

# User Manual for MATLAB scripts

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## I. Introduction

### ***I.1 What they do***

1. These scripts are designed to process data files obtained in the PMT surface scan and quantum efficiency experiments. The results are presented in both numerical and graphical form.
2. The surface scan the scripts (especially the *pamunif.m* script) compute the parameters of the ideal surface as described in [1]. They also produce the intensity plot, the radial profile plot and the azimuthal profile plots.
3. The quantum efficiency (QE) scripts display the quantum efficiency plot and they compute the average of QE over the range 380-450 nm.

### ***I.2 What they do not do***

1. The scripts were not written to be foolproof. If one gives them a reason to crash they will crash. (They might also crash without a reason)
2. They cannot guess the correct initial values for the optimization process.
3. They cannot detect a corrupted or incorrect data file. (or, more precisely, they will detect it by crashing)

4. They do not check the content of the data files. So, for example, if the file name is 033222S.txt but the serial number (SN) of the tube inside that file is 022333 the script will not report an error or warning.

## II. Basic Functionality

The basic functionality is provided by the following files: *main.m*, *pamunif.m*, *qe.m*, *optim.m*. Unless you want something not provided by the current release, you will have to deal mainly with *main.m*. This is the file you will need to run in order to process a single data file containing either surface scan data or QE data.

### II.1 Installation and folder structure

For basic functionality only, the main files should be installed together in the same folder. The location of this folder as well as the location and naming of data files are irrelevant for basic functionality.

### II.2 Customizing the processing parameters

Sometimes you might want (or need) to customize some aspects of the processing of the data files. In the following we describe the parameters that can be modified in the *main.m* file.

#### II.2.1 Customizing the radial and azimuthal profiles

line 13: **delta\_r** is the increment used to build the radial profile of the PMT. The default value is **0.5** (mm). It does not make sense to use a value much smaller than the diameter of the light beam falling on the PMT.

line 15: **delta\_sig** is the increment used in the azimuthal profile. The default value is **10** (%). A too small value of this parameter will produce a very “noisy” profile.

line 16: **az\_radius** is the radius of the circle that will be used in computing the azimuthal profile. The default value is **12.5** (mm).

#### II.2.2 Customizing the optimization process

line 19: **MaxIter** is the maximum number of iterations of the optimization process. For a better accuracy use more than 250 iterations. The default value is **2000**.

line 21: **Weighted** specifies whether the minimization process uses the weights of the data points or does not use them. Set this parameter to **1** - weighted, **0** - without weights. The default value is **1** (i.e. weighted).

#### II.2.3 Customizing the graphics options

line 24: **autoclosefig** – Set this parameter equal to **1** if you want the script to automatically close the figures with plots after saving them to files (either in the “fig” or “png” formats) or set this parameter equal to **0** if you want to keep the figures open. The default value is **0**.

line 25: **savefig** Set this parameter equal to **0** (default) if you do not want the script to save the figures it created as a result of data analysis. Set it equal to 1 in order to save the figures in the “png” format; equal to 2 to save the figures in the MATLAB’s “fig” format; equal to 3 to save the figures in both “png” and “fig” formats.

### II.3 Running the script

- Change the current MATLAB directory to point to the folder containing the main scripts
- Run the *main.m* script. It will display a File Dialog Box asking you to point to the data file you want to be processed.
- Locate and select the data file to be processed.
- Depending on the selected graphics options (see II.2.3) the figures will be saved in the same folder as the data file and with the same name as the original data file but with either “fig” or “png” extensions.

## III. Extended Functionality

The extended functionality adds two main benefits to the basic functionality described above: a) it allows you to process an entire folder containing data files at once; b) in addition to generating figure files it will also produce web pages ready to be displayed on the web with little additional work.

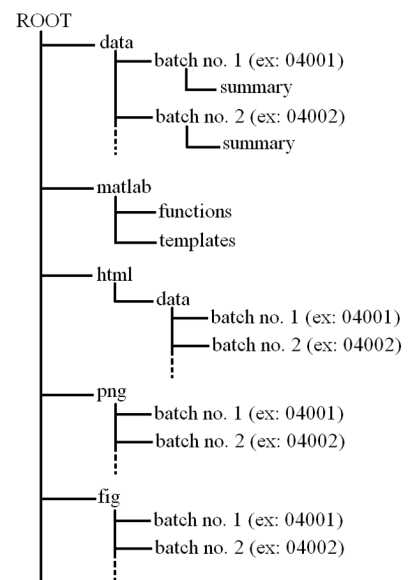
### III.1 Installation and folder structure

#### III.1.1 Installing the MATLAB script files

For extended functionality the files have to be installed according to a very particular folder structure. Everywhere in this document we will assume the existence of a **ROOT** folder (for example, named **pmt\_test**). The main files (*automain.m*, *pamunif.m*, *qe.m*, *optim.m*) have to be copied to the **matlab** folder (see Figure 1 at right) which is inside the **pmt\_test** folder. The functions used by *automain.m* (*get\_last\_update.m*, *get\_root\_path.m*, *get\_snlst.m*, *read\_fact\_file.m*, *read\_snlst\_file.m*, *saveplot.m*, *save\_list\_html.m*, *save\_snlst.m*, *save\_summary\_html.m*) must be copied to the **functions** folder inside the **matlab** folder. Also the **templates** folder containing html templates used to generate WEB pages must be placed inside the **matlab** folder.

#### III.1.2 Installing the data files

In order for the automated processing to work, the data files also must be placed according to the following rules:



**Figure 1. Folder structure required for extended functionality**

- Create a **data** folder inside the **ROOT/pmt\_test** folder;
- Inside the **data** folder create a folder with the name set equal to the batch number you want to process (for example **04001**);
- Place all your data files into that folder;
- If you have a factory data file containing a list of PMTs (usually named “*batch number*”.*DAT* – example: *04001.DAT*):
  - Change the extension of the factory file to “*txt*” (so that now it will be *04001.txt*);
  - Copy the factory file to the folder having the same name as the factory file (which is usually the batch number). This is also the directory in which you have placed the data files pertaining to this batch;
- If the factory file is not available but you have a complete list of the serial numbers of the PMTs in that batch:
  - Create a text file called “*snlist.txt*” and type the serial numbers on separate lines;
  - Place this file into the folder containing the data files pertaining to this batch;
- If neither factory file nor the “*snlist.txt*” is available the script will look for text files (containing the experimental data) with the following names: *xxxS.txt* (surface scan data files) and *xxxQE.txt* (quantum efficiency data files). Here *xxx* stands for serial number of the PMT (it might have more than 3 digits). Using these file names it will build a file “*snlist.txt*” and will place it into the folder **ROOT/data/”batch number”/summary**;
- After processing the data folder, the factory data file and/or the “*snlist.txt*” file will be moved from **ROOT/data/”batch number”** folder to **ROOT/data/”batch number”/summary** folder;

### ***III.2 Customizing the processing parameters***

With exception of the line numbers everything said in the section II.2 applies to the parameters in the *automain.m* MATLAB script. There are, though, two additional options:

line 34: **savesummaryfiles** Set this parameter equal to 1 if you want the script to save a brief summary of the analysis to a text file in the folder **ROOT/data/”batch number”/summary**; set it equal to **0** (default) otherwise.

line 43: **NA\_tb\_cell\_da** This parameter let you specify what will appear in the cells of the data analysis summary table when no data are available. You can enter any text you want but the usual values are: “N/A” or “&nbsp;,” which makes the cell empty if no data are available.

NOTE: The **savefig** parameter is no longer an option. It must have the value **3** otherwise the produced web pages will contain broken hyperlinks.

### **III.3 Running the script**

- Change the current MATLAB directory to point to the folder containing the main scripts (**ROOT/matlab**)
- Run the *automain.m* script. It will display a Directory Dialog Box asking you to point to the folder containing the data files you want to be processed.
- Locate and select the data folder to be processed;
- The scripts will create graphics files with “fig” or “png” extensions and will place them in the folders **ROOT/fig/”batch number”** and **ROOT/png/”batch number”**.
- The scripts will create a web page for each processed tube named *xxx.htm* (where *xxx* stands for serial number).
- It will also produce two web pages related to the batch: *list.htm* and *summary.htm*. These files as well as *xxx.htm* files (described above) will be placed into the folder **ROOT/html/data/”batch number”**

### **III.4 Additional notes**

- a) The produced web pages rely on the folder structure described above (otherwise the hyperlinks will not work).
- b) The scripts will not update the *batchlst.htm* and *serial.htm* files located in **ROOT/html** folder. It is your responsibility to keep them updated. The index file *index.htm* normally should be placed in the **ROOT** directory.

### **III.5 What if the scripts crash?**

In the unfortunate case when the MATLAB scripts will crash you will have to start over. One difficulty you might encounter in doing that is that some files created by the previous run have their handles open and now the Windows will not allow the scripts to access these files. In this case there are two solutions:

1. Close/Exit MATLAB. Start over;
2. Type “**fclose all**” (without quotation marks) in the command window of the MATLAB. This will close all opened file handles.

## **Appendix: The structure of the data files**

For any type of experiment (quantum efficiency, surface scan, etc.) the data file is comprised of two sections: header section and data section.

**The Header Section.** The first line of the header section tells the file version (currently it is the version 3). Second line describes the test mode (QE, surface scan, etc.) These two lines are followed by the following sections: “Info”, “Scan Parameters”, “NF90 Motors Settings”, “Picoameter”, “Optical Power Meter”. The entries in these sections are mostly self-explanatory. We will mention here some of the entries.

The “**Info**” section lists the tube manufacturer, tube model and its serial number, tube gain, and high voltage applied to the tube.

The “**Scan Parameters**” section describes the values of various parameters defining the scan. The *Wavelength* parameter is the wavelength used for surface scans. *Start Wavelength*, *End Wavelength*, and *Wavelength step* refer to quantum efficiency measurements, reading calibration data from silicon detector, and optical density measurements. For QE measurements, a neutral filter is placed in the front of the PMT. The optical density of the filter is a function of the wavelength. This function is approximated with a polynomial of a degree  $n$  (up to 7) like this:

$$OD(\lambda) = \sum_{k=0}^n c_k \lambda^k$$

The coefficients  $c_k$  are given in the *Polynomial Coefficients* parameter of the “**Scan Parameters**” section.

**The Data Section for Surface Scans** is composed of two matrices. First one contains the readings of the current at various positions at the surface of the PMT and the second matrix contains the errors associated with these reading. The first line in the data section tells the number of rows and columns in these matrices. This line is followed by two parameters: *X coordinates* and *Y coordinates*. These two parameters tell the exact geometric positions on the surface of the PMT corresponding to rows and columns in the matrices. These two lines are followed by the two matrices described above.

**The Data Section for Quantum Efficiency Measurements**. The first line in the data section tells the number of rows and columns in the data table which follows that line. The rows in the table correspond to measurements performed for different wavelengths. During the quantum efficiency measurement the optical fiber is positioned at several points at the surface of the PMT (Measuring the current just at the center of the PMT does not take into account the variations of the sensitivity of the PMT across its surface. The final current is the average of such readings at different positions). The columns in the table have the following meaning:

1. Wavelength  $\lambda$  in nm
2. The reading of the current  $I$  from PMT (in Amps)
3. Same as above but corrected for the presence of the filter  $\tilde{I} \equiv I_{\text{corrected}} = 10^{OD(\lambda)} I$
4. The error associated with the corrected current  $(\frac{1}{N} \sum_{k=1}^N \Delta \tilde{I}_k)$  where  $\Delta \tilde{I}_k$  is the error associated with the reading of the current at one optical fiber position.  $N$  is the number of *QE Scan Points* (see “**Scan Parameters**” section of the header file)
5. The error of the corrected current which takes into account the variations of the sensitivity of the PMTs across their surface:  $\Delta \tilde{I} = \sqrt{\frac{1}{N-1} \sum_{k=1}^N (\tilde{I}_{\text{av}} - \tilde{I}_k)^2}$
6. The reading of the optical power of the light (Watts)

7. The error associated with the reading of the optical power
8. Quantum Efficiency
9. Error associated with QE computed using column 4 (see above)
10. Same as above but computed using column 5

## **References**

1. PMT effective radius and uniformity testing. Mihai Cara, Rudy Gilmore, John Finley