DGUI *

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USER GUIDE
FOR THE GUI ACCOMPANYING THE
BEAM DYNAMICS CODE DYNAC

Modified and maintained by:
E. Tanke

Contact:
E. Tanke, e-mail: dynacatgithub@gmail.com

DYNAC WEBSITE
https://github.com/dynac-source

* See Software License Agreement on next page

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1 INTRODUCTION

To give an alternative to DYNAC program execution and data analysis from the command line in a shell, a Graphical User Interface (GUI) has been written. Like for the DYNAC code itself, the GUI (called DGUI) can be used on three different operating systems (linux, MAC and Windows). DGUI V1 was based on the DISLIN graphics package, whereas DGUI V2 is based on python3. The intent is to stay with a python-based GUI. This User Guide (UG) will walk you through the steps to get started.

With DGUI, the user can:
- select a particle distribution file (.dst) and plot it, plot its concomitant profiles or plot both
- select a DYNAC input file and subsequently execute the DYNAC code with this file with the DYNAC binary of choice
- start the "plotit" facility (see DYNAC UG) to plot the graphs requested in the DYNAC input file
- plot RMS emittances as a function of the longitudinal coordinate z
- plot beam energy and phase as a function of the longitudinal coordinate z
- plot beam size (extremes and or RMS) as a function of the longitudinal coordinate z
- plot the beam centroid (horizontal and vertical) and transmission
- plot horizontal and vertical dispersion as a function of the longitudinal coordinate z
- plot beam losses as a function of the longitudinal coordinate z

In addition, graph limits can be changed and the graphs can be copied and/or saved as files.

Functionality will be added over time to the GUI, whereby user input is very much encouraged.

2 INSTALLATION

Prior to installing the DYNAC GUI, one will need to ensure one has the appropriate Python version and Python libraries installed. This is covered in section 2.1 below.

This chapter covers the entire initial installation of the graphics software components. For installation of DGUI updates, and assuming python3.10 and the python3.10 libraries needed by DGUI are already installed on your system, you can skip section 2.1.

2.1 Installation of python3.10

This section describes how to install python3.10, with specifics given for three different operating systems.

In what follows, shell/terminal commands are marked in magenta text, output to the shell terminal is marked in blue. At the time of release of this UG, functionality of DGUI V2R5 had been successfully tested with python versions 3.8, 3.9 and 3.10 on linux mint 20 (Uma), windows (11) and MAC (Big Sur).

2.1.1 MAC Specifics

One of the GUI buttons invokes gnuplot with an x11 terminal. Check that the x11 terminal works properly with gnuplot (see also DGS00006 in chapter 6.2).

2.1.1.1 Python installation

To verify if python3 is installed and operable, open a terminal window and type

```
python3 -V
```

and you should then see something like the following:

```
Python 3.10.4
```

The actual version will depend on the version of python you installed but has to be a Python 3 version (not a Python 2 version).

If python3 is not installed, download python3 from https://www.python.org/downloads/ and follow instructions for installation.

2.1.1.2 Installation of Python libraries required by DGUI

To install these Python libraries; one can use the pip3 facility. Make sure pip3 is up to date with:

```
pip3 install --upgrade pip
```

Install the required libraries:
pip3 install numpy
pip3 install matplotlib
pip3 install pandas
pip3 install pyqtgraph
pip3 install pyqt5
pip3 install scipy
pip3 install lmfit
pip3 install colorcet
Alternatively, and depending on your python installation, you can use commands like
python3 -m pip install pyqt5

If the system complains about insufficient privileges, you may need to insert sudo -H in front of the offending command, e.g.
sudo -H pip3 install matplotlib

2.1.2 Linux Specifics

2.1.2.1 Python installation

To verify if python3 is installed and operable, open a terminal window and type
python3 -V
or, depending on your installation, for instance
python3.10 -V
and you should then see something like the following:
Python 3.10.4
The actual version will depend on the version of python you installed but has to be a Python 3 version (not a Python 2 version).
If python3 is not installed, download python3 from https://www.python.org/downloads/ and follow instructions for installation.

2.1.2.2 Installation of Python libraries required by DGUI

To install these Python libraries; one can use the pip facility. You can check the version of pip with:
python3.10 -m pip --version
Install the required libraries:
python3.10 -m pip install numpy
python3.10 -m pip install matplotlib
python3.10 -m pip install pandas
python3.10 -m pip install pyqtgraph
python3.10 -m pip install pyqt5
python3.10 -m pip install scipy
python3.10 -m pip install lmfit
python3.10 -m pip install colorcet

If the system complains about insufficient privileges, you may need to insert sudo -H in front of the offending command, e.g.
sudo -H python3.10 -m pip install matplotlib

2.1.3 Windows Specifics

2.1.3.1 Python installation

To verify if python3 is installed and operable, open a DOS window and type
python –V
and you should then see something like the following:
Python 3.10.4
The actual version will depend on the version of python you installed but has to be a Python 3 version (not a Python 2 version).
If python3 is not installed, download python3 from https://www.python.org/downloads/windows and follow instructions for installation. As an example, one can use the Windows X86-64 executable installer.

2.1.3.2 Installation of Python libraries required by DGUI

To install these Python libraries; one can use the pip facility. Make sure pip is up to date with:
pip install --upgrade pip
or if this gives you an error, you will be prompted with an alternative command. This may require using a DOS window with administrative privileges.

Install the “wheel” library:
pip install wheel
and install these required libraries:
pip install pyqtgraph
pip install pyqt5
pip install scipy
pip install lmfit
pip install colorcet
Also install these required libraries:
pip install pandas
pip install kiwisolver
pip install matplotlib
or download these last 3 libraries from http://www.lfd.uci.edu/~gohlke/pythonlibs/ and install them, e.g.
pip install pandas-0.24.2-cp37-cp37m-win32.whl
The actual version number may be a more recent one than the ones listed here. Note that kiwisolver has to be installed before matplotlib.

If numpy was not installed when pyqtgraph was installed, then download it also from
http://www.lfd.uci.edu/~gohlke/pythonlibs/ and install:
pip install numpy-1.13.0+mkl-cp36-cp36m-win32.whl
Again, the actual version number may be a more recent one than the one listed here.

2.2 Installation of DGUI

This UG, as well as other required files will be automatically installed if the full DYNAC package (V6R19 or newer, V7R2 is recommended) was obtained from the DYNAC webpage and successfully installed. You will then need to ***rename the example dgui.ini file*** you got ***from the DYNAC web site to dgui.ini.***

If, instead, you are only wanting to update an existing DGUI, then proceed to section 2.2.1.

The dgui.py script and the dgui.ini file will be located in the dynac/dgui folder (or dynac\dgui folder for windows). The first line in the dgui.ini file needs to be the path to the dynac executable, e.g.
/Users/yourname/dynac/bin
for linux or MAC and as an example for windows:
C:\dynac\bin

Following these mandatory lines in the dgui.ini file, the user can set preferred options. The lines with these options are not mandatory.
The default program to open the User Guide PDFs is Acrobat. On linux it may be of interest to change this to Evince or xreader (see section 4.1.3).
PDFVIEWER acrobat
PDFVIEWER evince
PDFVIEWER xreader

By default, when making density plots, the colormap (called "default" in the list below) that was available in DGUI V2R1 will be used. This can be changed by the user with the following entry in dgui.ini:
COLORMAP my_preferred_colormap
Here my_preferred_colormap is the colormap of your preference, but it needs to be one of the following:
gnuplot2_r
gist_earth_r
gist_stern
viridis
nipy_spectral
jet
diverging_rainbow_bgymr_45_85_c67
rainbow_bgyr_35_85_c72
linear_tritanopic_krjcw_5_98_c46
linear_worb_100_25_c53
linear_wcmr_100_45_c42
linear_kryw_5_100_c67
linear_kryw_0_100_c71
default

By default, when plotting profiles related to distribution files, raw data is being used. One can change this to plotting fitted data, whereby a Gaussian fit is used (see section 4.2.3).
PROFILES raw
PROFILES fitted

2.2.1 Updating DGUI

This section applies if you wish to update the existing DGUI software on your system.

In view of updating to DGUI V2R5 from older DGUI revisions, it is suggested to create a new sub-folder (e.g. named Archive) inside the dynac/dgui folder (dynac\dgui for windows). Rename the existing dgui.py (e.g. by appending Version_Revision to it) and move it to Archive. Likewise, in the dynac/help folder (dynac\help for Windows) create a new sub-folder (e.g. named Archive). Rename the existing UG (e.g. DGUI_V2R4.pdf) and move it to Archive.

Then download this UG (V2R5) to the dynac/help directory from the DYNAC website:
https://github.com/dynac-source
and the dgui.py script to the dynac/dgui directory. If not installed yet, also download the dynicon.png to the dynac/bin directory.

2.3 Testing DGUI

DGUI V2R5 requires python3.8 or newer. Check the version of python by typing one of the following (depending on operating system):

python3.10 -V
or
python3 -V
or
python -V

If you do not have python3 installed, then follow the instructions in section 2.1. If python3.8 or newer is successfully installed, you will need to add libraries that DGUI requires, if they are not installed already. Section 2.1 has instructions on how to add these.

Open a terminal window and go to the dgui directory. Run the DGUI executable by typing:

python3 dgui.py -v
or
python3.10 dgui.py -v
for MAC or Linux, or
python dgui.py -v
for Windows.

You should then see the text "DGUI" and the version and revision numbers and date, e.g.

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The available options available at the startup of DGUI can be looked at by typing

python3 dgui.py -h
or
python3.10 dgui.py -h
for MAC or Linux, or
python dgui.py -h
for Windows.

You should then see the text DGUI and the version number, e.g.

```
usage: dgui.py [-h] [-v] [--version] [-p P]

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optional arguments:
  -h, --help    show this help message and exit
  -v            show DGUI version number and exit
  --version     show DGUI version number and exit
  -p P          here P is the path to the location of dgui.py; no space between -p and the path! -pP is mandatory if
                none of the other optional arguments are used
```

Finally, for MAC or Linux, start DGUI by typing

python3 dgui.py -p*path_to_dgui*
or
python3.10 dgui.py -p*path_to_dgui*

Instead, for Windows type

python dgui.py -p*path_to_dgui*

where *path_to_dgui* is the path to the location where dgui.py is stored. **There should be no space between "-p" and the path_to_dgui and no leading tilde ~ character in the path name.**
You should now obtain a window similar to the one in Fig.1.

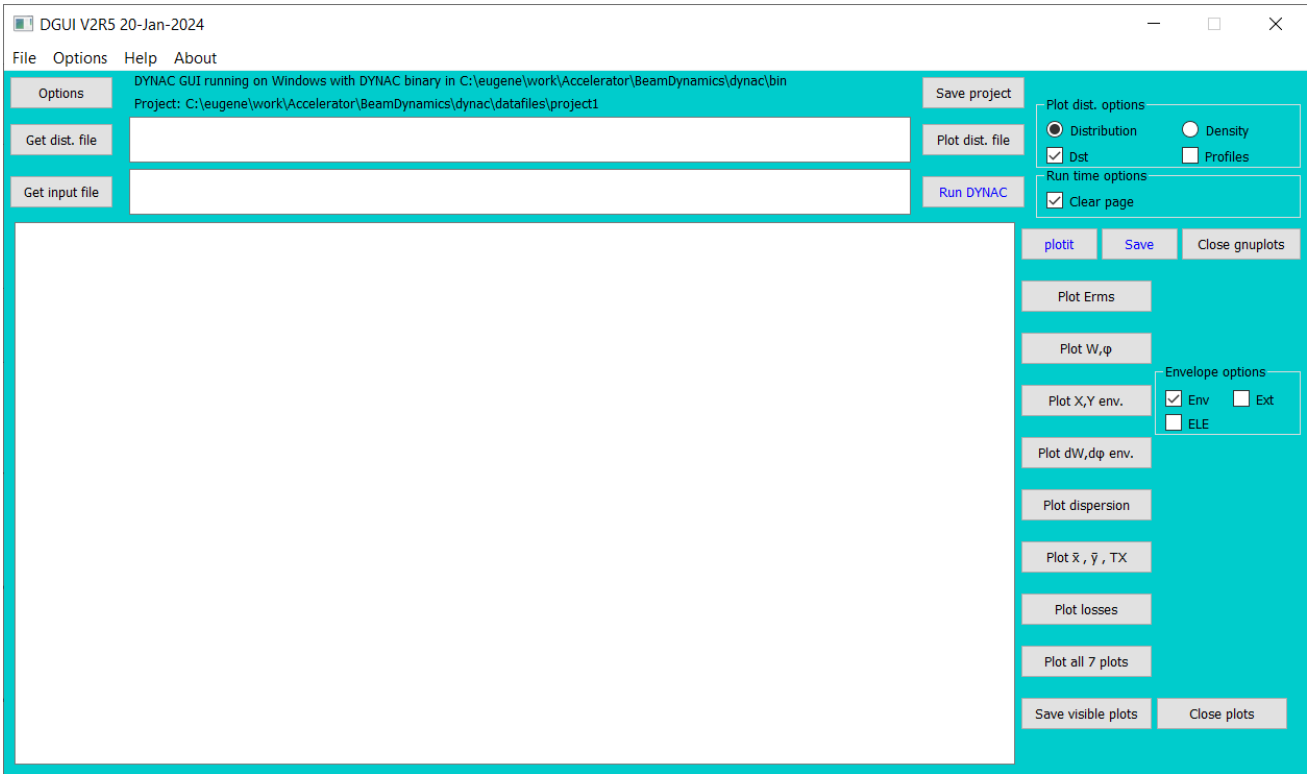

Figure 1: DGUI window (this one for Windows 10, similar ones for MAC and linux)

Now click on “File” in the menu bar and select “Close DGUI”. Also, Ctrl-Q on Windows or command-Q on MAC will close DGUI.

3 PREPARING FOR EASE OF USE

The following steps are recommended for ease of use of the GUI and are OS dependent.

3.1 MAC

Make an alias such that one can start DGUI without having to give the arguments each time you start the GUI. As an example, for the C-shell, something like the following line can be added in the .cshrc file (this file is located in the top directory):
alias dg 'python3 /path_to_dynac/dynac/dgui/dgui.py -p*path_to_dgui*'

Of course, the paths need to be replaced by the appropriate ones in this example. **Again, there should be no space between "-p" and the path_to_dgui and no leading tilde ~ character in the path names.** Then either type
source .cshrc
or open a new shell/terminal window. You can now start DGUI by typing
dg
from any directory.
If you normally use the bash shell, you will need to edit .bashrc instead.

You can also make a shortcut, for instance on the desktop:

- In the folder of your preference, create a shell script file with the following contents:
  python3 /path_to_dynac/dynac/dgui/dgui.py -p*path_to_dgui*
  whereby one needs to replace path_to_dynac and *path_to_dgui* by what applies and save the file with .sh as extension (in what follows, the file name dgsc.sh is assumed)
- Change the access mode to allow execution, e.g.
  chmod a+x dgsc.sh
- From the MAC **Applications**, run **Automator**
- Under **Choose a type for your document:** choose **Application** and click on **Choose**
- Type run in the Actions search box
- Double click **Run Shell Script**
- In the text box under "Run Shell Script" type the path to and name of your shell script, e.g.
  /home/william/dgsc.sh
- Next click **File** on the menu bar and select **Save…**
- Give the short cut a name and behind Where: select Desktop
- Next to **File Format:** select **Application**
- Click on **Save**

3.2 LINUX

Make an alias such that one can start DGUI without having to give the arguments each time you start the GUI. As an example, for the bash-shell, something like the following line can be added in the .bashrc file (this file is located in the top directory):
alias dg='python3.10 /path_to_dynac/dynac/dgui/dgui.py -p*path_to_dgui*'

Of course, the paths need to be replaced by the appropriate ones in this example. **Again, there should be no space between "-p" and the path_to_dgui and no leading tilde ~ character in the path names.** Then either type
source .bashrc
or open a new shell/terminal window. You can now start DGUI by typing
dg
from any directory.
If you normally use the C shell, you will need to edit .cshrc instead.

3.3 WINDOWS

Assuming you have added the dynac\bin directory to your Windows PATH, the following will make it such that one can start DGUI without having to give the arguments each time. Create a file called dg.bat in the dynac\bin directory and edit it to contain the following:

python c:\path_to_dynac\dynac\dgui\dgui.py -p*path_to_dgui*

Of course, the paths need to be replaced by the appropriate ones in this example. **Again, there should be no space between "-p" and the path_to_dgui and no leading tilde ~ character in the path names.**

You can now start DGUI by typing

dg

from any directory.

You can also make a shortcut, for instance on the desktop:

- Right-click a blank space on the Windows desktop, a folder, or in a directory
- Move your mouse cursor over **New** in the drop-down menu that appears
- Then select **Shortcut**
- On the Create Shortcut window, type c:\path_to_dynac\dynac\dgui\dgui.py -p*path_to_dgui* directly in the field under "Type the location of this item..."
- Then click **Next**
- Finally, give a name to the shortcut, e.g. dgui

One can access the User Guides from the GUI (see section 4.1.3), whereby on Windows**,** AcroRd32.exe will be used to open them. It may be necessary to add the path to this .exe to the Windows PATH, as an example do this by opening a DOS window and type:

set PATH=%PATH%;C:\Program Files (x86)\Adobe\Acrobat Reader DC\Reader

and

setx PATH "%PATH%;C:\Program Files (x86)\Adobe\Acrobat Reader DC\Reader"

If AcroRd32.exe is in a different directory than in this example, change the DOS commands accordingly. These commands only need to be given once.

4 USER INTERFACE

This chapter describes the functionality and usage of the GUI. To start DGUI, click on the DGUI short cut on the desktop (this assumes you followed instructions as per chapter 3) or open a terminal window (MAC/linux) or MS-DOS window (Windows) and type the following command (this assumes you followed instructions as per chapter 3):
dg
You should now have a window similar to the one shown in Fig.1.

In what follows, buttons and input fields on the GUI window are marked in magenta text, output to the terminal is marked in blue. To exit DGUI, click "File" on the menu bar and select "Close DGUI".

4.1 MAIN WINDOW MENU BAR

4.1.1 File

The options below "File" in the menu bar are:
"Open input file", which has the same functionality as the "Get input file" button on the main window
"Open dist. file", which has the same functionality as the "Get dist. file" button on the main window
"Set project files directory", see section 4.6.
"Save project files", see section 4.6.
"Open dist. file", which has the same functionality as the "Get dist. file" button on the main window
"Close DGUI", which will cause the DGUI and the DGUI options window (if open) to close. It will not close any graphics windows that may be open.
"Close all windows", like "Close DGUI", but it will also close any graphics windows that may be open.

4.1.2 Options

There are 2 options below "Options" in the menu bar:
"Print Screen", with which one can print the full screen to file.
"List software versions", with which one can display the versions of the different software packages related to the DYNAC environment.

4.1.3 Help

The UGs for DGUI as well as for DYNAC can be directly accessed by clicking on "Help" in the menu bar and selecting the UG of interest. The UGs are in the form of PDF files.

On **Windows,** AcroRd32.exe will be used to open them. You may need to add the path to this exe to the Windows PATH (see section 3.3).

On **MAC**, the "open" command will be used to open the PDF files.

On **linux**, xreader will be used by default. Alternatively, acroread or evince can be used. You can change your preference on the fly by clicking on the gray "Options" button: an options window will pop up (see Fig.7), from where one can select the "acroread" or "evince" button in the "Open User Guides" field. If you wish to change the default, open the dgui.ini file in the dynac/dgui directory and add or change the line containing PDFVIEWER, e.g.
PDFVIEWER acrobat
or
PDFVIEWER evince

4.1.4 About

The "About DGUI" option below "About" in the menu bar will "about" information in a pop-up menu.

4.2 VISUALIZING STORED PARTICLE DISTRIBUTIONS

Click the "Get dist. file" button and select the distribution file (typically with .dst as file extension) of interest using the pop-up window.

If you do not have any distribution files yet, you can for instance use the procedure under **4.3** to run DYNAC, whereby one selects the SNS example input file from the dynac/datafiles directory. This input file uses IFLAG=100 under WRBEAM to generate an output distribution file called sns_mebt_dtl_out.dst
If it does not, you can get an updated version of the input file from the DYNAC website.

4.2.1 Plotting distributions that are consistent with the DYNAC WRBEAM flag IFLAG set to less than 100

With older versions of DYNAC, the first line of a particle distribution did not contain numbers for IFLAG, the RF frequency and the beam energy. As the phase will be plotted in degrees, the frequency is required. You need to add these numbers in the distribution file*, change the IFLAG number and then refer to the section below related to IFLAG >= 100.

4.2.2 Plotting distributions that are consistent with the DYNAC WRBEAM flag IFLAG set to 100 or larger

Click the "Plot dist. file" button and you will see particle distribution plots for X-X', Y-Y', X-PHI on top and Y-X, W-PHI, Y-PHI at the bottom; an example is shown in Fig.2 for a multi-charge state distribution.

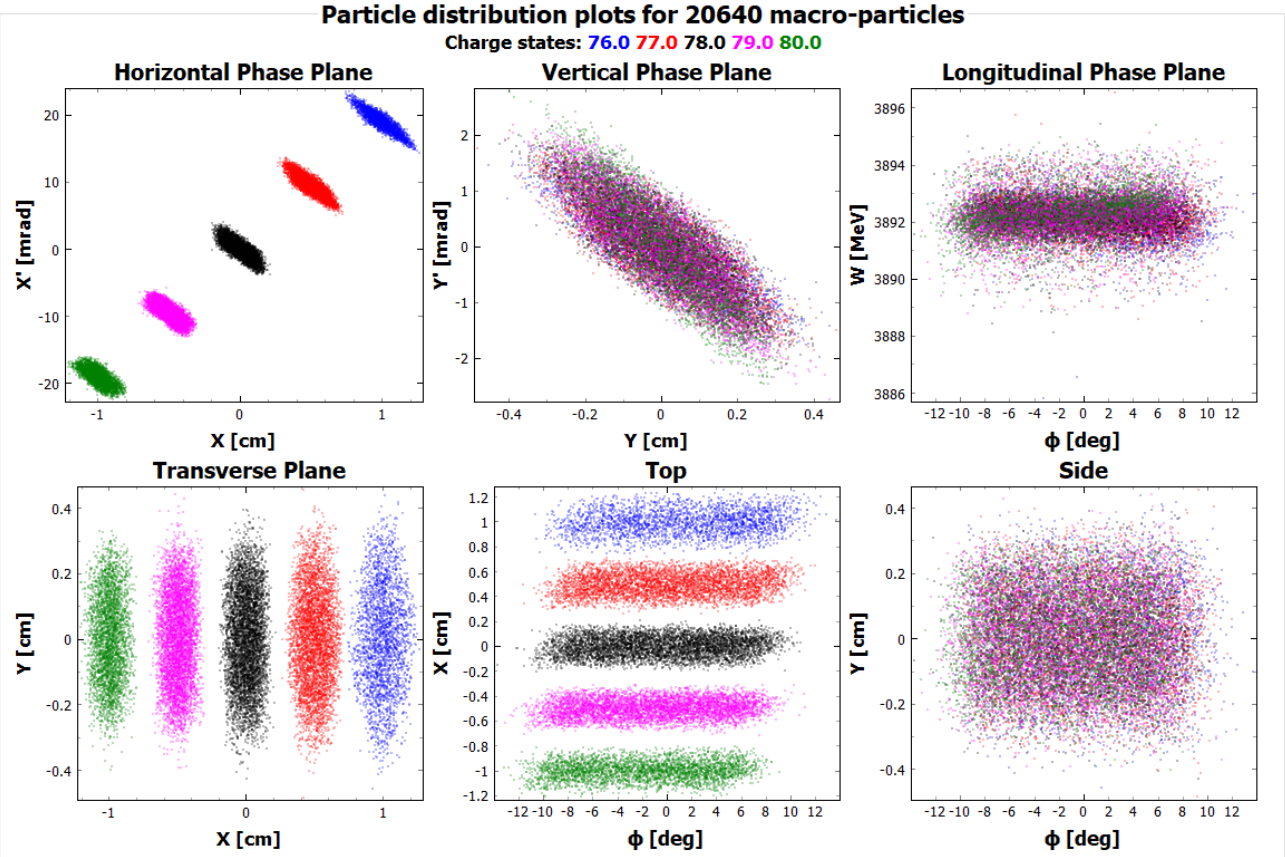

Figure 2: Particle distribution plot for a multi-charge state beam

4.2.3 Plotting profiles

By default, "Plot dist. file" only causes the distributions to be plotted: "Dst" (in the "Plot dist. options" field, top right of window) is selected by default. One can, however, also plot the profiles that are defined by these distributions, by selecting "Pro" and subsequently clicking the "Plot dist. file" button again. One can also just plot the profiles by deselecting "Dst" (only "Pro" selected) and subsequently clicking the "Plot dist. file" button again. Profiles will only be shown in the X-X', Y-Y' and W-PHI phase planes. An example is shown in Fig.3 for a single charge state distribution.

* In the old distribution file format, the first line contains the number of particles, followed by two dummy parameters. In the new distribution file format, the first line contains at a minimum the number of particles, followed by IFLAG (see DYNAC UG), the frequency (MHz) and the beam energy (MeV).

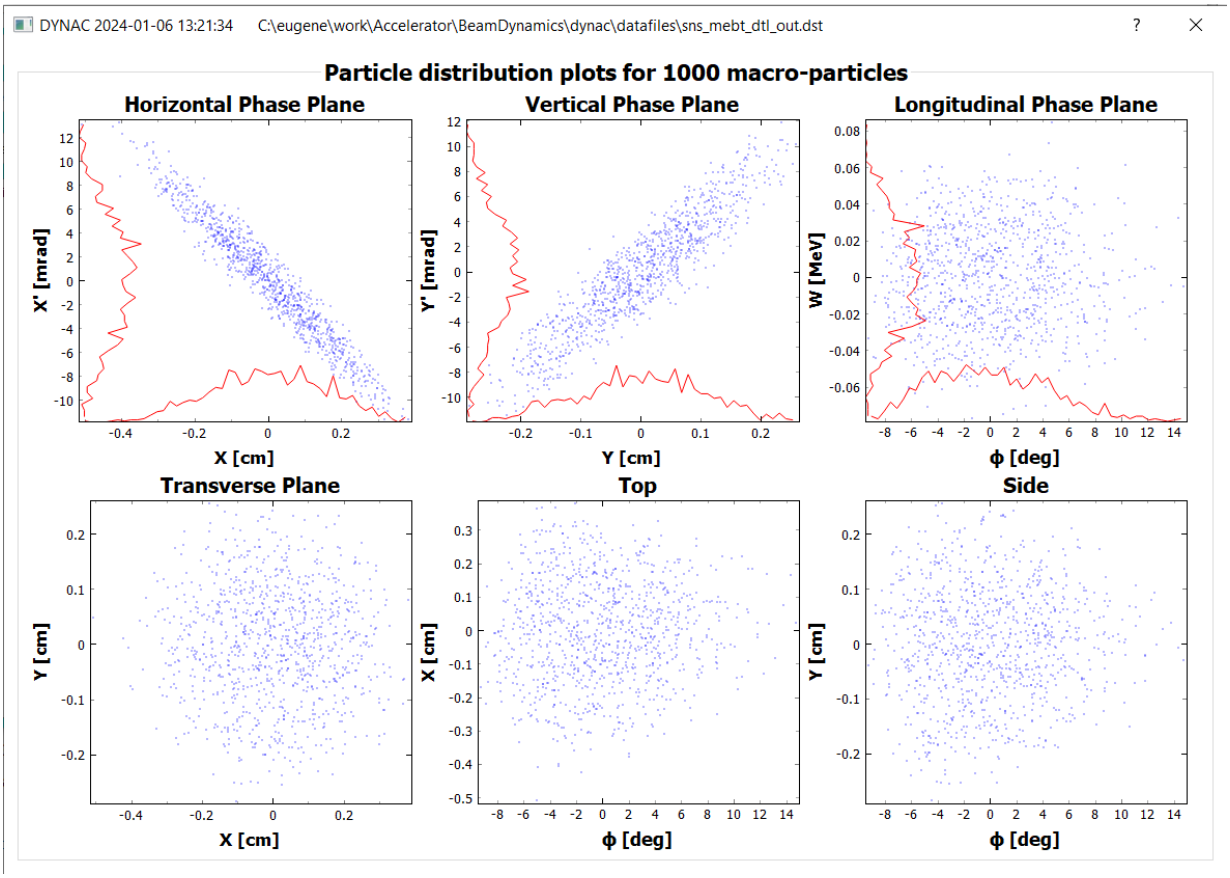

Figure 3: Particle distribution plot for a single charge state beam, including profiles based on raw data.

By default, the profiles will be based on the raw binned data. One can apply a Gaussian fit to these data by clicking the "Options" button, and in the DYNAC GUI OPTIONS window (see Fig.7) that will appear, selecting the "Fit" check box in the "Data in the profiles are to be" field. One can choose either option (see Fig.4 for result), both, or neither.

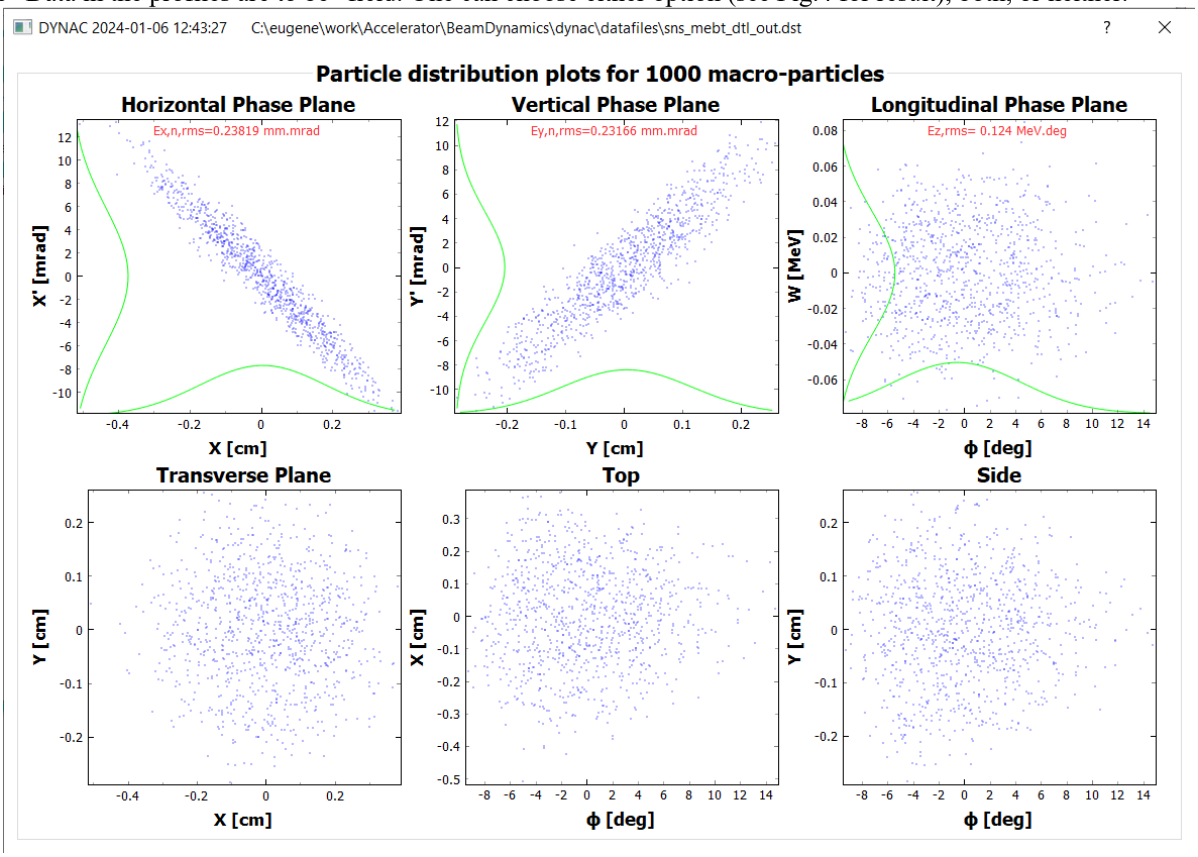

Figure 4: Particle distribution plot for a single charge state beam, including profiles based on fitted data, with printout of emittance values. This printout of emittance values can be selected in the DYNAC GUI OPTIONS window (see Fig.7).

If upon opening DGUI, you wish the default to be “Fitted” data, one can modify the dgui.ini to achieve this. In dgui.ini add the following line after the first line:
PROFILES fitted

The amplitudes of the profiles can be adjusted by using the amplitude buttons (ranging from 1 to 4) in the “Amplitude of profiles” field in the DGUI options window (see Fig.7).

4.2.4 Changing scales on plots
By default, auto scaling is in effect. To change the scale on any of the plots, right-click on the plot of interest and change the settings in the pop-up menu (Fig.5).

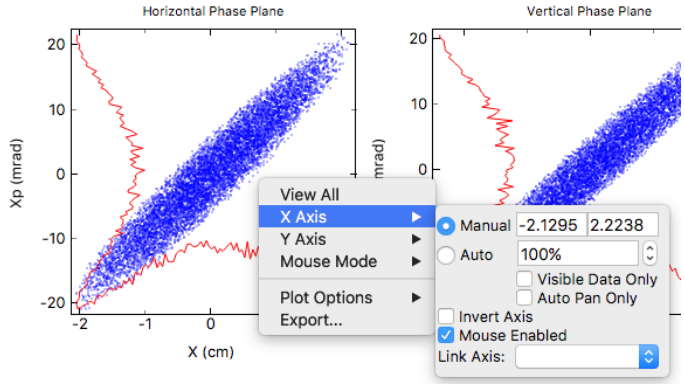

Figure 5: A pop-up window appears after right-clicking a plot.

When left-clicking on a plot, one can displace the graph by continuing to press the mouse button and moving the mouse simultaneously. Following this, an A button will appear. You can left-click this button to go back to the original setting before the move.

One can also set the default graph limits in the dgui.ini file, e.g.
RANGES X -1. 1.
RANGES XP -100. 100.
RANGES Y -1. 1.
RANGES YP -100. 100.
RANGES Z -180. 180.
RANGES ZP -1. 12.

These will be used if one selects “User” in the “Graph limits based on” field in the DGUI Options window (see Fig.7). One can also change these graph limits on the fly. This is done by changing the setting(s) at the bottom of the DGUI Options window (see Fig.7) and subsequently clicking the “Update graph limits” button below.

One can optionally display the values of the RMS emittances in the top three plots if one selects “Display” in the “Emittance values” field in the DGUI Options window (see Fig.7). In that case these values will be plotted at the top of the aforementioned three plots. By selecting “at the bottom” as well, they will be displayed at the bottom. The transverse emittances are normalized. To calculate the normalized emittance, the AMU of the particle is needed. It has a default value of 1 (protons), but can be changed at the bottom of the DYNAC GUI OPTIONS window (see Fig.7).

4.2.5 Plotting distributions as density plots
Change from the default distribution plot to a density plot by selecting the ”Density“ radio button (in the “Plot dist. options” field) and click the “Plot dist. file” button. Fig.6 shows an example result corresponding to the same particle distribution as shown in Fig.3.

The plot shown in Fig.6 uses an interpolation method to establish the local densities, which is the default. One can also choose a (much slower) KDE (Kernel Density Estimation) method. To do so, click the “Options” button, and in the DYNAC GUI OPTIONS window (see Fig.7) that will appear, select the “KDE” button in the “Density plot method” field.

The plot shown in Fig.6 uses an interpolation method to establish the local densities, which is the default. One can also choose a (much slower) KDE (Kernel Density Estimation) method. To do so, click the “Options” button, and in the DYNAC GUI OPTIONS window (see Fig.7) that will appear, select the “KDE” button in the “Density plot method” field.

One can change the colormap on the fly in the DGUI options window, as well as set a default colormap in the DGUI.ini file (see Chapter 2). Now click the "Plot dist. file" button again. Fig.8 shows an example result corresponding to the same particle distribution as shown in Fig.6.

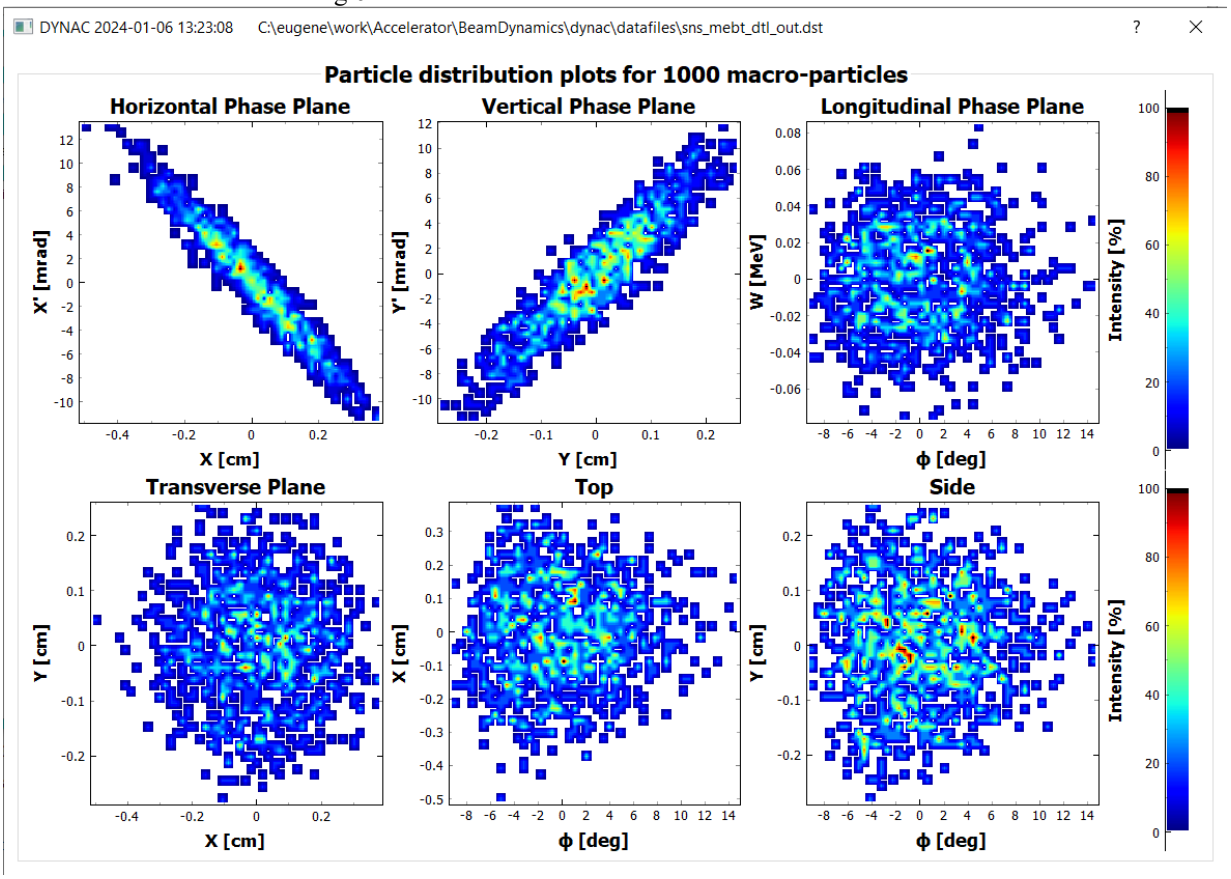

Figure 6: Same particle distribution as represented in Fig.3, but shown as a density plot based on interpolation

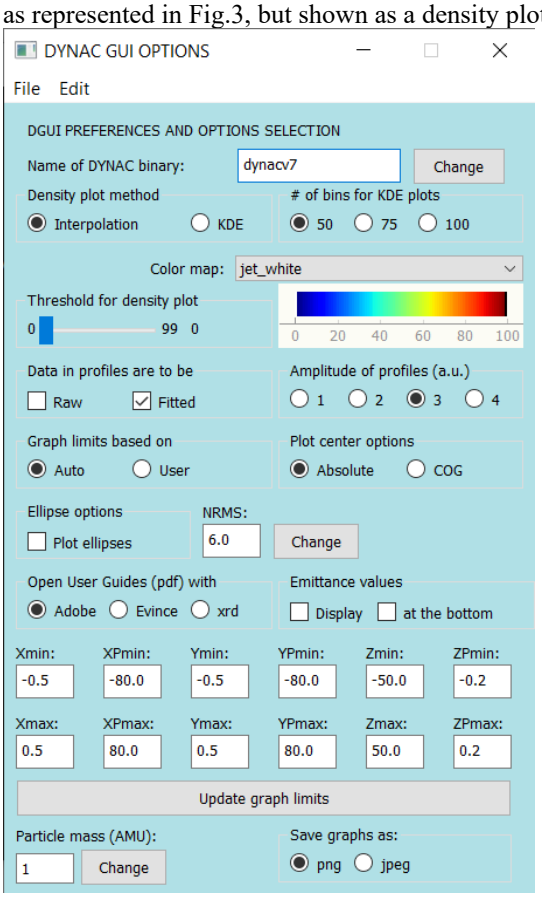

Figure 7: DYNAC GUI OPTIONS window

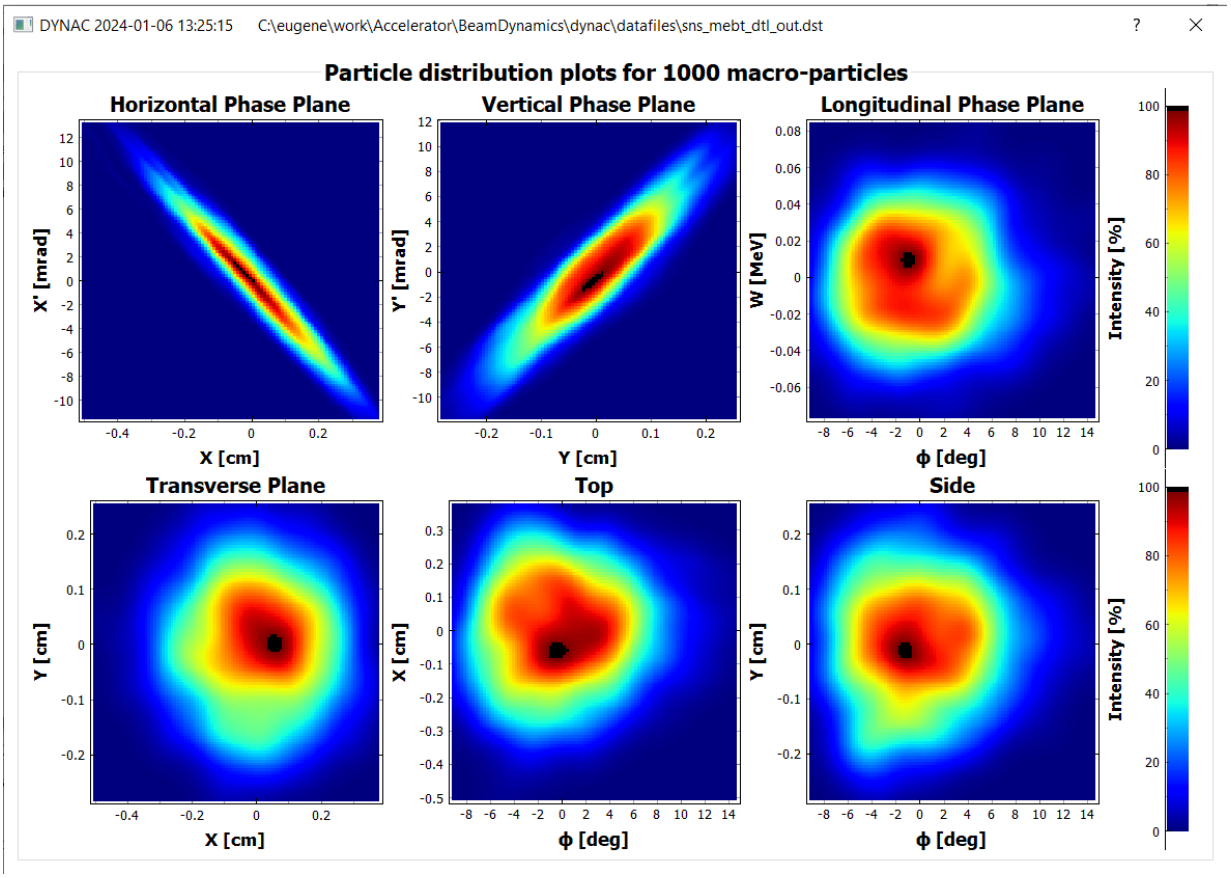

Figure 8: Same particle distribution as represented in Fig.6, but with a density plot based on a KDE method.

The granularity of the kernels in the plot can be changed by changing the number of bins used by the KDE method. To do so, change the number of bins in the DYNAC GUI OPTIONS window (see Fig.7). The higher the number, the finer the resolution (and the longer it takes to calculate the plot!).

One can change the threshold for the density plots by changing the slider in the "Threshold for density plot" field in the DYNAC GUI OPTIONS window. Click the "Plot dist. file" button again to see the result. This works for both types of density plots. On Windows, the first time you use the slider, you may need to click next to it to activate it.

4.2.6 Plotting ellipses

By selecting "Plot ellipses" in the "Ellipse options" field in the DGUI Options window (see Fig.7), ellipses will be plotted on three of the six particle distribution plots (longitudinal and both transverse emittances). The size of the ellipses can be set in terms of multiples of the RMS size by changing the numerical field marked NRMS in the DGUI Options window. Once the numerical entry has been entered, one has to click the adjacent "Change" button for the value to take effect.

4.3 DYNAC PROGRAM EXECUTION

Prior to starting the DYNAC program, one needs to select an input file by clicking on "Get input file" and choosing the DYNAC input file of interest.

Once the input file has been selected, you can click the "Run DYNAC" button. Text output from DYNAC will be displayed in the large text box below in the main window. Program execution can be interrupted by typing ctrl-I (cmd-I on MAC) or by clicking the "Run DYNAC" button once more.
If one were to run DYNAC again, by default the text in the text box will be cleared before the new output is displayed in it. By deselecting "Clear page" in the "Run time options" field, new text blocks will be displayed above the existing ones in the text box.

The DYNAC executable can be changed by entering the name of the binary in the appropriate text file in the DGUI options box and subsequently clicking the adjacent "Change" button. The default can be set in the dgui.ini file by entering
DYNACVERSION dynacv7
or for instance
DYNACVERSION dynacv6_0
for this older version of DYNAC (do not use versions older than V6R19). The name of the binary (without extension) should be the same as in the dynac/bin directory.

4.4 PLOTS BASED ON THE DYNAC INPUT FILE

In the DYNAC input file one can request plots based on various cards (EMITGR, PROFGR etc). After executing the DYNAC program with the input file of choice (see section 4.3), and assuming that plot cards were present in the input file, one can plot the results from these cards by clicking on the "plotit" button. This will start gnuplot and will make one window per requested plot. All plots will be plotted at once. Text output from plotit will be printed in the DYNAC GUI main window large text box.
Clicking on the "Save" button (to the right of the "plotit" button) will cause the gnuplot graphics windows to be saved as picture files. The picture file format (.png or .jpeg) can be selected in the DYNAC GUI OPTIONS window (see Fig.7).
Clicking on the "Close gnuplots" button will cause any open gnuplot graphics windows to be closed.

4.5 PLOTTING WITH THE GUI

In using the plot options mentioned in this section, data is read from the dynac.print and/or dynac.dmp files and subsequently plotted. If you want to ensure that you get plots of the data you want, make sure to execute DYNAC with the input file of your choice (see section 4.4) prior to plotting.
Clicking on the "Save visible plots" button (bottom right of the main DGUI window) will cause the visible DGUI graphics windows to be saved as picture files. The picture file format (.png or .jpeg) can be selected in the DYNAC GUI OPTIONS window (see Fig.7).
Clicking on the "Close plots" button will cause any open graphics windows to be closed (with the exception of the gnuplot graphics windows).
Changing scales can be achieved as described under ***Changing scales (4.2.4)***. If the legend of any of the plots below is obscured by the plotted data, you can simply left-click the legend, drag it and drop it to a location in the plot where it will not be obscured.

4.5.1 Plot Erms

With this option, 2 graphs will be displayed as a function of the position along the beam axis (z): the top one will show the normalized transverse RMS emittances, the bottom one the longitudinal RMS emittance (example in Fig.9).

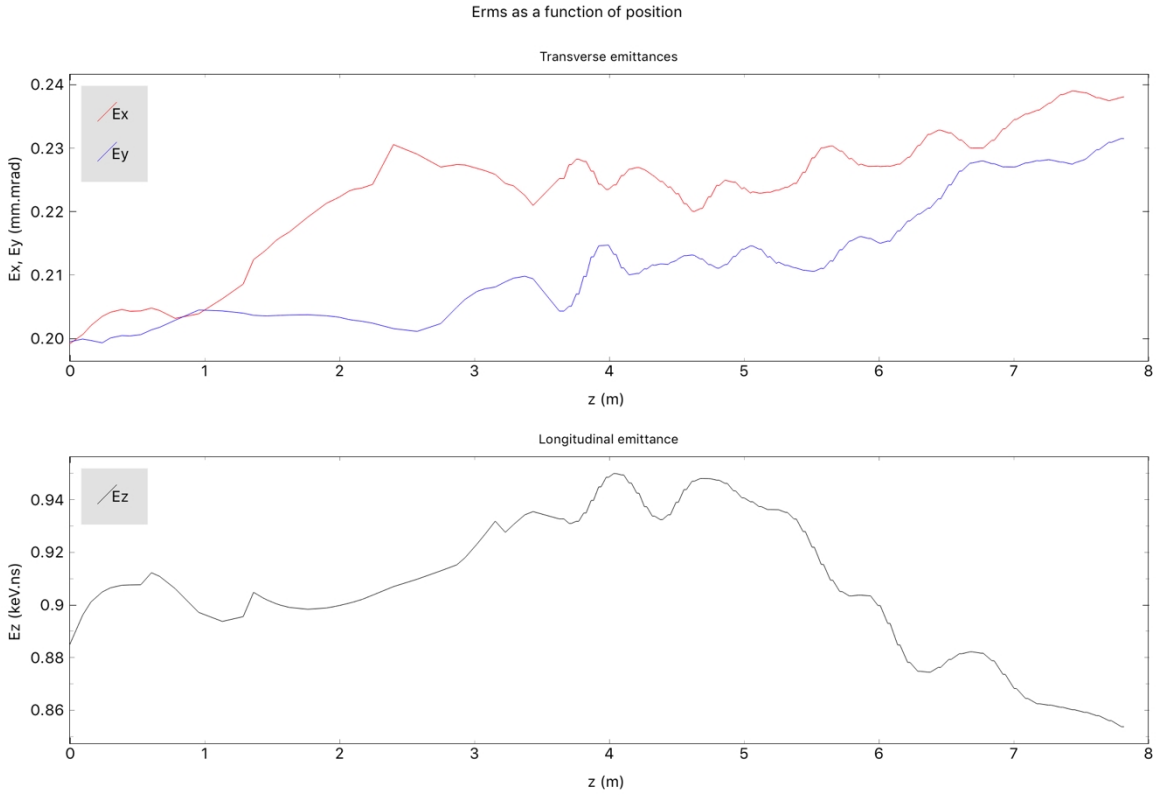

Figure 9: Example of a result obtained with ***Plot Erms***.

4.5.2 Plot W,φ

With this option, 2 graphs will be displayed as a function of the position along the beam axis (z): the top one will show the energy of the reference (Wref) as well as of the COG (Wcog), the bottom one the synchronous phase (φ_s).

4.5.3 Plot X,Y env.

By default, the "Env" box (in the "Envelope options" field) is selected. With this option, 2 graphs will be displayed as a function of the position along the beam axis (z): the top one will show a curve corresponding to the horizontal RMS beam size, the bottom one will show a curve corresponding to the vertical RMS beam size.

One can also select the "Ext" box (in the "Envelope options" field); with this option the largest horizontal extents (top graph) and largest vertical extents (bottom graph) will be plotted.

In addition, one can plot the beam line elements by selecting the "ELE" box (in the "Envelope options" field); see Fig.10 for an example. The color coding of the beam line elements and their "labeling" is as follows:

- RF elements are **green**: RFQ cells "RFQ", DTL gaps (CAVSC) "C", cavities (CAVMC and CAVNUM) "CA", bunchers (BUNCHER) "B" and multi-harmonic bunchers (MHB) "MHB"
- Solenoids (SOLENOID, FSOLE) "S" are **cyan**
- Quadrupoles are **red**: (QUADRUPO) "Q", (QUAFK) "Q"
- Quadrupole-Sextupole combinations (QUADSXT) "QS" are **red**
- Electrostatic quadrupoles (QUAELEC) "Q" are **red** with a **green** border
- Magnetic dipoles (BMAGNET) "DI" are **yellow**
- Electrostatic dipoles (EDFLEC) "DI" are **yellow** with a **green** border
- Sextupoles (SEXTUPO) "SX" are **magenta**

Drifts (DRIFT) are not displayed and are not labeled either.

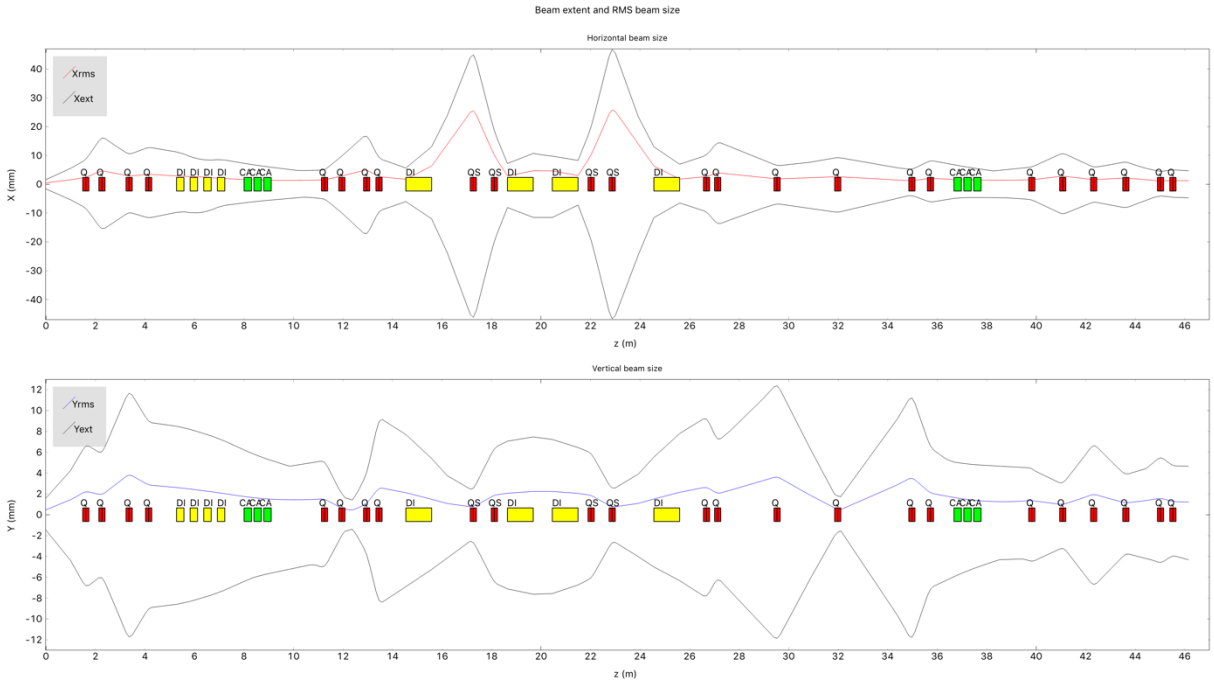

Figure 10: Example of a result obtained with ***Plot X,Y env.***

4.5.4 Plot dW, dφ env.

By default, the "Env" box (in the "Envelope options" field) is selected. With this option, 2 graphs will be displayed as a function of the position along the beam axis (z): the top one will show a curve corresponding to the RMS energy spread (dW_{rms}), the bottom one the RMS phase extent ($d\varphi_{rms}$).
One can also select the "Ext" box (in the "Envelope options" field); with this option the largest transverse extents (top graph) and largest phase extents (bottom graph) will be plotted.

4.5.5 Plot dispersion

With this option, 2 graphs will be displayed as a function of the position along the beam axis (z): the top one will show the dispersion in x (Dx) and the bottom one the dispersion in y (Dy).
It should be noted that in non-dispersive beam lines, one will observe very small values for Dx and Dy, which are an artifact of the calculation and are essentially in the noise.

4.5.6 Plot $\bar{x}$, $\bar{y}$, TX

With this option, plots of the average position in X and Y as a function of the position along the beam axis (z) will be made. In addition, the transmission (TX) as a function of the position along the beam axis (z) will also be plotted.

4.5.7 Plot losses

With this option, beam loss will be plotted as a function of the position along the beam axis (z). Here beam loss is defined in terms of relative beam loss (in %) per unit length with the beam available at the input as reference. Also, the beam line elements will be plotted (see Fig.11), with the same definition of color coding and labeling of the beam line elements as in section 4.5.3. In this example one can observe that there is also a loss in the drift after the cavity.

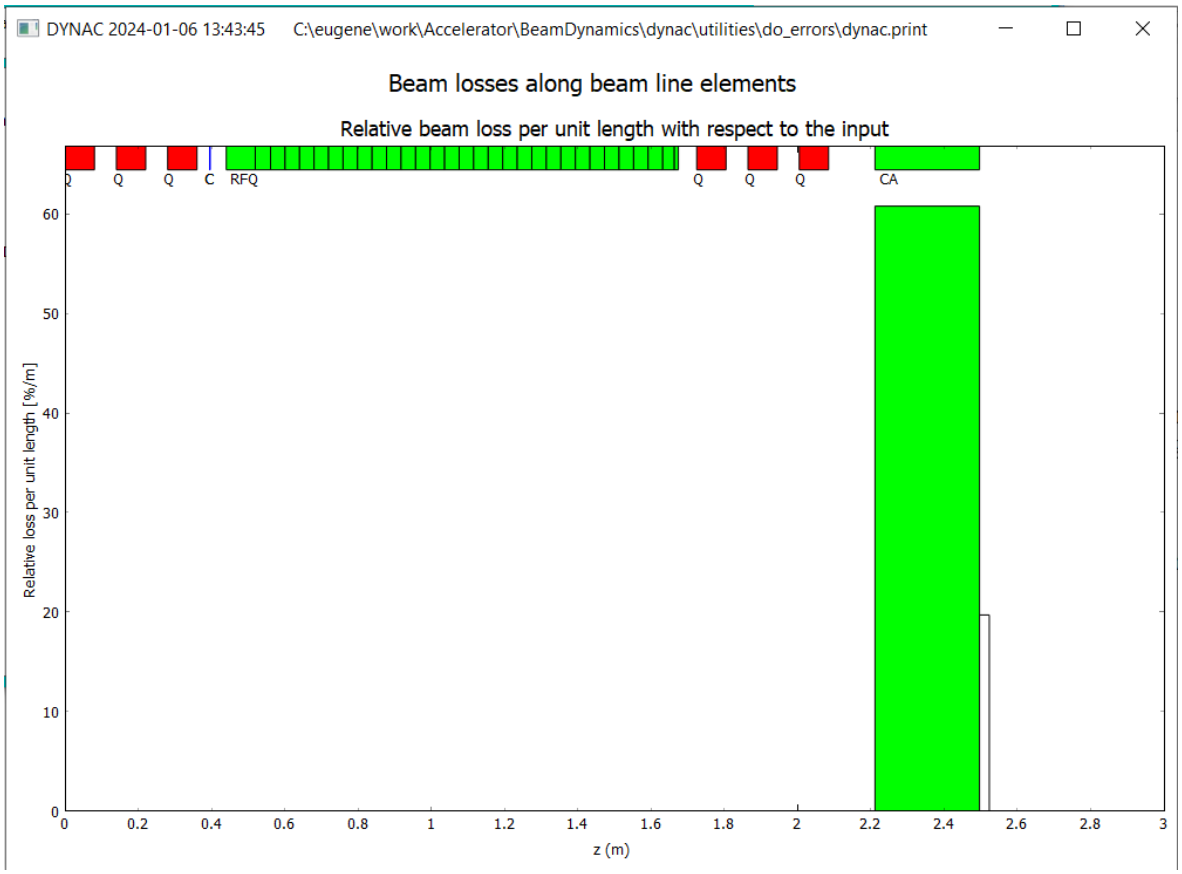

Figure 11: Example of a result obtained with ***Plot losses.***

4.6 WORKING WITH PROJECT DIRECTORIES

In view of working on different beam dynamics studies (e.g. related to different accelerators) or with different beam dynamics files for the same accelerator (e.g. different parts of the accelerator), DGUI offers the option of structuring (sub-)directories and copying files to these.

4.6.1 Set projects file directory

In order to set a project directory, click on "File" (left top of DGUI window) and select "Set projects file directory". The current directory, in case you have already set one, will be listed at the top of the main DGUI window (see example outlined in red in Fig.12).

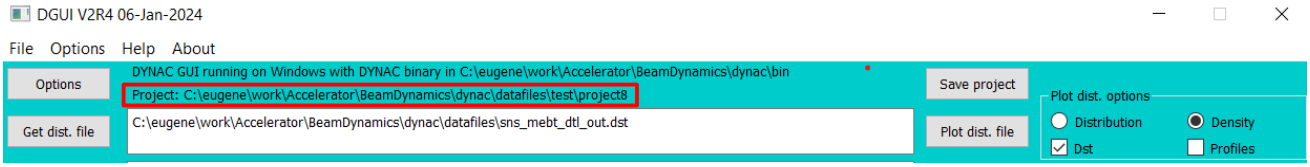

Figure 12: The current project directory is listed at the top of the DGUI main window.

You are then asked if you wish to change the current directory, after which you can create a new one, or select a different one. Following this, you can select a directory.

4.6.1 Save project files

Once the project directory has been selected, you can save relevant files associated with a particular beam dynamics simulation to this directory. To do so, click on "File" (left top of DGUI window) and select "Save project files". You will get a pop-up window as in Fig.13, where you can select the type of files you want to save in the project directory.

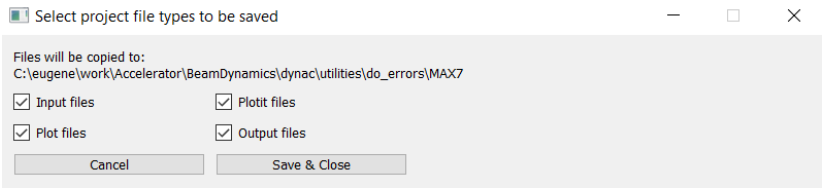

Figure 13: Pop-window, in which one can select the type of files to be saved to the project directory.

Following this, a new pop-up will appear (see Figure 14); here one sets the project (or case) number. This will create a sub-directory to the directory chosen in the previous step. The sub-directory name will be "project" followed by the number you selected. As an example, selecting "1", will greate a sub-directory called "project1".

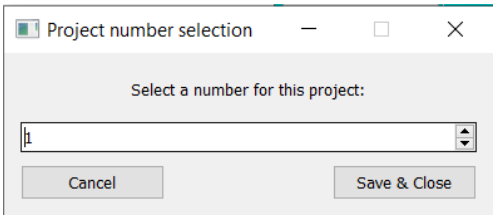

Figure 14: Pop-window, in which one can select the type of files to be saved to the project directory.

5 GLOSSARY

COG	**Center Of Gravity (of the beam)**
GUI	**Graphical User Interface**
KDE	**Kernel Distribution Estimation**
OS	**Operating System**
RF	**Radio Frequency**
RMS	**Root Mean Squared**
UG	**User Guide**

6 KNOWN ISSUES

In the lists below, unresolved or potential issued are listed.

6.1 ISSUES RELATED DGUI

In this section, issues will be listed that are definite issues with the DGUI python script itself.

6.2 ISSUES RELATED TO THE DGUI ENVIRONMENT

The issues listed in this section, seem to be ones related to the DGUI system environment.

DGS00001 Print screen: works on MAC, Windows, linux mint; not yet demonstrated on centos linux
DGS00002 Printing a window by right-clicking: works on MAC, Windows, linux mint; not yet demonstrated on centos linux
DGS00003 Exporting a partial scene from a distribution plot: works on MAC, Windows; does not work properly on centos linux, linux mint (no particles are printed)
DGS00005 On Windows, the first time you use the "Threshold for density plot" slider (DYNAC GUI OPTIONS window), you may need to click next to it to activate it.

6.2.1 Closed issues

DGS00004 Closed because the following error does not occur on MAC Sierra or Catalina and is anyhow not fatal.
On more recent MAC OSs, one may see an error when opening a file:
objc[63527]: Class FIFinderSyncExtensionHost is implemented in both
/System/Library/PrivateFrameworks/FinderKit.framework/FinderKit (0x136e80c90) and
/System/Library/PrivateFrameworks/FileProvider.framework/
OverrideBundles/FinderSyncCollaborationFileProviderOverride.bundle/Contents/MacOS/
FinderSyncCollaborationFileProviderOverride (0x145828cd8). One of the two will be used. Which one is undefined.
DGS00006 Closed On MAC OS, the plotit button will not work if the gnuplot X11 terminal was not installed. To fix this, re-install gnuplot with the necessary terminal (X11, but also wxt and/or qt); this can be conveniently done with macports. Also ensure xquartz is installed.