, create a results table and plot the initial asymmetry vs. magnet current.

## Run log

44989	"Haematite on Ag T=295 F=100.0"	Thu 5. Dec 09:38:14 2013	"calibration" Current	0.00 Amp
44990	"Haematite on Ag T=295 F=100.0"	Thu 5. Dec 09:44:33 2013	"calibration" Current	0.25 Amp
44991	"Haematite on Ag T=295 F=100.0"	Thu 5. Dec 09:53:12 2013	"calibration" Current	0.50 Amp
44992	"Haematite on Ag T=295 F=100.0"	Thu 5. Dec 10:00:58 2013	"calibration" Current	0.75 Amp
44993	"Haematite on Ag T=295 F=100.0"	Thu 5. Dec 10:06:06 2013	"calibration" Current	1.00 Amp
44994	"Haematite on Ag T=295 F=100.0"	Thu 5. Dec 10:15:26 2013	"calibration" Current	-0.25 Amp
44995	"Haematite on Ag T=295 F=100.0"	Thu 5. Dec 10:21:13 2013	"calibration" Current	-0.50 Amp
44996	"Haematite on Ag T=295 F=100.0"	Thu 5. Dec 10:26:53 2013	"calibration" Current	-0.75 Amp
44997	"Haematite on Ag T=295 F=100.0"	Thu 5. Dec 10:33:37 2013	"calibration" Current	-1.00 Amps

## Tip

-  The steering magnet current is not logged on EMu. When you view your Results Table, enter the current values by modifying the RunNumber column NOTE you may have to change the column from Read Only before you can enter the currents

## Example two: the range curve

### Aim

If a sample is too thin then the muon's momentum will carry it straight through the material. On the other hand, if the material in front of the sample (i.e. mylar attached to a

sample holder or perhaps the beam windows on a cryostat) is too thick then the muon may not have enough energy to pass and reach the sample. To ensure muons thermalize in the sample, the instrument scientist needs to know the density required to stop the particles.

This information is determined via a range curve

## Task

Fit the data sets below using a suitable relaxation function, create a results table and plot the initial asymmetry vs. number of Ti foils

- ✚ Determine how many foils are needed before none of the muons land in the quartz
- ✚ From this value, determine the density (in  $\text{mg}/\text{cm}^2$ ) required to stop all muons

## Run log

18888	Quartz sample with	0	Titanium foils in front
18889	Quartz sample with	0	Titanium foils in front
18890	Quartz sample with	1	Titanium foils in front
18891	Quartz sample with	2	Titanium foils in front
18892	Quartz sample with	3	Titanium foils in front
18893	Quartz sample with	4	Titanium foils in front
18894	Quartz sample with	5	Titanium foils in front
18895	Quartz sample with	6	Titanium foils in front
18896	Quartz sample with	7	Titanium foils in front
18897	Quartz sample with	8	Titanium foils in front
18898	Quartz sample with	9	Titanium foils in front
18899	Quartz sample with	10	Titanium foils in front

Density of Ti :  $4.5 \text{ g}\cdot\text{cm}^{-3}$

Thickness of foils:  $30 \mu\text{m}$

## Example three: determining $t_0$

### Aim

Using transverse field calibration data from a silver sample, you will determine a value of  $t_0$  for the EMu spectrometer. If  $t_0$  is correct the phase of the TF oscillation should be field independent.


### Task


Guess an initial value for  $t_0$  (suggestion use  $0.3 \mu\text{s}$ ). Fit the data sets below using a suitable relaxation function, create a results table and plot the phase of the oscillation (in rads) vs. muon Larmor frequency (in rads/sec)

#### Useful pointers:

- once you have fitted the first data set, fix  $A_0$  and  $\lambda$
- ensure you fit over the same time range for all data sets
- make sure that the frequency value you get equates to the field applied
- $\gamma_\mu = 13.6 \text{ kHz/gauss}$  and remember to convert to radians

#### Is the phase field independent?

 The gradient of the rate of muon Larmor phase (in rads ) vs. change of applied field (in rads.sec) gives the amount by which to adjust your initial  $t_0$  guess

 Find the gradient, adjust your  $t_0$  guess and refit a few data points between 20 and 100 G to ensure that phi is constant (within error)

## Run log

18850	Ag sample with	Transverse Field = 20 Gauss
18851	Ag sample with	40
18852	Ag sample with	60
18853	Ag sample with	80
18854	Ag sample with	100
18855	Ag sample with	10
18856	Ag sample with	30
18857	Ag sample with	50
18858	Ag sample with	70
18859	Ag sample with	90
18860	Ag sample with	5
18861	Ag sample with	15
18862	Ag sample with	25
18863	Ag sample with	35

## Example four: frequency dependence

### Aim

Using transverse field calibration data collected from a quartz sample, you will investigate the frequency response of the EMu instrument.

### Task

Fit the data sets below using a suitable relaxation function. Note: quartz has both diamagnetic and muonium fractions which will need to be modelled

- ✚ Plot the precessional frequency of the muonium fraction vs. asymmetry with error bars
- ✚ What do you notice?
- ✚ What is the upper resolvable frequency of the EMu spectrometer?

## Run log

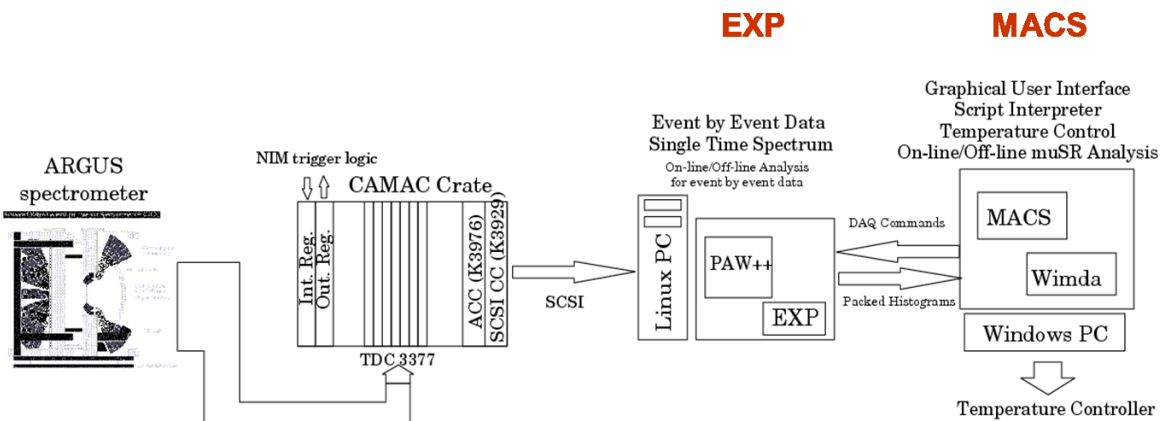
19626	Quartz sample with	Transverse Field = 0.5 Gauss
19627	Quartz sample with	Transverse Field = 1.0 Gauss
19628	Quartz sample with	Transverse Field = 1.5 Gauss
19629	Quartz sample with	Transverse Field = 2.0 Gauss
19630	Quartz sample with	Transverse Field = 2.5 Gauss
19631	Quartz sample with	Transverse Field = 3.0 Gauss
19632	Quartz sample with	Transverse Field = 3.5 Gauss
19633	Quartz sample with	Transverse Field = 4.0 Gauss
19634	Quartz sample with	Transverse Field = 4.5 Gauss
19635	Quartz sample with	Transverse Field = 5.0 Gauss
19636	Quartz sample with	Transverse Field = 5.5 Gauss
19637	Quartz sample with	Transverse Field = 6.0 Gauss
19638	Quartz sample with	Transverse Field = 6.5 Gauss
19639	Quartz sample with	Transverse Field = 7.0 Gauss
19640	Quartz sample with	Transverse Field = 7.5 Gauss
19641	Quartz sample with	Transverse Field = 8.0 Gauss
19642	Quartz sample with	Transverse Field = 8.5 Gauss
19643	Quartz sample with	Transverse Field = 9.0 Gauss



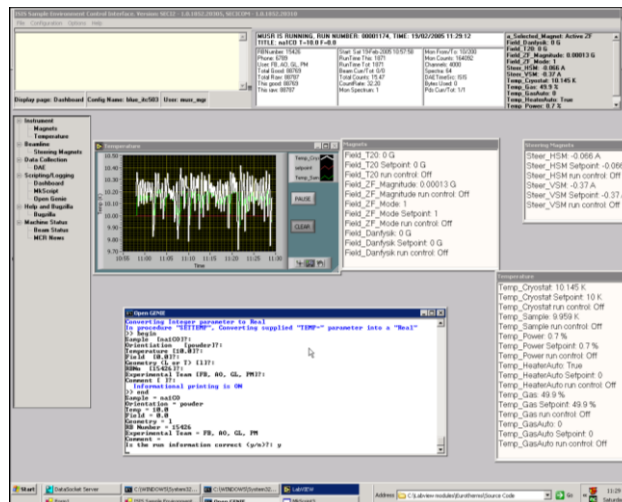
## Appendix I: a bit about acquisition and data formats

Currently the muon instruments use two different acquisition systems:

- a) **MACS/EXP** - hybrid Windows/Linux system as used on ARGUS



- b) **SECI** - Windows based control system as used on MUSR, EMU and HiFi



Once a run has ended the saved data is stored in the following locations on the ISIS network:

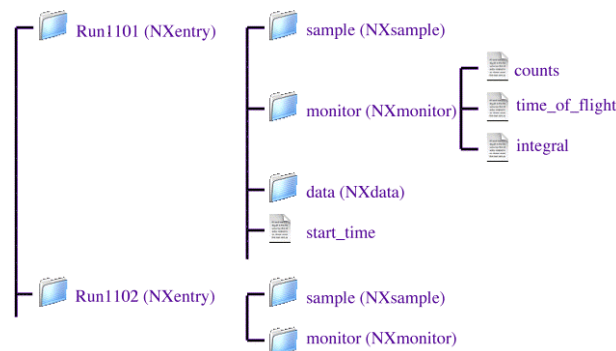
**HIFI**            \\hifi\data\hifi00010000.nxs  
**EMU**             \\emu\data\emu00010000.nxs  
**MUSR**          \\musr\data\musr00010000.nxs  
**ARGUS**         \\ndw656\macs\nexus\argus0010000.nxs

All muon data at ISIS is NOW stored in NeXuS format (nexusformat.org) however older RAL binary format (.ral) data still exists. A typical run file size is 200-600 kb but data compression can reduce the size by up to a factor of 7

**SECI data format**    NeXus-1: hierarchical, extendable format (.nxs), soon Nexus-2  
**MACS data format**    Nexus-2 (.nxs) plus RAL binary format (.ral)

The NeXuS data format itself is based on the NCSA Hierarchical Data Format (HDF, hdfgroup.org) and is comprised of three components:

1. A set of subroutines to make it easy to read and write NeXus files
2. A set of design principles to help people understand what is in them
3. A set of instrument definitions to allow development of portable analysis software



ISIS NeXus muon definitions can be found at: [www.isis.stfc.ac.uk/groups/muons/downloads](http://www.isis.stfc.ac.uk/groups/muons/downloads)