PBO Lab™ 2.0

(Particle Beam Optics Laboratory)

User Manual

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

ISBN 1-892267-03-9

Printed in the United States of America.

Published by AccelSoft Inc., *San Diego, California*.

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PBO Lab™ 2.0

Introduction

Particle
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PBO Lab Overview

The Particle Beam Optics Laboratory (PBO Lab) is a unique user interface shell that provides an environment for the graphical set up of beamline models and the execution of multiple computational programs used for the design and analysis of particle optics systems and accelerators. Computational codes are integrated together as Application Modules in the PBO Lab environment. A single beamline model in PBO Lab can be used for design and analysis tasks with any of the installed Application Modules. PBO Lab generates the appropriate native inputs without requiring any knowledge of the various formats and specific syntax needed by the different programs.

The Particle Beam Optics Laboratory provides an intuitive and easy-to-use graphic user interface that integrates a variety of optics programs as Application Modules in a single software package.

Refer to the PBO Lab Application Modules Section in the Getting Started Chapter.

None of the Application Modules are required in order to use PBO Lab. PBO Lab provides a built-in first-order optics module to graphically illustrate the qualitative optical features of a beamline. In addition, an extensive interactive tutorial system has been integrated with PBO Lab to assist users with the technology of accelerators and various beam physics phenomena.

Refer to the Chapter on PBO Lab Analysis Tools - Focusing and Bending Modules.

This Chapter provides a brief summary of the different PBO Lab Application Modules. The remainder of this manual describes the application-independent features of the PBO Lab environment. Each of the computational codes supported by PBO Lab is described separately in the Application Module Supplements to the PBO Lab User Manual.

PBO Laboratory has been developed specifically to support several different particle optics design and analysis codes, including:

TRANSPORT,
TURTLE,
MARYLIE and
TRACE 3-D.

PBO Lab is implemented with the second generation Multi-Platform Shell for Particle Accelerator Related Codes (S.P.A.R.C.-MP) application framework. A variety of computer platforms are supported by PBO Lab. Although there are some minor differences, the user interface is consistent for all platforms. All of the figures in this manual have been produced from PBO Lab running under Windows™ on a desktop personal computer.

The consistent treatment of varied features in the different optics programs enhances the productive use of these codes in the PBO Lab environment.

TRANSPORT Summary

The TRANSPORT optics program is a matrix multiplication code that includes the ability to model optics up to and including third order.

TRANSPORT is a FORTRAN matrix multiplication program developed for modeling charged particle optics. The program is particularly useful for the design and simulation of static-magnetic beam transport systems, although it can be applied to other problems in accelerator design as well. The version included with PBO Lab has the ability to model beamlines to first-, second- and third-order. TRANSPORT has a variety of fitting and problem constraint capabilities, and can be used to examine the effects of field errors, component misalignments and similar non-ideal beamline conditions.

TURTLE Summary

The TURTLE program supports the analysis of beamlines designed for TRANSPORT and includes multi-particle ray tracing.

The TURTLE (Trace Unlimited Rays Through Lumped Elements) program is useful to support the analysis of beamlines designed with TRANSPORT. TURTLE is a FORTRAN program that allows the evaluation of the effect of aberrations that exist in beams with small phase space volume. These include higher order chromatic aberrations, effects of non-linearities in magnetic fields, and higher order geometric aberrations due to the accumulation of second-order effects.

MARYLIE Summary

The MARYLIE program is based on Lie algebraic methods and is useful for both linear transport systems and circulating storage rings. It can be used to compute transfer maps, trace particle rays and carry out tracking simulations.

MARYLIE is a FORTRAN program for beam transport and tracking, based on a Lie algebraic formulation of charged particle trajectory calculations. MARYLIE is useful for the design and evaluation of both linear transport systems and circulating storage rings. The program is able to compute transfer maps and trace rays through single or multiple beamline elements for the full six-dimensional phase space without the use of numerical integration of traditional matrix methods. The effects of high-order aberrations are computed as an integral part of the Lie algebra approach. All non-linearities, including chromatic effects, through third order are included.

TRACE 3-D Summary

TRACE 3-D is a FORTRAN beam dynamics program that calculates the envelopes and phase-space ellipses of a bunched beam, including linear space-charge forces, through a beamline. TRACE 3-D also supports fourteen different types of fitting or beam-matching options. Matching options will vary Initial Beam parameters for a matched beam in X,Y planes, Z plane, X,Y,Z planes (Upright), or in X,Y,Z planes. Fitting options will vary element parameters to fit a desired beam in X, in Y, or in the Z plane, in X,Y planes, or in X,Y,Z planes. The Initial Beam can also be fit for a desired beam in X,Y,Z planes. In addition, TRACE 3-D can vary element parameters for fitting desired R-Matrix or Sigma-Matrix elements, fitting for a round beam, or fitting for specified phase advances in selected phase planes.

The TRACE 3-D program calculates the envelopes and phase-space ellipses of a bunched beam, including linear space-charge forces, through a beamline.

Application Module Professional Versions

FORTRAN source code for several of the PBO Lab Applications Modules are available in Professional Versions. The Professional Version of an Application Module allows the user to modify the FORTRAN physics code in order to customize PBO Lab for their specific or unique requirements. Contact AccelSoft for further information.

Future Application Modules

Additional Applications Modules for PBO Lab are planned for the future, and several are currently under development. Information on new Application Modules for each computer platform supported by PBO Lab will be posted on the AccelSoft web site (www.ghga.com/accelsoft) as they become available.

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PBO Lab™ 2.0

Getting Started

Particle
Beam
Optics
Laboratory

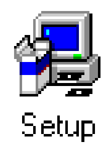
This Chapter is intended to provide users with a brief introduction to PBO Lab that will get them up and running quickly. It covers the installation and registration of the PBO Lab application and provides an overview of the use of the software.

Installing PBO Lab

The PBO Lab software is distributed on CD-ROM and includes the PBO Lab application, the required libraries, Tutorials and some example files. Installation requires approximately 15 MB of free disk space.

Installation on the PC

To install the PBO Lab application on a PC running Windows or Windows NT, insert the Windows PBO Lab CD and double-click the Setup icon as shown in Figure 1. Setup will guide you through the installation process. Simply follow the instructions of the Setup Wizard.



Run Setup on the PBO Lab CD to install the PBO Lab application on your PC.

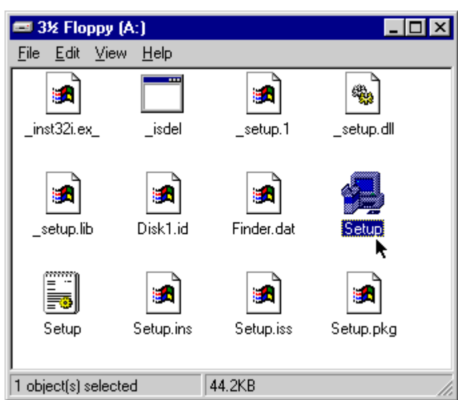
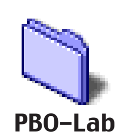


Figure 1. Double-click the "Setup" Application.

Installation on the Macintosh

To install the PBO Lab application on a Macintosh PowerPC running Mac OS version 7 and up, insert the Mac PBO Lab CD and simply drag the PBO-Lab folder to your hard drive.



Drag the PBO- Lab folder to your hard drive to install the PBO Lab application on your Mac.

For work stations refer to the platform-specific Installation Supplement distributed with the PBO Lab software for these platforms.

Uninstalling PBO Lab

On the PC, you can uninstall PBO Lab using "Add/Remove Programs" in your Control Panels Folder.

To uninstall the PBO Lab application under Windows or Windows NT, run the "Add/Remove Applications" tool in your Control Panel folder. Select the PBO Lab application from the tool's list of programs and press the uninstall button. This will remove the PBO Lab application and all of the libraries that were installed with PBO Lab.

On the Mac, you can uninstall PBO Lab by simply dragging the PBO-Lab Folder to the trash.

To uninstall the PBO Lab application on a Macintosh, simply drag the PBO-Lab folder to the trash.

For work stations refer to the platform-specific Installation Supplement distributed with the PBO Lab software for these platforms.

PBO Lab Registration

Registering PBO Lab for the first time

After installing PBO Lab it must be registered with either a Demo License Number or with your Personal License Number assigned when you purchased the software.

The Particle Beam Optics Laboratory and individual Application Modules are distributed on a single CD ROM. After installing the software on your hard drive, it must be registered with either a 30-Day Evaluation License Number or with your Personal License Number assigned when you purchased the software. A CD Key is also required that tells PBO Lab which Application Modules will be activated. Both the License Number and CD Key are on the Packing Slip shipped with PBO Lab and on the CD case itself. A 30-Day Evaluation License Number allows for a 30 day evaluation period of the PBO Lab software. When the software is purchased, a Personal License Number will be provided.

Upgrading to a newer version of PBO Lab

If you have previously installed PBO Lab with a Personal License Number, then you do not need to reregister after upgrading to a newer version.

If you have already registered with a Personal License Number and CD Key and have received an updated version of the PBO Lab software, you do not need to reregister. Simply replace the older version of PBO Lab on your hard drive with the updated version. Refer to the *Uninstall* and *Installation* Sections in this Chapter.

Activating additional Application Modules

If you are already registered with a Personal License Number and CD Key, and have now purchased additional Application Module(s), you will need to reregister the software in order to activate the new Module(s). A new CD Key will be assigned to your Personal License Number when you purchase additional Application Modules. Start PBO Lab and open the Registration window from the Tutorial menu. After entering your new CD Key you will need to quit and restart the PBO Lab application. This will insure that the new Application Modules are activated properly.

You will need to reregister with your new CD Key if you have purchased additional PBO Lab Application Modules.

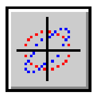
If you received a new PBO Lab CD (updated version) when you purchased additional Application Modules, you will need to install the new version and reregister the software as described previously.

Upgrading from the PBO Lab 30-Day Evaluation

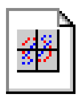
If you are upgrading from the 30-Day Evaluation License, you must reregister with your new Personal License Number and CD Key included with your purchase of the PBO Lab software. Start PBO Lab and open the Registration window with the Register button in the Demo Dialog window. After entering your new Personal License Number and CD Key in the Registration window, you will need to quit and restart the PBO Lab application. This will insure that any Application Modules included in your purchase are activated properly.

If you have registered with a 30-Day Evaluation License Number, you will need to reregister with your new Personal License Number and CD Key when you purchase PBO Lab.

Running PBO Lab



Double-clicking the PBO Lab application icon will open an untitled PBO Lab Document Window.



PBO Lab model file icon.

The PBO Lab application is started by double-clicking the PBO Lab application icon. A new untitled Document Window will be opened. Use the Open command in the File Menu to open a specific model file. Figure 2 illustrates the principal parts of the PBO Lab Document Window: the Palette Bar, Menu Bar, Button Bar, Global Parameters, the Work Space and beamline Model Space. Document Windows may be expanded horizontally and vertically. An unlimited number of Document Windows may be opened at any one time.

On the Macintosh, the Menu Bar is at the top of the monitor. This maintains the native look and feel for the Mac OS. On other platforms, the Menu Bar appears in application windows as illustrated in Figure 2 below. Otherwise the user interface is consistent for all platforms supported by PBO Lab.

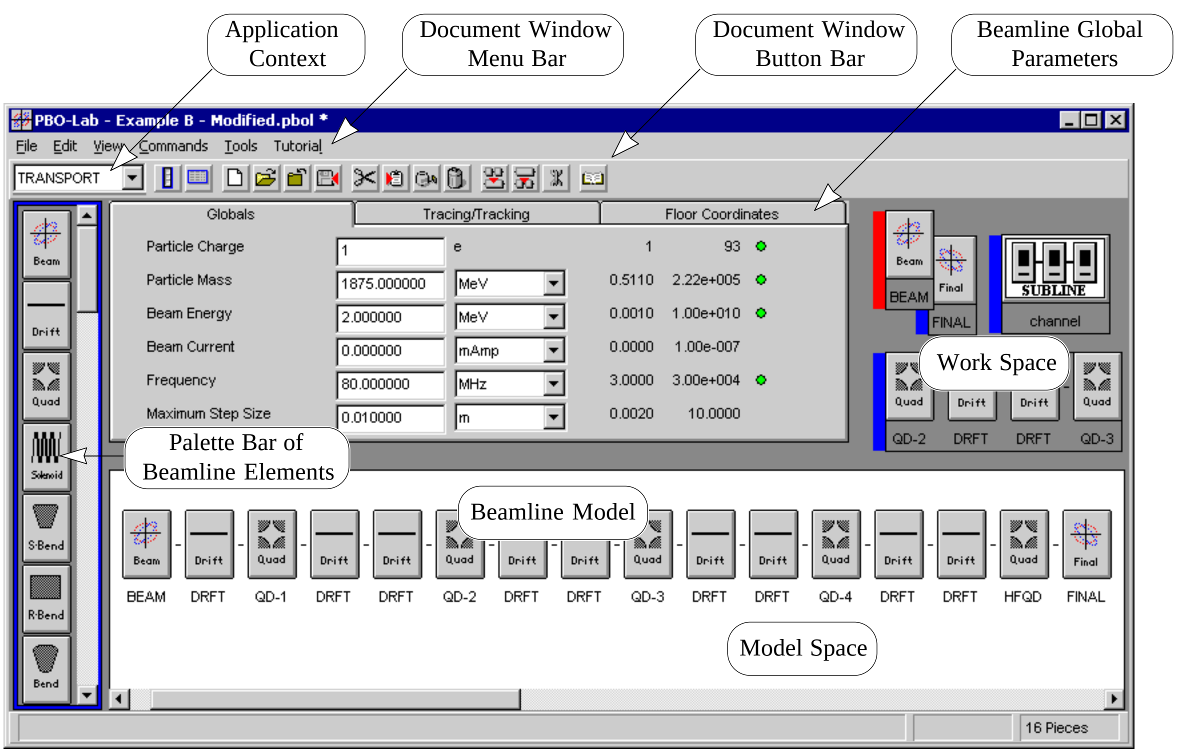


Figure 2. PBO Lab Document Window.

PBO Lab Application Modules

A variety of particle beam analysis and design programs are implemented as Application Modules in the PBO Lab user interface. A specific Application Context is selected with a pop-up menu in the Document Window Button Bar as illustrated in Figure 2. The Application Context is used to provide the user with various application-specific feedback such as the native inputs for an application. The applications listed in the Application Context pop-up depend on which Application Modules are installed in your version of PBO Lab.

The Application Context is used to display and access application-specific inputs for each of the installed Application Modules.

Other parts of the PBO Lab user interface will also have different content based on the installed applications. For example, some menus have application-specific sub-menus for each installed Application. There are also some user interface windows that are either completely application-specific or, in some cases, include application-specific tab panels for the different Application Modules. The Special Parameter Settings window is an example of a PBO Lab window with application-specific tab panels. Application-specific aspects of the user interface are described separately in individual Application Module Supplements to the PBO Lab User Manual.

PBO Lab menus contain application-specific sub- menus for each of the installed applications. The Menu commands do not depend on the current Application Context.

The Application Context pop-up in the Document Window does not have to be set to a particular application in order to execute commands for that Application Module. However, the Application Context selection is used to indicate which input parameters are native inputs for the current context. Native inputs are indicated in the Global Parameters and in each Piece Window using green dots that appear to the right of a parameter. The Application Context is also used in the Marker and Final Pieces for setting a location-specific Constraint or Diagnostic. Creating a new Constraint or Diagnostic with these pieces will always open the appropriate application-specific window for the current Application Context.

Application-specific windows provide access to native inputs that are not shared between installed applications. The selected Application Context is used to activate application-specific buttons and, in some cases, determine which application-specific windows will be opened.

Building a Beam Line Model and Editing Input Parameters

Refer to the Beamline Global Parameters Section in the User Interface Chapter for a description of the PBO Lab Global Parameters. Refer to the Global Parameters Section in each Application Module Supplement for a description of application-specific Beamline Global Parameters.

PBO Lab utilizes several sets of user input parameters to describe an accelerator beamline model for the different computational programs integrated with the interface. The user inputs that provide data for running the Application Modules are grouped by the following:

- Global Parameters
- Piece Parameters
- Command Control Parameters
- Options and Output Parameters

All parameters in PBO Lab have defaults built in. Once a beamline has been constructed graphically, with or without any parameter editing, a beamline model is completely defined for executing any of the installed Application Modules.

The first step in building a PBO Lab beamline model is to review the Global Parameters.

The Beamline Global Parameters are set in a scrollable panel at the top of each Document Window. The Global Parameter panel contains input parameters such as the *Particle Charge*, *Particle Mass* and *Beam Energy* that are global to the entire beamline. Various units options are available for several of the Global Parameters. For example, Figure 3 illustrates the use of a units pop-up for inputting the *Beam Energy* in terms of the equivalent momentum units (in p(GeV/c)).

The Beam Energy in PBO Lab can be specified in any one of several ways. Options include specifying the relativistic β or γ of the particle, the particle momentum, as well as the traditional beam energy units of eV, keV, MeV or GeV. The PBO Lab interface automatically converts between units when the pop-up selection is changed.

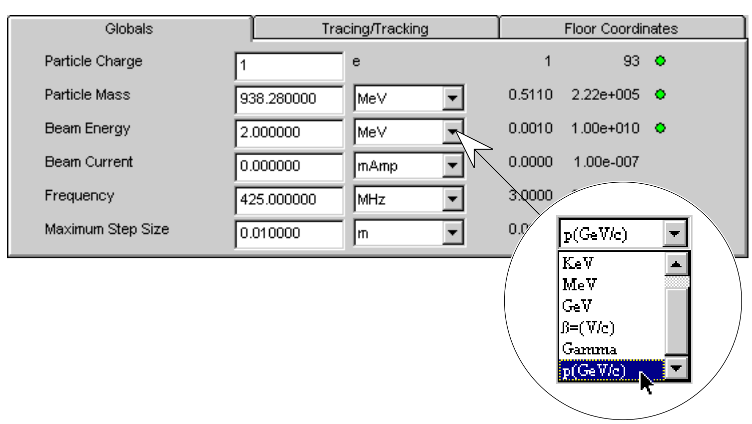


Figure 3. Global Parameter Panel of the Document Window Illustrating a Pop-up Units Menu.

The second step is to "build" a beamline to be modeled. An accelerator beamline model is built by selecting and dragging the beamline pieces from the Palette Bar to the Model Space of the Document Window. Figure 4 illustrates an example of a Document Window with a short quadrupole lattice model built on the Model Space. Other beamline segments, sublines and pieces shown in Figure 4 are saved on the Work Space.

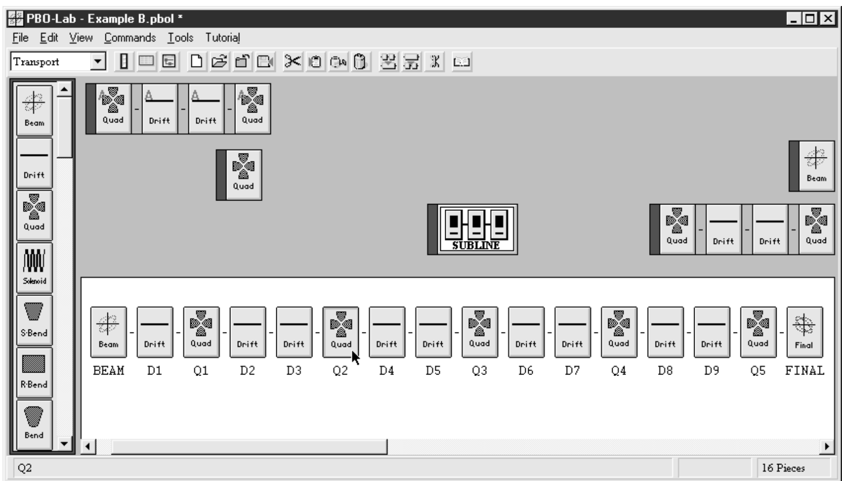


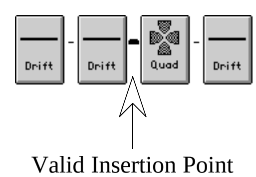
Figure 4. Beamlines on the Model Space and Work Space of a Document Window.

A beamline is constructed by dragging Piece icons from the Palette Bar to the Model Space. Pieces may also be placed on the Work Space.

The Global Parameters panel may be closed to provide more area for the Work Space.

A colored tab is used to select and drag Selections on the Work Space. The tab is red when a selection has been made.

The scrolling Palette Bar provides access to all of the beamline pieces available in PBO Lab. Selecting, dragging and dropping a piece on the Model Space will result in that piece being attached to the end of the beamline model nearest the drop point. Pieces from the Palette Bar or Work Space may be inserted between pieces in the beamline model by making a selection and dragging it to a connection point. Connection points are identified by the black lines between each piece in the beamline. A bold connection line indicates that a valid insertion point has been located while dragging a selection from the Palette Bar or from the Work Space. Releasing the mouse button (dropping the selection) while the connection line is bold will insert the selection at that location in the beamline model.



A bold connection line indicates that a valid insertion point has been located while dragging a selection from the Palette Bar or the Work Space.

All parameters in PBO Lab have defaults built in. Once a beamline has been constructed graphically, with or without any parameter editing, a beamline model is completely defined.

The Piece Parameters define all inputs for each piece in the beamline model. Double-clicking on an individual piece, such as one of the "Quad" pieces in the example shown in Figure 4, opens a Piece Window like that illustrated in Figure 5. The beamline element parameters are edited in Piece Windows. Application-specific Special Parameter Settings are also accessed in the Piece Windows: for example, the user can select a parameter as a match variable or import variable or define an algebraic expression for the parameter. The "S" button to the left of each parameter is used to open a Special Parameter Settings Window as illustrated in Figure 5. The Special Settings Windows have tab panels that provide access to application-specific options. These are described in the individual Application Module Supplements to the PBO Lab User Manual.

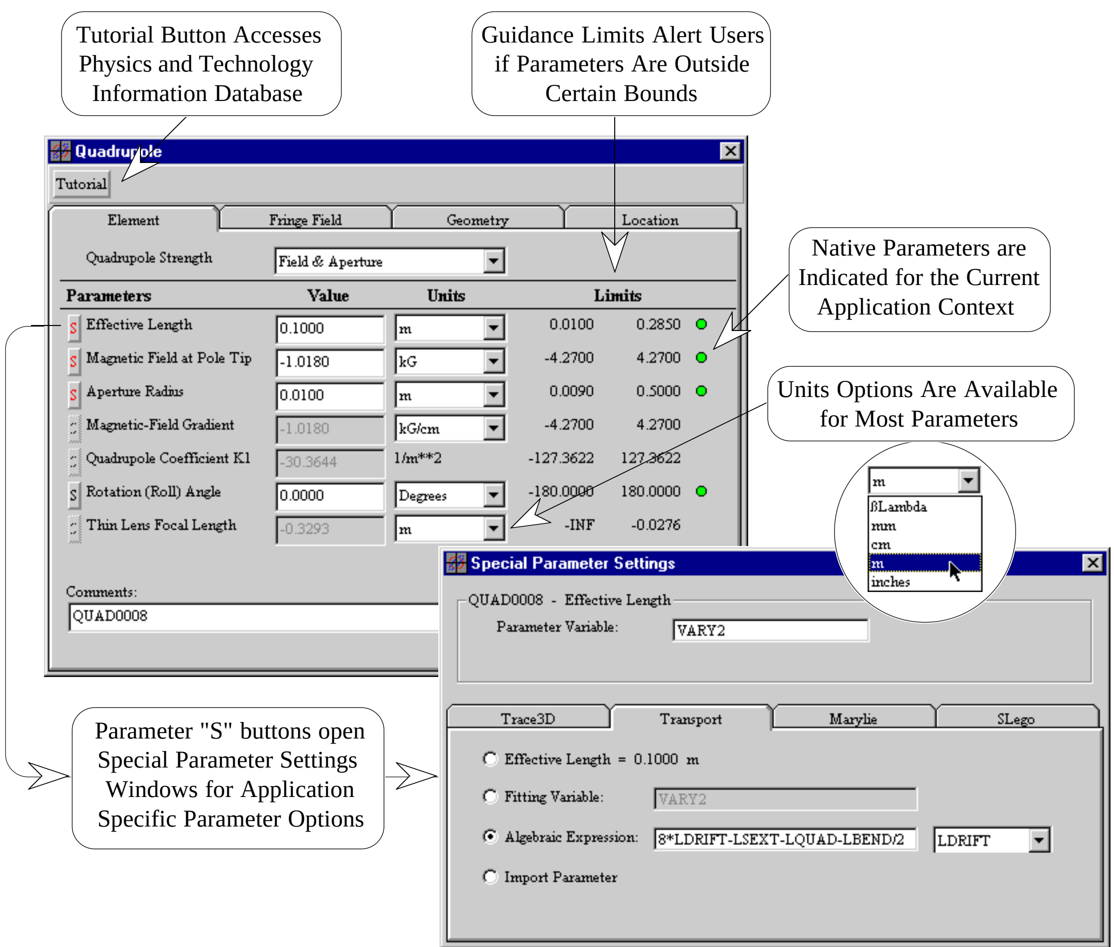


Figure 5. PBO Lab Piece Window and Special Parameter Settings Window.

Some Piece Windows have their input parameters grouped in tab panels, such as those of the Quadrupole Piece shown in Figure 6, which includes tab panels for Fringe Field, Geometry and Location Parameters. Many pieces provide a variety of parameter sets that may be used to define the element. For example, a quadrupole may be minimally defined by length and quad coefficient value; or by length, aperture and pole tip magnetic field; or by length and magnetic field gradient.

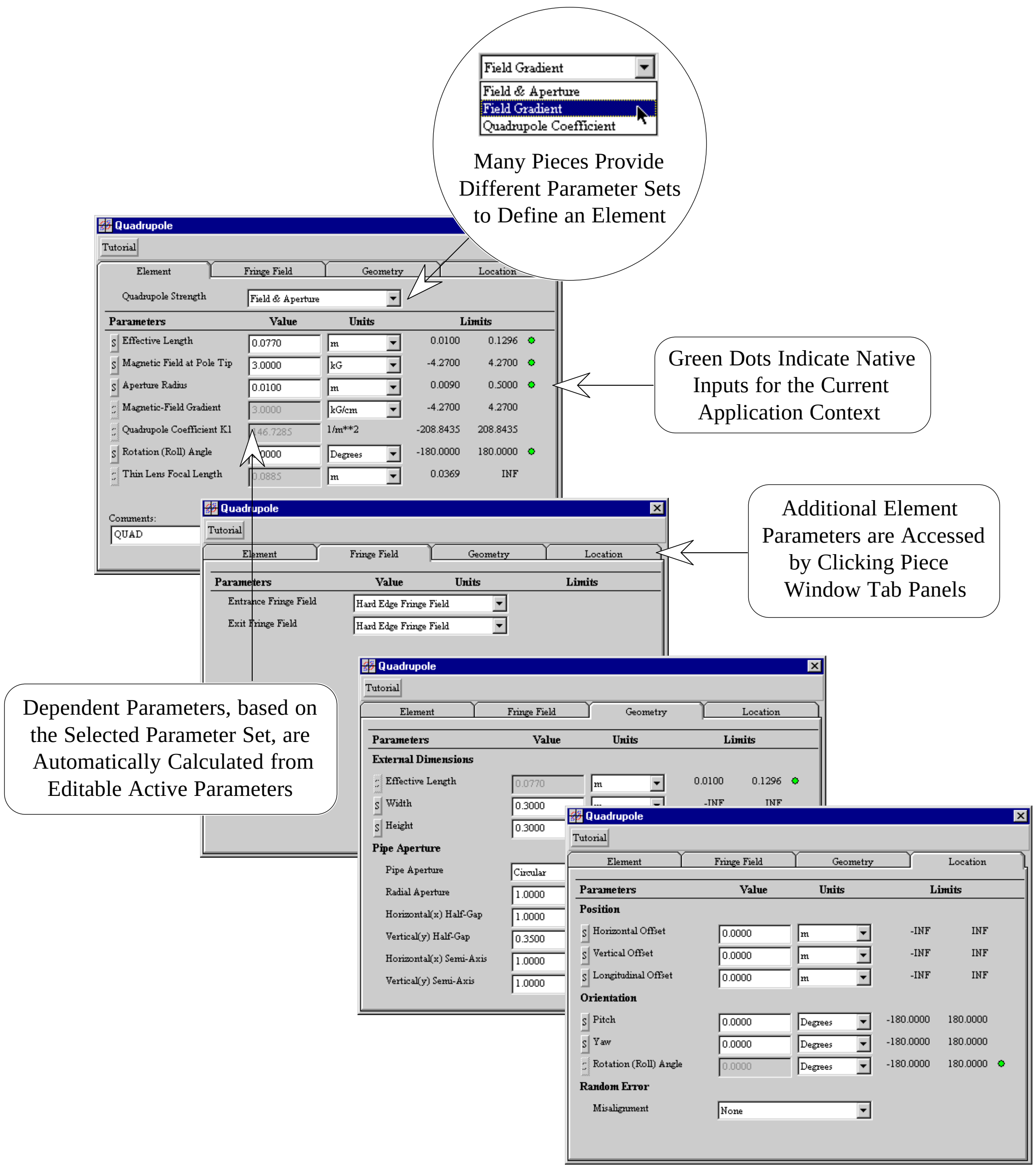


Figure 6. Parameter Sets and Tab Panels for the Quadrupole Piece Window.

Many pieces provide multiple parameter sets that may be used to define the element.

Automatic calculations are made between the different parameters sets, allowing the user to select the parameters to specify an element independent of the native inputs used by specific applications. In Figure 6, the Quadrupole Strength selection switches between the different parameter sets available for the Quadrupole Piece. Dependent parameters are automatically calculated by PBO Lab and are not editable. Which parameters are dependent is based on the parameter set selection.

A green dot next to a parameter indicates a native input for the current Application Context.

The user interface indicates which parameters are used as native inputs for the current Application Context. Green dots to the right of parameters in the Piece Windows indicate the native inputs for the current selection in the Application Context pop-up of the Document Window.

Different units options are provided for most Piece Parameters. The units selections are independent of the specific units required by the different applications.

A variety of different units options may be selected for each parameter independent of the native units required by the different computational codes. Several unit pop-ups include "smart units", which scale dynamically with certain Global Parameters. For example, all parameters that have the dimensions of length include "β-Lambda" as a units option. The value of the β, the relativistic velocity parameter of the particle, is determined by the Global Parameter values for the *Particle Energy* and *Mass*, while the value of λ is set by the *Radio Frequency* Global Parameter.

Guidance limits are provided for each Piece Parameter. However, any value for a parameter may be used. The guidance limits are "soft" and are only used to alert the user if the set of input parameters may have impractical consequences.

Expert system-type rules provide guidance for editing input parameters and additional displays, such as effective focal lengths and phase space plots, which provide useful feedback to the user. The guidance limits are "soft" and are not used to restrict the input; any parameter value may be entered. The limits are intended to provide the user with estimates of a practical range for each parameter.

All parameters in PBO Lab have defaults built in. Once a beamline has been constructed graphically, with or without any parameter editing, a beamline model is completely defined.

The *Getting Started* Chapter of the User Manual is only intended to provide the user with a brief overview of the PBO Lab environment. The remainder of the User Manual provides more information on the material presented here, as well as other important subjects on the use of the PBO Lab. All users are encouraged to read the entire User Manual. Application-specific aspects of the user interface are described separately in individual Application Module Supplements to the PBO Lab User Manual.

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PBO Lab™ 2.0

User Interface

Particle Beam Optics Laboratory

This Chapter provides a description of the PBO Lab user interface and defines the terms that are used to refer to different parts of the interface. Familiarity with the preceding *Getting Started* Chapter is assumed.

The Document Window

The PBO Lab Document Window is the main user interface for building a beamline model and performing analysis tasks with that model. Figure 7 diagrams the primary parts of the PBO Lab Document Window that are described in this Chapter.

Document Windows are the primary PBO Lab interface for a beamline model.

An unlimited number of Document Windows may be open at any one time, with different beamline models in each window. Beamline elements or groups of elements may be exchanged between Document Windows using the *Copy* and *Paste* commands.

An unlimited number of Document Windows may be open at any one time.

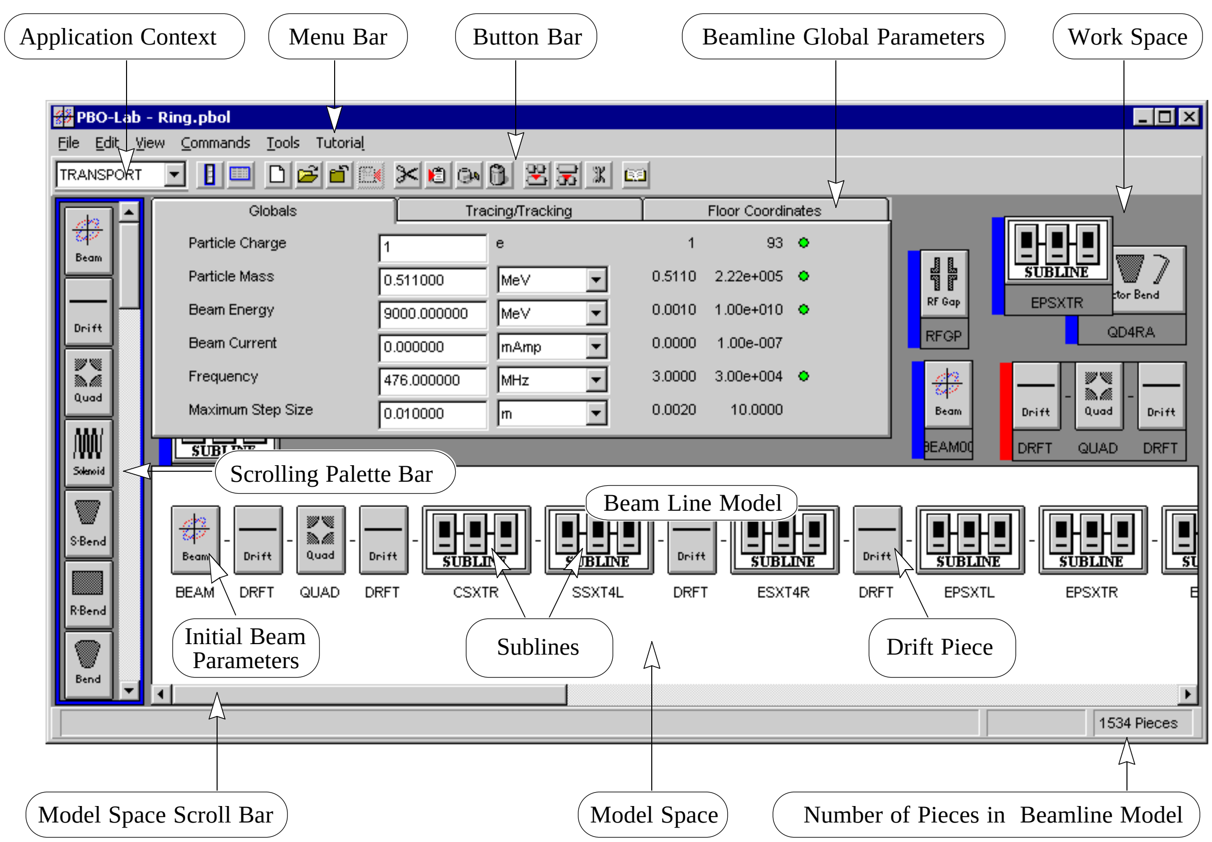


Figure 7. Primary Parts of the PBO Lab Document Window.

A beamline to be modeled is built on the Model Space of a Document Window.

Pieces are selected from the Palette Bar and dropped onto the Model Space.

The commands to Hide or Show the Palette Bar and to Hide or Show the Global Parameters can be used to increase the size of the Model Space and Work Space in the Document Window.

The Document Window is divided into two main areas, the Model Space and the Work Space. A beamline model is constructed by dragging elements from the Palette Bar to the Model Space. The Work Space provides an area to store elements and beamline segments that are not treated as components in the beamline model. Input parameters for individual elements in the beamline are accessed by double-clicking the Piece icons in the Model Space. Beamline Global Parameters, which apply to the entire beamline model, are displayed over the Work Space and can be toggled on and off from the View menu or the Button Bar. The Palette Bar on the left edge of the Document Window can also be hidden in order to maximize the Work Space and Model Space areas in the Document Window, as illustrated in Figure 8 below.

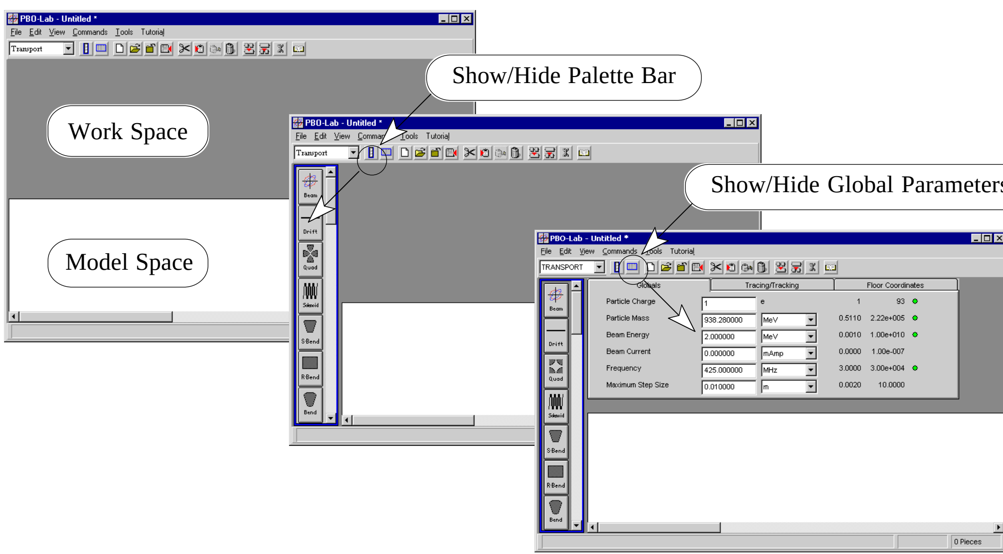


Figure 8. Document Work Space and Model Space.

A variety of computer platforms are supported by PBO Lab. Although there are some minor differences, the user interface as described here is consistent for all platforms.

The following Sections describe the primary components of the PBO Lab Document Window, including the Model Space and Work Space, the Menu Bar, Button Bar, Palette Bar, and Global Parameters. The user interface for element input parameters and beamline construction features are also described here.

The Menu Bar

The PBO Lab interface has six pull-down menus in the Menu Bar. Figure 9 below illustrates the first three pull-down menus: File, Edit and View. These are discussed below. The Commands, Tools, and Tutorial menus are described separately. The content for some of the menus is dependent on which of the available Application and Tool Modules are currently installed in PBO Lab.

On the Mac OS, the Menu Bar is not in the Document Window. It is at the top of the screen, which is the standard for that platform.

The Application Module sub-menus only appear for installed Modules, so your menus may look different from those shown in Figure 9.

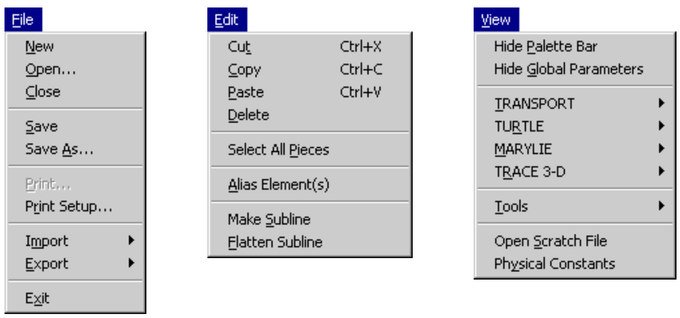


Figure 9. PBO Lab File, Edit and View Menus.

File Menu

The first menu is the File Menu. The *New* command opens a new untitled PBO Lab Document Window. The *Open* command is used to open a previously saved model. Both the *New* and *Open* commands will create and activate a new PBO Lab Document Window. The *Close* command is used to close the active Document Window. The *Save* and *Save As* commands are for saving the current model in the active Document Window. The *Print Setup* command opens the standard printer setup dialog. The *Import* and *Export* commands have sub-menus for installed Application Modules. Applications that support the *Import* command will allow PBO Lab to construct a beamline model from native Input files. The *Export* command can be used to write native Input files. The last command in the File Menu is *Exit*, which closes all windows and quits PBO Lab. PBO Lab will prompt you to save open Documents before quitting. The File commands follow the standards for each of the platforms supported by PBO Lab for tasks such as opening dialogs to load model files, etc. Users unfamiliar with the standard file dialogs should consult their operating system documentation for additional information.

There are buttons in the Document Window Button Bar for the standard File menu commands.

Create a New PBO Lab Document

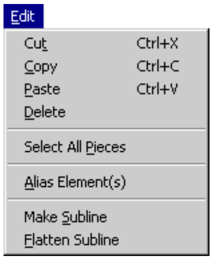
Open an Existing Document File

Close the Current Document Window

Save the Current PBO Lab Document

Export and Import Menu commands allow the user to read and write native input.

Edit Menu

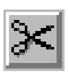


Edit Menu.

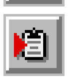
Edit menu commands can be used to copy and paste beamline pieces within, and between, Document windows.

The second menu in the Document Window is the Edit Menu, which has eight commands organized into four groups. The first group contains standard *Cut*/*Copy*/*Paste* and *Delete* commands for beamline components. The next three groups contain commands that are used to manipulate the beamline model and are described in the *Beamline Construction* Section of this Chapter.

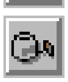
There are buttons in the Document window Button Bar for the standard Edit menu commands. These commands operate on a selection of piece(s) in the beamline model.



Cut Selection to the Clipboard



Copy Selection to the Clipboard



Paste Clipboard on Work Space

Delete Model Selection

The *Cut* command deletes (cuts) any selected pieces from the beamline model and copies them to the clipboard for future pasting to the current Document or to another Document Window. The *Copy* command is used to copy selected pieces to the clipboard for future pasting without deleting the selection. The *Paste* command places the contents of the clipboard (if valid PBO Lab model data) on the Work Space of the active Document Window. The *Delete* command deletes any selected pieces from the Document Window but does not copy them to the clipboard. Deleted selections are permanently disposed. There are also buttons in the Document Window Button Bar that perform equivalent operations.

Use the right mouse button after a selection is made in a numerical edit field in order to cut, copy or paste numerical data.

Numerical parameter values can be cut, copied and pasted by pressing the right mouse button after a selection is made in the edit field of the parameter. A contextual menu will appear to the right of the edit field for the selection that provides *Cut*, *Copy* and *Paste* commands. The number will be stored on the clipboard when using cut or copy, replacing any existing clip. The numerical clip can be pasted into another numeric edit field or a text window. Figure 18 in the *Piece Windows* Section illustrates an example of cut, copy and paste commands for parameter data.

Use the Select All Pieces command to quickly select the entire beamline model in the Document Window Model Space. Note that Allias Pieces can not be copied between Document Windows, except when using the Multiple Model mode (see PBO Lab User Preferences).

The remaining commands in the Edit Menu are used to manipulate the beamline model. The *Select All Pieces* command does exactly that: the entire beamline model is selected in the Document Window Model Space. This can be used with the *Copy* and *Paste* commands to store a temporary copy of the beamline on the Work Space or to copy the beamline to another Document Window.

The last three commands in the Edit Menu, *Alias Elements*, *Make Subline* and *Flatten Subline*, are beamline editing features for configuring the beamline representation. The *Alias Elements* command is used to create an Alias to the current selection in the beamline model. The *Make Subline* and *Flatten Subline* commands are used to collapse and expand a selection of elements in the beamline. These commands do nothing if a selection has not been made in the beamline model. These beamline editing commands are described in the *Beam Line Construction* Section.

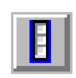
An Alias is a component with a persistent link to another component in the beamline model.

Subline commands in the Edit Menu can be used to group a selection of elements into a single Subline component in the beamline or to flatten a Subline into individual elements.

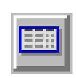
View Menu

The third menu is the View Menu. The first command is *Hide/Show Palette*, which allows the user to hide (or show) the Palette Bar on the left edge of the Document Window. The second command is *Hide/Show Global Parameters*, which lets the user hide (or show) the beamline Global Parameters in the Document Window.

View Menu.



Hide or Show the Palette Bar



Hide or Show the Global Parameters

The Button Bar can also be used to hide/show the Palette Bar and the Global Parameters.

The next group of commands in the View Menu contains application-specific sub-menus for any installed PBO Lab Application Modules, such as the Application Module sub-menus shown in Figure 10. These sub-menus provide quick access for viewing various native text files used by, or created by, the different Application Modules that are described in the individual Application Module Supplements to the PBO Lab User Manual.

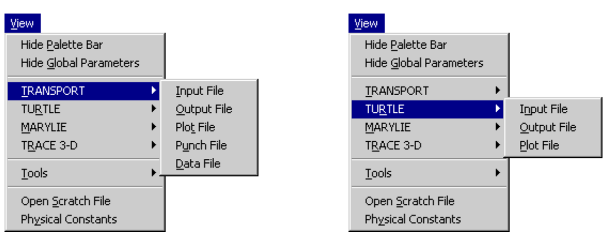


Figure 10. View Sub-Menus for the TRANSPORT and TURTLE Application Modules.

Figure 10 illustrates the View Menu for PBO Lab with the TRANSPORT and TURTLE Application Modules installed. When additional Application Modules are installed, the View Menu will include sub-menus for those modules as well.

The next item in the View Menu is the *Tools* sub-menu, which contains two commands for opening data files generated by the PBO Lab Focusing Module. Refer to the *Analysis Tools* Chapter for a description of these files. The last two commands in the View Menu, *Open Scratch File* and *Physical Constants* are not application-specific. The *Open Scratch File* command is used to provide quick access to a scratch text file that may be used for storing any text data. The *Physical Constants* command opens a window containing a variety of physical constants used by PBO Lab and the different Application Modules. This window also includes a convenient list of common particle masses that may be copied and pasted into the Global Parameters *Particle Mass* field. Figure 11 illustrates the Physical Constants Window. The numerical values for these constants can not be changed in this window. However, the value fields are active (editable) to allow these values to be copied to the system clipboard.

The Open Scratch File command is used to provide quick access to a scratch text file that may be used for storing any text data.

The Physical Constants command opens a window containing a variety of physical constants used by PBO Lab and the different Application Modules.

Numerical values can be copied from the Physical Constants Window using the right mouse button to bring up a contextual menu for a selected value.

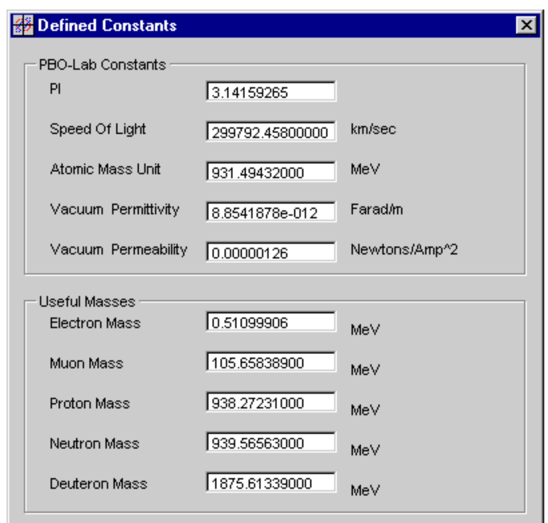


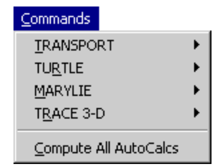
Figure 11. Physical Constants Window.

Commands Menu

The fourth menu is the Commands Menu. The content of this menu depends on which PBO Lab Application Modules are currently installed. Any installed Modules will include an application-specific sub-menu in the Commands Menu. Individual commands for each of the Modules are described in the respective Application Module Supplements to the PBO Lab User Manual.

The last item in the Commands Menu is the *Compute All Auto Calcs* command, which is application-independent. This command will update all dependent beamline parameters in Piece Windows that have alternative parameter sets available. Refer to the *Piece Window* Section later in this Chapter.

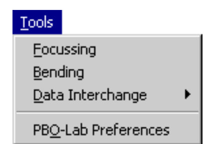
The Commands, Tools and Tutorial Menus are unique to PBO Lab and are discussed separately in this User Manual.



Commands Menu.

Tools Menu

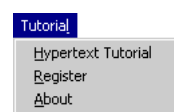
The fifth menu is the Tools Menu. The *Focusing* and *Bending* commands in this menu access interactive tool windows for single particle trajectories and beam envelopes. These Tools are described in Chapter 4: *Analysis Tools*. The next item in the Tools Menu is the *Data Interchange* submenu. This is described separately in the *External Data Interface* Section of Chapter 4 . The last item in the Tools Menu is for *PBO Lab Preferences*, which are described in the *Preferences* Section of Chapter 4.



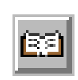
Tools Menu.

Tutorial Menu

The last menu discussed in this Chapter is the Tutorial Menu. This menu has three items. The first is the *Hypertext Tutorial* command. This command opens the main PBO Lab Tutorial Window, which contains a hypertext table of contents for the tutorial help files available in PBO Lab. The interactive tutorials and help features that are integrated with the PBO Lab application are described in Chapter 5. The second item in the Tutorial Menu is the *Register* command, which opens the Registration Window. Refer to the *Registration* Section in the *Getting Started* Chapter for a description of PBO Lab registration. The third item in the Tutorial Menu is the *About* command, which brings up a window displaying PBO Lab credits and version number.



Tutorial Menu.



Launch HyperText Tutorials

Tutorial buttons in Piece Windows provide access to specific interactive physics tutorials for those pieces.

The Button Bar

The Button Bar provides quick access to a variety of File, Edit and View menu commands.

The Document Window Button Bar provides quick access to a variety of File, Edit and View Menu commands. Controls in the Button Bar are separated into four groups: Document Window Operations, File Operations, Model Editing Operations and Model Topology Operations. The last button launches the Hypertext Tutorials. Figure 12 illustrates the different operational groups and the function of each button.

The Application Context is used to display and access application-specific inputs for each of the installed Application Modules.

The first control in the Button Bar specifies the Application Context, which is used to provide feedback on the native inputs for a particular application and to determine which user interface windows will be opened for application-specific inputs and options. The applications listed in the application context pop-up depend on which Application Modules are installed in your version of PBO Lab. Refer to the PBO Lab *Application Modules* Section in the *Getting Started* Chapter.

The remainder of the Button Bar controls duplicate various File, Edit and View Menu commands. Refer to the preceding *Menu Bar* Section for descriptions of the different functions listed in Figure 12 below.

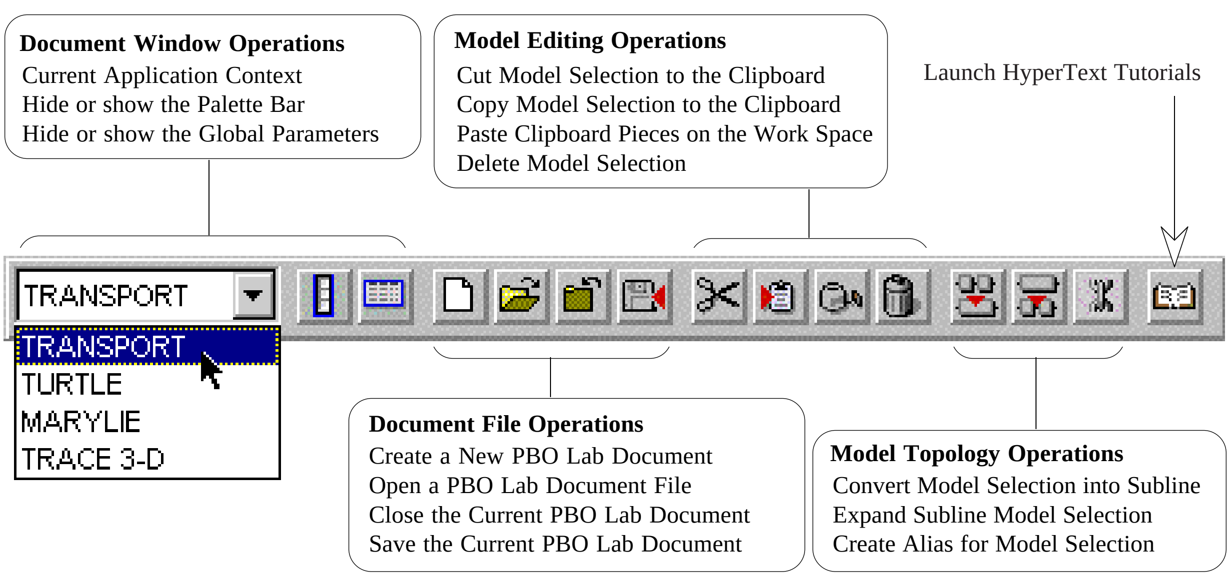


Figure 12. Document Window Button Bar.

The Palette Bar

The Palette Bar (on the left side of the Document Window) contains Piece icons for each of the beamline elements available in PBO Lab. Pieces are selected from the palette and dragged to the Model Space of the Document Window to "build" an accelerator beamline. The Palette Bar can be toggled on and off from the View Menu or from the Document Window Button Bar. The Palette Bar expands with the height of the Document Window. Pieces that are not visible are accessed by scrolling the Palette Bar.

The scrolling Palette Bar contains Piece icons for all of the beamline elements available in PBO Lab.

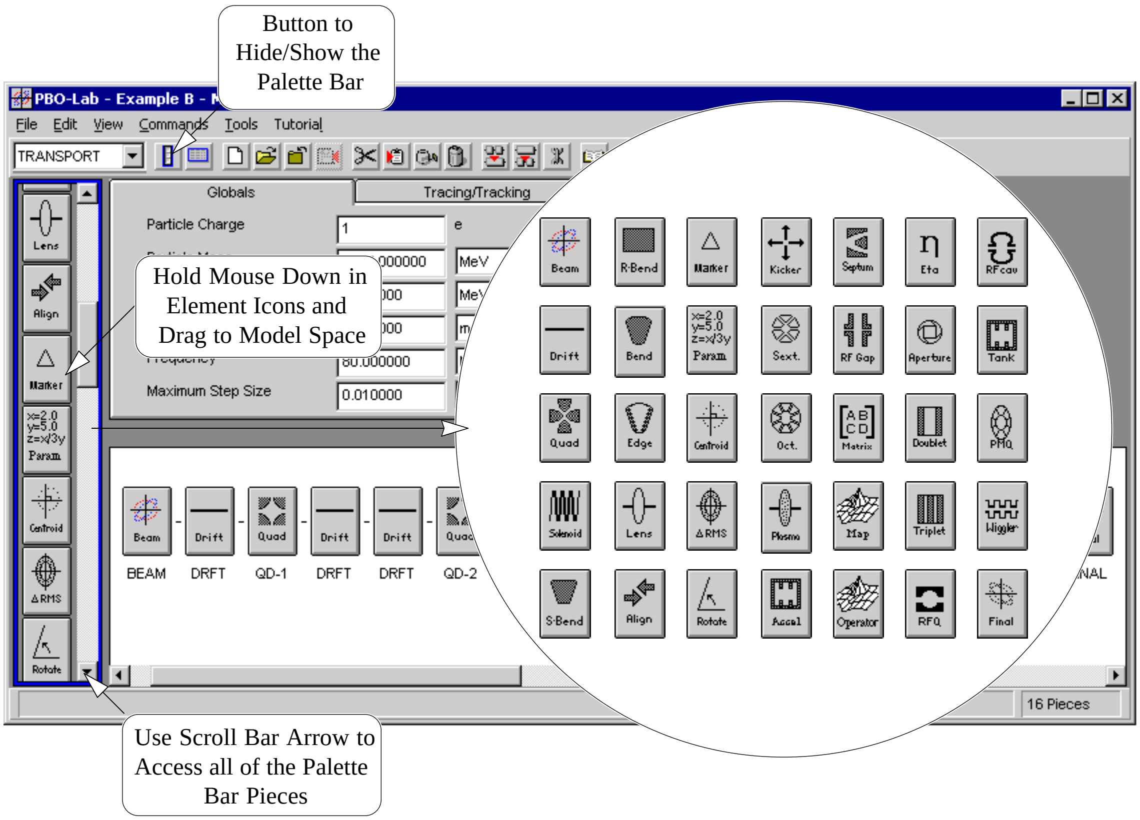


Figure 13. Scrolling Palette Bar of Beam Line Elements.

Figure 13 illustrates a variety of different elements available in PBO Lab. Some Pieces are specific to particular Application Modules. The total number of Pieces in the Palette Bar depends on the installed Application Modules. PBO Lab will only use supported elements when generating native inputs for a specific Application Module.

Some Pieces in the PBO Lab Palette Bar are specific to particular Application Modules. Refer to the individual Application Module Supplements.

Beamline Global Parameters

Toggle the display of the Global Parameters in the Document Window from the View Menu . The Button Bar also provides an equivalent control to Hide or Show the Global Parameters.

The Beamline Global Parameters are the top level user inputs for a beamline model in a PBO Lab Document Window. They include specifications for the *Particle Charge*, *Particle Mass*, *Beam Energy*, *Beam Current* and *Frequency*, among others. The Global Parameters are editable in three tab panels that float over the Work Space area in the Document Window. Figure 14 illustrates all of the inputs that are available in the three Global Parameter tab panels: *Globals*, *Tracing/Tracking* and *Floor Coordinates*.

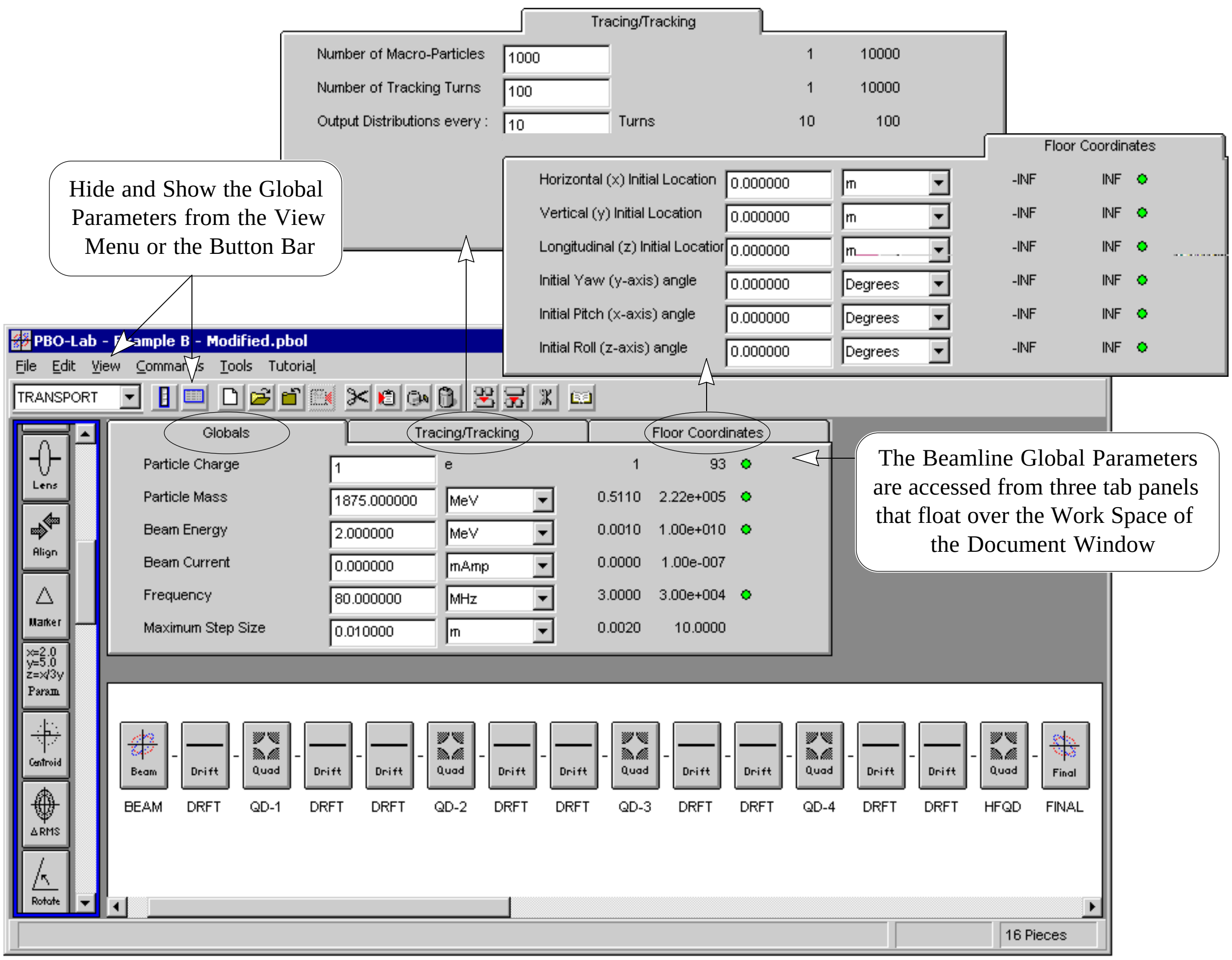


Figure 14. Beamline Global Parameters in the Document Window.

Global Parameters that are native inputs for the different Application Modules are indicated with green dots to the right of those parameters. Green dots are based on the current Application Context.

Some Global Parameters are used by PBO Lab to calculate dependent parameters, guidance limits and provide numerical feedback for interactive Tutorial windows. Table1 lists the PBO Lab Global Parameters and indicates the different uses for these parameters by the different Application Modules and by the PBO Lab user interface, Tutorials and/or Tools.

Table 1. PBO Lab Beamline Global Parameters.

Beamline Global Parameters	**PBOL**	**TRANSPORT**	**TURTLE**	**TRACE3D**	**MARYLIE**
Particle Charge	•	•	•	•	•
Particle Mass	•	•	•	•	•
Beam Energy	•	•	•	•	•
Beam Current	•			•	
Frequency	•	•	•	•	•
Maximum Step Size	•			•	
Tracing/Tracking Parameters					
Number of Macro Particles			•		•
Number of Tracking Turns					•
Output Distributions					•
Floor Coordinate Parameters					
Horizontal (x) Initial Location		•			
Vertical (y) Initial Location		•			
Longitudinal (z) Initial Location		•			
Initial Yaw (y-axis) Angle		•			
Initial Pitch (x-axis) Angle		•			
Initial Roll (z-axis) Angle		•			

The Maximum Step Size Global Parameter is used by PBO Lab in the Focusing and Bending Modules to define the number of calculation steps used for the ray trace and envelope calculations.

The *Tracking/Tracing* tab panel has parameters that are used by the TURTLE and MARYLIE Application Modules. These parameters are described in each of the

Application Module Supplements for those applications. Also included with the Global Parameters are a set of initial floor coordinate parameters accessed from the *Floor Coordinates* tab panel. These parameters are used exclusively by the TRANSPORT Application Module to specify the initial coordinates and the orientation of the reference trajectory. Refer to the PBO Lab TRANSPORT Application Module Supplement for a description of these parameters.

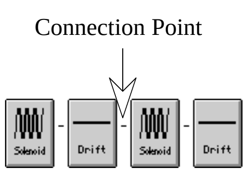
The Floor Coordinates parameters are used exclusively by the TRANSPORT Application Module. Refer to the Application Module Supplement for a description of these parameters.

The Model Space

The Model Space of the Document Window is where the accelerator elements are placed to construct a beamline model. Pieces are "dragged" to the Model Space from the Palette Bar or the Work Space (discussed below). Pieces from the Palette Bar may be placed on either the Model Space or the Work Space. The first piece that is "dragged" to the Model Space may be placed anywhere. Once the first piece is placed, the following pieces "snap" on to the end closest to where the piece was "let go" when the mouse button was released.

The Getting Started Section describes the Model Space and Work Space in the PBO Lab the Document window.

Pieces may also be inserted between pieces in the beamline by droping them at connection points in the beamline model. Connection points are represented by lines between elements in the beamline on the Model Space Pane. To insert a piece, drag a selection over a connection point and release the mouse button. The connection point will be bold while the mouse is correctly located on it. Releasing the mouse button inserts the selection in the beamline model at that point. Note that there can never be "loose" pieces in the Model Space. All pieces are either inserted at connection points or snapped to an end of the beamline model.

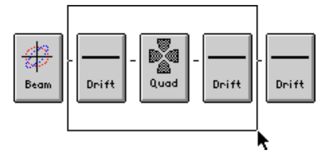


Pieces may be inserted into the beamline at connection points between pieces on the Model Space.

The scroll bar for the Model Space controls the positioning of the model with respect to the window, and can be adjusted by the user. The Model Space is large and can accommodate a large number of accelerator elements. The beamline assembled on the Model Space constitutes the model whose data will be used in running the different Application Modules.

Organizing the beamline model using Sublines provides room for more pieces in the Model Space of the Document Window.

A selection of multiple pieces is made by using the mouse to enclose the desired selection with a drag box. Hold down the mouse button while dragging a box around the desired selection. Release the mouse button and the pieces within the box will be selected. The Model Space will scroll automatically while dragging a box that exceeds the currently visible beamline elements. To select the entire beamline model, use the *Select All Pieces* command in the Edit Menu.



Drag a box around pieces with the mouse to make a selection of multiple pieces.

A single piece or group of pieces may be selected and copied, cut or deleted using the appropriate commands from the Edit Menu. These actions are very similar to the standard Copy, Cut and Delete actions of many other applications. The keyboard equivalents of the Edit Menu commands are the standards for your particular platform. The Delete action removes the selected pieces from the beamline model. All information associated with these pieces is permanently disposed.

Pieces in the Model Space may be cut, copied, and deleted using either the Edit Menu commands, the keyboard equivalents or the Button Bar controls.

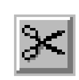
Alias Pieces can not be cut or copied to another Document Window.

Delete Model Selection

The Copy action makes a copy of the selected pieces and associated information (parameter settings) and stores that data on the clipboard. The pieces may later be pasted onto any Document Window. The original pieces and the data associated with them are unaffected in the source Document Window. The Cut action is similar to the Copy action, except that the original pieces and associated data are deleted from the Document Window. Cut makes a copy of the pieces and associated information and stores it on the clipboard. The pieces may then be pasted on to any Document Window. The Paste action will place the contents of the clipboard (if it is valid piece data from a previous cut or copy) on the Work Space of the current Document Window. The piece(s) will appear in the lower left corner of the Work Space. (The Work Space is discussed in the following Section.)

Beamline information for copied or cut pieces is retained on the clipboard as a PBO Lab subline description.

Copy Model Selection
to the Clipboard



Cut Model Selection
to the Clipboard

Paste Clipboard Pieces
on the Work Space

A single piece or a selection of pieces may be dragged from the Model Space to the Work Space. This action automatically creates copies of the piece(s). The original pieces and the data associated with them are unaffected and remain on the Model Space. To move a piece or group of

Pieces may be moved within the beamline by holding down the shift key while dragging the selection to a new location in the beamline.

pieces from one position in the beamline to another position, hold down the shift key while dragging the selection to a new location in the beamline model. The arrow will change to a small piece icon with the word “move”. When the mouse button is released over a connection point in the beamline, the selection will be deleted from its original location and inserted in the new location. Pieces can also be moved between the Work Space and Model Space using the shift key.

Dragging piece selections between the Model Space and the Work Space automatically generates a copy of the selection.

The Work Space

The Work Space is the shaded area of the Document Window. Additional Work Space may be accessed by “hiding” the Global Parameters and the Palette Bar as shown in Figure 8 and in Figure 15 below. This may be done from the Button Bar or from the View Menu.

The Work Space can be used to store Pieces, Sublines and selections of Pieces and Sublines as illustrated in Figure 15. Beamline fragments on the Work Space are saved with the Document but are not considered part of the beamline model.

The Work Space is most helpful when used in conjunction with the Model Space.

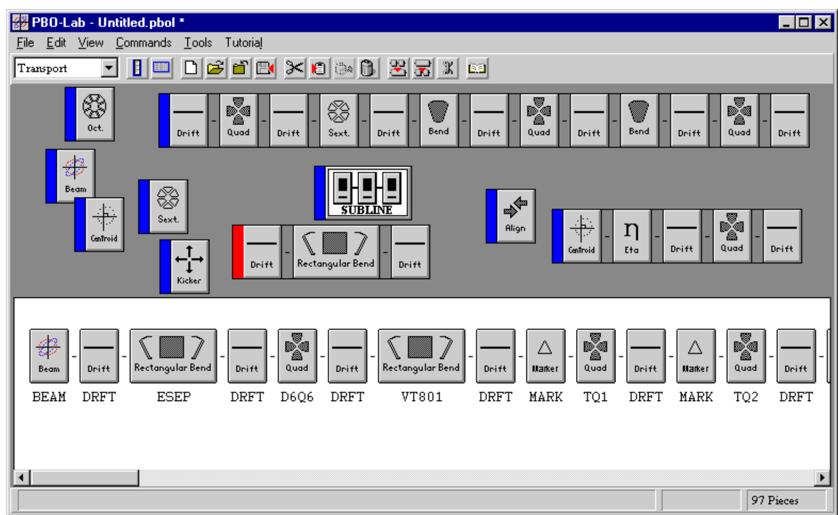
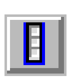
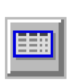


Figure 15. “Hiding” the Global Parameters and the Palette Bar in the Document Window.



Hide or Show the Palette Bar in the Document Window



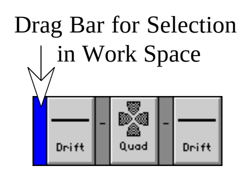
Hide or Show the Beam Line Global Parameters

Pieces may be placed on the Work Space either by dragging them from the Palette Bar or the Model Space. When a piece or a group of pieces is dragged from the Model Space to the Work Space, it can be placed anywhere on the Work Space. Pieces are not grouped on the Work Space unless they were grouped prior to being placed on the Work Space. No pieces are inserted into a model structure when placed on the Work Space. A group of pieces placed on the Work Space will remain in their original configuration and cannot be separated on the Work Space. (Of course, they can be dragged to the Model Space, a subset selected, and then that subset placed on the Work Space.) A piece or a group of pieces may also be copied, cut or deleted from the Work Space with the same result as in the case of the Model Space. Any existing data on the clipboard will be erased when either copy or cut is executed.

If a piece or group of pieces have been previously copied or cut from either the Work Space or the Model Space, they may be placed on the Work Space by pasting them from the clipboard. The Paste action is similar to that of other applications. Once pieces have been pasted to the Work Space, they may then be dragged to the beamline in the Model Space.

When a Paste command is executed, the existing set of Pieces currently on the clipboard will appear on the Work Space. They may then be dragged to the beamline in the Model Space.

There may be many individual “loose” pieces or groups of pieces on the Work Space as shown in Figure 15. These may be moved around and located on the Work Space as desired. Selections on the Work Space are dragged by clicking on the drag bar and holding the mouse button down while dragging the selection. Selections in the Work Space have a Red Drag Bar; unselected items have a Blue Drag Bar. These Work Space pieces are not part of the beamline model and these Pieces are not used when an Application Module command is executed. Only the pieces on the Model Space of a Document Window are used to define the beamline model input. However, Global Parameters associated with the model are utilized for Work Space pieces, for example, in displaying “smart units” for the input parameters of these pieces. The Work Space pieces are retained when a model is saved using the *Save* or *Save As* commands from the File Menu (Figure 9) or the Button Bar (Figure 12).



Selections made on the Work Space can be moved while holding the mouse button down on the drag bar of the selection.

Pieces stored on the Work Space are persistent until deleted by the user. The contents of the Work Space is retained in the model file when a Save, or Save As, command is executed.

The Work Space can be used for several purposes; for example, to store a repeated set of pieces that will be used several times in a beamline. The parameters of pieces on the Work Space may be set independently of the beamline pieces on the Model Space and are not affected by changes to the beamline model, with the exception of Alias pieces.

Refer to the Alias Piece Section later in this Chapter.

Piece Windows

Input parameters for beamline elements are accessed in PBO Lab Piece Windows. Figure 16 illustrates double-clicking a Quadrupole Piece icon in the beamline model to open a Quad Piece Window. Piece Windows can be opened for pieces in the Model Space and Work Space as well as Subline Windows or Focusing and Bending Module Windows.

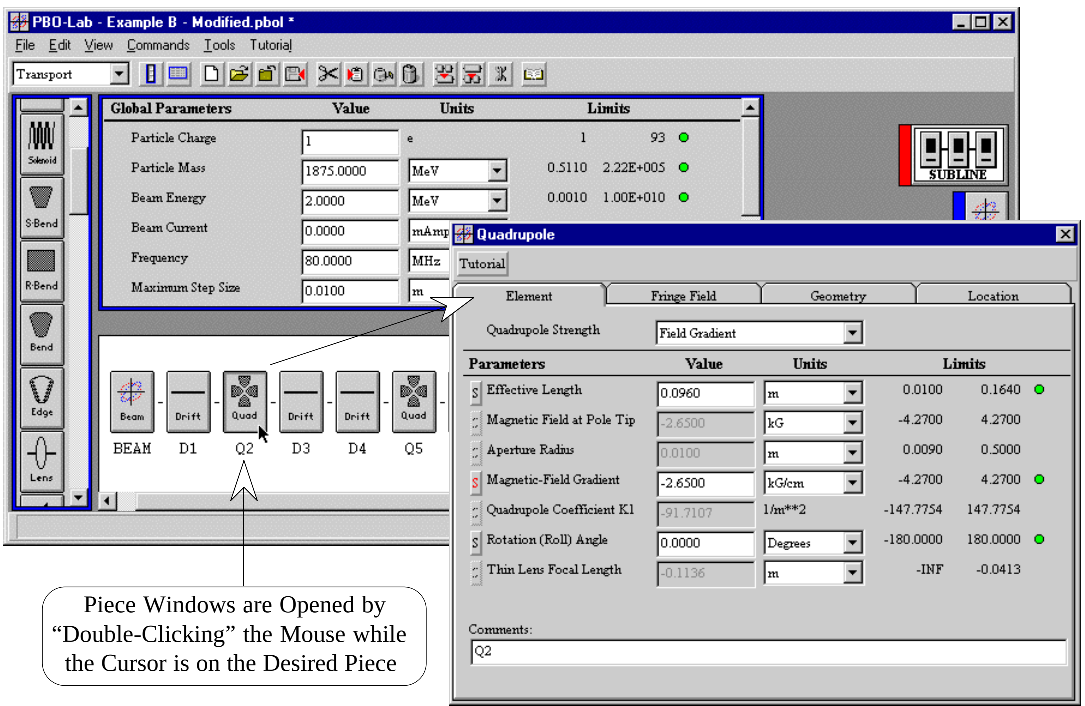


Figure 16. Opening the Piece Window for a Quadrupole Element.

Each Piece Window contains a Title Bar with Close Box, a Button Bar and one or more parameter data records. Some Piece Windows have tab panels that provide access to additional parameters, such as the Quadrupole Piece Window shown in Figure 16. Each parameter data record includes four fields of data: (1) a word description of the Parameter, (2) a Value field for entering numerical data or a pop-up selection menu, (3) a Units field that provides options through pop-up menus and (4) Limits fields, which provide input guidance using a set of knowledge-based rules.

Many parameters also have a Special "S" button that is used to open a Special Parameter Settings Window for specifying application-specific options, such as selecting a parameter as a fitting or import variable or defining an algebraic expression for the parameter. An example of a Special Parameter Settings Window is shown in Figure 17. The "S-Windows" have Application tab panels that provide access to application-specific options for installed Application Modules. These are described in the individual Application Module Supplements to the PBO Lab User Manual.

Most Piece Windows have multiple tab panels that provide additional inputs such as location and geometry parameters.

Figure 17 illustrates several features of the PBO Lab Piece Windows that are described in this Section. Default values are defined for all parameters so that both the topology of the beamline and a complete set of input data are defined automatically when a piece is placed in the beamline model.

Default values are defined for all piece parameters so that a complete set of native input data is defined automatically for any Application Module when a piece is placed in the beamline model.

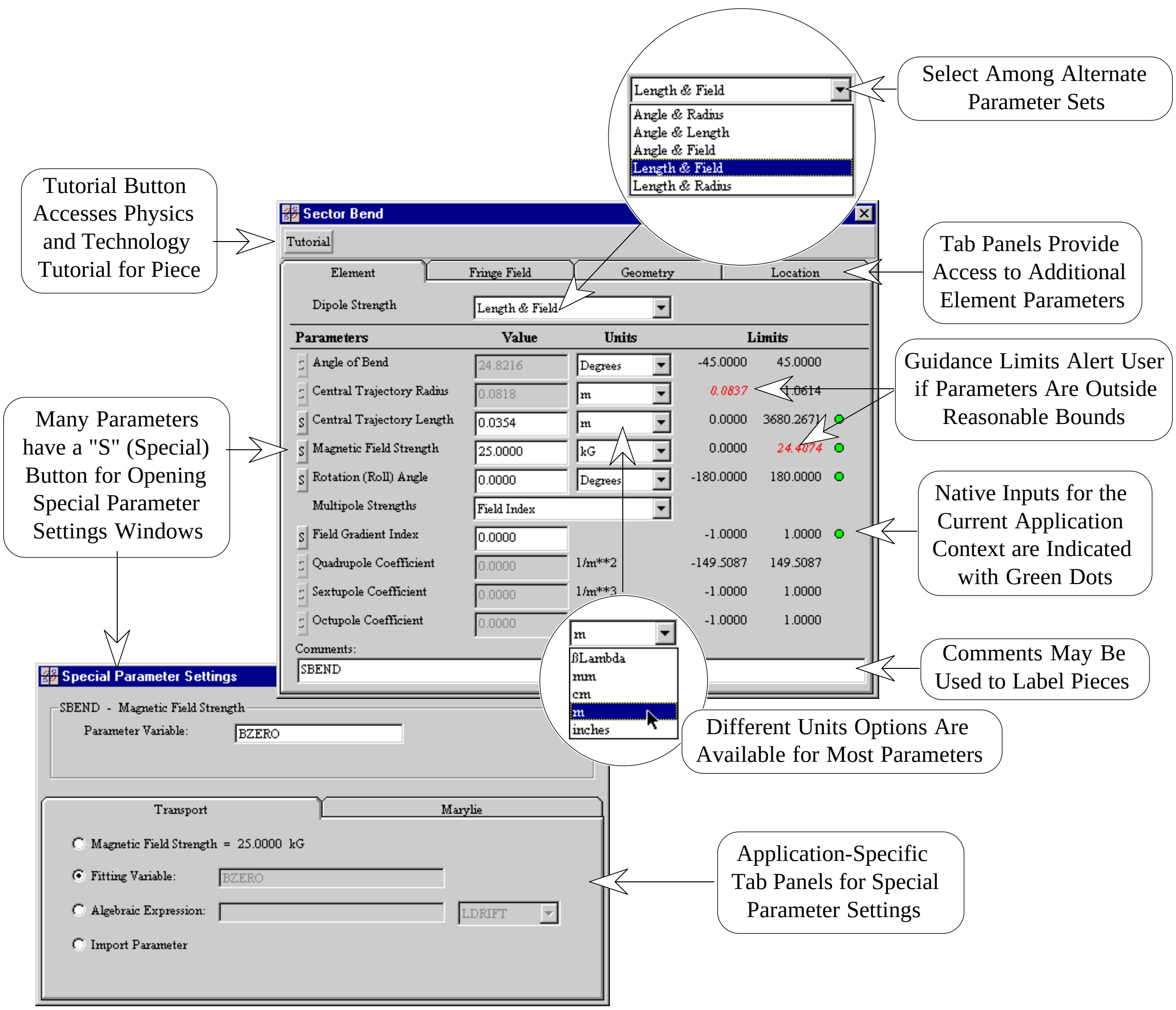


Figure 17. Piece Window for the Sector Bend (SBend) Element.

The Piece Window Button Bar (at the top of the Piece Window) includes a *Tutorial* button for many of the beamline elements, such as the Sector Bend shown in Figure 17. Other application-specific buttons may be found for installed Application Modules. These are described in the individual Application Module Supplements to the PBO Lab User Manual.

Green dots appear to the right of Piece Parameters to indicate the native inputs for the selected Application Context.

The Green Dots to the right of some parameters indicate which parameters will be used as native inputs for the Application Module that is currently selected in the Application Context pop-up. To examine the native parameters for a different application, simply leave the Piece Window open and change the Application Context in the Button Bar of the Document Window. The green dots are for application-specific feedback only. Switching the Application Context has no effect on piece parameters. A parameter is not required to be an active (editable) parameter in order to be used as native input. It may be calculated from related parameters that have been chosen to define a Piece. Alternate Parameter Sets are described later in this Section.

All Piece Parameters have built in defaults. However, to minimally define a Piece for a specific Application Context, review the green dot (native) parameters.

The primary beamline Element parameters are always displayed on the front tab panel in a Piece Window, as shown in Figures 16 and 17 for the Quadrupole and Sector Bend. Additional (secondary) parameters may be included in other tab panels as illustrated for the Quad Piece Window in Figure 6 of the *Getting Started* Chapter. Most Application Modules require only a subset of the primary element parameters (indicated with application-specific green dots). Secondary parameters may be used for a variety of calculations in PBO Lab Tutorials and Tools and for some application-specific inputs.

All Piece Parameters have default values built-in so that an element is defined automatically when it is placed in the beamline model.

All parameters have built-in defaults. A piece is completely defined for all Application Modules when it is placed in the beamline model. PBO Lab will generate the required native inputs in the appropriate format and syntax for installed Application Modules. To minimally define an element for a specific Application Module, select that application in the Application Context pop-up and review the default values for the green dot (native) element parameters.

All of the numerical inputs in a Piece Window are entered in parameter Value fields. When a number is changed in a Value field and the “Enter” key is pressed, the new number is immediately updated and any limits or auto-calculated dependent parameters related to that parameter are also updated. A value will also be updated when the mouse is clicked outside the Value field or if the window is closed. However, using the Enter key is the recommended procedure to update a parameter value in order to examine updated guidance limits and any dependent parameters.

After entering a numerical value, use the “Enter” key to accept that value.

Numerical values may be cut, copied and pasted using the right mouse button to bring up a contextual menu as shown in Figure 18 below.

Copy and paste in Value fields using the right mouse button to bring up a contextual menu.

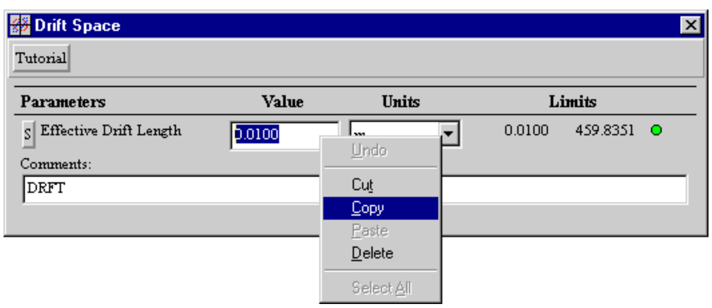


Figure 18. Cut, Copy and Paste of Numeric Values.

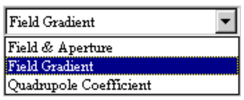
The user may select different units for a parameter by choosing the appropriate option from one of the Units field pop-up menus. Several pop-up menus include “smart units.” These are units that scale dynamically with certain Global Parameters and other parameters from Piece Windows. For example, all parameters that have the dimensions of length include “β-Lambda” as a units option (Figure 17). The value of the β, the relativistic velocity parameter of the particle, is determined by the Global Parameter values for the Particle Energy and Particle Mass, while the value of l is set by the Global Frequency Parameter.

Most parameters provide a variety of units options including dynamic “smart units”.

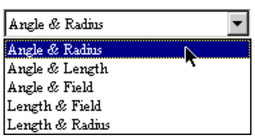
Guidance limits are displayed for each Piece Parameter. However, the guidance limits are “soft”, and any value for an input parameter may be used.

Piece Windows also contain lower and upper guidance “limits” for each parameter. These guidance limits are not used to restrict the input. Any value may be entered for a parameter.

The guidance limits are intended to provide estimates of a practical range for a parameter value based on beamline Global Parameters and possibly other parameters in the Piece Window.



The Quadrupole Strength pop-up is used to toggle between parameter sets in the Quad Piece Window (Figure 16).



The Dipole Strength pop-up used to toggle between different parameter sets in the Sector Bend Piece Window (Figure 17).

Some Piece Windows contain more than one parameter set for specifying a beamline element. Top level pop-ups above the parameter header in Piece Windows are used to activate alternate parameter sets for specifying an element. For example, the Quadrupole Strength in the Quad Piece Window shown in Figure 16 and the Dipole Strength in the Sector Bend shown in Figure 17 both provide alternate parameter sets for these elements. Parameter Value fields are activated (editable) and deactivated (non-editable) based on the parameter set selection. Inactive, dependent parameters are auto-calculated based on active user editable parameters. PBO Lab indicates which parameters will be used for the current Application Context. However, it is possible to specify an element for a particular Application Module using a parameter set that is not supported by that application. PBO Lab will auto-calculate the required inputs for specifying an element in the native format required for each Application Module.

Beam Piece

The beamline model must start with a Beam Piece in order to generate the initial beam for the Focusing and Bending Modules.

PBO Lab uses the Beam Piece to generate the initial beam for the Trajectories Module described in Section 4 PBO Lab Analysis Tools. The Beam Piece can be used to specify the initial beam in two different ways, referred to as the Semi-Axes representation and Courant-Snyder (Twiss) parameter representation. The Semi-Axes representation is more general and allows for the complete specification of the beam sigma matrix, including correlations between different phase planes. The Twiss parameter representation is useful for specifying initial beams in which the phase planes (horizontal, vertical and longitudinal) are decoupled.

Both the Semi-Axes and Courant-Snyder (Twiss) input panes are shown in Figure 19 for the Beam Piece window. There is a Button Bar at the top of the window, two tab panels for parameter inputs (Beam and Centroid Parameters) and a set of dynamic phase space ellipse plots for the beam parameters. The Particle Distribution Type pop-up is used to generate multi-particle distributions for certain Application Modules (e.g. TURTLE, MARYLIE).

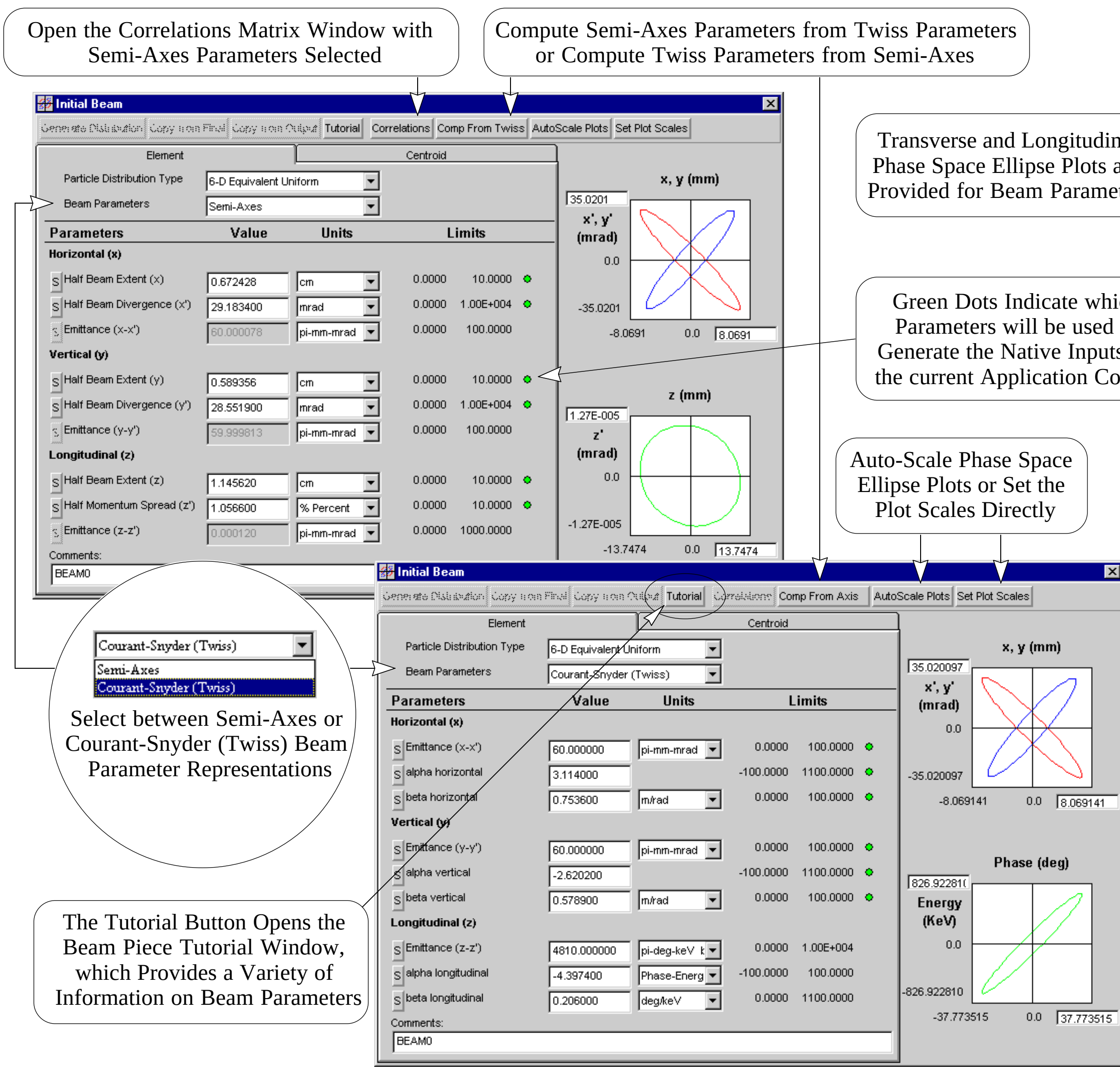


Figure 19 Semi-Axes and Courant-Snyder (Twiss) Beam Piece Parameters.

The Green dots to the right of individual parameters indicate which will be used to generate TRANSPORT input.

When the Twiss Beam Parameters are selected, the Compute From Semi-Axes button will calculate the equivalent Twiss parameters for the current Semi-Axes parameters. When the Semi-Axes parameter set is selected the Compute From Twiss button will calculate the equivalent Semi-Axes parameters for the current Twiss parameters. The Compute From... button is in the Button Bar at the top of the Beam Piece Window.

With the Semi-Axes Beam Parameters representation correlations may also be included in the beam description.

When Semi-Axes Beam Parameters are selected, correlations may be included in the beam description using the Correlations button in the Button Bar of the Beam Piece Window. The Correlations button opens the Correlation Matrix Window shown in Figure 20. Correlations may be entered directly as off-diagonal elements of the sigma-matrix, or by entering values for the reduced sigma matrix.

The Beam Correlations Matrix Window is opened with the Correlations button in the Beam Piece window.

Correlations may be entered directly as off-diagonal elements of the sigma-matrix, or by entering values for the reduced sigma matrix.

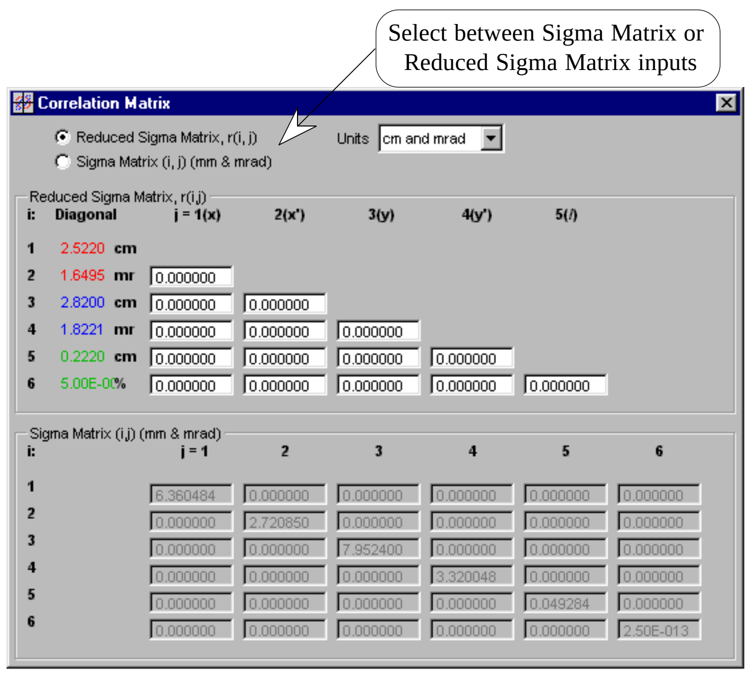


Figure 20 Beam Correlation Matrix Window.

The Beam Piece window includes dynamic phase space ellipse plots for the current beam parameters. The top plot shows the horizontal (red) and vertical (blue) transverse phase space ellipses. The bottom plot is the longitudinal phase space ellipse. The axis scales for the phase space ellipse plots can be calculated automatically with the Auto Scale Plots button in the Button Bar at the top of the window or the scales may be set directly by the user with the Set Plot Scale button.

The Beam Piece Windows include phase space ellipse plots for the current Beam Parameters.

Beam Line Construction

The PBO Lab environment uses a sophisticated beamline object model for the persistent storage and graphic representation of beamline models. The beamline object model supports both flat and hierarchical beamline topologies and is used to generate the native beamline descriptions for each of the Application Modules supported by PBO Lab. A flat model description refers to a beamline model in which every component is represented by an individual element in the model. With a hierarchical model, the beamline topology is organized using sublines that encapsulate multiple elements in the beamline model.

The beamline object model supports both flat and hierarchical beamline organization and is used to generate the native beamline descriptions for each of the Application Modules supported by PBO Lab.

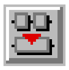
The object model also supports the ability to create Alias Pieces. An Alias Piece can be created for an individual piece, a subline, or a selection of multiple pieces and sublines in the beamline model.

An Alias is a component with a persistent link to another component.

An Alias is a component with a persistent link to another component and is capable of storing deviations from the original data without duplication of redundant data. A number of benefits can be realized using sublines in combination with the ability to create Aliases, including more efficient problem setup, compact views of very large models and elimination of redundant data storage within highly symmetrical beamlines. Refer to the *Alias* Section later in this Chapter for more information on Aliases.

An Alias is capable of storing any deviation from the original parameter data without duplicating any of the redundant data.

Sublines



Encapsulate a Selection into a Subline

A Subline is created by making a selection in the beamline model and then choosing the Make Subline command in the Edit menu or by pressing the Subline button in the Document Window Button Bar. The selection will be replaced with a single Subline icon in the beamline model. Figure 21 illustrates making a selection of pieces and grouping those pieces into a subline.

A Subline is created by making a selection in the beamline model and then choosing the Make Subline command in the Edit Menu or by pressing the Subline button in the Document Window Button Bar.

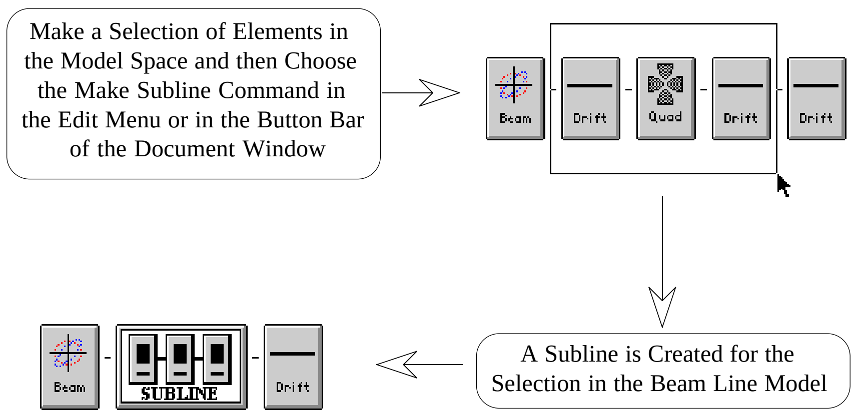


Figure 21. Making a Subline in the Beam Line Model.

To select a set of element icons that extends beyond the visible portion of the Model Space Pane, hold down the Control (Ctrl) key, select the elements, and then scroll the Model Space Pane to access and select additional elements.

Sublines can only be created for selections in the Model Space. However, sublines can be stored on the Work Space by dragging a copy from the beamline model. Sublines may be nested to any level (i.e. a subline may contain other sublines).

Double-click a Subline icon to open a Subline Window in order to access the individual pieces inside the subline.

Figure 22 illustrates double-clicking a Subline icon to open a Subline Window. The Subline Window provides access to the individual pieces inside the subline.

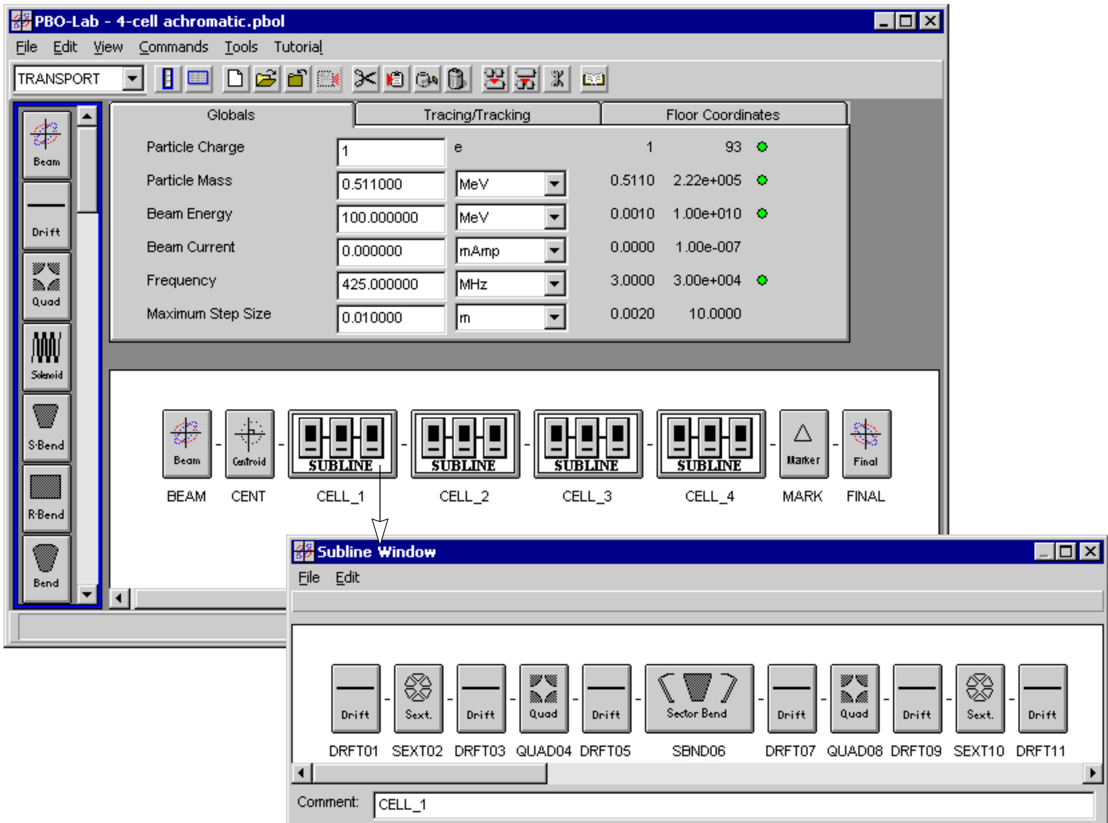
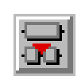


Figure 22. Opening a Subline in the Beamline Model.

A subline can be expanded (flattened) to restore individual element representations in the beamline model by selecting a Subline and then choosing the Flatten Subline command in the Edit Menu or by pressing the Flatten button in the Document Window Button Bar.



Expand (Flatten) the Selected Subline

Creating Sublines does not alter the components within the Subline; only the beamline topology is affected. Although some Application Modules do not support hierarchical beamline representations in their native beam line description formats, PBO Lab will generate a flat description from a hierarchical representation when necessary.

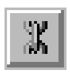
To expand a Subline, select it and choose the Flatten Subline command in the Edit Menu or the Button Bar of the Document Window.

Aliases

An Alias is a component defined by a link to another component in the beamline model.

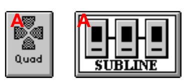
An Alias in PBO Lab is a beamline component defined by a persistent and dynamic link to another beamline component, where “component”, as used here, refers to either a single Piece, a Subline or a selection of multiple Pieces and/or Sublines. An Alias can be created for a selection in the beamline model and is capable of storing deviations from the original data without duplication of redundant data. When the parameters of the original component are modified, the changes are realized in all Aliases that reference that component and any specified deviations are applied.

An Alias is created by first making a selection in the beamline model and then selecting the Alias Element command in the Edit Menu or by using the Alias button in the Button Bar of the Document Window.



Create an Alias Piece
for a Model Selection

An Alias is created by making a selection in the beamline model and then choosing the Alias Element(s) command in the Edit Menu or by pressing the Alias button in the Document Window Button Bar. An Alias will appear in the Work Space for the selected model pieces. (The new Alias placed on the Work Space may be partially covered by the beamline Global Parameters.) Alias components are easily identifiable by the red letter “A” appearing on the Piece icon.



Aliases are easily identified by the red letter “A” that appears on the piece icon.

The original component referenced by an Alias is accessible from the Alias Piece Window using the “Original Element” button at the top of the window.

Once an Alias has been created on the Work Space, it may be placed in the beamline model by dragging a copy to the Model Space and inserting it between elements or at either end of the beamline model. The original component referenced by an Alias is not affected when the Alias is created. However, the original component cannot be deleted until all Aliases that reference it have been deleted. The original component referenced by an Alias is accessible from the Alias Window using the “Original Element” button at the top of the Piece Window. Pressing this button will open the Original Piece Window referenced by the Alias.

When an Alias is initially created, by default there are no deviations from the original piece parameters. Parameter deviations must be explicitly assigned in an Alias Piece Window.

Any modifications to original parameters are automatically realized in all Aliases of that element.

When an Alias is initially created, none of the Alias Parameters have any deviation from the original component, in effect creating an identical representation of the original component. This is a common usage for Aliases in large models with many duplicated elements.

Table 2 describes the different options available for specifying parameter deviations for an Alias or over-riding a parameter value completely.

Table 2. Parameter Deviation for Alias Pieces.

Deviation	Description
No Deviation (default)	There is no deviation from the original parameter value: Alias parameter = original parameter value
Deviation	The specified Error value is taken to be a numerical deviation: Alias parameter = original value + Error
% Deviation	The specified Error value is taken to be a percent deviation: Alias parameter = original value + original value*(Error/100)
Actual Value	The specified Error value is taken to be the actual value: Alias parameter = Error

To include a deviation for a particular parameter, double-click the Alias Piece icon to open the Alias Piece Window. If the Alias is a subline, open the Subline Window and then open the individual Piece Window for the Alias from within the Subline Window. A typical example is shown in Figure 23 for a Quadrupole Alias, which has a percent deviation of 0.02 kG on the Magnetic Field Parameter. The original value for this parameter is 3.0 kG, the Error is 0.1 and percent deviation has been selected. This defines a Quadrupole that is identical to the original, with the exception of the Magnetic Field Parameter, which is taken to be 3.003 kG (3.0 + 3.0*(0.1/100)). Any modifications to the original Quadrupole parameters will automatically be realized in all Aliases of that element. This is also true for inputs that have been specified as variable parameters in the original element. For example, the Length Parameter of the original Quad could have been set to vary during a fitting operation. The Length will be variable in all Aliases to that Quad during fitting, but each Alias Quad could still have different values specified for other parameters.

There are some restrictions on Alias Pieces, for example, an Alias can be duplicated in a Document Window by dragging a copy from the beamline model to the Work Space, but it can not be cut or copied with Edit Menu commands or with the Button Bar controls. However, if the PBO Lab application is started in the Multiple Document Mode (refer to the *PBO Lab Preferences* Section) Aliases can be copied and pasted between different Document Windows.

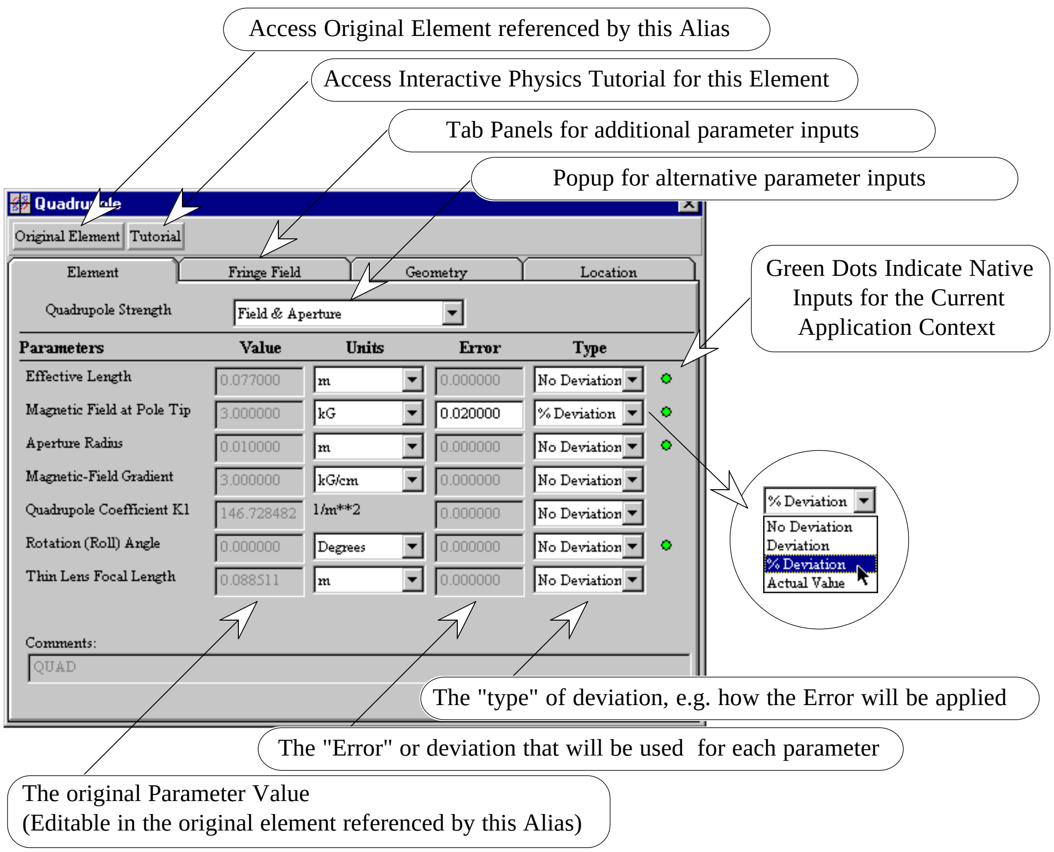


Figure 23. Example of a Piece Window for a Quadrupole Alias.

For a description of application-specific user interface features and commands, refer to the individual Application Module Supplement distributed with each Module. The following two Chapters describe the PBO Lab Analysis Tools and interactive Tutorials.

PBO Lab™ 2.0

Analysis Tools

Particle
Beam
Optics
Laboratory

This Chapter describes the PBO Lab Focusing and Bending Modules, Plot Tools, Data Interchange Tools and PBO Lab Preferences.

Focusing & Bending Modules

Single particle trajectories and beam envelopes may be analyzed using the PBO Lab Focusing and Bending Modules, accessed from the Tools Menu. The Tools pull-down menu is illustrated in Figure 24 and contains two options (*Focusing* and *Bending*) that are described in this Chapter.

Single particle trajectories and beam envelopes may be computed and displayed using the PBO Lab Focusing and Bending Modules.

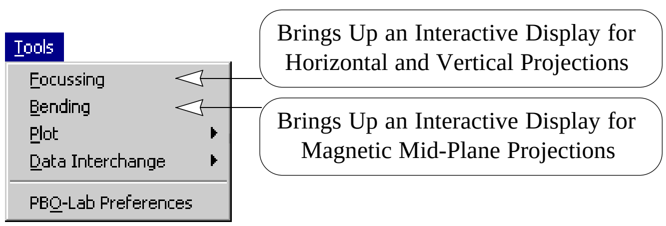


Figure 24. PBO Lab Tools Menu.

The PBO Lab focusing and bending tools use a first-order optics code developed to support interactive graphical displays of single particle trajectories and beam envelopes. They are independent of installed Application Modules and running the tools is not required to set up or execute any of the Application Modules.

A built-in first-order optics module is used to support the interactive graphical displays of single particle trajectories and beam envelopes in the Focusing and Bending Modules.

The Focusing and Bending Modules do not utilize any of the PBO Lab Application Modules for computations. However, beamline parameter values can be modified while using the interactive Analysis Tools, which can result in different numerical data (e.g. drift lengths, bend and edge angles) assigned to the elements in the beamline model.

Element parameter values in the beamline model of the Document Window can be modified while using the interactive Piece Sliders of the Focusing Module or the Angle Dials of the Bending Tool. It is recommended that you save your work prior to making any adjustments in these Tool Windows.

It is recommended that you save your work prior to making any adjustments in the Focusing and Bending Modules Windows since changes will be reflected in the beamline model.

Focusing Module

The *Focusing* command in the Tools Menu opens a focusing tool window entitled Transverse Projections of a Particle Trace. The primary components of the Focusing Module Window are illustrated in Figure 25 and include a button bar, an iconic representation of the beamline model, an interactive scaled image of the beamline model, transverse phase space ellipses, Twiss parameters and beam cross section. The horizontal and vertical projections of a particle trace with the specified initial coordinates are graphed over the scaled image of the beamline model as illustrated in Figure 26.

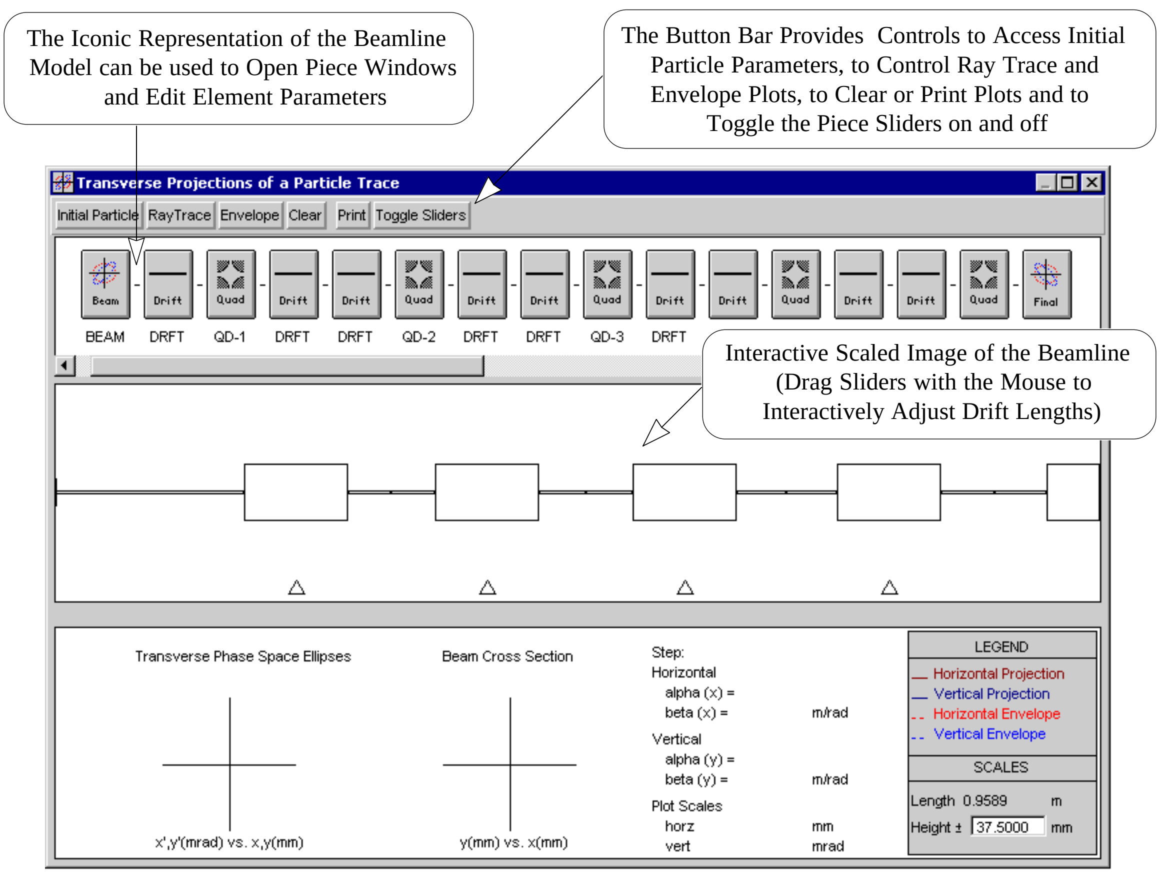


Figure 25. Focusing Module Window.

The Focusing Module uses a built-in first-order optics code to graphically illustrate the qualitative optical features of a beamline. This module is not intended to be as accurate as the Application Modules available in PBO Lab.

The Button Bar at the top of the Focusing Module Window contains buttons for *Initial Particle* specification, particle *Ray Trace*, beam *Envelopes*, *Clear*, *Print* and *Toggle Sliders*. The iconic representation of the beamline is identical to that on the Model Space of the Document Window. Central in the Focusing Module Window is the layout of the beamline model, with all distances along the beamline (moving horizontally) and the apertures of the elements (shown vertically) drawn to scale. Effective drift lengths can be adjusted graphically with Piece Slider controls along the beamline. At the bottom of the window is a transverse phase space ellipse and beam cross section display. The beam x (horizontal) and y (vertical) envelopes are displayed by selecting the *Envelopes* button. The result is shown in Figure 26 below.

The plot of each plane's envelope and phase ellipse are color coded as indicated in the legend. The horizontal envelope and phase space ellipse are all plotted in red. The corresponding vertical plots are displayed in blue.

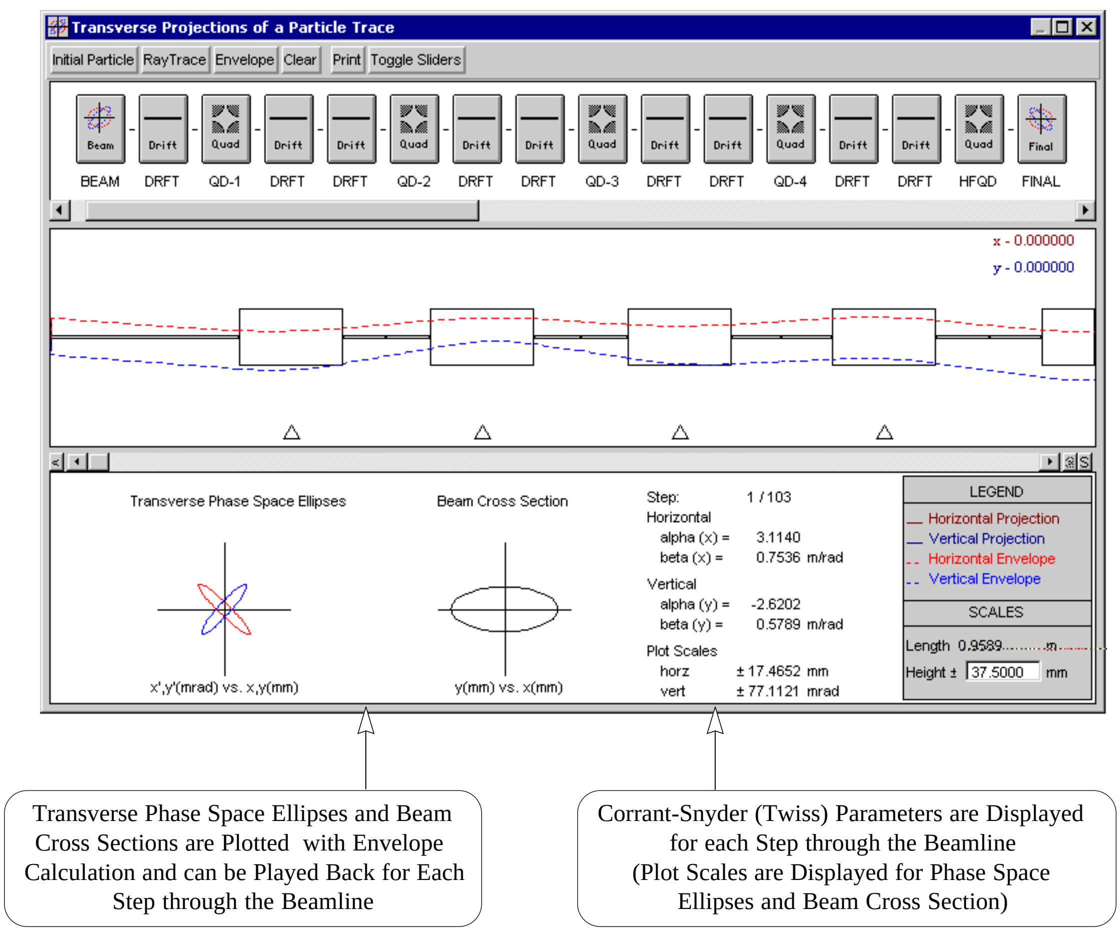


Figure 26. Envelopes in the Focusing Module Window.

Initial Particle Parameters are accessed in a separate window that is opened with the Initial Particle button in the Focusing Module Window.

The beam x (horizontal) and y (vertical) projection of a single particle trace are displayed by selecting the *Ray Trace* button. The result is shown in Figure 27 below. The plot of each plane's trajectory are color coded as indicated in the Legend. The horizontal projection is plotted in red and the corresponding vertical projection is displayed in blue. The Initial Particle Parameters are accessed with the *Initial Particle* button in the Button Bar at the top of the Focusing Module Window.

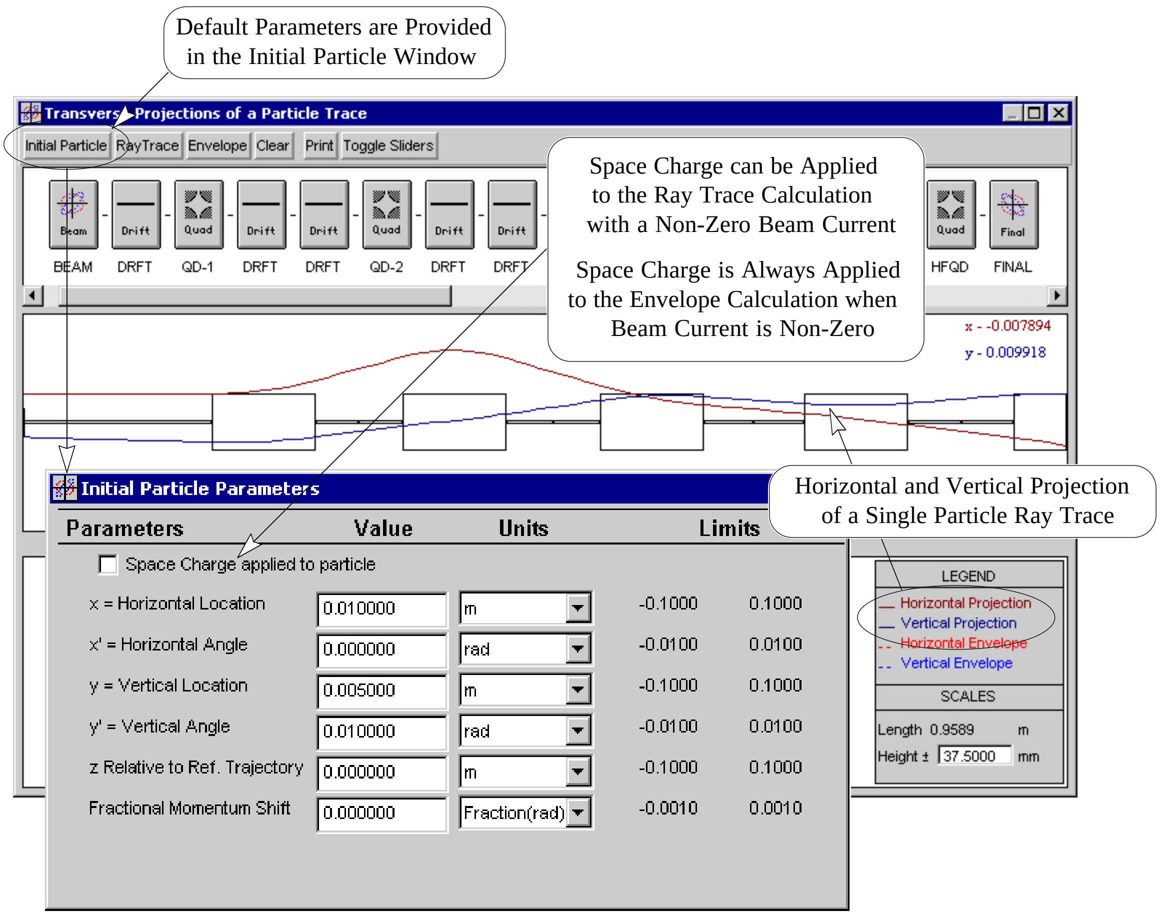


Figure 27. Particle Ray Trace in the Focusing Module Window.

Space Charge forces are included in the ray calculations when the Space Charge check box is selected in the Initial Particle Parameters Window and the Beam Current Global Parameter is non-zero.

When the Space Charge check box has been checked in the Initial Particle Window, linear space charge forces, determined by the *Beam Current* Global Parameter, are included in the equations used for the Ray Trace calculations. Space charge forces are always included in the Envelope calculations if the Beam Current Global Parameter is non-zero.

A number of qualitative features of the transverse optical properties for a beamline may be examined using the focusing tools. Two types of Slider Controls are included in order to interactively study a beamline. Individual *Piece Sliders* allow the user to move the position of the optical elements along the beamline. Figure 28 shows these Piece Sliders in the Focusing Window.

Piece Sliders move optical elements back and forth along the beamline.

The Toggle Sliders button hides and shows the Piece Sliders in the Focusing Module Window.

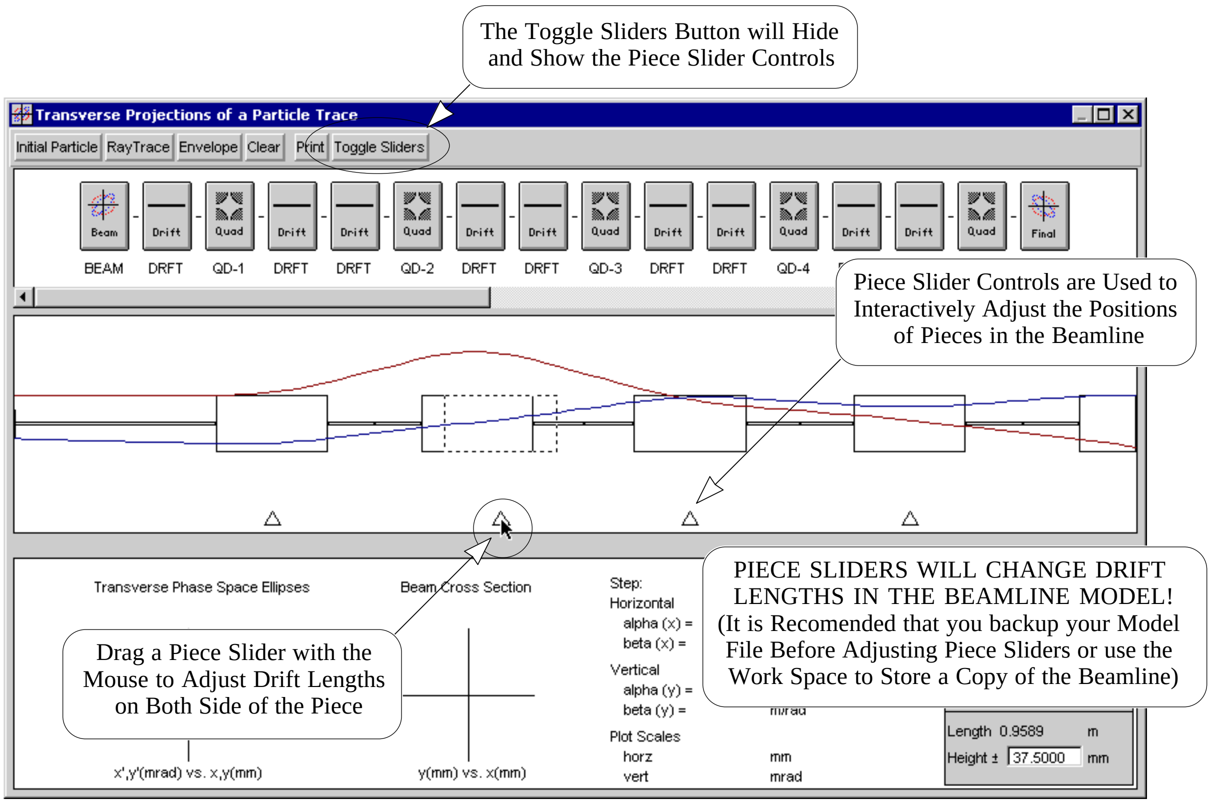


Figure 28. Using the Piece Slider Controls.

Using the Piece Sliders to adjust the locations of elements causes a change in the lengths of the adjacent drift elements. This will result in a modification of the drift lengths in the beamline model. An example of the use of the Piece Sliders would be to adjust the initial positions of certain optical elements to achieve graphically (or qualitatively) a particular feature of the envelopes, or of a particle trajectory such as that for a characteristic ray. However, in order to avoid any inadvertent changes in the drift lengths contained in an important file, it is recommended that the file be saved before making any Piece Slider adjustments.

After making Piece Slider adjustments, either the Ray Trace or Envelope button can be used to update the display on the scaled image of the beamline model.

It is recommended that the file be saved before making any Piece Slider adjustments.

The Envelope Slider is used to select a location in the beamline model for displaying the phase space ellipses and beam cross section.

Using the Envelope Slider controls will not result in any modifications to beamline element parameters.

The second type of Slider Control is the *Envelope Slider*, which is used to select the location in the beamline where the phase space ellipses and beam cross section are displayed. The Envelope Slider has additional control buttons located at each end of the slider. Figure 29 identifies these controls, which can be used to (1) discretely step through the beamline (right control buttons), or (2) move continuously and automatically through the beamline (left control button). When the continuous play (left) button is selected, the Envelope Slider control moves from left to right across the central pane, while the lower pane provides an animated display of the phase space ellipses and beam cross section, corresponding to the Envelope Slider control location.

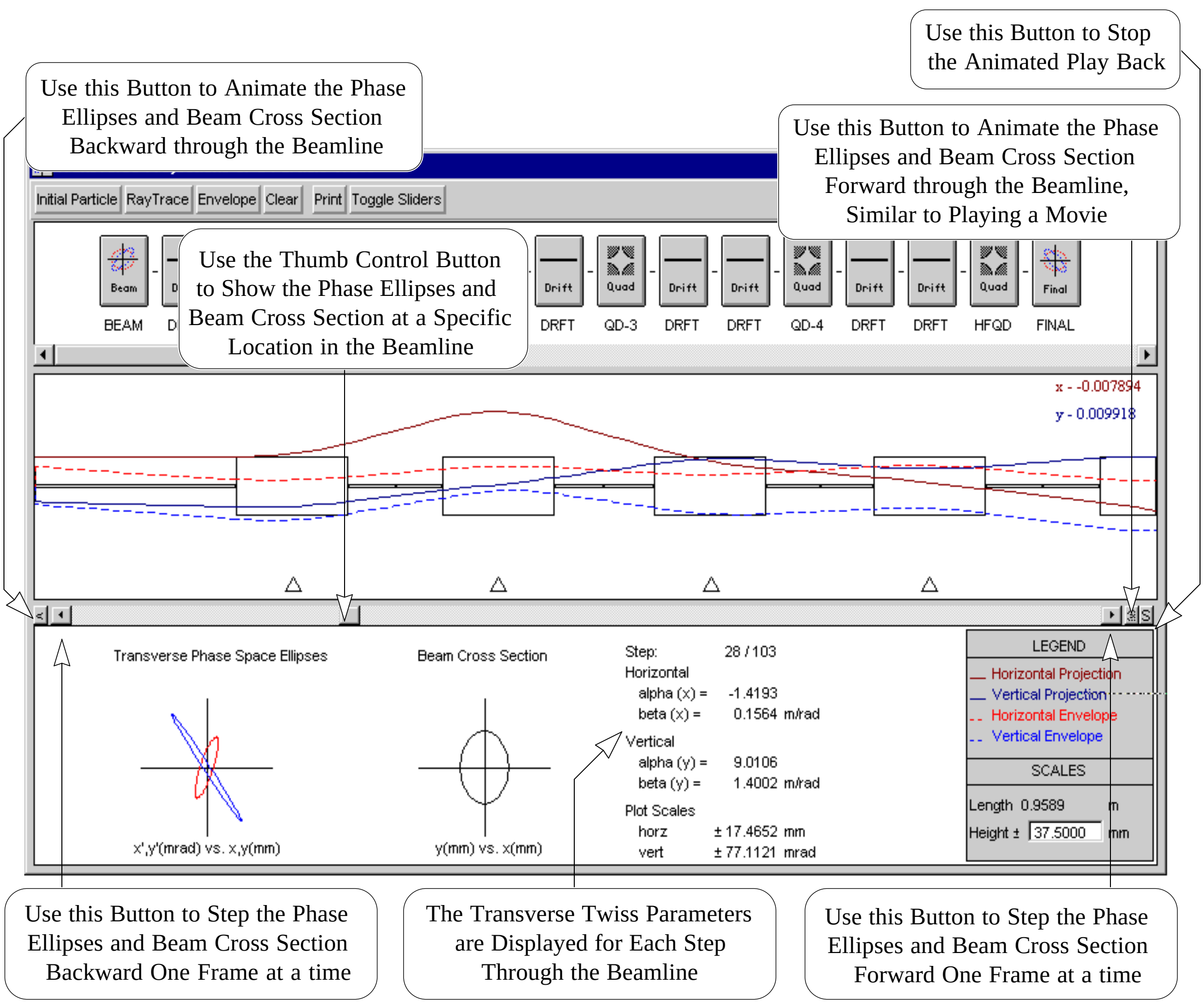
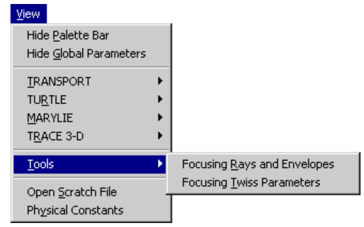


Figure 29. “Playing” the Envelopes Like a Movie.

The Corrant-Snyder (Twiss) parameters corresponding to the phase space ellipses are displayed for each step through the beamline as illustrated in Figure 29. This data is also written to the *"TwissParameters"* disk file that can be opened from the Tools sub-menu in the View Menu of the Document Window. The envelope and ray data is written to the *"EnvelopesAndRays"* disk file, which is also opened from the Tools sub-menu. Writing these files can slow down the ray and envelope calculations so preferences are provided to disable this feature. The *Focusing and Bending* tab panel in the *PBO Lab Preferences* window has options to disable the writing these files. (Refer to the *PBO Lab Preferences* Section in this Chapter.)



Focusing data files are accessed from the Tools sub-menu in the View Menu of the Document Window.

The number of steps used for calculating the rays and envelopes depends on the *Maximum Step Size* Global Parameter, which is the last parameter in the Globals tab panel in the Document Window. The number of discreet steps is derived from the overall beamline length and the Maximum Step Size Global Parameter. The total number of steps and the current step are shown in the Focusing Module Window above the Twiss parameters display. In Figure 29 the Envelope Slider control has been placed at step 28 of 103 discrete steps for the entire beamline. Below the display of Twiss parameters, the horizontal and vertical plot scales are shown for the phase space ellipses and beam cross section plots.

The step size used in the ray and envelope calculations is based on the Maximum Step Size Global Parameter in the Globals tab panel in the Document Window.

The overall beamline length is displayed in the lower right corner of the Focusing Module Window along with a scalable value for the Height of the beamline image. The Height represents the distance from the center line in the scaled image of the beamline model and can be changed without recalculating the rays and envelopes.

Bending Module

The *Bending* command in the Tools Menu brings up a window entitled Magnetic Mid-Plane Projections of a Particle Trace. An example of the Bending Module Window is shown in Figure 30 below.

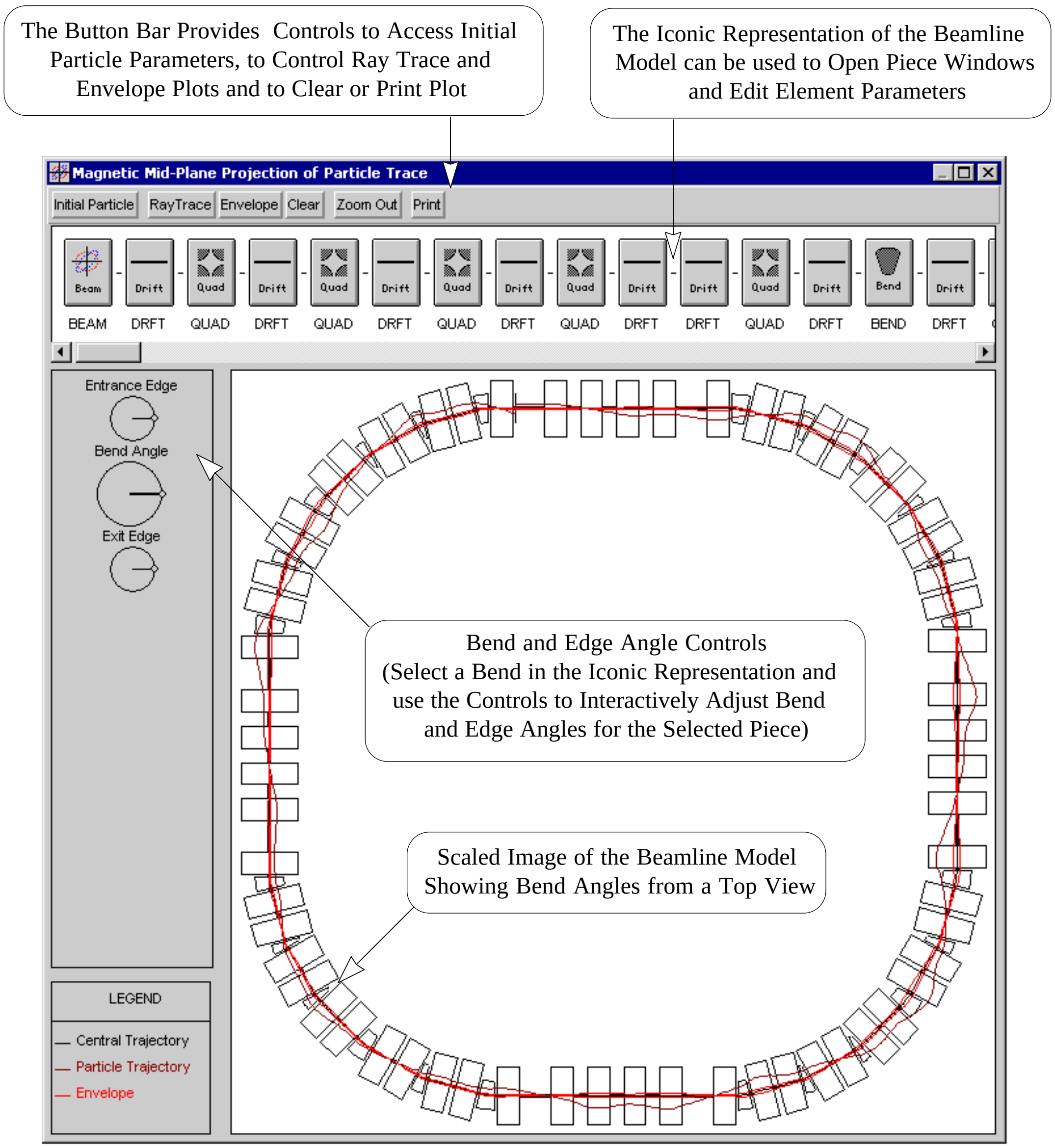


Figure 30. Bending Module Window.

The example illustrated in Figure 30 shows the magnetic mid-plane projection for both the reference trajectory and the single particle ray. The reference trajectory and the single particle ray are drawn with the *RayTrace* button. The magnetic mid-plane projection of the beam envelope is drawn using the *Envelope* button.

The RayTrace button shows the magnetic mid-plane projection for both the reference trajectory and single particle ray. The magnetic mid-plane projection of the beam envelope is drawn using the Envelope button.

The Bending Module uses a built-in first-order optics code to graphically illustrate the qualitative optical features of a beamline. The trajectories module is not intended to be as accurate as the Application Modules available in PBO Lab.

The layout of the Bending Module Window is similar to that of the Focusing Module Window. The principle difference is in the central pane of the window, where an image of the magnetic mid-plane for the beamline is drawn. All bends are viewed perpendicular to the plane of the bend in this type of plot. The reference trajectory lies in the magnetic mid-plane. The bending tool traces out this reference (or central) orbit through the beamline. The projection of any other single trajectory specified by the Initial Particle Parameters Window is also traced. The Initial Particle Parameters Window is accessed from the Button Bar at the top of the Bending Module Window. The Bend Control panel located on the left side of the central pane in the Bending Module Window is used to adjust the bend and edge angles in any of the bending magnets. Changes made with these controls will be reflected in the beamline on the Model Space. Bend and edge angles are modified with the Dial controls after selecting a Bend Piece in the iconic representation of the model displayed at the top of the window. The beamline image in the central pane will be redrawn reflecting the new angle.

The Bend Controls, located on the left side of the central pane, can be used to adjust the reference trajectory deflection angle for a selected Bend Piece. It is recommended that you save your work prior to making any adjustments with the Dial Controls.

As illustrated in Figure 31, the Bending Module Window also supports a Zoom feature. To Zoom-In on a specific area, use the mouse to drag a rectangle around the region you wish to enlarge (holding down the mouse button while dragging). When the mouse button is released, the image will be redrawn, enlarged to the size of the central pane. The Zoom-Out button restores the previous image.

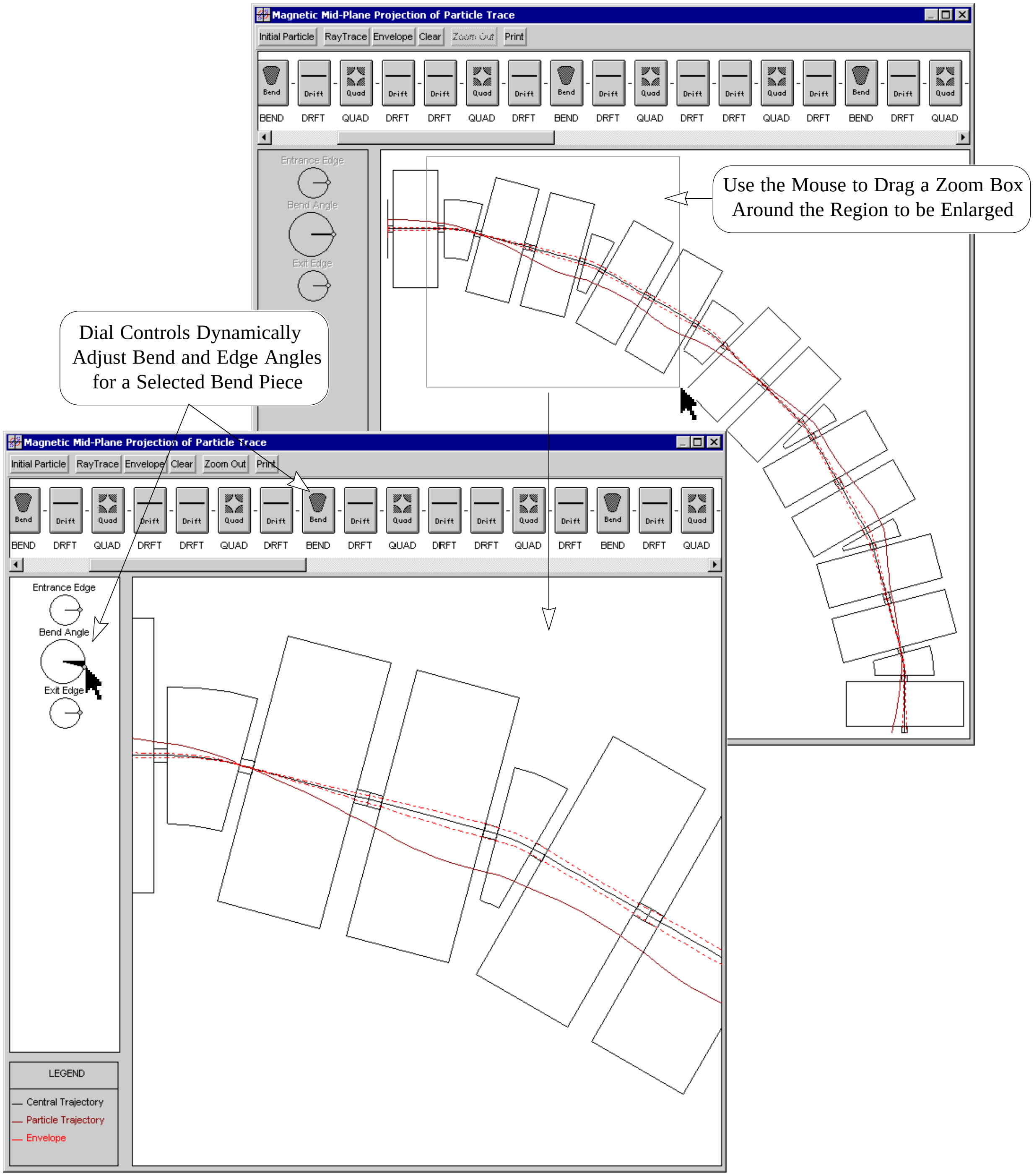


Figure 31. Zoom-In Feature of the Bending Module Window.

The Bending Module Window may be resized by dragging the lower right corner of window. The central pane of the window will be constrained to a square in order to maintain the proper perspective for the scaled image.

A subset of the all the availible PBO Lab optical elements are supported in the Focusing and Bending Modules. The list to the right summarizes which Pieces are, and are not, supported by the trajectories tools. Models containing those Pieces that are not supported can result in unpredictable displays and should be removed from the beamline on the Model Space prior to using the Focusing and Bending Modules. In addition, not all supported Pieces have been fully tested for numerical accuracy in the trajectories tools for this release of PBO Lab, and so caution is urged. Future releases of PBO Lab will incorporate full support for additional PBO Lab Pieces on the Palette Bar. Of course, certain Pieces, such as the Marker and Final, do not impact the calculation of single particle trajectories or envelopes.

This Section completes the discussion of using the PBO Lab focusing and bending analysis tools. The analysis tools do not use any of the Application Modules, and are not required to set up or run any of the PBO Lab Application Modules. The following Section describes the PBO Lab Plot Tool, which can be used to plot data generated with the Focusing Module.

Pieces Utilized in the Focusing and Beding Modules

Beam
Drift
Quad
Solenoid
S-Bend
R-Bend
Bend
Edge
Thin Lens
Centroid
RF Gap
Matrix
Rotate

Pieces Not Utilized in the Focusing and Beding Modules

RMS Beam
Align
Kicker
Sextupole
Octupole
Plasma Lens
Accelerator
Septum

Pieces Not Impacting in the Focusing and Beding Modules

Marker
Final

Plot Tool

The Particle Beam Optics Laboratory supports a Plot Tool which is accessed from the Tools Menu as illustrated in Figure 32. The Plot Tool is not dependent on any of the Application Modules available in PBO Lab.

The Plot Tool allows data generated from the Focusing Module or from external data files to be displayed in interactive Plot Windows. None of the PBO Lab Application Modules are required to use the PBO Lab Plot Tool.

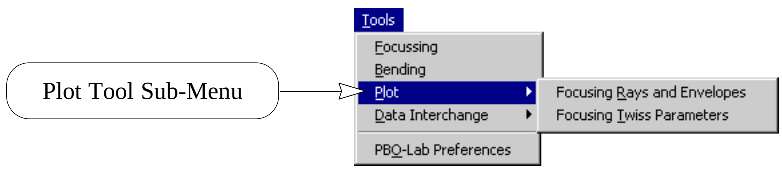


Figure 32. Plot Tool Sub-Menu.

The Plot Tool allows data generated from the Focusing Module to be displayed in interactive Plot Windows. The Plot Windows provide a variety of features including support for loading external data files for plotting. Figure 33 illustrates the Plot Window for the Twiss Parameters data that is generated with the Focusing Module.

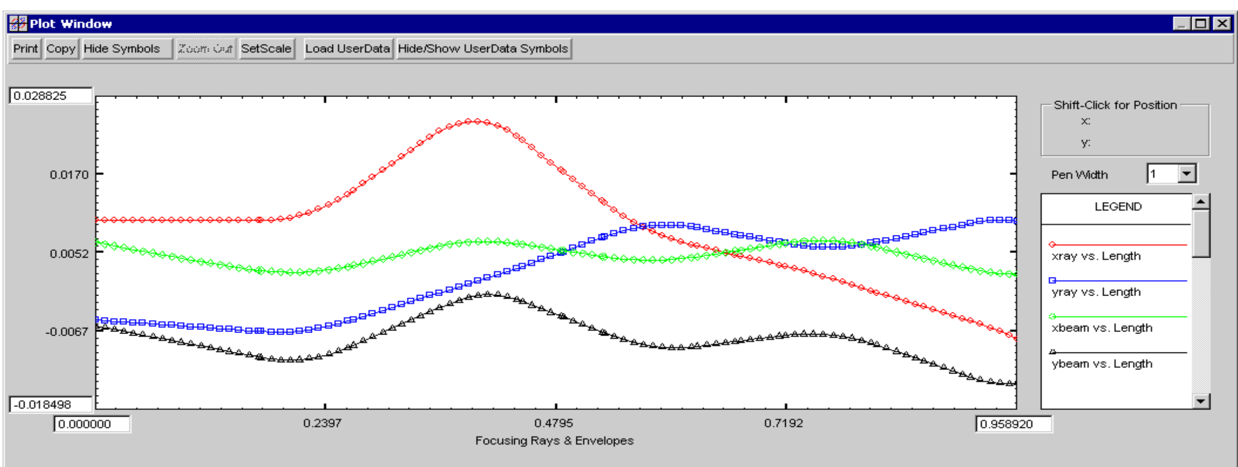


Figure 33. Plot Tool Window for Focusing Ray and Envelope Data.

The Plot Window shown in Figure 33 has been resized horizontally and the plot scales have been set to run from zero to the physical length of the beamline calculated by the Focusing Module.

Graph Plot Windows

Once a graph has been generated, the Graph Plot Window may be left open and additional plot specifications can be selected. New Graph Windows will be opened with subsequent runs so an unlimited number of Graph Plot Windows may be created and left open for simultaneous viewing. The Graph Plot Windows may be resized from thumb-nail size to full-screen. Figure 34 shows some example Graph Plot Windows for data generated with the different Application Modules available in PBO Lab.

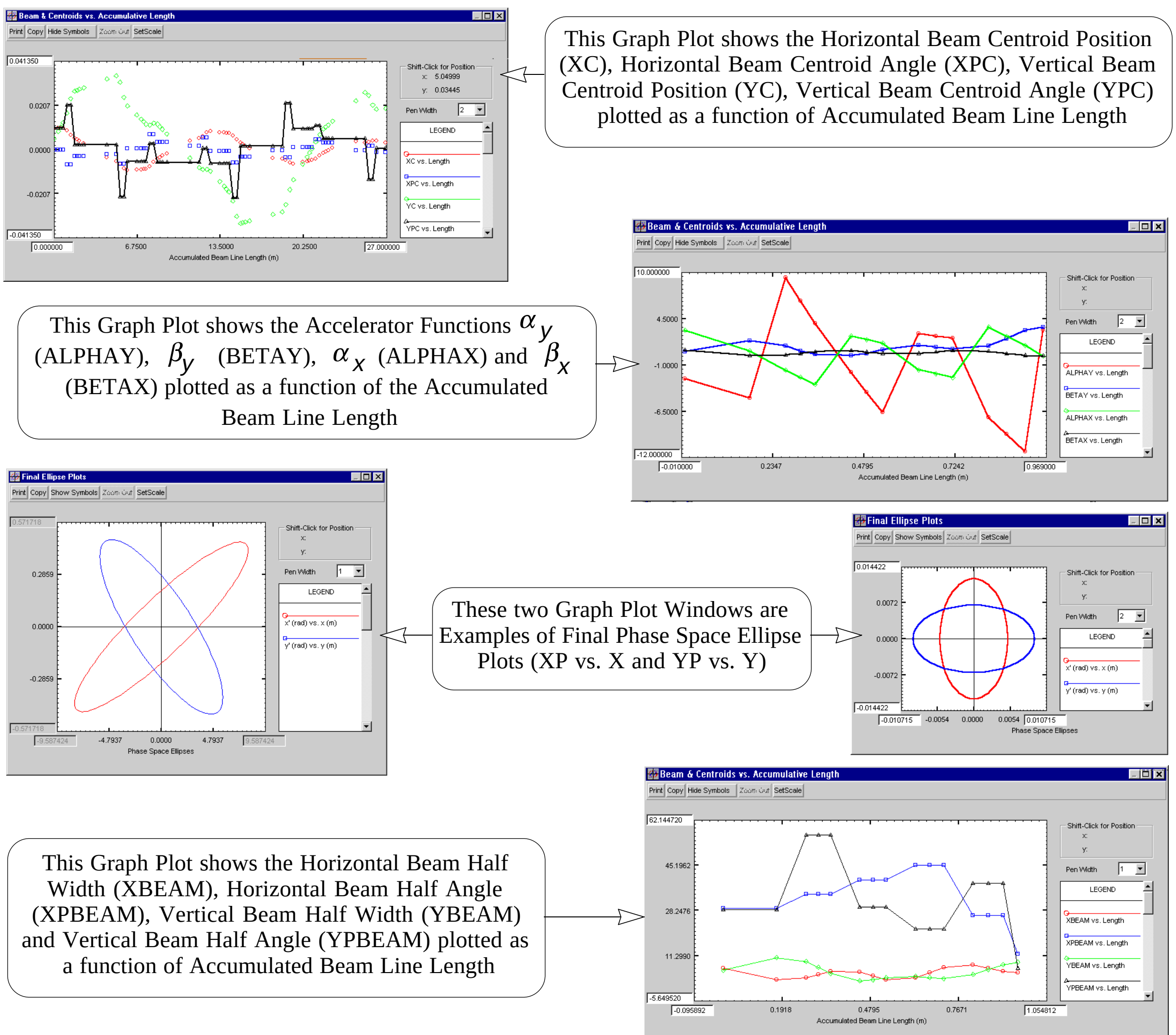


Figure 34. PBO Lab Graph Plot Windows.

The Button Bar at the top of Graph Plot window provides controls for printing and copying the graph.

Several interactive features are available to the user in the PBO Lab Graph Plot Windows. A Button Bar at the top of the window provides options for printing the graph and for copying the graph to the system clipboard.

Each plot variable is drawn in a different color, and is identified in the Legend. Clicking on a plot variable in the Legend will hide or show that data in the Graph Plot Window. Above the Legend is a *Pen Width* pop-up with selections that range from one to five. The default is one and for most graphs this is the preferred pen width.

The coordinates for any data point can be shown by clicking on the symbol for the desired point while holding down the shift key.

Symbols for specific data points can be displayed by pressing the *Show Symbols* button. The coordinates of any plotted point can then be displayed by clicking on the symbol for that point while holding the shift key down.

Graph scales are automatically calculated to fit the data set. However, using the Set Scale button, scales may be modified directly in the Graph Plot Window.

Graph scales are automatically calculated to fit the data set. However, using the *Set Scale* button, the vertical and horizontal scales of the graph may be directly modified. The Set Scale button activates the min and max plot scales on the plot axes. Simply type in the desired value and press the Enter key. You can also use the mouse to quickly zoom in on a specific region of the graph.

Any region of the graph can be enlarged (Zoomed In) by holding down the mouse button while making a drag box for the desired zoom region.

Any region of a graph can be enlarged (Zoomed-In) by making a drag box with the mouse. Move the mouse to the upper left corner of the region to be zoomed, and hold down the left mouse button while dragging to the lower right corner of the desired zoom region. A drag box will be displayed during this action. When the mouse button is released, the graph will be redrawn so that the region enclosed by the drag box occupies the entire plotting area. Figure 35 on the following page illustrates this feature.

Figure 35 illustrates a Zoom-In region that has been created by using the mouse (with button held down) to make a drag box around the desired zoom region. The window at the bottom of Figure 35 shows the zoomed graph after releasing the mouse button. An unlimited number of zooms are available for any region of the graph, providing an increasingly detailed display of the plot data, by using multiple applications of the Zoom feature. The *Zoom-Out* button is used to return the graph to the previous zoom level.

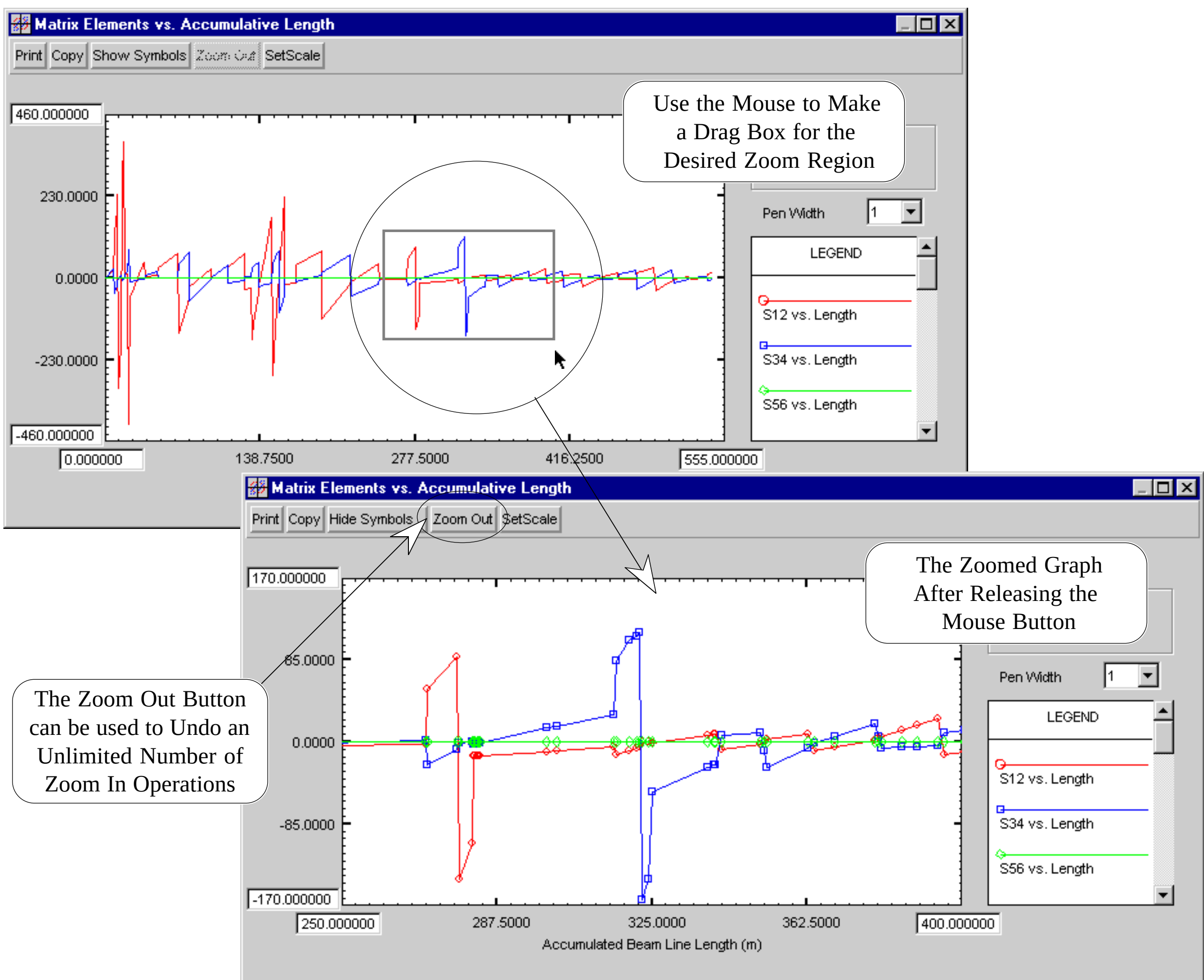


Figure 35. Example illustrating drag box Zoom-In feature.

Loading User Data into Graph Plot Windows

User specified plot data can easily be incorporated into PBO Lab Graph Plot Windows for line plots as a function of beamline length.

PBO Lab Graph Plot Windows include support for loading user specified plot data files. This allows plot data to be loaded directly into Graph Plot Windows that are created for line plots as a function of beamline length. This feature can be used for a variety of purposes including loading external data such as control system diagnostics into Graph Plot Windows for comparison with simulation results from the different PBO Lab Application Modules (e.g. TRANSPORT, MARYLIE, etc.). The Load User Data option can also be used to accumulate the plot results from multiple runs of an Application Module or to compare results from different Application Modules in a single Graph Plot Window. Plot data generated with the PBO Lab Focusing Module can also be combined with Graph Plots produced with the different Application Modules.

Refer to the Plot Specification Section of the TRANSPORT Application Module Supplement.

Refer to the Plot Specification Section of the MARYLIE Application Module Supplement.

The Load User Data feature is available in any Graph Plot Window created from the Tools-Plot sub-menu, as well as any Graph Plot Window generated from a TRANSPORT Plot Specification for Matrix Elements vs. Length, and Envelopes, Centroids and Lattice Functions vs. Length. User plot data may also be added to Graph Plot windows generated from MARYLIE Plot Specifications for Lattice Functions, Lattice Properties, Anharmonic Lattice Parameters and Envelopes as a function of beamline length.

Any of the Length plot data files generated by the different PBO Lab Application Modules or by the PBO Lab Focusing Module can be loaded directly into PBO Lab Graph Plots Windows.

User specified plot data is incorporated into Graph Plot Windows using the *Load User Data* button in the Button Bar at the top of the Graph Plot Window. A standard open file dialog is then used to select a plot data file. Any of the Length plot data files generated by the different PBO Lab Application Modules or by the PBO Lab Focusing Module can be loaded directly. External data sources can created and loaded by using the standard format described next.

The format for external (user supplied) plot data files is identical to the format of the Length plot data files generated by the various PBO Lab Application Modules and the Twiss Parameter data file generated with the PBO Lab Focusing Module. The View menu provides commands for opening and editing these plot files in a text window.

The Format of user plot data files is identical to the line plot data files generated by the various PBO Lab Application Modules.

The header at the top of the file must contain the keyword "Length" as the first column heading, followed by any number of user defined column headings for each column of user specified plot data. Each column of plot data will be used to plot a line as a function of the lengths in the first column. Figure 36 illustrates an example of a user supplied data file.

The first column of the Plot Data file is for length data and must have the "Length" heading. Any number of columns may follow with any user specified column heading. Each of these columns are used to plot lines as a function of the lengths in the first column.

LENGTH	S12	S34
0.30	145.0	-397.0
0.31	120.0	-370.0
0.32	149.0	-399.0
0.33	160.0	-410.0
0.47	-102.0	232.0
0.48	-119.0	252.0
0.49	-133.0	267.0
0.50	-122.0	257.0
0.66	122.0	-145.0
0.67	96.0	-119.0
0.68	125.0	-148.0
0.69	136.0	-159.0
0.85	-142.0	554.0
0.86	-156.0	527.0
0.87	-145.0	552.0
0.88	-116.0	567.0

Figure 36. User supplied plot data file.

A row of data represents a point along the cumulative beamline length. The length (taken from column one) is used as the horizontal coordinate and the data from each column in a row represents the vertical coordinate of the points that will be plotted with a solid colored symbol in the Graph Plot Window. There is no limit on the number of rows. The number of columns (excluding the length column) represents the number of lines that will be plotted. There is no limit on the number of columns. However, the first column must be length data.

There is no limit on the the number of rows and columns in a User Data file.

Symbols can be connected with lines by clicking on the legend string for that data set in the Legend of the Graph Plot Window.

By default the user data files loaded into a Graph Plot Window are initially drawn with symbols only, as illustrated in Figure 37. Data points from each column can be connected with lines by clicking on the legend string for that data set in the Legend of the Graph Plot Window. Colors are assigned starting with red, then blue, green and black, based on the column order in the plot data file. This sequence repeats for additional columns.

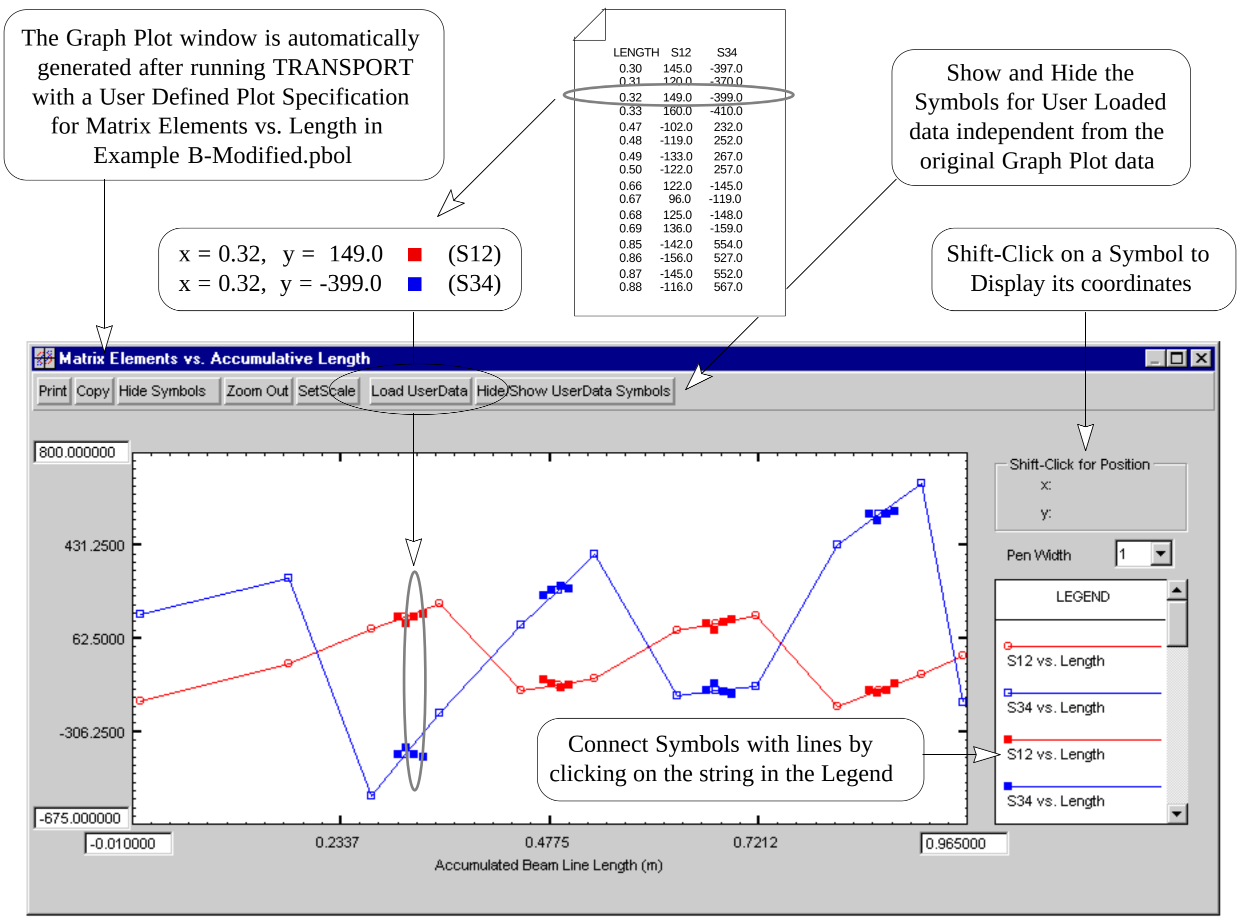


Figure 37. Loading User Defined Plot Data in PBO Lab Graph Plot Windows.

Symbols for user loaded data are always solid squares. Use the Hide/ Show User Data Symbols button to toggle the display for these symbols

The symbols for user loaded data points are always drawn with solid squares. These can be hidden with the *Hide/ Show User Data Symbols* button in the Button Bar of the Graph Plot Window, independent of the original plot data symbols. There is no limit on the number of plot data files that can be loaded into a Graph Plot Window.

Figure 38 illustrates an example of the Load User Data option using the “Example B-modified.pbol” model file distributed with PBO Lab. The Plot Specification has been changed to show two of the fitting constraint variables (S12 and S34 Sigma matrix elements) as a function of the cumulative beamline length. The Load User Data option is used to compare the plot results before and after fitting in the same Graph Plot Window. The Graph Plot Window from the first TRANSPORT run (without fitting) is used to Load the "TransportPlot" data file generated in the second TRANSPORT run (with Fitting).

The User Plot Data option can be used to accumulate plot data for comparison of multiple runs.

Refer to the Transport Plot Specification Section of the TRANSPORT Application Module Supplement.

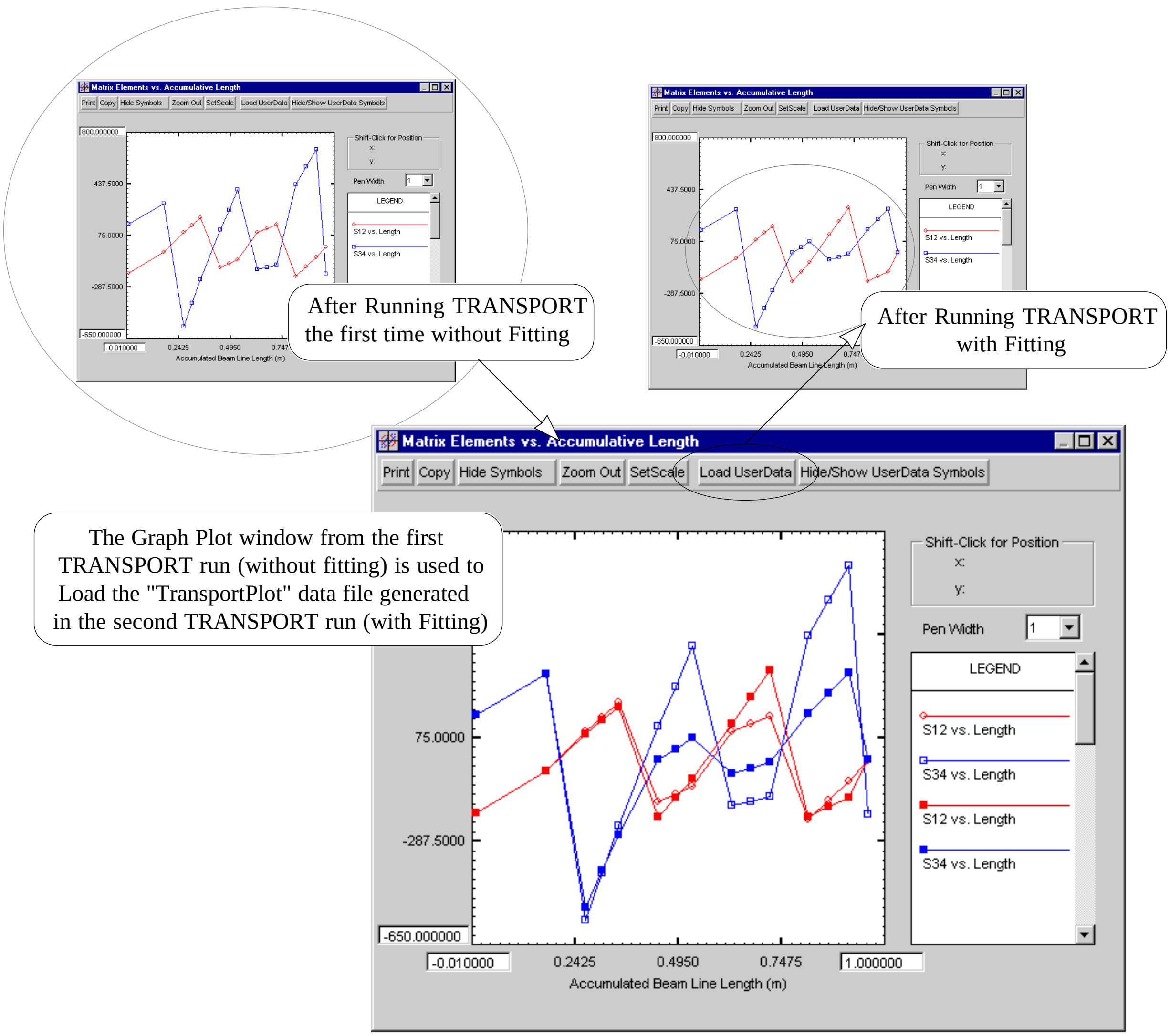


Figure 38. Accumulation of Plot Data for Multiple Runs (before and after Fitting).

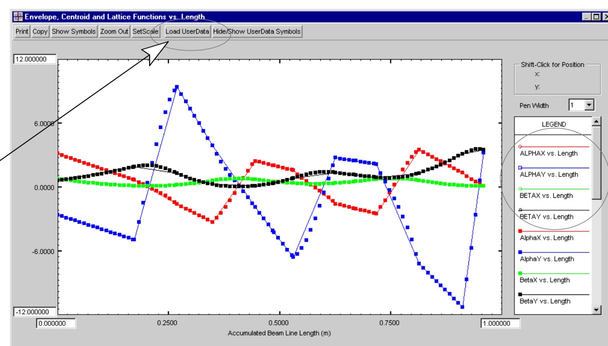
Refer to the Focusing Modules Section in this Chapter.

Plot data generated with the PBO Lab Focusing Module can also be combined with beamline length plots produced with the different Application Modules. Figure 39 illustrates an example using “Example B-modified.pbol” with the Plot Specification changed to show the AlphaX, AlphaY, BetaX and BetaY Beam Twiss Parameters. The “TwissParameters” data file produced with the PBO Lab Focusing Module is then loaded in to the Graph Plot Window after running TRANSPORT.

The "TransportPlot" data file is used to automatically generate the User Defined TRANSPORT Plot Specification following the execution of TRANSPORT.

LENGTH	ALPHAX	ALPHAY	BETAX	BETAY
0.00000	3.11399	-2.62021	0.75360	0.57890
0.17300	0.65834	-4.97074	0.10098	1.89214
0.26900	-1.63084	9.36867	0.17467	1.28986
0.30875	-2.46368	6.63293	0.33742	0.65379
0.34850	-3.29652	3.89721	0.56639	0.23522
0.44450	2.43303	-1.90052	0.68465	0.08393
0.48724	2.00106	-4.24902	0.49513	0.34676
0.52998	1.56909	-6.59751	0.34254	0.81034
0.62598	-1.58558	2.72163	0.34379	1.34114
0.67172	-2.05310	2.43490	0.51023	1.10528
0.71746	-2.52064	2.14817	0.71943	0.89565
0.81346	3.47456	-7.22131	0.58879	1.28003
0.86219	2.39264	-9.24461	0.30288	2.08242
0.91092	1.31071	-11.26784	0.12242	3.08198
0.95892	0.06436	3.17925	0.06070	3.50011

The Specified TRANSPORT Plot is automatically generated for ALPHAX, ALPHAY, BETAX and BETAY as a function of the beamline length. Each point is one step (element by element) along the cummulative length of the beamline.



The solid square symbols show the User Data loaded from the TwissParameters data file.

The "TwissParameters" Data File is generated from the PBO Lab Focusing Tool:

Length	AlphaX	AlphaY	BetaX	BetaY
0.000000e+000	3.114000e+000	-2.620200e+000	7.536000e-001	5.789000e-001
1.000000e-002	2.972055e+000	-2.756069e+000	6.927395e-001	6.326627e-001
2.000000e-002	2.830109e+000	-2.891938e+000	6.347178e-001	6.891428e-001
3.000000e-002	2.688164e+000	-3.027807e+000	5.795351e-001	7.483402e-001
4.000000e-002	2.546219e+000	-3.163675e+000	5.271912e-001	8.102550e-001
5.000000e-002	2.404274e+000	-3.299544e+000	4.776863e-001	8.748872e-001
6.000000e-002	2.262328e+000	-3.435413e+000	4.310203e-001	9.422368e-001
7.000000e-002	2.120383e+000	-3.571282e+000	3.871932e-001	1.012304e+000
8.000000e-002	1.978438e+000	-3.707151e+000	3.462050e-001	1.085088e+000
9.000000e-002	1.836493e+000	-3.843020e+000	3.080557e-001	1.160590e+000
1.000000e-001	1.694547e+000	-3.978889e+000	2.727453e-001	1.238809e+000
1.100000e-001	1.552602e+000	-4.114757e+000	2.402738e-001	1.319745e+000
1.200000e-001	1.410657e+000	-4.250626e+000	2.106412e-001	1.403399e+000
1.300000e-001	1.268711e+000	-4.386495e+000	1.838475e-001	1.489770e+000
...				
9.209200e-001	9.984910e-001	-8.665198e+000	9.939680e-002	3.281914e+000
9.309200e-001	7.230047e-001	-5.745665e+000	8.223428e-002	3.426465e+000
9.409200e-001	4.741225e-001	-2.615999e+000	7.029947e-002	3.510338e+000
9.509200e-001	2.426863e-001	6.093390e-001	6.315322e-002	3.530466e+000
9.589200e-001	6.436229e-002	3.179234e+000	6.070162e-002	3.500098e+000

A step size of 0.01 meters (103 steps) was used to gather more data points along the length of the beamline in the TwissParameters data file.

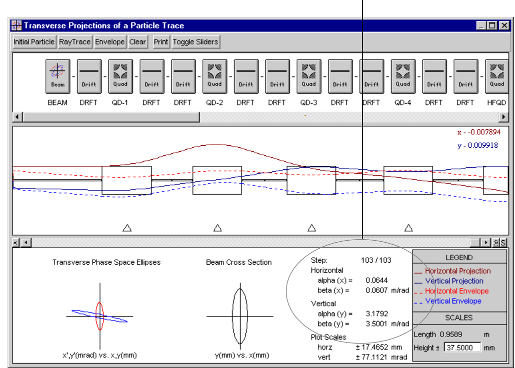


Figure 39. PBO Lab focusing data loaded into a Graph Plot Window.

Data Interchange Tool

The Particle Beam Optics Laboratory supports an ASCII file-based data interchange for beamline element parameters. Element parameters for Pieces in the beamline may be selected as Import Variables in the Special Parameter Settings Windows. These parameters can then be loaded from an external data file or written to a data file from PBO Lab. Selected parameters are imported into PBO Lab or exported from PBO Lab using the commands in the Data Interchange sub-menu of the Tools menu.

Element parameters for Pieces in the beamline model may be loaded from an external data file using the Data Interchange Tool.

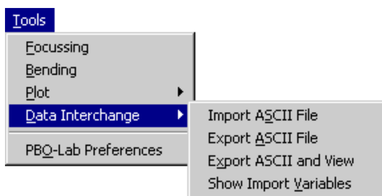


Figure 40. Data Interchange Sub-Menu.

The Data Interchange sub-menu is accessed from the Tool menu in the Document Window.

There are three commands in the Data Interchange sub-menu, as illustrated in Figure 40: *Import ASCII File*, *Export ASCII File* and *Export ASCII and View*. The first command is used to import parameters into the PBO Lab beamline model from an external text file. The second command is used to Export selected parameters to a text file. The third command is equivalent to the Export ASCII File command, in that it generates an export file for selected parameters, but it also opens the file in a Text Editor Window.

Import parameters are selected in Special Parameter Settings Windows (S-Windows). Figure 41 illustrates selecting a Quadrupole Magnetic Field Gradient parameter as an interchange variable in the TRANSPORT tab panel of the S-Window. S-Windows have application-specific tab panels for installed Application Modules that are described in the individual Application Module Supplements. A parameter that has been selected as an Import Parameter can not be defined as a Fitting Variable or Algebraic Expression for TRANSPORT. Similar constraints are imposed for selecting interchange variables in other application-specific tab panels in Parameter S-Windows.

Import parameters are selected in Special Parameter Settings Windows (S-Windows) accessed with parameter S-Buttons in the Piece Windows.

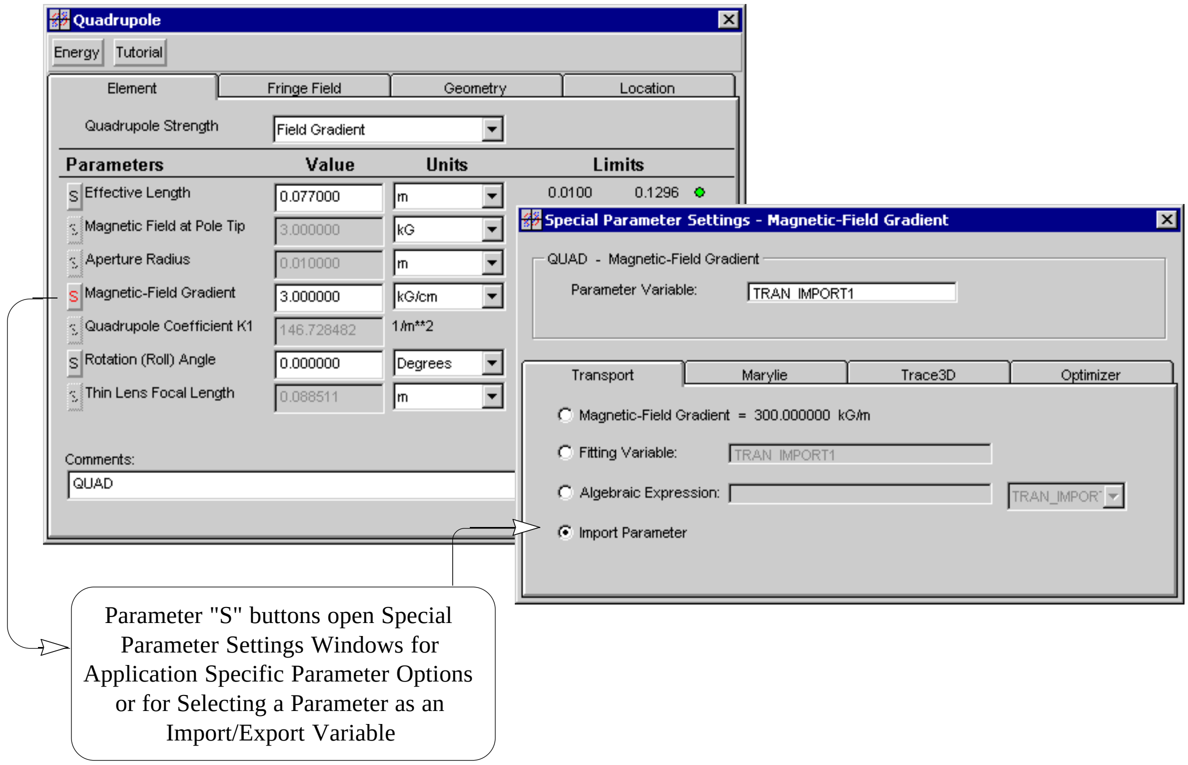


Figure 41. Selecting a Parameter as an Interchange Variable.

Import Parameters are application-specific and therefore PBO Lab requires an Application Module to be installed in order to select Import Parameters in the beamline. Figure 42 shows an S-Window with no Application Modules installed.

PBO Lab requires an Application Module to be installed in order to select Import Parameters in the Special Parameter Settings Windows.

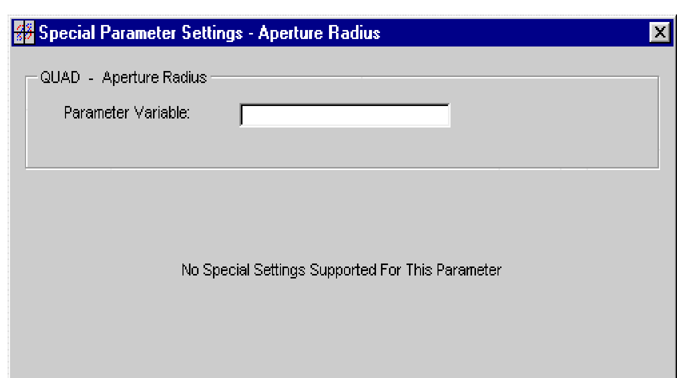


Figure 42. Special Parameter Settings Window with no Application Modules installed.

Once Import Variables have been selected in the beamline model, the Export ASCII and View command can be used to create an external data file containing those parameters. The data file will be automatically opened in a Text Editor Window as illustrated in Figure 43.

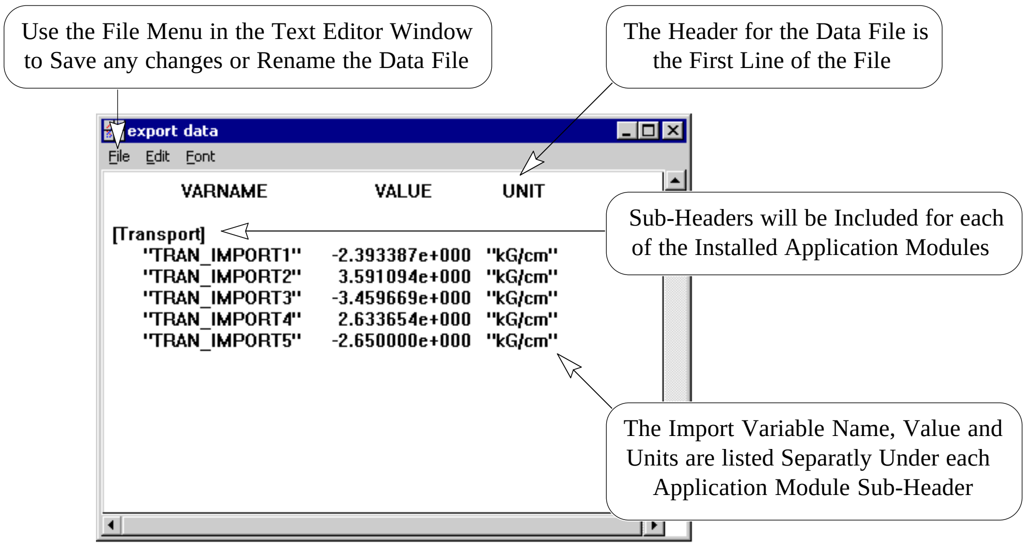


Figure 43. Generating an External Data File for Import Parameters.

The syntax for importing external data is identical to the export file syntax shown in Figure 43. It may be convenient to use the Export ASCII and View command to generate an export data file and then use that file as a templet for your import data file. This insures that the data file will correspond with the selected Import Variables in the beamline model. Each entry in the Import file must have a Variable Name that matches the names assigned to the Import Parameter selections in the beamline model. The Variable Name is followed by the numerical Parameter Value in the units shown in the Export file templet. However the quoted units strings are not required in an Import file. Import Parameters are matched by name in PBO Lab so that the order they appear in the Import file is not important. Entries in the Import file that do not have corresponding Variable Names in the beamline model will be ignored. The File Menu in the text editor window can be used to save any changes or to rename the file. The Edit Menu supports the standard cut, copy and paste commands. The Font Menu can be used to change the font in the Text Editor Window.

It may be convenient to use the Export ASCII and View command to generate an export data file and then use that file as a templet for your import data file.

Import Parameters are matched by name so their order is not important. However, entries that do not have corresponding Variable Names in the beamline model will be ignored.

Double clicking an entry in the Import Variable List Window will open the associated Piece Window for that Parameter.

Import Variable List Window

PBO Lab provides a List Window that organizes all of the user specified Import Variables for the entire beamline model. The Import Variable List Window is accessed from the Data Interchange sub-menu in the Tools Menu as illustrated in Figure 44. The List Window shows the Piece Label, Parameter Name, Parameter Variable Name, Parameter Value and Units for each Import Variable selected in the beamline model. Double clicking an entry in the List Window will open the associated Piece Window containing that Import Variable.

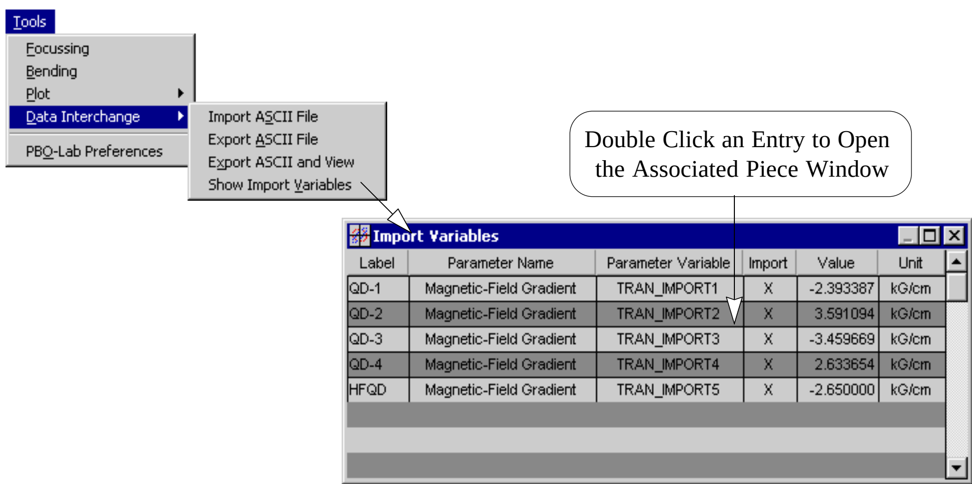


Figure 44. All Import Variables can be accessed from a List Window.

PBO Lab User Preferences

The Particle Beam Optics Laboratory has a Preferences Window which is accessed from the *PBO Lab Preferences* menu command in the Tools Menu of the Document Window.

PBO Lab Preferences are accessed from the Tools Menu of the Document Window.

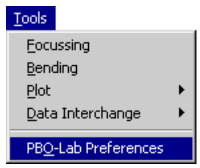


Figure 45. PBO Lab Preferences Menu Command.

There are three tab panels in the PBO Lab Preferences Window as illustrated in Figure 46. The *Main* tab panel contains general PBO Lab preferences. The *Simulations* tab panel has Application Module preferences and the *Focusing & Bending* tab panel contains preferences for the PBO Lab Focusing and Bending Modules.

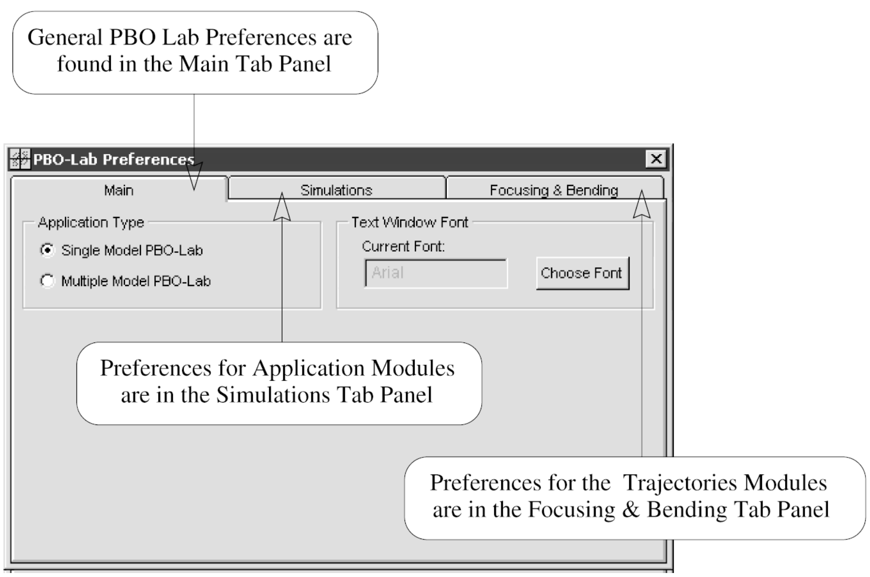


Figure 46. PBO Lab Preferences Window.

The Main tab panel of the PBO Lab Preferences Window has selections for Application Type and Text Window Font. The Application Type preference is a special feature for PBO Lab that supports the definition of beamline models that can reference elements (using Alias Pieces) between multiple Document Windows. The default for

Refer to the Section on Aliases in the PBO Lab Interface Chapter.

Multiple Document Mode allows beamline elements to be Aliased between Document Windows in the same beamline problem.

the Application Type preference is Single Model (Single Document Mode), which is the normal configuration for the PBO Lab user interface. The Multiple Model Application Type (Multiple Document Mode) modifies the user interface so that a persistent link can be maintained between multiple Document Windows. The user interface for Document Windows is the same in both configurations. However, there is a special Problem Setup user interface, shown in Figure 47, that is used in the Multiple Document Mode.

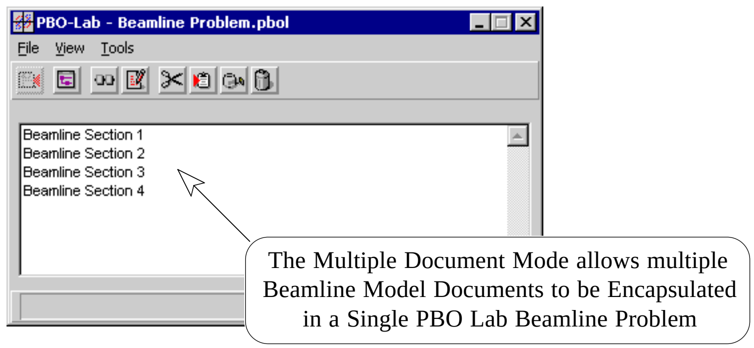


Figure 47. Multiple Document Mode Problem Setup Window .

The Multiple Document Mode and Problem Setup Window are only required in special cases where beamline elements need to be Aliased between Document Windows.

With the Multiple Document Mode configuration, multiple Documents are created and linked together in the Problem Setup Window. The most significant feature of the Multiple Document Mode is that beamline elements can be Aliased between Document Windows in the same beamline problem. The Multiple Document Mode and Problem Setup Window are only required in special cases where beamline elements need to be Aliased between Document Windows. Using the Problem Setup Window is described in a special Supplement to the PBO Lab User Manual that is available by request from AccelSoft.

The standard PBO Lab configuration (Single Document Mode) does not permit Aliases of beamline elements to be created between Documents. An Alert, such as that shown in Figure 48, results when trying to Copy an Alias Piece to another Document Window.

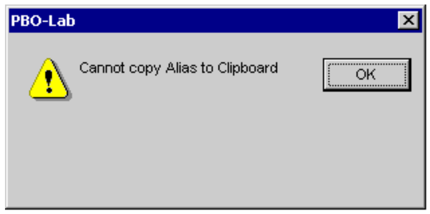


Figure 48. Cannot Copy Alias Alert.

In addition to the Application Type Preference, the Main tab panel of the PBO Lab Preferences Window also has a user preference for changing the font that will be used in PBO Lab text editor windows. The *Choose Font* button opens a standard font selection window as illustrated in Figure 49. The font selection and size is applied to all of the PBO Lab text windows, including those opened automatically for displaying computational results of Application Modules and Text Windows opened using the various View Menu commands in the Document Window.

The Text Window Font Preference is used to change the font in PBO Lab Text Editor Windows.

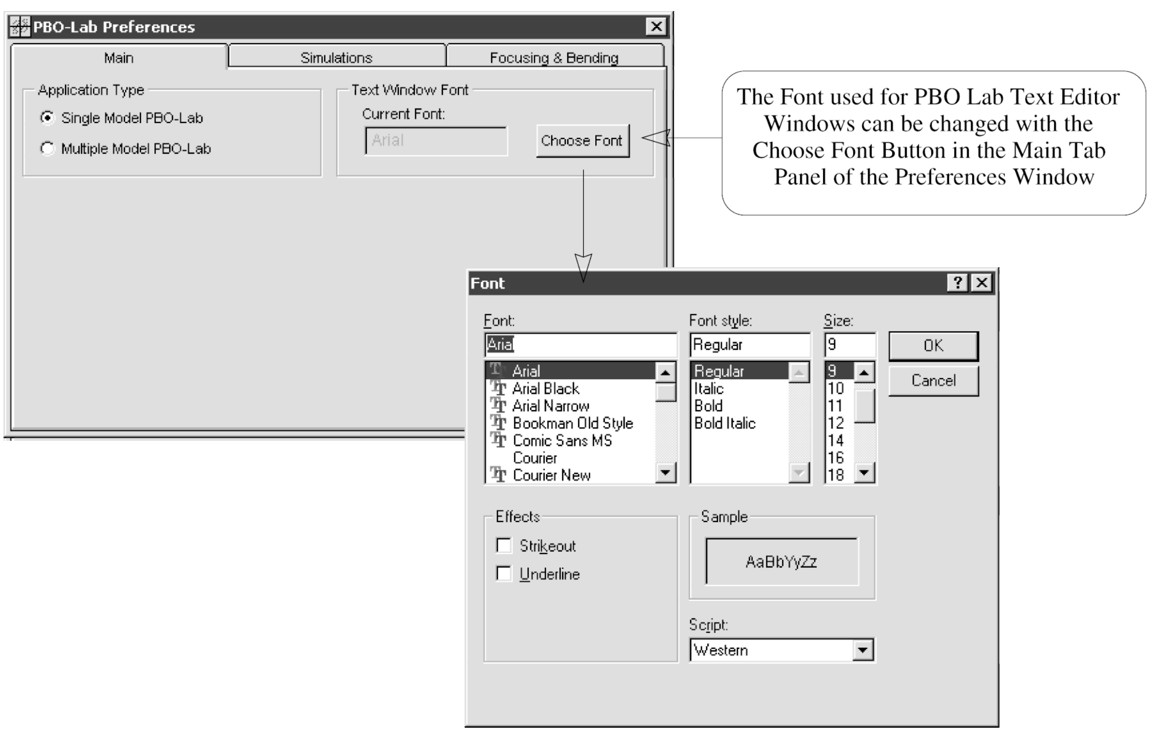


Figure 49. Selecting the Font for Text Editor Windows.

The Simulations tab panel is used for application-specific user preferences.

The Simulations tab panel in the PBO Lab Preferences Window, shown in Figure 50, is for application-specific user preferences. There is a Transport preference that has been included here for generating the native TRANSPORT input for either version 1.0 or for the new version 1.5 TRANSPORT application. Previous versions of PBO Lab have used the 1.0 version of TRANSPORT, which has since been replaced with the 1.5 version of the application. This user preference is included for those users who wish to continue using the older version of the TRANSPORT application that was shipped with previous versions of PBO Lab. The default for this preference is for the newer TRANSPORT 1.5 version, which is currently being distributed as part of the TRANSPORT Application Module for PBO Lab.

PBO Lab can generate native input for both TRANSPORT versions 1.0 and 1.5.

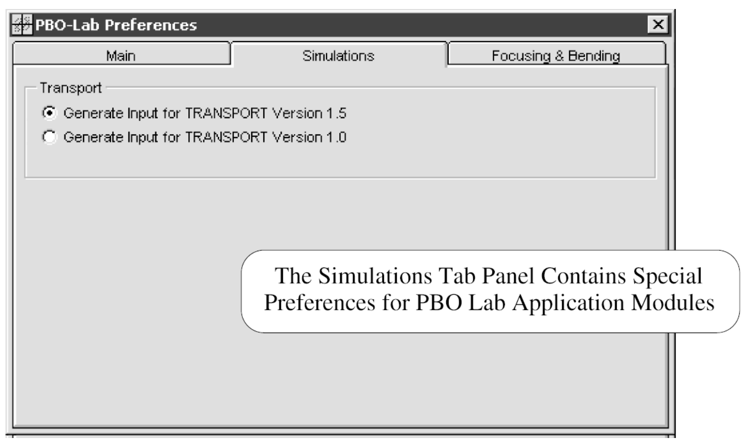


Figure 50. Simulations Tab Panel for PBO Lab User Preferences.

The Focusing & Bending tab panel has user preferences for the PBO Lab Focusing Module and the Bending Module.

The Focusing & Bending tab panel of the Preferences Window has user preferences for the PBO Lab Focusing Module and the Bending Trajectories Module. The Initial Beam preferences are used in both the Focusing and Bending Modules for the Envelope calculations. The Diagnostic preferences are used in the Focusing Module to generate data files from the Ray Trace and Envelope calculations.

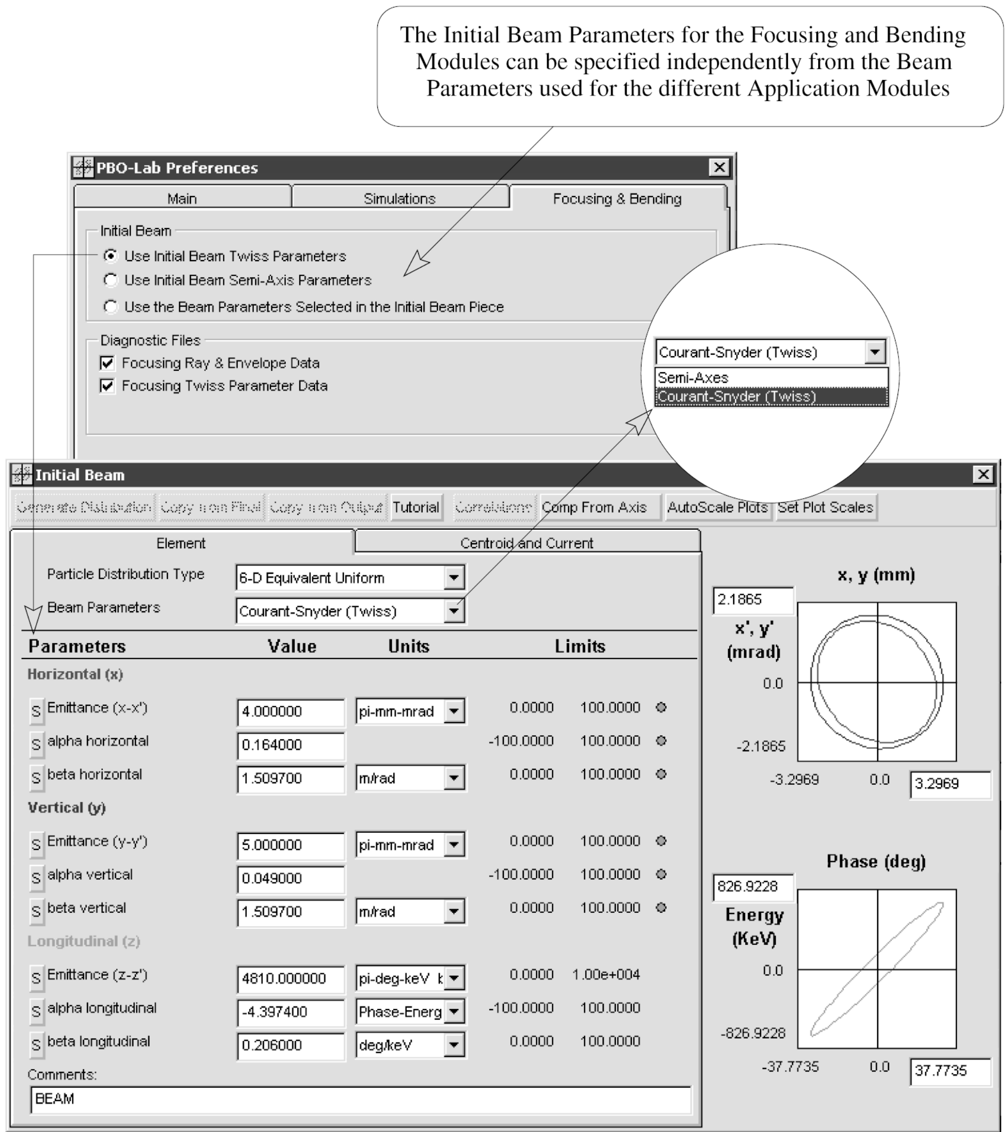


Figure 51. Initial Beam Parameters for the Focusing and Bending Modules.

Figure 51 illustrates the Focusing & Bending tab panel of the Preferences Window. There are three Initial Beam Preferences for use with the Focusing and the Bending Modules. The three selections refer to the Beam Piece parameters that will be used for Envelope calculations. The first selection is the default and is used to specify an initial beam with the Courant-Snyder (Twiss) parameters of the Initial Beam Piece in the beamline model of the Document Window. The second selection specifies an initial beam with the Semi-Axes parameters from the Initial Beam Piece.

Refer to the Sections on the PBO Lab Focusing and Bending Modules in this Chapter.

The third selection will use the current setting for the Beam Parameters pop-up in the Initial Beam Piece, either Twiss or Semi-Axes parameters. Figure 51 illustrates the relationship between the Initial Beam Piece and the Initial Beam preferences for the Focusing & Bending Modules. Note that the Initial Beam Piece contains two independent sets of beam parameters, one for the Twiss representation and another for Semi-Axes. If either of the first two selections in the Initial Beam Preferences are used then the selected parameters will be used independent of the Beam Parameters selection in the Beam Piece Window. If the last preference is selected, then the Focusing and Bending Modules will use the parameters corresponding to the Beam Parameters selection in the Beam Piece Window.

The Diagnostic Files Preferences are used in the Focusing Module. There are two check boxes that correspond to numerical data files which can be generated for the Ray Trace and the Envelope plots in the Focusing Module Window. The ray and envelope data and the phase space ellipse data can be written to data files by selecting these preferences. If these preferences are not selected then the data is calculated for the plots in the Focusing Module Window but it is not written to the individual data files. Turning these preferences off will speed up the processing time for large models and for calculations with a very small Maximum Step Size Global Parameter setting. These data files are overwritten each time the Ray Trace or Envelope calculations are made. The format of these files is compatable for loading into a PBO Lab Graph Plot Window. There are specific commands in the Tools menu (Figure 52) for opening Plot Windows for both the Focusing Rays & Envelopes data file and the Focusing Twiss Parameters data file when these user preferences have been selected.

Commands in the Tools menu can be used to open Plot Windows for both the Focusing Rays & Envelopes data file and the Focusing Twiss Parameters data file. Refer to the previous Section in this Chapter on the PBO Lab Plot Tool.

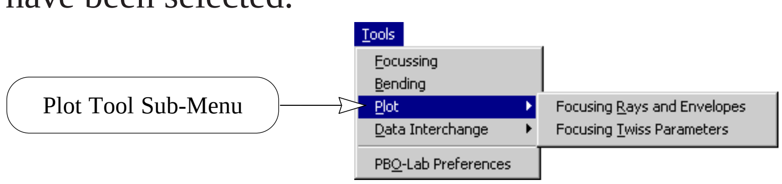


Figure 52. Plot Tool Sub-Menu.

This Section completes the discussion of the PBO Lab Analysis Tools and User Preferences. The Analysis Tools do not require installation of any PBO Lab Application Module, and Analysis Tools are not required in order to set up beamline models or run any of the Application Modules.

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PBO Lab™ 2.0

Tutorials

**Particle
Beam
Optics
Laboratory**

This Section describes the interactive tutorials and help features that are integrated with the PBO Lab application. The tutorials are aimed at assisting first-time users in understanding the beam optics models upon which TRANSPORT relies, as well as for learning about the technology of accelerators and various beam physics phenomena. These educational features were developed in part under a Small Business Innovation Research (SBIR) grant (No. DE-FG03-94ER81767) from the U. S. Department of Energy to supplement the Shell for Particle Accelerator Related Codes (S.P.A.R.C.). The tutorials do not use TRANSPORT, nor do they result in any additional data written to the Transport Input files.

Tutorial Modules

An extensive interactive tutorial system has been integrated with the PBO Lab user interface. This Section summarizes how the interactive tutorial system is used.

The PBO Lab Tutorials are composed of a series of Tutorial Modules, each of which contains two primary components: an interactive Pictorial and a hypertext Tutorial. The two components work together for each Tutorial Module, and each module can be navigated independently. A Tutorial Module is opened by selecting the Tutorial button that appears in the upper right corner of Piece Windows and other PBO Lab windows. This opens the interactive Pictorial Window, which is navigated using the PREV and NEXT buttons in the lower left panel of the window. The hypertext Tutorial is opened using the Go button in the bottom right panel of the Pictorial Windows. The hypertext Tutorials for all of the Tutorial Modules can also be opened using the Hypertext Help command in the Help menu of the PBO Lab Document Window.

PBO Lab Pieces Supported with Tutorial and Pictorial Modules:

Beam
Drift
Quad
Sextupole
Bend
S-Bend
R-Bend
Edge
RMS Beam
Centroid
Solenoid
Thin Lens
Rotate

The hypertext pages of each Tutorial Module provide links to many parts of the PBO Lab tutorial system. Hyperlinks are generally of two types. Pop-up topics provide brief information on the hyperlink selection, and the pop-up window used to display the material disappears on the next mouse or keyboard action by the user.

Tutorial Equation pages provide the user with a set of specialized scientific calculators that contain built-in functions related to the physics and technology of charged particle optics.

Entries in the PBO Lab Glossary are examples of the use of pop-up topics. Discussion topics present more detailed information on the hyperlink selection, and will usually contain further hyperlinks to additional information in the PBO Lab Tutorial system. Discussion topics follow an outline format in which the user has several options for navigating through the discussion topic pages. In addition, there are Pictorial pages that are associated with specific Tutorial buttons in the PBO Lab windows. The Pictorial topics are navigated as though advancing or retreating through a slide show presentation.

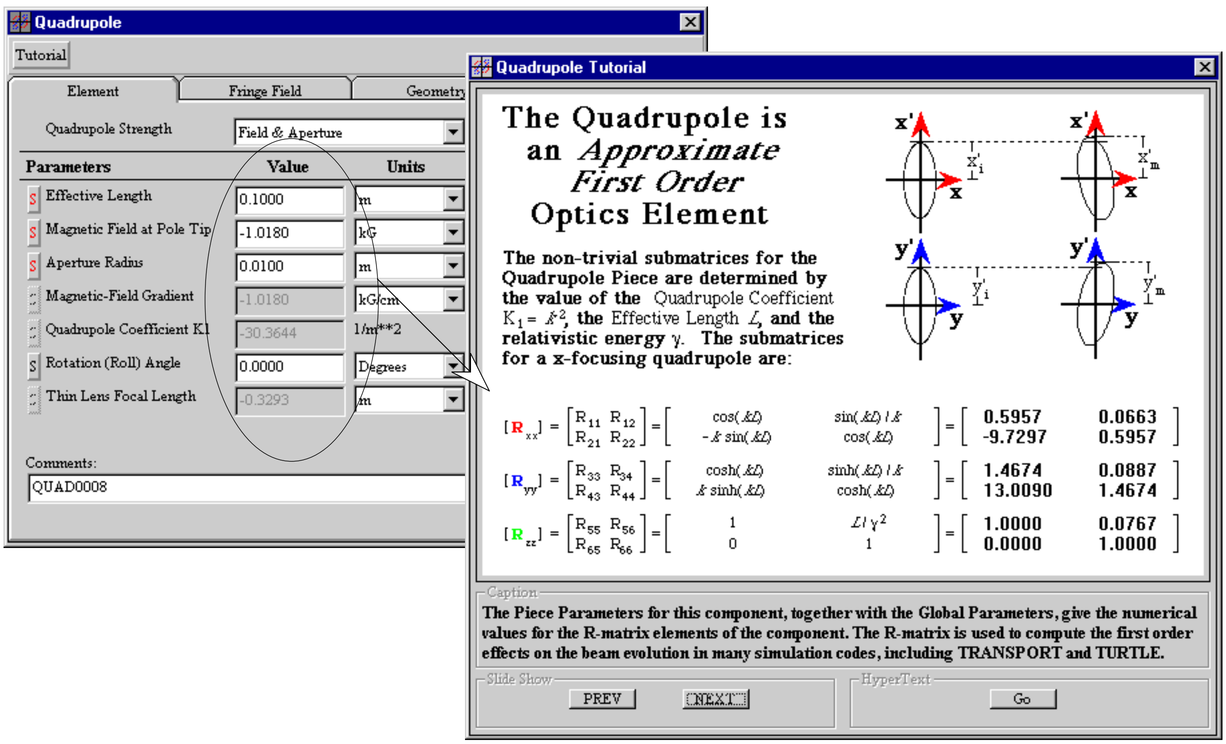


Figure 53. Quadrupole Interactive Tutorial Equation Page.

Pictorial Pages

Selecting the Tutorial button that appears in the upper right corner of a PBO Lab Piece Window activates the interactive Pictorial associated with that beamline element. The Pictorial pages present results pertinent to the optics modeling or calculations for the user inputs of that particular PBO Lab window. The pages displayed in the Pictorial Window are navigated using the buttons labeled PREV and NEXT, located in the lower left panel of the Window.

The content of Pictorial pages is adjusted interactively based upon the current values of the user input parameters in the window. For example Figure 53 shows an equation page in a Quadrupole Pictorial that gives the R-matrices and illustrates the first order effects on the two transverse phase planes. When the user changes the quadrupole strength or any other parameter, the page is automatically updated to reflect the new parameters.

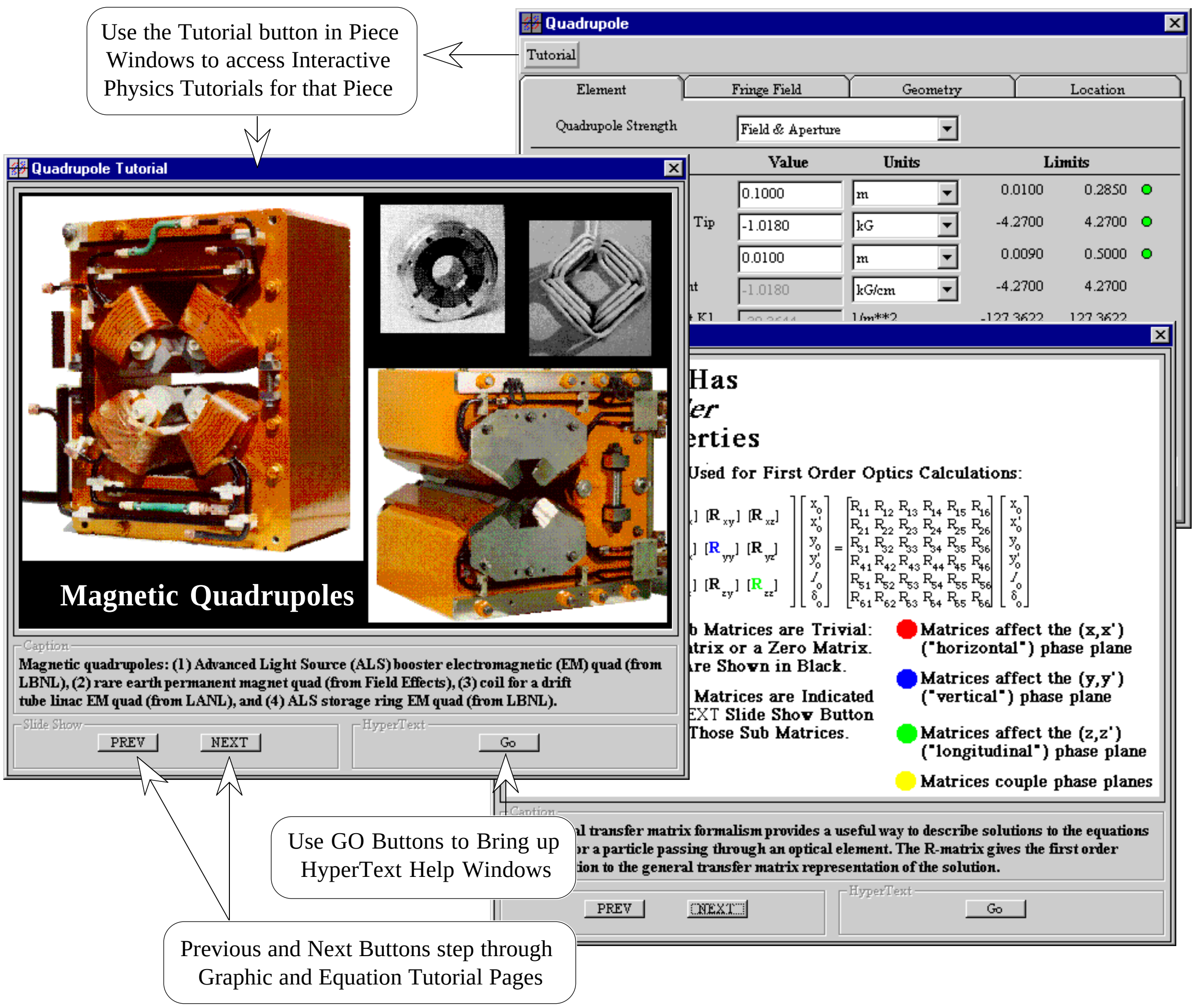


Figure 54. Using the PBO Lab Interactive Tutorials.

Graphic elements and text, as well as numerical data, are updated. Each page is tied to a particular PBO Lab window so that the Pictorials for different windows, including those for the same type of beamline element (e.g. two different quadrupoles), will display a distinct set of pages associated with the parameter settings of that element. Consequently, the Piece Window and its Pictorial Equation pages can be used together as a specialized calculator with built-in optics and technology functions. Figure 54 shows additional Tutorial Pages for a Quadrupole beamline element.

Hypertext Tutorials

A more detailed treatment of material is presented in the hypertext component of PBO Lab Tutorial Modules, which is activated using the Go button located on the lower right panel of each Tutorial Window. Figure 55 illustrates a hypertext Tutorial Window for a Quadrupole element.

You may navigate forward or backward through your selected tutorial pages using the corresponding buttons located in the bottom panel of the tutorial windows.

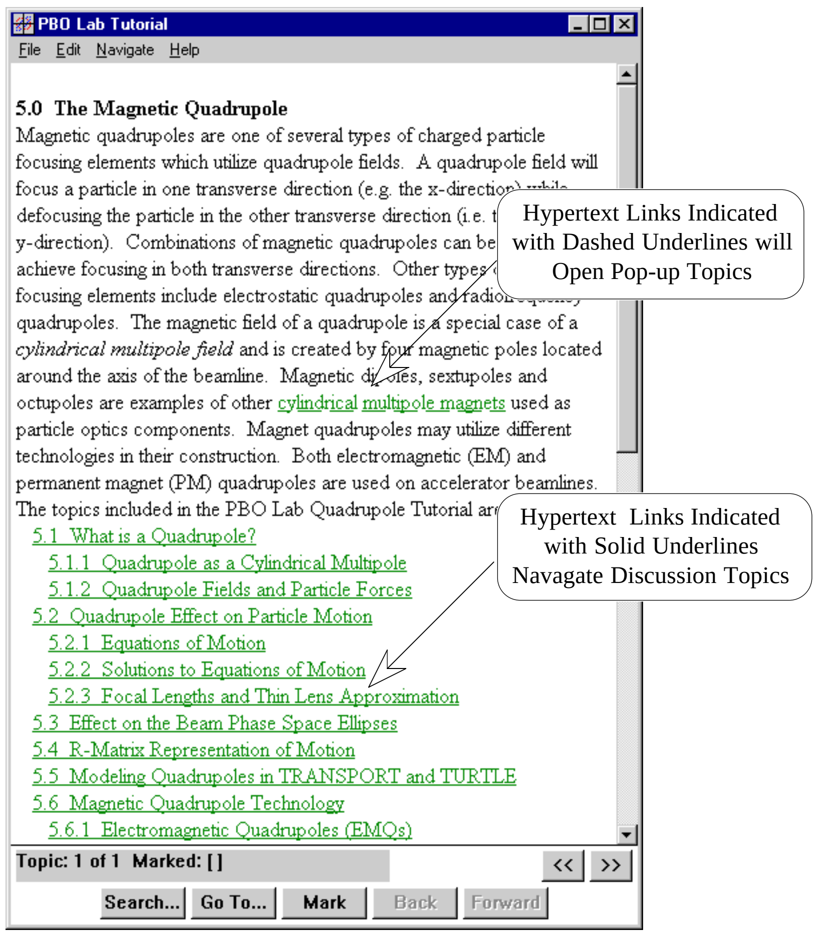


Figure 55. Hypertext Tutorial Window for Quadrupole.

The hypertext component of each Tutorial Module provides links to many parts of the PBO Lab tutorial system. Hyperlinks are generally of two types: discussion topics and pop-up topics. Hypertext links for discussion topics are indicated by solid underlines and are used to navigate a series of pages that frequently contain hypertext links to other information, including links to other pages in the series and links to other discussion topics in the PBO Lab Tutorials. Hypertext links for pop-up topics are indicated by dashed underlines. Pop-up topics provide brief information on the selected hypertext topic. The pop-up window used to display the material disappears on a subsequent mouse click or keyboard action (Figure 55).

Discussion topics present more detailed information on the selected hyperlink topic, and may contain further hyperlinks to additional information in the PBO Lab Tutorial. Discussion topics follow an outline format and the user has several options for navigating the pages.

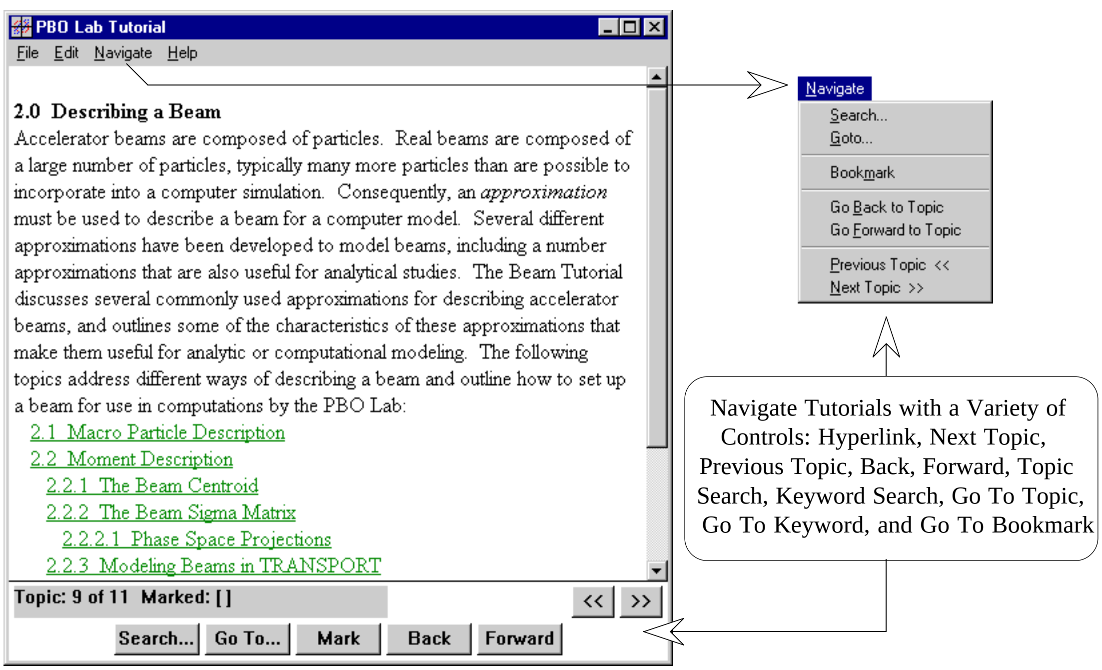


Figure 56. Navigating PBO Lab Hypertext Tutorials.

The commands in the Navigate menu and the buttons at the bottom of the hypertext Tutorial Window can be used to navigate through the Tutorial Pages (Figure 56). The *Next Topic* button (marked with the symbol >>), follows the outline format of the discussion topic. The *Previous Topic* button (marked with the symbol <<) is used to browse backwards through a discussion topic. The *Back* button is used to navigate backward through previously selected links. The *Forward* button can then be used to page forward again through visited links. The *Search* button opens the Topic Search Dialog, which is used to search the tutorial database by Topic or by Keyword. The *GoTo* button opens the Topic GoTo Dialog. The *Mark* button is used to place a bookmark for the current page, which can then be used in a Search or GoTo command.

All main discussion topics conclude with a pop-up topic that provides a summary of the material covered in that particular topic. A summary of the material covered in any main discussion topic may also be viewed using the “GO! ->” pop-up topic hyperlink as illustrated in Figure 57, which shows the Magnetic Quadrupole summary.

Hypertext links indicated by broken underlines bring up pop-up windows such as additional Glossary definitions.

In contrast, links that have solid underlines navigate Discussion topics, which are typically a series of pages on a particular subject in the PBO Lab Tutorial.

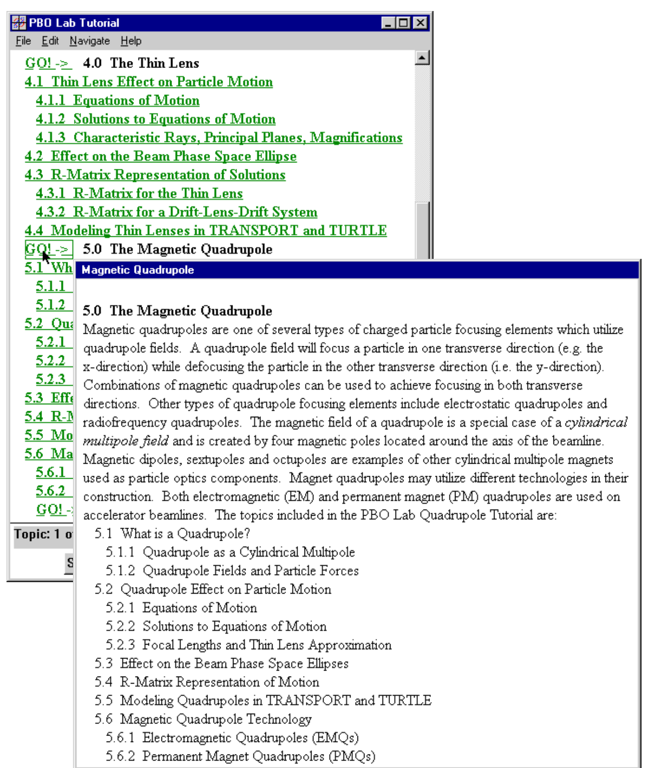


Figure 57. Hypertext Tutorial Pop-up Topic of Magnetic Quadrupole Summary.

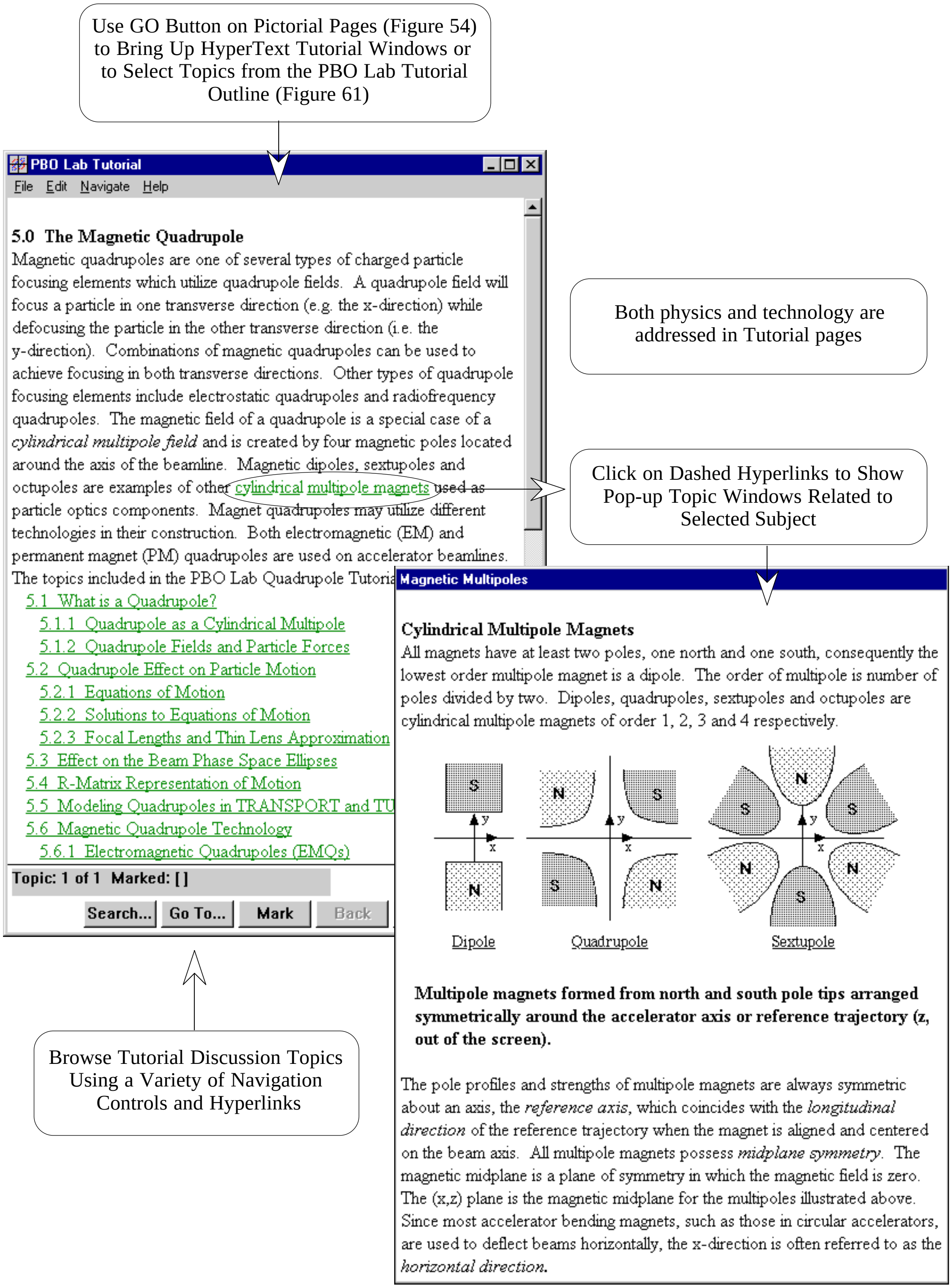


Figure 58. Hypertext Tutorial Windows for a Quadrupole Element.

Particle Beam Optics Glossary

The Particle Beam Optics Glossary contains definitions and brief discussions of many of the concepts and terms used in particle optics and in accelerator physics and engineering. Individual entries in the PBO Lab Glossary appear as Pop-up Topics when selected using hypertext links from other parts of the PBO Lab Tutorial. The Glossary may also be browsed using the *GoTo* button or menu command in any Hypertext Tutorial window and then using the Glossary option as shown in Figure 59 below.

Use the Topic GoTo Dialog to access user defined bookmarks, the PBO Glossary or the tutorial outline pages.

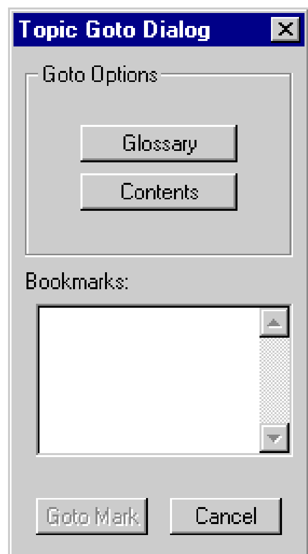


Figure 59. Topic GoTo Dialog.

Selecting the *Glossary* button in the Topic GoTo Window activates a hypertext Tutorial Window for the Particle Beam Optics Glossary as illustrated in Figure 60. Use the *Next Topic* button (marked with the symbol >>) to browse through the Glossary. The *Previous Topic* button (marked with the symbol <<) is used to browse backwards through the Glossary. Clicking on hypertext links may be used to access additional Glossary definitions and further explore selected subjects in other parts of the PBO Lab Tutorial.

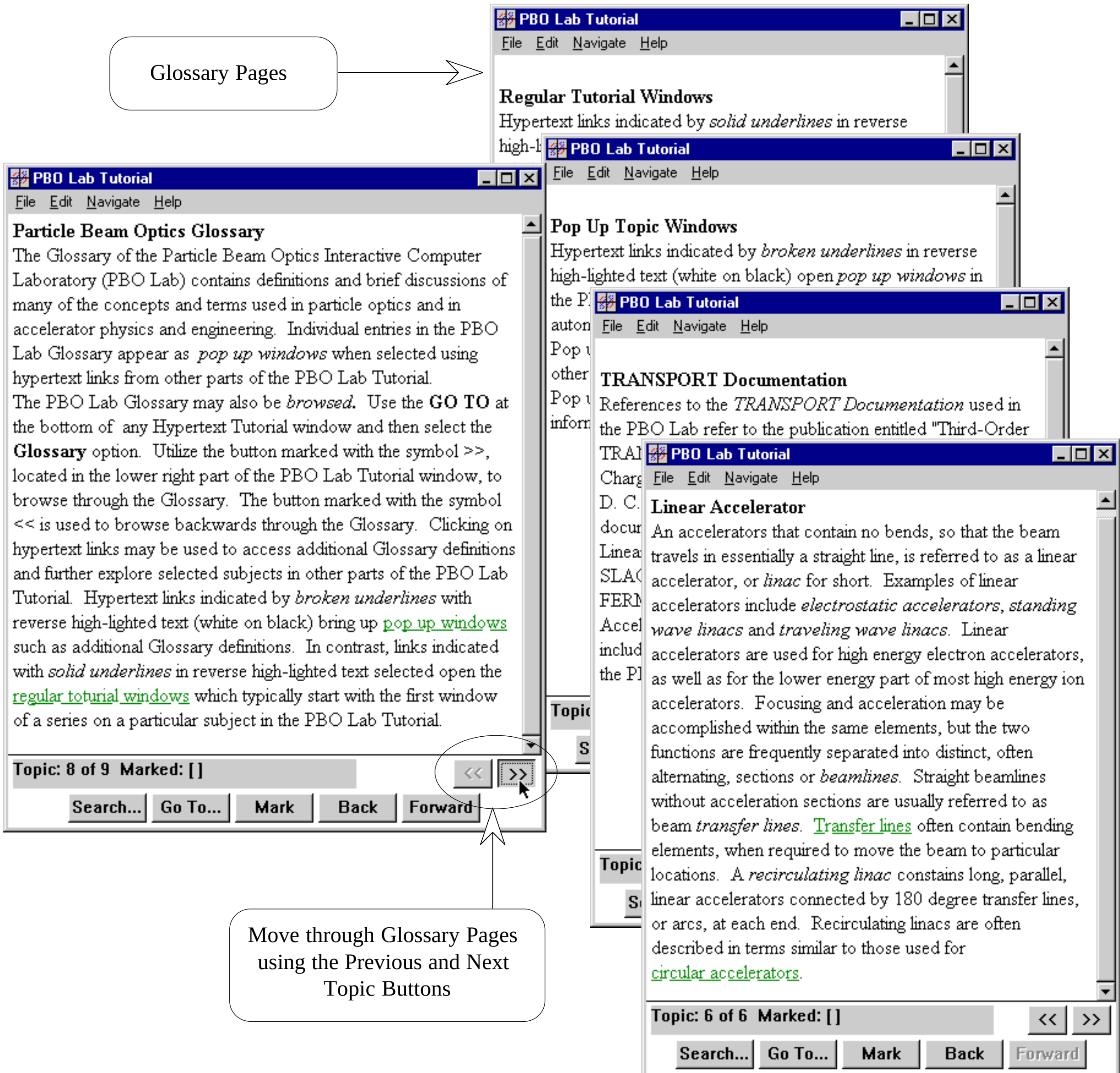
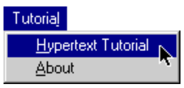


Figure 60. PBO Lab Particle Beam Optics Glossary.

PBO Lab Tutorial Outline

A hypertext outline for all the PBO Lab Tutorial discussion topics can be opened using the Hypertext Tutorial Menu command in the Document Window. The outline can also be accessed from the *Contents* button in the Topic GoTo Dialog as shown in Figure 61 below. Any topic may be selected from the outline and accessed using the discussion topic hyperlinks.



Use the Hypertext Help command in Tutorial Menu to open a hypertext outline for all the PBO Lab Tutorial discussion topics.

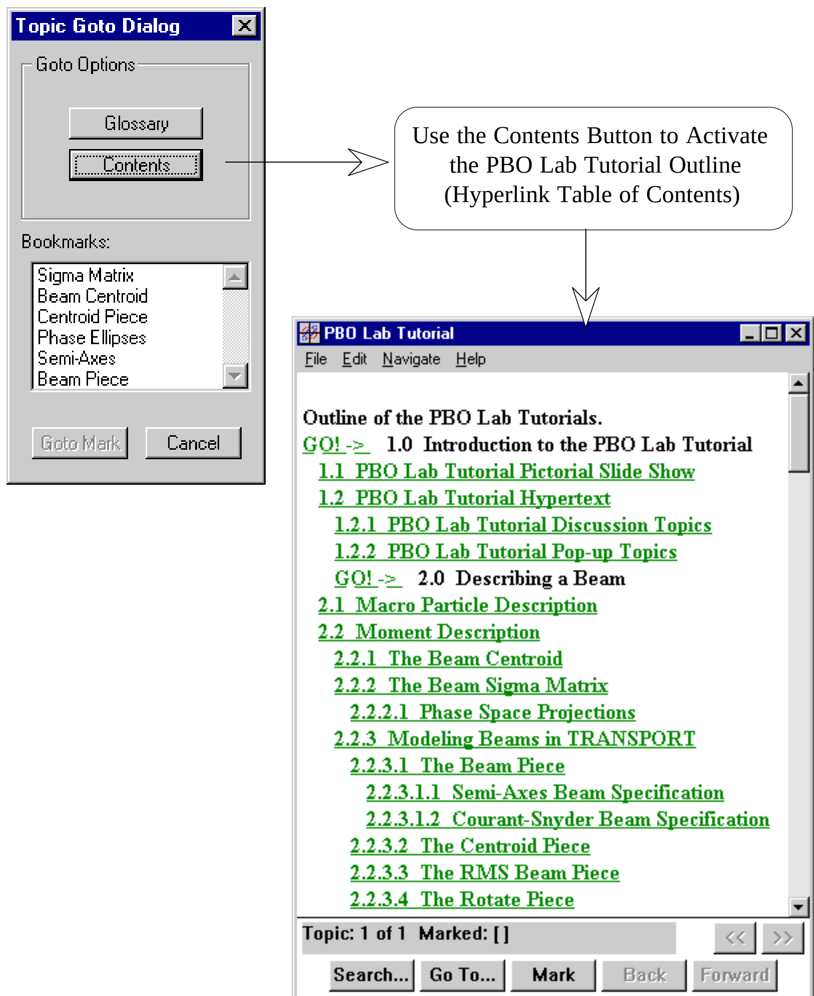


Figure 61. PBO Lab Tutorial Hypertext Outline.

Using Tutorial Bookmarks

The Topic GoTo Dialog can also be used to access any user-defined bookmarks. Bring up the Topic GoTo Dialog (Figure 62) from the *GoTo* button at the bottom of a Tutorial Window or from the GoTo item in the Navigate Menu. Select a pre-defined bookmark in the list of bookmarks and go to that page using the *GoTo Mark* button.

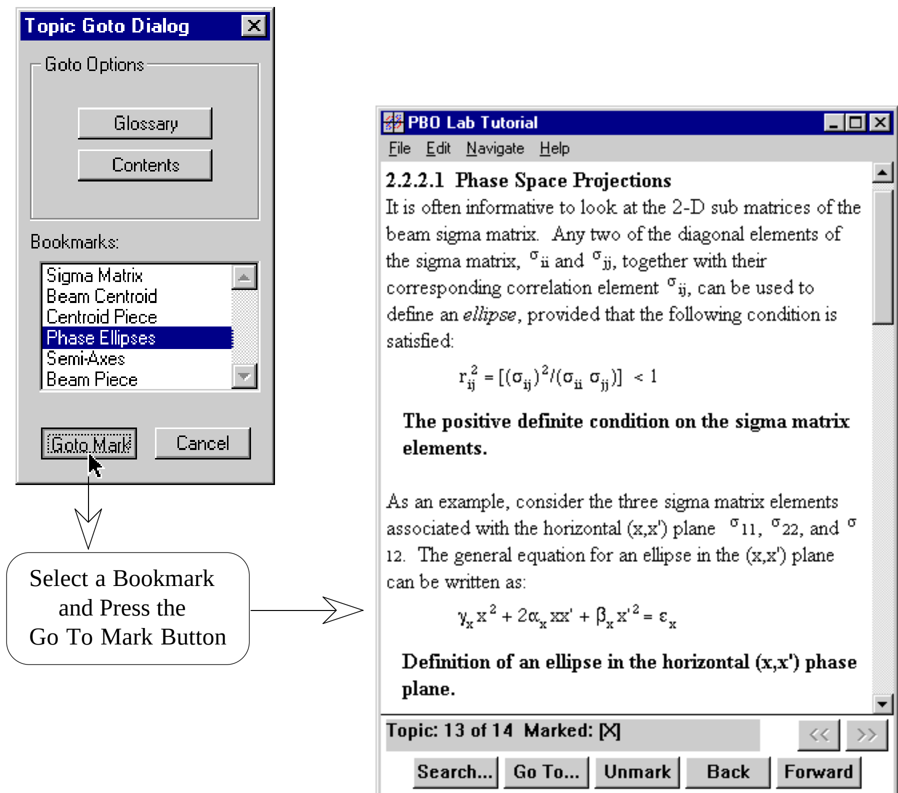


Figure 62. GoTo a User Defined Bookmark.

Bookmarks are defined for a Tutorial Page using the *Mark* button at the bottom of a Tutorial Window, or by using the Bookmark command in the Navigation Menu of a Tutorial Window. A previously defined bookmark may also be removed. If a Tutorial Page is already marked, then using the *Unmark* button or menu command will remove the page from the bookmark list.

Searching Tutorial Pages

The *Search* command in the Navigate Menu of Tutorial Windows, or the *Search* button at the bottom of the Tutorial Windows, is used to bring up the Topic Search Dialog shown in Figure 63. PBO Lab Tutorials can be searched by discussion topics and by keywords. After selecting an item from the list of topics or keywords, use the *GoTo Selection* button to bring up the selected Tutorial Page.

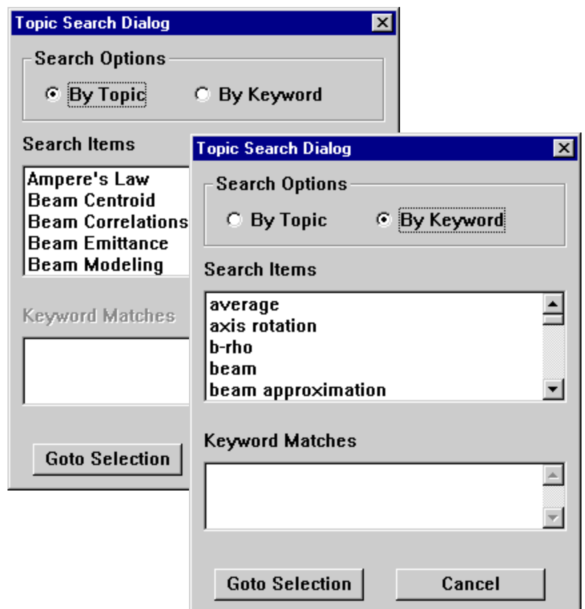
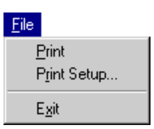
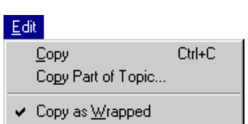


Figure 63. Topic Search Dialog.



Use File Menu commands to print tutorial pages.



Use Edit Menu commands to copy tutorial pages.

Printing and Copying Tutorial Pages

The content of the PBO Lab Tutorial Pages may be printed using the *Print* command in the File Menu of the Tutorial Window. Alternatively, the Copy and Copy Part of Topic commands in the Edit Menu may be used to copy the content of the PBO Lab Tutorial Pages to the system clipboard. The content can then be pasted into a text or graphics program of your choice.

This Section completes the discussion of using the PBO Lab Tutorial system. The tutorials do not require any of the PBO Lab Application Modules to be installed, and they are not required in order to set up beamline models or run any of the Application Modules.

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