

New ROOT Graphical User Interfaces for fitting

D. González Maline, L. Moneta, I. Antcheva

CERN, Geneva, Switzerland

E-mail: David.Gonzalez.Maline@cern.ch

Abstract. ROOT, as a scientific data analysis framework, provides extensive capabilities via Graphical User Interfaces (GUI) for performing interactive analysis and visualizing data objects like histograms and graphs. A new interface for fitting has been developed for performing, exploring and comparing fits on data point sets such as histograms, multi-dimensional graphs or trees. With this new interface, users can build interactively the fit model function, set parameter values and constraints and select fit and minimization methods with their options. Functionality for visualizing the fit results is as well provided, with the possibility of drawing residuals or confidence intervals. Furthermore, the new fit panel reacts as a standalone application and it does not prevent users from interacting with other windows. We will describe in great detail the functionality of this user interface, covering as well new capabilities provided by the new fitting and minimization tools introduced recently in the ROOT framework.

1. Introduction

The ROOT mathematical work package ([1] and [2]) provides and support a coherent set of mathematical and statistical libraries required for simulation, reconstruction and analysis of high energy physics data. Although there is an appropriate homogeneity among the fitting interfaces, there are still many details that differ among the methods provided. This is mainly due to the high number of tools integrated in the math work package and in ROOT in general and also due to the number of possibilities the framework offers.

The user might have trouble learning and configuring the parameters of the algorithm due to the complexity of the different packages. Although ROOT works with both interpreted and compiled C scripts (see [4]), users may have difficulty to configure the fitting interactively.

An example of a very simple fitting is shown next (see [3] for more details and examples), where a simple histogram is created and filled with following a Gaussian distribution. Nevertheless, real cases can be much more complex if we have to create a complicated analysis function, in case we need to preprocess the data or if we want to use another fitting package.

```
TH1D* h1 = new TH1D("h1", "h1-title", 100, 0, 10);
TF1* f1 = new TF1("f1", "gaus", 0, 10);
f1->SetParameters(1,5,2.5);
h1->FillRandom("f1", 1000);
h1->Draw();
h1->Fit("gaus", "+LE", "SAME", 2.4, 8.6);
```

Modern systems assist the user with GUIs that abstract the user from the underlying interface. In Matlab, the Fit Editor and the Curve Fitting Tool ([5]) are clear examples of

this. In ROOT, a similar interface is called the Fit Panel and it has been in the framework since the very beginning.

The following sections will present the Fit Panel interface by describing all the options and possibilities it offers to the users, as well as a dedicated section for the advanced methods the user can access directly from the GUI after the fitting has been done. Finally we will discuss the implication of this work and what future improvements and developments are planned to be done.

2. The Fit Panel

The Fit Panel was introduced into the ROOT framework in the earlier versions of it (see [6]). It was fully redesign and improved in version 5.14. This latter version was used as a base for the new Fit Panel, introduced in version 5.22. The new GUIs keeps the latest design as much as possible, but the inside has been changed according to the recent developments in the mathematical libraries. It also includes some new functionality, where the most important are the advanced tools or the ability to recognize different data sets or user functions.

The GUIs of the Fit Panel is shown in Figure 1. The panel is divided in three different zones based on the hierarchical task analysis of the fitting process. First we have the **Data Set** section, followed by the **Fit Function** section. At the bottom we can find the last section that is composed of a tabular panel with two subsections that are both shown in the figure. The next section will explain what they all mean and how they are meant to be used.

Users can access the Fit Panel in several ways. They can either draw the object or data set that they want to fit. Once the data is drawn in the canvas, right clicking over it will display a pop up menu with the menu entry **Fit Panel**. Nevertheless, if several objects are drawn together in the same canvas, the user might not have direct access to the desired data. If this is the case, they can still access the interface through the Tools title of the canvas menu bar. There is a third way to get this GUI, that is through the ROOT browser. Once the user opens a root file with the browser and right click over an object for fitting, the Fit Panel appears as an option and can be launched directly from there.

3. Fitting with the Fit Panel

Although the default settings of the Fit Panel elements are based on the most common options used for general fitting, the user can access through the GUI most of the options available in ROOT. The process to select them is made in three simple steps for any object or data set that can be fitted inside the framework.

First of all, although the Fit Panel will try to make an intelligent guess of the data to be fitted, the user will have a choice of data from the **Data Set** section of the GUI. The Fit Panel will present here all the drawn objects in the current session of ROOT, as well as all the registered objects. This includes all types of Histograms and Profiles (except THnsparse), one and two dimensional graphs and trees. In case of the latter, a dialog window will ask for the variables to be considered and the possible cuts with a format identical to the one used in `TTree::Draw()` ([7]). This selection will be added to the **Data Set** list.

After this, the user has to set up the function to be used for the fitting. The Fit Function section in the GUIs is where the user will make most of the decisions for this step. The Fit Panel presents here several options. It provides the user with a default set of predefined functions if the selected object is one dimensional. Some examples are gaussians, polynomials, square root function, exponentials or even the landau distribution. It will also display, in the subset **User Functions**, all the functions registered in the current instantiation of ROOT, which includes the ones made from scripts. Finally there is another subset that lists all the functions used previously for fitting with the Fit Panel. If the user does not find a function suitable for the

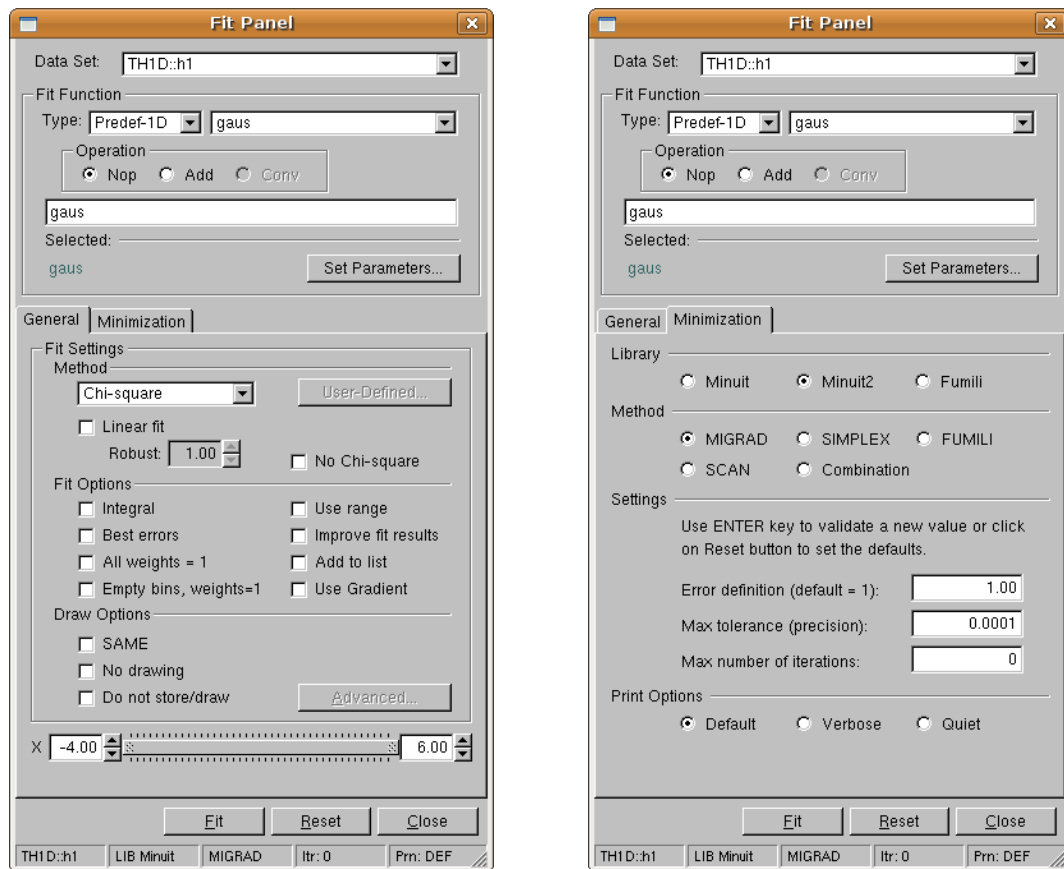


Figure 1. The Fit Panel as in ROOT 5.22. It shows here the lower tap with both the **General** and **Minimization** sections.

fitting or if they want to make a quick and dirty try, they can always type the function in the provided text field, respecting the syntax of the `TFormula` class.

As the fitting process is meant to find the right variables for the parameters of the fitting function, the Fit Panel also provides the user with a visual help to tweak their value before running the algorithm. Though the **Set Parameters** button, a dialog window similar to the one in Figure 2 will allow the user to modify the parameter values with an immediate visualization of the fit function on the current canvas. The panel will retrieve the names of the parameters, if any, and display each one of them row wise. This panel will allow the user to:

- Set the value of the parameter. This value will be the one passed to the minimization algorithm. Careful assignment of such a value might help the algorithm to avoid finding local minima.
- Fix the parameters to a certain value using the corresponding check box.
- Bound the parameters to a defined range. Such range can be set either through the slider, or setting the minimum and maximum values manually.
- Set the parameter step. This is required by some of the minimization algorithms like Minuit.

The third and last step is to customize the configuration for the fitting. For this, the user is provided with a tab panel divided into sections, the **General** tab for all the options that are fitting specific and the **Minimization** tab, that contains all the options specific to the minimization

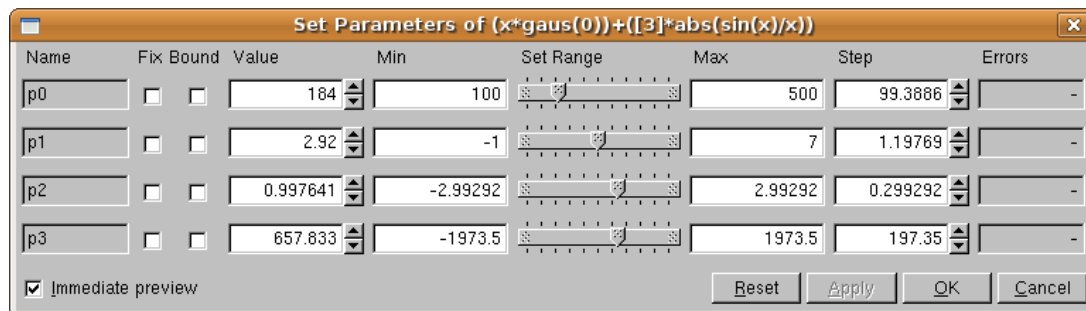


Figure 2. This window will allow the user to play with the parameters so that they are in an appropriate status before running the fitting algorithm.

algorithm itself and that are necessary to solve the fitting problem. The options in the **General** tab are:

- **Method:** It leaves the user to choose what method will be used for fitting, this includes the Chi-square method, binned and unbinned likelihood methods. For example, one dimensional histograms can be fitted using the Chi-square method. This depends on the type of data to be fitted. In case of linear functions, the user can also choose to perform a linear fit, with the possibility to select the robustness of the method.
- **Fit Options:** This includes integral, best errors, all weights equal to one, empty bins and all weights equal to one, use the range set in the slider, improve fit results, add to list and gradient. These options are all explained in the documentation regarding the fitting methods ([9]).
- **Draw Options:** including same, that will draw the result of the fitting in the same canvas without cleaning it before, no drawing and do not store/draw.
- **Advanced tools:** This will be explained in section 4.
- **Range setting:** The Fit Panel will draw a slider by dimension, up to two. Thus it allows the user to set the range for the fitting and, whereas possible, draw such a range in the current canvas. The limits of the range are automatically set to the maximum range the data can have. Notice that, if the check box Use Range is on, this bar will immediately reflect the range of the data, according to the function range.

On the minimization tab the options will be:

- **Library:** This is a selection of libraries the Fit Panel knows how to work with. They will provide different implementations for different minimization algorithms. The available libraries are Minuit, Minuit2 and Fumili.
- **Method:** Once the library has been selected, the different algorithms supported by it will be selectable from here. The options for the Minuit and Minuit2 libraries are Migrad, Simplex, Fumili, Scan or combination.
- **Settings:** The different methods have some settings that the user can personalize. They include the error definition, which is one by default, the maximum tolerance for least square fits and the maximum number of iterations the algorithm will run.
- **Print Options:** This will define the level of output the minimization method will display by the command line. There are three different options, verbose, where maximum output will be displayed, quiet, where nothing is displayed and default.

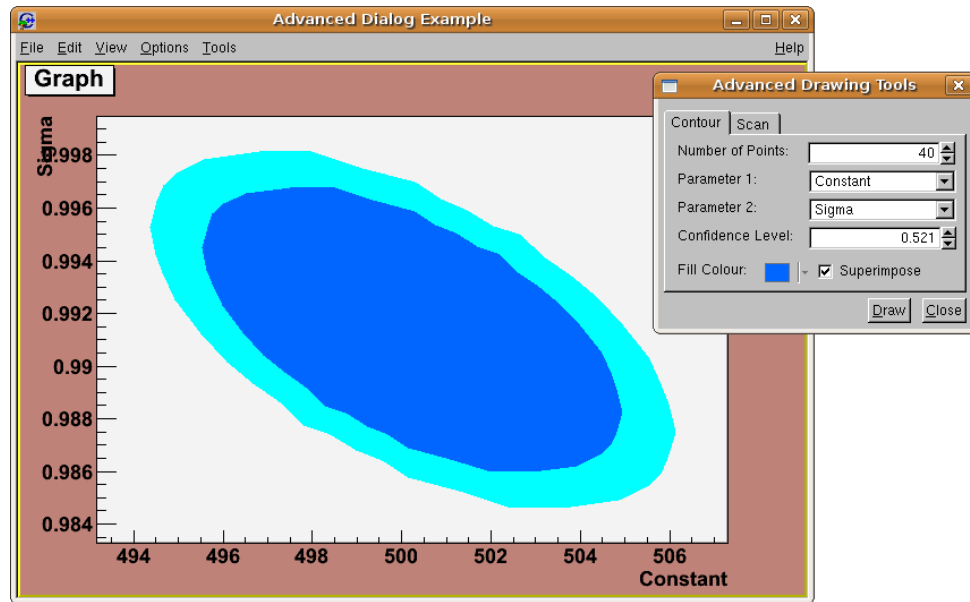


Figure 3. Contour graphics with the Advanced Drawing Tools panel

4. Advanced Tools

After the fitting has been done, the Fit Panel allows the user to easily calculate the contour of the function, its confidence levels or even the scan plot of likelihood. These three functions are activated with the **Advanced** button, which will display a dialog window with a tab panel inside for each of the functions.

4.1. Contour Method

The contour method will create a two dimensional contour around two selected parameters. The user can select, as shown in Figure 3:

- The two parameters the method will work with from a drop down list.
- The confidence level that will determined the level of the contour, with a default value of 0.683
- The number of points that will be used to draw the contour, with a default value of 40.
- The color that will be used to fill the contour graph.

The user will have the option to draw two different contours, with two different confidence levels on the same canvas as long as they click the **Superimpose** button after the first one was drawn.

4.2. Scan

This method will display a scan plot of the minimization function, like the chi-square or the likelihood function, around a range of the parameter value specified by the user. By default the scan is performed around the minimum within a range of two times the error. The user can choose the parameter to scan and also the number of points that will compose the scan.

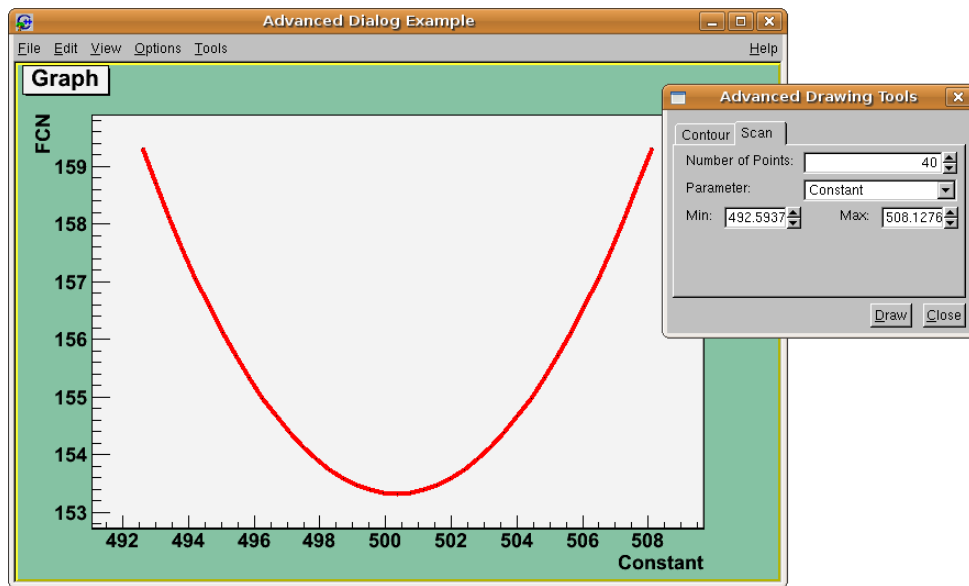


Figure 4. Scan plot of the selected parameter.

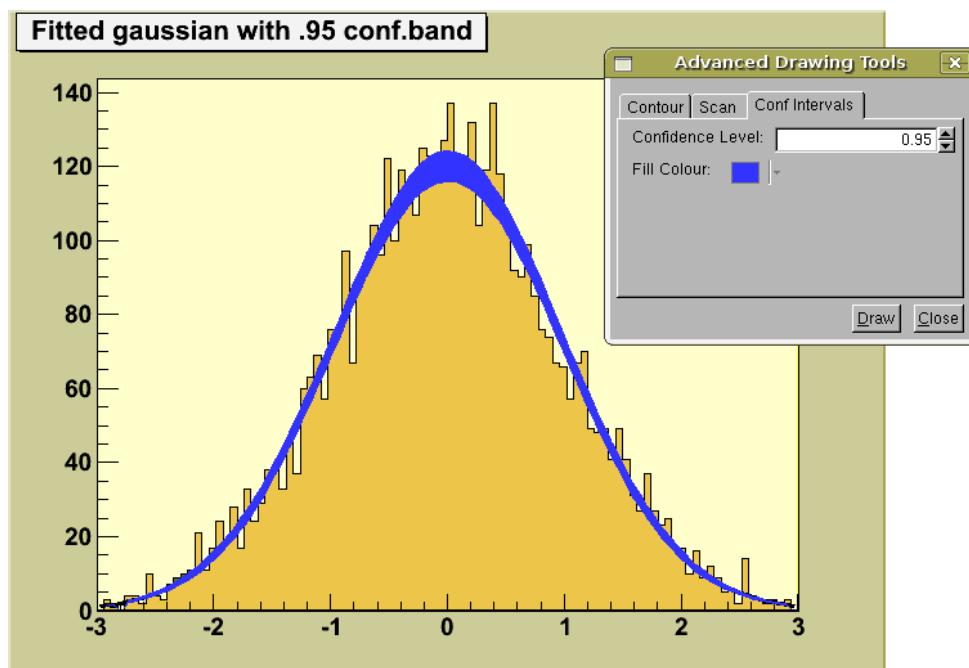


Figure 5. Confidence levels of the fitting function.

4.3. Confidence Levels

This panel will draw the confidence level of the fit function with respect to the data. The user can vary here the color of the graph to be drawn and the confidence level used by the algorithm, with a default value is 0.683 (1σ).

5. Conclusions and Future work

We have shown the new developments performed since ROOT 5.14 in the Fit Panel. This included a wider range of objects supported by the GUI, including trees. It also includes internal developments to adapt the code to the new developments in the mathematical libraries. We also showed all the options the GUI provides to the end user through the **General** and **Minimization** tabs and how the user can tune the parameters of the fit function to help the minimization algorithm find the global minima. Finally, the Fit Panel now gives the possibility to perform advanced analysis on the results of the fitting, like contour plots, scan and confidence intervals of the fitting function.

Future developments in the Fit Panel will include RooFit classes that will describe probability density functions (pdf's). These classes provides the functionality to combine pdf's to build complex fitting models. It will also integrate a new interface to control the parallelization of the fitting algorithm which is currently being developed in the mathematical libraries.

6. References

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- [5] Matlab's Curve Fitting Toolbox. <http://www.mathworks.com/access/helpdesk/help/toolbox/curvefit>
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