PBO Lab™ 2.0
(Particle Beam Optics Laboratory)
User Manual Supplement:

MARYLIE Application Module

Distributed by

AccelSoft, Inc.
P. O. Box 2813
Del Mar, CA 92014 USA

(858) 677-0133
accelsoft@ghga.com
www.ghga.com/accelsoft

PBO Lab 2.0 User Manual, MARYLIE Application Module

Second Printing: June, 2006

ISBN 1-892267-09-8

Printed in the United States of America.

MARYLIE is a FORTRAN program maintained and distributed by Dr. Alex Dragt. MARYLIE is included with the PBO Lab software with the written permission of Dr. Alex Dragt. This Section discusses the PBO Lab Commands and the output options for the MARYLIE Application Module. The MARYLIE program is described in the MARYLIE 3.0 User's Manual, which is included in the PBO Lab 2.0 User Manual Supplement: MARYLIE Application Module.

REVISION RECORD:
June 1998, February 1999, April 1999

MARYLIE is included with the PBO Lab software under a written agreement with Dr. Alex Dragt. The MARYLIE program is described in the PBO Lab 2.0 User Manual Supplement: MARYLIE Application Module, which is included with the PBO Lab MARYLIE Module software.

This page intentionally left blank.

Table of Contents

Table of Contents (continued)

1. Getting Started

This Section is intended as a quick start introduction for running the MARYLIE Application Module. The remainder of this Supplement describes the PBO Lab user interface features that are specific to the MARYLIE Application Module. Refer to the PBO Lab User Manual for more general information on the PBO Lab user interface. The MARYLIE 3.0 User's Manual describes the MARYLIE program.

Running MARYLIE

Set the Application Context for MARYLIE in the Application Context pop-up, which is located in the Document window button bar.

When the MARYLIE Application Module is installed in PBO Lab, a MARYLIE option will be added to the Application Context pop-up in Document windows. The Application Context is used to indicate native inputs and in some cases access application-specific parameters for an Application Module. MARYLIE sub-menus will also be placed in the *View* and *Commands* menus.

The Commands pull-down menu in the PBO Lab Document window contains sub-menus for any installed Application Modules. Execution of MARYLIE is accomplished from the MARYLIE Commands sub-menu as illustrated in Figure 1.

The MARYLIE Commands sub-menu is used to select various Command options for running the MARYLIE Application Module.

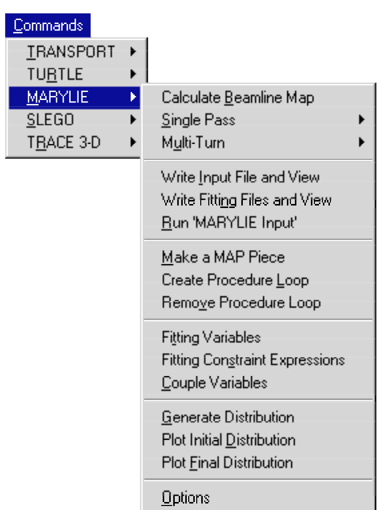


Figure 1 MARYLIE Commands Sub-Menu.

The Commands sub-menu for the MARYLIE Application Module is divided into six groups of commands in Figure 2 below. The first group contains the primary execution commands for Calculating a Beam Line Map and for performing a Single-Pass or Multi-Turn Ray Trace or Element by Element Ray Trace. When using these commands, MARYLIE will be executed automatically after application-specific (native) input is generated from the beam line in the Document Model Space.

The MARYLIE Application Module provides several options for executing the MARYLIE program.

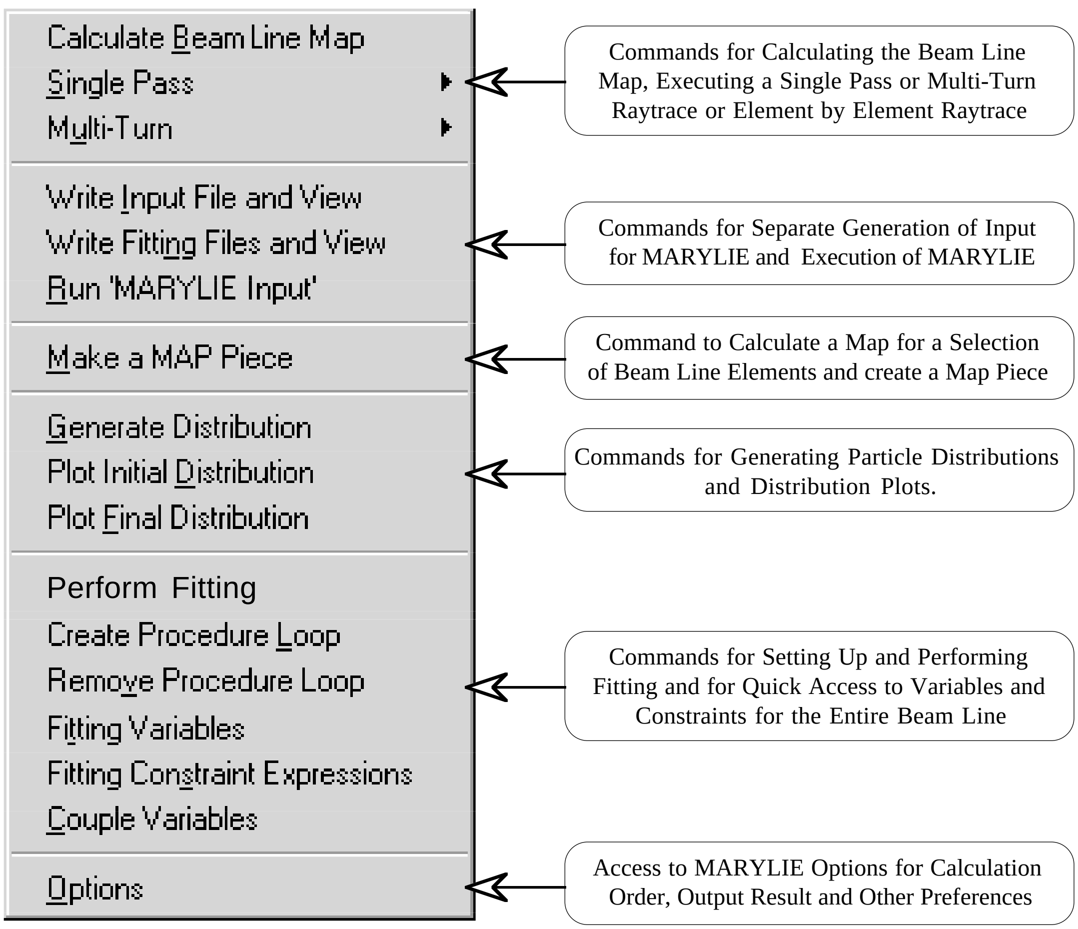


Figure 2 MARYLIE Application Module - Commands Sub-Menu.

The second group of commands are used generate native MARYLIE input without automatically executing the program. The inputs generated by PBO Lab can be edited directly and then the last command in this group can be used to execute MARYLIE with the modified inputs. These commands are provided for expert users that are experienced with the format and syntax of the various MARYLIE input files.

Input generated from PBO Lab can be edited prior to running MARYLIE.

The next group contains one command that is used to create a Map Piece for a selection of pieces in the beam line model. Lie Maps are an integral part of the MARYLIE program and the Map Piece provides an intelligent user interface for editing and visualizing map data. The Map Piece encapsulates, organizes and displays map data. The Map Piece also supports saving and loading map data using external files. The *Map Piece* Section describes the Map Piece window and the *Make Map Piece* command in the *Beam Line Elements* Section.

Refer to the Map Piece Section.

Options for generating particle distributions and plotting initial and final distributions are in the next group commands. The *Beam Piece* Section describes these commands.

Refer to the Beam Piece Section.

There are a variety of commands in the next group that are used to set-up and perform fitting. The first command in this group is used to execute MARYLIE and perform the specified fitting procedures. The next two commands are for creating and removing Procedure Loop Sublines. The last three commands in this group are used for display and access to the fitting and coupling variables and the fitting constraints for the entire beam line model. Refer to the *MARYLIE Fitting* Section for a description the fitting commands and the specification of fitting procedures.

Refer to the Fitting Section.

The last group in the MARYLIE Commands menu contains one command to access MARYLIE options for calculation order and output result, in addition to output file options and various other preferences. These options are discussed in the *MARYLIE Options* Section.

Refer to the Options Section.

This Getting Started Section is only intended as a brief overview of running the MARYLIE Application Module in PBO Lab. The remainder of this Supplement provides more information on the material presented in the Getting Started Section, as well as other important subjects on the use of MARYLIE in PBO Lab. Refer to the PBO Lab User Manual for more general information on the PBO Lab user interface. All users are encouraged to read the entire User Manual.

2. User Interface

This Section describes the user interface components that are specific to the MARYLIE Application Module. Refer to the *Getting Started* and *User Interface* Chapters of the PBO Lab User Manual for more information on the PBO Lab user interface. The MARYLIE 3.0 User's Manual describes the MARYLIE program and is referenced from this Supplement.

Beam Line Global Parameters

The Beam Line Global Parameters were introduced in the *Getting Started* and *User Interface* Chapters of the PBO Lab User Manual. This Section discusses the Global Parameters that are used by the MARYLIE Application Module.

The native Global Parameters for MARYLIE include the Particle Charge, Particle Mass, Beam Energy and Frequency. These parameters are indicated with Green Dots in the Document window shown in Figure 3 below. These parameters are also used for a variety of PBO Lab calculations and displays.

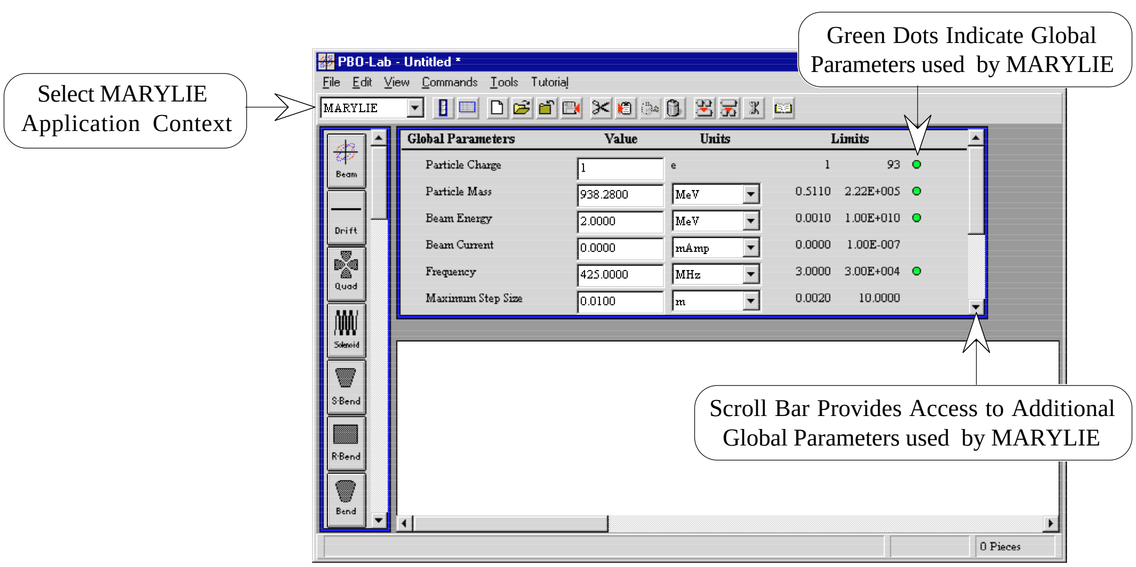


Figure 3 MARYLIE Application Context.

MARYLIE also uses the last three Global Parameters, (not shown in Figure 3) which are accessed using the scroll bar on the right side of the Global Parameters display. The Number of Macro-Particles parameter is used with Beam Piece parameters to specify an initial particle distribution. The Number of Tracking Turns parameter specifies the number of "turns" through the beam line model. The Output Distributions parameter is used to specify on which turns data will be collected for multiple turns through the model.

Beam Line Elements

The PBO Lab Pieces implemented for MARYLIE are listed in Table 1 below. Native MARYLIE inputs for these elements are indicated in the Piece windows. As with the Global Parameters, Green Dots are found to the right of Piece parameters that are native inputs. (The Application Context must be set for MARYLIE in the Button Bar of the Document window.)

Table 1 PBO Lab Pieces implemented for MARYLIE

Beam	Sector Bend	Lens	Marker
Drift	Rectangular Bend	Rotate	Map
Quadrupole	Bend	Sextupole	Operator
Solenoid	Edge	Octupole	Analyze
RF Gap			

The Piece window user interface is described in the *Getting Started* and *User Interface* Chapters of the PBO Lab User Manual. However, the Map, Operator and Analyze Pieces have application-specific interfaces which are described separately in this Section. In addition to these Pieces, the Beam Piece and the Marker Piece also have MARYLIE specific features. The Beam Piece is described next. The Marker Piece is described separately in this Section.

Beam Piece

The PBO Lab Beam Piece is used to select between four different particle distribution types for MARYLIE: 6-D Equivalent Uniform, 4-D Equivalent Uniform (KV), Gaussian (5-Sigma) and Rectangular. The distribution type is selected with the *Particle Distribution Type* pop-up at the top of the Beam Piece window. The Particle Distribution Type pop-up is shown in Figure 4, with the default 6-D Equivalent Uniform distribution type selected.

The MARYLIE initial particle distribution is also defined by the Twiss parameters in the Beam Piece window. The Courant-Snyder (Twiss) parameter set is selected in Figure 4, illustrating the Green Dots for the MARYLIE Application Context.

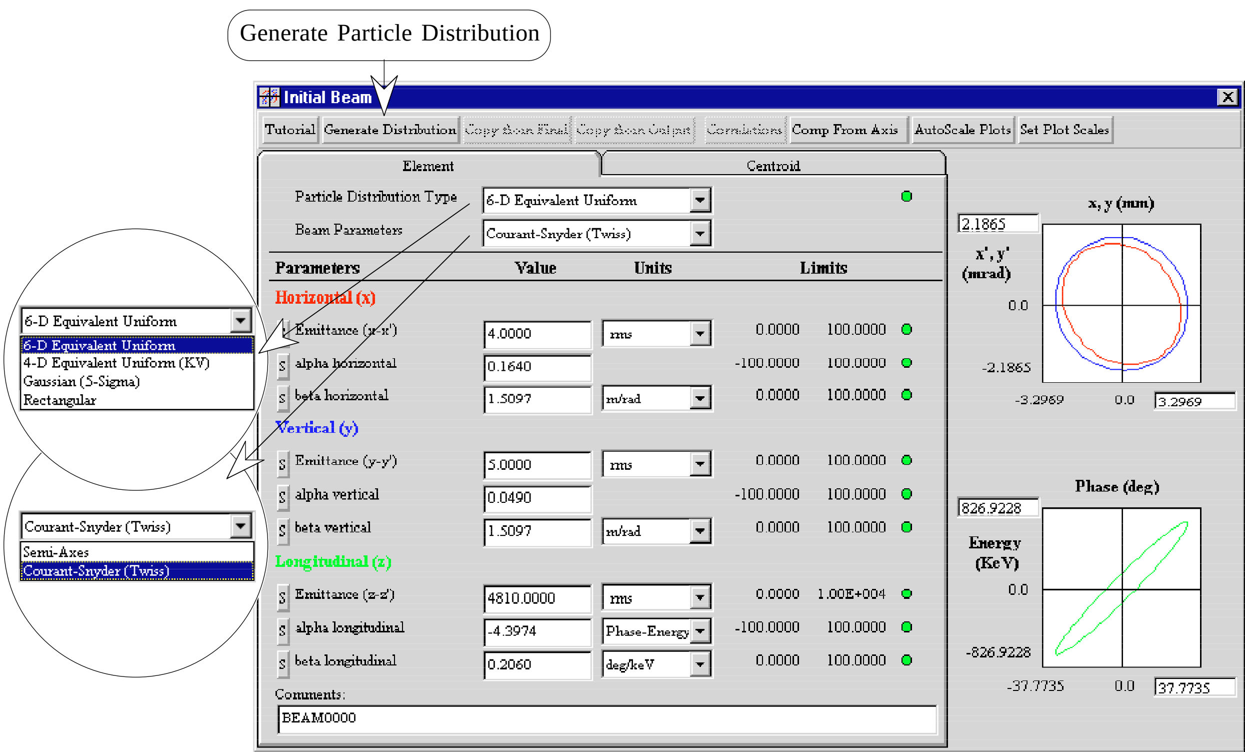


Figure 4 Beam Piece Particle Distribution.

The Beam Parameters pop-up may be used to select between the Twiss parameter set of the Semi-Axis beam parameters. These are independent sets of persistent parameter data that can be used to define two different initial beams or can be defined as two different representations of the same beam. When the Twiss beam parameters are selected, the *Compute From Semi-Axis* button will calculate the equivalent Twiss parameters for the current Semi-Axis parameters. When the Semi-Axis parameter set is selected the *Compute From Twiss* button will calculate the equivalent Semi-Axis parameters for the current Twiss parameters. The *Compute From...* button is in the button bar at the top of the Beam Piece window.

The *Generate Distribution* button in the Beam Piece window is used to generate and plot the specified particle distribution. The Marylie Input and Emittance files are generated from the Beam Piece parameters and Globals. MARYLIE is called to generate the new Distribution file, but the standard output file is not opened. Instead a Plot Specification window is opened. Figure 5 illustrates the Plot Specification window and example initial distribution plot windows.

Existing MARYLIE Input and Output files are over-written with the Generate Distribution button.

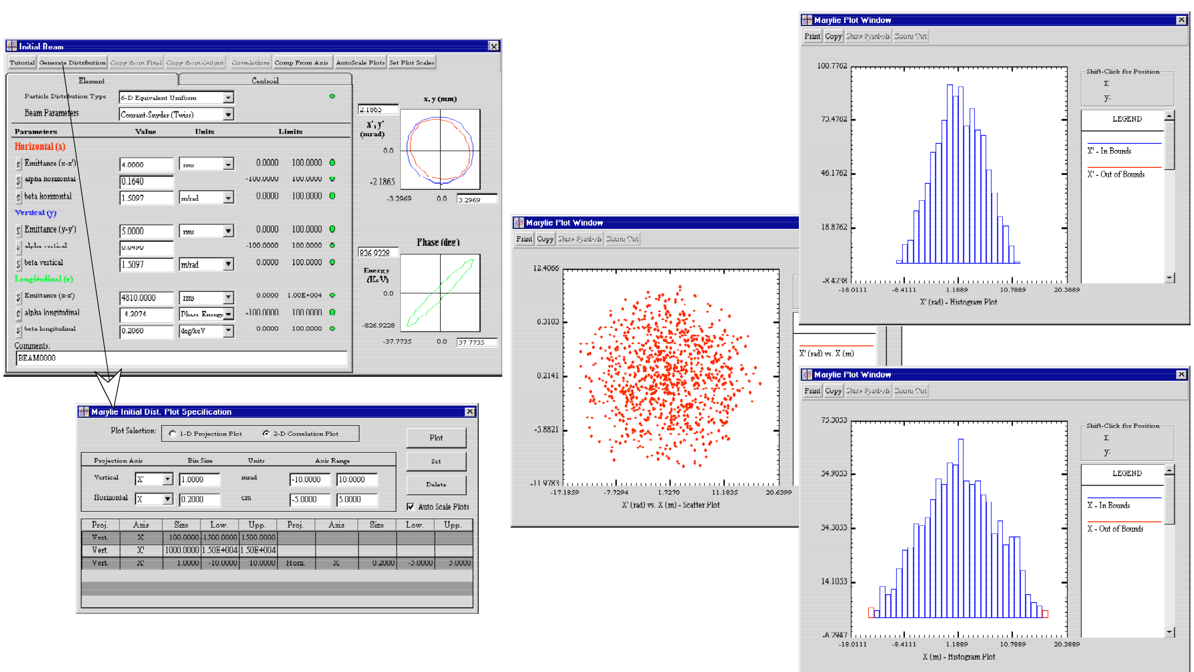


Figure 5 Generate and Plot Particle Distributions from the Beam Piece.

Several features of the Plot Specification window are illustrated in Figure 6 below. Radio buttons at the top of the window select between 1-D Projection and 2-D Correlation plots.

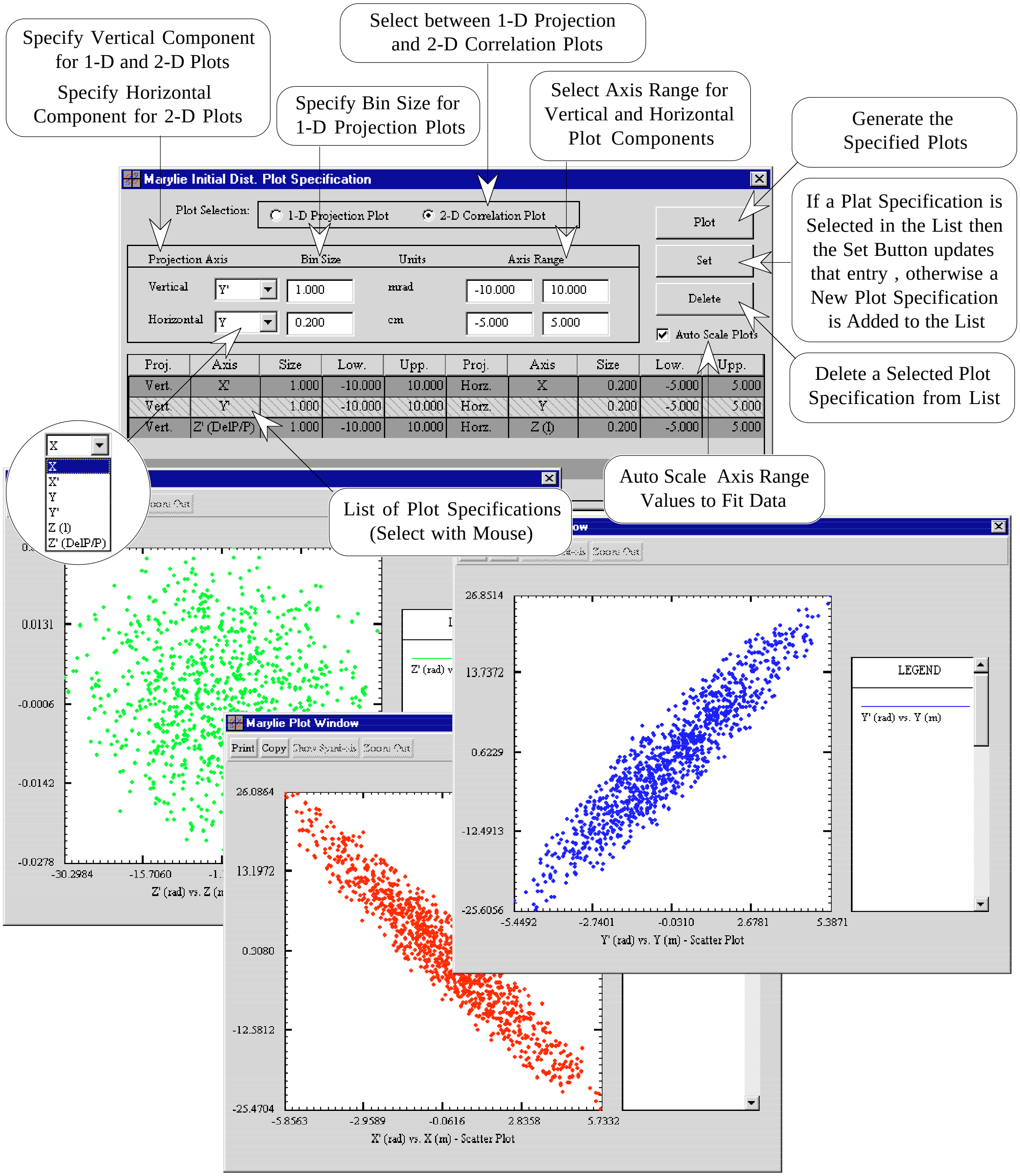


Figure 6 Initial Distribution Plot Specification Window.

The Distribution data generated by MARYLIE is six-columns of real numbers (x, xP, y, yP, z, zP) that can be used to produce any combination of 1-D plots projection and 2-D correlation plots. The Plot Specification window illustrated in Figure 6 shows the Projection Axis pop-ups for selecting Vertical and Horizontal data from the six column Distribution data. The Plot Specification window also includes a check box for auto scaling the graph axes to fit the data. Alternatively, the axes may be specified directly in the input fields provided. The bin size input field is used for generating 1-D Projection plots. The Plot button is used to generate the specified plots in individual Plot Windows, as illustrated in Figure 6.

Any parameters for any Beam Piece in the Document window (Model Space or Work Space) can be used to generate and plot an initial distribution. However, the Distribution file is overwritten by MARYLIE each time a new distribution is requested. (In the case of execution commands such as Ray Trace, a new Distribution file will be automatically requested unless this option has been disabled in the MARYLIE Options window.) Any plot specifications that are made from a Beam Piece window are persistent with that Beam piece. Another Beam Piece will have independent plot specifications. There are also commands in the MARYLIE Commands menu to generate and plot initial distributions. The *Generate Distribution* command uses the Beam parameters of the first Beam Piece found in the beam line model (walking the model left to right) in order to write the required input for MARYLIE to generate an initial distribution. This command does not automatically open the Marylie Output window or the Plot Specification window. It simply generates the input files and calls MARYLIE. The *Plot Initial Distribution* command can be used to open a Plot Specification window for the Distribution data file. (This command can be used at any time to specify up to six plots of the Distribution data file, independent of any Beam Pieces.)

Any plot specifications that are made from a Beam Piece are persistent data with that Beam piece. Another Beam Piece will have an independent set of plot specifications

Command menu items to Create Distribution and Plot Initial Distribution are similar to generating a distribution from a Beam Piece.

Map Piece

Lie Algebraic Maps are an integral part of the MARYLIE program and the PBO Lab Map Piece provides an intelligent user interface for editing and visualizing MARYLIE map data. The Map Piece encapsulates, organizes and displays map data, in addition to saving and loading map data using external files.

A Map Piece can be created for a selection of elements in the beam line model, or a default identity map can be dragged from the Palette Bar and inserted into the beam line model. The data for an existing Map Piece can be written to an external file and Map data can be loaded into a Map piece from a previously generated map data file. However, it is not necessary to save Map Pieces in separate external files. All of the data for Map Pieces in the Work Space and Model Space are saved with the PBO Lab Document. The *Make Map Piece* command in the MARYLIE Commands sub-menu is used to create a new Map Piece for the current beam line model selection, as illustrated in Figure 7.

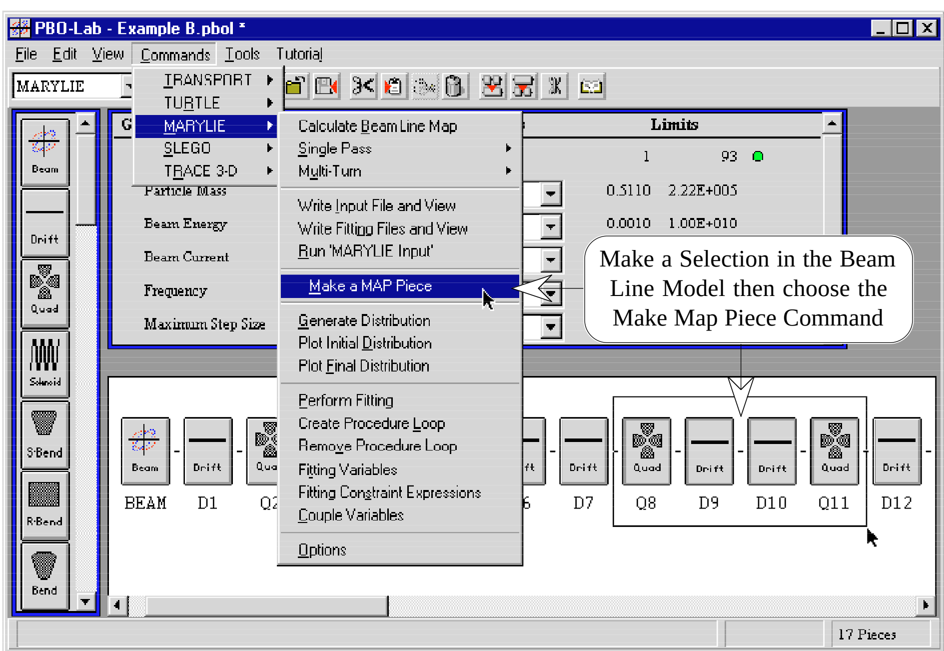


Figure 7 Making a Map Piece from a Selection in the Beam Line Model.

A Map can only be made from pieces in the Model Space of the Document window. If the Make Map Piece command is used without a selection in the beam line model then there will be an alert and a Map Piece will not be created. A selection of Pieces in the beam line may contain standard Elements, Sublines, Procedure Loops, other Map Pieces, and Aliases of all these as well. A selection may be a single Piece or include the entire beam line model. Creating a Map for the entire beam line is the same as using the *Calculate Beam Line Map* command, except that using the Map Piece loads that data into a Map Piece and the Calculate command writes the map data to the Marylie Output file.

Create a Map of the entire beam line for faster tracking calculations.

When the *Make Map* command is executed with a valid selection in the beam line model, then PBO Lab will generate the required inputs and call MARYLIE to generate a map data file. Following the execution of MARYLIE the Marylie Output file is not automatically opened, instead the map data file is automatically loaded into a new Map Piece which is created on the Work Space of the Document window. It can be placed in the beam line by dragging it with the mouse and inserting it into the model at the desired location. The original selection of pieces used to create the Map are not changed in the beam line. The new Map could be used to replace those pieces, resulting in more efficient tracking calculations. However, pieces used to create a Map can not be recovered from the Map data.

Alternatively, a Map Piece can be used in the beam line by dragging a default identity Map from the Palette Bar to the Model Space of the Document window. This is illustrated in Figure 8. Placing a default Map Piece in this way could be used for loading Map data from an external file, editing map data directly, or the Map Piece could be followed by *Map Operator* and/or *Analyze Map* Pieces to archive a desired result.

A default Map Piece (from the Palette Bar) represents an identity map. The first-order matrix is an identity matrix and all $f3$ and $f4$ coefficient are zero, so there is no data in the $f3$ and $f4$ tab panels of a default Map.

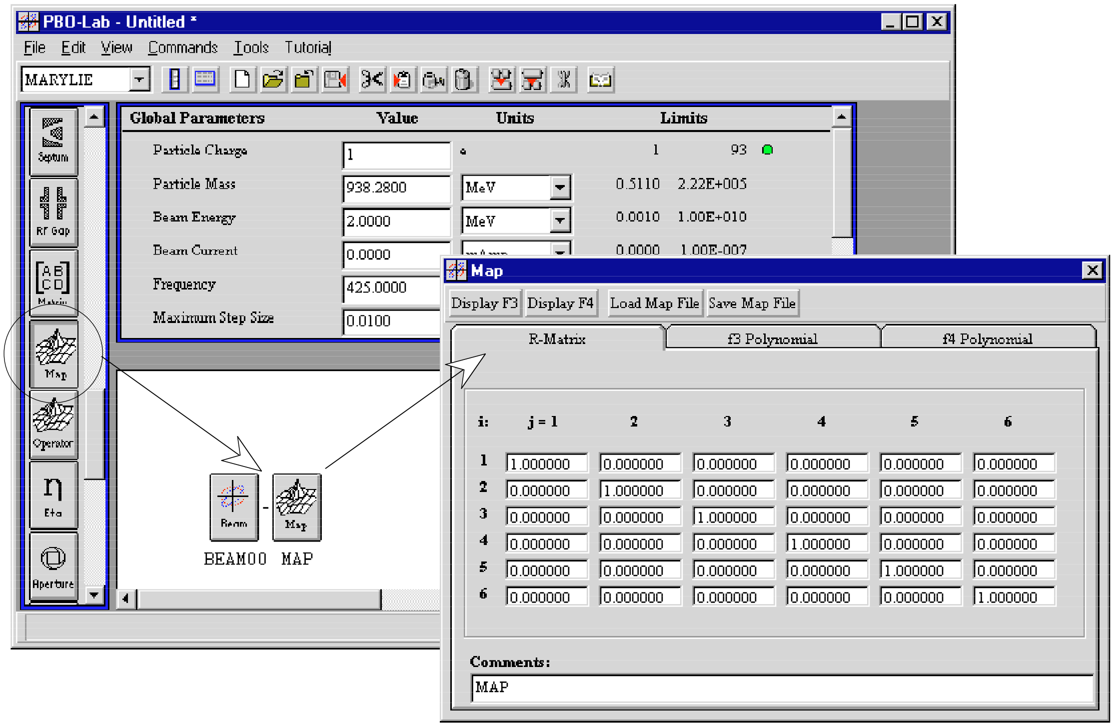


Figure 8 Dragging a Default Identity Map Piece from the Palette Bar.

The Map Piece window has a button bar and three tab panels. The front tab panel is for the first order matrix data of the map. The second and third panels are used for non-zero $f3$ and $f4$ polynomial coefficients of the map data. These coefficient values are cataloged by an index and a term code. Figure 9 illustrates a Map Piece window, showing the R-Matrix panel and the two polynomial coefficient panels. The $f3$ and $f4$ panels are identical with the exception of an additional pop-up used to specify $f4$ polynomial terms.

Figure 9 illustrates the series of pop-ups that are used for specifying a polynomial term, which is represented by a particular term code in MARYLIE. The pop-up choices are {x,Px,y,Py,z,Pz and None}. These are “smart” pop-ups that dynamically adjust themselves in series to provide only valid choices based on previous choices (e.g. choices for the second pop-up depend on the selection in the first and choices for the third depend on the second). Only the choices that include or are below the selection of the previous pop-up in the series are valid choices for the next pop-up.

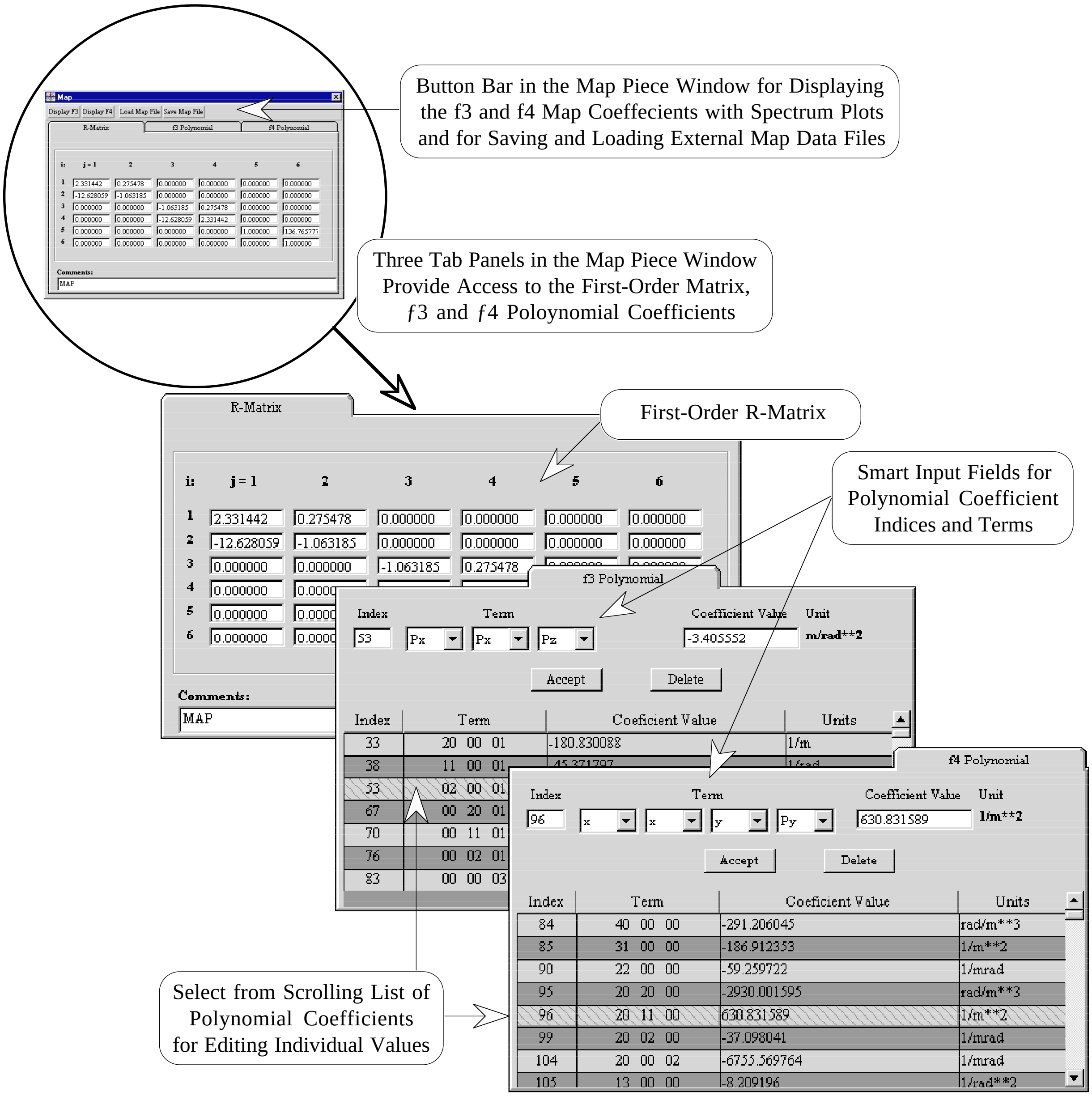


Figure 9 Map Piece User Interface Window.

Figure 9 illustrates several features of the Map Piece user interface including an editable display for the first-order matrix of the map, sorted lists for non-zero ƒ3 and ƒ4 polynomial coefficients and smart input fields for specifying polynomial terms by index or by using the term pop-up controls.

Figure 10 illustrates an example for the "x^2yPy" polynomial term (index 96). The first and second pop-ups are set to "x", representing x^2, the third pop-up is set to "y" so the forth pop-up can only contain {y,Py,z,Pz and None}. If "z" was selected then the forth pop-up would contain {z, Pz and None}. These pop-up selections define the MARYLIE term code (20 11 00), which in turn has an associated index (96), which together identify a particular polynomial term"x^2yPy".

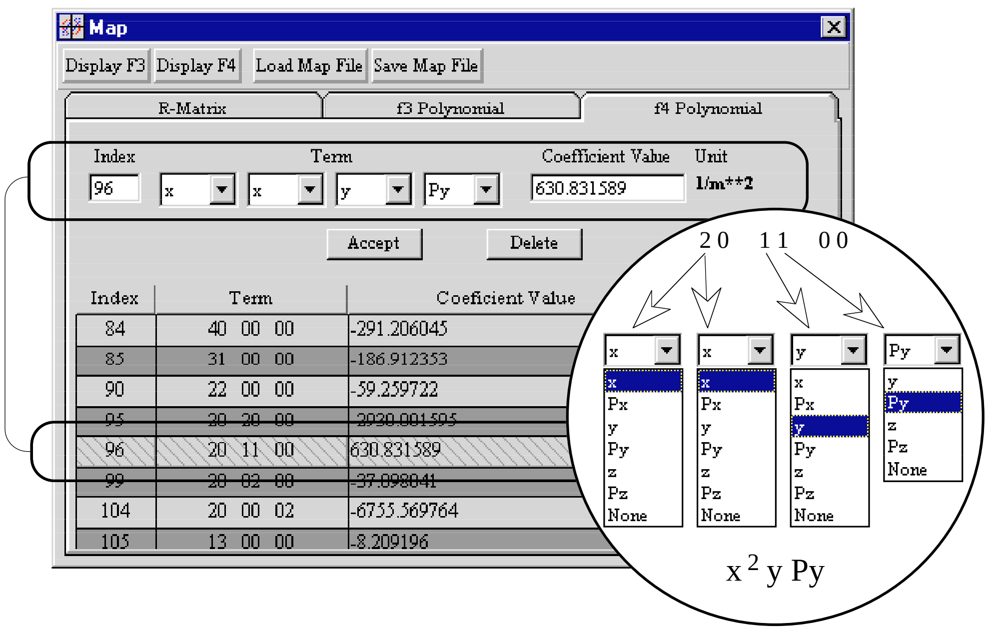


Figure 10 Map Piece Window - ƒ4 Polynomial Terms..

Non-zero coefficients are displayed in the scrolling lists at the bottom of the ƒ3 and ƒ4 panels. Coefficients are added to the list by setting the term pop-ups, the coefficient value and pressing the "Accept" button. Coefficients already in the list are edited by selecting from the list and changing the coefficient value, then pressing the "Accept" button. Similarly the "Delete" button will remove a selected coefficient. Selecting from the list will hilight the selection and automatically set the term pop-ups and coefficient value so the user can edit or delete the selection. The lists of non-zero polynomial coefficients in both the ƒ3 and ƒ4 tab panels are sorted by index.

Duplicate and non-valid entries are not allowed in the coefficient lists. If an invalid polynomial term is specified by index or a valid term is already in the list, then there will be a warring alert.

The Map Piece also provides two buttons in the Button Bar of the Piece window for generating Spectrum Plots of the *f*3 and *f*4 polynomial coefficients. An example is is illustrated in Figure 11 below. The Spectrum Plots show the relative magnitude of coefficient values (vertical axis) for all coefficients (horizontal axis). The Spectrum Plot windows support zoom-in and zoom-out features

Valid *f*3 polynomial coefficients range from index 1 to 83 and the range for *f*4 is 84 to 209. Refer to the MARYLIE User's Manual for a complete listing of indices and terms.

Polynomial coefficients can be quickly visualized with Map Spectrum Plots.

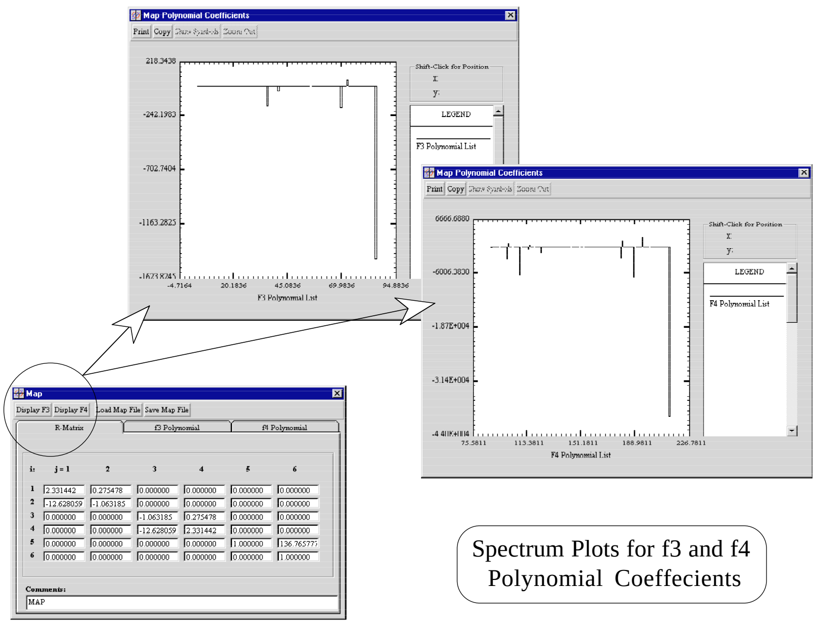


Figure 11 Spectrum Plots for *f*3 and *f*4 Coefficients.

Map Operator Piece

The Map Operator Piece provides an interface for a variety of simple and advanced map operations that are supported by MARYLIE. Map operations are applied to the transfer map at a specific locations in the beam line during a MARYLIE execution. The location is established graphically by simply dragging Operator Pieces from the Palette Bar and inserting them at the desired locations in the beam line model.

Select the map operation to be performed in the Operator Piece window (double-click the Operator Piece after placing it in the beam line). An Operator Piece performs only one operation. However several Operator Pieces may be used sequentially or separately in the beam line.

The Map Operator Piece window is illustrated in Figure 12 below. The front tab panel is for *Simple Operations* that replace the existing map based on the selected map operation. The existing map is the map calculated up to the location of the Operator Piece in the beam line. Simple operations require no inputs, simply select the radio button corresponding to the desired map operation and it will be applied at that location in the beam line model.

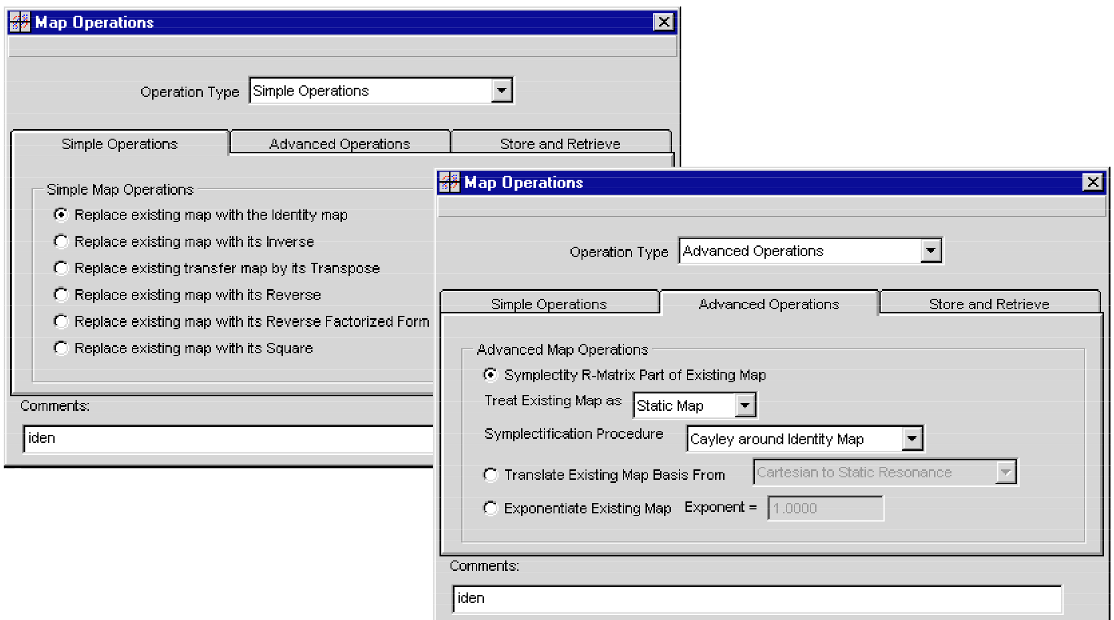


Figure 12 Simple Operations Tab Panel in the Map Operator Piece Window.

The second tab panel in the Map Piece window is for *Advanced Operations*. There are three advanced operations that provide additional pop-up selections or other inputs that become active when the radio button for a particular operation is selected.

Each Map Operations Piece can implement a Simple or an Advanced Operation Type. The Operation Type is specified by the pop-up at the top of the Piece window.

Map Analyzer Piece

The *Map Analyzer* Piece is special PBO Lab piece for the MARYLIE Application Module. It is similar to the Marker Piece, because it is used to specify a variety diagnostic outputs at specific locations in the beam line model. However this piece is only used by the MARYLIE Application Module. A Map Analyzer Piece in the beam line model performs a single analysis task at that location in the beam line model. Figure 13 shows an example of the Map Analyzer Piece window.

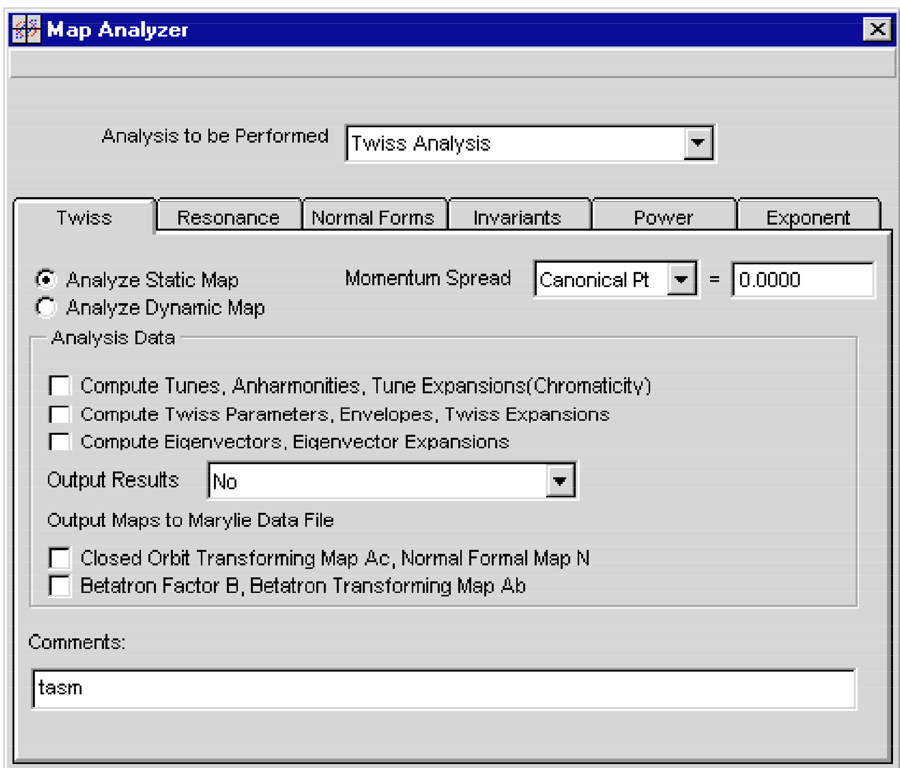


Figure 13 Performing Map Analysis tasks with the Analyze Map Piece.

The pop-up at the top of the Map Analzer window is used to specify the particular type of map analysis to be performed. Input parameters for each of the analysis tasks are provided on separate tab panels in the Piece window. Each of the analysis tasks supported by the Map Analyzer Piece are described here, including twiss analysis, resonance analysis, normal form analysis, invariant analysis and computing the power of the normal form.

Twiss Analysis

The front tab panel of the Analyze Map Piece window provides options for performing Twiss Analysis. Figure 14 illustrates the Twiss Analysis tab panel. Twiss analysis can be performed on either the static or dynamic map, which is selected with the radio buttons at the top of the tab panel. The other choices vary depending on this option. For static Map analysis a Momentum Spread Variable must also be specified. For both static and dynamic analysis, there are three options that may be selected. For static analysis these are: (1) Compute Tunes and Anharmonities, (2) Compute Twiss Parameters and Envelopes, and (3) Compute Eigenvectors. For dynamic analysis these three options include Tune Expansions (Chromaticities) for option (1), Twiss Expansions for option (2), and Eignvector Expansions for option (3).

Refer to the MARYLIE User's Manual, Section 8.2 & 8.3

Analysis results may be written to either the Marylie Output file or the Marylie Data file. Alternatively, output may be directed to both files or neither file. This option is specified with the Output Result pop-up in the Twiss Analysis tab panel. Additional map data may also be written to the Marylie Data file with the last two options in the tab panel. These options are based on the static or dynamic analysis option at the top of the tab panel. For dynamic analysis the choices for map output include the normalized map and the Normal Form map. For static analysis the choices include the closed orbit transforming map with the normal form map and the betatron Factor with the betatron transforming map.

Resonance Analysis

The required inputs for the *Resonance Analysis* task are on a separate tab panel in the Map Analyzer Piece window. The options for this analysis are similar to the Twiss analysis task. There are radio buttons for static and dynamic map analysis. There are also options for directing the output to a specific file and for writing out map data to the Marylie Data file.

Refer to the MARYLIE User's Manual, Section 8.4 & 8.5

Normal Form Analysis

The *Normal Form Analysis* tab panel of the Analyze Piece includes choices for static and dynamic analysis. There are also options for output including normal form for exponents and the complete pseudo Hamiltonian which can be directed to the selected output file. In addition there are two options for normalizing map and normal form map data output.

Refer to the MARYLIE User's Manual, Section 8.8 & 8.9

Invariant Analysis

The *Invariant Analysis* tab panel of the Map Analyzer Piece has one option for regular invariant output to a specified file and two options for writing the Normalizing map and normal form map to the Marylie Data file. As with the other map analysis tasks, there are radio buttons for selecting static or dynamic analysis.

Refer to the MARYLIE User's Manual, Section 8.10 & 8.11

Power of Normal Form

The last analysis task is for computing the power of the normal form. The tab panel for this task contains the required inputs including static or dynamic analysis options, an input field for the power and selections for both the source and target maps.

Refer to the MARYLIE User's Manual, Section 8.12 & 8.13

Marker Piece

The Marker Piece is a special PBO Lab Piece that is used to specify application-specific Constraints and Diagnostics at specific locations in the beam line model. A Marker Piece window is shown in Figure 15.

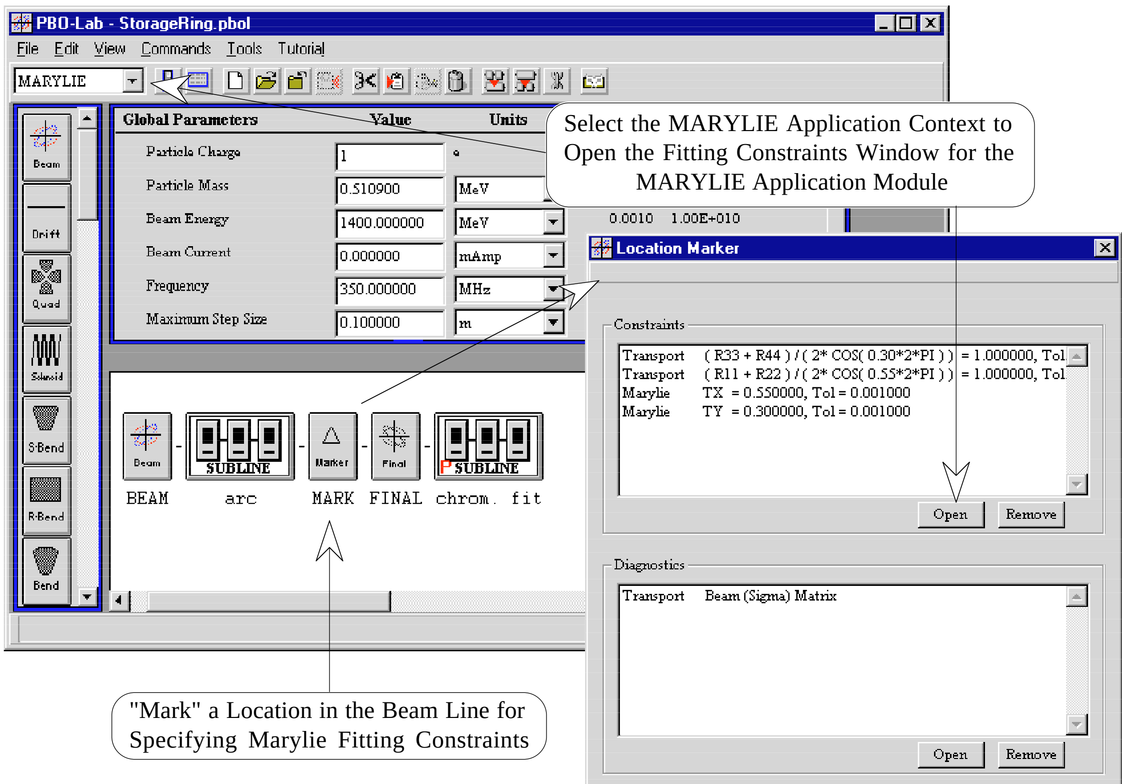


Figure 15 Marker Piece Constraints and Diagnostics.

There are two scrollable lists in the Marker Piece window that display selected Constraints and Diagnostics for any installed Application Module. The example shown in Figure 15 has Constraints specified for both TRANSPORT and MARYLIE. A single Diagnostic is specified for the TRANSPORT Module. Application-specific windows, tailored to the particular capabilities of each Application Module, are used to specify Constraints and Diagnostics. The Open buttons in the Marker Piece window are used to open the Constraint and Diagnostic windows for the current Application Context. The Application Context pop-up must be set for the MARYLIE Application Module as illustrated in Figure 15.

Refer to the MARYLIE Fitting Section for a description of the Marker Piece and Marylie Fitting Constraints.

The *Open* Constraints button opens the Marylie Fitting Constraints window, which is discussed in the Fitting Section. The *Open* Diagnostics button in the Marker Piece window opens the MARYLIE Dianostics window.. Marylie "Diagnostics" are also supported for specific beam line locations with other Pieces, such as the Map Operator and Map Analyzer Pieces described previously. These pieces are tailored to the particular capabilities of the MARYLIE program.

Procedure Loops

Procedure Loops are a special type of subline in the beam line topology. In addition to the properties of Sublines, Procedure Loops provide a means of looping through a subline for a specified number of iterations. The Procedure Loop subline is only used by the MARYLIE Application Module, and is treated as a normal Subline by other Application Modules.

A Procedure Loop Subline is only used by the MARYLIE Module, and is treated as a normal Subline by any other Application Module.

Creating a Procedure Loop subline is similar to creating a Subline. However, the command for a Procedure Loop is in the MARYLIE sub-menu of the Commands menu and there is no Button Bar equivalent. The MARYLIE sub-menu in the Commands menu is only available when the MARYLIE Application Module is installed. After making a selection in the beam line model, choose the *Create Procedure Loop* command in the MARYLIE Commands sub-menu. The selection will be turned into a Procedure Loop and you will be prompted to enter a value for the number of loop iterations. Once the Procedure Loop Subline is created, the number of iterations can be modified in the Procedure Loop Subline window. To remove a selected Procedure Loop, choose the *Remove Procedure Loop* command in the MARYLIE Commands sub-menu. A Procedure Loop Subline can also be removed (flattened) with the *Flatten Subline* command in the *Edit* menu.

The commands for creating and removing Procedure Loop Sublines are in the MARYLIE sub-menu of the Commands menu, which is only available when the MARYLIE Application Module is installed.

A Procedure Loop can be easily identified in the beam line model by the red letter "P" in the lower left corner of the Subline icon.

Procedure Loop Sublines are easily identified by the red letter "P" that appears on the piece icon.

Marylie Options

A variety of options including calculation order and output result, in addition to output file options and various other preferences are specified in the Marylie Options window. The Options window is opened with the last command in the MARYLIE Commands menu, as illustrated in Figure 16 below. Options apply to the entire beam line model in the Model Space of the Document window.

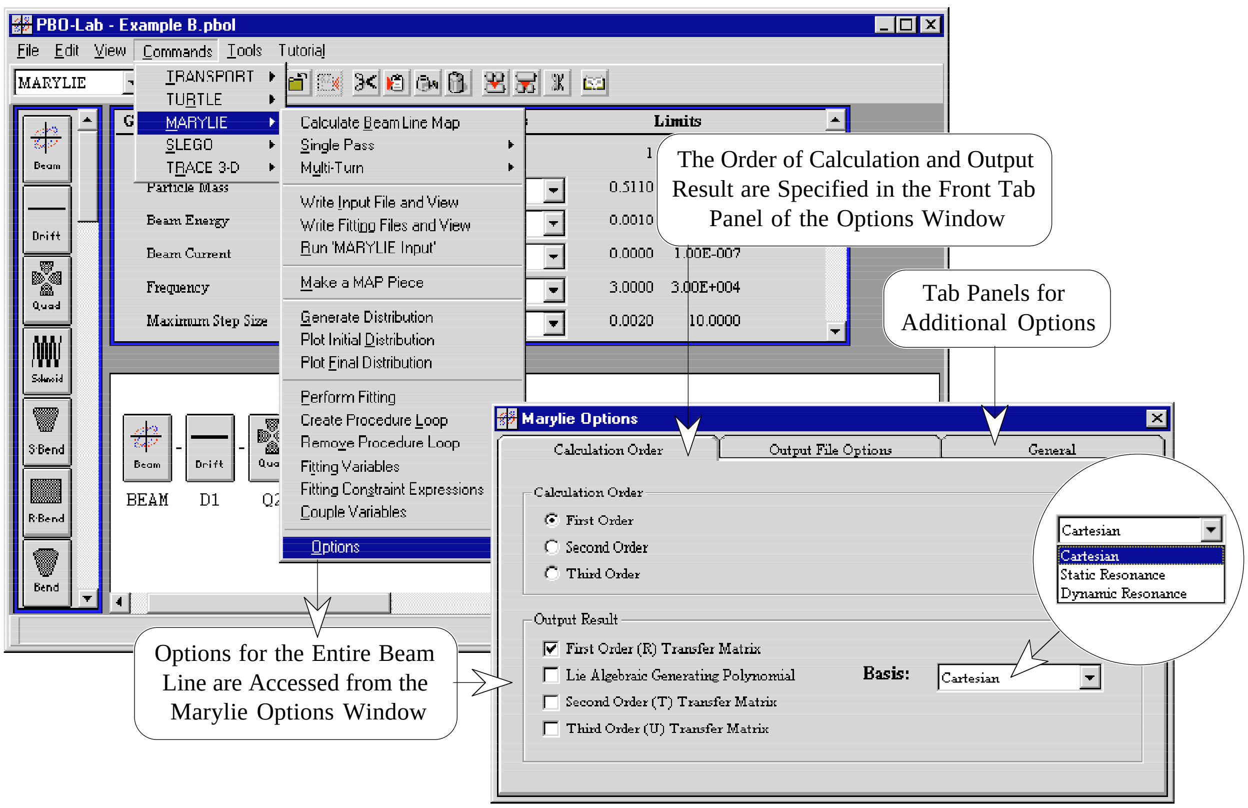


Figure 16 MARYLIE Application Module Options Window.

Calculation Order and Output Result

The order of calculation and output result are specified in the front tab panel of the Marylie Options window, as illustrated in Figure 16. A pop-up is provided for selecting between Cartesian, Static Resonance and Dynamic Resonance basis used for Lie algebraic generating polynomials.

Output File Options

The second tab panel shown in Figure 17 provides check boxes for three output file options. The *Echo Master Input File* option is selected by default. This option causes the input file generated by PBO Lab to be printed at the top of the output file. The next option is also selected by default. During fitting operations, diagnostic output will be written to the output file if the *Print Details During Fitting* option has been selected.

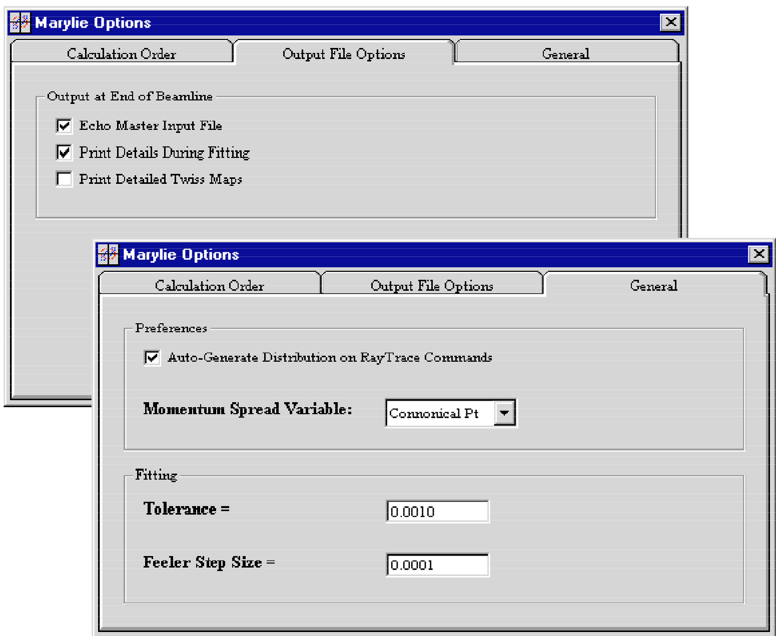


Figure 17 Additional Tab Panels in Options Window.

General

The first option in the General tab panel shown in Figure 17, is used to automatically recalculate an initial distribution prior to execution of MARYLIE. The initial distribution will be defined by the first Beam Piece in the beam line model. A new distribution will be generated each time a ray trace command is executed. This options is on by default. When this option off, there must be an existing initial distribution file in the application folder in order to execute ray trace commands.

This Auto-Generate option should be off if a previously generated distribution is to be used exclusively. Refer to the *Beam Piece* Section and the *Execution Commands* Section for more information.

The next option is the Momentum Spread Variable. There are two choices for the Momentum Spread Variable: “Connonial Pt” and “Delta delP/P”. There are are also two options for Tolerance and Feeler Step Size that are applied to all fitting procedures in a beam line model.

Execution Commands

The first group of commands in the MARYLIE Commands sub-menu will automatically execute MARYLIE after generating application-specific (native) input from the beam line in Model Space of the Document window. Each of these commands results in the Marylie Output file being automatically displayed in a scrollable text window after execution of MARYLIE. This file can be opened anytime using the *Input File* option in the MARYLIE sub-menu in the *View* menu. The Marylie Data file can also be opened in the *View* menu. Depending on selected options, the content of these files may include the first-order matrix, non-zero elements in the second and third-order matrices, and non-zero coefficients in the Lie algebraic generating polynomial. These options are described in the MARYLIE Options Section. Both the the input and output files are overwritten on each execution of MARYLIE. Use the *Save As* command in the *File* menu of the text window to rename any I/O files if desired.

Calculate Beam Line Map

The *Calculate Beam Line Map* command was described in the *Running MARYLIE* Section. Following the execution of this command, a Marylie Output file will be displayed. The content depends on the Output Result and other Output Options that are specified in the MARYLIE Options window.

Ray Trace Commands

There are two main Ray Trace commands in the MARYLIE Commands menu. One is for a *Single Pass* ray trace and the other is for a *Multi-Turn* ray trace. Each of these commands has a sub-menu with options for *Ray Trace* or *Element by Element Ray Trace*.

The *Single Pass* commands are used to trace particle rays once through the beam line model resulting in a final particle distribution. The initial distribution is specified with the Beam Piece, which must be in the beam line model for all Ray Trace commands.

The *Multi-Turn* commands trace rays through the model for multiple "turns". The initial particle distribution is passed through the beam line model, as it is for the *Single Pass* command, but the resulting distribution is passed through the beam line again and this cycle is repeated for a specified number of turns, which yields the final particle distribution. The number of turns through the model is specified with the *Number of Tracking Turns* Global Parameter.

The *Ray Trace* commands (single pass and multi-turn) trace particles through the beam line model using a single transfer map for the entire beam line. The *Element by Element Ray Trace* commands calculate individual transfer maps for each element in the beam line, resulting in a slower but more accurate ray trace.

Write and View Commands

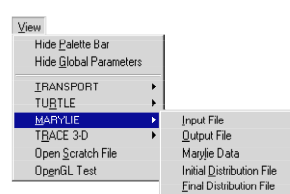
The second group of commands are used to generate native input without automatically executing MARYLIE, allowing the input generated by PBO Lab to be edited prior to running MARYLIE. This provides total access to the native execution of the program for expert users that are experienced with the format and syntax of the various Marylie input files. The command *Write Input File and View* generates a MARYLIE master input file named "Marylie Input" from the beam line model. This file is opened in an editable text window, but MARYLIE is not executed.

Modifications may be made to the input file and saved using the *Save* command in the *File* menu of the text window. This file can be used as input to MARYLIE with the *Run 'Marylie Input'* command. This command is used to execute MARYLIE without generating new input. Any changes made to the Marylie Input file will not be overwritten with model data. The existing input files in the application folder will be used to execute MARYLIE.

Write Fitting Files and View is another write-and-view command that is used to generate the input files that define fitting variables, constraints and procedures for MARYLIE. This command does not execute the MARYLIE program. The fitting files are generated from settings in beam line model and can be displayed in editable text windows. These files are used when MARYLIE is executed with the *Run 'Marylie Input'* command. The existing master input file will be over written when the fitting files are generated. The Marylie Input file must include the appropriate commands to instruct MARYLIE to perform the operations specified by the fitting files. The input file is automatically opened in an editable text window. The *File* menu of the text window can be used to *Open* any of the fitting input files. Refer to the *MARYLIE Fitting* Section for additional information.

MARYLIE View Menu Commands

The MARYLIE Master Input File (MIF) is generated by PBO Lab from the beam line model in the Document window. This file is entitled "Marylie Input". This file can be displayed and edited at any time with the *Input* item in the MARYLIE sub-menu of the *View* menu in the Document window. Similarly the Marylie Output and Marylie Data file can be opened and displayed in an editable text window with commands in the *View* menu. The raw data files for both initial and final particle distributions can also be opened with *View* menu commands.



MARYLIE View Sub-menu.

MARYLIE Distribution Plots

Three commands in the MARYLIE Commands menu (Figure 18) are used to generate and plot distribution data. The *Generate Distribution* command is used to create an initial particle distribution. The Marylie Input and Emittance files are generated from the beam line Beam Piece and Global Parameters. MARYLIE creates a new Distribution file, but the standard output file in not opened
following execution. The *Plot Initial Distribution* command can be used to open a Plot Specification window for initial distribution data. This command can be used any time there is an existing Distribution file in the application folder. Refer to the Beam Piece subsection for a description of particle distributions.

The Generate Distribution command is equivalent to using the Generate Distribution button in the Beam Piece window.

The *Plot Final Distribution* command is used to open the Plot Specification window for the final distribution data generated by MARYLIE with a Ray Trace command. Figure 18 shows the Plots Specification window and several Marylie Plot windows.

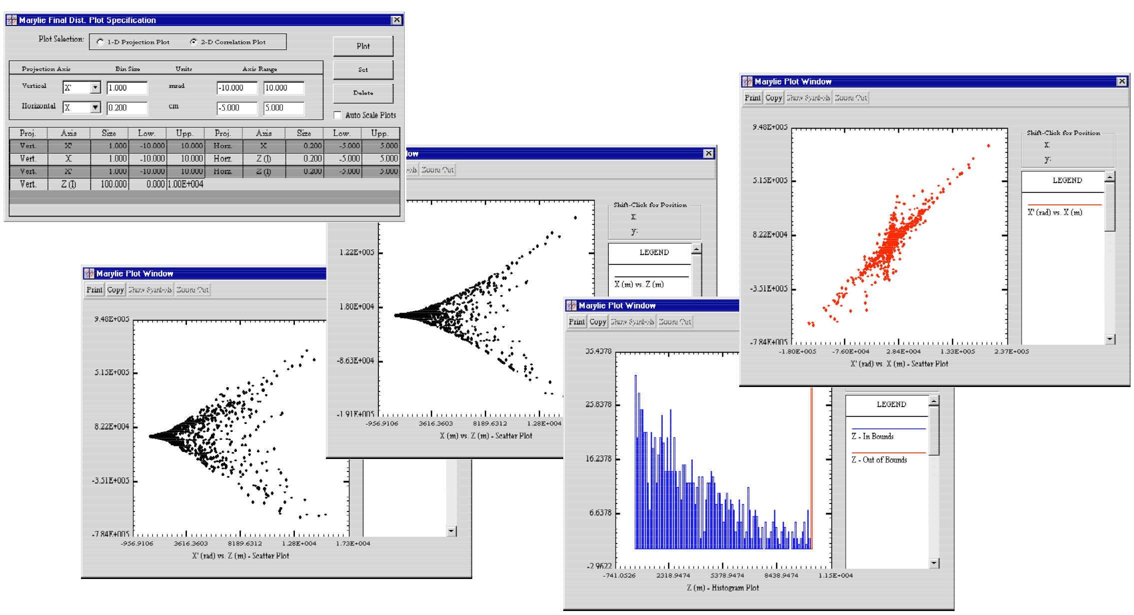


Figure 18 Final Distribution Plots.

3. MARYLIE Fitting

The MARYLIE program can be used to find solutions for a variety of beam line design problems. Problems are formulated in terms of user-specified variables and constraints. Beam line parameters are varied in an attempt to satisfy ("fit") constraints within a specified tolerence. A Procedure loop is used to specify the scope of a fitting operation. Procedure Loops provide a means of looping through a subline for a specified number of iterations. After specifing fitting variables, constraints and procedure loops in the beam line model the Perform Fitting command in the Marylie Commands menu is used to execute the fitting procedures. MARYLIE will attempt fitting for each procedure loop until the constraints have been fit within tolerence or the maximum number of iterations has been reached in the procedure loop. When the fitting procedures are completed the resulting values for fitting variables are shown in the Update Fitting and Coupling Parameters window. The new parameter values may then be used to update the beam line model.

Refer to the Procedure Loops Section in this Chapter.

Specifing Variable Parameters

A Variable Parameter is specified in the Special Parameter Settings window, which is opened by pressing the Special ("S") button to the left of the parameter in the Piece Window. Figure 19 illustrates selecting a Quadrupole Magnetic-Field Gradient parameter as a fitting variable; pressing the "S" button for this parameter opens the Special Parameter Settings window.

All variable parameter selections are saved with the beam line model when using a Save, or Save As, command.

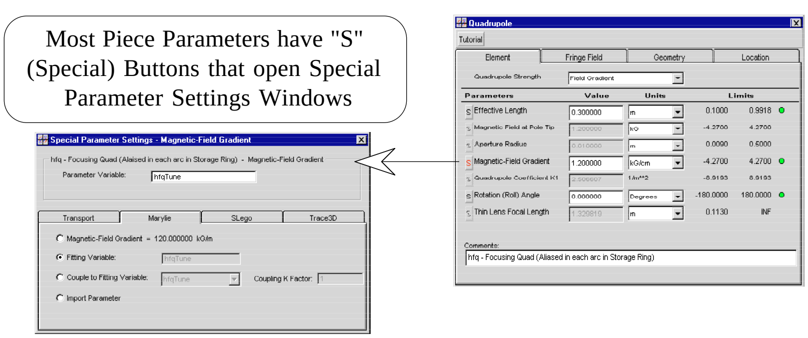


Figure 19 Special Parameter Settings Window.

Special Parameter Settings Window

The Special Parameter Settings window is used for specifying application-specific options. The "S-Windows" have Application tab panels that provide access to application-specific options for all installed Application Modules. Special parameter settings are retained when the model is saved with the Save or Save As command.

The MARYLIE Application Module supports specifing a parameter as a fitting variable, coupling variable or import variable. Figure 20 shows the Marylie tab panel for a Quadrupole Magnetic-Field Gradient parameter.

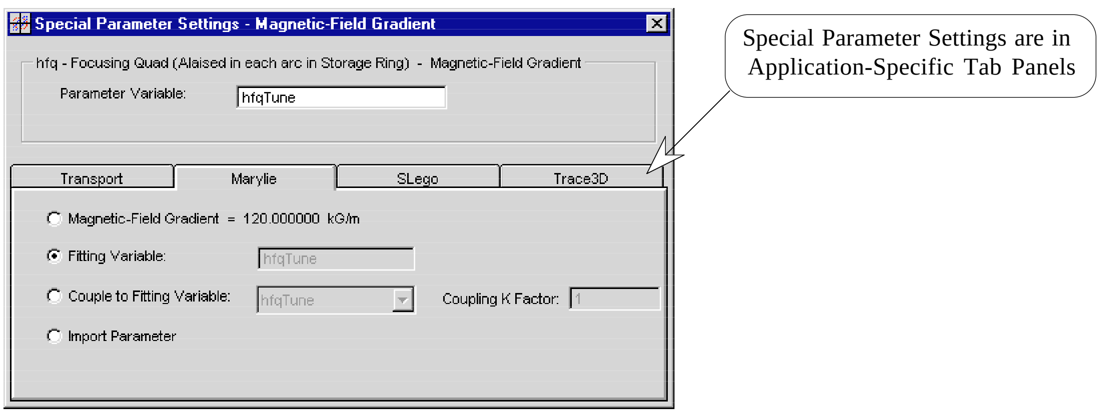


Figure 20 Special Parameter Settings for the Marylie Module.

The top panel of the S-window displays the Piece comment and the selected parameter name. There is an input field for a Parameter Variable name. When required, a default name will be generated if a name has not been entered in the Parameter Variable field at the top of the S-window. The same Parameter Variable name is used for all installed Application Modules.

The bottom half of the window will contain tab panels for the different application modules. When the Marylie Application Module is installed there will be a Marylie tab panel in the Special Parameter Settings window if that parameter is a native MARYLIE input and it is supported as a variable parameter by the MARYLIE program. Otherwise there will not be a tab panel for Marylie.

The first radio button in the Marylie tab panel is the default selection. It indicates that the parameter is defined by the numerical value entered in the piece window, i.e. there are no special settings for this parameter. The second radio-button selects the parameter as a variable parameter and the third radio-button selects it as a coupling variable. If the parameter is selected as a coupling variable then the pop-up to the right becomes active. This pop-up contains a list of all the specified fitting variables in the beam line model. The parameter may be coupled to any fitting variable by choosing it from this pop-up list. There is also an input field for the Coupling K Factor used for coupling variables.

Fitting Variables Window

PBO Lab provides windows that list all of the fitting variables and coupling variables for the entire beam line model. These windows can be used to quickly access the piece windows for elements with fitting variables or coupling parameters. Figure 21 illustrates opening the Fitting Variables window from the MARYLIE Commands menu. The header at the top of these windows can be used to adjust the width of each column in the window. To resize a column place the mouse over the divider line in the column header. When the arrow turns into a cross-hair the column can be resized by holding the mouse button down while draging horizontally.

Couple Variables Window

The Couple Variables windows lists all of the parameters that are coupled to fitting variables in the entire beam line model. As with the Fitting Variables window, double-clicking an entry in this window allows you to quickly access the piece windows for that parameter. Figure 21 shows the Couple Variables command in the MARYLIE Commands menu.

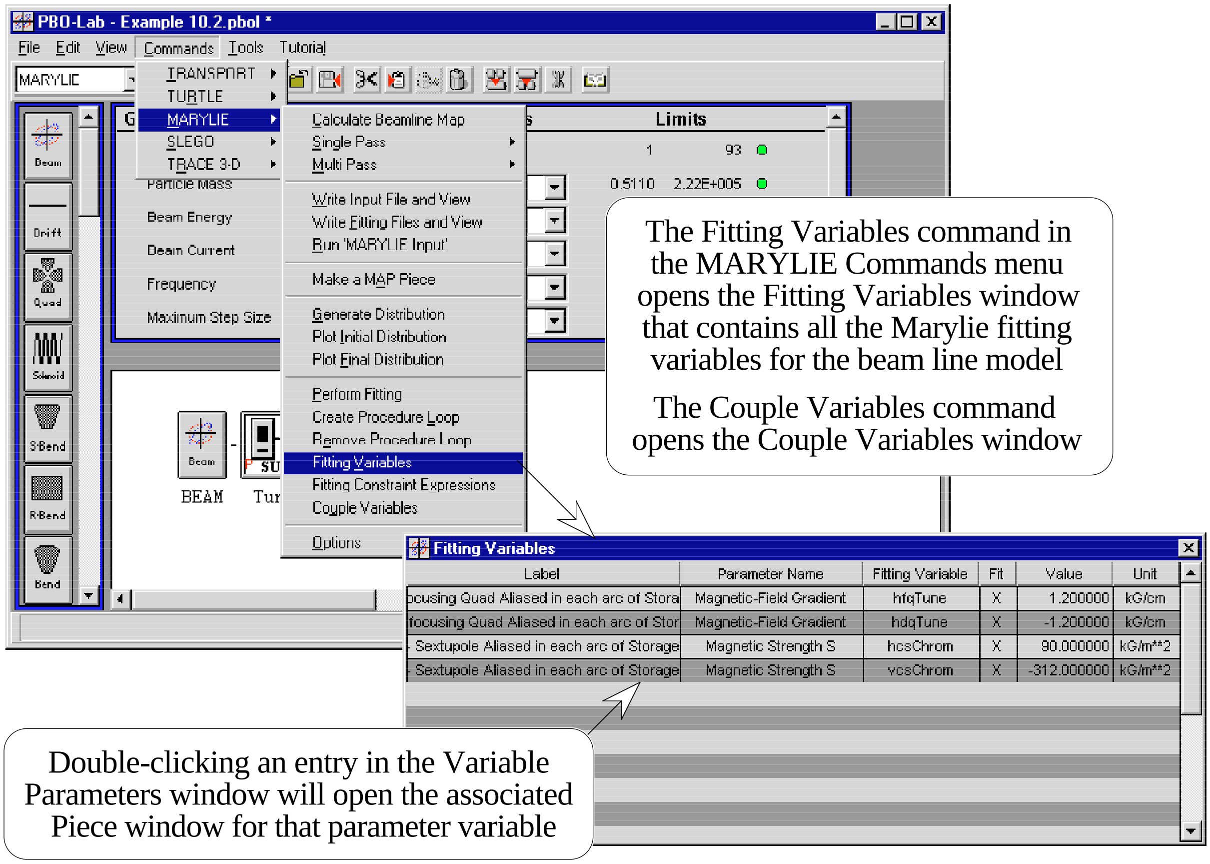


Figure 21 Example of the Marylie Fitting Variables Window.

Fitting Constraints

Fitting constraints are specified at specific locations in the beam line using a Marker Piece. Drag a Marker Piece from the Palette Bar and insert it at the desired location in the beam line model. This may or may not be the end of the beam line. Open the Marker window by double clicking the Piece icon as illustrated in Figure 22.

For a general description of the Marker Piece refer to the Marker Piece Section.

A Marker Piece is used to define application-specific constraints and diagnostics that are dependent on a specific location in the beam line model. A Marker Piece can be used by all installed Application Modules and is therefore dependent on the Application Context switch setting in the Document window. The Marker Piece window has two panels. Each panel displays a list of the currently selected Constraints and Diagnostics for all Application Modules.

The Open buttons in the Marker Piece window use the Application Context switch in the Document window to open the appropreate application-specific user interface window.

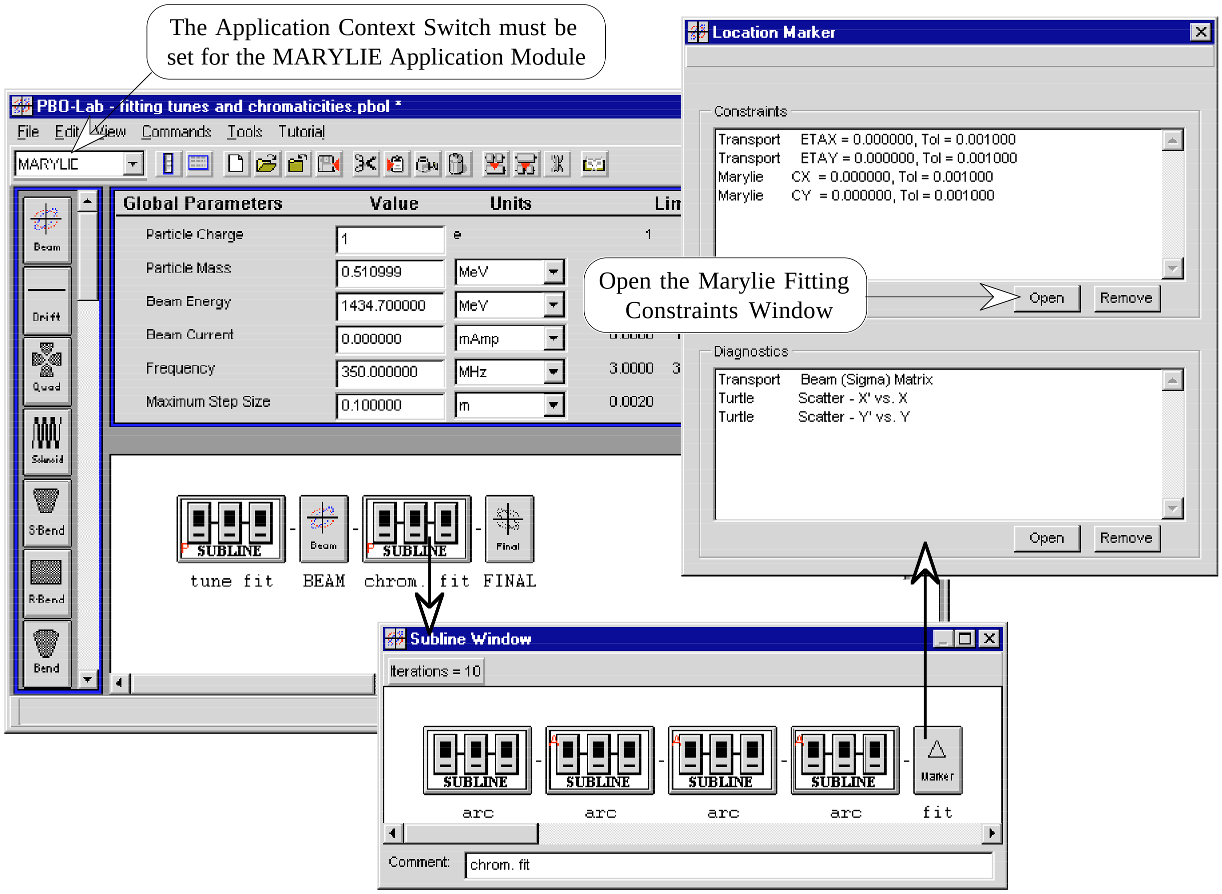


Figure 22 Fitting Constraints and the Marker Piece window.

The Marker Piece window shown in Figure 22 has fitting constraints for both the TRANSPORT and MARYLIE Application Modules, as well as diagnostics for the TRANSPORT and TURTLE Modules. Each entry is preceeded by the application name. Making a selection in these lists and pressing the Remove button will delete that entry from the list. Pressing the Open button in the Constraints panel will open the Fitting Constraints window for the currently selected Application in the Application Context switch. To open the Marylie Fitting Constraints window the Application Context switch must be set for the MARYLIE Application Module. Similarly, the Open button in the Diagnostics panel will open the application-specific user interface window for the current Application Context. However, not all of the Application Modules have location specific Constraint and/or Diagnostic options,.in which case no window will be opened.

The Marker Piece can be used to define application-specific constraints and diagnostics at specific beam line locations.

The Final Piece has the same functionality as the Marker Piece for the Marylie Module.

Fitting Constraints Window

A Marylie Fitting Constraints window can be opened by double-clicking any Marker or Final Piece in the beam line model. The Open button in the Constraints panel of the Marker Piece window opens the Fitting Constraints window. However, the Application Context popup at the top of the Piece window must be set to MARYLIE. Figure 23 below illustrates the primary features of the Marylie Fitting Constraints window. A variety of program variables can be selected as Constraint Expressions. The Fitting Constraints window groups fitting constraints into seven catagories: Lattice Functions, Lattice Properties, Anharmonic Lattice Parameters, Emittances, Lie Polynomial Coefficients, Beam Matrix elements (reduced sigma matrix) and elements of the first-order transfer matrix (R-Matrix).

The Tolerance value shown at the top of the window is used for all constraints. This value is specified in the Marylie Options window. Refer to Marylie Options Section.

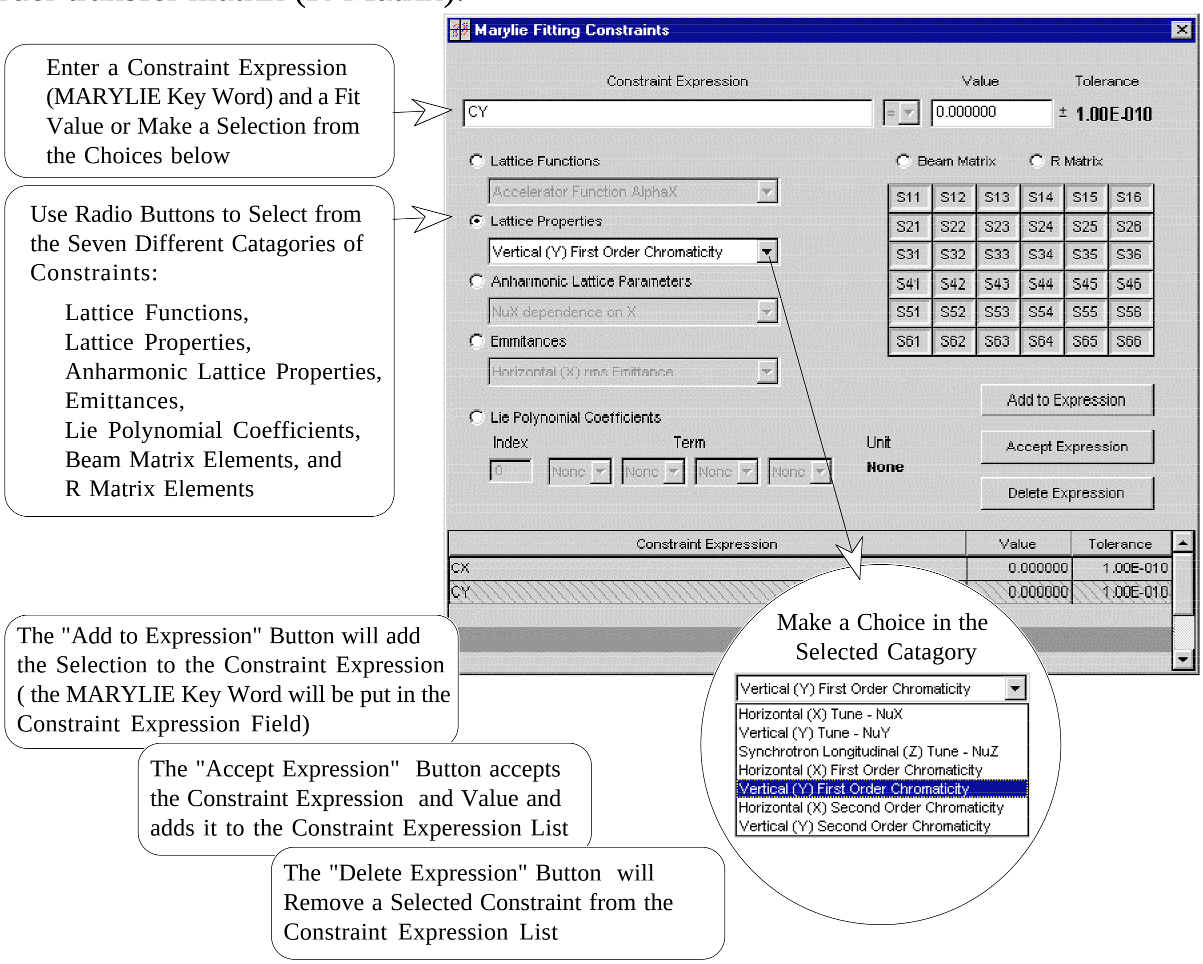


Figure 23 Marylie Fitting Constraints Window.

Table 1 lists the different selections in each catagory for fitting constraints.

Table 1. Pop-up Fitting Constraints

Lattice Functions	Keyword
Accelerator Function AlphaX	ax
Accelerator Function BetaX	bx
Accelerator Function GammaX	gx
Accelerator Function AlphaY	ay
Accelerator Function BetaY	by
Accelerator Function GammaY	gy
Accelerator Function AlphaZ	at
Accelerator Function BetaZ	bt
Accelerator Function GammaZ	gt
Accelerator Function EtaX	dz1
Accelerator Function DeltaX	dz2
Accelerator Function EtaY	dz3
Accelerator Function DeltaY	dz4

Emittances	Keyword
Horizontal (X) rms Emittance	ex
Vertical (Y) rms Emittance	ey
Longitudinal (Z) rms Emit.	et

Beam Matrix	Keyword
Sigma (σ) Matrix Element	S(i,j)

Lattice Properties	Keyword
Horizontal (X) Tune	tx
Vertical (Y) Tune	ty
Synchrotron Longitudinal (Z) Tune	ts
Horizontal (X) First Order Chrom.	cx
Vertical (Y) First Order Chromaticity	cy
Horizontal (X) Second Order Chrom.	qx
Vertical (Y) Second Order Chrom.	qy

Anharmonic Parameters	Keyword
Horz. (NuX) Tune, dependence on X	hh
Vertical (NuY) Tune, depend. on Y	vv
Long. (NuZ) Tune, dependence on Z	tt
Horz. (NuX) Tune, dependence on Y	hv
Vertical (NuY) Tune, depend. on X	hv
Horz. (NuX) Tune dependence on Z	ht
Long. (NuZ) Tune, dependence on X	ht
Vertical Tune (NuY) depend. on Z	vt
Long. (NuZ) Tune, dependence on Y	vt

R-Matrix	Keyword
1st Order Transfer Matrix Element	R(i,j)

Lie Polynomial Coefficients	Keyword
Individual Polynomial Coefficients	F(k)

The Constraint Expression field at the top of the Fitting Constraints window can be used to directly enter MARYLIE keywords. After assigning a fit Value, the Accept Expression button is used to add the constraint to the list at the bottom of the window.

You don't need to know the keyword to specify a constraint. Simply chose a constraint catagory by selecting one of the seven radio buttons, then pick a constraint from the various selections in that catagory and press the Add to Expression button. The MARYLIE keyword will be automatically entered into the Constraint Expression field. After assigning a fit Value, use the Accept Expression button to add the constraint to the list at the bottom of the window.

The Constraint Expression list at the bottom of the window lists all of the fitting constraints defined for this Marker location in the beam line model. To select an existing constraint click on the entry in the Constraint Expression list. The selection will be hi-lited in the list and the edit fields at the top of the window will be updated with the selection. To edit an existing constraint, select it from the list, make any changes and press the Accept Expression button; the selected constraint will be updated with the changes. The Delete Expression button is used to remove an existing constraint. Select the constraint in the Constraint Expression list and press the Delete Expression button. A constraint can also be deleted directly from the Marker Piece window without opening the Fitting Constraints window. Select the constraint in the Constraints list in the Marker (or Final) Piece window and then press the Remove button.

Constraint Expressions List Window

The Constraint Expression List window provides quick access to fitting constraints over the entire beam line. Simply double click an entry in the list to open the associated Marker Piece Window.

Multiple Marker Pieces in the beam line model can be used to specify fitting constraints at different locations in the beam line. However, all of the constraints defined for the entire beam line model are listed together in the Constraint Expressions List window shown in Figure 24.

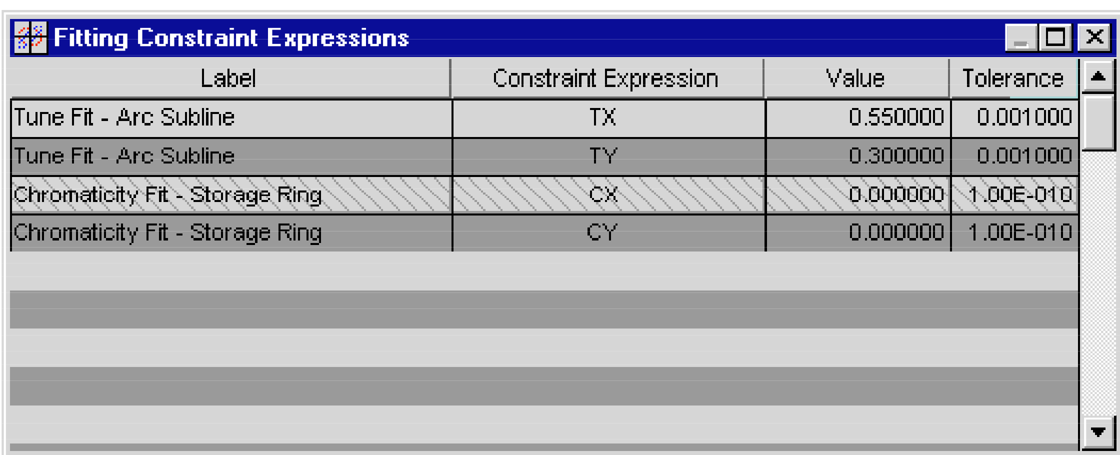


Figure 24 Marylie Fitting Constraint Expressions List Window.

Fitting Procedure Loops

The final step required for a MARYLIE fitting problem is to specify a fitting Procedure Loop. Procedure Loops are a special type of subline that is created for a selection of Pieces in the beam line model. The *Procedure Loop* Section provides a general description the Procedure Loop. The Procedure Loop Subline is only used by the MARYLIE Application Module, and is treated as regular Subline by other Application Modules.

The Procedure Loop Subline is a MARYLIE object. It is treated as a normal Subline by all other Application Modules.

Procedure Loop sublines are used to define the scope of a fitting problem, i.e. the segment of the beam line that will be looped over durring the fitting operation. The maximum number of fitting iterations is also specified with the Procedure loop. A Procedure Loop subline is created in the beam line model like a normal Subline, by selecting a segment of the beam line and chosing the *Create Procedure Loop* command in the MARYLIE Commands menu. The Procedure Loop subline must include at least one Marker or Final Piece that specifies one or more fitting constraints. It must also include Pieces with specified fitting variables. A Procedure Loop may include the entire beam line model or a particular segment of the beam line. The *Select All* command followed by the *Create Procedure Loop* command will make a Procedure Loop for the entire beam line model. Selections within the beam line model can be made by holding down the mouse button while dragging a box around the desired Pieces in the model space. The control key can be used to make a larger selection from a series of selections. For example, if the beam line model needs to be scrolled to select more pieces than are visible in the model space; make the first selection and then hold down the control key while making another selection with the mouse. Larger models can also be organized with nested Sublines, which may also be included in Procedure Loops just like any other beam line element.

The commands for creating and removing Procedure Loop Sublines are in the MARYLIE sub-menu of the Commands menu, which is only available when the MARYLIE Application Module is installed.

Procedure Loop Sublines are readily identified by the red "P" that appears on the piece icon.

To remove a Procedure Loop (flatten a selected Procudere Loop subline), choose the *Remove Procedure Loop* command in the MARYLIE *Commands* menu or the *Flatten Subline* command in the *Edit* menu. The Flatten Subline button in the Button Bar will also flatten a Procedure Loop.

Perform Fitting

The *Perform Fitting* command in the MARYLIE Commands menu (Figure 25) is used to execute any fitting procedures specified in the beam line model. Once fitting variables and constraints have been defined and Procedure Loops have been created, the *Perform Fitting* command will generate the required input files and execute MARYLIE.

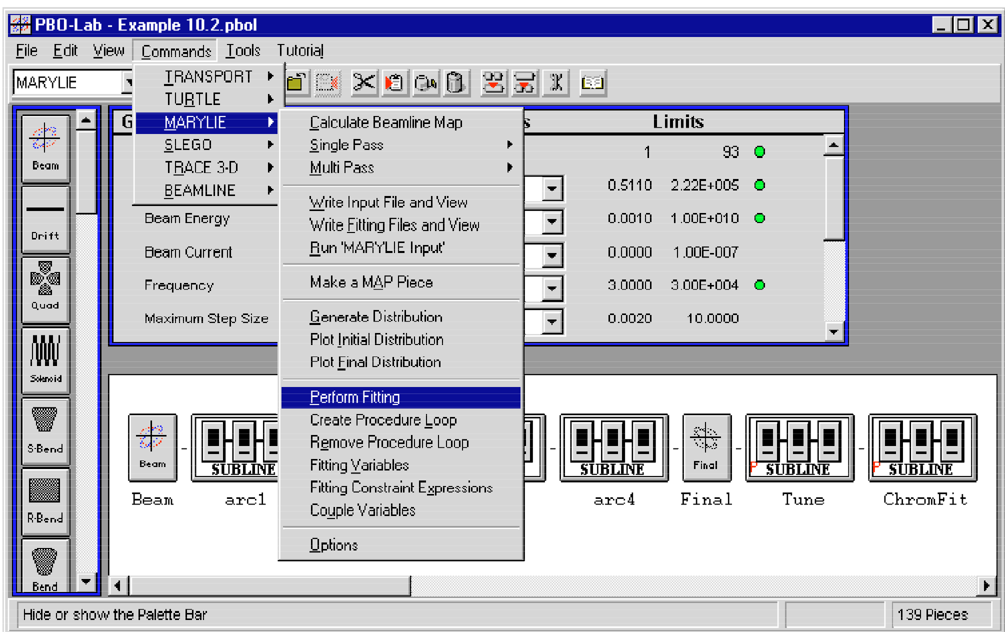


Figure 25 Execute MARYLIE Fitting with the Perform Fitting Command.

Update Parameter Variables

After MARYLIE has completed a fitting task, the new values for parameter variables can be used to update the model. The Update Parameter Variables Window, ,opened automatically following a fitting procedure, is used to examine the new values for each of the parameter variables and update the beam line model.

After a fitting operation the fitted parameter variables are displayed in an Update window. However, the beam line model is not changed until the fit values are explicitly accepted in the Update window.

The Update Parameter Variables Window contains two scrolling list for variable and coupling parameters. The list at the top of the window displays all of the user specified Marylie fitting variables (variable parameters) for the entire beam line. The list at the bottom contains any user specified parameters that are coupled to specific fitting variable parameters. Both the variable and coupling parameter lists have buttons for updating the beam line model with the new fitted parameter values.

Double-click a variable or coupling entry to open the Piece window for that parameter.

The Update All Values button can be used to update all of the variable parameters in one step. Alternatively the Update Selected Value button can be used to update variable parameters individually. (There are identical buttons for the Coupling Parameters in the lower half of the window.) To update parameters individually make a selection in the list of parameters and press the Update Selected Value button. When a selection is made in the list it will be hilited as shown in Figure 26. Using the mouse to double-click a list entry will open the Piece window for that parameter.

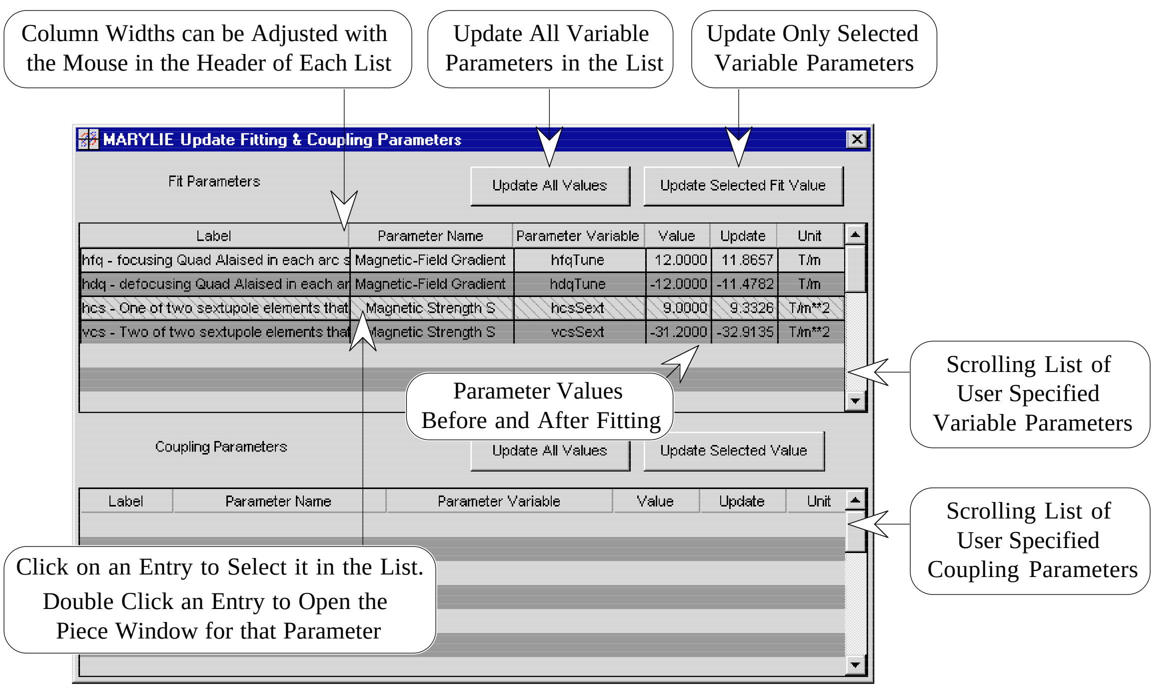


Figure 26 Update Parameter Variables Window.

The Update Parameter Variables window can be left open and the beam line will not be updated with the new fit values until one of the Update buttons is used. However, if the window is closed prior to updating the beam line, then the fitting results are disposed and the beam line model is unchanged.

MARYLIE Type-Code Mnemonics

A cross reference of all MARYLIE type-code mnemonics to their corresponding PBO Lab graphic interface components is provided in Table 2. The MARYLIE type-code mnemonics are those listed in Section 13.1 of the MARYLIE 3.0 User's Manual. Table 2 repeats from that Section the brief summary of each type code's purpose and the MARYLIE 3.0 User's Manual subsection reference. The corresponding PBO Lab component is given in the right-most column.

Comments under the PBO Lab Component column in parentheses indicate items that have no corresponding interface component. Some of the MARYLIE type codes are not relevant "(Not used in PBO Lab)". Other type codes are created automatically by the PBO Lab "(Automatically done)". In addition, certain type codes have yet not been implemented in MARYLIE "(Not yet in MARYLIE)", or require the Profession version of PBO Lab in order to customize the MARYLIE Module "(Requires user-written code)". MARYLIE type-code mnemonics where the corresponding PBO Lab Component is indicated as "---" do not have an interface component in the current beta version of PBO Lab 2.0, but will be implemented in a future release. Finally, a few type codes do not yet have a strict one-to-one correspondence with any PBO Lab Component, but are utilized by certain PBO Lab 'macro commands'; the PBO Lab Components which create these macro commands are indicated in parenthesis "(Beam Piece)".

Software updates occur more frequently than user manual update, and new capabilities are being added to the MARYLIE Module. Contact AccelSoft (accelsoft@ghga.com) if there is a question concerning any particular feature.

Table 2. Cross reference of MARYLIE type-code mnemonics, listed alphabetically, to PBO Lab interface components.

Type Code	Purpose	MARYLIE Subsection	PBO Lab Component
aim	Specify quantities to be fit or optimized and set target values.	9.5	Marker Piece
amap	Apply map to a function or moments.	8.17	---
arc	Arc for accounting purposes.	6.31	(Not yet in MARYLIE)
arot	Axial rotation.	6.14	Rotate Piece
asni	Apply script *N* inverse.	8.29	---
bell	Ring bell at terminal.	7.31	(Not used in PBO Lab)
bgen	Generate beam.	8.34	Beam Piece
bip	Begin inner procedure.	9.1	Create Procedure Loop
bop	Begin outer procedure.	9.2	Create Procedure Loop
cbm	Change or write out beam parameters.	7.39	(Not used in PBO Lab)
cdf	Change drop file.	7.30	(Not used in PBO Lab)
cf	Close files.	7.23	(Automatically done)
cfbd	Combined function bend.	6.8	Bend, S-Bend Pieces
cfqd	Combined function magnetic quadrupole.	6.24	---
cfrn	Change or write out values of fringe field parameters for combined function dipole.	6.29	Bend, S-Bend Pieces
circ	Set parameters and circulate.	7.3	Commands Menu
cod	Compute off-momentum closed orbit data.	8.1	---
con1 con5 :	Constraints.	9.12	(Requires user-written code)
cplm	"Compressed" approximation to low order multipoles.	6.17	---
cps1 : cps9	Capture parameter set.	9.15	---
csym	Check symplectic condition.	8.31	---
ctr	Change tune range.	8.28	---
dapt	Compute dynamic aperture.	9.19	---
dia	Dynamic invariant analysis.	8.11	Map Analyzer Piece
dims	Dimensions.	7.40	(Not yet in MARYLIE)
dism	Dispersion matrix.	6.22	Eta Piece
dnor	Dynamic normal form analysis.	8.9	Map Analyzer Piece
dp	Data point.	6.26	---
dpol	Dispersion polynomial.	7.38	---
drft	Drift space.	6.1	Drift Piece
eapt	Aperture the beam with an elliptic aperture.	7.19	---
end	Halt execution. Must be an entry of a #labor list.	7.1	(Automatically done)
exp	Compute exponential.	8.7	Map Operator Piece
fadm	Fourier analyze dynamic map.	8.16	(Not yet in MARYLIE)

Table 2. Cross reference of MARYLIE type-code mnemonics (continued).

Type Code	Purpose	MARYLIE Subsection	PBO Lab Component
fasm	Fourier analyze static map.	8.15	(Not yet in MARYLIE)
fit	Carry out fitting operation.	9.7	Procedure Loop
flag	Change or write out values of flags and defaults.	9.17	(Not used in PBO Lab)
fps	Free parameter set.	9.16	(Not yet in MARYLIE)
frng	Used for hard-edge dipole fringe fields.	6.7	Bend, S-Bend Pieces
ftm	Filter the existing transfer map.	7.22	---
fwa	Copy file to working array	8.39	(Not used in PBO Lab)
gbdy	Used for the body of a general bending magnet.	6.6	Bend, S-Bend Pieces
gbnd	General bending magnet.	6.4	Bend,S-Bend, R-Bend Pieces
gbuf	Get buffer contents.	8.14	Map Operator Piece
geom	Compute geometry of a loop.	8.38	Floor Coords., Lattice Plots
grad	Compute gradient matrix.	9.13	---
gtm	Get a transfer map from storage.	7.17	Map Operator Piece
iden	Replace existing transfer map by the identity map.	7.8	Map Operator Piece
inf	Change or write out values of infinities.	7.35	(Not used in PBO Lab)
lnv	Replace existing transfer map by its inverse	7.9	Map Operator Piece
jmap	Map with matrix part J.	6.18	---
mark,	Marker.	6.25	Marker, Final Pieces
mask	Mask off selected portions of existing transfer map.	7.13	Options-Calculation Order
mn	Compute matrix norm.	8.33	Map Math Piece
moma	Moment analysis.	8.37	---
mrto	Merit function (sum of squares).	9.10	---
mrtl : mrt5	Merit functions (user written).	9.11	(Requires user-written code)
mss	Minimize sum of squares optimization.	9.8	---
nbnd	Normal entry bending magnet, with or without fringe fields.	6.2	Bend, S-Bend Pieces
num	Number lines in a file.	7.27	(Not used in PBO Lab)
octe	Electric octupole.	6.12	---
octm	Magnetic octupole.	6.11	Octupole Piece
of	Open files.	7.24	(Automatically done)
opt	General optimization.	9.9	---
padd	Add two polynomials.	8.19	Map Math Piece
paws	Pause.	7.34	(Not used in PBO Lab)
pb	Poisson bracket two polynomials.	8.21	Map Math Piece

Table 2. Cross reference of MARYLIE type-code mnemonics (continued).

Type Code	Purpose	MARYLIE Subsection	PBO Lab Component
pbnd	Parallel faced bending magnet, with fringe fields and equal entry and exit angles.	6.3	R-Bend Piece
pdnf	Compute power of dynamic normal form.	8.13	Map Analyzer Piece
pmif	Print contents of Master Input File (file 11)	7.4	Options - Echo MIF
pmul	Multiply two polynomials.	8.20	Map Math Piece
pnlp	Compute power of nonlinear part.	8.30	Map Math Piece
pold	Polar decomposition of a map.	8.22	Map Math Piece
ppa	Principal planes analysis.	8.36	(Not yet in MARYLIE)
prot	Used for leading and trailing pole face rotations.	6.5	Bend, S-Bend Pieces
ps1 : ps9	Parameter set specification.	7.25	Param Piece
psnf	Compute power of static normal form.	8.12	Map Analyzer Piece
psp	Polynomial scalar product.	8.32	Map Math Piece
ptm	Print transfer map.	7.7	Marker Piece & Options
pval	Evaluate a polynomial.	8.23	---
quad	Magnetic quadrupole.	6.9	Quad Piece
radm	Resonance analyze dynamic map.	8.5	Map Analyzer Piece
rapt	Aperture the beam with a rectangular aperture.	7.18	Aperture Piece
rasm	Resonance analyze static map.	8.4	Map Analyzer Piece
recm	REC quadrupole multiplet.	6.27	---
rev	Replace existing transfer map by its reversed map.	7.11	Map Operator Piece
revf	Replace existing transfer map by reverse factorized form.	7.12	Map Operator Piece
rmap	Random map.	6.30	---
rpsl : rps9	Random parameter set specification.	7.26	---
rset	Reset menu entries.	9.18	(Not used in PBO Lab)
rt	Perform a ray trace.	7.2	Commands Menu
r****	Random counterpart of the element with type-code mnemonic****.	6.19	---
scan	Scan parameter space.	9.14	---
sext	Magnetic sextupole.	6.10	Sextupole Piece
sia	Static invariant analysis.	8.10	Map Analyzer Piece
smul	Multiply a polynomial by a scalar.	8.18	Map Math Piece
snor	Static normal form analysis.	8.8	Map Analyzer Piece
sol	Solenoid.	6.23	Solenoid Piece

Table 2. Cross reference of MARYLIE type-code mnemonics (continued).

Type Code	Purpose	MARYLIE Subsection	PBO Lab Component
spce	Space for accounting purposes.	6.28	---
sq	Select quantities.	8.26	Fitting Constrants
sqr	Square the existing transfer map.	7.15	Map Operator Piece
srfc	Short RF cavity.	6.13	RF Gap Piece
stm	Store the existing transfer map.	7.16	Map Operator Piece
symp	Symplectify matrix portion of transfer map.	7.14	Map Operator Piece
tadm	Twiss analyze dynamic map.	8.3	Map Analyzer Piece
tasm	Twiss analyze static map.	8.2	Map Analyzer Piece
tbas	Translate basis.	8.6	Map Operator Piece
thlm	"Thin lens" approximation to low order multipoles.	6.16	---
tic	Translate initial conditions.	8.35	Centroid Piece
time	Write out execution time.	7.29	(Not used in PBO Lab)
tip	Terminate inner procedure.	9.3	Create Procedure Loop
tmi	Input matrix elements and polynomial coefficients from an external file.	7.5	Map Piece
tmo	Ouptut matrix elements and polynomial coefficients to an external file.	7.6	Map Piece
top	Terminate outer procedure.	9.4	Create Procedure Loop
tpol	Twiss polynomial.	7.37	Beam Piece
tran	Replace existing transfer map by its "transpose".	7.10	Map Operator Piece
trda	Transport dynamic *A*.	8.25	(Not yet in MARYLIE)
trsa	Transport static *A*.	8.24	(Not yet in MARYLIE)
twsm	Linear matrix transformation specified in terms of twiss parameters.	6.15	(Beam Piece)
usr1	User specified subroutines that act on phase space data.	6.20	(Requires user-written code)
:			
usr10			
usr11	User specified subroutines that produce or act on maps.	6.21	(Requires user-written code)
:			
usr20			
vary	Specify quantities to be varied.	9.6	S-Window on Pieces
wcl	Write contents of a loop.	7.33	---
whst	Write history of beam loss.	7.21	---
wmrt	Write out value of merit function.	7.32	---
wnd	Window a beam.	7.20	Aperture Piece
wps	Write out parameters in a parameter set.	7.28	---
wsq	Write selected quantities.	8.27	(Create Procedure Loop)
wuca	Write out contents of ucalc array.	7.41	---
zer	Change or write out values of zeroes.	7.36	(Not used in PBO Lab)